Nonequilibrium quark dynamics in ultrarelativistic heavy ion collisions^{B,G}

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Heavy ion collisions at the CERN-SPS (and possibly at the upper end of the planned SIS/200 at GSI) are supposed to reach the transition form hadronic matter to the quark-gluon plasma. The analysis of collective observables such as flow allows to speculate that this transition may show up even down to AGS energies. The description of such a collision by microscopic models thus must treat properly the degrees of freedom emerging from soft QCD.

Such a model can be realized by treating quarks as classical particles interacting according to a two-body color potential [1]. The Hamiltonian of this quark molecular dynamics (qMD) reads

$$\mathcal{H} = \sum_{i=1}^{N} \sqrt{\mathbf{p}_i^2 + m_i^2} - \frac{1}{2} \sum_{i,j} C_{ij}^{c} \left(\frac{3}{4} \frac{\alpha_s}{|\mathbf{r}_i - \mathbf{r}_j|} + \kappa \, |\mathbf{r}_i - \mathbf{r}_j| \right)$$

where the well known Cornell-potential is used to describe the quark interaction. Sign and relative strength of the interaction are described by the color factor C_{ij}^{c}, depending on the color combination of each pair. Confining properties are ensured by the linear increase of $V(r)$ at large distances. The time evolution of such a system yields colorless quark clusters which are mapped to hadrons.

When coupled to a hadronic transport model such as UrQMD[2] to create the initial quark distribution, the qMD can provide us with detailed information about the dynamics of the quark system and the parton-hadron conversion. Correlations between the quarks clustering to build new hadrons can be studied [3].

Hadrons of the colliding nuclei are propagated in UrQMD, producing new hadrons in inelastic collisions and preformed hadrons in string excitations. Once complete overlap of the impinging nuclei is reached, all hadrons with at least one collision or within their formation time are broken up in their (valence) quark content. These quarks are then propagated in qMD, finally hadronizing again.

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A measure of the relative mixing within the quark system and thus for thermalization is the relative number of hadrons formed by quarks from the same initial hadron versus hadrons formed by quarks from different initial hadrons. This ratio is surprisingly flat ($r \simeq 0.3$ for the Pb+Pb collision – spectators are not included!) over the whole energy range from SIS/200 to SPS from 20 to 160 GeV/N. It also shows only a moderate dependence on the impact paramter (figure 1).

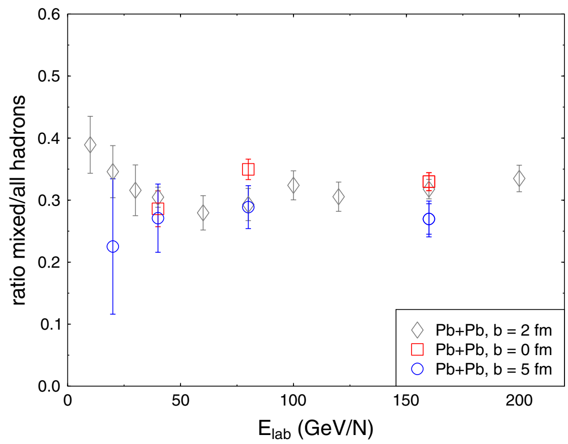

Figure 1: Excitation function of ratio of mixed to total hadrons for Pb+Pb collisions with diffrent impact parameters (b= 0, 2, 5 fm).

Since a value of $r = 1$ indicates complete rearrangement of quarks and thus complete loss of correlations in the quark system, one would expect a much larger value of r, considering the presumed transition to the quark-gluon plasma in Pb+Pb collisions at 160 GeV/N,

One finds, however, in increase in the ratio of mixed to direct hadrons if one takes into account in the qMD phase only those hadrons (and preformed hadrons) from UrQMD which have undergone at least two collisions (figure 2 – circles and squares).

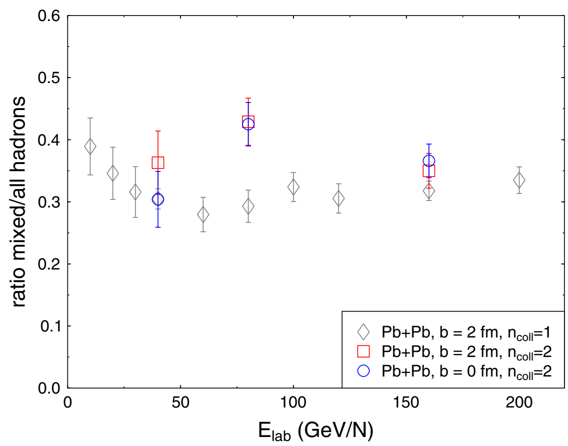

Figure 2: Excitation function of ratio of mixed to total hadrons for Pb+Pb collisions.

References

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