

# Heavy flavor results from PHENIX at RHIC

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on behalf of the PHENIX collaboration  
LLR – École polytechnique / IN2P3

Deep Inelastic Scattering  
Madrid, 2009, April 27<sup>th</sup>

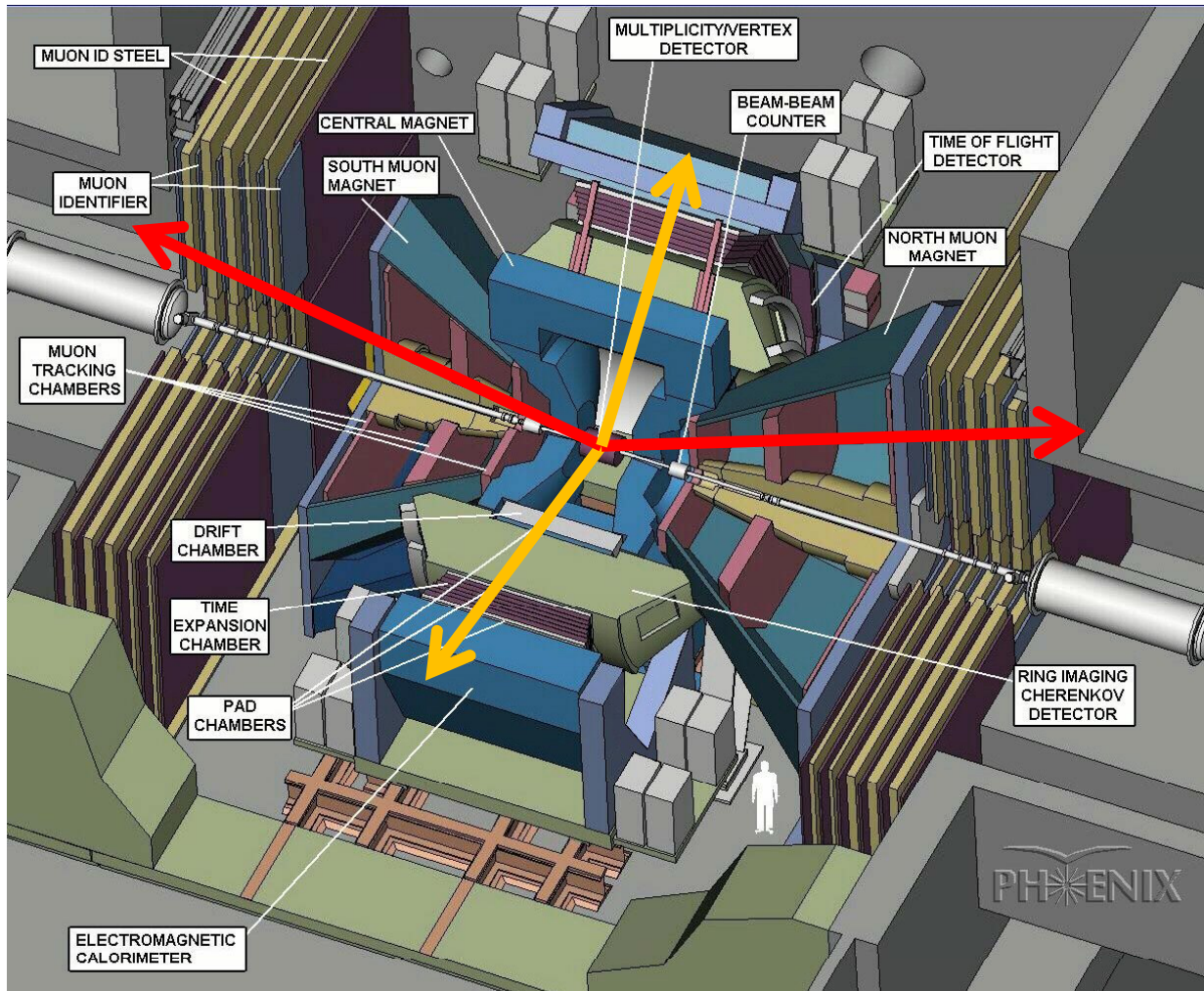


# As an introduction

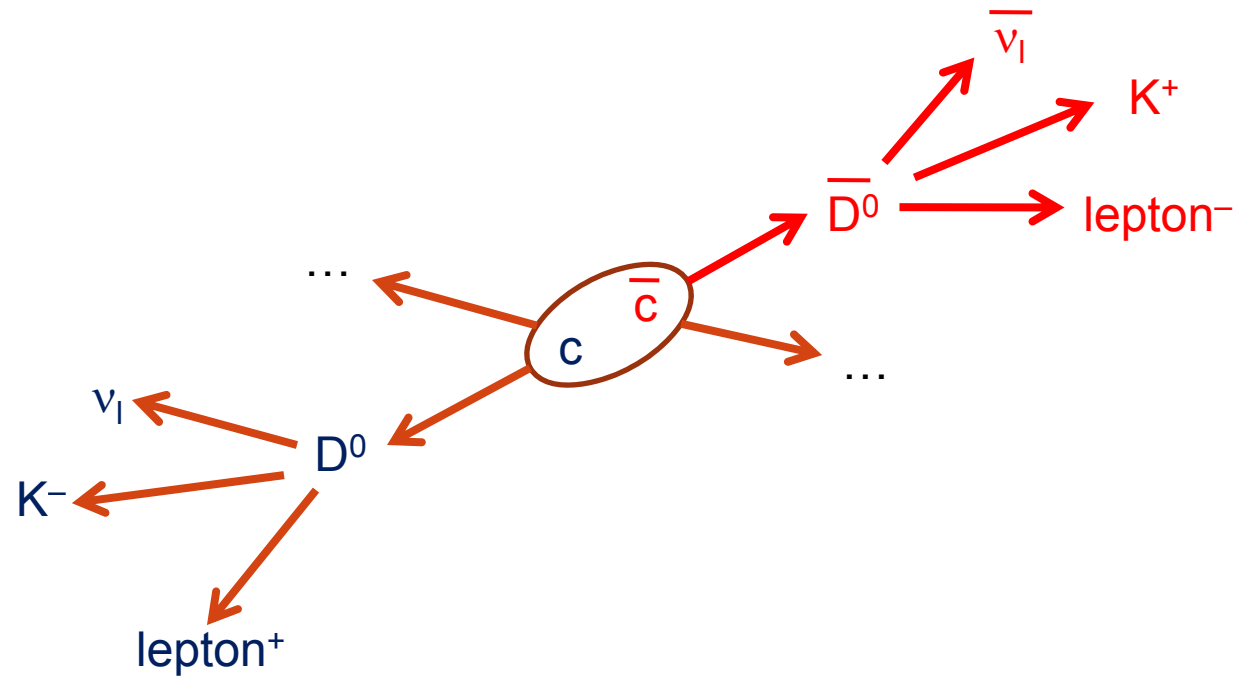
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- Phenix primary goal is the study of the quark gluon plasma, through A+A collisions
- Need good references from...  
p+p and d+A collisions ← this talk, outlining:
  - Open charm and beauty in p+p collisions
    - From single electron at  $y \approx 0$ , single muon at  $y \approx 1.7$ ,
    - From dielectron, e-h and e- $\mu$  correlations...
  - Quarkonia in p+p collisions
    - $J/\psi$ ,  $\psi'$  and  $\Upsilon$  at  $y=0$ ,  $J/\psi$  at  $y \approx 1.7$ ,  $J/\psi$  polarisation
  - $J/\psi$  in d+Au collisions

# The PHENIX apparatus



- Electron in RICH and EMCAL
  - $|\eta| < 0.35$
  - $p_e > 0.2 \text{ GeV}/c$
  - $\Delta\phi = 2 \times 90^\circ$(also hadrons)
- Muon in tracker and identifier
  - $1.2 < |\eta| < 2.4$
  - $p_\mu > 2 \text{ GeV}/c$
  - $\Delta\phi = 360^\circ$(stopped hadrons)



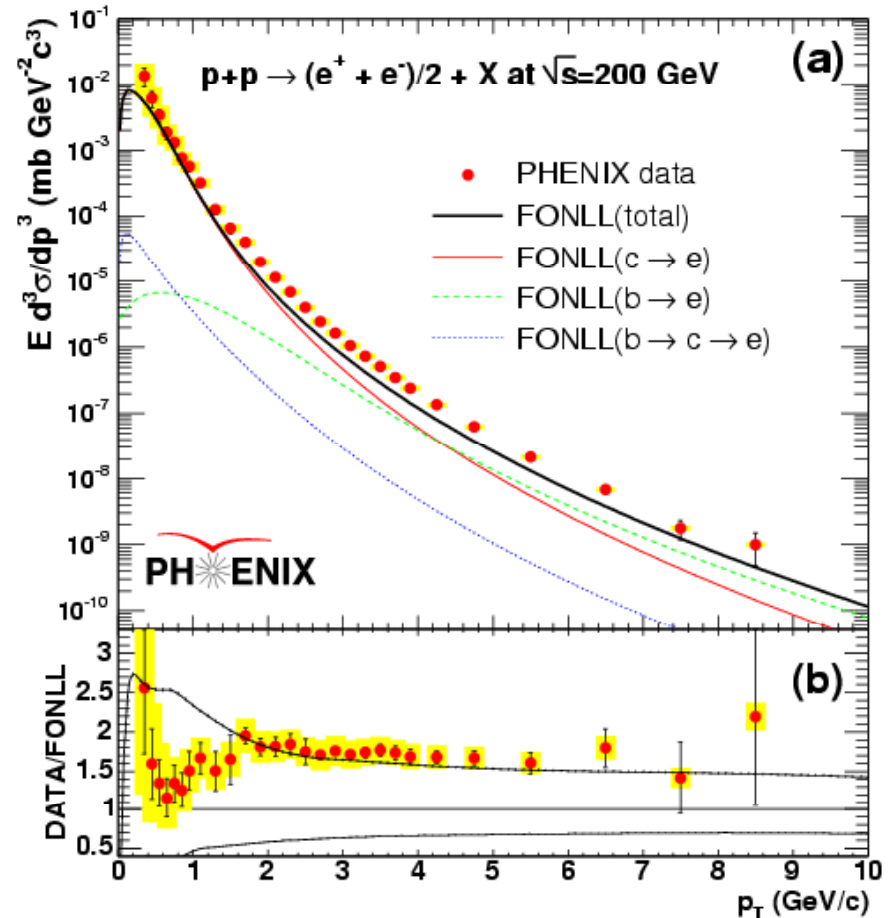
Single leptons, dilepton correlations, or hadron-lepton kinematics

## OPEN CHARM AND BEAUTY

# Total heavy flavour from single electrons

- Subtract the cocktail of known (measured) sources:
  - $\pi^0$  and  $\eta$  Dalitz decays, conversion, etc.
- Crosscheck by inserting a converter
- Agreement with FONLL calculation, with uncertainties
- Charm xsection derived:

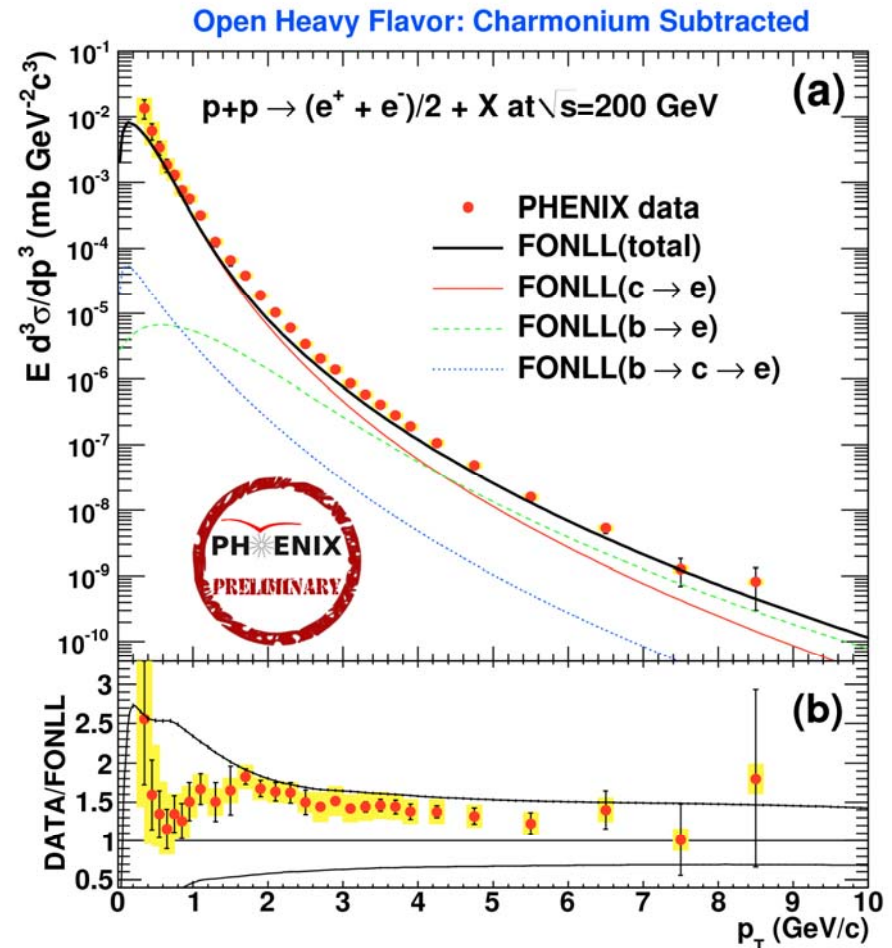
$$\sigma_{cc} = 567 \pm 57 \pm 224 \mu\text{b}$$



PRL97 (2006) 252002

# Open heavy flavour from single electrons

- New: Subtract J/ $\psi$ , Upsilon and Drell-Yan  
< 20% decrease for  $p_T > 5 \text{ GeV}/c$
- Better agreement with FONLL calculation
- Low  $p_T$  dominated by charm
- Does not allow to separate b contribution

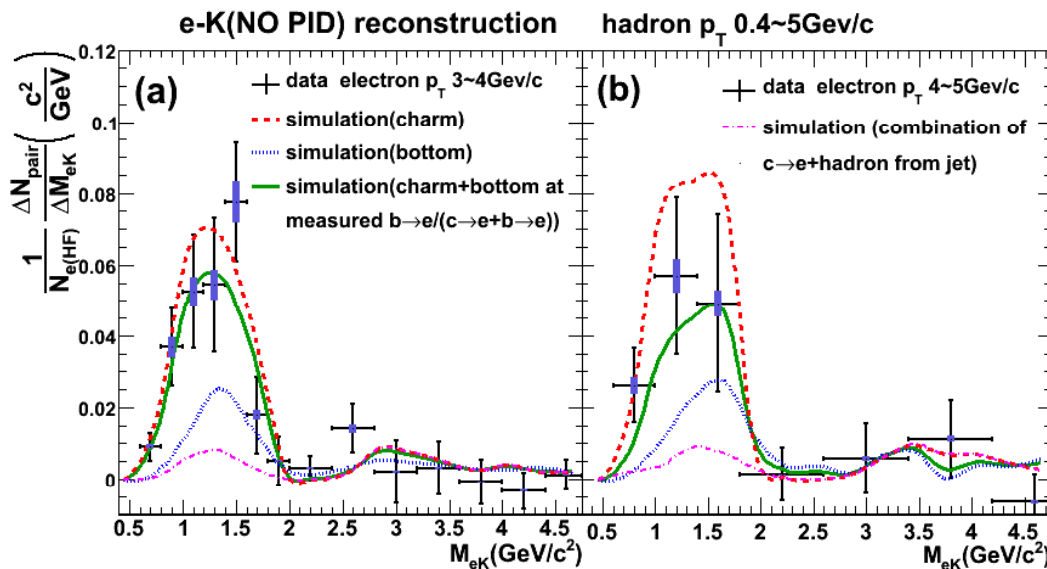
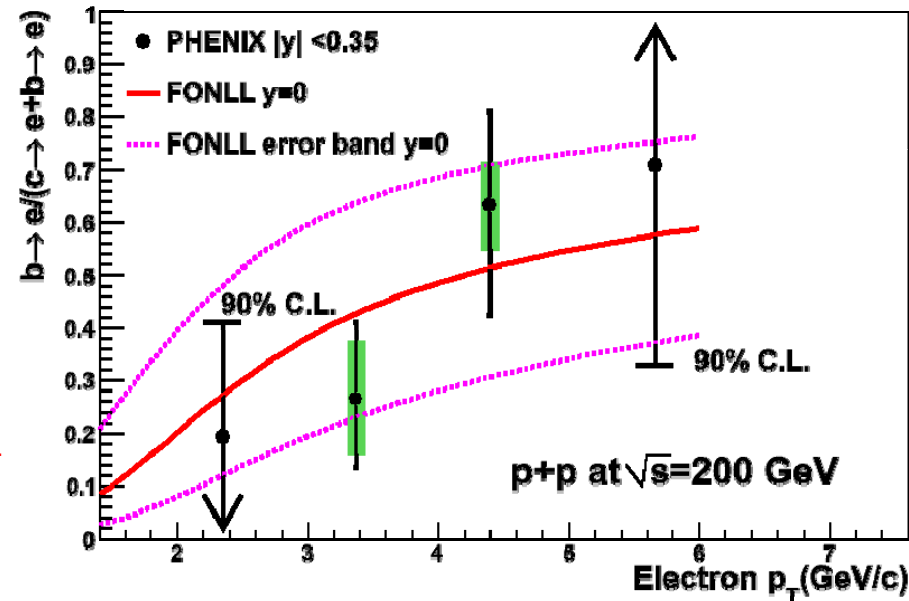
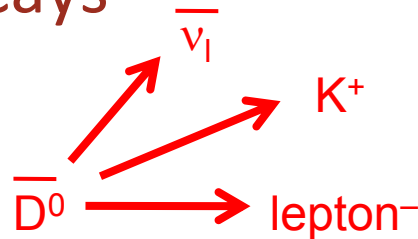


A. Dion, QuarkMatter09



# b/c+b from e-K correlations

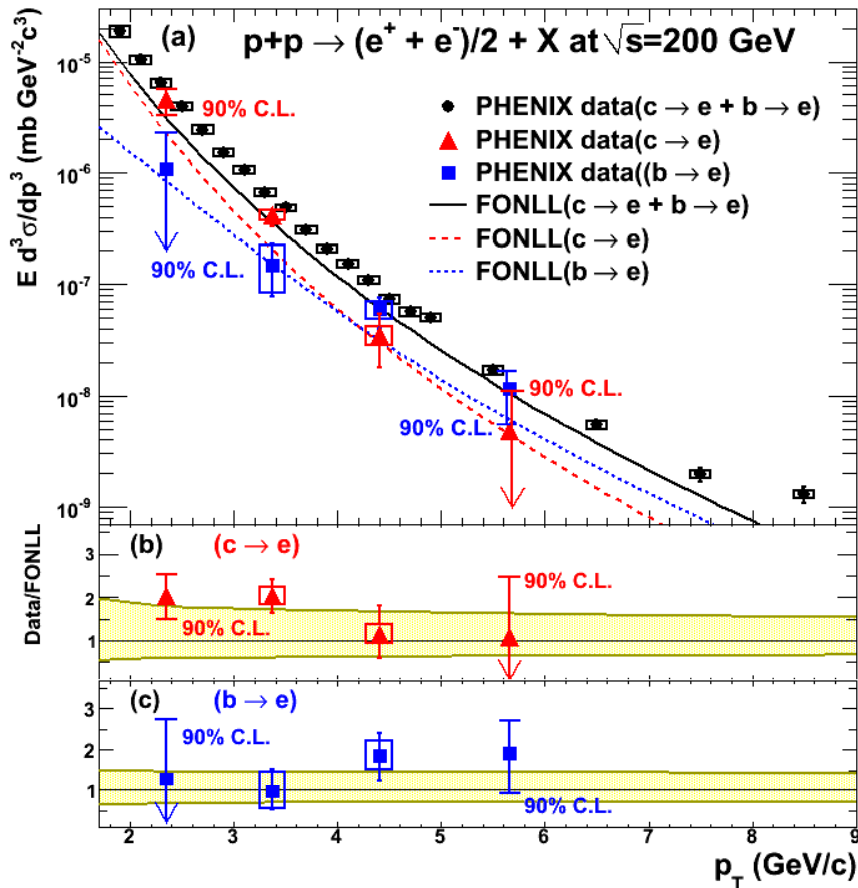
- e-K invariant mass per electron is different for c and b decays



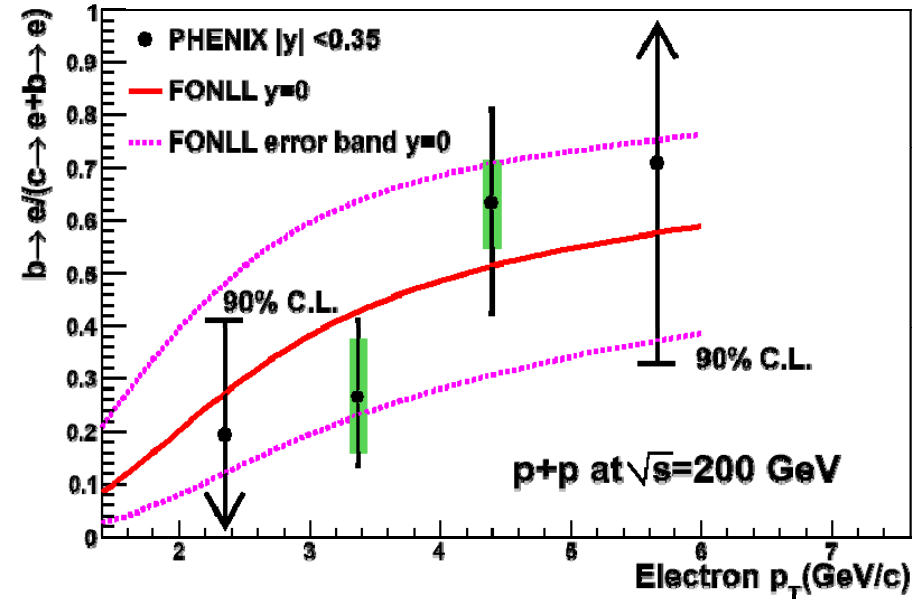
Contribution from b large above 4 GeV/c

arXiv:0903.4851, submitted to PRL

# b/c+b from e-h correlations



$$\sigma_{bb} = 3.2_{-1.1}^{+1.2} {}_{-1.3}^{+1.4} \mu\text{b}$$

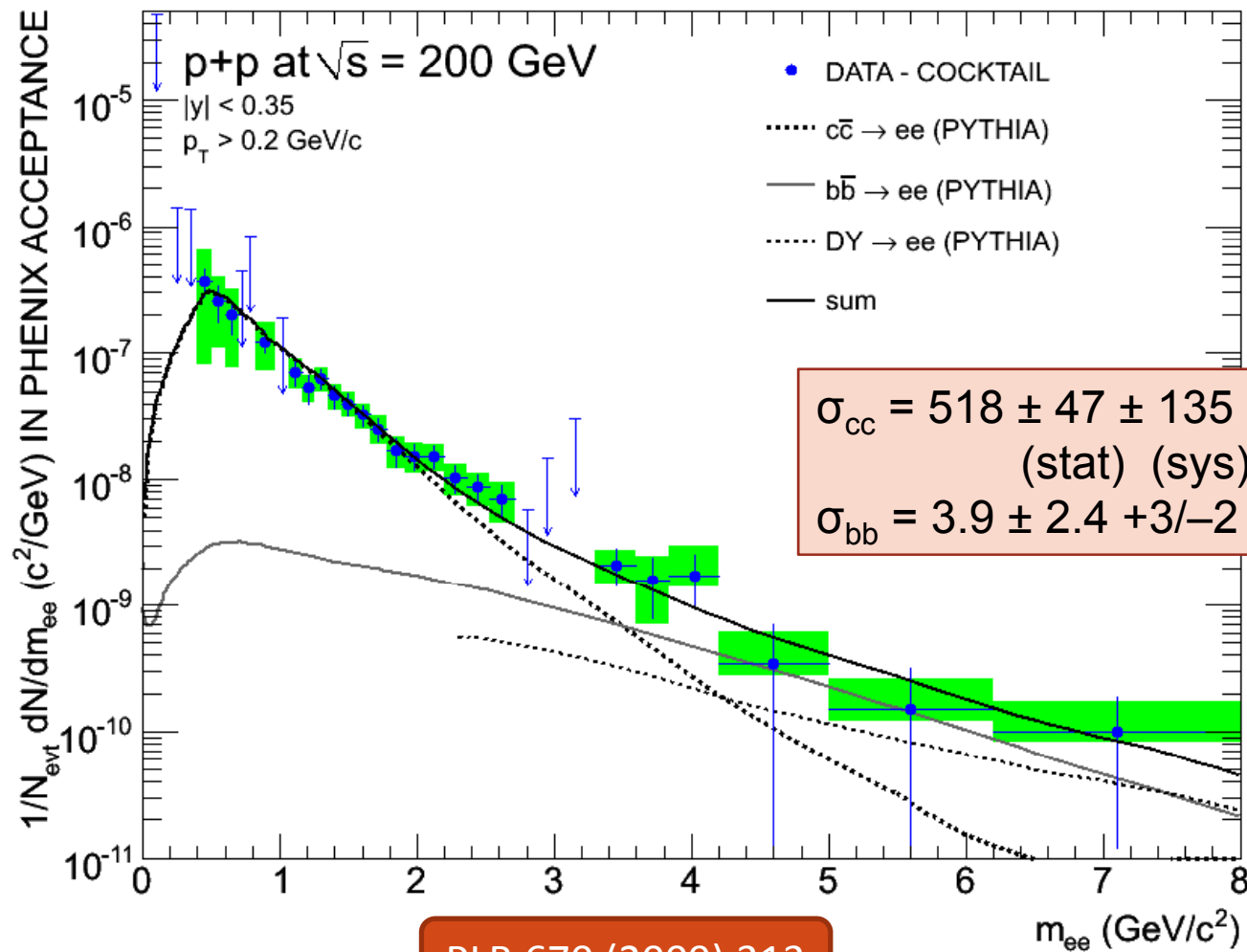


Together with  
single electron,  
provide individual  
b and c spectra

arXiv:0903.4851, submitted to PRL



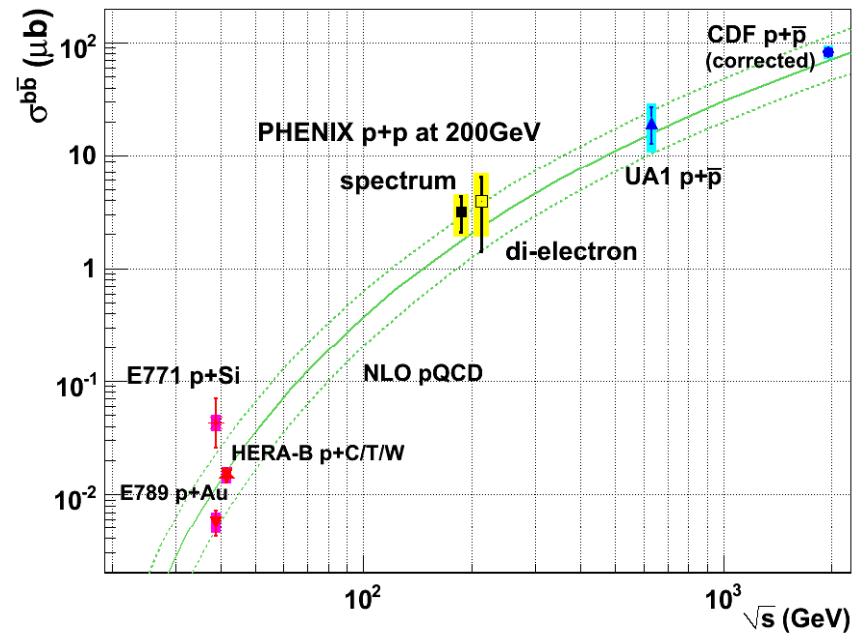
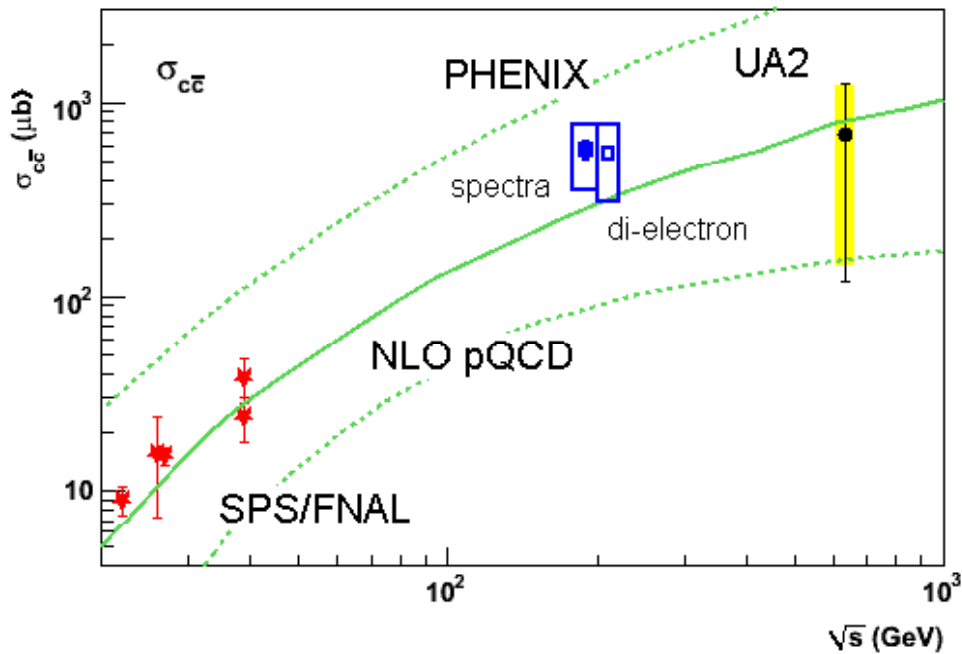
# c and b from dielectron



PLB 670 (2009) 313

# c and b cross sections

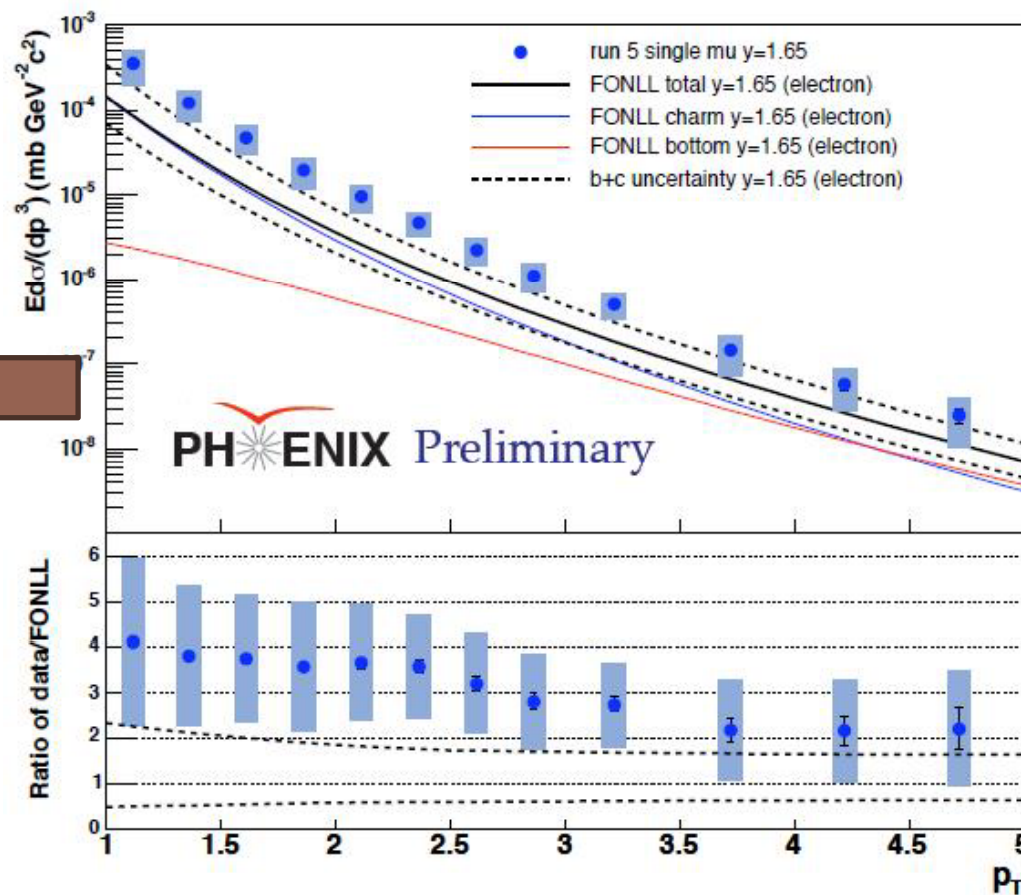
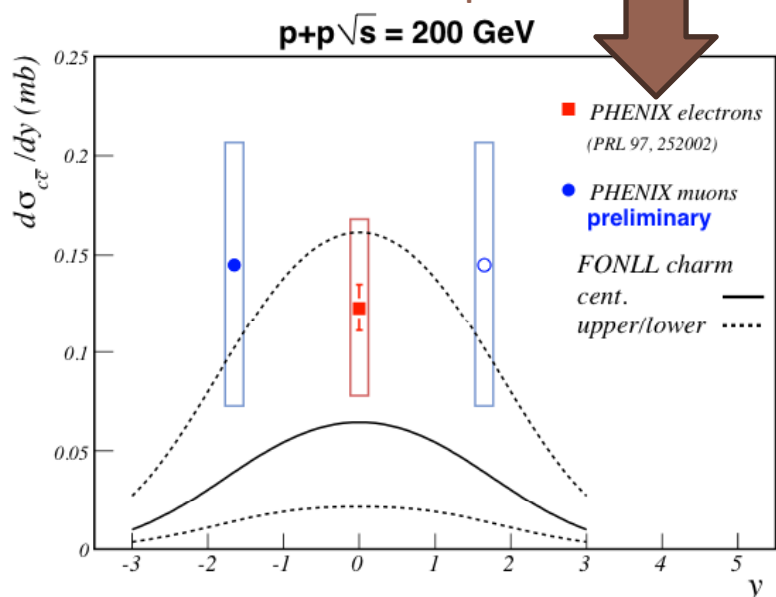
$\sigma_{cc}$  and  $\sigma_{bb}$  from single electron and dielectron agree with each other, and with NLO pQCD



# Charm from single muon at forward rapidity

- Use vertex distribution and stopped hadrons to control backgrounds

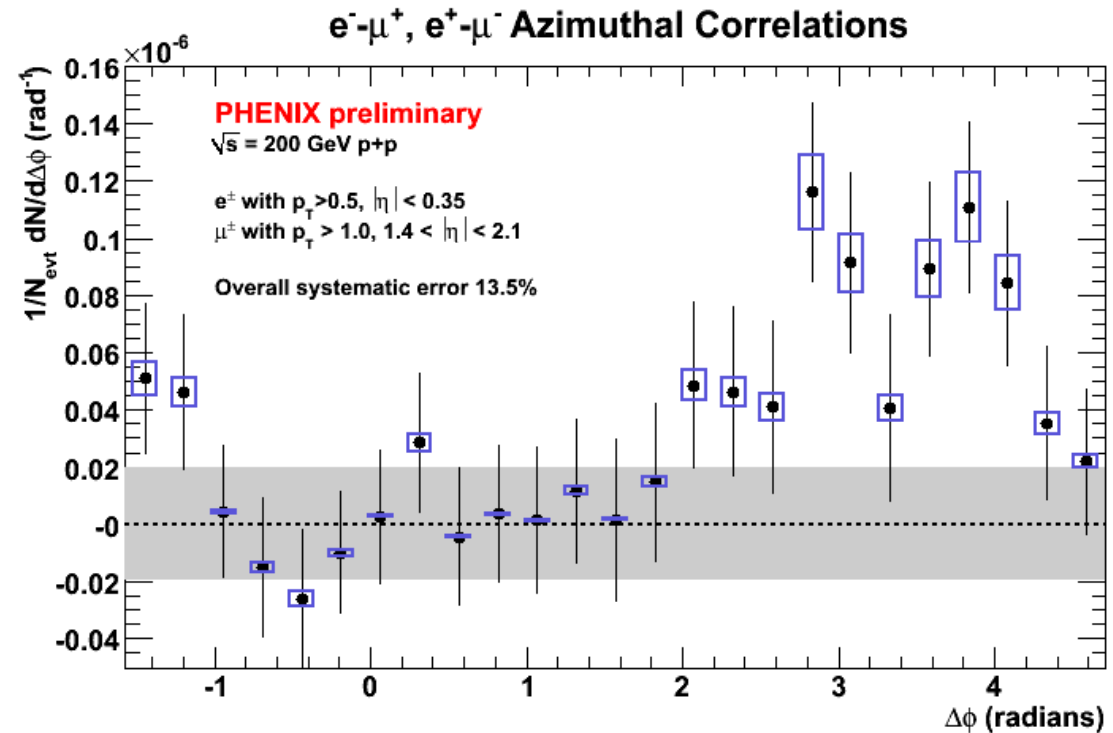
Extrapolation to low  $p_T$



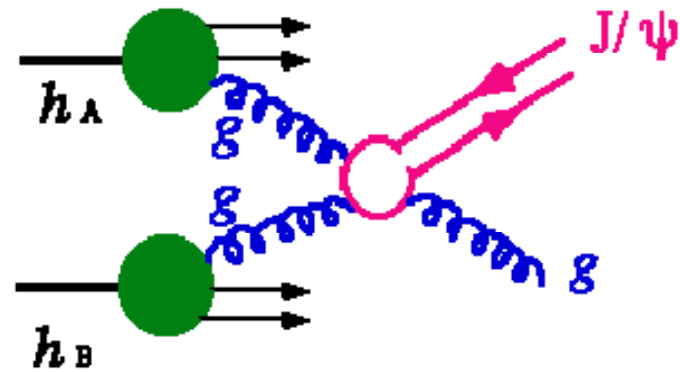
D. Hornback, QuarkMatter08

# Midrapidity e + forward $\mu$ correlations

- Long awaited golden channel for heavy flavors
- Angular correlation  $\rightarrow$
- Proof of principle for future charm cross section (intermediate rapidity)



T. Engelmore, QuarkMatter09

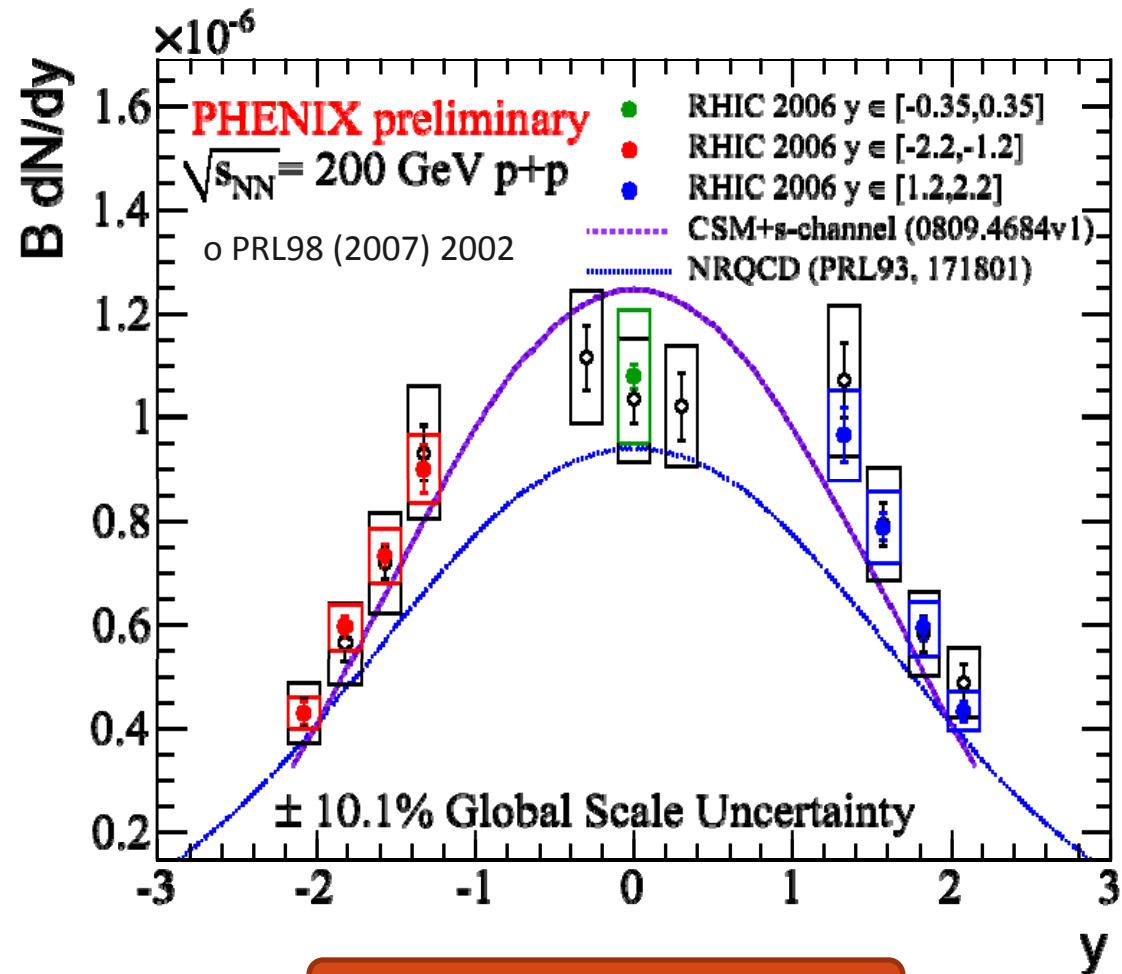


$J/\psi$  vs  $p_T$  and  $y$ ,  $J/\psi$  polarisation,  $\psi'$  and  $Y$ ,  $J/\psi$  in d+Au collisions...

## QUARKONIA

# J/ψ versus rapidity

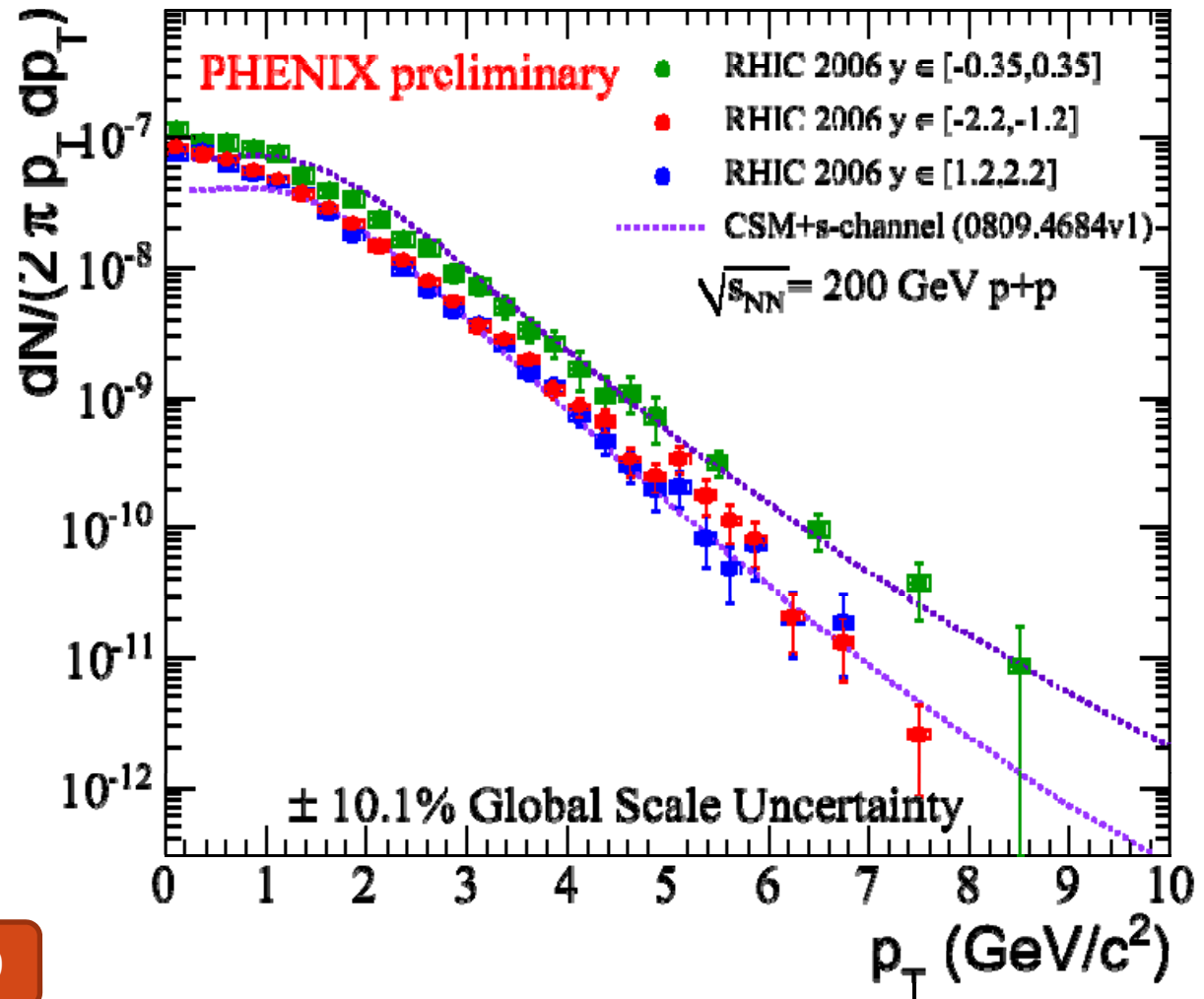
- Improved statistics
- Reducing systematics...



C. da Silva, QuarkMatter09

# J/ψ versus $p_T$

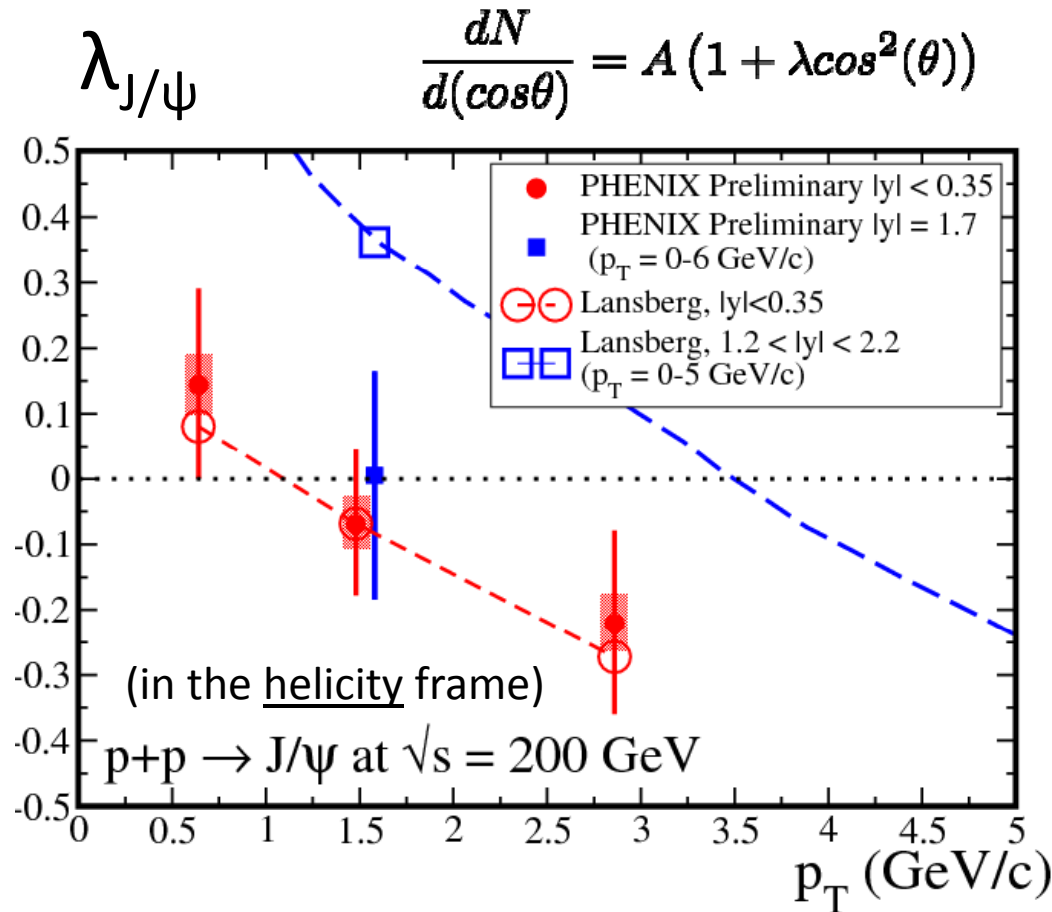
- Extended  $p_T$



C. da Silva, QuarkMatter09



# J/ψ polarization



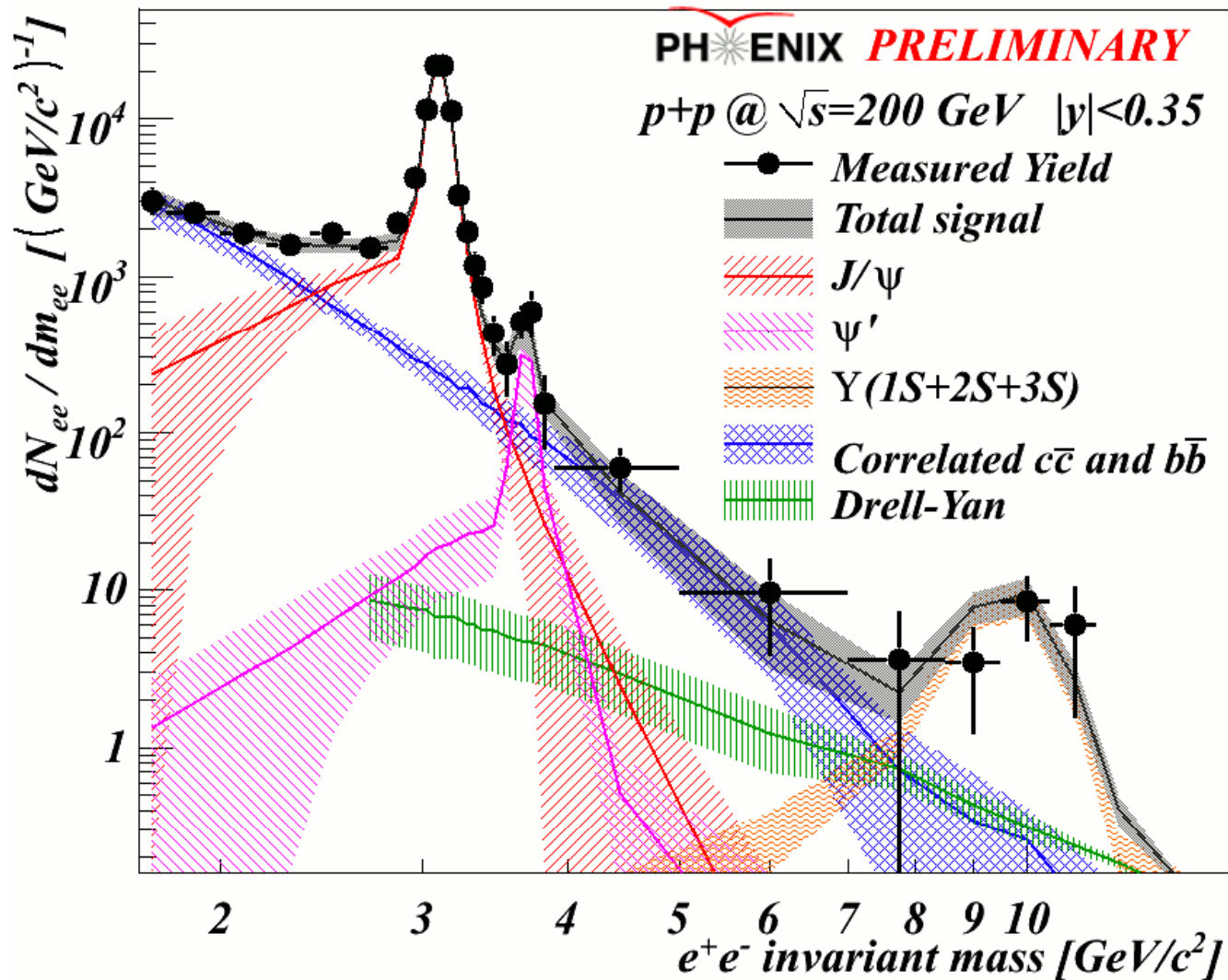
- New colour singlet model + s-channel cut (off shell charm quarks)
  - Adjusted to Tevatron
- working well for:
  - rapidity and (low)  $p_T$
  - polarization at  $y \approx 0$
- less ( $\approx 2\sigma$ ) for:
  - Polarization at  $y \approx 1.7$

$\lambda < 0$  longitudinal  
 $\lambda > 0$  transverse

M. Donadelli, PANIC08

Habersettl and Lansberg  
PRL100 (2008) 032006

# Other quarkonia @ $y=0$

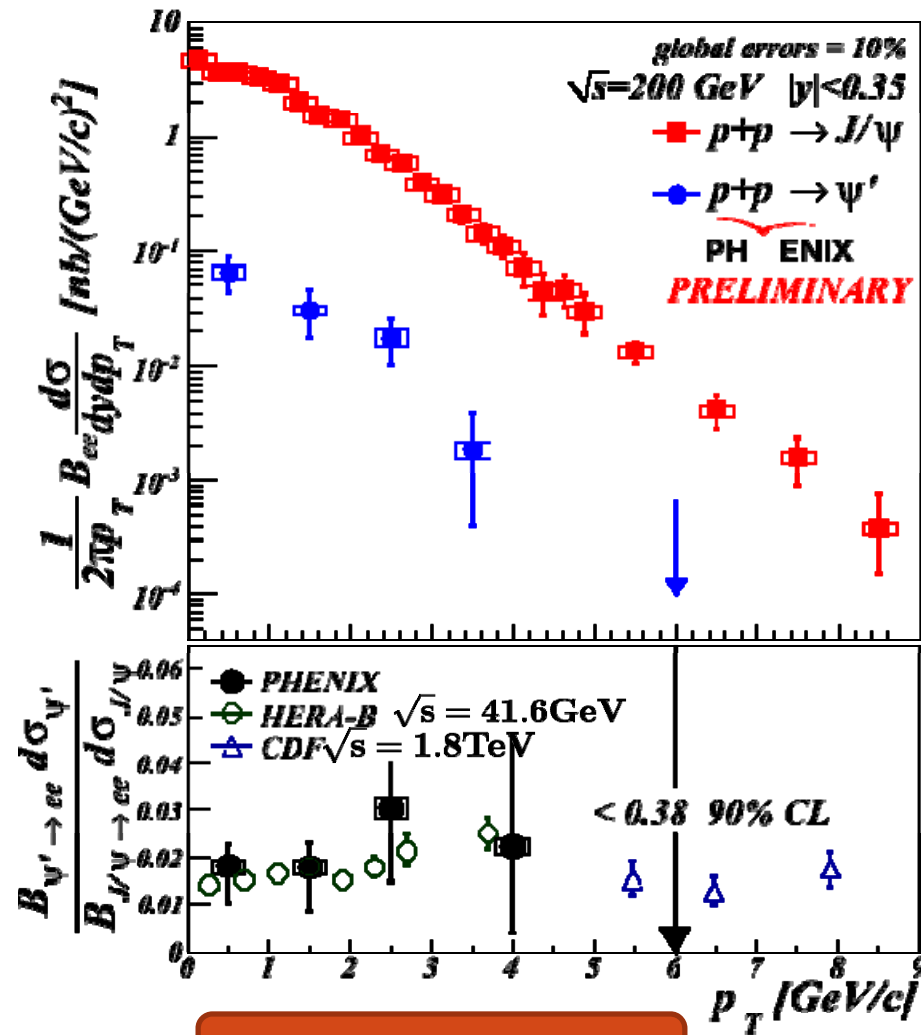


C. da Silva, QuarkMatter09

# $\psi'$ @ midrapidity

- $\psi'/\psi$  ratio
  - Of the order of 2%
  - No strong  $p_T$  dependence

- Feed down to  $J/\psi$ 
  - =  $8.6 \pm 2.5$  % from  $\psi$
  - < 42 % (90 % CL) from  $\chi_c$
  - $\approx$  1 to 4 % from B



M. Donadelli, PANIC08

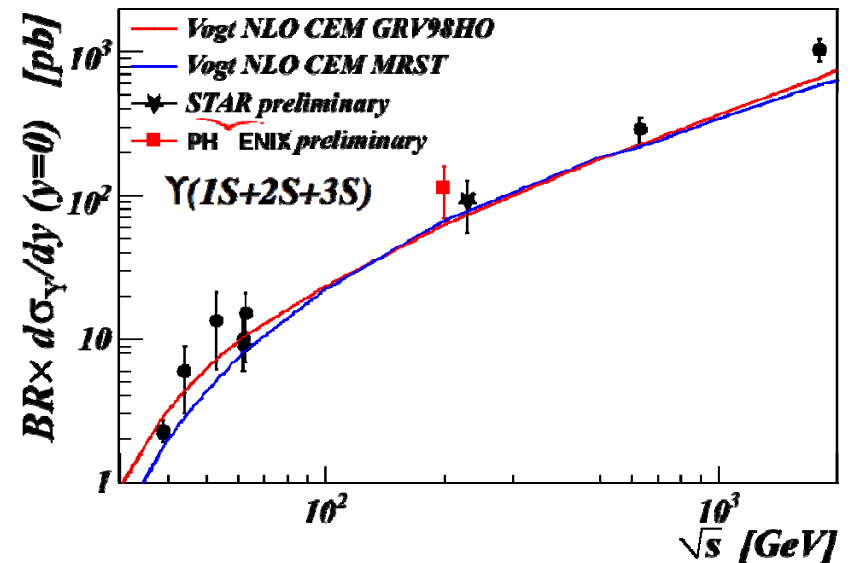
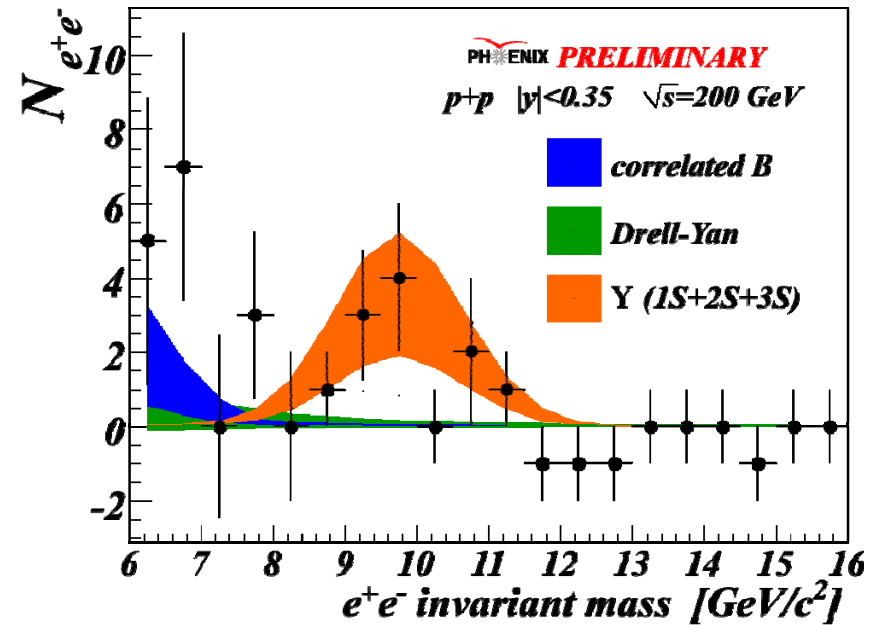
# New: Upsilon @ midrapidity

- 12 unlike and 1 like sign pairs in [8.5;11.5] GeV/c<sup>2</sup>
- Background < 15%
  - (1.6 counts)
  - Drell-Yan and B decays
- Derived xsection:

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

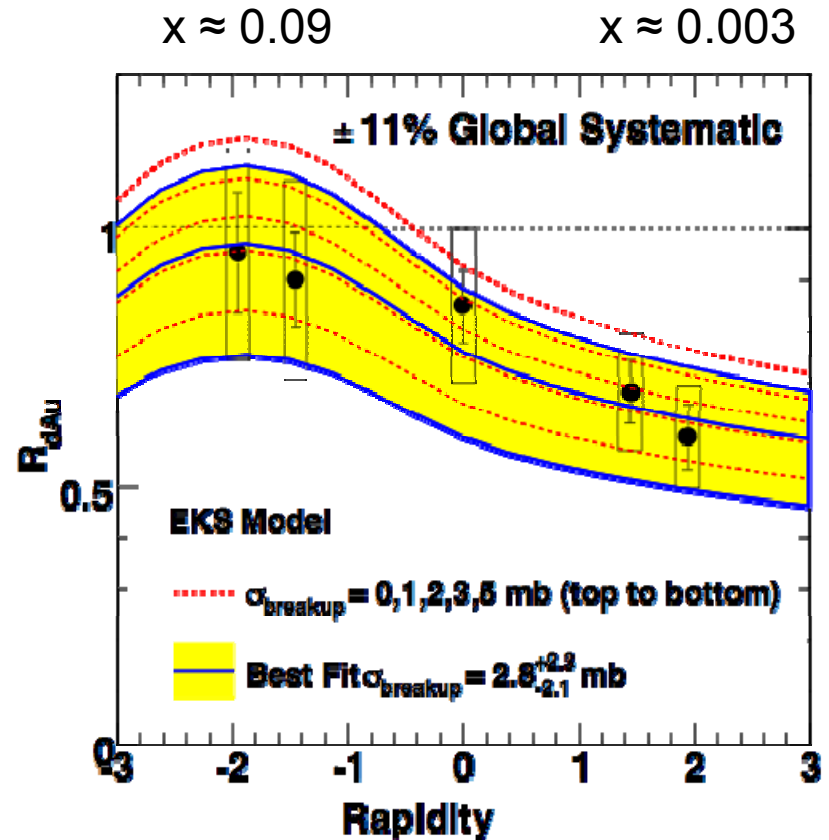
... follows world trend

C. da Silva, QuarkMatter09



# J/ψ in d+Au collisions

- At RHIC, we expect two normal nuclear effects:
  - Gluon pdf modification, various models...
  - J/ψ absorption on nucleons ( $\sigma_{\text{abs}}$ )
- As an example, a fit to data assuming the EKS shadowing scheme →
- Large uncertainties  
> 2 mb on  $\sigma_{\text{abs}}$



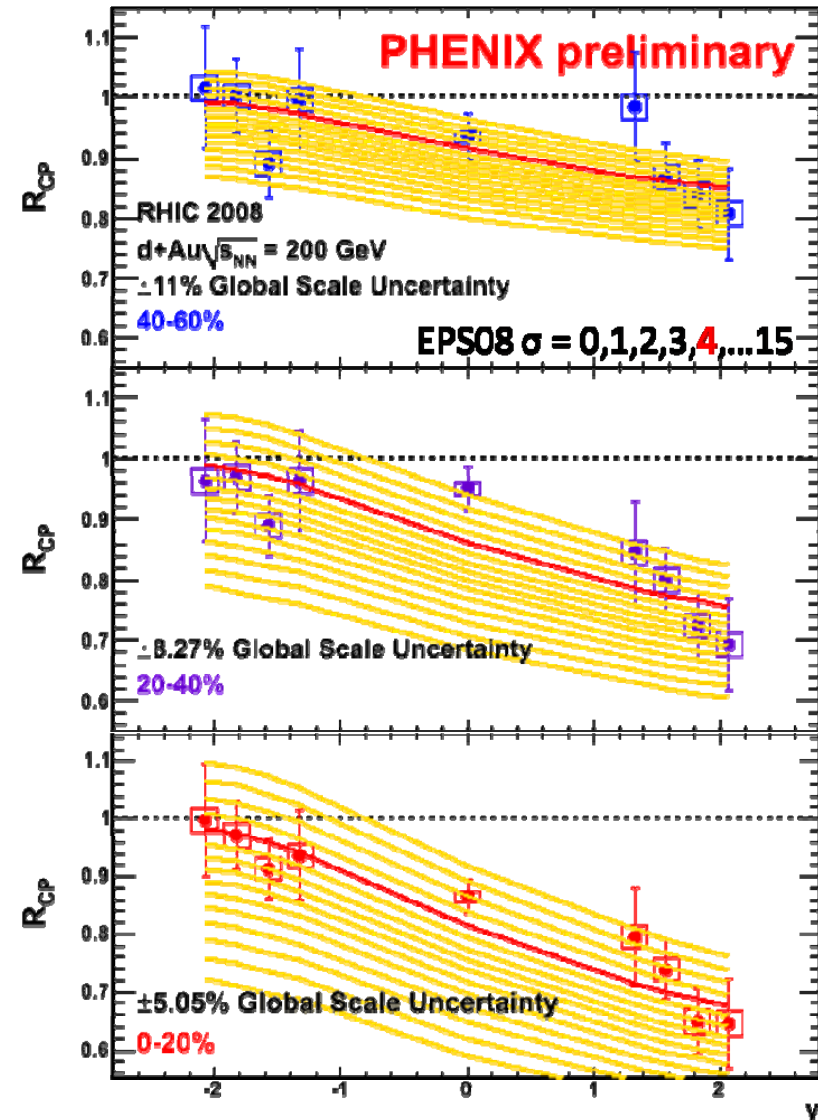
PRC77 (2008) 024912  
Erratum: arXiv/0903.4845

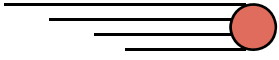
# J/ψ in d+Au collisions

- Analysis of run 8
  - (30 x run3)
  - Allows more binning
  - $R_{CP}$  for now (systematic cancelling out)
  - $R_{dA}$  underway...

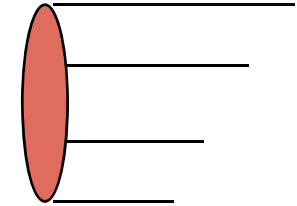
$$R_{CP}^{0-20\%} = \frac{N_{inv}^{0-20\%} / \langle N_{coll}^{0-20\%} \rangle}{N_{inv}^{60-88\%} / \langle N_{coll}^{60-88\%} \rangle}$$

C. da Silva, A. Linden-Levy, QuarkMatter09



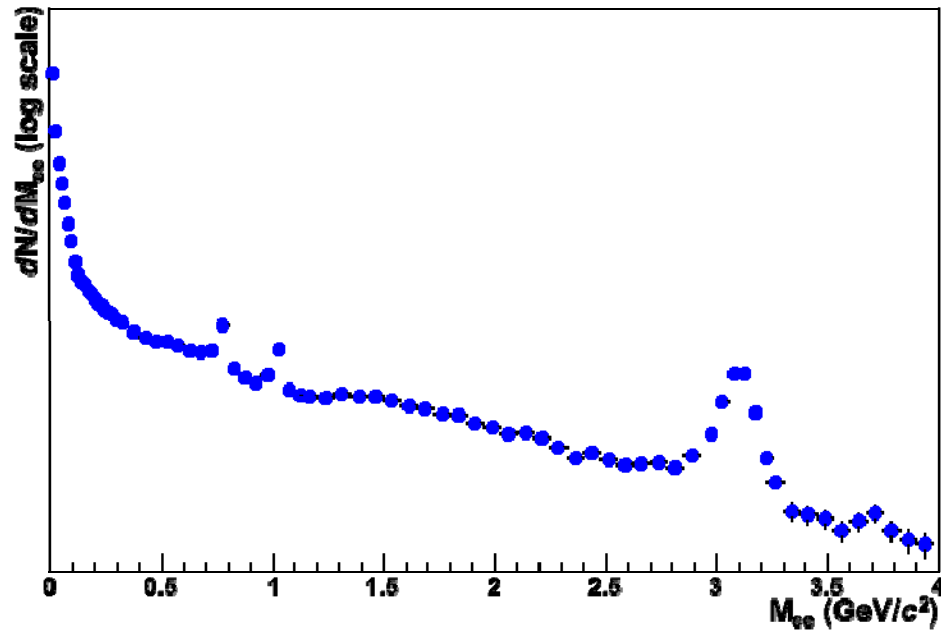


# Other quarkonia in d+Au ?



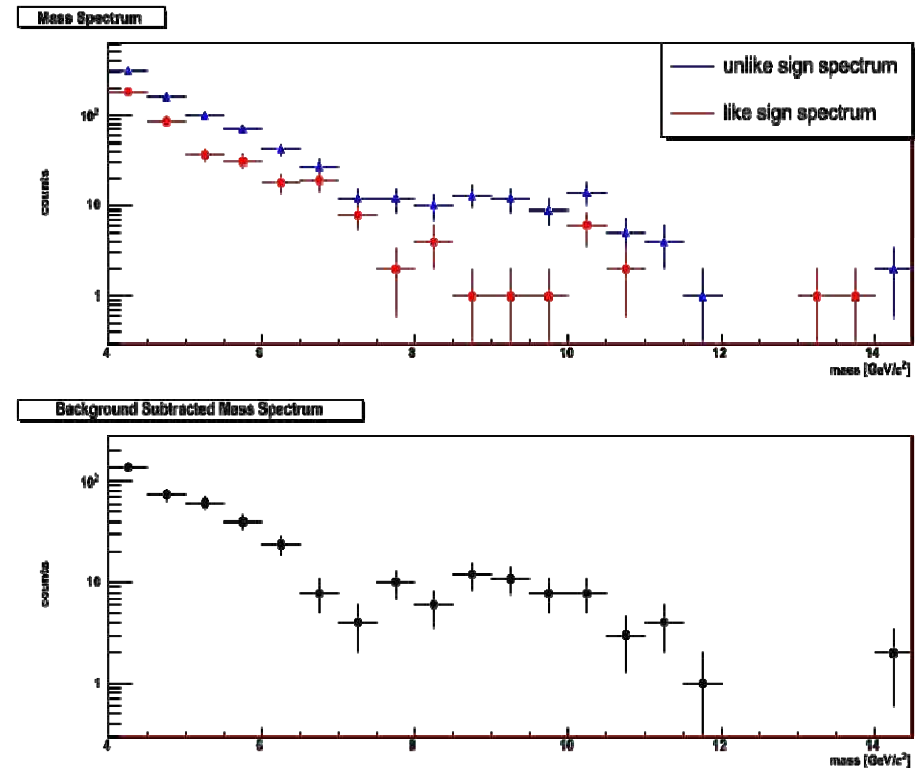
Work in progress...

$\psi'$  from dielectrons



→ RHIC also providing p+p collisions @ 500 GeV this year

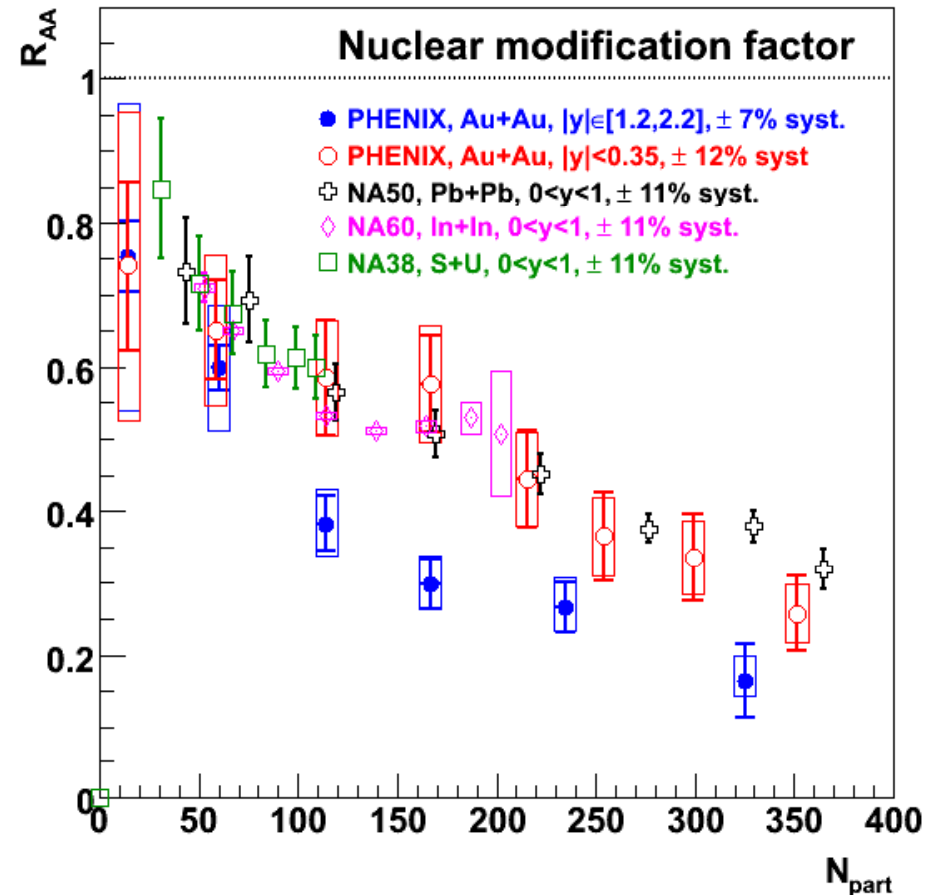
Upsilon from dielectrons and dimuons...





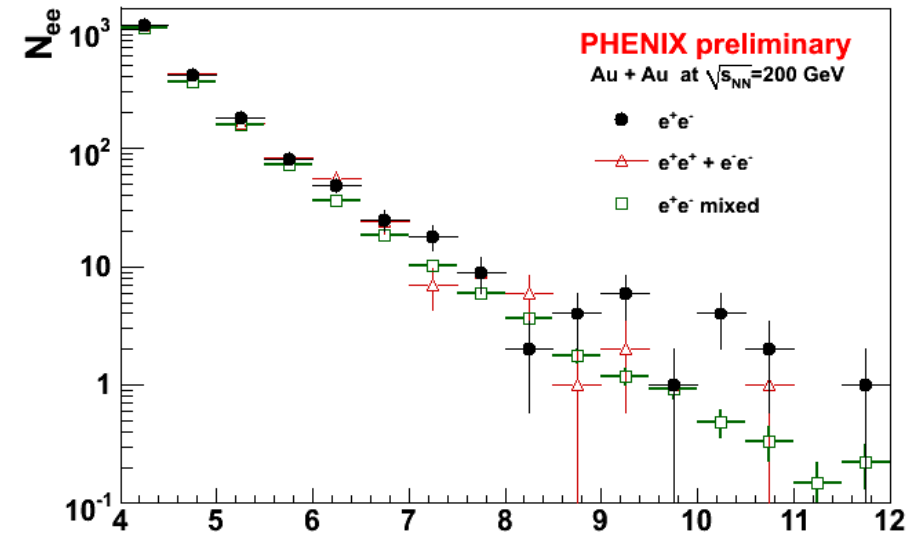
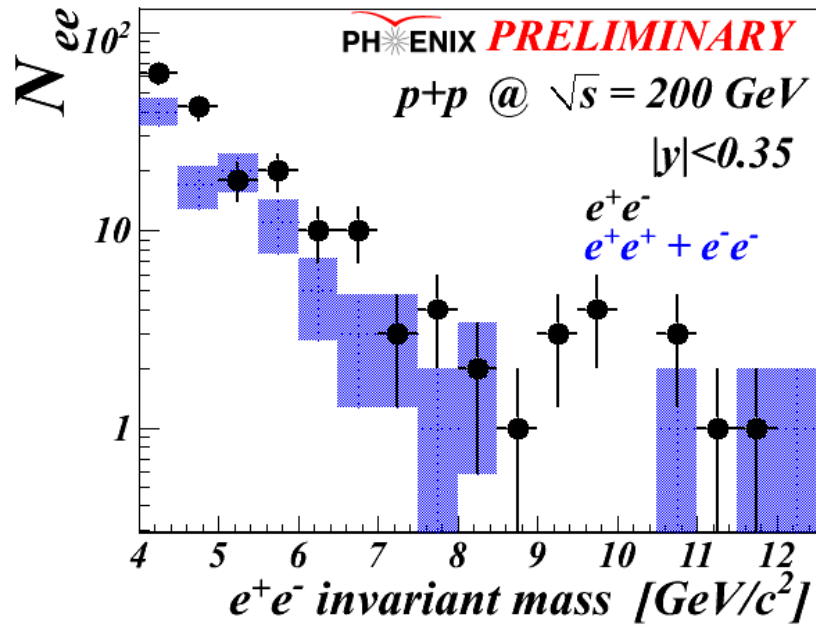
# As an outlook...

- All of the above are important inputs to understand the quarkonia suppression observed in Au+Au collisions @ RHIC, which is indeed puzzling:
  - Why are  $J/\psi$  more suppressed at forward rapidity?
  - At midrapidity, why are they suppressed as at lower energy?

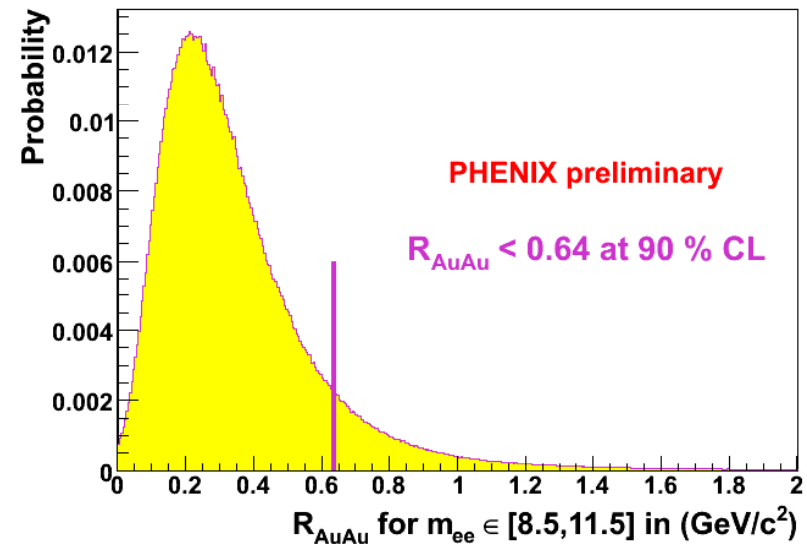


# BACK UP SLIDES

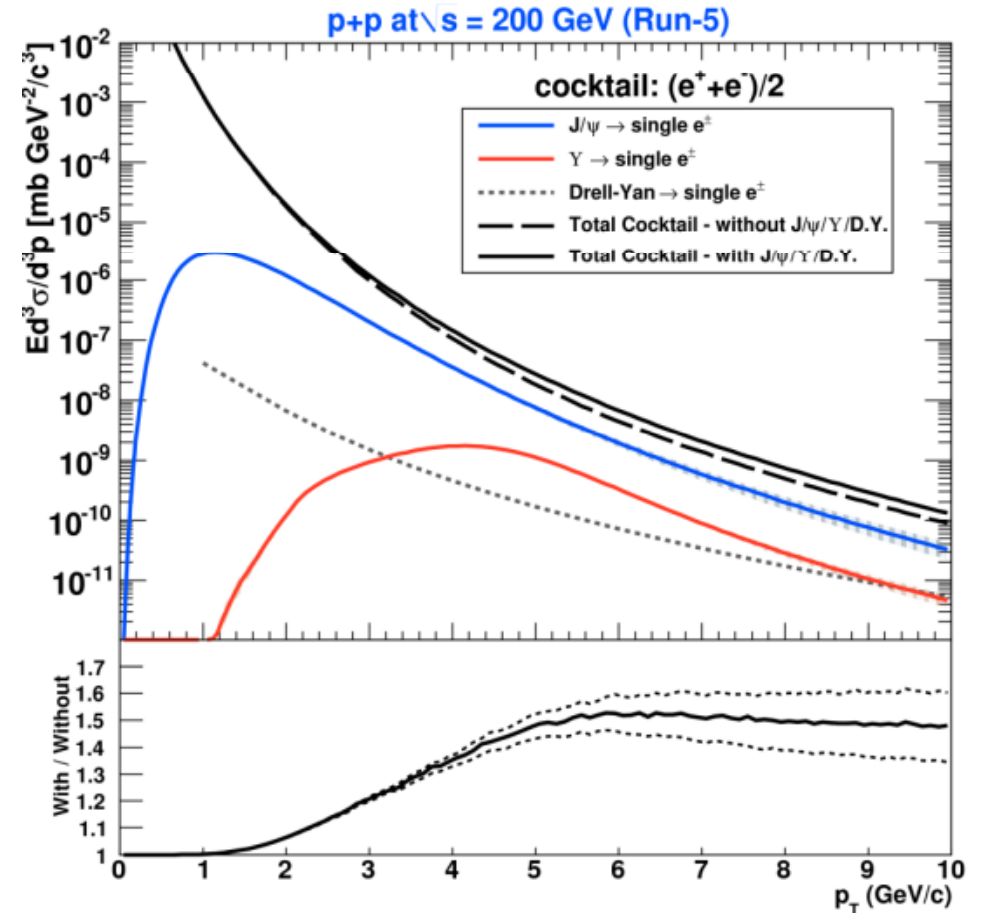
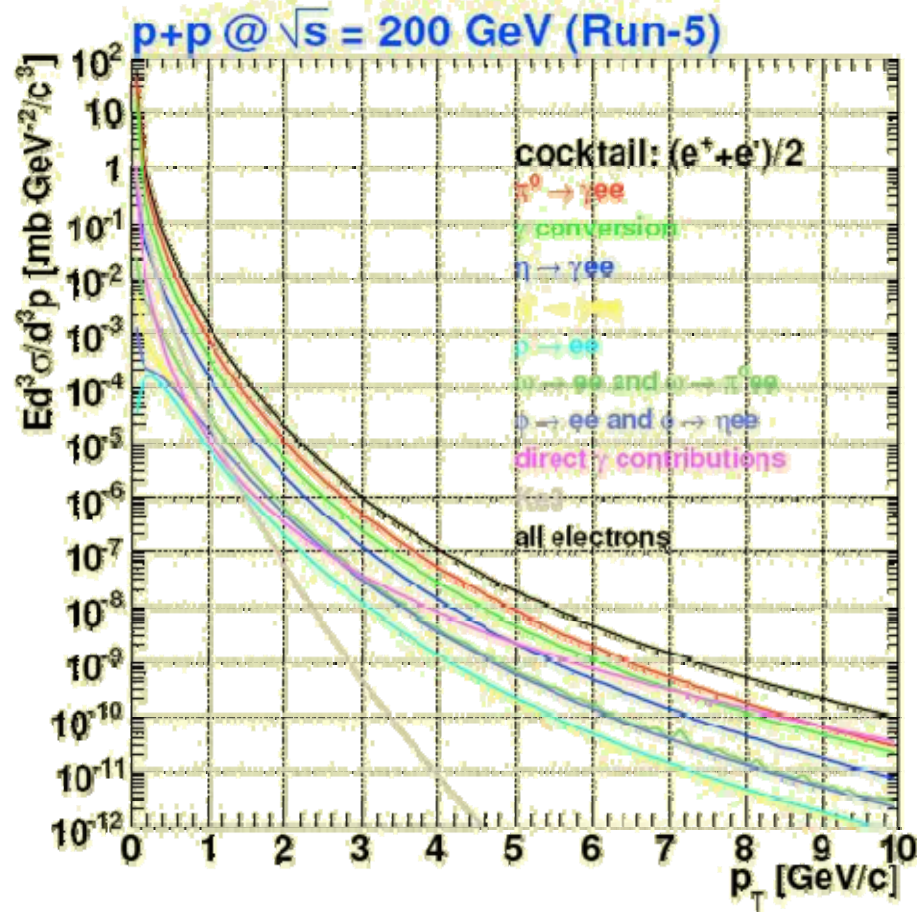
# Upsilon in Au+Au



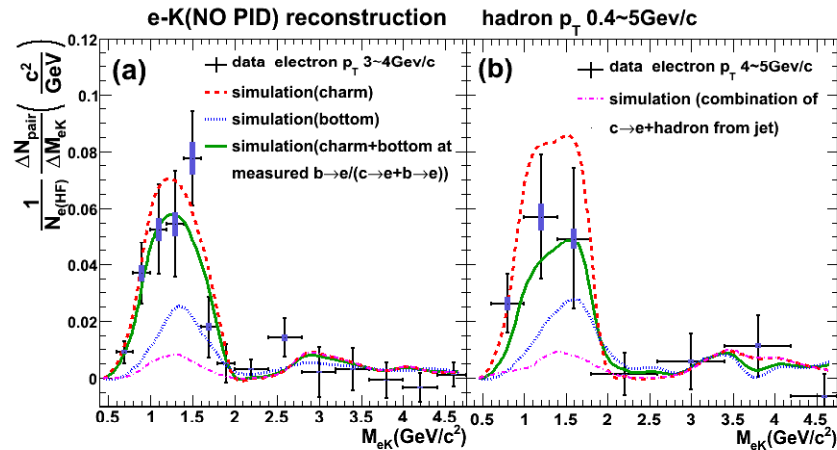
- $R_{AA} < 0.64$  @ 90%
  - In  $[9.5; 11.5] \text{ GeV}/c^2$
  - Whatever it is...



# Single electron cocktail



# e-h correlations

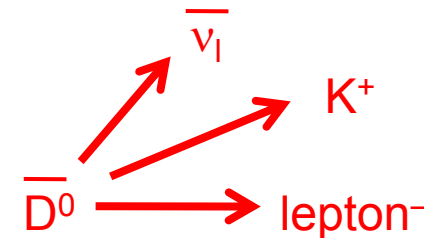


- e-K (no PID)
- Unlike sign near-side pairs
- Subtract like sign pairs
- Tagging efficiency for c and b from Pythia

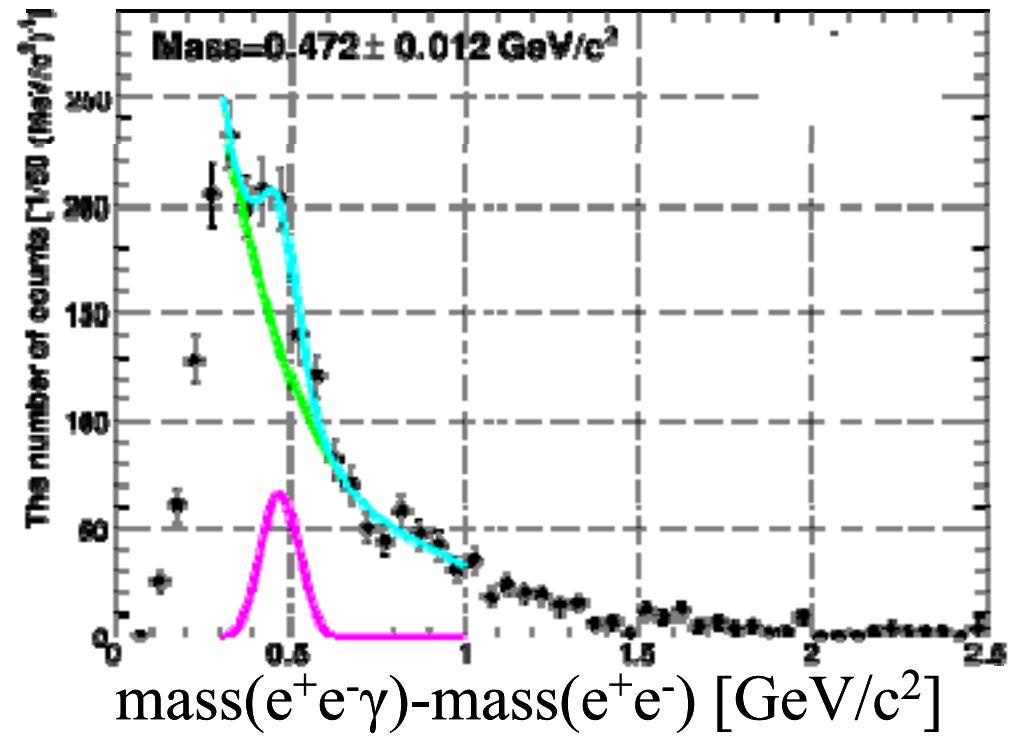
$$\epsilon_{data} \equiv \frac{N_{tag}}{N_{e(non-photic)}} = \frac{N_{c \rightarrow tag} + N_{b \rightarrow tag}}{N_{c \rightarrow e} + N_{b \rightarrow e}}$$

$$\epsilon_c \equiv \frac{N_{c \rightarrow tag}}{N_{c \rightarrow e}}, \quad \epsilon_b \equiv \frac{N_{b \rightarrow tag}}{N_{b \rightarrow e}}$$

$$\frac{N_{b \rightarrow e}}{N_{c \rightarrow e} + N_{b \rightarrow e}} = \frac{\epsilon_c - \epsilon_{data}}{\epsilon_c - \epsilon_b}$$



$\chi_c$



# J/ψ polarisation

