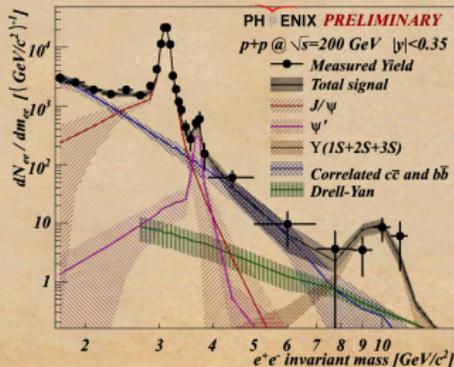


Hadroproduction of Charmonium Excited States and Bottomonium at $\sqrt{s_{NN}} = 200 \text{ GeV}$ Measured by PHENIX

Cesar Luiz da Silva for the PHENIX Collaboration

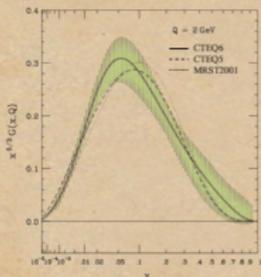
Iowa State University

3rd Joint Meeting of the APS DNP and JPS - Hawaii 10/15/2009

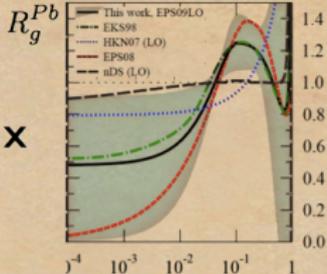


Quarkonia Production and Dissociation

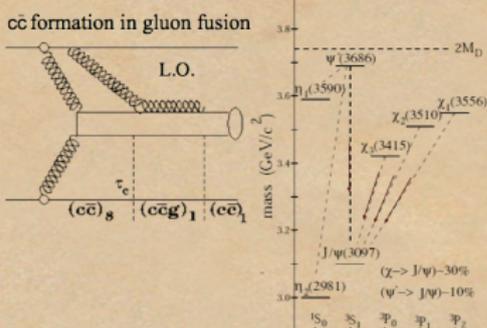
Gluon distribution in p



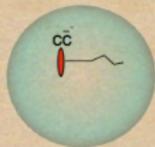
Gluon distribution modification in A



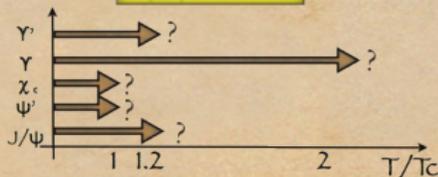
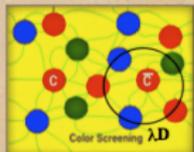
$c\bar{c}$ spectroscopy and decays



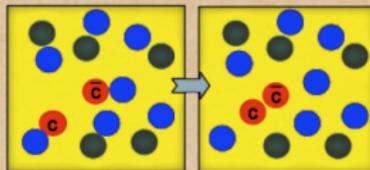
breakup in hadrons



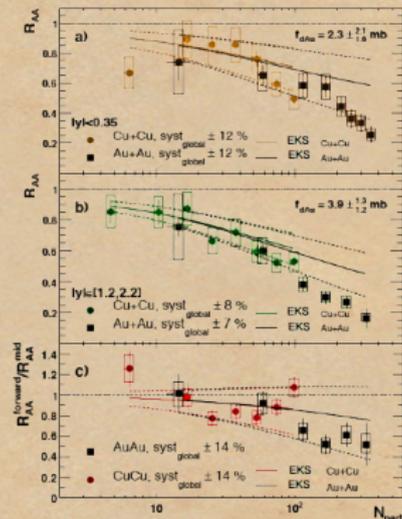
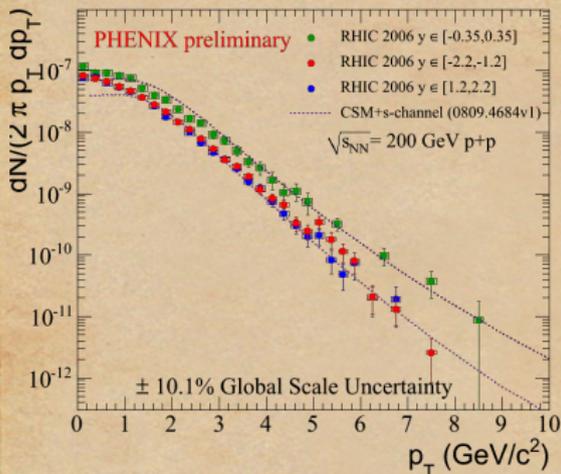
Color Screening Dissociation in sQGP



Charmonium recombination in sQGP

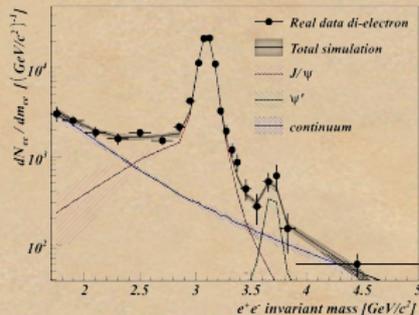
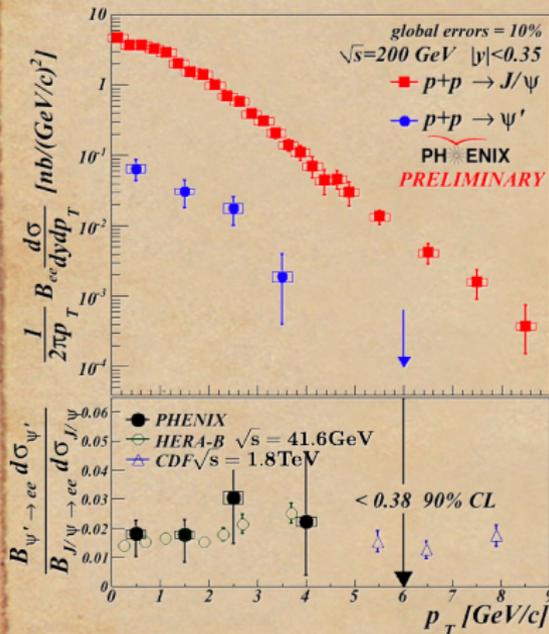


Limitations of the J/ψ measurements



- J/ψ measurements include feed-down contributions from ψ' , χ_C and B , cannot be directly compared with production models
- the $c\bar{c}$ that cross the medium is in a final state (J/ψ , χ_C or ψ') or just a pre-resonant state?
- J/ψ suppression observed in Au + Au collisions could be only from ψ' and χ_C feed-down contributions?
- ONE NEEDS TO MEASURE THE EXCITED CHARMONIUM STATES TO FULLY UNDERSTAND the J/ψ YIELDS

ψ' Measurement in $p+p$ collisions



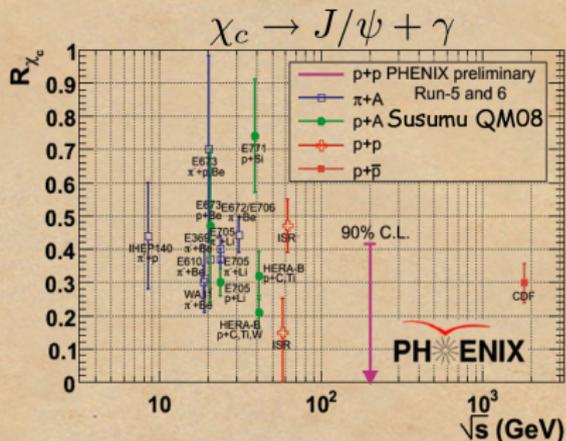
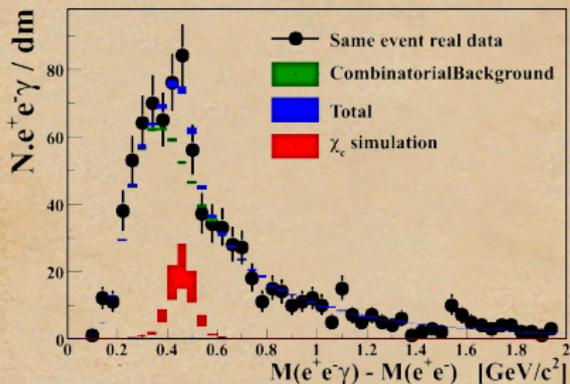
- no change in the ψ' to J/ψ cross section ratio for an extended collision energy and transverse momentum
- preliminary feed-down contribution to J/ψ is

$$F_{\psi'}^{J/\psi} = B(\psi' \rightarrow J/\psi) \frac{B_{ee}^{\psi'} \sigma_{\psi'}}{B_{ee}^{J/\psi} \sigma_{J/\psi}} \frac{B_{ee}^{J/\psi}}{B_{ee}^{\psi'}}$$

$$= 8.6 \pm 2.5\%$$

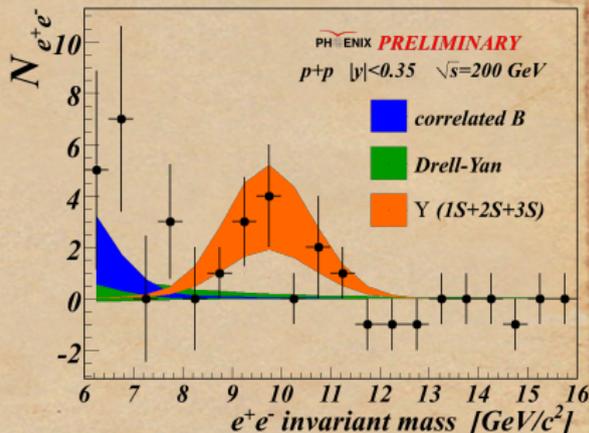
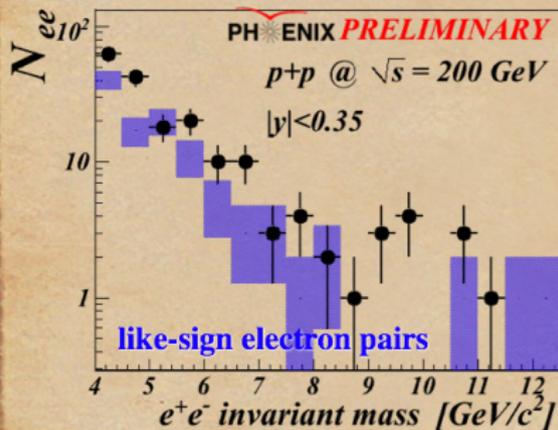
- word average $F_{\psi'}^{J/\psi} = 8.1 \pm 0.3\%$ [JHEP 0810:004,2008]

$\chi_c \rightarrow J/\psi + \gamma$ in $p+p$ collisions



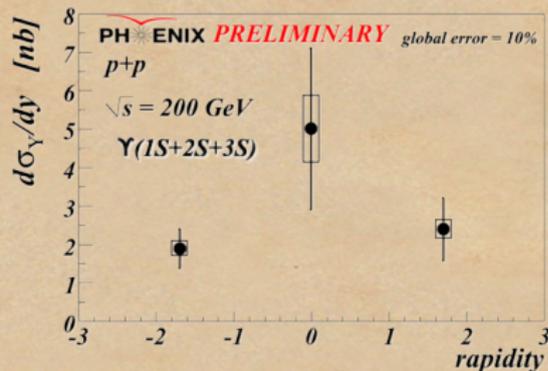
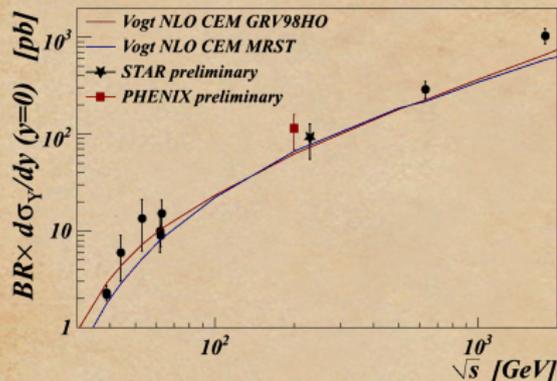
- difficult measurement given the very low energy of the photon decay
- preliminary studies resulted in $F_{\chi_c}^{J/\psi} < 42\%$ (90% CL)
- mean value and uncertainties results on the way
- world average $25 \pm 5\%$ [JHEP 0810:004,2008]

Bottomonium signal in $p+p$ collisions



- 12 unlike-sign pairs and 1 like-sign pair $\in [8.5, 11.5] \text{ GeV}/c^2$ mass region
- correlated BB mesons and Drell Yan continuum estimated to be $< 15\%$ in this mass region, < 1.6 counts

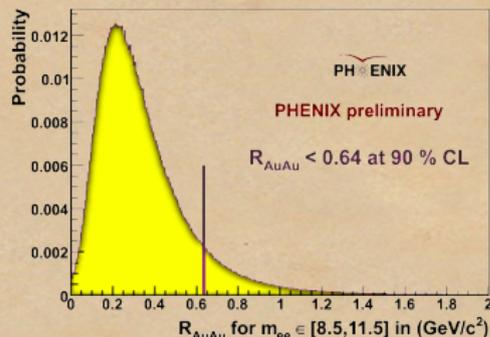
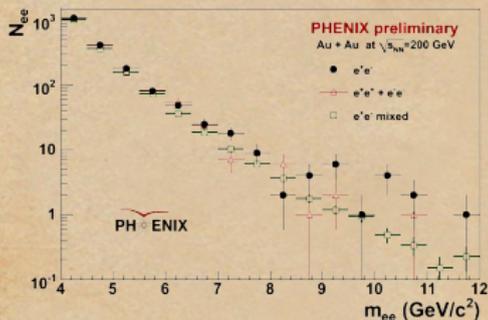
$\Upsilon(1S+2S+3S)$ cross section



- b quarks are more non-relativistic than c ones allowing more reliable theoretical predictions
- preliminary observation of the Υ cross section follows world trend and Color Evaporation Model (CEM) prediction [R. Vogt]
- looking for p_T and rapidity theoretical estimations at $\sqrt{s}=200$ GeV

$$B \frac{d\sigma}{dy} \Big|_{|y| < 0.35} = 114^{+46}_{-45} pb \quad (1)$$

High Mass Nuclear Modification Factor (R_{AA}) in $Au + Au$ Collisions

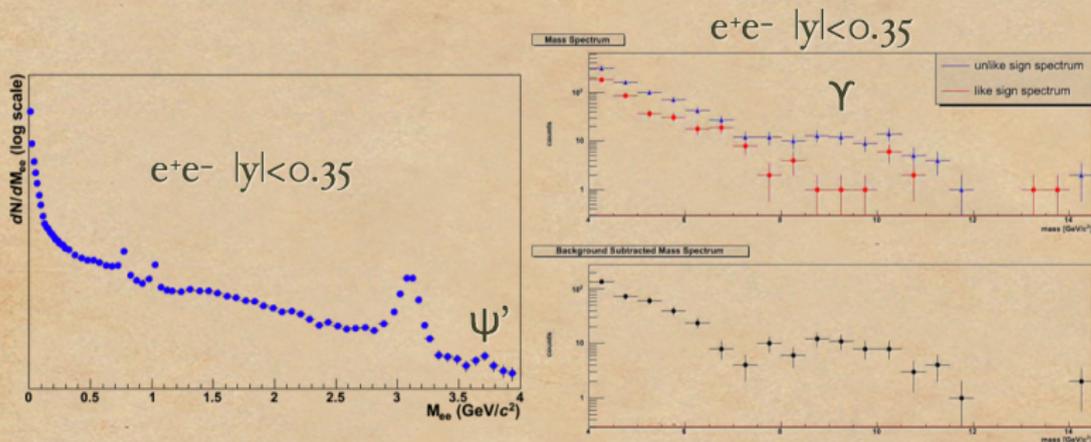


- 17 unlike-sign and 5 like-sign pairs in the Υ family mass range $[8.5, 11.5]$ GeV/c^2
- no continuum subtraction, the actual $R_{AA}(\Upsilon(1S + 2S + 3S))$ can be lower than what is measured here

$$\frac{R_{AA}([8.5, 11.5])}{R_{AA}(J/\psi)} = \frac{\frac{N([8.5, 11.5])/A\epsilon(\Upsilon)_{AA}}{N_{coll} \times N([8.5, 11.5])_{pp}/A\epsilon(\Upsilon)_{pp}}}{\frac{N(J/\psi)/A\epsilon(J/\psi)_{AA}}{N_{coll} \times N(J/\psi)_{pp}/A\epsilon(J/\psi)_{pp}}} \quad \frac{N_{coll} A\epsilon(\Upsilon)_{pp}/A\epsilon(\Upsilon)_{AA}}{N_{coll} A\epsilon(J/\psi)_{pp}/A\epsilon(J/\psi)_{AA}} \approx 1$$

- suppression observed compatible with dissociation of the $2S+3S$ states and feed-down contributions to $1S$ state
- given the small amount of b quarks at RHIC energy, there is a small chance for Υ coalescence turning its suppression easier to interpret

Perspectives in $d+Au$ collisions



- if the nuclear modification factor of ψ' , χ_c is the same as for J/ψ , that could indicate that the $c\bar{c}$ is not formed yet when crossing the nucleus
- $R_{dA}(\Upsilon)$ can help to understand the cold nuclear matter contribution to the suppression observed in Au + Au collisions
- we already observed ψ' and Υ signals in our high luminosity 2008 $d+Au$ data

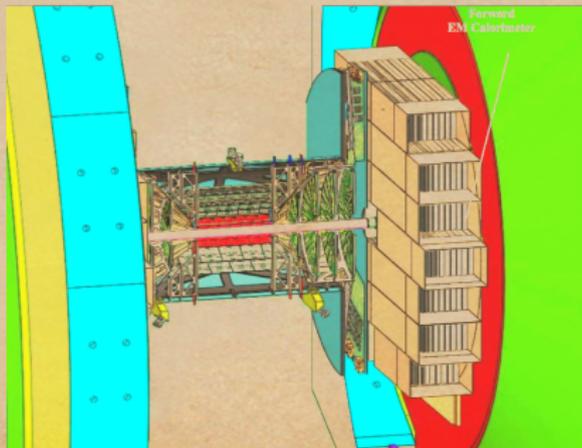
Detector Upgrades

Electromagnetic Calorimeters

- important to measure χ_c at large rapidity ranges
- upcoming results from PHENIX MPC ($3.1 < \eta < 3.9$)
- PHENIX FOCAL ($1.5 < \eta < 3.0$)

Vertex Detectors

- PHENIX Silicon Vertex (SVTX) and Forward Vertex (FVTX) detectors
- measure B contributions by displaced vertex determination
- discrimination of ψ' peak at PHENIX forward rapidity



Conclusions and Outlook

- PHENIX has shown the ability to measure different charmonium states and bottomonia
- ψ' and χ_C ratio to J/ψ results in $p+p$ collisions seems to confirm what was observed in other facilities and energy collision
- bottomonia in $p+p$ collisions follow the word trend
- first observation of the Υ suppression in Au + Au collisions, valuable information to understand the color screening scenario
- $B \rightarrow J/\psi$ decay can be observed with SVTX
- extended rapidity for ψ' and χ_C can be accessible with the FVTX and FOCAL

Thanks for your attention !!!