Stony Brook University

Second international workshop on Collectivity in Small Collision Systems (CSCS2018)

Physics of Small Systems from PHENIX

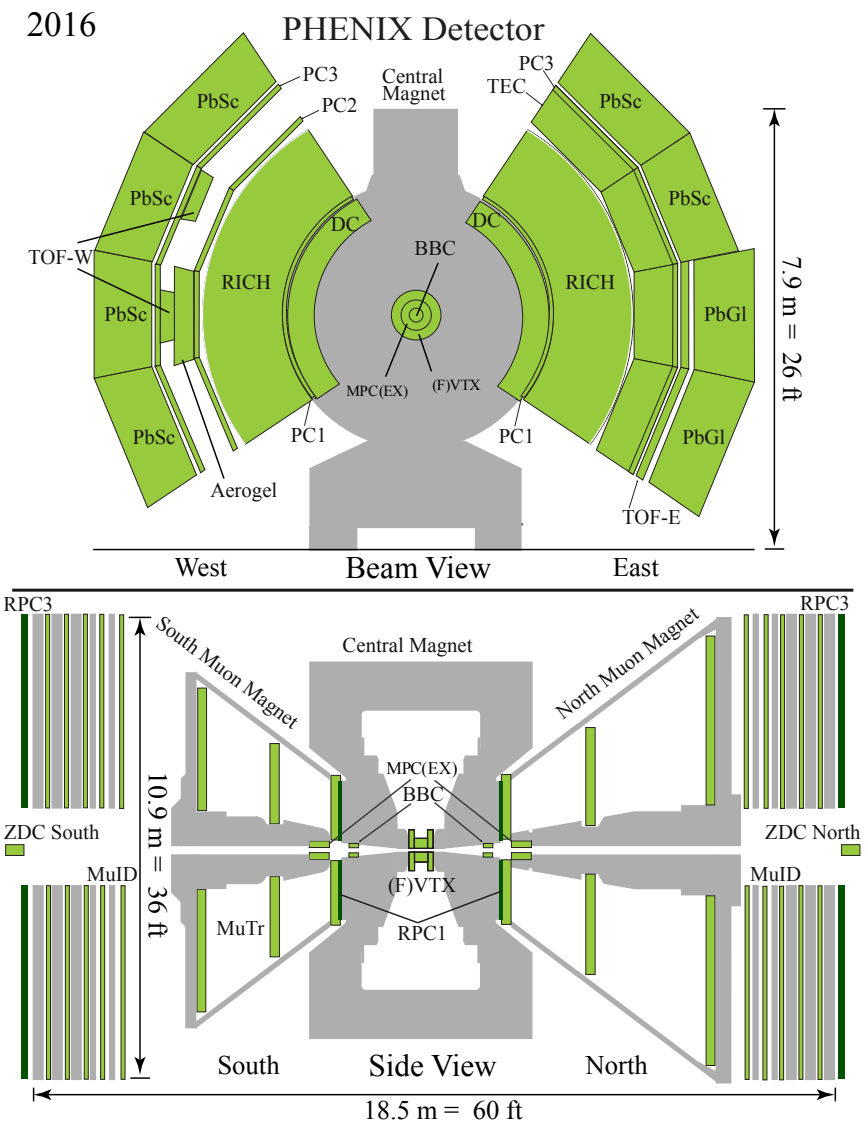
Carlos Pérez Lara (SBU)

Wuhan, China. June 2018

Small Systems Results from PHENIX

- Correlations
- Nuclear Modification Factors
- Heavy Flavour
- Photons

Detector Setup



Central

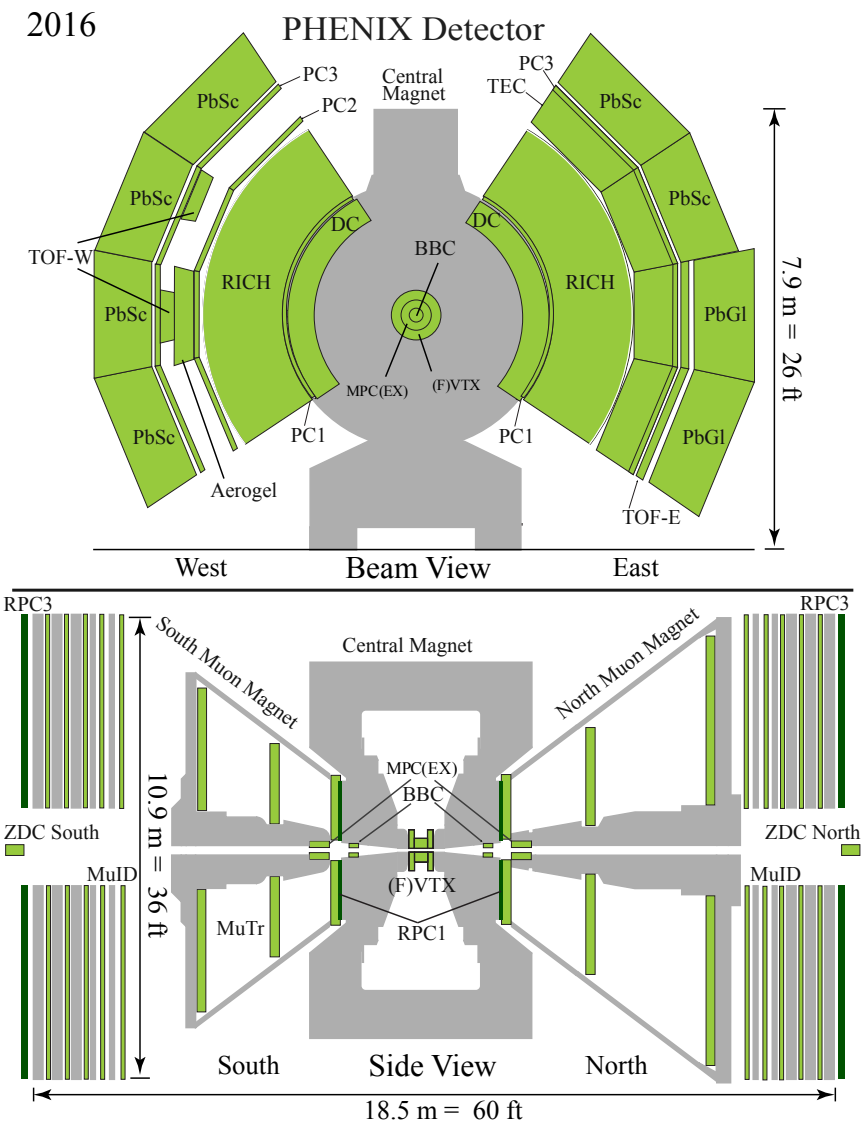
Eta [-0.35,+0.35] | Phi Coverage Pi

Electromagnetic Calorimetry
- PbSc
- PbGl

Tracking
- Drift Chamber
- Pad Chamber 1, 2, 3

Particle Identification
- TOF-W/E
- RICH

Detector Setup



Forward

|Eta| [2,4]

Phi Coverage TwoPi

Electromagnetic Calorimetry

- PbWO4

Tracking

- Muon Chambers
- Silicon Strips
- Silicon Pads

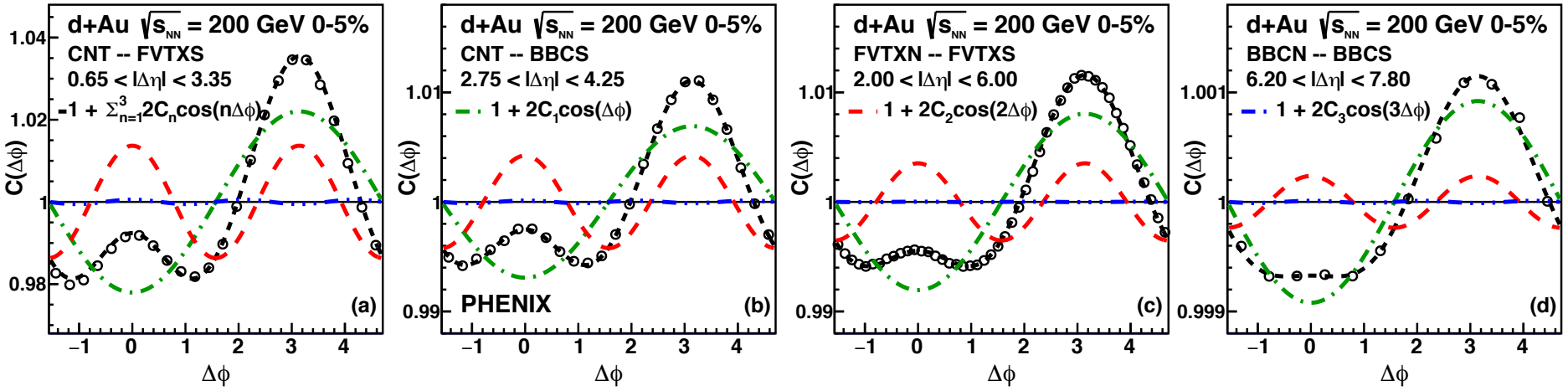
- **Beam-Beam Counter**

Particle Identification

- via DCA

CORRELATIONS

Correlation Function



Eta Gap [0.65, 3.35] [2.75, 4.25] [2.00, 6.00] [6.20, 7.80]

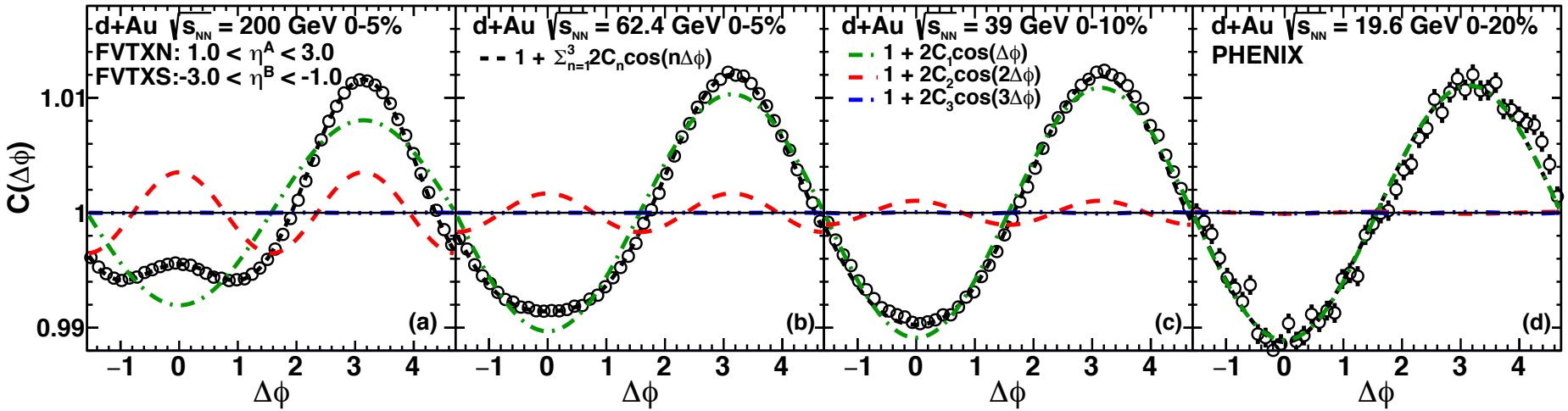
- Strong C_1 and C_2 coefficients present for most central d+Au collisions @ 200 GeV

Phys. Rev. C 96 064905 (2017)

d+Au

200

Correlation Function



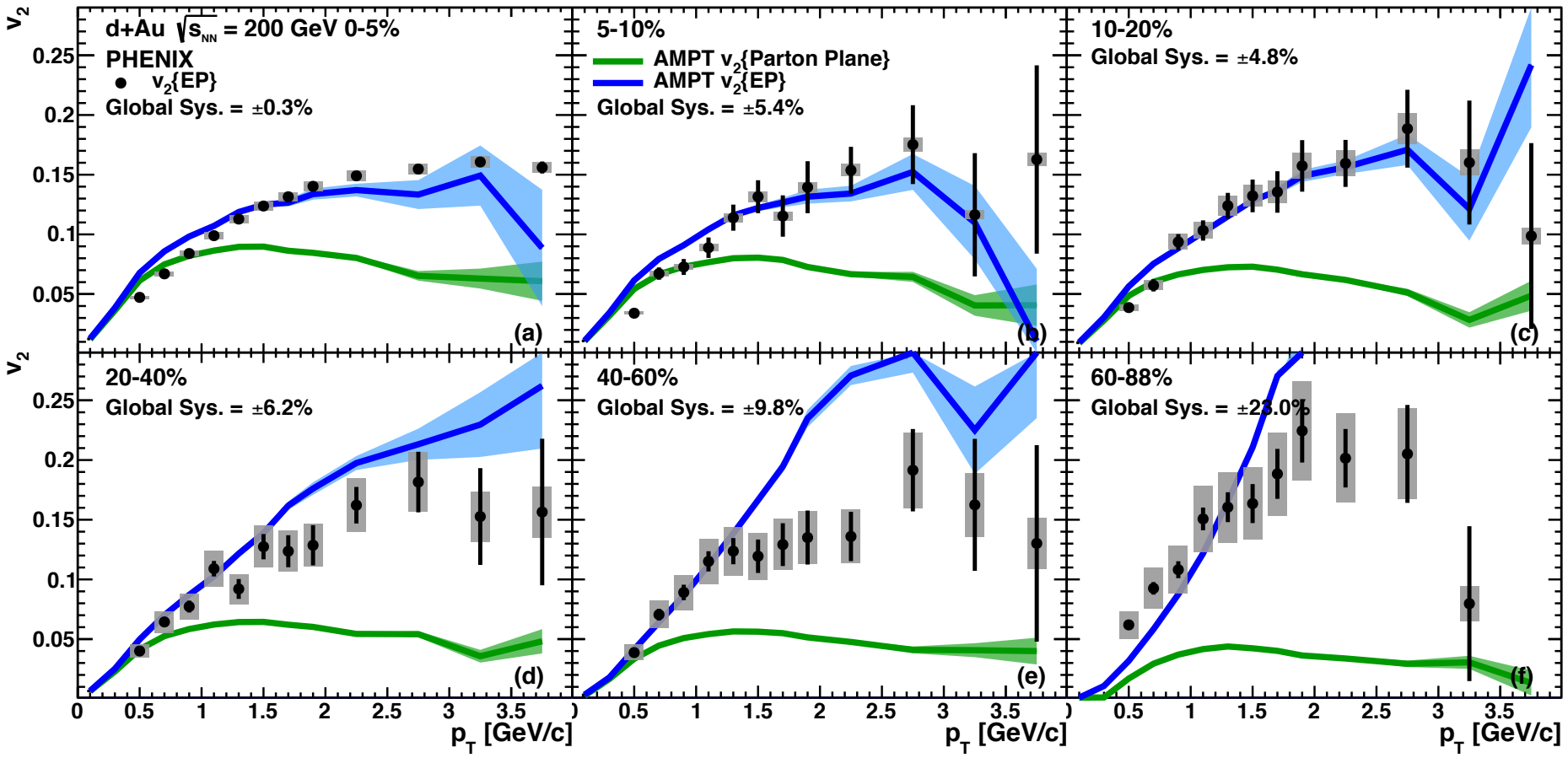
sqrt(s) 200 62.4 39 19.6

- Strong C_1 and C_2 coefficients present for most central d+Au collisions at different energies

Phys. Rev. C 96 064905 (2017)

d+Au | 20 | 39 | 62 | 200

$v_2(p_T)$ for Charged Particles @ 200 GeV



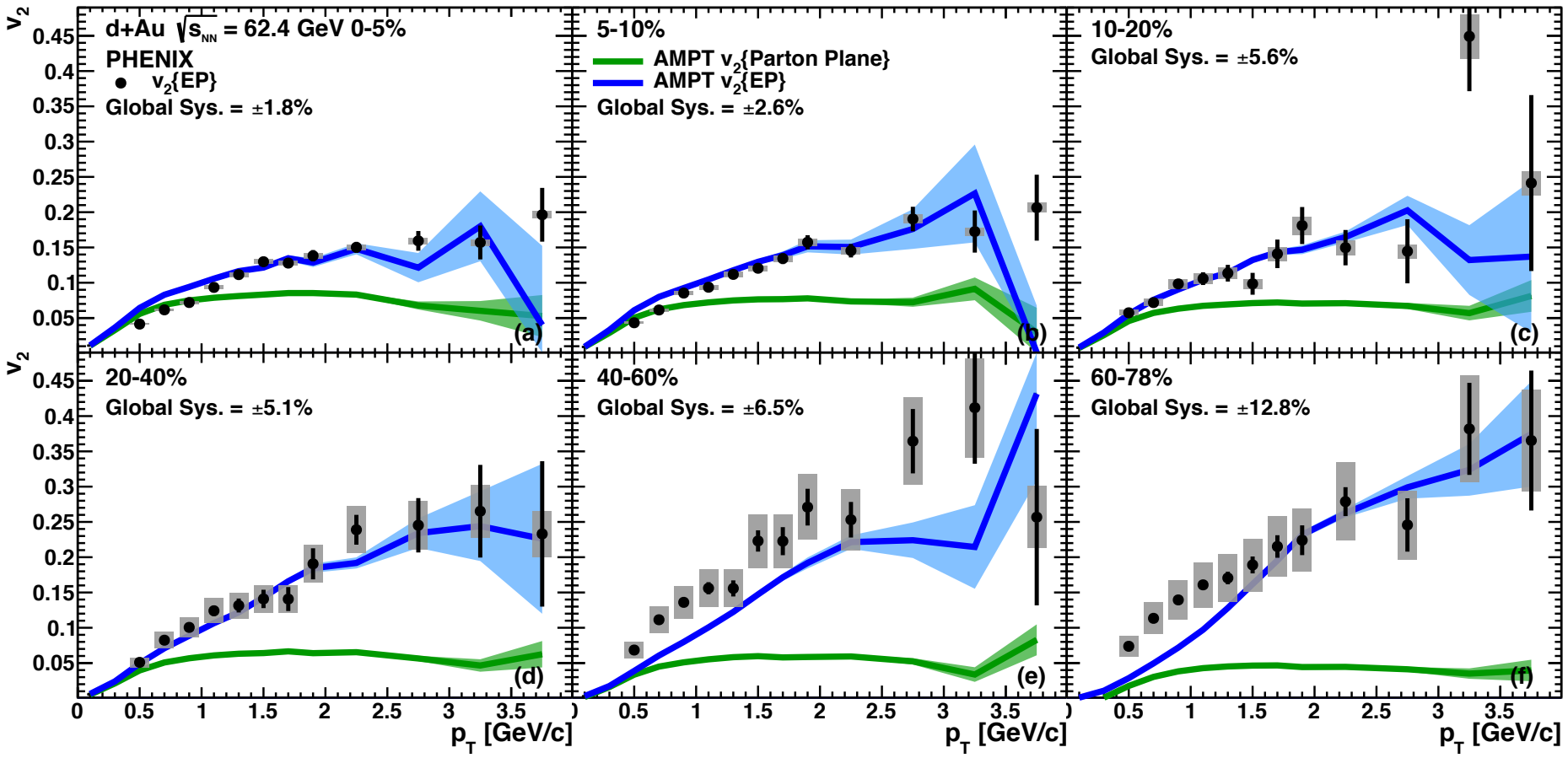
- v_2 signal present in all centralities
- v_2 reproduced by AMPT when simulating EP reconstruction. Difference nonflow?

Phys. Rev. C 96 064905 (2017)

d+Au

200

$v_2(p_T)$ for Charged Particles @ 62.4 GeV



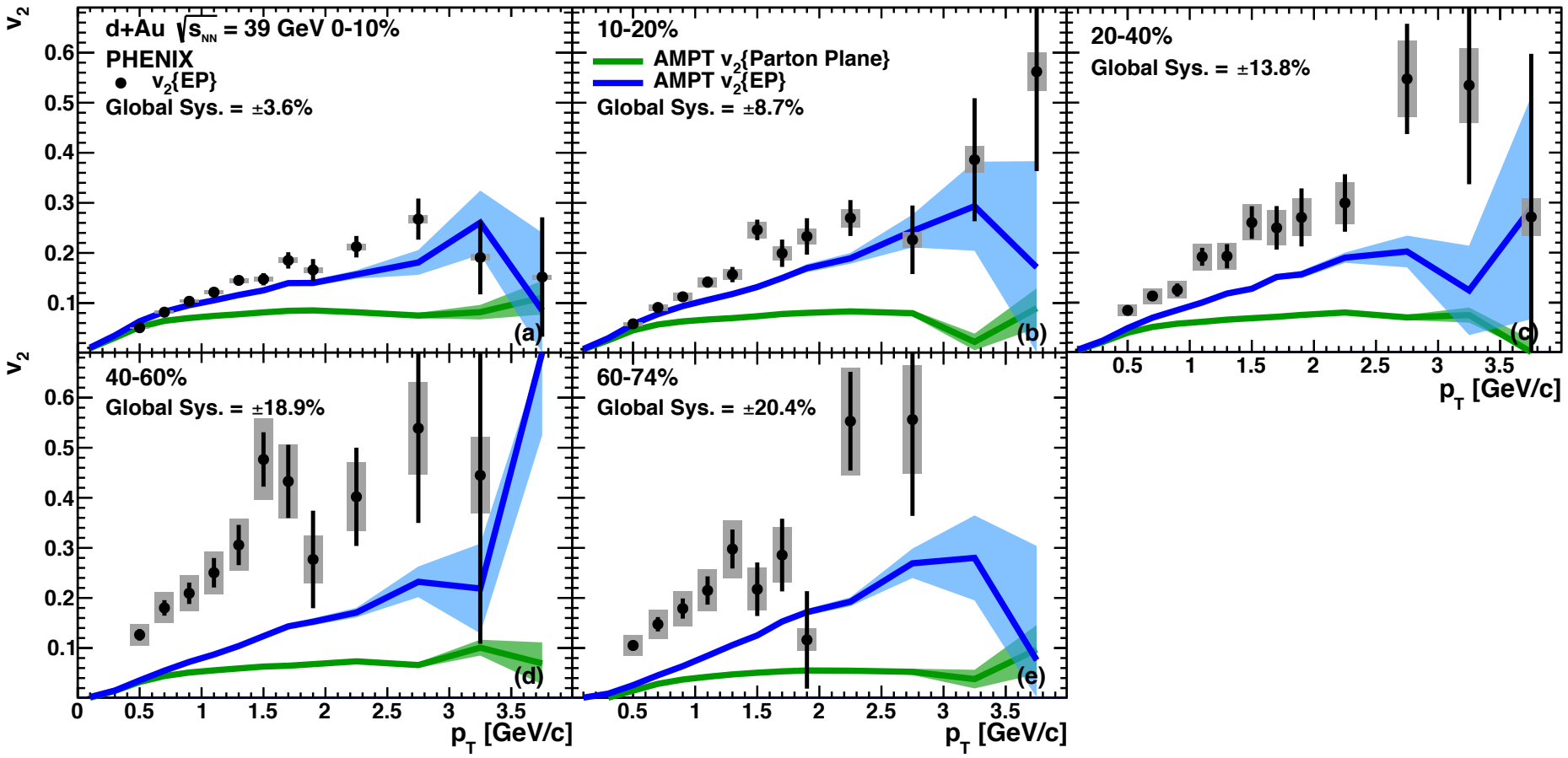
- v_2 signal present in all centralities. Also large for 62.4 GeV
- v_2 reproduced by AMPT when simulating EP reconstruction. Difference nonflow?

Phys. Rev. C 96 064905 (2017)

d+Au

62

$v_2(p_T)$ for Charged Particles @ 39 GeV



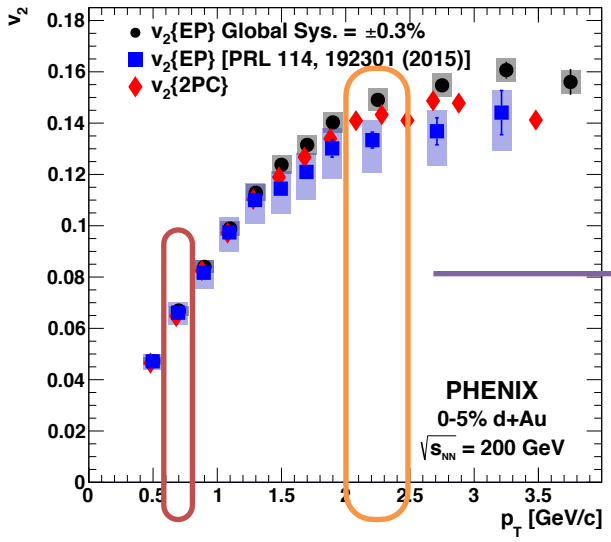
- v_2 signal present in all centralities. Also large for 62.4 and 39 GeV
- v_2 reproduced by AMPT when simulating EP reconstruction. Difference nonflow?

Phys. Rev. C 96 064905 (2017)

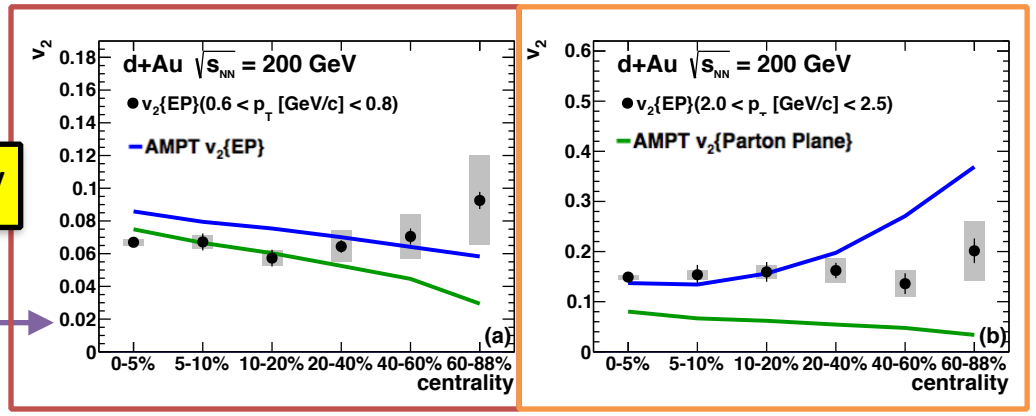
d+Au

39

v_2 vs Centrality



200 GeV

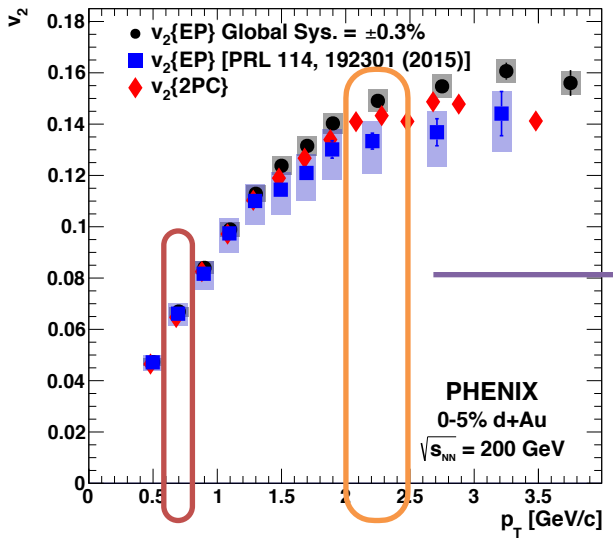


- Relative non-flow component higher for most peripheral centralities and higher p_T

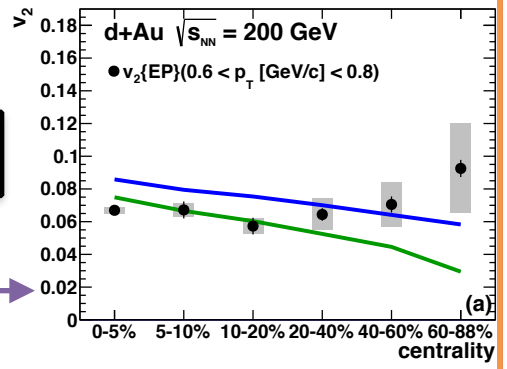
Phys. Rev. C 96 064905 (2017)

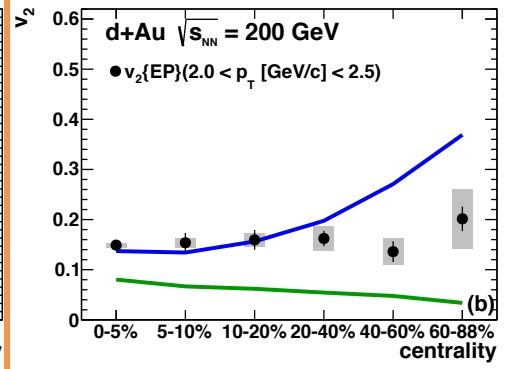
d+Au

v_2 vs Centrality

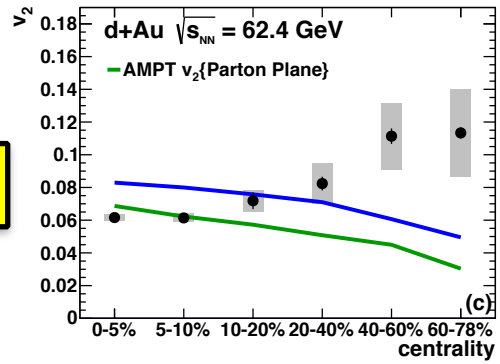


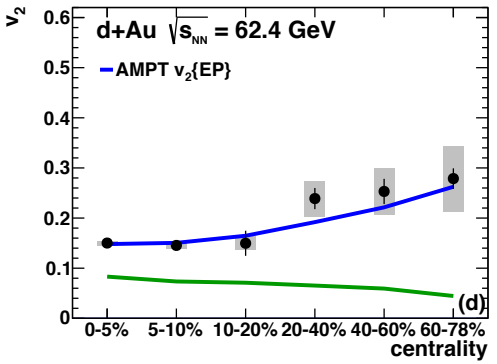
200 GeV



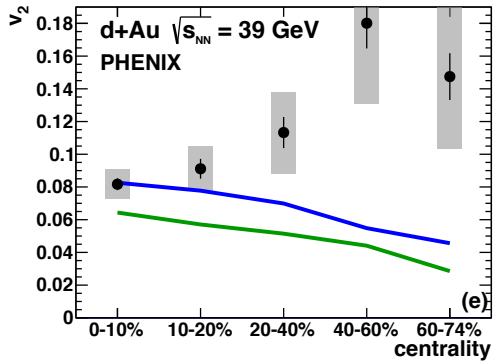


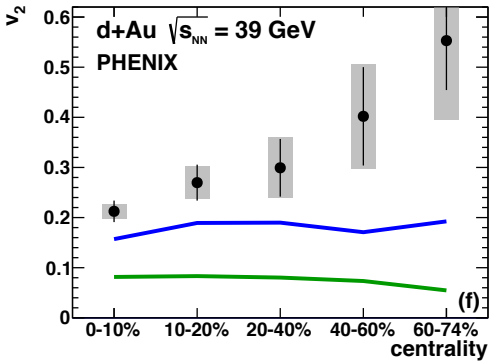
62.4 GeV





39 GeV



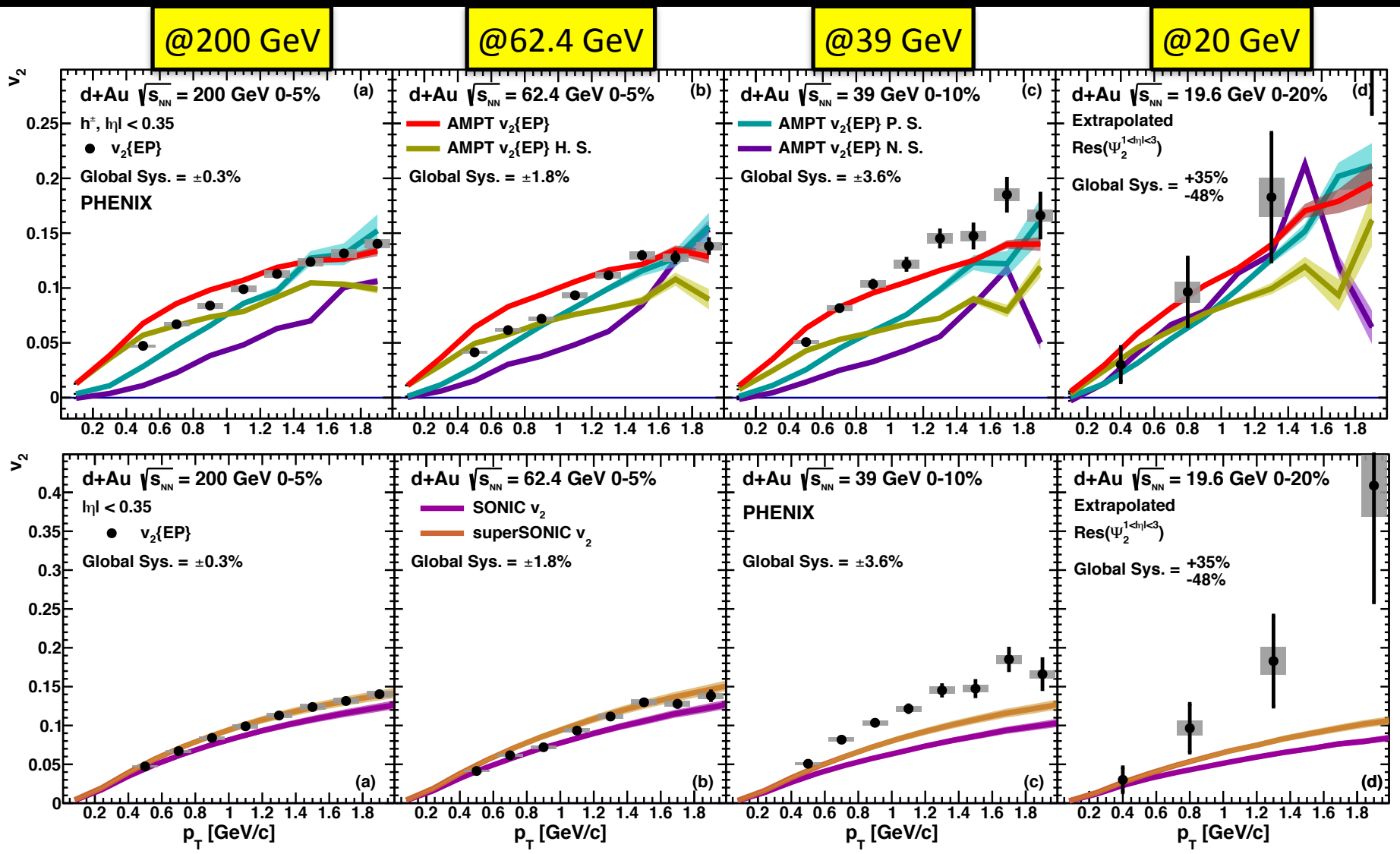


- Relative non-flow component higher for most peripheral centralities and higher p_T
- Same trend in all energies

d+Au

Phys. Rev. C 96 064905 (2017)

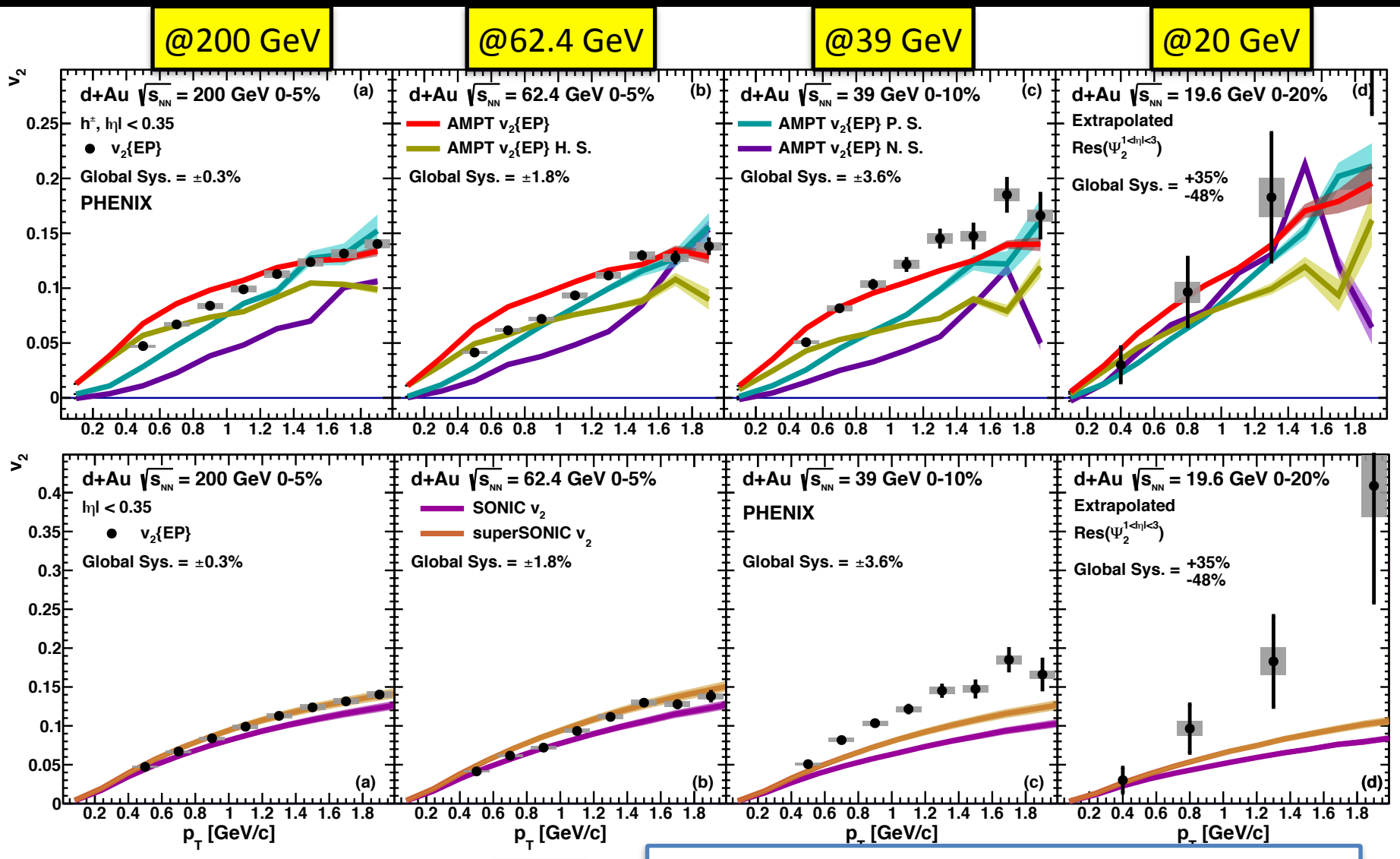
$v_2(p_T)$ for Most Central Low p_T



Phys. Rev. C 96 064905 (2017)

d+Au

$v_2(p_T)$ for Most Central Low p_T



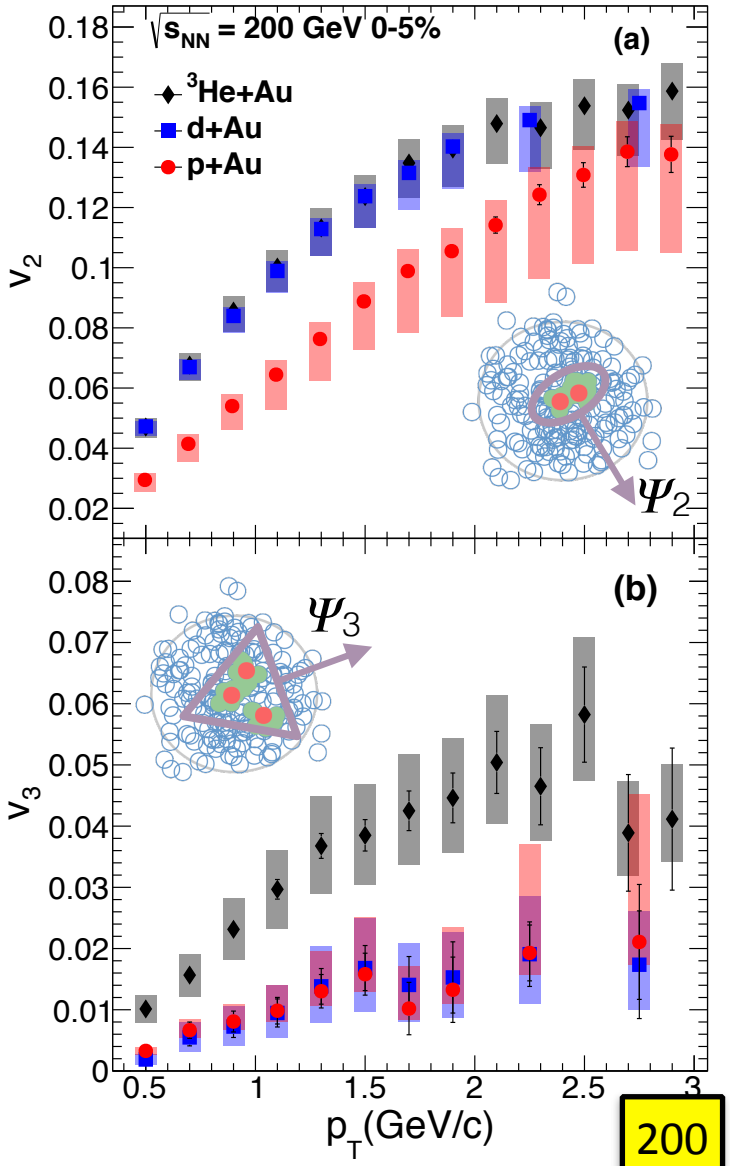
Phys. Rev. C 96 064905 (2017)

d+Au

- All energies well reproduced by AMPT
- 200 and 62.4 GeV well reproduced by Hydro

v_2 and v_3 for Most Central Collisions

- Interesting scaling of v_2 and v_3 with system size
  - d+Au v_2 close to ^{3}He+Au
  - d+Au v_3 close to p+Au

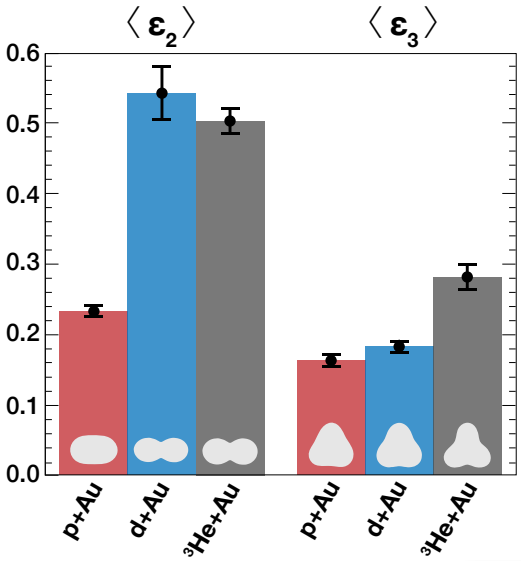


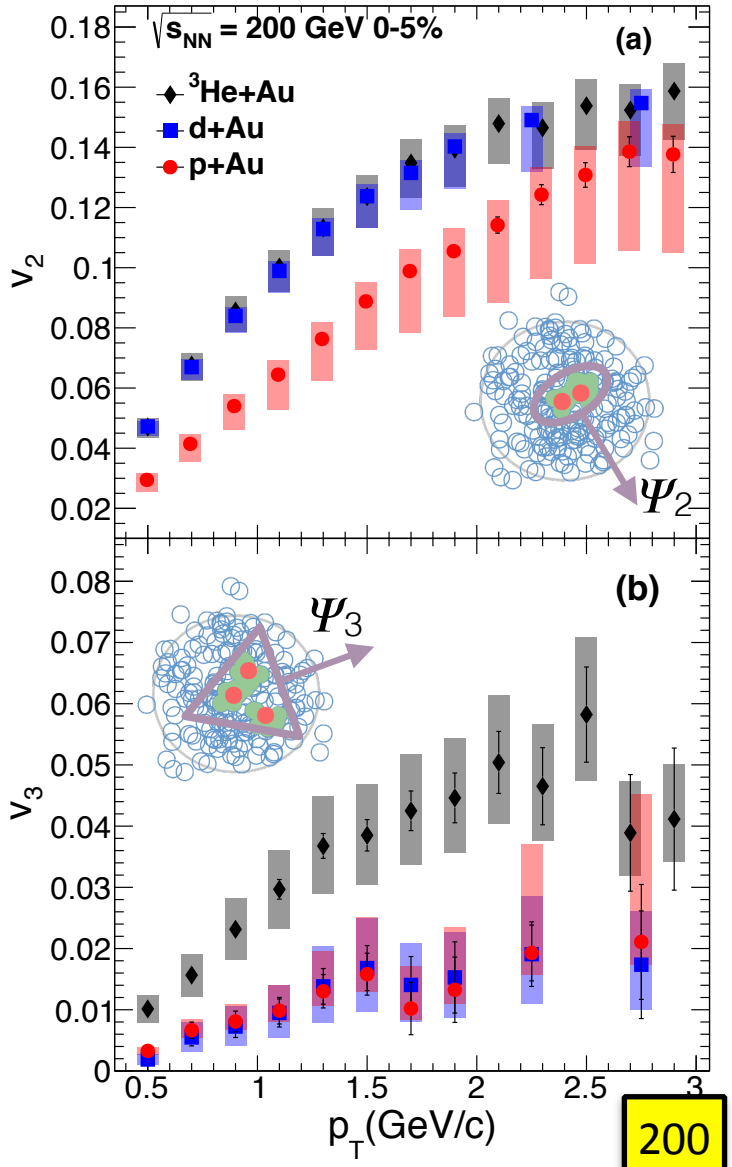
arXiv:1805.02973 (2018)

p+Au | d+Au | ^{3}He+Au | 200

v_2, v_3 <==?==> Initial Eccentricity

- Interesting scaling of v_2 and v_3 with system size
- Same scaling in initial eccentricity
- What is the mechanism behind this scaling?



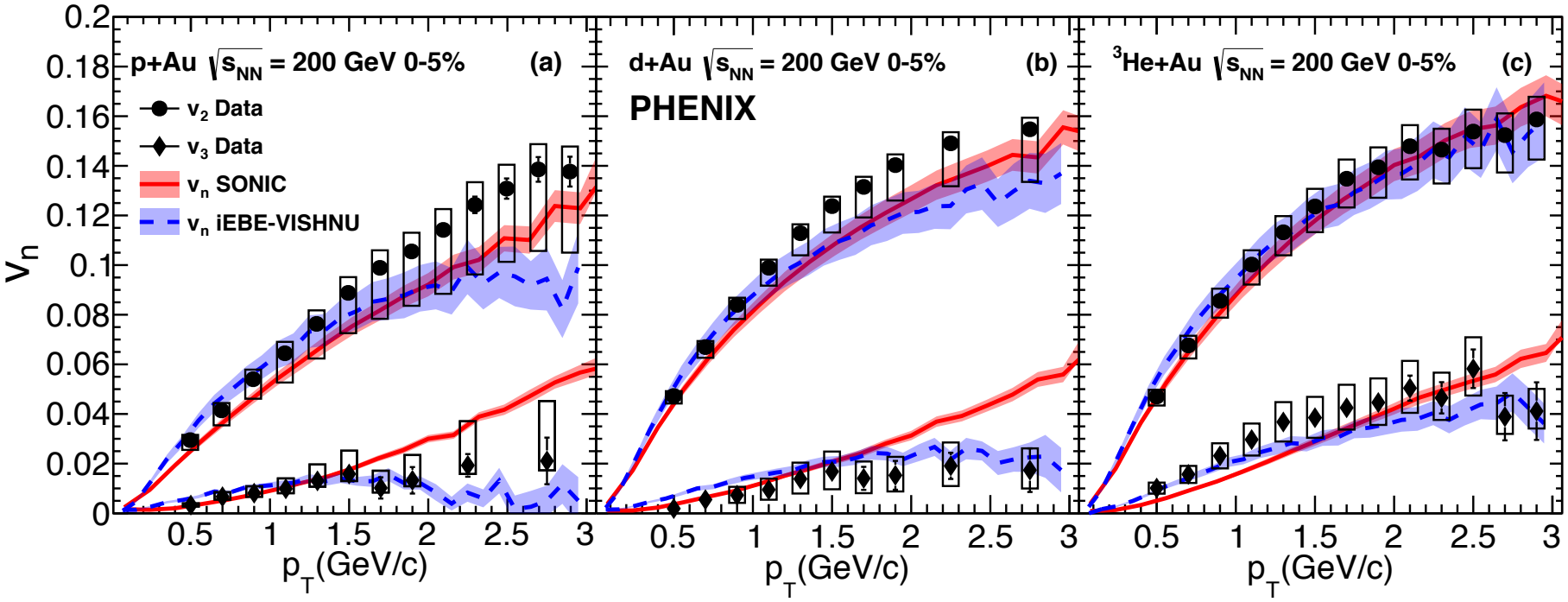


arXiv:1805.02973 (2018)

p+Au d+Au ³He+Au

200

v_2, v_3 <= HYDRO == Initial Eccentricity

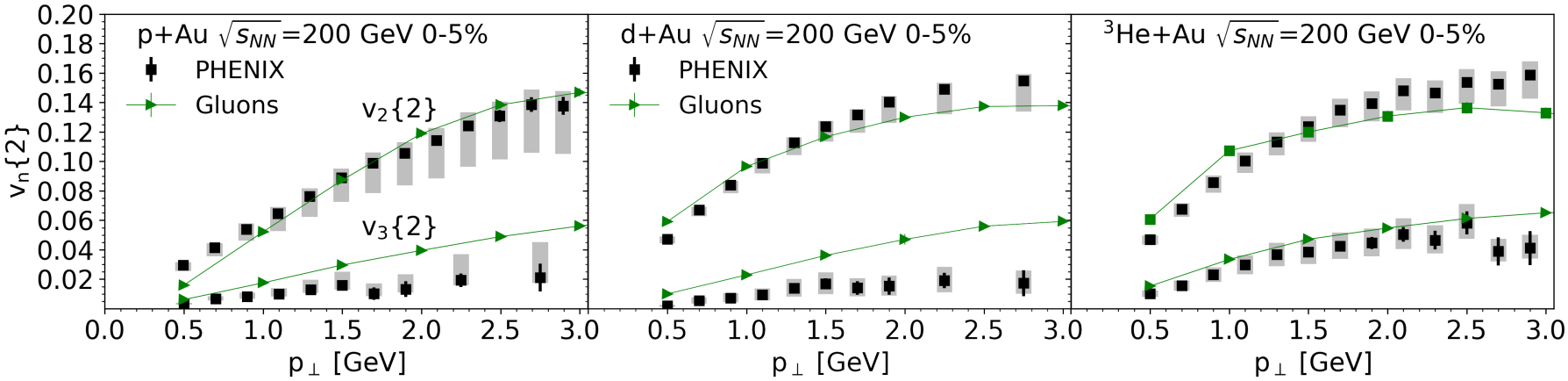


- Hydro models reproduce the p_T dependence quite well for all systems

- Supports that QGP droplet is created in these small systems

arXiv:1805.02973 (2018) p+Au d+Au ^{3}He+Au 200

v_2, v_3 <= CGC EFT == Initial State Correlations



- Recent study extended the CFC effective theory to next to leading order couplings which also provide a scaling in the resulting v_2 and v_3 for asymmetric systems.

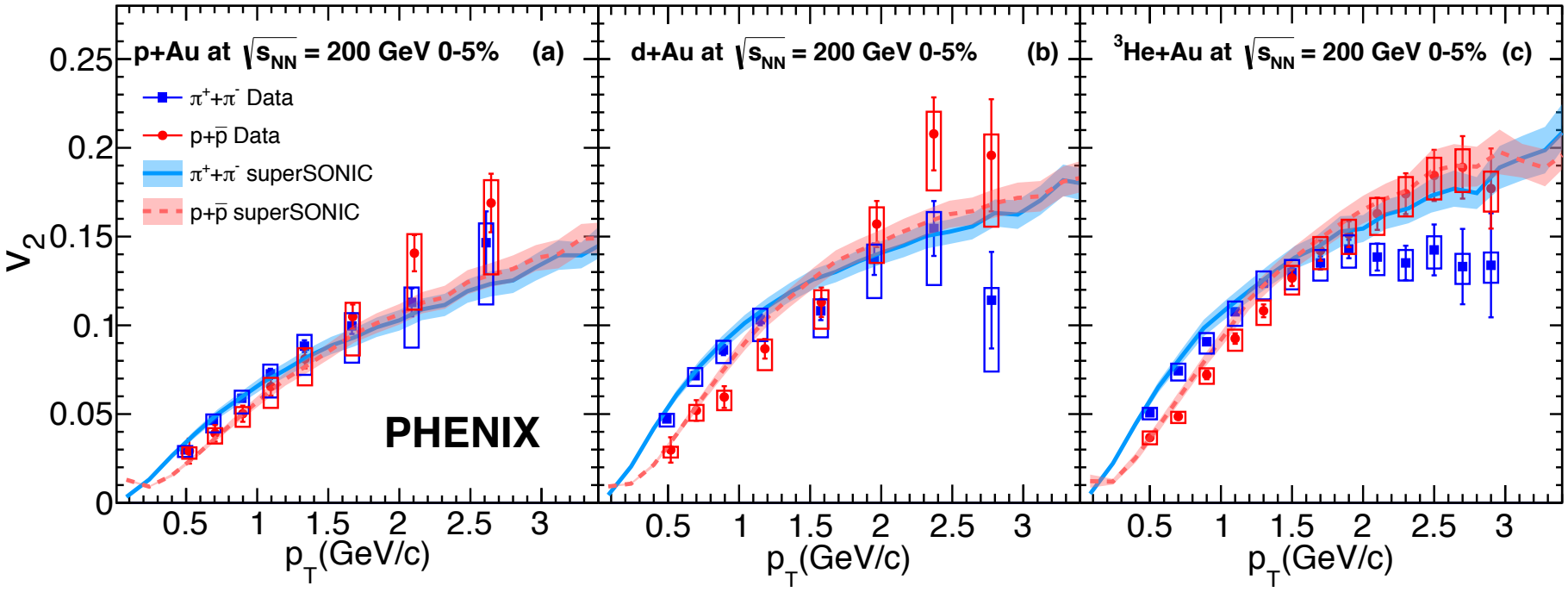
- CFC EFT also reproduces quite well the v_2 p_T trend for all systems, however overshoots v_3 in the smallest systems

- Supports that signals found are a result of the correlations created by gluons coupling in the initial state. No medium needed.

arXiv:1805.09342 (2018) p+Au d+Au ^{3}He+Au 200

Particle Production Mechanism

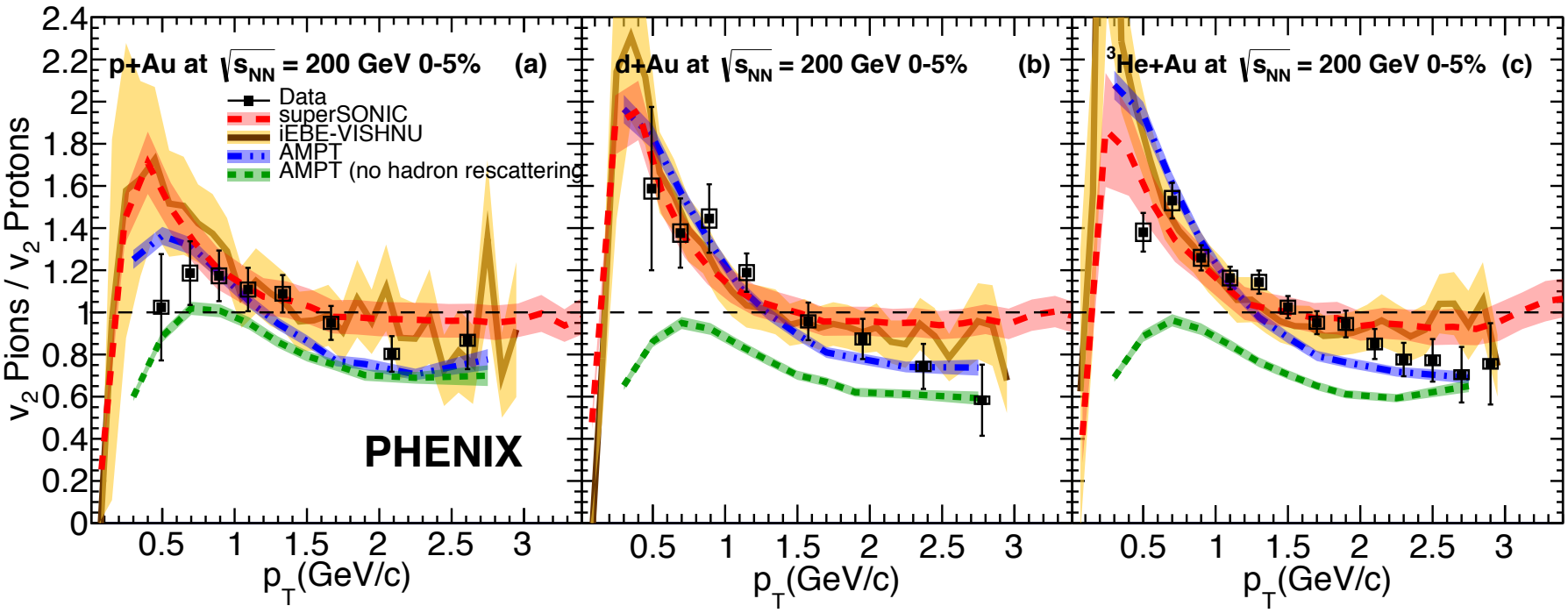
$v_2(p_T)$ Mass Dependence



- Large difference in v_2 for pions and protons.
- Hydro reproduces quite well low p_T data.

arXiv:1710.09736 (2017) p+Au d+Au ^{3}He+Au 200

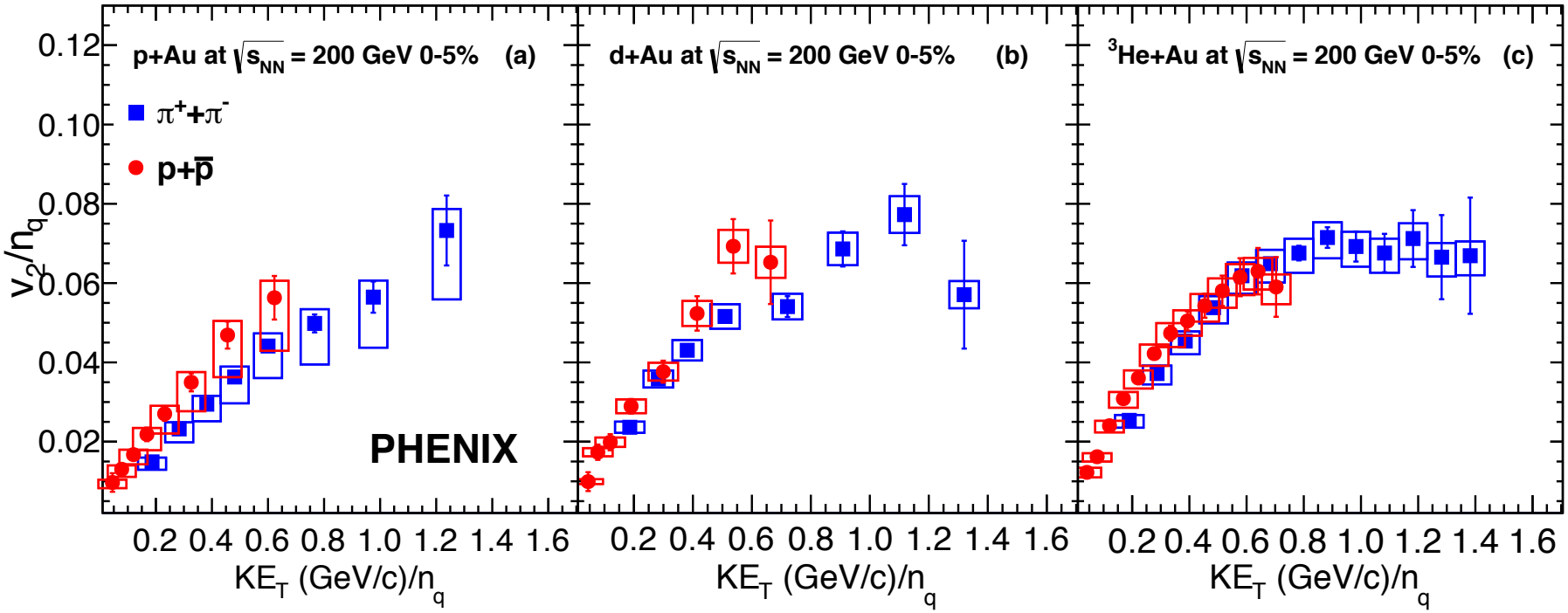
$v_2(p_T)$ Mass Dependence



- Large difference in v_2 for pions and protons.
- Hydro reproduces quite well low p_T data.
- So does AMPT which suggests that most of the difference is build-up at hadronic phase.

arXiv:1710.09736 (2017) p+Au d+Au ^{3}He+Au 200

Partonic $v_2(p_T)$ Test



- Test of scaling with constituent quarks.
- Approximate quark scaling holds very well for the three different systems.

arXiv:1710.09736 (2017) p+Au d+Au ^{3}He+Au 200

Forward Rapidities

NUCLEAR MODIFICATION FACTOR

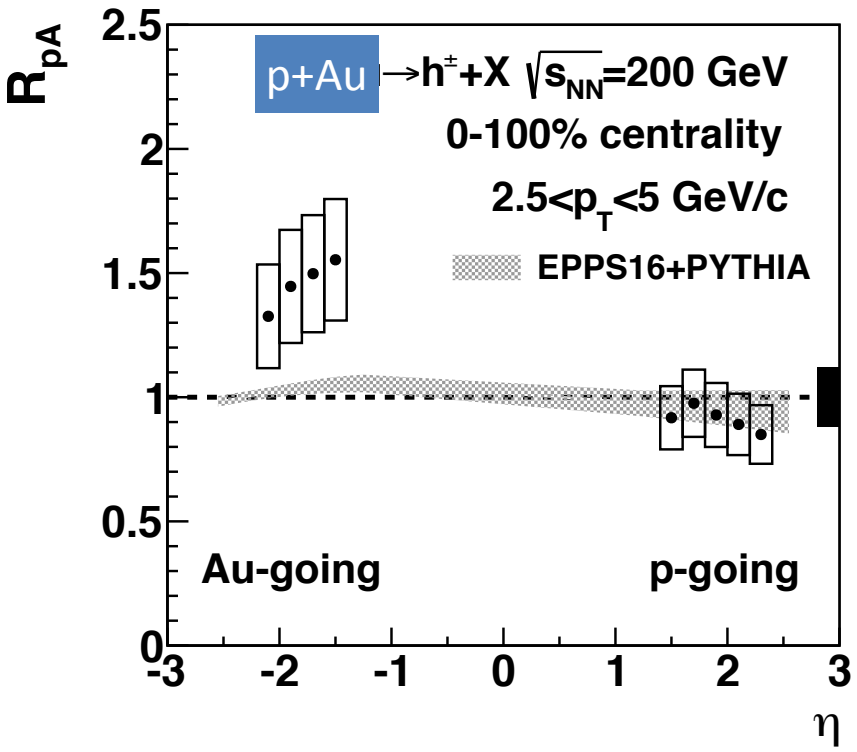
R_{AA} in Heavy Ion Collisions

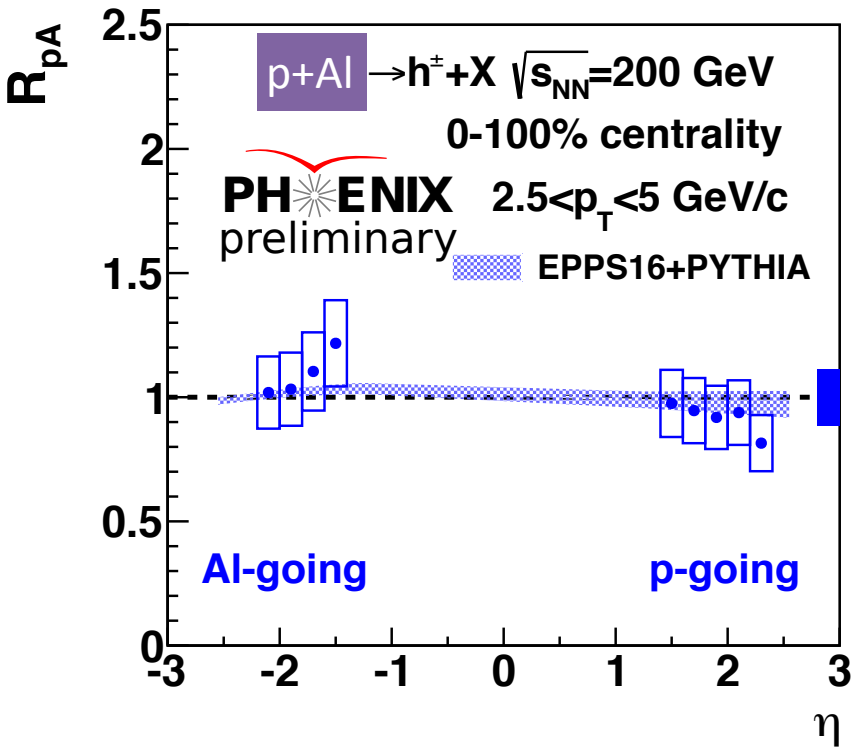
- RAA is one of the (oldest) golden experimental observables in studying the physics of heavy ion collisions.

- It measures the relative yield found in AA to the respective scaled pp measurement, which helps characterise the role of in-medium modification.

- R_{pA} has been also used to study cold-matter effects, such as nuclear shadowing or gluon-saturation, specially at forward rapidities.

R_{pA}(eta) for Charged Hadrons



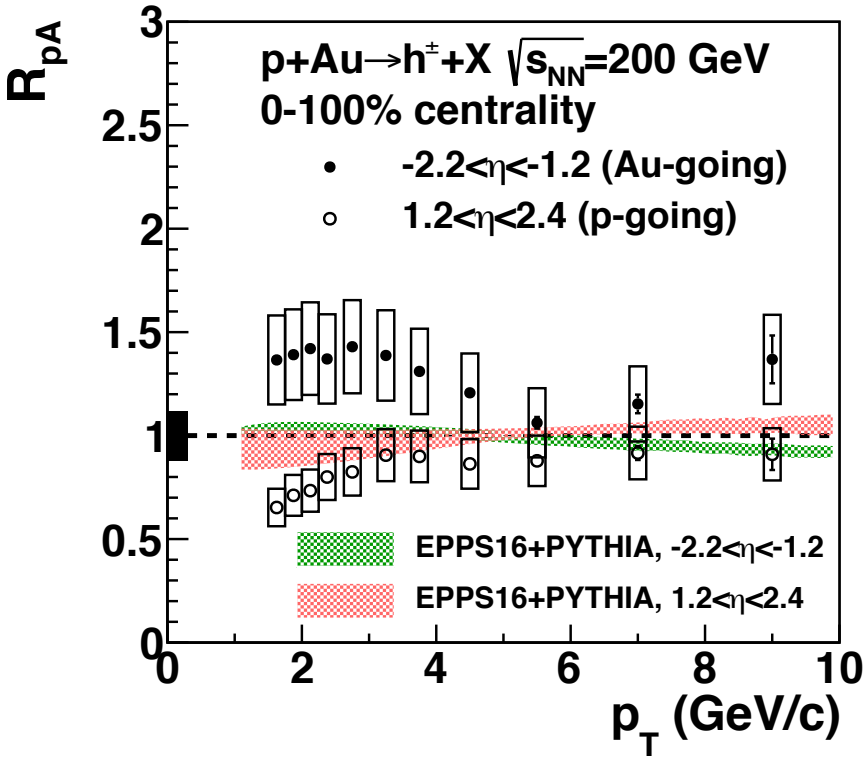


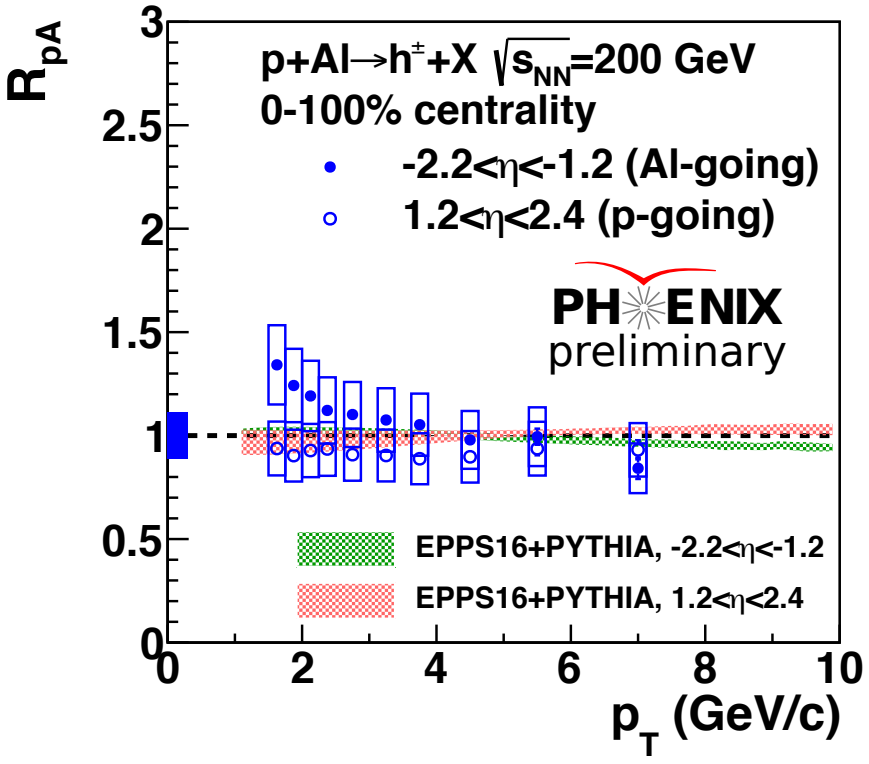
- Enhancement found in Au-going direction not reproducible by EPPS16.

Where does it come from?

p+Au p+Al

R_{pA}(pT) for Charged Hadrons





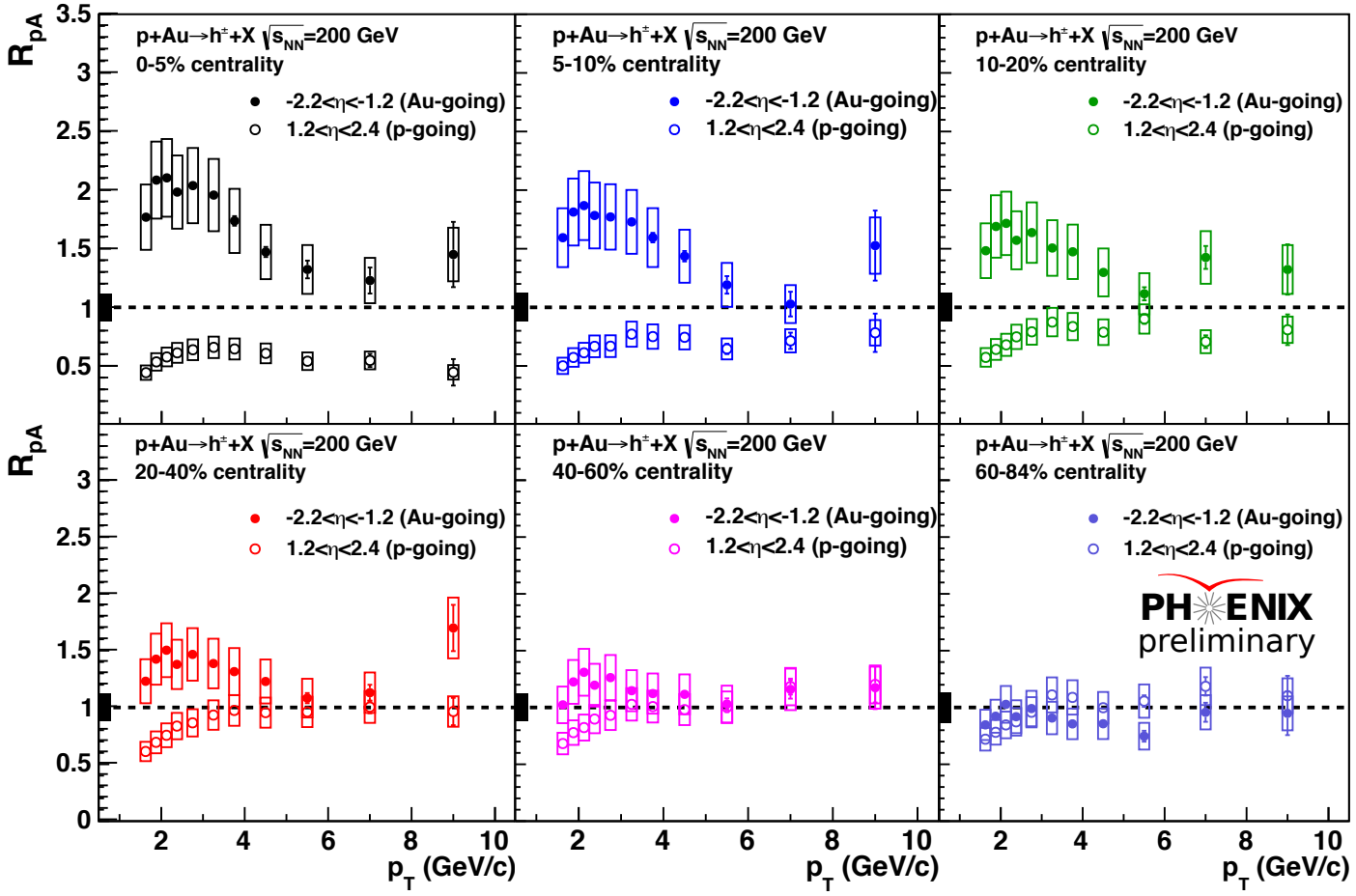
- Enhancement found in Au-going direction not reproducible by EPPS16.

- Enhancement mainly for p_T <5 GeV

p+Au p+Al

Where does it come from?

Centrality Dependence of $R_{pA}(pT)$



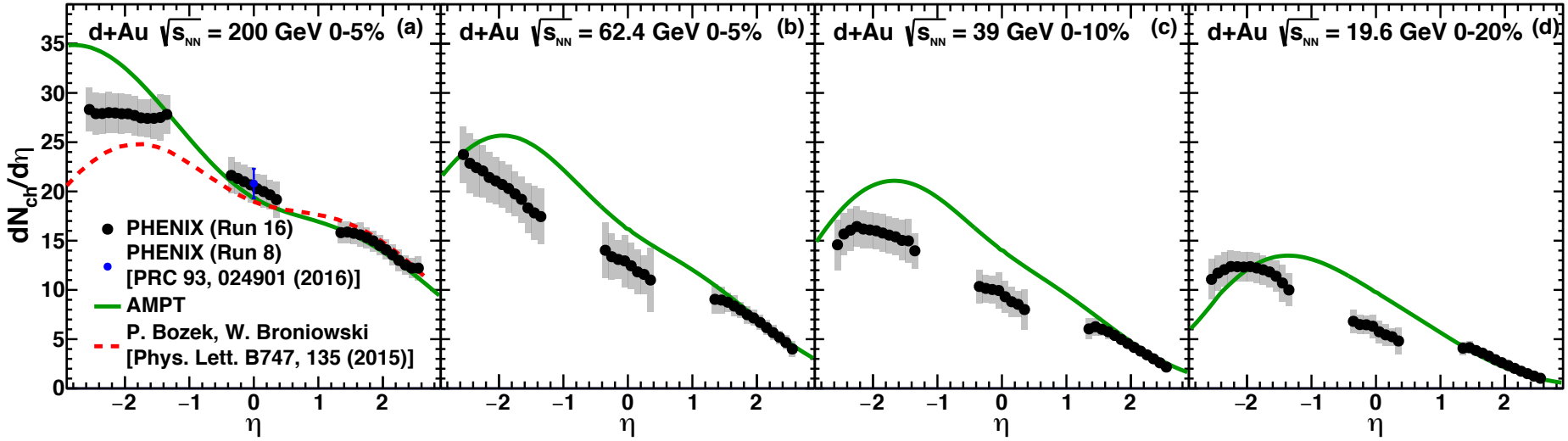
- Enhancement mainly for p_T <5 GeV and centrality dependent.

p+Au

Where does it come from?

Particle Production Mechanism

N_{ch} vs Eta



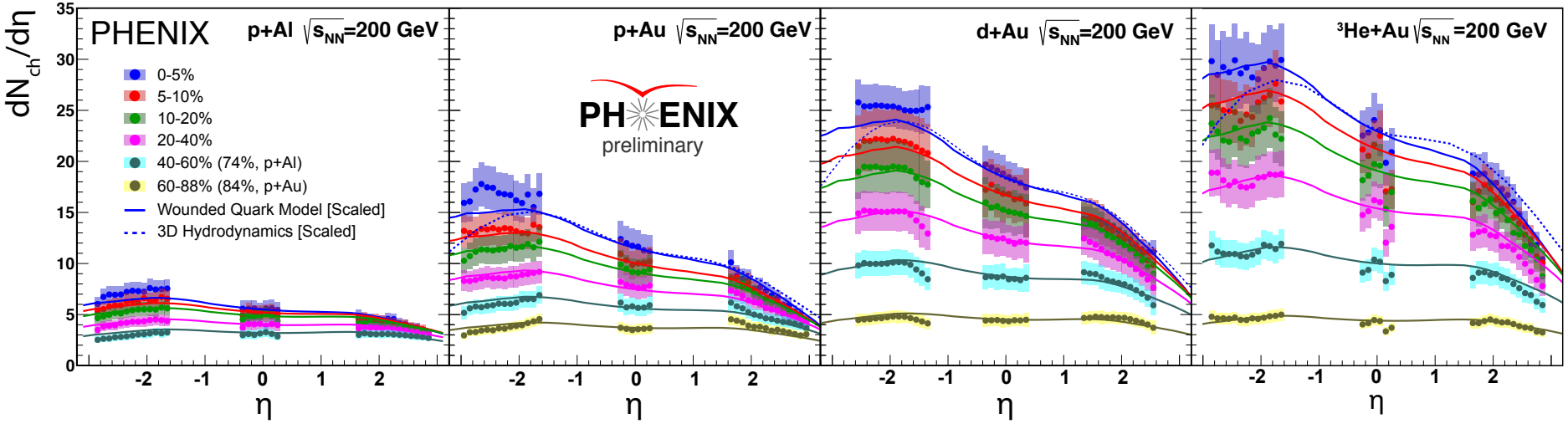
- Both AMP and Hydro qualitatively predict an enhancement in the Au-going direction.

- AMPT describes also the measured trend in d+Au with collisional energy.

Phys. Rev. C 96 064905 (2017)

d+Au | 20 | 39 | 62 | 200

N_{ch} vs Eta



- Both AMP and Hydro qualitatively predict an enhancement in the Au-going direction.
- AMPT describes also the measured trend in d+Au with collisional energy.
- Hydro describes quite well the data from different systems at all centralities

Phys. Rev. C 96 064905 (2017) p+Al p+Au d+Au ^{3}He+Au 200

HEAVY FLAVOUR

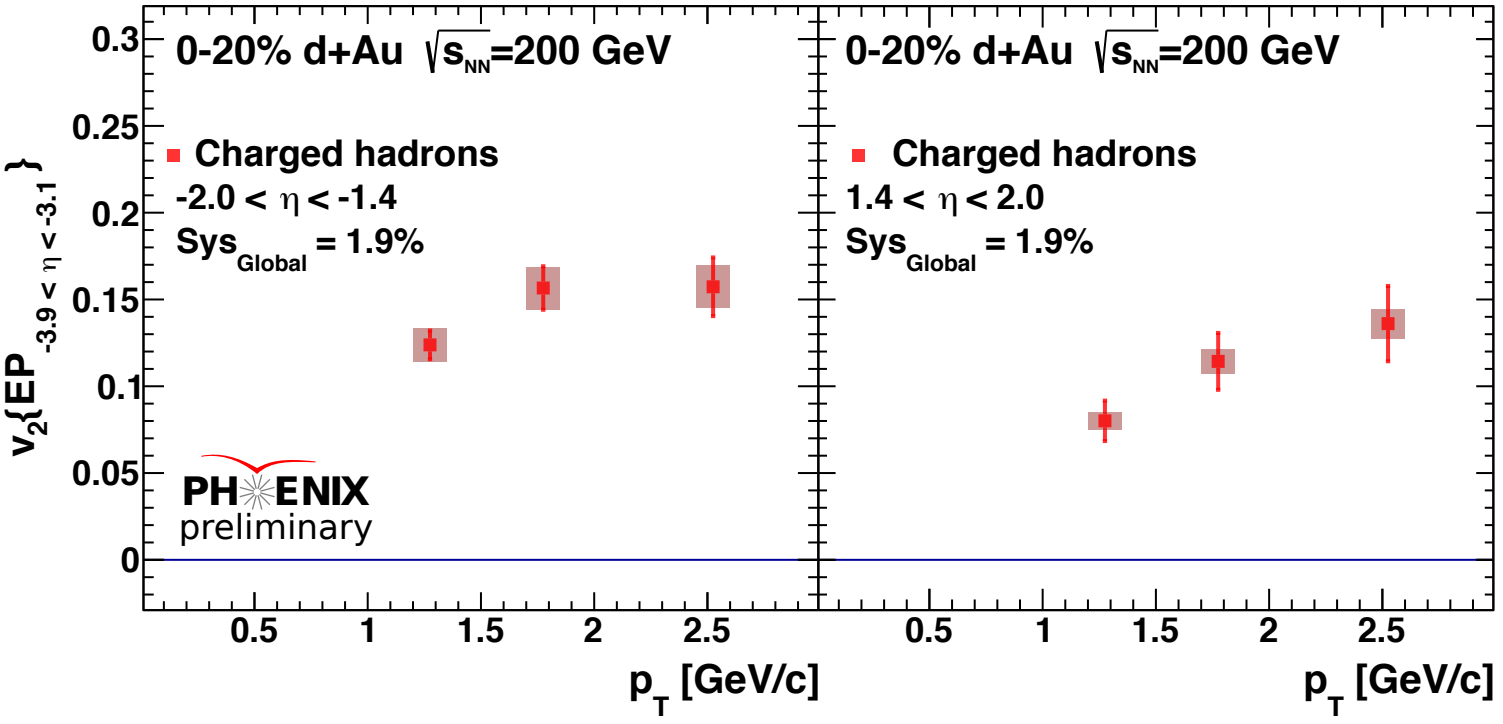
Heavy Flavour in Heavy Ion Collisions

- In Heavy Ion Collisions, heavy flavour particles are expected to be produced mainly in the hard scattering.

- A large (comparable to ch-particles) azimuthal anisotropy has been found for HF-particles in several experiments, species and energies, which suggests some degree of sensitivity to the collective expansion.

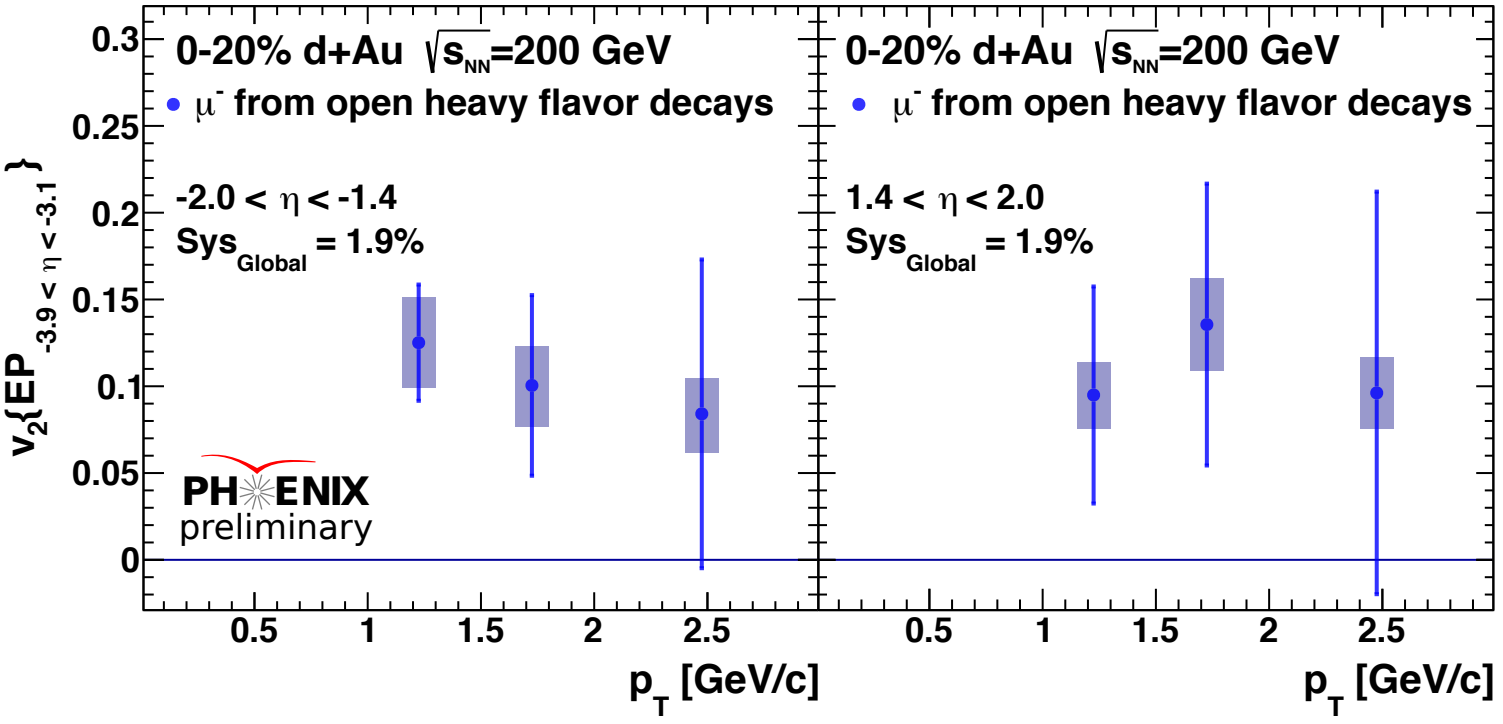
- How about small systems, low energies?

Charge Hadrons v_2



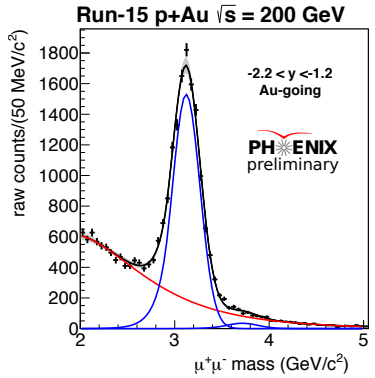
- Charge Particle v_2 measured at forwards and backwards rapidity

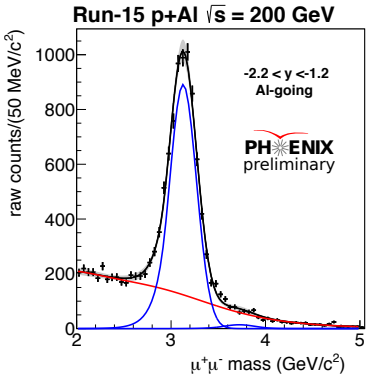
v_2 of Muons from Heavy Flavour Decays

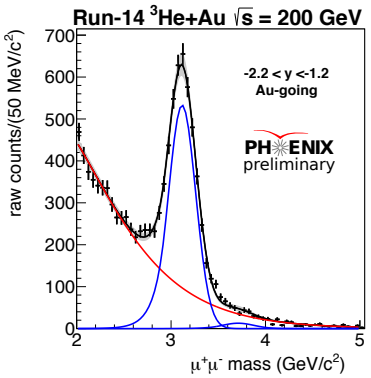


- Muons from heavy flavour decays are obtained from MC templates.
- Large (comparable to charged hadrons) v_2 is found.

Inclusive J/Psi @ Forward Rapidities

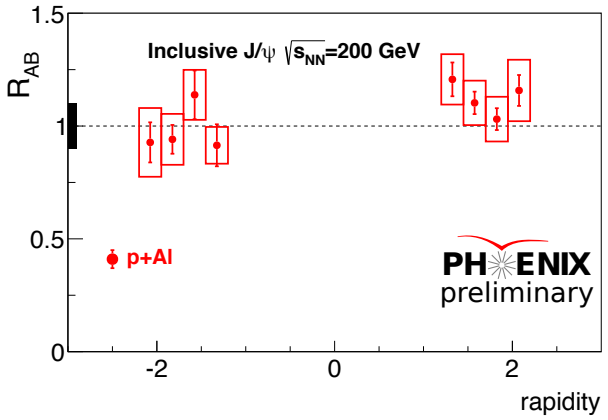


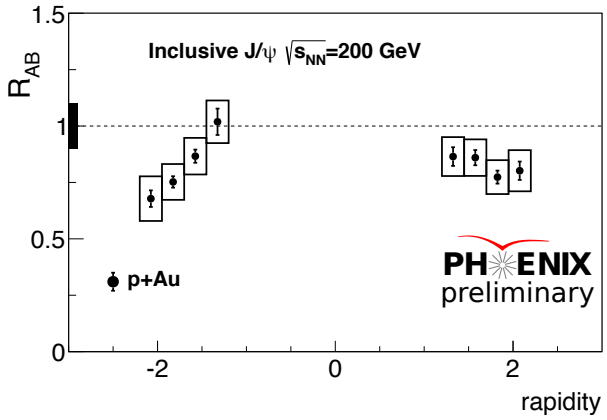


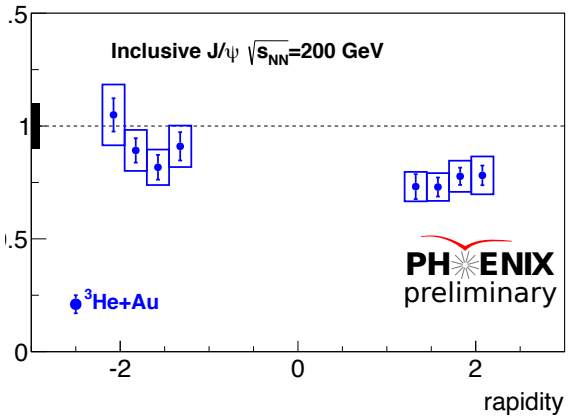


- Preliminary results for closed states hint to suppression even for Au-going direction.

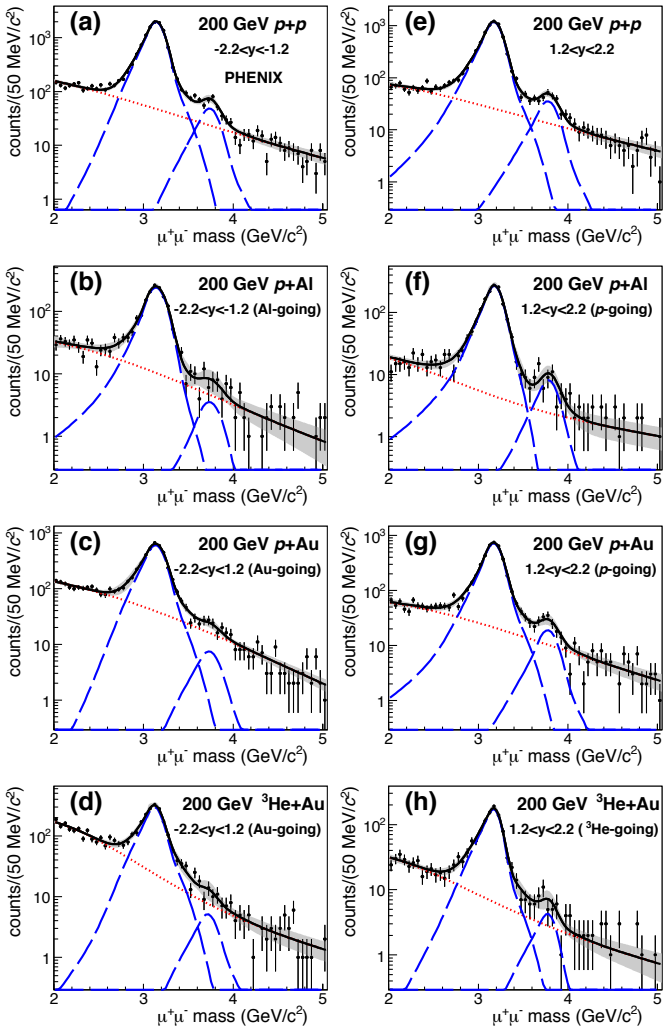
- Are mechanisms responsible for enhancement of charged particles less effective with quarkonia?



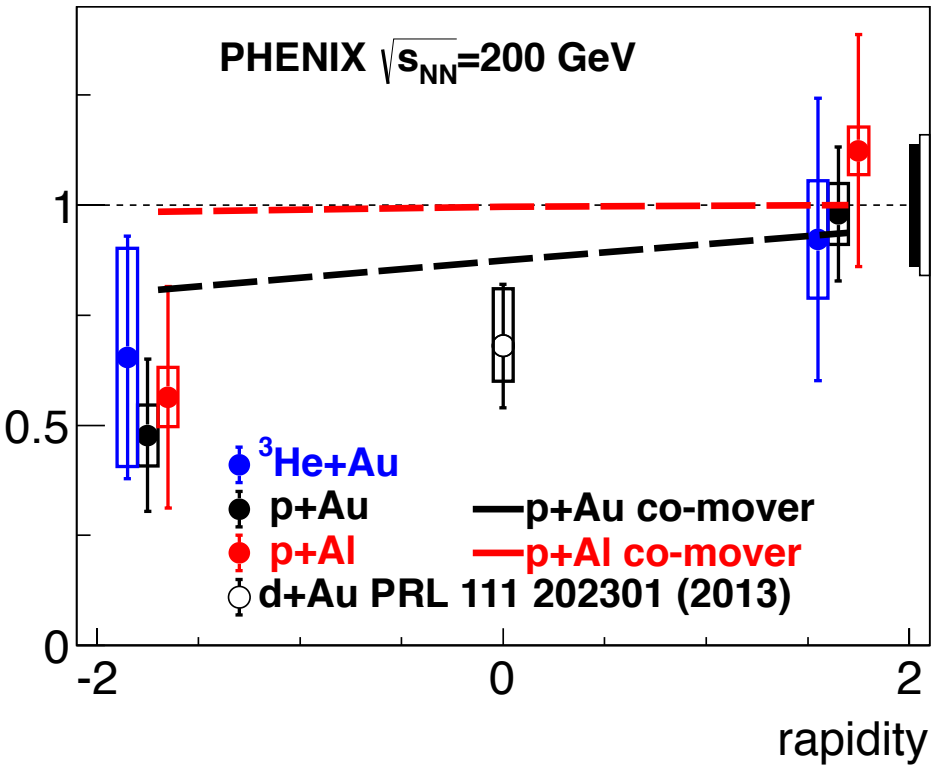




Psi(2S) / Psi(1S) Ratios in SS



$$\left[\frac{\sigma_{\psi(2s)}}{\sigma_{\psi(1s)}}\right]^{p/^3He+A} \Big/ \left[\frac{\sigma_{\psi(2s)}}{\sigma_{\psi(1s)}}\right]^{p+p}$$

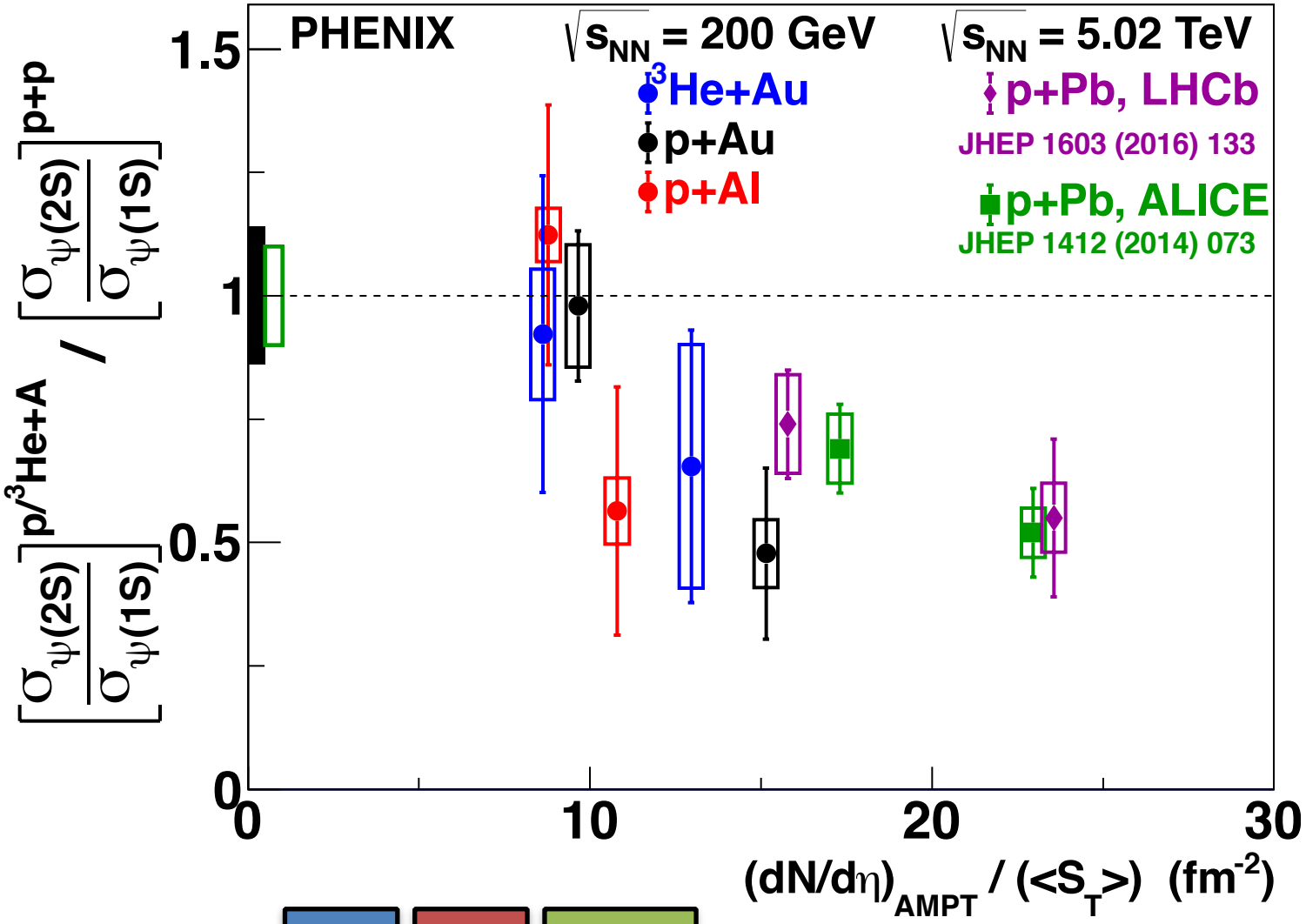


- Sequential suppression of exited states also present is small systems?

PRC 95, 034904 (2017)

p+Au | d+Au | ^{3}He+Au | 200

A Transition?



PRC 95, 034904 (2017)

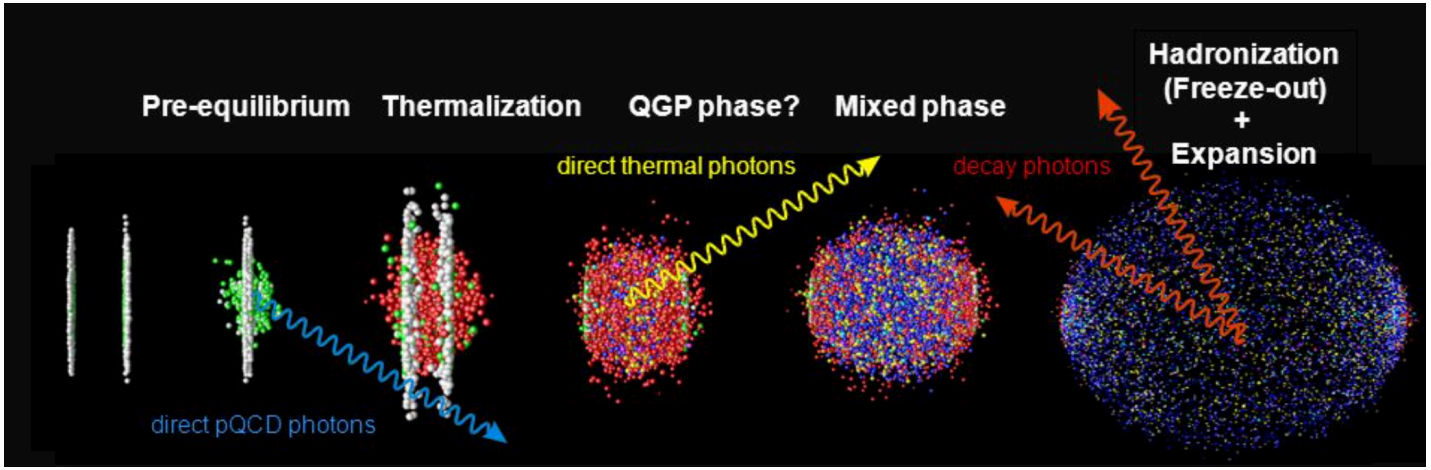
p+Au | d+Au | ^{3}He+Au

200

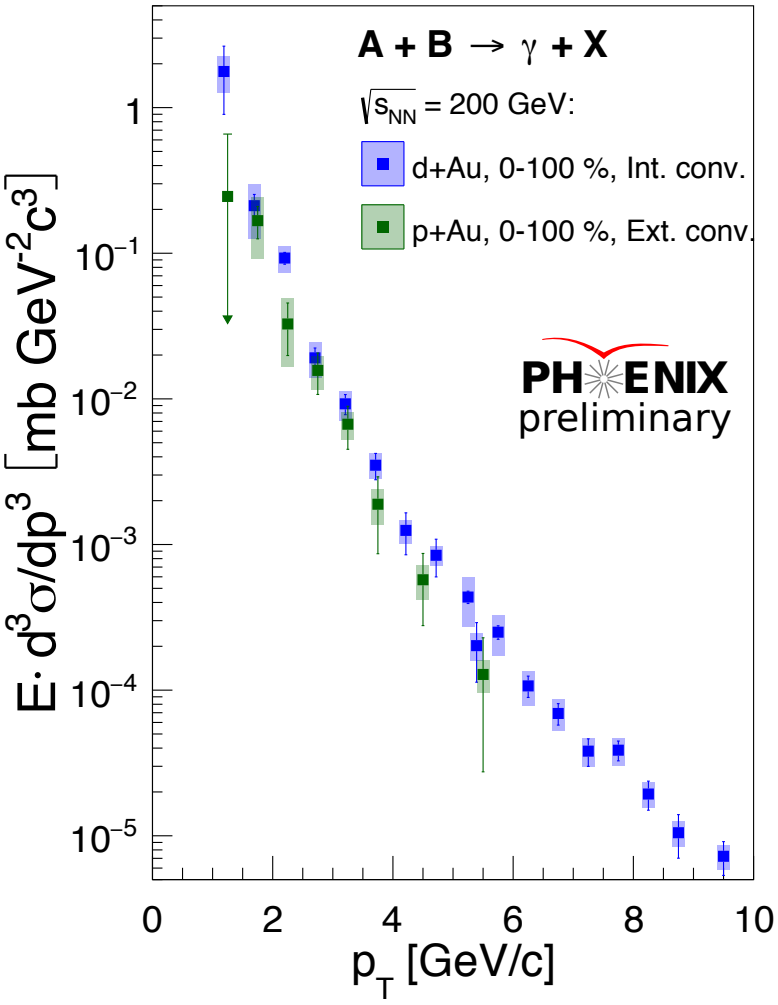
PHOTONS

Photons in Heavy Ion Collisions

- Photons from Heavy Ion Collisions
  - Direct Photons
    - Initial State hard scattering (prompt) pQCD
    - Thermal Temperature from Fireball (QGP)
  - Hadronic Photons
    - Decay products Underlying Event



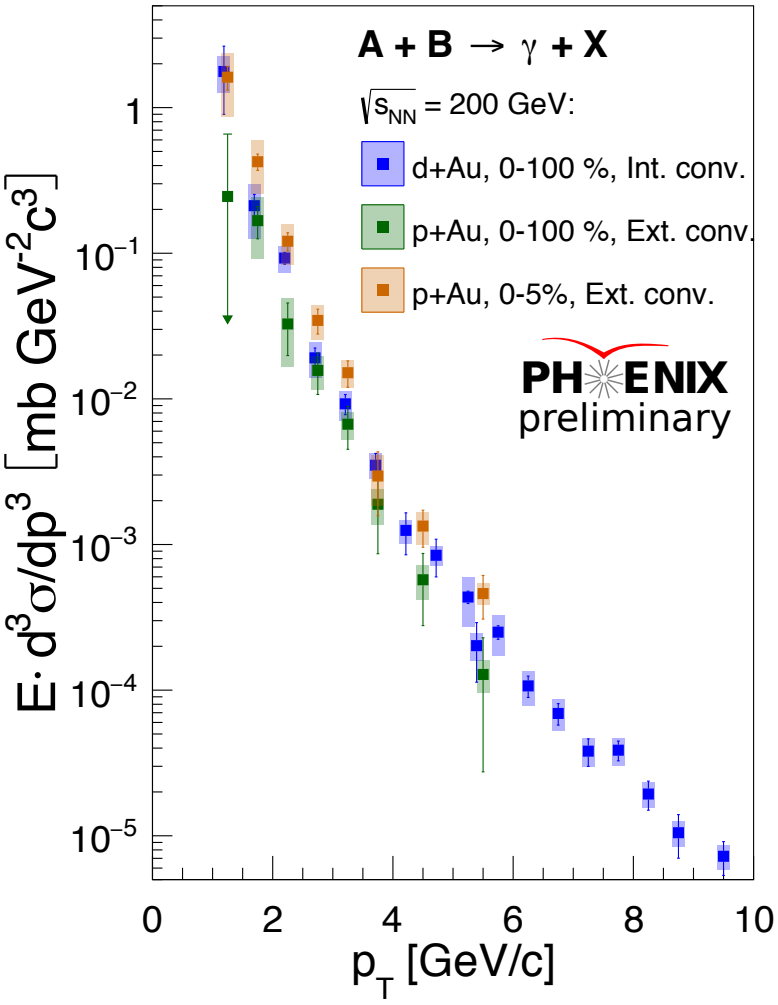
Direct Photon Yields @ 200 GeV in SS



- Small increase in photons production in d+Au wrt p+Au for minimum bias collisions

p+Au d+Au

Direct Photon Yields @ 200 GeV in SS

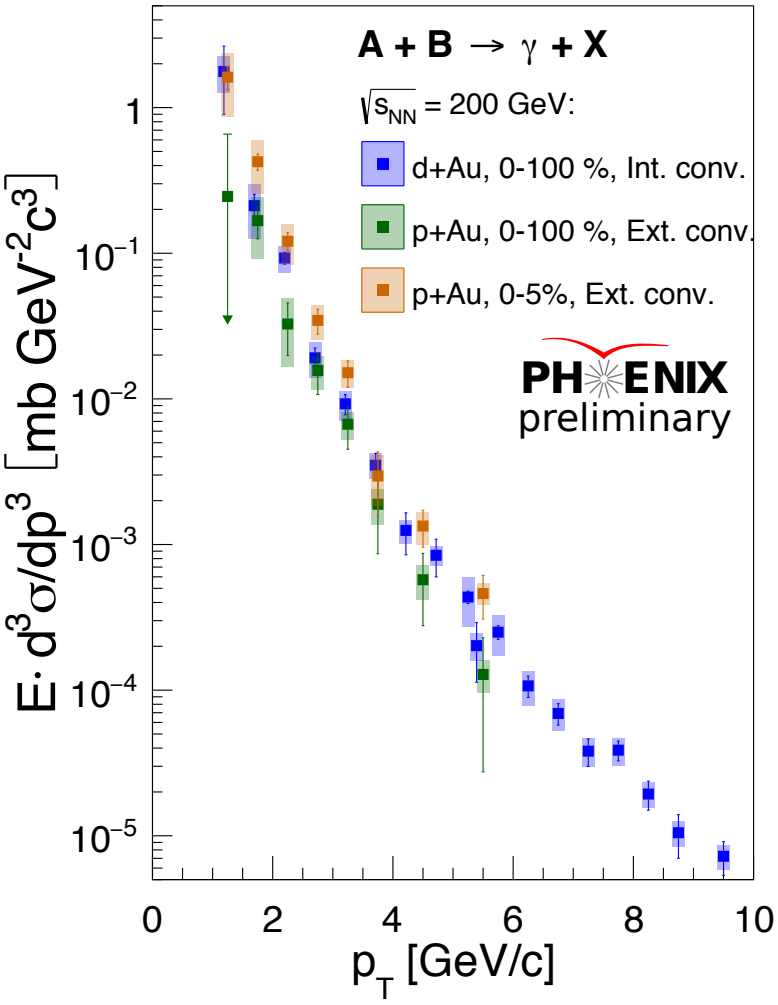


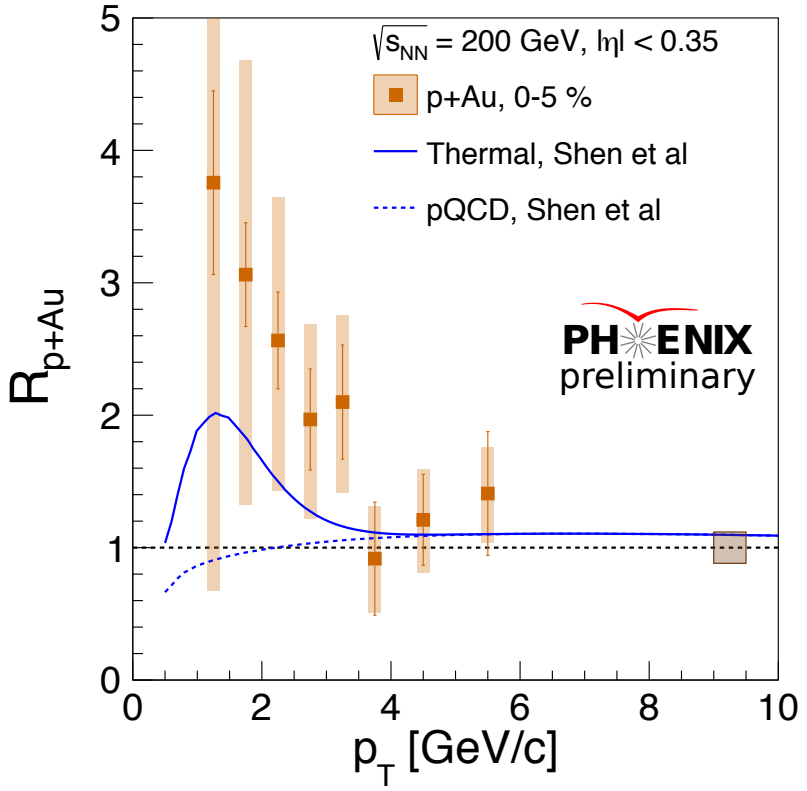
- Small increase in photons production in d+Au wrt p+Au for minimum bias collisions

- Significant increase found at low p_T in most central p+Au Collisions wrt Minimum Bias

p+Au d+Au

Direct Photon Yields @ 200 GeV in SS





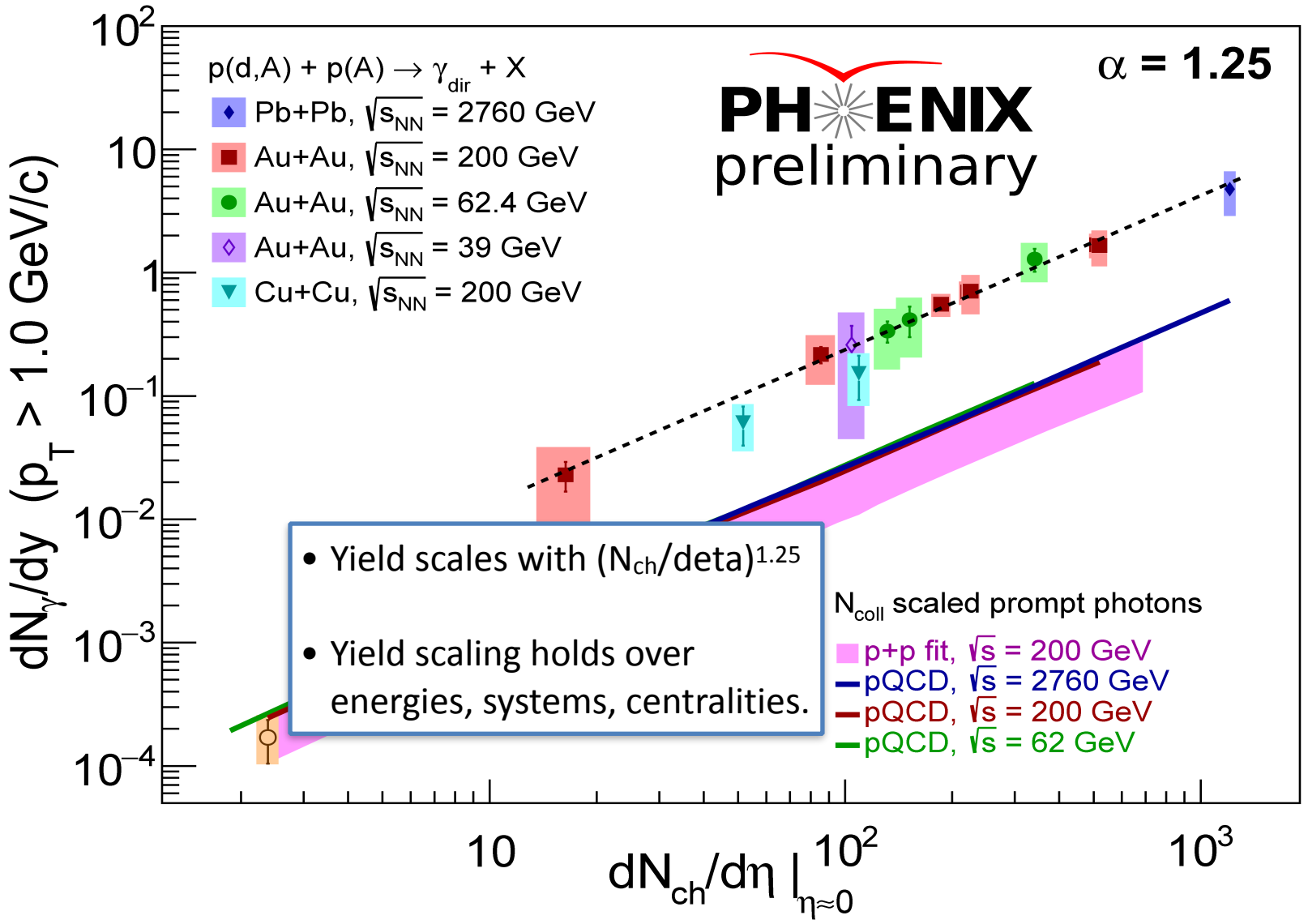
- Significant increase found at low p_T in most central p+Au Collisions wrt Minimum Bias

- Does it have a thermal origin?

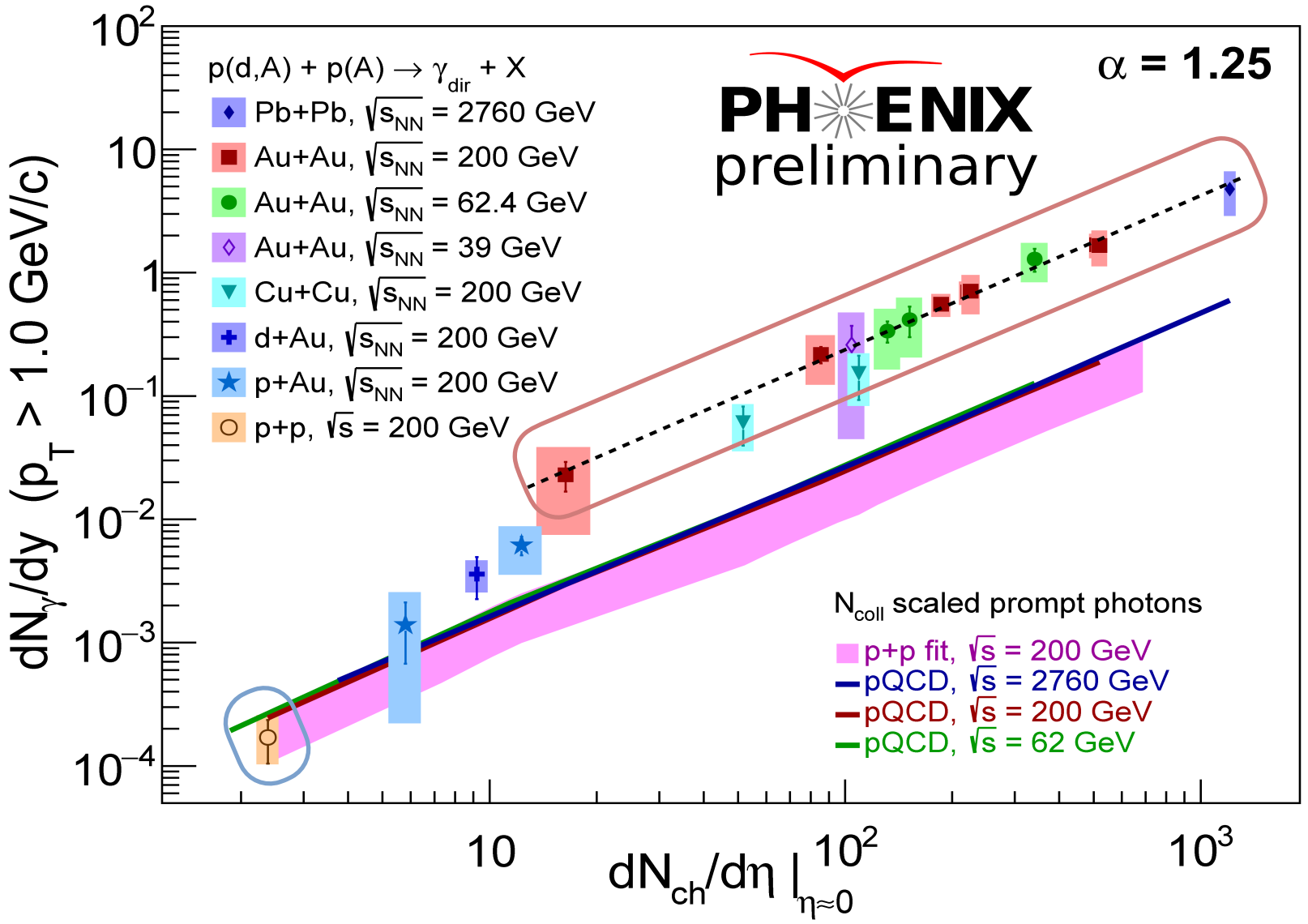
p+Au d+Au

200

Direct Photon Scaling in HIC



A Transition?



Outlook

- Finite “flow-like” signals in SS from 20 to 200 GeV and for different system sizes.
- Strong correlation between v_n and initial (spatial) anisotropy.

- AMPT (Scattering), Hydro (QGP droplet) , CGC (Initial Momentum Correlations) can reproduce many of these signals over full range of pt, eta and collision energies, though with different accuracies.

- Hint of leading mechanism for particle production from heavy flavour particles and photons. Models?

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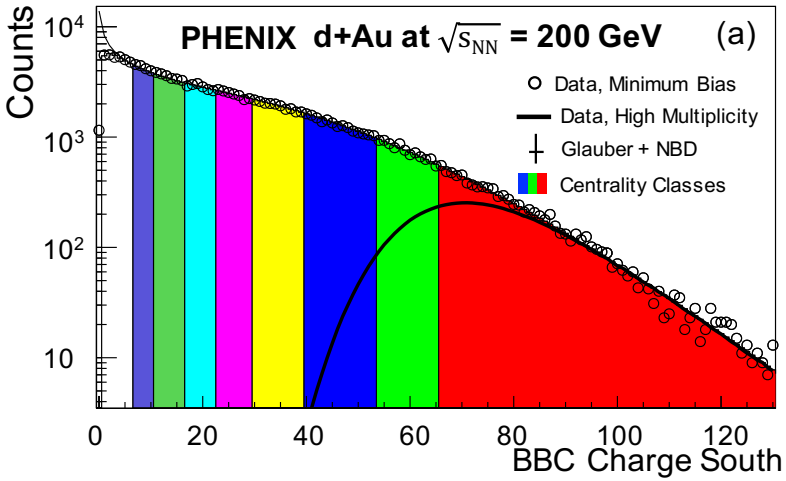
Thanks!

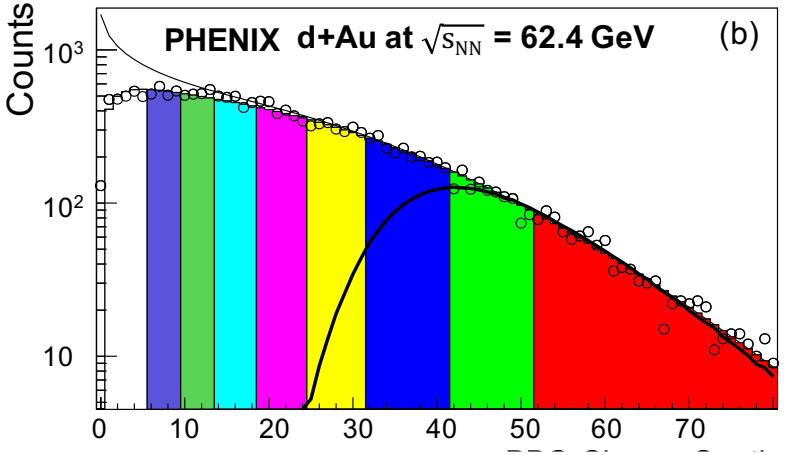
How close are we to a unified answer?

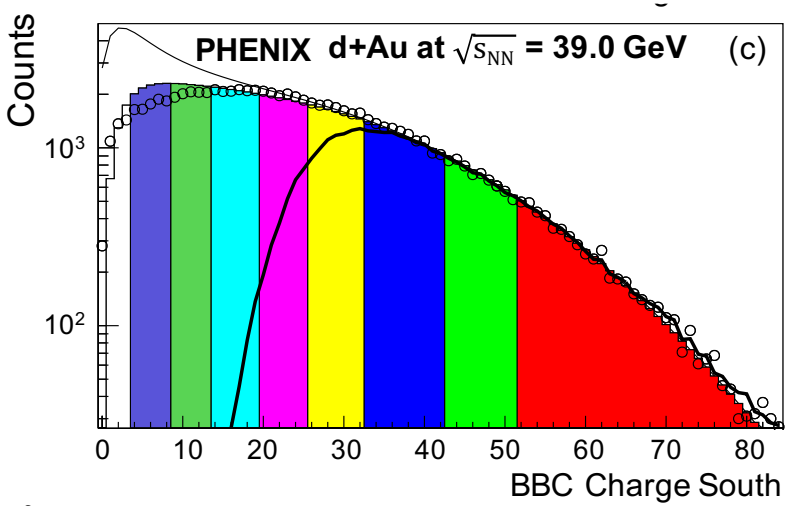
BACKUP

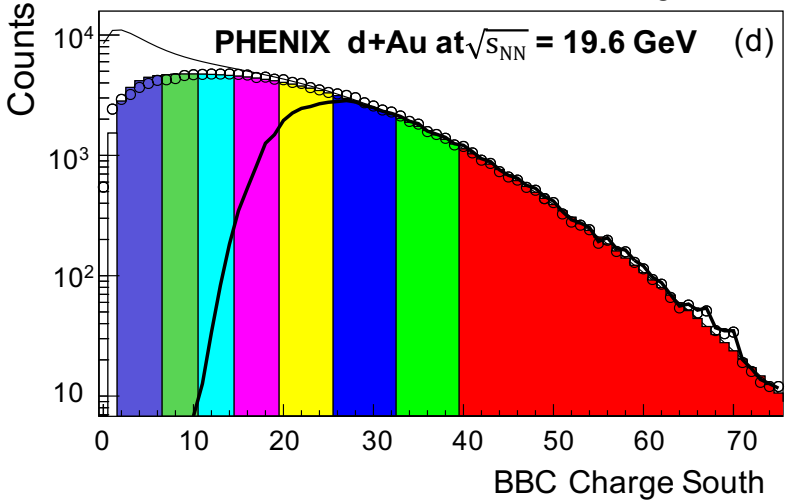
Centrality Classification

d+Au





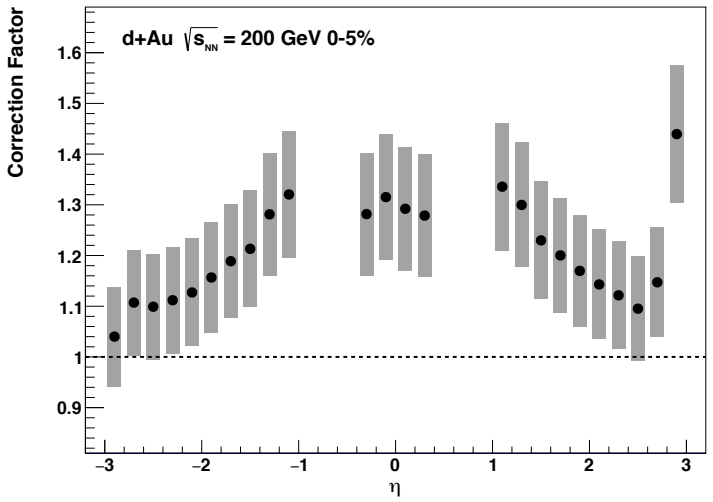


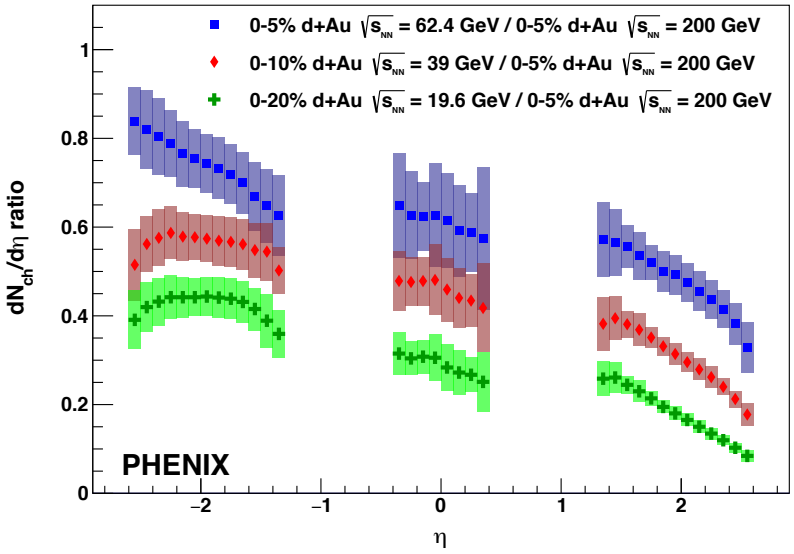


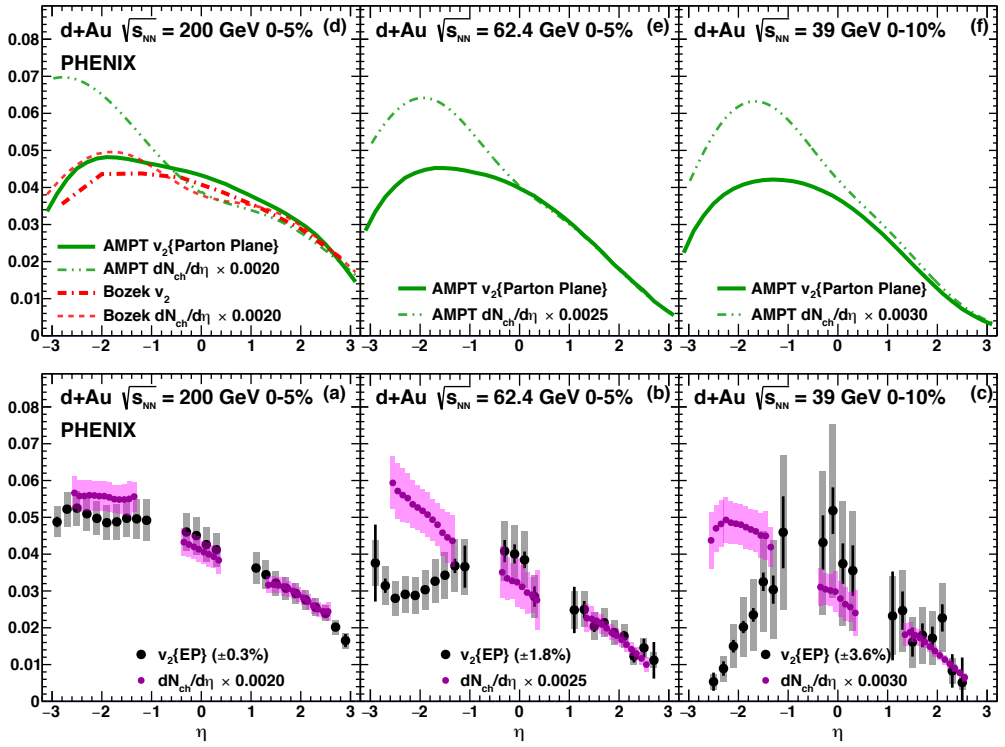
Phys. Rev. C 96 064905 (2017)

More on dNch/deta

d+Au

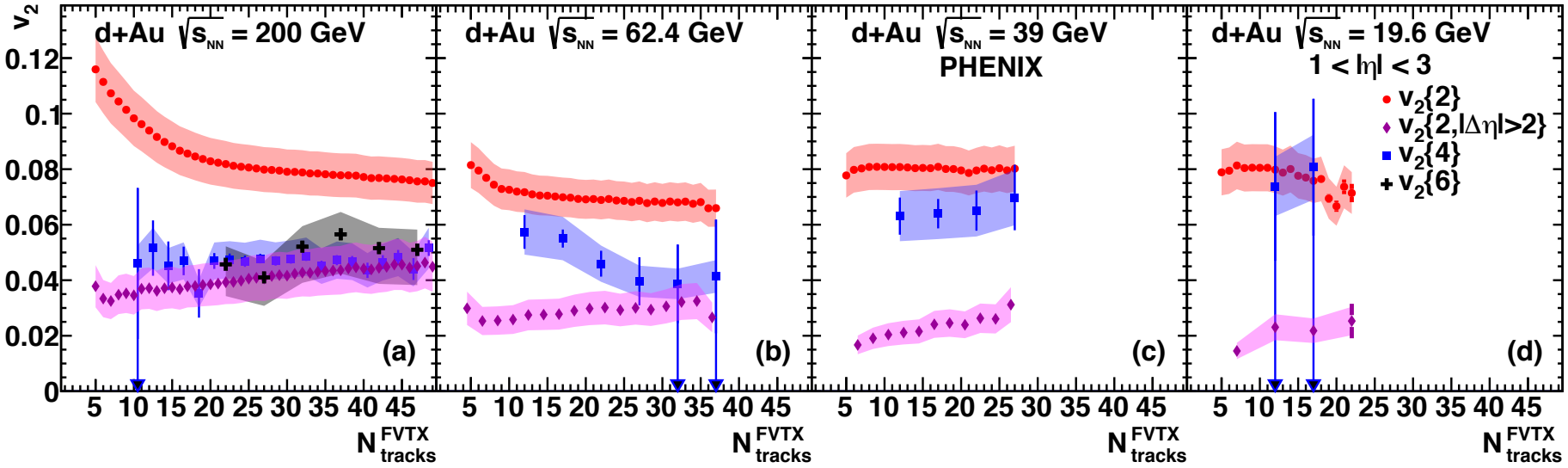






Phys. Rev. C 96 064905 (2017)

v_2 at Forward Rapidities via MPC

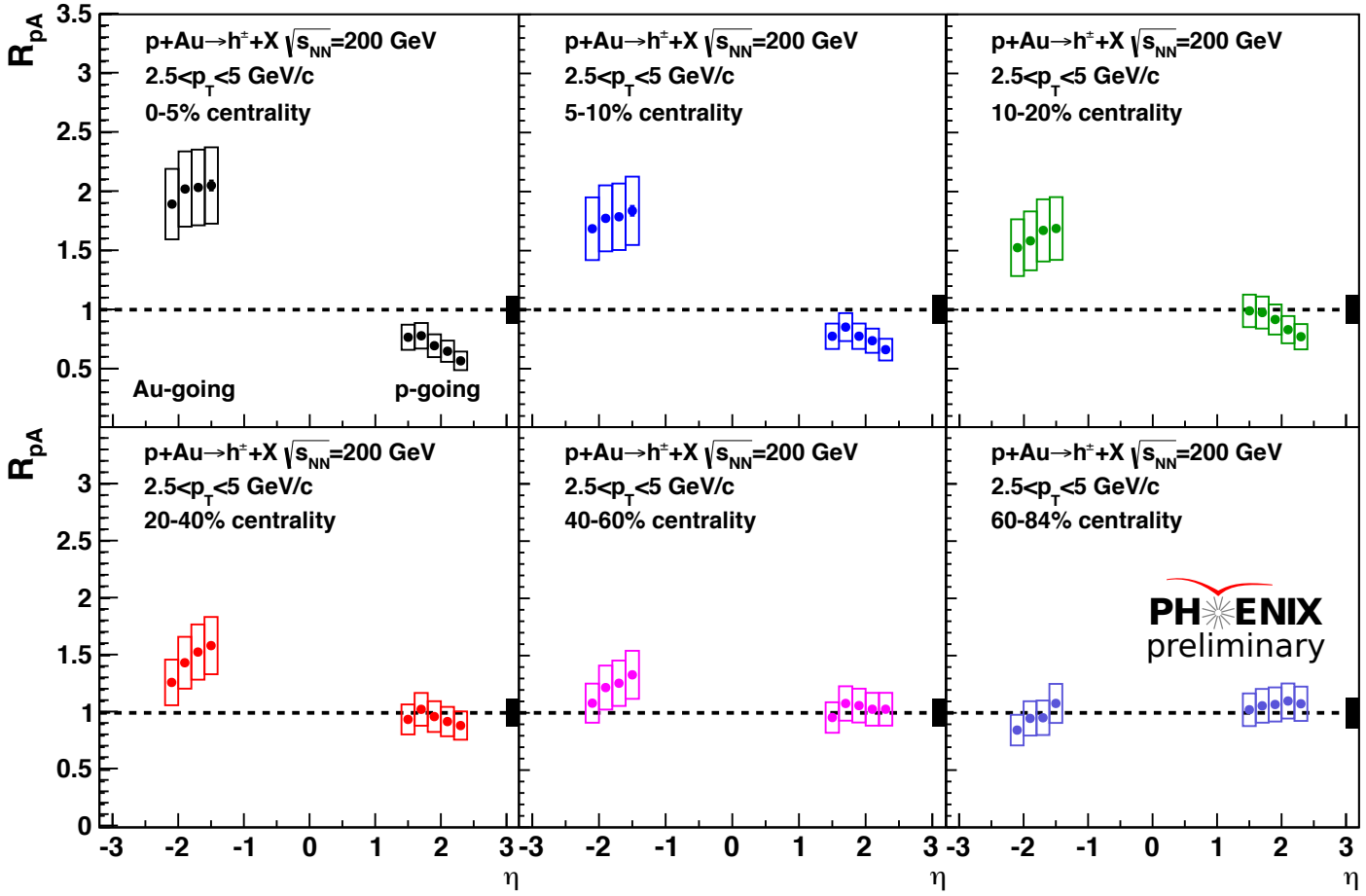


- Why? By increasing the number of particles in the correlation, a progressive suppression of non-flow can be achieved.

Phys. Rev. Lett. 120, 062302 (2018)

d+Au | 20 | 39 | 62 | 200

Centrality Dependence of R_{pA}(eta)

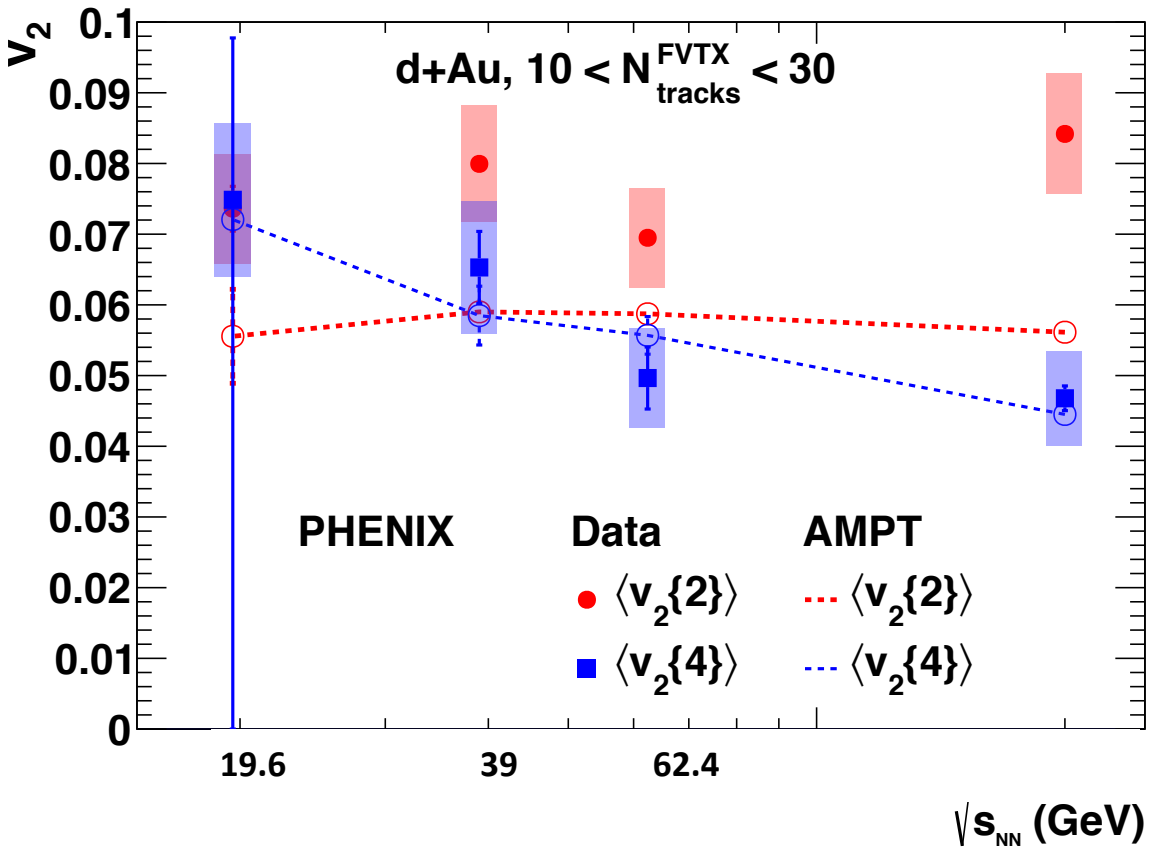


- Enhancement mainly for p_T <5 GeV and centrality dependent.

p+Au

Where does it come from?

$v_2\{2\}$, $v_2\{4\}$ at Different Energies



Phys. Rev. Lett. 120, 062302 (2018)

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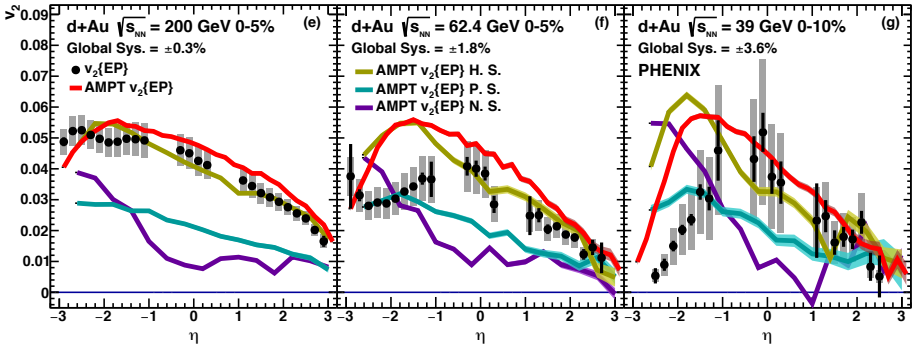
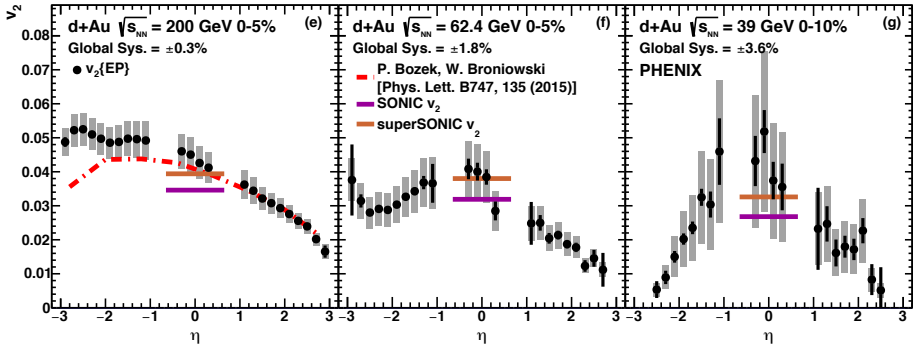
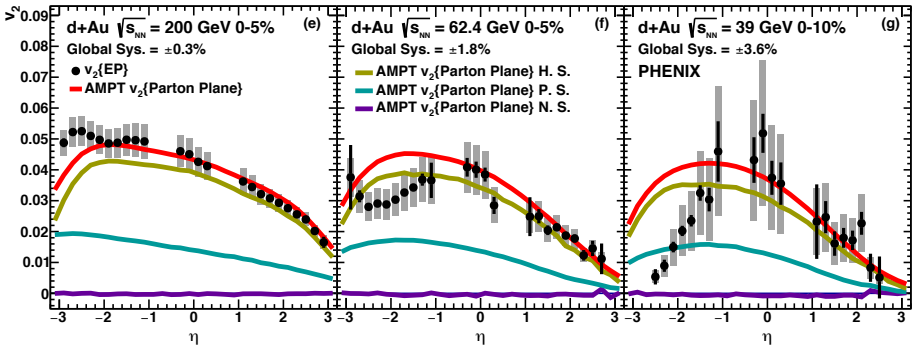
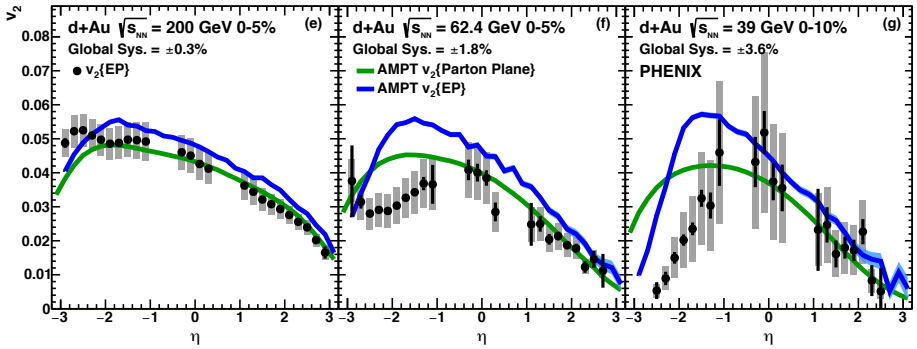
More on v2(eta)

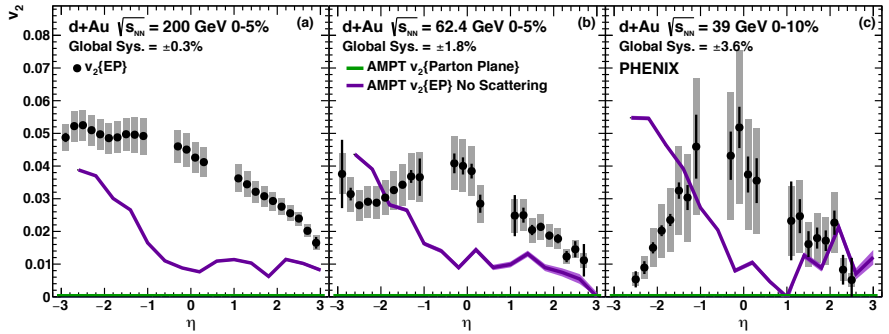
d+Au







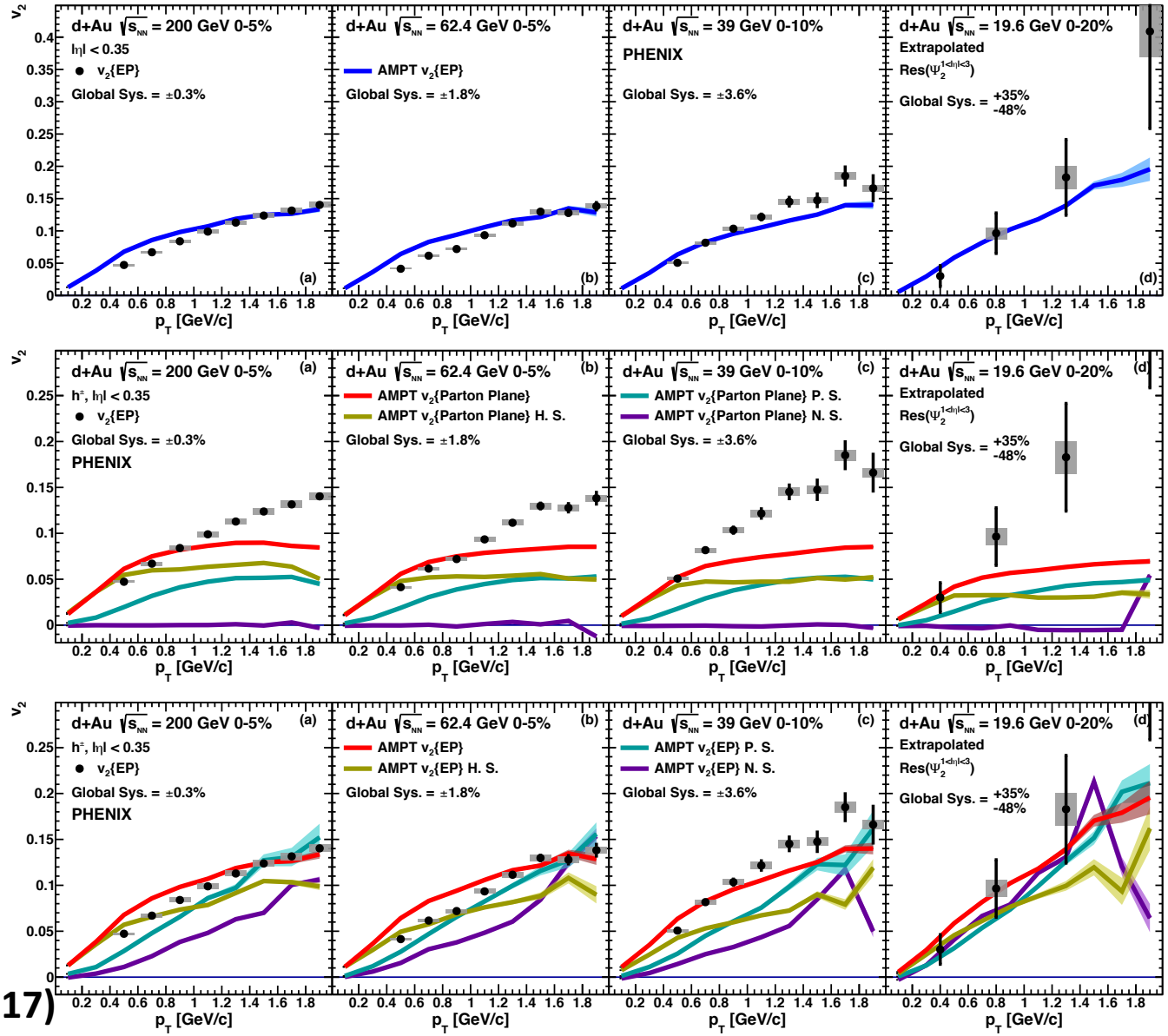




Phys. Rev. C 96 064905 (2017)

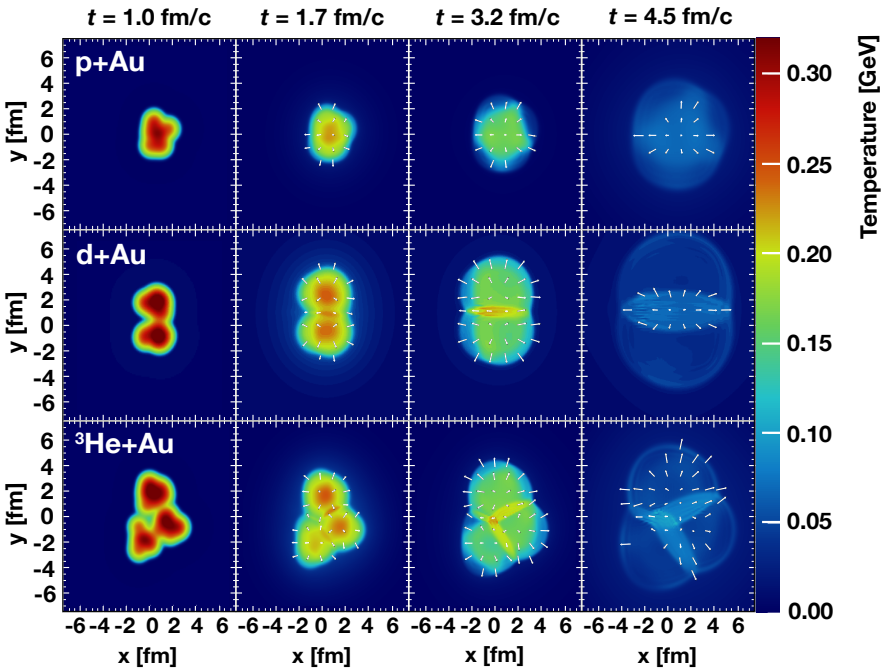
More on v2(pt)

d+Au



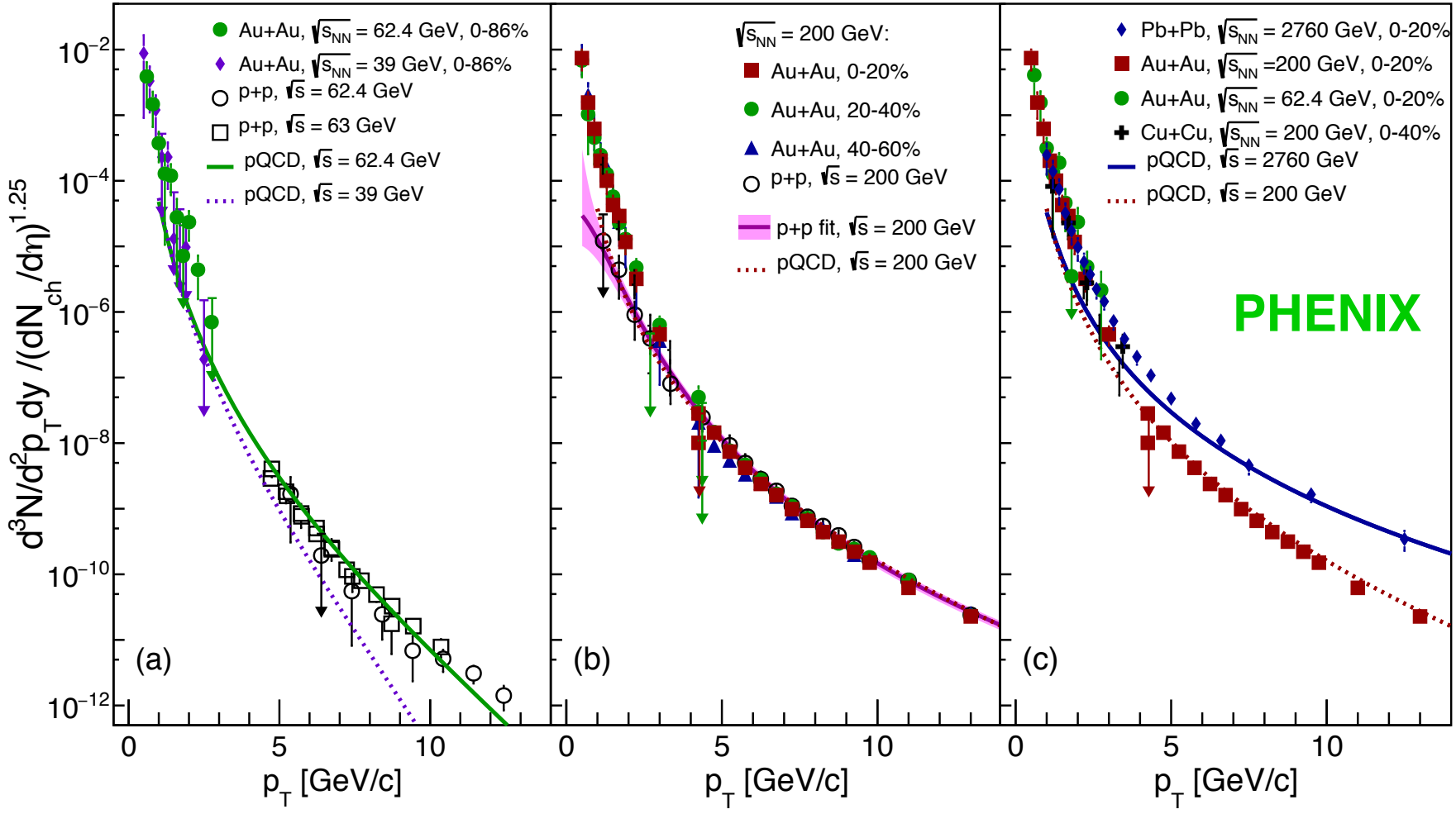
Phys. Rev. C 96 064905 (2017)

Hydro Evolution



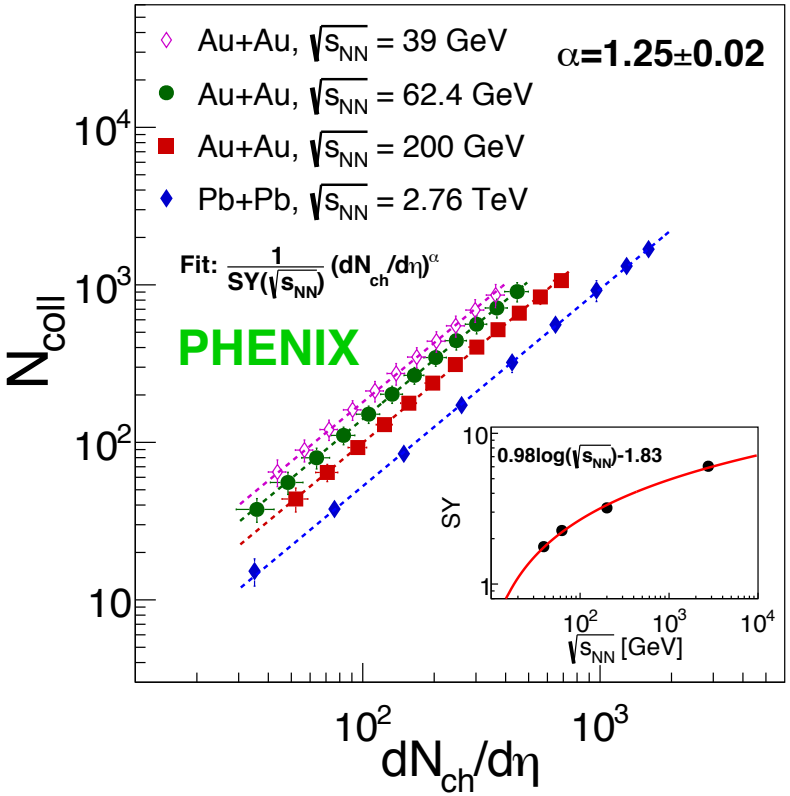
arXiv:1805.02973 (2018) p+Au d+Au ^{3}He+Au

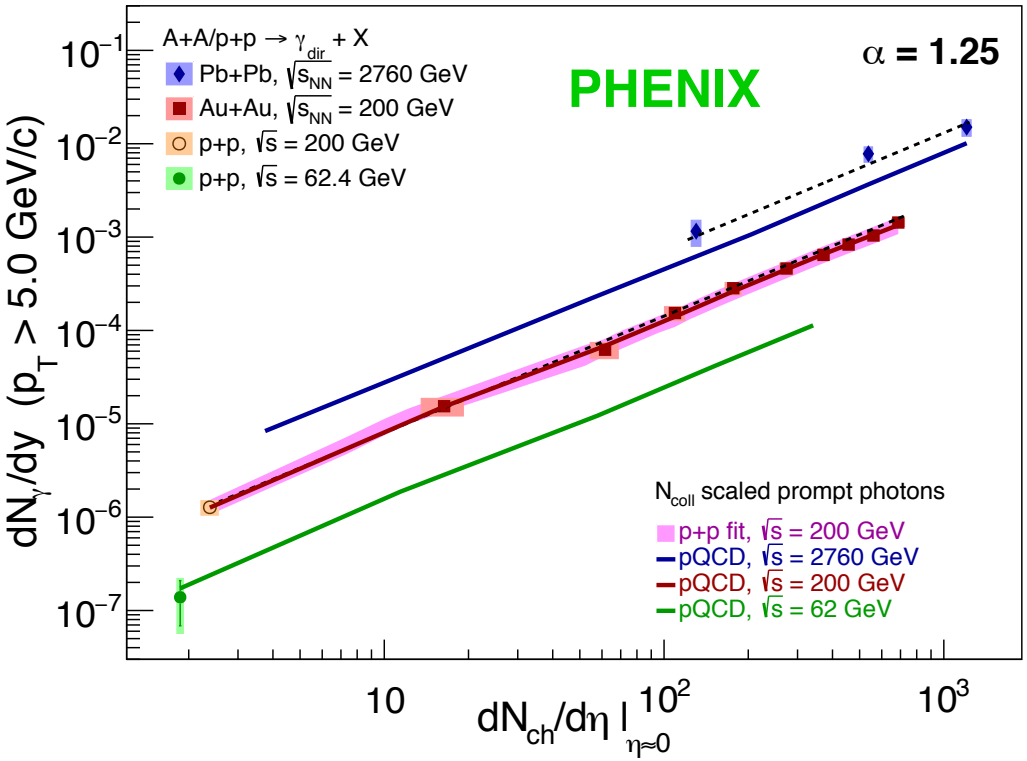
Photons in HIC



arXiv:1805.04084 (2018)

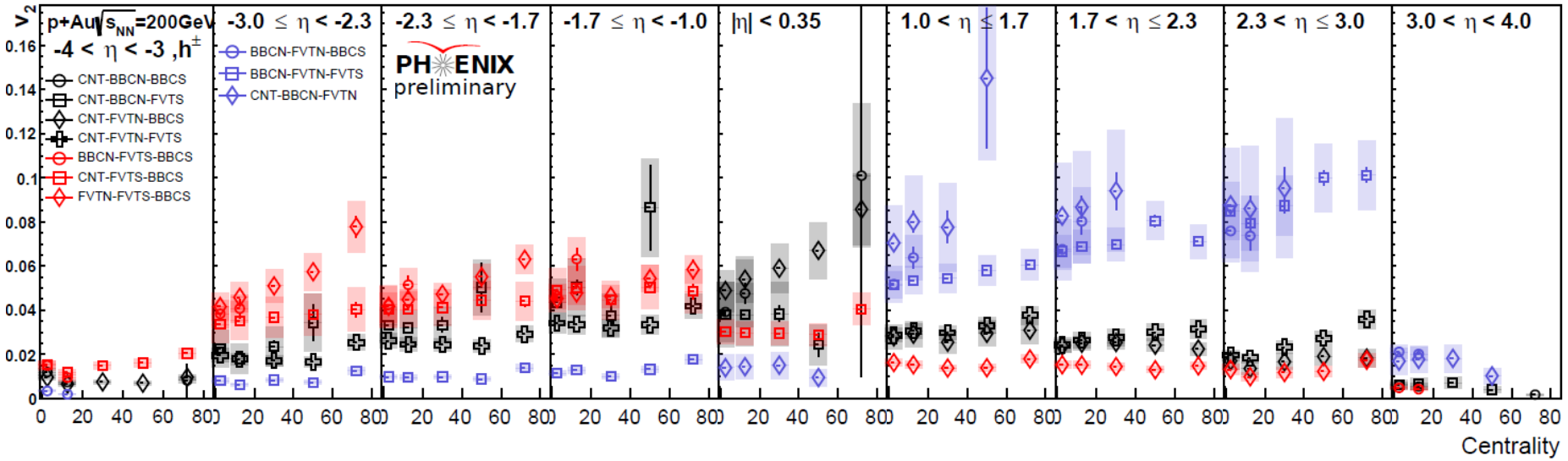
Photons in HIC



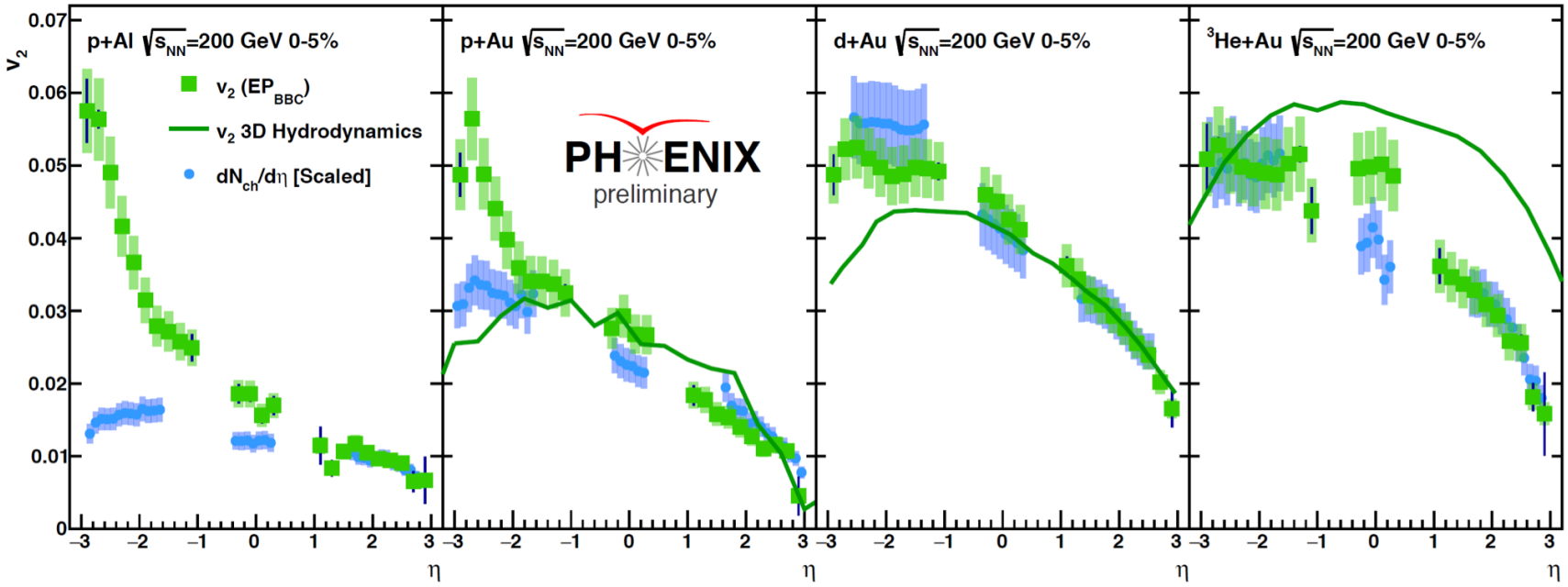


arXiv:1805.04084 (2018)

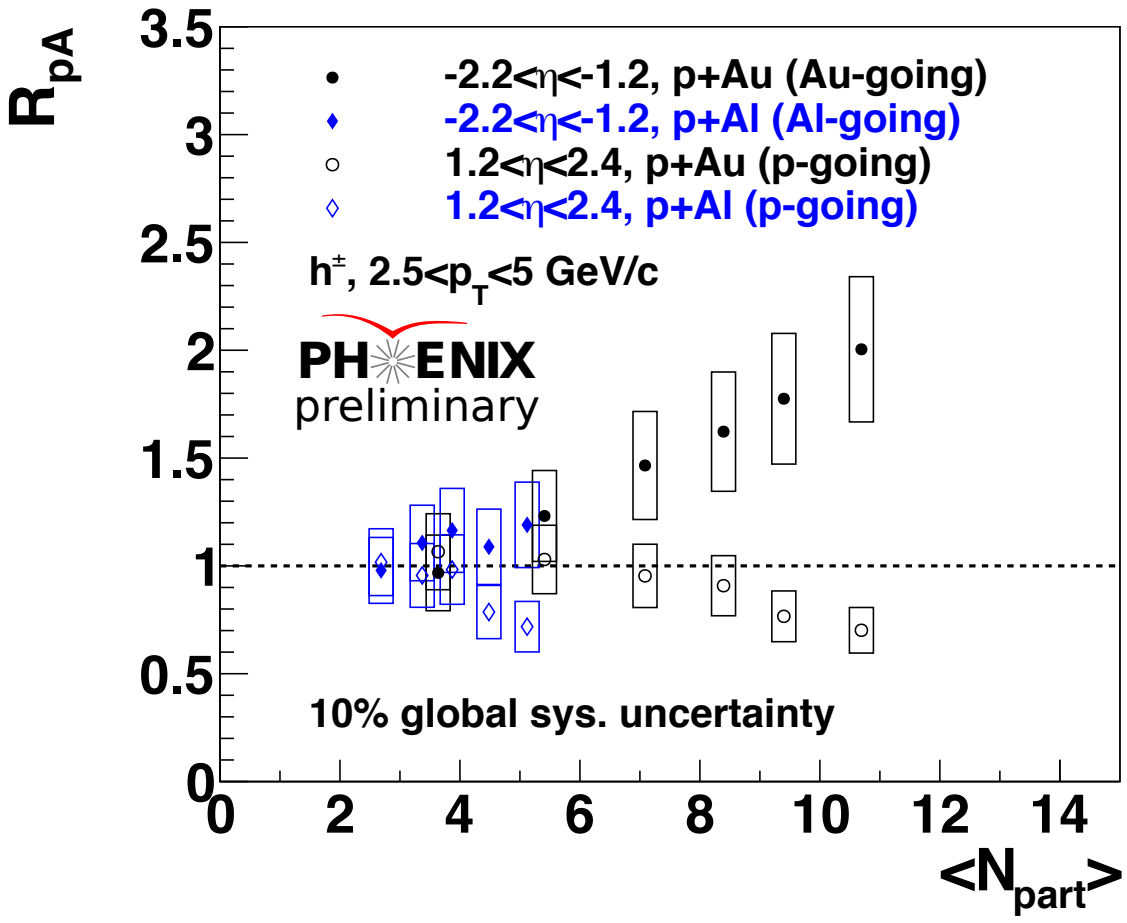
v2(eta) large rapidity coverage



v2(eta) system scan



RpA in SS

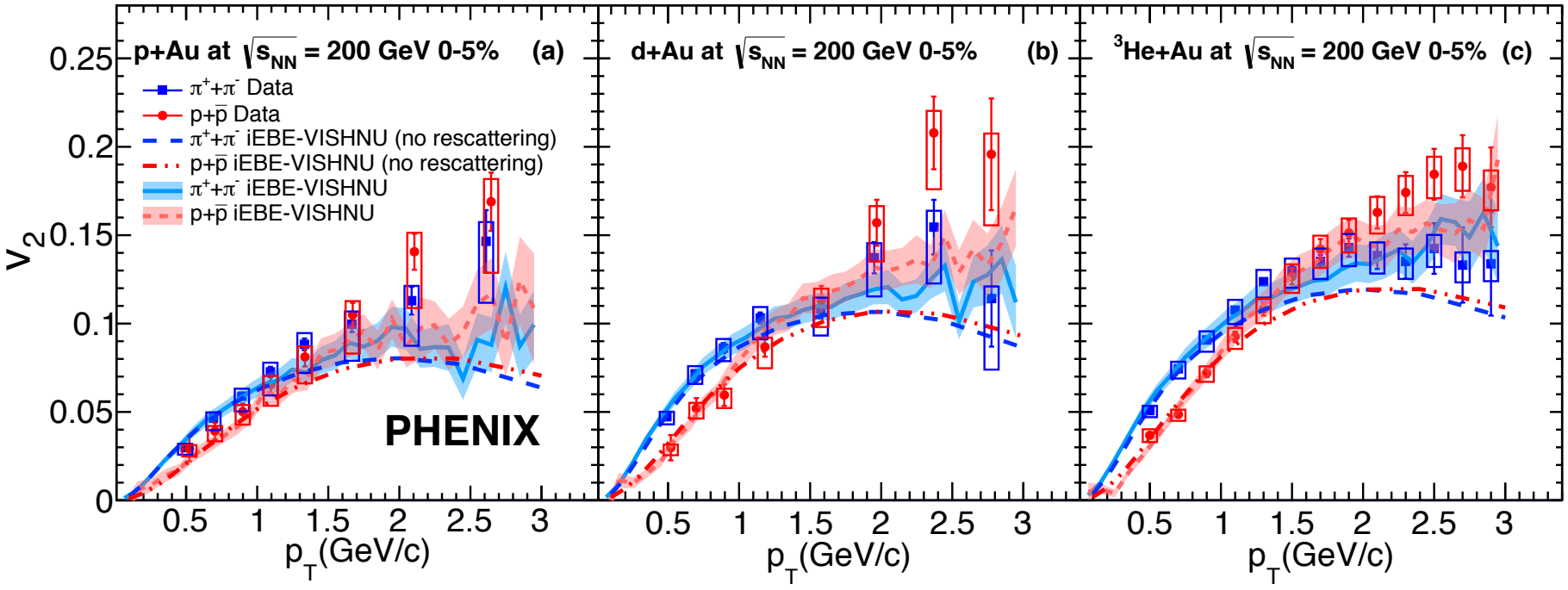


- Enhancement mainly from PT<5 GeV and centrality dependent.

p+Au p+Al

Where does it come from?

v2 Mass Dependence

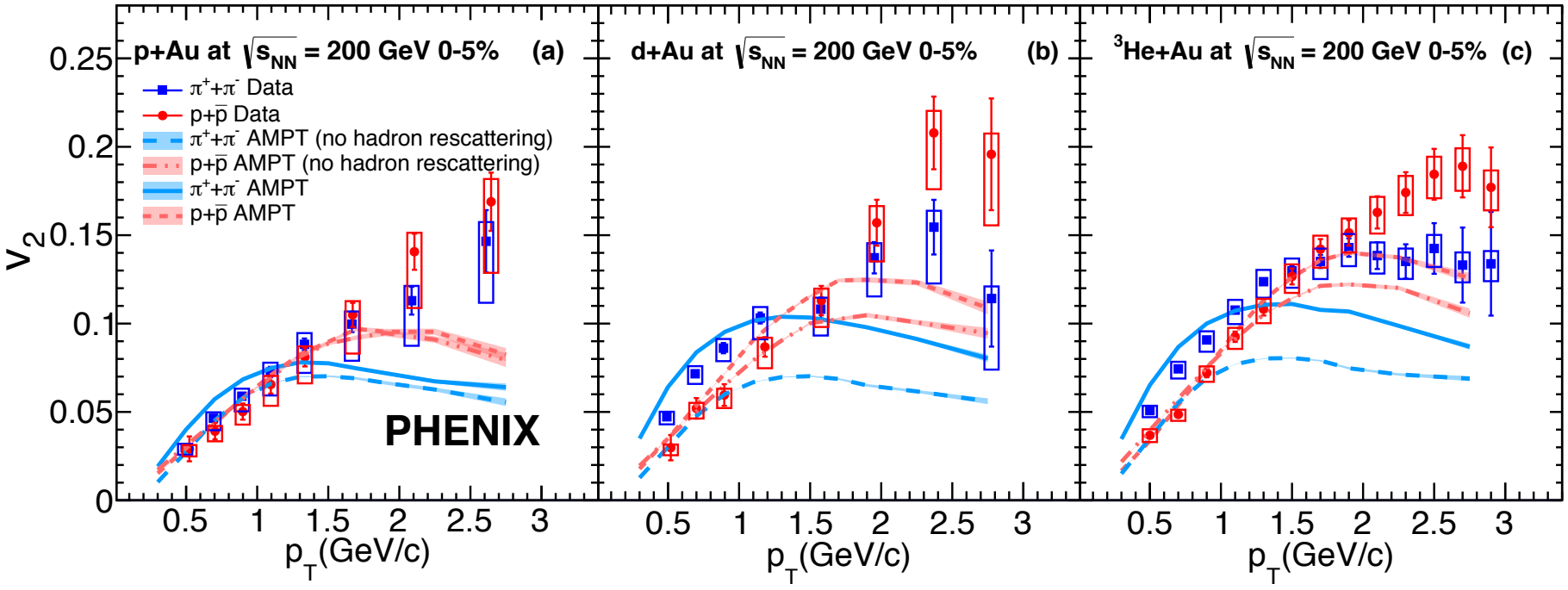


arXiv:1710.09736 (2017)

p+Au d+Au ^{3}He+Au

200

v2 Mass Dependence



arXiv:1710.09736 (2017)

p+Au | d+Au | ^{3}He+Au

200