TRANSVERSE SPIN PHYSICS AT PHENIX

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We report the transverse spin physics results of the PHENIX experiment. Using the collision of transversely polarized proton beams at $\sqrt{s} = 200$ GeV, we have measured single spin asymmetries (A_N) of pions at central rapidity and neutrons at very forward region. We also discuss the prospects from the current and near future runs of the PHENIX experiment.

1. Physics Interests

The spin structure of transversely polarized nucleon is very attractive as it is expected to be different from the helicity structure of longitudinally polarized nucleon because of relativistic effect and thus it provides another key to understand the nature of the nucleon. Especially, transversity of quarks (δq) is a very important spin structure function as fundamental as helicity structure function (Δq and Δg). However, it is mostly unexplored and our knowledge is very poor.

In proton-proton collisions, transversity can give single spin asymmetries (A_N) via Collins effect[1] and double spin asymmetries (A_{TT}) in various particle production channels initiated by (anti-)quarks. However, other mechanisms are possible to produce spin observables; in the case of A_N, especially, several mechanisms such as Sivers effect[2], higher-twist effect[3,4] are suggested. Therefore, we need measurements at various channels and kinematic regions to disentangle these mechanisms.

Transverse spin physics in proton-proton collision at very forward region is also interesting. In this region, reaction is dominated by soft and non-perturbative processes, and is often described by Regge theory. Spin observables give good test grounds for the Regge theory, because Pomeron exchange gives no spin-flip amplitude so that observables that require spin-flip amplitude, such as A_N, are zero in naive expectations.

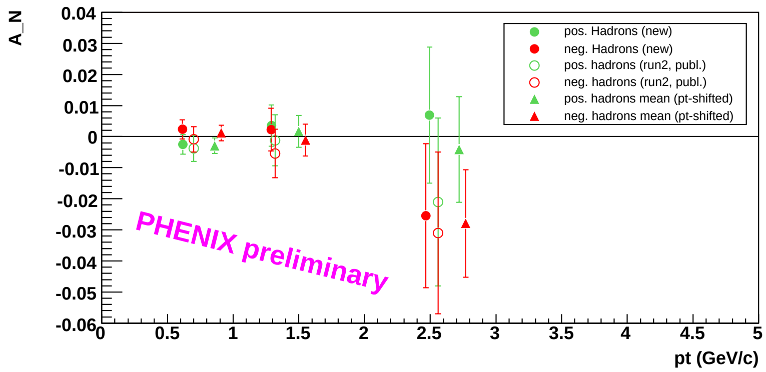

Figure 1. Preliminary result from 2005 data on A_N for single charged hadrons at mid-rapidity. Previous PHENIX result[6] is also shown for comparison. Additional scaling errors of 20% (present result) and 30% (previous result) due to uncertainty in beam polarization are not shown on the figure.

2. The PHENIX Experiment

PHENIX is an experiment at the Relativistic Heavy Ion Collider (RHIC), and is specialized in the measurement of photons, electrons, and muons as well as high-transverse-momentum (p_T) particles in collisions of heavy ions or polarized protons. It has a high rate capability and sophisticated trigger systems as well as with good particle identification, allowing measurement of rare processes. The PHENIX detector[5] consists of two detector arms (Central Arms) to cover mid-rapidity region ($|\eta| < 0.35$), forward detectors (Muon Arms) for identifying and tracking muons in $1.2 < |\eta| < 2.4$, and several detectors to provide interaction triggers.

In PHENIX, following data were accumulated for transverse spin physics; in year 2001-2002, we took 0.15 pb^{-1} with average polarization $\sim 15\%$ at $\sqrt{s} = 200$ GeV. Another 0.15 pb^{-1} was collected in 2005 with much better polarization ($\sim 47\%$) at the same energy. In addition, a few days of beam time was devoted to data taking at $\sqrt{s} = 410$ GeV. This year (2006) was the first run to accumulate a significant amount of data and we took 2.7 pb^{-1} at $\sqrt{s} = 200$ GeV and 20 nb^{-1} at $\sqrt{s} = 62.4$ GeV with good polarization ($\sim 60\%$).

3. Results and Discussions

Figure 1 shows the preliminary result of A_N for inclusive charged hadrons in mid-rapidity from 2005 data. The fact that the detector acceptance

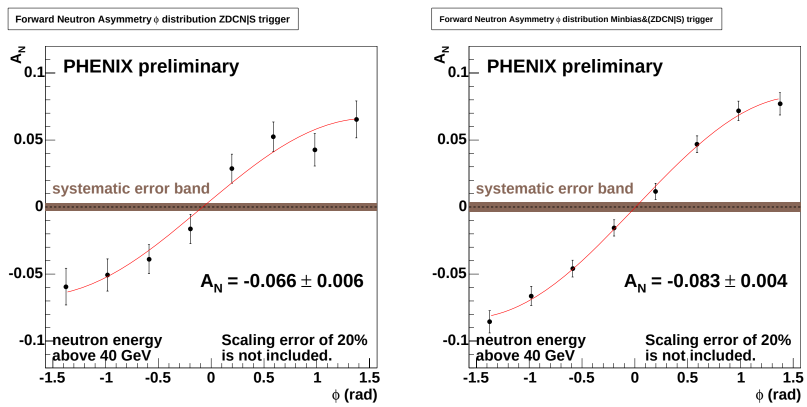

Figure 2. A_N of very forward neutrons at $\sqrt{s} = 200$ GeV and $x_F > 0.4$. Left: A_N of single neutrons. Right: A_N of neutrons when other particles are detected in the region of $3.0 < |\eta| < 3.9$.

is not left-right symmetric due to bend by magnetic field was taken into account by modifying the square-root formula. The obtained A_N was consistent with zero for both positive and negative hadrons. This result is also consistent with the previously published data[6], which is plotted on Fig. 1 for comparison.

The present result is quite interesting in contrast with the results from forward region[7,8,9]. While A_N was as large as $\sim 10\%$ for positive and neutral pions at $x_F \sim 0.3$ and $p_T \sim 1$ GeV/c, the PHENIX results show that the A_N is zero within a few % at $x_F \sim 0$ for the same p_T. This might be related to the difference of dominant subprocesses (qg in forward rapidity and gg in mid-rapidity, respectively) in these two kinematic regions.

Figure 2 shows the A_N of very forward neutrons detected by hadron calorimeters called Zero Degree Calorimeter (ZDC) located at 18 m away from the collision point along the beam axis. Large asymmetry was observed in forward neutrons. This asymmetry was even larger when other particles were detected in both of the two the Beam-Beam Counters (BBC) covering the forward and backward regions of $3.0 < |\eta| < 3.9$ (see the right of Fig. 2). In both cases, A_N for backward neutrons was found to be consistent with zero within the statistical error.

An intersting question is how the asymmetry is produced. A hint may come from a measurement of A_N of coincident (unidentified) particles at BBC. A significant negative asymmetry was observed for forward

BBC, with a preliminary value of $-4.50 \pm 0.50 \pm 0.22\%$. A smaller positive asymmetry was found for backward BBC, with a prelminary value of $2.28 \pm 0.55 \pm 0.10\%$. These results are consistent with a naive picture of diffractive process, where N^* or Δ^* is produced with large A_N and then decays into neutron and other particles, but not consistent with a kickout-recoil picture where negative neutron asymmetry is produced as a recoil of a particle production with large positive A_N.

Other hints on the mechanism can be obtained by measuring energy and p_T dependences of the asymmetry. For this purpose, we took data at different energies ($\sqrt{s}$ = 410 GeV and 62.4 GeV). A quick analysis shows the asymmetry persists at these energies, and we are analyzing the data in detail to obtain quantitative result. Also, in this point of view, it is interesting that the asymmetry disappears for protons at $\eta = 5.1$ as reported by BRAHMS[7].

4. Future Prospects

With the high statistics data taken in 2006, we expect significant physics results will be obtained. One topic we want to note here is that an asymmetry measurement of back-to-back two particle correlation, originating from back-to-back jets, as proposed by Boer and Vogelsang[10] to determine Sivers function, is possible with the amount of data taken in this year. We also introduced a new electro-magnetic calorimeter (Muon Piston Calorimeter) in the forward region ($3.1 < |\eta| < 3.65$), and measurements of A_N for forward π^0 and direct photon become possible from 2006.

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