ROLE OF FLUCTUATIONS IN HEAVY ION REACTIONS*

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Nuclear density fluctuations are introduced into BUU simulations of reactions between heavy ions. In cases of spinoidal instabilities of the interacting systems they strongly enhance a production of light and intermediate mass fragments.

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The mean field approaches to studies of reactions between heavy ions have proved to be very successful in describing the dynamical evolution of the interacting systems in regions of stability of nuclear matter. However, if the nuclear matter enters into a region of instability, the fluctuations might become extremely important. The mean field formalism does not include any kind of fluctuations.

We discuss here the occurrence of spinoidal (volume) instabilities which may develop when after initial compression the expansion brings the system in the overlapping zone (neck area) below the critical density. If the interaction time and the time for growing of instabilities are of the same order, the fluctuation will be amplified by the mean field.

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The dynamical evolution of the colliding system is described by using Boltzmann- Uheling-Uhlenbeck (BUU) formalism which includes a collision term $I_{\rm coll}$ depending on an effective nucleon-nucleon cross section. The test particle method with 100-200 test particles per nucleon has been used to solve the BUU equation [1].

$$\frac{\partial f}{\partial t} + \frac{\vec{p}}{m}\vec{\nabla}_r f - \vec{\nabla}_r U \vec{\nabla}_p f = I_{\rm coll}\,. \tag{1}$$

The distribution function $f(\vec{r},\vec{p},t)$ is written as a linear combination of isotropic Gaussian packets corresponding to the test particles. The self-consistent mean-field potential U is taken in the form of a simplified Skyrme interaction. Here m is a nucleon mass. As the colliding system, described by the distribution function $f(\vec{r},\vec{p},t)$ obtained by solving a BUU equation starts to expand, density fluctuations are introduced in the coordinate space, in a statistically consistent way. The variance of these fluctuations $\sigma_\rho^2(\vec{r},t)$ is determined by assuming a Fermi gas at local thermal equilibrium [2].

$$\sigma_\rho^2 = \frac{16\pi m\sqrt{2m}}{Vh^3}\sqrt{\varepsilon_{\rm F}}T\left[1 - \frac{\pi^2T^2}{12\varepsilon_{\rm F}^2} + ...\right]\,. \tag{2}$$

Here T is the local temperature, $\varepsilon_{\rm F}$ a local Fermi energy and V denotes the volume of a part of the system — a cell — where the fluctuation is being introduced. Since $\varepsilon_{\rm F}$ depends on density only, we divide the system into cells and in each of them we need to find the temperature T and the density ρ, in order to determine the variance σ_ρ^2.Roughly speaking, the density in any cell is proportional to the number of test particles inside the cell. The local temperature of a gas of Fermions can be estimated from the knowledge of kinetic energy density. In each cell we make a random change of density in agreement with a Gaussian distribution with the previously calculated variance σ_ρ^2. The procedure must conserve total mass, total charge, momentum and energy of the system. After the density fluctuation has been introduced, the BUU formalism is used again to follow the further evolution of the system, since it is the mean field that will determine whether the fluctuation will evolve.

The method previously tested for incomplete fusion of Ni + Ni at 30 MeV/A [2], has been applied to a deep inelastic collision of Ar with Fe at 45 and 53 MeV/A. The fluctuations lead to a rich spectrum of reactions outcomes. They strongly enhance a production of light and intermediate mass fragments. The mean field alone does not describe the experimentally observed multifragmentation process [3]. The inclusion of density fluctuations is absolutely essential.

REFERENCES

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