Neutral Pion Double Longitudinal Spin 
Asymmetry in Proton-Proton Collisions at 
$\sqrt{s} = 200$ GeV Using the PHENIX Detector

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Abstract. New results from polarized p-p collisions at $\sqrt{s} = 200$ GeV of double longitudinal spin asymmetry in $\pi^0$ production using the PHENIX detector in the 2005 RHIC run are presented. Both positive and negative maximal gluon polarization scenarios are inconsistent with the data. The data is consistent with small $|\Delta g|$, including $\Delta g = 0$.

INTRODUCTION

In the past 20 years, polarized DIS fixed target experiments have established that the quarks carry 20-30% of the nucleon spin. The remainder must be due to gluon spin and the orbital angular momentum of the quarks and gluons. In proton-proton collisions, we can examine the gluon spin contribution through lowest order gluon-gluon and gluon-quark interactions. In this report, we focus on the double longitudinal spin asymmetry, $A_{LL}$, of $\pi^0$ production for $\eta < |0.35|$.

We define $A_{LL}$ as

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}},$$

(1)

where $\sigma_{++}$ ($\sigma_{+-}$) is the measured cross section, in this case of the $\pi^0$, with same (opposite) helicity beams. Rewriting this in terms of our measured quantities, we get

$$A_{LL} = \frac{1}{|P_1||P_2|} \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}, \quad R = \frac{L_{++}}{L_{+-}}.$$

(2)

where $L$ is the integrated luminosity, $R$ is the relative luminosity, $P_1$ and $P_2$ are beam polarizations and $N$ is the particle yield.

MEASUREMENT

In 2005, the absolute polarization in RHIC was measured with a polarized hydrogen gas jet target [1]. A proton-Carbon Coulomb Nuclear Interference (CNI) polarimeter [2] was used on a fill-by-fill basis for measuring the relative polarization. For 2005, the average polarization was 47%, with 20% relative error per beam. This gives a 40% scaling uncertainty in $A_{LL}^{\pi^0}$. 

TABLE 1. Comparison between RHIC runs. The 2005 run was a substantial increase in figure of merit over previous runs due to increases in both polarization and integrated luminosity.

|          | Polarization (%) | Integrated Luminosity | Figure of Merit (P^4L) |
|----------|------------------|-----------------------|------------------------|
| 2003 RHIC run | 27               | 220 nb⁻¹              | 1.17 nb⁻¹              |
| 2004 RHIC run | 40               | 75 nb⁻¹               | 1.92 nb⁻¹              |
| 2005 RHIC run | 47               | 1.8 pb⁻¹              | 87.8 nb⁻¹              |

The stable beam polarization direction in RHIC is vertical. For longitudinal spin measurements, the beams pass through spin rotators to align the polarization vector with beam momentum. Polarization direction in PHENIX is measured by observing the single transverse spin asymmetry of forward neutron production [3]. In 2005, both beams were found to be above 98% longitudinally polarized at PHENIX.

To measure relative luminosity, we use beam-beam counters [3]. In PHENIX for the 2005 run, uncertainty in relative luminosity was \( \Delta R = 1.0 \times 10^{-4} \), corresponding to a \( \Delta A_{LL} = 2.3 \times 10^{-4} \).

The electromagnetic calorimeter of PHENIX central arms [4] and a high \( p_T \) photon trigger are used to measure \( \pi^0 \) yield. The \( \pi^0 \) cross section for the 2005 run was found to be in good agreement with results from previous runs [5]. NLO QCD calculations are consistent with \( \pi^0 \) cross section, which gives us confidence when comparing our final \( A_{LL} \) results with theoretical expectations for different values of \( \Delta G \).

**ASYMMETRY CALCULATION**

Asymmetry is calculated using Eq. 2 for the diphoton invariant-mass range of ±25 MeV/c² around the \( \pi^0 \) peak (\( A_{LL}^{\pi^0 +BG} \)) and in two 50 MeV/c² mass regions on either side (\( A_{LL}^{BG} \)). Fitting the mass peak, we obtain \( w_{BG} \), the fraction of background in the peak region. To obtain the \( A_{LL}^{\pi^0} \), we use

\[
A_{LL}^{\pi^0} = \frac{A_{LL}^{\pi^0 +BG} - w_{BG}A_{LL}^{BG}}{1 - w_{BG}}.
\]

To evaluate systematic error between bunches and fills, we use bunch shuffling [3]. For the 2005 run, bunch-to-bunch and fill-to-fill systematic uncertainty is negligible with our current statistics.

**\( \pi^0 A_{LL} \) RESULTS**

PHENIX has previously obtained \( A_{LL}^{\pi^0} \) for the 2003 RHIC run [3] and the 2004 RHIC run [6]. These results are shown in Fig. 1 (a) along with the 2005 run result. Table 1 lists the average polarization, integrated luminosity (used in \( A_{LL}^{\pi^0} \) analysis), and figure of merit (\( P^4L \)) for the three RHIC runs. The 2005 RHIC run showed a substantial gain in...
The figure of merit, due to increase in polarization and luminosity at RHIC. Results from the three runs are consistent.

Figure 1 (b) shows the 2005 run result with 4 theory curves. Confidence level between our data and GRSV standard range from 17.1-21.7%, accounting for 40% scaling uncertainty from beam polarization. No uncertainty from theory is considered. Three other theory curves, GRSV-max (ΔG = G), ΔG = −G, and ΔG = 0, all with input scale $Q^2 = 0.4$ GeV$^2$, are also shown. Confidence level ranges for comparing our data with each are 0.0-0.0%, 0.0-0.7% and 16.7-18.4%, respectively. From these, we conclude that our data disagree with maximal gluon polarization (ΔG = G or ΔG = −G) but are consistent with GRSV standard and ΔG = 0.

**SUMMARY**

In the 2005 RHIC run, $A_{LL}^{π^0}$ was measured at mid-rapidity and $\sqrt{s} = 200$ GeV with the PHENIX detector. The figure of merit was significantly higher than previous runs due to increases in polarization and integrated luminosity. Results are consistent with GRSV standard and ΔG = 0, but disagree with positive and negative maximal ΔG.

**REFERENCES**

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