On the production of deutron-like and proton-like clusters in energetic heavy-ion collisions

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Introduction

The ultimate goal and motivation behind heavy-ion collisions at intermediate energies is to create the hot and dense zone of the nuclear matter. The nucleons which are located in the geometrical overlap of the projectile and target constitute the participant matter whereas non-overlapping nucleons constitute the spectator matter. The participant volume is linked with the production of composite particles [1, 2]. The another reason for the interest in the light particle yields is their connection to the entropy. The multiplicity of the light mass clusters is also found to be an indicator of global stopping in heavy-ion collisions [3]. In the present work, we aim to see how the yields of deuteron-like (d_{like}) and proton-like (p_{like}) behave as a function of participant charge multiplicity and we shall also compare our results with available experimental data. We define the yields of d_{like} and p_{like} (N_p) clusters in the following way [4, 5]:

$$d_{like} = Y(A=2) + \frac{3}{2}Y(A=3) + 3Y(A=4) \quad (1)$$

where Y(A = n) stands for the number of fragments with mass 'n' in one event.

$$p_{like} = \frac{Z_P + Z_T}{A_P + A_T}[Y(A=1) + 2Y(A=2) + 3Y(A=3) + 4Y(A=4)] \quad (2)$$

where $Z_P + Z_T$ and $A_P + A_T$ define the total charge and mass of the colliding system.

The present study is carried out within the framework of the isospin-dependent quantum molecular dynamics (IQMD) model [6].

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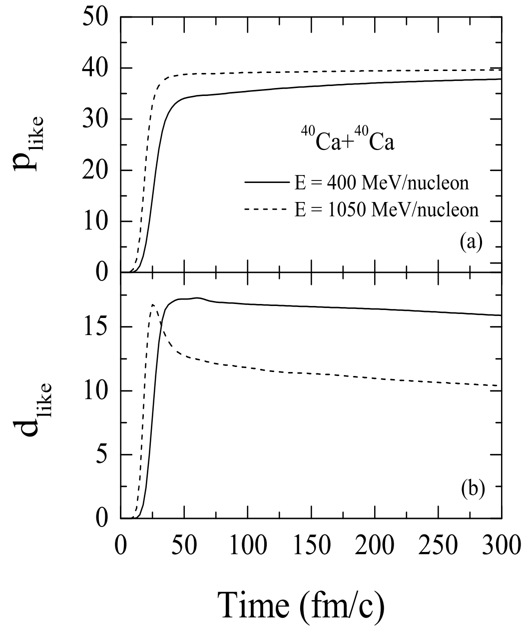

FIG. 1: The preliminary yields of p_{like} (upper panel) and d_{like} (lower panel) clusters obtained during the evolution of central ^{40}Ca $+^{40}$Ca collisions at incident energies of 400 and 1050 MeV/nucleon.

Results and Discussion

We simulated the reactions of ^{40}Ca $+^{40}$Ca (at 400 and 1050 MeV/nucleon) and ^{93}Nb $+^{93}$Nb (at 400 and 650 MeV/nucleon) over the whole range of impact parameter. We, here, used a soft equation of state along with standard isospin- and energy-dependent cross section.

In Fig. 1, we display the time evolution of yields of p_{like} (upper panel) and d_{like} (lower panel) clusters for the reactions of ^{40}Ca $+^{40}$Ca at incident energies of 400 (solid lines) and 1050 MeV/nucleon (dashed lines). One can see that the yields of p_{like} and d_{like} clusters

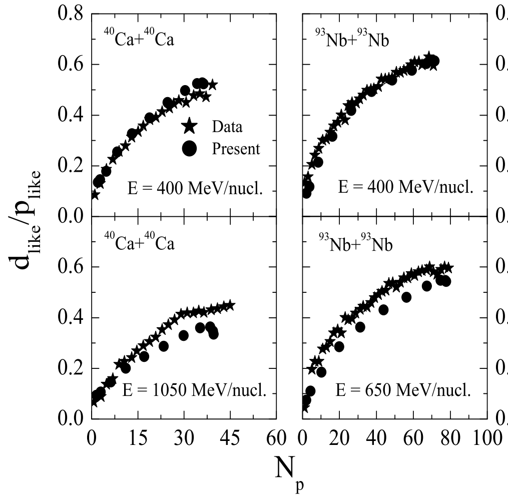

FIG. 2: The d_{like}/p_{like} ratio as a function of baryon charge multiplicity N_p. The preliminary model calculations (solid circles) are compared with experimental data (solid stars) [7]. The results are shown here for the reactions of Ca + Ca (left panels) and Nb + Nb (right panels).

saturate just after the compression (t $\sim$ 40-45 fm/c) irrespective of the incident energy chosen. At this time, the comparison with the experimental data can be made as yields of the composite particles are well settled.

In Fig. 2, we display the ratio of d_{like} to p_{like} clusters as a function of participant proton multiplicity. The results of the Plastic Ball experiments [7] are also displayed for the comparison. The yield ratios are calculated typically after 40 fm/c, when average nucleonic density attains the saturation value and nn collisions practically cease. The d_{like}/p_{like} ratio is found to decrease with increase in the impact parameter (alternately, increases with N_p) pointing towards more production in central collisions compared to peripheral collisions. In Refs. [2, 5, 7], it has also been shown that N_p remains same for nearly central collisions and decrease sharply for semi-central collisions and peripheral collisions. For central impact parameters (or, higher N_p values), the d_{like}/p_{like} ratio reach an asymptotic value indicating that for central events, small variation in the impact parameter does not alter the results. One clearly sees that our model describes well the experimental d_{like}/p_{like} ratio which is found to increase with N_p.

Acknowledgments

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References

[1] P. J. Siemens and J. I. Kapsutra, Phys. Rev. Lett. **43**, 1486 (1979).

[2] J. Aichelin and E. A. Remler, Phys. Rev. C **35**, 1291 (1987).

[3] J. K. Dhawan *et al.*, Phys. Rev. C **74**, 057901 (2006).

[4] Y. K. Vermani and R. K. Puri, Nucl. Phys. A **847**, 243 (2010).

[5] G. Peilert, H. Stöcker, W. Greiner, A. Rosenhauer, A. Bohnet, and J. Aichelin, Phys. Rev. C **39**, 1402 (1989).

[6] C. Hartnack *et al.*, Eur. Phys. J. A **1**, 151 (1998); S. Gautam *et al.*, Phys. Rev. C **86**, 034607 (2012); S. Kaur and R. K. Puri, Phys. Rev. C **87**, 014620 (2013); R. Bansal *et al.*, Phys. Rev. C **87**, 061602(R) (2013).

[7] K. G. R. Doss, *et al.*, Phys. Rev. C **32**, 116 (1985).