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Dependence from the Isospin of the entrance channel in Projectile-like (PLF) break-up at Fermi energies

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Summary. — The reactions ^{124}Xe + ^{64}Zn and ^{64}Ni at 35 *A* MeV beam incident energy (InKiIsSy, Inverse Kinematic Isobaric System) were studied at INFN-LNS with the 4π CHIMERA detector and compared to results of previous studied reactions ^{124,112}Sn + ^{64,58}Ni. The Intermediate Mass Fragments (IMF) production probability and emission mechanism in the projectile-like fragments (PLF) fission were studied by using, as main observable, the angle between the center of mass velocity of the kinematical reconstructed PLF* respect to the relative velocity of the PLF* break-up fragments. We show that prompt-dynamical emission is enhanced by increasing the projectile and target Isospin content in the entrance channel. It is found that the dynamical emission increases, separately, at the increasing of the projectile and target isospin respectively. Experimental results are compared within the framework of the Constrained Molecular Dynamic code.

1. – Introduction

In semi-peripheral collisions at Fermi energies the reaction scenario is dominated by the production of an excited projectile-like (PLF) and target-like (TLF) fragments. An important cross-section is associated with the detection, together with the PLF and TLF residues of Intermediate Mass Fragments (IMF), i.e. with fragments having an

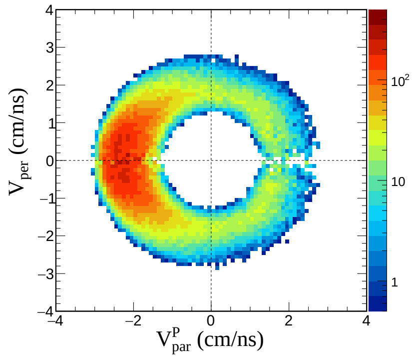

Fig. 1. – Galilean invariant cross-section for the light fragment in the binary splitting of a PLF in the reference frame of the reconstructed PLF source for the reaction ^{124}Xe + ^{64}Ni and for mass asymmetry between the two fragments of $2.6 < A_H/A_L < 4.6$.

atomic number Z ranging between 3 and 20. A remarkable aspect of IMFs and light particles emission mechanism is the fact that they are produced from shortest times (pre-equilibrium, prompt neck rupture emission) to longer time-scales (sequential decay), along the dynamical path of the reaction [1]. Of particular interest is the case where the IMF is originated by the break-up or fission of a shape deformed and rotating projectile-like remnants. In this last case two PLF break-up mechanisms mainly contribute to the process [2]: i) an equilibrated fission where the two fission-like fragments are isotropic in the PLF reference frame. ii) an aligned break-up with the recoil velocity of the PLF residue, indicating a dynamical (fast) binary break-up (dynamical fission).

Dynamical fission is sensitive to the entrance channel isospin: in fact in Ref. [3], by comparing the two reactions $^{124}Sn +^{64} Ni$ and $^{112}Sn +^{58} Ni$ reaction at 35 A MeV, it was shown that as a function of the IMF's atomic number the equilibrated break-up presents the same cross section for the two systems while the dynamical splitting has a greater cross section for the neutron rich system. A new experiment studying the reactions ^{124}Xe + ^{64}Zn and ^{64}Ni at 35 A MeV beam incident energy was conducted at INFN-LNS with the 4π CHIMERA detector and compared to results of previous studied reactions. By using isobaric systems, any mass effect on fission dynamics is ruled out and the observed phenomena is attributed to the different N/Z ratio (Isospin) of the entrance channel. Details of the experimental setup and analysis methods are presented in a incoming paper [4]. In the following, we shall focus on the main results and a first comparison of the data within the framework of the constrained molecular dynamics (CoMD-III) model.

2. – Results

Events were selected by requiring that the IMF multiplicity of detected M_{IMF} is strictly equal to one (apart the PLF and TLF residues) and rejecting events in which IMFs originates from the TLFs fragmentation or decay. For the pair of fragments PLF-IMF with masses respectively A_H and A_L satisfying this scenario we construct the Galilean invariant cross section for the lighter fragment (IMF,A_L) in the reference frame of the projectile-like reconstructed source. Fig. 1 shows this plot in the reaction ^{124}Xe+^{64}N for $2.6 < A_H/A_L < 4.6$. This last condition selects a mass asymmetric binary splitting. Fig.

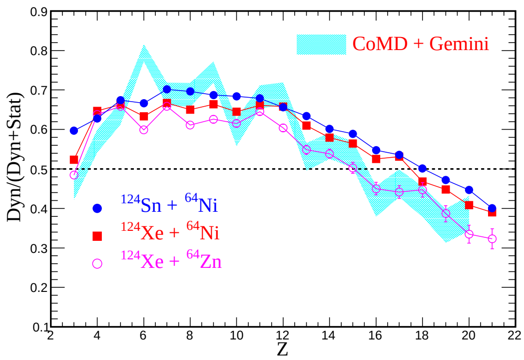

Fig. 2. – Ratio of the dynamical component vs. the total (statistical+dynamical) as a function of the IMF atomic number Z for three isobaric systems. The hashed cyan area indicates results of a CoMD+GEMINI simulation (see text) for the ^{124}Xe + ^{64}Ni system.

1 well illustrate the main characteristic of the PLF asymmetric binary break-up: in fact we clearly observe a forward-backward emission asymmetry superimposed to an isotropic emission all along the Coulomb rings as expected for a statistical decay or equilibrated fission. In the dynamical fission process the light fragment is prevalently emitted in a aligned configuration in the backward direction with respect the heavier fragment [3, 5]. For this reasons, in order to estimate the probability between statistical and dynamical IMFs emission as a function of the IMF atomic number we use, as main observable, the angle $\cos(\theta_{prox})$ between the center of mass velocity of the kinematical reconstructed PLF respect to the relative velocity of the PLF break-up fragments [3].

The $\cos(\theta_{prox})$ angular distribution is expected to be symmetric with respect $\cos(\theta_{prox})$ =0 for a statistical PLF decay. On the contrary the aligned backward emission characteristic of a dynamical break-up will present an angular distribution with a prominent peak at $\cos(\theta_{prox}) \approx 1$. This angle, often referred as $\cos(\alpha)$, can be also used as a “chronometer” in order to study the rotation of the binary fissioning system [6] as a function of the N/Z of the break-up fragments [7, 8, 5]. In our analysis it is used to evaluate the dynamical component as a function of the IMF’s atomic number, subtracting from the total $\cos(\theta_{prox})$ distribution, the portion of angular distribution that is symmetric around $\cos(\theta_{prox}) = 0$. The ratio of the dynamical component respect to dynamical+statistical one as a function of the IMFs atomic number is presented in Fig. 2 for the three isobaric systems ^{124}Xe + ^{64}Ni, ^{124}Xe + ^{64}Zn and ^{124}Sn + ^{64}Ni. It is clearly seen that the IMFs dynamical emission probability increases with the N/Z of the system and also it increases just changing the N/Z of the target from ^{64}Zn to the more neutron rich ^{64}Ni. This is better seen in Fig. 3 where the average dynamical fraction for $6 \leq Z \leq 18$ is plotted as a function of a empirically weighted N/Z content of the systems $(1 \times (N/Z)_{proj} + 2 \times (N/Z)_{targ})/3$. The linear correlation shows that the dynamical emission probability, given a heavy projectile on a lighter target, is twice sensitive to a variation of the N/Z of the target with respect to the one of the projectile.

These results are an important benchmark for microscopic transport models. Fig. 2 we present as a dashed area a comparison of the experimental data for the reaction $^{124}Xe+^{64}Ni$ with a calculation within the frame of the constrained molecular dynamics, CoMD-III code [9]. The $^{124}Xe+^{64}Ni$ reaction at 35 A MeV is simulated up to 600 fm/c. After this reaction time, the secondary decay of fragments is followed by using

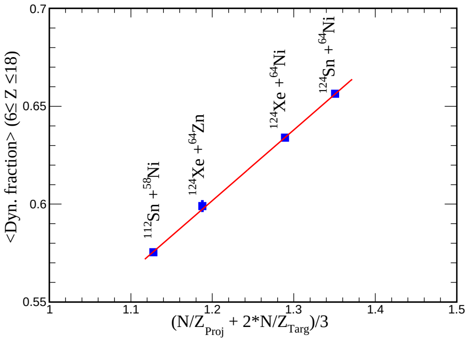

Fig. 3. – For $6 \le Z \le 18$ the dynamical emission probability is plotted as a function of the weighted mean $(1 \times (N/Z)_{proj} + 2 \times (N/Z)_{targ})/3$ for the studied systems.

the GEMINI code. The data are analysed as the experimental ones, and the fraction of dynamical emitted IMFs is calculated as a function of the IMFs atomic number. Data were filtered by the detector geometry. The preliminary comparison between data and calculation seems very promising. It is interesting to note that the CoMD model gives also the possibility to vary the isospin-dependent part of the interaction in order to provide different parametrizations of the symmetry energy component of the EOS [10, 5, 11].

3. – Summary

We studied the isobaric systems ^{124}Xe + ^{64}Zn and ^{64}Ni at 35 *A* MeV beam incident energy and compared them to previous studied reactions ^{124,112}Sn + ^{64,58}Ni. We find that prompt-dynamical emission is enhanced by increasing the projectile and target Isospin content in the entrance channel. The dynamical emission increases, separately, at the increasing of the projectile and target isospin respectively. A systematic comparison of data with the CoMD model was started in order to deeply understand the mechanisms behind this isospin effects and the role of the symmetry energy of Nuclear Equation of State in the IMFs prompt-dynamical emission. In 2019 we shall extend these studies at lower beam incident energy in the transition energy region from Coulomb to Fermi energies around 20 *A* MeV with stable beams (experiment "CHIFAR"), by using the CHIMERA array coupled with 10 modules of the FARCOS correlator [12]

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