

Is created matter equilibrated?

W. Reisdorf, A. Andronic, A. Gobbi, O. N. Hartmann, N. Herrmann¹, K.D. Hildenbrand, Y.J. Kim, M. Kirejczyk, P. Koczoń, T. Kress, Y. Leifels, A. Schüttauf, Z. Tymiński
FOPI Collaboration, GSI Darmstadt, ¹ Universität Heidelberg

Recent data analyses of heavy ion reactions have shown that it is possible to describe rather well created particle ratios by two parameters, an effective 'chemical' temperature T and baryochemical potential μ_B , assuming *local* chemical equilibration [1]. Before putting such parameters in a 'phase diagram' of 'hot nuclear matter' one has to be aware that while such a striking simplification of our description of particle yields in a dynamical situation is a *necessary* condition, it is not a *sufficient* condition to firmly establish the conclusion of equilibration. Evidently, the complexity of heavy ion collisions seems to warrant sufficient cross-couplings between the most abundant exit channels that some sort of common, phase-space related, parameterization is possible. This important and ubiquitous observation is highly non-trivial and deserves further critical investigations.

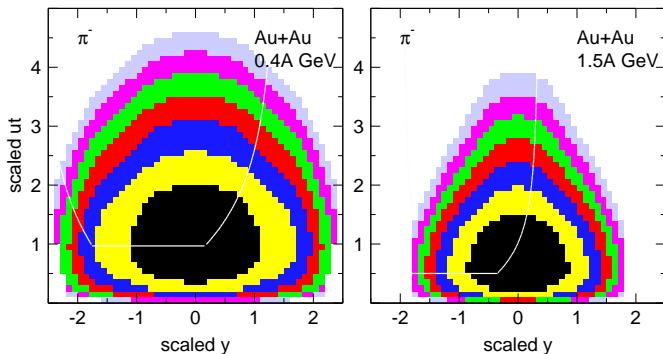


Fig. 1. π^- multiplicity distributions for central collisions of Au+Au at 0.4A (left) and 1.5A GeV. The transverse 4-velocities u_t (ordinates) and the rapidities (abscissa) are in (beam-) scaled units. The contours differ by a factor 1.5, the represented area accounts for 96% of the total yields (2.9 ± 0.4 , resp. 35 ± 4).

As shown in companion reports [2], the FOPI collaboration has been able in the last years to gather rather convincing evidence that 2d-momentum distributions in central collisions at SIS energies testify unequivocally that momentum space is not globally or even locally 'equilibrated'. Since the high energy statistical approaches are dominated by the yields of matter *created* in the collisions, we have undertaken efforts to assess the equilibration (in momentum space) of pions. At SIS energies created matter is a perturbative probe of the collision dynamics: even in the upper SIS energy range only about 10% of the available energy is carried by pions (other created particles do not play a role in the energy balance).

Fig. 1 shows the scaled 2-dimensional momentum distribution of π^- mesons emitted in central ($\hat{b} < 0.15$) collisions of Au+Au at 0.4A and 1.5A GeV. Although FOPI covers a large part of 4π , we have used reflection symmetry and extrapolation to obtain the complete picture. The apparatus limits, constrained essentially to the backward hemisphere and to transverse momenta $p_t > 63$ MeV/c,

are given in the figure. At 0.4A GeV (1.5A GeV) the extrapolated part represents 33% (25%) of the total yields. Note that in this scaled diagram the distributions extend far beyond the target (-1) and projectile (+1) rapidities, particularly at the lower beam energy. At both energies we see a midrapidity source suggesting to the naive observer a high degree of 'thermalization', perhaps broadened somewhat by 'flow'. Since pions are very light particles it is difficult to accurately assess the 'flow'/'thermal' fraction.

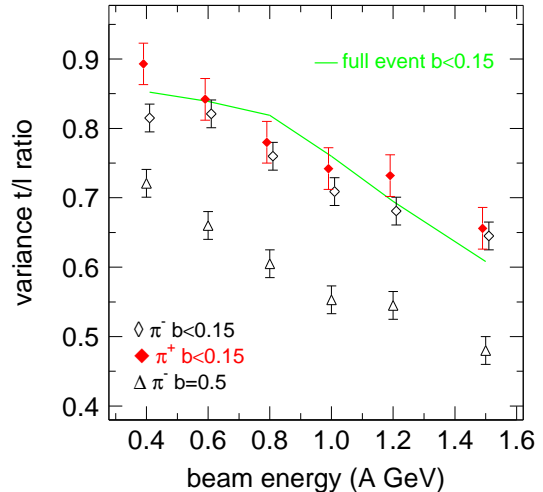


Fig. 2. Excitation functions for the ratio of variances ($var_{t/l}$) of the transverse and longitudinal rapidity distributions. Full diamonds: π^+ , central. Open diamonds: π^- , central. Open triangles: π^- , semi-central. The solid curve is for baryonic matter. While the overall systematic errors are estimated to be 15%, the indicated point-by-point errors are smaller.

Less model-dependent insight can be gained by studying the excitation function and centrality dependence of the ratio $var_{t/l}$ of the variances of the transverse to that of the longitudinal rapidity, as shown in Fig. 2. We find that a) $var_{t/l}$ is similar for π^+ and π^- mesons and is significantly below unity; b) in the energy range studied it decreases with increasing energy; c) it follows closely the values found for (preexisting) baryonic matter [2]; d) it is significantly lower when switching to smaller 'fireballs' by choosing less central ($\hat{b} = 0.5$) collisions. While our studies of baryonic matter suggested that two counter-flowing 'fluids' still partially survive in this energy regime [2], this report suggests that created matter is not a separate third fluid, but rather follows to a large degree the non-equilibrium features of the two 'parent' fluids.

References

- [1] P. Braun-Munzinger *et al.* Phys. Lett. B **365**, 1 (1996); **465**, 15 (1999); **518**, (2001)
- [2] W. Reisdorf *et al.*, Hong *et al.*, this Report