"Pressure Equilibration" in Ultrarelativistic Heavy Ion Collisions^B

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Almost 30 years ago hydrodynamics was used for the first time to describe heavy ion collisions at BEVALAC energies. The success of the macroscopic description of the collision dynamics indicated the creation of a hot and dense state of nuclear matter. The great advantage of such an approach is that the equation of state (EoS) of nuclear matter enters directly into the hydrodynamic equations and it is easy to implement phase transitions. This success motivated the application of (one-fluid) hydrodynamics also for higher impact energies. The assumption of instantaneous thermalization of projectile and target matter in this model leads to a maximum deposition of energy in the central reaction zone, so that already at AGS energies the phase transition to a quark-gluon plasma (QGP) could be reached. This, for instance, leads to the breakdown of the directed flow in the reaction plane since the pressure is not increasing anymore while the system is in the mixed phase [1].

However, the assumption of instantaneous thermalization becomes unrealistic when the rapidity gap of projectile and target is large. Considering pp collisions at 24 AGeV [2] the protons loose only one unit in rapidity and can be identified even after the collision. It takes the nucleons several collisions to reach thermal equilibrium. Moreover, the produced particles are also separated in phasespace.

In our hydrodynamical model, we therefore consider three different fluids [3, 4] corresponding to projectile and target nucleons and the produced particles, the so-called *fireball*. We assume local thermal equilibrium within each fluid but not among different fluids. Due to the above described forward-backward peaking of the pp-cross section nucleons are not allowed to leave their individual fluids, so that the fireball remains net baryon free. The coupling of the two nucleonic fluids is parametrized assuming free binary NN-collisions [5]. While penetrating each other, projectile and target fluid loose energy to the fireball. The recoupling of the nucleonic fluids with the fireball is neglected here. The fluids are propagated separately in three spacial dimensions so that investigations with different impact parameters are possible. When the local thermal velocities become comparable to the relative velocities of the (nucleonic) fluids they are merged into one. For the nucleons we use the EoS of an ideal nonrelativistic gas with compressional energy. Only the fireball may undergo a phase transition.

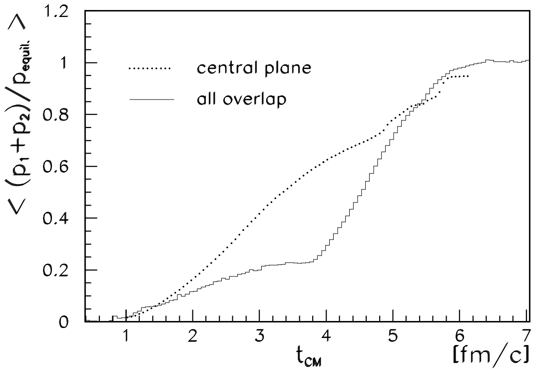

Figure 1: Total pressure of the nucleonic fluids divided by equilibrium pressure (Au(11AGeV)+Au, b=0).

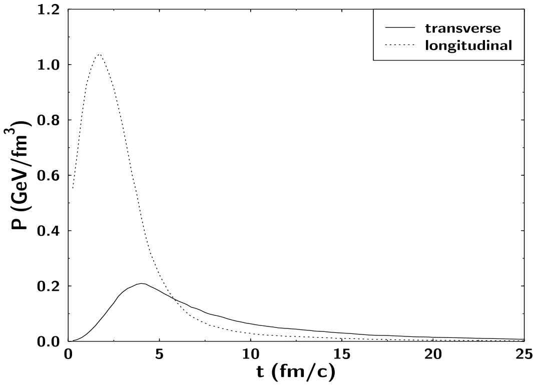

Figure 2: Longitudinal and transverse pressure in the central region of Au(11AGeV)+Au, b=0 in UrQMD.

In Fig. 1 we show the sum of the individual pressures of the nucleonic fluids divided by the corresponding equilibrium pressure, i.e. the pressure of the fluids if they were equilibrated. This ratio is averaged over the central plane perpendicular to the beam axis or over the overlap volume of the nuclei, respectively. One observes that it takes $\approx$ 5 fm/c = $2R_{Au}/\gamma_{CM}$ to reach the equilibrium pressure. A similar result is obtained within a microscopic cascade model (UrQMD, [6]). Until $\approx$ 5fm/c the longitudinal pressure is much larger than the transverse one (Fig. 2). The pressures are averaged over a cylindrical volume of transverse radius 6 fm and of 2 fm length. As a consequence of these nonequilibrium effects, even without a first order phase transition, the directed nucleon flow is considerably lower as compared to models where instant equilibration is assumed (e.g. one-fluid hydrodynamics)[4].

References

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