Measurement of double helicity asymmetries in $\pi^\pm$ production at mid-rapidity at PHENIX

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Motivation

- Jaffe-Manohar Sum Rule:

\[ \text{Proton Spin} = \frac{1}{2} = \frac{1}{2} \Delta \Sigma + \Delta G + L_q + L_g \]

  - \(\Delta \Sigma\): reasonably well measured. only 30% of proton spin.
  - Where is the missing part? (spin crisis)

- Many experimental endeavors to measure \(\Delta G\):
  - Polarized DIS (evolution), SIDIS (high pT hadrons/charmed mesons)
  - Polarized p+p collisions at RHIC and \(A_{LL}\) measurement:
Motivation: Accessing $\Delta G$ via $A_{LL}$ in $p+p$ col.

\[ A_{LL} = \frac{d\Delta \sigma}{d\sigma} = \frac{\sum_{f_1, f_2=q, \bar{q}, g} \Delta f_1 \otimes \Delta f_2 \otimes \Delta \hat{\sigma}^{f_1 f_2 \to fX} \otimes D_f^h}{\sum_{f_1, f_2=q, \bar{q}, g} f_1 \otimes f_2 \otimes \hat{\sigma}^{f_1 f_2 \to fX} \otimes D_f^h} \]

"Measured Particles"
Motivation: "Directly" access the sign of $\Delta G$

- q-g scattering starts to dominate at RHIC $p_T$ above $\sim 5$ GeV/c.
- Preferential fragmentation of $u$ to $\pi^+$ and $d$ to $\pi$. 

\[ A_{LL}^{\pi^+} \approx a_{gg} \Delta g \Delta g + \frac{a_{ug}}{a_{ug}} \Delta u \Delta g \]
\[ > 0 \quad > 0 \]
\[ A_{LL}^{\pi^-} \approx a_{gg} \Delta g \Delta g + \frac{a_{dg}}{a_{dg}} \Delta d \Delta g \]
\[ > 0 \quad < 0 \]

\[ \Delta g > 0 \rightarrow A_{LL}^{\pi^+} > A_{LL}^{\pi^-} \]

and vice versa
- The uncertainties have been reduced for $x > 0.05$ based on RHIC data up to Run-2009.

- Expanding experimental sensitivity to lower $x$ region, $x < 0.05$, with PHENIX $\pi^0$ at 510 GeV.

- Confirms non-zero gluon polarization via hadron production.

- $\pi^\pm$ as potential direct indicator for the sign of $\Delta g$ via pion $A_{LL}$ ordering.
• 14 (150) pb\(^{-1}\) polarized p+p data available from dataset in 2009 (2013).
• Higher rate of Run-13 than that of Run-9.
• Due to the lack of hadron trigger in PHENIX, the statistical precision of the π\(^{\pm}\) data is limited in both Run-9 and Run-13.
• Alternatively, high \(p_T\) γ triggers are used for high \(p_T\) π\(^{\pm}\) analysis.
Particle (π±) ID and background sources

- Trigger π± with a BBC and EMCal.
- Track can be divided into two categories according to RICH response at $p_T$ 5~16GeV/c.
  - RICH Hit: $e^±$ and π±.
  - No RICH Hit: $K^±$ and p(-bar).

<table>
<thead>
<tr>
<th>Particle</th>
<th>Electron</th>
<th>Pion</th>
<th>Kaon</th>
<th>Proton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold</td>
<td>30MeV/c</td>
<td>4.7GeV/c</td>
<td>16GeV/c</td>
<td>30GeV/c</td>
</tr>
</tbody>
</table>

Raw Particle Spectra

- Good Track Cut
- + RICH Hit On

Counts vs. $p_T$ [GeV/c]
Particle (π±) ID and background sources (continued)

- e± backgrounds:
  - Primary e± easily removed with e/p and shower shape cuts.
  - The tracking algorithm assumes that tracks originate from the vertex. Therefore, off-vertex tracks may be mis-reconstructed with an arbitrarily large momentum ($p_T \sim 1/\alpha$).
  - Conversion e± (decay-in-flight) removed by applying cuts on the deviation of the hit position from the track model projection (also shower shape cut and others).
Measuring $A_{LL}$ in experiment

\[
A_{LL}^\pi = \frac{d\Delta \sigma}{d\sigma} = \frac{l}{|P_B P_Y|} \frac{N_{++} - R N_{+-}}{N_{++} + R N_{+-}}
\]

\[
R = \frac{L_{++}}{L_{+-}}
\]
Improvement of statistical precision of $\pi^\pm$ $A_{LL}$ in Run-13.

Expanding experimental sensitivity to lower $x_T$ region, < 0.05, with in Run-13.
Theory curves follow measured $A_{LL}$ within statistical uncertainty.

As a complementary probe, might help to double-check the sign of the gluon polarization.
Summary and outlook

- $A_{LL}$ in $\pi^\pm$ production are sensitive to the sign of the gluon polarization.
- $A_{LL}$ in $\pi^\pm$ production at 510 GeV has been measured for the first time in the world.
- As a complementary probe with improved statistics, might help to double-check the gluon polarization.
Thanks!
Latest $\pi^\pm X$-section results at 200 GeV with Run–9 data

$\pi^\pm$ background < 2% averaged over the $p_T$ range, thanks to the Hadron Blinder Detector (HBD).

PHENIX $\pi^\pm$ are in good agreement with Star $\pi^\pm$ and the DSS14 recent global fit.
• The world’s only polarized p+p collider
  - Longitudinal or transverse polarization
  - Up to $\sqrt{s} = 510$ GeV
• **Tracking**
  - Drift Chamber (DC)
  - Pad Chamber (PC1/PC3)
  - Silicon Vertex Tracker (VTX) in 2013

• **$\pi^{\pm}$ Identification**
  - Ring Imaging Cherenkov Detector (RICH)
  - Electromagnetic Calorimeter (PbSc/PbGl)
  - Hadron Blider Detector (HBD) in 2009

• **Relative Luminosity**
  - Beam Beam Counter (BBC)
  - Zero Degree Calorimeter (ZDC)

• **Acceptance**
  - $|\eta|<0.35$
  - $\Delta\phi = 2 \times \pi/2$