Non-Equillibrium Effects in the EOS in Heavy Ion Collisions

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One of the goals of the investigation of relativistic heavy ion collisions has been to obtain information on the nuclear matter equation-of-state (EOS). While naively one would expect to directly "see" states of high density and temperature, it was found that during most of the evolution the system is not in thermal equilibrium but rather characterized by non-equilibrated momentum distributions [1]. It is thus important to estimate these non-equilibirum effects in the determination of the EOS in heavy ion collisions. These effects are not apparent when using phenomenological fields, as e.g. Skyrme parametrizations. However, microscopic fields, which are generated by the G-Matrix, depend on the medium, i.e. the non-equilibirum configuration . In principle, one would have to solve the Brückner G-Matrix consistent with the transport equation which is far beyond present capabilities.

However, calculations show that the non-equilibrium configurations can be described as two finite-temperature Fermi spheres (or relativistically ellipsoids) with a finite relative velocity. Physically this system represents two interpenetrating and interacting nuclear matter streams, which we call Colliding Nuclear Matter (CNM). The parameters can easily be determined in a transport calculation at each time-space point.

The G-Matrix for such CNM configurations has not yet been calculated in the Dirac-Brückner approach. We have developed a covariant procedure to extrapolate from thermalized nuclear matter on the basis of density-, momentum- and temperature-dependent coupling functions [2]. We then compare three increasingly realistic approximations: In the Local Density Approximation (LDA) one has one cold Fermi sphere, i.a. neglects non-equilibrium effects. In the (symmetric) CNM approximation we use two cold Fermi spheres with the same (averaged) density. In the asymmetric version (ACNM) we allow different densities. Temperature effects have not yet been implemented. The explicit momentum dependence has been averaged over the configuration, thus only the relative momentum dependence remains. We have shown that the separation of the Fermi spheres leads to an effective softening of the EOS because nucleons can be packed more closely [3].

In Fig.1 and 2 we compare these approximations with FOPI data for $Au + Au$ collisions for the in-plane flow v_1 and the elliptic flow v_2 (see also [4]). The ACNM model is always between the other two. For v_1 there is not a big effect. For v_2 the LDA gives too much squeeze-out, the CNM is an improvement, and ACNM also reproduces details of the data. In Fig.3 we show the energy dependence of the p_t-integrated elliptic flow from GANIS to AGS data. The ACNM model provides a good description.

In summary, it is shown that the inclusion of non-equilibrium effects is important to reliably extract the EOS in heavy ion collisions. Doing this it is shown that microscopic fields derived from Brückner theory reproduce also dynamics of heavy ion reactions.

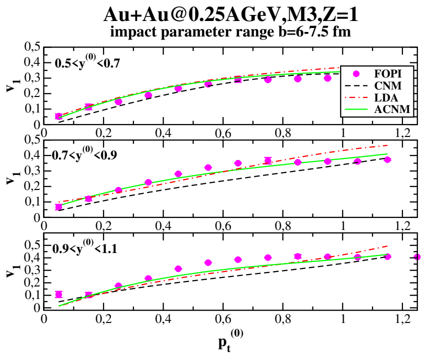

Fig. 1: In-plane collective flow as function of transverse momentum at different rapidity intervals for semicentral $Au + Au$ collisions at 0.25 AGeV.

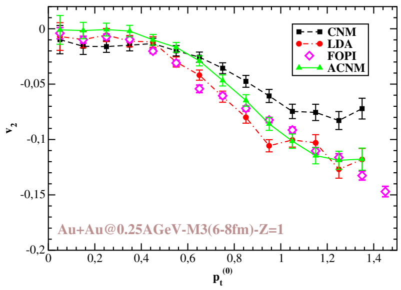

Fig. 2: Out-of-plane elliptic flow at mid-rapidity as in Fig.1.

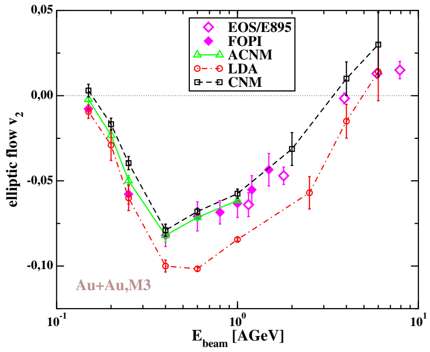

Fig. 3: Energy dependence of elliptic flow in peripheral $Au + Au$ collisions with the models discussed in the text.

References

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