Neutral Pion Measurements in Polarized Proton Collisions from PHENIX at RHIC

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The Relativistic Heavy Ion Collider (RHIC) started operation as a polarized proton collider in December, 2001 with transverse-spin beams. This report presents the preliminary result for the absolute neutral pion production cross section at $\sqrt{s}=200$ GeV in the mid-rapidity region by the PHENIX experiment. We compare this result to the prediction of a next-to-leading order perturbative QCD calculation. The measurement of the neutral pion asymmetries in this run and in future runs are also discussed.

1. Introduction

During the 2001–02 run (run-2), the Relativistic Heavy Ion Collider (RHIC) was successfully operated for the first time as a proton collider at a center of mass energy ($\sqrt{s}$) of 200 GeV with transversely polarized beams. From the data collected by the PHENIX experiment [1], we report the spin-averaged neutral pion (π^0) cross section measurement at mid-rapidity [2] and compare it with a next-to-leading order (NLO) perturbative QCD calculation [3,4].

From this data sample, we also anticipate extracting a measurement of the single transverse-spin asymmetry (A_N) for neutral pions produced at $x_F \sim 0$ with p_T up to $\sim$8 GeV/c. Interest in this measurement arises from the observation of large ($\sim 30\%$) asymmetries in $p_{\uparrow}p \rightarrow \pi X$ at forward angles by the Fermilab E704 experiment [5] at $\sqrt{s}=19.4$ GeV. Such large asymmetries were surprising because, at leading order, pQCD predicted only small effects. Presently, it is recognized that it is possible to have large asymmetries due to for example, contributions from a twist-three effect [6] or time-reversal odd fragmentation functions [7].

In upcoming runs, the protons will be longitudinally polarized so that the gluon polarization ($\Delta g/g$) can be probed by measuring double longitudinal-spin asymmetries (A_{LL}). Since the acceptance of the PHENIX detector is limited, we intend to measure the asymmetry for neutral pions as an alternative to jets.

2. Experimental Procedure and Analysis Procedure

In run-2, the PHENIX experiment operated with two central arm spectrometers and one muon arm spectrometer. This work utilized the electromagnetic calorimeters (EMCal) in

Table 1
Summary of the p_T dependent systematic error; there is also a normalization error of 30% not noted here since it is independent of p_T.

correction term	source	estimate
raw yield of π^0	background subtraction	<5%
	hot/warm towers	2-3%
	run dependence	<10%(MB) <6%(EMCal)
π^0 acceptance, efficiency, and smearing correction	fast MC statistical error	<1%
	edge towers	<5%
	position resolution	0-1%
	energy absolute calibration	3-8%
	energy non-linearity	0-10%
	energy resolution	<3%
trigger efficiency correction	EMCal high p_T trigger threshold	<10%

the central arms, each of which has an azimuthal coverage of 90^0 and a pseudo-rapidity coverage of ±0.35, and other detectors for triggering. The EMCal consists of six lead scintillator sampling calorimeter (PbSc) sectors and two lead glass (PbGl) sectors. In this paper, we will report only the measurement done with five of the six PbSc sectors [2].

During the proton run in run-2, PHENIX recorded integrated luminosity of 0.15 pb^{-1}. For the central arm, these data were collected by using two triggers: the minimum bias (MB) trigger and the newly installed EMCal triggers. The sample at high p_T was collected with a coincidence between the MB trigger and one of the EMCal triggers, which consisted of EMCal tower sum trigger with an 0.8 GeV threshold.

The raw yield of neutral pions in each p_T bin was determined from the invariant mass distribution for two photon clusters. The acceptance, efficiency, and smearing correction was computed from a Monte Carlo simulation of the EMCal. For the EMCal trigger sample, the π^0 yield was corrected for the trigger efficiency. Using the MB dataset, the π^0 threshold curve in p_T was determined for the EMCal trigger and found to plateau at 80% above a p_T of $\sim$3 GeV/c. The bias for π^0 detection arising from the MB trigger condition was measured to be 75%, independent of p_T up to $\sim$5 GeV/c, by using the data sample collected with another one of the EMCal triggers which did not impose the MB requirement. This value was consistent with an estimate from a PYTHIA+GEANT simulation of the experiment and thus also used to correct the data at higher p_T.

The MB trigger efficiency of 51% was obtained from a PYTHIA+GEANT simulation of the experiment. Presently, we have assigned a normalization error of 30% based on the difference between the cross section measurement from van der Meer (vernier) scans and the total proton-proton cross section. We anticipate that this error will be reduced to $\sim$15% with further analysis.

3. Results and Discussion

Figure 1 shows the measured cross sections for the MB and the EMCal trigger samples along with the p_T dependent systematic error which are separately tabulated in Table 1. This result is compared with an NLO pQCD calculation [3] using the formalism

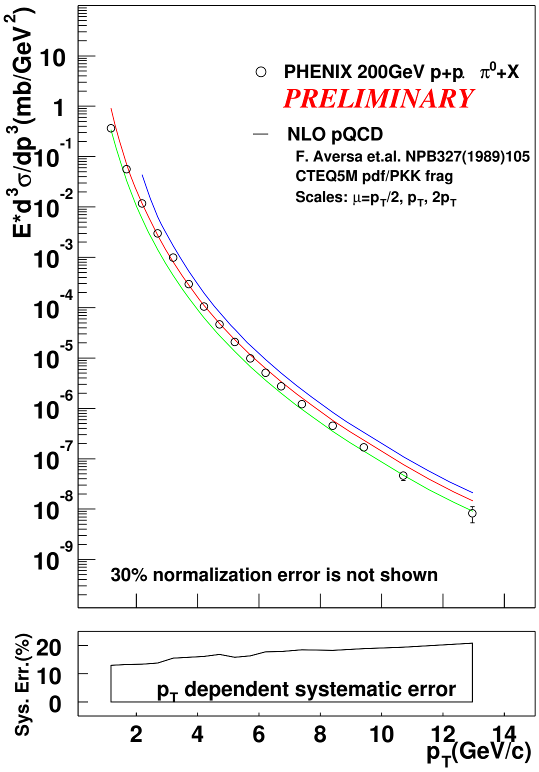

Figure 1. The inclusive neutral pion cross section. A comparison of the measurement with an NLO pQCD calculation using $p_T/2$ (top line), p_T (middle line), and $2p_T$ (bottom line) renormalization and factorization scales. The p_T dependent systematic error of the data is shown in the lower box of each panel.

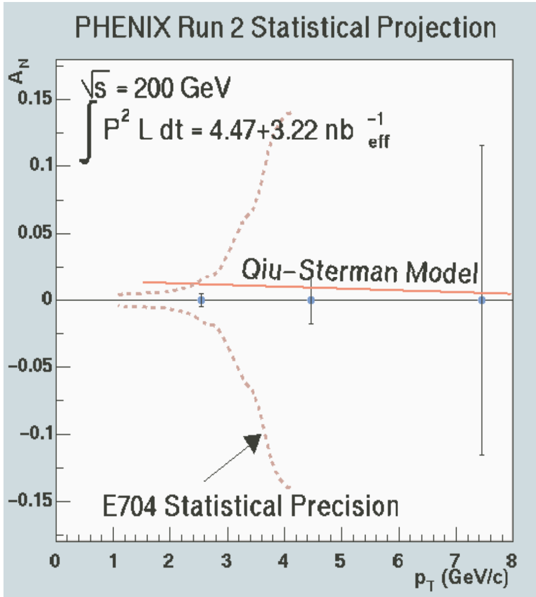

Figure 2. The expected precision for a measurement of A_N (points) in comparison to the precision of the E704 measurement (dashed line).

of F. Adversa *et al.* [4] with the CTEQ5M parton distribution functions [8] and the PKK fragmentation functions [9]. The data for the lower p_T range is shown from the MB trigger samples to avoid the larger systematic error of the EMCal trigger samples. Over the full p_T range, this calculation is consistent with our measurement within the systematic errors. This measurement provides a baseline for high p_T heavy-ion physics [10].

Since the protons were transversely polarized with, on average, 14% polarization in one beam and 17% in the other, we anticipate making a measurement of A_N. Figure 2 shows the statistical precision of such a measurement in comparison to the precision of the E704 result. The Qiu-Sterman model calculation on the figure was made with their code, although their model is not applicable in this kinematic region [6].

In the upcoming runs, we expect higher polarization of 50% and integrated luminosity of 3 pb^{-1} in run-3 (2003) and 30 pb^{-1} in run-4 (2004). Expectation of the non-zero A_{LL} measurement of neutral pions and charged hadrons is shown in Fig.3 and compared with predictions from NLO pQCD model calculations. When extracting $\Delta g/g$, all channels will be utilized.

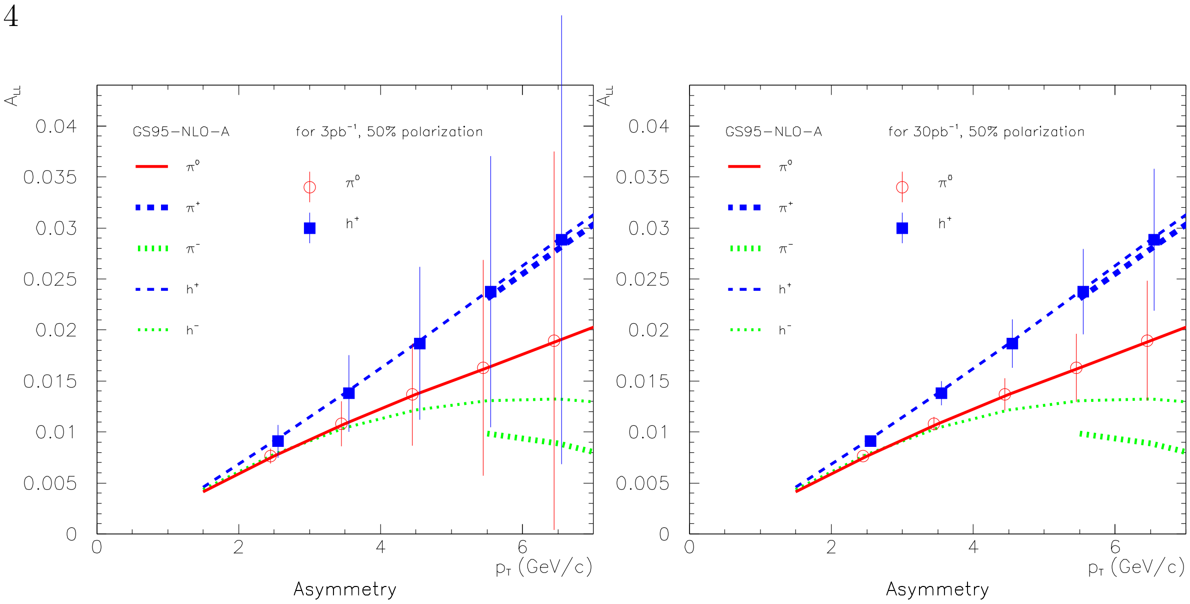

Figure 3. Expectation for the A_{LL} measurements of neutral pions and charged hadrons in run-3 (left) and run-4 (right).

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REFERENCES

1. D. P. Morrison, Nucl. Phys. A **638**, 565c (1998); J. T. Mitchell *et al.*, Nucl. Instrum. Meth. **A482**, 491 (2002).
2. H. Torii for the PHENIX Collaboration, Proceedings of the Quark Matter 2002, in press (nucl-ex/0210005).
3. Private communication with W. Vogelsang.
4. F. Aversa, P. Chiappetta, M. Greco and J.-Ph. Guillet, Nucl. Phys. **B327**, 105 (1989).
5. D. L. Adams *et al.*, Phys. Lett. **B264**, 462 (1991); Phys. Rev. **D53**, 4747 (1996).
6. J. W. Qiu and G. Sterman, Phys. Rev. **D59**, 014004 (1999).
7. M. Anselmino *et al.*, Phys. Rev. **D60**, 054027 (1999).
8. H. L. Lai *et al.*, Eur. Phys. Jour. **C12**, 375(2000).
9. B. A. Kniehl, G. Kramer and B. Potter, Nucl. Phys. **B582**, 514 (2000).
10. D. G. d'Enterria for the PHENIX Collaboration, Proceedings of the Quark Matter 2002, in press (hep-ex/0209051).