Recent Spin Results at PHENIX

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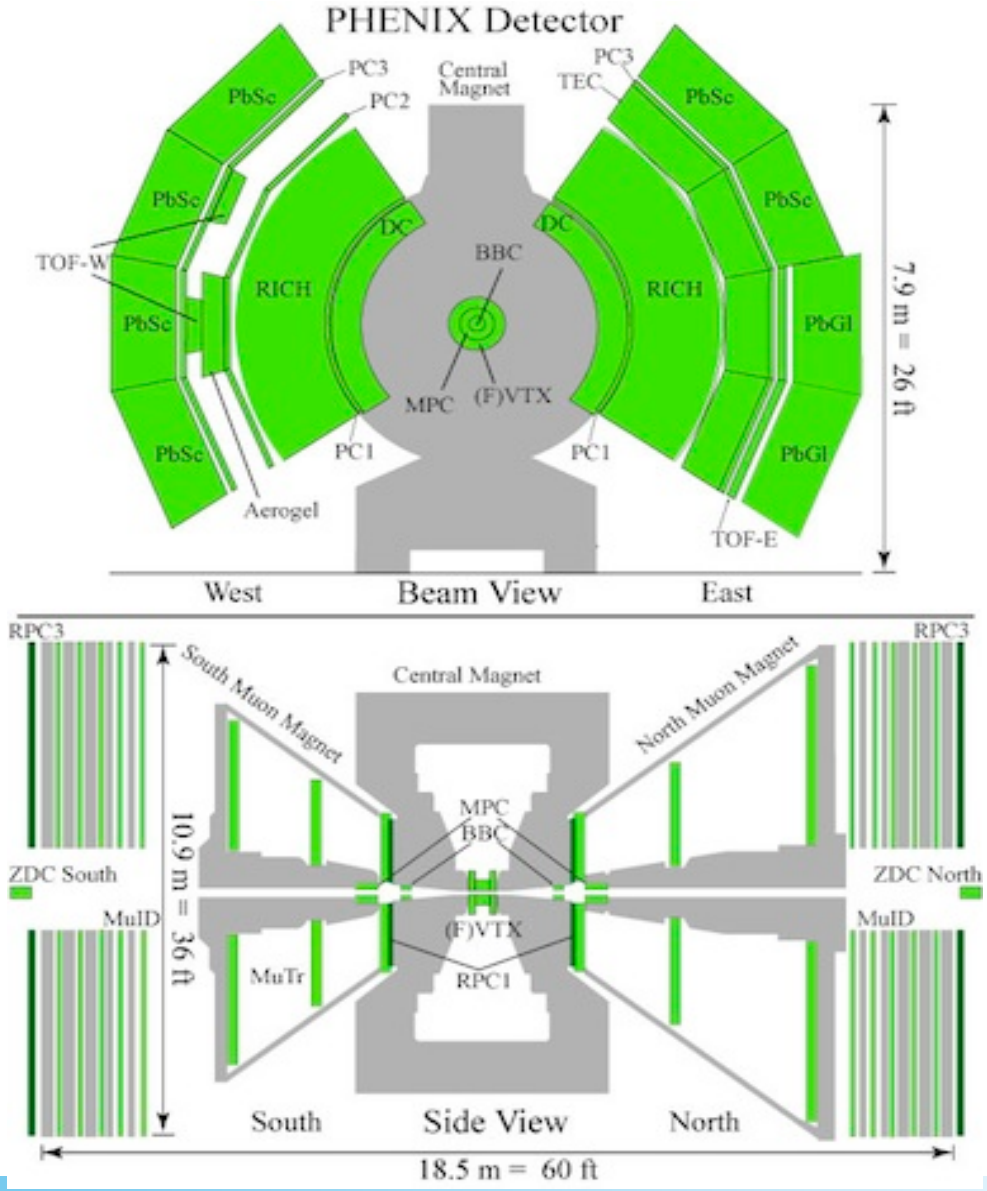
PHENIX

PHENIX Experiment

- Central Arms (|η| < 0.35)
  - Tracking: DC and PC
  - EM Calorimeter
- Forward Arms
  - Muon arms (1.2 < |η| < 2.4)
  - Zero Degree Calorimeter (ZDC)
- Completed data collection in 2016

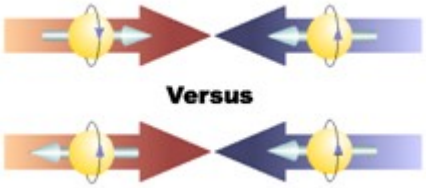


Gluon Spin

- Gluon helicity distribution function Δg(*x*) is measured to find Δ*G*, the gluon spin contribution.

$$\Delta G \equiv \int_0^1 \Delta g(x) dx$$

- The Δg(*x*) is found via the longitudinal double spin asymmetry, A_{LL}



Polarized PDFs

Parton-level hard scattering cross section calculable in pQCD

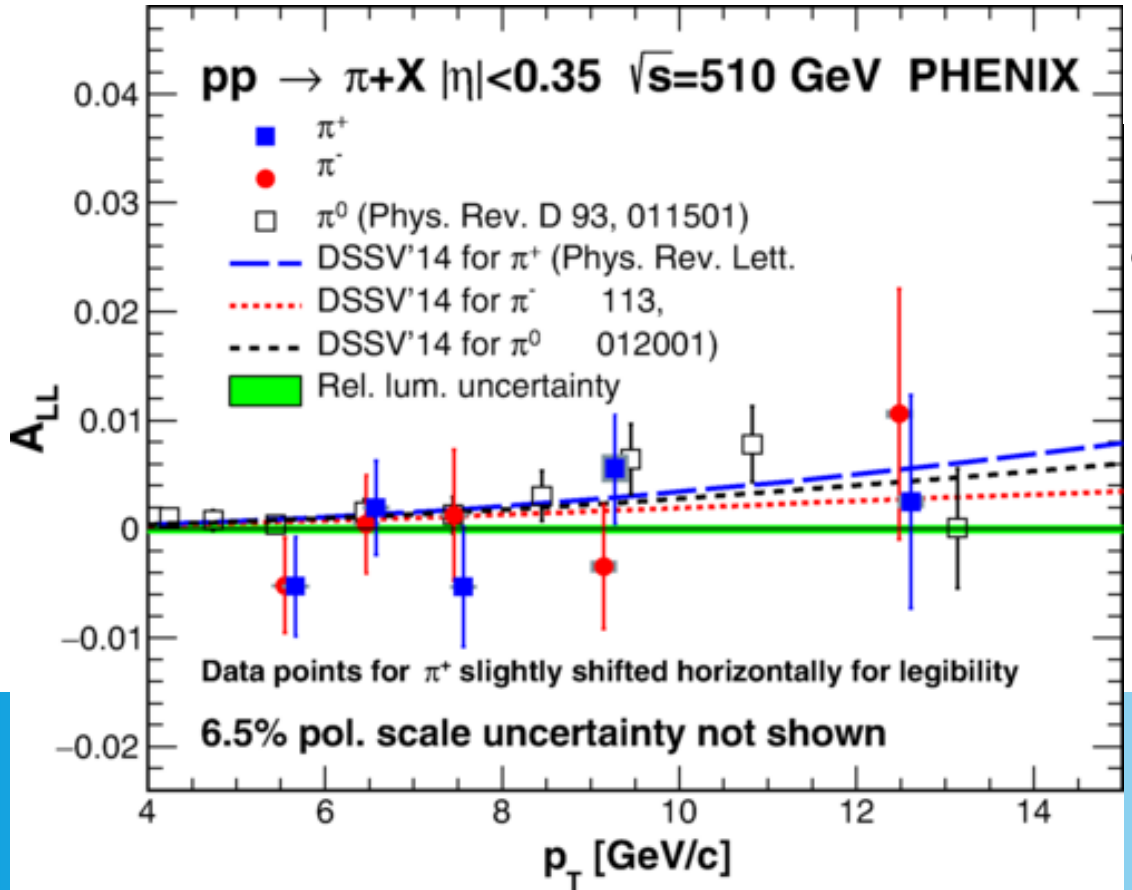
$$A_{LL} \equiv \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}} \propto \frac{\sum_{a,b,c=q,\bar{q},g} \Delta f_a \otimes \Delta f_b \otimes d\hat{\sigma}^{f_a f_b \to f_c X} \otimes D_{f_c}^{\pi^0}}{\sum_{a,b,c=q,\bar{q},g} f_a \otimes f_b \otimes \hat{\sigma}^{f_a f_b \to f_c X} \otimes D_{f_c}^{\pi^0}}$$

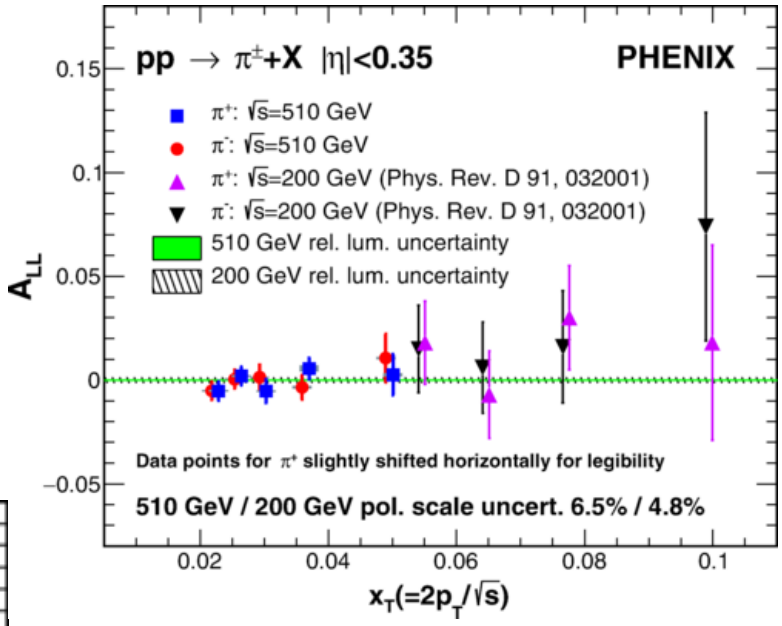
Unpolarized PDFs

Fragmentation functions from e+e- scattering

Charged Pion A_{LL} at 510 GeV

- First PHENIX measurement at 510 GeV
- Consistent with DSSV global fits within statistical uncertainty



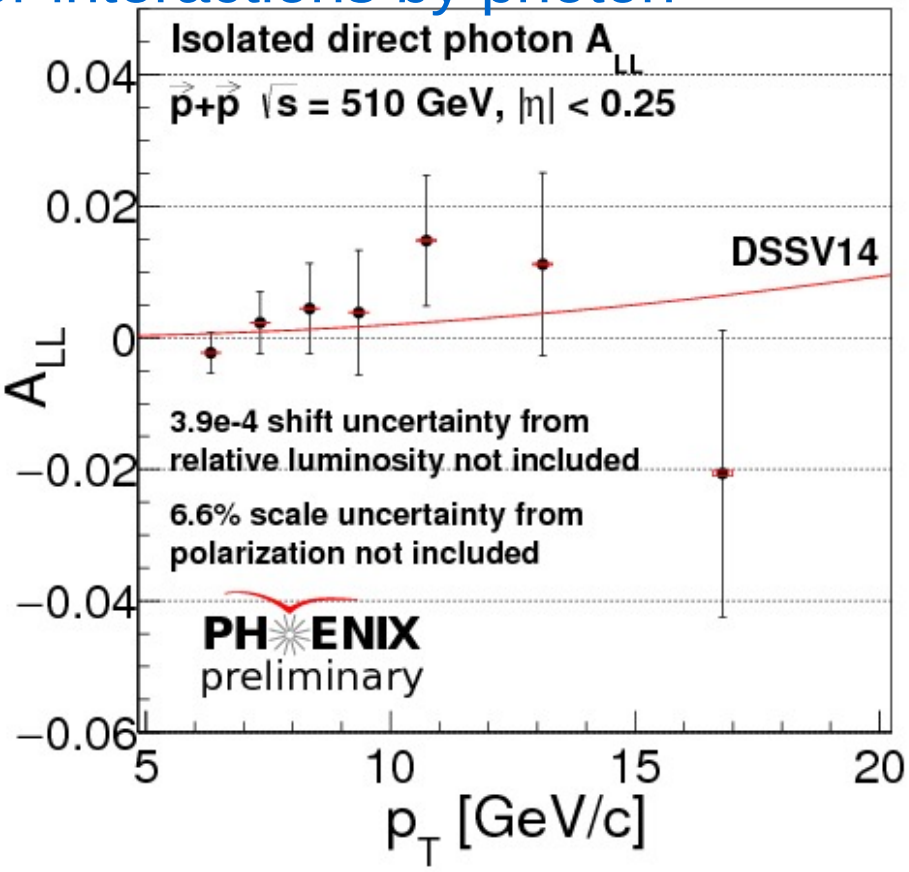


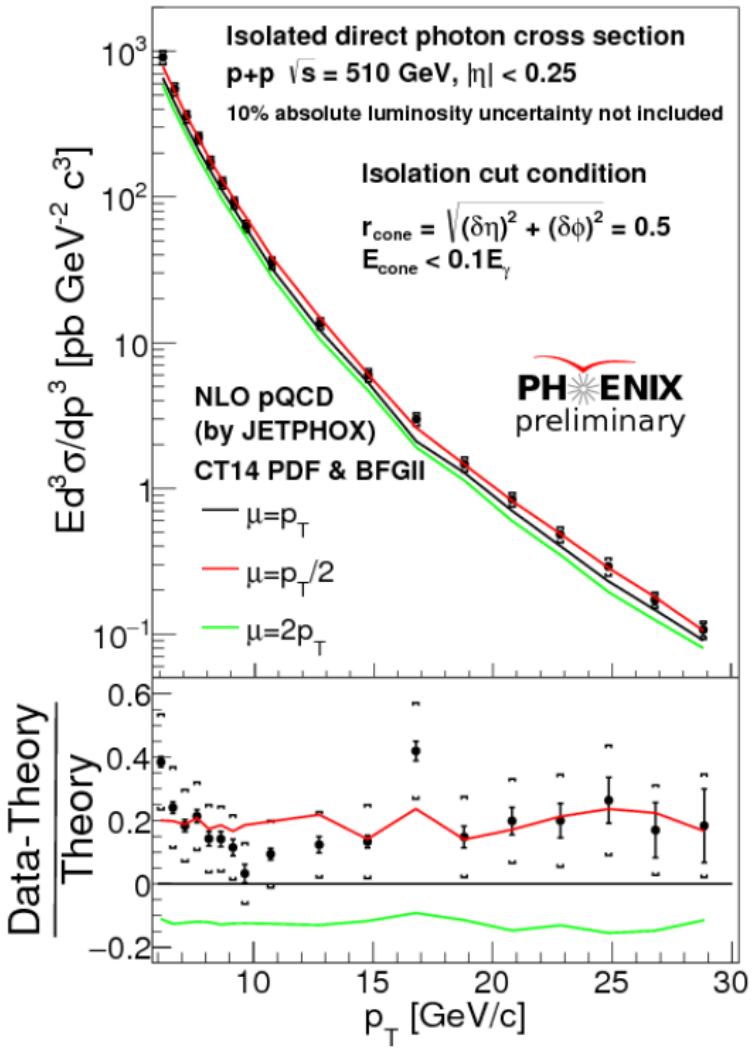
Phys. Rev. D 102, 032001 (2020)

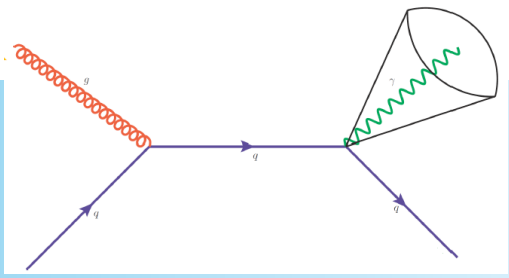
- Charged pions potential indicator for sign of Δg via pion A_{LL} ordering

Direct Photon A_{LL} at 510 GeV

- First PHENIX direct photon cross section and A_{LL} at 510 GeV
- "Golden" channel to access gluon polarization since hard interaction is mostly q-g
  - No color interactions by photon

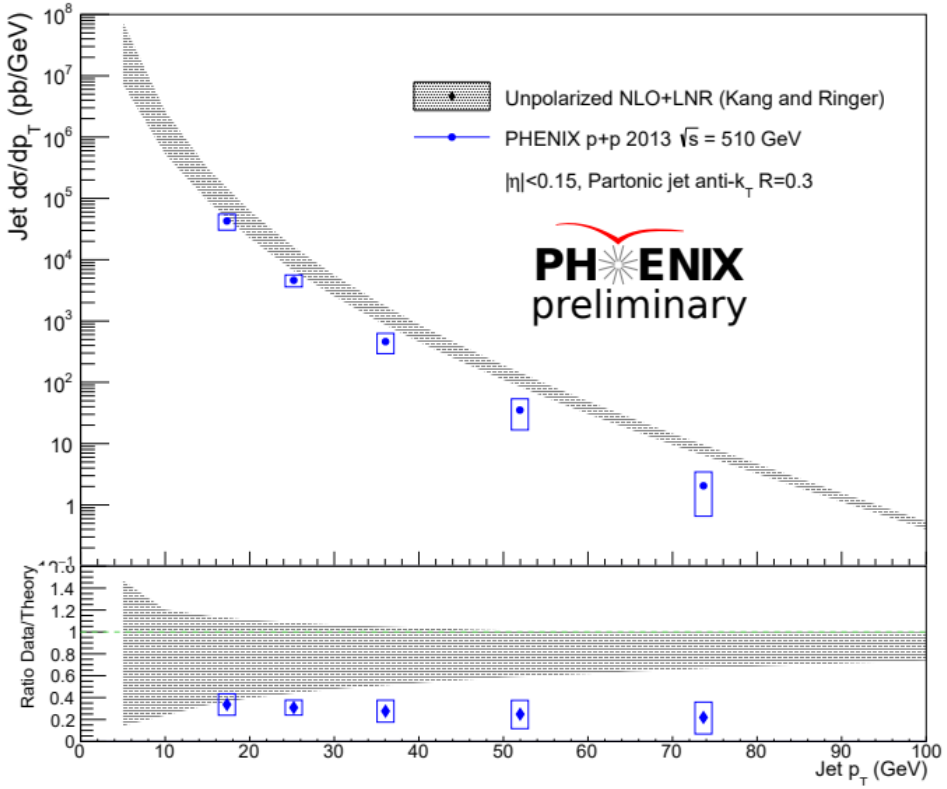


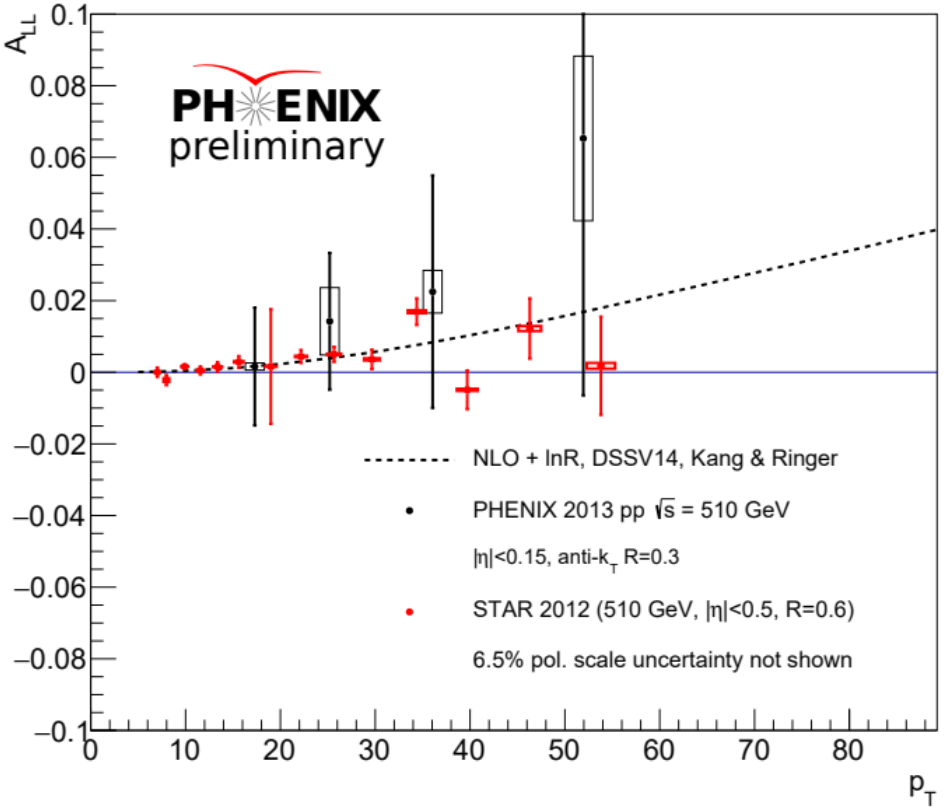




Jet A_{LL} at 510 GeV

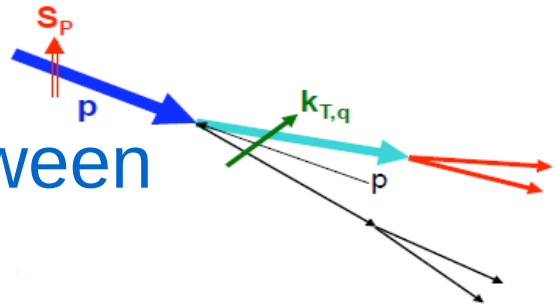
- First jet A_{LL} at PHENIX
  - Unfolded to correct for underlying event and detector effects
- Cross section below NLO prediction
  - Similar to LHC finding for small R

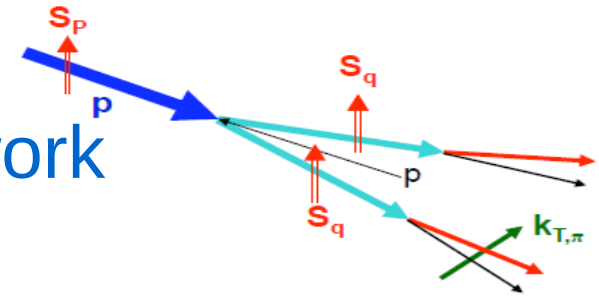




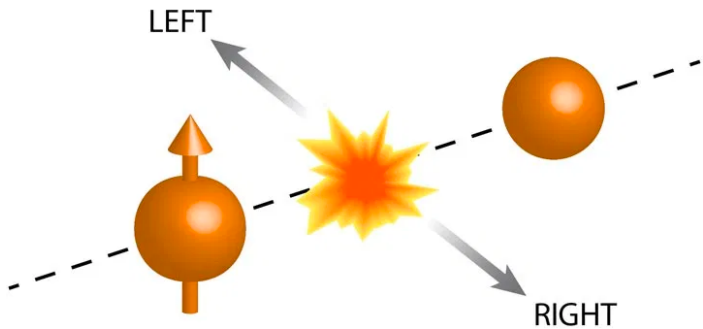
Origin of TSSAs

- Transverse momentum dependent (TMD) distributions and fragmentations
  - Sivers effect (initial state): correlation between nucleon spin and parton momentum
  - Collins effect (final state): correlation between fragmenting parton and hadron transverse momentum
- Multi-parton correlation in collinear framework
  - Initial state or in fragmentation process
  - SSA appears as twist-3 observable



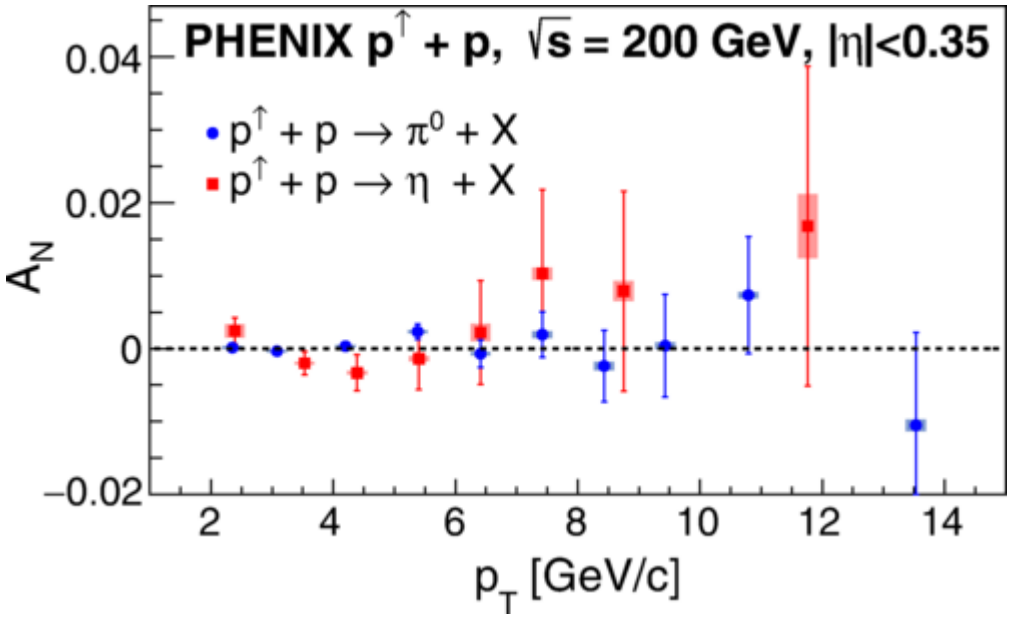


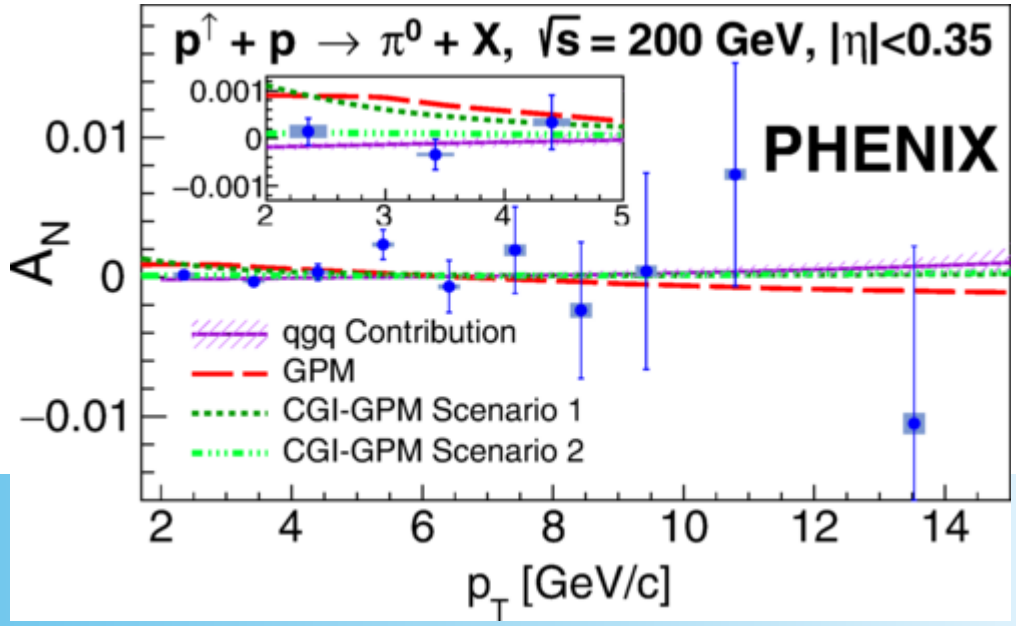
$$A_N = \frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}}$$



η and π^0 A_N at 200 GeV

- Sensitive to both initial and final state effects
- Mid-rapidity sensitive to gluon spin-momentum correlations
- New data significantly improves precision
- Asymmetries consistent with zero

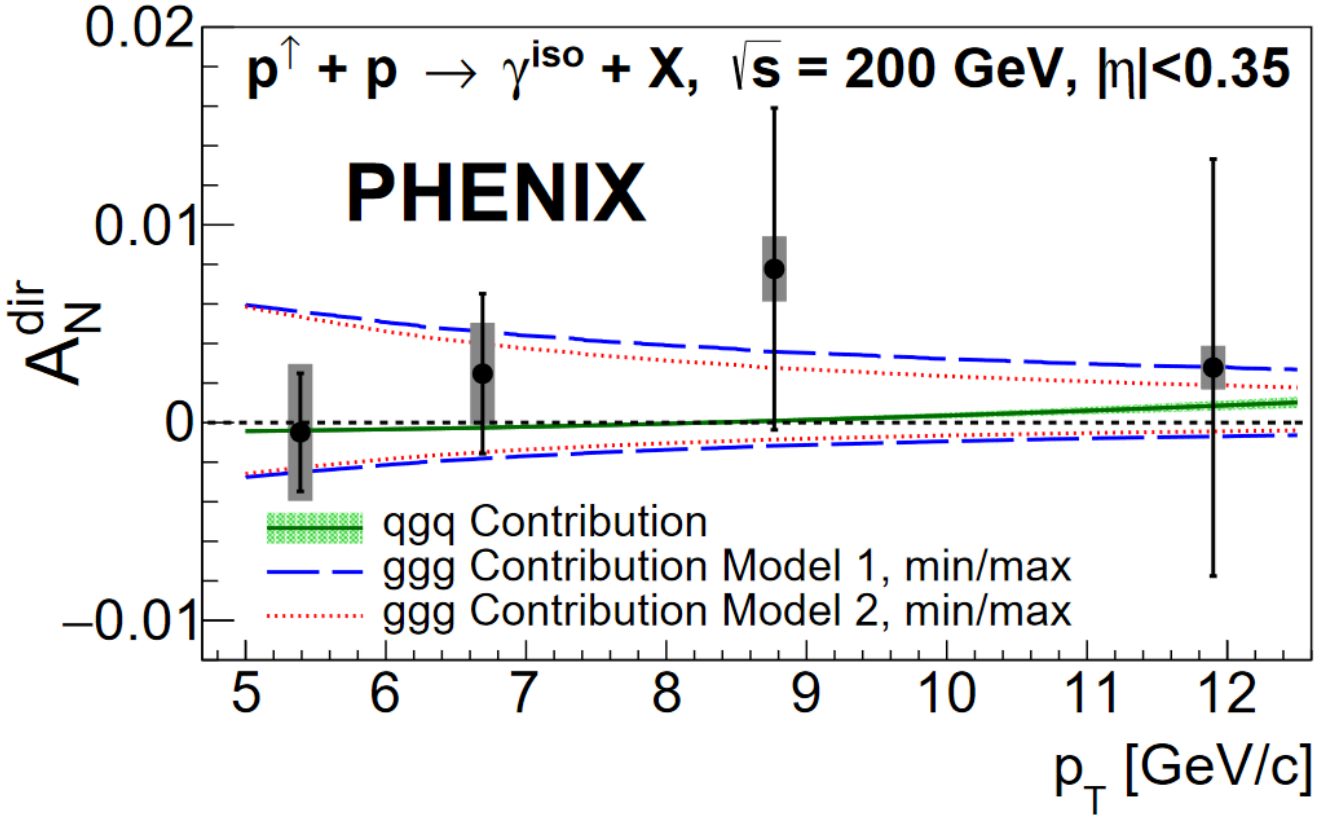




PRD103, 052009

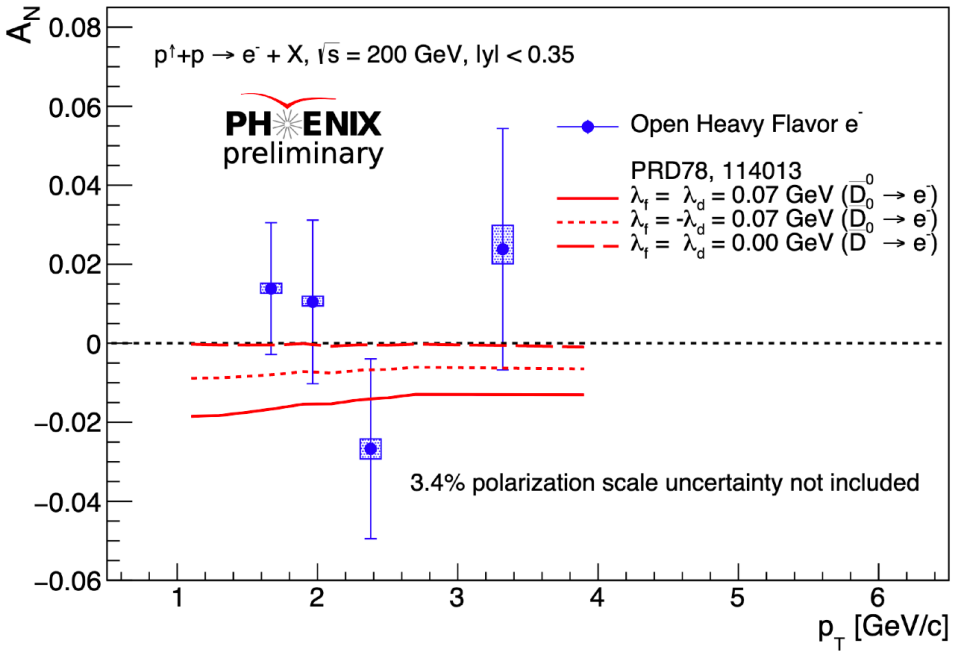
Direct Photon A_N at 200 GeV

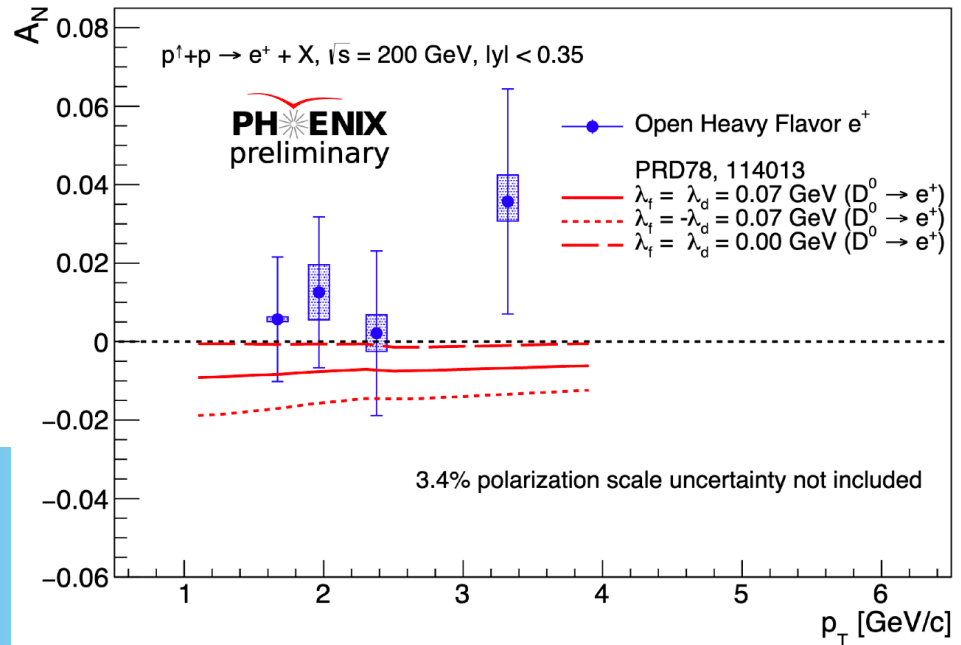
- Sensitive to initial state effects
  - Production dominated by q+g → q+γ
- First measurement at PHENIX
  - Accepted by PRL (arXiv:2102.13585[hep-ex])
  - Help constrain trigluon correlation function



Open Heavy Flavor Electron A_N at 200 GeV

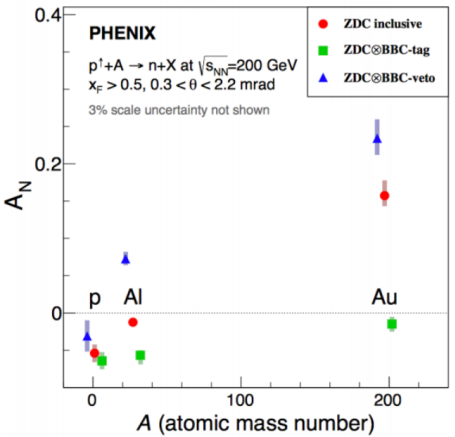
- Mostly produced by gg at RHIC energies
- Sensitive to trigluon correlations in collinear framework
- Dominant contribution from open Charm production
- Asymmetry consistent with zero within uncertainty

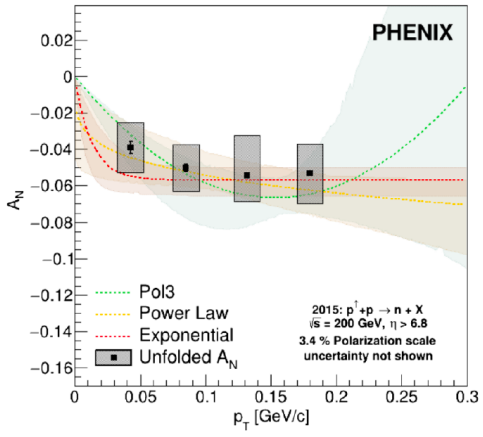


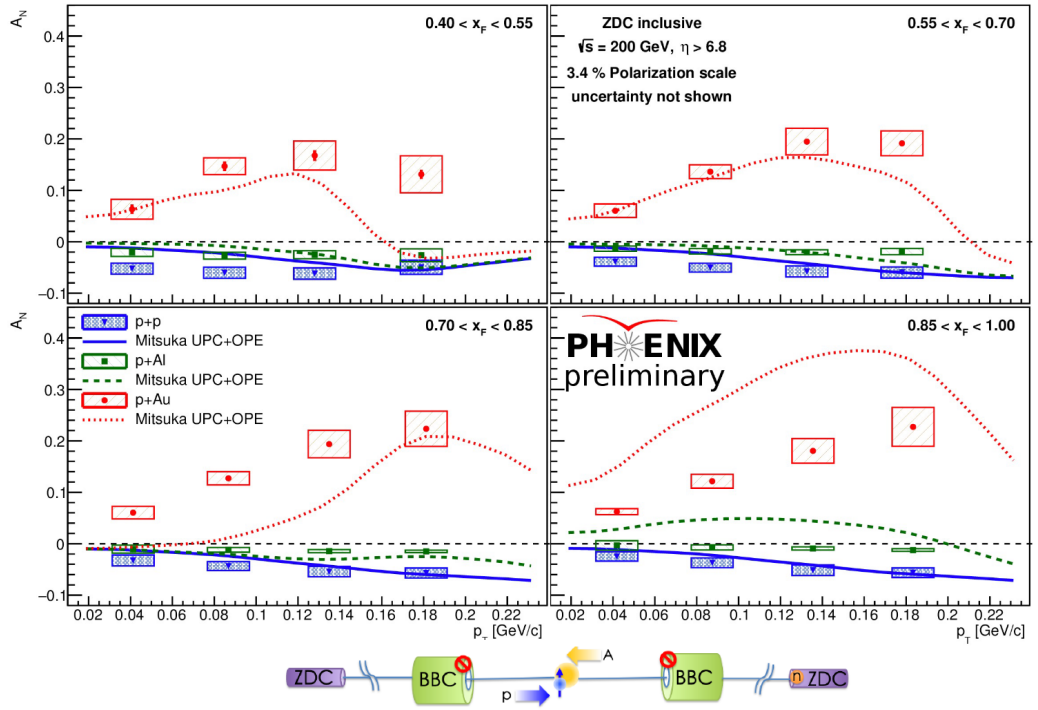


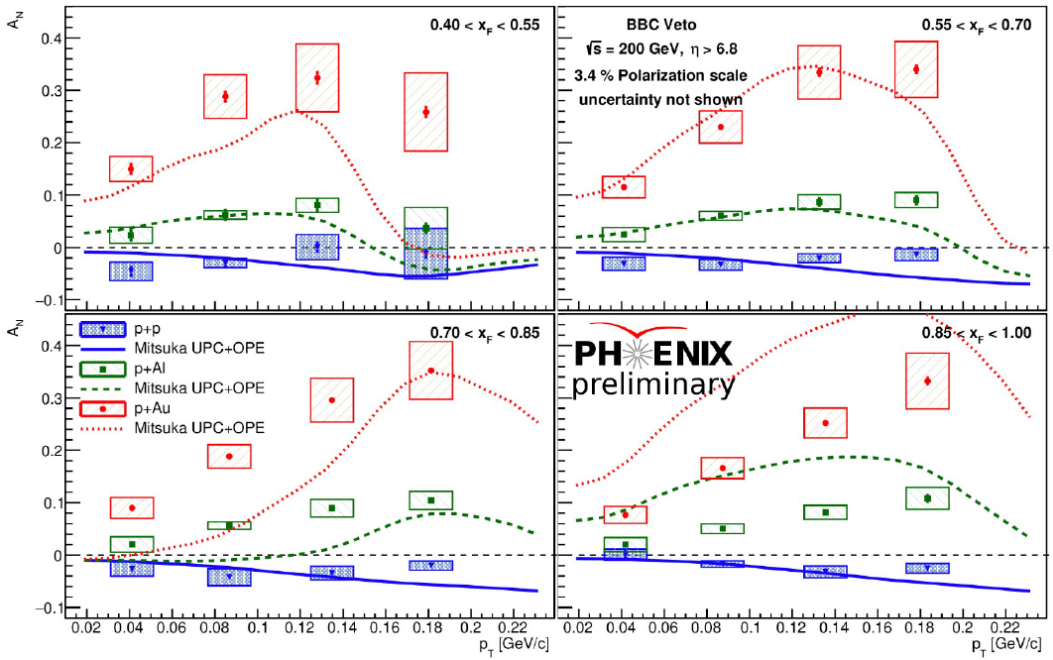
Neutron A_N at 200 GeV

- Forward measurement (eta > 6.8)
- Nuclear dependent neutron A_N (PRL 120, 022001 (2018))
- P_T dependence of A_N in p+p (PRD 103, 032007 (2021))
- Asymmetry show p_T dependence and broken down in X_F and detector activity
  - Enhance/suppress UPC contribution









Summary

- PHENIX spin program continues to elucidate our understanding of QCD
- Results:
  - Longitudinal spin analyses:
    - Jet, direct photon, charged pion A_{LL}
  - Transverse spin analyses:
    - Direct photon, π^0 and η, heavy flavor electron, and neutron A_N
- Still more to come in the future!