Heavy vector meson results at PHENIX

Kwangbok Lee, LANL
for the PHENIX collaboration

DIS 2011, Newport News, VA

Outline

- p + p collision (J/ψ, χ_c, ψ', Υ)

  -> Baseline for the study of nuclear and Quark Gluon Plasma(QGP) effects, production mechanisms.

- d + A collision (J/ψ, Υ)

  -> Cold nuclear matter(CNM) -> Extract it from hot nuclear effect,

  -> Baseline for QGP effects

- A + A collision (J/ψ, Υ)

  -> Hot nuclear matter -> Study QGP

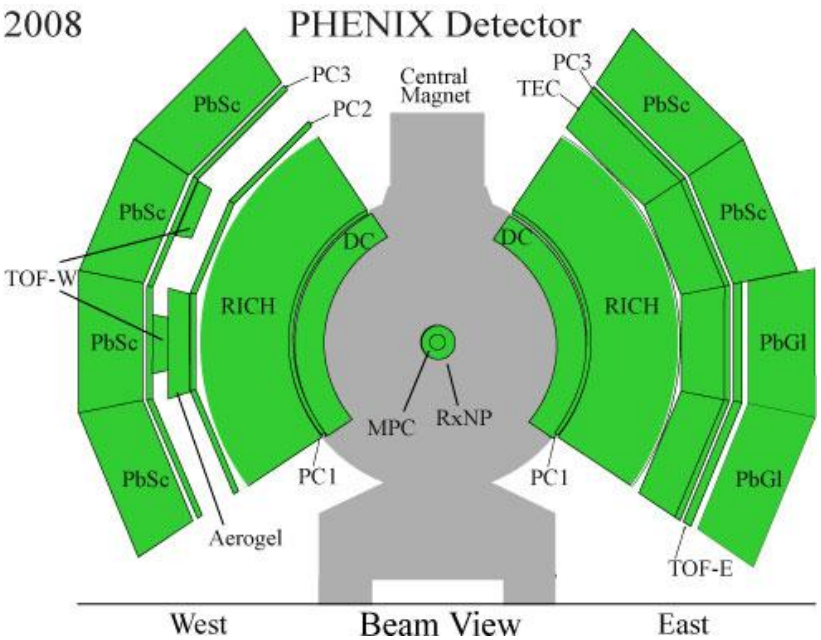
- Quarkonia studies,

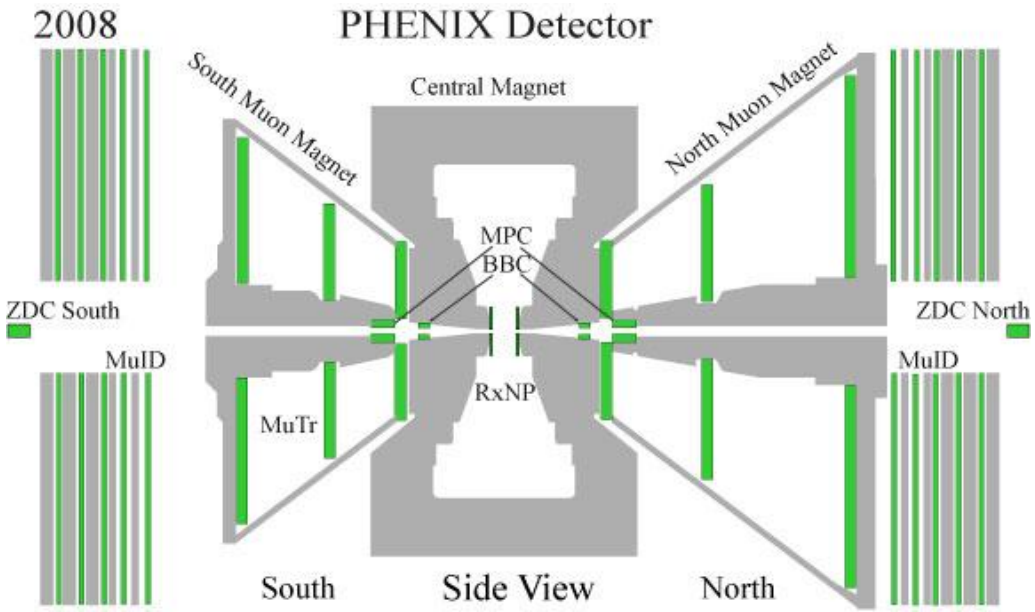
  -> understand suppression from CNM and from QGP effects

	$c\bar{c}$			$b\bar{b}$		
state	J/ψ (1S)	χ_c (1P)	ψ' (2S)	Υ (1S)	Υ (2S)	Υ (3S)
mass [GeV]	3.10	3.53	3.68	9.46	10.02	10.36
radius [fm]	0.25	0.36	0.45	0.14	0.28	0.39
ΔE [GeV]	0.64	0.20	0.05	1.10	0.54	0.20

hep-ph/0609197v1 H. Satz

PHENIX detectors

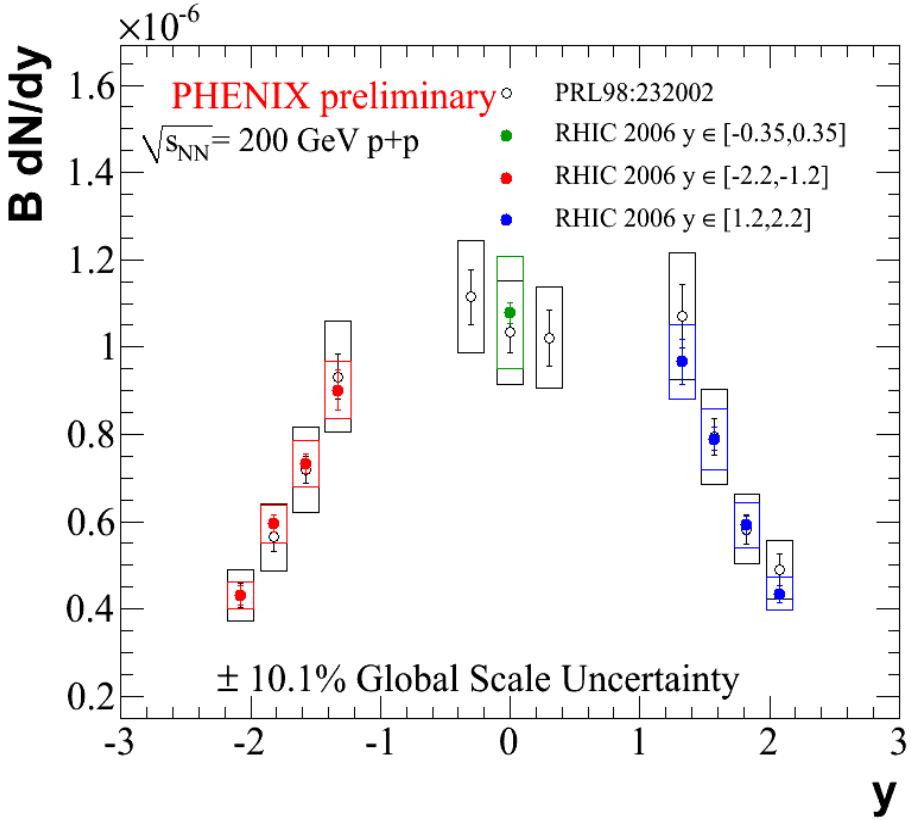


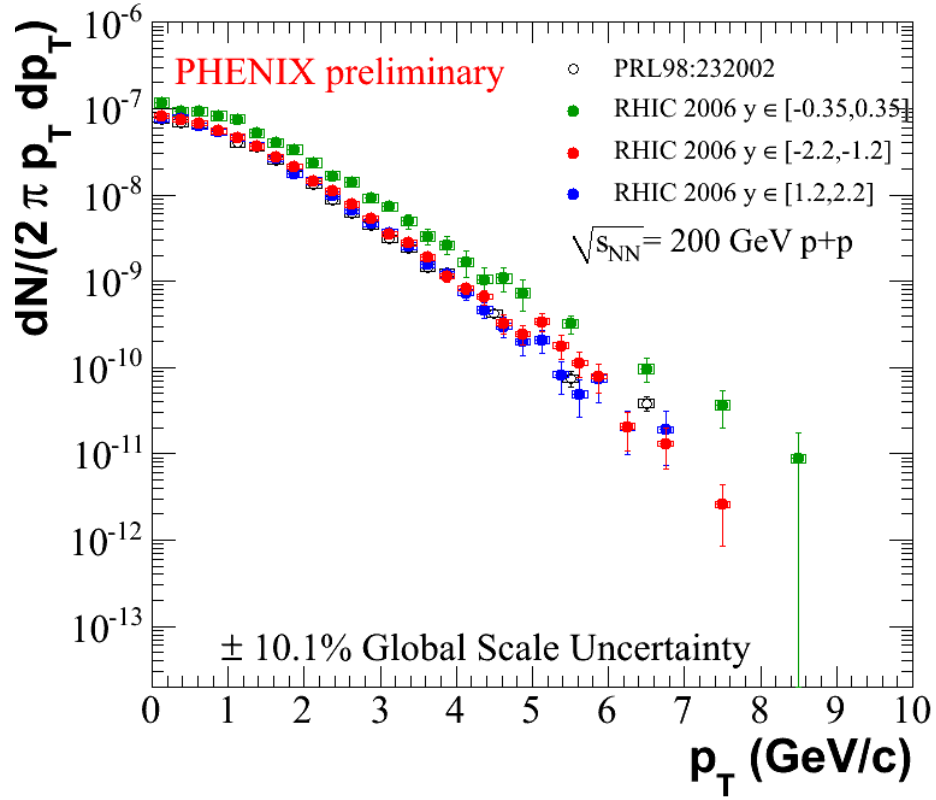


Mid rapidity: Quarkonia → e^+e^-
$|y|<0.35$, $\Delta\Phi = 2 \times \pi/2$,
$p>0.2$ GeV/c

Forward rapidity: Quarkonia → $\mu^+\mu^-$
$1.2<|y|<2.2$, $\Delta\Phi=2\pi$,
$p>2$ GeV/c

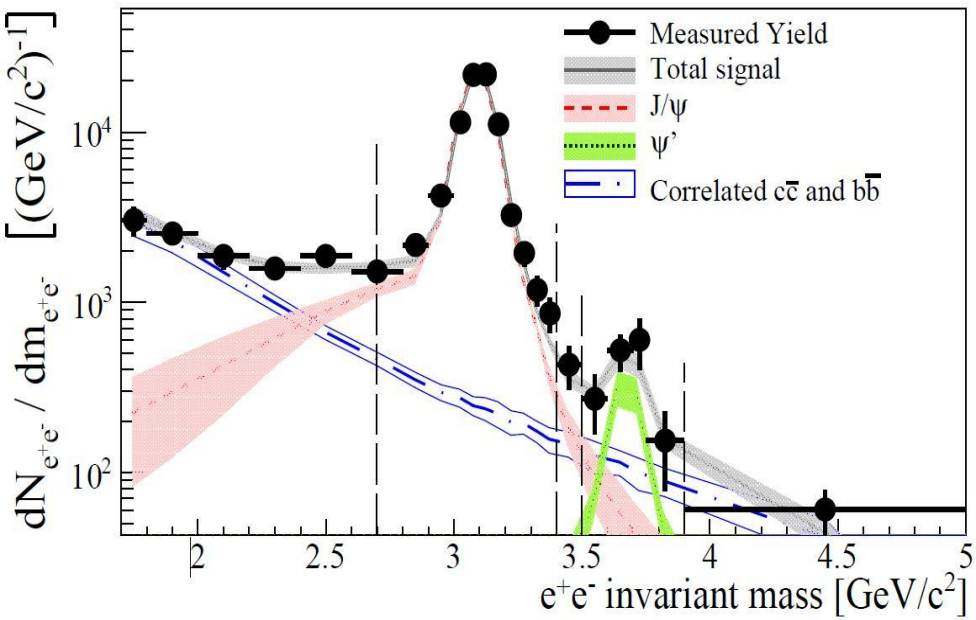
J/ψ spectra in p+p

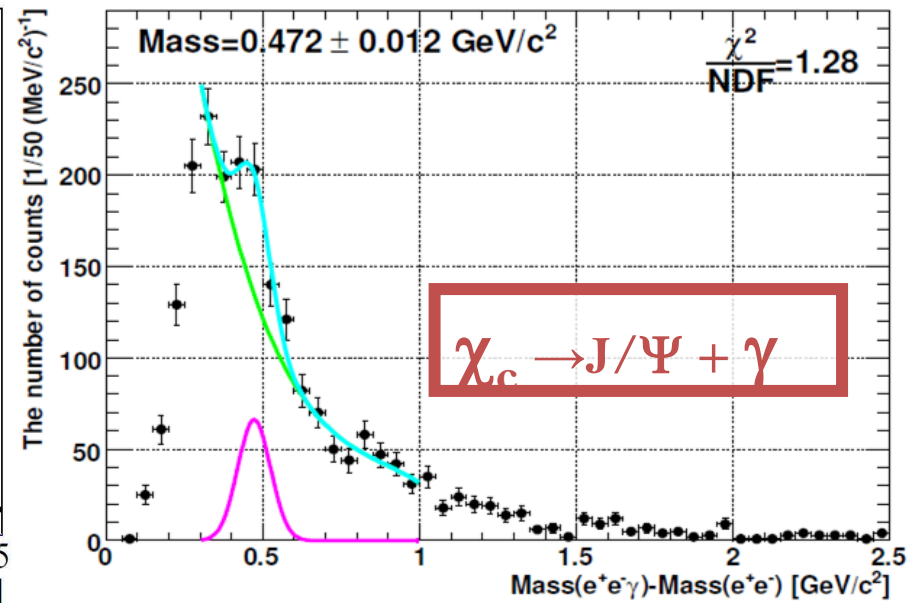




- Comparing with run6 result and previous published result
- Combined result with run6 and run8 is expected to be released very soon
- Can study production mechanisms of Color Evaporation Model, Color Octet Model, Color Singlet Model, etc. with parton distribution functions

ψ′ and χ_c in p+p





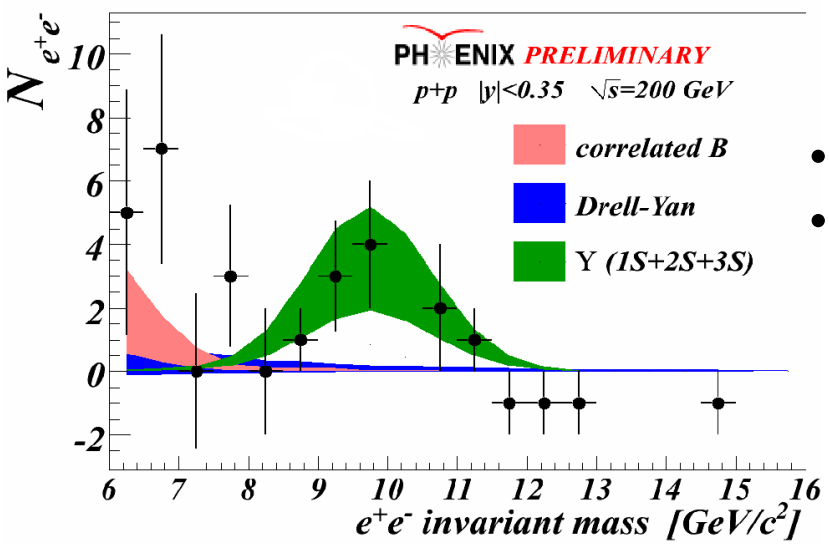
J/ψ from ψ′ = 8.6 ± 2.5 %

J/ψ from χ_c < 42% (90%C.L.)

-0.35 < y < 0.35

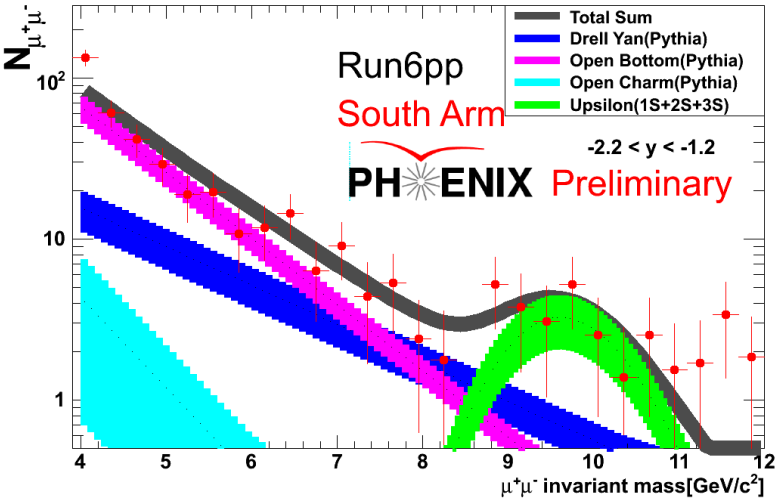
- Mid-rapidty ψ′ and χ_c
- Can study feed down fraction to J/ψ
- Can give a clue to understand J/ψ suppression in heavy ion collisions since these have less binding energy than J/ψ
- These results are expected to be released very soon.

ϒ distributions in p+p

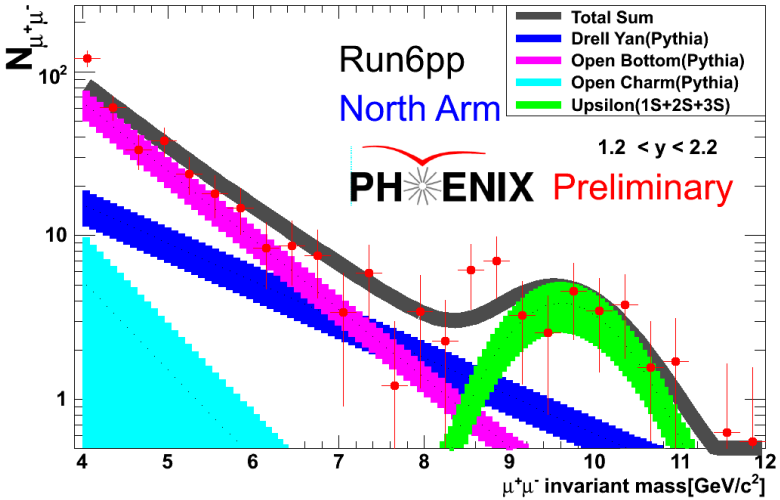


-0.35 < y < 0.35

- Higher mass region for ϒ
- Physical backgrounds of Drell Yan, open charm and open beauty are simulated and subtracted off with corresponding systematic uncertainties.

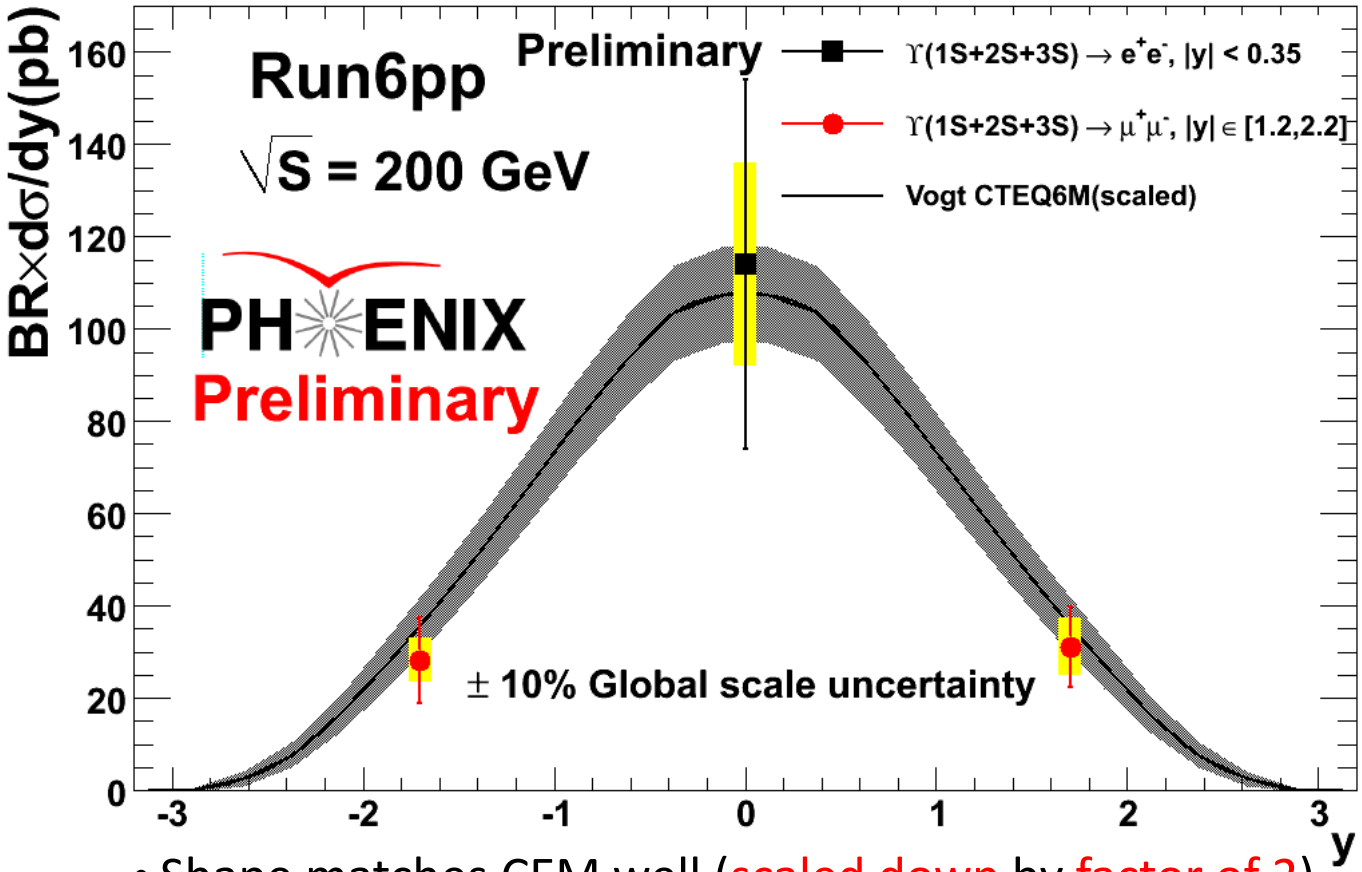


-2.2 < y < -1.2



1.2 < y < 2.2

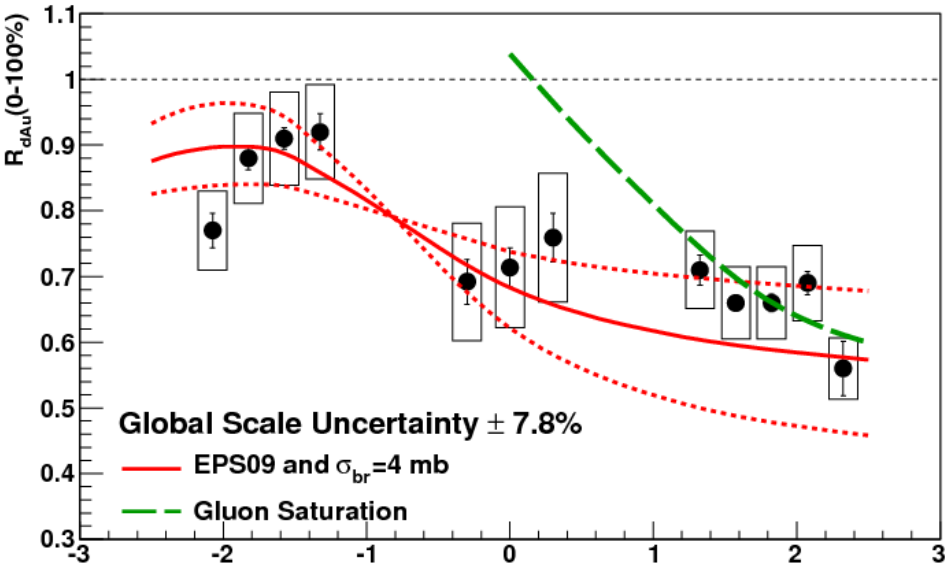
ϒ cross section in p + p



- Shape matches CEM well (scaled down by factor of 2) with CTEQ6M

J/ψ in d+Au

arXiv:1010.1246



-2.2<y<-1.2 -0.35<y<0.35 1.2<y<2.2

x ~ 0.1 x ~ 0.03 x ~ 0.005

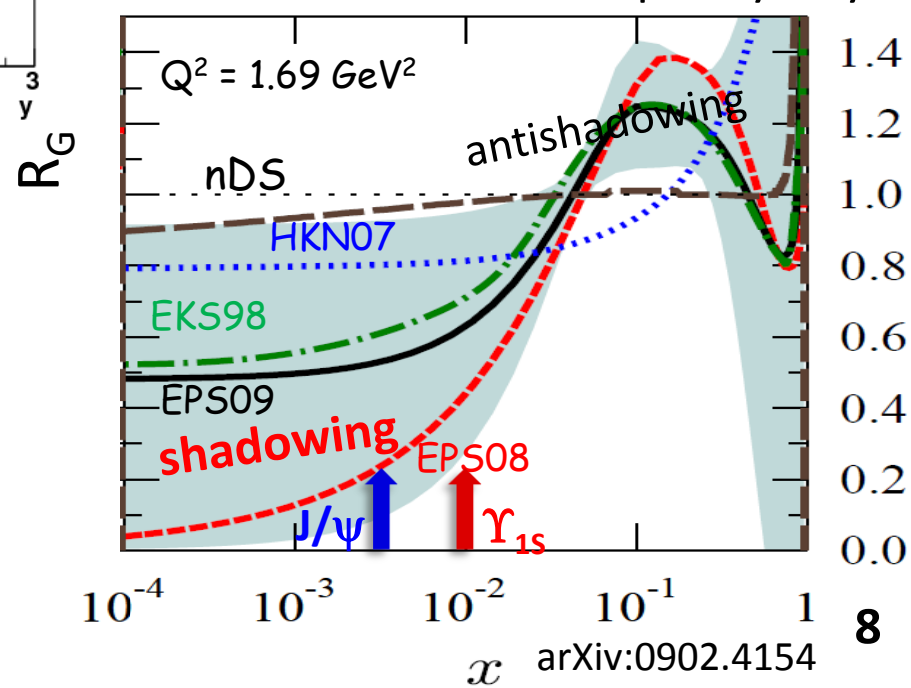
d → ← Au

$$R_{dAu} = \frac{N_{inv}^{dAu} \Big/ \left\langle N_{coll}^{dAu} \right\rangle}{N_{inv}^{pp}}$$

- New large statistics 2008 d+Au
- EPS09 + $\sigma_{breakup}$ = 4mb(red line)
- Dashed lines are the maximum variation
- Gluon Saturation(green line)

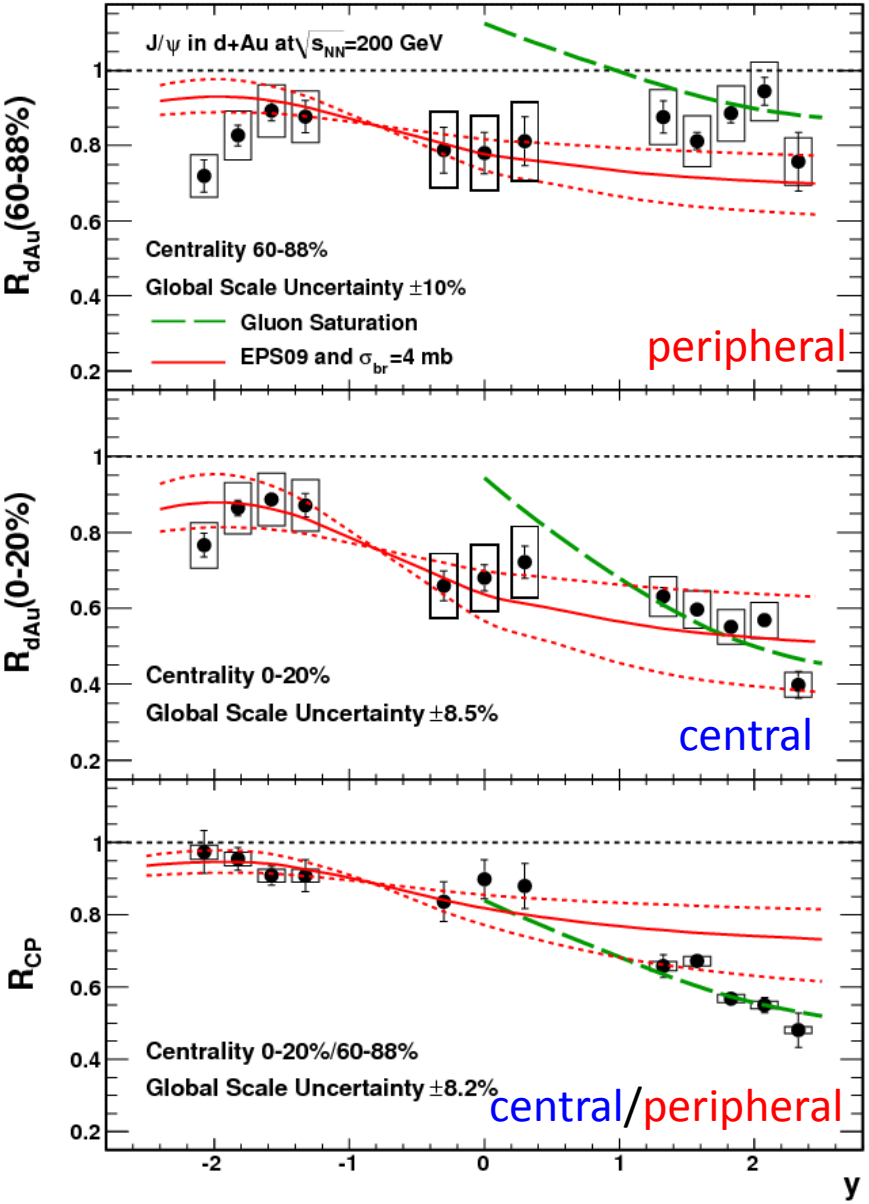
Nucl.Phys.A770:40-56,2006

- Good agreement at low x
- Deviates from the data quickly as y<1



arXiv:0902.4154

J/ψ in d+Au



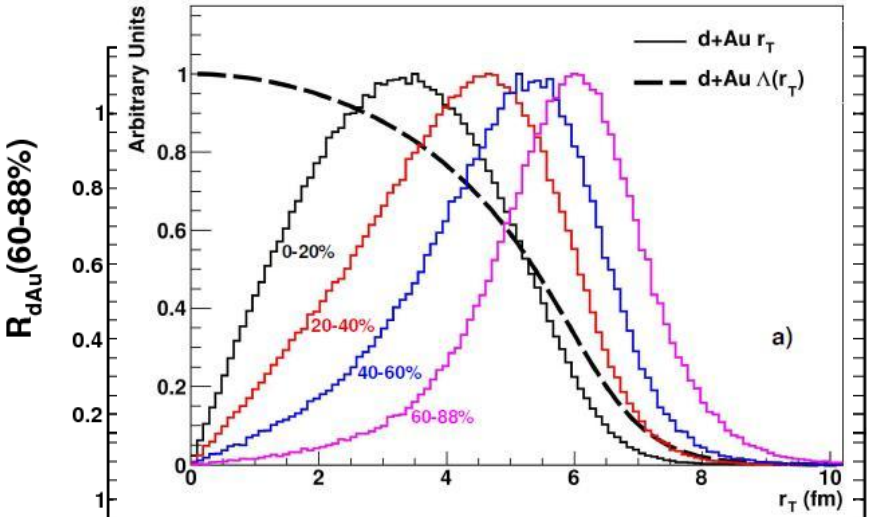
- EPS09(linear) + fixed Breakup cross section(exponential) for central and peripheral collisions
- Forward rapidity data inconsistent with a linear dependence on thickness
- Expect the nuclear effects are dependent on the geometric thickness through the gold nucleus

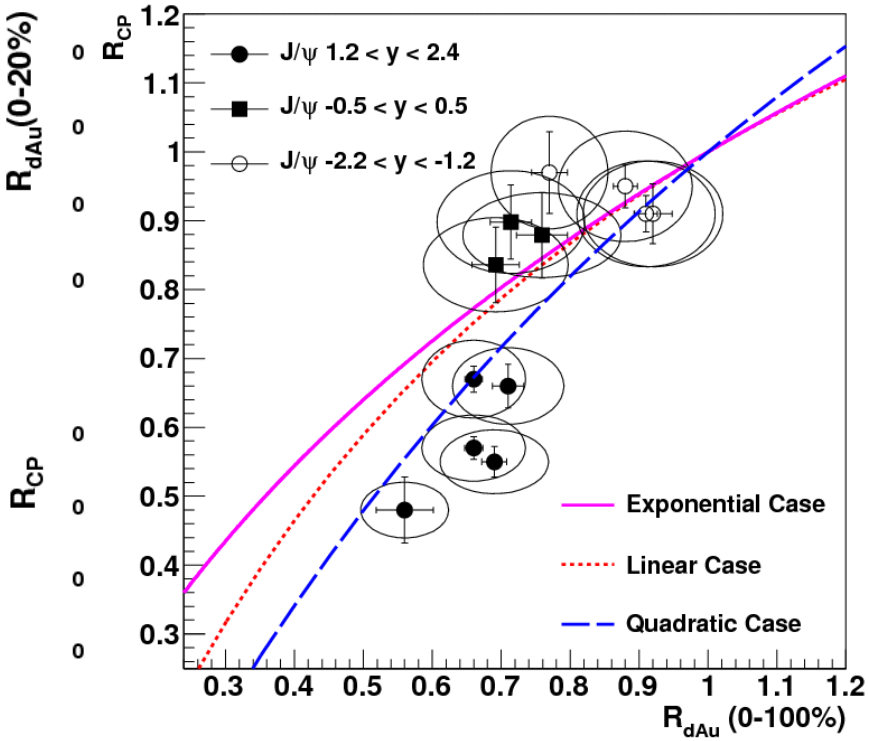
- Need to consider modification stronger than linear or exponential dependence on density-weighted longitudinal thickness like quadratic

$$R_{CP}(0-20\%) = \frac{R_{dAu}(0-20\%)}{R_{dAu}(60-88\%)}$$

arXiv:1010.1246

J/ψ in d+Au





$$Exponential: M(r_T) = e^{-a\Lambda(r_T)}$$

$$Linear: M(r_T) = 1.0 - a\Lambda(r_T)$$

$$Quadratic: M(r_T) = 1.0 - a\Lambda(r_T)^2$$

r_T: transverse radial positions of the nucleon-nucleon collisions relative to the center of the gold nucleus

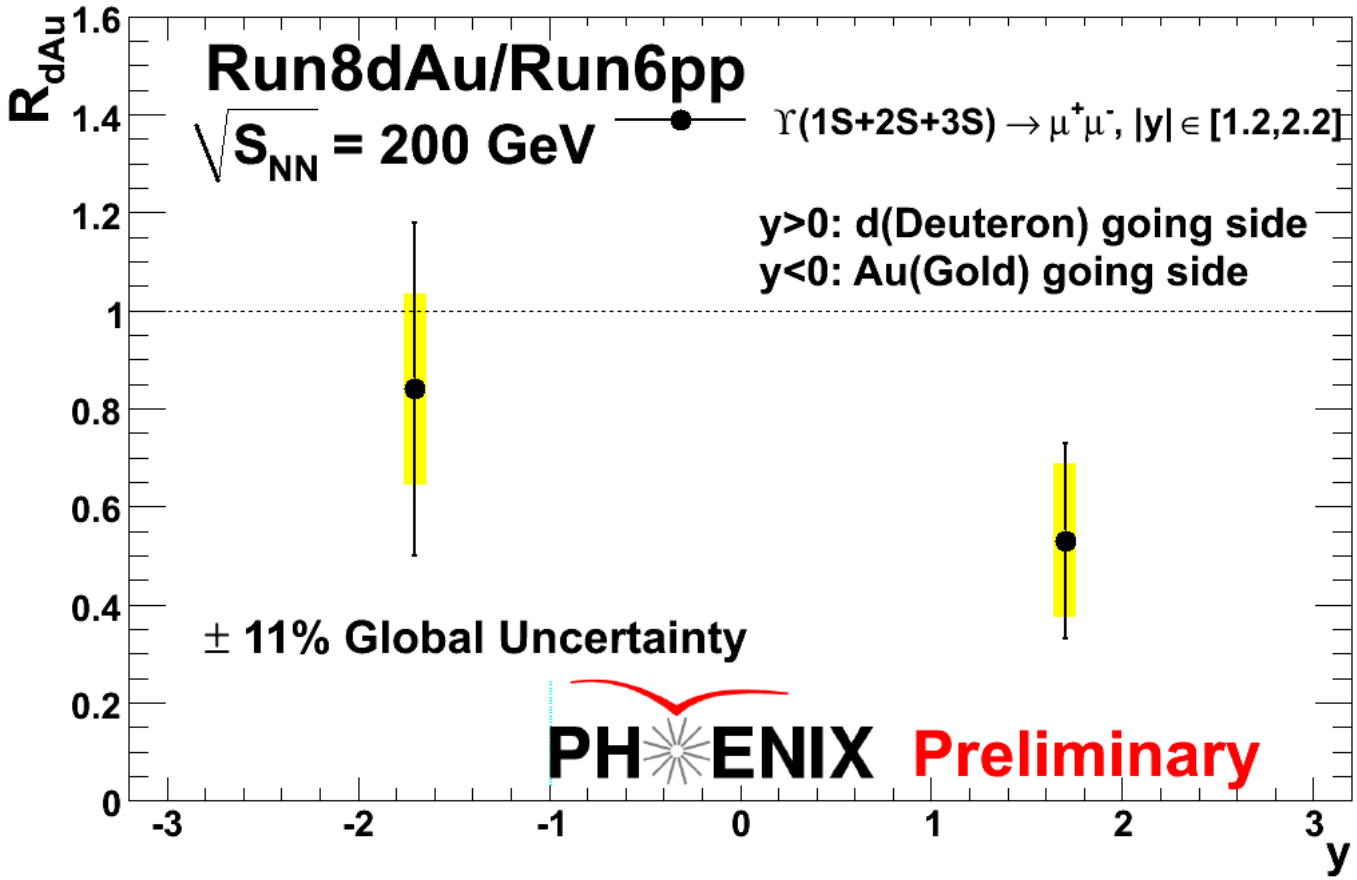
$\Lambda(r_T)$: density weighted longitudinal thickness through the gold nucleus

- Need to consider modification stronger than linear or exponential dependence on density-weighted longitudinal thickness like quadratic

$$R_{CP}(0-20\%) = \frac{R_{dAu}(0-20\%)}{R_{dAu}(60-88\%)}$$

arXiv:1010.1246

ϒ in d+Au

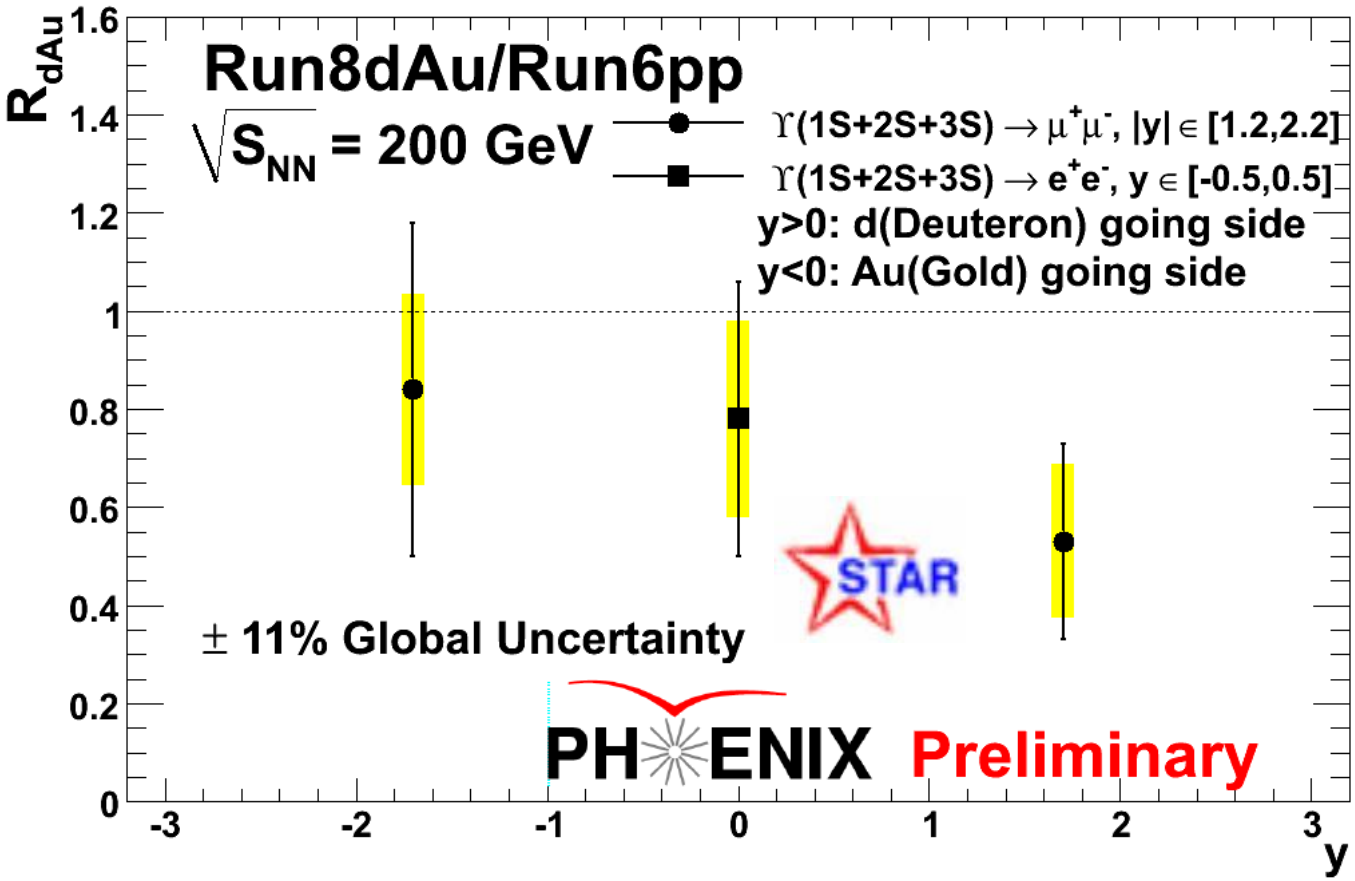


-2.2<y<-1.2
x ~ 0.2

1.2<y<2.2
x ~ 0.01

- Shows suppression at low x region

ϒ in d+Au



-2.2<y<-1.2
x ~ 0.2

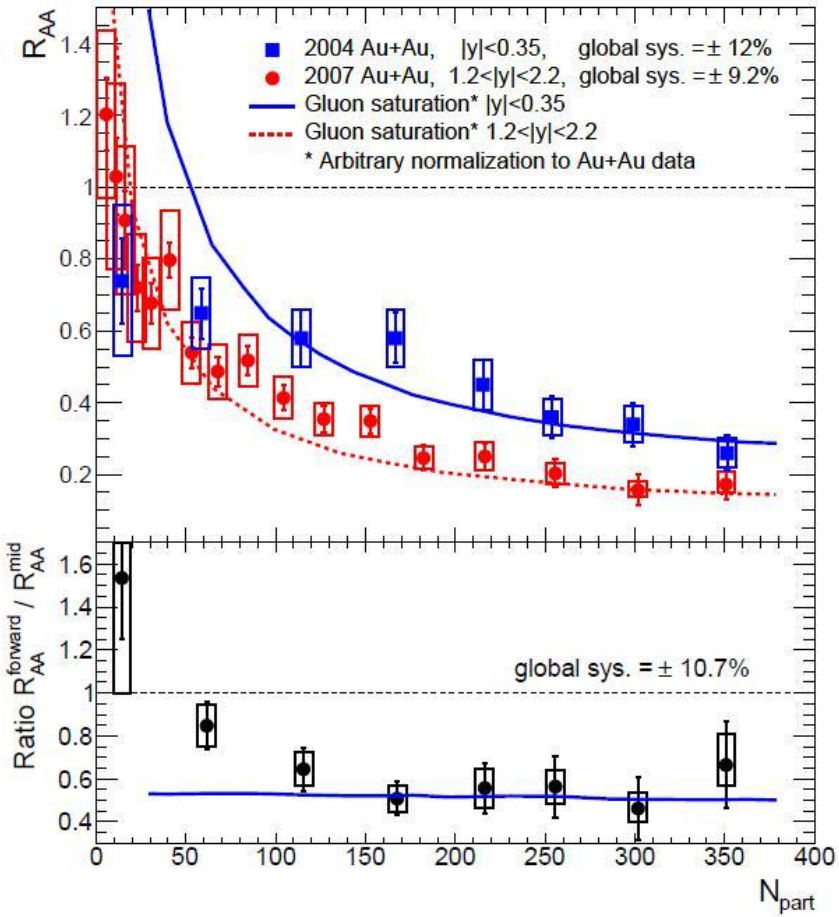
1.2<y<2.2
x ~ 0.01

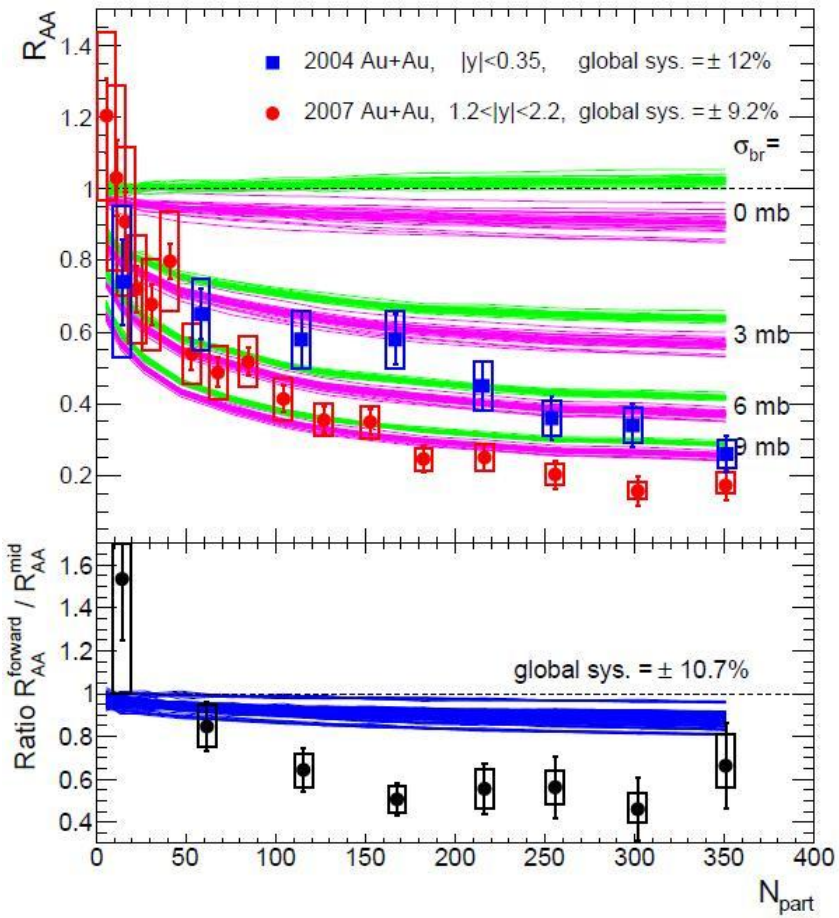
- Shows suppression at low x region

J/ψ R_{AA} vs N_{part} in A+A

New 2007 data

More comparisons are shown at arXiv:1103.6269

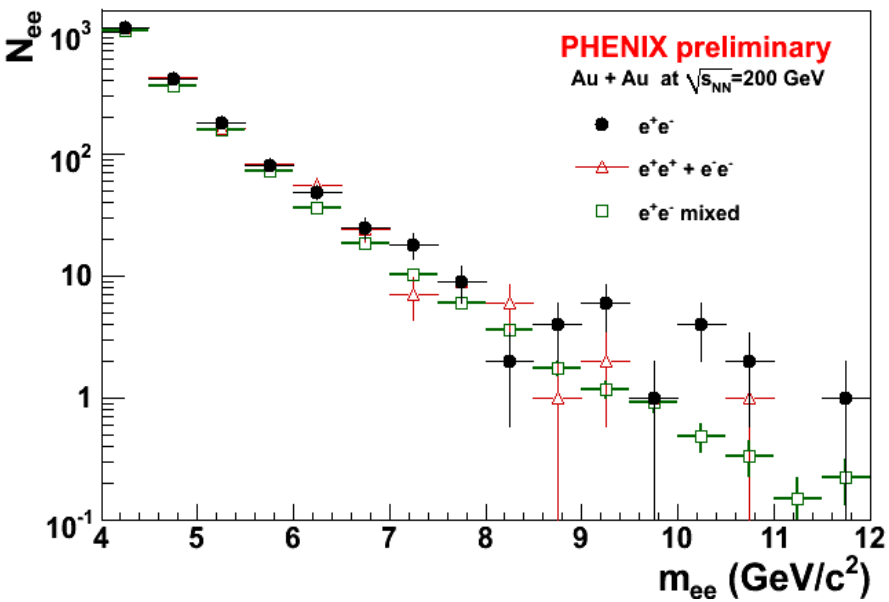


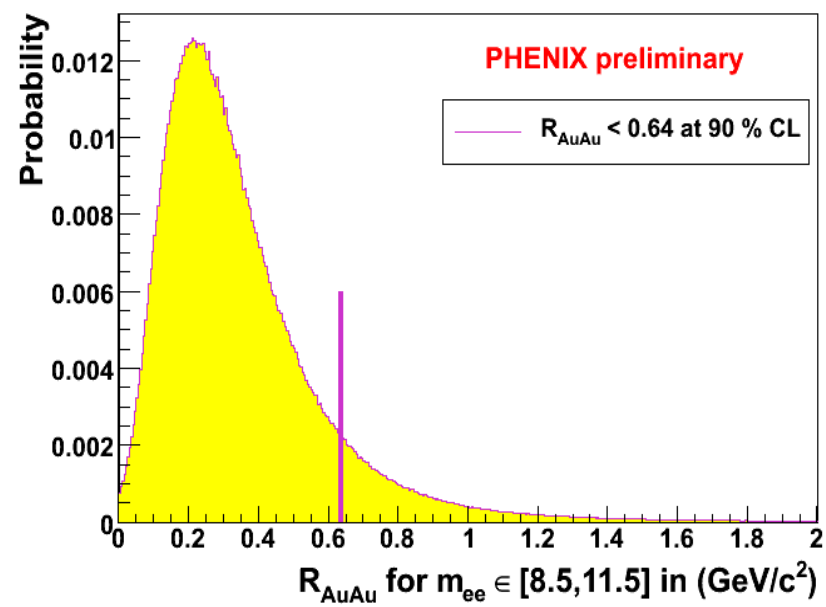


Color Glass Condensate(CGC)
Arbitrary normalization by mid rapidity

Shadowing/Nuclear absorption/Initial state parton energy loss

ϒ (or rather: high mass di-leptons) R_{AA} in A+A





-0.35 < y < 0.35

R_{AuAu} [8.5,11.5] < 0.64 at 90% C.L.

- Derived a 90% C.L. for high-mass dileptons R_{AA}

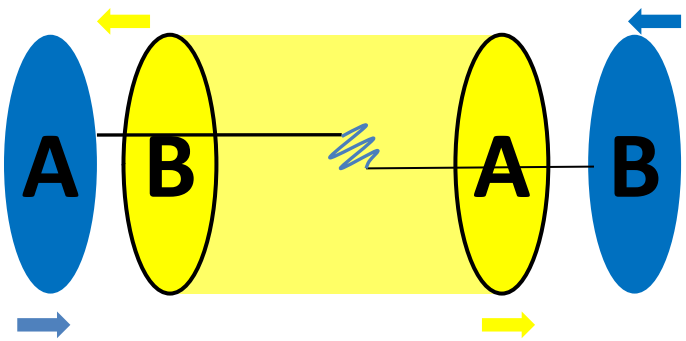
Conclusions

- Quarkonia measurement is a good probe to understand matter created in the heavy ion collision.
- Forward rapidity dAu data are inconsistent with a linear dependence on thickness of CNM effects.
- Quantitative extraction of the hot nuclear matter effects is compromised by lack of understanding of the cold nuclear matter baseline.
- χ_c, ψ', Υ(1S+2S+3S) measurements as well as J/ψ are expected to be finalized soon.

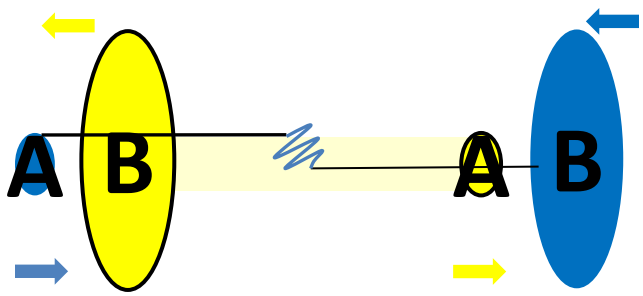
Back up

Cold Nuclear Matter (CNM)

- Since, in *p*(*d*)A collisions, no hot and dense medium is expected to be created, the matter created is called cold nuclear matter (CNM).
- The CNM can provide the quantitative comparison to the measurement of A + A collision so can provide a better understanding of the effects beyond CNM from hot and dense nuclear matter.
- CNM is an interesting matter itself.



Schematic illustration of Au + Au collision

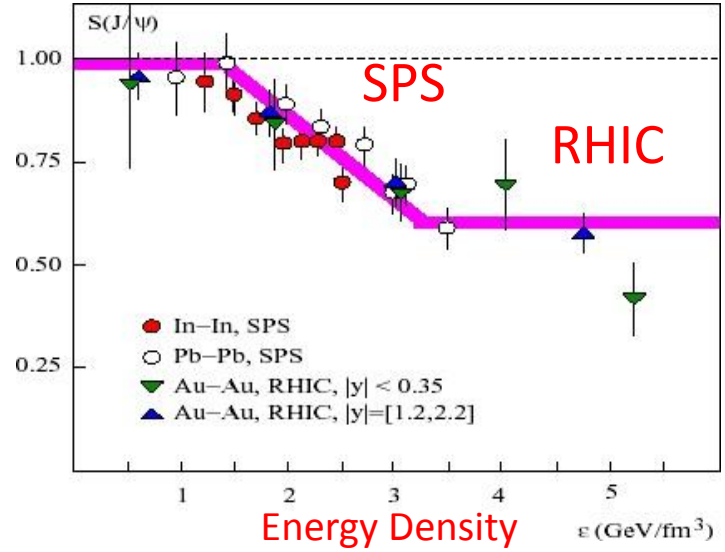


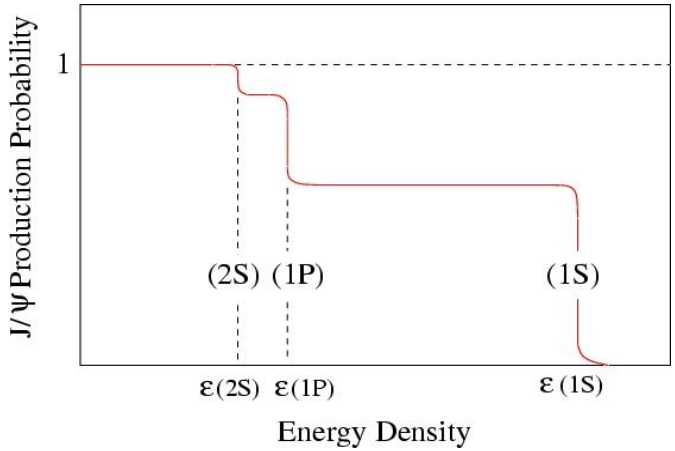
Schematic illustration of *d* + Au collision

J/ψ suppression in A+A

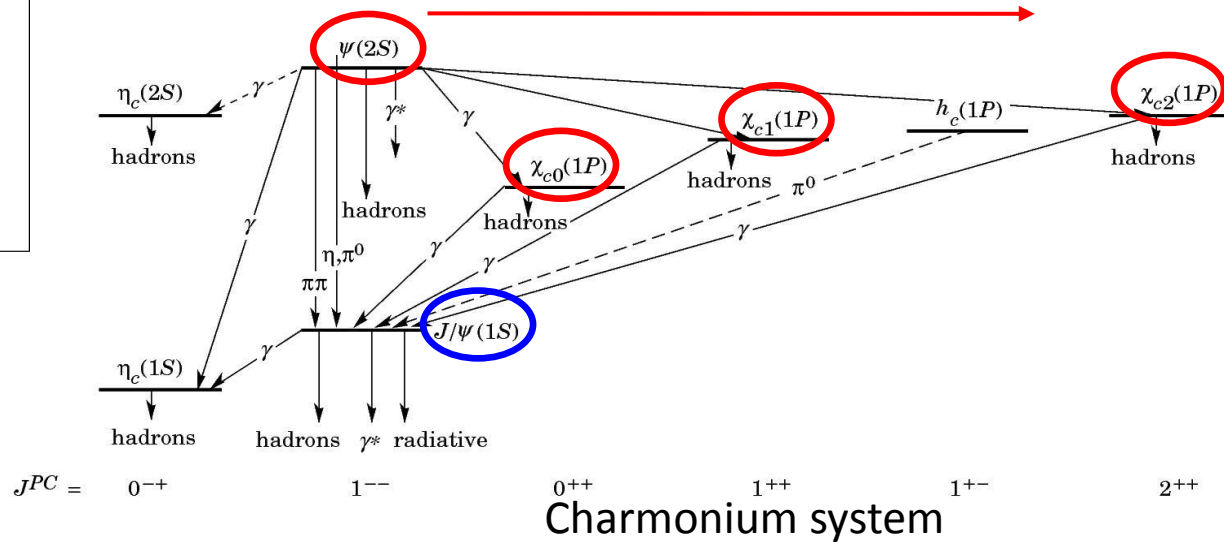
Several scenarios may contribute:

- Suppression by the color screening
- Cold nuclear matter (CNM) effect
- Regeneration effect





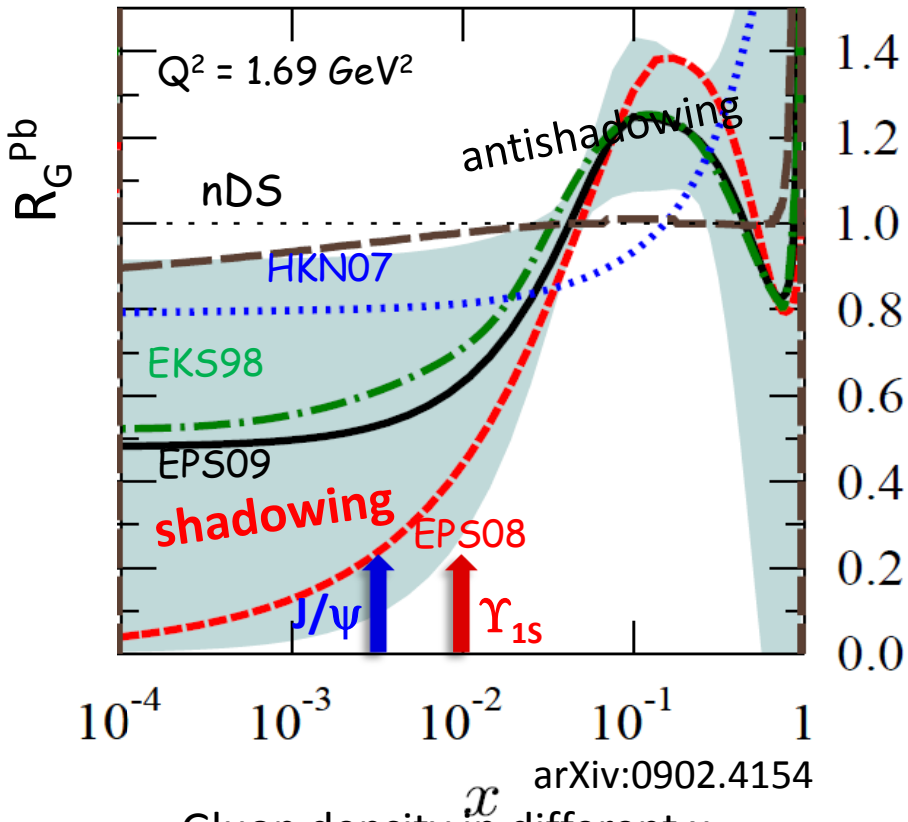
Satz, hep-ph/0512217



Charmonium system

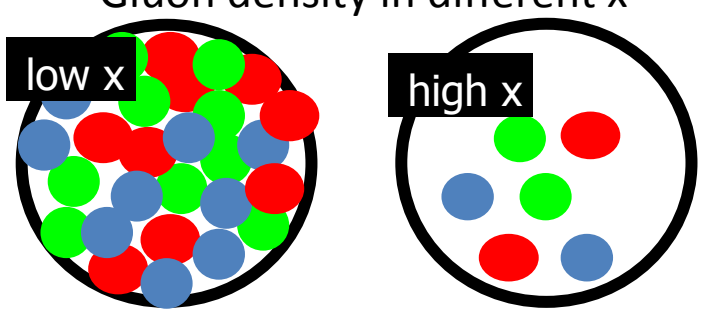
Sequential J/ψ suppression by colour screening

Cold Nuclear Matter (CNM)

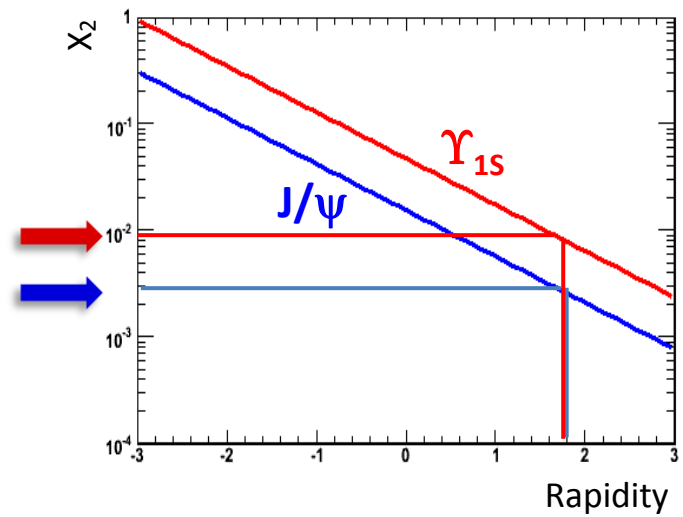


arXiv:0902.4154

Gluon density in different x



- Shadowing model
- Nuclear absorption
- Include $\sigma_{breakup}$ to account for break-up of the $c\bar{c}$ pair while passing through the nucleus.
- Initial state parton energy loss



$$x_2 = \frac{m}{\sqrt{s}} e^{-y}$$

Nuclear modification factors

$$R_{dAu} = \frac{N_{inv}^{dAu} \Big/ \left\langle N_{coll}^{dAu} \right\rangle}{N_{inv}^{pp}}$$

$$R_{CP}^{0-20\%} = \frac{N_{inv}^{0-20\%} \Big/ \left\langle N_{coll}^{0-20\%} \right\rangle}{N_{inv}^{60-88\%} \Big/ \left\langle N_{coll}^{60-88\%} \right\rangle}$$

	pp	dAu (all centralities)	dAu (0-20%)	dAu (60-88%)
N_{coll}	1	7.6 ± 0.4	15.1 ± 1.0	3.2 ± 0.2

N_{coll} : number of binary (pp) collisions in one HI collision.

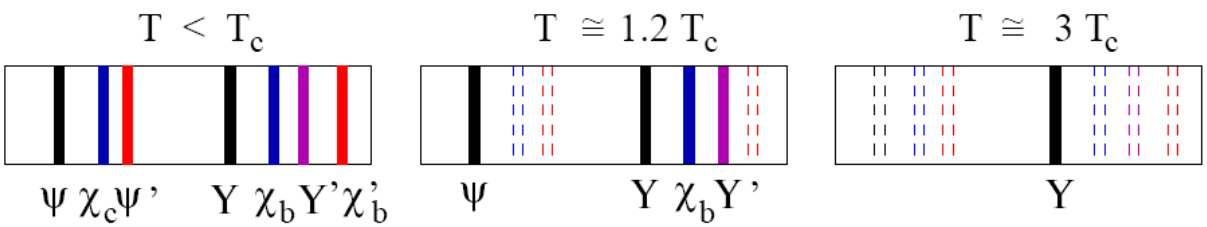
- If the production of AA behaves like in pp, $R_{dAu} = R_{cp} = 1$
- If there is suppression, R_{dAu} , $R_{cp} < 1$

Quarkonia & Color deconfinement

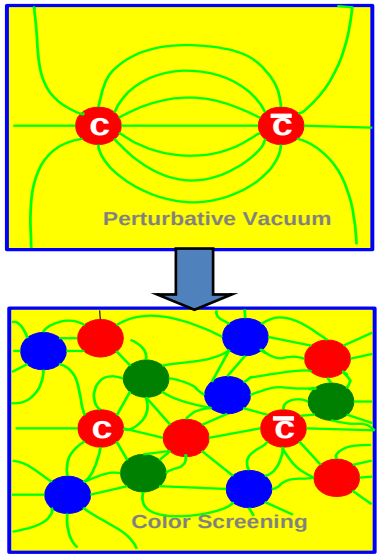
	$c\bar{c}$		$b\bar{b}$		
state	J/ψ (1S)	χ_c (1P)	Υ (1S)	Υ (2S)	Υ (3S)
mass [GeV]	3.10	3.53	9.46	10.02	10.36
radius [fm]	0.25	0.36	0.14	0.28	0.39
T_d/T_c	2.10	1.16	> 4.0	1.60	1.17

hep-ph/0609197v1 H. Satz

- Each quarkonium has different binding radius.



hep-ph/0512217



Schematic of color screening

- At RHIC, Υ_{3S} melts and the Υ_{2S} is likely to melt, the Υ_{1S} is expected to survive. - S. Digal et.al., Phys. Lett. B 514 (2001) 57.
  C-Y Wong, Phys. Rev. C 72 (2005) 034906.