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Isospin influence on the decay modes of the systems produced in the ^{78,86}Kr $+^{40,48}$ Ca reactions at 10 AMeV

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Abstract

The results of the analysis of the reactions $^{78,86}Kr +^{40,48} Ca$ at 10 AMeV are presented. The experiment was performed at the INFN Laboratori Nazionali del Sud (LNS) in Catania by using the 4π multidetector CHIMERA, with beams delivered by the Superconductive Cyclotron. The competition among the various disintegration paths and in particular the isospin effects on the decay modes of the produced composite systems are investigated; this provides information about fundamental nuclear quantities such as level density, fission barrier and viscosity. Different isotopic composition and relative richness are observed among the reaction products of the two systems. An odd-even staggering effect is present in the charge distributions, in particular for the light fragments produced by the neutron-poor system. The kinematical characteristics of the IMF seem to indicate a high degree of the relaxation of the formed system. Besides, global features analysis seems to show some differences in the contribution arising from the various reaction mechanisms for the two reactions.

1 Introduction

Nuclear reactions between medium-mass nuclei at low energy domain are characterized by the competition between binary processes and compound nucleus de-excitations. The isospin plays a crucial role in the competition between these decay channels, thus novel information on fundamental nuclear quantities such as level density, fission barrier and viscosity could be extracted across the long isotopic chains of compound nuclei, extending from the neutron-rich to neutron-poor side. The neutron richness influence on the formation and decay modes of compound nuclei ^{118}Ba and ^{134}Ba, produced respectively in the $^{78}Kr +^{40} Ca$ and $^{86}Kr +^{48} Ca$ reactions at 10 AMeV are investigated [1, 2]. The experiment was performed by using the 4π multidetector, for charge particles, CHIMERA [3], allowing precise measurements of velocity, angular distributions and a good identification [4] of the reaction products with low energy thresholds.

2 Experimental results

2.1 Fission Fragments characteristics

The decay modes populate the whole mass/charge domain from evaporated light charged particles (LCP) up to the Evaporation Residues (ER) with the symmetric Fission Fragments (FF) and the Intermediate Mass Fragments (IMF) in between. The IMF cross section production exhibits for both systems a strong even-odd effect, the staggering, due to a preferential production of fragments with an even value of the atomic number. In agreement with other examples in literature [5–7] the staggering is more pronounced for the n-poor system respect to the n-rich one, in particular for Z<10 reaction products as it is shown in fig. 1. This effect persists for higher Z, but with a smaller amplitude.

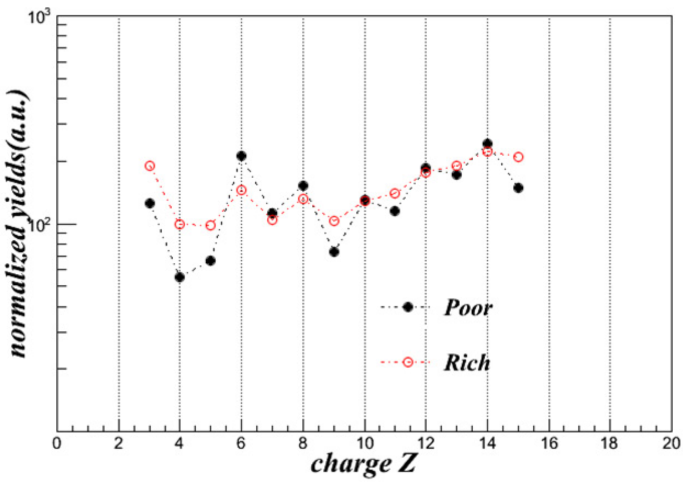

Figure 1: IMF Charge distributions, in red for the $^{86}Kr +^{48} Ca$ reaction, in black for the $^{78}Kr +^{40} Ca$ reaction (color on line)

The analysis of the kinematical features of the IMF indicates a high relaxation of the degrees of freedom, suggesting a production via a long lived system. In fact the mean values of the velocity of the IMF in the center of mass frame (left hand panel of figure 2), that are independent of the emission angle, show a quasilinear decrease increasing the atomic number and they are well reproduced by the values predicted by the systematic of Viola, with the Hinde's correction for the asymmetric fission [8]. Besides the angular distributions of the IMF and the other FFs, in the center of mass frame, follow a $1/sin\theta_{c.m.}$ behavior as it is shown in right hand panel of the figure 2.

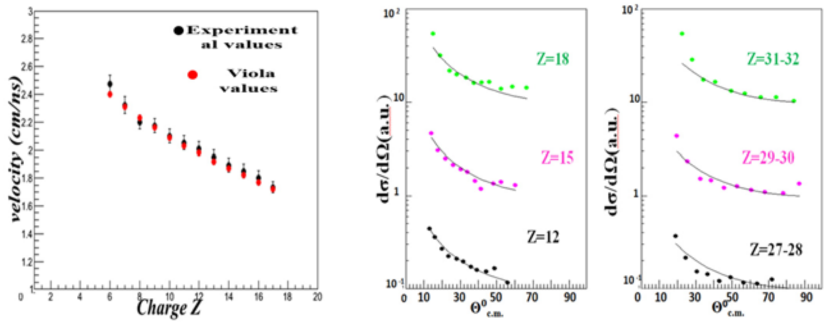

Figure 2: For the $^{78}Kr + ^{40}Ca$ reaction. Comparison of the mean values of the velocity, averaged over all angles, with the values of Viola (Left). FFs angular distributions, in the center of mass frame, the solid line is $1/sin\theta_{c.m.}$ (Right) (color on line)

2.2 Evaporation Residues features

In the figure 3 are reported the angular distributions of the heavier reaction products in the laboratory frame; these distributions are very strongly forward peaked, as it is expected for the evaporation residues. Besides the extracted centroids of the velocity spectra at each angle θ, in the laboratory frame, lie along the solid line, that represents the velocity of the Compound Nucleus (CN) multiplied by the $cos\theta$. This is a signal that these products have the same velocity of the Compound Nucleus.

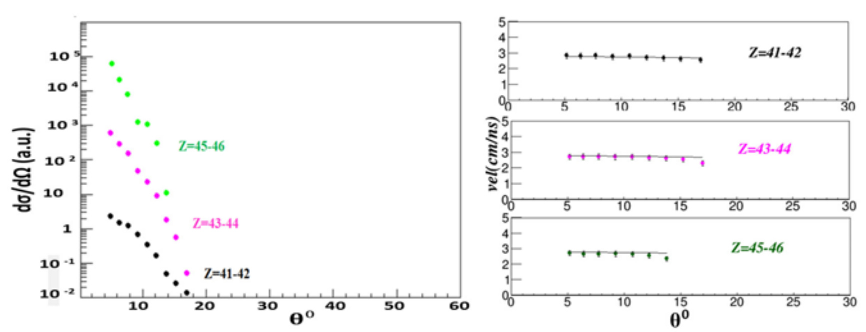

Figure 3: Left hand panel: the angular distributions in the laboratory frame for ER. Right hand panel: values of the mean velocity in the laboratory frame for Er at different angles θ.

2.3 Global decay patterns

Complete events are selected by imposing the conditions: detected mass $M_{tot} > 90$ and momentum $P_{tot} > 0.7P_{beam}$. By looking at the plot mass versus parallel velocity for each reaction product, shown in fig 4, some qualitative information about the competition among the different decay channels could be extracted. In fact in this plot the different reaction products, fragments coming from the Fusion-Fission and Quasi-Fission or Evaporation Residues, can be easily localized. The analysis shows that the ER/FF ratio is higher for the n-poor system compared to n-rich one.

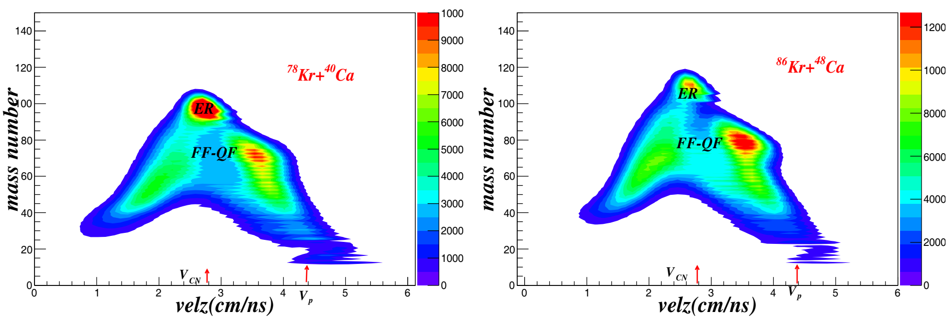

Figure 4: mass vs parallel velocity plot for the n-poor system (Left) and for the n-rich one (Right)

3 Conclusions

Some results of the analysis of the reactions $^{78}Kr+^{40}Ca$ and $^{86}Kr+^{48}Ca$ at 10 AMeV are presented. The exit channel retains some memories of the entrance channel, in fact the reaction products are neutron richer in the reaction $^{86}Kr+^{48}Ca$ [9]. As a consequence, deep differences in the isotopic composition and relative abundance in the production cross sections of the fragments produced are observed. An even-odd staggering effect is observed in the IMF charge distributions and it is stronger for the n-poor system. The angular distributions and the features of the velocity of the IMF suggest a high degree of relaxation of the degrees of freedom of the system formed in the collisions before the breakup, as in a typical fusion-fission like reaction mechanism. The analysis of the kinematical characteristics of the ER suggests that these products have the same velocity of the CN. The analysis of global features seems to show differences in the contribution arising from the various reaction mechanisms like fusion-fission, quasi-fission and fusion-evaporation. Data analysis are in progress. Important information could be obtained from the study of the LCP-FF, LCP-IMF and LCP-ER coincidences. To confirm the preliminary qualitative results, it is necessary to complete the calculations of the cross sections. Precise comparisons with statistical and dynamical models are necessary to provide indications of the isospin influence on the competition between different decays modes of the Compound Nuclei. In order to study the evolution, with isospin asymmetry, of the reaction dynamics and to investigate the interplay between the nuclear structure and reaction mechanism a LOI was presented at the "Second SPES International Workshop at INFN-LNL" to study the reactions: $^{92}Kr +^{40,48} Ca$ at 10 AMeV by using neutron rich radioactive beams.

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