Single Spin Asymmetries in the BRAHMS Experiment

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Abstract. The BRAHMS experiment at RHIC have measured the transverese spin asymmetries in polarized pp induced pion production at RHIC. The results from the RHIC run-5 shows a significant asymmetry for π^+ and π^- at moderate x_F. The trend of the data is in agreement with lower energy data while the absolute value are surprisingly large. The $p_T$dependence is a rough agreement with the pQCD expectations of being inversely propotional to p_T.

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In the last decade or so, measurements of transverse single spin asymmetries in pp collisions with polarized beams have attracted much theoretical and experimental interest. Results at low beam energies[1] ($\sqrt{s}$=20 show a sizeable asymmetry up to 30% at relative large Feynman-x (x_F) and at moderate p_T. It was expected, naively, from lowest order QCD estimates that the cross sections should have little spin dependence. In order to get a non-zero value both spin-flip amplitudes, a phase difference in the intrinsic states as well as a non zero scattering angle is necessary. This makes it a higher order effect that can be either in the initial state or in the final state parton scattering.

The asymmetry or analyzing power A_N is defined as $(\sigma^+ - \sigma^-)/(\sigma^+ + \sigma^-)$, where $\sigma^{+(-)}$ is a spin dependent cross section for the scattering $pp \to \pi X$, and with the spin direction oriented up or down transversely to the beam momentum.scattering plane. The target is either un-polarized or the cross sections are averaged over target polarization states. The experiments [1] has shown that $A_N(\pi^+) > A_N(\pi^0) > 0 > A_N(\pi^-)$. The preliminary data from BRAHMS from a short run in 2004 at 200 GeV showed non-zero spin asymmetries for π^+ and π^- at moderate x_F [2]. The STAR experiment observed a positive A_N for π^0 at large x_F at RHIC [3]. The BRAHMS experiment at RHIC is primarily designed and operated to make measurements of semi-inclusive spectra of identified hadrons over a wide range in rapidity and p_T. The PID coverage for pions up to momenta of 35 GeV/c and the option to measure at 2.3 degrees ($\eta \approx 4$) makes it well suited to study transverse Single Spin Asymmetries for identified pions at moderate x_F. The present contribution presents the preliminary results of A_N for π^+ and π^- at moderate values of x_F in pp collisions at 200 GeV at RHIC from the higher statistics run-5.

The BRAHMS forward spectrometer consists of 4 dipole magnets, 5 tracking chambers, two Time-Of-Flight systems and a Ring Imaging Chrenkov Detector (RICH) for particle identification. The angular coverage of the spectrometer is from 2.3 to 15 degrees, and the solid angle 0.8 msr. Details of experimental setup can be found in [4].

The accpetance of the BRAHMS spectrometer, does not exactly correspond to a fixed angle experiment, albeit there still is a roughly linear relation between $p_T$and $x_F$as shown in Fig. 1 for $\theta = 2.3$ degrees at the maximum field setting of 7.2 Tm in the spectrometer. The momentum resolution $\delta p/p$ is estimated to be 1% at momenta of 22 GeV/c. Scattering angles of 2.3^{o} and 4^{o} are shown on the figure. Thus care should be taken when comparing to both other experiments (STAR) and to theory.

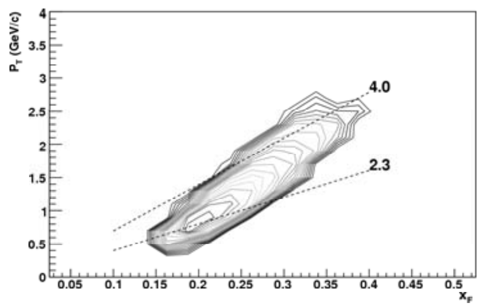

FIGURE 1. Acceptance in the BRAHMS experiment for pions at the nominal setting of 2.3 degrees in p_T vs. x_F. The dashed lines indicates the p_T- x_F correlations for fixed angles of 2.3^{o} and 4^{o}, respectively.

Complete tracks were reconstructed from local track measurements in at least 4 of the 5 chambers, and its momentum from 3 independent measurements. The tracks are required to project cleanly through the spectrometer. An approximate vertex can be determined from the timing measurements in sets of symmetricaly placed Cherenkov counters (CC) around the beam pipe at 1.9 and 6.1 meters CHECK . The position resolution of the vertex determination is about 2 cm from these measurements. In addition vertex positions and live rates are obtained from a set of Cherenkov Counters (BB) with limited acceptance at $\pm$2.15m and a pair of Zero Degree Calorimetres (ZDC) placed at $\pm$18m. The tracks accepted in the spectrometer are required to point backward to these measurements with an accuracy of 30 cm and to be within a narrow range of (-40,20) cm of the nominal interaction point. Due to the measuring angle of 2.3 degree, the spectrometer tends to accepts track weighted towards negative vertex positions. The particle identification of the pions is done exclusively using the RICH. It is required that the calculated radius for pion is within .25 cm from the measured radius, and at the same time more than .30 cm away from the estimated radius assuming the track is from a kaon. This corresponds to about a 2 and 2.5 σ cuts, respectively.

In the RHIC accelerator the transverse spin polarization is altered between the up to 112 bunches of polarized protons that forms the beam in each of the two rings. Thus most experimental time-dependent effects originating from the spectrometer and the vertex determination cancel out when constructing the raw asymmetries

$$\varepsilon = (N^+ - L*N^-)/(N^+ + L*N^-)$$

The $N^{+(-)}$ represents the yield of pions in a given kinematic bin where the beam spin direction is up or down relative to the reaction plane determined by $k_{beam} \times k_{out}$. The factor L is the ratio of the luminosity of bunches with positive polaraization to those of negative polarization thus accounting for non-uniform bunch intensities. The luminosity ratio is determined independently from the spectrometer data using several measures of collision rates from the CC, BB, and ZDC detector systems. It is estimated that the systematic error from the relative luminosity measurements is in order of 0.5%.

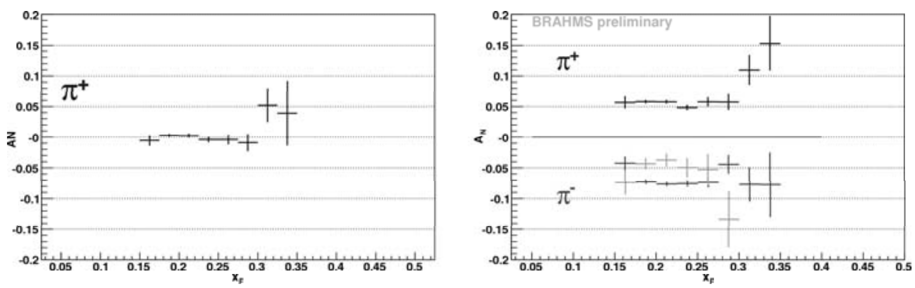

FIGURE 2. Analyzing power A_N for π^+ and π^- at positive x_F(right hand panel) and negative x_F(left panel).

The asymmetry is the in turn determined from $A_N = \varepsilon/P$. The polarization (P) as determined from the online CNI measurements [5] is $\approx 50\%$ for the stores used. The systematic error on beam polarizations is $\approx 20\%$ and represents a scaling error on the values of A_N. This error is expected to be reduced after the final analysis of CNI data. The measured asymmetries corrected for the beam polarization is shown in Fig. 1 for π^- and π^+ vs. x_F. The data for π^- in the right panel were obtained from measurement at 2.3^o and 4^o, respectively. The 4^o data corresponds at the same $x_F$to a higher $p_T$value. In the x_F range of of 0.15 to 0.3 the mean p_T falls by approximately 40%. In the same panel is shown the results for π^- at the 2.3^o data with values that are of opposite sign and approximately the same absolute value, possibly slightly smaller. By utilizing the polarization of the beam (yellow) moving away from the spectrometer one can determine the asymmetry at negative $x_F$value. The resulting asymmetries are shown in the left panel of the figure demonstrating that near zero value are obtained in this region. The result is consistent with that obtained for π^0 by STAR.

In summary, data from polarized proton data from BRAHMS were obtained in the RHIC Run-5 and shows a finite A_N for π^+ and π^- with sign ordering as observed previously in E704 at FNAL. Data obtained at a larger angle setting corresponding to a larger value of p_T shows the magnitude of the asymmetry falls with p_T and is approximately proportional to $1/p_T$.

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