

Are High- p_T Pions Suppressed in Pb+Pb Collisions at $\sqrt{s_{NN}} = 17.3$ GeV?

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Abstract. Transverse momentum spectra of neutral pions in the range $0.7 < p_T < 3.2$ GeV/ c have been measured at $2.3 \lesssim \eta \lesssim 3.0$ by the WA98 experiment in p+C and p+Pb collisions at $\sqrt{s_{NN}} = 17.3$ GeV. Scaled by the number of nucleon-nucleon collisions (N_{coll}) the π^0 yields in p+C and p+Pb at $p_T \approx 2.0$ – 2.5 GeV/ c are higher than the respective yields in central Pb+Pb collisions with $N_{part} \gtrsim 300$. This observation is qualitatively consistent with expectations from parton energy loss.

1. Introduction

The suppression of high- p_T hadrons observed at RHIC in central Cu+Cu and Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV is most naturally explained by jet-quenching models which attribute the suppression to parton energy loss in a quark-gluon plasma (QGP). With the aid of these models the strength of the suppression can be related to medium properties such as the initial gluon density. The dependence of the hadron suppression on the transverse momentum (p_T) of the produced particles and on the centrality of the collisions was studied at RHIC. However, not much is known about the dependence on the center-of-mass energy ($\sqrt{s_{NN}}$) of the collision. In particular, it is an open question whether jet-quenching plays a role in Pb+Pb collisions at the CERN SPS energy of $\sqrt{s_{NN}} = 17.3$ GeV [1, 2].

In central Pb+Pb collisions at $\sqrt{s_{NN}} = 17.3$ GeV the initial energy density as estimated from the measured transverse energy is above the critical value $\varepsilon_c \approx 0.7$ GeV/fm³ for the transition to the QGP [3]. Thus, it is reasonable to expect that high- p_T particle production is affected by the created medium. The problem at the CERN SPS energy is that p+p reference data are not available. Therefore, different p+p parameterizations have been employed to study nuclear effects in Pb+Pb collisions [1, 4]. Moreover, hadron suppression due to parton energy loss might be compensated by an enhancement due to initial state multiple soft scattering of the incoming partons (“nuclear k_T -enhancement”), an effect which is expected to be stronger at $\sqrt{s_{NN}} = 17.3$ GeV than at $\sqrt{s_{NN}} = 200$ GeV [2, 5].

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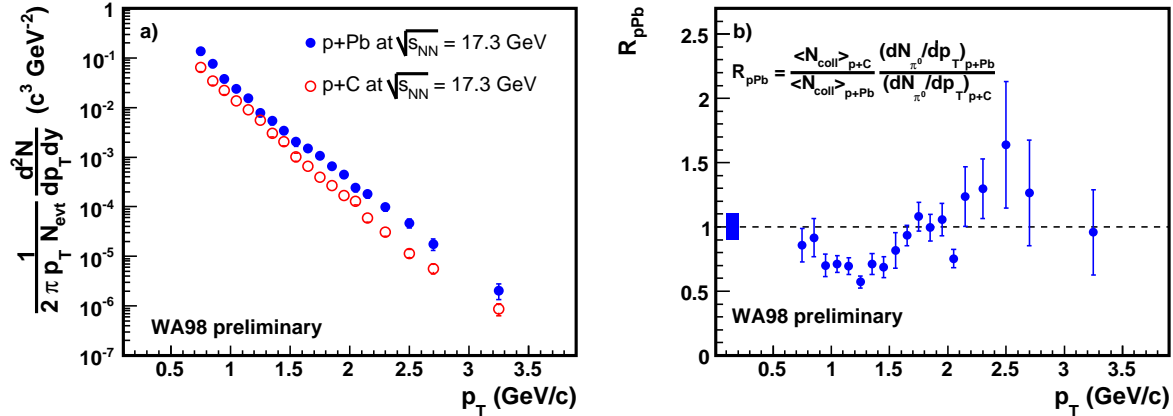


Figure 1. a) Invariant neutral pion yield in minimum bias p+C and p+Pb collisions. b) Ratio p+Pb/p+C of the π^0 yields normalized to the respective N_{coll} values.

The WA98 collaboration has measured the centrality dependence of neutral pion production in Pb+Pb collisions at $\sqrt{s_{NN}} = 17.3 \text{ GeV}$ in the range $0.5 \lesssim p_T \lesssim 4 \text{ GeV}/c$ [4]. Here, we present data on neutral pion production in p+C and p+Pb collisions at the same energy which were taken in 1996. The p+C π^0 spectrum can be used as a replacement for a p+p reference since the nuclear k_T -enhancement is expected to be small [5]. By comparing the π^0 production in p+C and p+Pb collisions one can study the strength of the nuclear k_T -enhancement at the CERN SPS energy. Finally, by using the p+Pb spectrum as a reference for the Pb+Pb data it is expected that the nuclear k_T -enhancement in Pb+Pb is partially cancelled by the enhancement in p+Pb so that possible effects of parton energy loss can be seen more clearly.

2. Results

In the WA98 experiment π^0 yields were measured by detecting photons from the decay $\pi^0 \rightarrow \gamma\gamma$ with a highly-segmented lead glass calorimeter. This detector was located 21.5 m downstream of the target and subtended the pseudorapidity range $2.3 \lesssim \eta \lesssim 3.0$. The measurement of the transverse energy (E_T) with a hadronic calorimeter in the range $3.5 \lesssim \eta \lesssim 5.5$ provided the minimum bias trigger. The measured minimum bias cross section σ_{mb} for p+C (p+Pb) of 170 mb (1341 mb) corresponds to 74 % (76 %) of the total geometric cross section. A p_T reach of the π^0 spectra in p+C and p+Pb comparable to that in Pb+Pb could only be achieved by employing a high-energy photon (HEP) trigger based on the energy signal seen by the lead glass calorimeter.

The fully corrected invariant π^0 yields in p+C and p+Pb collisions at $\sqrt{s_{NN}} = 17.3 \text{ GeV}$ are shown in Figure 1a. For both spectra the transition between the minimum bias and the HEP sample takes place at $p_T = 1.7 \text{ GeV}/c$. Figure 1b shows the ratio of the π^0 spectra where each spectrum was normalized to the number of binary nucleon-nucleon collisions. A Glauber Monte Carlo calculation with a nucleon-nucleon inelastic cross section of $\sigma_{\text{inel}}^{\text{NN}} = 32 \text{ mb}$ yields $\langle N_{\text{coll}} \rangle_{\text{p+C}} = 1.7 \pm 0.2$ and $\langle N_{\text{coll}} \rangle_{\text{p+Pb}} = 4.2 \pm 0.4$.

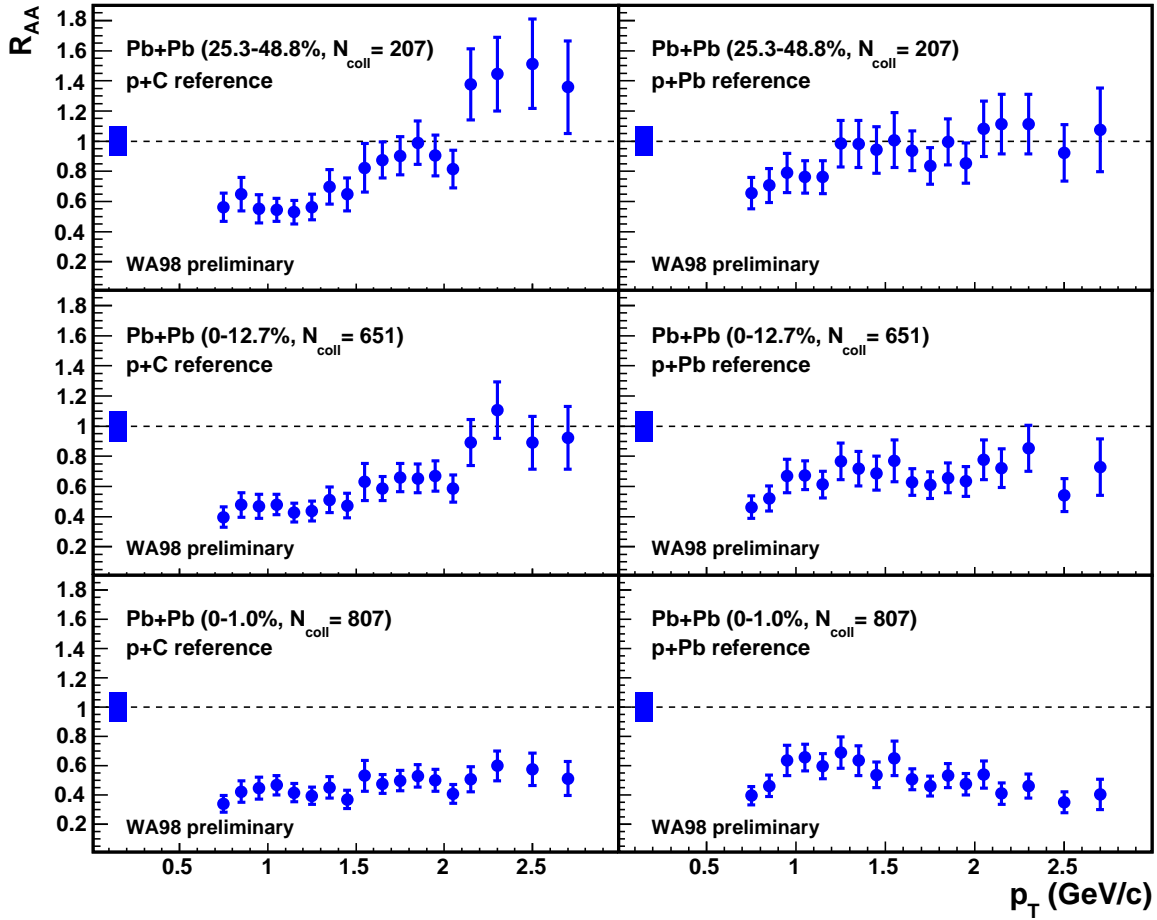


Figure 2. Nuclear modification factor R_{AA} for three Pb+Pb centrality classes with p+C (left panel) and p+Pb (right panel) data as reference. The boxes indicate the uncertainty of the ratio $\langle T_{p+B} \rangle / \langle T_{Pb+Pb} \rangle$.

The centrality bias due to the minimum bias trigger was taken into account in the calculation. Consistent with the expectation of a stronger nuclear k_T -enhancement for heavier nuclei the π^0 spectrum in p+Pb appears to be slightly flatter than in p+C.

A possible suppression of high- p_T π^0 's in Pb+Pb collisions can be quantified with a nuclear modification factor defined as

$$R_{AA} = \frac{\langle T_{p+B} \rangle}{\langle T_{A+A} \rangle} \frac{dN_{\pi^0}/dp_T|_{A+A}}{dN_{\pi^0}/dp_T|_{p+B}} \quad (1)$$

where $\langle T_{X+Y} \rangle = \langle N_{coll} \rangle_{X+Y} / \sigma_{inel}^{NN}$. In the absence of nuclear effects R_{AA} is expected to be unity for $p_T \gtrsim 2$ GeV/c where hard scattering is expected to dominate particle production. The $\langle N_{coll} \rangle$ values for Pb+Pb given in [4] were determined with the event generator VENUS by applying cuts to the simulated E_T corresponding to the same fraction of σ_{mb}^{Pb+Pb} as the cuts applied to the measured E_T . The simulated E_T described the measured E_T well, including the fluctuations in central Pb+Pb collisions, [3] so that a centrality class corresponding to the 1% most central collisions was defined. By using $\langle T_{X+Y} \rangle$ in Eq. 1 the small difference between σ_{inel}^{NN} at $\sqrt{s_{NN}} = 17.3$ GeV used in VENUS

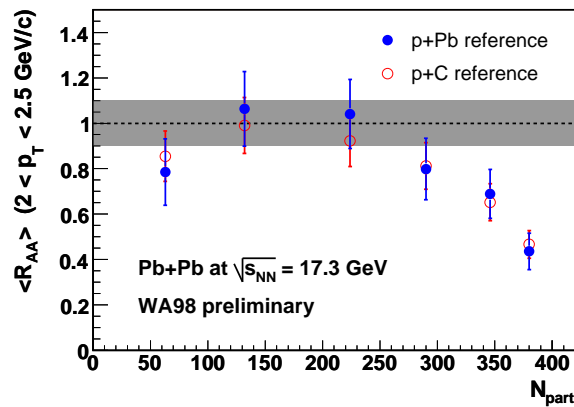


Figure 3. Centrality dependence of $\langle R_{AA} \rangle$ for Pb+Pb collisions at $\sqrt{s_{NN}} = 17.3$ GeV. $\langle R_{AA} \rangle$ was obtained by fitting $R_{AA}(p_T)$ with a constant at $2.0 < p_T < 2.5$ GeV/ c .

(29.6 mb) and in the Glauber Monte Carlo calculation for p+C and p+Pb (32 mb) does not affect R_{AA} .

Figure 2 shows that for semi-central Pb+Pb collisions (25.3 – 48.8% of σ_{mb}^{Pb+Pb}) R_{AA} is consistent with N_{coll} scaling for $p_T \gtrsim 2$ GeV/ c . A first indication of a suppression ($R_{AA} \approx 0.7$) is visible for the 12.7% most central Pb+Pb collisions using p+Pb data as reference. For the 1% most central Pb+Pb collisions a suppression is observed for the p+Pb reference as well as for the p+C reference. Moreover, a change of the shape of the π^0 spectrum for the 1% becomes visible. The centrality dependence of R_{AA} is shown in Figure 3. The suppression for $N_{part} \gtrsim 300$ appears to increase with centrality so that the approximate N_{coll} scaling for $50 \lesssim N_{part} \lesssim 300$ might well be due to a compensation of parton energy loss and nuclear k_T -enhancement.

3. Conclusions

Neutral pion spectra from p+C and p+Pb collisions at $\sqrt{s_{NN}} = 17.3$ GeV have been measured and were used as a baseline in the nuclear modification factor for Pb+Pb collisions at the same energy. Relative to N_{coll} scaling expected for hard processes in the absence of nuclear effects a suppression of π^0 yields for $p_T \gtrsim 2$ GeV/ c has been observed in central ($N_{part} \gtrsim 300$) Pb+Pb collisions. This observation is qualitatively consistent with models which assume parton energy loss at $\sqrt{s_{NN}} = 17.3$ GeV.

References

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