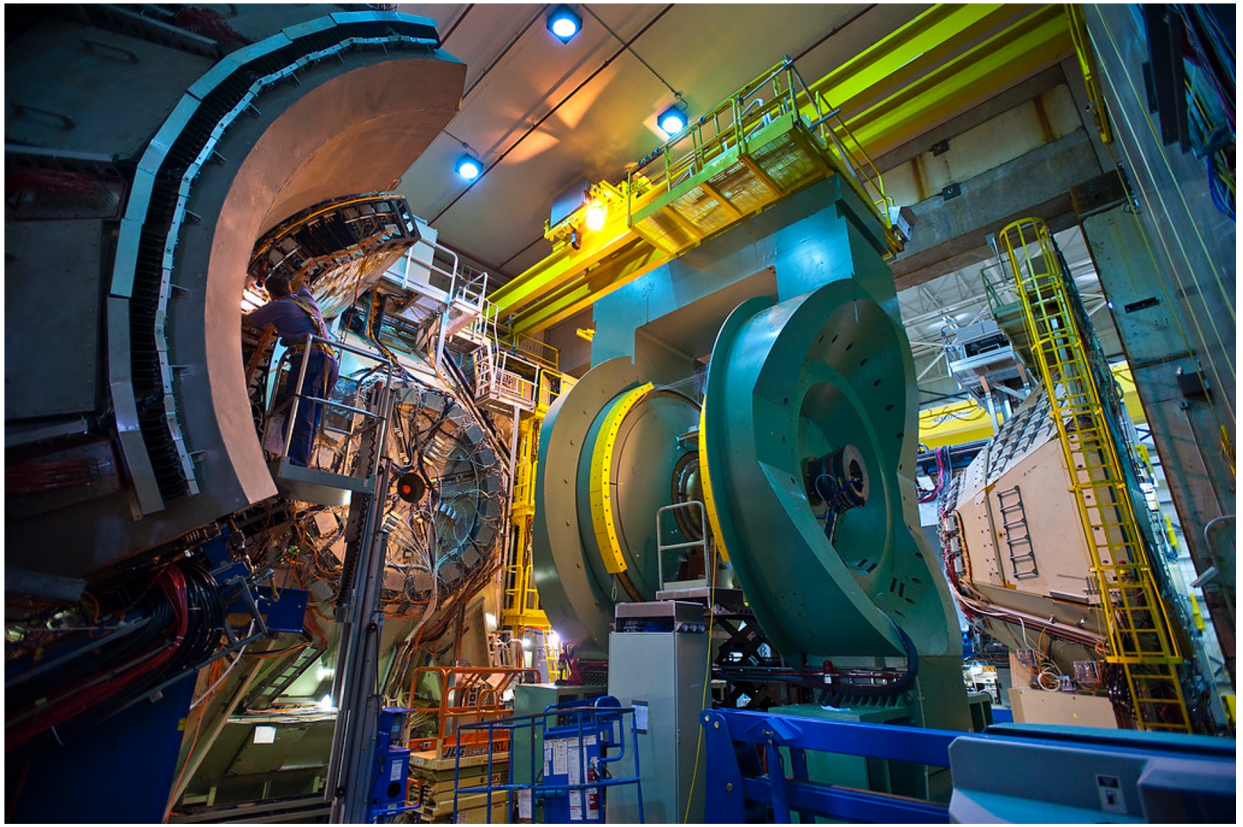
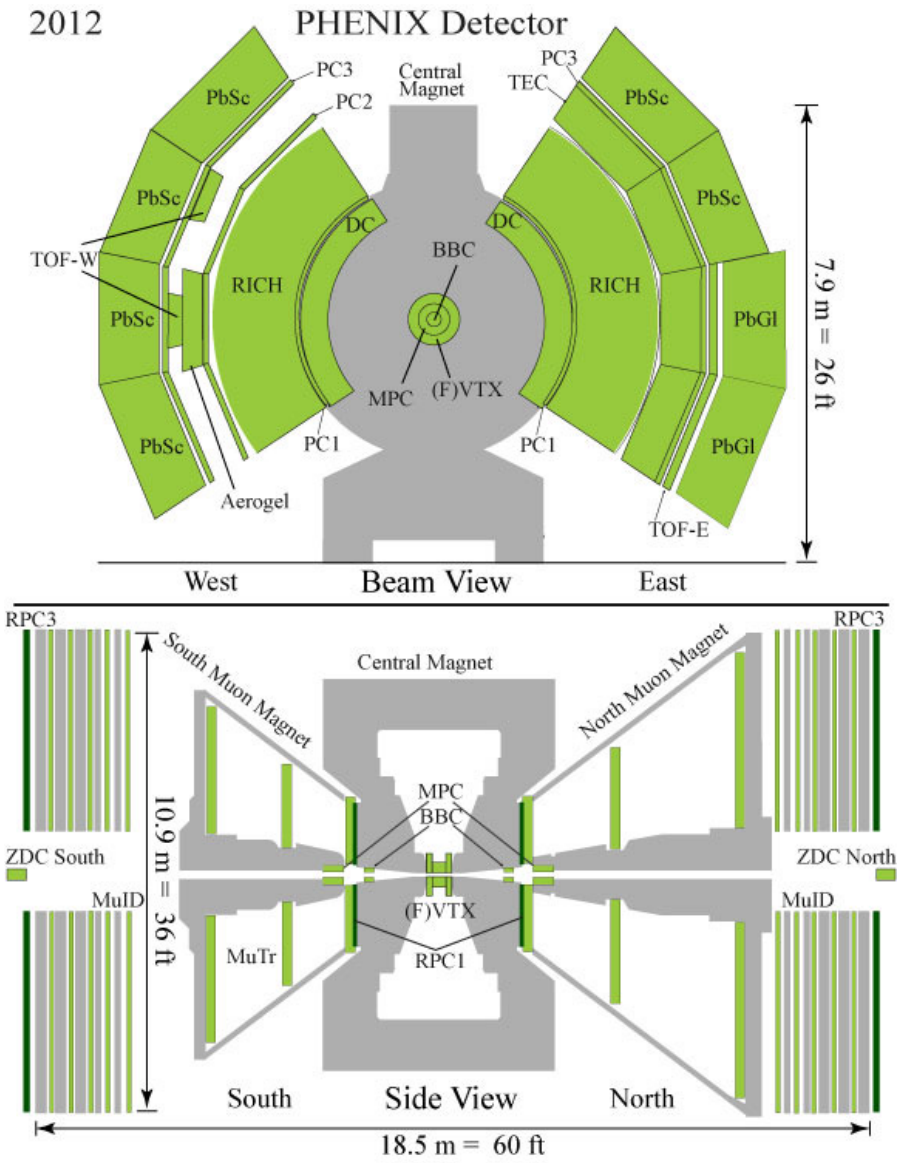
PHENIX HIGHLIGHTS



Cesar Luiz da Silva
Los Alamos National Lab

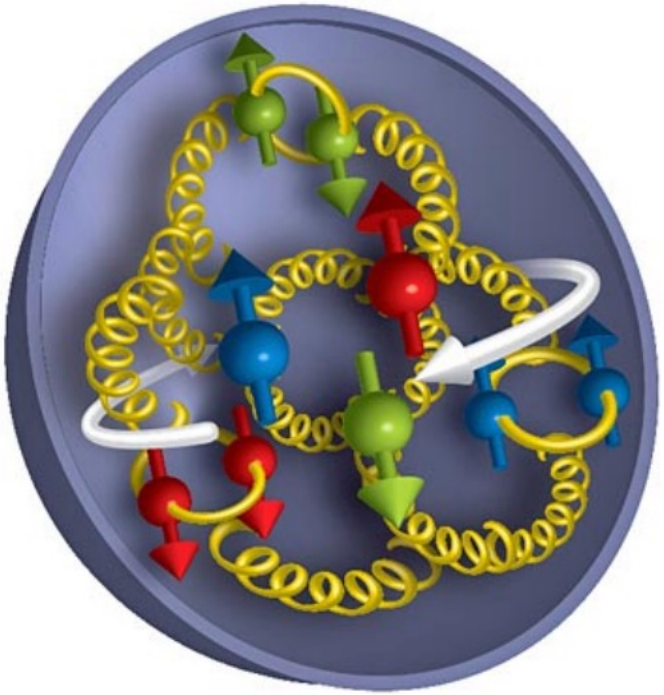
PHENIX Detector



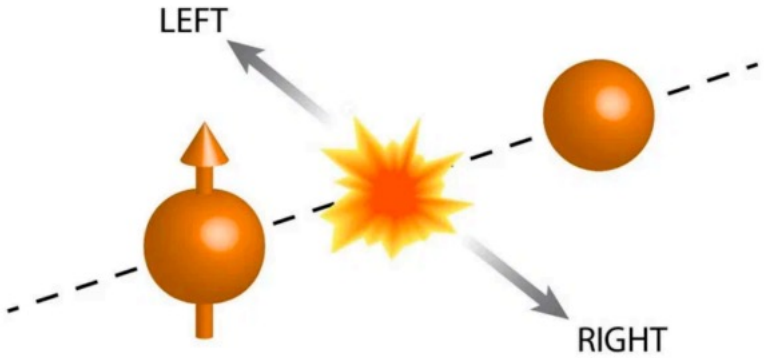
4-spectrometer arms

- Central detector $|\eta| < 0.35$
- Forward/backward detector $1.2 < |\eta| < 2.2$

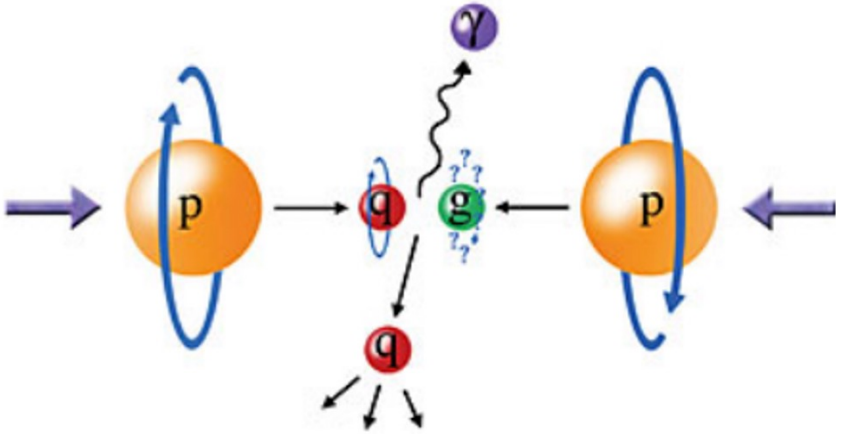
Ended operations in 2016 but still produce new results from the large data acquired during its final years



SPIN



Direct γ longitudinal spin asymmetry



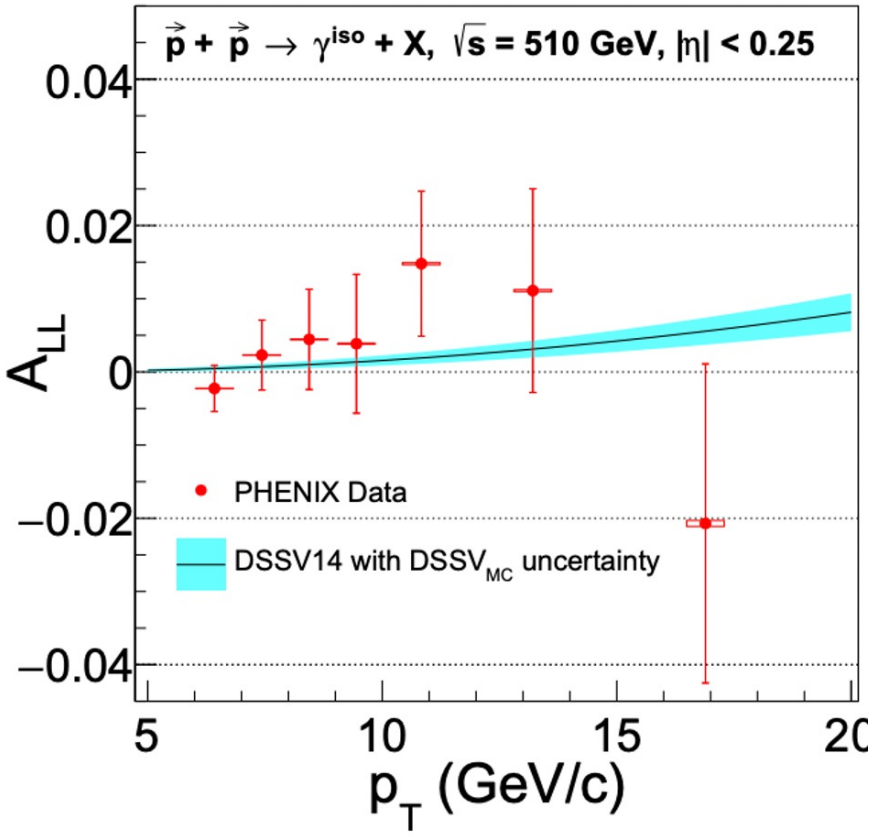
$$A_{LL}^{pp\to\gamma X} \sim \frac{\Delta q(x_q)}{q(x_q)} \cdot \frac{\Delta g(x_g)}{g(x_g)} \cdot a_{LL}^{qg\to\gamma q}$$

Direct photons from the inverse Compton process is the most direct way to probe gluons

First measurement ever. It will provide an independent constraint to Δg

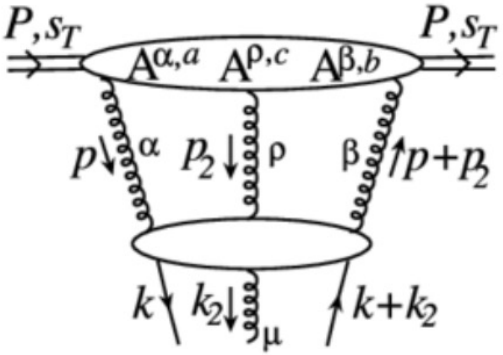
arXiv:2202.08158

$$A_{LL} = \frac{\Delta\sigma}{\sigma} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$$



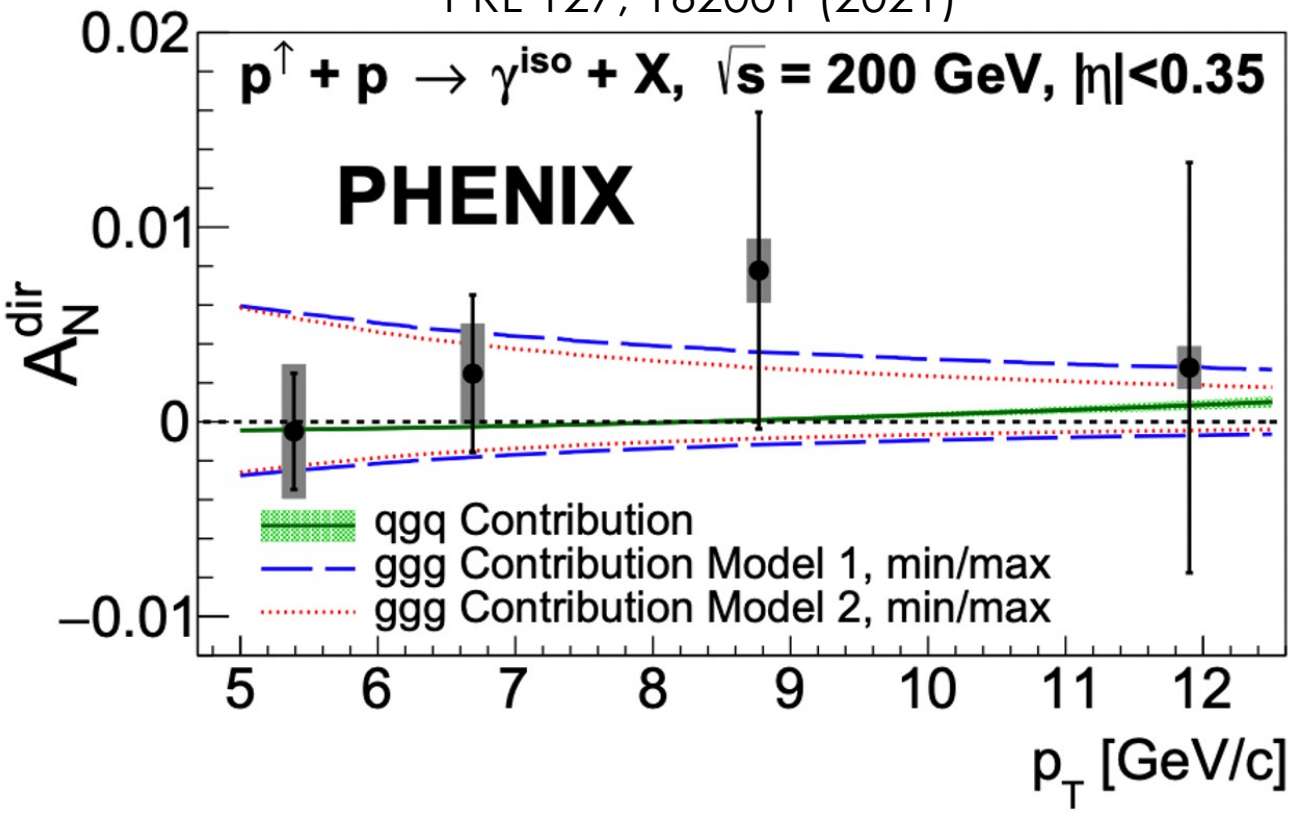
Zhongling Ji presentation on Wednesday

Direct γ transverse spin asymmetry



PRD.79.016003(2009)

PRL 127, 162001 (2021)

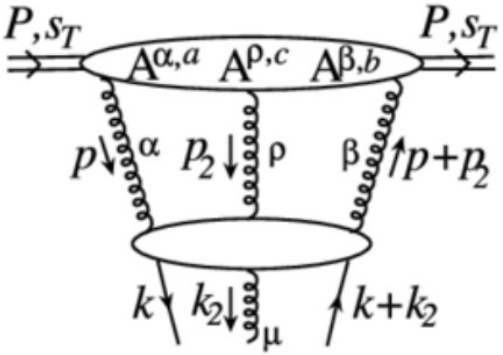


Constrain trigluon spin-momentum correlations

Uncertainties up to a factor of 50 smaller than previous E704 measurements

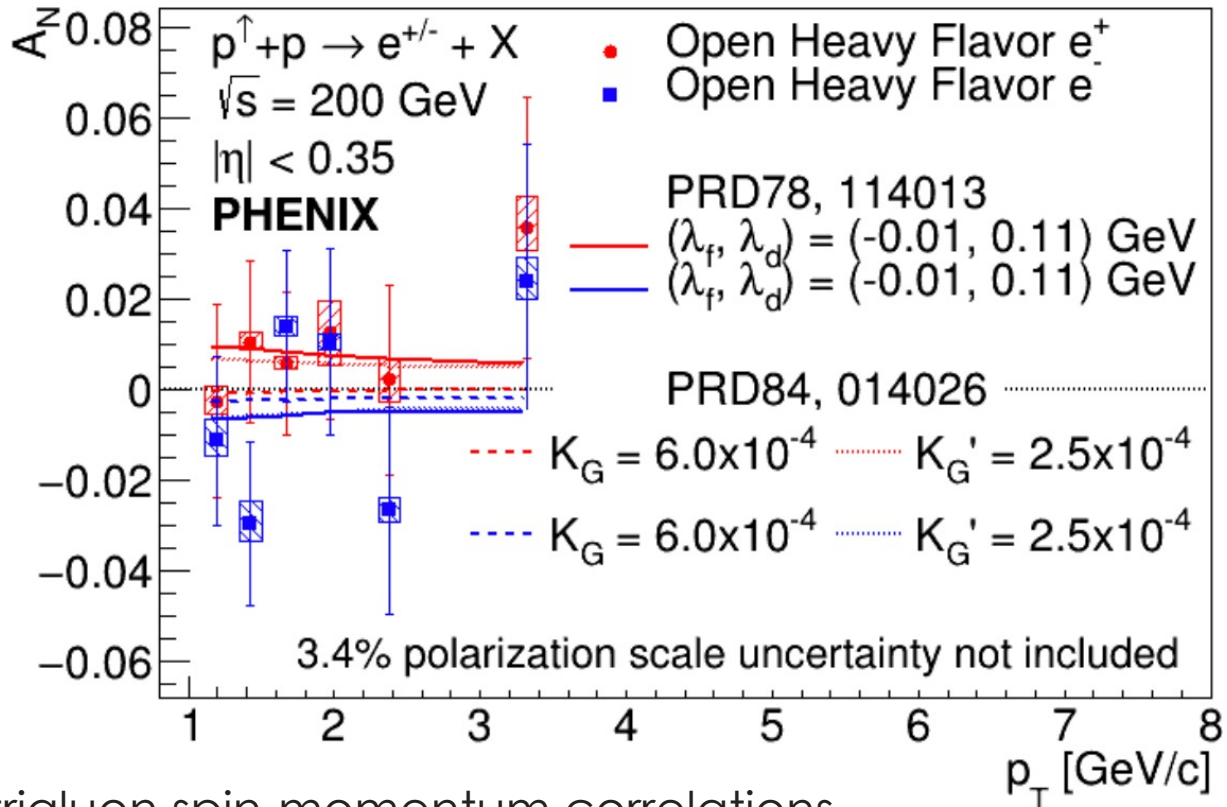
Step toward creating a more three-dimensional picture of proton structure

Heavy Flavor transverse spin asymmetry



PRD.79.016003(2009)

arXiv:2204.12899



Yet another constrain to trigluon spin-momentum correlations

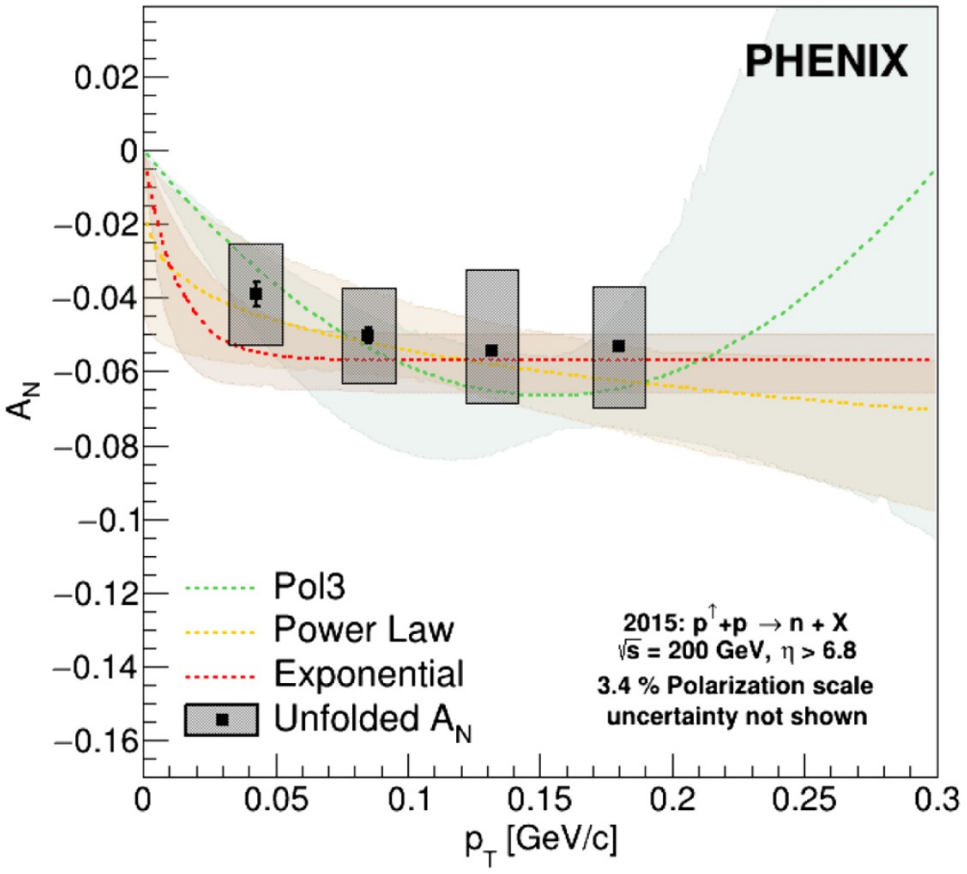
Tri-gluon correlation functions :

- Antisymmetric : $T_G^{(f)}(x,x) = \lambda_f G(x)$ $\quad\quad \lambda_f = -0.01 \pm 0.03$ GeV
- Symmetric : $T_G^{(d)}(x,x) = \lambda_d G(x)$ $\quad\quad \lambda_d = 0.11 \pm 0.09$ GeV

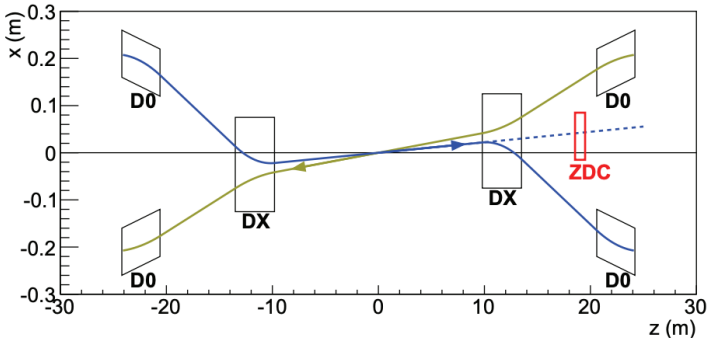
Neutron Transverse Spin Asymmetry

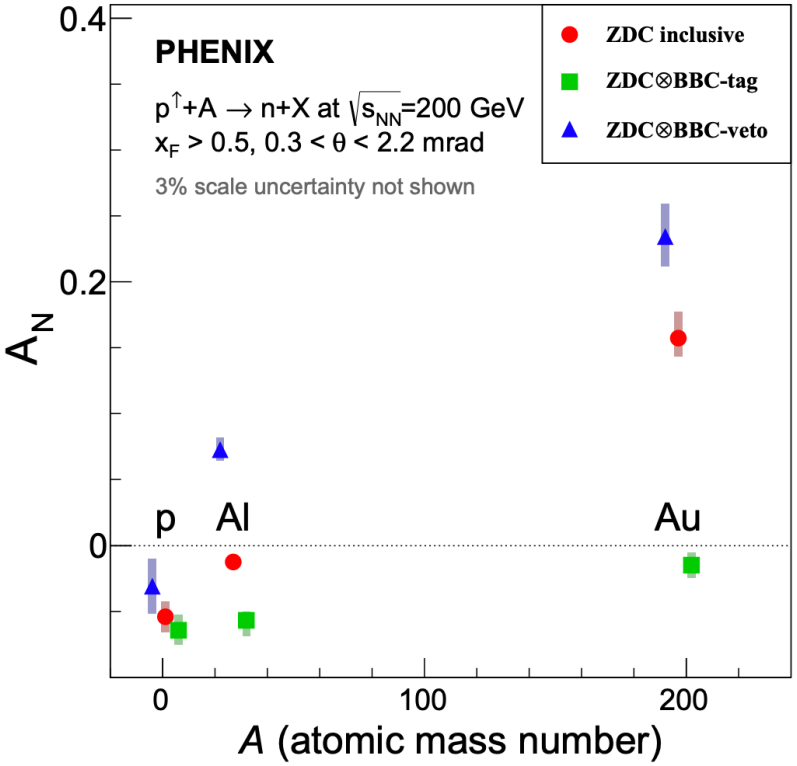
- Exploring the p_T of Transverse Single Spin Asymmetry in p+p collisions
- $\eta > 6.8$

PRD 103, 032007 (2021)



Transverse Spin Asymmetry in p+A



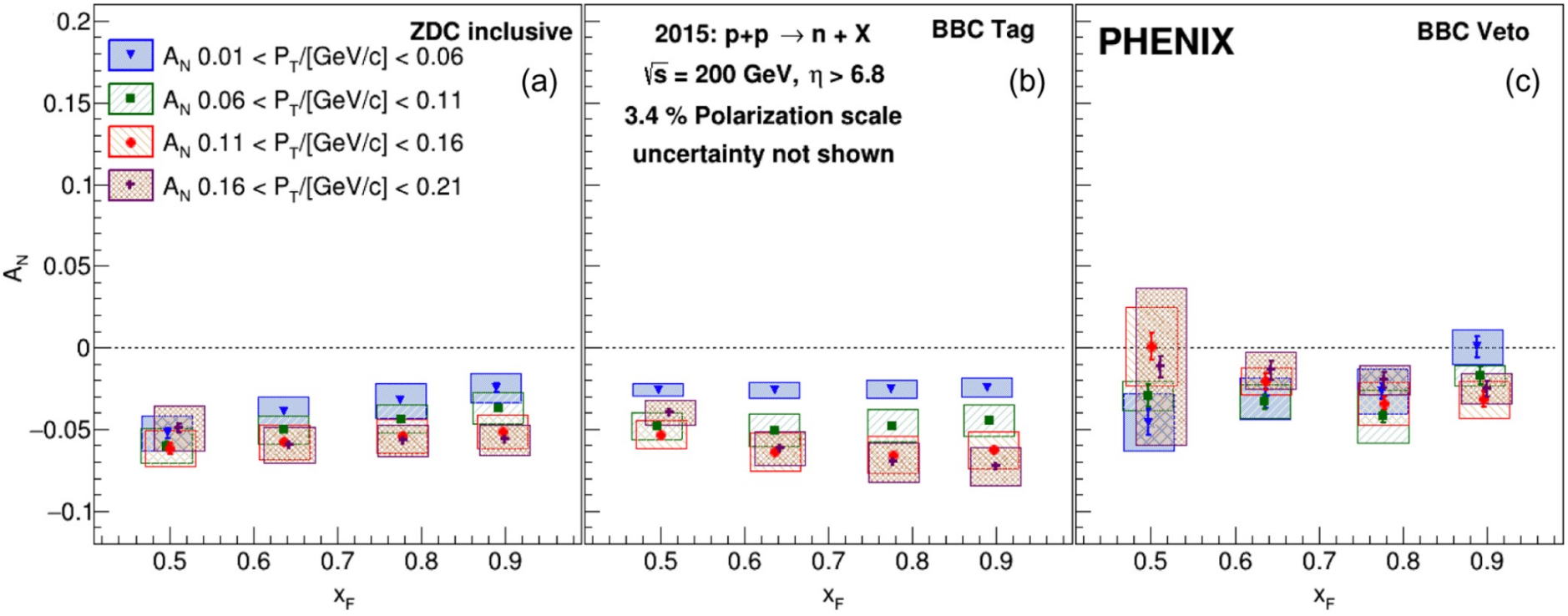


PRL 120, 022001 (2018)

- ZDC⊗BBC-tag(N ∩ S): Select hadronic interactions
- ZDC⊗BBC-veto(N ∩ S): Select Ultra-Peripheral Collisions interactions
- Strong A dependence seems to come from Ultra-Peripheral Collisions events

Transverse Spin Asymmetry in p+p

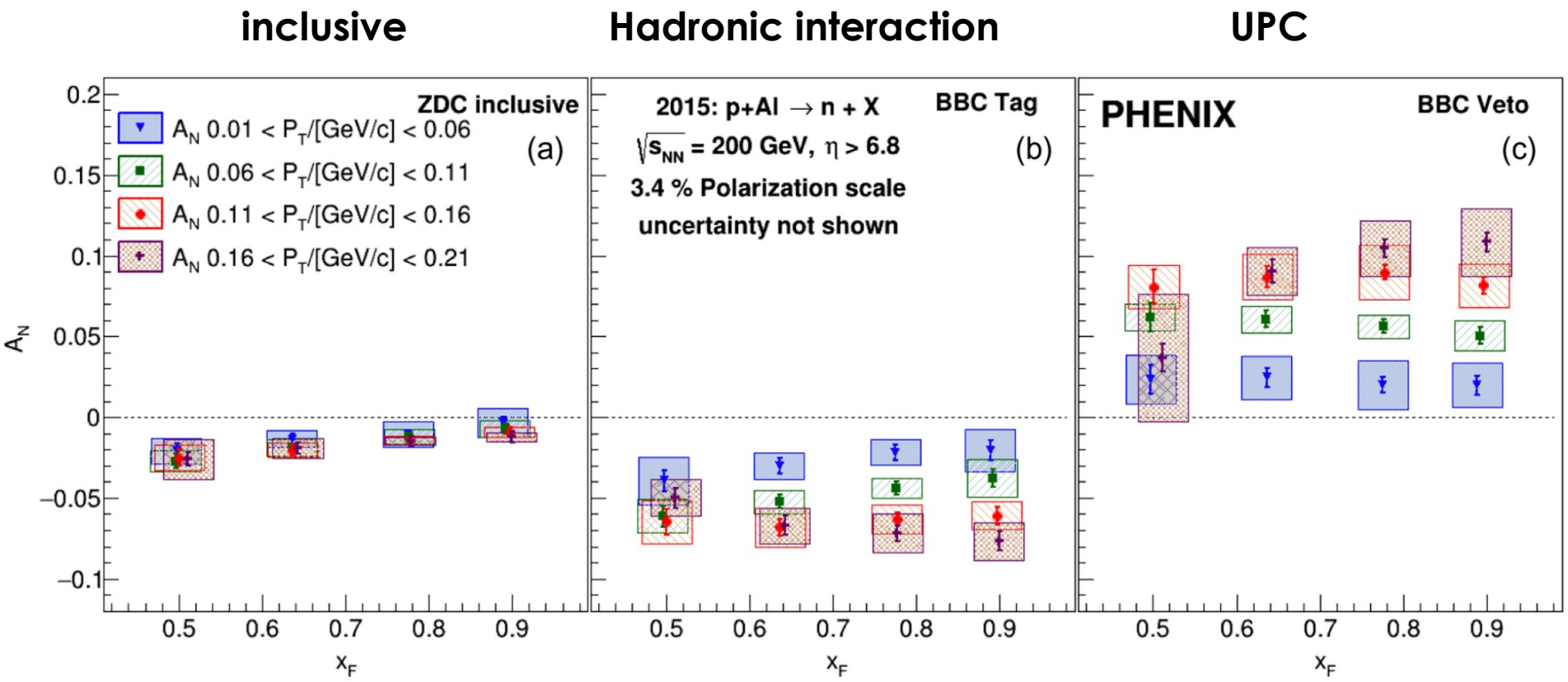
PRD 105, 032004 (2022)



- negative A_N in all conditions
- Increasing magnitude with neutral p_T with BBC tag

Transverse Spin Asymmetry in p+Al

PRD 105, 032004 (2022)

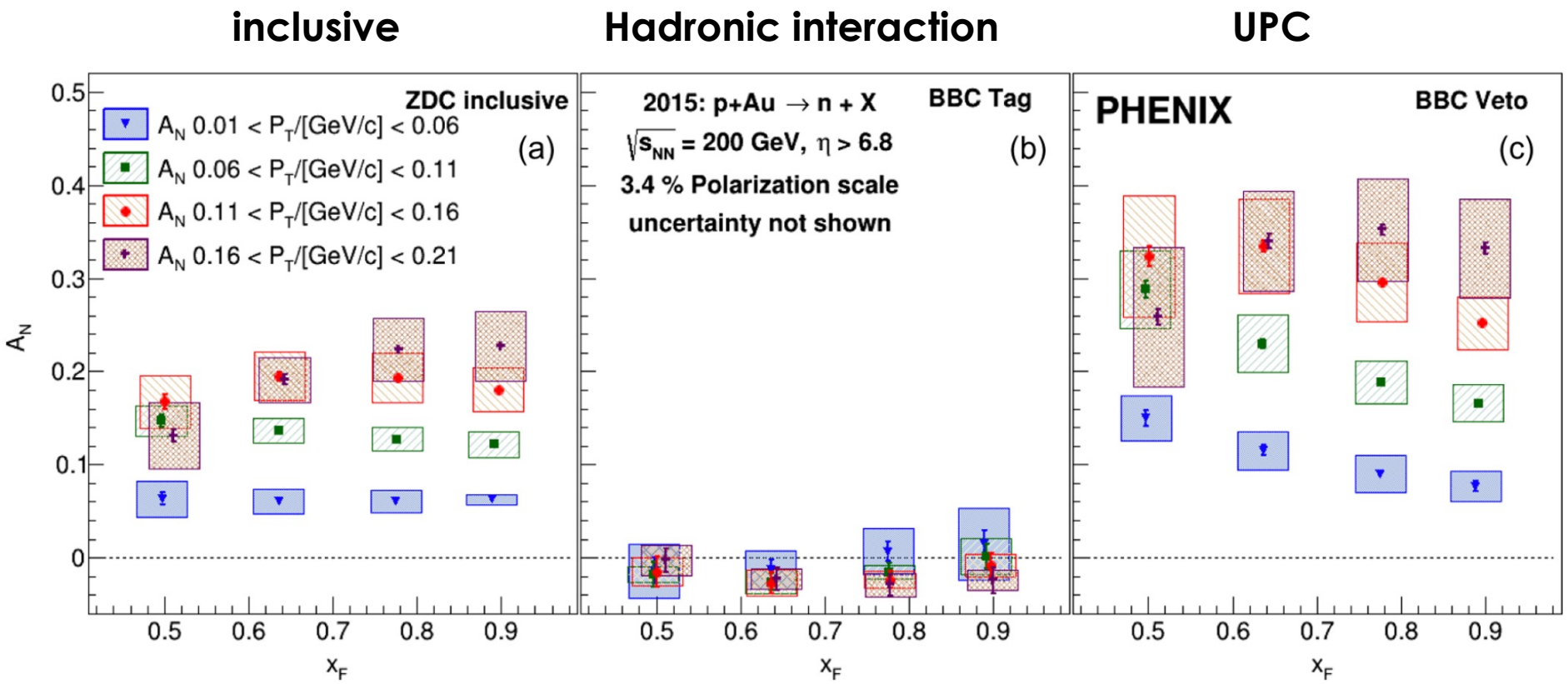


- negative A_N in hadronic interactions
- positive AN in Ultra-Peripheral Collisions
- both magnitudes increasing with neutron p_T

Transverse Spin Asymmetry in p+Au

PRD 105, 032004 (2022)

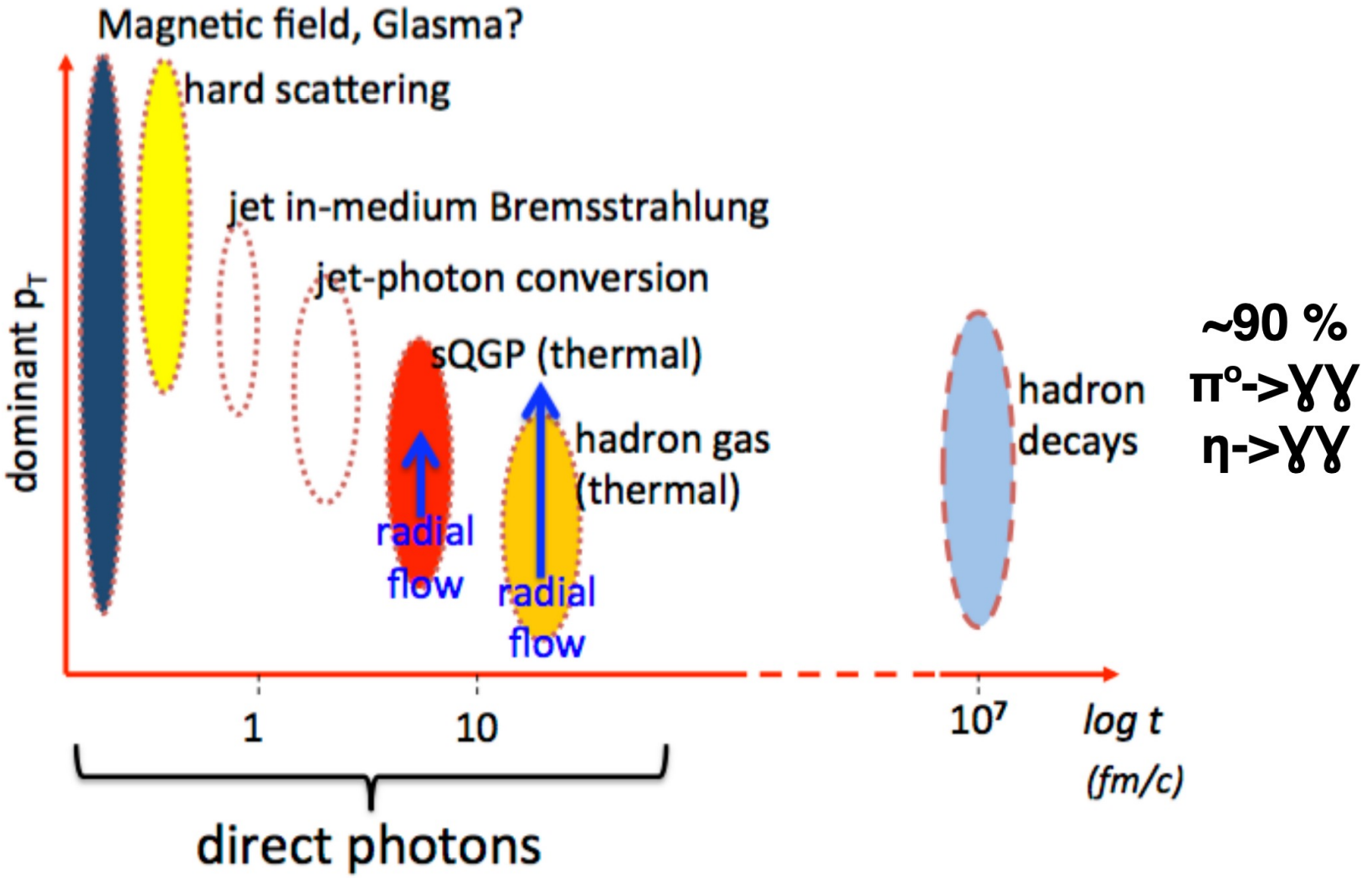
Caution : Scale changed



- Effects in UPC have strong dependence with Z. May not be seen in p+p
- New data greatly improve the general understanding of how hadronic and photon-induced processes create single spin asymmetries

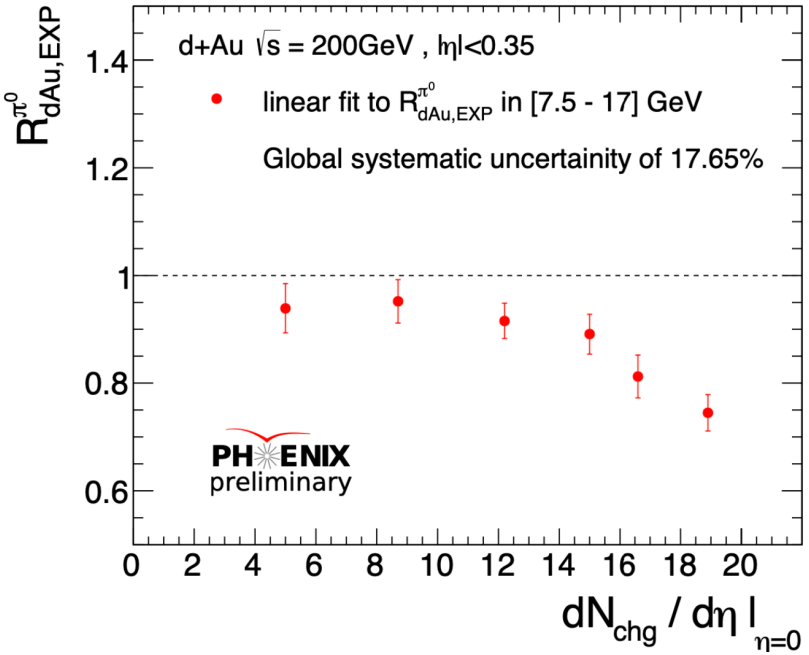
Heavy Ion

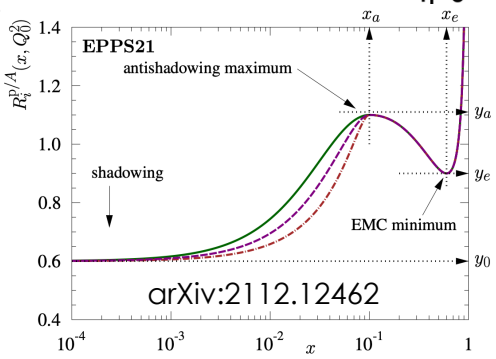
Direct Photons in Au+Au



High p_T photon, π^0

$$R^{\pi^0}_{dAu,EXP} = \frac{R^{\pi^0}_{dAu,GL}}{R^{\gamma}_{dAu,GL}} = \frac{(Y^{\pi^0}_{dAu}/Y^{\pi^0}_{pp})}{(Y^{\gamma}_{dAu}/Y^{\gamma}_{pp})} = \frac{(Y^{\pi^0}_{dAu}/Y^{\gamma}_{dAu})}{(Y^{\pi^0}_{pp}/Y^{\gamma}_{pp})}$$



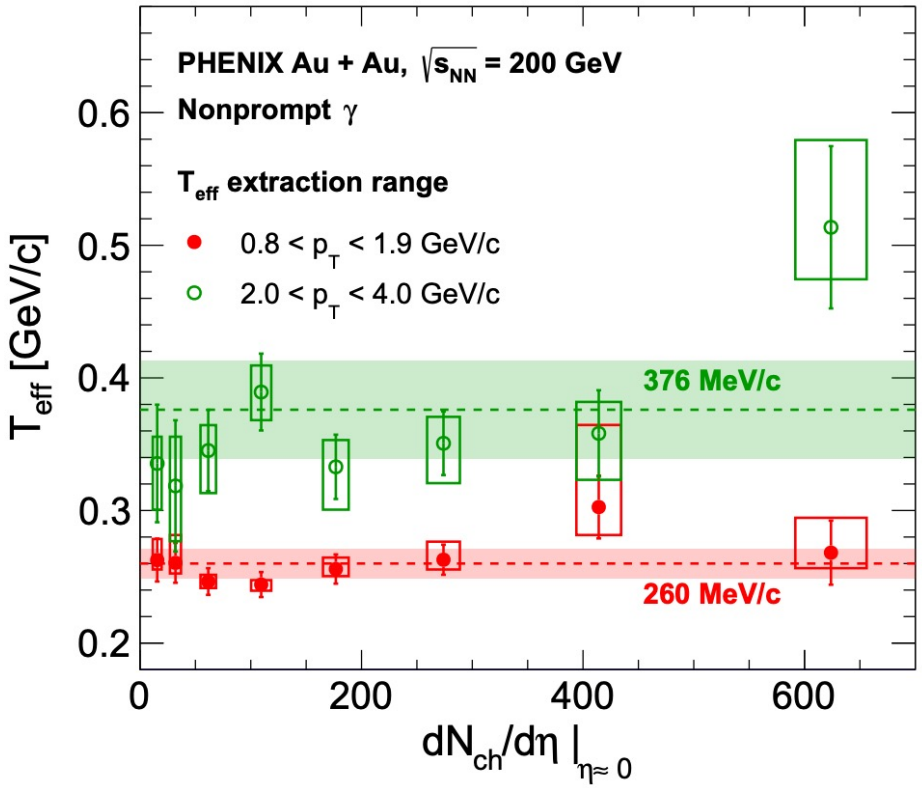


- Using non-interactive direct photons as a reference
- π^0 yield relative to direct photon shows no enhancement as seen in R_{xA} measured at RHIC and LHC
- Indication that RxA is prone to bias in the Glauber model calculations in small systems
- Suppression observed at high event activity
  - Energy loss ?
  - Initial-state EMC effect ?
- Paper under preparation

Non-prompt direct photon in Au+Au

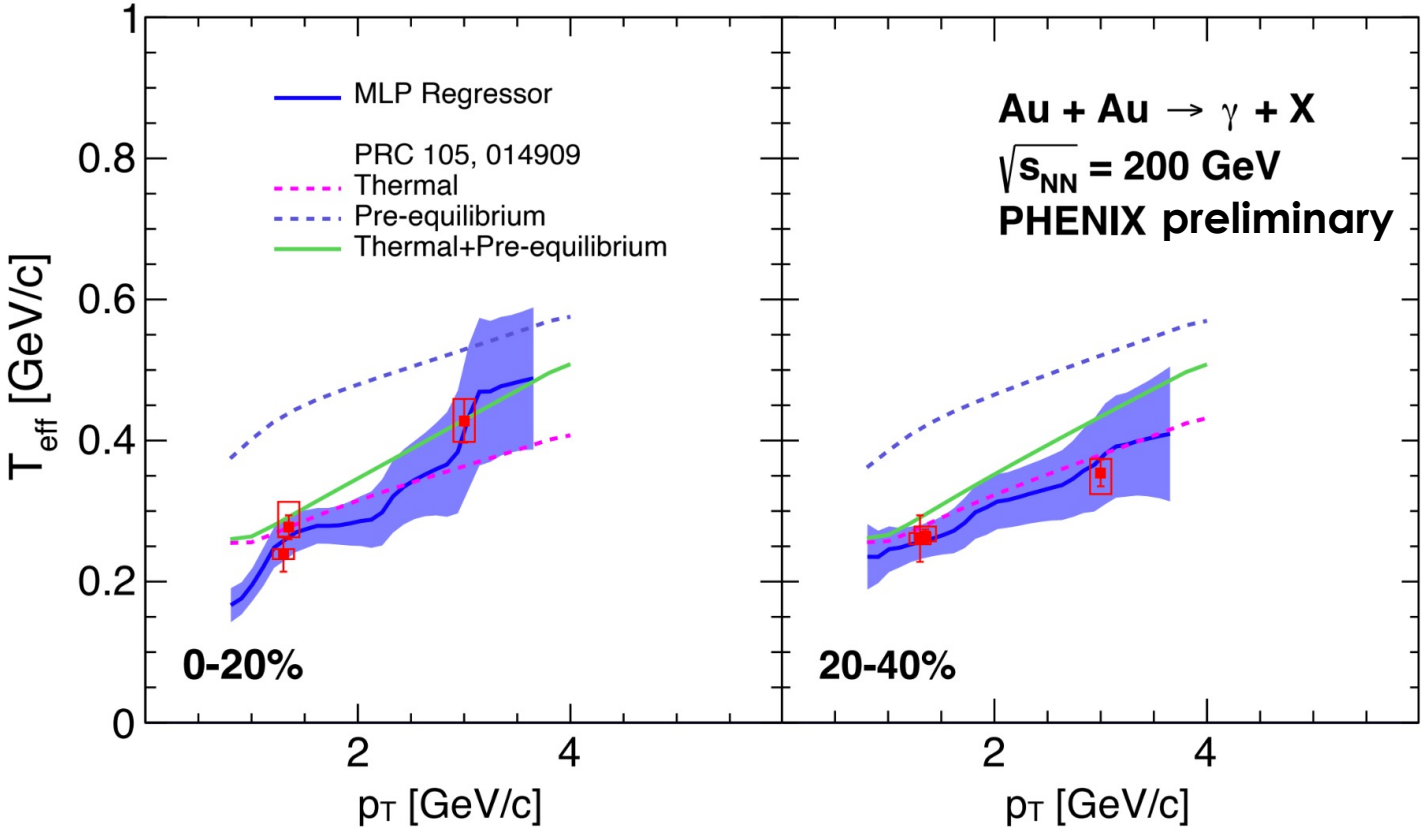
Non-prompt photons = Direct photon – Ncoll pp scale

arXiv:2203.17187



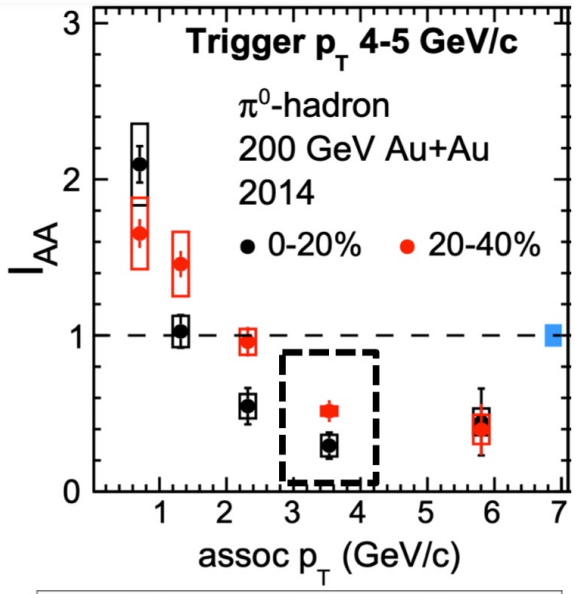
- Mostly radiation that is emitted during the collision from the hot-expanding fireball
- Yield slope (T_{eff}) increases with p_T :
  - high p_T reaches early stages of collision and pre-equilibrium stage.
- No significant change of the slope with event activity

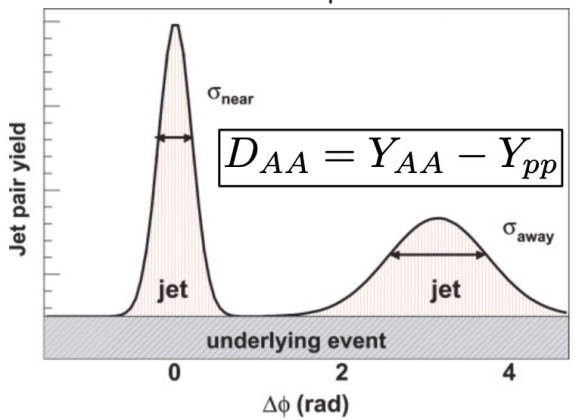
T_{eff} from non-prompt direct photon

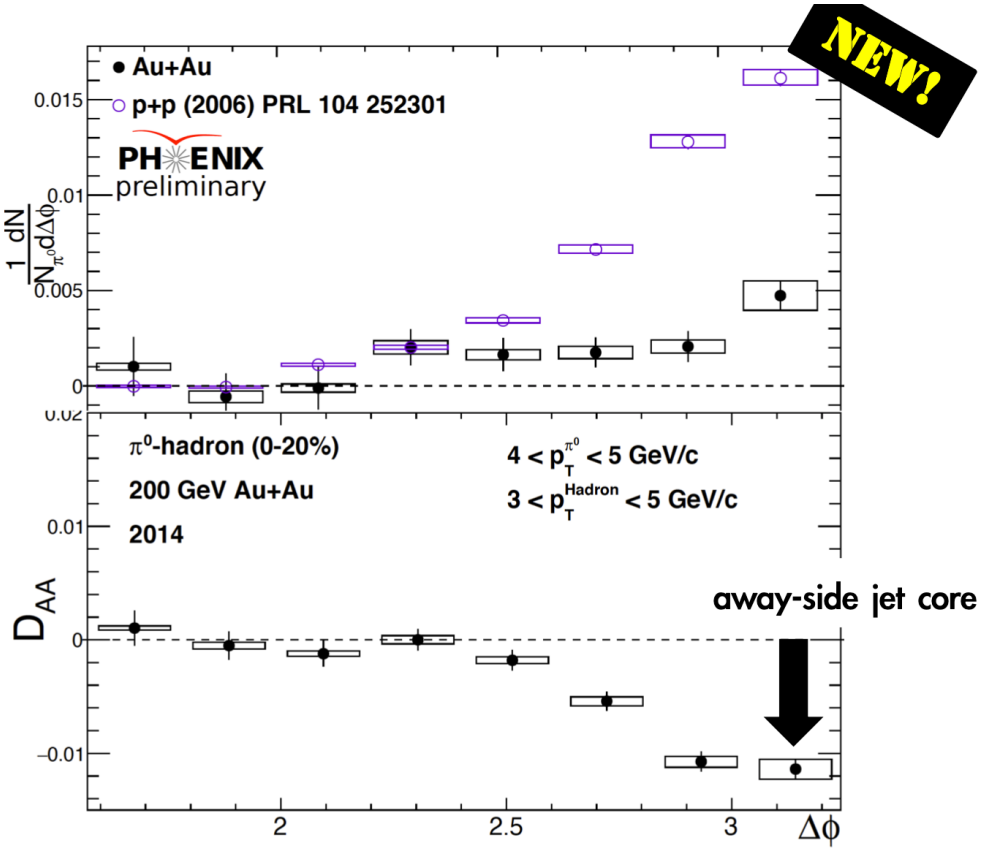


- New theoretical calculation Phys. Rev. C105, 014909
- Multi-Layer Perceptron — a machine learning based regression algorithm
- T_{eff} consistent with thermal + pre-equilibrium stages in central events

π^0-hadron correlation

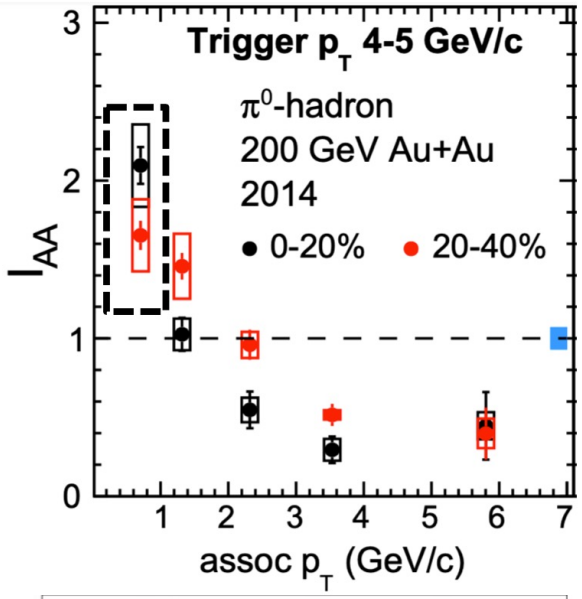


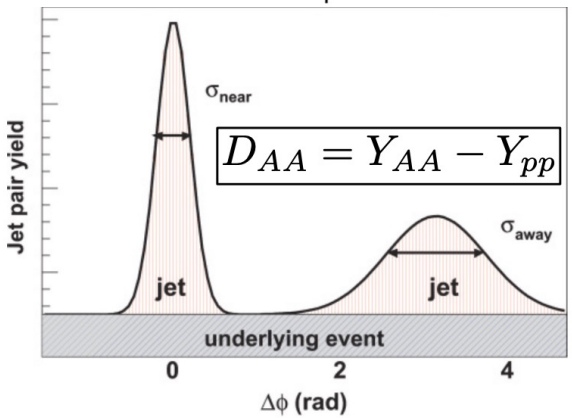


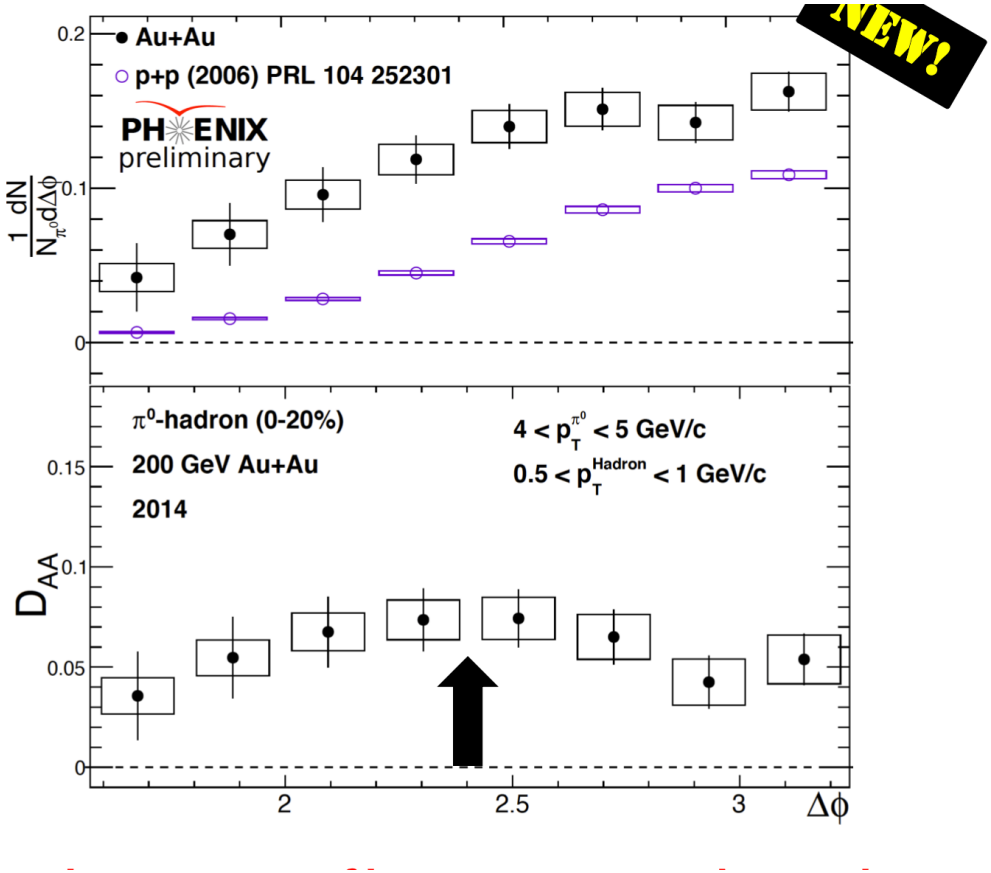


- Suppression at the core of the away-side jet

pi0-hadron correlation







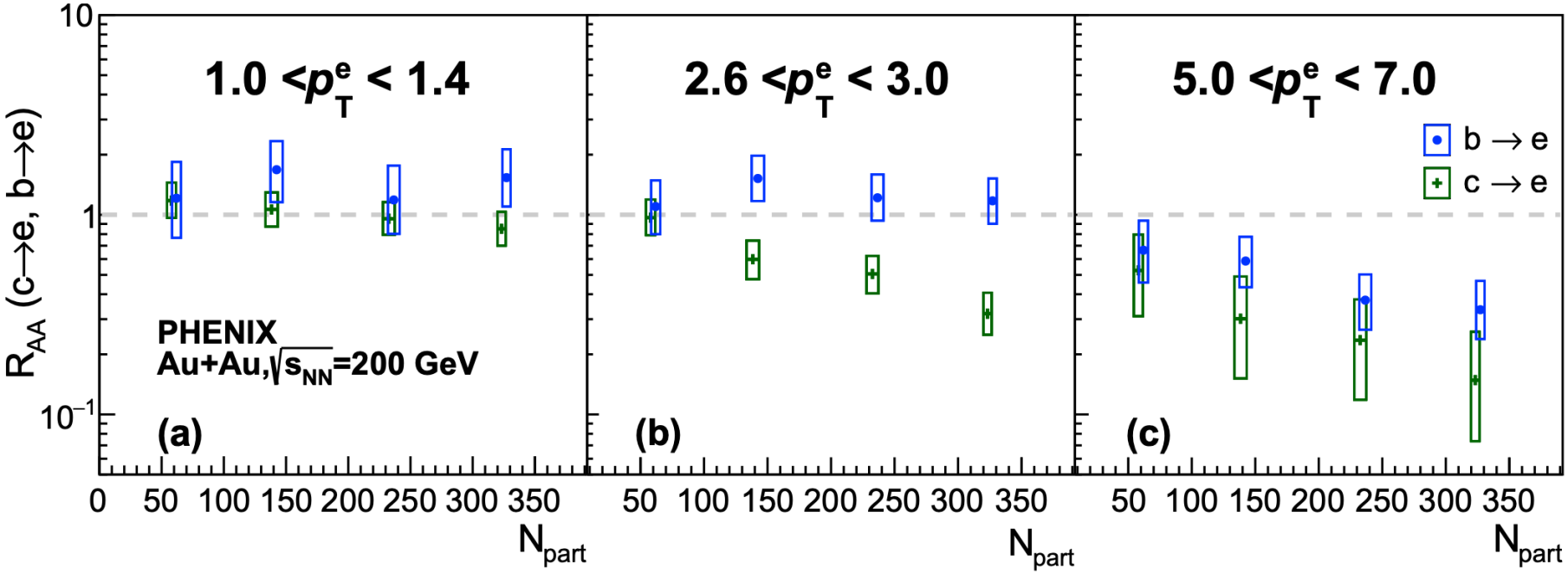
- Enhancement for the entire jet cone
- Paper coming soon

Anthony Hodges (GSU)

Heavy Flavor Energy Loss

arXiv:2203.17058

Electrons from heavy flavor



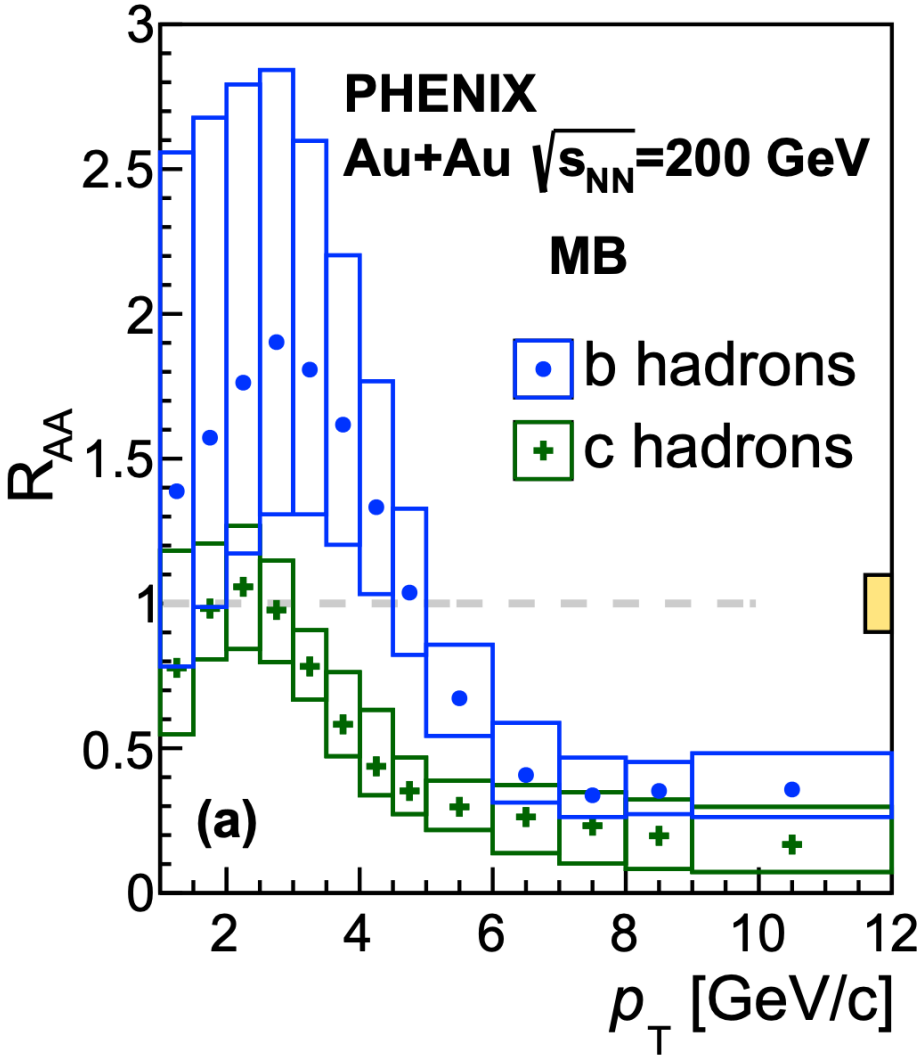
No suppression

Charm suppression

charm+bottom suppression

Heavy Flavor Energy Loss

arXiv:2203.17058



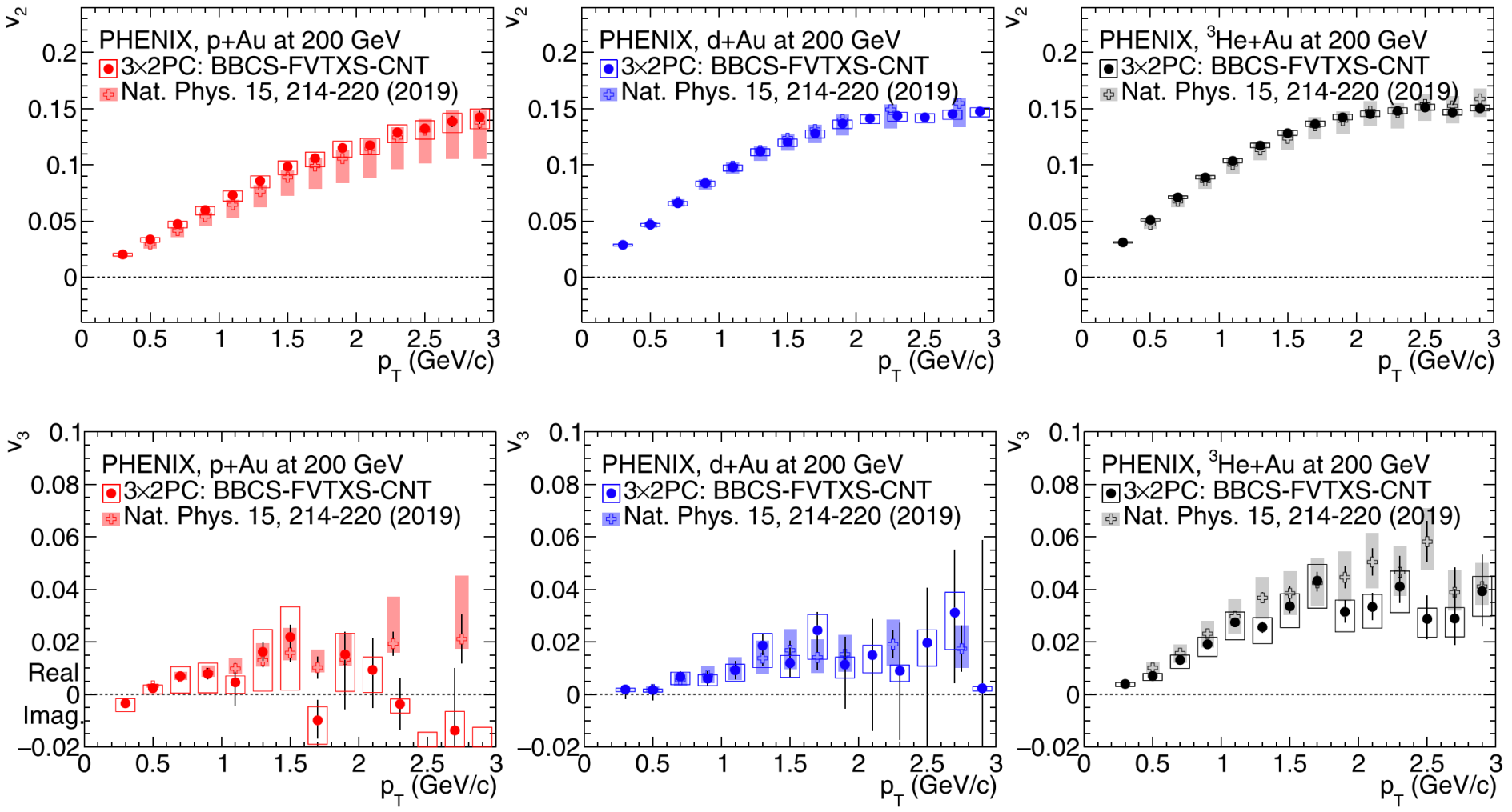
Unfolded charm and bottom hadron yields indicate the same trend

$$E^{c}_{loss} > E^{b}_{loss}$$

Result in agreement with the mass dependency of the radiative energy loss

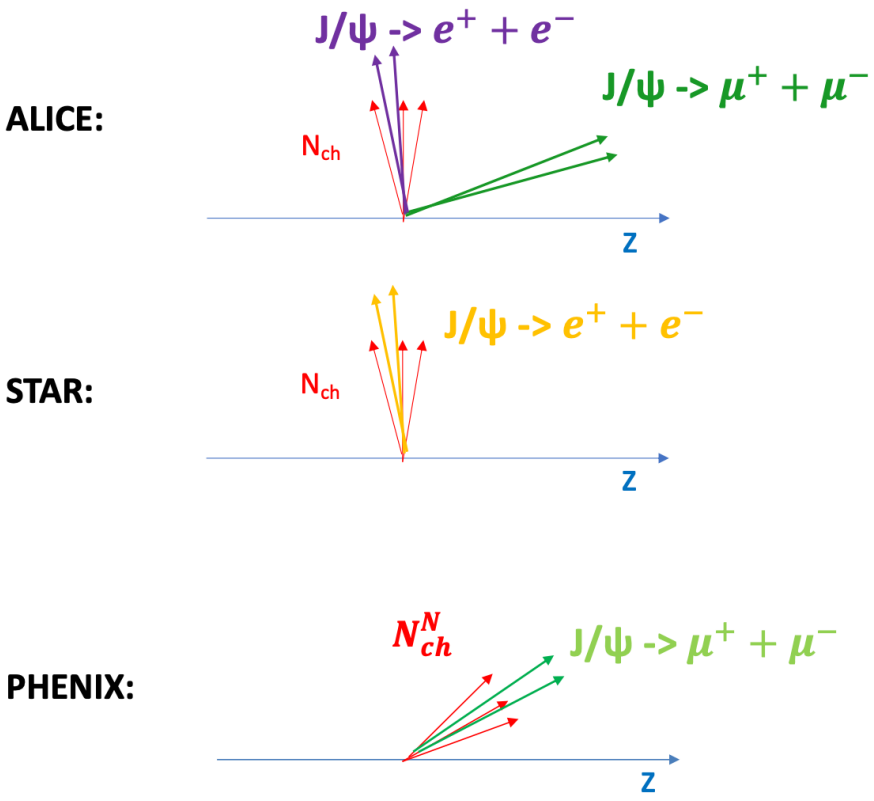
Collectivity in Small Systems

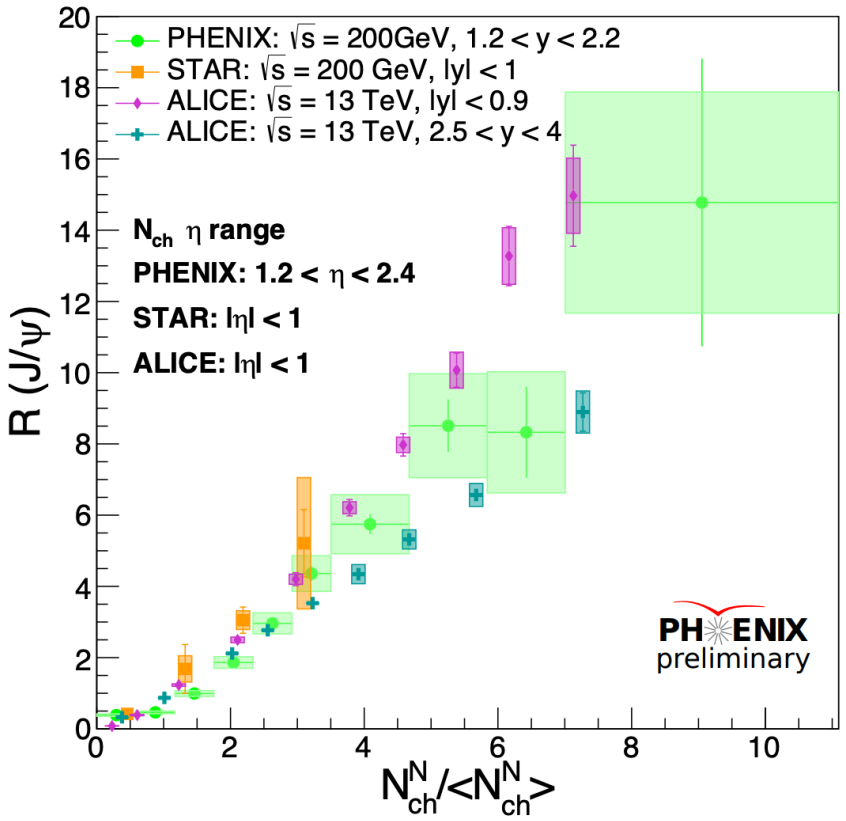
PRC 105, 024901 (2022)



Consistent results between 2PC and event plane methods.

Event multiplicity dependent J/ψ yield





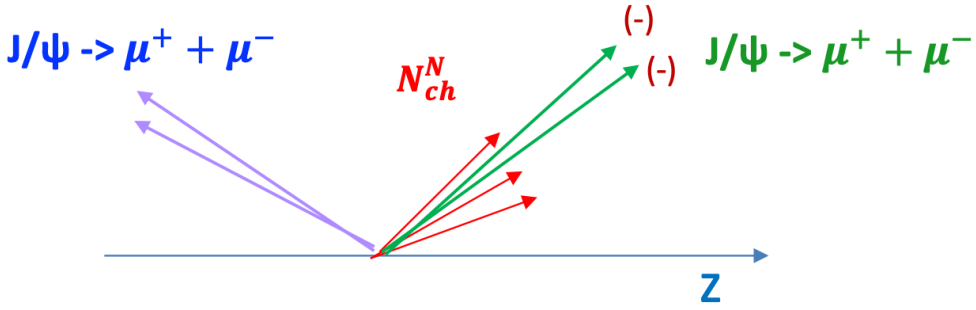
- Large dependence with local track multiplicity
- Result consistent with observations at ALICE and STAR
- Large slope attributed to multi-parton interactions in p+p collisions

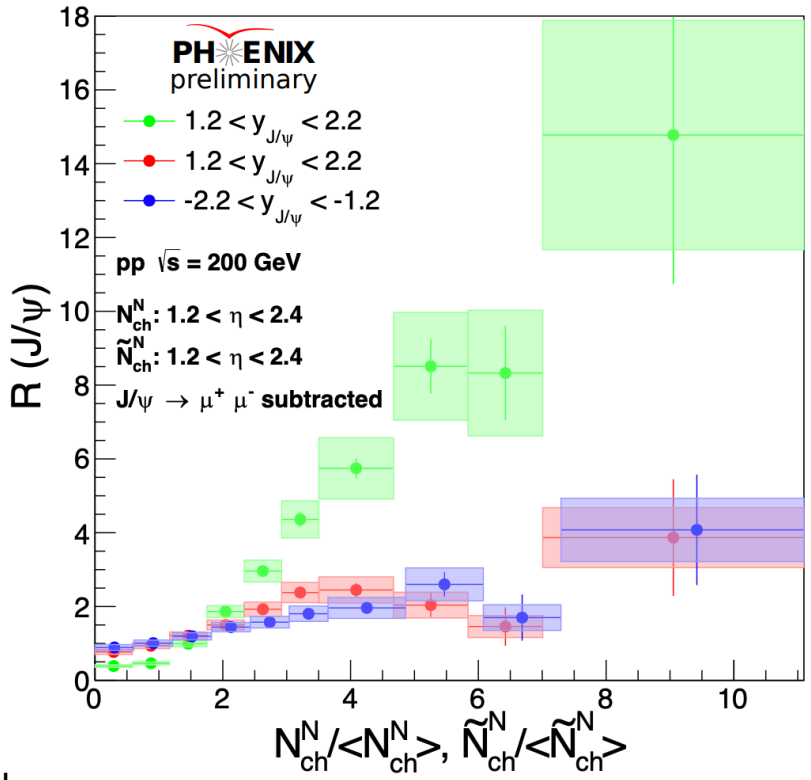
Event multiplicity dependent J/ψ yield

J/ψ and tracks in the same rapidity

J/ψ and tracks in the opposite rapidity

J/ψ and tracks in the same rapidity, tracks from J/psi removed from track count

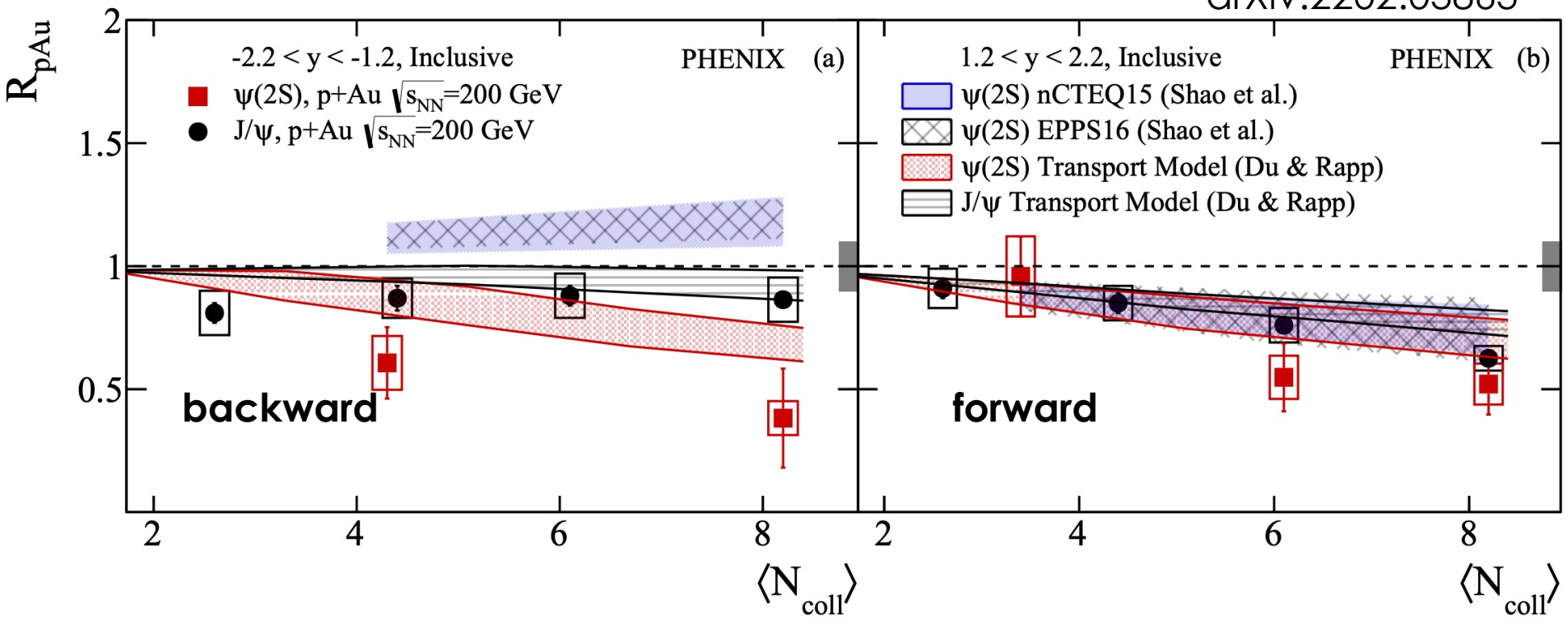




- large dependence significantly reduced when
  - removing tracks belonging to J/ψ or
  - Using non-local track multiplicity
- Is there still room for Multi-Parton Interactions ?
- Paper coming up soon

$\psi(2S)$ in p+Au

arXiv:2202.03863



- $\psi(2S)$ R_{pAu} consistent with J/ψ at forward rapidity where initial-state effects dominate
- $\psi(2S)$ is more suppressed than J/ψ at backward rapidity where final-state effects are important
- Results consistent with observations in LHC

Data and Analysis Preservation (DAP)

Knowledge management: analysis preservation is more than just software preservation

Minimum goal: reproducibility of (newly) published result (in principle "forever")

- new, standardized analysis notes (template-based), mandatory since 2020
- all analysis codes, macros, auxiliary files stored in HPSS since 2020
- published data uploaded in HEPData (since 2020)
- older publications uploaded retroactively
  currently 62 uploads from about 200 PHENIX publications, growing

Maximum goal: making re-analysis (with different conditions) possible "forever", in principle even for "outsiders"

- Docker/REAna ("Reproducible Analysis")
- high pT direct photons in d+Au) already implemented
- Plan to do the same with at least one of each signature PHENIX analysis
  (muons, dielectrons, spin asymmetry, hadron flow, etc.)

Availability: everything in github (private access) and Zenodo (public access)

First from RHIC to publish data and simplified analysis tools on CERN OpenData for the general public

All info available from the new "DAP website" https://www.phenix.bnl.gov/ in Analysis tab

Conclusions

- A still vibrant PHENIX collaboration despite competing efforts
- PHENIX physics program still unique in several studies of QCD and QGP
- Students who came after PHENIX ended of operation is still a vital part of PHENIX collaboration and responsible for much more discoveries

Thank you very much !!!