Test of EOS in Heavy Ion Collisions

R. A. Ionescu [a], T. Gaitanos, C. Fuchs [b], and H. H. Wolter
[b] Institut für Theoretische Physik, Universiät Tübingen, Germany,
[a] also: National Institute of Physics and Nuclear Engineering, Bucharest, Romania

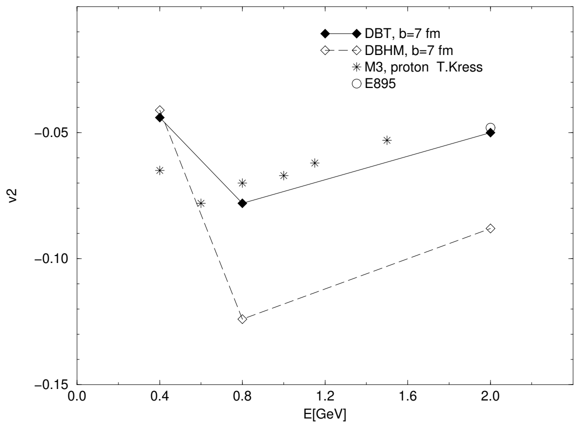
The equation-of-state (EOS) of hadronic nuclear matter is a fundamental fundamental quantitiy which is to be investigated in heavy ion collisions at intermediate incident energies between several 100 MeV to several GeV per nucleon. The question of the EOS is still not settled after many years of investigation because of the complicated reaction mechanism in such collisions and because of the various observed quantities that may depend on the EOS.

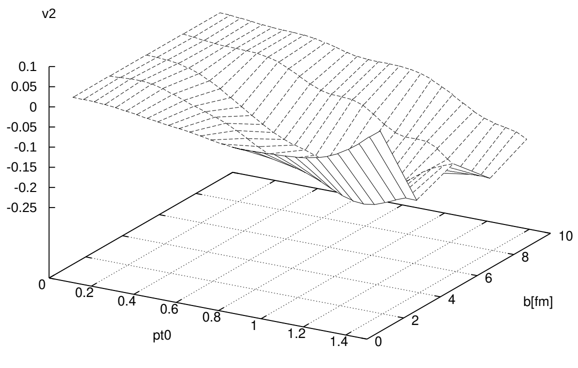
Usually the EOS is parametrized in terms of phenomenological non-relativistic (Skyrme-type) or relativistic (Walecka-type) funtionals of the density (and nuclear momentum).However, it is of great interest to investigate whether an EOS, derived from a realistic nucleon-nucleon interaction is also able to describe heavy ion collisions. At present the most successful scheme to describe NN-scattering, nuclear matter and finite nuclei is the (relativistic) Dirac-Brückner-HF approach, which includes two-body correlations. However, different DB models employ different approximations, e.g. in the treatment of the negative energy contributions, which lead to different behaviors with respect to the density and momentum dependence. To apply DB mean fields in heavy ion collisions is a way to test this behavior at higher densities and momenta. In doing so, however, the non-equilibrium effects in a heavy ion collisison have to be taken into account, which means that the self energies in a heavy ion collisions are not identical to those of ground state nuclear matter. Approximate methods to include these into the effective mean fields in a local phase space configuration approximation were developed in our group earlier [1].

The quantity that most directly depends on the EOS and has been extensively investigated both theoretically and experimentally is the nucleon flow, i.e. the momentum distribution of the final emitted hadrons. In modern analyses the nucleon yield is represented for each incident energy as a function of centrality (impact parameter), rapidity (longitudinal momentum), transverse momentum $p_t^{(0)}$ (normalized to the incident momentum), and azimuthal angle ϕ. The angular dependence is represented as a Fourier series in $cos\phi$ with the first coefficients v_1 (sideward flow) and v_2 (elliptic flow). The argument has been put forward that, in particular, the $p_t^{(0)}$ - dependence is sensitive to the momentum dependence of the EOS at high densities [2]. We have tested two particular DB-models from Groningen (Malfliet, *et al.*) and Tübingen (Fuchs, *et al.*). The Tübingen work excludes spurious negative energy contributions and leads to a slightly softer EOS and less repulsive momentum dependence at high densities. We have studied Au+Au collisions between 250 and 2000 MeV per nucleon and compared to FOPI data. We find that generally the microscopic mean fields are able to describe experimental data, provided the non-equilibrium features are taken into account [3].

We have started a more systematic analysis of the differential sideward and elliptic flow, in order to test the microscopic prescription of the mean field more sensitively. In Fig. 1 we show the elliptic flow v_2 as a function of transverse momentum and impact parameter for 400 AMeV calculated with the Tübingen mean field. A characteristic behaviour is seen which is generally consistent with recent new data from the FOPI collaboration. An exception may be the behaviour for large impact parameter and large p_t, which may point to a deficiency of the DB model, which has to be further investigated. In Fig. 2 we show the same elliptic flow integrated over p_t for the two different models in comparison with some data. It is evident that this global quantity is better described by the Tübingen model. This also emphasizes, that the differential quantities contain more detailed information.

These investigations show that microscopic mean fields are able to decribe observables in intermediate energy heavy ion collisisons, if non-equilibrium effects are accounted for. The even provide ways to destinguish between different DB approximations. Keeping in mind that these DB field describe as well nuclear matter ans finite nuclei (in a local density approximation) these studies result in the tentatively optimistic result that in a relativistic framework microscopic effective interactions are able to describe nuclear systems under very different conditions.





References

[1] T. Gaitanos, *et al.*, Phys. Lett. **B478** (200) 79
[2] P. Danielewicz, Nucl. Phys. **A673** (2000) 375
[3] T. Gaitanos, *et al.*, Eur. Phs. J **A12** (2001) 421