Effect of system size asymmetry on Muti-fragmentation in Heavy-Ion collisions

Varinderjit Kaur[1],* Suneel Kumar[1], Rajeev K. Puri[2]
[1]*School 0f Physics and Material Science, Thapar University, Patiala - 147004, INDIA*
[2]*Deptartment of Physics, Panjab University, Chandigarh- 160014, INDIA*
* *email:Suneel.Kumar@thapar.edu*

Introduction

Heavy-Ion collisions at intermediate energies are the centre of interest in present day nuclear research. It allows searching for a large number of observables which may be used as indicators of the properties of nuclear matter in conditions vastly different than in normal nuclei such as high densities and excitation energies [1]. Frequently these observables are related to the quantitative description of the production of secondary particles, compression of dense nuclear matter, its equilibration during the reaction and its decay into single particles and many intermediate mass fragments, the so called multifragmentation [2]. Multi-fragmentation is generally considered a low density phenomenon, with a high degree of thermalization believed to be reached. Several reports in the recent years clearly suggest the dependence of fragmentation pattern on the size of colliding nuclei, incident energy as well as on the impact parameter. However, a very little attention has been paid to the system size asymmetric effects in multi-fragmentation which are expected to increase with the increasing size of the system.

A theoretical investigation has been carried out by analyzing the different fragment multiplicities using four different set of reactions of ${}_{8}O^{16}$ + ${}_{54}Xe^{136}$, ${}_{14}Si^{28}$ + ${}_{54}Xe^{124}$, ${}_{14}Si^{28}$ + ${}_{50}Sn^{124}$, ${}_{20}Ca^{40}$ + ${}_{50}Sn^{112}$. We have studied the reaction mechanisms by choosing the different isotopes of Xe and Sn for the above systems such that the total number of nucleons remains constant in each set, i.e. 152. The simulations have been carried out at different beam energies from 50MeV/nucl. to 250MeV/nucl. for the semi-central impact parameter $\hat{b}$ = 0.3 within the frame work of Isospin Quantum Molecular Dynamics (IQMD) Model [3]. The isospin is treated explicitly (in the so-called IQMD model) by including Coulomb potential, symmetry potential and different NN cross-sections.

Our aim, therefore, is two fold. First to study the energy dependence of different fragments for different systems. Second is to explore the fragment production as a function of asymmetry of the system at different beam energies.

The Model: IQMD

Semi classical microscopic ***improved version*** of QMD model which is based on event by event method & includes

1) **Isospin** dependent Coulomb potential.
2) Symmetry Potential.
3) NN cross-section.

Heavy-ion collisions are simulated by generating the phase space (x, y, z, p_x, p_y, p_z) of two colliding nuclei at different time steps such that (x, y, z) are the position coordinates and (p_x, p_y, p_z) are the momentum coordinates.

Three steps of simulation are:
1. Initialization of projectile and target.

$$\Phi_i(\mathbf{r},\mathbf{p},t) = \frac{1}{(2\pi L)^{3/4}}\, e^{-(\mathbf{r}-\mathbf{r_i}(t))^2/2L}\, e^{i\,\mathbf{p}_i(t).\mathbf{r}/\hbar}$$

2. Propagation of (A_T+A_P) nucleon system.

Each nucleon propagates under the classical Hamilton's equations of motion, given by

$$\frac{d\boldsymbol{r}_i}{d\boldsymbol{t}} = \frac{\partial < \boldsymbol{H} >}{\partial \boldsymbol{p}_i} \qquad \frac{d\boldsymbol{p}_i}{d\boldsymbol{t}} = -\frac{\partial < \boldsymbol{H} >}{\partial \boldsymbol{r}_i}$$

Where <H> = <T> + <V> is the Hamiltonian.

$$V^{ij} = V^{ij}_{Skyrme} + V^{ij}_{Yuk} + V^{ij}_{Coul} + V^{ij}_{mdi} + V^{ij}_{Sym}$$

is the total interaction potential.

3. NN collisions and Particle production.

$$d < |r_i - r_j| = \sqrt{\frac{\sigma_{nn}}{\pi}}$$

Results and Discussions:

The effect of system size asymmetry on the multiplicity of nucleons/fragments has been studied in fig: 1 Here we display the multiplicities of different mass fragments i.e. nucleons, LMF's and IMF's at different energies. One can see that the isospin asymmetry due to different neutron/proton ratios in each combination play a significant role in the production of nucleons/fragments.

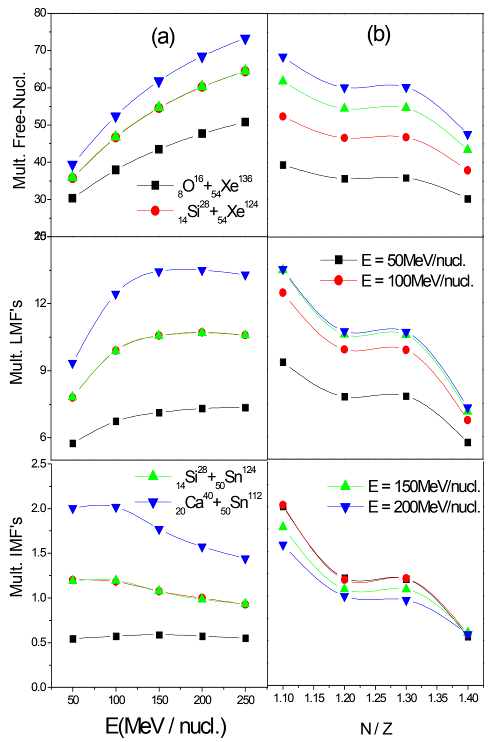

Fig. 1 Different fragment multiplicities as a function of energy (left) and N/Z ratio (right) respectively for different asymmetric systems at semi-central collisions.

From fig.1 (a), it is clear that since the excited compound nucleus decays by the emission of nucleons and fragments, as a result, free nucleons and LMF's show a rise up to 150MeV/nucleon and then become almost constant. Heaviest projectile show largest number of free particles and LMF's as compared to lightest projectile. However, the IMF emission is due to the spectator matter, so a clear rise and fall in the multiplicities of IMF's is observed with the increase in the incident energy.

Fig. 1(b), shows the distribution of different fragments with N/Z ratio of the respective systems. The different curves in each panel show the analysis at different beam energies. A sharp change is visible for low value of N/Z (${}_{20}Ca^{40}+{}_{50}Sn^{112}$) which saturates for higher N/Z (${}_{8}O^{16}+{}_{54}Xe^{136}$) value. In other words, the multiplicity of different nucleons/fragments dominates the physics at low N/Z ratio. As the cross-section for nn, np and pp is different, therefore, the results are expected to show change for the study carried out with different nn cross-sections.

References

[1] J. Aichelin, Phys. Rep. **202**, 233 (1991) ; J. Aichelin and H. Sto¨cker, Phys. Rev. Lett. **176**, 14 (1986).

[2] Jaivir Singh, Suneel Kumar and Rajeev K. Puri, PRC**63**, 054603(2000).

[3] C. Hartnack, Ph.D thesis, GSI-Report (1993).