On evolution of the density fluctuation

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Nuclear cold fragmentation leads to the large density redistribution and indicates the formation of a binary or possibly multi-center quasistationary nuclear systems, which lives $\sim\ 10^{-21}$ sec without reaching statistical equilibrium. The existence of a central region of constant density and a well shaped surface region makes it possible to describe a clustering in the region of nuclear surface, including the neck region. Nuclear density falls considerably down in the region of nuclear surface, the fluctuations of the nuclear density may develop and lead to fragmentation processes.

In this short report, we present one possible way to describe the density fluctuation in the framework of nonlinear nuclear hydrodynamics, The general quantum scheme to analyze the large amplitude vibrational and vortical modes and their coupling is given [1]. In the semiclassical limit one derives the semi hydrodynamical equations of motion. The initial state with the density fluctuation in the surface region could be simulated via the following simplest way: $n(\vec{r}; t = 0) \equiv \overline{n} + \tilde{n}$, where $\overline{n}(r, z)$ is the density distribution of a stationary state. The initial density fluctuation $\tilde{n}(r, z, \theta) \ \equiv\ \Lambda n_0 \,\mathrm{sech}^2\,(\tilde{r}/b)\,,\ \ \tilde{r}\ \equiv\ \sqrt{r^2 - 2rz_0\cos\theta + z_0^2}$, where r, θ, z are the spherical polar coordinates of a point, z_0 controls the distance between centers of the two density waves [2]. Our preliminary estimations show that, the existing three dimensional hydrodynamical codes should be rebuilt to deal correctly with the gradient terms. Therefore we consider here to the simplest case: the small time in the beginning of the evolution of the effective one dimensional system. We selected the initial state with not moving density waves ($u(z, 0) = 0$). Therefore, in the beginning of the evolution, at the first small time step δt, the density distribution will be the same, as the initial one, and the corresponding velocity distribution is proportional to the effective "force"

$$n(z, \delta t) \approx\ n(z, 0). \qquad u(z, \delta t) \approx \frac{d}{dz}\Big(\frac{1}{m}\frac{\delta \mathcal{W}}{\delta n}\Big)\cdot \delta t$$

$$\begin{aligned}\frac{\delta \mathcal{W}}{\delta n} \ &=\ \frac{\hbar^2\xi^2}{2m}\left(-2\frac{\Delta n}{n} + \frac{|\nabla n|^2}{n^2}\right) - 2\gamma\Delta n \\ &+\ \ 2A_1 n + (2+\alpha)A_7 n^{1+\alpha} + \frac{5}{3}\kappa n^{2/3} + \frac{8}{3}\kappa\beta n^{5/3}\end{aligned}$$

where all parameters can be fixed using the integrals of motion $A = \overline{A} + \tilde{A} = \int nd^3r$, $\overline{A} = \int \overline{n}d^3r$ $\tilde{A} = \int \tilde{n}d^3\tilde{r}$ and the parameters of Skyrme type forces. The initial one dimensional density distribution simulating the three dimensional system with α-particle ($\tilde{A}$=4) in the surface region of a large nucleus ($\overline{A}\sim\ 100$) are presented in Fig. 1 for $z_0 = R_{\overline{A}}$ and in Fig. 2 for $z_0 = R_{\overline{A}} + R_{\tilde{A}}$ respectively. The dashed curve describes the initial large nucleus $\overline{n}(z, 0)$, the dotted curve - the density fluctuation $\tilde{n}(z, 0)$. The solid line corresponds to the total density. The respective velocity distributions ($u(z, \delta t)$ are presented (in the same arbitrary units) in the right sides of these figures,. One can see the complicate flux leading to dispersion of an initial density "bump", in the case of large overlapping densities Fig. 1, and the practically negligible flux at the "touching" distance Fig. 2. These preliminary results can be considered only as the first estimations. The complete three dimensional calculations are in progress.

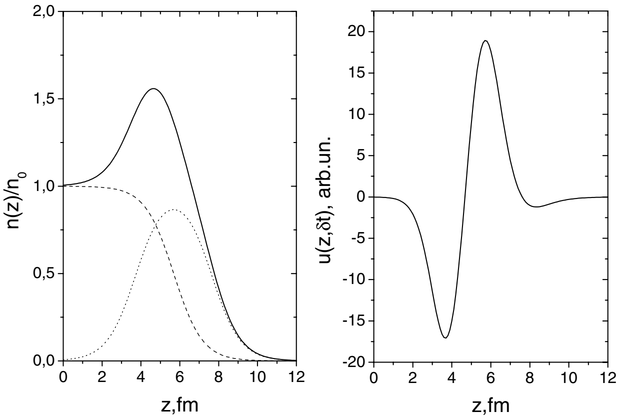

Figure 1: The initial one dimensional density distribution simulating the three dimensional system with α-particle ($\tilde{A}$=4) in the surface region of a large nucleus ($\overline{A}$=100) for $z_0 = R_{\overline{A}}$. The corresponding velocity distribution in the beginning of evolution (in arbitrary units).

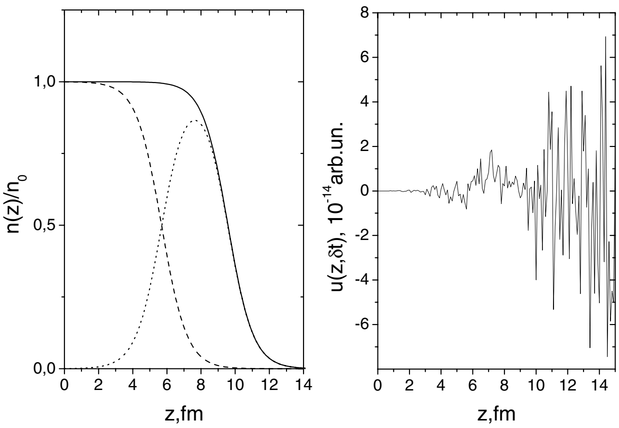

Figure 2: The same as Fig. 1 for the $z_0 = R_{\overline{A}} + R_{\tilde{A}}$. One can see the practically negligible flux in the case of the "touching" distance.

References

[1] V.G. Kartavenko, K.A. Gridnev, J. Maruhn and W. Greiner, Phys. Atomic Nucl. **66** (2003) 1439.

[2] K.A. Gridnev, V.G. Kartavenko, S.N. Fadeev and W. Greiner, Nucl. Phys. A **722C** (2003) 409.