Isotope analysis in central heavy ion collisions at intermediate energies

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Heavy-ion collisions can be considered a powerful tool to explore the nuclear equation of state (EOS) of nuclear matter under laboratory controlled conditions. With the growing availability of radioactive beam facilities, the influence of the isospin degree of freedom on nuclear structure and reaction mechanisms is being extensively explored. One of its goals is to have a better knowledge of the symmetry term of the nuclear equation of state. In particular, stable and radioactive beams over a wide range of N/Z asymmetries allow to explore the asymmetric nuclear EOS and the density dependence of the symmetry energy term. These studies are further stimulated by the fact that the symmetry energy and its density dependence determines several properties of neutron stars as well as features of exotic nuclear systems as neutron halo nuclei.

According to statistical and dynamical models the isotopic composition of fragments emitted in multi-fragmentation phenomena observed in central heavy-ion collisions at intermediate energies should be sensitive to the density dependence of the symmetry term and therefore can provide information on the symmetry energy at low density. Indeed, in these reactions complex fragments are expected to be formed at sub-saturation densities ($\rho \sim 0.1\text{-}0.5\rho_0$) and temperatures T=3-5 MeV.

The study of the production yields of isotopically resolved nuclear particles and fragments can complete the knowledge of the EOS, by providing information on the N/Z degree of freedom, and are essential in searching for possible occurrence of critical phenomena generated by fluctuations in the proton concentration of asymmetric nuclear matter.

We present two different sets of data collected with 4 π detectors at LNS and LNL. In particular $^{124}Sn+^{64}Ni$ and $^{112}Sn+^{58}Ni$ reactions at 35 A MeV incident energy were studied by using the 688 Si–CsI telescopes of the forward part ($1^\circ<\theta_{lab}<30^\circ$) of CHIMERA multi-detector at Laboratori Nazionali del Sud [1]. The most central collisions were selected by means of a multidimensional analysis of the experimental observables. An "isoscaling analysis" for light isotopes was obtained which permitted to observe a scaling behaviour of the yield ratio of isotopes emitted in two reactions differing only in isospin. This allowed drawing an estimate of the symmetry energy around 18 MeV [2].

Isotope analysis has been performed also for fragments produced in central collisions at lower incident energy. Beams of ^{32}S were accelerated at 14.5 AMeV on ^{58}Ni and ^{64}Ni targets at Laboratori Nazionali di Legnaro. The reaction products were detected with the forward GARFIELD chamber [3] coupled to the Ring Counter [4], an ancillary apparatus, specially designed to measure at small polar angles. The very good mass resolution of the Ring Counter Si-CsI telescopes and the good coverage of the phase space of the whole apparatus enables us to carry out accurate studies of the thermodynamics of excited systems with different isospin content (N/Z) at low energies, corresponding to the opening of the multi-fragmentation mechanism where the hot composite systems formed is expected to enter in the liquid-gas coexistence region [5]. The detected isotopes of light fragments ($3 \leq Z \leq 8$) provide information on break-up temperatures of the emitting sources. Moreover, ratios characterizing relative population of different pairs of isotopes make it possible to extract the relative neutron to proton density for the two reactions, which may provide information on a possible isospin distillation mechanism related to a phenomenon of the liquid–gas phase transition in asymmetric systems.

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