

PHENIX Highlights

Sanghwa Park



Stony Brook University

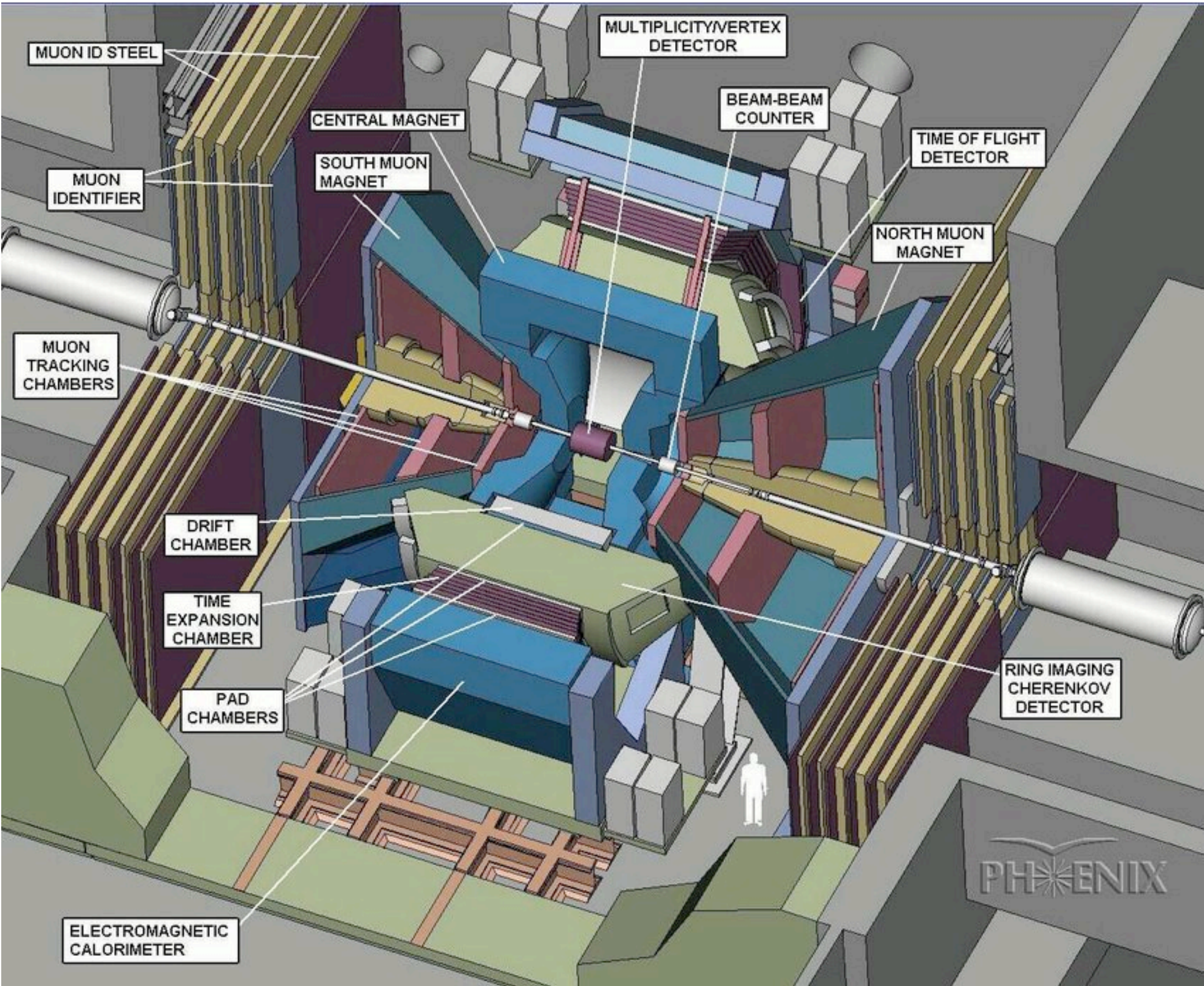
for the PHENIX Collaboration

**RHIC & AGS
Annual Users' Meeting 2021**



- PHENIX has completed data taking in 2016
- Now fully in analysis mode, many interesting new results!
- Studying the proton spin structure from polarized proton collisions
- QGP properties from different energies and collisions species

\sqrt{s} [GeV]	p+p	p+Al	p+Au	d+Au	³ He+Au	Cu+Cu	Cu+Au	Au+Au	U+U
510	✓								
200	✓	✓	✓	✓	✓	✓	✓	✓	✓
130								✓	
62.4	✓			✓		✓		✓	
39				✓				✓	
27								✓	
20				✓		✓		✓	
14.5								✓	
7.7								✓	



Cold QCD Highlights

Longitudinal spin results:

New results sensitive to gluon polarization via direct photon and jet production

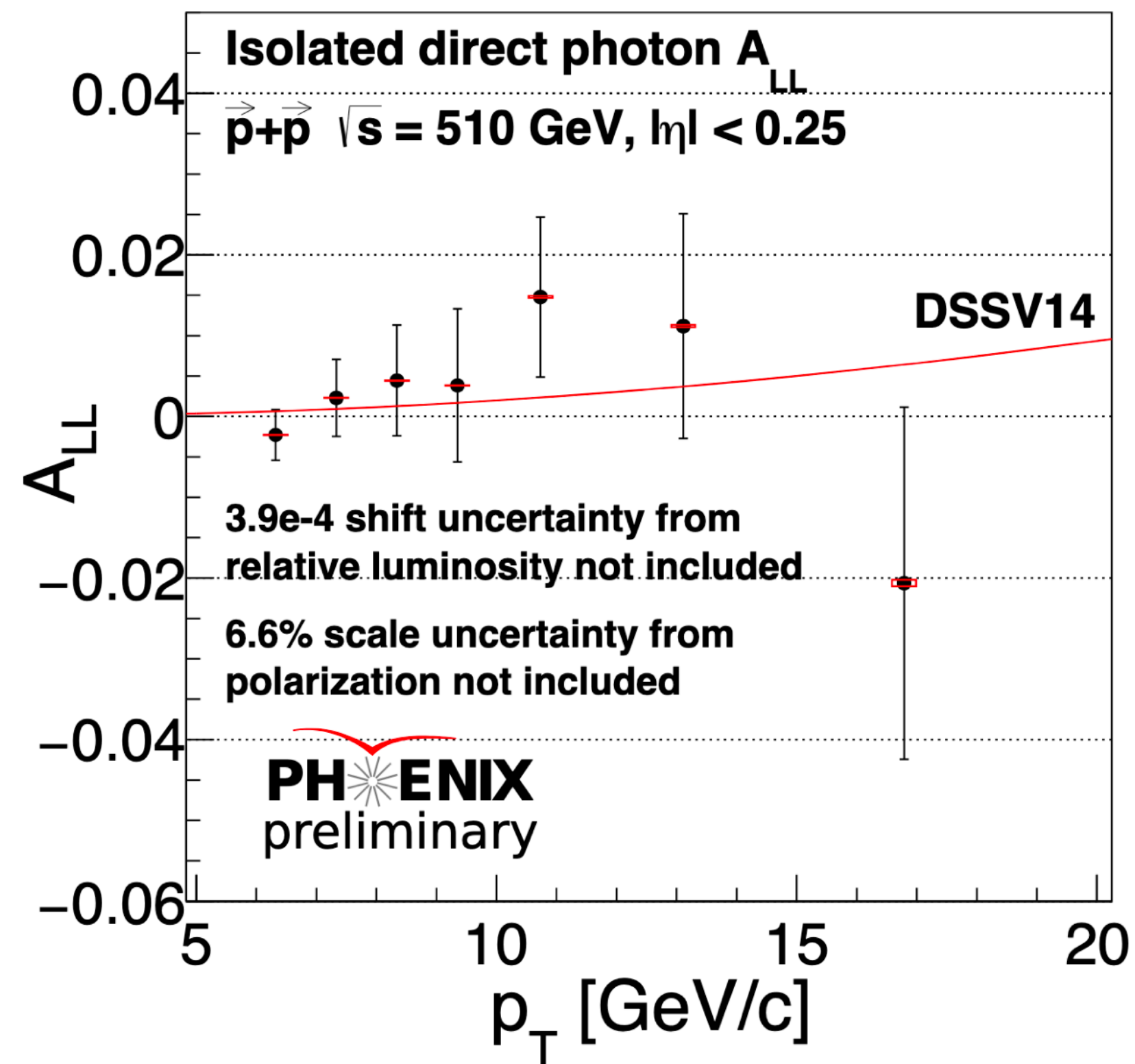
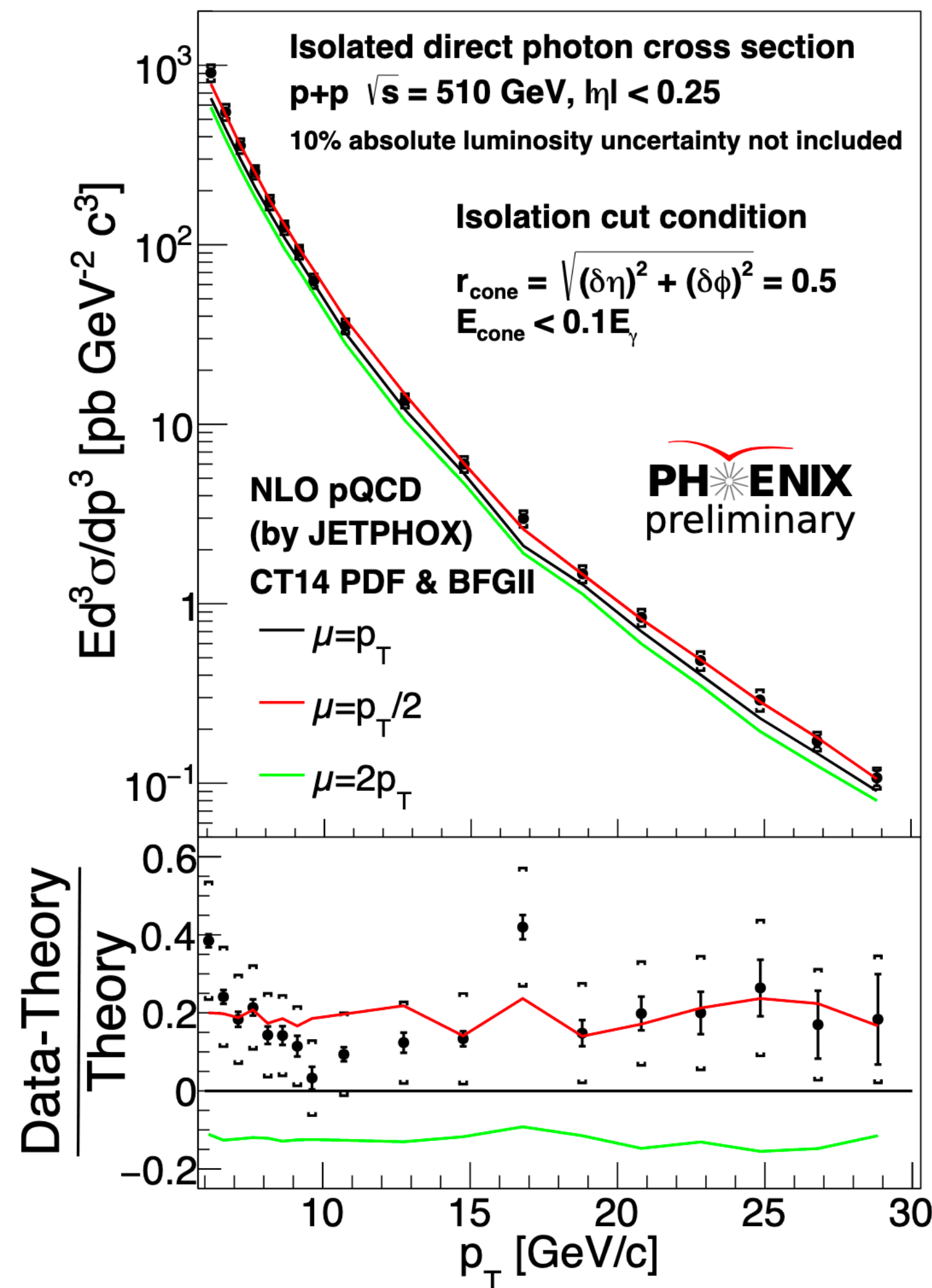
Transverse spin phenomena:

Spin-momentum correlations in the transversely polarized proton

Very forward neutron A_N

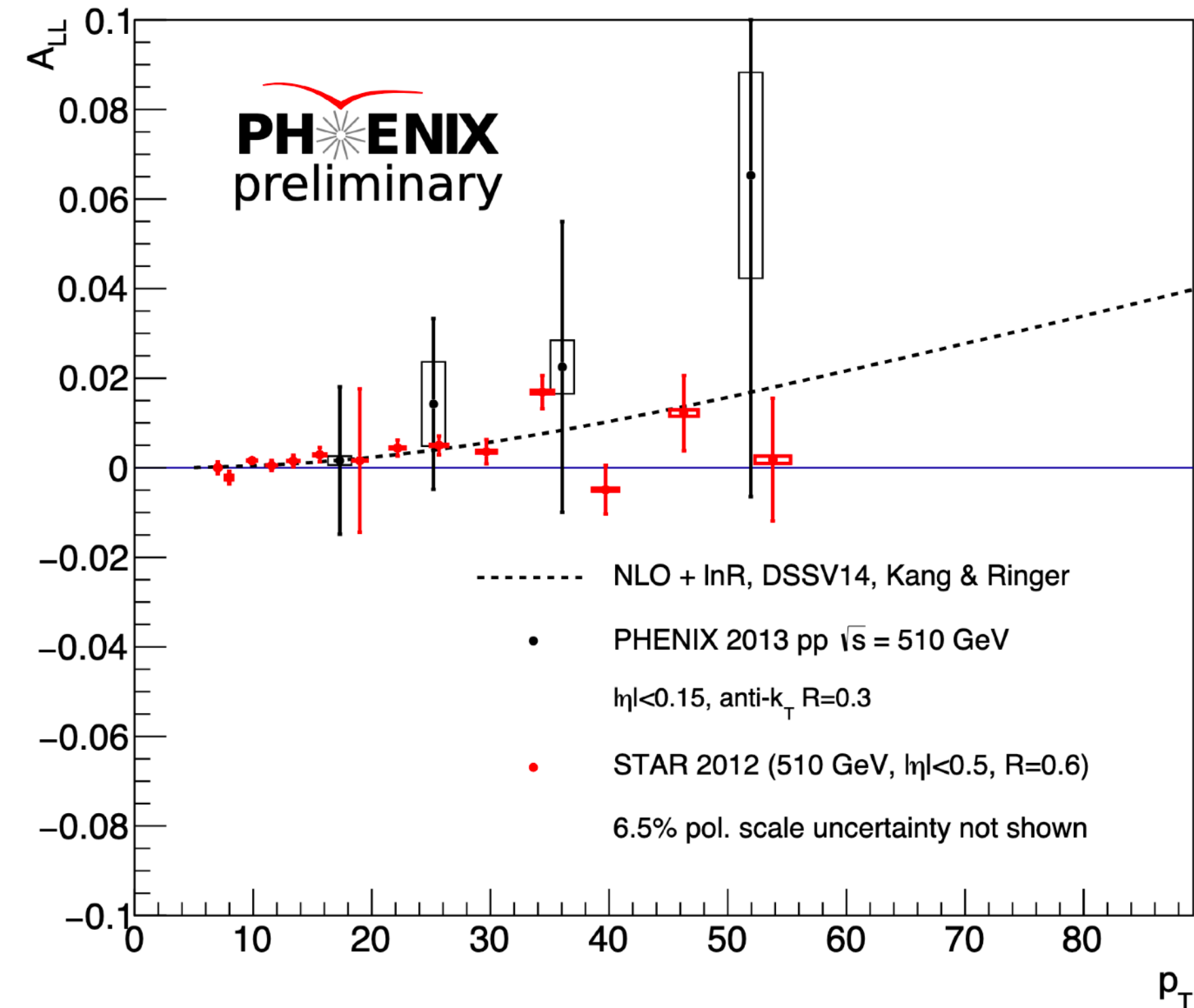
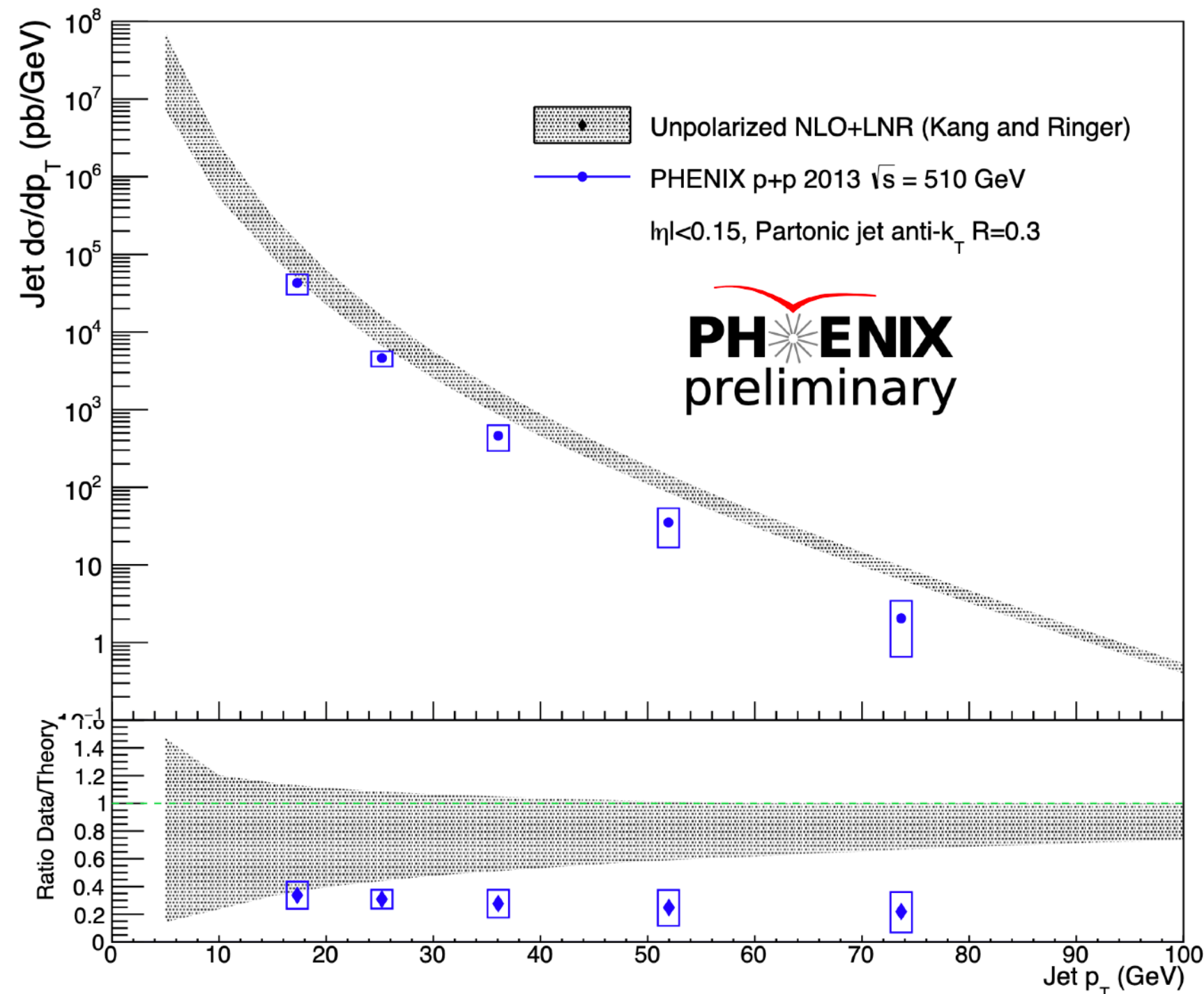
See talk by Benard Mulilo:
Spin Workshop at AUM

Direct photon cross section and A_{LL}



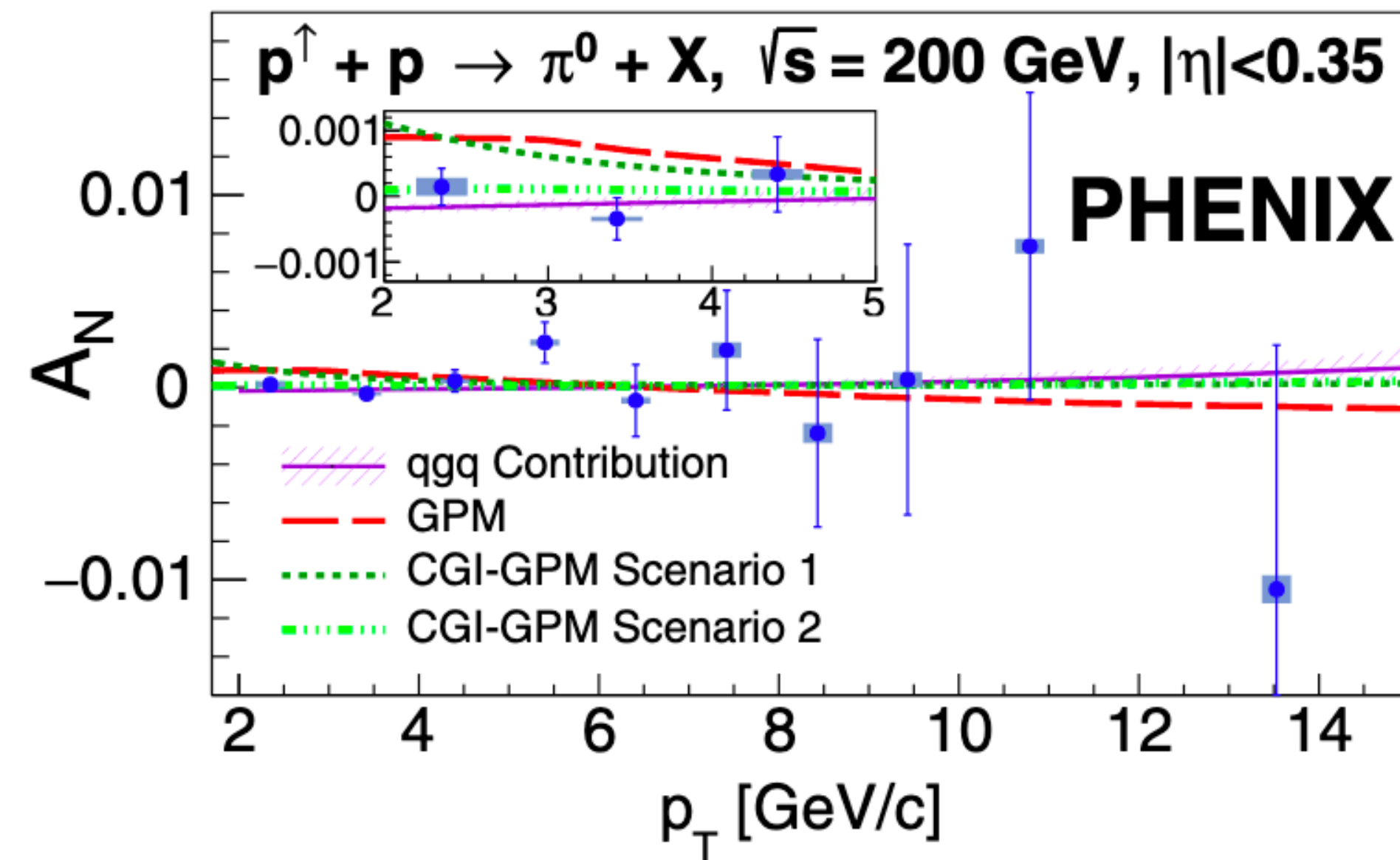
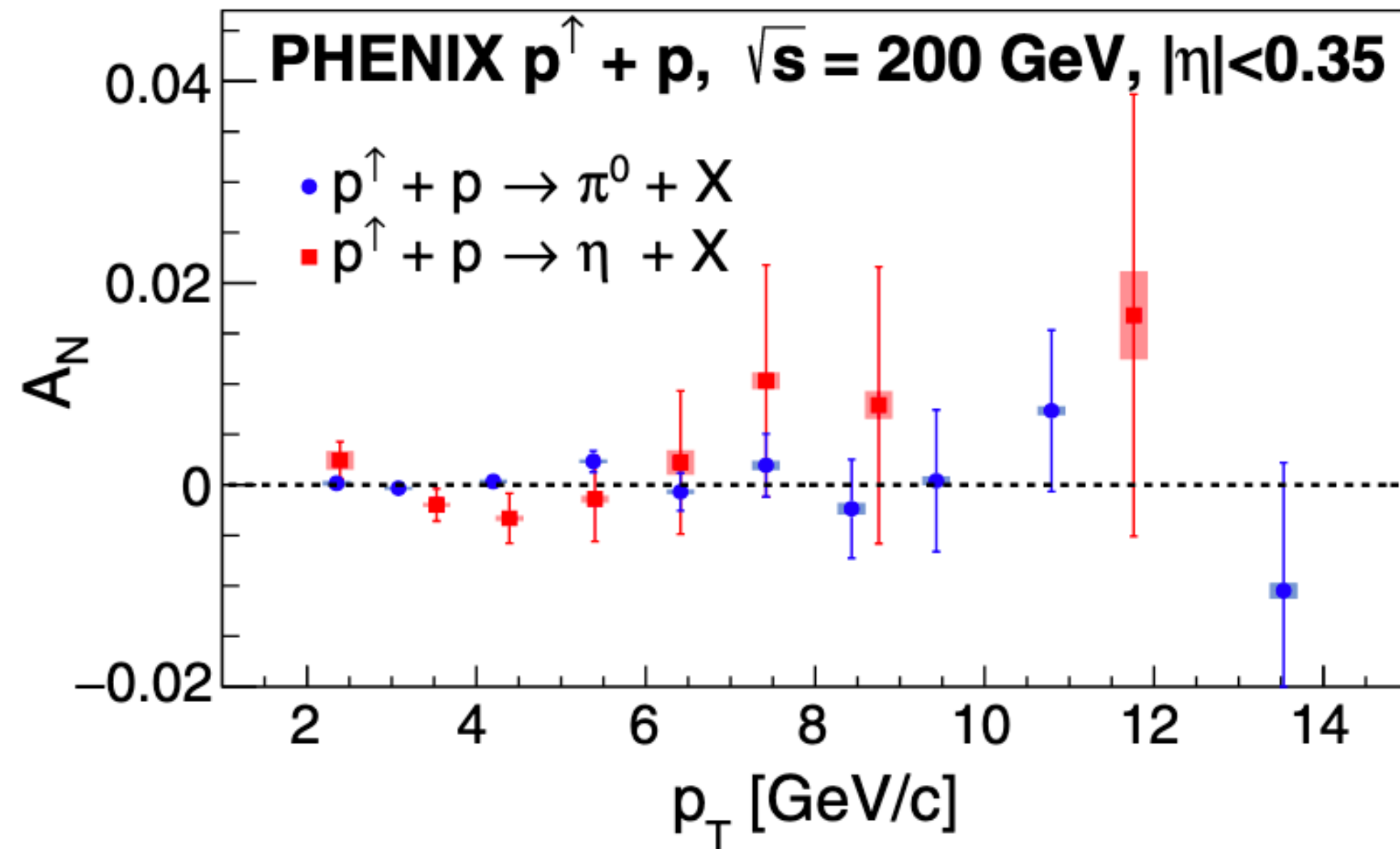
- First measurements at 510 GeV
- Direct photons - theoretically clean measurement
- Quark-gluon Compton process dominates cross section
- DSSV14 calculation consistent with the data

Jet Cross Section and A_{LL} @ 510 GeV



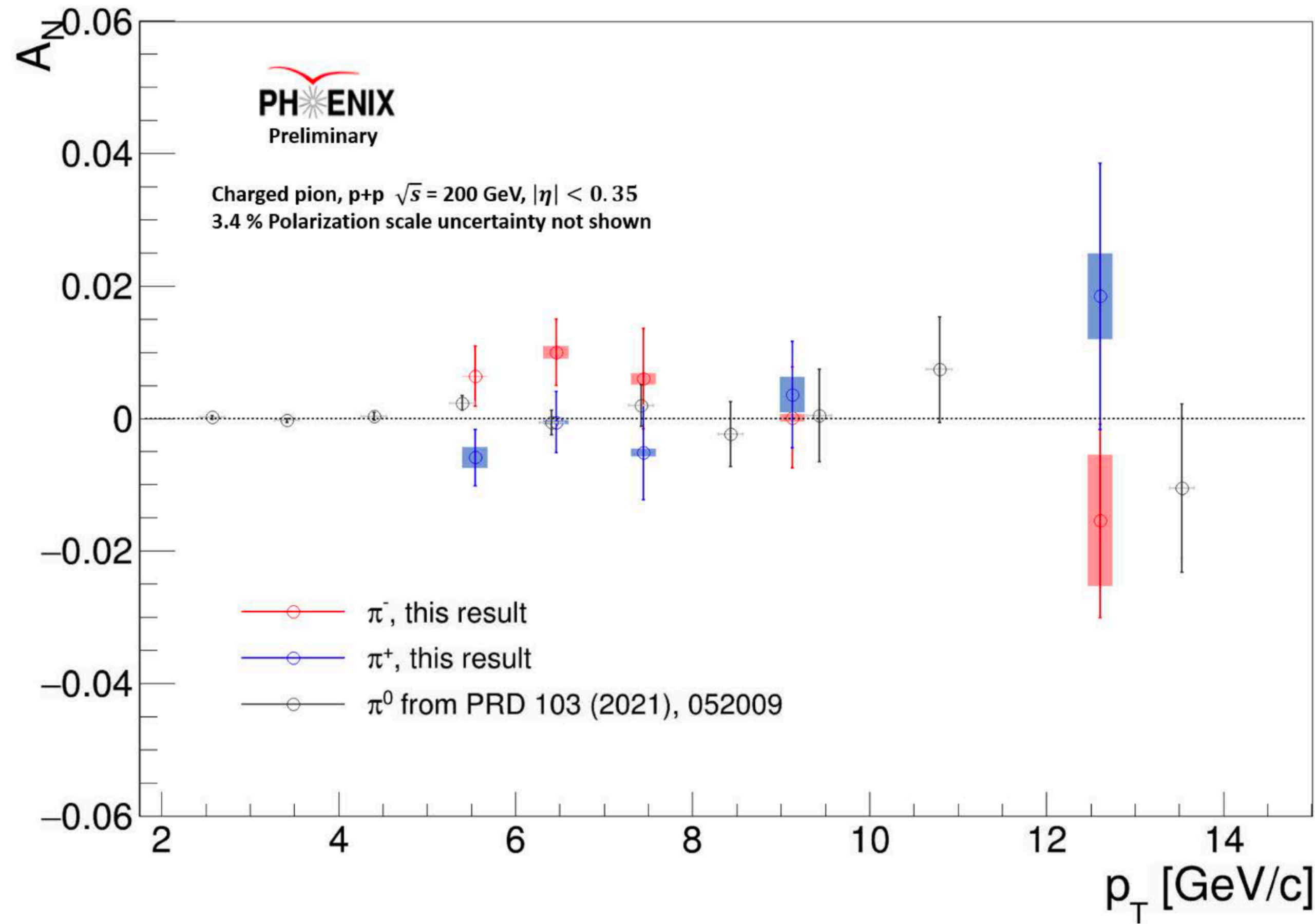
- Jet reconstructed with anti- k_T $R=0.3$
- NLO+LNR calculation overestimates the cross section (similar findings from LHC for small R using anti- k_T method)
- First jet A_{LL} result from PHENIX, asymmetry consistent with zero and STAR measurements

π^0 and η A_N at Midrapidity



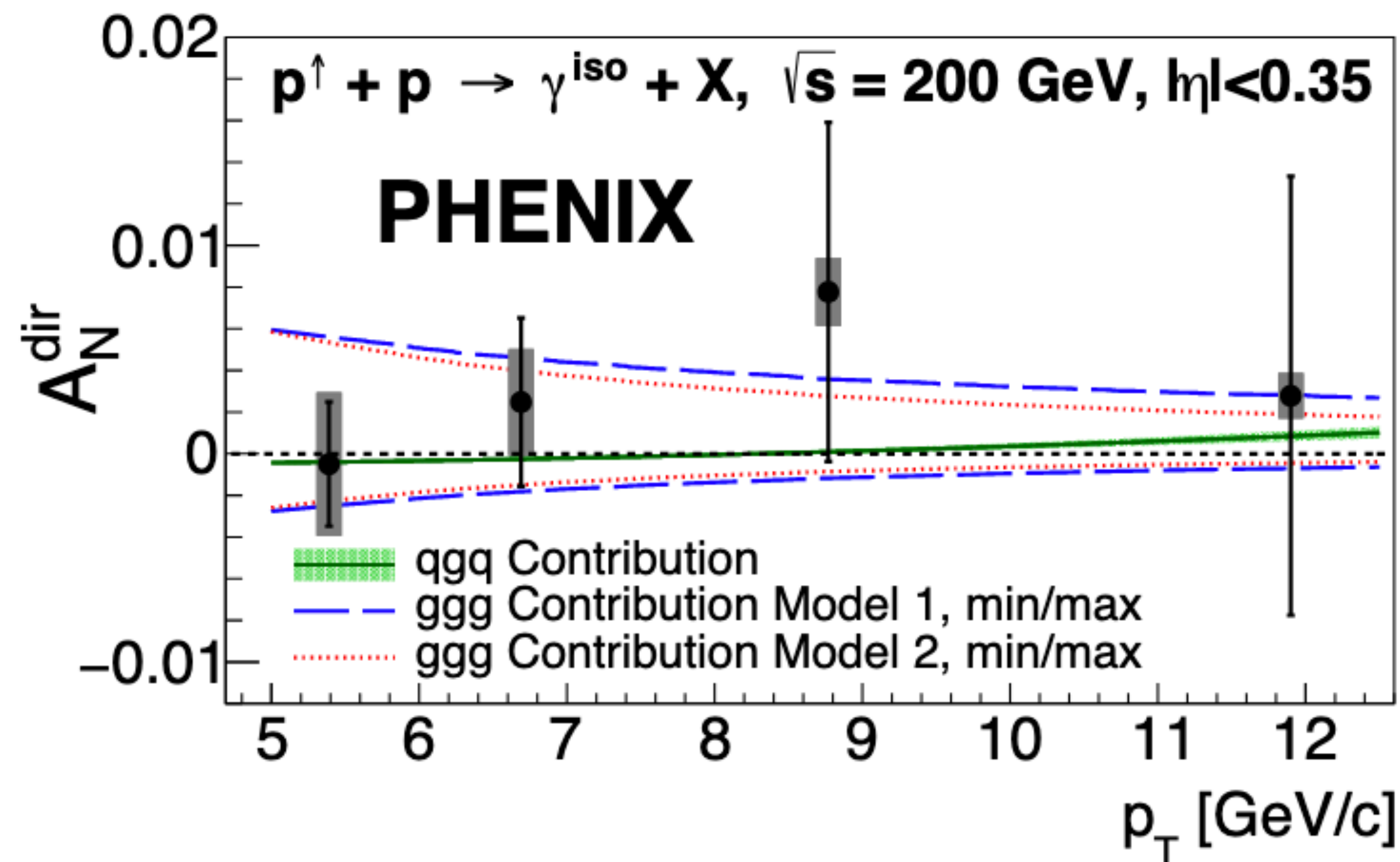
- New 200 GeV results [PRD103, 052009](#)
- Asymmetry consistent with zero, new data significantly improved precision compared to previous PHENIX results
- Sensitive to both initial and final state effects
- Midrapidity measurements are sensitive to gluons

Charged pion A_N at Midrapidity



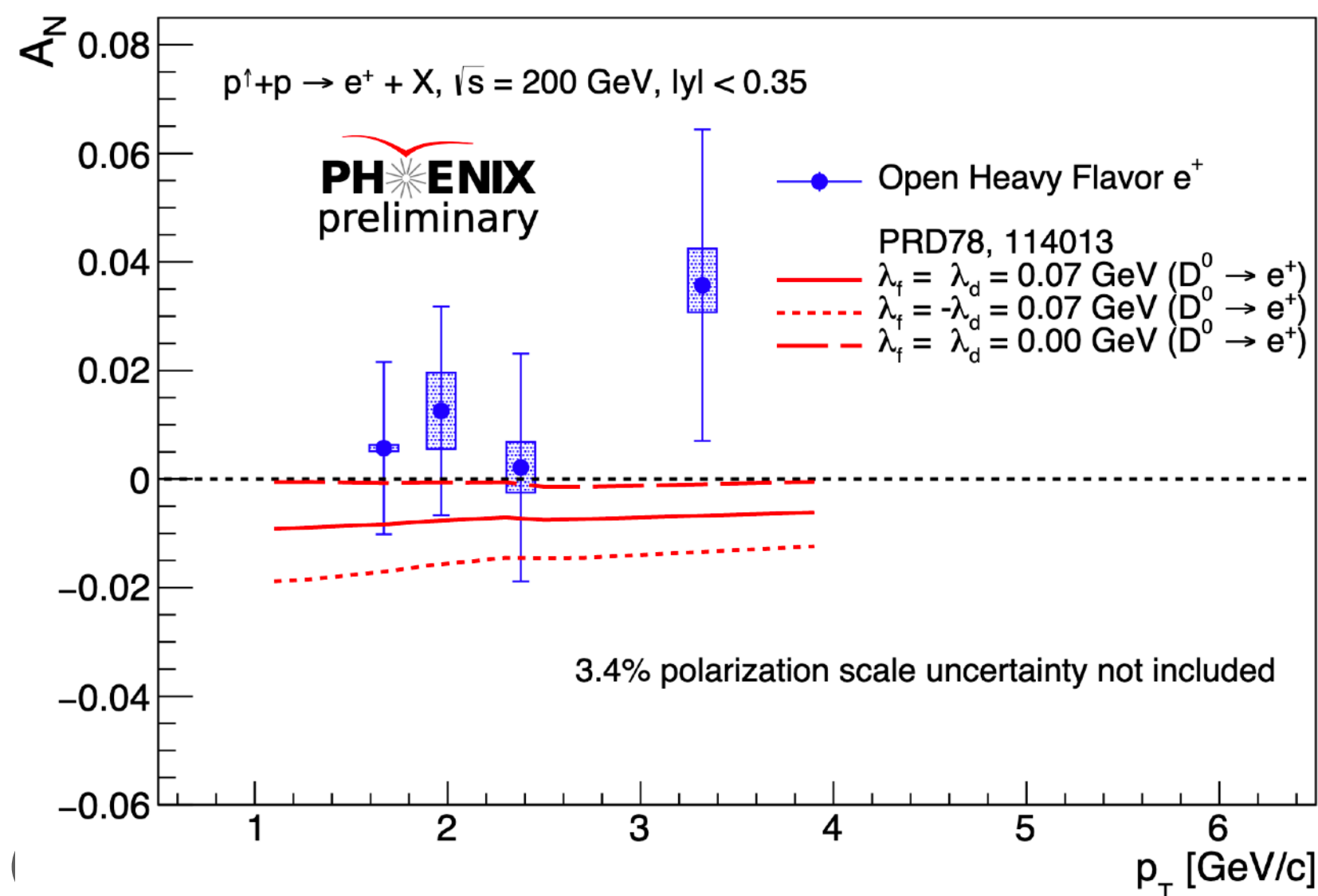
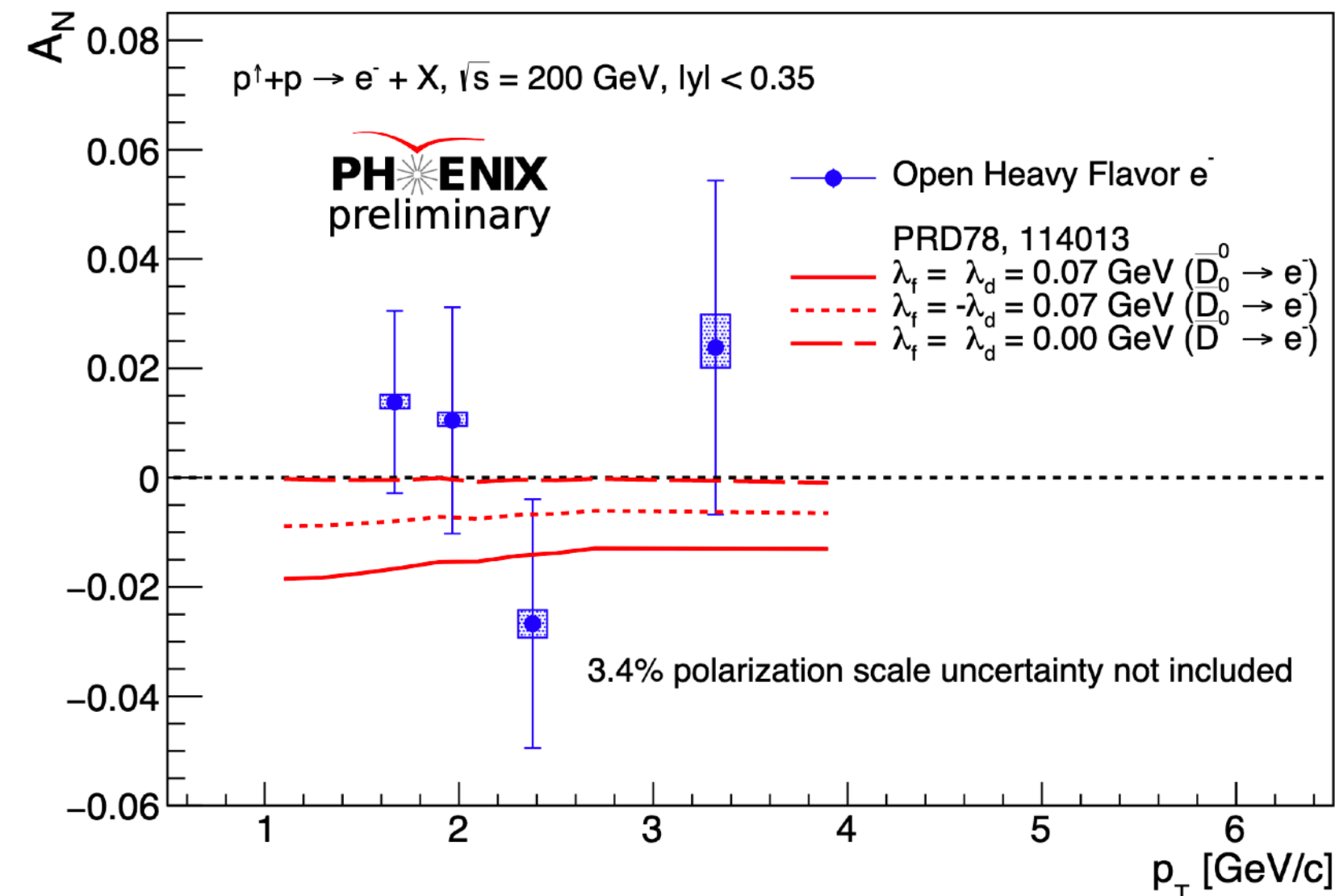
- First PHENIX results of charged pion A_N at midrapidity @ 200 GeV
- Asymmetries consistent with zero, but a slight indication that π^+ and π^- behave differently at lower p_T

Direct photon A_N



- Production cross section dominated by $q + g \rightarrow q + \gamma$
- Sensitive to initial state gluon dynamics at midrapidity
- Will constrain the trigluon correlation function when included in the global analysis
- First measurement at RHIC, submitted to PRL ([arXiv:2102.13585 \[hep-ex\]](https://arxiv.org/abs/2102.13585))

Open heavy flavor electron A_N

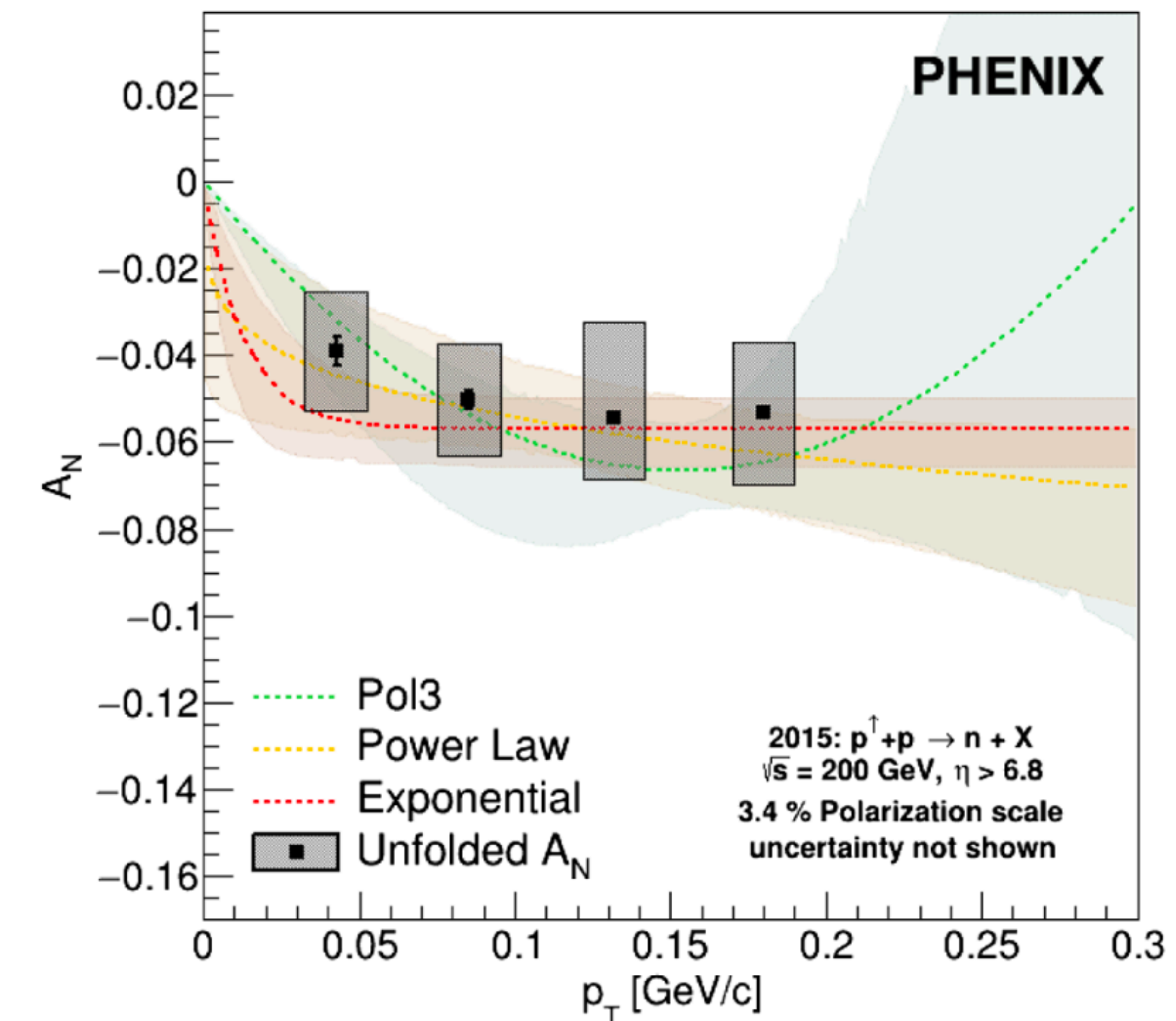
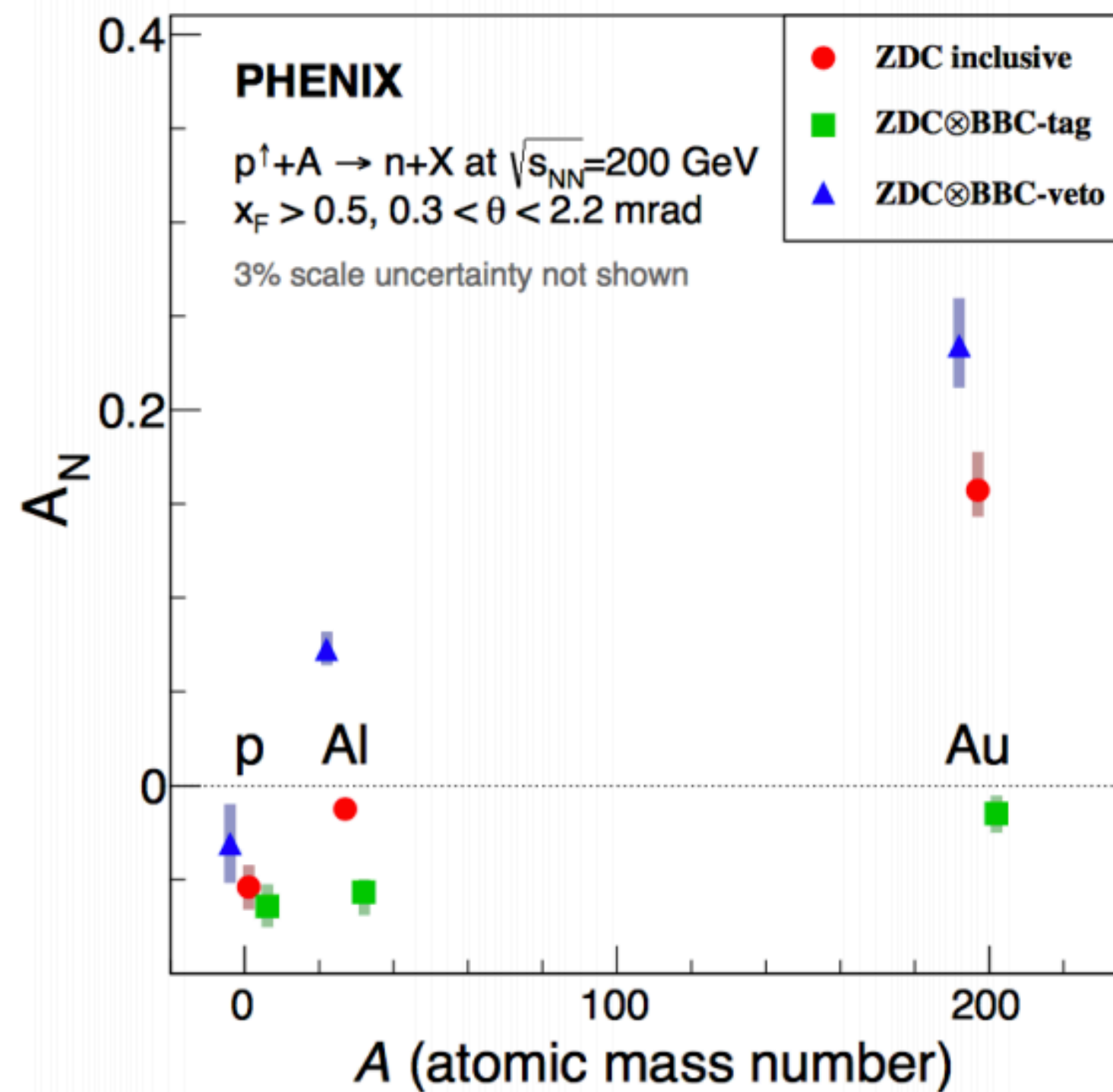


- At RHIC energies, mostly produced by gg fusion, ideal to study gluons
- Sensitive to trigluon correlations in the collinear framework
- Open charm production is dominant contribution
- Asymmetries consistent with zero within the uncertainties for the given p_T range
- Results compared with calculations for $D^0 \rightarrow e^\pm$ (PRD78, 114013)
 - Ordering of the curves different for e^+ and e^- , sensitive to constrain the normalization parameters of ggg correlates w.r.t unpolarized gluon PDF

Check out poster presentation by Dillon Fitzelard (Michigan)

pT dependence of forward neutron A_N

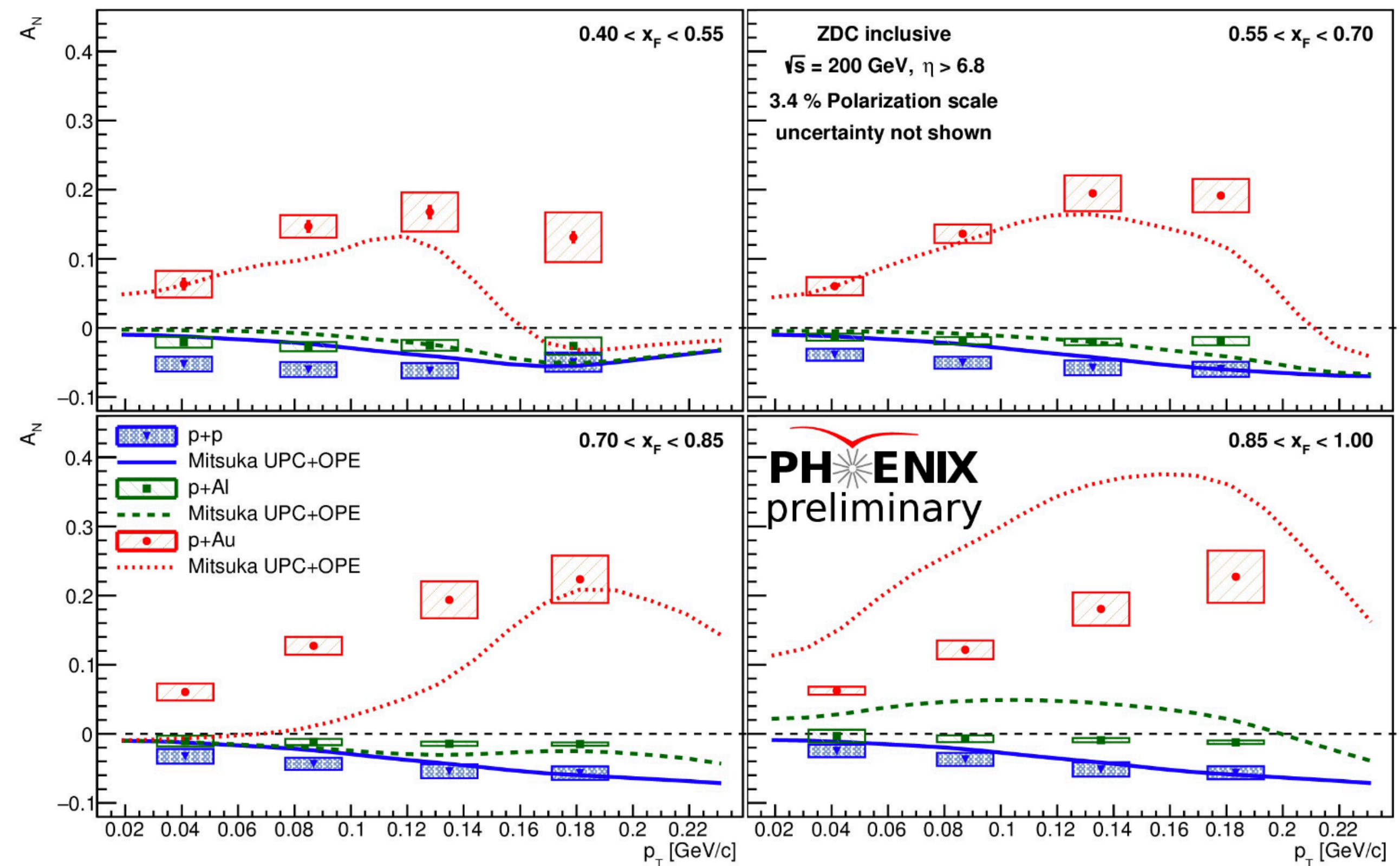
- Strong nuclear dependence of forward neutron A_N (PRL 120, 022001)
- Explicit pT dependence of the asymmetries: Phys. Rev. D 103, 032007 (2021)



pT and xF dependence of forward neutron A_N

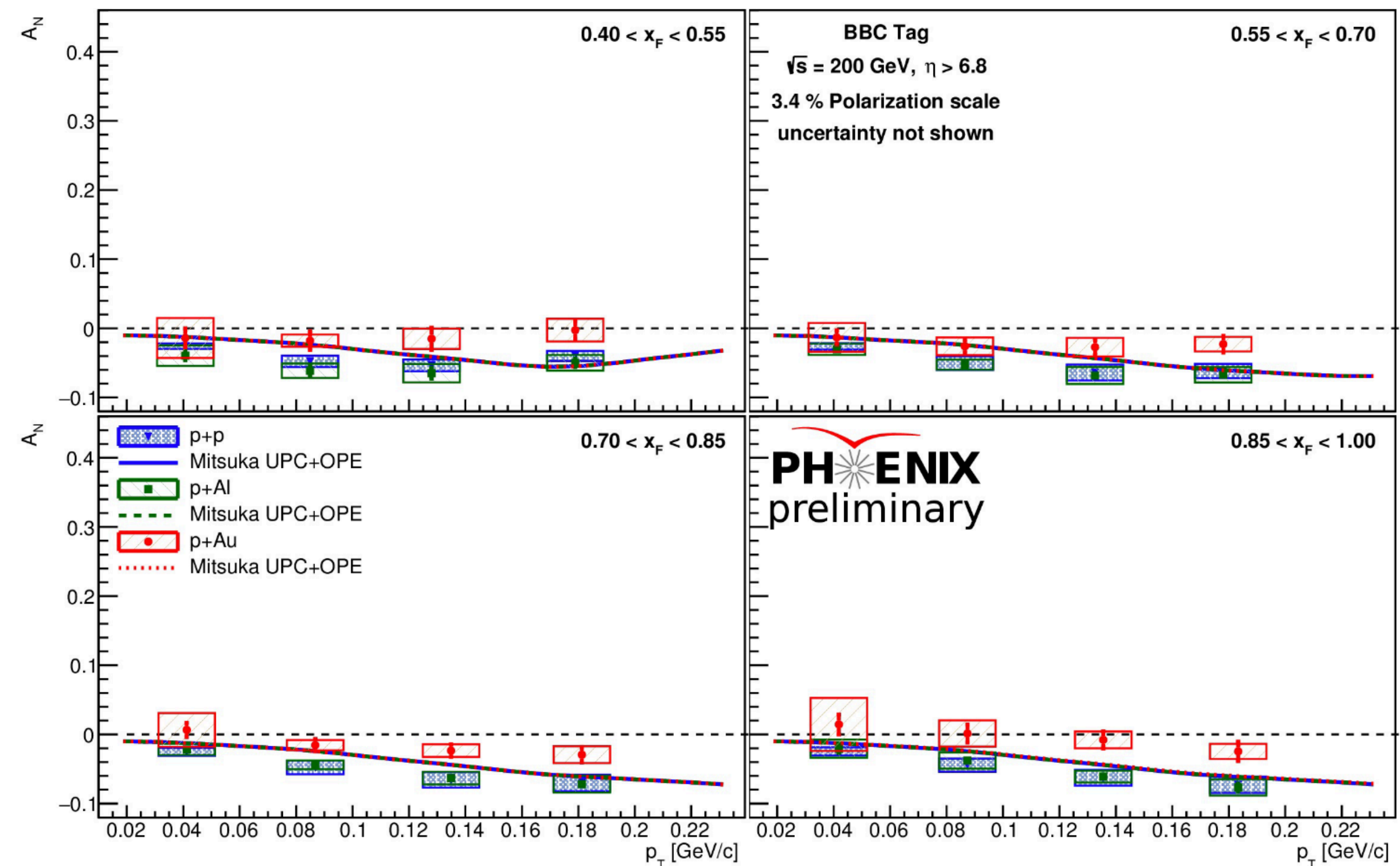
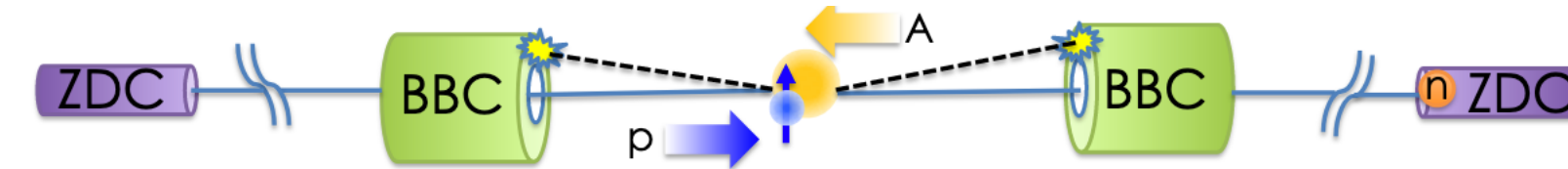
- Strong nuclear dependence of forward neutron A_N (PRL 120, 022001)
- Explicit pT dependence of the asymmetries: Phys. Rev. D 103, 032007 (2021)
- Extending further to include xF dependence as well as correlation with other detector activity
 - Enhance / suppress UPC contribution

Inclusive neutron trigger



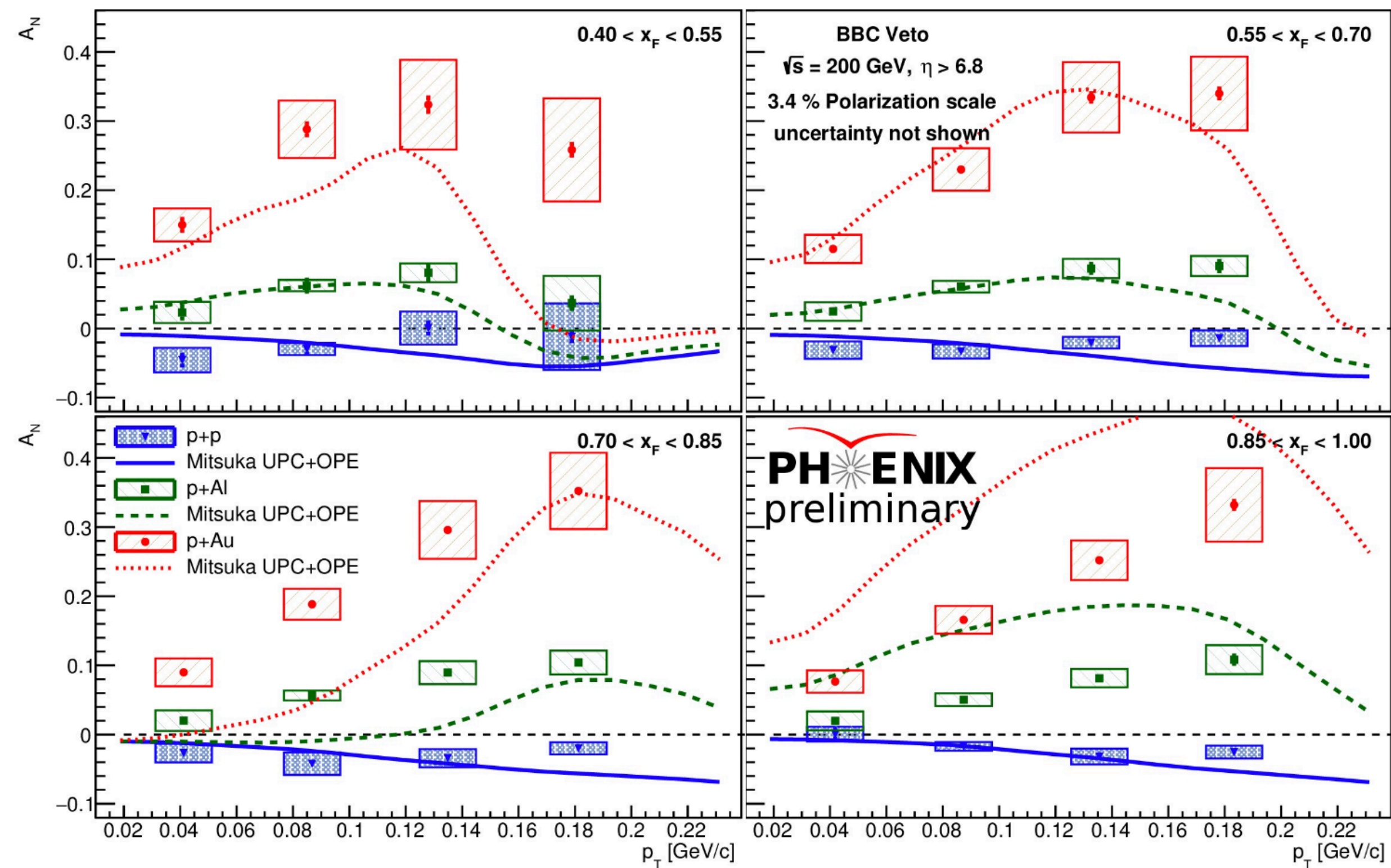
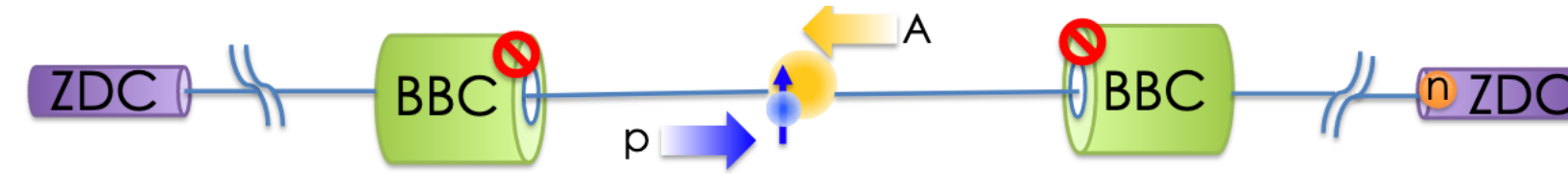
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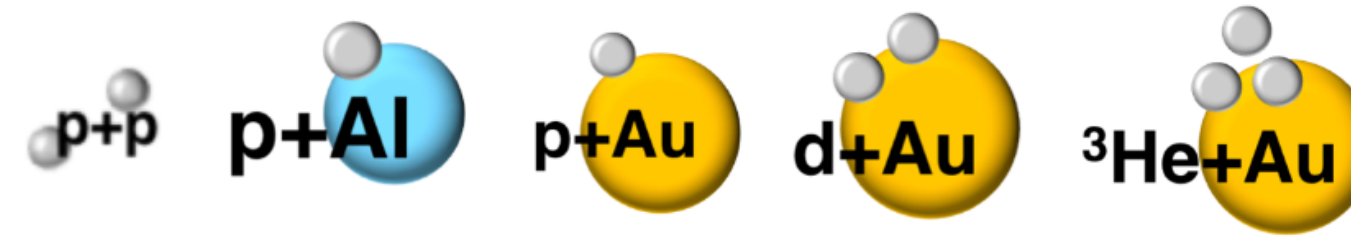


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Small systems



Nuclear modification in small systems

Identified hadrons

J/psi and psi'

J/psi polarization

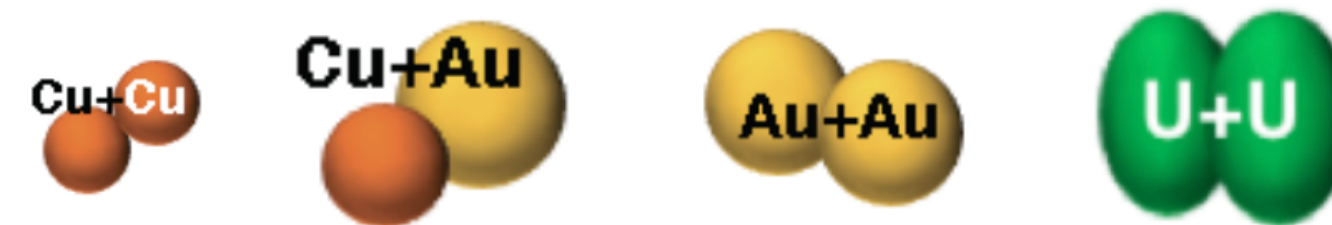
Jet cross section in p+p

Flows in small systems

See talk by Marzia Rosati:
HF workshop at AUM

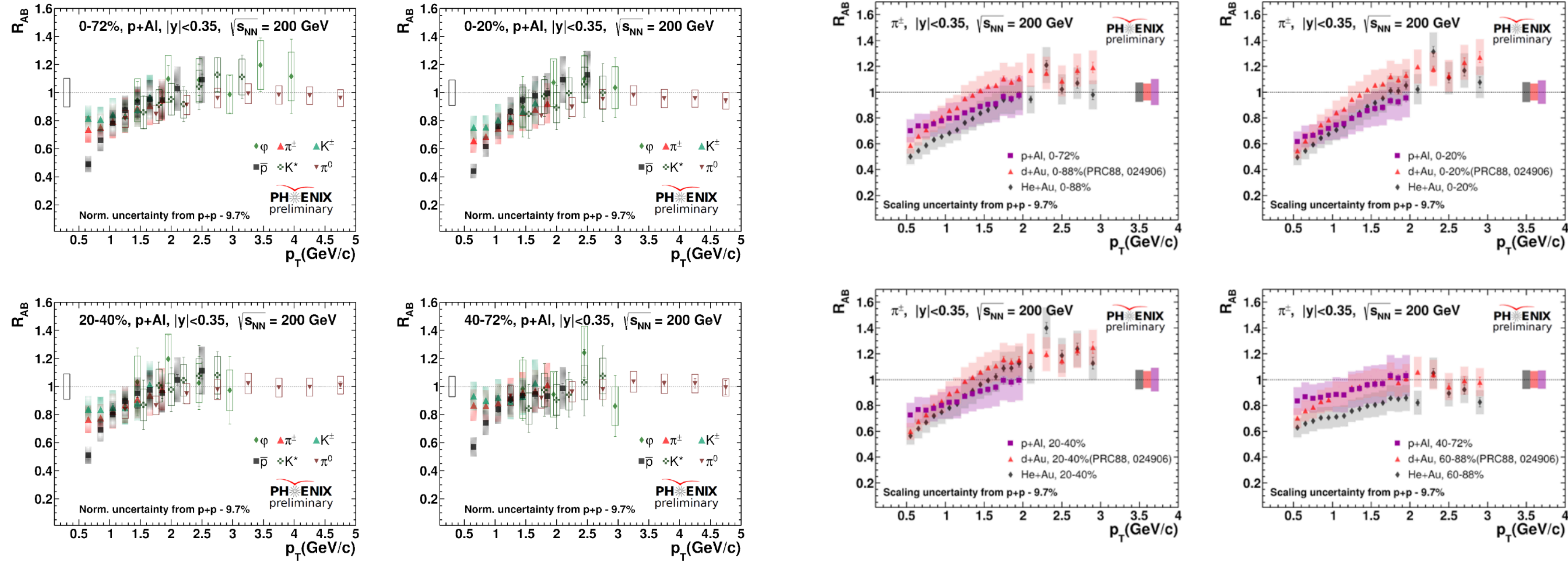
Talk by James Nagle:
Small system Workshop at AUM

Large systems

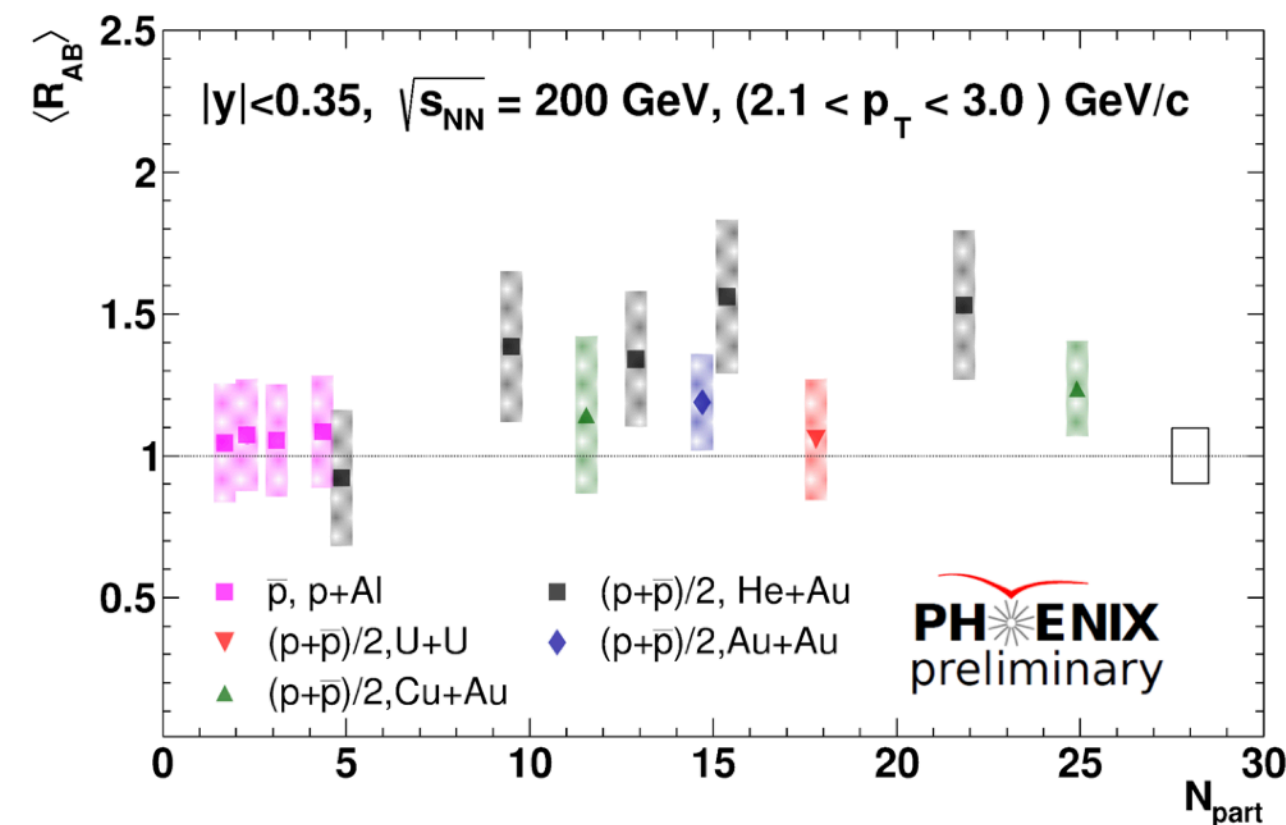


Identified hadron nuclear modification in large systems
gamma-hadron correlations

R_{AB} in p+Al for different light hadrons



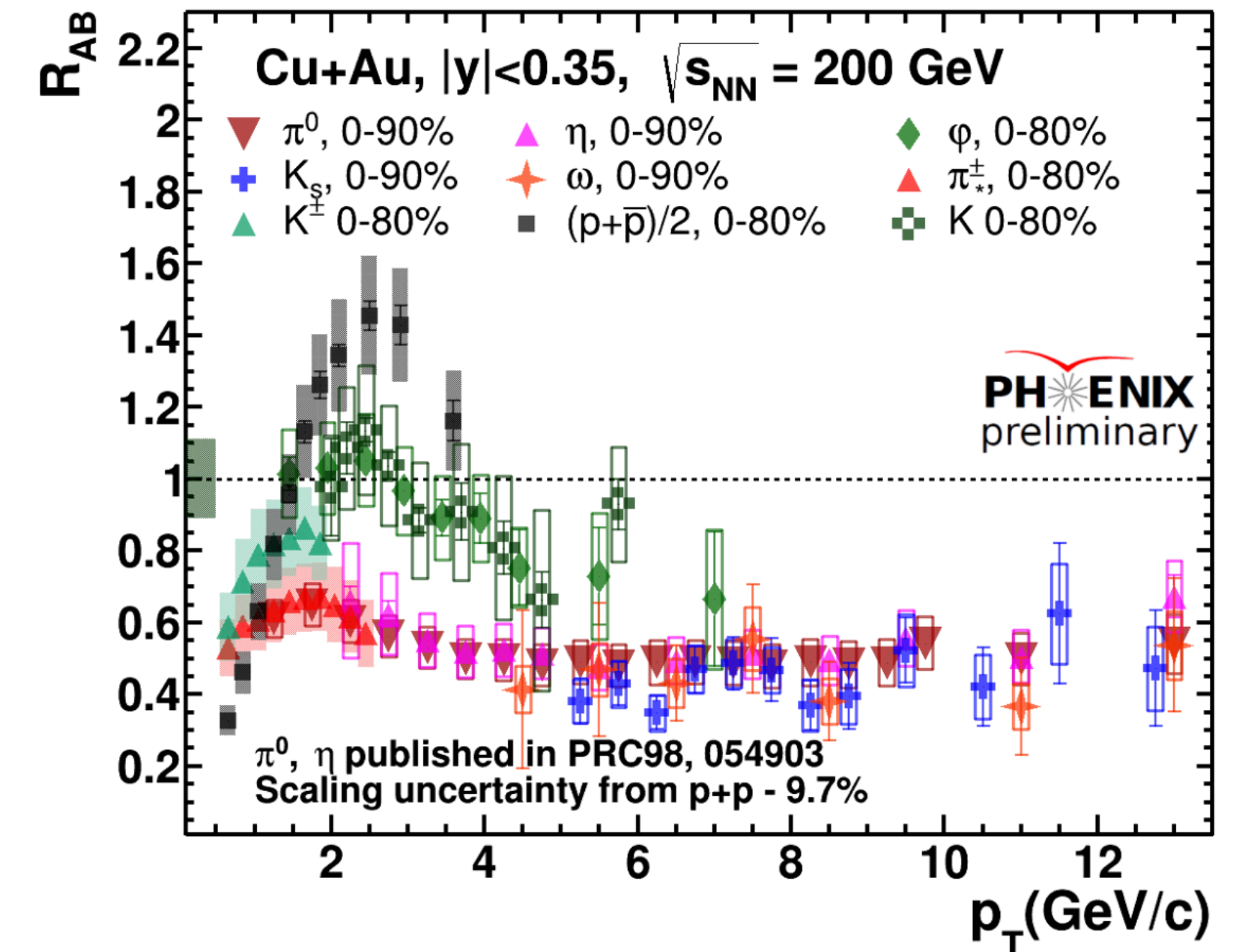
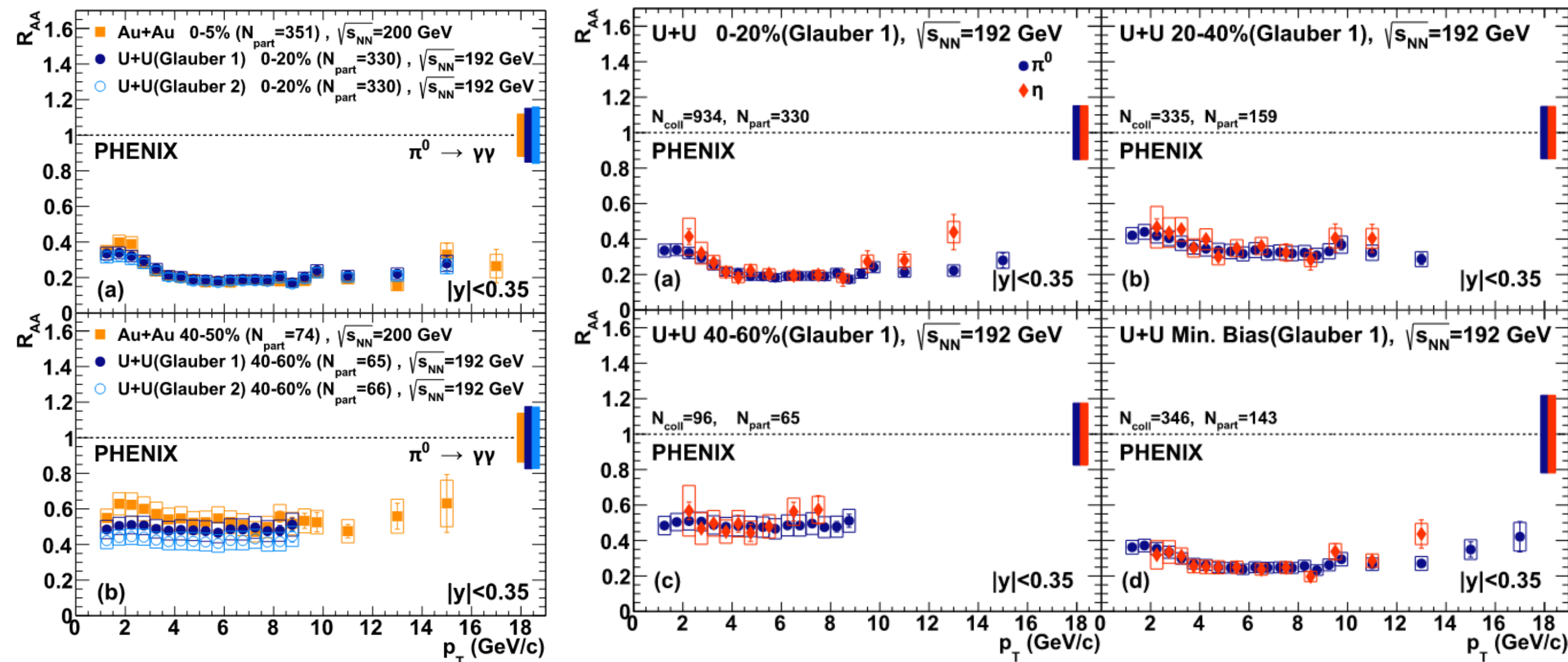
- Light hadron R_{AB} are all consistent in p+Al in all centralities, no \bar{p} enhancement observed



- Slope in p+Al is smaller than d+Au and He+Au
- Integrated R_{AB} for \bar{p} in p+Al is consistent with unity and smaller than other collisions

Identified hadron nuclear modification

Phys. Rev. C102, 064905 (2020)

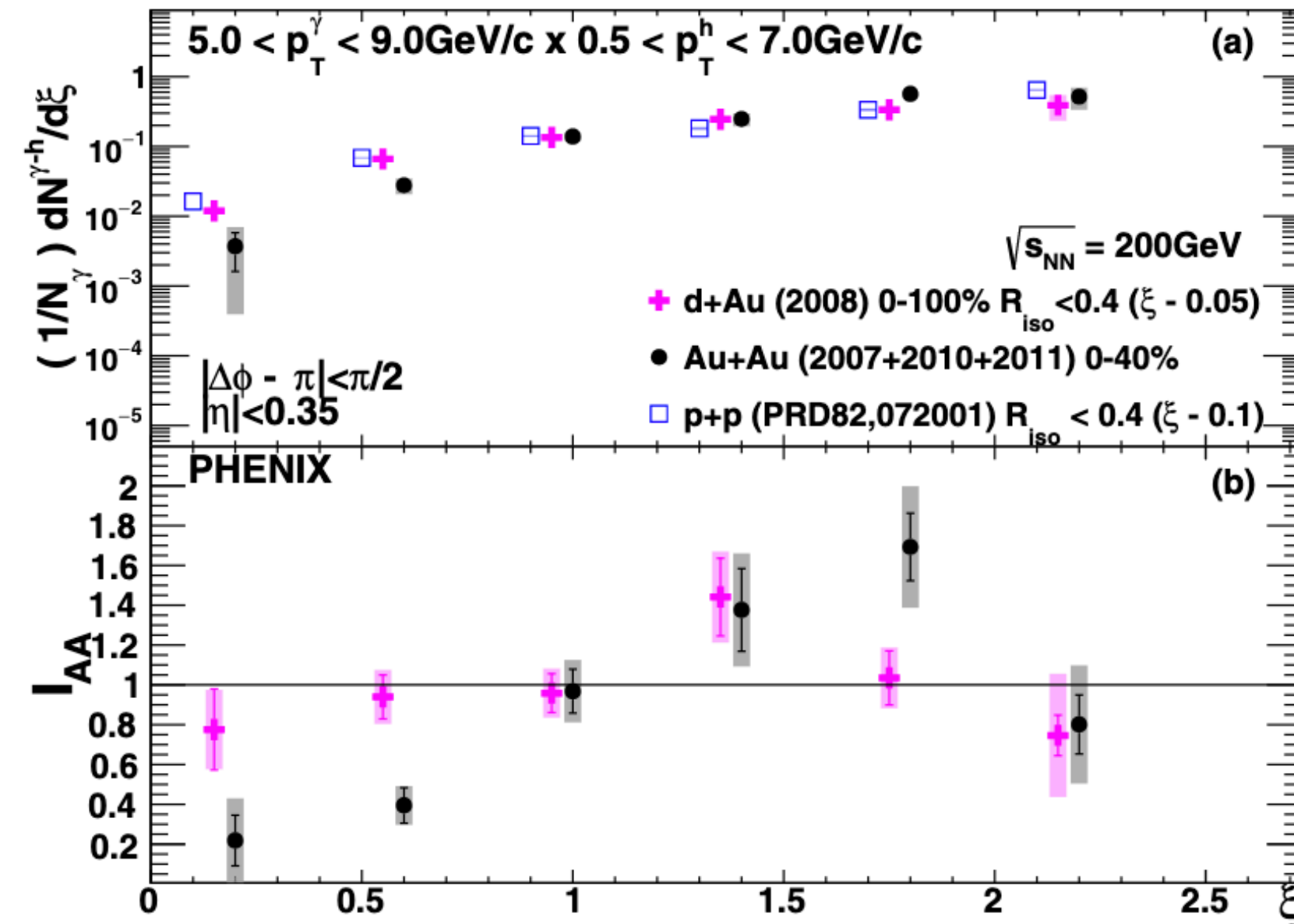


- π^0 and η nuclear modification in U+U
- Similar suppression from U+U compared to Au+Au in both central and peripheral collisions

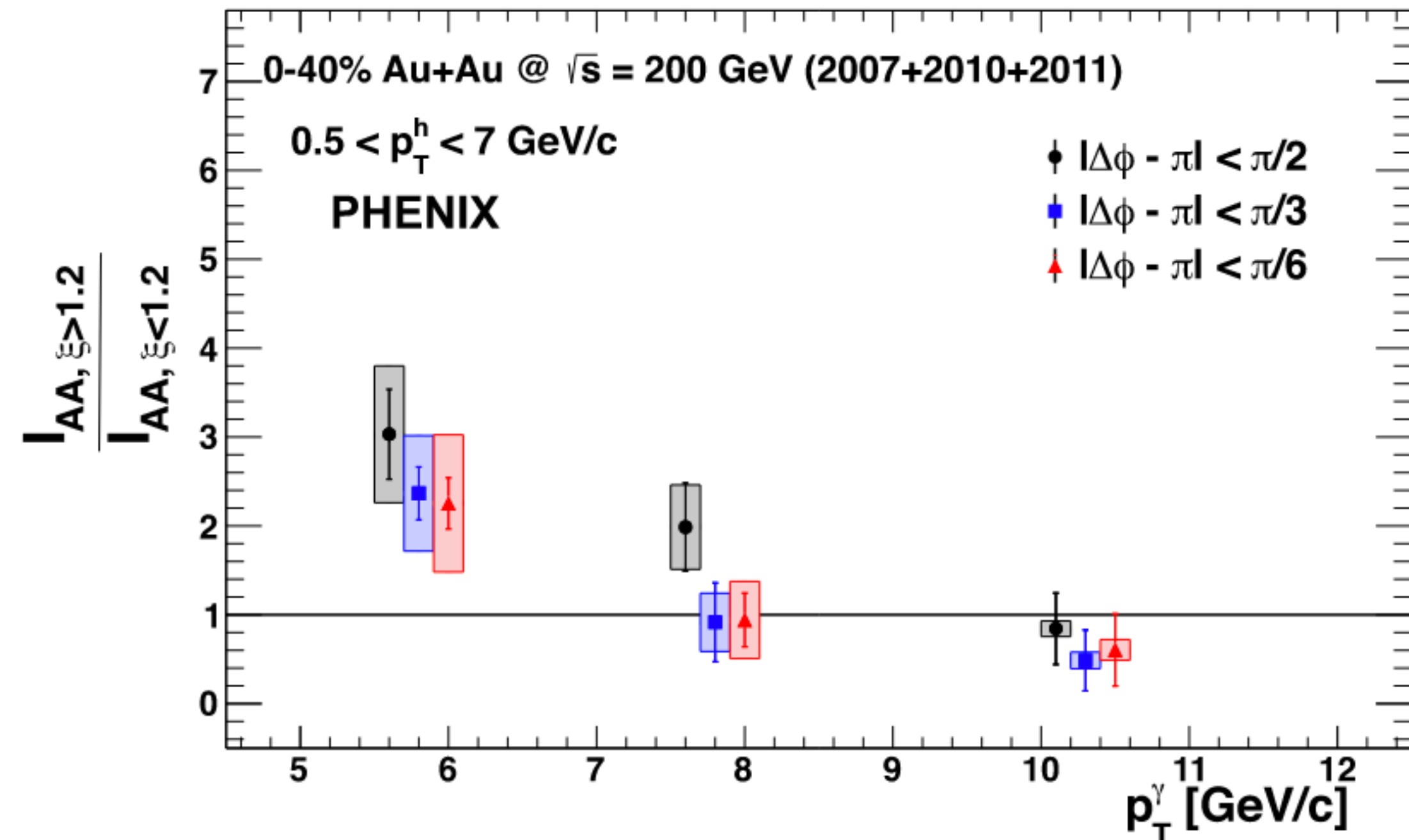
- Similar behavior for all species at high p_T
- Ordering at lower p_T
 - Not mass scaling ($R_{AB}^\phi < R_{AB}^p$, $m_\phi \approx m_p$)
 - Strange enhancement
- Difference disappear gradually in peripheral collisions

Gamma-hadron correlations

Phys. Rev. C102, 054910

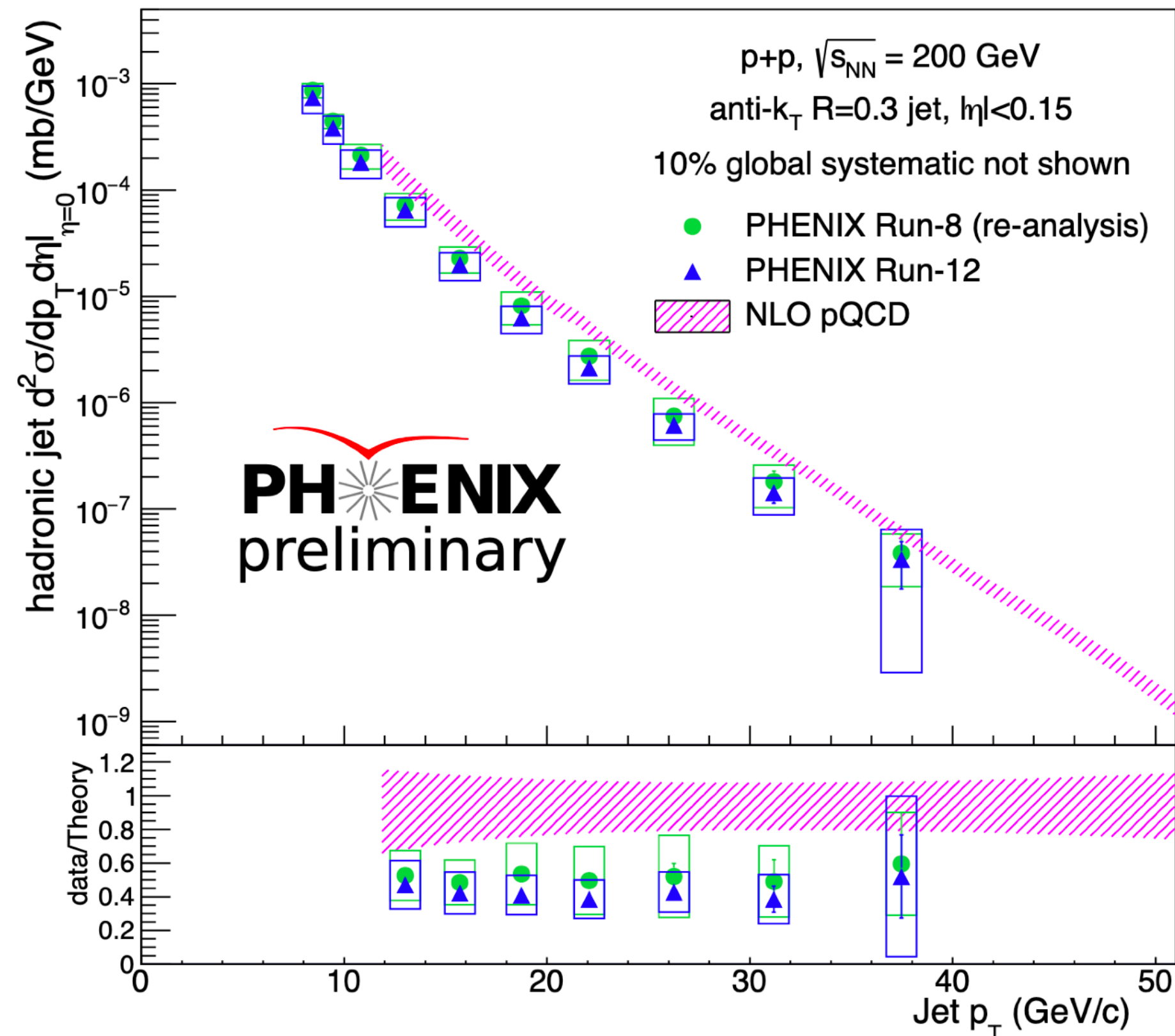


- Clear suppression in Au+Au at low ξ and enhancement at high ξ
- Transition from suppression to enhancement $\xi \sim 1.2$
- d+Au I_{dA} is consistent with unity across all ξ range

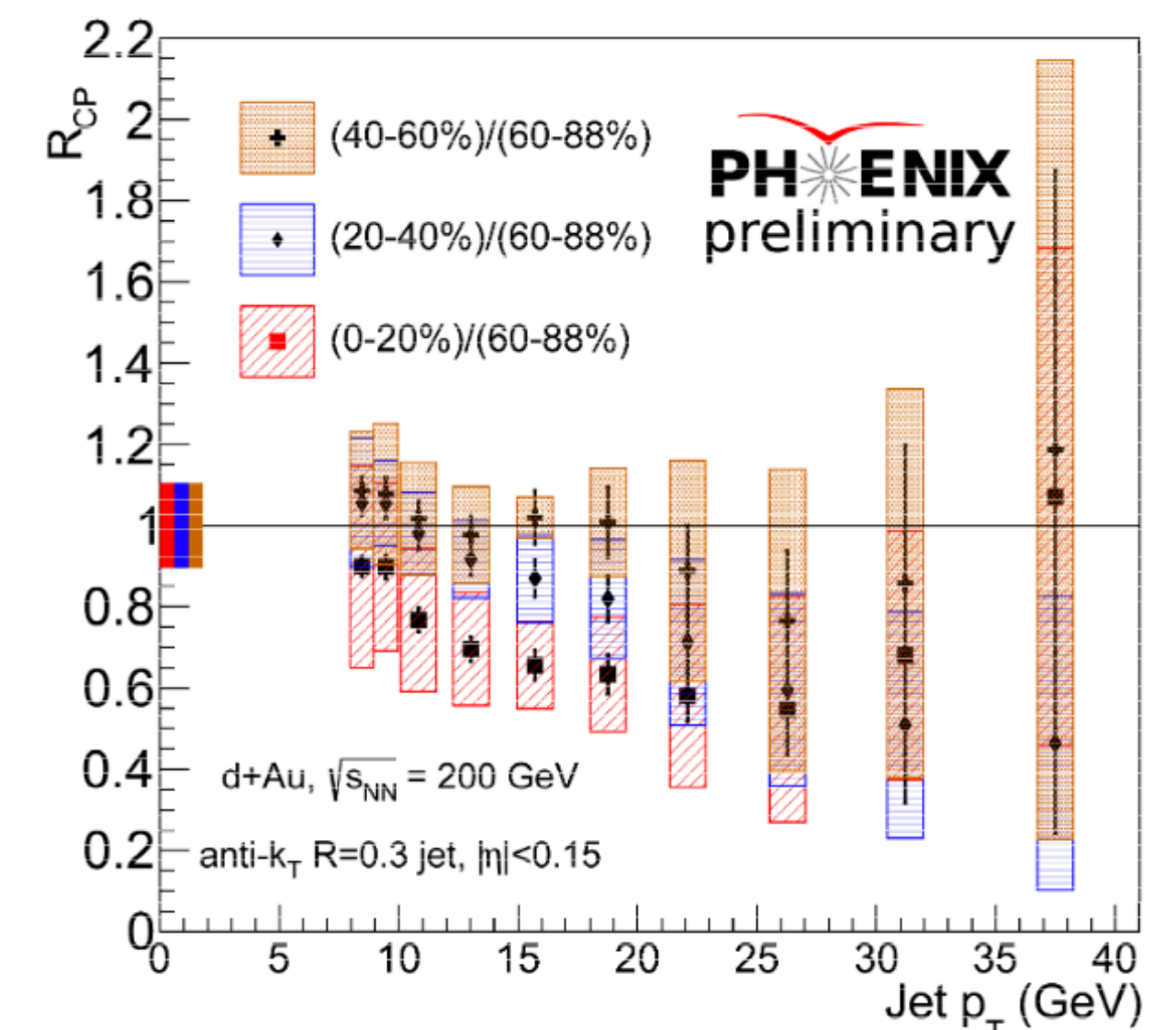
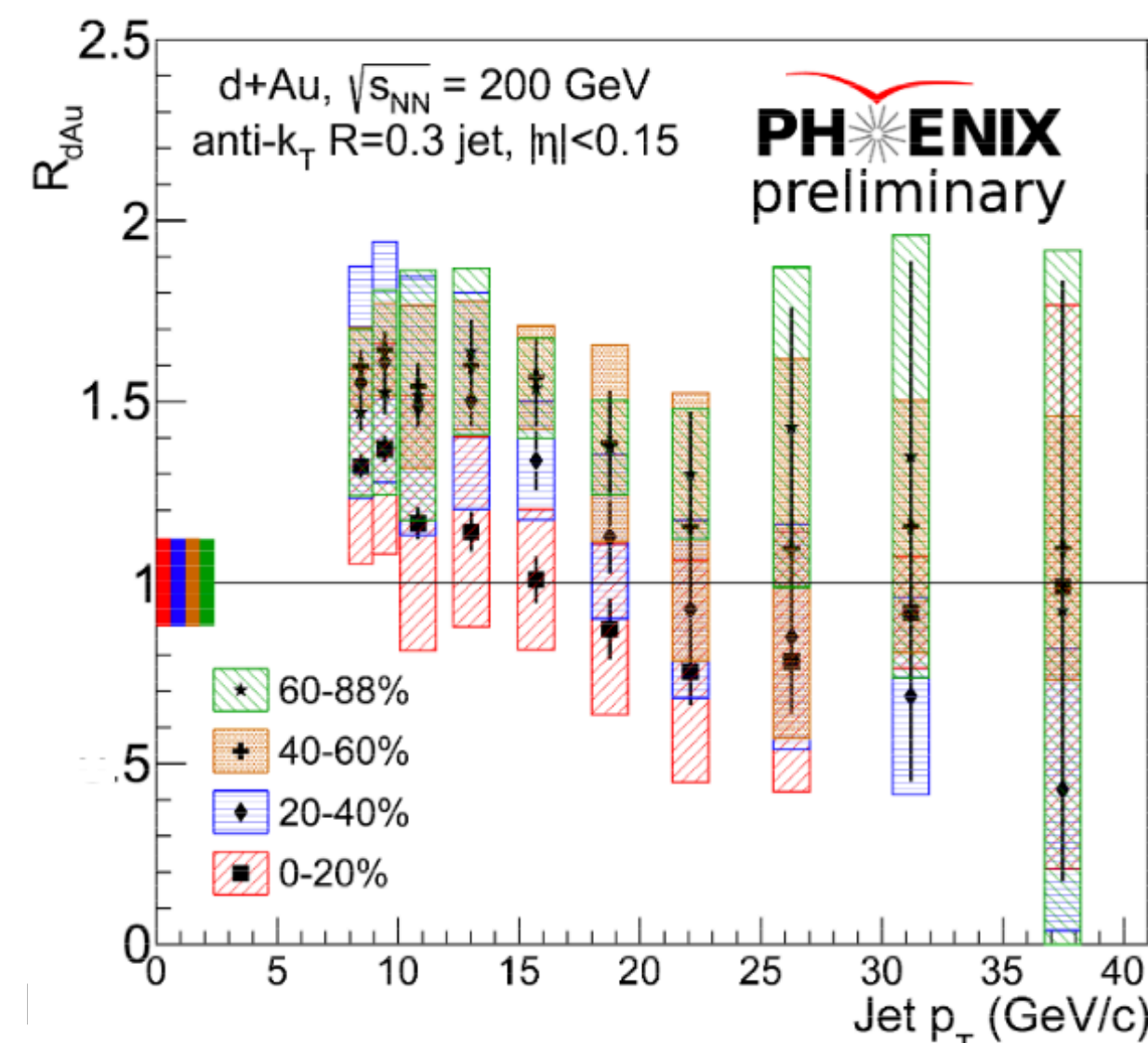


- The enhancement is largest for softer jets and for the full away-side integration range, implying that jets with lower energy are boarded more than higher energy jets

Jet cross sections in p+p at 200 GeV

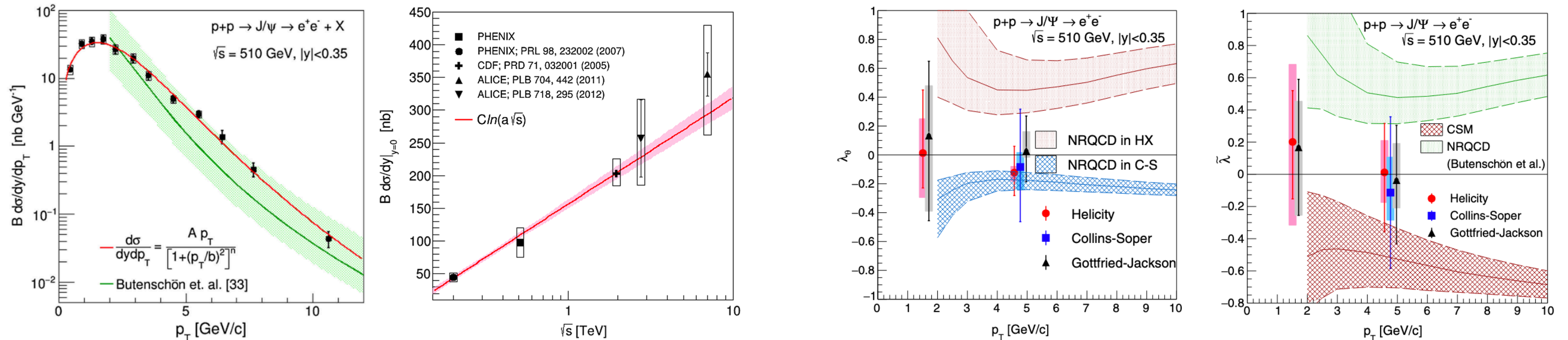


- New preliminary result from Run12 200 GeV p+p
- Re-analysis of Run8 data, after eliminating noisy calorimeter towers
 - Run8 and Run12 results show good agreement
- The new preliminary supersedes the previously published result (PRL116, 122301, erratum in preparation)
- R_{dAu} and R_{CP} re-evaluated

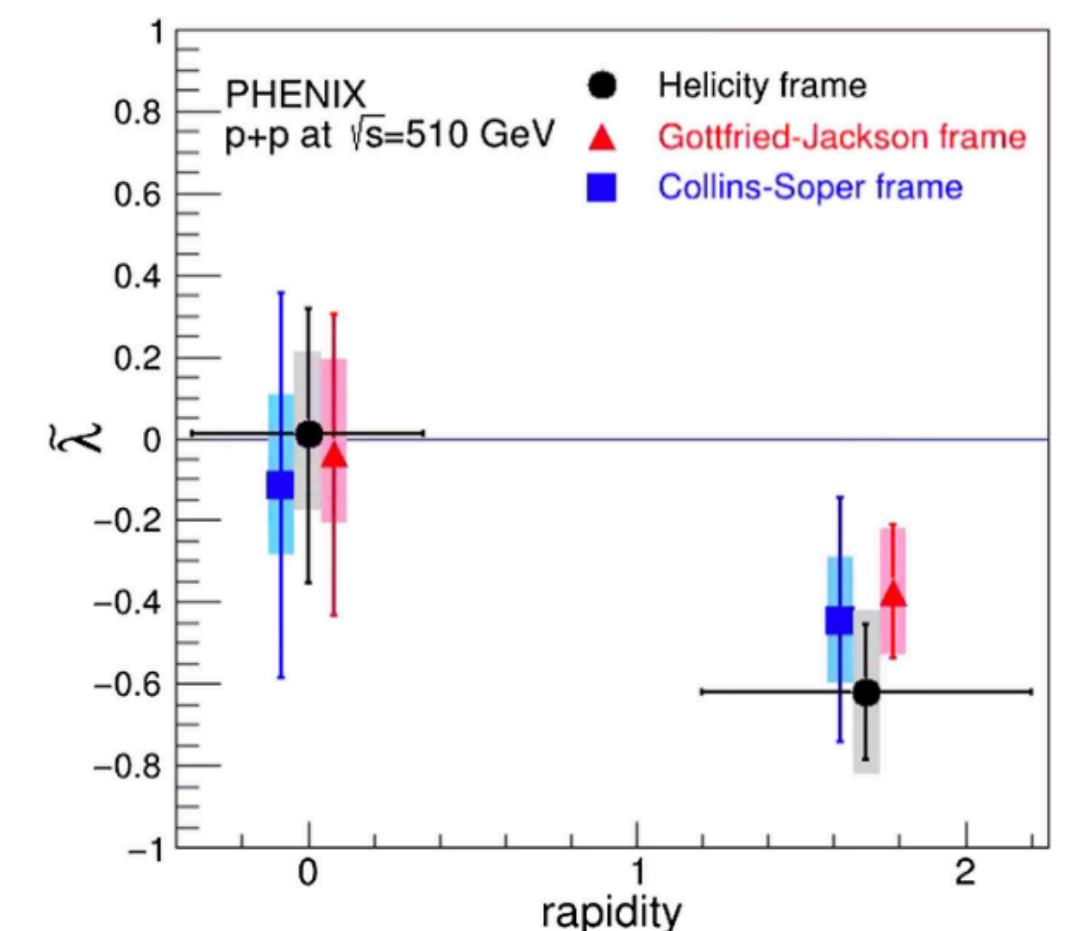


J/psi production in p+p @ 510 GeV

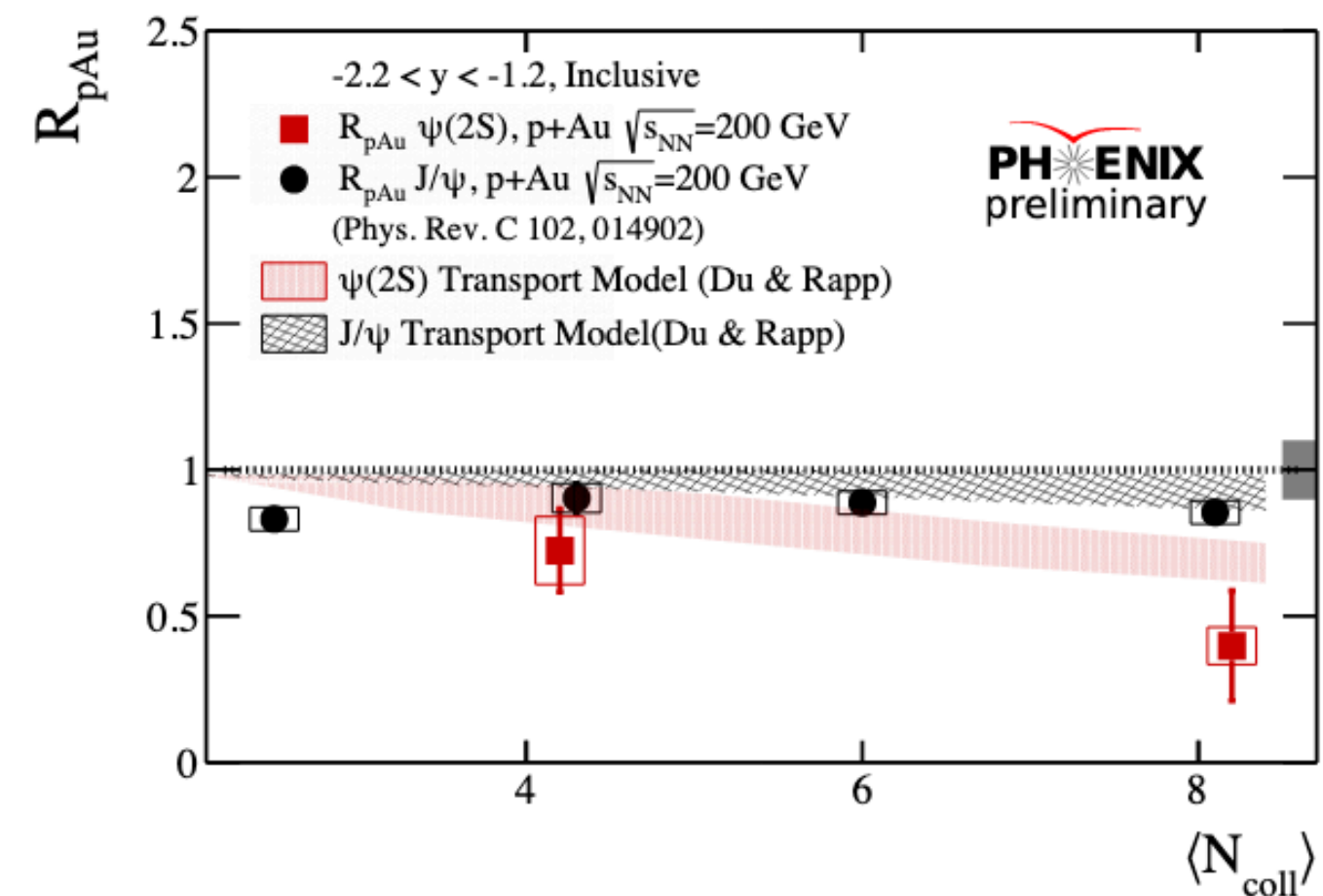
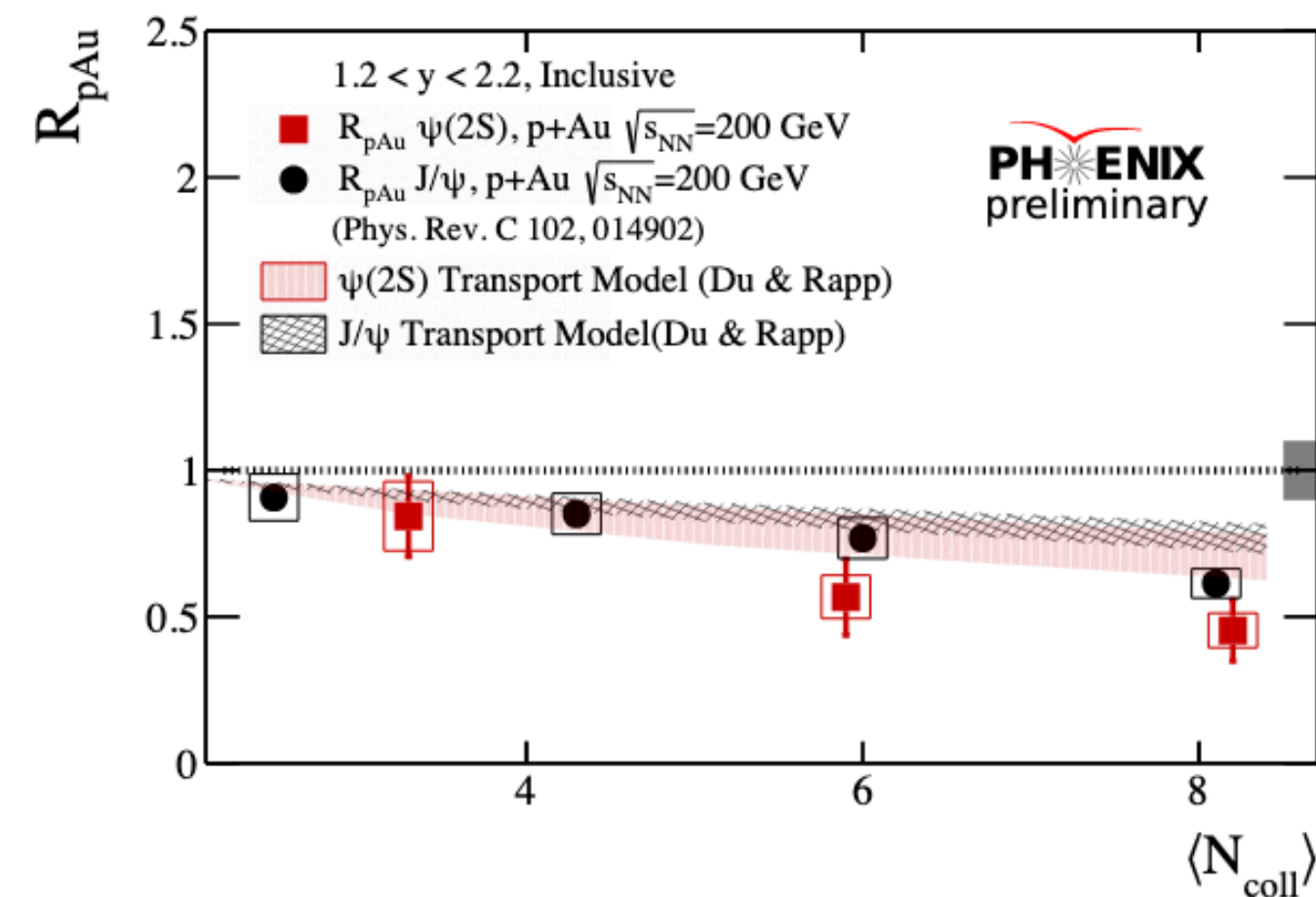
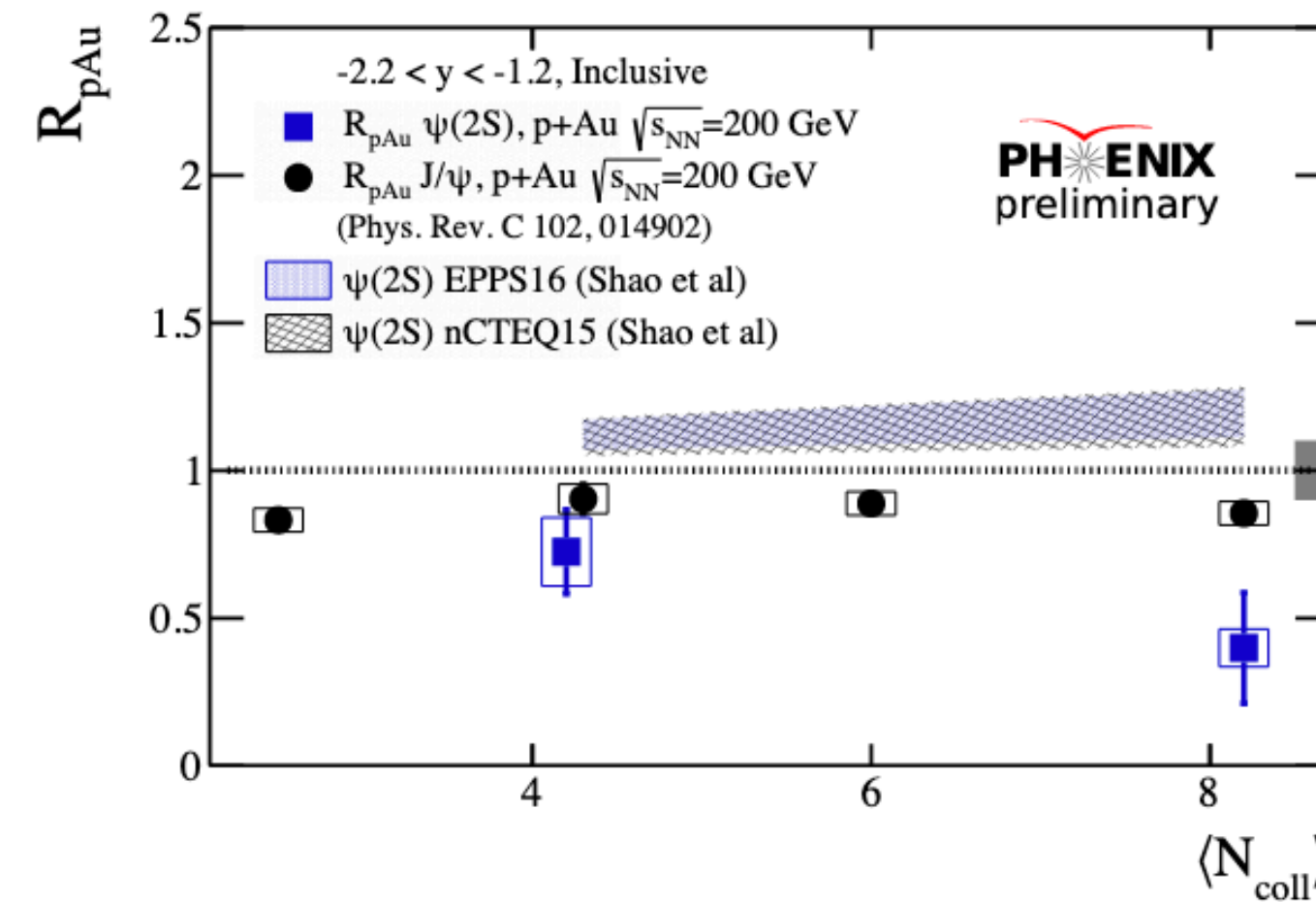
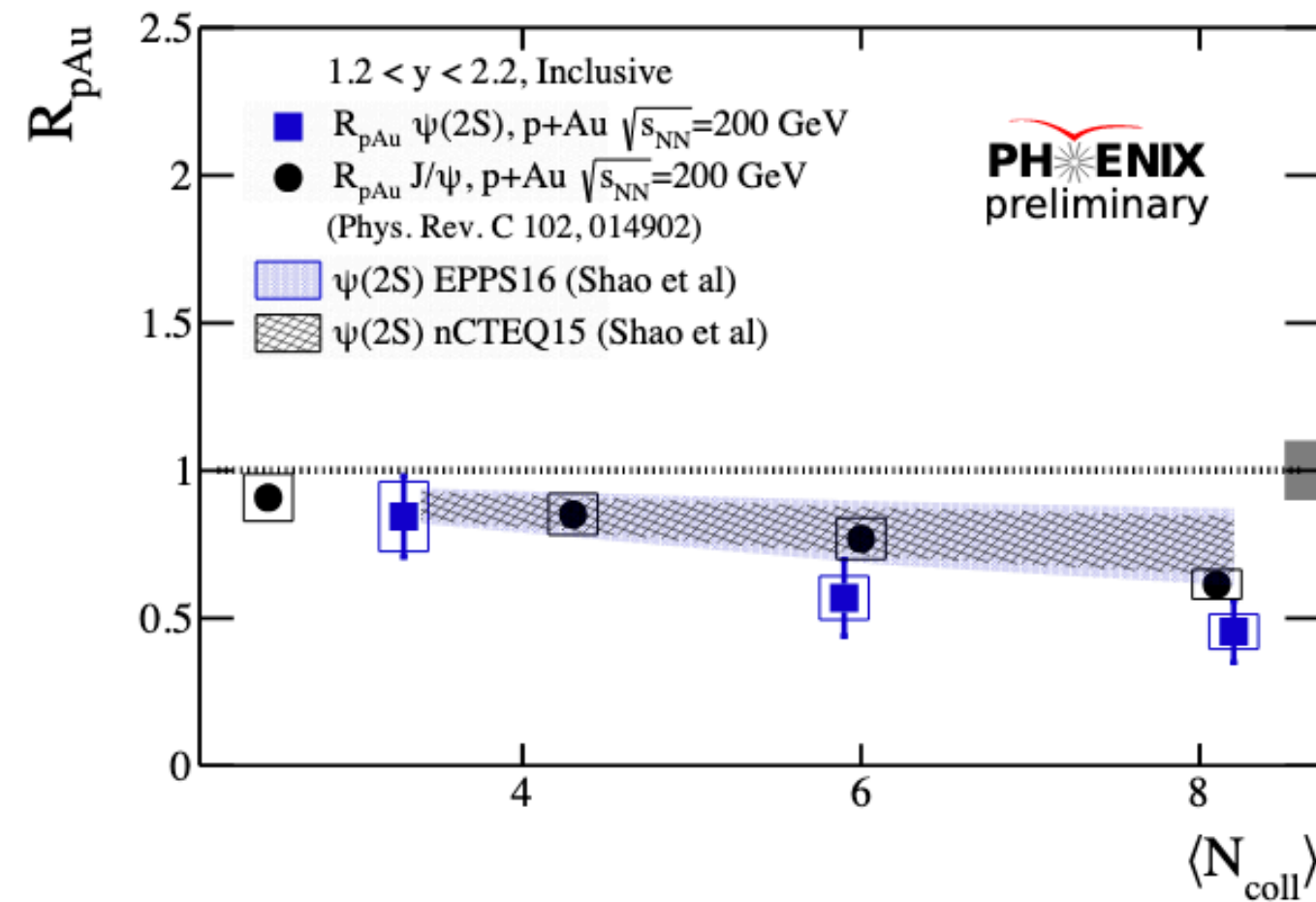
PHYS. REV. D **102**, 072008 (2020)



- First midrapidity J/psi cross section measurement at 510 GeV, NRQCD calculation consistent with the data (forward rapidity results published Phys. Rev. D101, 052006)
- J/psi decay angular coefficients (aka J/psi polarization) at midrapidity from 2-dim analysis
 - Results suggest the net polarization consistent with zero within uncertainties
 - λ_θ consistent with the 200 GeV result (1-dim analysis)
 - Previously published 510 GeV results at forward rapidity shows negative polarization

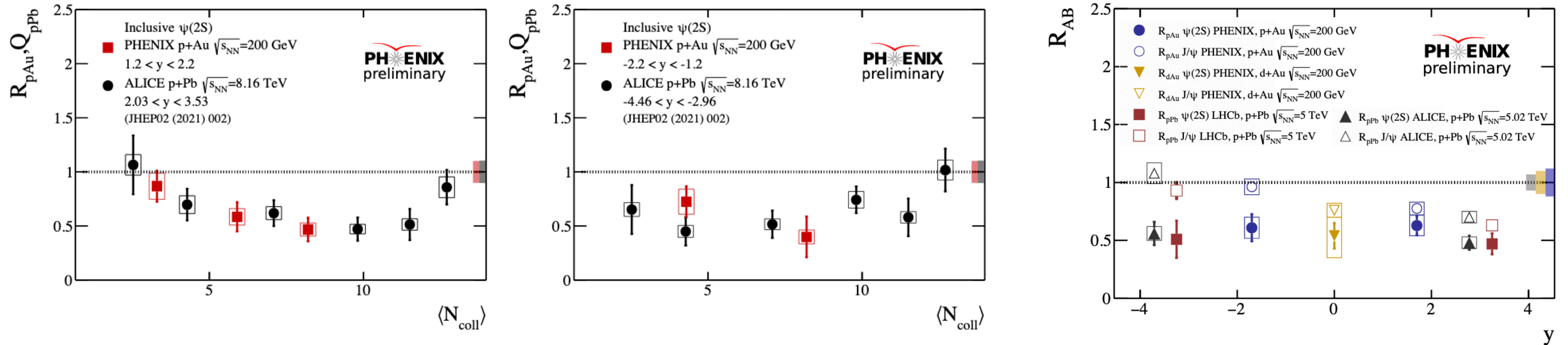


J/ψ and $\psi(2S)$ nuclear modification



- J/ψ and $\psi(2S)$ modification follow similar trend at forward rapidity, well described by theory
- Clear differences in $\psi(2S)$ modification in most central collisions
 - consistent with final state effects in small system collisions

J/ψ and $\psi(2S)$ nuclear modification



- Similar $\psi(2S)$ modification from PHENIX and LHC at forward rapidity
 - CNM effects appear to be dominant
- Also very similar results from PHENIX and LHC at backward rapidity
 - Final state effects are important in small system collisions
- Stronger suppression for $\psi(2S)$ compared to J/ψ at backward rapidity

Summary

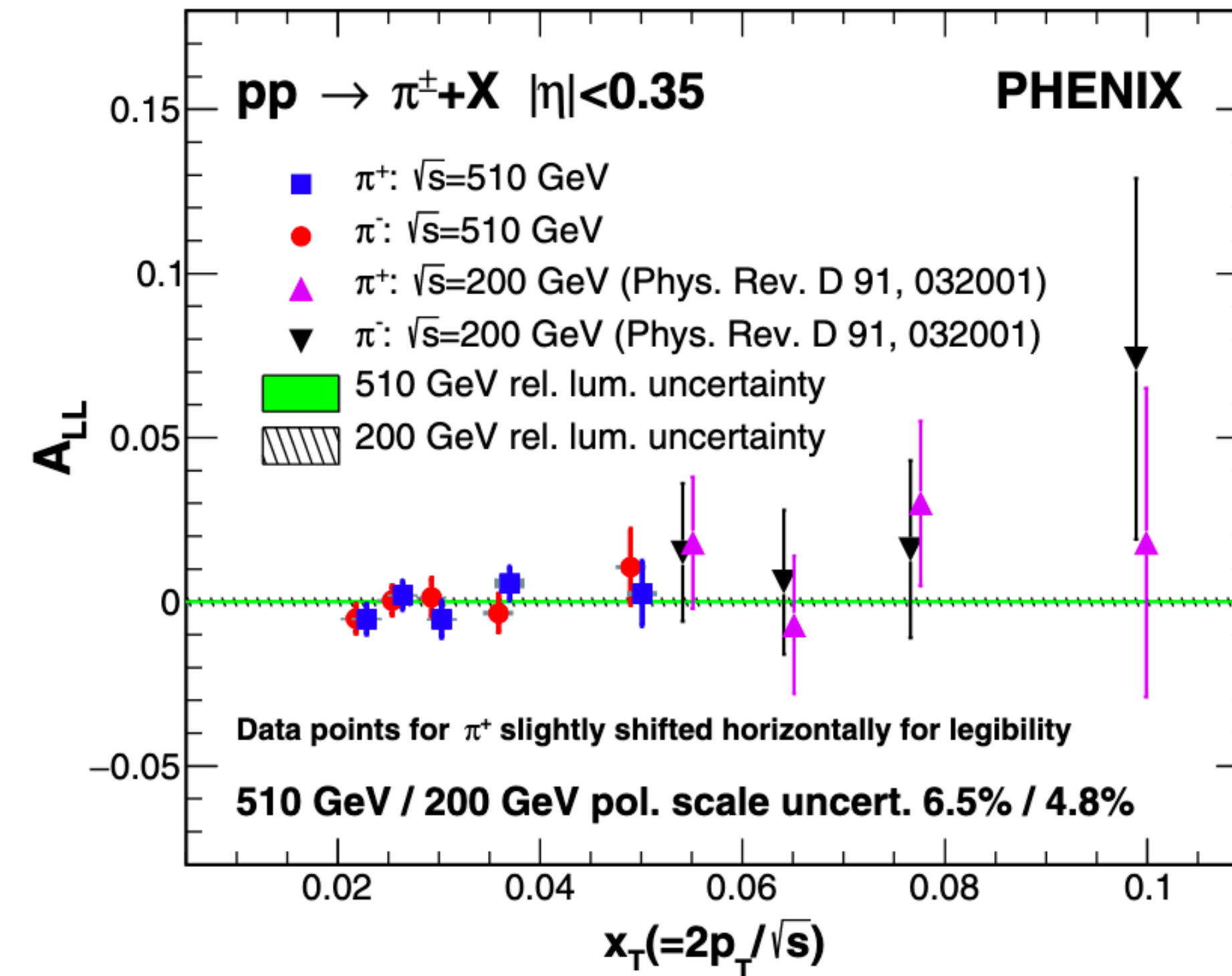
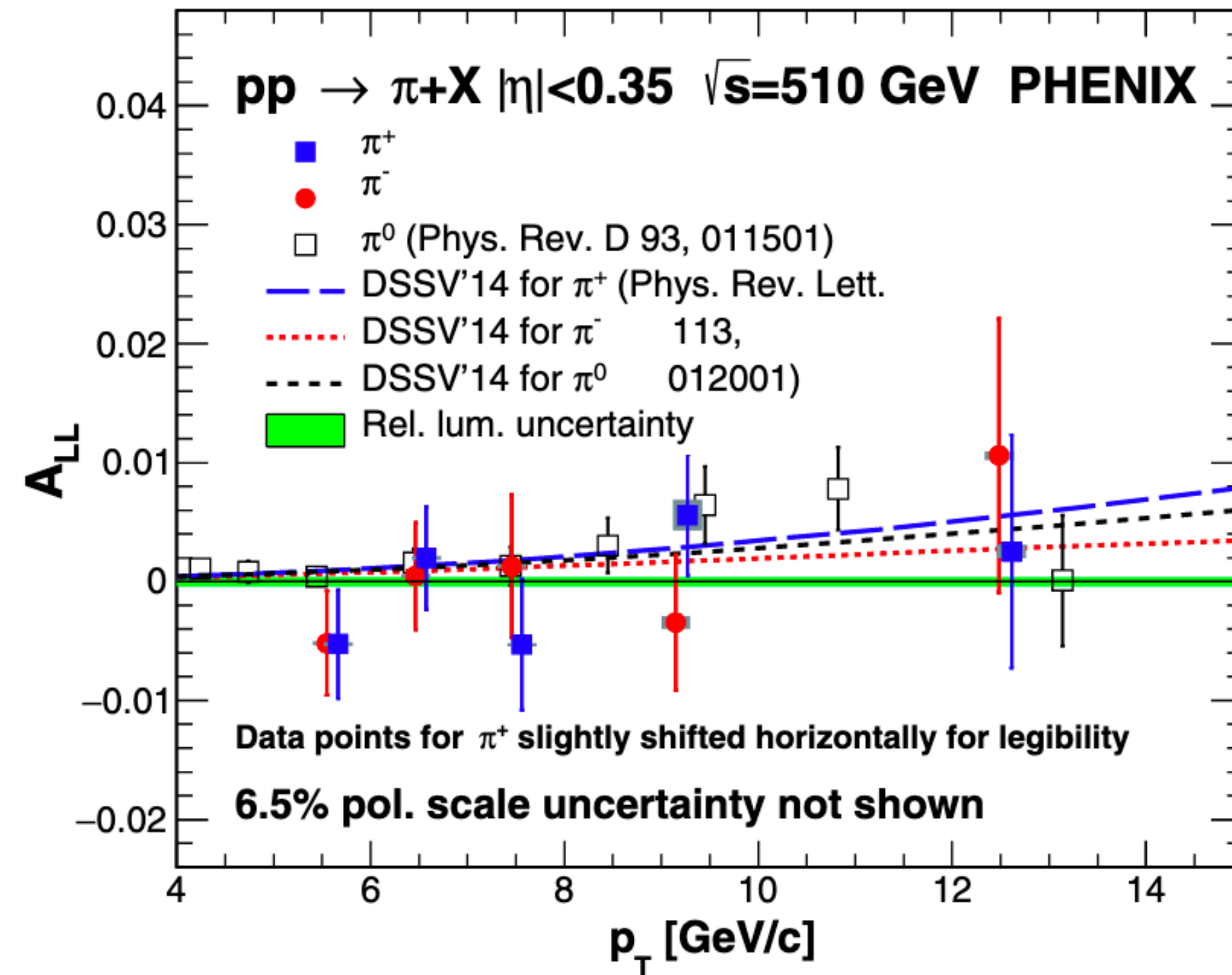
- Many interesting new results:
 - New A_{LL} measurements of direct photons and jets will provide an independent constraint on the gluon polarization
 - Transverse spin asymmetry results to study nonperturbative spin-momentum and spin-spin correlations in the proton
 - Explicit p_T and x_F dependence of forward neutron A_N provides additional details
 - Identified hadron R_{AA} independent of collision species in Au+Au and U+U
 - New midrapidity J/psi polarization results
 - Strong suppression of psi' than J/psi at backward rapidity
- **More to come, stay tuned!**

Recent PHENIX publication

- **Charged pion ALL at 510 GeV:**
Phys. Rev. D 102, 032001
- **First RHIC direct photon AN at 200 GeV:**
([2102.13585 \[hep-ex\]](#))
- **High precision pi0 and eta meson AN at 200 GeV:**
Phys. Rev. D 103, 052009
- **pT dependence of forward neutron AN:**
Phys. Rev. D 103, 032007
- **π^0 and η nuclear modification in U+U:**
Phys. Rev. C102, 064905
- **Gamma-hadron correlation:**
Phys. Rev. C102, 054910
- **Midrapidity J/psi xsec and polarization at 510 GeV:**
Phys. Rev. D102, 072008

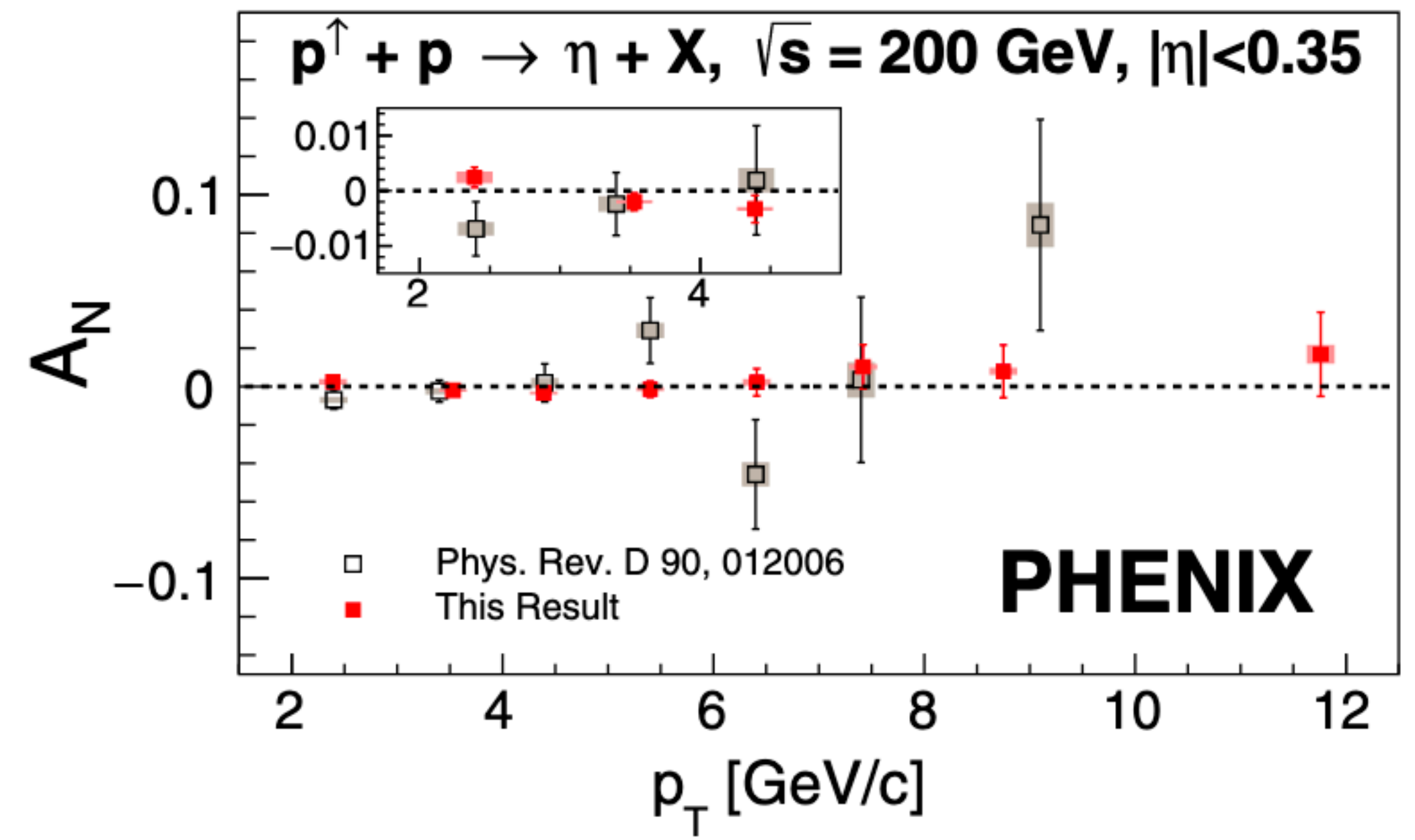
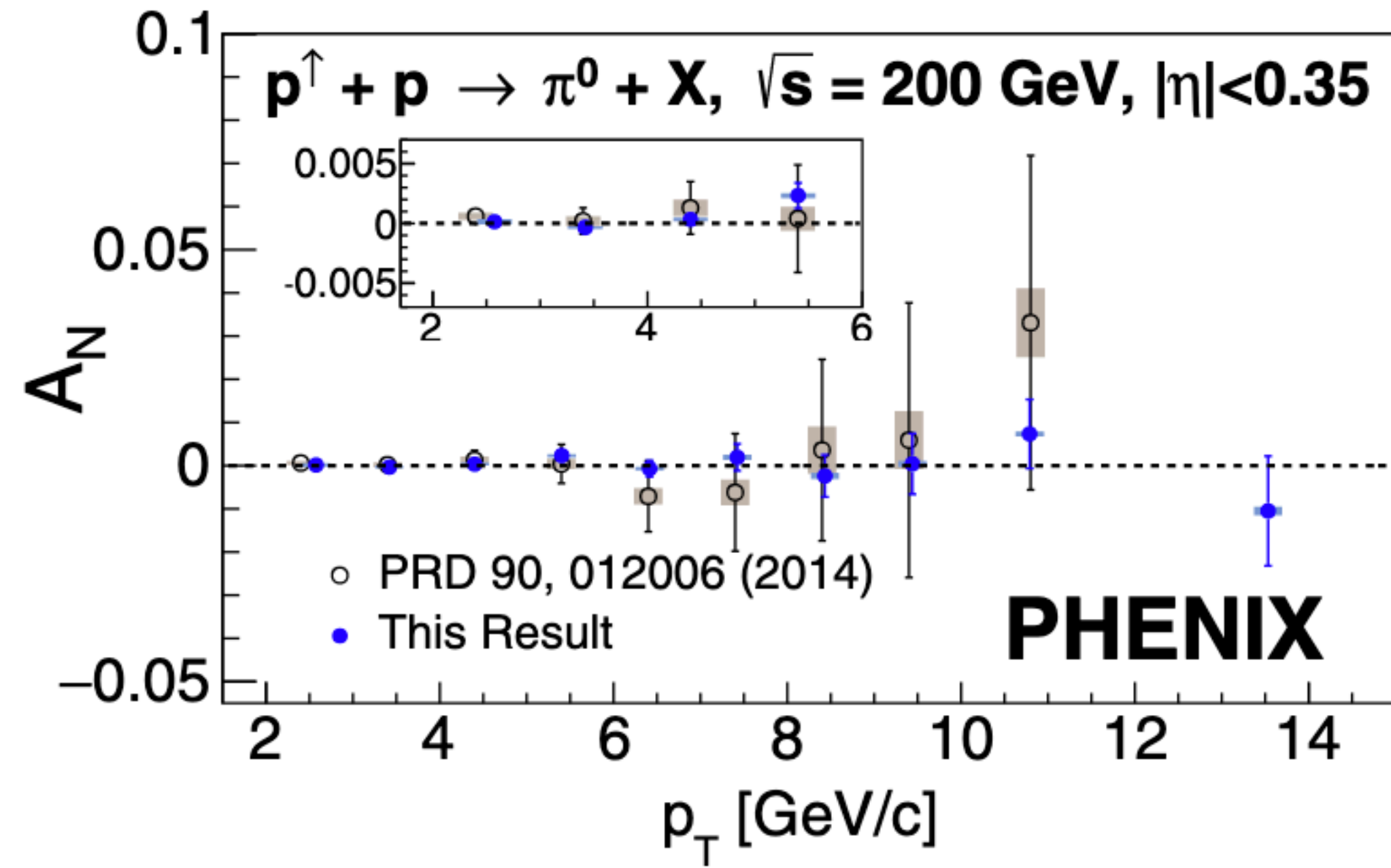
Backup

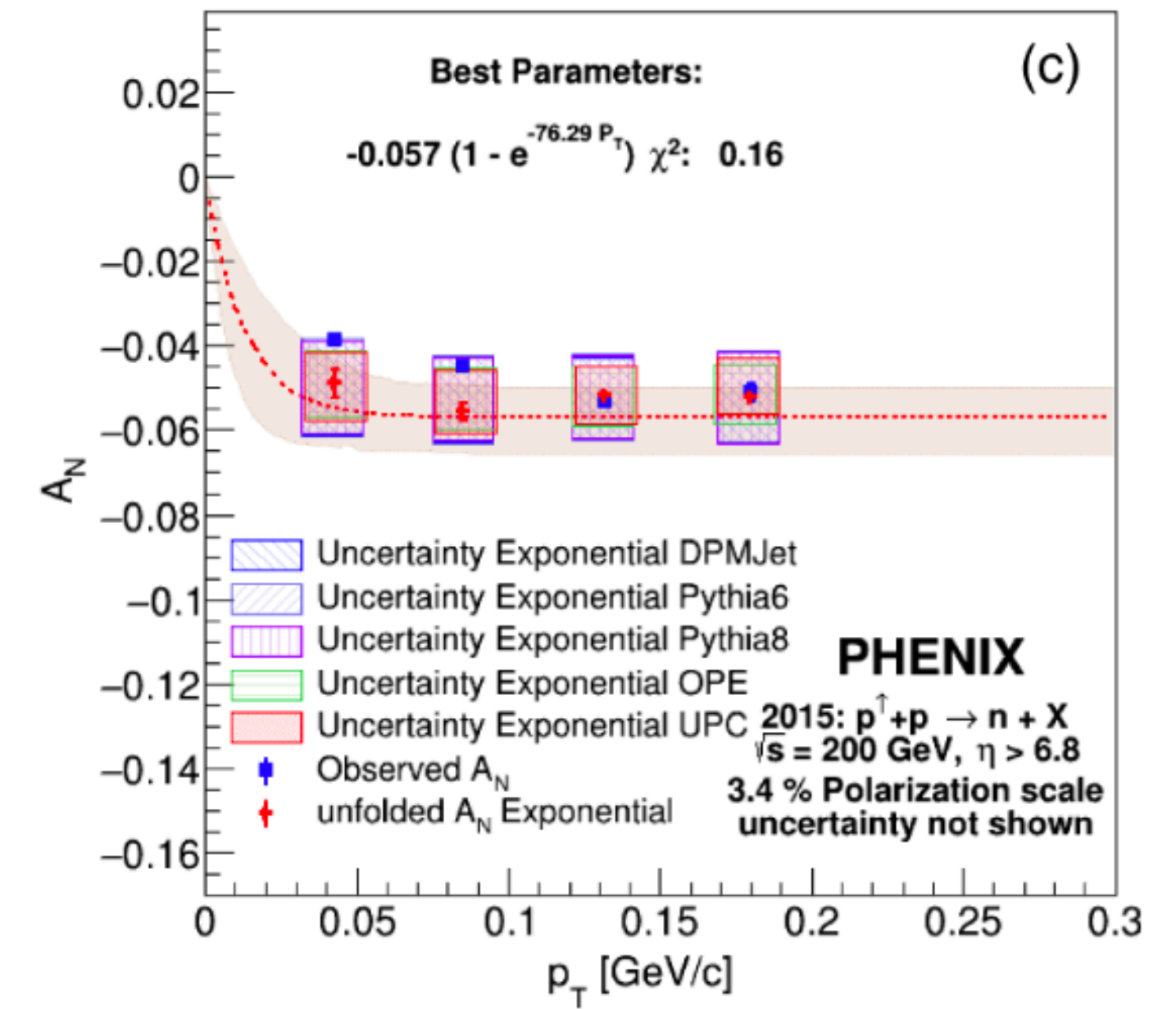
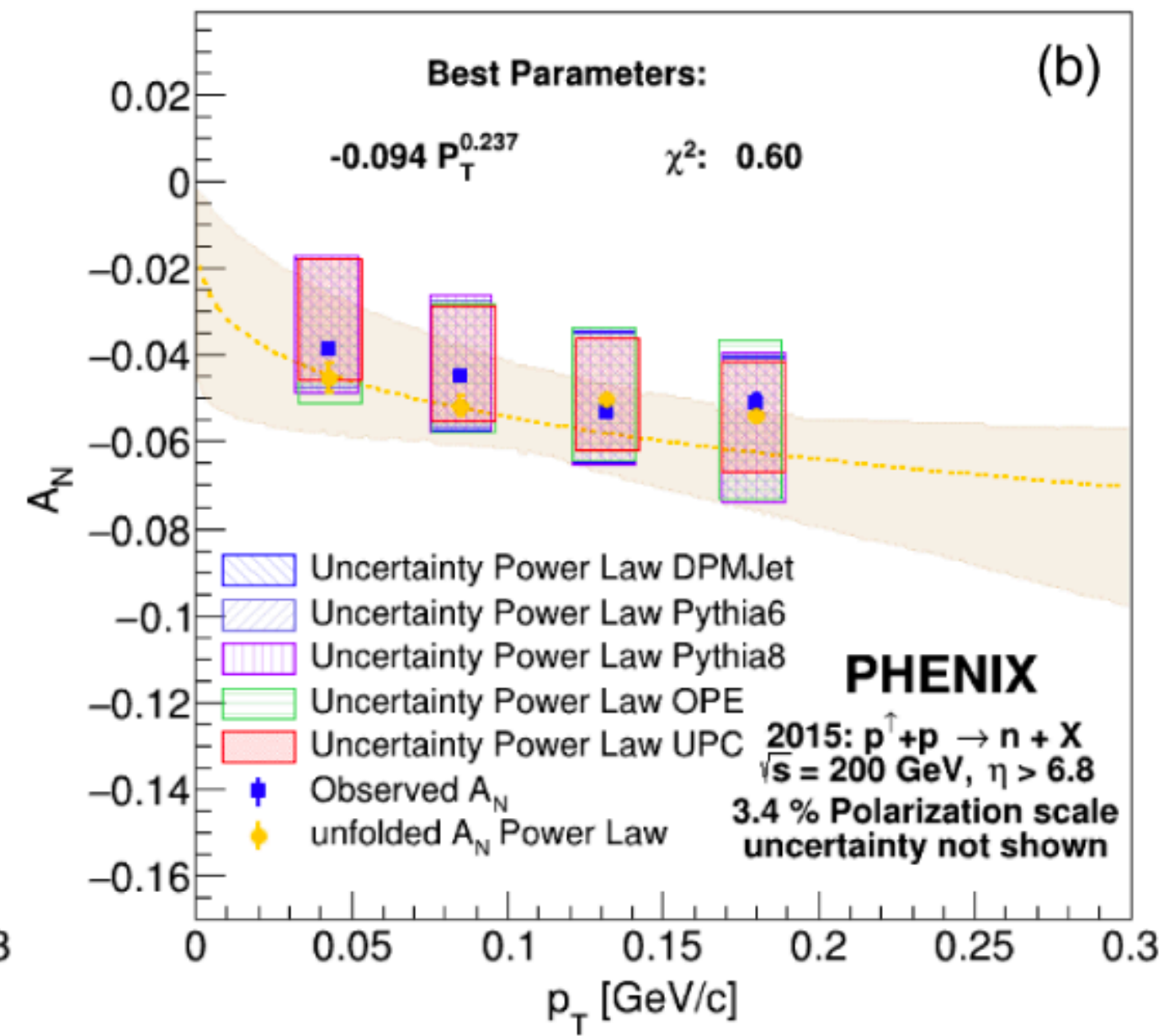
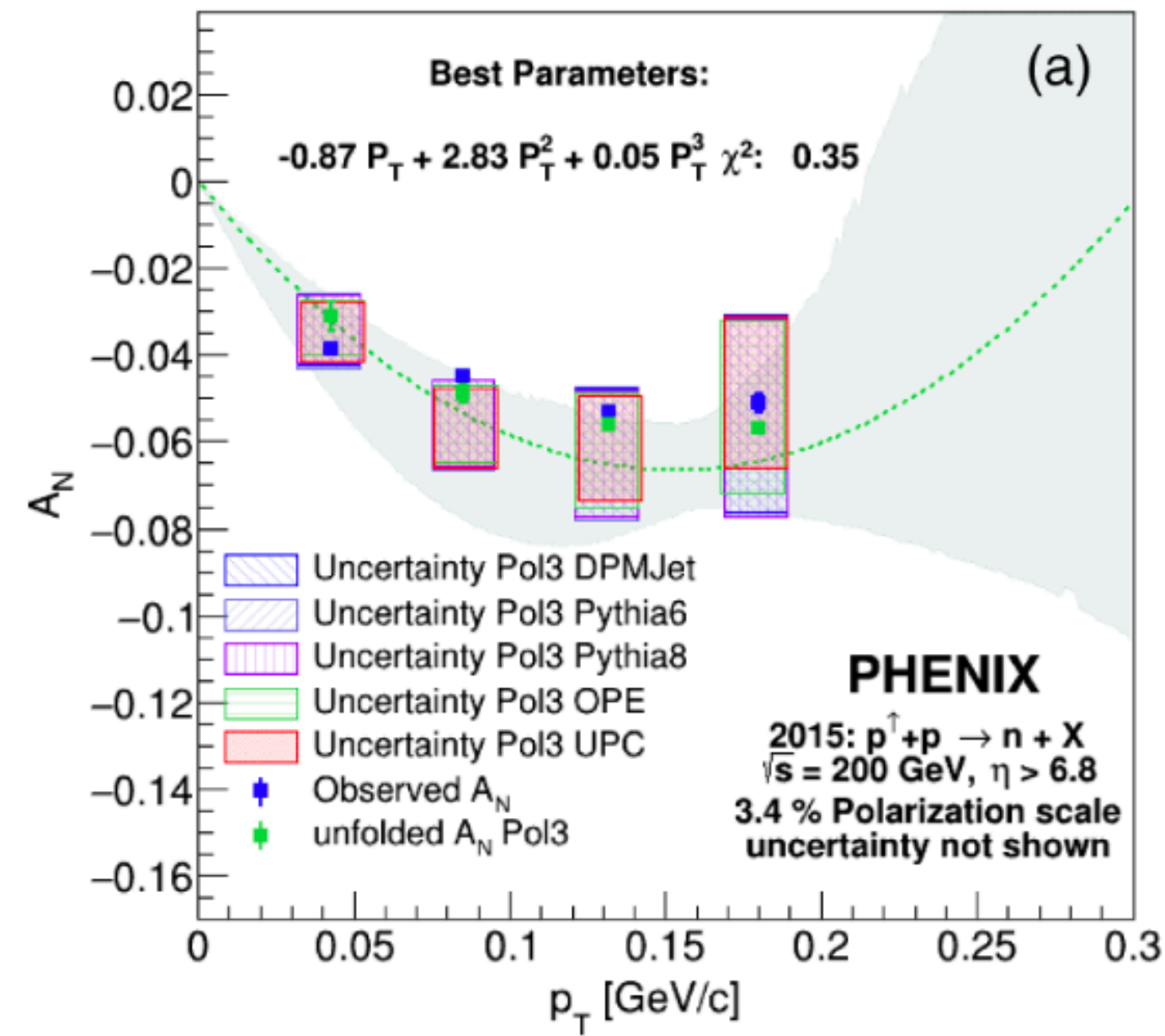
Charged pion A_{LL} @ 510 GeV

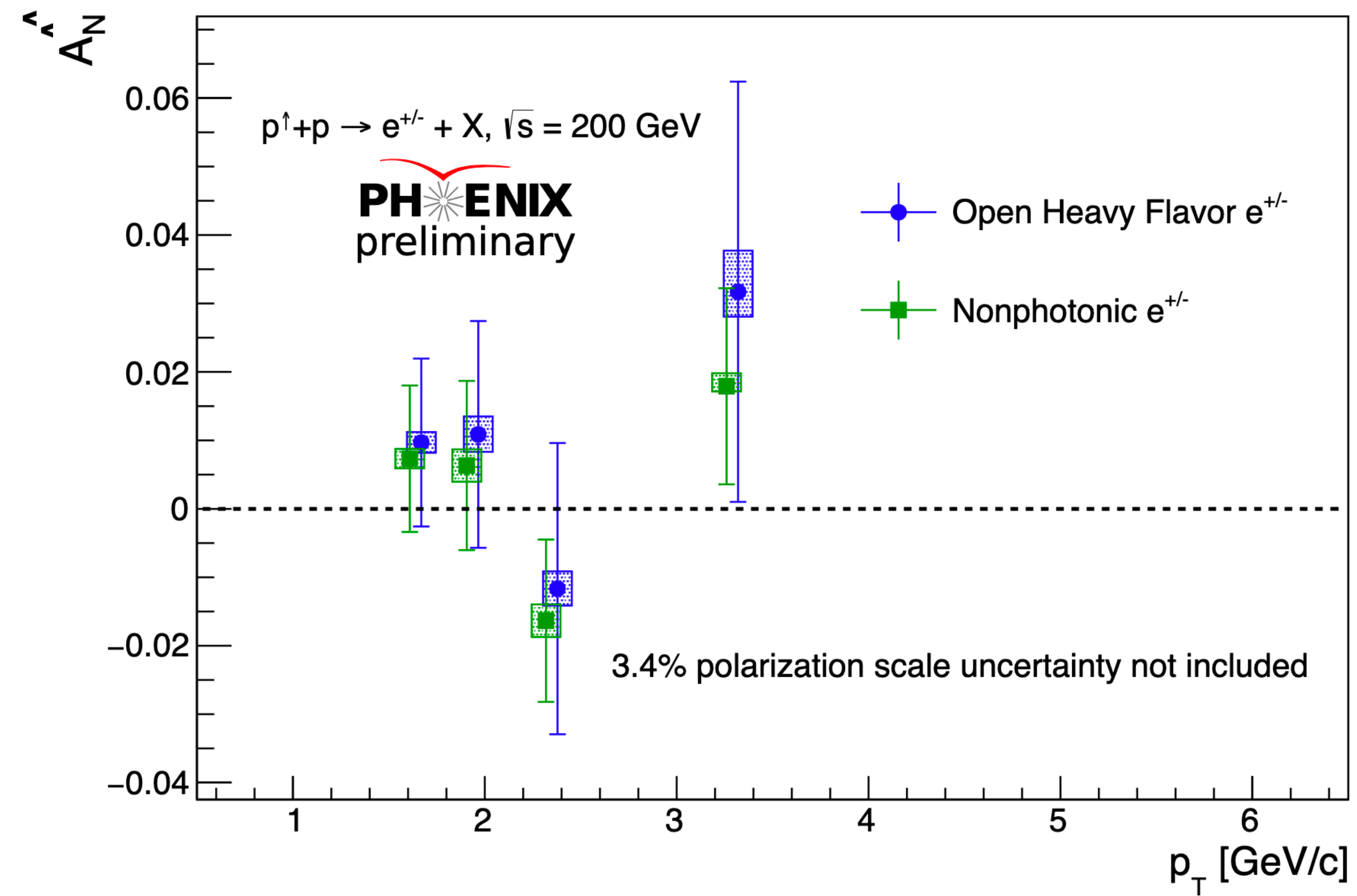


- First measurement at 510 GeV, consistent with the positive gluon polarization from DSSV global fits within the uncertainties
- Charged pions potential indicator for sign of Δg via pion A_{LL} ordering

Phys. Rev. D 103, 052009



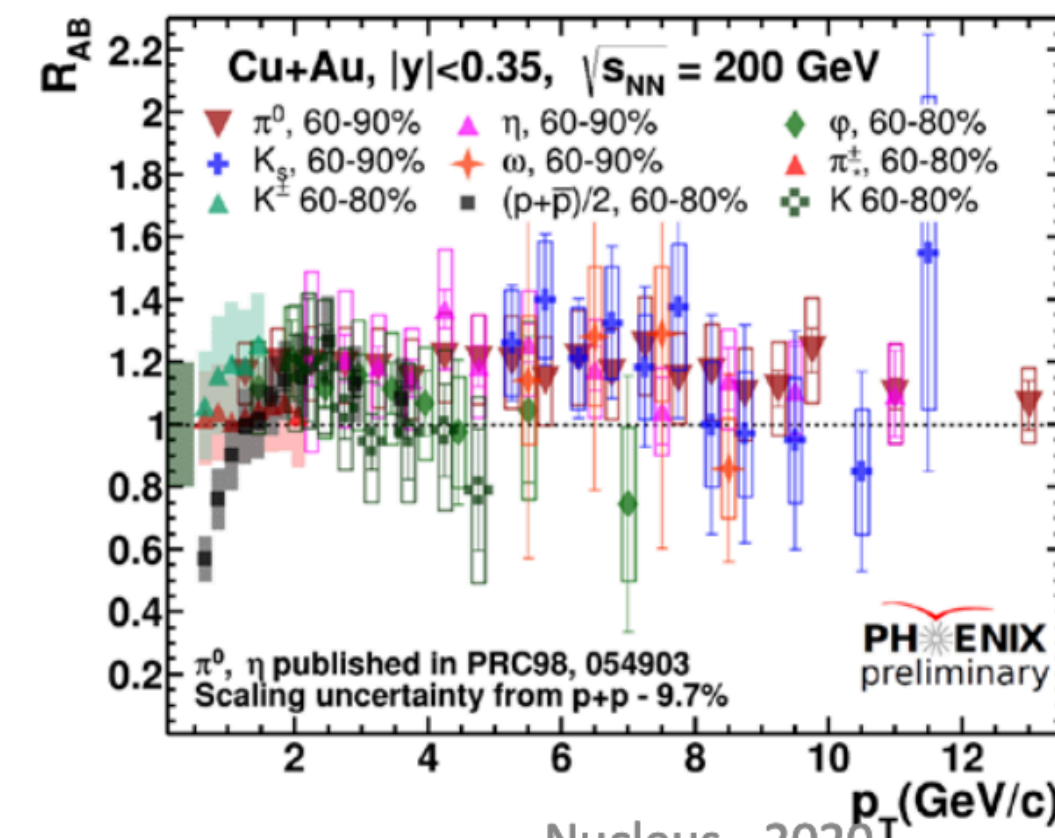
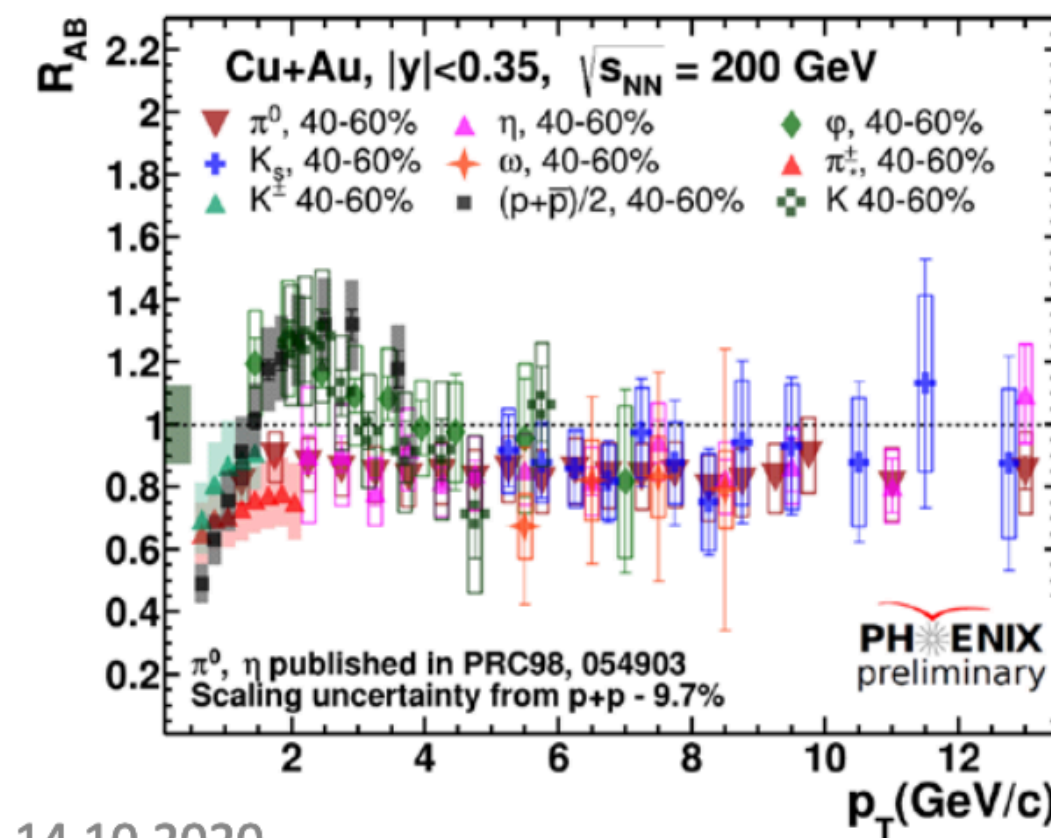
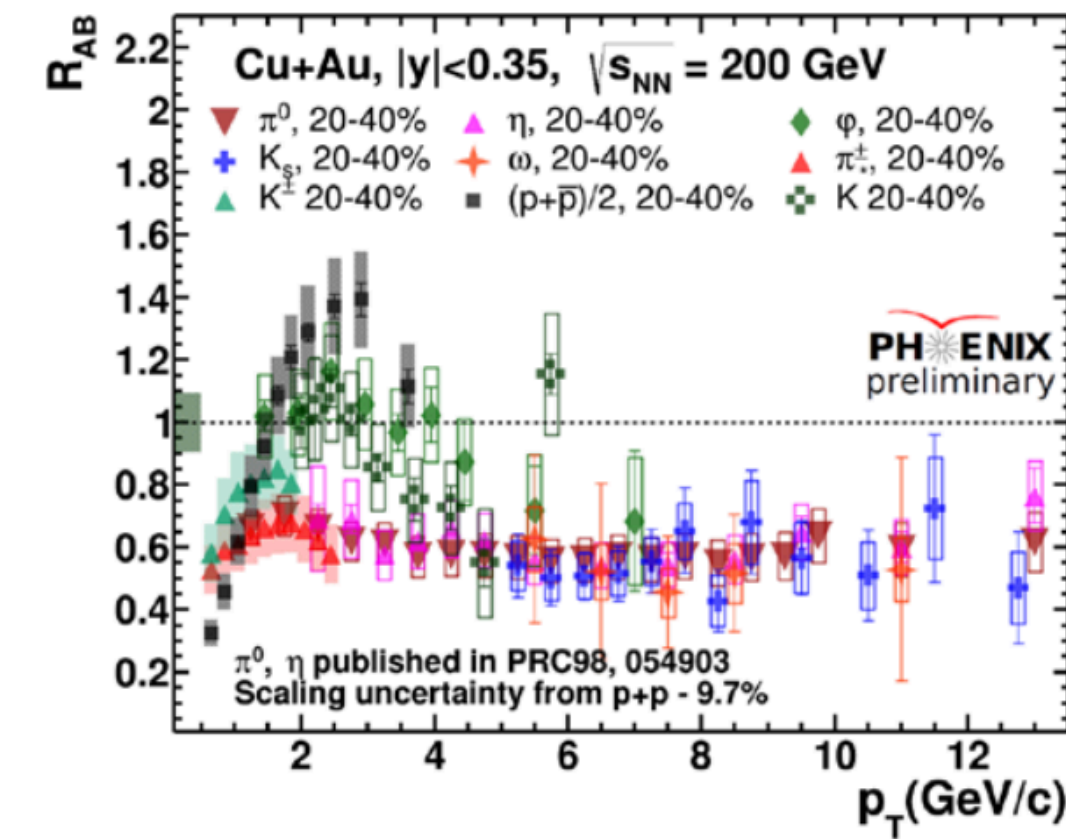
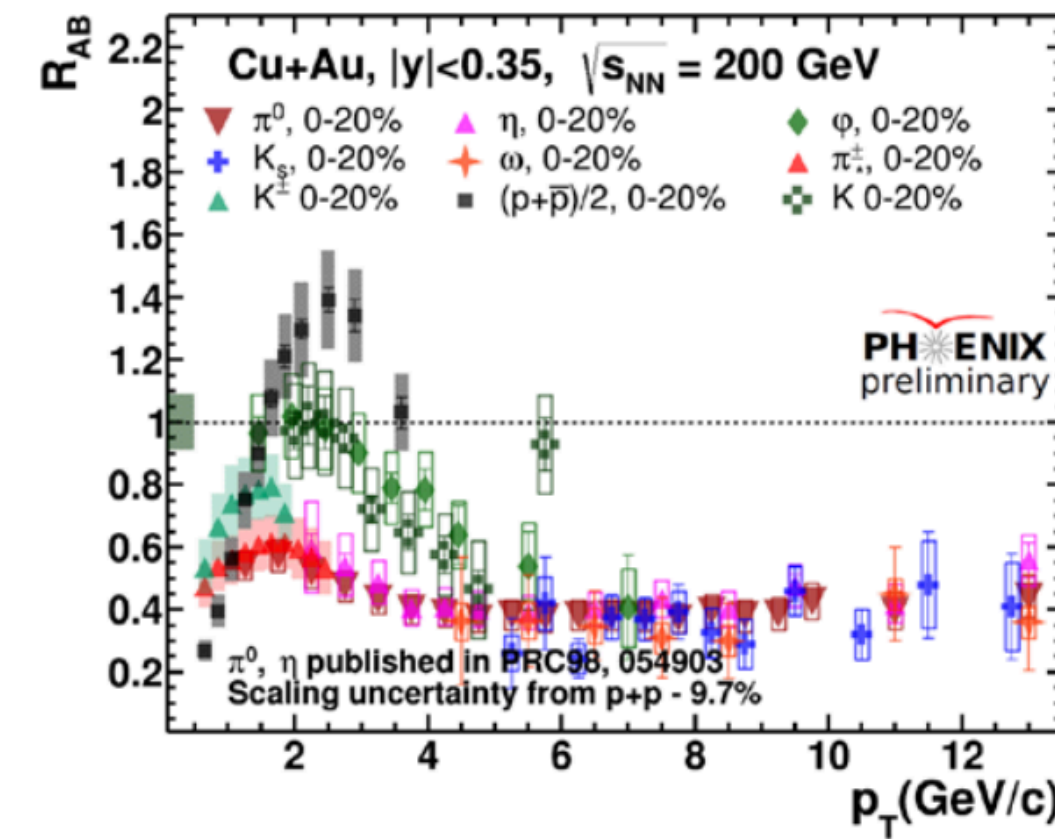
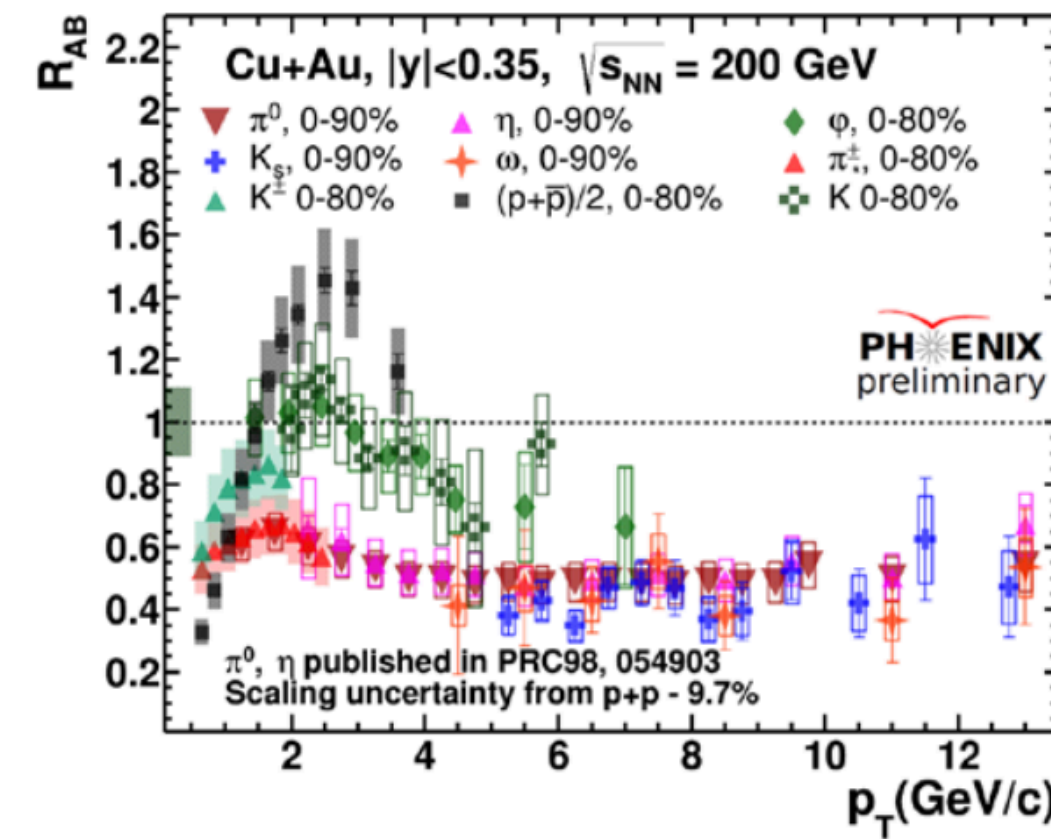






POLYTECH

Light hadron R_{AB} in Cu+Au, $\sqrt{s_{NN}} = 200$ GeV



➤ This differences gradually disappear with decreasing centrality.