Proceedings of the DIS'2004, Štrbské Pleso, Slovakia

LONGITUDINAL DOUBLE SPIN ASYMMETRIES IN NEUTRAL PION PRODUCTION AT PHENIX

FRANK BAUER
FOR THE PHENIX COLLABORATION
University of California, Riverside
BNL - Physics Bldg. 510c - Upton, NY 11973
E-mail: fbauer@rcf.rhic.bnl.gov

Polarized proton-proton collisions can be used to probe the gluon polarization. One promising method is the measurement of double longitudinal spin asymmetries (A_{LL}) in high p_T particle production. In April of 2003, the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) provided the first collisions of longitudinally polarized protons at $\sqrt{s} = 200$ GeV with an average beam polarization of about 26%. In this period PHENIX accumulated about $0.22 pb^{-1}$. We report on first PHENIX results for the double longitudinal spin asymmetry (A_{LL}) for inclusive π^0 production at midrapidity.

1 Introduction

One goal of the RHIC spin program is to unravel the spin structure of the proton. The contributions of the various quarks (Δq) measured at SLAC, CERN and DESY using polarized deeply inelastic (DIS) lepton nucleon scattering was found to be surprisingly small. Determining the gluon contribution (ΔG) to the nucleon spin is therefore an important step in understanding the spin structure of the proton. Polarized $\vec{p}\vec{p}$ scattering is a new technique that is now becoming available which will be able to pursue the measurement of ΔG. At RHIC the gluon polarization will be probed by measurements of longitudinal double spin asymmetries A_{LL} [1]. At the PHENIX experiment the measurement of A_{LL} for inclusive π^0 production [2] is a promising candidate. Measurements of the unpolarized cross section [3] showed a good agreement with next-to-leading-order pertubative QCD calculations over 8 orders of magnitude.

2 Polarized protons at RHIC

RHIC is the first high-energy accelerator designed to collide polarized proton beams. The two RHIC rings (called blue and yellow) cross at six interaction points. Two siberian snakes for each ring help maintain the transverse polarization of the proton beams during acceleration. In 2003 spin rotators on either side of two IPs (one of them the PHENIX experiment) were successfully commissioned, allowing for the first time to collide longitudinally polarized protons at a center of mass energy ($\sqrt{s}$) of 200 GeV. Each ring was filled with 56 polarized proton bunches. An injection pattern was chosen so that in one ring alternating bunches had opposite polarization, while the other ring had bunch pairs with alternating polarization directions.

The polarization was measured with polarimeters using proton-carbon scattering in the Coulomb Nuclear Interference kinematic region [4]. The average polarization for the data analyzed was 26%. The uncertainty of the analyzing power of this process is 30%.

The PHENIX experiment confirmed and monitored the longitudinal polarization directions by measuring asymmetries in forward neutron scattering. Large transverse single spin asymmetries were discovered in 2001-2 for this channel [5]. Observation of no asymmetries would therefore indicate a complete spin rotation and longitudinal polarization. The average asymmetry observed for all data runs selected for the analysis indicated that the longitudinal components of the proton spin the two beams were $0.974^{+0.014}_{-0.041}$ and $0.993^{+0.005}_{-0.023}$, respectively.

3 Determination of A_{LL}

The double spin asymmetry A_{LL} is determined by measuring the number N of produced π^0's for same $(++)$ and opposite $(+-)$ helicity states.

$$A_{LL} = \frac{1}{|\langle P_B P_Y \rangle|} \cdot \frac{N_{++} - \mathcal{R} N_{+-}}{N_{++} + \mathcal{R} N_{+-}} \qquad \text{with} \qquad \mathcal{R} = \frac{\mathcal{L}_{++}}{\mathcal{L}_{+-}}, \tag{1}$$

where P_B and P_Y are the beam polarizations for the blue and yellow beam and $\mathcal{L}$ denotes the integrated luminosities for the different helicity states.

A collider has significant differences from traditional fixed target experiments. Advantageous is the occurrence of very fast polarization reversals at the level of the bunch crossing frequency, much faster than any variations of detector responses and therefore reducing systematic errors of this kind considerably. A challenge for collider experiments is the possibility of accidental correlations between polarization directions and luminosity of the colliding beams. For this reason an accurate measurement of the relative luminosity $\mathcal{R}$ of bunch crossings with different polarization directions is required.

4 Relative luminosity

At PHENIX the relative luminosity $\mathcal{R}$ was determined with two Beam-Beam Counters (BBC, [6]) which are located along the beam line at ± 1.44 m from the nominal interaction point and covering the pseudorapidity range $\pm(3.0\text{-}3.9)$ and full azimuthal range. The BBC is a very suitable luminosity monitor due to its low background ($\sim 10^{-4}$) and high statistics. A second monitor, a Zero Degree Calorimeter (ZDC, [7]) covering a very different kinematic range, was used as a cross check to confirm the zero-A_{LL} of the BBC measurement and to estimate the accuracy δR of the relative luminosity measurements to be $2.5 \cdot 10^{-4}$, which makes the statistical accuracy of the π^0 yields the dominant source for the uncertainty of the A_{LL} measurement.

5 π^0 measurement

The neutral pions are reconstructed using a fine granulated electromagnetic calorimeter (EMCal, [8]) which covers the pseudorapidity range $|\eta|<0.35$ and an azimuth angle of $\approx 180°$. To enrich the data with high-p_T π^0's, a high-p_T photon trigger based on the deposited energy in the EMCal was used. The trigger efficiency reached a plateau at a photon energy of ~ 3 GeV. The photon trigger efficiency for π^0's varied from 6% in the 1-2 GeV/c p_T bin to 95% in the 4-5 GeV/c p_T bin.

Fig. 1 shows the two-photon invariant mass distribution. The number of π^0's is obtained by integrating the two-photon invariant mass distributions in a ± 25 MeV/c^2 mass window around the π^0 mass (black area). Cuts on shower profile, time of flight and energy asymmetry are used to reduce combinatorial and hadronic background. With these cuts the background contribution (combinatorial+hadronic) varies from 27% in the 1-2 GeV/c bin to 8% in the 4-5 GeV/c bin.

To correct for the background contribution to the A_{LL} measurements, A_{LL}^{bckg} for the background is measured from the yields in two windows adjacent to the π^0 peak (grey area in Fig. 1). To get the background-corrected $A_{LL}^{\pi^0}$, the following correction was applied:

$$A_{LL}^{\pi^0} = \frac{A_{LL} - rA_{LL}^{bckg}}{1-r}, \qquad \sigma_{A_{LL}^{\pi^0}} = \frac{\sqrt{\sigma^2_{A_{LL}} + r^2\sigma^2_{A_{LL}^{bckg}}}}{1-r}, \tag{2}$$

where r is the background contribution to the π^0 yield.

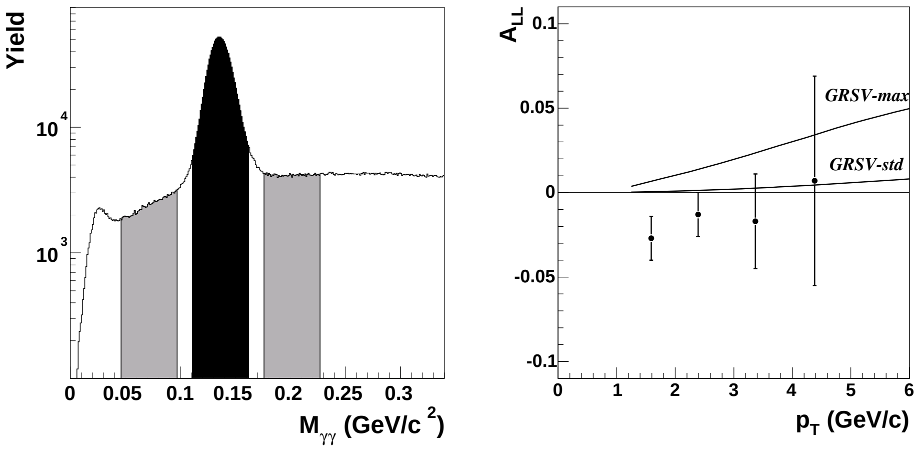

Figure 1. **Left:** Two-photon invariant mass distribution. The black area indicates the signal region. The grey area is used for background subtraction. **Right:** PHENIX A_{LL} data points vs. theory calculations (lines). A total scale uncertainty of 65% from the CNI polarimeter analyzing power uncertainty (correlated for the two beams) and polarization measurement uncertainty (uncorrelated) is not included.

6 A_{LL} results

The double spin asymmetry A_{LL} is determined for each RHIC fill using eq. 1. Each fill may have a different polarization, but the polarization during one fill is constant. The final A_{LL} is obtained by fitting a constant to the fill-dependent A_{LL} values. Fig. 1 shows the background-corrected $A_{LL}^{\pi^0}$ results (points) and a comparison with two theoretical calculations [9]. The spread of these two theory curves reflects the uncertainty of the gluon-polarization from DIS experiments.

A number of systematic checks for the π^0-reconstruction as well as for the A_{LL}-determination were performed. Variations of photon identification criteria or the mass window range showed no effect on A_{LL}. Further systematic checks consisted of determining the parity violating single spin asymmetry $A_L = -\frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$ as well as the double spin asymmetries between $(++)$ and $(--)$ and between $(+-)$ and $(-+)$ helicity states. These parity violating asymmetries were consistent with zero.

7 Summary and Outlook

A first measurement of the double longitudinal spin asymmetry A_{LL} of neutral pions in polarized $\vec{p}\vec{p}$ collisions at $\sqrt{s} = 200$ GeV was made by the PHENIX experiment. The observed asymmetry is small. The obtained sensitivity is not yet sufficient to discriminate between different gluon polarization models but is comparable to the uncertainty of global fits to existing DIS data[10]. Improvements of the polarization as well as the luminosity will reduce these uncertainties considerably in the near future. The installation of a polarized hydrogen jet-target will provide an absolute polarization measurement at the 10% level.

Acknowledgements

PHENIX acknowledges support from the Department of Energy and NSF (U.S.A.), MEXT and JSPS (Japan), CNPq and FAPESP (Brazil), NSFC (China), CNRS-IN2P3 and CEA (France), BMBF, DAAD, and AvH (Germany), OTKA (Hungary), DAE and DST (India), ISF (Israel), KRF and CHEP (Korea), RAS, RMAE, and RMS (Russia), VR and KAW (Sweden), U.S.CRDF for the FSU, US-Hungarian NSF-OTKA-MTA, and US-Israel BSF.

References

1. S. Kretzer, these proceedings
2. S.S. Adler *et al.* hep-ex/0404027
3. S.S. Adler *et al.* Phys. Rev. Lett. 91, 241803 (2003).
4. O. Jinnouchi *et al.*, AIP Conf. Proc. 675: 817-825, 2003.
5. A. Bazilevsky *et al.*, AIP Conf. Proc. 675: 584-588, 2003.
6. M. Allen *et al.*, Nucl Instrum. Methods **A499**, 549 (2003).
7. C. Adler *et al.*, Nucl Instrum. Methods **A470**, 488 (2001).
8. L. Aphecetche *et al.*, Nucl Instrum. Methods **A499**, 521 (2003).
9. M. Glück *et al.*, Phys. Rev. **D63**, 094005 (2001).
10. K. Sudoh, these proceedings