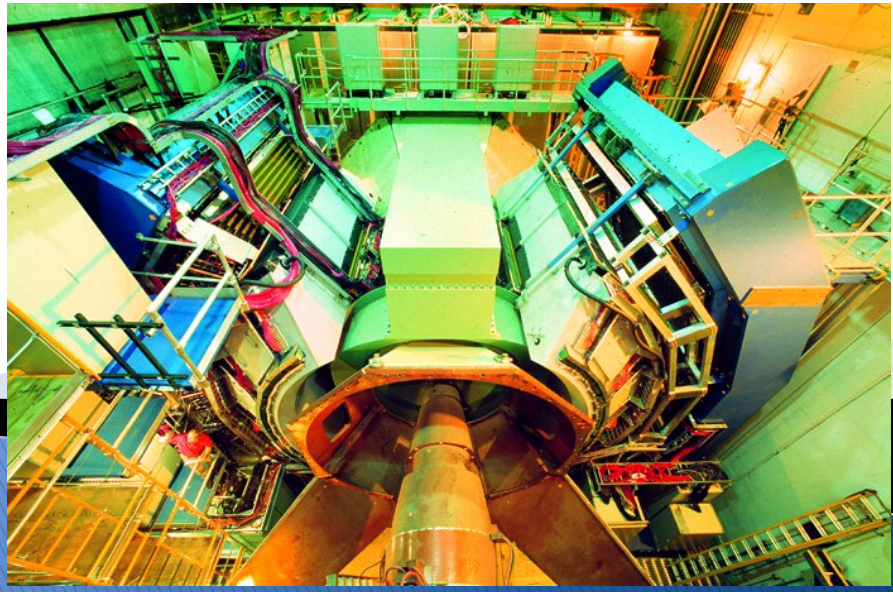
Recent results from PHENIX

Marzia Rosati
Iowa State University

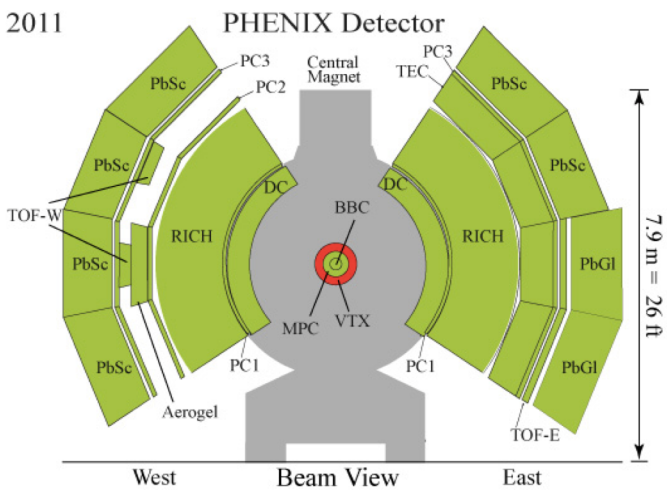


The PHENIX Experiment at RHIC

Hadrons, electron, photons

$|\eta|<0.35$ $\Delta\Phi = 2 \times \pi/2$

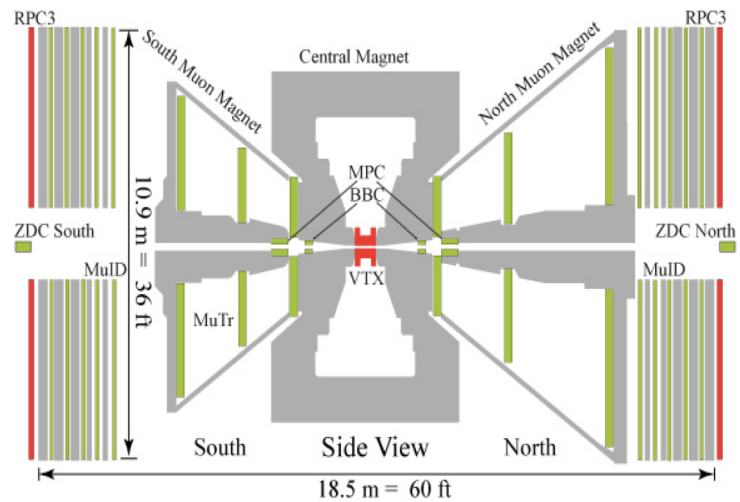
CENTRAL ARMS



Muons

$-2.2<\eta<-1.2$ $1.2<\eta<2.2$ $\Delta\Phi=2\pi$

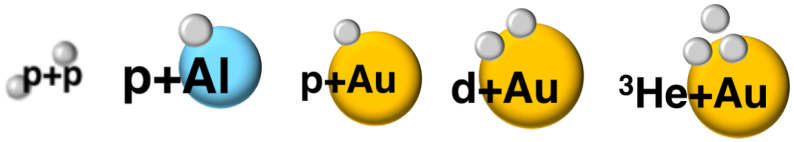
MUON ARMS



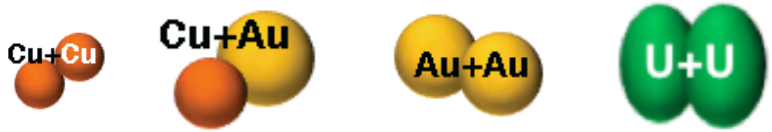
PHENIX exploited RHIC versatility:

- 16 years of operation
- 9 collision species
- 9 collision energies

Outline

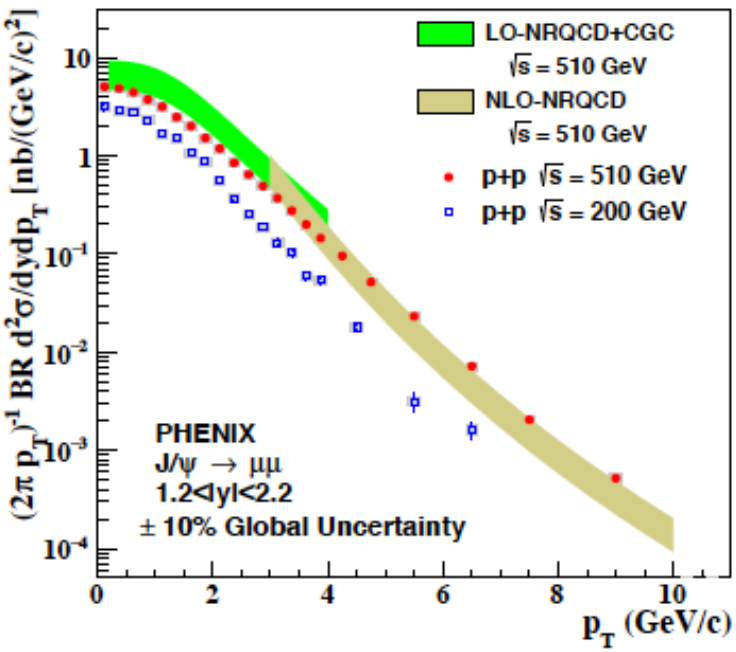


- Small systems
  - Quarkonia
  - Heavy Flavor production
  - Hadron production
  - Jet modification
  - Photon production

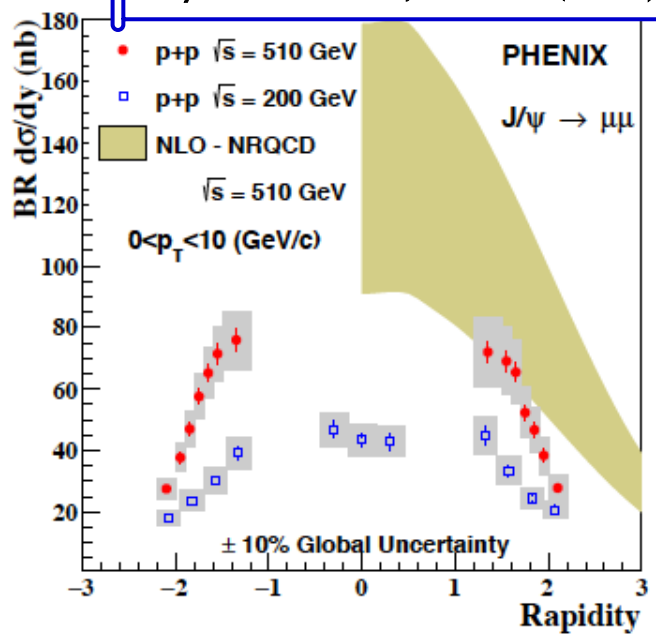


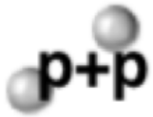
- Large systems
  - Hadron production
  - Heavy Flavor production
  - Jet modification

Quarkonia Production in p+p collisions



Phys. Rev. D 101, 052006 (2020)





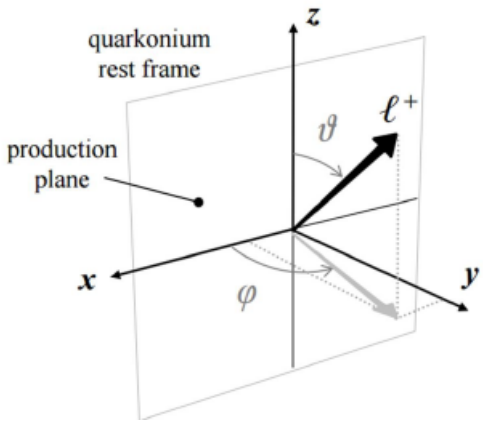
- LO-NRQCD+CGC calculations overestimate the data at low p_T .
- The NLO-NRQCD calculations are consistent with the data at intermediate p_T , 3-5 GeV/c but systematically below the data

Quarkonia Production in p+p collisions

- Quarkonia angular distributions provide an additional handle on distinguishing production mechanisms.

$$\tilde{\lambda} = \frac{\lambda_\theta + 3\lambda_\phi}{1 - \lambda_\phi}$$

$$\frac{d\sigma}{d(\cos\vartheta)d\varphi} \propto 1 + \lambda_\vartheta \cos^2\vartheta + \lambda_{\vartheta\varphi} \sin(2\vartheta)\cos\varphi + \lambda_\phi sin^2\vartheta \cos 2\varphi$$



Helicity (HX): J/y momentum in lab frame, explores final state effects Gottfried-Jackson (GJ): beam particle momentum, fixed target experiments. Collins-Soper (CS): bisector of two colliding beams.

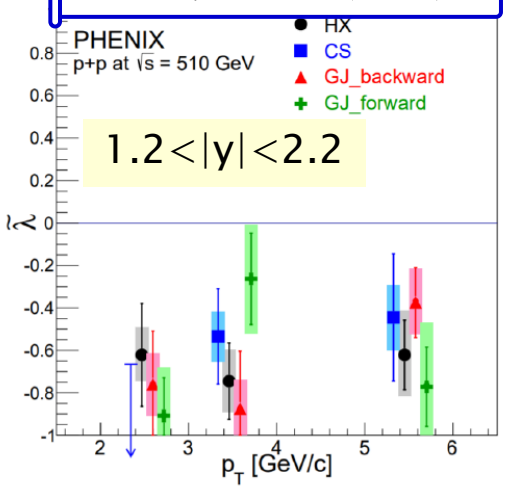
$\tilde{\lambda}$ is a frame-invariant parameter

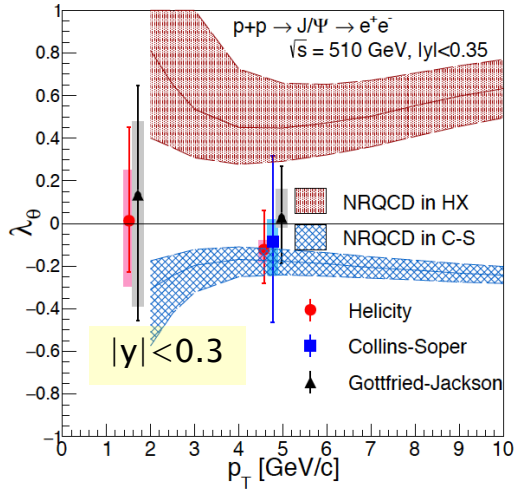
Quarkonia Production in p+p collisions

- Quarkonia angular distributions provide an additional handle on distinguishing production mechanisms.

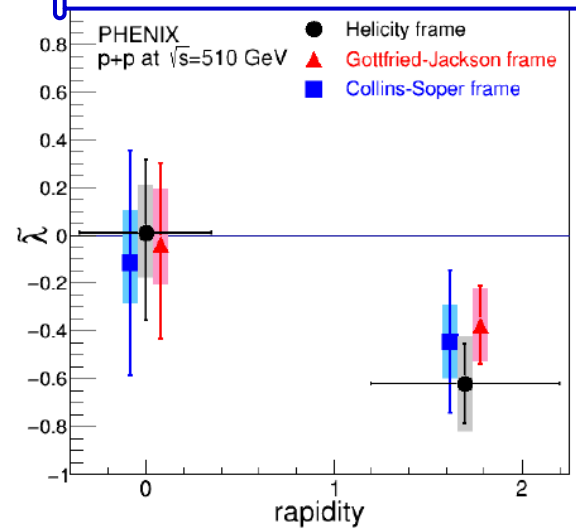
$$\tilde{\lambda} = \frac{\lambda_\theta + 3\lambda_\phi}{1 - \lambda_\phi}$$

PRD 95, 092003 (2017)





arXiv: 2005.14273 (sub. PRD)



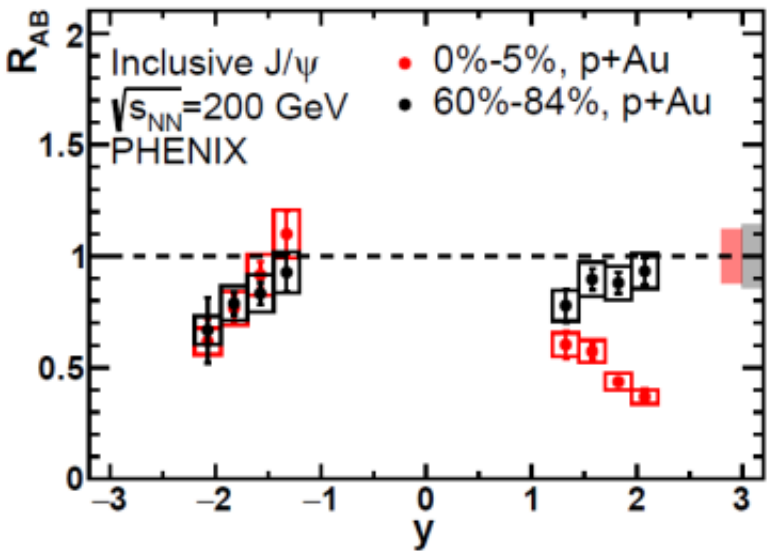
p+p

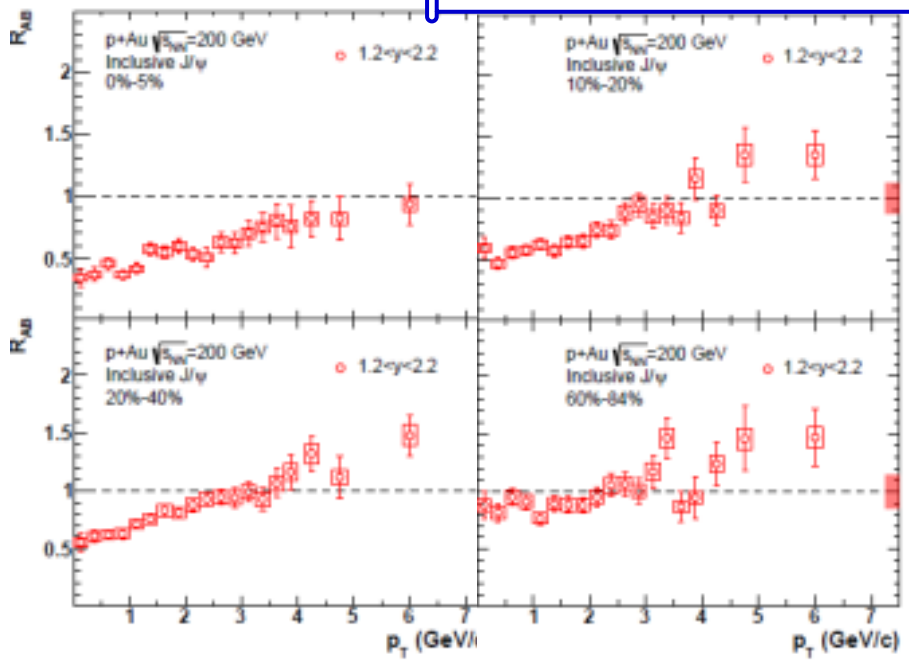
- No p_T dependence, given large uncertainty
- Data cannot rule out the models

Quarkonia in Small Systems

- Cold nuclear matter effects

arXiv:1910.14487 (acc. PRC)





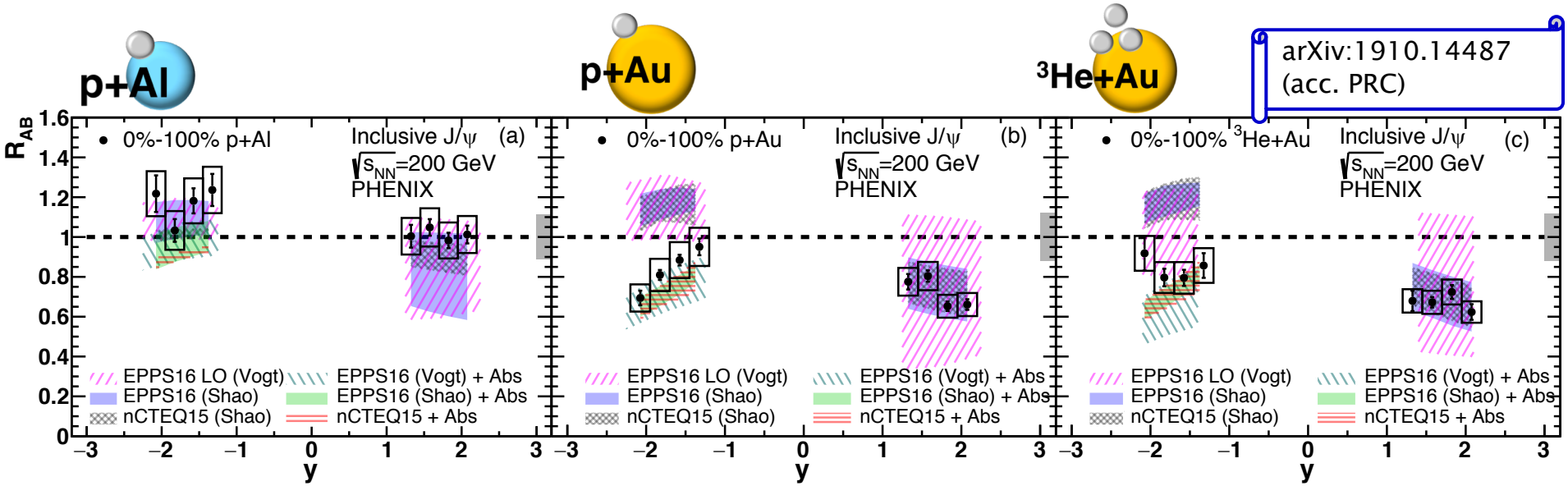
p+Au

- Very strong suppression at forward rapidity in 0–5%, little centrality dependence at backward
- At forward rapidity, strong p_T dependent suppression

Sanghoon Lim
02/06/2020, 11:20

Quarkonium in p+Al, p+Au, ^{3}He+Au

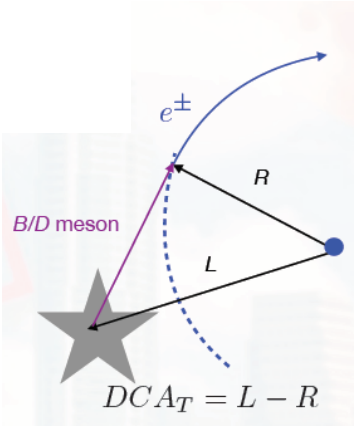
- Projectile and target size dependence
- Differential studies in p_T, rapidity, and centrality



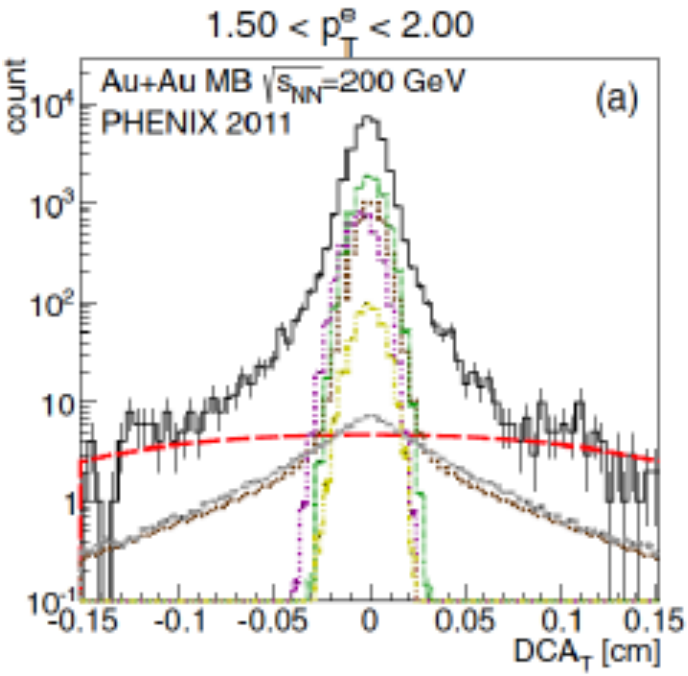
- nPDF show good agreement at forward
- nPDF + absorption show better agreement with the p/^{3}He+Au at backward rapidity

Sanghoon Lim
02/06/2020, 11:20

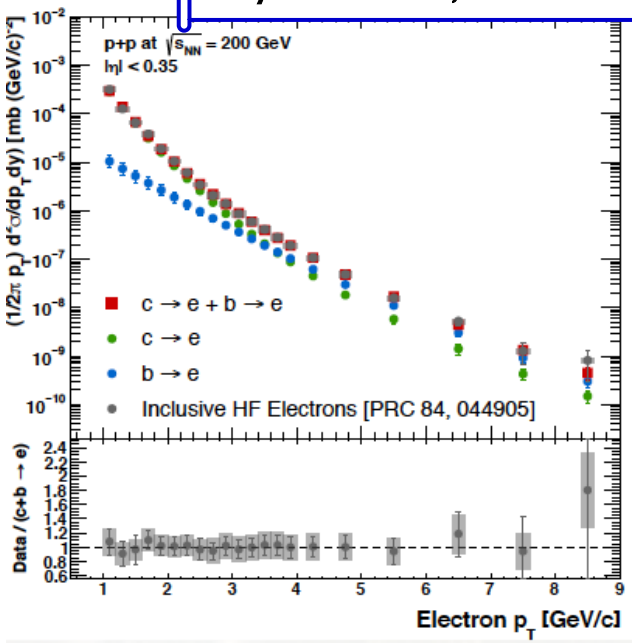
Heavy Flavor: b->e and c->e



- PHENIX measures electrons' distance of closest approach to extract heavy flavor production and b->e and c->e yields.



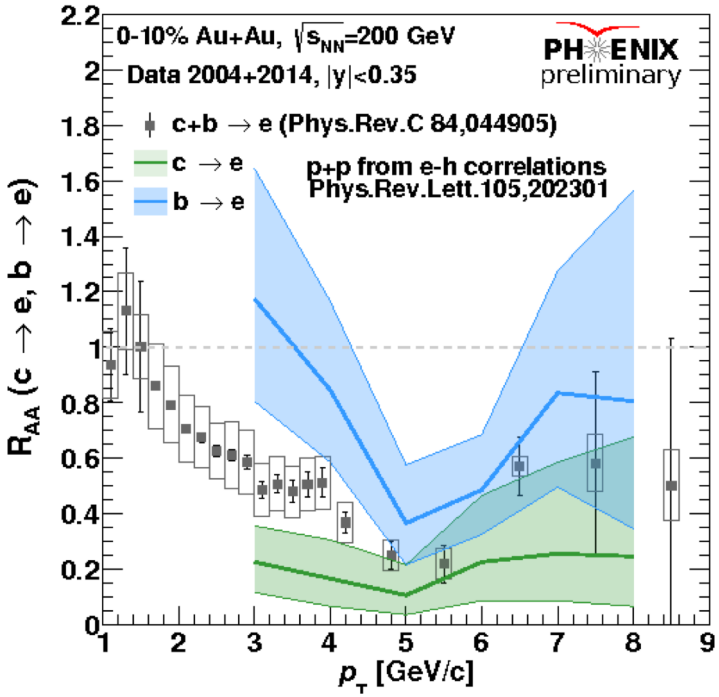
Phys. Rev. 99, 092003

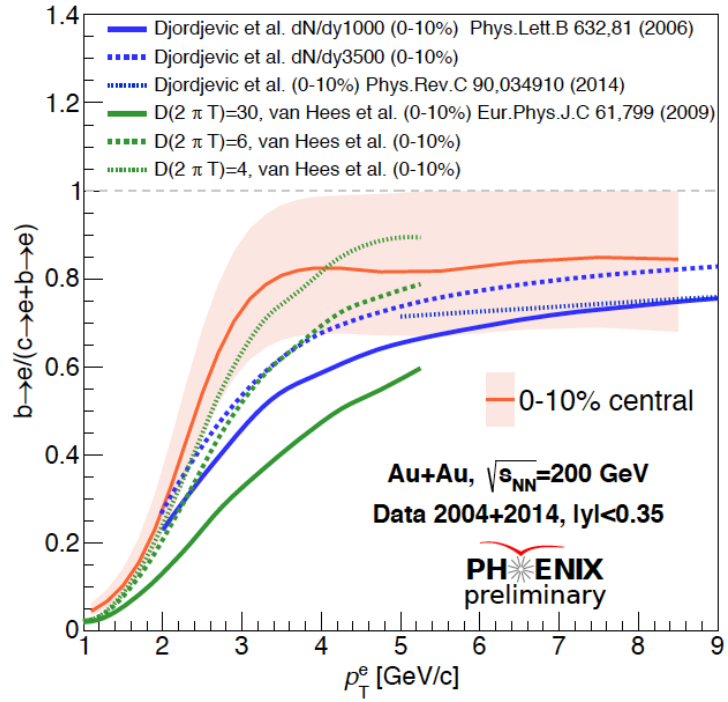


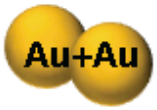
p+p

Ajeeta Khatiwada
01/06/2020, 13:35

Centrality dependence of b-> e and c->e



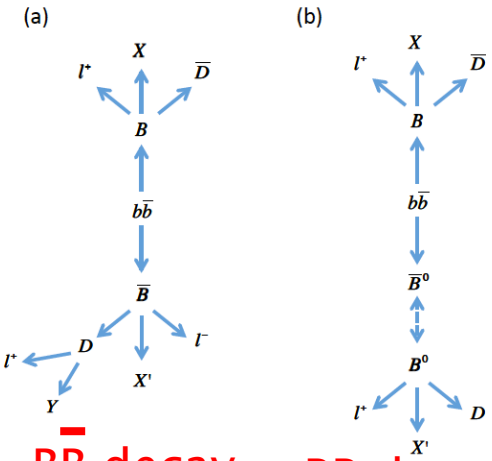




- T-Matrix model
  - large diffusion const ($2\pi T_D = 30$) inconsistent with data.
- Not enough precision to discriminate on parameters for DGLV

Ajeeta Khatiwada
01/06/2020, 13:35

$b\bar{b}$ production at forward rapidity



$\bar{B}\bar{B}$ decay

Primary decays are unlike sign Lepton pairs

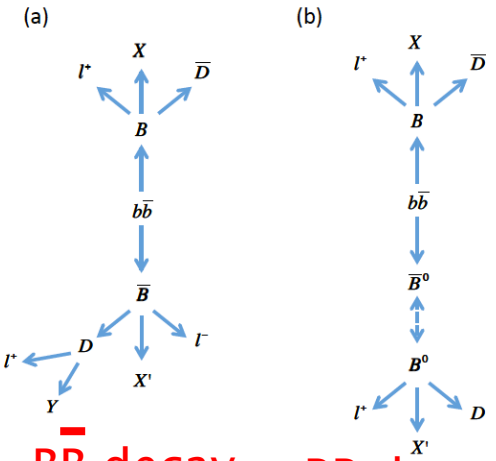
BB decay (oscillation)

Primary decays are like sign Lepton pairs

$$\sigma_{b\bar{b}}\,(\mu b) = 13.1 \pm 0.6 \pm 1.5 \pm 2.7\ mb$$

p+p

$b\bar{b}$ production at forward rapidity



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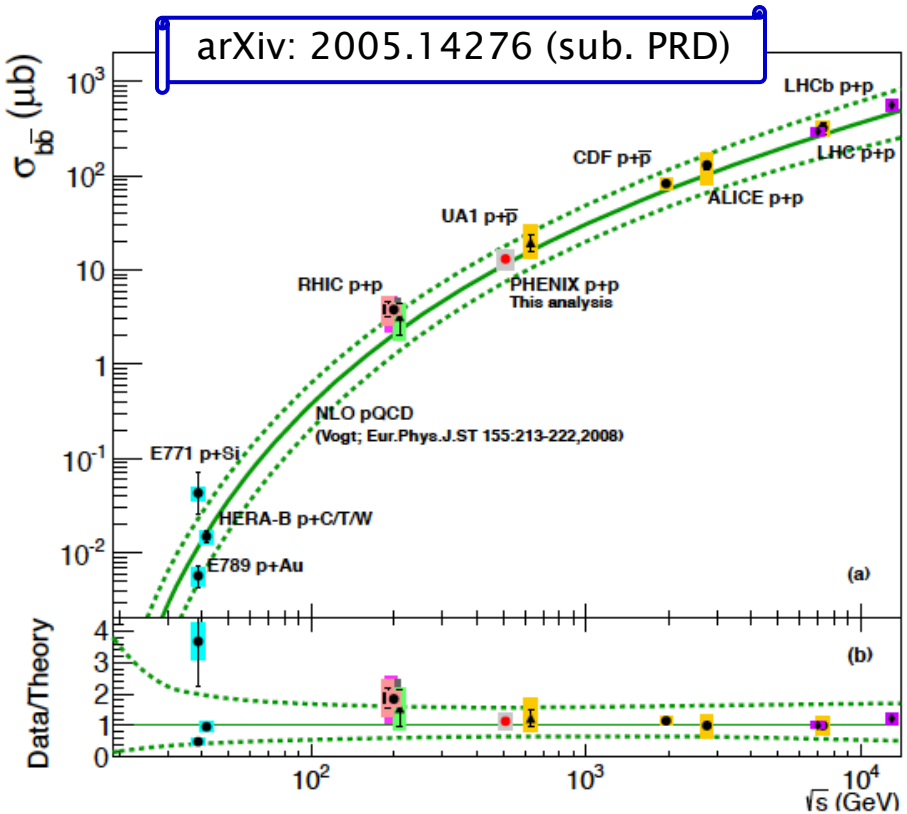
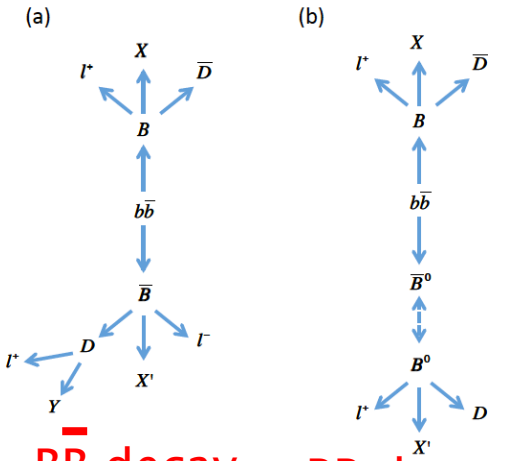


$b\bar{b}$ production at forward rapidity



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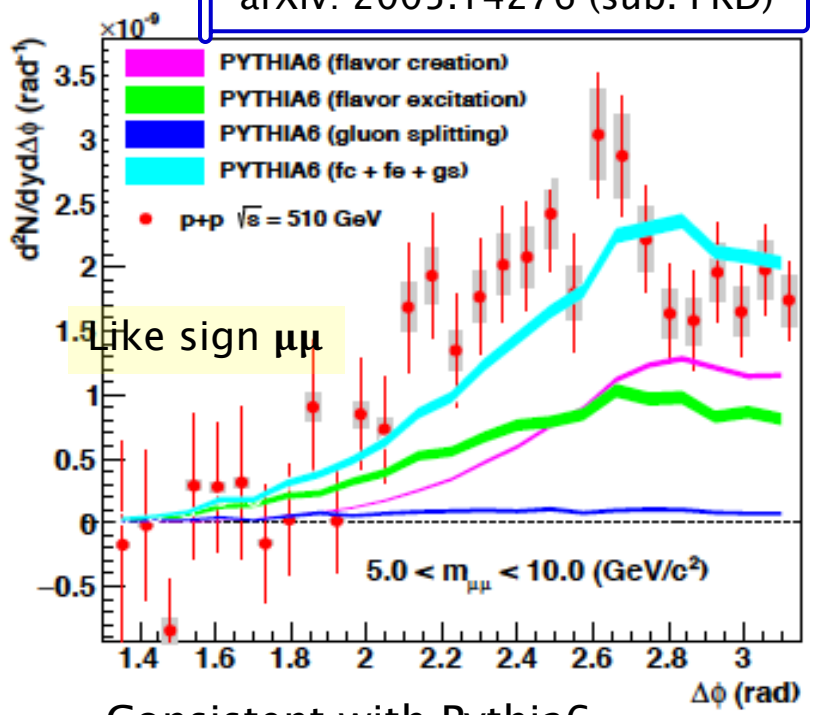
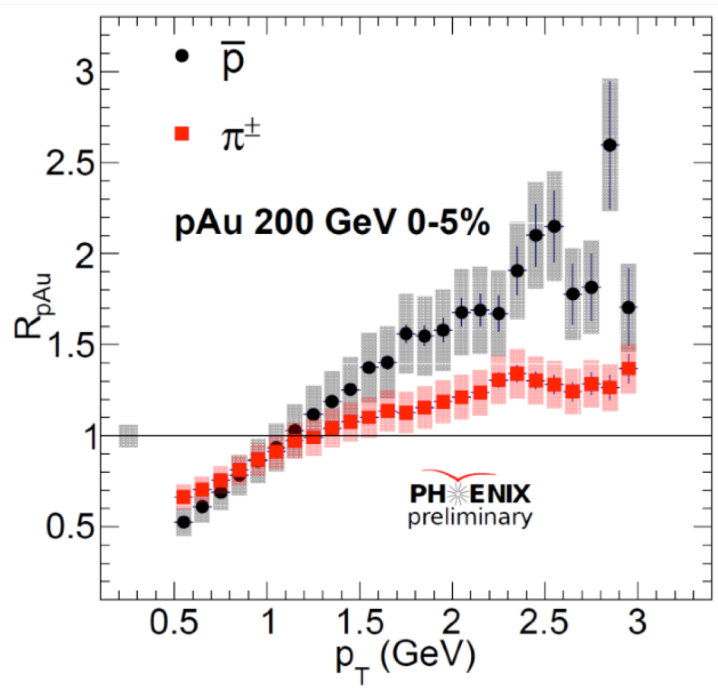
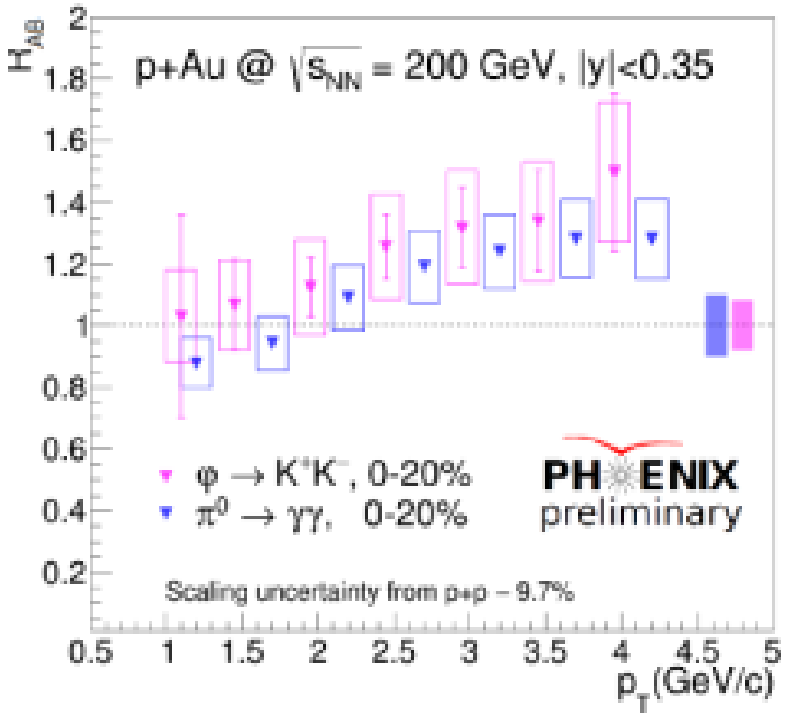
arXiv: 2005.14276 (sub. PRD)

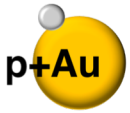


- Consistent with Pythia6
- Favors creation and excitation subprocesses

Hadron R_{pAu} for different particle species





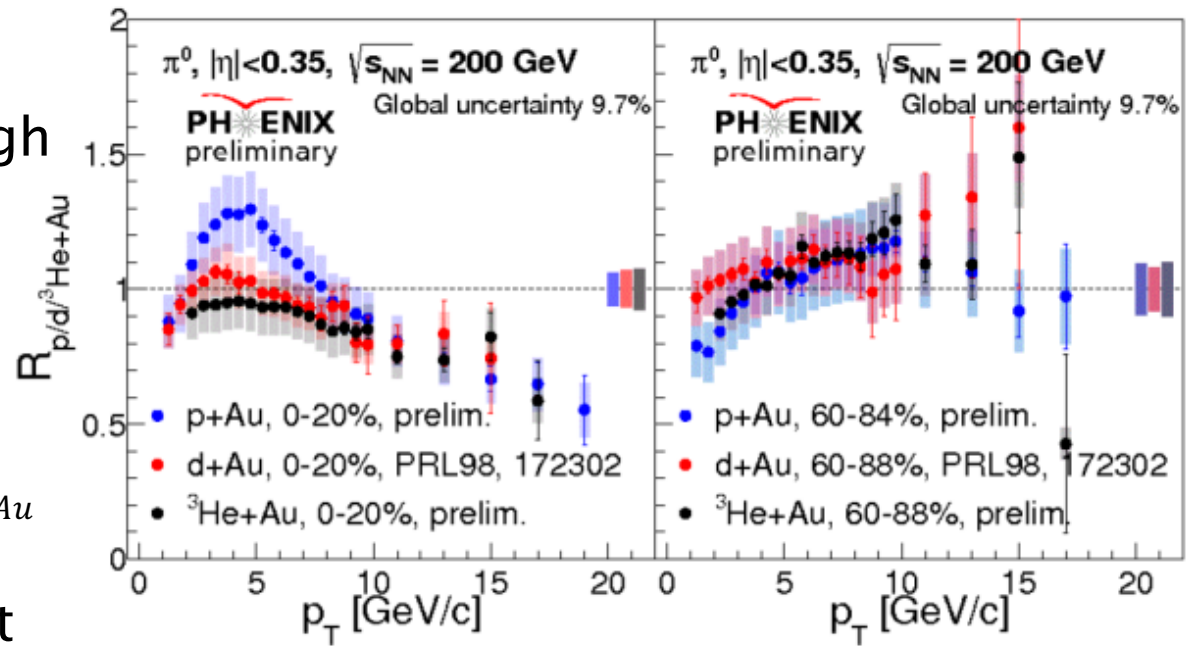


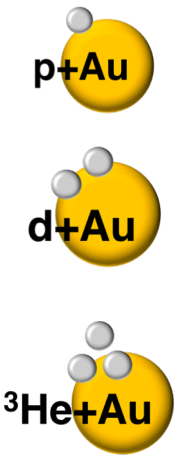
- Baryon enhancement observed in p+Au
- Phi and pion mesons have similar modification despite different mass

Axel Drees
04/06/2020, 11:35

π^0 Production in small systems

- Small systems consistent with each other at high p_T;
- In 0–20%
  - Ordering $R_{pAu} > R_{dAu} > R_{HeAu}$
  - Hint of suppression at high p_T





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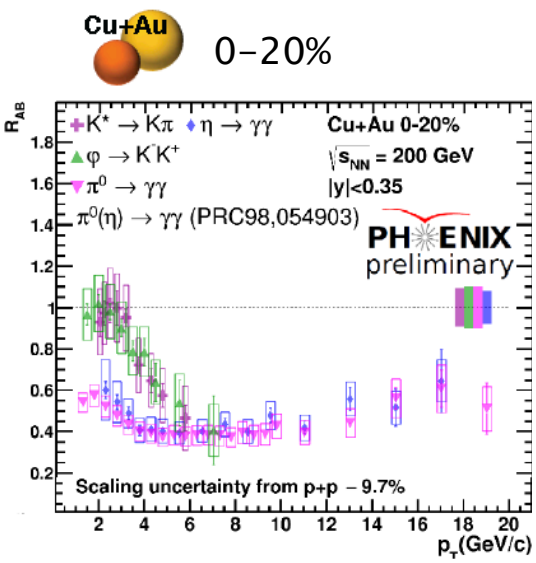
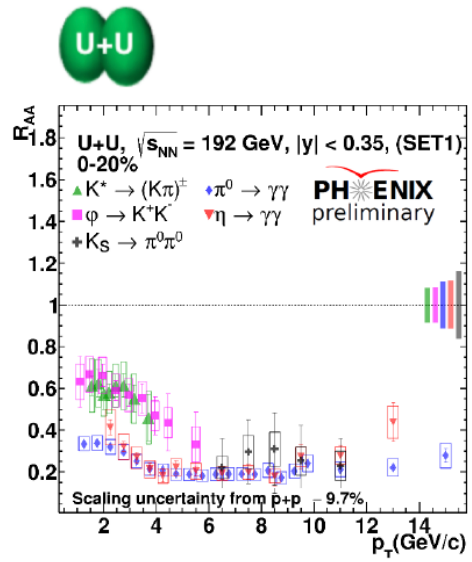
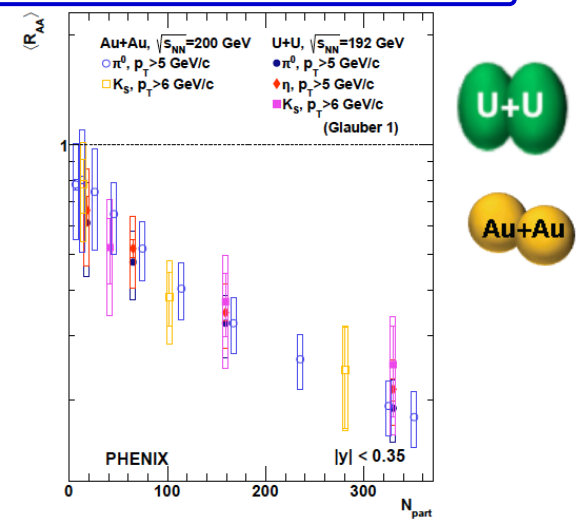
Hadron Production in Cu+Au, U+U





arXiv: 2005.14686(sub. PRC)



- Difference in R_{AA} for K^* and ϕ meson versus π^0 and η at low p_T : enhancement in mesons containing strange quarks
- Integrating R_{AA} for meson p_T>5GeV no difference

Axel Drees
04/06/2020, 11:35

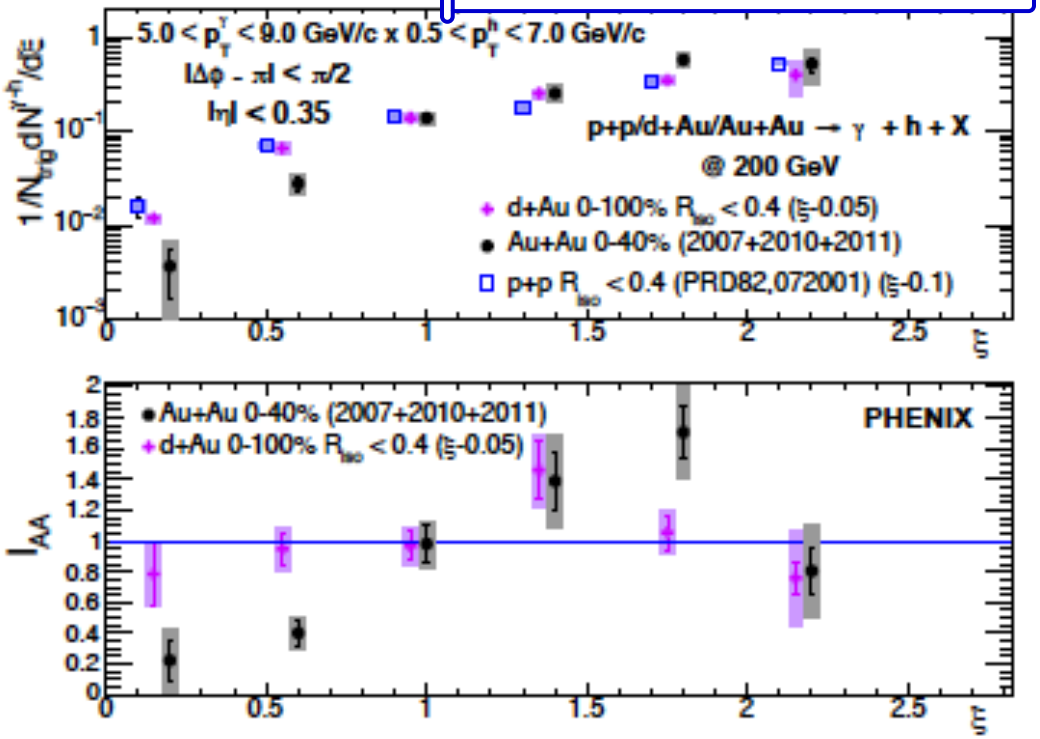
Photon-Hadron Correlations in Au+Au and d+Au

$$z_T = p_T^h / p_T^\gamma$$

$$\xi = ln(1/z_T)$$

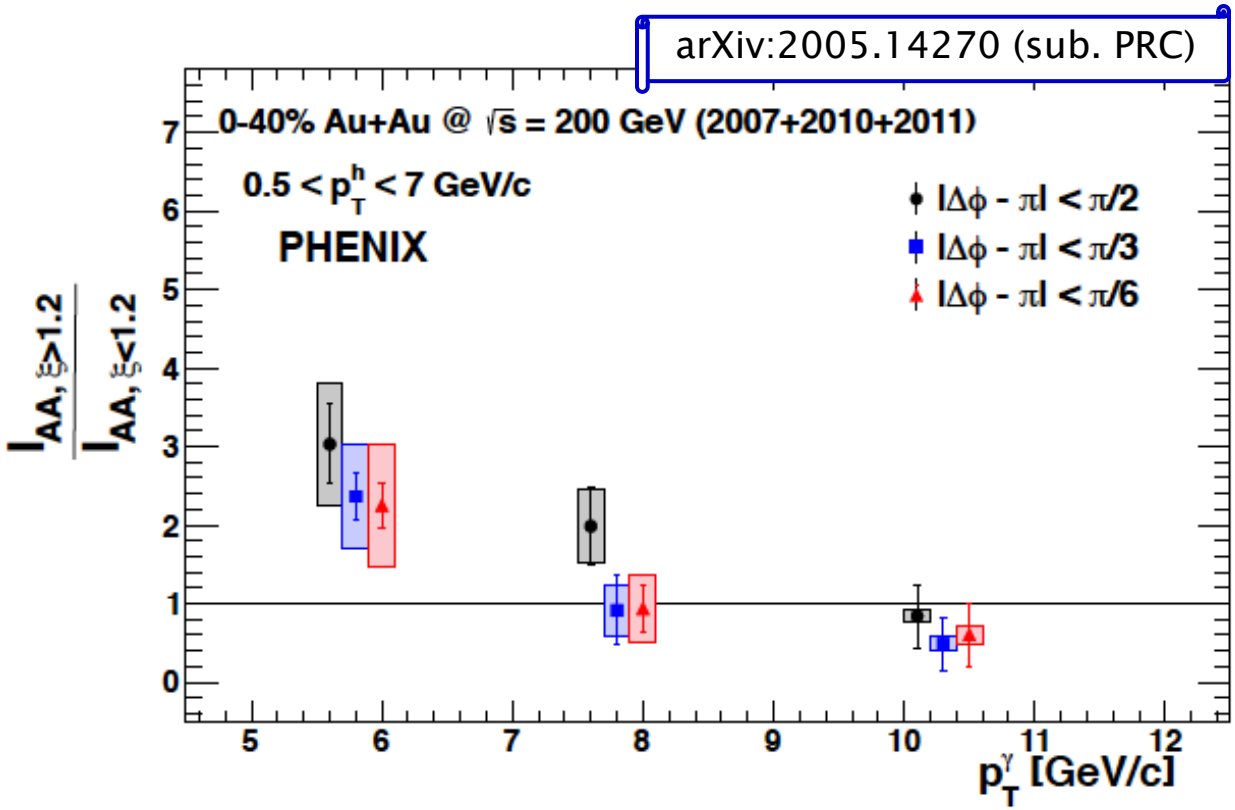
$$I_{AA} = \frac{Y_{Away}^{AA}}{Y_{Away}^{pp}}$$

arXiv:2005.14270 (sub. PRC)



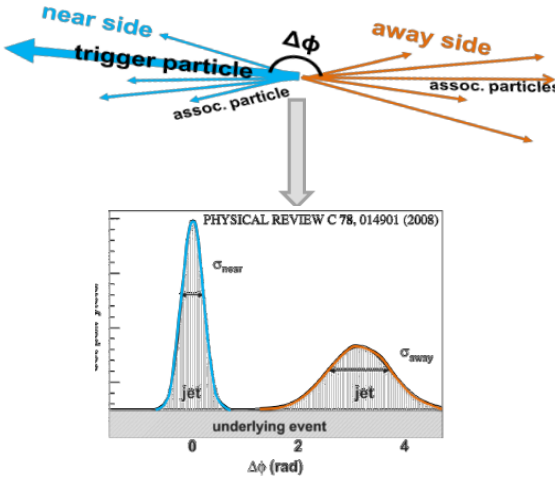
- Au+Au clear suppression at low ξ and enhancement at high ξ
- d+Au I_{dA} is consistent with unity across all ξ ranges

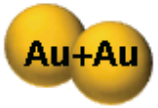
Photon-Hadron Correlations in Au+Au



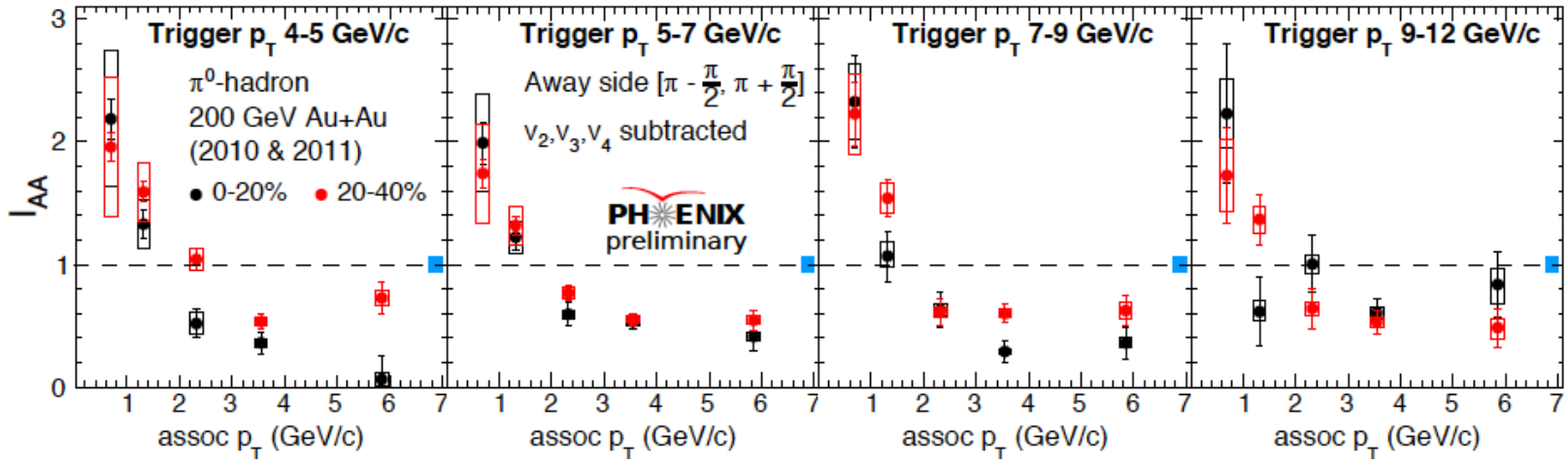
- The enhancement is largest for softer jets and for the full away-side integration range, implying that jets with lower energy are broadened more than higher energy jets.

π^0–Hadron Correlations in Au+Au





$$I_{AA} = \frac{Y^{AA}_{Away}}{Y^{pp}_{Away}}$$

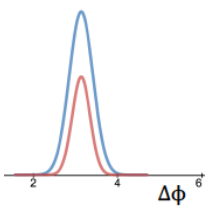


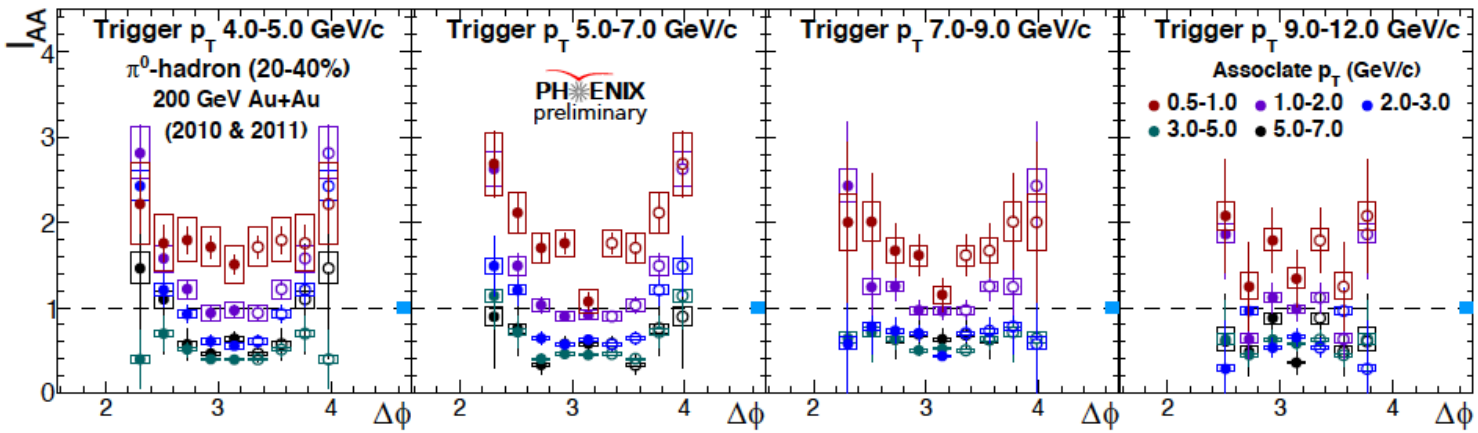
- Enhancement of yield ($I_{AA} > 1$) at low associate particle momentum
- Depletion ($I_{AA} < 1$) at high associate particle momentum

Cheuk-Ping Wong
01/06/2020, 13:55

π^0–Hadron in Au+Au vs associated p_T

- Calculate ratio in yields between Au+Au jet function and p+p baseline





- Shows modification to away-side jet peak at substructure level
- Skirt of jet is the first to see significant enhancement, most intense enhancement at wide angles

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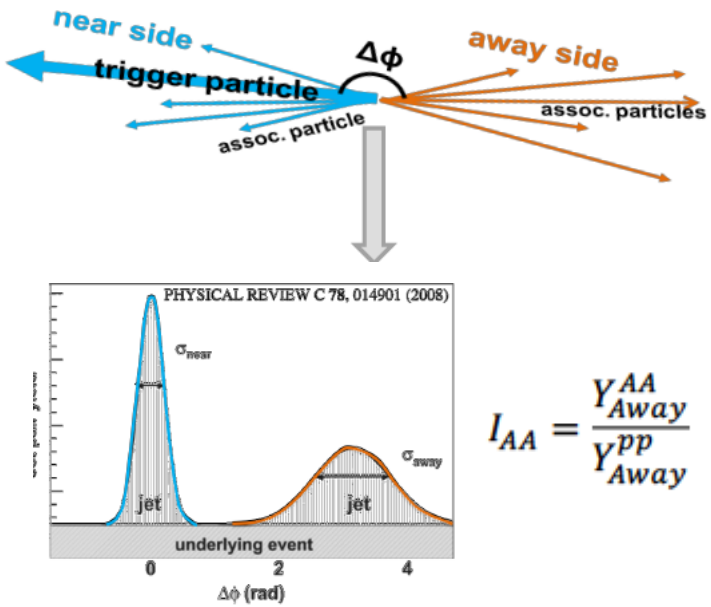
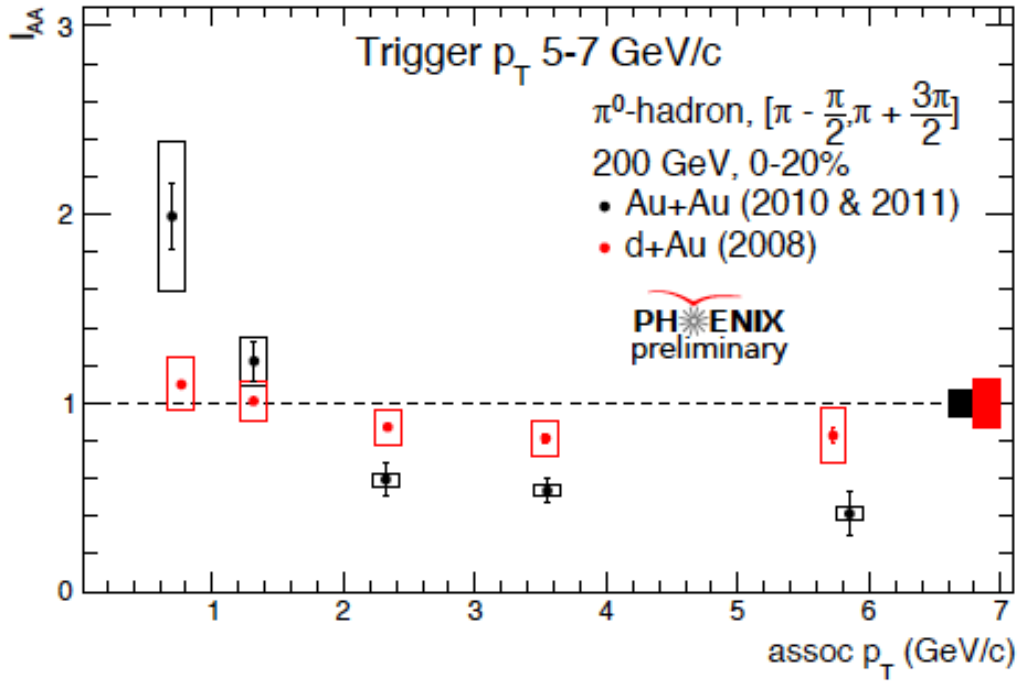
01/06/2020, 13:55

π^0–Hadron Correlations



$$I_{AA} = \frac{Y^{AA}_{Away}}{Y^{pp}_{Away}}$$

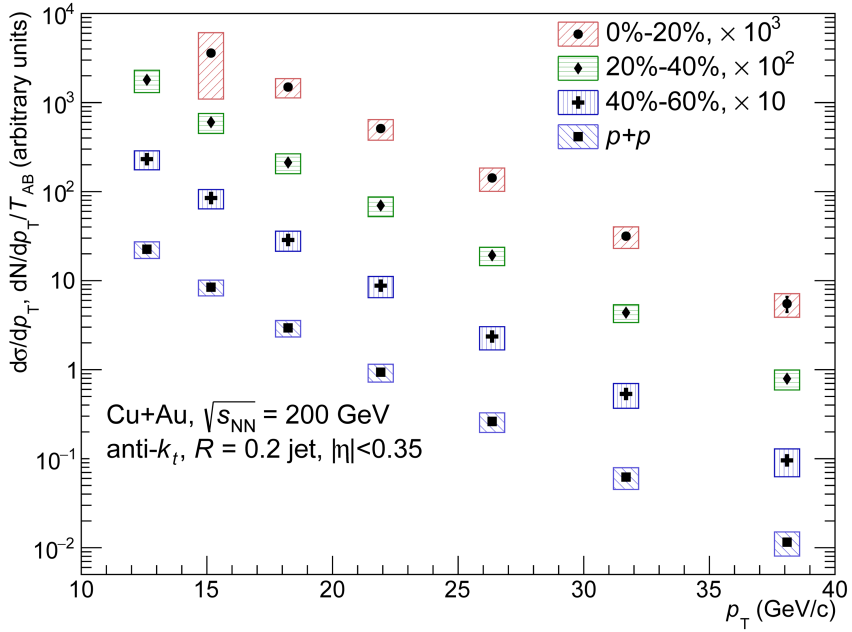


- Larger yield modification in Au+Au collisions than in d+Au collisions

Cheuk-Ping Wong
01/06/2020, 13:55

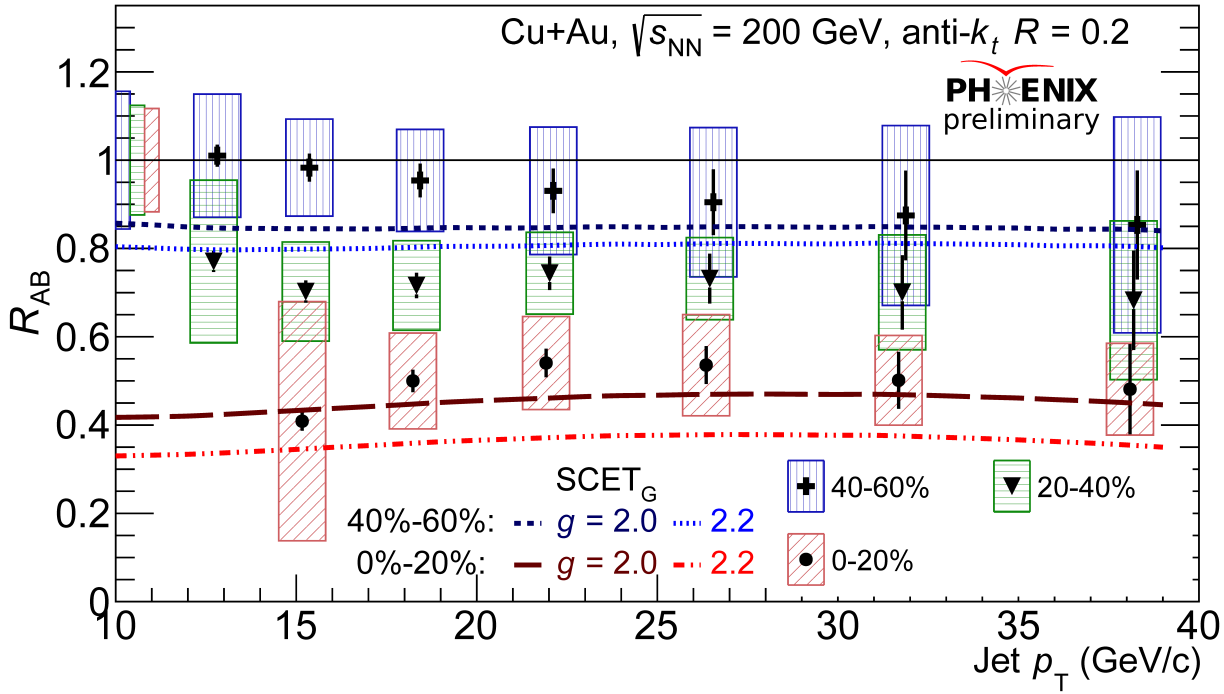
Jets Yields in p+p and Cu+Au

- Jet reconstructed with anti-k_T algorithm with R=0.2
- Spectra unfolded using the Singular Value Decomposition method to account for detector effects and centrality dependent underlying event fluctuations.



Milap Patel
02/06/2020, 11:40

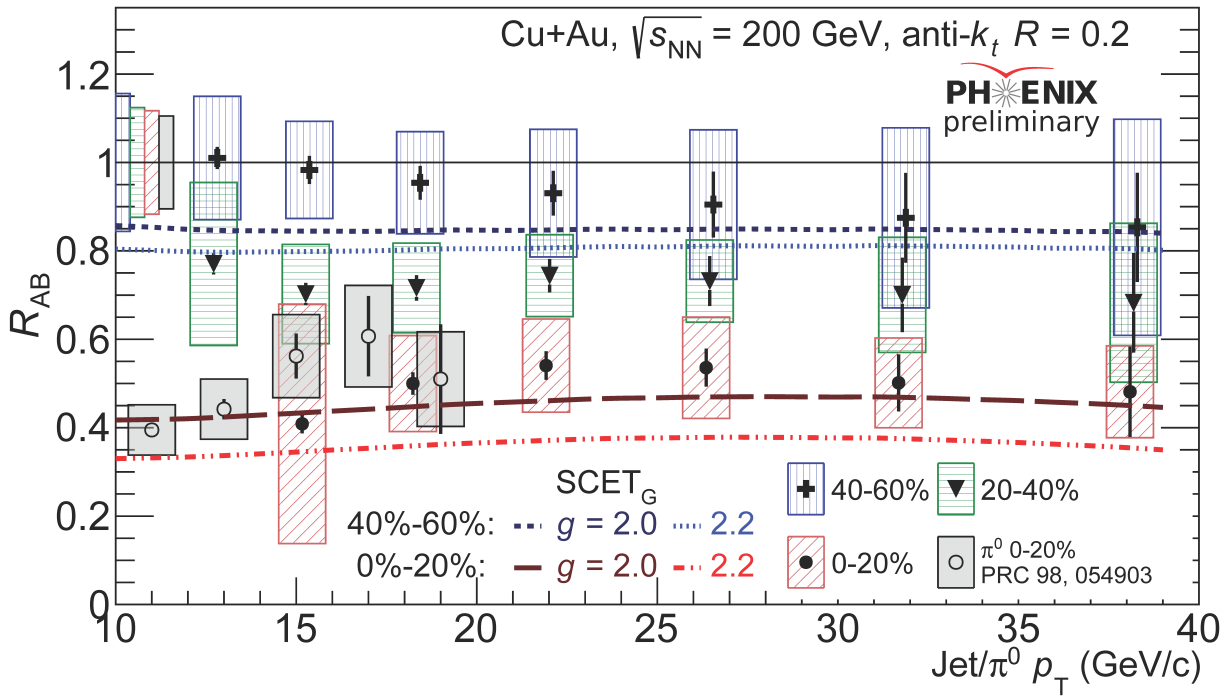
Jet R_{CuAu}



- R_{AB} is suppressed systematically as a function of centrality.

Milap Patel
02/06/2020, 11:40

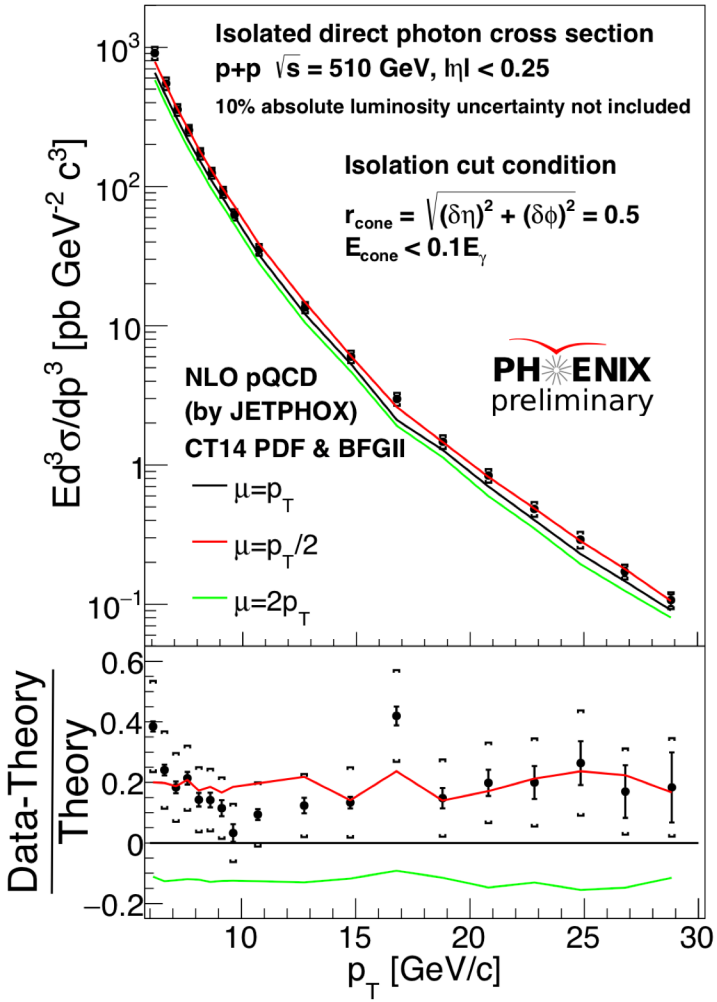
Jet R_{CuAu}



- R_{AB} is suppressed systematically as a function of centrality.
- Suppression is comparable to π^0 suppression and shows no p_T dependence.

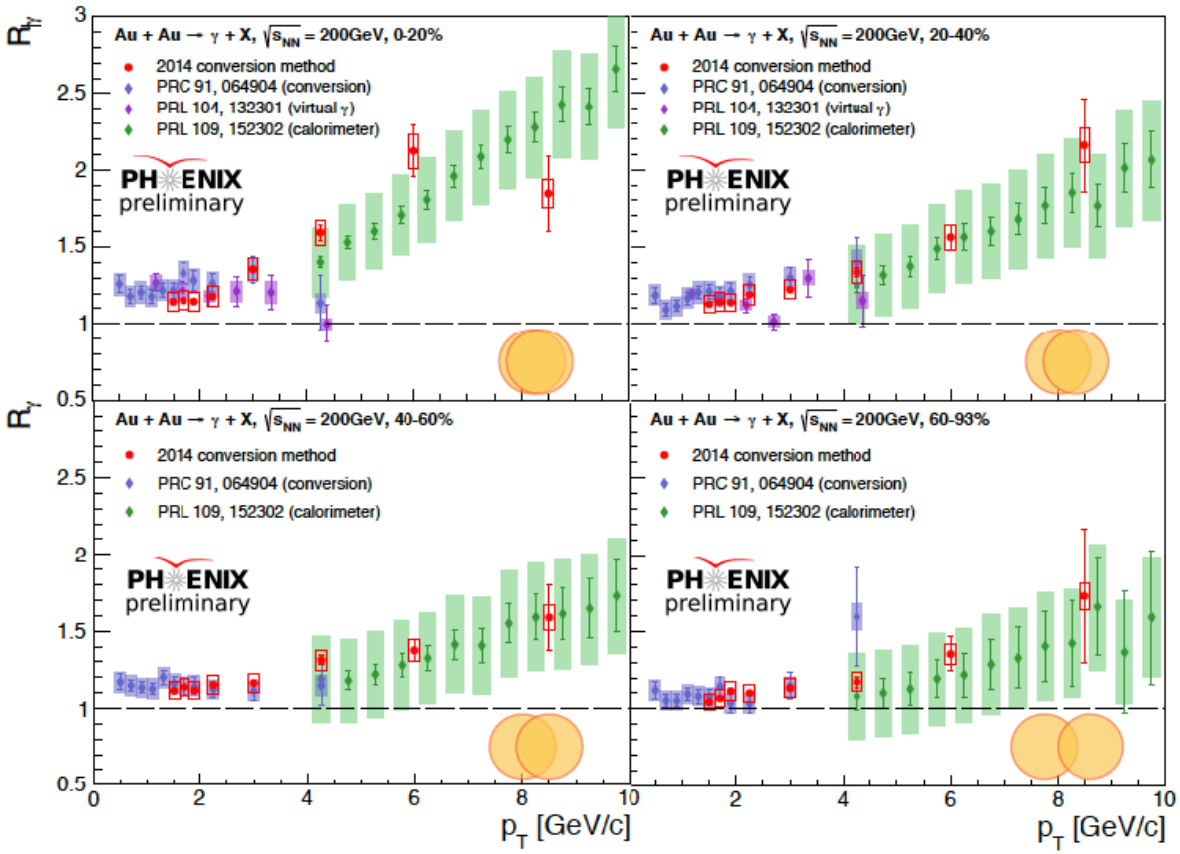
Milap Patel
02/06/2020, 11:40

Direct Photon Cross Section at $\sqrt{s}$ =510 GeV



- First measurement of direct photon cross section in pp $\sqrt{s}$ =510 GeV
- A NLO pQCD calculation agrees well with the measurement

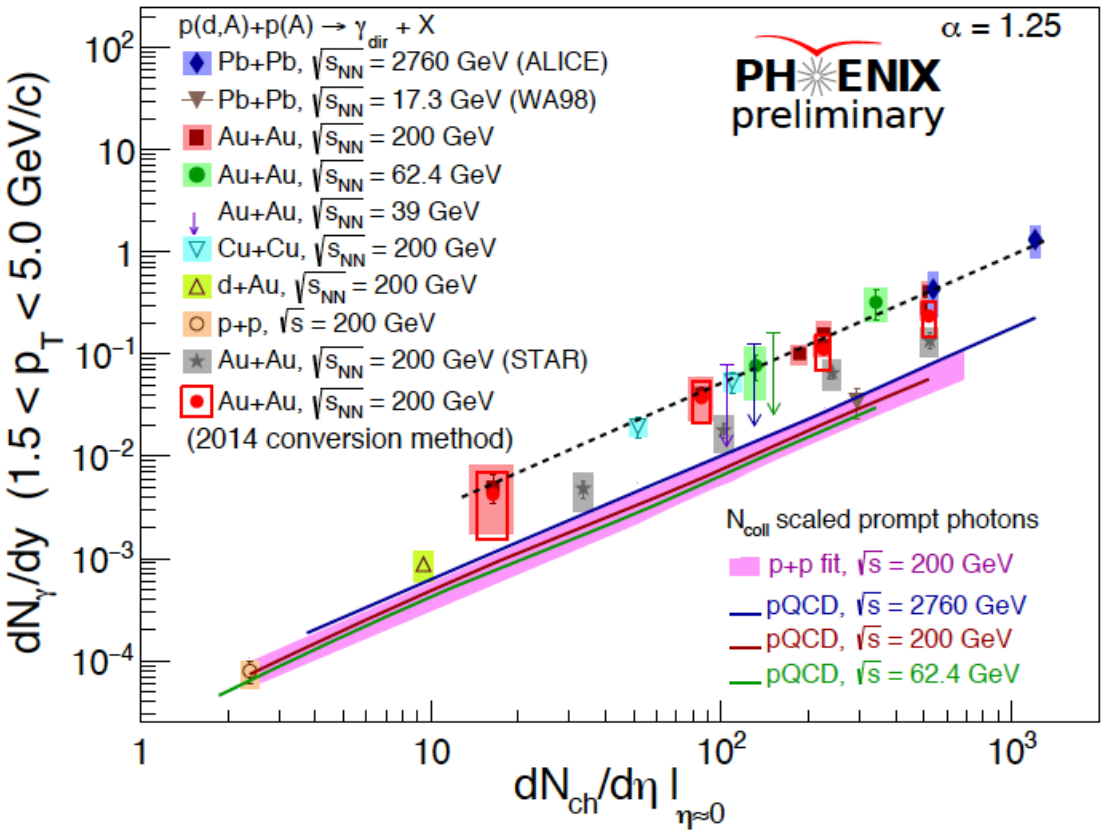
Direct Photon in Au+Au



$$R_\gamma = \frac{\text{Inclusive photons}}{\text{Photons from hadron decays}}$$

- New independent analysis of direct photon emission from data set with 10* statistics
  ⇒ Consistent with previous results

Photon Yields in small and large systems



Common scaling independent of collision energy or centrality for Au+Au and Pb+Pb at different energies;

very different from Ncoll-scaled p+p

Veronica Canoa Roman
01/06/2020 12:00

Summary

- J/ψ production provide insights on production mechanism and shows big change when increasing nuclear target size, small change when increasing projectile size
- Measurement of $c \rightarrow e$ and $b \rightarrow e$ spectra in p+p and Au+Au centrality dependence.
- Single hadron R_{AA} independent of collision species when selecting for similar N_{part} in Au+Au and U+U. Strangeness very important at low p_T but not at high p_T
- Correlation measurements show away-side broadening Indicates large-angle radiation of high-p_T partons
- Photon enhancement in small systems is important additional evidence in support of QGP droplet formation in small systems

PHENIX Posters

1. *"Heavy quark nuclear modification at forwardrapidity in Au+Au collisions at√sNN=200 GeV" by* Cesar Luiz da Silva
2. *"Direct Photon as the light at the end of the tnnel" by* Niveditha Ram
3. "*Jet modification with two particle correlations in Au+Au collisions at PHENIX*" by Megan Elizabeth Connors
4. *"Direct photon measurements in pp collisions at sqrt(s)=510 GeV"* by PHENIX Zhongling Ji
5. *"π^0 Azimuthal Anisotropy in Central d+Au Collisions at 200 GeV with PHENIX at RHIC"* by Carlos E. Perez Lara
6. "*Low pT direct photon in small systems at PHENIX experiment*" by Veronica Canoa Roman
7. "*Neutral pion v_2 at low and high pT in Central dAu collisions measured with PHENIX at the RHIC top energies* " by Carlos Eugenio Perez Lara
8. *"PHENIX measurement of the high pT direct photon production in p+A collisions and its implication to the initial state of the system " by* Niveditha Ramasubramanian
9. "*PHENIX Results on In-Medium Jet Modification Using π0 and Direct Photon-Triggered Two-Particle Correlations*" by Anthony Hodges
10. "*PHENIX results on quark flavor dependence of flow in Au+Au collisions" by* Takashi Hachiya

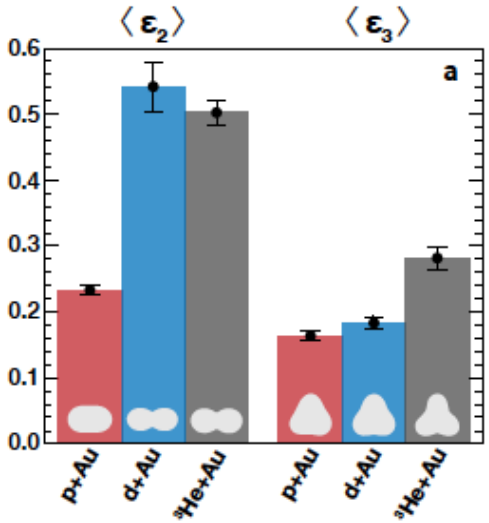
Backup

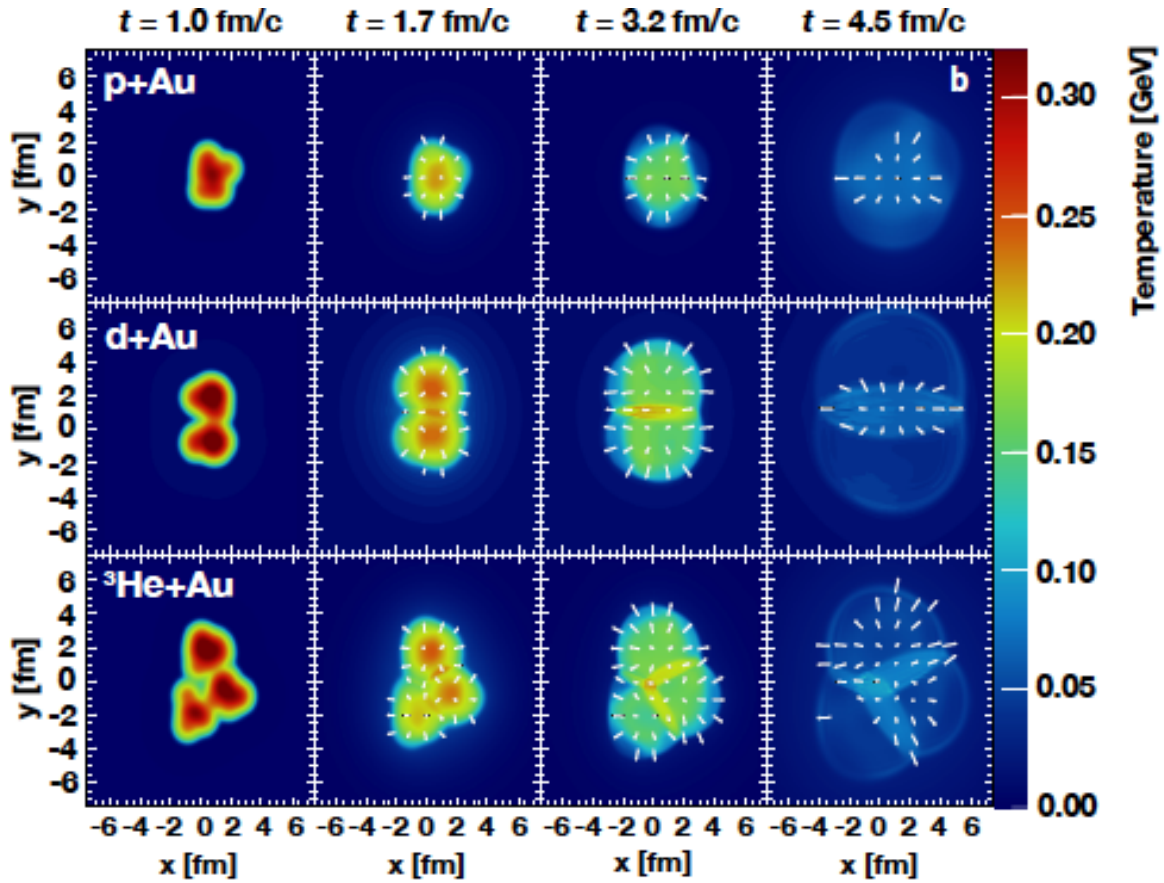
Talks

1. "*New PHENIX Results on Mid-Rapidity Bottom and Charm Production in Au+Au collisions at* $\sqrt{s_{NN}}$*= 200 GeV*"
   by Ajeeta Khatiwada 01/06/2020, 13:35
2. *"PHENIX results on direct photon production from Au+Au collisions"* by Veronica Canoa Roman – 01/06/2020, 12:00
3. *"Exploring potential jet modification in small collision systems with two particle correlations at PHENIX"*
   by Cheuk-Ping Wong 01/06/2020, 13:55
4. "*PHENIX results on J/psi from small systems*"
   by Sanghoon Lim 02/06/2020, 11:20
5. "*Reconstructed Jet Measurements in p+p, p+Au and Cu+Au collision using PHENIX*" by Milap Patel 02/06/2020, 11:40
6. "*PHENIX results on nuclear modification of hadron production in small and large systems*" by Axel Drees 04/06/2020, 11:35

Testing hydro by controlling geometry

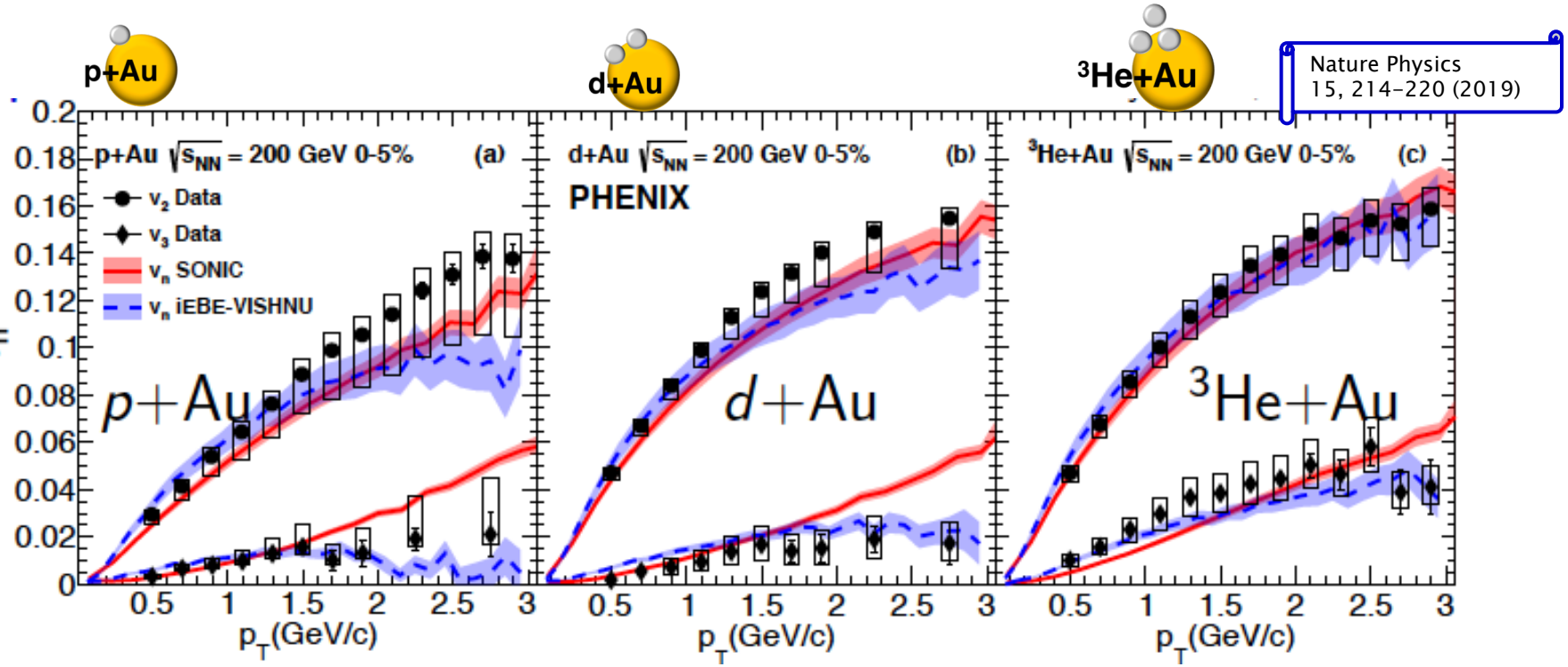
Nature Physics 15, 214–220 (2019)





- SONIC model: Habich, M., Nagle, J. L. & Romatschke, Eur. Phys. J. C 75, 15 (2015).

Testing hydro by controlling geometry



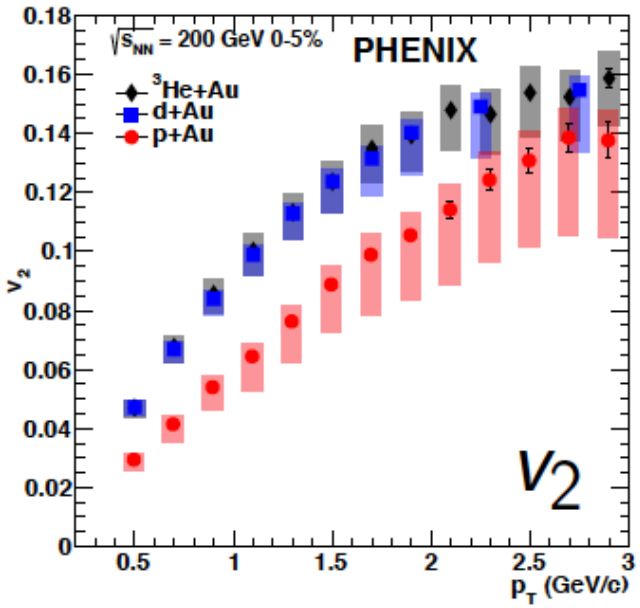
- v2 and v3 ordering matches e_2 and e_3 ordering in all systems
- Regardless of mechanism, the correlation is geometrical
- v_2 and v_3 vs p_T described very well by hydro in all three systems

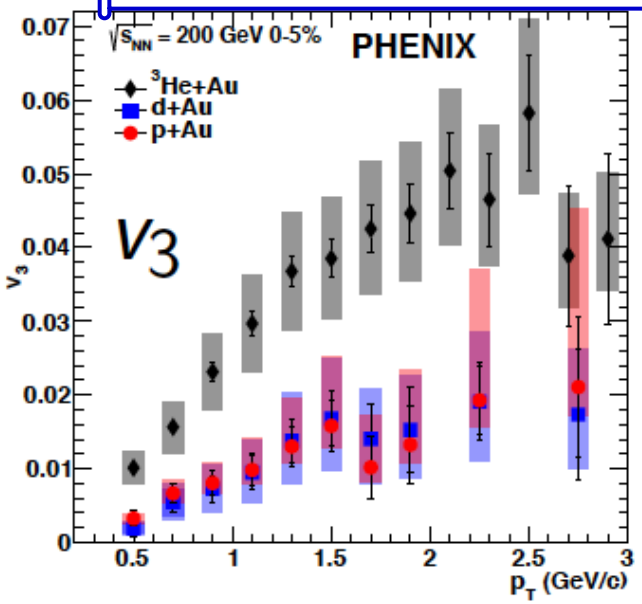
iEBE-VISHNU: C. Shen et al., Phys. Rev. C 95, 014906 (2017).

SONIC: M. Habich et al., Eur. Phys. J. C 75, 15 (2015).

Testing hydro by controlling geometry

Nature Physics 15, 214–220 (2019)





- Results are confirmed by three-subsystem two-particle correlation (3x2PC)
- Apparent violation of naive EP resolution scaling is likely explained by beam angle, beam offset, and central carriage misalignment