High Precision Measurement of Transversity using Di-hadron Correlations in p↑+p Collisions at $\sqrt{s} = 500$ GeV at STAR

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Overview

• Why measure $\pi^+\pi^-$ correlations?

• Some analysis details

• Asymmetry measurements vs $\eta$, $p_T$ and $M_{\text{Inv}}$

• Conclusions
Motivation

• Di-hadron correlations allow point-to-point transversity measurements in SIDIS
• High precision data lacking at relatively high $x$
• Measuring transversity from polarized $p+p$ data
  – collinear framework
  – high precision, reduced $u$-quark dominance
  – test of universality (SIDIS vs $p+p$)
  – new kinematic regime
• 2011 polarized $p+p$ collisions at 500 GeV with 25 pb$^{-1}$ integrated luminosity
• $P_{\text{beam}} = 53\%$
• Solenoidal Tracker at RHIC (STAR)
• Charged pions measured in Time Projection Chamber
  – $2\pi$ azimuthal coverage
  – $-1 < \eta < 1$
• Endcap and Barrel electromagnetic calorimeters and vertex position detector used to select events
Charged Pion Purity Estimates

<table>
<thead>
<tr>
<th>p_T range (GeV/c)</th>
<th>Pion purity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 – 2.0</td>
<td>0.97</td>
</tr>
<tr>
<td>2.0 – 3.0</td>
<td>0.94</td>
</tr>
<tr>
<td>3.0 – 4.0</td>
<td>0.88</td>
</tr>
<tr>
<td>4.0 – 6.0</td>
<td>0.83</td>
</tr>
<tr>
<td>6.0 – 8.0</td>
<td>0.86</td>
</tr>
<tr>
<td>&gt; 8.0</td>
<td>0.97</td>
</tr>
</tbody>
</table>

- Use $dE/dx$ to identify pions

- $n\sigma(\pi) \approx \text{# of } \sigma \text{ in } z = \ln\left(\frac{dE/dx_{\text{measured}}}{dE/dx_{\text{parameterized}}}\right)$ distribution

- Excellent pion purity samples
Asymmetry Observable

- Calculated for $P_B$ as incident beam, $P_A$ as target
- Incident beam is polarized and target unpolarized by summing over bunches
- Pion separation = $\sqrt{(\Delta \eta^2 + \Delta \phi^2)} < 0.7$
- $A_{UT} \propto h_1 \cdot H_1^{\perp}$
  - Transversity ($h_1$)
  - Interference
    Fragmentation Function ($H_1^{\perp}$)
- $A_{UT}$ is expected to depend on the invariant mass ($M_{inv}$) and $p_T$ of the pion pair

$$\varphi_{RS} = \varphi_S - \varphi_R$$
Extract $A_{UT}$

- Particle $p_T > 1.5$ GeV/c
- Pair $p_T > 3.75$ GeV/c
- For a given $M_{Inv}$, $p_T$ bin the asymmetry is calculated for 8 $\phi_{RS}$ bins
- The asymmetry is the amplitude extracted from a single-parameter fit
- Example shown here is one $M_{Inv}, p_T$ bin

$$A_{UT}(\phi_{RS}) = \frac{1}{P} \frac{\sqrt{N \uparrow (\phi_{RS})N \downarrow (\phi_{RS} + \pi)} - \sqrt{N \downarrow (\phi_{RS})N \uparrow (\phi_{RS} + \pi)}}{\sqrt{N \uparrow (\phi_{RS})N \downarrow (\phi_{RS} + \pi)} + \sqrt{N \downarrow (\phi_{RS})N \uparrow (\phi_{RS} + \pi)}}$$
Asymmetry ($\eta,p_T$)

- $A_{UT}$ as a function of $\eta$ plotted for 5 $p_T$ bins

- Significant asymmetry seen at high $\eta$ and high $<p_T>$
Asymmetry ($\eta, p_T$)

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Asymmetry ($M_{\text{inv}}, p_T$)

- $A_{UT}$ as a function of $M_{\text{inv}}$ plotted for 5 $p_T$ bins

- Avg $M_{\text{inv}}$ in each $M_{\text{inv}}$ bin decreases with decreasing $<p_T>$

- Significant asymmetry seen at mid-$M_{\text{inv}}$ and high $<p_T>$
Asymmetry \((M_{\text{Inv}}, p_T)\)

- \(A_{UT}\) as a function of \(M_{\text{Inv}}\) plotted for 5 \(p_T\) bins

- Avg \(M_{\text{Inv}}\) in each \(M_{\text{Inv}}\) bin decreases with decreasing \(<p_T>\)

- Significant asymmetry seen at mid-\(M_{\text{Inv}}\) and high \(<p_T>\)
Asymmetry \((p_T, M_{\text{Inv}})\)

- \(A_{UT}\) as a function of \(p_T\) plotted for 5 \(M_{\text{Inv}}\) bins

- Avg \(p_T\) in each \(p_T\) bin slightly decreases with decreasing \(<M_{\text{Inv}}>\)

- Asymmetry rises significantly for high \(p_T\) and high \(M_{\text{Inv}}\)

![Graph showing asymmetry as a function of \(p_T\) and \(M_{\text{Inv}}\)](image-url)
Asymmetry \((p_T,M_{\text{Inv}})\)

- \(A_{UT}\) as a function of \(p_T\) plotted for 5 \(M_{\text{Inv}}\) bins

- Avg \(p_T\) in each \(p_T\) bin slightly decreases with decreasing \(<M_{\text{Inv}}>\)

- Asymmetry rises significantly for high \(p_T\) and high \(M_{\text{Inv}}\)

4.5% scale uncertainty from beam polarization
The events we choose to record are biased towards pions that fragment from quarks.

There should be no asymmetry for pion pairs that come from gluons.

To account for the bias a dilution correction is estimated in the top panel:

- Quarks/partons ratio of biased data over the quarks/partons ratio of unbiased sample

Correction not applied to data.

4.5% scale uncertainty from beam polarization.
Results for $\eta^{\pi^+\pi^-} < 0$

STAR Preliminary

Asymmetry nearly zero
<x> Coverage at STAR

- High precision asymmetries measured at relatively high <x> and high effective $Q^2$

Bacchetta, Courtoy, Radici, JHEP 1303 (2013) 119
Conclusions

• Preliminary STAR data show high precision pion pair correlation asymmetries at large $p_T$ and $M_{Inv}$ for $\eta^{\pi^+\pi^-} > 0$

• These results are at much higher $Q^2$ and sample a different mixture of quark flavors than SIDIS

• Results may be used to test universality of transverse polarization dependent quantities (SIDIS vs $p+p$)

• STAR results from 2012 polarized $p+p$ collisions at $\sqrt{s} = 200$ GeV coming soon (higher precision than 2006)