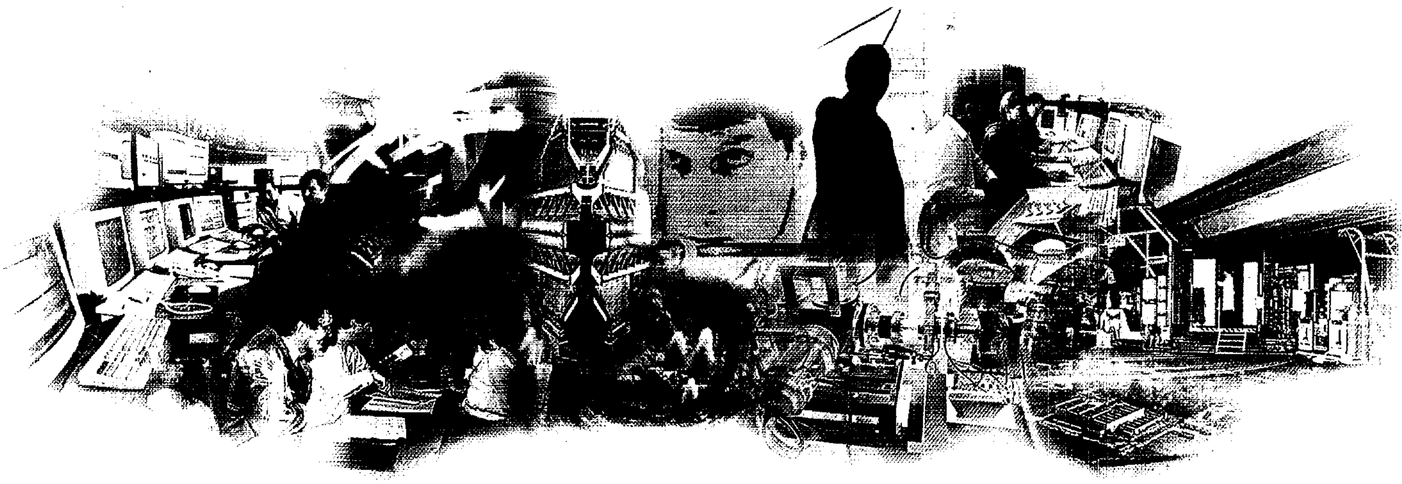
Research at GANIL - A Compilation 1998-2000

J.D. Frankland, H. Rothard, M. Bex



GANIL

Grand Accélérateur National d'Ions Lourds
Laboratoire commun CEA / DSM - CNRS / IN2P3

RESEARCH AT GANIL 1998/2000

A COMPILATION

PLEASE BE AWARE THAT
ALL OF THE MISSING PAGES IN THIS DOCUMENT
WERE ORIGINALLY BLANK

RESEARCH AT GANIL

A Compilation

1998 - 2000

Editors : J. Frankland, H, Rothard, M. Bex
Typing and layout of the manuscript : M. Campbell, S. Geswend

January 2002

CONTENTS

FOREWORD

The present compilation tends to reflect a variety of experimental and theoretical works performed at GANIL in the years 1998-2000. This "just-before-SPIRAL" period was characterized in nuclear physics by a strong increase in the number of experiments dedicated to the study of the structure of nuclei far from stability. The identification of the doubly-magic ^{48}Ni and study of the neighbouring nuclei are among the most spectacular results of this research.

Another intriguing observation, the detection of the bound four-neutron cluster, if confirmed, may become one of the greatest discoveries in nuclear physics of recent years. Many interesting and often pioneering results were obtained in the study of nuclear halo and the shell closures (N=20, 28 and 40) in the neutron rich nuclei. The shape coexistence in the region of light Kr isotopes studied via isomeric states is one of the new and promising fields of research at GANIL. These, and other not less interesting results in nuclear structure studies were obtained using an impressive palette of experimental techniques including elastic and inelastic scattering on light targets, direct and break-up reactions, neutron interferometry and in-beam γ-ray spectroscopy. Decay spectroscopy tools are becoming more and more sophisticated and have allowed in particular for precision measurements of β-delayed neutrons and protons, conversion electrons from isomers, as well as g-factors and sub-nanosecond lifetimes of isomeric or excited states.

During this period the first experiments on the synthesis of heavy and super heavy nuclei took place at the LISE spectrometer showing the existence of an important potential for new discoveries and spectroscopic studies in this region of the chart of nuclei.

The first evidences for the observation of the liquid-gas phase transition of nuclear matter marked studies of hot nuclei formed in nuclear collisions by the INDRA collaboration. Sophisticated and original methods of data analysis as well as extensive theoretical calculations allow to take full benefit of the different campaigns performed with this powerful 4π charged particle detector array. At lower excitation energies an original application of the crystal blocking technique coupled with the 4π neutron array ORION allowed to measure the evolution of fission times in a previously inaccessible range.

Contributions concerning the SIRa test bench and the VAMOS and EXOGAM spectrometers reflect the important efforts in R&D of the experimental equipment dedicated to the new SPIRAL beams and experiments.

Last but not least, the interdisciplinary research at GANIL is in better shape than ever. The proof is in the very important number of contributions dealing with swift heavy ions used in atomic, solid state and condensed physics, in radiation chemistry and radiobiology. The new equipment installed at the LIMBE lines, the IRRSUD irradiation facility and the radiobiology laboratory currently under construction should ensure rapid progress and a continuously increasing number of users in this domain in the coming years.

Dominique Goutte
Director of GANIL

Marek Lewitowicz
Deputy Director of GANIL

NUCLEAR PHYSICS

1 - NUCLEAR THEORY

I. NUCLEAR THEORY

II. EXOTIC NUCLEI : REACTIONS

III. EXOTIC NUCLEI : SPECTROSCOPY

IV. HOT NUCLEI AND NUCLEAR MATTER

V. INSTRUMENTATION

INTERDISCIPLINARY RESEARCH

1. INSTRUMENTATION

2. COLLISION OF IONS WITH ATOMS AND MOLECULES

3. COLLISIONS WITH SOLIDS AND SURFACES : TRANSPORT PHENOMENA, ENERGY DEPOSITION AND SPUTTERING

4. INDUCED EFFETS IN CONDENSED MATTER INCLUDING NANO-STRUCTURATION

5. RADIATION CHEMISTRY AND RADIOBIOLOGIE

Description of exotic nuclei using the shell model embedded in the continuum

K. Bennaceur, N. Michel, F. Nowacki, J. Okołowicz and M. Płoszajczak

GANIL - Kraków - Oak Ridge - Strasbourg Collaboration

The theoretical description of weakly bound exotic nuclei close to the drip-line, such as, *e.g.*, ^{8}B on the proton rich side of the drip line or ^{11}Be, ^{11}Li on the neutron rich side of the drip line, is challenging due to the proximity of particle continuum which implies the strong modification of effective nucleon - nucleon interaction and causes the unusual spatial properties (halo structures, a large diffusivity) of nucleon density distribution . For well bound nuclei close to the β - stability line, microscopic description of states in the subspace of (quasi-) bound states is given by the nuclear shell model (SM), whereas the subspace of scattering states is treated in terms of the coupled channels equations. The validity of this basic paradigm is certainly questionable in weakly bound exotic nuclei, where number of excited bound states or narrow resonances is small and , moreover, they couple strongly to the particle continuum. For that reason, we have developed the Shell Model Embedded in the Continuum (SMEC) where the *realistic* N-particle wave functions of the SM are coupled by the residual nucleon - nucleon interaction to the one-particle scattering continuum. In this unified framework, with the same microscopic input, one can describe both spectra and electromagnetic transition matrix elements, $\beta-$decays, in particular first-forbidden $\beta-$ decays in mirror nuclei, as well as the capture reactions (p,γ), (n,γ), Coulomb dissociation reaction and various elastic and inelastic (p,p'), (n,n') scattering processes [1].

[1] K. Bennaceur, F. Nowacki, J. Okołowicz, and M. Płoszajczak, J. Phys. **G24** (1998) 1631; K. Bennaceur, F. Nowacki, J. Okołowicz, and M. Płoszajczak, Nucl. Phys. **A 651** (1999) 289. K. Bennaceur, F. Nowacki, J. Okołowicz, and M. Płoszajczak, Acta Phys. Pol. **B31** (2000) 311. R. Shyam, K. Bennaceur, J. Okołowicz, and M. Płoszajczak, Nucl. Phys. **A669** (2000) 65. K. Bennaceur, F. Nowacki, J. Okołowicz, and M. Płoszajczak, Nucl. Phys. **A671** (2000) 203. K. Bennaceur, N. Michel, F. Nowacki, J. Okołowicz, and M. Płoszajczak, Phys. Lett. **B488** (2000) 75; M. Płoszajczak, K. Bannaceur, N. Michel, F. Nowacki and J. Okołowicz, RIKEN Review **39** (2001) 11; N. Michel, J. Okołowicz, and M. Płoszajczak, NATO Advanced Research Workshop Brijuni (2001), nucl-th/0110041.

Statistical aspect of the coupling to the continuum

S. Drożdż, J. Okołowicz, M. Płoszajczak and I. Rotter

MPI-Dresden - GANIL - Kraków - Strasbourg Collaboration

Relating properties of nuclei to the ensembles of random matrices is of great interest. A potential agreement reflects those aspects that are generic and thus do not depend on the detailed form of the Hamiltonian matrix, while deviations identify certain system-specific, non-random properties of the system. The nuclear states are embedded in the continuum and the system should be considered as an open quantum system. Applicability of the related scattering ensemble of non-Hermitian random matrices has never been verified. For the first time, various global characteristics of the coupling between the bound and scattering states have been explicitly studied based on realistic Shell Model Embedded in the Continuum [1] for ^{24}Mg in the *sd* valence space [2]. In particular, such characteristics are related to those of the scattering ensemble. It is found that in the region of higher density of states the coupling to continuum is largely consistent with the statistical model. However, assumption of channel equivalence in the statistical model is strongly violated, what contradicts the orthogonal invariance arguments and results in strong reduction of the number of effectively involved channels.

[1] K. Bennaceur, F. Nowacki, J. Okołowicz, and M. Płoszajczak, J. Phys. **G24** (1998) 1631;
- K. Bennaceur, F. Nowacki, J. Okołowicz, and M. Płoszajczak, Nucl. Phys. **A 651** (1999) 289.
[2] S. Drożdż, J. Okołowicz, M. Płoszajczak and I. Rotter, Phys. Rev. **C62** (2000) 24313.

Pairing anti-halo effect

K. Bennaceur, J. Dobaczewski and M. Płoszajczak

GANIL - Oak Ridge - Warsaw Collaboration

Continuum effects in the weakly bound nuclei close to the drip-line have been investigated using the analytically soluble Pöschl-Teller-Ginocchio potential [1]. Pairing correlations are studied within the Hartree-Fock-Bogoliubov method. We show that both resonant and non-resonant continuum phase space is active in creating the pairing field. The influence of positive-energy phase space has been quantified in terms of localizations of states within the nuclear volume. An increase of neutron radii with decreasing binding is a well-known fact, both in experiment (the show-case ^{11}Li nucleus) and in mean-field theories. Roughly speaking, the weakly bound nuclei are larger than the strongly bound nuclei with the same neutron numbers. Such an increase is, of course, very nicely born out by the HFB theory. We have studied another question, namely, whether or not the nuclei with the weakly-bound ℓ=0 s.p. orbitals are larger than those that do not have such orbitals available near the Fermi surface [2]. Our analysis shows that the answer is negative: for weakly-bound even-N nuclei, positions of ℓ=0 orbitals *are not essential* in building up their large radii, *i.e.* the additional pairing binding energy acts against a development of an infinite rms radius.

[1] K. Bennaceur, J. Dobaczewski, M. Płoszajczak, Phys. Rev. **C 60** (1999) 034308.
[2] K. Bennaceur, J. Dobaczewski and M. Płoszajczak, Phys. Lett. **B 496** (2000) 154-160.

Dynamical symmetries in quantal many-body systems

P. Van Isacker
GANIL, BP 55027, F-14076 Caen Cedex 5, France

The determination of the properties of a quantal system of N interacting particles moving in an external potential requires the solution of the eigenvalue equation associated with the second-quantised hamiltonian

$$\hat{H} = \sum_i \epsilon_i a_i^\dagger a_i + \sum_{ijkl} v_{ijkl} a_i^\dagger a_j^\dagger a_k a_l + \cdots . \tag{1}$$

The operators $a_i^\dagger$ and a_i are creation and annihilation operators for the particles, characterised by an index i which labels a set of single-particle states in the confining potential and which may also include possible intrinsic quantum numbers such as spin, isospin, colour... The coefficients ϵ_i are single-particle energies and the v_{ijkl} are two-body interactions; higher-order interactions can be included, if needed. The (unitary) Lie algebra generated by the operators $a_i^\dagger a_j$ over an appropriate set of single-particle states is called the *spectrum generating* (or also *dynamical*) algebra $G_{\rm SGA}$ of the system.

The solution of the eigenvalue problem for N particles associated with (1) requires the diagonalisation of $\hat{H}$ in the symmetric representation $[N]$ of $G_{\rm SGA}$ in case of bosons or in the anti-symmetric representation $[1^N]$ of $G_{\rm SGA}$ in case of fermions. In many situations of interest, the hamiltonian will have a lower symmetry $G_{\rm SYM} \subset G_{\rm SGA}$, that is, $\hat{H}$ will commute with transformations that constitute a symmetry algebra $G_{\rm SYM}$. The enumeration of all hamiltonians of the type (1) that are *analytically solvable* and that conserve the symmetry $G_{\rm SYM}$ requires the knowledge of all nested algebraic chains of the type

$$G_{\rm SGA} \supset G \supset G' \supset \cdots \supset G_{\rm SYM}. \tag{2}$$

To appreciate the relevance of this classification, one notes that associated with each chain (2) is a hamiltonian

$$\hat{H} = \sum_n \kappa_n \hat{C}_n[G] + \sum_n \kappa'_n \hat{C}_n[G'] + \cdots , \tag{3}$$

where κ_n are coefficients and $\hat{C}_n[G]$ denotes a Casimir invariant of the algebra G of order n in its generators. Since $\hat{C}_n[G]$ commutes with all elements of G (by definition), one can easily convince oneself that $\hat{H}$ in (3) is written as a sum of commuting operators; as a result its eigenstates are labelled by the quantum numbers associated with these commuting operators. Note that the condition of the *nesting* of the algebras is crucial for constructing a set of commuting operators and hence for obtaining an analytical solution. Also, although (3) is written in an abstract form in terms of Casimir invariants, it should be emphasised that it corresponds to a particular choice of the general hamiltonian (1) with the order of the interactions determined by the maximal order n of the invariants. Thus a *generic* scheme is established for finding all analytically solvable hamiltonians (1).

This approach to find analytical eigensolutions for a system of interacting bosons and/or fermions has received prominence with the work of Arima and Iachello [1] who proposed a U(6) dynamical algebra for the description of collective nuclear excitations.

These ideas have been further developed in my research over the last few years and, in particular, three aspects have been highlighted:

1. *Dynamical symmetries of the nuclear shell model.* It should indeed not be forgotten that, although these symmetry methods certainly crystalised with the work of Arima and Iachello, they had been used before in the context of the nuclear shell model and in different models of physics in general. One of the purposes of the review [2] was to summarise these older ideas due to Wigner, Racah and Elliott and to cast them into a form that made clear the connection with the approach of Arima and Iachello.

2. *Partial dynamical symmetries.* A dynamical symmetry requires the single-particle energies ϵ_i and the two-body interactions v_{ijkl} to satisfy certain conditions that imply the solvability of *all* eigenstates of the hamiltonian (1). Recently, it has become clear that these conditions can be relaxed: hamiltonians can be constructed for which *all* dynamical symmetries G, G',... are conserved for *part* of the eigenspectrum [3] or for which *part* of the dynamical symmetries are conserved for the *entire* eigenspectrum [4]. The implications of these generalisations are still under investigation.

3. *(Partial) dynamical symmetries in other physical systems.* These symmetry-based methods are powerful and applications to other domains of physics are possible. (See, e.g., the monograph [5] for a review of developments in molecular physics.) Preliminary work on quantal systems of current interest (e.g. quantum dots and artificial atoms) has been carried out and will receive increasing attention in future research.

[1] F. Iachello and A. Arima, *The Interacting Boson Model* (Cambridge University Press, Cambridge, 1987).
[2] P. Van Isacker, Rep. Progr. Phys. **62** (1999) 1661.
[3] Y. Alhassid and A. Leviatan, J. Phys. A **25** (1992) L1265.
[4] P. Van Isacker, Phys. Rev. Lett. **83** (1999) 4269.
[5] A. Frank and P. Van Isacker, *Algebraic Methods in Molecular and Nuclear Physics* (Wiley-Interscience, New York, 1994).

Nuclear supersymmetry stands the test

P. Van Isacker
GANIL, BP 55027, F-14076 Caen Cedex 5, France

Applications of supersymmetry that link the properties of boson-like (even-mass) and fermion-like (odd-mass) nuclei have been proposed in the eighties in the context of different models of varying complexity. Only recently, as the culmination of sustained effort by many people, the most complex scheme that involves odd–odd nuclei has been validated experimentally.

The distinction between bosons and fermions is one of the most fundamental aspects of quantum theory. Bosons are the mediators of the forces in nature (photons, W and Z bosons, gluons, gravitons) and have integer spin while fermions are the matter particles (electrons, quarks, neutrinos, etc.) and have half-integer spin. Bosons and fermions have fundamentally different statistical properties: bosons are sociable and do not object to sharing the same quantum numbers with each other. Fermions, on the other hand, shy away from each other because the Pauli exclusion principle forbids them from occupying the same quantum state.

One of the major breakthroughs in physics this century has been the development of theories that treat bosons and fermions on an equal footing. Thus each elementary boson has a much heavier 'supersymmetric' partner that is a fermion and vice versa. The photon has a massive partner called the 'photino', for instance, while each quark is partnered by a corresponding 'squark' and so on. Currently there is no evidence for supersymmetric particles despite dedicated searches at the world's high-energy particle accelerators.

Nuclear physics also has its supersymmetric theory. The mathematical theory behind this is the same as in elementary particle physics. The physics of nuclear supersymmetry is somewhat more mundane than the high-energy version but, on the other hand, has already been subjected to direct experimental verification.

In the standard portrayal of the nucleus, known as the nuclear shell model, the core of the atom is described in terms of a collection of interacting nucleons (i.e. neutrons and protons) all of which are fermions. Since tens, even hundreds of nucleons may be involved, this description can be complex and there is no exact solution that can account for all the properties of such a nucleus. Fortunately, the nuclear interaction encourages identical nucleons to pair up (i.e. protons with protons and neutrons with neutrons) so that they behave like bosons that can then be treated as nuclear building blocks. The first model of the nucleus in terms of interacting bosons was proposed in 1975 by Akito Arima and Francesco Iachello [1,2].

In 1980 Iachello realised [3] that supersymmetric theory could also be applied to nuclei because of the simultaneous occurrence of fermions and bosons, albeit effective bosons made from pairs of fermions. In practice, a nucleus containing an even number of protons and neutrons (an even–even nucleus) could be linked to a nucleus comprising an even number of protons and an odd number of neutrons (even–odd) or one with an odd number of protons and even number of neutrons (odd–even).

Iachello's suggestion prompted frantic activity as several experimental teams around the world sought to verify the validity of the conjectured relation between nuclei that previously had been thought to behave very differently. And several pairs of nuclei—such as ^{190}Os (even–even) and ^{191}Ir (odd–even), and ^{194}Pt (even–even) and ^{195}Pt (even–odd)—were indeed found to obey the relations proposed by Iachello. Later several experimental teams found more supersymmetric pairs of nuclei providing firm evidence for this aspect of nuclear supersymmetry (for a review, see [4]). In all these examples, the nuclei in each pair differed from one another by either a single proton or a neutron. There was, however, one piece missing from this nuclear supersymmetric jigsaw. It should be possible to further transform both an odd–even nucleus and an even–odd nucleus into one with an odd number of both protons and neutrons.

In 1985 we proposed [5] that the properties of quartets of nuclei (consisting of an even–even, an even–odd, an odd–even and an odd–odd member) could be linked by supersymmetry. Although the proposed theoretical formalism of 'quartet supersymmetry' was elegant, there was scant experimental evidence for it. In particular, data were lacking on the fourth, odd–odd member of the proposed quartets.

In 1991 Jan Jolie set up a research programme to investigate the problem in detail (see the news item [6] in Physics World). In recent years he has led several research teams and used a range of different nuclear reactions to painstakingly map out the energy spectrum of ^{196}Au (an odd–odd nucleus). Its spectrum can be predicted by applying supersymmetric transformations to the previously well measured energy spectra of ^{194}Pt and ^{195}Au, and the energy spectrum of ^{195}Pt, which was remeasured in the course of this investigation.

For example, in one of the reported experiments ^{197}Au was bombarded with polarized deuterons [7]. A particular reaction involved the deuteron picking up a neutron, hence transmuting the target nucleus into an excited state of ^{196}Au. Jolie and co-workers measured the energy and scattering angle of the outgoing triton and studied the decay of ^{196}Au as it emitted gamma rays to learn about the excited states of ^{196}Au. The researchers also studied other reactions involving different combinations of projectile and target nuclei at several energies to crosscheck the results. The team established several new energy levels in the ^{196}Au spectrum due to the improved energy resolution of their gamma-ray detector compared with earlier experiments. The revised energy spectrum now agrees with the supersymmetry prediction based on a fit to the energy spectra of the three other nuclei in the quartet, and thus vindicates the theory (see Figure 1).

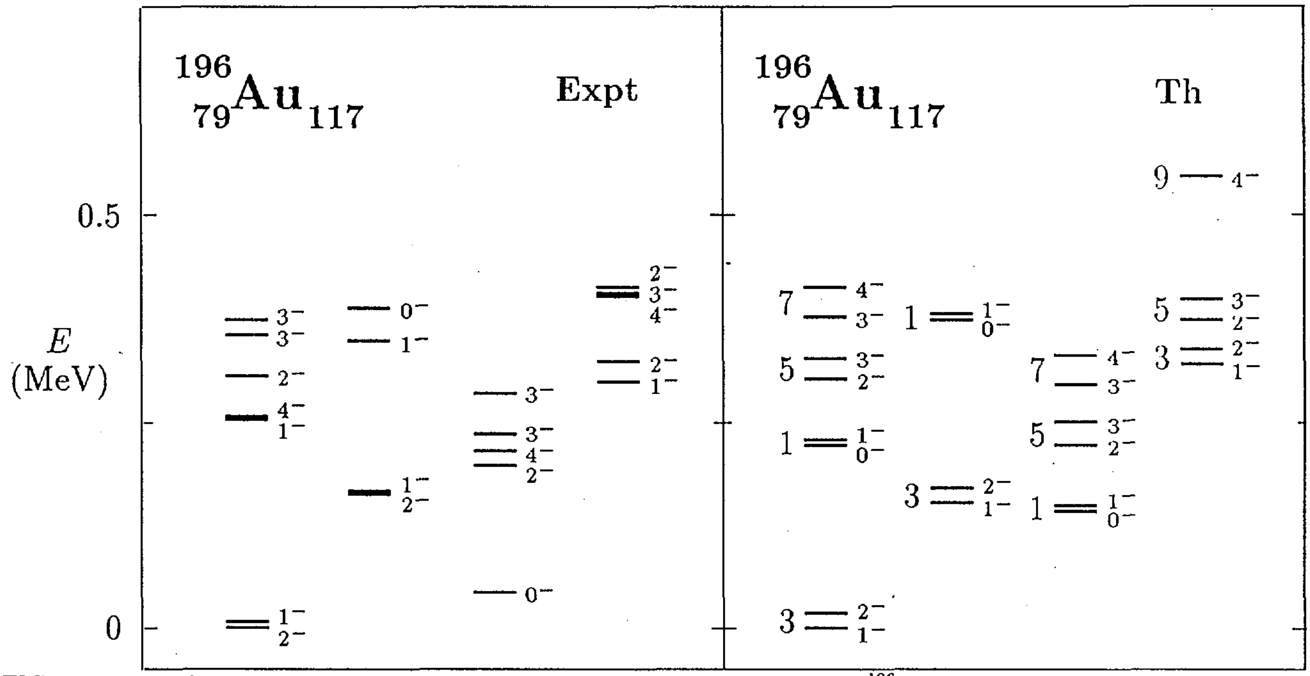


FIG. 1. Observed and calculated energy spectrum of negative-parity states in ^{196}Au. Levels are labelled by their angular momentum and parity J^{π} (right) and an additional quantum number $\tilde{L}$ (left). The theoretical result is obtained from a fit to the three other nuclei in the quartet.

The search is now on for more examples of nuclear quartets to acquire a microscopic understanding of nuclear supersymmetry in terms of nucleon–nucleon interactions.

---

[1] A. Arima and F. Iachello, *Phys. Rev. Lett.* **35** (1975) 1069.
[2] F. Iachello and A. Arima, *The Interacting Boson Model* (Cambridge University Press, Cambridge, 1987).
[3] F. Iachello, *Phys. Rev. Lett.* **44** (1980) 772.
[4] F. Iachello and P. Van Isacker, *The Interacting Boson–Fermion Model* (Cambridge University Press, Cambridge, 1991)
[5] P. Van Isacker, J. Jolie, K. Heyde and A. Frank, *Phys. Rev. Lett.* **54** (1985) 653.
[6] P. Van Isacker, Physics World **12** No 10 (1999) 19.
[7] A. Metz, J. Jolie, G. Graw, R. Hertenberger, J. Gröger, C. Günther, N. Warr and Y. Eisermann, *Phys. Rev. Lett.* **83** (1999) 1542.

Phase transitions in finite systems: curvature anomalies in the thermodynamical potential

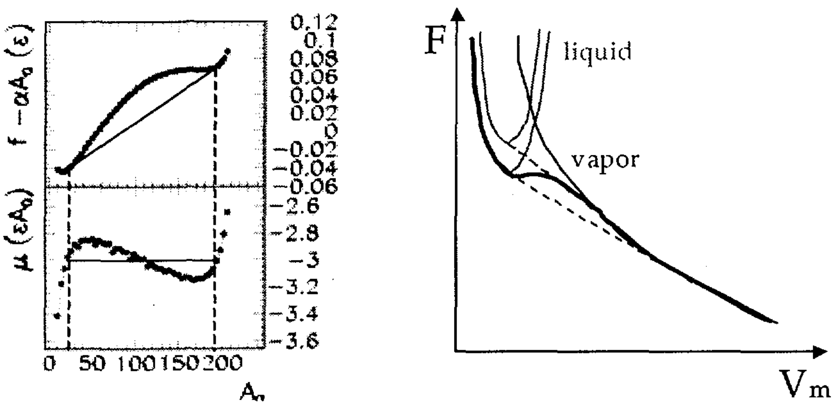
F.Gulminelli, Ph.Chomaz, V.Duflot

LPC-GANIL

It has been proposed that first order phase transitions in finite systems can be univocally signed through a curvature anomaly of the entropy[1,2]. As the energy deposited in a system is increased, the sudden opening of a collective channel causes a convexity in the entropy. This convex intruder cannot be cured by including mixed partitions within the usual Maxwell construction because of the interphase surface entropy which is negligeable only in the thermodynamical limit. As a result the specific heat shows a negative branch .

This idea can been generalized to any statistical ensemble with at least one extensive variable allowing to sample the coexistence region[3] . Let us consider a generic extensive observable *b*. The statistical ensemble where *b* (and only *b*) is fixed is associated to the thermodynamical potential $\bar{W}(b)$.

If the system is undergoing a first order phase transition and *b* can be considered as (one of the) order parameters of the transition, then $\bar{W}(b)$ will present a concavity anomaly in the transition region. If one defines the intensive variable conjugated to *b* , $\lambda = d\bar{W}/db$, the function $\lambda(b)$ will show a backbending in the coexistence region and $d\lambda/db$ will have a negative branch. Two examples taken from the liquid gas phase transition in the canonical ensemble are illustrated in figure 1.



The exact canonical partition function of the lattice gas model is calculated [3] at a subcritical temperature. A clear convexity anomaly is apparent leading to a backbending in the chemical potential and a region of negative susceptibility $\chi = \partial\mu/\partial A$. A standard Maxwell construction (straight line in figure 1) would correspond to mixed partitions obtained as a linear combination of a liquid-like fraction at a high mass A_l and a vapor-like fraction at a low mass A_v in proportions α and $(1-\alpha)$ respectively. At the thermodynamical limit such partitions have a free energy $f = \alpha f_l + (1-\alpha) f_v$, with f_l (f_v) the free energy per particle of the liquid (vapor). However for the finite system mass conservation implies that in the coexistence region ($A_v < A < A_l$) the liquid fraction is smaller than A_l and consequently its surface free energy is higher. The free energy per particle of the mixed partitions will then be higher than the estimation from the Maxwell construction. The very same physical effect is visible in the right part of figure 1 which shows an analytical calculation of the free energy of a finite liquid drop in equilibrium with its vapor schematized as an ideal gas [4]. For a given value of the molar volume, the equilibrium pressure is given by the slope of the tangent construction between the liquid drop and the vapor free energy. As the vapor fraction increases, the liquid drop size decreases and its free energy is shifted upwards; the slope of the tangent consequently increases, leading to a concave intruder in the free energy and a backbending in the p(V) equation of state, i.e. a region of negative compressibility.

Figure 1 implies that convexity anomalies in first order phase transitions are not restricted to the microcanonical ensemble; in particular concerning the liquid-gas phase transition both the volume V and the particle number A can be considered as order parameters; the phase transition in a finite system can be signed by negative compressibility and susceptibility and not only by a negative microcanonical heat capacity as previously proposed [2].

1cm

[1] M.S.S.Challa and J.H.Hetherington, Phys.Rev.Lett. 60 (1988) 77.

[2] D.H.E. Gross, cond-mat/0004268, cond-mat/0006087

[3] F.Gulminelli and P.Chomaz, Phys. Rev. Lett. 82 (1999) 1402.

[4] L.G.Moretto et al., nucl-th/0012037

Topology of event distributions and phase transitions in finite systems

F.Gulminelli, Ph.Chomaz, V.Duflot

LPC-GANIL

It has been proposed to define and classify phase transitions in finite systems either according to the distribution of zeroes of the canonical partition sum in the complex temperature plane [1] or through a curvature anomaly of the microcanonical entropy[2]. We propose the possible bimodality of the probability distribution of observable quantities as a connection between these ideas.

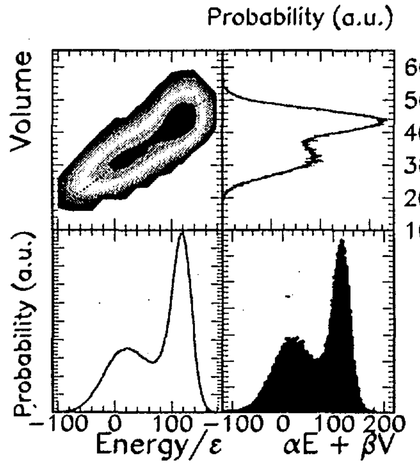
Let us consider a set of K independent observables, $\hat{B}_k$, which form a space containing one possible order parameter. We can sort events according to the results of the measurement $\mathbf{b}^{(i)} \equiv (b_k^{(i)})$ and thus define a probability distribution $P(\mathbf{b})$. In the absence of a phase transition $\log P(\mathbf{b})$ is expected to be concave. An abnormal (e.g. bimodal) behavior of $P(\mathbf{b})$ or a convexity anomaly signals a phase transition.

This definition of phase transition from the topology of $P(\mathbf{b})$ generalizes the definitions based on convexity anomalies of thermodynamical potentials. Any Boltzmann-Gibbs equilibrium is obtained by maximizing the Shannon information entropy $S \equiv -\mathrm{Tr}\hat{D}\log\hat{D}$ ($\hat{D}$ being the density matrix) under the constraints of the various observables $\hat{B}_k$ known in average. Then $P(\mathbf{b})$ can be written as

$$\log P_{\mathcal{F}\lambda\alpha}(\mathbf{b}) = \log \bar{W}_{\mathcal{F}\lambda}(\mathbf{b}) - \sum_{k=1}^{K} \alpha_k b_k - \log Z_{\mathcal{F}\lambda\alpha} \qquad \#$$

where α_k are Lagrange multipliers and $\bar{W}(\mathbf{b}) = Z_0 P_0(\mathbf{b})$ is the partition sum of the statistical ensemble associated with fixed values, $\mathbf{b}$, of all the observables. Indeed, the two partition sums are related through the usual Laplace transform $Z_\alpha = \int d\mathbf{b}\ \bar{W}(\mathbf{b})\exp(-\boldsymbol{\alpha}\mathbf{b})$. Eq.(1) clearly demonstrates that the convexity anomalies of the thermodynamical potential $\log \bar{W}(\mathbf{b})$ can be traced back from $\log P_\alpha(\mathbf{b})$. If $\bar{W}$ has an abnormal curvature, then α_k presents a back-bending.

Let us take the example of the liquid-gas phase transition in a system of n particles for which only the average volume is known. In such a case we can define an observable $\hat{B}_1$ as a measure of the size of the system; for example the cubic radius $\hat{B}_1 = \sum_i \hat{r}_i^3 \equiv \hat{V}$. Then a Lagrange multiplier λ_V has to be introduced which has the dimension of a pressure divided by a temperature. In a canonical ensemble with an inverse temperature β a complete information is contained in the distribution $P_{\beta\lambda_v}(e,v) = \bar{W}(e,v) Z_{\beta\lambda_v}^{-1} \exp - (\beta e + \lambda_v v)$. This leads to the density of states $\bar{W}(e,v)$ with a volume v and an energy e. In the first order phase transition region the probability distribution presented in figure 1 is bimodal. We can look for an order parameter $\hat{Q} = x\hat{E} + y\hat{V}$ which provides the best separation of the two phases.



On the other hand if we cannot measure both the volume v and the energy e we are left either with $P_{\beta\lambda_v}(e)$ giving access to the isobar microcanonical partition sum $\bar{W}_{\lambda_v}(e)$ or with the probability $P_{\beta\lambda_v}(v)$ leading to the isochore canonical partition sum $\bar{Z}_{\beta}(v)$. Since both probability distribution are bimodal the associated partition sum do have anomalous concavity intruders ,*i.e.* negative heat capacity as well as negative compressibility.

The presented definition can be related to the usual one at the thermodynamical limit. In fact one can show [3] that within a double saddle point approximation the loci of zeroes of the partition sum Z_{α}corresponds to a line perpendicular to the real axis with a uniform distribution as expected for a first order phase transition. If the order parameter is sufficiently collective it will survive until the infinite volume and infinite number limit. If the anomaly also survives the saddle point approximation will be correct and the finite size phase transition becomes the one known in the bulk.

1cm

[1] P.Borrmann et al., Phys.Rev.Lett.84 (2000)3511.
[2] D. Gross, cond-mat/0004268 and 0006087
[3] Ph.Chomaz et al., cond-mat 0010365 and Phys.Rev.E, in press.

Bimodality in non-extensive statistics

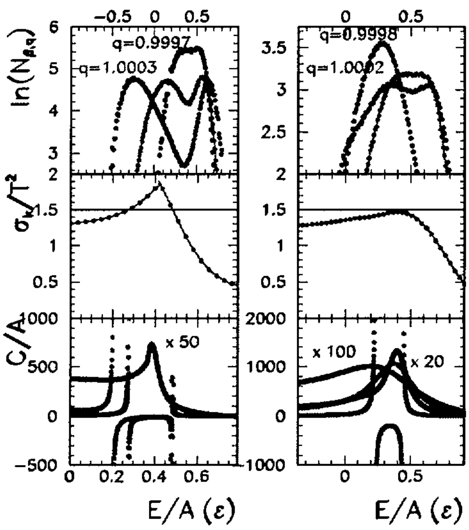
F.Gulminelli, Ph.Chomaz, V.Duflot

LPC-GANIL

We propose a definition of first order phase transitions in finite systems based on topology anomalies of the event distribution in the space of observations. This proposed definition is already under application in experiments[1] and allows to study phase transitions in Gibbs equilibria as well as in other ensembles such as the Tsallis ensemble. Let us consider a set of K independent observables, $\hat{B}_k$, which form a space containing one possible order parameter. We can sort events according to the results of the measurement $\mathbf{b}^{(i)} \equiv (b_k^{(i)})$ and thus define a probability distribution $P(\mathbf{b})$. In the absence of a phase transition $\log P(\mathbf{b})$ is expected to be concave. An abnormal (e.g. bimodal) behavior of $P(\mathbf{b})$ or a convexity anomaly signals a phase transition. More specifically, the larger eigenvalue of the tensor

$$T_{\xi}^{k,k'} \equiv \frac{\partial^2 \log P(\mathbf{b})}{\partial b_k \partial b_{k'}} \quad \#$$

becomes positive in presence of a first order phase transition. The associated eigenvector defines the local order parameter since it allows the best separation of the probability $P(\mathbf{b})$ into two components which can be recognized as the precursors of phases. If the largest eigenvalue is zero, the number of higher derivatives which are also zero defines the order of the phase transition.



The definition of phase transition from the topology of $P(\mathbf{b})$ contains and generalizes the definitions based on convexity anomalies of thermodynamical potentials [2]. Moreover it can be extended to other ensembles of events which do not correspond to a Gibbs statistics. As an example, we analyze the consequence of going from Gibbs to Tsallis[3] ensemble, for a system controlled by an external parameter λ (e.g. a pressure). For a given λ the system is characterized by a density of states $\bar{W}_\lambda(e)$. For a critical value of $\lambda = \lambda_c$ the associated entropy $S_\lambda(e) = \log \bar{W}_\lambda(e)$ presents a zero curvature and below a convex intruder. The Tsallis probability distribution reads ($q_1 = q - 1$) [3]

$$P^q_\lambda(e) = \bar{W}_\lambda(e)(1+q_1\beta e)^{-q/q_1}/Z^q_\lambda$$

Computing first and second derivatives of $\log P^q_\lambda$ one can see that the maximum of $\log P^q_\lambda$ occurs for the energy which fulfills the relation $\bar{T}_\lambda = (\beta^{-1} + q_1 e)/q$ where $\bar{T}$ is the microcanonical temperature while this point has a null curvature if $\bar{C}_\lambda = q/q_1$ where $\bar{C}_\lambda$ is the microcanonical heat capacity. Then the Tsallis critical point occurs above the microcanonical critical point and one expects a broader coexistence zone in the Tsallis ensemble. The curvature at the maximum of P^q_λ is $\bar{T}^2\partial^2_e \log P^q_\lambda = -1/\bar{C}_\lambda + q_1/q$. Far from the C divergence line, this curvature is not very different from the microcanonical heat capacity as long as q_1/q is small. The canonical and Tsallis distribution (q=1.2) are compared in figure 1. It is clear that the phase transition can be identified through the bimodality of the event distribution in the non extensive Tsallis statistics even if the associated properties such as the position of the critical point do change with the ensemble [4].

1cm

[1] M. Schmidt et al., Nature 393, 238 (1998) and to be published ;

O.Lopez et al., cont. to the XXXIX Win. Meet. on Nucl. Phys., Bormio (Italy), Ed. I. Iori, (2001) in press.

[2] Ph.Chomaz et al., cond-mat 0010365 and Phys.Rev.E, in press.

[3] C. Tsallis et al, Phys. A261 (1998) 534

[4] K.K.Gudima et al., Phys.Rev.Lett.85 (2000)4691.

Anomalous radial expansion of non-spherical source in central heavy-ion reactions

A. Le Fevre, K. Morawetz, M. Płoszajczak and V.D. Toneev

MPI-Dresden - Dubna - GANIL - GSI Collaboration

The shape influence of decaying thermalized source on various characteristics of multifragmentation as well as its interplay with effects of angular momentum and collective expansion have been studied in the extended statistical microcanonical multifragmentation model [1,2]. Due to the change in the Coulomb energy for deformed freeze-out configuration, the shape effect is clearly seen in the IMF's angular distributions (Z_{max}- angular distribution) as well as in the Θ_{flow} - distribution [2]. A surprising interplay between effects of non-spherical freeze-out shapes and the memory effects of nonequilibrium phase of the reaction, such as the rotation and the collective expansion of the source, has been demonstrated for the first time. The collective expansion allows to disclosure the source shape in the analysis using global variables as well as in the study of Z-dependence of the average kinetic energy. The shape of the average kinetic energy of fragments $E_k(Z)$ contains information about the exponent α in the parametrization of the collective radial expansion $v_b(r) = v_0 (r/R_0)^{\alpha}$, and to the lesser extend about the deformation of the source [2]. Comparison of the present model with the experimental data for central $Xe + Sn$ collisions at 50 $A \cdot MeV$ clearly shows the prolate deformation of the fragmenting source and the non-hubblean radial expansion ($\alpha > 1$) [2]. These results have been examined in the framework of the kinetic theory [3] where we found that in central heavy-ion reactions in the Fermi energy domain the radial expansion is non-hubblean and in the surface region scales proportional to a higher exponent ($\alpha > 1$) of the radius. The anomalous expansion velocity profile is accompanied by a power law nucleon density profile in the surface region [3]. Both these features of central heavy-ion reactions disappear at higher energies, and the system follows a uniform Hubble expansion ($\alpha \simeq 1$).

[1] D.H.E. Gross, Rep. Prog. Phys. **53** (1990) 605.

[2] A. Le Fevre, M. Płoszajczak, V.D. Toneev, Phys. Rev. **C 60** (1999) 051602.

[3] K. Morawetz, M. Ploszajczak, V.D. Toneev, Phys. Rev. **C 62** (2000) 064602.

Nuclear multifragmentation and phase transitions in the non-extensive statistics

R. Botet, J. González, K. Gudima, A.S. Parvan, M. Płoszajczak and V.D. Toneev

Caracas - Dubna - GANIL - Kishineu - Orsay Collaboration

We have applied the canonical quantum statistical model of nuclear multifragmentation generalized in the framework of recently proposed Tsallis non-extensive thermostatistics for the description of nuclear multifragmentation process [1]. This new model provides an alternative way of thinking about intuitively expected deviations from the thermodynamical equilibrium due to non-extensive correlations in the multifragmentation process. The test calculation in the system with $A = 197$ nucleons shows strong modification of the 'critical' behaviour associated with the nuclear liquid-gas phase transition for small deviations from the conventional Boltzmann-Gibbs statistical mechanics. To understand these intriguing results, we have investigated analytically the spherical spin model with infinite-range ferromagnetic interactions in the framework of non-extensive thermostatics [2]. We have shown that for repulsive correlations, a new weak-ferromagnetic phase develops in the spin system, in addition to standard paramagnetic and ferromagnetic phases. There is a tricritical point separating para, weak-ferro and ferro regimes. The transition from paramagnetic to weak-ferromagnetic phase is an unusual first order phase transition in which a discontinuity of the averaged order parameter appears, even for finite number of spins. This result puts in a new way the question of the stability of critical phenomena with respect to the long-ranged correlations.

[1] K.K. Gudima, A.S. Parvan, M. Płoszajczak and V.D. Toneev, Phys. Rev. Lett. **85** (2000) 4691.
[2] R. Botet, M. Płoszajczak and J.A. Gonzales A., Phys. Rev. **E** (2001), in print.

Universal features of fluctuations

R. Botet[1] and M. Płoszajczak[2]

[1] *Laboratoire de Physique des Solides - CNRS, Bâtiment 510, Université Paris-Sud, Centre d'Orsay, F-91405 Orsay*
[2] *GANIL*

Universal scaling laws of fluctuations (the Δ-scaling laws) can be derived for equilibrium and off-equilibrium systems when combined with the finite-size scaling analysis [1]. In any system in which the second-order critical behavior can be identified, the relation between order parameter, criticality and scaling law of fluctuations has been established and the relation between the scaling function and the critical exponents has been found. The theory has been applied to out-of-equilibrium aggregation models such as the Smoluchowski kinetic equations, the at-equilibrium Ising and percolation models. The universal scaling of fluctuations has been also demonstrated experimentally in heavy-ion collisions in the Fermi energy domain [2]. In these latter studies, charged fragments multiplicity and the charge of the largest fragment Z_{max} fluctuations for $Xe + Sn$ collisions in the range of bombarding energies between 25 $A \cdot MeV$ and 50 $A \cdot MeV$ have been shown to manifest model and approximation independent universal features of fluctuations which are expected in either ordered (low temperature) or disordered (high temperature) phases of matter.

[1] R. Botet and M. Płoszajczak, Phys. Rev. **E62** (2000) 1825;
- R. Botet and M. Płoszajczak, Nucl. Phys. **B** (Proc. Suppl.) **92** (2001) 101.
[2] R. Botet, M. Płoszajczak, A. Chbihi, B. Borderie, D. Durand and J. Frankland, Phys. Rev. Lett. **86** (2001) 3514.

2 - EXOTIC NUCLEI : REACTIONS

The detection of neutral nuclei

F.M. Marqués, M. Labiche, N.A. Orr

Laboratoire de Physique Corpusculaire,
IN2P3-CNRS, ISMRa et Université de Caen, F-14050 Caen cedex, France

for the E295 collaboration[1]

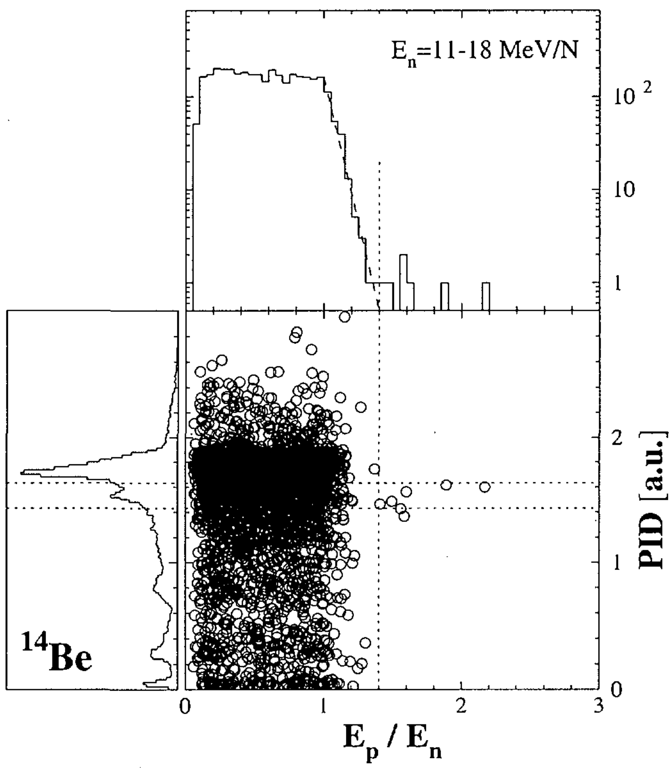
Going beyond the two-neutron haloes, it is interesting to speculate that multineutron halo systems and other very neutron-rich nuclei may contain components of the wave function in which the neutrons present a relatively compact cluster-like configuration. If bound multineutrons exist, they could therefore be emitted following the breakup of beams of such nuclei.

To date the majority of searches for multineutron clusters have relied on very low cross-section (typically $\sim$ 1 nb) direct reactions of the type $a(b,c)^{A}$n. In the breakup of very neutron-rich nuclei, relatively high cross-sections (typically $\sim$ 100 mb) are encountered. Consequently, even only a small component of the wave function corresponding to a multineutron cluster could result in a measurable yield with a moderate secondary beam intensity.

The main difficulty lies in the direct detection of a ^{A}n cluster liberated following the breakup. The technique that we have adopted is based on the detection of the recoiling proton in the liquid scintillator modules of DEMON [1,2]. Following n-p scattering, the proton recoils with an energy (E_p) up to that of the incident neutron. This may then be compared to the energy per nucleon of the incident particle derived from the time-of-flight (E_n). For a single neutron and an ideal detector $E_p/E_n \leq 1$ —taking into account finite resolutions the limit is $\sim$ 1.4. In the case of a multineutron cluster, E_p can exceed the incident energy per nucleon and E_p/E_n may take on a range of values extending beyond 1.4, up to $\sim$ 2.5 for a ^{3,4}n cluster.

The method has been applied to previous data from the breakup of ^{11}Li and ^{14}Be on C target. In the case of the ^{14}Be beam, 7 events have been observed with $E_p/E_n > 1.4$, all within the region centred on the ^{10}Be peak. After detailed analyses of the kinematics of these events and of the various backgrounds that may mimic such a signal, 6 events have been found to be consistent with the production and detection of a multineutron cluster. Special care has been taken to estimate the effects of pile-up, the detection of two or more neutrons in a single module. Three independent approaches were applied and it was concluded that at best pile-up may account for some 10 % of the observed signal. The formation of a bound tetraneutron in the breakup of ^{14}Be into ^{10}Be+^{4}n appears to be the most probable scenario.

The confirmation of the events observed with a higher intensity ^{14}Be beam, and the search for similar events in the breakup of ^{8}He, are being planned.



Scatter plot, and the projections onto both axes, of the particle identification parameter versus E_p/E_n for the data from the reaction C(^{14}Be,X+n). The PID has been projected for all neutron energies. The dotted lines correspond to $E_p/E_n = 1.4$ and to the region centred on the ^{10}Be peak [1].

[1] F.M. Marqués *et al.*, nucl-ex/0111001.
[2] N.A. Orr, nucl-ex/0108024.

SEARCH FOR TWO PROTON EMISSION IN LIGHT NUCLEI AT THE PROTON DRIP-LINE

T. Zerguerras[a)], D. Beaumel[a)], B. Blank[b)], Y. Blumenfeld[a)], M. Chartier[b)], M. Fallot[a)], J.Giovinnazzo[b)], C. Jouanne[c)], V. Lapoux[c)], I. Lhenry-Yvon[a)], W. Mittig[d)], P. Roussel-Chomaz[d)], H. Savajols[d)], J.A. Scarpaci[a)], A. Shrivastava[a)], T. Suomijärvi[a)] and M. Thoennessen[e)]

a) Institut de Physique Nucléaire, IN_2P_3-CNRS, 91406 Orsay, France

b) CEN Bordeaux-Gradignan, Le Haut-Vignau, F-33175 Gradignan Cedex, France

c) SPhN, DAPNIA, CEA Saclay, 91191 Gif sur Yvette Cedex, France

d) GANIL, BP 5027, 14021 Caen Cedex, France

e) NSCL, Michigan State University, East Lansing, Mi 48824, USA

One of the opportunities opened by the development of radioactive beam facilities is the study of nuclei located near and beyond the proton drip-line. New phenomena are predicted for light nuclei like the existence of proton halos and the two proton decay [1]. Two proton decay may occur through three mechanisms: a sequential emission through an intermediate state, a simultaneous emission of uncorrelated protons, also called democratic decay, or a diproton emission, i.e emission of a ^{2}He cluster with very strong *pp* correlations. The observation of this last decay mode could provide insight into clustering and three-body effects in nuclei.

Several experimental searches for diproton decay have been carried out over the last years. Only the first two processes have been clearly experimentally identified. Ground state two proton decay of ^{12}O ([2]) follows a sequential path through ^{11}N. The ground state $^6Be \to \alpha + p + p$ decay is fully democratic [3]. Other investigations on the decay of some resonant states have been performed. The most recent result was the observation of two proton decay from a resonant state of ^{18}Ne but it was not possible to distinguish between a ^{2}He emission or a democratic three-body decay [4].

In our experiment, the aim was to observe the 2p decay of several candidates around A=20. The method consists in detecting the three ejectiles, i.e. the two protons and the daughter nucleus, and measuring their energies and their emission angle, to reconstruct the invariant mass of the decaying nucleus. The experiment was performed at GANIL by using a secondary beam of ^{18}Ne (87% at 36MeV/A),^{17}F (11%, at 33MeV/A) and ^{20}Mg (2%, at 43MeV/A), produced by fragmentation of a primary beam of ^{24}Mg, at 95MeV/A and an intensity of 700nAe, on a 600mg/cm^2 ^{12}C production target. The radioactive beam bombarded a secondary 47mg/cm^2 ^{9}Be target to form unbound states.

Light charged particles were detected in the MUST array [5], located at 400mm from the ^{9}Be target, which provides identification, position and energy measurement of the protons. This detector consists of eight large area 60 $\times$ 60mm^2 double sided Si-strip, Si(Li), CsI telescopes. The four telescopes which covered the lower angle values, between 2^o and 12^o were equiped for the first time with four independant 29.5 $\times$ 29.5 $\times$ 30mm^3 CsI crystals, read out by photodiodes, in order to increase the granularity. The entire MUST array covered angles between 2^o and 20^o. Protons were identified through the E-ΔE method, using energy loss measurements in the strip and Si(Li) detectors. Because of the large emittance of the secondary radioactive beam, two MWPC chambers, the CATS [6], were used to reconstruct the trajectory of the incident nucleus. Charge and mass identification as well as momentum and emission angle of the daughter nucleus were provided by the SPEG spectrometer detection set-up.

Two types of coincidence events between decay products have been recorded : one proton and a nucleus, two protons and a heavy nucleus. Thanks to the first one, we could look for one proton emission from unbound states, and with the second check if we observe a possible ^{2}He emission. One proton unbound states have been observed, and the corresponding energy spectra reconstructed. Among them, ^{18}Na was observed for the first time.

Two proton emission from excited states of ^{17}Ne (see fig. 1) has been stud-

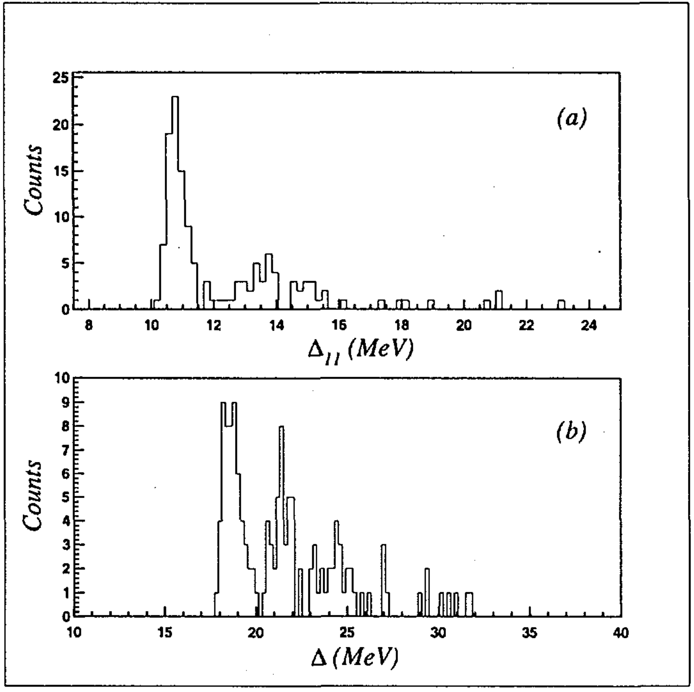


Figure 1: Invariant mass reconstruction: (a) with one of the two protons and the heavy nucleus, (b) with the two protons and the heavy nucleus.

ied. Spectrum (a) shows a partial invariant mass reconstructed with one of the two protons detected and the daughter ^{15}O nucleus. We observed a peak a a position close to the ground state of ^{16}F. Spectrum (b) shows the invariant mass spectrum of ^{15}O reconstructed with the three ejectiles. ^{17}Ne states above the proton emission threshold are observed. The peak in (a) is consistent with a two step desexcitation process where ^{17}Ne, excited above its proton emission threshold, emits one proton to form the unbound nucleus ^{16}F in its g.s or in one of its low lying excited states, which decays on turn by emitting a second proton.

References

[1] V.I. Goldansky, Nucl. Phys. **19**, 482 (1960).

[2] R.A. Kryger *et al.*, Phys. Rev. Lett. **74**, 860 (1995).

[3] O.V. Bochkarev *et al.*, Sov. J. Nucl. Phys. **55**, 955 (1992).

[4] J. Gómez del Campo *et al.*, Phys. Rev. Lett. **86**, 43 (2001).

[5] Y. Blumenfeld *et al.*, Nucl. Instrum. and Methods **A421**, 471 (1999).

[6] S. Ottini-Hustache *et al.*, Nucl. Instrum. and Methods **A431**, 476 (1999).

Measurement of the correlations in the ^{11}Be breakup and evidences for the towing mode. E337

J.A.Scarpaci[1], D.Lacroix[2], Y.Blumenfeld[1], C.Bourgeois[1], M.Chabot[1], Ph.Chomaz[3], P.Desesquelles[1], V.Duflot[3], J.Duprat[1], M.Fallot[1], N.Frascaria[1], D.Guillemaud-Mueller[1], S.Grévy[2], P.Roussel-Chomaz[3], H.Savajols[3], O.Sorlin[1],

1. Institut de Physique Nucléaire, IN2P3-CNRS, 91406 Orsay, France
2. Laboratoire de Physique Corpusculaire, IN2P3-CNRS, F-14050 Caen Cedex, France
3. G.A.N.I.L., CEA et IN2P3-CNRS, BP 5027, 14076 Caen Cedex, France

The break-up reaction of ^{11}Be on a Ti target was performed at 41 A.MeV in experiment E337. The ^{10}Be ejectile was measured in the SPEG spectrometer providing us with the angle and the momentum, whereas the neutrons were measured in 30 neutron detectors from the Northball array. The 74 BaF2s of the Château de Crystal were surrounding the target for the gamma detection.
Correlations between the ejectile and the neutron allow us to precisely characterize the reaction mechanisms involved in the break-up, in particular for the nuclear break-up. Our quantal calculations [1,2] predict a neutron and a ^{10}Be ejectile on each side of the beam corresponding to the towing mode i.e. the nuclear break-up.

Fig.1 shows the experimental neutron angular distributions when the neutron and the ejectile are measured on opposite sides of the beam (black circles) and the same side of the beam (empty circles). Detectors placed at small angle (<10°) were shielded by the spectrometer but no efficiency correction has been applied so far. However the correlations observed for larger neutron angles (>30°) confirm the dynamic of this break-up.

The two curves shown in Fig.1 come from our calculation of the break-up of ^{11}Be on a ^{48}Ti target. The plain line is for events where the emitted neutron and the ejectile are on opposite sides of the beam and the dashed curve is for emissions on the same side. The reduced angular acceptance of the spectrometer (±2° horizontally and ±0.5° vertically) is not taken into account in our calculations.

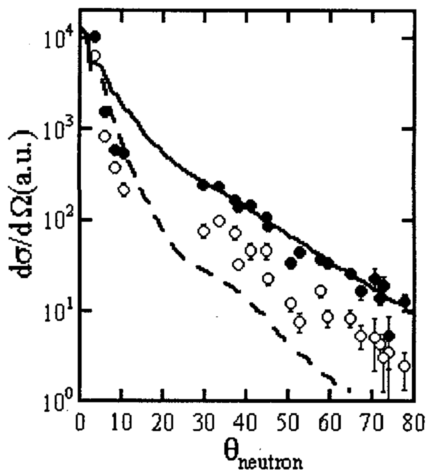


Fig 1: Angular distribution for the neutrons in coincidence with a ^{10}Be on the opposite side of the beam (black circles) and on the same side of the beam (empty circles). Predictions from our calculation are also shown (see text).

A further analysis of the data utilizing the observed gamma decay will allow us to select the *2+* excitation of the target that together with a *1d* neutron wave function of the halo account for about 20% of the ground state of ^{11}Be. In this case we expect to measure a different angular distribution for the neutron, characteristic of a larger angular momentum.

References

[1] D.Lacroix, J.A.Scarpaci and Ph.Comaz, Nucl. Phys. A 658 (1999) 273.
[2] M.Fallot, J.A.Scarpaci, D.Lacroix, Ph.Chomaz et J.Margueron, submitted to nuclear physics.

Cross Sections, Momentum Distributions and Neutron Angular Distributions for ^{11}Be Induced Reactions on Silicon

F. Negoita[1], C. Borcea[1], F. Carstoiu[1,6], M. Lewitowicz[2], M.G. Saint-Laurent[2], R. Anne[2], D. Guillemaud-Mueller[3], A.C. Mueller[3], F. Pougheon[3], O. Sorlin[3], A. Fomitchev[4], S. Lukyanov[4], Yu. Penionzhkevich[4], N. Skobelev[4], Z. Dlouhy[5]

[1]) IFIN-HH, P.O. Box MG-6, 76900 Bucharest-Magurele, Romania
[2]) GANIL(IN2P3/CNRS,DSM/CEA) BP 5027, 14021 Caen Cedex, France
[3]) IPN, CNRS-IN2P3, 91406 Orsay Cedex, France
[4]) FLNR, JINR, 141980 Dubna, Moscow Region, Russia
[5]) NPI, 250 68 Rez, Czech Republic
[6]) Department of Physics, University of Surrey, Guildford, Surrey, GU2 5XH, U.K.

A deeper understanding of ^{11}Be halo structure and its breakup mechanisms has been obtained in an experiment with radioactive beams performed [1] at GANIL with LISE3 spectrometer by means of the separate determination of the two major breakup components: dissociation (nuclear and coulombian) and stripping. The experimental set-up consisted mainly of a stack of silicon detectors which play the role of target, degrader and detection media and an array of neutron detectors operated in coincidence with the telescope [2]. The 43 MeV/nucleon ^{11}Be secondary beam as well as the ^{10}Be breakup fragments are stopped and identified in the telescope. The separation of breakup mechanisms is based on the fact that light charged particles emitted in the stripping reaction after the hard interaction of target with the neutron halo add an extra energy in the reaction detector. Therefore, a cross section integrated over the detector thickness can be obtained for stripping. In the case of a dissociation, due to the fact that the velocity is close to that of the projectile, the stopping power of the propagating particle does not change. The energy loss in the reaction detector is very close to that of ^{11}Be passing without reaction and the reaction detector can not be unambiguously assigned. Instead, the reaction energy can be estimated from the total energy deposited in telescope with the assumption that

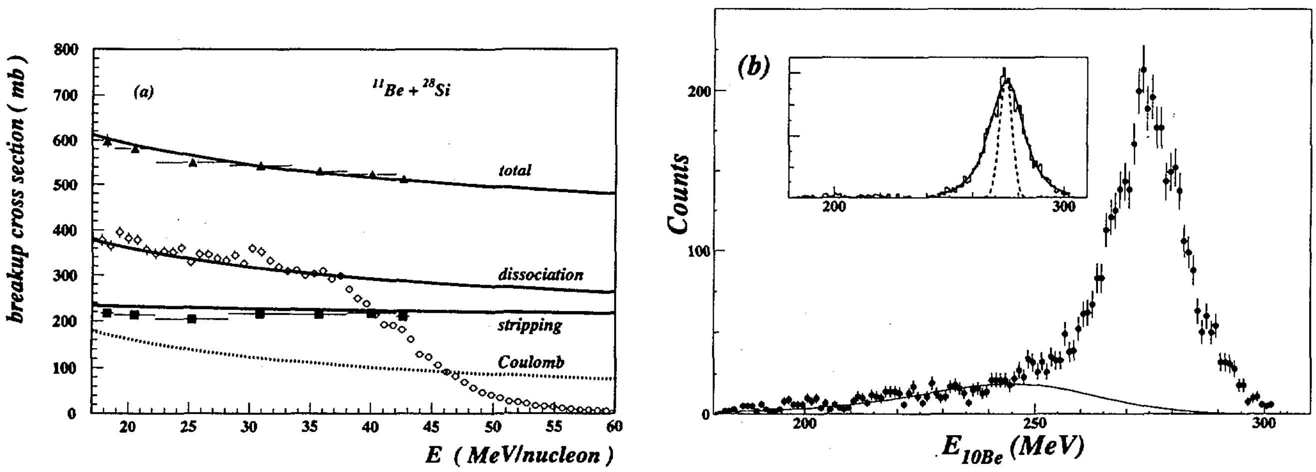


Figure 1: (a) One neutron breakup cross sections as a function of energy. Experimental data are shown by symbols. The full line is the result of the extended Glauber model. Coulomb dissociation is shown separately by dotted line. (b) Energy of the ^{10}Be core at the exit of reaction detector for stripping reactions in the third detector of the telescope. The continuous line represents the contribution of dumped collision breakup. The spectrum resulted after subtraction is plotted in the inset together with the simulation that fits the data. The dashed line is a simulation in which the longitudinal momentum of the core has been set to 0.

the energy of the core-fragment after breakup is in ration $m_{core}/m_{proj.}$=10/11 to the reaction energy at the reaction instant. Thus, a reaction energy spectrum is obtained and transformed in an excitation function. The procedure has been carefully tested on Monte Carlo simulated events [1, 3]. The cross sections results are plotted in Fig. 1(a). The fall of the experimental dissociation cross section around the incident energy is due to the deviation of core energy from the mentioned mean energy and gives access to the longitudinal momentum distribution of the core. A width of FWHM=40.5±1.5 MeV/c has been extracted for dissociation.

The longitudinal momentum distribution for stripping is determined form the energy of the core-fragment after the reaction detector. Such a spectrum is plotted in Fig. 1(b) for stripping in the third detector. The neutron measurements, after geometrical and intrinsic efficiency corrections, reveal that the about 50% of the ^{10}Be present in the left side tail of the distribution have an accompanying neutron with a velocity close to that of the projectile. We conclude that for these events the core energy is dumped in the collision with the target and some light charged particles are emitted that account for the extra energy loss in the reaction detector. The core nucleus survives, while the neutron could be or not absorbed in target. The new breakup mechanism was called *dumped collision breakup.* The contribution of this mechanism is drawn in Fig. 1(b). Its shape is given by the distribution of neutron coincident events. After subtraction, the distribution remains simetric and the deduced width of longitudinal momentum distribution is FWHM=44±2 MeV/c..

The two-neutron breakup cross section of ^{11}Be and the charge-changing cross section for both ^{11}Be and ^{10}Be have also been measured. A total reaction cross section of 2.17±0.07 b was then estimated for ^{11}Be at 30 MeV/nucleon. Angular and energy distributions of neutrons coincident with various reaction channels have been obtained, too.

An extended version of the Glauber model has been used to interpret these data. Special emphasis been put on the role played by the halo wave function in the integrated cross sections and momentum distributions. It has been shown that cross section can be expressed as an integral over the impact parameter of a distortion kernel and the halo valence density. The distortion kernel selects localization probabilities in the asymptotic region in a similar way as the Hűfner-Nemes model [4].

The same kernels enter momentum distributions for both mechanisms. Similarly, distortion kernels select only surface momentum components in the Wigner transform of the halo wave function. These features show that breakup reactions are surface peaked reactions and can be also used for astrophysical purposes.

References

[1] F. Negoita et al., Phys. Rev. **C59**(1999)2082.

[2] R. Anne et al., Nucl. Phys. **A575**(1994)125.

[3] J.M. Corre et al., Nucl. Instrum. Meth. **A359**(1995)511.

[4] J. Hűfner and M.C. Nemes, Phys. Rev. **C23**(1981)2538.

Search for t+t clustering in ^{6}He

L. Giot[a], S. Pita[a], P. Roussel-Chomaz[a],G. Ter-Akopian[b], W. Mittig[a], N. Alamanos[c], F. Auger[c], M-D. Cortina-Gil[d], Ch.E. Demonchy[a], J. Fernandez[d], C. Jouanne[c], A. Gillibert[c], V. Lapoux[c], L. Nalpas[c], E.C. Pollacco[c], A. Rodin[b], A. Pakou[a,e],H. Savajols[a], J.L. Sida[c]; S. Stepantsov[b], R. Wolski[b]

[a]*GANIL (DSM/CEA, IN2P3/CNRS), BP 5027, 14076 Caen Cedex 5, France*
[b]*FLNR,JINR, Dubna, P. O. Box 79, 101 000 Moscow, Russia*
[c]*CEA/DSM/DAPNIA/SPhN, Saclay, 91191 Gif-sur-Yvette Cedex, France*
[d]*Dpto Fisica de Particulas, Universidad Santiago de Compostela, 15706 Santiago de Compostela, Spain*
[e] *Department of Physics, The University of Ioannina, 45110 Ioannina, Greece*

The ^{6}He nucleus is now currently used as one of the benchmark nuclei to study the halo phenomenon and 3-body correlations [1], especially because the α-core can very well be represented as inert. However, in order to have a complete and detailed description of the ^{6}He wave function, the question arises whether the only contributions are the cigar and di-neutron configurations, where only ^{4}He and 2-n clusters intervene, or if some t+t clustering is also present.

In the case of ^{6}Li nucleus, it was shown that it was possible to have considerable α+d and ^{3}He+t clustering at the same time, and the importance of both configurations was studied by analysing angular distributions of the ^{6}Li(p,^{3}He)^{4}He reactions [2]. Following the same ideas, we measured recently at GANIL the complete angular distribution for the ^{6}He(p,^{3}H)^{4}He with the SPEG spectrometer and the MUST array, with a special emphasis on the most forward and backward angles which could not be measured in a previous experiment performed at JINR Dubna [3]. The figure presents the experimental set-up used in the present experiment : from right to left, two drift chambers used as beam tracking detectors, the target ladder, and the MUST array divided in two blocks at two symmetric positions around the entrance slits of SPEG. The data are presently under analysis.

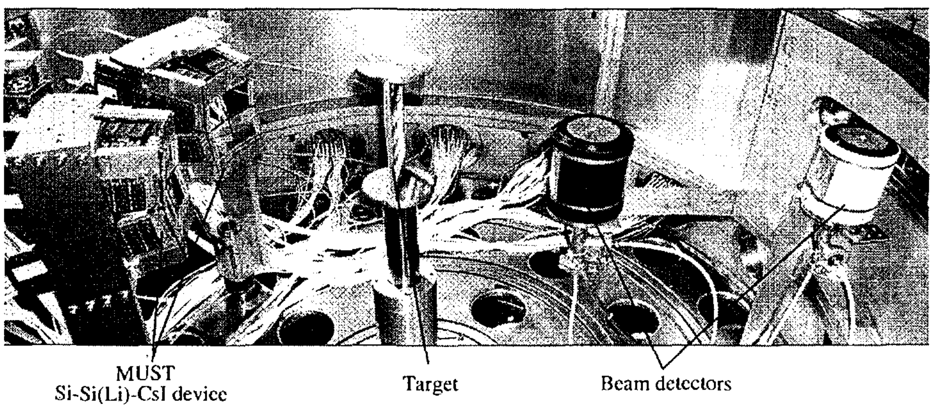


Figure 1: Experimental set-up in the SPEG reaction chamber

[1] M. Zhukov et al., Phys. Rep. 231 (1993) 151
[2] M. F. Werby et al, Phys. Rev. C 8 (1973) 106
[3] R. Wolski et al., Phys. Lett. B 467 (1999) 8

E269 Exotic nuclei
Coupling effects in the elastic scattering of ^{6}He on proton and carbon targets

---

V. Lapoux (vlapoux@cea.fr), A. Alamanos, F. Auger, V. Fékou-Youmbi, A. Gillibert, F. Marie, S. Ottini-Hustache, J-L. Sida
CEA-Saclay, DSM/DAPNIA/SPhN 91191 Gif-sur-Yvette, FRANCE
Y. Blumenfeld, M. Mac Cormick, F. Maréchal, J-A. Scarpaci, T. Suomijärvi
IPN-Orsay, IN2P3-CNRS, 91406 Orsay Cedex, FRANCE
J-M. Casandjian, M. Chartier, M.D Cortina-Gil, W. Mittig, F. de Oliveira Santos, P. Roussel-Chomaz
GANIL, Bld Henri Becquerel, BP 5027, 14021 Caen Cedex, FRANCE
N. A. Orr
LPC-ISMRA, Bld du Maréchal Juin, F-14050, Caen, France
J.H. Kelley
Department of Physics, Duke University Durham, North Carolina, 27708-0308.
K. W. Kemper
Physics Department, Florida State University, Tallahassee, Florida 32306-4350, USA.
A. Ostrowski
Department of Physics & Astronomy, University of Edinburgh, Edinburgh, EH9 3JZ UK.
J.S. Winfield
INFN-Laboratori Nazionali del Sud, Via S. Sofia 44, 95123 Catania ITALY

Motivations. The weak binding of light neutron-rich nuclei leads to "exotic" features such as halos [1, 2]. Nuclei such as ^{6}He exhibit much larger sizes than expected based on the short-range properties of the strong interaction. The halo is a direct consequence of the weak binding energies of the valence nucleons (S_{2n} $\{^6\text{He}\} = 975$ keV), which allows the wave functions to extend far from the core potential. The nucleus ^{6}He is the prototypical example of a two-neutron halo.

Another important effect of the weak binding is that the particle threshold for these nuclei is close to their ground state, which favours couplings to the continuum during their interaction with a target. For these nuclei one must take into account the interaction potential term due to transitions going to the excited states and then back to the ground state [3]. However its precise calculation requires the knowledge of the spectroscopy of the nucleus and also the knowledge of low-lying resonant states and couplings to the continuum. This term is called "polarization potential". It includes the couplings to the continuum. Our aim in the analysis of the elastic scattering is to know whether the weak binding of exotic nuclei should appreciably enhance the polarization potential and to determine a general form of this potential. We also wanted to know whether models and effective NN interactions in general well adapted to calculate the nucleus-nucleus interaction for stable nuclei, should be equally valid in the case of light exotic nuclei with a small neutron separation energy. Thus, to study the effect of this weak binding on the interaction potential between a light exotic nucleus and a target, we have measured cross sections for the elastic scattering of the neutron-rich nucleus ^{6}He on ^{12}C and proton targets at low energy at GANIL.

Experimental set-up. The secondary beam of ^{6}He was produced at an energy of E/A = 38.3 MeV with an intensity of 10^5 particles/s, by fragmentation of a 75 MeV/nucleon primary ^{13}C beam on a carbon production target located between the two superconducting solenoids of the SISSI device. Cross sections for the elastic scattering of ^{6}He on a polypropylene target were measured with the high resolution spectrometer SPEG [4]. The polypropylene target contains both hydrogen and carbon nuclei allowing a simultaneous measurement of the cross sections on ^{12}C and protons. The energy resolution $\frac{\Delta E}{E} = 10^{-3}$ of the SPEG allows the measurement of elastic scattering angular distributions of light nuclei without the contaminations from target excitations. The angulär resolution is of the order of 0.5° in the laboratory sytem.

Analysis of the elastic scattering on protons. Nucleus-nucleon elastic scattering can be described using the complex microscopic potential JLM [5] which only depends on the scattering energy and on the neutron and proton densities of the nucleus. The potential is deduced from calculations in infinite symmetric nuclear matter with the Brueckner matrix including the Reid hard-core nucleon-nucleon interaction. For nucleon energies up to 160 MeV, the nucleus-nucleon potential is obtained by applying the local density approximation. In the case of stable nuclei, it reproduces successfully a large range of proton and neutron elastic scattering angular distributions [6]. For light nuclei, it was demonstrated [7] that the JLM potential could reproduce the data by renormalizing the imaginary potential ($\lambda_W \sim 0.8$) and without any renormalization of the real part (λ_V=1). This prescription will be referred to below as the "standard JLM". The elastic data for ^{6}He + p are analyzed using the JLM potential, and presented in Fig. 1. In a three-body model [8], ^{6}He can be described as a tightly bound alpha particle plus two valence neutrons. The ^{6}He density used in the JLM calculation was a three-body density with a matter root mean square (rms) radius of 2.55 fm, which is close to the value obtained in the three-body model analysis [9] of the elastic scattering of ^{6}He by protons at intermediate energies, 700 MeV/nucleon [10]. The angular distributions of ^{6}He on proton are better

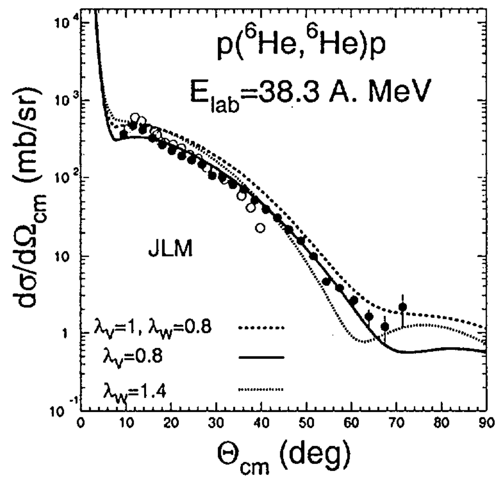


Figure 1: *Experimental cross sections for the elastic scattering of ^{6}He + p at E/A = 38.3 MeV compared to calculations using the JLM potential. The full circles correspond to the present data. The open circles are the data measured at 41.6 MeV/nucleon in a previous experiment [13]. Full line (respectively dotted line) corresponds to calculations in which the real part (imaginary) was renormalized. The dashed line corresponds to the standard JLM potential.*

reproduced when the real part of the JLM potential is reduced [11, 12], as seen in Fig. 1. We have applied this method successfully [12] to other data for ^{6}He on proton, measured at Riken [14] at E/A = 71 MeV and at Dubna [15] at E/A = 25 MeV. The origin of this effect was discussed in Ref. [3] and may be explained within the theory developed by Feshbach [16]. According to this theory, the interaction potential should be written as $U = V + U_{pol}$ where V is the usual real potential and U_{pol} is the dynamical polarization potential (DPP). V can be seen as the folding potential or the elastic potential described by microscopic or phenomenological models. It includes only the interaction between the projectile and the target ground states. U_{pol} is complex, non-local and energy-dependent, it arises from couplings to inelastic channels. With $U_{pol} = V_{pol} + iW_{pol}$, the total optical potential can be written as $U = V + V_{pol} + iW$ with W including W_{pol}. For well-bound nuclei, the probability to excite during the elastic scattering is weak, and the main contribution is imaginary, represented by the usual phenomenological imaginary part W. For weakly-bound nuclei, the enhancement of the coupling to the continuum leads to a greater influence of U_{pol} and then to the reduction of the real part of the nuclear potential. It corresponds to the observed effect in the ^{6}He+p scattering, analyzed with the JLM potential as shown in Fig. 1. A complex surface potential, with a repulsive real part, is expected to simulate the surface effects generated by the polarization potential [17]. As in Ref. [18] we have adopted a repulsive surface potential without a radius. It reduces the real part of the interaction potential. In the analysis described in Ref. [12], we have adopted for simplicity the CH89 optical potential parametrization [19] and the DPP U_{pol} is added to the CH89 potential for the ^{6}He+p reaction at 38.3 MeV/nucleon. The elastic cross sections are then calculated with the ECIS97 code [20]. The result for the ^{6}He + p system is given in Fig. 2. As for the JLM, the CH89 potential alone does not allow the data below 40° (dashed line) to be reproduced. But if we take into account the effects generated by the polarization potential, and use the DPP, the ^{6}He + p data are well reproduced (solid line). With the same method, either a renormalization of the

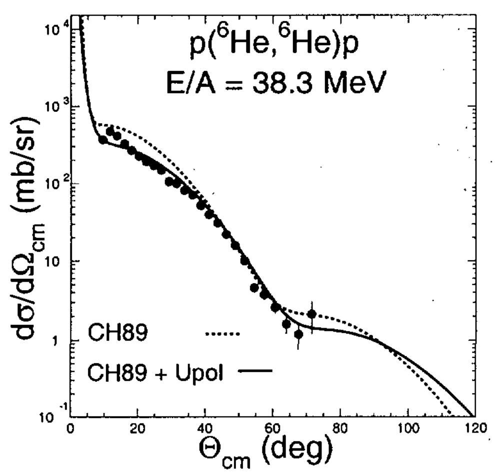


Figure 2: *Experimental cross sections of elastic scattering for ^{6}He + p at E/A = 38.3 MeV (circles) compared to calculations described in the text.*

JLM potential or a similar shape for the DPP as for ^{6}He + p, a set of data for the elastic scattering of ^{8}He on protons [14] have then been successfully reproduced [11, 12]. Similar effects are observed when analyzing the ^{10,11}Be +p data [11].

Nucleus-nucleus potential for the elastic scattering on carbon. The energy resolution was good enough to separate the elastic scattering from inelastic contributions. The real part of the potential of interaction between the exotic projectile and target was calculated within the framework of the folding model [21], by double folding over the effective NN interaction and over the matter density distributions of the projectile and of the target. The ^{12}C matter density is deduced from electron scattering measurements. The imaginary part is assumed to be a Woods-Saxon potential with three free parameters, as done in Ref. [21]. New density-dependent interactions were recently developed and applied successfully [22] to nucleus-nucleus systems for which the elastic scattering presented strong refractive patterns, as for instance, in the case of α + nucleus. The NN interaction we use is one of these interactions, namely the CDM3Y6 interaction. Starting

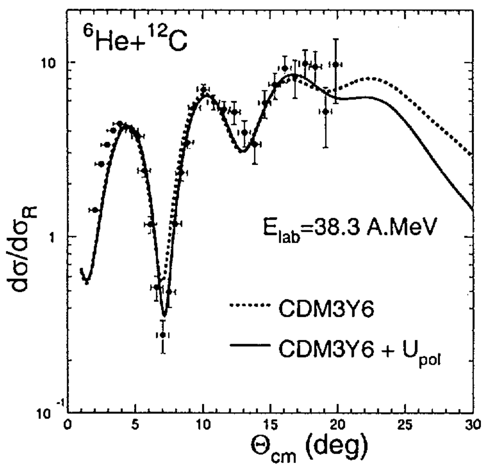


Figure 3: *Cross sections for the elastic scattering of ^{6}He + ^{12}C at E/A = 38.3 MeV compared to calculations using the folded potential (CDM3Y6-Paris). The solid curve is obtained by adding a complex surface potential simulating the DPP.*

from the imaginary part deduced from the analysis of Alpha elastic scattering on carbon [11], an imaginary potential W for ^{6}He on ^{12}C is obtained, together with the real part of the polarization potential V_{pol}, without renormalizing the real part of the potential. V_{pol} is of the same type as the polarization potential, deduced through the analysis of the scattering on protons.

In Fig.3, data are compared to calculations using the CDM3Y6 interaction, with and without the DPP. With the imaginary part W (W_I = 20 MeV, r_i = 1.13 fm and a_I =0.63 fm) and the DPP V_{pol}, the agreement with the data is satisfactory.

Conclusions. By taking into account the polarization potential, either with the surface DPP potential or the normalization of the real part of the nuclear potential, we have reproduced successfully the elastic scattering data for ^{6}He on proton.
For the nucleus-nucleus interaction, we have shown that with a density-dependent NN interaction like CDM3Y6 the folding model, together with a complex surface potential simulating the DPP, can describe the elastic scattering of a weakly bound nucleus like ^{6}He on a ^{12}C target.

The obtained features for the polarization potential are in agreement with the theoretical work made by Y. Sakuragi [23] for the elastic scattering of the stable weakly bound nucleus ^{6}Li. He showed that the coupling to the continuum produces a surface reduction of the usual elastic potential. Here, we have shown that it is a more general effect, and proved that the weak binding energy of an exotic nucleus involves an increase of the coupling probabilities to the continuum, which leads to a decrease of the elastic real potential. This effect must be taken into account in the study of reaction mechanisms at low energy ($E/A \leq 100$ MeV).

References

[1] P. G. Hansen and B. Jonson, Europhys. Lett **4**, 409 (1987).

[2] S. N. Ershov *et al.*, Phys. Rev. C **56**, 1483 (1997).

[3] M.E. Brandan and G. R. Satchler, Phys. Rep. **285**, 143 (1997).

[4] L. Bianchi *et al.*, NIM A **276**, 509 (1989).

[5] J.P. Jeukenne, A.Lejeune and C.Mahaux, Phys. Rev. C **16**, 80 (1977).

[6] S. Mellema, R.Finlay, F. Dietrich and F. Petrovich, Phys. Rev. C **28**, 2267 (1983).

[7] J.S.Petler *et al.*, Phys. Rev. C **32**, 673 (1985).

[8] B.V. Danilin *et al*, Phys. Lett. **B 302**, 129 (1993).

[9] J. Al-Khalili, J. Tostevin and I. Thompson, Phys. Rev. C **54**, 1843 (1996).

[10] G. D. Alkhazov & al, PRL **78**, 2313 (1997).

[11] V. Lapoux, PhD Thesis, Université d'Orsay, 1998, DAPNIA/SPHN-98-05T.

[12] V. Lapoux *et al.*., Phys. Lett. B **517** (2001).

[13] M. D. Cortina-Gil *et al.*, Phys. Lett. B **401**, 9 (1997).

[14] A.A. Korsheninnikov *et al.*, Nucl. Phys. A **617**, 45 (1997).

[15] R. Wolski *et al.*, Phys. Lett. B **467**, 8 (1999).

[16] H. Feshbach, Ann. Phys. **5**, 357 (1958).

[17] Y. Sakuragi, Phys. Rev C **35**, 2161 (1987).

[18] M. Hussein and G. Satchler, Nucl. Phys. A **567**, 165 (1994).

[19] R.L. Varner *et al.*, Phys. Rep. **57**, 201 (1991).

[20] J. Raynal, Phys. Rev. C **23**, 2571 (1981).

[21] G.R. Satchler, W.G. Love, Phys. Rep. **55**, 183 (1979).

[22] D. Khoa, G.R. Satchler, and W. von Oertzen, Phys. Rev. C **56**, 954 (1997).

[23] Y. Sakuragi & al., Prog. Th. Phys. **70** 4 (1983) 1047.

Neutron femtometry and correlations in the halo

F.M. Marqués, M. Labiche, N.A. Orr

Laboratoire de Physique Corpusculaire,
IN2P3-CNRS, ISMRa et Université de Caen, F-14050 Caen cedex, France

for the E295 collaboration[1]

The two neutrons in the halo of ^{6}He, ^{11}Li and ^{14}Be are a unique example of how the n-n interaction may lead to the particle stability of a nucleus, in which the core-n and n-n subsytems are unbound. The dissociation of these three nuclei by a Pb target into core+n+n has been measured at GANIL with the neutron (DEMON) and charged particle (CHARISSA) detector arrays [1].

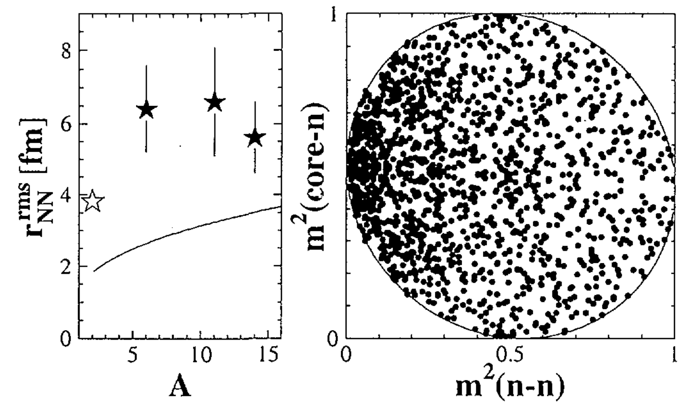
The technique of intensity interferometry, widely exploited in nuclear and particle physics, measures distances —in the fm range— between particles through the investigation of their correlations in momentum space. The rejection of neutron cross-talk [2] allowed us to apply this technique to the n-n data and therefore use DEMON as a "femtometer" of the halo [3].

The idea behind interferometry is that the differential cross-section measured corresponds to the phase space available to the particle pair modified by the interaction in the final state*. By mixing particles from different events one extracts the phase-space contribution, and then the ratio of measured-to-mixed distributions, the correlation function, isolates the effects of the interaction.

The correlation functions measured where compared to an analytical formalism depending on three parameters: the n-n scattering length and effective range, known, and the average n-n distance [3]. The values extracted for the three systems, $r_{nn}^{\rm rms} \sim 6$ fm, appear to preclude any strong dineutron component in the halo wave function at breakup.

The same analysis was applied to breakup of ^{11}Li and ^{14}Be on a C target, and somewhat larger separations, $r_{nn}^{\rm rms} \sim 8$ fm, were obtained. As core-n FSI/resonances in the exit channel would delay the emission of one of the neutrons, a three-body analysis was introduced [4] through the combination of n-n interferometry and Dalitz plots, which are extensively used in particle physics for the search of resonances in three-particle decays.

*Also by quantum statistics for identical particles.



Left: n-n distances obtained from the correlation function for ^{6}He, ^{11}Li and ^{14}Be, compared to the n-p distance in ^{2}H and to the one between two nucleons within a liquid drop (line) [3]. Right: Dalitz plot of the squared invariant masses for the ^{12}Be+n+n data [4].

The results indicate that the n-n interaction dominates dissociation by Pb, while in dissociation by C the n-n interaction effects decrease at the same time that core-n resonances appear. This new technique allows us to determine not only the n-n distance in the halo, but also the energy of the core-n resonances and the delay they introduce in the emission of the second neutron (their lifetime) [4].

These techniques have been recently applied to a spontaneous process in which two neutrons are emitted, the "n-n radioactivity" of ^{11}Li [5]. Preliminary results suggest that the decay into ^{9}Be+n+n proceeds through excited states in ^{11}Be, and that the neutron pair is emitted simultaneously.

[1] M. Labiche *et al.*, Phys. Rev. Lett. **86**, 600 (2001).
[2] F.M. Marqués *et al.*, Nucl. Instr. and Meth. A **450**, 109 (2000).
[3] F.M. Marqués *et al.*, Phys. Lett. B **476**, 219 (2000).
[4] F.M. Marqués *et al.*, Phys. Rev. C **64**, 061301 (2001).
[5] C. Timiş, Thèse Université de Caen (2001).

PROBING THE ^{6}HE HALO STRUCTURE WITH ELASTIC AND INELASTIC PROTON SCATTERING

A. Lagoyannis[1,2], F. Auger[1], A. Musumarra[1*], N. Alamanos[1], E. C. Pollacco[1], A. Pakou[2], Y. Blumenfeld[3], F. Braga[1], M. La Commara[4], A. Drouart[1], G. Fioni[1], A. Gillibert[1], E. Khan[3], V. Lapoux[1], W. Mittig[5], S. Ottini-Hustache[1], D. Pierroutsakou[4], M. Romoli[4], P. Roussel-Chomaz[5], M. Sandoli[4], D. Santonocito[3,*], J. A. Scarpaci[3], J.L. Sida[1] and T. Suomijärvi[3]

[1]*DSM/DAPNIA CEA SACLAY, 91191 Gif-sur-Yvette, France*

[2]*Department of Physics, The University of Ioannina, 45110 Ioannina, Greece*

[3]*Institut de Physique Nucléaire, IN2P3-CNRS, F-91406, Orsay, France*

[4]*University of Napoli and INFN Sezione di Napoli, I-80125, Napoli, Italy*

[5]*GANIL, BP 5027, F-14021, Caen, France*

S. Karataglidis[6,7] and K. Amos[8]

[6]*TRIUMF, 4004 Wesbrook Mall, Vancouver, British Columbia, V6T 2A3, Canada*

[7]*Theory Division, Los Alamos National Laboratory, Los Alamos, New Mexico, 87545*

[8]*School of Physics, University of Melbourne, Victoria 3010, Australia*

Proton elastic scattering and inelastic scattering to the first excited state of ^{6}He have been measured over a wide angular range using a 40.9A MeV ^{6}He beam. The data have been analyzed with a fully microscopic model of proton-nucleus scattering using ^{6}He wave functions generated from large space shell model calculations. The inelastic scattering data show a remarkable sensitivity to the halo structure of ^{6}He.

It is well known that neutron rich weakly bound light nuclei have abnormally large radii [1]. Considerable experimental and theoretical efforts have been devoted to the understanding of the structure of these so-called halo nuclei [2,3]. However, due to the low intensities of the available exotic beams, it is only recently that inelastic scattering and transfer reactions on light particles, which are among the best tools to probe deeply the structure of nuclei, could be undertaken under good conditions. Experimentally, the Borromean ^{6}He nucleus is a very good candidate for this kind of study since the first excited state is the 2^+ state at 1.87 MeV [4]. To study the microscopic structure of ^{6}He we measured elastic and inelastic scattering of ^{6}He from protons by making use of a new large acceptance detector array MUST [5].

The experiment was performed at the GANIL facility with a 40.9A MeV ^{6}He radioactive ion beam produced by fragmentation of a primary 75A MeV ^{13}C beam on a 8.45 mm thick C target. The secondary beam was purified with a 0.9 mm thick Al degrader. The beam intensity on the polypropylene $(CH_2)_3$ reaction target was 10^5 particles per second with a 2% total contamination of ^{8}Li and ^{9}Be. As the beam spot on the target covered 1 cm^2 with a maximum angular divergence of 1°, two X and Y position sensitive detectors, CATS [6], were placed at 155 cm and 27 cm in front of the target as illustrated in Fig. 1.

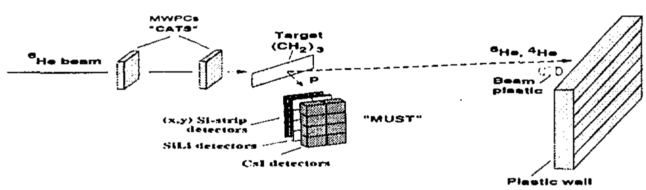


FIG. 1. The experimental set up.

*present address:INFN-Laboratori Nazionali del Sud, Via S. Sofia 44, 95123 Catania Italy

The recoiling protons were detected in MUST [5], an array of 8 three-stage telescopes 6 cm × 6 cm each. The first stages consist in double-sided Si-strip detectors (300 μm). They were placed at 15 cm from the target and covered the angular range between 46 and 90° in the laboratory frame. At this distance, the 1 mm wide strips result in an angular resolution of 0.4° in both X and Y directions. Protons of less than 6 MeV were stopped in these detectors and were identified down to 0.5 MeV by measurement of energy versus time of flight (E-TOF). The start of the TOF measurement was given by the passage of the incident particle in one CATS tracking detector and the overall time resolution was 1.2 ns. Protons in the energy range of 6 to 25 MeV were stopped in the second SiLi stage (3 mm) of the telescopes while those in the energy range from 25 to 70 MeV were stopped in the third CsI stage (15 mm). They were identified by the $\Delta E - E$ method. The ejectile was detected in coincidence with the recoiling proton to suppress the protons emitted from excited nuclei produced in central collisions of ^{6}He on the carbon contained in the target. The coincidence allowed also suppression of protons coming from reactions induced by the beam contaminants on the target. The ejectile was detected in a plastic wall, 50 cm x 50 cm situated at 75 cm behind the target. The large angular coverage of the wall was imposed by the in flight decay of ^{6}He ($^6\text{He} \rightarrow \alpha + 2n$) that occurs for excitation energies higher than the $2n$ separation energy of 0.9 MeV [4]. Identification and counting of the beam particles were achieved in a plastic scintillator with a diameter of 2.8 cm and centered at zero degrees.

To measure angular distributions down to 10° in the center of mass (85° in the laboratory) where the energy of the recoiling protons decreases down to 0.5 MeV, a 48 mg/cm^2 thick polypropylene target (density, 0.896 g/cm^3) was used. Good statistics at larger angles was obtained by using a 8.25 mg/cm^2 thick target. Elastic (respectively inelastic) events were extracted by requiring that a proton be detected in coincidence with a ^{6}He (respectively alpha particle). The background under the 2^+ peak was estimated for each bin of 2° in the laboratory. It represents between 10% and 30% of the peak depending on the angle. The uncertainty on this value stands at ±5% for all angles. Elastic and 2^+ state contributions were extracted for each 1° bin in the laboratory frame and normalized with the acceptance of the detection system, the target thickness (±5% uncertainty) and the number of incident ^{6}He (±3% uncertainty).

Angular distributions in the center of mass are presented in Fig. 2. The error bars given for elastic

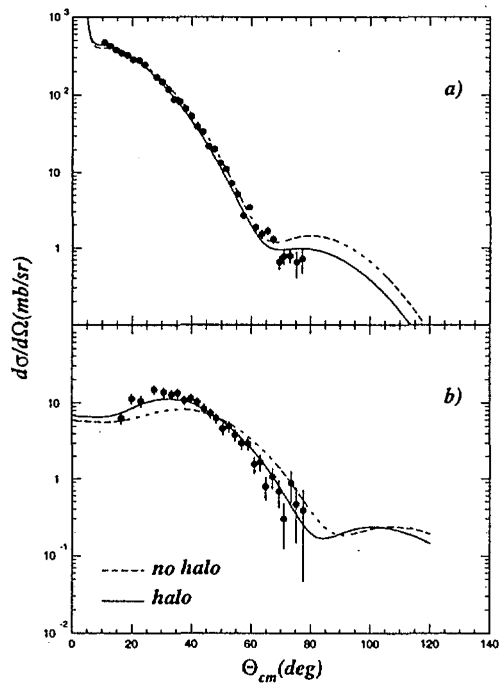


FIG. 2. Differential cross sections for the (a) elastic and (b) inelastic scattering to the of 2^+ state at 1.87 MeV of ^{6}He from hydrogen at 40.9A MeV. The present data (circles) are compared to the results of the calculations assuming no halo (dashed line) and halo (solid line) conditions.

scattering are purely statistical whereas the error bars quoted for the inelastic scattering include, in addition, the error due to the background subtraction.

Calculations for the elastic proton scattering data were made using a fully microscopic model of the optical potential [7]. In this model, the potential is obtained in coordinate space by folding a complex energy- and density-dependent effective nucleon-nucleon (NN) interaction with the one-body density-matrix elements (OBDME) and single particle bound states of the target generated by shell model calculations. Calculations of the transition amplitudes for the inelastic scattering have been done within the distorted wave approximation (DWA). The same effective NN interaction and shell model calculations used to make the g folding optical potential have been respectively used for the transition operator and the transition OBDME. The validity of the 40 MeV effective interaction has been verified by calculations of cross sections and analyzing powers of proton elastic scattering for different stable nuclei [9].

For the structure of ^{6}He we used the complete $6\hbar\omega$ wave functions of ref [10] or the complete $4\hbar\omega$ wave functions of ref [11] to specify the relevant ground state and $0^+ \rightarrow 2^+$ transition OBDME for ^{6}He. However, in both models the binding energy of the last neutron is larger than the experimental separation energy 1.87 MeV [4]. That would indicate that the size of the model spaces used is still too small to give the correct asymptotic behavior of the neutron density.

The $p-^6$He g folding optical potential made with the shell model prescribed HO functions is almost phase shift equivalent to that obtained using WS functions which allow to fit electron scattering for form factor of ^{6}Li [8]. This led us to use these WS functions but in order to specify the neutron halo in ^{6}He we changed the bound state WS potential so that the 0p-shell binding energy became 2 MeV which is close to the single neutron separation energy. The optical potential obtained using these adjusted WS single particle wave functions leads to the cross section hereafter designated as *halo*. Hence, the use of the HO single particle wave functions given by either shell model leads to the cross section that we designated as *no halo*.

The elastic scattering data [12] are compared in Fig. 2(a) to the halo (solid line) and no halo (dashed line) calculations. The two calculations are very similar up to 60° and notably differ at larger angles. The agreement of the calculations with the data is very good up to 60°. The few data beyond these angles are better reproduced by the halo description but it is clear that data at larger momentum transfers are required to use elastic scattering as a probe of the halo structure of ^{6}He.

The very good agreement obtained with the elastic scattering data is essential since it validates the g folding optical potential used to define the distorted waves in the DWA analysis of the inelastic scattering leading to the $2^+; T = 1$ state. Halo (solid line) and no halo (dashed line) calculated cross sections for the 2^+ state are presented in Fig. 2(b). Contrary to the elastic scattering, the sensitivity to the halo is important over the entire angular domain. The data [12] are very well reproduced by the halo calculation. The validity of the models used to predict the present data is corroborated by the very good agreement for the reaction cross section obtained between the halo result of the $4\hbar\omega$ model (353 mb and 406 mb for the no-halo and halo cases, respectively) and the experimental value (409 ± 22 mb [13]).

The sensitivity of the inelastic scattering data to the structure of ^{6}He and the success of the coordinate space scattering theories, based upon effective NN interactions used successfully in analyses of proton scattering from stable nuclei, open large perspectives for the study of the microscopic structure of exotic systems.

[1] I. Tanihata, Nucl. Phys. **A478** (1988) 795c.
[2] P. G. Hansen *et al.*, Ann. Rev. Nucl. Part. Sci **45** (1995) 591.
[3] B. Jonson and K. Riisager, Phil. Trans. Roy. Soc. (London) A **356** (1998) 2063.
[4] F. Ajzenberg-Selove, Nucl. Phys. **A490** (1988) 1.
[5] Y. Blumenfeld *et al.*, Nucl. Instr. and Meth. A **421** (1999) 471.
[6] S. Ottini *et al.*, Nucl. Instr. and Meth. A **431** (1999) 476.
[7] P. J. Dortmans and K. Amos, Phys. Rev. C **49** (1994) 1309.
[8] S. Karataglidis *et al.*, Phys. Rev. C **55** (1997) 2826 .
[9] P. K. Deb *et al.*, Phys. Rev. C. **63** (in press) (2000).
[10] P. Navrátil and B. R. Barrett, Phys. Rev. C **54** (1996) 2986; *ibid* **57** (1998) 3119.
[11] S. Karataglidis *et al.*, Phys. Rev. C **61** (2000) 024319.
[12] A. Lagoyannis *et al.*, Phys. Lett. B **518** (2001) 27.
[13] A. de Vismes *et al.*, Phys. Lett. B **505** (2001) 15.

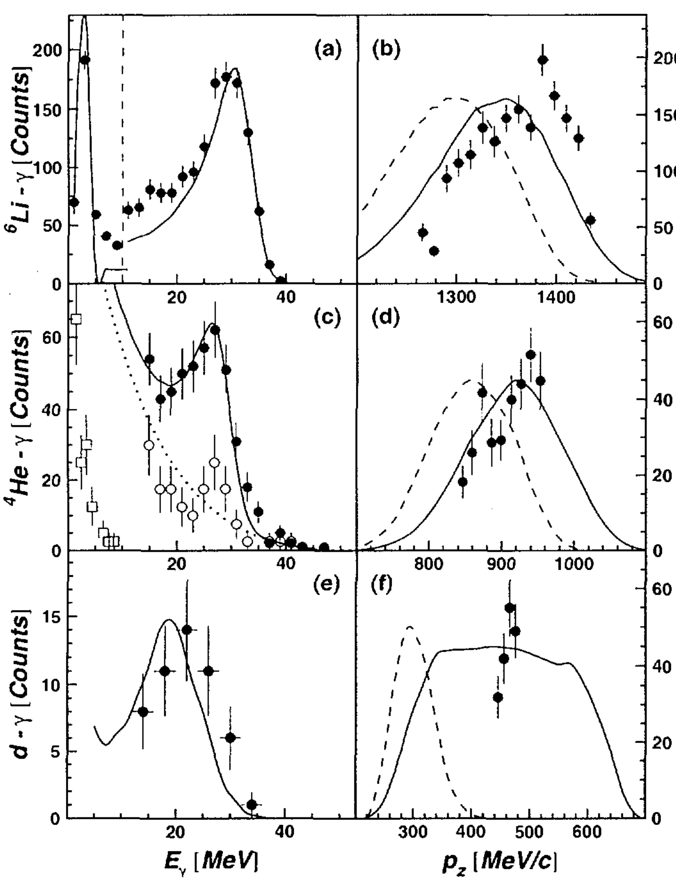
Probing two-neutron haloes by proton capture

E. Sauvan, F.M. Marqués, N.A. Orr

Laboratoire de Physique Corpusculaire,
IN2P3-CNRS, ISMRa et Université de Caen, F-14050 Caen cedex, France

for the E302 collaboration[1]

The correlations within the n-n halo, introduced in the preceeding contribution, were also investigated by an independent probe, radiative capture of protons. Owing to the lower cross-section of capture, only the Borromean system lying closer to stability, ^{6}He, was studied. The photon emitted in the collision of a ^{6}He beam at 40 MeV/N with a liquid Hydrogen target was measured with the "Château de Cristal" BaF_2 array [1,2].



γ-ray energy spectrum in the ^{6}He+p c.m. and momentum distribution of the coincident fragment for ^{6}Li (upper), α particles (middle) and deuterons (lower panels). The lines correspond to calculations of quasi-free capture on the ^{5}He cluster, the α core and one halo neutron, respectively [1].

A previous investigation of coherent bremsstrahlung production in the reaction α(p,γ) demonstrated that the high-energy photon spectrum was dominated by capture to form ^{5}Li [3]. Such results motivated the extension of this technique to study ^{6}He. Given a proton wavelength of 0.7 fm at 40 MeV, it could be possible to observe direct capture, as a quasi-free process, on the constituents of ^{6}He in addition to capture into ^{7}Li.

Moreover, the different quasi-free capture processes should lead to different E_γ in the range 20–40 MeV; importantly, the photon is not affected by FSI. The 74 BaF_2 of the Château were used for the first time to measure such high-energy photons.

Events were observed corresponding to capture on ^{6}He, the ^{5}He cluster, the α core and one halo neutron. The absence of capture on the dineutron subsystem suggests that the dominant configuration is α-n-n in which the n-n separation is relatively large, in agreement with the interferometry measurements undertaken with DEMON.

---

[1] E. Sauvan *et al.*, Phys. Rev. Lett. **87**, 042501 (2001).
[2] E. Sauvan, Thèse Université de Caen (2000).
[3] M. Hoefman *et al.*, Phys. Rev. Lett. **85**, 1404 (2000).

Reaction cross section and interaction potential of neutron rich nuclei on protons

A. de Vismes[a], P. Roussel-Chomaz[a], W. Mittig[a], A. Pakou[a,b], N. Alamanos[c], J-C. Angélique[d], F. Auger[c], J. Barrette[e], E. Bauge[f], A.V. Belozyorov[g], C. Borcea[h] F. Carstoiu[a,h], W. Catford[i], M-D. Cortina-Gil[j], J-P. Delaroche[f], Z. Dlouhy[k], A. Gillibert[c], D. Hirata[a], V. Lapoux[c], A. Lepine-Szily[l], S. M. Lukyanov [g], F. Marie[c], A. Musumarra[c,1], F. de Oliveira[a], N. Orr[d], S. Ottini[c], Y.E. Penionzhkevich[g], F. Sarazin[a,2], H. Savajols[a], N. Skobelev[g]

[a] *GANIL (DSM/CEA, IN2P3/CNRS), BP 5027, 14076 Caen Cedex 5, France*
[b] *Department of Physics, The University of Ioannina, 45110 Ioannina, Greece*
[c] *CEA/DSM/DAPNIA/SPhN, Saclay, 91191 Gif-sur-Yvette Cedex, France*
[d] *LPC, IN2P3/CNRS, ISMRa and Univ. of Caen, F-14050 Caen, France*
[e] *Mc Gill University, 845 Sherbrooke St., Montreal, Quebec, H3A 3R1, Canada*
[f] *DPTA/SPN-CEA, 91680 Bruyères-le-Chatel, Cedex 12, France*
[g] *FLNR,JINR, Dubna, P. O. Box 79, 101 000 Moscow, Russia*
[h] *Inst. Atomic Physics, P.O. Box MG6, Bucharest, Romania*
[i] *Department of Physics, University of Surrey, Guilford, Surrey GU2 7XH, UK*
[j] *Dpto Fisica de Particulas, Universidad Santiago de Compostela, 15706 Santiago de Compostela, Spain*
[k] *Nuclear Physics Institute, ASCR, 25068 Rez, Czech Republic*
[l] *IFUSP-Universidade de São Paulo, C.P. 66318, 05389-970 São Paulo, Brazil*

[1]present address:INFN-LNS, Via S. Sofia 44, 95123 Catania Italy
[2]present address:Department of Physics and Astronomy, Edinburgh, Scotland, UK

Reaction cross sections are of fundamental interest in nuclear physics, since they provide a measurement of the size of the nucleus. They are an effective tool for revealing unusual features in nuclei such as extended halo or neutron skins. They also complement elastic scattering data to obtain information on the nuclear interaction potential. Indeed, absorbing processes affect the elastic scattering angular distributions, therefore reaction cross sections can place restrictions on the amount of absorption, as represented by the imaginary potential.

In order to get a better understanding of the potential for neutron rich nuclei, reaction cross sections were measured for some stable and neutron rich nuclei(^{4,6}He, $^{7-9}$Li, $^{9-11}$Be, $^{21-24}$F, $^{22-26}$Ne $^{25-29}$Na and $^{29-32}$Mg) via the transmission method at intermediate energies ($\sim$ 34-76 A MeV) and using a cryogenic hydrogen target. For the stable nuclei ^{4}He, ^{7}Li and ^{9}Be, only one single data point existed previously for ^{9}Be in the energy range between 48 and 100 MeV. The experimental values obtained in the present work therefore fill this gap and are in good agreement with the general trend observed at lower and higher energy.

The data were compared to values calculated with either global phenomenological parametrizations [1-3] or the microscopic JLM approach [4], using different types of density distributions [5-7]. The value measured for ^{6}He can be reproduced within the JLM approach with normalization factors very close to the standard values for the isoscalar part of the potential, provided that a normalization of 1.4 was applied to the isovector part, thus confirming the weakness of the isovector potential in the JLM approach [8]. It should be noted that a simultaneous analysis of elastic scattering and charge exchange angular distributions with the present reaction cross section data for ^{6}He showed that the three data sets could be adequately reproduced with these normalization factors [9]. A significant increase of the imaginary part of the potential was necessary in order to reproduce the p+^{11}Be reaction cross section.

For the heavier nuclei studied in the present work, the values calculated with the CH89 parametrization of the optical potential systematically overestimated the data, while the GLOBAL parametrization yielded very satisfactory results (see Fig.1). Two types of calculations were performed within the JLM approach. The results obtained within the original approach with standard normalization factors were in rather good overall agreement with the data, while the values obtained within the modified approach significantly overestimated the experimental results, due to the larger strength of the imaginary potential. It should be mentioned that the modified JLM approach produced results in much better agreement with the present data when the imaginary normalization factor λ_w=0.8 was used. This result is an indication that the imaginary potential deduced from data for nuclei in the mass range A≥40 cannot be directly extrapolated to the lighter nuclei considered in the present work, maybe due to local effects of the LDA approximation.

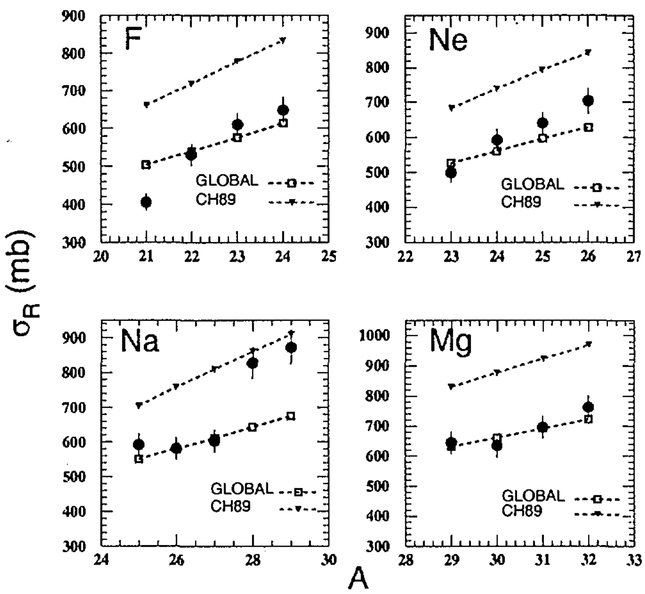


Figure 1: Experimental reaction cross sections for F, Ne, Na and Mg isotopes compared to calculated values obtained with the CH89 and GLOBAL optical potentials

[1] R.L. Varner et al., Phys. Rep. 201 (1991) 57.
[2] E.D. Cooper et al., Phys. Rev. C 47 (1993) 297.
[3] S. Hama et al., Phys. Rev. C 41 (1990) 2737.
[4] J.P. Jeukenne, A. Lejeune and C. Mahaux, Phys. Rev. C 16 (1977) 80.
[5] S. Karataglidis et al.,Phys. Rev C 61 (2000) 024319.
[6] J. S. Al-Khalili and J. A. Tostevin Phys. Rev. C 57 (1998) 1846.
[7] K. Arai et al., Phys. Rev. C59 (1999) 1432.
[8] F. S. Dietrich and F. Petrovich, in Proc. of Neutron-Nucleus Collisions -A Probe of Nuclear Structure, eds J. Rapaport, AIP Conference Proceedings, no 124 (AIP, New York, 1985) p. 90.
[9] A. de Vismes et al., Phys. Lett. B 505 (2001) 15

E323 Exotic nuclei
Study of neutron and proton deformations in ^{10}C and ^{11}C

C. Jouanne, V. Lapoux, N. Alamanos, F. Auger, A. Drouart,
A. Gillibert, G. Lobo, L. Nalpas, E. Pollacco, J-L. Sida.
CEA-Saclay, DSM/DAPNIA/SPhN 91191 Gif-sur-Yvette, FRANCE
Y. Blumenfeld, E. Khan, T. Suomijärvi, T. Zerguerras
IPN-Orsay, IN2P3-CNRS, 91406 Orsay Cedex, FRANCE
P. Roussel-Chomaz, H. Savajols
GANIL, Bld Henri Becquerel, BP 5027, 14021 Caen Cedex, FRANCE
A. Lagoyannis, A. Pakou
Department of Physics, The University of Ioannina, 45110 Ioannina, GREECE
A. Musumarra
INFN-Laboratori Nazionali del Sud, Via S. Sofia 44, 95123 Catania ITALY

The nuclei ^{10,11}C, like the other carbon isotopes described in the theory of the Antisymmetrized Molecular Dynamics (AMD) [1] are expected to have a proton density with an oblate deformation. Interesting phenomena can be seen along the carbon isotopic chain, from proton-drip line (^{8}C) to neutron-drip line (^{22}C) : the neutron density is more and more diffuse as the neutron number is increasing, and neutron halo features are expected, associated to the loosely bound nuclei, such as ^{17,19,22}C.
In the case of ^{10,11}C, we want to know whether these nuclei have neutron densities differently deformed from the proton densities. The aim of the ^{10,11}C(p,p') experiment was to obtain structure information for these two neutron-deficient radioactive nuclei and to compare data to calculations performed with different models, predicting the ground state and transition densities. The spectroscopy of ^{10,11}C is known and also the B(E2,$2^+ \rightarrow 0^+$) value for ^{10}C [2]. By (p,p') we probe the structure and we can test the prediction of models (either cluster or mean field models) for the densities. The nucleus-nucleon interaction for the elastic scattering on protons is calculated using the microscopic, complex and parameter-free JLM potential [3]. The JLM potential is used to perform the DWBA calculations leading to the inelastic (p,p') cross sections. These calculated cross sections are sensitive to the M_n/M_p factor, which is the ratio of the radial moments of the transition densities, $M_{p,n} = \int drr^{l+2}\rho^{tr}_{p,n}$.

We have measured at GANIL, with the MUST telescopes, elastic scattering and inelastic scattering transitions to the first excited states, below the proton separation threshold, for the nuclei ^{10,11}C. Inelastic scattering on proton, to the first excited state (2^+ at 3.35 MeV), for ^{10}C, were measured at E_{lab} = 45.3 MeV/nucleon (for ^{11}C, at 40.6 MeV/nucleon). For (p,p') reactions, the experimental apparatus MUST [4], an array of three-stage telescopes (a set of Si-strips, Sili and CsI telescopes) specifically designed to detect recoiling light charged particles, is used to measure angular distributions for elastic and inelastic scattering of radioactive beams on proton. The MUST detector has detected the recoil proton in coincidence with a plastic scintillator measuring the heavy nucleus focused at forward angle. The ^{10,11}C secondary beams were produced successively by fragmentation of a 95 A.MeV ^{12}C beam on a thick ^{12}C target located in the SISSI device. The profile of the incident beam was given by two multi-wire chambers (CATS), developed by the DAPNIA/SED. We fully reconstructed the kinematics of the (p,p'). In Fig. 1, the elastic

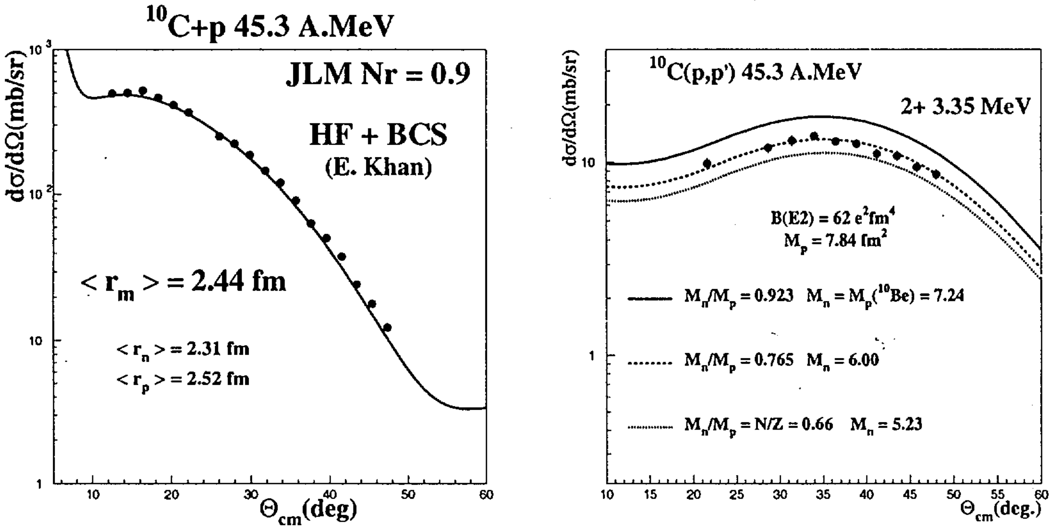


Figure 1: Experimental cross sections of the p(^{10}C,p') elastic (left part) and inelastic scattering (right part) for the 2^+ state ($E_x = 3.35$ MeV). The curves are calculated with the JLM potential. Details are in the text.

scattering results for ^{10}C are compared to the calculations using neutron and proton densities given within the HF + BCS framework. A good description is obtained with the HF densities, and with a renormalization of the real part of JLM by a factor 0.9 (left part of Fig. 1). This factor is then applied in the inelastic scattering analysis. Our analysis of the ^{10}C(p,p') data using the JLM model is consistent with an extended matter root mean square (rms) radius (2.45 $\pm$ 0.1 fm) of this nucleus which is greater than the value obtained for ^{12}C (rms = 2.3 fm [5]).

But neither the AMD transition densities [1] or the HF+ QRPA incorporated in our JLM calculations allow to reproduce the inelastic (p,p') data. In the right part of Fig. 1, we show three calculations : one taking the AMD densities of the mirror nucleus (^{10}Be) and using mirror symmetry (solid line), the other (dotted line) with a M_n/M_p factor equal to N/Z and the last one with the AMD proton transition density and a value for the M_n moment adjusted on the data. Moreover, our data, analyzed using JLM and a Tassie model [6], indicate a value for the M_n integral of 5.67 ± 1.24 fm^2. Further studies of the transition densities of these neutron deficient nuclei are in progress, which will help in determining if the cluster structure is relevant for the ground and excited states of ^{10,11}C.

References

[1] Y. Kanada-En'yo and H. Horiuchi, Phys. Rev. C **55**, 2860 (1997).

[2] P.Raghavan, At. Data Nucl. Data Tables 42, 189 (1989).

[3] J.P. Jeukenne, A.Lejeune and C.Mahaux, Phys. Rev. C **16**, 80 (1977).

[4] *The MUST collaboration*, NIM **A 421** (1999) 471-491.

[5] Atomic Data and Nuclear Data Tables, Vol. **39**, No. **2**, July 1988.

[6] G.R. Satchler, *Direct Nuclear Reactions*, CLARENDON PRESS, Oxford University Press 1983.

Elastic and inelastic proton scattering from the unstable ^{30}S and ^{34}Ar nuclei

E. Khan[a)], T. Suomijärvi[a)], Y. Blumenfeld[a)], Nguyen Van Giai[a)], N.Alamanos[b)], F. Auger[b)], D. Beaumel[a)], P. Delbourgo-Salvador[c)], A. Drouart[b)], S. Fortier[a)], N. Frascaria[a)], A. Gillibert[b)], C. Jouanne[b)], K. W. Kemper[d)], A. Lagoyannis[b)], V. Lapoux[b)], A. Lépine-Szily[e)], I. Lhenry[a)], F. Maréchal[d)], J.M. Maison[a)], A. Musumarra[b)], S. Ottini-Hustache[b)], P. Piattelli[f)], S. Pita[a)], E.C. Pollacco[b)], P. Roussel-Chomaz[g)], D. Santonocito[a)], J.E. Sauvestre[c)], J.A. Scarpaci[a)], T. Zerguerras[a)]

a) Institut de Physique Nucléaire, IN$_2$P$_3$-CNRS, 91406 Orsay, France
b) SPhN, DAPNIA, CEA Saclay, 91191 Gif sur Yvette Cedex, France
c) DPTA/SPN-CEA Bruyères, 91680 Bruyères-le-Châtel Cedex 12,France
d) Department of Physics, Florida State University, Tallahassee, Fl 32306, USA
e) IFUSP, DFN, C.P. 20516, 01498 Sao Paulo, S.P., Brazil
f) INFN-Laboratorio Nazionale del Sud, Via S. Sofia 44, Catania, Italy
g) GANIL, BP 5027, 14021 Caen Cedex, France

Proton scattering experiments at an energy of few tens of MeV were recently performed on the neutron-rich unstable isotopes ^{38,40}S [1] and ^{42,44}Ar [2]. Through comparison with Coulomb excitation measurements, phenomena such as the behavior of the N=20 and N=28 shell closures far from stability, neutron skins and the isoscalar/isovector character of low-lying collective excitations can be studied. For instance the neutron-rich ^{38}S nucleus appeared to have a strong neutron contribution to its 2_1^+ excitation. In order to complete the study of these isotopic chains, the measurement of proton scattering from the proton-rich nuclei ^{30}S and ^{34}Ar was undertaken.

Direct reactions on unstable nuclei are performed in inverse kinematics, where a secondary beam of the radioactive nucleus of interest bombards a target containing the light particles. Here the secondary beams of ^{30}S and ^{34}Ar were produced by fragmentation of a 95 MeV/A ^{36}Ar primary beam with an intensity of 2 eμA on a ^{12}C target. The beams were purified by traversing a plastic degrader placed in the dispersive plane of the α spectrometer. The final intensities on target of the 53 MeV/A ^{30}S and 47 MeV/A ^{34}Ar beams were 15x10^4 and 13x10^4 pps and the purities were 10% and 94% respectively. Due to the large emittance of these secondary beams, the incident nuclei were tracked event-by-event using two low pressure multiwire proportional chambers (CATS) [3] located 1.5 m and 0.3 m upstream from the target. The secondary beams impinged on a 2.7 mg/cm^2 $(CH_2)_n$ target. In order to select the elastic and inelastic reaction channels and reject beam impurities the scattered heavy nuclei were momentum analyzed by using the SPEG spectrometer and identified by energy loss and time-of-flight measurements. To gain access to the excitation energy and the scattering angle characterizing the reaction, the energy and angle of the recoiling protons were measured using the MUST array [4] consisting of eight silicon-strip detectors, placed at 20 cm from the target, backed by Si(Li) diodes and CsI crystals. The doubled-sided silicon strip detectors were 300 μm thick with 60 strips 1 mm wide on each side providing for localization in X and Y. The telescopes covered laboratory angles between 54^o and 87^o.

The extracted elastic, 2^+_1 (and 3^-_1 in the case of ^{34}Ar) angular distributions are shown on figure Fig.1. The dotted lines correspond to CCBA calculations using the Becchetti-Greenlees potential and allow to extract the multipolar deformation parameters : $\beta_2 = 0.32(3)$ for ^{30}S and $\beta_2 = 0.27(2), \beta_3 = 0.39(3)$ for ^{34}Ar. In order to perform a microscopic analysis of the data, we have employed self-consistent HF+BCS and QRPA microscopic models with Skyrme effective interactions, described in ref. [5]. The results shown here have been obtained using the SGII parameterization. In order to calculate angular distributions, complex optical and transition potentials were obtained by injecting the calculated ground state and transition densities into the Jeukenne, Lejeune and Mahaux (JLM) density dependent optical potential. Calculated angular distributions for the ground and excited states are shown by the solid lines in Fig.1. The agreement is very good, for the elastic and 2^+_1 states. The magnitude of the 3^-_1 angular distribution is slightly underestimated by the calculations. The calculated densities are thus well suited to analyze the microscopic properties of these nuclei. For both nuclei the proton and neutron densities are similar, excluding the presence of a proton skin, in contrast to the neutron-rich nuclei. The ratio of the multipole transition matrix elements M_n/M_p indicates that the 2^+_1 excitation are isoscalar for both nuclei.

[1] F. Maréchal et al., *Phys. Rev.* **C60** (1999) 034615.

[2] H. Scheit, F. Maréchal, T. Glasmacher et al., *Phys. Rev.* **C63** (2001) 014604.

[3] S. Ottini-Hustache et al., *Nucl. Instr. Meth. Phys. Res.* **A431** (1999) 476.

[4] Y. Blumenfeld et al., *Nucl. Instr. Meth. Phys. Res.* **A421** (1999) 471.

[5] E. Khan and Nguyen Van Giai, *Phys. Lett.* **B472** (2000) 253.

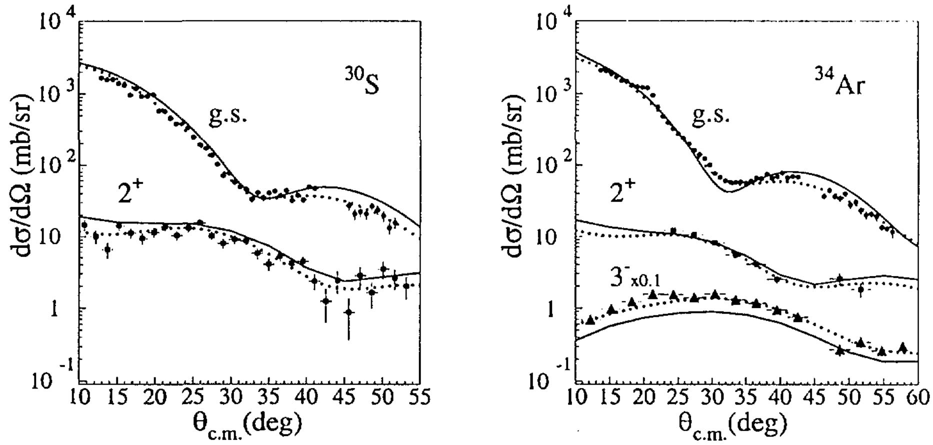


FIGURE 1. *Left* : 53 MeV/A (p,p') ^{30}S elastic and inelastic angular distributions for the 2^+_1 state. The dotted lines correspond to CCBA calculations using the Becchetti-Greenlees potential and the solid lines correspond to DWBA calculations using the JLM interaction folded with ground state and transition densities obtained with HF+BCS and QRPA models. *Right* : same for 47 MeV/A ^{34}Ar elastic and inelastic angular distributions for the 2^+_1 and the 3^-_1 states

Interplay between angular momentum transfer and nuclear structure in the production of isomers at intermediate energies

J.M. Daugas[a,b], R. Grzywacz[c], M. Lewitowicz[a], J.C. Angélique[d], L. Axelsson[e], C. Borcea[f], C. Longour[g], M.J. Lopez-Jimenez[a], G. Neyens[b] and F. de Oliveira-Santos[a]

[a] GANIL BP 55027, 14076 Caen Cedex 5, France
[b] IKS, University of Leuven, Celestijnenlaan 200 D, 3001 Leuven, Belgium
[c] Department of Physics, University of Tennessee, Knoxville TN-37996, USA
[d] LPC Caen, 14021 Caen cedex, France
[e] Fysika Institutionen, Chalmers Tekniska Högskola, 41296 Göteborg, Sweden
[f] IAP, Bucharest-Magurele P.O.Box MG6, Rumania
[g] IReS Strasbourg, Université Louis Pasteur, 67037 Strasbourg cedex 2, France

The study of nuclei produced in their isomeric states is one of the important tools in order to investigate the nuclear structure in fragments close as well as far from the projectile. It might be also employed to obtain information about the role of different reaction mechanisms in population of excited states. A better understanding of the fragmentation-like reaction mechanism and, in particular, of the transfer of angular momentum can be achieved by measuring the isomeric ratio F (number of fragments produced in the isomeric state divided by the total number of fragments for a given A and Z) as a function of the velocity of the outgoing fragment, which for peripheral reactions, to some extend, is related to the impact parameter.

The isomeric ratio F observed in fragmentation-like reactions varies from several to almost 100% [1, 2, 3]. In particular, the population of the Yrast and non-Yrast isomeric states has been observed to be significantly different, which reflects a complicated interplay between the structure of the produced isomer and the reaction mechanism involved.

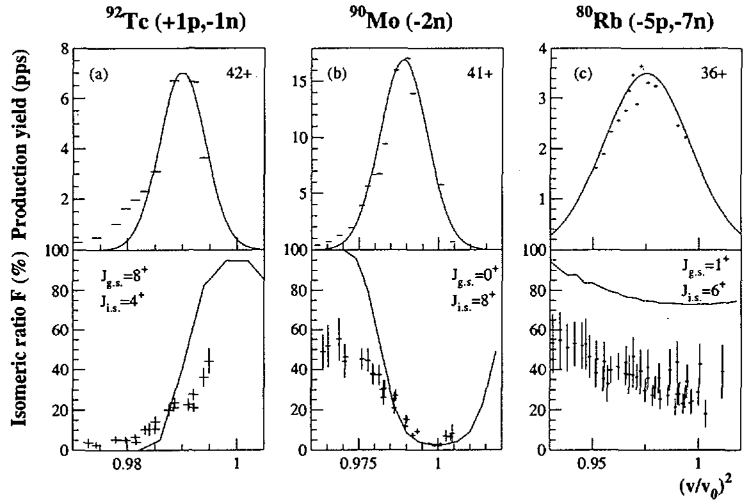


Figure 1: Yields (top) and isomeric ratios (bottom) for several isomers measured as a function of the ratio of the fragment velocity v over the beam velocity v_0 squared. Solid lines represent the calculated yield spectra (top) and the feeding of states with the spin greater (or lower for the ^{92}Tc) than the one of the isomer (bottom).

Isomeric ratios and momentum distributions of nuclei produced in the fragmentation of a 60AMeV ^{92}Mo beam on a thin ^{27}Al target have been studied in detail [4]. A strong dependence of the isomeric ratio on the structure of the isomer and on the reaction mechanism has been observed for the first time at intermediate energies. In the present work the isomeric ratio was measured for a large range of fragments as well as close as far from the projectile. This in turn allowed to study the angular momentum as a function of the number of transferred nucleons.

In this study, it has been observed that the isomeric ratio strongly depends on the fragment momentum distribution. As shown in figure 1 the measured distribution F(v) reaches its minimum (if $J_{isom.} > J_f$) or maximum (if $J_{isom.} < J_f$) value at the beam velocity. The F(v) distribution becomes almost flat for fragments far from the projectile (^{80}Rb). These results have been qualitatively reproduced in the framework of a simple model of nuclear fragmentation [4, 5, 6, 7]. Calculations using the kinematical fragmentation model [4, 5, 6] are presented in solid lines in figure 1. A strong correlation between the angular and linear momentum transfer in peripheral collision is indicated.

The results obtained in the present work have demonstrated the strong dependence of the isomeric states population in intermediate energy fragmentation reaction on the initial angular momentum transfer as well as on the nuclear structure of the final fragment.

References

[1] W.D. Schmidt-Ott *et al.*, Z. Phys. **A350**, 215 (1994).

[2] B.M. Young *et al.*, Phys. Lett. **B311**, 22 (1993).

[3] R. Grzywacz *et al.*, Phys. Lett. **B355**, 439 (1995).

[4] J.M. Daugas *et al.*, Phys. Rev. **C**, in press (2001).

[5] K. Asahi *et al.*, Phys. Lett. **B251**, 488 (1990).

[6] H. Okuno *et al.*, Phys. Lett. **B335**, 29 (1994).

[7] M. de Jong, A.V. Ignatyuk and K.-H. Schmidt, Nucl. Phys. **A613**, 435 (1997).

Nuclear spin alignment produced in a projectile fragmentation reaction

N.Coulier[a], D.L. Balabanski[a,b], D. Borremans[a], R. Coussement[a], J.M. Daugas[a,c], F. de Oliveira Santos[c], G. Georgiev[a], M. Lewitowicz[c], I. Matea[c], O. Naviliat-Cuncic[d] , M. Stanoiu[c], S. Teughels[a], K. Vyvey[a] and G. Neyens[a] [a]

University of Leuven, IKS, Celestijnenlaan 200 D, B-3001 Leuven, Belgium.
[b] Faculty of Physics, St. Kliment Ohridsky University of Sofia, BG-1164 Sofia, Bulgaria.
[c] GANIL, B.P. 5027, 14076 Caen Cedex 5, France.
[d] LPC Caen, 14050 Caen Cedex, France.

We report on the measurement of the initial spin orientation of ^{12}B, ^{13}B and ^{14}B produced in a fragmentation reaction of ^{18}O on a ^{9}Be target. To perform this experiment we have used the β-LMR method, which is a unique tool sensitive to both the spin polarization and the spin alignment [1]. Understanding the spin-orientation process is the key to allow studies of nuclear moments of nuclear states far from stability.
The aim of the study is to understand the change in the spin alignment as a function of the abraded nucleons in the fragmentation reaction. We have chosen a series of Boron isotopes of which the magnetic moment and the quadrupole interaction in a Mg single crystal are known. Consequently the magnetic field value where the resonances occur are known, so the nuclear spin orientation can be monitored. The spin alignment as well as the spin polarization can be deduced from the change in amplitude of the resonances by inverting the direction of the field [1].

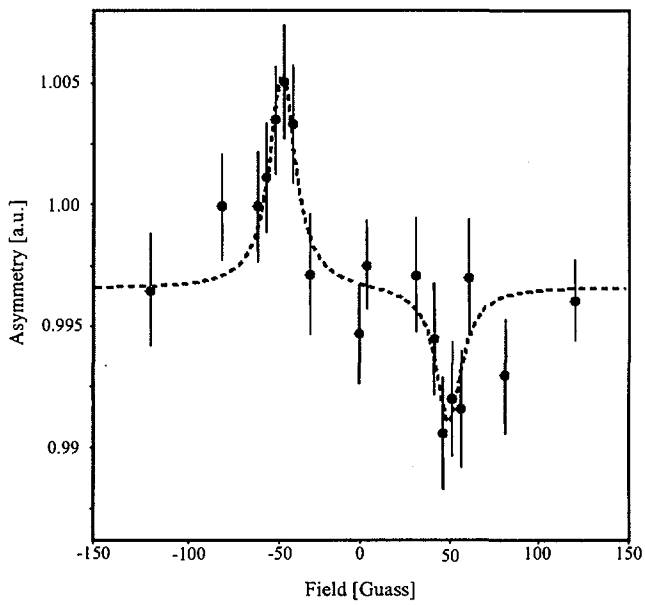


Figure 1: LMR of ^{12}B<u>Mg</u> for negative and positive magnetic fields.

A qualitative model assumes that the spin orientation is changing as a function of the momentum selection in the spectrometer [2, 3, 4]. To have an experimental proof of this signal in case of an aligned fragment beam, we have measured the spin alignment of the ^{12}B fragment for 5 different momentum selections.
Figure 1 shows an online result of a spin alignment measurement of ^{12}B in one of the momentum selections. At negative field values a resonance with a positive amplitude and at positive field values with a negative amplitude is measured. The inverting sign of the resonance is a signal of spin alignment [1]. If the amplitude of the positive and negative resonance differ, also spin polarization is present. The analysis is being done and the details of the experiment and the final result will be published later.
This work has been supported by the Access to Large Scale Facility of the EU under contract No. HPRICT199900019. D. Borremans is an assistent researcher and G. Neyens is a post doctoral researcher of the Flemish Science Foundation (FWO-Vlaanderen).

References

[1] N. Coulier et al., Phys. Rev. C 63 (2001) 4605

[2] K. Asahi et al., Phys. Rev. C 43 (1991) 456.

[3] H. Okuno et al., Phys. Lett. B335 (1994) 29.

[4] J.M. Daugas et al., Phys. Rev. C, to be published (2001).

Spin-polarisation of ^{27}Na and ^{31}Al intermediate energy projectile-like fragments

J. M. Daugas[a], D. Borremans[a], S. Teughels[a], D. L. Balabanski[a,b,c], N. Coulier[a], R. Coussement[a], G. Georgiev[a], M. Hass[d], M. Lewitowicz[e], I. Matea[e], F. de Oliveira-Santos[e], Yu. Penionzhkevich[f], W.-D. Schmidt-Ott[g], M. Stanoiu[e], K. Vyvey[a] and G. Neyens[a]

[a] Instituut voor Kern- en Stralingsfysica, University of Leuven, Celestijnenlaan 200 D, 3001 Leuven, Belgium

[b] Dept. of Physics and Astronomy, University of Tennesse, Knoxville, TN 37996, USA

[c] St. Kliment Ohridski University of Sofia, 1164 Sofia, Bulgaria

[d] The Weizmann Institute, Rehovot, Israel

[e] GANIL BP 55027, 14076 Caen Cedex 5, France

[f] FLNR, JINR 141980 Dubna, Moscow Region, Russia

[g] Physikalisches Institut der Universität, 37073 Göttingen, Germany

A secondary spin-polarised beam has been produced for the first time at the GANIL facility using the LISE3 spectrometer. The secondary beams of interest, ^{27}Na and ^{31}Al were coming from the projectile fragmentation of a ^{36}S beam at 77.5 AMeV onto a Be target.

The spin-polarisation of the produced fragments was detected by using the β-NMR experimental technique [1]. In order to have spin-polarisation, the primary beam has been tilted by an angle of 2° with respect to the secondary beam direction. This method was successfully applied for the first time by using the target located at the entrance of the LISE3 spectrometer. The experimental spin-polarisation obtained for different cuts in the momentum distribution is presented in figure 1. This shows that the spin-polarisation still exists for fragments far from the projectile (^{36}S $\rightarrow$ ^{27}Na), which opens new possibilities for investigations on the nuclear matter close to the drip-lines. In order to derive the spin-orientation at the reaction place, the amount of the experimentally detected spin-polarisation has to be corrected by geometrical and scattering effects which might destroy this orientation. GEANT simulations on this aspect are in progress.

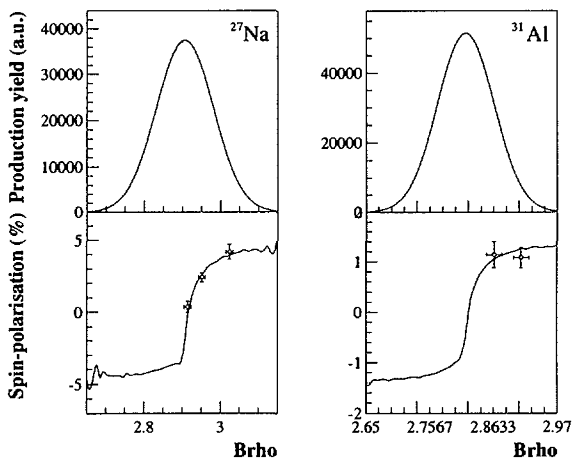


Figure 1: Production yields (top) and experimentally detected spin-polarisation (bottom) of the ^{27}Na and ^{31}Al fragments. The solid lines correspond to the prediction of the kinematical fragmentation model. Note that the theoretical curves have been scaled by a factor of 1/12 and 1/60 for the ^{27}Na and ^{31}Al respectively.

Experimental results have been quantitatively reproduced in the framework of a kinematical fragmentation model [2, 3, 4], using a spectator-participant picture with the position of the removed 'participant' part (the reaction angle θ) as a reaction parameter [3]. In the kinematical calculations which where performed within this model, the angular momentum **J**, which is transferred to the prefragment in the projectile rest frame, is taken into account as:

$$\mathbf{J} = \mathbf{R} \times \mathbf{k}$$

where **R** is the vector position of the abraded part and **k** its linear momentum.

By considering the z-axis as the beam axis it is then possible to obtain the amount of spin-polarisation P of the produced fragment as a function of the linear momentum. The spin-polarisation along the axis perpendicular to the reaction plane is defined by the classical expression:

$$P = \frac{J_x}{|J|}$$

The dependence of the experimental spin-polarisation has been compared with calculations performed within the framework of the kinematical fragmentation model (solid lines in figure 1). We found that data were best reproduced for a reaction angle θ=10° [3] and assuming one evaporated nucleon per 2 abraded nucleons. By using this model, we are able to calculate qualitatively the spin-polarisation of outgoing fragments. In turn, the predictive power of these calculations gives the possibility to perform successful experiments with the aim to measure the spin, quadrupole and magnetic moments of ground or isomeric states for nuclei far from the valley of stability.

This work have been supported by the European foundation Access to Research infrastructures action of the Improving Human Potential Program under Contract No. HPRI-CT-1999-00019. D.B. and G.N. acknowledges the FWO-Vlaanderen Belgium fellowships.

References

[1] N. Coulier *et al.*, Phys. Rev. **C59**, 1935 (1999) and references therein

[2] K. Asahi *et al.*, Phys. Rev. **C43**, 456 (1991)

[3] H. Okuno *et al.*, Phys. Lett. **B335**, 29 (1994)

[4] J.M. Daugas *et al.*, to be published in Phys. Rev. C, (2001)

EXPERIMENTS ON SUPER-HEAVY NUCLEI PRODUCTION

The FULIS collaboration: N. Alamanos[3], N. Amar[1], J.C. Angélique[1], R. Anne[2], G. Auger[2], F. Becker[2], R. Dayras[3], A. Drouart[3], J.M. Fontbonne[1], A. Gillibert[3], S. Grévy[1], D. Guerreau[2], F. Hanappe[1], R. Hue[2], A.S. Lalleman[2], N. Lecesne[2], T. Legou[1], M. Lewitowicz[2], R. Lichtenthäler[4], E. Liénard[1], L. Maunoury[5], W. Mittig[2], F. de Oliveira[2], N. Orr[1], J. Péter[1], E. Plagnol[6], G. Politi[7], E. Pollacco[3], M.G. Saint-Laurent[2], Z. Sosin[8], J.C. Steckmeyer[1], C. Stodel[2], J. Tillier[1], R. de Tourreil[2], A.C.C. Villari[2], J.P. Wieleczko[2], A. Wieloch[8]

[1]*: LPC, Caen.* [2]*: GANIL, Caen.* [3]*: DAPNIA/SPhN, C.E.N. Saclay.* [4]*: IFUSP, São Paulo.* [5]*: C.E.A. B3, Bruyères-le-Chatel.* [6]*: IPN, Orsay.* [7]*: INFN, Catania.* [8]*: Ins. Fyziki Uniw., Krakow.*

A program of experiments on the production and study of super-heavy nuclei has been undertaken at Ganil, taking advantage of the powerful velocity filter LISE3 (crossed magnetic and electric fields) and the very high intensity ECR Ion Sources.

A complete set-up has been built and tested (see figure). The main tool is the Wien filter, divided in two identical halves, and its triplets of quadrupoles. It was designed for the purification of exotic beams produced by the LISE magnetic device and several modifications were found to be necessary for the production and transport of complete fusion evaporation residues and the rejection of the primary beam :- a reaction chamber was added just before LISE3, - the upper plate in the first half of the filter was moved up, (the beam is thus deflected after this first half without hiting the plate and stopped on a water-cooled plate) - two pairs of independently movable slits and a beam profiler were installed at mid-filter. The suppression of unwanted products is improved by a dipole magnet located after the velocity filter.

The reaction chamber contains a wheel bearing 35 targets on a diameter of 670 mm and rotating at 2000 RPM, allowing targets with a low melting temperature (Pb, Bi) to sustain intense beams (several particle-μA). The time structure of the beam is synchronized with the rotation and a Si detector continuously monitors the status of each target. Smaller rotating targets are used for targets having a higher melting temperature.

The velocity of each product is obtained with 2 aluminized mylar foils and micro-channel plate detectors; its kinetic energy and localization are given by a X-Y Si implantation detector (Imp). The energy of α particles and fission fragments escaping from Imp is measured with a "tunnel" of 8 Si detectors. A Si veto detector is installed behind Imp to reject light particles which might punch through it. In order to measure long half-lives, when emission of α particles or fission fragment in the Imp is identified via electronics, the beam is immediately stopped for a short while, during which Imp1 is moved out and Imp2 comes in; then the beam is sent again. α particles escaping from Imp1 are then detected by Face1. It is thus possible to study α emission or spontaneous fission on long durations without any background. Specific electronics and data acquisition systems were developped. A fast analysis program allows us to identify decays via α or spontaneaous fission on line.

The transmission of fusion nuclei from the target position through the quadrupoles, filter and final dipole was studied via a simulation code, ZGOUBI. The optics was checked and the Wien filter was calibrated using low energy (0.25 MeV/u) ions. The response of the whole set-up was checked via fusion reactions with known cross sections and α decay chains: $^{204-206}$Fr nuclei formed via ^{86}Kr + ^{nat}Sb with cross sections of 10 to 300 μb,

^{260,261}Sg(106) nuclei formed via ^{54}Cr + ^{208}Pb with cross sections of 300-500 nb [1]. In this last case, a transmission efficiency above 60 % and a suppression factor of the primary beam of 2*10^{10} were achieved.

Measurements were made on the system ^{86}Kr+^{208}Pb at 5.27 MeV/u for which long α chains attributed to element 118 were observed [2]. With a total dose of 1.1x10^{18} ions on 300 μg/cm^2 targets, no such event was observed, in agreement with the results of SHIP [1].

A program based on cold fusion reactions will follow two directions: - use of ^{76}Ge or ^{82}Se projectiles in order to directly produce isotopes of Z=108-111 having two neutrons more than isotopes directly produced with ^{208}Pb or ^{209}Bi targets. - use of Pb and U projectiles in order to benefit from the advantages of inverse kinematics (gains in beam time and efficiency, improved quality of data) and make detailed studies of the characteristics of already observed isotopes and to produce new isotopes and new elements.

In the future, neutron-rich projectiles produced by SPIRAL will also be used.

[1] S. Hofmann and G. Münzenberg, Rev. Mod. Phys. (2000)

[2] V. Ninov et al., Phys. Rev. Lett. **83** (1999) 1108

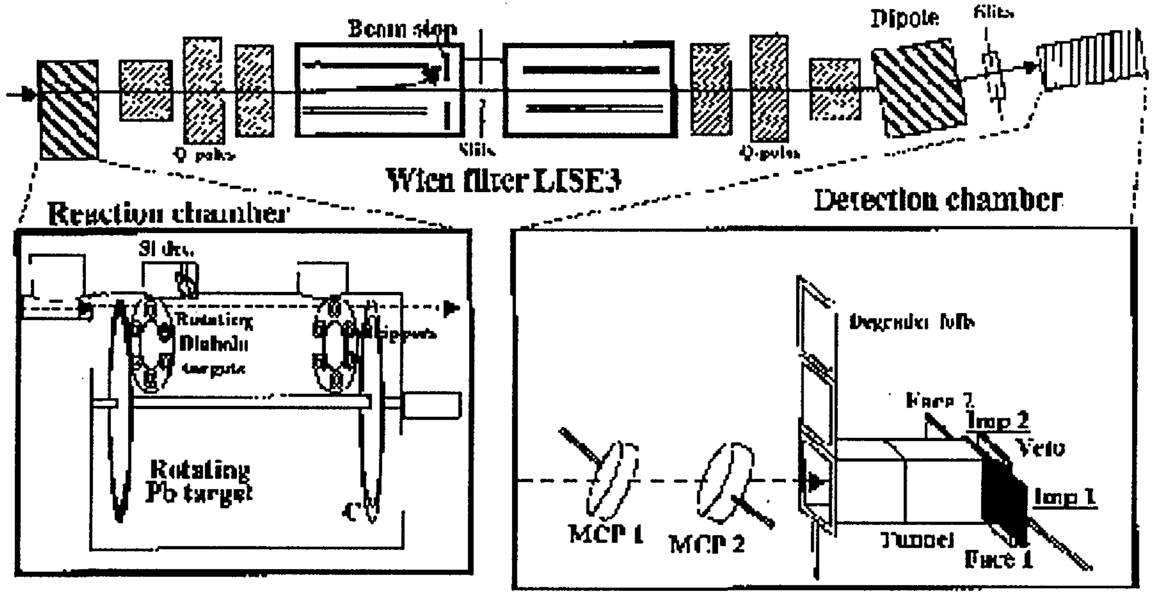


Figure: Experimental set-up.

3 - EXOTIC NUCLEI : SPECTROSCOPY

Study of the ^{22}Al β-decay

N.L. Achouri[1], J. Äystö[5], R. Beraud[4], B. Blank[3], G. Canchel[4], S. Czajkowski[3], F. de Oliveira Santos[2], A. Emsallem [4], J. Giovinazzo [3], A. Jokinen[5], A. Laird[6], M. Lewitowicz[2], C. Longour[3], A. Ostrowski[6], M. Stanoiu[2], J.C Thomas[3], and W. Trinder[2].

1 LPC Caen - ISMRA, 6 Bd du Mal Juin, F-14050 Caen Cedex, France.
2 GANIL, Bd Henri Becquerel, F-14000 Caen, France.
3 CENBG, Gradignan, France.
4 IPNL, université Claude Bernard de Lyon, Villeurbanne, France.
5 Department of Physics, University of Jyväskylä, Finland.
6 Department of Physics and Astronomy, University of Edinburgh, United Kingdom.

An ^{22}Al beam (60 pps, 95 % purity) was produced in the E313 experiment using the LISE3 magnetic spectrometer and by the fragmentation of an ^{36}Ar primary ions at 95 $MeV/nucleon$. The detection system was composed of three silicon detectors and a Ge clover detector in a close geometry.
After implantation of the separated fragments in the downstream edge of the second silicon detector, an energy spectrum in this detector of the β-delayed charged particles was obtained as shown in the figure 1, in white without any condition and in dark in coincidence with β-particles emitted in the direction of the last thick SiLi detector. This condition minimize the β energy loss in the second detector, providing a better resolution for the determination of the proton lines.
This study has much higher statistics than previous experiments ([1],[2],[3]) and has the added advantages of a greatly improved energy resolution and the measurement of the coincident γ-rays. As a result, a more precise assignment of the proton, 2p and α lines have been made as shown in the figure 2.

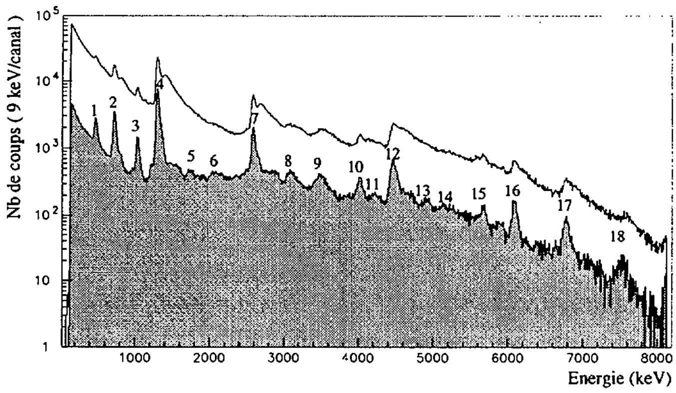


Figure 1: *Energy spectrum of ^{22}Al β-delayed charged particles . In white, without any coincidence. In dark, in coincidence with β-particles emitted to the last detector.*

A reliable determination of the spin of the ^{22}Al (not known) ground state has been possible. Indeed, the measured intensities of the γ rays from $\beta - \gamma$ transitions was compared to those predicted by shell model calculations. We concluded that the ^{22}Al ground state spin is a 4^+.

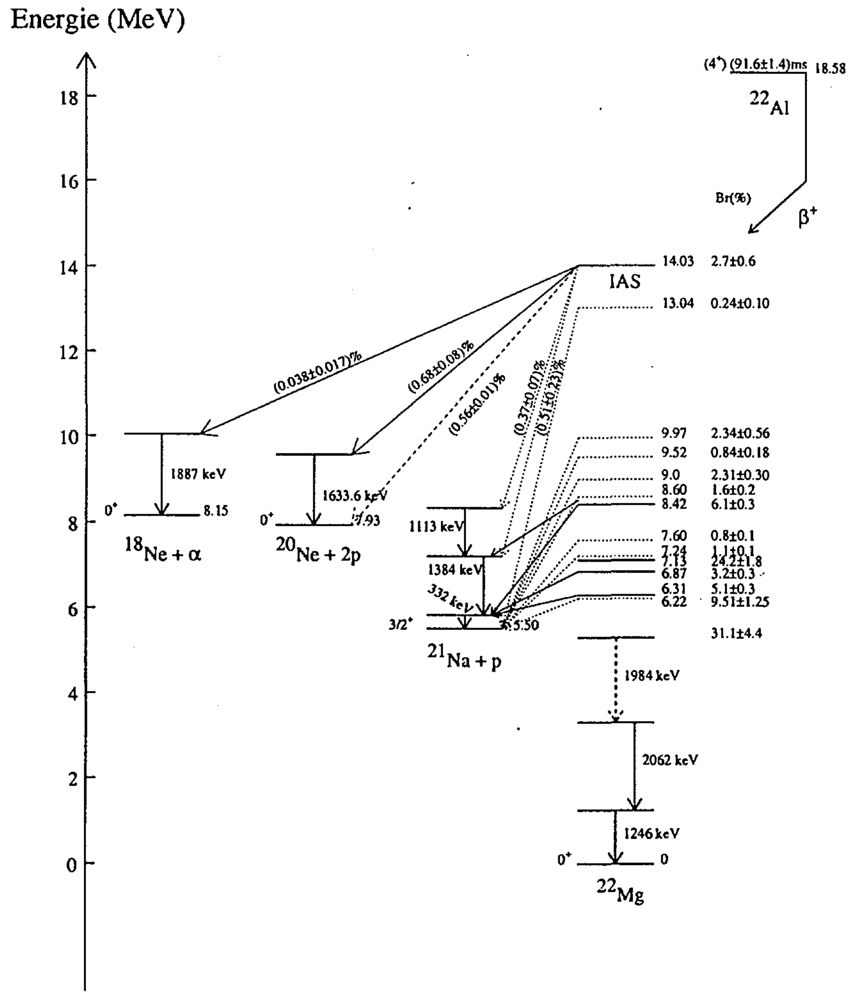


Figure 2: *Preliminary decay scheme of* ^{22}Al. *The proton lines without* γ*-rays coincidences are in dashed lines.*

[1] M.D. Cable et al., Phys. Rev. C volume 26, num. 4, p.1778 (1982)

[2] M.D. Cable et al., Phys. Rev. Lett. volume 50, num. 6, p.404 (1983)

[3] B. Blank et al., Nucl. phys. A 615, p.52 (1997)

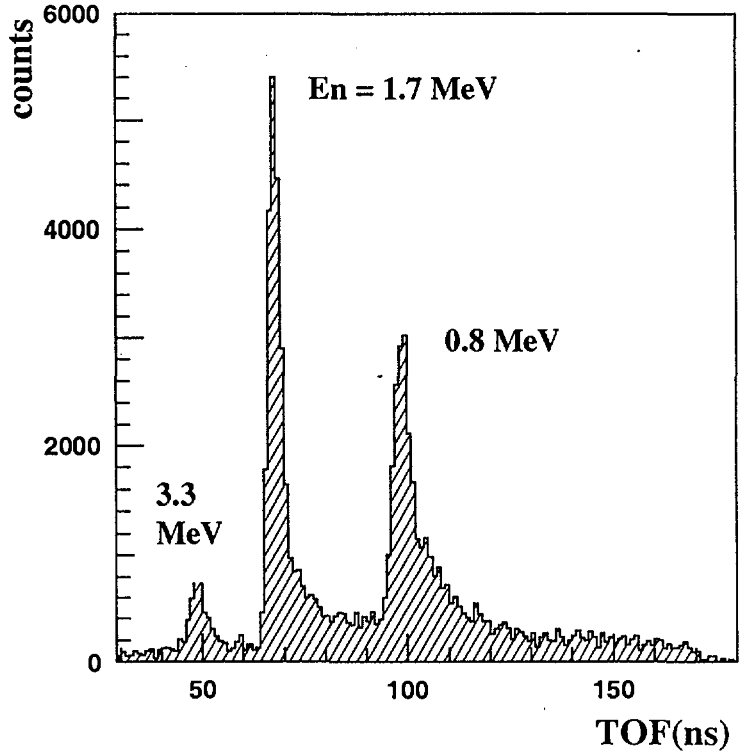
Decay spectroscopy with the TONNERRE array

N.L. Achouri[1], J.C. Angélique[1], P. Baumann[4], C Borcea[2], A. Buta[2], W. Catford[9], S. Courtin[4], J.M. Daugas[8], P. Dessagne[4], F. De Oliveira[3], Z. Dlouhy[7], S. Grévy[1], D. Guillemaud-Mueller[5], R. Hadeler[4], A. Knipper[4], F.R. Lecolley[1], J.L. Lecouey[1], M. Lewitowicz[3], E. Liénard[1], C. Miehe[4], J. Mrazek[7], F. Negoita[2], N.A. Orr[1], Y. Penionzhkevich[6], J. Peter[1], S. Pietri[1], E. Poirier[4], M. Stanoiu[3], O. Tarasov[3], C. Timis[2], G. Walter[4].

[1] *Laboratoire de Physique Porpusculaire F-14050 Caen Cedex, France.*
[2] *Institute of Atomic Physics, Bucharest-Magurele P.O Box MG6, Rumania.*
[3] *Grand Accélérateur National d'Ions Lourds, F-14021 Caen Cedex, France.*
[4] *Institut de Recherche Subatomique, BP20, F-67037 Strasbourg Cedex, France.*
[5] *Institut de Physique Nucléaire, F-91406 Orsay Cedex, France.*
[6] *Flerov Laboratory of Nuclear Reactions, JINR, 141980 Dubna, Russia.*
[7] *Nuclear Physics Institute, 250 68 Rez, Czech Republic.*
[8] *IKS, KU Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium.*
[9] *Department of Physics, University of Surrey, Guilford GU2 5Xh, UK.*

Decay studies provide one of the primary spectroscopic tools for the investigation of nuclei far from stability. For nuclei very far from stability high decay energies ($Q_\beta > 10$ MeV) along with relatively low proton or neutron separation energies in the daughter nucleus are encountered. As a result β-delayed particle emission often becomes the dominant decay mode. Access to the location and structure of unbound levels requires the measurement of the delayed particles - in particular the energies. For very neutron-rich nuclei, delayed neutron emission dominates, with delayed multi-neutron emission occurring in many cases. In the decay of ^{11}Li, for example, the delayed neutron emission probability, Pn is 92%, with P1n = 88% and P2n= 4%. The spectroscopy of neutron-rich nuclei thus requires a neutron detection system of high intrinsic efficiency and large acceptance. In this context the TONNERRE ("TONneau pour NEutrons REtardés") array was recently constructed by LPC-Caen in collaboration with IFIN-Bucharest [1].

The characteristics of the array have been determined using a ^{252}Cf neutron source and during a comissioning run at GANIL using beams of known delay-neutron emitters: ^{15}B, ^{16}C, ^{17}N and ^{11}Li [2] . In addition to the neutrons of known energies, a new neutron line at 3.3 MeV was observed in the β-decay of ^{16}C (see figure). The very low branching ratio (~1%) [3], and the fact that this transition had not been observed in previous experiments performed elsewhere indicate the utility of TONNERRE.



β-delayed neutron TOF spectrum for the decay of ^{16}C [3] .

More recently an experiment concerning the decay of ^{32,33}Mg and ^{34,35} Al was performed [4]. The goal was to investigate the collapse in the N=20 shell closure. In addition to TONNERRE, two clover detectors, a LEPS and eight low energy neutron counters were employed to undertake the measurements. Preliminary analysis shows three peaks in the delayed neutron spectrum of ^{32}Mg and four in that of ^{33}Mg. The resulting spectroscopic information should provide a useful test of large scale shell model calculations including np–nh excitations aimed at understanding the structural effects occurring in this region.

[1] T. Martin, Ph.D Thesis, Université de Caen LPCC T98-03, November 1998.
[2] A. Buta et al, NIMA 455 (2000) 412-423.
[3] S. Grévy et al, PRC, 63 (2001).
[4] J.C. Angélique et al, GANIL Proposal E333 and references therein.

Decay of proton-rich nuclei between ^{39}Ti and ^{49}Ni

J. Giovinazzo[1], B. Blank[1], C. Borcea[2], M. Chartier[1], S. Czajkowski[1], G. de France[3], R. Grzywacz[4], Z. Janas[4], M. Lewitowicz[3], F. de Oliveira Santos[3], M. Pfützner[4], M.S. Pravikoff[1], J.C. Thomas[1]

[1] *Centre d'Études Nucléaires de Bordeaux-Gradignan, CNRS/IN2P3, France*
[2] *Institute of Atomic Physics, Bucharest-Margurele, Romania*
[3] *Grand Accélérateur National d'Ions Lourds, Caen, France*
[4] *Institute of Experimental Physics, University of Warsaw, Poland*

The main purpose of the present experiment E312a at the LISE3 facility was first the observation of doubly-magic ^{48}Ni [1]. However, the experimental setup allowed also for the study of the decay of very proton rich nuclei in the $A = 40$ to 50 mass region. Most isotopes observed in this work are β-delayed two-proton emitters, and some of them are good candidates for the yet unobserved two-proton radioactivty [2, 3, 4] like ^{39}Ti, ^{42}Cr, ^{45}Fe and $^{48,49}Ni$.

The exotic nuclei were produced in the fragmentation of a $^{58}Ni^{26+}$ beam at 74.5 $MeV/nucleon$ on a natural nickel target. The isotopes were selected with the Alpha spectrometer and the LISE3 separator using a shaped beryllium degrader at the intermediate focal plane and the Wien filter. The secondary beam was implanted in a silicon telescope that allowed several energy, energy-loss and time of flight measurements on an event by event identification of the ions.
The decay occured in the implantation detector where the decay energy and its time characteristics were measured. The telescope was surrounded with 3 germanium detectors for the observation of γ deexcitation in coincidence with the decay.

During the expeximent, we could obtain new information concerning the decay of ^{39}Ti, $^{42,43}Cr$, ^{46}Mn, $^{45,46,47}Fe$ and ^{49}Ni. For the most exotic ones, ^{42}Cr, ^{45}Fe and ^{49}Ni, the half-life could be measured for the first time, while it has been determined with an increased accuracy for the other isotopes (see table 1).
Although many β-delayed proton transitions have been observed, only a few of them could be placed in a decay scheme. This requires coincidences with γ rays from the nuclear deexcitation, and the statistics were too low, except in the cases of ^{43}Cr and ^{47}Fe for which a first decay scheme could be deduced. For some identified transitions, we could deduce the excitation energy of the isobaric analog state in the daughter nucleus and estimate the mass excess of the decaying isotope from the isobaric multiplet mass equation.
The present experiment yielded no evidence for two-proton radioactivity from ^{39}Ti, ^{42}Cr or ^{49}Ni, and the proton energy distributions, together with the half-life estimates, are strongly in favour of a weak-interaction decay. In the case of ^{45}Fe and ^{48}Ni, higher statistics and an improved detection setup will be required to search for this decay mode.

References

[1] B. Blank *et al.*, *Phys. Rev. Lett. 84*, 1116 (2000).

isotope	theoretical prediction			experimen tal half-life	
	Gross Theory [5]	Ormand [3]	Hirsch *et al.* [6]	previous work	this work
^{40}Ti	56	56	–	54 ± 2 [8]	53.5 ± 2.5
				52.7 ± 1.5 [7]	
^{39}Ti	28	29	–	26^{+8}_{-7} [9]	31^{+6}_{-4}
^{43}Cr	21	14	23 - 57	21 ± 4 [10]	21.6 ± 0.7
^{42}Cr	21.2	17	12 - 33	–	$13.4^{+3.6}_{-2.4}$
^{46}Mn	35	37	–	41^{+7}_{-6} [10]	$34.0^{+4.5}_{-3.5}$
^{47}Fe	27.3	–	22 - 57	27^{+32}_{-10} [10]	21.8 ± 0.7
^{46}Fe	24.3	18	15 - 30	20^{+20}_{-8} [10]	$9.7^{+3.5}_{-4.3}$
^{45}Fe	11.7	7	7 - 30	–	6.0^{+17}_{-3}
^{49}Ni	10.7	–	7 - 20	–	12^{+5}_{-3}

Table 1: Comparison of theoretical predictions for β-decay half-lives to results from previous experiments and from the present work. All half-lives are given in ms.

[2] B. A. Brown *Phys. Rev. C 43*, R1513 (1991).
[3] W. E. Ormand *Phys. Rev. C 55*, 2407 (1997).
[4] B. J. Cole *Phys. Rev. C 54*, 1240 (1996).
[5] T. Tachibana *et al.*, *Prog. Theor. Phys. 84*, 641 (1990).
[6] M. Hirsch *et al.*, *At. Data Nucl. Data Tables 53*, 165 (1993).
[7] A. G. M. Bhattacharya *et al.*, *Phys. Rev. C 58*, 3677 (1998).
[8] W. Liu *et al.*, *Phys. Rev. C 58*, 2677 (1998).
[9] C. Détraz *et al.*, *Nucl. Phys. A519*, 529 (1990).
[10] V. Borrel *et al.*, *Z. Phys. A 344*, 135 (1992).

A new shape isomer in the N=Z nucleus ^{72}Kr

F. Becker[1,2], B. Blank[3], C. Borcea[4], E. Bouchez[1], A. Buta[4], A. Emsallem[5], G. de France[2], J. Genevey[6], F. Hannachi[7], K. Hauschild[1], A. Hürstel[1], W. Korten[1,*], Y. Le Coz[1], M. Lewitowicz[2], R. Lucas[1], I. Matea[2], F. Negoita[4], F. de Oliveira[2], D. Pantelica[4], J. Pinston[6], P. Rahkila[8], M. Rejmund[1], M. Stanoiu[2], Ch. Theisen[1]
[1]*CEA Saclay,* [2]*GANIL,* [3]*CENBG Bordeaux,* [4]*IFIN Bucarest,* [5]*IPN Lyon,* [6]*ISN Grenoble,* [7]*CSNSM Orsay,* [8]*Univ. of Jyväskylä*
* *Corresponding author:* **wkorten@cea.fr**

The neutron-deficient Krypton isotopes have a long-standing history as candidates for the occurence of coexistence between well-deformed prolate and oblate shapes. The presence of pronounced shell gaps for large prolate and oblate deformations for a proton number Z=36 is the main reason to expect this phenomenon. The neutron orbitals favour spherical shapes for the stable Krypton isotopes ($A \geq 78$) whereas pronounced deformation can occur for the lighter ones. The mixing of the prolate and the oblate 0^+ states is a function of the energy difference between them. Close to the N=Z line, prolate and oblate 0^+ states are expected within a few hundred keV of excitation energy.

Previous experiments have been performed to study the properties of neutron-deficient Krypton isotopes: the lightest isotope in which a long-lived, excited 0^+ state ("shape isomer") has been observed is ^{74}Kr studied by in-beam γ-ray and conversion-electron spectroscopy after fragmentation [1] and fusion-evaporation reactions [2].

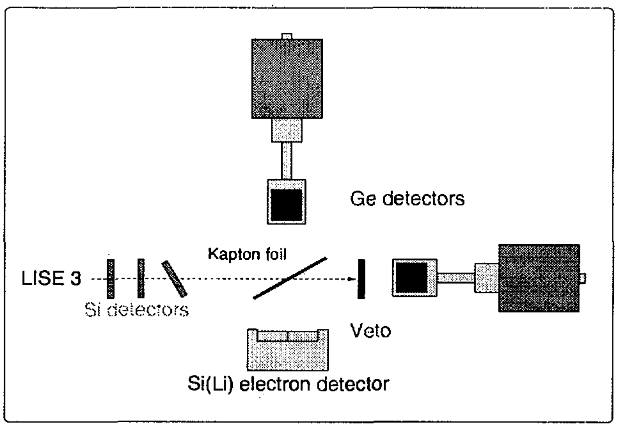


Figure 1: Fig. 1. Focal plane detection setup.

In our experiment, performed in August 2000, we have investigated isomeric states in very neutron-deficient nuclei around A=70. For the first time, we have performed a combined conversion-electron and γ-ray spectroscopy after a fragmentation reaction at GANIL. A 73 MeV.A ^{78}Kr beam on a Be target produced different fragments which were separated by the LISE3 spectrometer and implanted into a thin Kapton foil. The γ-ray and electron detection was performed at the focal plane of the spectrometer (Fig. 1): two segmented Clover detectors from the EXOGAM collaboration, one coaxial germanium detector and one LEPS for low energy γ-rays were used for γ detection. Electrons were measured with a two fold segmented Si(Li) detector mounted close to the implantation foil. With this method, isomeric transitions can be assigned event-by-event to a given fragment.

We observed at an excitation energy of 508 keV the isomeric state previously seen and assigned it unambigously to ^{74}Kr. Moreover, we have observed, in coincidence with ^{72}Kr fragments, K and L conversion lines in the electron spectrum corresponding to a 671 keV transition (see Fig. 2). No evidence for this transition was found in the γ-spectrum, identifying it as an E0 transition between an excited 0^+ state and the ground state . The lifetime of this state has been determined to be about 42 ns.

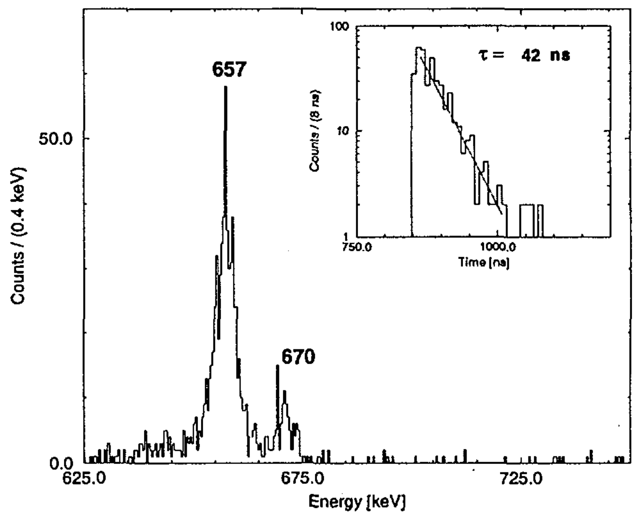


Figure 2: Fig. 2. Electron and time spectra for ^{72}Kr: decay of the 0^+ isomer.

Due to the energy and the lifetime of this state as well as the systematics of the heavier isotopes, the new excited state is interpreted as a prolate deformed shape isomer. For ^{72}Kr, the ground state is oblate. This is the first observation of a shape isomer in a N=Z nucleus. Lifetime measurements allow us to extract transition matrix elements that can be interpreted in a systematics of Krypton isotopes. In addition, it is particularly interesting to study the change in ground state shape from ^{80}Kr (prolate) to ^{72}Kr (oblate).

References

[1] C. Chandler et al., Phys. Rev. C **56**, R2924 (1997)

[2] F. Becker et al., Eur. Phys. J. A **4** 103 (1999) and Phys. Scripta 17 (2000)

Coupling of valence particles to the ^{70}Ni core studied via measurements of the B(E2) strength in ^{67,69,70}Ni and ^{71}Cu

H. Mach[a], M. Lewitowicz[b], M. Stanoiu[b], F. Becker[b], J. Blomqvist[c], M.G. Borge[d], R. Boutami[d], B. Cederwall[c], Z. Dlouhy[e], B. Fogelberg[a], L.M. Fraile[d], G. Georgiev[f], H. Grawe[g], R. Grzywacz[h,i], P.I. Johansson[j], W. Klamra[c], S. Lukyanov[k], M.N. Mineva[l], J. Mrazek[e], G. Neyens[f], F. de Oliveira Santos[b], M. Pfützner[i], Yu.E. Penionzhkevich[k], E. Ramström[a] and M. Sawicka[i]

[a] *ISV, Uppsala University, Nyköping, Sweden,* [b] *GANIL, Caen, France,*
[c] *Physics Dept., KTH, Stockholm, Sweden,* [d] *CISC, Madrid, Spain,*
[e] *NPI Rez, Czech Republic,* [f] *IKS - KU Leuven, Leuven, Belgium,*
[g] *GSI Darmstadt, Germany,* [h] *University of Tennessee, Knoxville, USA,*
[i] *IFD, Warsaw Univ., Warsaw, Poland,* [j] *NFL, Uppsala Univ., Nyköping, Sweden,*
[k] *FLNR, JINR Dubna, Russia,* [l] *Lund University, Lund, Sweden*

Sparce experimental information exists on heavy Ni nuclei, and thus the shell model (SM) results are well ahead of the experimental facts [1]. The situation is getting particularly interesting at ^{68}Ni, where the low-j p-orbits are filled and the next neutron goes into the large-j $g_{9/2}$ orbit. A strong pairing of $g_{9/2}$ neutrons was proposed in order to explain the presence of μs-isomers around ^{70}Ni. A hint is given by sequences of γ rays de-exciting the μs-isomers in ^{69}Ni (148-593-1044-594 keV) and ^{71}Cu (133-494-939-1188 keV), which have energies similar to the 183-448-970-1259 keV cascade in ^{70}Ni suggested as a sequence of E2 γ-rays de-exciting the 8^+, 6^+, 4^+ and 2^+ levels [2,3]. Assuming E2 nature of the 148, 133 and 183-keV isomeric transitions, their B(E2)'s fall into a narrow range of 0.6–2.2 W.u. The SM calculations reproduce [1] the energy sequence and isomeric lifetimes, but besides μs-lifetimes, and γ-ray intensities and energies, no other experimental information has been available to support interpretation of these high-spin structures.

We have employed a novel fast timing technique to determine the level lifetimes, which then serve to verify the proposed E2 nature of the 593-, 448-, and 494-keV transitions listed above and the 694-keV γ-ray in ^{67}Ni. The measurements on the neutron-rich nuclei around A=70 were performed at the LISE spectrometer in GANIL following fragmentation of the ^{76}Ge 61.8 MeV/u beam on a ^{9}Be target. We used a 512 μm Be target, which effective thickness could be increased by rotating it. In order to improve the selectivity of the fragments of interest a degrader of 220.5 μm Be was placed between two dipoles of the LISE spectrometer. For the identification and implantation of the ions we used a telescope made of three Si detectors. Two of them had the thickness of 300 μm while the position sensitive detector of 500 μm, in which the ions were implanted, was tilted at 45 degrees, and thus had an effective thickness of about 700 μm. The separation of the ions was mainly achieved from the energy loss in the second Si detector and the time of flight between the rf of the cyclotron and the time signal from the second Si detector.

Two settings of the LISE spectrometer were utilized in order to enhance studies of selected rare isotopes. In the first setting the intensity of the primary beam was about 400 enA and the effective target thickness was 738 μm, which allowed to sustain a counting rate of 200 pps and 400 pps for ^{70}Ni and ^{72}Cu, respectively, and smaller rates for ^{71}Cu and ^{71}Ni. The total counting rate in the implantation detector was about 1200 pps. In the second setting the intensity of the primary beam was about 110 enA while the effective target thickness was 520 μm. The counting rate was 580 pps for ^{67}Ni and 830 pps for ^{69}Cu. The total counting rate was about 2000 pps.

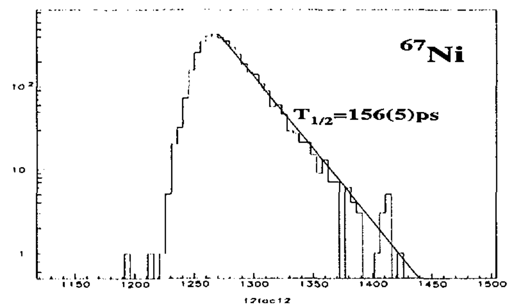
In this measurement a novel time-delayed technique using an array of four small BaF_2 detectors prepared and calibrated at the OSIRIS separator at Studsvik, was employed to search for level lifetimes from ~20 ns down to about 10 ps. The energy resolution of the BaF_2 detectors was about 10% at 661 keV and the time resolution was about 130 ps for a pair of two detectors measured at ~1.2 MeV γ-energy using a ^{60}Co source. Some details of the Advanced Time-Delyed Method calibrations and analysis techniques are described in [4,5]. Table 1 lists some of the measured lifetimes determined in the experiment.

The agreement of the experimental B(E2) values with the Shell Model predictions (using standard parameters for this region) is very close, implying a good predictive power of the calculations

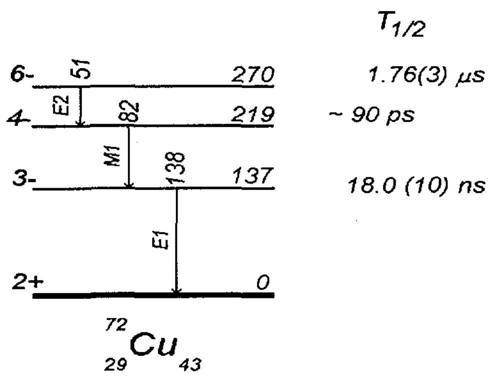
Table 1: *Level half-lives measured using Advanced Time-Delayed Method in nuclei around ^{70}Ni. Table includes also the experimental and Shell Model calculated B(E2) rates in Weisskopf units.*

Nucleus	Level E_x (keV)	J^π	$T_{1/2}$	De-exciting γ-ray (keV)	Multi-polarity	$B(E2)^{exp}$ (W.u.)	$B(E2)^{th}_{SM}$ (W.u.)
^{67}Ni	694	$5/2^-$	156(5) ps	694	E2	1.4	1.0 $^{a)}$
^{69}Ni	2552	$13/2^-$	517(24) ps	593	E2	0.63	1.3 $^{a)}$
^{70}Ni	2677	6^+	1057(31) ps	448	E2	1.7	1.8 $^{a)}$
^{71}Cu	2600	$15/2^-$	328(17) ps	494	E2	2.9	4.4 $^{b)}$
^{72}Cu	138	3^-	18.0(10) ns	138	E1		

$^{a)}$ using the effective charges of $e_\nu = 1.0\ e$ and $e_\pi = 1.5\ e$.
$^{b)}$ with $e_\nu = 1.5\ e$ and $e_\pi = 1.0\ e$.



and supporting the model interpretation of these nuclei. In particular, $T_{1/2}$=156(5) ps for the 694-keV level in ^{67}Ni (the time-delayed spectrum is shown above) gives B(E2) = 1.4 W.u. consistent with its proposed [1,6] $\nu f_{5/2} \rightarrow \nu p_{1/2}$ shell model interpretation. Table 1 lists also the lifetime of the 138 keV level in ^{72}Cu, which together with the lifetime limit for the 219 keV level did allow for the interpretation of the decay scheme of the 1.8 μs isomer in ^{72}Cu (shown below); for more details see [7]. A successful application of the BaF_2 array opens new possibilities for measurements of dynamic moments (via ps-lifetimes) in very exotic nuclei produced with low intensity.



References:

[1] H. Grawe et al., in *Shell Model 2000*, Riken, Japan, and references therein.
[2] R. Grzywacz et al., Phys. Rev. Lett. **81** 766 (1998).
[3] T. Ishii et al., Phys. Rev. Lett. **81**, 4100 (1998).
[4] H. Mach et al., Nucl. Instrum. Methods A **280**, 49 (1989) and references therein.
[5] H. Mach et al., Nucl. Phys. **A523**, 197 (1991) and references therein.
[6] T. Pawlat et al., Nucl. Phys. **A 574**, 623 (1994).
[7] H. Mach et al. contribution to the *Int. Symposium on Nuclear Structure Physics* NP2001, Göttingen, Germany, March 5-8, 2001, in press.

New short-lived isomeric states in neutron rich nuclei following the projectile fragmentation of ^{86}Kr beam

J.M. Daugas[a,b], R. Grzywacz[c,d], M. Lewitowicz[a], L. Achouri[e], J.C. Angélique[e], D. Baiborodin[a,f], K. Bennaceur[a,l], R. Bentida[g], R. Béraud[g], C.Borcea[h], C. Bingham[c], W.N. Catford[i], A. Emsallem[g], G. de France[a], H. Grawe[j], K.L. Jones[i], R.C. Lemmon[i], M.J. Lopez Jimenez[a], F. Nowacki[k], F. de Oliveira-Santos[a], M. Pfützner[d], P.H. Regan[i], K. Rykaczewski[d,l], J.E. Sauvestre[m], M. Sawicka[d], G. Sletten[n] and M. Stanoiu[a].

[a] GANIL BP 5027,14076 Caen Cedex 5, France
[b] IKS, KULeuven, Celestijnenlaan 200 D, 3001 Leuven, Belgium
[c] University of Tennessee, Knoxville, TN 37996, USA
[d] IFD, Warsaw University, Pl-00681 Warsaw, Hoża 69, Poland
[e] LPC Caen, 14021 Caen Cedex, France
[f] Nuclear Physics Institute, 250 68 Rez, Czech Republic
[g] IPN Lyon, 69622 Villeurbane Cedex, France
[h] IAP, Bucharest-Magurele P.O.Box MG6, Rumania
[i] Department of Physics, University of Surrey, Guildford, GU2 5XH, UK
[j] GSI, Postfach 110552, D-64220, Darmstadt, Germany
[k] LPT, Université Louis Pasteur, 67084 Strasbourg Cedex, France
[l] ORNL, Physics Division, Oak Ridge, TN 37830, USA
[m] CEA Bruyères le Châtel, BP 12, 91680 Bruyères le Châtel, France
[n] Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark

Short-lived (from few nanosecond to several microsecond) isomers have been studied for several years. The study of isomeric states is an important tool in order to obtain spectroscopic information on the nuclear structure of nuclei far from the valley of stability. The present experiment was performed in order to search and study new isomeric states in neutron rich nuclei in the potassium to germanium region produced by the fragmentation reaction of a ^{86}Kr beam. It is a continuation of the previous survey experiment where new spectroscopic information has been obtained for 13 isomeric states [1]. In this experiment, evidence for the existence of 10 more isomeric states was shown.

The experiment has been performed at GANIL using the LISE spectrometer [2]. The neutron rich ^{86}Kr beam with an energy of 60.5 AMeV impinged on a rotating 100μm thick ^{nat}Ni target. A 500μm thick Be backing placed behind the target allowed a reduction of the width of the charge states distribution of produced fragments. A 50μm thick Be wedge was used in the first dispersive plane of the spectrometer to remove light fragments and to further suppress non-fully-stripped ions. In order to reduce the time of flight of fragments to less than 200 ns (compared with 1.2μs in our previous experiment[1]) the experimental set-up was placed in the first achromatic focal point of LISE. The heavy ions were detected by a three-element Si-detector telescope. The silicon detectors were 300μm, 300μm and 500μm thick, respectively. The last detector was x and y position sensitive and it was mounted at an angle of 45° with respect to the beam axis. The last Si-detector was surrounded by 4 high-purity germanium detectors: one four-crystal clover of 120% relative efficiency (add-back including), two coaxial-type of 90% and 80% efficiency respectively and one low energy photon spectrometer (LEPS). In order to increase the geometrical efficiency of the setup, two detectors with the highest efficiency, were placed at about 1.5cm from the implantation Si-detector. The distance between the other two Ge-detectors and the beam axis was about 5cm. The sensitivity range for γ-ray energies was between 30 keV and 4 MeV. The total photopeak efficiency was measured to be 6.2(1)% for 1.3 MeV γ-rays. All detectors were mounted perpendicularly to the beam axis.

The lifetimes of isomeric states were measured by storing the time difference between the heavy ion implantation signal and delayed γ-rays. Two separate time ranges of up to 500 ns and 40 μs respectively were recorded for each Ge crystal using standard time-to-digital converter (TDC) and time-to-amplitude converter (TAC) modules respectively.

The identification of fragments in mass, atomic number and atomic charge was achieved by means of energy-loss, total-kinetic-energy and time-of-flight measurements. The independent confirmation of the fragment identification comes from the observation of characteristic γ-rays corresponding to the previously identified isomeric decays. All isomeric states reported in ref. [1] were observed also in the present experiment, in most cases, with much higher statistics.

In the table 1, a summary of the measured gamma rays and half-lives for the new observed isomeric states is presented.

Nucleus	E* (keV)	$T_{1/2}$ (ns)	I^π	F (%)	E_γ (kev)
^{50m}K	171.4	125(40)	(3⁻)	100(26)	**101, 127.4, 171.4** 70, 40
^{60m1}V	202.1	320(90)	(4⁺)		**98.9**
^{60m2}V	103.2	13(3)	(2⁺)		**103.2**
^{62m}Mn	y+113.3	95(2)	(4,5⁺)	43(14)	**113.3**
^{68m}Co	48.4	101(10)			**48.4**
^{70m}Co	437.3	54(10)	(4⁻)	5(1)	**155.8, 273.2,** 164.1
^{75m1}Cu	66.5	193(15)			**66.5**
^{75m2}Cu	61.8	1500(1000)			**61.8**
^{78m}Zn	2673	319(9)	8⁺	12(1)	**144.7,** 908.3 889.9, 729.6
^{78m}Ga	498.9	110(3)	(5)	21.4(10)	**46.1, 157.5, 217.8** **498.9,**453.9, 60.2 341.3, 281.3

Table 1: List of isomers observed with ^{86}Kr beam. For each isomers are given the deduced excitation energy, half-lives, tentative spin, isomeric ratio and energies of the observed γ-lines where assumed isomeric transitions are printed in bold.

Especially, a new isomeric state in ^{78}Zn has been identified and studied [3]. This result consists the first experimental evidence of the persistance of the N=50 shell gap in the vicinity of $^{78}_{28}Ni_{50}$.

References

[1] R. Grzywacz et al., *Phys.Rev.Lett.* **81**, 766 (1998)

[2] R. Anne et al., *Nucl. Inst. and Meth.* **A257**, 215 (1987)

[3] J.M. Daugas et al., *Phys. Lett.* **B476**,213 (2000)

Measurements of isomeric g-factors from projectile fragmentation

G. Georgiev[1,5], G. Neyens[1,2], M. Hass[3], D.L. Balabanski[1,4,5], C. Bingham[4], C. Borcea[6], N. Coulier[1], R. Coussement[1], J.M. Daugas[1,2], G. Defrance[2], G. Goldring[3], M. Górska[1,7], H. Grawe[7], R. Grzywacz[4,8], M. Lewitowicz[2], H. Mach[9], I. Matea[2,6], F. de Oliveira Santos[2], R.D. Page,[10], M. Pfützner[8], Yu. E. Penionzkevich[11], Zs. Podolyák[12], P.H. Regan[12], K. Rykaczewski[13], M. Sawicka[8], N.A. Smirnova[1,2], Yu. Sobolev[11], M. Stanoiu[2,6], S. Teughels[1], K. Vyvey[1]

1. University of Leuven, IKS, Celestijnenlaan 200 D, B-3001 Leuven, Belgium;
2. GANIL, BP 55027, F-14076 Caen Cedex 5, France;
3. The Weizmann Institute, Rehovot, Israel;
4. University of Tennessee, Knoxville, USA;
5. St. Kliment Ohridski University of Sofia, Bulgaria;
6. NIPNE, Bucharest, Romania;
7. GSI, Darmstadt, Germany;
8. IEP, Warsaw University, Poland;
9. ISV, Uppsala University, Nyköping, Sweden;
10. Oliver Lodge Laboratory, University of Liverpool, UK;
11. FLNR-JINR, Dubna, Russia;
12. University of Surrey, Guildford, GU2 7XH, UK;
13. Oak Ridge National Laboratory, Physics Division, Oak Ridge, USA

In the last few years one observes an increased experimental and theoretical interest towards the neutron-rich nuclei around ^{68}Ni triggered by an indirect evidence for existence of a sub-shell closure at $N = 40$ implied by the large excitation energy of the 2_1^+ state in ^{68}Ni [1]. On the other hand systematics of the two neutron separation energies (S_{2n}) at ^{68}Ni, do not provide evidence for such a change in the orbital spacing away of stability [2] and puts into question the suggested sub-shell closure. In order to provide additional experimental evidence on these nuclei, we have applied the TDPAD technique to measure g factors of the isomeric states around ^{68}Ni. The g factors of the nuclear states represent a sensitive probe of the nuclear structure and can shed light on the detailed composition of the nuclear wave functions.

This was the first application of the TDPAD technique on species produced in projectile-fragmentation reactions. A successful application of this technique became possible by combining it with the time-delayed γ -ion correlation technique and utilizing the alignment of the nuclear ensemble provided by the reaction mechanism.

The neutron-rich nuclei were produced by the fragmentation of a ^{76}Ge, 61.6 MeV/u. beam on a Be target at GANIL, France. The LISE spectrometer was used to select the nuclei of interest and their identification was obtained by the ΔE *vs.* TOF technique. The isomers in ^{66}Co ($T_{1/2}$=830ns), ^{67}Ni ($T_{1/2}$=13.3μs) and ^{69}Cu ($T_{1/2}$=350ns), previously studied in deep-inelastic and projectile-fragmentation reactions [3, 4, 5, 6], were investigated after their implantation into a Cu foil. The foil was mounted between the poles of an electromagnet producing a constant magnetic field in vertical direction. The time dependent γ-ray anisotropy from the isomeric transitions was observed using 2 Ge Clover detectors positioned in the horizontal plane.

Some typical results of the observed oscillation patterns are presented in Fig. 1. The measured g factor of ^{69m}Cu ($|g| = 0.195(9)$) is well reproduced by the shell-model calculations, which favor $\pi p_{3/2} \otimes \nu p_{1/2} g_{9/2}$ as main component of the wave function of the isomer. The result for ^{67m}Ni ($|g| = 0.126(4)$) implies that core polarization effects may play an important role in its structure. The experimental g factor can be theoretically reproduced by introducing a 1.7% mixing of the spin-flip $\pi(f_{7/2}^{-1}f_{5/2})_{1^+} \otimes \nu g_{9/2}$ configuration into the wave function, which otherwise has mainly a $\nu g_{9/2}$ component. This result is discussed in more details in Ref. [7]. As for the $T_{1/2}$=830 ns isomeric state in ^{66}Co, it is quite difficult to interpret the measured g factor ($|g| = 0.157(8)$), since neither spins nor parities have been determined for the ground and the isomeric states. Nevertheless, the g factor value suggests presence of the $\nu g_{9/2}$ particles in its wave function.

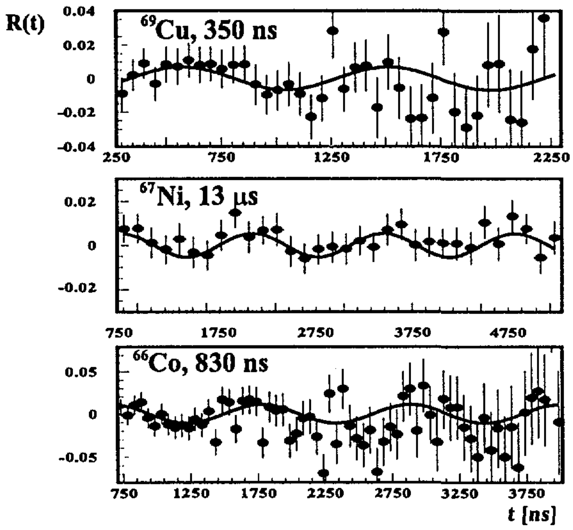


Figure 1: *TDPAD pattern obtained for ^{69m}Cu, ^{67m}Ni, and ^{66m}Co.*

The results of this experiment demonstrate the sensitivity of the g-factor observable to the details of the nuclear structure and the feasibility of such a type of measurements on isomeric states in the neutron rich region of the nuclidic chart produced by projectile-fragmentation reaction.

This work has been supported by the Access to Large Scale Facility program under the TMR program of the EU, under contract nr. ERBFMGECT950036. We are grateful to the EXOGAM-collaboration and to the CEA, Saclay (France), EPSRC, Liverpool (UK) and NBI (Denmark) for providing Clover detectors. G.N. is a post doctoral researcher of the Flemish Science Foundation (FWO-Vlaanderen).

References

[1] R. Broda *et al.*, Phys. Rev. Lett. **74**, 868 (1995).

[2] H. Seifert *et al.*, Z. Phys. **A349**, 25 (1994).

[3] T. Pawlat *et al.*, Nucl. Phys. **A574**, 623 (1994).

[4] R. Broda *et al.*, in: Fission and Properties of Neutron-rich Nuclei, Proc. Intern. Conf., Sanibel Island, Florida 1997;Eds. J.H.Hamilton, A.V.Ramayya, 202 (1998).

[5] R. Grzywacz *et al.*, Phys. Rev. Lett. **81**, 766 (1998).

[6] T. Ishii *et al.*, Phys. Rev. Lett. **84**, 39 (2000).

[7] G. Georgiev *et al.*, submitted to Phys. Rev. Lett.

g-factor and spin of ^{31}Al measured with β-NMR.

D. Borremans[1], G. Neyens[1,2], S. Teughels[1], L.Achouri[2], D.L. Balabanski[1,3], N. Coulier[1], R. Coussement[1], J.-M. Daugas[1,2], G. de France[2], F. de Oliveira Santos[2], A.De Vismes[2], G. Georgiev[1], M. Lewitowicz[2], I.Matea[2], Yu.E.Penionzhkevich[4], P. Roussel-Chomaz[2], H.Savajols[2], W.-D.Schmidt-Ott[5], Yu.Sobolev[4], N.A. Smirnova[1], M.Stanoiu[2], O.Tarasov[2,4], K. Vyvey[1], L.Weissman[1]

[1] University of Leuven, IKS, Celestijnenlaan 200 D, B-3001 Leuven, Belgium

[2] GANIL, BP 55027, F-14076 Caen Cedex 5, France

[3] St. Kliment Ohridski University of Sofia, BG-1164 Sofia, Bulgaria

[4] FLNR-JINR, Dubna, Russia

[5] Zweites Physikalisches Institut, Universität Göttingen, Bunsenstraße 7-9, D-37073, Germany

We have measured the magnetic moment of the $T_{1/2} = 640$ ms ground state of ^{31}Al [1] using the β-Nuclear Magnetic Resonance (NMR) technique [2]. In order to produce spin-polarized projectile fragments, the $^{36}S^{16+}$ primary beam (77.5 MeV/u) was tilted by 2^o with respect to the secondary beam that was selected by the LISE spectrometer. A rotating ^{9}Be-target in the LISE target chamber was used (177 mg/cm^2). The possibility to produce a spin-polarized secondary beam, was verified by measuring the known magnetic moment of ^{27}Na [3]. A 99% pure secondary beam of ^{31}Al was selected using the LISE-spectrometer and implanted in a cubic MgO single crystal at room temperature. A static magnetic field B_0 up to 2000 G was induced by two coils positioned above and below the vacuum chamber in which the crystal was mounted. Around the MgO crystal, a small teflon RF-coil induced a small RF-field B_{rf} (perpendicular to the static magnetic field) with a constant frequency ν_{rf}. The presence of these two magnetic interactions will resonantly destroy the spin-polarization at a magnetic field which is proportional to the g-factor. These resonances are measured by monitoring the β asymmetry as a function of the static magnetic field strength [4]. The RF-frequency was modulated such that in a first rough scan a wide g-factor range could be covered in 6 data points at fields between $B_0 = 430\,G$ and $B_0 = 920\,G$. A frequency modulation of $\Delta\nu_{rf} = 35\,kHz$ with $\nu_{rf} = 450\,kHz$ was used. The ^{31}Al fragments were selected in the outer wing of the momentum distribution (denoted p_1 in fig.1d). The target was tilted by 56^o. After this rough scan, we made two fine scans at $\nu_{rf} = 1\,MHz$, $\Delta\nu_{rf} = 12\,kHz$ with different selections of the momentum distribution: one at the outer wing (p_1), like in the rough scan and one in the middle of the wing, i.e. the target at 51^0 (denoted p_2 in fig.1d). The experimental data confirm the dependence of the spin-polarization and the momentum of the fragments, predicted in the existing kinematic models of spin-orientation in projectile-fragmentation reactions [5, 6].
We have measured a g-factor of $|g| = 1.52(2)$. According to shell model calculations in a *sd* model space using the USD interaction [7], the g-factor for the $I^\pi = 3/2+$ state is 0.8, while for the $I^\pi = 5/2^+$ it is 1.52. Thus the ground state spin of ^{31}Al is unambiguously assigned as $I^\pi = 5/2^+$. In this state the $\pi d_{5/2}^5 \nu d_{5/2}^6 s_{1/2}^2 d_{3/2}^2$ configuration contributes to 57% of the wave function [8].

We acknowledge support from the Access to Large Scale Facility program under the TMR program of the EU, under contract nr. HPRI-CT-1999-00019. G.N., N.A.S. are post-doctoral researchers and D.B. is an assistant researcher of the Flemish Science Foundation FWO-Vlaanderen.

References

[1] G.Klotz et al., Phys.Rev.C47 (1993), 2502

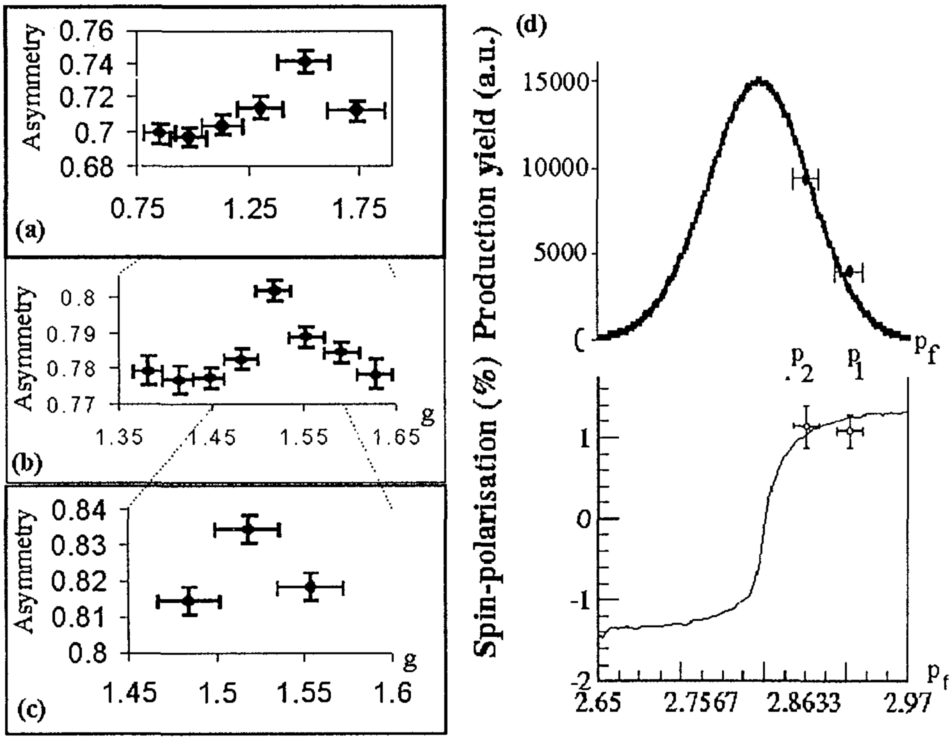


Figure 1: (a) *Rough scan with* $\nu_{rf} = (450 \pm 35)\,kHz$, $B_{rf} = 8\,G$ *and Wien filter on.* (b-c) *Fine scans with* $\nu_{rf} = (1000 \pm 12)\,kHz$, $B_{rf} = 10\,G$ *and the Wien filter off. The linear momentum of the fragments in sections* $(a-b)$ *corresponds to* p_1 *and in section* (c) *to* p_2.
(d) *Experimental polarization and fragment yield as a function of the momentum distribution.*

[2] C.P. Slichter, 'Principles of Magnetic Resonance', edited by M. Carona, P. Fulde and H.-J. Queusser (Springer-Verlag, Berlin, Heidelberg, New York, (1987)

[3] J.M. Daugas et al.,in preparation

[4] N. Coulier, G. Neyens, S. Teughels, D.L. Balabanski, R. Coussement, G. Georgiev, S. Ternier, K. Vyvey, W.F. Rogers, Phys. Rev. C **59**,1935 (1999)

[5] K. Asahi, M. Ishihara, T. Ichihara, M. Fukuda, T. Kubo, Y. Gono, A.C. Mueller, R. Anne, D. Bazin, D. Guillemaud-Mueller, R. Bimbot, W.D. Schmidt-Ott, J.Kasagi,Phys. Rev.C43,456 (1991)

[6] J.M. Daugas et al., Research at GANIL, a compilation, 1998-2000

[7] B. H. Wildenthal, Progr. Part. Nucl. Phys. 11, 5(1983)

[8] D. Borremans et al.,in preparation

Electric and Nuclear Transition Strength in ^{30,32}Mg

N. Alamanos, F. Auger, J. Barrette, F. Braga, V. Chiste, M.D. Cortina-Gil, Z. Dlouhy, A. Gillibert, V. Lapoux, A. Lepine, M. Lewitowicz, R. Lichtenthaler, R. Liguori-Neto, S. Lukyanov, M. MacCormick, F. Marie, W. Mittig, F. de Oliveira Santos, N. Orr, A. Ostrowski, S. Ottini, A. Pakou, Y. Penionzhkevich, P. Roussel-Chomaz, J. L. Sida

DAPNIA/SPhN, Instituto de Fisica-Universidade de São Paulo, GANIL, LPC (Caen), McGill University, University of Edinburgh, University of Ioannina, Laboratory of Nuclear Reactions (Dubna), Institute of Nuclear Physics (Rez)

The persistence of magic numbers far from stability has been an issue of much interest ever since the neutron-rich Na and Mg nuclei around N=20 were found to be more bound than expected from a spherical closed-shell prescription [1]. Shell model calculations [2–6] have demonstrated that for the Z=10-12, N=19-22 nuclei, the $2\hbar\omega$ configurations, arising from the excitation of a pair of neutrons across the N=20 shell gap to the fp-orbits, are more strongly bound than the $0\hbar\omega$ states and dominate the ground-state configurations, producing the so-called "island of inversion" [3]. A related question is whether the deformation of proton and neutron distributions is identical or if a decoupling of the corresponding densities occurs. Identical deformations are predicted in the relativistic mean field [7] and in the antisymmetrized molecular dynamics model [8], whereas in the Hartree-Fock-Bogoliubov (HFB) [9] and in the shell model [6] different deformations are obtained. Recent constrained HF calculations with a separable monopole interaction [10] predict similar proton and neutron deformations. An experimental determination of the neutron and proton deformations of ^{24,30,32}Mg was undertaken at GANIL (Caen) via inelastic scattering of secondary ^{24,30,32}Mg beams on ^{208}Pb and ^{12}C targets. For the N=Z ^{24}Mg nucleus, these parameters are well known [11] and the present data were thus used to test our experimental methods.

The inelastic scattering events were identified by the γ-ray deexcitation measured in coincidence with the Mg nuclei. The γ-detection system consisted of two sets of 7 hexagonal NaI detectors around the target at $\sim 90°$ relative to the beam axis above and below the target. The Doppler-shift and broadening due to the in-flight γ-ray emission of the scattered Mg nuclei was corrected event-by-event using the relative angle between the scattered Mg nuclei detected in Si telescopes and the NaI detector. In fig.1 we display the γ-ray energy spectra for ^{32}Mg+^{12}C and ^{30}Mg+^{12}C inelastic scattering summed over all NaI detectors. A peak at 0.885 MeV is clearly seen in the ^{32}Mg spectrum corresponding to the transition from the first 2^+ state to the ground-state [15]. In the ^{30}Mg spectrum the 1.482 MeV transition from the first 2^+ state to the ground-state [16] is observed. The experimental angle integrated de-excitation cross-section, σ_{exp}, is defined as,

$$\sigma_{exp} = \frac{N_{coin}}{N_{inc} N_{target} \epsilon} \qquad (1)$$

where N_{inc} is the total number of incident Mg projectiles, N_{target} the number of target atoms per cm^2, ϵ the experimental efficiency of the NaI and Si detectors.

The contribution of higher lying excited states, which

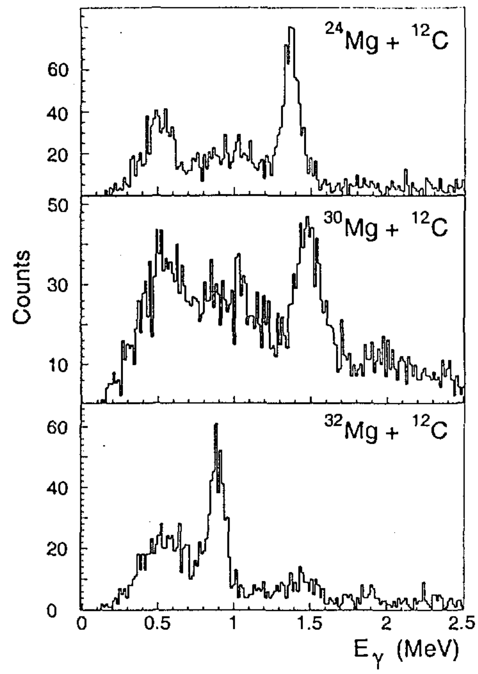


FIG. 1. Doppler corrected γ-ray spectra for the ^{24}Mg,^{30}Mg and ^{32}Mg projectiles on a ^{12}C target.

decay to the first 2^+ state - the feeding cross-section, $\sigma_{feed}(J^\pi \rightarrow 2^+)$ - had to be subtracted to obtain the final experimental excitation cross-sections, $\sigma_{exp}(0^+ \rightarrow 2^+)$.

In the case of ^{24}Mg the level scheme is known and the feeding cross section was calculated using the code ECIS94 [17] : it was found to contribute for 20% to the total cross section. The higher lying excited states of ^{30,32}Mg are not so well known as for ^{24}Mg, thus precluding a detailed calculation of the feeding contributions. The feeding contributions for ^{30,32}Mg were consequently estimated by scaling the feeding cross-section of ^{24}Mg according to the particle separation energies in ^{24}Mg, ^{30}Mg and ^{32}Mg. This correction is based on the assumptions that the total feeding cross-section should be proportional to the highest excitation energy which still decays by γ-emission. The detailed calculations for the feeding contribution included all possible higher lying states.

The ECIS94 code with a symmetric rotational form factor was used to calculate the excitation cross-section $\sigma_{cal}(0^+ \rightarrow 2^+)$ with two deformation lengths as free parameters, the charge and optical deformation lengths $\beta_c R_c$ and $\beta_{opt} R_{opt}$, in order to reproduce the experimental excitation cross-sections $\sigma_{exp}(0^+ \rightarrow 2^+)$ for both targets. The mass deformation length was obtained under the assumption $\beta_N R_N = \beta_{opt} R_{opt}$. The inelastic excita-

	This work				Ref. [7]		Ref. [6]		Ref. [10]	
	β_c	β_N	$\beta_c R_c$	$\beta_N R_N$	$\beta_c R_c$	$\beta_N R_N$	$\beta_c R_c$	$\beta_N R_N$	$\beta_c R_c$	$\beta_N R_N$
^{24}Mg	0.57±0.04	0.57±0.05	1.97±0.14	1.97±0.18	1.45	1.37	-	-	2.50	2.35
^{30}Mg	0.52±0.035	0.50±0.045	1.95±0.13	1.86±0.17	0.91	0.73	-	0-	1.97	1.82
^{32}Mg	0.61±0.045	0.54±0.05	2.31±0.17	2.08±0.19	1.34	1.41	1.45	0.91	1.96	1.84

TABLE I. The deformation parameters and deformation lengths of ^{24,30,32}Mg compared with different calculations.

	This work	Ref. [12]	Ref. [13]	Ref. [6]	Ref. [20]	Ref. [10]	Ref. [21]
	$B(E2)e^2fm^4$	$B(E2)e^2fm^4$	$B(E2)e^2fm^4$	$B(E2)e^2fm^4$	$B(E2)e^2fm^4$	$B(E2)e^2fm^4$	$B(E2)e^2fm^4$
^{24}Mg	383±53	-	-	-	-	616	-
^{30}Mg	435 ±58	-	295±26	242	200	442	182
^{32}Mg	622±90	454±78	333±70	490/650	333	456	593

TABLE II. The reduced transition probabilities $B(E2, 0^+ \rightarrow 2^+)$ of ^{24,30,32}Mg compared to previous experimental results and calculations. The $B(E2)$ values of ref.[6] were obtained from 2p-2h and 4p-4h ground-state configurations for ^{32}Mg and 0p-0h for ^{30}Mg.

tion induced by ^{208}Pb depends mainly on $\beta_c R_c$ and little on $\beta_N R_N$ over the angular range considered here. In the case of ^{12}C induced excitation and due to the low atomic number of the target, the main contribution arises from $\beta_N R_N$. When describing the scattering of each Mg isotope on both targets, we use the same Coulomb and nuclear deformation lengths $\beta_c R_c$ and $\beta_N R_N$(with $R_c=R_N=1.20A^{1/3}$ fm). The calculations were performed with different optical potentials and the final uncertainty in the β-values includes this effect of the uncertainty in the optical potentials.

The deformation parameters β_c and β_N deduced in this way for ^{30}Mg and ^{32}Mg are presented in Table I together with the results of different calculations. An important feature can be observed immediately: the charge and mass deformations are identical within the uncertainties for both nuclei. This result is in agreement with the predictions of Ref. [7,8,10] and disagrees with the predictions of Ref. [6,9].

The $B(E2)$ values were calculated from the β_c values using $R_c=1.20A^{1/3}$fm and

$$B(E2, 0^+ \rightarrow 2^+) = [(3/4\pi) Z e R_c^2 \beta_{c,2}]^2 \qquad (2)$$

They are presented in Table II with previous experimental results and theory. Our $B(E2)$ value for ^{32}Mg agrees within uncertainties with the results of [12], while our $B(E2)$ values for ^{30,32}Mg are sizeably higher than the values reported in Ref. [13], For ^{32}Mg, the results of the shell model [4,6] calculations are in reasonable agreement with our measured values. The HFB calculations of Ref. [20] predict lower transition probabilities both for ^{30}Mg and ^{32}Mg. The constrained HF calculations of Ref. [10] with a separable interaction predict similar and large deformations for ^{30,32}Mg. In Ref. [21], ^{30,32,34}Mg were calculated using a quadrupole constrained mean-field basis and an angular momentum projected energy. For ^{32}Mg, the $B(E2)$ value agrees very well with our experimental value, while for ^{30}Mg, the predicted B(E2) value is much lower.

In conclusion, we have measured the Coulomb and nuclear deformation lengths of ^{30,32}Mg through the inelastic excitation of intermediate energy secondary beams on ^{208}Pb and ^{12}C targets. Both nuclei exhibit similarly large charge and mass deformations. The analysis within the collective model resulted in identical mass and charge deformations, showing thus no hint of a large decoupling of neutron and proton deformations in this region. The ^{30}Mg nucleus exhibits a much larger transition strength than predicted previously raising the question of a strong collective behaviour and its belonging to the "island of inversion".

[1] N. A. Orr et al., Phys. Lett. B258 29 (1991) and references therein.
[2] A. Poves, J. Retamosa, Phys. Lett. B184 311 (1987).
[3] E. K. Warburton, J. A. Becker, B. A. Brown, Phys. Rev. C41 1147 (1990).
[4] N. Fukunishi, T. Otsuka, T. Sebe, Phys. Lett. B296 279 (1992).
[5] A. Poves, J. Retamosa, Nucl. Phys. A571 221 (1994).
[6] E. Caurier et al., Phys. Rev. C58 2033 (1998).
[7] D. Hirata, private communication.
[8] Y. Kanada-Enyó, private communication.
[9] J. Terasaki et al., Nucl. Phys. A621 706 (1997).
[10] P. D. Stevenson, J. Rikovska Stone, M. R. Straayer, to be published.
[11] S. Raman et al.,At. Data Nucl. Data Tab. 36 1-96(1987).
[12] T. Motobayashi et al., Phys. Lett. B346 9 (1995).
[13] B.V. Pritychenko et al, Phys. Lett. B 461 322 (1999).
[14] R. Anne, A. C. Mueller Nucl. Instr. Meth. B70 276 (1992).
[15] D. Guillemaud-Mueller et al. Nuc. Phys. A426 37 (1984).
[16] P. M. Endt, Nucl. Phys. A521 1 (1990).
[17] J. Raynal, Coupled-Channels code ECIS94 unpublished.
[18] J. Barrette et al.,Phys. Lett. B209 182 (1988).
[19] R.A.Broglia, A.Winther,Heavy Ion Reactions-Vol.1 The Benjamin/Cummings Pub Co.1981.
[20] M. Girod, private communication.
[21] R. Rodriguez-Guzman,J.L.Egido,L.M.Robledo, Phys. Lett. B474 15 (2000).

Beta Decay studies of neutron-rich nuclei around N=40

O. Sorlin[1], C. Donzaud[1], J. C. Angélique[2], F. Azaiez[1], C. Bourgeois[1], V. Chiste[1], Z. Dlouhy[3], S. Grévy[2], D. Guillemaud-Mueller[1], F. Ibrahim[1], M. Lewitowicz[4], S.M. Lukyanov[5], J. Mrasek[3], Yu.-E. Penionzhkevich[5], F. de Oliveira Santos[4], F. Pougheon[1], M.G. Saint-Laurent[4], M. Stanoiu[4]

[1] Institut de Physique Nucléaire, IN2P3-CNRS, F-91406 Orsay Cedex, France
[2] LPC, ISMRA, F-14050 Caen Cedex, France,
[3] Nuclear Physics Institute, AS CR, CZ 25068, Rez, Czech Republic
[4] GANIL, B. P. 5027, F-14076 Caen Cedex, France
[5] FLNR, JINR, 141980 Dubna, Moscow region, Russia

The neutron-rich $_{22}$Ti-$_{27}$Co isotopes have been produced at GANIL by the fragmentation of a 61.8 A.MeV ^{76}Ge beam of mean intensity 1.2 eμA onto a ^{58}Ni target of 140 μm-thickness. A carbon foil of 9.5 mg.cm^{-2} was placed behind the production target to act as a stripper. Fragments of interest were separated by the LISE3 achromatic spectrometer. A wedge-shaped Be foil of 219 μm-thickness was placed in the intermediate focal plane of the spectrometer in order to reduce the rate of nuclei close to stability. Nuclei transmitted during this experiment are shown in Fig. 1. The selected nuclei were

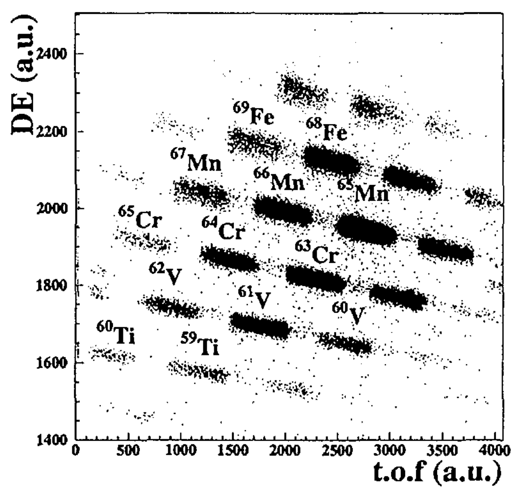


Figure 1: Identification of the nuclei produced in the experiment by their energy loss (DE) and time of flight (t.o.f).

identified by means of 3 consecutive 300, 300, 1500 μm silicon detectors placed close to the final focal plane of LISE3. They were implanted in the last detector divided in sixteen 3 mm-wide, 46 mm-height vertical strips. In each strip, the energy and time for heavy ions as well as for the β-particles coming from their decay were measured. Each time a nucleus was implanted, the primary beam was switched off during 1 second to prevent the implantation of other nuclei which would act as β-contaminants. A β-event was considered as valid if occuring in the same strip #i as the precursor nucleus or in one of the neighbouring strips #i-1 and #i+1. With these requirements, a clean correlation between the precursor nucleus and its β's is found, with a beta-efficiency of $\epsilon_\beta \sim 95\%$. The fitting procedure to determine the half-lives of nuclei is described in [1]. Half-lives of five new nuclei (^{60}Ti,^{63}V, ^{65}Cr, ^{69,70}Fe) have been determined, and better accuracy is obtained in the decay-study of ^{61,62}V, $^{62-64}$Cr, ^{68}Fe. Four Ge detectors were placed in a cross geometry around the implantation detector for the detection of the main γ transitions. For instance, the strong γ-lines observed in the decay of ^{60}V and

^{62}V have been attributed to the $2^+ \to 0^+$ transitions in even-even nuclei ^{60}Cr and ^{62}Cr, respectively. Preliminary results concerning these decays are shown in Fig.2.

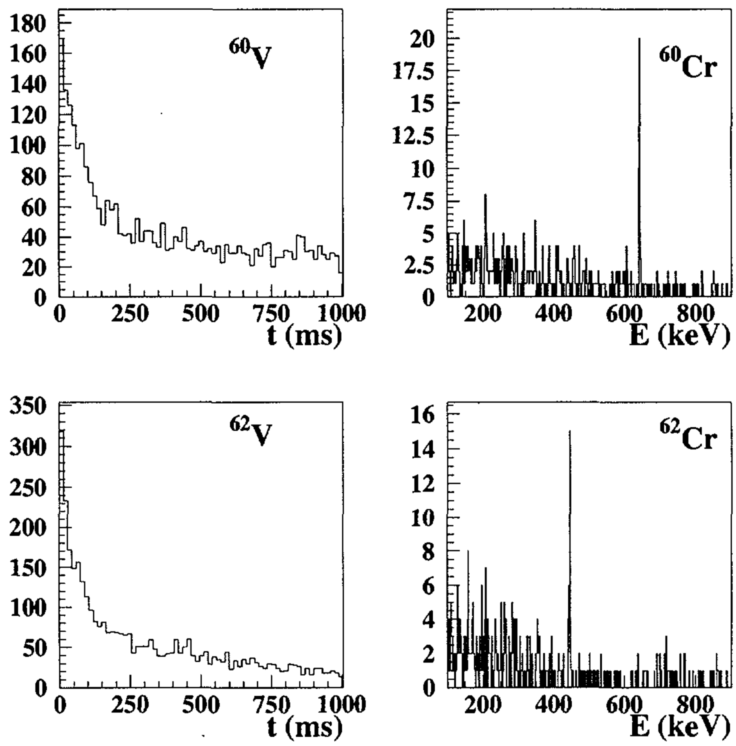


Figure 2: left: Decay curves of ^{60}V and ^{62}V. right: Gamma-spectra obtained from the beta-decay of ^{60}V and ^{62}V to ^{60}Cr and ^{62}Cr respectively.

The 2^+ energy of ^{60}Cr, 646(1) keV, is much lower than that of the isotones ^{66}Zn, ^{64}Ni and ^{62}Fe at 1039, 1345 and 877 keV respectively. Similarily, the 2^+ energy of ^{62}Cr, E(2^+)=446(1) keV, is the lowest among N=38 isotones. The steep decrease in energy in the Cr chain indicates that the Cr isotopes are strongly deformed. On the basis of the low 2^+ energies in $^{60,62}_{24}$Cr and the significant drop of 2^+ energy in $^{66}_{26}$Fe$_{40}$ [2], it is very likely that $^{64}_{24}$Cr$_{40}$ would be the most deformed N=40 nucleus. The spherical shell-gap at N=40 (as evidenced in $^{68}_{28}$Ni) is not strong enough to overcome the development of deformation at Z=24, which corresponds to a half occupancy of $\pi f_{7/2}$ shell. The four protons above Z=20 are filling two downsloping orbitals in the Nilsson picture as the deformation parameter is increased. Important astrophysical consequences of this subshell effect disappearance are foreseen.

References

[1] O. Sorlin et al., Nucl. Phys. A669 (2000) 351.

[2] M. Hannawald et al., Phys. Rev. Lett. 82 (1999) 1391.

Melting of the N=28 shell closure in neutron rich S and Ar nuclei

D. Sohler[a], M. Stanoiu[c], J. Timár[a], F. Azaiez[b], Zs. Dombrádi[a], O. Sorlin[b], F. Amorini[b], D. Baiborodin[d], A. Bauchet[e], F. Becker[f], M. Belleguic[b], C. Borcea[g], C. Bourgeois[b], Z. Dlouhy[h], C. Donzaud[b], J. Duprat[b], D. Guillemaud-Mueller[b], F. Ibrahim[b], M. J. Lopez[c], R. Lucas[i], S. M. Lukyanov[d], V. Maslov[d], J. Mrazek[h], C. Moore[j], F. Nowacki[k], B. M. Nyakó[a], Yu.-E. Penionzhkevich[d], L. Petizon[b], M. G. Saint-Laurent[c], F. Sarazin[c], J. A. Scarpaci[b], G. Sletten[l], C. Stodel[b], M. Taylor[j], C. Theisen[f], G. Voltolini[c]

[a]*Institute of Nuclear Research, H-4001 Debrecen, Pf. 51, Hungary,* [b]*IPN, IN2P3-CNRS, Orsay, France,* [c]*GANIL, Caen, France,* [d]*FLNR, JINR, Dubna, Russia,* [e]*CSNSM, IN2P3-CNRS, Orsay, France,* [f]*CEA-Saclay, Gif sur Yvette, France,* [g]*IAP, Bucharest-Magurele, Romania,* [h]*NPI, Rez, Czech Republic,* [i]*IPN, Lyon, France,* [j]*OLL, Univ. of Liverpool, Liverpool, UK,* [k] *Univ. L. Pasteur, Strasbourg, France* [l]*NBI, Copenhagen, Denmark*

Structure of the neutron rich ^{40,42,44}S and ^{45,46}Ar nuclei has been investigated through in-beam γ spectroscopic study of fragmentation of a 60 Mev·A ^{48}Ca beam on a thin Be target. E_γ, I_γ, $\gamma\gamma$-coincidence and for the first time at intermediate energy γ-ray angular distributions were measured.

It has been shown that the angular momentum of the projectile like fragments is aligned, and as a result of it, the γ rays emitted from the reaction have an unisotropic angular distribution. From the angular distributions measured relative to the angular distribution of the strong 1577 keV stretched E2 transition in ^{46}Ar the angular momentum transferred by the γ rays could be deduced.

Using the results of the $\gamma\gamma$-coincidence measurements and the multiplicity dependence of the γ intensities, which corresponds to an inclusive coincidence measurement, the level schemes previously containing only a single γ transition were significantly extended. An additional help was provided for the level scheme construction by the finding, according to which the intensity of the ground state population in all the nuclei produced is nearly the same and is proportional to the photo peak efficiency. On the basis of the deduced angular momentum transfer spin–parity values were also deduced for the excited states.

The $E_{4_1^+}/E_{2_1^+}$ ratios in ^{40}S and ^{42}S are 2.5 and 3.0, respectively, suggesting that ^{40}S has a transitional character, while ^{42}S is a rotor. The energy of the 2_2^+ state, and the weakness of the $2_2^+ \rightarrow 0_1^+$ transition suggest that ^{42}S is triaxial with an average γ value of 23–25°.

As a consequence of a decreased $f_{7/2}$ - $p_{3/2}$ neutron energy difference both the mean field theories and the Monte-Carlo shell model calculations predict a prolate/oblate shape coexistence in ^{44}S. The experimental data are in coincidence with such a hypotheses, and suggest the newly found 1620 keV state to be the oblate 0^+.

The presence of a low lying low energy ΔI=1 transition in ^{45}Ar similarly to the case in ^{41}Ar, indicates that the $f_{7/2}$ neutron state is not a simple hole on the closed $N = 28$ shell, but contains a strong $f_{7/2}^{-3}$ component, too. This means that some of the neutrons are pushed up to higher lying states, thus the $N = 28$ shell closure is broken even in the Ar isotopes, in spite of the fact that these nuclei are not deformed.

Evidence of doubly magic structure in ^{68}Ni nucleus

O. Sorlin[1], S. Leenhardt[1], C. Donzaud[1], F. Azaiez[1], F. Amorini[1,*], A. Astier[2], D. Baiborodin [3], M. Belleguic[1], K. Bienczak[4], C. Bourgeois[1], C. Borcea[5], H. Brenning [1], Z. Dlouhy[3], Zs. Dombrádi[6], E. Dragulescu[5], J. Duprat[1], M. Gorska[7], H. Grawe[7], S. Grévy[8], D. Guillemaud-Mueller[1], G. Hagemann[9], B. Herskind[9], J. Kiener[10], R. Lemmon[11,#], M. Lewitowicz[4], D. Pantalica[6], S.M. Lukyanov[12], D.Mc. Cullen[13], Yu.-E. Penionzhkevich[12], P. Mayet[7], F. de Oliveira Santos[4], L. Petizon[1], F. Pougheon[1], N. Redon[2], M.G. Saint-Laurent[4], J.A. Scarpaci[1], G. Sletten[9], M. Stanoiu[4], O. Tarasov[12], Ch. Theisen[14]

[1] Institut de Physique Nucléaire, IN2P3-CNRS, F-91406 Orsay Cedex, France
[2] Institut de Physique Nucléaire Lyon, F-69622 Villeurbanne Cedex, France
[3] Nuclear Physics Institute, AS CR, CZ 25068, Rez, Czech Republic
[4] GANIL, B. P. 5027, F-14076 Caen Cedex, France
[5] IFIN-HH, P. O. Box MG-6, 76900 Bucarest-Magurele, Rumania
[6] Institute of Nuclear Research, H-4001 Debrecen, Pf. 51, Hungary
[7] GSI, Postfach 110552, D-64200 Darmstadt, Germany
[8] LPC, ISMRA, F-14050 Caen Cedex, France,
[9] NBI, University of Copenhagen, Copenhagen, Denmark
[10] CSNSM, F-91405 Orsay Cedex, France
[11] Department of Physics, University of Surrey, Guilford GU2 7XH, U.K.
[12] FLNR, JINR, 141980 Dubna, Moscow region, Russia
[13] Oliver Lodge Laboratory, University of Liverpool, Liverpool L69 7ZE,U.K.
[14] CEA-Saclay, DAPNIA-SPhN, F-91191 Gif sur Yvette Cedex, France
*present address: INFN -Laboratori Nazionali del Sud, via S.Sofia 44, 95123 Catania, Italy
#present address: CRLC, Daresbury Laboratory, Daresbury, Warrington, WA4 4AD,U.K.

^{66,68}Ni nuclei have been produced in the fragmentation of a 65.9·A MeV $^{70}Zn^{29+}$ beam onto 140μm-thick ^{58}Ni target. They have been selected by the LISE3 spectrometer in two different magnetic rigidity settings. A wedge-shaped Be-foil of 217μm thickness was inserted between the two dipoles of LISE3 to perform an additional energy-loss selection. Beam rates of 18000s^{-1} and 15000s^{-1} have been obtained for ^{66}Ni and ^{68}Ni isotopes respectively. Coulomb excitation of these two nuclei at $v/c \sim 0.3$ was induced by a 99% pure ^{208}Pb target of 220 mg/cm^2 thickness located at the final focal plane of LISE3. The target was surrounded by four segmented clover Ge detectors placed at 90 degrees at a distance of 5.5 cm of the target, yielding a photopeak efficiency of ϵ_γ=4.0% at 1.3 MeV . Two annular silicon detectors were mounted 50 cm behind the lead target in order to identify the deflected nuclei by their energy losses and residual energies. Nuclei coming out of the target with angles smaller than 1.5 degree were detected in a plastic scintillator two meters downstream. This detector also served to monitor the secondary beam intensity and determine the total number of implanted nuclei N_n. Photons emitted in flight in coincidence with the scattered nuclei were detected in segmented Ge clover-detectors. Each Ge crystal representing a "leaf" of the clover is longitudinally segmented in four quadrants, reducing the angular acceptance of the individual detector elements. The add-back mode has been used for the detection of the high-energy γ-lines, increasing the efficiency by 40% for a γ at 2.033 MeV, leading to ϵ_γ=3.4%. The Doppler-corrected spectra for the Coulomb excitation of ^{66}Ni and ^{68}Ni are shown in Fig.1. From the total number of γ rays with respect to the number N_n of nuclei impinging onto the target, B(E2) values have been determined [1] (Fig. 2).

The 'bell-shape" behaviour of the $B(E2\uparrow)$ values (Fig. 2) in the Ni isotopes provides a clear illustration of the structural evolution between the two magic nuclei ^{56}Ni and ^{68}Ni. As neutrons are added to ^{56}Ni, possibilities of creating 2^+ excitations via particle(s)-hole(s) excitations (p-h) are gradually increased until the number of p-h reaches a maximum value at the mid fp-shell, e.g. at ^{62}Ni. While filling the fp orbits up to N=40, the amount of quadrupole excitations is drastically reduced to a value which is about three times smaller than that of ^{56}Ni [3, 4]. The low B(E2) of ^{68}Ni, 265(60)e^2fm^4, is a specific feature of doubly magic nucleus. Its value is comparable in Weisskopf units

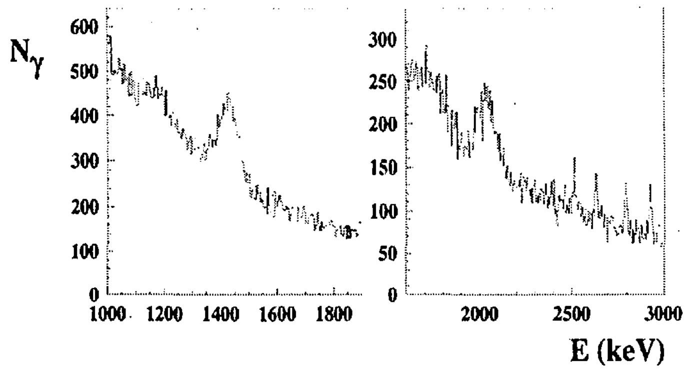


Figure 1: γ-energy spectra obtained in the Ge-clover detectors from the Coulomb excitation of ^{66}Ni(left) and ^{68}Ni(right). These spectra are Doppler-corrected.

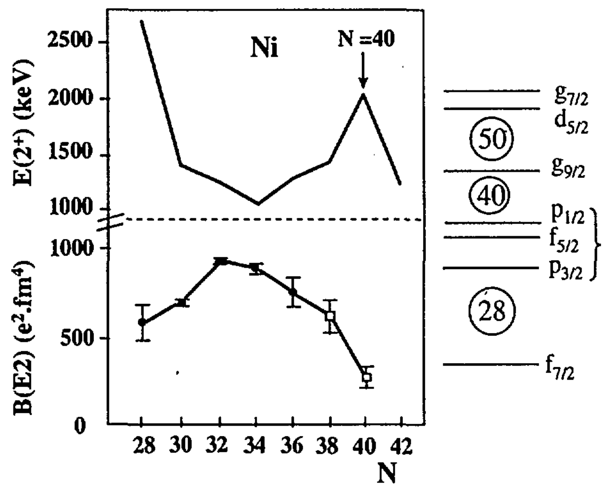


Figure 2: Experimental 2^+ energies and B(E2) values for ^{56}Ni to ^{68}Ni nuclei. Empty squares in the B(E2) curve indicate the new results. B(E2) of $^{58-64}$Ni are taken from [2].

(3.2(7) W.u.) to the cases of the doubly magic ^{16}O (3.3(3) W.u.), ^{40}Ca (2.3(4) W.u.) and ^{48}Ca (1.6(5) W.u.). The hindrance of 2^+ excitations across N=40 comes from two reasons: The first is the presence of an energy gap across N=40 which hampers the excitation of neutrons. The second is that a change in parity is occuring across N=40 between the fp and gd orbitals since these two groups of levels originate from different Harmonic-Oscillator shells. Therefore, positive parity excitations as 2^+ ones, cannot be made by 1p-1h excitations when the fp shells are completely filled. The only possibility left is to promote a pair of neutrons from one of the fp orbitals into the g shell, and to couple them to 2^+. This requires more energy, *i.e.* E(2_1^+) increases, and B(E2;$0^+ \rightarrow 2^+$) decreases, as this transition can proceed only via small admixtures in the wavefunction.

References

[1] O. Sorlin et al., submitted to PRL and S. Leenhardt thesis, IPN Orsay, 2000.

[2] S. Raman et al., At. Data and Nucl. Data Tables 36 (1987) 1.

[3] G. Kraus et al., Phys. Rev. Lett. 73 (1994) 1773.

[4] Y. Yanagisawa et al., in proc. of the ENAM98 conference, eds B. M. Sherrill et al., p. 610.

4 - HOT NUCLEI AND NUCLEAR MATTER

Fine Structure of Giant Resonances in ^{208}Pb A. Drouart

(adrouart@cea.fr)[1],N. Alamanos[1],F. Auger[1], A. de Vismes[2], N. Frascaria[3], A. Gillibert[1], C. Jouanne[1], D. Lacroix[4], V. Lapoux[1], G. Lobo[1], W. Mittig[2], S. Ottini-Hustache[2], E.C. Pollacco[1], P. Roussel-Chomaz[2], F. Sarazin[2], H. Savajols[2], J.-L. Sida[1].
[1]CEA-Saclay, DAPNIA-SPhN, 91191 Gif-sur-Yvette, France
[2]GANIL (CEA/DSM - CNRS/IN_2P_3), BP 5027, 14076 Caen Cedex, France
[3]IPN Orsay, 91406 Orsay Cedex, France
[4]LPC Caen, CNRS/IN_2P_3, 14050 Cean Cedex, France

A 50 MeV/A ^{17}O beam impinged on a thin (350μg/cm^2) self-supported ^{208}Pb target. The scattered ions were measured after a dispersive dipole. Two drift chambers allowed the reconstruction of their trajectories near the focal plane of the spectrometer with a resolution of 350 μm. This lead to the determination of the energy and the scattering angle of the ions. A ionization chamber and a scintillating plastic detector provided the energy loss and the total energy for a mass and charge identification.

The giant resonance region appears as a broad increase of the cross section above the particle emission threshold, that is from 7 MeV up to ≈20 MeV for ^{208}Pb as shown in 1. Seven peaks were observed on this broad bump for energies of 7.5, 8.1, 9.05, 9.45, 10.2, 10.8, 11.3 MeV respectively. They were consistent with the position of peaks observed in other experiments using different probes like electron (Kilgus & al [4]) and proton scattering (Bertrand & al [3]) or photo absorption measurements (Belayev [2]). There is an ambiguity in the literature concerning the multipolarity assignment of the structures which differs from one experiment to another. With the present experimental data we expect to raise these ambiguities.

The first step of the analysis was to disentangle the contributions in the spectra due to the GQR and GDR excitation. The nuclear continuum underlying the resonances was taken as a straight line fitted to the high energy part of the spectra and joined smoothly to a curve which decreased to zero at the neutron separation threshold. The GQR was assumed to have a gaussian shape of mean energy 10.6 MeV and 2.4 MeV FWHM. The shape of the GDR (Lorentzian) was obtained from photo absorption measurements. The exponential dependence of the Coulomb excitation probability results in a strong enhancement of the low-energy portion of the GDR and to a shift of its centroid. The resulting response function is a deformed lorentzian curve with a mean energy of 12.6 MeV (see figure 1). The angular distributions of the GQR and GDR were compared to coupled-channel calculations using phenomenological optical potentials. They exhaust 100% (GDR), and 60% (GQR) of the energy weighted sum rule. This is consistent with previous experimental results [1].

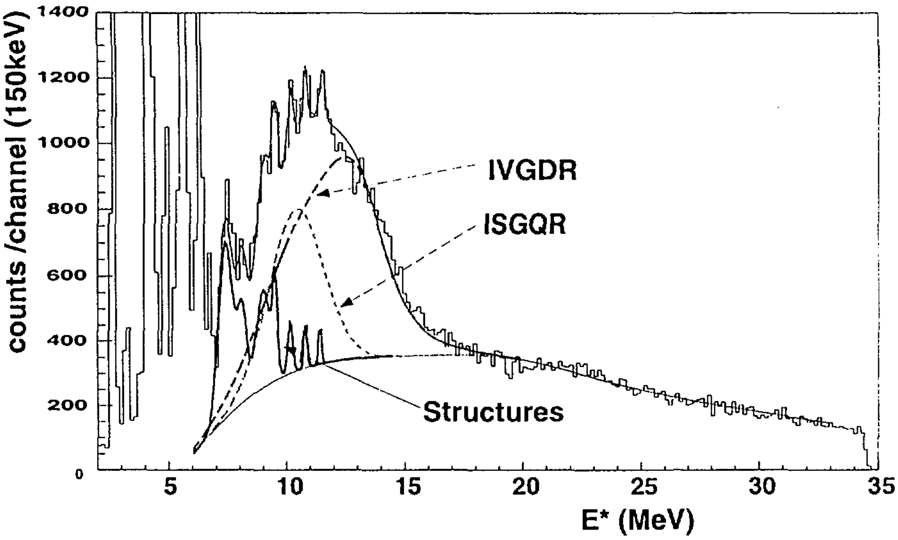


Figure 1: Contributions of giant dipole (GDR) and quadrupole (GQR) resonances on the top of the background. Visible structures above 9 MeV are also represented by gaussian peaks.

The second step of the analysis consisted of subtracting the contributions due to the giant resonances and to the background from the experimental spectra, for different scattering angles, in order to obtain the angular distribution of the remaining part of the strength function. It was described by several gaussian curves (figure 1). The small statistics of these structures did not allow to plot precise angular distributions. We have plotted the angular distributions for two wide angular ranges : between 4.25 and 5° (center of mass) and 5.25 to 6°, in order to pin down the difference between the L=1 and L=2 structures. Due to the large uncertainties and the low statistics, we cannot draw firm conclusions on the multipolarity of the structures located in the higher energy part of the spectra. However, our results show that the structures from 7 to 9.5 MeV of excitation energy have a main L=1 component. Indeed, this result is also confirmed by a high resolution photo absorption measurement, in which the same structures and at the same excitation energy [2] were observed. Due to the strong coulombian enhancement of the low energy portion of the GDR, the present experiment is very sensitive to dipole excitations. This effect is absent in the (e,e') or (p,p') reactions, making the observation of such small L=1 structures difficult in a region where the L=2 component is strong.

The Lorentzian shape of the GDR was obtained by a first order fit of photo absorption measurements. In a further step of the analysis instead of using a Lorentzian to describe the GDR we have used the measured high resolution photo absorption results. The contribution of the GDR to our spectra was thus precisely determined. After subtraction of this component and of the background from the spectra we obtain the distribution of the L=2 strength or concomitantly the distribution of the B(E2) strength (see figure 2). This analysis shows that the distribution of the L=2 strength has a shape which is close to the commonly used Gaussian shape. The comparison of this L=2 strength distribution with theoretical calculations ([5], [6]) has still to be done.

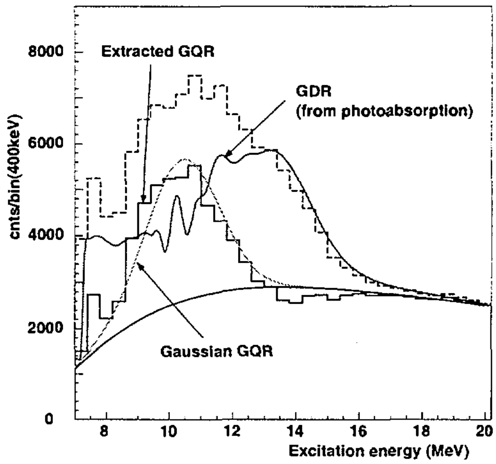


Figure 2: Contribution of giant dipolar resonance deduced from photoabsorption measurements (see text) and remaining strength function (mainly L=2).

In summary, we have shown that heavy ion inelastic scattering measurements can be used to obtain information on the fine structure of excited states. These measurements provide also valuable information on the B(E2) strength distribution in ^{208}Pb in the giant resonance region.

References

[1] J. Barrette & al., Phys. Let. B **209** (1988) 182–186.

[2] S. N. Belyaev & al., Sov. J. Nucl. Phys. **55** (1992) 157–161.

[3] F.E. Bertrand & al., Phys. Rev. C **34** (1986) 45–59.

[4] G. Kilgus & al., Z. Phys. A **326** (1987) 41–50.

[5] D. Lacroix, P. Chomaz & S. Ayik, Phys. Rev. C **58** (1998) 2154–2160.

[6] V. Yu. Ponomarev & al., Nucl. Phys. **A569** (1994) 333c–342c.

Multiphonon decay measured with the INDRA plus SPEG ensemble.
E336

M.Fallot[a], N. Frascaria[a], J.A. Scarpaci[a],Y. Blumenfeld[a], A.Chbihi[b], Ph. Chomaz[b], P.Desesquelles[a], J.Frankland[b], E. Khan[a], P. Chomaz-Roussel[b], JL Laville[b], E. Plagnol[a], E.C.Pollacco[c], J.C. Roynette[a] and T.Zerguerras[a]

(a) Institut de Physique Nucléaire, IN2P3-CNRS, 91406 Orsay, France
(b) GANIL, BP 5027, 14076 Caen Cedex 5
(c) CEA/DAPNIA SPhN 91191 Gif-sur-Yvettes Cedex

Multiphonon excitations built with giant resonances are a good tool to probe the elasticity of the atomic nucleus [1]. Not only the excitation energy of the double and triple phonons are relevant but also their excitation cross section will shed light on the coupling between phonons, hence the anharmonicity of the nucleus.

Previous experiments have shown the characteristic decay of the second giant quadrupole resonance in several nuclei with the use of a weak solid angle proton (or neutron) detector (~2% of 4π). This new experiment aimed at the measurement of the inelastic scattering of ^{40}Ca on a ^{40}Ca at 50 MeV/A by measuring both the ejectile in the spectrometer SPEG and the decaying charged particles in 240 CsI of the INDRA detector covering 94% of 4π. This large covering allows the measurement of complete decaying events using the new drift chambers of SPEG detection and a thin target (200 μg/cm^2). An energy resolution of 300 keV was achieved for the ^{40}Ca ejectile instead of the 800 keV obtained in previous experiments.

As for the INDRA detectors the identification and the energy calibration is now achieved for the protons. A missing energy spectrum has been extracted for the giant resonance region and is compared to the one from a previous experiment on the same reaction in Fig.1. The ground state of the daughter ^{39}K as well as the first excited states, largely due to direct decay as already measured in ref.[2], are observed. Note the improvement in energy resolution of a factor 2.

The calibration of INDRA for the other light charged particles is under way as well as a classification of the complete events with all decaying charged particles, allowing for a reconstruction of the excitation energies of the daughter ^{38}Ar and ^{37}Cl nuclei. The multiphonon region and its characteristic direct decay pattern will be looked for.

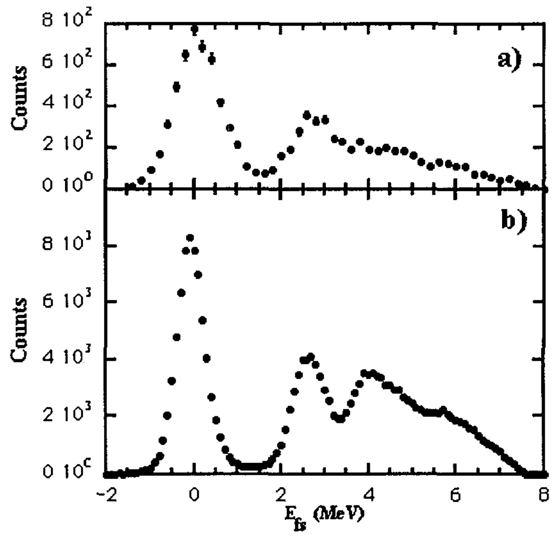


Fig.1 Missing energy spectrum for the decay of the giant resonance region (from 12 to 20 MeV) through proton emission. Fig.a is from a previous experiment and fig. b from this experiment.

References

[1] Ph.Chomaz and N.Frascaria, Physics Report, vol 252 (1995).
[2] J.A. Scarpaci et al., Phys.Rev.Lett. **71** (1993) 3766.

Fission time of heavy nuclei

S. Basnary, A. Chbihi, J. D. Frankland, M. Morjean
GANIL, DSM/CEA, IN2P3/CNRS ,BP 55027, F-14076 Caen Cedex 5, France

F. Barrue, M. Chevallier, D. Dauvergne, R. Kirsch, P. Lautesse, J. C. Poizat
IPN Lyon, IN2P3/CNRS, Univ. Cl. Bernard,
43 Bd. 11 Novembre 1918, F-69622 Villeurbanne Cedex, France

C. Cohen, H. Ellmer, J. M. Guigner, A. L'Hoir
GPS, 2 place Jussieu, F-75251 Paris Cedex 05, France

D. Jacquet
IPN Orsay, BP 1, F-91406 Orsay Cedex, France

M. Toulemonde
CIRIL, BP 5133, F-14040 Caen Cedex, France

The fission times of excited nuclei are expected to be quite sensitive to the magnitude of the nuclear dissipation involved during the fission process [1] and should therefore provide valuable pieces of information on the dynamics of this process. The possibility to determine nuclear lifetimes using the blocking technique in single crystals was suggested in 1965 [2] and various experimental efforts have been undertaken since that time to apply this technique to the very complex fission process [3]. Three major improvements to this application have been recently carried out in experiments performed at GANIL in order to determine the fission times of uranium [4, 5] and lead nuclei. For these experiments, silicon single crystals have been bombarded either with uranium or lead projectiles at 24 and 29 MeV/nucleon, respectively. The first improvement results from the use of reverse kinematics to form, in peripheral nuclear reactions, excited projectile-like nuclei that undergo fission: the rather high projectile-like velocities shift the sensitivity limit of the blocking technique towards shorter times [4]. Furthermore, these high velocities give access to an unambiguous identification of the fissioning nuclei from the measured atomic numbers of the coincident fission fragments. The second improvement results from the determination of the fissioning nucleus excitation energy using ORION, a 4π neutron detector: the fission time evolution can be followed over a wide range of temperature in a single data taking. The third improvement arises from the inclusion in the data analyses of post-scission emission [5]: this emission was not considered in the previous blocking experiments, leading to an overestimation of the times.

Figure 1 presents the evolution of the blocking ratio BR with excitation energy for uranium and lead-like nuclei. BR is a quantitative representation of the blocking pattern filling [5]. $BR = 1$ corresponds to fission times longer than 10^{-16}s, whereas the BR values indicated by the dashed lines correspond to fission times shorter than, or equal to, 3×10^{-19}s. For the uranium nuclei, a very strong evolution is observed and fission times have been already determined for excitation energies up to 250 MeV [5]. With the Pb projectiles, no significant data could be collected for excitation energies lower than 130 MeV due to the low fission probabilities resulting from the higher fission barriers involved. However, for excitation energies between 130 MeV and about 260 MeV, the BR values, as well as the shape of the blocking patterns, indicate fission times longer than 3×10^{-19}s. Therefore, the very direct blocking technique in single crystals indicates both for uranium and lead-like nuclei much longer fission times than those usually inferred from simulations performed with statistical models in order to reproduce data like pre-scission multiplicities, fission probabilities or heavy residue productions. Nevertheless, the results of these simulations are strongly dependent on assumptions made on the entrance

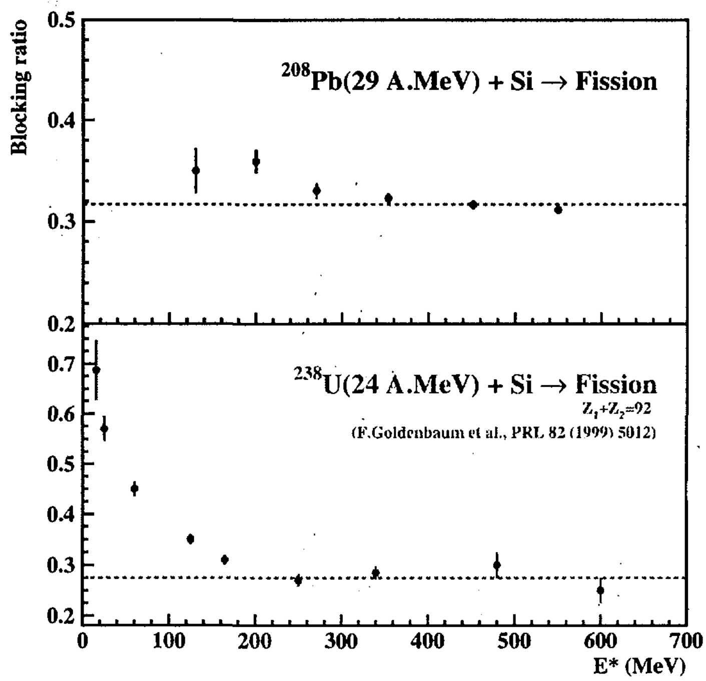


Figure 1: Blocking ratio as a function of the initial excitation energy.

channel reaction mechanisms, on the level density parameters and on their evolution with excitation energy and deformation. Therefore, our straightforward measurements of fission times should impose quite strong constraints on the statistical model parameters.

References

[1] I. Gontchar, M. Morjean and S. Basnary, Ganil Report **P0018** (2000), accepted for publication in Eur. Phys .Lett.

[2] D. S. Gemmell and R. E. Holland, Phys. Rev. Lett. **14**, 945 (1965)

[3] W. M. Gibson, Ann. Rev. Nucl. Sci. **25**, 465 (1975)

[4] M. Morjean et al., Nucl. Phys. **A630**, 200c (1998)

[5] F. Goldenbaum et al., Phys. Rev. Lett. **82**, 5012 (1999)

Evidence for Spinodal Decomposition in Nuclear Multifragmentation

B. Borderie[1], G. Tăbăcaru[1,2], Ph. Chomaz[3], M. Colonna[4], A. Guarnera[4], M. Pârlog[2], M.F Rivet[1] and the INDRA Collaboration

[1] *Institut de Physique Nucléaire, IN2P3-CNRS, F-91406 Orsay Cedex, France.*
[2] *NIPNE, RO-76900 Bucharest-Măgurele, Romania.*
[3] *GANIL, CEA et IN2P3-CNRS, B.P. 5027, F-14076 Caen Cedex, France.*
[4] *Laboratorio Nazionale del Sud, Viale Andrea Doria, I-95129 Catania, Italy.*

One among the many theories developed to explain multifragmentation considers volume instabilities of the spinodal type. Indeed, during a collision the nuclear system may enter the liquid-gas phase coexistence region (at low density) and even the unstable spinodal region (domain of negative incompressibility) where the growth of density fluctuations may induce multifragmentation. Within this theoretical scenario a breakup into nearly equal-sized "primitive" fragments should be favored in relation with the wavelengths of the most unstable modes present in the spinodal region. However this simple picture is expected to be strongly blurred by several effects, and only a weak proportion of multifragmentation events with nearly equal-sized fragments is expected. We investigated, using a very sensitive method of charge correlations, the occurrence of equal-sized fragment partitions in a selected sample of experimental events, corresponding to a fused system undergoing multifragmentation.

Charged reaction products from central $^{129}Xe +^{nat} Sn$ collisions at 32 MeV/nucleon were detected with the INDRA 4π array at the GANIL accelerator. Thanks to the high performances of INDRA, all fragments with charge $Z \leq 20$ were identified with a resolution of one charge unit. The event selection for fused systems required the detection of at least 80% of the charge of the system, and that the event flow angle be larger than 60^o.[1]

The correlation method used is appropriate to search for weak signals; its originality consists of the fact that all information on fragments of one event is condensed in two variables to construct the charge correlation,defined by the expression: $\left.\frac{Y(\Delta Z,<Z>)}{Y'(\Delta Z,<Z>)}\right|_M$ where $Y(\Delta Z, < Z >)$ is the yield of selected events with $< Z >$ and ΔZ values; M is the fragment (Z> 4) multiplicity, $< Z >$ denotes the average fragment charge of the event and ΔZ the standard deviation; the denominator represents the uncorrelated yield. If events with nearly equal-sized fragments are produced, we expect to see peaks appearing in the first ΔZ bin (0-1) and it is indeed what is observed for each fragment multiplicity[2]

To estimate whether the enhancement of events with equal-sized fragments is statistically significant and quantify their occurrence, we built charge correlations for all selected events, whatever their multiplicity, by replacing the variable $< Z >$ by $Z_{tot} = \mathrm{M} \times < Z >$. Uncorrelated events are thus built and weighted in proportion to real events of each multiplicity. Higher order correlation functions for the first bin in ΔZ are displayed in Fig. 1 with their statistical errors; the solid line corresponds to an extrapolated "background".[2] All events corresponding to the three points whose error bar is fully located above this line correspond to a statistically significant enhancement of equal-sized fragment partitions. The probabilities that these values which are higher than the background simply arise from statistical fluctuations are 0.048 (Z_{tot}=45), 0.038 (Z_{tot}=51) and 0.022 (Z_{tot}=57). The number of significant events amounts to 0.1% of selected fusion events.

Dynamical stochastic mean-field simulations[1] were performed for head-on collisions only. Spinodal decomposition is simulated using the Brownian one-Body (BoB) dynamics

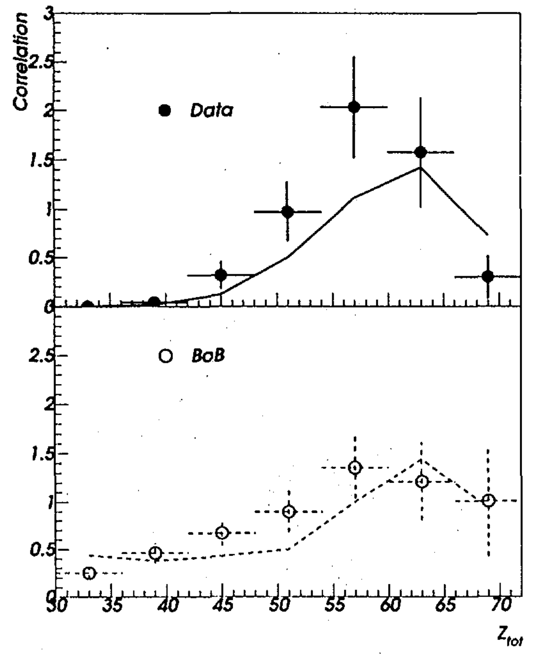


Figure 1: Higher-order charge correlations: quantitative results for experimental data (upper panel) and simulations (lower panel). Symbols indicate the events where ΔZ = 0-1, curves show the background defined extrapolating ΔZ > 2. Vertical bars correspond to statistical errors and horizontal bars define Z_{tot} bins.

which consists in employing a Brownian force in the kinetic equations. In a following step the fragment deexcitation was followed while preserving space-time correlations. Finally the events were filtered to account for the experimental device. These complete simulations well reproduce multiplicity and charge distributions of fragments and their average kinetic energies.[1] To refine the comparison, higher-order charge correlations were calculated for the simulated events. Although all events in the simulation arise from spinodal decomposition, only a very small fraction, similar (0.15%) to the experimental one, exhibits final partitions with equal-sized fragments, as suspected for finite systems. A detailed quantitative comparison is displayed in fig. 1. The similarities between experimental and calculated events allow one to attribute all experimental fusion-multifragmentation events to spinodal decomposition. The peaks observed near $\Delta Z=0$ in the higher-order charge correlations are thus fossil fingerprints of the partitions expected from spinodal decomposition.

It is interesting to underline that a sample of SMM events, which account for multiplicity and Z distributions and for the average kinetic energy of fragments,[3] shows no partition with $\Delta Z < 2$.

In summary, charge correlation functions for fusion events which undergo multifragmentation show a weak but unambiguously enhanced production of events with equal-sized fragments. Supported by theoretical simulations we interpret this enhancement as a signature of spinodal instabilities as the origin of multifragmentation in the Fermi energy domain. Spinodal instabilities are thus shown for the first time in a finite system. Moreover the occurrence of spinodal decomposition demonstrates the presence of a liquid-gas coexistence region and gives a strong argument in favor of the existence of a first order liquid-gas phase transition in finite nuclear systems.

References

[1] J.D. Frankland et al., (INDRA coll.) nucl-ex/0007019-020 and Nucl. Phys. A in press.

[2] B. Borderie et al., (INDRA coll.) Phys. Rev. Lett. 86 (2001) 3252

[3] N. Le Neindre, Ph. D. thesis, Université de Caen, LPCC T 99-02 (1999).

Charge correlation from a one-source pattern in Ni + Au collisions at intermediate energies: a signal for spinodal disassembly ?

B. Guiot[1], P. Désesquelles[2], J.L. Laville[1]
for the INDRA Collaboration

[1] GANIL, CEA et IN2P3-CNRS, B.P. 55027, F-14076 Caen Cedex, France.
[2] Institut de Physique Nucléaire, IN2P3-CNRS, F-91406 Orsay Cedex, France.

1 Introduction

The search for characteristic signals able to evidence critical behaviours in multifragmenting hot nuclei shows presently a large gain of interest [1, 2, 3]. It has recently been proposed [4] a sensitive method to find, in second order charge correlations, some "fossile" track of a spinodal decay characterized by a yield of fragments of same sizes, as predicted by recent theoretical developments [5]. Such an approach has been recently applied on the Xe+Sn system at 32 MeV/u by the INDRA Collaboration [6, 7]: evidence has been claimed for a significant enhancement in the correlation pattern between the mean value and the standard deviation of the charge of the fragments pertaining to events with five IMF's (Intermediate Mass Fragments). We examine these correlation patterns in a set of fusion-like data selected in 32 MeV/u and 52 MeV/u Ni + Au central collisions. This selection was performed by an original method which rests upon a Factorial Discriminant Analysis (FDA).

2 Single Source Event Selection

The FDA procedure developped in [8, 9] leads to use a powerful Discriminant variable Dv built up as a multilinear combination of observables. It is first constructed from simulated filtered events, and then calculated with the experimental ones and was shown to provide a clear separation between single and poly-source events.

Fig.1 shows its selective power: the Dv variable is fitted by the sum of two gaussiens; the right one represents the "poly-source" contribution and the left one the single-source contribution. The grey and hatched parts select "pure" samples of them [9]. The bottom diagrams illustrate each case with the correlation between the two biggest fragments; the right one, devoted to the poly-source sample exhibits mainly the projectile-like component (i.e. $Zmax1 \leq 28$ with a rather small $Zmax2 \leq 2$). This characterizes a binary-like pattern (most the the target-like contribution is undetected because of the energy threshold of INDRA). At reverse the left diagram shows the large IMF distribution resulting of the fusion-like emitter. This confirms the efficiency of the Dv variable to disentangle various reaction mechanisms and to identify a single-source emission.

The IMF decay of that fusion-like sample suggests that the process has overcome the multifragmentation threshold, and is a very good candidate for such an investigation of critical signals with IMF's multiplicities ranging from $Mimf = 3$ to 5. Similar conclusions might be derived for the system Ni + Au at 32 MeV/u: the same FDA procedure leads to the selection of single source events – the IMF decay of which is characterized by the correlation Zmax2 versus Zmax1. The hot single-source selected in the Ni + Au system gathers most of the initial mass estimated to be about 215 nucleons over 256.

3 The charge correlation function

The correlation method consists in calculating the ratio C = 1+R = N/D, where $N(<Z>,\sigma)$ is the number of coincident events for given mean value and standard deviation of its charges. $D(<Z>,\sigma)$ stands for the

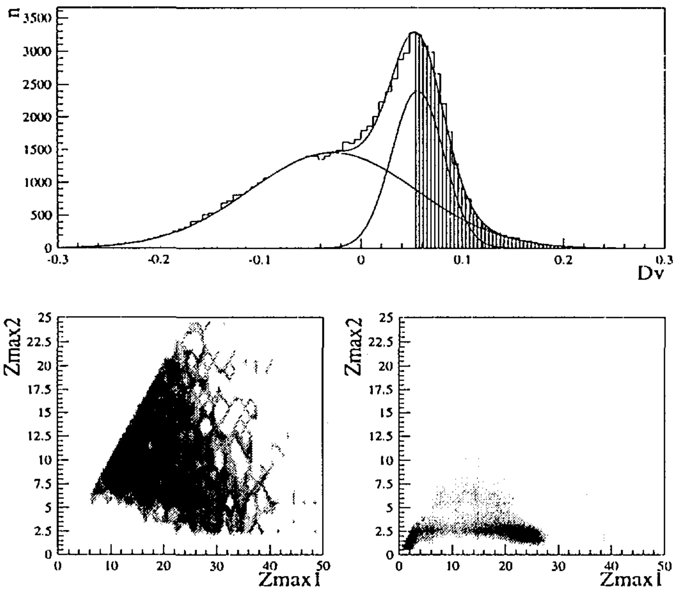


Figure 1: Top: Dv distribution for Ni+Au 52 MeV/u collisions, and two gaussien fit. Bottom: correlation plots between the two biggest fragments of the event ($Zmax1 \geq Zmax2$), for central (left) and peripheral (right) collisions.

"uncorrelated background". Its suitable definition is the most difficult point of the method. The use of a correlation technics rests upon the following idea: at the time of the supposed spinodal decomposition, primary fragments of equal sizes are simultaneously produced more or less excited; then they endeavour sequential decay which smears out most of the primary information on the fragment size which – at the cold final stage of the reaction – is a "fossil" signature, i.e. a very small signal among a huge background (de-correlated component). This background has to be estimated in a realistic way since it is expected to contain every step of the process story: out-of-equilibrium contamination, formation and decay of the hot nucleus and also the filtering effect of the detector.

This background is usually built up by taking fragments from different events for a given IMF multiplicity and then calculating their mean value and standard deviation. This procedure has to be repeated several times in order to explore all possible partitions. We use another method which is strictly equivalent to an infinite number of random sortings. Indeed the denominator can be calculated algebrically [10]. We only need the normalized experimental charge distribution for that given fragment multiplicity.

4 Results

The charge correlation patterns associated with the IMF decay of the fusion-like emitters are presented in fig. 2 and 3. The bin in standard deviation was fixed to one atomic number unit. No clear signal is visible in the 32 MeV/u case. Reversely, one observes an enhancement at 52 MeV/u around $<Z>\simeq 12$ and $<Z>\simeq 9$ which rises significantly above the background for both Mimf = 3 and 4 respectively. An estimate of its shape extrapolated to $\sigma = 0$ allows the signal subtraction with a confidence level of 95%. The presence of the signal might be directly due to the difference in convertible energy. The excitation energies have been evaluated to 5 and 7 MeV/u at 32 and 52 MeV/u respectively [11]: one may infer that a higher excitation energy causes a wider opening of the multifragmentation channel and hereto increases the probability of spinodal decay. Indeed the increase of the incident energy leads to a higher initial compression ot the system; this compression is supposed to allow the system to enter more deeply the spinodal region [5]. This result is confirmed by the fact that the

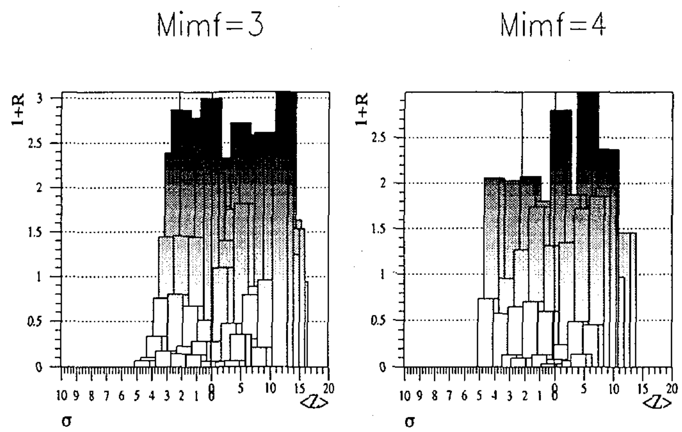


Figure 2: Charge correlation pattern of the Ni+Au fusion-like IMF decay at 32 MeV/u.

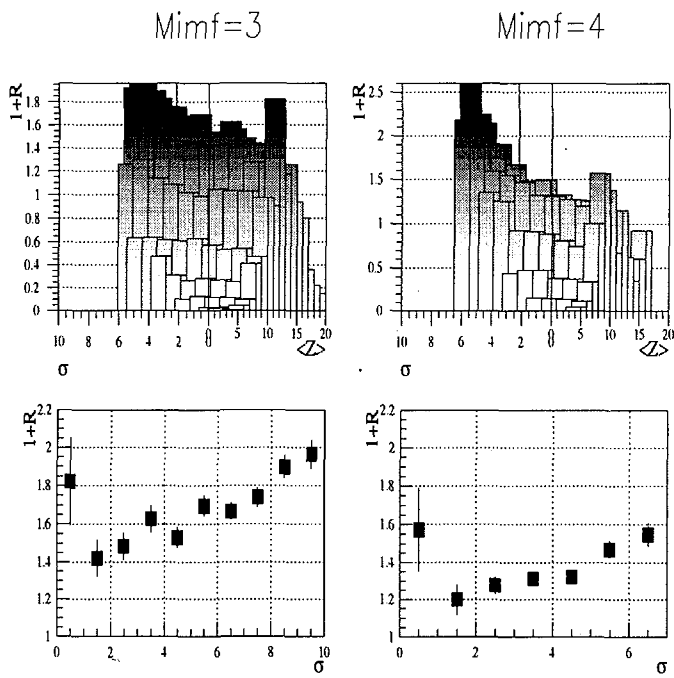


Figure 3: Top: same as 2, for 52 MeV/u. Bottom: evolution of the correlation function with σ, for <Z>=12 (left) and <Z>=9 (right).

phenomenon is observed in Xe+Sn collisions at 32 MeV/u (260 nucleons, excitation energy 7 MeV/u), i.e. in very similar conditions of size and excitation energy. It seems that the signal manifests itself in a rather narrow gate of excitation energy: it is not seen in Xe+Sn at higher beam energy (50 MeV/u leading to 12 MeV/u for the hot source). One may suggest that such critical phenomena are restricted to a small window in excitation energy.

5 Outlooks

The method needs some improvement, especially for a non ambiguous estimate of the denominator. An attempt to calculate it accounting for the role of experimental effects (total measured charge of the fusion-like nucleus; charge dependant detection efficiency of the decay IMF's) and the effects of charge conservation is now in progress.

Nevertheless, the charge correlation patterns presented here in the case of two incident energies 32 and 52 MeV/u leads to the following conclusion: the signal is observed in the latter and not in the former; this result suggests that the occurence of the signal should be very sensitive to the excitation energy since it seems that the phenomenon only appears in a rather small domain of it. At that time, other approaches, presently in progress seem to bring some coherent conclusions between the observation (or non observation) of both negative branch of caloric capacities and Z correlations; for instance, both are observed in Xe+Sn collisions at 32 MeV/u; and not at 50 MeV/u. Similar conclusions are given concerning the Ni+Au system [13]. Systematic studies including several systems implying various sizes and excitation energies are needed to derive convincing conclusions on this fascinating topic of possible spinodal phase transitions in nuclear matter.

References

[1] N. Marie and INDRA coll., Phys. Lett. **B391** (1997)15.

[2] J. D. Frankland thesis, University of PARIS XI Orsay, France, 1998.

[3] M. F. Rivet and INDRA coll, Phys. Lett. **B430** (1998)217; B. Guiot thesis, GANIL, Caen(France), in progress.

[4] L. G. Moretto et al., Phys. Rev. Lett. **77**(1996)2634.

[5] P. Chomaz et al., Phys. Lett. **B353** (1995)417 , and ref. therein.

[6] G Tabacaru thesis, University of PARIS VII (France),1999.

[7] B Borderie et al., Phys. Rev. Lett. **86**(2001) 3252.

[8] A. M. Maskey thesis, University of Lyon (France), 1999.

[9] P. Désesquelles et al., Phys. Rev. **C62**(2000)024614.

[10] P. Désesquelles, private communication.

[11] N. Bellaize thesis, University of Caen(France), 2000.

[12] J. P. Bondorf et al., Phys. Rep., **257** (1995)133.

[13] O. Lopez, Proceedings of the XXXIXth Winter Meeting on Nuclear Physics, Bormio 2001, to be published.

Thermal hard-photons in the reaction ^{129}Xe+^{112}Sn at 50A MeV

R. Ortega[a], L. Aphecetche[b], H. Delagrange[b], D. d'Enterria[b,a], G. Martínez[b], M. Mora[b], and Y. Schutz[b] for the TAPS collaboration

a) UAB (Barcelona), b) SUBATECH (Nantes)

It has been observed in heavy-ion reactions at intermediate bombarding energies (20A MeV$\leq\epsilon_{lab}\leq$ 100A MeV) that aside from the dominant hard-photon ($E_\gamma \geq 30$ MeV) emission in preequilibrium proton-neutron bremsstrahlung collisions, a softer hard-photon component is emitted in secondary NN collisions during the intermediate dissipative stages of the reaction [1, 2]. The main goal of experiment E300 performed at GANIL in May 1998 is to investigate such thermal hard-photon production in multifragmentation reactions of the ^{129}Xe+$^{\mathrm{nat}}$Sn at 50A MeV system. It has been recently demonstrated that, -in Ar-induced reactions at 60A MeV-, this second hard-photon component really emerges from a thermalized source [3] during the time scale when the multifragmentation process is supposed to take place (50 fm/c - 200 fm/c). Experiment E300 aims at confirming the validity of such conclusion in multifragment collisions of a more symmetric system with higher excitation energy. The final goal is to pin down the physical mechanism leading to multifragmentation and to study the possible connection of this nuclear decay-channel with the liquid-gas phase transition of nuclear matter. To carry out this investigation, inclusive and exclusive hard-photon measurements are analyzed, exploiting the performances of a complete detection system. The TAPS photon spectrometer was coupled for the first time with three different charged-particle multidetectors: the "Silicon Strip Detector" (SSD), the Washington University "Dwarf Ball" (DB) and the KVI "Forward Wall"(FW).

The double-source analysis (a double exponential fit with two different inverse slope parameters) of the inclusive hard-photon spectrum measured in ^{129}Xe+$^{\mathrm{nat}}$Sn (fig. 1) indicates that the hard-photon distribution can be described with a direct plus a thermal bremsstrahlung contributions, accounting for 78 % and 22 % of the total hard-photon yield, respectively. The inclusive hard-photon angular distribution confirms also this result [4]. The measured thermal slope, E_0^t, follows the recently observed linear dependence on the available energy in the nucleus-nucleus center-of-mass, E_{Cc}^{AA}, [3] consistent with a thermal bremsstrahlung emission from secondary NN collisions. The thermal slope is directly correlated with the temperature of the source [2] yielding a value of T$\approx$ 5 MeV [5]. In the present moment, exclusive thermal bremsstrahlung emission in central and multifragmentation exit-channels are being analyzed.

References

[1] G. Martínez *et al.,* Phys. Lett. **B349**, 23 (1995); F. Marqués *et al.,* Phys. Lett. **B349**, 30 (1995).

[2] Y. Schutz *et al.,* Nucl. Phys. **A622**, 404 (1997).

[3] D. G. d'Enterria *et al.,* submitted to Phys. Rev. Lett. nucl-ex/0012009.

[4] R. Ortega, Tesina Departament de Física, Universitat Autònoma de Barcelona, April 2001.

[5] D. G. d'Enterria *et al.,* in preparation.

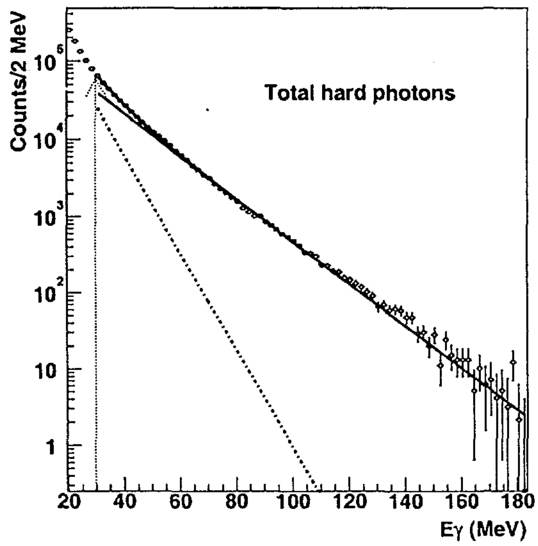


Figure 1: The experimental inclusive hard-photon spectrum measured for the reaction $^{129}Xe + {}^{nat}Sn$ in the NN center-of-mass frame. The thermal (dashed line) and direct (solid line) exponential contributions are shown.

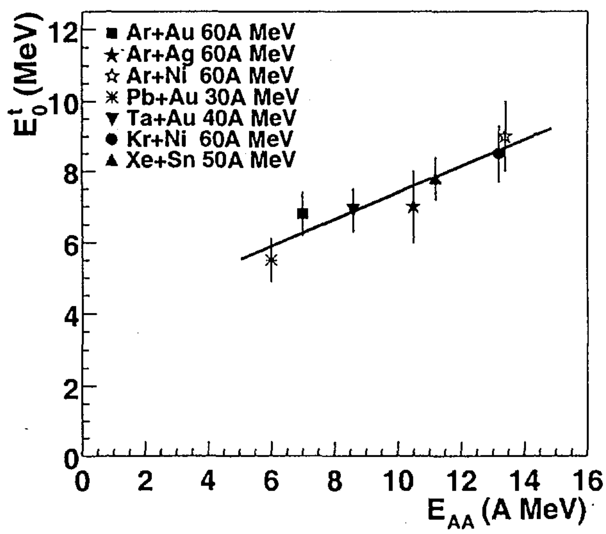


Figure 2: Thermal hard-photon slopes E_0^t, measured at $\theta_\gamma^{lab} = 90°$, plotted as a function of the Coulomb corrected nucleus-nucleus center-of-mass energy E_{Cc}^{AA}. The measurements correspond to different TAPS experiments including the reaction reported here. From [4].

Study of fusion-like heavy residue and IMF production in heavy-ion collisions close to the onset of multifragmentation

J.D. Frankland, A. Chbihi, I. Dauvin, S. Hudan and A. Mignon
for the INDRA collaboration

GANIL, B.P. 55027, 14076 CAEN Cedex 05, FRANCE

^{129}Xe+^{nat}Sn collisions were measured with the INDRA 4π charged product array [1] during the first campaign of measures conducted at GANIL and since then many new and interesting analyses and results have been published using these data [2]. However, as most of these studies concentrated on the phenomenon of nuclear multifragmentation commonly associated with central collisions at around and above the Fermi energy, the lowest measured bombarding energy of 25 AMeV received little attention until recently. We have undertaken a new study of these data which shows that once again low cross-section central collisions observed with such a powerful microscope as INDRA reveal new and unusual features which can help to understand the origins of multifragmentation.

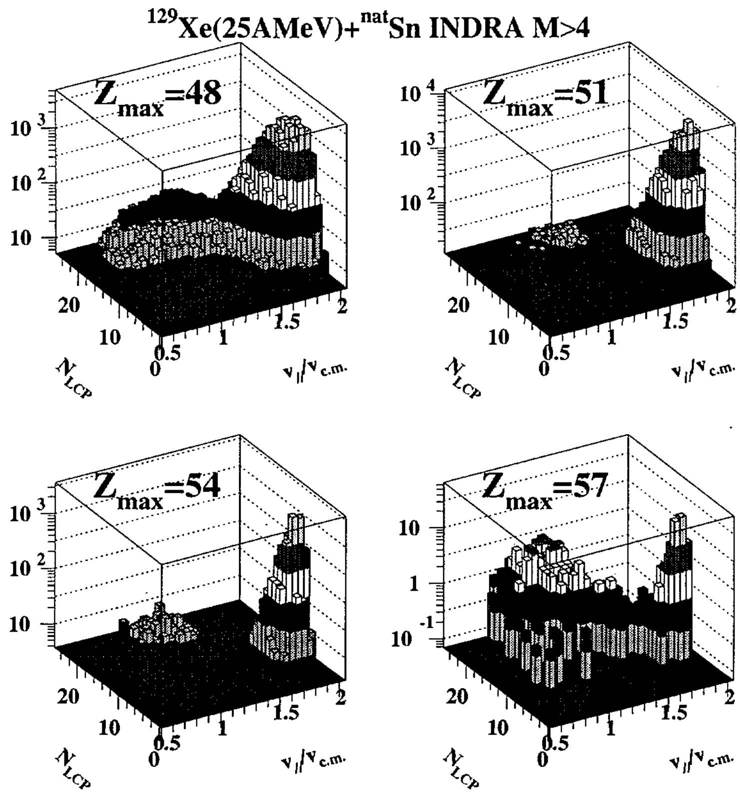


Fig.1: Heavy residue yield as a function of charge, velocity and LCP multiplicity

Fig. 1 shows the measured yield of heavy residues (being the largest identified nucleus in each event, atomic number Z_{max}) in the 25 A-MeV collisions as a function of recoil velocity and coincident multiplicity of light charged particles (LCP, isotopes of hydrogen and helium). For residues with $Z \geq 48$ two contributions are clearly distingushable. One corresponds to recoil velocities near the projectile velocity ($v_{//} \sim 2v_{c.m.}$) and is associated with low LCP multiplicities: this contribution, which disappears for residues larger than $Z_{max} \sim 57$, can be attributed to residues of projectile-like nuclei produced after deeply-inelastic interactions with the target. The second contribution associates large LCP multiplicities (> 10 particles) with (on average) centre-of-mass velocity residues, as one expects in the case of (incomplete) fusion for a symmetric system, or at the least in the case of very large transfers of mass and charge between projectile and target. This contribution has been observed for residues up to $Z_{max} = 70$, suggesting that we have measured the heavy residues of some kind of (incomplete) fusion reaction. Indeed, coincident LCP are compatible with evaporation by a single heavy nucleus at rest in the centre of mass frame.

In order to make a controlled study of these fusion-like reactions, we restricted our analysis to events for which we were able to unambiguously separate out the residue belonging to the centre-of-mass velocity component. It should be noted that we were unable to clearly distinguish between the two components for residues smaller than Z_{max} = 48, therefore our highly restrictive selection introduces an unphysical cut-off in the residue distribution (see Fig.2). It is certain that our selection only retains the tail of the whole distribution of residue sizes and the measured cross-section of 12mb is a lower limit.

Fig.2 shows the yield of IMF's ($Z \geq 3$) observed in coincidence with the selected residues (HR on the figure). On average, 2 IMF's are detected in each event with a mean total charge of around 15 units. It should be noted that for the selected events the mean total detected charge (including HR, IMF and LCP) is equal to around 85% of the sum of projectile and target Z, therefore INDRA provides very exclusive measurements of such reactions. For ^{129}Xe+^{nat}Sn collisions at 25 MeV/nucleon the available energy is around 6 AMeV, so we can expect in the case of incomplete fusion (central collisions) the formation of heavy nuclei ($Z \sim 80-90$) with excitation energies (~3–5 AMeV) associated with the onset of multifragmentation. It is therefore very interesting to examine the associated IMF production in detail.

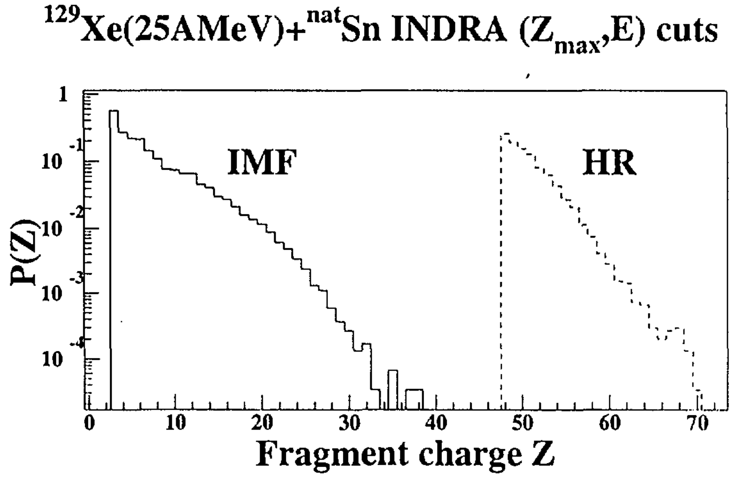


Fig.2: Charge distributions of heavy residues (HR) and IMF detected in events selected according to HR charge and laboratory recoil energy (see text).

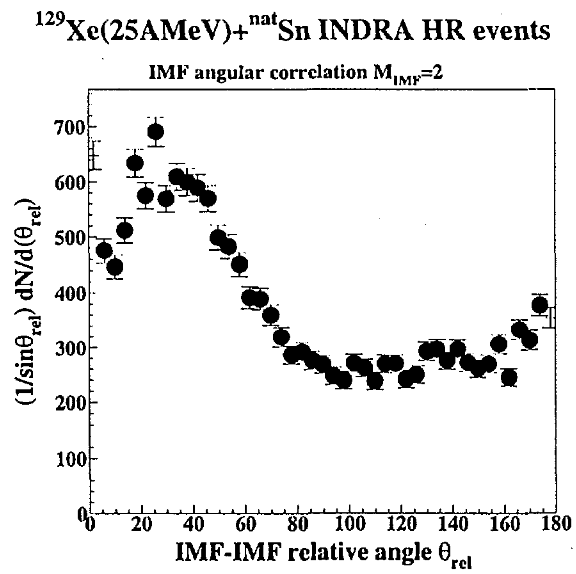


Fig.3: IMF-IMF relative angle distribution for HR + IMF + IMF events. Vertical bars show statistical errors.

IMF's produced by the multifragmentation (phase transition) of some thermally excited nuclear source, or by the sequential equilibrated decay (evaporation) of the same, should be statistically independent and uncorrelated apart from kinematic (i.e. momentum conservation) and exit-channel (Coulomb) interaction effects (see for example [3]). Fig.3 shows the distribution of the polar angle between the momenta of the 2 IMF's detected in coincidence with a heavy residue. In addition to an isotropic 'background' compatible with a statistical process, small relative angles are favoured showing that the 2 IMF's can be correlated in velocity space. A simple subtraction gives an estimate of the importance of this correlated production which corresponds to 25% of 2-IMF events.

In order to interpret this result we have performed three-body Coulomb trajectory calculations to test different kinematical scenarios [4]. We were unable to reproduce the small-angle correlations of Fig. 3 ($\theta_{rel} < 90^o$) assuming sequential isotropic emission of IMF's by the excited parent of the heavy residue, whatever the time-scale of the process ('evaporation' and 'multifragmentation' scenarios). On the other hand one can reproduce the observed correlations by assuming that the 2 IMF's are the result of the break-up of a small remnant of either projectile or target after a massive transfer towards the other partner of the reaction. Our simulations have allowed us to extract the time-scale for this process, the data being best reproduced when the remnant undergoes break-up 250-350 fm/c after the projectile-target interaction (Fig.4). In this scenario, the deduced mean charge of the initial excited heavy nucleus is $Z \approx 90$.

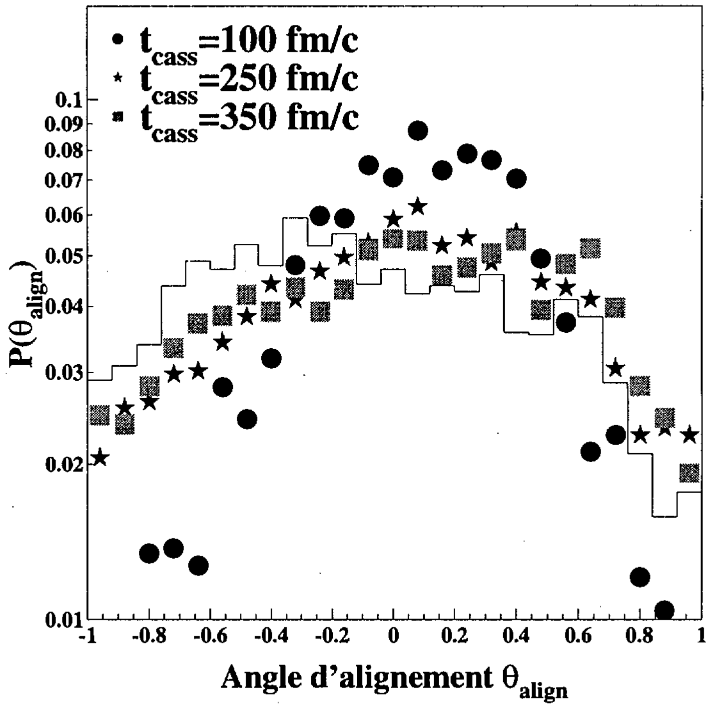


Fig.4: Comparison of data with three-body Coulomb trajectory calculations. Histogram: data for correlated IMF pairs ($\theta_{rel} \leq 50^o$). θ_{align} is the angle between the IMF-IMF relative velocity and the direction of motion of the centre-of-mass of the IMF's.

In conclusion, we found that central collisions of ^{129}Xe+^{nat}Sn at 25 MeV/nucleon can produce heavy fusion-like residues with $Z \leq 70$. For such a heavy symmetric system ($Z_1Z_2 \approx 2700$) this may be due to fusion or to deeply-inelastic reactions involving very large mass transfers from one to the other of the participating nuclei. In addition, part of the coincident IMF yield, expected to signal the onset of multifragmentation and the nuclear liquid-gas phase transition at these energies, may be explained by an entrance-channel (dynamic) effect unrelated to the decay of the hot compound system, which mainly evaporates light particles.

One may wonder to what extent these two observations are related. In this scenario, the correlated IMF production drains excitation energy that would otherwise have been deposited in the compound nucleus, thereby increasing the survival probability of a heavy residue. At the same time the two IMF, being small nuclei ($Z_1 + Z_2 \approx 15$), are most probably neutron 'poor' ($N \approx Z$) and we may speculate that they act also to 'drain' protons from the compound nucleus, increasing its N/Z ratio and hence its fission survival probability.

At the time of writing (April 2001) a new INDRA experiment is underway at GANIL in order to test these hypotheses at lower bombarding energies ($E_{inc} \leq 20$ MeV/nucleon) [5]. One of the first results of these measures will be the excitation function for the production of heavy residues in central collisions of ^{129}Xe+^{nat}Sn from $\sim$ 10 to $\sim$ 30 MeV/nucleon. At lower energies the evolution of the size of the heavy residue should tell us whether the reaction mechanism is dominated by fusion or by massive transfers. Also, the addition to INDRA of a few high-resolution telescopes permitting isotopic identification of fragments up to oxygen will allow to measure the average N/Z of the correlated IMF yield.

References

[1] J. Pouthas, B. Borderie, R. Dayras, E. Plagnol, M.F. Rivet, F. Saint-Laurent, J.C. Steckmeyer et al, Nucl. Inst. and Meth. A357(1995)418

[2] N. Marie et al, Phys. Lett. B391(1997)15; J. Lukasik et al, Phys. Rev. C55(1997)1906; M.F. Rivet et al, Phys. Lett. B430(1998)217-222; N. Marie et al, Phys. Rev. C 58(1998)256-269; A. Wieloch et al, Phys. Lett. B432(1998)29-36; R. Nebauer et al, Nucl. Phys. A658(1999)67-93; E. Plagnol et al, Phys. Rev. C61(2000)014606; D. Gourio et al, Eur. Phys. J. A7(2000)245-253; V. Métivier et al, Nucl. Phys. A672(2000)357-375; F. Bocage et al, Nucl. Phys. A676(2000)391-408; M. Germain et al, Phys. Lett. B488(2000)211-217; J.C. Steckmeyer et al, Nucl. Phys. A686(2001)537; B. Borderie et al, Phys. Rev. Lett. 86(2001)3252; R. Botet et al, Phys. Rev. Lett. 86(2001)3514

[3] *Statistical models for nuclear decay: from evaporation to vaporization*, A.J. Cole, Institute of Physics Publishing, 2000

[4] I. Dauvin, IN^2P^3 *Janus* training report, September 2000 (unpublished)

[5] GANIL experimental proposal E373 (September 2000), *Excitation function of fusion-like heavy residues produced in collisions of very heavy systems*, J.D. Frankland, A. Chbihi et al

Light particle production in Ar+Ni induced reactions (E207)

P. Buchet, J.L. Charvet, R. Dayras, D. Doré, A. Hürstel, R. Legrain, L. Nalpas, C. Volant
DAPNIA/SPhN, CEA/Saclay, 91191 Gif-sur-Yvette Cedex, France
and the INDRA collaboration

The properties of light charged particles (LCP) produced in the ^{36}Ar+^{58}Ni reaction have been investigated from 32 to 95 A.MeV bombarding energies with the 4π detection array INDRA. An important fraction of these particles is produced around mid-rapidity with unusually high transverse energies and peculiar emission patterns [1] which preclude the achievement of a global thermal equilibrium. From these observations, we took a phenomenological approach consisting in disentangling the various sources of LCP emission [2, 3, 4]. As a first step, we assumed three sources of emission, each in thermal equilibrium. Two sources are assimilated to the excited quasi-projectiles (QP) and quasi-targets (QT) and the third one to the zone of overlap between the projectile and the target. The atomic number Z_{max} of the detected QP is taken as an indicator of the centrality of the collision: large QP's are produced in peripheral collisions whereas light QP's are produced in more central collisions.

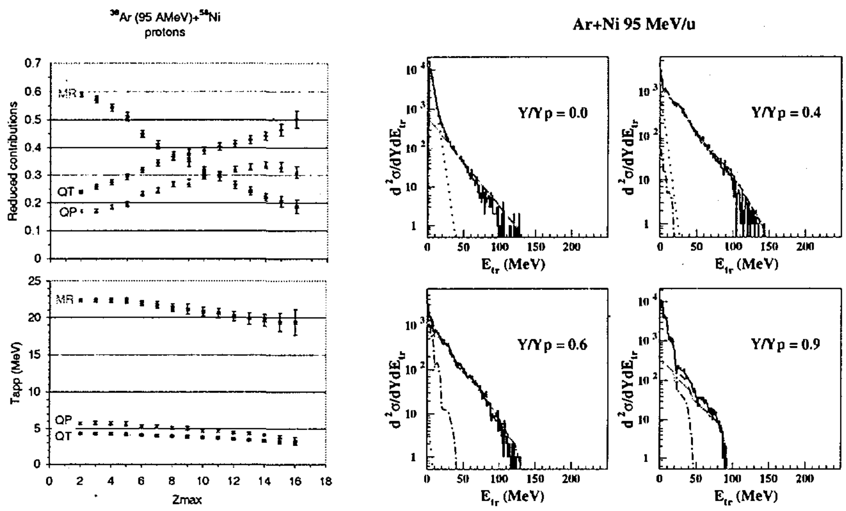


Figure 1: *Left panel:* Characteristics of the protons emitted in the ^{36}Ar+^{58}Ni induced reactions at 95 A.MeV vs. the quasi-projectile (QP) atomic number Z_{max}. *Top:* Fractions of the protons emitted by the QP's, the QT's and at mid-rapidity (MR). *Bottom:* apparent temperatures of the three emission sources. *Right panel:* Transverse energy spectra of protons emitted in coincidence with a QP of Z_{max}=14 for 4 different bins, 0.1 unit wide, in reduced rapidity. The full histograms are the experimental data. The dotted, grey, dash-dotted and dashed lines represent respectively the contributions of the QT, mid-rapidity, QP sources and of their sum. The observed structures in the spectra are due to the detector granularity.

A good description of all proton characteristics (kinetic and transverse energies, angular distributions) is obtained at all bombarding energies. At 95 A.MeV, the main results are summarised in fig. 1. The left top panel shows the contribution of each source to the proton production as a function of the QP atomic number Z_{max}. The left bottom panel shows the evolution of the apparent temperatures T_{app} of the sources as a function of Z_{max}. The temperatures of the QP and QT sources increase slowly from $\sim$ 3 MeV in peripheral collisions to $\sim$ 5 MeV in central collisions. The apparent temperature of the mid-rapidity source is much higher and is very close to the available c.m. energy per nucleon (22.3 A.MeV). The right panel of fig. 1 is a comparison between the experimental transverse energy spectra for protons emitted

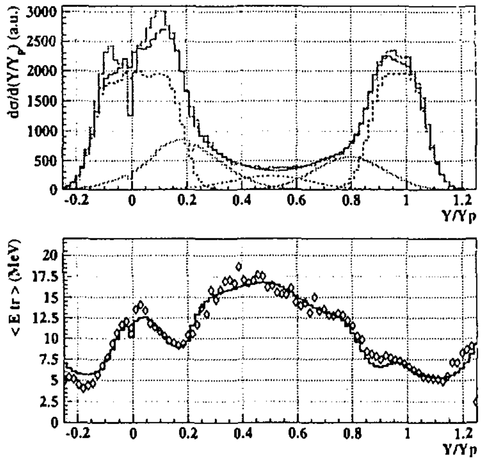


Figure 2: *Top panel.* Experimental rapidity spectrum (grey curve) for α-particles produced in the $^{36}Ar+^{58}Ni$ reaction at 95 A.MeV bombarding energy in coincidence with a PLF of Z_{max}=14. The overall fit is indicated by the black curve. The PLF and TLF components are shown by the black dashed curves, the MR component by the black dot-dashed curve and the two sources corresponding to nucleon-α and α-nucleon scattering by the dotted curves. *Bottom panel.* Average transverse energy $< E_{tr} >$ as a function of the reduced rapidity Y/Y_p for the same α-particles. The data are the open diamonds, the result of the fit is given by the black curve.

in coincidence with QP's of Z_{max}=14 for 4 different bins in reduced rapidity, and the spectra calculated with the fit parameters. Near the rapidities of the QT (Y/Y_p=0.0) and of the QP (Y/Y_p=0.9), one clearly notices a low energy component (evaporation from the QT or the QP) and a high energy component due to mid-rapidity emission.

For composite particles $(d, t, ^3He, \alpha)$, these three-source fits are less successful in reproducing the data. Indeed, rapidity spectra show an excess of high energy particles in the front of the TLF source and in the back of the PLF source at reduced rapidities which correspond respectively to the nucleon-cluster and cluster-nucleon rapidities. Considering those two extra sources of emission, the results are presented in fig. 2, for α-particles emitted in coincidence with a PLF of Z_{max}=14 at 95 A.MeV. The agreement with the experimental data is excellent. With this prescription, the properties (velocity and temperature) of the QP and QT sources become independent of the emitted light particle type as they should for truly thermalized evaporating sources. Concerning the MR source, its velocity is close to the c.m. velocity and its temperature close to available c.m. energy per nucleon.

In view of these results, it is clear that global thermal equilibrium is not reached during the collision. The QP and QT excitation energies are much smaller than previously estimated assuming a pure binary scenario and full thermalization of the excitation energy stored inside the QT and QP remnants [5].

References

[1] T. Lefort *et al.*, Nucl. Phys. **A662**, 397 (2000).

[2] D. Doré *et al.*, Phys. Lett. **B491**, 15 (2000).

[3] Ph. Buchet, Ph.D. Thesis, Université de Caen, 1999.

[4] A. Hürstel *et al.*, XXXVIIIth International Winter Meeting on Nuclear Physics, Bormio, Italy, 25-29 January 2000. Proceedings edited by I. Iori, Ricerca Scientifica ed Educatione Permanente Suppl. 116, 587 (2000).

[5] B. Borderie *et al.* Phys. Lett. **B338**, 224 (1996).

5 - INSTRUMENTATION

Target-ion-source development on SIRa in 2001

F. Landré-Pellemoine, M.-G. Saint-Laurent, J.-M. Cassandjian, G. Gaubert, S. Gibouin, Y. Huguet, P. Jardin, S. Kandri-Rody, N. Lecesne, R. Leroy, C. Marry, L. Maunoury*, J.Y. Pacquet, C. Stodel, A.C.C Villari

GANIL, CEA-DSM et IN2P3-CNRS, B.P. 55027, F-14076 Caen Cedex France

*and CIRIL, CEA-CNRS, BP 5133, F-14070 Caen Cedex 05 FRANCE

J.C. Angélique

LPC Caen – ISMRA, 6 Bd du M^al Juin, F-14050 Caen Cedex, FRANCE

O. Bajeat, C. Lau

IPN Orsay, F-91406 Orsay Cedex FRANCE

The goal of R&D work undertaken by the SIRa group is to increase the diversity, the intensity and the reliability of radioactive beams.

1. Targets for radioactive Argon and Neon beams

The target is made from carbon graphite composed of 1μm grains (see Figure 1). Yields of radioactive isotopes ^{17,18,19}Ne were measured with a 400W incident beam on SIRa. Extrapolated yields before acceleration calculated for SPIRAL with 2kW intensity are, for a 5^+ charge state: 2.6 10^8 for ^{19}Ne, 4.6 10^7 for ^{18}Ne, and 9.0 10^5 for ^{17}Ne. This target has been tested off-line during 50 10-hour periods (total duration 20 days); for this purpose, an ohmic power of 1900W (giving an estimated on-axis temperature of 2300K) was set on its central axis. The target has undergone 50 rapid temperature variations, allowing tests of the thermomechanical constraints due to expansion. Such a target was used on-line with success for the first SPIRAL experiment.

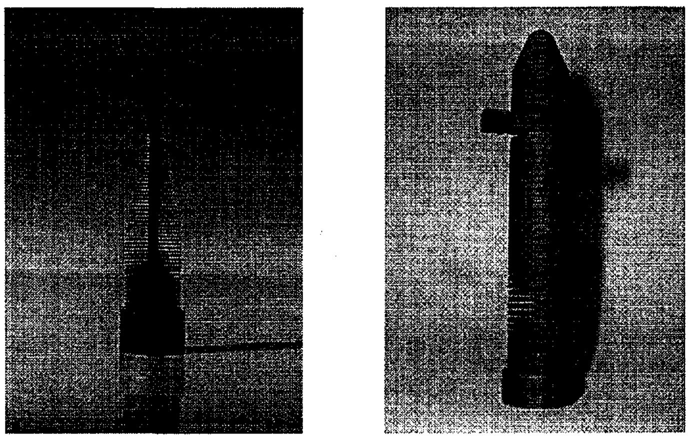


Figure 1: Carbon graphite targets used for (left) Argon and Neon radioactive beams (right) Helium radioactive beams.

2. Targets for radioactive Helium beams

This target, made of 1μm carbon grains, consists of 2 parts in order to benefit from both projectile and target fragmentation (see Figure 1). Thermal simulations and tests have shown that it should withstand 1.5kW of primary beam. Auxiliary ohmic heating power of 800W (for ^{6}He) or 1000W (for ^{8}He) is necessary in the 2nd part of the target in order to get enough temperature for fast diffusion. ^{8}He requires a higher temperature than ^{6}He (1600K instead of 1200K) in order to diffuse faster out of the grain without loss, due to its very short radioactive half-life (119ms). This 2nd part of the target has been tested during 30 days with an on-axis auxiliary ohmic power of 1200W. It underwent 75 rapid temperature variations without apparent damage.

Tests will be necessary during the first trials of SPIRAL in order to determine the reliability between 1.5kW and 2kW. Losses for Helium beams are principally due to the ionisation efficiency in the Nanogan-III source which is only ~10%, of which 90% for the 1^+ charge state and 10% for the 2^+.

3. Research into short-period radioactive beams ^{31}Ar (15ms), ^{17}Ne (108ms), ^{13}O (8ms), ^{11}Li (8.5ms)

Current targets are composed of thin strips (0.5mm) made of 1μm carbon grains. Diffusion-effusion measurements were made for isotopes ^{17}Ne (108ms), ^{6}He (807ms) (see Figure 2), and ^{8}He (119ms) in order to better understand the measured beam currents and, in particular, why ^{31}Ar (15ms) was not observed with this 1μm-grain target. Effusion times of the order of 130ms and 80ms were deduced for target strip thicknesses of 1.5mm and 0.5mm respectively. These values seem to be independent of the temperature (in the measured range) and independent of the isotope (^{6}He, ^{8}He, ^{17}Ne). If these targets are still relatively well adapted for the production of relatively short-lived isotopes such as ^{17}Ne (108ms), ^{8}He (119ms) and ^{32}Ar (98ms), they pose a problem for very short-lived isotopes such as ^{31}Ar (15ms), ^{13}O (8ms) and ^{11}Li (8.5ms).

Before the making of a new target, it is important to measure ^{31}Ar production with the current target and the 2kW SPIRAL beam because the temperature distribution with the 2kW beam will be more favourable to the diffusion of ^{31}Ar out of the grain than the 400W beam on SIRa with 1.6kW auxiliary heating.

In any case, a new target requiring R&D will need to be realised in order to increase intensities: either we will retain carbon targets with thinner strips made by electroerosion in order to decrease inter-grain effusion or we will use another graphite with faster diffusion, or another possibility would be to construct tantalum targets with ~3μm-thick strips. A comparative study of the diffusion-effusion properties of Ta and different C targets should be made.

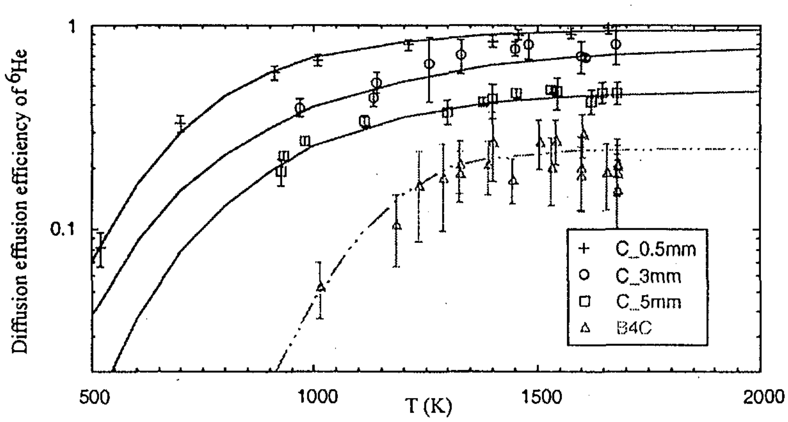


Figure 2: Diffusion-effusion efficiency of 6He measured for different thicknesses of carbon targets.

4. Improvement of the Monolithe target-ion source dedicated to alkaline elements

The alkaline elements require a surface ionisation source. The first production system showed that the tungsten oxide ioniser was not stable at high temperatures. The target-ion source has been modified in order to be rebuilt along the lines of a hot cavity source made of carbon. This system should be suited to K, Na and Li beams with however some reservations as regards very short-lived isotopes (<100ms), as it has been shown for ^{31}Ar. This system should be tested in beam in 2002.

VAMOS : A High Resolution Large Momentum and Angular Acceptance Spectrometer Especially Designed for the Use with Radioactive Ion Beams from SPIRAL

The radioactive ion beams (RIB) that are and will be delivered by the SPIRAL cyclotron of the large-scale facility GANIL need a high transmission transport system from the ion source to the target and an efficient detection system. High angular acceptance can and has been achieved using high field superconducting solenoids, such as the SISSI device at Ganil. Here supplementary conditions must be satisfied, especially space around the target must be available for efficient coincidence experiments, and good particle identification must be possible. Choice and optimisation of all constituents for these combined conditions was the subject of the spectrometer project.

Hence, the following spectrometer configurations were examined in detail: a gas-filled spectrometer, a big bore superconducting solenoid combined with a dipole analyser, and a superconducting solenoid doublet in front of the existing spectrometer LISE, a velocity filter such as the FMA at Atlas(Argonne,USA). All these solutions included high field superconducting magnets near the target. This however implies very high stray fields, of the order of several tesla near the solenoids. These stray fields render the use of ancillary detectors, in particular of phototubes for γ-detection very difficult. This is why in the final solution a doublet of very huge Q-poles replaces the solenoids. The geometrical aberrations were the object of a difficult and lengthy study. It was found that standard descriptions of fringe fields give completely erroneous results in the case of large solid angles as in the present case. Higher order corrections were found to be necessary, and will be introduced in the final Q-pole construction. A Wien velocity filter was added with respect to the initial project. The final original solution elaborated has the possibility to work in different optical modes. It renders possible the combination of the characteristics of different spectrometers used in this domain, as resumed in the table below:

mode	Elements	in operation	function
1	Q-poles Dipole Filter	yes no no	SOLENO type wide acceptance facility
2	Q-poles Dipole Filter	yes yes no	SUSAN- type dispersive facility
3	Q-poles Dipole Filter	yes yes yes	GANIL/LieseIII or SHIP type beam rejection and/or M/Q resolution

Here Soleno, LiseIII and Ship are spectrometers in operation at IPN/Orsay, Ganil/Caen and GSI/Darmstadt respectively. Susan was a project in the U.K. These unique characteristics made us call this spectrometer VAMOS, VAriable MOde high acceptance Spectrometer for identifying products of reactions induced by SPIRAL beams. The flexibility of use is increased further by a variable distance between the target and doublet of Q-poles. Besides the variable optics, the spectrometer is unique by its very big solid angle of 100msr. A big effort was done to define the detection system associated with the spectrometer. The use of light radioactive beams will very often imply the necessity of the detection and identification of very low energy recoil reaction products. Special detectors for such low energies are presently under development. Combination of different detection systems will make it possible to detect and identify ions with energies from 100keV/nucleon to 25MeV/nucleon. In June 1998, a memorandum of Understanding was signed for the construction of the spectrometer that started immediately after. The spectrometer is scheduled to become operational in begin of 2001. An up to date description can be found on the internet at the address http://www.ganil.fr/vamos/index.html.

The following mechanisms will be probably the main reactions to be studied in conjunction with SPIRAL:

a) Elastic and inelastic scattering in reverse kinematics; reverse kinematics transfer reactions

This field allows the study of interaction potential properties, matter distributions and properties of independent particles far from stability. This involves A(p,p'), A(d,p), ... type reactions where A is the incident beam and p or d the target. In a standard experiment in this extreme reverse kinematics, the light recoil nuclei, p,d, ... are detected by a light particle multidetector like MUST or MEGA. The energy and angle resolution will be obtained by these multidetectors, which have a very good granularity and energy resolution. To obtain spectra without too much background, it is nevertheless necessary to detect the ejected particle by coincidence. Due to the reverse kinematics, the maximum angle of the ejectile is below 10 degrees in all the cases of interest. As the recoil angles are very close to 0 degrees, the direct beam must be eliminated. The ejectile energy is typically 5 to 20 MeV/nucleon and identification of M and Z is desirable.

b) Deep inelastic scattering

This type of reaction can be used to produce new nuclei; the experiments at Dubna in the 70's showed the power of this method, which has, nevertheless, been little used, since the angle covered by the reaction products is very wide and collecting the nuclei is thus difficult. A very wide solid angle spectrometer is thus a preferred instrument for this domain. Recent model calculations also predict that this reaction starting with secondary beams should give cross sections for nuclei far from stability by some orders of magnitude above those obtained with stable beams.

Studying mechanisms of the N/Z ratio equilibration as a function of the isospin is another subject of great interest with the secondary beams.

For these two topics, M and N must be identified for nuclei with M values that are often above 100. The energy of the reaction products is from 1 to 5 MeV/nucleon, maximum acceptance is required, as well as detection angles up to around 90o.

c) Fusion-evaporation

By using secondary beams, new nuclei are going to be accessible by this reaction channel, both on the side of proton-rich nuclei, in particular close to the N=Z line, and neutron-rich nuclei, generally not accessible by stable beams due to high neutron evaporation at the beginning of the evaporation cascade. With the SPIRAL beams foreseen in the first phase, and even more with the secondary beams obtained by fission induced by a deuton beam, the formation of new transuranic nuclei should also be possible.

The majority of the experiments in this domain are going to be realised with direct kinematics, with rather low energies of the evaporation residues, the order of 0.1 to 1 MeV/nucleon. Highly specific detectors will be required to obtain good identifications at such low energies. The residues will be identified by coincidence with prompt radiations (gamma, n, p,...) observed by detectors around the target, or with delayed radiations (gamma, p, n, fission, ...) by implantation-disintegration correlations.

M/Q and M identification will have to be possible for the heaviest masses (A>250). The low energy of the reaction products implies that very wide angles (5 to 10 degrees) will have to be covered. Rejection of the direct beam is indispensable for these experiments which are, necessarily, centered at 0 degrees.

Only very high resolution experiments, but with a greatly reduced efficiency could be performed using the existing SPEG and LISE spectrometers.

The above considerations were formulated in three working meetings, each of them with around one hundred participants. Starting with these conclusions, four meetings of more limited groups, with around 15 persons, have looked for the most suitable technical solution. A report of all these meetings is available on request. This work was jointly financed by an RTD (Research and Technical Development) European Union contract. This contract was signed by GANIL, GSI, Daresbury, Surrey and Liverpool. Outside of this contract, other institutions have actively participated in the conception and optimisation, in particular, the IPN at Orsay, the SPhN at Saclay, the CRN at Bordeaux, and the Universities of Giessen , Manchester and Prague.

This collaboration elaborated an ensemble of characteristics has allowed us to define a new type of spectrometer having a solid angle an order of magnitude greater than those existing and with different operating modes. It combines a good resolution spectrometer with a velocity filter allowing either M/Q dispersion or rejection of the beam for 0 degrees measurements and also with a focusing without dispersion operating mode similar to a solenoid.

The time shedule for the project was the following:

1996: prospection of most promising physics domains and appropriate technical solutions. A quite quantitative evaluation is necessary in order to get realistic constraints for a project. This prospection ended with the selection of two technical solutions for further study. In order to achieve this very technical aim, after the first large meetings on this subject involving about one hundred participants, the number of participants was limited to persons being directly implied in the subject and willing to contribute actively.

1997: One project was selected between those selected before, and was studied in sufficient detail to achieve a complete project that could be submitted to the financing authorities, and served as technical basis for the eventual construction. An intermediate report was made available for mid 1997, in order to ask for financing in 1998.

1998: signature of a convention for the construction of a spectrometer; finalization of all options; begin of construction if agreement of the financing authorities is obtained

1999-2001: construction

2001: first operation

A general view of the final spectrometer is shown on figure 1.

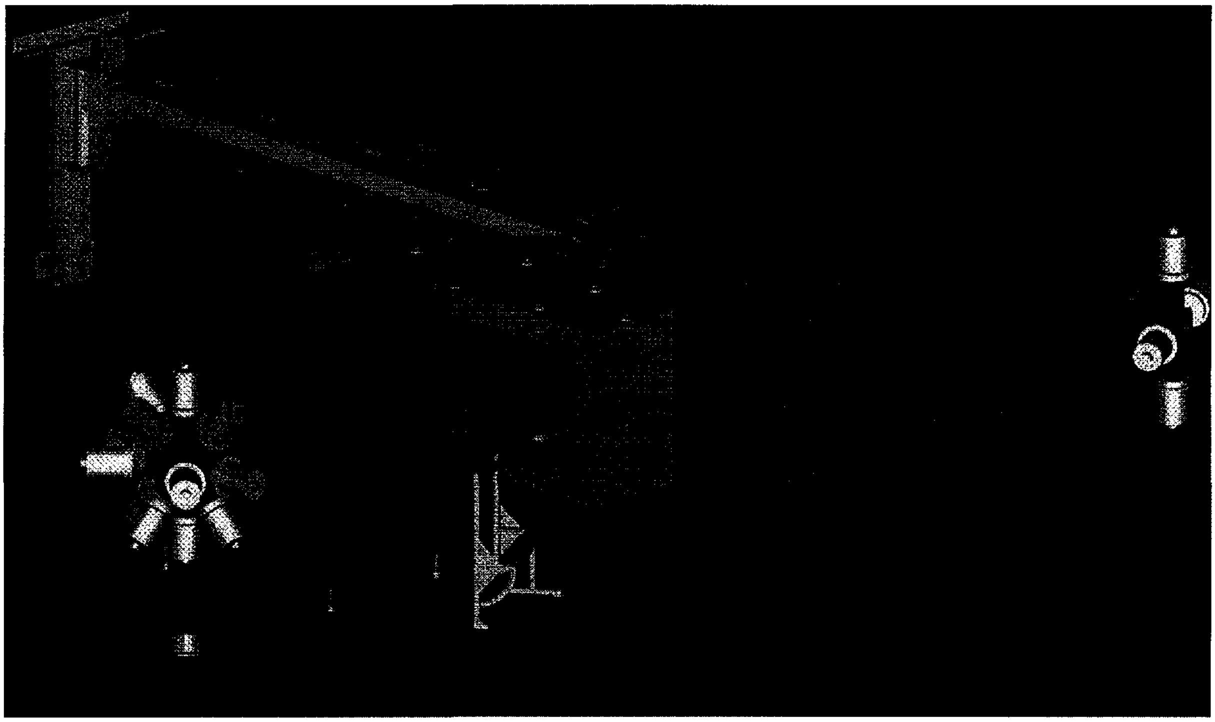


Figure 1 General vue of the Vamos spectrometer

A very general problem with high acceptance spectrometers is the increase of aberrations. This implies that software corrections will be necessary to get the final resolution. This however nonetheless implies that the mesured quantities, such as final angle and position, allow to reconstruct the quantities of physical interest without ambiguities. This would not have been the case if the spectrometer would have been constructed without higher order corrections. The main tool to do so was found to be in higher order corrections (up to 7th order) in the pole shape of the 2nd Q-pole. Images of the expected focal angle versus position can be seen on figure 2, before correction.

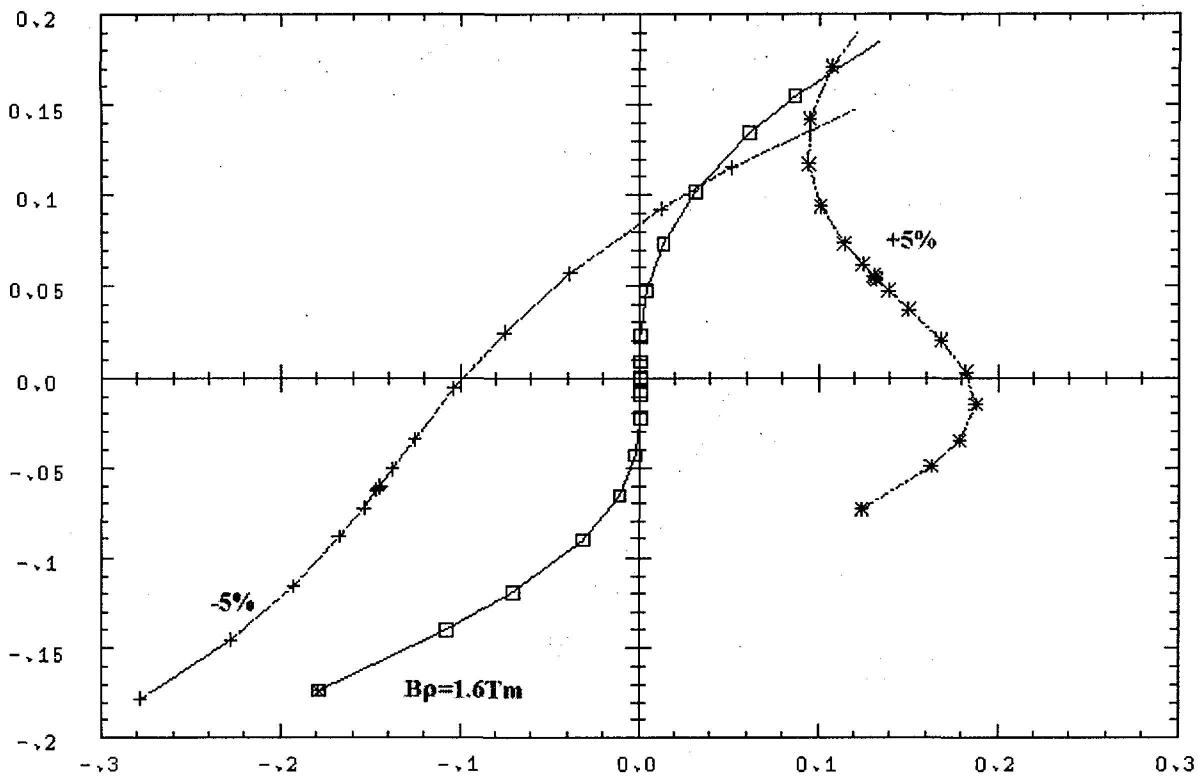
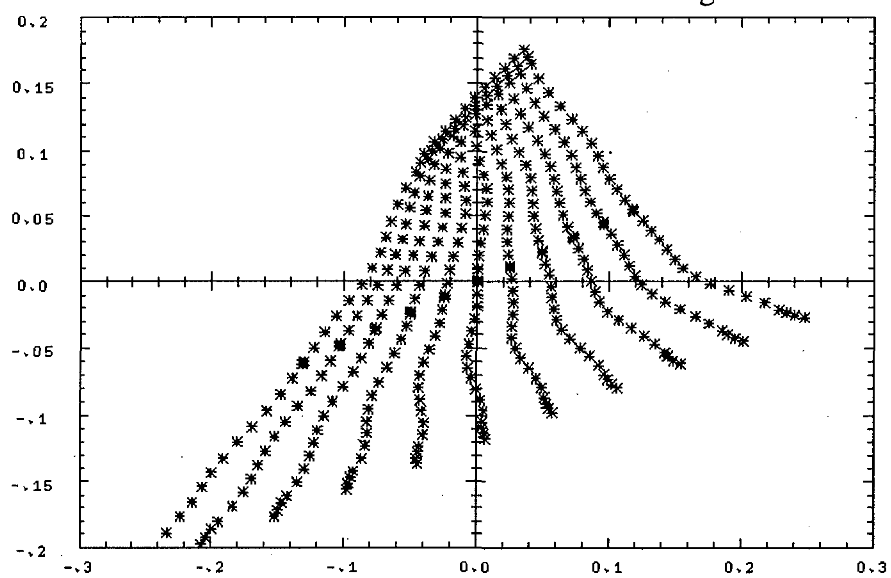


Figure 2:aberrations in the focal plane x-t before corrections

These aberrations are calculated with full 3 dimensional TOSCA field maps. This method can be used to introduce higher order corrections to reduce the aberrations. The most suited place to do so was the second Q-pole, where the pole shapes where modelled to introduce these correctionbs. The result is shown on figure 3.



A first experimental result obtained with an alpha source in september is shown on figure 4. It can be seen that the observed focal plane image corresponds very closely, even in fine details, to the calculated one. This image shows, beside the fact that it illustrates that VAMOS with its detection system became operational, the high predictive power of 3D field calculations coupled to ray tracing programs. The good agreement between the theory and this experimental result let us hope that the reconstruction problem will be solved quite rapidly, and that VAMOS will be in next future a versatile and powerful tool for the use of secondary beams from Spiral.

H.Savajols, W.Mittig and R.Anne

Figure 4 Focal plane image obtained with an alpha source.

The EXOGAM array : design, present status and perspectives

G. de France, B. Cahan, J.M. Casandjian, C. Houarner, L. Olivier, B. Piquet, B. Raine, F. Saillant, M. Tripon, A. Vigot, G. Voltolini and the EXOGAM collaboration

EXOGAM is a European collaboration to build a highly efficient and powerful gamma-ray spectrometer for nuclear spectroscopy using the exotic radioactive beams from SPIRAL.

The Memorandum of Understanding - MoU - describes the project in detail and is available on the GANIL web site. This include the physics case as well as a complete technical description of the adopted design. The present contribution is partly extracted from the MoU and gives a brief description of EXOGAM which is a high efficiency array of γ-ray detectors with associated high voltage, autofill system, cabling and mechanics and a dedicated electronics and data acquisition system. In addition, a complete status of the implementation of EXOGAM at GANIL will be made and R & D works initiated by the EXOGAM group at GANIL to go beyond the current possibilities of the array will be detailed.

1. The EXOGAM array

Radioactive beam spectroscopy presents new demands on the design of a γ-ray spectrometer. The beam intensity, at least at the start up of the new facility, is expected to be much lower than with stable beams, by a factor of 10 or even 1000 lower. EXOGAM must therefore be designed to maximise the total photopeak efficiency. This demand of very high efficiency must be achieved for both low (X-ray energies) and high γ-ray energy (i.e. 5-6 MeV). Such high energies will be observed, for example, in Coulomb excitation of light nuclei or β-decay studies.

Whatever the type of nuclear reaction, the interest of the physicists is always in the very rare events. In the analysis it must be possible to extract tiny peaks from a possibly huge background (correlated Compton background; background from the radioactivity from the target; scattered beams within the target chamber; etc.) To achieve this it is vital to have a very good peak to background ratio and energy resolution.

The third fundamental criterion specific to the use of a multidetector array with radioactive beams is its modularity. There will be a large variety of nuclear reactions using radioactive beams on which the design of a detection system must be based. The experimental conditions will be very different from one experiment to another in terms of γ-ray energy (from X-rays of tens of keV to γ-ray energies up to 5-6 MeV), of multiplicity (from one to ~15 coincident photons); of recoil velocity (from zero to ~ 10 % of light velocity); and of kinematics of the reaction mechanism (from recoiling fusion products emitted at ~ 0° or scattered particles between 0° and 180°). This variety means that the setup of the array must be adapted for each experiment. This will also be a strong constraint not only on the choice of the individual detector but also on the mechanical structure to maintain the high photopeak efficiency. The radioactive nature of the beam is also a concern and shielding of the detectors becomes an important design criterion.

It is also clear that in addition to the detection of gamma radiation it will be vital to have ancillary detectors available to detect both light and heavy charged particles and neutrons.

To best fit with these sometime conflicting demands, EXOGAM will consist of an array of high resolution germanium detectors. These will be arranged to give a high photopeak efficiency of ≥20 % for 1.3 MeV gamma-rays.

Segmented Clover detectors will be used in the array to give the optimum coverage and performances in a radioactive beam environment. Segmentation is required to optimize efficiency, energy resolution for γ-ray from recoiling reaction products, and minimisation of multiple-hit events. The EXOGAM Clover will be based on the use of large Ge crystals, 60 mm in diameter and 90 mm long, before shaping (se figure 1).

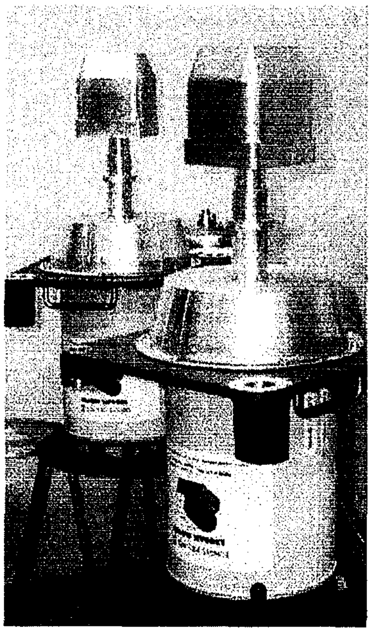


Figure 1 : the EXOGAM Clover

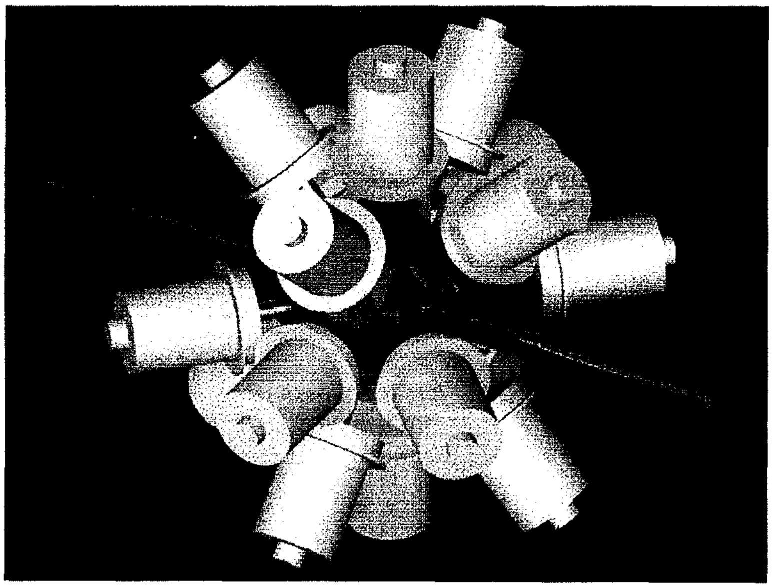


Figure 2 : CAD drawings of the EXOGAM array with 16 detectors without shield and in the most compact configuration.

These Ge detectors will be separated by BGO suppression shields. They will also have passive heavy metal collimators. The shields will be operated in two configurations. The first is with the back catcher and rear-side element, configuration A, and the second with the additional side elements, configuration B. A CAD drawings of EXOGAM in configuration A is shown in figure 2.

An electronics system is needed to process energy and timing information, make trigger decisions and relay data onto an acquisition system. The electronics will be based on the VXI and VME electronics systems in which the UK and France have expertise. It comprises a DT32 bus output from the VXI electronics, an event builder using VME processors, a tape server and several workstations for event monitoring and sorting. The data acquisition system is capable of recording data up to 2 Mbyte/s.

It is envisaged that the array will be used with several ancillary detectors as their use in association with the gamma-ray array will be vital to obtain efficiently the data necessary to achieve the physics goals. A major ancillary detector is the high resolution large acceptance spectrometer VAMOS. This spectrometer imposes additional design considerations for EXOGAM such as the rotation of the array or the shielding of the anti-Compton photomultiplier tubes against the fringent field from the first quadrupole.

2. Status of the project

This section gives a summary of the status of the EXOGAM project as it is at the end of 2001.

2.1. Detectors

Two companies, Eurisys Mesures (EM) and Perkin Elmer (PE) have been contacted by the EXOGAM collaboration for the provision of the Clovers. The UK, Finland and Sweden ordered 8 detectors from PE whereas France (SPhN Saclay and GANIL) ordered 6 from EM. The 2 remaining detectors are not yet attributed. The first prototypes, one from each company, were delivered to the collaboration in the middle of 1999. Since then, detailed measurements, tests and inspections have been performed in the various laboratories and institutions of the collaboration. Several problems such as lack of efficiency in some crystals, crosstalks, instability in the electronics of the detectors, problems on the overall quality of the internal cabling and electromagnetic compatibility (bad grounding, lack of HV filter or poor mother board quality) have been identified in both of these prototypes and modifications have been demanded for the serial detectors.

In a second step and after the modifications have been done, the first serial detectors were delivered to GANIL (EM) and to Sweden (PE) in mid 2000. After a complete check, the EM Clover has been decared to meet all the specifications and approved. The four following detectors were then delivered at a rythm of one every 2 months. Unfortunately, the PE Clover has been damaged during its journey to Sweden and was observed to be microphonic. Therefore it has been sent back for repair and checking.

The last serial detector ordered to EM is expected to be delivered early January at GANIL. The PE detectors are expected to be delivered in early 2002. Both prototype will be brought up to the same specification as the series detectors oce delivery of the main series detectors is complete. The main design specifications for the EXOGAM Clover are given in the folowing table:

	Phot. Efficiency (1.3 MeV, d=11cm)	Energy resolution (inner contact)	Energy resolution (outer contact)
Crystal	~ $1.7 \cdot 10^{-3}$	~ 2.3 keV	~ 3.2 keV

In addition to these large Clovers, it has been agreed that the EXOGAM collaboration will be in charge of the use, deployment and maintenance of the smaller EUROBALL size segmented Clovers bought several years ago by some EXOGAM members. There are 4 of these small Clovers (2 are from the UK, 1 from NBI and 1 from SPhN Saclay).

According the latest plan, it is hoped to have 9 large Clovers in addition to the 4 smaller ones in March 2002, for the first EXOGAM experiment with SPIRAL. However, the EXOGAM detectors have already been used many times at GANIL to study exotic nuclei produced via fragmentation of the beam. Germanium detectors have been requested extensively, and indeed the schedule for the 6 first months of 2002 contains 13 experiments -91 days of beam time (in which 31 are SPIRAL)- using Clover detectors.

The anti-Compton shields are made up with three distinct layers (see figure 3) and can be used in two configurations : the closed packed configuration A and the pulled back one, configuration B. The first one consists in the side catcher (BGO) and the back catcher (CsI), the combination of the two covering the rear part of the Ge while the front faces of two neighbouring Clovers are touching each other.

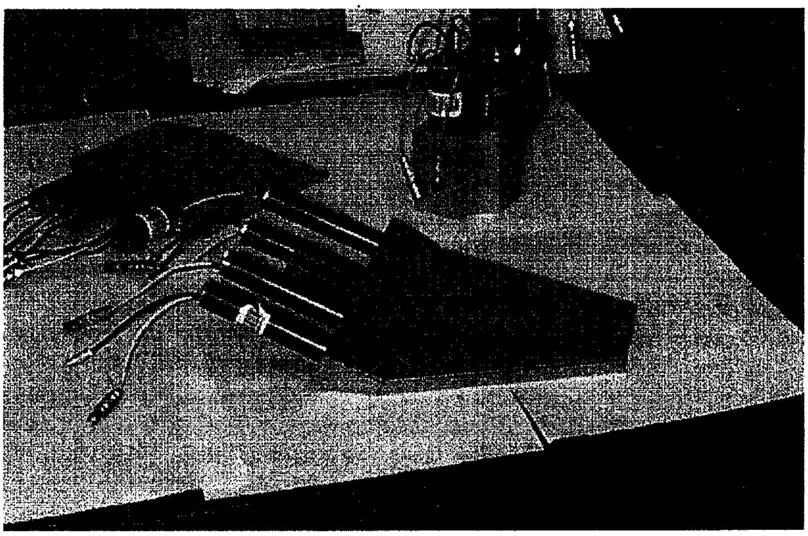


Figure 3 : The three distinct pieces for the shield : the side shield (front), the side catcher (left) and the back catcher.

This configuration is the most compact (the front face of the Clovers are at about 11 cm from the target point) hence the most efficient at very low multiplicity. Configuration B will be used when the number of coincident gamma rays is rather high (typically 15) when the losses due to multiple hits is far too large if the distance to the target is maintained at 11 cm. In this geometry, the detectors are at 15 cm from the targets. Pulling back the detectors allows for the third layer of BGO to be inserted between neighbouring detectors which improves the peak to background ratio by about 20 %. The following table summarizes the efficiencies and peak-to-background ratio for EXOGAM in configuration A and B :

	Phot. Efficiency (%)		Peak/total (%)	
	662 keV	1.33 MeV	662 keV	1.33 MeV
EXOGAM conf. A (d ~ 11 cm)	28	20	57	47
EXOGAM conf. B (d ~ 15 cm)	17	12	72	60

Today 12 complete shields have been ordered from SCIONIX, 6 are delivered, the rest is expected before March 2002. These shields are designed in such a way that they can be also used to veto the small Clovers. Therefore, 12 suppressed Clovers should hopefully be available in March 2002.

2.2. Electronics and data acquisition

VXI electronics will equip the various signals from the EXOGAM detectors. They consist in signals : from the crystals (high resolution) also called inner; from the segments (lower resolution) also called outer and from the anti Compton shields. The electronics use the VXI (VME extension for instrumentation) bus standard. This standard allows a large card size to be used and the mixing of both high density analogue signal processing and digital circuits on the same card. VXI cards are built for specific applications, for example, detector signal processing, digitisation and event triggering.

Each Clover and associated shield generates 4 inner, 16 outer and 8 shield (4 BGO and 4 CsI) signals. For the full EXOGAM array, this is therefore 64 inner; 256 outer and 128 BGO+CsI channels.

The VXI modules in the EXOGAM system will be:

- Ge detector card electronics
- BGO card (4 shields per card)
- Master Trigger card (1 card)
- Resource Managers, type STR8032 (1 per crate)
- Crate readout cards, type STR8080 (1 per crate)

Each inner contact card comprises eight channels (i.e. two Clovers) measuring energy, timing and radial hit position. The energy is measured in 2 ranges from 0-6 MeV and from 0-20 MeV (which can be switched to 0-3 MeV) with 16 bits ADCs. The timing is measured from the time the CFD fires to either the next beam timing (RF) pulse or to the time of the Fast Trigger (first level trigger, also acting as a global timing reference). The radial hit position determination, combined with the segmentation of the detector, will enable precise hit localisation. The position is determined by analysis of a current pulse obtained by differentiating the charge pulse from the preamplifiers. The pulse shape analysis method will be either a digital processing using a DSP to analyze samples from a flash ADC (65 MHz), or an analogue processing using the steepest slope algorithm. The former method is more versatile while the latter is simpler. The choice between the 2 methods will be made after further tests. The inner contact cards have been designed by IPNO/CSNSM and they are available for experiments.

One outer contact cards is capable to handle 4 crystals (each being electrically segmented in 4 segments). Including one spare per crystal, this gives 20 channels per card. Each channel will measure energy and timing informations as well as hit localisation in the same way as for the inner contact card. This latter feature will be incoporated in a second step but the design of the outer contact card already include this extension.

The design specifications for the outer contacts took a longer time since timing and hit localization depend strongly on the quality of the preamplifier pulse. The improvement observed on the prototype and even further on the serial Clover as compared with the first estimate allows us to decide to include both of the possibilities. The prototypes will be tested from February to April 2002. The outer contact cards have been designed by GANIL/CSNSM. Before these cards are available, the segments are equipped with CAEN 16 channels amplifiers and the GANIL 64 ADC cards.

The suppression shields for each of the Ge detectors consist of many BGO crystals each with a photomultiplier tube. The signals from the photomultiplier tubes are buffered through line drivers and are coupled close to the detector to give four signals per Clover shield. The anti-Compton card is design to handle 4 complete shields.

The four signals from a shield will be handled by a single channel of electronics which will measure the sum energy and the timing of the OR of the four inputs measured against either the beam pulse (RF) or the 1st level trigger Fast Trigger (FT). The choice of the timing measurement will be controlled by the user. In addition to energy and timing, a 4 bit hit pattern will be generated from each shield. One BGO VXI card will handle six suppression shields. The BGO/CsI cards have been designed by CLRC Daresbury/University of Liverpool. The prototype has been tested and the production has started. They will be made available for March 2002.

The data acquisition system is based on the MIDAS package (Multiple Instance Data Acquisition System, which is a development of the software system initially developed for Eurogam) associated with the standard GANIL acquisition system. A Graphical User interface (GUI) running within a Unix environment is used for all interaction between the user and the data acquisition electronics. All configurations of the system can be performed dynamically using the graphical tools. Setup, control and monitoring of electronics in VXI, CAMAC and VME is possible remotely using the GUI.

The VXI crates are read out via a 32 bit data bus (DT32) into a VME crate (event builder) where the data is checked and formatted for output to tape. The event builder passes the formatted data via a broadcast data network (Fast Ethernet) to a Tape Server (a standard VMS GANIL acquisition workstation which manages a farm of tape drives and outputs the data to one or more of the drives.Event monitoring and sorting is performed by several UNIX wokstations spying the data network. It can be also performed by the tape server which offers this functionnality.

The complete setup including electronics has been extensively tested and debugged both with sources and several beam time periods and is operational at GANIL.

2.3. Mechanics and infrastructure

The infrastructure required for EXOGAM itself include essentially the high voltage and LN2 automatic filling system as well as the installation of grounding plate common to both G1 and G2. In addition an electronics and detector laboratory have been completely setup in order to ensure repairs and annealing of the detectors. One of the major auxiliary detector expected to work with EXOGAM will be the VAMOS large acceptance recoil spectrometer. It is therefore planned to interconnect in the most efficient way these two large devices. The design of the various mechanical sub systems have been a difficult challenge since each of these has firstly to cope with the VAMOS rotation and secondly to be common in the two areas. These systems include :

- the platform with its cable ducts
- the frame for supporting the EXOGAM array
- the target loader support frame
- the array splitting mechanism
- the lifting frame
- the overall platform alignment mechanism
- the clamping plate

The design work has been done mainly in the UK in close contact with GANIL engineers. The installation and assembly of all these parts will start mid January 2002 and will last for 2 months. This is a very important step forward in the project and it is planned to run the first EXOGAM experiment with an ^{8}He beam from SPIRAL early April in its final configuration.

In addition to G1 and G2, the EXOGAM detectors are extensively used at the LISE focal plane (decay experiments), around the SPEG target position (in-beam spectroscopy) and also at the VAMOS focal plane for recoil decay tagging experiment. To safely used the detectors in these variuos configurations, a mechanical structure and an LN2 automatic filling system has been built and are available.

3. EXOGAM related R&D works

Finally, an R&D project, called PADT (PreAmplificateur pour Detecteur Tracking) has started at GANIL initiated by EXOGAM. This project consists of the design and development of high quality preamplifiers and associated mother boards for the EXOGAM Clovers. The goals are several folds and concern the necessity of a high quality maintenance, the cost effectiveness of it, the potentiality to improve the performances and the local knowledge.

GANIL is involved in a very ambitious european project called AGATA (Advanced Gamma-ray Tracking Array) aiming at the full reconstruction of a gamma-ray interaction in a Ge detector. This requires the control of several challenging techniques such as the analysis of the preamplifier pulse shapes and the localisation of the impact with a resolution better than a couple of millimeters, the reconstruction of Compton scattering events, the identification of each single gamma-ray track within a possibly large number of detected photons, etc. GANIL is involved in the detector electronics and it is planned to improve step-by-step the preamplifier and the associated mother board designed for EXOGAM in such a way that is can be used for tracking purposes. This require a lot of effort in particular in the performances (noise, timing), miniaturization (37 or 65 segments per detector) and consumption.

Today, a first design of preamplifier has been made and tested in a collaboration involving India and Romania in addition to GANIL manpower and in discussion with european laboratories like GSI and also with Berkeley. This preamplifier is under validation and will be installed on part of the EXOGAM Clovers. A second design is already under test which looks very promising.

PUBLICATION LIST

1998

Beta-decay of ligh nuclei close to the proton drip-line : ^{40}Ti and ^{35}Ca
LEWITOWICZ M., TRINDER W., BHATTACHARYA M., ADELBERGER E.G., ANGELIQUE J.C., ANNE R., AYSTO J., BORCEA C., DAUGAS J.M., DONZAUD C., GARCIA A., GREVY S., GYZYWACZ R., GUILLEMAUD-MUELLER D., JOKINEN A., KALOSKAMIS N.I., LEENHARD S., LOPEZ M.J., MUELLER A.C., DE OLIVEIRA F., OSTROWSKI A., POUGHEON F., SAINT-LAURENT M.G., SIISKONEN T., SORLIN O., SWANSON H.E.
GANIL - Caen, Notre Dame Univ. - Notre Dame, Washington Univ. - Seattle, LPC - Caen, Jyvaskyla Univ. - Jyvaskyla, IAP - Bucharest-Magurele, IPN - Orsay
Nuovo Cimento 111A, 6,7 (1998) 835.
SNEC 98
Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions.XVI
PADOVA (IT)
31 Mars 1998
98 152 A

β-decay of neutron rich isotopes of fluorine and neo
TARASOV O.B., ALLATT R., ANGELIQUE J.C., ANNE R., BORCEA C., DLOUHY Z., DONZAUD C., GREVY S., GUILLEMAUD-MUELLER D., IZOSIMOV I.N., LEWITOWICZ M., LUKYANOV S.M., NOWACKI F., MUELLER A.C., OGANESSIAN Yu.Ts., ORR N.A., OSTROWSKI A.N., PAGE R.D., PENIONZHKEVICH Yu.E., POUGHEON F., REED A., SAINT-LAURENT M.G., SCHWAB W., SIISKONEN T., SOKOL E.A., SORLIN O., SUHONEN J., TRINDER W., WINFIELD J.S.
FLNR JINR - Dubna, LPC - Caen, IAP - Bucharest, IPN - Orsay, Jyväskylä Univ. - Jyväskylä, Liverpool Univ. - Liverpool, GANIL - Caen, NPI - Rez, Radium Institute - St. Petersburg
Heavy Ion Physics
VI International School-Seminar. Heavy Ion Physics
DUBNA (RU)
22 Septembre 1997
98 144 A

Beta-delayed proton spectroscopy of ^{24}Si
CZAJKOWSKI S. , ANDRIAMONJE S., BLANK B., BOUE F., DEL MORAL R., DUFOUR J.P., FLEURY A., POURRE P., PRAVIKOFF M.S., HANELT E., SCHMIDT K.H., ORR N.A.
CENBG - GRADIGNAN, INST. FUR KERNPHYSIK - DARMSTADT, GSI - DARMSTADT, LPC ISMRA - CAEN
Nuclear Physics A628 (1998) 537.
98 05 A

Charge-exchange reaction induced by light neutron rich beams : the case of p(^{6}He, ^{6}Li) n
CORTINA-GIL M.D., PAKOU A., ALAMANOS N., MITTIG W., ROUSSEL-CHOMAZ P., AUGER F., BARRETTE J., BLUMENFELD Y., CASANDJIAN J.M., CHARTIER M., DIETRICH F., FEKOU-YOUMBI V., FERNANDEZ B., FRASCARIA N., GILLIBERT A., LAURENT H., LEPINE-SZILY A., ORR N., PASCALON V., SCARPACI J.A., SIDA B., SUOMIJARVI T.
GANIL - Caen, CEA Saclay - Gif-sur-Yvette, Mc Gill Univ. - Montreal, LLNL - Livermore, IPN - Orsay, IFUSP DFN - Sao Paulo, LPC ISMRA - Caen, Ioannina Univ. - Ioannina
Heavy Ion Physics
VI International School-Seminar. Heavy Ion Physics
DUBNA (RU)
22 Septembre 1997
98 142 A

Charge-exchange reaction with light neutron-rich beams
CORTINA-GIL M.D. et al., PAKOU A., ALAMANOS N., MITTIG W., ROUSSEL-CHOMAZ P., AUGER F., BARRETTE J., BLUMENFELD Y., CASANDJIAN J.M., CHARTIER M., DIETRICH F., FEKOU-YOUMBI V., FERNANDEZ B., FRASCARIA N., GILLIBERT A., LAURENT H., LEPINE-SZILY A., ORR N., PASCALON V., SCARPACI J.A., SIDA J.L., SUOMIJARVI T.
GANIL - Caen, CEA Saclay - Gif-sur-Yvette, FRL Mc Gill Univ. - Montreal, LLNL - Livermore, IPN - Orsay, IFUSP DFN - Sao Paulo, LPC ISMRA - Caen, Ioannina Univ. - Ioannina
Journal of Physics G24 (1998) 1547.
98 95 A

Competing T = 0 and T = 1 structures in the N = Z nucleus $^{62}_{31}Ga$
VINCENT S.M. , REGAN P.H., WARNER D.D., BARK R.A., BLUMENFELD D., CARPENTER M.P., DAVIDS C.N., GELLETLY W., JANSSENS R.V.F., O'LEARY C.D., LISTER C.J., SIMPSON J., SEWERYNIAK D., SAITOH T., SCHWARTZ J., TORMANEN S., JUILLET O., NOWACKI F., VAN ISACKER P.
Surrey Univ. - Guildford, CCLRC Daresbury Lab. - Warrington, Niels Bohr Inst. Tandem Acc. Lab. - Roskilde , ANL - Argonne, Staffordshire Univ. - Stoke-on-Trent, Yale Univ. - New Haven, Jyväskylä Univ. - Jyväskylä, GANIL - Caen, LPT - Strasbourg
Physics Letters B437 (1998) 264.
98 88 A

The equation of state for cold nuclear matter as seen in nucleus-nucleus scattering
NUOFFER F. , BARNITZKY G., CLEMENT H., BLAZEVIC A., BOHLEN H.G., GEBAUER B., VON OERTZEN W., WILPERT M., WILPERT T., LEPINE-SZILY A., MITTIG W., OSTROWSKI A.N., ROUSSEL-CHOMAZ P.
Tübingen Univ. - Tübingen, HMI - Berlin, GANIL - Caen
Il Nuovo Cimento 111A, 8-9 (1998) 971.
Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions
XVI Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Consitions
PADOVA (IT)
31 Mars 1998
98 138 A

Etats extrêmes des noyaux - Matière nucléaire très chaude en équilibre thermodynamique
Images de la Physique 1998
98 140 A

Finite temperature nuclear response in the extended random phase approximation
LACROIX D., CHOMAZ Ph., AYIK S.
GANIL - Caen, Tennessee Techn. Univ. - Cookeville
Physical Review C58, 4 (1998) 2154.
98 85 A

First observation of excited states in the neutron deficient nuclei ^{168}Pt and ^{170}Pt
KING S.L. , SIMPSON J., PAGE R.D., AMZAL N., BACK T., CEDERWALL B., COCKS J.F.C., CULLEN D.M., GREENLEES P.T., HARDER M.K., HELARIUTTA K., JONES P., JULIN R., JUUTINEN S., KANKAANPAA H., KEENAN A., KETTUNEN H., KUUSINIEMI P., LEINO M., LEMMON R., MUIKKU M., SAVELIUS A., UUSITALO J., VAN ISACKER P.
Oliver Lodge Lab. Univ. of Liverpool - Liverpool, CLRC Daresbury Lab. - Daresbury, Royal Inst. of Tech. - Stockholm, Jyväskylä Univ. - Jyväskylä, Brighton Univ. - Brighton, GANIL - Caen
Physics Letters B443 (1998) 82.
98 101 A

Mass measurement far from stability
MITTIG W. , LEPINE-SZILY A., ORR N.A.
GANIL - CAEN, INST. DE FISICA-SAO PAULO UNIV. - SAO PAULO, LPC ISMRA - CAEN
Annu. Rev. Nucl. Sci. 47 (1997) 27.
98 41 A

The masses of ^{70,71} Se
CHARTIER M. , MITTIG W., ORR N.A., ANGELIQUE J.C., AUDI G., CASANDJIAN J.M., CUNSOLO A., DONZAUD C., FOTI A., LEPINE-SZILY A., LEWITOWICZ M., LUKYANOV S., MAC CORMICK M., MORRISSEY D.J., OSTROWSKI A.N., SHERRILL B.M., STEPHAN C., SUOMIJARVI T., TASSAN-GOT L., VIEIRA D.J., VILLARI A.C.C., WOUTERS J.M.
GANIL - Caen, LPC ISMRA - Caen, CSNSM - Orsay, Dipart. di Fis. and INFN - Catania, IPN - Orsay, IFUSP - Sao Paulo, LNR JINR - Dubna, NSCL MSU - East Lansing, LANL - Los Alamos
Nuclear Physics A637 (1998) 3.
98 69 A

New Island of ms Isomers in Neutron-Rich Nuclei around the Z = 28 and N = 40 shell Closures
GRZYWACZ R. , BERAUD R., BORCEA C., EMSALLEM A., GLOGOWSKI M., GRAWE H., GUILLEMAUD-MUELLER D., HJORTH-JENSEN M., HOURY M., LEWITOWICZ M., MUELLER A.C., NOWAK A., PLOCHOCKI A., PFUTZNER M., RYKACZEWSKI K., SAINT-LAURENT M.G., SAUVESTRE J.E., SCHAEFER M., SORLIN O., SZERYPO J., TRINDER W., VITERITTI S., WINFIELD J.
IFD Warsaw Univ. - Warsaw, GANIL - Caen, Tennessee Univ. - Knoxville, IPNL - Villeurbanne, IAP - Bucharest-Magurele, GSI - Darmstadt, IPN - Orsay, NORDITA - Copenhagen, ORNL - Oak Ridge, IKS - Leuven, CE Bruyères-le-Châtel, Göttingen Univ. - Göttingen
Physical Review Letters 81, 4 (1998) 766.
98 77 A

Non-Linear vibrations in stable and exotic nuclei
CHOMAZ PH., VOLPE C., ANDRES M.V., CATARA F., LANZA E.G.
GANIL - CAEN, SEVILLA UNIV. - SEVILLA, CATANIA UNIV. AND INFN - CATANIA
Topics on the structure and interactions of nuclei far from the stability
INTERNATIONAL WORKSHOP ON PHYSICS OF UNSTABLE NUCLEAR BEAMS.1
SAO PAULO (BR)
*28 Août 1996*98 08 A

Le noyau dans tous ses états
Les défis du CEA 71 (1998) 6.
98 130 A

Nuclear structure studies of bound and unbound states in drip-line nuclei
BOHLEN H.G., VON OERTZEN W., KALPAKCHIEVA R., BLAZEVIC A., GEBAUER B., GRIMES S.M., LEPINE-SZILY A., MASSEY T.N., MITTIG W., OSTROWSKI A.N., OLIVEIRA J.M., ROUSSEL-CHOMAZ P., THUMMERER S., WILPERT M.
HMI - Berlin, FLNR JINR - Dubna, Ohio Univ. - Ohio, IFUSP - Sao Paulo, GANIL - Caen, Edinburgh Univ. - Edinburg
Nuovo Cimento 111A, 6,7 (1998) 841.
SNEC 98
Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions.XVI
PADOVA (IT)
31 Mars 1998
98 153 A

Observation of Fermi Superallowed β^+ Decays in Heavy Odd-Odd, N = Z Nuclei : Evidence for 0^+ Ground States in ^{78}Y, ^{82}Nb, and ^{86}Tc
LONGOUR C. , GARCES NARRO J., BLANK B., LEWITOWICZ M., MIEHE CH., REGAN P.H., APPLEBE D., AXELSSON L., BRUCE A.M., CATFORD W.N., CHANDLER C., CLARK R.M., CULLEN D.M., CZAJKOWSKI S., DAUGAS J.M., DESSAGNE PH., FLEURY A., FRANKLAND L., GELLETLY W., GIOVINAZZO J., GREENHALGH B., CRZYWACZ R., HARDER M., JONES K.L., KELSALL N., KSZCZOT T., PAGE R.D., PEARSON C.J., REED A.T., SORLIN O., WADSWORTH R.
IReS & Univ. Louis Pasteur - Strasbourg, Surrey Univ. - Guildford, CENBG - Gradignan, GANIL - Caen, Oliver Lodge Lab. - Liverpool, Chalmers Univ. of Tech. - Göteborg, Dept. of Mechanical Engineering - Brighton, NSD LBNL - Berkeley, York Univ. - York, IEP Warsaw Univ. - Warsaw, IPN - Orsay
Physical Review Letters 81, 16 (1998) 3337
98 84 A

Phase transition with an isospin dependent lattice gas mode
GULMINELLI F., CHOMAZ P.
LPC - CAEN, GANIL - CAEN
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.349
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS

BORMIO (IT)
26 Janvier 1998
98 49 A

Production of nuclei in ^{32,34,36}S-induced reactions in the energy range 6÷75 MeV/A
TARASOV O.B., PENIONZHKEVICH Yu.E., ANNE R., BAIBORODIN D.S., BORCEA C., DLOUHY Z., GUILLEMAUD-MUELLER D., FOMICHEV A.S., KALPAKCHIEVA R., LEWITOWICZ M., LUKYANOV S.M., MAIDIKOV V.Z., MUELLER A.C., OGANESSIAN Yu.Ts., SAINT-LAURENT M.G., SKOBELEV N.K., SORLIN O., TONEEV V.D., TRINDER W.
FLNR JINR - Dubna, IAP - Bucharest, IPN - Orsay, GANIL - Caen, NPI - Rez, BLTP JINR - Dubna
Heavy Ion Physics
VI International School-Seminar
DUBNA (RU)
22 Septembre 1997
98 146 A

Production of an isomeric beam and total reaction cross section measurement
Topics on the structure and interactions of nuclei far from the stability line
INTERNATIONAL WORKSHOP ON PHYSICS OF UNSTABLE NUCLEAR BEAMS.1
SAO PAULO (BR)
28 Août 1996
ETHVIGNOT T. , LESTRADE D., DELBOURGO-SALVADOR P., MEOT V., SAUVESTRE J.E., SZMIGIEL M., BONNEREAU B., LEFEVRE A., LEWOTOWICZ M., SAINT-LAURENT M.G., MUELLER A.C., SORLIN O., MARIE F.
CEA - BRUYERES LE CHATEL, GANIL - CAEN, IPN - ORSAY, CEA SACLAY - GIF SUR YVETTE
98 10 A

Quadrupole and Magnetic Moment Measurements on Spin-Aligned Projectile Fragments
NEYENS G., COULIER N., TEUGHELS S., TERNIER S., VYVEY K., COUSSEMENT R., BALABANSKI D.L., CASANDJIAN J.M., CHARTIER M., CORTINA-GIL M.D., LEWITOWICZ M., MITTIG W., OSTROWSKI A.N., ROUSSEL-CHOMAZ P., ALAMANOS N., LEPINE-SZILY A., ROGERS W.
Inst. voor Kern- en Stralingsfysica - Leuven, GANIL - Caen, DAPNIA CE Saclay - Gif sur Yvette, Sao Paulo Univ. - Sao Paulo, Westmont College - Santa Barbara
APH N.S., Heavy Ion Physics 7 (1998) 101.
98 108 A

The quadrupole moment of ^{18}N, measured with the Level Mixing Resonance (LMR) method
COULIER N., NEYENS G., TEUGHELS S., GEORGIEV G., TERNIER S., VYVEY K., GOUSSEMENT R., BALABANSKI D.L., CORTINA-GIL D., LEWITOWICZ M., MITTIG W., DE OLIVEIRA SANTOS F., ROUSSEL-CHOMAZ P., ROGERS W., LEPINE-SZILY A.
Leuven Univ. - Leuven, GANIL - Caen, Westmont College - Santa Barbara, Sao Paulo Univ. - Sao Paulo
Nuovo Cimento 111A, 6,7 (1998) 727.
SNEC 98
Nuclear Divisional Conference Structure of Nuclei Under Extreme Conditions.XVI
PADOVA (IT)
31 Mars 1998
98 150 A

Refractive scattering and Reactions in the ^{16}O + ^{16}O system
von OERTZEN W., PERSHIN R., BOHLEN H.G., BLAZEVIC A., WILPERT M., BARTNITZKY G., CLEMENT H., SIEGLER J., ROUSSEL-CHOMAZ P., MITTIG W., OSTROWSKI A., GILLIBERT A., CASANDJIAN J.M.
HMI - Berlin, St. Petersburg Univ. - St. Petersburg, Tübingen Univ. - Tübingen, GANIL - Caen
Heavy Ion Physics
VI International School-Seminar. Heavy Ion Physics
DUBNA (RU)
*22 Septembre 1997*98 145 A

Refractive Scattering and Reactions and the EOS of Nuclear Matter : the $^{16}O+^{16}O$ System
VON OERTZEN W. , PERSHIN R., BOHLEN H.G., BLASEVIC A., WILPERT M., BARTNITZKY G., CLEMENT H., SIEGLER J., ROUSSEL-CHOMAZ P., MITTIG W., OSTROWSKI A., GILLIBERT A., CASANDJIAN J.M.
HAHN-MEITNER-INSTITUT - BERLIN, INSTITUTE OF PHYSICS - ST PETERSBURG, PHYSIKALISHES INSTITUT DER UNIVERSITAT - TUBINGEN, GANIL - CAEN
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.522
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 55 A

Spectroscopy of the unbound nucleus ^{11}N by the $^{12}C(^{14}N,^{15}C)^{11}N$ transfer reaction
LEPINE-SZILY A. , OLIVEIRA J.M., OSTROWSKI A.N., BOHLEN H.G., LICHTENTHALER R., BLAZEVIC A., BORCEA C., GUIMARAES V., KALPAKCHIEVA R., LAPOUX V., MAC CORMICK M., OLIVEIRA F., VON OERTZEN W., ORR N.A., ROUSSEL-CHOMAZ P., STOLLA TH., WINFIELD J.S.
IFUSP - SAO PAULO, SOROCABA UNIV. SOROCABA, EDINBURGH UNIV. - EDINBURGH, HMI - BERLIN, IAP - BUCAREST, UNIP - SAO PAULO, FLNR JINR - DUBNA, CEN SACLAY - GIF SUR YVETTE, GANIL - CAEN, LPC ISMRA - CAEN
Physical Review Letters 80 (1998) 1601.
98 21 A

Study of the very neutron-rich nuclei around N=20 with a ^{36}S beam
PENIONZHKEVICH Yu.E., ALLAT R., ANGELIQUE J.C., ANNE R., BORCEA C., DLOUHY Z., DONZAUD C., GREVY S., GUILLEMAUD-MUELLER D., LEWITOWICZ M., KUKYANOV S.M., MUELLER A.C., NOWACKI F., OGANESSIAN Yu.Ts., ORR N.A., OSTROWSKI A.N., PAGE R.D., POUGHEON F., REED A., SAINT-LAURENT M.G., SCHWAB W., SOKOL E.A., SORLIN O., TARASOV O.B., TRINDER W., WINFIELD J.S.
FLNR JINR - Dubna, Liverpool Univ. - Liverpool, LPC - Caen, GANIL - Caen, IAP - Bucharest-Magurele, NPI - Rez, IPN - Orsay
Heavy Ion Physics
VI International School-Seminar. Heavy Ion Physics
DUBNA (RU)
22 Septembre 1997
98 143 A

Superdeformation in $^{147,148}Eu$: Identical bands and $\pi6^1$- $\pi6^3$ crossings
HASLIP D.S. , KINTZ N., FLIBOTTE S., AUSTIN R.A.E., de FRANCE G., DEVLIN M., FINCK CH., GALINDO-URIBARRI A., GERVAIS G., LAFOSSE D.R., LAMPMAN T.J., LEE I.Y., LERMA F., MACCHIAVELLI A.O., MAcLEOD R.W., MULLINS S.M., NIEMINEN J.M., RODINGER T., SARANTITES D.G., STEZOWSKI O., SVENSSON C.E., VIVIEN J.P., WADDINGTON J.C., WARD D., WILSON J.N.
McMASTER UNIV. - HAMILTON, IRS - STRASBOURG, GANIL - CAEN, WASHINGTON UNIV. - SAINT LOUIS, ORNL - OAK RIDGE, LBL - BERKELEY, DEPT. NUCL. PHYS. - CANBERRA
Physical Review C57, 5 (1998) 2196.
98 34 A

A symmetry based mass formula for Λ hypernuclei
LEVAI G., CSEH J., VAN ISACKER P., JUILLET O.
INR Hungarian Acad. Sci. - Debrecen, GANIL - Caen
Nuclear Physics A639 (1998) 161c.
Nuclear and Hadronic Physics
International Conference on Hypernuclear and Strange Particle Physics
BROOKHAVEN NATIONAL LABORATORY
13 Octobre 1997
98 82 A

Systematic survey of ΔI =4 bifurcation in A ~150 superdeformed nuclei

HASLIP D.S. , FLIBOTTE S., AUSTIN R.A.E., de FRANCE G., DEVLIN M., FINCK CH., GALINDO-URIBARRI A., GERVAIS G., KINTZ N., LAFOSSE D.R., LAMPMANN T.J., LERMA F., MULLINS S.M., NIEMINEN J.M., RODINGER T., SARANTITES D.G., STEZOWSKI O., SVENSSON C.E., VIVIEN J.P., WADDINGTON J.C., WILSON J.N.
MacMaster Univ. - Hamilton, GANIL - Caen, Washington Univ. - Saint Louis, IRS - Strasbourg, ORNL - Oak Ridge, Dept. Nucl. Phys. ANU - Canberra
Physical Review C58, 5 (1998) R2649.
98 103 A

The caloric curve of Nuclei
PETER J.
LPC ISMRA - Caen
Il Nuovo Cimento 111A, 8-9 (1998) 977.
Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions
XVI Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions
PADOVA (IT)
31 Mars 1998
98 137 B

Charge-exchange reaction induced by ^{6}He and nuclear densities
CORTINA-GIL M.D. , PAKOU A., ALAMANOS N., MITTIG W., ROUSSEL-CHOMAZ P., AUGER F., BARRETTE J., BLUMENFELD Y., CASANDJIAN J.M., CHARTIER M., DIETRICH F., FEKOU-YOUMBI V., FERNANDEZ B., FRASCARIA N., GILLIBERT A., LAURENT H., LEPINE-SZILY A., ORR N., PASCALON V., SCARPACI J.A., SIDA J.L., SUOMIJARVI T.
GANIL - Caen, CEA Saclay - Gif-sur-Yvette, Mc Gill Univ. - Montreal, LLNL - Livermore, IPN - Orsay, IFUSP DFN - Sao Paulo, LPC ISMRA - Caen, Ioannina Univ. - Ioannina
Nuclear Physics A641 (1998) 263.
98 90 B

Compound nuclear lifetimes at high excitation energies via a new statistical fluctuation method
CASANDJIAN J.M. , MITTIG W., PAKOU A., ALAMANOS N., AUGER G., AUGER F., CHARTIER M., CORTINA-GIL D., FEKOU-YOUMBI V., FERNANDEZ B., GILLIBERT A., LEPINE A., MAcCORMICK M., OSTROWSKI A., ROUSSEL-CHOMAZ P., SIDA J.L.
GANIL - Caen, DAPNIA CEA Saclay - Gif sur Yvette, Ioannina Univ. - Ioannina, IFUSP DFN - Sao Paulo
Physics Letters B430 (1998) 43.
98 63 B

Dynamical effects in peripheral and semi-central collisions at intermediate energy
TIREL O. , AUGER G., ASSENARD M., BACRI CH.O., BOCAGE F., BOUGAULT R., BROU R., BUCHET PH., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., EUDES P., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GOURIO D., GUINET D., GULMINELLI F., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LE FEVRE A., LEFORT T., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., POLITI G., RAHMANI A., REPOSEUR T., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., VIENT E., VOLANT C., WIELECZKO J.P.
GANIL - CAEN, LPC - CAEN, SUBATECH - NANTES, DAPNIA - SACLAY, IPN - ORSAY, IPN - LYON, NUCLEAR INSTITUTE FOR PHYSICS AND NUCLEAR ENGINEERING - BUCAREST, UNIV. DI NAPOLI
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.289
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 47 B

λ-ray production by inelastic proton scattering on ^{16}O and ^{12}C

KIENER J., BERHEIDE M., ACHOURI N.L., BOUGHRARA A., COC A., LEFEBVRE A., DE OLIVEIRA SANTOS F., VIEU CH.
CSNSM - Orsay, LPC ISMRA - Caen, USTHB - Algiers, GANIL - Caen
Physical Review C58, 4 (1998) 2174.
98 86 B

Heavy fragment production in ^{40}Ar + ^{232}Th reactions at 27A, 44A, and 77A MeV
BERTHOUMIEUX E. , POLLACCO E.C., VOLANT C., BERTHIER B., CASSAGNOU Y., CHARVET J.L., COLONNA M., DAYRAS R., LEGRAIN R., MAZUR C., DE FILIPPO E., CUNSOLO A., FOTI A., LANZANO G., PAGANO A., URSO S., CAVALLARO SL., BARTH R., LIPS V., OESCHLER H., HARAR S., NORBECK E.
CEA SACLAY - GIF SUR YVETTE, INFN - CATANIA, INFN LNS - CATANIA, INST. FUR KERNPHYSIK - DARMSTADT, GANIL - CAEN, IOWA UNIV. - IOWA
Physical Review C57, 4 (1998) 1788.
98 24 B

IMF-IMF azimuthal correlations as a tool to probe reaction dynamics in ^{36}Ar + ^{48}Ti at 45 A MeV
SNELLINGS R.J.M. , VAN DEN BRINK A., DE HAAS A.P., HABETS J.J.L.M., HULSBERGEN W., KAMERMANS R., KUIJER P.G., DE LAAT C.T.A.M., OSTENDORF R.W., PEGHAIRE A., PRENDERGAST E.P.
NIKHEF - UTRECHT, KVI - GRONONGEN, GANIL - CAEN
Physics Letters B426 (1998) 263.
98 42 B

Independence of fragment charge distributions of the size of heavy multifragmenting sources
RIVET M.F. , BACRI CH.O., BORDERIE B., FRANKLAND J.D., ASSENARD M., AUGER G., BOCAGE F., BOUGAULT R., BROU R., BUCHET PH., CHBIHI A., COLIN J., DAYRAS R., DEMEYER A., DORE D., DURAND D., EUDES P., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LE FEVRE A., LEFORT T., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RAHMANI A., REPOSEUR T., ROSATO E., SAINT-LAURENT F., SALOU S., SQUALLI M., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VINTACHE D., VOLANT C., WIELECZKO J.P., GUARNERA A., COLONNA M., CHOMAZ PH.
IPN - Orsay, SUBATECH - Nantes, GANIL - Caen, LPC ISMRA - Caen, DAPNIA CE Saclay - Gif sur Yvette, IPN - Villeurbanne, NIPNE - Bucharest-Magurele, DSF Univ. Federico II - Napoli
Physics Letters B430 (1998) 217.
98 61 B

Is reducibility in nuclear multifragmentation related to thermal scaling ?
WIELOCH A. , PLAGNOL E., CUSSOL D., PETER J., ASSENARD M., AUGER G., BACRI CH.O., BOCAGE F., BORDERIE B., BOUGAULT R., BROU R., BUCHET PH., CHARVET J.L., CHBIHI A., COLIN J., DAYRAS R., DEMEYER A., DORE D., DURAND D., EUDES P., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GOURIO D., GUINET D., GULMINELLI F., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LE FEVRE A., LEFORT T., LEGRAIN R., LOPEZ O., LOUVEL M., NALPAS L., NGUYEN A.D., PARLOG M., POLITI G., RAHMANI A., REPOSEUR T., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P.
LPC - Caen, CE Saclay - Gif-sur-Yvette, GANIL - Caen, IPN - Orsay, IPNL - Villeurbanne, SUBATECH - Nantes, DSF Napoli Univ. - Napoli, NIPNE - Bucharest
Physics Letters B432 (1998) 29.
98 73 B

Microscopic description of Coulomb and nuclear excitation of multiphonon states in heavy ion collisions
LANZA E.G., ANDRES M.V., CATARA F., CHOMAZ PH., VOLPE C.
Dipart. di Fis. Univ. di Catania and INFN - Catania, Dept. Fis. At. Mol. y Nucl. Sevilla Univ. - Sevilla, GANIL - Caen, IPN - Orsay

Nuclear Physics A636 (1998) 452.
98 62 B

A new phenomenon in heavy ion inelastic scattering : the towing mode
SCARPACI J.A. , BEAUMEL D., BLUMENFELD Y., CHOMAZ PH., FRASCARIA N., JONGMAN J., LACROIX D., LAURENT H., LHENRY I., MARECHAL F., PASCALON-ROZIER V., ROUSSEL-CHOMAZ P., ROYNETTE J.C., SUOMIJARVI T., VAN DER WOUDE A.
IPN - Orsay, GANIL - Caen, KVI - Groningen
Physics Letters B428 (1998) 241.
98 59 B

Nuclear spin alignment and quadrupole moment of light projectile fragments studied with the level mixing resonance (LMR) method
NEYENS G. , COULIER N., TERNIER S., VYVEY K., COUSSEMENT R., BALABANSKI D., CASSANDJIAN J.M., CHARTIER M., CORTINA-GIL M.D., LEWITOWICZ M., MITTIG W., OSTROWSKI A.N., ROUSSEL-CHOMAZ P., ALAMANOS N., LEPINE-SZILY A.
KATHOLIEKE UNIVERSITEIT - LEUVEN, GANIL - CAEN, CEN SACLAY - GIF SUR YVETTE, SAO PAULO UNIVERSITY - SAO PAULO
Topics on the structure and interactions of nuclei far from the stability line
INTERNATIONAL WORKSHOP ON PHYSICS OF UNSTABLE NUCLEAR BEAMS.1
SAO PAULO (BR)
28 Août 1996
98 11 B ·

Observation of the Mott effect in heavy ion collisions
BOZEK P. , DANIELEWICZ P., GUDIMA K., PLOSZAJCZAK M.
YITP KYOTO UNIV. - KYOTO, INP - KRAKOW, NSCL MSU - EAST LANSING , GANIL - CAEN, IAP MOLDOVA ACAD. OF SCI. - KISHINEU
Physics Letters B421 (1998) 31.
98 25 B

Response functions of the 4π detector ORION to 10-70 MeV Neutrons
PERIER Y. , LOTT B., EL MASRI Y., GALIN J., KEUTGEN TH., LE FAOU J.H., MORJEAN M., PEGHAIRE A., QUEDNAU B.M., TILQUIN I.
GANIL - Caen, IPN FNRS Univ. Catholique de Louvain - Louvain-la-Neuve
NIM A413 (1998) 312.
98 93 B

Study of short-lived isomers produced in the fragmentation-like reactions
LEWITOWICZ M., GRZYWACZ R., RYKACZEWSKI K., PFUTZNER M.
GANIL - Caen, IEP - Warsaw, ORNL - Oak Ridge, GSI - Darmstadt
Heavy Ion Physics
VI International School-Seminar
DUBNA (RU)
22 Septembre 1997
98 147 B

Study of subshell closure at N = 40 by Coulomb excitation
LEEHHARDT S., AZAIEZ F., SORLIN O., BELLEGUIC M., ANGELIQUE J.C., BORCEA C., BOURGEOIS C., DAUGAS J.M., DELONCLE I., DONZAUD C., DUPRAT J., GILLIBERT A., GREVY S., GUILLEMAUD-MUELLER A.C., KIENER J., LEWITOWICZ M., MARIE F., MUELLER A.C., DE OLIVEIRA F., ORR N., PENIONZHKEVICH YU.E., PORQUET M.G., POUGHEON F., SAINT-LAURENT M.G., SOBOLEV YU., WINFIELD J.
IPN - Orsay, CSNSM - Orsay, GANIL - Caen, LPC - Caen, CE Saclay - Gif-sur-Yvette, IAP - Bucharest, FLNR - JINR - Dubna
Nuovo Cimento 111A, 6,7 (1998) 733.
SNEC 98
Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions.XVI

PADOVA (IT)
*31 Mars 1998*98 151 B

Coulomb Excitation of Radioactive Beams at GANIL
AZAIEZ F., SORLIN O.
IPN - Orsay
Nuclear Physics News 8, 3 (1998) 4.
98 89 C

Exotic beams produced by fast neutrons
CLAPIER F. , MUELLER A.C., OBERT J., BAJEAT O., DUCOURTIEUX M., FERRO A., HORBOWA A., KOTFILA L., LAU C., LEFORT H., KANDRI-RODY S., PAUWELS N., POTIER J.C., PROUST J., PUTAUX J.C., LIANG C.F., PARIS P., VILLARI A.C.C., LICHTENTHALER R., MAUNOURY L., LETTRY J.
IPN - Orsay, CSNSM - Orsay, GANIL - Caen, CERN - Geneve
Physical Review Special Topics - Acelerators and Beams 1 (1998) 13501-1
98 107 C

Exploratory coupled channels calculations for loosely bound carbon isotopes
RIDIKAS D., SMEDBERG M.H., VAAGEN J.S., ZHUKOV M.V.
GANIL - CAEN, CHALMERS UNIV. OF TECHN. GOTEBORG UNIV. - GOTEBORG, BERGEN UNIV. - BERGEN, NORDITA - COPENHAGEN
Nuclear Physics A628 (1998) 363.
98 06 C

First beta-dacay studies of the neutron-rich isotopes $^{53-55}$Sc and $^{56-59}$V
SORLIN O. , BORREL V., GREVY S., GUILLEMAUD-MUELLER D., MUELLER A.C., POUGHEON F., BOHMER W., KRATZ K.L., MEHREN T., MOLLER P., PFEIFFER B., RAUSCHER T., SAINT-LAURENT M.G., ANNE R., LEWITOWICZ M., OSTROWSKI A., DORFLER T., SCHMIDT-OTT W.D.
IPN - ORSAY, MAINZ UNIV. - MAINZ, GANIL - CAEN, GOTTINGEN UNIV. - GOTTINGEN
Nuclear Physics A632 (1998) 205.
98 32 C

Inelastic Proton Scattering of Unstable Nuclei
MARECHAL F. , AZHARI A., BAZIN D., BLUMENFELD Y., BROWN J.A., COTTLE P.D., FAUERBACH M., GLASMACHER T., HIRZEBRUCH S., JEWELL J.K., KELLEY J.H., KEMPER K.W., MANTICA P.F., MORISSEY D.J., OTTINI S., RILEY L.A., SCARPACI J.A., STEINER M., SUOMIJARVI T.
IPN - ORSAY, NSCL MSU - EAST LANSING, FSU - TALLAHASSEE, CE SACLAY - GIF SUR YVETTE
Tours Symposium on Nuclear Physics.3
AIP CONFERENCE PROCEEDINGS.425
TOURS SYMPOSIUM ON NUCLEAR PHYSICS.3
TOURS (FR)
2 Septembre 1997
98 31 C

Isomeric states in ^{66}As
GRZYWACZ R. , ANDRIAMONJE S., BLANK B., BOUE F., CZAJKOWSKI S., DAVI F., DEL MORAL R., DONZAUD C., DUFOUR J.P., FLEURY A., GRAWE H., GREWE A., HEINZ A., JANAS Z., JUNGHANS A.R., KARNY M., LEWITOWICZ M., MUSQUERE A., FLUTZNER M., PORQUET M.G., PRAVIKOFF M.S., SAUVESTRE J.E., SUMMERER K.
IFD Warsaw Univ. - Warsaw, Tennessee Univ. - Knoxville, CENBG - Gradignan, IPN - Orsay, GSI - Darmstadt, Inst. für Kernphysik TU Darmstadt - Darmstadt, GANIL - Caen, CSNSM - Orsay, CE Bruyères-le-Châtel - Bruyères-le-Châtel
Physics Letters B429 (1998) 247.
98 67 C

Mass measurement of the doubly-magic nucleus ^{100}Sn

CHARTIER M. , AUGER G., MITTIG W., LEPINE-SZILY A., FIFIELD L.K., CASANDJIAN J.M., CHABERT M., FERME J., GILLIBERT A., LEWITOWICZ M., MAC CORMICK M., MOSCATELLO M.H., ODLAND O.H., ORR N.A., POLITI G., SPITAELS C., VILLARI A.C.C.
GANIL - CAEN, IFUSP - SAO PAULO, AUSTRALIAN NATIONAL UNIV. - CANBERRA, CEN SACLAY - GIF SUR YVETTE, BERGEN UNIV. - BERGEN, LPC ISMRA - CAEN, CATANIA UNIV. - CATANIA
Topics on the structure and interactions of nuclei far from the stability line
INTERNATIONAL WORKSHOP ON PHYSICS OF UNSTABLE NUCLEAR BEAMS.1
SAO PAULO (BR)
28 Août 1996
98 12 C

Mass and Nuclear Moment Measurement with High and Low Energy RIB's
MITTIG W.
GANIL - CAEN
Tours Symposium on Nuclear Physics.3
AIP CONFERENCE PROCEEDINGS.425
TOURS SYMPOSIUM ON NUCLEAR PHYSICS.3
TOURS (FR)
2 Septembre 1997
98 29 C

New isotopes and isomers produced by the fragmentation of ^{238}U at 1000 MeV/nucleon
PLÜTZNER M. , ARMBRUSTER P., BAUMANN T., BENLLIURE J., BERNAS M., CATFORD W.N., CORTINA-GIL D., DAUGAS J.M., GEISSEL H., GORSKA M., GRAWE H., GRZYWACZ R., HELLSTROM M., IWASA N., JANAS Z., JUNGHANS A.R., KARNY M., LEENHARDT S., LEWITOWICZ M., MUELLER A.C., de OLIVEIRA F., REGAN P.H., REJMUND M., RYKACZEWSKI K., SUMMERER K.
IEP Warsaw Univ. - Warszawa, GSI - Darmstadt, IPN - Orsay, Surrey Univ. - Guildford, GANIL - Caen, ORNL - Oak Ridge
Physics Letters B444 (1998) 32.
98 100 C

New μs-isomers and isomeric beams
RYKACZEWSKI K. , GRZYWACZ R., LEWITOWICZ M., PFUTZNER M.
ORNL - OAK RIDGE, WARSAW UNIV. - WARSAW, GANIL - CAEN, GSI - DARMSTADT
Nuclear Physics A630 (1998) 307c.
INTERNATIONAL CONFERENCE ON NUCLEUS-NUCLEUS COLLISIONS.6
GATLINBURG (USA)
2 Juin 1997
98 04 C

Production of multicharged radioactive ion beams : New results for the 1 + Æ n+ method with the MINIMAFIOS and SARA-CAPRICE electron cyclotron resonance ion sources
LAMY T. , BRUANDET J.F., CHAUVIN N., CURDY J.C., FRUNEAU M., GELLER R., GIMOND G., SOLE P., VIEUX-ROCHAS J.L., GAUBERT G., MAUNOURY L., SORTAIS P., VILLARI A.C.C.
ISN - Grenoble, GANIL - Caen
Review of Scientific Instruments 69, 3 (1998) 1322.
98 111 C

Production of an isomeric beam and total reaction cross section measurement
ETHVIGNOT T. , LESTRADE D., DELBOURGO-SALVADOR P., MEOT V., SAUVESTRE J.E., SZMIGIEL M., BONNEREAU B., LEFEVRE A., LEWITOWICZ M., SAINT-LAURENT M.G., MUELLER A.C., SORLIN O., MARIE F.
CEA - BRUYERES-LE-CHATEL, GANIL - CAEN, IPN - ORSAY, CEA SACLAY - GIF SUR YVETTE
Research with Fission Fragments
INTERNATIONAL WORKSHOP ON RESEARCH WITH FISSION FRAGMENTS
28 Octobre 1996
98 27 C

The September 1997 status of SPIRAL project and future developments
ALAMANOS N.
CEA SACLAY - GIF SUR YVETTE
Tours Symposium on Nuclear Physics.3
AIP CONFERENCE PROCEEDINGS.425
TOURS SYMPOSIUM ON NUCLEAR PHYSICS.3
TOURS (FR)
2 Septembre 1997
98 30 C

Chemical and kinematical properties of mid-rapidity emissions in Ar + Ni collisions from 52 to 95 A.MeV
LEFORT T. , CUSSOL D., PETER J., ASSENARD M., AUGER G., BACRI CH.O., BOCAGE F., BOUGAULT R., BROU R., BUCHET PH., CHARVET J.L., CHBIHI A., COLIN J., DAYRAS R., DEMEYER A., DORE D., DURAND D., EUDES P., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GOURIO D., GUINET D., GULMINELLI F., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LE FEVRE A., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PLAGNOL E., POLITI G., RAHMANI A., REPOSEUR T., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P., WIELOCH A.
LPC - CAEN, SUBATECH - NANTES, GANIL - CAEN, IPN - ORSAY, DAPNIA - SACLAY, IPN - VILLEURBANNE, N.I.P.N.E. - BUCHAREST, UNIV. DI MILANO
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.395
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 51 D

Comparison between data measured by INDRA and the prediction of the NBV transport model for $^{36}Ar+^{58}Ni$ reaction at 95 A. MeV
GALICHET E. , GULMINELLI F., GUINET D.C.R., ASSENARD M., AUGER G., BACRI CH.O., BOCAGE F., BORDERIE B., BOUGAULT R., BROU R., BUCHET P., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., EUDES P., FRANKLAND J.D., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GOURIO D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LE FEVRE A., LEFORT T., LEGRAIN R., LeNEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., POLITI G., RAHMANI A., REPOSEUR T., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P.
IPN - ORSAY, LPC - CAEN, GANIL - CAEN, IPN - LYON, DAPNIA - SACLAY, SUBATECH - NANTES, N.I.P.N.E. - BUCHAREST, INFN - NAPOLI, INFN - CATANIA
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.410
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 52 D

A direct determination of fission lifetimes as a function of excitation energy by the blocking technique
MORJEAN M., CHEVALLIER M., COHEN C., DAUVERGNE D., DURAL J., GALIN J., GOLDENBAUM F., JACQUET D., KIRSCH R., LIENARD E., LOTT B., PEGHAIRE A., PERIER Y., POIZAT J.C., PREVOT G., REMILLIEUX J., SCHMAUS D., TOULEMONDE M.
GANIL - Caen, IPNL - Villeurbanne, GPS - Paris, IPN - Orsay, CIRIL - Caen
Heavy Ion Physics
VI international School-Seminar
DUBNA (RU)
22 Septembre 1997

98 148 D

Direct fission lifetime measurements as a function of temperature and fission charge asymmetry
GOLDENBAUM F. , CHEVALLIER M., COHEN C., DAUVERGNE D., DURAL J., GALIN J., JACQUET D., KIRSCH R., LIENARD E., LOTT B., MORJEAN M., PEGHAIRE A., PERIER Y., POIZAT J.C., PREVOT G., REMILLIEUX J., SCHMAUS D., TOULEMONDE M.
GANIL - CAEN, IPN - LYON, GPS - PARIS, IPN - ORSAY, CIRIL - CAEN
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.265
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 46 D

Diversity of fragment sizes in multifragmentation of gold nuclei induced by relativistic ^{3}He ions
BRZYCHCZYK J. , POLLACCO E.C., VOLANT C., LACROIX D., LEGRAIN R., KWIATKOWSKI K., BRACKEN D.S., MORLEY K.B., RENSHAW F.E., VIOLA V.E., YODER N.R., CUGNON J., KORTELING R.G., BREUER H.
CE Saclay - Gif-sur-Yvette, GANIL - Caen, Indiana Univ. Cyclotron Facility - Bloomington, Liège Univ. - Liège, Simon Fraser Univ. - Burnaby, Maryland Univ. - College Park
Physical Review C58, 3 (1998) R1372.
98 80 D

Dynamics of binary dissipative collisions at GANIL energies
HANAPPE F.
PNTPM ULB - Bruxelles
Il Nuovo Cimento 111A, 8-9 (1998) 853.
Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions
XVI Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions
PADOVA (IT)
31 Mars 1998
98 139 D

Evolution of fission lifetime with temperature : a straightforward measurement by the blocking technique
MORJEAN M. , CHEVALLIER M., COHEN C., DAUVERGNE D., DURAL J., GALIN J., GOLDENBAUM F., JACQUET D., KIRSCH R., LIENARD E., LOTT B., PEGHAIRE A., PERIER Y., POIZAT J.C., PREVOT G., REMILLIEUX J., SCHMAUS D., TOULEMONDE M.
GANIL - CAEN, IPNL - VILLEURBANNE, GPS - PARIS, IPN - ORSAY, CIRIL - CAEN
Tours Symposium on Nuclear Physics.3
AIP CONFERENCE PROCEEDINGS 425 (1998) 134.
TOURS SYMPOSIUM ON NUCLEAR PHYSICS.3
TOURS (FR)
2 Septembre 1997
98 28 D

Fission lifetime measured by the blocking technique as a function of excitation energy in the 24 A MeV ^{238}U+^{28}Si reaction
MORJEAN M. , CHEVALLIER M., COHEN C., DAUVERGNE D., DURAL J., GALIN J., GOLDENBAUM F., JACQUET D., KIRSCH R., LIENARD E., LOTT B., PEGHAIRE A., PERIER Y., POIZAT J.C., PREVOT G., REMILIEUX J., SCHMAUS D., TOULEMONDE M.
GANIL - CAEN, IPNL - VILLEURBANNE, GPS - PARIS, IPN - ORSAY, CIRIL - CAEN
Nuclear Physics A630 (1998) 200c.
International Conference on Nucleus-Nucleus Collisions.6
GATLINBURG (USA)
2 Juin 1997

98 02 D

Formation and decay of hot nuclei in 475 MeV, 2 GeV proton- and 2 GeV ^{3}He-induced reactions on Ag, Bi, Au, and U

LEDOUX X. , BOHLEN H.G., CUGNON J., FUCHS H., GALIN J., GATTY B., GEBAUER B., GUERREAU D., HILSCHER D., JACQUET D., JAHNKE U., JOSSET M., LERAY S., LOTT B., MORJEAN M., QUEDNAU B.M., ROSCHERT G., ROSSNER H., PEGHAIRE A., PIENKOWSKI L., SIEMSSEN R.H., STEPHAN C.
GANIL - CAEN, HMI - BERLIN, LIEGE UNIV. - LIEGE, IPN - ORSAY, LNS - GIF-SUR-YVETTE, HEAVY ION LAB. WARSAW UNIV. - WARSAW, KVI - GRONINGEN
Physical Review C57, 5 (1998) 2375.
98 33 D

Hard photons and energetic protons as probes of the nuclear dynamics at intermediate energy

SAPIENZA P. , CONIGLIONE R., MIGNECO E., AGODI C., ALBA R., BELLIA G., COLONNA M., DEL ZOPPO A., FINOCCHIARO P., LOUKACHINE K., MAIOLINO C., PIATELLI P., SANTONOCITO D., VENTURA P.G., COLONNA N., BRUNO M., D'AGOSTINO M., MASTINU P.F., FIANDRI M.L., GRAMEGNA F., IORI I., FABBIETTI L., MORONI A., MARGAGLIOTTI G.V., MILAZZO P.M., RUI R., VANNINI G., BLUMENFELD Y., SUOMIJARVI T., FRASCARIA N., ROYNETTE J.C., SCARPACI J.A., ALAMANOS N., AUGER F., GILLIBERT A., CHOMAZ P., PEGHAIRE A.
INFN LNS - Catania, INFN - Bari, INFN and Dipart. di Fis. - Bologna, INFN and Lab. Naz. di Legnaro - Padova, INFN and Dipart. di Fis. - Milano, INFN and Dipart. di Fis. - Trieste, IPN - Orsay, DAPNIA CEN Saclay - Gif sur Yvette, GANIL - Caen
Il Nuovo Cimento 111A, 8-9 (1998) 999.
Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions
XVI Nuclear Physics Divisional Conference Structure of Nuclei Under Extreme Conditions
PADOVA (IT)
31 Mars 1998
98 136 D

Hard photon and energetic proton emission in heavy ion collisions at intermediate energy

SAPIENZA P. , CONIGLIONE R., MIGNECO E., AGODI C., ALBA R., BELLIA G., DEL ZOPPO A., FINOCCHIARO P., LOUKACHINE K., MAIOLINO C., PIATELLI P., SANTONOCITO D., BLUMENFELD Y., LE FAOU J.H., SUOMIJARVI T., FRASCARIA N., ROYNETTE J.C., SCARPACI J.A., GARRON J.P., GILLIBERT A., ALAMANOS N., AUGER F., PEGHAIRE A., CHOMAZ PH.
INFN LNS - CATANIA, IPN - ORSAY, DAPNIA CEA SACLAY - GIF SUR YVETTE, GANIL - CAEN
Nuclear Physics A630 (1998) 215c.
International Conference on Nucleus-Nucleus Collisions.6.
GATLINBURG (USA)
2 Juin 1997
98 03 D

Impact parameter dependence of linear momentum transfer and the role of two-body dissipation mechanisms in heavy ion collisions around the Fermi energy

PIATELLI P. , SANTONOCITO D., BLUMENFELD Y., SUOMIJARVI T., AGODI C., ALAMANOS N., ALBA R., AUGER F., BELLIA G., CHOMAZ PH., COLONNA M., CONIGLIONE R., DEL ZOPPO A., FINOCCHIARO P., FRASCARIA N., GILLIBERT A., LE FAOU J.H., LOUKACHINE K., MAIOLINO C., MIGNECO E., ROYNETTE J.C., SAPIENZA P., SCARPACI J.A.
INFN LNS - Catania, IPN - Orsay, DAPNIA CE Saclay - Gif sur Yvette, GANIL - Caen
Physics Letters B442 (1998) 48.
98 97 D

Interplay between the neutron halo structure of the projectile and the reaction mechanisms at intermediate bombarding energies

LOTT B., PERIER Y., GALIN J., LIENARD E., MORJEAN M., PEGHAIRE A., QUEDNAU B.M., VILLARI A.C.C., ORR N.A.
GANIL -CAEN, LPC - CAEN

International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.537
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 56 D

Mechanism of multi-nucleon transfer reactions
BOHLEN H.G., von OERTZEN W., BLAZEVIC A., GEBAUER B., THUMMERER S., WILPERT M., KALPAKCHIEVA R., GRIMES S.M., MASSEY T.N., LEPINE-SZILY A., OLIVEIRA J.M., MITTIG W., ROUSSEL-CHOMAZ P., OSTROWSKI A.N.
HMI - Berlin, FLNR JINR - Dubna, Ohio Univ. - Athens, IFUSP - Sao Paulo, GANIL - Caen, Edinburgh Univ. - Edinburgh
Heavy Ion Physics
VI International School-Seminar
DUBNA (RU)
22 Septembre 1997
98 154 D

Neutrino absorption efficiency of an ^{40}Ar detector from the b decay of ^{40}Ti
BHATTACHARYA M. , GARCIA A., KALOSKAMIS N.L., ADELBERGER E.G., SWANSON H.E., ANNE R., LEWITOWICZ M., SAINT-LAURENT M.G., TRINDER W., DONZAUD C., GUILLEMAUD-MUELLER D., LEENHARDT S., MUELLER A.C., POUGHEON F., SORLIN O.
Notre Dame Univ. - Notre Dame, Washington Univ. - Washington, GANIL - Caen, IPN - Orsay
Physical Review C58, 6 (1998) 3677.
98 99 D

Neutron multiplicity distributions for 200 MeV/proton-, deuteron-and ^{4}He-induced spallation reactions in thick Pb targets
LOTT B., CNIGNIET F., GALIN J., GOLDENBAUM F., HILSCHER D., LIENARD A., PEGHAIRE A., PERIER Y., QUIAN X.
GANIL - Caen, HMI - Berlin
NIM A414 (1998) 117.
98 79 D

Neutron multiplicity distributions for GEV proton induced spallation reactions of thin and thick targets of PB and U
HILSCHER D. , GOLDENBAUM F., JAHNKE U., PIENKOWSKI L., GALIN J., LOTT B., QUEDNAU B.
HMI - Berlin, GANIL - Caen
Nuclear Methods forTransmutation of Nuclear Waste : Problems, Perspective, Cooperative Research
International Workshop on Nuclear Methods for Transmutation of Nuclear Waste : problems, perspectives, Cooperative Research
DUBNA (RU)
29 Mai 1996
98 18 D

Neutron production by hadron-induced spallation reactions in thin and thick Pb and U targets from 1 to 5 GeV
HILSCHER D., JAHNKE U., GOLDENBAUM F., PIENKOWSKI L., GALIN J., LOTT B.
HMI - Berlin, GANIL - Caen
NIM A414 (1998) 100.
98 110 D

Production of nuclei in ^{32,34,36}S-induced reactions in the energy range 6-75 MeV/A
TARASOV O.B. , PENIONZHKEVICH YU.E., ANNE R., BAIBORODIN D.S., BORCEA C., DLOUHY Z., GUILLEMAUD-MUELLER D., FOMICHEV A.S., KALPAKCHIEVA R., LEWITOWICZ M., LUKYANOV S.M., MAIDIKOV V.Z., MUELLER A.C., OGANESSIAN YU.TS., SAINT-LAURENT M.G., SKOBELEV N.K., SORLIN O., TONEEV V.D., TRINDER W.

Nuclear Physics A629 (1998) 605.
98 23 D

Quasi-projectile and mid-rapidity characteristics in the $^{36}Ar+^{58}Ni$ reaction at 95A MEV
DORE D. , BORDERIE B., CHARVET J.L., DAYRAS R., NALPAS L., RIVET M.F., ASSENARD M., AUGER G., BACRI CH.O., BOCAGE F., BOUGAULT R., BROU R., BUCHET P., CHBIHI A., COLIN J., CUSSOL D., DEMEYER A., DURAND D., EUDES P., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GOURIO D., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LE FEVRE A., LEFORT T., LEGRAIN R., LeNEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P.
DAPNIA - SACLAY, IPN - ORSAY, GANIL - CAEN, LPC - CAEN, IPN - LYON, SUBATECH - NANTES, N.I.P.N.E. - BUCHAREST, UNIV. DI NAPOLI, GSI - DARMSTADT
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.381
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 50 D

Role of Two-Body Dissipation Mechanisms in Heavy Ion Collisions Around the Fermi Energy
SANTONOCITO D. , PIATELLI P., BLUMENFELD Y., SUOMIJARVI T., AGODI C., ALAMANOS N., ALBA R., AUGER F., BELLIA G., CHOMAZ PH., CONIGLIONE R., DEL ZOPPO A., FINOCCHIARO P., FRASCARIA N., GARRON J.P., GILLIBERT A., LOUKACHINE K., LE FAOU J.H., MAIOLINO C., MIGNECO E., ROYNETTE J.C., SAPIENZA P., SCARPACI J.A.
IPN - ORSAY, INFN - CATANIA, DAPNIA - SACLAY, GANIL - CAEN, UNIVERSITA DI CATANIA - CATANIA
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.467
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 53 D

Space Time Characterization of Nuclear Matter in Fragmentation Processes
NGUYEN A.D. , BOUGAULT R., CHBIHI A., DURAND D., GULMINELLI F., LOPEZ O., SALOU S., WIELECZKO J.P., ASSENARD M., AUGER G., BACRI CH.O., BOCAGE F., BORDERIE B., BROU R., BUCHET PH., CHARVET J.L., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., EUDES P., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GOURIO D., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LE FEVRE A., LEFORT T., LEGRAIN R., LE NEINDRE N., LOUVEL M., MASKAY A.M., NALPAS L., PARLOG M., PETER J., PLAGNOL E., POLITI G., RAHMANI A., REPOSEUR T., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C.
LPC - CAEN, DAPNIA - SACLAY, GANIL - CAEN, IPN - ORSAY, IPN - VILLEURBANNE, SUBATECH - NANTES, UNIV. DI NAPOLI, N.I.P.N.E. - BUCAREST
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl.112, p.307
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 48 D

Thermalizing Nuclear Matter Probed by Hard Photons
SCHUTZ Y. , and the TAPS collaboration
GANIL - CAEN, GSI - DARMSTADT, GIESSEN UNIVERSITY - GIESSEN, KVI - GRONINGEN, VALENCIA UNIVERSITY - VALENCIA, NPI - REZ
Nuclear Physics A630 (1998) 126c.
International Conference on Nucleus-Nucleus Collisions.6

GATLINBURG (USA)
2 Juin 1997
98 01 D

Two-neutron interferometry measurements
PLUTA J. , BIZARD G., DESESQUELLES P., DLUGOSZ A., DORVAUX O., DUDA P., DURAND D., ERAZMUS B., HANAPPE F., JAKOBSSON B., LEBRUN C., LECOLLEY F.R., LEDNICKY R., LESZCZYNSKI P., MIKHAILOV K., MILLER K., NOREN B., PAWLAK T., PRZEWLOCKI M., SKEPPSTEDT O., STAVINSKY A., STUTTGE L., TAMAIN B., WOSINSKA K.
Warsaw Univ. of Techn. - Warsaw, LPC ISMRA - Caen, ISN - Grenoble, IRS - Strasbourg, SUBATECH - Nantes, ULB - Bruxelles, Lund Univ. - Lund, Czech Acad. of Sci. - Prague, ITEP - Moscow, Chalmers Univ. of Techn. - Göteborg
NIM A411 (1998) 417.
98 72 D

Experimental determination of fragment excitation energies in multifragmentation events
MARIE N. , CHBIHI A., NATOWITZ J.B., LE FEVRE A., SALOU S., WIELECZKO J.P., GINGRAS L., ASSENARD M., AUGER G., BACRI CH.O., BOCAGE F., BORDERIE B., BOUGAULT R., BROU R., BUCHET P., CHARVET J.L., CIBOR J., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., EUDES P., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GOURIO D., GUINET D., HAGEL K., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEFORT T., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MAJKA Z., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RAHMANI A., REPOSEUR T., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TIREL O., VIENT E., VOLANT C., WADA R.
Texas A&M Univ. - College Station, GANIL - Caen, SUBATECH - Nantes, IPN - Orsay, LPC ISMRA - Caen, CE Saclay - Gif sur Yvette, IPNL - Villeurbanne, NIPNE - Bucharest-Magurele, Napoli Univ. - Napoli, GSI - Darmstadt, Jagellonian Univ. - Krakow
Physical Review C58, 1 (1998) 256.
98 78 E

Inclusive measurements of light charged particles emitted in the reaction $^{40}Ar + ^{27}Al$ at 60A MeV
LANZANO G., PAGANO A., BLANCATO G., DE FILIPPO E., GERACI M., DAYRAS R., BERTHIER B., GADI-DAYRAS F., LEGRAIN R., POLLACCO E., HEUSCH B.
INFN - Catania, CE Saclay - Gif sur Yvette, IReS and Univ. Louis Pasteur - Strasbourg
Physical Review C58, 1 (1998) 281.
98 76 E

Multistep Production ofη and Hard η^0 Mesons in Subthreshold Au-Au Collisions
WOLF A.R. , APPENHEIMER M., AVERBECK R., CHARBONNIER Y., DIAZ J., DOPPENSCHMIDT A., HEJNY V., HLAVAC S., HOLZMANN R., KUGLER A., LOHNER H., MARIN A., METAG V., NOVOTNY R., OSTENDORF R.W., PLESKAC R., SCHUBERT A., SCHUTZ Y., SIMON R.S., STRATMANN R., STROHER H., TLUSTY P., VOGT P.H., WAGNER V., WEIB J., WILSCHUT H.W., WISSMANN F., WOLF M.
II. PHYSIK. INST. UNIV. GIESSEN - Giessen, GSI - Darmstadt, GANIL - Caen, IFC CM UNIV. VALENCIA - Burjassot, IFK UNIV. FRANKFURT - Frankfurt, NPI - Rez, KVI - Groningen
Physical Review Letters 80 (1998) 5281-5284
98 43 E

Neutral meson production in p-Be and p-Au collisions at 450 GeV beam energy
AGAKICHIEV G. , APPENHEIMER M., AVERBECK R., BALLESTER F., BAUR R., BRENSCHEDE A., DIAZ J., DREES A., FASCHINGBAUER U., FERRERO J.L., FISCHER P., FRAENKEL Z., FRANKE M., FUCHS CH., GATTI E., GLASSEL P., GUNZEL TH., DE LOS HEROS C.P., HESS F., HOLZMANN R., IRMSCHER D., JACOB C., KUHN W., LENKEIT B., LOHNER H., MARIN A., MARQUES F.M., MARTINEZ G., METAG V., NOTHEISEN M., NOVOTNY R., OLSEN L.H., OSTENDORF R., PANEBRATTSEV Y., PFEIFFER A., RAVINOVICH I., REHAK P., SAMPIETRO M., SCHON A., SCHUKRAFT J., SCHUTZ Y., SHIMANSKY S.,

SHOR A., SIMON R.S., SPECHT H.J., STEINER V., TAPPROGGE S., TEL-ZUR G., TSERRUYA I., ULLRICH TH., WILSCHUT H., WURM J.P., YUREVICH V.
MPI - Heidelberg, Giessen Univ. - Giessen, GSI - Darmstadt, IFC - Burjassot, Heidelberg Univ. - Heidelberg, Weizmann Inst. - Rehovot, Politecnico di Milano - Milano, KVI - Groningen, GANIL - Caen, BNL - Upton, CERN - Geneva
The European Physical Journal C4 (1998) 249.
98 60 E

Systematic study of low-mass electron pair production in p-Be and p-Au collisions at 450 GeV/c
AGAKICHIEV G., APPENHEIMER M., AVERBECK R., BALLESTER F., BAUR R., BRENSCHEDE A., DIAZ J., DREES A., FASCHINGBAUER U., FERRERO J.L., FISCHER P., FRAENKEL Z., FRANKE M., FUCHS CH., GATTI E., GLASSEL P., GUNZEL TH., DE LOS HEROS C.P., HESS F., HOLZMANN R., IOUREVITCH V., IRMSCHER D., JACOB C., KULN W., LENKEIT B., LOHNER H., MARIN A., MARQUES F.M., MARTINEZ G., METAG V., NOTHEISEN M., NOVOTNY R., OLSEN L.H., OSTENDORF R., PANEBRATTSEV Y., PFEIFFER A., RAVINOVICH I., REHAK P., SAMPIETRO M., SCHON A., SCHUKRAFT J., SCHUTZ Y., SHIMANSKY S., SHOR A., SIMON R.S., SPECHT H.J., STEINER V., TAPPROGGE S., TEL-ZUR G., TSERRUYA I., ULLRICH TH., WILSCHUT H., WURM J.P.
MPI - Heidelberg, Giessen Univ. - Giessen, GSI - Darmstadt, IFC - Burjassot, Heidelberg Univ. - Heidelberg, Weizmann Inst. Sci. - Rehovot, Politecnico di Milano - Milano, CERN - Geneva, KVI - Groningen, GANIL - Caen, BNL - Upton
The European Physical Journal C4 (1998) 231.
98 58 E

The quest for (in) coherence
TURRISI R.
GANIL - CAEN
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, 136
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
6 Octobre 1998
98 45 F

Substhreshold neutral pion production studied in 190 MeV proton-induced reactions
APHECETCHE L.
GANIL - CAEN
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.77
PROCEEDINGS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 44 F

Subthreshold neutral pion production in p + A collisions
APHECETCHE L.
GANIL - Caen
Electromagnetic and Hadronic Probes of Nuclear Matter
Proceedings of the TAPS Workshop IV
MONT SAINTE ODILE (FR)
*14 Septembre 1997*98 133 F

Systematics of pion production in intermediate energy heavy-ion reactions
MARTINEZ G.
GANIL - Caen
Electromagnetic and Hadronic Probes of Nuclear Matter
Proceedings of the TAPS Workshop IV
MONT SAINTE ODILE (FR)

14 Septembre 1997
98 134 F

General purpose high-performance electron cyclotron resonance ion source for production of multicharged ions
SORTAIS P., BEX L., MAUNOURY L., LAMY T., VILLARI A.C.C.
GANIL - Caen, ISN - Grenoble
Review of Scientific instruments 69 (1998) 656.
7th INTERNATIONAL CONFERENCE ON ION SOURCES
TAORMINA (IT)
7 Septembre 1997
98 14 H

Production of metallic ions with an ECRIS at GANIL
BEX L. , DUPUIS M., FLAMBARD J.L., LEHERISSIER P., RATAUD J.P.
GANIL - CAEN
Review of Scientific Instruments 69 (1998) 792.
7th INTERNATIONAL CONFERENCE ON ION SOURCES
TAORMINA (IT)
7 Septembre 1997
98 13 H

EXOGAM : A γ-ray spectrometer for nuclear structure studies at
AZAIEZ F., KORTEN W.
IPN - ORSAY, CEA SACLAY - GIF SUR YVETTE
Nuclear Physics News Vol. 7, No. 4 (1997) 21.
98 20 I

Actual Motivations in Applied Research with Heavy Ions : The Joint Efforts of CIRIL and GANIL
DELAGRANGE H.
GANIL - Caen
Heavy Ion Physics
VI International School-Seminar
DUBNA (RU)
22 Septembre 1997
98 149 J

L'intérêt de la sélection du faisceau $^{(12)}$C par rapport au $^{(13)}$C pour la radiothérapie du cancer
FARES G. , HACHEM A., BIMBOT R., ROUSSEL-CHOMAZ P., ANNE R., MIREA M., BELAHBIB S., BENFOUGHAL T., CABOT C., CLAPIER F., FREEMAN R., LEWITOWICZ M., SAINT-LAURENT M.G., SAUVESTRE J.E., SIDA J.L.
LPES CRESA - Nice, IPN - Orsay, GANIL - Caen, CRN - Strasbourg, PNN DAM - Bruyères-le-Châtel
J. Chim. Phys. 95 (1998) 731.
98 65 J

The SPIRAL radioactive beam facility at GANIL : status and perspectives
GUERREAU D.
GANIL - Caen
Heavy Ion Physics
VI International School-Seminar. Heavy Ion Physics
DUBNA (RU)
22 Septembre 1997
98 141 S

Contraints due to the production of radioactive ion beams in the SPIRAL project
LEROY R., HUGUET Y., JARDIN P., MARRY C., PACQUET J.Y., VILLARI A.C.C.

Review of Scientific Instruments 69 (1998), 758.
7th INTERNATIONAL CONFERENCE ON ION SOURCES
TAORMINA (IT)
7 Septembre 1997
98 15 S

The SPIRAL radioactive ion beam facility at GANIL
LAUNE B.
IPN - Orsay, GANIL - Caen
Application of Accelerators in Research and Industry
AIP Conference Proceedings 392, 381
Proceedings of the Fourteenth International Conference
DENTON (TEXAS)
6 Novembre 1996
98 16 S

The SPIRAL radioactive beam facility at GANIL
GUERREAU D.
GANIL - Caen
Topics on the structure and interactions of nuclei far from the stability line
FIRST INTERNATIONAL WORKSHOP ON PHYSICS OF UNSTABLE NUCLEAR BEAMS.1
SAO PAULO (BR)
28 Août 1996
98 07 S

A simulation of the temperature distribution in the SPIRAL target
LICHTENTHALER R. , FOURY P., ANGELIQUE J.C., BERTRAND P., BLANK B., BAJEAT O., BOY L., DUCOURTIEUX M., JARDIN P., LECESNE N., LEPINE-SZILY , LEWITOWICZ M., LIANG C.F., LOISELET M., LEFORT H., LEROY R., MANDIN J., MARRY C., MAUNOURY L., OBERT J., ORR N., PACQUET J.Y., PUTAUX J.C., RYCKWAERT G., ROBERT E., SAINT-LAURENT M.G., SORTAIS P., TOULEMONDE M., TIRREL I., VILLARI A.C.C.
GANIL - Caen, IFUSP - SAO PAULO, IPN - Orsay, LPC ISMRA - Caen, CENBG - Bordeaux, CSNSM - Orsay, CRC IPN - Louvain la Neuve, CIRIL - Caen
NIM B140 (1998) 415-425
98 57 S

Anomalous diffusion in peripheral heavy-ion collisions and the Langevin formalism
PLOSZAJCZAK M., STROKOWSKI T.
GANIL - Caen, INP - Krakow
Innovative Computational Methods in Nuclear Many-Body Problems
International Symposium on Innovative Computational Methods in Nuclear Many-Body Problems
OSAKA (JP)
10 Novembre 1997
98 131 T

Beating of monopole modes in nuclear dynamics
LACROIX D., CHOMAZ Ph.
GANIL - Caen
Nuclear Physics A641 (1998) 107.
98 87 T

Boltzmann-Langevin Approaches
CHOMAZ Ph.
GANIL - Caen
Innovative Computational Methods in Nuclear Many-Body Problems
International Symposium on Innovative Computational Methods in Nuclear Many-Body Problems
OSAKA (JP)

10 Novembre 1997
98 132 T

Expansion and evaporation of hot nuclei : comparison between semi-classical and quantal mean-field approaches
LACROIX D., CHOMAZ Ph.
GANIL - Caen
Nuclear Physics A636 (1998) 85.
98 64 T

The fermion SO(8) model and its connection with an IBM-4 with L = 0 bosons
VAN ISACKER P., DUKELSKY J., PITTEL S., JUILLET O.
GANIL - Caen, Inst. de Estructura de la Materia - Madrid, Bartol Res. Inst. - Newark
Journal of Physics G24 (1998) 1261.
98 70 T

Hartree-Bose mean-field approximation for the interacting boson model (IBM-3)
GARCIA-RAMOS J.E., ARIAS J.M., DUKELSKY J., MOYA DE GUERRA E., VAN ISACKER P.
DFAMyN SEVILLA UNIV. - SEVILLA, INST. DE ESTRUCTURA DE LA MATERIA - MADRID, GANIL - CAEN
Physical Review C57, 2 (1998) R479.
98 22 T

Intrinsic structure of two-phonon states in the interacting boson model
GARCIA-RAMOS , ALONSO C.E., ARIAS J.M., VAN ISACKER P., VITTURI A.
DFAMN Univ. de Sevilla - Sevilla, GANIL - Caen, INFN - Padova
Nuclear Physics A637 (1998) 529.
98 91 T

An introduction to the physics of non-equilibrium phenomena
PLOSZAJCZAK M., BOTET R., SROKOWSKI T.
GANIL - Caen, LPS Univ. Paris-Sud - Orsay, INP - Krakow
Electromagnetic and Hadronic Probes of Nuclear Matter
Proceedings of the TAPS Workshop IV
MONT SAINTE ODILE (FR)
14 Septembre 1997
98 135 T

Mass formula for L hypernuclei based on SU(6) symmetry
LEVAI G., CSEH J., VAN ISACKER P., JUILLET O.
INR Hungarian Acad. Sci. - Debrecen, GANIL - Caen
Physics Letters B433 (1998) 250.
98 75 T

Quantum Extension of Mean-Field Dynamics
LACROIX D., CHOMAZ P., AYIK S.
GANIL - CAEN, TENNESSEE TECHNOLOGICAL UNIVERSITY - COOKVILLE
International Winter Meeting on Nuclear Physics
Ricerca Scientifica ed Educazione Permanente Suppl. 112, p.485
PROCEEDINS OF THE XXXVI INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
BORMIO (IT)
26 Janvier 1998
98 54 T

Quantum and statistical fluctuations in dynamical symmetry breaking
WEN W., CHAU HUU-TAI P., LACROIX D., CHOMAZ Ph., AYIK S.
GANIL - Caen, Tennessee Techn. Univ. - Cookeville, IMP - Lanzhou
Nuclear Physics A637 (1998) 15.
98 68 T

Radiative capture reaction $^{7}Be\ (p,g)^{8}B$ in the continuum shell model
BENNACEUR K. , NOWACKI F., OKOLOWICZ J., PLOSZAJCZAK M.
GANIL - Caen, LPTS - Strasbourg, INP - Krakow
HIRSCHEGG'98 : Nuclear Astrophysics
Proceedings of the International Xorkshop XXXVI on Gross Properties of Nuclei and Nuclear Excitations
HIRSCHEGG (AT)
11 Janvier 1998
98 17 T

Rotational dependence of Coulomb energy differences
SHEIKH J.A. , WARNER D.D., VAN ISACKER P.
Surrey Univ. - Guildford, CLRC Daresbury Lab. - Warrington, GANIL - Caen
Physics Letters B443 (1998) 16.
98 102 T

Solving the generalized Langevin equation with the algebraically correlated noise
SROKOWSKI T. , PLOSZAJCZAK M.
INP - KRAKOW, GANIL - CAEN
Physical Review E57, 4 (1998) 3829.
98 26 T

Spinodal decomposition in nuclear molecular dynamics
COLONNA M., CHOMAZ Ph.
GANIL - Caen, CEN Saclay - Gif sur Yvette, LNS - Catania
Physics Letters B436 (1998) 1.
98 83 T

Time-dependent Hartree-Fock simulation of the expansion of abraded nuclei
LACROIX D., CHOMAZ Ph.
GANIL - Caen
Physical Review C58, 3 (1998) 1604.
98 81 T

Universal features of the off-equilibrium fragmentation with Gaussian dissipation
BOTET R., PLOSZAJCZAK M.
LPS Univ. Paris-Sud - Orsay, GANIL - Caen
Physical Review E57, No.6 (1998) 7305.
98 66 T

1999

Alpha energy distribution as a probe for the feeding of ND and SD bands in $^{151,152}Dy$ nuclei
AICHE M., ALEONARD M.M., BARREAU G., BOIVIN D., BOURGINE F., CHEMIN J.F., SCHEURER J.N., DOAN T.P., BRONDI A., LA RANA G., MORO R., PRINCIPE A., VARDACI E., CURIEN D., DUCHENE G., de FRANCE G., BECK F.A., HAAS B., VIVIEN J.P., HANNACHI F.
CENBG - Gradignan, INFN & DSF - Napoli, IRS & Univ. Louis Pasteur - Strasbourg, GANIL - Caen, CSNSM - Orsay
European Physical Journal A6 (1999) 121.
99 103 A

Anomalous E 1 and E 2 strengths in ^{40}Ca and ^{48}Ca at low excitation energy : A comparative study
OTTINI-HUSTACHE S., ALAMANOS N., AUGER F., CASTEL B., BLUMENFELD Y., CHISTE V., FRASCARIA N., GILLIBERT A., JOUANNE C., LAPOUX V., MARIE F., MITTIG W., ROYNETTE J.C., SCARPACI J.A.
CEA Saclay - Gif sur Yvette, Queen'S University - Kingston, IPN - Orsay, GANIL - Caen
Physical Review C59, 6 (1999) 3429.
99 59 A

β-decay of ^{35}Ca
TRINDER W., ANGELIQUE J.C., ANNE R., AYSTO J., BORCEA C., DAUGAS J.M., GUILLEMAUD-MUELLER D., GREVY S., GRZYWACZ R., JOKINEN A., LEWITOWICZ M., LOPEZ M.J., de OLIVEIRA F., OSTROWSKI A.N., SIISKONEN T., SAINT-LAURENT M.G.
GANIL - Caen, PLC - Caen, Jyvaskyla Univ. - Jyvaskyla, IAP - Bucharest-Magurele, IPN - Orsay, IEP Warsaw Univ. - Warsaw, Dept. of Phys. and Astr. Univ. of Edinburgh - Edinburgh
Physics Letters B459 (1999) 67.
99 68 A

Chaotic scattering on surfaces and collisional damping of collective modes
MORAWETZ K., VOGT M., FUHRMANN U., LIPAVSKY P., SPICKA V.
LPC - Caen, GANIL - Caen, Rostock Univ. - Rostock, Acad. of Sciences - Praha
Physical Review C60 (1999) 054601.
99 144 A

Cross sections, momentum distributions, and neutron angular distributions for ^{11}Be induced reactions on silicon
NEGOITA F., BORCEA C., CARSTOIU F., LEWITOWICZ M., SAINT-LAURENT M.G., ANNE R., GUILLEMAUD-MUELLER D., MUELLER A.C., POUGHEON F., SORLIN O., FOMITCHEV A., LUKYANOV S., PENIONZHKEVICH Yu., SKOBELEV N., DLOUHY Z.
IFIN-HH - Bucharest-Magurele, GANIL - Caen, IPN - Orsay, FLNR JINR - Dubna, NPI - Rez, Surrey Univ. - Guildford
Physical Review C59, 4 (1999) 2082.
99 23 A

Disappearence of Collective Motion in Very Hot Nuclei
PIATELLI P., SUOMIJARVI T., BLUMENFELD Y., SANTONOCITO D., AGODI C., ALAMANOS N., ALBA R., AUGER F., BELLIA G., CHOMAZ PH., COLONNA M., CONIGLIONE R., DEL ZOPPO A., FINOCCHIARO P., FRASCARIA N., GILLIBERT A., LE FAOU J.H., LOUKACHINE K., MAIOLINO C., MIGNECO E., ROYNETTE J.C., SAPIENZA P., SCARPACI J.A.
INFN LNS - Catania, IPN - Orsay, CEN Saclay - Gif sur Yvette, GANIL - Caen
Nuclear Physics A649 (1999) 181c.
99 58 A

Elastic and Inelastic Proton Scattering on the Unstable ^{20}O Nucleus Measured with the "MUST" Detector Array
KHAN E., BLUMENFELD Y., SUOMIJARVI T., NGUYEN VAN GIAI, ALAMANOS N., AUGER F., COLO G., FRASCARIA N., GILLIBERT A., GLASMACHER T., GODWIN M., LAPOUX V., LHENRY I., MARECHAL F.,

MORISSEY D.J., MUSUMARRA A., ORR N., OTTINI S., PIATELLI P., POLLACCO E.C., ROUSSEL-CHOMAZ P., ROYNETTE J.C., SANTONOCITO D., SAUVESTRE J.E., SCARPACI J.A., VOLPE C.
IPN - Orsay, CEA Saclay - Gif sur Yvette, INFN - Milano, NSCL MSU - East Lansing, LPC - Caen, INFN LNS - Catania, GANIL - Caen, DPTA SPN CEA Bruyères - Bruyères-le-Châtel
Ricerca Scientifica ed Educazione Permanente Suppl. 114 (1999) 448.
BORMIO 1999
International Winter Meeting on Nuclear Physics.37
BORMIO (IT)
25 Janvier 1999
99 93 A

Evolution of a spallation reaction : experiment and Monte Carlo simulation
ENKE M., HERBACH C.M., HILSCHER D., JAHNKE U., SCHAPIRO O., LETOURNEAU A., GALIN J., GOLDENBAUM F., LOTT B., PEGHAIRE A., FILGES D., NEEF R.D., NUNIGHOFF K., PAUL N., SCHAAL H., STERZENBACH G., TIETZE A., PIENKOWSKI L.
HMI - Berlin, GANIL - Caen, inst. für Kernphysik - Jülich, Heavy Ion Lab. Warsaw Univ. - Warszawa
Nuclear Physics A657 (1999) 317.
99 102 A

Excitation of multiple giant dipole resonances : from spherical to deformed nuclei
ANDRES M.V., LANZA E.G., VAN ISACKER P., VOLPE C., CATARA F.
Sevilla Univ. - Sevilla, INFN - Catania, GANIL - Caen, IPN - Orsay
Physics Letters B470 (1999) 6.
99 153 A

Experimental and theoretical search for a phase transition in nuclear fragmentation
CHBIHI A., SCHAPIRO O., SALOU S., GROSS D.H.E.
GANIL - Caen, HMI - Berlin
The European Physical Journal A5 (1999) 251.
99 63 A

Importance of Coulomb dissociation of the deuteron on nucleon production reactions
RIDIKAS D., MITTIG W., TOSTEVIN J.A.
GANIL - Caen, Surrey Univ. - Guildford
Physical Review Letters 82, 7 (1999) 1402
99 13 A

Magnetic Moment of the 1^- Ground State in ^{18}N Measured with a New β Level Mixing Nuclear Magnetic Resonance Technique
NEYENS G. , COULIER N., TEUGHELS S., GEORGIEV G., BROWN B.A., ROGERS W.F., BALABANSKI D.L., COUSSEMENT R., LEPINE-SZILY A., LEWITOWICZ M., MITTIG W., de OLIVEIRA SANTOS F., ROUSSEL-CHOMAZ P., TERNIER S., VYVEY K., CORTINA-GIL D.
Inst. voor Kern-en Stralingsfysika - Leuven, NSCL MSU - East Lansing, Oxford Univ. - Oxford, Westmont College - Santa Barbara, Sao Paulo Univ. - Sao Paulo, GANIL - Caen, GSI - Darmstadt
Physical Review Letters 82, 3 (1999) 497.
99 02 A

The Magnetic and Quadrupole Moment of Oriented Nuclei Measured with the β-LMR-NMR
TEUGHELS S., NEYENS G., COULIER N., GEORGIEV G., TERNIER S., VYVEY K., BALABANSKI D.L., COUSSEMENT R., ROGERS W.F., CORTINA-GIL D., DE OLIVEIRA F., LEWITOWICZ M., MITTIG W., ROUSSEL-CHOMAZ P., LEPINE-SZILY A.
Leuven Univ. - Leuven, Westmont College - Santa Barbara, GANIL - Caen, IP Sao Paulo Univ. - Sao Paulo
AIP Conference Proceedings.455
ENAM 98 AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 106 A

A mass measurement experiment to investigate the shell closures far from stability
SARAZIN F., SAVAJOLS H., MITTIG W., ROUSSEL-CHOMAZ P., AUGER G., BAIBORODIN D., BELOZYOROV A.V., BORCEA C., DLOUHY Z., GILLIBERT A., LALLEMAN A.S., LEWITOWICZ M., LUKYANOV S.M., NOWACKI F., de OLIVEIRA F., ORR N., PENIONZHKEVICH Y.E., REN Z., RIDIKAS D., SAKURAI H., TARASOV O., de VISMES A.
GANIL - Caen, Nucl.Phys.Inst. - Rez, LNR JINR - Dubna, IAP - Bucharest, CEN Saclay - Gif sur Yvette, LPT - Strasbourg, LPC - Caen, RIKEN - Saitama
Ricerca Scientifica ed Educazione Permanente Suppl. 114 (1999) 388.
BORMIO 99
International Winter Meeting on Nuclear Physics.37
BORMIO (IT)
25 Janvier 1999
99 90 A

Microscopic description of multiphonon states excitation in heavy ion collisions
LANZA E.G., ANDRES M.V., CATARA F., CHOMAZ PH., VOLPE C.
INFN - Catania, FAMN Univ. de Sevilla - Sevilla, INFN - Catania, GANIL - Caen, IPN - Orsay
Nuclear Physics A654 (1999) 792c.
INPC/98
International Nuclear Physics Conference
PARIS (FR)
24 Août 1998
99 130 A

New approach to the nuclear in beam γ spectroscopy of neutron rich nuclei at N=20 using projectile fragmentation
LOPEZ-JIMEREZ M.J., BELLEGUIC M., STANOIU M., SAINT-LAURENT M.G., ACHOURI L., ANGELIQUE J.C., AZAIEZ F., BOURGEOIS C., BORCEA C., DAUGAS J.M., DE FRANCE G., DE OLIVEIRA F., DLOUHY Z., DONZAUD M., DUPRAT J., GANGNANT P., GREVY S., LEENHARDT S., LEWITOWICZ M., LIBIN J.F., MARQUES M., PENIONZHKEVITCH Y., PETIZON L., PORQUET M.G., SAUVESTRE J.E., SAVAJOLS H., SKOBELEV N., SORLIN O.
GANIL - Caen, IPN - Orsay, IAP - Bucharest-Magurele, LPC - Caen, NPI - Rez, FLNR JINR - Dubna, CSNSM - Orsay, DAM CE Bruyères-Le-Châtel - Bruyères-Le-Châtel
Ricerca Scientifica ed Educazione Permanente Suppl. 114 (1999) 416.
BORMIO 99
International Winter Meeting on Nuclear Physics.37
BORMIO (IT)
25 Janvier 1999
99 92 A

Observation of the Z = N + 1 Nuclei 77/39Y, 79/40Zr, and 83/42Mo
JANAS Z. , LEWITOWICZ M., SAINT-LAURENT M.G., WINFIELD J.S.
CENBG - Gradignan, IEP Warsaw Univ. - Warsaw, Surrey Univ. - Guildford, Dept. Mechan. Eng. Univ. of Brighton - Brighton, IRS - Strasbourg, GANIL - Caen, LPC ISMRA - Caen, Oliver Lodge Lab. Univ. of Liverpool- liverpool, York Univ. - York, CCLRC Daresbury Lab. - Warrington
Physical Review Letters 82, 2 (1999) 295.
99 01 A

Paving the way for nuclear polymers
VON OERTZEN W.
HMI - BERLIN
Physics World 12, 5 (1999) 22.
99 33 A

Persistence of the N=28 Shell Closure far from Stability
SARAZIN F., SAVAJOLS H., MITTIG W., AUGER G., BAIBORODIN D., BELOZYOROV A.V., BORCEA C., GILLIBERT A., LALLEMAN A.S., LEWITOWICZ M., LUKYANOV S.M., DE OLIVEIRA F., ORR N., PENIONZHKEVICH Y.E., RIDIKAS D., ROUSSEL-CHOMAZ P., SAKURAI H., de WISMES A.

GANIL - Caen, CEN Saclay - Gif sur Yvette, LNR JINR - Dubna, IAP - Bucharest, RIKEN - Saitama, LPC ISMRA - Caen
AIP Confernce Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 104 A

Probing Thermalizing Nuclear Matter with Hard Photons
SCHUTZ Y.
GANIL - Caen
Nuclear Matter in Different Phases and Transitions
Workshop on Nuclear Matter in Different Phases and Transitions
LES HOUCHES (FR)
31 Mars 1998
99 99 A

Production and study of short-lived isomers at intermediate energies
DAUGAS J.M., GRZYWACZ R., LEWITOWICZ M., ACHOURI L., ANGELIQUE J.C., AXELSSON L., BAIBORODIN D., BENTIDA R., BERAUD R., BORCEA C., BINGHAM C., CATFORD W., EMSALLEM A., de FRANCE G., GRAWE H., JONES K.L., LEMMON R.C., LONGOUR C., LOPEZ-JIMENEZ M.J., de OLIVEIRA-SANTOS F., PLUTZNER M., REGAN P.H., RYKACZEWSKI K., SAUVESTRE J.E., SAWICKA M., SLETTEN G., STANOIU M.
GANIL - Caen, Tennessee Univ. - Knoxville, IFD Warsaw Univ. - Warsaw, LPC - Caen, Nucl.Phys.Inst. - Rez, IPN Lyon - Villeurbanne, IAP - Bucharest-Magurele, Surrey Univ. Guildford, GSI - Darmstadt, IRES Univ. Louis Pasteur - Strasbourg, ORNL - Oak Ridge, CEA Bruyères le Châtel , NBI - Copenhagen
Ricerca Scientifica ed Educazione Permanente Suppl. 114 (1999) 395.
BORMIO 99
International Winter Meeting on Nuclear Physics.37
BORMIO (IT)
25 Janvier 1999
99 91 A

Pseudo-SU(4) Symmetry in Pf-Shell Nuclei
VAN ISACKER P., JUILLET O., NOWACKI F.
GANIL - Caen, LPT - Strasbourg
Physical Review Letters 82, 10 (1999) 2060.
99 10 A

Study of the ^{7}Be (p,γ) ^{8}B and ^{7}Li (n,γ) ^{8}Li capture reactions using the shell model embedded in the continuum
BENNACEUR K., NOWACKI F., OKOLOWICZ J., PLOSZAJCZAK M.
GANIL - Caen, LPT - Strasbourg, INP - Krakow
Nuclear Physics A651 (1999) 289.
99 57 A

Study of μs-isomers in neutron-rich nuclei around Z=28 and N=40 shell closures
LEWITOWICZ M., DAUGAS J.M., CRZYWACZ R., ACHOURI L., ANGELIQUE J.C., BAIBORODIN D., BENTIDA R., BERAUD R., BINGHAM C., BORCEA C., CATFORD W., EMSALLEM A., de FRANCE G., GLOGOWSKI M., GRAWE H., GUILLEMAUD-MUELLER D., HOURY M., HURSKANEN S., JONES K.L., LEMMON R.C., MUELLER A.C., NOWAK A., de OLIVEIRA-SANTOS F., PLOCHOCKI A., PFUTZNER M., REGAN P.H., RYKACZEWSKI K., SAINT-LAURENT M.G., SAUVESTRE J.E., SAWICKA M., SCHAEFER M., SLETTEN G., SORLIN O., STANOIU M., SZERYPO J., TRINDER W., VITERITTI S., WINFIELD J.
GANIL - Caen, IFD Warsaw Univ. - Warsaw, Tennessee Univ. - Knoxville, LPC - Caen, NPI - Rez, IPNL - Villeurbanne, IAP - Bucharest-Magurele, Surrey Univ. - Guildford, GSI - Darmstadt, IPN - Orsay, ORNL - Oak Ridge, CEA - Bruyères-le-Châtel, Göttingen Univ. - Göttingen, NBI - Copenhagen
Nuclear Physics A654 (1999) 687c.

INPC/98
International Nuclear Physics Conference
PARIS (FR)
24 Août 1998
99 126 A

Subshell closure study at N=40 by Coulomb excitation and β-decay
LEENHARDT S., AZAUEZ F., SORLIN O., BELLEGUIC M., BOURGEOIS C., DONZAUD C., DUPRAT J., GREVY S., GUILLEMAUD-MUELLER D., MUELLER A.C., POUGHEON F., LELONCLE I., KIENER J., PORQUET M.G., DAUGAS J.M., LEWITOWICZ M., de OLIVEIRA F., SAINT-LAURENT M.G., WINFIELD J., ANGELIQUE J.C., ORR N., GILLIBERT A., MARIE N., BORCEA C., PENIONZHKEVICH YU.E., SOBOLEV YU., BERAUD R., CANCHEL G., CHABANAT E., EMSALEM A., LONGOUR C., SAUVESTRE J.E.
IPN - Orsay, CSNSM - Orsay, GANIL - Caen, LPC - Caen, CE Saclay - Gif-sur-Yvette, IAP - Bucharest, FLNR JINR - Dubna, IPNL - Villeurbanne, IRS - Strasbourg, CEN - Bruyères-le-Châtel
Nuclear Physics A654 (1999) 683c.
INPC/ 98
International Nuclear Physics Conference
PARIS (FR)
24 Août 1998
99 125 A

Supersymmetry stands the test
VAN ISACKER P.
GANIL - Caen
Physics World 12, 10 (1999) 19.
99 98 A

Angular momentum transfer in the Xe + Sn collisions
GENOUIN-DUHAMEL E., STECKMEYER J.C., VIENT E., COLIN J., DURAND D., AUGER G., BACRI CH.O., BELLAIZE N., BOCAGE F., BORDERIE B., BOUGAULT R., BROU R., BUCHET P., CHARVET J.L., CHBIHI A., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., FRANKLAND J.D., GALICHET E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., N'GUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VOLANT C., WIELECZKO J.P.
LPC - Caen, GANIL - Caen, IPN - Orsay, CEA Saclay - Gif sur Yvette, IPN - Villeurbanne, NIPNE - Bucharest-Magurele, INFN - Napoli
Ricerca Scientifica ed Educazione Permanente Suppl. 114 (1999) 230.
BORMIO 99
International Winter Meeting on Nuclear Physics.37
BORMIO (IT)
25 Janvier 1999
99 87 B

Coherent bremsstrahlung in α + p reactions at 50 MeV/nucleon
HOEFMAN M., WILSCHUT H.W., APHECETCHE L., BACELAR J.S., DELAGRANGE H., DIAZ J., van GOETHEM M.J., HOLZMANN R., HUISMAN H., KALANTAR-NAYESTANAKI N., KUGLER A., LOHNER H., MARTINEZ G., MESSCHENDORP J.G., OSTENDORF R.W., SCHADMAND S., SCHUTZ Y., SEIP M., SIEMSSEN R.H., SIMON R.S., TURRISI R., VOLKERTS M., WAGNER V.
KVI - Groningen, GANIL - Caen, IFC - Burjassot, GSI - Darmstadt, NPI - Rez
Nuclear Physics A654 (1999) 779c.
INPC/98
International Nuclear Physics Conference
PARIS (FR)
24 Août 1998
99 129 B

Correlation between reaction mechanism, kinetic energy release and neutron emission in $^{40}Ar + ^{159}Tb$ collision at 9.5 MeV/nucleon
KOZIK E., BLOCKI J., BUDZANOWSKI A., GALIN J., HILSCHER D., HOMEYER H., JAHNKE U., KOZIK T., SOSIN Z.
Niewodniczanski Inst. Nucl. Phys. - Cracow, Soltan Inst. Nucl. Studies - Otwock, GANIL - Caen, HMI - Berlin, Jagellonian Univ. - Cracow
Acta Physica Polonica B30 (1999) 139.
99 72 B

Dynamical Aspects of Fragment Production in Heavy Ion collisions
PLAGNOL E., AUGER G., ASSENARD M., BACRI C.O., BENLLIURE J., BISQUER E., BORDERIE B., BOUGAULT R., BROU R., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DeFILIPPO E., DEMEYER A., DORE D., DURAND D., EUDES PH., GENOUX-LUBAIN A., GERLIC E., GERMAIN M., GOURIO D., GUINET D., LAFOREST R., LAUTESSE P., LAVILLE J.L., LEBRETON L., LEBRUN C., LECOLLEY J.F., LEFEVRE A., LEFORT T., LEGRAIN R., LOPEZ O., LOUVEL M., NALPAS L., MARIE N., METIVIER V., PARLOG M., PETER J., POLITI O., POLLACCO E.C., RAHMANI A., REGIMBART R., REPOSEUR T., ROSATO E., RIVET M.F., SAINT-LAURENT F., SALOU S., SIWEK A., SQUALLI M., STECKMEYER J.C., STERN M., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P., WIELOCH A., YuGANG M.
IPN - Orsay, CEN Saclay - Gif sur Yvette, GANIL - Caen, IPNL - Villeurbanne, LPC - Caen, SUBATECH - Nantes
Nuclear Physics A654 (1999) 815c.
INPC/98
International Nuclear Physics Conference
PARIS (FR)
24 Août 1998
99 132 B

Evaporation, multifragmentation, vaporisation aux énergies intermédiaires
CHBIHI A.
GANIL - Caen
De la radioactivité naturelle aux faisceaux exotiques - Recherche fondamentale et Applications
Rencontre Franco-Marocaine de Physique Nucléaire
EL JADIDA (MA)
10 Mars 1999
99 157 B

Multifragmentation in Heavy Ion Reactions : Dynamical Effects and Thermalization
PLAGNOL E., BACRI CH.O., BORDERIE B., FRANKLAND J., RIVET M.F., TASSAN-GOT L., AUGER G., CHBIHI A., LAVILLE J.L., LE FEVRE A., SALOU S., TIREL O., SAINT-LAURENT F., WIELECZKO J.P., BUCHET PH., CHARVET J.L., DAYRAS R., DORE D., LEGRAIN R., NALPAS L., VOLANT C., BOCAGE F., BOUGAULT R., BROU R., COLIN J., CUSSOL D., DURAND D., GENOUIN-DUHAMEL E., LECOLLEY J.F., LEFORT T., LE NEINDRE N., LOPEZ O., LOUVEL M., NGUYEN A.D., PETER J., STECKMEYER J.C., TAMAIN B., VIENT E., DEMEYER A., GALICHET E., GERLIC E., GUINET D., LAUTESSE P., MASKAY A.M., STERN M., ROSATO E., PARLOG M., TABACARU G., ASSENARD M., EUDES P., GERMAIN M., RAHMANI A., REPOSEUR T.
IPN - Orsay, GANIL - Caen, DAPNIA CEA Saclay - Gif sur Yvette, LPC - Caen, IPN - Orsay, Frederico Univ. - Napoli, NIPNE - Bucharest-Magurele, SUBATECH - Nantes
Nuclear Matter in Different Phases and Transitions
Workshop on Nuclear Matter in Different Phases and Transitions
LES HOUCHES
31 Mars 1998
99 101 B

Multifragmentation of heavy systems at intermediate energies
D'AGOSTINO M., BRUNO M., BONASERA A., BOTVINA A.S., BOUGAULT R., CANNATA F., DESESQUELLES P., FIANDRI M.L., FUSCHINI E., GERACI E., GULMINELLI F., IORI I., LE NEINDRE N.,

MARGAGLIOTTI G.V., MORONI A., PAGANO A., RUI R., TONETTO F., VANNINI G., BONDORF J.P., MISHUSTIN I.N.
INFN - Bologna, INFN LNS - Catania, INR - Moscow, LPC - Caen, GANIL - Caen, INFN - Catania, INFN - Trieste, NBI - Copenhagen, Kurchatov Inst. - Moscow
HIRSCHEGG '99 : Multifragmentation
International Workshop XXVII on Gross Properties of Nuclei and Nuclear Excitations
HIRSCHEGG (AT)
17 Janvier 1999
99 19 B

Multifragmentation of nonspherical nuclei
LE FEVRE A., PLOSZAJCZAK M., TONEEV V.D.
GANIL - Caen, JINR - Dubna
Physical Review C60 (1999) 051602.
99 145 B

Study of thermometers for measuring a microcanonical phase transition in nuclear fragmentation
LE FEVRE A., SCHAPIRO O., CHBIHI A.
GANIL - Caen, HMI - Berlin
Nuclear Physics A657 (1999) 446.
99 124 B

Thermal and chemical equilibrium for vaporizing sources
BORDERIE B., GULMINELLI F., RIVET M.F., TASSAN-GOT L., ASSENARD M., AUGER G., BOCAGE F., BOUGAULT R., BROU R., BUCHET PH., COLIN J., DAYRAS R., DEMEYER A., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEFORT T., LEGRAIN R., LE NEINDRE N., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PLAGNOL E., RAHMANI A., REPOSEUR T., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TIREL O., VINTACHE D., VOLANT C.
IPN - Orsay, LPC ISMRA - Caen, SUBATECH - Nantes, GANIL - Caen, DAPNIA CEA Saclay - Gif sur Yvette, IPN - Villeurbanne, NIPNE - Bucharest-Magurele, INFN - Napoli
The European Physical Journal A6 (1999) 197.
99 97 B

Beta Decay Half-Lives of Neutron Rich Ti-Co Isotopes around N=40
SORLIN O., DONZAUD C., AXELSSON L., BELLEGUIC M., BERAUD R., BORCEA C., CANCHEL G., CHABANAT E., DAUGAS J.M., EMSALLEM A., GUILLEMAUD-MUELLER D., KRATZ K.L., LEENHARDT S., LEWITOWICZ M., LONGOUR C., LOPEZ M.J., DE OLIVEIRA F., PETIZON L., PFEIFFER B., POUGHEON F., SAINT-LAURENT M.G., SAUVESTRE J.E.
IPN - Orsay, Chalmers Tekniska Högskola - Göteborg, IPNL - Villeurbanne, GANIL - Caen, IAP - Bucharest-Magurele, Mainz Univ. - Mainz, IReS - Strasbourg, CE - Bruyères le Châtel
The Beta Decay, from Weak Interaction to Nuclear Structure
Workshop on the Beta Decay, from Weak Interaction to Nuclear Structure
STRASBOURG (FR)
17 Mars 1999
99 136 C

Beta decay half-lives of neutron rich Ti-Co isotopes around N = 40
SORLIN O., DONZAUD C., AXELSSON L., BELLEGUIC M., BERAUD R., BORCEA C., CANCHEL G., CHABANAT E., DAUGAS J.M., EMSALLEM A., GUILLEMAUD-MUELLER D., KRATZ K.L., LEENHARDT S., LEWITOWICZ M., LONGOUR C., LOPEZ M.J., de OLIVEIRA SANTOS F., PETIZON L., PFEIFFER B., POUGHEON F., SAINT-LAURENT M.G., SAUVESTRE J.E.
IPN - Orsay, Chalmers Tekniska Högskola - Göteborg, IPNL - Villeurbanne, GANIL - Caen, IAP - Bucarest-Marugele, Mainz Univ. - Mainz, IReS - Strasbourg, CE - Bruyères-le-Châtel
Nuclear Physics A660 (1999) 3.
99 156 C

β-Decay Study of ^{40}Ti and ^{35}Ca at Ganil
LEWITOWICZ M., TRINDER W., BHATTACHARYA M., ADELBERGER E.G., ANGELIQUE J.C., ANNE R., AYSTO J., BORCEA C., DAUGAS J.M., DONZAUD C., GARCIA A., GUILLEMAUD-MUELLER D., GREVY S., GRZYWACZ R., JOKINEN A., LEENHARDT S., LOPEZ M.J., DE OLIVEIRA F., OSTROWSKI A.N., SIISKONEN T., SAINT-LAURENT M.G., SORLIN O., SWANSON H.E.
GANIL - Caen, Notre Dame Univ. - Notre Dame, Washington Univ. - Seattle, LPC - Caen, Jyväskyla Univ. - Jyväskyla, IAP - Bucharest-Magurele, IPN - Orsay, IEP Warsaw Univ. - Warsaw, Edinburgh Univ. - Edinburgh
The Beta Decay, from Weak Interaction to Nuclear Structure
Workshop on the Beta Decay, from Weak Interaction to Nuclear Structure
STRASBOURG (FR)
17 Mars 1999
99 138 C

Cluster structure of ^{6}He studied by means of ^{6}He + p reaction at 25 MeV/n energy
WOLSKI R., FOMICHEV A.S., RODIN A.M., SIDORCHUK S.I., STEPANTSOV S.V., TER-AKOPIAN G.M., CHELNOKOV M.L., GORSHKOV V.A., LAVRENTEV A.YU., OGANESSIAN YU.TS., ROUSSEL-CHOMAZ P., MITTIG W., DAVID I.
INP - Cracow, FLNR JINR - Dubna, GANIL - Caen, IAP - Bucharest
Physics Letters B467 (1999) 8.
99 149 C

Core-breakup reactions of the halo nuclei ^{11}Be and ^{11}Li : momentum distributions and shadow effects
GREVY S., AXELSSON L., ANGELIQUE J.C., ANNE R., GUILLEMAUD-MUELLER D., HANSEN P.G., HORNSHOJ P., JONSON B., LEWITOWICZ M., MUELLER A.C., NILSSON T., NYMAN G., ORR N.A., POUGHEON F., RIISAGER K., SAINT-LAURENT M.G., SMEDBERG M., SORLIN O.
IPN - Orsay, Fysiska Institutionen - Gothenburg, LPC ISMRA - Caen, GANIL - Caen, NSCL MSU - East Lansing, Aarhus Univ. - Aarhus
Nuclear Physics A650 (1999) 47.
99 24 C

Core excitation in ^{11}Be$_{gs}$ via the p(^{11}Be, ^{10}Be) d reaction
FORTIER S., PITA S., WINFIELD J.S., CATFORD W.N., ORR N.A., VAN DE WIELE J., BLUMENFELD Y., CHAPMAN R., CHAPPELL S.P.G., CLARKE N.M., CURTIS N., FREER M., GALES S., JONES K.L., LANGEVIN-JOLIOT H., LAURENT H., LHENRY I., MAISON J.M., ROUSSEL-CHOMAZ P., SHAWCROSS M., SMITH M., SPOHR K., SUOMIJARVI T., de VISMES A.
IPN - Orsay, Surrey Univ. - Guildford, LPC - Caen, DEEP Univ. of Paisley - Paisley, Oxford Univ. - Oxford, Birmingham Univ. - Birmingham, GANIL - Caen
Physics Letters B461 (1999) 22.
99 122 C

Critical Behavior in the Coexistence Region of Finite Systems
GULMINELLI F., CHOMAZ Ph.
LPC ISMRA - Caen, GANIL - Caen
Physical Review C59, 3 (1999) 1555.
99 05 C

Dripline nuclei produced by quasi-fragmentation of the ^{32,34,36}S primary beams
DLOUHY Z., PENIONZHKEVICH Yu., ANNE R., BAIBORODIN D., BORCEA C., FOMICHEV A., GUILLEMAUD-MUELLER D., KALPAKCHIEVA R., LEWITOWICZ M., LUKYANOV S., MUELLER A.C., OGANESSIAN Yu., PAGE R.D., REED A., SAINT-LAURENT M.G., SOKOL E., SKOBELEV N., SORLIN O., TARASOV O., TONNEV V., TRINDER W.
NPI - Rez, FLNR JINR - Dubna, GANIL - Caen, IAP - Bucharest-Magurele, IPN - Orsay, Liverpool Univ. - Liverpool
Journal of Physics G25 (1999) 859.
99 31 C

Elastic and inelastic proton scattering on the unstable ^{20}O nucleus measured with the "MUST" detector array
KHAN E., BLUMENFELD Y., SUOMIJARVI T., ALAMANOS N., AUGER F., FRASCARIA N., GILLIBERT A., GLASMACHER T., GODWIN M., LAPOUX V., LHENRY I., MARECHAL F., MORISSEY D.J., MUSUMARA A., ORR N., OTTINI S., PIATTELLI P., POLLACCO E.C., ROUSSEL-CHOMAZ P., ROYNETTE J.C., SANTONOCITO D., SAUVESTRE J.E., SCARPACI J.A.
IPN - Orsay, CEA Saclay - Gif sur Yvette, NSCL MSU - East Lansing, LPC - Caen, INFN LNS - Catania, GANIL - Caen, CEA Bruyères - Bruyères le Châtel
ENAM 98
AIP Conference Proceedings.455
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 114 C

Exotic Clustering and Halo States in $^{12,14}Be$
ORR N.A., FREER M.
LPC - Caen, School of Phys. and Astr. - Birmingham
Nuclear Physics A654 (1999) 710c.
INPC/98
International Nuclear Physics Conference
PARIS (FR)
24 Août 1998
99 127 C

Exotic decay modes at the proton drip line
BLANK B.
CENBG - Gradignan
Journal of Physics G 25 (1999) 629.
99 25 C

Exotic Molecular and Halo States in $^{12,14}Be$
FREER M., ORR N.A., LABICHE M., MARQUES F.M., ANGELIQUE J.C., AXELSSON L., BENOIT B., BERGMANN U., BORGE M.J.G., CATFORD W.N., CHAPPELL S.P.G., CLARKE N.M., COSTA G., CURTIS N., D'ARRIGO A., DE OLIVEIRA F., de GOES BRENNARD E., DORVAUX O., FULTON B.R., GARDINA G., GREGORI C., GREVY S., GUILLEMAUD-MUELLER D., HANAPPE F., HEUSCH B., JONSON B., KELLY G., LE BRUN C., LEENHARDT S., LEWITOWICZ M., MARKENROTH K., MOTTA M., MUELLER A.C., MURGATROYD J.T., NILSSON T., NINANE A., NYMAN G., PIQUERAS I., RIISAGER K., SAINT-LAURENT M.G., SARAZIN F., SINGER S., SORLIN O., STUTTGE L., WATSON D.L.
School of Phys. & Astr. - Birmingham, LPC ISMRA - Caen, Chalmers Tekniska Högskola - Göteborg, ULB - Bruxelles, Aarhus Univ. - Aarhus, Surrey Univ. - Guildford, Oxford Univ. - Oxford, IReS - Strasbourg, Messina Univ. - Messina, IEM - Madrid, IPN - Orsay, Staffordshire Univ. - Stoke-on-Trent, GANIL - Caen, UCL - Louvain-la-Neuve, York Univ. - York
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 110 C

Exotic Molecular States in ^{12}Be
FREER M. , ANGELIQUE J.C., AXELSSON L., BENOIT B., BERGMANN U., CATFORD W.N., CHAPPELL S.P.G., CLARKE N.M., CURTIS N., D'ARRIGO A., de GOES BRENNARD E., DORVAUX O., FULTON B.R., GIARDINA G., GREGORI C., GREVY S., HANAPPE F., KELLY G., LABICHE M., LE BRUN C., LEENHARDT S., LEWITOWICZ M., MARKENROTH K., MARQUES F.M., MOTTA M., MURGATROYD J.T., NILSSON T., NINANE A., ORR N.A., PIQUERAS I., SAINT LAURENT M.G., SINGER S.M., SORLIN O., STUTTGE L., WATSON D.L.

School of Phys. and Astr. Univ. of Birmingham - Birmingham , LPC ISMRA - Caen, Fysica Institutionen - Göteborg, ULB - Bruxelles, Aarhus Univ. - Aarhus, Surrey Univ. - Guildford, Nucl. and Astr. Lab. Univ. of Oxford - Oxford, IRS Univ. Louis Pasteur - Strasbourg, INFN and Dip. di Fisica Univ. di Messina - Messina, Inst. Estructura de la Materia - Madrid, IPN - Orsay, School of Sci. Staffordshire Univ. - Stoke-on-Trent, GANIL - Caen, York Univ. - York
Physical Review Letters 82, 7 (1999) 1383.
99 04 C

Experimental Investigation of N = Z Nuclei Around A ~ 80 Through Radioactive Decay
LONGOUR C., APPLEBE D., AXELSSON L., BLANK B., BORGE M.J.G., BRUCE A.M., CATFORD W.N., CHANDLER C., CLARK R., CULLEN D., CZAJKOWSKI S., DAUGAS J.M., DESSAGNE P., FLEURY A., FRANKLAND L., CARCES NARRO J., GELLETLY W., GIOVINAZZO J., GREENHALGH B., GRZYWACZ R., HARDER M., HUCK A., JOKINEN A., JONES K.L., KELSALL N., KNIPPER A., KSZCZOT T., LEWITOWICZ M., MARGUIER G., MIEHE C., PAGE R.D., PEARSON C.J., PIQUERAS I., RAMDHANE M., RAUCH V., REGAN P.H., REED A.T., SORLIN O., TENGBLAD O., WADSWORTH R.
IReS - Strasbourg, Liverpool Univ. - Liverpool, Chalmers Univ. of Techn. - Göteborg, CENBG - Gradignan, IEM - Madrid, Brighton Univ. - Brighton, Surrey Univ. - Guildford, LBNL - Berkeley, GANIL - Caen, York Univ. - York, Warsaw Univ. - Warsaw, Jyväskylä Univ. - Jyväskylä, Constantine Univ. - Constantine, IPN - Orsay
The Beta Decay, from Weak Interaction to Nuclear Structure
Workshop on the Beta Decay, From Weak Interaction to Nuclear Structure
STRASBOURG (FR)
17 Mars 1999
99 137 C

Half-lives of the odd-odd N = Z nuclei ^{78}Y, ^{82}Nb, ^{86}Tc
LONGOUR C., GARCES NARRO J., BLANK B., LEWITOWICZ M., MIEHE Ch., REGAN P.H., APPLEBE D., AXELSSON L., BRUCE A.M., CATFORD W.N., CHANDLER C., CLARK R.M., CULLEN D.M., CZAJKOWSKI S., DAUGAS J.M., DESSAGNE Ph., FLEURY A., FRANKLAND L., GELLETLY W., GIOVINAZZO J., GREENHALGH B., GRZYWACZ R., HARDER M., JONES K.L., KELSALL N., KSZCZOT T., PAGE R.D., PEARSON C.J., REED A.T., SORLIN O., WADSWORTH R.
IReS et Univ. Louis Pasteur - Strasbourg, Surrey Univ. - Guildford, CENBG - Gradignan, GANIL - Caen, Oliver Lodge Lab. - Liverpool, Chalmers Univ. of Tech. - Göteborg, Dept. Mech. Eng. Univ. of Brighton - Brighton, Nucl. Sci. Div. LBNL - Berkeley, York Univ. - York, IEP Warsaw Univ. - Warsaw, IPN - Orsay
Journal of Physics G25 (1999) 759.
99 29 C

Indication for superallowed Fermi decay from the N=Z nuclei ^{78}Y, ^{82}Nb, ^{86}Tc
DESSAGNE PH., LONGOUR C., GARCES NARRO J., APPLEBE D., AXELSSON L., BLANK B., BRUCE A.M., CATFORD W.N., CHANDLER C., CLARK R., CULLEN D., CZAJKOWSKI S., DAUGAS J.M., FLEURY A., FRANKLAND L., GELLETLY W., GIOVINAZZO J., GREEHALGH B., GRZYWACZ R., HARDER M., JONES K.L., KELSALL N., KSZCZOT T., LEWITOWICZ M., MIEHE CH., PAGE R.D., PEARSON C.J., REED A.T., REGAN P.H., SORLIN O., WADSWORTH R.
IReS - Strasbourg, Surrey Univ. - Guildford, Oliver Lodge Lab. Univ. of Liverpool - Liverpool , Chalmers Univ. of Techn. - Göteborg, CENBG - Gradignan, Brighton Univ. - Brighton, NSD LBNL - Berkeley, GANIL - Caen, York Univ. - York, Inst. of Expt. Phys. Warsaw Univ. - Warsaw, IPN - Orsay
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 119 C

Interaction radii of proton-rich radioactive nuclei at A=60-80
LIMA G.F., LEPINE-SZILY A., VILLARI A.C.C., MITTIG W., CHARTIER M., LICHTENTHALER R., HIRATA D., ANGELIQUE J.C., AUDI G., CASANDJIAN J.M., CUNSOLO A., DONZEAUD C., FOTI A., GILLIBERT A., LEWITOWICZ M., LUKYANOV S., MAcCORMICK M., MORRISSEY D.J., ORR N.A., OSTROWSKI A.N., SHERRILL B.M., STEPHAN C., SUOMIJARVI T., TASSAN-GOT L., VIEIRA D.J., WOUTERS J.M.

IFUSP - Sao Paulo, GANIL - Caen, SPring-8 - Hyogo, LPC ISMRA - Caen, CSNSM - Orsay, INFN - Catania, IPN - Orsay, CEN Saclay - Gif sur Yvette, LNR JINR - Dubna, NSCL MSU - East Lansing, Edinburgh Univ. - Edinburgh, LANL - Los Alamos
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 105 C

Interfaces of Nuclear Structure Studies - Decay VS. In-Beam Experiments
GRAWE H., GORSKA M., HU Z., ROECKL E., LIPOGLAVSEK M., FAHLANDER C., NYBERG J., GRZYWACZ R., RYKACZEWSKI K., DAUGAS J.M., LEWITOWICZ M.
GSI - Darmstadt, Lund Univ. - Lund, TSL Uppsala Univ. - Uppsala, Tennessee Univ. - Knowville, ORNL - Oak Ridge, GANIL - Caen
The Beta Decay, from Weak Interaction to Nuclear Structure
Workshop on the Beta Decay, from Weak Interaction to Nuclear Structure
STRASBOURG (FR)
17 Mars 1999
99 139 C

Interplay between Nuclear Structure and Reaction Mechanism in the Production of
DAUGAS J.M., LEWITOWICZ M., ANNE R., ANGELIQUE J.C., AXELSSON L., BERAUD R., BORCEA C., CHABANNAT E., ETHVIGNOT TH., FRANCHOO S., GLOGOWSKI M., GRZYWACZ R., GRAWE H., GUILLEMAUD-MUELLER D., HUYSE M., JANAS Z., KARNY M., LONGOUR C., LOPEZ-JIMENEZ M.J., MUELLER A.C., NOWAK A., de OLIVEIRA-SANTOS F., ORR N.A., PLOCHOCKI A., PFUTZNER M., RYKACZEWSKI K., SAINT-LAURENT M.G., SAUVESTRE J.E., SORLIN O., VAN DUPPEN P., WINFIELD J.S.
GANIL - Caen, LPC - Caen, Dept. of Physics - Göteborg, IPNL - Villeurbanne, IAP - Bucharest, IKS KU - Leuven, IFD Warsaw Univ. - Warsaw, GSI - Darmstadt, IPN - Orsay, IReS - Strasbourg, CEA - Bruyères le Châtel
Projectile-like Short-lived Isomers
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 115 C

Microsecond isomers studies
GRZYWACZ R.
Tennessee Univ. - Knoxville, Warsaw Univ. - Warsaw, GANIL - Caen, Surrey Univ. - Guildford, CENBG - Gradignan, IPN - Orsay, FLNR JINR - Dubna, LPC - Caen, GSI - Darmstadt, CEN - Bruyères-le-Chatel, IPNL - Villeurbanne, IAP - Bucharest, KUL - Leuven, NORDITA - Copenhagen, ORNL - Oak Ridge, CSNSM - Orsay, Daresbury Lab. - Warrington , Göttingen Univ. - Göttingen, Tennessee Univ. - Cookeville, Brighton Univ. - Brighton, Liverpool Univ. - Liverpool, York Univ. - York
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 113 C

Neutron Angular Distributions from the Core Break-up Reactions of the ^{11}Be and ^{11}Li Halo Nuclei
GREVY S., AXELSSON L., ANGELIQUE J.C., ANNE R., GUILLEMAUD-MUELLER D., HANSEN P.G., HORNHOJ P., JONSON B., LEWITOWICZ M., MUELLER A.C., NILSSON T., NYMAN G., ORR N., POUGHEON F., RIISAGER K., SAINT-LAURENT M.G., SMEDBERG M., SORLIN O.

IPN - Orsay, Chalmers Tekniska Högskola - Göteborg, LPC - Caen, GANIL - Caen, NSCL MSU - East Lansing, Aarhus Univ. - Aarhus
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 111 C

Production et étude des isomères de durée de vie courte aux énergies GANIL
EL JADIDA (MA)
10 Mars 1999
DAUGAS J.M.
De la radioactivité naturelle aux faisceaux exotiques - Recherche fondamentale et Applications
Rencontre Franco-Marocaine de Physique Nucléaire
99 159 C

Protons versus Deuterons for Energy Generation
RIDIKAS D., MITTIG W.
GANIL - Caen
Accelerator Driven Transmutation Technologies and Applications
International Conference on Accelerator Driven Transmutation Technologies and Applications.3
PRAGUE (CZ)
7 Juin 1999
99 155 C

Radioactivity of neutron-rich oxygen, fluorine, and neon isotopes
REED A.T., TARASOV O., PAGE R.D., GUILLEMAUD-MUELLER D., PENIONZHKEVICH YU.E., ALLATT R.G., ANGELIQUE J.C., ANNE R., BORCEA C., BURJAN V., CATFORD W.N., DLOUHY Z., DONZAUD C., GREVY S., LEWITOWICZ M., LUKYANOV S.M., MARQUES F.M., MARTINEZ G., MUELLER A.C., NOLAN P.J., NOVAK J., ORR N.A., POUGHEON F., REGAN P.H., SAINT-LAURENT M.G., SIISKONEN T., SOKOL E., SORLIN O., SUHONEN J., TRINDER W., VINCENT S.M.
Oliver Lodge Lab. - Liverpool, FLNR JINR - Dubna, IPN - Orsay, LPC - Caen, GANIL - Caen, IAP - Bucharest-Marugele, NPI - Rez, Surrey Univ. - Guildford, Jyväskylä Univ. - Jyväskylä
Physical Review C60 (1999) 024311-1
99 83 C

Relativistic mean-field study on proton skins and proton halos in exotic nuclei
ZHOUGZHOU REN, MITTIG W., SARAZIN F.
GANIL - Caen, ITP Univ. of Tuebingen - Tuebingen, Nanjing Univ. - Nanjing
Nuclear Physics A652 (1999) 250.
99 64 C

Spectroscopy of Neutron Rich Nuclei in the Vicinity of N=20
REED A.T., PAGE R.D., ALLATT R.G., NOLAN P.J., GUILLEMAUD-MUELLER D., DONZAUD C., GREVY S., MUELLER A.C., POUGHEON F., SORLIN O., PENIONZHKEVICH YU., LUKYANOV S., SOKOL E., TARASOV O., ANGELIQUE J.C., MARQUES F.M., ORR N.A., ANNE R., LEWITOWICZ M., MARTINEZ G., SAINT-LAURENT M.G., TRINDER W., BORCEA C., BURJAN V., DLOUHY Z., NOVAK J., CATFORD W.N., REGAN P.H., VINCENT S.M.
Liverpool Univ. - Liverpool, IPN - Orsay, FLNR JINR - Dubna, LPC - Caen, GANIL - Caen, IAP - Bucharest-Magurele, NPI - Rez, Surrey Univ. - Guildford
AIP Conference Proceedings.455
ENAM 98
IAP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 118 C

Structure of ^{11}Be from the (p, d) reaction in inverse kinematics
WINFIELD J.S., FORTIER S., CATFORD W.N., PITA S., ORR N.A., BLUMENFELD Y., CHAPMAN R., CHAPPELL S.P.G., CLARKE N.M., CURTIS N., FREER M., GALES S., JONES K.L., LANGEVIN-JOLIOT H., LAURENT H., LHENRY I., MAISON J.M., ROUSSEL-CHOMAZ P., SCHAWCROSS M., SMITH M., SPOHR K., SUOMIJARVI T., de VISMES A.
IPN - Orsay, Surrey Univ. - Guildford, LPC - Caen, Paisley Univ. - Paisley, Oxford Univ. - Oxford, School of Phys. and Space Res. - Birmingham, GANIL - Caen
Journal of Physics G25 (1999) 755.
99 28 C

Study of ^{11}Be structure via the p(^{11}Be, ^{10}Be)d reaction
FORTIER S., WINFIELD J.S., PITA S., CATFORD W.N., ORR N.A., BLUMENFELD Y., CHAPMAN R., CHAPPELL S.P.G., CLARKE N.M., CURTIS N., FREER M., GALES S., JONES K.L., LANGEVIN-JOLIOT H., LAURENT H., LHENRY I., MAISON J.M., ROUSSEL-CHOMAZ P., SHAWCROSS M., SMITH M., SPOHR K., SUOMIJARVI T., de VISMES A.
IPN - Orsay, Surrey Univ. - Guidford, LPC - Caen, Paisley Univ. - Paisley, Oxford Univ. - Oxford, Birmingham Univ. - Birmingham, GANIL - Caen
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 107 C

Study of neutron-rich nuclei near the N=20 neutron closed shell
ALLATT R., ANGELIQUE J.C., ANNE R., BORCEA C., DLOUHY Z., DONZAUD C., GREVY S., GUILLEMAUD-MUELLER D., LEWITOWICZ M., LUKYANOV S., MUELLER A.C., NOWACKI F., ORR N.A., PENIONZHKEVICH YU.E., PAGE R.D., POUGHEON F., REED A., SAINT-LAURENT M.G., SCHWAB W., SOKOL E., TARASOV O., TRINDER W., WINFIELD J.S.
FLNR JINR - Dubna, Liverpool Univ. - Liverpool, LPC ISMRA Caen Univ. - Caen, GANIL - Caen, IAP - Bucharest-Magurele, NPI - Rez, IPN - Orsay
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 116 C

Study of the unbound nucleus ^{11}N by th $^{12}C(^{14}N, ^{15}C)^{11}N$ transfer reaction
LEPINE-SZILY A., OLIVEIRA J.M., OSTROWSKI A.N., BOHLEN H.G., LICHTENTHALER R., BLAZEVIC A., BORCEA C., GUIMARAES V., KALPAKCHIEVA R., LAPOUX V., MAcCORMICK M., DE OLIVEIRA F., von OERTZEN W., ORR N.A., ROUSSEL-CHOMAZ P., STOLLA TH., WINFIELD J.S.
IFUSP - Sao Paulo, Sorocaba Univ. - Sorocaba, Edinburgh Univ. - Edinburgh, HMI - Berlin, IAP - Bucarest, UNIP-Objectivo - Sao Paulo, FLNR JINR - Dubna, CEN Saclay - Gif sur Yvette, GANIL - Caen, LPC ISMRA - Caen
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 112 C

Towards a Complete Picture of ^{11}Be Interaction with Silicon
BORCEA C., CARSTOIU F., NEGOITA F., LEWITOWICZ M., SAINT-LAURENT M.G., ANNE R., GUILLEMAUD-MUELLER D., MUELLER A.C., POUGHEON F., SORLIN O., FOMITCHEV A., LUKYANOV S., PENIONZHKEVICH YU., SKOBELEV N., DLOUHY Z.
IFIN HH - Bucharest-Magurele, GANIL - Caen, IPN - Orsay, FLNR JINR - Dubna, NPI - Rez
AIP Conference Proceedings.455

ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 109 C

The use of (d,xn) reactions : RIB production and energy generation
RIDIKAS D., MITTIG W.
GANIL - Caen
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 121 C

Visualizing ^{11} N by resonance reactions
AXELSSON L., MARKENROTH K., BORGE M.J.G., FAYANS S., GOLDBERG V.Z., GREVY S., GUILLEMAUD-MUELLER D., JONSON B., KALLMAN K.M., LONNROTH T., LEWITOWICZ M., MANNGARD P., MARTEL I., MUELLER A.C., MUKHA I., NILSSON T., NYMAN G., ORR N.A., RIISAGER K., ROGATCHEV G.V., SAINT-LAURENT M.G., SERIKOV I.N., SORLIN O., TENGBLAD O., WENANDER F., WINFIELD J.S., WOLSKI R.
Chalmers - Göteborg, CSIC - Madrid, RSC - Moscow, IPN - Orsay, Aabo Akademi - Turku, GANIL - Caen, Aarhus Univ. - Aarhus, LPC - Caen, JINR - Dubna
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 108 C

Decay of Hot Nuclei Formed with Energetic Antiprotons (PS208)
PIENKOWSKI L., BOHNE W., EADES J., EDIGY T.V., FIGUERA P., FUCHS H., GALIN J., GOLDENBAUM F., GOLUBEVA YE.S., GULDA K., HILSCHER D., ILJINOV A.S., JAHNKE U., JASTRZEBSKI J., KURCEWICZ W., LOTT B., MORJEAN M., PAUSCH G., PEGHAIRE A., POLSTER D., PROSCHITZKI S., QUEDNAU B., ROSSNER H., SCHMID S., SCHMID W., ZIEM P.
HMI - Berlin, CERN - Geneve, TU München - Garching, GANIL - Caen, INR Russian Acad. of Sci. - Moscow, Warsaw Univ. - Warzawa, FZ Rossendorf - Dresden, IPN - Orsay
Nuclear Physics A655, 1,2 (1999) 269c.
LEAP 98
Fifth Biennial Conference on Low Energy Antiproton Physics
VILLASIMIUS (IT)
7 Septembre 1998
99 85 D

Decay modes of nuclei following antiproton interaction
GOLDENBAUM F., BOHNE W., EADES J., EDIGY T.v., FIGUERA P., FUCHS H., GALIN J., GULDA K., HILSCHER D., JAHNKE U., JASTRZEBSKI J., KURCEWICZ W., LOTT B., MORJEAN M., PAUSCH G., PEGHAIRE A., PIENKOWSKI L., POLSTER D., PROSCHITZKI S., QUEDNAU B., ROSSNER H., SCHMID S., SCHMID W., ZIEM P.
HMI - Berlin, CERN - Geneve, TU-München - Garching, GANIL - Caen, Warsaw Univ. - Warszawa, FZ-Rossendorf - Dresden, IPN - Orsay
HIRSCHEGG '99 : Multifragmentation
International Workshop XXVII on Gross Properties of Nuclei and Nuclear Excitations
HIRSCHEGG (AT)
17 Janvier 1999
99 18 D

Dynamical Effects in Nuclear Collisions in the Fermi Energy Range : The Case of Heavy Systems
BOCAGE F., COLIN J., LOUVEL M., AUGER G., BACRI CH.O., BELLAIZE N., BORDERIE B., BOUGAULT R., BROU R., BUCHET P., CHARVET J.L., CHBIHI A., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEGRAIN R., LE NEINDRE N., LOPEZ O., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TIREL O., TASSAN-GOT L., VIENT E., VOLANT C., WIELECZKO J.P., LE BRUN C., GENOUX-LUBAIN A., RUDOLF G., STUTTGE L.
LPC - Caen, GANIL - Caen, IPN - Orsay, CEA Saclay - Gif sur Yvette, IPN - Orsay, NIPNE - Bucharest-Magurele, INFN - Napoli, IRES Univ. Louis Pasteur - Strasbourg
Ricerca Scientifica ed Educazione Permanente Suppl. 114 (1999) 241.
BORMIO 99
International Winter Meeting on Nuclear Physics.37
BORMIO (IT)
25 Janvier 1999
99 88 D

First experiments with the FUSION detector
FEKOU-YOUMBI V., SIDA J.L., ALAMANOS N., CHARLOT X., MAZUR C., MOUGEOT A., AUGER F., BAZIN D., BORCEA C., CABOT C., CUNSOLO A., FOTI A., GILLIBERT A., LECESNE N., LEPINE A., LEWITOWICZ M., LIGUORI-NETO R., MARIE F., MITTIG W., MOLS J.P., OTTINI S., POLLACCO E.C., OSTROWSKI A., RIALLOT M., ROUSSEL-CHOMAZ P., VOLANT C., FENG Y.Y.
CEA Saclay - Gif sur Yvette, GANIL - Caen, IPNE - Bucharest Magurele, IPN - Orsay, DF and INFN - Catania, IFU - Sao Paulo, IMP - Lanzhou
NIM A437 (1999) 490.
99 143 D

Fission Time Evolution with Excitation Energy from a Crystal Blocking Experiment
GOLDENDAUM F., MORJEAN M., GALIN J., LIENARD E., LOTT B., PEGHAIRE A., PERIER Y., CHEVALLIER M., DAUVERGNE D., KIRSCH R., POIZAT J.C., REMILLIEUX J., COHEN C., L'HOIR A., PREVOT G., SCHMAUS D., DURAL J., TOULEMONDE M., JACQUET D.
GANIL - Caen, IPNL - Villeurbanne, GPS - Paris, CIRIL - Caen, IPN - Orsay
Physical Review Letters 82, 25 (1999) 5012.
99 61 D

Interplay between the neutron halo structure and reaction mechanisms in collisions of 35 MeV/nucleon ^{6}He with Au
PERIER Y., LOTT B., GALIN J., LIENARD E., MORJEAN M., ORR N.A., PEGHAIRE A., QUEDNAU B.M., VILLARI A.C.C.
GANIL - Caen, LPC - Caen
Physics Letters B459 (1999) 55.
99 67 D

Measurement of small flows in heavy ion collisions around the balance energy
LEFORT T., CUSSOL D., PETER J., AUGER G., BACRI CH.O., BELLAIZE N., BOCAGE F., BORDERIE B., BOUGAULT R., BROU R., BUCHET PH., CHARVET J.L., CHBIHI A., COLIN J., DAYRAS R., DEMEYER A., DORE D., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P.
LPC - Caen, GANIL - Caen, IPN - Orsay, CEA Saclay - Gif sur Yvette, IPN - Villeurbanne, NIPNE - Bucharest-Magurele, INFN - Napoli
Ricerca Scientifica ed Educazione Permanente Suppl. 114 (1999) 216.
BORMIO 99
International Winter Meeting on Nuclear Physics.37

BORMIO (IT)
15 Janvier 1999
99 86 D

Multifragmentation of non-spherical nuclei : preliminary analysis of central Xe + Sn collisions at 50 MeV.A
LE FEVRE A., PLOSZAJCZAK M., TONEEV V.D.
GANIL - Caen
HIRSCHEGG'99 - Multifragmentation
International Workshop XXVII on Gross Properties of Nuclei and Nuclear Excitations
HIRSCHEGG (AT)
17 Janvier 1999
99 17 D

Reaction mechanisms and multi-fragment emission around the Fermi energy
TAMAIN B., METIVIER V., COLIN J., CUSSOL D., LEFORT T., KUKASIK J., PLAGNOL E., AUGER G., BACRI C.O., BELLAIZE N., BOCAGE F., BORDERIE B., BOUGAULT R., BROU R., BUCHET P., DURAND D., FRANKLAND J., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., N'GUYEN A.D., PARLOG M., PETER J., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., TABACARU G., TASSAN-GOT L., TIREL O., VIENT E., VINTACHE D., VOLANT C., WIELECZKO J.P., CHARVET J.L., CHBIHI A., DAYRAS R., DEMEYER A., DORE D.
LPC - Caen, GANIL - Caen, IPN - Orsay, CEA Saclay - Gif sur Yvette, IPNL - Villeurbanne, NINE - Bucharest-Magurele, INFN - Napoli, SUBATECH - Nantes
HIRSCHEGG'99 : Multifragmentation
International Workshop XXVII on Gross Properties of Nuclei and Nuclear Excitations
HIRSCHEGG (AT)
17 Janvier 1999
99 15 D

Study of the excitation energy sharing and dynamics using the neutron detector DéMON in ^{86}Kr + ^{165}Ho Collisions at 60 A MeV
DORVAUX O., STUTTGE L., HANAPPE F., RUDOLF G., BIZARD G., COSTA G.J., DURAND D., GUILLAUME G., HEUSCH B., HUCK A., LE BRUN C., LECOLLEY F.R., MOUATASSIM S., NINANE A., TAMAIN B., TOMASEVIC S.
IRS - Strasbourg, ULB - Bruxelles, LPC - Caen
Nuclear Physics A651 (1999) 225.
99 56 D

Time dependence of the multifragmentation process in 50 A.MeV Xe+Sn reactions
BOUGAULT R., WIELECZKO J.P., D'AGOSTINO M., FRIEDMAN W.A., LE NEINDRE N., GULMINELLI F., CHBIHI A., SALOU S., AUGER G., BACRI C.O., BELLAIZE N., BOCAGE F., BORDERIE B., BROU R., BUCHET P., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEGRAIN R., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., N'GUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C.
LPC - Caen, GANIL - Caen, IPN - Orsay, CEA Saclay - Gif sur Yvette, IPNL - Villeurbanne, NIPNE - Bucharest-Magurele, INFN - Napoli
HIRSCHEGG'99 : Multifragmentation
International Workshop XXVII on Gross Properties of Nuclei and Nuclear Excitations
HIRSCHEGG (AT)
17 Janvier 1999
99 16 D

Some regularities in the production of isotopes in ^{32,34,36}S - induced reactions in the energy range 6-75 A MeV

TARASOV O.B., PENIONZHKEVICH YU.E., ANNE R., BAIBORODIN D.S., BELOZYOROV A.V., BORCEA C., DLOUHY Z., GUILLEMAUD-MUELLER D., KALPAKCHIEVA R., LEWITOWICZ M., LUKYANOV S.M., MAIDIKOV V.Z., MUELLER A.C., OGANESSIAN YU.TS., SAINT-LAURENT M.G., SKOBELEV N.K., SORLIN O., TONEEV V.D., TRINDER W.
FLNR JINR - Dubna, GANIL - Caen, IAP - Bucharest-Magurele, NPI - Rez, IPN - Orsay, Bogoliubov Lab. of Theor. Phys. JINR - Dubna
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 117 D

Formation and Decay of Nuclei Heated with High-Energy Antiprotons
LOTT B., BOHNE W., EADES J., EGIDY T.v., FIGUERA P., FUCHS H., GALIN J., GULDA K., GOLDENBAUM F., HILSCHER D., JAHNKE U., JASTRZEBSKI J., KURCEWICZ W., MORJEAN M., PAUSCH G., PEGHAIRE A., PIENKOWSKI L., POLSTER D., PROSCHITZKI S., QUEDNAU B., ROSSNER H., SCHMID S., SCHMID W., ZIEM P.
HMI - Berlin, CERN-PPE - Geneve, TU-München - Garching, GANIL - Caen, Warsaw Univ. - Warzawa, FZ-Rossendorf - Dresden, IPN - Orsay
Nuclear Physics A654 (1999) 803c.
INPC/98
International Nuclear Physics Conference
PARIS (FR)
14 Août 1998
99 131 D

Multifragmentation of heavy systems around the Fermi Energy : Compression, radial expansion and volume instabilities
RIVET M.F., BORDERIE B., FRANKLAND J.D., BACRI Ch.O., PARLOG M., SQUALLI M., TABACARU G., COLONNA M., GUARNERA A., CHOMAZ Ph., AUGER G., BELLAIZE N., BOCAGE F., BOUGAULT R., BROU R., BUCHET P., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEFORT T., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PETER J., PLAGNOL E., ROSATO E., SALOU S., SAINT-LAURENT F., STECKMEYER J.C., STERN M., TAMAIN B., TIREL O., TASSAN-GOT L., VIENT E., VOLANT C., WIELECZKO J.P.
IPN - Orsay, NIPNE - Bucharest-Magurele, GANIL - Caen, LNS - Catania, LPC - Caen, CEA Saclay - Gif sur Yvette, IPNL - Villeurbanne, INFN - Napoli
HIRSCHEGG '99 : Multifragmentation International Workshop XXVII on Gross Properties and Nuclear Excitations
HIRSCHEGG (AT)
17 Janvier 1999
99 21 D

Prevalence of Fission and Evaporation in the Decay of Heavy Nuclei Excited up to 1000 MeV with Energetic Antiprotons
JAHNKE U., BOHNE W., von EGIDY T., FIGUERA P., GALIN J., GOLDENBAUM F., HILSCHER D., JASTRZEBSKI J., LOTT B., MORJEAN M., PAUSCH G., PEGHAIRE A., PIENKOWSKI L., POLSTER D., PROSCHITZKI S., QUEDNAU B., ROSSNER H., SCHMID S., SCHMID W.
HMI - Berlin, München Univ. - München, GANIL - Caen, Heavy Ion Lab. Warsaw Univ. - Warszawa, FZ-Rossendorf - Dresden, IPN - Orsay
Physical Review Letters 83, 24 (1999) 4959.
99 150 D

Angular Momentum Sharing in Dissipative Collisions
CASINI G., POGGI G., BINI M., CALAMAI S., MAURENZIG P.R., OLMI A., PASQUALI G., STEFANINI A.A., TACCETTI N., STECKMEYER J.C., LAFOREST R., SAINT-LAURENT F.

INFN & Firenze Univ. - Florence, LPC ISMRA & Univ. - Caen, GANIL - Caen
Physical Review Letters 83, 13 (1999) 2537.
99 96 E

Neutrons produits dans des cibles épaisses de Be et ^{238}U irradiées par des deutons de 100 MeV/u et dans une cible épaisse de C irradiée par des ^{36}Ar de 95 MeV/u. Longueurs d'atténuation dans du béton de l'activation de l'uranium
PAUWELS N., PROUST J., BAJARD M., BELIER G., CLAPIER F., ETHVIGNOT T., GARA P., GRANIER T., LEROY R., LIANG C.F., MIREA M., OBERT J., VILLARI A.C.C.
IPN - Orsay, IPNE - Bucarest, CEA - Bruyères-Le-Châtel, CSNSM - Orsay, GANIL - Caen
Radioprotection 34, 3 (1999) 335.
99 148 E

Deep-Subthreshold η and π^0 Production Probing Pion Dynamics in the Reaction Ar + Ca at 180 A MeV
MARTINEZ G., CHARBONNIER Y., APHECETCHE L., DELAGRANGE H., GUDIMA K.K., MATULEWICZ T., PLOSZAJCZAK M., SCHUTZ Y., TONEEV V., TURRISI R., APPENHEIMER M., METAG V., NOVOTNY R., STROHER H., WOLF A.R., WOLF M., WEIB J., AVERBECK R., HLAVAC S., HOLZMANN R., LEFEVRE F., SIMON R.S., STRATMANN R., WISSMANN F., HOEFMAN M., van GOETHEM M.J., LOHNER H., OSTENDORF R.W., SIEMSSEN R.H., VOGT P., WILSCHUT H.W., DIAZ J., MARIN A., KUGLER A., TLUSTY P., WAGNER V., DOPPENSCHMIDT A.
GANIL - Caen, Giessen Univ. - Giessen, GSI - Darmstadt, KVI - Groningen, IFIC Univ. de Valencia-CSIC - Burjassot, INP - Rez, IEP Warsaw Univ. - Warsaw, Frankfurt Univ. - Frankfurt
Physical Review Letters 83, 8 (1999) 1538.
99 84 E

Kaon production in nucleus-nucleus collisions at 92 MeV per nucleon
LEGRAIN R., LECOLLEY J.F., LECOLLEY F.R., ALAMANOS N., BIANCHI L., CASSAGNOU Y., DABROWSKI H., ERAZMUS B., JULIEN J., LEBRUN D., LE BRUN Ch., MOUGEOT A., HAMEAU P., PERRIN G., de SAINTIGNON P., SIDA J.L., WIELECZKO J.P.
DAPNIA CEA Saclay - Gif sur Yvette, LPC ISMRA - Caen, GANIL - Caen, SUBATECH - Nantes, ISN - Grenoble
Physical Review C59, 3 (1999) 1464.
99 12 E

Photon production in heavy-ion collisions close to the pion threshold
MARTINEZ G., APHECETCHE L., CHARBONNIER Y., DELAGRANGE H., d'ENTERRIA D., MATULEWICZ T., SCHUTZ Y., TURRISI R., APPENHEIMER M., METAG V., NOVOTNY R., STROHER H., WOLF A.R., WOLF M., WEISS J., AVERBECK R., HLAVAC S., HOLZMANN R., LEFEVRE F., SIMON R.S., STRATMANN R., WISSMANN F., HOEFMAN M., VAN GOETHEM M.J., LOHNER H., OSTENDORF R.W., SIEMSSEN R.H., VOGT P., WILSCHUT H.W., DIAZ J., MARIN A., KUGLER A., TLUSTY P., WAGNER V., DOPPENSCHMIDT A.
GANIL - Caen, Giessen Univ. - Giessen, GSI - Darmstadt, KVI - Groningen, IFC - Burjassot, INP - Rez, IEP Warsaw Univ. - Warsaw, Inst. für Kernphysik Frankfurt Univ. - Frankfurt-am-Main
Physics Letters B461 (1999) 28.
99 123 E

Thermal Bremsstrahlung in heavy-ion reactions at Fermi energies
d'ENTERRIA D.G., MARTINEZ G.
GANIL - Caen, GSI - Darmstadt, KVI - Groningen, IFIC - Valencia, NPI - Rez, PIG Univ. - Giessen
Ricerca Scientifica ed Educazione Permanente Suppl. 114 (1999) 268.
BORMIO 99 International Winter Meeting on Nuclear Physics.37
BORMIO (IT)
25 Janvier 1999
99 89 E

Users face SPIRAL delay
SANDERS E.
Physics World 12, 11 (1999) 9.

99 135 G

Automatic beam tuning at GANIL
SAVALLE A., GILLETTE P., LEMAITRE E., LECORCHE E., LEBOUCHER C., MOSCATELLO M.H.
GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 48 H

Beam Current Measurements with Logarithmic Converter
JAMET C., PETIT E.
GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 40 H

Beam profile and beam time structure monitors for the extracted beams from the Ganil cyclotrons
ANNE R., VIGNET J.L., GEORGET Y., HUE R., TRIBOUILLARD C.
GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 39 H

Can we make a control system do what the operator wants ?
BUSSE W., BLUMER T., COLLINS J.C., DAVID L., KROON P., LASSILA A., MOUAT M.
HMI - Berlin, PSI - Villigen, IUCF - Bloomington, GANIL - Caen, KVI - Groningen, Jyväskylä Univ. - Jyväskylä, TRIUMF - Vancouver
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 47 H

Control Electronics for the CIME RF System
LEYGE J.F., DI GIACOMO M., DUCOUDRET B., LECHARTIER M., SCHMIECHEN G., MENAGER L., DOUTRESSOULLES C.
GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 37 H

Design and Manufacturing Tools for RF Resonators at GANIL
DI GIACOMO M.
GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 36 H

Diagnostic System Dedicated to the Radioactive Ion Beams at the SPIRAL Facility
LAUNE B., MALARD M., ANNE R., BIBET D., GUILLOT J., LECORCHE E., PIQUET B., RAINE B., TRIBOUILLARD C., ULRICH M., VILLARI A.C.C.
IPN - Orsay, GANIL - Caen
Cyclotrons and their applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 34 H

Experience with high intensity operation of the GANIL facility
BARON E., BAELDE J.L., BERTHE C., BIBET D., CHABERT A., JAMET C., GUDEWICZ P., LOYER F., MOSCATELLO M.H., PETIT E., RICAUD C., SAVALLE A., SENECAL G.
GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 45 H

The first target ion source system for the SPIRAL project : results of the on line tests
LEROY R., ANGELIQUE J.C., BAJEAT O., BERTRAND P., BLANK B., DUCOURTIEUX M., FOURY P., GAUBERT G., HUGUET Y., KANDRI-RODY S., JARDIN P., LECESNE N., LEPINE A., LEWITOWICZ M., MARRY C., MAUNOURY L., OBERT J., ORR N.A., PACQUET J.Y., PROUST J., PUTAUX J.C., SAINT-LAURENT M.G., SORTAIS P., VILLARI A.C.C.
GANIL - Caen, LPC ISMRA - Caen, CENBG - Gradignan, IPN - Orsay, IFUSP - Sao Paulo
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 44 H

Identification System for SPIRAL
KANDRI-RODY S., LAUNE B., ETASSE D., GAUTIER J.M., SAINT-LAURENT M.G., RAINE B., LEBLAY J.P., LECESNE N., OLIVIER L., PIQUET B., VILLARI A., WITTWER G.
IPN - Orsay, Chouaib Doukkali Univ. - El Jadida, LPC - Caen, GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 42 H

The radiation safety access control at GANIL and the Rib SPIRAL facility
LUONG T.T., DEROY J.C., DE SAINT JORES P., MARTINA L.
GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 50 H

Recent Developments for Beam Intensity increase Operation
ANDRE T., ANGER P., BAELDE J.L., BAUMGARTEN R., DOUTRESSOULLES C., DUCOUDRET B., ETAIX G., JAMET C., MARIETTE C., PETIT E., TICHOUX G.
GANIL - Caen
Cyclotrons and their Applications 1998

Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 38 H

Software trends for both the GANIL & SPIRAL control
DAVID L., LECORCHE E.
GANIL - Caen
Cyclotrons and their applications 1998
Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 49 H

SHyPIE : A new source for on line production of multicharged radioactive condensable ion beams
LECESNE N., ANGELIQUE J.C., BLANK B., CLAPIER F., DUCOURTIEUX M., FOURY P., GAUBERT G., HUGUET Y., KANDRI-RODY S., JARDIN P., LEPINE A., LEROY R., LEWITOWICZ M., MARRY C., MAUNOURY L., OBERT J., ORR N.A., PACQUET J.Y., PAUWELS N., PROUST J., PUTAUX J.C., ROBERT E., SAINT-LAURENT M.G., SERON D., SORTAIS P., VILLARI A.C.C.
GANIL - Caen, LPC ISMRA - Caen, CENBG - Gradignan, IPN - Orsay, IFUSP - Sao Paulo
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 43 H

Spiral Facility : First Results on the Cime Cyclotron obtained with Stable Ion Beams
BOURGAREL M.P.
GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 41 H

SPIRAL facility at GANIL : Ion beam simulation and optimisation method for the CIME cyclotron injection system
BERTRAND P., BIBET D., BOURGAREL M.P., BRU B., CHABERT A., DAUDIN F., DUVAL M., OZILLE M., RICAUD C., VARENNE F.
GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 46 H

Système d'identification pour SPIRAL
KANDRI-RODY S., ETASSE D., GAUTIER J.M., SAINT LAURENT M.G., RAINE B., LEBLAY J.P., LECESNE N., OLIVIER L., LAUNE B., PIQUET B., VILLARI A.C., WITTWER G.
IPN - Orsay, LPC ISMRA - Caen, GANIL - Caen
De la radioactivité naturelle aux faisceaux exotiques - Recherche fondamentale et Applications Rencontre Franco-Marocaine de Physique Nucléaire
EL JADIDA (MA)
10 Mars 1999
99 160 H

Vacuum system performances onSPIRAL facility

HORBOWA A., DOLEGIEVIEZ P.
IPN - Orsay, GANIL - Caen
Cyclotrons and their Applications 1998
Proceedings of the Fifteenth International Conference on Cyclotrons and their Applications
CAEN (FR)
14 Juin 1998
99 35 H

An analytic solution for energy loss and time-of-flight calculations for intermediate-energy light ions
SNELLINGS R.J.M., HULSBERGEN W., PRENDERGAST E.P., van den BRINK A., de HAAS A.P., HABETS J.J.L.M., KAMERMANS R., KOOPMANS M., KUIJER P.G., de LAAT C.T.A.M., OSTENDORF R.W., PEGHAIRE A., ROSSEWIJ M.
LBNL - Berkeley, NIKHEF - Utrecht, KVI - Groningen, GANIL - Caen
NIM A438 (1999) 368.
99 151 I

CATS, a low pressure multiwire proportionnal chamber for secondary beam tracking at GANIL
OTTINI-HUSTACHE S., MAZUR C., AUGER F., MUSUMARRA A., ALAMANOS N., CAHAN B., GILLIBERT A., LAGOYANNIS A., MAILLARD O., POLLACCO E., SIDA J.L., RIALLOT M.
DAPNIA CE SACLAY - Gif sur Yvette
NIM A431 (1999) 476.
99 69 I

EXOGAM et la détection gamma auprès des faisceaux radioactifs : du multidétecteur à son utilisation
de FRANCE G.
GANIL - Caen
De la radioactivité naturelle aux faisceaux exotiques - Recherche fondamentale et Applications
Rencontre Franco-Marocaine de Physique Nucléaire
EL JADIDA (MA)
10 Mars 1999
99 158 I

EXOGAM : A λ-ray Spectrometer for Exotic Beams
de FRANCE G.
GANIL - Caen
AIP Conference Proceedings.455
ENAM 98
AIP CONFERENCE PROCEEDINGS
BELLAIRE (USA)
23 Juin 1998
99 120 I

EXOGAM : a γ-ray spectrometer for radioactive beams
AZAIEZ F.
IPN - Orsay
Nuclear Physics A654 (1999) 1003c.
INPC/98
International Nuclear Physics Conference
PARIS (FR)
24 Août 1998
99 133 I

Measurements on a prototype segmented Clover detector
SHEPHERD S.L., NOLAN P.J., CULLEN D.M., APPELBE D.E., SIMPSON J., GERL J., KASPAR M., KLEINBOEHL A., PETER I., REJMUND M., SCHAFFNER H., SCHLEGEL C., de FRANCE G.

Oliver Lodge Lab. - Liverpool, Daresbury Lab. - Warrington, GSI - Darmstadt, GANIL - Caen
NIM A434 (1999) 373.
99 94 I

Pulse-height defect in the passivated ion-implanted Si detectors of the INDRA array
TABACARU G., BORDERIE B., OUATIZERGA A., PARLOG M., RIVET M.F., AUGER C., BACRI CH.O., BOCAGE F., BOUGAULT R., BROU R., BUCHET PH., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., ECOMARD P., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LE FEVRE A., LEFORT T., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., NALPAS L., NGUYEN A.D., PLAGNOL E., ROSATO E., SAINT-LAURENT F., SALOU S., SQUALLI M., STECKMEYER J.C., STERN M., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P.
IPN - Orsay, NIPNE - Bucharest-Magurele, GANIL - Caen, LPC - Caen, CEA Saclay - Gif sur Yvette, IPN - Villeurbanne, Dipart. di Sci. Fis. - Napoli
NIM A428 (1999) 379.
99 51 I

TONNERRE : A new Detector for Delayed-Neutron Spectroscopy
ACHOURI N.L., ANGELIQUE J.C., BORCEA C., BUTA A., CRUCERU I., DE OLIVEIRA F., GENOUX-LUBAIN A., GREVY S., LIENARD E., LE BRUN C., LEWITOWICZ M., MARQUES F.M., MARTIN T., NEGOITA F., ORR N.A., PETER J., SANDU M., TIMIS C.
LPC - Caen, IFIN NIPNE - Bucharest, GANIL - Caen, LPC - Aubière
The Beta Decay, from Weak Interaction to Nuclear Structure
Workshop on the Beta Decay, from Weak Interaction to Nuclear Structure
STRASBOURG (FR)
17 Mars 1999
99 140 I

VAMOS : a VAriable MOde high acceptance Spectrometer
SAVAYOLS H., VAMOS collaboration
CENB - Gradignan, CEN Saclay - Gif sur Yvette, GANIL - Caen, IPN - Orsay, GSI - Darmstadt, Giessen Univ. - Giessen, CCLRC - Daresbury, Liverpool Univ. - Liverpool, Manchester Univ. - Manchester, Surrey Univ. - Guildford
Nuclear Physics A654 (1999) 1027c.
INPC/98
International Nuclear Physics Conference
PARIS (FR)
24 Août 1998
99 134 I

The linear buncher of SPIRAL Beam test of a prototype
CHABERT A., RICAUD Ch., BOY L., MONSANGLANT B., LE COZ W.
GANIL - Caen, IPN - Orsay
NIM A423 (1999) 7.
99 06 S

An algebraic approach to shape coexistence
DE COSTER C., DE BEULE J., DECROIX B., HEYDE K., OROS A.M., VAN ISACKER P.
Vakgroep Subat. en Stralingsfysica - Gent, GANIL - Caen
Journal of Physics G25 (1999) 671.
99 26 T

Boltzmann-Langevin Approaches
CHOMAZ PH.
GANIL - Caen
Nuclear Matter in Different Phases and Transitions
Workshop on Nuclear Matter in Different Phases and Transitions
LES HOUCHES (FR)

31 Mars 1998
99 100 T

Boson expansion methods applied to a two-level model in the sutdy of multiple giant resonances
VOLPE C., CHOMAZ Ph., ANDRES M.V., CATARA F., LANZA E.G.
IPN - Orsay, GANIL - Caen, Sevilla Univ. - Sevilla, INFN - Catania
Nuclear Physics A647 (1999) 246.
99 14 T

Continuum effects for the mean-field and pairing properties of weakly bound nuclei
BENNACEUR K., DOBACZEWSKI J., PLASZAJCZAK M.
GANIL - Caen, ITP Warsaw Univ. - Warsaw, Tennessee Univ. - Knoxville, Joint Inst. for Heavy Ion Res. - Oak Ridge
Physical Review V60 (1999) 034308-1.
99 95 T

Dynamical symmetries in the structure of nuclei
VAN ISACKER P.
GANIL - Caen
Report on Progress in Physics 62 (1999) 1661.
99 152 T

Dynamical Symmetry and Higher-Order Interactions
VAN ISACKER P.
GANIL - Caen
Physical Review Letters 83, 21 (1999) 4269.
99 142 T

Energy correlations as thermodynamical signals for phase transitions in finite systems
CHOMAZ Ph., GULMINELLI F.
GANIL - Caen, LPC - Caen
Nuclear Physics A647 (1999) 153.
99 11 T

The extended proton-neutron interacting boson model and possible applications
DECROIX B., DE COSTER C., HEYDE K., OROS A.M., DE BEULE J., VAN ISACKER P.
Vakgroep Subat. en Stralingsfysica - Gent, GANIL - Caen
Journal of Physics G25 (1999) 855.
99 30 T

The interacting Boson Model with SU(3) Charge Symmetry and Its Application to Even-Even N≈Z Nuclei
GARCIA-RAMOS J.E., VAN ISACKER P.
Sevilla Univ. - Sevilla, GANIL - Caen
Annals of Physics 274 (1999) 45.
99 52 T

Mean field instabilities
CHOMAZ Ph., LACROIX D., JACQUOT B., COLONNA M., AYIK S.
GANIL - Caen, LNS - Catania, TTU - Cookeville
HIRSCHEGG '99 : Multifragmentation
International Workshop XXVII on Gross Properties of Nuclei and Nuclear Excitations
HIRSCHEGG (AT)
17 Janvier 1999
99 22 T

Multiple Collective Vibrations and Nonlinear Dynamics in Mean-Field Approaches

VOLPE C., CHOMAZ PH.
GANIL - Caen, IPN - Orsay
Physical Review Letters 83, 6 (1999) 1119.
99 66 T

Multiscale fluctuations in the nuclear response
LACROIX D., CHOMAZ PH.
GANIL - Caen
Physical Review C60 (1999) 064307-1.
99 154 T

On the simulation of extended TDHF theory
LACROIX D., CHOMAZ Ph., AYIK S.
GANIL - Caen, Tennessee Techn. Univ. - Cookeville
Nuclear Physics A651 (1999) 369.
99 62 T

Phase transitions in finite systems : observable signals
GULMINELLI F., CHOMAZ Ph.
LPC - Caen, GANIL - Caen
HIRSCHEGG '99 : Multifragmentation
International Workshop XXVII on Gross Properties of Nuclei and Nuclear Excitations
HIRSCHEGG (AT)
*17 Janvier 1999*99 20 T

Phase transition in an isospin dependent Lattice Gas Model
CHOMAZ Ph., GULMINELLI F.
GANIL - Caen, LPC ISMRA - Caen
Physics Letters B447 (1999) 221.
99 09 T

Pseudo SU (4) symmetry in nuclei
VAN ISACKER P., JUILLET O.
GANIL - Caen
Nuclear Physics A654 (1999) 739c.
INPC/98
International Nuclear Physics Conference
PARIS (FR)
24 Août 1998
99 128 T

Theoretical description of the towing mode through a time-dependent quantum calculation
LACROIX D., SCARPACI J.A., CHOMAZ PH.
GANIL - Caen, IPN - Orsay
Nuclear Physics A658 (1999) 273.
99 141 T

T = 0 and T = 1 pairs in N ~ Z Nuclei
VAN ISACKER P., JUILLET O.
GANIL - Caen
Journal of Physics G25 (1999) 675.
99 27 T

2000

Anharmonic double-phonon excitations in the interacting boson model
GARCIA-RAMOS J.E., ARIAS J.M., VAN ISACKER P.
Inst. for Theor. Phys. - Gent, Dept. de Fis. At. Mol. y Nucl. - Sevilla, GANIL - Caen
Physical Review C62 (2000) 064309-1.
00 111 A

Analysis of the $^{16}O(p,g)^{17}F$ capture reaction using the shell model embedded in the continuum
BENNACEUR K., NOWACKI F., OKOLOWICZ J., PLOSZAJCZAK M.
GANIL - Caen, LPT - Strasbourg, INP - Krakow
Nuclear Physics A671 (2000) 203.
00 41 A

Capture reactions of astrophysical interest in the shell model embedded in the continuum
BENNACEUR K., NOWACKI F., OKOLOWICZ J., PLOSZAJCZAK M.
GANIL - Caen, LPT - Strasbourg, INP - Krakow
Acta Polonica B31, 2 (2000) 311.
00 68 A

Collisional damping and collisional coupling in the nuclear collective response
CHOMAZ PH., LACROIX D., AYIK S., COLONNA M.
GANIL - Caen, LPC - Caen, Tennessee Techn. Univ. - Cookeville, LNS - Catania
Physical Review C62 (2000) 024307-1.
00 62 A

Collisional effects in the finite temperature dipole response of ^{120}Sn and ^{208}Pb
LACROIX D., CHOMAZ P., AYIK S.
LPC - Caen, GANIL - Caen, Tennessee Techn. Univ. - Cookeville
Physics Letters B489 (2000) 137.
00 78 A

Electromagnetic properties of low-excitation states in ^{191}Ir and ^{193}Ir and supersymmetry schemes
BEZAKOVA E., STUCHBERY A.E., BOLOTIN H.H., SEALE W.A., KUYUCAK S., VAN ISACKER P.
The Australian Nat. Univ. - Canberra, Melbourne Univ. - Victoria, GANIL - Caen
Nuclear Physics A669 (2000) 241.
00 24 A

Excitation of multiple giant dipole resonances : from spherical to deformed nuclei
ANDRES M.V., LANZA E.G., VAN ISACKER P., VOLPE C., CATARA F.
Sevilla Univ. - Sevilla, INFN - Catania, GANIL - Caen, IPN - Orsay
Physics Letters B470 (1999) 6.
99 153 A

First direct proof of internal conversion between bound states
CARREYRE T., HARSTON M.R., AICHE M., BOURGINE F., CHEMIN J.F., CLAVERIE G., GOURDOUR J.P., SCHEURER J.N., ATTALLAH F., BOGAERT G., KIENER J., LEFEBVRE A., DURELL J., GRANDIN J.P., MEYERHOF W.E., PHILLIPS W.
CENBG - Gradignan, CEA Saclay - Gif sur Yvette, GSI - Darmstadt, CSNSM - Orsay, Manchester Univ. - Manchester, CIRIL - Caen, Stanford Univ. - Stanford
Physical Review C62 (2000) 024311-1
00 64 A

Global analysis of proton nucleus reaction cross sections
DE VISMES A., ROUSSEL-CHOMAZ P., CARSTOIU F.
GANIL - Caen, IFIN-HH - Bucharest-Magurele
Physical Review C62 (2000) 064612-1.
00 113 A

L'harmonie de coeurs d'atomes
CHOMAZ PH., BLUMENFELD Y., SCARPACI J.A.
GANIL - Caen, IPN - Orsay
Pour la Science 279 (2001) 32.
01 03 A

Inclusive proton production cross sections in (d,xp) reactions induced by 100 MeV deuterons
RIDIKAS D., MITTIG W., SAVAJOLS H., ROUSSEL-CHOMAZ P., FORTSCH S.V., LAWRIE J.J., STEYN G.F.
GANIL - Caen, NAC - Faure
Physical Review C63 (2000) 014610.
00 168 A

Interrelation between the isoscalar octupole phonon and the proton-neutron mixed-symmetry quadrupole phonon in near-spherical nuclei
SMIRNOVA N.A., PIETRALLA N., MIZUSAKI T., VAN ISACKER P.
GANIL - Caen, CSNSM - Orsay, INP - Moscow, Inst. für Kernphysik - Köln, Yale Univ. - New Haven, Senshu Univ. - Kanagawa
Nuclear Physics A678 (2000) 235.
00 79 A

Low-lying collective states in neutron-rich oxygen isotopes via proton scattering
KHAN E., BLUMENFELD Y., NGUYEN VAN GIAI, SUOMIJARVI T., ALAMANOS N., AUGER F., COLO G., FRASCARIA N., GILLIBERT A., GLASMACHER T., GODWIN M., KEMPER K.W., LAPOUX V., LHENRY I., MARECHAL F., MORRISSEY D.J., MUSUMARRA A., ORR N.A., OTTINI-HUSTACHE S., PIATTELLI P., POLLACCO E.C., ROUSSEL-CHOMAZ P., ROYNETTE J.C., SANTONOCITO D., SAUVESTRE J.E., SCARPACI J.A., VOLPE C.
IPN - Orsay, DAPNIA CEA Saclay - Gif sur Yvette, INFN - Milan, NSCL MSU - East Lansing, Florida State Univ. - Tallahassee, LPC ISMRA - Caen, INFN LNS - Catania, GANIL - Caen, SPN CEA Bruyères - Bruyères-le-Châtel
Physics Letters B490 (2000) 45.
00 85 A

Negative heat capacity in the critical region of nuclear fragmentation : an experimental evidence of the liquid-gas phase transition
D'AGOSTINO M., GULMINELLI F., CHOMAZ PH., BRUNO M., CANNATA F., BOUGAULT R., GRAMEGNA F., IORI I., LE NEINDRE N., MARGAGLIOTTI G.V., MORONI A., VANNINI G.
INFN - Bologna, LPC - Caen, GANIL - Caen, INFN - Legnaro, INFN - Milano, INFN - Trieste
Physics Letters B473 (2000) 219.
00 07 A

Le noyau atomique en pleines formes
CHOMAZ PH.
GANIL - Caen
La Recherche 335 (2000) 26.
00 84 A

Pairing anti-halo effect
BENNACEUR K., DOBACZEWSKI J., PLOSZAJCZAK M.
CE - Bruyères-le-Châtel, GANIL - Caen, ITP Warsaw Univ. - Warsaw
Physics Letters B496 (2000) 154.
00 109 A

Shell model description of $^{16}O(p,g)$ ^{17}F and $^{16}O(p,p)$ ^{16}O reactions
BENNACEUR K., MICHEL N., NOWACKI F., OKOLOWICZ J., PLOSZAJCZAK M.
GANIL - Caen, CE - Bruyères-le-Châtel, LPT - Strasbourg, INP - Krakow
Physics Letters B488 (2000) 75.
00 71 A

Statistical aspects of nuclear coupling to continuum
DROZDZ S., OKOLOWICZ J., PLOSZAJCZAK M., ROTTER I.
INP - Krakow, GANIL - Caen, MPI - Dresden
Physical Review C62 (2000) 024313-1.
00 63 A

Study of diffractive and refractive structure in the elastic ^{16}O + ^{16}O scattering at incident energies ranging from 124 to 1120 MeV
KHOA D.T., VON OERTZEN W., BOHLEN H.G., NUOFFER F.
HMI - Berlin, Inst. Nucl. Sci. & Techn. - Hanoi, Tubingen Univ. - Tubingen
Nuclear Physics A672 (2000) 387.
00 43 A

Two-neutron interferometry as a probe of the nuclear halo
MARQUES F.M., LABICHE M., ORR N.A., ANGELIQUE J.C., AXELSSON L., BENOIT B., BERGMANN U.C., BORGE M.J.G., CATFORD W.N., CHAPPELL S.P.G., CLARKE N.M., COSTA G., CURTIS N., D'ARRIGO A., de OLIVEIRA SANTOS F., de GOES BRENNAND E., DORVAUX O., FREER M., FULTON B.R., GIARDINA G., GREGORI C., GREVY S., GUILLEMAUD-MUELLER D., HANAPPE F., HEUSCH B., JONSON B., LE BRUN C., LEENHARDT S., LEWITOWICZ M., LOPEZ M.J., MARKENROTH K., MOTTA M., MUELLER A.C., NILSSON T., NINANE A., NYMAN G., PIQUERAS I., RIISAGER K., SAINT LAURENT M.G., SARAZIN F., SINGER S.M., SORLIN O., STUTTGE L.
LPC - Caen, Chalmers Tekniska Högskola - Göteborg, ULB - Bruxelles, Aarhus Univ. - Aarhus, Inst. de Estruc. de la Materia - Madrid, Surrey Univ. - Guildford, Oxford Univ. - Oxford, School of Phys. and Astr. - Birmingham, IReS - Strasbourg, GANIL - Caen, IPN - Orsay, Messina Univ. - Messina
Physics Letters B476 (2000) 219.
00 15 A

Digital filtering : a common analysis for data and mean field theories in heavy-ions collisions at intermediate energy
LECOLLEY J.F., GALICHET E., GUINET D.C.R., BOUGAULT R., GULMINELLI F., AUGER G., BACRI CH.O., BOCAGE F., BORDERIE B., BROU R., BUCHET P., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., FRANKLAND J.D., GENOUIN-DUHAMEL E., GERLIC E., LAUTESSE P., LAVILLE J.L., LEFORT T., LEGRAIN R., LeNEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P.
LPC - Caen, IPNL - Villeurbanne, GANIL - Caen, IPN - Orsay, CEA Saclay - Gif sur Tvette, NIPNE - Bucharest, Napoli Univ. - Napoli
NIM A441 (2000) 517.
00 13 B

Dynamical effects in nuclear collisions in the Fermi energy range : aligned breakup of heavy projectiles
BOCAGE F., COLIN J., LOUVEL M., AUGER G., BACRI CH.O., BELLAIZE N., BORDERIE B., BOUGAULT R., BROU R., BUCHET P., CHARVET J.L., CHBIHI A., CUSSOL D., DAYRAS R., DE CESARE N., DEMEYER A., DORE D., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEGRAIN R., LE NEINDRE N., LOPEZ O., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TIREL O., TASSAN-GOT L., VIENT E., VIGILANTE M., VOLANT C., WIELECZKO J.P., LE BRUN C., GENOUX-LUBAIN A., RUDOLF G., STUTTGE L.

LPC - Caen, GANIL - Caen, IPN - Orsay, CEA Saclay - Gif sur Yvette, IPN - Villeurbanne, NIPNE - Bucharest-Magurele, INFN - Napoli, IReS - Strasbourg
Nuclear Physics A676 (2000) 391.
00 60 B

Effect of the intermediate velocity emissions on the quasi-projectile properties for the Ar + Ni system at 95 A MeV
DORE D., BUCHET PH., CHARVET J.L., DAYRAS R., NALPAS L., CUSSOL D., LEFORT T., LEGRAIN R., VOLANT C., AUGER G., BACRI CH.O., BELLAIZE N., BOCAGE F., BOUGAULT R., BOURIQUET B., BROU R., CHBIHI A., COLIN J., DEMEYER A., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., HUDAN S., LAUTESSE P., LAVAUD F., LAVILLE J.L., LECOLLEY J.F., LEDUC C., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NORMAND J., PARLOG M., PAWLOWSKI P., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., WIELECZKO J.P.
CEA Saclay - Gif sur Yvette, LPC - Caen, GANIL - Caen, IPN - Orsay, IPNL - Villeurbanne, NIPNE - Bucharest, DSF Univ. di Napoli - Napoli, CNAM - Paris
Physics Letters B491 (2000) 15.
00 88 B

Emission time scale of light particles in the Xe + Sn at 50 AMeV. A probe for dynamical emission ?
GOURIO D., ARDOUIN D., ASSENARD M., AUGER G., BACRI CH.O., BELLAIZE N., BENKIRANE A., BENLLIURE J., BERTHIER B., BISQUER E., BORDERIE B., BOUGAULT R., BOX P., BROU R., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DE FILIPPO E., DEMEYER A., DONNET C., DURAND D., ECOMARD P., EUDES P., GERMAIN M., GUINET D., LAKEHAL-AYAT L., LAUTESSE P., LAVILLE J.L., LEBRETON L., LE BRUN C., LECOLLEY J.F., LEFORT T., LEFEVRE A., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MARIE N., METIVIER V., NALPAS L., OUATIZERGA A., PARLOG M., PETER J., PLAGNOL E., POLLACO E., RAHMANI A., REGIMBART R., REPOSEUR T., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., SQUALLI M., STECKMEYER J.C., TABACARU G., TAMAIN B., TASSAN-GOT L., VIENT E., VOLANT C., WIELECZKO J.P., WIELOCH A., YUASA-NAKAGAWA K.
GSI - Darmstadt, SUBATECH - Nantes, GANIL - Caen, IPN - Orsay, LPC - Caen, CEA Saclay - Gif sur Yvette, IPNL - Villeurbanne, NIPNE - Bucharest-Magurele, DSF Sezione INFN - Napoli
The European Physical Journal A7 (2000) 245.
00 20 B

Evidence for dynamical proton emission in peripheral Xe + Sn collisions at 50 MeV/u
GERMAIN M., GOURIO D., EUDES PH., LAVILLE J.L., REPOSEUR T., ARDOUIN D., ASSENARD M., AUGER G., BACRI C.O., BOCAGE F., BORDERIE B., BOUGAULT R., BROU R., BUCHET P., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., GULMINELLI F., LAUTESSE P., LAUTRIDOU P., LEBRUN C., LECOLLEY J.F., LEFORT T., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., METIVIER V., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RAHMANI A., RIVET M.F., ROSATO E., ROY R., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TIREL O., TASSAN-GOT L., VIENT E., VOLANT C., WIELECZKO J.P.
SUBATECH - Nantes, GSI - Darmstadt, GANIL - Caen, IPN - Orsay, LPC - Caen, CEA Saclay - Gif sur Yvette, IPN Lyon - Villeurbanne, NIPNE - Bucharest-Magurele, INFN - Napoli, Laval Univ. - Québec
Physics Letters B488 (2000) 211.
00 81 B

First results from two-nucleon interferometry experiment, E286, at GANIL
PRZEWLOCKI M., PLUTA J., HANAPPE F., MATERNA TH., STUTTGE L., ANGELIQUE J.C., BENOIT B., DE GOES BRENNAND E., BIZARD G., COLIN J., COSTA G., DESESQUELLES P., DORVAUX O., DURAND D., ERAZMUS B., GOSSIAUX P.B., HARTNACK C., KIELISZEK A., KIRCHNER T., KULESHOV S., LEBRUN C., LEDNICKY R., LESZCZYNSKI P., MARQUES M., MARTIN L., MIKHAILOV K., MILLER K., NEUBAUER R., PAPATHEOFANOUS G., PAWLAK T., STARANOWICZ A., STAVINSKY A., TAMAIN B., VLASOV A., VOROBYEV L., WOSINSKA K.

Warsaw Univ. of Techn. - Warsaw, ULB - Bruxelles, IReS - Strasbourg, LPC - Caen, ISN - Grenoble, SUBATECH - Nantes, Czech Acad. of Sci. - Prague, Inst. of Theor. and Experim. Phys. - Moscow
Acta Physica Polonica B31, 2 (2000) 379.
00 70 B

Flow and multifragmentation of ^{24}Mg + ^{27}Al at intermediate energies
PRENDERGAST E.P., van den BRINK A., de HAAS A.P., KAMERMANS R., KUIJER P.G., de LAAT C.T.A.M., OSTENDORF R.W., OTI E., PEGHAIRE A., SNELLINGS R.J.M.
NIKHEF - Utrecht, KVI - Groningen, GANIL - Caen, LBNL - Berkeley
Physical Review C61 (2000) 024611.
00 11 B

Fragmentation and damping of the collective response in extended random-phase approximation
AYIK S., LACROIX D., CHOMAZ PH.
Tennessee Techn. Univ. - Cookeville, GANIL - Caen
Physical Review C61 (2000) 014608-1.
00 01 B

Mass scaling of reaction mechanisms in intermediate energy heavy ion collisions
METIVIER V., TAMAIN B., AUGER G., BACRI C.O., BENLLIURE J., BOCAGE F., BORDERIE B., BOUGAULT R., BROU R., BUCHET PH., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., ECOMARD P., EUDES P., GOURIO D., GUINET D., LAFOREST R., LAUTESSE P., LAVILLE J.L., LEBRETON L., LECOLLEY J.F., LE FEVRE A., LEGRAIN R., LOPEZ O., LOUVEL M., MARIE N., NALPAS L., PARLOG M., PETER J., PLAGNOL E., RAHMANI A., REPOSEUR T., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., TASSAN-GOT L., VIENT E., VOLANT C., WIELECZKO J.P.
LPC - Caen, SUBATECH - Nantes, GANIL - Caen, IPN - Orsay, CEA Saclay - Gif sur Yvette, IPNL - Villeurbanne, INFN - Napoli, Santiago de Compostela Univ. - Santiago de Compostela
Nuclear Physics A672 (2000) 357.
00 44 B

Onset of midvelocity emissions in symmetric heavy ion reactions
PLAGNOL E., LUKASIK J., AYGER G., BACRI CH.O., BELLAIZE N., BOCAGE F., BORDERIE B., BOUGAULT R., BROU R., BUCHET P., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P.
GANIL - Caen, IPN - Orsay, LPC - Caen, CEA Saclay - Gif sur Yvette, IPN - Villeurbanne, NIP-NE - Bucharest-Magurele, INFN - Napoli
Physical Review C61 (2000) 014606-1.
00 02 B

Reaction mechanisms and multifragmentation processes in ^{64}Zn + ^{58}Ni at 35A - 79A MeV
WADA R., HAGEL K., CIBOR J., GONIN M., KEUTGEN TH., MURRAY M., NATOWICZ J.B., STECKMEYER J.C., KERAMBRUM A., ANGELIQUE J.C., AUGER A., BIZARD G., BROU R., CABOT C., CREMA E., CUSSOL D., DURAND D., EL MASRI Y., EUDES P., HE Z.Y., JEONG S.C., LEBRUN C., PATRY J.P., PEGHAIRE A., PETER J., REGIMBART R., ROSATO E., SAINT-LAURENT F., TAMAIN B., VIENT E.
Texas A&M Univ. - College Station, Tohoku Univ. - Sendai, LPC - Caen, GANIL - Caen, UCL - Louvain-Neuve, SUBATECH - Nantes, Napoli Univ. - Napoli
Physical Review C62 (2000) 034601-1.
00 66 B

Study of intermediate velocity products in the Ar + Ni collisions between 52 and 95 A.MeV
LEFORT T., DORE D., CUSSOL D., MA Y.G., PETER J., DAYRAS R., ASSENARD M., AUGER G., BACRI CH.O., BOCAGE F., BOUGAULT R., BROU R., BUCHET PH., CHARVET J.L., CHBIHI A., COLIN J., DEMEYER A., DURAND D., EUDES P., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GERMAIN M., GOURIO D., GUINET D., HURST B., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LE FEVRE A., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., N'GUYEN A.D., PARLOG M., PLAGNOL E., POLITI G., RAHMANI A., REPOSEUR T., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P., WIELOCH A.
LPC - Caen, CEA Saclay - Gif sur Yvette, SUBATECH - Nantes, GANIL - Caen, IPN - Orsay, IPNL - Villeurbanne, NIPNE - Bucharest , Napoli Univ. - Napoli
Nuclear Physics A662 (2000) 397.
00 12 B

Two-nucleon correlations at small relative velocities in heavy ion collisions
PLUTA J., PAWLAK T., GOSSIAUX P.B., KIELISZEK A., HANAPPE F., MATERNA TH., STRUTTGE L., ANGELIQUE J.C., BENOIT B., DE GOES BRENNAND E., BIZARD G., COLIN J., COSTA G., DESESQUELLES P., DORVAUX O., DURAND D., ERAZMUS B., HARTNACK C., KIRCHNER T., KULESHOV S., LEBRUN C., LEDNICKY R., LESZCZYNSKI P., MARQUES M., MARTIN L., MIKHAILOV K., MILLER K., NEUBAUER R., PAPATHEOFANOUS G., PRZEWLOCKI M., STARANOWICZ A., STAVINSKY A., TAMAIN B., VLASOV A., VOROBYEV L., WOSINSKA K.
Warsaw Univ. of Techn. - Warsaw, SUBATECH - Nantes, ULB - Bruxelles, IReS - Strasbourg, LPC - Caen, ISN - Grenoble, Czech Acad. of Sci. - Prague, Inst. of Theor. and Experim. Phys. - Moscow
Acta Physica Polonica B31, 2 (2000) 371.
00 69 B

Two-neutron correlations at small relative momenta in ^{400}Ar + ^{197}Au collisions at 60 MeV/nucleon
PLUTA J., WOSINSKA K., BASRAK Z., BIZARD G., BENOIT B., DESESQUELLES P., DORVAUX O., DURAND D., ERAZMUS B., HANAPPE F., JAKOBSSON B., LEBRUN C., LECOLLEY F.R., LEDNICKY R., LESZCZYNSKI P., MIKHAILOV K., MILLER K., NOREN B., PAWLAK T., PRZEWLOCKI M., SKEPPSTEDT O., STARANOWICZ A., STAVINSKIY A., STUTTGE L., TAMAIN B.
Warsaw Univ. - Warsaw, Ruder Boskovic Inst. - Zagreb, LPC - Caen, ULB - Bruxelles, ISN - Grenoble, Univ. of Jyväskylä - Jyväskylä, SUBATECH - Nantes, Univ. of Lund - Lund, Inst. of Phys. ASCR - Prague, ITEP - Moscow, Chalmers Univ. of Techn. - Göteborg, IReS - Strasbourg
Euro. Phys. J. A9 (2000) 63.
00 101 B

Vaporization and multifragmentation in the reaction 1.2 GeV p + Cu and Ag
PIENKOWSKI L., BOHNE W., von EGIDY T., FIGUERA P., GALIN J., GOLDENBAUM F., HILSCHER D., JAHNKE U., JASTRZEBSKI J., LOTT B., MORJEAN M., PAUSCH G., PEGHAIRE A., POLSTER D., PROSCHITZKI S., QUEDNAU B., ROSSNER H., SCHMID S., SCHMID W.
HMI - Berlin, TU-München - Garching, GANIL - Caen, Warsaw Univ. - Warszawa, FZ-Rossendorf - Dresden, IPN - Orsay
Physics Letters B472 (2000) 15.
00 03 B

Crossing the dripline to ^{11}N using elastic resonance scattering
MARKENROTH K., AXELSSON L., BAXTER S., BORGE M.J.G., DONZAUD C., FAYANS S., FYNBO H.O.U., GOLDBERG V.Z., GREVY S., GUILLEMAUD-MUELLER D., JONSON B., KALLMAN K.M., LEENHARDT S., LEWITOWICZ M., LONNROTH T., MANNGARD P., MARTEL I., MUELLER A.C., MUKHA I., NILSSON T., NYMAN G., ORR N.A., RIISAGER K., ROGACHEV G.V., SAINT-LAURENT M.G., SERIKOV I.N., SHUL'GINA N.B., SORLIN O., STEINER M., TENGBAD O., THOENNESSEN M., TRYGGESTAD E., TRZASKA W.H., WENANDER F., WINFIELD J.S., WOLSKI R.
Chalmers Tekniska Högskola - Göteborg, NSCL MSU - East Lansing, Inst. Estr. Mater. - Madrid, IPN - Orsay, Kurchatov Inst. - Moscow, CERN - Geneve, Abo Akademi - Turku, GANIL - Caen, Aarhus Univ. - Aarhus, LPC

- Caen, INP - Cracow, Technische Univ. - Darmstadt, Jyväskylä Univ. - Jyväskylä, Notre Dame Univ. - Notre Dame
Physical Review C62 (2000) 034308-1.
00 86 C

Deriving the angular variation of p-- distributions for halo neutrons with robust statistics
AXELSSON L., ANGELIQUE J.C., ANNE R., GREVY S., GUILLEMAUD-MUELLER D., HORNSHOJ P., JONSON B., LEWITOWICZ M., MUELLER A.C., NILSSON T., NYMAN G., ORR N.A., POUGHEON F., RIISAGER K., SAINT-LAURENT M.G., SMEDBERG M., SORLIN O.
Chalmers and Göteborg Univ. - Göteborg, LPC - Caen, GANIL - Caen, IPN - Orsay, Aarhus Univ. - Aarhus
Nuclear Physics A679 (2001) 215.
01 01 C

Discovery of Doubly Magic ^{48}Ni
BLANCK B., CHARTIER M., CZAJKOWSKI S., GIOVINAZZO J., PRAVIKOFF M.S., THOMAS J.C., de FRANCE G., de OLIVEIRA SANTOS F., LEWITOWICZ M., BORCEA C., GRZYWACZ R., JANAS Z., PFUTZNER M.
CENBG - Gradignan, GANIL - Caen, IAP - Bucharest-Magurele, IEP Univ. of Warsaw - Warsaw
Physical Review Letters 84, 6 (2000) 1116.
00 04 C

Discovery of doubly magic nickel
GANIL - Caen
CERN Courrier 40, 3 (2000) 27.
00 21 C

Erratum to "Beta decay half-lives of neutron rich Ti-Co isotopes around N = 40"
SORLIN O., DONZAUD C., AXELSSON L., BELLEGUIC M., BERAUD R., BORCEA C., CANCHEL G., CHABANAT E., DAUGAS J.M., EMSALLEM A., GIROD M., GUILLEMAUD-MUELLER D., KRATZ K.L., LEENHARDT S., LEWITOWICZ M., LONGOUR C., LOPEZ M.J., DE OLIVEIRA SANTOS F., PETIZON L., PFEIFFER B., POUGHEON F., SAINT-LAURENT M.G., SAUVESTRE J.E.
IPN - Orsay, Chalmers Tekniska Högskola - Göteborg, IPNL - Villeurbanne, GANIL - Caen, IAP - Bucharest-Magurele, CE - Bruyères-le-Châtel, Mainz Univ. - Mainz, IReS - Strasbourg
Nuclear Physics A669 (2000) 351.
00 23 C

First observation of doubly-magic ^{48}Ni
GIOVINAZZO J., BLANK B., BORCEA C., CHARTIER M., CZAJKOWSKI S., FLEURY A., de FRANCE G., GRZYWACZ R., JANAS Z., LEWITOWICZ M., de OLIVIERA F., PFUTZNER M., PRAVIKOFF M.S., THOMAS J.C.
CENBG - Gradignan, GANIL - Caen, IAP - Bucharest-Magurele, IEP Warsaw Univ. - Warsaw
Proton-emitting nuclei
PROCON'99 First International Symposium
OAK RIDGE (US)
7 Octobre 1999
00 45 C

Halo Structure of 14Be
LABICHE M., ORR N.A., MARQUES F.M., ANGELIQUE J.C., AXELSSON L., BENOIT B., BERGMANN U.C., BORGE M.J.G., CATFORD W.N., CHAPPELL S.P.G., CLARKE N.M., COSTA G., CURTIS N., D'ARRIGO A., DE GOES BRENNAND E., DORVAUX O., FAZIO G., FREER M., FULTON B.R., GIARDINA G., GREVY S., GUILLEMAUD-MUELLER D., HANAPPE F., HEUSCH B., JONES K.L., JONSON B., LE BRUN C., LEENHARDT S., LEWITOWICZ M., LOPEZ M.J., MARKENROTH K., MUELLER A.C., NILSSON T., NINANE A., NYMAN G., DE OLIVEIRA F., PIQUERAS I., RIISAGER K., SAINT-LAURENT M.G., SARAZIN F., SINGER S.M., SORLIN O., STUTTGE L.
LPC - Caen, Chalmers Tekniska Högskola - Göteborg, ULB - Bruxelles, Aarhus Univ. - Aarhus, Inst. Estr. Mat. - Madrid, Surrey Univ. - Guildford, Oxford Univ. - Oxford, Birmingham Univ. - Birmingham, IRS - Strasbourg, Messina Univ. - Messina, IPN - Orsay, GANIL - Caen

Physical Review Letters 86, 4 (2001)
01 02 C

Indication of changes in neutron shell closures in light very neutron-rich nuclei
DLOUHY Z., ANGELIQUE J.C., ANNE R., AUGER G., AZAIEZ F., BAIBORODIN D., BORCEA C., CAURIER E., GREVY S., GILLIBERT A., GUILLEMAUD-MUELLER D., LALLEMAN A.S., LEWITOWICZ M., LOPEZ-JIMENEZ M.J., LUKYANOV S.M., MITTIG W., MRAZEK J., MUELLER A.C., NOWACKI F., OGANESSIAN YU.TZ., DE OLIVEIRA F., ORR N., PAGE R.D., PENIONZHKEVICH YU.E., POUGHEON F., REED A.T., REN Z., RIDIKAS D., ROUSSEL-CHOMAZ P., SAINT-LAURENT M.G., SARAZIN F., SAVAJOLS H., SORLIN O., TARASOV O., THIAMOVA G., DE VISMES A., WINFIELD J.
GANIL - Caen, NPI - Rez, FLNR JINR - Dubna, IPN - Orsay, Oliver Lodge Lab. - Liverpool, LPC - Caen, INPNE - Bucharest-Magurele, IReS - Strasbourg, CEN Saclay - Gif-fur-Yvette, LPT - Strasbourg
Ricerca Scientifica ed Educazione Permanente Supplemento 115 (2000) 651.
International Conference on Nuclear Reaction Mechanisms.9
VARENNA (IT)
5 Juin 2000
00 97 C

The 8^+ isomer in ^{78}Zn and the doubly magic character of ^{78}Ni
DAUGAS J.M., GRZYWACZ R., LEWITOWICZ M., ACHOURI L., ANGELIQUE J.C., BAIBORODIN D., BENNACEUR K., BENTIDA R., BERAUD R., BORCEA C., BINGHAM C., CATFORD W.N., EMSALLEM A., de FRANCE G., GRAWE H., JONES K.L., LEMMON R.C., LOPEZ JIMENEZ M.J., NOWACKI F., de OLIVEIRA SANTOS F., PFUTZNER M., REGAN P.H., RYKACZEWSKI K., SAUVESTRE J.E., SAWICKA M., SLETTEN G., STANOIU M.
GANIL - Caen, Tennessee Univ. - Knoxville, IFD Warsaw Univ. - Warsaw, LPC - Caen, NPI - Rez, IPNL - Villeurbanne, IAP - Bucharest-Magurele, Surrey Univ. - Guildford, GSI - Darmstadt, LPT Univ. Louis Pasteur - Strasbourg, ORNL - Oak Ridge, CEA - Bruyères le Châtel, NBI - Copenhagen
Physics Letters B476 (2000) 213.
00 14 C

In-Beam Gamma Spectroscopy of Very Neutron-rich Nuclei at GANIL
BELLEGUIC M., LOPEZ-JIMENEZ M., STANOIU M., AZAIEZ F., SAINT-LAURENT M.G., SORLIN O., ACHOURI N.L., ANGELIQUE J.C., BORCEA C., BOURGEOIS C., DAUGAS J.M., DONZAUD C., DE OLIVEIRA-SANTOS F., DLOUHY Z., DUPRAT J., GREVY S., GUILLEMAU-MUELLER D., LEENHARDT S., LEWITOWICZ M., MITTIG W., MUELLER A.C., ORR N., PENIONZHKEVICH YU.E., PORQUET M.G., POUGHEON F., ROUSSEL-CHOMAZ P., SAUVESTRE J.E., SAVAJOLS H., SOBOLEV YU.
IPN - Orsay, GANIL - Caen, IAP - Bucarest, FLNR JINR - Dubna, LPC - Caen, CSNSM - Orsay, CE Bruyères-le-Châtel - Bruyères-le-Châtel, NPI - Rez
Physica Scripta T88 (2000) 122.
Achievements and Perspectives in Nuclear Structure
International Conference on Achievements and Perspectives in Nuclear Structure
AGHIA PALAGHIA (GR)
11 Juillet 1999
00 74 C

In-Beam Gamma-Spectroscopy at GANIL : Present and Future
AZAIEZ F.
IPN - Orsay
Physica Scripta T88 (2000) 118.
Achievements and Perspectives in Nuclear Structure
International Conference on Achievements and Perspective in Nuclear Structure
AGHIA PALAGHIA (GR)
11 Juillet 1999
00 73 C

Isomer spectroscopy of neutron rich $^{190}W_{116}$
PODOLYAK Z., REGAN P.H., PFUTZNER M., GERL J., HELLSTROM M., CAAMANO M., MAYET P., SCHLEGEL CH., APRAHAMIAN A., BENLLIURE J., BRUCE A.M., BUTLER P.A., CORTINA GIL D., CULLEN

D.M., DORING J., ENQVIST T., REJMUND F., FOX C., GARCES NARRO J., GEISSEL H., GELLETLY W., GIOVINAZZO J., GORSKA M., GRAWE H., GRZYWACZ R., KLEINBOHL A., KORTEN W., LEWITOWICZ M., LUCAS R., MACH H., MINEVA M., O'LEARY C.D., DE OLIVEIRA F., PEARSON C.J., REJMUND M., SAWICKA M., SCHAFFNER H., SCHMIDT K., THEISEN CH., WALKER P.M., WARNER D.D., WHELDON C., WOLLERSHEIM H.J., WOODING S.C., XU F.R.
Univ. of Surrey - Guildford, IEP Warsaw Univ. - Warsaw, GSI - Darmstadt, Lund Univ. - Lund, Univ. of Santiago de Compostela, Univ. of Brighton, Univ. of Liverpool, IPN - Orsay, CENBG - Gradignan, Univ. of Tennessee - Knoxville, CEA Saclay - Gif sur Yvette, GANIL - Caen, Upssala Univ. - Nykoping, CSNSM - Orsay, CLRC Daresbury Lab. - Warrington
Physics Letters B491 (2000) 225.
00 87 C

K-Isomers in Very Neutron-Rich Nuclei Around Mass 180
SCHLEGEL C., REGAN P.H., PFUTZNER M., GERL J., HELLSTROM M., PODOLYAK Z., CAAMANO M., MAYET P., APRAHAMIAN A., BENLLIURE J., BRUCE A.M., BUTLER P.A., CORTINA GIL D., CULLEN D.M., DORING J., ENQUIST T., FARGET F., FOX C., GARCES NARRO J., GELLETLY W., GIOVINAZZO J., GORSKA M., GRAWE H., GRZYWACZ R., KLEINHOHL A., KORTEN W., LEWITOWICZ M., LUCAS R., MACH H., MINEVA M., O'LEARY C., DE OLIVEIRA F., PEARSON C.J., REJMUND M., SAWICKA M., SCHAFFNER H., SCHMIDT K., THEISEN CH., WALKER P.M., WARNER D.D., WHELDON C., WOLLERSHEIM H.J., WOODING S., XU F.
GSI - Darmstadt, Univ. of Surrey - Guildford, IEP - Warsaw Univ. - Warsaw, Lund Univ. - Lund, Univ. de Santiago de Compostela , Univ. of Brighton - Brighton, Univ. of Liverpool - Liverpool, IPN - Orsay, CNRS - Bordeaux, Univ. of Tennessee - Knoxville, CEA Saclay - Gif sur Yvette, GANIL - Caen, Daresbury Laboratory - Warrington, Uppsala Univ. - Nykoping
Physica Scripta T88 (2000) 72.
Achievements and Perspectives in Nuclear Structure
International Conference on Achievements and Perspectives in Nuclear Structure
AGHIA PALAGHIA (GR)
10 Juillet 1999
00 72 C

Neutron cross-talk rejection in a modular array and the detection of halo neutrons
MARQUES F.M., LABICHE M., ORR N.A., SARAZIN F., ANGELIQUE J.C.
LPC - Caen
NIM A450 (2000) 109.
00 59 C

The NuPECC Working Group on Radioactive Nuclear Beam Facilities
BENNETT E., VAN DUPPEN P., GEISSEL H., HEYDE K., JONSON B., KESTER O., KORNER G.E., MITTIG W., MUELLER A.C., MUNZENBERG G., RAVN H.L., RIISAGER K., SCHRIEDER G., SHOTTER A., VAAGEN J.S., VERVIER J.
CLRC - Rutherford, KU - Leuven, GSI - Darmstadt, Gent Univ. - Gent, Chalmers Univ. - Göteborg, TUM - München, IPN - Orsay, CERN - Genève, Aarhus Univ. - Aarhus, Edinburgh Univ. - Edinburgh, Bergen Univ. - Bergen, UCL - Louvain-la-Neuve
NuPECC, April 2000, p. 1-96.
00 116 C

Observation of isomeric states in neutron deficient A ~80 nuclei following the projectile fragmentation of ^{92}Mo
CHANDLER C., REGAN P.H., BLANCK B., PEARSON C.J., BRUCE A.M., CATFORD W.N., CURTIS N., CZAJKOWSKI S., DESSAGNE PH., FLEURY A., GELLETLY W., GIOVINAZZO J., GRZYWACZ R., JANAS Z., LEWITOWICZ M., MARCHAND C., MIEHE CH., ORR N.A., PAGE R.D., PRAVIKOFF M.S., REED A.T., SAINT-LAURENT M.G., VINCENT S.M., WADSWORTH R., WARNER D.D., WINFIELD J.S., XU F.
Surrey Univ. - Guildford, CENBG - Gradignan, Brighton Univ. - Brighton, IReS - Strasbourg, IEP Warsaw Univ. - Warsaw, GANIL - Caen, LPC ISMRA - Caen, Oliver Lodge Lab. - Liverpool, York Univ. - York, CLRC Daresbury Lab. - Warrington
Physical Review C61 (2000) 044309-1.
00 26 C

Observation of the ^{11}N ground state
OLIVEIRA J.M., LEPINE-SZILY A., BOHLEN H.G., ISTRIWSJU A.N., LICHTENTHALER R., DI PIETRO A., LAIRD A.M., LIMA G.F., MAUNOURY L., DE OLIVEIRA SANTOS F., ROUSSEL-CHOMAZ P., SAVAJOLS H., TRINDER W., VILLARI A.C.C., DE VISMES A.
IFUSP - Sao Paulo, CEBES - Sorocaba, HMI - Berlin, Edinburgh Univ. - Edinburgh, GANIL - Caen
Physical Review Letters 84, 18 (2000) 4056.
00 28 C

One-neutron removal reactions on neutron-rich psd-shell nuclei
SAUVAN E., CARSTOIU F., ORR N.A., ANGELIQUE J.C., CATFORD W.N., CLARKE N.M., MAC CORMICK M., CURTIS N., FREER M., GREVY S., LE BRUN C., LEWITOWICZ M., LIEGARD E., MARQUES F.M., ROUSSEL-CHOMAZ P., SAINT-LAURENT M.G., SHAWCROSS M., WINFIELD J.S.
LPC - Caen, IFIN HH - Bucharest-Magurele, Univ. of Surrey - Guildford, School of Phys. & Astr. - Birmingham, GANIL - Caen, IPN - Orsay
Physics Letters B491 (2000) 1.
00 89 C

Production of neutron-rich isotopes in fission of uranium induced by neutrons of 20 MeV average energy
LHERSONNEAU G., DENDOOVEN P., CANCHEL G., HUIKARI J., JARDIN P., JOKINEN A., KOLHINEN V., LAU C., LEBRETON L., MUELLER A.C., NIEMINEN A., NUMMELA S., PENTTILA H., PERAJARVI K., RADIVOJEVIC Z., RUBCHENYA V., SAINT-LAURENT M.G., TRZASKA W.H., VAKHTIN D., VERVIER J., VILLARI A.C.C., WANG J.C., AYSTO J.
Jyväskylä Univ. - Jyväskylä, Centre de Recherche du Cyclotron - Louvain-La-Neuve, GANIL - Caen, IPN - Orsay, Khlopin Radium Inst. - Saint Peterburg
The European Physical Journal A9 (2000) 385.
00 115 C

Researchers Perform Quite a Magic Trick : Making Nickel-48 Materialize
Physics Today 33, No. 2 (2000) 19.
00 10 C

Search and study of proton-rich nuclei - The discovery of doubly-magic ^{48}Ni
BLANK B., BORCEA C., CHARTIER M., CZAJKOWSKI S., FLEURY A., de FRANCE G., GIOVINAZZO J., GRZYWACZ R., JANAS Z., LEWITOWICZ M., de OLIVEIRA F., PFUTZNER M., PRAVIKOFF M.S., THOMAS J.C.
CEN - Bordeaux-Gradignan, IAP - Bucharest-Magurele, GANIL - Caen, IEP Warsaw Univ. - Warsaw
Ricerca Scientifica ed Educazione Permanente Suppl. 116 (2000) 63.
BORMIO 2000
Universita degli studi di Milan
International Winter Meeting on Nuclear Physics.38
BORMIO (IT)
24 Janvier 2000
00 46 C

Shape coexistence and the N = 28 Shell Closure Far from Stability
SARAZIN F., SAVAJOLS H., MITTIG W., NOWACKI F., ORR N.A., REN Z., ROUSSEL-CHOMAZ P., AUGER G., BAIBORODIN D., BELOZYOROV A.V., BORCEA C., CAURIER E., DLOUHY Z., GILLIBERT A., LALLEMAN A.S., LEWITOWICZ M., LUKYANOV S.M., DE OLIVEIRA F., PENIONZHKEVICH Y.E., RIDIKAS D., SAKURAI H., TARASOV O., DE VISMES A.
GANIL - Caen, LPT - Strasbourg, LPC - Caen, NPI - Rez, JINR - Dubna, IAP - Bucharest-Magurele, IRES - Strasbourg, CEN Saclay - Gif-sur-Yvette, RIKEN - Saitama
Physical Review Letters 84, 22 (2000) 5062.
00 38 C

Anomalous radial expansion in central heavy-ion reactions
MORAWETZ K., PLOSZAJCZAK M., TONEEV V.D.
LPC ISMRA - Caen, GANIL - Caen, JINR - Dubna
Physical Review C62 (2000) 064602-1.
00 112 D

Contribution of prompt emissions to the production of intermediate velocity light particles in the $^{36}Ar + ^{58}Ni$ reaction at 95 MeV/nucleon
PAWLOWSKI P., BORDERIE B., AUGER G., BACRI CH.O., BELLAIZE N., BOCAGE F., BOUGAULT R., BROU R., BUCHET P., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P.
IPN - Orsay, GANIL - Caen, LPC ISMRA - Caen, CEA Saclay - Gif sur Yvette, IPNL - Villeurbanne, NIPNE - Bucharest-Magurele, INFN - Napoli
Ricerca Scientifica ed Educazione Permanente Supplemento 115 (2000) 509.
International Conference on Nuclear Reaction Mechanisms
International Conference on Nuclear Reaction Mechanisms.9
VARENNA (IT)
5 Juin 2000
00 96 D

Dynamical and statistical emission of light charged particles in $^{36}Ar + ^{58}Ni$ induced reactions between 32 and 95 AMeV
HURSTEL A., BUCHET PH., DORE D., CHARVET J.L., DAYRAS R., GUY J., LEGRAIN R., NALPAS L., VOLANT C., AUGER G., BACRI CH.O., BELLAIZE N., BOCAGE F., BORDERIE B., BOUGAULT R., BOURIQUET B., BROU R., CHBIHI A., COLIN J., CUSSOL D., DEMEYER A., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., HUDAN S., LAUTESSE P., LAVAUD F., LAVILLE J.L., LECOLLEY J.F., LEDUC C., LEFORT T., MASKAY A.M., LE NEINDRE N., LOPEZ O., LOUVEL M., NGUYEN A.D., PAWLOWSKI P., PLAGNOL E., PARLOG M., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VIGILANTE M., WIELECZKO J.P.
CEA Saclay - Gif sur Yvette, GANIL - Caen, IPN - Orsay, LPC - Caen, IPN - Villeurbanne, CNAM - Paris, IPNE - Bucharest, Univ. Di Napoli - Napoli
Ricerca Scientifica ed Educazione Permanente Suppl. 116 (2000) 587.
BORMIO 2000
Universita degli studi di Milano
International Winter Meeting on Nuclear Physics
BORMIO (IT)
24 Janvier 2000
00 56 E

Neutrons produced by 1.22 GeV antiproton interactions with nuclei
VON EGIDY T., FIGUERA P., GALIN J., GOLDENBAUM F., GOLUBEVA YE.S., HASINOFF M., HILSCHER D., ILJINOV A.S., JAHNKE U., KRAUSE M., KURCEWICZ W., LEDOUX X., LOTT B., MAIER L., MANRIQUE DE LARA M., PAUSCH G., PIENKOWSKI L., QUEDNAU B., SCHOTT W., SCHRODER W.U., TOKE J.
München Univ. - Garching, HMI - Berlin, GANIL - Caen, INR Russian Acad. Sci. - Moscow, Univ. of British Columbia - Vancouver, IEP Warsaw Univ. - Warszawa, Forschungszentrum Rossendorf - Dresden, Heavy Ion Lab. Warsaw Univ. - Warszawa, Rochester Univ. - New York
The European Physical Journal A8 (2000) 197.
00 57 E

Neutron production in bombardments of thin and thick W, Hg, Pb targets by 0.4, 0.8, 1.2 and 2.5 GeV protons
LETOURNEAU A., GALIN J., GOLDENBAUM F., LOTT B., PEGHAIRE A., ENKE M., HILSCHER D., JAHNKE U., NUNIGHOFF K., FILGES D., NEEF R.D., PAUL N., SCHAAL H., STERZENBACH G., TIETZE A.

GANIL - Caen, HMI - Berlin, Institut für Kernphysik - Jülich
NIM B170 (2000) 299.
00 76 D

New method for the discrimination of single-source events in heavy-ion collisions
DESESQUELLES P., MASKAY A.M., LAUTESSE P., DEMEYER A., GERLIC E., GUINET D., STERN M., LAVILLE J.L., AUGER G., BACRI CH.O., BEAULIEU L., BELLAIZE N., BOCAGE F., BORDERIE B., BOUGAULT R., BOURIQUET B., BROU R., BUCHET P., COLIN J., DE CESARE N., DORE D., DURAND D., FRANKLAND J.D., GAGNE P., GALICHET E., GENOUIN-DUHAMEL E., GERMAIN M., HUDAN S., LAFOREST R., LAVAUD F., LECOLLEY J.F., LEDUC C., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., NALPAS L., NORMAND J., PARLOG M., RIVET M.F., ROSATO E., ROY R., SAINT-LAURENT F., STECKMEYER J.C., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VIGILANTE M., VOLANT C., WIELECZKO J.P.
GANIL - Caen, IPN - Orsay, LPC - Caen, CEA Saclay - Gif sur Yvette, IPN - Villeurbanne, NIPNE - Bucharest-Magurele, DSF INFN - Napoli, CNAM - Paris, SUBATECH - Nantes, Laval Univ. - Sainte-Foy
Physical Review C62 (2000) 024614-1.
00 65 D

Role of nucleon-nucleon collisions in the Ar + Ni reactions
DORE D., VOLANT C., CUGNON J., LEGRAIN R., AUGER G., BACRI CH.O., BELLAIZE N., BORDERIE B., BOUGAULT R., BOURIQUET B., BROU R., BUCHET PH., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., GUIOT B., HUDAN S., LAUTESSE P., LAVAUD F., LAVILLE J.L., LECOLLEY J.F., LEDUC C., LENEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NORMAND J., PAWLOWSKI P., PARLOG M., PETER J., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., TABACARU G., TAMAIN B., TASSAN-GOT L., VIENT E., WIELECZKO J.P.
CEA Saclay - Gif sur Yvette, Univ. of Liège - Liège, GANIL - Caen, IPN - Orsay, LPC - Caen, IPNL - Villeurbanne, CNAM - Paris, NIPNE - Bucharest, Univ. di Napoli - Napoli
Ricerca Scientifica ed Educazione Permanente Supplemento 115 (2000) 499.
International Conference on Nuclear Reaction Mechanisms.9
VARENNA (IT)
5 Juin 2000
00 94 D

Bremsstrahlung in the nuclear medium : search for coherence phenomena
WILSCHUT H.W., VAN GOETHEM M.J., LOHNER H.
KVI - Groningen
Czechoslovak Journal of Physics 50 (2000) Suppl. S4, p.113.
TAPS'99
TAPS Workshop V : Electromagnetic and mesonic probes of nuclear matter
PRAGUE (CZ)
00 171 E

Coherent Bremsstrahlung in the a + p System at 50 MeV/nucleon
HOEFMAN M., APHECETCHE L., BACELAR J.C.S., DELAGRANGE H., DESCOUVEMONT P., DIAZ J., D'ENTERRIA D., VAN GOETHEM M.J., HOLZMANN R., HUISMAN H., KALANTAR-NAYESTANAKI N., KUGLER A., LOHNER H., MARQUES F.M., MARTINEZ G., MESSCHENDORP J.G., OSTENDORF R.W., SCHADMAND S., SIEMSSEN R.H., SIMON R.S., SCHUTZ Y., TIMMERMANS R., TURRISI R., VOLKERTS M., WAGNER V., WELLER H., WILSCHUT H.W., WULF E.
KVI - Groningen, GANIL - Caen, ULB - Brussels, IFC - Burjassot, GSI - Darmstadt, NPI - Prahy, LPC - Caen, TUNL Duke Univ. - Durham
Physical Review Letters 86, 7 (2000) 1404.
00 61 E

Dynamical and statistical emission of light charged particles in ^{36}Ar + ^{58}Ni induced reactions between 32 and 95 AMeV
HURSTEL A., BUCHET PH., DORE D., CHARVET J.L., DAYRAS R., GUY J., LEGRAIN R., NALPAS L., VOLANT C., AUGER G., BACRI CH.O., BELLAIZE N., BOCAGE F., BORDERIE B., BOUGAULT R.,

BOURIQUET B., BROU R., CHBIHI A., COLIN J., CUSSOL D., DEMEYER A., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., HUDAN S., LAUTESSE P., LAVAUD F., LAVILLE J.L., LECOLLEY J.F., LEDUC C., LEFORT T., MASKAY A.M., LE NEINDRE N., LOPEZ O., LOUVEL M., NGUYEN A.D., PAWLOWSKI P., PLAGNOL E., PARLOG M., RIVET M.F., ROSATO E., SAINT-LAURENT F., STECKMEYER J.C., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VIGILANTE M., WIELECZKO J.P.
CEA Saclay - Gif sur Yvette, GANIL - Caen, IPN - Orsay, LPC - Caen, IPN - Villeurbanne, CNAM - Paris, IPNE - Bucharest, Univ. Di Napoli - Napoli
Ricerca Scientifica ed Educazione Permanente Suppl. 116 (2000) 587.
BORMIO 2000
Universita degli studi di Milano
International Winter Meeting on Nuclear Physics
BORMIO (IT)
24 Janvier 2000
00 56 E

Experimental determination of neutron spectra produced by bombarding thick targets : Deuterons (100 MeV/u) on ^{9}Be, deuterons (100 MeV/u) on ^{238}U and ^{36}Ar (95 MeV/u) on ^{12}C
PAUWELS N., CLAPIER F., GARA P., MIREA M., PROUST J.
IPN - Orsay, IPNE - Bucarest
NIM B160 (2000) 315.
00 05 E

Hard photon production in the reaction Xe + Sn at 50 A MeV
ORTEGA R.
Universitat Autonoma de Barcelona
Czechoslovak Journal of Physics 50 (2000) Suppl. S4, p.91.
TAPS'99
TAPS Workshop V : Electromagnetic and mesonic probes of nuclear matter
PRAGUE (CZ)
4 Septembre 1999
00 169 E

Light particles emitted with very forward quasi-projectiles in the fragmentation of 44 MeV amu^{-1} ^{40}Ar on ^{27}Al, ^{58,64}Ni, and ^{197}Au
ROUSSEL P., BACRI CH.O., BORREL V., KASHY E., STEPHAN C., TASSAN-GOT L., BEAUMEL D., BERNAS M., CLAPIER F., MIREA M.
IPN - Orsay, MSU - East Lansing, IAP - Bucharest
J. Phys. G: Nucl.Part.Phys. 26 (2000) 1641.
00 106 E

Neutrons produced by 1.22 GeV antiproton interactions with nuclei
VON EGIDY T., FIGUERA P., GALIN J., GOLDENBAUM F., GOLUBEVA YE.S., HASINOFF M., HILSCHER D., ILJINOV A.S., JAHNKE U., KRAUSE M., KURCEWICZ W., LEDOUX X., LOTT B., MAIER L., MANRIQUE DE LARA M., PAUSCH G., PIENKOWSKI L., QUEDNAU B., SCHOTT W., SCHRODER W.U., TOKE J.
München Univ. - Garching, HMI - Berlin, GANIL - Caen, INR Russian Acad. Sci. - Moscow, Univ. of British Columbia - Vancouver, IEP Warsaw Univ. - Warszawa, Forschungszentrum Rossendorf - Dresden, Heavy Ion Lab. Warsaw Univ. - Warszawa, Rochester Univ. - New York
The European Physical Journal A8 (2000) 197.
00 57 E

Particle production in proton-induced reactions in thick and thin targets
LETOURNEAU A., BOHM A., ENKE M., FILGES D., GALIN J., GOLDENBAUM F., HERBACH C.M., HILSCHER D., JAHNKE U., LOTT B., NEEF R.D., NUNIGHOFF K., PAUL N., PEGHAIRE A., PIENKOWSKI L., SCHAAL H., SCHRODER W.U., STERZENBACH G., TISHCHENKO V.G., TIETZE A., TOKE J.
GANIL - Caen, HMI - Berlin, Inst. für Kernphysik - Jülich, Rochester Univ. - Rochester, Warsaw Univ. - Warsaw
Ricerca Scientifica ed educazione Permanente Suppl. 116 (2000) 498.
BORMIO 2000

Universita degli studi di Milano
International Winter Meeting on Nuclear Physics.38
BORMIO (IT)
24 Janvier 2000
00 55 E

Phase Transitions in Strong Interactions : Status and Perspectives
INSOLIA A., COSTA S., TUVE C.
Univ. di Catania and INFN
CRIS 2000
3rd Catania Relativistic Ion Studies
ACICASTELLO (IT)
22 Mai 2000
01 04 E

Pre-equilibrium emission and reaction dynamics around the Fermi energy
SAPIENZA P., CONIGLIONE R., MIGNECO E., AGODI C., ALBA R., BELLIA G., COLONNA M., DEL ZOPPO A., FINOCCHIARO P., GRECO V., LOUKACHINE K., MAIOLINO C., PIATTELLI P., SANTONOCITO D., VENTURA P.G., COLONNA N., BRUNO M., D'AGOSTINO M., MASTINU P.F., FIANDRI M.L., GRAMEGNA F., IORI I., FABBIETTI L., MORONI A., MARGAGLIOTTI G.V., MILAZZO P.M., RUI R., TONETTO F., VANNINI G., BLUMENFELD Y., SCARPACI J.A.
INFN - Catania, INFN - Bari, INFN - Bologna, INFN - Padova, INFN - Milano, INFN - Trieste, IPN - Orsay
Ricerca Scientifica ed Educazione Permanente Suppl. 116 (2000) 492.
BORMIO 2000
Universita degli studi di Milano
International Winter Meeting on Nuclear Physics.38
BORMIO (IT)
24 Janvier 2000
00 54 E

Prompt light particle emission in the ^{36}Ar + ^{58}Ni reaction at 95 MeV/nucleon
PAWLOWSKI P., BORDERIE B., AUGER G., BACRI CH.O., BELLAIZE N., BOCAGE F., BOUGAULT R., BROU R., BUCHET P., CHARVET J.L., CHBIHI A., COLIN J., CUSSOL D., DAYRAS R., DEMEYER A., DORE D., DURAND D., FRANKLAND J.D., GALICHET E., GENOUIN-DUHAMEL E., GERLIC E., GUINET D., LAUTESSE P., LAVILLE J.L., LECOLLEY J.F., LEGRAIN R., LE NEINDRE N., LOPEZ O., LOUVEL M., MASKAY A.M., NALPAS L., NGUYEN A.D., PARLOG M., PETER J., PLAGNOL E., RIVET M.F., ROSATO E., SAINT-LAURENT F., SALOU S., STECKMEYER J.C., STERN M., TABACARU G., TAMAIN B., TASSAN-GOT L., TIREL O., VIENT E., VOLANT C., WIELECZKO J.P.
IPN - Orsay, GANIL - Caen, LPC - Caen, DAPNIA CEA Saclay - Gif-sur-Yvette, IPN - Villeurbanne, NIPNE - Bucharest-Magurele, INFN - Napoli, CNAM - Paris
The European Physical Journal A9 (2000) 371.
00 114 E

Thermal hard-photons probing multifragmentation in nuclear collisions around the Fermi energy
D'ENTERRIA D.G., MARTINEZ G.
GANIL - Caen
Czechoslovak Journal of Physics 50 (2000) Suppl. S4, p. 103.
TAPS'99
TAPS Workshop V : Electromagnetic and Mesonic Probes of Nuclear Matter
PRAGUE (CZ)
4 Septembre 1999
00 170 E

Les liaisons du cuivre
MONNEAU Ph.
SDMS - St Romans
Vide 296, 2/4 (2000) 147.

00 104 H

The MAGNEX large-acceptance magnetic spectrometer
CUNSOLO A., CAPPUZZELLO F., FOTI A., LAZZARO A., MELITA A.L., NOCIFORO C., SHCHEPUNOV V., VINCIGUERRA D., WINFIELD J.S., BELOZYOROV A.V., MALISHEV O., YEREMIN A., MITTIG W., ROUSSEL-CHOMAZ P., SAVAJOLS H.
INFN/LNS - Catania, JINR - Dubna, GANIL - Caen
Ricerca Scientifica ed Educazione Permanente Supplemento 115 (2000) 661.
International Conference on Nuclear Reaction Mechanism.9
VARENNA (IT)
5 Juin 2000
00 93 I

TONNERRE : an array for delayed-neutron decay spectroscopy
BUTA A., MARTIN T., TIMIS C., ACHOURI N., ANGELIQUE J.C., BORCEA C., CRUCERU I., GENOUX-LUBAIN A., GREVY S., LEWITOWICZ M., LIENARD E., MARQUES F.M., NEGOITA F., DE OLIVEIRA F., ORR N.A., PETER J., SANDU M.
LPC - Caen, NIPNE - Bucharest, GANIL - Caen, LPC - Aubière
NIM A455 (2000) 412.
00 108 I

Abnormal kinetic-energy fluctuations and critical behaviors in the microcanonical lattice gas model
GULMINELLI F., CHOMAZ PH., DUFLOT V.
LPC - Caen, GANIL - Caen
Europhysics Letters 50 (4) (2000) 434.
00 39 T

Anharmonic double-g vibrations in nuclei and their description in the interacting boson model
GARCIA-RAMOS J.E., ALONSO C.E., ARIAS J.M., VAN ISACKER P.
Sevilla Univ. - Sevilla, GANIL - Caen
Physical Review C61 (2000) 047305.
00 25 T

Atomic Bose-Einstein condensation with three-body interactions and collective excitations
GAMMAL A., FREDERICO T., TOMIO L., CHOMAZ PH.
Universidade Estadual Paulista - Sao Paulo, Centro Tecnico Aeroespacial - Sao José dos Campos , GANIL - Caen
J.Phys. B: At. Mol. Opt. Phys. 33 (2000) 4053.
00 105 T

Caloric curves and energy fluctuations in the microcanonical liquid-gas phase transition
CHOMAZ PH., DUFLOT V., GULMINELLI F.
GANIL - Caen, LPC - Caen
Physical Review Letters 85, 17 (2000) 3587.
00 91 T

Diffusion over a saddle with a Langevin equation
ABE Y., BOILLEY D., BERTRAND G., GIRAUD G., WADA T.
YITP Kyoto Univ. - Kyoto, GANIL - Caen, CE Saclay - Gif sur Yvette, Konan Univ. - Kobe
Physical Review E61, 2 (2000) 1125.
00 06 T

Dynamical constraints on phase transitions
MORAWETZ K.
LPC - Caen, GANIL - Caen

Physical Review C62 (2000) 044606-1.
00 92 T

General response function for interacting quantum liquids
MORAWETZ K., FUHRMANN U.
LPC - Caen, Rostock Univ. - Rostock
Physical Review E61, 3 (2000) 2272.
00 19 T

Influence of the spin-orbit coupling on nuclear superfluidity along the N = Z line
JUILLET O., JOSSE S.
GANIL - Caen
European Physical Journal A8 (2000) 291.
00 80 T

Intrinsic state an extended version of the interacting boson model
GARCIA-RAMOS J.E., ARIAS J.M., DUKELSKY J., VAN ISACKER P.
Universidad de Sevilla - Sevilla, Inst. de Estructura de la Materia - Madrid, GANIL - Caen
Physical Review C61 (2000) 034305-1.
00 09 T

Liquid-gas phase transition in Bose-Einstein condensates with time evolution
GAMMAL A., FREDERICO T., TOMIO L., CHOMAZ PH.
Univ. Estadual Paulista - Sao Paulo, Inst. Tecnologico da Aeronautica - Sao José dos Campos, GANIL - Caen
Physical Review A61 (2000) 051602-1.
00 37 T

Momentum conservation and local field corrections for the response of interacting Fermi gases
MORAWETZ K., FUHRMANN U.
LPC - Caen, GANIL - Caen, Rostock Univ. - Rostock
Physical Review E62, 3 (2000) 4382.
00 90 T

Negative heat capacity in the critical region of nuclear fragmentation : an experimental evidence of the liquid-gas phase transition
D'AGOSTINO M., GULMINELLI F., CHOMAZ PH., BRUNO M., CANNATA F., LE NEINDRE N., BOUGAULT R., FIANDRI M.L., FUSCHINI E., GRAMEGNA F., IORI I., MARGAGLIOTTI G.V., MORONI A., VANNINI G., VERONDINI E.
INFN - Bologna, LPC - Caen, GANIL - Caen, INFN - Legnaro, INFN - Milano, INFN - Trieste
Ricerca Scientifica ed Educazione Permanente Suppl. 116 (2000) 386.
BORMIO 2000
Universita degli studi di Milano
International Winter Meeting on Nuclear Physics.38
BORMIO (IT)
24 Janvier 2000
00 50 T

Negative heat capacity in the microcanonical lattice gas model
GULMINELLI F., CHOMAZ PH., DUFLOT V.
LPC - Caen, GANIL - Caen
Ricerca Scientifica ed Educazione Permanente Suppl. 116 (2000) 366.
International Winter Meeting on Nuclear Physics.38
BORMIO 2000
BORMIO (IT)
24 Janvier 2000
00 49 T

Phase transition in finite systems
CHOMAZ PH., DUFLOT V., GULMINELLI F.
GANIL - Caen, LPC - Caen
Ricerca Scientifica ed Educazione Permanente Suppl. 116 (2000) 336.
BORMIO 2000
Universita Degli Studi di Milano
International Winter Meeting on Nuclear Physics.38
BORMIO (IT)
24 Janvier 2000
00 47 T

Quantum response of finite Fermi systems and the relation of the Lyapunov exponent to transport coefficients
MORAWETZ K.
LPC - Caen
Physical Review E61, 3 (2000) 2555.
00 18 T

Quantum statistical model of nuclear multifragmentation in the canonical ensemble method
PARVAN A.S., TONEEV V.D., PLOSZAJCZAK M.
JINR - Dubna, IAP - Kishineu, GANIL - Caen
Nuclear Physics A676 (2000) 409.
00 58 T

Role of the surface in the critical behavior of finite systems
DUFLOT V., CHOMAZ PH., GULMINELLI F.
GANIL - Caen, LPC - Caen
Physics Letters B476 (2000) 279.
00 16 T

Role of the surface in the critical behavior of finite systems
DUFLOT V., CHOMAZ PH., GULMINELLI F.
GANIL - Caen, LPC - Caen
Ricerca Scientifica ed Educazione Permanente Suppl. 116 (2000) 360.
BORMIO 2000
Universita degli studi di Milano
International Winter Meeting on Nuclear Physics.38
BORMIO (IT)
24 Janvier 2000
00 48 T

SU (3) realization of the rigid asymmetric rotor within the interacting boson model
SMIRNOV Y.F., SMIRNOVA N.A., VAN ISACKER P.
Inst. de Ciencias Nucleares - Mexico, GANIL - Caen, INP - Moscow
Physical Review C61 (2000) 041302-1.
00 27 T

Transport with three-particle interaction
MORAWETZ K.
LPC - Caen
Physical Review C63 (2000) 014609-1.
00 167 T

Universal features of the order-parameter fluctuations : Reversible and irreversible aggregation
BOTET R., PLOSZAJCZAK M.
LPS Univ. Paris-Sud - Orsay, GANIL - Caen

Physical Review E62, 2 (2000) 1825.
00 77 T

Radioactive Beams and nuclear structure at GANIL : present status and perspectives with SPIRAL

GUERREAU D.
GANIL - Caen

NUCLEAR SHELLS - 50 YEARS
International Conference on Nuclear Physics SHELLS - 50
DUBNA (RU)
21 Avril 1999
00 42 S

INTERDISCIPLINARY RESEARCH

1 - INSTRUMENTATION

LIMBE : Highly charged ion beams of low energy at GANIL

L. Maunoury[1], R. Leroy[2], T. Been[1], L. Guillaume[1], D. Leclerc[1], A. Lepoutre[1], V. Mouton[1], J.M. Ramillion[1], R. Vicquelin[1], G. Gaubert[2], J.Y. Pacquet[2]

[1]CIRIL, BP 5133, 14070 Caen Cedex 05
[2]GANIL, BP 5027, 14076 Caen Cedex 05

Since 1990, different ECRIS ("Electron Cyclotron Resonance Ion Source") named ECR3, ECR4, ECR4M, SuperShypie and NanoganII have been used for Ion-surface, Ion-atom and Ion-molecule research. The CIRIL (Centre Interdisciplinaire de Recherche Ions-Laser - Caen), LPAN (Laboratoire de Physique Atomique et Nucléaire - Paris) and HMI (Hahn-Meitner Institut – Berlin) have been the main user laboratories.

Whether the ECRIS quality, placed at our disposal by the GANIL, has allowed to obtain many physics results leading to numerous thesis and publications, the rather poor beam qualities have restricted the development of new experiments. In this way, the LIMBE conception has been decided. Now, LIMBE has already been mounted, tested and the first beam has been delivered in the middle of 2000.

LIMBE is composed of an ECR ion source named "SUPERHYPIE" [1] and two beam lines. The SUPERSHYPIE ECR ion source is able to provide many highly charged ion beams as we can see on the table 1. The typical intensities were measured with a Faraday cup placed at the focal plane of the analysing dipole magnet and for an energy of about 17 keV/q. The ECRIS is mounted on a high voltage platform able to furnish a beam with an energy range between 1.5 and 25 keV/q. At this time, the maximum magnetic rigidity is 0.05 T.m. Two beam lines can be alternately used. They are dedicated to transport high current intensities with very high emittance up to 150 π.mm.mrad.

Ion	Current	Ion	Current
He^{+}	*1500 μA*	He^{2+}	*1500 μA*
C^{4+}	*250 μA*	O^{6+}	*450 μA*
O^{7+}	*140 μA*	N^{7+}	*3.5 μA*
Ne^{8+}	*170 μA*	Ne^{10+}	*1.2 μA*
Ar^{8+}	*250 μA*	Ar^{14+}	*23 μA*
Ar^{16+}	*1.9 μA*	Ar^{17+}	*0.08 μA*
$^{84}Kr^{19+}$	*15 μA*	$^{84}Kr^{24+}$	*4 μA*
Xe^{23+}	*11 μA*	Xe^{27+}	*4.2 μA*

Table 1

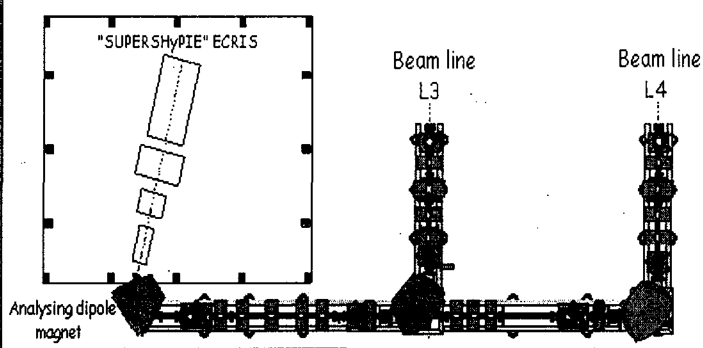


Figure 1

The vacuum values inside the beam lines are around 5.10^{-9} mbar and limit greatly the charge exchange with residual gas. The transmission is very high: better than 80% for L3 and better than 60% for L4. In order to tune the beam, LIMBE is equipped with five beam profile monitors and three Faraday cups. The beam can be cut by a set of horizontal slices placed at the focal plane of the analysing dipole magnet. All procedures (adjustment of dipole and quadrupole currents, beam profiling, vacuum, etc...) are supervised and visualised by computers.

Beam time request is examined by the Program Advisory Committee for Interdisciplinary Research at GANIL. The first experiment was managed by the team of F. Frémont et al.: this experiment was devoted to collisions between O^{7+} + CO and He^{2+} + CO [2]. Twelve experiments have been accepted up to now and about six [3,4,5,6] have been successfully performed (by mid may 2001).

For the future, two projects will be realised. The first one will be the magnetic rigidity increase up to 0.136 T.m by the exchange of the analysing dipole magnet (102° switched for a 90°). The second one will be the merging of the AIM (Grenoble) facility with the LIMBE facility. In the medium term, six beam lines and two ECR ion sources will be available for Physicists.

References :

[1] D. Leclerc et al., *Journées Source d'ions*, Ganil, Caen, 18-19 Mars 1999

[2] F. Frémont et al.,
VII th International Conference on the Physics of Highly Charged Ions,
Berkley, California, August 2000
(see also the contribution by Sobocinsky et al. in this compilation).

[3] S. Martin et al., Phys Rev A 62, 022707, 2000

[4] Z.J. Zhang and H. Naramoto, Phys. Rev. B 58(19), 12652, 1998

[5] N. Bechu, Thesis, University Pierre et Marie Curie, Paris, 1999

[6] B. Ban d'Etat et al., see the contribution by Haranger et al. on sputtering by highly charged ions in this compilation).

IRRSUD : New irradiation facility at GANIL

This line has been built up by the GANIL groups in collaboration with the CIRIL laboratory.

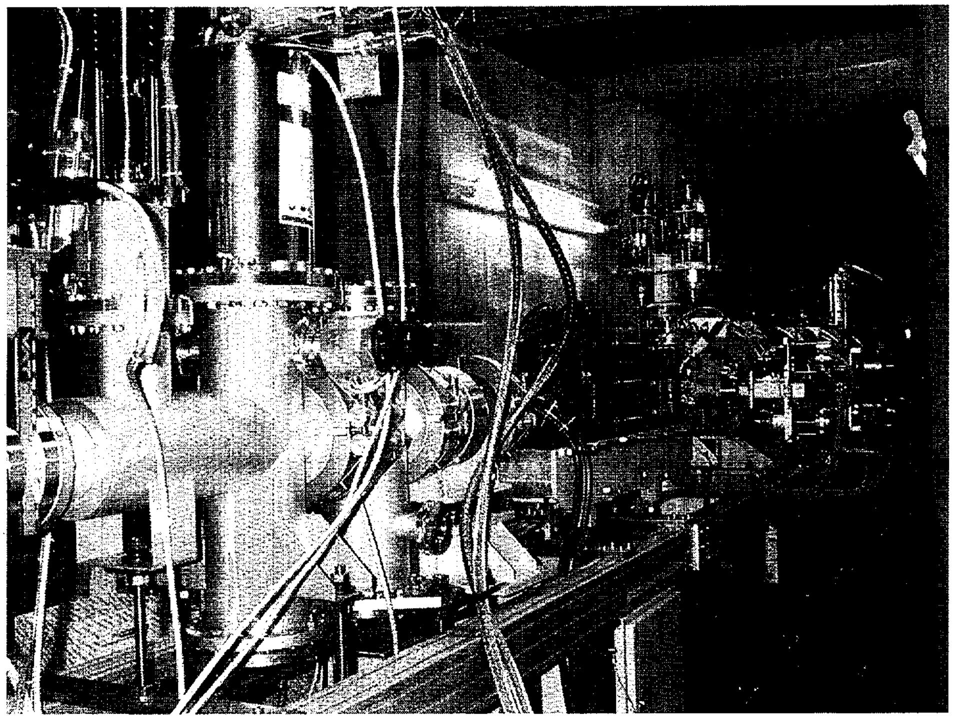


Figure: *End of the beam line implanted near the cyclotron injectors of the GANIL accelerator.*

A new irradiation facility has been mounted at the output of the two first compact cyclotrons (C01 and C02) of the GANIL accelerator. When one of the cyclotron is used to produce a beam for high energy physics, the second cyclotron can deliver a beam for material irradiation. Compared to the previous existing irradiation points, the characteristics of beams accelerated by C01 or C02 available at IRRSUD will be as shown in the table below. It is expected that the first beam will be delivered by the autumn of this year.

	Injectors (C01, C02)		SME (CSS1)		HE (CSS2)	
Ion	***flux(note)***	***energy***	flux	energy	flux	energy
	Ion.cm^{-2}	***MeV/amu***	Ion.cm^{-2}	MeV/u	Ion.cm^{-2}	MeV/u
Ne	***5 10^{12}***	***0.3 - 1***	1 10^{11}	3.7 - 13.4	2 10^{12}	23 - 95
Ar	***2 10^{12}***	***0.3 - 1***	5 10^{11}	3.7 - 13.6	8 10^{11}	23 - 95
Kr	***5 10^{11}***	***0.3 - 0.9***	2 10^{11}	3.7 - 11.5	4 10^{11}	23 - 73
Xe	***3 10^{11}***	***0.3 - 0.7***	8 10^{10}	3.7 - 7	1.6 10^{11}	23 - 44
Pb	***2 10^{10}***	***0.3 - 0.45***	2 10^{9}	3.7 - 4.5	2 10^{9}	23 - 29

Table: *IRRSUD energy and intensity beam characteristics. Note that flux and maximal energy depend on the charge state chosen at the source output.*

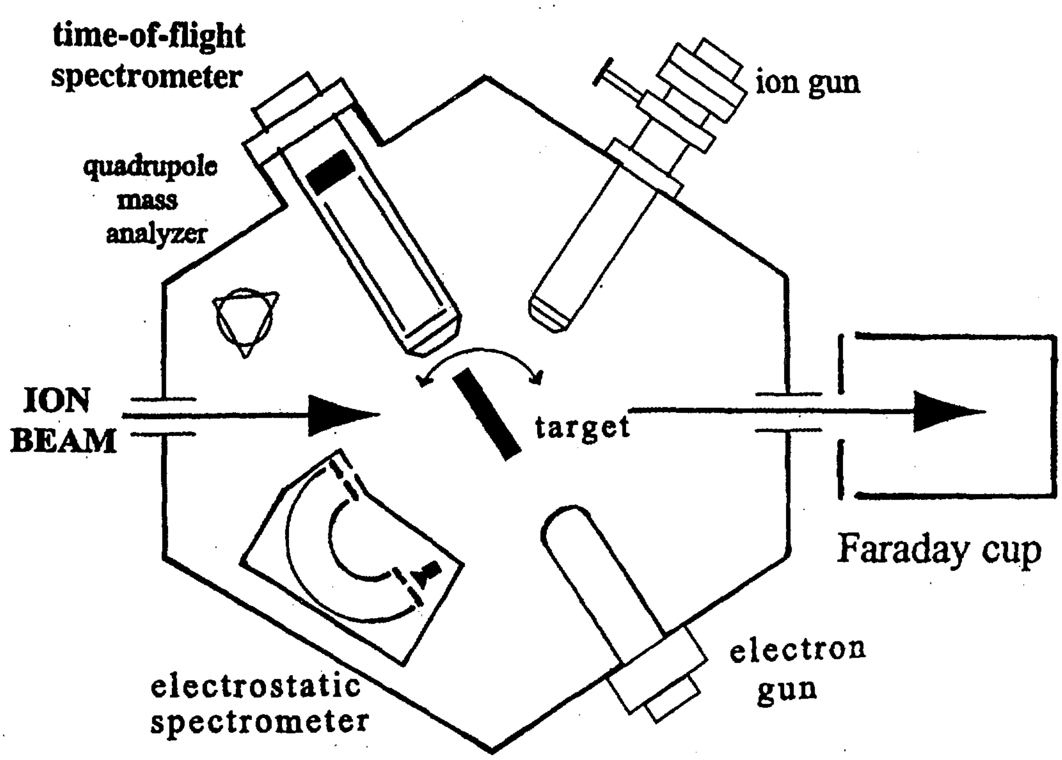
UHV chamber for studies of secondary particle emission from surfaces

M. Caron[%], M. Jung[§], F. Haranger, V. Mouton, D. Lelièvre, H. Rothard

Centre Interdisciplinaire de Recherche Ions Lasers CIRIL (CEA-CNRS-ISMRA), Rue Claude Bloch, BP 5133, F-14070 Caen Cedex 05, France

[%]now at: *PHILIPS GmbH, Philips Research Laboratories, Luminescence and Electron Emission D303, Weisshausstrasse 2, D-52066 Aachen, Germany*
[§]now at: *ELS - Elektronik Laser System GmbH, Reinheimer Str. 11, D-64846 Groß-Zimmern, Germany*

The interaction of a swift heavy ion with solids leads to the emission of a large number of secondary particles (electrons, ions, neutrals) which serve as messenger for the mechanisms of energy deposition and damage creation. Up to now, most studies at large accelerators have only been performed in standard vacuum with uncontrolled surfaces. Therefore, we developed an ultrahigh vacuum (UHV) set-up especially designed for experiments on secondary particle emission from surfaces at GANIL. Results concerning high charge effects in electron emission and first studies of electronic sputtering and desorption are reported elsewhere in this compilation.



The whole set-up was mounted on a mobile support for easy transportation and rapid installation. Differential pumping chambers (p ≈ 10^{-8} mbar) upstream and downstream of the main UHV chamber (p ≈ 5.10^{-10} mbar) allow mounting on standard vacuum beam lines (p ≈ 10^{-7} mbar). It is equipped with an ion sputter gun (Ar ions of 500 eV energy) for surface cleaning. An electrostatic spectrometer allows the measurement of electron spectra (also Auger electrons for surface control). The set-up is also equipped with a quadrupole mass analyzer for residual gas analysis. A Time-of-Flight spectrometer is used for measurements of secondary ion ejection. In addition to external ion beams, a pulsed electron gun (energy range 0.3 - 10 keV) can be used as primary particle source.

Literature: M. Caron et al., Nucl. Instrum. Meth. B146 (1998) 126.

2 - COLLISIONS OF IONS WITH ATOMS AND MOLECULES

One- and two-K-shell vacancy production in Li by 95 MeV/u Ar^{18+}

N. Stolterfoht[1], J.-Y. Chesnel[2], B. Sulik[3], F. Frémont[2], D. Hennecart[2], X. Husson[2], D. Lecler[2], A. Cassimi[2], J.-P. Grandin[2], J. Rangama[2], B. Skogvall[1], J.-H. Bremer[1], and J.A. Tanis[4]

[1]Hahn-Meitner-Institut GmbH, Bereich Festkorperphysik, D-14109 Berlin, Germany
[2]CIRIL, Unité Mixte CEA-CNRS-ISMRA et Université de Caen, F-14050 Caen Cedex 4, France
[3]Institute of Nuclear Research (ATOMKI), H-4001 Debrecen, Hungary
[4]Department of Physics, Western Michigan University, Kalamazoo, Michigan 49008

A comprehensive study of single K-shell excitation and double-K-shell-vacancy production in atomic Li induced by 95 MeV/u Ar^{18+} projectiles was performed in collaboration with the group of atomic physics at CIRIL (P460). At this high velocity (v/c = 0.42), excitation and ionisation should be well described by perturbation theories, and connections to photoinduced processes are expected. High-resolution spectra for Auger-electron emission, resulting from the deexcitation of singly- or doubly-excited states, were measured for various electron emission angles. A typical high-resolution spectrum is shown in Fig. 1. Both single-K-shell excitation and double-K-shell vacancy production show strong dependencies on the electron emission angle. Single-K-shell excitation results mainly from dipole-like transitions, showing that the fast ions can be considered a source of virtual photons. Experimental anisotropy parameters for the (1s2snp) ^2P states resulting from single-K-shell excitation were found to be in good agreement with predictions of the Born approximation. In the case of double-K-shell-vacancy production, the two K vacancies come about mainly by ionisation plus excitation of the atomic Li target, giving rise to excited states in Li^+. Strong line intensities from the $2s^2\ ^1S$ and 2s3s ^3S excited states are explained in terms of *shake* processes [1], providing direct spectral identification for the electron-electron *(e-e)* interaction in producing the doubly vacant K-shell configurations. Production of the 2s3s ^3S state, with intensity larger than that of the $2s^2\ ^1S$ state, is attributed to a correlated *double-shake* process [2] that involves a dynamical manifestation of the Pauli exclusion principle. Production of the 2s2p ^3P state is attributed *partly* to the dielectronic [3] manifestation of the *e-e* interaction, resulting from slow electron emission, in which the mutual interaction of the two electrons leads to an exchange of angular momentum. To identify separately the dielectronic contribution to the 2s2p ^3P state an additional experiment (P509) has later been performed at GANIL by using a 60-MeV/u Kr^{34+} ions of roughly the same velocity as the present projectiles, but with a charge about two times larger.

References:

[1] J.H. McGuire, Electron Correlation Dynamics in Atomic Collisions, Cambridge Univ. Press, 1997
[2] J.A. Tanis *et al.*, Phys. Rev. Lett. **83**, 1131 (1999) ; Phys. Rev. A **62**, 032715 (2000).
[3] N. Stolterfoht, Nucl. Instr. Meth. Phys. Res. B **53**, 477 (1991).

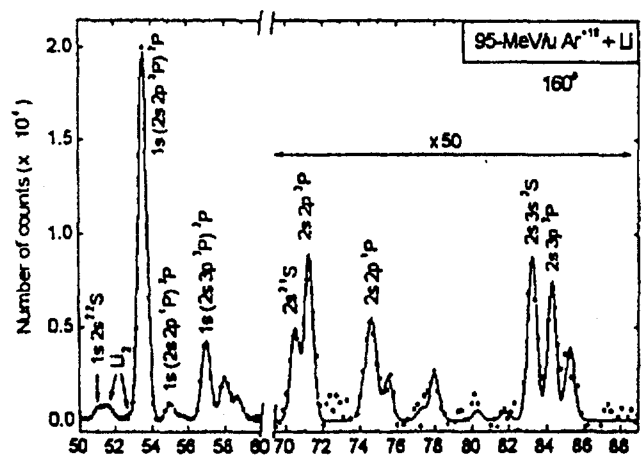


Fig.1: *High-resolution Auger spectrum at 160° emission angle for 95 MeV/u Ar^{18+} + Li collisions. The region from 50-60 eV corresponds to single-K-shell excitation, while the region 70-85 eV corresponds to double-K-shell-vacancy production.*

This work was supported by the German-French Cooperation Programme PROCOPE and the German-Hungarian Intergovernmental Collaboration, the Hungarian Academic Research Fund, and the Hungarian Scientific Research Foundation and the Division of Chemical Sciences, Office of Basic Energy Sciences, Office of Energy Research, U.S. Department of Energy.

Production of double-K-shell vacancies in Li by 60.2 MeV/u Kr^{34+}

N. Stolterfoht[1], J. Rangama[2], J.-Y. Chesnel[2], J.A. Tanis[2,3], B. Sulik[4], F. Frémont[2], D. Hennecart[2], X. Husson[2], A. Cassimi[2], V. Hoffmann[1], and B. Skogvall[1]

[1]*Hahn-Meitner-Institut GmbH, Bereich Festkörperphysik, D-14109 Berlin, Germany*
[2]*CIRIL, Unité Mixte CEA-CNRS-ISMRA et Université de Caen, F-14050 Caen Cedex 4, France*
[3]*Department of Physics, Western Michigan University, Kalamazoo, Michigan 49008*
[4]*Institute of Nuclear Research (ATOMKI), H-4001 Debrecen, Hungary*

Production of K-shell-vacancies in atomic Li induced by 60.2 MeV/u Kr^{34+} projectiles was investigated (P509) to complement the experiment P460 performed previously at GANIL with 95 MeV/u Ar^{18+} ions. In fast collisions, the perturbation strength of the projectile scales with Z/v, where Z and v are the projectile charge and velocity, respectively. Hence, the perturbation strength of 60.2 MeV/u Kr^{34+} projectiles ($Z/v = 0.7$ a.u.) differs from that of 95 MeV/u Ar^{18+} projectiles ($Z/v = 0.3$ a.u.) by a factor larger than two. High-resolution spectra for Auger-electron emission, resulting from the deexcitation of doubly-excited states of lithium, were measured for various electron emission angles. A typical high-resolution spectrum is shown in Fig. 1, and compared with a spectrum obtained previously with a 95-MeV/u Ar^{18+} ion beam (P460).

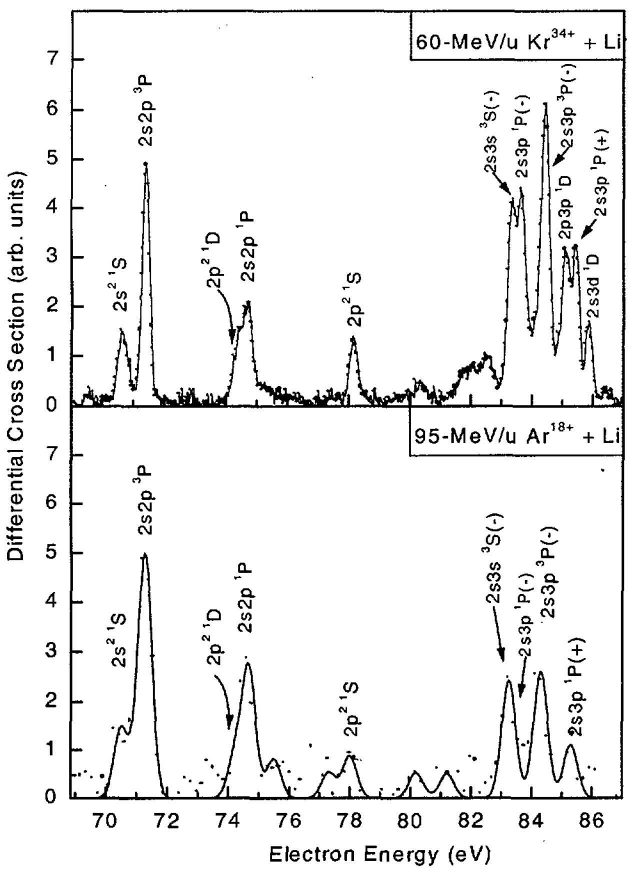


Fig.1: *High-resolution Auger spectra for 60.2 MeV/u Kr^{34+} + Li (upper part) and 95 MeV/u Ar^{18+} + Li (lower part) collisions. The Auger electron emission follows the production of double K-shell vacancies.*

The spectra show that the two K vacancies come about mainly by ionisation plus excitation of the atomic Li target, giving rise to excited states in Li^+. Double *K*-shell vacancy production in Li is primarily produced by two mechanisms: (i) TS2 where the incident projectile interacts independently with each electron in a single collision and (ii) TS1 where a single projectile-electron interaction is followed by an electron-electron (*e-e*) interaction.

The *e-e* interaction has two aspects corresponding on whether the first electron is emitted slowly or suddenly. For slow emission, subsequent transition of a second electron involves the mutual interaction of the two active electrons, which is the *dielectronic* [1] manifestation of the *e-e* interaction. On the other hand, sudden emission can result in a *shake* process [2], where the subsequent transition is due to the change in the potential seen by the second electron. From perturbation theory it follows that the transition probability for TS1 depends on $(Z/v)^2$ whereas the transition probability for TS2 depends on $(Z/v)^4$. Hence, the study of double *K*-vacancy production at various Z/v values allows for a detailed investigation of the mechanisms.

The production of the *S* states is due to a *shake* process [(P460), 3], following the sudden emission of the first active electron. In contrast to the *S* states, the production of the *P* and *D* states can originate from the TS2 process and/or from the *dielectronic e-e* interaction. Hence, in accordance with perturbation theory, the enhancement of the relative population of the *P* and *D* states observed when using Kr^{34+} projectiles (see Fig. 1) is due to the fact that the relative contribution of TS2 increases with increasing Z/v. From the comparison between the spectra obtained with Ar and Kr, the TS1 and TS2 contributions to the mechanisms producing the *P* and *D* states can separately be identified and evaluated. Since the *P* and *D* states cannot be produced by shake [3], identification of the TS1 contribution to the *P* and *D* states makes it possible to separate the *dielectronic* contribution to the *e-e* interaction. Thus, combination of the present results with those obtained previously during the experiment P460 shows that the shake and dielectronic contributions to the *e-e* interaction can be separately identified from spectral intensities alone.

Lastly, it should be noted that at the beginning of the beam time preliminary measurements were performed using a H_2 gas target. The two-center molecular structure of H_2 makes it an interesting target when bombarded with fast ions. A detailed analysis of the test spectra combined with theory has given evidence for interference effects produced by the coherent emission of electrons from the two H atoms (in analogy with Young's two-slit experiment).

References:

[1] N. Stolterfoht, Nucl. Instr. Meth. Phys. Res. B **53**, 477 (1991).
[2] J.H. McGuire, *Electron Correlation Dynamics in Atomic Collisions,* (Cambridge Univ. Press, Cambridge, 1997).
[3] J.A. Tanis *et al.*, Phys. Rev. Lett. **83**, 1131 (1999) ; Phys. Rev. A **62**, 032715 (2000).

This work was supported by the French-German Collaboration Programme PROCOPE, the Hungarian OTKA-Grant (To32942), the Hungarian-German S&T Collaboration (TeT, D17/99), the U.S. Department of Energy, Office of Basic Energy Science and the Transnational Access to Research Infrastructures under the EC contract number HPRI-CT-1999-00019.

Mechanisms responsible for the capture of inner-shell electrons in slow He^{2+} + CO collisions

P. Sobocinski, J. Rangama, J.-Y. Chesnel, M. Tarisien, L. Adoui, A. Cassimi, X. Husson and F. Frémont,

Centre Interdisciplinaire de Recherche Ions Lasers, Unité Mixte CEA-CNRS-ISMRA-Université de Caen Basse Normandie, 6 Bd du Maréchal Juin, F-14050 Caen Cedex, France

Electron capture in slow He^{2+} + CO collisions has been studied using Auger electron spectroscopy at the ECR source of GANIL. Electrons ranging from 1 to 500 eV were detected. For the system He^{2+} + CO at a projectile energy of 16 keV, it was first shown that the major contribution of the total cross section is due to non fragmented CO^{+} ions. However, a large production of CO^{3+} molecular ions (~ 17%), compared to the production of CO^{2+} ions (~ 28%) was found.

This result was surprising, since He^{2+} can capture only two electrons from the target, and direct ionization of the target is unlikely to occur at low impact energies. Moreover, the kinetic energy release (KER) during the dissociation of CO^{2+} and CO^{3+} ions was found to be significantly different from that observed in photon-induced or swift heavy ion-induced dissociation.

To explain these trends, the primary collision process was discussed in terms of the extended over-barrier model (EOBM). From the EOBM calculations, it was suggested that the CO^{3+} production is due to double capture involving outer and *inner* electrons from the target. Thus, after the capture the residual CO^{2+} ion may decay by means of a Auger transition.

Hence, we have investigated the capture mechanisms in order to gain insights into the role of inner- and outer-CO electrons. We measured energy spectra of autoionization arising from collisions of He^{2+} on CO molecules at a projectile velocity of about 0.4 atomic units. A particular effort was devoted to low energy spectra following He^{2+} + CO collisions to give evidence for the capture of inner-valence electrons.

Velocity dependence of the $n\ell m_\ell$ distributions produced by state-selective electron capture in slow Ar^{8+}-X {X≡alkaline target}

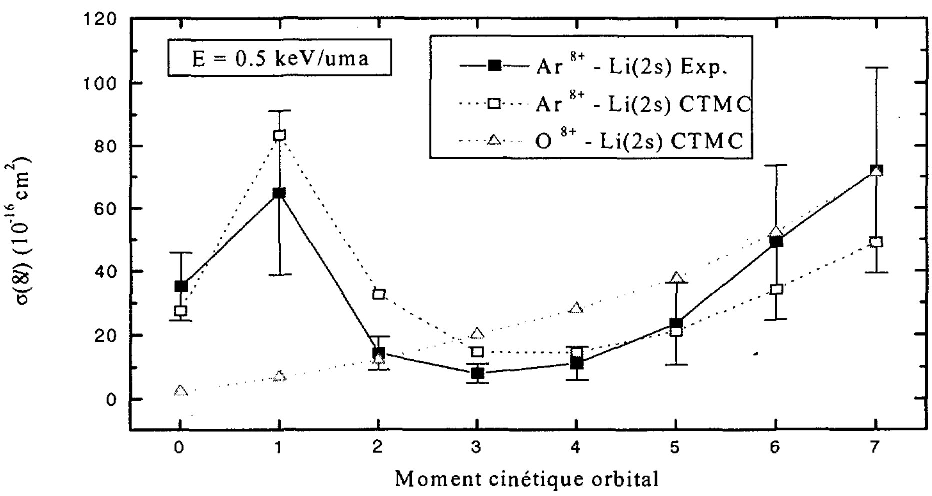
V. Bazin, P. Boduch P., M. Chantepie, E. Jacquet , H. Kucal, C. Laulhé, D. Lecler, J. Pascale

CIRIL (CEA-CNRS-ISMRA), 6 bd. du Maréchal Juin, F-14050 Caen Cedex 04

Collisions between slow Ar^{8+} produced by an ECR source at GANIL and an alkaline target in its ground state or in its first excited configuration were performed in the 0.1-5 keV/u energy collision range by photon spectroscopy in the 200-600 nm wavelength domain. For this energy range, the prevailing process is the capture of the external electron of the target into excited radiative states defined by n (the principal quantum number), ℓ (the orbital quantum number) and m_ℓ (the magnetic quantum number) : Ar^{8+} + Li ($1s^2 2s$) $\rightarrow Ar^{7+}(n\ell m_\ell)^*$ + Li^+

Detection of the corresponding emitted photons allows to determine the production cross section $\sigma(n\ell)$ for each populated configuration versus the collision energy. A typical $n\ell$ distributions for the Ar^{8+}-Li(2s) system are shown in figure 1 for n = 8 and a slow collision energy (0.5 keV/u) and compared to CTMC simulation for the same system and for the iso-charged system O^{8+}-Li(2s).

Figure 1

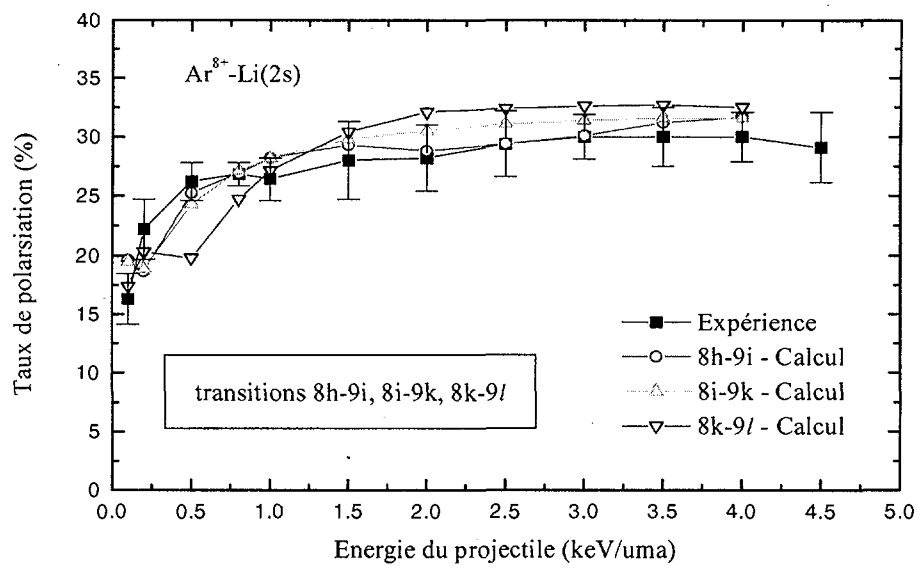


The present $n\ell$ distribution is not statistic: only low and high ℓ values configurations are mainly populated. Such a distribution is the result of the competition between the core electron effect of the projectile and the Stark effect of the residual ion target. The high ℓ value configurations are nearly degenerated and can be mixed by Stark effect thus leading to the population of the highest ℓ values. The production of the low ℓ value configurations is due to the core electron effect. These configurations are not degenerated and cannot be mixed by the Stark effect. This explanation is confirmed by the comparison with the CTMC simulation on the O^{8+}-Li(2s). In this case, the projectile is a bare ion and all $n\ell$ configurations of the O^{7+} ions are degenerated and can be mixed by Stark effect (figure 1). This core electron effect is velocity dependent and vanishes at higher collision energy.

Concerning the collision system Ar^{8+}-Cs(6p) with a laser excited target, new lines are observed. They correspond to the shift of the reaction window to higher n values (for example n=14). Concerning the $n\ell$ distribution, only lines from high ℓ value configurations are observed and the corresponding distribution is the same as in a system with a non-excited target. In this kind of experiment, the target can be excited and aligned either parallel or perpendicularly to the ion bean direction. No anisotropy effect due to this initial alignment is observed on the $n\ell$ distribution.

The m_ℓ distribution is determined from the polarisation degree of each single electron capture lines and from CTMC simulations. The polarisation degree is defined as $P = \frac{I_{//} - I_{\perp}}{I_{//} + I_{\perp}}$ where $I_{//}$ is the light intensity polarised parallel to the ion beam direction and $I_{\perp}$ the light intensity polarised perpendicular to the ion beam direction. P can be expressed in terms of the $\sigma(m_\ell)$ production cross section in the m_ℓ sub-states. Such cross sections are calculated with the CTMC method. If the agreement between the experimental and theoretical values of the polarisation degrees is good, we can assume that the $m\ell$ CTMC should be a good picture of the real m_ℓ distribution. An example of the evolution of the polarisation degrees (exp. + theo., versus collision energy) for the Ar^{8+}-Li(2s) system is shown in figure 2.

Figure 2



The experimental and theoretical results are in a very good agreement. For the higher collision energy, the polarization degree is positive and of the order of 30%. The corresponding $m\ell$ distribution is very sharp around low m_ℓ values (m_ℓ=0 and m_ℓ=±1). The initial populated states are redistributed by Stark effect and intershell rotational couplings. As the collision energy decreases, P decreases, too : the $m\ell$ distribution becomes wider. Due to the presence of the core electrons, the rotational coupling becomes an intrashell coupling yielding to a widening of the $m\ell$ distribution. For the system with an excited target, no alignment effect is observed on $m\ell$ distribution.

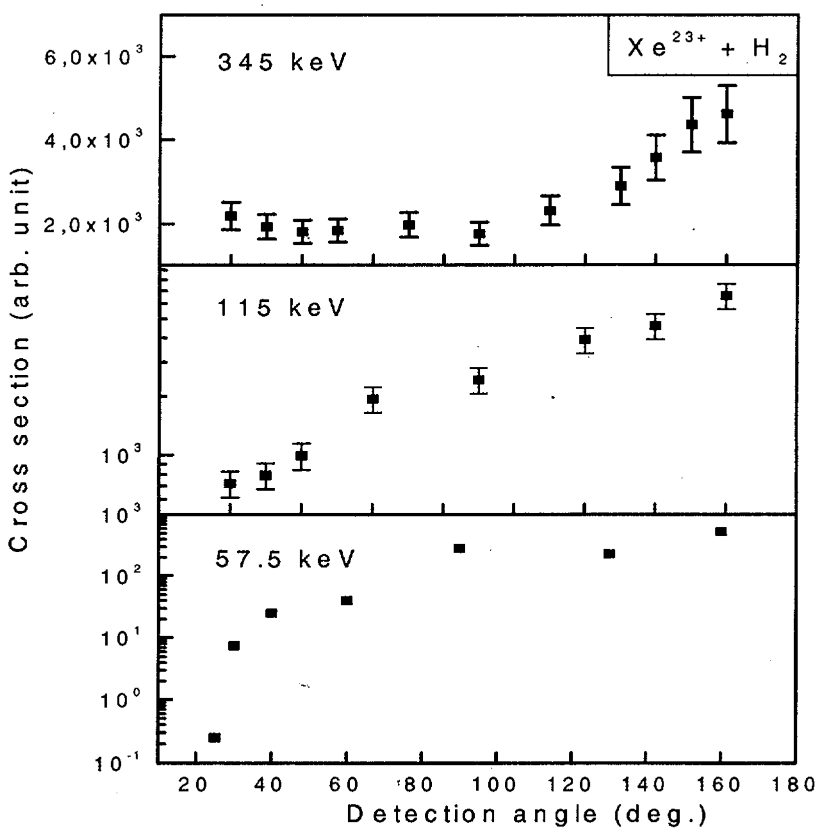
Literature: C. Laulhé et al., J. Phys. B 30 1517 (1997); C. Laulhé et al., J. Phys. B 30 2899 (1997); V. Bazin et al., PRA 62 52706 (2000); V. Bazin et al., PRA, submitted (2001).

Fragmentation of H_2 following the impact of highly charged ions at low velocity

F. Frémont[†], C. Bedouet[†], M. Tarisien[†], L. Adoui[†],
A. Cassimi[†], A. Dubois[‡], J.-Y. Chesnel[†], X. Husson[†]

[†] *Centre Interdisciplinaire de Recherche Ions Lasers, Unité Mixte CEA-CNRS-ISMRA-Université de Caen Basse-Normandie, 6 Bd du Maréchal Juin, F-14050 Caen Cedex, France*
[‡] *Laboratoire de Chimie Physique-Matière et Rayonnement, 11 rue P. et M. Curie, F-75231 Paris Cedex, France*

The fragmentation of H_2^{2+} ions following double capture in slow Xe^{23+} + H_2 and O^{5+} + H_2 collisions has been studied at the ECR source (GANIL). The emitted protons have been detected as a function of the observation angle. For both systems, the energy distribution of the ionic fragments was found to depend significantly onto the detection angle, whereas the Franck-Condon picture predicts a transition leading to an energy of about 9.5 eV for each fragment. To explain the deviation from the Franck-Condon picture, two models have been introduced. The first model, which does not take into account the influence of the projectile on each fragment (post-collision interaction) shows that, at a projectile velocity of ~ 0.4 a.u., the proton energies originate mainly from both the recoil energy of the center of mass of the ionized molecule during the collision, and the molecular dissociation energy (~ 9.5 eV).



To give evidence for the specific role of the projectile, measurements were performed at lower impact energies. For the system Xe^{23+} + H_2, the analysis of the fragment emission cross sections reveals that the protons are repulsed in backward directions (see figure), due to the Coulomb forces induced by the projectile.

Molecular fragmentation following swift collisions with multicharged ions: beyond the "Coulomb Explosion" picture

L.Adoui[1], M.Tarisien[1], F.Frémont[1], B.Gervais[1], A.Dubois[2], M.Krishnamurthy[3], Sanjay Kumar[4], D.Mathur[3] , A.Cassimi[1]

[1]*CIRIL, CEA/CNRS/ISMRA/Université de Caen, BP5133, F-14070 Caen Cedex 5, France*
[2]*Laboratoire de Chimie Physique, Matière et Rayonnement, Univ. Pierre et Marie Curie, France*
[3]*Tata Institute of Fundamental Research, Homi Bhabha Road, Mumbai 400 005, India*
[4]*Department of Chemistry, Indian Institute of Technology, Madras, Chennai 600 036, India*

The recent emergence of imaging technique gives rise to a growing interest in the understanding of ion-molecule fragmentation dynamics as one can expect to go further in the description of all of the stages of the collision. Information on the fragmentation dynamics is obtained from the coincident measurement of the momentum vector of all the fragments. Recoil Ion Momentum Spectroscopy is improved to match high Kinetic Energy Release (KER) resolution for a wide range of collision energies together with angular distribution measurement. The principle of RIMS technique has been widely detailed especially when applied to ion-atom collision studies [1]. From the time of flight and the impact position measurements of all the fragments on a Position Sensitive Detector (PSD), the initial momentum of each fragment is deduced *via* simple algebra. The main adaptations of this technique to the molecule fragmentation study concerns the multihit capability requirements and the strong electric field needed to maintain the 4π solid angle efficiency. The time and the position resolutions lead to an achievable momentum resolution $\Delta p/p$ of about 5.10^{-3} corresponding to an energy resolution of 250 meV for recoil energies of the order of 10eV. All of the projectiles used in this study were provided by the GANIL facilities (Caen, France). The experiments with swift projectiles (11.4 MeV/u O^{7+} and 8 MeV/u Ni^{24+}) were performed on the SME (Sortie Moyenne Energie) line (P469), while the low-energy projectiles (few keV/u) were produced by the 14.5GHz electron cyclotron resonance source of LIMBE (Ligne d'Ions Multichargés de Basse Energie).

Numerous experiments have recently been devoted to the multiple ionization of small molecules such as CO or N_2 by various high energy projectiles and to the dissociation of subsequent $(CO)^{q+}$ or $(N_2)^{q+}$ ions. The deviation of the KER distribution widths compared to those predicted by the simple Coulomb Explosion Model has been the motivation to go further in the description of the scenario of the fragmentation. The KER distributions for the $(CO)^{2+} \rightarrow C^+ + O^+$ dissociation channel induced by 8 MeV/u Ni^{24+} projectiles is presented in figure 1. A similar structure has been observed in the case of 11.4 MeV/u O^{7+} projectiles [2]. The 250 meV KER resolution together with high-level computations of dication potential energy curves (65 excited states were considered) and application of time-dependent wavepacket dynamics lead to a succesful attempt to assign each line of the observed structure in the KER to an excited state of the transient molecular dication produced during the collision [2]. This is a direct experimental evidence of the limitations of the coulombic representation (which predicts a 12.8eV mean energy value) to reproduce the molecular fragmentation dynamics induced by ion impact. These results demonstrate the ability of this technique to investigate molecular ion spectroscopy and to test the validity of computed theoretical molecular potential energy surfaces. The direction of the molecular axis with regard to the beam direction is derived from the momenta measurement. The alignment dependence for one selected fragmentation channel $(CO)^{5+} \rightarrow C^{3+} + O^{2+}$ is presented in figure 2. The angular distribution exhibits no angular preference as $d\sigma/d\theta$ can be well approached by a $\sin\theta$ law where θ is the angle between the molecule internuclear axis and the ion beam direction. This result is qualitatively understood in terms of mean impact parameter *b* value : the more distant the electron removal takes place, the more blurred this alignment dependence. This is the case in the very high velocity-high charge regime.

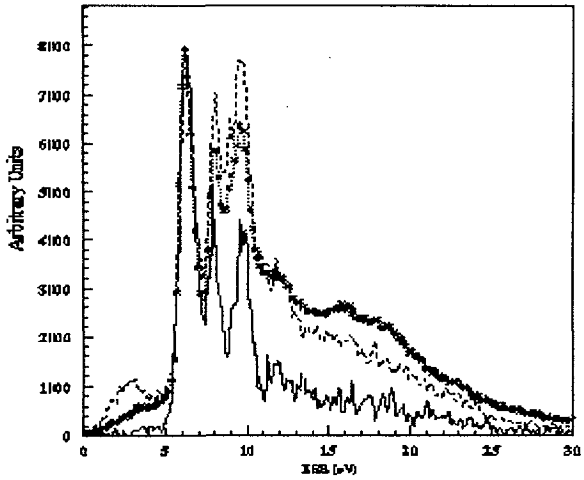


Fig.1: *Comparison between Kinetic Energy Release (KER) distribution for the $C^+ + O^+$ fragmentation channel induced by 8MeV/A Ni^{24+} (dashed curve with symbols), by 11.4MeV/A O^{7+} (dashed curve) and 4keV/A O^{7+} (straight line) projectiles.*

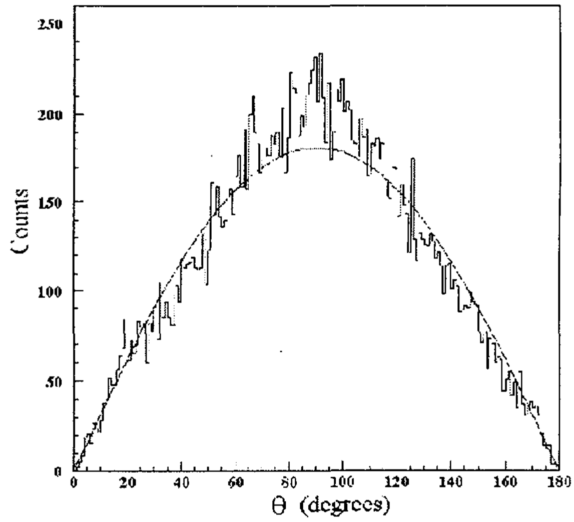


Fig.2: *Alignment dependence for the multiple ionization of CO molecules in collision with 8MeV/A Ni^{24+} projectiles in the case of the dissociation channel and comparison to a sine distribution.*

A dependence of the KER distributions upon the K=Q/v ratio (where Q is the projectile charge state and v its velocity) usually defined to characterize the interaction strength between the projectile and the target is also realized by a comparison with the swift 11.4 MeV/u O^{7+} ion-induced results. This comparison between the high energy O^{7+} (K = 0.3) and Ni^{24+} (K = 1.3) projectiles for the same $(CO)^{2+} \rightarrow C^+ + O^+$ dissociation channel is presented in figure 1. It indicates that an increase in the interaction strength results in a more efficient population of high-lying dissociating states and consequently in an increase of the mean kinetic energy value. Similar behaviour has already been reported in this interaction regime.

The experiment was also performed with low-energy 4 keV/u O^{7+} projectiles in order to compare the dissociation induced by two different primary processes (*i.e.* by electron capture process rather than by ionization). The results are also shown in figure 1. If the main structures are similar in both cases, a difference between the relative dication excited-state populations produced either by electron capture or by direct ionization is evidenced. The enhanced line intensity for high KER values, in the high projectile energy case, is attributed to the fact that electronic excitation during the collision is more likely to occur in this energy regime. This interpretation is strengthened dealing with the component below 2 eV and attributed to highly excited CO^+ states autoionizing to a dissociative state leading to a $C^+ + O^+$ ion pair below the threshold for metastable CO^{2+} formation [2].

The high density of molecular excited states makes impossible a similar line assignment (as realised for q = 2) for more highly charged molecular ion $(CO)^{q+}$ with $q \geq 3$. Very recently, in order to overcome this difficulty, Siegmann et *al.* [3] developped a more elaborate semi-phenomeno-logical model of Coulomb fragmentation based on a statistical description of the individual potential energy curves of the molecular ion. They attribute the increase of the width distribution for high q values to the spread of the potential energy curves due to the mutual polarization of the molecular fragments. The mean energy value and the width of the KER distribution are well reproduced by this model.

References: [1] Cassimi A., Nouvelles du GANIL **63**, 13 (1998)
[2] Tarisien et al., J. Phys. B : At. Mol. Opt. Phys. **33**, L11 (2000).
[3] Siegmann, B., Werner, U., Mann, R., Kabachnik, N.M. and Lutz H.O., Phys. Rev. A **62**, 022718 (2000)

Multi-fragmentation dynamics in molecular physics

M.Tarisien, L.Adoui, F.Frémont, B.Gervais, A.Cassimi

*CIRIL, CEA/CNRS/ISMRA/Université de Caen, rue Claude Bloch, BP5133,
F-14070 Caen Cedex 5, France*

The measurement of the momentum vector of each fragment becomes of the first importance to characterize the fragmentation dynamics in the case of a tri-atomic molecule such as CO_2 and fixed-in-space molecule experiments are possible. Even a slight bend of the tri-atomic molecule leads the fragments to move in a plane rather than on an axis as in the case of diatomic molecules. We present here preliminary results for the 8 MeV/u Ni^{24+} -induced CO_2 fragmentation (P460). In order to explore the geometry modification of the molecule during the dissociation process for each fragmentation channel $(CO_2)^{q+*} \rightarrow C^{q1+} + O^{q2+} + O^{q3+}$, we define as characteristic variables the angles θ and χ, where θ (the so-called "bend angle") and χ are defined in fig.1. These velocity-space coordinates can be used to discriminate if the dissociation process is "concerted" (the two C-O bonds break simultaneously, *i.e.* on a time shorter than the other characteristic times) or "sequential" (one C-O bond is broken, then the other one breaks eventually after a rotation of the residual molecular fragment center-of-mass).

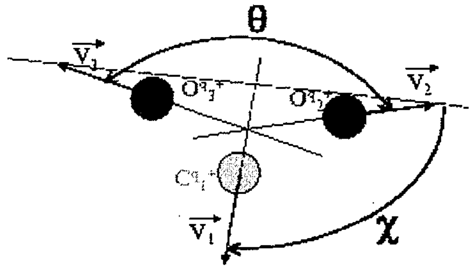
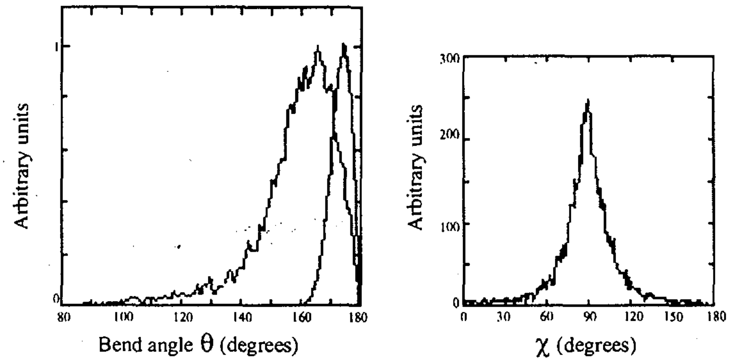


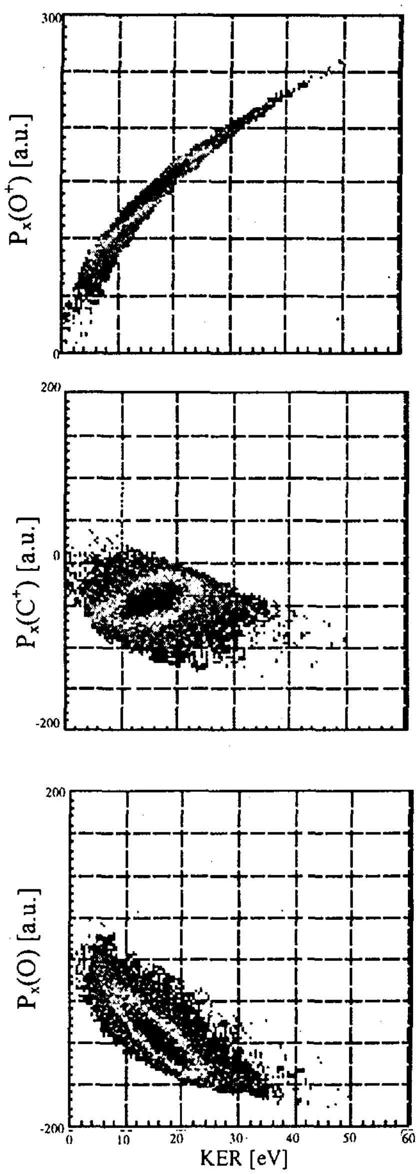
Fig.1: *Definition of the velocity-space angles in the case of the CO_2 molecule.*

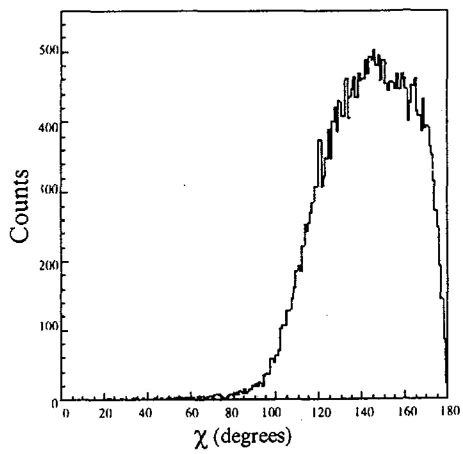
The results for θ and χ distributions are presented in figure 2 in the case of $C^+ + O^+ + O^+$ exit channel. The χ distribution is found to be strongly peaked at a value of 90°, characteristic of a concerted fragmentation. The width of the distribution is of the same order than that in the case of the $H^+ + H^+ + O^+$ channel coming from the fragmentation of the H_2O molecule [1]. In this latter work, the width was well reproduced by an *ab initio* calculation taking into account the few lowest excited state of the transient $(H_2O)^{3+}$ and assuming a purely concerted breakup. The θ distribution is presented compared to the ground-state zero point distribution of the neutral molecule. The most probable value is in this case shifted toward the smaller values of θ -the molecule slightly bends before breaking- but we can note above all the extension of this distribution down to approximately 100°. No such bending has yet been observed in low-energy Ar^{8+} [2] or in laser [3] –induced CO_2 fragmentation. The analysis of the evolution of each fragment momentum on the whole range of KER accessible for this dissociation channel (approximately from 15 to 80 eV) leads to the conclusion that for all of those energies, the fragmentation is mainly concerted with a C^+ fragment nearly at rest and two O^+ fragments leaving "simultaneously" in opposite directions.

The same angular distributions are also determined in the case of the $(CO_2)^{2+*} \rightarrow C^+ + O^+ + O$ dissociation channel. Since the neutral fragments are not detected, these results are derived from the C^+ and O^+ coincidences. The χ distribution is now found to be quite uniform in the 90°-180° range (figure 3). A stepwise interpretation of the fragmentation is thus possible for this channel. The θ distribution shifts slightly to smaller values. More interesting is the analysis of the momentum of each fragment versus the KER values. If we choose to define as the x-axis of the frame of reference in the fragmentation plane (xOy) the O^+ direction, then the three collision partners contribute to the momentum balance in the x-direction while the C^+ and O fragments have opposite momentum component in the y-direction.



<u>Fig.2:</u> *θ and χ distributions in the case of $C^+ + O^+ + O^+$ final state following a 8MeV/u Ni^{24+}-induced CO_2 molecule fragmentation. The ground-state zero-point distribution of the neutral molecule (dotted line) is superimposed to the experimental distribution (straight line).*





<u>Fig.3:</u> *χ distribution in the case of $C^+ + O^+ + O$ final state following a 8 MeV/u Ni^{24+}-induced CO_2 molecule fragmentation.*

<u>Fig.4:</u> *x-momentum component versus KER values for each fragment in the case of the of $C^+ + O^+ + O$ final state following a 8MeV/u Ni^{24+}-induced CO_2 molecule fragmentation (see text for the x-axis definition).*

We present in figure 4 this x-momentum component versus the KER value. We can see that the O^+ fragment momentum is found to increase with the KER values for the three fragments. Most of the events are clustered close to the maximum kinematically accessible by the energy and momentum conservation rules. This maximum corresponds to the configuration where the O^+ fragment is emitted in one direction with a momentum which compensates the momentum of the center-of-mass of the residual $(CO)^+$ molecular ion. We can see, for example, that for a KER value of approximately 10 eV, the C^+ and O fragments are emitted in the opposite direction compared to the O^+ fragment and share approximately equally the momentum. Then, increasing the KER value (*i.e.* going to higher excited molecular ion states), the situation tends to look like the one observed for the $C^+ + O^+ + O^+$ dissociation channel. In conclusion, the $(CO_2)^{2+*} \rightarrow C^+ + O^+ + O$ dissociation seems to be rather sequential with preferentially first a O^+ - $(CO)^+$ intermediate stage and then a fragmentation of the residual molecular ion in its center-of-mass. Further data analysis are still in progress but these first results are promising to enlighten the fragmentation dynamics of more complex systems.

References: [1] Werner, U., Beckord, K., Becker, J. and Lutz, H.O., Phys. Rev. Letters **74** 1962 (1995).
[2] Sanderson J.H., et al, Phys. Rev. A **59** 4817 (1999).
[3] Bryan W.A. et al, J. Phys. B : At. Mol. Opt. Phys. **33** 745 (2000).

3 - COLLISIONS WITH SOLIDS AND SURFACES : TRANSPORT PHENOMENA, ENERGY DEPOSITION AND SPUTTERING

Fast electron ejection from swift heavy ion collisions with solids studied with the multidetector ARGOS

G. Lanzanò[1], E. De Filippo[1], D. Mahboub[2], H. Rothard[3], C. Volant[4], S. Aiello[1], A. Anzalone[2], N. Arena[1], S. Cavallaro[2], E. Geraci[2], M.Geraci[1], F. Giustolisi[2], A. Pagano[1], G. Politi[1], D.H. Jakubassa-Amundsen[5],

[1]*Istituto Nazionale di Fisica Nucleare, Sezione di Catania and Dipartimento di Fisica Corso Italia 57, 95129 Catania, Italy*
[2]*Istituto Nazionale di Fisica Nucleare, Laboratorio Nazionale del Sud, Catania*
[3]*CIRIL (CEA/CNRS/ISMRA), BP 5133, 14070 Caen Cedex 05, France*
[4]*DAPNIA/SPhN, CEA/Saclay, 91191 Gif-sur-Yvette Cedex, France*
[5]*Physics Section, University of Munich, Am Coulombwall 1, 85748 Garching, Germany*

This experiment (P525) concerns the application of the powerful large detector array ARGOS, initially designed for nuclear physics studies, to atomic collision experiments at GANIL (with 95 A MeV Ar and 29 A MeV Pb beams). The aim was to measure absolute doubly differential cross sections for fast electron ejection from solid foils. Such data are important for modelling energy deposition in condensed matter in view of applications of heavy ion beams in radiobiology and materials science. This experiment is an example for a fruitful interdisciplinary collaboration of atomic, solid state and nuclear physicists. The measurements took place in the large scattering chamber NAUTILUS of GANIL, which was recently removed from cave G1 and re-installed in cave G4. Thanks to the important efforts of the GANIL staff, NAUTILUS became fully operational in 2000, and the experiment could be performed as planned. The measurements with a high quality Argon beam of good time resolution made the determination of absolute electron emission cross sections possible.

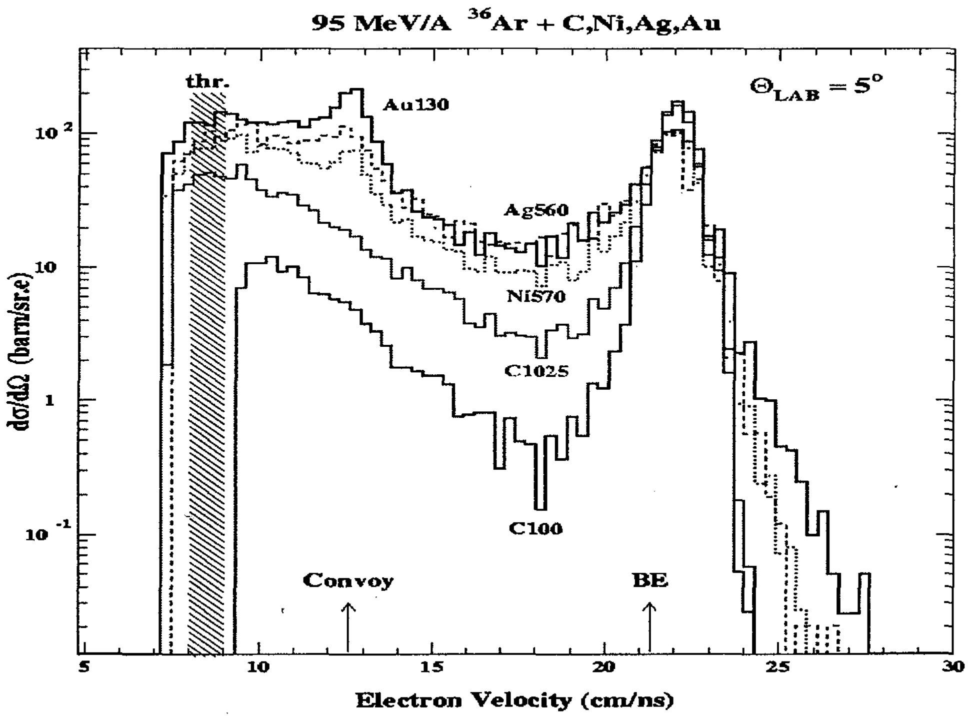


Figure 1

As an example, we show forward - (fig.1) and backward electron spectra (fig.2) for the collision systems 95 A MeV ^{36}Ar on C, Ni, Ar and Au. In the forward spectra, two distinct components are observed : convoy electrons travelling with approximately projectile velocity, and electrons from binary projectile - target electron collisions. Binary encounter electron ejection in forward direction can be well described by relativistic ionisation and electron transport theory [1,2].

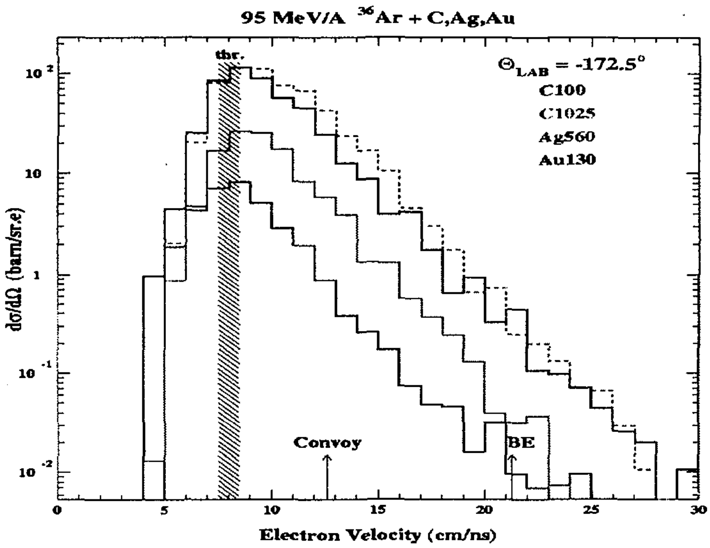


Figure 2

An unexpectedly large fraction of high energy electrons at large emission angles and in backward direction (see fig. 2) and a high velocity wing on the BE peak was observed [3,4]. These effects are related to electron transport in solids. A possible mechanism involves multiple collision sequences of electrons between target and projectile nuclei. This is often referred to as "Fermi-shuttle". A part of the BE electrons produced in the collision interacts with the target atoms along the ion trajectory and are scattered back with a certain probability of colliding again with an incoming nucleus. The probability of such higher order processes may be sharply enhanced in ion-solid compared to ion-atom collisions, because of the high target nucleus density. The importance of this effect seems to increase with projectile atomic number. Also, the target dependence of convoy electron emission reveals interesting features [4]. Further analysis of the data from the Ar (July 2000) and the Pb (November 2000) experiments is going on.

References:

[1] D.H. Jakubassa-Amundsen and H. Rothard, Phys. Rev. **A60** (1999) 385.

[2] H. Rothard, G.Lanzanò, E. DeFilippo, D. Mahboub, D.H. Jakubassa-Amundsen *Theory and Measurement of of absolute doubly differential Cross Sections of Binary Encounter Electron Ejection in Collisions of swift heavy Ions with Solids* J. Phys. B: At. Mol. Opt. Phys. **34** (2001) 3261

[3] G. Lanzanò et al., Phys. Rev. Lett. **83** (1999) 4518, Phys. Rev. **A63**, 032702 (2001).

[4] G. Lanzanò, E. DeFilippo, D. Mahboub, H. Rothard, C. Volant, S. Aiello, A. Anzalone, N. Arena, S. Cavallaro, E. Geraci, M. Geraci, F. Giustolisi, A. Pagano, G. Politi, *Absolute Cross Sections for Fast Electron Ejection by swift highly charged Ions and Evidence for "Fermi Shuttle" Acceleration*, Physica Scripta **T92** (2001) 68

This work has been supported by the European Community-Access to Research Infrastructure action of the Improving Human Potential Programme, contract N° HPRI-CT 1999-00019.

High charge effects in electron emission induced by swift highly charged ion impact on carbon

M. Caron*, M. Beuve, B. Gervais, H. Rothard

Centre Interdisciplinaire de Recherche Ions Laser (Unité Mixte CEA/CNRS/ISMRA)
CIRIL, BP 5133, Rue Claude Bloch, F-14070 CAEN Cedex 05, France
**now at: PHILIPS GmbH, Philips Research Laboratories, Luminescence and Electron Emission D303, Weisshausstrasse 2, D-52066 Aachen, Germany*

The most basic consequence of the interaction of ions with matter is ionisation and subsequent electron emission. It is a long-standing question which scaling laws apply to heavy ion induced electron ejection from solids. Commonly assumed scaling factors are the electronic stopping power or the perturbation parameter $(q_P/v_P)^2$. Strong deviations from such simple scaling were observed for low energy electron ejection with increasing perturbation (e.g., increasing ion charge at fixed velocity).

Recent experimental results and theoretical calculations point towards so-called "saturation effects" in primary ionisation, whereas often assumed collective effects on low energy electron transport seem to be of minor importance [1]. Here, we report on studies of high charge effects at the medium energy facility SME of GANIL (P476). Energy spectra and total yields of electrons emitted from sputter-cleaned amorphous carbon targets bombarded with swift ions were recorded with a UHV set-up (which is described elsewhere in this compilation). The velocity of the ions was held constant (E_p/M_p = 9 MeV/u, v_P = 19 at. u.), while the charge of the projectile q_p was changed from 6 to 45.

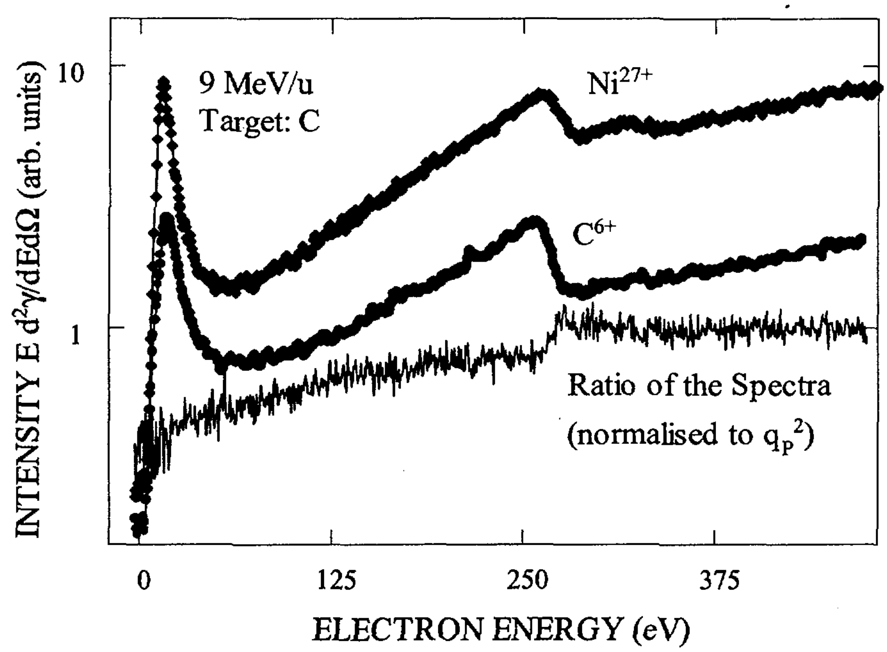


Figure 1

The shape of these spectra strongly depends on q_p as can be seen from figure 1. It shows electron spectra induced by a light ion (C^{6+}) and a medium heavy ion (Ni^{27+}) and their ratio (divided by q^2). At large electron energy, a simple q_p^2 scaling law is observed (i.e., the ratio normalised to the square of the charge equals 1). In contrast, for low electron energy (below the 1s ionisation threshold) a strong reduction effect with increasing q_p appears [2]. We observed similar high charge effects concerning the projectile dependence of electron yields from carbon foils [1].

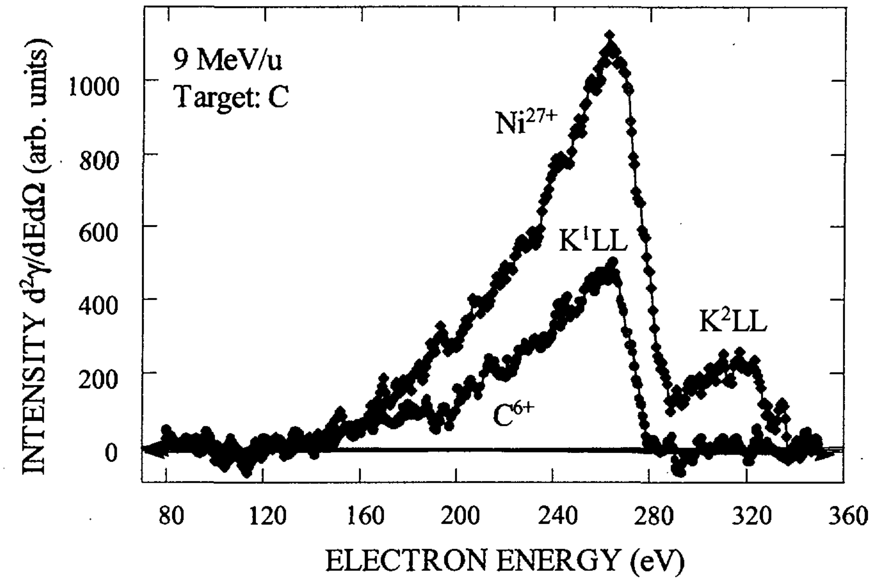


Figure 2

On the high energy side of the well known carbon KLL Auger peak at 270 eV appears the hypersatellite K^2LL line due to the double ionisation of the K shell [2] for high projectile charge only (figure 2). The corresponding Auger transition of one electron from the completely filled L shell to the doubly ionised K shell can be observed at about 312 eV. The dependence of this multiple ionisation process (which is a specific strong perturbation effect being negligible for low ionising radiation) as a function of q_p increases from a threshold up to a saturation.

Furthermore, from a careful analysis of the shape of these carbon Auger spectra including background subtraction and deconvolution techniques (for instrumental transmission, and for electron transport accounted for by a numerical simulation), we clearly observe a projectile charge dependence of the shape of the primary Auger electron spectrum. This effect is strongly connected to a modification of the electronic structure of the solid target at the moment of the Auger decay. Different possible interpretations of this effect exist (see [3] and references therein), such an increase of the "electronic temperature" or a structural modification of the material.

References:

[1] M. Beuve, M. Caron, B. Gervais, H. Rothard, Phys. Rev. **B62** (2000) 8818.
[2] M. Caron, H. Rothard, M. Beuve, B. Gervais, Physica Scripta **T80** (1999) 331.
[3] M. Caron, H. Rothard, M. Beuve, B. Gervais, Physica Scripta **T92** (2001) 281.

Ar^{17+} exited state populations through solid and gaseous carbon targets: a new sensitive test for transport theories

E. Lamour[*], L. Adoui[¶], B. Ban d'Etat[¶], A. Cassimi[¶], C. Fourment[*], B. Gervais[¶], C. Lauhlé[¶], H. Rothard[¶], J.P. Rozet[*], C. Stéphan[§], M. Tarisien[¶] and D. Vernhet[*]

[*] *GPS, Universités Paris 7 et 6, 2 place Jussieu 75251 Paris cedex 5, France*
[¶] *CIRIL, Rue Claude Bloch, 14070 Caen Cedex 5, France*
[§] *IPN, Université Paris Sud, BP n°1 91405 Orsay cedex, France*

Transport of electrons in excited states of fast ions through solids as a probe of ion-solid interactions is a subject of current investigation. A complete understanding of this problem, directly related to ion stopping power, is also important, for instance, in the optimization of the production of high intensity ion beams. The complexity of the problem is due to the fact that various aspects of the interaction have to be taken into account. Namely, the *multiple collisions* that projectile electrons suffer with particles in the solid, the *strong target polarization* induced by the incoming highly charged ions (the wake field) and the *radiative decay* of the ion.

Thus, studies on the production and on the transport of core-excited states have been performed with a different degree of sensitivity to either the individual process involved (like total or partial ionization and excitation cross sections) and/or to the dynamical screening induced by the wake field. The most recent results have been obtained in the case of the transport of Kr^{35+} inner-shells initially populated either by capture or by excitation processes[1,2,4]. The use of a large range of carbon target thickness has allowed to study the transport from single collision conditions to equilibrium. The major part of the evolution of *np* ($n \leq 4$) core state populations with thickness is relatively well described by the collisional aspect of the interaction contrary to the evolution of $3lj$ excited sub-states which gives a direct signature of the collective response of the medium. Precisely, the $3lj$ populations are sensitive to this response for very thin foils for which Stark mixing is dominant whereas collisional processes become important for thicker foils. We also have shown that the knowledge of the initial state of the ion prior to transport is an essential parameter.

To get quantitative information on the relative importance of collisional and dynamical mixing and also on the *initial conditions*, we have studied Ar^{17+} excited states produced by capture through solid and gaseous (CH_4) carbon targets at impact velocity of 23 a.u. (P500). Actually, the population of the projectile excited states is more sensitive, for this system, to the dynamical response of the medium than in the case of Kr ions on carbon foils. Great improvements in the resolving power of the crystal spectrometers on one hand, and an optimization of the intensity and quality of the beam, on the other hand, allowed us to obtain a wide range of experimental data. We have recorded spectra of the entire $np \rightarrow 1s$ Lyman series, of the 2E1 decay mode of the $2s_{1/2}$ metastable state and, also of helium-like transitions (mainly $1s2p \rightarrow 1s^2$). Concerning the Lyman lines, we were able to distinguish the *np* states for $n \leq 12$, as well as the $2p_{1/2}$ substate from the $2p_{3/2}$ one. Comparisons between the gaseous and solid targets (see, for instance, figure 1, where both spectra are normalized to the $2p_{3/2} \rightarrow 1s_{1/2}$ transition) show already an enhancement in the population of $2p_{1/2}$ substate compared to the $2p_{3/2}$ component for solid targets. This effect is a direct signature of a specific solid target effect predicted by our most recent calculations, and consistent with our previous observations on the $2s$-$2p$ mixing[2]. Besides this difference, the study of the entire series of *np* states will provide information on the projectile electron – target electron interactions of two types: direct electron - electron interaction through collisional processes (like excitation) and/or through the collective response of the target electrons (the wake field). Concerning the helium-like transitions, we have evaluated the evolution of the $^3P/^1P_1$ ratio as a function of the target thickness (figure 2); ratio which will give even more information on the wake field since induced Stark effect is not any more linear for these states and radiative decay times are also very different.

In parallel, many efforts have been recently devoted to the development of ion transport descriptions. Nowadays, we are able to take into account both aspects of the target response and, this, for two different types of approximation[3,4]. The first one is a quantum mechanical approach, solving a set of master equations, which allows selectively turning "on" or "off" the collisional and dynamical mixing on different projectile excited states. In figure 3, we can visualize the effect of wake field on the evolution of the $2s_{1/2}$ population with target thickness. The second model is based on a Monte Carlo simulation and can be performed using both classical and quantum approaches in the calculation. A completely comparison with the experimental data provides a very sensitive test for quantum effects.

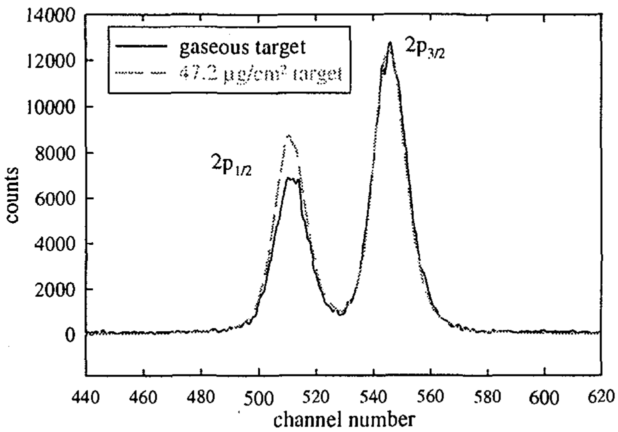


Figure 1: *Comparison between solid and gaseous target: spectra of $2pj \rightarrow 1s_{1/2}$ transitions (the spectra are normalized to the $2p_{3/2} \rightarrow 1s_{1/2}$ transition).*

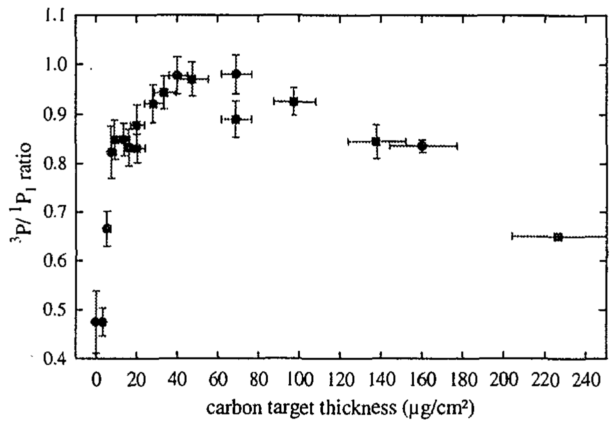


Figure 2: *Preliminary results on $1s2p \rightarrow 1s^2$ lines: $^3P(^3P_1+^3P_2)\,/\,^1P_1$ ratio as a function of carbon target thickness.*

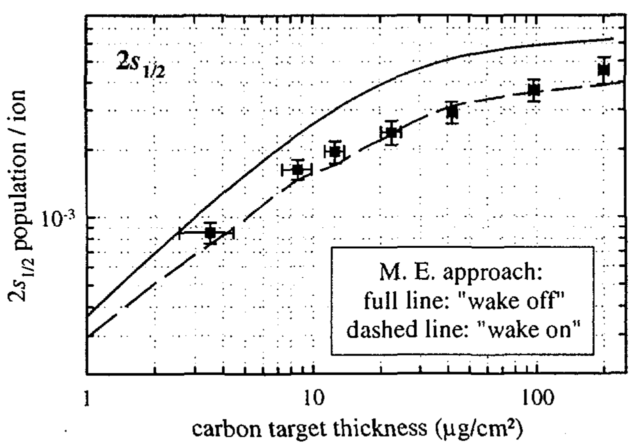


Figure 3: *Absolute $2s_{1/2}$ population of Ar^{17+} ions as a function of carbon target thickness. Comparison with the master equation (ME) approach (first model in the text) without and with the wake field effect.*

References:

1. Vernhet D. et al. (1998) J. Phys. **B31**, 117-119
2. Vernhet D. et al. (2000) AIP 500, 666-676
3. Vernhet D. et al. (2001) Phys. Scripta **T92**, 233-236
4. Reinhold C.O. et al. 2000 J. Phys. **B33**, L111-L117

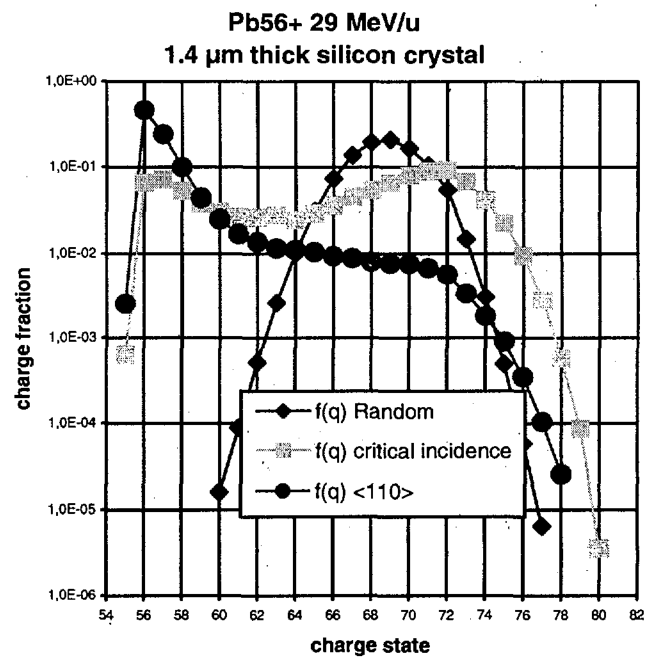
Channeling of fast Pb^{56+} ions in a thin silicon crystal: simultaneous measurements of energy loss, charge exchange and secondary electron emission

L.Adoui [1], A.Billebaud [2], F.Barrué [3], A.Cassimi [1], M.Chevallier [3], C.Cohen [4], D.Dauvergne [3], C.Demonchy [5], L.Giot [5], R.Kirsch [3], A.L'Hoir [4], W.Mittig [5], S.Pita [5], J.C.Poizat [3], C.Ray [3], H.Rothard [1], P.Roussel-Chomaz [5] and M.Toulemonde [1]

[1] *CIRIL, BP 5133, 14070 Caen Cedex 05, France*
[2] *Institut des Sciences Nucléaires, 38026 Grenoble Cedex, France*
[3] *Institut de Physique Nucléaire de Lyon, Univ. Lyon I, 69622 Villeurbanne Cedex, France*
[4] *GPS, 2 Place Jussieu, 75251 Paris Cedex 05, France*
[5] *GANIL, BP 5027, 14076 Caen Cedex 5, France*

We sent 29 MeV/u Pb^{56+} ions along axial and planar directions of a 1.4µm thick silicon crystal. In this event-by-event experiment we observed the correlation between energy loss (measured with high resolution), charge exchange, and the multiplicity of the electron emission from entrance and emergence surfaces of the crystal (P542). X-ray emission was also recorded. The trajectory of a given ion in the crystal can be deduced quite precisely from the study of the correlation. The multiplicity distribution of backward electron emission is observed to be tightly connected to the impact parameter of the projectile when it enters the crystal, and, much less markedly, on the entrance angle of the projectile trajectory. This demonstrates that backward electron emission is dominated by very near surface interaction. This is true also, but to a much lesser extent, for forward electron emission, to which bulk interaction contributes significantly. Our experiments provide precise information on the electronic interaction of hyperchanneled projectiles frozen in their initial charge state and on projectiles with critical transverse energy, that spend a significant part of their dwell time in atomic rows or planes.

The Figure shows charge state distributions obtained for axial orientation, random orientation and critical incidence (the beam incidence angle being close to the channeling critical angle). On the one hand, we get the usual feature of frozen charge state for well channeled ions. On the other hand, ions undergoing close collisions with atomic strings can reach higher charge states than in random crystal orientation conditions. Thus thin crystals, of the order of a few thousands Angströms, could be used as very efficient strippers for heavy ions.



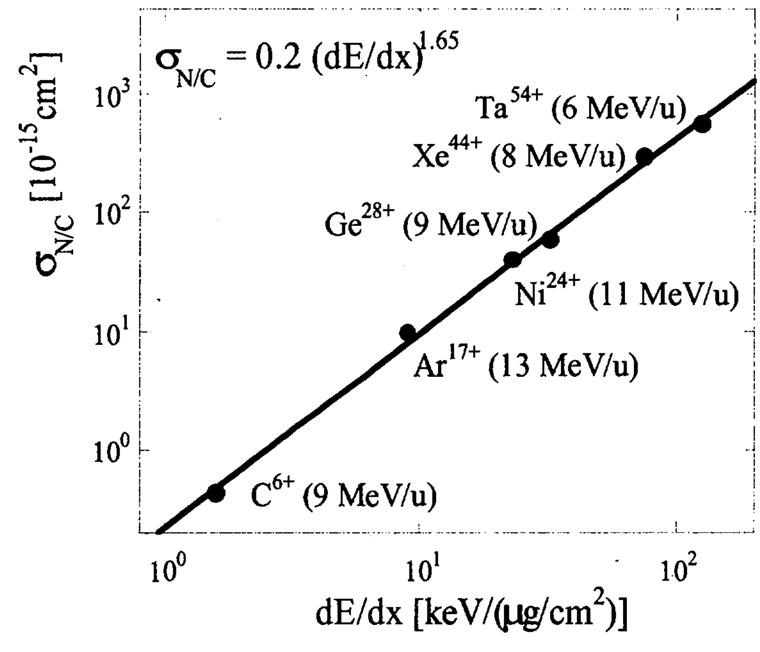
Electronic sputtering of nitrogen on carbon by swift highly charged ions

M. Caron[1,%], F. Haranger[1], B. Ban d'Etat[1], P. Boduch[1],
A. Clouvas[2], T. Jalowy[3], R. Neugebauer[3], C. Potiriadis[4], H. Rothard[1]

[1]*Centre Interdisciplinaire de Recherche Ions Lasers CIRIL (CEA-CNRS-ISMRA), Rue Claude Bloch, BP 5133, F-14070 Caen Cedex 05, France*
[2]*Department of Electrical and Computer Engineering, Aristotelian University, GR-54006 Thessaloniki, Greece*
[3]*Institut für Kernphysik, J.-W. Goethe Universität, August-Euler-Strasse 6, D-60486 Frankfurt am Main, Germany*
[4]*Greek Atomic Energy Commission, GR-15310 Agia Paraskevi, Greece*
[%]now at: *PHILIPS GmbH, Philips Research Laboratories, Luminescence and Electron Emission D303, Weisshausstrasse 2, D-52066 Aachen, Germany*

Sputtering at low projectile energies due to elastic collisions is rather well understood. In contrast, much less is known about the mechanisms leading to sputtering by electronic energy loss ("*electronic sputtering*") at high energies and with highly charged ions. Therefore, sputtering of nitrogen on carbon was studied as a function of the electronic energy loss dE/dx and the projectile charge q with swift highly charged heavy ions at GANIL-SME (P471, Z = 6-73, q = 6-54, E = 6-13 MeV/u) in the UHV set-up for secondary particle emission of CIRIL (described elsewhere in this compilation). An indirect method based on the extremely surface sensitive electron yield measurement was used to deduce the cross section $\sigma_{N/C}$ for sputtering of nitrogen from sputter-cleaned amorphous carbon targets previously exposed to nitrogen.

A strong correlation is found with the parameter dE/dx and in a lesser extend with q: $\sigma_{N/C}$ varies approximately as $\sigma \sim (dE/dx)^{1.65}$ or $\sigma \sim q^{3.3}$. This q-dependence is close to the cubic charge dependence observed for the emission of H^+ secondary ions which are believed to be emitted from the very surface. However, the power law $\sigma \sim (dE/dx)^{1.65}$, related to the electronic energy loss gives the best empirical description. It is close to a quadratic law thus rather pointing towards a thermal evaporation-like effect.



Literature: M. Caron, A. Clouvas, R.Neugebauer, C. Potiriadis, H. Rothard, Physica Scripta **T92** (2001) 205

M. Caron, F. Haranger, H. Rothard, B. Ban d'Etat, P. Boduch, A. Clouvas, C. Potiriadis, R.Neugebauer, T. Jalowy, Nucl. Instrum. Meth. **B179** (2001) 167

This work has been supported by the European Community-Access to Research Infrastructure action of the Improving Human Potential Programme, contract N° HPRI-CT 1999-00019.

Electronic sputtering of "polymer-like" amorphous carbon

F. Pawlak[1], Ch. Dufour[2], A. Laurent[3], E. Paumier[1,2],
J. Pérrière[3], J. P. Stoquert[4] and M. Toulemonde[1]

[1] *CIRIL, Laboratoire commun CEA-CNRS-ISMRA , BP 5133 14070 Caen-cedex 5 (France)*
[2] *LERMAT-ISMRA, 6 B^{d} Maréchal Juin, 14050 Caen-cedex 5 (France)*
[3] *GPS, URA 17, Univ. Paris VII et VI, tour 23, 2 pl. Jussieu, 75251 Paris-cédex 05, France.*
[4] *Laboratoire PHASE, CNRS, 67037 Strasbourg-cédex 2, France.*

Mixed hydrogenated and deuterated amorphous carbon films have been irradiated at GANIL in the MeV/u energy range with an electronic stopping power varying between 1 keV nm^{-1} and 13 keV nm^{-1} (P376).

These films contain 10% of hydrogen and 30% of deuterium. Hydrogen (H) and deuterium (D) contents versus dE/dx and fluence were determined by Elastic Recoil Detection Analysis. The content evolution of C-H and C-D bondings was determined by infrared absorption measurements.

The main effects due to MeV/u ion irradiations are the decrease of C-D bondings content and deuterium relative content (D/C atomic ratio) as a function of fluence. A long time after the irradiation C-H bondings content and the hydrogen relative concentration (H/C atomic ratio) increase.

The hydrogen absorption cross section is equal to the deuterium effusion cross section within the experimental errors whatever is the physical characterisations (ion beam analysis or infrared absorption). Moreover, both techniques give the same cross sections and the deduced track radii are reported in figure 1. It appears that such a process appears above a S_e threshold value of 0.4 keV/nm [1].

Hence the following interpretation is proposed: during irradiation hydrogen and deuterium atoms are ejected from the ion tracks leaving carbon dangling bonds. Afterwards these dangling bonds are compensated by hydrogen atoms coming from the ambient air and diffusing inside the irradiated material along the latent track.

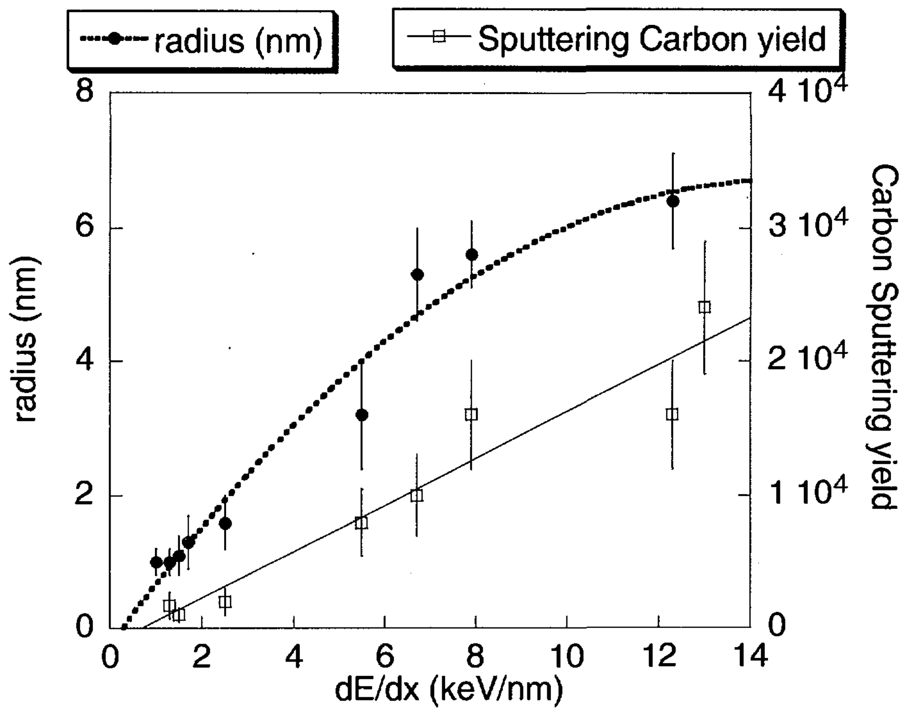


Figure 1: *latent track radii versus dE/dx compare to carbon sputtering yield.*

Using Rutherford backscattering RBS, the remaining carbon contents versus the fluence have been quantified [2]. The yield of carbon sputtering is then deduced and reported in the figure 1. It increases significantly above a S_e threshold value of 0.8 keV/nm, equal or slightly higher than the S_e threshold value of deuterium effusion. It is shown that at the highest value of S_e (Pb and U) the electronic stopping power sputtering is very efficient: around 10^4 carbon per incident ion.

References:

[1] F. Pawlak, Ch. Dufour, A. Laurent, E. Paumier, J. Perrière, J. P. Stoquert and M. Toulemonde Nucl. Instr. Meth. **B131** (1997) 135

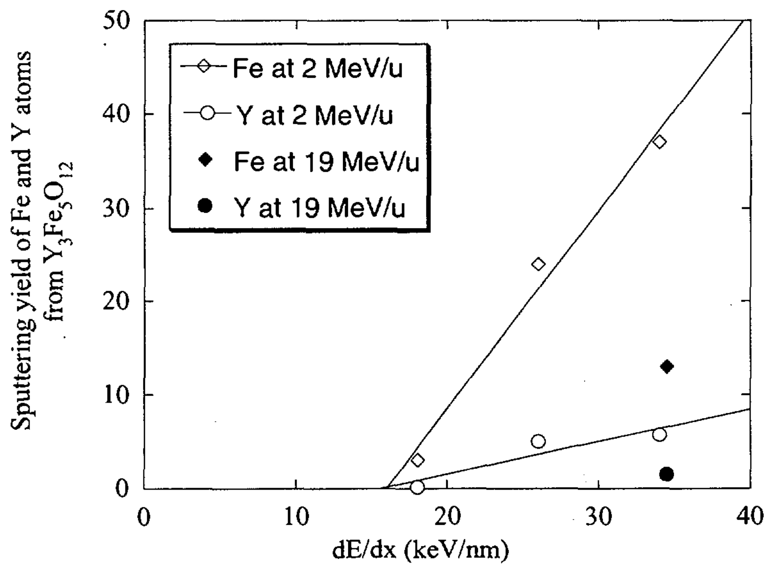
[2] F. Pawlak, Ch. Dufour, A. Laurent, E. Paumier, J. Perrière, J. P. Stoquert and M. Toulemonde Nucl. Instr. Meth. **B151** (1999) 140

Velocity effect in the sputtering of yttrium iron garnet by swift heavy ions

M. Toulemonde[1], S. Bouffard[1], M. Caron[1], H. Rothard[1], N. Kahlfaoui[1,2], A. Meftah[3], S. Schlutig[1] and J. P. Stoquert[4]

[1]CIRIL, Laboratoire commun CEA-CNRS-IMRA , BP 5133 14070 Caen-cedex 5 (France)
[2]USTHB, Institut de physique, BP32, El-Alia, Bab Ezzouar, 16111 Alger (Algérie)
[3] Centre Universitaire de Skikda, BP 26,Route El-Hadaik, 21000 Skikda (Algérie)
[4]Laboratoire PHASE, 23 rue du Loess, 67037 Strasbourg cedex (France)

The sputtering of yttrium iron garnet ($Y_3Fe_5O_{12}$) has been studied in the electronic stopping power regime in order to verify that the so called "velocity effect" observed in the track formation [1] does also exist when measuring the total sputtering. Single crystal of $Y_3Fe_5O_{12}$ have been irradiated at room temperature with Xe ions at 19 MeV/u through a pure aluminum foil placed 1 mm in front of the sample (P442). The sputtered atoms are collected on this aluminum foil called the catcher. Several irradiations spots were used in front of the same catcher in order to avoid track damage overlapping. The maximum fluence per points were 10^{12} Xe/cm^2 while the total fluence used were 10^{13} Xe/cm^2. The catcher was analyzed using Rutherford backscattering spectrometry (RBS) with a ^{12}C beam. With such a carbon beam the sensitivity is as low as $2*10^{11}$ Fe/cm^2.



The yields of the sputtered Fe and Y atoms are presented in the figure, and compared to previous measurements of sputtering made with ions at a mean energy of 2 MeV/u [2]. It is clear that, for the nearly same value of electronic stopping power (35 keV/nm), the sputtering yield is lower at high energy (19 MeV/u) compared to the low energy (2 MeV/u) irradiation. This confirms that the "velocity effect" is also observed for the total sputtering yield.

References:

[1] A. Meftah, F. Brisard, J.M. Costantini, M. Hage-Ali, J.P.Stoquert, F. Studer and M. Toulemonde, Phys. Rev. **B48** (1993) 920

[2] A.Meftah, M. Djebara, J.P. Stoquert, F. Studer and M. Toulemonde, Nucl. Instr. Meth. **B107** (1996) 242

Neutral uranium atoms sputtered by electronic excitation in uranium dioxide

S. Schlutig[∇], S. Bouffard[∇], M. Bonnin-Mosbah[♦], J.P. Duraud[♦◊] and S. Ayrault[♦]

∇ *Centre Interdisciplinaire de Recherche Ions Lasers, CEA-CNRS-ISMRA, BP 5133, 14070 Caen cedex 5, France*

♦ *Laboratoire Pierre Süe, CEA-CNRS, CEA-Saclay, 91191 Gif sur Yvette cedex, France.*

◊ *CEA-Grenoble, DSM/DRFMC, 17 rue des martyrs, 38054 Grenoble cedex 9, France*

The high density of electronic excitation induced in the track of a swift heavy ion is responsible of extend damage in many materials. The mechanisms of conversion of electronic excitation into atomic displacements are still debated. At the material surface, the emission of particles under irradiation with swift heavy ions comes probably from the same mechanisms. Thus, information about these mechanisms may be obtained from the analyses of the angular and velocity distributions of the emitted particles.

In the first approach, the experiments consist in measuring the angular distribution of the neutral uranium atoms ejected from a surface of uranium dioxide bombarded by different ions accelerated at the GANIL medium energy beamline (P403, P442, P467). The sputtered Uranium atoms have been collected on the surface of a mica foil and detected by a subsequent fission of the ^{235}U in a flux of thermal neutron in the Orphée nuclear reactor (CEA-Saclay). The Uranium fission fragments produced tracks in the mica foil, which are counted after chemical etching. The angular distribution of the sputtered atoms is deduced from the etched track density. The figure 1 shows an example of angular distribution obtained after an irradiation with xenon ions.

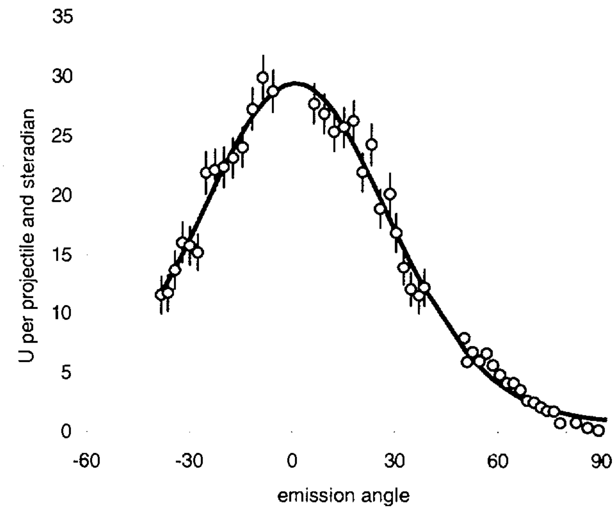


Figure 1: *Angular distribution of the uranium ejected from a uranium dioxide surface by the impact of Xe ions at energy of 7.6 MeV/u.*

The main results are the following:

- In UO_2, the sputtering by electronic excitation is efficient above an electronic stopping power of about 10 keV/nm.
- For an electronic stopping power of 55 keV/nm, the total sputtering yield is equal to 100 Uranium atoms per incident ion.
- The uranium atoms are preferentially emitted along the perpendicular to the target surface. The best fit of the angular distribution is obtained with a supersonic gas expansion law (figure 1) in accordance with a collective emission of atoms.
- The preferential direction of the emission is always perpendicular to the surface target whatever the projectile incidence angle may be.

In the next future, the experiments will consist in the determination of the angular distribution of the uranium clusters emitted from the surface and the measurement of the velocity distribution of the neutral atoms and of the ions sputtered by electronic excitation.

References: S. Schlutig, thesis, University of Caen (2001)
S. Bouffard et al., Nucl. Instrum. Meth. B141 (1998) 272

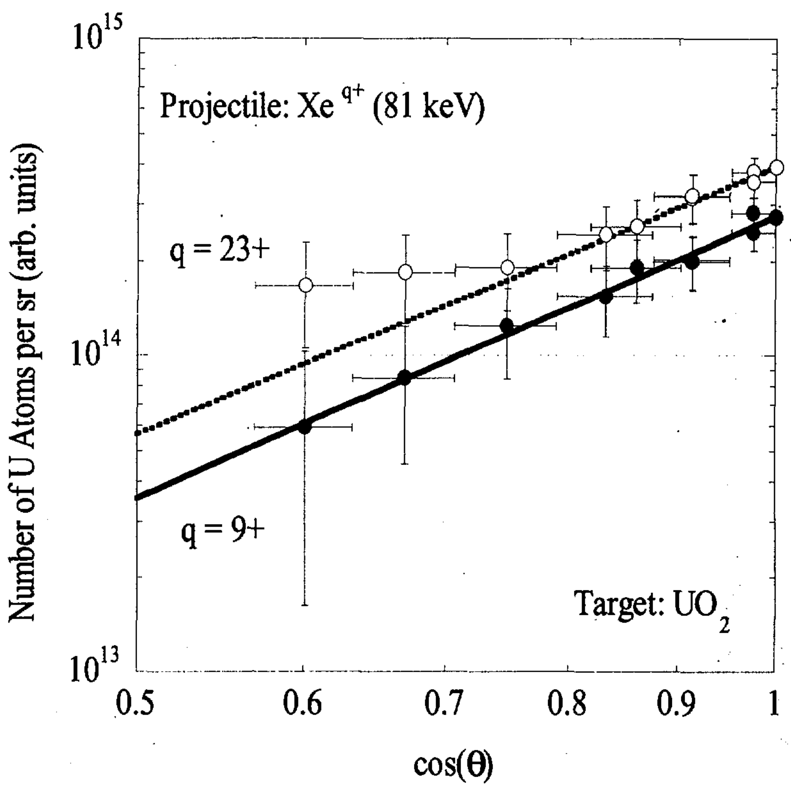
Sputtering induced by slow highly charged ions

F. Haranger, B. Ban-d'Etat, A. Benyagoub, Ph. Boduch, S. Bouffard, H. Rothard

Centre Interdisciplinaire de Recherche Ions Lasers CIRIL (CEA-CNRS-ISMRA)
Rue Claude Bloch, BP 5133, F-14070 CAEN Cedex 05, France

First experiments on sputtering induced by the interaction of slow highly charged ions with solid targets (L5) were performed at LIMBE (described elsewhere in this compilation) in September 2000. A uranium dioxide target was bombarded with Xe^{q+} ions of 81 keV kinetic energy (charge states q = 9+ and q = 23+ extracted at 9 keV/q and 3.56 keV/q, respectively). The total sputtering yield and, simultaneously, the angular distribution of the sputtered particles were measured as a function of the projectile charge q by means of the "collector method", where the emitted particles are deposited on collectors such as ultra-pure aluminium or mica. The choice of the UO_2 target was, on one hand, guided by the fairly large number of existing results obtained with swift (MeV/u) heavy ions provided by GANIL using the same experimental set up [1]. On the other hand, UO_2 makes it possible to use two different independent methods for the determination of the sputtering yield and its angular distribution from the analysis of the number of deposited sputtered particles on the collector. The first one relies on the use of mica collectors where the fission products of uranium atoms induced by subsequent neutron irradiation can create latent ion tracks which can be individually counted with a microscope. The second method uses a catcher made of a ultra pure aluminium foil where the collected uranium atoms can readily be analysed by the Rutherford Backscattering Spectrometry (RBS) technique.

The results reported here show an enhancement of the yield with the incident ion charge in agreement with the results obtained by other groups, and the angular distribution follows a cosine to the 2.8 th power law similar to the observations made with swift heavy ions for the lower charge state q= 9 [1]. In contrast, for q = 23, deviations from such a simple scaling are observed. This is possibly related to the influence of the high projectile charge (electronic excitation, potential sputtering). Experiments with other charge states are planned. Also, attempts are being made to measure the velocity distribution of the sputtered particles, still using a collector analysed by the RBS method.



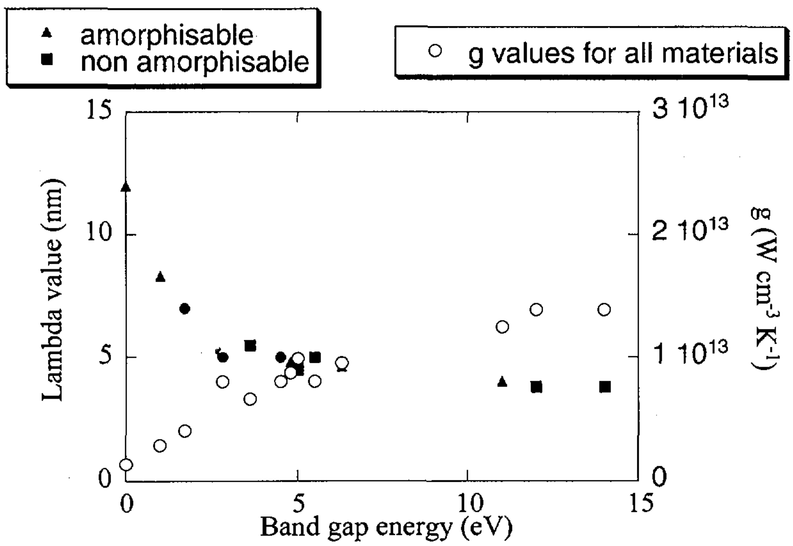
Reference: [1] S. Bouffard, J.P. Duraud, M. Mosbah, S. Schlutig, Nucl. Instrum. Meth. **B141** (1998) 372.

Transient thermal processes in heavy ion irradiation of crystalline inorganic insulators

M. Toulemonde[1], Ch. Dufour[2], A. Meftah[3], E.Paumier[1,2]

[1] *CIRIL, Laboratoire CEA-CNRS-ISMRA, BP5133, 14070 Caen-cedex 5, (France)*
[2] *LERMAT-ISMRA, Université de Caen, B[d] du Maréchal Juin, 14050 Caen-cedex, (France)*
[3] *LIRM, ENSET, BP 26, Merdj-eddib, 21000 Skikda, (Algeria)*

A review of matter transformation induced in crystalline inorganic insulators by swift heavy ions [1,2] was made. The emphasis is made on results obtained on amorphisable materials like SiO_2 quartz and $Gd_3Ga_5O_{12}$ and on non-amorphisable ones like LiF and CaF_2. Assuming that the latent tracks result from a transient thermal process, a quantitative development of an inelastic thermal spike model is proposed [2]. In this model, only one free parameter is used: the electron-lattice interaction mean free path λ directly linked to the electron-phonon coupling constant g [2]. With this parameter it is possible to describe all the observations assuming that latent tracks may result either from a rapid quenching of a cylinder of matter in which the energy transferred from the electrons has overcome the energy necessary to reach a quasi-molten phase in the case of amorphisable materials or from a rapid quenching of a cylinder of matter which has overcome the sublimation energy in the case of non-amorphisable materials. The evolution of the λ (and g) parameter is presented in the figure.



As described by Haglung and Kelly [3], the electron phonon coupling increases when the band gap energy increases. This supports the hypothesis that a transient thermal process could be the mechanism of the track formation.

References:

[1] M. Toulemonde, S. Bouffard and F. Studer Nucl. Instr. Meth. **B91** (1994) 108
[2] M. Toulemonde, Ch. Dufour, A. Meftah, and E. Paumier, Nucl. Instr. Meth. **B166-167** (2000) 903
[3] R.F. Haglung and R. Kelly, in "SPU92", *Fundamental Processes in Sputtering of Atoms and Molecules* (edited by P. Sigmund), Mat. Fys. Medd. **43** (1993) 1

4 - INDUCED EFFECTS IN CONDENSED MATTER, INCLUDING NANOSTRUCTURATION

Amorphization and recristallisation of Yttrium Iron Garnet under swift heavy ion beams

J.-M. Costantini[1,*], J.M. Desvignes[2], and M. Toulemonde[3],

[1]*CEA, DPTA/SPMC, B.P. 12, F-91680 Bruyères-le-Châtel, France.*
[2]*CNRS, LMMM., 1, Place A. Briand, F-92195 Meudon Cedex, France.*
[3]*CIRIL, B.P. 5133, Rue C. Bloch, F-14070 Caen Cedex 5, France.*
[*]*Now at: CEA/SACLAY, DMN/SEMI, F-91191 GIF-SUR-YVETTE CEDEX, France,*
email : costantini@drnsac.cea.fr

The room-temperature dc conductivity is used to monitor the damage and structural modifications induced by swift heavy ion irradiations in yttrium iron garnet ($Y_3Fe_5O_{12}$ or YIG) epitaxial layers doped with calcium (CaYIG) or silicon (SiYIG), with a variable conductivity due to a variable degree of compensation, and amorphous YIG layers. Irradiations are performed with heavy ions in the 0.8-6 MeV amu^{-1} energy range, in the electronic slowing down regime, with an electronic stopping power ranging between 7 and 41 MeV μm^{-1} above the amorphous track formation threshold (4.5 MeV μm^{-1}) in this low-ion velocity range. A conductivity decrease versus ion fluence is found in the case of the high-conductivity uncompensated epilayers whereas an increase occurs for the low-conductivity compensated ones, either p-type (CaYIG) or n-type (SiYIG). These results are discussed by considering the competing effects of disorder on the carrier density and mobility in the case of compensated and uncompensated semiconductors.

In both cases, the low-fluence data display a plateau at around the same conductivity value corresponding to the amorphous YIG above an amorphous fraction around 50% regardless of the ions. All the high-fluence data exhibit a power-law behaviour without saturation, above a threshold fluence decreasing with increasing amorphisation cross-section (A). These results are interpreted by the formation of amorphous tracks and of a more conducting nanophase after recrystallisation of the tracks under ion impacts. All the data are rescaled versus the product of A times fluence (ϕ) where amorphisation dominates for $A\phi \leq 1$, whereas recrystallisation dominates for $A\phi > 10$. However, significantly larger A values than the ones previously determined from the RBS-channeling data are derived from a mean-field analysis of the low-fluence conductivity data with a 2D Bruggeman model. These deviations are ascribed to a contribution of the crystalline track-halos where internal stresses are accumulated due to the atomic density difference between the crystal and amorphous phase.

A simple phenomenological approach of the amorphisation and recrystallisation processes is proposed on the basis of two kinetic rate equations with a recrystallisation cross-section (S) at least one order of magnitude smaller than A. These S values are in agreement with a thermal spike model assuming vaporisation of the amorphous YIG phase along the ion path. At such high temperatures in the ion tracks, the garnet phase may decompose into a more conducting nanocrystalline phase. Finally, an $\exp(-T)^{-1/4}$ law for the thermal dependence of conductivity at low temperature is found in the nanophase like in the amorphous one, most probably because of the strong contribution of the disordered grain boundary cores in the conduction process.

Literature: Journal of Applied Physics, **87** (2000) 4164-4174.

Interaction of fast heavy ions with a surface and subsurface layer of crystals at grazing angles of incidence

I. Vorobyova

Department of Crystal Physics, Kharkov National University, 61077, Ukraine

Tracks induced on surfaces of layered (gypsum, mica) and nonlayered (lithium fluoride, fluorite) crystals by Sn and Ta ions with energy of 1 $MeV \cdot u^{-1}$ (experiment numbers: P 430, P 456), and Pb ions with energy of 4,46 MeV/u (experiment number: P 515) were studied by the method of shadow replica electron microscopy. The irradiations were carried out at angles of 0,5°, 1°, 2° and 3° relative to the surface plane of the crystals. Lengths and widths of two kinds of tracks induced by the same ions were compared: 1) surface tracks which are formed on a clean crystal surface and 2) island tracks which are formed in an island film of gold (with island radius and separation of ≤ 5 nm) deposited on the crystal surface prior to irradiation. The following points were established:

1. At angles of ion incidence of 1°, 2° and 3°, the initial part of the surface track is a groove whose width first increases and then decreases as the ion passes from the surface deeper into the crystal. On the second part the groove is transformed into a hump whose height decreases along the length of the track. The groove and hump lengths are practically the same. Finally, the hump subsides at the point where the ion has penetrated too deeply to continue contributing significant energy density to the surface region. At angle of irradiation of 0,5°, the groove length is roughly two times longer than the hump length. It is shown that at very small angles of ion incidence, the formation of a surface track is initiated at a point where the ion has not yet penetrated the crystal surface, but rather moves above the surface plane at distance of ≤ 1nm. But the following observation turned out unexpected - the groove width is a many times greater than this distance. It is difficult to rationalize such widths of the surface tracks without invoking collective effects whereby energy deposited in a zone of limited size can affect a much wider region.

2. The island track is the strip on the crystal surfaces where islands have been removed by one incident ion. Length and width of the island tracks are much greater than length and width of the surface tracks at the same irradiation conditions. One incident Pb ion with an angle of incidence of r 0,5° removes from the surface more than 400 islands. Part of these islands are removed from a portion of the crystal surface above the ion path where a surface track is not formed already, i.e. where no plastic deformation of the surface occurs. The quantity and shape of the islands removed from the surface during the track formation process were investigated with the help of collectors. It was established that a portion of the islands are removed from the crystal surface without changing of their size and shape. Moreover, a small pieces of the island film is removed from the crystal surface in the track end, i.e. when the ion is moving in the subsurface layer of the crystal. It was shown that two mechanisms play a main role in island track formation: 1) irradiation of the islands by δ-electrons; 2) the "dusting" of the islands under the interaction with the surface of a shock wave.

3. The lengths of both kinds of tracks are greater on the surfaces of layered crystals than on the surfaces of nonlayered crystals. Moreover, at grazing angles of incidence, many ions are observed to move at a depth ≤ 20 nm parallel with the layered crystal surface resulting in formation of ultra-long tracks. It is proposed that in the layered crystals the ions can reach the channeling regime even if their angle of incidence is greater than a certain critical angle of channeling.

Literature: I. Vorobyova, Nucl. Instrum. Meth. **B174** (2001) 70.

Study of ion beam induced swelling in fluorite as an inert matrix model

M. Boccanfuso[1], A. Benyagoub[1], K. Schwartz[2], M. Toulemonde[1] and C. Trautmann[2]

[1] *CIRIL, CEA/CNRS/ISMRA, BP 5133, 14070 Caen Cedex 5 (France)*
[2] *GSI, Materialforschung, Planckstrasse 1, 64291 Darmstadt (Germany)*

In order to gain a better understanding of the mechanism leading to swelling in non-amorphisable fluorite type materials in the electronic stopping power regime, calcium fluoride (CaF_2) was used as model material for inert matrices. CaF_2 single crystals were irradiated with various heavy ions (from ^{32}S to ^{209}Bi) of specific energies between 1 and 12 MeV u^{-1}, covering the range of energy loss S_e between 1.5 and 27 keV/nm (P527). Using a profilometer, out-of-plane swelling was measured by scanning over the border line between irradiated and virgin areas of the sample surface. Figure 1 shows the step height l evolution versus fluence Φ.

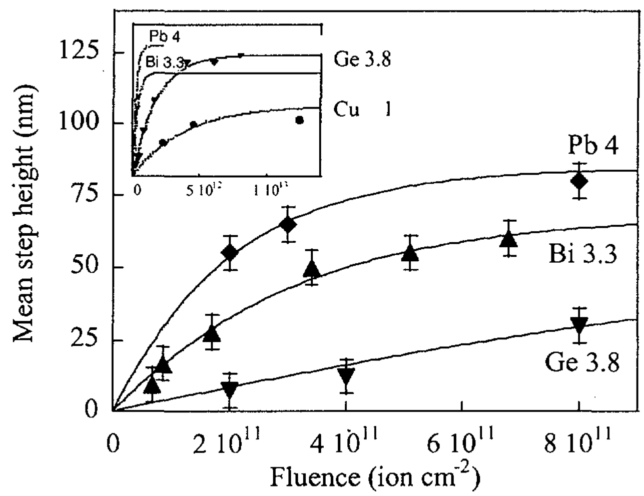


Fig.1: *Mean step height evolution versus the fluence for different ions at different energies in MeV/u.*

Comparing the swelling measurement of various ion species, it is apparent that different saturation values l_S are obtained at high fluences (see Fig. 1). Dividing this saturation value by the range R_p of the irradiating ion allows to relate swelling to a relative density change in the irradiated material. The obtained data are plotted as a function of the mean energy loss $<S_e>$ (the total energy of the incident ion divided by the range) in Fig. 2. At a value of about 5 keV nm^{-1}, the value, l_S/R_p, increases, indicating a change in the damage mechanism. Thereafter, it reaches a nearly constant value corresponding to a relative density change $\Delta\rho/\rho_{initial}$ of 2.7±0.4 ‰.

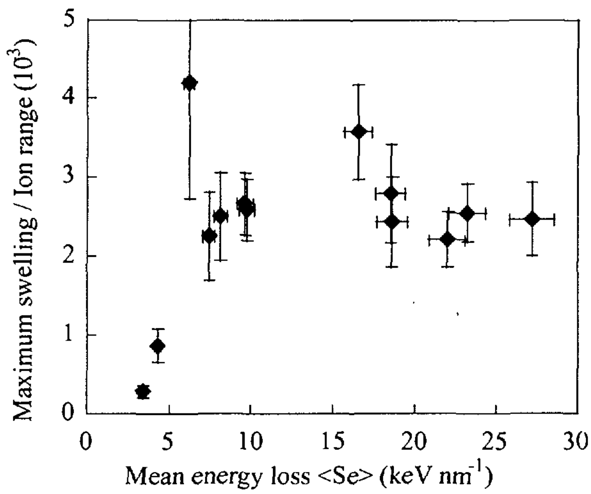


Fig. 2: l_S/R_p related to the relative density change as a function of the mean energy loss.

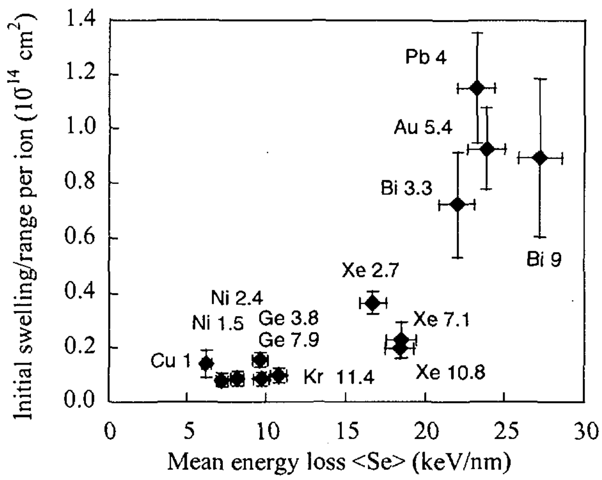


Fig. 3: *Initial swelling per ion normalised by the range versus the mean energy loss (the ion energy is indicated in MeV u^{-1}).*

Another quantitative comparison concerns the initial swelling rate in a fluence regime where track overlapping can be neglected. For this purpose, we consider the initial slope $(\Delta l/\Delta\Phi)_{\Phi=0}$ of the step height increase versus fluence divided by the ion range R_p. This normalised initial swelling rate is plotted as a function of $<S_e>$ in Figure 3. Contrary to previous observations [1,2,3], the present evolution of the initial swelling does not appear to be linear.

The evolution of the step height from a linear regime to saturation (Fig. 2) indicates that swelling can be associated with a cylindrical volume of transformed matter. Under this assumption, the linear regime would correspond to single ion impacts while saturation is reached when several tracks overlap. A law of the form $l = l_S[1\text{-}\exp(-\pi \cdot r^2 \cdot \Phi)]$ was fitted to the experimental results and an effective radius r of the tracks was extracted which is quite large as compared to the electron microscopy observations [4].

References:

[1] C. Trautmann, J.M. Costantini, A. Meftah, K. Schwartz, J.P. Stoquert, M. Toulemonde, MRS proc. **504** (1998) 123.

[2] M. Toulemonde, A. Meftah, J.M. Costantini, K. Schwartz, C. Trautmann, Nucl. Instr. and Meth. **B146** (1998) 426.

[3] C. Trautmann, M. Toulemonde, K. Schwartz, J.M. Costantini, A. Müller, Nucl. Instr. and Meth. **B164-165** (2000) 365.

[4] J. Jensen, A. Dunlop, S. Della-Negra, Nucl. Instr. and Meth. **B141** (1998) 753.

Swelling of lithium fluoride under ion irradiation

C. Trautmann[1], M. Toulemonde[2], J.M. Costantini[3], J.J. Grob[4], K. Schwartz[1]

[1] Materialforshung GSI, 1 Planck Str. 64291 Darmstadt (Allemagne)
[2] CIRIL, Laboratoire commun CEA-CNRS-Ismra , BP 5133 14070 Caen- cedex 5 (France)
[3] CEA/Saclay, DMN/SEMI 91191 Gif sur Yvette cedex (France)
[4] Lab. PHASE 67037 Strasbourg-cedex 2 (France).

Under the irradiation with swift heavy ions, lithium fluoride crystals exhibit a remarkable volume increase. Quantitative studies were performed on 1 mm thick single crystals cleaved along one of the (100) planes. Polished surfaces were irradiated using various ion species (C up to U) and energies at a 7 MV tandem (Bruyères-le-Châtel), at GANIL/Caen (P485), and at the Unilac (GSI).

The free expansion of the irradiated volume is limited by the constraint of the undamaged matrix. As a consequence, the volume bulges outwards mainly normal to the sample surface. A quantitative analysis of the out-of-plane swelling was performed with a profilometer (Dektak 8000). Typical scans with a diamond-tipped stylus over the border line between an irradiated and a virgin area of the sample surface are shown in Fig. 1.

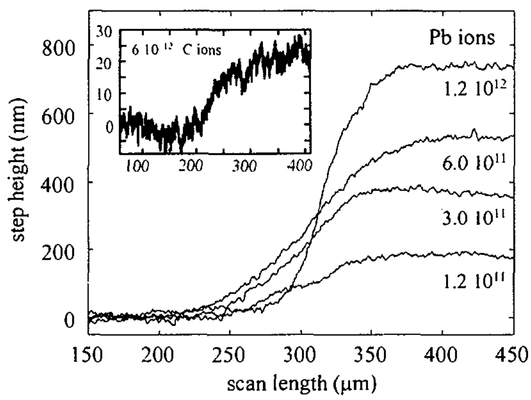


Fig. 1: *Profilometer scans from a virgin (left) to an irradiated (right) area of crystals exposed to Pb (4 MeV/u) and C (11 MeV/u) (inset) ions of various fluences (ions/cm^2).*

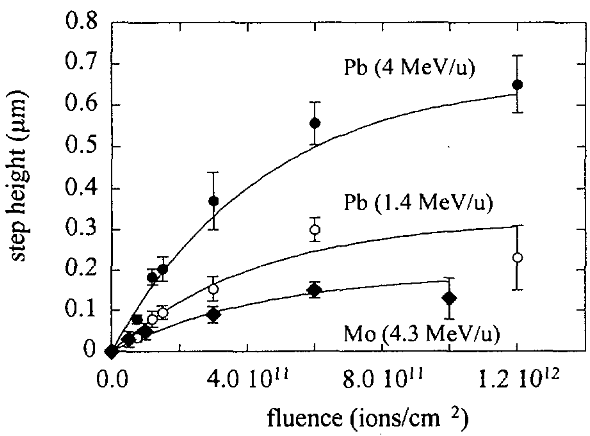


Fig. 2: *Step height of Pb and Mo irradiations as a function of the fluence.*

Depending on the electronic energy loss, the fluence, and the total range of the ions, the out-of-plane swelling varied between 10 and 700 nm. For all ions, the evolution of the step height vs. fluence is characterised by an initial linear increase approaching saturation at high ion fluences (Fig. 2) due to increased track overlapping.

In order to test the correlation between swelling and energy loss, we determined the relative contribution of each single ion per unit damage length. This was done by plotting the mean energy loss versus the swelling rate in the linear regime normalised by the projected ion range ($\Delta l / (\Delta\phi * R)$) (Fig. 3). The logarithmic presentation gives evidence for the extremely small swelling of carbon ions which is in good agreement with volume changes due to the creation of single Frenkel pairs. For heavier ions, above a critical energy loss of about 4.2 keV/nm, the swelling becomes 2 to 3 orders of magnitude larger indicating more complex defects such as clusters and voids. It is interesting to note that swelling appears at much lower energy losses than the threshold of 10 keV/nm found earlier for track etching and small angle x-ray diffraction [1,2].

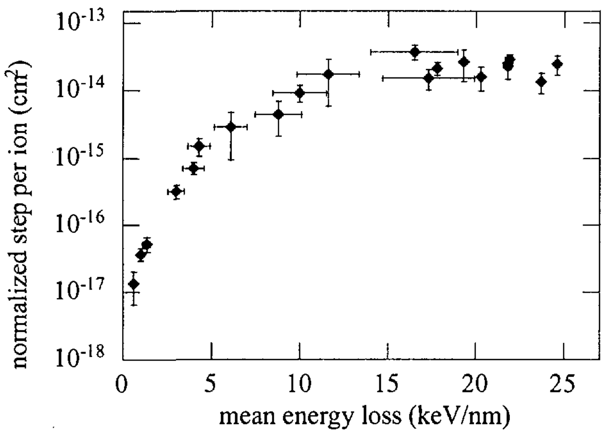


Fig. 3: *The initial swelling normalised by the ion range ($\Delta l / (\Delta\phi * R)$) vs. the mean energy loss.*

At present, the nature of the damage responsible for this huge swelling in LiF is an open question. In the case of oxide material (such as Al_2O_3, $LiNbO_3$, SiO_2 quartz, and $Gd_3Ga_5O_{12}$ [3]), swelling is interpreted as a change of density of the irradiated part due to a transition from the crystalline to the amorphous phase. Because of the strong ionic binding character, local amorphisation is not expected for LiF.

References:

[1] C. Trautmann, K. Schwartz, J.M. Costantini, T. Steckenreiter, M. Toulemonde, Nucl. Instr. and Meth. **B146** (1998) 367

[2] K. Schwartz, C. Trautmann, T. Steckenreiter, O. Geiss, M. Krämer, Phys. Rev. **B58** (1998) 1123

[3] M. Toulemonde, A. Meftah, J.M. Costantini, K. Schwartz, C. Trautmann, Nucl. Instr. and Meth. **B146** (1998) 426 and Refs. therein.

Semiconductors under irradiation

A. Colder, M. Levalois and P. Marie

LERMAT, ISMRA, FRE CNRS 2149, 6 Boulevard du Maréchal Juin, 14050 CAEN Cedex

a) Fundamental research

A few years ago, n-type germanium has been irradiated with low doses ($dpa_{max} = 10^{-5}$) at room temperature by different swift heavy ions (SHI) at the GANIL accelerator. By using Deep Level Transient Spectroscopy (DLTS) and Hall effect measurements, a n to p-type transition has been observed whatever the incident ion. The created defects have been identified: they are vacancy-doping impurity, vacancy-oxygen complexes and divacancy. By simulating the Hall effect curves, using the DLTS results, no specific effect of the electronic energy deposited had been evidenced [1,2].

Moreover, we have performed recently new DLTS and Hall effect measurements on uranium and lead (P360 experiment), proton and electron irradiated n-type germanium samples [3]. Different behaviours have been observed according to the incident projectile. In the case of SHI and proton irradiation, the Fermi level goes down in the forbidden band and draws near the valence band whereas it stabilises in the middle of the gap in the case of electron irradiation. This difference shows that a specific defect is created by SHI and proton in comparison with the electron irradiation. The more realistic hypothesis is that this specific defect is a multivacancy complex (including more than two vacancies) [4].

On the other hand, new experiments have been carried out by W. Assmann (Munich) on high doses irradiated germanium ($dpa_{max} = 8$). They used a few hundred of MeV heavy ion beams (such as iodine or gold) and the samples have been characterised by using canalisation Rutherford Back-Scattering (RBS-C), MEB and MET measurements. It has been shown that an agglomeration of vacancies to voids appears, forming a buried layer with a porous structure. The sponge-like structure takes place nor when the electronic energy loss is maximum, neither when the nuclear collision are predominant but a few micrometers before the stopping area of the ions (when the ratio of the electronic to the nuclear energy loss is about 10).

In order to clarify the respective influence of some parameters such as the electronic and nuclear energy deposited, the electronic energy density, the projectile velocity, an experiment has been proposed (P497). The purpose was to link the specific defect created by SHI or proton to the voids which appear when the dose increases. As a matter of fact, this defect is probably the precursor of the voids which are created at high doses. With this aim in view, we carried out Hall Effect measurements, RBS-C measurements at Munich with the help of W. Assmann and Annihilation Positron Spectroscopy (PAS) measurements at Orléans with the help of M.F. Barthe and P. Desgardin. All the samples have been irradiated with fluences so as the obtained values of dpa are between 10^{-5} and 1.

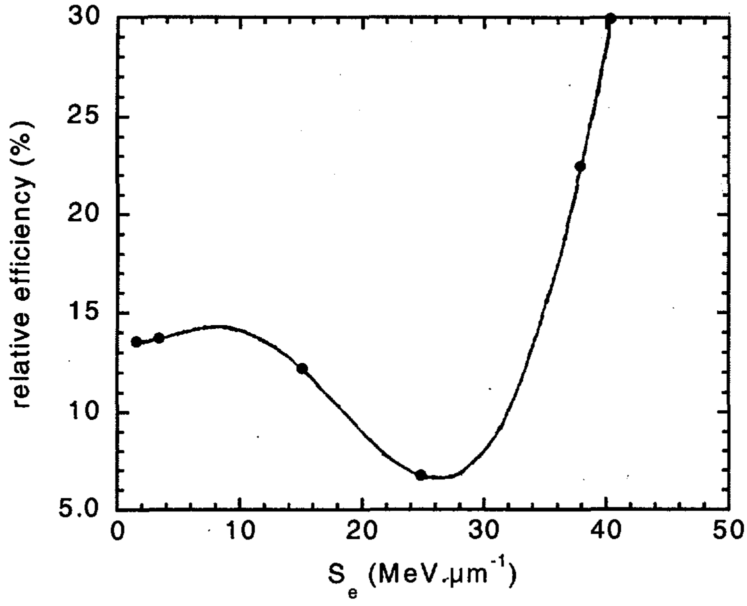


Figure 1

Concerning the Hall effect measurements, the Fermi level draws very near the valence band so as the germanium becomes degenerate. Meanwhile, it is possible to account for the observed experimental variations by simulating the Hall coefficient versus the fluence for different ions. The figure 1 shows the relative damage efficiency (η_{exp}/η_{TRIM}) of each irradiation versus the electronic energy deposited S_e. As in the case of some metal, we observe an annealing of defects for intermediate values of S_e, and above a threshold (about 30 MeV.μm^{-1}), an increase of the defect production due to the high value of S_e. The first RBS-C results show that lead ions induce a significant damage (31 % at 3.10^{-2} dpa) while in the case of argon ions, no damage has been observed. By using PAS measurements, it seems that the number of vacancy inside the defects increases with the dose whatever the incident ion. These measurements are actually in progress in order to get accurate informations about the probable multivacancy defect.

b) Applied research

The aim of the following study (P387) was to understand the deterioration of detectors irradiated with different projectiles at room temperature. In collaboration with the INFN of Milan, we have irradiated both detectors and silicon substrate (from those they are elaborated). So, we have interpreted the performance evolution of the detectors from the results obtained by Hall effect measurements on the substrate. Beyond a fluence which depends on the projectile, the substrate reaches an intrinsic state, and the detectors are no longer running. As a matter of fact, we have observed an increase in the leak current and a degradation of the capacity-voltage characteristics of the detectors.

The collaboration with the INFN goes on and we have obtained, from the GARI facility (AP 98-02), new experiment schedule in order to test the behaviour of electronic devices (HF2C-MOS type) elaborated from different doping concentration silicon. Besides, these devices have also been irradiated with neutron at the ENEA of Rome.

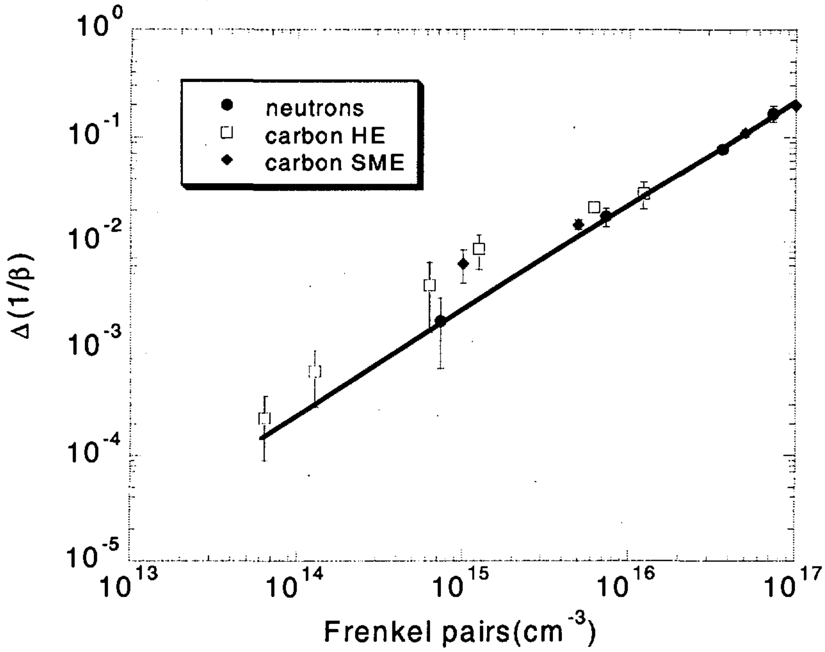


Figure 2

The purpose is to control the devices submitted to an hostile environment, in particular when they are integrated in satellites. The first studies show that we can link the degradation of the gain to the theoretical defect concentration (calculated with the TRIM's code) [6]. We have plotted on the figure 2 the degradation of the inverse of the gain versus the Frenkel pairs concentration. So, we are able to forecast, whatever the incident projectile and for a value of damage, the gain degradation of the devices [5].

References:

1. *Damage induced in semiconductors by swift heavy ion irradiation.*
M. LEVALOIS, P. MARIE, Nucl. Inst. Meth B, **B156**, 1999, 64-71.

2. *A comparative study of radiation damage on high resistivity silicon.*
P. MANGIAGALLI, M. LEVALOIS, P. MARIE, P.G. RANCOITA, M. RATTAGGI, Eur. Phys. J. AP **6**, 1999, 121-130.

3. *Study of electron, proton and swift heavy ion irradiation of n-type germanium using deep level transient spectroscopy.*
A. COLDER, M. LEVALOIS and P. MARIE, J.A.P. **88(5)**, 2000, 3082-3084.

4. *Defect creation kinetics in swift heavy ions, protons and electrons irradiated germanium.*
A. COLDER, M. LEVALOIS and P. MARIE, Eur. Phys. J. AP **13(2)**, 2001, 89-96.

5. *Study of radiation effects on bipolar transistors.*
A. COLDER, N. CROITORU, P. D'ANGELO, M. DE MARCHI, G. FALLICA, S. LEONARDI, M. LEVALOIS, S. MARCOLONGO, P. MARIE, R. MODICA, P.G. RANCOITA and A. SEIDMAN, Nucl. Inst. Meth. **B** (2001) (accepted).

Effect of swift heavy ion irradiation on the structure of Fe/Zr multilayers

A. Michel[1], C. Jaouen[1], C. Dufour[2], and B. Gervais[3]

[1]Laboratoire de Métallurgie Physique, Université de Poitiers, SP2MI, Bd Pierre et Marie Curie, BP 179, 86962 Futuroscope-Chasseneuil, France
[2]Laboratoire de Physique des Matériaux, Université de Nancy I, BP 239, 54506 Vandoeuvre Cedex, France
[3]CIRIL, BP 5133, 14070 Caen Cedex 05, France

It is now well established that irradiation with GeV-energy monoatomic ions, where the electronic energy loss is typically in the tens of keV/nm range, can induce defect creation, phase transformation, as well as ion beam mixing in metallic systems. The mechanisms underlying these effects are not yet entirely understood. The aim of this study is to investigate the mixing on an atomic scale, which enables to identify the involved mechanisms.

For this purpose, the Fe/Zr multilayer system is ideal, since both Fe and Zr are known to be sensitive to electronic energy transfer. Moreover, the formation of metastable amorphous FeZr alloys is expected in a very large compositional range. Furthermore, the structural transition in the FeZr system results in different magnetic properties: amorphous Fe_xZr_{1-x} compounds are paramagnetic or diamagnetic depending on the value of x.

The Fe/Zr multilayers were grown by sputtering deposition in a high vacuum deposition room. Equal thickness Fe and Zr layers were deposited, leading to a stochiometry of Fe_2Zr, and the total bilayer thickness was chosen to be 8 nm. For the as-deposited samples, the Zr layers are amorphous while the Fe layers are polycrystalline having a strong <110> texture along the growth direction. The irradiation of the samples was performed at 77 K using 0.94 GeV ^{208}Pb ions at GANIL (Experiment P490). Damage generation during the irradiation was monitored by *in-situ* resistivity measurements. Additionally, the changes in the crystal structure and the thickness of the Fe layers were investigated using X-ray diffraction (with measurements taken in both high angle and low angle symmetric geometry), backscattering ^{57}Fe Mössbauer spectroscopy, and HRTEM. The same techniques were also used to study the irradiation effects induced by low energy ions: 270 keV ^{40}Ar and 130 keV ^{4}He, these latter irradiation experiments were performed in LMP, at Poitiers.

The refinement of the high angle X-ray diffraction spectra yields information on both the amorphisation of the Fe layers, and the interfacial evolution. The evolution of Fe amorphisation, as obtained from both high-angle X-ray diffraction (Fig. 1) and Mössbauer spectroscopy, points to a two-stage structural transition mechanism:

- At low fluence ($\phi < 4\ 10^{12}$ Pb/cm^2), the amorphisation is almost exclusively due to an interfacial reaction;
- At higher fluences, the abrupt increase in the amorphous fraction f_{am} clearly shows that the whole of the Fe layer becomes amorphous.

This two-stage transformation is also confirmed by the *in-situ* electrical resistivity measurements, the behaviour of which corresponds to a sigmoïdal curve.

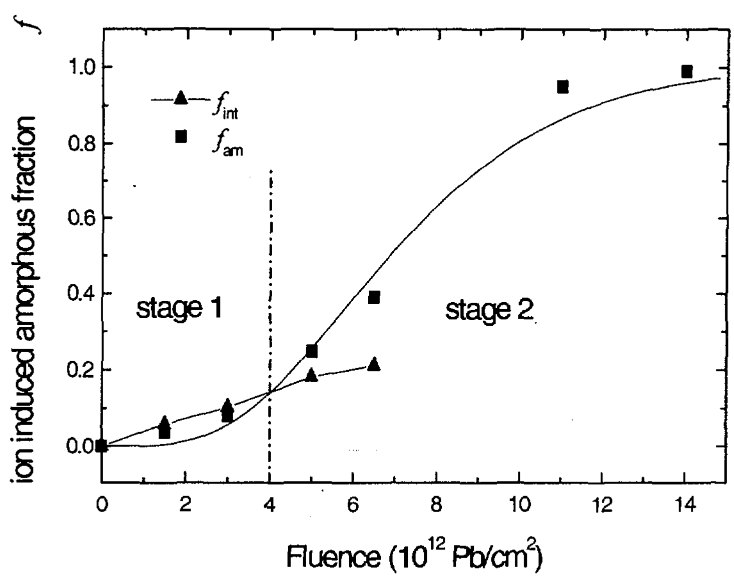


Figure 1:

Ion induced amorphous Fe fraction, as determined from X-ray diffraction spectra. f_{int} is the fraction of Fe atoms involved in interfacial reaction, and f_{am} describes the total amorphous fraction of Fe atoms.

The first stage is associated with the planar growth of an Fe_xZr_{1-x} amorphous interdiffused layer at the interfaces. The ion-induced atomic rearrangements favour the relaxation of the initial compressive residual stresses. The analysis of the kinetics of the mixing gives evidence for an interfacial reaction inside the ion tracks. The extension is limited, it does not exceed 2 atomic planes at each interface. Such a process, spontaneously observed as a solid state reaction during annealing, may be enhanced by defect creation and migration. Nevertheless, the observed diffusion length appears also consistent with a very prompt diffusion in a liquid state.

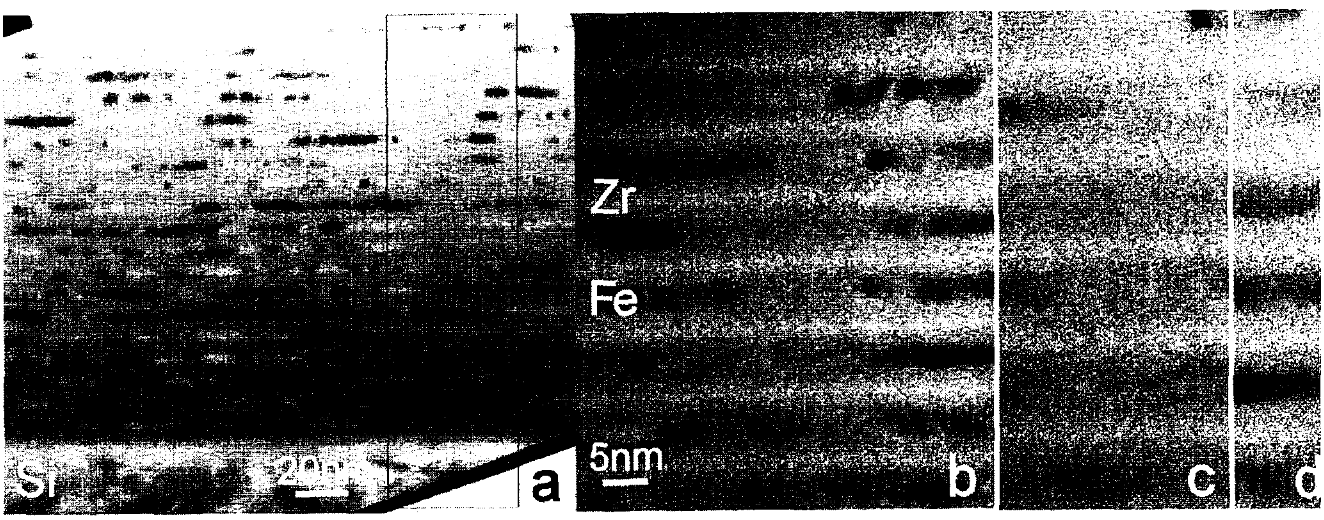


Figure 2: a. *General view of a [Fe 39Å/Zr 37Å] ×35 multilayer after irradiation with 6.5 10^{12} Pb/cm^2*

b. *Higher magnification image on the area shown by the rectangle in a.*

c. *Amorphous area in the central part of b.*

d. *Crystalline parts visible at the right of image b.*

The second stage is a total amorphisation of the Fe layers, but without complete mixing. Indeed, X-ray reflectometry experiments, as well as HRTEM observations on the samples irradiated at high fluence show that the composition modulation is still visible. TEM shows a partial mixing, with unequal bright and dark layer contrast. Actually, the layer mixing continues after amorphisation, but with an extremely low efficiency.

In fact, the crystal to amorphous transition in the Fe layers takes place as the thickness of the crystalline Fe layer becomes smaller than a critical value of e_{Fe}*(Pb)~34 Å. That requires the occurrence of successive ion impacts. The amorphisation of the crystalline Fe layers was also carefully monitored for the low energy ion irradiation: for both He and Ar ions, a similar 2-stage evolution of amorphisation was observed, but the saturation values for the interfacial process are different, leading to different values for the critical thickness (e_{Fe}*(Ar)~28 Å and e_{Fe}*(He)~24 Å).

HRTEM micrographs (Fig.2) taken on a sample irradiated with 6.5 10^{12} Pb/cm^2 are in agreement with this interpretation: only some areas of the sample become amorphous whereas in the neighbouring areas the Fe layers are remain crystalline, with a thickness just above 34 Å. From these results, we conclude that crystalline collapsing into an amorphous phase occurs as a result of the combined effect of a critical thickness and a transient disorder and not by effect of the dissolution of Zr atoms in the Fe layers.

To sum up, it has been shown that irradiation with GeV Pb ions induces a very efficient mixing via electronic energy deposition. The kinetic analysis suggests a significant interfacial reaction in the wake of ion. It has to be mentioned that low energy ion irradiation effects in Fe/Zr were also analysed and consistently explained with purely ballistic mixing effects. Surprisingly, the microstructural evolution under high-energy ion irradiation shows a very similar sequence.

Concluding, this study puts forward the occurrence in the ion path of a very high transient disorder able to induce interfacial and intralayer atomic rearrangements but, due to the lack of specific signature, it provides no real arguments in favour of a thermal spike mechanism.

References:

C. Jaouen, A. Michel, J. Pacaud, C. Dufour, Ph. Bauer, B. Gervais, Nucl. Instr. Methods **B 148** 176-183 (1999)

A. Michel, C. Jaouen, J. Pacaud, C. Dufour, B. Gervais, E-MRS Strasbourg, June 2000.

Interfacial reactions induced by high energy electronic excitations in Tb/Fe multilayers

J. Juraszek[a], A. Fnidiki[a], J. Teillet[a], M. Toulemonde[b] and A. Benyagoub[b]

[a] *Groupe de Physique des Matériaux, UMR 6634 CNRS-Université de Rouen F-76821 Mont Saint Aignan cedex*
[b] *Laboratoire CIRIL BP 5133 F-14070 Caen cedex 05*

The aim of this work is to study the transformations of the interfaces in metallic multilayers irradiated with swift heavy ions. We used nanometric Tb/Fe multilayers because their magnetic properties are strongly influenced by the quality of interfaces and internal stresses [1]. ^{57}Fe probe layers deposited at the interfaces were characterised by ^{57}Fe conversion electron Mössbauer spectrometry (CEMS).

The multilayered samples were deposited onto a Si substrate by thermal evaporation in a ultra-high vacuum system. The nominal thicknesses are 1.9 and 3.8 nm for the Tb and Fe layers respectively. The Tb layers are amorphous while the Fe layers are nanocrystallised. Two monolayers of ^{57}Fe were deposited either at the top or the bottom of natural iron layers (containing only 2.2 at. % of ^{57}Fe). The corresponding Mössbauer spectra are characteristics of the Tb-on-Fe and Fe-on-Tb interfaces, respectively. The shape of these spectra shows that the Tb-on-^{57}Fe interface is sharp while the ^{57}Fe-on-Tb interface is amorphous and diffuse (Fig. 1).

Irradiations were performed at the IRASME and IRABAT facilities of CIRIL using Ar, Kr, Sn, Pb and U ions (P510) of increasing electronic stopping powers (S_e). We investigated the effect of S_e, the fluence and the ion beam direction on the environment of the probe atoms.

The spectra of the probe layers are left unchanged after Ar ion irradiation, but an in-plane magnetic anisotropy is induced after Kr ion irradiation This evidences for an electronic stopping power threshold, ranging between 6 and 18 keV/nm, for interfacial reactions induced by electronic excitation in metallic multilayers.

For $S_e > 30$ keV/nm, we showed that the transformations induced by irradiation depend on the interface under consideration. Fig. 2 presents the evolution of the fraction of crystallised ^{57}Fe atoms as a function of the fluence for Sn (S_e=36 keV/nm) and U ions (S_e=63 keV/nm). The continuous decrease of F_α for the initially sharp Tb-on-Fe interface evidences for mixing between Fe and Tb atoms.

For the diffuse Fe-on-Tb interface, a first increase of F_α at low fluence indicates recrystallisation of a fraction of the probes induced by the electronic slowing down of the ions. At high fluence, the decrease of F_α while the fluence is raising indicates that interatomic mixing is the dominant mechanism [2].

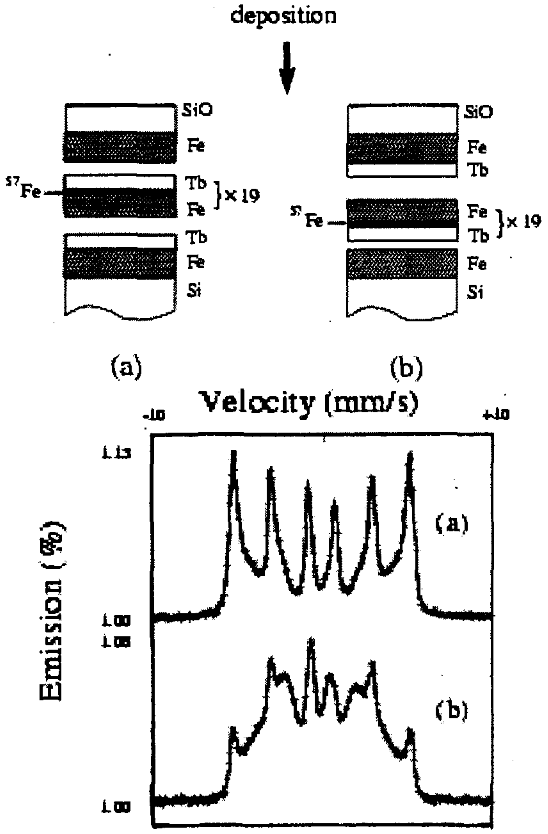


Fig. 1: *(top) Schematic representation of the deposition of ^{57}Fe probe layers at the Tb-on-Fe (a) and Fe-on-Tb (b) interfaces in the Tb/Fe multilayers.*

(bottom) The corresponding Mössbauer spectra.

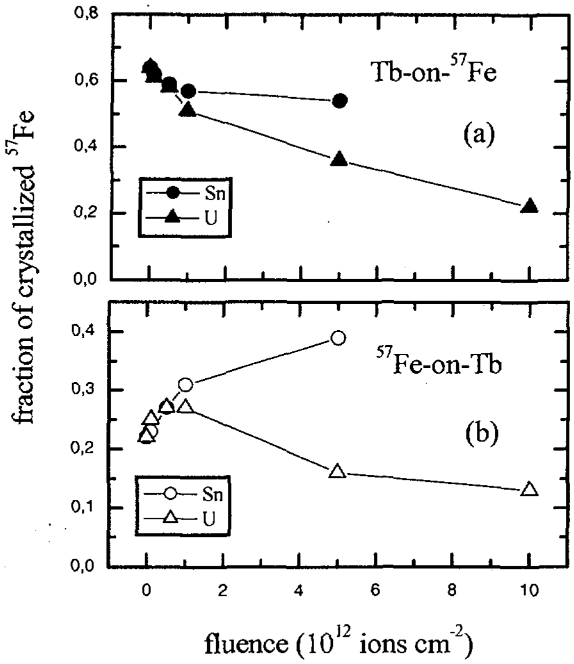


Fig. 2: *Evolution, versus the ion fluence, of the fraction of ^{57}Fe atoms in the crystalline α-phase as compared to all Fe atoms, for the Tb-on-^{57}Fe (a) and ^{57}Fe-on-Tb (b) interface irradiated by Sn ions (S_e=36 keV/nm, circles) and U ions (S_e=63.5 keV/nm, triangles).*

We have performed an original experiment with these probe layers to test the hypothesis of a directional effect of the ion beam. Two pieces of the same sample were put face to face and irradiated under normal incidence by a high energy Pb ion beam. This procedure allowed us to investigate irradiation effects at a given interface irradiated with ions coming from Tb to Fe layers and, in opposite direction, from Fe to Tb layers. There was no visible change in the Mössbauer spectra for the two directions of the ion beam, indicating that there is no directional effect for the interfacial mixing induced by high energy electronic excitations in metallic multilayers [3].

References:

[1] J. Juraszek, A. Fnidiki, J. Teillet, F. Richomme, N. H. Duc, M. Toulemonde and W. Keune, Appl. Phys. Lett. **74** (1999) 2378.

[2] J. Juraszek, A. Fnidiki, J. Teillet, M. Toulemonde and A. Benyagoub, submitted to Phys. Rev. **B**

[3] J. Juraszek, A. Fnidiki, J. Teillet, M. Toulemonde, A. Michel and W. Keune, Phys. Rev. **B61** (2000) 12.

Introduction of columnar defects by Pb 6 GeV irradiations in high Tc superconductors or in ferromagnetic manganites

V. Hardy, S. Hebert, M. Hervieu, Ch. Simon, J. Provost, A. Wahl, G. Villard, J. Wolfman
Laboratoire CRISMAT, ISMRA, 14050 CAEN

J. C. Soret, V. TaPhuoc, L. Ammor, A. Ruyter, R. DeSousa
LEMA Université de Tours, 38000 TOURS

Heavy ions irradiation creates in oxides columnar defects of about 10 nm of diameter, all across the samples on about 100 µm. These defects are a very interesting tool in order to study the pinning of the topological defects of the long range order. In the case of ferromagnets, these defects are the magnetic domain boundaries, which are clearly pinned by these defects, increasing a lot the coercive fields. In the case of superconducting cuprates, they pin the vortices, increasing the critical currents and the position of the irreversibility lines (P424, P470, P528).

Publications:

- V. Hardy, S. Hebert, M. Hervieu, Ch. Simon, J. Provost, A. Wahl, A. Ruyter, Influence of the inclination of the columnar defects on the reversible magnetization of high Tc superconductors Phys. Rev. **B58**, 15218 (1998)
- S. Hebert, V. Hardy, G. Villard, M. Hervieu, Ch. Simon, J. Provost, Vortex pinning by different angular distributions of columnar defects in Bi-2212 Phys. Rev. **B57**, 649 (1998)
- S. Hebert, V. Hardy, G. Villard, M. Hervieu, Ch. Simon, J. Provost, Pinning enhancement in Bi-2212 by tilting the columnar defects from the c-axis, Physica **C299**, 259 (1998)
- S. Hebert, V. Hardy, G. Villard, Ch. Simon, J. Provost, Improvement of the vortex pinning properties by increasing the size of the columnar defects NIM **B146**, 545 (1998)
- S. Hebert, M. Hervieu, V. Hardy, T. Aouaroun, Ch. Simon, J. Provost, E. Milani, C. Aruta, G. Balestrino, Pillar defects, a new type of track in Pb irradiated Bi-2212 thin films, NIM **B142**, 319 (1998)
- V. Hardy, S. Hebert, C. Goupil, Ch. Simon, J. Provost, M. Hervieu, P. Lejay, Vortex pinning by splayed columnar defects in YBa2Cu3O7 : Influence of large crossing angles, Phys. Rev. **B59**, 8455 (1999).
-S. Hebert, V. Hardy, Ch. Simon, J. Provost, Large pinning efficiency of orthogonal columnar defects in a weakly anisotropic high-Tc superconductor , Phys. Rev. **B60**, 13175 (1999).
-V. Hardy, S. Hebert, J. Provost, Ch. Simon, Effects of crossed columnar defects on vortex pinning in Bi-2212, Eur. Phys. J B 16, 107 (2000).
- V. Hardy, M. Hervieu, Ch. Simon, J. Provost, P. Lejay, Vortex pinning by a Gaussian splay of columnar defects in YBa2Cu3O7 : Influence of large crossing angles, Phys. Rev. **B62**, 691 (2000).
- J. Provost, V. Hardy, Ch. Simon, M. Hervieu, D. Groult, S. Hebert, Pinning of columnar defects in anisotropic high Tc superconductor Bi-2212, Inter. J. of Inorg. Mater. **2**, 635 (2000).
- J. C. Soret, V. TaPhuoc, L. Ammor, A. Ruyter, R. DeSousa, E. Olive, G. Villard, A. Wahl, Ch. Simon, Origin of the variable range hopping in Bi-2212 with columnar defects, Phys. Rev. **B61**, 9800 (2000).
- J. Wolfman, M. Hervieu, Ch. Simon,
Introduction of columnar defects in colossal magnetoresistive manganites by heavy ions irradiation
NIM **B** (2001) in press
- J.C. Soret, L. Ammor, V. Ta Phuoc, R. De Sousa, A. Ruyter, A. Wahl, et G. Villard, Bose-glass behaviour in $Bi_2Sr_2Ca_{1-x}Y_xCu_2O_8$ crytals with columnar defects : experimental evidence for variable-range hopping, Solid St. Commun. **109**, 461 (1999).
- L. Ammor, R. de Sousa, J.C. Soret, V. Ta Phuoc, A. Ruyter, a. Wahl et E. Olive, « Vortex dynamics and phase diagram of BSCCO in the presence of columnar defects », J. Phys.:Condens. Matter **12** , 4217 (2000).
- S. Hebert, G. Perkins, M. Abd el Salam, "Interplay between two families of columnar defects in Bi-2212 crystals", Phys. Rev. **B62**, 15230 (2000).

Vortex matter and columnar defects in oxide superconductors

C.J. van der Beek[1], M. Konczykowski[1], P.H. Kes[2]

[1]*Laboratoire des Solides Irradiés, CNRS UMR 7642 and CEA/DSM/DRECAM, Ecole Polytechnique, 91128 PALAISEAU, France*

[2]*Kamerlingh Omnes Laboratory, Leiden University, P.O. Box 9506, Leiden, The Netherlands*

The system of vortex lines in irradiated layered high temperature superconductors constitutes an ideal playground for the study of many-body systems interacting on large length scales, and is therefore of interest to both statistical physics and condensed matter physics. Namely, the structure of the oxide material imposes a stack-like structure on the vortex lines, each line being constituted of individual "pancake vortices" in the CuO_2 layers. Furthermore, the irradiated material contains amorphous columnar tracks of diameter comparable to the vortex core diameter - each such track is a preferred "trap" or "pinning" site for a vortex line. Both the vortex line density and the trap density can be varied over several orders of magnitude: while vortex density can be tuned by the external field to values typically between 5×10^6 to 5×10^{11} (1 G to 10 T), the accurate control of the ion fluence at CIRIL means that the trap density can be varied over the same parameter range. The interactions between pancakes and between pancakes and traps can be tuned by varying the material parameters by oxygen doping.

The vortex system in irradiated layered superconductors in also unique in that the critical current for "pancake vortices" is high so that "pancakes" are preferentially located on the tracks, and yet, the pinning energy is low with respect to temperature, so that vortex segments can easily move between traps (or "sites"). Hence, the magnetisation is reversible over a large part of the (B,T) diagram (i.e. density versus temperature) of our "vortex matter". The reversible magnetisation, which is equivalent to the vortex chemical potential, can therefore be directly measured, which allows us to extract the separate components contributing to the vortex free energy: self-energy of the vortex line lattice, pinning energy, and entropy. From this, one can deduce the distribution of the pancake vortices over the system of columns. It appears that if the columnar defect density is high with respect to the vortex density, pancakes belonging to a given stack (vortex line) may spread out over different columns, thereby increasing the entropy of the vortex lattice and decreasing its energy. In this regime, the critical current of the superconductor disappears when "pancake stacks" (i.e. vortex lines) overlap, i.e. when vortex lines become entangled. At higher fields or low defect densities, pancakes vortices belonging to a given stack (vortex line) are forced to line up on the same ion track, so that these stacks effectively behave as coupled lines. In this regime, the vortex mobility is entirely determined by the number of free (available) column sites - exactly as in the case of electronic transport in doped semiconductors. This leads to the counterintuitive result that the threshold field at which the critical current disappears *decreases* with *increasing* density of pinning sites.

Literature:

C.J. van der Beek, M. Konczykowski, R.J. Drost, P.H. Kes, N. Chikumoto, and S. Bouffard *Entropy, vortex interactions, and the phase diagram of heavy-ion irradiated $Bi_2Sr_2CaCu_2O_8$* Phys. Rev. **B 61** (2000) 4259.

C.J. van der Beek, M. Konczykowski, R.J. Drost, P.H. Kes, A.V. Samoilov, N.Chikumoto, S. Bouffard, and M.V. Feigel'man *Entropy, vortex interactions, and the phase diagram of heavy-ion irradiated BSCCO'*, Physica **C332**, 1-4 (2000) 178

C.J. van der Beek, M. Konczykowski, A.V. Samoilov, N. Chikumoto, S. Bouffard, and M.V. Feigel'man, *Defect-unbinding and the Bose-glass transition in layered superconductors*, Phys. Rev. Lett. **86**, 5136 (2001).

Swift heavy ions for magnetic nanostructures

J.P.Nozières*, M.Ghidini*, N.M.Dempsey**, B.Gervais***, D.Givord*

**Laboratoire L.Néel, CNRS, BP166X 38042 Grenoble Cedex, France*
*** Department of Physics, Trinity College Dublin, Dublin 2, Ireland*
****CIRIL, rue Claude Bloch, 14070 Caen Cedex 05 , France*

The science of magnetic nanostructures has boomed in the past 10 years thanks to the advent of advanced thin film technology and lithographic techniques which allow the preparation of 2-D (films), 1-D (wires) and 0-D (dots) objects with a well controlled geometry. However, conventional fabrication techniques based on photolithography are limited by diffraction effects to 50-100 nm whether using light, X-rays or electrons. As swift heavy ions are known to create defects at the nm-scale, it is tempting to use them to prepare truly nanometric structures. The basic idea of such an approach lies in the structural dependence of the magnetic properties, in particular for intermetallic rare-earth/transition metal alloys. For Co-based alloys, for example, the crystalline state is non or weakly magnetic (low magnetisation, low Curie temperature), whereas it exhibits a large magnetocrystalline anisotropy and hence a large coercive field, while the amorphous state is ferromagnetic with a large magnetisation, a high Curie temperature but a negligible macroscopic anisotropy. The only drawback of using swift heavy ions is the metallic nature of the targets, which requires high stopping power ions to overcome the amorphisation threshold (around 40 keV/nm in YCo_2).

Two characteristic length scales have to be considered in magnetic materials : the exchange length Λ, of the order of a few interatomic spacings and the domain wall width δ, which varies from a few nanometers for permanent magnets to hundreds of nanometers for soft magnetic materials. When the physical dimensions of a system become comparable to Λ, strong modifications of the *intrinsic* magnetic properties are expected, such as the ordering temperature, the magnetic anisotropy and the spontaneous magnetisation. This has been indeed thoroughly investigated in ultra thin films a few monolayers-thick (2-D objects). When the physical dimensions (grain size, particle size, defect size,..) are comparable to δ, one expects modifications of the materials *extrinsic* magnetic properties such as the magnetic domain configuration and the magnetisation processes. This is for example the case in lithographically patterned submicronic arrays of ferromagnetic particles. We give here two examples of irradiation-induced effects which illustrate effects on the intrinsic and extrinsic properties.

Magnetic wires in YCo_2: A truely 1-D magnetic nanostructure

Irradiation of µm-thick YCo_2 films with Pb and U ions (P466) result in a random array of ferromagnetic wires with diameters in the range 1-2 nm, embedded in a paramagnetic matrix . The most spectacular effect of this reduced dimensionnality is the enhanced temperature dependence of the reduced magnetisation m=Ms(T)/Ms(T=10K) shown in figure 1. The data are compared to those obtained for a bulk (3D) fully amorphous film. A strong deviation from the bulk behaviour is observed as the wire diameter is decreased. The *intrinsic* nature of the effect is confirmed by ferromagnetic resonance which probes magnetisation on a time scale well below the thermal relaxation time. The data can be qualitatively described by calculations of the spin wave excitation spectrum within the classical framework of spin wave theory adapted to a 1-D geometry for a finite square lattice of ferromagnetic chains, in the limit of long wavelength, non-interacting spin waves.

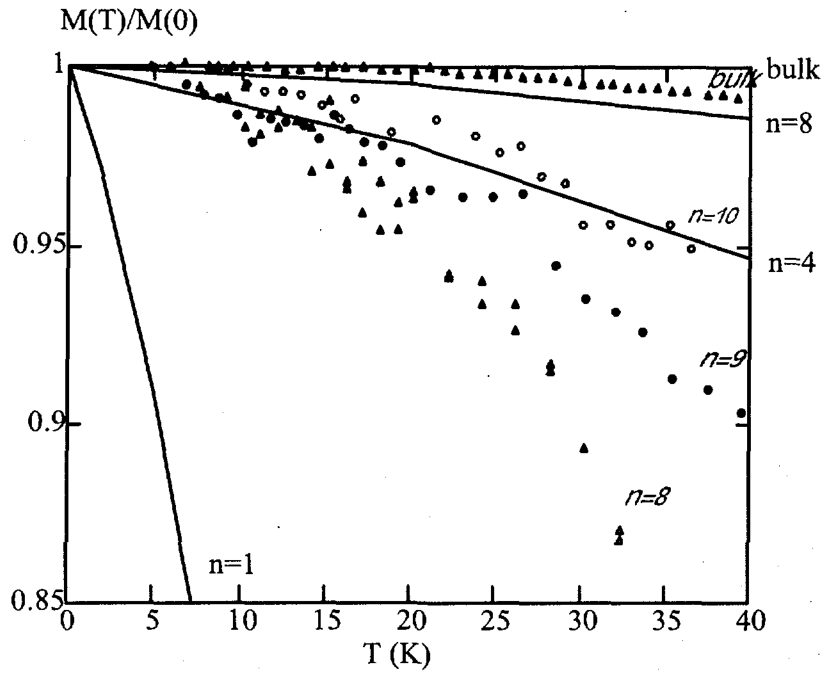


Figure 1:

Thermal dependence of the reduced magnetisa-tion in YCo_2 wires. The diameter is normalised to the mean interatomic dis-tance (n=d/2.5). The full lines correspond to spin wave calculations for a square wire.

Domain wall pinning in bulk permanent magnets

Magnetisation reversal in permanent magnets occurs by the nucleation of a small reverse domain at a defect, followed by the propagation of the created domain wall throughout the bulk of the grain. One approach to increase the coercivity, hence the 'hardness' of the magnet, is to hinder the motion of the domain walls by structural and/or anisotropy defects. Simple one-dimensional models predict this so-called domain wall pinning to be most efficient for defect sizes of the order of the domain wall width, i.e. 3-10 nm in large magnetocrystalline anisotropy compounds.

The precipitation of latent tracks in $Sm_2Fe_{17}N_3$ powders is accompanied by a five-fold increase of the coercive field (figure 2). The virgin magnetisation curves exhibit a change in behaviour typical of the onset of domain wall pinning. Such domain wall pinning, *extrinsic* by nature, is attributed to the highly disordered latent tracks, in which the wall energy is minimised due to the law magnetocrystalline anisotropy.

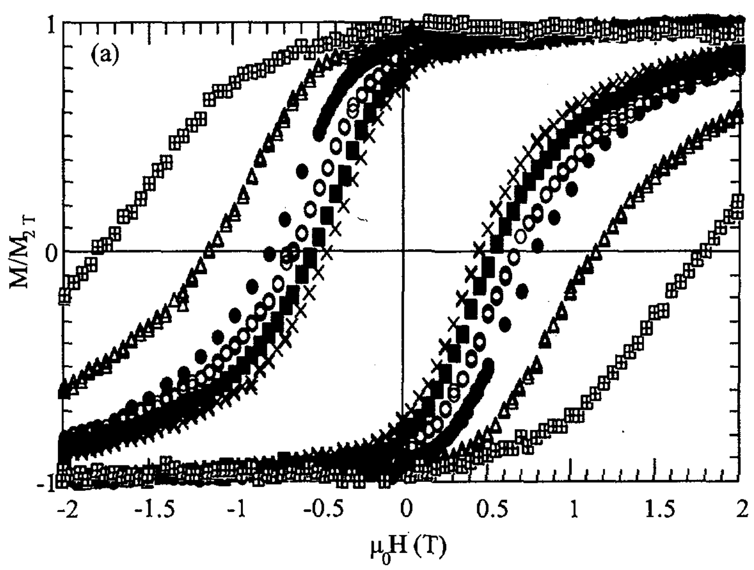


Figure 2:

Hysteresis cycles of $Sm_2Fe_{17}N_3$ powders.

× : *non irradiated*
■ :10^{11}
○ :10^{12}
● : $2.5x10^{12}$
△ : $5x10^{12}$
⊞ : $2x10^{13}$ *ions/cm*^{2}.

Cross-links induced by swift heavy ion irradiation in polystyrene

S. Bouffard[∇], E. Balanzat[∇], J.P. Busnel[♦]

∇ *Centre Interdisciplinaire de Recherche Ions Lasers, CEA-CNRS-ISMRA, BP 5133, 14070 Caen cedex 5, France*

♦ *Laboratoire de Physico-Chimie Macromoléculaire, Université du Maine, BP 535, 72017 Le Mans, France.*

The description of the polymer cross-linking induced by irradiation with high-energy ions is a difficult problem. Indeed, the cross-links are not induced randomly as under electron or gamma irradiation: the probability to produce several events close to each other is high. Under swift heavy ion irradiation, the production of large molecular masses directly in the path of a single ion is favoured.

We have measured the evolution of the molecular mass distribution by steric exclusion chromatography as a function of the dose absorbed by the polymer for different incident particules: 2 MeV electrons (LSI-Palaiseau), 2.5 MeV protons (Aramis CSNSM Orsay) and 9.4 MeV/u Carbon, 11.4 MeV/u Sulphur, 60 and 7.8 MeV/u Krypton ions (GANIL, P283 and P333). The figure 1 shows the evolution of the molecular mass distribution with the dose for an irradiation with Carbon ions. From these mass distributions we can quantify the number of cross-links produced as a function of the absorbed dose. The figure 2 shows the differential yield for cross-linking as a function of the number of cross-links induced per chain. When the electronic stopping power increases, the probability to produce a multiple cross-linking increases by several orders of magnitude.

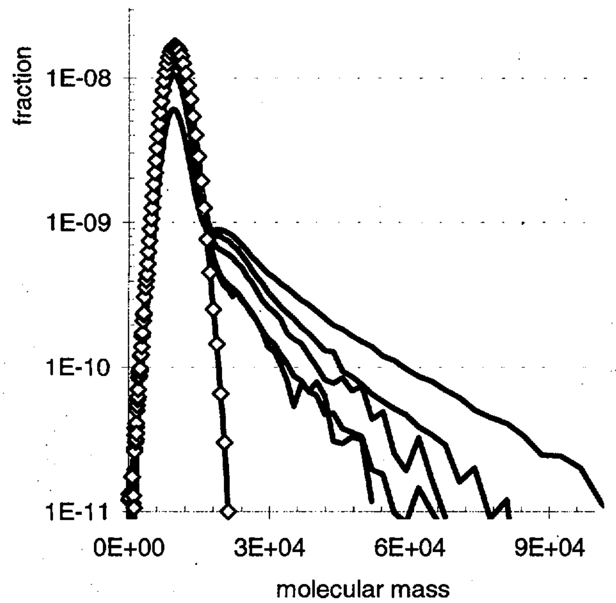


Figure 1: *Evolution of the molecular mass distribution of polystyrene irradiated with 9.4 MeV/amu Carbon ions at a dose ranging from 0 to 0.7 MGray. The diamond symbols indicate the original mass distribution.*

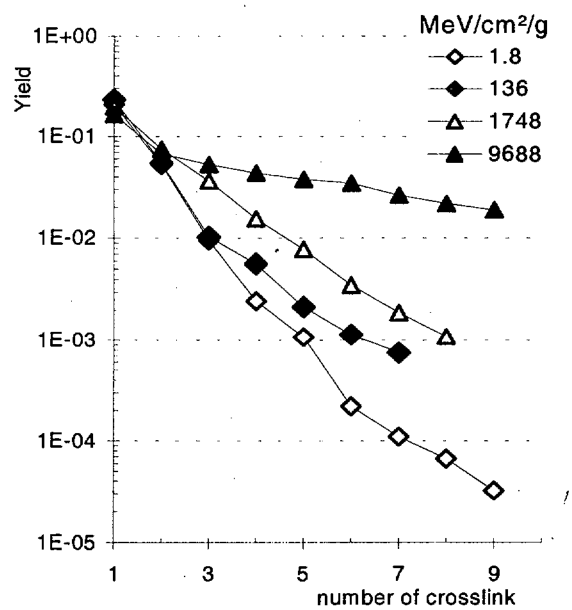


Figure 2: *Evolution, for different electronic stopping power values, of the differential yield of cross-linking for polystyrene as a function of the number of cross-links per chain.*

Reference: *Cross-links induced by swift heavy ion irradiation in polystyrene.*
S. Bouffard, E. Balanzat, C. Leroy, J.P. Busnel, G. Guevelou, NIM **B131** (1997) 79-84.

LET effects on the molecular emission of aliphatic polymers

V. Picq, J.M. Ramillon, E. Balanzat

CIRIL, CNRS/CEA/ISMRA, BP 5133, 14070 Caen Cedex 5, France.

Swift heavy ions induce a huge density of electron-hole pairs along their path. This high Linear Energy Transfer, LET, gives rise to damage processes which are different to those prevailing under classical electron or gamma-ray irradiations. We have during the last ten years systematically studied the LET effects on aliphatic polymers using an on-line analysis of the irradiated films by Fourier Transform InfraRed spectroscopy (FTIR).

Irradiation of polymers induces permanent modifications of the macromolecules and the concomitant formation of small volatile molecules. Analysing the gas release is then an alternative experimental approach for analysing the damage process. We have, during the last years, developed such measurements on the Medium Energy Line (SME) of GANIL. The study of the both in-film damage and gas release provided a complete picture of the damage process and a better understanding of what is a latent track in a polymer.

We have used two different techniques to analyse the released molecules: 1) the analysis of the residual vacuum of the irradiation chambers by mass spectroscopy 2) the analysis by infrared spectroscopy of the gas mixture released. The last technique has provided more accurate radiochemical yields for the most of the hydrocarbon molecules formed.

Three fully aliphatic polymers were studied: polyethylene (PE), polypropylene (PP) and polybutene (PB). They mainly differ by the nature of the side group (none for PE, $-CH_3$ for PP, $-CH_2CH_3$ for PB). Irradiations have been performed with particles of increasing LET: electron beams (LET = $3.5\ 10^{-3}$ MeV/mg/cm^2) and different ion beams within a LET range from ≈ 2 to ≈ 40 MeV/mg/cm^2.

Increasing LET induces a huge increase of the yields of hydrocarbon molecules. We can distinguish two LET domains. In the low LET range, the hydrocarbon emission is ruled by the side group departure; the yield is zero for PE, moderated for PP and PB and formed by methane and two carbon atom molecules in respectively PP and PB. Above a LET threshold at ≈ 5 MeV/mg/cm^2, a chain fragmentation process is triggered. For the highest LET studied, the total hydrocarbon yields are very high. They become similar in the three polymers (see figure 1).

After a LET transition zone, from the side group departure regime to the chain fragmentation regime, the composition of the gas mixture released stabilises with respect to the LET variation; while the gas yields always increase when increasing LET. So, at high LET, in each polymer, a typical gas mixture is formed probably in a radius around the ion path that increases when increasing LET. Somme common features characterise the gas mixture released at high TEL. We could mention the predominance of highly unsaturated molecules and the high yield of acetylene and propadiene. Moreover, some isomer molecules as propyne and propadiene have systematically very different yields. This shows that some specific molecules have a much greater stability in the very chemically reactive zone of the core track or shows that these molecules are the favourite by-products of chemical reactions in this hot zone. Even at high LET, the chemical formula of each polymer has still a slight influence. This is seen on the yields of some characteristic molecules.

Finally, in PB we could quantify the relative stability of bonds involving secondary and tertiary carbons. For that, we have measured at low LET the yields of methane and two carbon atom molecules.

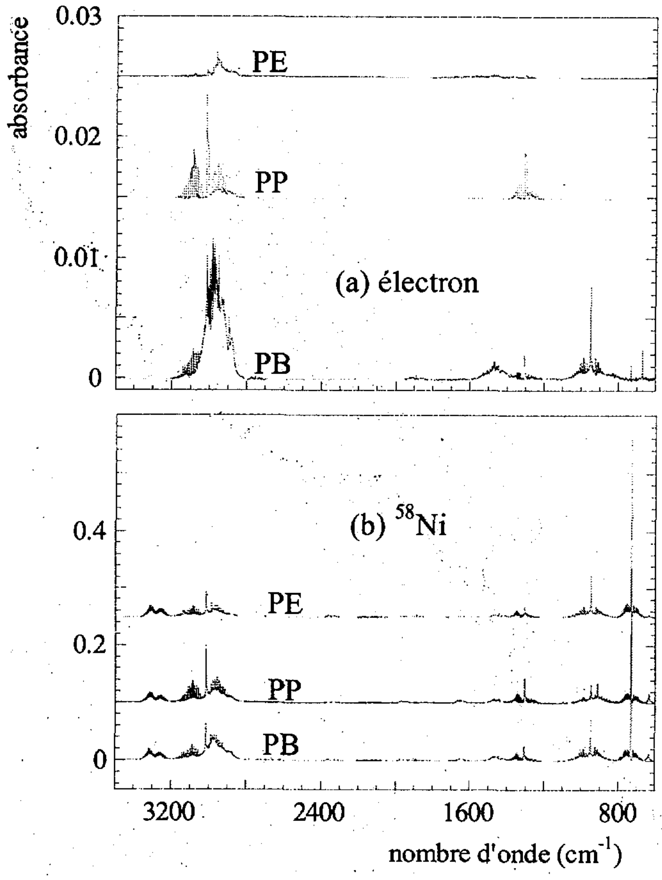


Figure 1: *Infrared spectra of the gas mixture released by PE, PP and PB films irradiated by:*
a) 1 MeV electrons LET ≈ $3,5\times10^{-3}$ MeV.mg^{-1}.cm^{2}
b) 6 MeV/A ^{58}Ni LET ≈ 39 MeV.mg^{-1}.cm^{2}.
The film thickness is ≈ 25 µm; the absorbed dose is ≈2 Mgy
At low LET the yields are small and correspond to the departure of the side group. The spectra are very different for the three polymers.
At high LET the yields are very high and correspond to a chain fragmentation process. The incidence of the nature of the polymer on the gas release is weak.

References:

[1] E. Balanzat, S. Bouffard, A. Le Moel, N. Betz, Nucl. Instr. Methods. **B91** (1994) 140
[2] E. Balanzat, N. Betz and S. Bouffard, Nucl. Instr. Methods. **B105** (1995) 46
[3] E. Balanzat, S. Bouffard, A. Bouquerel, J. Devy and Chr. Gaté, Nucl. Instr. Methods **B116** (1996) 159
[4] V. Picq J. M. Ramillon, E. Balanzat, Nucl. Instr. Methods **B146** (1998) 496
[5] V. Picq, E. Balanzat, Nucl. Instr. Methods **B151** (1999) 76

Swift heavy ion effects in polymers

N. Betz, A. Le Bouedec, S. Esnouf, C. Aymes-Chodur, A. Le Moël

CEA/Saclay, DSM/DRECAM/LSI/LPI - Bat. 466, 91191 Gif-sur-Yvette Cedex, France

Since 1986, our team in Saclay is interested in radiation effects in polymers. The pioneer work on the swift heavy ion (SHI) effects in polymers was performed in collaboration with the CIRIL, Caen, France. These former studies focused mainly on the polymer surface evolution under ionising radiation. Since then, our interest grew in the field of chemical modifications induced by SHI in the bulk of the polymer. Modification of polymer properties was also investigated. When a polymer is irradiated with ionising radiations such as electrons or γ-rays, modifications occurs which consists in crosslinking, unsaturations (isolated and conjugated), chain scissions, gas evolution, amorphisation and radical formation. These latter can have different life-times. The transient species can be observed at low temperature while the stable ones exist at room temperature and can be detected several days or months later. Among such radicals, those created in poly(vinylidene fluoride) (PVDF) are especially stable and have life-time of several years even if samples are kept at room temperature. Very few publications deal with radicals induced in polymers by SHI, and none of them offers a clear characterisation of the species observed, though these species are necessarily involved in the formation of the other defects. The knowledge of radicals is crucial for the understanding of the formation mechanism of the other defects. In addition, radicals confer to the polymer a chemical reactivity responsible for post-irradiation processes and allowing grafting of monomers.

1) The study of radicals by electron spin resonance (ESR)

In earlier studies[1], it was found that some defects such as alkynes groups are created only when polymers are irradiated with high electronic stopping power ((dE/dx)e) radiations such as SHI are. Similarly, it was found that in PVDF and in addition to the usual alkyle and peroxy radicals, radicals specific of the SHI/PVDF interaction exist[2]. This latter radical shows an isotropic ESR signal and no hyperfine structure is resolved. The gyromagnetic factor is close to that of the free electron. Its shape is close to a Lorentzian and its line-width is about 0.5 mT. The intensity of the ESR signal which measures the electronic contribution of the magnetic susceptibility follows a Curie law which indicates that these centres are isolated and allows the concentration of the paramagnetic species to be determined. The absence of hyperfine structure indicates that the radical is localised in a highly crosslinked carbon structure. Indeed the radical resembles those formed in pyrolysed polymers. Therefore this radical is attributed to a dangling bond localised in a carbon cluster as observed in amorphous carbon. It can be observed at very low absorbed doses when the polymer is not carbonised. Crosslinking occurs in PVDF. Our solubility results show that the presence of an insoluble fraction correlates with the observation of the dangling bond[3]. Irradiations with various ions ranging from O to Sn from the medium energy line facility in order to study the effect of (dE/dx)e on the formation of the dangling bond have been performed. Analysis of the results is in progress. Though the dangling bond is now spectroscopically well characterised, some questions still remain : Could it be formed in other polymers than PVDF ? What is its formation mechanism, direct creation in the track core or is there an effect of the overlapping of tracks ? Is the formation of such centres an indication of pyrolytic effects in the swift heavy ion - polymer interaction ?

2) Radiation grafting

Once radicals are generated in the polymer bulk, grafting of monomers able to polymerise is possible. The grafting of polystyrene (PS) occurs in the latent tracks and the anisotropy of the SHI/polymer interaction is maintained. When the grafting yield increases, the surface is progressively covered until a homogeneous layer is obtained as previously revealed using X-ray electron spectroscopy. We present here results obtained using scanning electron microscopy and ESR spectroscopy which stresses the crucial role of crystallinity.

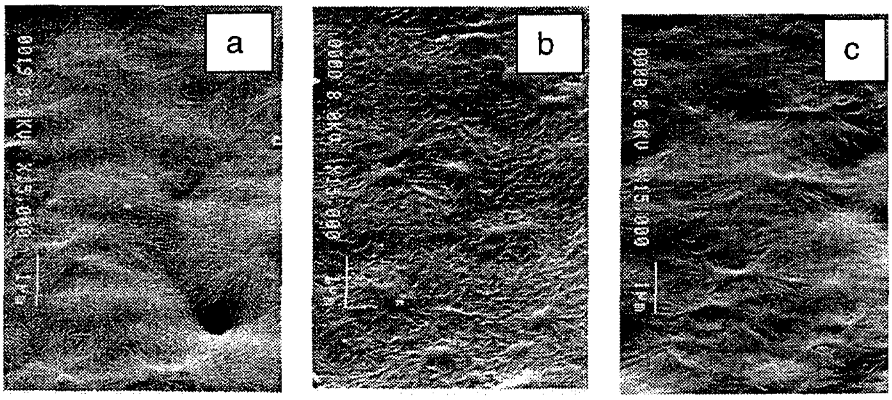


Figure 1: *SEM micrographs (x 15000), a) virgin PVDF showing its spherolitic structure, b) PS grafted PVDF, Ar irradiation, fluence : 4.23 10^9 cm^{-2}, absorbed dose : 10 kGy, grafting yield : 5 %, c) same irradiation conditions, grafting yield : 14 %.*

The Figure 1 shows the surface of virgin PVDF compared to that of an Ar irradiated and PS grafted PVDF PS-g-PVDF. Irradiated samples show the same surface than the virgin PVDF. It is observed that a PS network appears as the grafting yield increases. Small nodules are seen which are linked to each other by filaments thus conferring a dendritic-like structure to the PS grafted domains. This structure is a perfect mime of the underlying spherolitic PVDF structure which is still observed at rather high grafting yields (14%).

Analysis of the macromolecular weight distribution of the grafted chains was performed· Parameters such as the absorbed dose, the (dE/dx)e, the grafting time and the monomer concentration are varied. Very long PS chains (number average molecular weight of 1600000) are formed in the very beginning of grafting (30 min). At very high doses, interpretation of results are complicated by the presence of crosslinking: Only the soluble fraction can be analyzed by steric exclusion chromatography while it is observed that PS is embedded in the insoluble fraction and thus not analysed. The surface structure of the grafted polymer, analysed using X-ray photoelectron spectroscopy, was also studied as a function of (dE/dx)e. Several ions were used (O, Ar, Kr, Sn from the medium energy line facility) covering the (dE/dx)e-range of 2 to 60 $MeV.cm^2.mg^{-1}$. Radiation grafting was also performed using 8 MeV electrons in order to compare the different surface structures obtained. The grafting yields used for this study are in all cases small so that the surface is only partially covered. When irradiation conditions are such that a single latent track regime is obtained, the heterogeneity of grafting is large. When overlapping of latent tracks occurs, the homogeneity of the grafted domains becomes comparable to that of the electron grafting. When (dE/dx)e increases, the quantity of grafted PS per ion track increases. As the number of radicals per ion track increases when (dE/dx)e increases, the length of the grafted chains should become smaller as (dE/dx)e grows. This is what was observed in our preliminary experiments.

These studies have been initiated. Another interesting point is to understand the grafting mechanism by identifying the nature of the initiating radicals and the nature of the chemical bond existing between the polymer substrate and the grafted chain. This work is in progress.

References:

[1] N. Betz, A. Le Moël, E. Balanzat, J. M. Ramillon, J. Lamotte, J. P. Gallas, J. Jaskierowicz, *A FTIR study of PVDF irradiated by means of swift heavy ions*, J. Polym. Sci.-Polym. Phys. **B32** (1994) 1493.

[2] N. Betz, E. Petersohn, A. L. Moël, *Free radicals in swift heavy ion irradiated fluoropolymers: an electron spin resonance study*, Radiation Physics and Chemistry **47** (1995) 411.

[3] N. Betz, E. Petersohn, A. L. Moël, *Swift heavy ions effects in fluoropolymers: radicals and crosslinking*, Nuclear Instruments and Methods in Physics Research **116** (1996) 207.

Thin track etched membrane: realisation and use as template for the synthesis of nanostructures

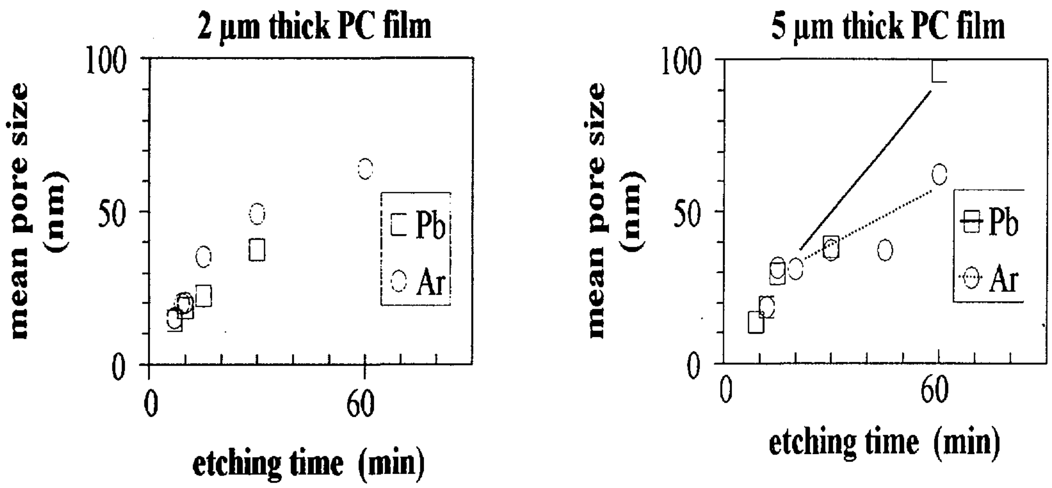
L. Dauginet-De Pra, E. Ferain

Unité de Physique et de Chimie des Hauts Polymères, Université catholique de Louvain
Croix du Sud 1, 1348 Louvain-la-Neuve, Belgium
http://www.poly.ucl.ac.be/Fr/POLY/

Template synthesis of nanoscale materials by filling the porosity of a track etched membrane is a method intensively used. It gives the opportunity to realise metallic or polymeric thin hollows or full cylinders noteworthy for their high-aspect ratio [1-4]. Such nanoscale materials are liable to applications [5,6] in e.g. electronics, optics, magnetism and materials or biomedical sciences, but display also more fundamental interests as the nanowires properties may considerably differ from the properties of the related bulk material [1,7-11].

To have accurate membranes for the synthesis of geometrically controlled nanostructures, the existing etching process has been significantly enhanced [12-14]; it is now currently applied for the lab-scale production of nanoporous membranes made from 20 μm thick PC film with perfectly cylindrical pores in the 15-100 nm size range. However, experiments show that the synthesis of nanomaterials in pores smaller than 30 nn is not obvious and the corresponding pore filling rate is very low. Therefore, different options have been considered to improve this rate, as e.g. the use of a thinner PC film.

In this work, the realisation of nanoporous membranes from 2 and 5 μm thick films have been considered. More precisely, these films have been first irradiated using two different heavy ion beams -Ar @ 5.50 MeV/u and Pb @ 4.48 MeV/u- and then used for the preparation of nanoporous membranes (P522). The etching kinetics, determined from the mean pore size measured by scanning electron microscopy, has been determined (figure 1). From these results, it appears that the used ion does not influence significantly the pore growing rate, at least for pore sizes smaller than 40 nm. Above 40 nm, and probably due to the more extensive track, pore growing rate seems to be higher with Pb irradiated films.



These nanoporous membranes have been used as template for the chemical and electrochemical synthesis of polypyrrole nanotubules, and pores with a diameter around 20 nm have been successfully filled.

Our attention is now focused on the realisation of supported nanoporous templates consisting in thin PC layer (around 200 nm thick) deposited on a rigid support.[15] We intend to realise ultrasmall holes (<10 nm) for the synthesis of very tiny nanomaterials and for the study of their fundamental properties.

Acknowledgements to S. Demoustier-Champagne and R. Legras

References:

1 M. Delvaux, J. Duchet, P.-Y. Stavaux, R. Legras, S. Demoustier-Champagne, *Chemical and electrochemical synthesis of polyaniline micro- and nanotubules*, Synthetic Metals **113** (2000) 275-280

2 S. Demoustier-Champagne, J. Duchet, R. Legras, *Chemical and electrochemical synthesis of polypyrrole nanotubules*, Synthetic Metals **101** (1999) 20-21

3 L. Piraux, S. Dubois, J.L. Duvail, A. Radulescu, S. Demoustier-Champagne, E. Ferain, R. Legras, *Fabrication and properties of organic and metal nanocylinders in nanoporous membranes*, Journal of Material Research **14(7)** (1999) 3042-3050

4 L. Piraux, S. Dubois, S. Demoustier-Champagne, *Template synthesis of nanoscale materials using the membrane porosity*, Nuclear Instruments and Methods in Physics Research **B131** (1997) 357-363

5 J.-L. Maurice, D. Imhoff, P. Etienne, O. Durand, S. Dubois, L. Piraux, J.-M. George, P. Galtier, A. Fert, *Microstructure of magnetic metallic superlattices grown by electrodeposition in membrane nanopores*, Journal of Magnetism and Magnetic Materials **184(1)** (1998) 1-18

6 K. Ounadjela, R. Ferre, L. Louail, J. M. George, J. L. Maurice, L. Piraux, S. Dubois, *Magnetization reversal in cobalt and nickel electrodeposited nanowires*, J. Appl. Phys. (1997), **81(8, Pt. 2B)**, 5455-5457

7 S. Cuenot, S. Demoustier-Champagne, B. Nysten, *Elastic modulus of polypyrrole nanotubes*, Physical Review Letters **85(8)** (2000) 1690-1693

8 S. Demoustier-Champagne, P.-Y. Stavaux, *Effect of electrolyte concentration and nature on the morphology and the electrical properties of electropolymerized polypyrrole nanotubules*, Chemistry of Materials **11(3)** (1999) 829-834

9 S. Demoustier-Champagne, E. Ferain, C. Jérôme, R. Jérôme, R. Legras, *Electrochemically synthesised polypyrrole nanotubules : effects of different experimental conditions*, European Polymer Journal **34(12)** (1998) 1767-1774

10 J. Duchet, R. Legras, S. Demoustier-Champagne, *Chemical synthesis of polypyrrole : structure-properties relationship*, Synthetic Metals **98** (1998) 113-122

11 L. Piraux, J.M. George, J.F. Despres, C. Leroy, E. Ferain, R. Legras, K. Ounadjela, A. Fert, *Giant magnetoresistance in magnetic multilayered nanowires*, Applied Physic Letters 65(19) (1994) 2484-2486

12 E. Ferain, R. Legras, *Characterisation of nanoporous particle track etched membrane*, Nuclear Instruments and Methods in Physics Research **B131** (1997) 97-102

13 E. Ferain, R. Legras, *Pore shape control in nanoporous particle track etched membrane*, Nuclear Instruments and Methods in Physics Research **B174** (2001) 116-122

14 E. Ferain, R. Legras, *Controlled production of nanoporous particle track etched membrane*, accepted for publication in Radiation Measurements (2001)

15 L. Dauginet-De Pra, E. Ferain, R. Legras, S. Demoustier-Champagne, *Realisation of supported particle track etched membranes and their use as template for the synthesis of polypyrrole nanotubes*, to be published

Swift heavy ion irradiation grafting of polymers: obtention of haemocompatible surfaces

N. Betz[1], C. Aymes-Chodur[1], A. Le Moël[1], M.-C. Porte-Durrieu[1,2], C. Baquey[2]

(1) CEA/Saclay, DSM/DRECAM/LSI/LPI - Bat. 466, 91191 Gif sur Yvette Cedex, FRANCE.
(2) INSERM U.443, University Victor Segalen-Bordeaux 2, 146 rue Léo Saignat, 33076 Bordeaux Cedex, FRANCE.

Since 1980, numerous studies have been undertaken in the field of vascular prostheses, but no solution has been found to prevent the formation of a blood clot in small diameter ones (internal diameter < 5 mm). Numerous ways of those biomaterials surfaces treatment have been developed, one of which consists in producing « heparin-like » surfaces. We used the synthesis adjusted by Jozefonvicz et al. [Fougnot C., Jozefonvicz J., Samana M. et Bara L., Ann. Biomed. Eng., **7**, 429 (1779)], whose protocol uses polystyrene (PS) chemically modified with the active groups of the heparin, a powerful blood anti-clotting substance. We adapted this synthesis to two fluoropolymer films, poly(vinylidene difluoride) (PVDF) and its copolymer with hexafluoropropylene (P(VDF/HFP)) which exhibit better mechanical properties and ageing under blood stress than PS. The synthesis includes three steps: irradiation, PS grafting, and functionalisation with COOH and SO_2NH groups to confer the material "heparin-like" properties [C. Aymes-Chodur, S. Dapoz, N. Betz, A. Le Moël, M.-C. Porté-Durrieu, C. Baquey, Research at GANIL 1996-97 (1998) 157].

Swift heavy ions were chosen as irradiation mean rather than electron or γ-ray irradiations, because they are able to induce reactive sites in a polymer at very low doses, without modifying fluoropolymers chemical and mechanical properties. The additional HFP group present in the PVDF copolymer, increases its plasticity and allows the processing of P(VDF/HFP) in the form of tubing (500 µm thick and 4 mm internal diameter) which are closer to the vascular prostheses design shape. The High Energy Line facility is required to irradiate tubing because of their thickness. Irradiations were performed with ^{36}Ar (84.19 MeV/a) under an oxygen atmosphere.

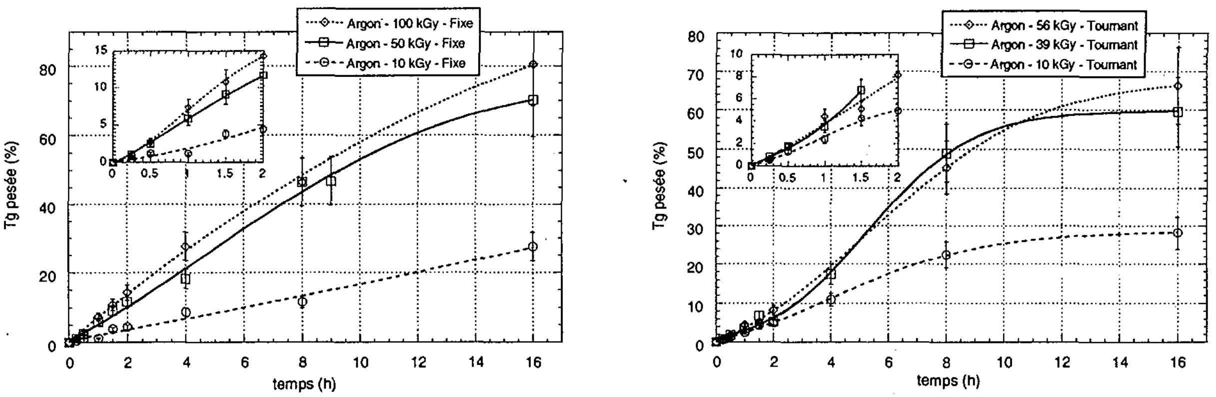


Figure 1: *Grafting kinetics of P(VDF/HFP) tubing, 500 µm thickness, left: non-rotating, and right: rotating*

Two systems have been built, one for a static tubing irradiation and the other, motor equipped, allowing the rotational movement of the tube on its axis. In the first assembly, several tubes can be mounted on a frame scanned up and down perpendicularly to the ion beam. This system increases the irradiation capacity as the time necessary to get a dose of 100 kGy is long and as the number of samples needed by the biological tests is very important. The second assembly has been built in order to get a more uniform tubing irradiation. The tubing are mounted on a rotating rod, fixed on the frame which scans vertically in front of the beam. As the irradiation time is much higher in this case than in the former system, only few tubing have been irradiated, the aim being the comparison of grafting yields for both systems. The main difference between the two systems lies in the absorbed dose distribution within the tubing thickness. In the first case, the ions go through a thickness varying from 1 mm to 3.1 mm (50 % variation) whereas in the second one, the beam is always radial to the tubing and goes through the same 500 µm thickness (10 % variation between internal and external surfaces).

The Figure 1 shows PS grafting kinetics results obtained with the two irradiation systems. Comparison is possible only for the absorbed doses of 10 et 50 (56) kGy. If the initial grafting rates are similar for both systems, the inhibition period is much longer in the case of the rotating system (almost a factor of 10). As can be seen from Figure 2, a grafting front exists. These results suggest that an absorbed dose of 40 kGy and grafting times of 4 h would be suitable for further experiments.

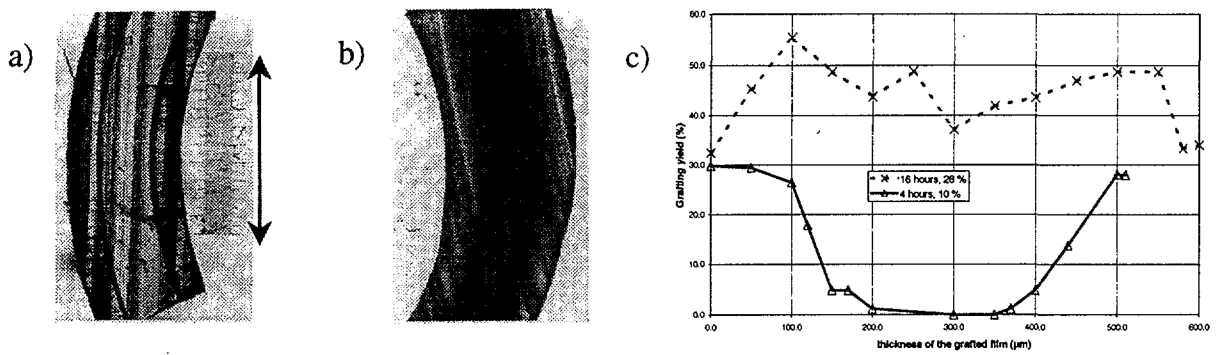


Figure 2: *Optical microscopy of PS grafted P(VDF/HFP) tubing, a) 4 hours of grafting, the grafted zone is of roughly 150 µm, the tubing is 500 µm thick, b) 16 hours of grafting, grafting occurs through the entire tubing thickness which increases up to 620 µm, c) infrared microscopy results on both samples, the grafting yield is calculated over the thickness every 20 µm. (scale on cliché a represents 1 mm and is valid for cliché b)*

Two types of radicals can be observed in PVDF polymers and copolymers using ESR spectroscopy: alkyl radicals originating from chain scission and atom abstraction from the main chain, and peroxy radicals due to the reaction of the formers with oxygen. The concentration of alkyl radicals in the non-rotating tubing, is twice lower than that of the peroxy radicals at 10 kGy. It increases as the absorbed dose increases, and is 3 time-fold larger at 100 kGy. When the PS grafting is performed, the total number of radicals decreases. Still, from comparison with results obtained on films, and with other ionising radiation, it is reasonable to assume that only peroxy radicals induce the PS grafting. The biological tests are done in Bordeaux (INSERM U443) at each step of the films synthesis on both PVDF and P(VDF/HFP). These materials remain biocompatible after functionalisation which in addition increases the haemocompatibility properties of the material. Hydrophilicity increases but protein adsorption also. Understanding the protein adsorption mechanism is of importance for the development of such materials. P(VDF/HFP) exhibiting lower surface rugosity seems to be more adequate from this point of view. Functionalisation of tubing has to performed on waved or knitted P(VDF/HFP) tubing to allow further experiments.

Publications issued from this work:

1. C. Aymes-Chodur, thèse de doctorat de l'Université Victor Segalen Bordeaux 2, 17 nov. 1998.
2. M.-C. Durrieu-Porté, thèse de doctorat de l'Université Victor Segalen Bordeaux 2, 23 nov. 1998.
3. Porté-Durrieu, M.-C., Aymes-Chodur, C., Vergne, C., Betz, N. & Baquey, C. *Surface treatment of biomaterials by gamma and swift heavy ions grafting.* NIM **B151**, 404-415 (1999).
4. Porté-Durrieu, M.-C., Aymes-Chodur, C., Betz, N. & Baquey, C. *Elaboration of "heparin-like" polymers using swift heavy ion and gamma radiations. Part I : preparation and characterization of the materials*, Journal of Biomedical Materials Research **52**, 119-127 (2000).

Acknowledgements: The authors thank the Aquitaine region for supporting 2 grants CTCR "CEA/Région". The CIRIL team is acknowledged for its precious help during irradiations at GANIL and for the realisation of the tubing irradiation systems.

5 - RADIATION CHEMISTRY AND RADIOBIOLOGIE

Radical and Molecular Species formed in liquid Water under high LET Particles Irradiation : Time-resolved and continuous eEperiments.

G. Baldacchino*, V. Wasselin-Trupin*, S. Bouffard**, E. Balanzat**, M. Gardes-Albert***, Z. Abedinzadeh***, D. Jore***, S. Deycard**** and B. Hickel*

*CEA/Saclay DSM/DRECAM/SCM URA 331 CNRS Bât. 546, 91191 Gif/Yvette cedex
** CIRIL (CEA-CNRS-ISMRA), rue Cl. Bloch, BP 5133, 14070 Caen cedex 05
*** Laboratoire de Chimie-Physique, UMR 8601, 45, rue des Saints Pères, 75270 Paris cedex 06
**** Faculté de Pharmacie, 1, rue Vaubenard, 14000 Caen, France

Keywords : LET, heavy ions, pulse radiolysis, water radiolysis, superoxide anion, hydrated electron, hydrogen peroxide.

Three chemical species resulting from the high LET irradiation of liquid water have been investigated : hydrated electron $e_{aq}^{\bullet -}$, superoxide anion $O_2^{\bullet -}$ and hydrogen peroxide H_2O_2. This latter one is a stable product which can be analysed a few minutes after irradiation. The two other are unstable and react very early in the ion tracks. They need a time-resolved experiment to be analysed a few nanoseconds after a pulse irradiation. Nevertheless, most of the papers in the literature present the radiolytic yields determined with the scavenger method [see for instance ref. 1]. However this is not a direct method which thus cannot be accurate, although a time-dependence of the yield could be obtained by a Laplace transform of the concentration-dependent curve. A comparison with the results obtained with this method was also discussed [3,5-8].

These experiments (P461,P492) have been performed at the GANIL cyclotron (Caen-France) with $^{16}O^{8+}$ (95 MeV/A) and $^{40}Ar^{18+}$ (95 MeV/A) particles whose Linear Energy Transfer ($LET = (dE/dx)_{elec}$) is, respectively, two (50 eV/nm) and three (250 eV/nm) orders of magnitude greater than of electron beams or gamma rays. The LET value remains almost constant within the thickness of the water samples due to the high energy of the particles. Most of time in the literature, the yields were obtained with mean values of LET [1].

The chemistry in water is thus considerably modified at the first moments after the ionisation. More particularly, the radiolytic yields of the radicals, like hydrated electron, decrease when the LET is increased. It is then possible to show the inhomogeneity of the chemistry around the ion tracks and to compare these results with Monte Carlo simulations.

Pulsed radiolysis with heavy ion beams

$e_{aq}^{\bullet -}$ *: a time-resolved absorption experiment*

An original experiment has been performed with O^{8+} ion beam of 1 ns pulse duration, which has a constant LET of 50 eV/nm in the water sample (Figure 1). After a fast formation within the pulse duration, a very fast non-exponential decrease of hydrated electron is observed within the 50 ns time range. This decrease is attributed to the chemical reactions of hydrated electrons in a very high local concentration of radical species close to the ion track (named core track in the theory developed by Mozumder [2]).

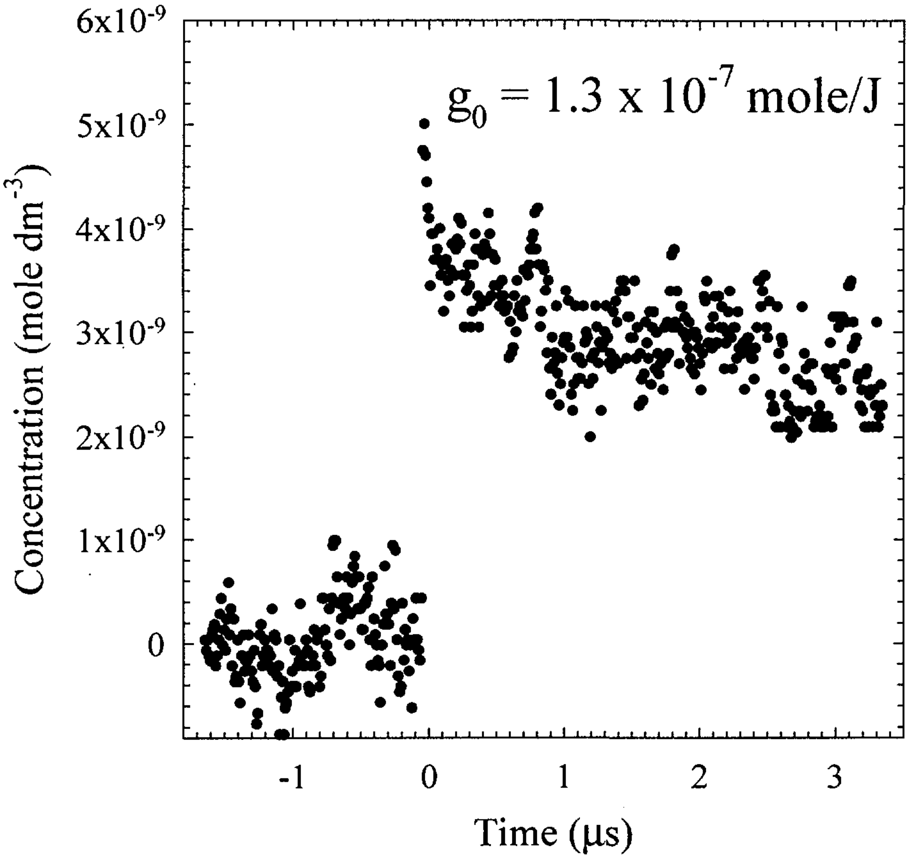


Figure 1 : *Formation and decrease of hydrated electron concentration in pure deaerated water after a 1 ns pulse of O^{8+} ions (1.5 GeV). LET = 50 keV/μm, λ = 670 nm.*

The radiolytic yields determined after the end of the pulse are very low and correspond to a concentration of about 10^{-8} mol.dm^{-3} [3]. It then confirms that radical-radical reactions are favoured in the tracks where concentrations of hydrated electron are very high. These results will have to be compared with those obtained by Monte Carlo simulation. The preliminary simulations already confirm this experimental behaviour [4].

$O_2^{\bullet-}$ *: a time resolved chemiluminescence experiment*

The superoxide anion $O_2^{\bullet-}$ is produced with a radiolytic yield higher than zero in deaerated water with high LET particles. This species has a great interest in radiobiology and therapy because of its dismutation reaction leading to the highly oxidant species H_2O_2 [5]. Several hypothesis has been mentioned concerning its formation inside the tracks but without any proof. More over, like hydrated electron, the yield measurements in high LET conditions were performed by analysing final stable products after irradiation. This method is not direct, not precise and involves high concentrations of reactive solutes (scavengers).

A method based on chemiluminescent reaction with luminol species has been developed to determine superoxide yields at early times after irradiation. This method was calibrated with an electron pulse [6] and allowed to detect very low concentrations of superoxide and hydroxyl radical $OH^{\bullet}$ between 10^{-5} M and 10^{-8} M. The yields obtained with a Ar^{18+} pulsed beam having a LET of 250 keV/µm (pulse duration between 10 µs and 2 ms) are $G(O_2^{\bullet-}) \geq 2{,}7\text{x}10^{-8}$ mol.J^{-1} and $G(OH^{\bullet})= 2{,}2\text{x}10^{-8}$ mol.J^{-1}[7].

Analysis of hydrogen peroxide escaped from the tracks

Hydrogen peroxide molecules are produced by the radical-radical reactions $OH^{\bullet} + OH^{\bullet}$. With high LET particles irradiations, H_2O_2 is formed in the tracks where the concentration of $OH^{\bullet}$ is high. As a result, its radiolytic yield increases with LET. The determination of the H_2O_2 yields were often deduced from the calculation. In this work, the yields have been determined with chemiluminescence measurements. The water solutions contained scavenger species that prevent H_2O_2 from reacting with $OH^{\bullet}$ or $e_{aq}^{\bullet-}$. Carbon ions were used for irradiations of the solutions. These ions have enough energy to have a constant LET in the water. The results compared to those obtained with other particles irradiation show that the LET parameter is not sufficient to depict the local repartition of the radicals around the ionisation track. The energy of the particles, their charge, their size have to be taken into account too [8].

References:

[1] LaVerne *et al., J. Phys. Chem.*, **97**,1993, 10720-10724.
[2] Mozumder, *Fundamentals of Radiation Chemistry*, Academic Press,1999, pp. 50-67.
[3] Baldacchino *et al., Nuclear Instruments and Methods in Physics Research* **B 146**,1998, 528-532.
[4] Frongillo *et al., J. Chim. Phys.* **93**,1996, 93-102.
[5] Baldacchino *et al., Radiation Research* **149**,1998, 128-133
[6] Wasselin *et al., Can. J. Physiol. Pharmacol.* **79**/2,2001, 171-175.
[7] Wasselin *et al., J. Phys. Chem. A* **104**,2000, 8709-8714.
[8] Wasselin, « Primary Processes in Radiation Chemistry. Effect of the Linear Energy Transfer in Water Radiolysis », PhD Thesis, University of Orsay, France,2000, n° 6184.

Detection of clustered lesions induced in plasmid DNA by heavy ions

Evelyne SAGE[1], Céline GIUSTRANTI[1], Cécile PEREZ[1], Solange ROUSSET[1], Emmanuel BALANZAT[2]

[1]*CNRS UMR 2027, Institut Curie, Centre Universitaire Bat. 110, 91405 Orsay Cedex*
[2] *CIRIL, CEA/CNRS/ISMRA, BP 5133, 14070 Caen Cedex 05*

In the present experiment P495 (a follow-up of P374, P397 and P464), we proposed to detect locally multiply damaged sites (LMDS) formed in DNA after exposure to a beam of heavy ions. This proposal was part of a more global project aiming at better understanding the interaction of high LET radiation with genetic material, and to gain insight into the mechanism of formation of DNA damage by ionising radiation. The ultimate goal is to estimate how clustered lesions, likely the most deleterious damage produced also, but at a lesser extent, by low LET radiation, are processed by the cellular machinery.

A simple tool, plasmid DNA (pBS, 2961bp) was irradiated in dry state, under vacuum, with ^{12}C (12.4 MeV/u, LET 127 keV/µm), ^{36}S (11.4 MeV/u, LET 1010 & 1650 keV/µm), ^{125}Te (3.88 MeV/u, LET 7830 keV/µm), or with γ rays from ^{137}Cs source. Plasmid DNA was also irradiated in solution, at various concentrations, with ^{36}S (77.5 MeV/u, LET 224 & 429 keV/µm) or with γ rays. Single (SSB) and double (DSB) strand breaks were quantified by electrophoresis and electron microscopy. Base damage was revealed as sites sensitive to specific DNA repair enzyme (like Fpg protein), using similar methodologies as for strand breaks.

Altogether data showed that SSB decreased with increasing LET, whereas DNA fragmentation is more extensive at higher LET. When DNA was irradiated in solution, base damage was rather evenly distributed; in opposite, when dry DNA was exposed to the beam, base damage was predominantly observed in molecules that also carried a SSB or a DSB. Furthermore, the number of base lesions per broken plasmid molecule increased with LET, as shown in the table. These last multiple damage corresponds to the predicted clustered lesions, since it is produced by a single ion track. This is the first direct observation of a type of LMDS. In addition, the results indicated that even though the same types of lesions were formed by direct (dry state) and indirect (in solution) effect, there distribution greatly varied. Damage induced by indirect effect is essentially sparsely distributed, whereas those formed by direct effect are located in a spatially close proximity. We were able to show that the complexity of the multiple damage increased with LET, as revealed by the table.

Nb of Fpg protein bound per plasmid	supercoiled plasmid molecules				damaged plasmid molecules			
	unirrad.	^{12}C	^{36}S	^{125}T	unirrad.	^{12}C	^{36}S	^{125}T
0	84.1	78.3	100	52.2	78.7	44	36.1	27.2
1	14.4	21.7	_	35.9	18.6	45.8	33.7	38
2	1.5	0	_	11.9	2.7	7.9	24.1	23.7
3	0	0		_	_	2.3	6.1	5.7
4 or more	_	_	_	_	_	_	_	5.4

Distribution of DNA plasmid molecules as a function of the number of base lesions per plasmid. Base damage is revealed by the covalent binding of Fpg protein at the damaged site and visualised by electron microscopy.

Effect of LET on the formation of oxidized DNA bases in cells exposed to ionizing radiation

Jean-Luc Ravanat, Jean-Pierre Pouget, Sandrine Frelon, Thierry Douki & Jean Cadet

Laboratoire "Lésions des Acides Nucléiques", DRFMC / SCIB UMR 5046, CEA/Grenoble, F-38054 Grenoble Cedex 9, France (jravanat@cea.fr)

The purpose of the present work (experiments: P517 &P535) was to evaluate the effect of linear energy transfer (LET) on the formation of DNA lesions in cells exposed to ionizing radiations. The DNA lesions were measured in cells exposed either to low-LET radiation produced by gamma rays from a ^{60}Co source or to a beam of $^{12}C^{6+}$ particles. Such irradiation conditions correspond to about 25 keV/µm and 0.2 kev/µm for irradiation by $^{12}C^{6+}$ particles or upon gamma irradiation produced by the ^{60}Co source, respectively.

To evaluate the damage to DNA, lesions were measured by an high performance liquid chromatographic system coupled to tandem mass spectrometry, consecutively to DNA extraction and hydrolysis [Frelon *et al* Chem. Res. Toxicol. (2000) **13**, 1002-1010]. Among the different DNA lesions measured, the four diastereomers of thymidine glycols (ThdGly, Figure 1) constitute the main radiation-induced base modifications with a yield of about 0.1 and 0.06 lesion per 10^6 bases per Gy for gamma rays and carbon particles, respectively. For both types of radiation four other DNA lesions were significantly generated which importance was found to decrease in the following order : FapyGua> 5-HmdUrd > 5-FordUrd > 8-oxodGuo. In addition, FapyAde and 8-oxodAdo are produced in about one order of magnitude lower yields than those of the other modifications.

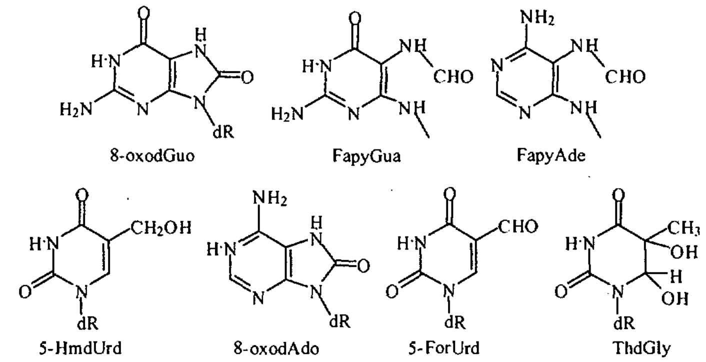


Figure 1 : Structure of the DNA modifications measured in the presented study

Table 1: *Yield of formation of the different measured DNA lesions in cells exposed to either gamma rays of high LET particles ($^{12}C^{6+}$)*

Lesion	ThdGly	5-FordUrd	5-HMdUrd	8-oxodGuo	FapyGua	8-oxodAdo	FapyAde
Gamma	0.097	0.022	0.029	0.020	0.039	0.003	0.005
$^{12}C^{+}$	0.062	0.011	0.012	0.010	0.022	0.003	0.001

As a striking observation (Table 1), the yield of formation of the measured DNA lesion was found to be, on the average, two-fold lower under high LET (carbon particles) than for low-LET radiation (gamma). The relative formation of the different DNA lesions was found to be similar between the two types of irradiation, indicating that, even using high LET particles, the indirect effect (radiolysis of water) of the ionizing radiation is the major process responsible for the formation of the currently measured DNA lesions.

High LET irradiation activates p38 kinase and its downstream target ATF2 in normal human fibroblasts

Jaap Kool[§], Hans van Dam[*], Alex van der Eb[§], and Carrol Terleth[§]

[§]Department of Radiation Genetics and Chemical Mutagenesis, [*]Department of Molecular Cell Biology, Leiden University Medical Centre, Leiden, The Netherlands

Exposure of human cells to cellular stresses activates stress signalling pathways in the cell. These signalling pathways regulate the response of the cell. Cellular stresses can induce, for example, DNA or protein damage. Cells can be confronted with many stimuli causing cellular stress, like UV irradiation, pH shifts, heat, mechanical stress, DNA-damaging drugs and ionising radiation. Depending on type and severity of the cellular stress, different responses are possible; cells can stop growing temporarily to repair the damage and continue growing afterwards, they can enter a permanent growth arrest and they can also go into apoptosis, i.e. programmed cell death.

The detection of stresses and the regulation of the responses to these stresses are essential to proper cell functioning. Different signal transduction pathways in the cell are involved and co-operate in stress signalling. These signal transduction pathways consist of proteins that activate their substrates via the addition of a phosphate group to a specific amino acid in their substrate. Signal transduction pathways regulate, among other, transcription factors that control expression of genes. Via phosphorylation of transcription factors, expression of certain genes can be enhanced or reduced. The mitogen activated protein kinases (MAPK's) play an essential role in signal transduction pathways. This family of proteins can be divided in three groups. The c-Jun NH2 terminal kinases (JNK) and the p38 kinases, which seem to be mainly involved in stress signalling, and the ERK family, which is predominantly activated by signals that involve the regulation of cellular growth. JNK and p38 kinases and their downstream targets can be activated by a range of stresses (reviewed by Tibbles and Woodgett, 1999; Davis, 2000).

Ionising radiation causes mainly double strand DNA breaks, and we were interested to examine the effects of ionising radiation, and in particular the effects of high LET irradiation, on the stress signalling pathways. The effects were compared to effects of UV-light, another agent giving rise to DNA damage, which is a potent activator of JNK and p38 and their targets. Normal human fibroblasts (VH10) were irradiated with argon particles, and protein samples were isolated at different times after radiation. Using Western blotting analysis, activation of MAPK and their downstream targets was examined.

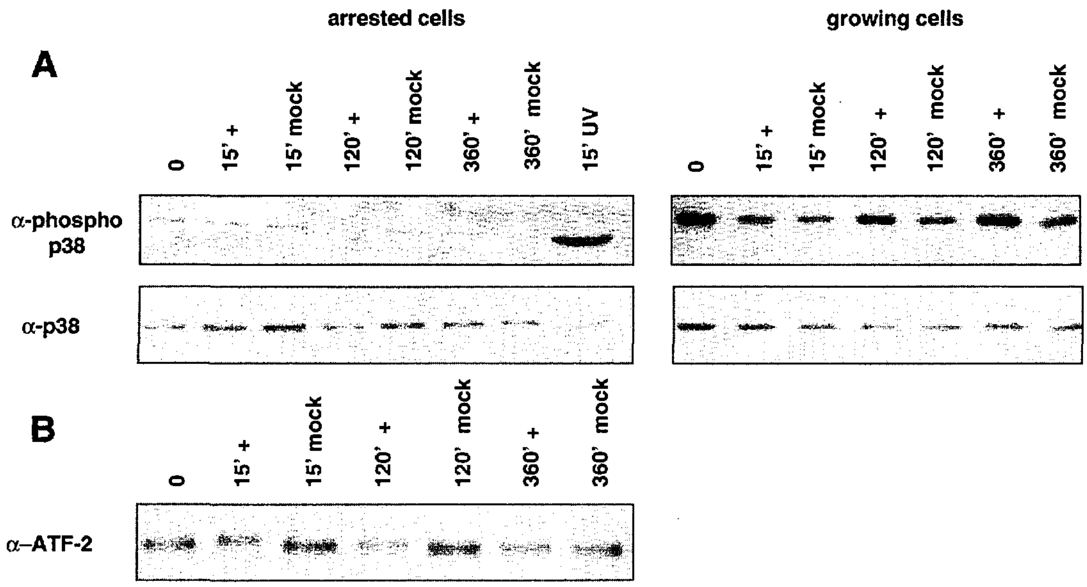


Figure 1: *Activation of p38 and ATF2 after high LET irradiation. Protein lysates were made of normal VH10 cells after irradiation with 15.10^6 particles of 95MeV/u argon.* (a) *Activation of p38 was examined with antibodies raised against the phosphorylated form of p38.*
(b) *Activation of ATF2 was examined with an antibody against the ATF2 protein, since activated ATF2 has a lower electrophoretic mobility than the non-activated ATF2.*

We found that in non-growing arrested cells irradiated with high LET (experiment number P558) neither p38 nor JNK was activated (fig.1a). ATF2, a downstream transcription factor of these MAPK's, however, was phosphorylated, as becomes clear from the shift of the protein in the gel (fig.1b). Also genes regulated by ATF2 showed increased expression (data not shown). These results are reminiscent of results we obtained with X-rays, but in sharp contrast to the effects of UV light, which activates JNK and p38 very strongly.

In asynchronously growing VH10 cells, that were high LET irradiated, a clear increase was found in the amount of phosphorylated p38, indicating that in these cells p38 is activated after irradiation (fig.1a). This suggests that activation of p38 is cell-cycle dependent. Upon X-ray irradiation in different stages of the cell cycle, we have indeed found that clear differences exist in the activation of p38 and its targets (data not shown). Further experiments are required to determine in which stage of the cell cycle p38 and its targets are most sensitive to high LET radiation. Furthermore, we are interested in determining which kinase(s) is responsible for ATF2 activation in the arrested cells.

References:

Tibbles LA, Woodgett JR. (1999) *Cell. Mol. Life. Sci.,* **55**, 1230-54

Davis RJ. (2000) *Cell,* **103**, 239-252

Study of early damage induce in human cells irradiated with high-LET ions, role in chromosomal instability

I. Testard[1], R. Blaise[2], L. Martins[2] and L. Sabatier[2]

1.CIRIL-GANIL BP5133 14070 Caen Cedex 5
2.CEA-FAR, DSV-DRR-LRO, BP6 92265 Fontenay-aux-Roses Cedex

High-LET ions have a high efficiency to induce many biological damage in irradiated cells. Some lesions occurred soon after the exposure: DNA breaks, chromosome aberrations[1], modification of gene or protein expression, cell death. But the irradiation can result in later damage such as mutations, cell transformation, carcinogenesis, genomic and chromosomal instability[2]. The possible links between early and late damage are still unclear and recent studies suggest that delayed effects can appear in cells that have not been touched by any ion. This phenomenon, called "bystander effect", would involve intercellular communication where extra-cellular factors or aberrant cell signalling effects in hit cells produce these outcomes in neighbour un-hit cells[3].

In the experiment P566 (following experiment P468) we aimed to measure some of the early stress signals induced in the hours/days following irradiation of human cells and to correlate them to the impact of an ion in a cell. We also planed to follow delayed chromosomal instability that could appear in these cells a long time after their irradiation. Up to know, we mainly focused on the analysis of chromosomal instability as the study of intercellular communications necessitated the development of a special culture device where the cells could grown on track detector, be irradiated in vertical position, and staining or immunocytochemistry performed on the detector.

Different kind of human cells were irradiated in these experiments. Three lines of fibrotic fibroblasts (fibroblasts were collagen synthesis is up-regulated) and one line of primary fibroblasts were irradiated in 1999 with ^{36}Ar (95 MeV/u, LET 242 keV/μm). We measured the cell mortality directly induced by the irradiation the days following the exposure to 10^5, $5x10^5$, 10^6, $2x10^6$, $5x10^6$, 10^7 and 10^8 particles/cm^2. We observed no striking effect of the fluence delivered. The delayed chromosomal instability was explored in the cells irradiated at $2x10^6$ particles/cm^2. For this purpose, the cells were maintained in culture and preparations for cytogenetic analyses were realized 48 h after the irradiation (1st cell division) and then all the 3 passages (P) up to P9 after the exposure. The cells have been frozen at different passages in order to continue the study after the analysis of the first samples.

At least 100 cells must be analyzed for chromosome aberrations for each points. To improve the comparison of normal and fibrotic fibroblast, an another primary line was irradiated with ^{36}Ar, 95 MeV/u last march at 10^6 and $4x10^6$ particles/cm^2. The cultures are currently followed along cell divisions as described above, control cells are at P12, whereas irradiated cells are at P10, thus having a lower proliferation. In addition to chromosome preparation, a part of the cells have been frozen at P10 (and will be it also at later passages) in order to extract and analyze DNA, RNA and proteins which are involved in apoptosis, cell cycle regulation and telomere dynamic. All these samples will be processed when cells reach senescence to allow comparisons along cell divisions.

In this experiment, we have also irradiated at low fluences cancer cells (HeLa) grown on track detectors in order to correlate the induction of apoptosis to ion tracks. The cells were fixed and stained for apoptosis detection just after the irradiation and then every 24 hours, during 5 days. We are now acquiring images using a confocal microscope to localize precisely the apoptotic cells (Figure 1). After these stage, we will proceed to the revelation of the ion tracks on the detectors

(Figure 2) and will use again the confocal microscope to demonstrate if the emergence of apoptotis in a cell is correlated to an ion hit or not. The part of this work is done in collaboration with the GRECAN (Groupe Régional d'Etudes sur le Cancer, CJF INSERM 9603) where an automated microscope coupled to image analysis is under development to identify, localize and retrieve individual nuclei or intracellular molecules. With this system we expect better results than those obtained up to now by the confocal analysis.

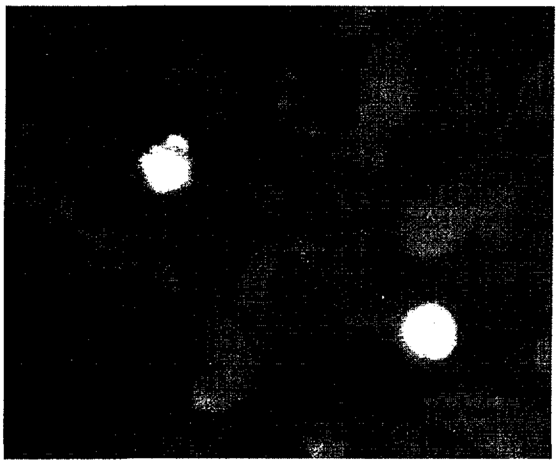


Figure 1: *HeLa cells 60h after irradiation with ^{36}Ar at 95 MeV/u, $2x10^5$ particles/cm^2 (x63). Apoptotic cells (here, 2 cells) are detected after fixation and staining of the DNA with DAPI (1 μg/ml).*

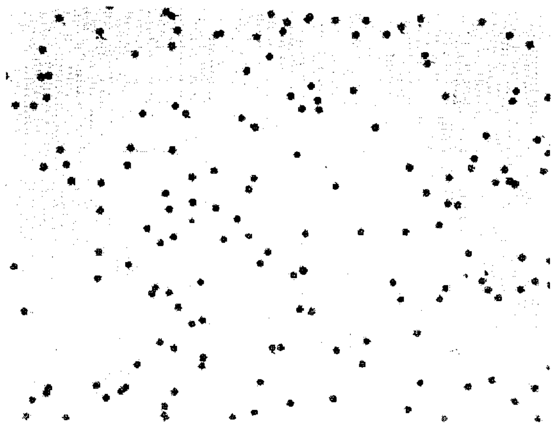


Figure 2: *Track detector (CR 39) irradiated with ^{36}Ar at 95 MeV/u, $1.5x10^5$ particles/cm^2 (x20). Tracks are revealed in KOH 12N at 80°C.*

References:

1. Testard, I., Dutrillaux, B. & Sabatier, L.; *Chromosomal aberrations induced in human lymphocytes by high-LET irradiation.* International Journal of Radiation Biology **72**, 423-433 (1997).
2. Sabatier, L., Dutrillaux, B. & Martins, M. B.; *Chromosomal instability.* Nature **357**, 548 (1992).
3. Azzam, E. I., de Toledo, S. M., Gooding, T. & Little, J. B.; *Intercellular communication is involved in the bystander regulation of gene expression in human cells exposed to very low fluences of alpha particles.* Radiation Research **150**, 497-504 (1998).

Effects of heavy ions on neuroimmune regulations

C. Marquette, L. Lebaron-Jacobs, J.M. Bertho, J. Wysoky,
*D. Clarençon, *J. Mathieu, *M. Galonnier, J. Aigueperse

Institute for Protection and Safety Nuclear, Human Health Protection and Dosimetry Division, Fontenay aux Roses, France.
** Service of Army Health and Research, Department of Radiobiology and Radiopathology, La Tronche, France.*

During Russian and American short- and long-term space flights, neuroimmune dysregulations have been observed in man and rats for up to three months after the return. During Extra-Vehicular Activity, radiation exposure risk is greater to elicit short and/or long-term deleterious effects on the functional capacity of the neuroimmune system. In order to assess the effects of high LET events on neuroimmune networks, our preliminary ground-based study was to investigate brain, neuroendocrine (hypothalamic-pituitary-adrenal (HPA) axis) and immune responses in mouse after low dose radiation exposure with high LET particles. Of particular importance is the interaction of these 3 systems, close related, and highly sensitive to ionizing radiation. Moreover, they play an essential role in the maintenance of homeostasis, so the alterations of one these activities may contribute to general dysfunction up to disease susceptibility. It is thus of interest to study the effects of the heavy ions on the functional neuro-immune regulatory networks and particularly the radiation-induced inflammatory process.

These studies constitute the ground base experiments of a space research project proposed and accepted by the CNES in 1998 and 1999. Two proposals for Ganil experiments were submitted and accepted by the committee in 1998 and 1999. Here is presented the summary of results from the 2 first irradiation experiments (^{12}C and ^{16}O) using the GANIL accelerator.

Thus, results from dosages and biological tests done, allowed to get information on the brain reaction, the HPA axis and the immune activation by heavy ions irradiation at low dose (42 mGy, 95 MeV/u, 2.10^3 particles/cm^2) and on a long period (from hours up to 4 months).

Brain results:

- ✓ Cytokine (interleukine-1) dosage showed that within hours after radiation an increase of concentrations occurred compared to sham irradiated mice. This IL-1 result indicated that a very early neuroimmune response was initiated at the brain level. As described, this cytokine is widely implicated in the HPA axis activation/regulation and immune reaction in various aggressive conditions. Thus that would suggest that neuroimmune regulatory networks are very sensitive to very low dose of heavy ions, which could be deleterious in case of long exposure for homeostasis.

- ✓ Immunochemistry studies suggested that at long term (after 2 months) a diffuse activation of inflammatory reaction by brain cells appeared throughout the cerebral parenchyma.

- ✓ Electroencephalogram registration: For the dose of 42 mGy, any significant alteration of EEG recording was observed in 3 irradiated mice versus sham. On contrary, for one mouse, which received 84 mGy, a decrease of about 40 % of REM sleep occurred at day 12, with the highest decrease at day 23 (about -80%) followed by a slight recovery (-56%) at the end of the experiment.

Neuroendocrine results:

- ✓ Three days after radiation exposure there seemed that an activation of HPA axis (associated with an increase in neuroendocrine hormones) occurred, which could be a response to developing radiation sickness as it has been previously described.

Immune results:

- ✓ No caspase activation, (an enzyme which activates numerous enzymes accounting for the irreversible cell death) was detected in lymphoid organs following radiation exposure. That would mean that in these experimental conditions, heavy ion radiation did not induce a caspase-dependent apoptosis in these lymphoid organs. Moreover, thymus and spleen weights and cellularity were not significantly modified after the irradiation. However, the neuroendocrine alterations observed could induce immune modifications such as the variation of the proportion of the different lymphocyte subsets and the functionality of the immune system. Further experiments are necessary to test this hypothesis.

Conclusions

Results of these first experiments suggest that brain is particularly sensitive to low dose of heavy ions, and induced responses that suppose neuroimmune alterations. These various radiation-induced reactions should be probably at the origin of an inflammatory response, which is probably more deleterious for the organism and implicates endocrine, immune and nervous cells. The mechanisms involved remain to be elucidated and further experiments are necessary to complete and assess radiation-induced neuroimmune dysregulations. This question is of importance because these reactions could be one of the parameters limiting the long-term space missions.

Effects of heavy ions on neuroimmune regulations

L. Lebaron-Jacobs

Institut de Protection et de Sûreté Nucléaire, Département de Protection de la santé de l'Homme et de Dosimétrie, Section Autonome de Radiobiologie Appliquée à la Médecine

Introduction

During American and Russian short and long-term space flights neuroimmune dysregulations have been observed in man and rats for up to three months after the return. During Extra-Vehicular Activity, radiation exposure risk is greater to elicit short and/or long-term deleterious effects on the functional capacity of the neuroimmune system. In order to assess the effects of high LET events on neuroimmune networks, our preliminary ground-based study was to investigate brain inflammatory responses in mouse after low dose radiation exposure with high LET particles. Of particular importance is the interaction of the CNS and the hypothalamic-pituitary-adrenal (HPA) axis the latter being most sensitive to ionizing radiation. Moreover, the HPA axis plays an essential role in the maintenance of homeostasis, so the alterations in HPA activity may contribute to disease susceptibility. It is thus of interest to study the effects of the ionizing radiation on the functional neuro-immune regulatory networks and particularly the radiation-induced inflammatory process.

Material and methods

Animals were anesthetized with Ketamine (150 mg/kg, i.p.), placed on a metal sheet and irradiated to a dose of 42 mGy using a ^{12}C beam (95 MeV/u, $2x10^3$ particles/cm^2, LET=300 keV/µm) at the GANIL accelerator (Caen, France) on October 1998 (P469). The characteristics of the (^{12}C, 95 MeV/u) beam makes the mouse irradiation homogeneous because of its range: 2.54 cm. Two tissue-equivalent chambers were placed at each ends of the metal sheet to verify the absorbed dose. Sham-irradiated control mice were treated similarly, but not exposed to the beam. Blood was collected rapidly at euthanasia by decapitation at 1 hour to 2 months following radiation exposure or sham irradiation. All data are expressed as means ± standard deviation and compared using the non-parametric Mann-Whitney test. Significance levels were set at $p < 0.05$.

Results

Just after the heavy ion exposure, we noticed a bilateral eye oedema in mice. This eye oedema persisted for around 24 hours. Exposure of mice to heavy ions (^{12}C, 95 MeV/a, 42 mGy) significantly increased plasma corticosterone levels at 6 hours and 3 days compared with the corticosterone levels at each of these times after sham irradiation (Fig. 1). It should be noted that the plasma corticosterone levels 1-, 3-, 6-, 10- and 24 hours after sham irradiation were significantly greater than the basal morning plasma corticosterone prior to any irradiation procedure or at 3 days after radiation exposure. These values probably reflect both the diurnal rhythm and the action of anesthetics on the release of corticosterone. The data in Fig. 2 show the plasma ACTH levels following ^{12}C irradiation. A significant increase in the level of circulating ACTH was observed 3 days and 1 month after ^{12}C irradiation compared with sham irradiated ACTH levels. It is interesting to note that plasma ACTH levels of irradiated animals are always greater than the corresponding controls. The reason for these observations is unclear.

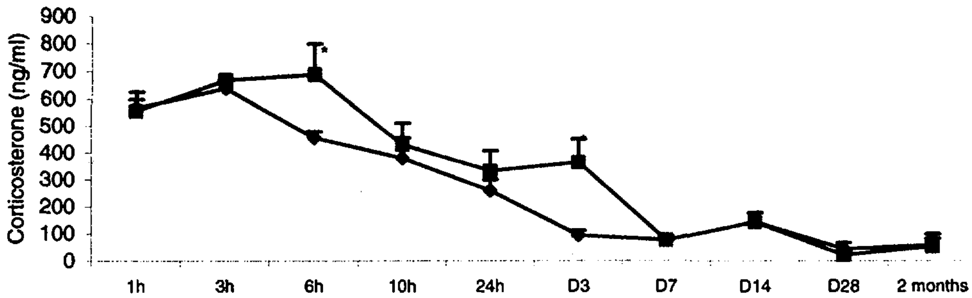


Fig. 1: *Plasma corticosterone levels in mice following (^{12}C, 95MeV/u, 42 mGy) irradiation. Corticosterone was measured in plasma of sham-irradiated (◆) or ^{12}C irradiated mice (■) from 1 hour to 2 months following exposure. Corticosterone concentrations were assessed as described in materials and methods. Values are means ± sd of 3 animals. *: $p<0.05$*

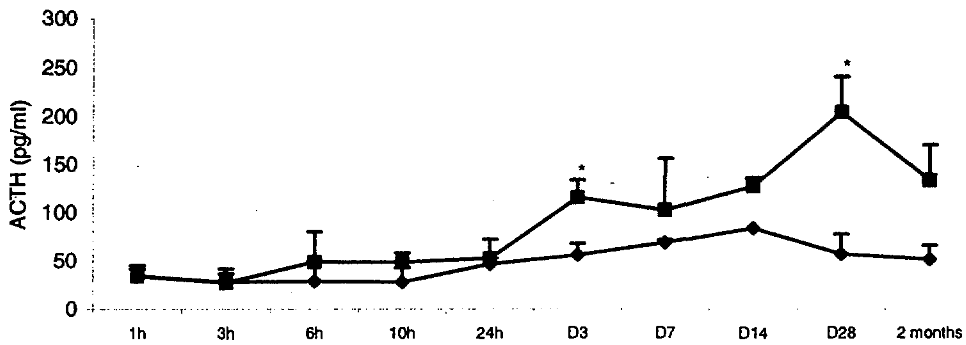


Fig. 2: *Plasma ACTH levels in mice following (^{12}C, 95MeV/u, 42 mGy) irradiation. ACTH was measured in plasma of sham-irradiated (◆) or ^{12}C irradiated mice (■) from 1 hour to 2 months following exposure. ACTH concentrations were assessed as described in materials and methods. Values are means ± sd of 3 animals. *: $p< 0.05$*

Discussion

Our results show an activation of the HPA axis following heavy ion irradiation. Plasma corticosterone increased in a biphasic manner, peaking approximately 6 hours and 3 days after radiation exposure. The first phase could be a "stress response" and the later phase a response to developing radiation sickness as it has been previously described. Three days after radiation exposure there were concomitant changes in plasma levels of ACTH and corticosterone. This late radiation-induced reaction is probably at the origin of an inflammatory response, which is probably more deleterious for the organism and implicates endocrine, immune and nervous cells. The mechanisms involved remain to be elucidated. This question is of importance because this late reaction could be one of the parameters limiting the long-term space missions.

Another experiment was performed on June 1999 (P523) using a ^{16}O beam (95MeV/u, $2x10^3$ particles/cm^2) at the GANIL accelerator, but our results concerning the HPA axis response were no significant probably because of the non homogeneous irradiation of the mouse (^{16}O range: 1.88 cm).

AUTHOR INDEX

AUTHOR INDEX

Imprimerie ALFA B Caen
Mars 2002

GANIL

GRAND ACCÉLÉRATEUR NATIONAL D'IONS LOURDS
BP 5527 - 14076 CAEN CEDEX 05 FRANCE
TEL 02 31 45 46 47
FAX 02 31 45 46 65
www.ganil.fr