Transverse Single Spin Asymmetry Measurement with J/Ψ in Polarized p+p Collisions at RHIC

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Outline

- Introduction
- J/Ψ measurement
- Result and summary

Introduction

- Large A_N were observed by E704 Experiment at $\sqrt{s}$ = 20 GeV
- Large A_N persists at RHIC energies (STAR, BRAHMS)
- pQCD predicts only small A_N at leading order
- Mechanism for producing these asymmetries still not clear
- Various models have tried to explain:

Sivers effect

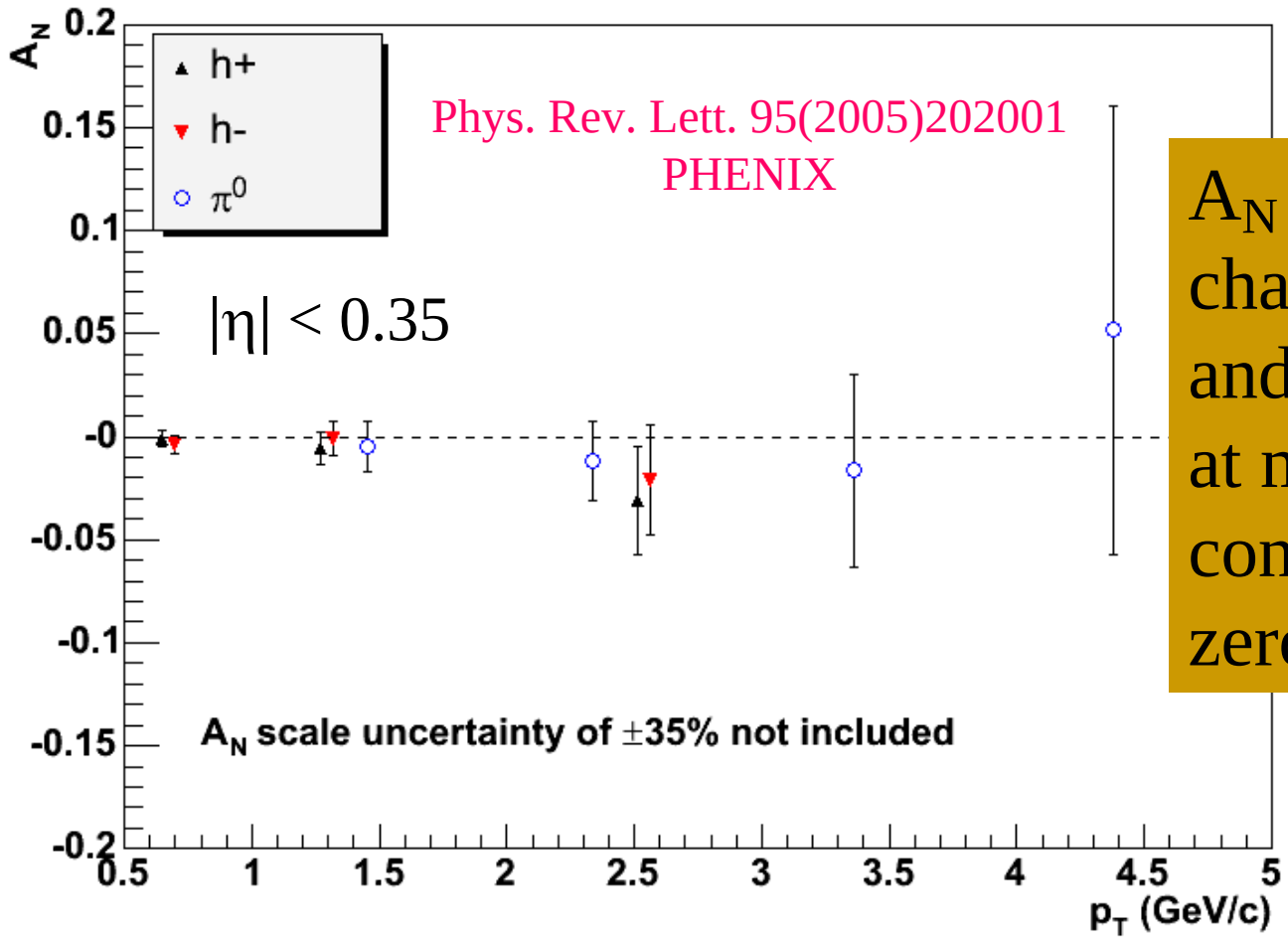
transversely asymmetric k_t quark and gluon distributions

Collins effect

transversity distribution + spin-dependent fragmentation functions

Higher twist effect

A_N of Mid-rapidity Neutral Pions and Charged Hadrons



A_N for both charged hadrons and neutral pions at mid-rapidity consistent with zero

Why J/Ψ A_N

- Minimize Collins' effects

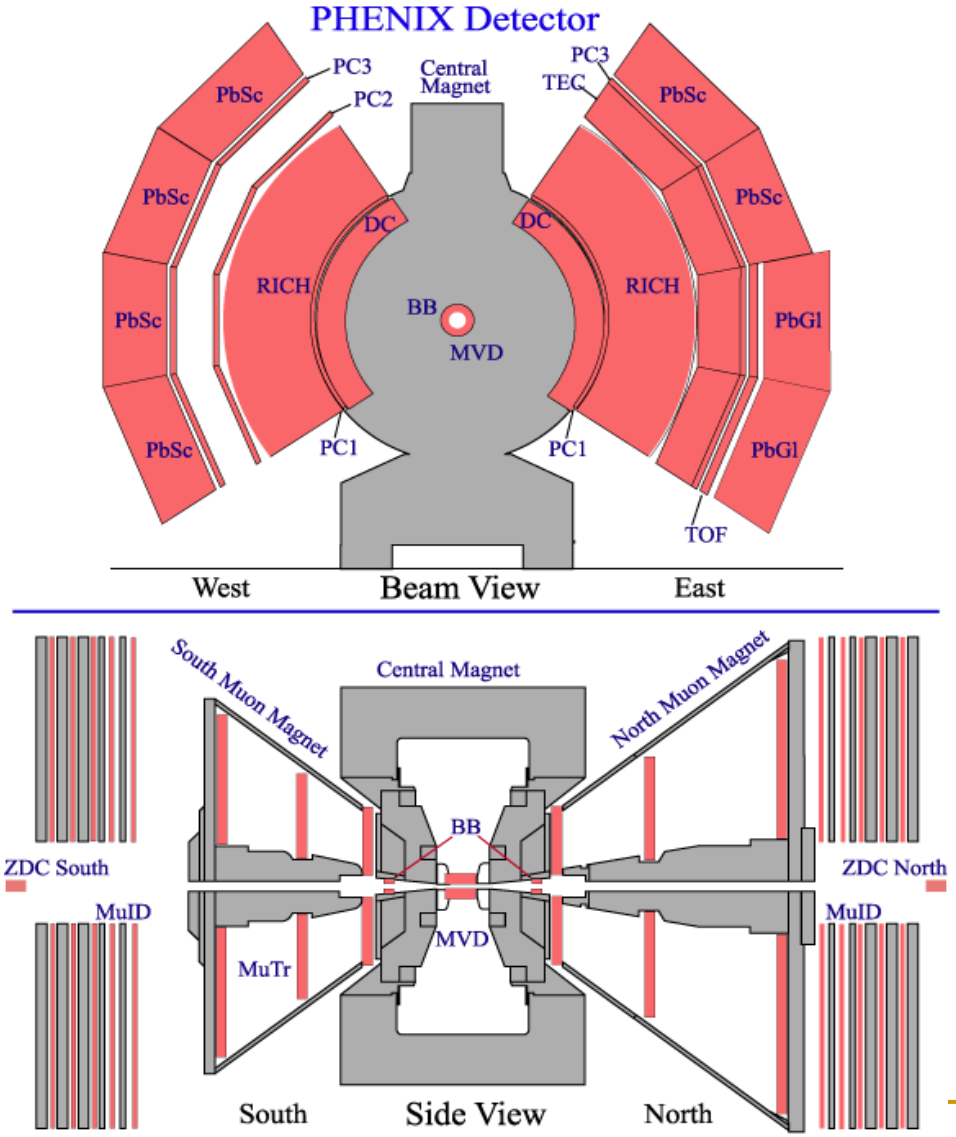
  * J/Ψ production dominated by gluon interactions at RHIC

  * gluon has zero transversity

- Measure gluon Sivers function

- Important to understand the origin of observed A_N at large x_F

PHENIX Detector



Central arms

Track charged particles and detect electromagnetic processes

Photons, electrons, identified charged hadrons

$|\eta| < 0.35$

Forward muon arms

Track and identify muons

South arm: $-2.0 < \eta < 1.2$

North arm: $1.2 < \eta < 2.4$

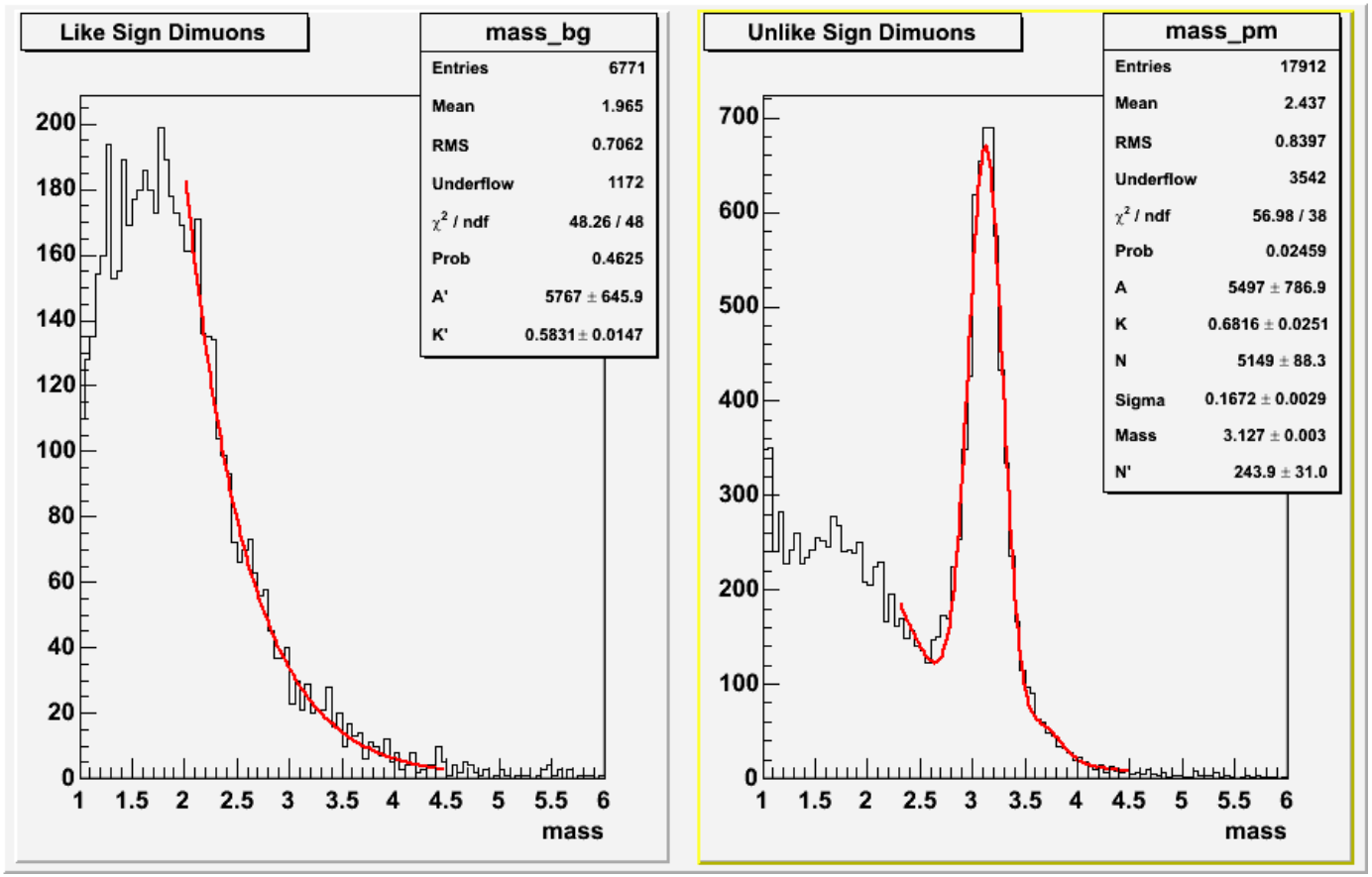
Two global detector

(1) Beam-beam counters

(2) Zero-degree calorimeters

Determine when there's a collision

Like/Unlike charge signed dimuon mass spectra



$$\frac{dN}{dM} = A \cdot e^{-K \cdot M} + N \cdot \frac{1}{2\pi\sqrt{\sigma}} e^{-\frac{(M - M_{J/\psi})^2}{2\sigma^2}} + N' \cdot \frac{1}{2\pi\sqrt{\sigma}} e^{-\frac{(M - M_{\psi'})^2}{2\sigma^2}}$$

Asymmetry calculation

- Square root formula

$$A_N^{incl} = \frac{1}{P} \cdot \frac{\sqrt{N_L^{\uparrow} \cdot N_R^{\downarrow}} - \sqrt{N_R^{\uparrow} \cdot N_L^{\downarrow}}}{\sqrt{N_L^{\uparrow} \cdot N_R^{\downarrow}} + \sqrt{N_R^{\uparrow} \cdot N_L^{\downarrow}}}$$

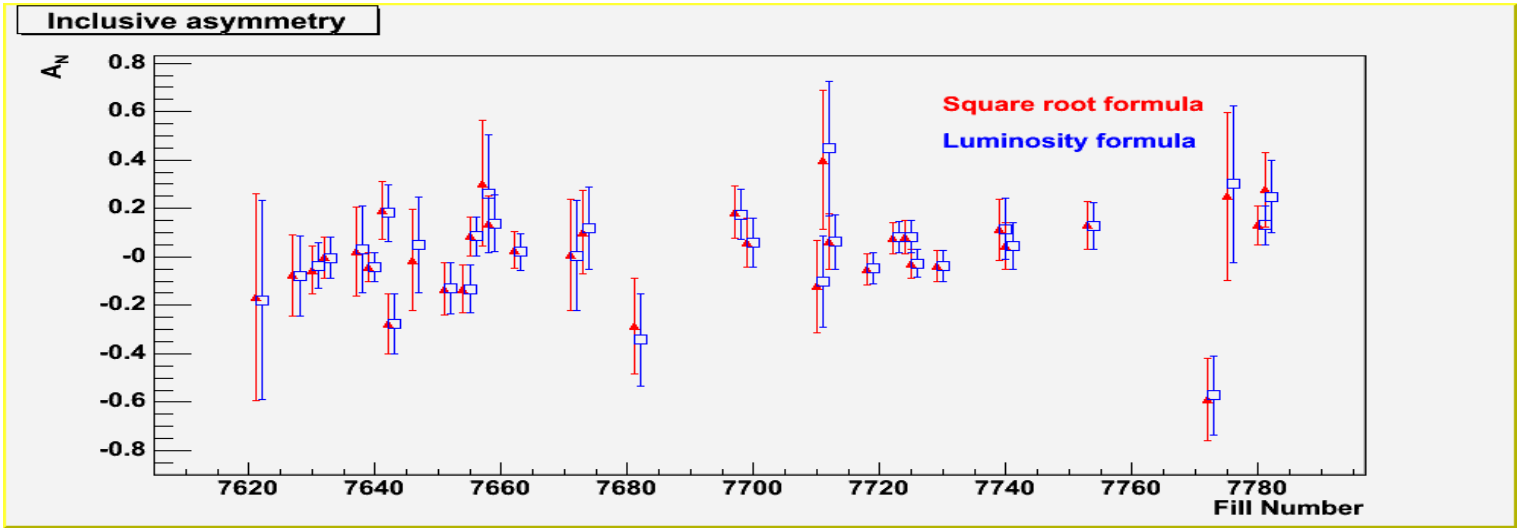
- Luminosity formula

$$A_N^{incl} = \frac{1}{P} \cdot \frac{N^{\uparrow} - R \cdot N^{\downarrow}}{N^{\uparrow} + R \cdot N^{\downarrow}} \qquad R = \frac{L^{\uparrow}}{L^{\downarrow}}$$

$$A_N^{J/\Psi} = \frac{A^{incl} - r \cdot A^{BG}}{1 - r}$$

$$\delta A_N^{J/\Psi} = \frac{\sqrt{(\delta A^{incl})^2 + r^2 \cdot (\delta A^{BG})^2}}{1 - r}$$

$$r = \frac{N^{BG}}{N^{incl}}$$



Background estimation

- From Drell-Yan, Open charm, Light hadrons, etc.
- Three methods:

-- Sideband from unlike sign dimuon pairs:

$2.0 < m < 2.5$

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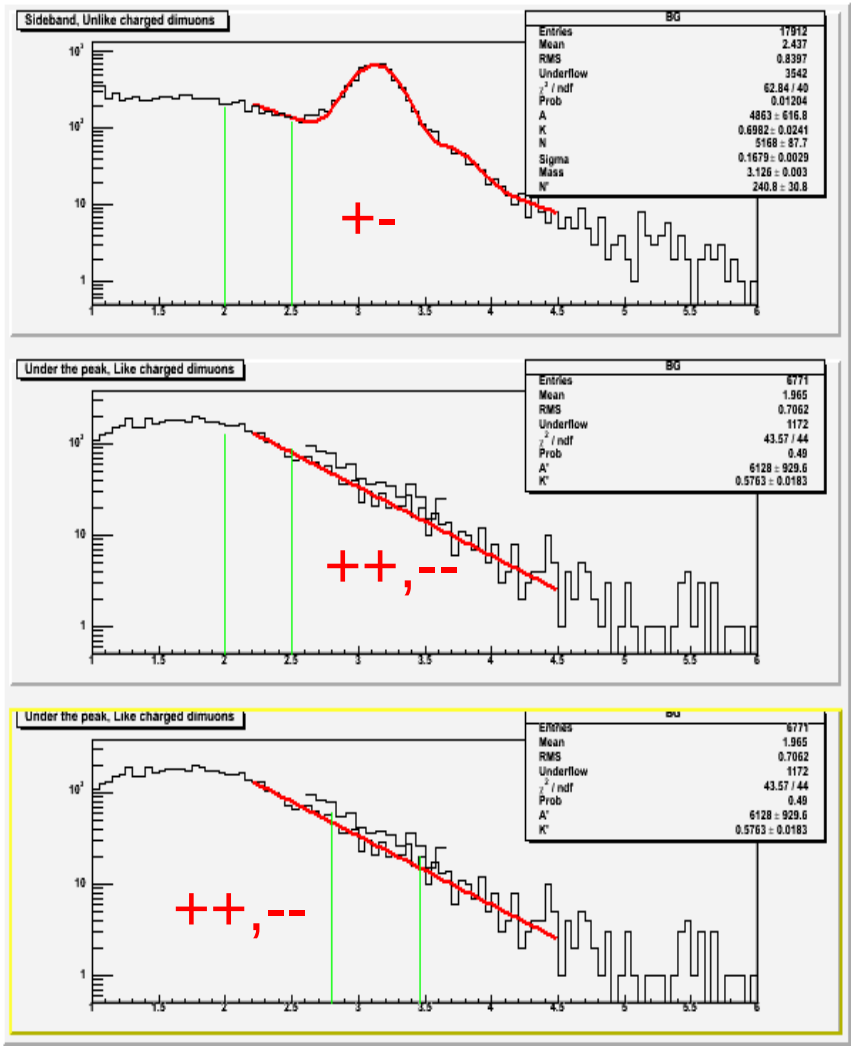
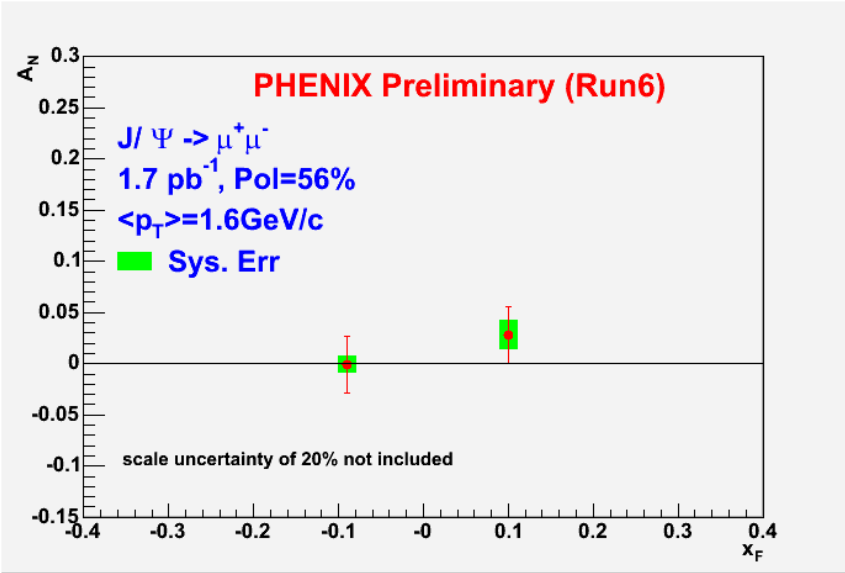
$2.0 < m < 2.5$

-- Same sign dimuon pairs under the J/Ψ peak



A_N vs. x_F



Theoretical prediction:

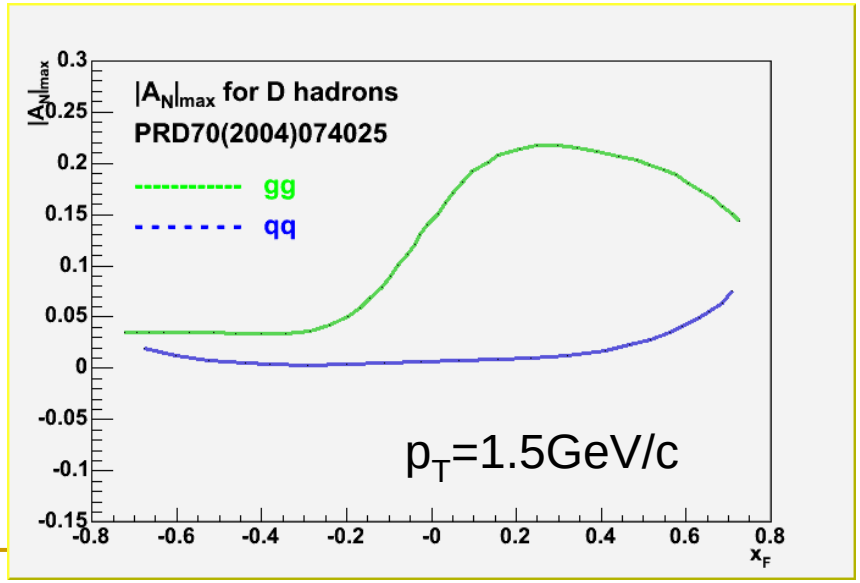
For open charm production

-- quark Sivers function set to its maximum

gluon silver function set to 0

-- gluon Sivers function set to its maximum

quark silver function set to 0



Disfavor the maximum contribution of gluon Sivers function

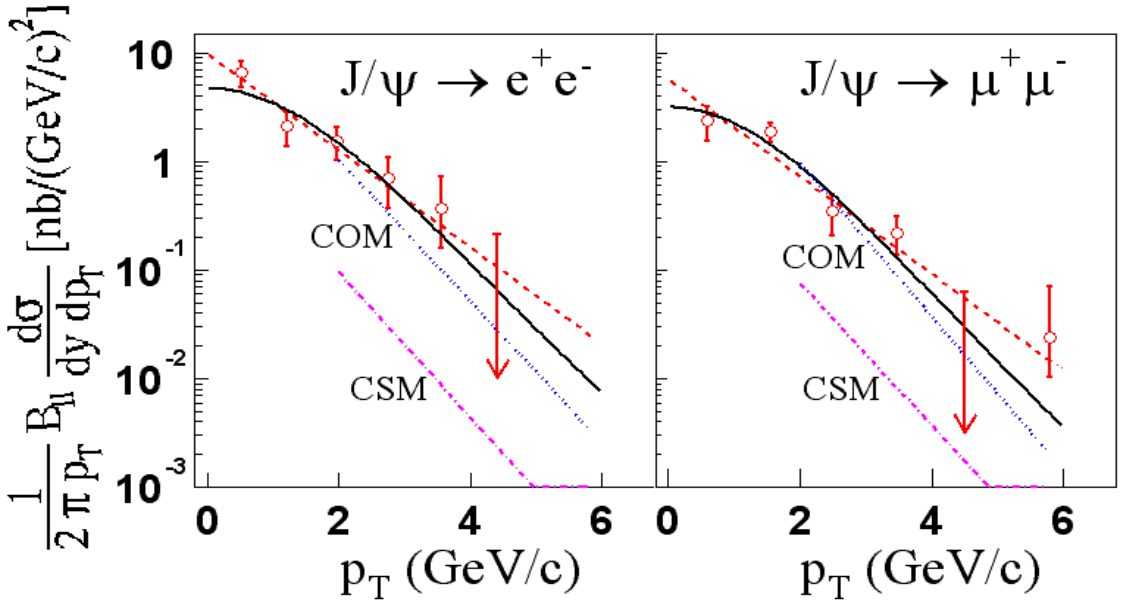
Summary and Outlook

- First measurement of transverse single spin asymmetry in J/Ψ production from transverse polarized p-p collisions at $x_F \approx \pm 0.1$
  - Almost pure gluon fusion
- Disfavor the maximum contribution of gluon Sivers function
- The theoretical work in progress
- Open charm and beauty A_N in progress

Backup slides

NLO QCD and PHENIX data

PHENIX, PRL 92, 051802 (2004)



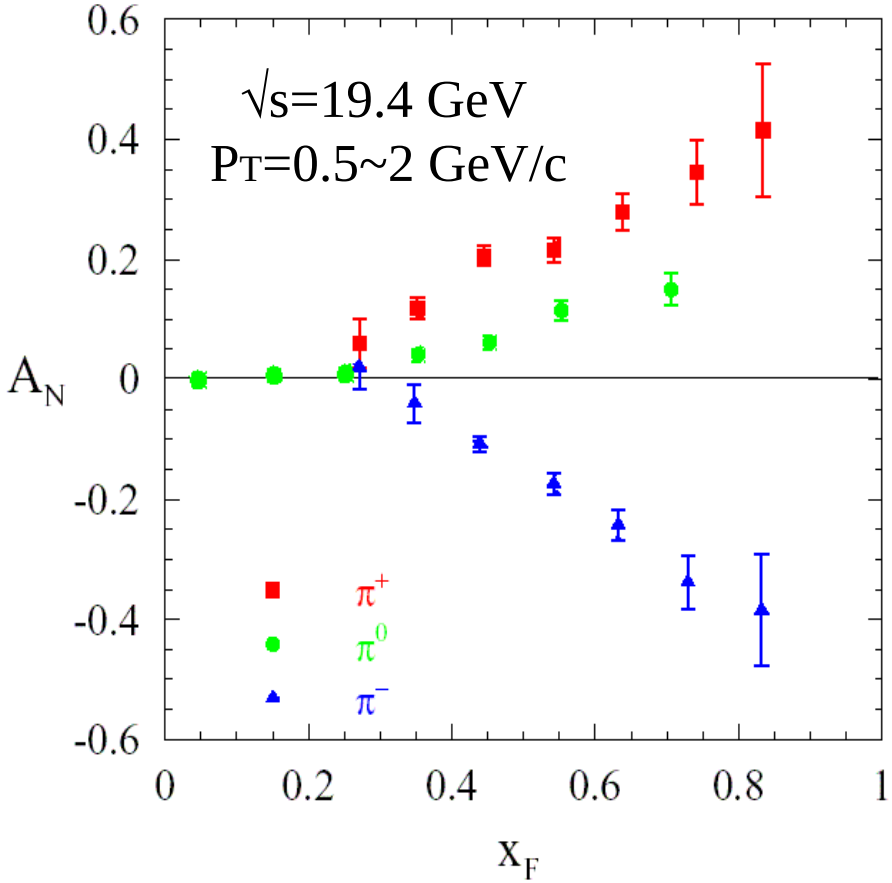
Theoretical predictions of J/Ψ production at RHIC are in good agreement with the PHENIX data: COM process dominant

- PRD 68 (2003) 034003 G. Nayak, M. Liu, F. Cooper
- PRL 93 (2004) 171801 F. Cooper, M. Liu, G. Nayak

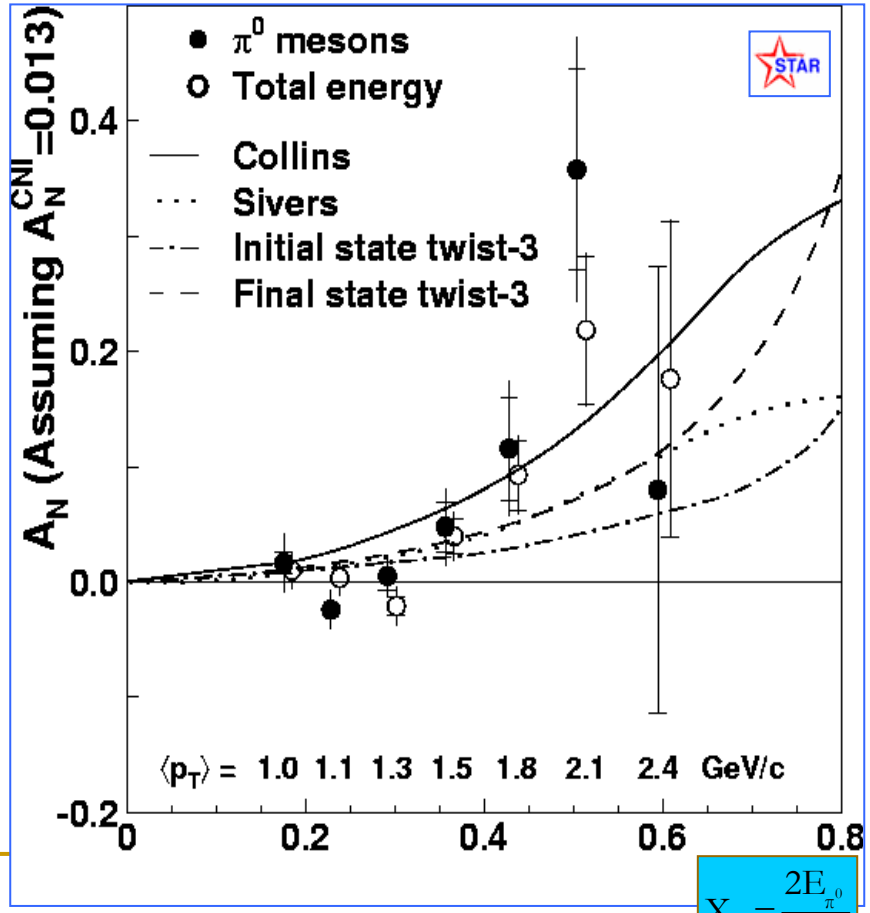
$$pp \rightarrow \pi + X$$

$$A_N = \frac{1}{P}\frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}}$$

Phys. Lett. B 264 (1991) 462

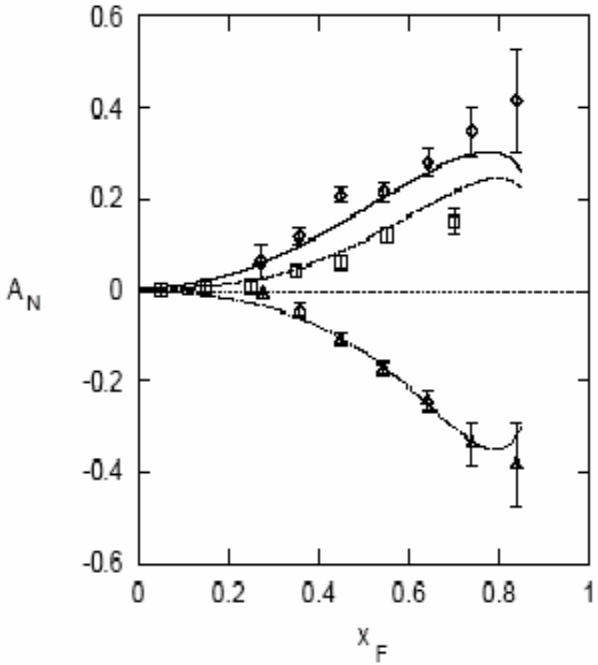


Phys. Rev. Lett. 92 (2004) 171801

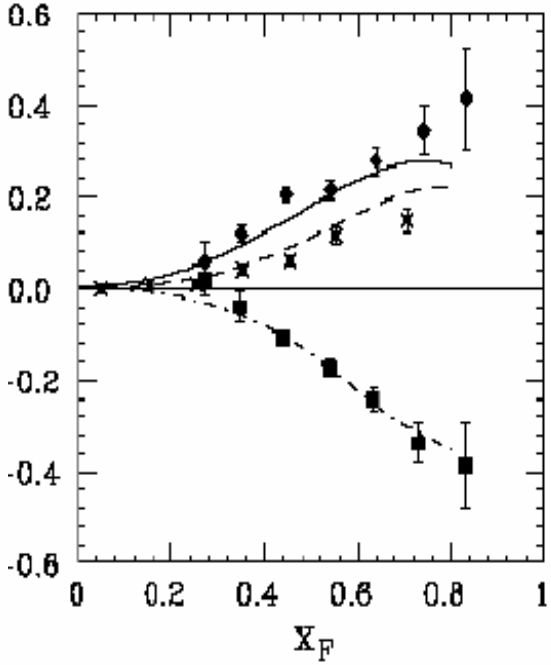


$$X_F = \frac{2E_{\pi^0}}{\sqrt{s}}$$

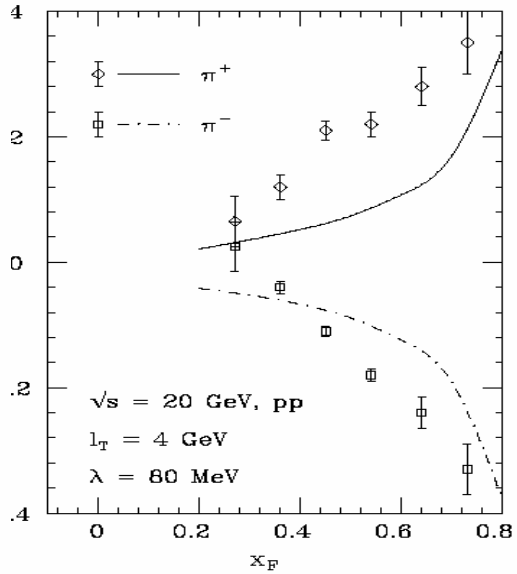
E704 Data vs. theories



Theory: Collins only



Theory: Sivers only



Theory: higher twist