

Double Helicity Asymmetry from π^0 and Constraining the ΔG

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Outlines

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

Spin Composition of Proton

Initial Thought:

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

Proton spin crisis begin!!!

- Current Understanding:

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

$\Delta G = ???$

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

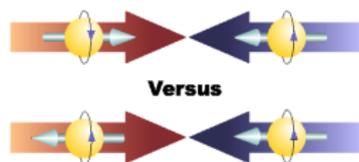
Accessing ΔG in $p + p$: A_{LL}

- Longitudinal spin program at PHENIX \Rightarrow
Gluon polarization distribution

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

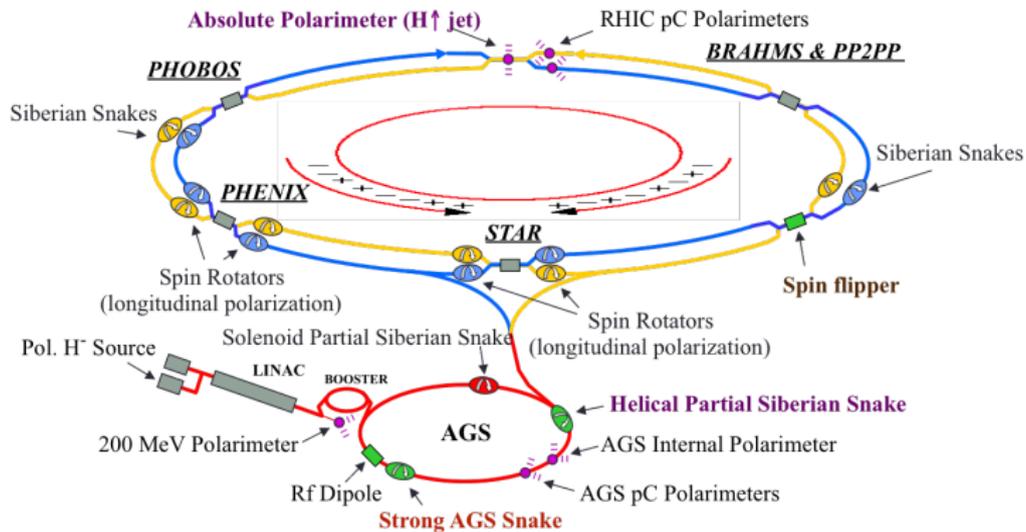
- **Asymmetries**

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



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

Relativistic Heavy Ion Collider



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

PHENIX Detectors and A_{LL} Calculation

Electromagnetic Calorimeter:

- PbSc and PbGl

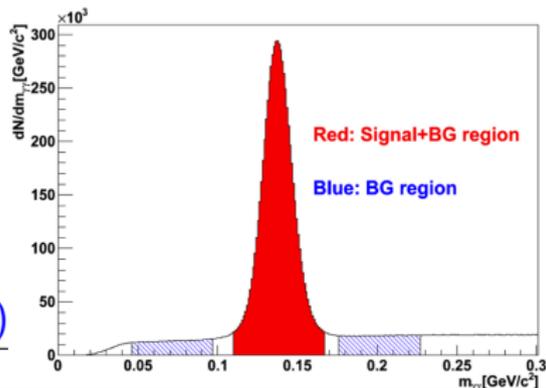
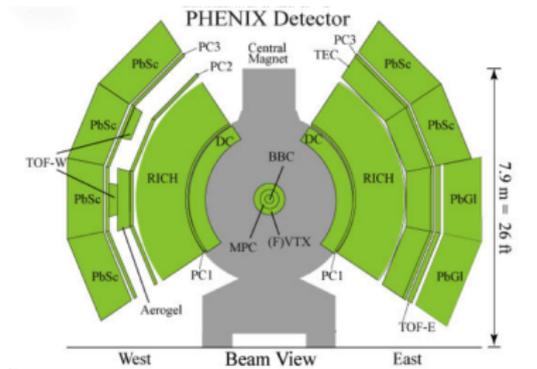
Relative Luminosity:

- Beam Beam Counter (BBC) ($3.0 < \eta < 3.9$)
- Zero Degree Calorimeter (ZDC)

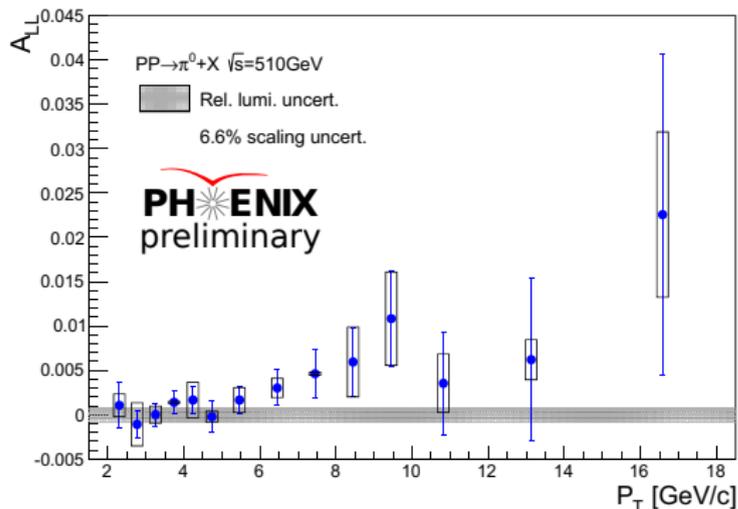
Calculating A_{LL} from π^0 :

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

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

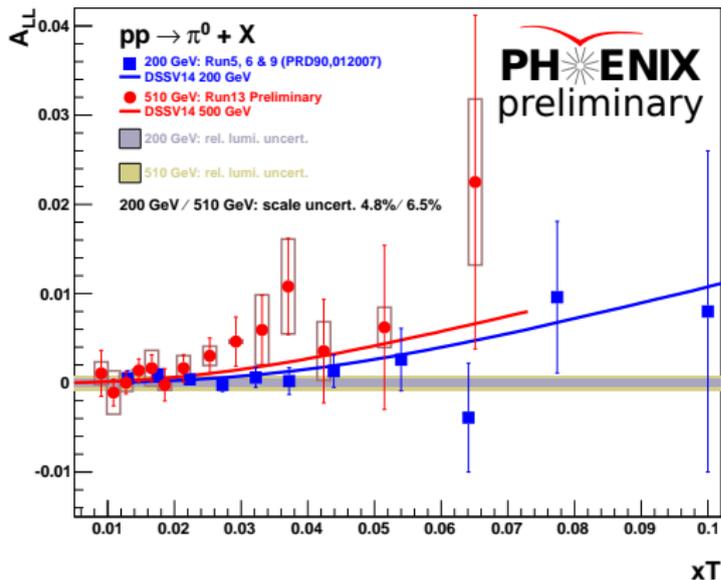


Double Helicity Asymmetry of π^0



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

Double Helicity Asymmetry of π^0



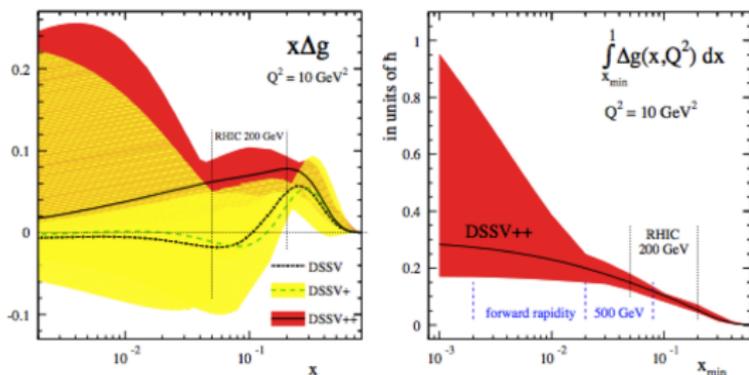
- Data gives larger asymmetry compared to previous results.
- Also, Data favor larger A_{LL} than the DSSV best fit predicts.

Here:

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

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

Summary and Future Work

- PHENIX has measured A_{LL} of π^0 production in the years 2005, 2006, 2009 and 2013. π^0 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

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

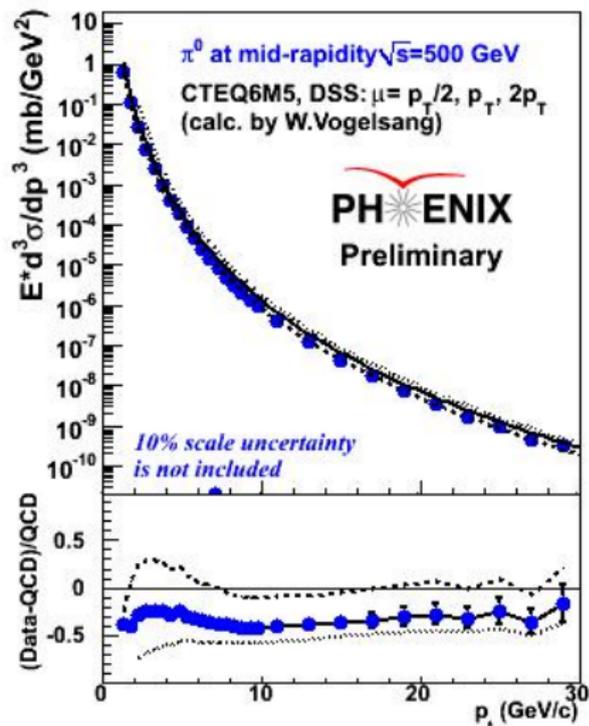
- Preliminary results from the year 2013 pp collision at $\sqrt{s} = 510$ GeV have shown larger asymmetry compared to the year 2009, at $\sqrt{s} = 200$ GeV
- Results will be used in global analysis for constraining Δg
- Analysis is still ongoing and smaller statistical and systematic uncertainty is 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 $> 2\%$
- $-15 \text{ ns} < \text{TOF} < +15 \text{ ns}$