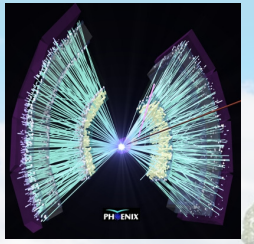


PHENIX highlights: Recent results from PHENIX

Maya SHIMOMURA for the PHENIX Collaboration

Nara Women's University

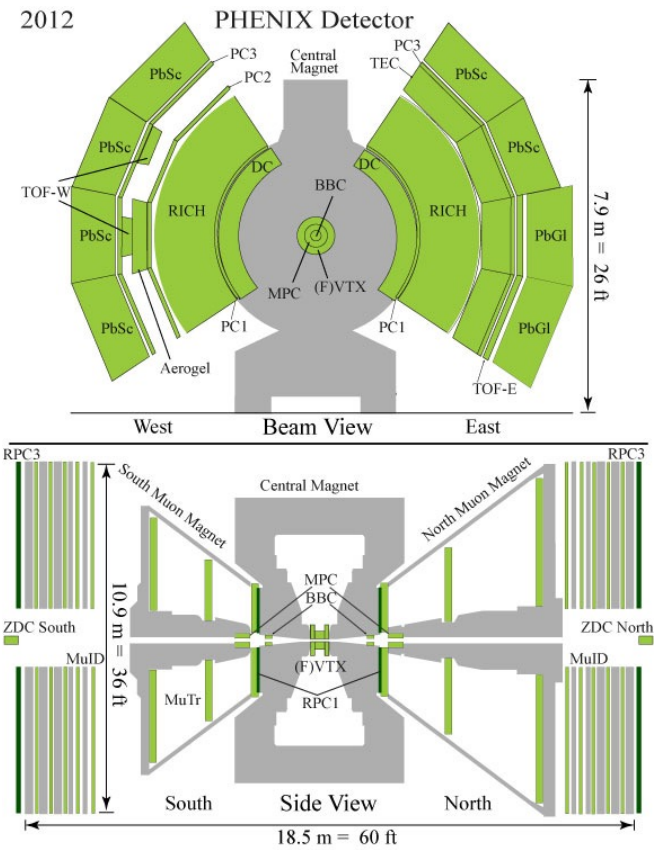
June 3rd, 2024

The 21st International Conference on Strangeness in Quark Matter (SQM 2024)

Palais de la Musique et des Congrès

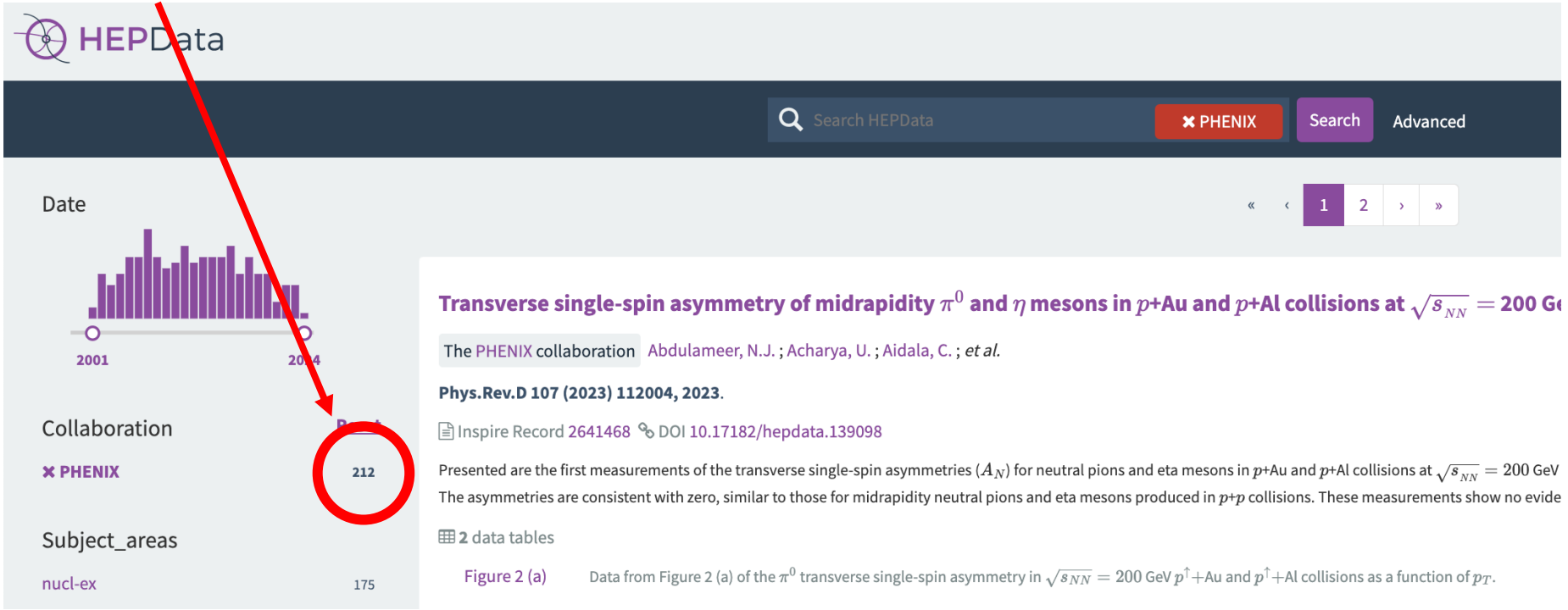
THE PHENIX EXPERIMENT

- Data with 9 collision species and 9 collision energies have been obtained
- Data taking is completed in 2016
- Collaboration is actively working for data analysis



PHENIX results are in HEPData!!

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



In this talk

Recent publications from PHENIX

(1) [PRC 109, 044907 (2024)] Charm and bottom quark production in AuAu collisions at $\sqrt{s_{NN}} = 200$GeV

(2) [PRC 109, 044912 (2024)] Non-prompt direct-photon production in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

(3) [PRC 109, 054910 (2024)] Identified charged-hadron production in p+Al, 3He+Au, and Cu+Au collisions at $\sqrt{s_{NN}} = 200$GeV and in U+U collisions at $\sqrt{s_{NN}} = 193$GeV

(4) [PRC107,014907 (2023)] Measurement of ϕ-meson production in Cu+Au collisions at $\sqrt{s_{NN}} = 200$ GeV and U+U collisions at $\sqrt{s_{NN}} = 193$ GeV

(5) [arXiv:2303.12899] Disentangling centrality bias and final-state effects in the production of high-p_T π^0 using direct γ in d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

Contents

(1)Heavy flavor at mid and forward rapidity

(2)Direct photon with large statistics

(3)PID Charged hadron measurement at various collision systems

- π^0 R_{AA} with experimental N_{coll} at small system

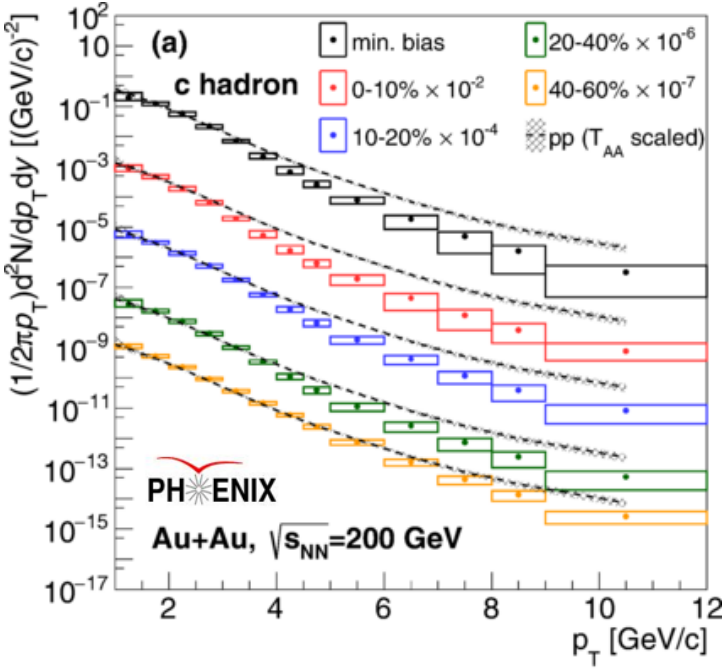
(1)Heavy flavor at mid and forward rapidity

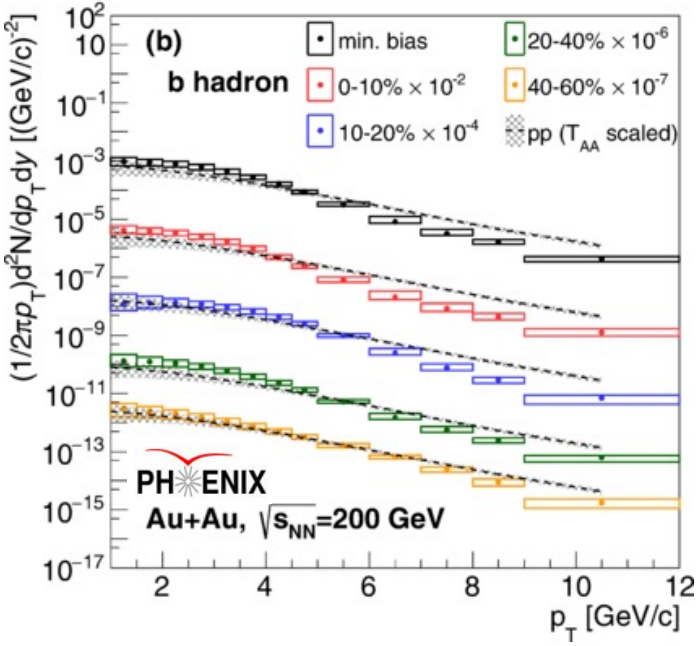
Details will be discussed at

L.Bichon III's Talk (Track2-HF) on 6/5 (Wed)

Heavy flavor (c, b)

PHENIX, PRC 109, 044907 (2024)

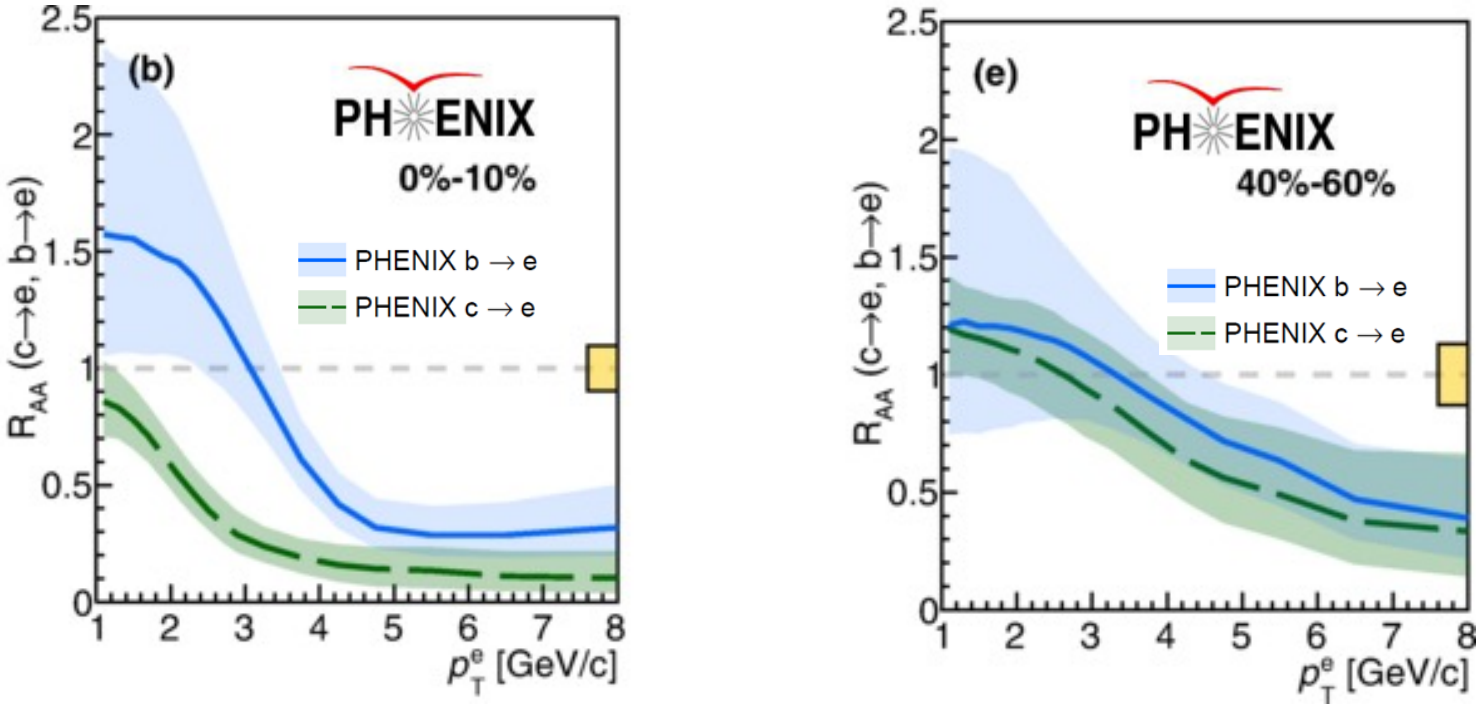




- c hadron and b hadron p_T spectra in Au+Au are measured in MB, 0-10, 10-20, 20-40, 40-60% compared with p+p scaled by T_{AA}

Centrality dependence of R_{AA}(b→e) & R_{AA}(c→e)

PHENIX, PRC 109, 044907 (2024)

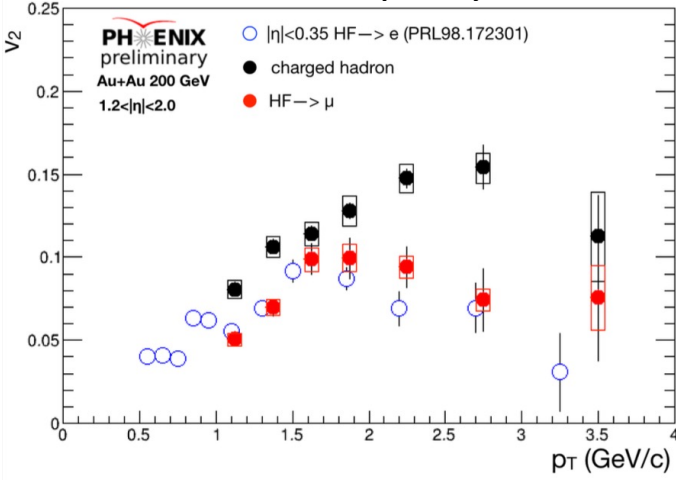


- In 0-10%, bottom and charm suppression are clearly seen while in 40-60%, bottom and charm are similar and less suppressed
- Centrality dependence is clearly seen

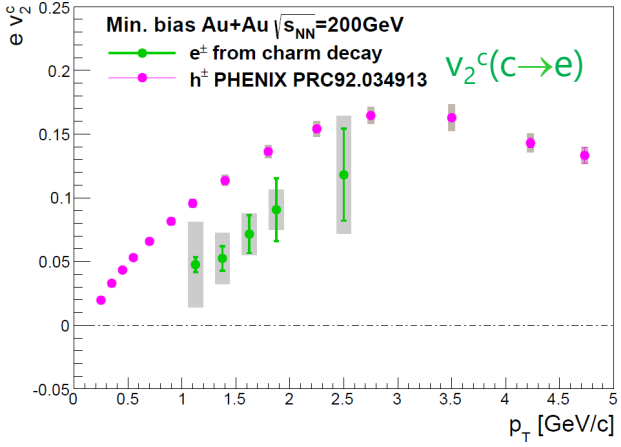
HF v_2 in Au+Au

L.Bichon III's Talk (Track2-HF) on Wed

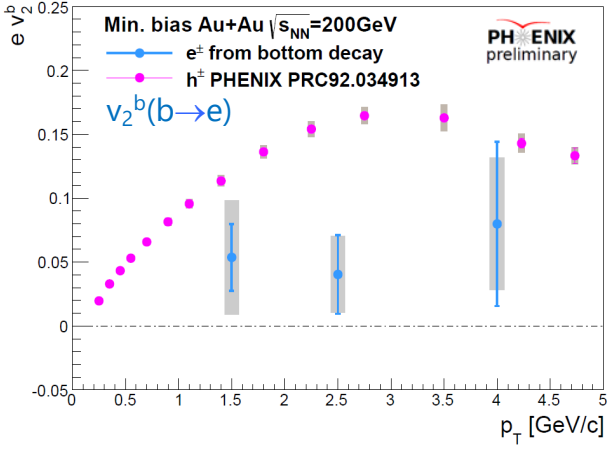
Forward rapidity



Mid rapidity



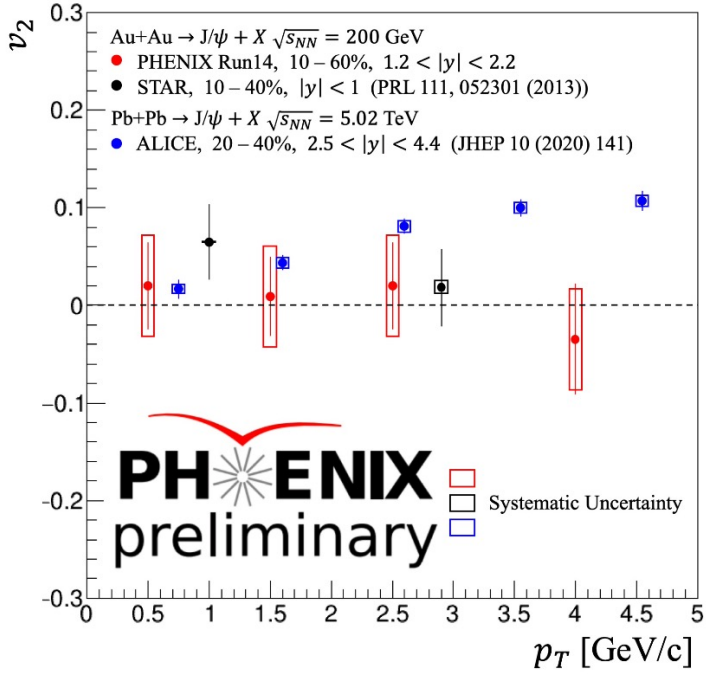
Mid rapidity

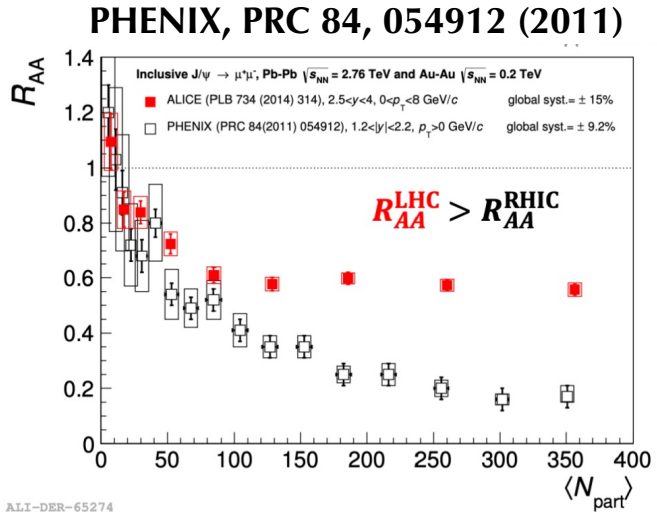


- HF v_2 is positive both at forward and mid rapidity and mostly consistent
- Hadron v_2 > HF v_2 and v_{2c} > v_{2b},
- Heavier quarks has less flow as expected

Forward J/ψ v_2 compared with LHC

L.Bichon III's Talk (Track2-HF) on Wed





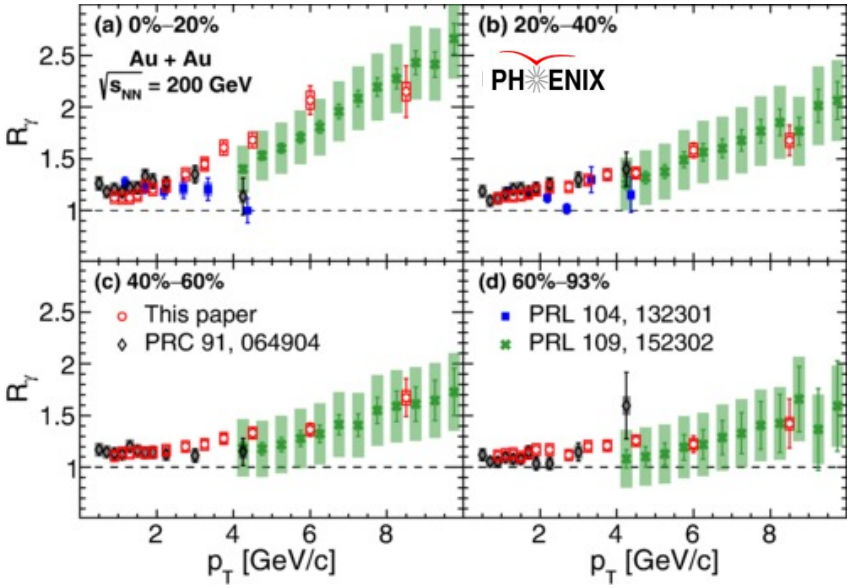
- Forward J/ψ v_2 at RHIC is consistent with zero, while it's non-zero at LHC energy

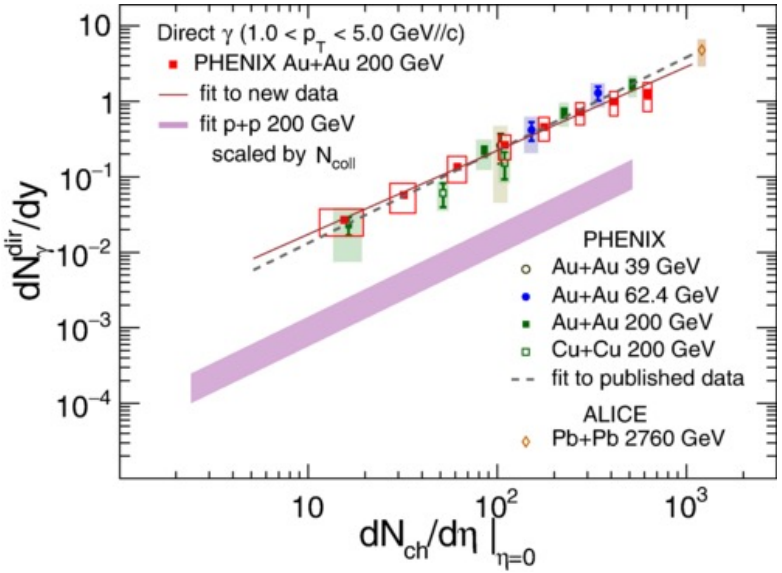
-> Consistent to the regeneration scenario of charm and anti-charm at LHC energy

(2)Direct photon with large statistics

Direct photon in Au+Au

PHENIX, PRC 109, 044912 (2024)



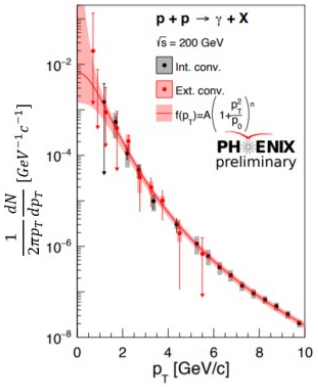


- External conversion method and large statistics give precise measurement for wider p_T ranges for all centrality bins
  - The scaling of yields holds for various large systems

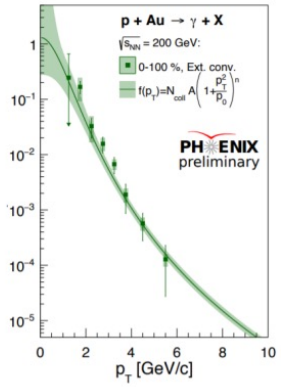
PHENIX, PRC 109, 044912 (2024)

Direct photon enhancement with system size

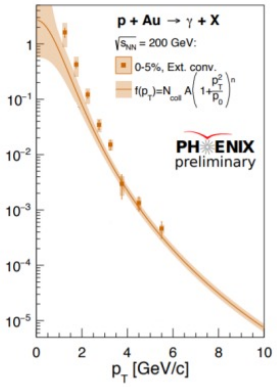
pp



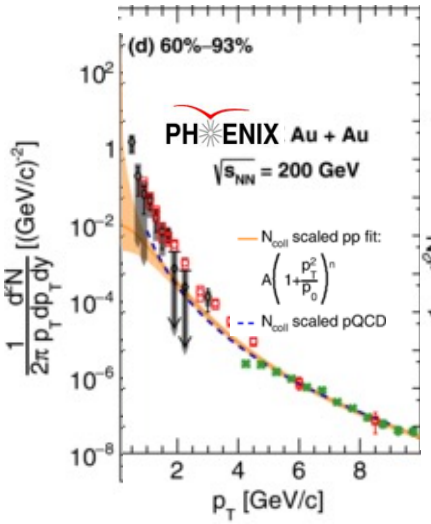
pAu



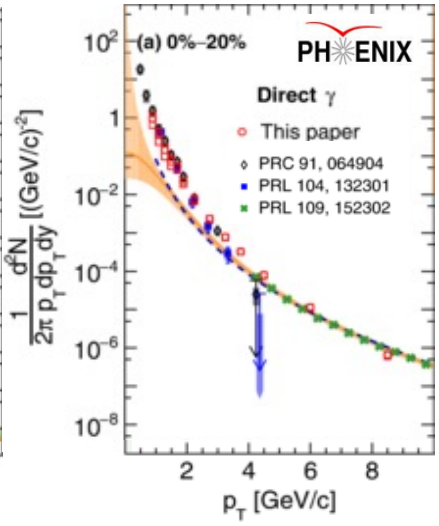
pAu 0-5%



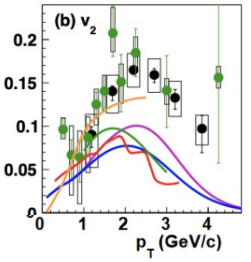
AuAu 60-93%



AuAu 0-20%

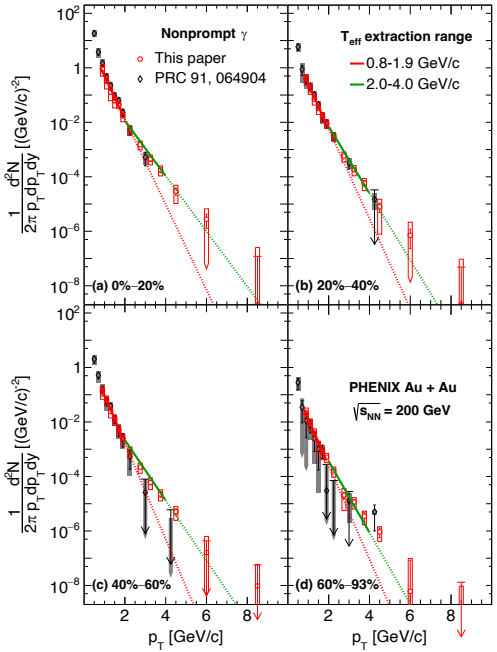


- Larger system has more enhancement at low p_T compared with N_{coll} scaled pp → seems to relate to QGP size?
- Yield enhancement at low p_T and large v_2 at high p_T →might be due to hadronization photons ??

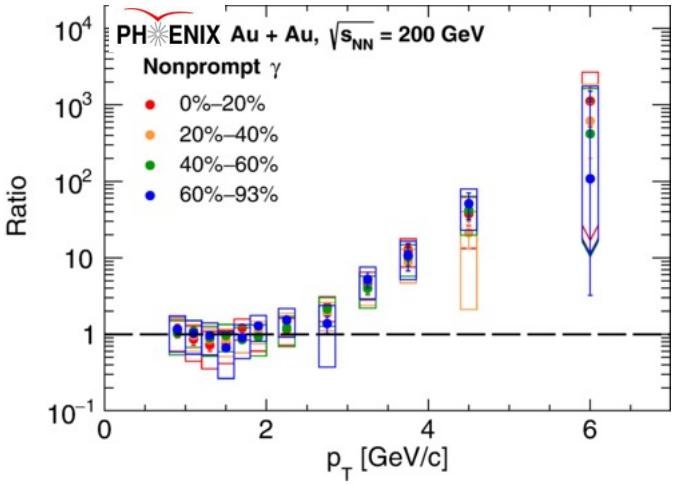


PHENIX, PRC 109, 044912 (2024)

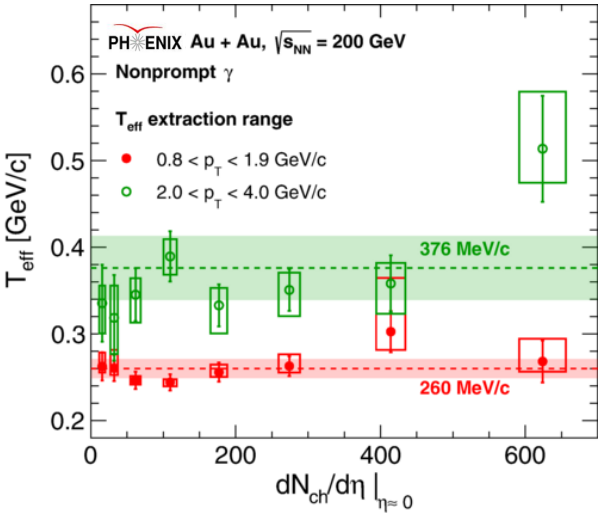
T_{eff} of non-prompt photons



Ratio = data/exp fit
(T_{eff} fixed to 0.26GeV/c)



T_{eff} is free parameter



T_{eff} of non-prompt photons has p_T dependence
but no-clear multiplicity dependence

(3)PID Charged hadron measurement at various collision systems

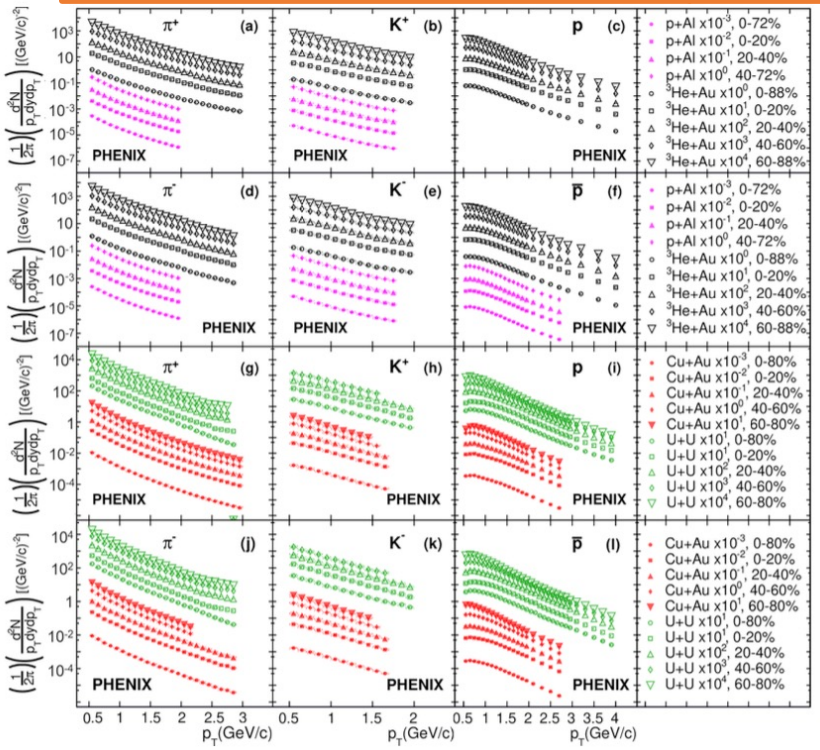
Details will be discussed at

R.Nouicer’s Talk (Track1-LF) on 6/4 (Tue)

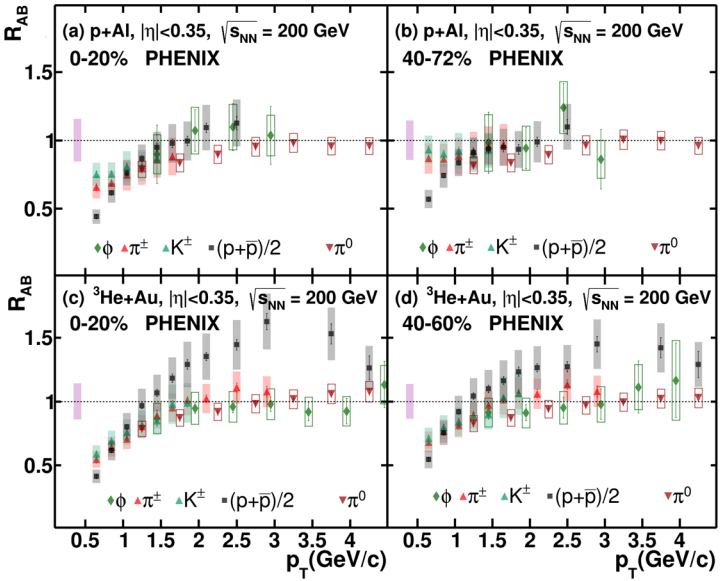
R.Nouicer's Talk (Track1-LF) on Tue

PID Charged hadrons

PHENIX, PRC 109, 054910 (2024)



PHENIX, PRC 107, 014907 (2023)

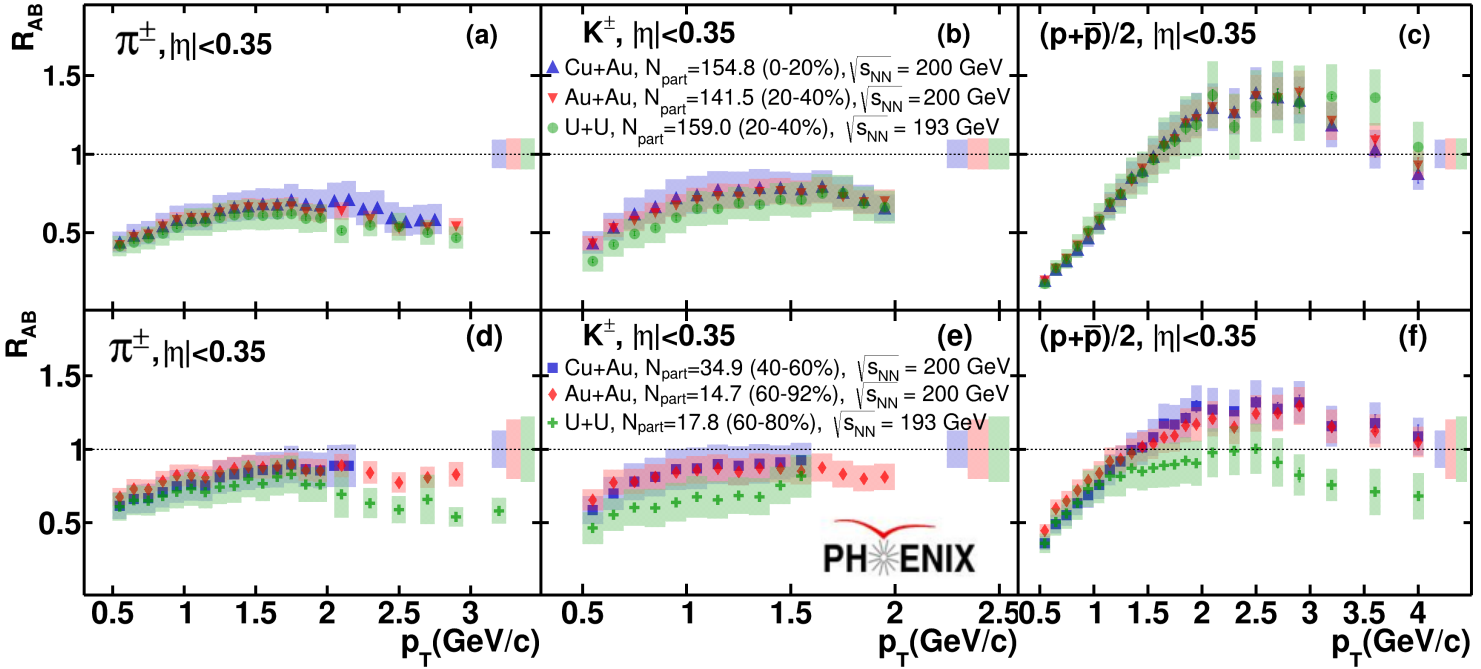


The systematic study of various collision systems are preformed

R_{AB} in Large systems

R.Nouicer's Talk (Track1-LF) on Tue

PHENIX, PRC 109, 054910 (2024)

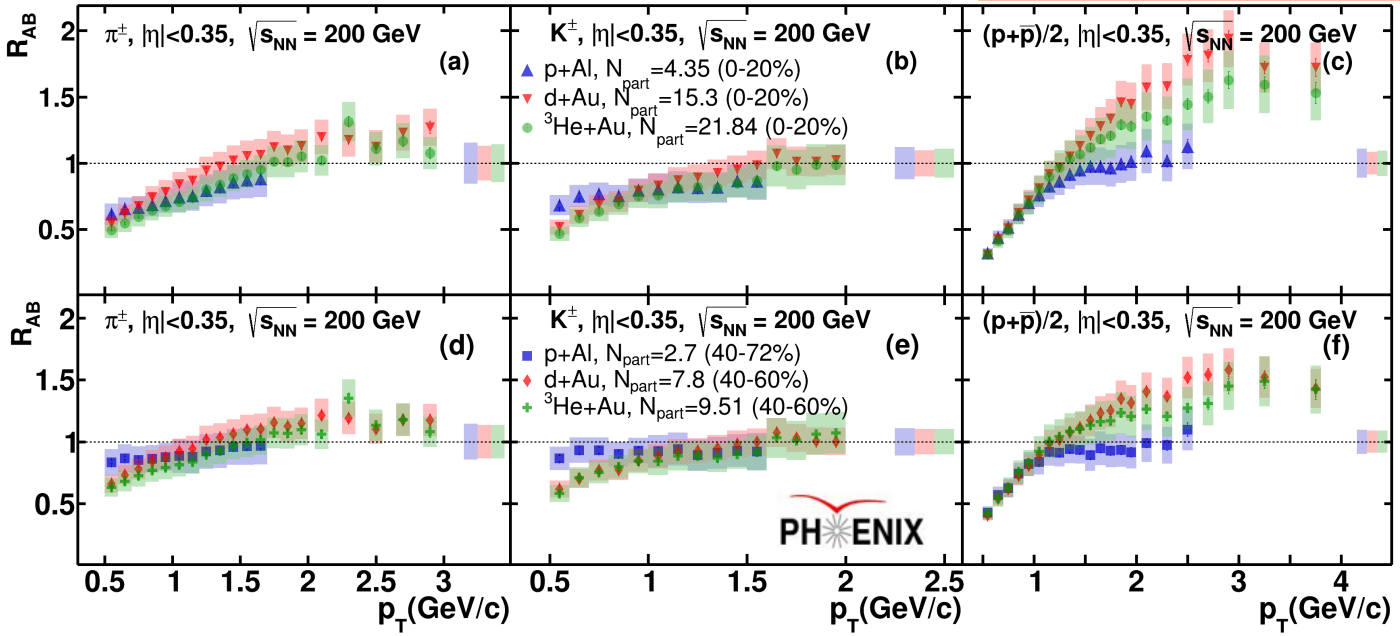


R_{AA} in large system depends on collision overlap size (N_{part}) but not collision systems

R_{AB} in small systems

R.Nouicer's Talk (Track1-LF) on Tue

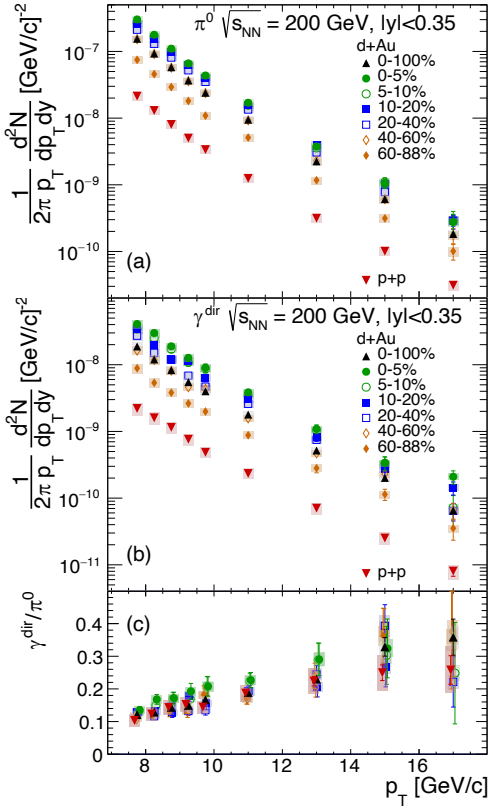
PHENIX, PRC 109, 054910 (2024)



- Small system also 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

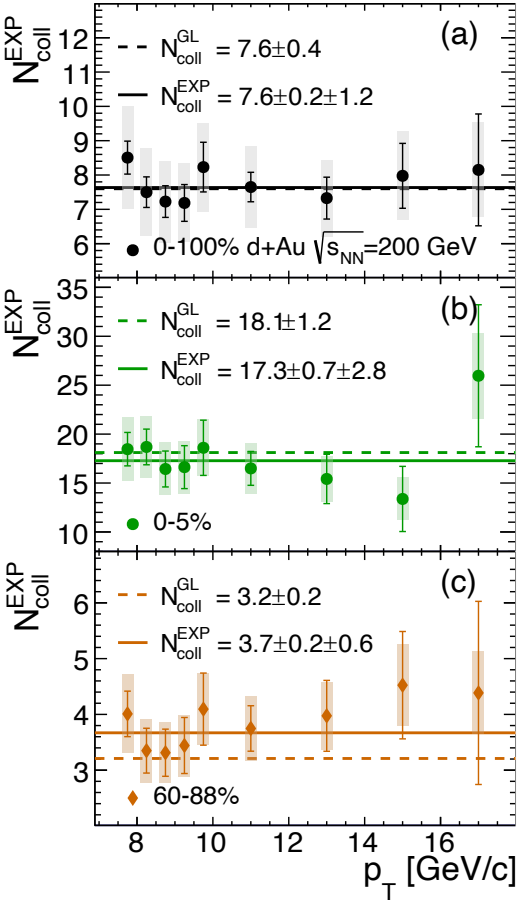
γ^{dir} and π^0 spectra in d+Au

PHENIX, arXiv:2303.12899



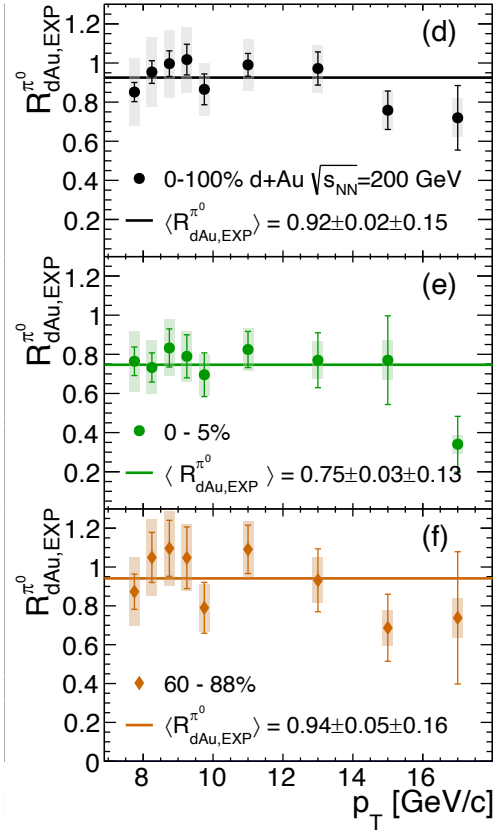
Since γ^{dir} is not suppressed, N_{coll} can be redefined by γ^{dir} ratio of d+Au to pp experimentally

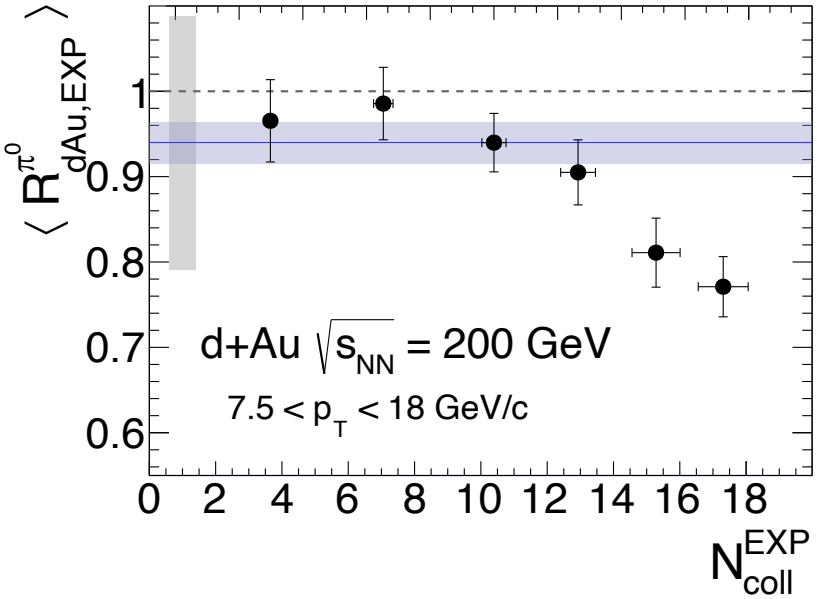
$$N_{\mathrm{coll}}^{\mathrm{EXP}}(p_T) = \frac{Y_{dAu}^{\gamma^{dir}}(p_T)}{Y_{pp}^{\gamma^{dir}}(p_T)}$$



Redefined R_{dAu} with experimental N_{coll}

PHENIX, arXiv:2303.12899





Clear suppression can be seen at central in d+Au while it's consistent to 1 at peripheral

Summary

- Heavy flavor
  - c/b separated HF R_{AA} and v_2 are successfully measured at various centrality bins and clear mass dependence can be seen at central.
  - Measurement of the forward J/ψ v_2 are also performed and it's consistent to zero unlike LHC result.
- Direct photons
  - External conversion method and large statistics give precise measurement for wide p_T ranges and all centrality bins, and the scaling of yields holds for various large systems.
  - Non-prompt direct photon are extracted and show the T_{eff} has the dependences of the p_T
- Charged hadrons
  - PHENIX measured charged hadron production at small to large various collision systems and found mostly R_{AA} only depends on overlap volume(N_{part}).
  - Experimental N_{coll} gives non-GL biased $R_{dAu,}$ and indicates the clear yield suppression at central.

Recent publications in this talk from PHENIX

(1) [PRC 109, 044907 (2024)] Charm and bottom quark production in AuAu collisions at sqrt(sNN)=200GeV

L.Bichon III's Talk (Track2-HF) on 6/5 (Wed)

(2) [PRC 109, 044912 (2024)] Non-prompt direct-photon production in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV

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(5)[arXiv:2303.12899] Disentangling centrality bias and final-state effects in the production of high-pT π0 using direct γ in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV

PHENIX is active. New results are coming. Stay tune!

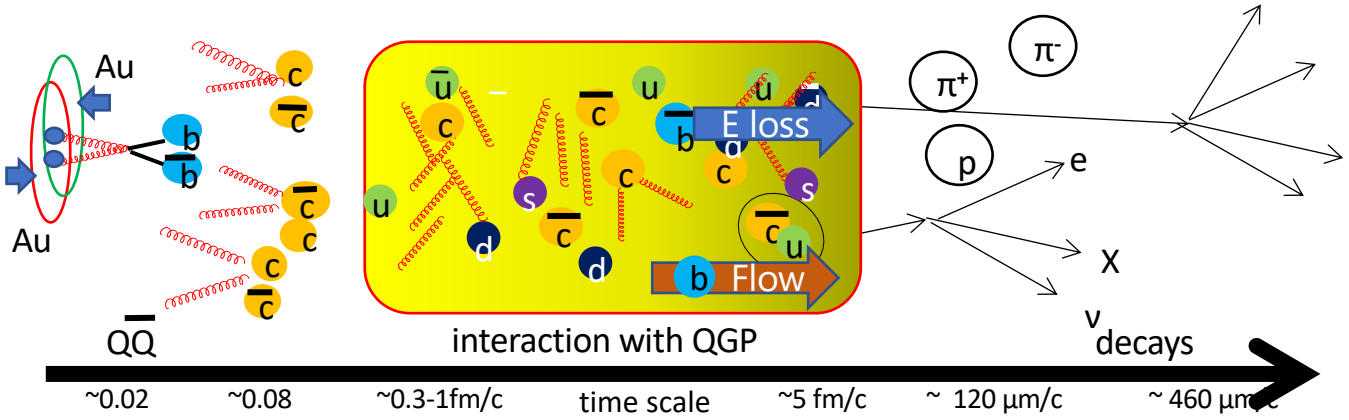
Additional materials (Back Up)

Why heavy flavor, bottom & charm ?

- Mainly created at early stage of the collision
  - Production can be calculated by pQCD
- Passing through QGP
  - Suffer energy loss and flow effects – p_T and angular distributions can be modified in QGP

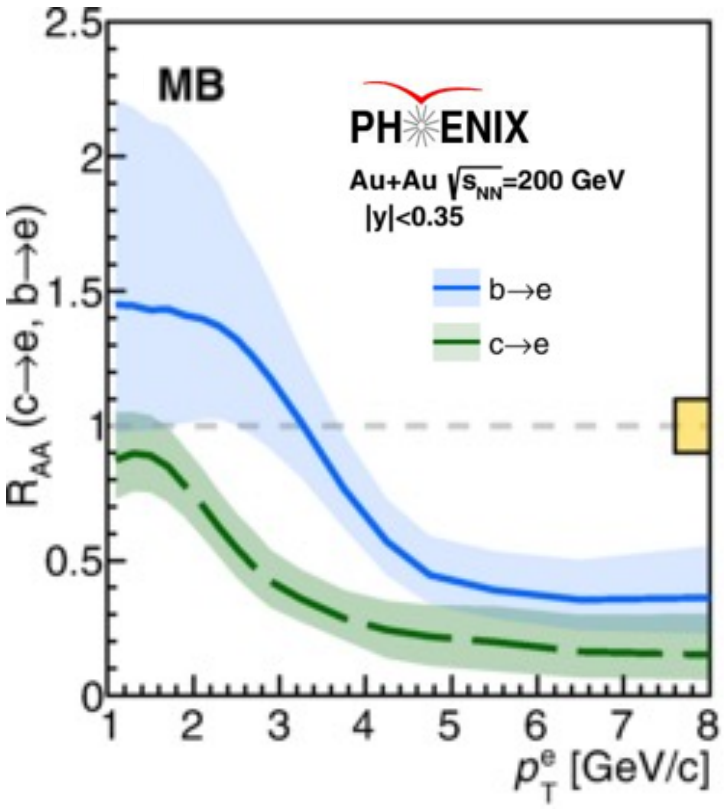
Mc~1.3GeV >> T_{QGP} ~400MeV

Mb~4.5GeV >> Λ_{QCD} ~200MeV



Modification of Heavy flavor is good tool to study property of QGP

R_{AA}(b→e) & R_{AA}(c→e) in Au+Au 200GeV

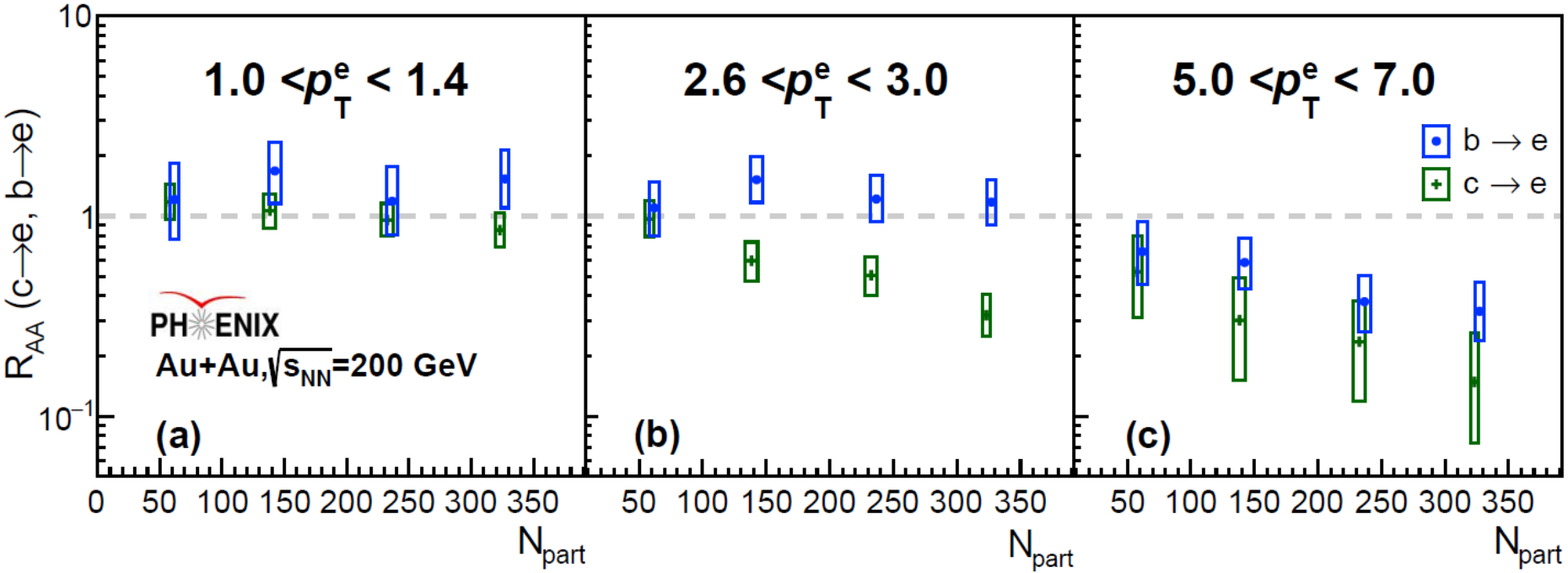


PHENIX, PRC 109, 044907 (2024)

- Nuclear modification factor R_{AA}
  - Broad p_T range : 1 – 8 GeV/c
  - Small uncertainty with new p+p baseline
- Low p_T : R_{AA}(b->e) ~ R_{AA}(c->e) = 1
- Mid p_T : R_{AA}(b->e) > R_{AA}(c->e)
- High p_T: R_{AA}(b->e) ~ R_{AA}(c->e) < 1
- Bottom suppression is different from charm
  - Clear p_T dependence

Charm and Bottom R_{AA} vs N_{part}

PHENIX, PRC 109, 044907 (2024)



$R_{AA}(c\rightarrow e) \sim R_{AA}(b\rightarrow e) \sim 1$

$R_{AA}(c\rightarrow e) < R_{AA}(b\rightarrow e)$
$R_{AA}(b\rightarrow e) \sim 1$

$R_{AA}(c\rightarrow e) \sim R_{AA}(b\rightarrow e) < 1$

Clear centrality and p_T dependence are observed

Talk list

(1)Rachid Nouicer Jun 4 11:00AM Track1-LF

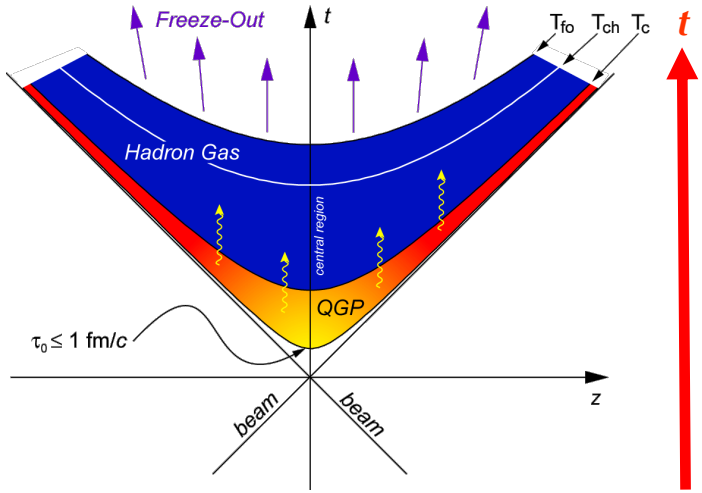
Scaling Properties of ϕ-Meson and Light Charged Hadron Production in Small and Large Systems at PHENIX

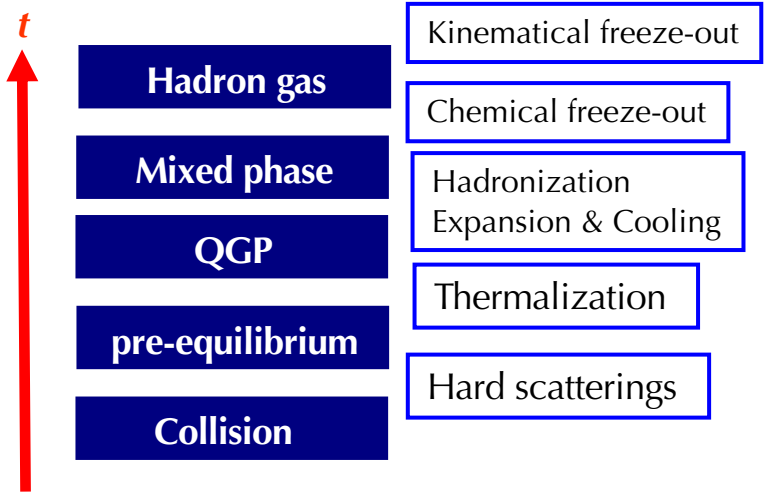
(2)Luis Bichon III Jun 5 9:30 AM Track2-HF

Forward rapidity elliptic flow measurements in PHENIX Au+Au collisions at 200 GeV

Time evolution

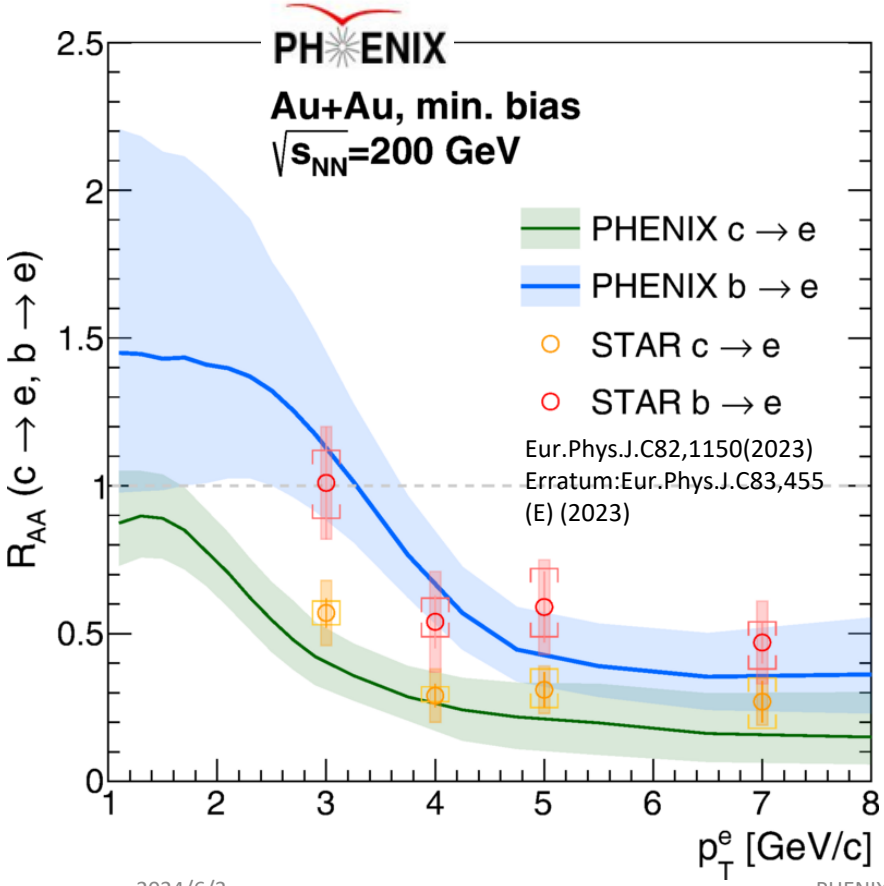
The matter produced in the high energy heavy ion collision is expected to undergo several stages from the initial hard scattering to the final hadron emission.





Need a comprehensive understanding from initial hard scattering to final freeze out.

R_{AA}(b→e) & R_{AA}(c→e) comparison with STAR 0-80%

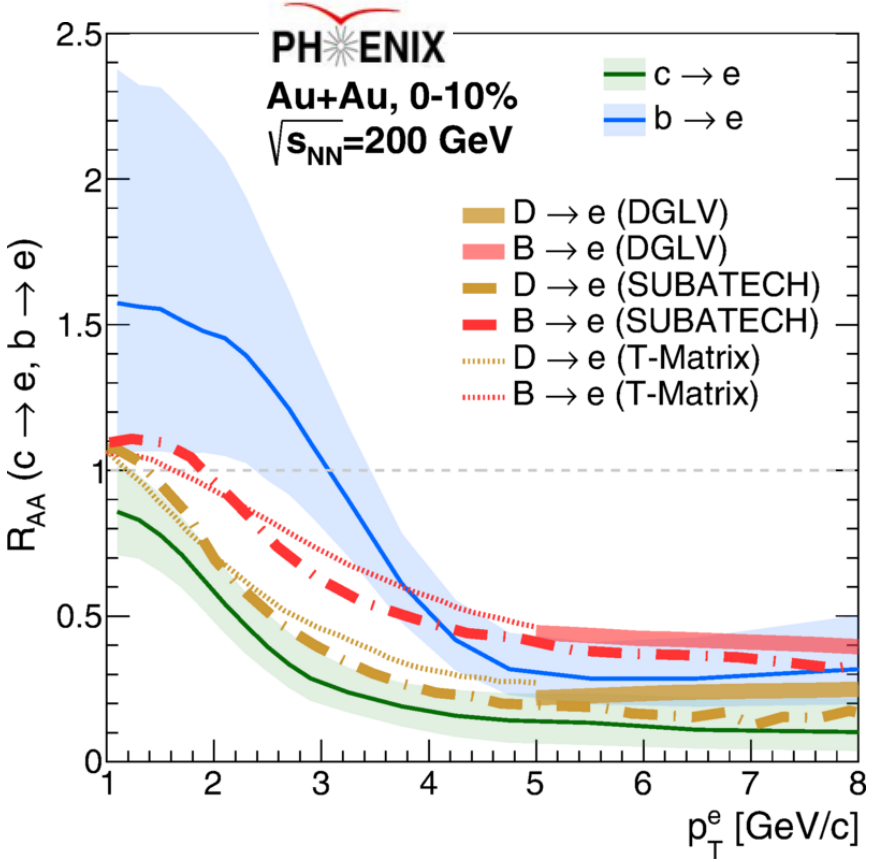


PHENIX, PRC 109, 044907 (2024)

- PHENIX MB and STAR 0-80% are in good agreement within uncertainties

Comparison with Models

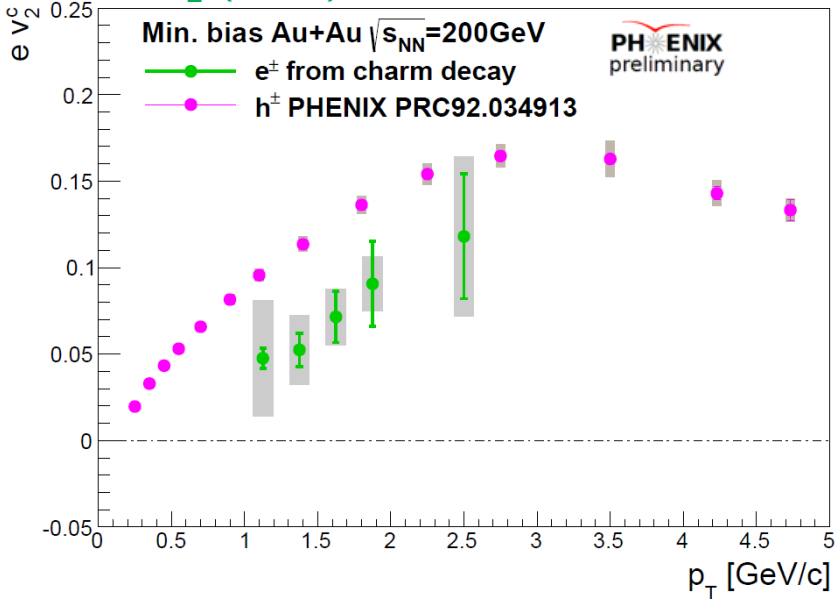
PHENIX, PRC 109, 044907 (2024)



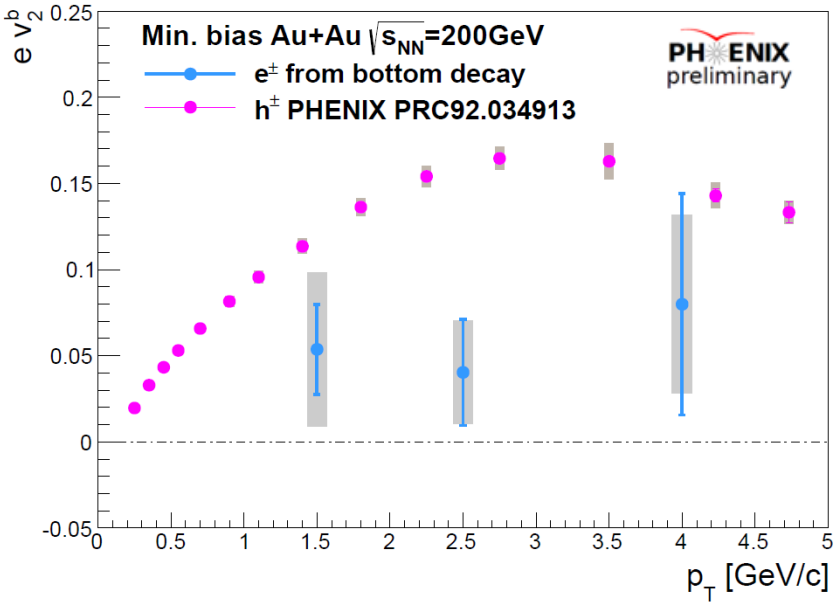
- Compared with 3 models
  - DGLV (Phys. Rev. C 90 034910)
    - E-loss + plasma w/ static potentials
  - SUBATECH (Phys. Rev. C 78 014904)
    - : E-loss + running coupling
  - T-Matrix + diffusion ($2\pi TD=4$) (Phys. Rev. Lett. 100 192301)
    - Strongly coupled QGP
- Models qualitatively consistent with data
  - Mass dependent energy loss agree with the mass dependent suppression
  - Bottom models underestimates the data
  - Charm models slightly higher than data

$v_2^c(c \to e)$ and $v_2^b(b \to e)$ in Au+Au 200GeV

$v_2^c(c \to e)$

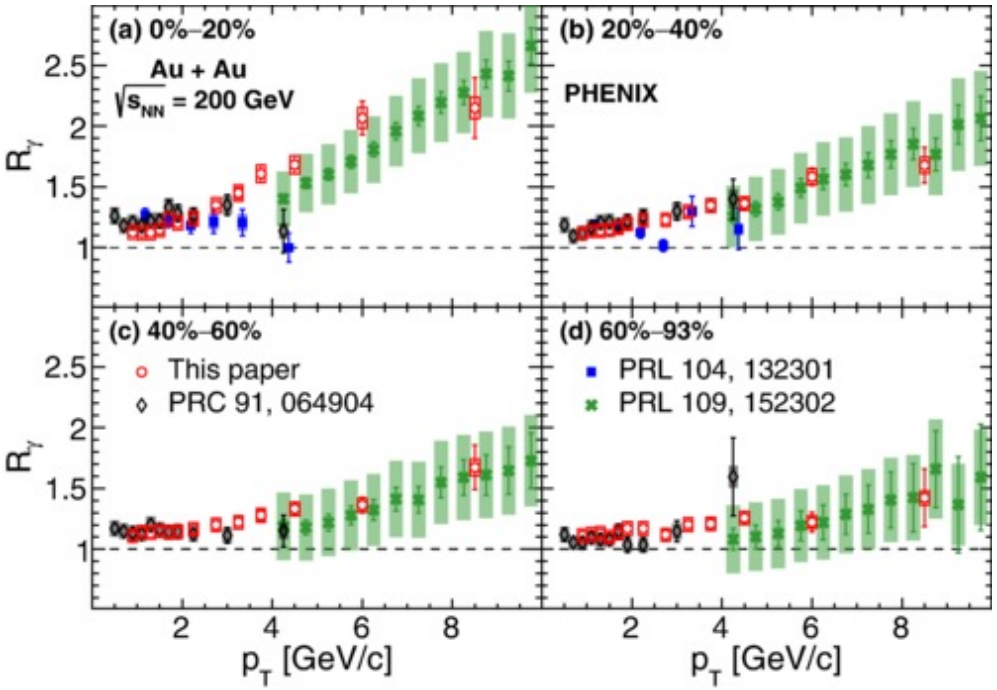


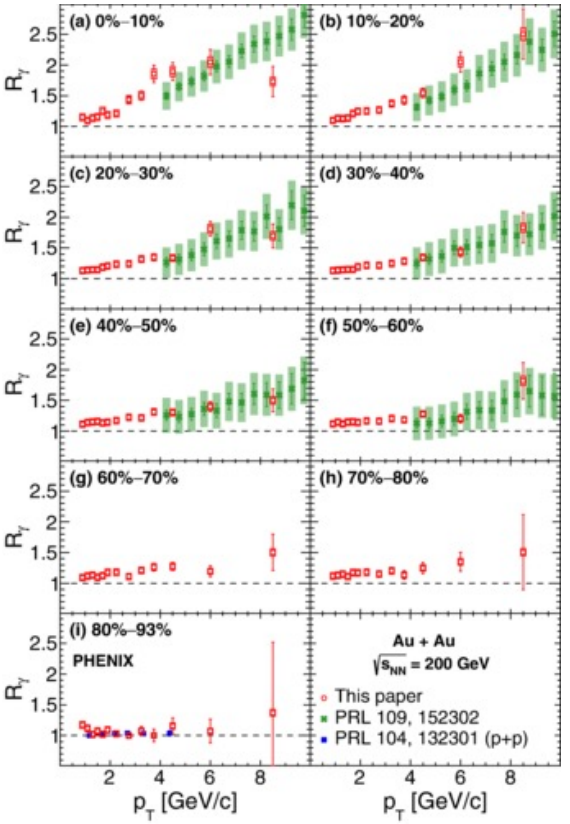
$v_2^b(b \to e)$

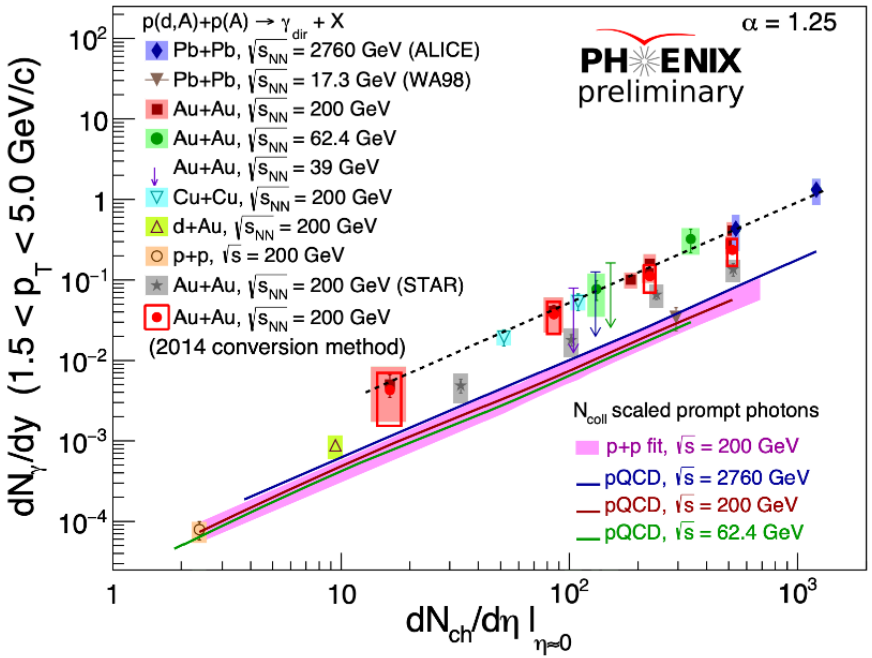


- $c \to e$ v_2 is positive with ~3.5 sigma
- A hint of positive $b \to e$ v_2 with 1.1 sigma
- Final v_2 result with improved yield unfolding coming soon

Rγ of direct photons

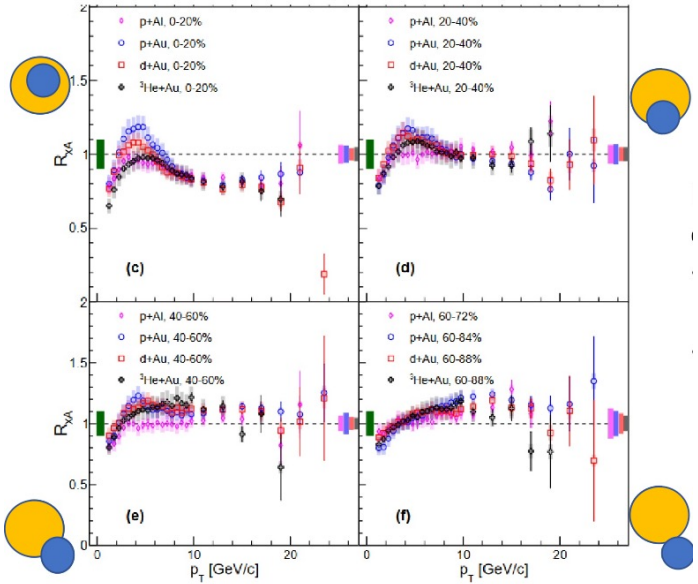





p(d,A)+p(A) → γ dir + X
α = 1.25
PHENIX
preliminary
Pb+Pb, √sNN = 2760 GeV (ALICE)
Pb+Pb, √sNN = 17.3 GeV (WA98)
Au+Au, √sNN = 200 GeV
Au+Au, √sNN = 62.4 GeV
Au+Au, √sNN = 39 GeV
Cu+Cu, √sNN = 200 GeV
d+Au, √sNN = 200 GeV
p+p, √s = 200 GeV
Au+Au, √sNN = 200 GeV (STAR)
Au+Au, √sNN = 200 GeV
(2014 conversion method)
Ncoll scaled prompt photons
p+p fit, √s = 200 GeV
pQCD, √s = 2760 GeV
pQCD, √s = 200 GeV
pQCD, √s = 62.4 GeV
dNγ/dy (1.5 < pT < 5.0 GeV/c)
dNch/dη |η=0

Small system RAA before.

$$R_{AA}(pt) = \frac{\frac{dN_{AA}}{dp_T}}{\langle N_{coll} \rangle \frac{dN_{pp}}{dp_T}}$$



Phys.Rev.C 105 (2022) 064902

The enhancement in peripheral collisions has no clear explanation.
Is the centrality dependence real ?
<Ncoll> in GM has bias.

arXiv:2404.17660 is Denis's paper which indicates that initial fluctuation also could give the suppression of π^0 in d + Au