

Cold nuclear matter effects on ϕ meson and heavy flavor production in d+Au collisions at $\sqrt{s_{NN}} = 200$ GeV

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Motivation

Understand cold nuclear matter effects in order to disentangle hot nuclear (QGP related) effects in A+A collisions.

Cold nuclear matter effects: Modification of the production cross section in a nuclear target. Generally depend on rapidity, p_T , and mass of the probe.

$$R_{dAu} = \frac{d^2 N_{dAu}/dydp_T}{N_{coll} \times d^2 N_{pp}/dydp_T}$$

CNM effects include:

- **Shadowing** – modified parton distributions in nuclei
- Initial state energy loss of partons
- Cronin effect – multiple elastic scattering of partons
- **Breakup** of precursor quarkonia by nucleon collisions during the nuclear crossing

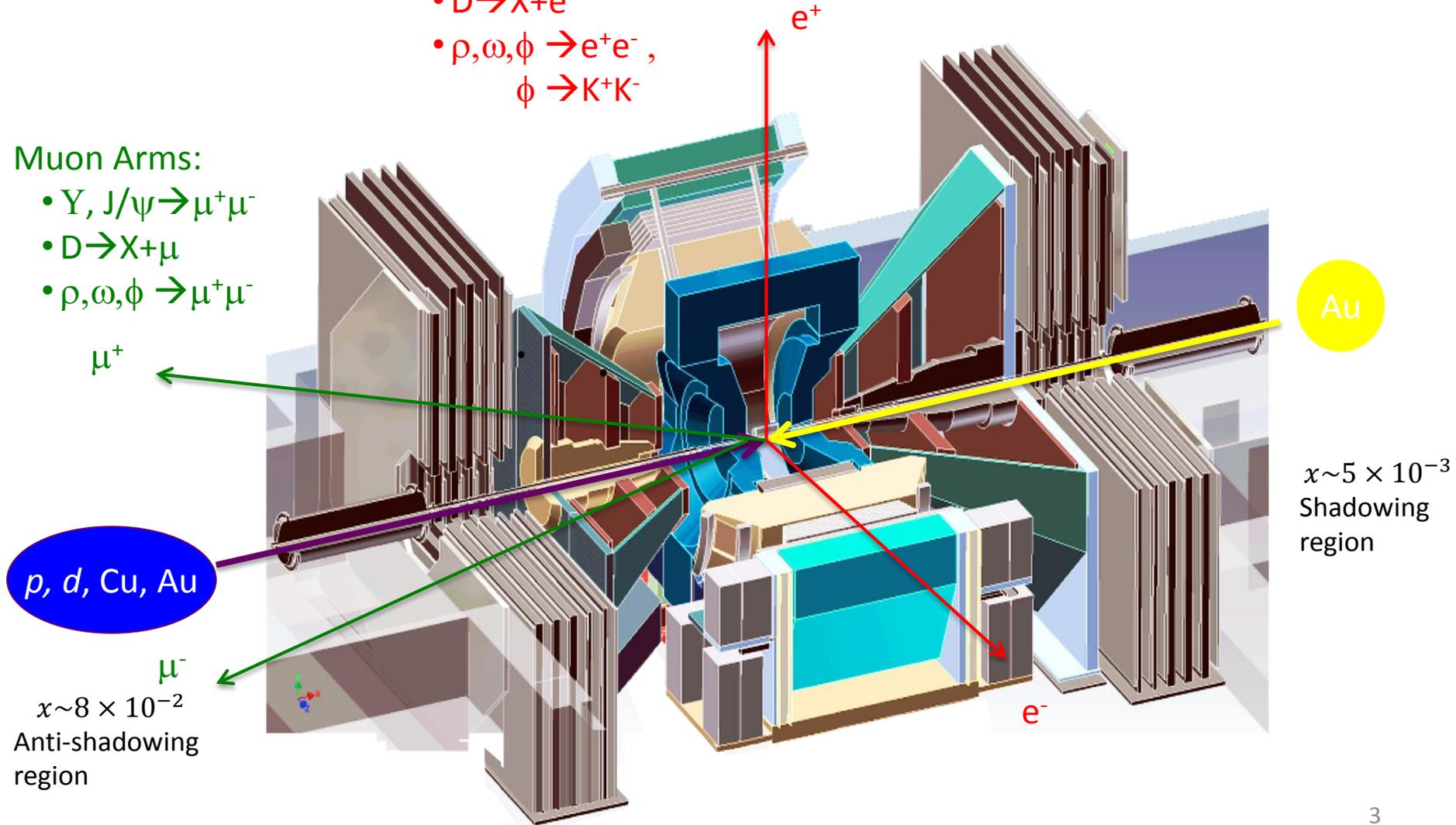
The PHENIX Detector

Central Arms:

- $Y, J/\psi, \psi' \rightarrow e^+e^-$
- $D \rightarrow X+e$
- $\rho, \omega, \phi \rightarrow e^+e^-$,
 $\phi \rightarrow K^+K^-$

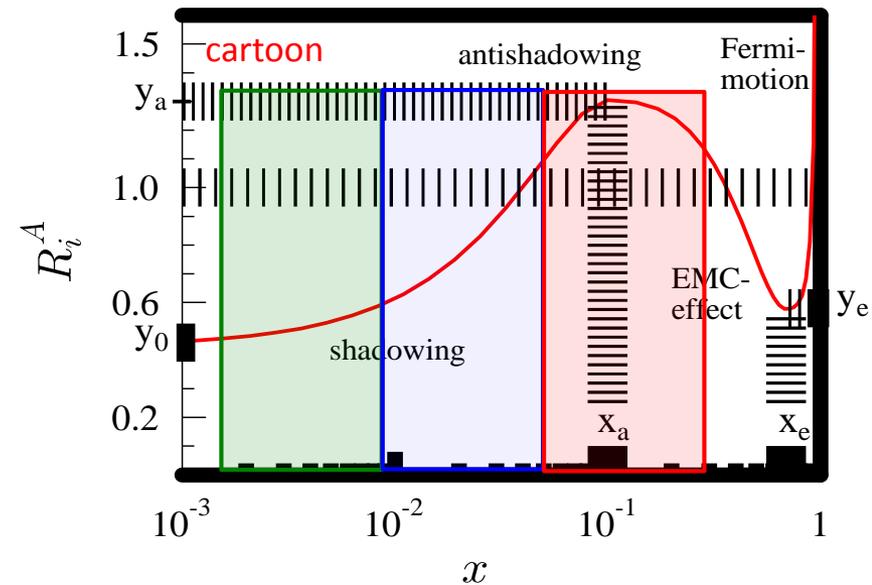
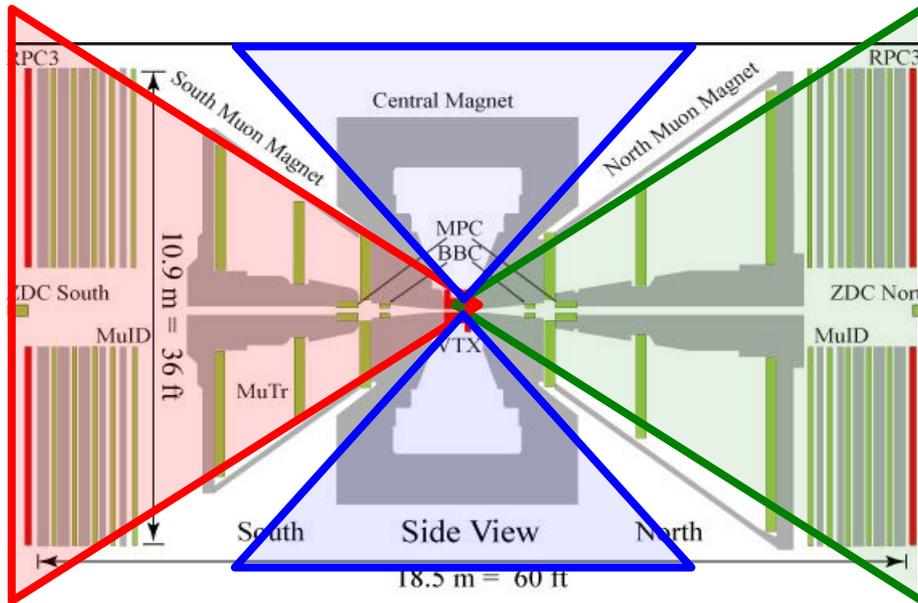
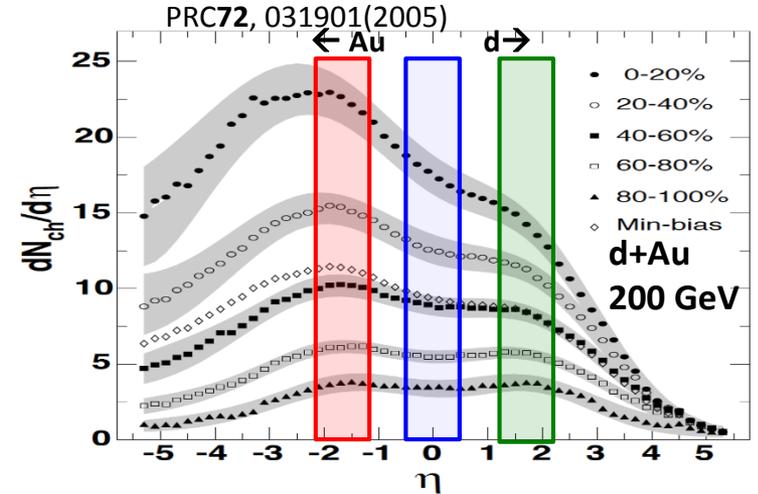
Muon Arms:

- $Y, J/\psi \rightarrow \mu^+\mu^-$
- $D \rightarrow X+\mu$
- $\rho, \omega, \phi \rightarrow \mu^+\mu^-$

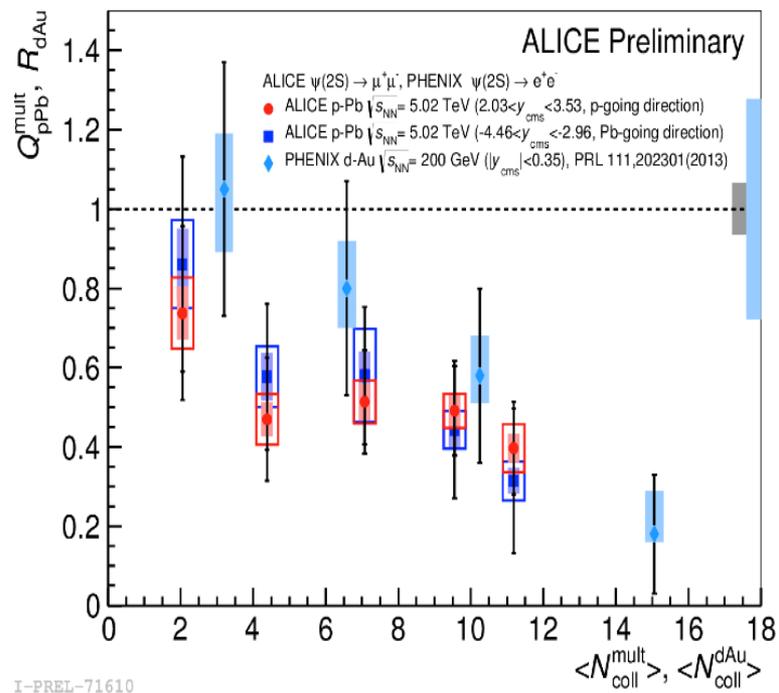
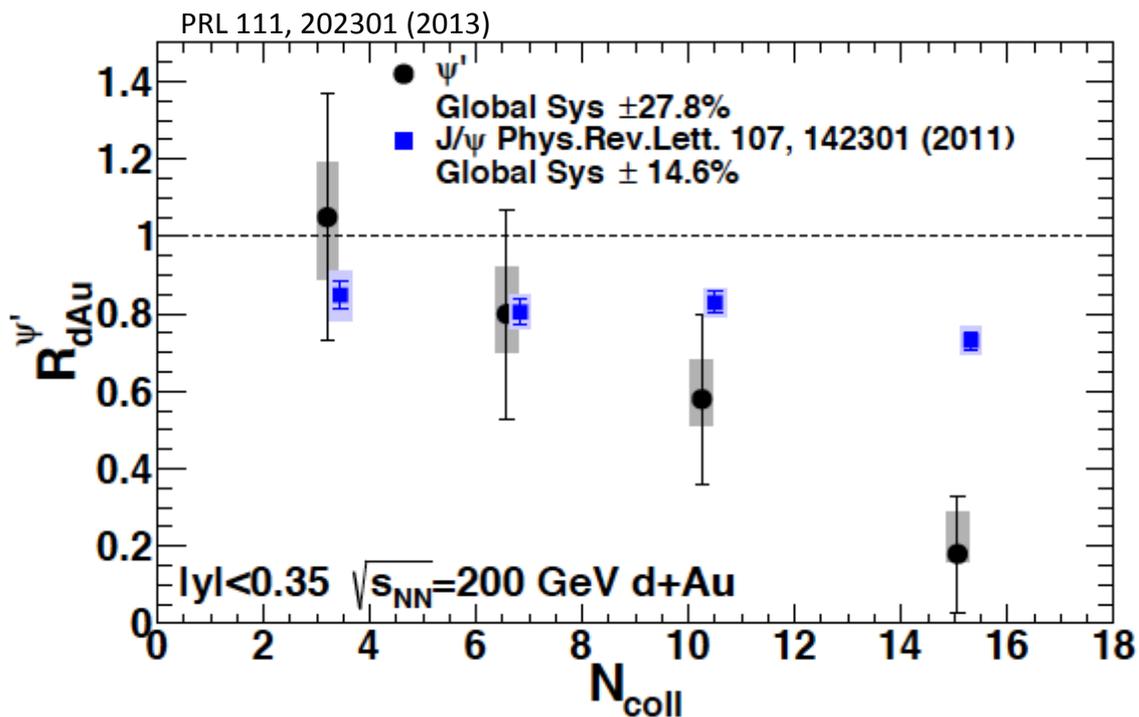


What can be done at PHENIX?

- PHENIX recorded $d+Au$ collisions in 2003 & 2008 @ $\sqrt{s_{NN}} = 200$ GeV.
- Large rapidity coverage: $1.2 < |y| < 2.2$ and $|y| < 0.35$



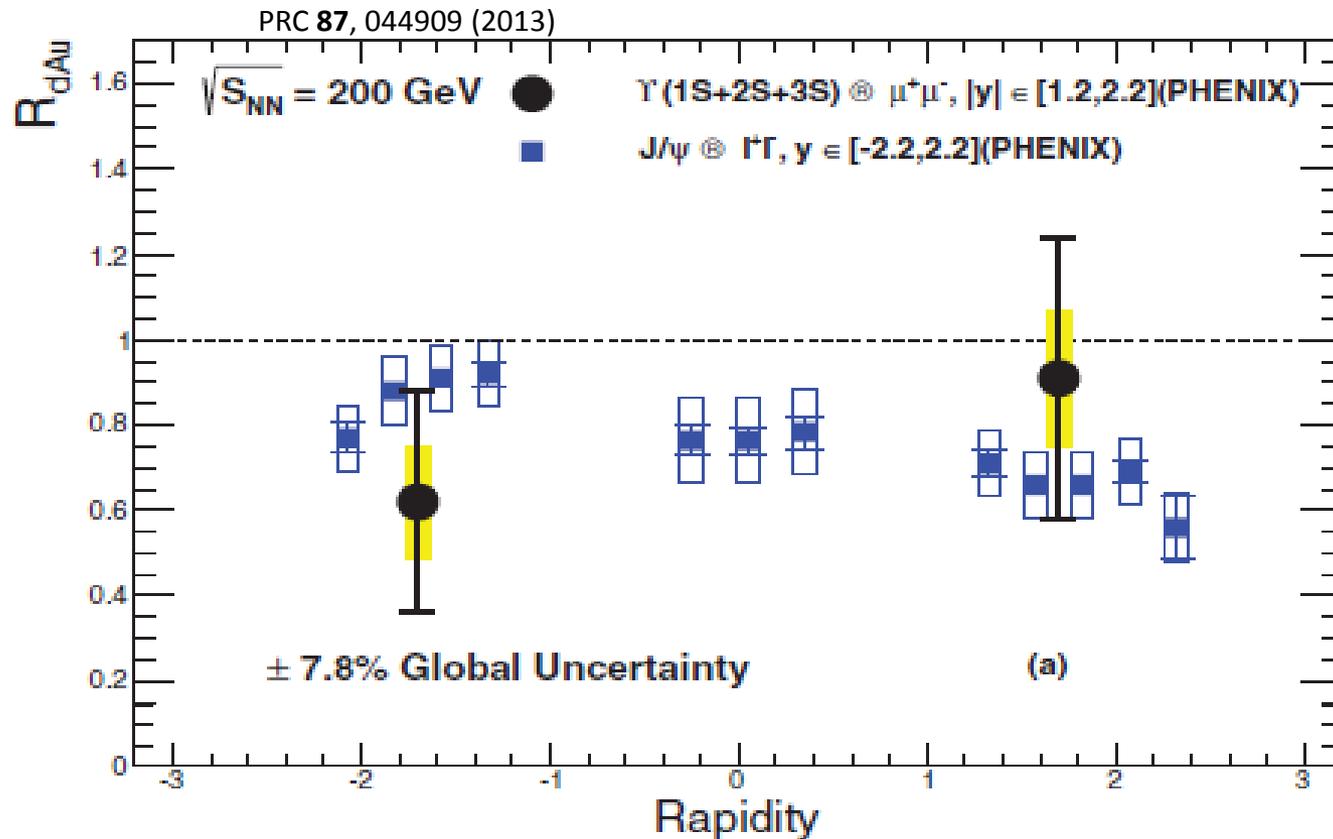
CNM for J/ψ and ψ'



- PHENIX: ψ' suppressed more than J/ψ at midrapidity rapidity, in d+Au. Time spent in nucleus (breakup) does not hold as explanation for PHENIX data.
Different effects modify the charmonium production!
- Similar behavior seen by ALICE in p+Pb collisions at 5.02 TeV

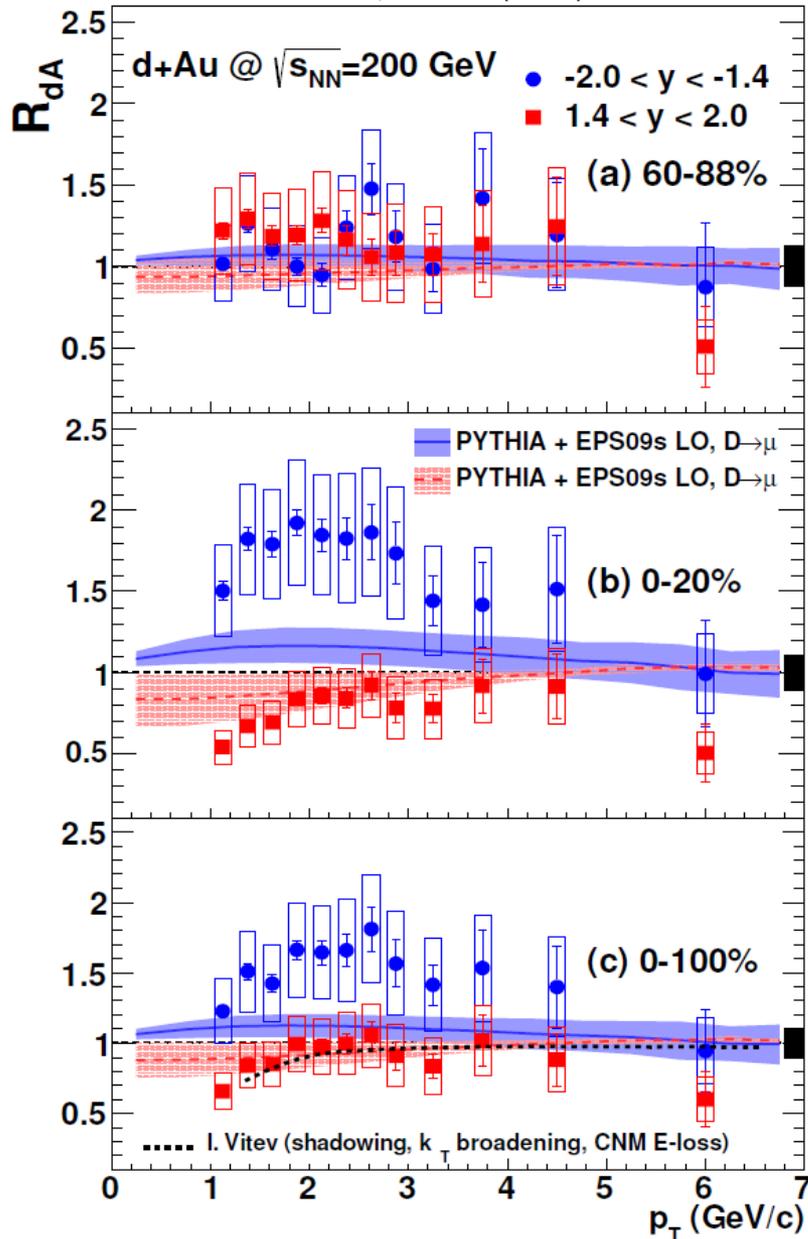
What About Upsilons?

- Possible suppression at backward rapidity (but error bars large)
- Challenging to make significantly better measurements with PHENIX.



CNM for Open Heavy Flavor

PRL 112, 252301 (2014)

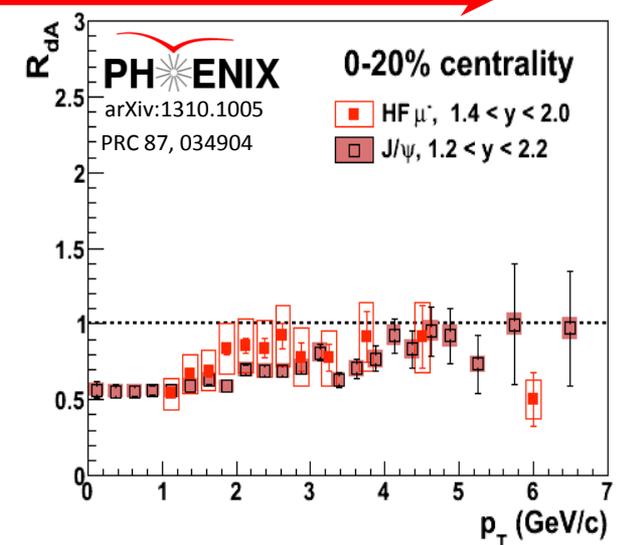
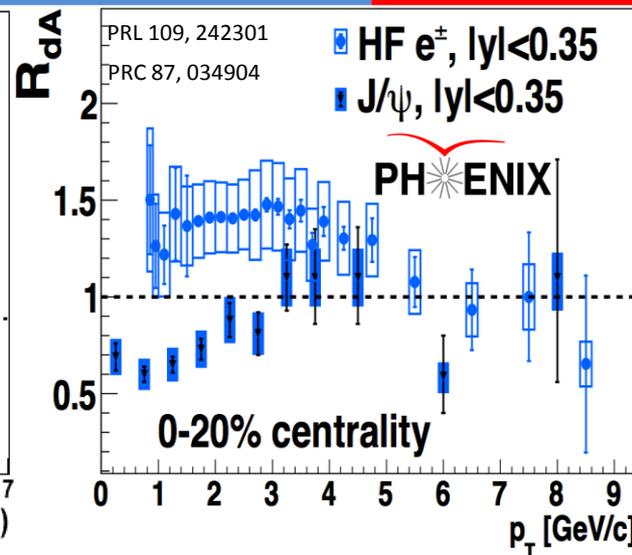
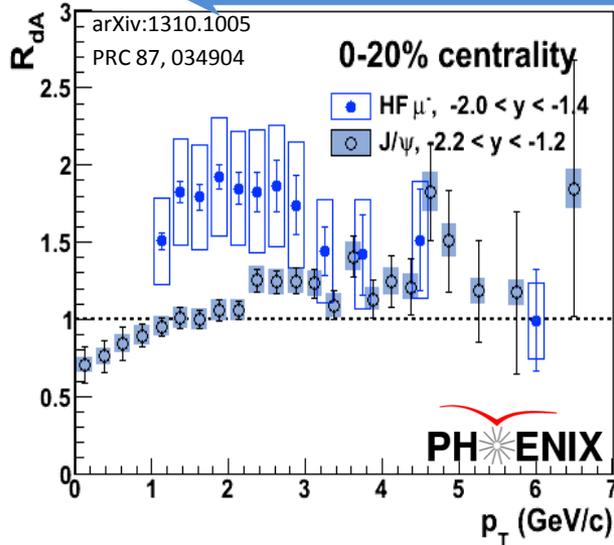


- Theoretical approaches, PYTHIA + EPS09s nPDF parameterization and the same
 - Small suppression (shadowing)
 - Good agreement w/ data
 - can't reproduce backward rapidity data?
- Vitev - shadowing + p_T broadening + Initial State E-loss
 - Increasing suppression @ low- p_T
 - Better reproduces low- p_T behavior seen in data

Open vs closed Heavy Flavor

← Higher final particle density

→ Probing lower- x gluons in Au



❖ Caveat: Different kinematics

Backward & Mid Rapidity

- DIFFERENT behavior
- **Enhancement** in OHF **suppression** in J/ψ

⇒ Evidence for cc breakup effects?

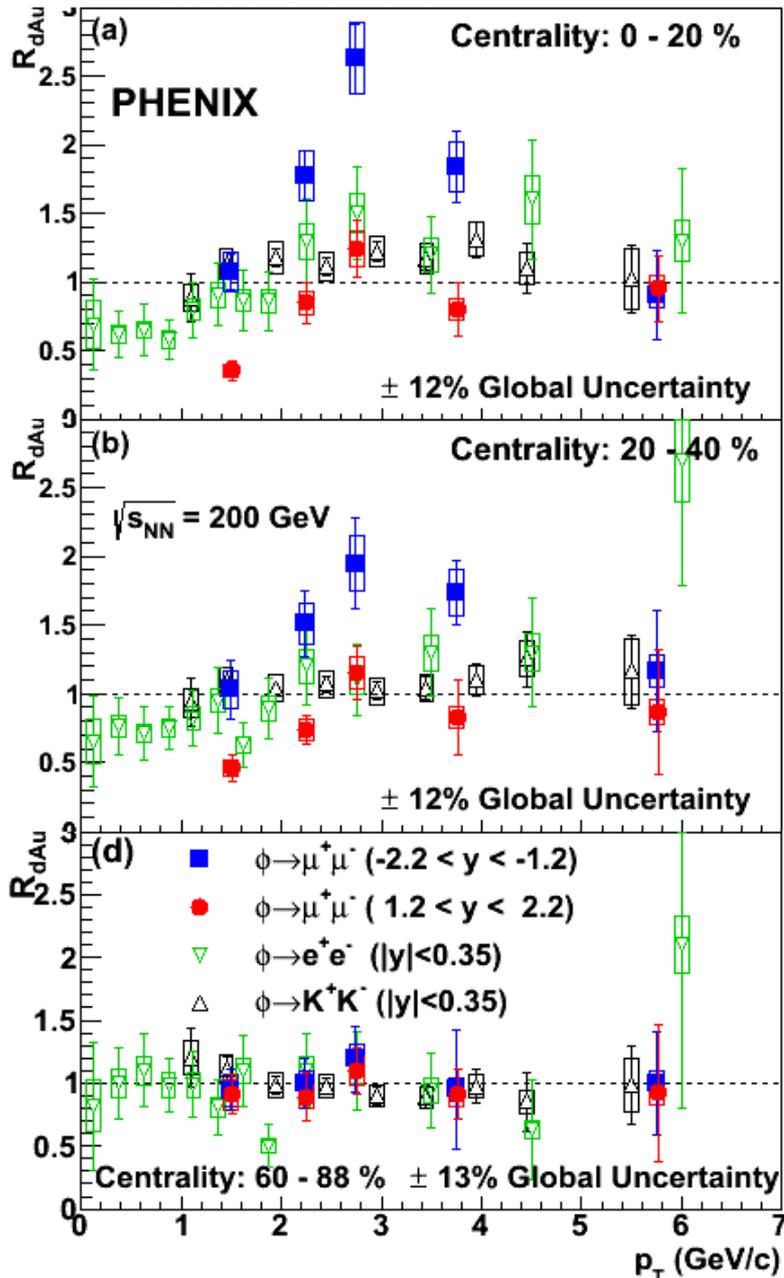
Forward Rapidity:

- SIMILAR behavior
- Short time traversing nuclei
- Low comover density

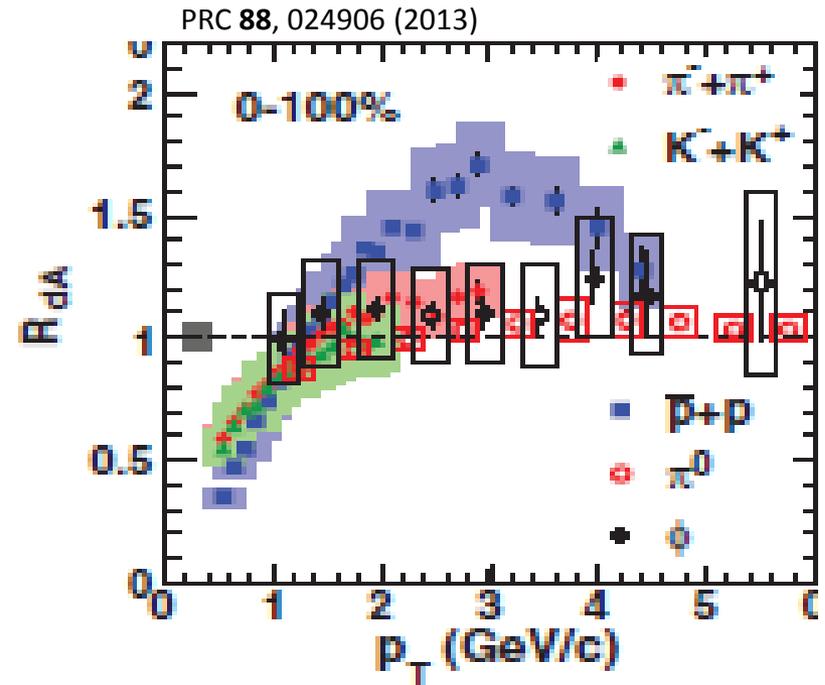
⇒ Same mechanism responsible for suppression?

CNM for ϕ Meson

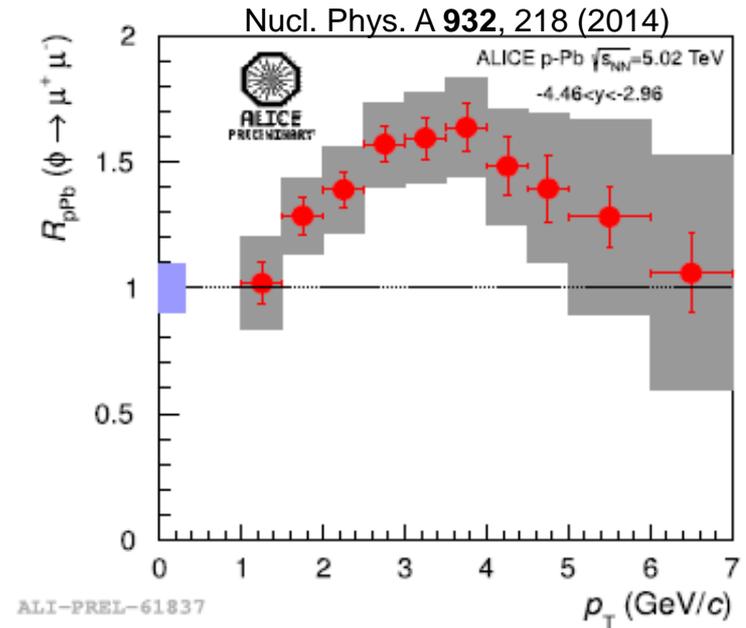
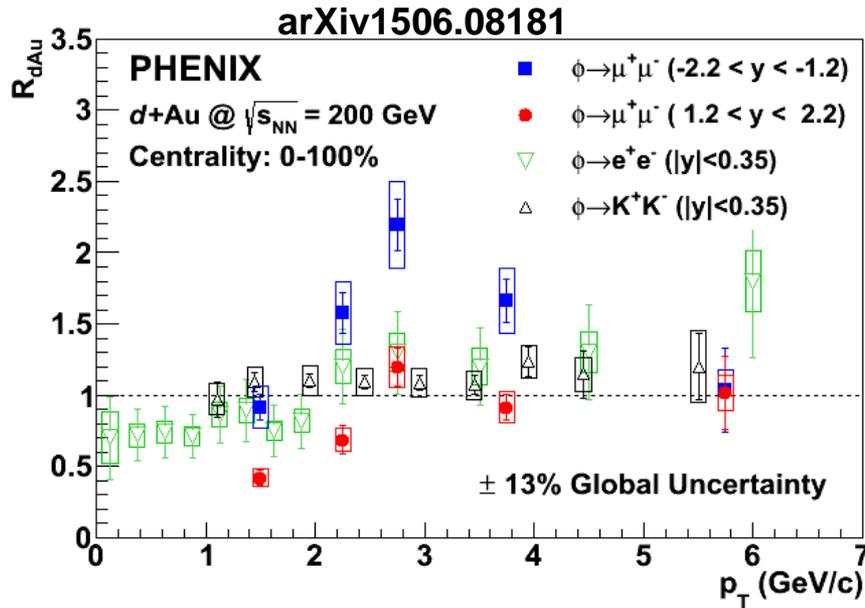
arXiv1506.08181



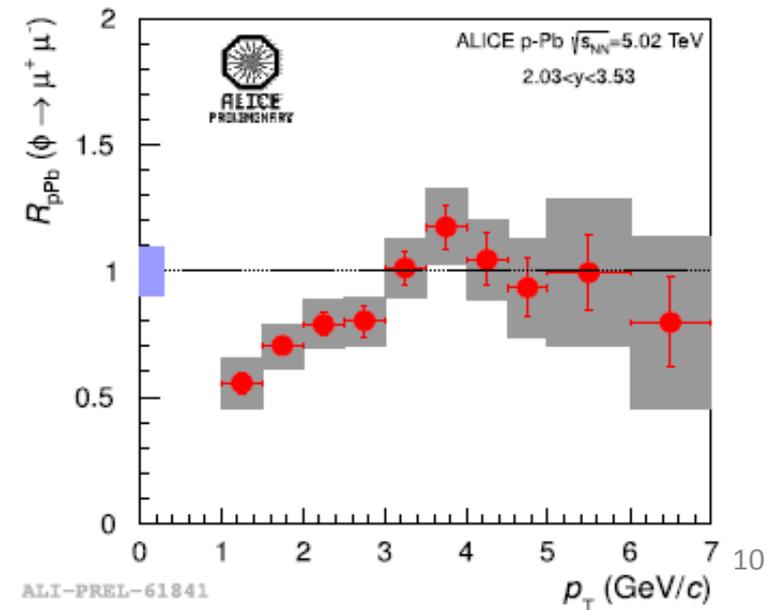
- An **enhancement** (**suppression**) has been observed at **backward** (**forward**) rapidity region in most central $d+Au$ collision.
- ❖ The observed **enhancement** at **backward** rapidity is a typical behavior of a Cronin effect.



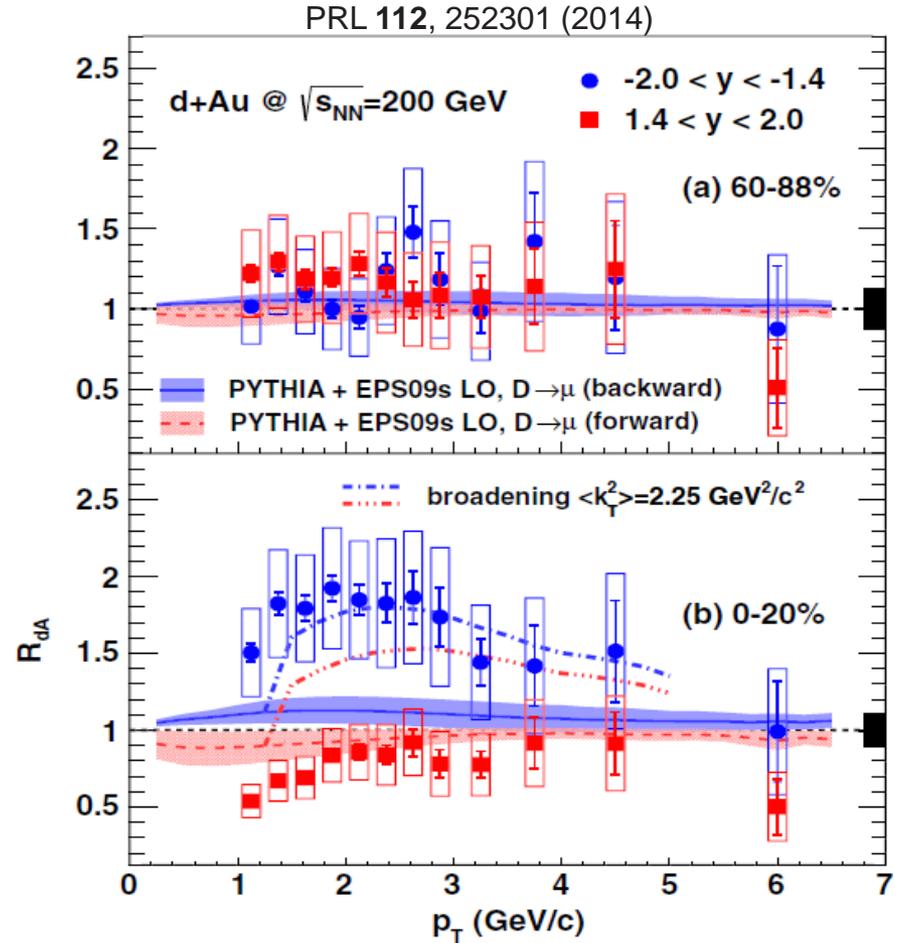
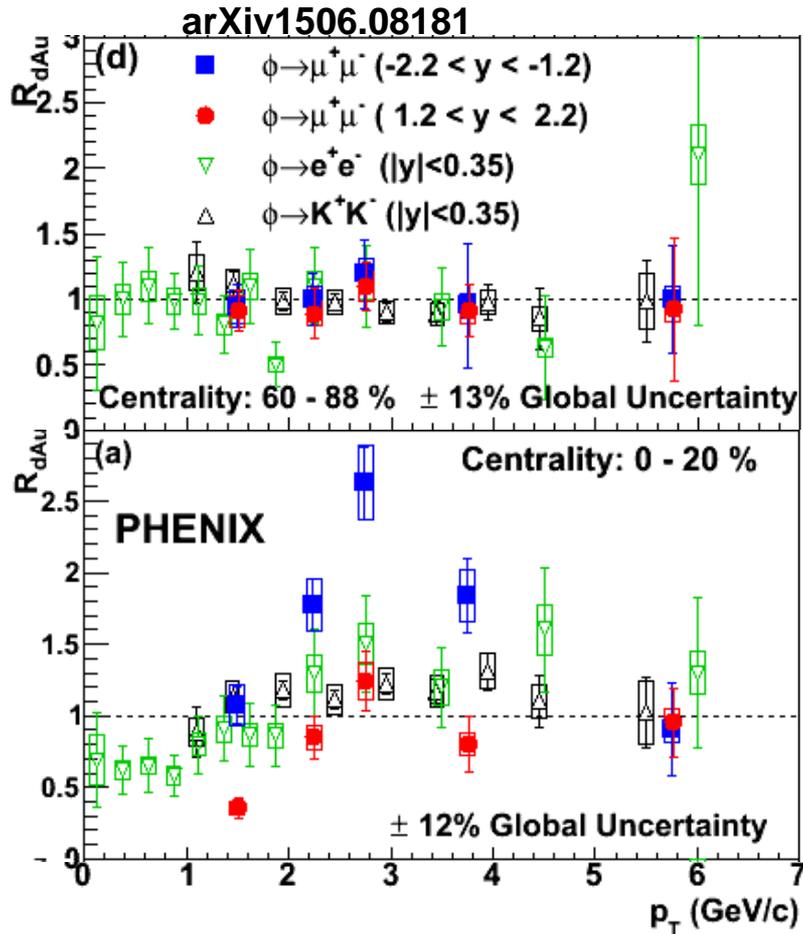
Other ϕ Measurements



- ❖ The R_{dAu} enhancement (suppression) in the Au-going (d -going) direction is consistent with what is observed by the **ALICE** collaboration at $\sqrt{s_{NN}} = 5.02$ TeV in $p+Pb$ collisions



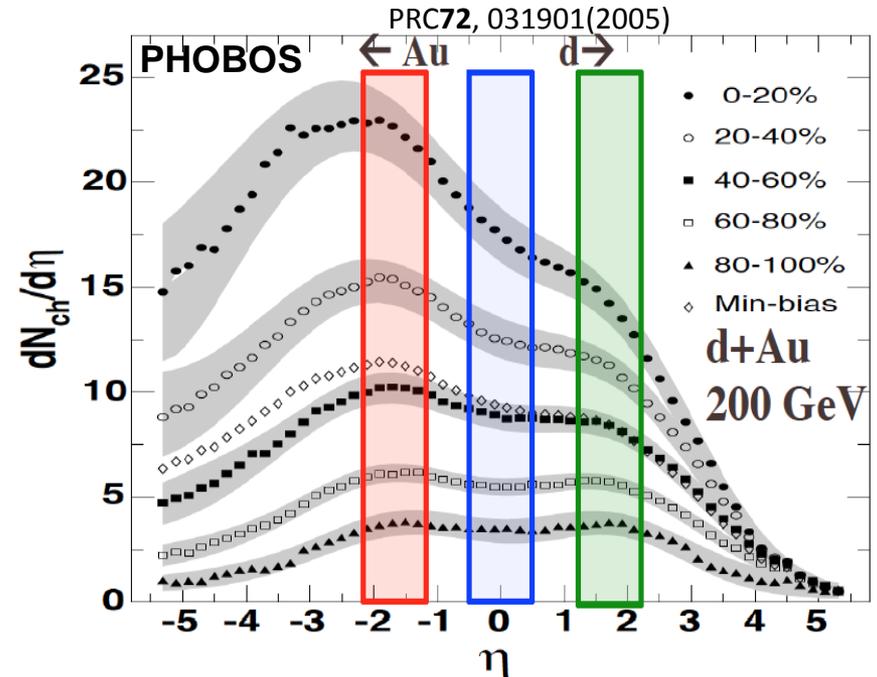
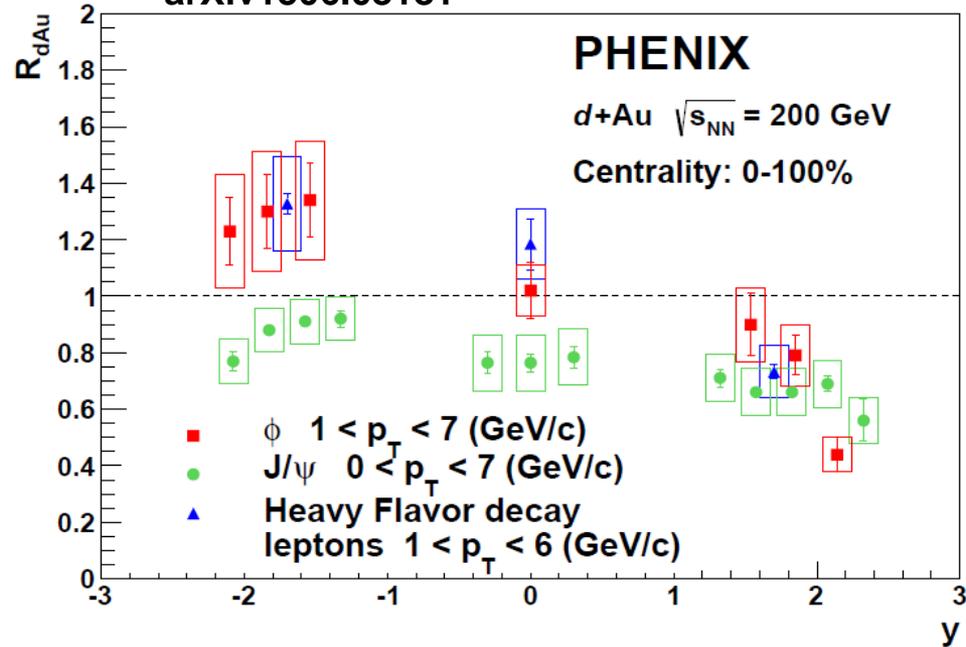
ϕ Meson vs Open Heavy Flavor



- No modification in most peripheral
- Similar enhancement in most central

ϕ Meson vs Open & closed Heavy Flavor

arXiv1506.08181



❖ Similar nuclear modifications to those in ϕ production as a function of rapidity is observed in heavy flavor decay leptons and inclusive charged hadrons production \Rightarrow

Similar cold nuclear matter effects

OR

Different processes act on open HF and ϕ . The match May be a coincidence

Outlook!

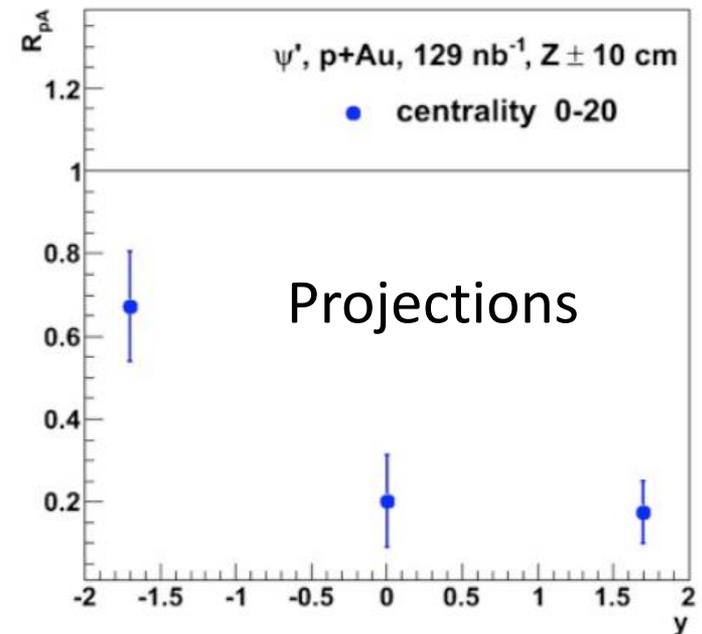
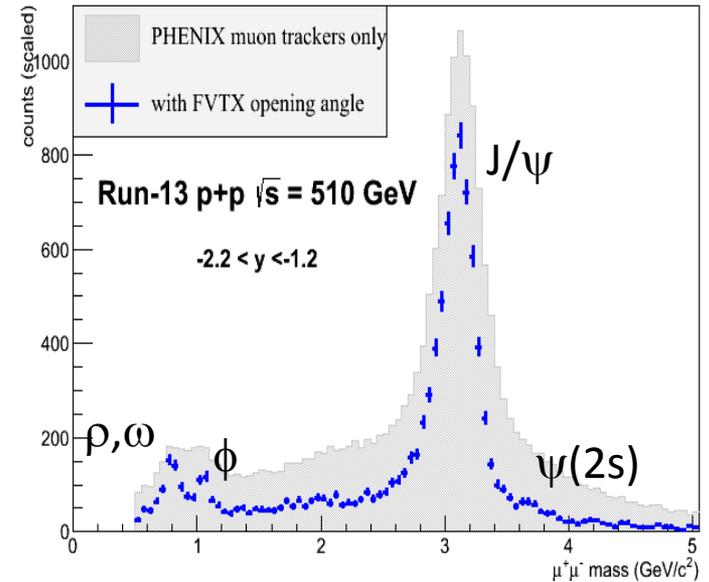
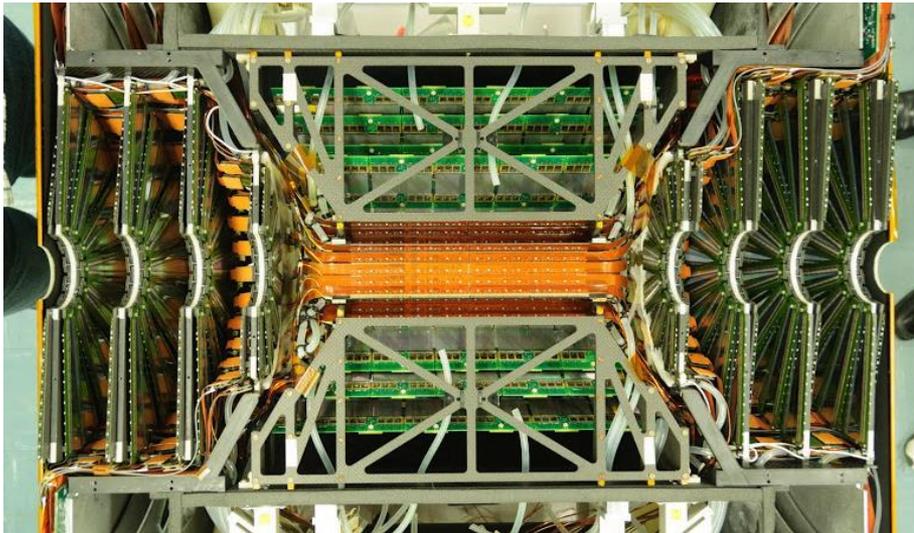
2015 RHIC run included p+Au

Run 15 p+Au
luminosity

	wide vertex - 403.41 nb ⁻¹
	30 cm vertex - 206.20 nb ⁻¹
	10 cm vertex - 80.21 nb ⁻¹

- ❖ FVTX allows $\psi(2S)$ at forward/backward rapidity
- ❖ p+Au don't have complication of d - easier comparison to LHC

NIMA 755, 44 (2014)



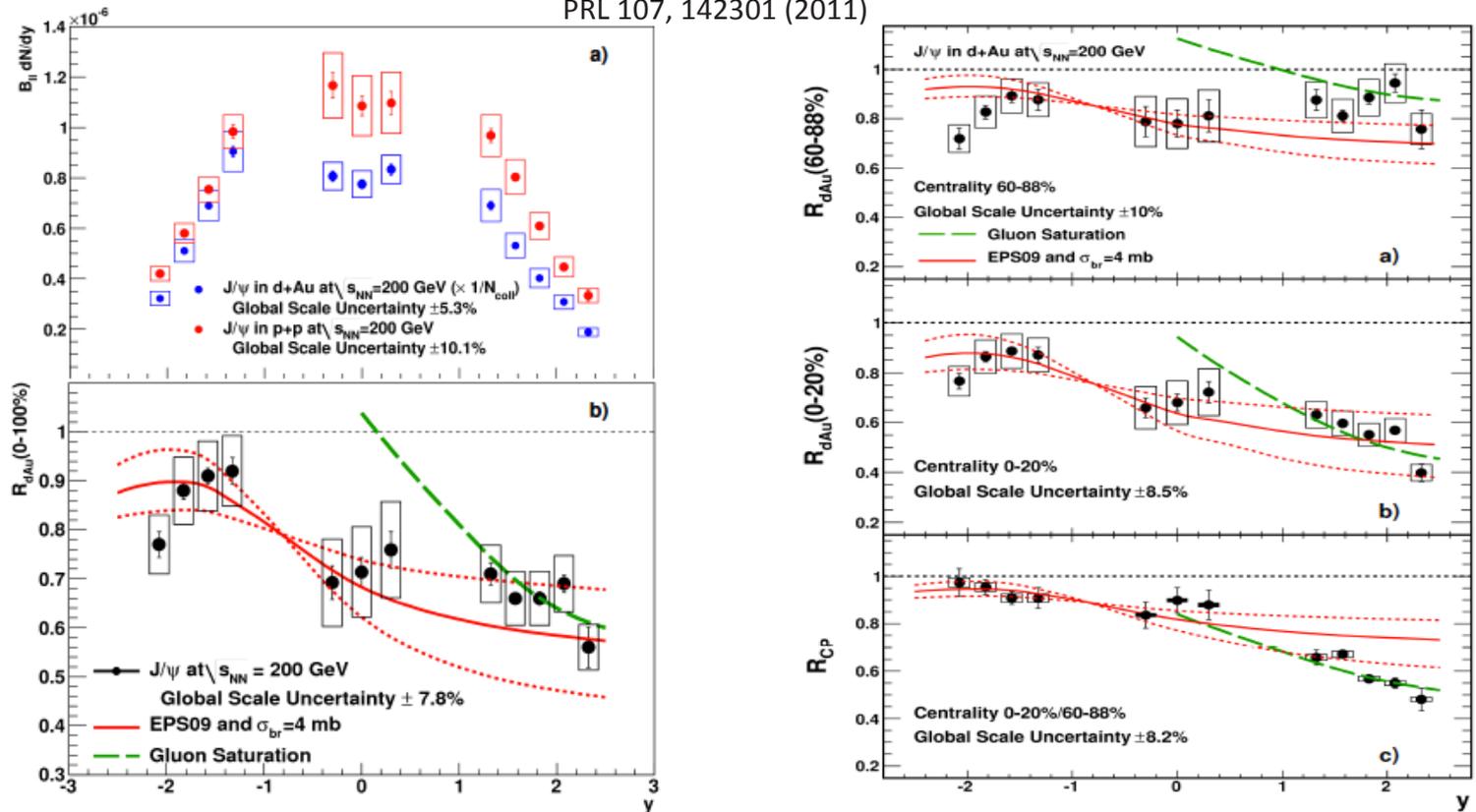
Summary

- PHENIX collaboration measured various probes over a wide range of rapidity and p_T to study CNM effects.
- ψ' suppressed beyond J/ψ at midrapidity rapidity, in $d+Au$. Owing to the time spent in nucleus, breakup does not hold as explanation for PHENIX data.
- Similar OHF suppression to J/ψ at forward rapidity \Rightarrow **Same mechanism responsible for suppression**
- Different OHF enhancement from J/ψ at backward rapidity \Rightarrow **Evidence for cc breakup effects!**
- An **enhancement (suppression)** of ϕ has been observed at **backward (forward)** rapidity region in most central $d+Au$ collisions
- Similar behavior was previously observed for inclusive charged hadrons and open heavy \Rightarrow similar cold nuclear matter effects?
- New data set ($p+Au$) collected in 2015 will allow ψ' measurement at backward and forward rapidities along with other probes in less complicated $p+Au$ collisions

Backup

CNM for J/ψ Meson

PRL 107, 142301 (2011)



- Forward rapidity shows more suppression than central/backward rapidities. Centrality-dependent.
- CNM (gluon shadowing, nuclear breakup) can't describe centrality dep.
- Effects of gluon saturation may play an important role in understanding the forward rapidity modifications.
- Other explanations involving initial-state parton energy loss?