Microscopic Interactions and Flow in Heavy Ion Collisions^B

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Relativistic heavy ion collisions have been extensively investigated to determine the equation-of-state (eos) of nuclear matter using phenomenological effective fields of the non-relativistic Skyrme or the relativistic Walecka type. It is found generally that a soft eos with momentum dependence can decribe much of the data in the SIS energy range. It is, however, of fundamental interest to test also microscopic fields derived from NN- interactions by many-body theory. We have previously used self energies from relativistic Brueckner calculations (DB) and have shown that these satisfactorily explain the data for flow observables [1], however, only if non-equlibrium effects are considered, i.e. taking into account that the momentum distribution is not equilibrated during a large part of an energetic heavy ion collision, which changes the effective fields. The non-equlibrium effects effectively soften the eos.

However, different approximations have been used in DB calculations, which may lead to similar saturation properties and results for finite nuclei but to different behaviours for higher density and momentum. It may thus be possible to distinguish different DB models in heavy ion collisions. Here we have tested two particular DB models: one from the Groningen group (DBHM)[2], and a more recent one from the Tübingen group (DBT) [3]. The latter takes care to eliminate spurious contributions from negative energy states, and leads to a softer eos at higher densities and to less repulsion at higher momenta.

We have performed a detailed study of flow observables in $Au + Au$ collisions [4], which have been investigated extensively by the FOPI collaboration [5]. We discuss differential flow observables: stopping or longitudinal flow and transverse in-plane and out-of-plane flow. We have used the common description in terms of the Fourier coefficients of the azimuthal distributions: v_1 (flow) and v_2 (elliptic flow), as functions of the normalized rapidity $Y^{(0)}$ and the total transverse momentum $p_t^{(0)}$. As an example in fig.1 we show for forward rapidities and different fragments the flow as a function of the transverse momentum. It is seen that the two DB models yield different results and that the DBT model reproduces preliminary FOPI data [5] better, which was not so clearly seen in global observables, like the directed flow (not shown here [4]). Similar in fig.2 we show an excitation function of the elliptic flow compared to data from different sources. We see that the DBT model reproduced the data considerably better, in particular the recent FOPI data between 400 Mev and 1 GeV. Similar results are found for other flow observables: above 400 MeV the softer and less repulsive DBT model seems to be preferred, below in some cases the DBHM model has advantages.

Thus we generally find that microscopic fields succeed also to reproduce more exclusive flow variables, thus leading to a rather unified picture of nuclear fields for nuclear matter, finite nuclei and heavy ion collisions. In the more detailed comparisons it was shown that different DB approximations can indeed be distinguished by looking at differential flow observables.

References

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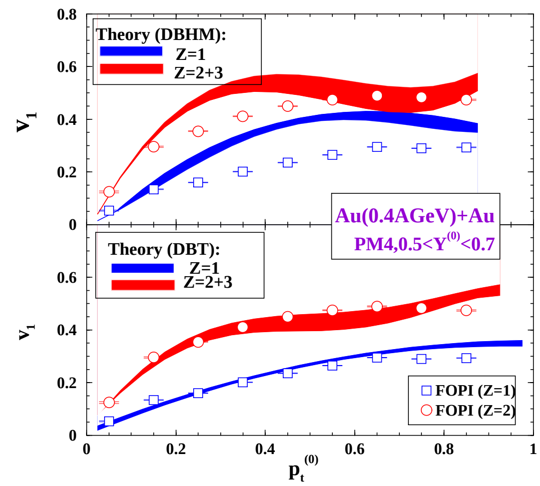

Figure 1: In-plane flow for semi-central Au+Au collisions at 400 AMeV for protons and light fragments [5] in comparisons to calculations using different DB fields. Statistical errors of the calculation are indicated by bands.

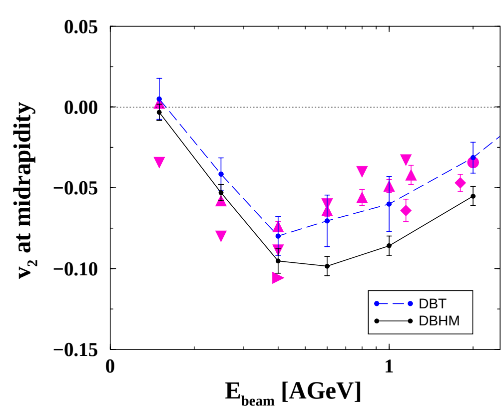

Figure 2: Energy dependence of the elliptic flow v_2 at mid-rapidity. The data denoted by upright triangles are taken from the FOPI collaboration [5], the others from others sources [4].