Competition between fusion-evaporation and multifragmentation in central collision in $^{58}Ni+^{48}Ca$ reaction at 25 AMeV

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Abstract – The main features of the reaction products in $^{58}Ni+^{48}Ca$ central collisions at $E_{lab}(Ni)$=25 AMeV have been analyzed in order to investigate the competition of different reaction mechanisms. In particular, some global observables and their correlations, able to characterise the pattern of central collisions, have been constructed, in event-by-event mode, in order to disentangle about the competition between residues of fusion-evaporation processes and clusters produced by the decay of a well defined (if any) transient nuclear system undergoing multifragmentation. The description of the method adopted to select central collisions and some new results are presented. The data were collected by using the CHIMERA 4π device.

INTRODUCTION

Heavy Ion collisions in the Fermi energy domain are characterised by the coexistence of the one-body (mean field) and the two-body (nucleon-nucleon) dissipation. In particular, in this paper we explore central collisions where the formation of single highly excited sources are expected. The region of small impact parameter at intermediate energies is of great interest, because it allows to investigate the competition between fusion-evaporation processes, in which an heavy residue is observed in the exit channel as a result of statistical sequential decay process of a compound nucleus, and the so-called multifragmentation prompt decay in several fragments of intermediate masses by a transient unstable system at sub-saturation nuclear density [1].

EXPERIMENT

The experiment was performed at the INFN-Laboratori Nazionali del Sud, with ion beams of ^{58}Ni accelerated at 25 AMeV by the LNS Superconducting Cyclotron against self-supporting ^{48}Ca target, embedded between two carbon foils in order to reduce their oxydation. The emitted fragments were detected by the CHIMERA 4π multidetector [2], consisting of 1192 Silicon-CsI(Tl) telescopes arranged in 26 rings covering 95% of the total solid angle. Events were registered when the Silicon detectors of at least two telescopes were fired. In order to reject incomplete or incorrectly reconstructed events we have chosen to analyze only those events where the total detected charge ranged between the 70% and 105% of the total incoming charge; the same condition was imposed to the total longitudinal momentum (i.e. projection of the total momentum along the beam axis) respect to the linear momentum of the projectile.

EVENT SELECTION METHOD

Since we are interested to central collisions, the first part of the analysis was devoted to the choice of the selection method. A crude selection on the particle multiplicity of charged particles is not able to fully disentangle central collisions from more semi-peripheral ones; a much better

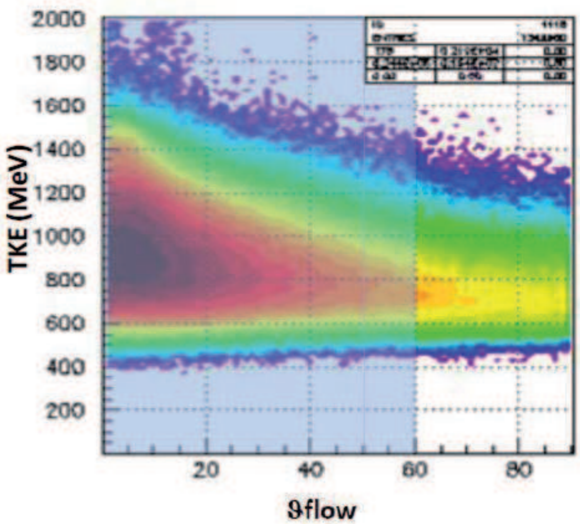

Fig.1 Correlation between ϑ-flow angle and total kinetic energy for all complete events. The obscured zone reflects events that we discard in our analysis.

observable to select central collision is obtained by means of cuts on Total Kinetic Energy (TKE) and ϑ-flow angle correlation [3,4]. Fig.1 shows such a correlation between ϑ-flow angle and the TKE for all the selected events. ϑ-flow gives the orientation of the principal axis of the ellipsoid momentum-tensor with respect to the beam direction. In fig.1 the TKE is calculated as sum of the kinetic energies of all detected particles. The less dissipative collisions are cut-off from our selection of centrality by selecting events having ϑ-flow >60°.

FUSION-EVAPORATION AND MULTIFRAGMENTATION EVENTS

To better characterize these central events we performed a correlation between the longitudinal component (i.e. along the beam axis) of velocity, v_{par}, and the mass for both fragments, which we denote as IMFs (fragments with Z≥3), and light particles emitted. This correlation is shown in fig.2 for the reaction in study.
In this figure we can clearly see an abundant presence of heavy fragments with mass around 60-70 amu and longitudinal velocity close to centre of mass velocity (v_{cm}=3,8 cm/ns). This fragments are good candidates for representing evaporation residues.

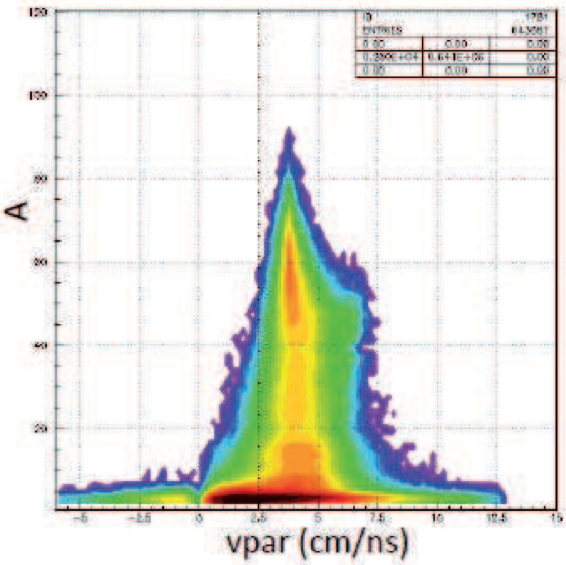

Fig.2 Correlation between the longitudinal component of velocity and mass for charged particles detected in selected central events.

In order to isolate and to elucidate better this contribution to the emission of fragments and to understand the origin of the events characterized by presence of this heavy fragment, in fig.3 the same correlation of fig.2 is shown for the largest fragment present in each event.

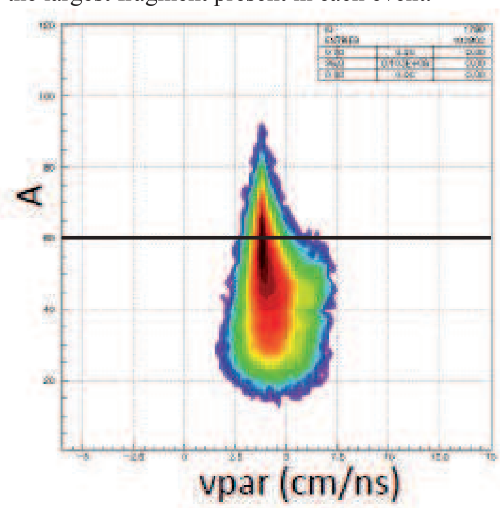

Fig.3 Longitudinal velocity-mass correlation for the biggest fragment emitted in central collisions.

Our analysis shows that the biggest fragment with mass 60 uma or larger is preferentially emitted together with light particles (3-4) and a few lighter fragments. This behaviour can be deduced through the fig.4a-b, where the IMF and light particle multiplicities, M_{IMF} and M_{LP} respectively, are shown for events in the upper part of fig.3, and confirmed in fig4c, where the mass distributions of the three biggest fragments for the same events are reported.

Therefore, we interpret events with such a big residue as formation of an equilibrated compound system of primary mass evaluated around 75-80 amu, which sequentially evaporates light particles.

These events constitute an important contribution of the total selected events, classified as "central collision events''. Quantitative evaluations to quote the associated cross sections are in progress.

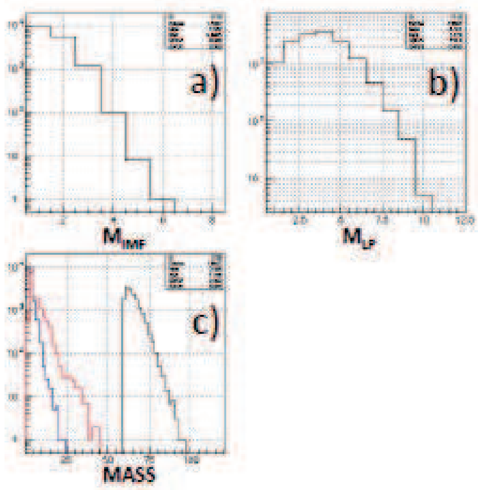

Fig.4: IMF (a) and light particle (b) multiplicity for central events where the biggest fragment has mass larger than 60 amu. c) Mass distributions of the three heaviest fragments emitted in the same events.

Among the events in the lower part of fig.3 (i.e. events where the biggest mass is less than 60 amu), there are candidates for multifragmentation-like phenomena of an highly excited source formed in central collisions. We made a further selection of these events by imposing cuts on high values of fragment multiplicity M_{IMF}.

We notice that, in such events, the probability for the presence of massive fragments is still not vanishing. However, as the multiplicity M_{IMF} is increased, the mass distributions of the three biggest fragments in each event show the characteristic features of typical multifragmentation events with the tendency towards the splitting of the system in fragments with equal masses.

In fig.5 the mass-distributions of these three biggest fragments are reported, for $M_{IMF}>4$. However, further studies are required to sign unambiguously the origin of these fragments. The analysis is in progress.

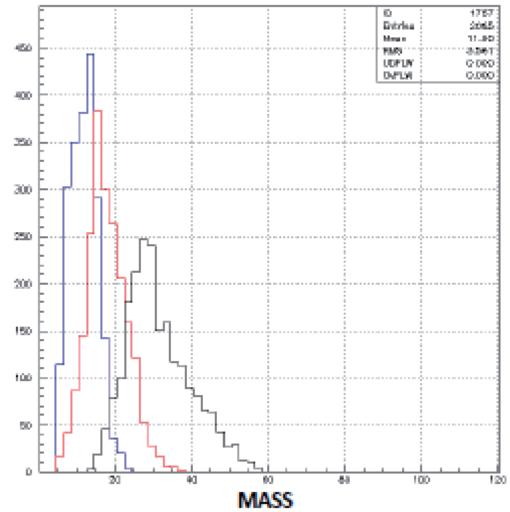

Fig.5: Mass distributions of the three heavier fragments emitted for $M_{IMF}>4$ (see text).

CONCLUSIONS

We report preliminary results about experimental features of fragments produced in central $^{58}Ni+^{48}Ca$ collisions at 25 AMeV, performed at LNS by using 4π CHIMERA multidetector.

The adopted selection method for central collisions is discussed, and different observables and correlations have been analyzed in order to study the competition among different reaction processes. In particular mass and velocity distributions of the emitted fragments and some global variables like multiplicity of IMFs and light particles, theta flow angle, kinetic energy loss, have been analysed in order to characterize the selected events.

Our analysis, still in progress, is mainly devoted to disentangle fusion-evaporation from multifragmentation of sources formed in central collisions.

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