Dynamical effects of momentum dependence of the nuclear mean field(*)

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Summary. — We suggest several ways to study dynamical effects of the momentum dependence of the nuclear mean field in medium energy heavy-ion collisions, from incomplete fusion to multifragmentation events. We present dynamical simulations based on a new transport code with a quite general form of mean-field non-locality and we compare with local effective forces giving the same equilibrium properties. We clearly see observable effects on the onset of instabilities, on rates and angular distributions of pre-equilibrium particle emissions and on rapidity distributions of vaporization events for central collisions at intermediate energies.

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1. – Introduction

The presence of correlations in a nuclear system necessarily leads to a momentum dependence of the self-consistent mean field [1-4]. It is however also well known that momentum-independent and momentum-dependent potentials with similar saturation properties, binding energy density and compressibility, give similar equilibrium parameters for excited nuclear matter. Therefore a thorough study of momentum dependence can only be based on observables associated to non-equilibrium dynamics, i.e. collective modes and reaction mechanisms. Many theoretical analyses have been performed on momentum dependence effects on collective flows and balance energies, i.e. on the transition

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from mean field to hydrodynamical regimes in reaction mechanisms for intermediate and high-energy heavy-ion collisions [5-7].

In this report we will show that it is possible to extract independent information on two important non-equilibrium properties, nucleon-nucleon (NN) cross-sections and velocity dependence of the mean field from observable effects in low-energy reaction mechanisms.

We will focus the attention on two quite different physical scenarios for reaction mechanisms in heavy-ion collisions: i) Pre-equilibrium emissions in incomplete fusion events at relatively low energies; ii) Vaporization events in central collisions at intermediate energies. We will show that spectra and angular distributions of fast emitted particles (case i)) and rapidity distributions (case ii)) are particularly sensitive to the momentum dependence of the mean field and not much affected by $\sigma_{NN}$ variations.

We will use the Gale-Bertsch-Das Gupta (GBD) form of the mean-field non-locality, constructed on a Skyrme type effective interaction [5]. We remark that in a large dynamical range the results are quite similar to other nonlocal forces [8, 9].

In sect. 2 we introduce the new transport equation code for simulations with momentum-dependent fields. In sect. 3 we analyse incomplete fusion reactions discussing some effects on density oscillations and on pre-equilibrium particle emission. In sect. 4 we show some results for vaporizations events and finally some conclusions are drawn in sect. 5.

2. – Nuclear dynamics with momentum-dependent fields

We have extended the well-established Boltzmann-Nordheim-Vlasov transport approach [2, 3, 10-16] to momentum-dependent mean fields. We have considered the quite general GBD form [5, 9] of momentum dependence in a Skyrme-like effective mean field

$$U(\rho, p) = A\left(\frac{\rho}{\rho_0}\right) + B\left(\frac{\rho}{\rho_0}\right)^{7/6} + \frac{C}{\rho_0} \int d^3 p' \frac{f(r, p')}{1 + \left(\frac{p' - \rho}{\Lambda}\right)^2} +$$

$$+ C \frac{\rho}{\rho_0} \frac{1}{1 + \left(\frac{\rho - \rho_0}{\Lambda}\right)^2},$$

where $A = -144.9 \text{ MeV}, B = 203.3 \text{ MeV}, C = -75 \text{ MeV}$ and $\Lambda = 1.5 p_F(0)$, with $p_F(0)$ Fermi momentum at saturation density $\rho_0$. The corresponding potential energy density gives NM saturation properties $E/N = -16 \text{ MeV}, \rho_0 = 0.163 \text{ fm}^{-3}$ and a compression modulus $K = 215 \text{ MeV}$, i.e. a soft Equation of State [5] and $m^* = 0.7m$.

In the following we will compare results in collision dynamics with two momentum-independent mean fields

$$U(\rho) = A\left(\frac{\rho}{\rho_0}\right) + B\left(\frac{\rho}{\rho_0}\right)^{\sigma}$$

with parameters fixed in order to have the same cold NM binding energy and saturation density but two different compressibilities:

a) $K = 200 \text{ MeV (SOFT LOCAL)}, A = -356 \text{ MeV}, B = 303 \text{ MeV}, \sigma = 7/6,$

b) $K = 380 \text{ MeV (STIFF LOCAL)}, A = -124 \text{ MeV}, B = 70.5 \text{ MeV}, \sigma = 2.$