Abstract. In the RHIC run of 2006, PHENIX recorded data from about 20 \(nb^{-1}\) of transversely polarized \(p+p\) collisions at \(\sqrt{s} = 62.4\) GeV and polarization of about 50%. Also in this last run PHENIX successfully commissioned a new \(PbWO_4\) based electromagnetic calorimeter, the Muon Piston Calorimeter (MPC), covering \(2\pi\) in azimuth and \(3.1 < \eta < 3.7\). The forward coverage allows PHENIX to measure high \(x_F\) \(\pi^0\) production. We present the current status of the analysis for the single inclusive \(\pi^0\) transverse asymmetry \(A_N\) at forward rapidities in PHENIX.

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INTRODUCTION

Transverse single spin asymmetries in hadronic collisions have had a long history of surprises, such as the observation by the E704 collaboration of very large asymmetries in inclusive pion production at high \(x_F\) in \(\sqrt{s} = 19.4\) GeV transversely polarized \(p^+p\) collisions\([1, 2]\). Naively in leading twist perturbative QCD one expects these asymmetries to be power suppressed such that \(A_N \sim \alpha_S m_q / p_T\)\([3]\). It was thought that at higher energies these asymmetries would be strongly suppressed. Quite surprisingly, however, large asymmetries were discovered to persist even at collider energies by first STAR and then the Brahms collaboration\([4, 5]\).

These asymmetries are interesting because they point toward some new understanding of internal proton structure, such as the existence of a new non-perturbative function like the Sivers function\([6]\), or perhaps a non-zero transversity distribution in conjunction with a transversely dependent fragmentation function\([7]\) (Collins effect). Of particular interest is that these effects occur in a regime where NLO pQCD calculations correctly predict the unpolarized cross-sections. Therefore the hope is that one can understand these asymmetries unambiguously, such as with a higher twist expansion approach\([8, 9]\), or by taking into account the transverse motion of partons in a LO collinearly factorized approach with non-perturbative, transverse-momentum dependent functions\([10]\). Further progress in theoretical understanding requires more differential measurements such as the \(p_T\) and \(x_F\) dependence of the asymmetry, as well as di-hadron correlations\([11]\) to distinguish between the above approaches.

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MPC DATA ANALYSIS AND CURRENT STATUS

Before the 2006 run, PHENIX initiated a program to install a calorimeter inside the hole at the front of the muon magnet piston to extend the kinematic reach of PHENIX calorimetry to more forward rapidities. The muon piston holes are cylindrical with a depth of 43.1 cm and a diameter of 42 cm. The small size of the area, proximity to the interaction point, and sizable magnetic fields enforce tight constraints on the calorimeter’s design, requiring a compact material with short radiation length and small moliere radius and a readout that is insensitive to magnetic fields. PHENIX chose a design, based on that of the ALICE PHOS detector, of a highly segmented lead-tungstate crystal array with Avalanche Photodiode (APD) readout. Lead-tungstate is one of the best candidate materials for a compact calorimeter since it has one of the smallest radiation length (0.89 cm) and moliere radius (2.0 cm) of any known scintillator. PHENIX installed 192 crystals of size $2.2 \times 2.2 \times 18$ cm$^3$ in the south piston hole in time for the 2006 RHIC run. The calorimeter sits around the beam-pipe 223 cm from the interaction point and covers $3.1 < \eta < 3.7$. The layout of the south MPC is shown in figure 1. Another 220 crystals will be installed in the north piston hole for 2007. Further details on the MPC hardware can be found in the contribution of A. Kazantsev in these proceedings.

The data shown here were taken with the PHENIX detector at RHIC during two days of the 2006 $p^+p$ run, at a beam energy of $\sqrt{s} = 62.4$ GeV. A total integrated luminosity of $\sim 20$ nb$^{-1}$ of data were collected. The data are triggered with the MPC using 4x4 tower energy sums at a threshold of $\sim 5$ GeV, corresponding to good trigger efficiency for $\pi^0$ at $\sim 10$ GeV. An additional 80 nb$^{-1}$ of data were taken with longitudinally polarized beams at the same beam energy.

The MPC clustering algorithm is based on that developed for the PHENIX central arm calorimeter. In this algorithm the known shower shape from test-beam measurements is used to reconstruct the hit location and energy of photons when the two photons are separated enough to see two peaks. Alternative algorithms are being investigated which would have greater effectiveness at higher energies,

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2 This idea was first suggested by K. Imai and Y. Goto in 1996, and rediscovered recently. See http://www.phenix.bnl.gov/WWW/publish/goto/Polarimetry/pol1.html
where the probability for the two decay photons to merge within the same or adjacent towers is large, and it becomes difficult to separate one versus two photon showers. The algorithms are evaluated by simulation. In figure 2 the invariant mass distribution $m_{\gamma\gamma}$ of cluster pairs is shown, along with pairs generated for clusters from mixed events. Mixing clusters from different events provides an estimate of the combinatorial background. Note that a region in the lower right quadrant of the MPC was excluded in this plot due to issues with electronics noise. Currently, the energy scale has been checked with the MIP peak and $\pi^0$ peak and both have been found to be consistent to better than 10%.

The single transverse spin raw asymmetry as a function of $\phi$ was calculated using the square-root formula\cite{14, 15}

$$A(\phi) = \frac{1}{P_B} \varepsilon_N(\phi) = \frac{1}{P_B} \frac{d\sigma^\uparrow \phi - d\sigma^\downarrow \phi}{d\sigma^\uparrow \phi + d\sigma^\downarrow \phi} = \frac{1}{P_B} \frac{\sqrt{N_L^\uparrow \phi N_R^\downarrow \phi} - \sqrt{N_L^\downarrow \phi N_R^\uparrow \phi}}{\sqrt{N_L^\uparrow \phi N_R^\downarrow \phi} + \sqrt{N_L^\downarrow \phi N_R^\uparrow \phi}}$$

(1)

which largely cancels out differences in detector and beam asymmetries. $\phi$ is the azimuthal angle relative to the beam polarization direction, and $d\sigma^\uparrow \phi$ represents the cross-section into the $\phi$ direction for a vertically polarized beam with polarization $P_B$. The asymmetry $A_N$ is then the amplitude of this asymmetry modulation, $A(\phi) = A_N \sin(\phi)$.

In figure 3 we have plotted on the left (right) the raw asymmetry $\varepsilon_N(\phi)$ for photon pairs within the $\pi^0$ mass peak for the cases where the yellow (blue) beam is polarized. In PHENIX the yellow beam is the proton beam heading towards the MPC, and the blue beam is the one heading away.

3: Raw asymmetries from reconstructed photon pairs within $0.05 < m_{\gamma\gamma} < 0.25$ GeV and $9 < E_{\gamma\gamma} < 12$ GeV. The asymmetry has not been corrected for combinatoric background or beam polarization.

There is a non-zero asymmetry for the case where the yellow beam is polarized, corresponding to positive $x_F$ with respect to the polarized beam. This asymmetry has been seen to increase from low $x_F$ to higher $x_F$, and is well described by a $\sin(\phi)$ functional form. For the case of the polarized blue beam (corresponding to negative $x_F$) the asymmetry is consistent with zero. As an additional cross-check, the asymmetries were found to be consistent with zero for the longitudinally polarized runs, as expected since then the residual transverse polarization is small.
CONCLUSIONS AND FUTURE PLANS

PHENIX has successfully commissioned a new forward electromagnetic calorimeter, the south MPC, during the 2006 RHIC run, and plans to install the north MPC in time for 2007. With an early version of the clustering code, π0's have been identified in the MPC and a non-zero transverse asymmetry has been seen in p↑p collisions at √s = 62.4 GeV. Much work remains in improving the reconstruction code and in understanding any other artifacts of the data, such as noise issues, backgrounds, and improving the determination of the energy scale, before PHENIX can finalize the cross-section and asymmetry results from the MPC. The validity of a perturbative theoretical interpretation of this data-set is currently under study. It is known that NLO pQCD fails to correctly describe the inclusive cross-section correctly at these energies in the forward rapidities [16]. However, including threshold resummation should improve the agreement [17].

Besides the transversely polarized data at 62.4 GeV, PHENIX also collected 80 nb−1 of longitudinally polarized data at √s = 62.4 GeV and another 7.5 pb−1 of longitudinally polarized data at √s = 200 GeV during the 2006 run. The installation of the MPC allows PHENIX to confirm and contribute to previous measurements at high xF in RHIC collisions. Beyond mapping out the xF and pT dependence of AN, the high rate capabilities of the PHENIX DAQ will allow excellent triggering capability for di-hadron correlation measurements between forward π0 and mid-rapidity hadrons. Di-hadron measurements are particularly interesting since they should help to distinguish between an asymmetry from an initial state effect (Sivers) or a final state effect (Collins plus transversity). Additionally, di-hadron correlations constrain the kinematics of the initial scattered partons and therefore provide greater sensitivity to the sampled momentum fraction x of those partons.

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