A hybrid model for studying nuclear multifragmentation around the Fermi energy domain

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Nuclear multifragmentation is an important technique for studying reaction mechanisms in fermi energy domain. Different theoretical models have been already developed for throwing light on the nuclear multifragmentation reaction and for explaining experimental data. These models are mainly classified into two categories: (i) Dynamical models and (ii) Statistical models. The dynamical models are based on more microscopic calculations where the time evolution of projectile and target nucleons are studied. In statistical models, the clusterization technique is nicely incorporated but the disadvantage of statistical model is that the calculation starts by assuming some initial conditions. These conditions are either parameterized or obtained from some experimental observables. In this work, we have developed a hybrid model for explaining multifragmentation reaction around the fermi energy domain where the initial conditions for the thermodynamical model are set up almost entirely by the Boltzmann-Uehling-Uhlenbeck (BUU) calculation [1].

We exemplify our method with central collision reactions ^{129}Xe+^{119}Sn at projectile beam energy 45 MeV/nucleon. We start BUU calculation when two nuclei in their respective ground states approach each other with specified velocities in centre of mass frame. The mean field potential energy density is [2]:

$$v(\rho(\vec{r})) = \frac{A}{2}\rho^2(\vec{r}) + \frac{B}{\sigma+1}\rho^{\sigma+1}(\vec{r}) + \frac{c\rho_0^{1/3}}{2}\frac{\rho(\vec{r})}{\rho_0}\nabla_r^2[\frac{\rho(\vec{r})}{\rho_0}] \quad (1)$$

The ground state energies and initial positions as well as momenta of the test particles are determined by the Thomas Fermi (TF) method. In BUU calculation, each nucleon is represented by 100 test particles. When almost all collisions are completed, there are some test particles which are far away from the central dense region. So there is no interaction between these test particles and the central dense region. These are mainly emitted due to the pre-equilibrium emission. In experiments about 20% of nucleons are emitted as fast pre-equilibrium particles. Hence we choose the test particles which create 80% of the total mass (i.e. A_0=198) from the most central dense region. By adding the kinetic and potential energies of these selected test particles, the excited state energy of the fragmenting system is obtained. Fig. 2 shows the variation of excited state energy with time. It is clear that after t=100 fm/c, the excited state energy becomes

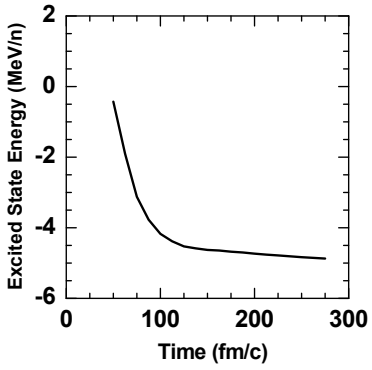

FIG. 1: Excited State energy variation with time obtained from dynamical BUU calculation for ^{129}Xe on ^{119}Sn reaction at 45 MeV/nucleon.

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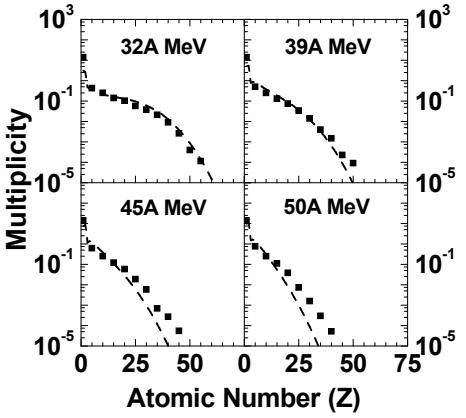

FIG. 2: Theoretical charge distribution (dashed lines) for $^{129}Xe+^{119}Sn$ reaction at different energies compared with experimental data (squares).

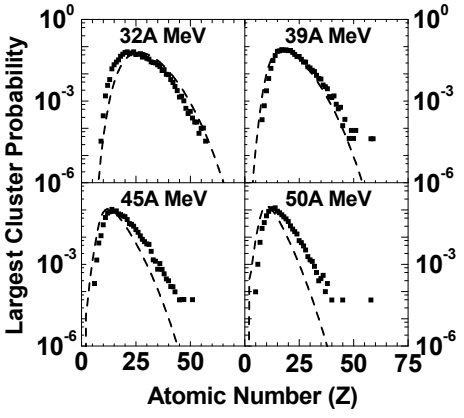

FIG. 3: Theoretical largest cluster probability distribution (dashed lines) for ^{129}Xe on ^{119}Sn reaction at different beam energies compared with experimental data (squares).

independent of time. For calculating the ground state energy, we have again used the TF method for a spherical nucleus of mass A_0=198. Subtracting the ground state energy from excited state energy, the excitation (E^*) is obtained.

The Canonical Thermodynamical Model (CTM) [3] is used to study the fragmentation of the compound nuclear system corresponding to this excitation (E^*). To avoid extensive computation in BUU calculation, the Coulomb effect is neglected and we have not classified between the protons and neutrons. But in CTM, we have considered the neutron to proton ratio of the compound nuclear system to be same as that of the combination of original projectile and target. CTM calculation is done at a temperature T which satisfies the condition

$$E^*_{N_0,Z_0} - B_{N_0,Z_0} = \sum_{i,j} \langle n_{i,j} \rangle [\frac{3T}{2} + \frac{aT^2}{\epsilon_0} - B_{i,j}]$$

Here $a = i + j$ and $\langle n_{i,j} \rangle$ is the average multiplicity of the fragments having i neutrons and j protons produced at temperature T and can be written as

$$\langle n_{i,j} \rangle = \omega_{i,j} \frac{Q_{N_0-i,Z_0-j}}{Q_{N_0,Z_0}}$$

where Q_{N_0,Z_0} is the total partition function and $\omega_{i,j}$ is the partition function of the composite. Finally the decay of the excited fragments are calculated by the evaporation model [4] based on Weisskopf's formalism.

In order to check the accuracy of the model, theoretical results have been compared with experimental data. Fig. 2 shows the comparison of charge distribution at projectile beam energies 32, 39, 45 and 50 MeV/nucleon. With the increase of energy, fragmentation is more, therefore higher fragment multiplicities gradually decrease. Fig. 3 represents the largest cluster probability distribution. Since with the increase of energy breaking increases, therefore the peak of the largest cluster probability distribution shifts towards the lower atomic number side and the width of the distribution gradually decreases. In each case nice agreement between theoretical result and experimental data is obtained.

References

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