CENTRALITY DEPENDENCE OF NEUTRAL PION PRODUCTION IN 158 A·GeV ^{208}Pb+^{208}Pb COLLISIONS

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The measured WA98 neutral pion spectrum from central Pb+Pb reactions (10% of min. bias cross section) as a function of $m_T - m_0$ is shown in Fig. 1. The data are compared to predictions of the string model Monte Carlo generators FRITIOF 7.02 [1] and VENUS 4.12 [2]. As already observed in S+Au reactions [3], both generators fail to describe the data well at large m_T. The FRITIOF prediction is more than an order of magnitude lower at high m_T while VENUS significantly overpredicts the data. Alternatively, it has recently been shown that perturbative QCD calculations, including initial state multiple scattering and intrinsic p_T [4], are able to describe the preliminary WA98 data at intermediate and high p_T. This prediction is included in Fig. 1 as a solid line. The pQCD calculation shows a very good agreement in the high m_T region. This surprising agreement has been interpreted as an indication for unexpectedly small effects of parton energy loss [4].

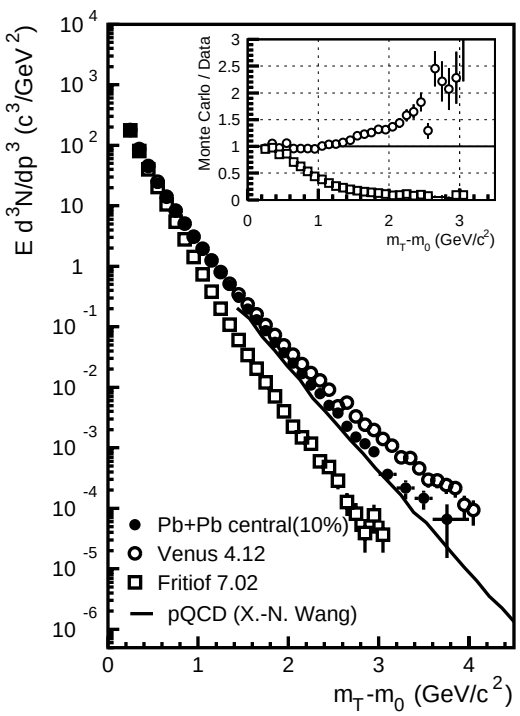

Figure 1: Transverse mass spectra of neutral pions in central collisions of 158 A·GeV Pb+Pb. Invariant yields per event are compared to calculations using the FRITIOF 7.02 [1] and VENUS 4.12 [2] Monte Carlo programs. Predictions of a pQCD calculation [4] are included as a solid line. The inset shows the ratios of the results of the Monte Carlo codes to the experimental data.

In order to demonstrate a consistent description of nuclear effects, it is important to investigate the details of the pion production as a function of the system size. To study the

centrality dependence of the spectral shape in a manner which is independent of model or fit function, we have used the truncated mean transverse momentum $\langle p_T(p_T^{min})\rangle$, where

$$\langle p_T(p_T^{min})\rangle = \left(\int_{p_T^{min}}^{\infty} p_T \frac{dN}{dp_T} dp_T \Big/ \int_{p_T^{min}}^{\infty} \frac{dN}{dp_T} dp_T \right) - p_T^{min}. \quad (1)$$

The lower cutoff $p_T^{min} = 0.4$ GeV/c is introduced to avoid systematic errors from extrapolation to low p_T and has been chosen according to the lowest p_T of the present data where systematic uncertainties imposed by the necessary corrections are still small.

Figure 2 shows $\langle p_T(p_T^{min})\rangle$ as a function of the average number of participants N_{part} for 158 A·GeV ^{208}Pb+Pb collisions. For comparison, $\langle p_T(p_T^{min})\rangle$ values for 200 A·GeV S+Au [3] and from a parametrization of pp data [5] are also included. N_{part} is extracted by the assumption of a monotonic relation between impact parameter and transverse energy and using the resulting correspondence between measured cross section and impact parameter. The average number of participants is calculated from nuclear geometry using the extracted impact parameter. Together these data show the general trend of a rapid increase of $\langle p_T(p_T^{min})\rangle$ compared to pp results for small system sizes. For N_{part} greater than about 30, the mean transverse momentum appears to attain a limiting value of $\approx 280\,\mathrm{MeV}/c$. Venus 4.12 [2] calculations show a qualitatively similar behavior, although the values of $\langle p_T(p_T^{min})\rangle$ are somewhat lower than the experimental data.

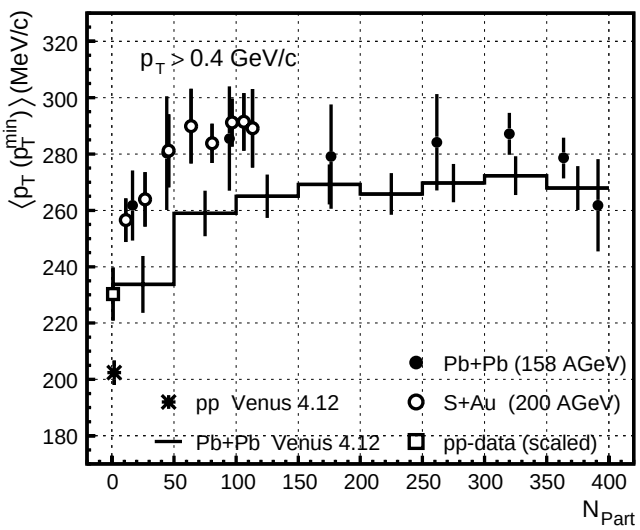

Figure 2: Truncated mean transverse momentum $\langle p_T(p_T^{min})\rangle$ of π^0 mesons as defined by Eq. 1 plotted as a function of the average number of participants N_{part}. The solid circles correspond to the 8 E_T based centrality selections for Pb+Pb. The open square shows $\langle p_T(p_T^{min})\rangle$ extracted from a parametrization of pp data scaled to the same cms-energy [5], the open circles the results for S+Au collisions at 200 A·GeV [3]. For comparison, results from Venus 4.12 [2] are included as histograms for Pb+Pb collisions and as a star for pp. A cut parameter $p_T^{min} = 0.4\,\mathrm{GeV}/c$ was used.

More detailed information about the centrality dependence of the pion spectral shape and yield is shown in Fig. 3 where the neutral pion yield per event has been parameter-

ized as $Ed^3N/dp^3 \propto N_{part}^{\alpha(p_T)} \cdot \sigma_0(p_T)$. The results for $N_{part} > 30$ are well described by this scaling with an exponent $\alpha(p_T) \approx 1.3$, independent of p_T. Consistent with the previous discussion, the results indicate a constant spectral shape over the entire interval of measurement from $0.5 < p_T < 3$ GeV/c. The observed $N_{part}^{4/3}$ scaling for symmetric systems implies a scaling with the number of nucleon collisions, as confirmed by a similar analysis. However, this scaling does not extrapolate from the pp results. On the contrary, when comparing semi-peripheral Pb+Pb collisions with pp, the exponent α varies over the entire p_T interval, confirming the very different spectral shapes.

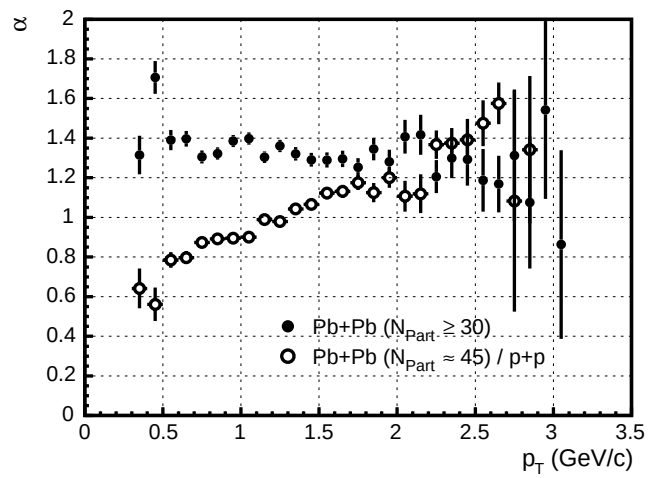

Figure 3: The exponent $\alpha(p_T)$ of the dependence of the π^0 yield on the average number of participants N_{part} plotted as a function of the transverse momentum for 158 A·GeV Pb+Pb. The solid circles are calculated based on a fit to the centrality selections with $N_{part} \geq 30$. The open circles are calculated based on the ratio of the semi-peripheral data ($N_{part} \approx 45$) to a parameterization of pp data.

In summary, we have analyzed the centrality dependence of high precision transverse momentum spectra of neutral pions from 158 A·GeV Pb+Pb collisions. The neutral pion spectra are observed to show increasing deviation from pp results with increasing centrality, indicating the importance of multiple scattering effects. However, for centralities with more than about 30 participating nucleons, the shape of the transverse momentum spectrum becomes invariant over the interval $0.5 < p_T < 3$ GeV/c. In this interval the pion yield scales like $N_{part}^{1.3}$, or like the number of nucleon collisions, for this range of centralities. Since the amount of rescattering increases with centrality, the invariance of the spectral shape with respect to the number of rescatterings most naturally suggests a dominantly thermal emission process. It will be important to determine whether cascade models which reproduce the observed invariant spectral shape will support the interpretation as an "effective" thermalization due to significant rescattering.

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