



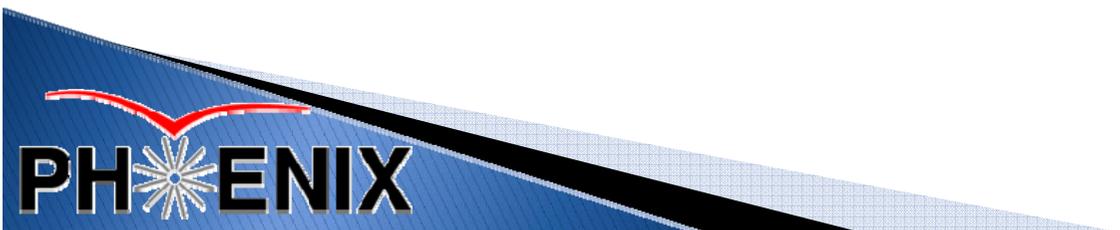
Quarkonia Production at PHENIX in AA Collisions

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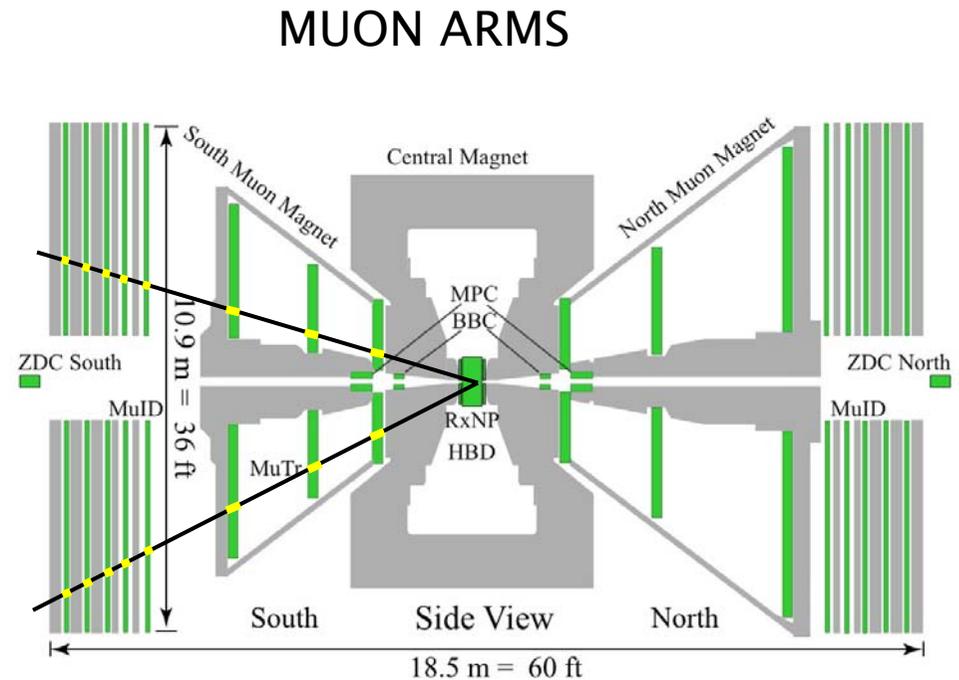
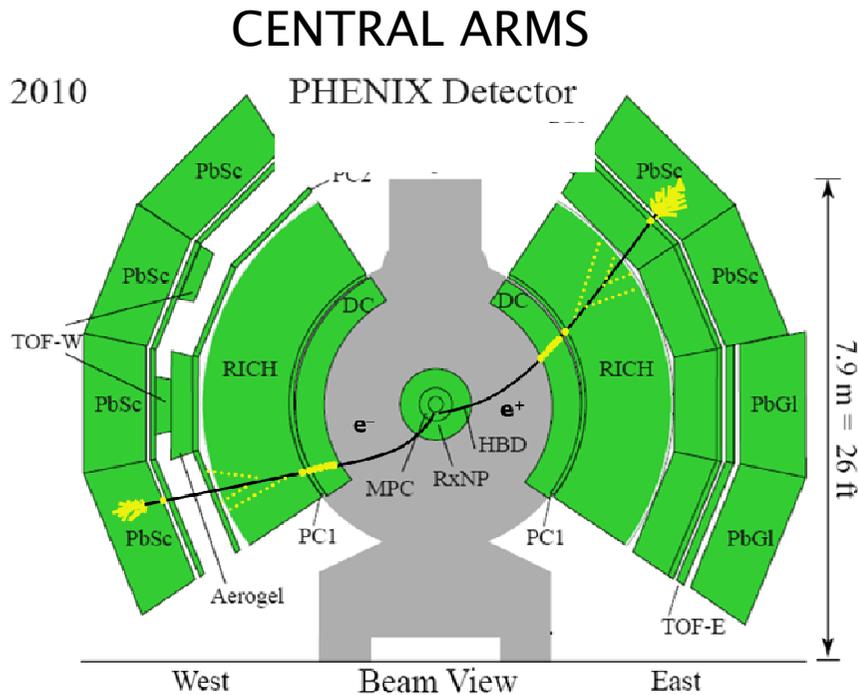


Outline

- Charmonium production in p+p, d+Au collisions: a look at our baseline
- J/ψ production in Au+Au collisions at 200 GeV
- J/ψ production in Au+Au at lower energies
- Near term upgrades
- PHENIX in the next decade: sPHENIX



PHENIX Experiment



- Hadrons, electron, photons
 $|\eta| < 0.35$ $\Delta\Phi = 2 \times \pi/2$
- $J/\psi \rightarrow e^+e^-$, $\psi' \rightarrow e^+e^-$, $\chi \rightarrow e^+e^- \gamma$,
 $Y \rightarrow e^+e^-$

- Muons
 $-2.2 < \eta < -1.2$ $1.2 < \eta < 2.2$ $\Delta\Phi = 2\pi$
muon $p > 2 \text{ GeV}/c$
- $J/\psi \rightarrow \mu^+\mu^-$, $\psi' \rightarrow \mu^+\mu^-$,
 $Y \rightarrow \mu^+\mu^-$

PHENIX Quarkonia Objectives

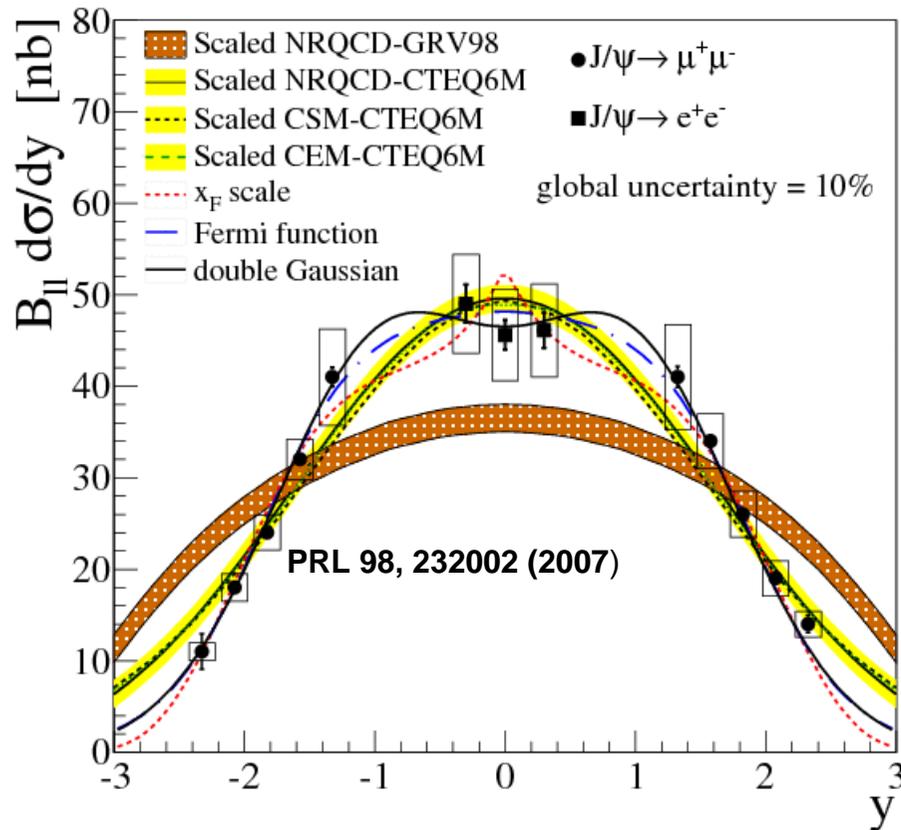
- Measure as many quarkonium states as possible in a variety of collision systems to characterize:
 - ❑ Production in nucleon–nucleon
 - ❑ Cold nuclear matter effects
 - ❑ Production in hot nuclear matter

	J/ψ	ψ'	χ _c	Υ
p+p	☺	☺	☺	☺
d+Au	☺	☺	☺	☺
Cu+Cu	☺			
Au+Au	☺			☺

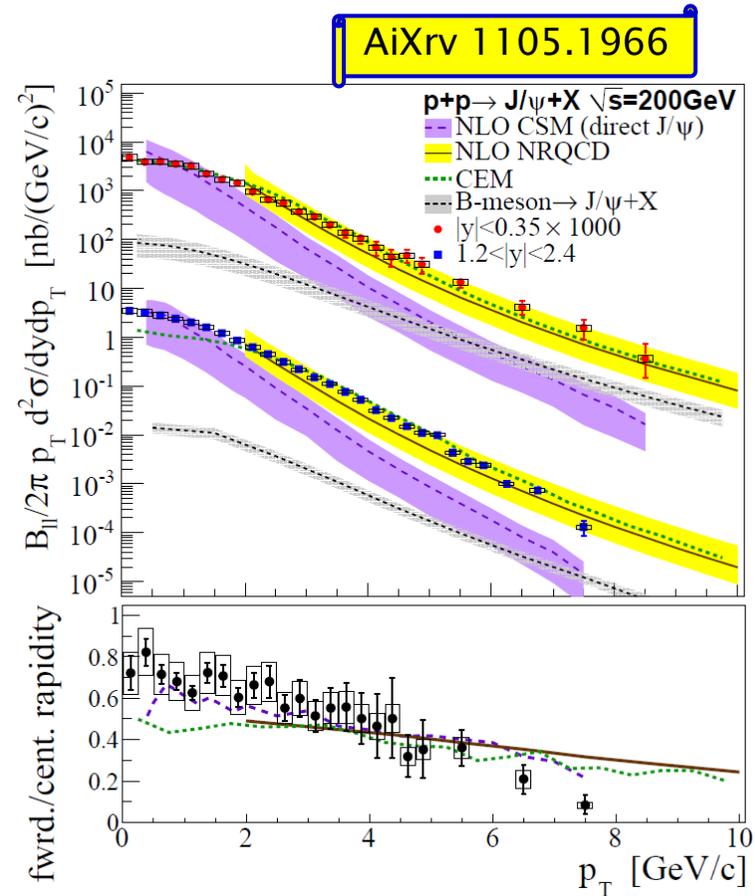
☺ done!

☺ ongoing

J/ ψ production in p+p collisions at 200 GeV: the reference



Total J/ ψ cross-section :
 181 ± 22 nb
 (stat. + sys.)

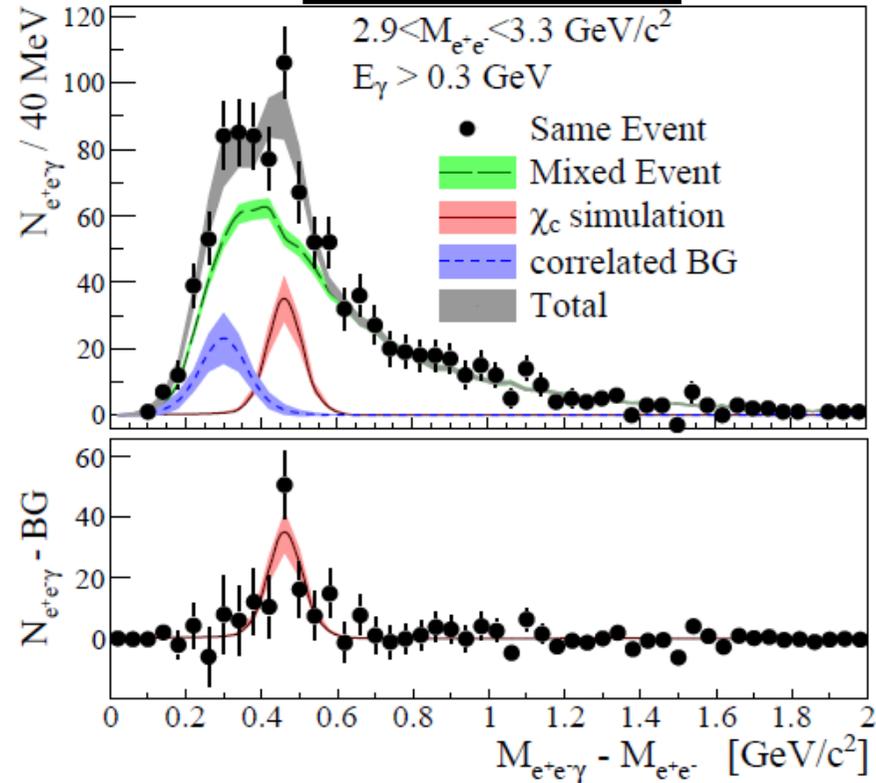
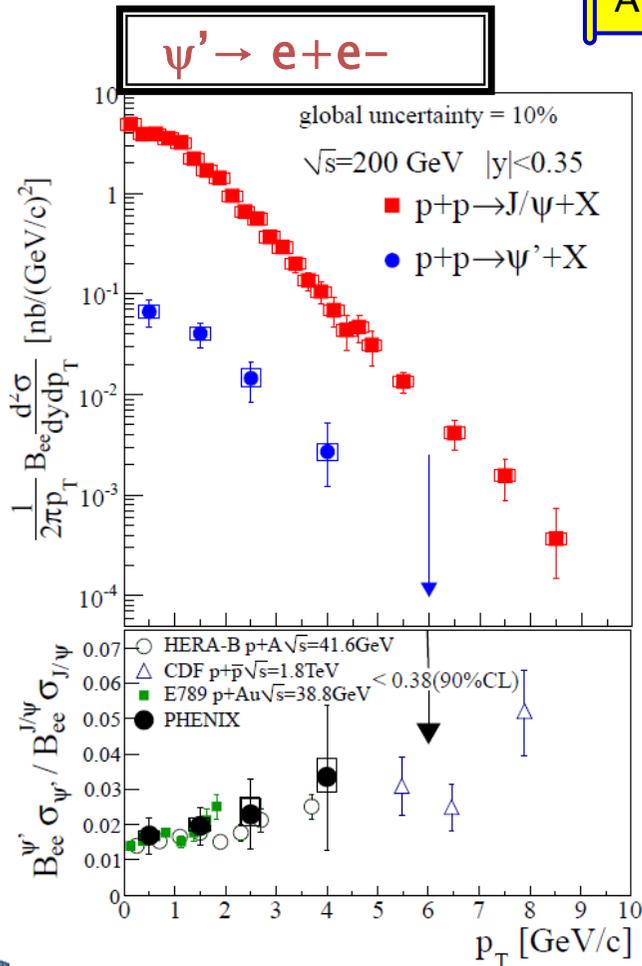


Agreement with CTEQ6,
 supports contribution from
 octet states

ψ' and χ_c production in p+p collisions : measuring J/ψ feed-down

AiXrv 1105.1966

$\chi_c \rightarrow J/\psi + \gamma$

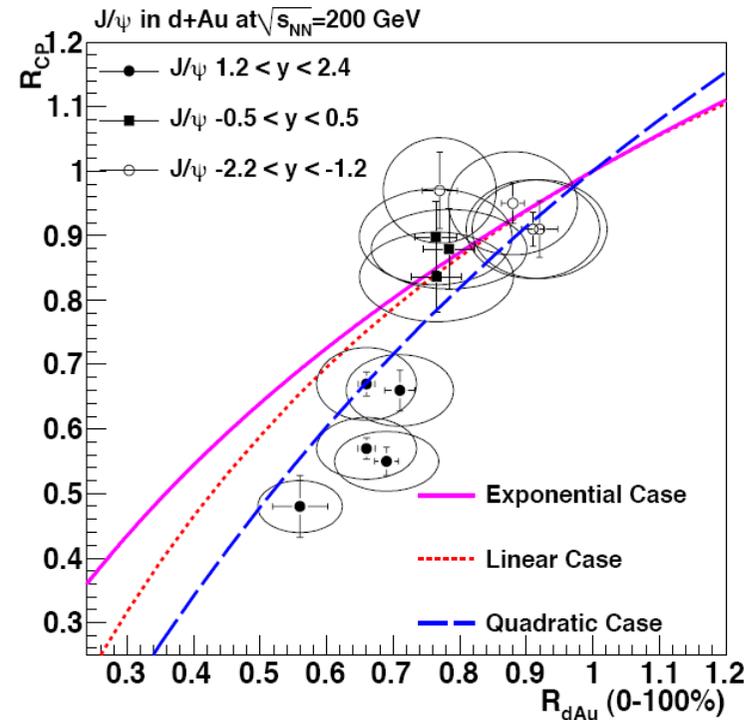
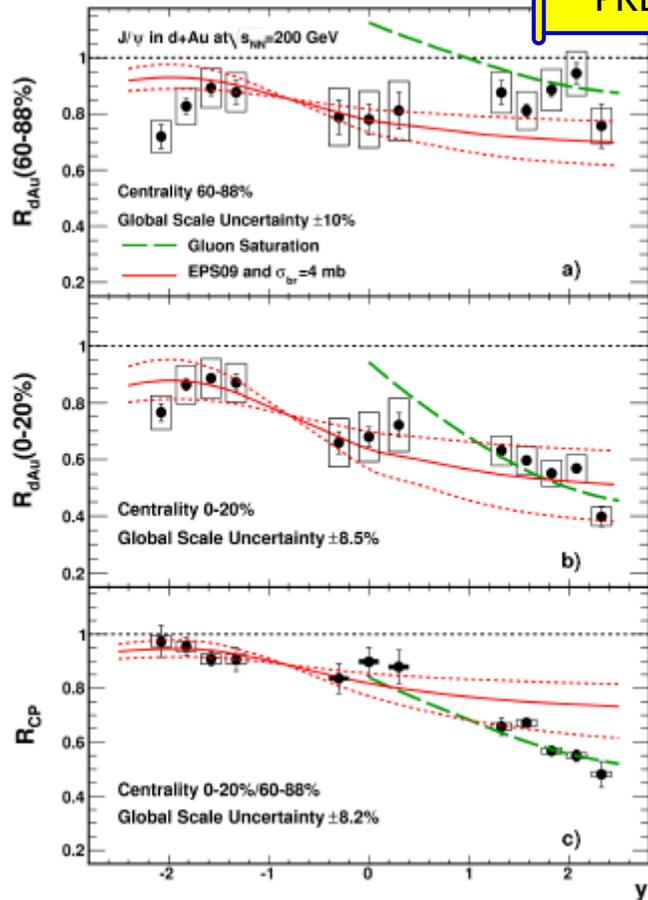


$$F_{\psi'}^{J/\psi} = \frac{B_{J/\psi}^{\psi'} \sigma_{\psi'}}{\sigma_{J/\psi}} = 9.6 \pm 2.4\%$$

$$F_{\chi_c}^{J/\psi} = \frac{N_{\chi_c}}{N_{J/\psi}} \frac{1}{\langle \epsilon_{\chi_c} / \epsilon_{J/\psi} \rangle} = 32 \pm 9\%$$

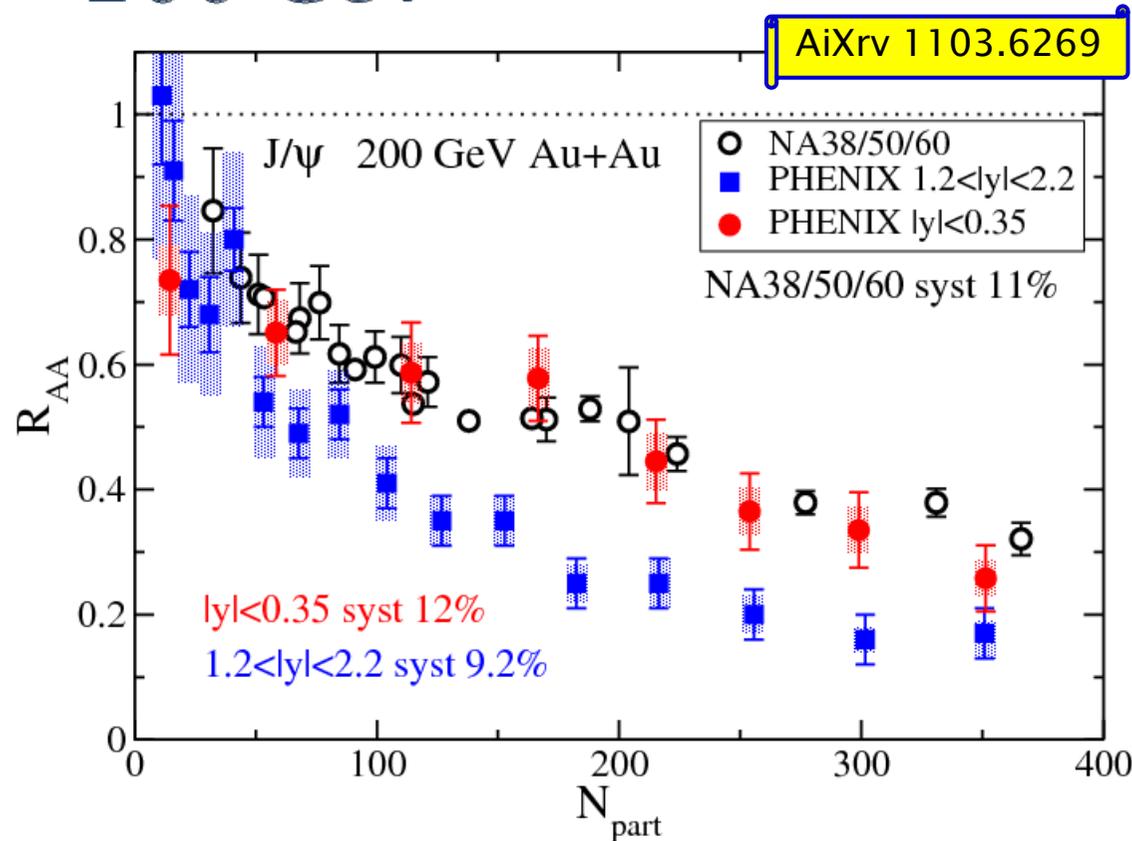
J/ ψ production in d+Au collisions at 200 GeV the CNM measurement

PRL 107, 142301 (2011)



- EPS09 with assumed linear thickness dependence fails to describe centrality dependence of forward rapidity region.

J/ψ production in Au+Au collisions at 200 GeV



➤ Nuclear suppression factor

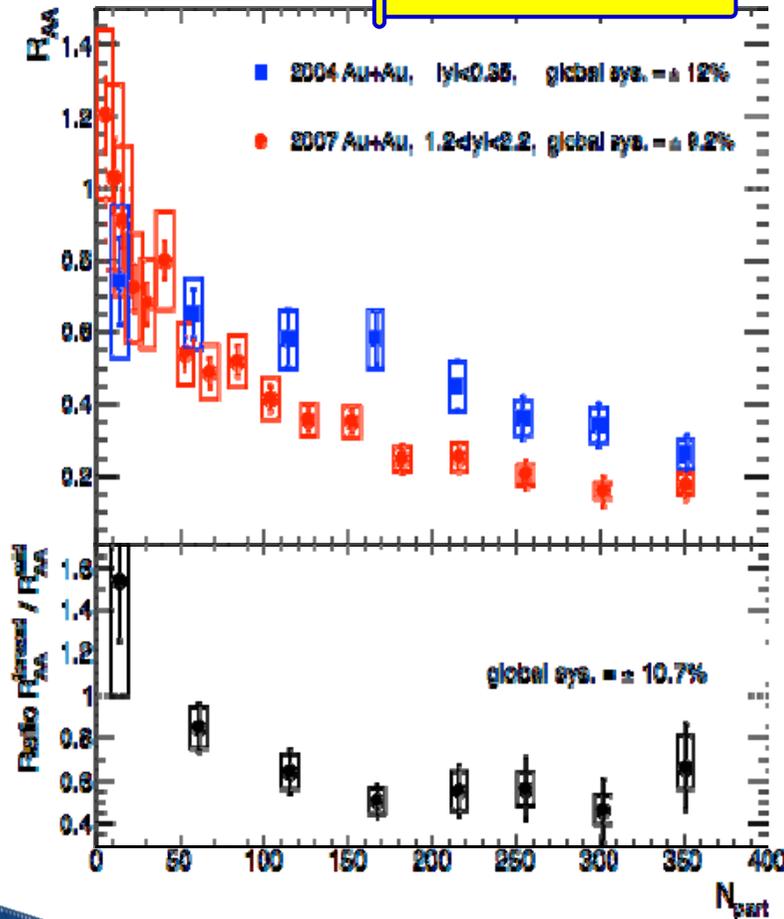
$$R_{AA}(y) = \frac{dN_{AA}/dy}{\langle N_{coll} \rangle \times dN_{pp}/dy}$$

➤ Overall suppression of J/ψ is nearly identical between RHIC, SPS, & LHC ??

Many competing effects need systematic study

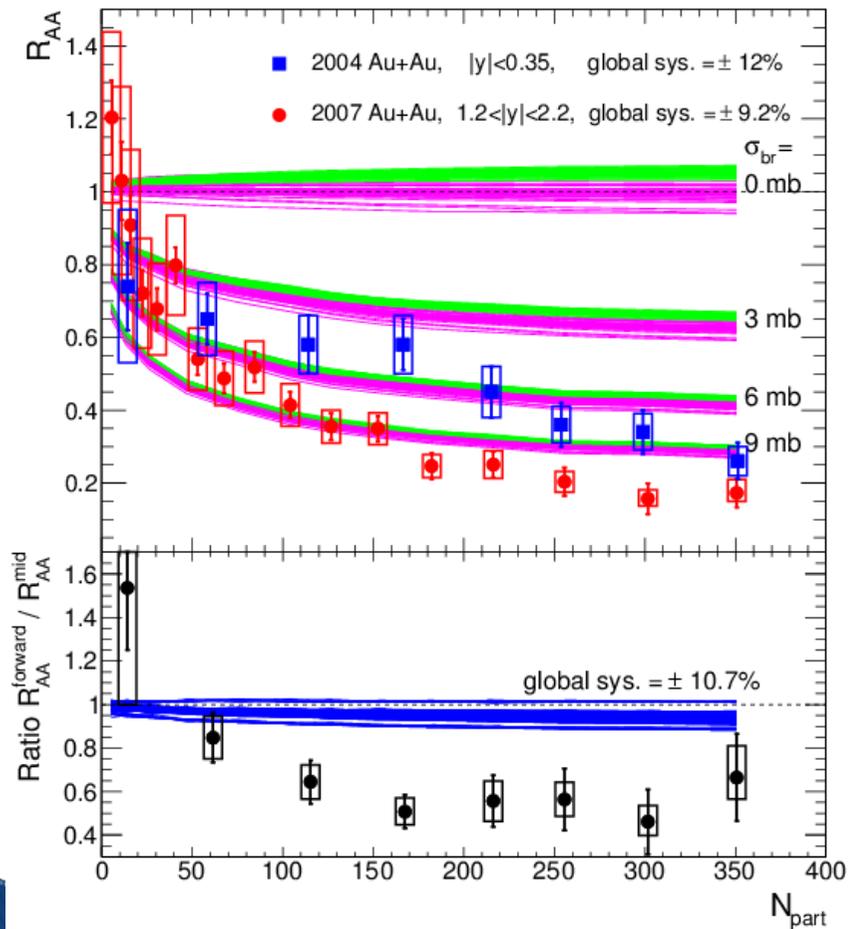
J/ ψ production in Au+Au collisions at 200 GeV

AiXrv 1103.6269



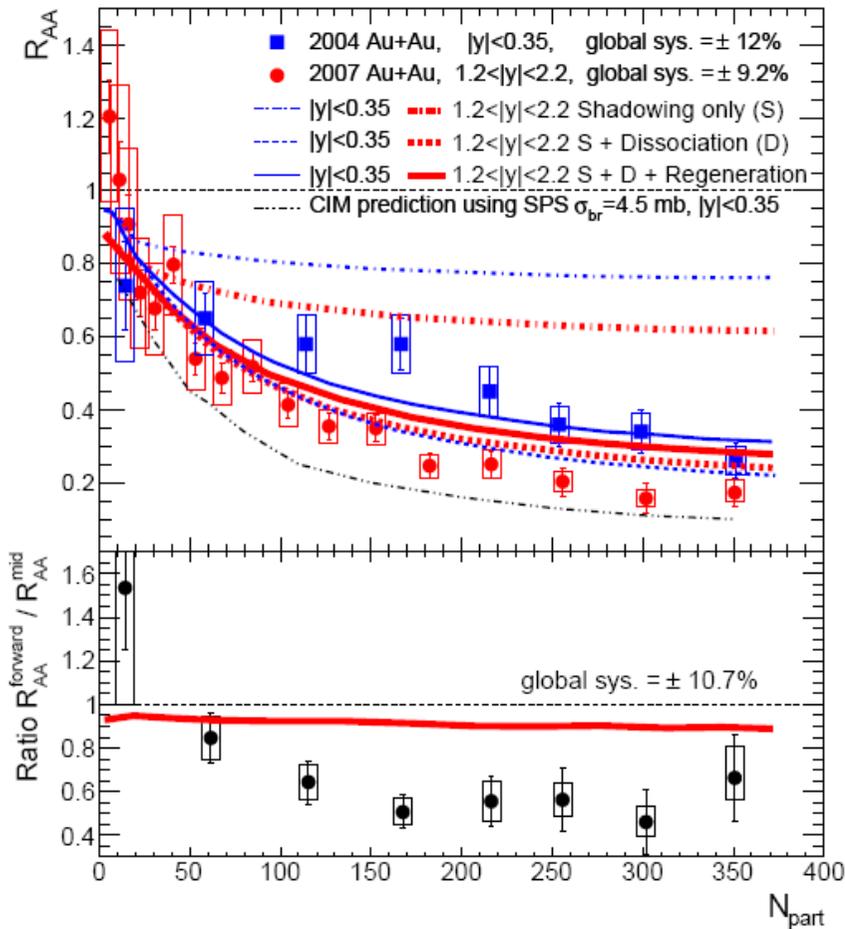
- Forward-rapidity is suppressed more than Mid-rapidity
 - Stronger forward rapidity suppression due to CNM effects?
 - Regeneration at mid-rapidity reduces suppression relative to forward (and gives net suppression similar to SPS)?

Model Comparison: Shadowing/Nuclear Absorption/Initial-state Energy Loss Model



- Projection of EPS09 shadowing and σ_{br} to Au+Au collision in mid-rapidity and forward-rapidity doesn't reproduce R_{AA} or the ratio between rapidities.

Model Comparison: Comover Interaction Model

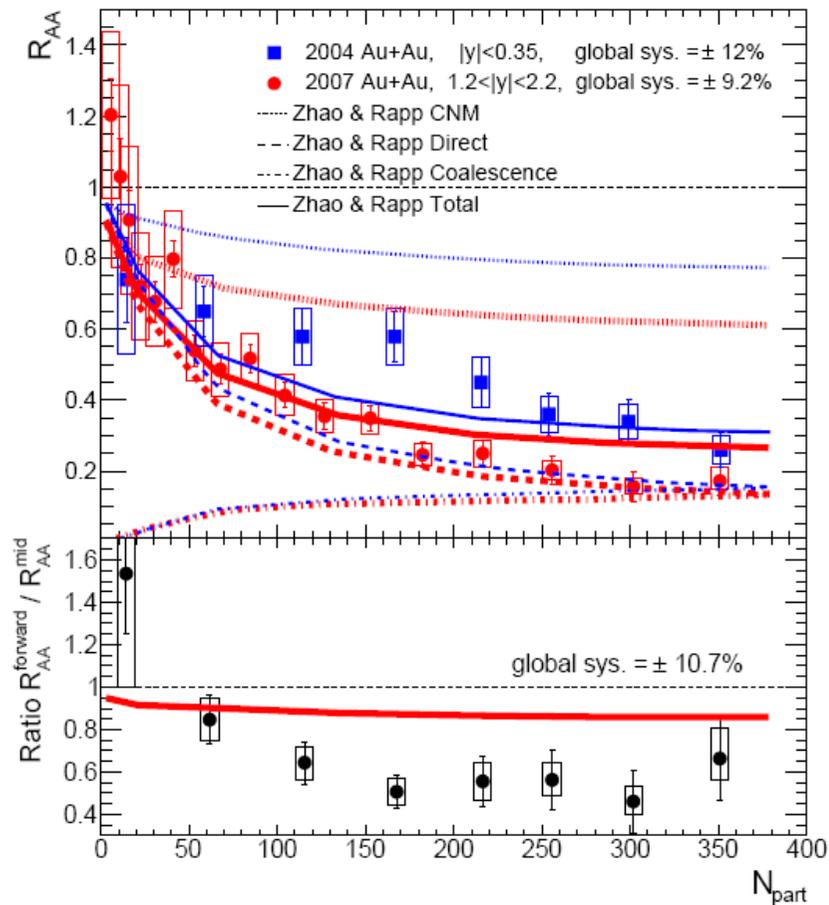


- Combine x -dependent nuclear absorption (but $\sigma_{br} = 0$ at mid-rapidity) with hot, dissociative comoving medium ($\sigma_{co} = 0.65$ mb).
- Predicts similar suppression at forward and mid-rapidity

[22] A. Capella and E. G. Ferreiro, The European Physical Journal C **42**, 419 (2005), hep-ph/0505032.

[23] A. Capella, L. Bravina, E. G. Ferreiro, A. B. Kaidalov, K. Tywoniuk, and E. Zabrodin, Eur. Phys. J. C **58**, 437 (2008), 0712.4331.

Model Comparison: QGP/ Hadron Gas Model/Coalescence



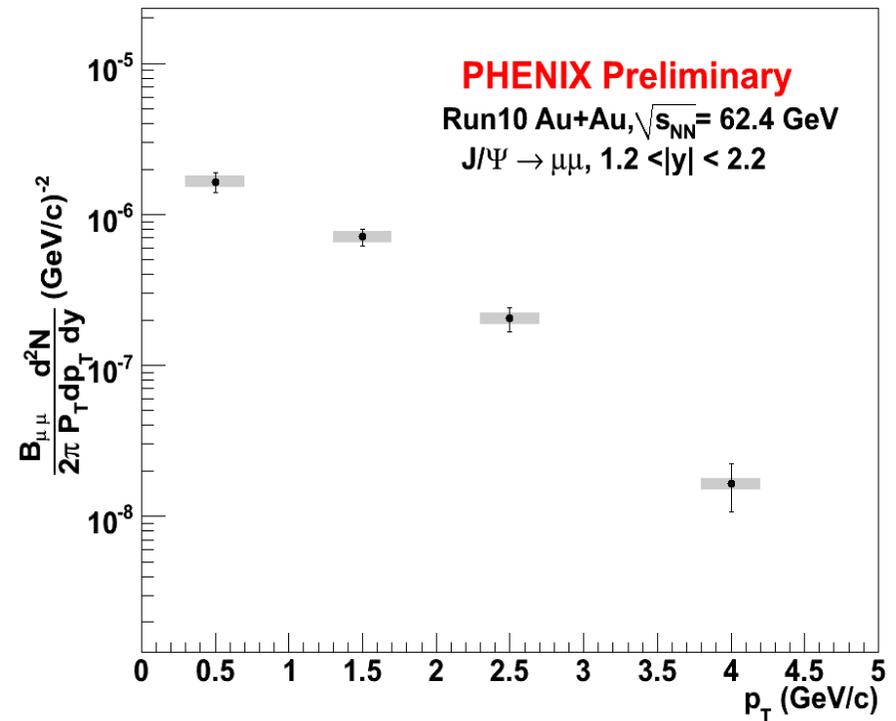
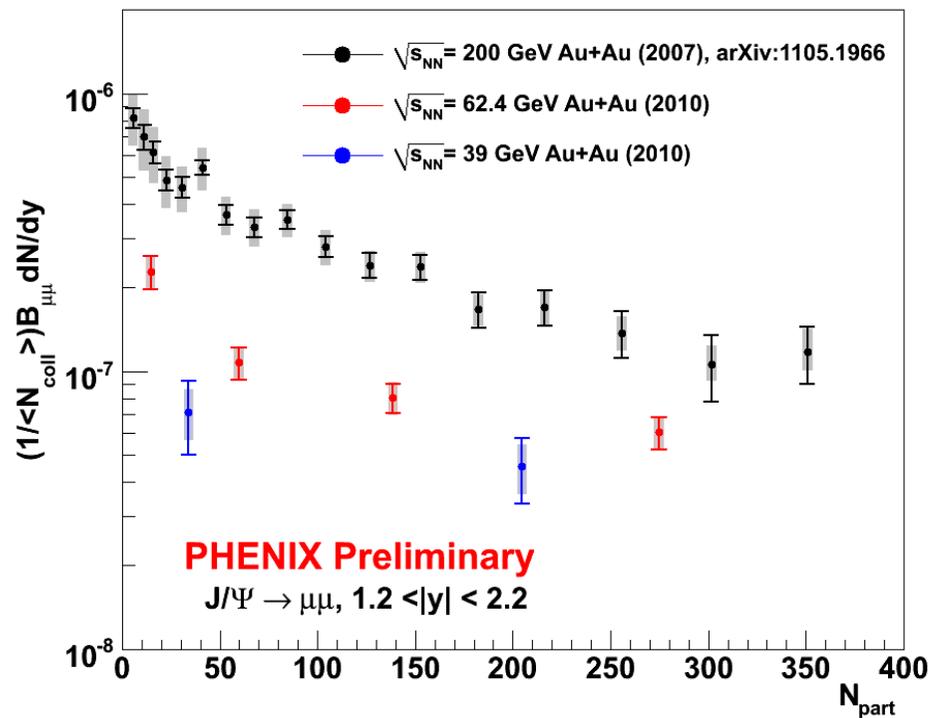
- Trend in qualitative agreement with data but, contrary to the data, it predicts similar suppression for forward and peripheral

X. Zhao and R. Rapp, Phys. Lett. B **664**, 253 (2008), 0712.2407.

X. Zhao and R. Rapp, Eur. Phys. J. **62**, C109 (2009), 0810.4566.

J/ ψ 's in Au+Au collisions at lower energies

- In 2010 PHENIX collected 700M (200M) MB events from 62.4 GeV (39 GeV) Au+Au collisions.

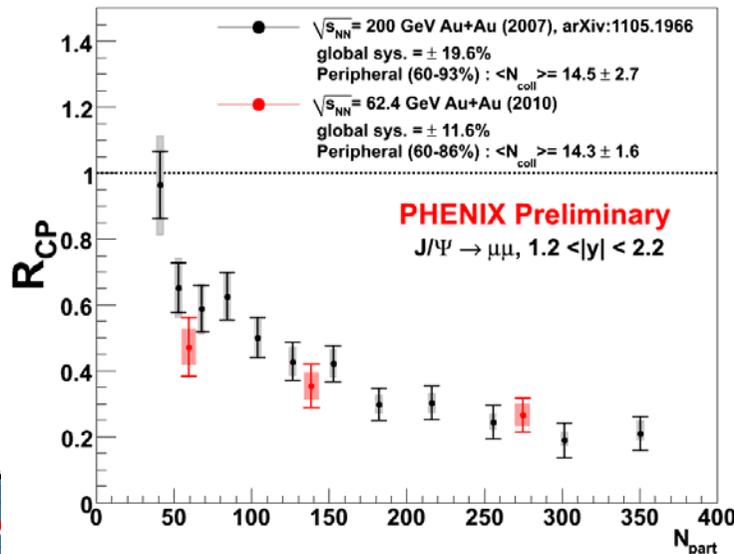


Rapidity $1.2 < |y| < 2.2$

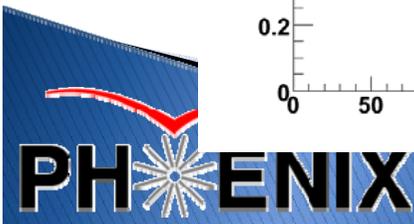
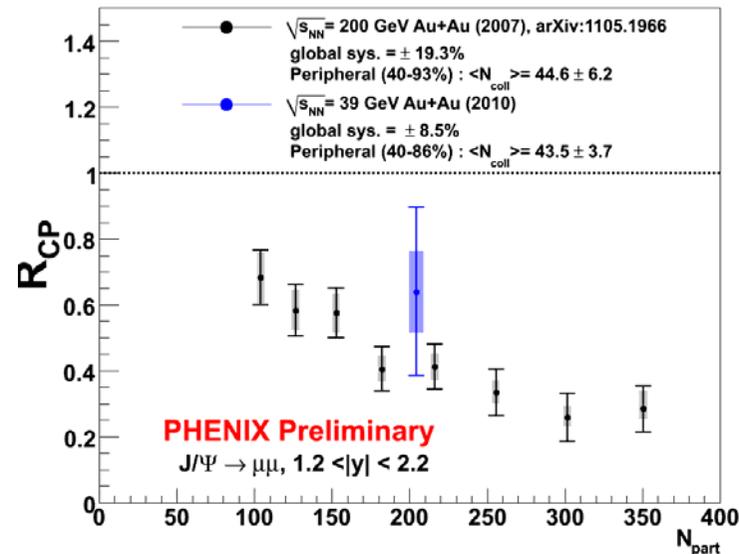
J/ψ in Au+Au collisions at lower energies (II)

- No pp reference available so using Rcp with same peripheral range as a reference in the comparison (similar Ncoll)
- suppression similar in all energies given the current uncertainties
- but, CNM effects expected to be different $x \propto \frac{1}{\sqrt{s}}$

62 GeV

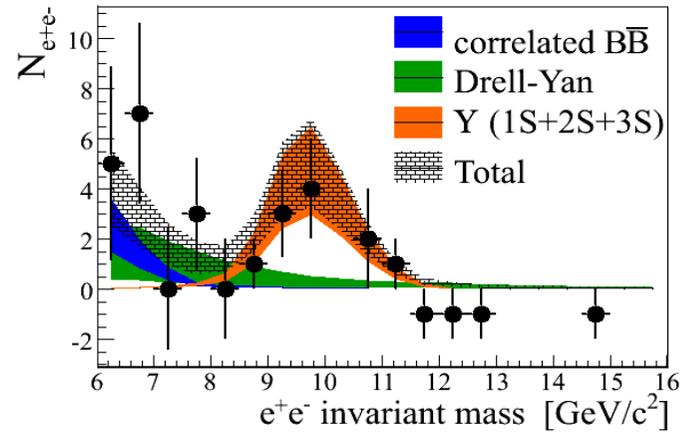
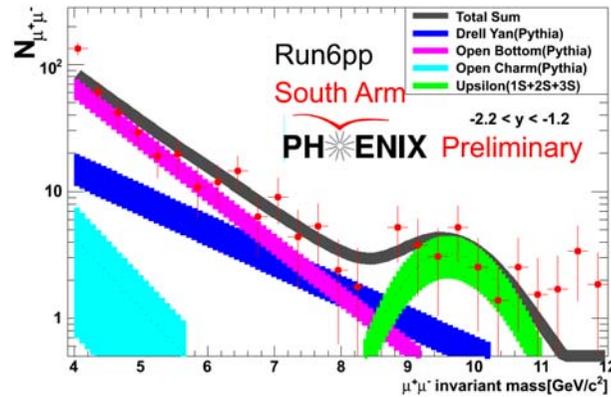


39 GeV

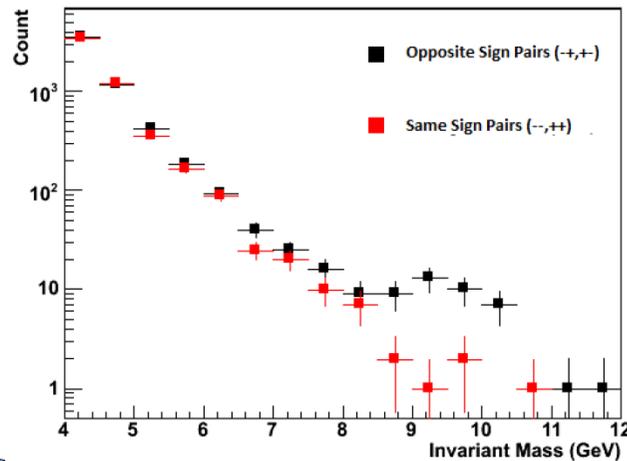


Y program beginning at PHENIX

Production Measurement in pp collisions and Au+Au underway



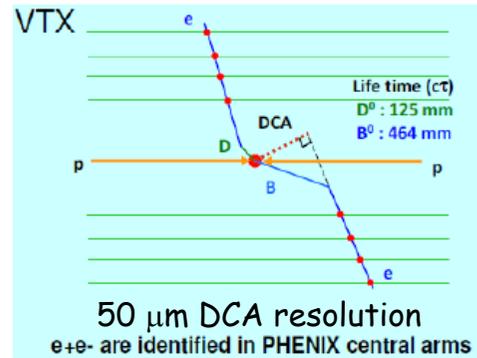
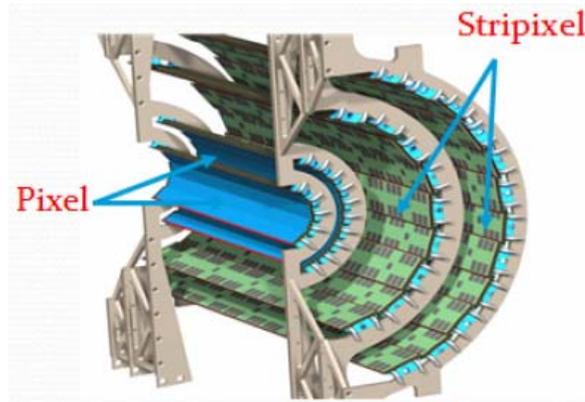
Invariant Mass Spectra in the Region[4,12GeV]



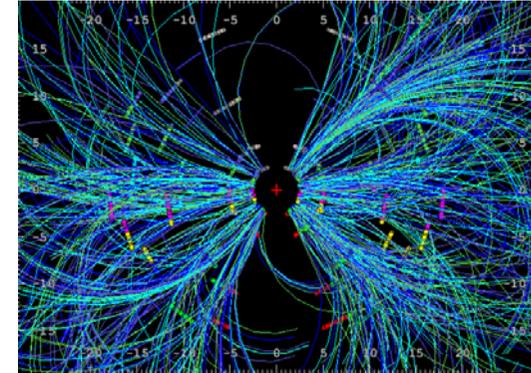
Significant Signal in AuAu

$\Rightarrow R_{AA}$ of $Y(1s+2S+3S)$
coming soon!

PHENIX near-term upgrades: VTX



Au+Au event

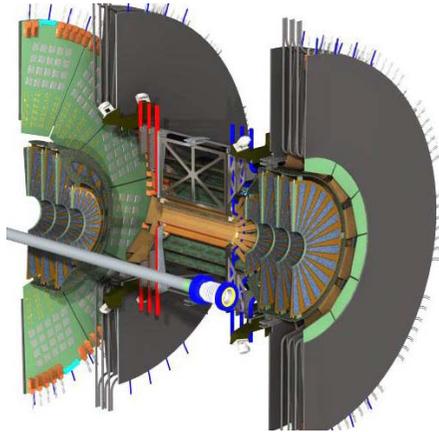


- VTX ($|y| < 1$)
 - Installed successfully in 2011
- Allow measurements of c/b separation through displaced vertex measurements.

end view of VTX

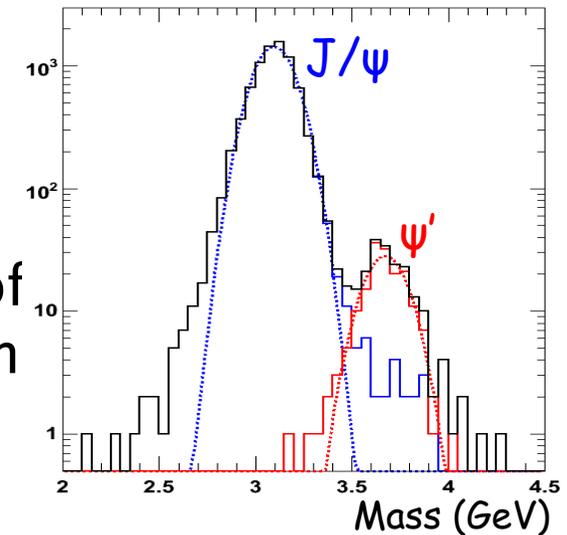
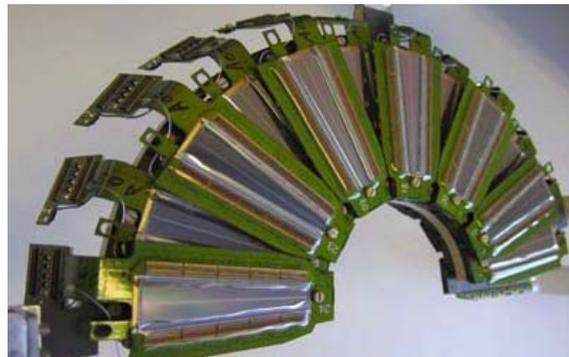


PHENIX near-term upgrades: FVTX



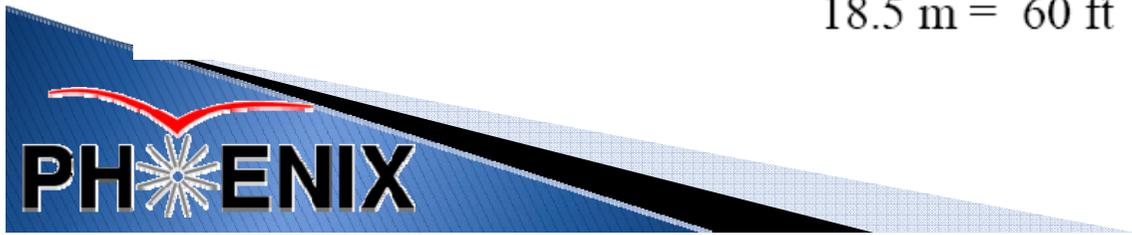
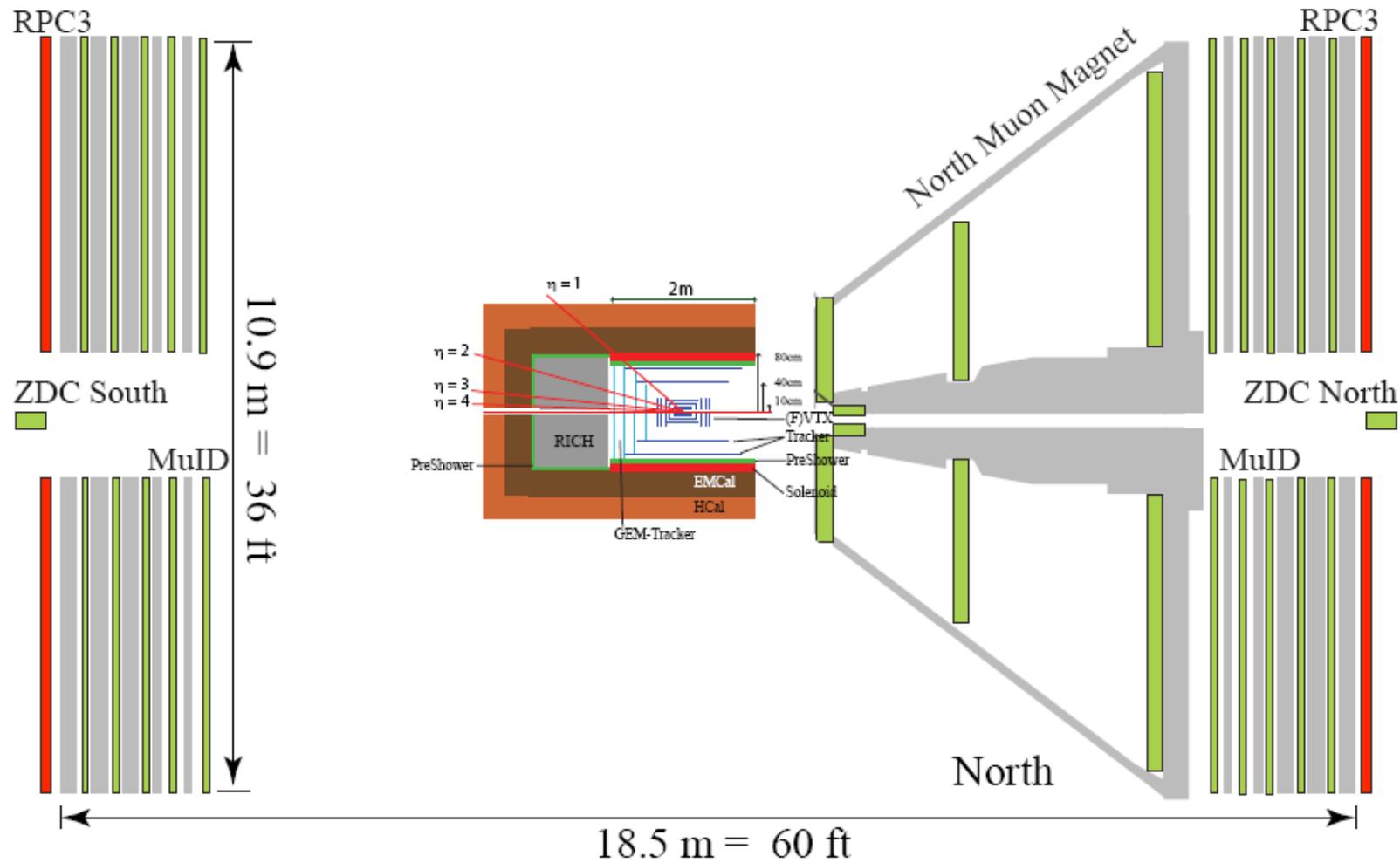
➤ FVTX ($1.2 < |y| < 2.4$)

- Currently being installed for 2012 run
- Allow measurements of c/b separation through displaced vertex measurements.
- Will also reduce background and improve mass resolution in muon arms

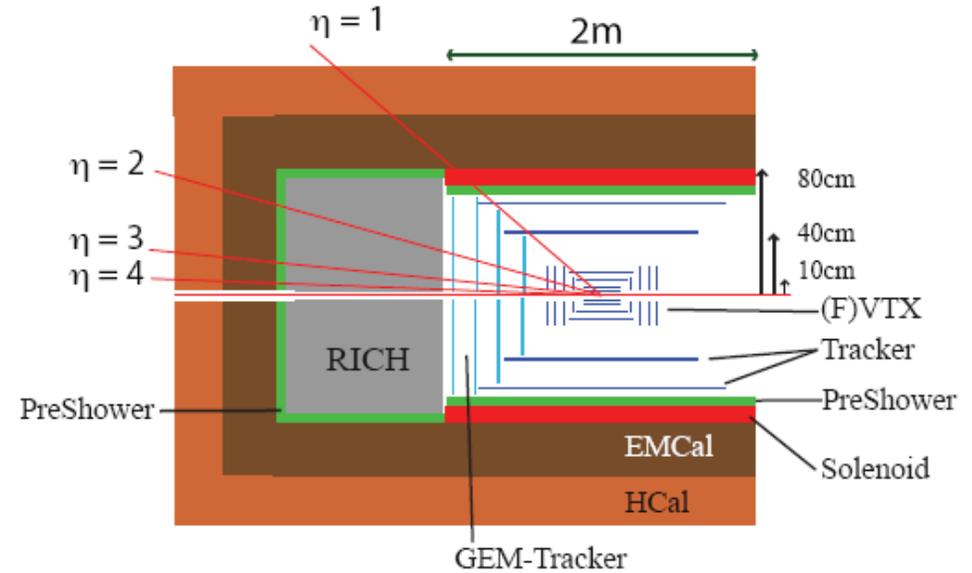


Improved separation of ψ' from J/ψ with FVTX

PHENIX → sPHENIX the long term plan



sPHENIX Plan



- maintain PHENIX high rate capability
 - record lots of heavy ion data without rare triggers
- hadronic calorimetry
- forward detectors for useful for spin, asymmetric collisions & e-p/e-A, A-A
- large uniform acceptance
 - ❖ ~10-fold acceptance increase for quarkonia
 - ❖ good mass resolution : Υ states resolved

Conclusions

- PHENIX observed no change in J/ψ suppression over a wide range of energies
- Geometry dependence of the nuclear effects experimentally studied
- Υ is being studied in several systems and different rapidity ranges
- Upcoming PHENIX VTX upgrade will provide measurement of ψ' at forward rapidity

