MICHIGAN STATE UNIVERSITY

CYCLOTRON LABORATORY

NON STATISTICAL NATURE OF THE TRANSVERSE MOMENTUM SPECTRUM IN ULTRARELATIVISTIC HEAVY ION COLLISIONS

H.W. BARZ, G. BERTSCH, D. KUSNEZOV and H. SCHULZ

JULY 1990

MSUCL-736

MSUCL-736
July, 1990

NON STATISTICAL NATURE OF THE TRANSVERSE MOMENTUM SPECTRUM IN ULTRARELATIVISTIC HEAVY ION COLLISIONS

H. W. BARZ[a], G. BERTSCH, D. KUSNEZOV AND H. SCHULZ[a]

NSCL and Department of Physics, Michigan State University,
East Lansing, *MI 48824-1321*
[a] *Zentralinstitut für Kernforschung, Rossendorf, DDR-8051 Dresden, Germany*

ABSTRACT

We examine the role of decays of excited hadrons in shaping the transverse momentum spectrum of pious in ultrarelativistic heavy ions collisions. No reasonable statistical model can reproduce the experimentally observed peak in the spectrum at low transverse momentum.

A striking difference has been observed in the pion spectrum produced by nuclear collisions as compared to nucleon-nucleon collisions at ultrarelativistic energy, namely an enhancement of low-transverse momentum pions in nuclear collisions [1,2] . The origin of this puzzling phenomenon, which accounts for roughly 30% of the observed pions, is vigorously debated in the literature [3-9]. Atwater et al. [5] and Lee and Heinz [6] interpreted the additional peaking in the pion spectrum as a collective flow effect. However Kusnezov and Bertsch [7] pointed out that a covariant treatment of the freezeout surface gives a convex shaped spectrum and cannot account for the experimentally observed behaviour at low $p_\perp$. Shuryak has explored the change of the pion dispersion relation in the medium in connection with the cool component of the pion spectrum [4]. Kataja and Ruuskanen [8] fit the spectrum by assuming that the pions are strongly out of chemical equilibrium. Brown et al. [9] pointed out that at temperatures of the order $\sim 150 - 200\,MeV$ the excited states of the hadrons have to be taken into account, since the pions originating from the decay of the excited baryon states may increase the total pion yield at low $p_\perp$ values and in this way may explain the observed peak structure.

In this note we wish to examine this idea in more detail. Parenthetically, we mention that in low energy nuclear collisions, decays of excited nuclei lower the visible temperatures of products in the final state [10] . We consider here an initial state that is some statistical mixture of light quark mesons and baryons. We limit the mesons to the $q\bar{q}$ states with zero orbital momentum: the π, ρ, ω, and η mesons.

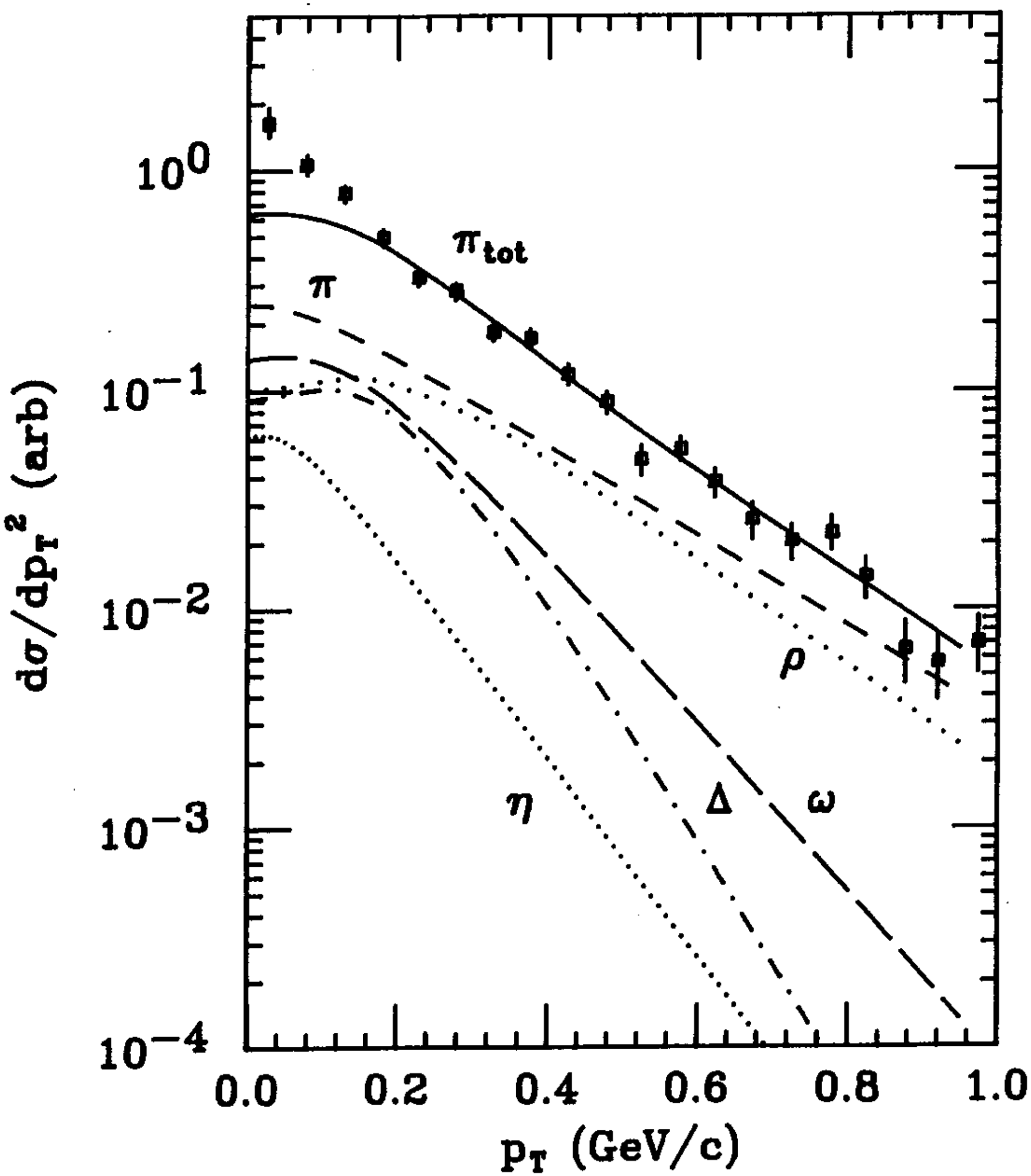
Two extreme statistical models can be imagined. In the first model, the hadronic abundances are calculated by assuming chemical equilibrium. Then the meson abundances are determined by a single parameter, the temperature. One additional parameter, the baryon abundance, specifies the model completely. In the second model, we assume that the mesons have the statistical weights associated with their spin and isospin degeneracies. That is, the mesons are formed in the ratio $\pi : \rho : \omega : \eta \sim 3 : 9 : 3 : 1$. This model is suggested by string abundance is chosen as one baryon for every 5 final state pions. This is the approximate ratio of participant nucleons, calculated by a geometric overlap, to the observed final state pions in collisions of O+Au or S+S. One sees that for low momenta all hadrons under consideration give approximately the same contribution to the total pion yield. The η mesons give an insignificant contribution in the π^- yield, but would be somewhat more important in the π^0 spectrum, because they decay preferentially to π^0 channels. However all the pions originating from the hadronic decays do not produce a peaking of the spectrum at low momenta. The shape of the Δ spectrum is flat at low momentum, so it does not seem possible that any admixture of baryons could explain the data. For momenta $p_\perp > 0.2\,GeV/c$ most of the secondary pions come from ρ meson decay. Their yield is almost comparable with that of the primordial pions.

In fig. 2 we show the corresponding results under the assumption that the primordial hadrons have abuadances given by their statistical weights. This spectrum is practically indistinguishable from the result of the equilibrium model. The experimental spectrum is again well reproduced at high transverse momentum. In this model, more pions come from decays of ρ mesons than from any other single source. The η meson has only negligible contribution to the overall π^- spectrum. However, since 32% of the width of the η decays through the $3\pi^0$ channel, the contribution of the η in the π^0 spectrum would exceed that of the primordial pions. Again, the baryon component is incapable of significantly altering the shape of the spectrum.

Although we have considered a longitudinally boost invariant scenario, this actually provides for more low $p_\perp$ peaking than non-boost invariance. By shifting η to $(\eta - y)$ in Eq. (2) and multiplying the resulting integrand by the longitudinal rapidity distribution $\exp(-(\eta-\eta_0)^2/2\sigma^2)$, we can obtain the non-invariant modification to Eq. (3). The resulting distributions are typically found to enhance the transverse spectrum at $p_\perp \sim m'$, where m' is the mass of the decaying resonance that produces pions, over the value at $p_\perp = 0$. By neglecting this longitudinal shape ($\sigma \gg 1$), the enhancement is smoothed out, further peaking the low $p_\perp$

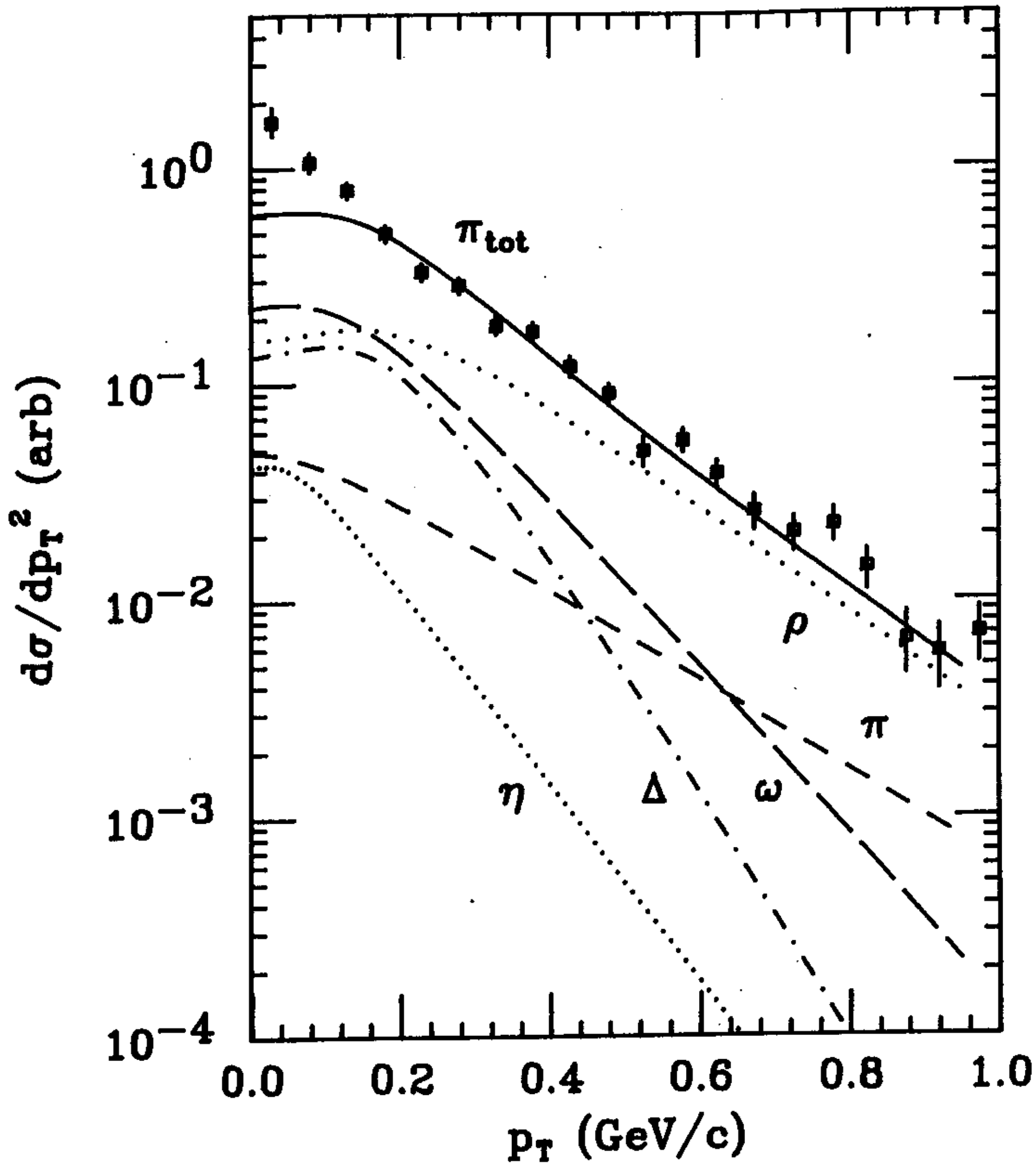
REFERENCES

1. J.W. Harris for the NA38 collaboration, Nucl. Phys. A498 (1989) 133
2. The NA35 collaboration: H.Stroebele et al., Z. Phys. C38 (1988) 89
3. E. Shuryak, Phys. Lett. 27B (1988) 345
4. E. Shuryak, preprint BNL-44522 (1990)
5. T.W. Atwater, P.S. Freier and J. Kapusta, Phys. Lett. 199B (1987) 30
6. K.S. Lee and U. Heinz, Z. Phys. C43 (1989) 425
7. D. Kusnezov and G.F. Bertsch, Phys. Rev. C40 (1989) 2075
8. M. Kataja and P.V. Ruuskanen, Phys. Lett. B243 (1990) 181
9. G.E. Brown, J. Stachel and G.M. Welke, in preparation
10. C.K. Gelbke and D. Boal, Prog. Part. Nucl. Phys. 19 (1987) 33



dσ/dp_T² (arb)
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
0.0
0.2
0.4
0.6
0.8
1.0
p_T (GeV/c)
π_tot
π
ρ
η
Δ
ω

FIGURE 1



dσ/dpT² (arb)
10⁰
10⁻¹
10⁻²
10⁻³
10⁻⁴
πtot
ρ
π
η
Δ
ω
0.0
0.2
0.4
0.6
0.8
1.0
pT (GeV/c)

FIGURE 2