

PHENIX OVERVIEW

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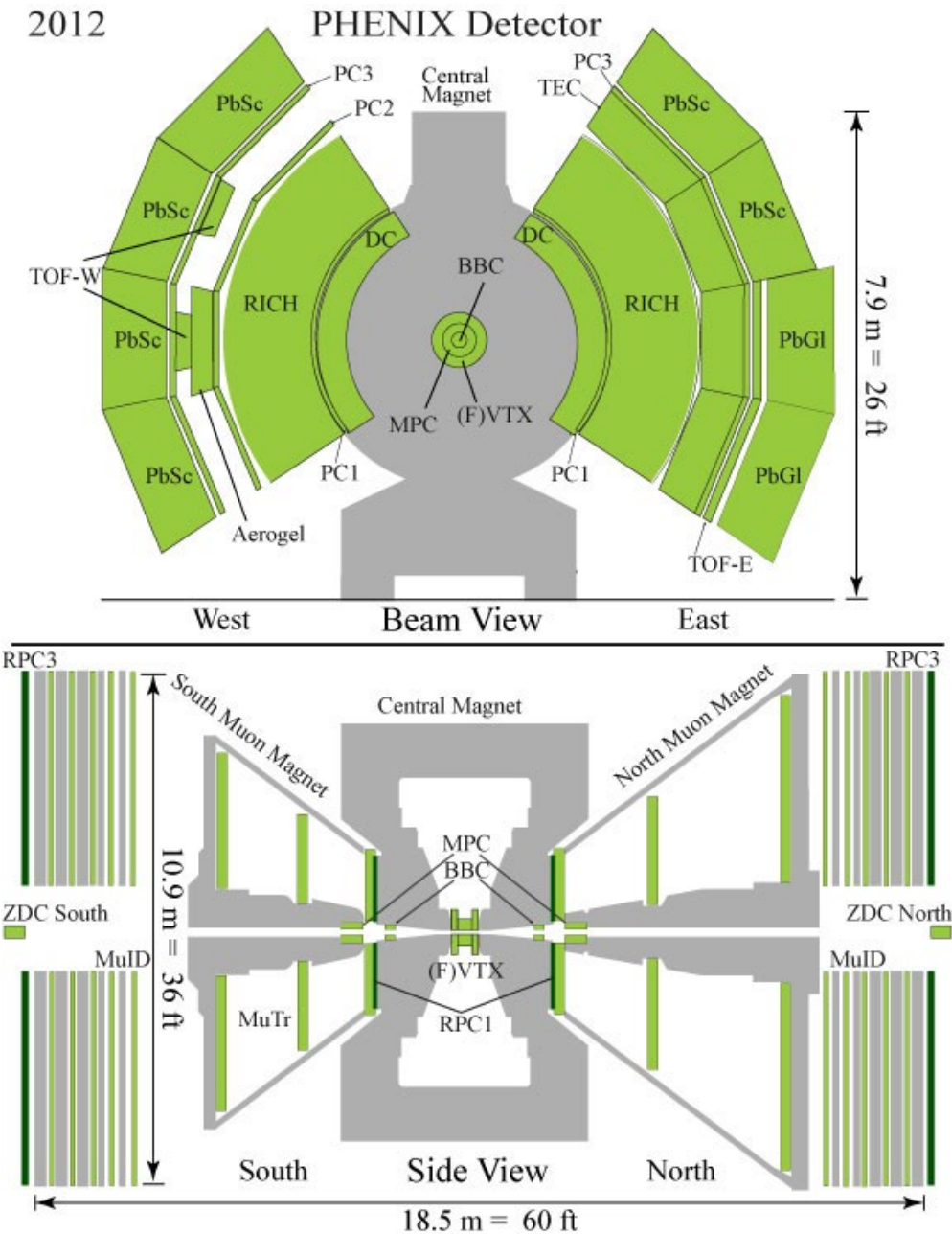


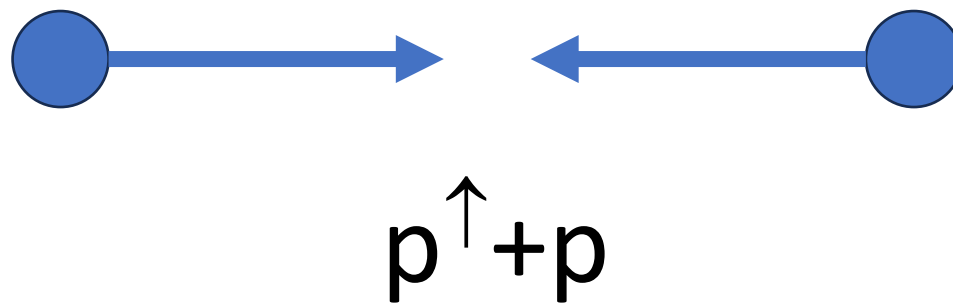
HP2024
NAGASAKI

THE PHENIX EXPERIMENT

- 9 collision species and 9 collision energies obtained
- Data taking completed in 2016
- Collaboration is actively working for analyses

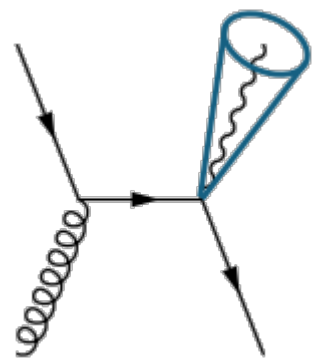
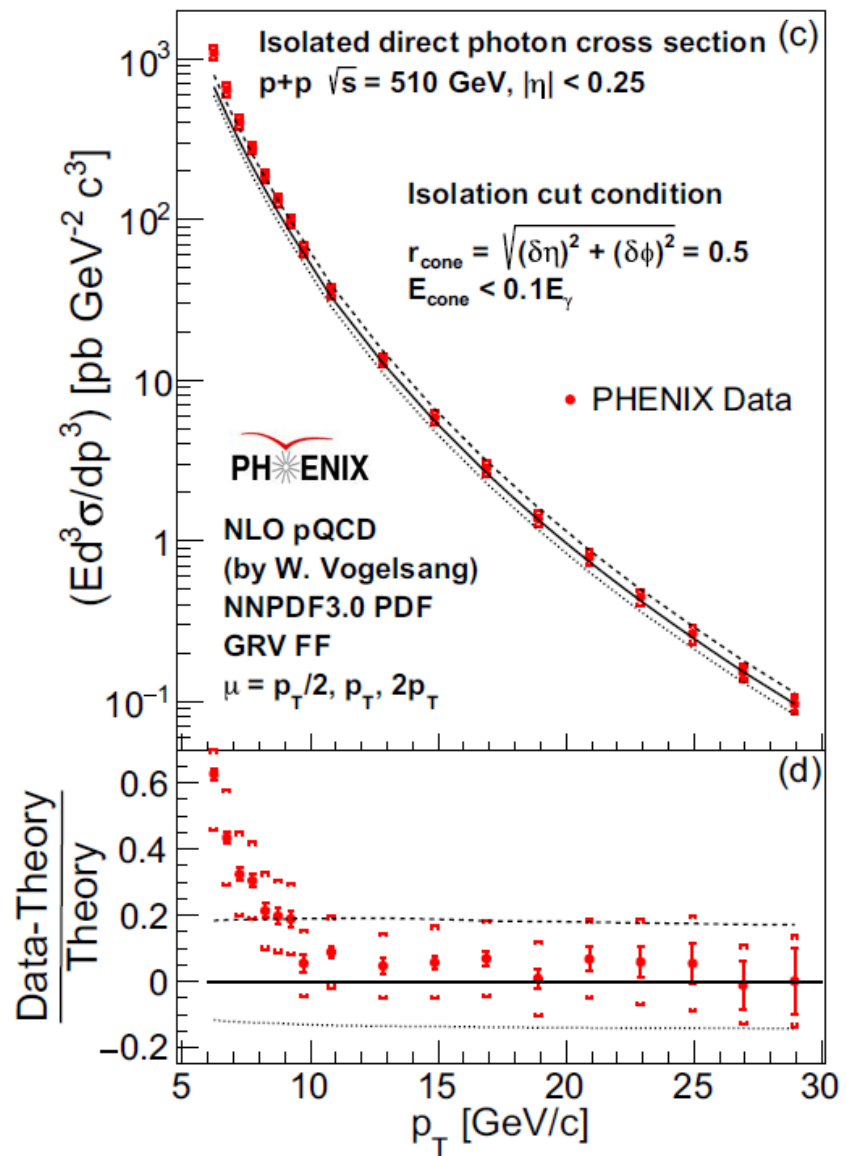
| $\sqrt{s_{NN}}$ [GeV] |  |  |  |  |  |  |  |  |  |  |
|-----------------------|---|---|---|---|---|---|--|---|---|---|
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| 200 | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
| 130 | | | | | | | | | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |
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| 7.7 | | | | <input checked="" type="checkbox"/> | | | | | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> |





Direct Photon in p+p 510GeV

Ralf Seidl (Mon. 14:40 nPDF)

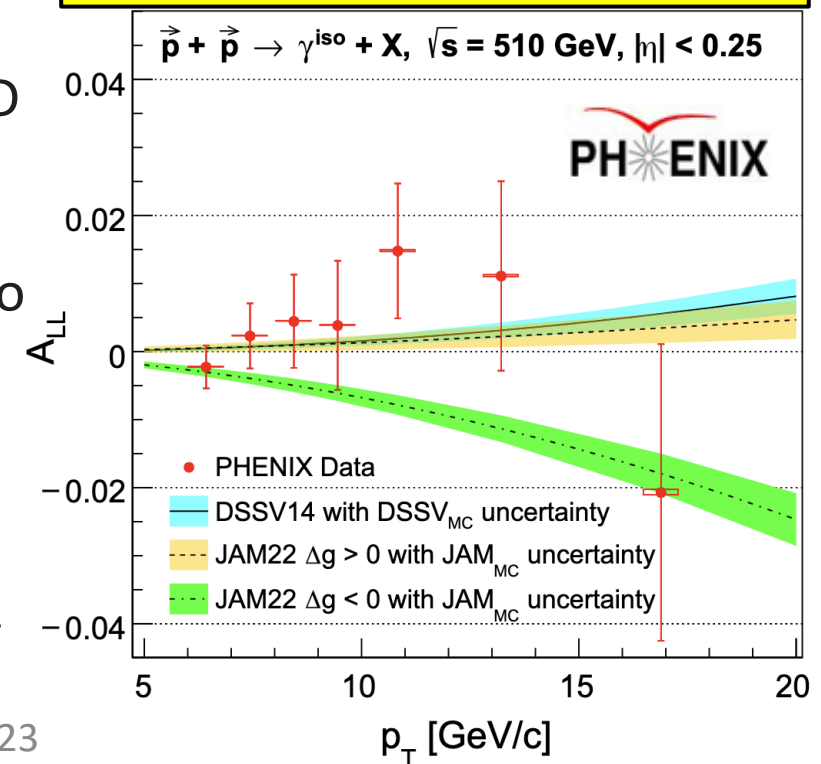


$$\frac{1}{2} = \frac{1}{2} \Sigma \Delta q + \Delta g + L$$

| | | | |
|-------------|------------|------------|--------------------------|
| Proton Spin | Quark Spin | Gluon Spin | Orbital Angular Momentum |
|-------------|------------|------------|--------------------------|

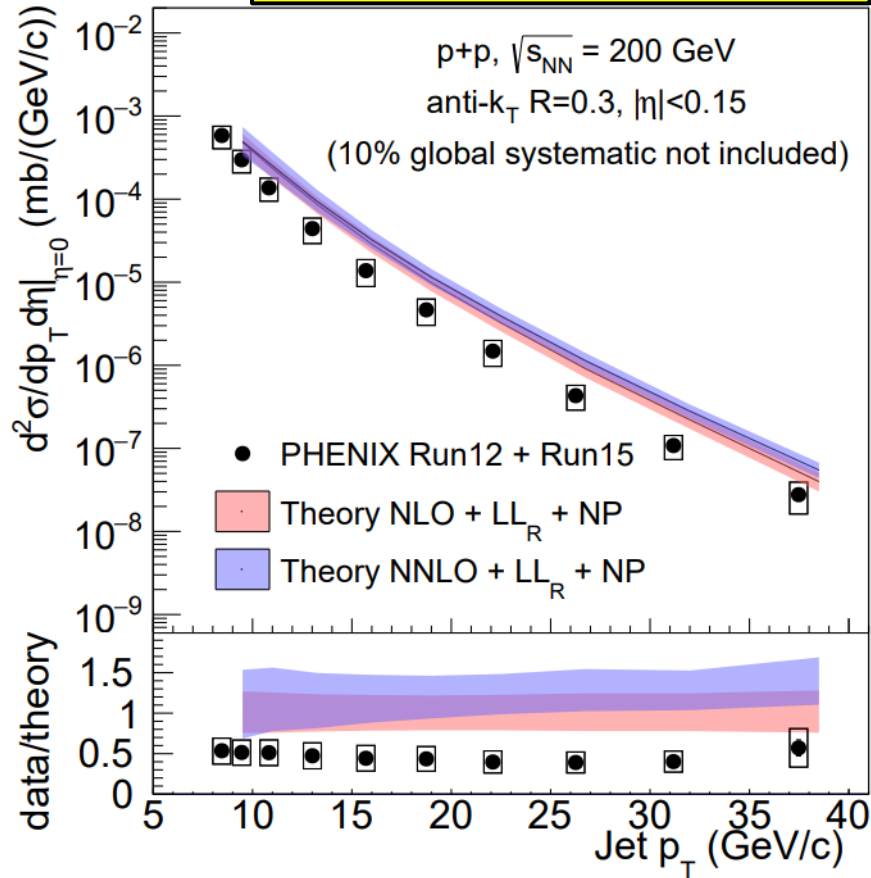
- Direct photon is sensitive to the gluons in proton
- Xsec is described by NLO pQCD
- Direct photon A_{LL} is sensitive to the sign of the gluon contribution
- **Gluon spin is aligned to the same direction of proton spin**

PHENIX, PRL 130, 251901 (2023)



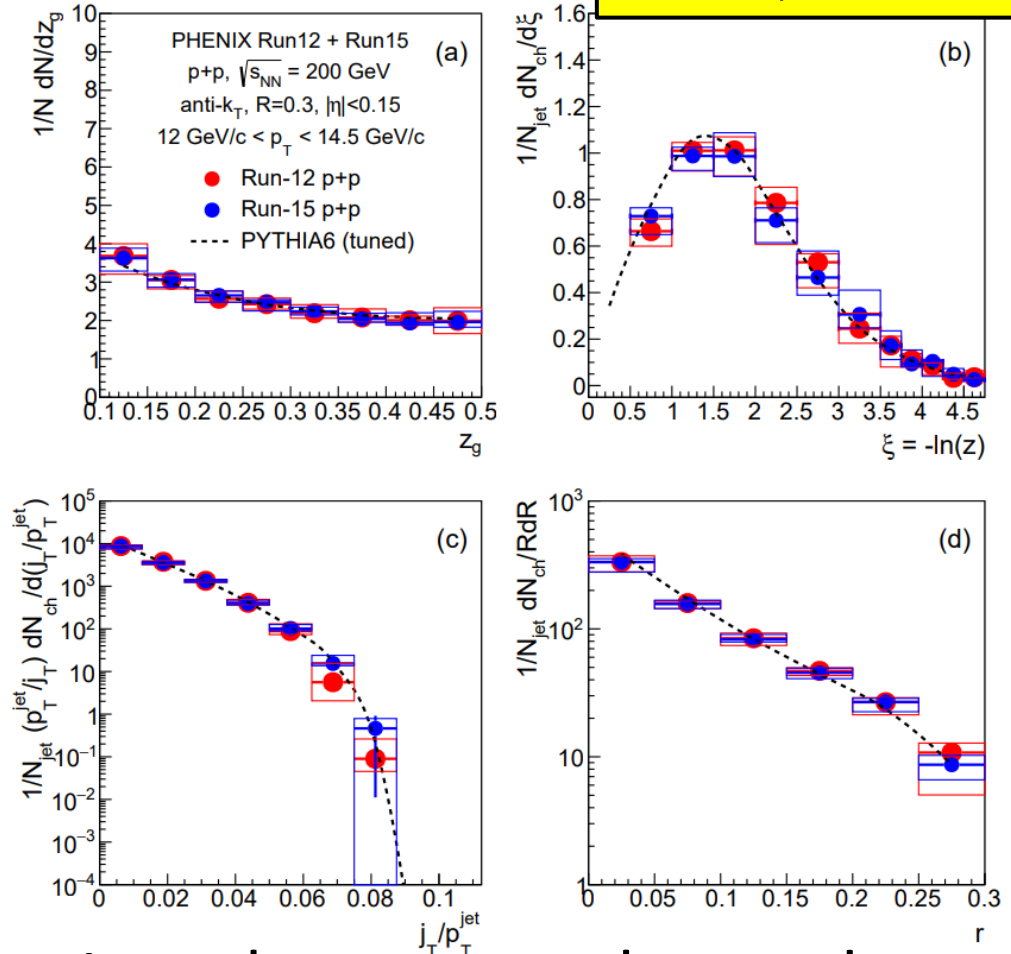
Jet cross section and substructure

PHENIX, arXiv:2408.11144



- Jet cross section with $R < 0.3$
- NLO + NP overestimates the data
 - Limitation of NP correction

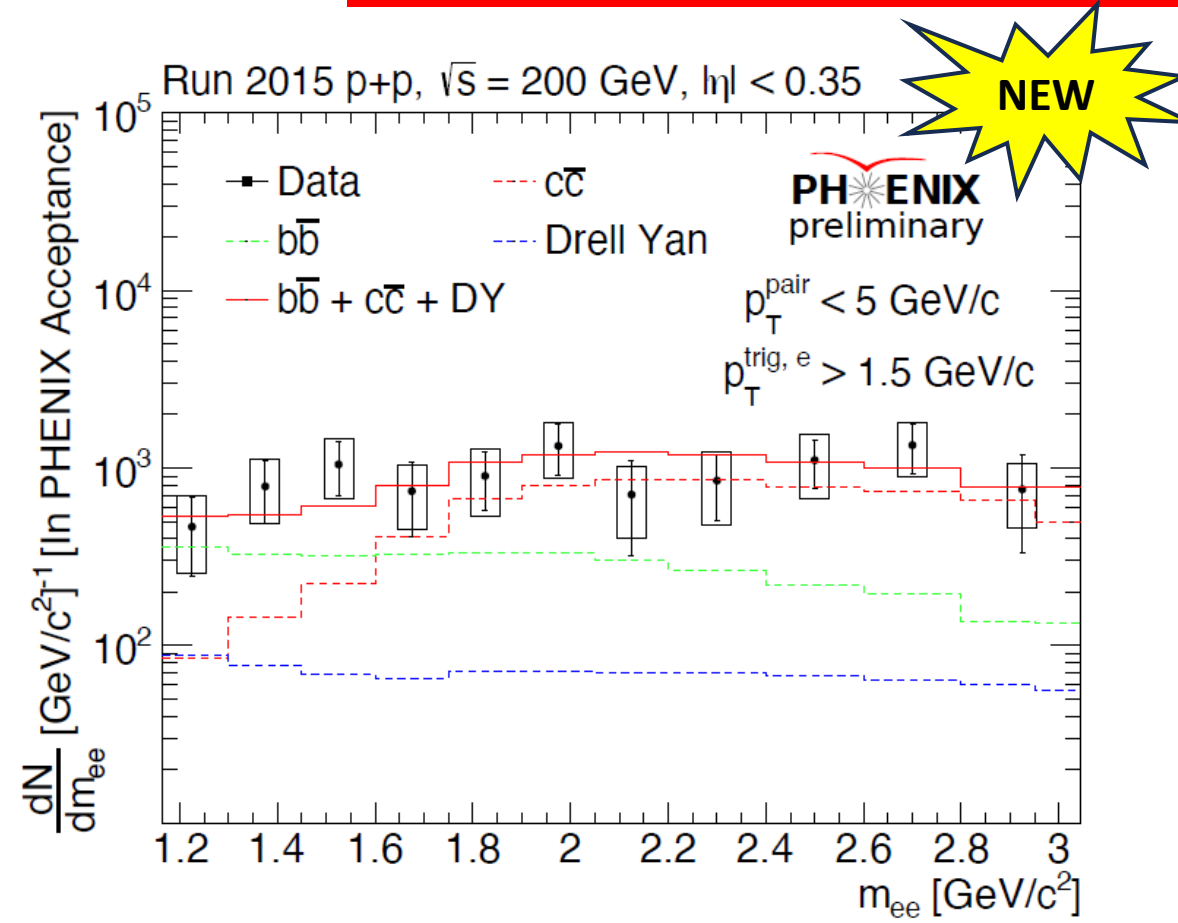
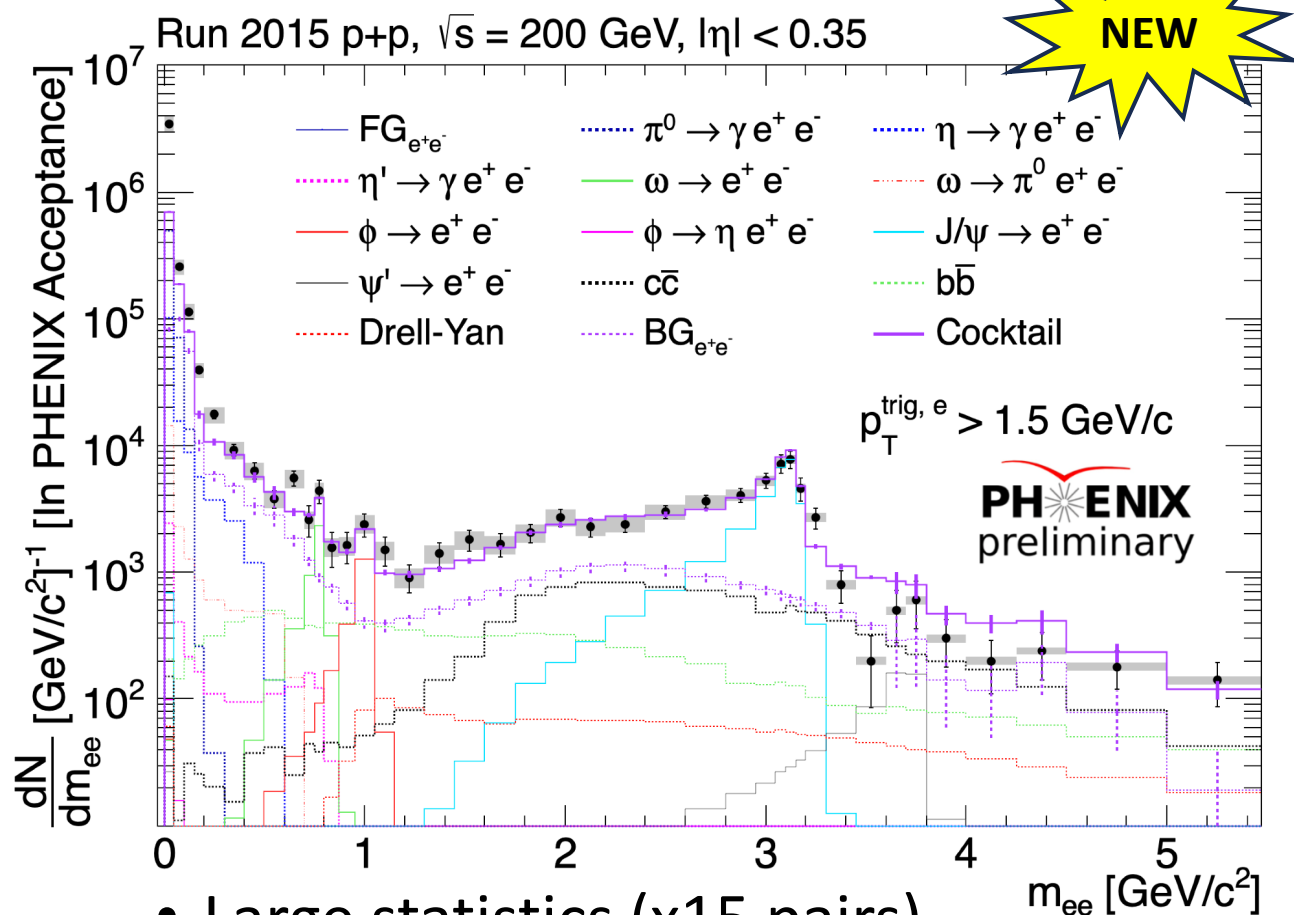
PHENIX, arXiv:2408.11144



- Jet substructure observed
- Tuned PYTHIA can reproduce the data

Dileptons in p+p 200GeV

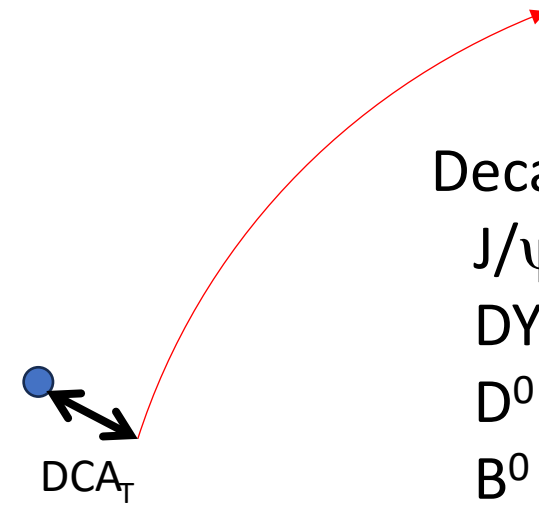
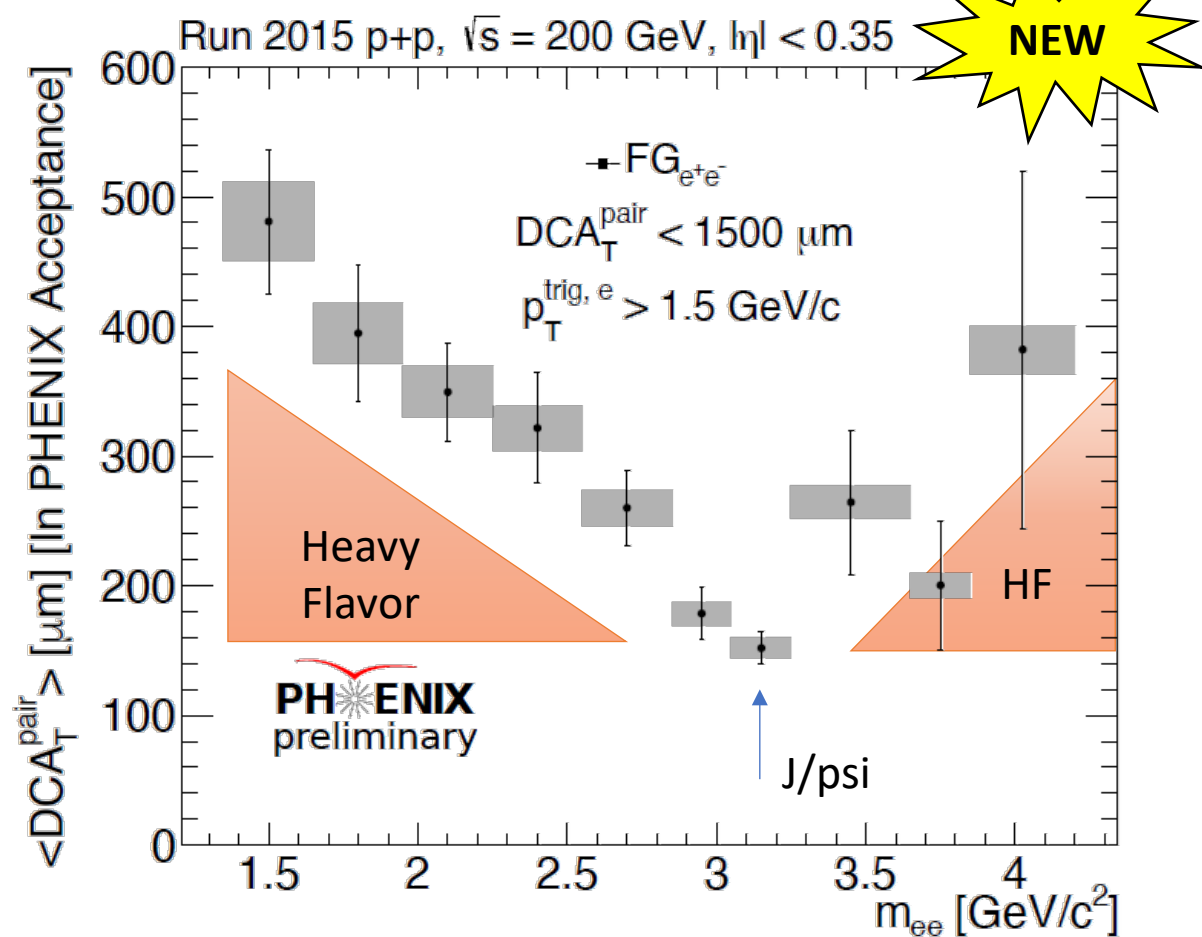
Vassu Doomra (Tue. 11:10 Thermal)



- Large statistics (x15 pairs)
- Good agreement with the cocktail calculation
- Baseline for thermal photons at IMR in Au+Au

Dileptons in DCA_T space

Vassu Doomra (Tue. 11:10 Thermal)



Decay length:

$J/\psi \sim 0 \mu m$

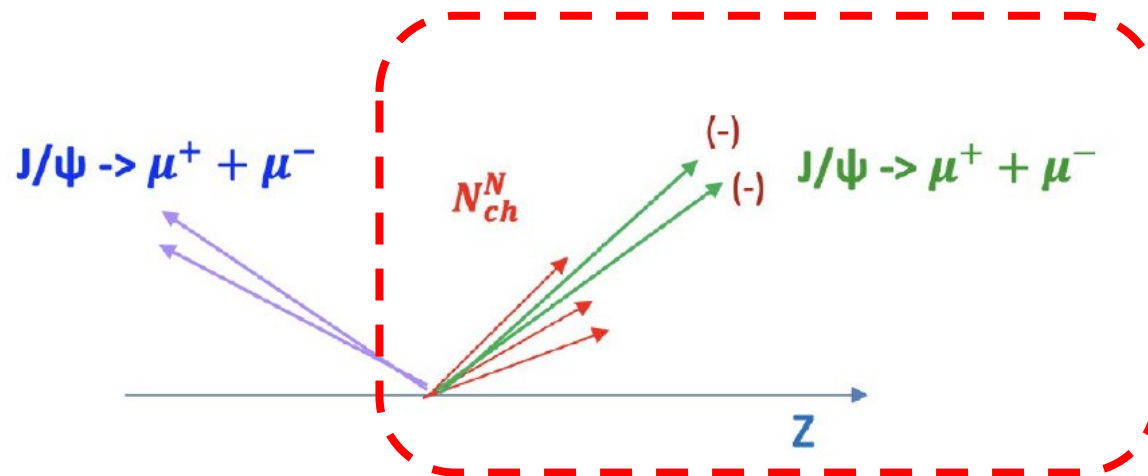
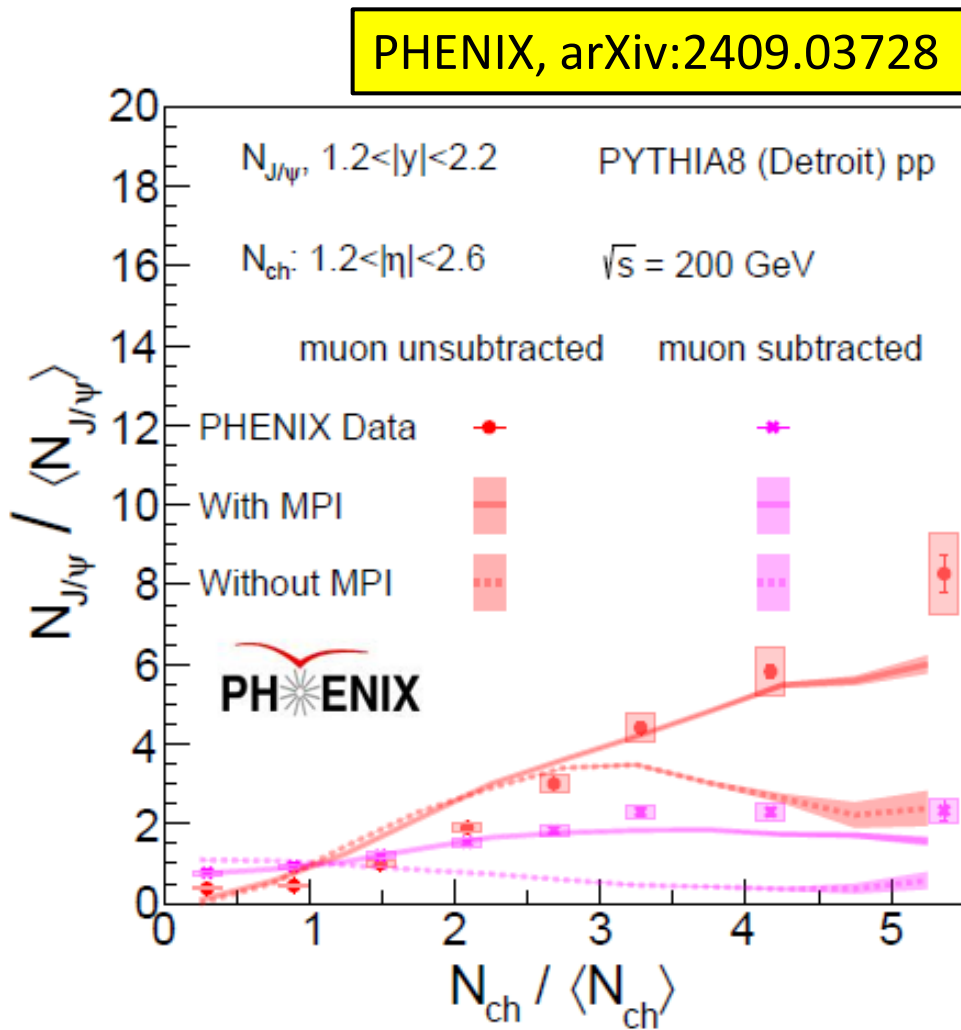
$DY \sim 0 \mu m$

$D^0 \sim 120 \mu m$

$B^0 \sim 450 \mu m$

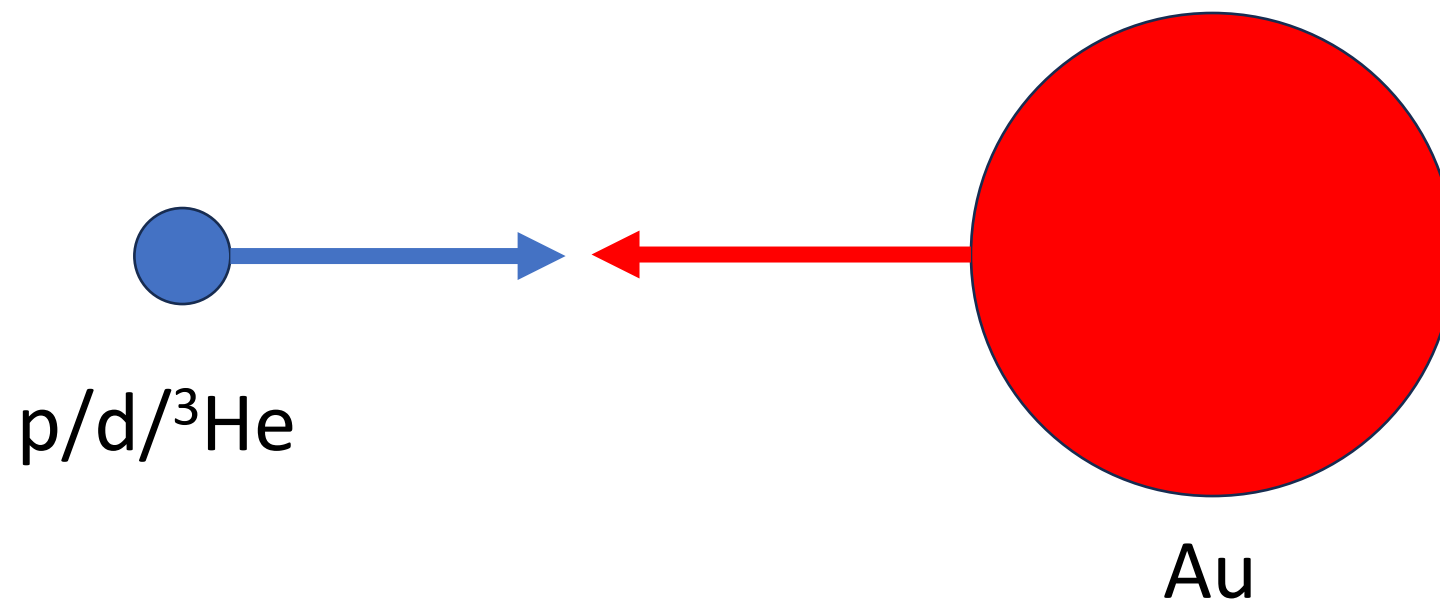
- Minimum DCA_T at J/ψ as expected
- Next step: separate Open HF from others using DCA, stay tuned

J/ψ vs N_{ch} in p+p

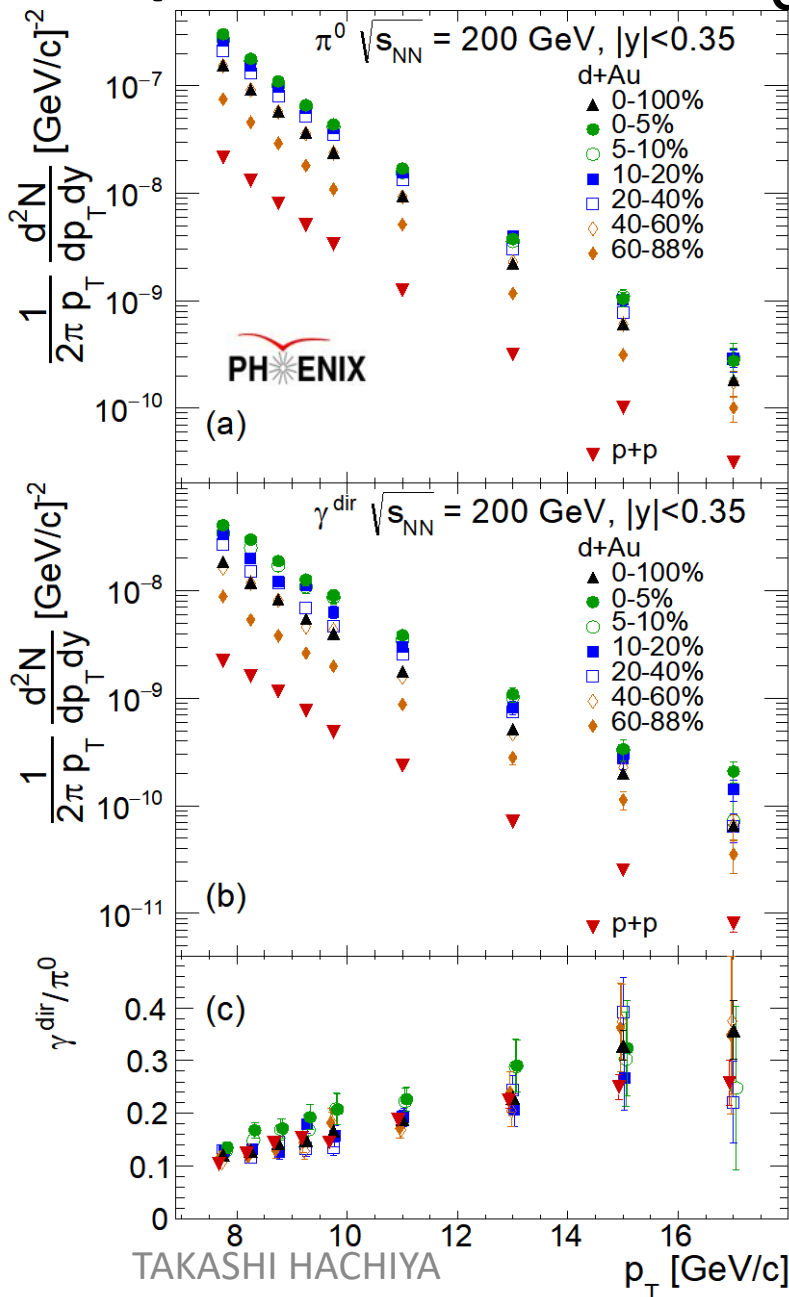


- J/ψ and charged particles going to the same rapidity window – J/ψ inside Jet
- J/ψ yield increasing with multiplicity
 - Less increasing by removing the $\mu^+ \mu^-$ from the multiplicity
- Data described by PYTHIA with MPI

Small System



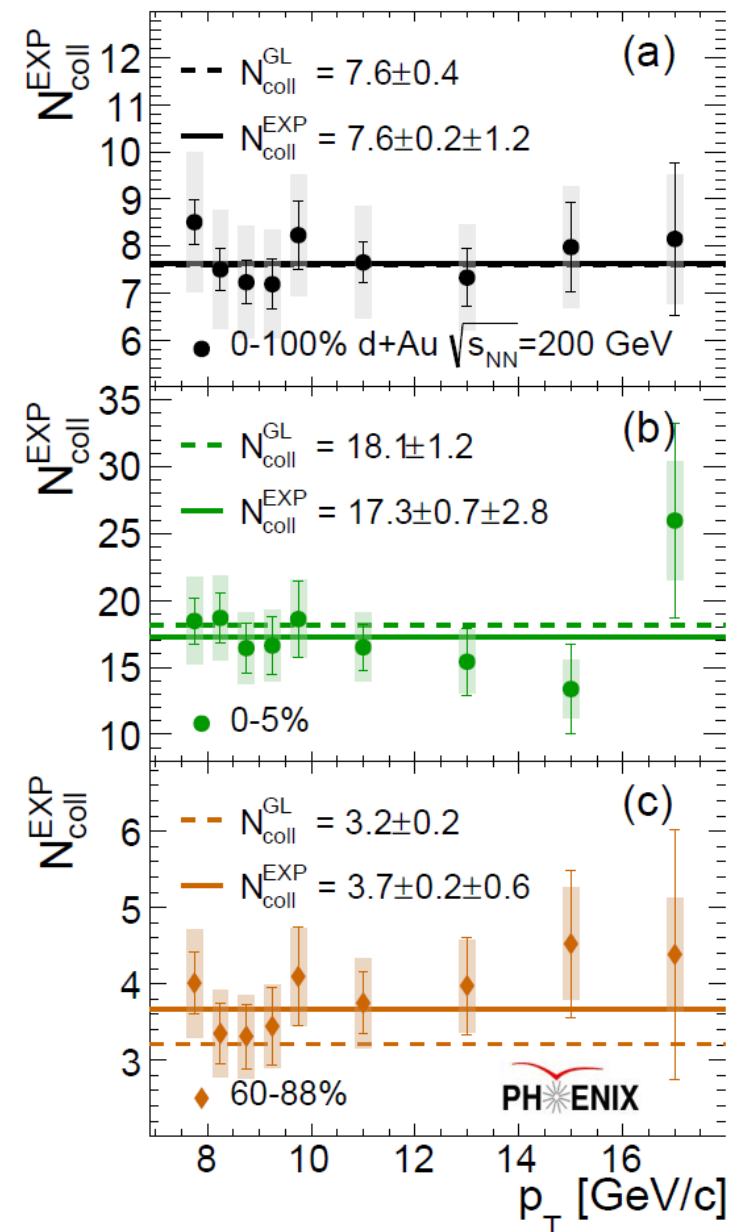
Experimental N_{coll} for d+Au



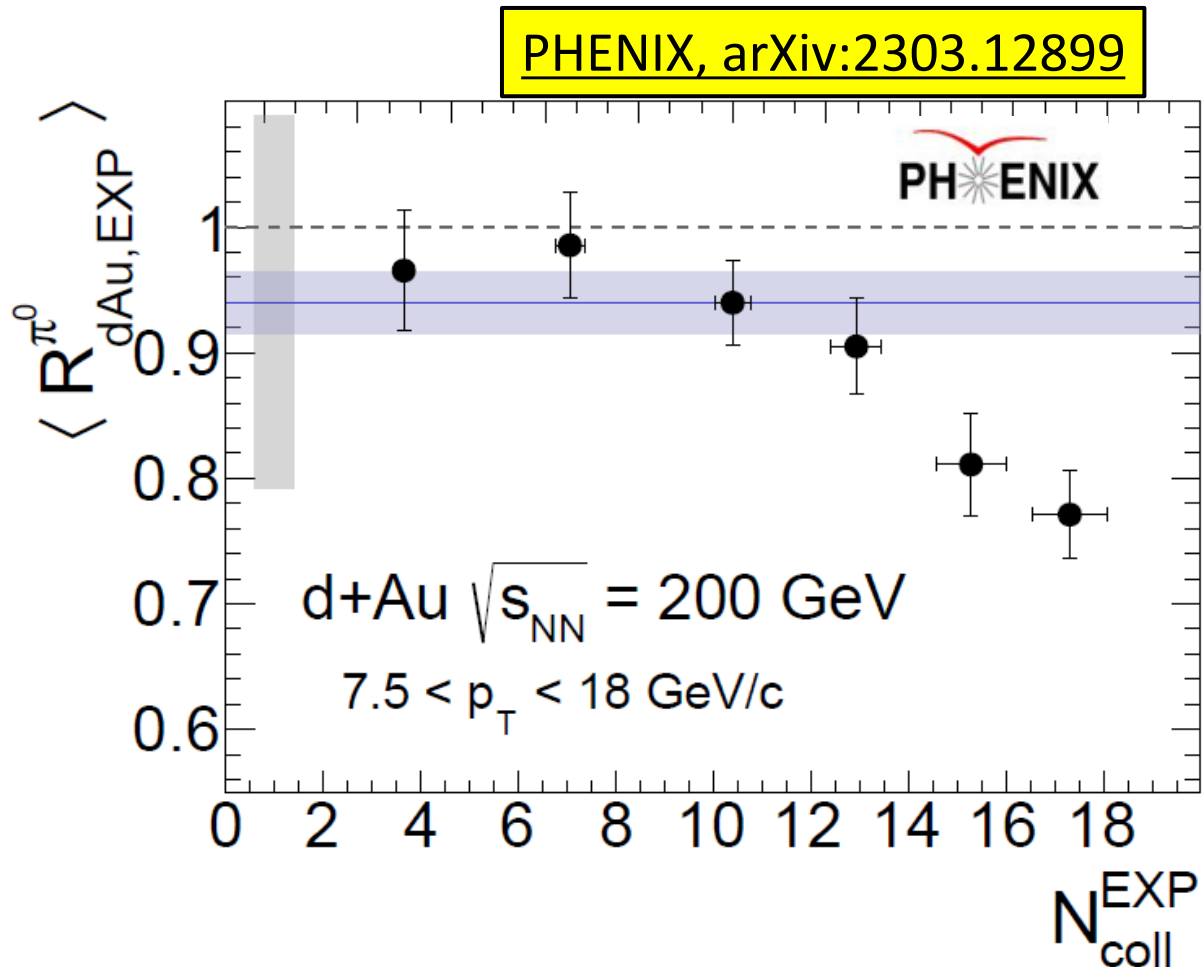
Since γ^{dir} produced by initial hard scattering, N_{coll} can be redefined by γ^{dir} ratio of d+Au to p+p experimentally

$$N_{\text{coll}}^{\text{EXP}}(p_T) = \frac{Y_{d\text{Au}}^{\gamma^{\text{dir}}}(p_T)}{Y_{pp}^{\gamma^{\text{dir}}}(p_T)}$$

PHENIX, arXiv:2303.12899



γ^{dir} and π^0 spectra in d+Au

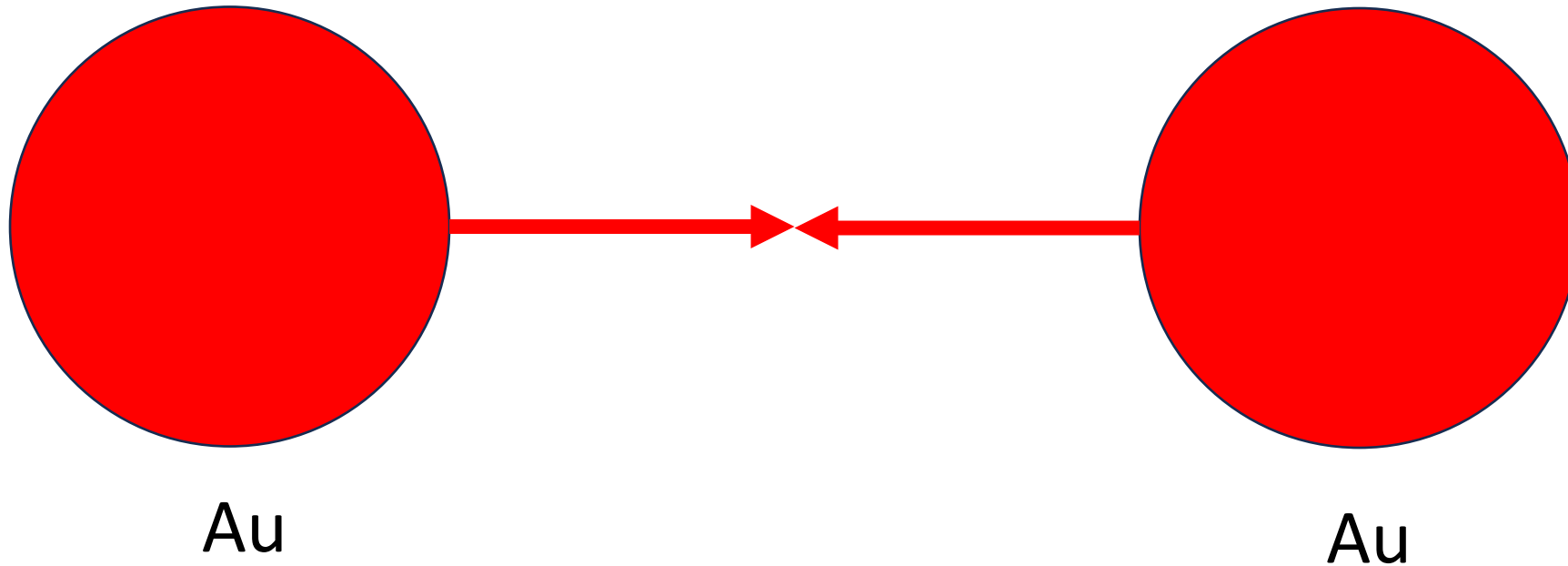


- No π^0 enhancement in peripheral
- π^0 suppression in central collisions

Other possible interpretation
e.g. D. Perepelitsa (Mon. 14:40)

- More results coming. Stay tuned

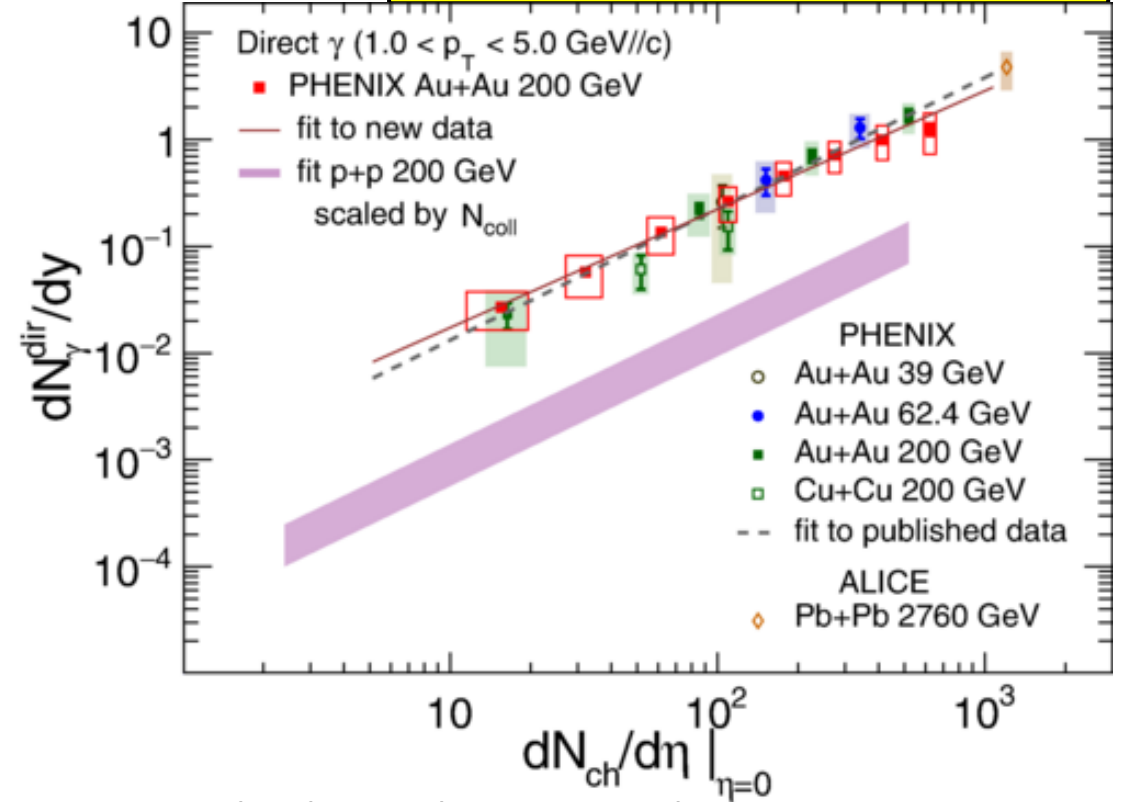
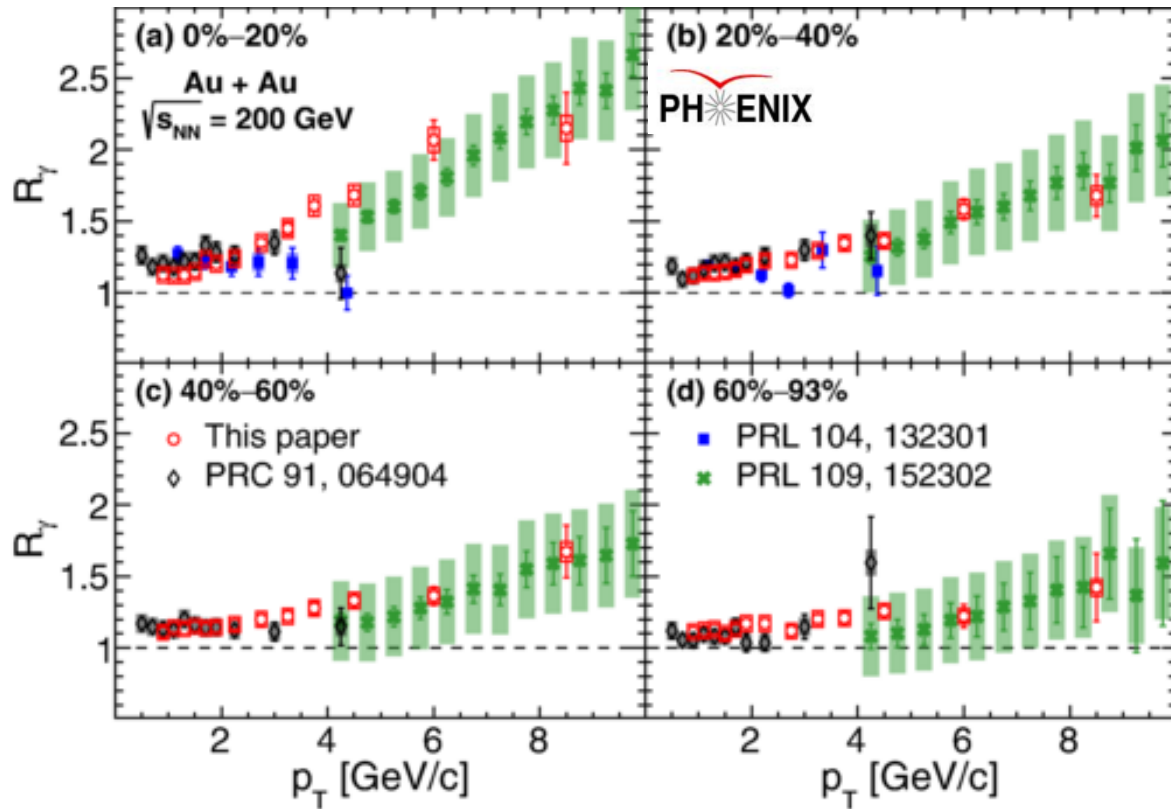
Large System A+A



Direct photons in Au+Au

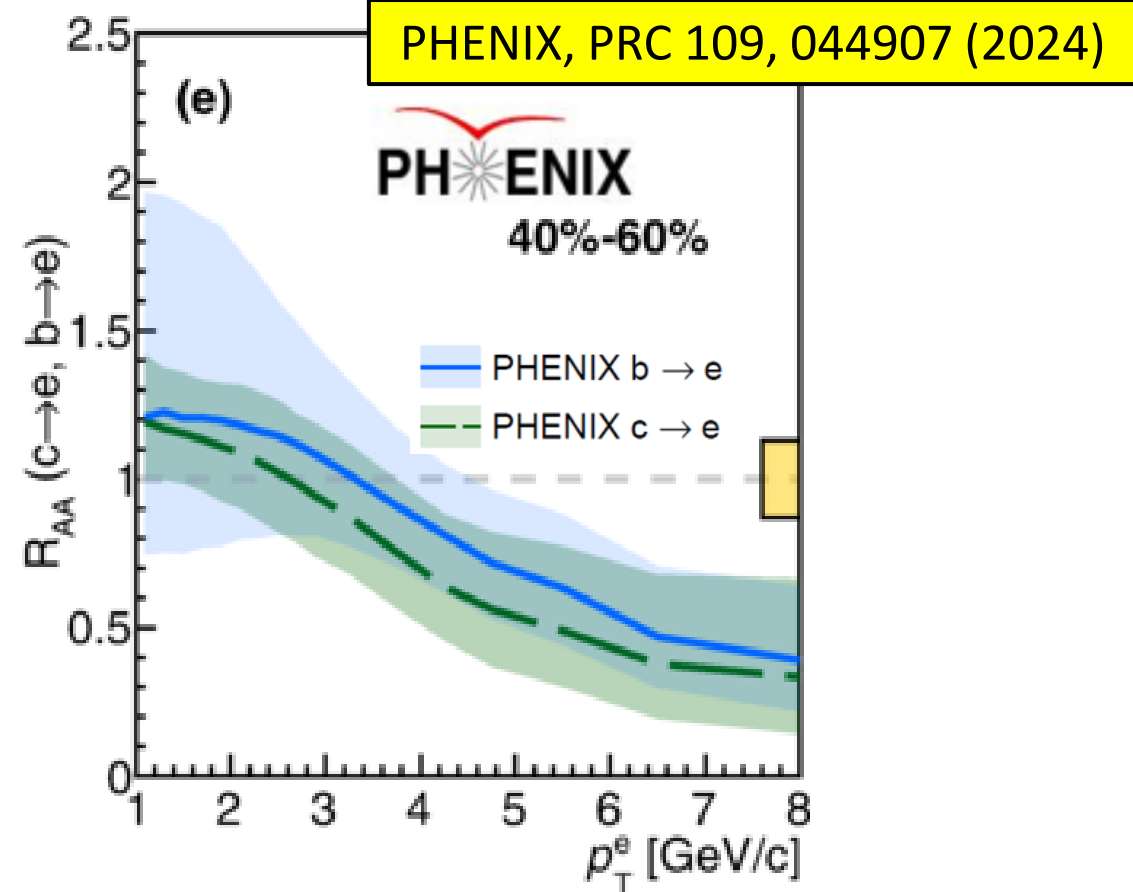
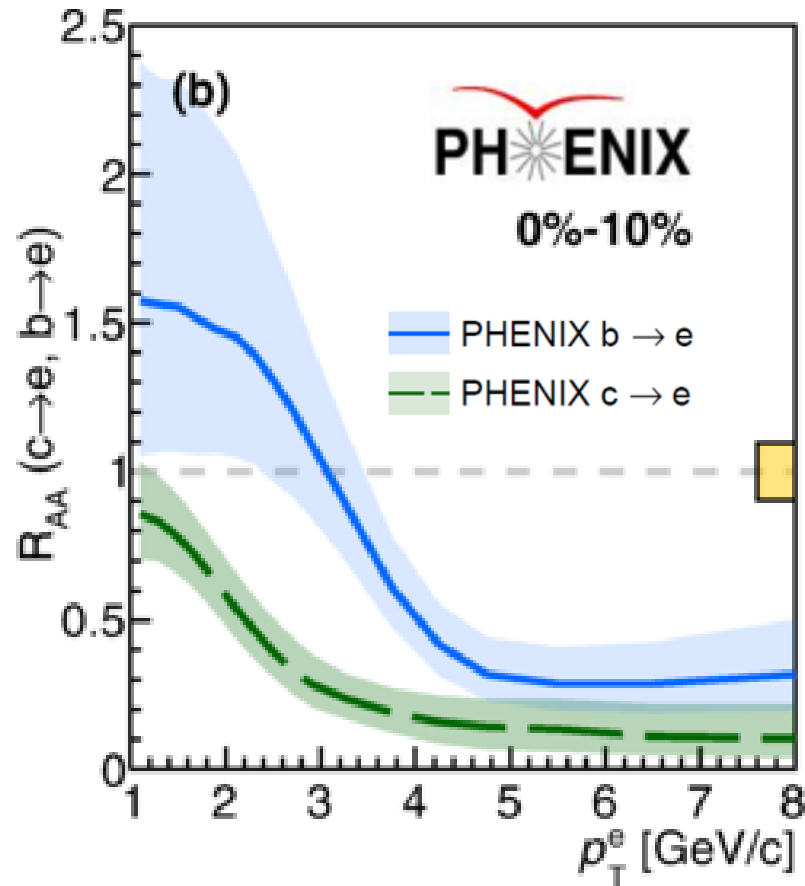
Vassu Doomra (Tue. 11:10 Thermal)

PHENIX, PRC 109, 044912 (2024)



- External conversion method and large statistics give precise measurement for wider p_T ranges for all centrality bins
- The scaling of yields holds for various large systems

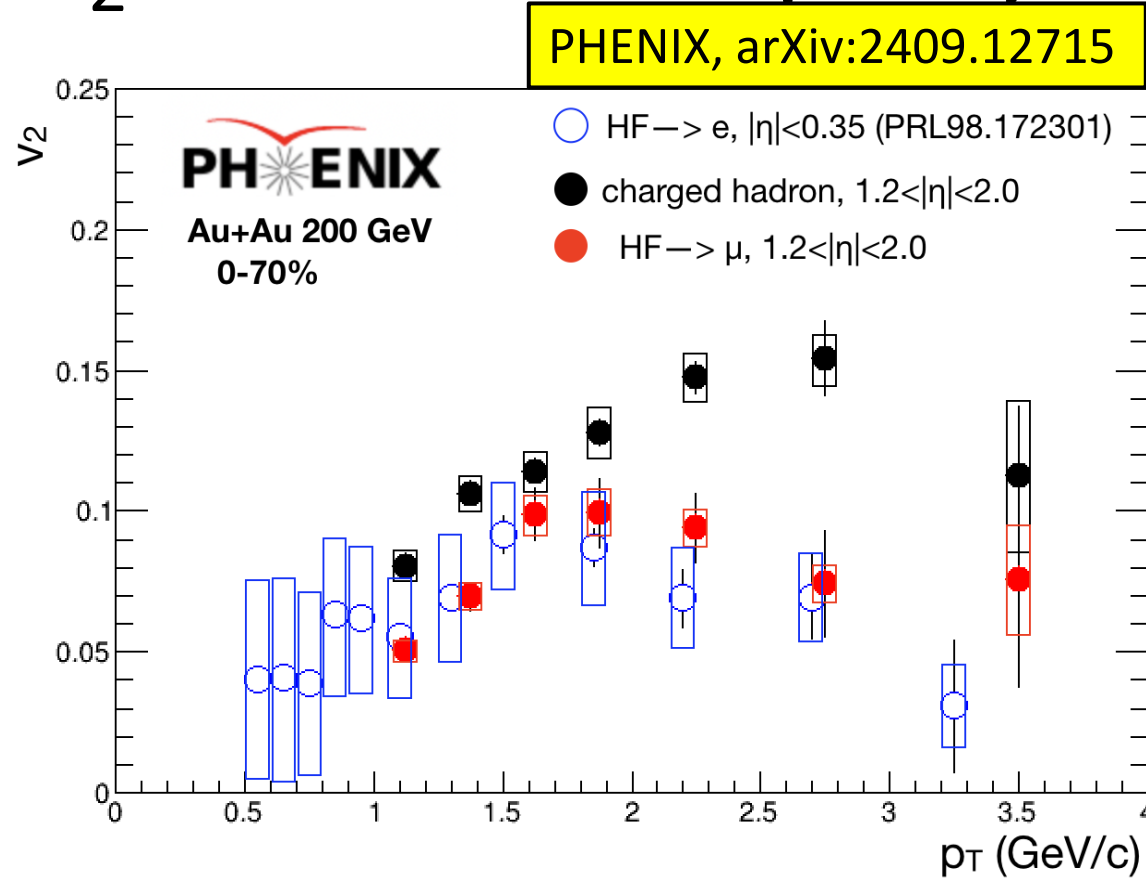
Centrality dependence of $R_{AA}(b \rightarrow e)$ & $R_{AA}(c \rightarrow e)$



- In 0-10%, bottom and charm suppression are clearly seen
- in 40-60%, bottom and charm are similar and less suppressed
- Centrality dependence is clearly seen

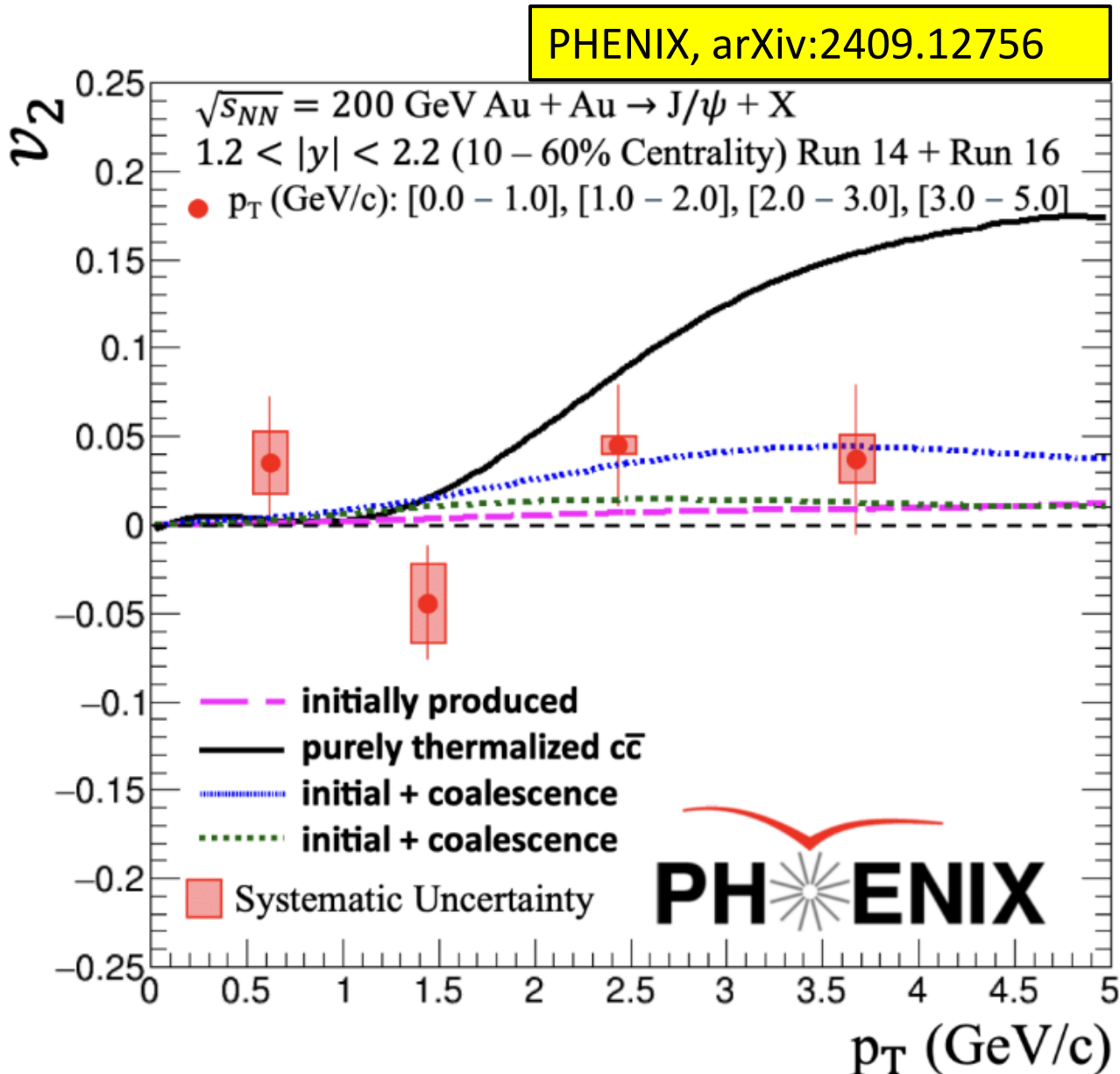
Heavy flavor v_2 at forward rapidity

Julia Velkovska (Mon. 16:30 HQ)



- First observation of significant heavy flavor v_2 at the forward rapidity
- Consistent with mid-rapidity HF results
- Smaller than charged hadron v_2

J/ψ v₂ at Forward rapidity



Forward J/ψ v₂ at RHIC is consistent with zero

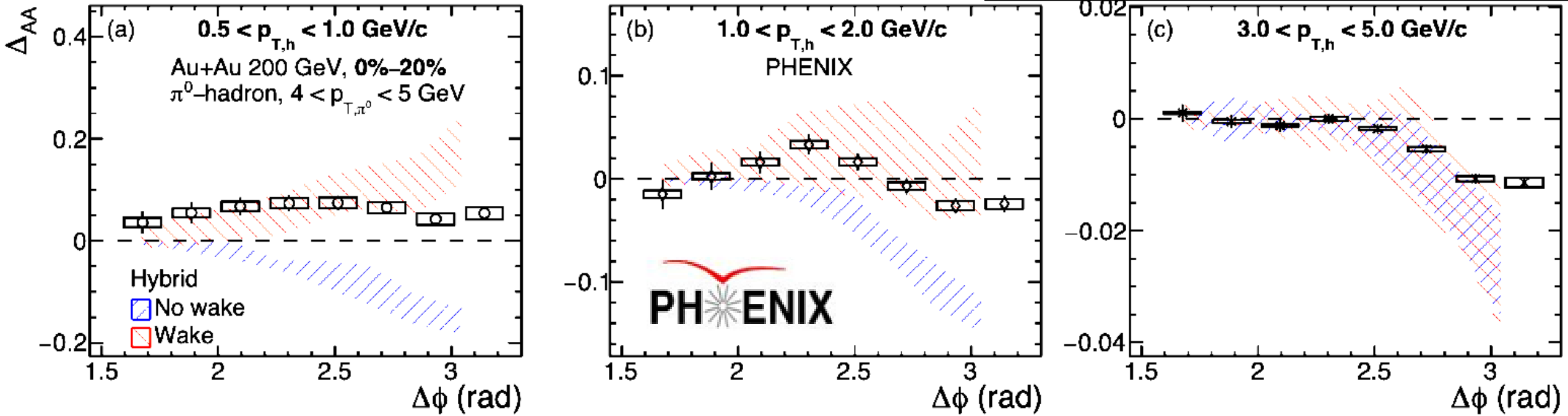
Coalescence in the partial thermalization also consistent with the data

Medium response to jets in Au+Au

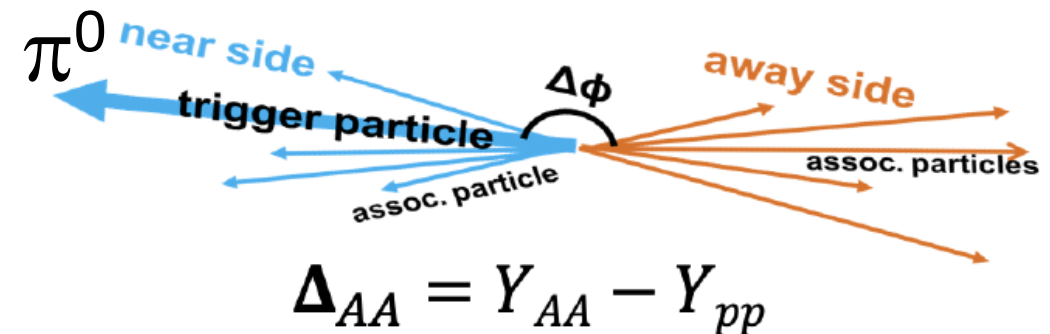
Anthony Hodges (poster #305)

Triggered π^0 $4 < p_T < 5$ GeV/c

PHENIX, PRC accepted (arXiv:2406.08301)



- Transition from suppression for high p_T enhancement for low p_T
- Hybrid model with medium response consistent with PHENIX results



- PHENIX Talks
 - **Ralf Seidl (Mon. 14:40 nPDF)** PHENIX cold QCD and spin physics results
 - **Julia Velkovska (Mon. 16:30 HQ)** Elliptic flow measurements of light and heavy flavor hadrons, and J/ψ in Au+Au collisions at forward rapidity with PHENIX
 - **Vassu Doomra (Tue. 11:10 Thermal)** Measurements of direct photons and dileptons at PHENIX
 - **Daniel Firak (Tue. 15:35 Jet in Sm. Sys)** Measurement of high p_T direct photon and neutral pions in small collision systems at PHENIX
- PHENIX Posters
 - **Susumu Sato (#283)** Measurement of identified charged-hadron and π^0 production in $p + Al$, $3He + Au$, $Cu + Au$, and $U + U$ collisions at PHENIX
 - **Anthony Hodges (#305)** Quantifying in-medium jet structure modification and medium response with direct photon and π^0 triggered hadron correlations in PHENIX

Summary

PHENIX produces many interesting results of **Direct photon, Dilepton, Heavy flavor**, and **Jet** results in small and large system

- P+P
 - Direct photon production consistent with NLO pQCD and Gluon spin likely to be positive
 - Jet cross section and substructure
 - New dilepton measurement with large statistics
- Small System
 - Suppression in central d+Au but no enhancement in peripheral
- Au+Au
 - Direct photon v_2 with large statistics
 - Different R_{AA} for $c \rightarrow e$ and $b \rightarrow e$
 - Significant HF v_2 at forward rapidity for the first time at RHIC
 - Zero v_2 for J/ψ unlike LHC result
 - Medium response via 2 particle correlation

More interesting and important measurements from PHENIX coming soon!

Recent publications

- arXiv:2406.08301 Jet modification via π^0 -hadron correlations in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV
- PRC109, 044912 (2024) Non-prompt photons in Au+Au $\sqrt{s_{NN}} = 200$ GeV
- PRC109, 044907 (2024) Charm and bottom production in Au+Au $\sqrt{s_{NN}} = 200$ GeV
- PRC109, 054910 (2024) Identified charged hadron production in p+Al, $^3\text{He}+\text{Au}$, and Cu+Au at $\sqrt{s_{NN}} = 200$ and U+U at $\sqrt{s_{NN}} = 193$ GeV
- PRD108, 072016 (2023) Transverse spin asymmetry of h in p+p, p+Al, and p+Au $\sqrt{s_{NN}} = 200$ GeV
- PRL130, 251901 (2023) Direct photon cross section in p+p $s = 510$ GeV
- PRD107, 112004 (2023) Transverse spin asymmetry of 0, in p+Al and p+Au $\sqrt{s_{NN}} = 200$ GeV
- PRD107, 052012 (2023) Transverse spin asymmetry of heavy flavor decay electrons
- PRC107, 024914 (2023) Low p_T in Au+Au at $\sqrt{s_{NN}} = 39$ and 62.4 GeV
- PRC107, 024907 (2023) Flow in p+p, p+Al, d+Au, $^3\text{He}+\text{Au}$ $\sqrt{s_{NN}} = 200$ GeV
- PRC107, 014907 (2023) ϕ in Cu+Au and U+U $\sqrt{s_{NN}} = 200$ GeV
- arXiv:2303.12899 Suppression of high p_T π^0 relative to direct in central d+Au $\sqrt{s_{NN}} = 200$ GeV

PHENIX results in HEPData!!

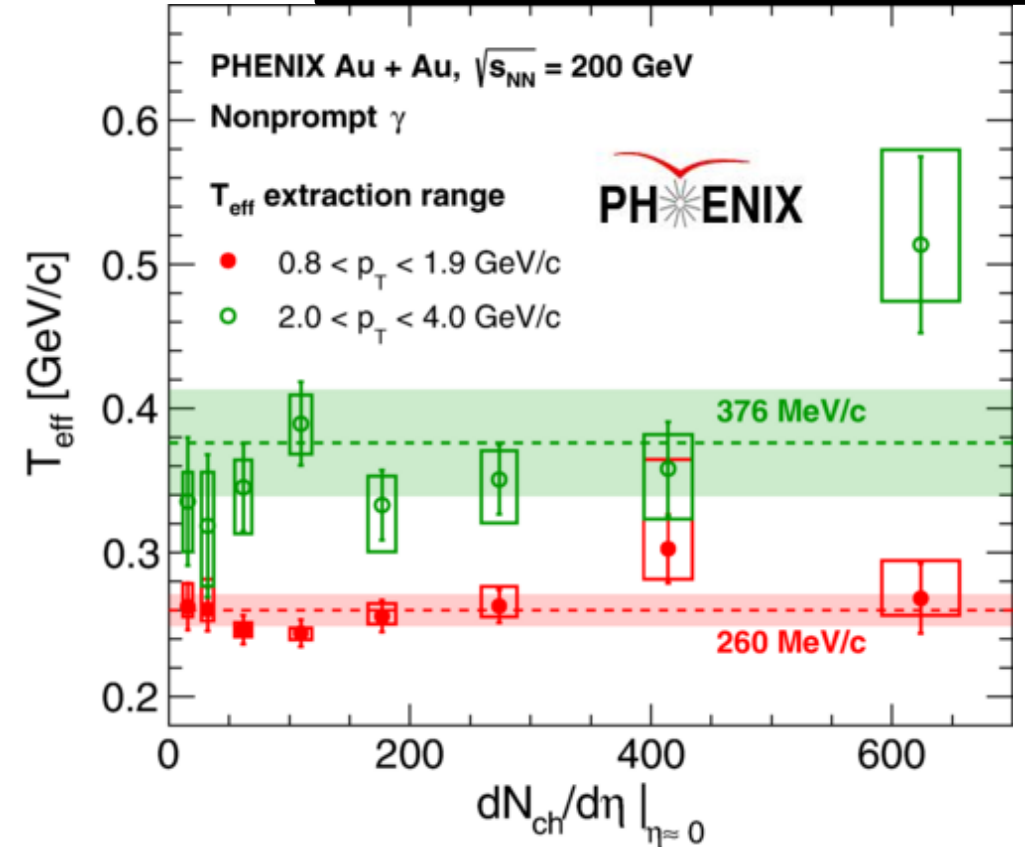
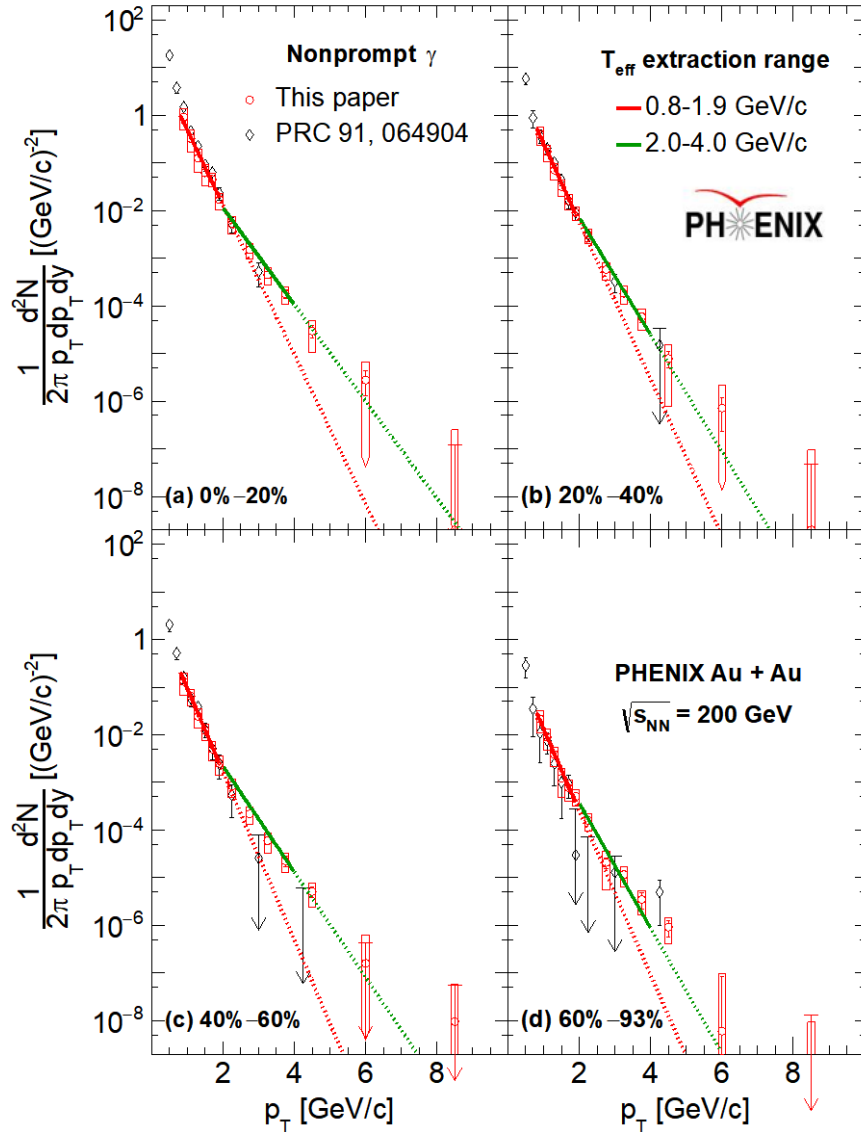
- 213 papers are in the database and ready to use!

The screenshot shows the HEPData website interface. At the top left is the HEPData logo. On the right, there are links for 'About', 'Submission Help', 'File Formats', and 'Sign in'. Below the logo is a search bar with the text 'Search HEPData'. To the right of the search bar are filters for 'PHENIX' and '[2000, 200...'. A 'Search' button and an 'Advanced' link are also present. Below the search bar, there are controls for 'Max results', 'Sort by', and 'Reverse order'. The text 'Showing 10 of 213 results' is displayed. On the left side, there is a histogram showing the distribution of results by date, with a 'Date' label and a 'Reset' link. Below the histogram is a 'Collaboration' filter with a 'Reset' link and a count of '213'. A red circle highlights the '213' count, and a red arrow points from the top left towards it. Below the histogram, there are 'Subject_areas' filters for 'nucl-ex' (176) and 'TAKASHI HACHIYA'. The main content area shows a search result for a paper titled 'Transverse single-spin asymmetry of midrapidity π^0 and η mesons in p +Au and p +Al collisions at $\sqrt{s_{NN}} = 200$ GeV'. The authors listed are 'The PHENIX collaboration Abdulameer, N.J.; Acharya, U.; Aidala, C.; et al.'. The paper is cited as 'Phys.Rev.D 107 (2023) 112004, 2023.' and has an Inspire Record 2641468 and DOI 10.17182/hepdata.139098. The abstract states: 'Presented are the first measurements of the transverse single-spin asymmetries (A_N) for neutral pions and eta mesons in p +Au and p +Al collisions at $\sqrt{s_{NN}} = 200$ GeV in the pseudorapidity range $|\eta| < 0.35$ with the PHENIX detector at the Relativistic Heavy Ion Collider. The asymmetries are consistent with zero, similar to those for midrapidity...'. There are '2 data tables' associated with the paper. A figure caption reads: 'Figure 2 Data from Figure 2 (a) of the π^0 transverse single-spin asymmetry in $\sqrt{s_{NN}} = 200$ GeV p^\dagger +Au and p^\dagger +Al collisions as a function of p_T .'

T_{eff} of non-prompt photons

Vassu Doomra (Tue. 11:10 Thermal)

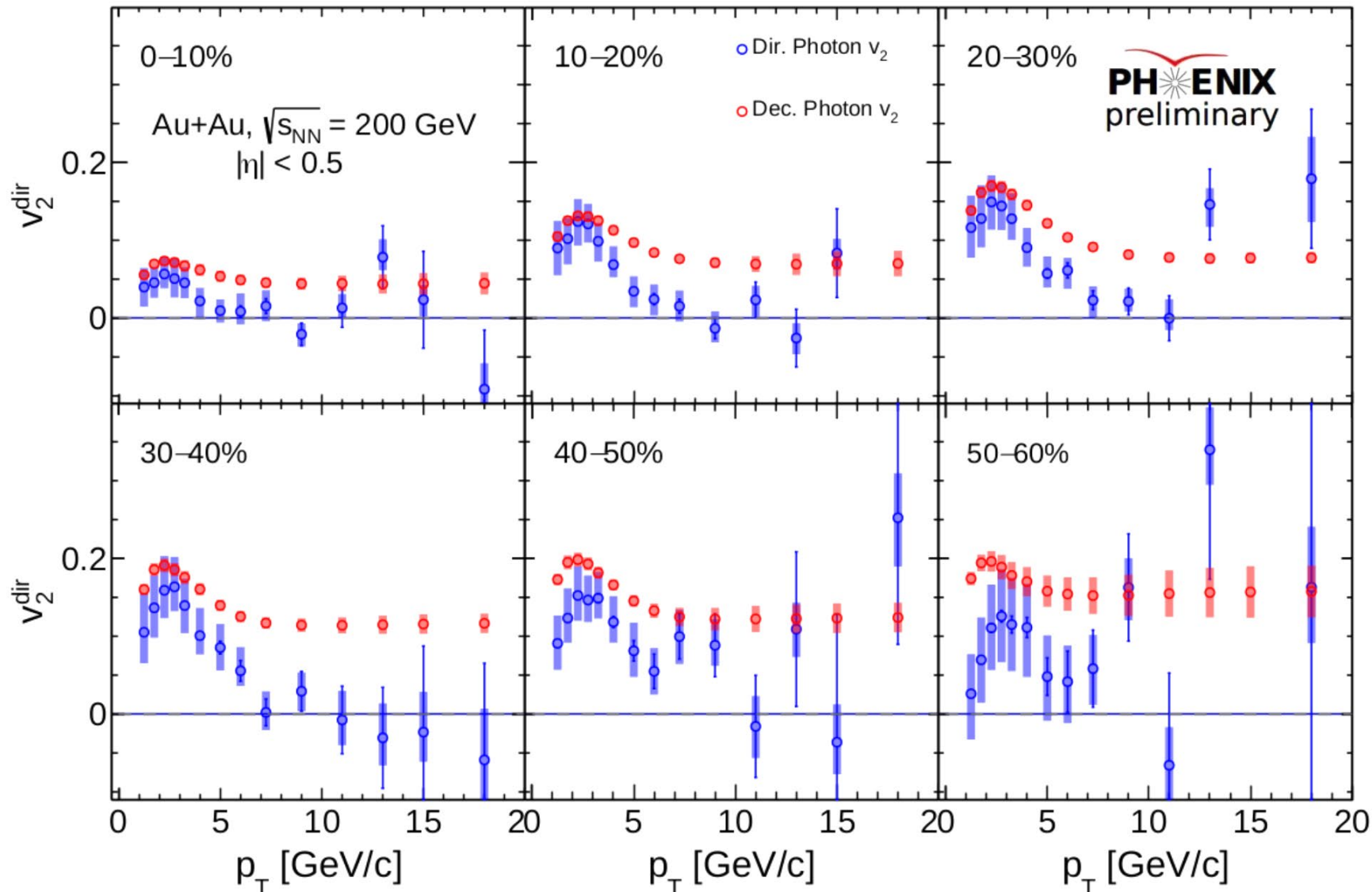
PHENIX, PRC 109, 044912 (2024)



T_{eff} of non-prompt photons has p_T dependence
 but no obvious multiplicity dependence
 Slope is 1.11 ± 0.02 (stat) ± 0.09 (sys)

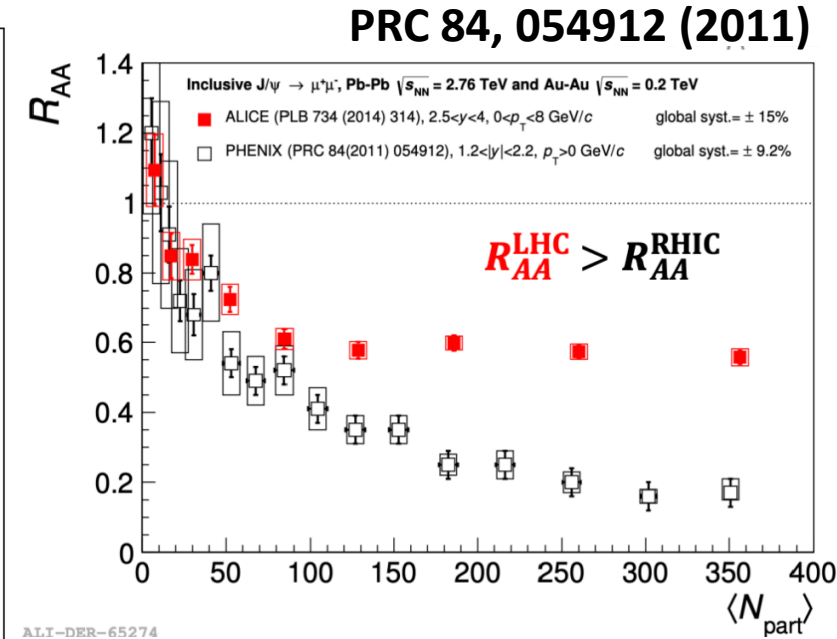
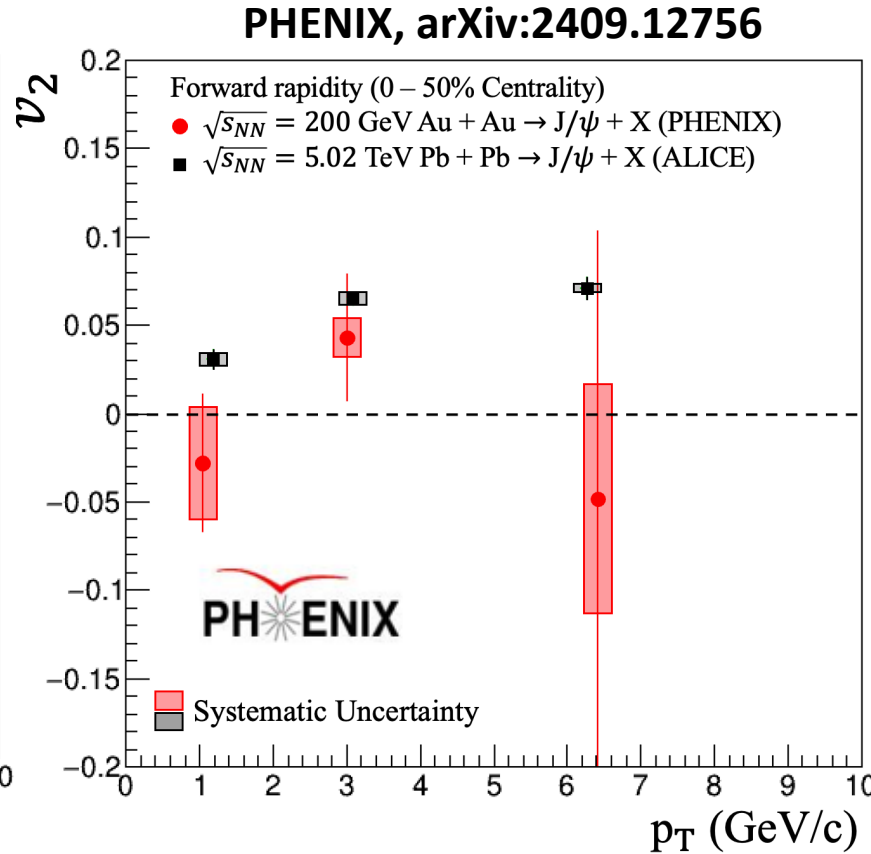
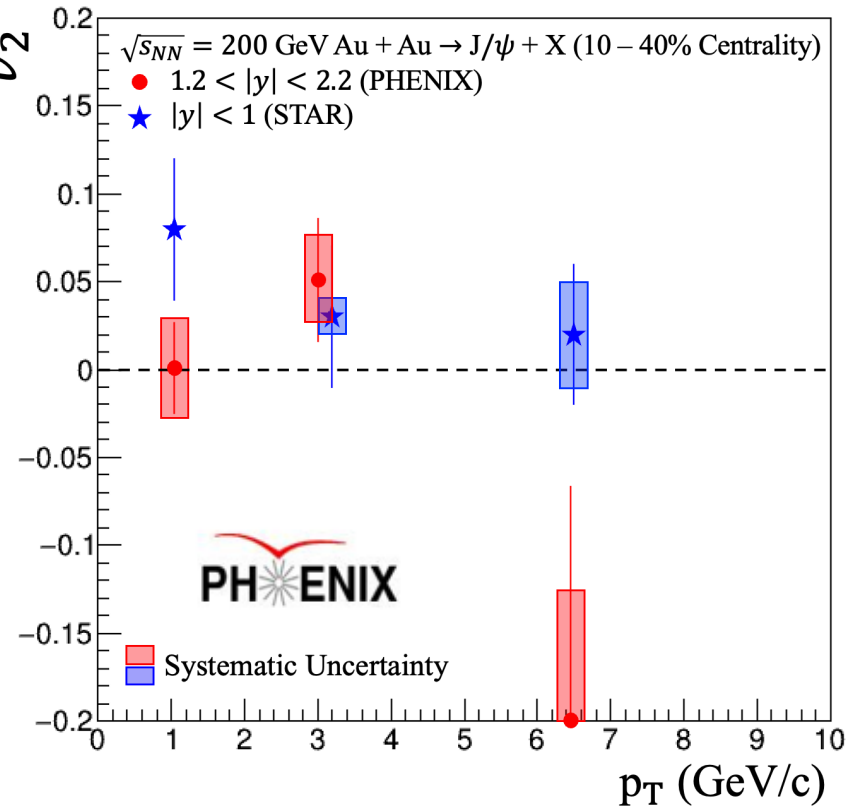
Direct photons v_2 in Au+Au

Vassu Doomra (Tue. 11:10 Thermal)



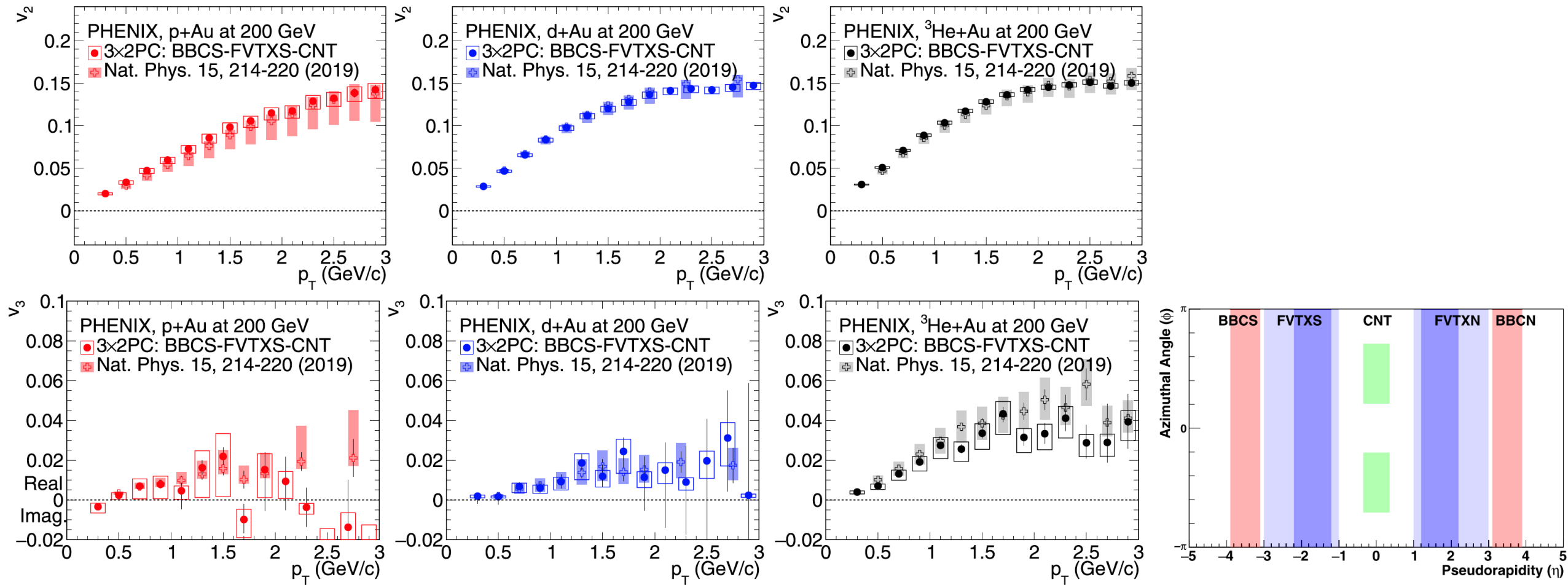
- Finer centrality bin (10%)
- Significant reduction in statistical and systematic uncertainties from previous measurement
- Similar to hadrons at low p_T
- Results consistent with zero at high p_T (dominant prompt photon)

J/ψ v₂ at Forward rapidity



Forward J/ψ v₂ at RHIC is consistent with zero, but non-zero at LHC
 → Consistent to the cc regeneration scenario at LHC

v2 and v3 in small system



- Using two particle correlations over large rapidity range
- **V2 and v3 consistent with previous results (Nature Physics), small droplet of QGP**

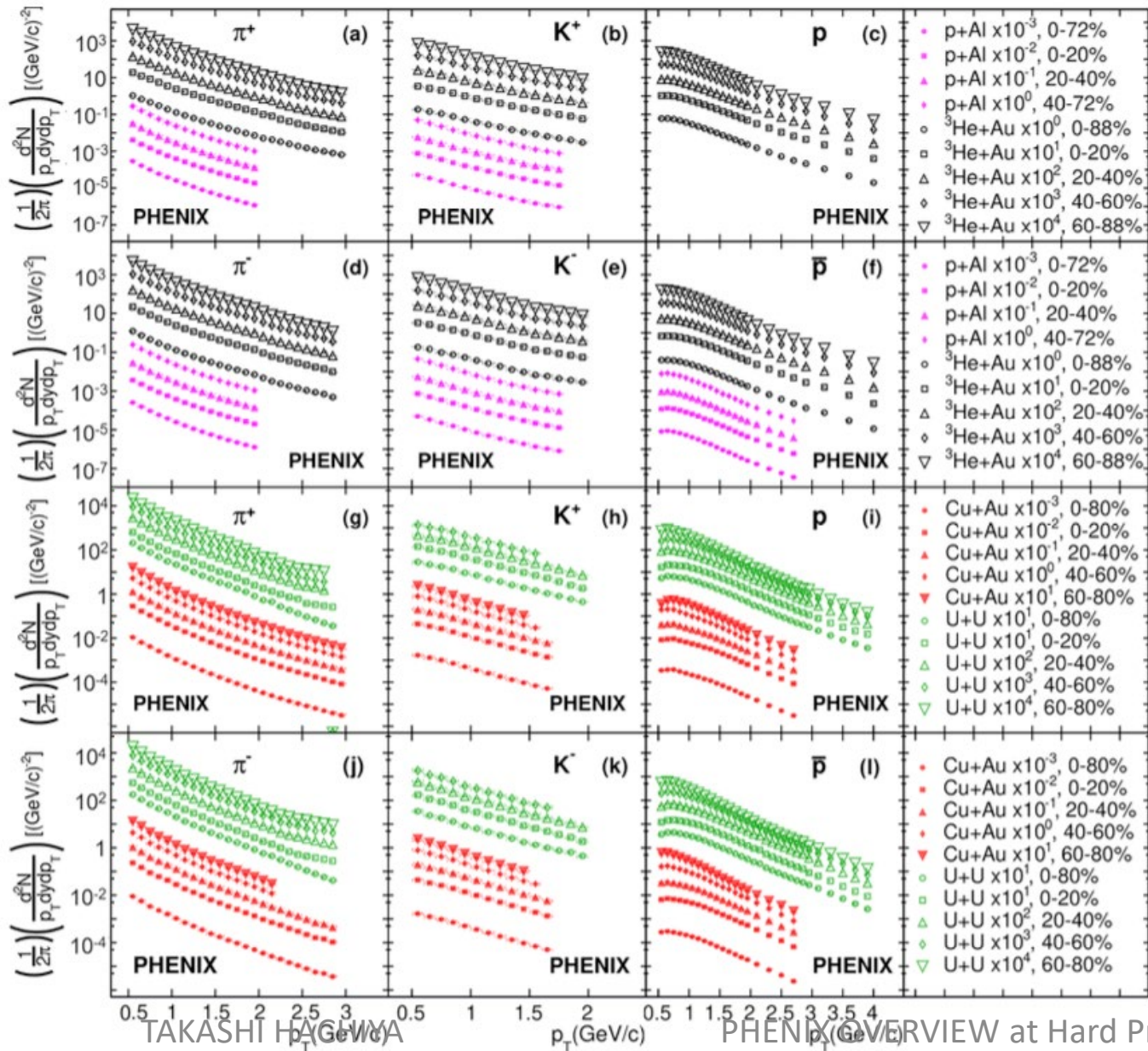
Rapidity choice is sensitive to non-flow effects

PID Charged hadrons

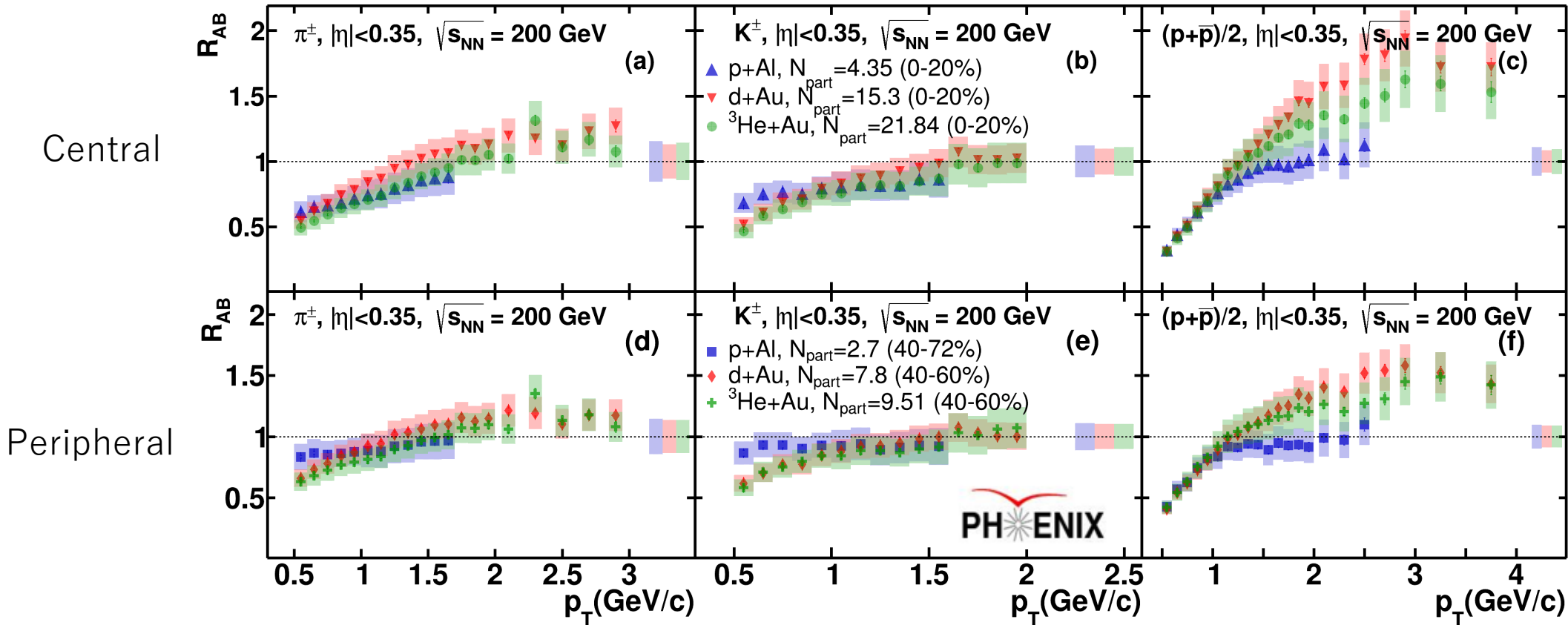
on Tue

PHENIX, PRC 109, 054910 (2024)

The systematic study of various collision systems are preformed



R_{AB} ($\pi/k/p$) in small systems

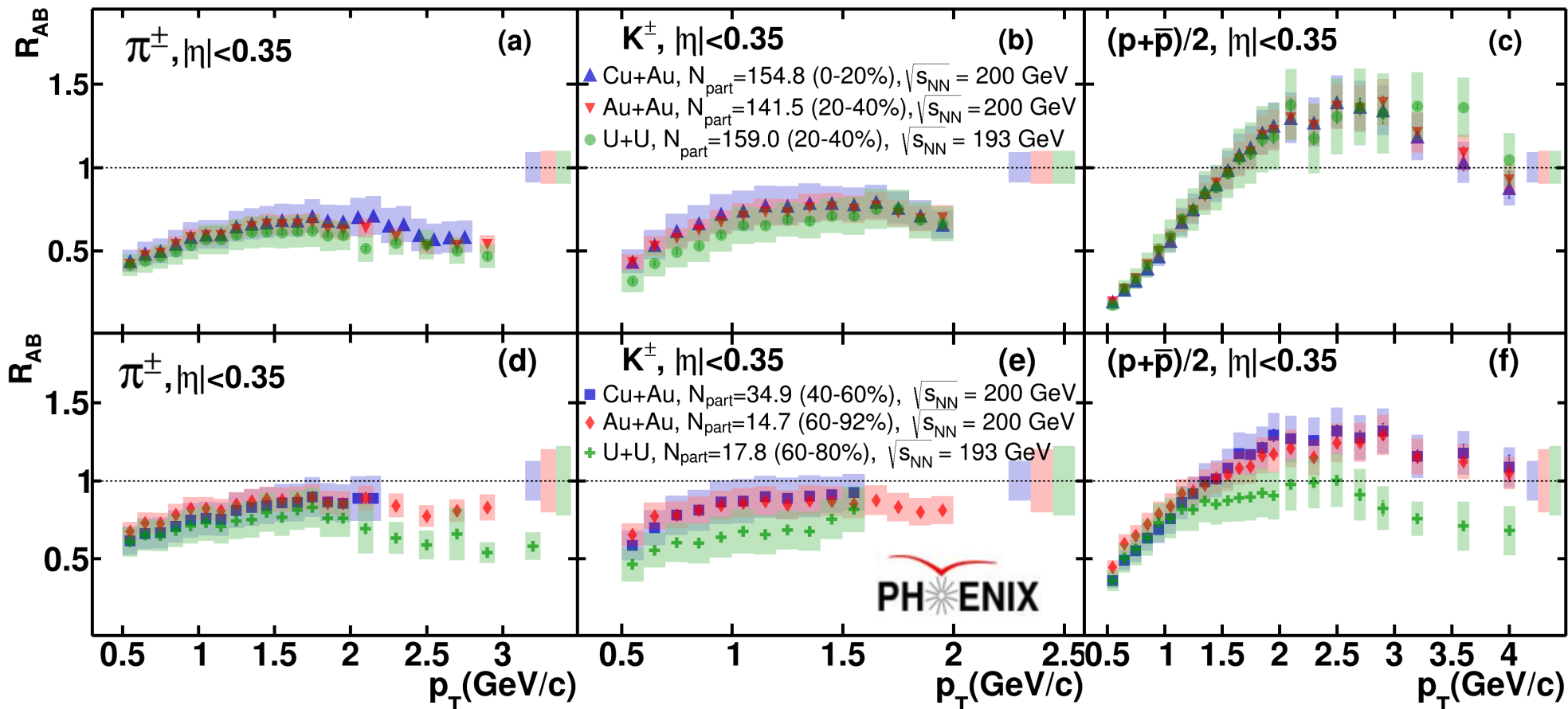


- Small system has dependence of the collision overlap size (N_{part})
- Proton R_{AB} at high p_T is not ordering of N_{part}
 - d+Au is imbalanced most

R_{AB} in Cu+Au, Au+Au, U+U

PHENIX, PRC 109, 054910 (2024)

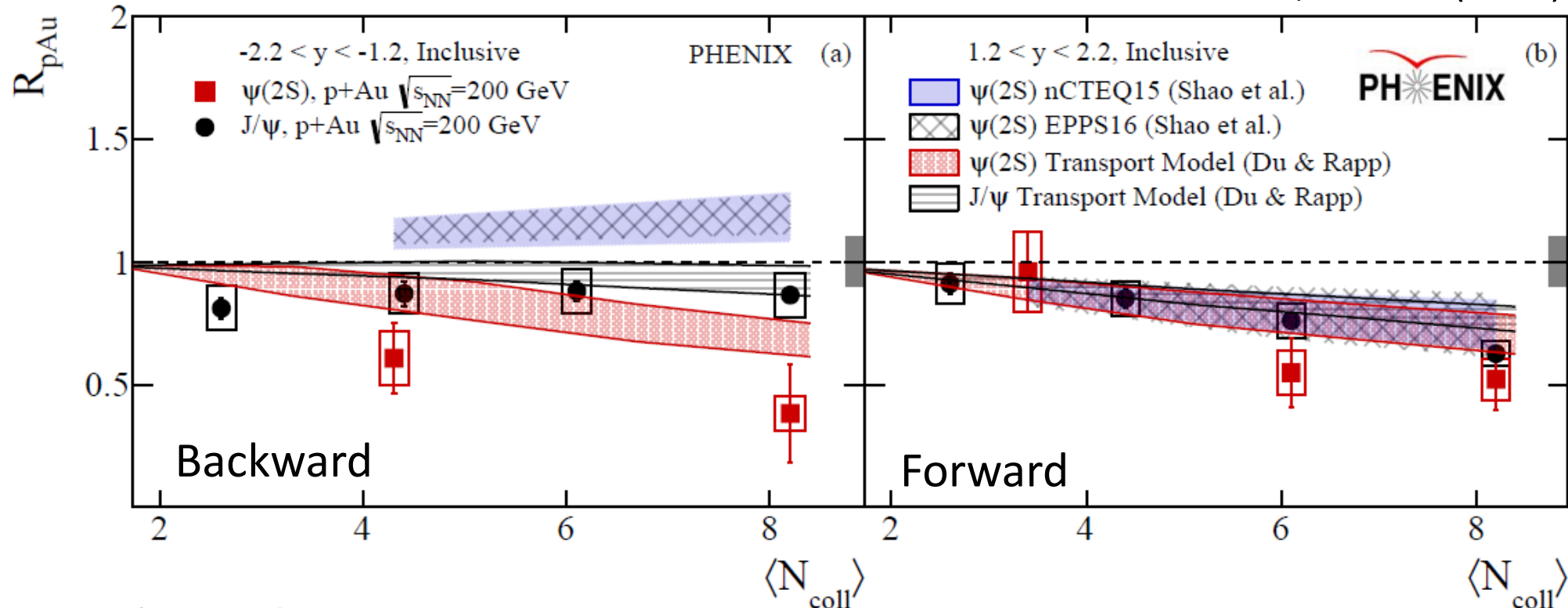
Central



R_{AA} in large system also depends on collision overlap size (N_{part}) but not collision systems

J/ψ and ψ(2S) in small systems

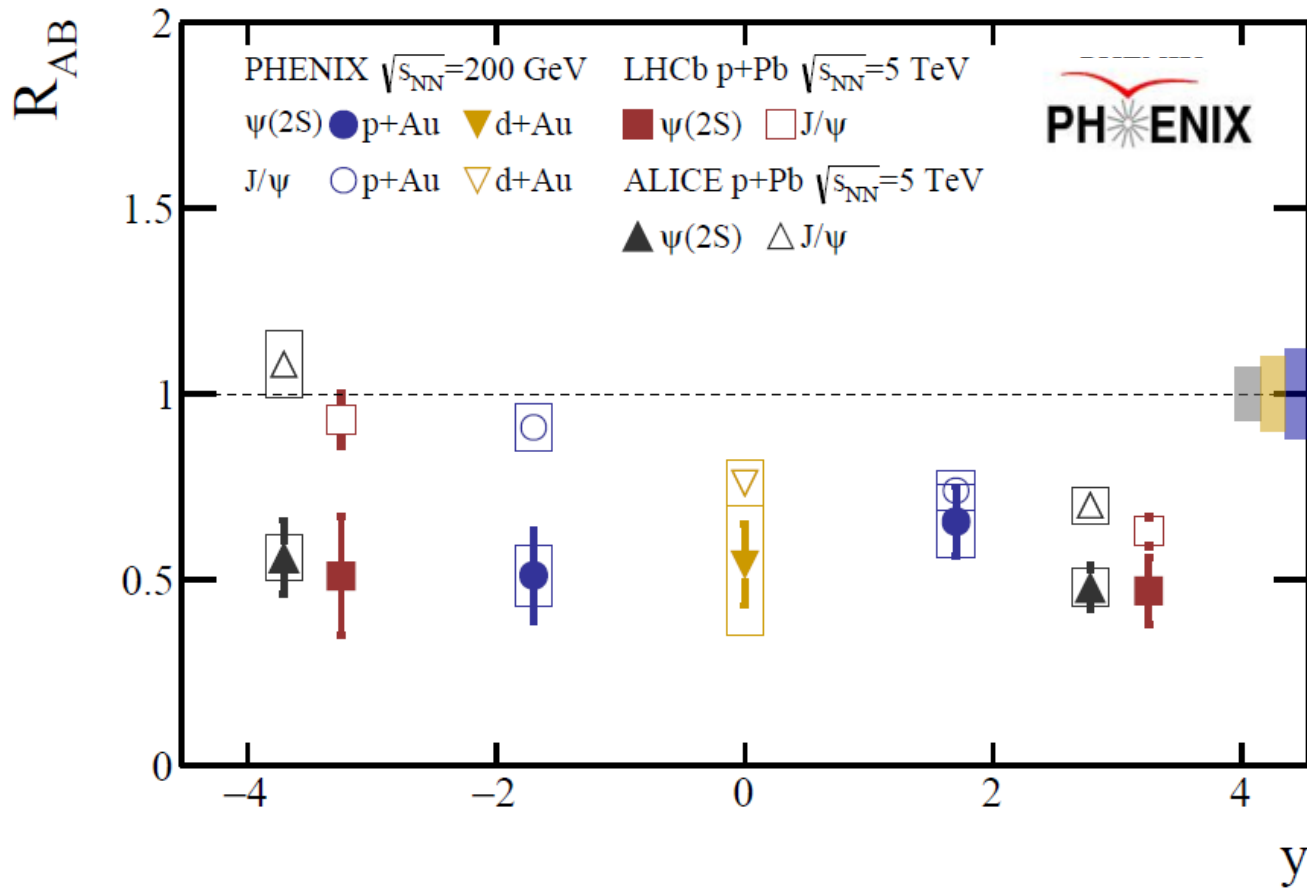
PRC 105, 064912 (2022)



- J/ψ modification consistent with INITIAL state effects at FW and BW rapidity
- ψ(2S) modification indicates presence of FINAL state effects at BW rapidity
 - Presence of co-movers? QGP?

J/ψ and ψ(2S) in small systems

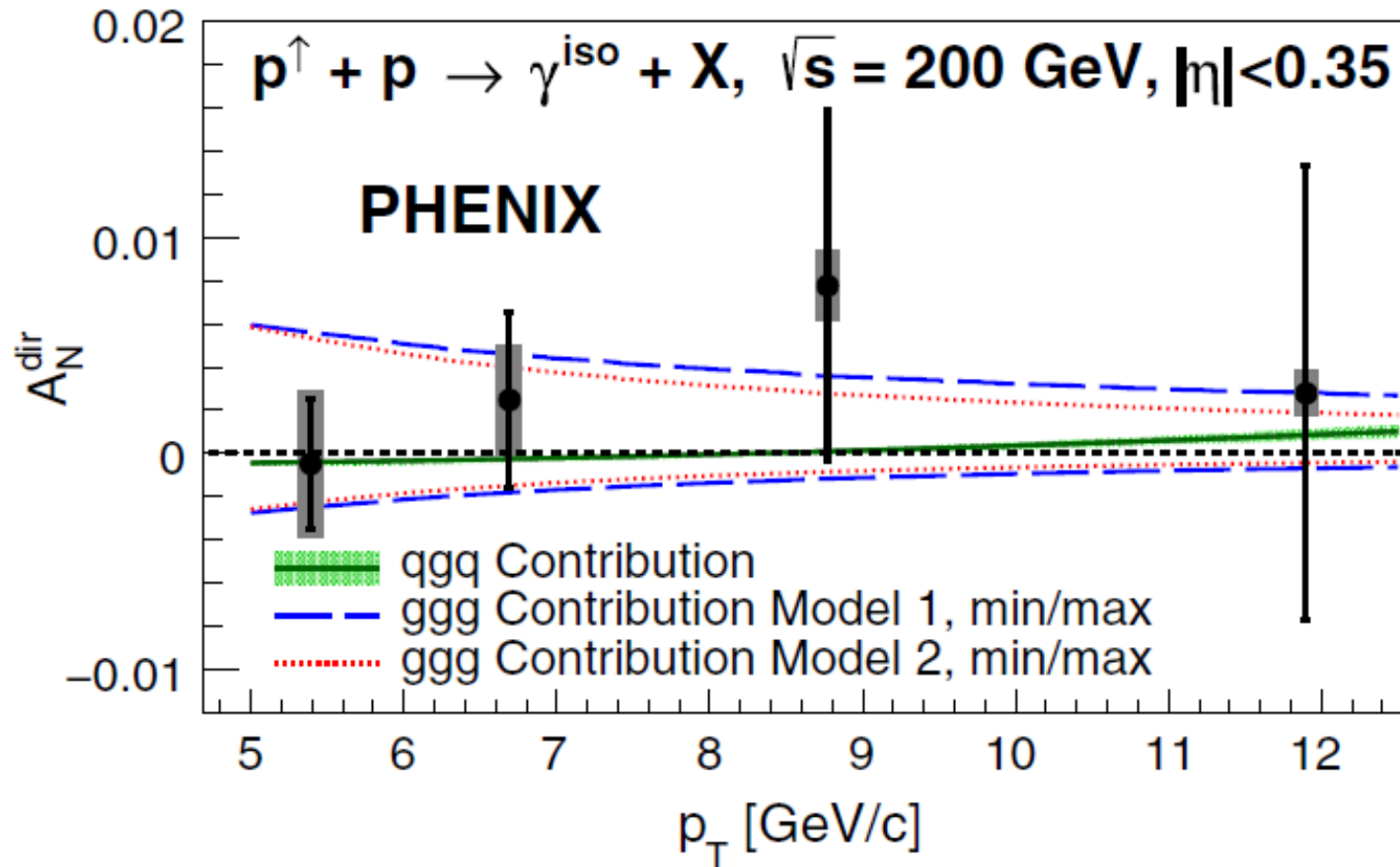
PRC 105, 064912 (2022)



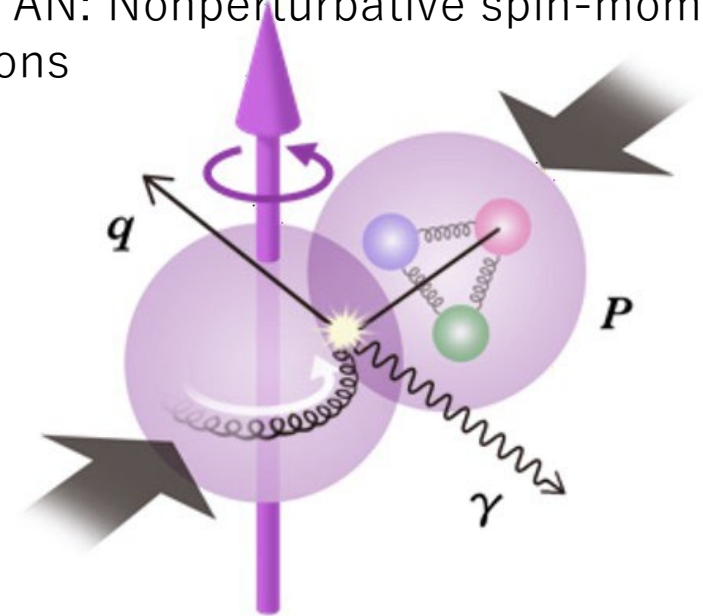
- J/ψ and ψ(2s) consistent with INITIAL state effects at FW
- ψ(2S) at BW indicates presence of FINAL state effects
 - Presence of co-movers? QGP?
- Similar patterns for J/ψ = and ψ(2S) found at RHIC and LHC

A_N of Direct Photons

Ralf Seidl (Mon. 14:40 nPDF)



Origin of A_N : Nonperturbative spin-momentum correlations



- Sensitive to gluon' orbital motion
- Consistent with zero
- Imply not as large as the maximum from the theoretical models

