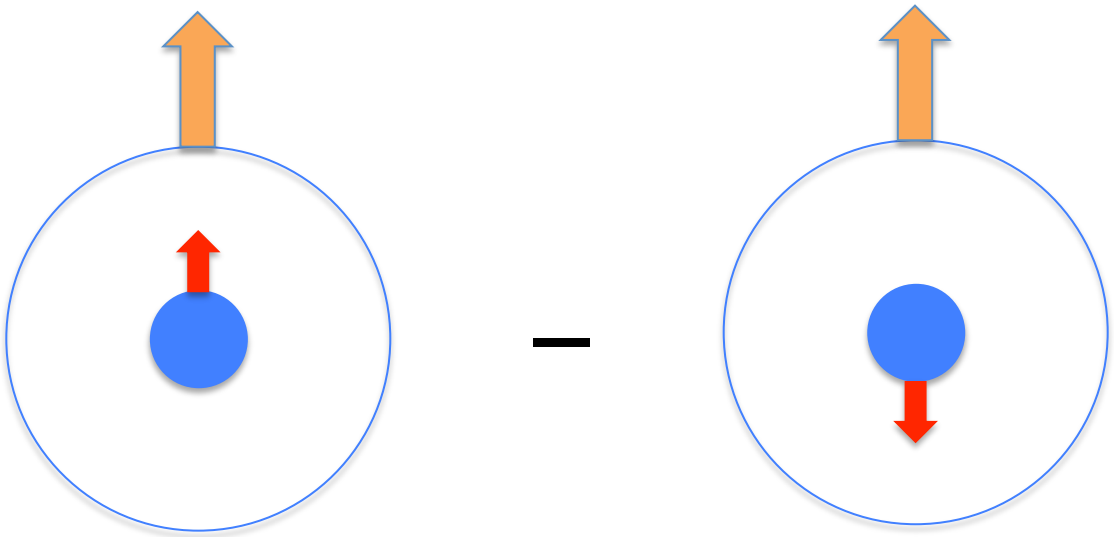
Azimuthal Single-Spin Asymmetries of Charged Hadrons in Jets at $\sqrt{s}$ = 200 GeV $p^{\uparrow}p$ Collisions at STAR

J. Kevin Adkins
For the STAR Collaboration

DNP 2013 – Newport News, VA
October 24, 2013

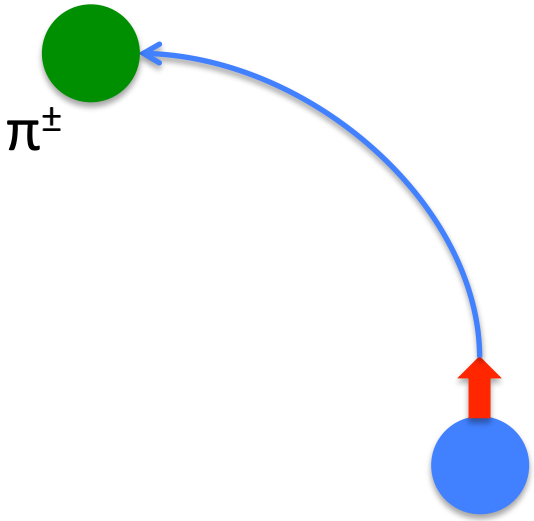
Physics in Transverse Collisions

- Transversity distribution – How are quarks polarized inside of a transversely polarized proton?



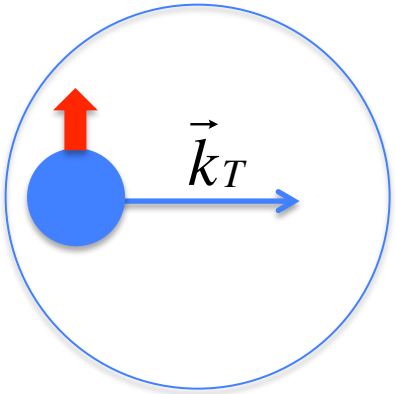
Physics in Transverse Collisions

- Collins fragmentation function (FF) – How is parent quark spin correlated with azimuthal distribution of hadrons?



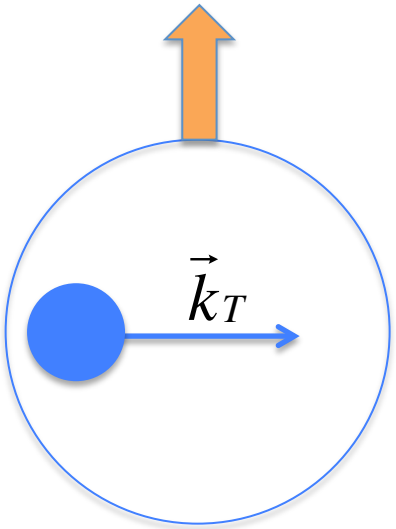
Physics in Transverse Collisions

- Boer-Mulders distribution – How is quark spin correlated to its transverse momentum in the proton?



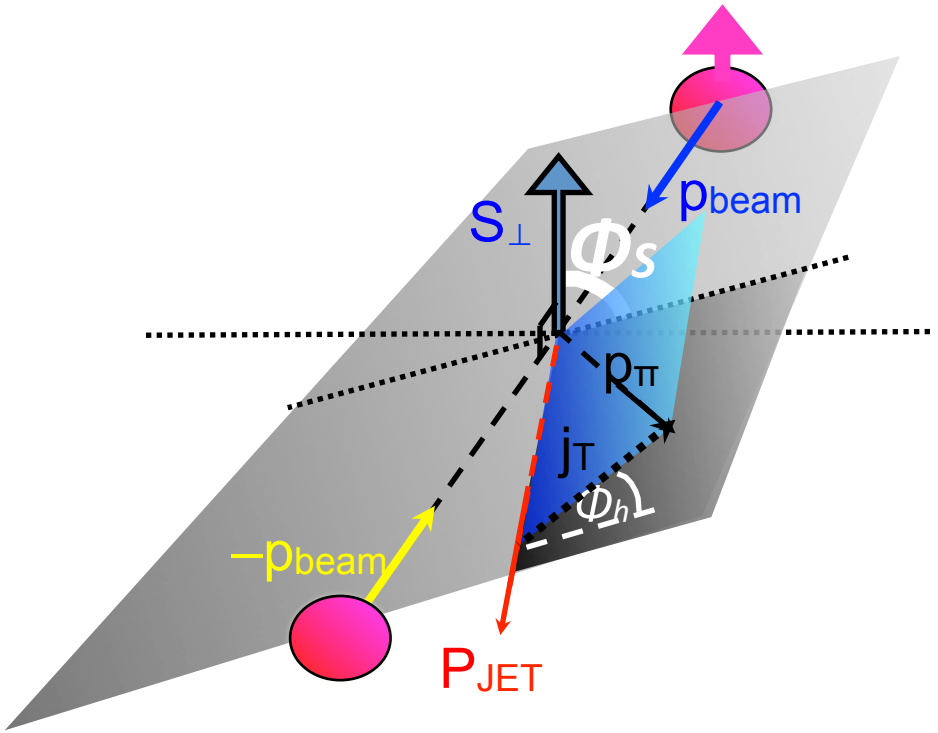
Physics in Transverse Collisions

- Sivers distribution – How is quark transverse momentum in a proton correlated with the proton spin?



Single Spin $p^{\uparrow}p$ Collisions

- ϕ_S defines angle between proton spin and reaction plane (Sivers)
- j_T defines particle transverse momentum in jet
- ϕ_H defines angle between jet particle transverse momentum and reaction plane
- $\phi_C = \phi_S - \phi_H$ (Collins)



Jet Single-Spin Asymmetries (SSA)

- Several moments contribute to SSA for quark-quark scattering in TMD factorization
- Sensitivity at STAR:

Terms in Numerator of TMD SSA for qq scattering	English Names	Modulate
$\Delta^N f_{a/A\uparrow} \bullet f_{b/B} \bullet D_{\pi/q}$	Sivers•PDF•FF	$\sin\left(\varphi_{S_A}\right)$
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$h_{1T}^{\perp a} \bullet \Delta^N f_{b\uparrow/B} \bullet D_{\pi/q}$	Pretzelocity•Boer-Mulder•FF	$\sin\left(\varphi_{S_A}\right)$
$h_1^a \bullet f_{b/B} \bullet \Delta D_{\pi/q\uparrow}$	Transversity•PDF •Collins	$\sin\left(\varphi_{S_A} - \varphi_\pi\right)$
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Phys. Rev. D 83 034021 (2011)

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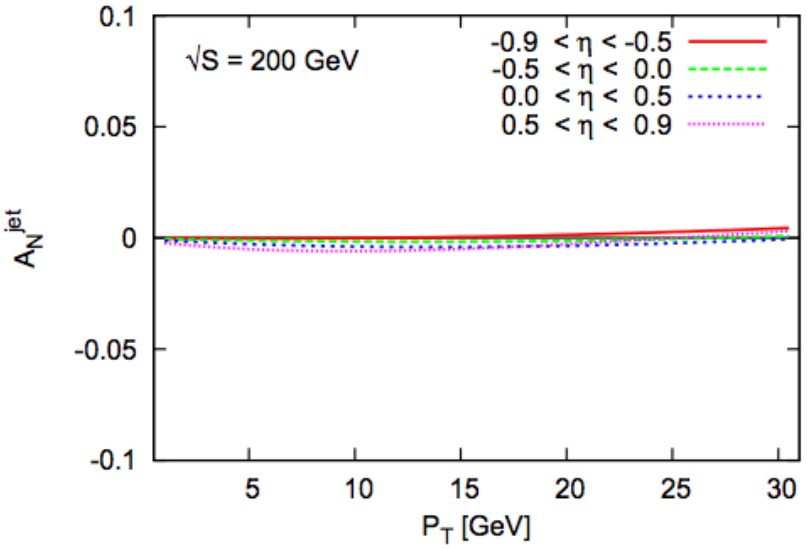
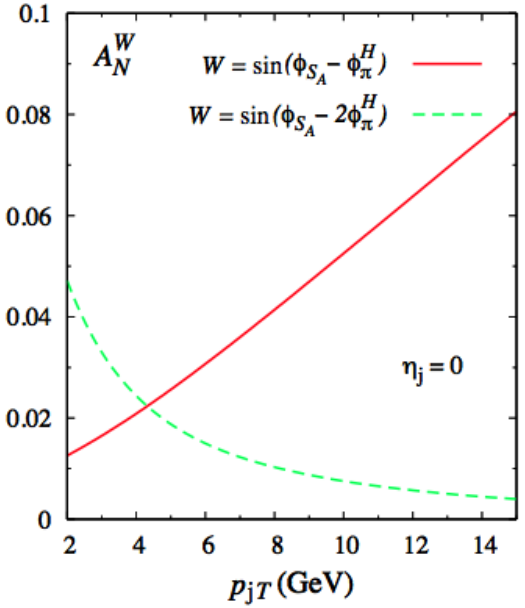
Theory Predictions



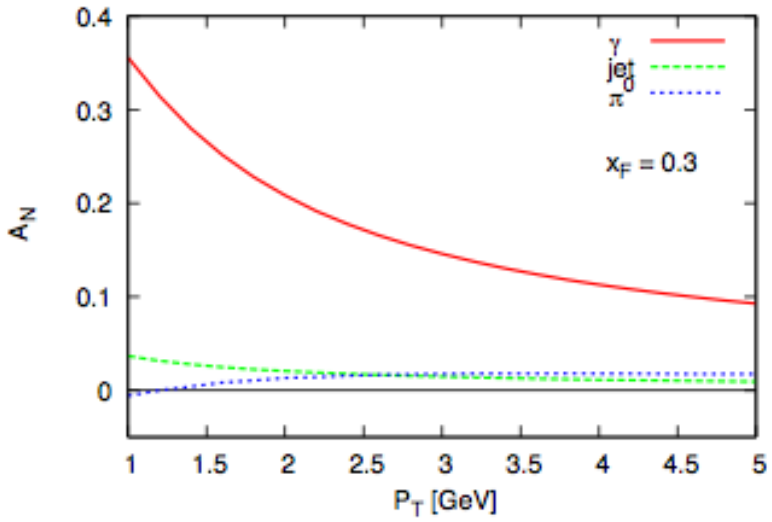
Kanazawa and Koike
Phys. Lett B 720, 161 (2013)



D' Alesio et. al.
Phys. Rev. D 83 034021 (2011)

- Twist 3 predicts Sivers asymmetry to be small at mid-rapidity, constrained by previous STAR analysis
  Phys. Rev. D 86 (2012) 32006
- Significant Collins asymmetries predicted at intermediate η as a function of jet p_T at √s = 200 GeV

Theory Predictions



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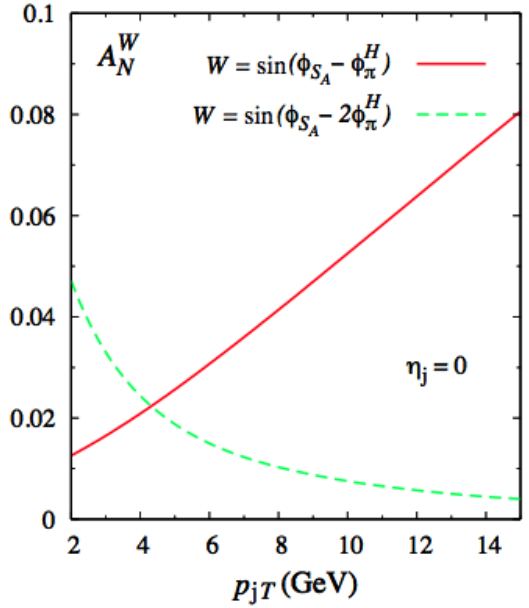

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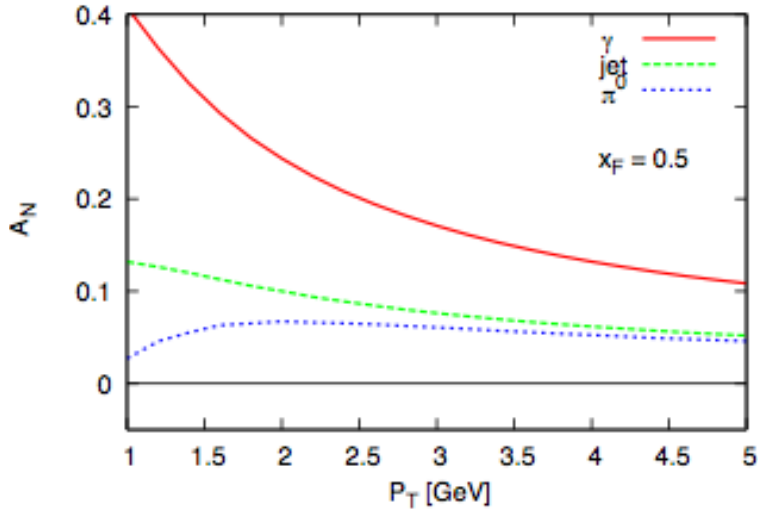

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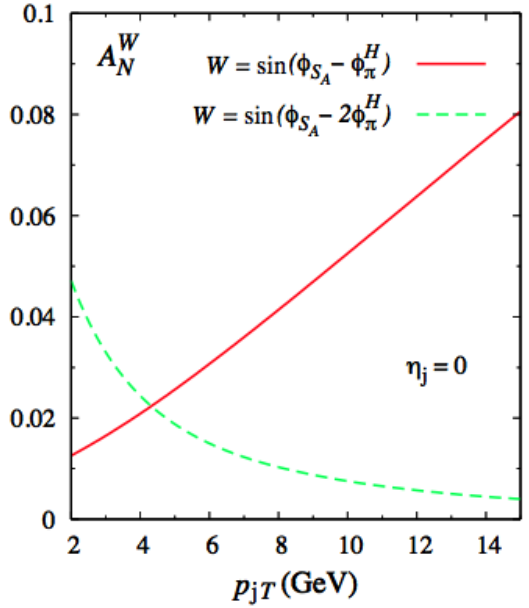

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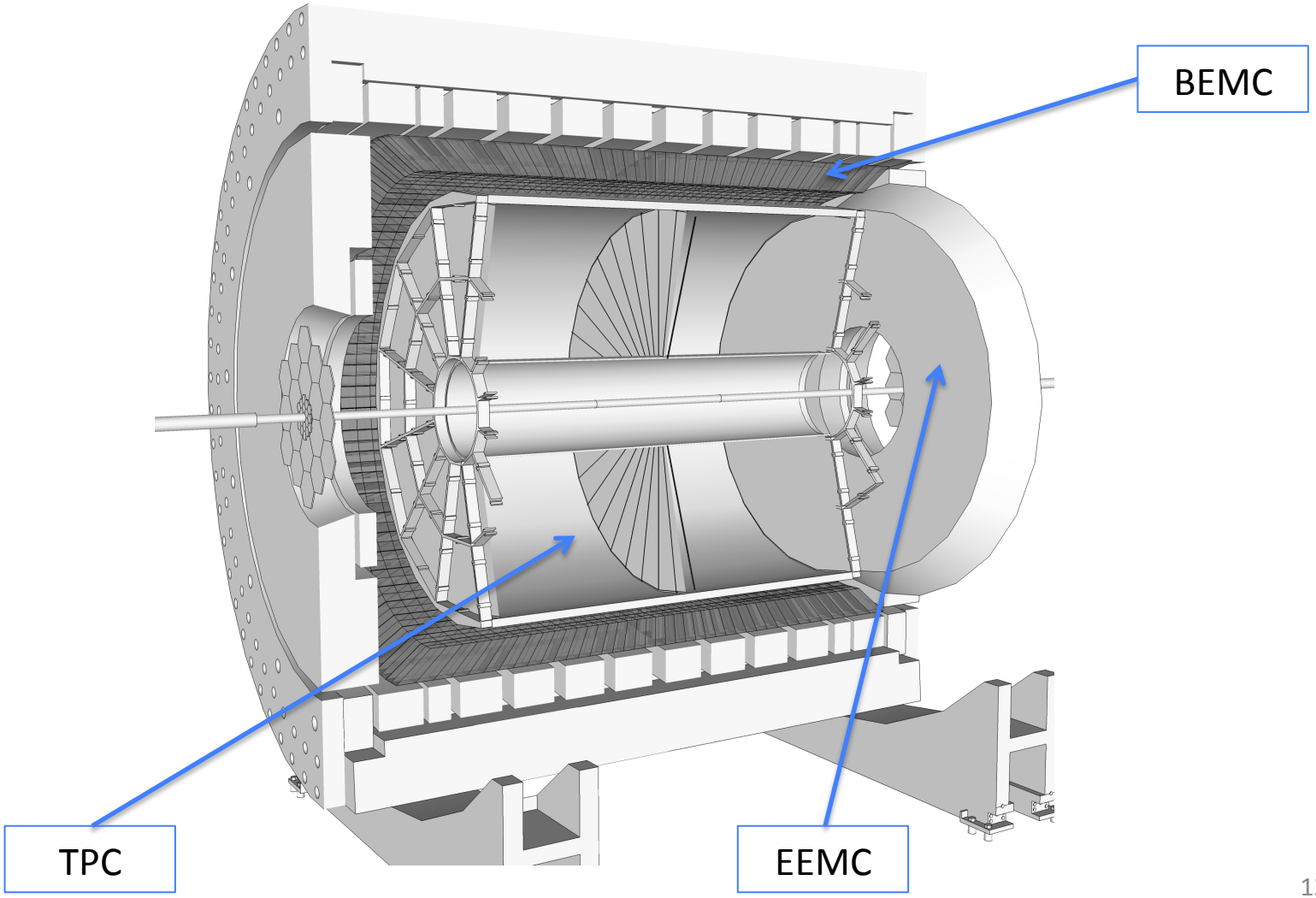
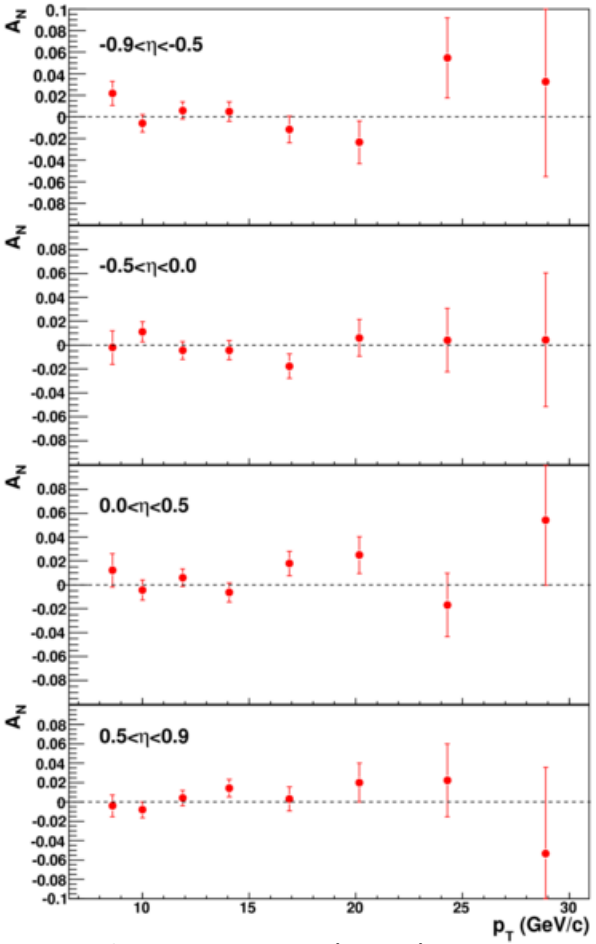
STAR Detector



Previous Results

- Limited statistics sample in Run 2006
- Hints of non-zero Collins asymmetries with possible charge separation
- Weighted moment analysis gives large systematic errors due to detector acceptance and efficiency
- Sivers asymmetries small and provided tighter theoretical constraints

Inclusive Jet A_N



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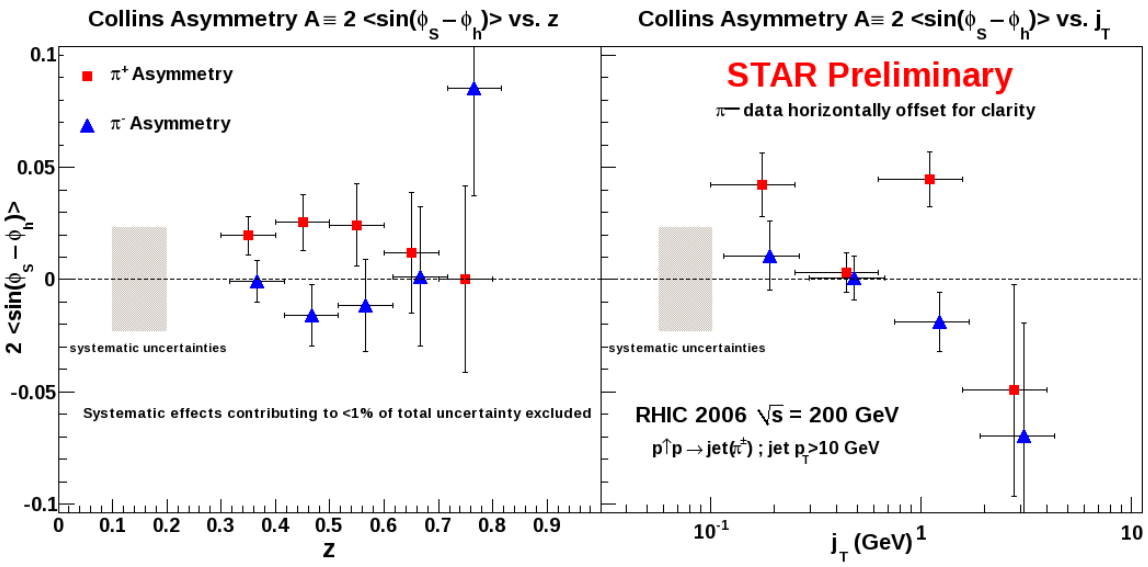
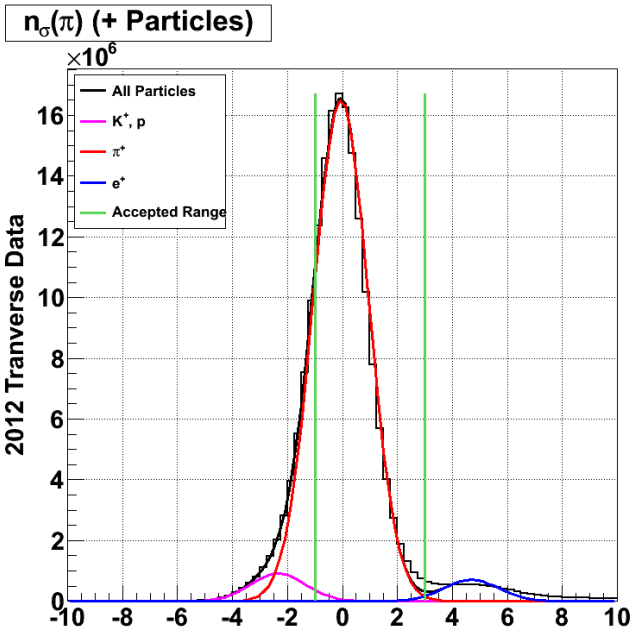
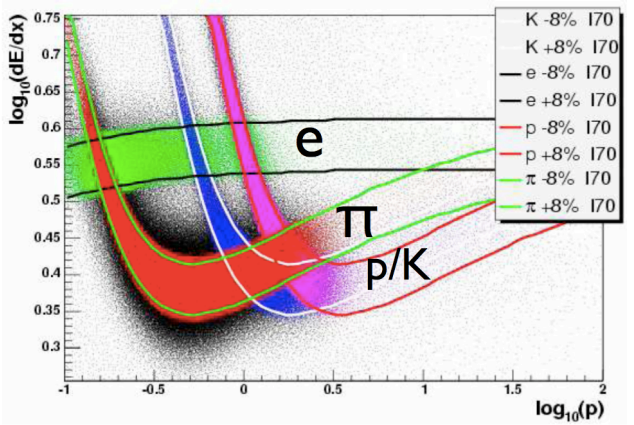


$$z = \frac{p_\pi}{p_{jet}}$$

Data From 2012 Run

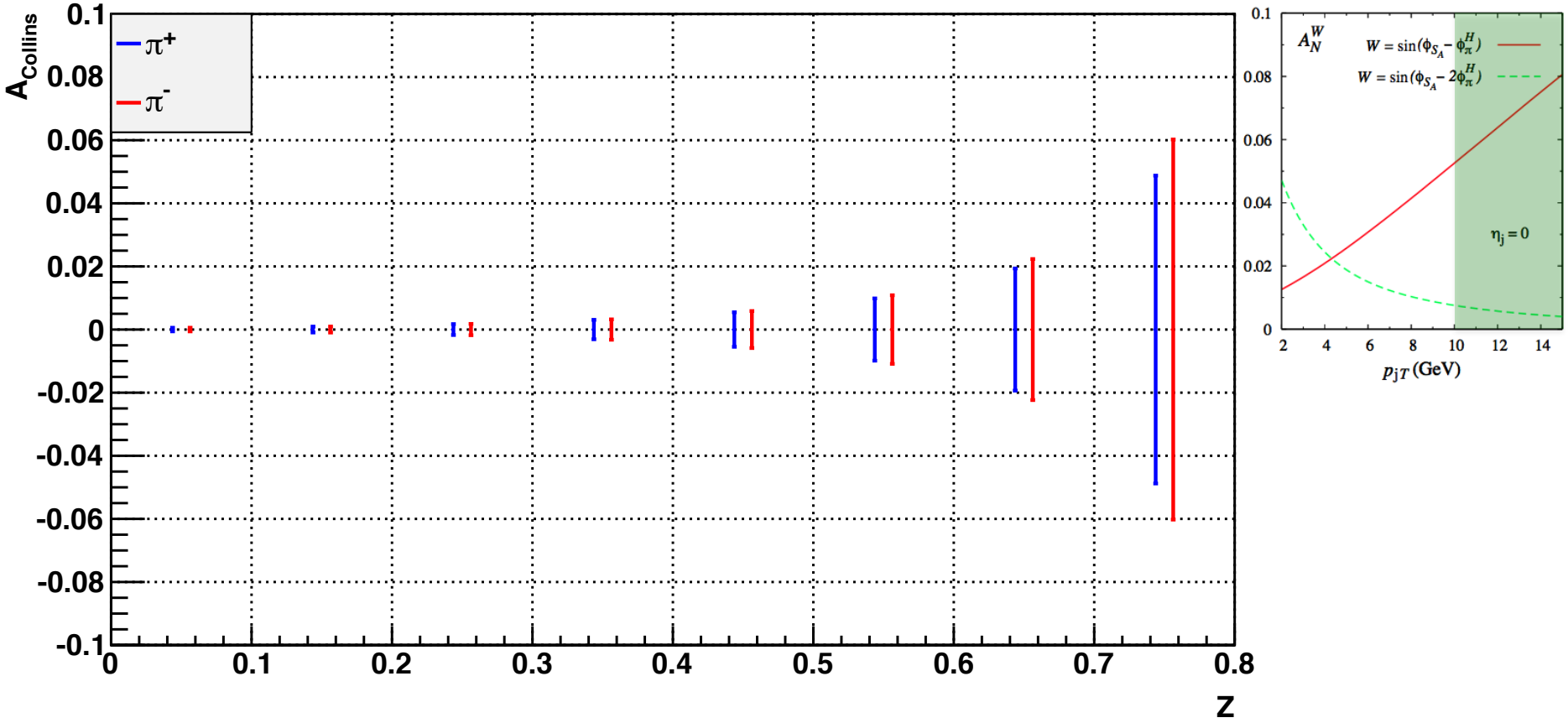
- 20 pb^{-1} transversely polarized proton collisions at √s = 200 GeV
  - Factor of 10 larger dataset than in 2006
- Average event weighted polarization: 63%
  - Improvement over 58% for run 2006
- Switch jet algorithm from midpoint cone to anti-kT with radius 0.6





Nucl.Instrum.Meth. A558:419-429,2006

Projected Statistical Uncertainty



$x_F > 0$, $p_T > 10$ GeV/c, $|\eta_{jet}| < 0.8$

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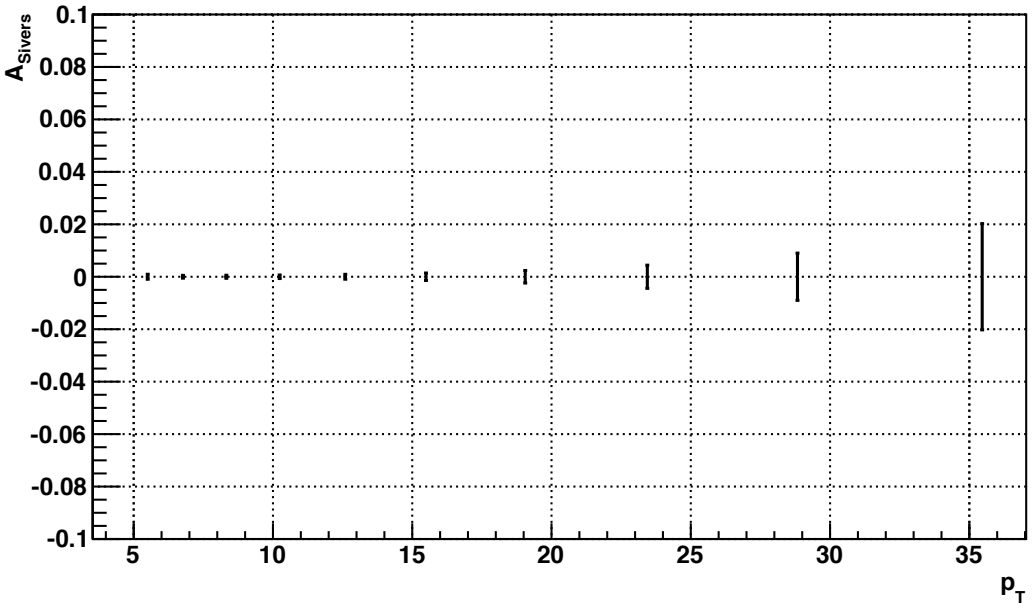
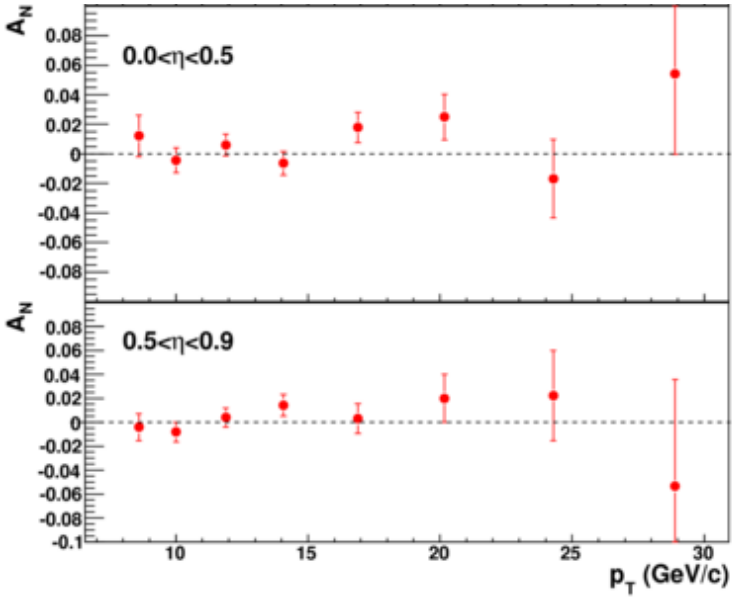




$x_F > 0$, $p_T > 5$ GeV/c, $|\eta_{jet}| < 0.8$

Outlook

- Increased statistical precision offers a bright future for transverse spin analyses at STAR
  - Help constrain Collins asymmetry
  - Coupled with results from 500 GeV asymmetries, we can learn about Q^2 evolution of Collins FF
    - More information in Jim Drachenberg's talk coming up shortly
  - We will have a good look at any charge separation
  - Is there a nonzero Sivers asymmetry at mid-rapidity?
- Precise Collins asymmetry measurements will help constrain transversity distribution
- Inspire further theoretical interest in transversely polarized hadronic collisions

Backup

Weighted Moment Analysis

- Mathematically the measured asymmetry is

$$A_{meas}(z) = \frac{\int A_N \sin^2(\phi_c) d\phi_c}{\int d\phi_c} = \frac{A_N}{2}$$

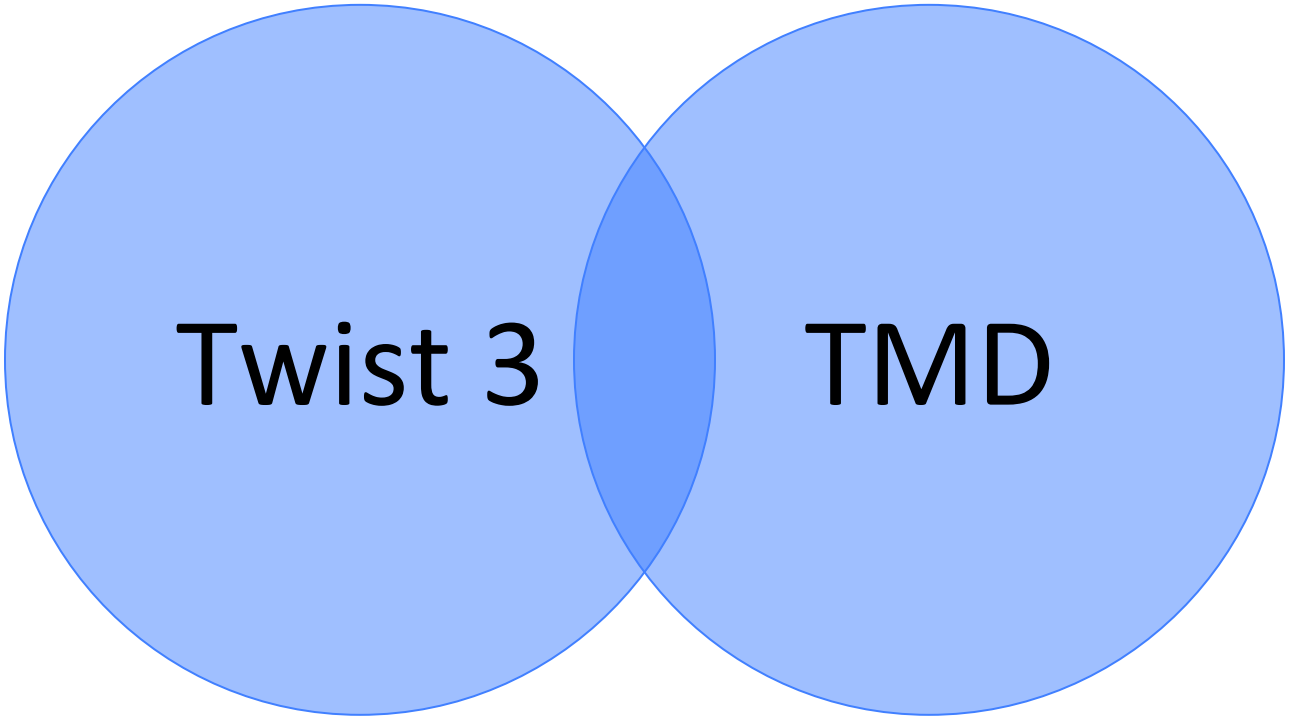
- So experimentally we measure the Collins asymmetry as

$$A_N = 2A_{meas}(z) = 2\left\langle \sin\left(\phi_S - \phi_H\right)\right\rangle$$

Momentum Scales in QCD Single-Spin Asymmetries

$\Lambda_{QCD} << P_T^{jet}$

$\Lambda_{QCD} \leq j_T << P_T^{jet}$



$\Lambda_{QCD} << j_T << P_T^{jet}$

In the “intermediate region” the approaches converge and we can describe SSA in terms of either

Soffer Bound

- Defines maximally allowed value of the transversity distribution

$$\Delta_T q(x) \leq \frac{1}{2}\left[q(x) + \Delta q(x)\right]$$