Single Spin Asymmetries in the BRAHMS Experiment

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Abstract. The BRAHMS experiment at RHIC has the capability to measure the transverese spin asymmetries in polarized pp induced pion production at RHIC. The first results from a short run show a signaificant 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.

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INTRODUCTION

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 moderate beam energies[1] 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 polarization states. The experiments [1] has shown that $A_N(\pi^+) > A_N(\pi^0) > 0 > A_N(\pi^-)$. A recent result from STAR [2] shows a positive A_N for π^0 at large x_F in pp collisions at 200 GeV. 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 40 GeV/c and the option to measure at 2.3 degrees ($\eta \approx 4$) makes it well suited to study Single Spin Asymmetries for identified pions at moderate x_F. The present contribution presents the first preliminary measurements of A_N for π^+ and π^- at moderate values of x_F in pp collisions at 200 GeV at RHIC.

RESULTS

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 [3]. For transverse spin measurements the kinematic variables of interest are x_F and p_T. Shown in Fig. 1 is the BRAHMS acceptance for the data taken at $\theta = 2.3$ 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. There is an approximate linear correlation between x_F and p_T. It should be pointed out that the acceptance does not corresponds to a that of a fixed angle. 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.

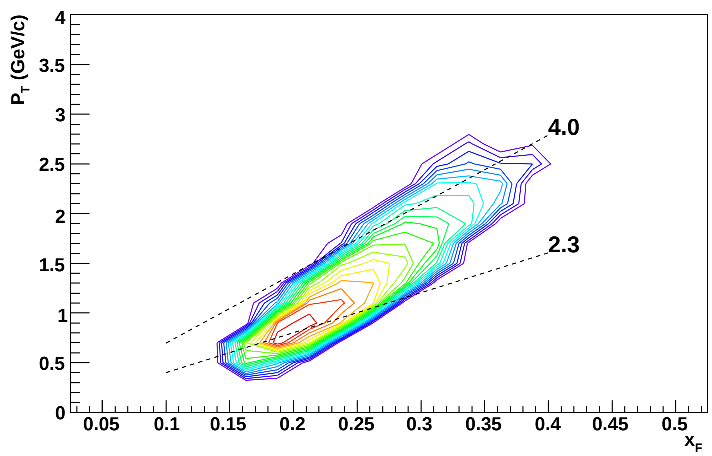

FIGURE 1. Acceptance in the BRAHMS experiment for pions at the nominal setting of 2.3 degrees in p_T vs. x_F. The dashed lines indicates the p_T- x_F correlations for fixed angles of 2.3^o and 4^o, respectively.

Tracks were reconstructed from 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 scintillator counters (INL) around the beam pipe at 1.5, 4.15 and 6.7 meters [4]. The position resolution of the vertex determination is about 10 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 requiered 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 from 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. Figure 2 shows the radius of rings determined in the RICH for all events, and for those identified as pions using the above mentioned cuts in the momentum range $p <$35 GeV/c. The contamination of kaons into the pion sample is estimated to be less than a few percent.

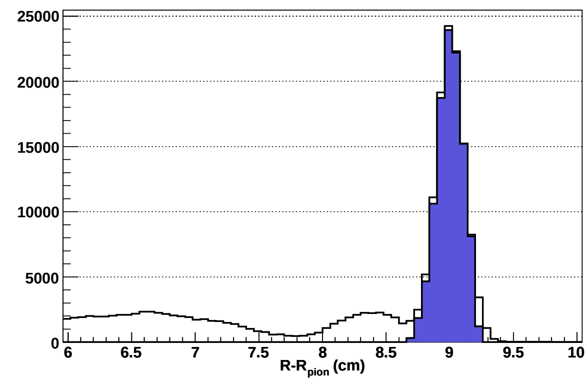

FIGURE 2. Distribution of radia of the rings in the RICH for accpeted particle in the spectrometer. The solid histogram represents those particles identified as pions.

In the RHIC accelerator the transverse spin polarization is altered between the 56 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 INEL, BB, and ZDC detector systems. It is estimated that the systematic error from the relative luminosity measurements is in order 0.5%.

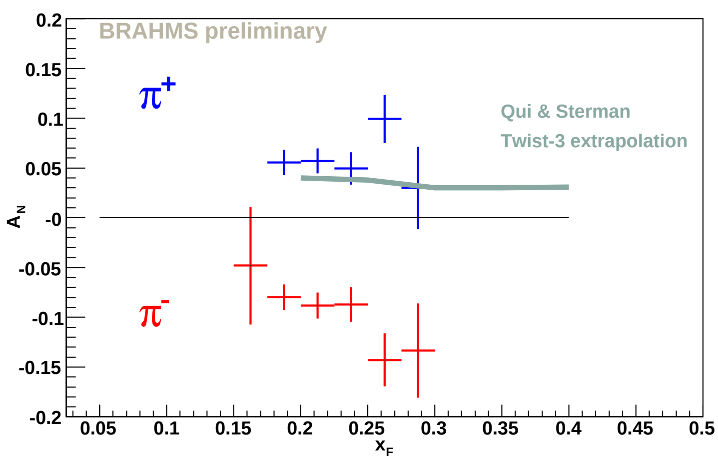

FIGURE 3. Analyzing power A_N for π^+ and π^- .

The asymmetry is the in turn determined from $A_N = \varepsilon/P$. The polarization (P) as determined from the CNI measurements [5] is $\approx$ 42% for the π^+ measurements and $\approx$ 38% for the for π^- measurements in the stores used. The systematic error on beam polarizations is $\approx$ 15% 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 raw asymmetries corrected for the beam polarization is shown in Fig. 3 for π^- and π^+ . The π^+ asymmetries are positive while the π^- are negative i.e. the same sign dependence as seen in the E704 data at lower energy.

Several theorectical models have been worked out for the single spin asymmetries to clarify the importance of inital vs. final state effects as put forward through the Sivers and Collins effects. In this contribution we compare the data vs. extrapolations of twist 3 (initial state) calculations by Qiu and Sterman [6]. The pQCD calculations are apriori not valid at the lower values of p_T covered in the present measurements. Never the less it gives a good estimate how kinematic cuts may effect predictions as to give rise to a near constant A_N in a limited range of x_F. Both the magnitude and the x_F dependence is in reasonable agreement with the data.

During run-5 RHIC has delivered much increased integrated luminosity and with a larger beam polarization of $45-55\%$. BRAHMS has added new vertex detector that will provide a global vertex resolution of $\approx$ 2 cm. Data have been recorded for π^+ and π^- in the x_F range of 0.15-0.35 with about 10-20 times the statistics in the data presented here.

In summary, the first data from polarized proton data from BRAHMS were obtained in the RHIC Run-4 and shows a finite A_N for π^+ and π^- with sign ordering as observed previously in E704 at FNAL. In addition the protons are found to have $A_N \approx 0$. Data from the ongoing RHIC Run-5 will give an order of magnitude better statistics and should enable BRAHMS to make comparisons to several theoretical models

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