On the study of fragmentation of loosely bound nuclei using dynamical model

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Introduction

The topic of halo nuclei represents a paradigm shift in the study of nuclear structure and reactions. Due to the interesting aspects involved in this topic, this is still regarded as a 'hot' topic almost 30 years after their discovery. Over the years, a large number of efforts have been performed both experimentally and theoretically to explore various aspects of the behavior of halo nuclei [1]. On one hand, the structural properties such as binding energy, radii etc. of halo nuclei are examined extensively. On the other hand, the effect of halo structure on nuclear reactions are also explored. For example, in Ref. [2] fusion probabilities of halo nuclei are discussed using different proximity based potentials. The study reveals that the barrier heights reduce effectively but the fusion cross section enhance for the fusion of halo nuclei. Sharma *et al.* [3] examined the reactions of $^{24-40}$Mg $+^{12}$C at projectile energies of 240 MeV/nucleon and explore various aspects of reaction dynamics using the Glauber model with the conjunction of densities from the relativistic mean field formulation. In another study, Liu *et al.* [4] studied the role of halo structure on fragmentation and momentum dissipation in the heavy-ion collisions in the incident energy range of 20 to 150 MeV/nucleon. They showed that the halo structure of nuclei increases the fragment multiplicity at low incident energies but the effect of halo structure disappears gradually at higher incident energies. Opposite behavior is reported on momentum dissipation in reactions. These studies reflect that the reaction dynamics is greatly affected if halo nuclei structure are incorporated for the study of reactions. We, in the present study, will explore the role of halo structured nuclei on fragment production.

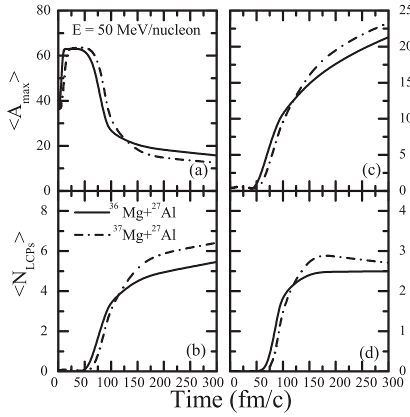

FIG. 1: The time evolution of the largest mass ($< A_{max} >$), and multiplicities of free nucleons $< N_{FNs} >$, $< N_{LCPs} >$ and $< N_{IMFs} >$, respectively, for the central collision of ^{36}Mg+^{27}Al and ^{37}Mg+^{27}Al at incident energy of 50 MeV/nucleon.

Results and Discussions

We simulated the central reactions of ^{36}Mg (^{37}Mg)+ ^{27}Al at an incident energy of 50 MeV/nucleon using soft equation of state and energy dependent nucleon-nucleon cross-section. Here, ^{37}Mg is a halo nucleus and ^{36}Mg is stable nucleus. The phase-space information of nucleons is generated using quantum molecular dynamics (QMD) [5, 6] model and is converted into fragment information with the help of secondary clusterization algorithm.

In Fig.1, we display the time evolution of the largest fragment ($< A_{max} >$) and multiplicities of free nucleons $< N_{FNs} >$, light charged particles $< N_{LCPs} >$ $[2 \leq A \leq 4]$

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and intermediate mass fragments $< N_{IMFs} >$ $[5 \leq A \leq A_{total}/3]$ for the central collisions of ^{36}Mg+^{27}Al (^{37}Mg+^{27}Al). The solid (dash-dotted) lines represent the calculations of ^{36}Mg+^{27}Al (^{37}Mg+^{27}Al) reactions. From the figure, we see that at initial stages of a reaction, one large excited unstable composite system ($< A_{max} >$) is formed which de-excites due to the pressure gradient of nuclear matter producing a large number of fragments. This de-excitation starts at around $t \sim 50$ fm/c for ^{36}Mg+^{27}Al and the emission of other fragments starts. This process terminates at $t \sim 150$ fm/c. For the case of ^{37}Mg induced reaction due to the halo structure less compression is achieved in the system, therefore, the composite system will de-excite slowly. Its de-excitation starts at around ~ 75 fm/c and hence the multiplicity of other fragments starts. We also note that the size of largest fragment for ^{37}Mg is smaller compared to ^{36}Mg induced reaction, opposite behavior is seen for multiplicity of other fragments. This can be understood as follows: the extended radius of ^{37}Mg causes the nucleons to exist at larger distances and hence as soon as they gain energy, they flew away as single particles and/or with some nearby nucleons. Thus decreasing the size of $< A_{max} >$ and increasing multiplicity of other fragments. The trends are consistent with the results of Ref. [4]. Now one question that still persists in the mind is the origin of the fragments. For this sake, we studied the rapidity of various fragments.

In Fig. 2, we display the rapidity of free nucleons, LCPs and IMFs. Symbols have the same meaning as in Fig.1. From the fig., we see that the free nucleons and LCPs originate from the central rapidities whereas IMFs mainly have origin from the target and projectile region [5]. We also see that for ^{37}Mg induced reaction the rapidities have larger peaks at projectile rapidity. This reflects more contribution for fragments from loose structure of the projectile. Collectively, the present results points that the production of fragments in heavy-ion reactions is increased if the halo structure of nuclei is taken into consideration.

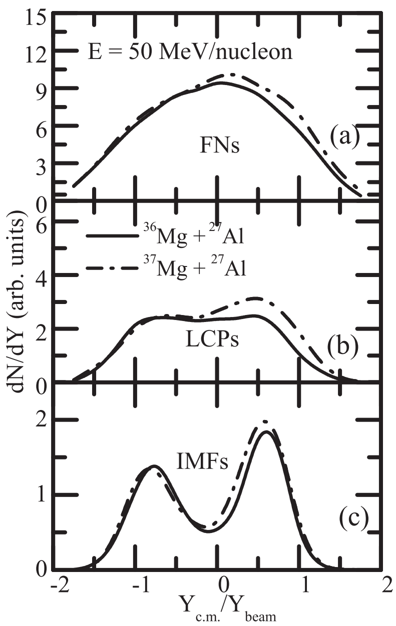

FIG. 2: The rapidity distribution (dN/dY) of free nucleons (top panel), LCPs (middle) and IMFs (bottom) at freeze out time t=300 fm/c for central collisions (b=0 fm) of ^{36}Mg+^{27}Al (^{37}Mg+^{27}Al) at an incident energy of 50 MeV/nucleon.

Acknowledgments

This work is funded by Council of Scientific and Industrial Research (CSIR), Govt. of India, via Grant No. 03 (1388)/16/EMR-II.

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