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Transverse Spin Dependent Azimuthal Correlations of Charged Pion Pairs in Run 2015 $p^{\uparrow} + p$ Collisions at $\sqrt{s} = 200$ GeV

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Motivation

•Theoretical Aspect:

✷ The transversely polarized cross – section of hadron pairs in $p\uparrow + p$ collisions can be written similar to :

$$d\sigma_{UT} \propto \sin(\phi_{RS}) \int dx_a\, dx_b\; f_1(x_a)\; h_1(x_b)\; \frac{d\Delta\hat{\sigma}}{d\hat{t}}\; H_1^{\sphericalangle}(z,\ M)$$

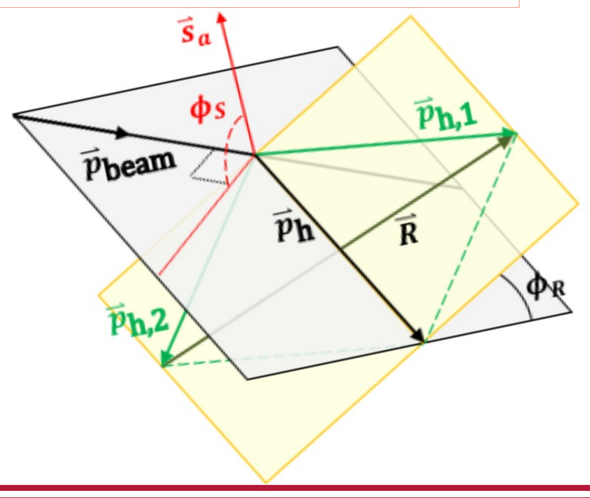
→ $\Delta\hat{\sigma}$ = Polarized parton cross – section with four momentum transfer $\hat{t}$
→ $f_1(x_a)$ = Unpolarized parton distribution function → $h_1(x)$ = Transversity
→ $H_1^{\sphericalangle}(z,\ M)$ = Di – hadron interference fragmentation function (IFF) as a function of z, the fractional energy w.r.t the fragmenting quark carried by hadron pair & its invariant mass, M.

✷ Cross-Ratio Formula :

$$A_{UT}\cdot P\cdot \sin(\phi_{RS}) = \frac{\sqrt{N\uparrow(\phi_{RS})\,N\downarrow(\phi_{RS}+\pi)} - \sqrt{N\downarrow(\phi_{RS})\,N\uparrow(\phi_{RS}+\pi)}}{\sqrt{N\uparrow(\phi_{RS})\,N\downarrow(\phi_{RS}+\pi)} + \sqrt{N\downarrow(\phi_{RS})\,N\uparrow(\phi_{RS}+\pi)}}$$

→ A_{UT} = Single spin asymmetry
→ P = Beam polarization
→ $N\uparrow(\downarrow)$ = Number of hadron pairs when the beam polarization is up (down).
→ $\phi_{RS} = \phi_R - \phi_S$

- The transversity distribution ($h^q_1(x)$) for quark flavor q and momentum fraction x, is not well known.
- $h^q_1(x)$ couples with its chiral odd partner: di-hadron interference fragmentation function $H_1^{\sphericalangle}(z,\ M)$, which can be measured independently to extract $h^q_1(x)$.

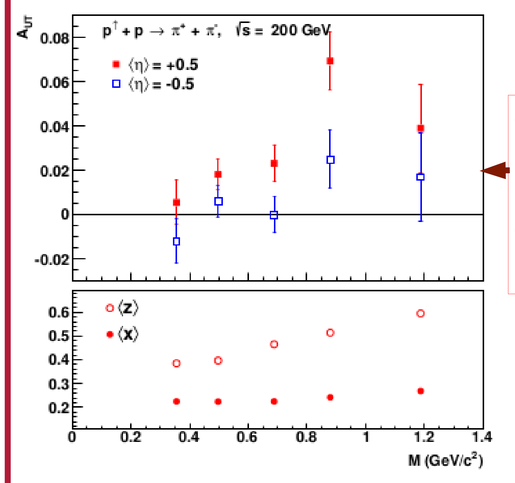


Run 2006 Analysis Summary

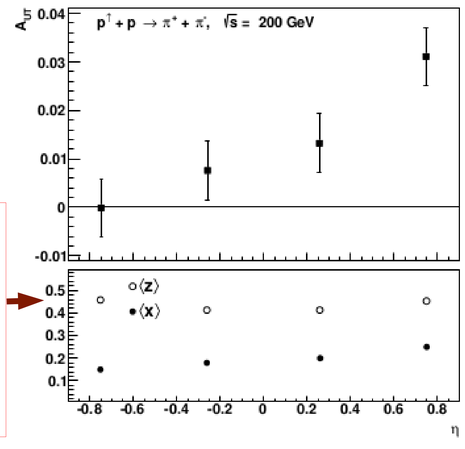
(L. Adamczyk, et al., Observation of Transverse Spin-Dependent Azimuthal Correlations of Charged Pion Pairs in $p^{\uparrow} + p$ at $\sqrt{s} = 200$ GeV, Phys. Rev. Lett. 115 (2015) 242501)

- RHIC Run 2006 (polarized proton-proton) data used for asymmetry measurement.
- Average beam polarization ≈ 60%
- $\int L\,dt = 1.8\ (pb)^{-1}$

- Pion track selection :
  → $P_t > 1.5$ GeV → $-1 < \eta < 1$
  → dca < 2 cm
  → PID : -1.3 < nSigmaPion < 2
  → Used all +/- pairs in one event
  → Z-Vertex within ± 60 cm
  → Opening Angle < 0.3
  → Minimum separation of 0.05 in (η, φ) space



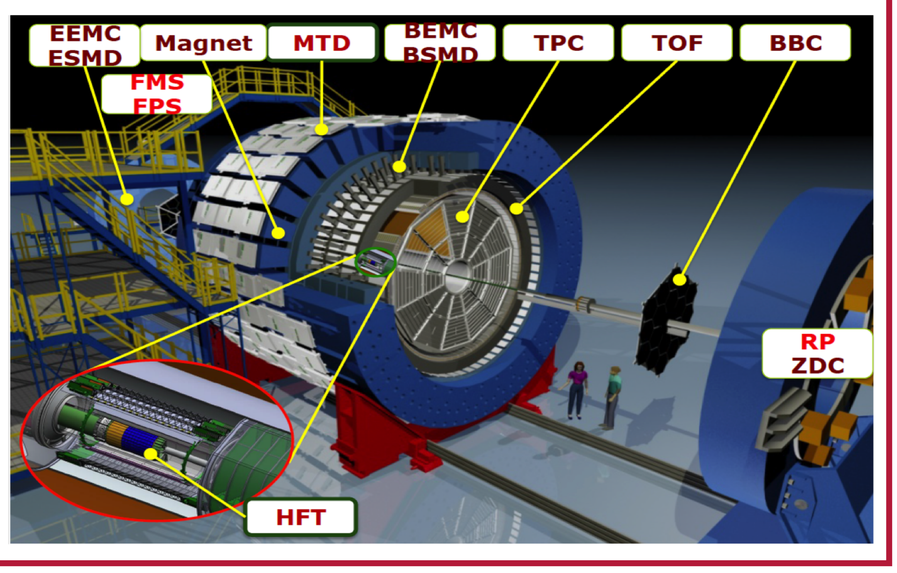
- A_{UT} as a function of Invariant Mass (M) (upper panel) and corresponding partonic variables x and z (lower panel).
- Clear enhancement of the signal around ρ-mass region ($m_\rho \approx 0.77$ GeV/c²) was observed.



- A_{UT} as a function of η (upper panel) and corresponding variables x and z($\pi^+\pi^-$) (lower panel)
  → <x> is linear with η (from 0.15-0.25)
  → <z> ≈ 0.4
  → A_{UT} reflects x dependence

STAR Detector

- **S**olenoidal **T**racker **A**t **R**HIC (**STAR**) is one of the major experiments at RHIC.
- Time Projection Chamber (TPC) provides tracking, measures momenta and identifies particles in central range |η| < 1 by measuring ionization energy loss, dE/dx.
- Barrel Time of Flight (TOF) within acceptance range |η| <1 over large solid angle improves particle identification, specifically important for multi-particle correlation studies.

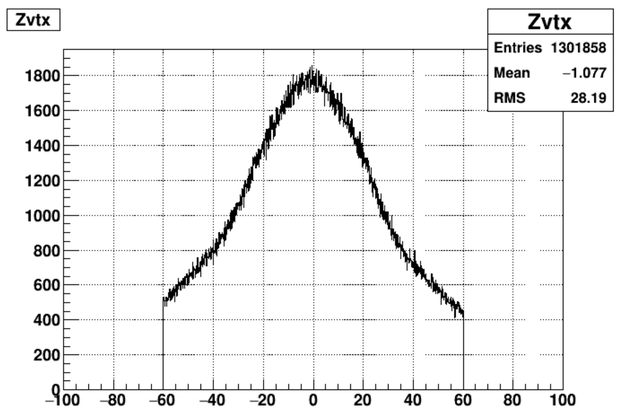


Updates: Run 2015 Analysis

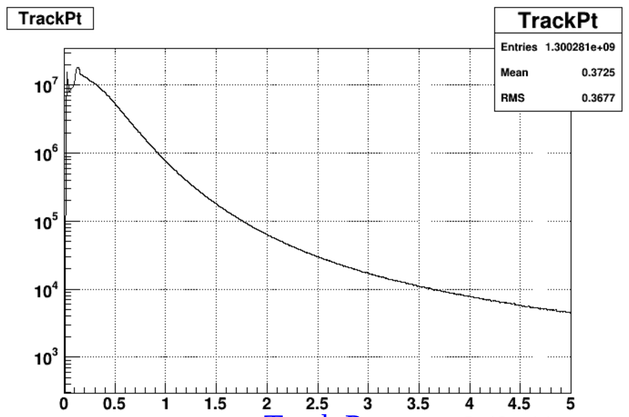
- A small sample of Run 2015 data has been looked at (≈ 0.1%).
- Sample plots are produced with limited selection cuts.

Track selection used:

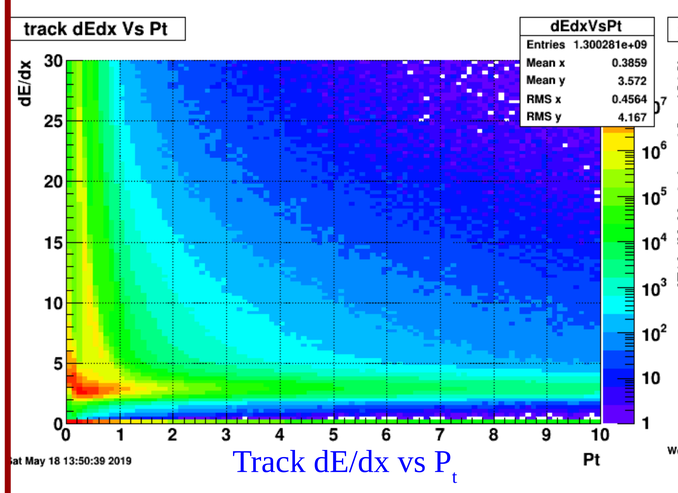
nSigmaPion ,	$-2 < n\sigma_\pi < 2$	FitRatio =	0.52
Pseudo rapidity,	$-1 < \eta < 1$	nHitMin =	15
Z-Vertex,	±60 cm	nHitMax =	100
TOF β*	< 0.03 (only if available)	nHitPossMin =	5



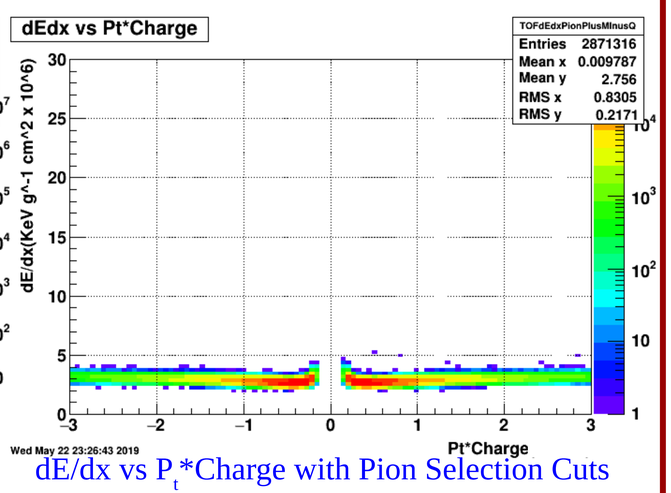
Z-Vertex Distribution



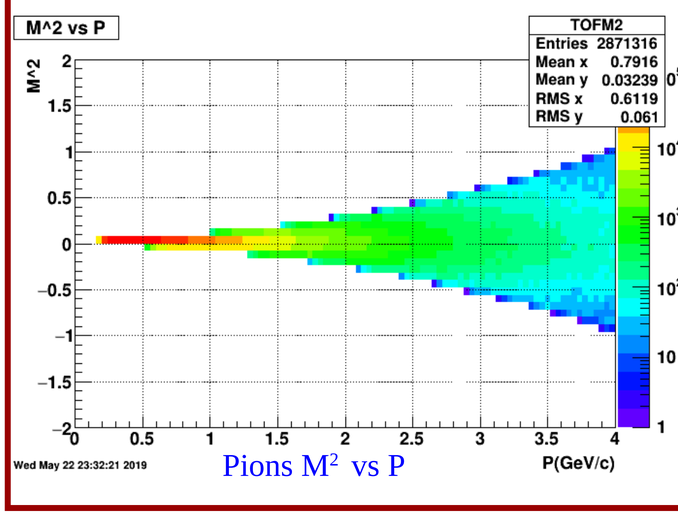
Track P_t



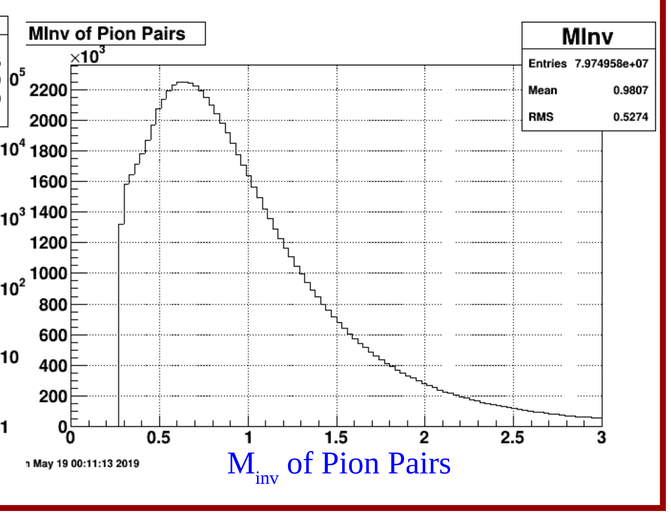
Track dE/dx vs P_t



dE/dx vs P_t*Charge with Pion Selection Cuts



Pions M^2 vs P



M_{inv} of Pion Pairs

Summary

- Azimuthal di-hadron correlation asymmetries are proportional to the product of transversity $h^q_1(x)$ and IFF $H_1^{\sphericalangle}(z,\ M)$.
- Transverse spin dependent charged pion pair correlation asymmetries (A_{UT}) were observed in run 2006 analysis in which A_{UT} is enhanced for M around ρ mass region and rises with p_t and η.
- With reference to previous analysis, the single spin asymmetry will be measured using run 2015 polarized proton-proton data.

- With small data sample, plots are produced for pion identification applying quality cuts in order to test analysis code.

Figure Of Merit (FOM):

Run 2006	Run 2015
Avg. Polz. (P_{06}) ≈ 60%	Avg. Polz.(P_{15}) ≈ 55%
$L_{06} = \int L dt = 1.8\ (pb)^{-1}$	$L_{15} = \int L dt = 64\ (pb)^{-1}$
$FOM_{(06)} = P^2_{06} \cdot L_{06} \approx 0.5$	$FOM_{(15)} = P^2_{15} \cdot L_{15} \approx 19$

Ratio = $FOM_{(15)}/FOM_{(06)} \approx 40$

- FOM shows that uncertainty in asymmetry measurement will be improved significantly.
- Since run 2015 collected significantly more data, this analysis will have better precision and improve our understanding of transversity.
- Analysis will provide a test for IFF's universality in comparison with SIDIS, e^+e^- and other available measurements.