Recent results from PHENIX

EPS-HEP 2013

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HEP 2013
Stockholm
18-24 July 2013
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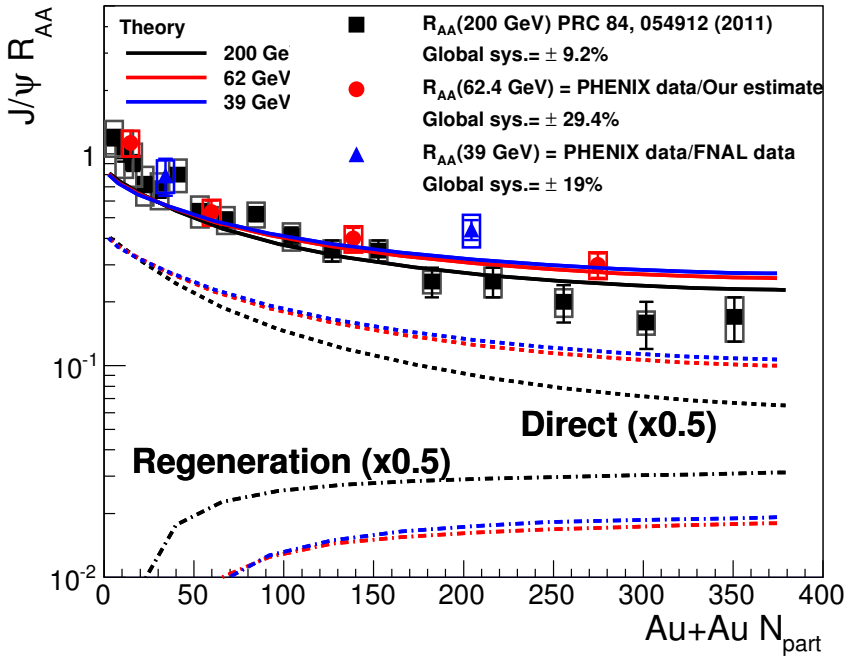
July 19, 2013

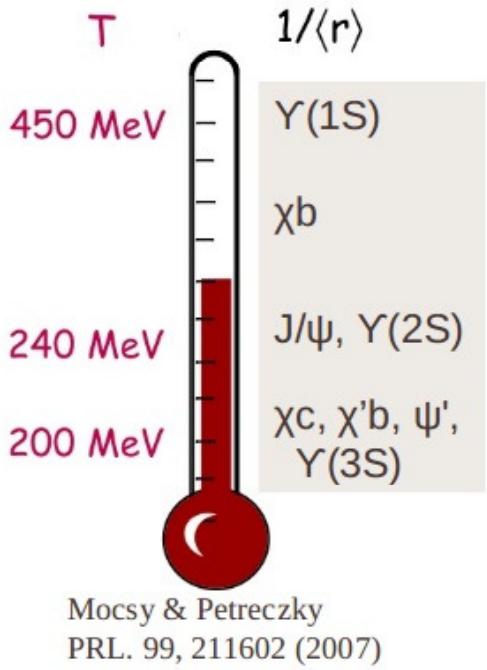
Outline

- Quarkonia
- Heavy flavor
- Electromagnetic probes
- Two particle correlations
- Disclaimer: many new results from PHENIX not covered in this talk

Quarkonia QGP-Thermometer

Phys. Rev. C 86, 064901 (2012)



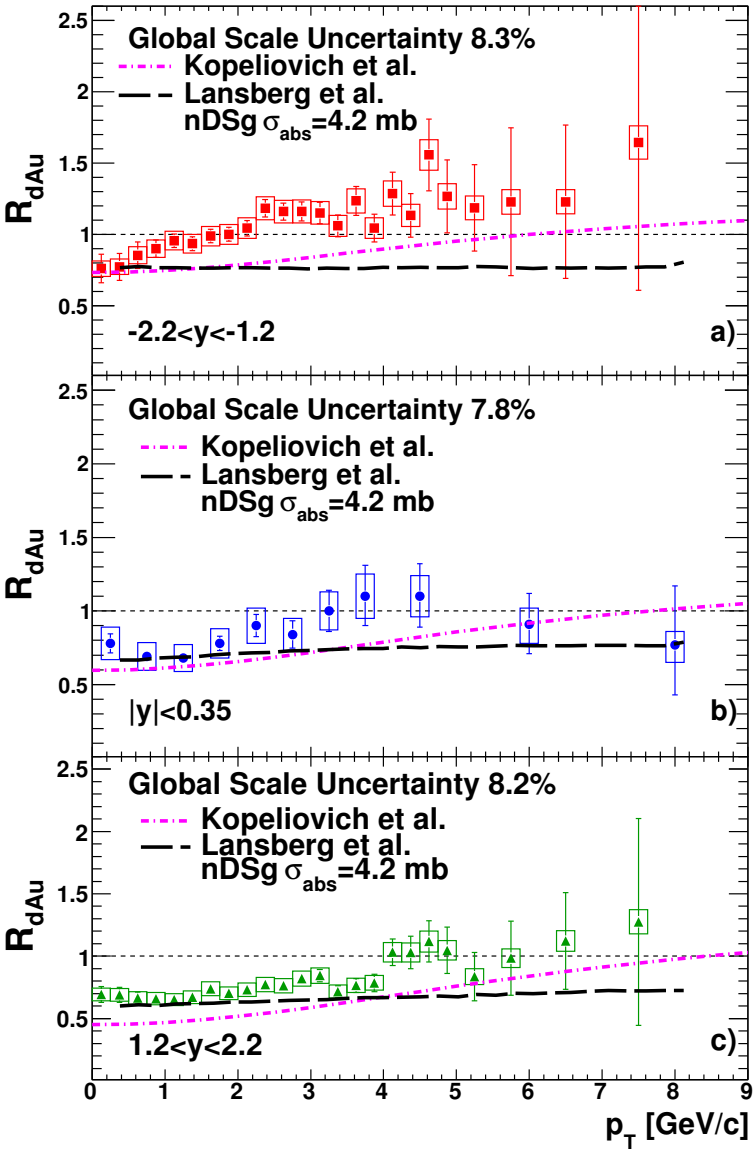


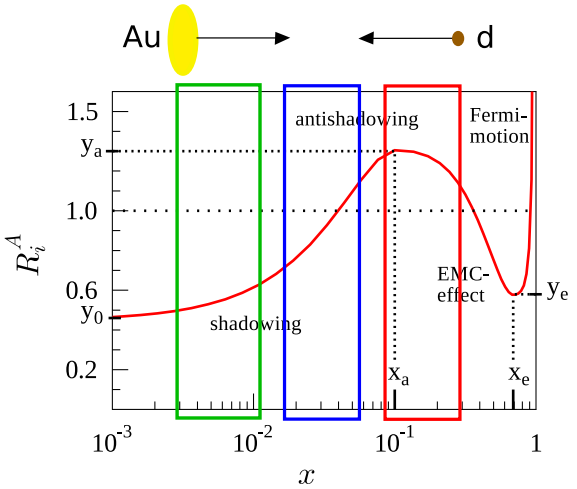
Mocsy & Petreczky
PRL. 99, 211602 (2007)

- Many ways to vary the temperature: ex: collision energy
- Interpretation of measurements not straightforward. Many competing effects
- CNM: Saturation, shadowing (nuclear PDF modification), Cronin, breakup
- In medium: Melting, Regeneration

CNM effects on J/ψ in d+Au

Phys. Rev. C 87, 034904 (2013)





- Modification of rate in d+Au collision
- Similar trends at mid and forward rapidities (Gradual increase, to ≈1 at ≈5 GeV/c^2)
- Backward rapidity (Au going direction) distinct shape: Early rise (at ≈1 GeV/c) overshoots 1.0
- Compatible with Cronin effect (caused by multiple scattering) stronger in the Au going direction

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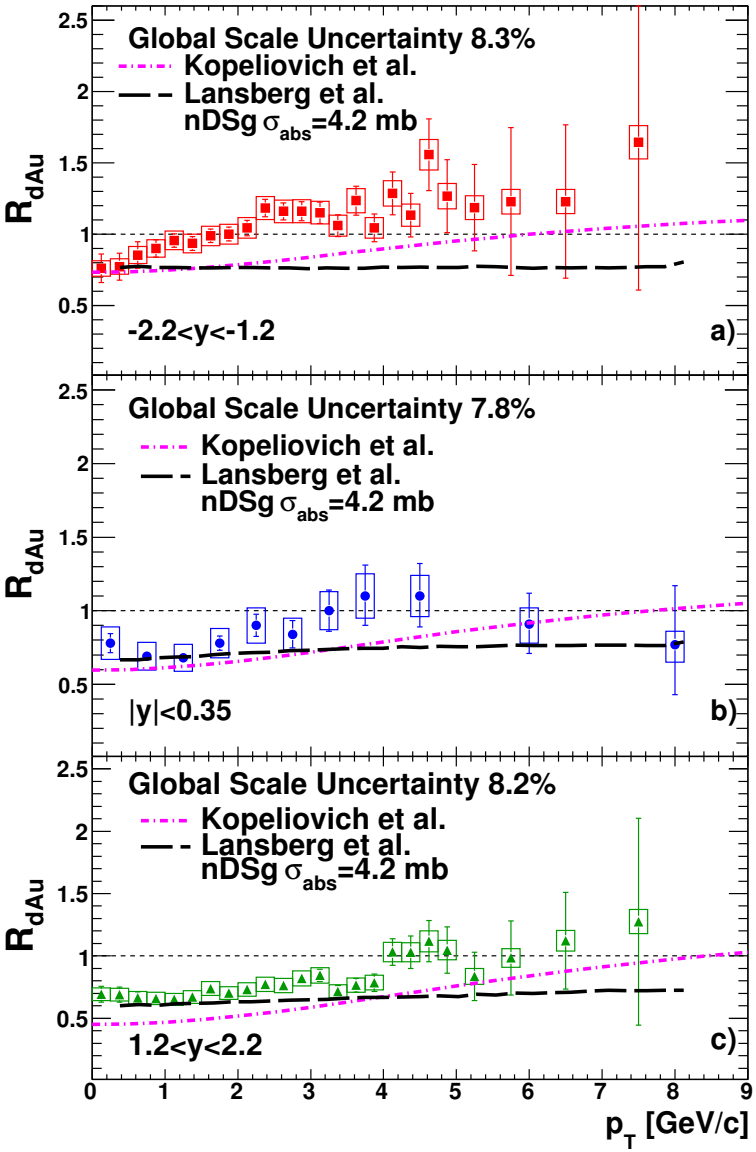
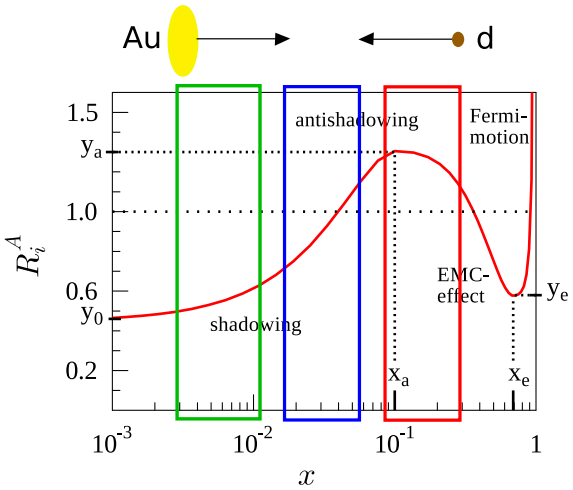
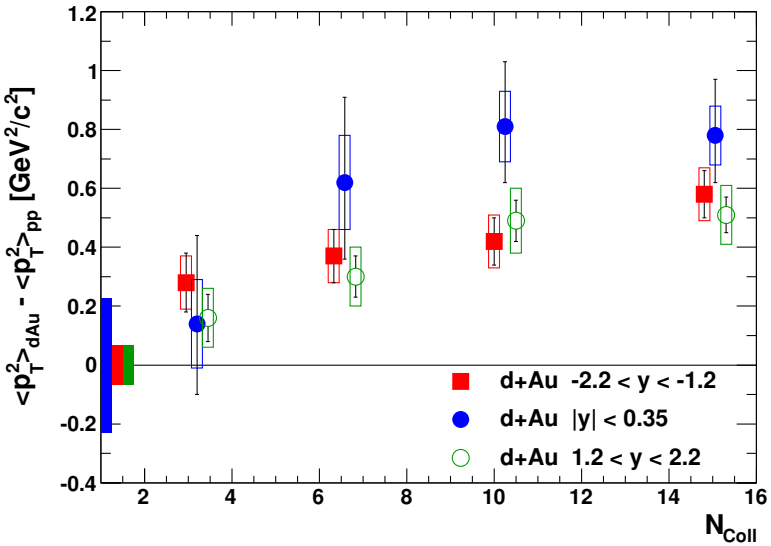
Phys. Rev. C 87, 034904 (2013)

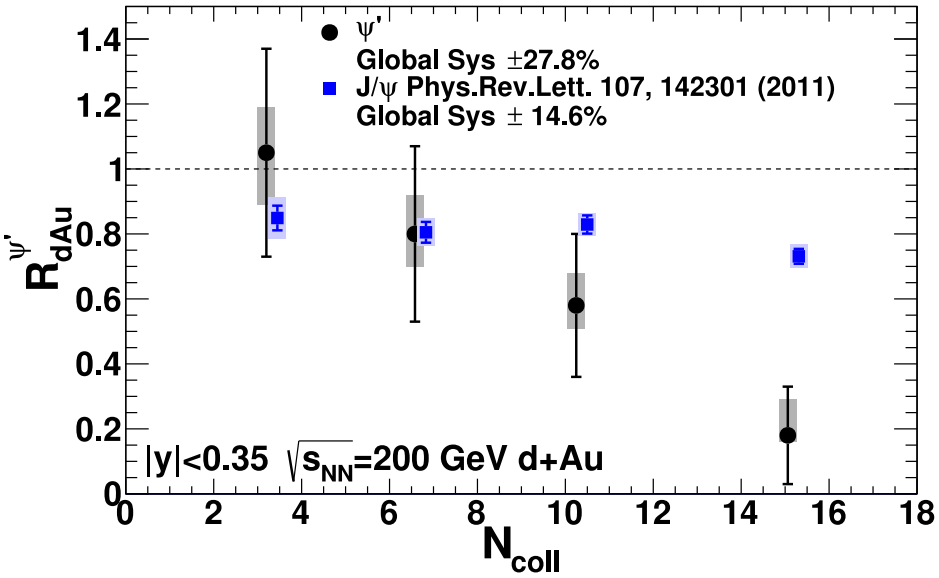




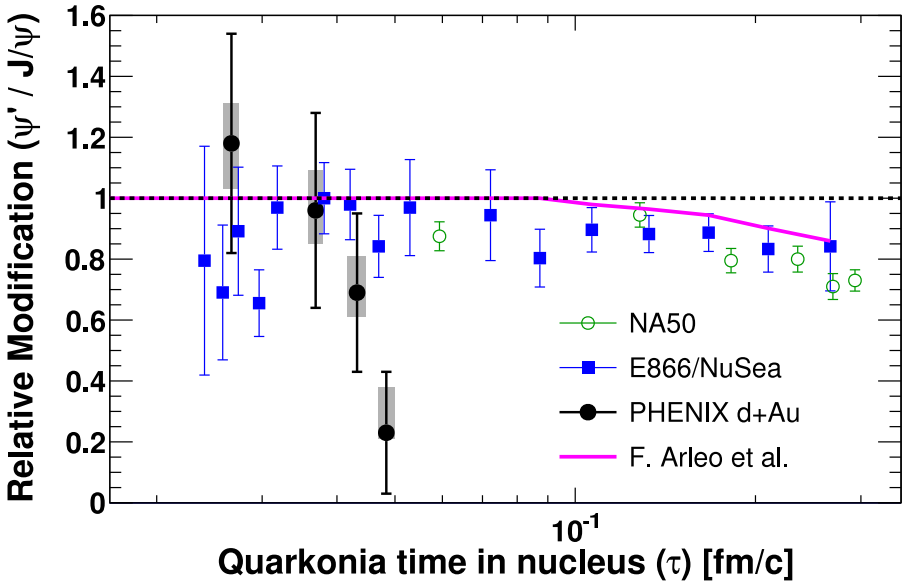


CNM effects on excited charmonia

arXiv:1305.5516



- As a function of N_{coll}, ψ' R_{dA} falls monotonically compared to J/ψ R_{dA}
- Simplistic explanation: ψ' easier to breakup in CNM than J/ψ due to size (larger breakup cross section)



- $R_{dA}(\psi')/R_{dA}(J/\psi)$ as a function of time in nucleus from PHENIX with data from other p+A experiments
- Invalidates a model that explains existing data in terms of an expanding pre-resonance (color neutral) $c\bar{c}$ state up until formation time

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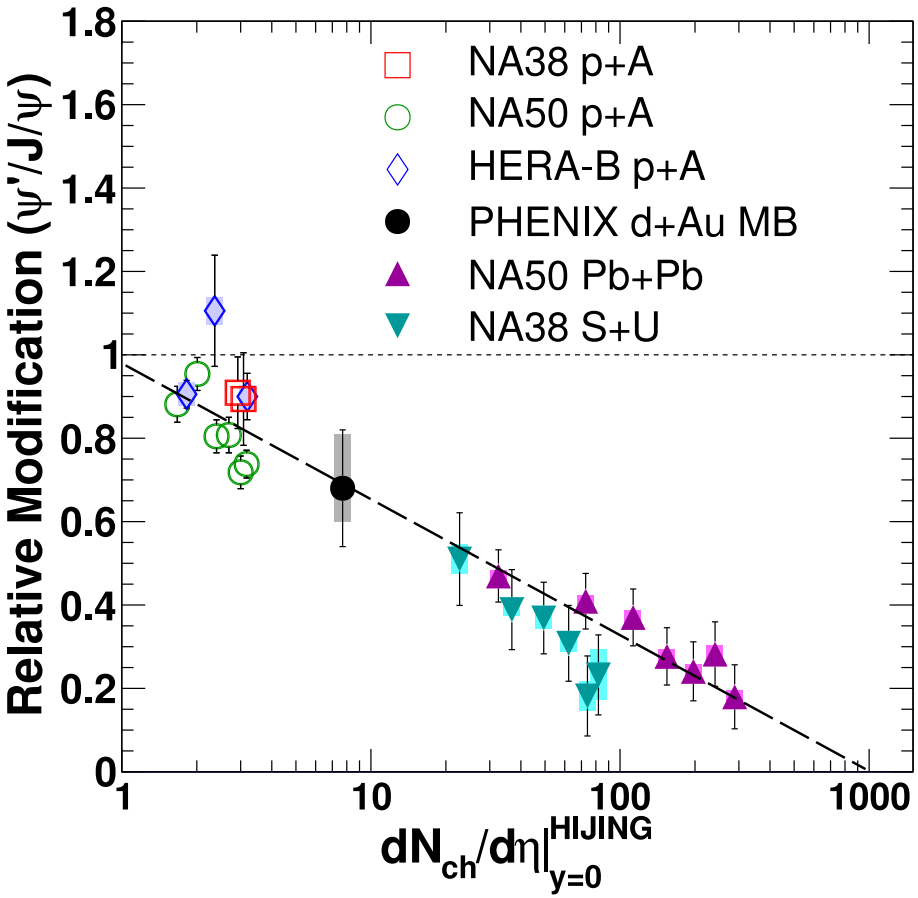

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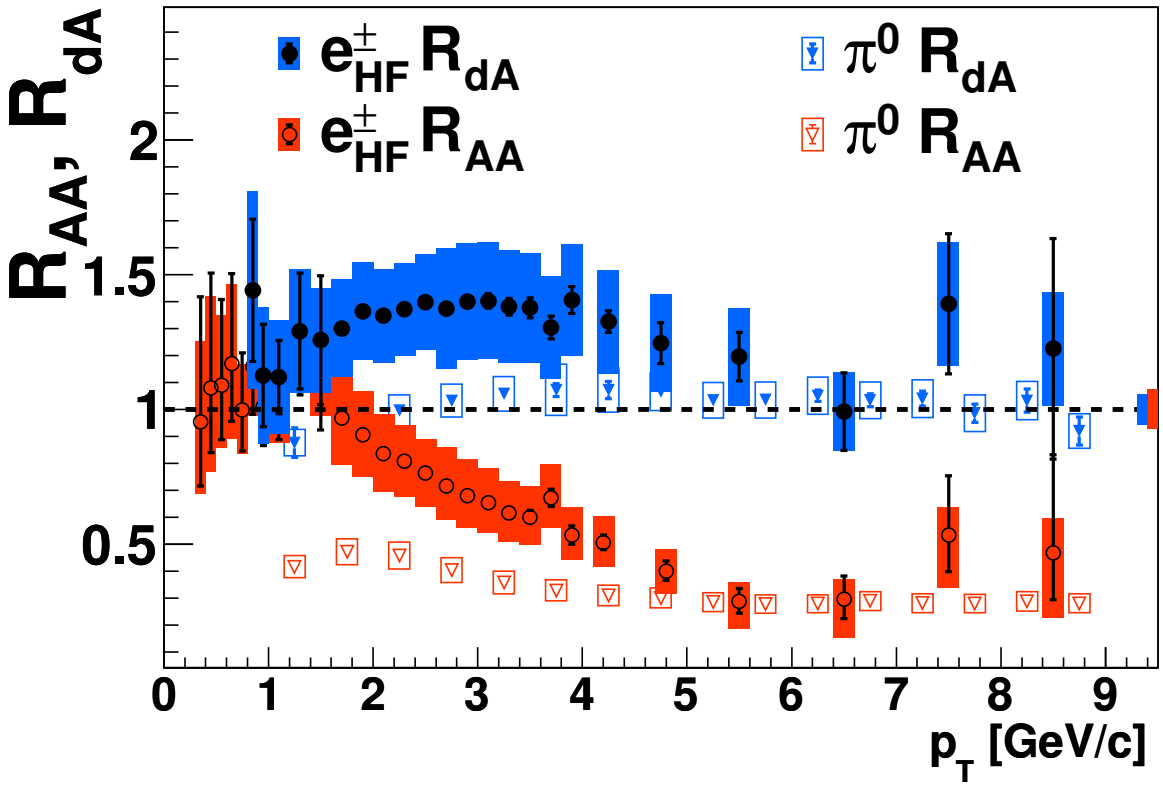
- $R_{dA}(\psi')/R_{dA}(J/\psi)$ from PHENIX data falls into world trend when plotted vs. charged multiplicity at mid rapidity (Comovers?)

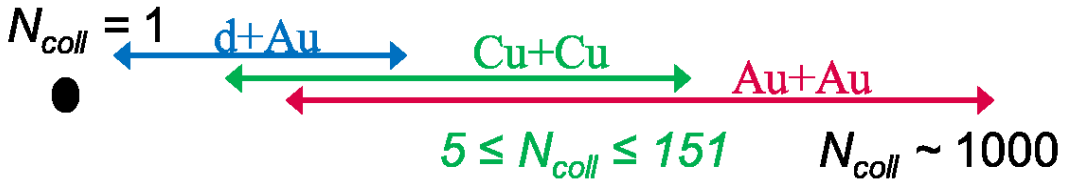
Open heavy flavor: unbound $Q\bar{Q}$ states

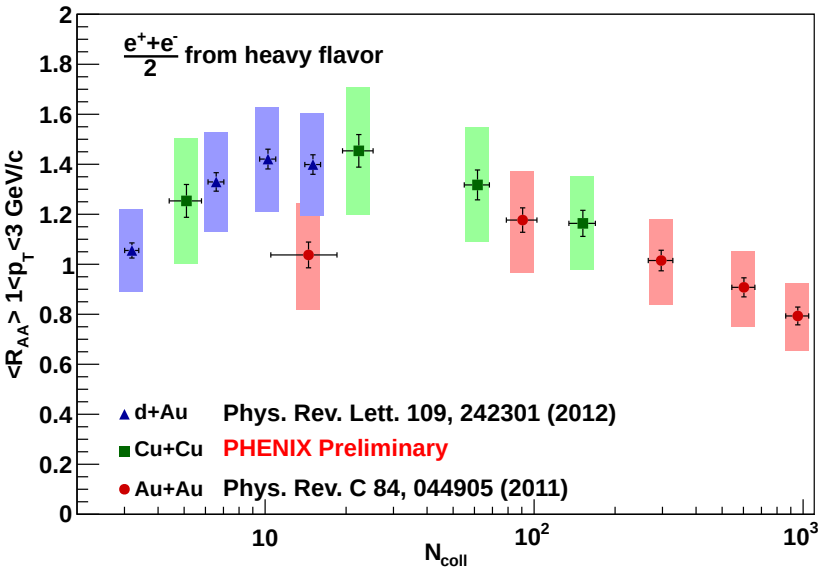


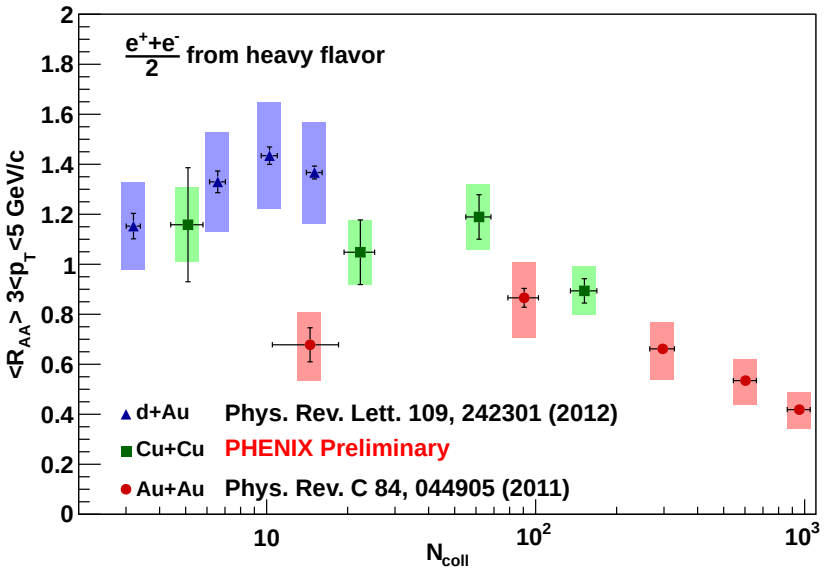
Phys. Rev. Lett. 109, 242301 (2012)

- Semileptonic decay of heavy flavor (no direct b-c separation)
- Share some initial state effects with quarkonia (Saturation, nPDF modification)
- Intrinsically useful: constraints on specific viscosity (η/s) of medium in A+A
- Suppression of HF $e^{\pm}$ in A+A wrt. d+Au baseline very similar to much lighter π^0
  $\Longrightarrow$ η/s very close to conjectured quantum limit of $1/4\pi$

N_{coll} dependence of HF electron modification

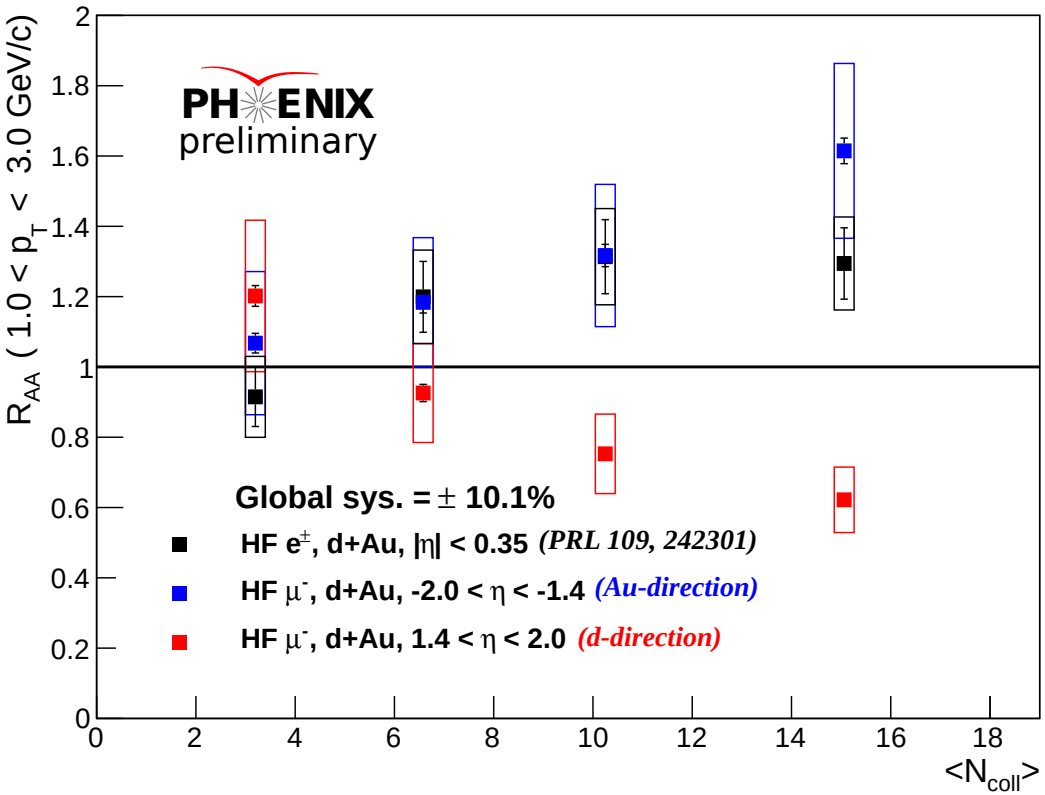






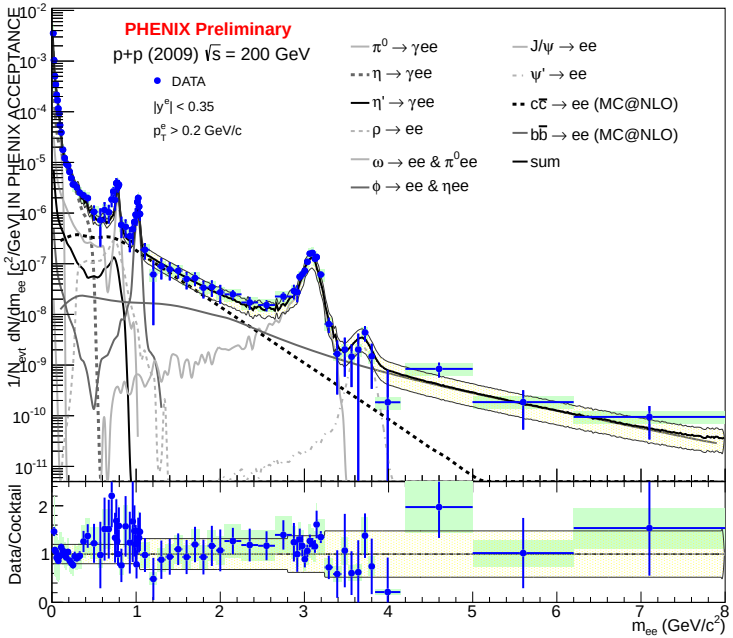
- Suppression as a function of N_{coll} covering three systems (d+Au, Cu+Cu and Au+Au)
- $R_{dA} \approx 1$ for peripheral d+Au, followed by enhancement for increasing N_{coll} and finally suppression in most central Au+Au events

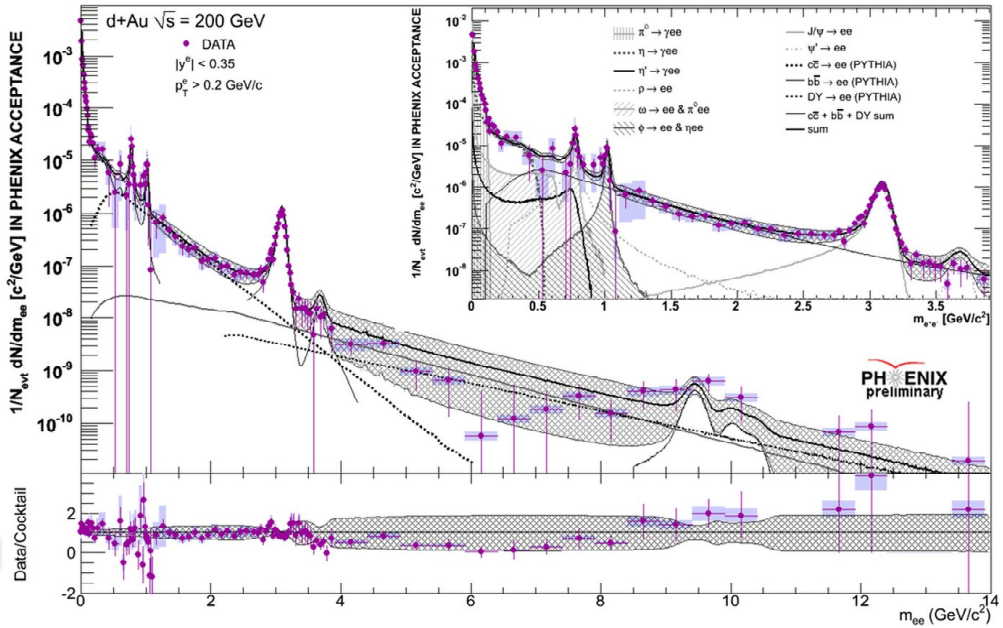
Rapidity dependence, Cronin effect?



- Consistent with J/ψ $R_{dA}(p_T)$: R_{dA} (backward rapidity) $>$ R_{dA} (forward rapidity)
- Unlike J/ψ, mid rapidity close to backward rapidity, currently not understood

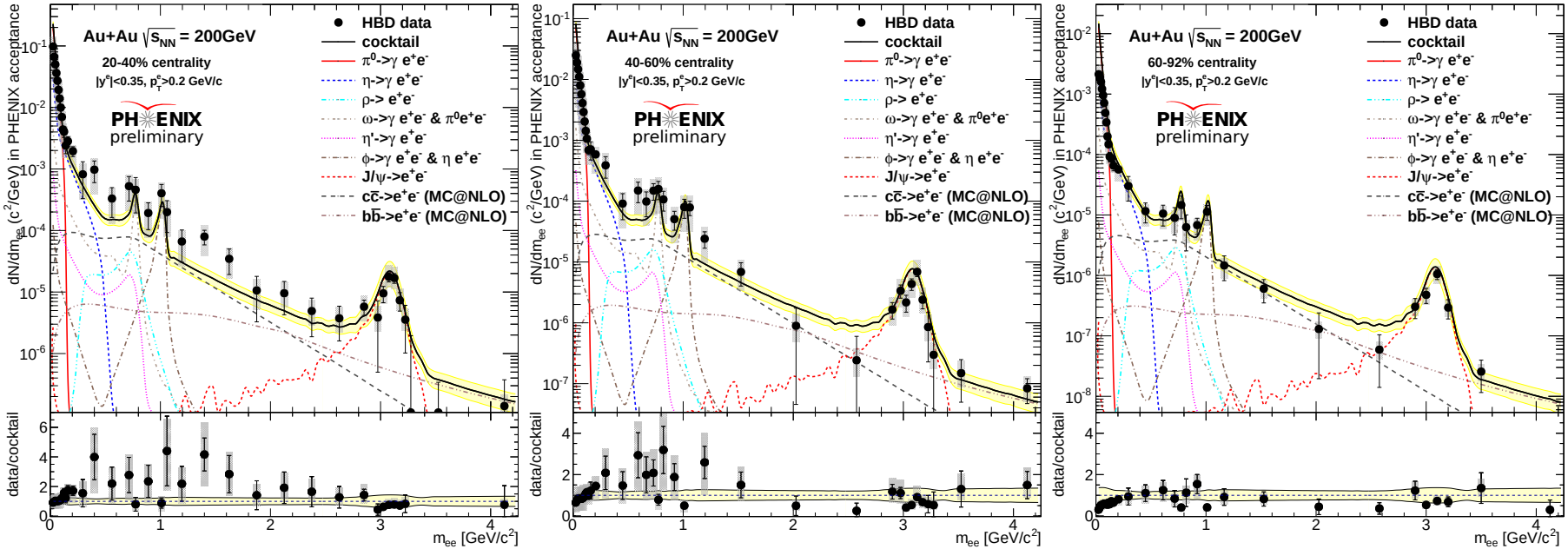
Dielectron continuum measurements, p+p, d+A





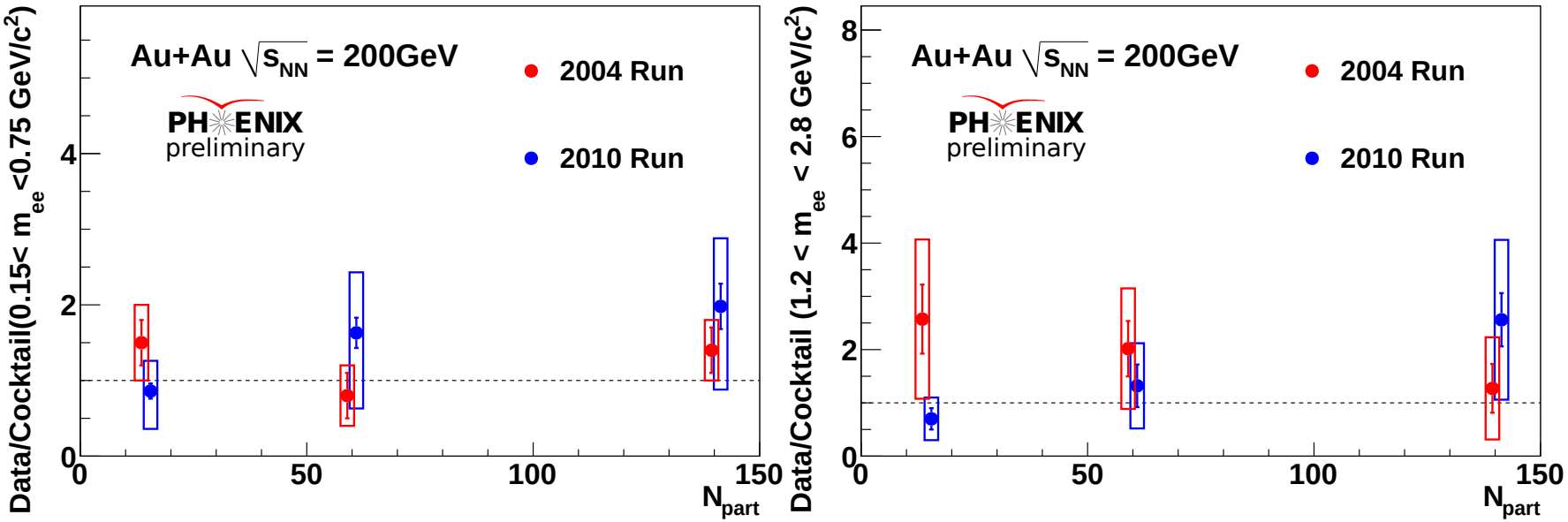
- Rich source of physics probes: quarkonia, HF, direct-γ, vector mesons, etc..
- New results from p+p (using HBD) and d+Au
- d+Au spectra show good agreement with expectation from all known hadronic decays

Dielectron continuum measurements Au+Au



- Semi-central to peripheral Au+Au using the HBD (work on central bins ongoing)

Dielectron continuum measurements Au+Au



- Semi-central to peripheral Au+Au using the HBD (work on central bins ongoing)
- Data/cocktail ratios in two mass regions consistent with previous published results, and show consistency with cocktail within systematic uncertainties

Direct photons: pQCD and thermal

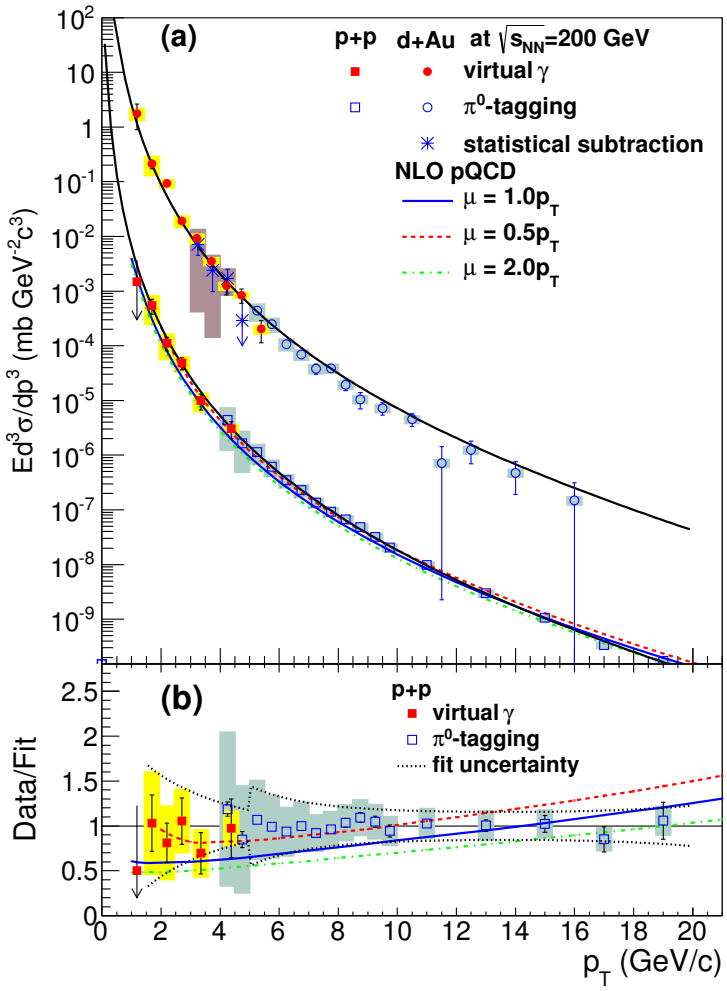
Phys. Rev. C 87, 054907 (2013)

Measurement methods

- High p_T: π^0 tagged/statistical subtraction (with overlap region)
- Low p_T: Internal conversion (low mass high p_T dileptons) and external conversion method

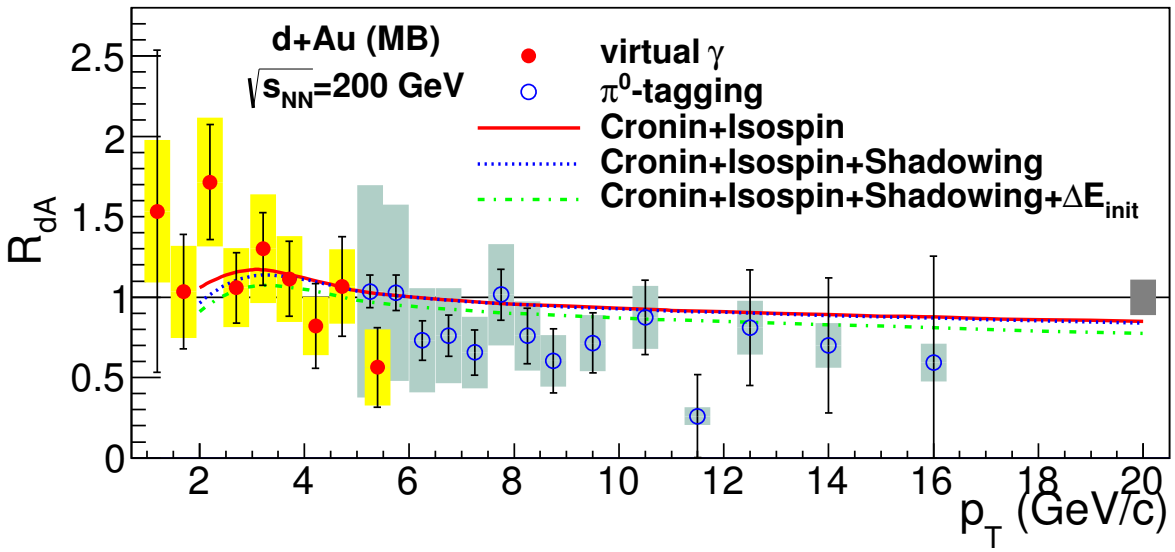
Sources of photons

- Low p_T: Dominated by thermal source (Time averaged medium temperature)
- High p_T: pQCD (Gluon Compton Scattering), fragmentation, Quark-jet conversion



Modification of direct photons

Phvs. Rev. C 87, 054907 (2013)



- d+Au yield consistent with multiple scenarios of CNM effects
- Consistent with R_{dA} of 1.0

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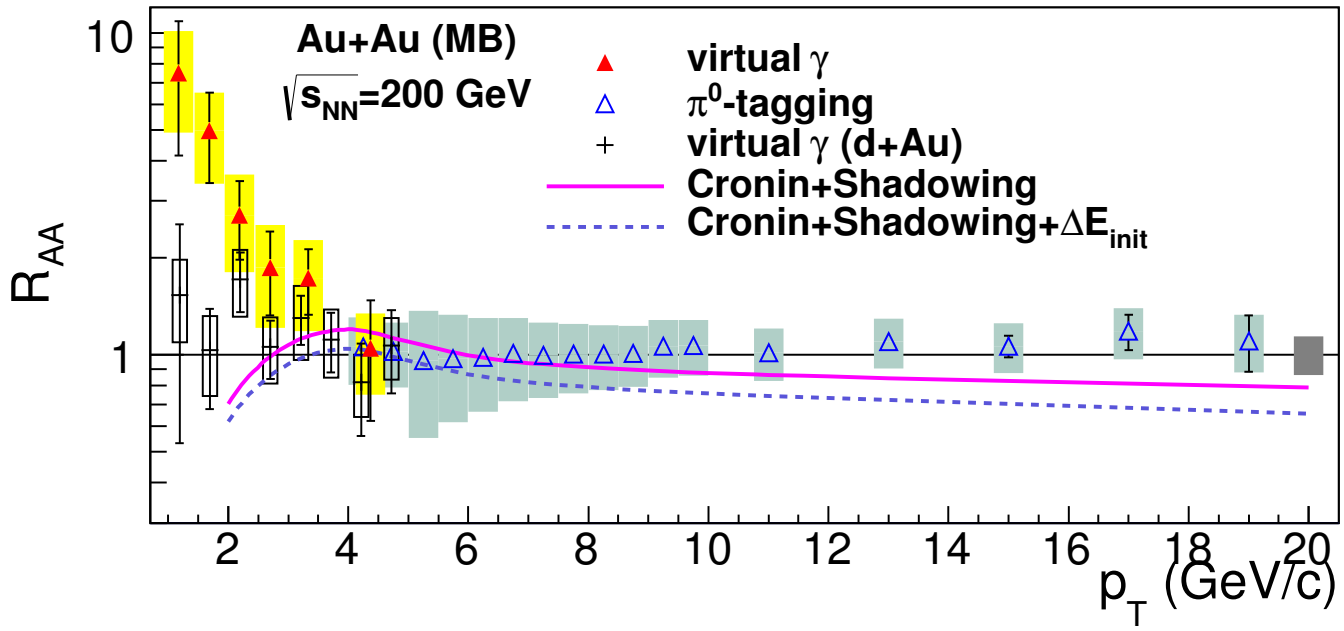
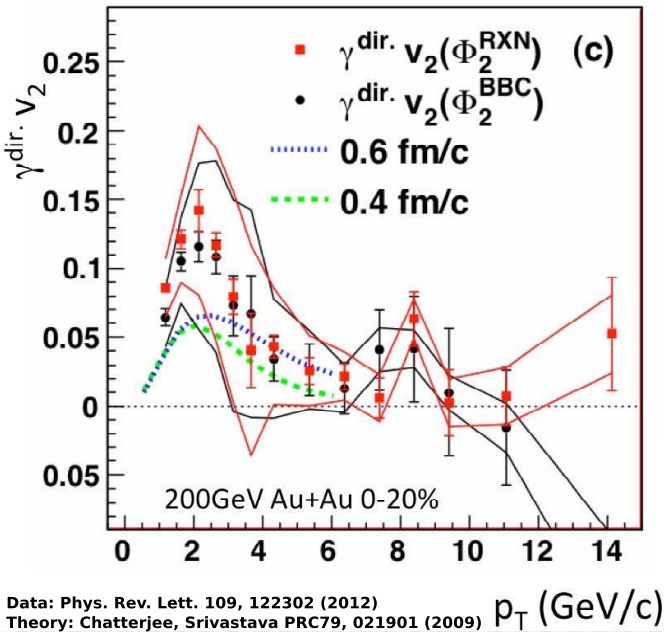
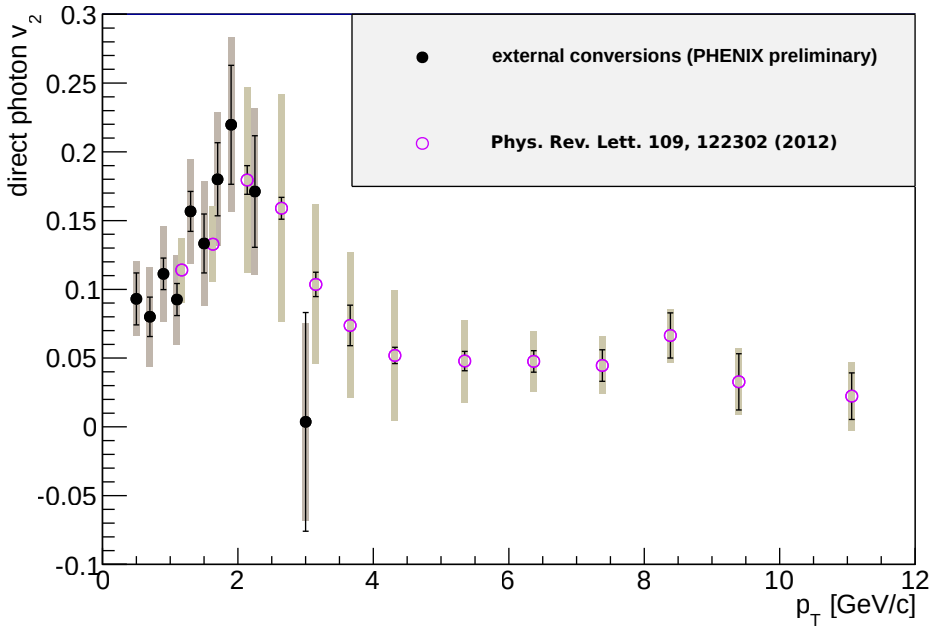
Phys. Rev. C 87. 054907 (2013)



- Au+Au yield consistent with R_{AA} of 1.0 at high p_T
- Strong deviation from scaled p+p below 4 GeV/c^2
  $\Longrightarrow$ Means to measure temperature (another QGP thermometer)

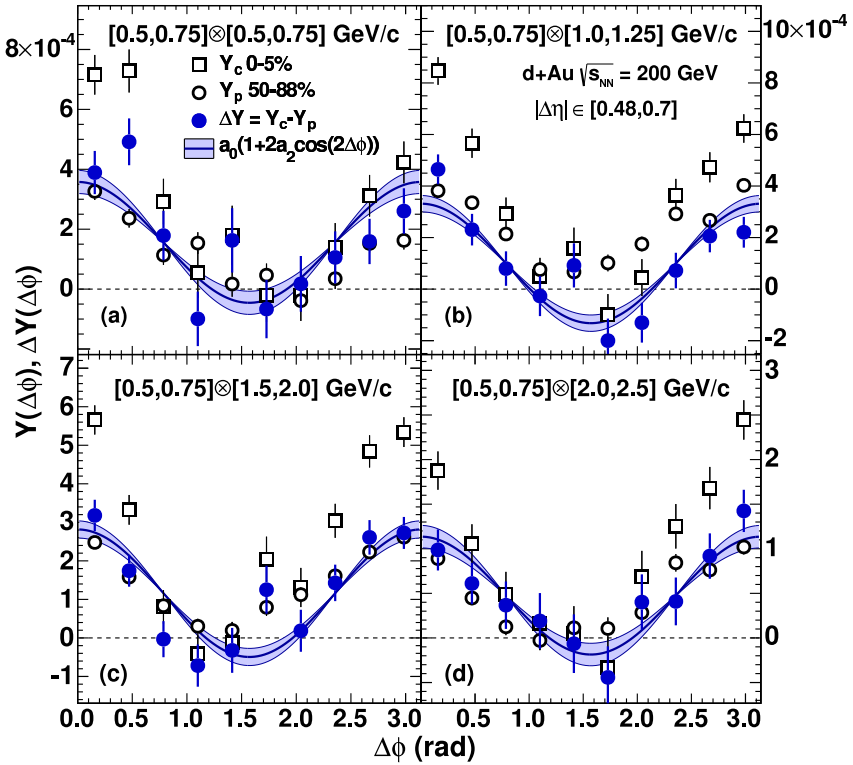
Flow of direct photons

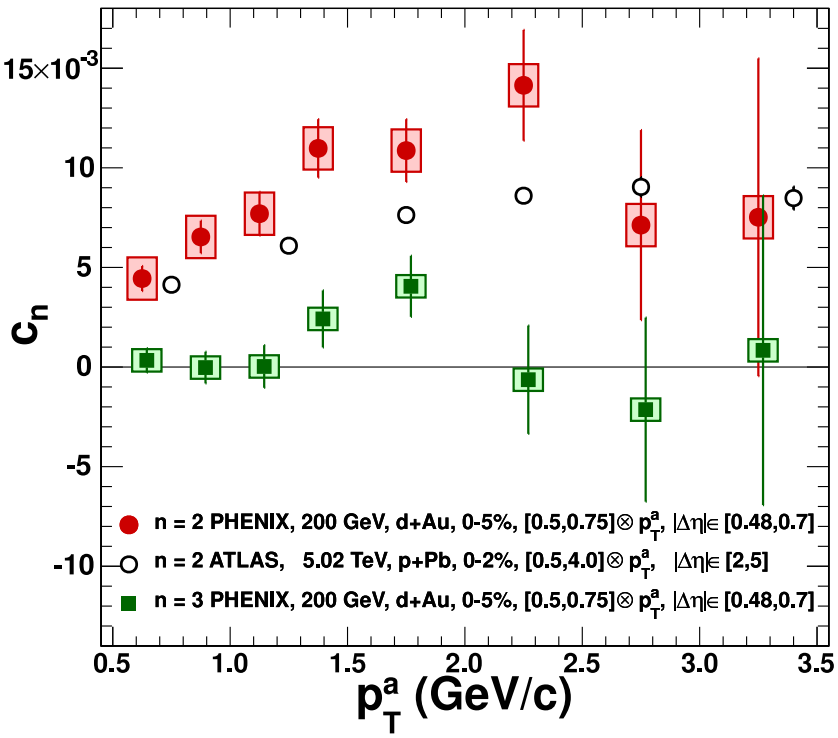




- Large p_T coverage (1-13 GeV/c^2), confirmed by external conversion method
- At high p_T
  - $v_2 \approx 0 \implies$ initial hard scattering
  - Not excluded: quark-jet conversion, fragmentation, negative but low v_2
- At low p_T:
  - Excess yield in Au+Au $\implies$ early production (temperature, rate fall rapidly with time)
  - Large $v_2 \implies$ late production (after flow is fully developed)
  - Reconciling these two big challenge to models

Anisotropy in d+Au



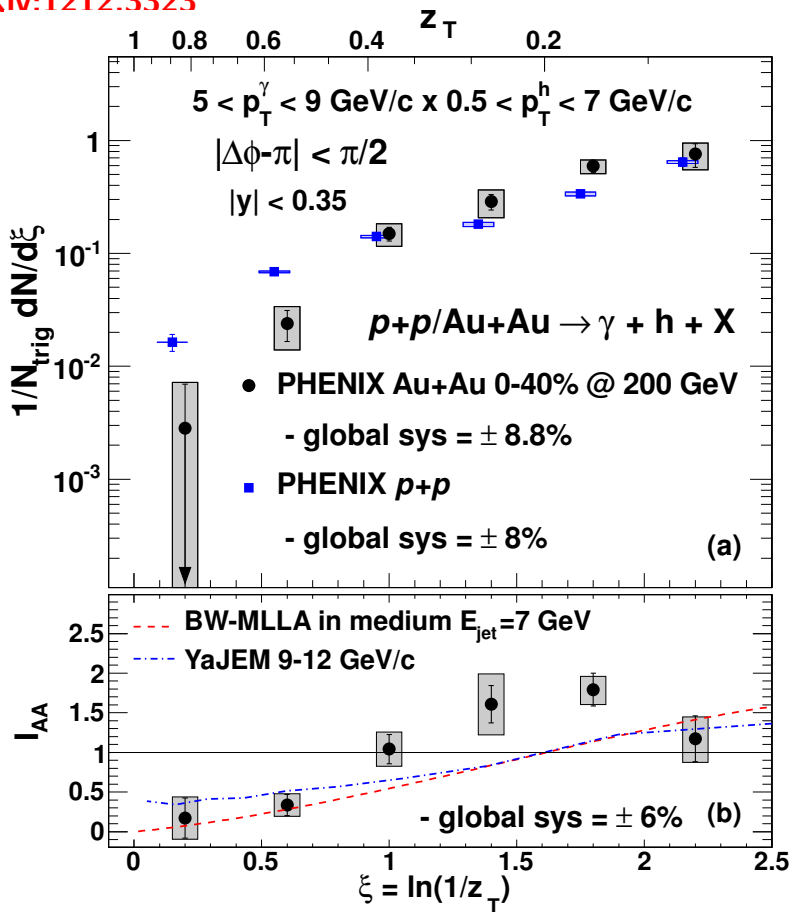


arXiv:1303.1794

- Subtract centrality independent correlations (jets and resonances) from central (0-5%) d+Au conditional yields estimated by peripheral d+Au conditional yields
- Remaining signal shows quadrupolar anisotropy not unlike Au+Au events
- Large second order moment, larger than at LHC with p+Pb, consistent with the increase in participant eccentricity going from p+Pb to d+Au. Small third order moment.
- Currently not clear if caused by collectivity or initial state parton saturation

Photon-hadron correlations

arXiv:1212.3323



- γ-h correlations: calibrated energy of recoiling parton
- Fragmentation function:
  - $D(z_T) = dN/dz_T$
    where $z_T = z_T^h / p_T^\gamma$ (p_T^γ proxy for p_T^{jet})
- $D(z_T)$ in Au+Au wrt. p+p shows suppression at high z_t and enhancement at lower z_T: medium modification of jet fragmentation

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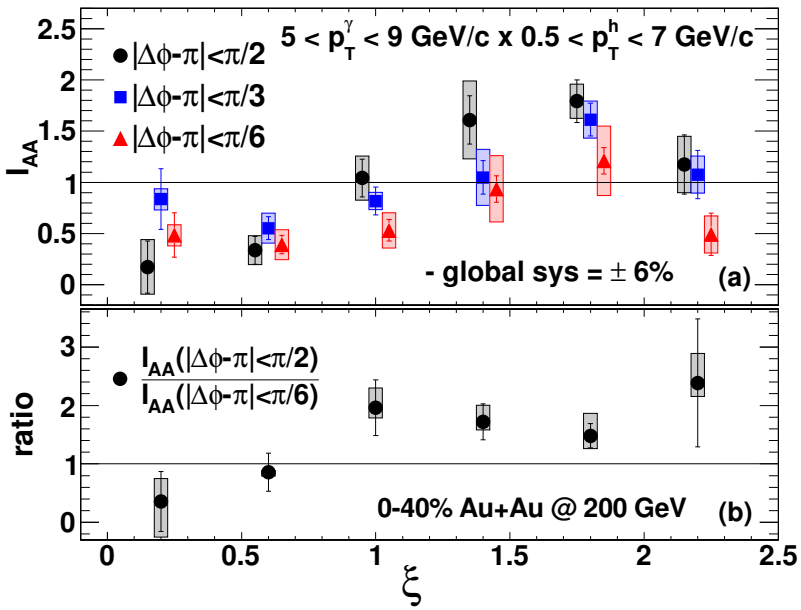

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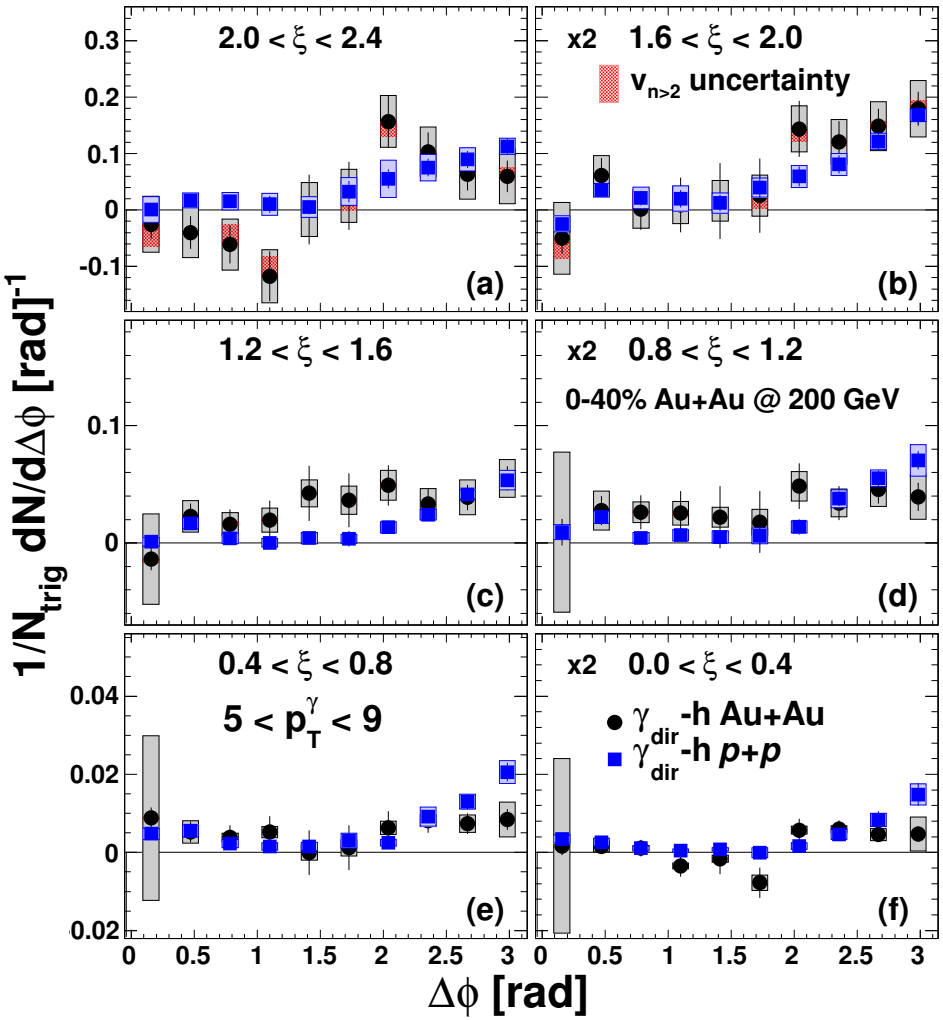
- $D(z_T)$ in Au+Au wrt. p+p shows suppression at high z_t and enhancement at lower z_T: medium modification of jet fragmentation
- Looking as a function of away side integration angle: the lost energy of leading partons goes to enhance low p_T fragments at larger angles

Summary

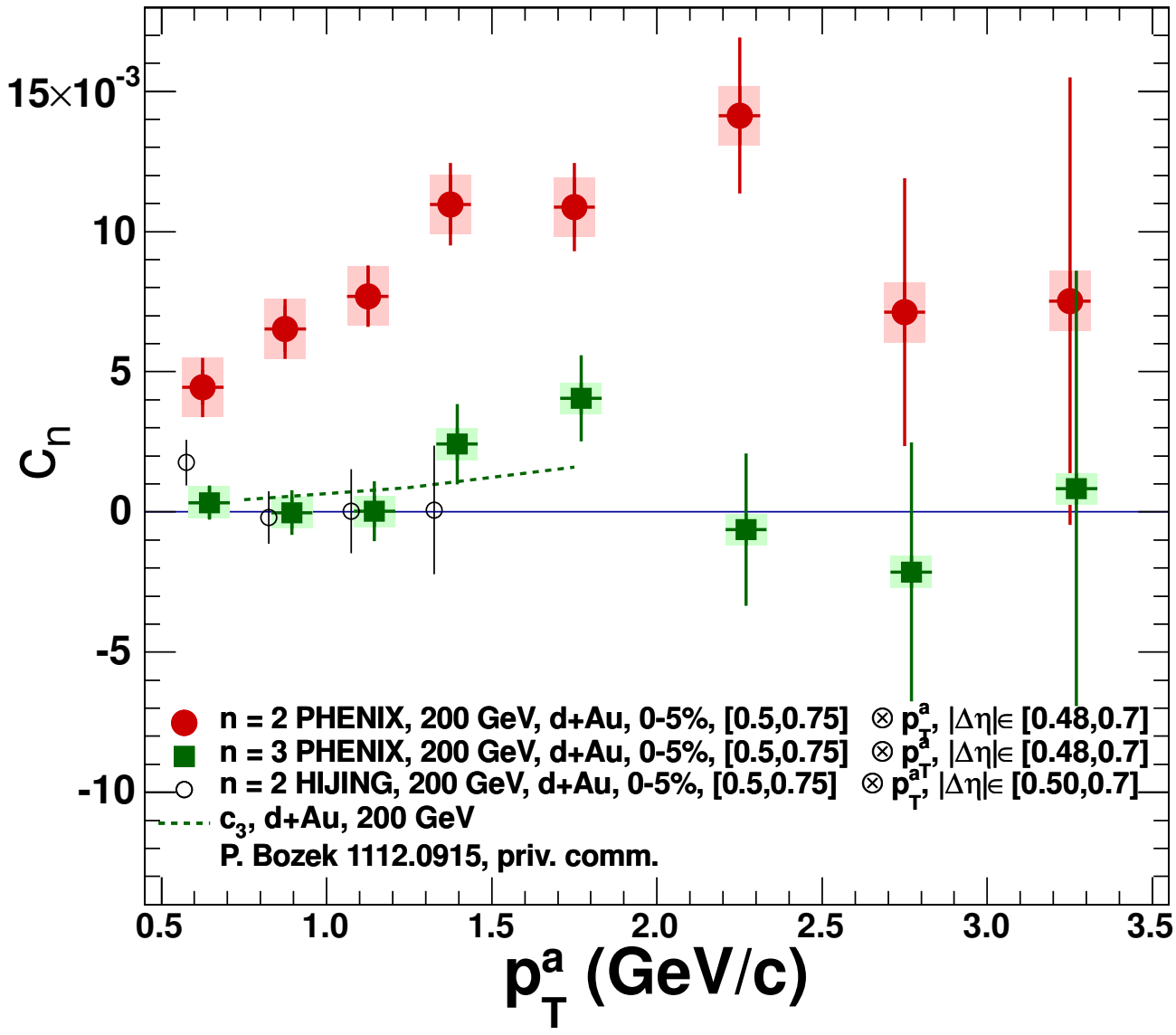
- Results on quarkonia from high luminosity d+Au collision confirm competing effects such Cronin enhancement and CNM breakup can influence interpretation of Au+Au results
- HF $e^{\pm}$ suppression in hot medium comparable to π^0 when Cronin-like enhancement in d+Au is taken into account, suggesting even lower specific viscosity attained in QGP
- Simultaneous explanation of large direct photon flow and enhanced spectra in Au+Au, both confirmed by independent analysis method, is a challenge to theoretical models
- γ-hadron correlation studies with higher statistics confirm medium modification of jets with lost energy going into soft particle production at larger away side angles

Backup Slides

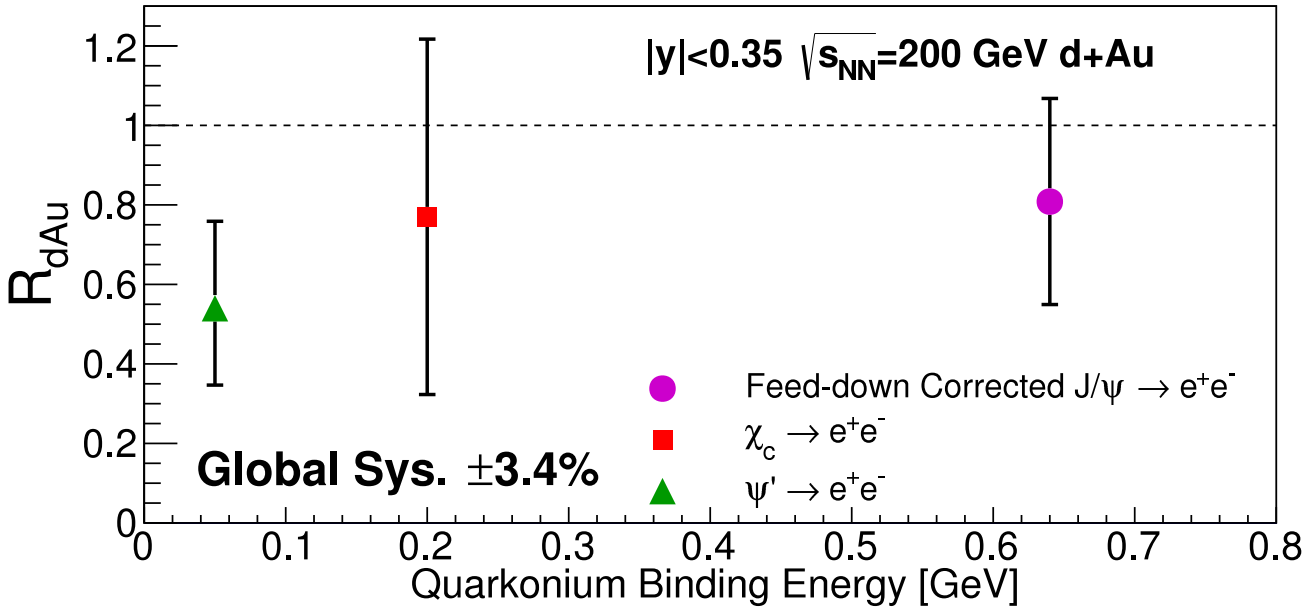
γ-h correlation functions



Anisotropy in d+Au compared to HIJING



Feed down from excited charmonia



- 42±9% of observed J/ψ in p+p are feed down from ψ' (9.7±2.4%) and χ_c (32±9%)
- Affects interpretation of d+Au and Au+Au due to the difference of binding energy
- B.E. of ψ' and χ_c smaller than J/ψ $\Longrightarrow$ up to 42% of observed J/ψ suppression can come be attributed to breakup and/or melting of ψ' and χ_c
- Prompt J/ψ R_{dA} is larger than apparent R_{dA}