PHENIX

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

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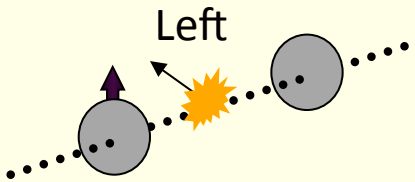
Motivation

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))

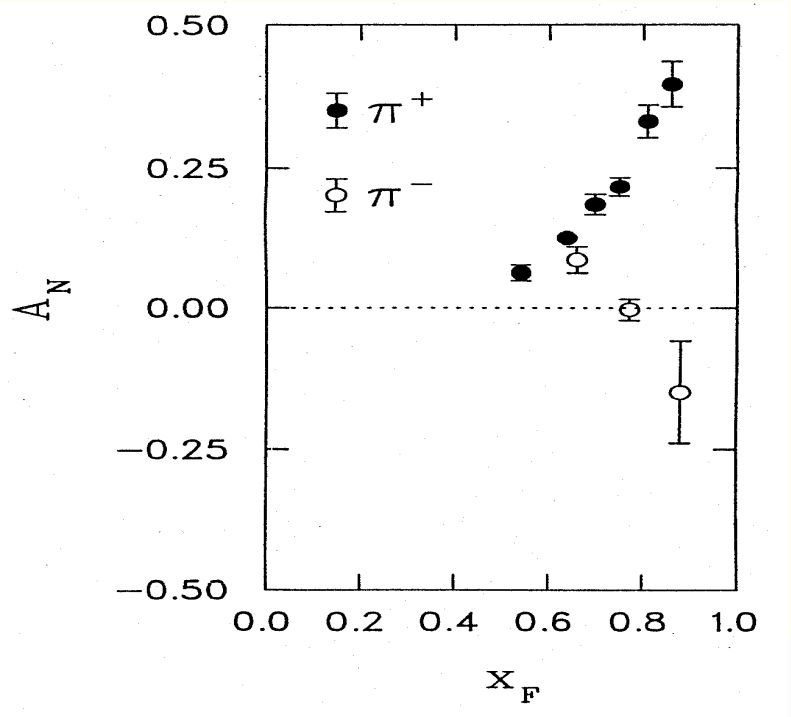
$$A_N \propto \frac{m_q}{\sqrt{s}}$$

A_N ~ 10^{-4} theory

Experiment Observations:

A_N ~ 10^{-1} observed

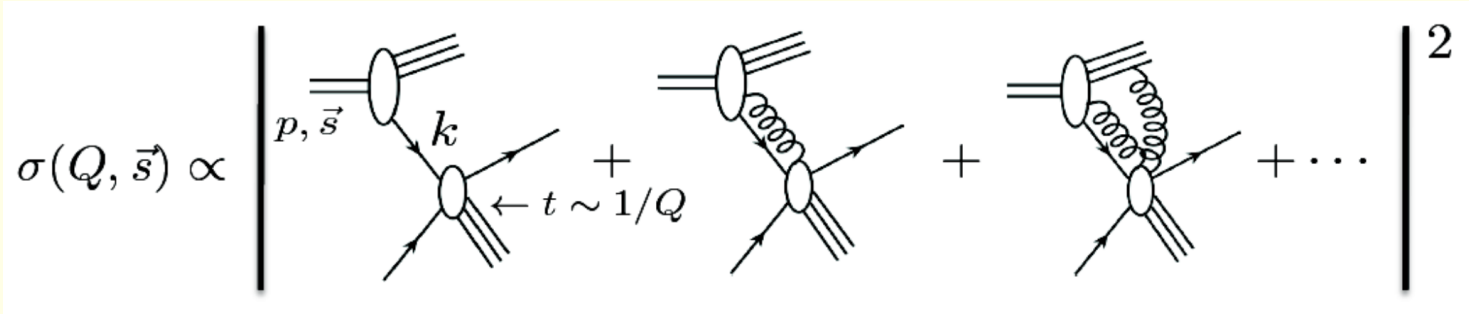
$$pp^{\uparrow} \rightarrow \pi + X$$



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 (initial state effect)

Twist-3 parton fragmentation func (final state effect)

(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))

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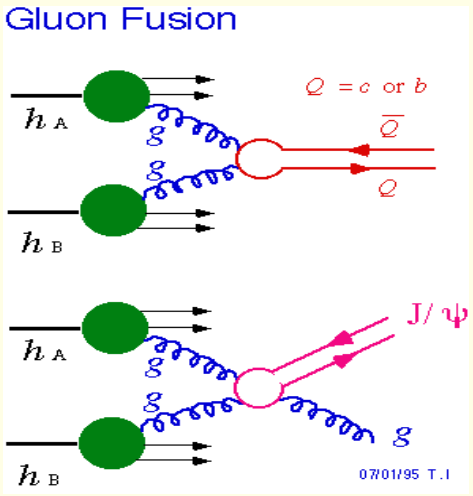
Heavy Flavor A_N

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

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



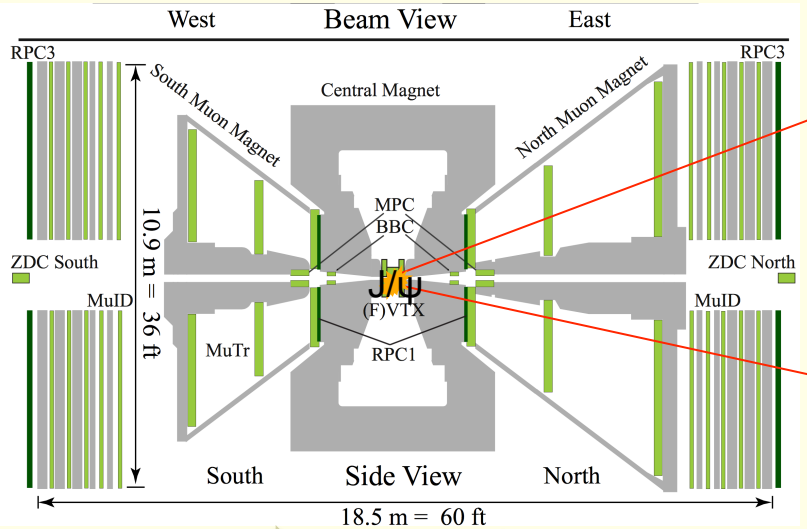
- Final state effect: Correlation between transversely polarized parton and transverse momentum of outgoing hadron.
  Heavy Flavor A_N -> minimized final state effects (gluon has zero transverse spin) -> sensitive to the initial state effects such as a gluon Qiu-Sterman and tri-gluon correlation.
  (Z.-B.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

- Also sensitive to J/ψ production mechanisms and QCD dynamics
  (D. Sivers, 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. Dimuons are measured by the forward arm at PHENIX.

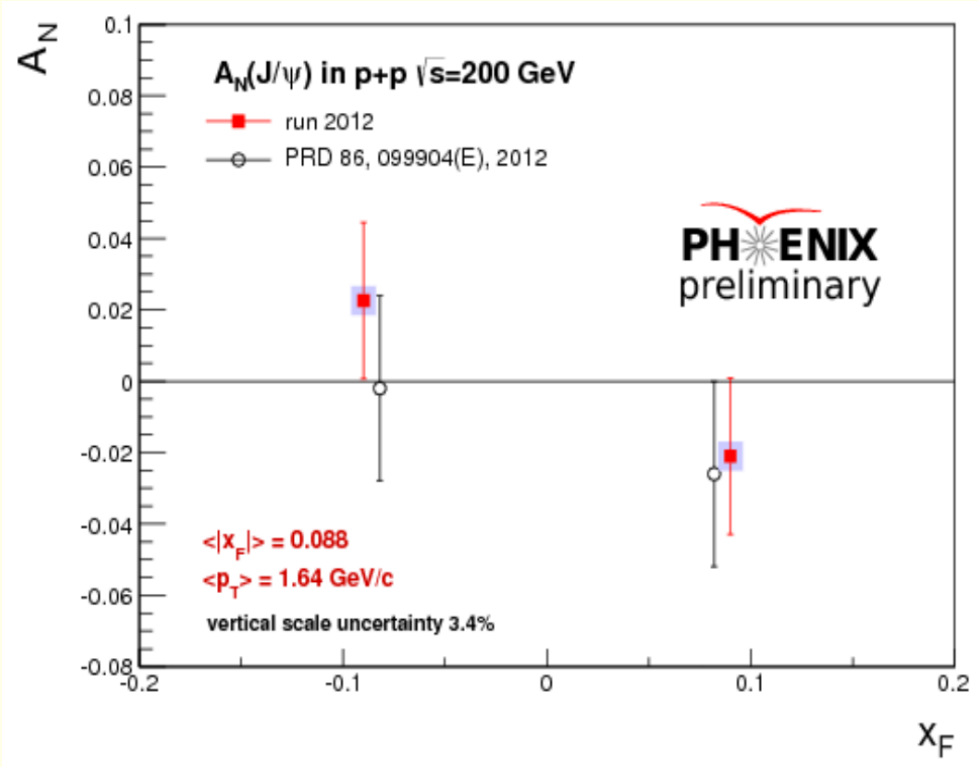
J/ψ P_T range : 0 - 10 GeV/c

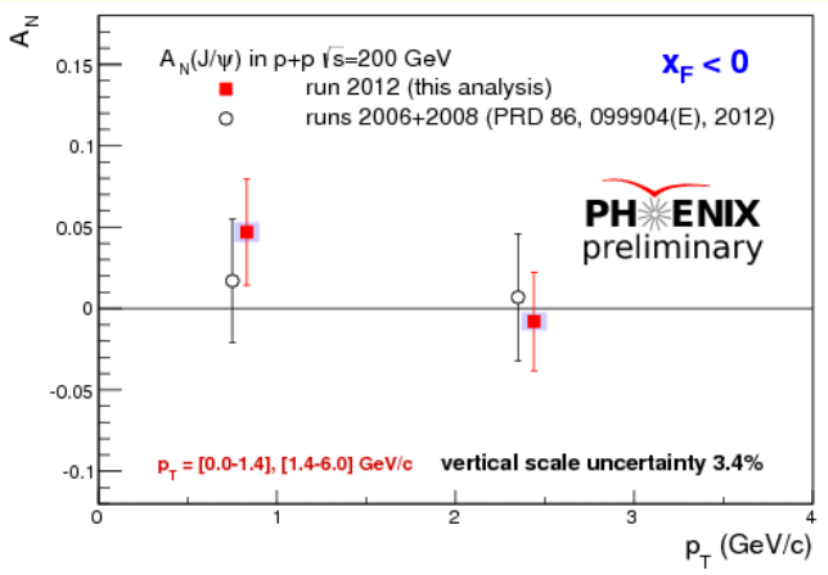


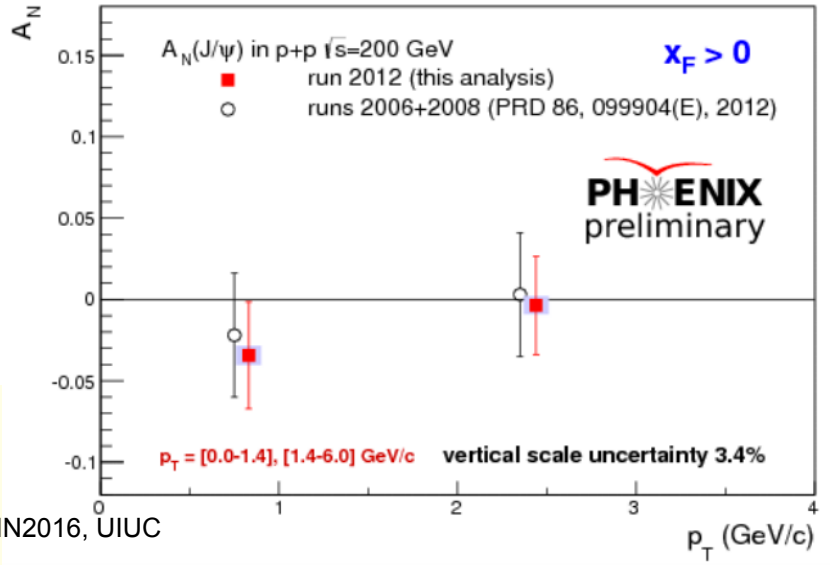
Pseudo-rapidity range: 1.2 < |y| < 2.2

Result and conclusion in previous years

- The result is consistent with 0
- Statistical uncertainties ~ 2.5%







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Why Run15?

- p+p collision at 200GeV in PHENIX

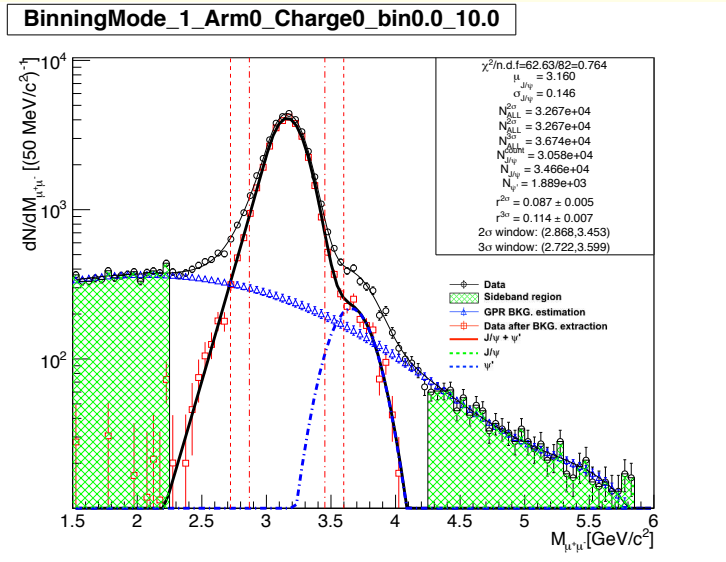
Run \ Lumi.\Pol	Luminosity (pb^{-1})	Polarization (%)
2006	1.8	53
2008	4.5	45
2012	9.2	60
2015	50	60

- Approximately 4x more luminosity in 2015 than in all previous runs combined.
- First time PHENIX runs p+Au. Offer a very good chance to test nuclear dependence ANs.

How we measure J/ψ A_N

- $A_N^{J/psi}$:

$$A_N^{J/psi} = \frac{A_N^{incl} - f \cdot A_N^{BG}}{1-f} \qquad \delta A_N^{Jpsi} = \frac{\sqrt{\delta^2 A_N^{Incl.} + f^2 * \delta^2 A_N^{Bkg}}}{1-f} \qquad f = \frac{N^{BG}}{N^{incl}}$$



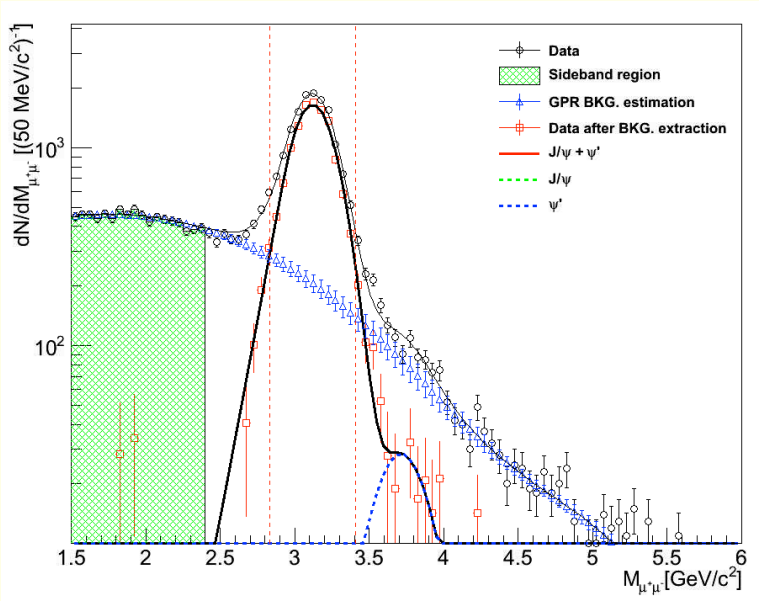
- Gaussian Process Regression method is used for estimating the background.
- Signal yields obtained by subtracting GPD background from inclusive dimuon data.

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

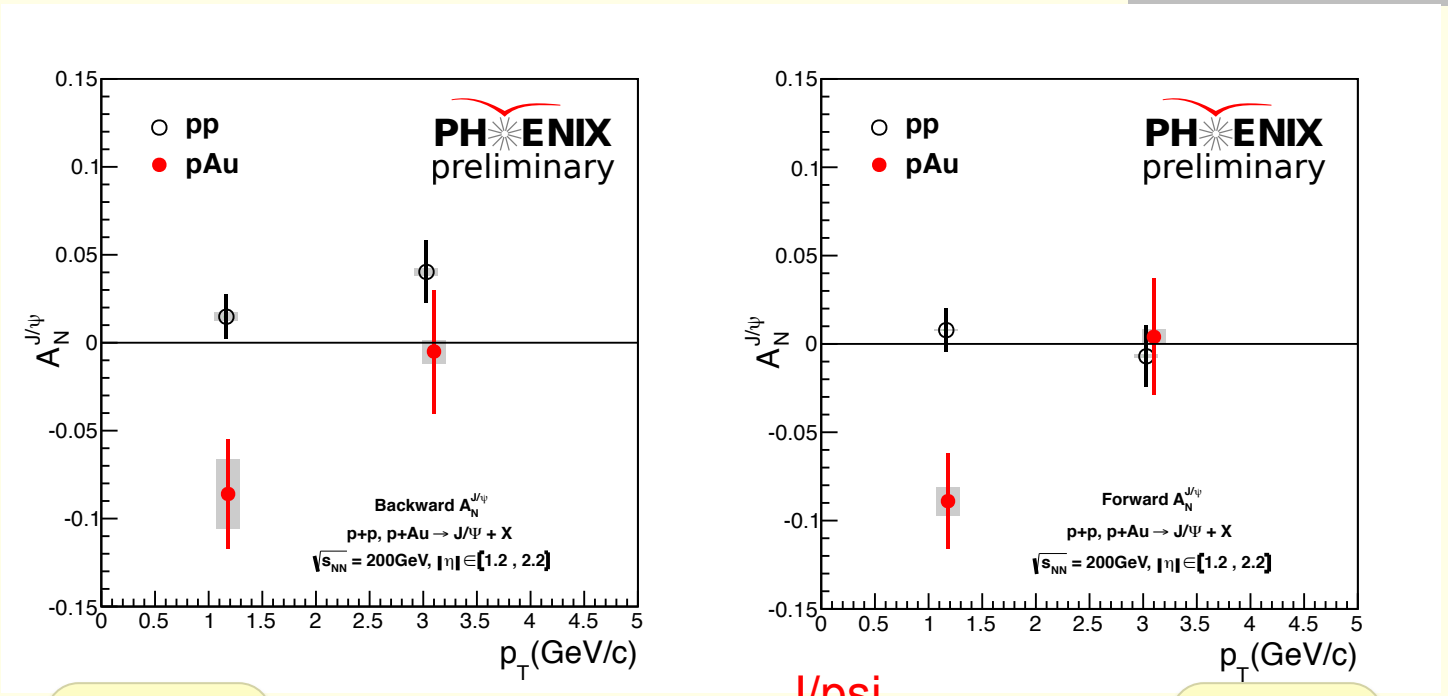
- A_N^{Incl} and A_N^{BG} are calculated with same method but different dimuon mass range.

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

A_N^{BG}: Unlike sign muon pairs in the invariant mass range $1.5 < m < 2.4$

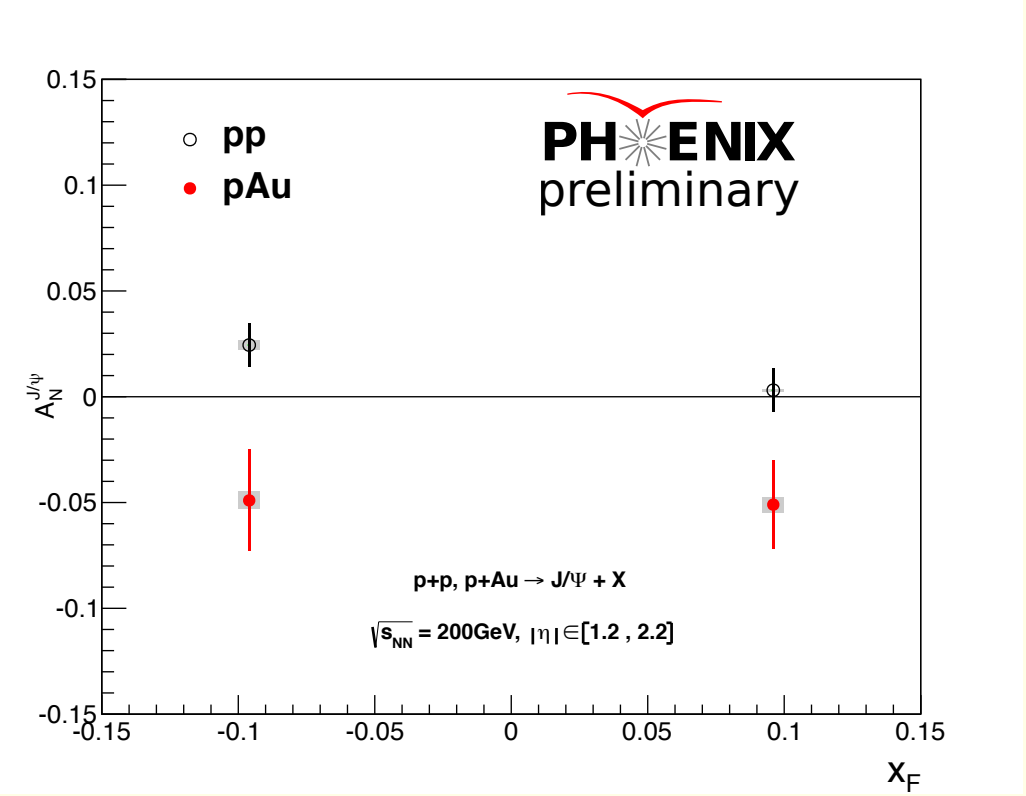


$A_N^{J/psi}$ vs. p_T



Indication of non-zero A_N (3-sigma level) in first p_T bin with pAu data in both forward and backward direction. pp result is consistent with previous result.

$A_N^{J/psi}$ vs. x_F



2-sigma level A_N with pAu data in both forward and backward direction.

pp result is consistent with previous result.

Summary

- New results for J/psi A_N in pp at 200GeV at PHENIX. Consistent with previous results with improved statistical precision ~1%(2015) compare with previous ones ~2%(2006, 2008 and 2012).
- First ever operation with pAu collision. Polarized pAu collisions indicate negative asymmetries (3-sigma level) at lower pT. This requires additional experimental and theoretical investigation.
- Further study will be performed to understand the origin of these asymmetries: Correlation studies with other detector systems to investigate other contributions such as ultra-peripheral (EM) collisions.

BACK UP

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…)

Azimuthal fitting