Heavy Ion Collisions as Test for Microscopic Nuclear Matter Models

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Intermediate energy heavy ion reactions ($E_{beam} = 100 \cdots 1000\ MeV/A$) are studied in order to obtain information about the equation of state (EOS) of nuclear matter (NM). This information is extracted by performing transport calculations of the collision, where the EOS is contained in the nuclear mean fields or self energies. At these energies we use relativistic transport models of the BUU-type [1], which are based on a meson-nucleon Lagrangian of the Walecka model, which can also be nonlinear in the scalar meson field [2].

A crucial question is the dependence of the mean fields on the local momentum distribution. A heavy ion reaction is a strongly non-equilibrium process with very anisotropic momentum configurations. Calculations show that the momentum distribution is well represented by that of two Fermi ellipsoids with finite temperature and a relative velocity [3]. In contrast the EOS rather refers to a spherical Fermi sphere. Since nuclear fields are known to be strongly momentum depentent due to the energy dependence of the optical potential one expects a significant effect from the momentum configuration on the extracted EOS.

In the mean field or Hartree approximation of the Walecka model the self energy only depends on the local density and thus corresponds to a single Fermi sphere, i.e. to the **L**ocal **D**ensity **A**pproximation (LDA). A momentum dependence is introduced by exchange contributions (Fock-term) and higher order correlations, as they are e.g. treated in the Dirac-Brueckner (DB) method. We start from the latter method by defining from the DB self energies density and momentum dependent vertex functions which effectively take into account exchange and correlation effects. The next step is to take into account the anisotropy of the non-equilibrium momentum configuration by calculating the self energy with these vertex functions for the two-Fermi ellipsoid configurations discussed above [4]. This approximation we call the **L**ocal (phase space) **C**onfiguration **A**pproximation (LCA). In this way calculations of heavy ion collisions are directly related in a parameterfree procedure to microscopic nuclear matter calculations.

In order to test this approach relative to experimental data we have investigated data on impact parameter selected nuclear flow observables in Au on Au collisions [5] as obtained in the FOPI collaboration at the GSI [6]. We also compare our microscopic DB-LCA approch to a theoretical treatment using phenomenological fields in a nonlinear Walecka parametrisation (NL2). In fig. 1 we show the transverse flow as a function of rapidity for different incident energies for central (PM5) and semicentral (PM4) collisions as selected by the charge fragment multiplicity [5,6]. It is seen that the DB-LCA method reproduces the data generally well and better than the phenomenological model (NL2). Fig. 2 shows the azimuthal anisotropy, the so-called squeeze-out ratio, depending on the beam energy selected only for higher transverse momenta $P_T^{(0)}$. As in fig. 1 the DB-LCA calculations yield a better description of the reaction dynamics perpendicular to the reaction plane relative to the phenomenological forces. Thus, these results indicate the applicability of microscopical NM models like the DB approach provided, if the non-equilibrium features of the phase space are carefully taken into account.

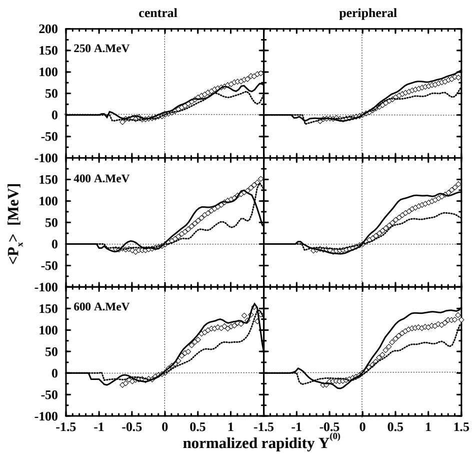

Fig. 1: Mean transverse flow $< p_x >$ per nucleon of protons for different Au on Au reactions. Solid: DB mean fields (LCA), dotted: Non-linear Walecka model, diamonds: data.

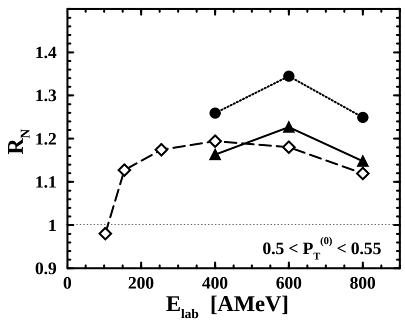

Fig. 2: Squeeze-out ratio for different beam energies for semicentral Au on Au reactions. Solid: DB mean fields (LCA), dotted: Non-linear Walecka model, diamonds: data.

References

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