Status Report on GANIL

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SUMMARY

The performances of GANIL are in constant progress and some special equipments are now installed which give a great operation flexibility. Moreover we now routinely accelerate ions from an external ECR source. We first report on these two aspects.

Then we will shortly describe two of our main experimental equipments namely the "SPEG" spectrometer and the "LISE" beam line both used in particular for exotic beam production and analysis.

We will conclude, mentionning the funded GANIL improvements :"2.5" transformation and "SME" beam line.

GANIL ion beams

Characteristics of the GANIL ion beams : Figure 1 shows the W(Z) characteristic of GANIL and the beams which have been obtained up to now.

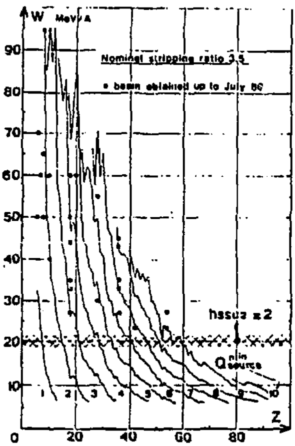


Fig.1 : W(Z) characteristic of GANIL when the most abundant charge state is selected behind the stripper.

The intensities on target range from ≈ 1.5 10^{12} pps (O16 at 94 Mev/A) down to ≈ 2.10^{9} pps (Mo100 at 23 MeV/A) i.e from ≈ 2 eμA down to ≈ 10 enA.

Beam characteristics at the entrance of the experimental areas are typically $\Delta W/W = 10^{-1}$ and εr, εz < 5 π mm.mrad. The time structure is determined by the ion source duty cycle (from 0.2 to 1), the RF frequency (from 6.6 to 13.6 MHz) and the bunch phase length (< 10°). Fig 2 shows the characteristics of a 34 MeV/A - 300 enA Kr beam at the output of SSC2 (behind the α - spectrometer).

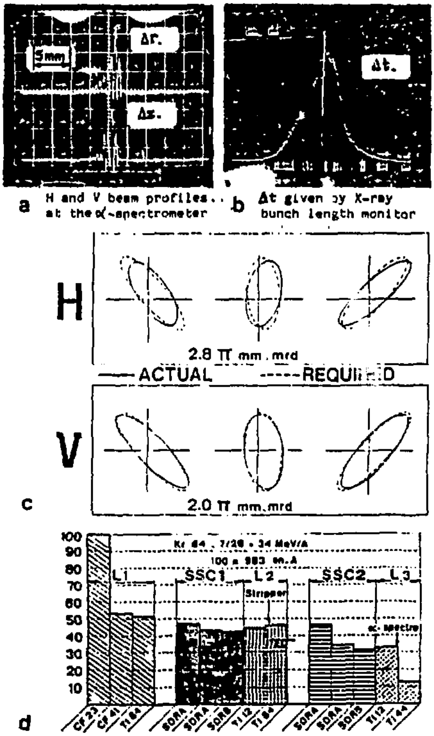
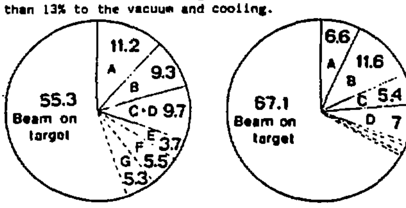


Fig.2 : Characteristics of a Kr beam :
a) energy spread = 1.2 °/oo FW ; 0.3‰ FWHM
b) phase spread = 6.7 ns FW, 2 ns FWHM (1 ns = 3°)
c) H and V emittances : not well matched in H plane.
d) transmission efficiency all along the machine.

Statistics on machine operation[1]: GANIL is operated 3 weeks per month and 10 months per year (1 month of shutdown for energy saving during winter and one more during the summer).

In 1985, the machine was operated for 4750 hours of which 80% (3780) were allocated to experiments. Fig.3 gives the distribution of these 4750 hours ; we can notice the rather long time needed for settings : initial settings and ion or energy changes which both imply complete retuning of the machine including SSC's magnet cycling. 434 hours were devoted to cure hard or software failures : about 28% being due to RF components, 17% to the various supplies, 20% to the control (electronics, diagnostics, computers) and less than 13% to the vacuum and cooling.



1985 (4750 h) JUNE 1986 (440 h)

Fig.3 : Running time repartition (%)
A) machine studies and new beam developments
B) initial settings for the runs
C + D) energy and ion changes during runs
E) scheduled maintenance during runs
F) failures during runs
G) special tunings required by physicists

GANIL improvements

During the last 18 months, the major improvement concerns the installation of an ECR external ion source on the second C02 injector but a lot of special devices which ease the GANIL operation or allow for special beam settings have been installed.

The external ECR ion source and axial injection[2] : Operated since Dec 85, the ECR ion source eases the life at GANIL due to the constant current it can deliver during very long periods of time. Moreover, due to the very low gas consumption (< 1 liter per month) we can use very expensive enriched isotopes (O18 : 98%, Kr84 -86 : 90 and 99%, Xe129 : 66%).

The characteristics of the beam from our ECR are very close to those obtained by R. GELLER :

- current ranging from 250eμA (O+2) to 20eμA (Kr+9)
- emittances à 90% ≈ (100± 25)πmm.mrad at 7 kV < Vext < 17 kV for the whole set of ions and intensities.

A second ECR providing also metallic ions is under construction at Grenoble and will be delivered by the end of this year.

Concerning the axial injection of the ions from our ECR source, we have immediately noted that the overall transmission from the source to the injector output was strongly dependent on the beam intensity due to the big reduction of the bunching factor under the space charge forces.

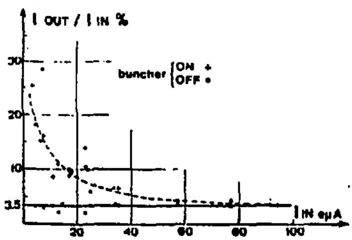


Fig.4 : Injector transmission with and without buncher as a function of the injected intensity

Typical transmissions are (see also fig.4)

- beam line from the ECR source to the injector : 50-60% to be improved by a better knowledge of initial conditions
- injector : without buncher ≈ 3.5% and with a double drift harmonic buncher more than 20% for low currents (< 10eμA injected) decreasing to 3.5% at high currents (< 100eμA).

As a consequence of these strong space charge effects and of our goal to accelerate higher intensities in the "2.5" version of GANIL[3] we are developping studies on these effects in the low energy part of the machine[a] (from the ECR source to the SSC1 output). We have already decided to move the buncher much closer to the injector than presently.

Special devices : Besides a continuous development of our diagnostic[5] and control systems, we have installed various devices all along the GANIL beam lines. We will note :

The intensity modulator[6]: it allows for the two possible time shared experiments, to receive different beam currents.

Located in the achromatic section in front of the α- spectrometer, two "V" shaped flanges, according to their respective position, define a squared aperture (0-40 mm). 150 msec are necessary to commute between the 2 positions corresponding to the 2 required intensities ; this time is to be compared to the 500 msec necessary to commute from one experimental cave to the other (pulsed dipoles). During the commutation the beam is switched off by acting on the RF of the injector.

Due to the squared shape of the modulator aperture, the beam on target is no more adapted (if the full beam was) and it may be necessary to retune the transfer lines for experiments.

Such a system very easily allows for an intensity ratio of 100 between two experiments.

The energy absorber : this device, located between SSC2 and the object point of the α-spectrometer, is a target which can be rotated between 0 and 45° in order to adjust its thickness as seen by the beam. Three main applications are used :

- slowing down the beam without having to retune the whole machine. For instance from a 44 MeV/A Ar+16 beam (εH ≈ 6π, εV ≈ 3π, ΔW/W ≈ 2 10^{-3}) we obtain, using a 700 μm target of graphite, a 27 MeV/A Ar+18 beam (εH=εV ≈ 18 π, ΔW/W ≈ 4.10^{-3}) with a 60% transmission.
- changing the charge state of the beam without important energy loss. For instance Kr+26 at 35 MeV/A through a 2.5 μm target of Ni gives the following charge state distribution = + 33 (10%), + 34 (37%), + 35 (39%), + 36 (13%).
- getting secondary beams for detector calibration. Figure 5 shows the spectrum of light ions given by a 44 MeV/A Ar beam stopped in an 1mm thick graphite target and analysed by the α-spectrometer. The different components allow for a fine energy calibration of the detectors for these particles.

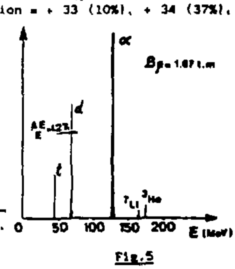


Fig.5

The fast beam chopper[7]: it is installed in the transfer line from the C02 injector to SSC1 and allows to select a given number of bunches at a given rate.

Two plates, 750 mm long with an adjustable and variable aperture (10 to 45 mm at the entrance to 45 to 90 mm at the output) perform a vertical deflection of the beam. The first one is at a constant voltage (< 2.5 kV) and the second one is supplied by pulses of equal voltage (30 nsec rising and falling times). The deflected beam is stopped on flanges located 3.1 m behind the electrodes.

The pulses are synchronized on the RF pilot of the machine, their phase is adjustable and their duration Δt can be chosen between 1 and 99 RF periods T ; therefore we can select from 1 to 99 bunches.

The repetition period can be chosen from 70 t to 70Δt + NT with N = 0-99990. Figure 6 shows as an example the selection of 1 and 8 bunches : the signals come from the movable phase spread probe of SSC1 positionned at one of the first accelerated turns.

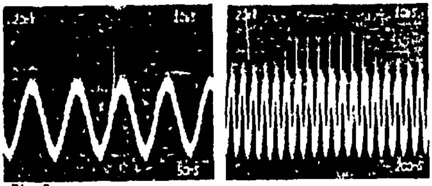


Fig.6

GANIL being operated with two time shared experiments it has been necessary to provide the possibility to turn off and on the chopper at the same rate as the commutation from one experiment to the other.

The system was first used for experiments in May 1986 and gave complete satisfaction, in particular no spurious pulses were detected.

After 3.5 years of operation, our knowledge of the machine and the skillness of the operators have increased so that we are able to deliver on targets beams of better and better qualities. For example, a 60 MeV/A Argon beam has been delivered for a channeling experiment with an angular divergence of (0.15± 0.05) mrad both in the H and V directions and ~ 5 mm spots on these two axis[8]. On the other hand, due mainly to the ECR ion source and to our feedback systems locked on beam phases, the stability of the machine is excellent and it is not unusual to see on a target a beam of really constant characteristics for more than 20 hours.

Experimental facilities of GANIL

Figure 7 shows the experimental areas of GANIL ; among the various equipments which are installed we chose to briefly present the "LISE" beam line and the "SPEG" spectrometer.

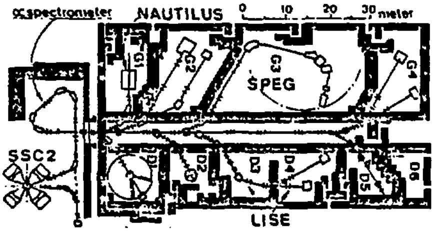


Fig.7 : The GANIL experimental areas

The "LISE" beam line[9] : "LISE" is used either for atomic physics (it provides H or He like atoms up to Xe) or for nuclear physics (reaction product separation and identification, secondary radioactive beams).
Two identical dipoles and 10 Q-poles give an achromatic focal point where a well shielded small size telescope gives the energy. The $B\rho$ is measured by a position sensitive detector in the intermediate dispersive focal plane and the velocity is deduced from a time of flight measurement. Therefore a very fine mass identification is achieved.

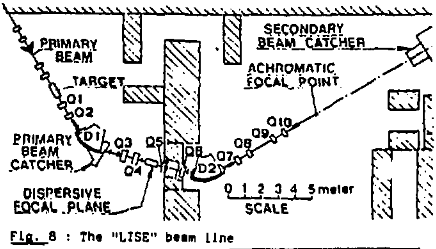


Fig. 8 : The "LISE" beam line

An intermediate stripping after the first dipole eliminates the components of the primary beam having the same $B\rho$ as the detected products.

As an example Fig.9 shows a result obtained with "LISE" in experiments aiming at new isotopes identification : we can in particular notice C22, N23 and the non existence of C21 for instance.

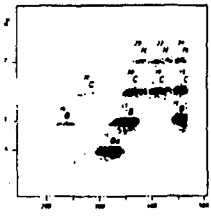


Fig.9

The "SPEG" spectrometer : SPEG is devoted to the study of discrete nuclear states with spacings of the order of 1 MeV or less at the GANIL energies which are typically 1 or 2 GeV. An excellent resolution is necessary and we chose to build an energy loss magnetic spectrometer with a maximum rigidity of 2.88 T.m. Its momentum resolution has been measured and turns to be 3. 10^{-5} lowered to 10^{-4} taking into account the target and the detectors. The solid angle is 7 msr (± 2° vertically and horizontally). The standard detection system consists of two X-Y drift chambers which give X-Y-θ and ϕ for the outgoing particles, their identification being made from the combination of time of flight measurements by parallel plate detectors and ΔE-E given by a big ionisation chamber.

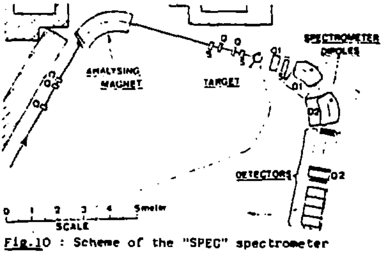


Fig.10 : Scheme of the "SPEG" spectrometer

A large number of experiments have already been performed since "SPEG" became operational in mid 85. We can mention studies on elastic scattering, transfer reactions, charge exchange, giant resonances and so on. As an illustration Fig.11 shows a result obtained in the study of the 208Pb(16O-15N)209Bi reaction.

Moreover SPEG proved to be a very precise tool for the mass determination of exotic nuclei : in this case, the target has to be located before the α spectrometer which provides a length of flight of 100 m.

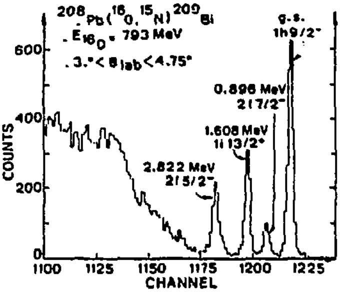


Fig.11 : 1 nucleon transfer leading to the first excited states of 209Bi

GANIL upgrading and additions

Two major developments of GANIL are going on : the "2.5" transformation and the "SME" adjunction. We will also note a possible industrial application of GANIL.

The "2.5" transformation : an invited paper at this conference being devoted to this upgrading, we just show on Fig.12 the W(Z) characteristics of GANIL in its "2.5" version as compared to the present ones. The achievement is foreseen for mid 89

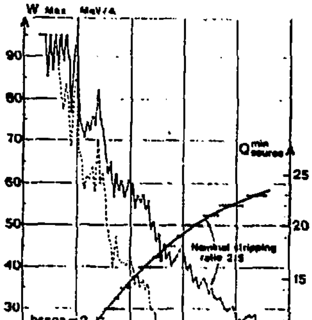


Fig.12 : Wmax (Z) characteristics of GANIL in the "3.5" and "2.5" versions and related minimum charge state at the ion source when the most abundant charge state is selected after stripping

The "SME" addition[10]: the medium energy output (Sortie Moyenne Energie) will use the presently lost charge states at the stripper level. This new facility will provide a specific experimental area and more beam time for atomic and solid state physics. The project implies a charge selection behind the stripper and new experimental facilities (either a new small building or eventually a new beam line going to one of our actual experimental cave : namely D1).

The charge selection, sketched on Fig.13, uses one dipole M1 and a septum magnet SM. Three additional dipoles providing (together with M1) an achromatic system will put the GANIL beam back on its initial direction (charge state Qo)

The drift length between the stripper and SSC2 will be increased giving a slight phase spread increase at the SSC2 input and as a consequence an increase of δW/W of the order of 10% at its output.

The charge state selected for the "SME" will be Qo-1 (6<Qo<25), Qo-2 (26<Qo<50) and Qo-3 (51<Qo<75) giving a beam at the stripping energy (4 to 15 MeV/A) in an emittance ≈ 18 π mm.mrad in the two transverse planes and with intensities ranging from 10^{11} pps for Z<10 to some 10^{7} pps for the heaviest elements.

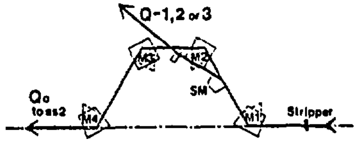


Fig.13

An industrial application at GANIL : the GANIL beams seemed well suited (ion masses and energy range) to the production of micro-porous filters in a wide thickness range (10 to a few hundreds of μ m). After a series of tests we have decided to built a special line devoted to this application.

A sweeping system spreads the beam on a large irradiation window with a good homogeneity and the 10^{11}-10^{12} pps allow for a fast production rate.

Of course, GANIL being devoted to fundamental research, any industrial use of its beam has to remain marginal and the various procedures from the irradiated material to the commercial filters should be made by an industrial firm taking in charge their treatments, conditionning and commercialization.

Conclusion

In its present state, and obviously when the "2.5" transformation becomes operationnal, GANIL is certainly an excellent tool. However, the scientific community always thinks of new capabilities that could for instance be provided by a very high intensity SSCO upstream of SSC1 and a cooling ring downstream of SSC2.

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