Study and comparison of the decay modes of the systems formed in the reactions ^{78}Kr+^{40}Ca and ^{86}Kr+^{48}Ca at 10 AMeV

S. Pirrone, G. Politi, M. La Commara, J.P. Wieleczko, G. Ademard, E. de Filippo, F. Amorini, L. Auditore, C. Beck, Eric Bonnet, et al.

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G. Politi[1,2], S. Pirrone[1], M. La Commara[3,4], J.P. Wieleczko[5], G. Ademard[5], E. De Filippo[1], M. Vigilante[3,4], F. Amorini[6], L. Auditore[7,8], C. Beck[9], I. Berceanu[10], E. Bonnet[5], B. Borderie[11], G. Cardella[1], A. Chbihi[5], M. Colonna[6], A. D'Onofrio[4,12], J.D. Frankland[5], E. Geraci[2,1], E. Henry[13], E. LaGuidara[1,14], G. Lanzalone[15,6], P. Lautesse[16], D. Lebhertz[5], N. LeNeindre[17], I. Lombardo[2,6], D. Loria[7,8], K. Mazurek[5], A. Pagano[1], M. Papa[1], E. Piasecki[18], F. Porto[2,6], M. Quinlann[13], F. Rizzo[2,6], E. Rosato[3,4], P. Russotto[2,6], W.U. Schroeder[13], G. Spadaccini[3,4], A. Trifirò[7,8], J. Toke[13], M. Trimarchi[7,8] and G. Verde[1]

[1]INFN - Catania, Italy
[2]Dipartimento di Fisica e Astronomia, Università di Catania, Italy
[3]Dipartimento di Scienze Fisiche, Università Federico II Napoli, Italy
[4]INFN - Napoli, Italy
[5]GANIL - Caen, France
[6]INFN LNS - Catania, Italy
[7]Dipartimento di Fisica, Università di Messina, Italy
[8]INFN Gruppo Collegato di Messina, Italy
[9]IN2P3 - IPHC Strasbourg, France
[10]IPNE, Bucharest, Romania
[11]IN2P3 - IPN Orsay, France
[12]Dipartimento di Scienze Ambientali - Seconda Università di Napoli, Caserta, Italy
[13]University of Rochester, USA
[14]Centro Siciliano Fisica Nucleare e Struttura della Materia, Catania, Italy
[15]Università Kore, Enna, Italy
[16]IN2P3 - IPN Lyon, France
[17]IN2P3 - LPC Caen, France
[18]University of Warsaw, Poland

Abstract. The first results of the ISODEC experiment, performed at the INFN Laboratori Nazionali del Sud (LNS) by using the CHIMERA detector, are presented. The principal aim of this experiment is to explore the isospin dependence of the decay modes of medium mass compound nuclei formed by fusion processes, by studying the competition between the various disintegration modes of ^{118,134}Ba nuclei produced in the reactions ^{78}Kr+^{40}Ca and ^{86}Kr+^{48}Ca at 10 AMeV. The studied systems allow in fact to produce compound nuclei with a large variation of N/Z, and such data will also provide new constraint on sophisticated models attempting to describe statistical and/or dynamical properties of excited nuclei. The experiment complements data already obtained at 5.5 AMeV for ^{78,82}Kr+^{40}Ca reactions, previously realized at GANIL by using the INDRA detector. First results show a strong staggering effects in the Z distributions, as well as different isotopic composition and enrichment for the reaction products in the two systems.

1 Introduction

The ISODEC experiment was recently performed at the INFN-Laboratori Nazionali del Sud (LNS), in order to study the competition between the various disintegration modes of ^{118,134}Ba compound nuclei produced in the reactions ^{78}Kr+^{40}Ca and ^{86}Kr+^{48}Ca at 10 AMeV.

This experiment is part of a project that aims to explore the isospin dependence of medium mass compound nuclei decay formed by fusion process. It is well know that the neutron enrichment of the compound nuclei is expected to play an important role on the various emission mechanisms, providing crucial information on fundamental nuclear quantities. The level density parameter for example plays a key role in the thermal properties of excited nuclei, and it is related to the effective mass, a property of the effective interaction that is sensitive to the neutron-proton composition of nuclei. The fission barriers depend strongly of the symmetry energy that is weakly constraining by existing data. Last, the viscosity reflects the coupling between collectives modes and intrinsic degree of freedom that is related to the Fermi energy level, an thus depends on the neutron-proton ratio. Thus the chemical composition influence the fission dynamics and a program of systematic measurements of fission cross-section for a large isotopic chain of compound nuclei, from neutron-rich to neutron-poor, can provide careful information on the subject.

The studied systems allow to produce compound nuclei with a large variation of N/Z, at very high angular momentum, and with similar excitation energy. Such a set of data also will provide new constraint on sophisticated model attempting to describe statistical and/or dynamical properties of excited nuclei. Finally, the experiment complements the data already obtained at 5.5 AMeV for ^{78,82}Kr+^{40}Ca reactions [1], realized with beams delivered by GANIL facility and by using the INDRA detector.

2 Experimental method

In this experiment the principal observables are the cross-sections, multiplicities, angular and kinetic energy distributions of the various emitted species (Intermediate Mass Fragments - IMFs, Light Charge Particles - LCPs, and Fission Fragments - FF). The measurement of these observables with sufficient accuracy requires good isotopic resolution and low energy thresholds for LCPs and IMFs, high granularity and broad angular acceptance, and the 4π CHIMERA multi detector [2] was a very suitable device to achieve this goal.

The CHIMERA array is operational since a long time and has proven its capabilities to provide accurate results in the intermediate energy regime, characterized by final states with a large number of charged products that populate a broad energy range. The device consist of 1192 detector telescopes, distributed on 9 rings in the forward part and 17 rings in spherical configuration in the backward part, for a geometrical efficiency of 94%; a sketch and a picture are presented in Figure 1.

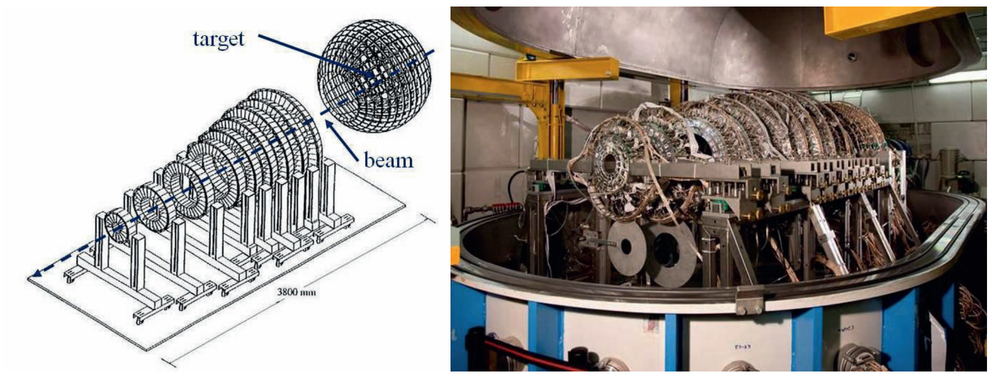

Fig. 1. Sketch and picture of Chimera device.

The single detection cell consists of a silicon detector (Si, thickness about 300 μm) followed by a Caesium IodineThallium crystal (CsI(T1), thickness ranges from 3 cm to 12 cm), coupled to a photodiode. The identification methods employed are:

- ΔE-E, for charge identification of the particles punching through the Si detector and stopped in the CsI(Tl), with also mass identification for particles with Z≤9;
- E-TOF (Time of Flight), for mass identification, velocity and energy measurement of the particles stopped in the Si detector;
- PSD (Pulse Shape Discrimination) in CsI(Tl), for isotopic identification of light charge particles;
- PSD in Si detector, for charge identification of the particles stopped in the Silicon detector.

This last method was recently upgraded in CHIMERA [3,4], and it allowed to work for the first time in a low energy range, where most of the particles are stopped in the first stage of the telescope. In Figure 2 a ΔE - RiseTime plot is presented for the n-poor system $^{78}Kr+^{40}Ca$ at 10 AMeV at θ =34°, showing the good charge identification obtained by the PSD methods for particles stopped in silicon detector.

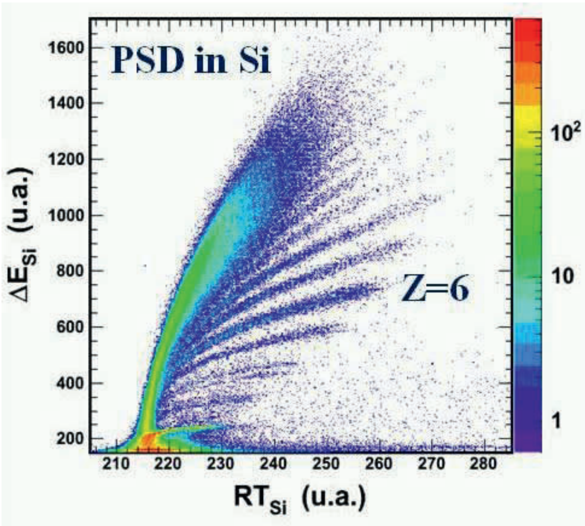

Fig. 2. ΔE - Rise Time plot for $^{78}Kr+^{40}Ca$, at θ =34°.

The CHIMERA multidetector is also characterized by a low energetic detection threshold, that is less of 0,5 AMeV for heavy ion and 1 AMeV for light particles. These characteristics allowed the complete identification of LCP from about 2 AMeV up to very high value of energy, the complete identification in charge and mass of the IMF (3<Z<12) products, the charge identification for products stopped in the Silicon up to Z =16, and up to about Z = 40 for the more energetic particles stopped in CsI.

Self-supporting 1 mg/cm^2 thick ^{40}Ca and ^{48}Ca realized by the INFN-LNL target service were bombarded with 10 AMeV $^{78,86}Kr$ beams delivered by the Superconductive Cyclotron at the INFN LNS facility. Inclusive and coincidence measurement were realized. Energy and time calibration measurements were performed by using ^{12}C, ^{16}O and proton beams, delivered by the TANDEM SPM of the LNS, at total energy ranging from 10 to 100 MeV.

3 First results

Very first results of the experiment referred qualitative mass distribution for lighter fragments, showing a different neutron enrichment according to the entrance channel N/Z [5].

Figure 3 show the energy spectra in the centre of mass frame for some of the intermediate mass fragments produced in the neutron rich system at θ_L =11°-13°. The shape of the spectra, showing a non symmetrical behaviour, probably reflect the influence on energy spectra of the isotopic composition for each detected fragment.

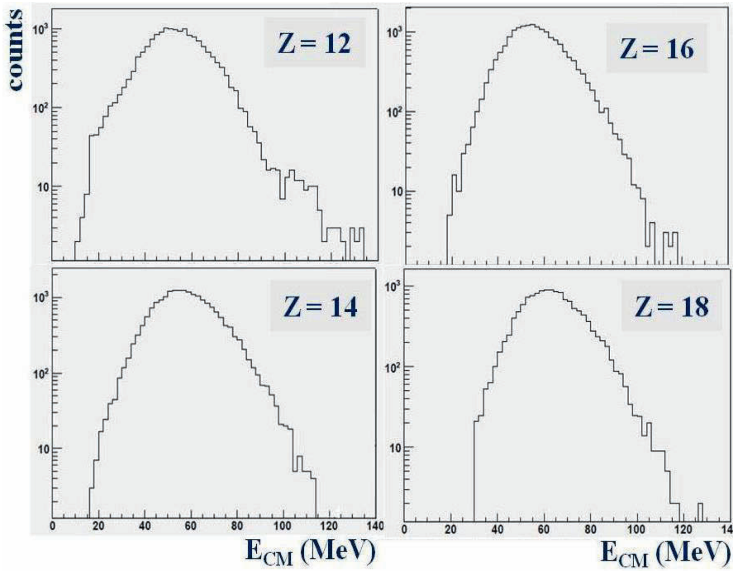

Fig. 3. Kinetic Energy spectra in the CM frame for different fragments detected at θ = 11°-13°.

In figure 4 it is shown an example of the relative mass distributions for the IMF with Z = 3, 4, 5, 6, for the two systems. It is evident the different isotopic composition and relative enrichment in correspondence of the same Z, for the compared systems. In particular this effect is evident for the Be element, that in the n-poor system is present with A=7,9 while in the n-rich system with A=9,10. These differences in the two systems show that a memory of the entrance channel is still present in this class of reaction products.

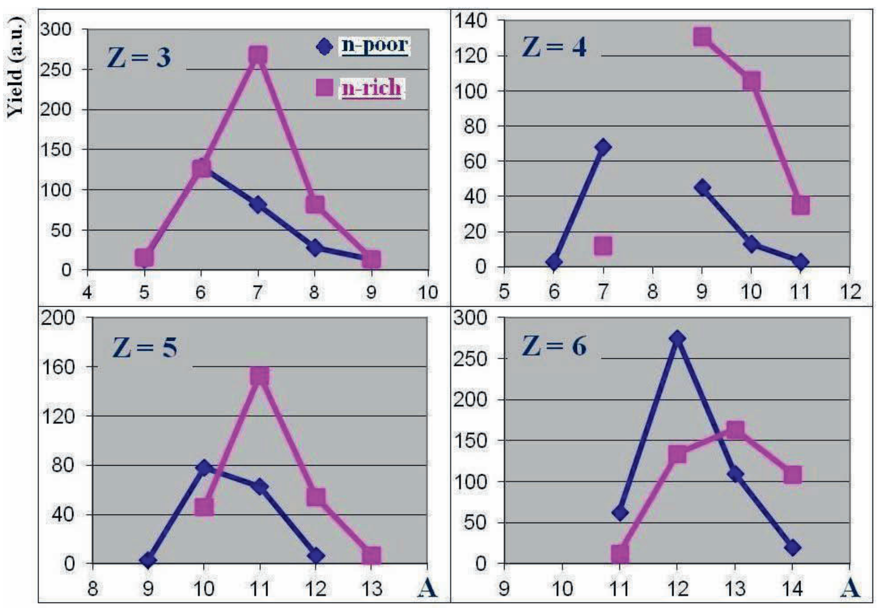

Fig. 4. Mass distributions of fragments with Z = 3, 4, 5, 6 for the two studied systems

By looking at the Figure 5, showing the yields for intermediate mass fragment for both systems, we can see a strong odd-even staggering of the Z yield for Z<10, and this effect persists for higher Z with a smaller amplitude. Besides we note that in the comparison between the two systems with different isospin, the even-odd staggering is more pronounced for the neutron-poor system. It seems also that the influence of the neutron excess is influent on the yields of the light fragments, but we have to wait the extraction of the absolute cross section to confirm this.

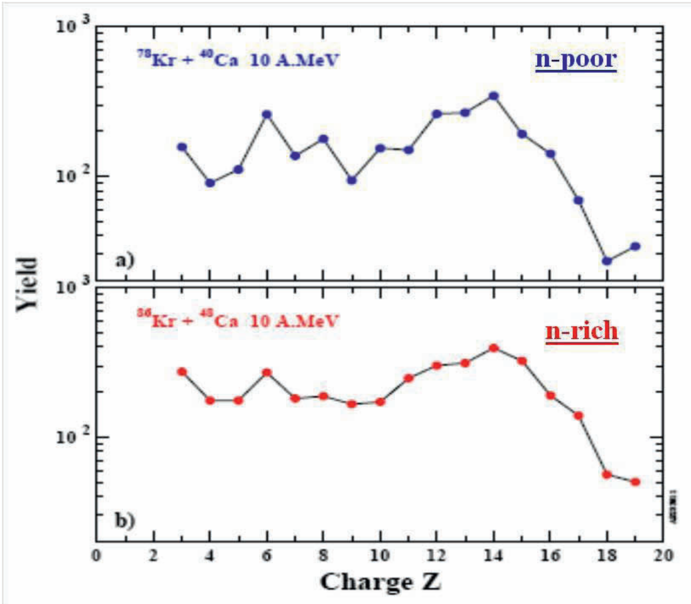

Fig. 5. Charge yield of fragments for the two systems

4 Conclusions and perspectives

The influence of the neutron richness on binary decays was investigated in ^{78,86}Kr+^{40,48}Ca reactions at 10 AMeV incident energy. First results on the experimental features of the fragments were shown, in particular energy in the centre of mass frame and charge and mass distributions at θ=11°-13° were reported and compared for the two system with different isospin degree.

Staggering effects are evident in the Z distributions, as well as different isotopic composition and enrichment for the reaction products in the two systems. Since the excitation energy and the maximum angular momentum stored in the intermediate system are similar in both reactions, the observed effects are probably due to the role of the N/Z degree of freedom on the decay channels.

Absolute cross sections calculations of the reaction products are in progress, and these could provide important indication on the isospin influence on the reaction mechanism and fragments production. Comparisons with theoretical models are in progress and from these we could estimate the influence of structural effects during the disintegration of the system.

References

1. G. Ademard et al., Phys. Rev. C **83**, 054619 (2011)
2. A. Pagano et al., Nucl. Phys. A **734**, 5044 (2004)
3. G. Politi et al., IEEE Nuclear Science Symposium Conference Record N28, 1140 (2006)
4. R. Bassini et al., IEEE Nuclear Science Symposium Conference Record N14, 173 (2006)
5. S. Pirrone et al., Proc. of FUSION11, Saint Malo – France, May 2011, in press.