Investigating the Transition Between Hydrodynamics and Transport *

D. Oliinychenko[1,3], *P. Huovinen*[2], *and H. Petersen*[1,2]
[1]Frankfurt Institute for Advanced Studies, Frankfurt am Main, Germany; [2]Institut für Theoretische Physik, Goethe Universität Frankfurt, Frankfurt am Main, Germany; [3]Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine

Hybrid (hydrodynamics+transport) models are well suited to describe the dynamics of heavy ion collisions. However, there are common technical issues within such models that remain unsolved. In particular the established procedure of transforming hydrodynamics to transport by sampling particles according to the positive contributions of the Cooper-Frye equation [1] results in violating conservation laws. Typically, the hope is that small negative contributions will not influence the final results too much. The goal of our study is to explore the applicability range of this approach. We systematically investigate the behavior of Cooper-Frye negative contributions, in particular their dependence on hadron sort, collision energy (we consider the energy range of $\sqrt{s_{NN}} = 2-20$ GeV) and the criterion for the transition.

The negative contributions are calculated in two different ways: (I) hydro-based, assuming local thermal equilibrium and (II) particle-based, out of equilibrium. For this purpose many UrQMD events are generated and obtained particle trajectories are used to calculate the energy-momentum tensor $T^{\mu\nu}(t, x, y, z)$ on a space grid. In each grid cell the energy momentum tensor is transformed to the Landau rest frame (LRF) and a surface of constant LRF energy density is generated: $T^{00}_{LRF}(t, x, y, z) = \epsilon_0$, where ϵ_0 is an arbitrary parameter varied in the range 0.3 - 0.6 GeV/fm^3. Such surface mimics a typical transition surface that is used in hybrid models. Temperature and chemical potentials on the surface are obtained from a hadron gas equation of state. The negative contributions on this surface are calculated (I) from Cooper-Frye formula and (II) explicitly counting underlying particles.

The main results are as follows. The ratio of negative to positive contributions $x = [dN^-/dy]/[dN^+/dy]$ decreases with particle mass. It also decreases with collision energy as illustrated by Fig.1. In Fig. 1 one can also see that the value of x at midrapidity is 12 % at $E = 10$ AGeV while at $E = 160$ AGeV it is already around 3 % . It was found that x slightly grows with ϵ_0 and considerably increases at forward and backward rapidity if smooth transition surface is perturbed. This may be important for event-by-event calculations. Finally, x tends to be smaller for out of equilibrium ”by particle” calculation than for Cooper-Frye calculation.

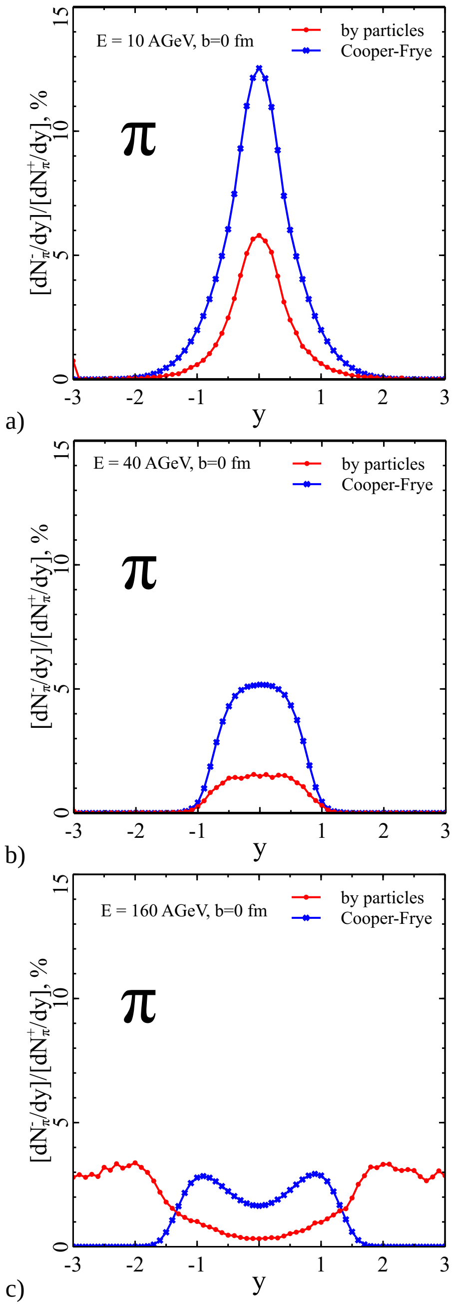

Figure 1: Negative contributions rapidity distribution for pions in central Au+Au collisions. $\epsilon_0 = 0.3$ GeV/fm^3. Crosses denote Cooper-Frye calculation while circles are ”by-particle” calculation. Collision energy is a): $E = 10$ AGeV, b): $E = 40$ AGeV, c): $E = 160$ AGeV

References

[1] F. Cooper, G. Frye, Phys. Rev. D 10, 186, 1974

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