PHENIX Experimental Overview

Darren McGlinchey

University of Colorado Boulder

Quark Matter 2017

Quark Matter 2017

PHENIX at QM17:

11 Parallel Talks

22 Posters

√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								✓	

Quark Matter 2017

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— covering —

8 Collision Systems

5 Collision energies

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2016 Data

Quark Matter 2017

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7.7								✓	

2016 Data

Collective Dynamics

EM Probes

Jets & high-p_T Hadrons

Open Heavy Flavor

Collective Dynamics

PHENIX results on longitudinal flow dynamics and event plane decorrelation in d+Au collisions from 19.6 to 200 GeV

***Ron Belmont* — 2.2: Tue 10:40**

PHENIX results on elliptic and triangular flow at mid-rapidity in d+Au collisions from 19.6 to 200 GeV

***Julia Velkovska* — 2.2: Tue 11:40**

PHENIX results on collective behavior in small systems from geometry-controlled experiments at sqrt{s_NN} = 200 GeV

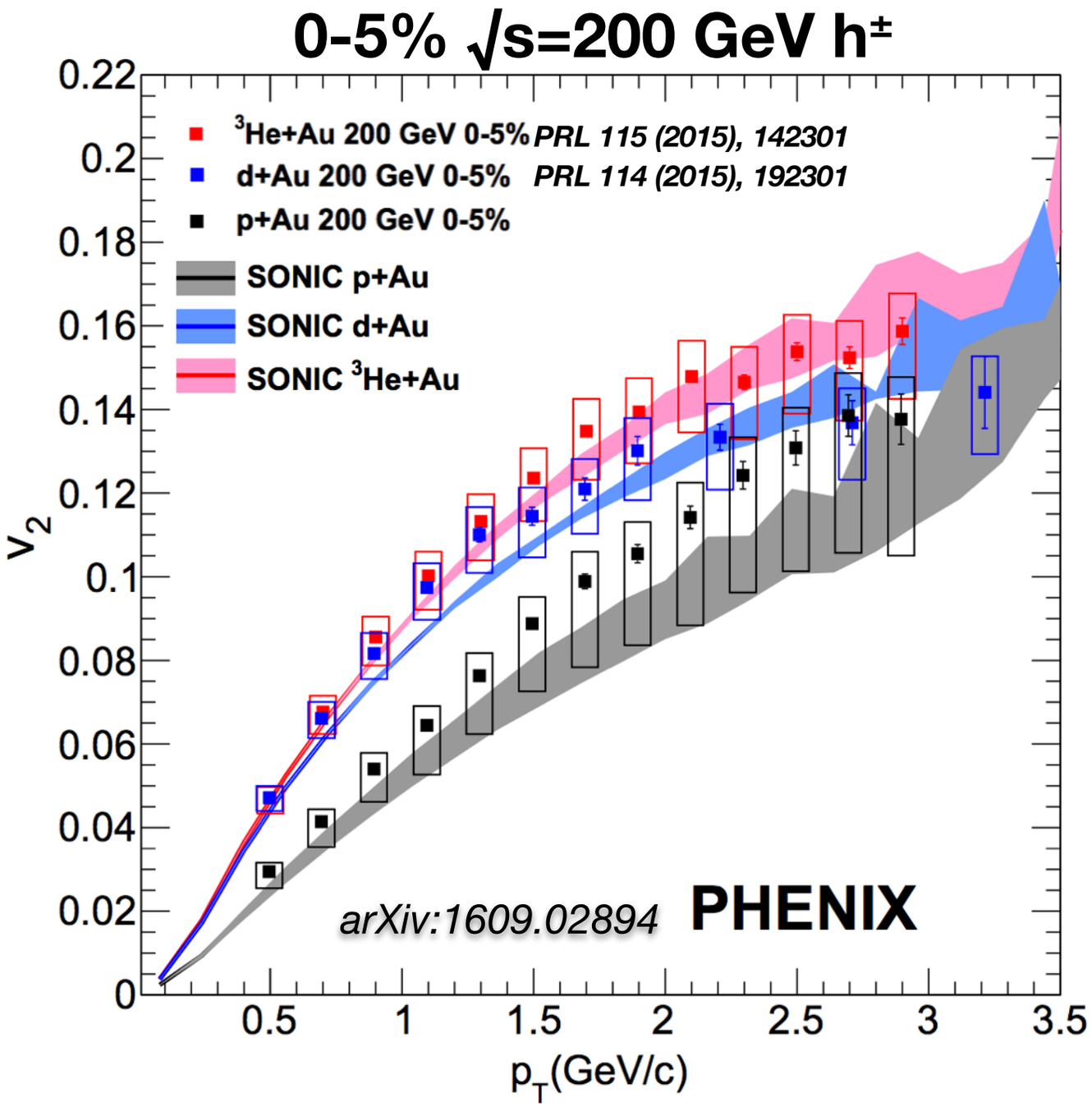
***Qiao Xu* — 6.1: Wed 11:20**

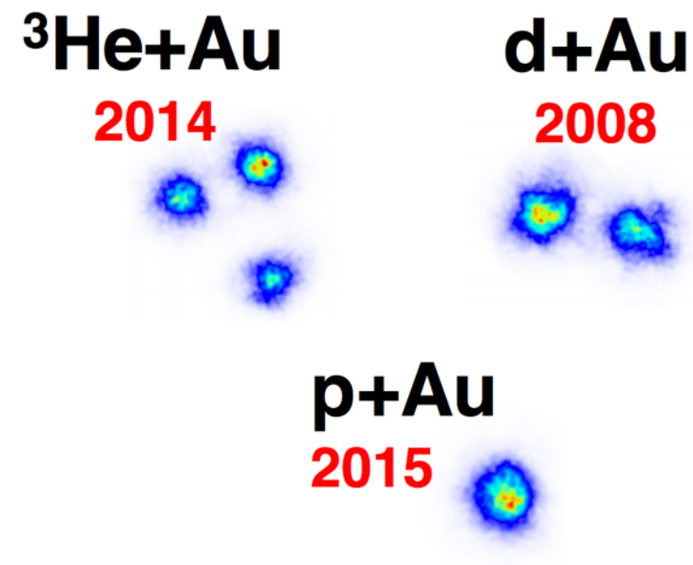
PHENIX results on charged-hadron azimuthal anisotropies in Au+Au collisions at center-of-mass energies from 39 to 200 GeV

***Maya Shimomura* — 7.3: Wed 15:00**

Small System Collectivity

Collective Dynamics





v_2 ordering:

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

Qiao Xu
6.1 - Wed 11:20

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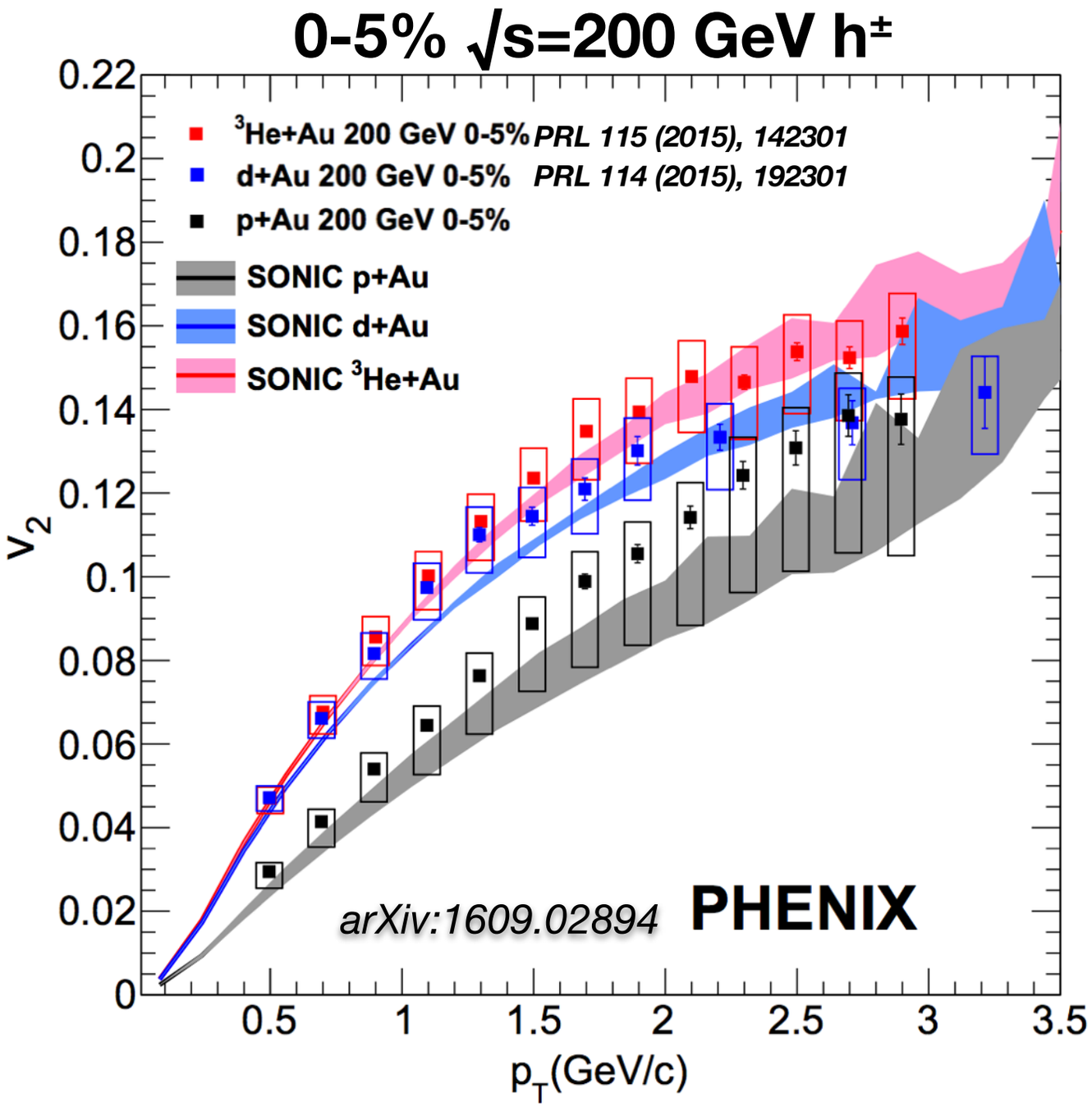
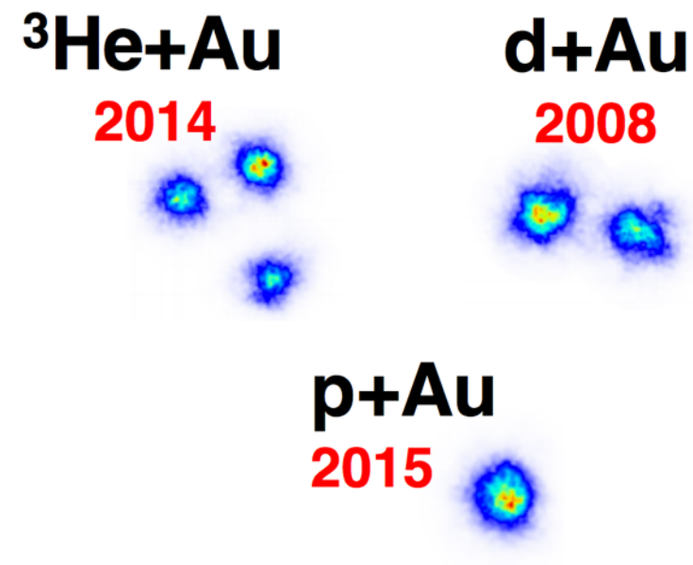




v_2 ordering:

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

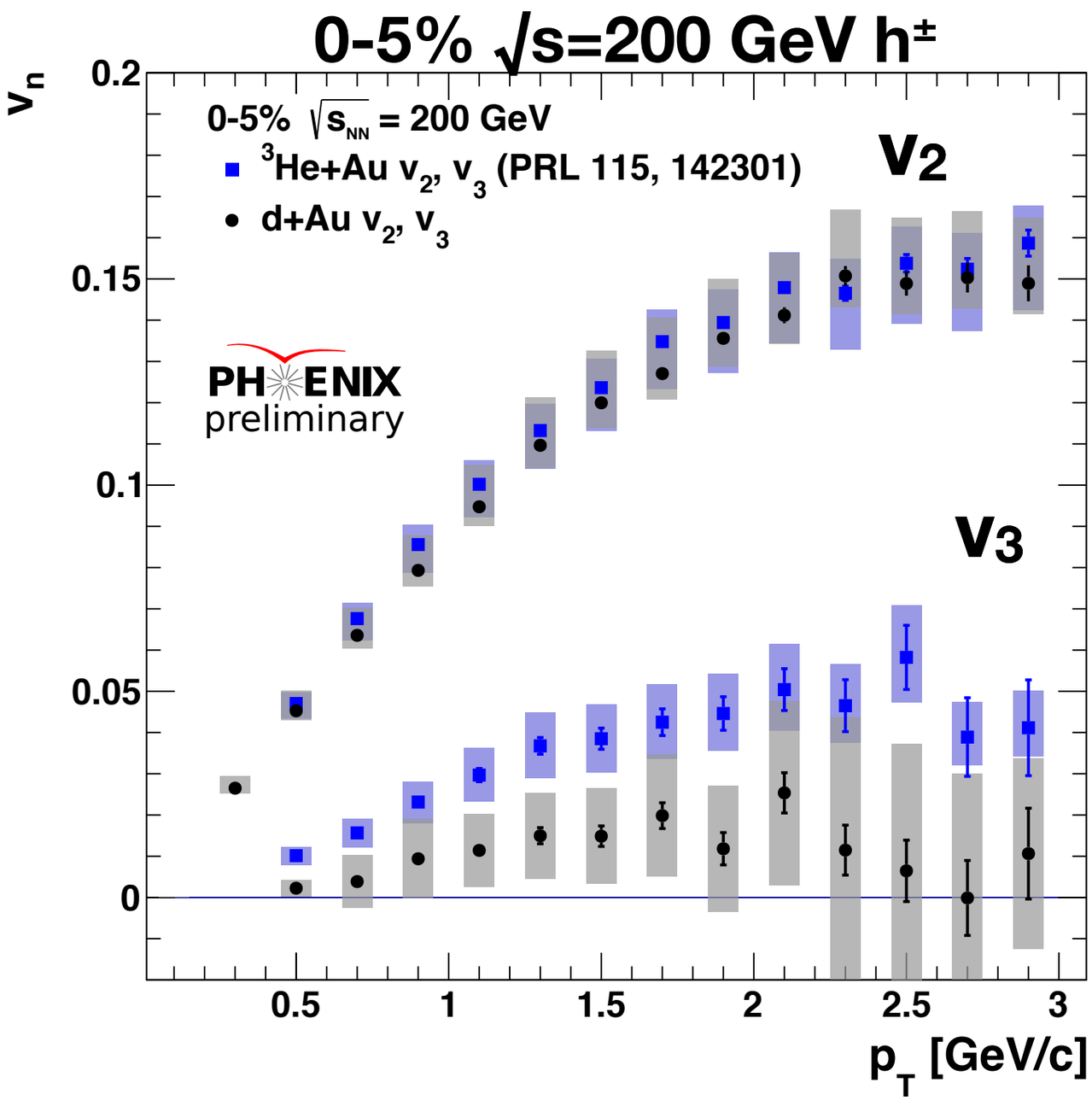
Also have:

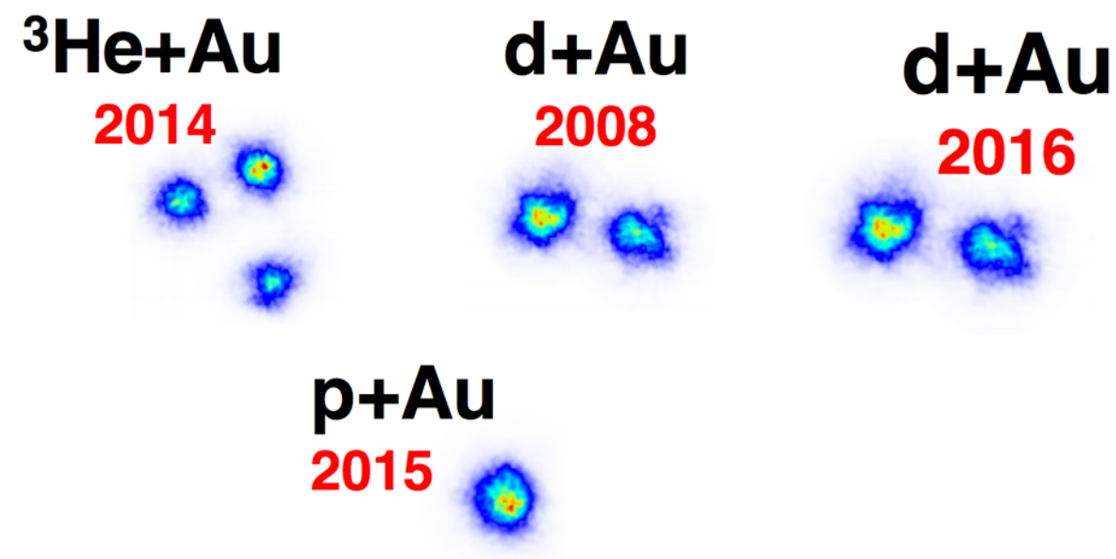
v_2 in p+Al

PID v_2 in p+Au

→ *Qiao Xu* **6.1 - Wed 11:20**

v_3 in d+Au

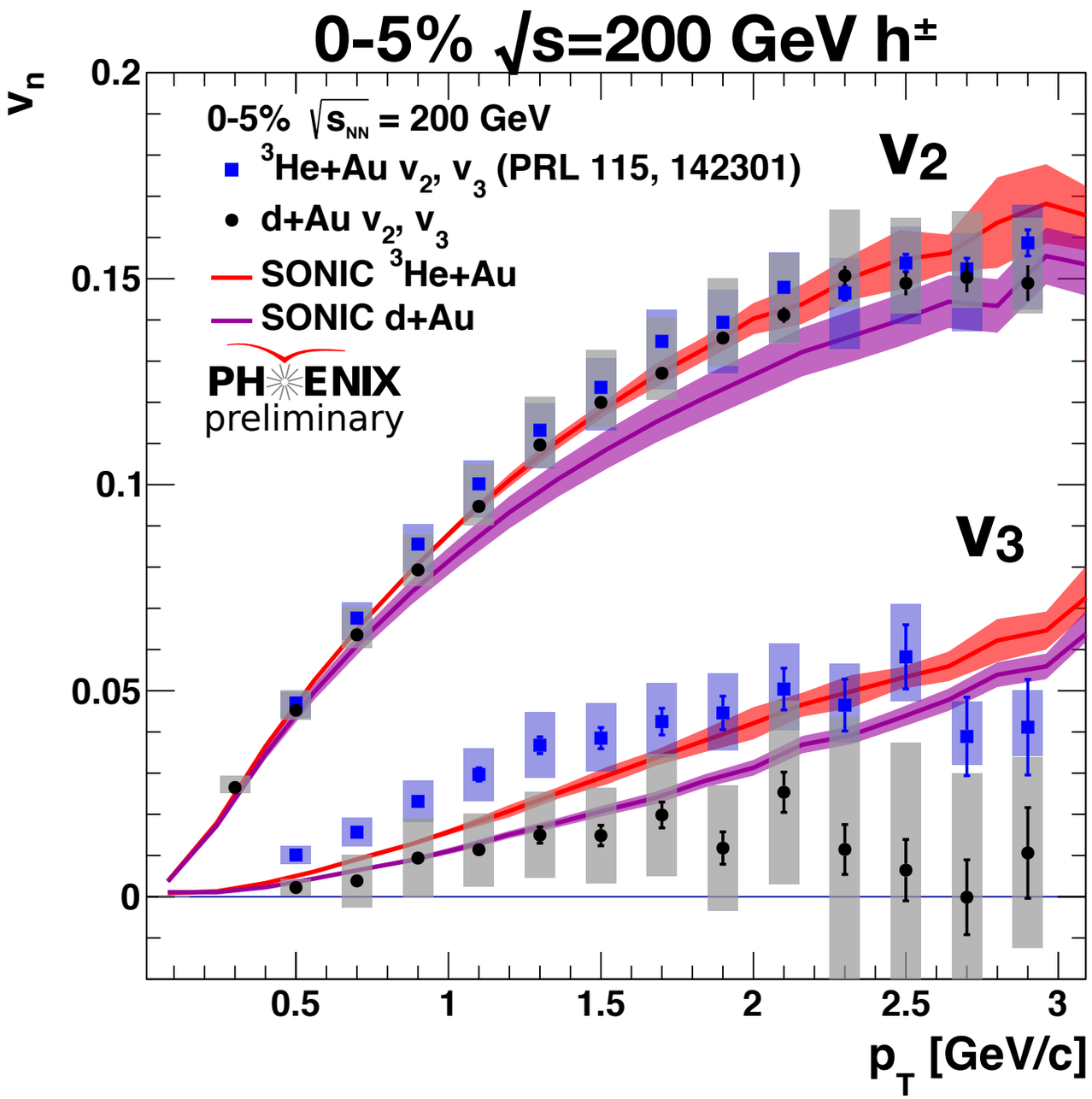


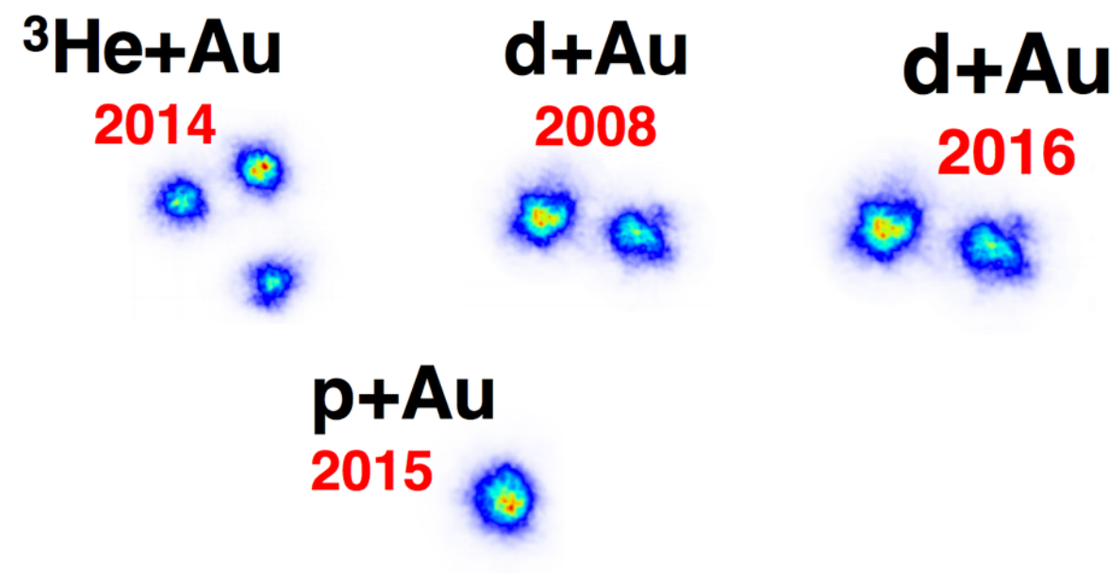


$v_3^{dAu} < v_3^{HeAu}$

Qiao Xu
6.1 - Wed 11:20

v_3 in d+Au



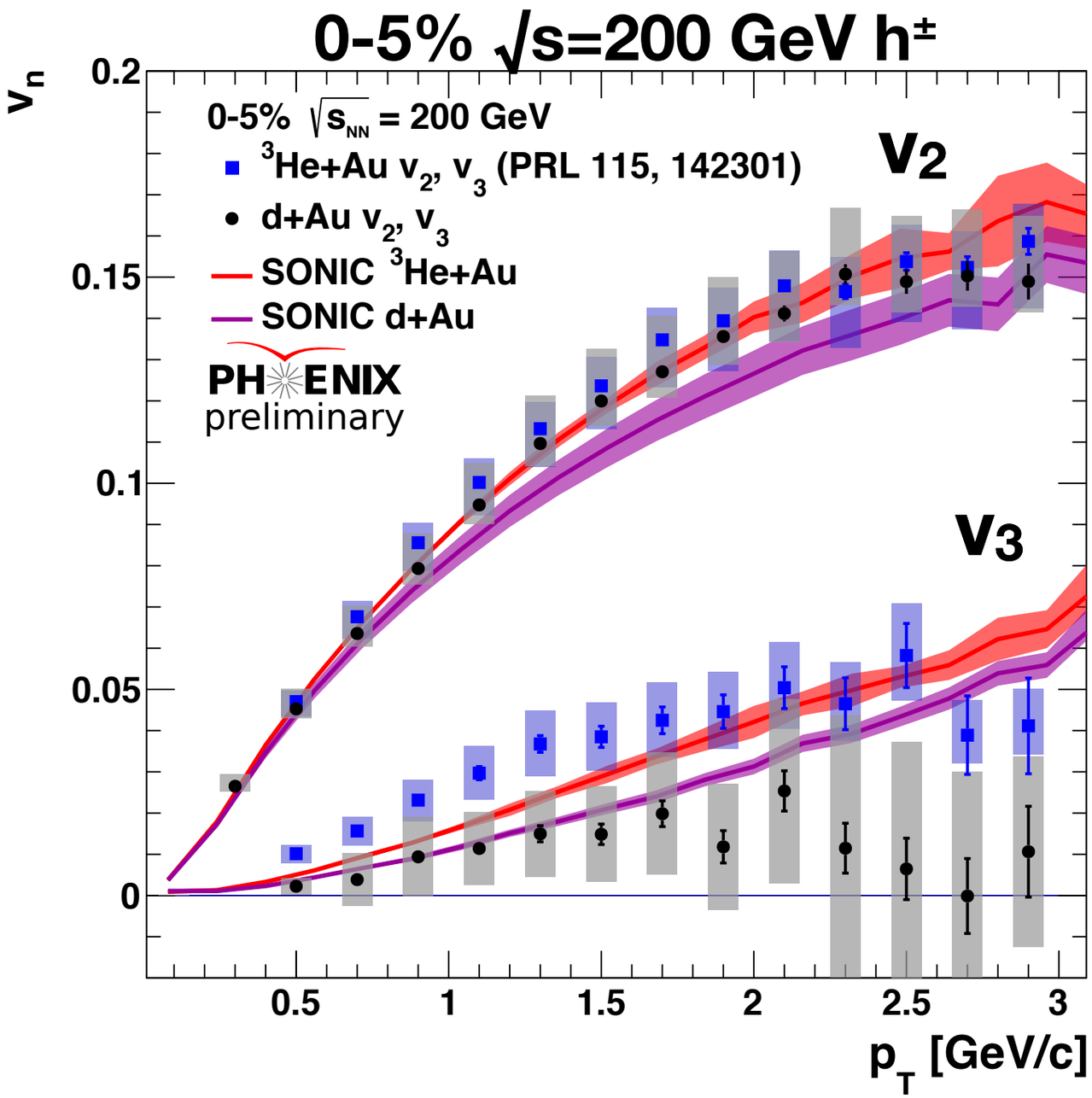


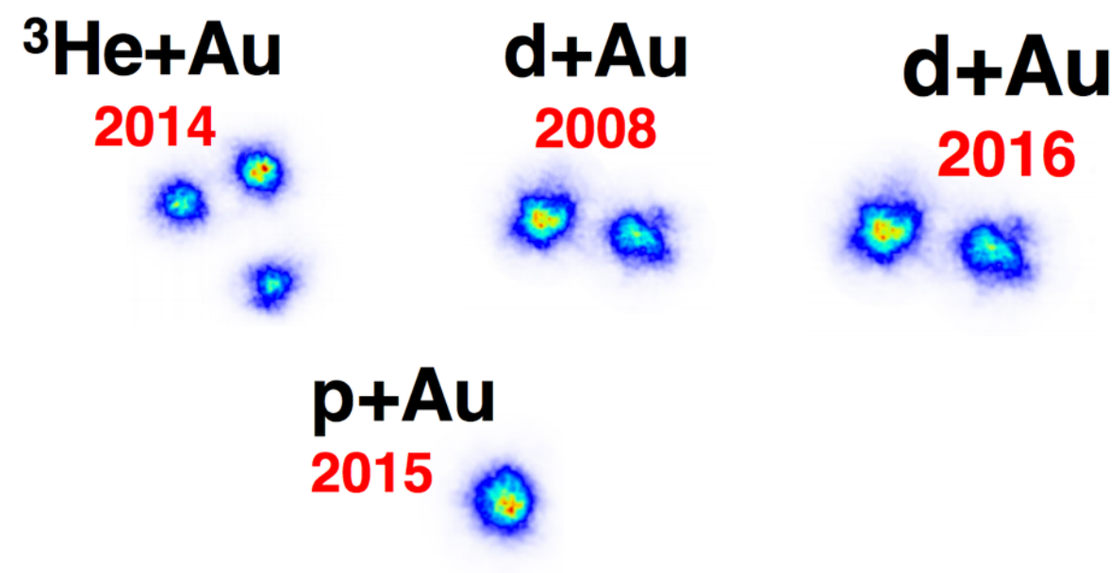
$v_3^{dAu} < v_3^{HeAu}$

Ordering consistent with expectations from initial geometry!

Qiao Xu
6.1 - Wed 11:20

v_3 in d+Au



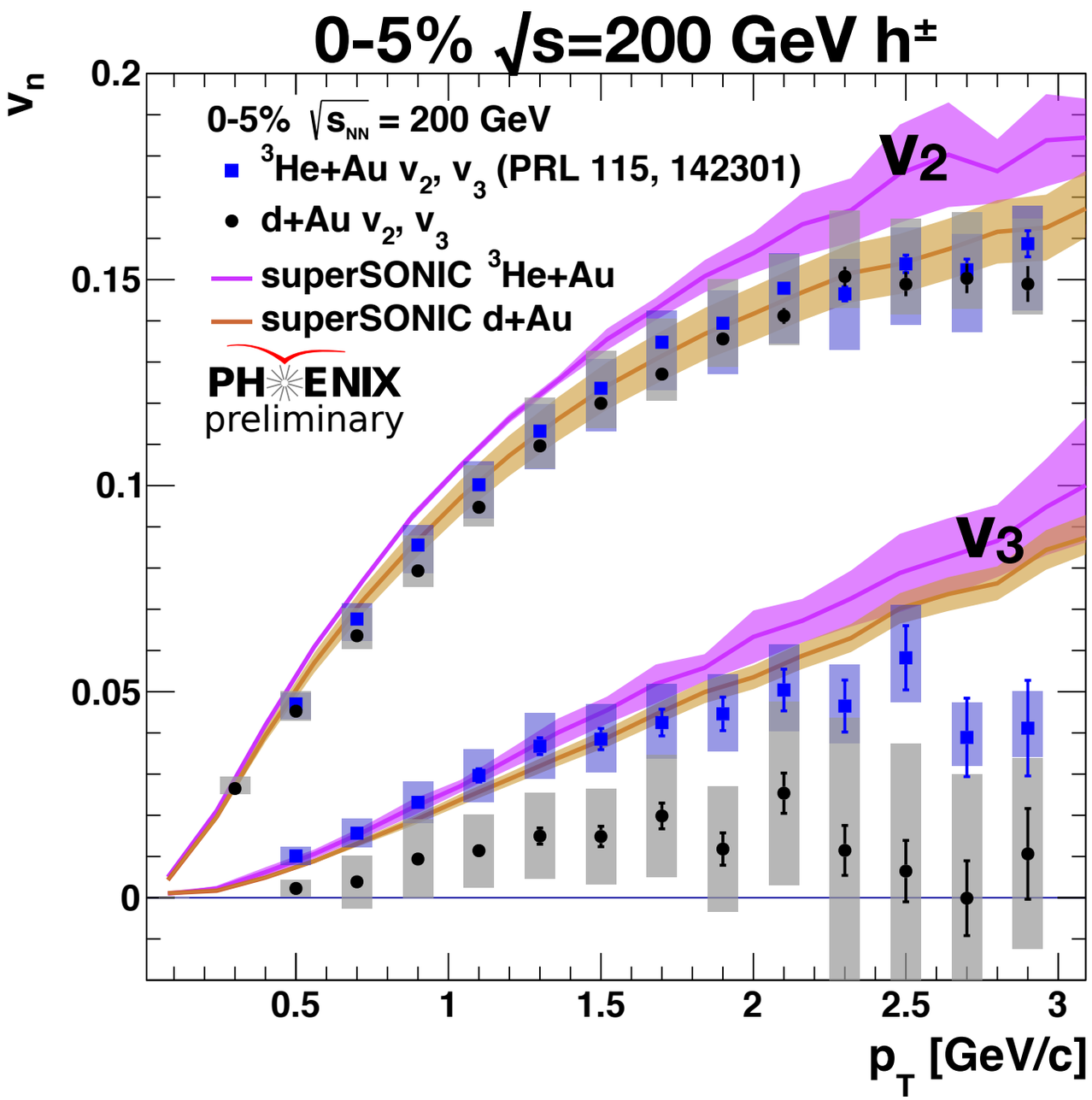


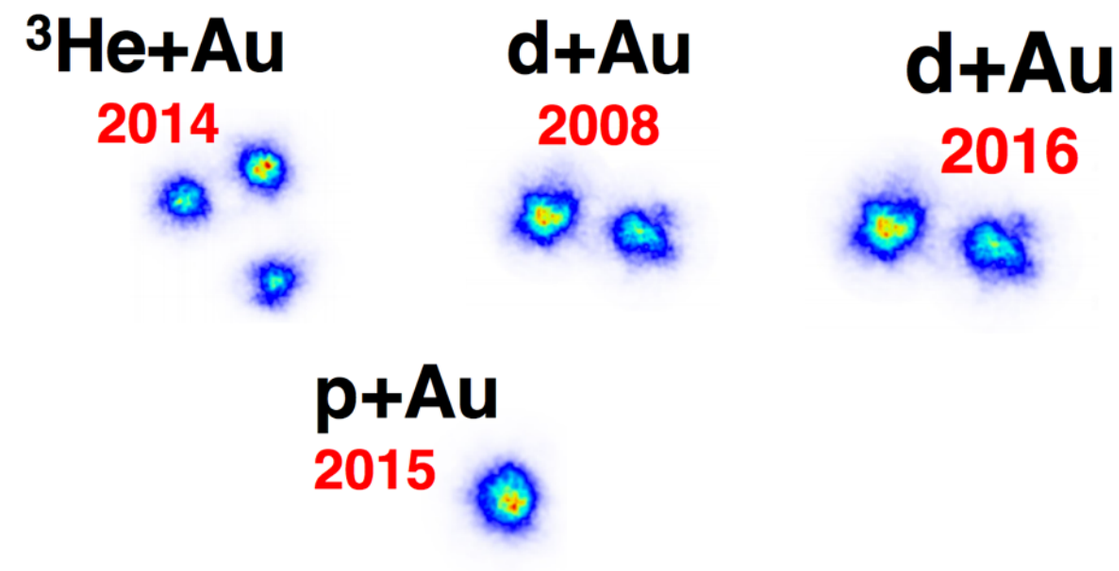
SONIC: no preflow

$v_3^{dAu} < v_3^{HeAu}$

Qiao Xu
6.1 - Wed 11:20

v_3 in d+Au





SONIC: no preflow

superSONIC: w/ preflow

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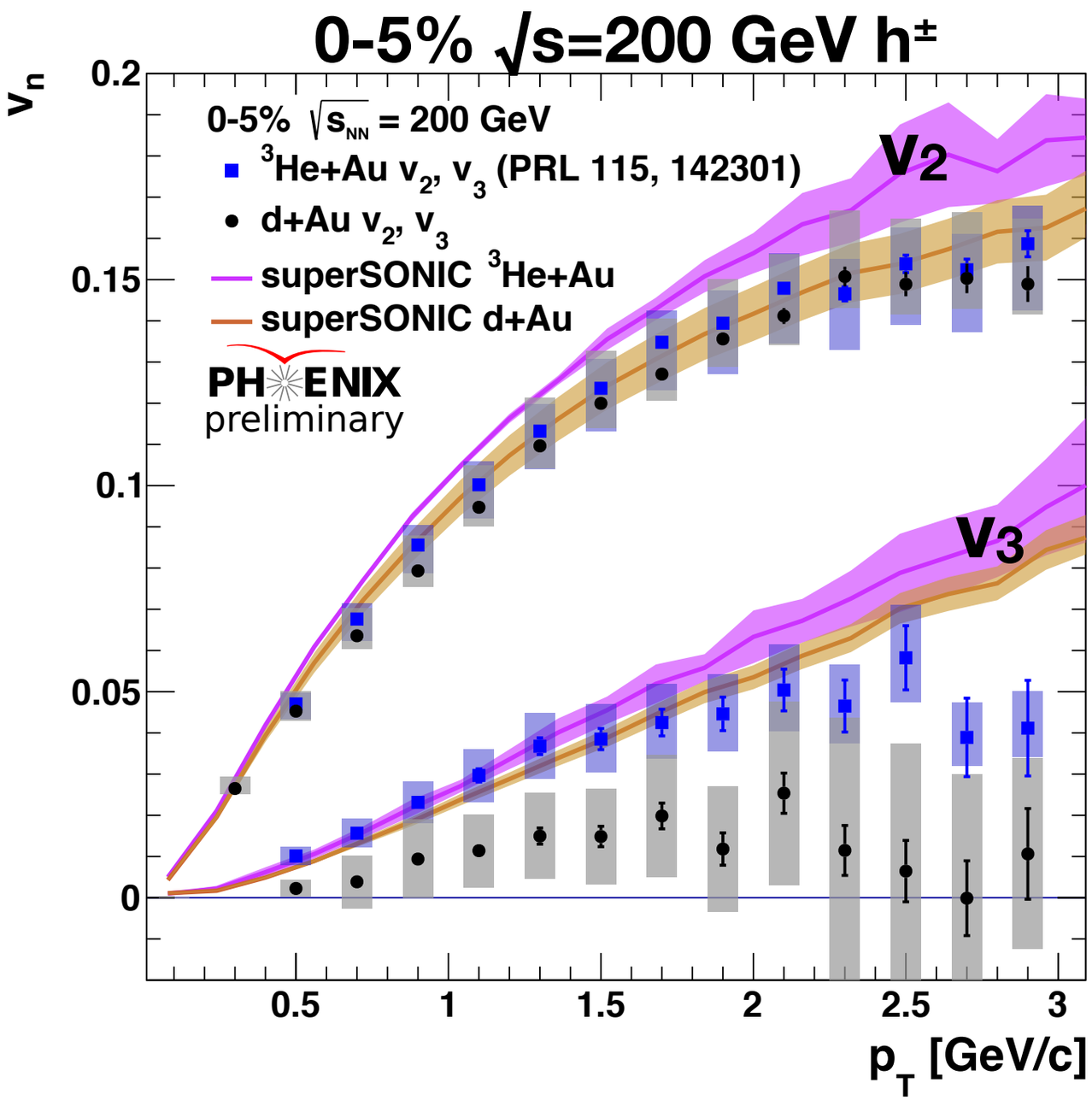
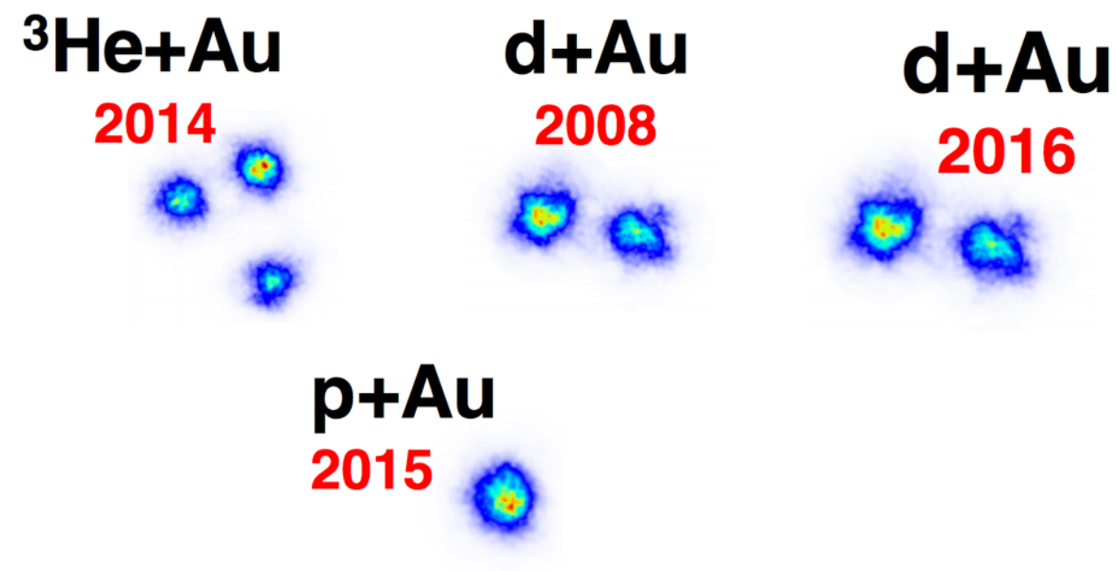
Qiao Xu
6.1 - Wed 11:20

v_3 in d+Au





SONIC: no preflow

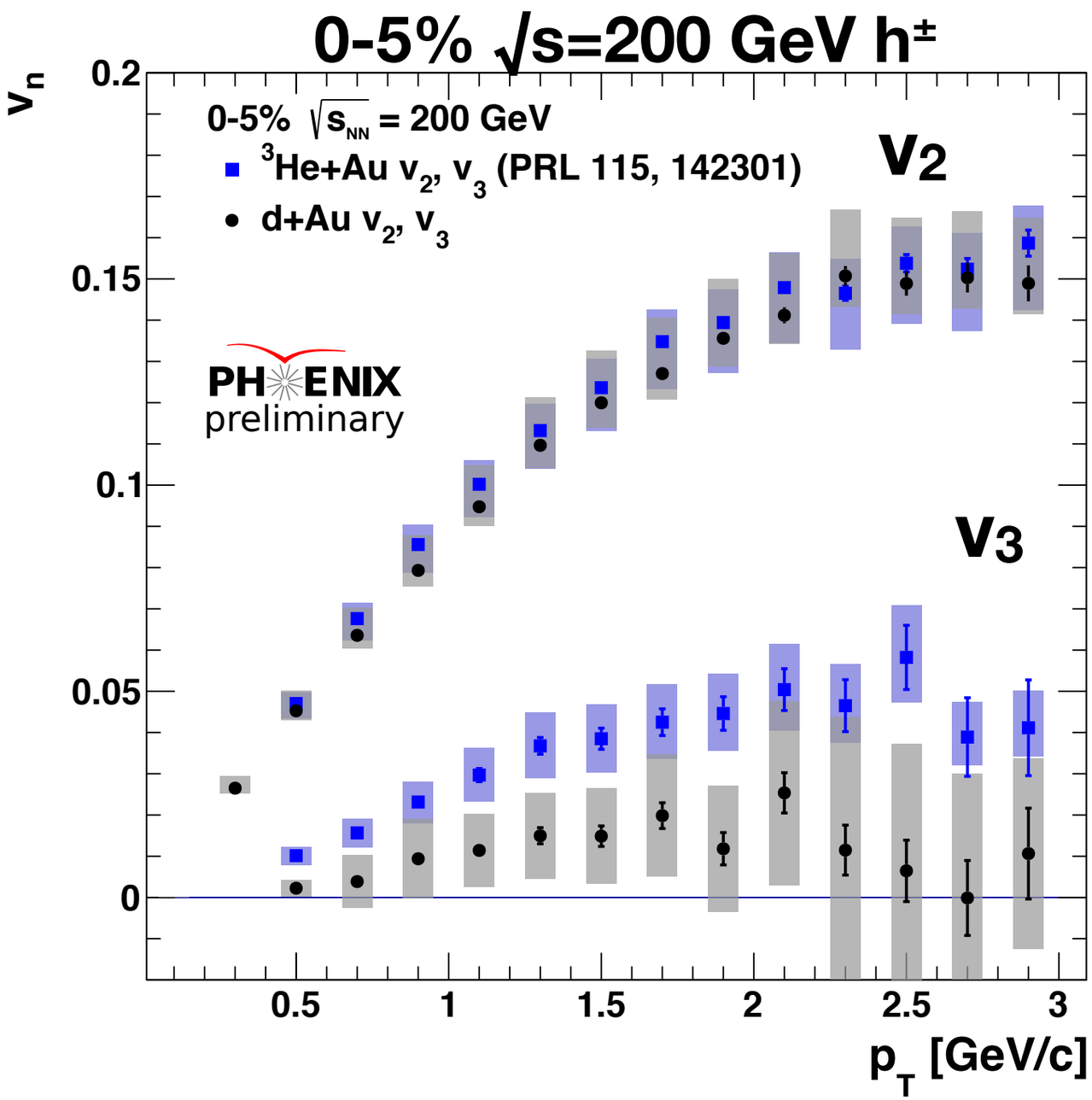
superSONIC: w/ preflow

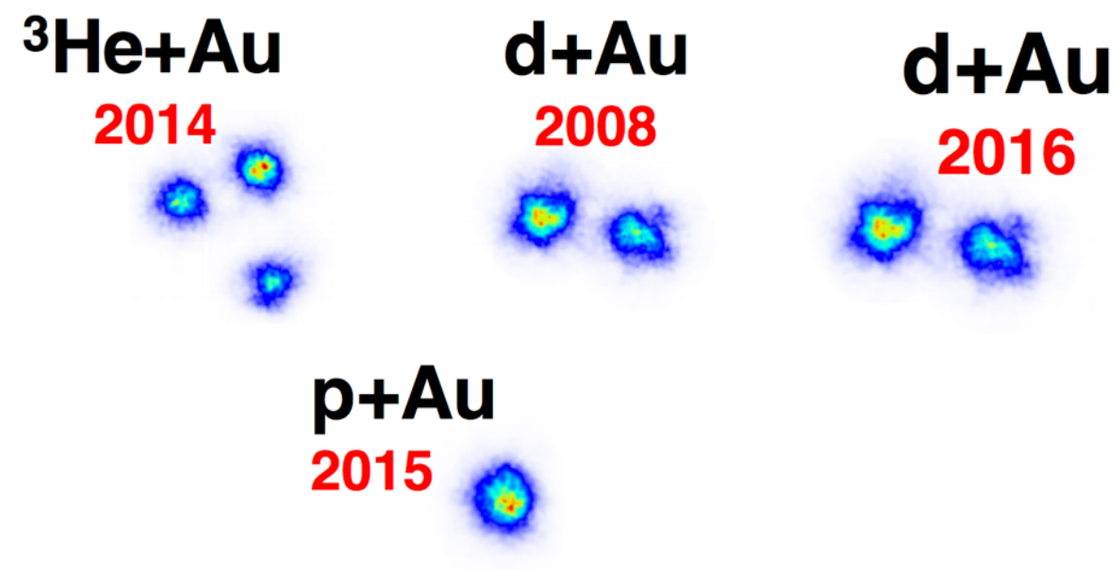
Indication that preflow may not be important at 200 GeV?

$v_3^{dAu} < v_3^{HeAu}$

Qiao Xu
6.1 - Wed 11:20

v_3 in d+Au





Geometry Scan:

Initial Geometry

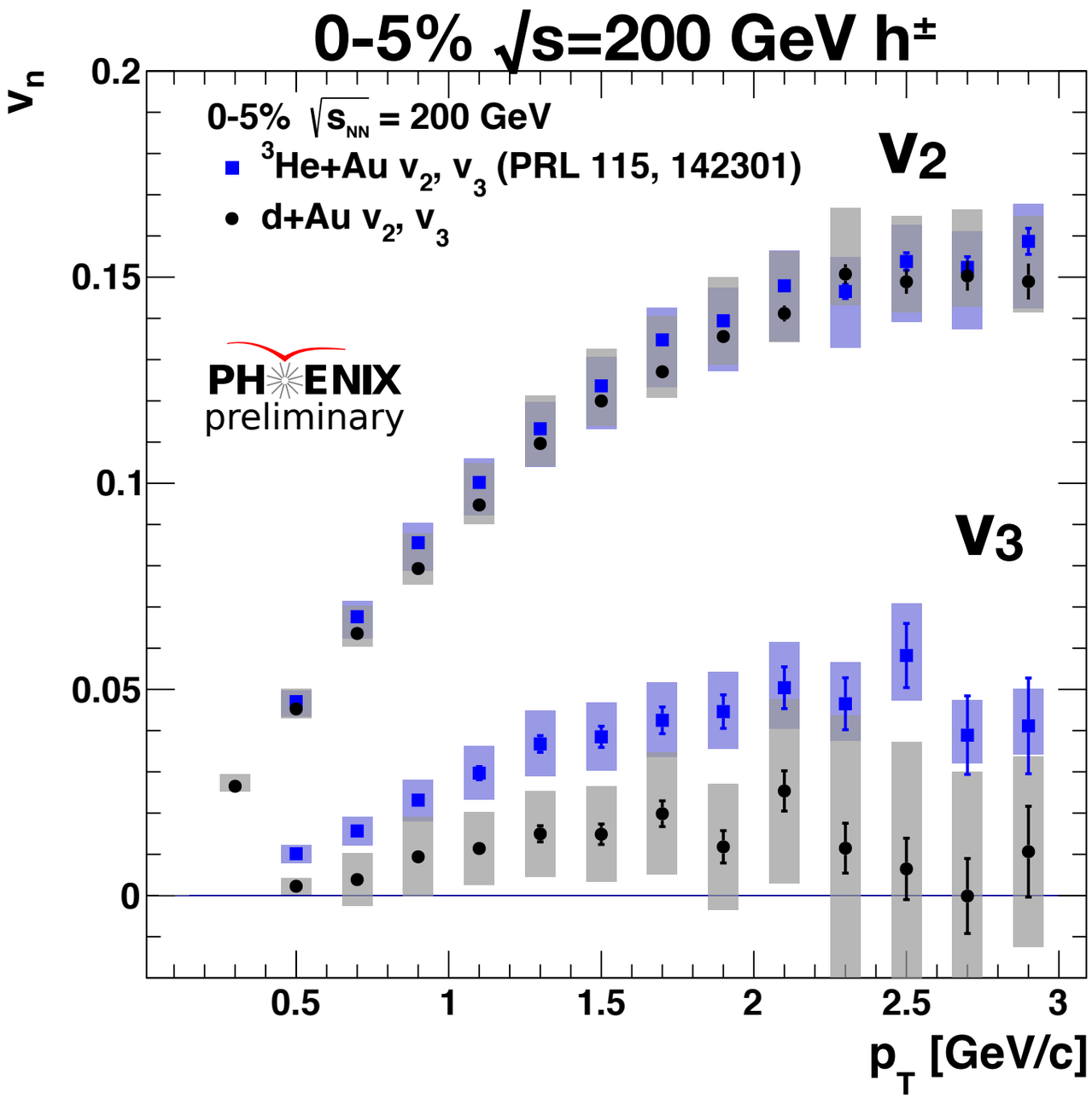
+

Final State Interactions

$v_3^{dAu} < v_3^{HeAu}$

Qiao Xu
6.1 - Wed 11:20

v_3 in d+Au



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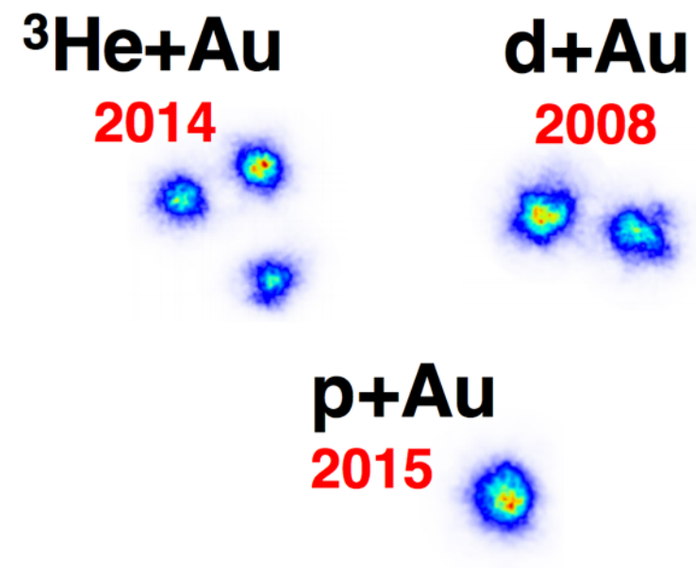
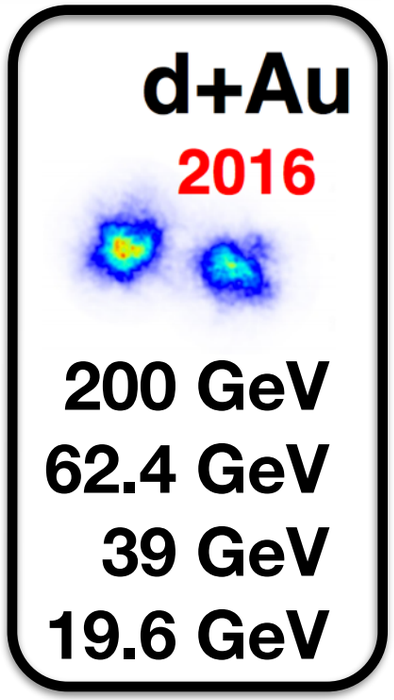




Geometry Scan:

Initial Geometry

+

Final State Interactions

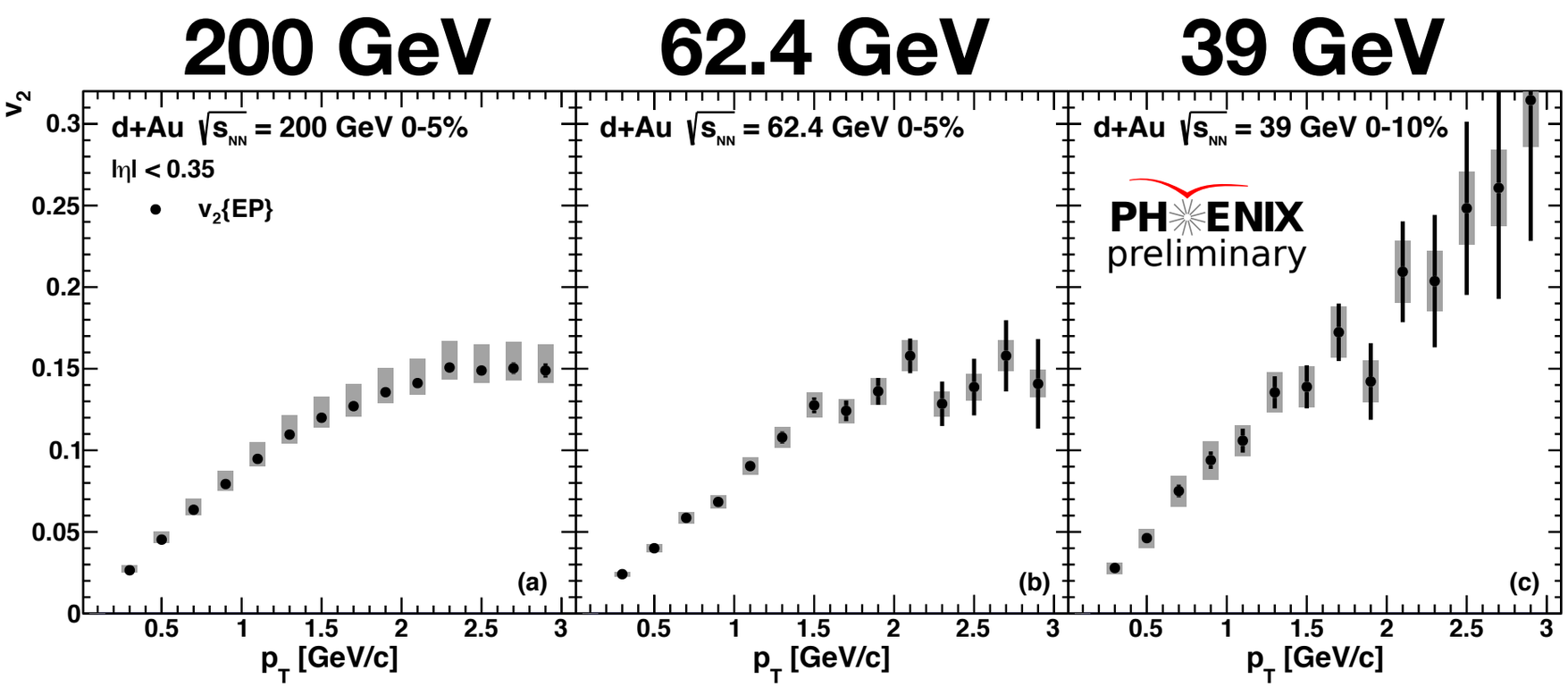
Energy Scan (2016):

How does flow in small systems depend on energy?

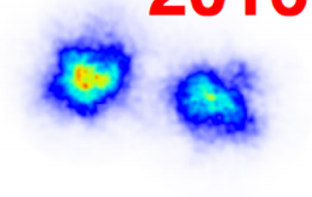
Qiao Xu
6.1 - Wed 11:20

Flow in the d+Au Beam Energy Scan

Collective Dynamics



d+Au
2016

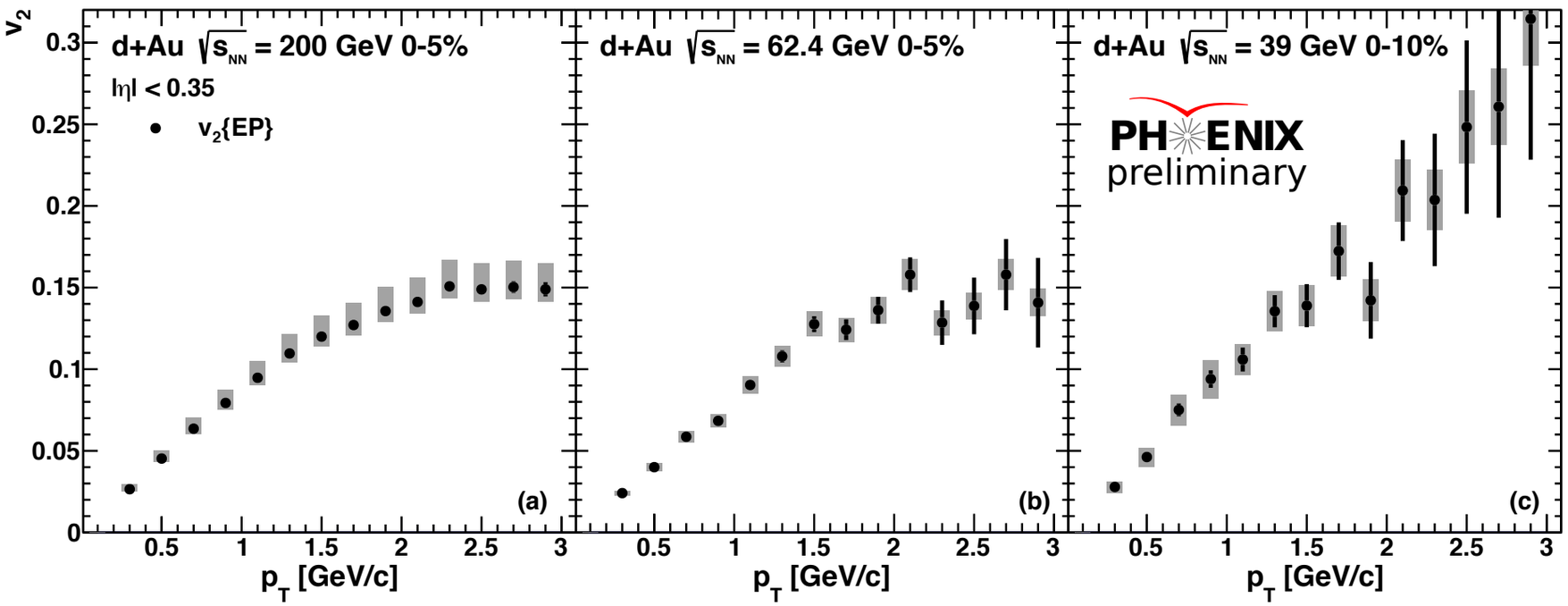


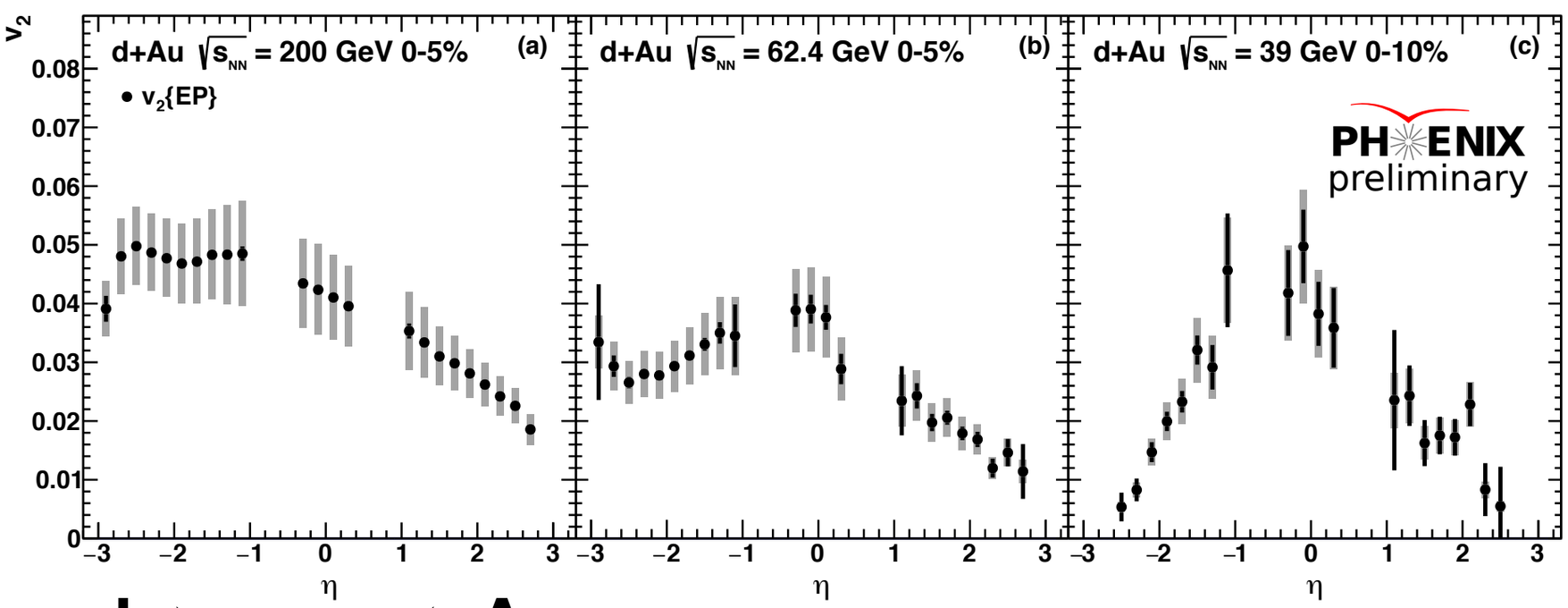
Julia Velkovska
2.2 - Tue 11:40

Flow in the d+Au Beam Energy Scan

Collective Dynamics

200 GeV **62.4 GeV** **39 GeV**

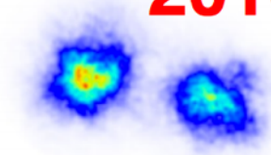




d→ **←Au**

d+Au

2016



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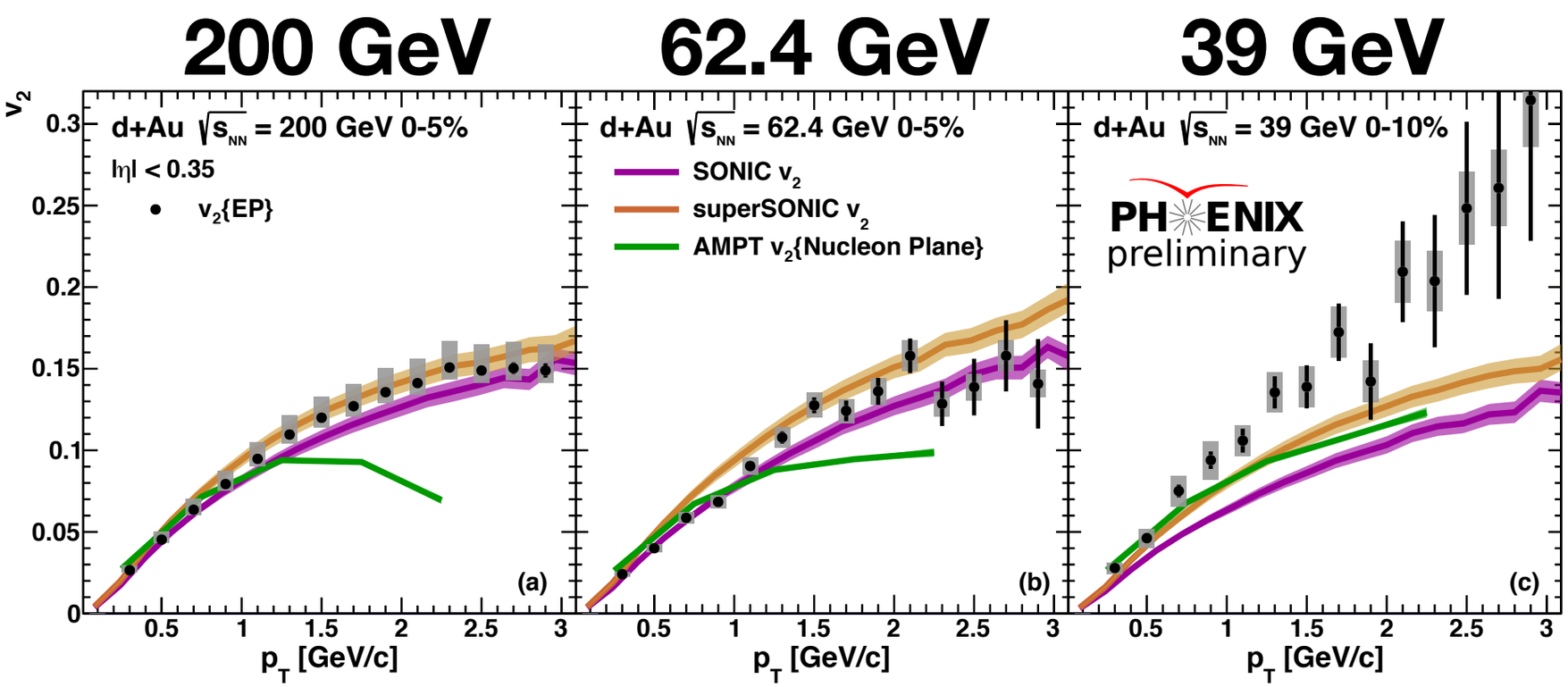
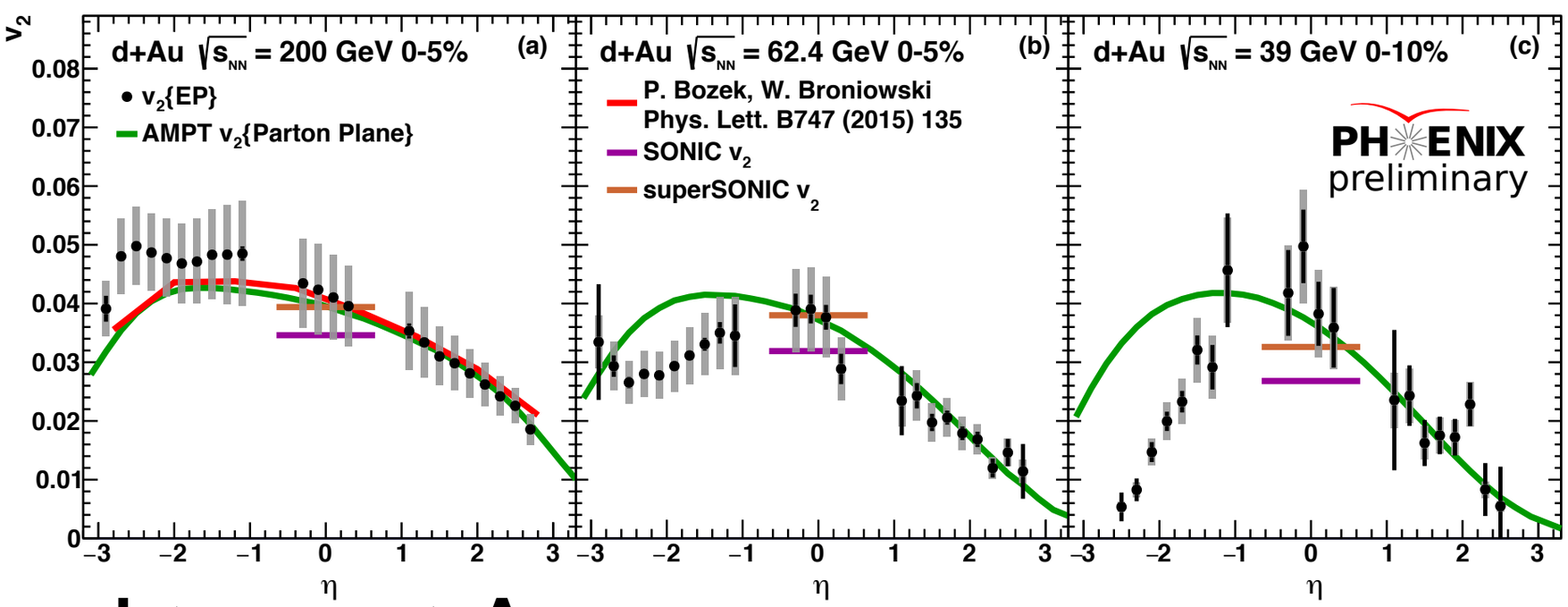
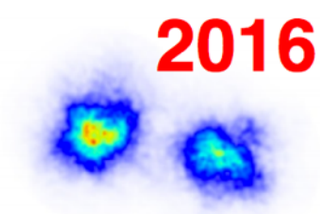




d→ ←Au



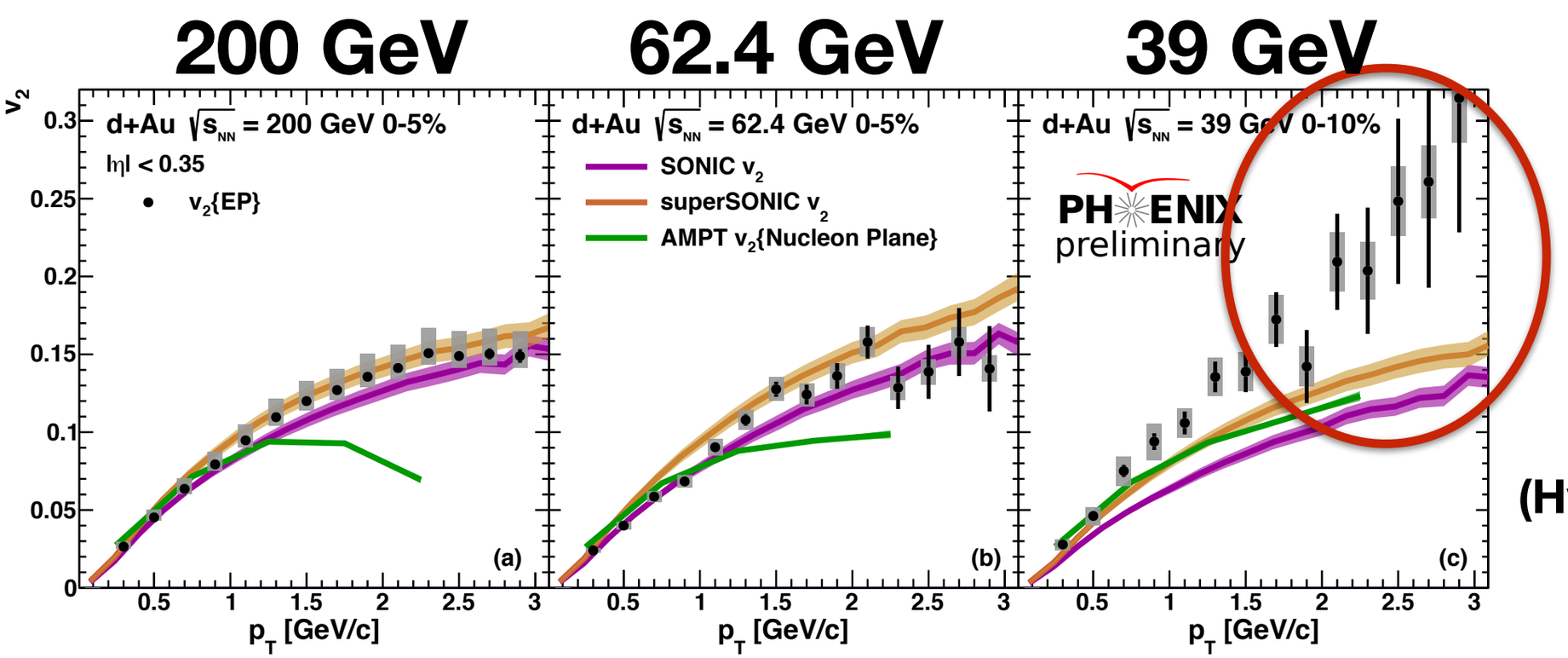
Initial Geometry
+
Final State interactions
(Hydro or parton scattering)

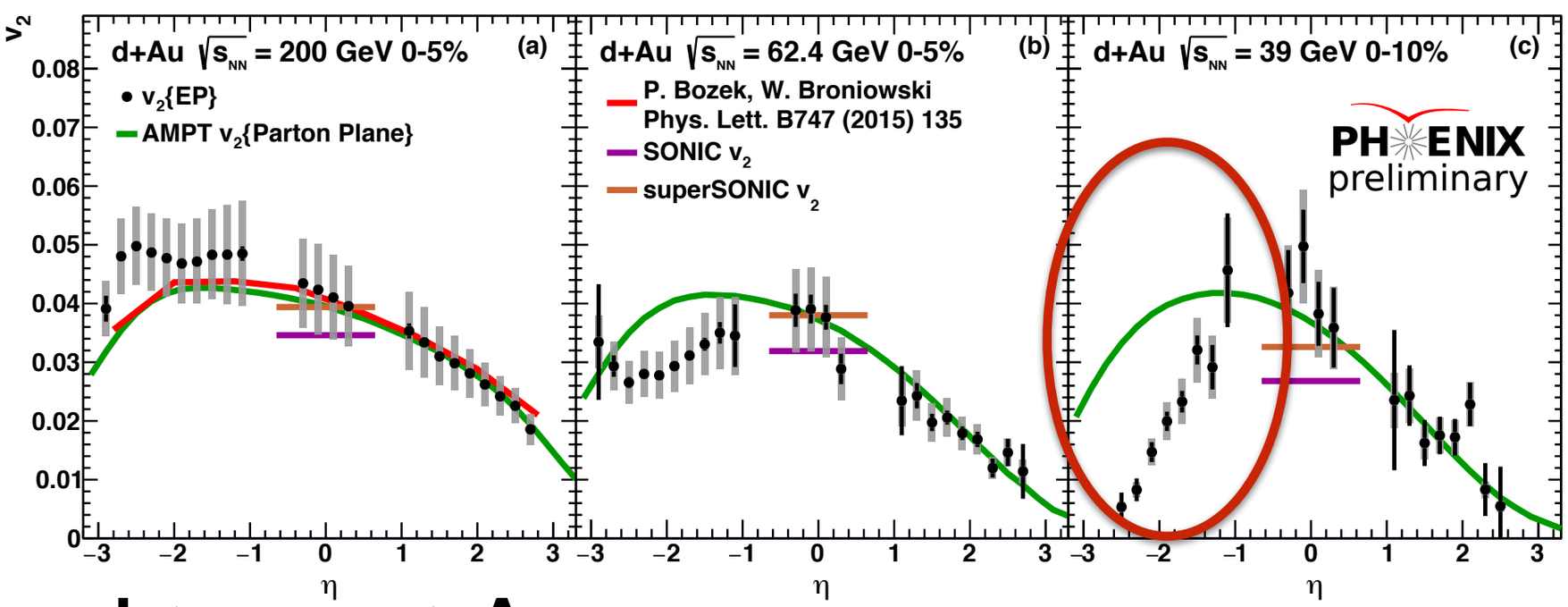
Good agreement at low-p_T & $\eta \geq 0$

Julia Velkovska
2.2 - Tue 11:40

Flow in the d+Au Beam Energy Scan

Collective Dynamics





d→ ←Au

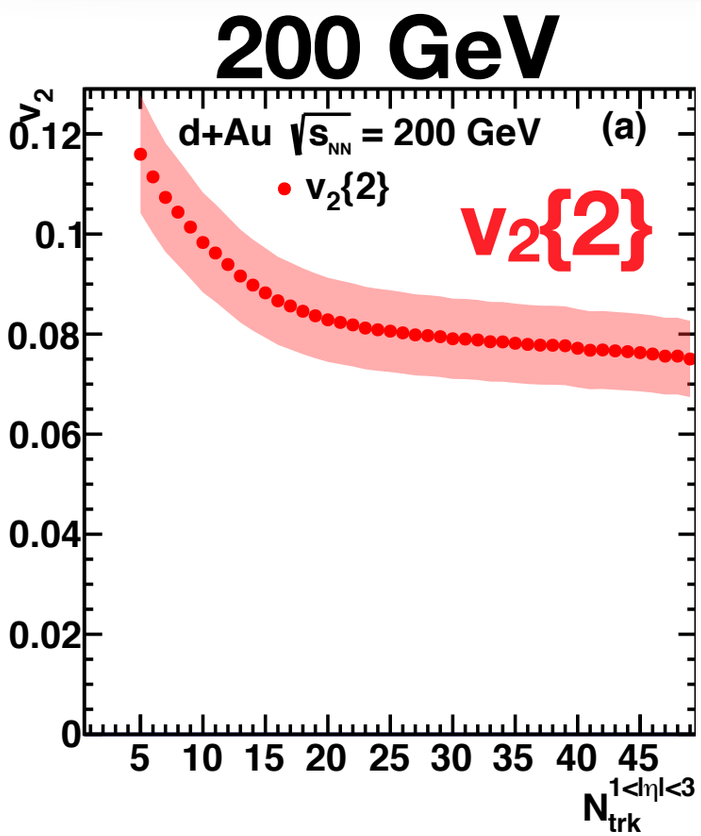
Initial Geometry
+
Final State interactions
(Hydro or parton scattering)

Good agreement at low-p_T & η≥0

Interesting non-flow effects at high-p_T & η<0

Julia Velkovska
2.2 - Tue 11:40

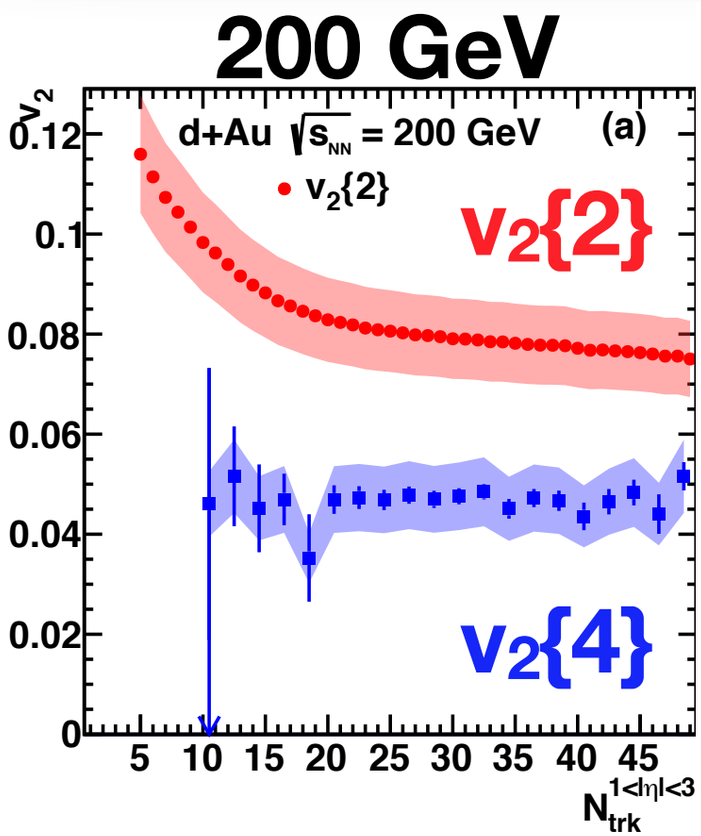
Multiparticle Correlations in Small



$v_2\{2\}$: 2 particle correlation

Ron Belmont
2.2 - Tue 10:40

Multiparticle Correlations in Small



$v_2\{2\}$: 2 particle correlation

$v_2\{4\}$: 4 particle correlation

Ron Belmont
2.2 - Tue 10:40

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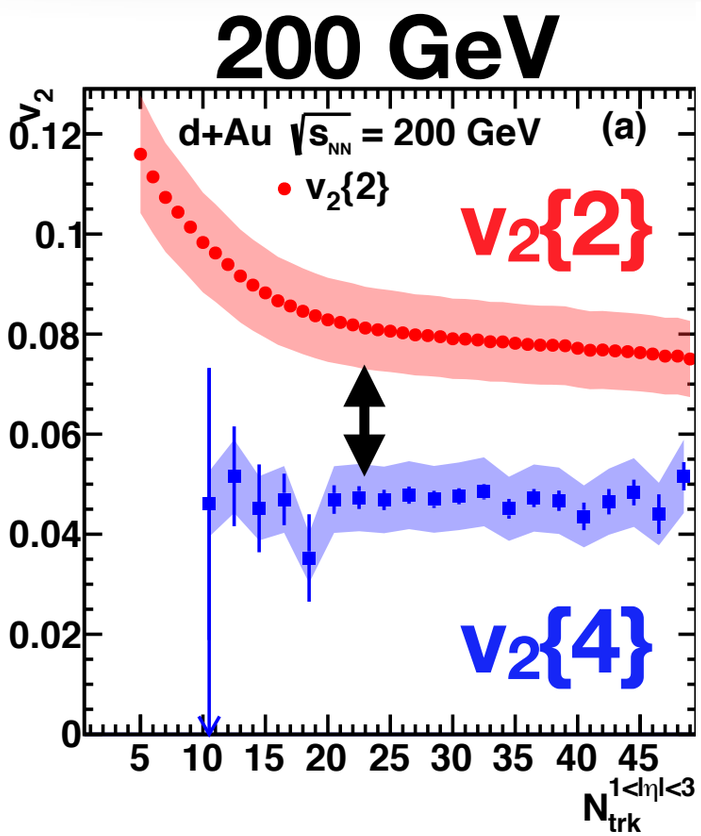

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$v_2\{4\}$: 4 particle correlation

<u>Separation:</u>

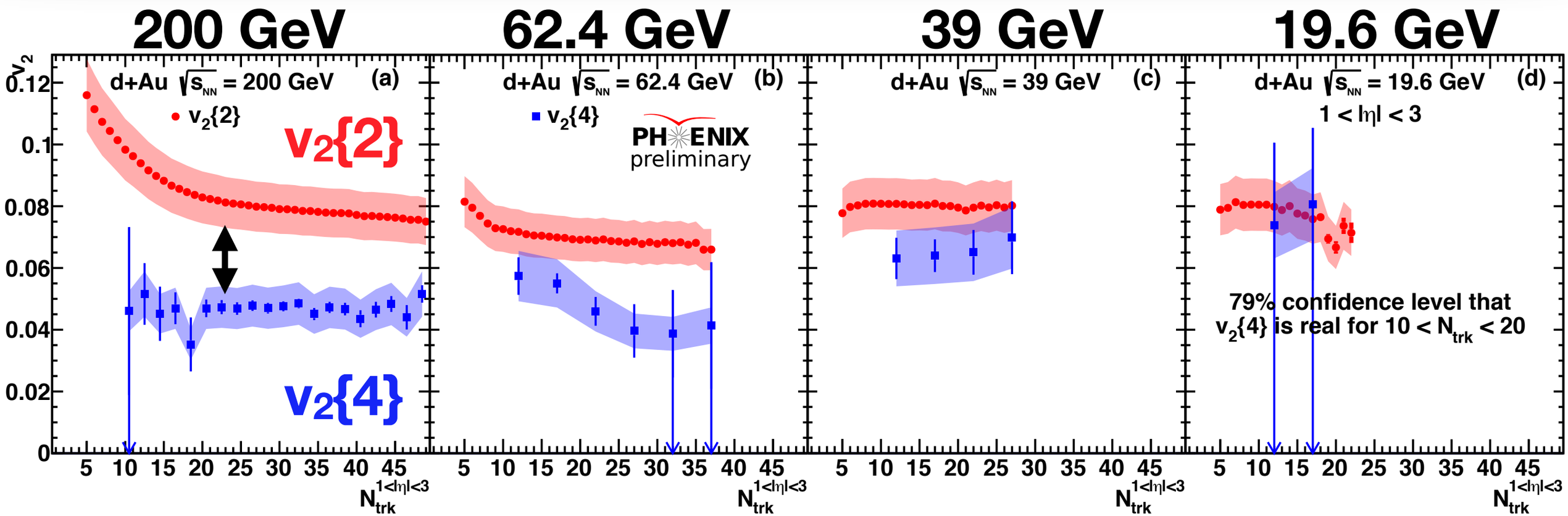
non-flow

+

fluctuations

Ron Belmont
2.2 - Tue 10:40

Multiparticle Correlations in Small



$v_2\{2\}$: 2 particle correlation

$v_2\{4\}$: 4 particle correlation

Real $v_2\{4\}$ at all 4 energies!

Evidence of collectivity down to 19.6 GeV

<u>Separation:</u>

non-flow

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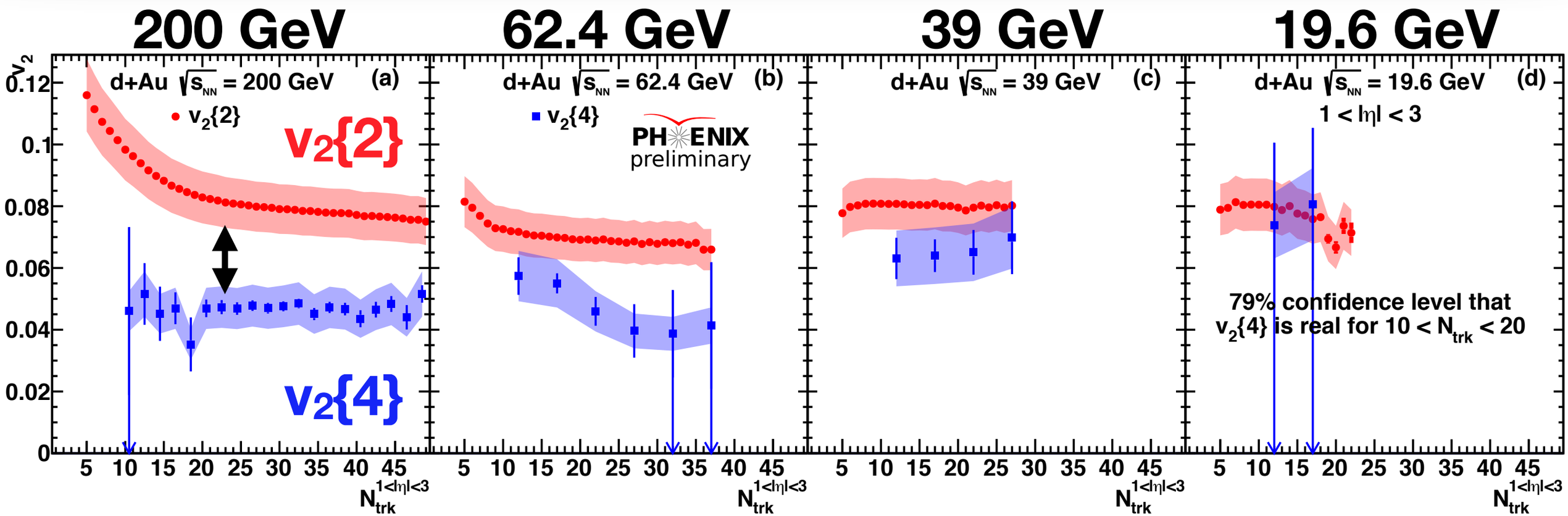
fluctuations

Ron Belmont
2.2 - Tue 10:40

Multiparticle Correlations in Small



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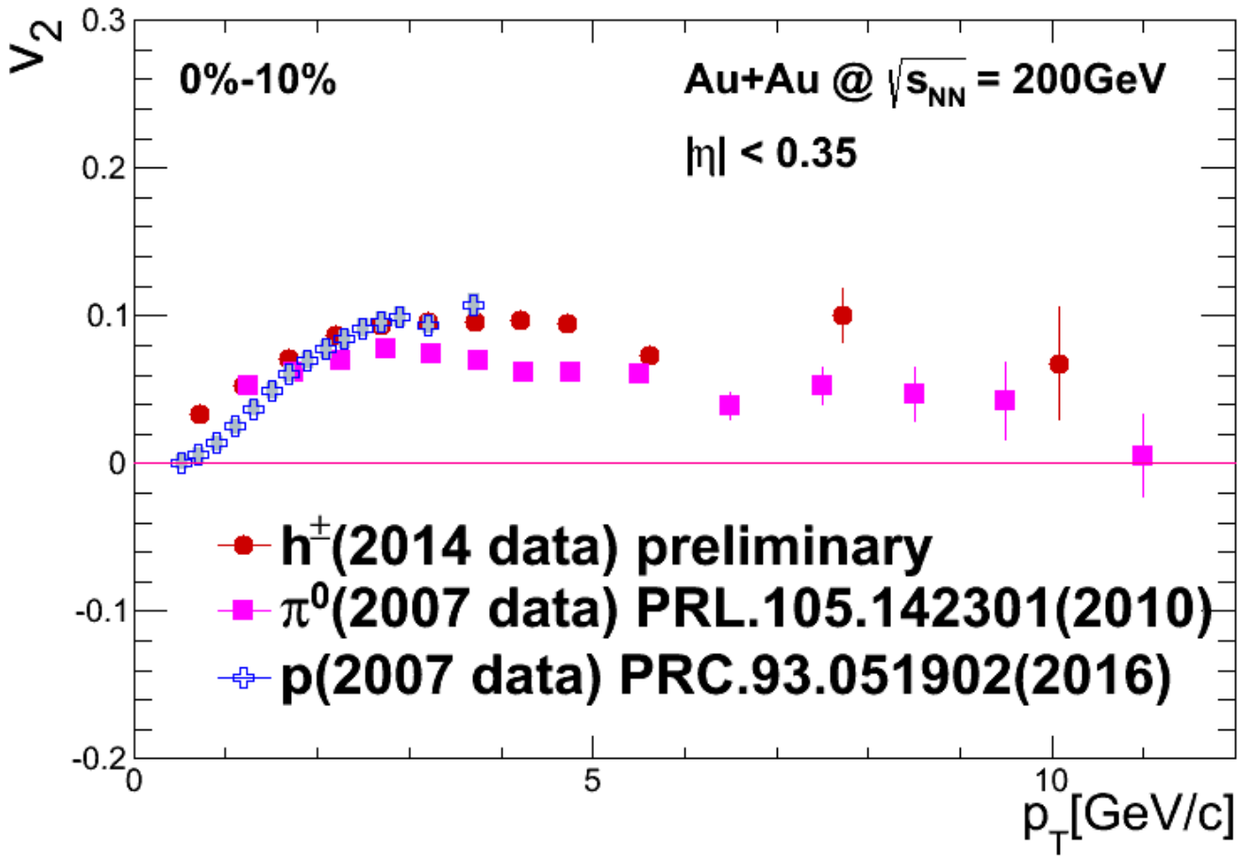
Also have cumulants in p+Au ⟶

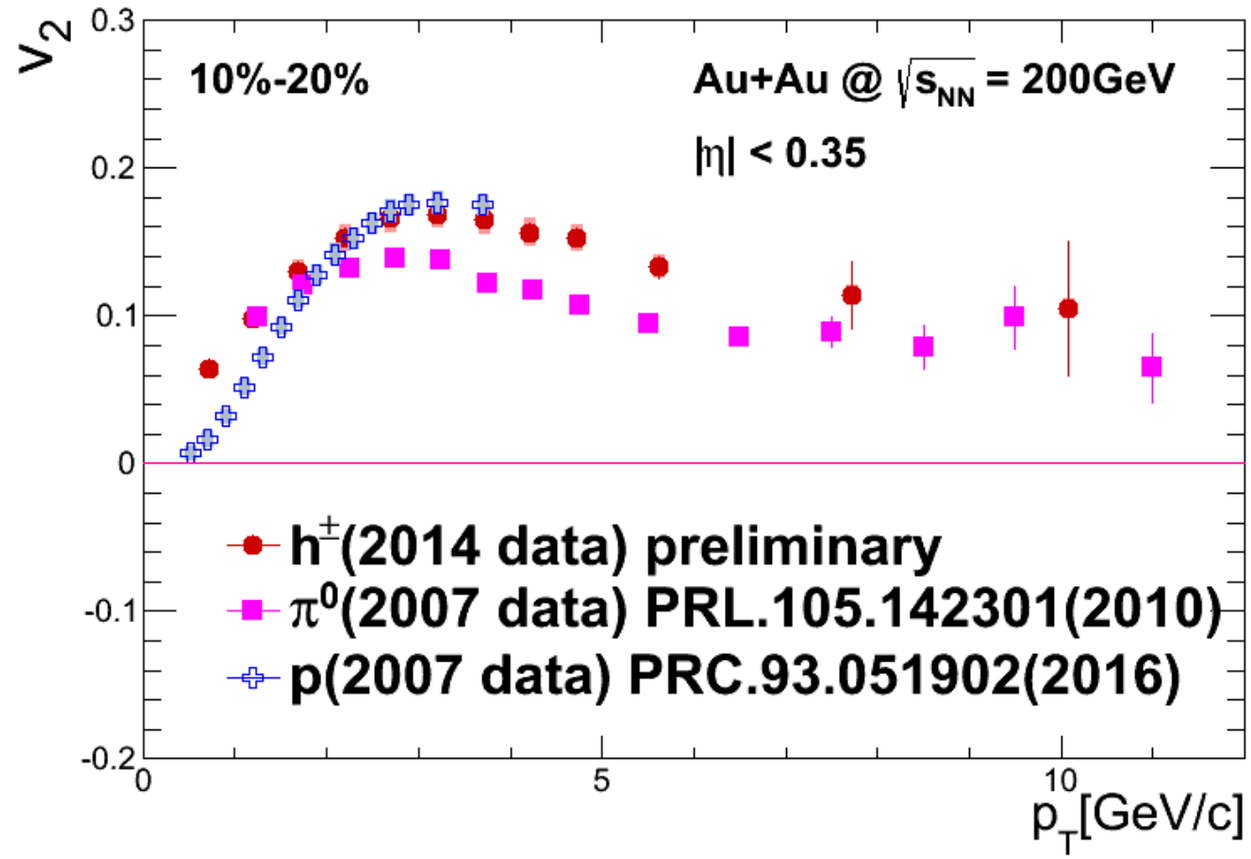
Ron Belmont
2.2 - Tue 10:40

High-p_T v_2 in Au+Au

0-10% Au+Au



10-20% Au+Au



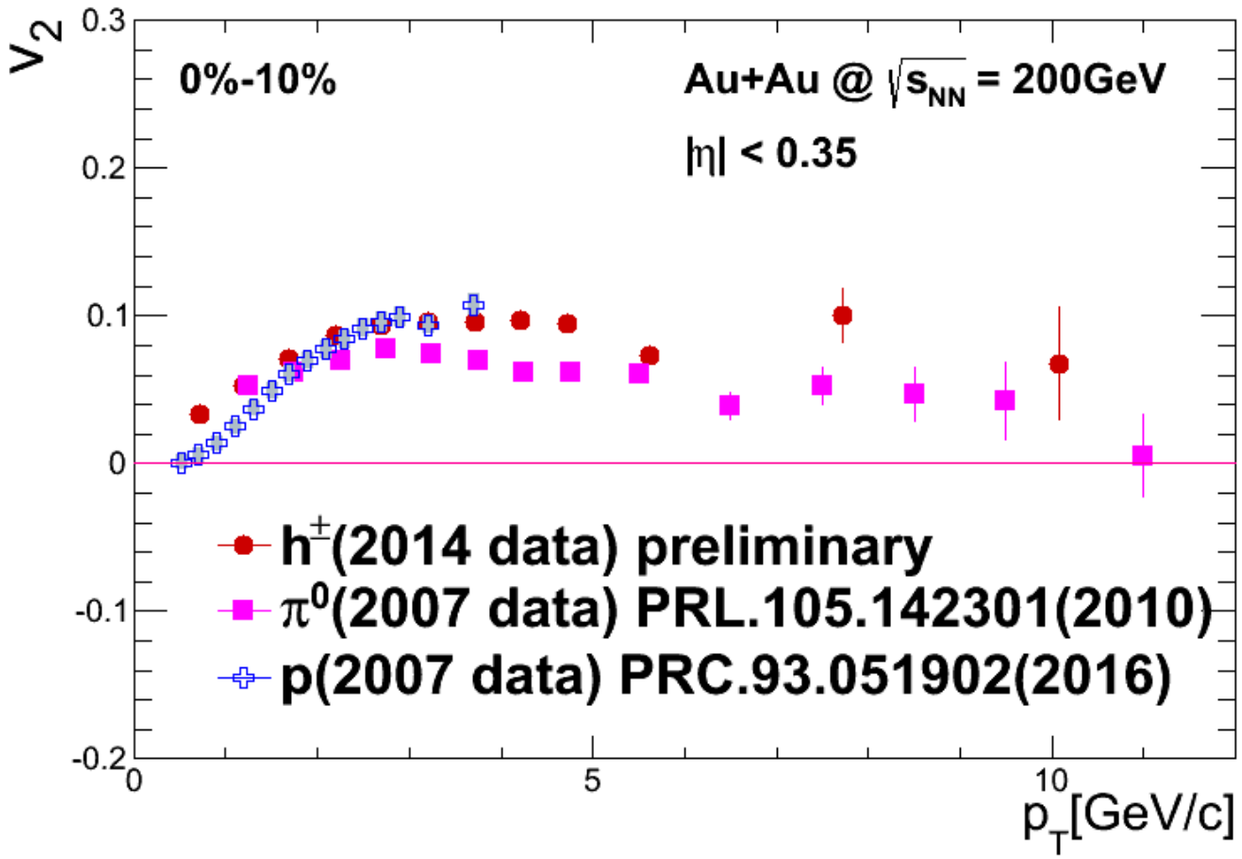
low-p_T: charged hadrons > π^0

high-p_T: charged hadrons ≈ π^0

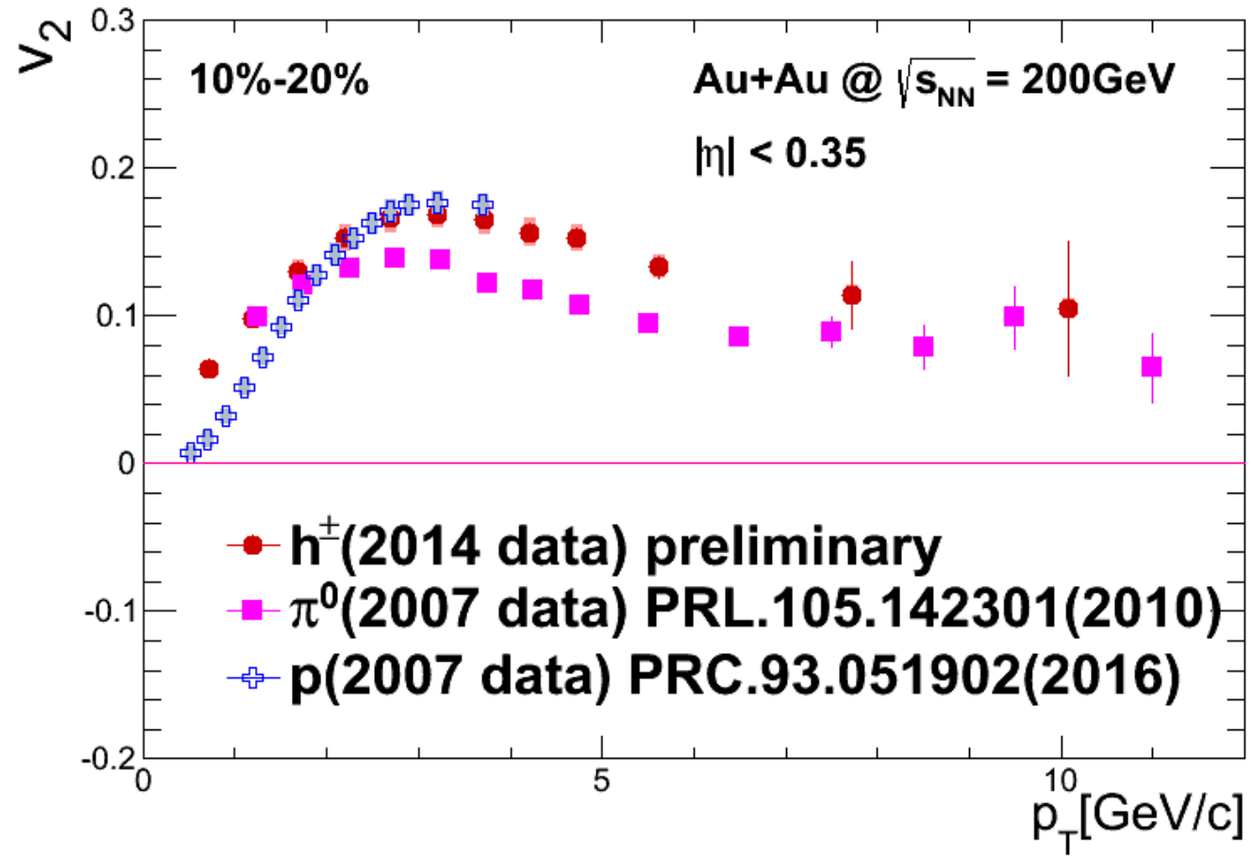
Maya Shimomura
7.3 - Wed 15:00

High-p_T v_2 in Au+Au

0-10% Au+Au



10-20% Au+Au



low-p_T: charged hadrons > π^0

high-p_T: charged hadrons ≈ π^0

Also have v_n in Cu+Au → *Maya Shimomura* **7.3 - Wed 15:00**

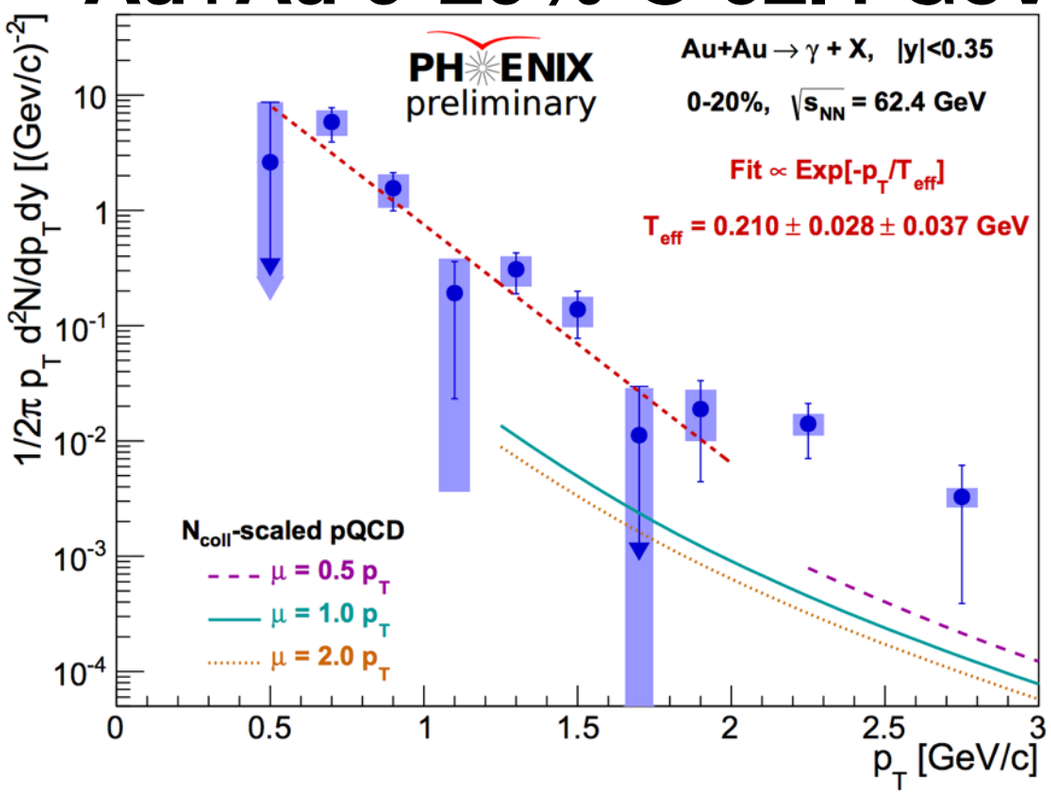
Electromagnetic Probes

PHENIX measurements of low momentum direct photons from large ion collisions as a function of beam energy and system size

***Deepali Sharma* — 2.3: Tue 11:00**

Direct Photon Inverse Slope

Au+Au 0-20% @ 62.4 GeV



New measurements of direct photon yield

Deepali Sharma
2.3 - Tue 11:00

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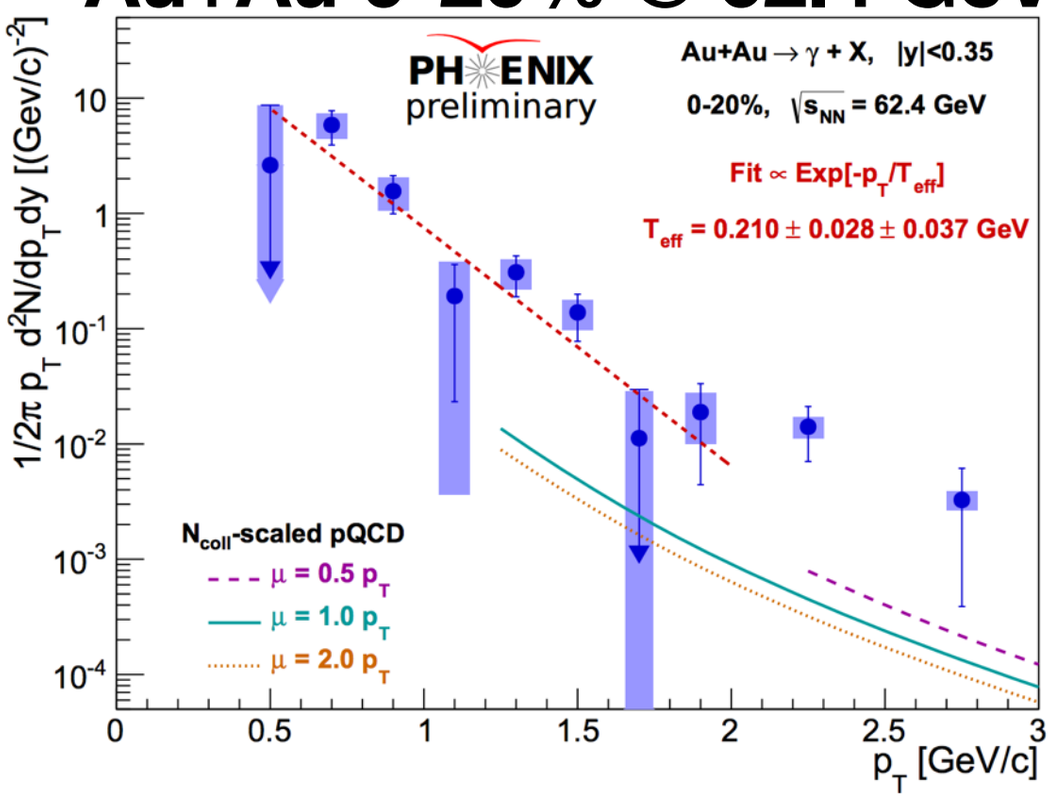
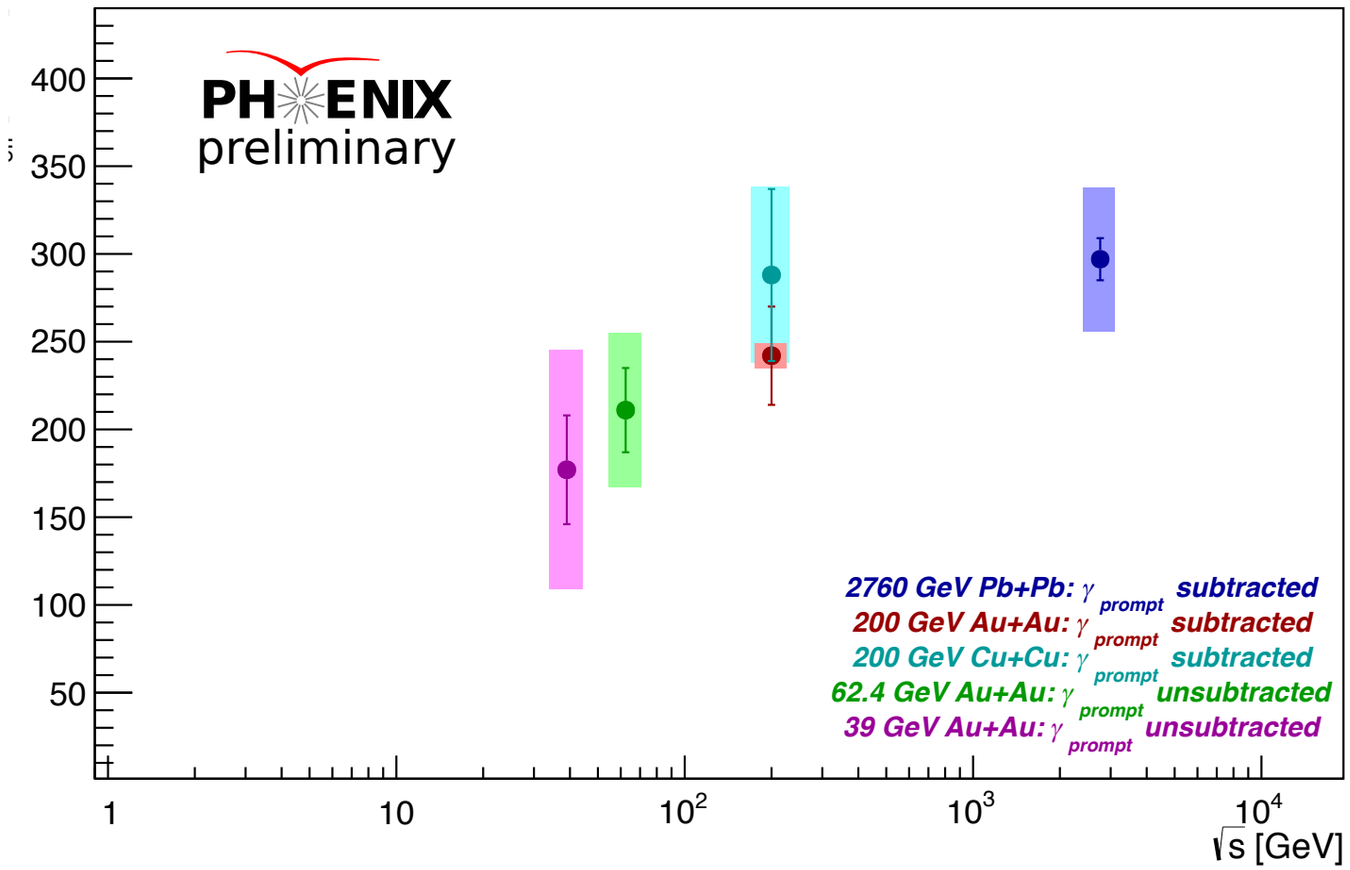


New measurements of direct photon yield

- **Au+Au @ 62.4 GeV**
- **Au+Au @ 39 GeV**
- **Cu+Cu @ 200 GeV**

T_{eff} vs. collision energy



Providing further constraints on the energy dependence of T_{eff}

Deepali Sharma
2.3 - Tue 11:00

Jets & High-p_T Hadrons

Study of Cold and Hot Nuclear Matter Effects on Jets with Direct Photon-Triggered Correlations from PHENIX

***Joe Osborn* — 1.4: Tue 08:30**

Studying Parton Energy Loss Using Meson Production in Large Collision Systems from PHENIX

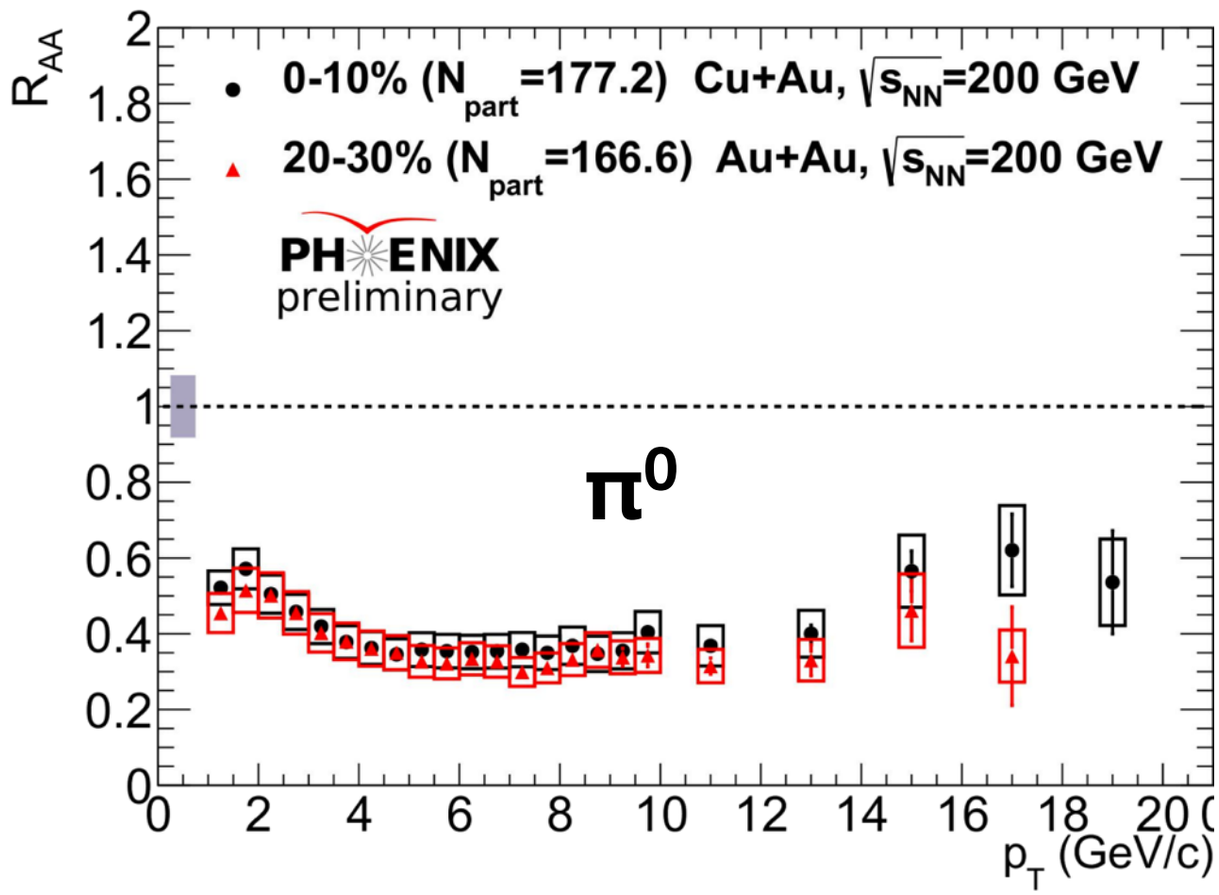
***Sergei Zharko* — 6.4: Wed 10:40**

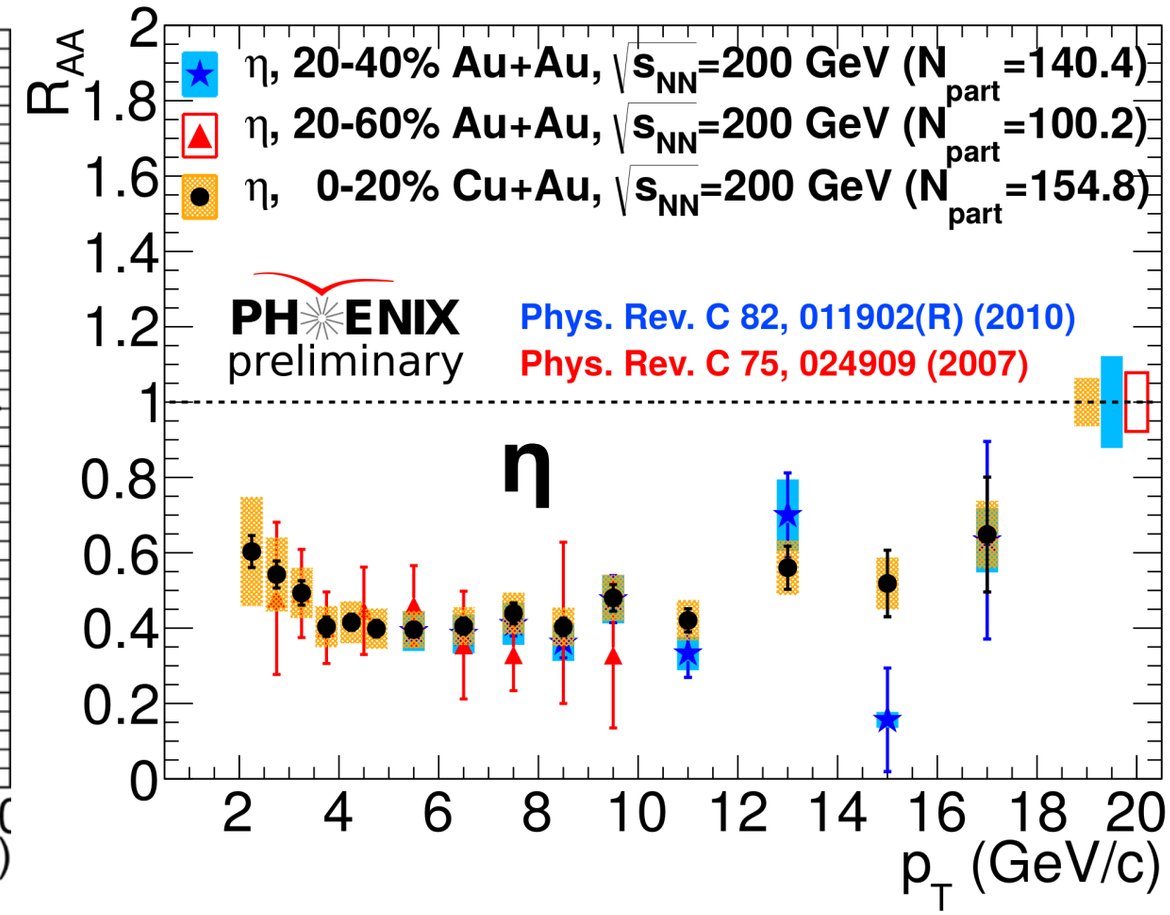
Systematic Study of Highly Asymmetric Systems Using pi0 Production at PHENIX

***Norbert Novitzky* — 6.4: Wed 11:00**

Hadron Modification in Cu+Au

Jets & high-p_T Hadrons



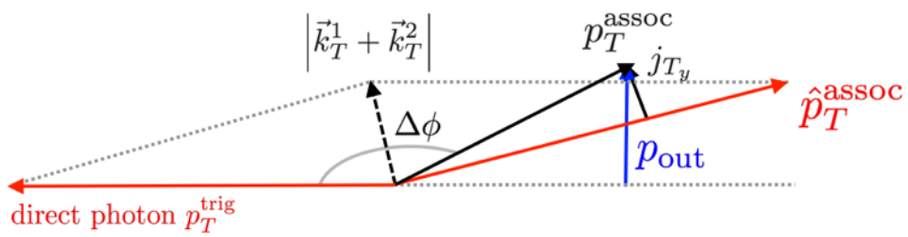


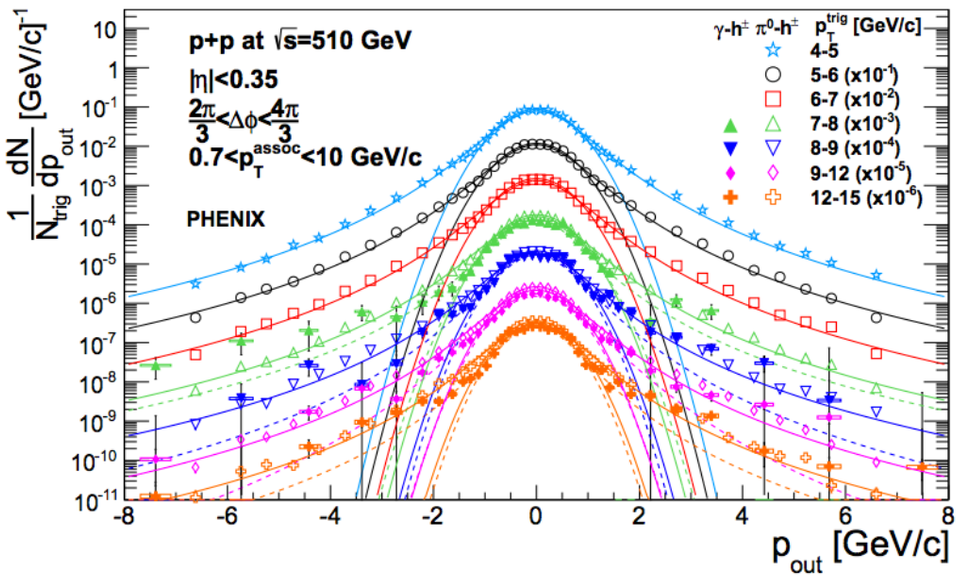
New measurement of π^0 & η in Cu+Au
Suppression pattern in good agreement with Au+Au at similar N_{part}

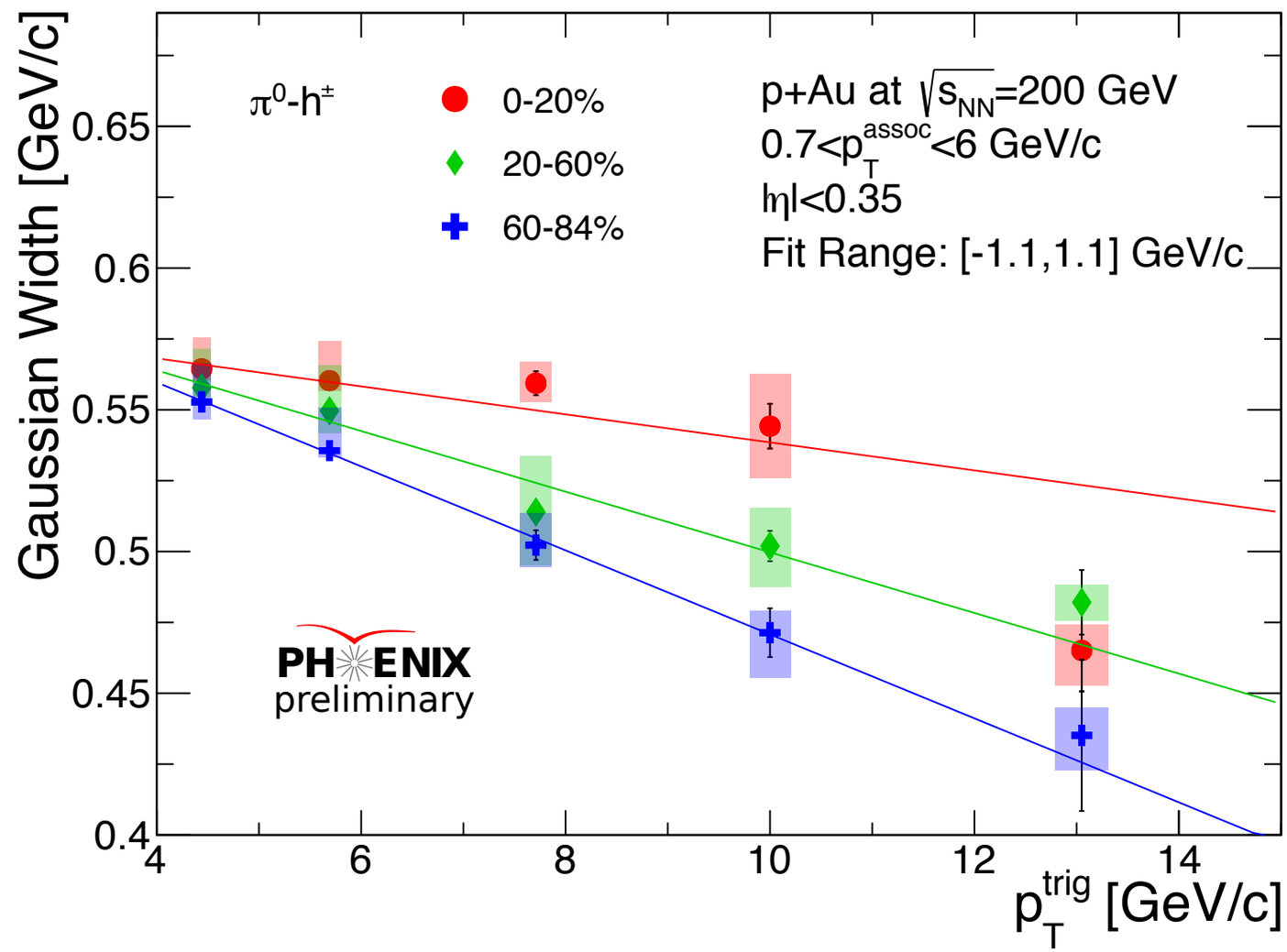
Sergei Zharko
6.4 - Wed 10:40

γ/π^0-h correlations in p+Au

Jets & high-p_T Hadrons







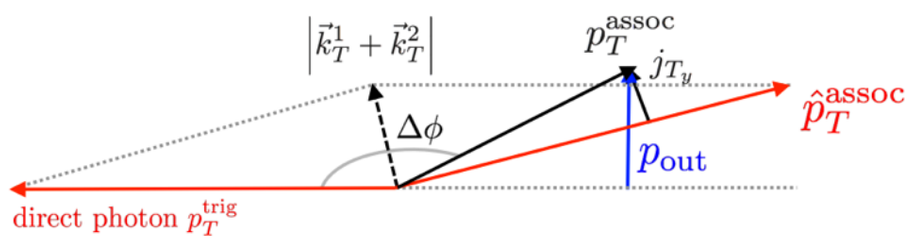
Gaussian widths decrease with $p_T^{\rm trig}$ and have interesting centrality dependence

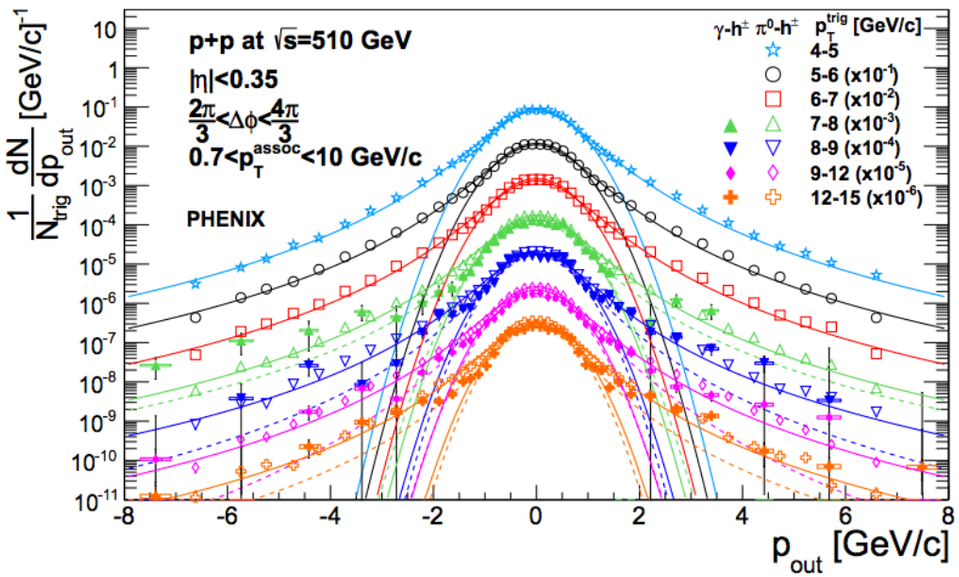
—

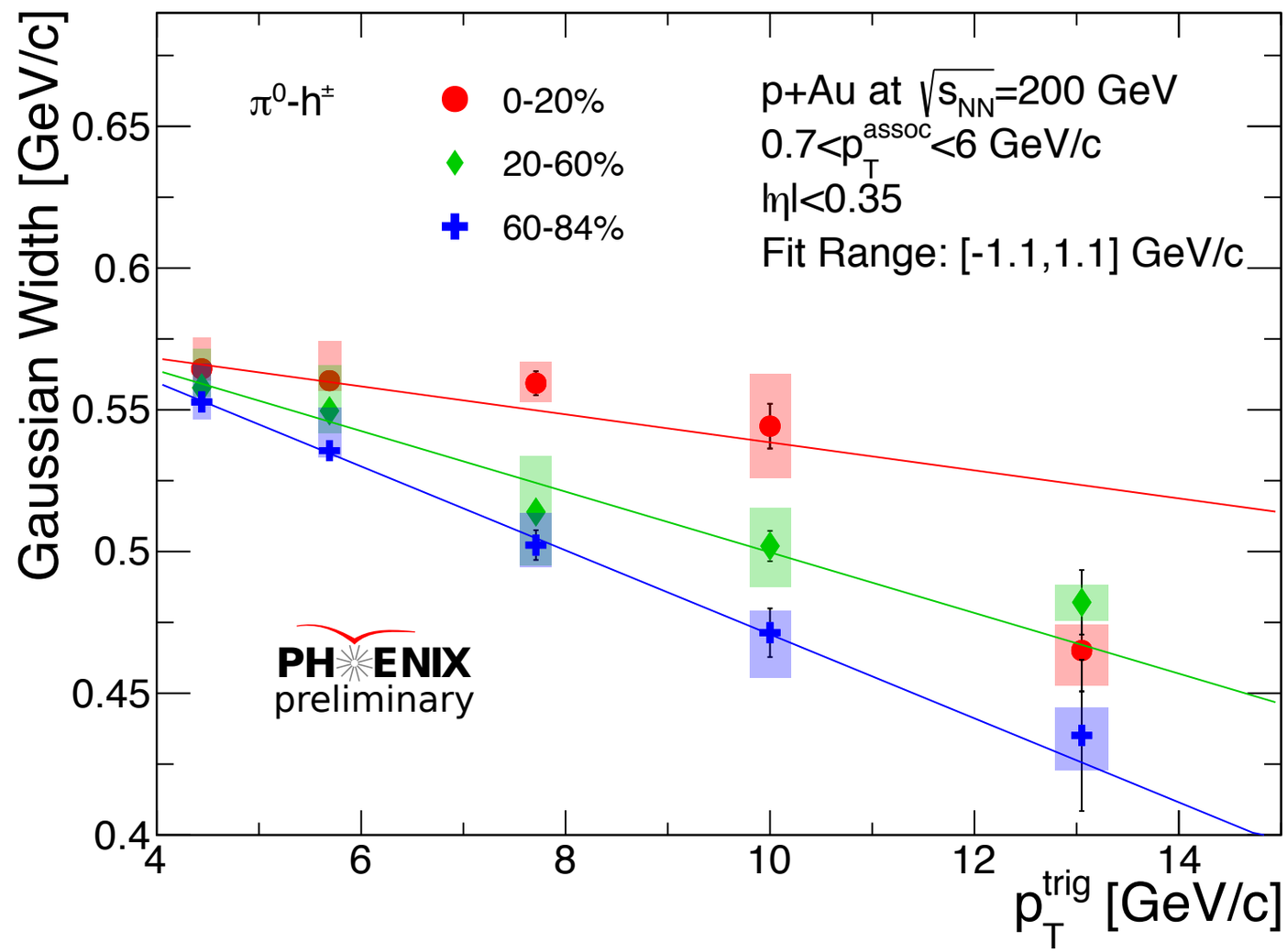
Interpretations ongoing

Joe Osborn
1.4 - Tue 08:30

γ/π^0-h correlations in p+Au







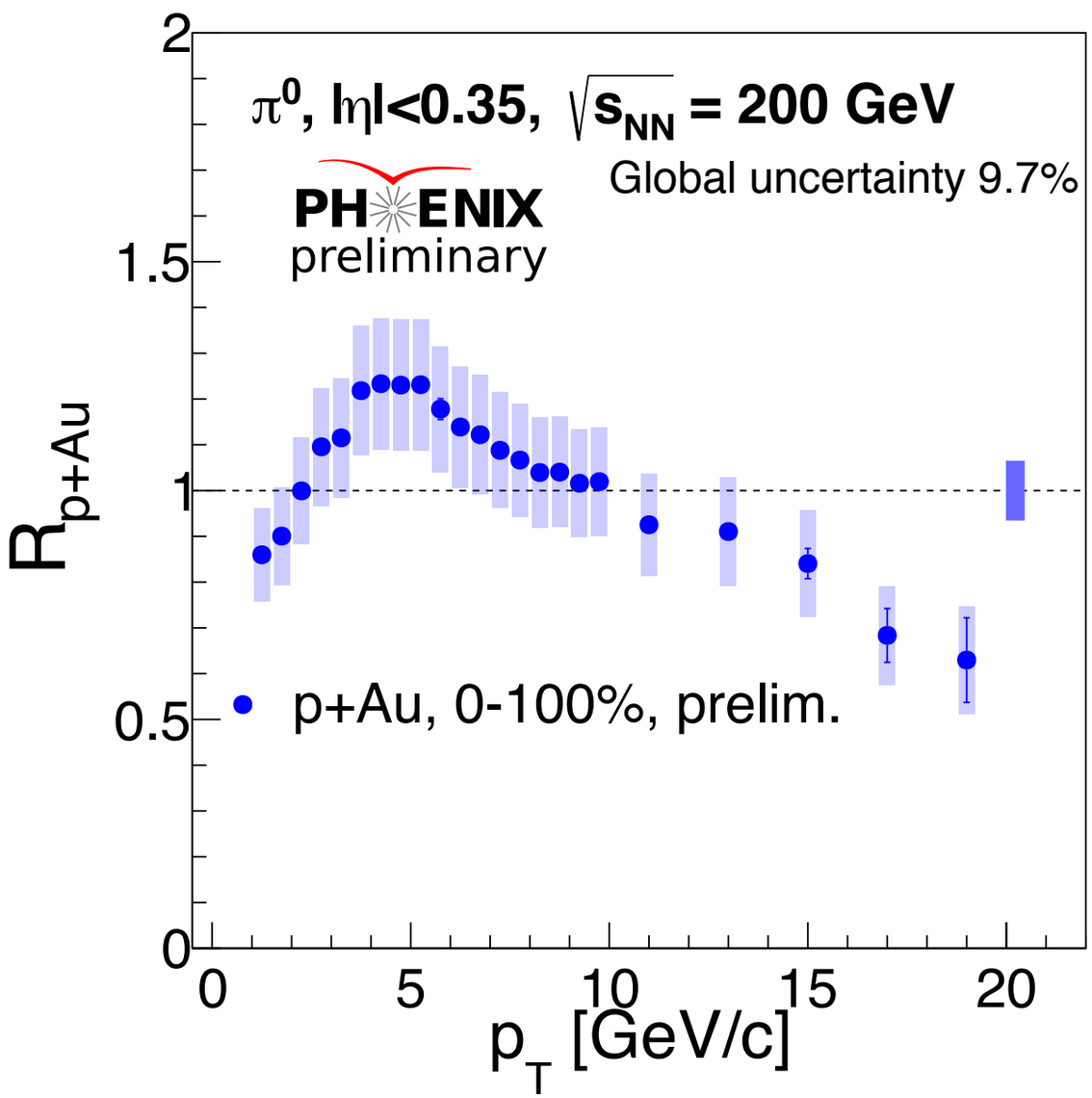
Gaussian widths decrease with $p_T^{\rm trig}$ and have interesting centrality dependence

—

Interpretations ongoing

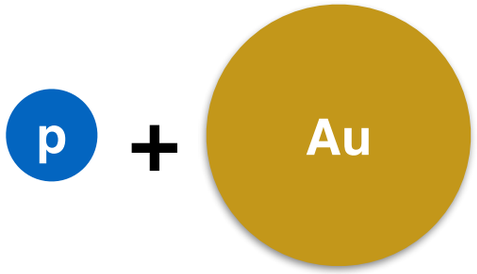
Also new γ-h correlations in p+p/d+Au/Au+Au → *Joe Osborn* **1.4 - Tue 08:30**

π^0 production in p/d/^{3}He+Au



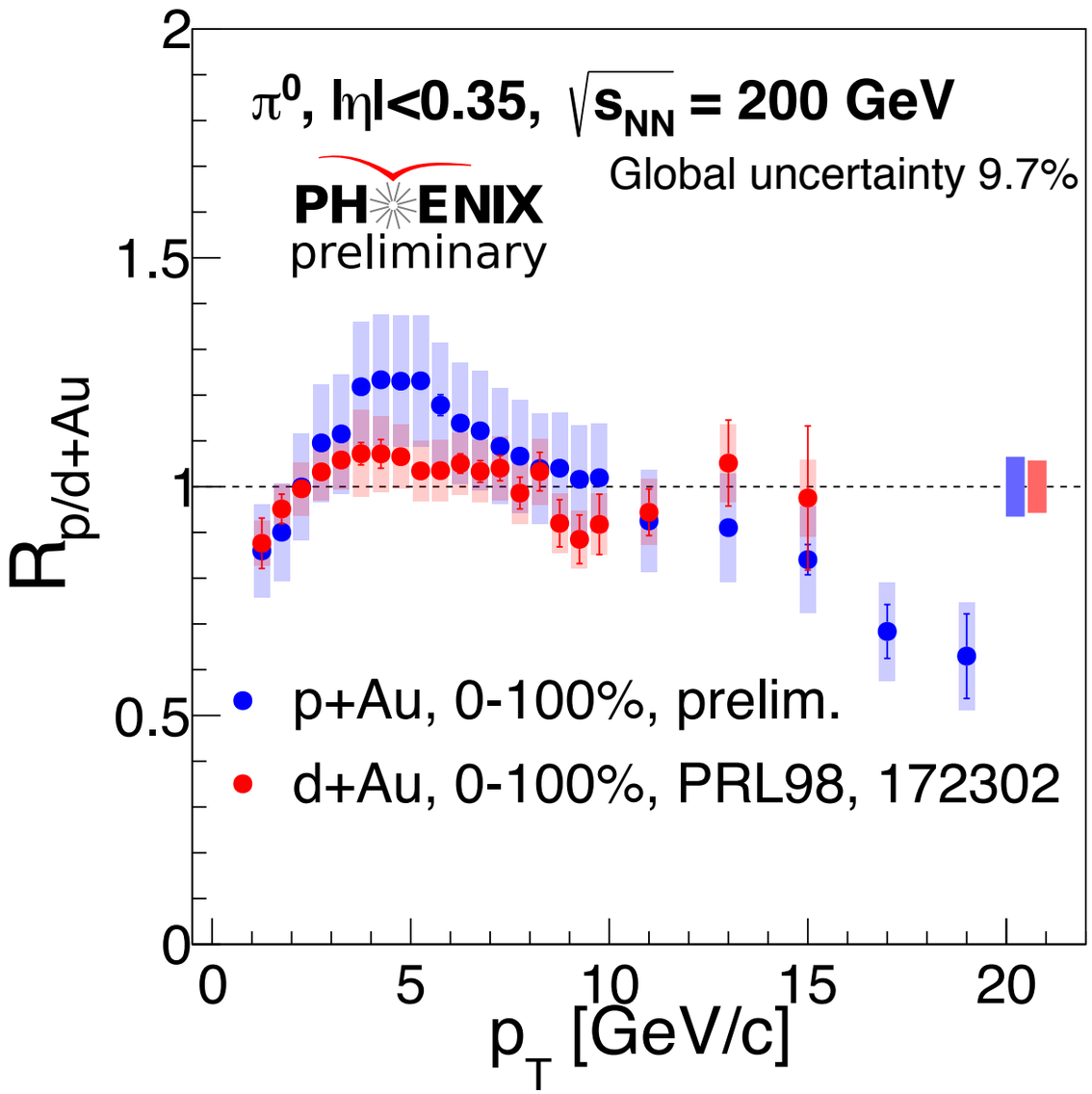
New π^0 modification in:

p+Au



Norbert Novitzky
6.4 - Wed 11:00

π^0 production in p/d/^{3}He+Au



New π^0 modification in:

p+Au

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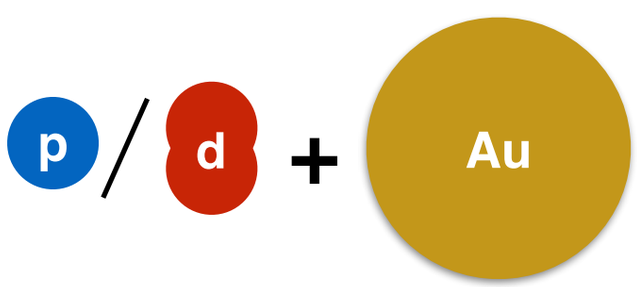
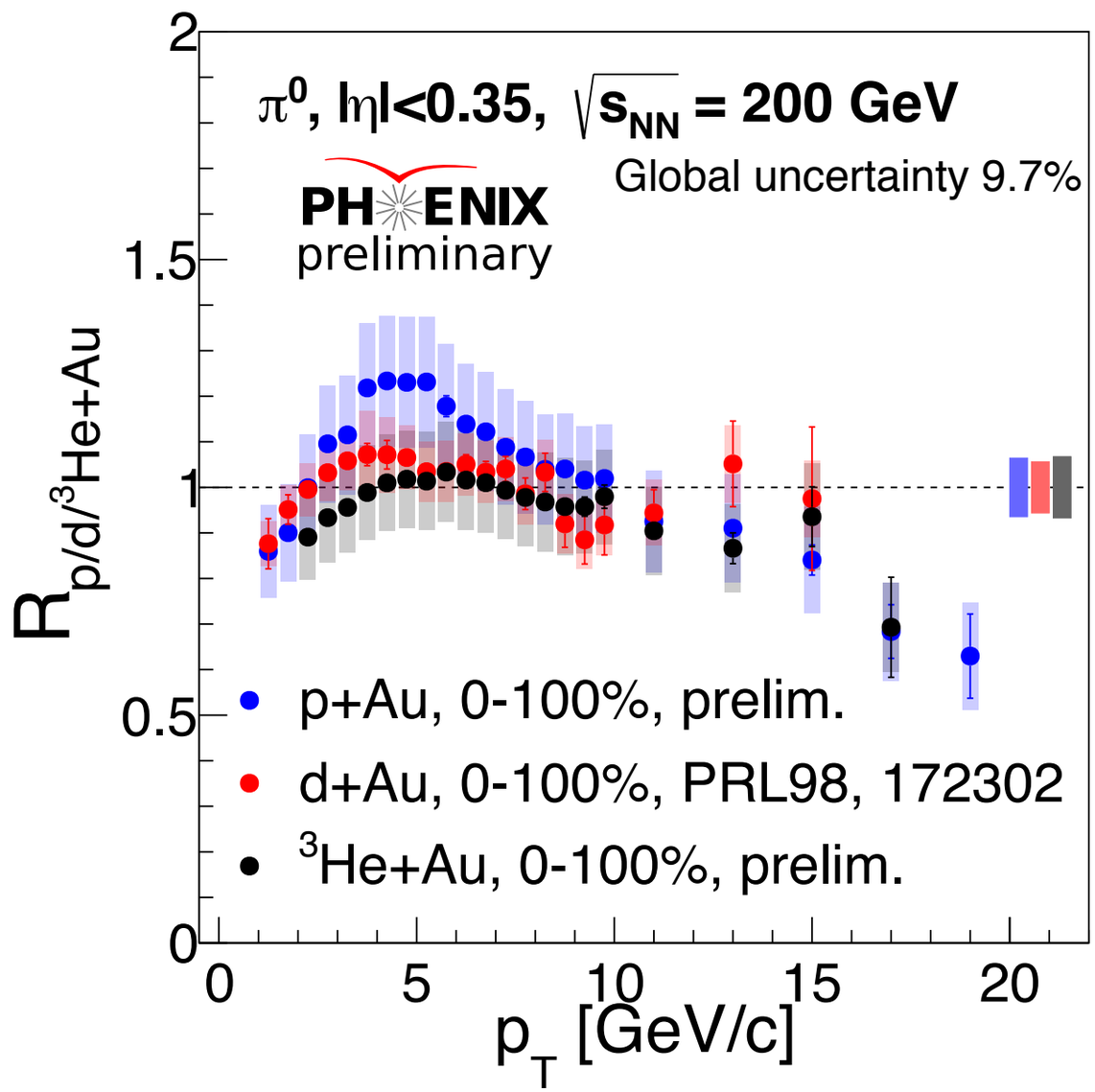


Norbert Novitzky
6.4 - Wed 11:00

π^0 production in p/d/^{3}He+Au



New π^0 modification in:

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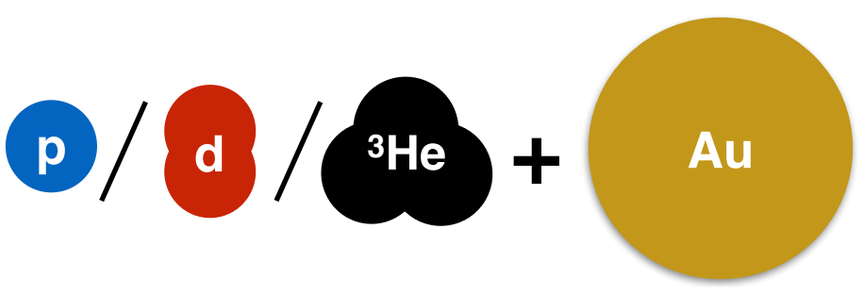
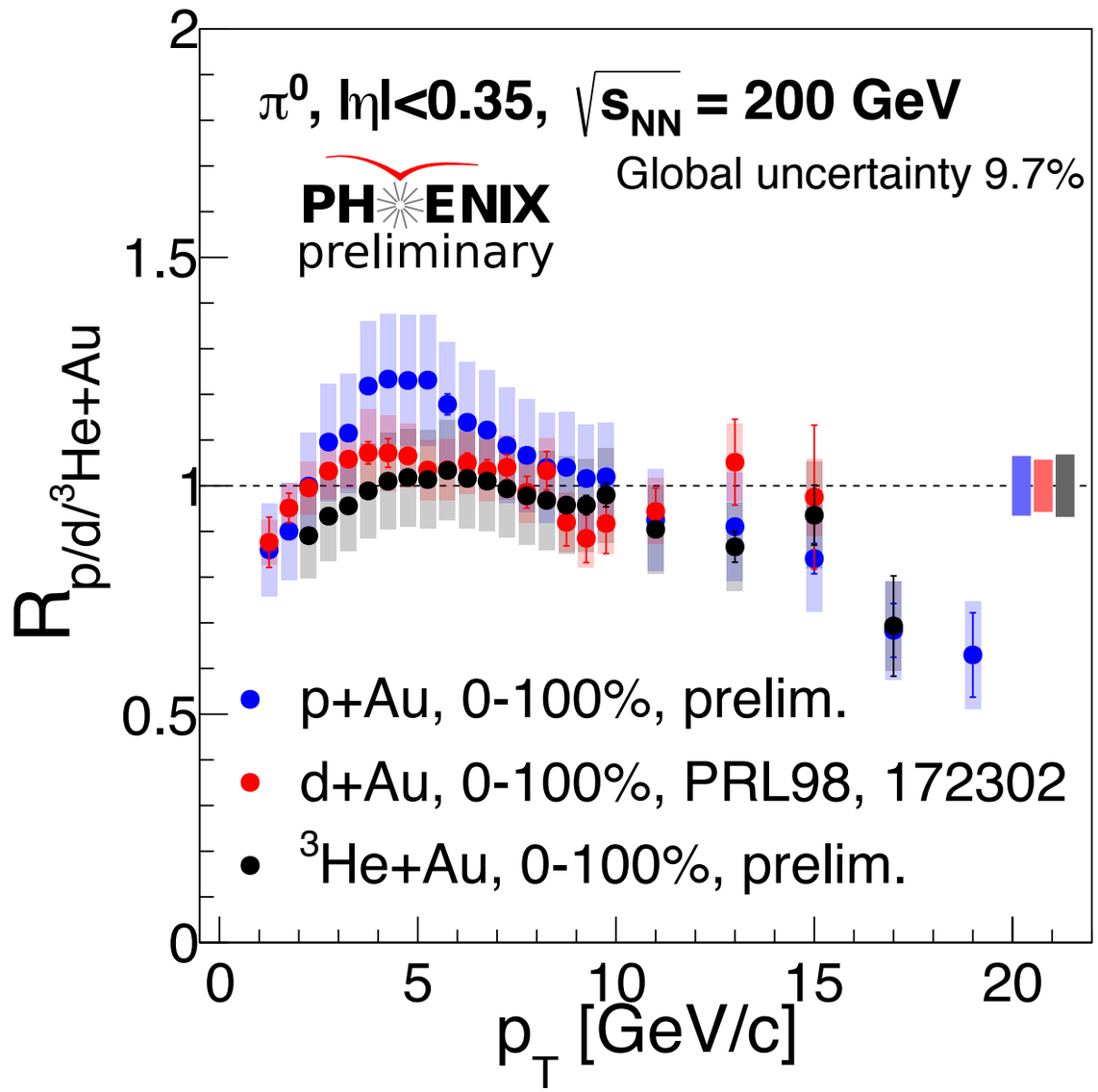
^{3}He+Au



Norbert Novitzky
6.4 - Wed 11:00

π^0 production in p/d/^{3}He+Au

Jets & high-p_T Hadrons



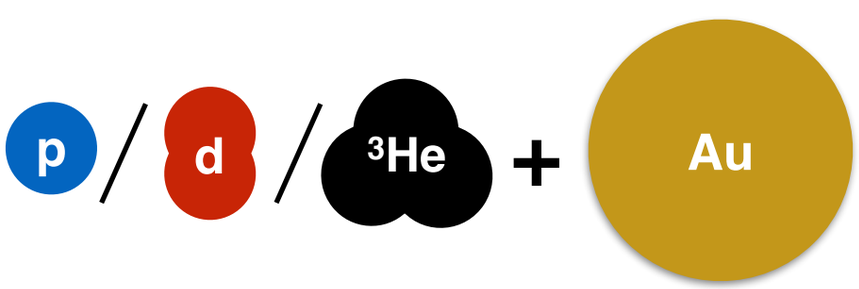
New π^0 modification in:

p+Au

d+Au

^{3}He+Au

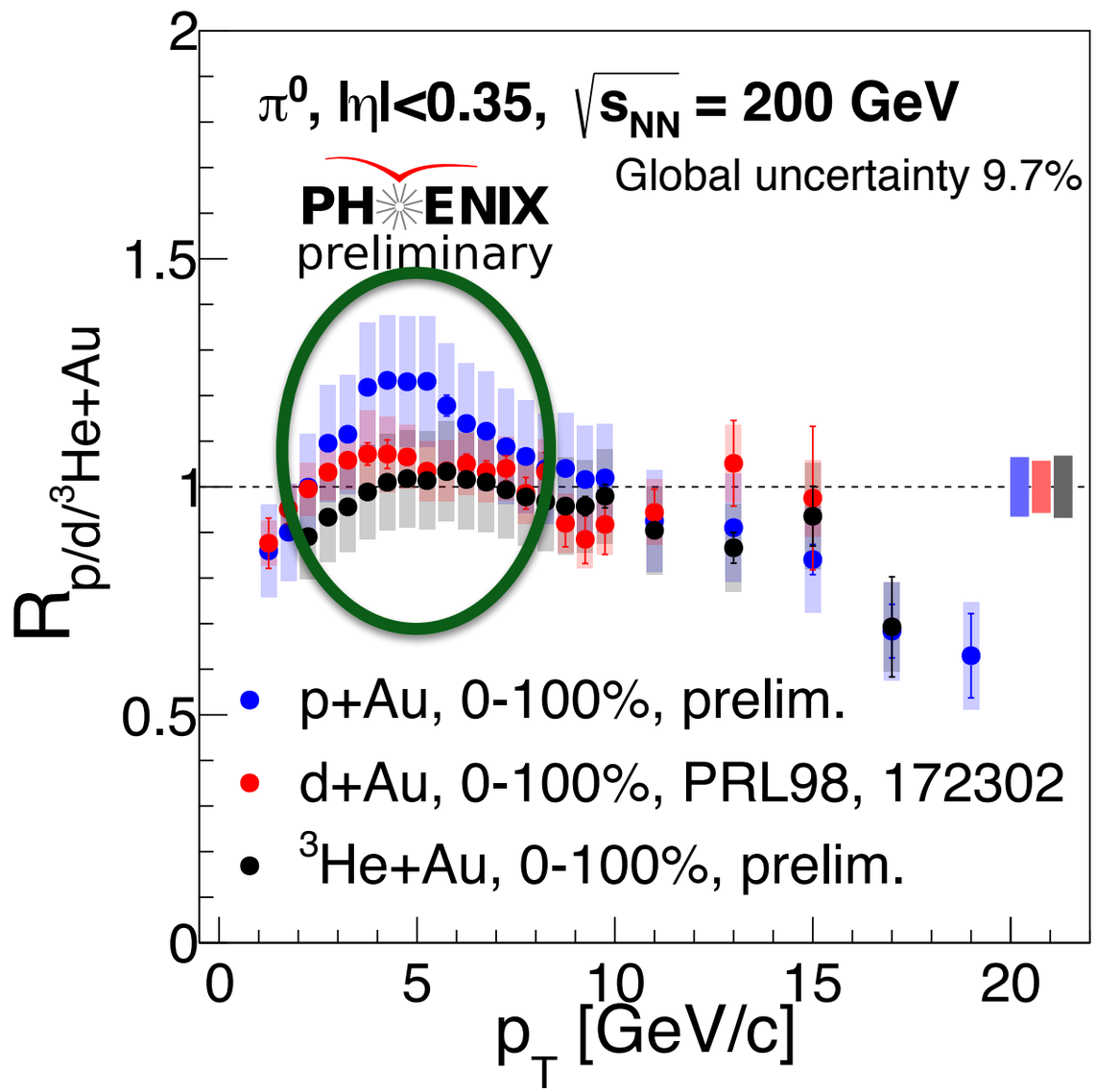
3 systems could help disentangle soft vs hard effects at low-p_T



Norbert Novitzky
6.4 - Wed 11:00

π^0 production in p/d/^{3}He+Au

Jets & high-p_T Hadrons



New π^0 modification in:

p+Au

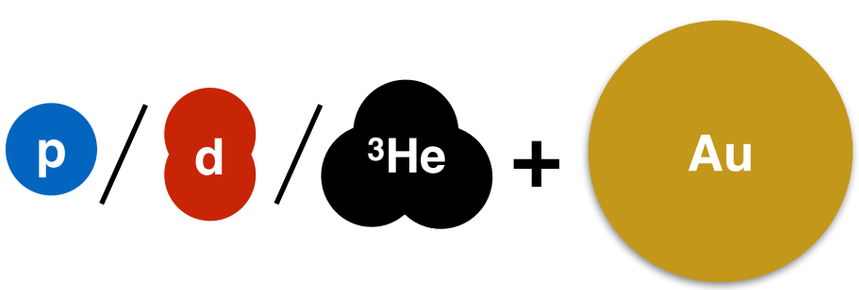
d+Au

^{3}He+Au

3 systems could help disentangle soft vs hard effects at low-p_T

at intermediate p_T

R_{p+Au} > R_{d+Au} > R^3_{He+Au}



Norbert Novitzky
6.4 - Wed 11:00

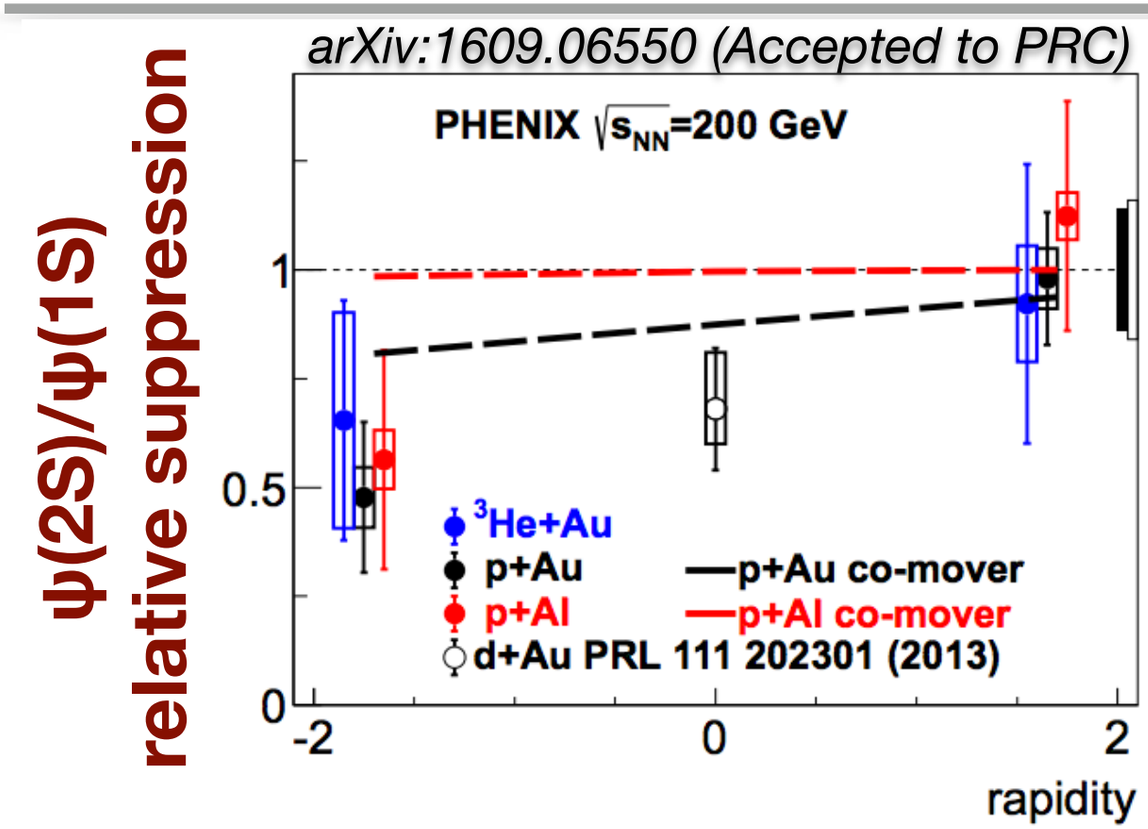
Heavy Flavor

PHENIX measurements of single electrons from charm and bottom decays at midrapidity in Au+Au collisions
***Kazuya Nagashima* — 7.4: Wed 15:20**

Nuclear Modification of B mesons in Collisions at 200 GeV measured through the B->J/psi decay by the PHENIX Experiment
***Cesar Luiz da Silva* — 8.4: Wed 16:30**

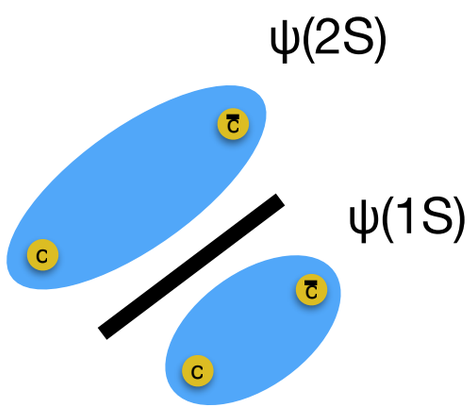
PHENIX measurements of open and hidden heavy flavor in p+p, p+Al, and p/d/3He+Au collisions across a wide range of rapidity
***Sanghoon Lim* — 8.4: Wed 17:10**

Quarkonia in Small Systems



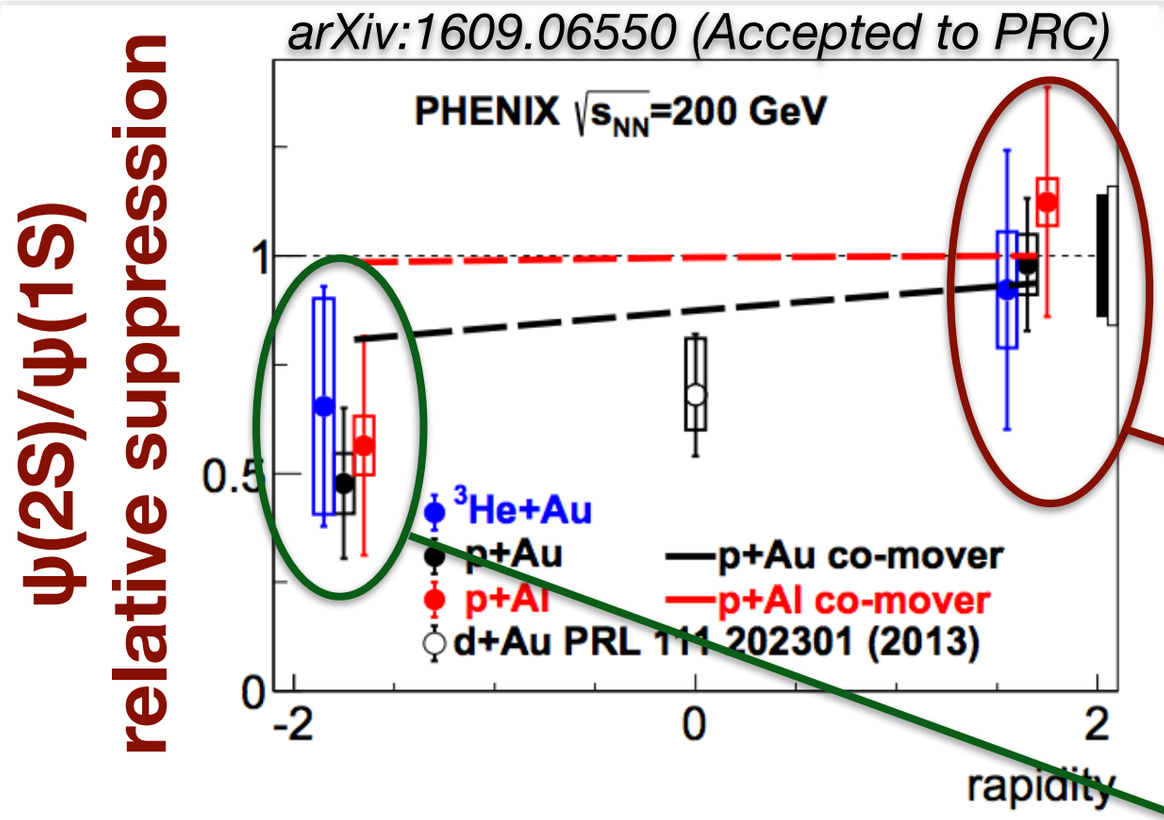
ψ(1S) suppressed in d+Au

p/^{3}He-going: similar suppression of ψ(2S) & ψ(1S)
A-going: stronger suppression of ψ(2S) than ψ(1S)



Sanghoon Lim
8.4 - Wed 17:10

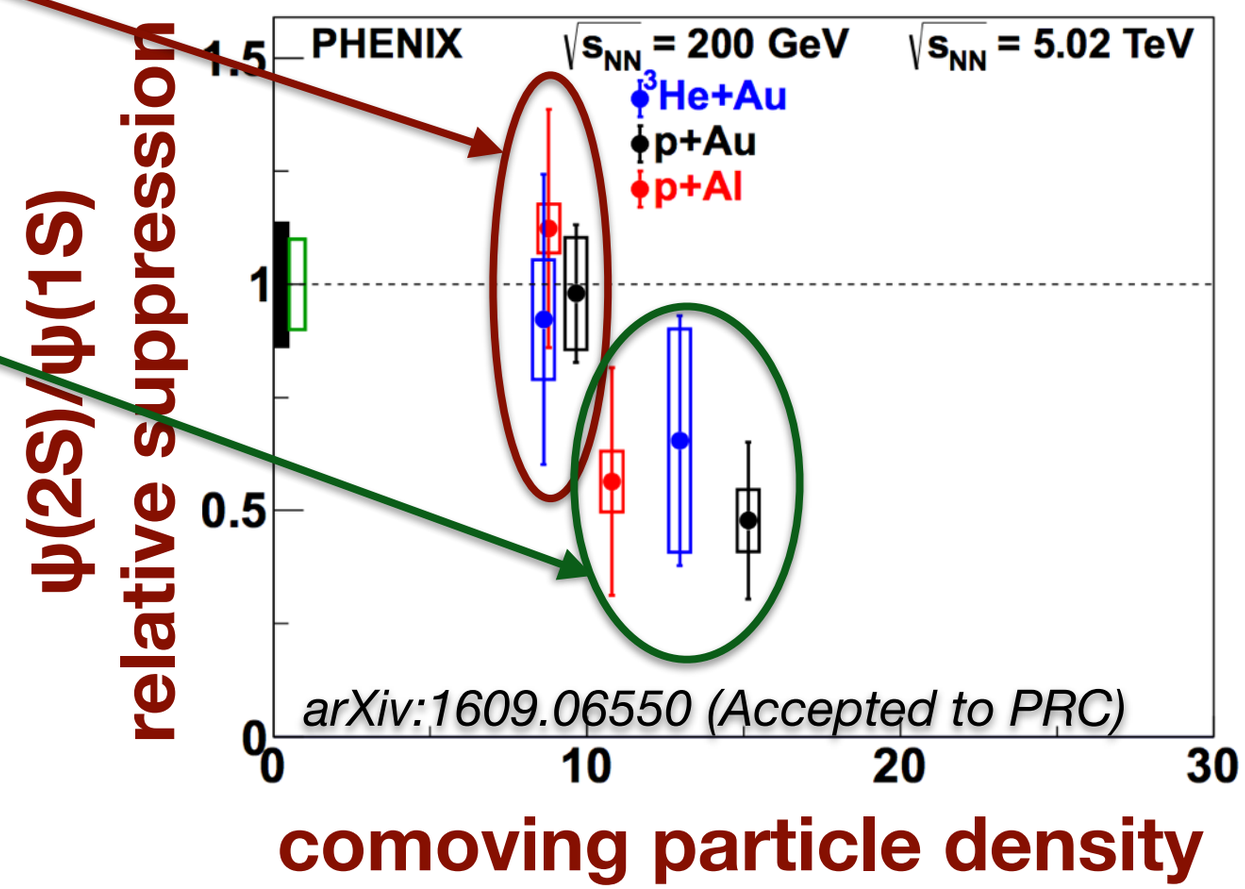
Quarkonia in Small Systems

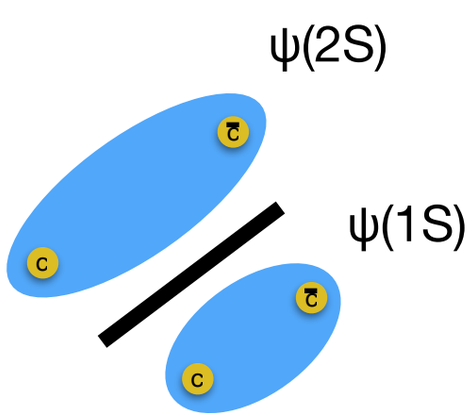


J/ψ suppressed in d+Au

p/^{3}He-going: similar ψ(2S) suppression

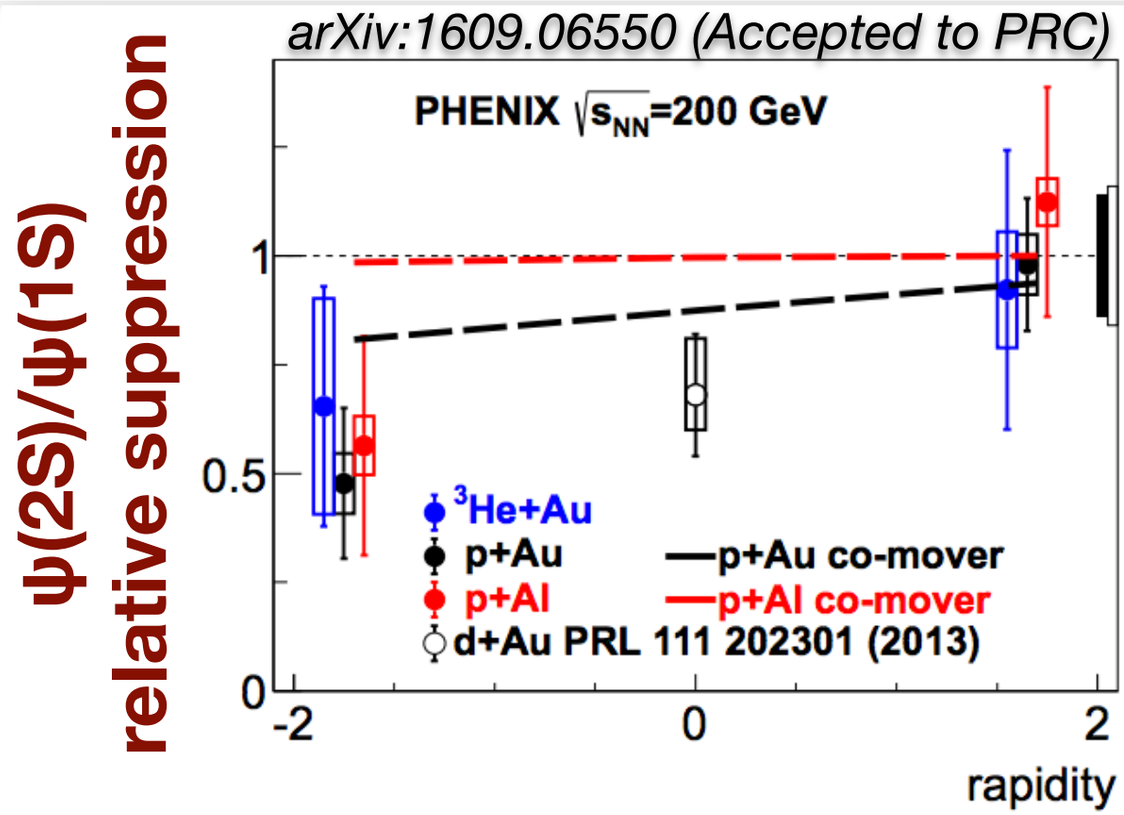
A-going: stronger ψ(2S) suppression





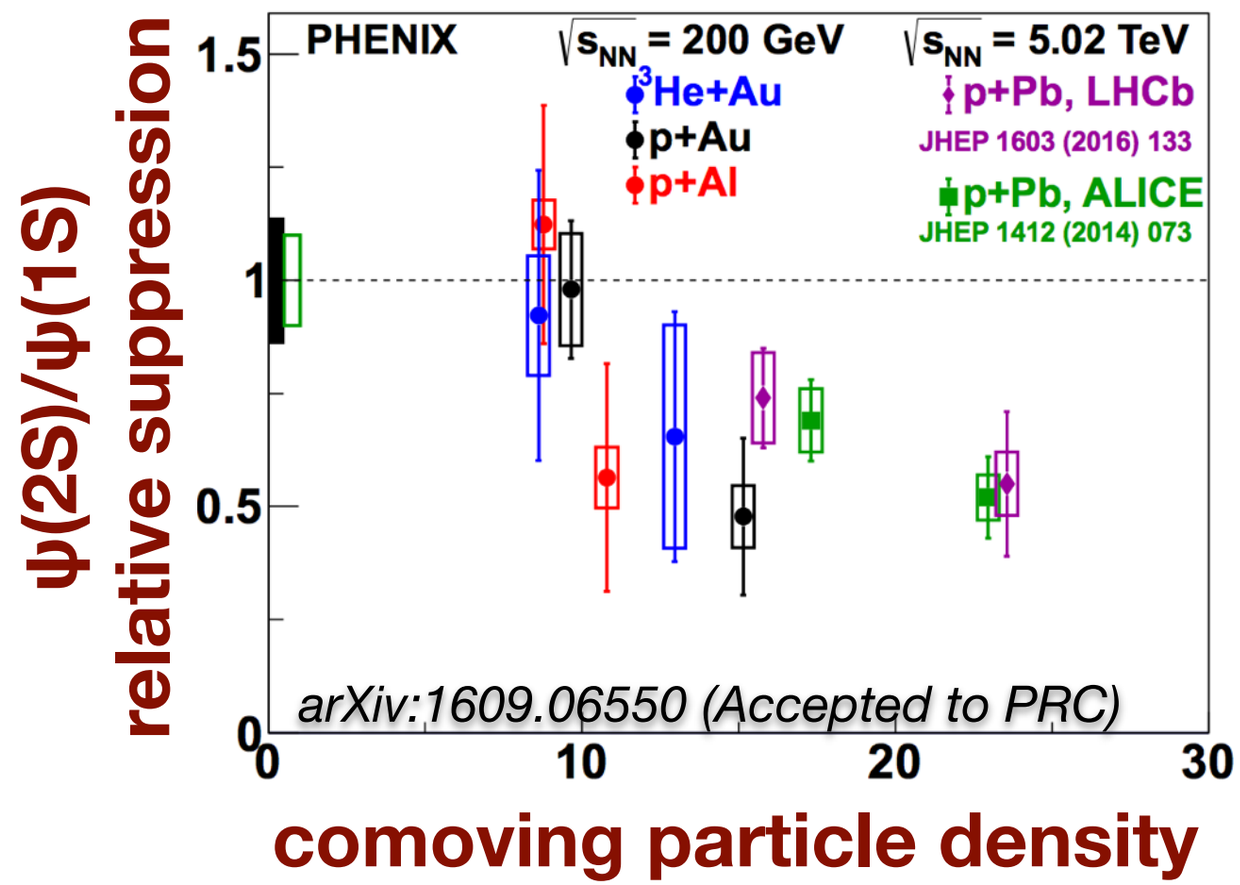
Sanghoon Lim
8.4 - Wed 17:10

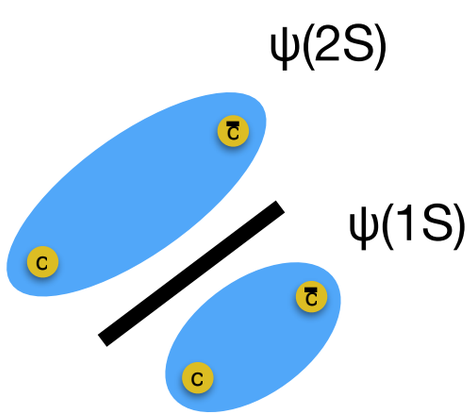
Quarkonia in Small Systems



J/ψ suppressed in d+Au

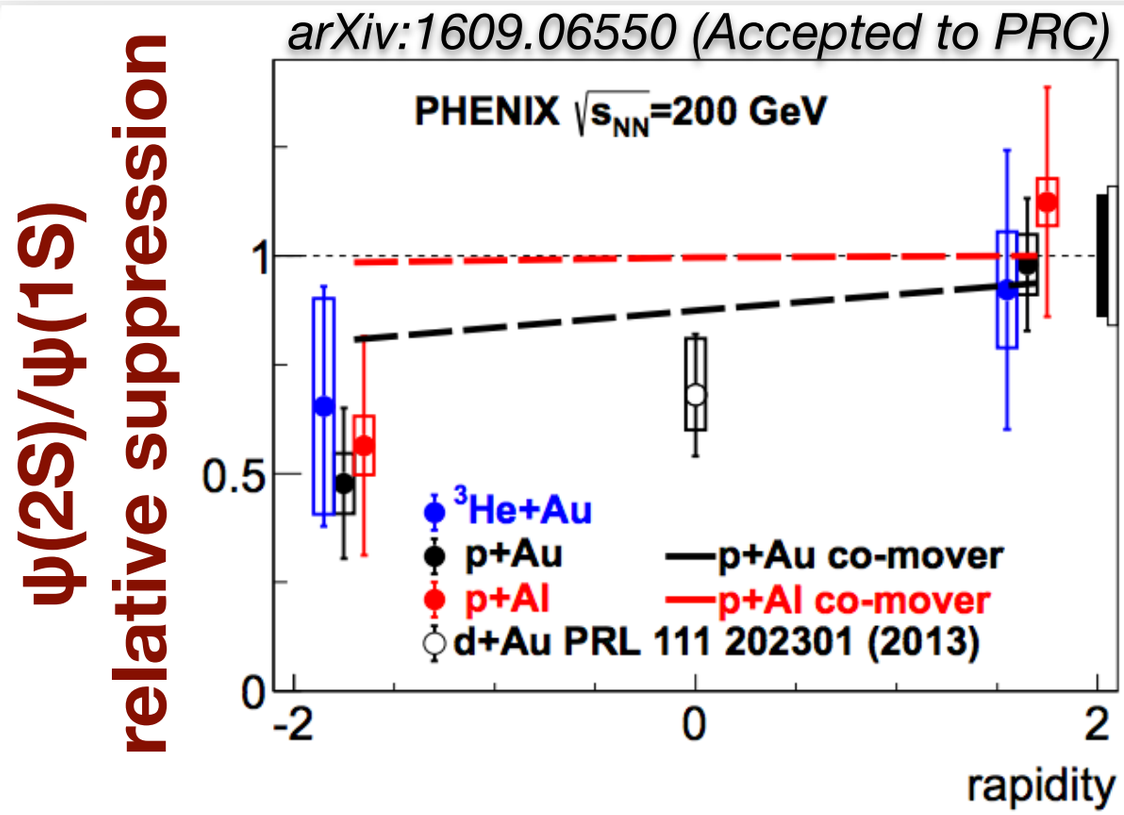
p/^{3}He-going: similar ψ(2S) suppression
A-going: stronger ψ(2S) suppression





Sanghoon Lim
8.4 - Wed 17:10

Quarkonia in Small Systems



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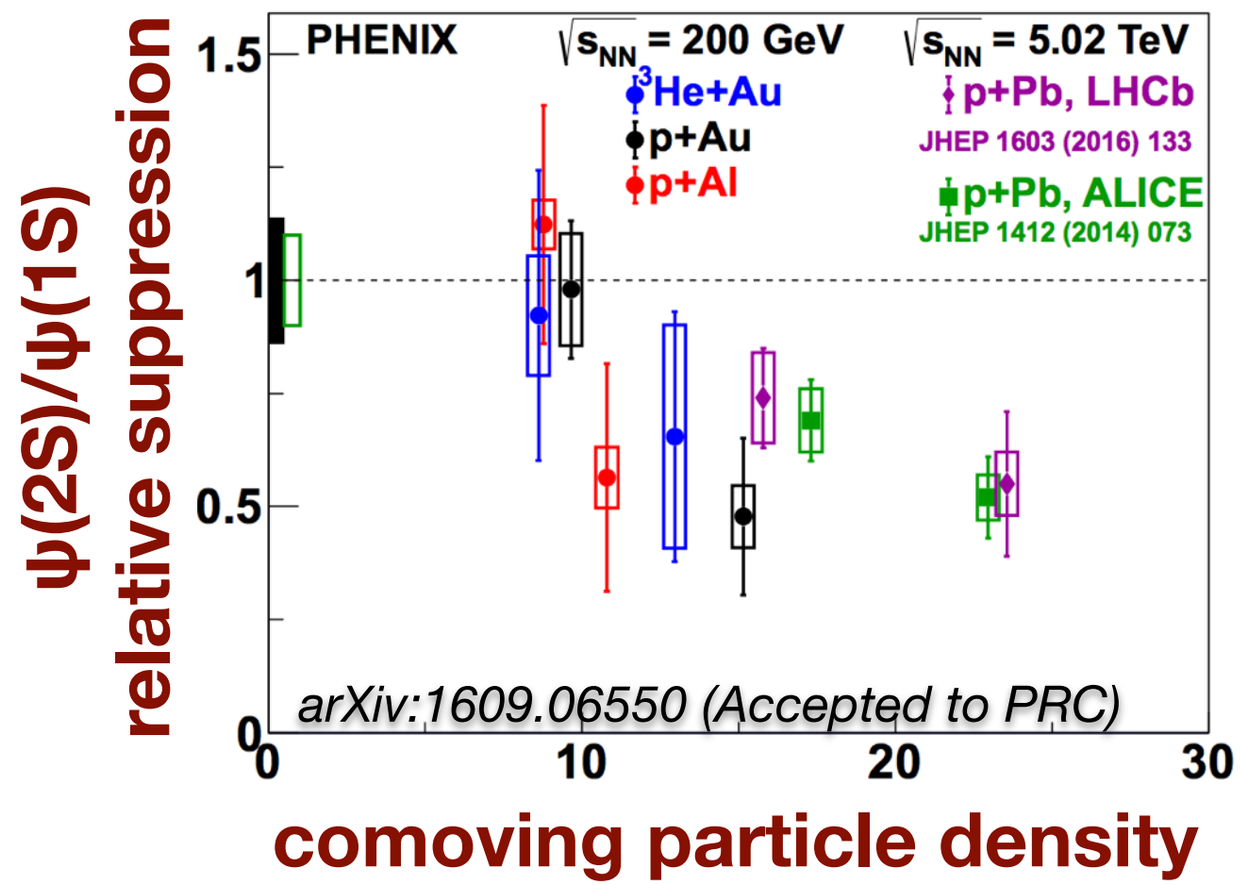
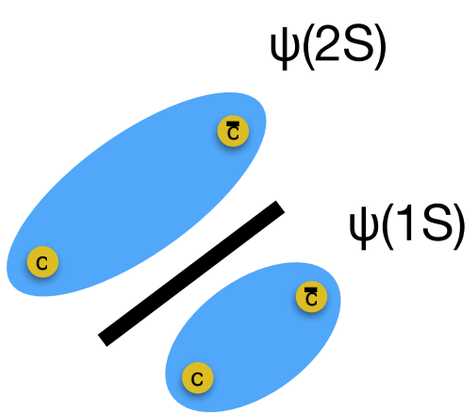


Consistent with the idea of breakup from final state interactions

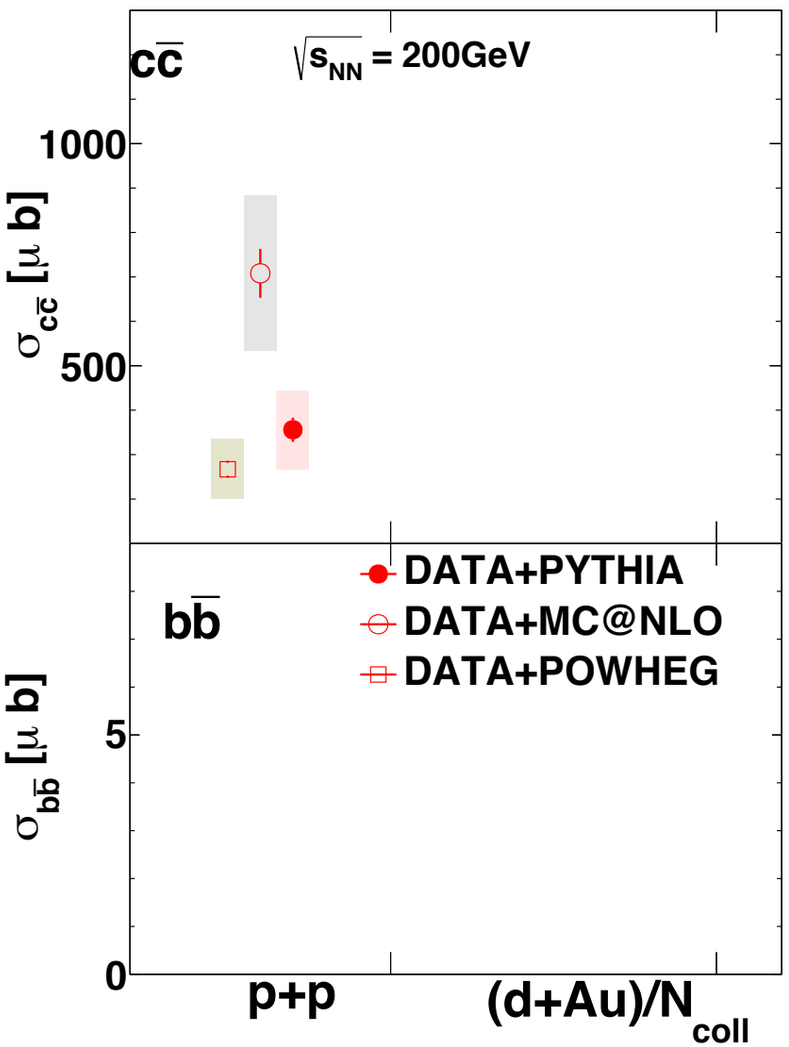


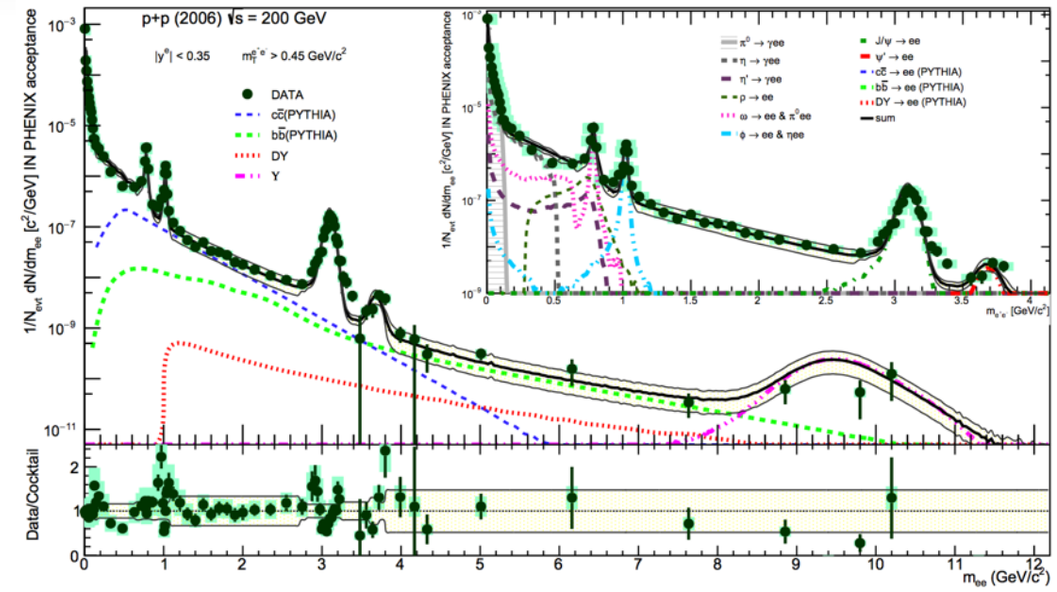
Sanghoon Lim
8.4 - Wed 17:10

Dielectrons in p+p and d+Au

New measurement of e^+e^- pairs from heavy flavor decays

arXiv:1702.01084





model assisted separation of **charm & bottom** using fits in **mass & p_T**

Sanghoon Lim
8.4 - Wed 17:10

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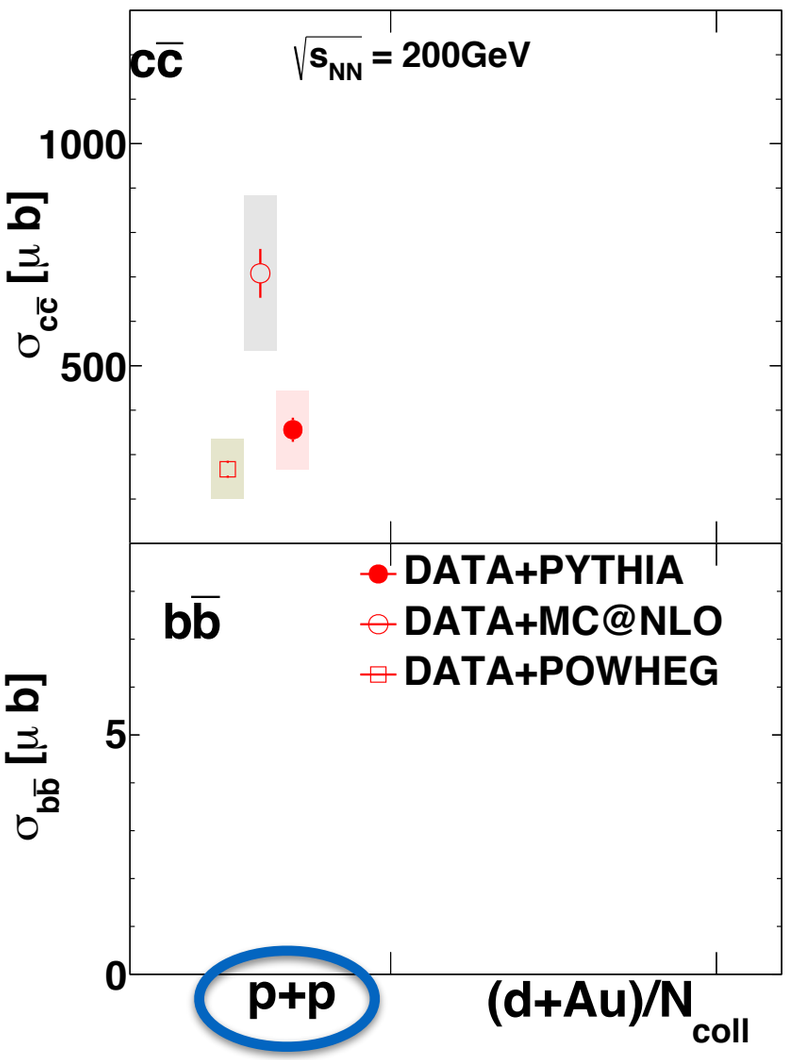

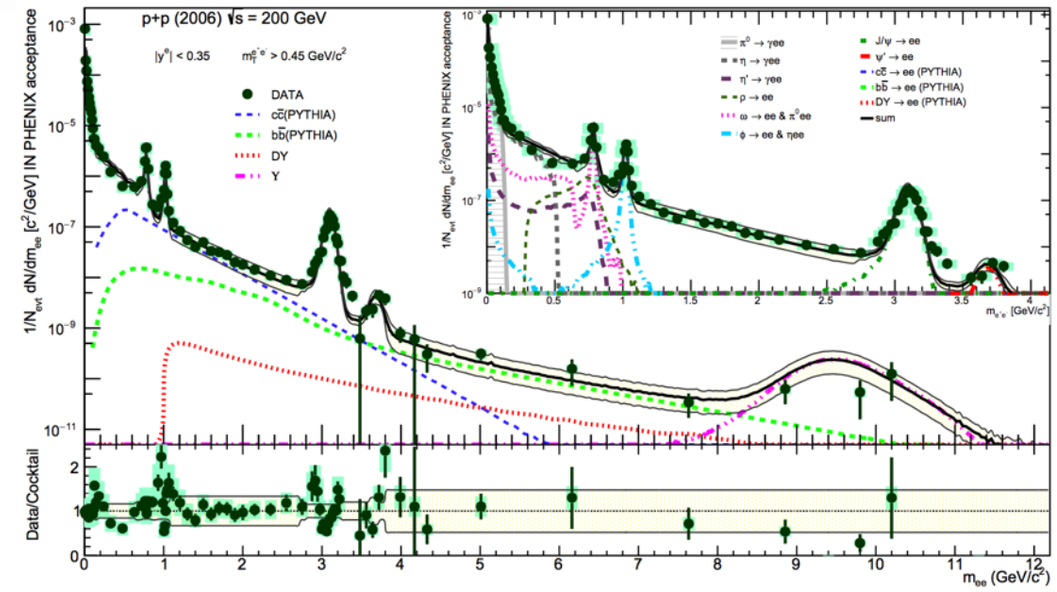

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Sanghoon Lim
8.4 - Wed 17:10

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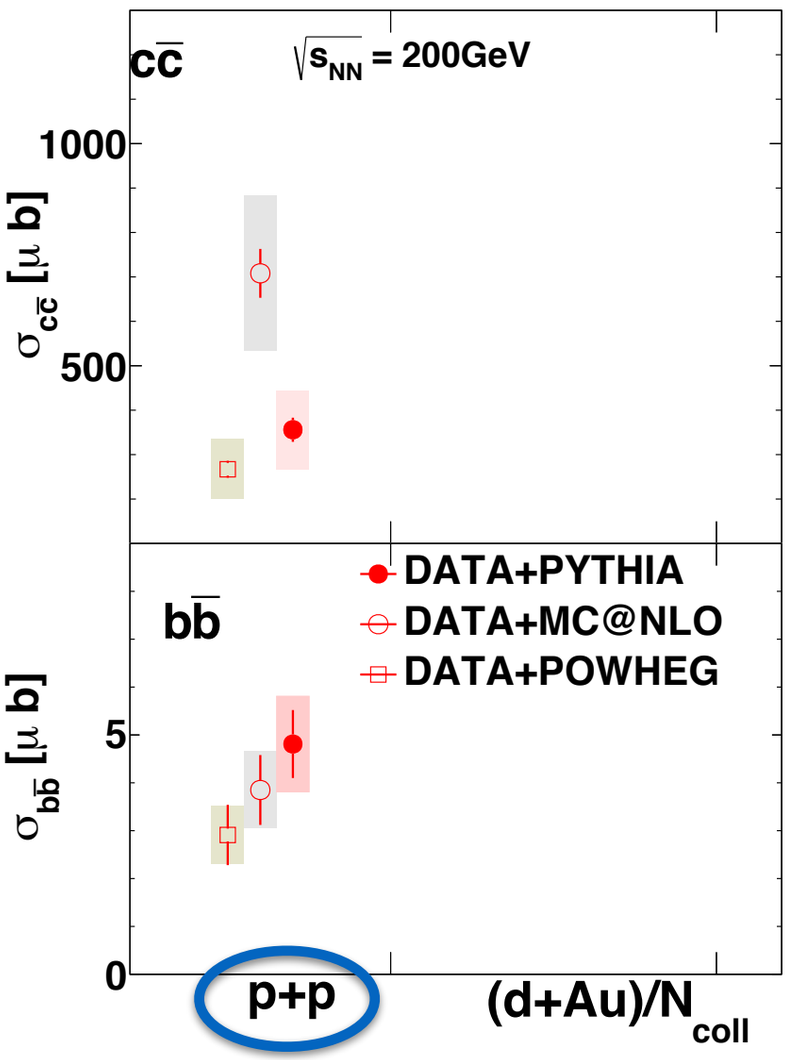

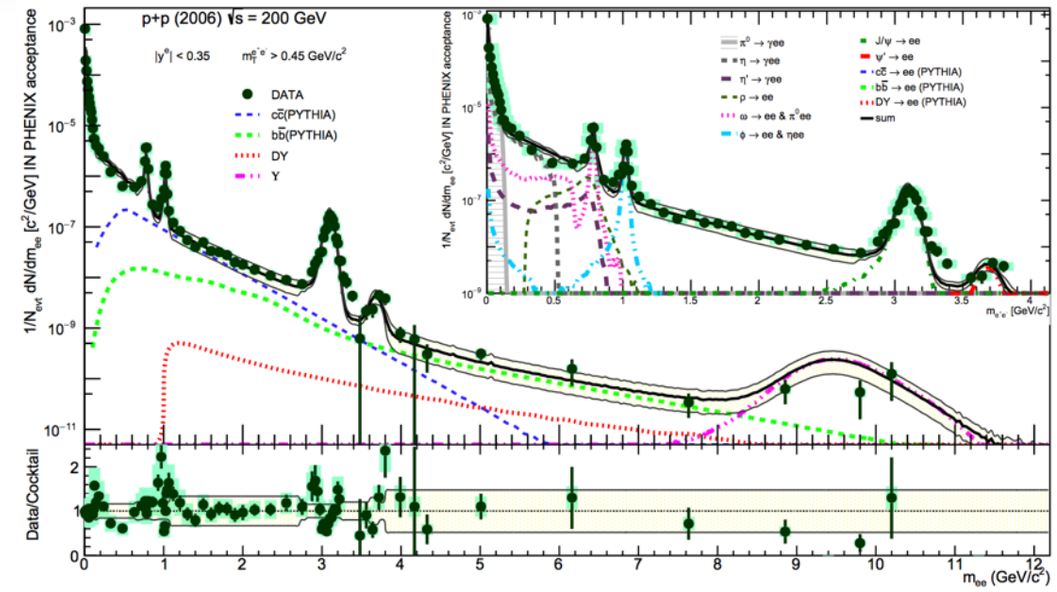

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Sanghoon Lim
8.4 - Wed 17:10

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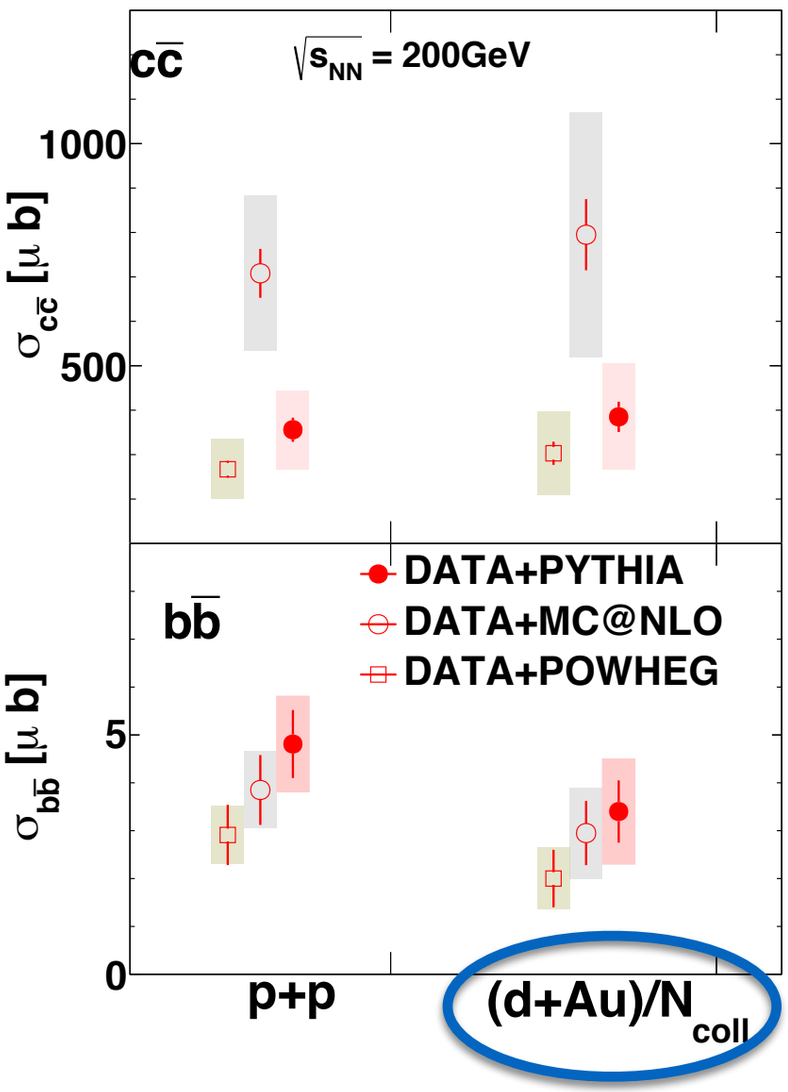

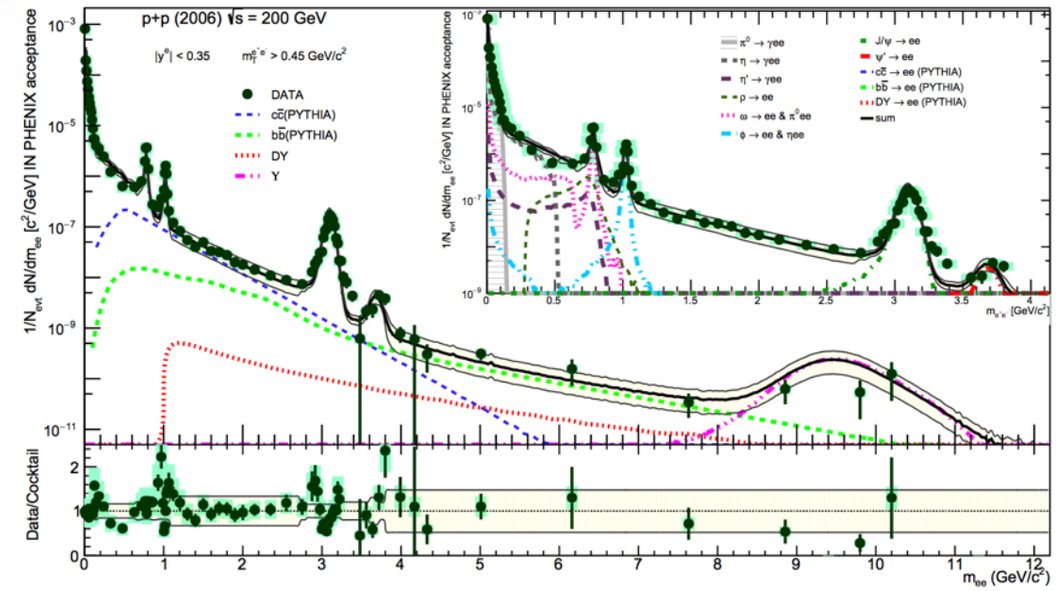

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Sanghoon Lim
8.4 - Wed 17:10

Dielectrons in p+p and d+Au

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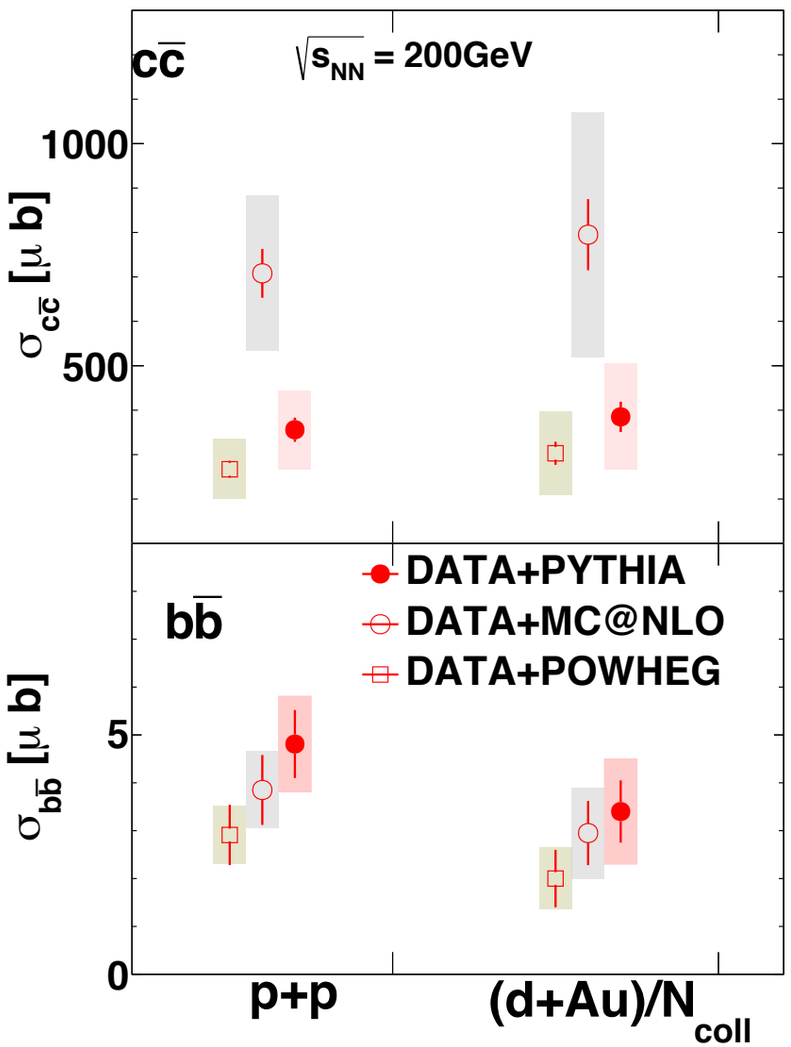
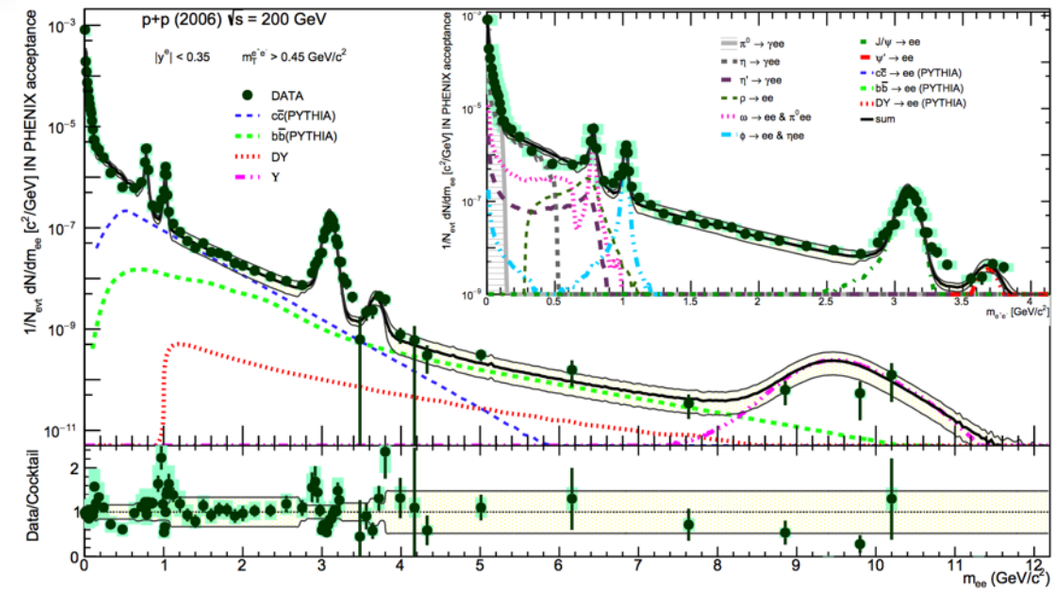
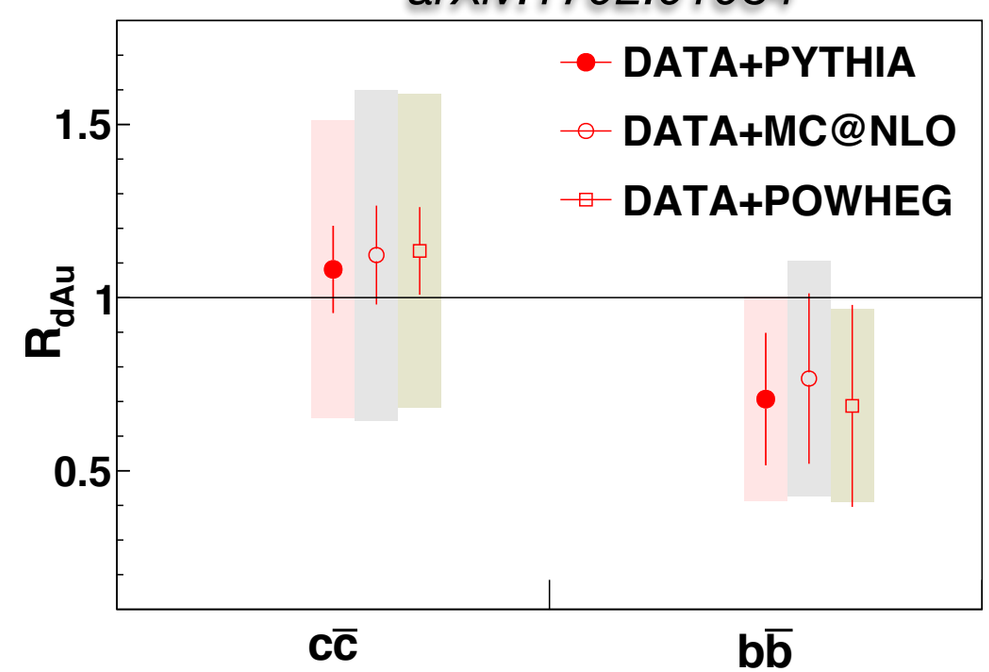




model assisted separation of **charm & bottom** using fits in **mass & p_T**

arXiv:1702.01084



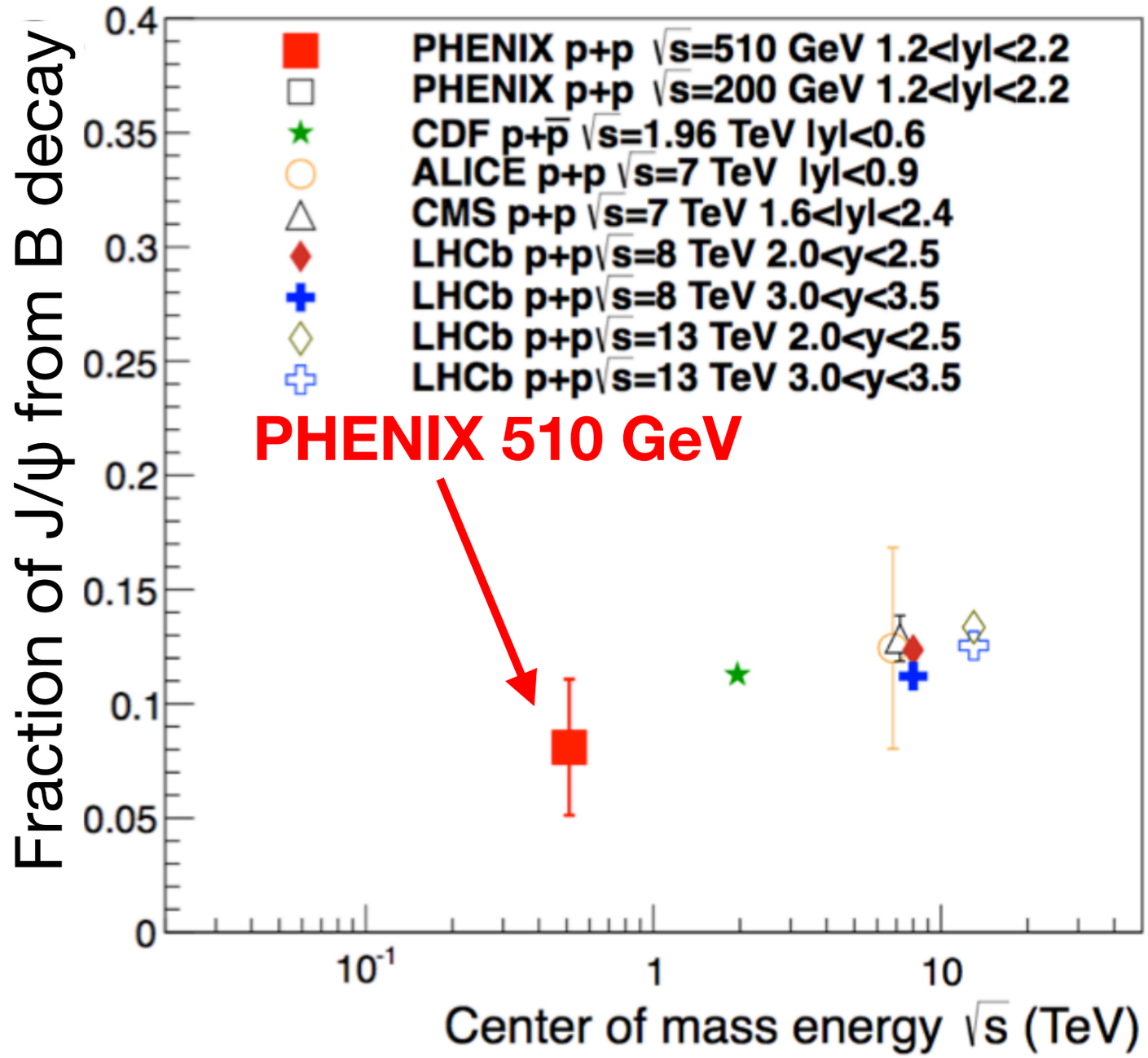
Models give consistent results of charm & bottom modification — consistent with binary scaling

Sanghoon Lim
8.4 - Wed 17:10

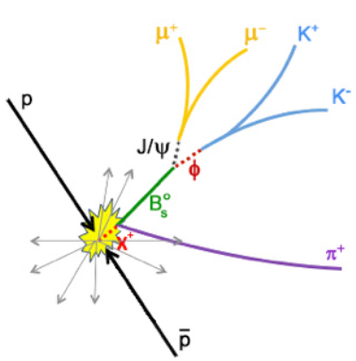
Fraction of J/ψ from B decays (p+p)

Measure J/ψ from B decay using Forward Silicon Vertex detector (FVTX)

p+p 510:
arXiv:1701.01342



B's measured down to $p_T = 0$!



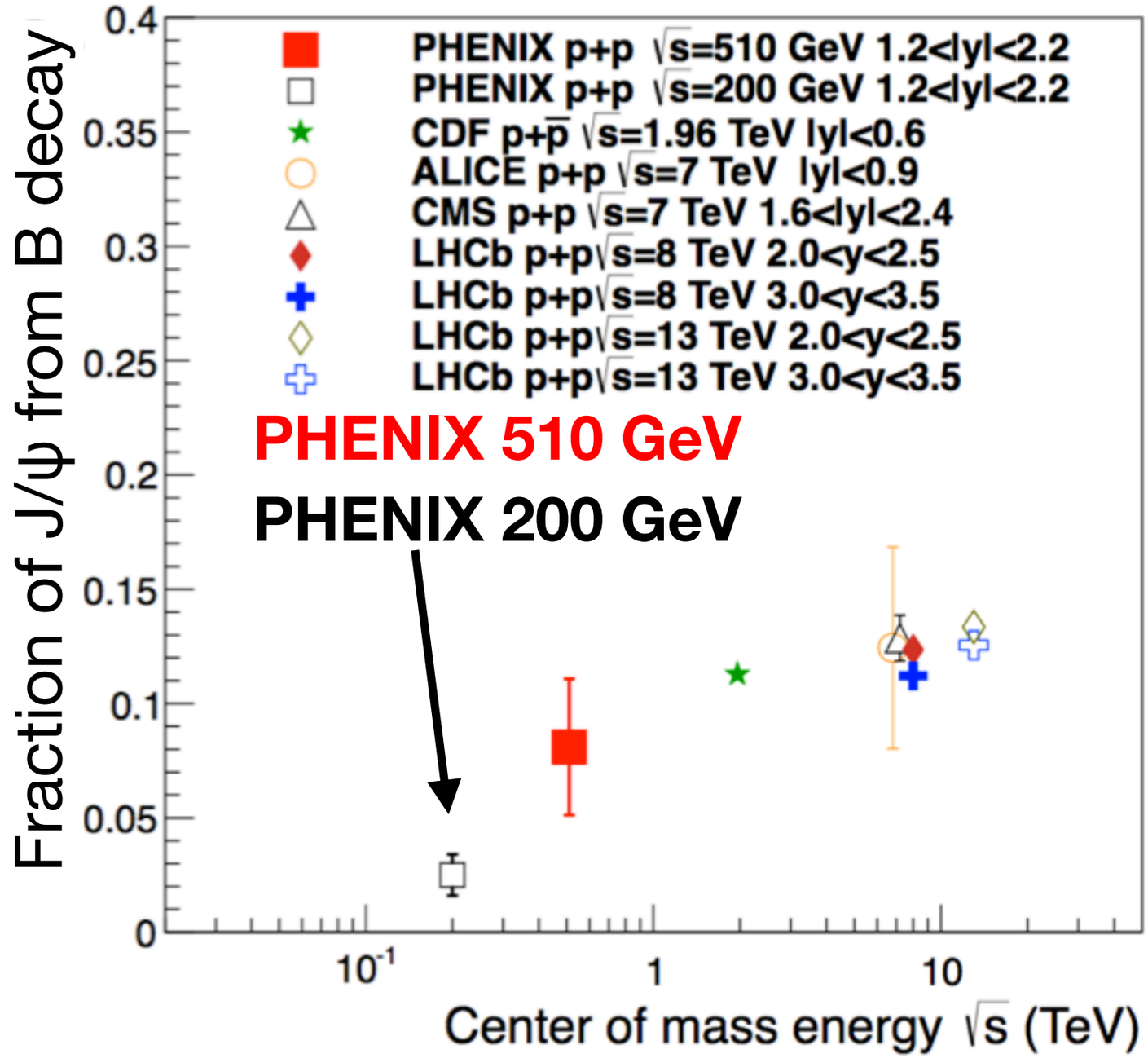
Cesar Luiz da Silva
8.4 - Wed 16:30

Fraction of J/ψ from B decays (p+p)

Measure J/ψ from B decay using Forward Silicon Vertex detector (FVTX)

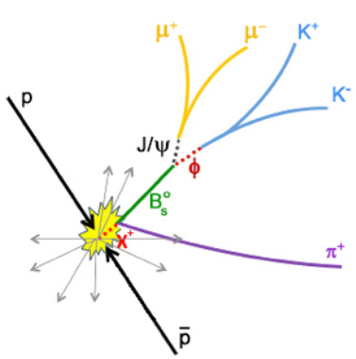
p+p 510: arXiv:1701.01342

p+p 200: arXiv:1702.01085



B's measured down to $p_T = 0$!

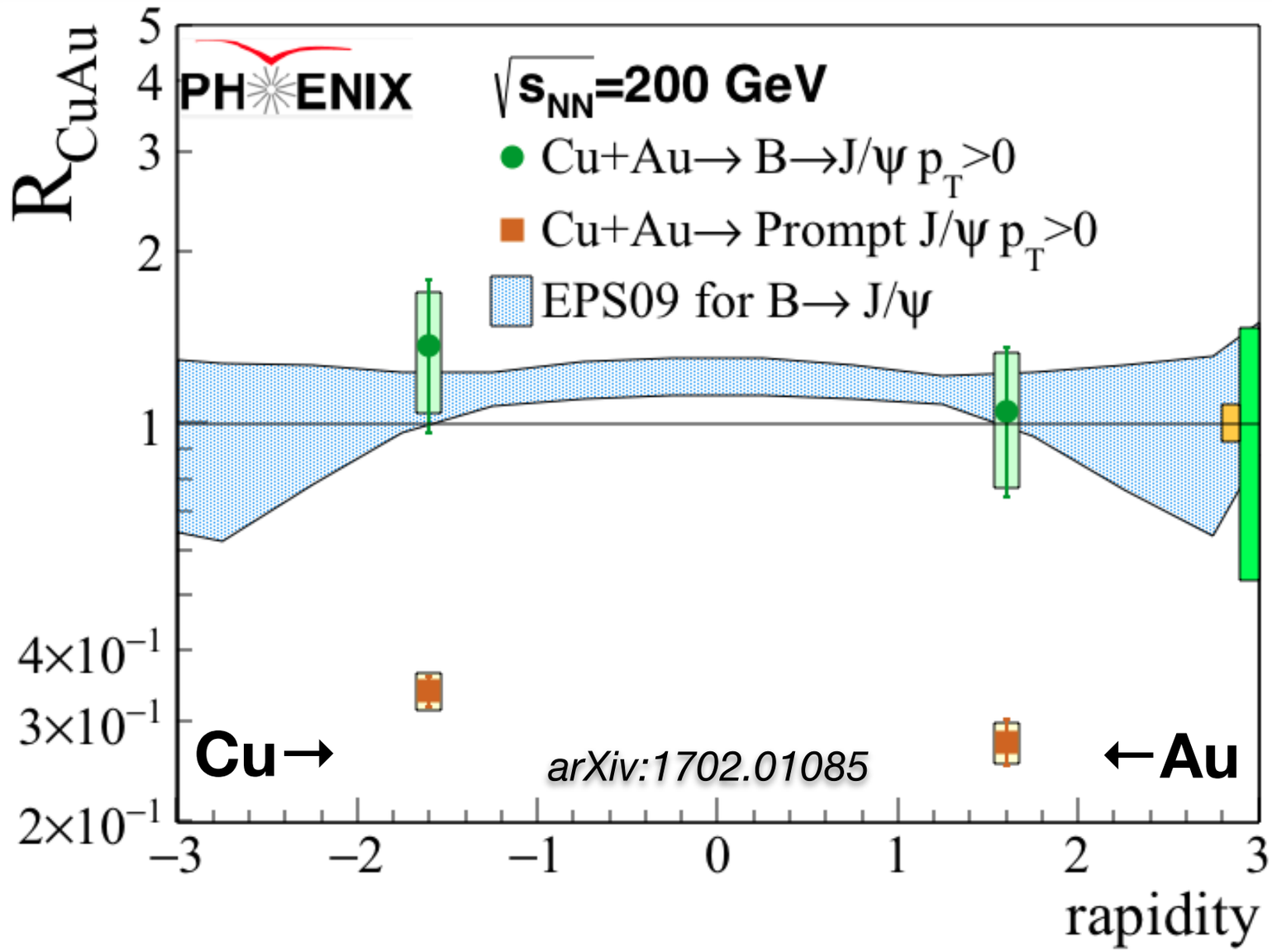
Now measured in p+p @ 200 GeV



Clear energy dependence

Cesar Luiz da Silva
8.4 - Wed 16:30

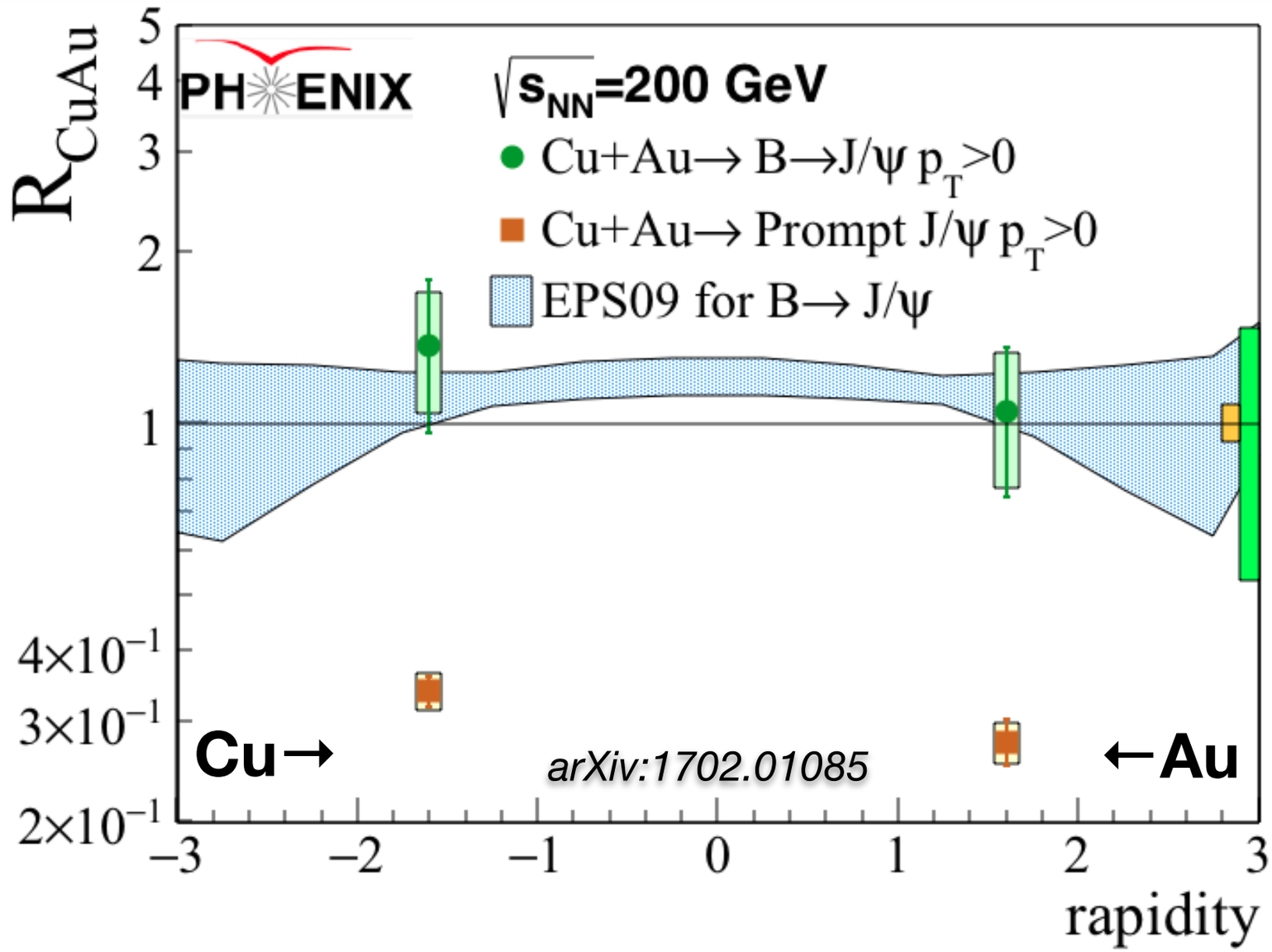
Fraction of J/ψ from B decays (Cu+Au)



Now using the measured B→J/ψ fraction in p+p @ 200 as the baseline!

Cesar Luiz da Silva
8.4 - Wed 16:30

Fraction of J/ψ from B decays (Cu+Au)

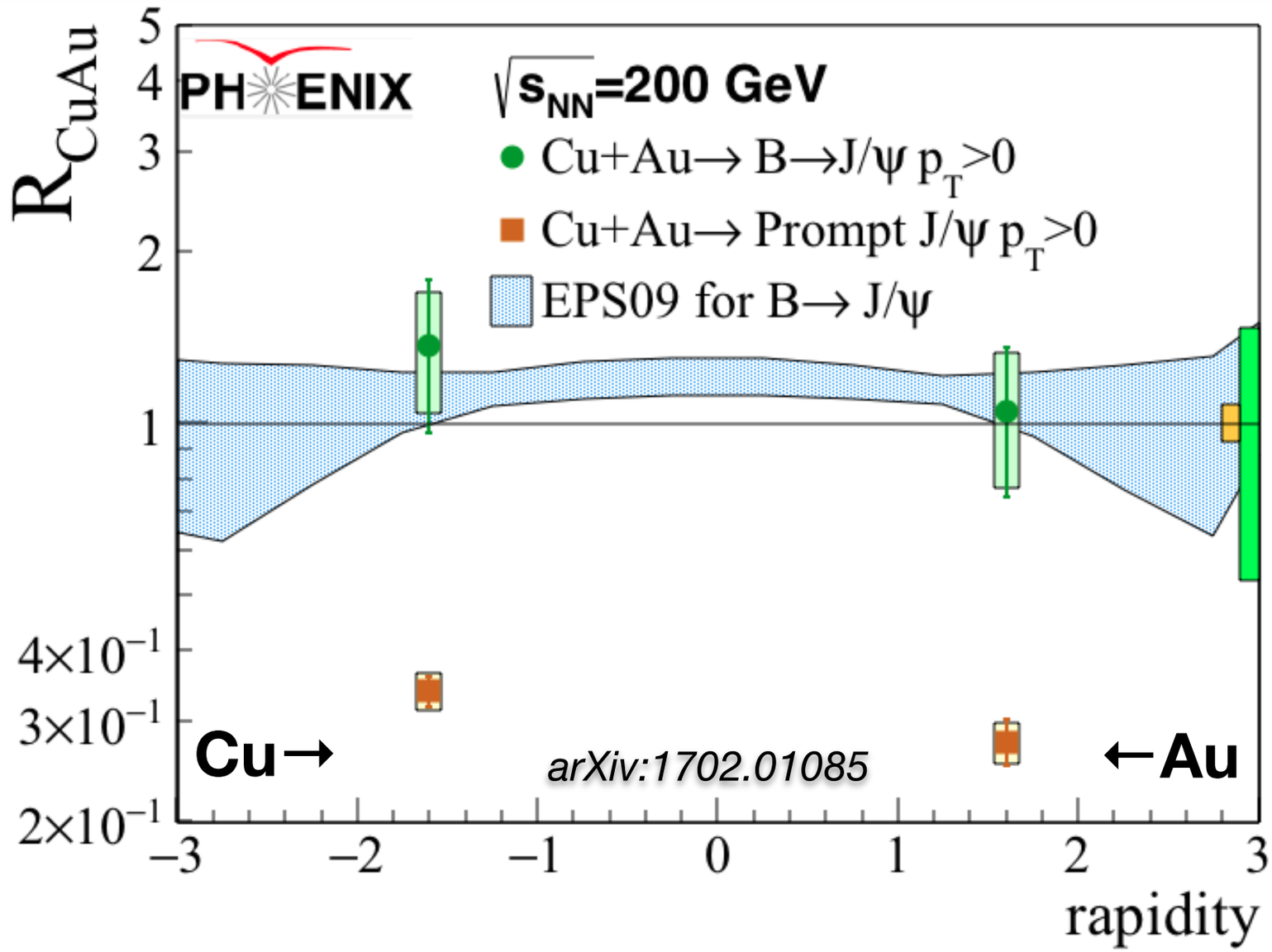


Now using the measured B→J/ψ fraction in p+p @ 200 as the baseline!

Non-prompt J/ψ R_{CuAu} consistent with binary scaling and expectations from nPDF (EPS09) modification

Cesar Luiz da Silva
8.4 - Wed 16:30

Fraction of J/ψ from B decays (Cu+Au)



Now using the measured B→J/ψ fraction in p+p @ 200 as the baseline!

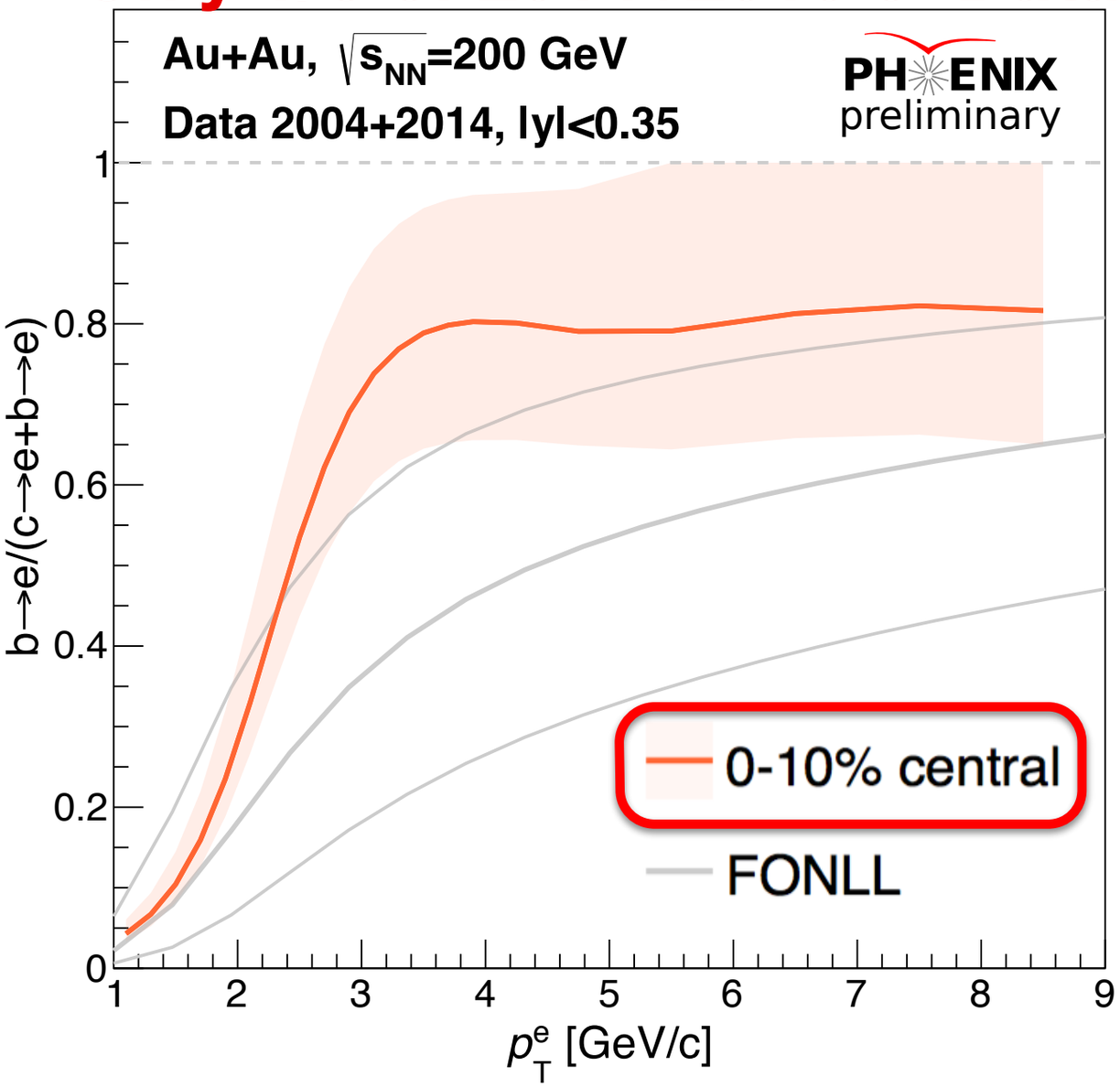
Non-prompt J/ψ R_{CuAu} consistent with binary scaling and expectations from nPDF (EPS09) modification

In contrast to highly suppressed prompt J/ψ

Cesar Luiz da Silva
8.4 - Wed 16:30

Separating Charm & Bottom

Only 1/8 of 2014+2016 e± Data!



Using previous "unfolding" method

(Phys.Rev. C93 (2016) no.3, 034904)

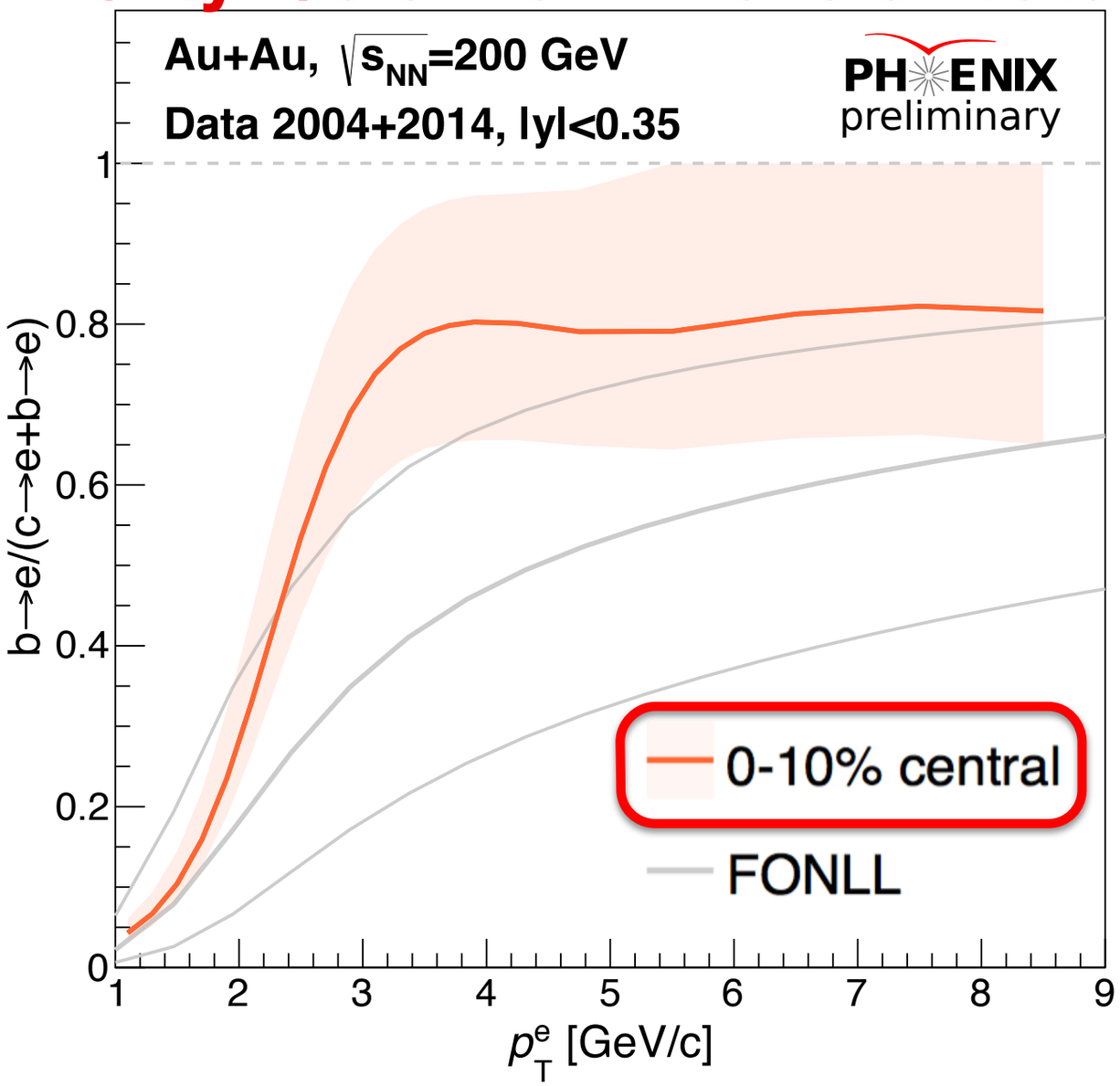
to look at central Au+Au collisions

Measuring charm/bottom separation in central Au+Au

Kazuya Nagashima
7.4 - Wed 15:20

Separating Charm & Bottom

Only 1/8 of 2014+2016 e± Data!



Measuring charm/bottom separation in central Au+Au

Using previous "unfolding" method

(Phys.Rev. C93 (2016) no.3, 034904)

to look at central Au+Au collisions

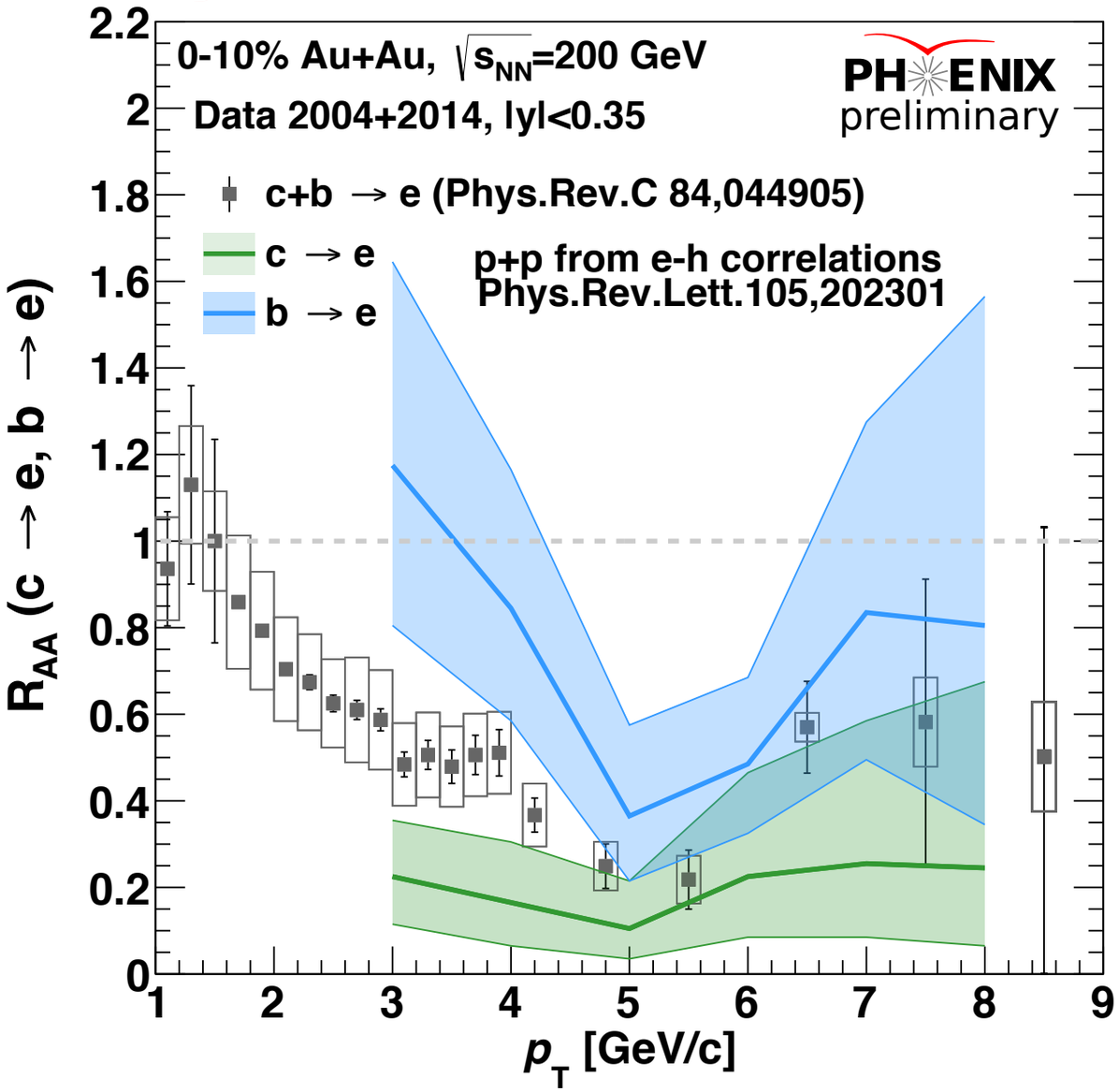
Au+Au b-fraction > FONLL p+p

Implies charm MORE suppressed than bottom

Kazuya Nagashima
7.4 - Wed 15:20

Separating Charm & Bottom

Only 1/8 of 2014+2016 e± Data!



Measuring charm/bottom separation in central Au+Au

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Clear separation of charm/bottom for p_T<5 GeV/c

R_{AA}(c→e) < R_{AA}(b→e)

Kazuya Nagashima
7.4 - Wed 15:20

Separating Charm & Bottom

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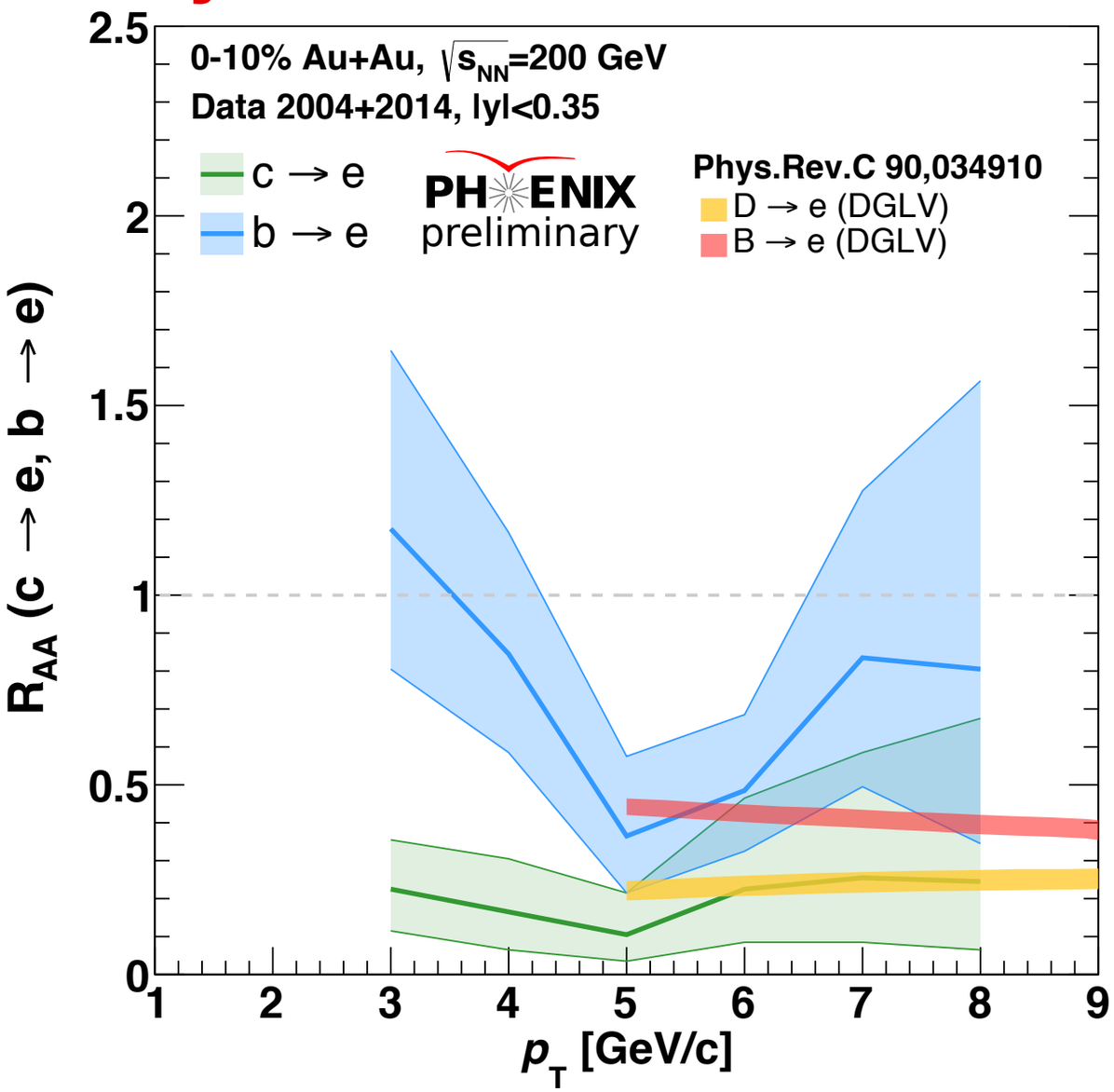


Measuring charm/bottom separation in central Au+Au

Using previous "unfolding" method

(Phys.Rev. C93 (2016) no.3, 034904)

to look at central Au+Au collisions

E-loss:

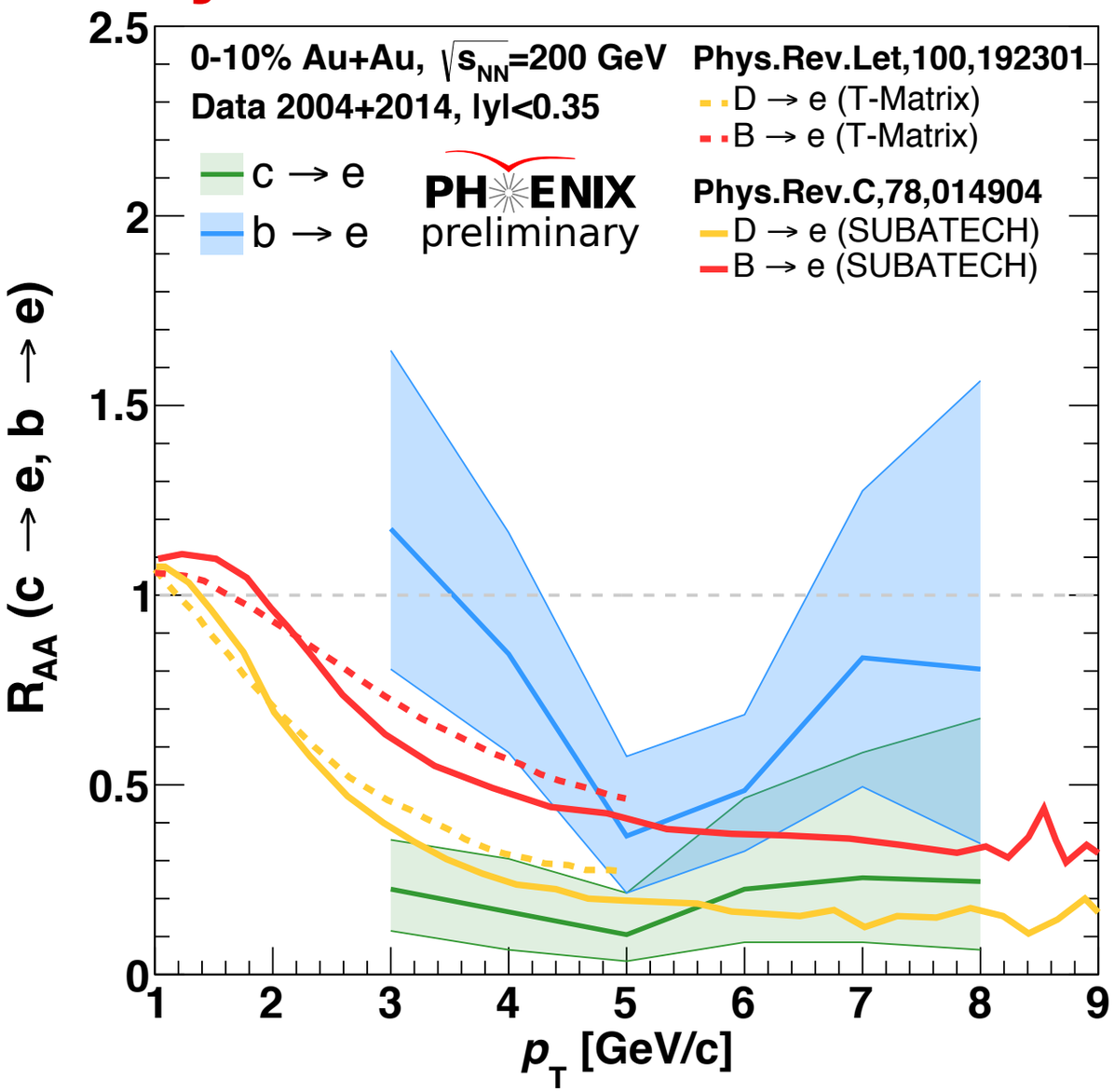
Reasonable agreement @ high-p_T

Need smaller uncertainties
x8 Au+Au data available!
p+p reference coming soon!

Kazuya Nagashima
7.4 - Wed 15:20

Separating Charm & Bottom

Only 1/8 of 2014+2016 e± Data!



Measuring charm/bottom separation in central Au+Au

Using previous "unfolding" method

(Phys.Rev. C93 (2016) no.3, 034904)

to look at central Au+Au collisions

Transport (Langevin):

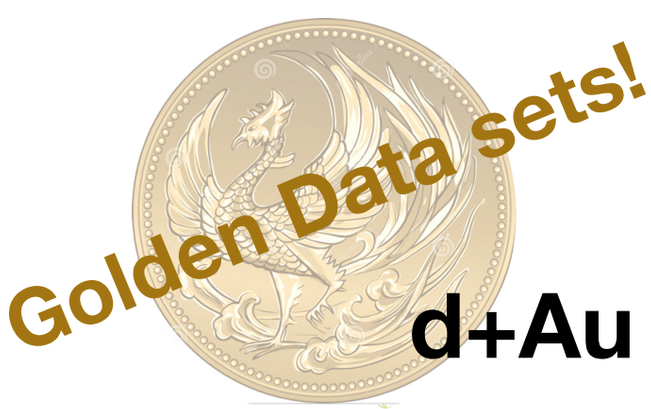
Reasonable agreement @ low-p_T

Theory needs large coupling!
More extreme separation?

Kazuya Nagashima
7.4 - Wed 15:20

The Bright Future of PHENIX

√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								✓	



Au+Au @ 200: 2014+2016 (~ 6 x 2011)

p+p @ 200: 2015

d+Au @ 200, 62.4, 39, 19.6: 2016

p+Au, ^{3}He+Au, p+Al @ 200: 2014-2016

PHENIX has lots of data left to analyze!

Thank You!

PHENIX Highlights at Quark Matter 2017

The PHENIX Collaboration will present comprehensive studies of QCD matter produced in Au+Au, Cu+Au, Cu+Cu, and U+U collisions, and in a variety of small systems with different initial geometries, in 12 talks and 45 posters. The highlights in the hard-probes sector include measurements of nuclear modifications of separated charm and beauty, jets, identified light-flavor hadrons, direct photons, and photon-hadron correlations. Collective dynamics is studied in detail in both large and small systems as a function of center-of-mass energy over a broad range of p_T and pseudorapidity; low p_T direct photons reveal thermal radiation from the produced systems.

Open Heavy Flavor

- R_{AA} of b→e and c→e in Au+Au collisions at 200 GeV and energy loss of heavy quarks: heavy quark propagation in QGP at RHIC.
  Session 7.4 Feb 8 (Wed) 15:20
- R_{AA} of B in Cu+Au at 200 GeV via measurements of $B \to J/\psi$ in p+p and Cu+Au collisions: B suppression at low p_T at RHIC.
  Session 8.4 Feb 8 (Wed) 16:30
- J/ψ, $\psi(2S)$, and open heavy flavor in $p+p$, p+Al, $p/d/^3$He+Au at 200 GeV: evolution of open heavy flavor and quarkonia dynamics.
  Session 8.4 Feb 8 (Wed) 17:10

Jets and High p_T hadrons

- Direct photon-hadron correlations in p+p, d+Au, and Au+Au collisions at 200 GeV: revealing jet modification.
  Session 1.4 Feb 7 (Tue) 8:30
- High p_T π^0 and η in Cu+Au and U+U collisions at 200 GeV: study of parton energy loss.
  Session 6.4 Feb 8 (Wed) 10:40
- High p_T π^0 in $p+p$, $p+A$, d+Au, and ^{3}He+Au at 200 GeV in $|y| < 0.35$ and π^0 in d+Au for $3.1 < \eta < 3.8$: probing nuclear and projectile wave-function and energy loss.
  Session 6.4 Feb 8 (Wed) 11:00

Electromagnetic Probes

- Low p_T direct photons in Au+Au at 39, 62, and 200 GeV, as well as in smaller collision systems: revealing the sources of thermal photons.
  Session 2.3 Feb 7 (Tue) 11:00

Collective Dynamics

- v_2 of charged hadrons over six units of pseudorapidity in d+Au collisions at 200, 62.4, 39, and 20 GeV: longitudinal dynamics in small systems.
  Session 2.2 Feb 7 (Tue) 10:40
- $v_2(p_T)$ and $v_3(p_T)$ of charged hadrons at mid-rapidity in high-multiplicity d+Au collisions at 200, 62.4, 39, and 20 GeV: onset of collectivity in small systems.
  Session 2.2 Feb 7 (Tue) 11:40
- $v_2(p_T)$ and $v_3(p_T)$ of charged and identified hadrons in p+Al, p+Au, d+Au, and ^{3}He+Au at 200 GeV: geometry-controlled systematic study of flow in small systems.
  Session 6.1 Feb 8 (Wed) 11:20
- $v_n(p_T)$ of charged hadrons in a wide range of p_T (up to 10 GeV/c) in Au+Au beam-energy scan from 39 to 200 GeV: role of collective flow, initial-state fluctuations, and interplay between soft and hard processes.
  Session 7.3 Feb 8 (Wed) 15:00

Posters

- **A14. Distance of Closest Approach and Unfolding Study to Infer Bottom and Charm Quark Production in p+p Collisions at sqrts = 200 GeV in the PHENIX experiment —** *Timothy Rinn*
- **B11. Measurement of the Invariant Yield of Electrons from the Semileptonic Decay of Heavy Flavor Mesons in p+p Collisions at sqrt_{s} = 200 GeV in the PHENIX Experiment —** *Javier Orjuela Koop*
- **D02. Phi Meson Production in Small Systems at Forward Rapidity with the PHENIX Detector at RHIC —** *Murad Sarsour*
- **F03. Low pT direct photon measurement in Au+Au at 200GeV with PHENIX —** *Wenqing Fan*
- **F04. Measurement of J/ψ Meson Polarization at Forward Rapidity in p+p Collisions at s√=510GeV by the PHENIX Experiment at RHIC —** *Alexandre Lebedev*
- **F15. Photon and neutral pion separation in the PHENIX MPC-EX detector —** *Jaehyeon Do*
- **G05. A Systematic Study of Neutral Pion Production in Small and Asymmetric Systems at PHENIX —** *Nicole Apadula*
- **I07. Isolated Photon - Hadron Correlations in Heavy Ion Collisions from PHENIX —** *Tyler Danley*
- **I13. PHENIX MPC-EX Detector Performance in Run 16 —** *Milap Patel*
- **I18. Inclusive muon yield from charm and bottom quark production at forward rapidity in p+p and p+Au collisions at sqrt(s) = 200 GeV in the PHENIX Detector —** *Jeongsu Bok*
- **J02. Single-Track π0 Reconstruction with the MPC-EX at PHENIX —** *Jason Bryslawskyj*
- **J08. Analysis status on low-momentum direct-photons in Cu+Cu collisions at sNN = 200 GeV at PHENIX —** *Tomoya Hoshino*
- **J17. PHENIX results on identified pion,kaon,proton and anti-proton transverse momentum distributions in p+Au collisions at sqrt(s_nn) = 200 GeV —** *Weizhuang Peng*
- **K03. Forward/Backward asymmetry of v_n in Cu+Au at RHIC-PHENIX —** *Hiroshi Nakagomi*
- **K12. PHENIX measurements of the pseudorapidity dependence of charged particle multiplicity in d+Au collisions at 200, 62.4, 39, and 19.6 GeV —** *Kurt Keys Hill*
- **L06. Studying heavy flavor production via unlike-sign and like-sign di-muon mass spectra in p+p collisions at √sNN = 200 GeV in the PHENIX Experiment —** *Yue Hang Leung*
- **L07. Collision energy dependent Levy analysis of Bose-Einstein correlation functions in Au+Au collisions at PHENIX —** *Dániel Kincses*
- **L08. Study of Jet-related Two-Particle Correlations in Highly Asymmetric Collision Systems with PHENIX —** *Abinash Pun Pun*
- **L11. Study of b-bbar production in p+p collisions at √s = 510 GeV in the PHENIX experiment at RHIC —** *Tristan Haseler*
- **L18. Low Momentum Direct Photons in Au+Au collisions at 39 GeV and 62.4 GeV measured by the PHENIX Experiment at RHIC —** *Vladimir Khachatryan*
- **N03. Forward photons in d+Au collisions at 200 GeV in the PHENIX Experiment —** *Carlos Eugenio Perez Lara*
- **N06. PHENIX results on three particle Bose-Einstein correlations in sNN = 200 GeV Au+Au collisions —** *Attila Bagoly*

Talks

- **Collective Dynamics**
  - **PHENIX results on longitudinal flow dynamics and event plane decorrelation in d+Au collisions from 19.6 to 200 GeV**
    — *Ron Belmont* — **2.2: Tue 10:40**
  - **PHENIX results on elliptic and triangular flow at mid-rapidity in d+Au collisions from 19.6 to 200 GeV**
    — *Julia Velkovska* — **2.2: Tue 11:40**
  - **PHENIX results on collective behavior in small systems from geometry-controlled experiments at sqrt{s_NN} = 200 GeV**
    — *Qiao Xu* — **6.1: Wed 11:20**
  - **PHENIX results on charged-hadron azimuthal anisotropies in Au+Au collisions at center-of-mass energies from 39 to 200 GeV**
    — *Maya Shimomura* — **7.3: Wed 15:00**
- **Open Heavy Flavor**
  - **PHENIX measurements of single electrons from charm and bottom decays at midrapidity in Au+Au collisions**
    — *Kazuya Nagashima* — **7.4: Wed 15:20**
  - **Nuclear Modification of B mesons in Collisions at 200 GeV measured through the B->J/psi decay by the PHENIX Experiment**
    — *Cesar Luiz da Silva* — **8.4: Wed 16:30**
  - **PHENIX measurements of open and hidden heavy flavor in p+p, p+Al, and p/d/3He+Au collisions across a wide range of rapidity**
    — *Sanghoon Lim* — **8.4: Wed 17:10**
- **Jets and High p_T Hadrons**
  - **Study of Cold and Hot Nuclear Matter Effects on Jets with Direct Photon-Triggered Correlations from PHENIX**
    — *Joseph Osborn* — **1.4: Tue 08:30**
  - **Studying Parton Energy Loss Using Meson Production in Large Collision Systems from PHENIX**
    — *Sergei Zharko* — **6.4: Wed 10:40**
  - **Systematic Study of Highly Asymmetric Systems Using pi0 Production at PHENIX**
    — *Norbert Novitzky* — **6.4: Wed 11:00**
- **Electromagnetic Probes**
  - **PHENIX measurements of low momentum direct photons from large ion collisions as a function of beam energy and system size**
    — *Deepali Sharma* — **2.3: Tue 11:00**