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Isospin influence on the decay modes of compound nuclei produced in the ^{78,86}Kr + ^{40,48} Ca at 10 MeV/nucleon

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Summary. — The study of the decay modes competition of the compound systems produced in the collisions ^{78}Kr+^{40}Ca and ^{86}Kr+^{48}Ca at 10 MeV/A is presented. In particular, the N/Z entrance channel influence on the decay paths of the compound systems, directly connected to the isospin influence, is investigated. The experiment was performed at the INFN Laboratori Nazionali del Sud (LNS) in Catania by using the 4π multi-detector CHIMERA. Charge, mass, angular distributions and kinematical features of the reaction products were studied. The analysis shows some differences in the contribution arising from the various reaction mechanisms for the neutron-poor and neutron-rich systems.

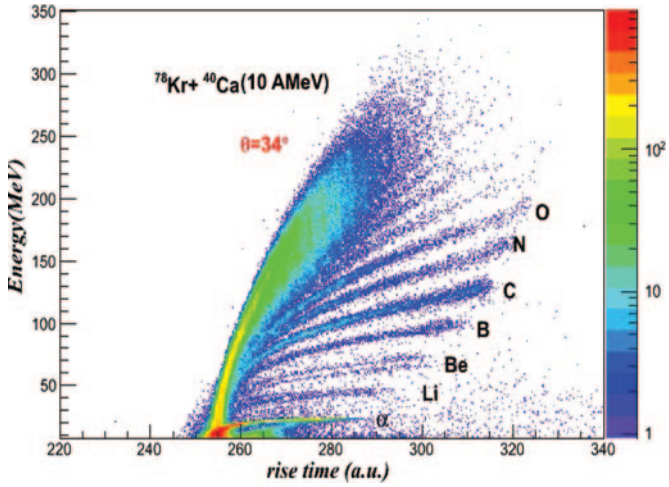

Fig. 1. – Energy-RiseTime plot for ^{78}Kr +^{40} Ca.

1. – Introduction

In this work, we present the up to date results of the ISODEC experiment [1-3], realized to study the competition among the various disintegration modes of ^{118,134}Ba compound nuclei produced in the reactions ^{78}Kr + ^{40}Ca (neutron-poor system) and ^{86}Kr +^{48} Ca (neutron-rich system) at 10 MeV/nucleon. The experiment was performed at the INFN Laboratori Nazionali del Sud (LNS) in Catania by using the 4π CHIMERA detector [4,5] and the beam delivered by the Superconductive Cyclotron. It complements and improves the data obtained at 5.5 MeV/A for ^{78,82}Kr+^{40} Ca reactions [6], previously realized with beams delivered by GANIL facility and by using the INDRA detector.

The two investigated systems are different for 16 neutrons, the maximum difference that we can get by using stable nuclei; this allows to produce compound nuclei with similar both spin distribution and excitation energy in a large domain of N/Z (from 1.11 to 1.39). Indeed, one expects that the N/Z ratio of the compound nucleus, plays an important role on its decay evaporation-process, providing crucial information on fundamental nuclear parameters as the level density, the fission barrier and the nuclear viscosity. Such a set of data also will provide new constraint on sophisticated models attempting to describe statistical and/or dynamical properties [7] of excited nuclei.

2. – Experimental set-up

In the experiment the key observables are the cross section, multiplicity, angular and kinetic energy distribution of the various reaction products (Intermediate Mass Fragments - IMFs, Light Charge Particles - LCPs, Evaporation Residues - ER, and Fission Fragments FF).

The CHIMERA [5, 8] array allows to us to detect the reaction products with a good isotopic resolution, a low energy threshold for LCPs and IMFs, a high angular resolution and a broad angular acceptance.

CHIMERA consists of 1192 detector telescopes, arranged on 9 rings in the forward part, that cover a polar angle from 1 to 30, and 17 rings in spherical configuration, that cover from 30 to 176. The geometrical efficiency is the 94%. In fig. 1 is reported as an

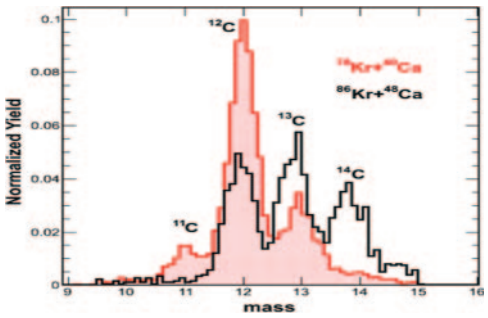

Fig. 2. – Carbon isotopes distributions at 15° for the two systems.

example the Energy (E_{Si}) *vs.* Rise Time (RT_{Si}) plot obtained by the PSD methods in Silicon detector, for the neutron poor system ^{78}Kr+^{40}Ca at 10 MeV/nucleon at $\theta = 34°$. Identification energy threshold of about 4.5 MeV/nucleon was obtained.

These characteristics allowed the complete identification of LCP in a wide energy range, the complete identification in charge and mass of the IMF ($3 \leq Z \leq 8$) products, the charge identification up to $Z = 14$–17 for fragments stopped in the silicon, and up to about $Z = 30$ for the most energetic particles stopped in CsI(Tl).

In particular, in fig. 2 is reported an example of isotopic identification for carbon isotopes is obtained at polar angle of 15° for the two systems [9].

3. – Experimental results

The influence of the isospin on the reaction mechanism and on the fragments production should appear in the charge distribution.

A comparison between the fragments yields as a function of their charge for the studied systems is presented in fig. 3. The IMF cross section behaviour exhibits for both systems a strong even-odd effect, the staggering, due to a preferential production of fragments with even value of the atomic number. In agreement with other examples in literature [6, 10, 11] the staggering is more pronounced for the neutron-poor system respect to the neutron-rich one, in particular for $Z \leq 10$ reaction products as it is shown in fig. 3. This effect persists for higher Z, but with a smaller amplitude.

It seems that the neutron excess in the entrance channel affects the yields of the light

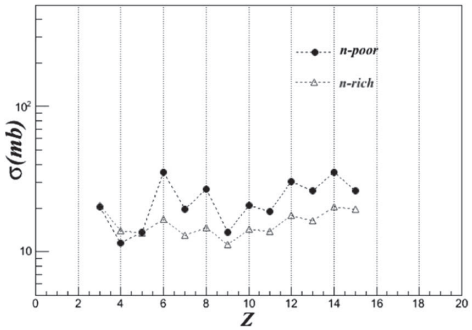

Fig. 3. – IMF Charge distributions.

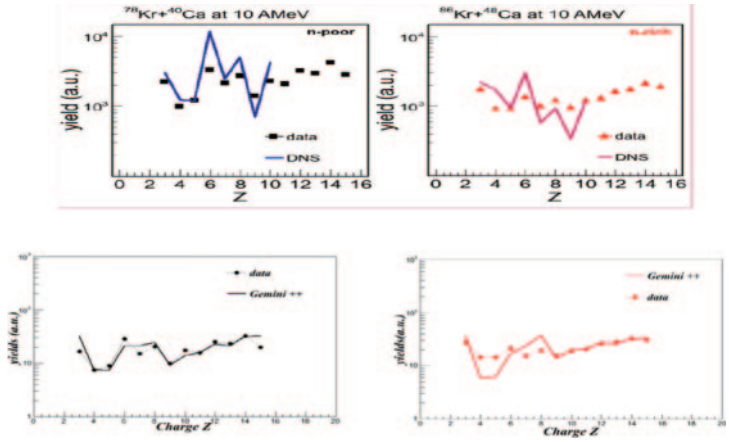

Fig. 4. – Top, comparison with DSN model; Bottom, comparison with GEMINI++ model.

fragments. An Influence can be originated also by structure effects [12] linked to the pairing forces, and it could be connected with the Symmetry Energy.

The charge distributions of the two systems were compared to the preliminary results of model calculations. In order to understand the origin of the different behaviour, we performed calculations with the dynamical DNS (DiNuclear System) model for $Z \leq 10$, and with the GEMINI ++ code, a Montecarlo Code basing on a recent statistical model, for Z up to 16.

Following the dynamical DNS (DiNuclear System) model, a dinuclear system is formed in the beginning of the reaction, that can go towards a not fully equilibrated fast-fission or towards an equilibrated fissioning compound nucleus. A detailed description of the model can be found in [13].

The simulation of GEMINI++ code reproduces the decay of the compound nucleus following the formalism of the Hauser-Feshbach [14], taking in account the probability of asymmetric fission obtained by L. Moretto in an extension of the transitional state model [15, 16]. The results of these comparisons are reported in fig. 4.

The calculations seem to be in a slightly better agreement in the case of the neutron-poor system in both cases. This behaviour could be the indication that the neutron enrichment could favour new mechanism in the production of intermediate mass fragments, not considered in the used models, neither dynamics or statistical.

In both systems, for higher Z, the oscillation of the staggering of the yields is decreasing as the atomic number increases in agreement with the experimental findings.

In order to investigate about the global features of the reactions complete events were selected by imposing the conditions of total detected mass $M_{tot} > 90$ and total momentum $P_{tot} > 0.7 P_{beam}$ [1,2]. By looking at the plot of the mass versus the parallel velocity for each reaction product, reported in fig. 5, we can extract qualitative information about the competition among the different decay channels. In fact in this plot the different reaction products, coming by the Fusion-Fission and Quasi-Fission decay process or by Evaporation Residues one, can be easily localized. The results show that the ER/FF ratio is higher for the neutron poor system compared to neutron rich one.

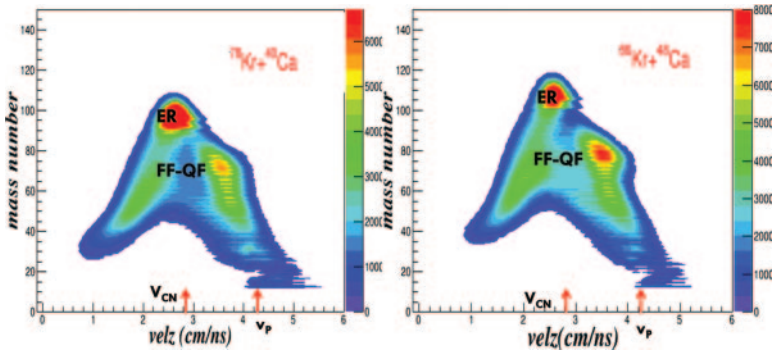

Fig. 5. – Mass *vs.* parallel velocity for the two systems.

4. – Conclusions

Results of the study of the ^{78}Kr$+^{40}$Ca and ^{86}Kr$+^{48}$Ca reactions at 10 MeV/nucleon incident energy are presented. Staggering effects are evident in the IMF charge distributions, as well as different isotopic composition and neutron enrichment for the reaction products in the two systems. Global features analys show differences between the two systems in the contribution arising from the various reaction mechanisms like fusion-fission, quasi-fission and fusion- evaporation.

The observed effects could be due to the role of the N/Z degree of freedom on the decay channels. Data analysis and more refined comparisons with theoretical models are in progress. A Letter of Intent has been presented for an experiment at the radioactive ion beam facility SPES at INFN-LNL, with $^{88-94}$Kr $+^{40,48}$ Ca at 10 Mev/A, in order to study these effects in higher N/Z systems and further improve the knowledge in this field.

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