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Largest fragment as an order parameter in thermal multifragmentation

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Abstract

The characteristics and behavior of the largest fragments in multifragmentation events originating from the interactions between light-ion projectile and heavy target at GeV energies were studied. It is supposed that the thermal multifragmentation component prevails in such interactions. The CR-39 plastic track detector was used and our experimental setup enabled the event-by-event analysis. The dependence of Z_{max} on atomic number of target and excitation energy was studied. The bimodality in charge asymmetry was also investigated. Our results show that Z_{max} may be used as a relevant order parameter in thermal multifragmentation.

Keywords: Multifragmentation; Heaviest fragment in event; Order parameter

1. Introduction

Since the first experiments with heavy ions were conducted, the size of the largest fragment (Z_{max}) in multifragmentation has been tentatively associated with an order parameter for the fragmentation phase transition. If this is true, we should expect for this observable a double-humped distribution if the transition is the first order (Binder and Landau, 1984), while its fluctuations should obey the first scaling law if the transition is continuous (Botet and Ploszajcak, 2000). Recently, the bimodality in charge asymmetry was observed in heavy-ion nuclear interactions around the Fermi energy and was regarded as a possible signature of a first-order phase transition in the studied systems (Pichon et al., 2005). As a relevant order parameters the charge (Z_{max}) of the largest fragment in decay and charge asymmetry (varsym) between the two heaviest fragments were proposed.

In this work, we examined the characteristics of the largest fragments in multifragmentation events produced in interactions 7 GeV ^{4}He + Ag, 14.6^{4}He + Ag, and 14.6^{4}He + Au. Since in such interactions only single hot source is formed and small angular momentum and compression are involved, it is supposed that we are dealing with thermal multifragmentation. The CR-39 plastic track detector was used in our experiment. The experimental setup enabled event-by-event analysis. As a sorting parameter of events we used Z_{bound} (Z_{bound} is the sum of atomic numbers of all fragments with $Z > 2$ emitted in one event). Z_{bound} is proportional to the impact parameter of the collision. The correlation between charge asymmetry and Z_{bound} was studied and bimodality signal was observed. The Δ-scaling properties of Z_{max} distributions show existence of two regimes: $\Delta \sim 0.5$ for events with large charge asymmetry and $\Delta \sim 1$ for events with small charge asymmetry.

2. Experiment

In our experiment a CR-39 plastic track detector was used in the sandwich technique. The experimental method was similar to the one we used in our previous experiments (Grabez, 1993). The Ag and Au targets were vacuum evaporated on sheets of a CR-39 detector. The free surface of the target was then covered with another CR-39 sheet. In this way the target was sandwiched between the two detector sheets, which enabled detection of the reaction products in 4π geometry. The dimensions of the CR-39 sheets used were $50 \times 50 \times 0.5$ mm. The thicknesses of the Ag and Au targets were 0.5–0.6 mg/cm^2 and were small enough so that the corrections due to the secondary interactions and absorption of reaction products in targets were not necessary. The stacks were irradiated by 7 and 14.6 GeV ^{4}He beams at Synchrophasotron in Dubna. After irradiation the targets were removed by dissolution. The tracks of emitted fragments were etched in a 6.25 N NaOH at 70 °C for 3 h in

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a mechanically stirred bath. Scanning and measurements have been done by one optical microscope. From the measured parameters of the finished tracks, the range (R), mean etch rate ratio (V_T/V_B), and emission angle (θ with respect to the beam direction were determined for each target fragment. From the values of R and V_T/V_B, the atomic number (Z) and energy per nucleon (E/A) were obtained in the usual way (Grabez et al., 1983). The available charge resolution according to the calibration results was $\Delta Z \leqslant 1$ for fragments with $Z < 30$, $\Delta Z \leqslant 2$ for heavier fragments with energy $E/A > 0.5$ MeV, and $\Delta Z \leqslant 4$ for heavy fragments with energy $E/A \leqslant 0.5$ MeV.

3. Results and discussion

Recently, INDRA Collaboration (Tabacaru et al., 2006) reported that a detailed study of the evolution of the average energy versus fragment charge, and of the average sizes of the ordered fragments versus fragment multiplicity shows special behavior of the largest fragment in each event. They examined the average fragment charge as a function of their multiplicity and rank. The results show that only atomic number of the largest fragment (Z_{max}) strongly varies with multiplicity, while the fragments of rank larger than 2 keep almost constant charge values. In Fig. 1 we present the atomic numbers of the ranked fragments for $M=2$ and 3 events from 14.6 GeV ^4He+Ag (Au) interactions as a function of Z_{bound} of the corresponding events. The points present the values averaged over Z_{bound} intervals of 10 or 20 units. It can be seen in the figure that the largest fragment again presents the special behavior. Namely, it can be seen that only Z_{max} is strongly dependent on Z_{bound}; the lighter fragments have almost constant charge numbers. We reported the similar results for target fragments from binary events produced in interaction 1 A GeV Au + Pb (Grabez and Wirth, 1999).

The charge asymmetry between the two heaviest fragments in one event is defined as: varsym$=(Z_{max\,1}-Z_{max\,2})/(Z_{max\,1}+Z_{max\,2})$. Thus varsym is close to 1 for a large asymmetry events

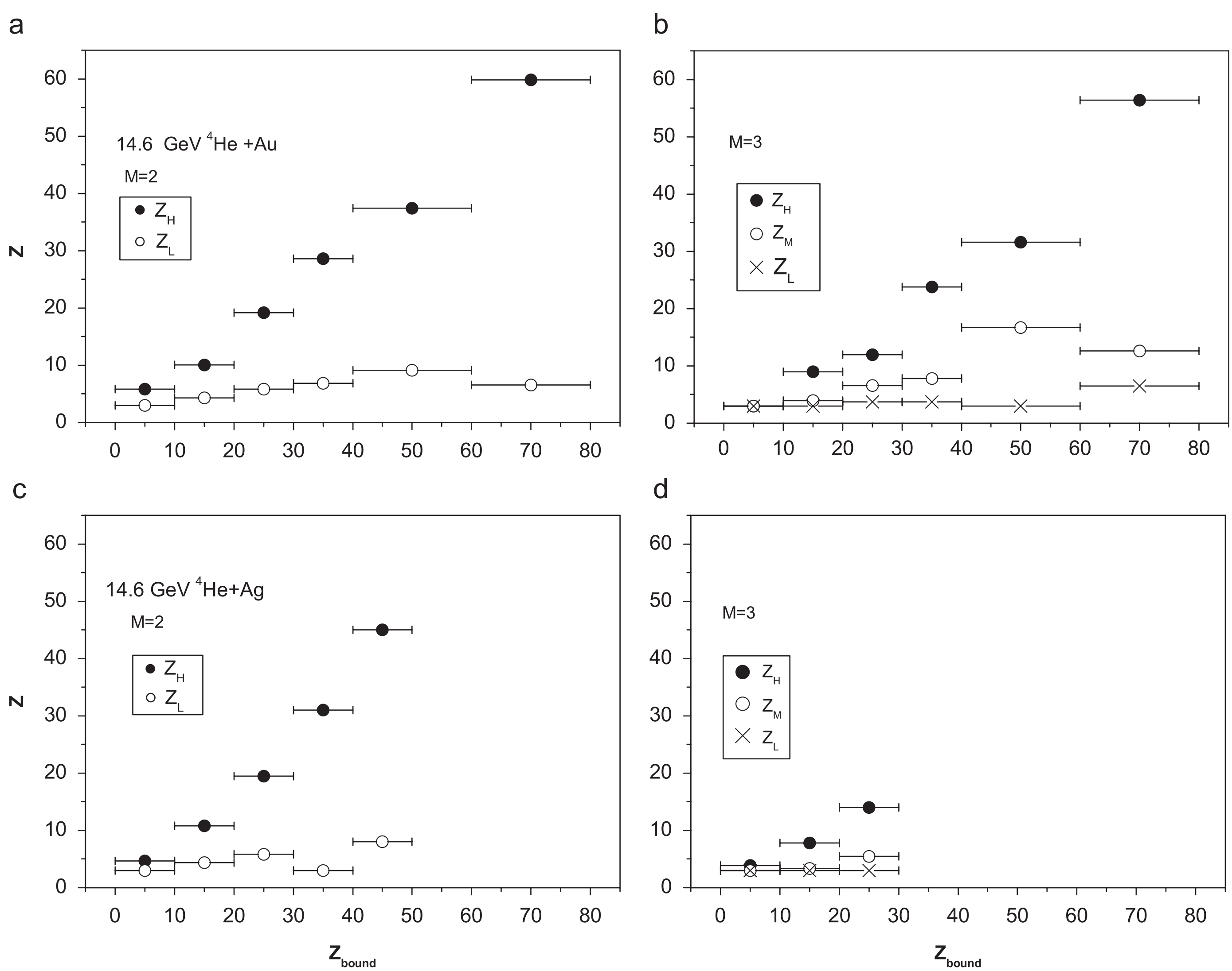

Fig. 1. Atomic numbers of the ranked fragments for $M=2$ and 3 events versus Z_{bound} of the corresponding events. (a) and (b) relates to the Au target, and (c) and (d) to the Ag target.