Single-spin Transverse Asymmetry in Charged Hadron Production in $\sqrt{s} = 200$ GeV p+p Collisions at PHENIX

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Abstract. We report on the status of the single-spin transverse asymmetry (A_N) measurements for charged hadrons with the PHENIX Central-arm detector. Data from transverse polarized proton-proton collision were collected during the last run (2001-2002) at the Relativistic Heavy Ion Collider at Brookhaven National Laboratory. The energy ($\sqrt{s} = 200$ GeV$/c$) is ten times higher than the previous experiments for A_N. Based on the charged hadron yield and the polarizations, an A_N measurement at the mid-rapidity region will be achieved 6-7% statistical error at the high transverse momentum range (6-8 GeV$/c$). The prospect for future runs is also discussed.

INTRODUCTION

Presently, one of the most important topics in the spin physics community is the investigation of the carrier of the proton spin. Because in the 1980's, DIS experiments revealed that the spin of quarks contribute only a part of proton spin. The next target is the gluon component (ΔG) which can be accessed by proton-proton collisions. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) provides the polarized proton-proton collisions at the highest energy in the world. ΔG signal appears in the double-spin longitudinal asymmetries (A_{LL}). A_{LL} in hadron production is expected to have different features for neutral pions and charged hadrons reflecting the different contributions of u, d quark and their polarizations. These differences grow with the transverse momentum (p_T) of the particles. The PHENIX detector is one of the multi-purpose detectors at RHIC. Its central arm detector covers the mid-rapidity region and, with the electromagnetic calorimeter trigger, is optimized to collect the high p_T particles. So, PHENIX can measure ΔG via these particles [1].

During the last RHIC run (RHIC RUN2), data were collected for transversely polarized proton-proton collision at $\sqrt{s} = 200$ GeV. From these data, perturbative QCD (pQCD) calculations can be confronted with new measurements of the production cross section and the left-right single-spin transverse asymmetry (A_N). In the latter case, the E704 experiment at FNAL measured A_N for neutral pions at mid-rapidity with a p_T range from 1 to 3 GeV$/c$ but at a smaller $\sqrt{s}$ of 19.4 GeV [2]. The data were consistent with zero, confirming the expectations of lowest order (twist-2) pQCD. The PHENIX

[1] For the full PHENIX Collaboration author list and acknowledgements, see Appendix "Collaborations" of this volume.

data can reach to higher p_T region than E704 and thus possibly be sensitive to higher order effects.

EXPERIMENTAL SETUP

During RHIC RUN2, proton-proton data were collected from December 2001 to January 2002. The total luminosity acquired by PHENIX was 0.15 pb^{-1} (January 8th to January 22nd). The averaged polarization was 14% in the blue beam and 17% in the yellow beam, as measured with the RHIC CNI polarimeters[3]. Each bunch in the beam had alternate polarization direction to reduce time-dependent variations both in the detector and in the beam.

The PHENIX Central Arm Detectors[4][5] consist of a west and an east spectrometer, each of which covers 90 degrees in azimuthal angle (ϕ) and ± 0.35 in pseudorapidity (η) where z-axis is aligned with the beam direction. A particle from an interaction, after traversing through a magnetic field, passes through Drift Chambers (DC), Pad Chambers (PC), Ring Image Cherenkov Counters (RICH) and Electromagnetic Calorimeters (EMCal). The azimuthal symmetric magnetic field exists inside of DC radius ($\sim$2m). A charged particle is kicked by the field in ϕ direction ($\int \mathrm{B} \cdot \mathrm{dl} = 0.78[\mathrm{T} \cdot \mathrm{m}]$). Its trajectory is reconstructed from the DC hits and, via the field map, used to determine the momentum. In addition, we used Beam-Beam Counters (BBC) situated at the beam forward region ($3.0 < |\eta| < 3.9$) to give a measure of the vertex position.

The simple interaction trigger (called the minimum-bias trigger) is formed from the BBC hit data and is used to collect for the low p_T sample Due to the rate, a factor 10 to 80 of prescale was needed. The trigger system is very important to maximize the yield of the high p_T sample. For this purpose, an EMCal level-1 trigger was installed just prior to the run. An energy threshold was set for a trigger unit which was 4 PMTs (covers about $10 \times 10[\mathrm{cm}^2]$ perpendicular to the particle direction). Other trigger units made from 16 PMTs were also functional, but were not used in this analysis. Fig. 1 shows the trigger turn-on curve as a function of the energy deposited in a trigger unit. For neutral pions, the trigger performance was studied and is well understood. Fig. 2 shows that the energy turn-on curve for photons is well reconstructed in the Monte-Carlo simulation. For charged hadrons, the situation differs from the case of neutral pions. Since the EMCal has less than one nuclear interaction length, some of the hadrons traverse the EMCal as minimum ionized particles. The total energy deposit distribution for $\pi^{\pm}$ had been obtained from the test beam measurements done at AGS [6] and CERN. By fitting empirical function, the efficiency of the charged pions as a function of the momenta were calculated and shown in Fig. 3. There are uncertainties in the fraction of energy deposit in the trigger unit to the total energy deposit.

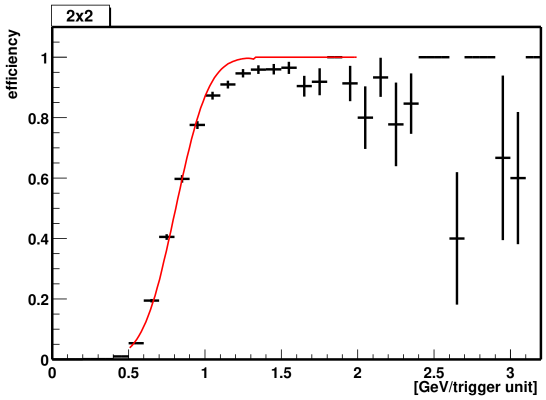

FIGURE 1. The EMCal trigger turn-on curve as a function of the energy deposit in the trigger unit.

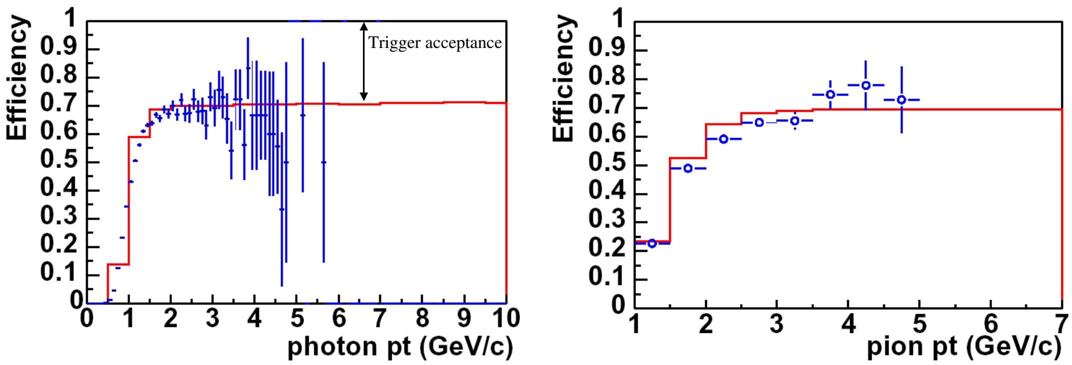

FIGURE 2. (left) The EMCal trigger photon efficiency as a function of transverse momentum (p_T). The points are from data; the line shows the prediction determined using each EMCal tile response. The plateau is consistent with the trigger acceptance. (right) Here the photon clusters are selected from π^0 daughters and plotted as a function of p_T of the π^0.

ANALYSIS

A charged track is defined as a track in the DC which projects to hits in the PC and back to the vertex point obtained from BBCs. Backgrounds such as low momentum electron not coming from the vertex point are eliminated with this combination. But in the case that a photon converts to electrons in front of the DC or a particle decays in flight, the kick offsets the magnetic field kick and such daughters will be assigned an incorrect momentum. The number of these daughters were estimated to be less than 10% in the p_T range p_T below 4 GeV$/c$. For the events taken with the EMCal trigger, this background is absent because it deposits too little energy in the EMCal to fire the trigger.

Fig. 4 shows the yield of the charged particles from 32 million minimum-bias triggered events and 19 million EMCal triggered events where, for the latter sample, an additional off-line EMCal deposit energy cut (E_{dep}[GeV] > 0.3312p[GeV$/c$] $+ 0.1636$) was

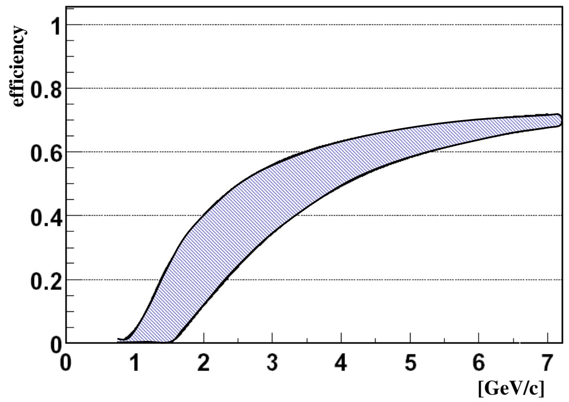

FIGURE 3. The EMCal $\pi^{\pm}$ efficiency computed with an empirical fit of the energy response of charged pions which was extracted from test beam data. The filled band represents to the width of the trigger turn-on curve.

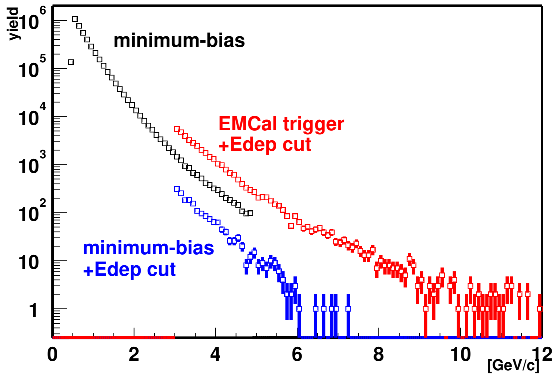

FIGURE 4. The charged hadron ($h^{\pm}$) yield for the RUN2 data set. The minimum-bias and the EMCal trigger events cover the low p_T and the high p_T regions, respectively.

imposed to minimize the p_T-dependence of the efficiency. The EMCal trigger not only increases the yield of high p_T particles, but also it significantly rejects the background contribution. From the comparison with the yield from minimum-bias+EMCal deposit cut sample, its gain was factor 20 ($p_T > 4$ GeV$/c$). Anti-protons might introduce another bias on the negative hadron component of the EMCal trigger sample, because they were favored due to the larger EMCal energy deposit of the annihilation process. The charged hadron production cross section will be obtained by the minimum-bias events. The A_N analysis at high p_T region will be performed using the EMCal triggered events.

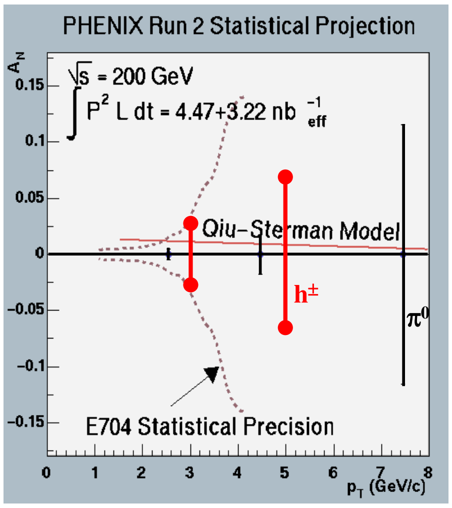

FIGURE 5. The estimated statistical error on the A_N compared with the expected PHENIX RUN2 π^0 precision and the E704 π^0 results.

SUMMARY AND OUTLOOK

Based on the yield of charged hadrons, the expected statistical error on the A_N measurement is shown in Fig. 5. It is calculated by $\delta A_N = \frac{1}{P} \cdot \frac{1}{\sqrt{N}}$, where P is polarization and N is the number of tracks, and we took 15% for P as a typical value. We can test A_N of charged hadrons at 7% level for the p_T range from 4 to 6 GeV/c. E704 couldn't reach this high in p_T. Fig. 5 also shows the estimation for neutral pions in RUN2 and E704 result on neutral pions. There are more statistics of neutral pions, because they have higher EMCal trigger efficiency and are less affected by reconstruction inefficiencies. The analysis is still on going to check the tracking resolution and the quality for the cross section measurement. The systematic error estimation for A_N measurement has yet to be undertaken.

During RHIC RUN3 and RUN4, we are planning to take data with longitudinally polarized proton-proton collisions[1]. The analysis procedure of the charged hadron sample described here is expected to be the one used in the future gluon polarization measurement made via this channel.

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