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

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Heavy ion collisions at the CERN-SPS 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

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

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].

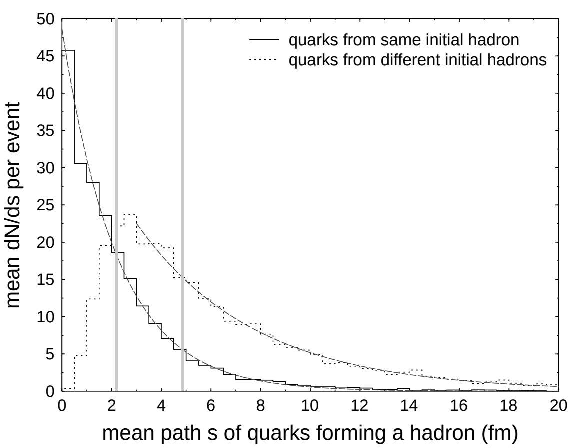

Figure 1: Hadronization in S+Au collisions at 200 GeV/N: Mean diffusion path of quarks forming a hadron from the same initial hadron (solid line) and from different initial hadrons (dashed line) within qMD. Fitting the decay profiles yields diffusion lengths of 2.2 fm and 4.8 fm.

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.

Figure 1 shows (for S+Au collisions at SPS energies of 200 GeV/N) the distribution for the mean path travelled by quarks forming a hadron (a) from the same initial hadron (solid line) and (b) from different initial hadrons (dotted line).

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 $r = 0.574 \pm 0.008$ for the S+Au collision (spectators are not included). 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,

First results for the excitation function of this ratio in Pb+Pb collisions, however, shows a different picture (Figure 2): a nearly constant value of about 0.3 is obtained for energies in the range from 20 to 160 GeV/N, nearly independent of the impact parameter. This surprising behavior needs clarification by further investigations.

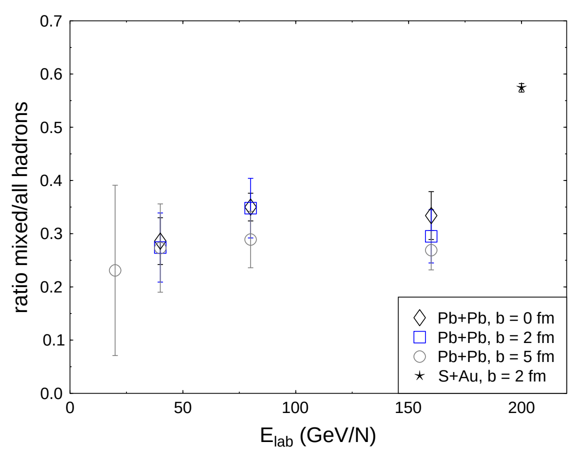

Figure 2: Excitation function of ratio of mixed to total hadrons for Pb+Pb collisions. The value for S+Au collision at 200 GeV/N is also shown.

References

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