Double Helicity Asymmetry from π^0 & J/ψ and Constraining the ΔG

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for the PHENIX Collaboration

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Related Subjects

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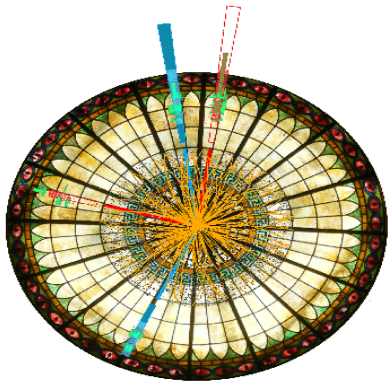


Outline

- Introduction
- Experimental Setups and Techniques
- Results & Impact on ΔG
- Summary and Future Works

Plan

Spin Composition of Proton

Initial Thought:

- Spin is carried out only by valence quarks
- EMC results show only small fraction of spin is carried out by quarks ~30%

Proton spin crisis!!!

- Current Understanding:

$$\langle S_z^p \rangle = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + \langle L_z^q \rangle + \langle L_z^g \rangle$$

ΔG =???

- $\vec{p}\,\vec{p}$ at **RHIC** ⇒ QCD lab: strongly interacting probes
- High $\sqrt{s}$ make NLO pQCD analysis more reliable
- **PHENIX spin program:**
  - Longitudinal spin program ⇒ **Gluon polarization distribution** + Anti-quark sea polarization
  - Transverse spin program ⇒ sensitivity to $< L_z >$ + Transversity

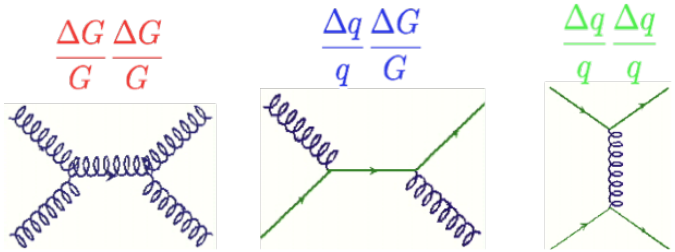
Accessing ΔG in p + p: A_{LL}

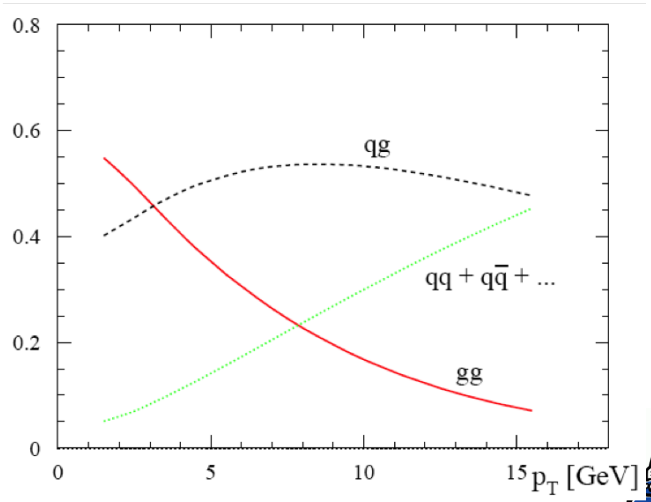
- Longitudinal spin program at PHENIX ⇒
  Gluon polarization distribution

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{\sum_{a,b,c=q,\bar{q},g} \Delta f_a \otimes \Delta f_b \otimes \Delta\hat{\sigma} \otimes D_{\pi/c}}{\sum_{a,b,c=q,\bar{q},g} f_a \otimes f_b \otimes \hat{\sigma} \otimes D_{\pi/c}}$$

- Roughly, we have:

$$A_{LL} \cong a_{gg}\Delta g^2 + b_{gq}\Delta g\Delta q + c_{qq}\Delta q^2$$

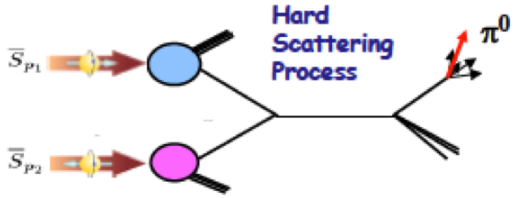




- Δf = Δq, extracted from pDIS

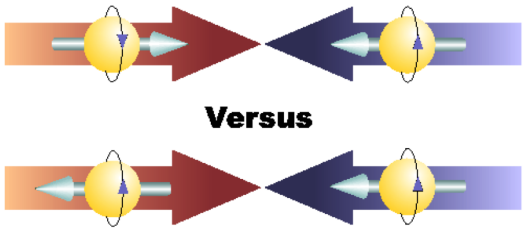
Measuring A_{LL}

- **Cross-sections**
  - Establish validity of Next to Leading Order perturbative QCD for RHIC kinematics
  - Test understanding of detector, measured observable and quality of simulations



- **Asymmetries**

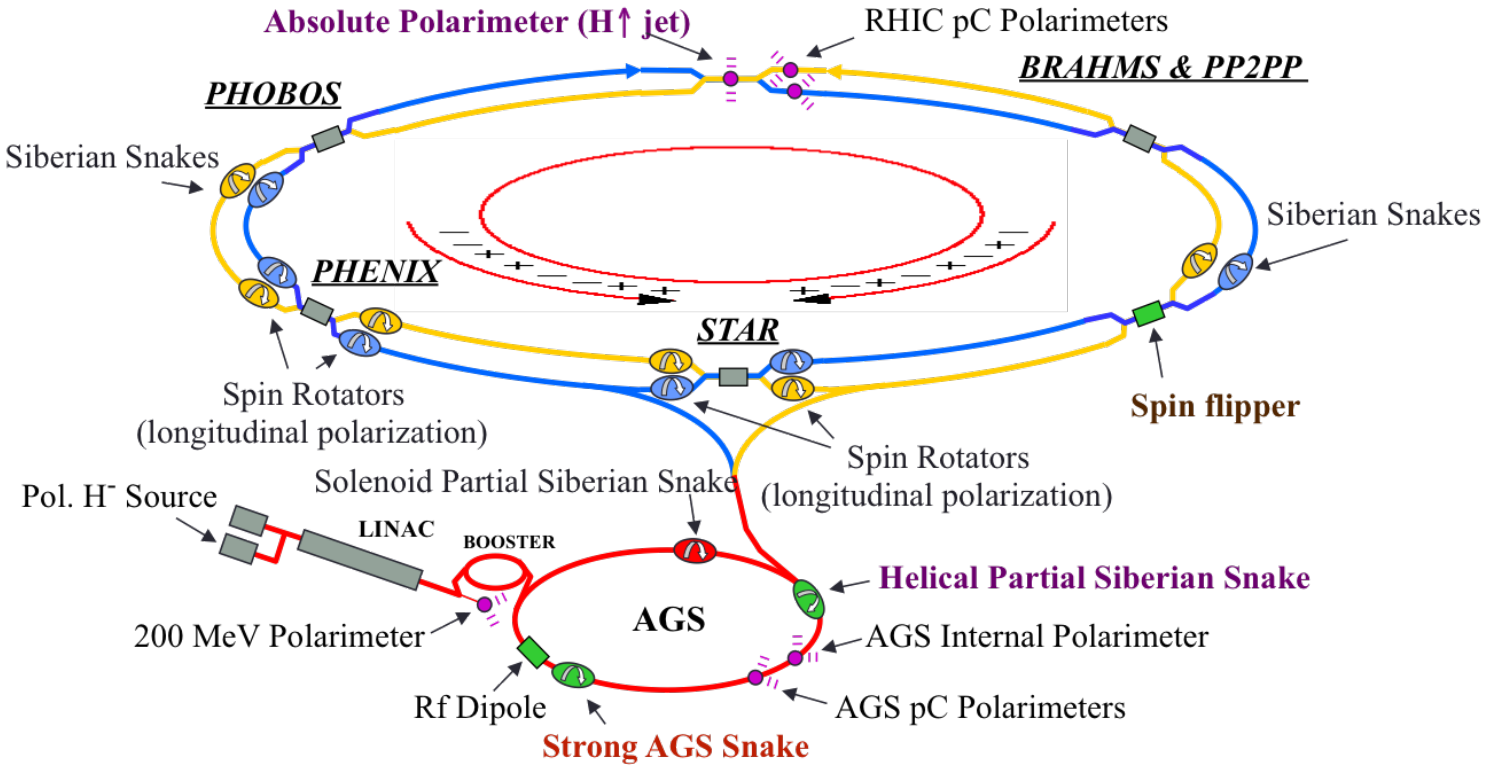
$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} = \frac{1}{P_b P_y} \frac{N_{++} - R N_{+-}}{N_{++} + R N_{+-}}$$



- Helicity Dependent Particle Yields (N)
  - π^0, π^{+-}, η, γ, J/ψ, etc
- Beam Polarization (P)
- Relative Luminosity (R = L_{++}/L_{+-})

Plan

Relativistic Heavy Ion Collider



- World first $\vec{p} + \vec{p}$ collider
  - Up to $\sqrt{s} = 510$ GeV
  - Integrated Luminosity 150 pb^{-1}, polarization ~ 56 % at $\sqrt{s} = 510$ GeV (2013)
  - Transverse or longitudinal polarization

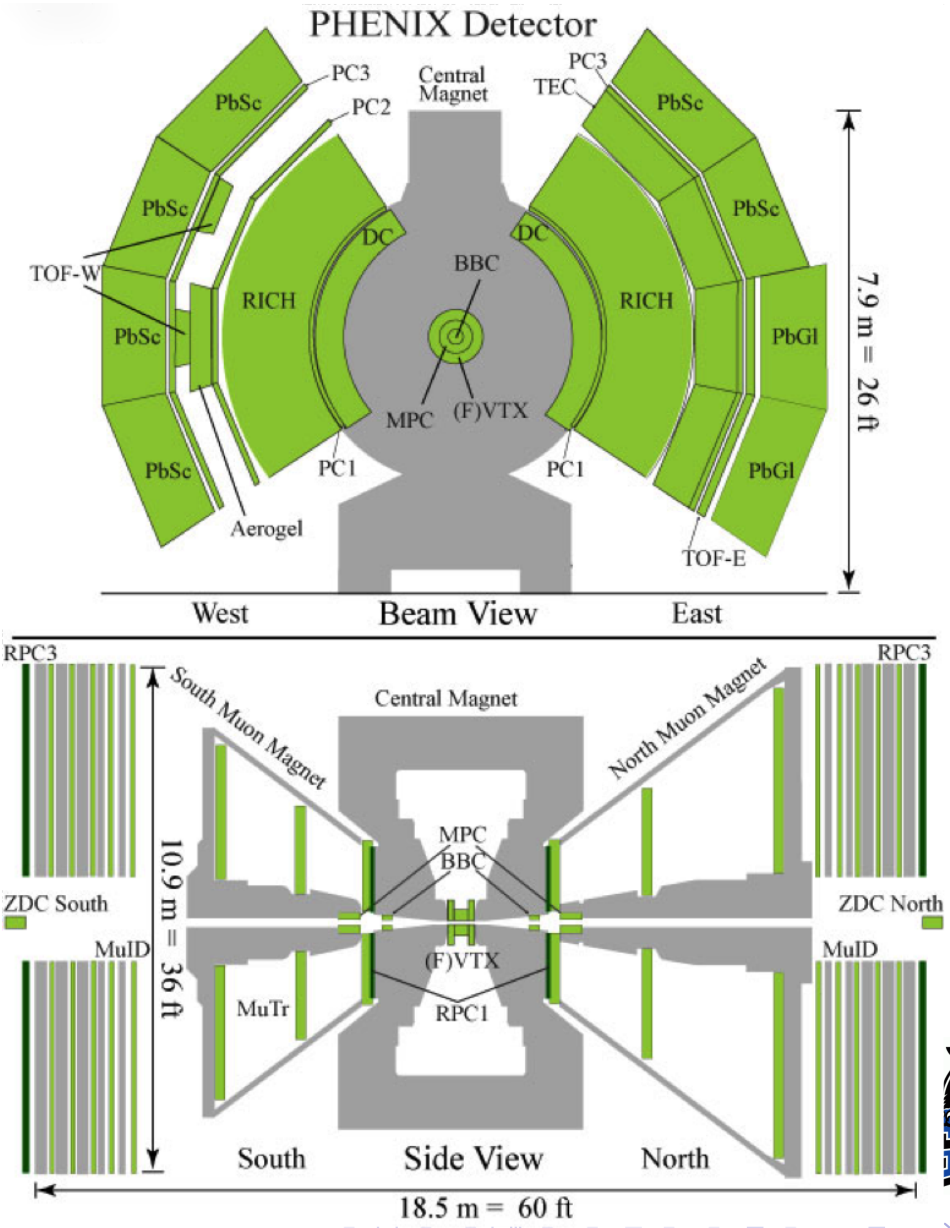
PHENIX Detectors

Central arm: $(\pi^0 \rightarrow \gamma\ \gamma)$

- Tracking: VTX, DC, PC
- EM Calorimeters: PbSc and PbGl
- $|\eta| < 0.35$, $\Delta\phi = 2 \times \frac{\pi}{2}$

Forward Muon Spectrometer: $(J/\psi \rightarrow \mu^+\ \mu^-)$

- BBC and ZDC for luminosity counter
- MuTr, MuID
- $1.2 < |\eta| < 2.2$, $\Delta\phi = 2\pi$



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Analysis Procedure for $\pi^0 \rightarrow \gamma\ \gamma$

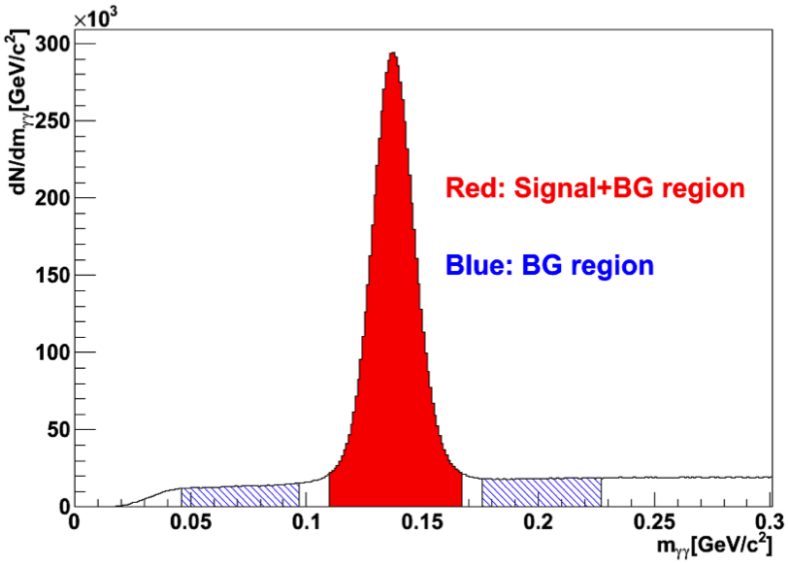
Calculating A_{LL} from π^0:

- Calculate $A_{LL}^{\pi^0+BG}$ and A_{LL}^{BG} separately
- Get background ratio (r) from fit

$$r = \frac{N^{BG}}{N^{SG+BG}}$$

- Subtract A_{LL}^{BG} from $A_{LL}^{\pi^0+BG}$:

$$A_{LL}^{\pi^0} = \frac{A_{LL}^{\pi^0+BG} - r \cdot A_{LL}^{BG}}{1 - r}$$



Analysis Procedure for $J/\psi \rightarrow \mu^+ \mu^-$

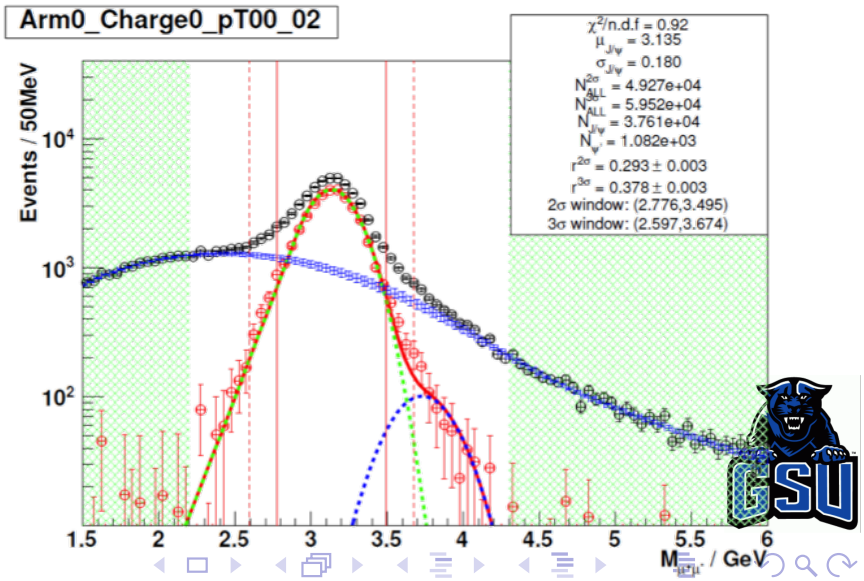
Calculating A_{LL} from J/ψ:

- Analyze south and north arm separately, and divide data from each arm into 3 p_T bins. So, 6 subsets total
- Sideband region is defined as 1.5 GeV $< M_{\mu\mu} <$ 2.5 GeV
- Fit each subsets for 2σ J/ψ mass window
- Get background ratio (r) from fit

$$r = \frac{N^{BG}}{N^{SG+BG}}$$

- Subtract A_{LL}^{BG} from $A_{LL}^{J/\psi+BG}$:

$$A_{LL}^{J/\psi} = \frac{A_{LL}^{(J/\psi+BG)} - r \cdot A_{LL}^{(BG)}}{1-r}$$



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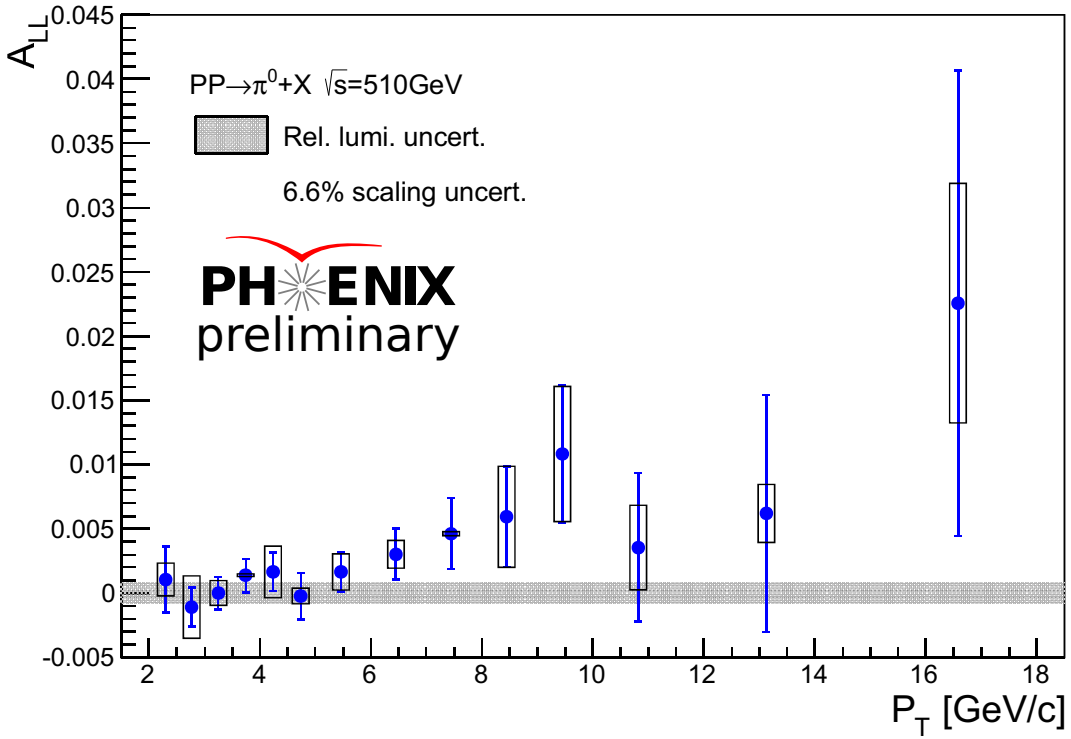
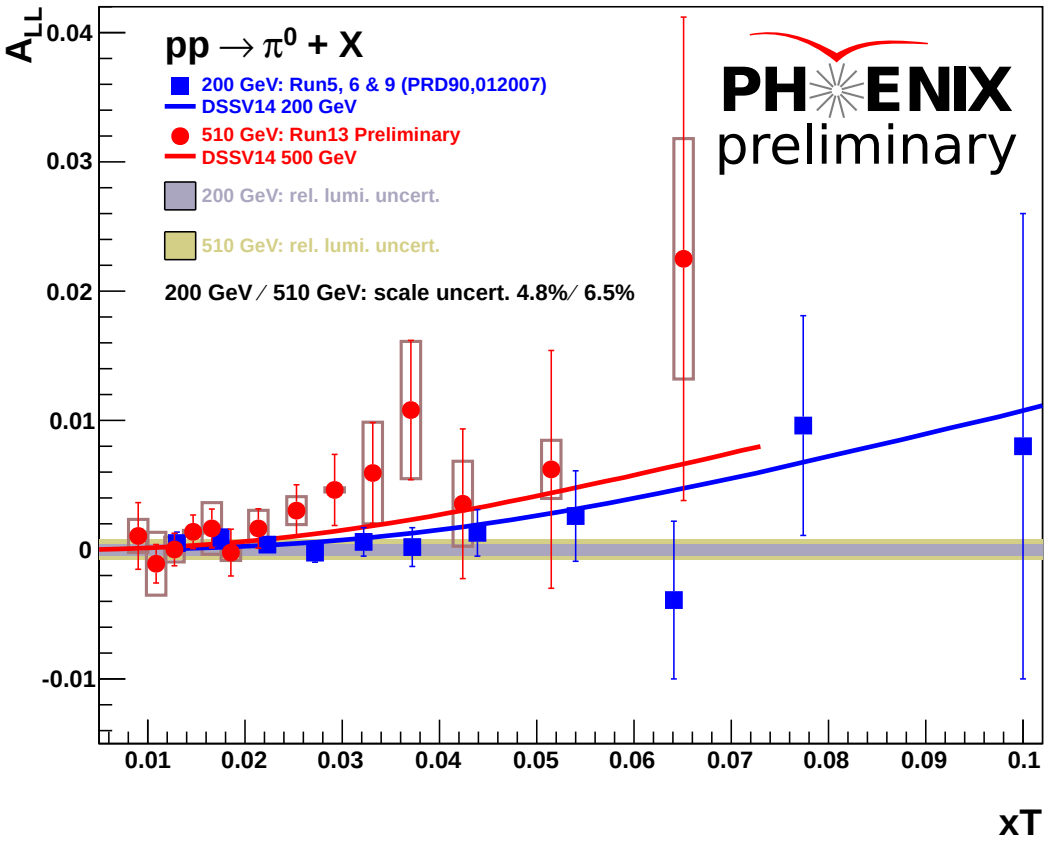
Double Helicity Asymmetry of π^0



- Large asymmetry is observed at $\sqrt{s}$ = 510 GeV
- Data to be used for global analysis

Double Helicity Asymmetry of π^0

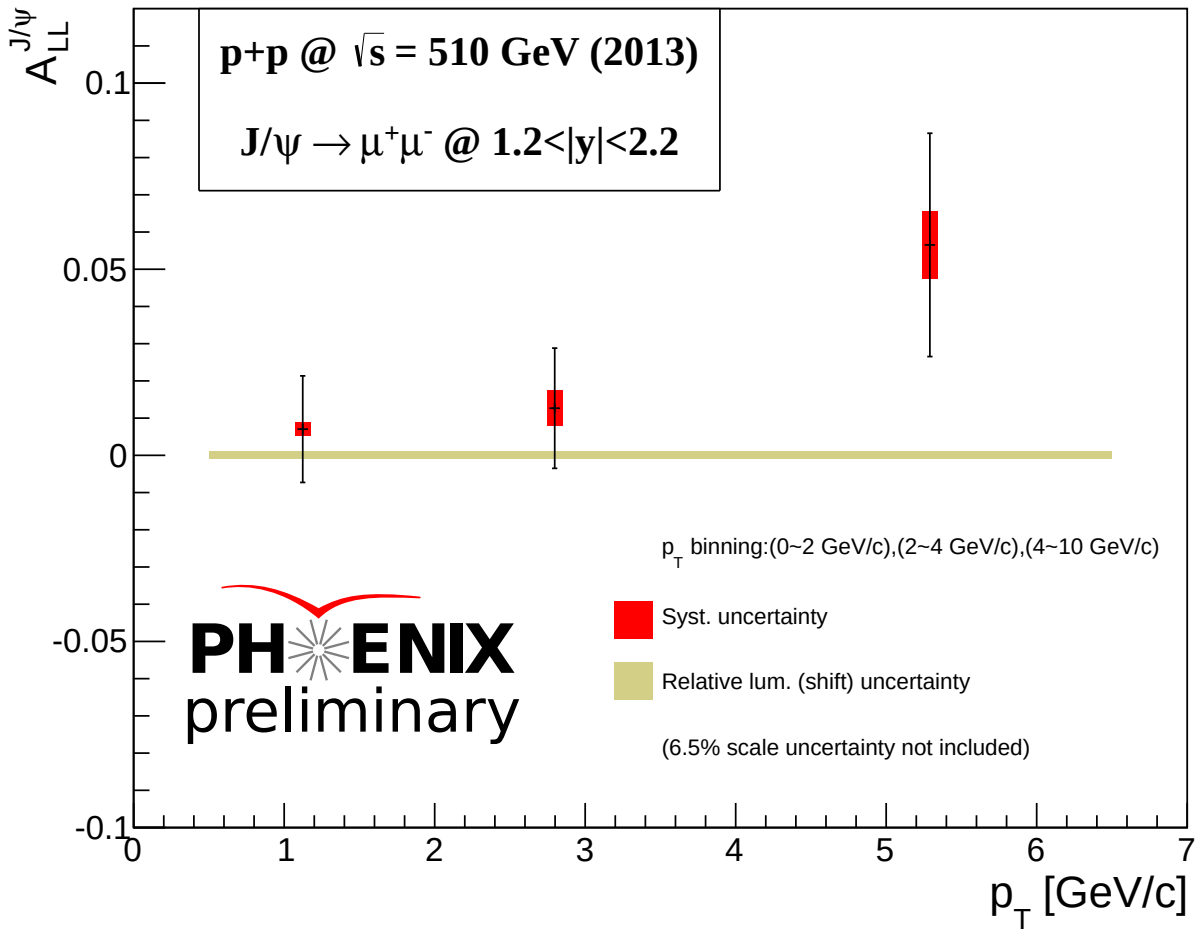


- Data gives larger asymmetry compared to previous results.
- Also, Data favor larger A_{LL} than the DSSV best fit predicts.

Here:

$$x_T = 2\frac{p_T}{\sqrt{s}}.$$

Double Helicity Asymmetry of J/ψ



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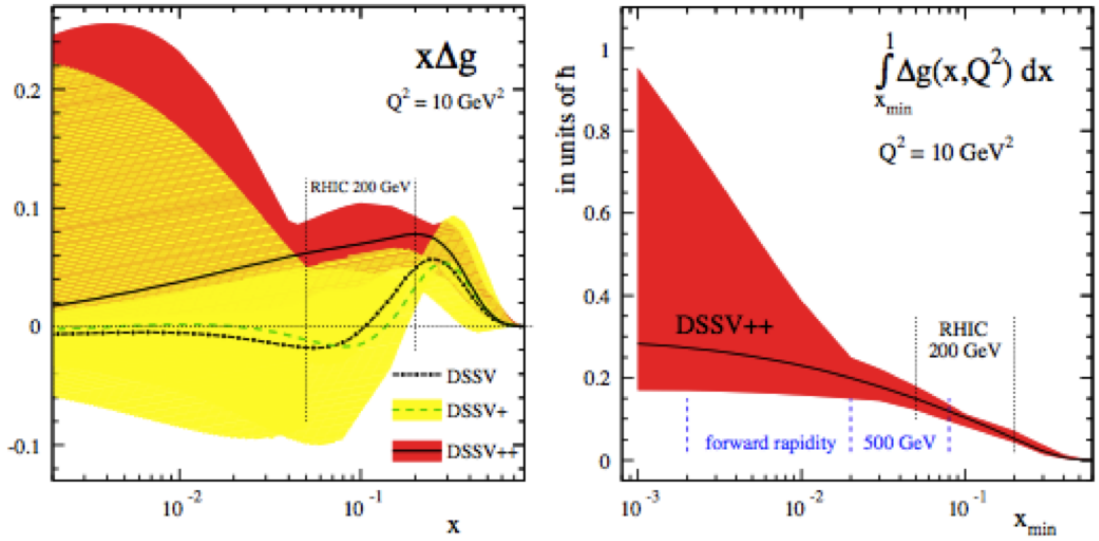
DSSV++ ΔG from RHIC Data

- DSSV++ includes RHIC data from 2009 which indicates a positive gluon spin for $0.05 < x < 1.0$



- Need to reduce large uncertainty at low x which is burying the contribution to ΔG
- New results at higher $\sqrt{s}$ will allow for better constraint at lower Bjorken x region

Plan

Summary and Future Work

- PHENIX has measured A_{LL} of π^0 and J/ψ production in different years. Data was included in global analysis (DSSV) Larger data sample in the year 2009 included in a new fit (DSSV++). DSSV++ indicates non-zero ΔG

$$\int_{0.05}^{1.0} \Delta g(x)dx = 0.2^{+0.06}_{-0.07}$$

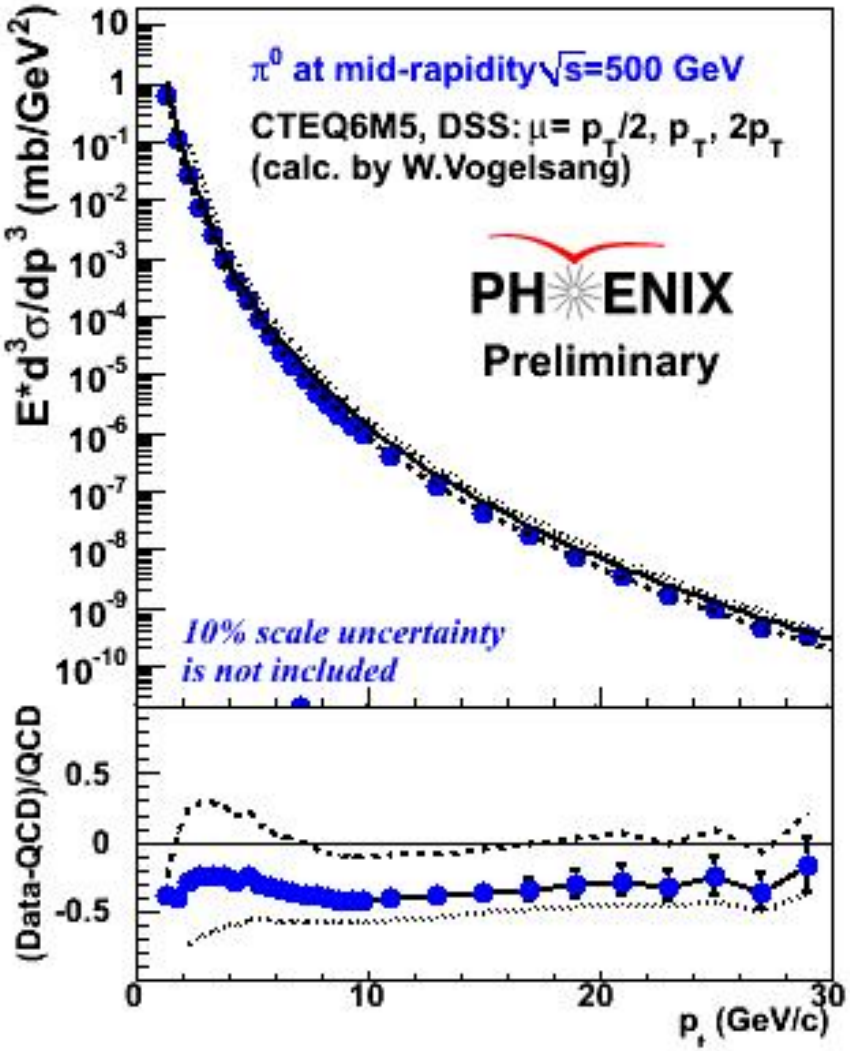
- Preliminary results of π^0 from the year 2013 pp collision at $\sqrt{s} = 510$ GeV have shown larger asymmetry compared to the year 2009, at $\sqrt{s}$ = 200 GeV
- Results will be used in global analysis for constraining Δg
- Analysis is still ongoing and smaller statistical and systematic uncertainty is expected

Thank You.

Backups

Backups.

Cross-section of π^0



- NLO pQCD calculations are consistent with cross-section measurements over several orders of magnitude
- pQCD suitable framework for treating polarization observables in these kinematics

Cut used:

- Triggers: ERT with energy thresholds (PbSc, PbGl) 4x4a: (4.7 GeV, 3.7 GeV), 4x4b (5.6 GeV, 4.7 GeV) and 4x4c (3.7 GeV, 3.7 GeV)
- Charge veto cut for removing charged hadrons
- probability cut of being EM shower $> 2\%$
- -15 ns $<$ TOF $<$ +15 ns