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TRANSVERSE SPIN AT PHENIX AND FUTURE PLANS

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The PHENIX experiment took data with transversely polarized proton beams in 2001-2002 and measured the transverse single spin asymmetries in inclusive neutral pion and non-identified charge hadrons at midrapidity and $\sqrt{s}=200$ GeV. The data near $X_F \sim 0$ cover a transverse momentum range from 0.5 to 5.0 GeV/c. The observed asymmetries are consistent with zero with good statistical accuracy. This paper presents the current work in light of earlier measurements at lower energies in this kinematic region and the future plans of the PHENIX detector.

1. Introduction

Large transverse single spin asymmetries in $p\uparrow p$ collisions have been observed in a number of experiments at energies ranging from $\sqrt{s}=5$ -10 GeV. Asymmetries approaching 30% were observed in inclusive pion production at large x_F ^{1,2}. In the kinematic region at midrapidity at high x_T and p_T up to 2 GeV/c, large asymmetries were also observed in inclusive π^0 and π^+ production but not in π^- production^{3,4,5}. From the low energy data one could surmise that the asymmetries tend to grow and reach a maximum near the kinematic limits. At higher energies $\sqrt{s}$ of 20 and 200 GeV where pQCD is considered applicable, asymmetries at large x_F persisted^{6,7}, however, the asymmetry in π^0 production at midrapidity was found to be zero up to p_T of 4 GeV/c⁸.

The data presented here were collected by the PHENIX detector in 2001-2002 with RHIC running with transversely polarized proton beams at $\sqrt{s}=200$ GeV. At these energies the measured unpolarized cross sections at midrapidity were found to agree well with the NLO pQCD calculations¹³ providing confidence that perturbative calculations are applicable to the polarized data, Figure 1.

Figure 1. Invariant cross section vs. p_T . The curves represent NLO pQCD calculations.

2. The experimental set up and data analysis

The RHIC beams had 56 bunches each, an average intensity of $5 \cdot 10^{10}$ per bunch, and bunch polarization $+-+-$ and $++--$ in each beam respectively. A total of 0.15 pb^{-1} were accumulated. The average beam polarization was 15% as measured by the p-Carbon CNI polarimeters with an overall scale uncertainty of 35% most of which is attributed to the lack of analyzing power of the physics process⁹. The relative luminosity between bunch collisions was determined for each fill using two sets of 2π azimuthally symmetric Beam Beam Counters (BBC) located at $\pm 1.44 \text{ m}$ from the interaction point. This was confirmed from a later run by a comparison with the Zero Degree Calorimeters at $\pm 18 \text{ m}$ that are sensitive to very forward neutrons. The accuracy was determined to about $2.5 \cdot 10^{-4}$.

The collision trigger utilized a coincidence between the BBC's which accounts for approximately 50% of the proton-proton inelastic cross section at 200 GeV and provides minimal bias to a vertical beam polarization. With a vertex position resolution of $\approx 2 \text{ cm}$ the trigger accepted events within 75 cm. The analyzed sample had a vertex cut of $\pm 30 \text{ cm}$. In order to enhance the neutral pion sample, a photon energy threshold of 0.8 GeV was added in coincidence. Charge particle reconstruction was carried out using the drift and pad chambers which cover $|\eta| < 0.35$ and $\Delta\phi = 90^\circ$. Conversion electrons were reduced to less than 1% by requiring no hits in

Figure 2. Single spin asymmetries in inclusive π^0 and unidentified hadron production.

the RICH counter with a pion threshold of 4.7 GeV/c. Decays from short lived particles could not be removed and accounted for less than 5% at the highest momenta.

The two photon effective mass was reconstructed using the EM-calorimeters with trigger efficiencies ranging from 24% to 78% and the π^0 peak widths ranged from 13.2 to 10.6 MeV/c² from low to high p_T . The yield was extracted at each transverse momentum within a mass cut of 0.12-0.16 GeV/c². The asymmetry in the background was calculated using 50 MeV/c² bins around the π^0 mass.

The asymmetries were calculated using the luminosity formula for each fill and then averaged over the whole run. With both beams polarized, single spin analyses were carried out independently using one polarized beam while averaging over the other. To assess the systematics, a bunch shuffling technique was also employed in which the spin direction of each bunch was assigned randomly assuring the same relative luminosities. The results indicate systematic uncertainties smaller than the statistical ones.

3. The results

The asymmetries in inclusive production at midrapidity and very low x_T in both neutral and unidentified charged hadrons are consistent with zero to within a few percent (figure 2). The data represent the first measurements at this energy and kinematic region. It is interesting to note that at low transverse momenta below p_T of 3 GeV/c gluon-gluon partonic interactions dominate. These results could be indicative of a low gluon contribution to

transverse asymmetries. The data are consistent with the results seen by E704⁸. These should be contrasted with the large asymmetries observed at STAR⁷ and more recently BRAHMS (unpublished) in inclusive pion production at forward x_F where valence quark interactions are likely to dominate.

Recently several theoretical models^{10,11,12} have been advanced to explain these asymmetries including higher-twist contributions, modifications to the parton distribution functions (Sivers effect), modifications to the fragmentation functions (Collins effect). These tend to explain the large x_F asymmetries but they have yet to delve into the midrapidity domain.

4. Future plans

Since these data were taken, significant progress has been attained in luminosity as well as the polarization such that it is reasonable to assume accumulating more than 1 pb^{-1} per week of running at polarization exceeding 40% (Run 5 in 2005). With 3 pb^{-1} PHENIX could extend the reach to $p_T \approx 10 \text{ GeV}/c$ with better than 5% statistical accuracy well into the regime of gluon-quark interactions. The installation of an aerogel counter will extend the particle identification range from the current 3 GeV using the TOF to about 9 GeV. The charged hadron trigger at higher momenta can be augmented by the RICH.

In addition, PHENIX is planning to explore the Sivers effect using leading back to back hadrons. Further out with the planned upgrade of a barrel Si vertex detector, back to back jets can be studied as well as exploration of the Collins effect using $\pi\pi$ interference which requires higher luminosities.

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