Measurement of Transverse SSA for J/ψ Production in Polarized p+p Collisions at PHENIX

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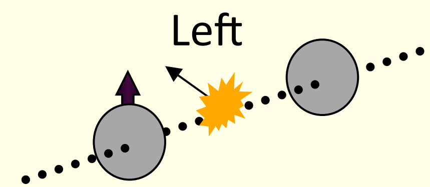
Motivation

Transverse Single Spin Asymmetries A_N

$$A_N = \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}}$$

$d\sigma^{\uparrow(\downarrow)}$ - Cross section for leftward scattering when beam polarization is spin-up(down)



Theory Expectation:

Small asymmetries at high energies

(Kane, Pumplin, Repko, PRL 41, 1689–1692 (1978))

$$A_N \propto \frac{m_q}{\sqrt{s}}$$

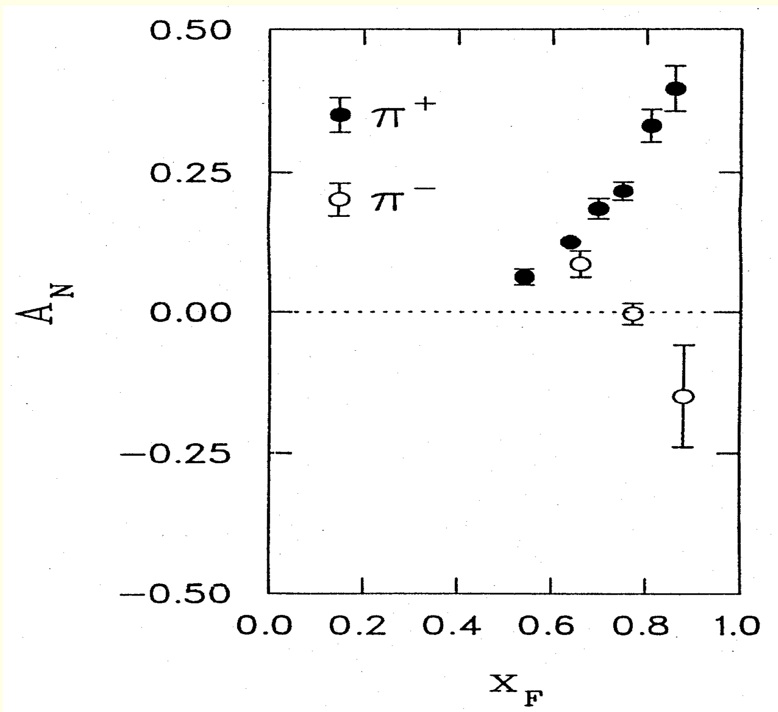
$A_N \sim 10^{-4}$ theory

Experiment Observations:

$A_N \sim 10^{-1}$ observed

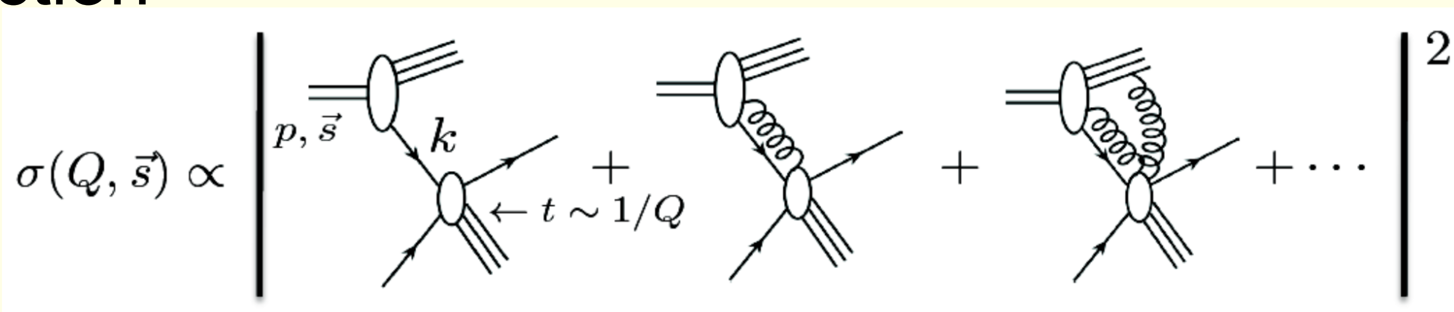
$$pp^{\uparrow} \longrightarrow \pi + X$$

W.H. Dragoset et al., PRL36, 929 (1976)



Theory: Twist-3 Collinear framework

- Multi-parton correlations contribute to the cross section



$$A_N \propto \sigma(pT, S_\perp) - \sigma(pT, -S_\perp)$$
$$\propto T^{(3)}(x,x,S_\perp) \otimes \hat{\sigma}_T \otimes D(z) + \delta q(x,S_\perp) \otimes D^{(3)}(z,z) + \cdots$$

Twist-3 parton correlation func

Twist-3 parton fragmentation func

(J.-W. Qiu, G. Sterman,
Single transverse spin asymmetries,
Phys. Rev. Lett. 67, 2264 (1991))

(Z. –B. Kang, F.Yuan, J. Zhou,
Collins Fragmentation and the
Single Transvers spin asymmetry,
Phys. Lett. . B691, 243-248 (2010))

Theory: TMD framework

- Transverse Momentum Dependent Functions

If factorization of TMD functions are valid in Semi-Inclusive Deep-Inelastic Scattering (SIDIS) processes, the cross section data are analyzed according to a factorized theoretical expression:

$$d\sigma^{lp\to lhX} = \sum_q f_{q/p}(x,k_\perp;Q^2) \otimes d\hat{\sigma}^{lq\to lq} \otimes D_{h/q}(x,p_\perp;Q^2)$$

Parton distribution func — hard-scattering interaction — fragmentation func

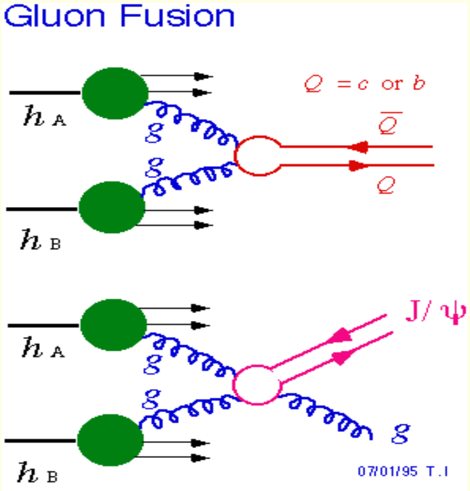
TMD Functions

(Sivers, Collins…)

Heavy Flavor A_N

- Heavy flavor production dominated by gluon gluon fusion at RHIC energy
  Pythia 6.1 simulation (LO)

$$c\bar{c}: \; gg \rightarrow c\bar{c} \quad 95\%$$
$$b\bar{b}: \; gg \rightarrow b\bar{b} \quad 85\%$$



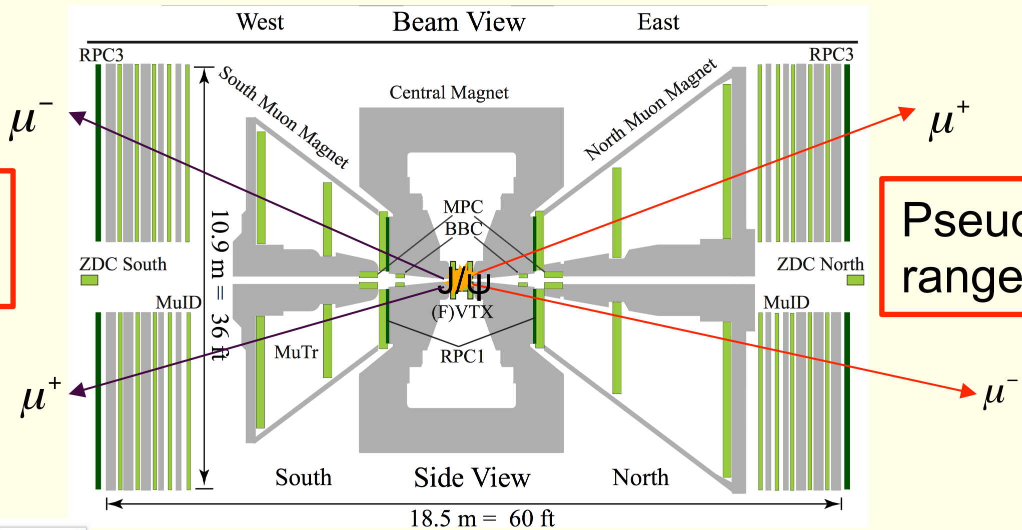
- Collins mechanism: Correlation between transversely polarized parton and transverse momentum of outgoing hadron.
  Heavy Flavor A_N -> minimized Collins effects -> sensitive to the initial state effects such as a gluon Qiu-Sterman and tri-gluon correlation.
  (Z.-B. Kang and J.-W. Qiu, Phys. Rev. D 78, 034005 (2008))

- Also sensitive to J/ψ production mechanisms and QCD dynamics
  (D. Silver, Phys. Rev. D 41, 83 (1990))

Measurement of Transverse SSA for J/ψ

- PHENIX measured transversely polarized p+p collision at $\sqrt{s} = 200GeV$ in 2006, 2008 and 2012.
- $J/\Psi \rightarrow \mu^{+}\mu^{-}$(dimuon) decay channel is used for J/ψ transverse SSA analysis. And dimuons are measured by the forward arm at PHENIX.

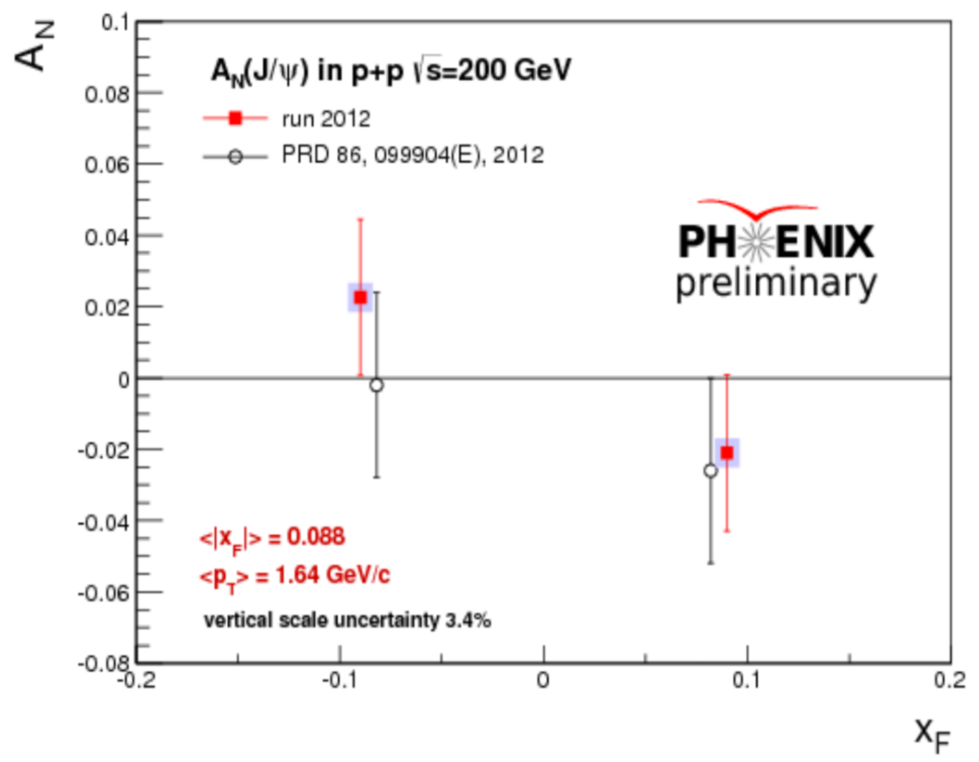
J/ψ P_T range : 0 - 10 GeV/c

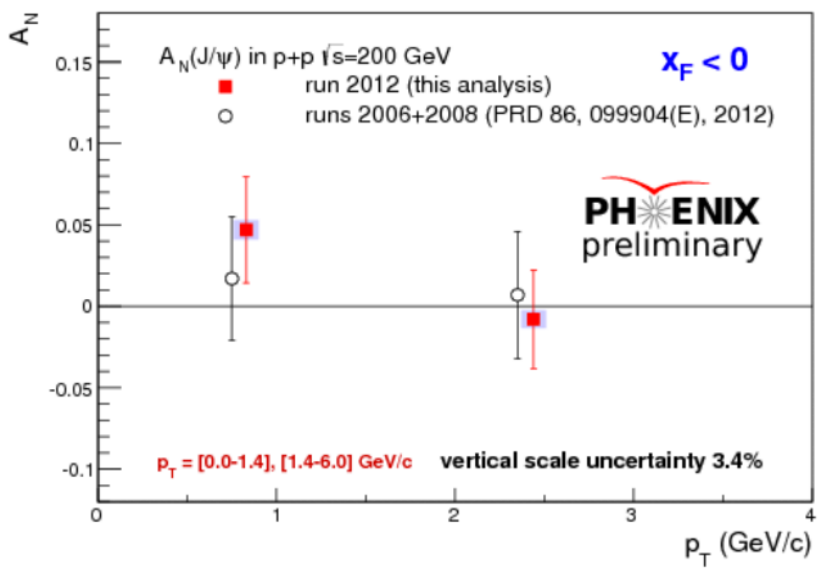


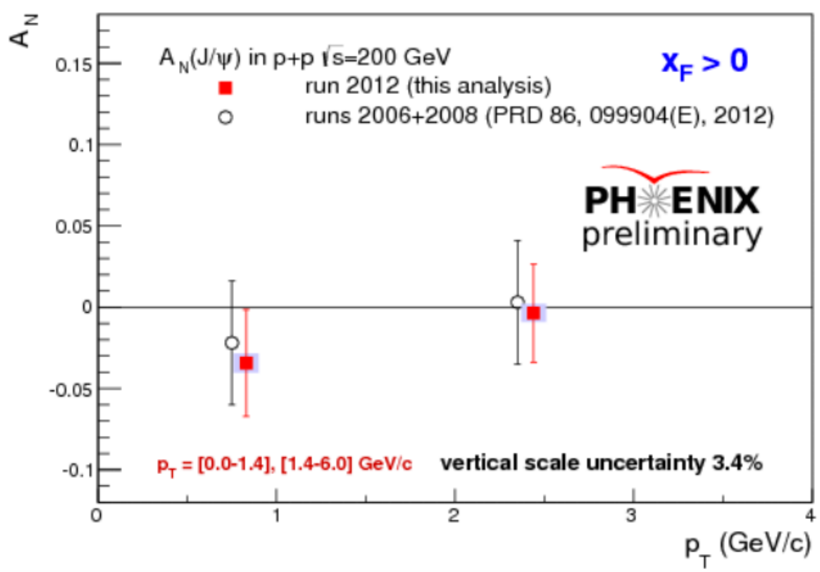
Pseudo-rapidity range: 1.2 < |y| < 2.2

Result and conclusion in previous years

- The result is consistent with 0
- Statistical uncertainties are dominant







Why Run15?

- p+p collision at 200GeV in PHENIX

Run \ Lumi.\Pol	Luminosity (pb^{-1})	Polarization (%)
2006	1.8	53
2008	4.5	45
2012	9.2	60
2015	50	60

- First time PHENIX runs p+Au. The ratio of A_N with polarized p+Au and p+p at 200GeV in Run15 is a unique test for saturation physics.

(Yuri Kovchegov, Single-spin Asymmetry in polarzed p+A collisions, A joint BNL-LANL-RBRC workshop to advocate and to prepare for the first polarized p+Au run at RHIC, 2013)

How we measure J/ψ A_N

- Formula for A_N:

$$A_N = \frac{A^{incl} - r \cdot A^{BG}}{1 - r} \qquad r = \frac{N^{BG}}{N^{incl}} = \frac{N^{incl} - N^{signal}}{N^{incl}}$$

- Inclusive and signal dimuon number can be got by fit the invariance mass distribution of dimuon:

$$f(M) = (A + BM + CM^2 + DM^3) + N_{J/\Psi} \cdot \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(M - M_{J/\Psi})^2}{2\sigma^2}} + N' \cdot \frac{1}{\sqrt{2\pi}\sigma'} e^{-\frac{(M - M_{\Psi'})^2}{2\sigma'^2}}$$

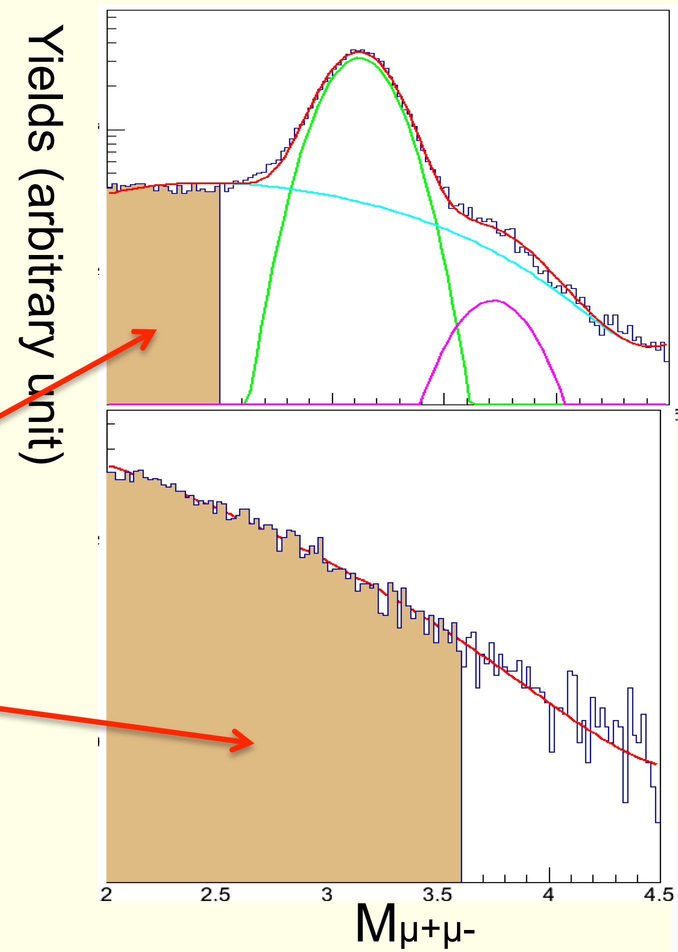
Background | J/ψ | ψ’

Getting A_N^{Incl} (A_N^{BG})

- A_N^{Incl} and A_N^{BG} are calculated with same method but different mass range and total charge of dimuon.

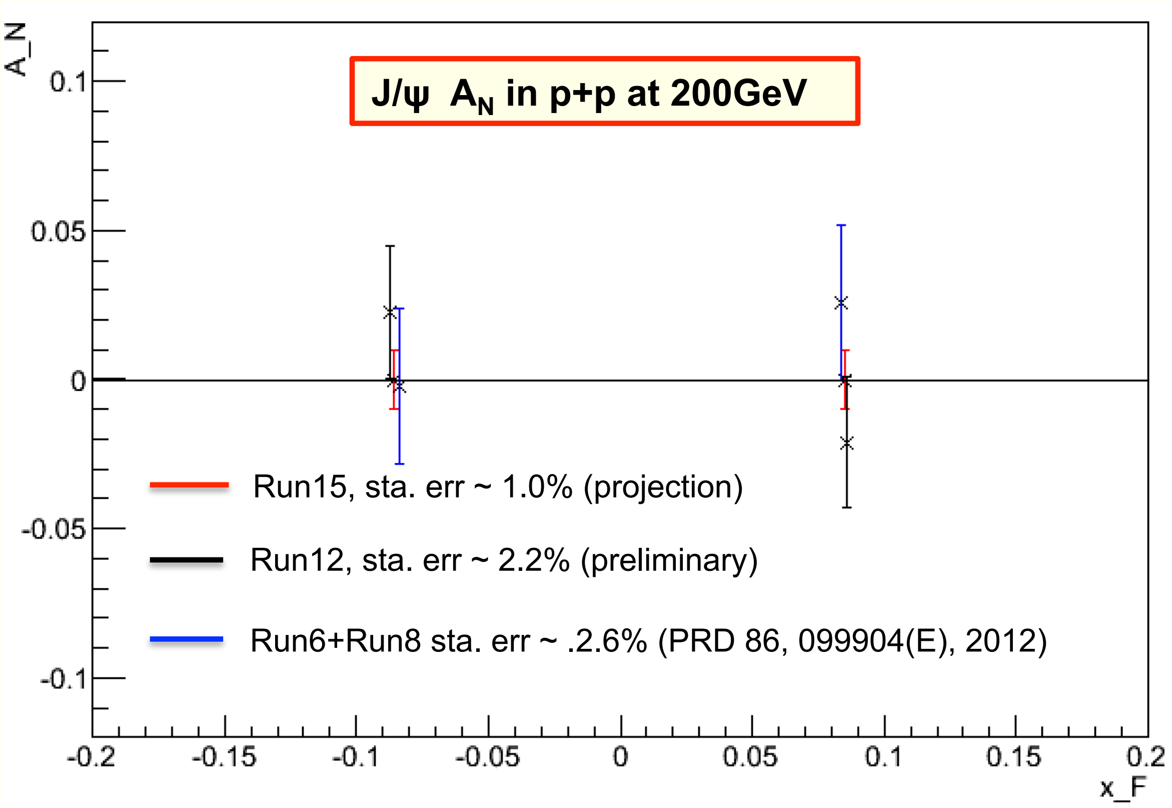
A_N^{Incl}: oppositely-charged muon pairs in the invariant mass range ±2σ around J/ψ mass.

A_N^{BG}: oppositely-charged muon pairs in the invariant mass range $2.0 < m < 2.5$ along with charged pairs of the same sign in invariant mass range $2.0 < m < 3.6$



Run15 projection

- The expected statistical uncertainty for Run15 is improved by factor of $1/\sqrt{5}$ compared with Run12.



Summary

- J/ψ A_N study in previous analysis at PHENIX is consistent with zero.
- Statistical uncertainties (~2.2%) are dominant.
- New data in 2015 will reduce the J/ψ A_N statistical error (~ 1%). Analysis is in process.
- Outlook: J/ψ A_N measurement in p+p and p+Au at 200GeV with Run15 data will provide very unique test for saturation physics.

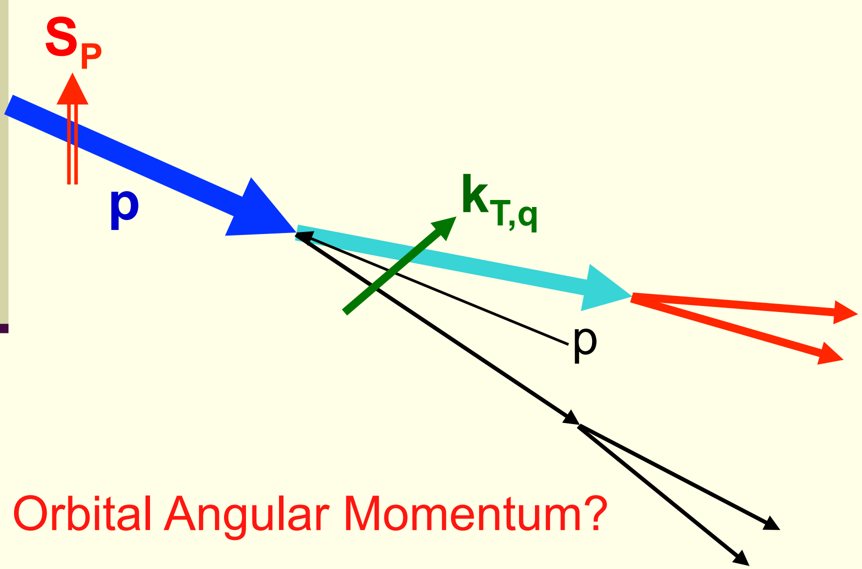
THANK YOU

Back up

Possible Mechanisms …

Sivers mechanism: Correlation between nucleon spin and parton k_T

Phys Rev D41 (1990) 83; 43 (1991) 261



Orbital Angular Momentum?

Collins mechanism: Transversity (quark polarization) * asymmetry in the jet fragmentation

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