Charged hadron transverse momentum distributions in Au+Au collisions at $\sqrt{s_{_{NN}}} = 200$ GeV

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We present transverse momentum distributions of charged hadrons produced in Au+Au collisions at $\sqrt{s_{_{NN}}} = 200$ GeV. The evolution of the spectra for transverse momenta p_T from 0.25 to 5 GeV/C is studied as a function of collision centrality. We find a significant change of the spectral shape between proton-antiproton and peripheral Au+Au collisions. When comparing peripheral to central Au+Au collisions, we find that the yields at the highest p_T exhibit approximate scaling with the number of participating nucleons, rather than scaling with the number of binary collisions.

In this paper, the yield of charged hadrons produced in collisions of gold nuclei at an energy of $\sqrt{s_{_{NN}}} = 200$ GeV is presented as a function of collision centrality and transverse momentum p_T. The data were taken with the PHOBOS detector [1,2] during the second run of the Relativistic Heavy-Ion Collider (RHIC) at the Brookhaven National Laboratory. In the theoretical analysis of particle production in hadronic and nuclear collisions, a distinction is often made between the relative contributions of "hard" parton-parton scattering processes and "soft" processes. Hard processes are expected to contribute an increasingly larger fraction of particle production with increasing collision energy and at higher p_T of the produced particles.

Collisions of heavy nuclei offer ideal conditions to test our understanding of this picture, as "hard" processes are expected to scale with the number of binary nucleon-nucleon collisions N_{coll}, whereas "soft" particle production is expected to exhibit scaling with the number of participating nucleons N_{part}. In the Glauber picture of nuclear collisions, N_{coll} approximately scales as $(N_{part})^{4/3}$. For central collisions of Au nuclei, one therefore obtains an increase in the ratio of $N_{coll}/(N_{part}/2)$ by a factor of six, relative to proton-proton collisions.

In Fig. 1 we present the invariant cross-section of charged hadrons as a function of transverse momentum for particles with a rapidity of $0.2 < y_\pi < 1.4$ assuming the pion mass for calculating y_π. The cross-sections were corrected for the geometrical acceptance of the detector, the reconstruction efficiency, the distortion due to binning and momentum resolution, "ghost" tracks, secondaries and weak decays [3,4].

Data are shown for 6 centrality bins, with $65 < \langle N_{part} \rangle < 344$ corresponding, in the Glauber picture, to $107 < \langle N_{coll} \rangle < 1050$. The increase with centrality of the integrated yields, over the studied centrality range, is consistent with the centrality evolution of the mid-rapidity particle density presented in [5].

The top left panel in Fig. 2 shows the ratio of the most peripheral bin ($\langle N_{part} \rangle = 65 \pm 4$) divided by $\langle N_{part}/2 \rangle \times f(p_T)$, where $f(p_T)$ is a fit of the invariant cross-section in proton-antiproton collisions at the same energy [6]. This comparison shows that already in Au+Au collisions with an impact parameter of about 10 fm, the spectral shape is dramatically modified relative to that in $p + \bar{p}$ collisions. It is worth noting that the ratio $\langle N_{coll} \rangle / \langle N_{part}/2 \rangle$ increases by a factor of about three from $p + \bar{p}$ to peripheral Au+Au collisions. The other panels in Fig. 2 show the evolution of same ratio upto the most central bin ($\langle N_{part} \rangle = 344 \pm 12$). We observe only a moderate change in spectral shape, relative to $p + \bar{p}$, when going from peripheral to central events.

Fig. 3 shows the evolution of the spectra with centrality. The spectra, normalized by $\langle N_{part}/2 \rangle$, in the six centrality bins have been divided by a fit to the normalized spectrum measured in the most peripheral bin. The centrality range in the Au+Au collisions covers a change in $\langle N_{coll} \rangle / \langle N_{part}/2 \rangle$ by about a factor of two. It is remarkable that the change in spectral shape over this range of centralities is small compared to that between peripheral Au+Au collisions and $p + \bar{p}$ collisions. In particular at high p_T, above 3 GeV/c, the yields scale to a good approximation as $\langle N_{part}/2 \rangle$ as a function of centrality.

Fig. 4 shows the scaling behaviour of the charged hadron relative yields in Au+Au and $p+\bar{p}$ collisions for different values of p_T. The yields were determined by interpolating the data shown in Fig. 1 using power law fits.

The observed trends can be contrasted with the expectation that particle production should be characterized by a change from $\langle N_{part} \rangle$ scaling at low p_T to $\langle N_{coll} \rangle$ scaling at high p_T. No corresponding increase in particle production per participant at $p_T = 3$ GeV/c and above is observed. Rather, the yields in this region scale approximately with the number of participating nucleons. Upcoming studies of d+Au collisions at RHIC will provide further insight into the modification of particle spectra in a nuclear environment.

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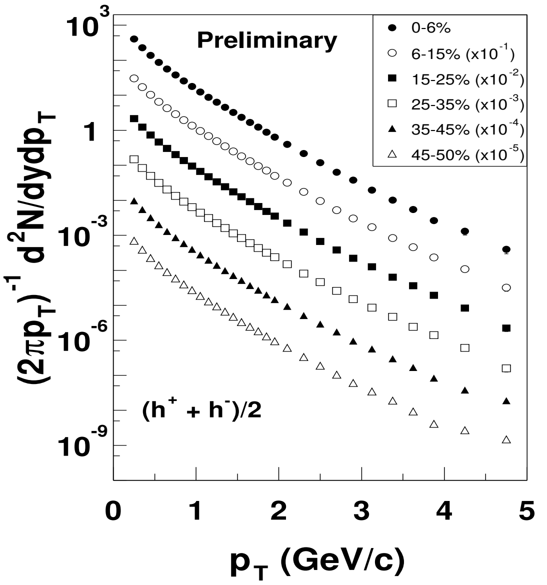

Figure 1. Invariant yields for charged hadrons as a function of p_T for 6 centrality bins. For clarity, consecutive bins are scaled by factors of 10.

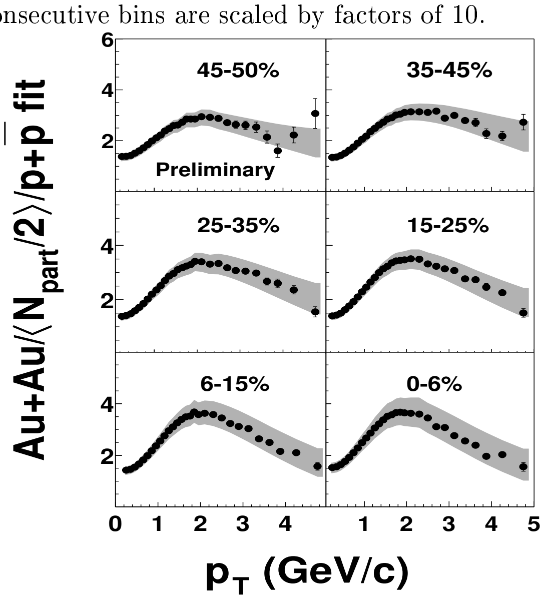

Figure 2. Ratio of the yield of charged hadrons in Au+Au collisions to a fit of proton-antiproton data scaled by $\langle N_{part}/2\rangle$ as a function of p_T.

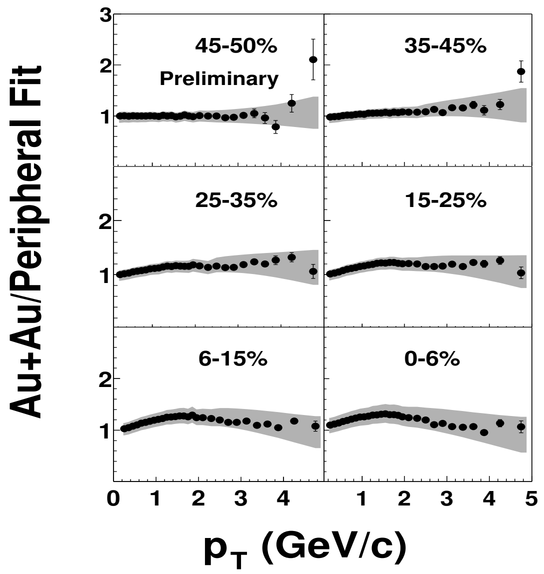

Figure 3. Charged hadron yield in Au+Au in six centrality bins, divided by a fit to the most peripheral bin and scaled by $\langle N_{part}/2\rangle$.

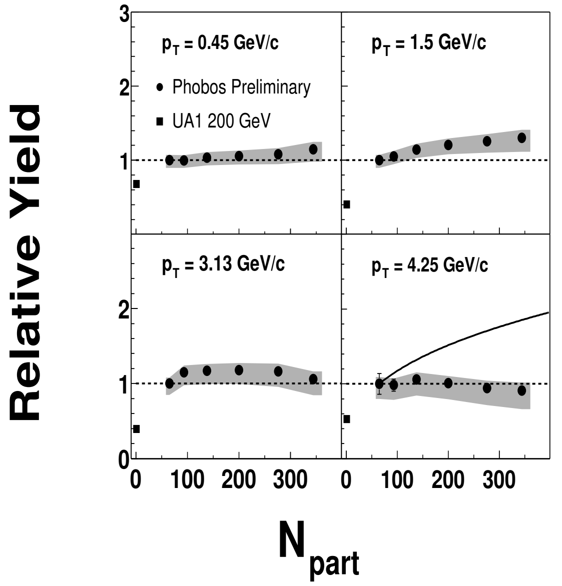

Figure 4. Charged hadron yield in Au+Au, normalized to the average yield in the 6 centrality bins, as a function of N_{part} at different p_T. The solid line in the right bottom panel shows the expectation from $\langle N_{coll}\rangle$ scaling.