



Denver, CO

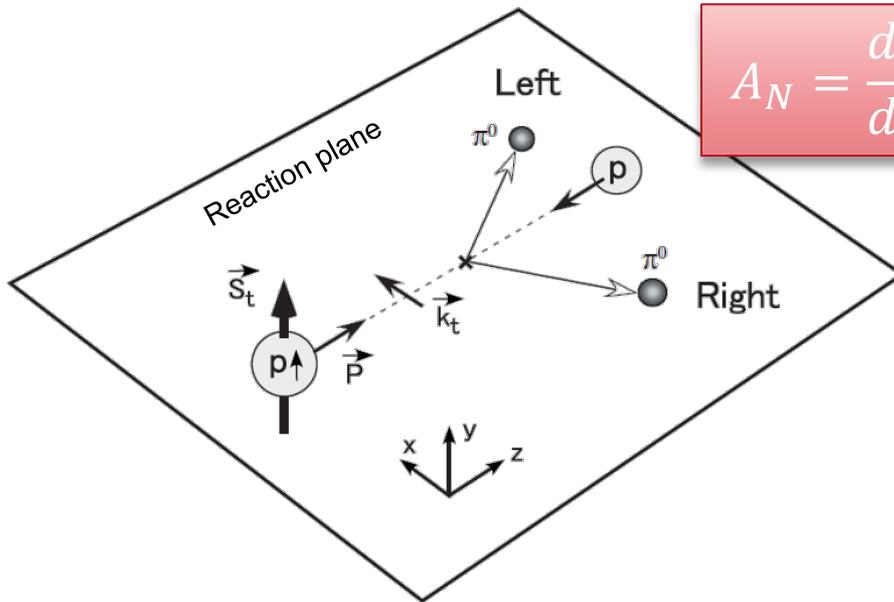


Transverse Single Spin Asymmetries in J/ψ Production in Proton-Proton Collisions

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for the PHENIX collaboration

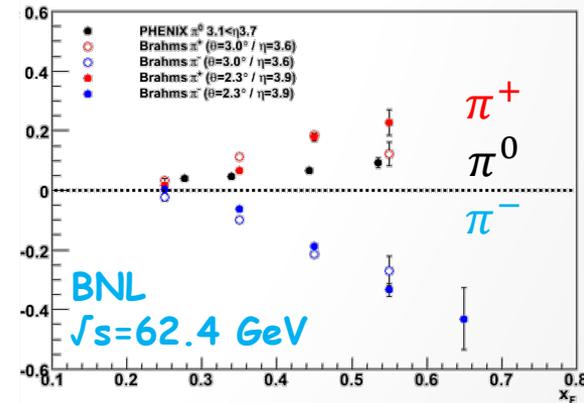
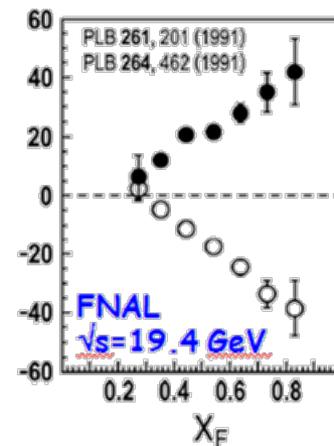
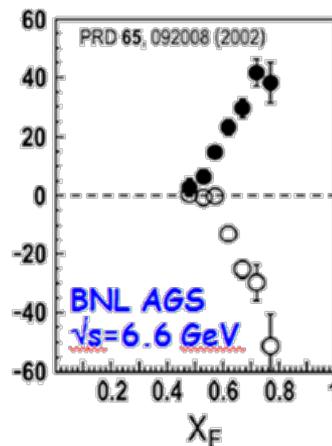
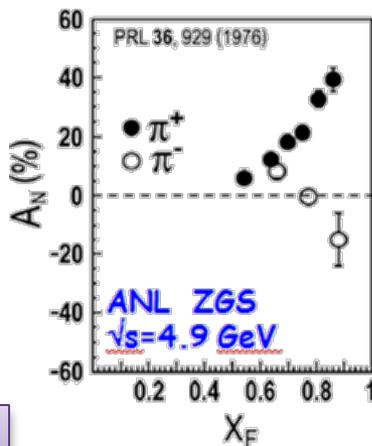
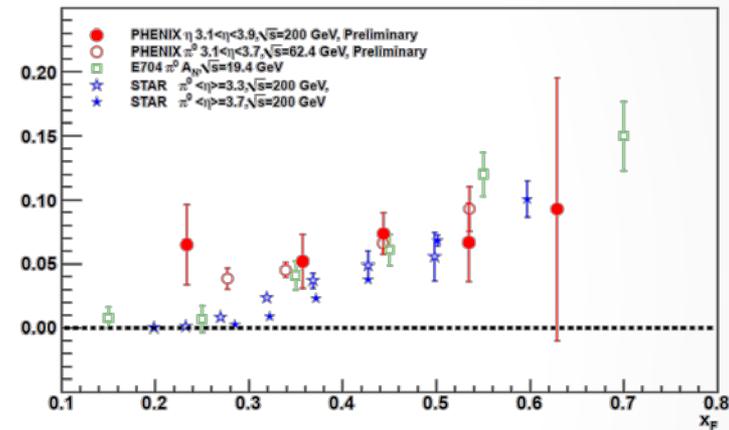


Transverse Spin Asymmetries



$$A_N = \frac{d\sigma_L - d\sigma_R}{d\sigma_L + d\sigma_R}$$

π^0 19.4, 62.4, 200 GeV



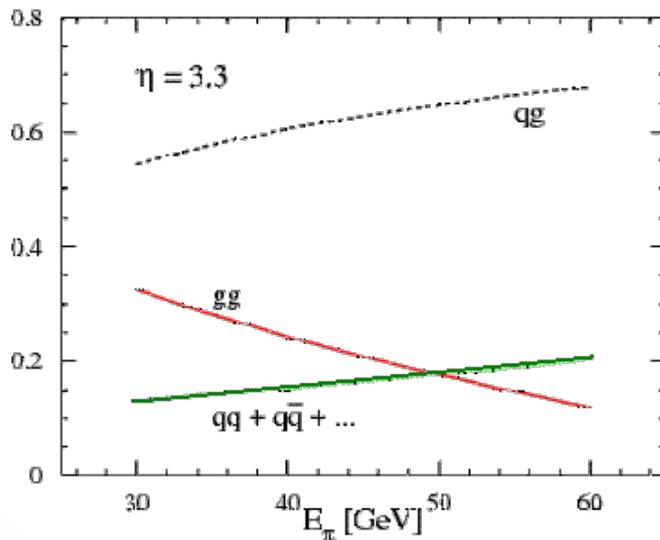
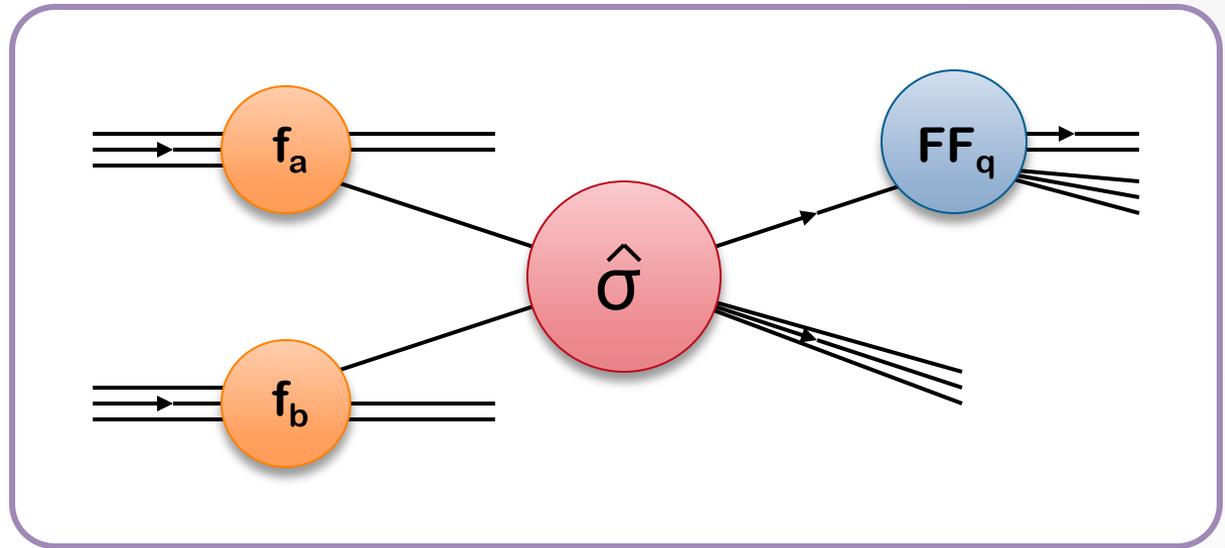
$$x_F = 2p_l / \sqrt{s}$$

Proton-Proton Collisions

❖ Initial State

❖ pQCD

❖ Final State



Process contribution in π^0 production

Need to disentangle effects

kinematics

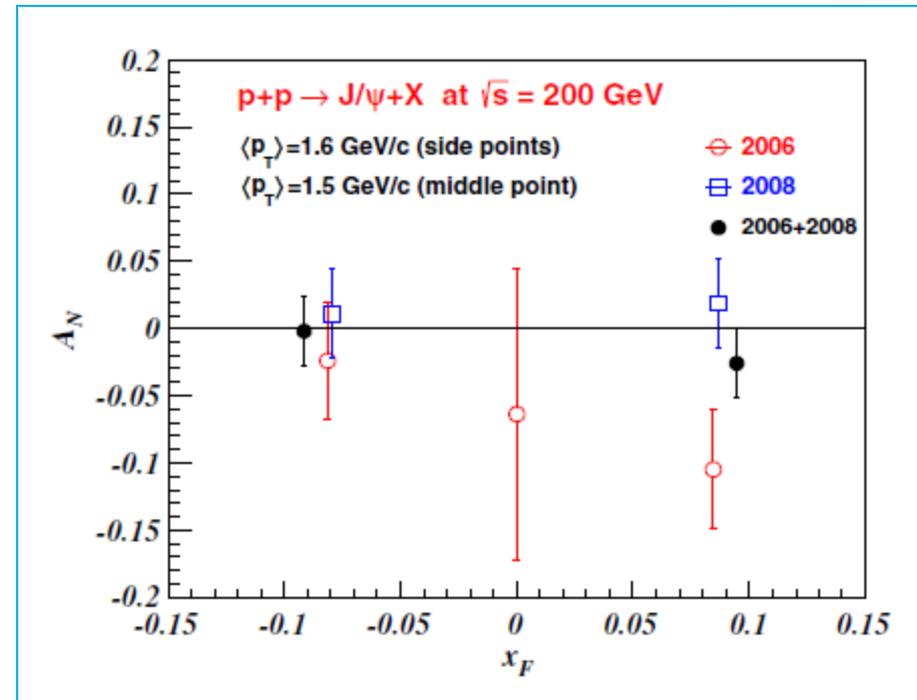
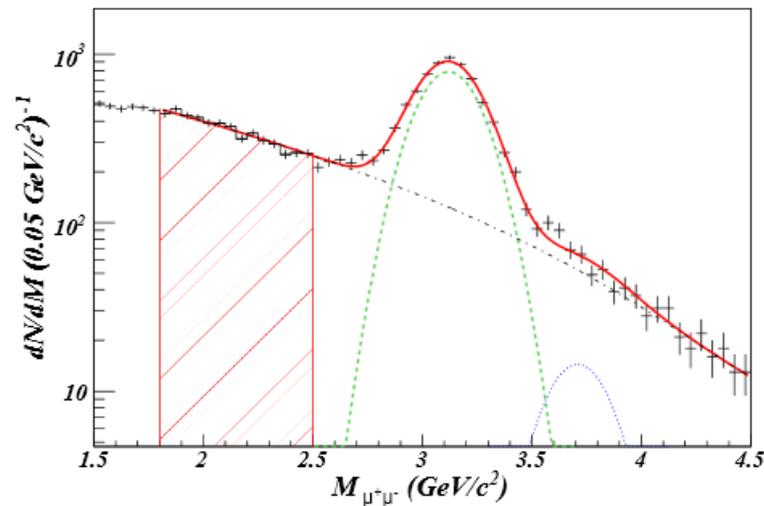
processes

probes \rightarrow heavy flavor

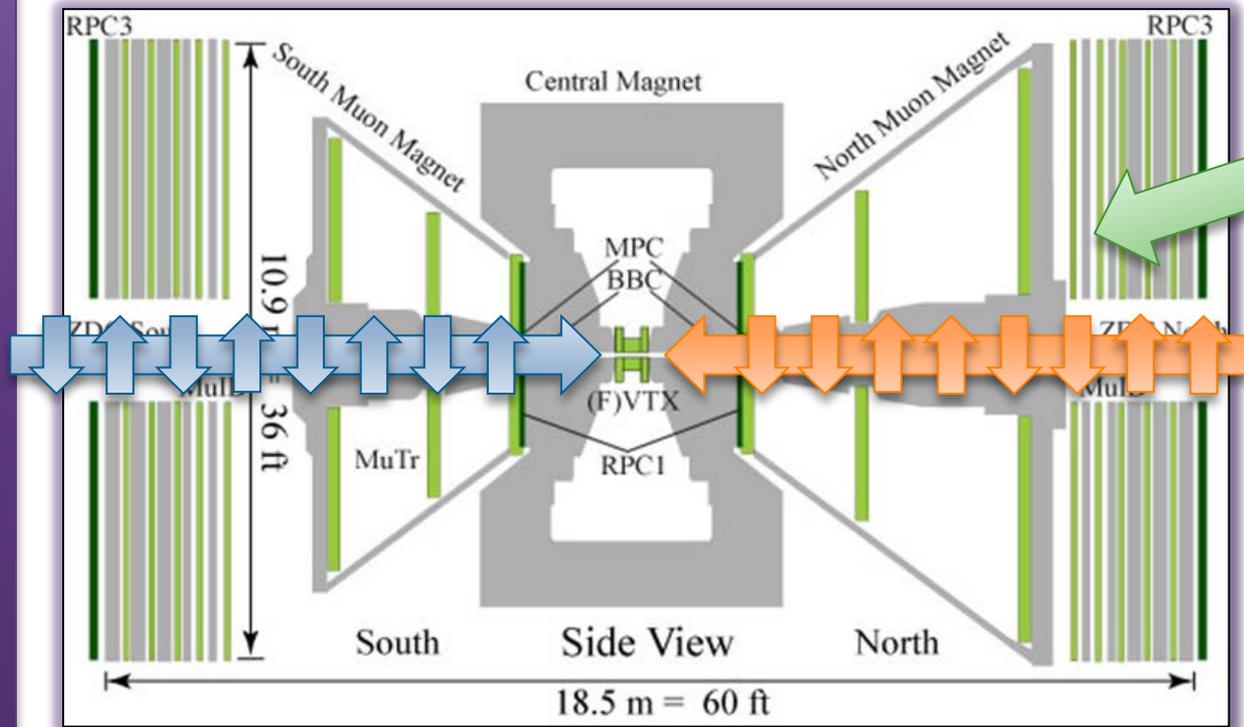
J/ψ Transverse Asymmetries

❖ PRD 86, 099904 (E), 2012

2006 vs. 2008 results at $x_F > 0$ problematic?



The PHENIX Detector



Muon Arms

- ❖ $1.2 < |\eta| < 2.4$
- ❖ J/ψ
- ❖ charged hadrons
- ❖ heavy flavor

Year	\sqrt{s} (GeV)	Pol. (%)	L (pb ⁻¹)	P ² L (pb ⁻¹)
2006	62	48	0.02	0.005
2006	200	57 (51)	2.7	0.7
2008	200	46	5.2	1.1
2012	200	58	9.2	3.1

Asymmetry Determination

❖ Conventional square-root method

- Needs assumptions for integration of cross section

$$\varepsilon = \frac{1}{\langle \cos \varphi \rangle} \cdot \frac{\sqrt{N_l^\uparrow \cdot N_R^\downarrow} - \sqrt{N_l^\downarrow \cdot N_R^\uparrow}}{\sqrt{N_l^\uparrow \cdot N_R^\downarrow} + \sqrt{N_l^\downarrow \cdot N_R^\uparrow}}$$

❖ Unbinned maximum likelihood method

- Sensitive to differences in luminosity of polarization states

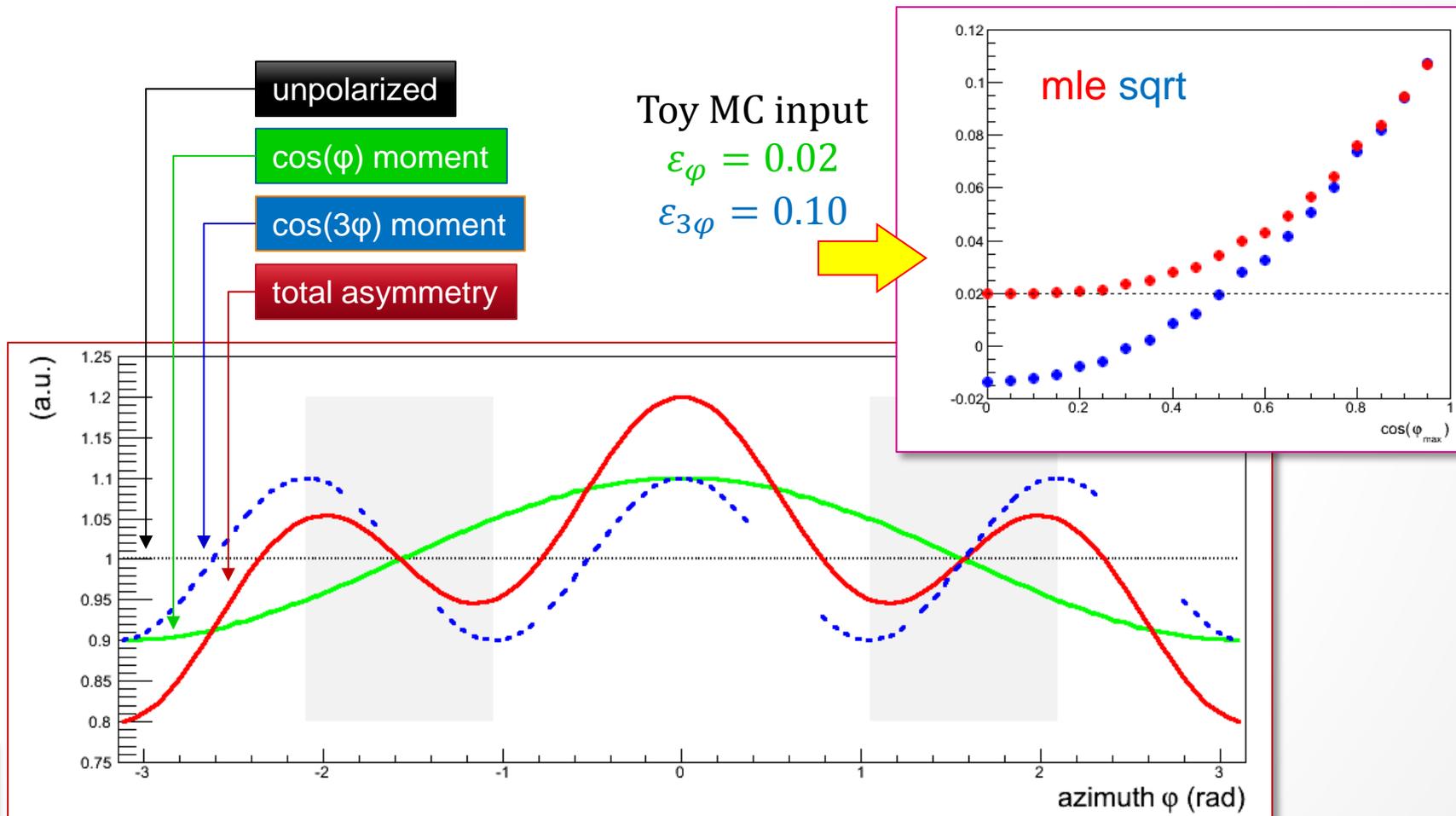
$$-\log \mathcal{L}(\varepsilon | \varphi) = - \sum_i \log[e \cdot (1 + \varepsilon \cdot \cos \varphi_i)]$$

❖ Background correction

$$\varepsilon = \frac{\varepsilon^{inc} - r \cdot \varepsilon^{bg}}{1 - r} \Rightarrow A_N = \frac{\varepsilon}{P_{beam}}$$

Higher Moments in Asymmetry

$$-\log \mathcal{L}(\varepsilon|\varphi) = -\sum_i \log(1 + \varepsilon_\varphi \cdot \cos \varphi_i + \varepsilon_{2\varphi} \cdot \cos 2\varphi_i + \varepsilon_{3\varphi} \cdot \cos 3\varphi_i)$$



Asymmetry Reproducibility



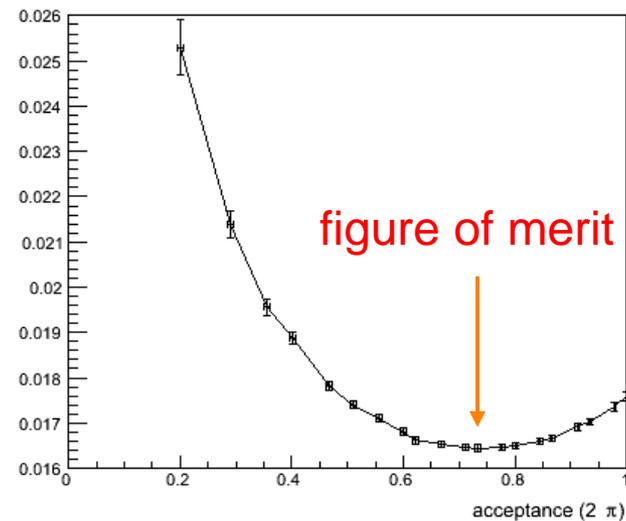
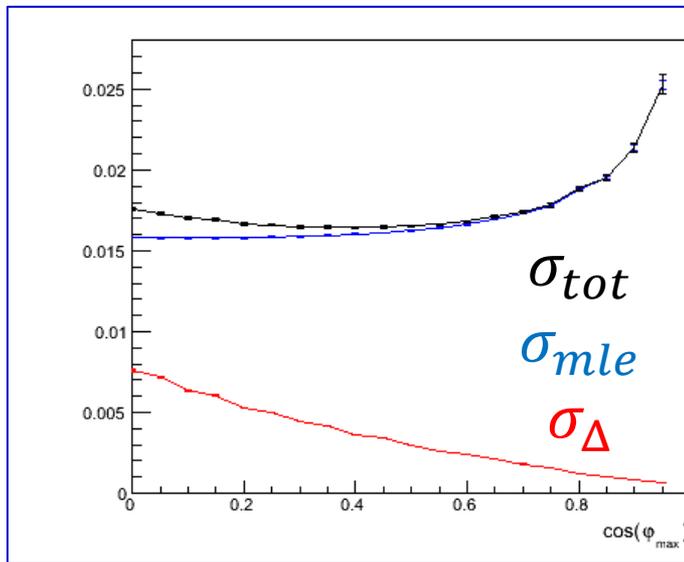
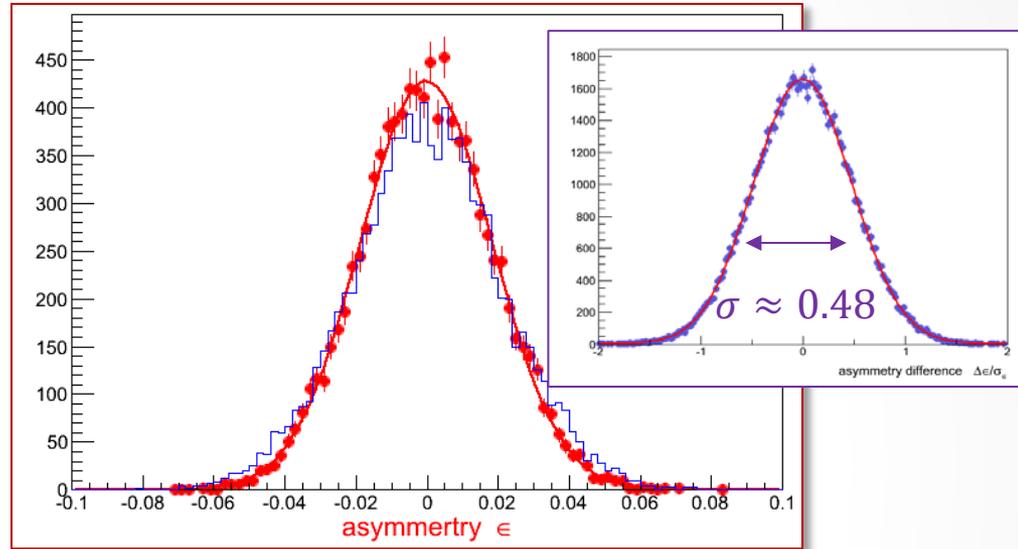
Toy Monte Carlo simulation

- max. like & sqrt asymmetries

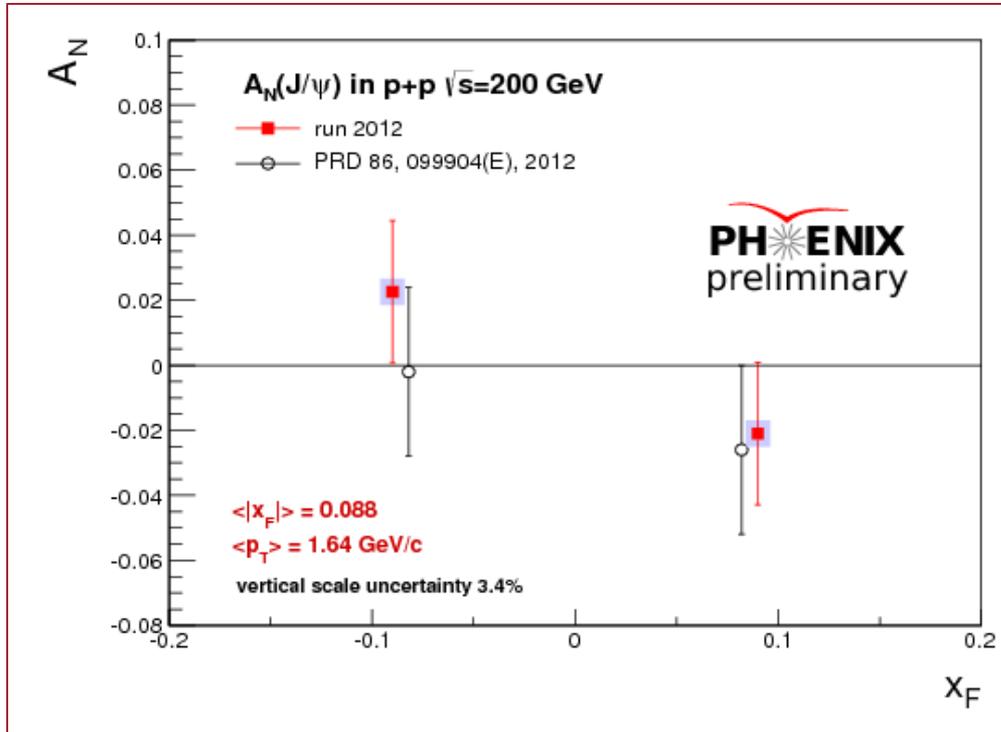


Difference is not zero

- Driven by acceptance where asymmetry is small
- Limit acceptance symmetrically $|\cos \varphi| > c_{threshold}$



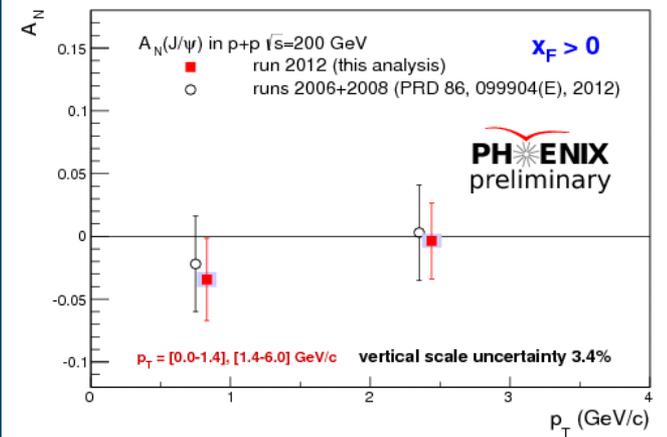
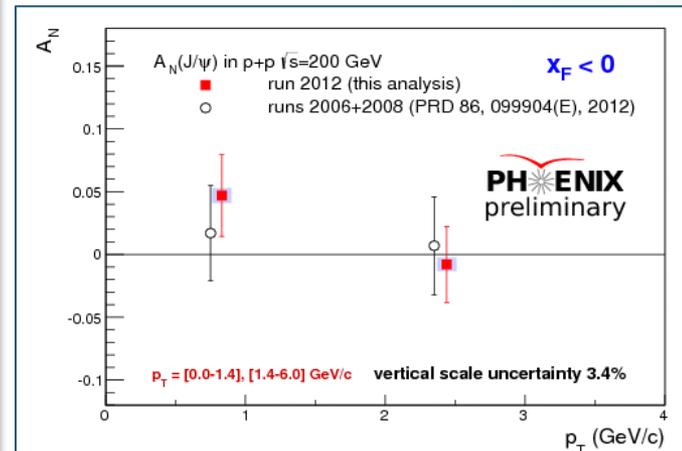
Comparison of Results



❖ Observed A_N are consistent with zero

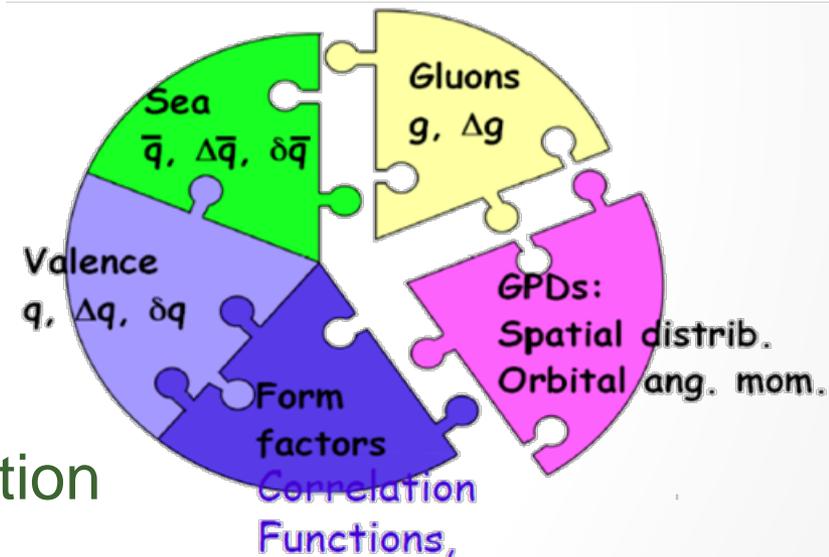
❖ Measured asymmetries are consistent between data sets

p_T dependence



What to take home...

- ❖ Non-vanishing transverse single spin asymmetries have been measured over a wide range of energies
- ❖ Details of mechanism not finally understood and need to be disentangled
- ❖ PHENIX has measured AN in J/ψ production
- ❖ Results are consistent with zero and between data sets
- ❖ Asymmetries are expected to help constrain gluon Sivers function



Transverse Asymmetries

