Fragment production from participant zone in intermediate energy heavy ion reactions

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Introduction

Participant-spectator nucleons depends on impact parameter and incident energy associated with colliding nuclei [1,2]. Participant zone is highly compressed and have high density, leads to production of particles and light mass fragments such as p, n, d, t, etc. The correlations among the nucleons are broken and most of nucleons loose their memory. On the other hand spectator part does not disintegrate completely, but decay and leads to production of free nucleons, medium and heavy mass fragments.

Important information about nuclear matter can be extracted, if we concentrate on the nuclear matter produced at relatively higher densities in the participant zone.

The study on fragment production from the participant zone is not only important for experimentalist, but also of great significance for theoreticians.

Isospin dependent Quantum molecular dynamics (IQMD) Model :

The IQMD[3] approach, which is a N-body theory, used ton study heavy ion collisions and treats different charge states of nucleons, deltas and pions. The model has been successfully used for the analysis of large number of observables from low to intermediate energies[4]. The isospin degree of freedom enters into calculations through mean field and cross-sections[5].

Initialization:

In IQMD initially we generate the nuclei that satisfy basic nucleus properties like binding energy, stability, Fermi momentum etc. Nucleons are represented by Gaussian-shaped density distribution

$$f_i(\vec{r},\vec{p},t) = \frac{1}{(\pi\hbar)^3} \times e^{-(\vec{r_i}-\vec{r_j})^{\frac{2}{2L}}} \times e^{[-(\vec{p}-\vec{p_i}(t))^2 \frac{L}{2\hbar^2}]} \quad (1.1)$$

Here Gaussian width L represents the interaction range of nucleons.

Propagation:

The nuclei which are successfully initialized are properly boosted towards each other using relativistic kinematics andthen the total interaction evaluated through the Hamiltonian equation of motion

$$\frac{dp_i}{dt} = -\frac{d\langle H\rangle}{dr_i}; \frac{dr_i}{dt} = \frac{d\langle H\rangle}{dp_i}; \quad (1.2)$$

Collisions:

At the time of propagation, two nucleons are assumed to suffer collision if the distance between their centroid

$$|\vec{r_i} - \vec{r_j}| \le \sqrt{\frac{\sigma_{tot}}{\pi}} \qquad \sigma_{tot = \sigma(\sqrt{s}, type)} \quad (1.3)$$

Where "type" represents the ingoing collision partners of the system (N -N, N -Δ, N - π etc.)

Results and Discussion:

In the present work we have simulated the symmetric reactions $^{40}_{20}$Ca + $^{40}_{20}$Ca,$_{58}$ ^{28}Ni + $^{58}_{28}$Ni , $^{93}_{41}$Nb + $^{93}_{41}$Nb , $^{101}_{44}$Ru + $^{101}_{44}$Ru , $^{131}_{54}$Xe + $^{131}_{54}$Xe, $^{167}_{68}$Er + $^{167}_{68}$Er , $^{197}_{79}$Au + $^{197}_{79}$Au involving 1000 events at incident energies between 40 and 1000 MeV/nucleon at different impact parameters. By employing the mass symmetric (colliding) nuclei, system size effects on fragmentation can be analyzed. In the following, we have displayed the percentage of light mass fragments production from the participant zone in nuclear reaction at intermediate energies.

We have displayed the percentage of LMF's (Light mass Fragment) (1≤ A ≤4) as a function of incident energies at saturation time i.e. 200 fm/c for the symmetric reaction $^{197}_{79}Au + ^{197}_{79}Au, ^{40}_{20}Ca + ^{40}_{20}Ca$ at scaled impact parameter ($\hat{b}$=0.1).

Formula used for calculating the yield percentage is :

$$\frac{(< LMF >) with\ collision \quad - (< LMF) >_{without\ collision}}{(< LMF >) with\ collision}$$

Large numbers of LMF's are produced with increase in incident energy. LMF's are more sensitive towards the geometry of collisions. Here we have investigate the LMF's(light mass fragments) from participant zone in case of symmetric reactions $^{197}_{79}Au + ^{197}_{79}Au$, $^{40}_{20}Ca + ^{40}_{20}Ca$ .The nucleons constituting these fragments must have suffered atleast one collision.

The phenomenon of production of LMF's cannot be observed in cluster radioactivity. Lots of experimental data is available for light charge particles.

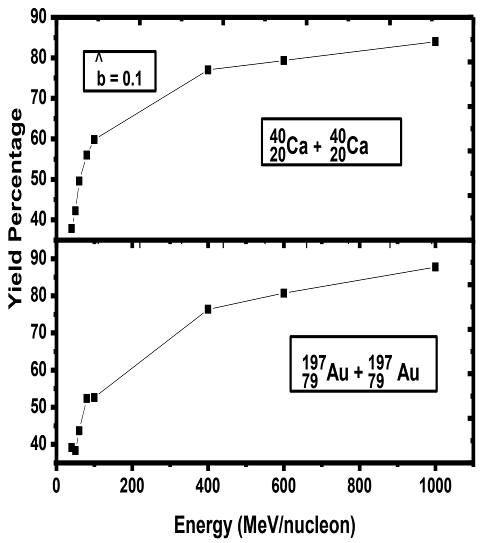

Fig 1 Light mass fragments produced from participant zone as a function of energy for symmetric reactions at scaled impact parameter ($\hat{b}$=0.1).

The production of LMF's from the participant zone gives us the conclusion that there is a signature of liquid gas – phase transition.

At higher energies due to breaking of correlation among the nucleons the production of heavier mass fragment decreases. It has been observed that about 80% of the LMF production takes place from the participant zone in heavy ion collisions at intermediate energies.

It would be interesting to calculate local density of participant zone where nucleons are suffering multiple collisions. The correlation between light mass production and nuclear stopping has been already established [6]. It would be interesting to correlate the production of light mass fragments from participant zone with anisotropic flow.

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