Multifragment production at low incident energies

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INTRODUCTION

The GARFIELD apparatus [1] has been designed and built with the aim of investigating reaction mechanisms in heavy ion collisions at the Tandem-ALPI heavy ion facility of the Laboratori Nazionali di Legnaro.

The aim of the experiment is to characterize the threshold of many-body channels, not well defined at low energy, where nevertheless recent statistical model calculations predict a possible phase transition. In particular, for a first order phase transition, it would be very interesting to investigate the transition from a low excitation energy region, where nuclei can be treated as a liquid, to a region where liquid (large fragments) and gas (small fragments and light particles) coexist.

EXPERIMENTAL SET-UP

The GARFIELD apparatus is a large acceptance detector, mainly composed by three parts to cover different angular regions. In the range from 30^o up to 150^o two drift chambers with microstrip readout [2], followed by CsI(Tl) detectors, allow the identification of fragments and light charged particles using the ΔE-E technique. The angular resolution is about 7.5^o in ϕ and 1^o in θ through the measurement of the electron drift time. The identification threshold is approximately 1 MeV/nucleon.

The forward angles have been covered a three stage annular telescope ($6^o<\theta_{lab}<18^o$), composed by 8 ionization chambers, a 300 μm thick strip silicon detector, and 16 CsI(Tl) crystals.

PHYSICAL MOTIVATIONS

The aim of the experiment is to characterize, at low energy, the onset of many fragment production, in the decay of systems formed in central collisions.

Statistical multifragmentation models predict already at about 1.5-2.5 MeV/nucleon anomalies of the thermostatistical observables such as:

- back-bending of the caloric equation of state $T(\varepsilon^*)$ [3],
- huge increase in the variances of the experimental observables [4,5].
- a negative branch in the heat capacity, where the temperature stays almost constant while additional energy is pumped in the system [6].

It is therefore clear that the search for possible 3-body decays at low excitation energy is relevant.

In multifragmentation models, a non-negligible probability of multiple fragment emission (a value of $P_3/P_2 \approx$ 4% is predicted) is present at about the energy where an S-shaped caloric curve is expected. Early experimental data seem to confirm these predictions [7].

PRELIMINARY RESULTS

The first measurements have been done on $^{32}S+^{58}Ni$ and $^{32}S+^{64}Ni$ systems at 11 MeV/nucleon (available center of mass energy of about 2.5 MeV).

The data reduction started by identifying the charge of the detected particles and fragments. By selecting events where 3 or more fragments are detected at large angles (GARFIELD) and no fragments are detected in the forward region (annular detector) we have multiple fragment emission comparable with theoretical prediction for a source formed in central collisions.

Dynamical model, as CMD (Classical Molecular Dynamics) [8], and statistical models, as SMM (Statistical Multifragmentation Model) [4] and GEMINI [9], show charge distributions in agreement with the experimental ones.

The comparison to CMD predictions for central and peripheral collisions confirms the hypothesis that the constraint of three fragments detected in GARFIELD (large angles) is compatible with a selection of central events.

The first moment of the two charge distributions ($N_c=\int_1^\infty N(Z)dZ$, $N_{frag}=\int_3^\infty N(Z)dZ$, where N(Z) in the charge yield normalized to the total number of events) and the charge distribution itself are rather similar for different de-excitation mechanisms (SMM, GEMINI, CMD); this does not imply however that these distributions are also similar event by event.

Indeed, by studying the correlation among fragment charges (like in the Dalitz plot), one can hope to distinguish the different origin of the fragment production.

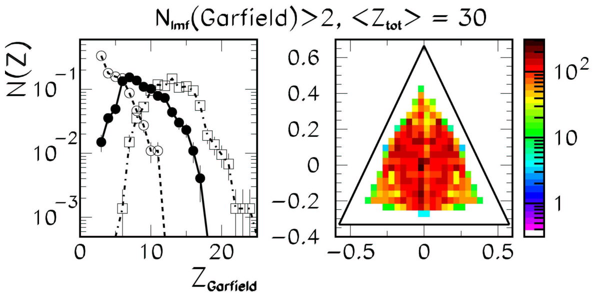

Figure 1. Charge distribution of the 3 largest fragments in each event (left panel) and Dalitz plot (right panel) for experimental data.

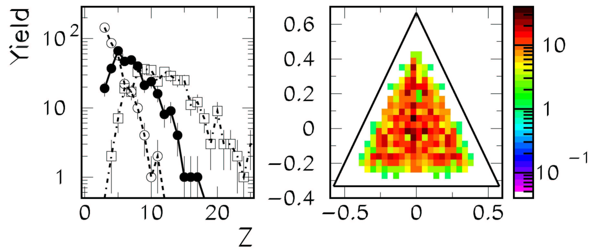

Figure 2. Same as figure 1 but for CMD model.

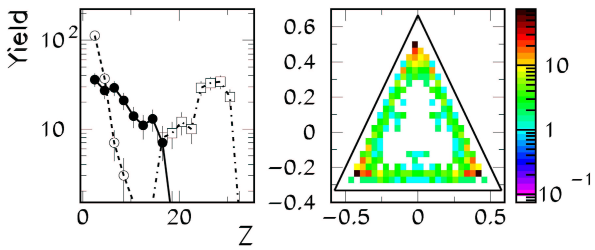

Figure 3. Same as figure 1 but for GEMINI code.

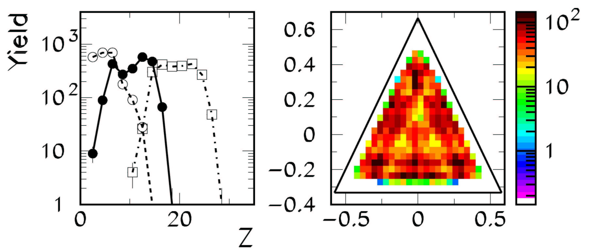

Figure 4. Same as figure 1 but for SMM model.

Three fragments similar in size are experimentally observed and this evidence is supported by the Z distribution of the three fragments where an overlap is clearly present (figure 1 left panel).

The dynamical model predicts the same behaviour, whereas in the statistical sequential model one heavy and two much lighter fragments are predicted. Finally the statistical multifragmentation model seems to be on the right way but the parameters are probably not optimized for such low energies and need a better setting.

A deeper analysis on velocity correlation among fragments has to be performed, to better select the emitting system and to provide an estimate of the average fragment emission time. This analysis is in progress.

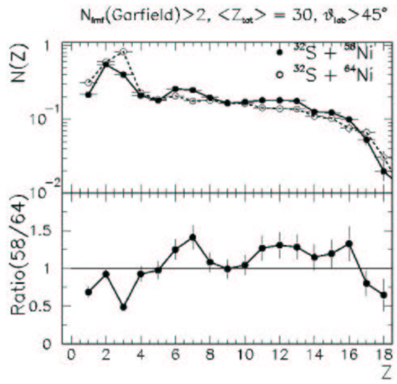

Figure 5. Charge distribution (upper panel) in the reactions $^{32}S+^{58}Ni$ and $^{32}S+^{64}Ni$, for events with at least 3 fragments detected in GARFIELD. Both distributions are normalized to the total number of events. Lower panel shows the ratio of the two charge distributions

Other interesting findings come from the analysis of the data obtained by changing the neutron content of the system. Comparing the charge distributions of ^{32}S +^{58}Ni (N/Z= 1.05) and $^{32}S+^{64}Ni$ (N/Z= 1.18), oscillations larger than statistical errors are evident, highlighted when the ratio between the charge distributions is calculated (figure 5).

This isospin effect could be traced back to the odd-even effect, still observed at higher energies [10] and could be ascribed to the opening/closure of the decay channels, due to the energy conservation constraint on the phase space. Further measurements are scheduled in 2002.

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