CHARGE AND MASS DISTRIBUTIONS OF IMF'S PRODUCED IN THE INTERACTION OF ^{58,62}NI WITH ^{40,48}CA AT AN INCIDENT ENERGY OF 25 A MEV

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Abstract

Studies of nuclear dynamics and thermodynamics have been performed by the NUCL-EX group with the 4π array CHIMERA at LNS, measuring the systems ^{58,62}Ni on ^{40,48}Ca at 25 AMeV. The production of light charged particles (LCP) and intermediate mass fragments (IMF) are being investigated as they can provide useful information about the properties of hot nuclear matter. A procedure to identify these products in charge and mass has been tuned. The analysis is still in progress, but preliminary comparisons of theoretical calculations to experimental elemental and isotopic spectra, already obtained for selected angular regions corresponding to a few CHIMERA rings, are presented.

1 INTRODUCTION

The existence of different phases for finite nuclear matter has been confirmed by several experimental signals [1]. The systematic investigation of the phase coexistence region, starting from the liquid side up to some AMeV of available energy is one of the aims of NUCL-EX collaboration. These studies will be performed through experiments both at INFN Laboratories in Legnaro (LNL) and Catania (LNS).

The first experiment has been performed at LNS using the CHIMERA apparatus in the final configuration (1192 detection cells) [2], with beams of ^{58,62}Ni at 25 MeV/A accelerated on ^{40,48}Ca target.

Basically, the production of light charged particles (LCP) and intermediate mass fragments (IMF) are being investigated as they can provide useful information about the properties of hot nuclear matter.

In order to identify the reaction products several identification methods are used. The ΔE-E method is applied to identify the charge of particles that punch through the silicon detectors. Moreover, an extension of this method to the high gain codified Silicon signals allows the isotopic identification for fragments with charge $Z\leq 9$ [3]. The mass of the fragments stopped in the silicon detectors can be extracted by using the time of flight technique. Finally, the light charged particles that punch through the silicon detector will be identified applying the pulse shape method to the CsI(Tl) fast and slow components [4].

2 LIGHT FRAGMENT IDENTIFICATION

In order to identify fragments in charge and mass, the ΔE-E method is used. For a particle that punches through the first stage of the telescope, the signal coming from the silicon detector can be used as ΔE signal while the CsI signal is used as residual energy signal.

As described in the procedure introduced in [3], sampling on the ΔE-E scatter plot some points on the lines of well defined isotopes, as ^{1}H, ^{4}He, ^{7}Li, ^{7}Be, ^{11}B, ^{12}C, a set of parameters of a Bethe-Bloch like formula were obtained for each detector so that a minimization routine determines, from the ADC channels, the atomic number and mass of the detected charged products. A one-dimensional mass spectrum (Fig. 1) is thus obtained for each charge with a very good resolution. Beryllium, Boron, Carbon isotopes up to Oxygen and sometimes Fluorine isotopes are clearly separated, as in previous measurements [3]. In addition, also the Hydrogen and Helium isotopes are identified by this procedure, having kept the acquisition thresholds as low as possible.

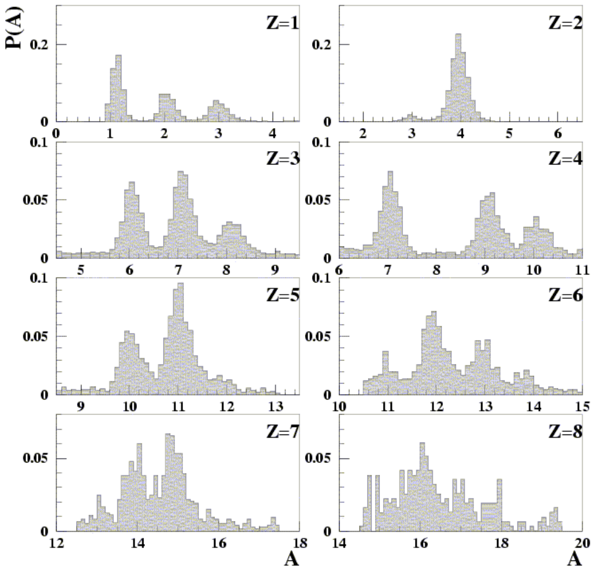

Figure 1 Mass distributions for fragments with 1≤Z≤8 obtained for a detector of the sphere (ring10) for ^{58}Ni+^{48}Ca system at 25 AMeV.

At variance with previous measurements [5], where a particle identification function customised for CHIMERA detectors was used in order to linearize the ΔE-E matrix, the same procedure of mass identification is adopted to obtain the charge identification for all the products that punch through the silicon detector. This is obtained adding to the above mentioned sampled isotopes, some points for the lines Z=10, 15, 20, 25. Even if the whole analysis is in progress, some preliminary comparisons with theoretical predictions can be done using the mass and charge identification obtained for an ensemble of calibrated detectors of 8° and 9° rings.

3 COMPARISONS WITH THEORETICAL CALCULATIONS

On the theoretical ground, calculations were made, for central collision of the two ions, with the Boltzmann Master Equation (BME) Theory [6]. The results obtained for the reaction ^{58}Ni+^{40}Ca are compared with data in Figs. 2 and 3 and show that they reproduce quite reasonably the experimental values. In particular, Fig.2 shows the charge distributions of ejectiles between Helium and Carbon and Fig. 3 their isotopic distributions (up to Z=5) for collisions of ^{58}Ni and ^{40}Ca at 25 A MeV in the angular range 21°– 22°. The large angle fragment emission roughly selects rather central collisions.

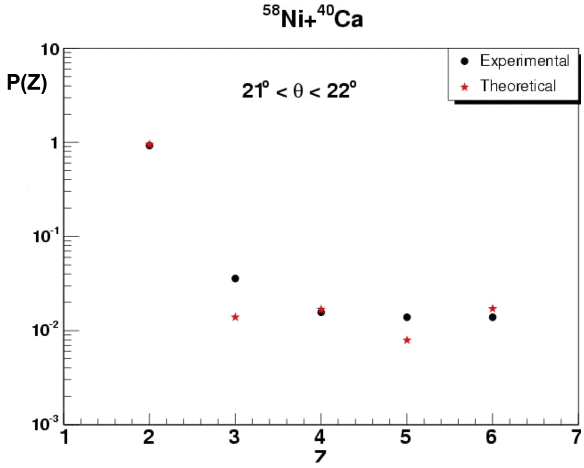

Figure 2 Relative charge distributions of the particles with 2≤Z≤6 emitted between 21° and 22° in the interaction of ^{58}Ni with ^{40}Ca at 25 AMeV. The experimental data are given by black full circles, the predicted values by red stars.

However, the contribution of peripheral collisions to the production of IMF cannot be neglected and calculations are in progress to include these mechanisms. This is made according to a model proposed long time ago by Karol [7], which evaluates the reaction cross section for a nuclear collision within a geometrical approach considering the interactions of individual nucleons of the colliding ions in the overlapping region formed once they come into contact. Since this model, among the approaches which have been proposed to evaluate heavy ion reaction cross sections, seems to be the one that best fits with the formalism underlying BME theory, we did improvements and generalizations in order to apply it to the present measurements.

Present calculations predict the production of charged products with rather high kinetic energies exceeding, in the considered polar range, about 70 MeV in the case of α-particles, 100 MeV in the case of Li and Be, and 150 MeV in the case of B and C. This suggests that the experimental thresholds should slightly affect the measured spectra. Within this model, the IMF's are found to be mainly produced by nucleon coalescence before thermalization, in contrast with the α-particles which are also emitted in the evaporation of hot equilibrated nuclei at the end of the nuclear thermalization phase.

This mechanism of dynamical clustering of IMF's is described in [8] and, as reminded above, allows to very satisfactorily reproduce the low energy component of IMF spectra measured in very asymmetric reactions induced by light ions on medium and heavy nuclei. For this latter case, the measured energetic forward emission of IMF's is described as the contribution of the projectile's break-up [8-9] which could be less relevant for heavier symmetric systems.

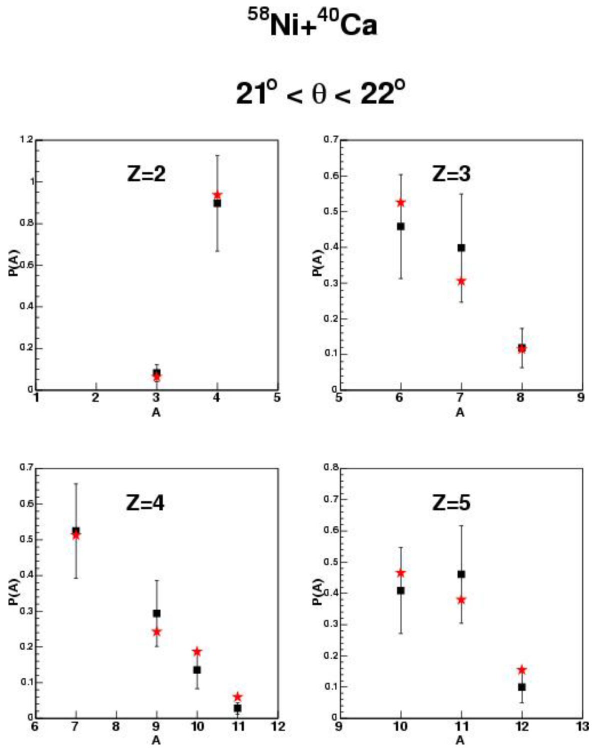

Figure 3 Relative mass distributions for ejectiles with 2≤ Z ≤ 5 emitted between 21º and 22º in the interaction of ^{58}Ni with ^{40}Ca at 25 A MeV. The experimental data are given by full squares, the predicted values by stars.

These coalescence processes could also play a role in the midvelocity emissions in symmetric systems at the Fermi regime [10] and it is also in this perspective that the present study has been undertaken.

Even if present calculations must be considered very preliminary, the results of these comparisons are encouraging.

The analysis is still in progress. For the near future, on the theoretical side, we are studying in order to include mechanisms due to different impact parameters. Concerning the experimental data, we are tuning an accurate selection of the events through refined statistical methods [11], in order to study very specific classes of reactions.

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