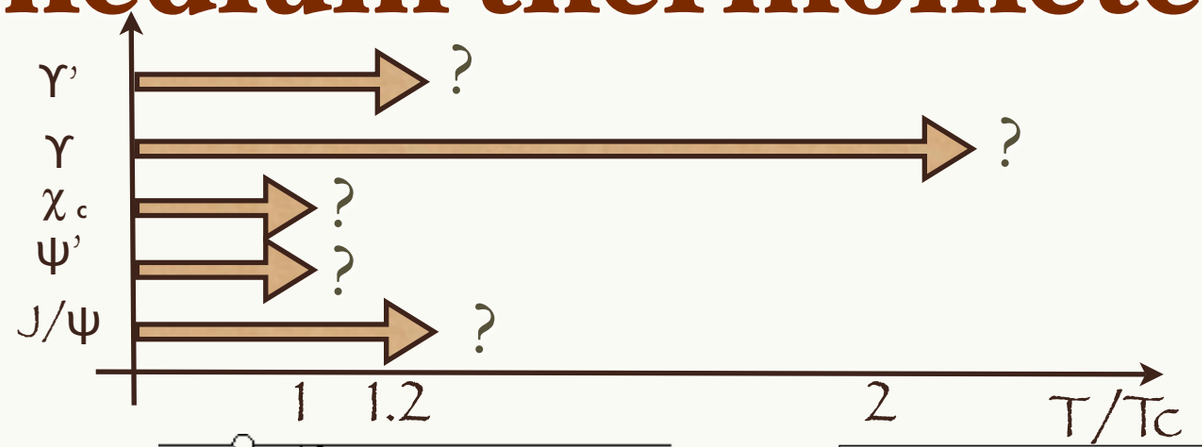
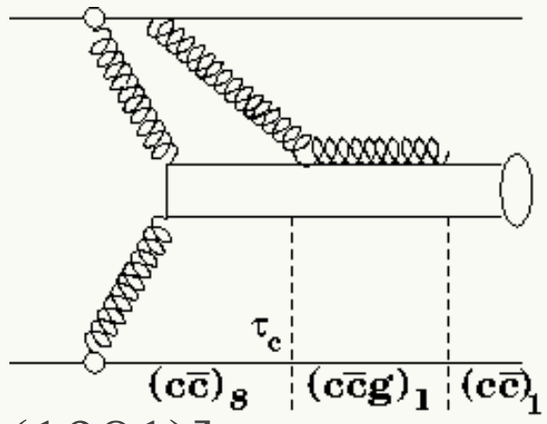
Quarkonia measurements in p+p and d+Au collisions at $\sqrt{s} = 200\text{GeV}$ by the PHENIX Collaboration.

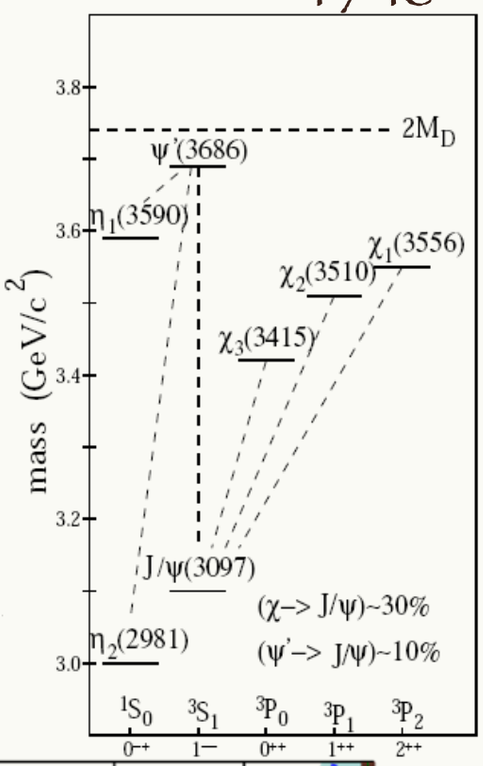
Cesar Luiz da Silva - Iowa State University
for the PHENIX Collaboration

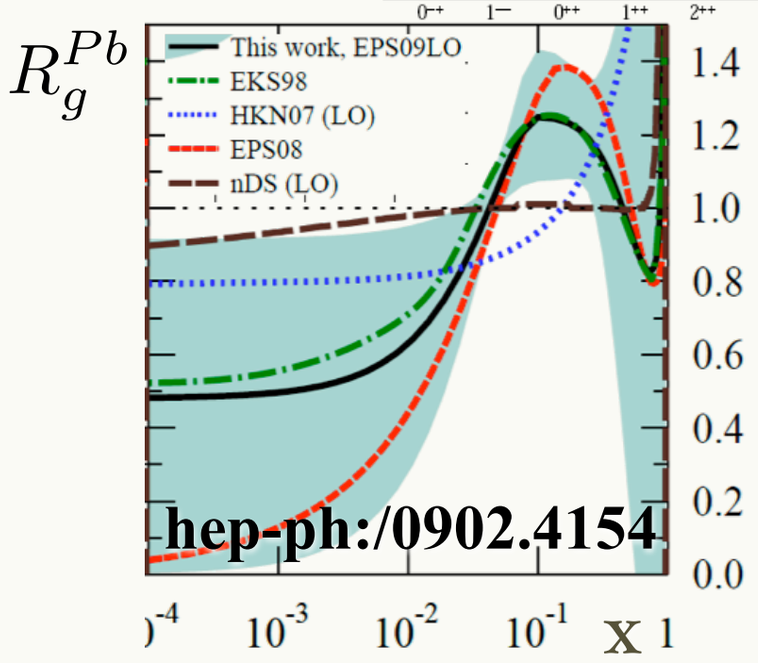
Using quarkonia as a medium thermometer

- Quarkonium dissociation has been long suggested to probe the temperature of the QGP
- to fully understand this "thermometer" requires:
  - p+p baseline:
    - production mechanism
      - color singlet (CSM) [PLB102, 364 (1981)]
      - CSM s-channel cut [PRL100,032006(2008)]
      - color octet (COM) [PRD51,1125(1995)]
      - color evaporation(CEM) [PLB67,217(1977)]
      - 3-gluon pQCD [Eur.Phys.J.C39,163(2005)]
    - feed-down contributions
  - Cold Nuclear Matter effects
    - parton distribution modifications
    - breakup in hadronic matter



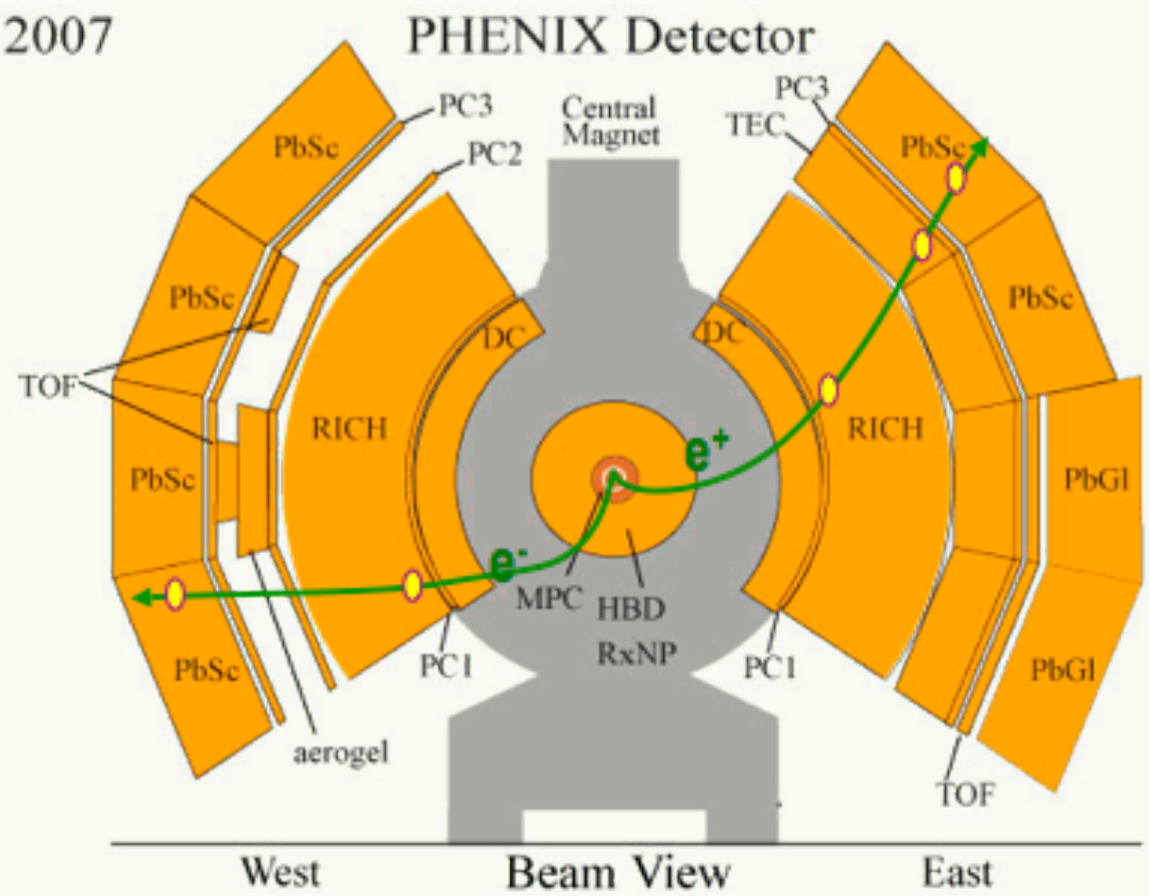




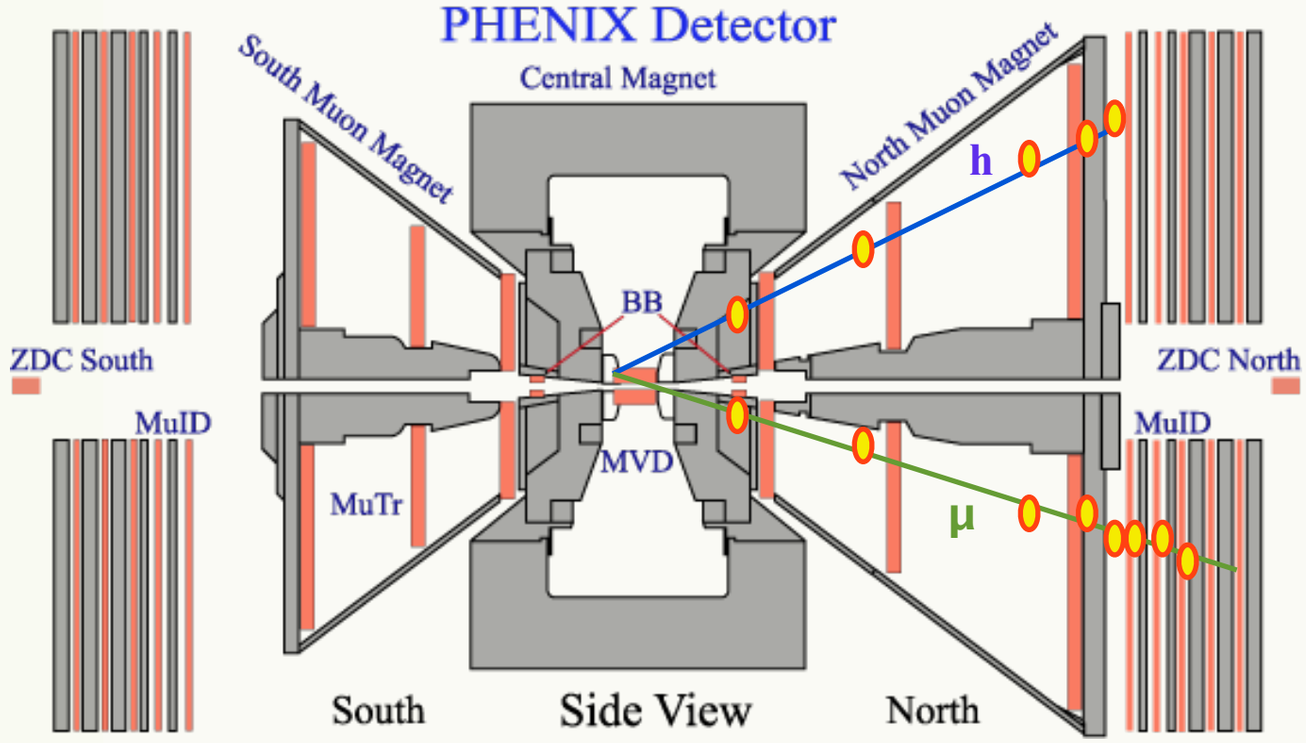


PHENIX Apparatus

Central Arms



Forward Arms



|η|<0.35 ΔΦ=2xπ/2

•full reconstruction of di-electrons

-2.2<η<-1.2 1.2<η<2.2 ΔΦ=2π

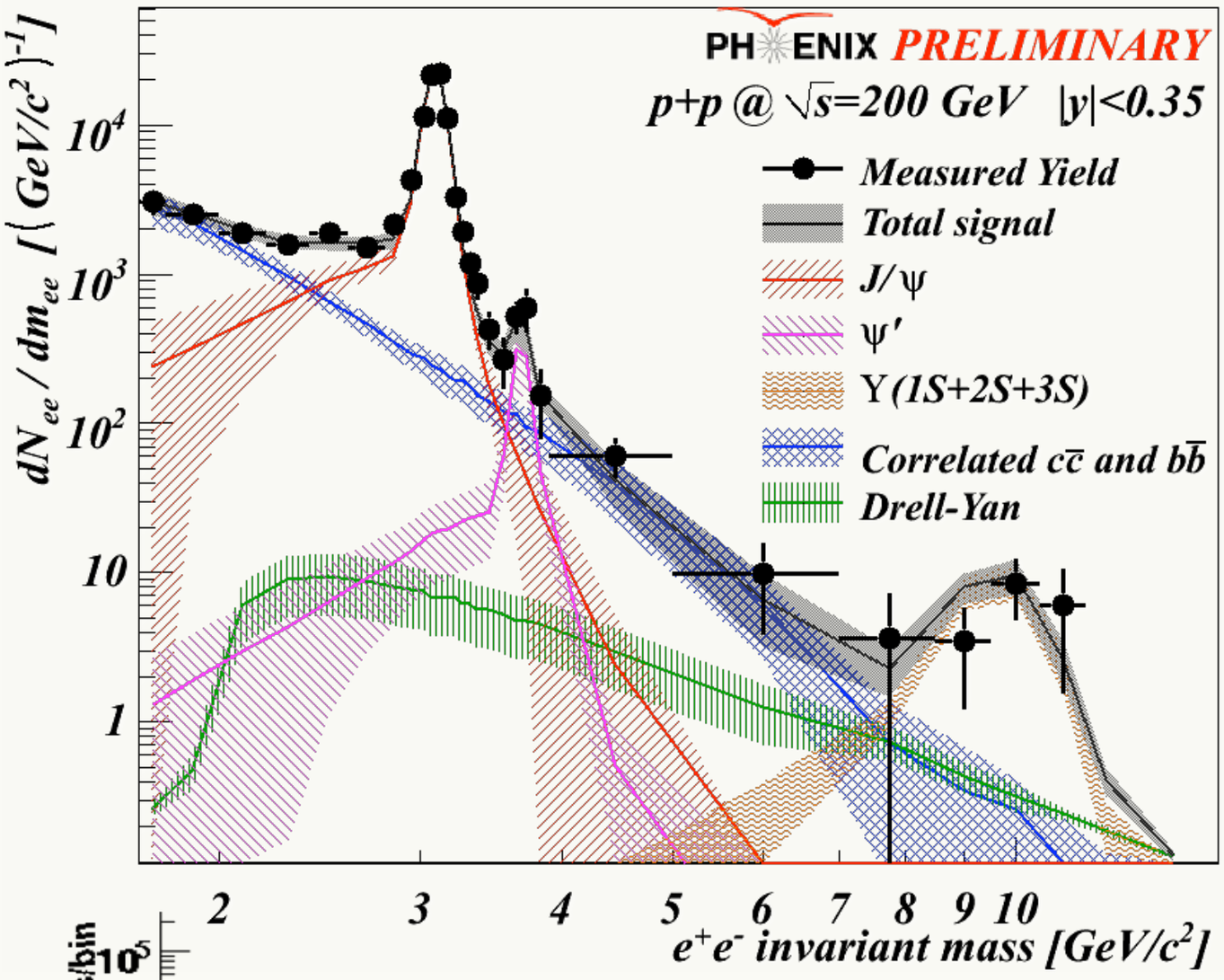
•full reconstruction of di-muons

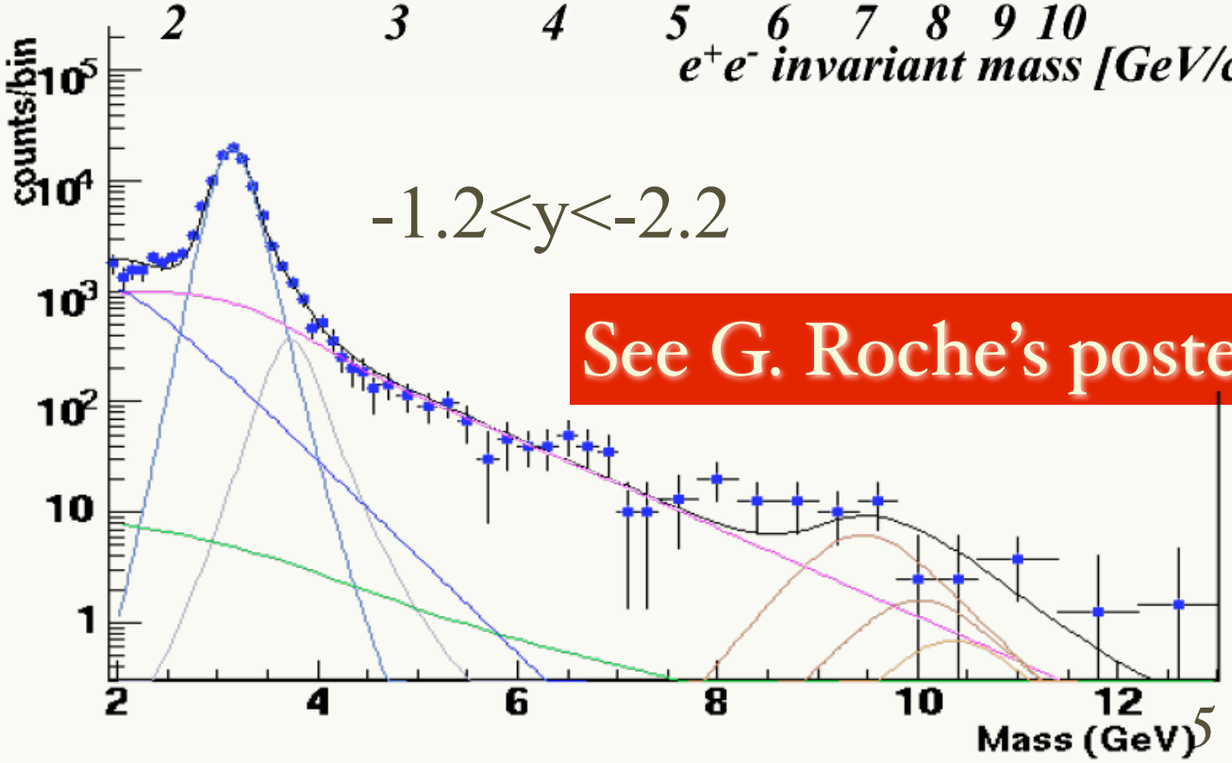
combinatorial background obtained from like-sign or mixed event pairs

- Studied in p+p collisions: J/ψ, ψ', χ_c, ϒ
- Studied in d+Au collisions: J/ψ, ψ', ϒ

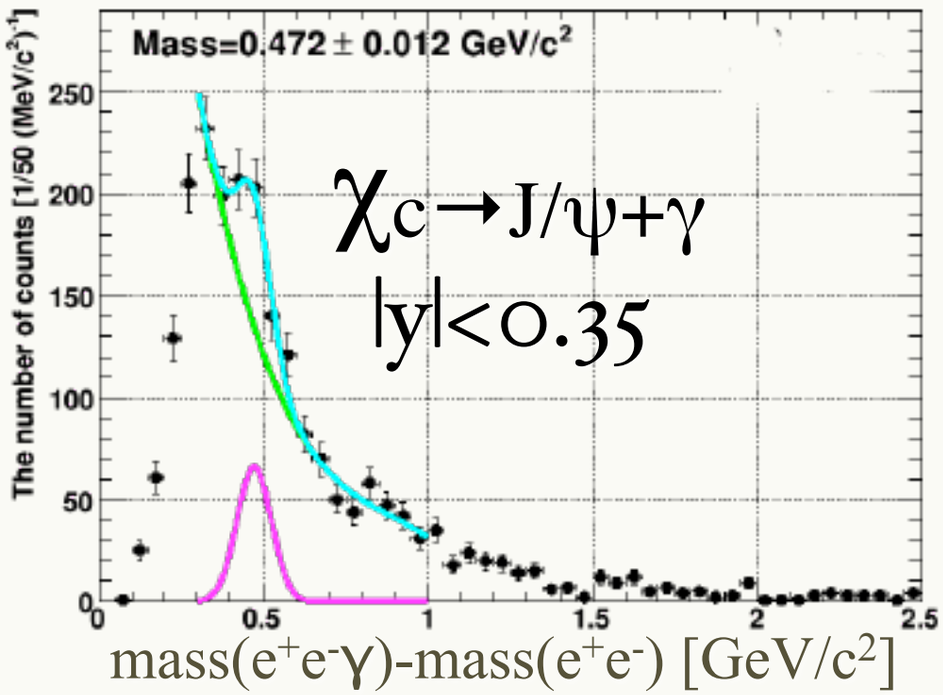
p+p baseline

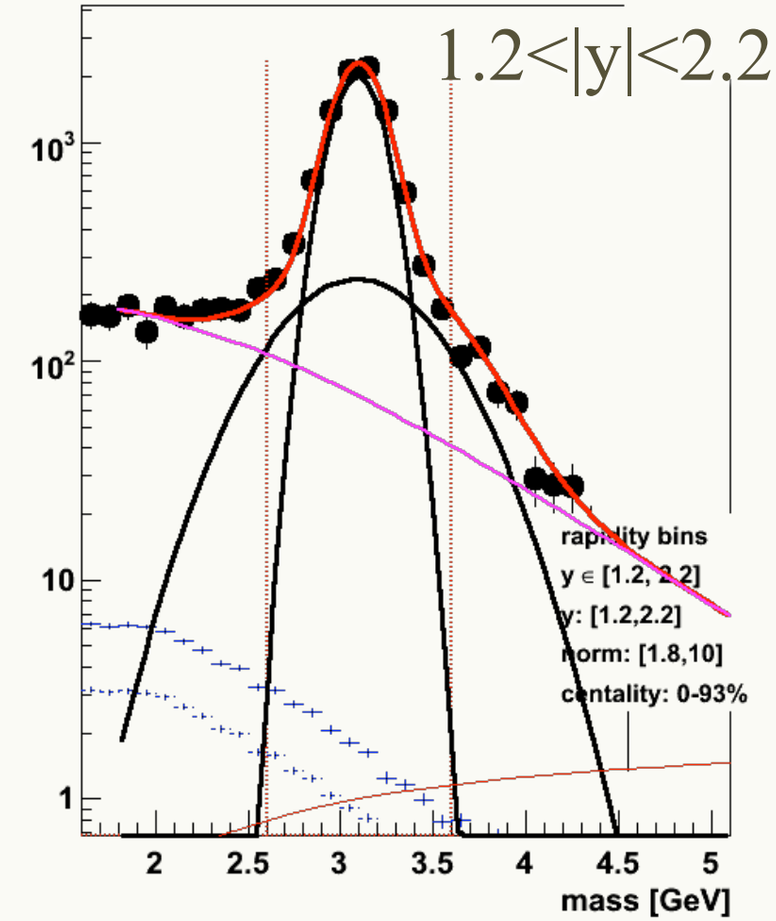
Quarkonia Measured by PHENIX



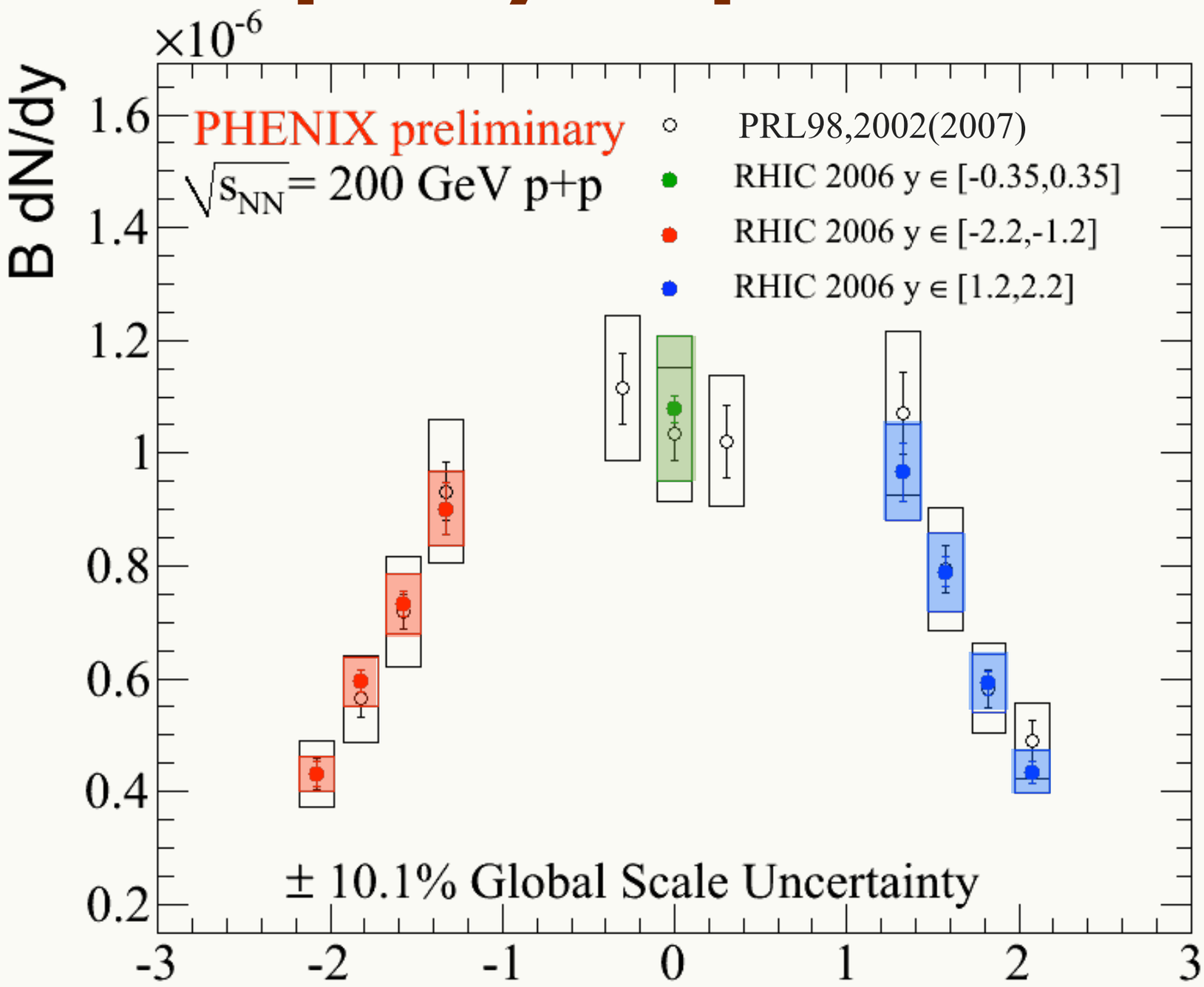


See G. Roche's poster





New J/ψ yield in *p*+*p* at $s^{1/2}$=200 GeV
Rapidity Dependence

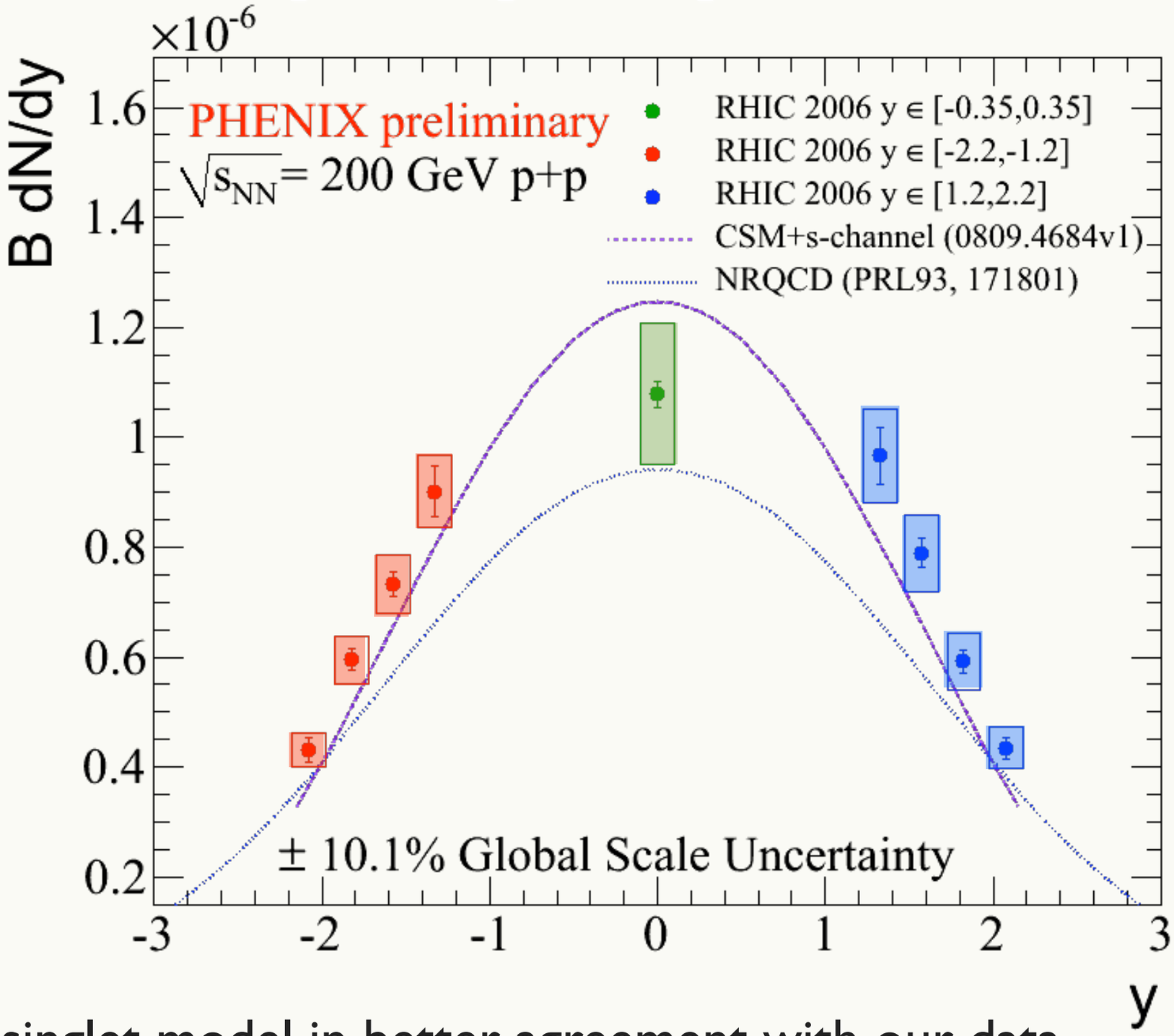


3x more statistics than that our previous publication.

Good agreement with previous results!

See M. Wysocki's poster

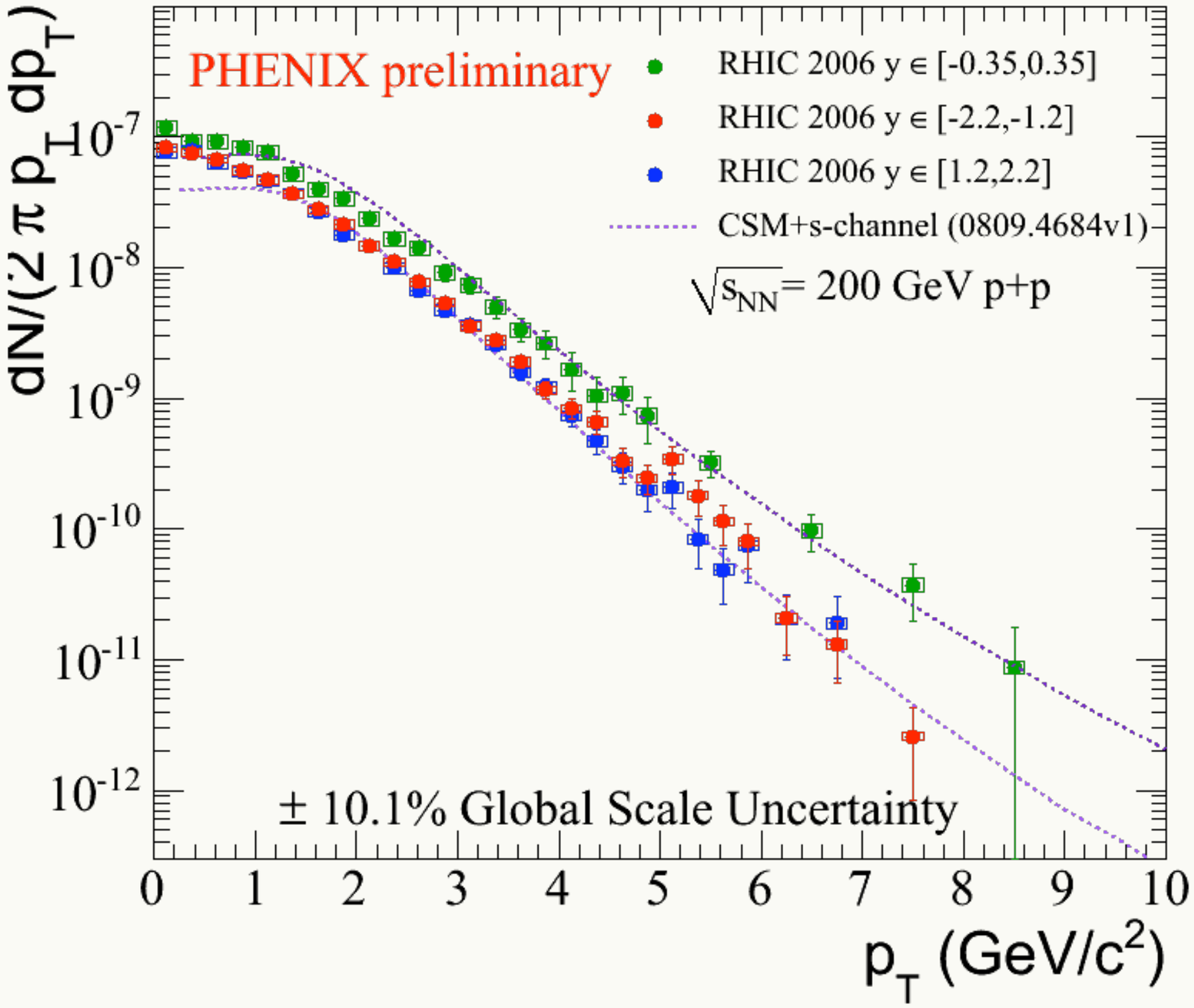
New J/ψ yield in *p*+*p* at $s^{1/2}$=200 GeV
Rapidity Dependence



New color singlet model in better agreement with our data.

See M. Wysocki's poster

New J/ψ yield in *p*+*p* at $s^{1/2}$=200 GeV



Good agreement with new CSM in p_T.

ψ' yield in *p*+*p* at $s^{1/2}$=200 GeV

See M. Donadelli's poster

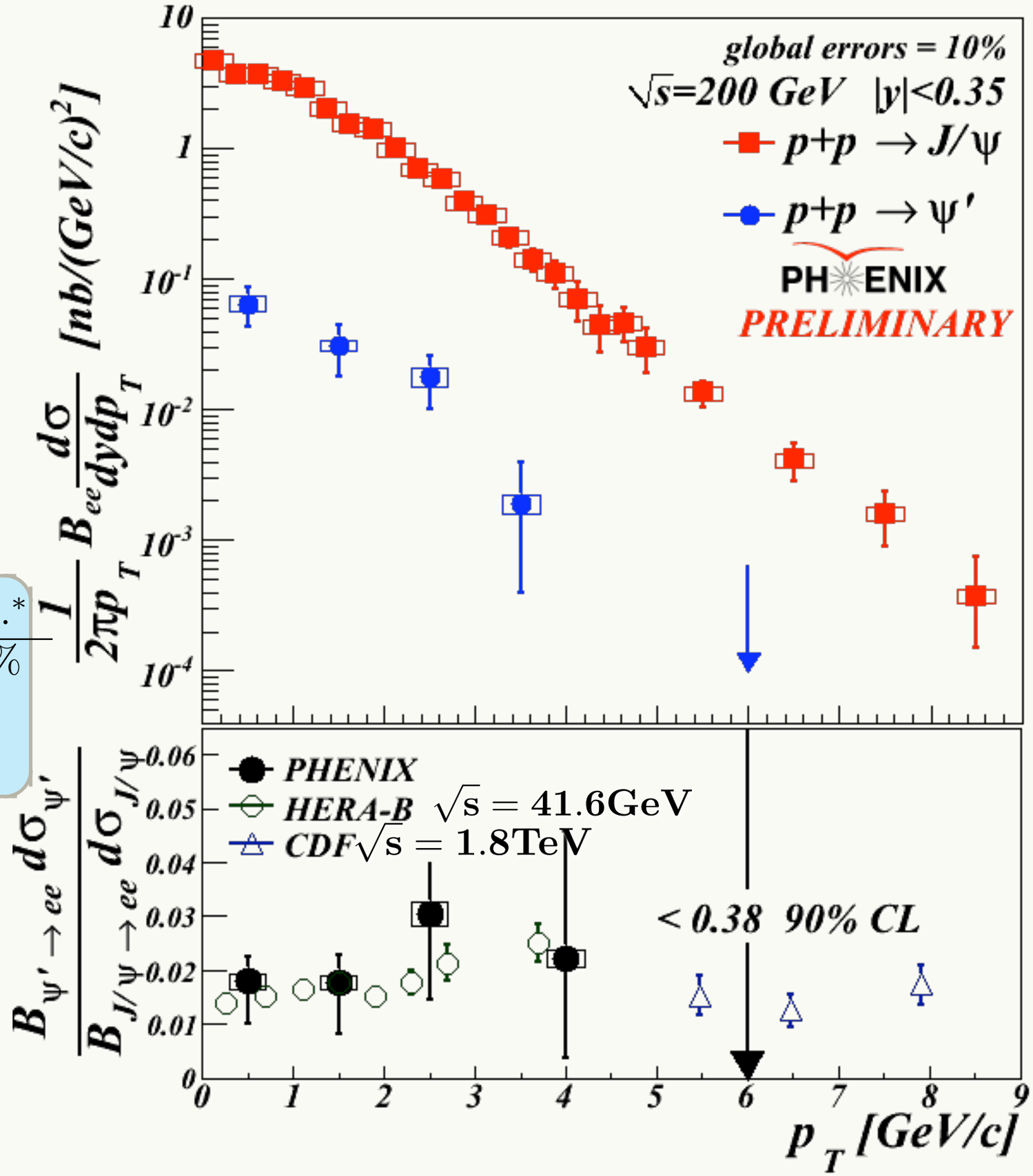
ψ' / J/ψ ratio in central rapidity doesn't show a strong energy or p_T dependence.

Feed-down to J/ψ:

decay	PHENIX	world avg.*
$\psi' \to J/\psi$	$8.6 \pm 2.5\%$	$8.1 \pm 0.3\%$
$\chi_c \to J/\psi$	$< 42\%$ (90% CL)	$25 \pm 5\%$

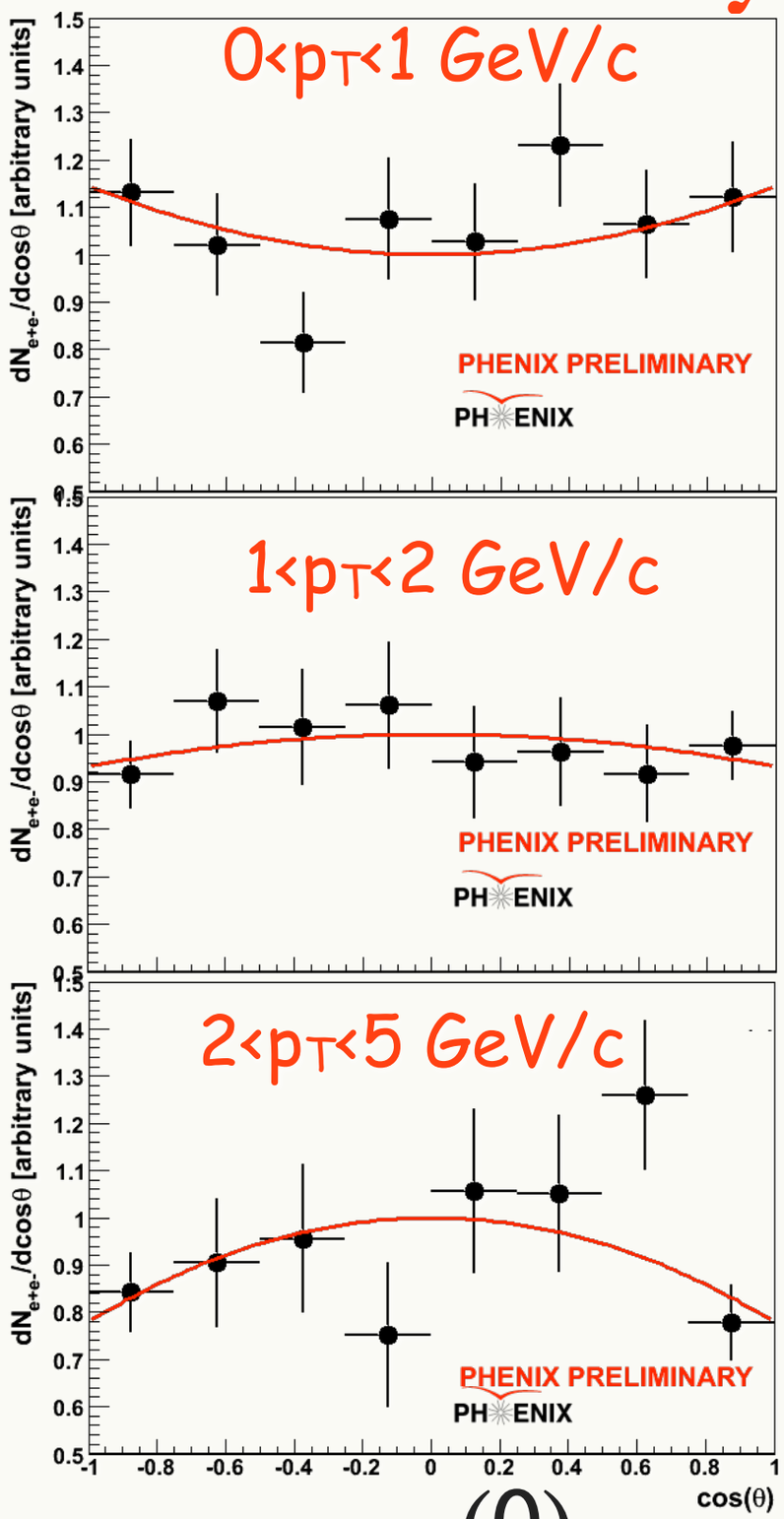
*P. Faccioli, et al., arXiv:0809.2153 [hep-ph]

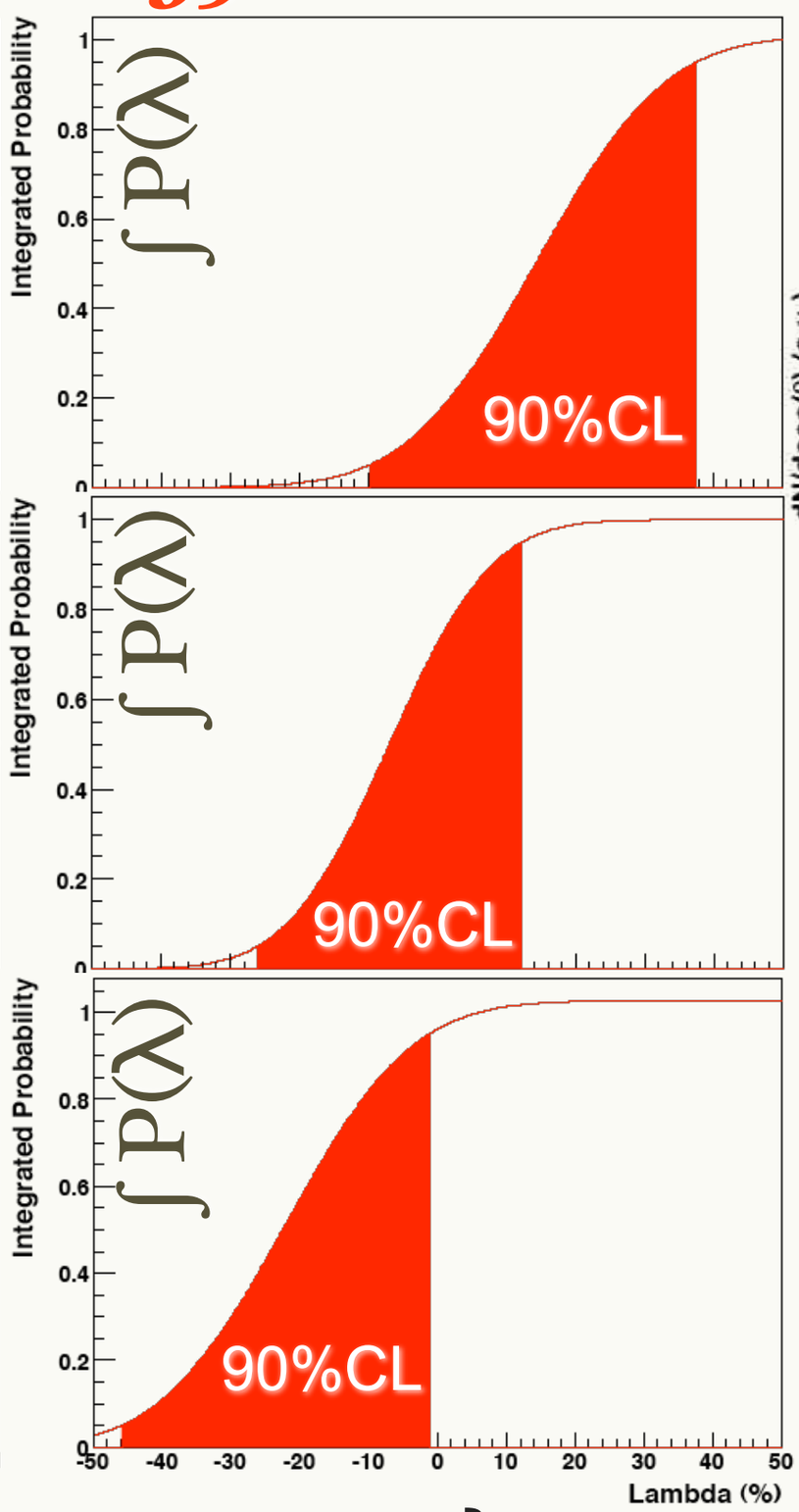
HERA-B: [Eur. Phys. J. C49, 545 (2007)]
CDF: PRL 79, 572 (1997).



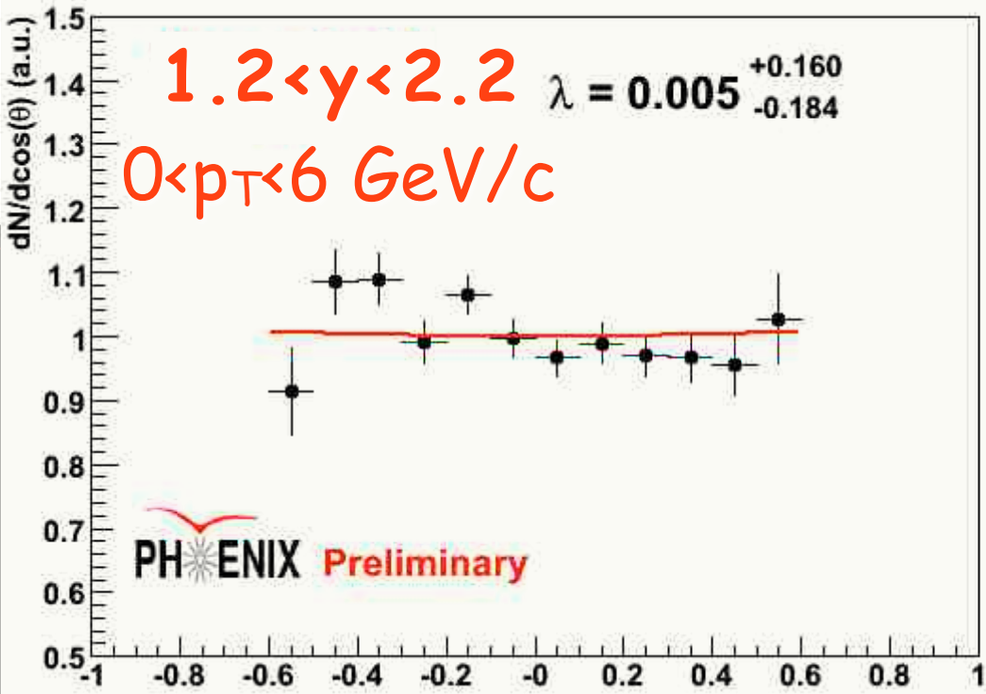
J/ψ polarization in *p*+*p* at $s^{1/2}$=200 GeV

|y|<0.35





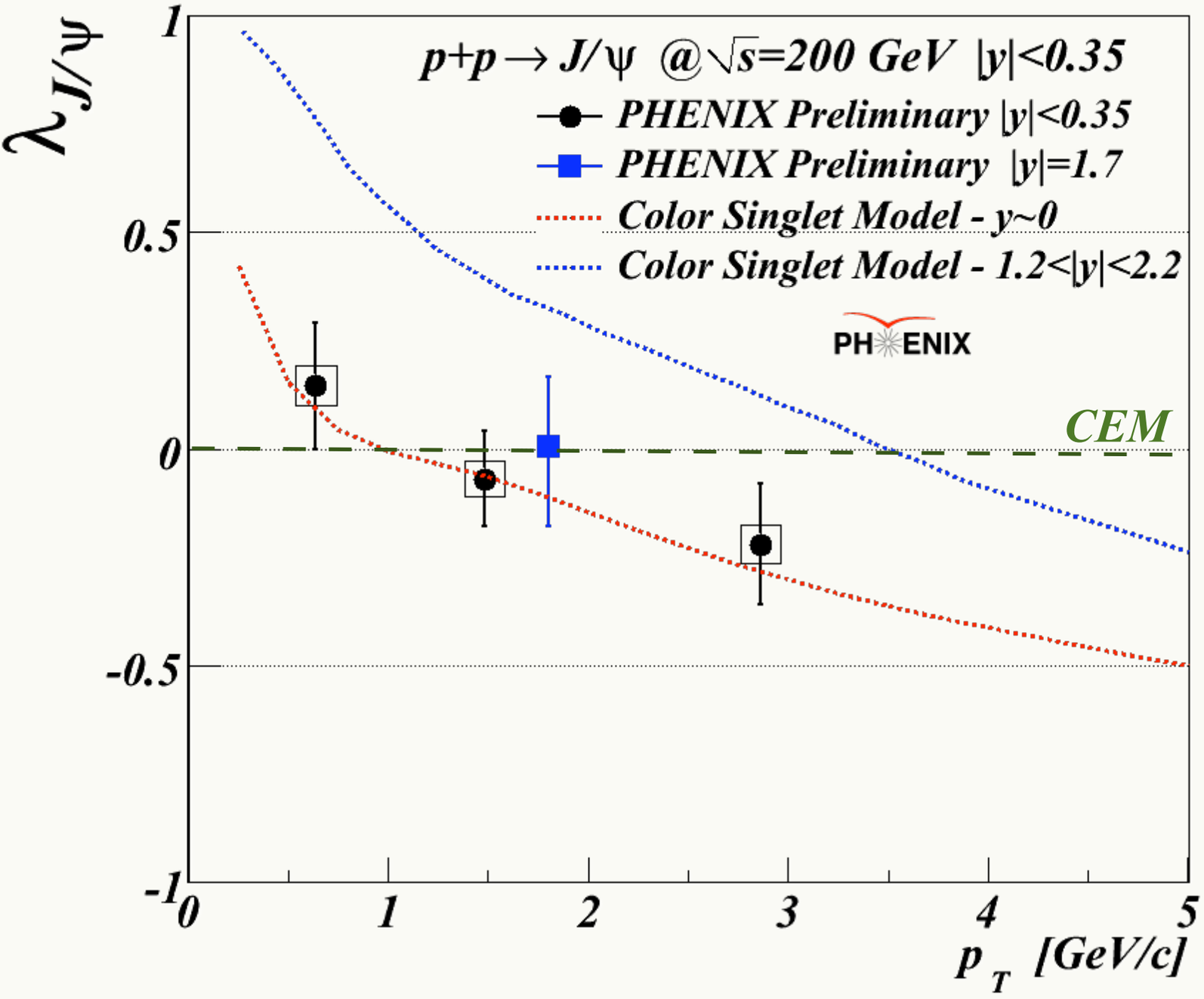
$$\frac{dN}{d(cos\theta)} = A\left(1 + \lambda cos^2(\theta)\right)$$



- inclusive J/ψ (prompt + feed down).
- J/ψ in helicity frame

See M. Donadelli's poster

J/ψ polarization in *p*+*p* at $s^{1/2}$=200 GeV



λ< longitudinal
λ>transverse

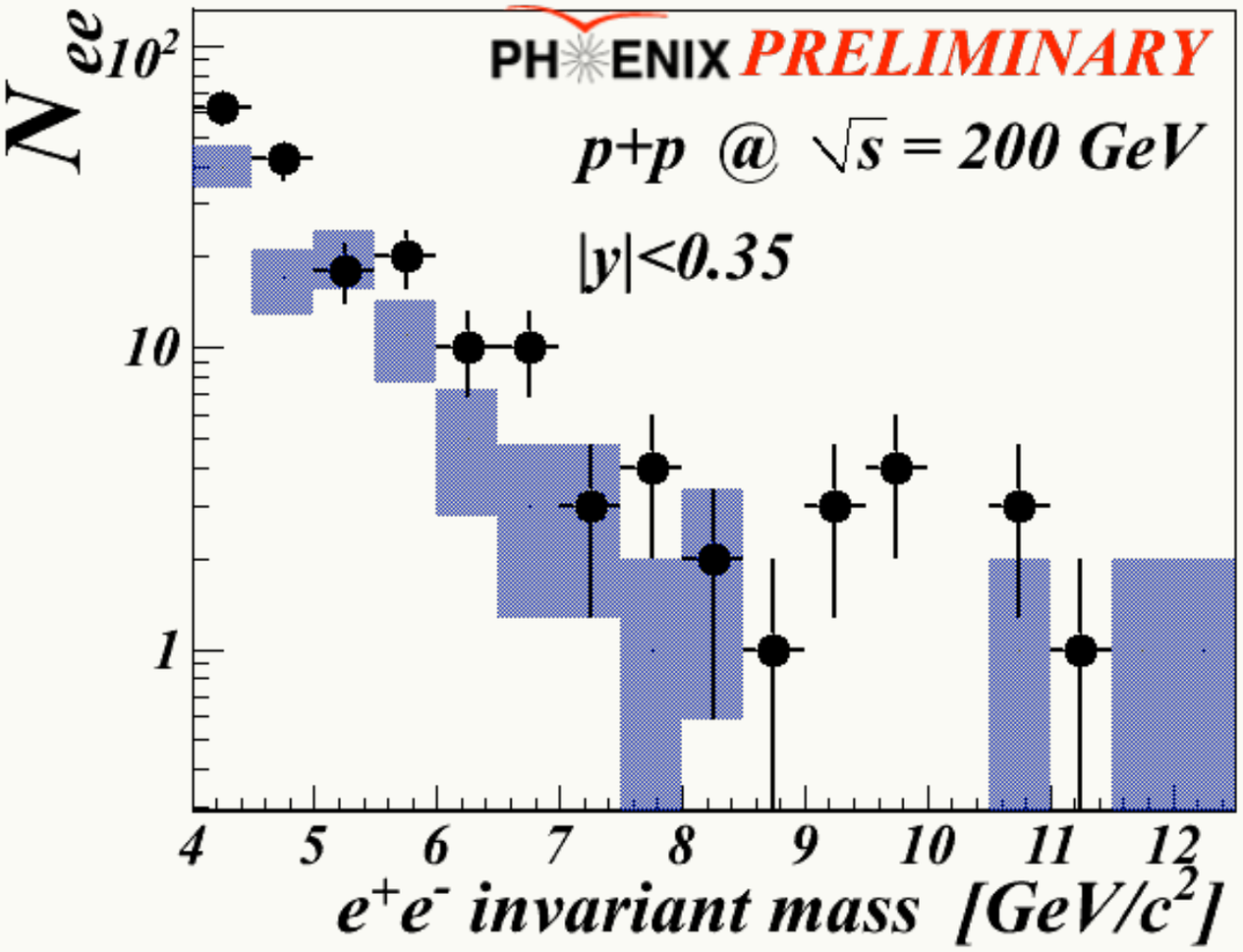
} H. Haberzettl and J. P. Lansberg, PRL100,032006 (2008)

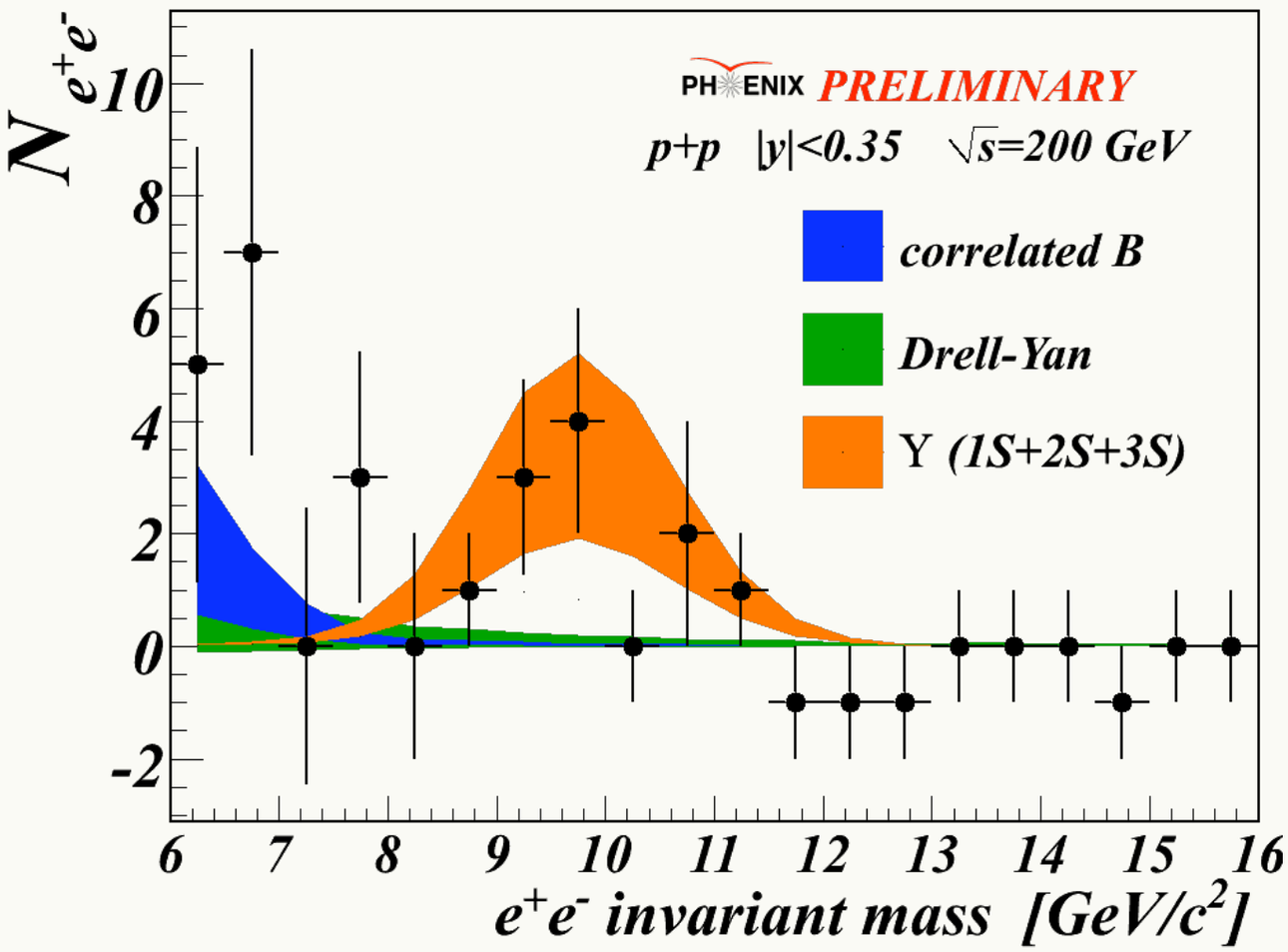
Consistent with new CSM at mid-rapidity.

3-gluon fusion pQCD [Khoze et al., Eur.Phys.J.C39,163(2005)] also predicts longitudinal polarization

- COM predicts $\lambda>0$ for $p_T>>M_{J/\psi}$ (not confirmed experimentally)
- Cannot rule out CEM, no prediction for COM at this p_T range.
- Important information as a reference for upcoming polarization measurement in d+Au and Au+Au

Υ(1S+2S+3S) yield in *p+p* at $s^{1/2}$=200 GeV





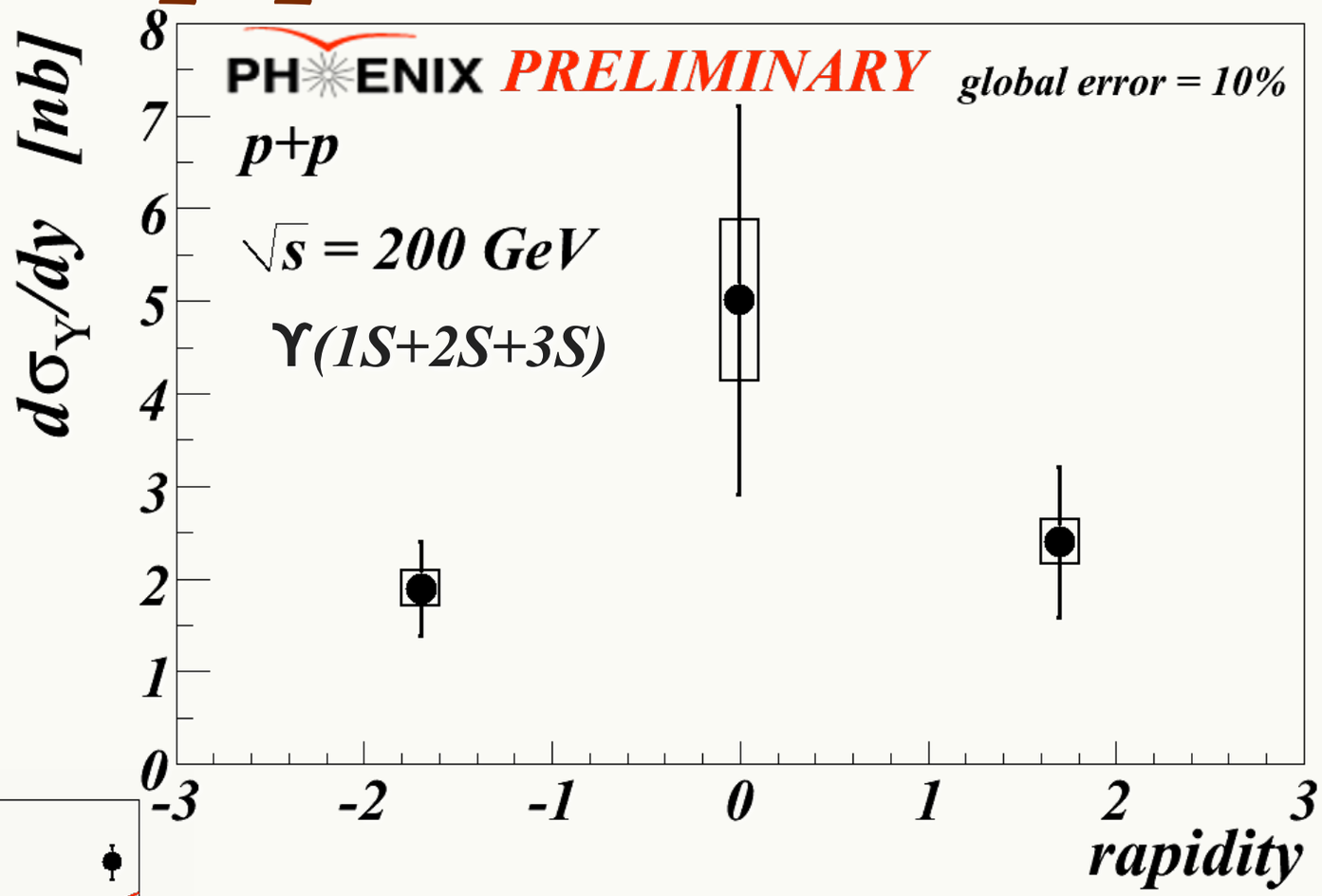
12 unlike-sign pairs and 1 like-sign pair in [8.5,11.5] GeV/c^2 mass region.

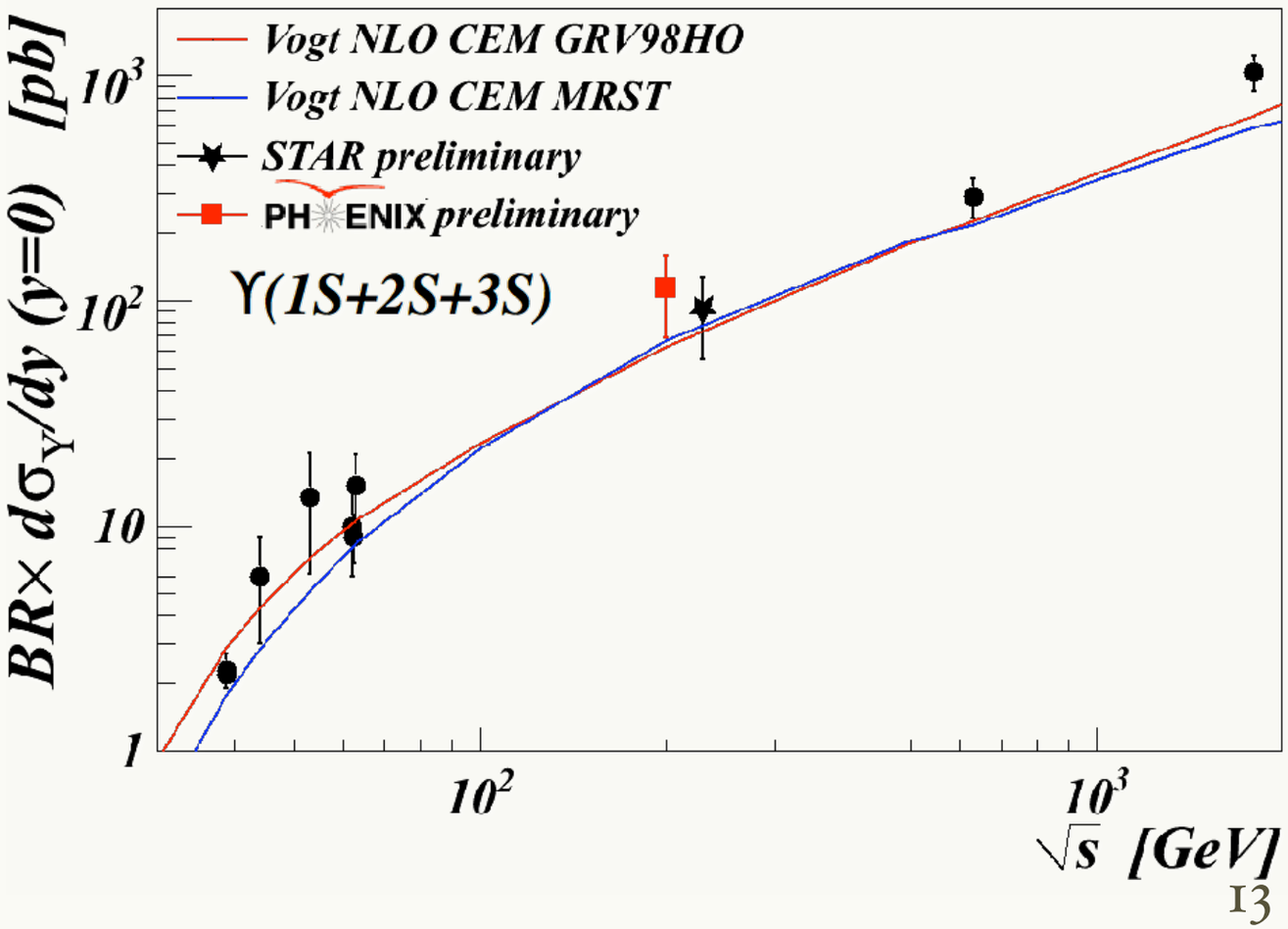
Continuum estimated to be <15%, or <1.6 counts.

Υ(1S+2S+3S) yield in p+p at $s^{1/2}$=200 GeV

Continuum removed only at mid-rapidity.

Rapidity dependence can be used to calculate total cross section.





$$B\frac{d\sigma_\Upsilon}{dy}\Big|_{|y|<0.35} = 114^{+46}_{-45}pb$$

Cross section at y~0 follows world trend

Compatible with STAR measurement.

d+Au

Cold Nuclear Matter Effects

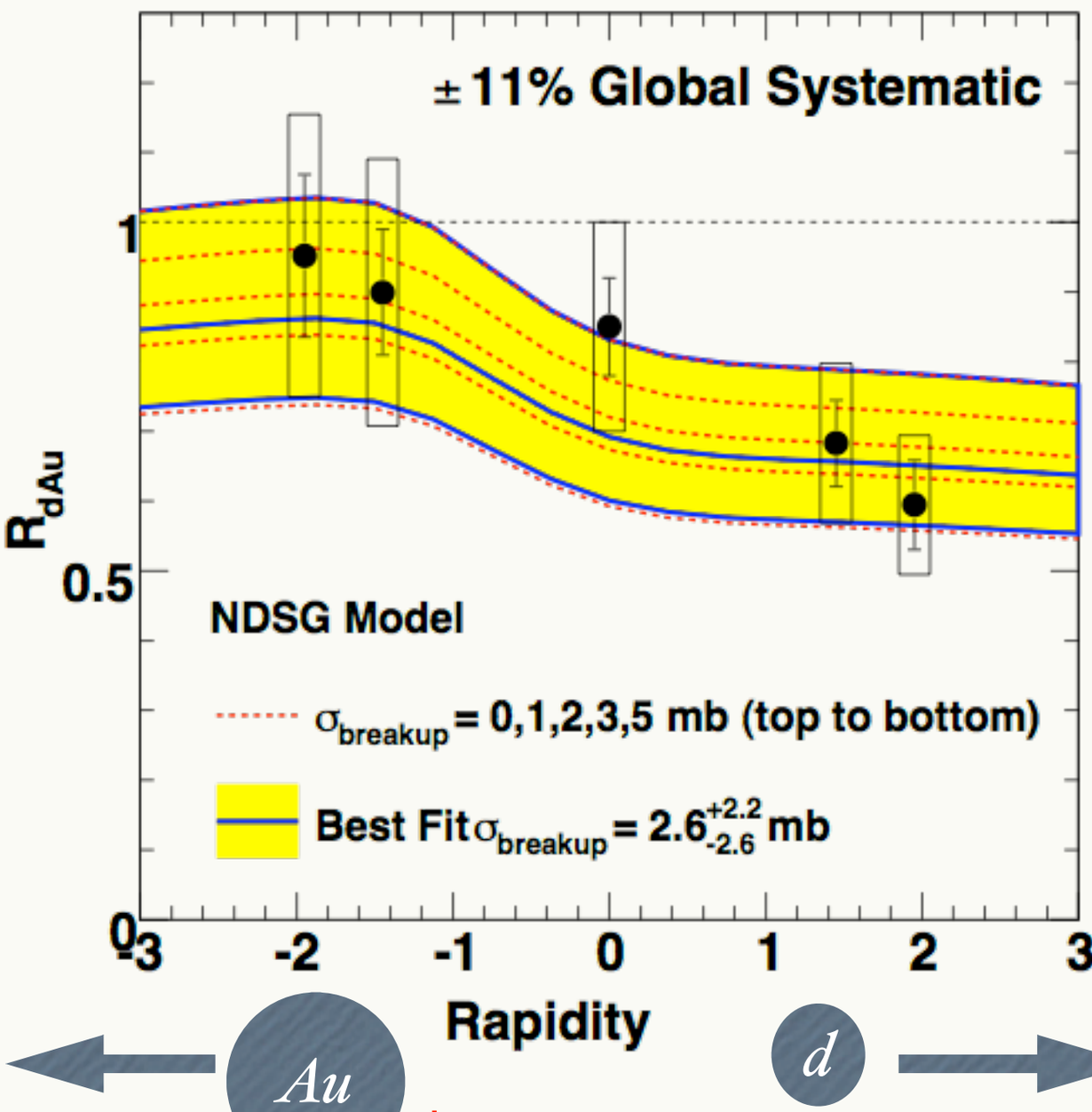
Understanding J/ψ suppression in d+Au

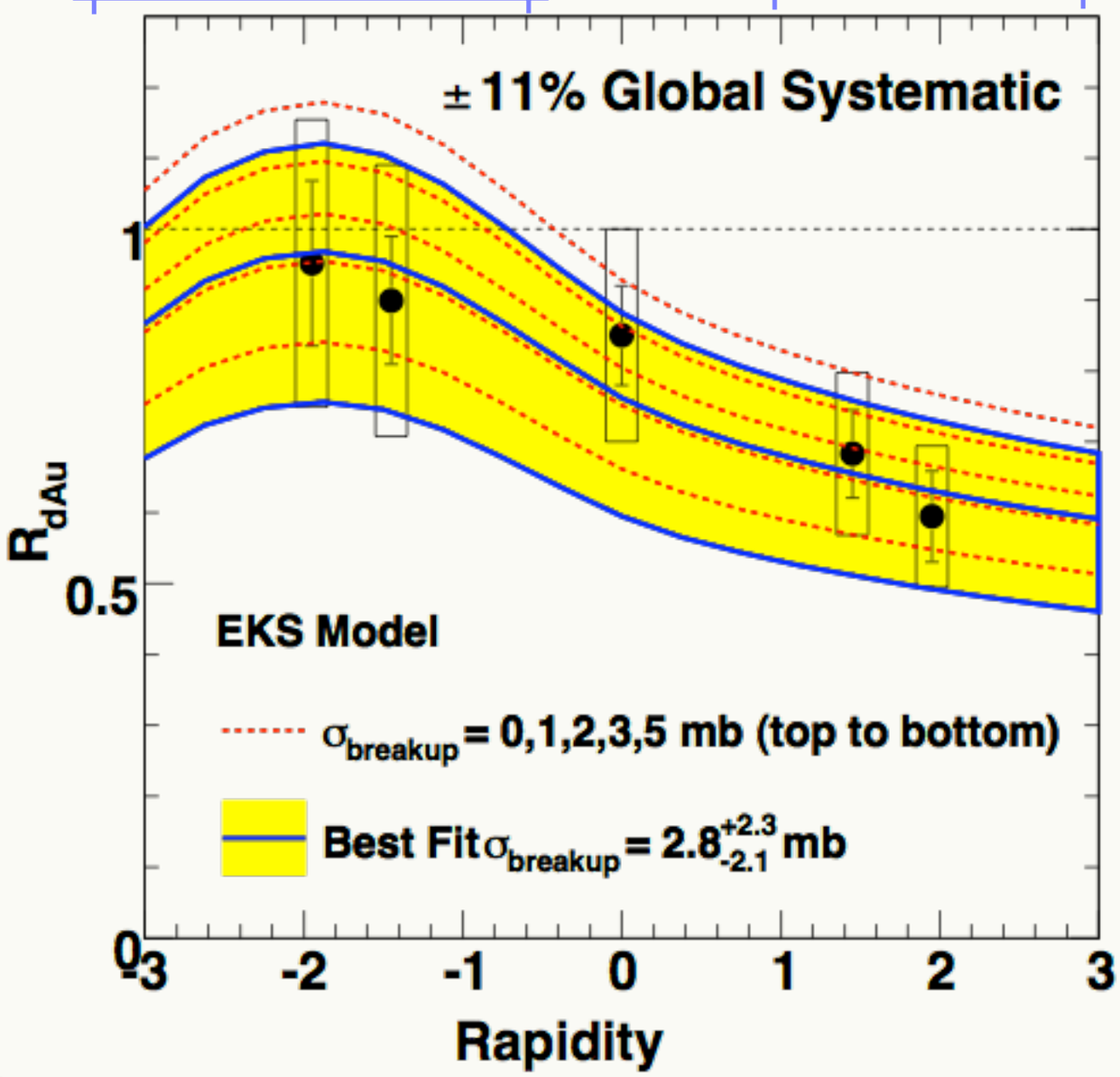
large x

small x

anti-shadowing region

shadowing region





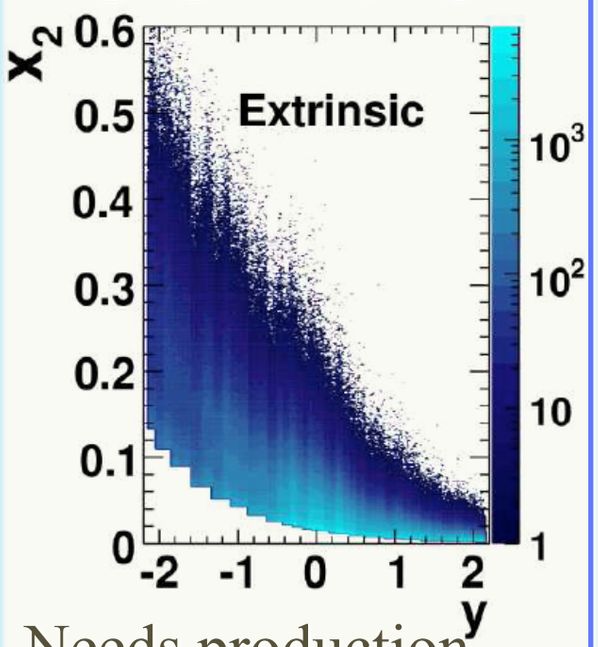
Au ← → *d*

PRC 77, 024912 (2008). Revised fits to account for all systematic errors. Erratum: arXiv:0903.4845 [nucl-ex]

CNM for different production kinematics

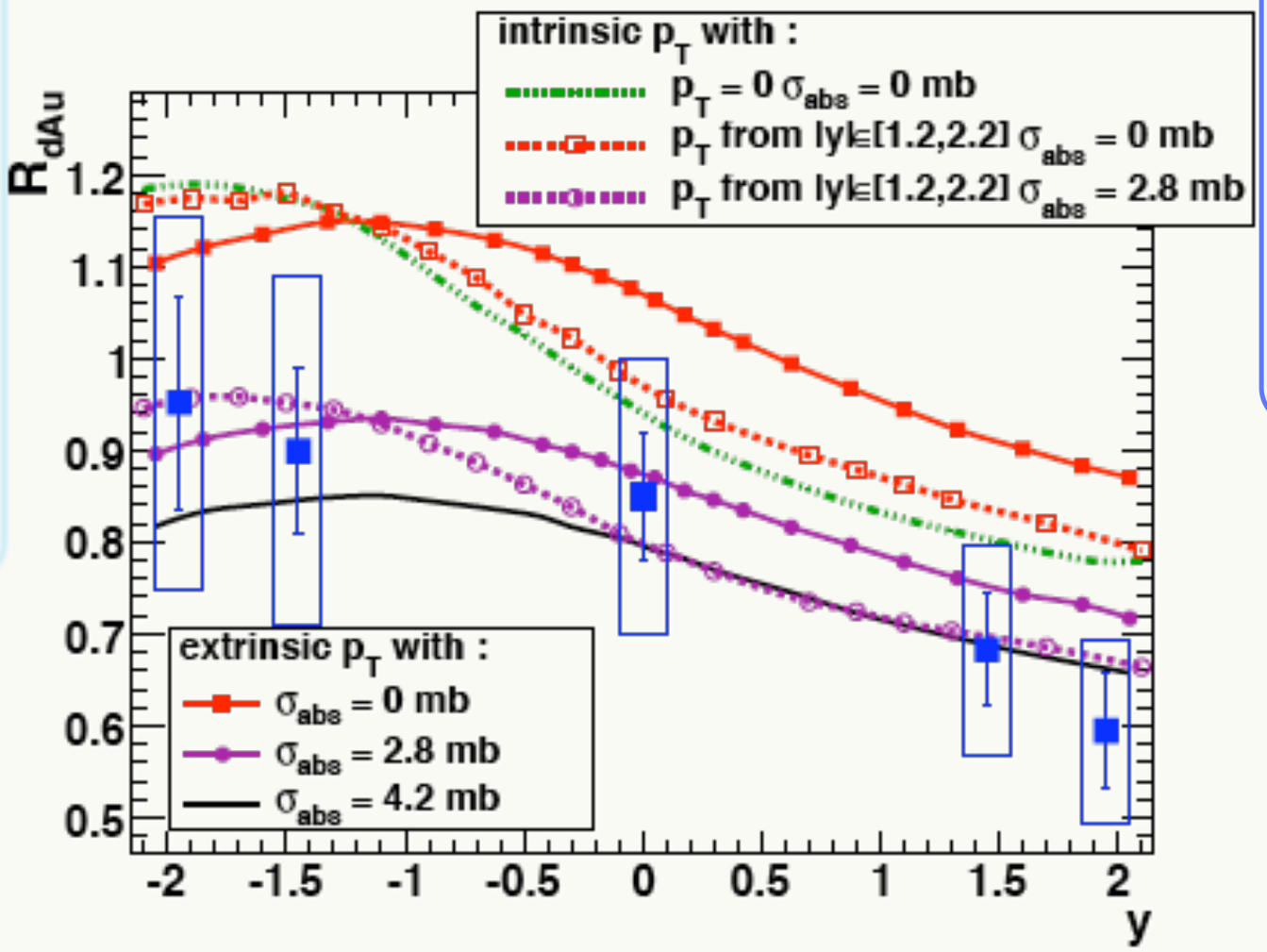
Extrinsic

$g+g \rightarrow J/\psi+g$



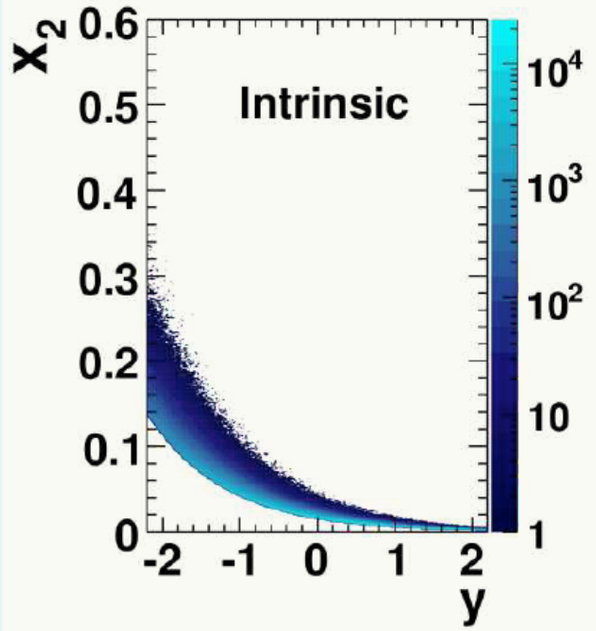
Needs production mechanism.
Using CSM s-channel

E.G. Ferreiro, F. Fleuret, J.P.Lansberg, A. Rakotozafindrabe. hep-ph/0809.4684



Intrinsic

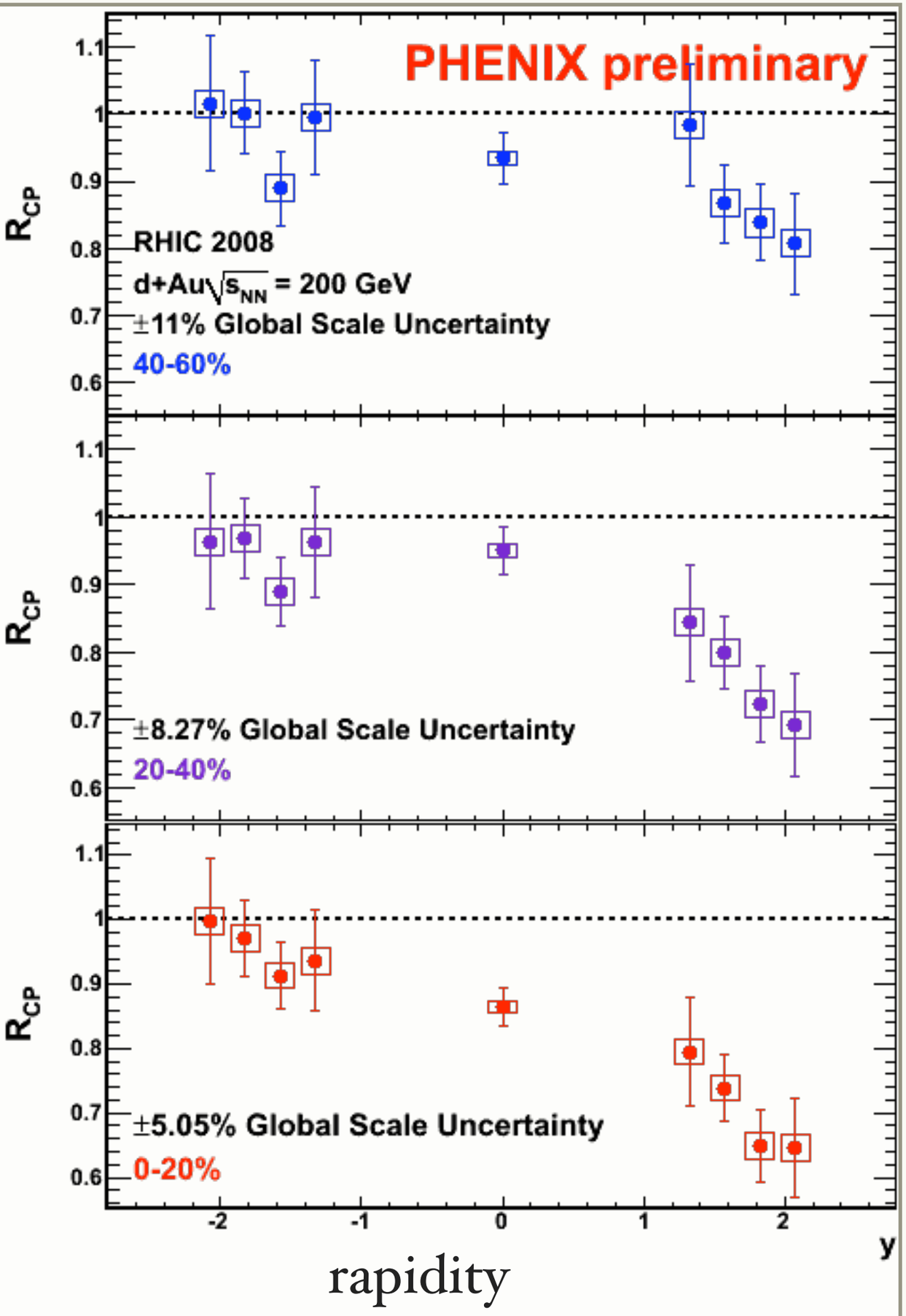
$g+g \rightarrow J/\psi$



Using EKS98

- Suppression from CNM depends on quarkonium production mechanism.
- x2 can be larger if production process is $p+p \rightarrow J/\psi+g$.

New d+Au results from 2008 RUN



$$R_{cp} = \frac{1}{N_{coll}/N^{p}_{coll}} \frac{dN/dy}{dN/dy^{p}}$$

$$p \equiv \text{60-88\% centrality}$$

Intrinsic calculation

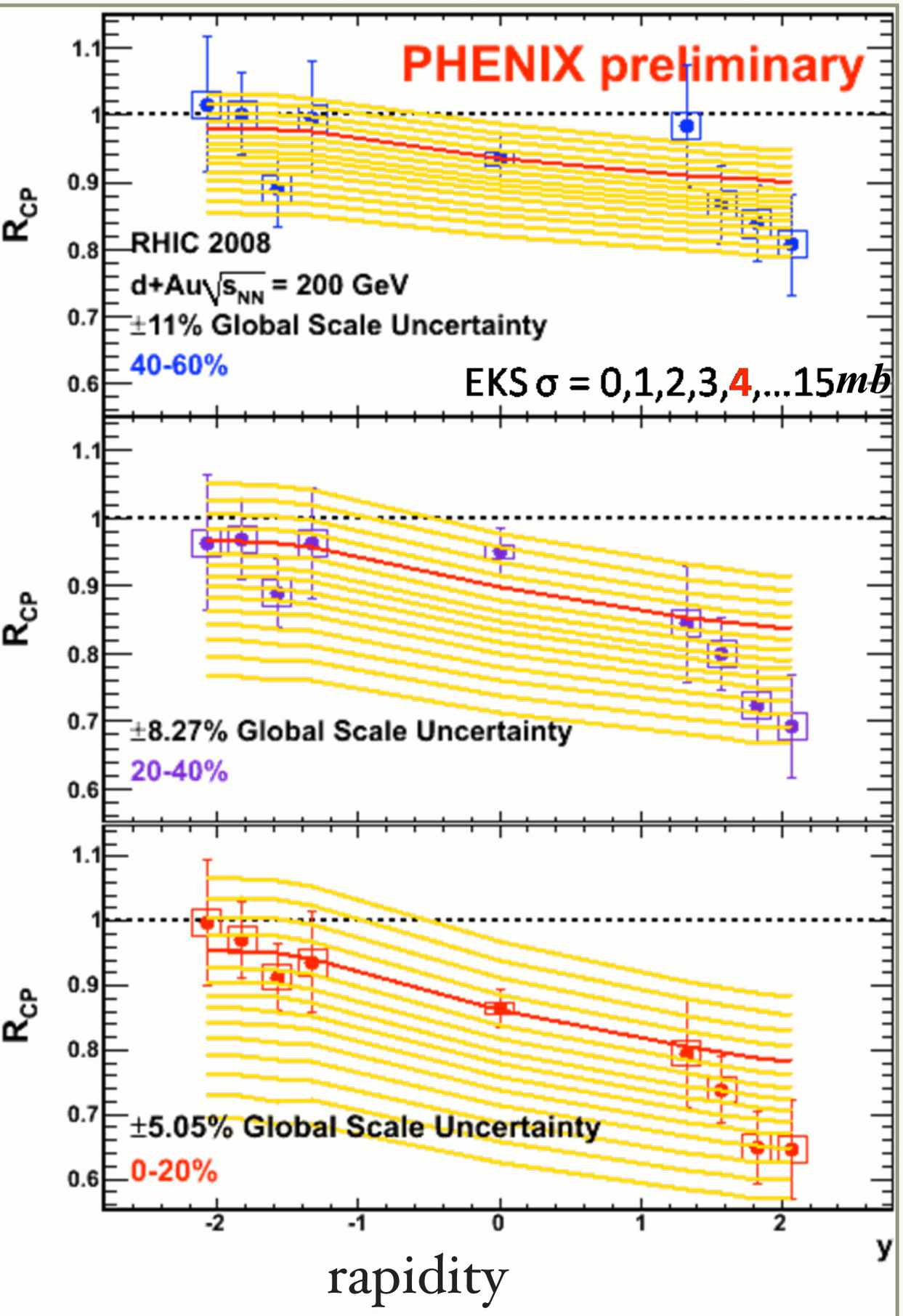
30x more statistics than 2003 run.

Most of systematic errors cancel out in R_{cp}.

Upcoming fits to R_{dA} can better constrain $\sigma_{breakup}$.

See D. McGlinchey's poster

New d+Au results from 2008 RUN



$$R_{cp} = \frac{1}{N_{coll}/N^{p}_{coll}} \frac{dN/dy}{dN/dy^{p}}$$

$$p \equiv \text{60-88\% centrality}$$

EKS98

Intrinsic calculation

30x more statistics than 2003 run.

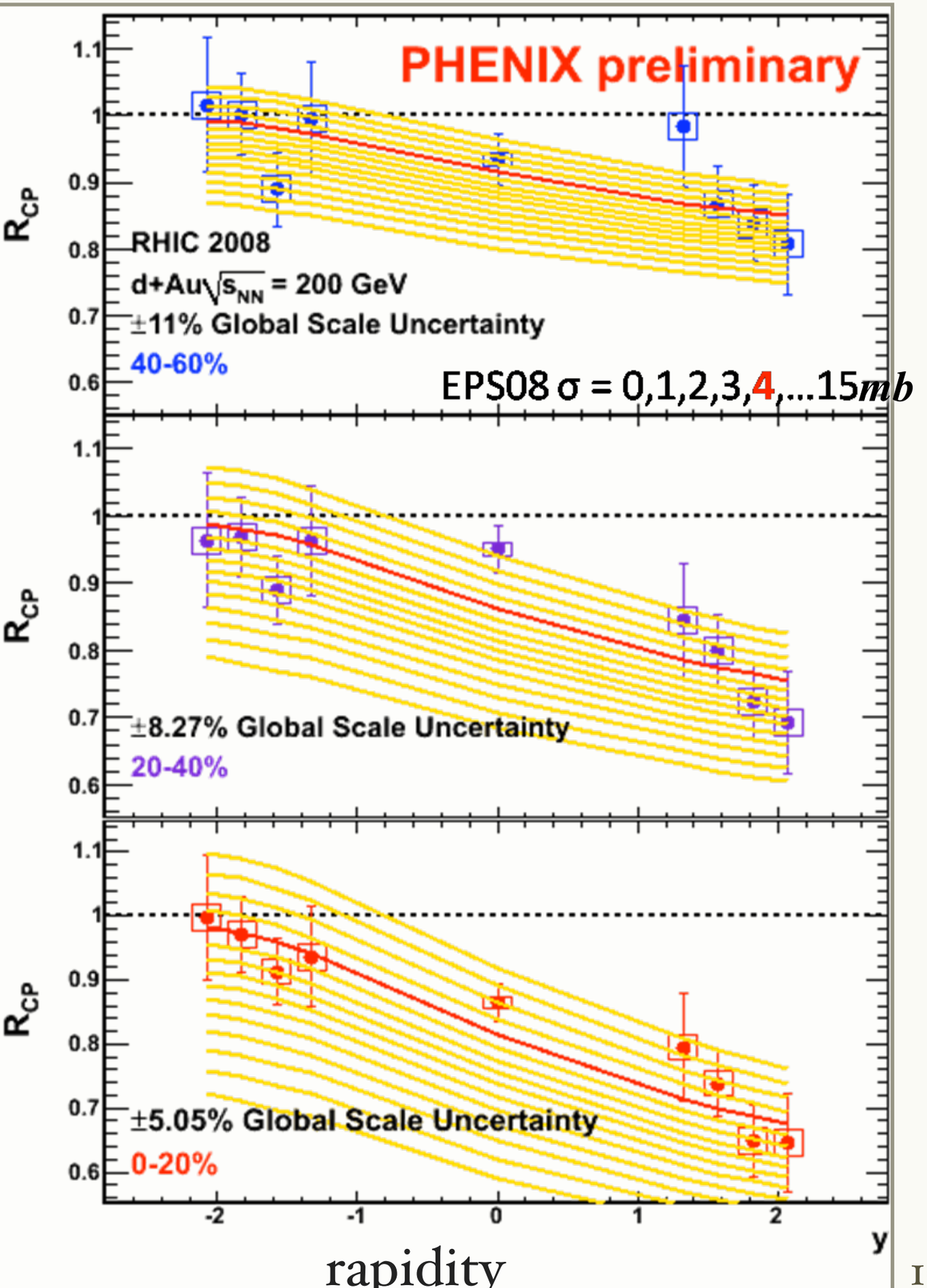
Most of systematic errors cancel out in R_{cp}.

Upcoming fits to R_{dA} can better constrain $\sigma_{breakup}$.

Curves: R. Vogt - private communication

See D. McGlinchey's poster

New d+Au results from 2008 RUN



$$R_{cp} = \frac{1}{N_{coll}/N^{p}_{coll}} \frac{dN/dy}{dN/dy^{p}}$$

$$p \equiv \text{60-88\% centrality}$$

EPS08

Intrinsic calculation

30x more statistics than 2003 run.

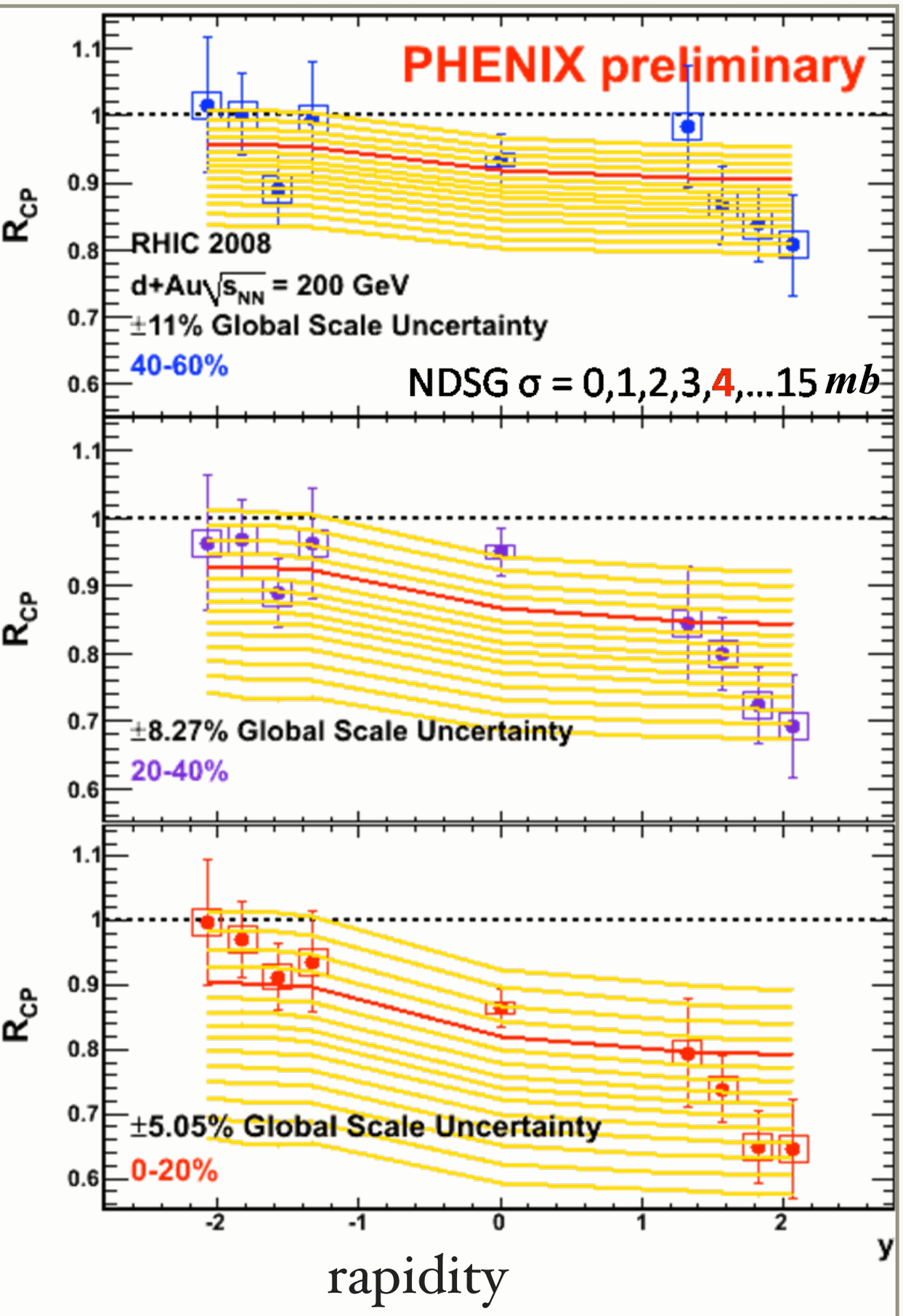
Most of systematic errors cancel out in R_{cp}.

Upcoming fits to R_{dA} can better constrain $\sigma_{breakup}$.

Curves: R. Vogt - private communication

See D. McGlinchey's poster

New d+Au results from 2008 RUN



$$R_{cp} = \frac{1}{N_{coll}/N^{p}_{coll}} \frac{dN/dy}{dN/dy^{p}}$$

$$p \equiv \text{60-88\% centrality}$$

NDSG

Intrinsic calculation

30x more statistics than 2003 run.

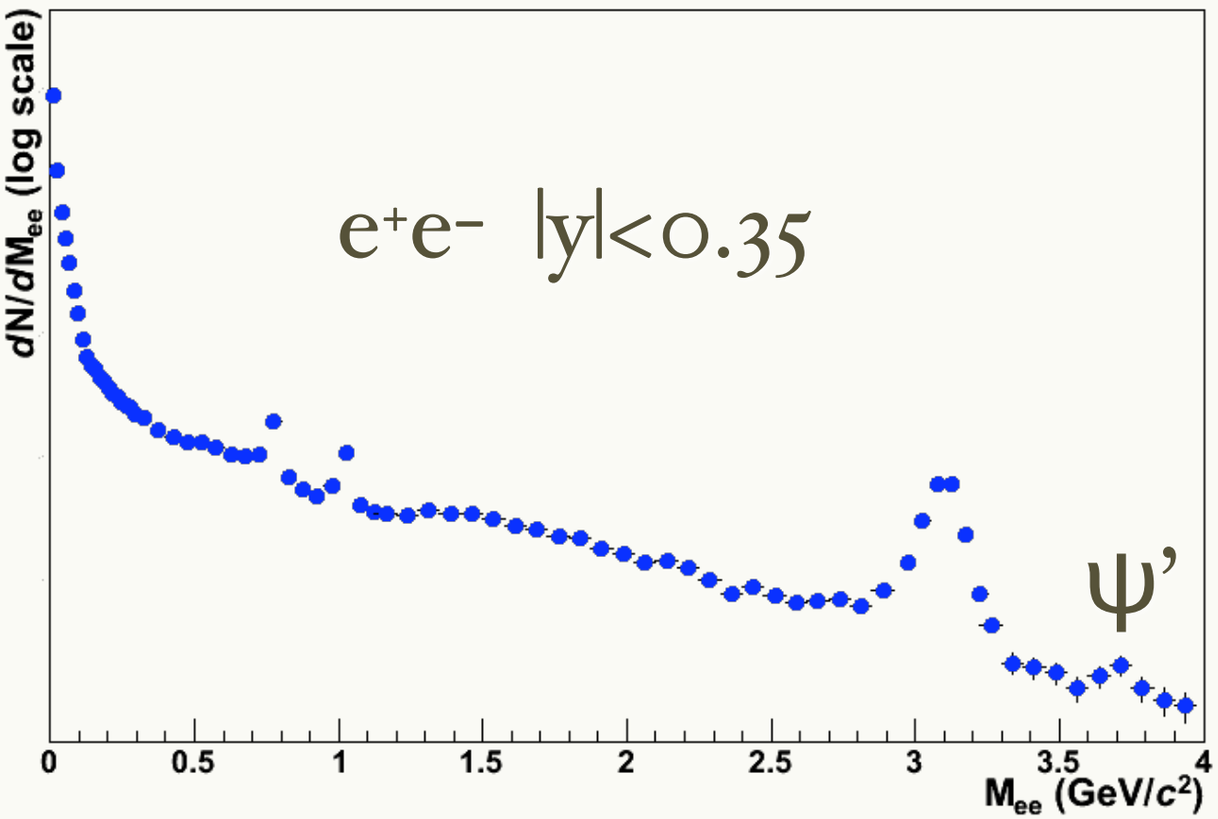
Most of systematic errors cancel out in R_{cp}.

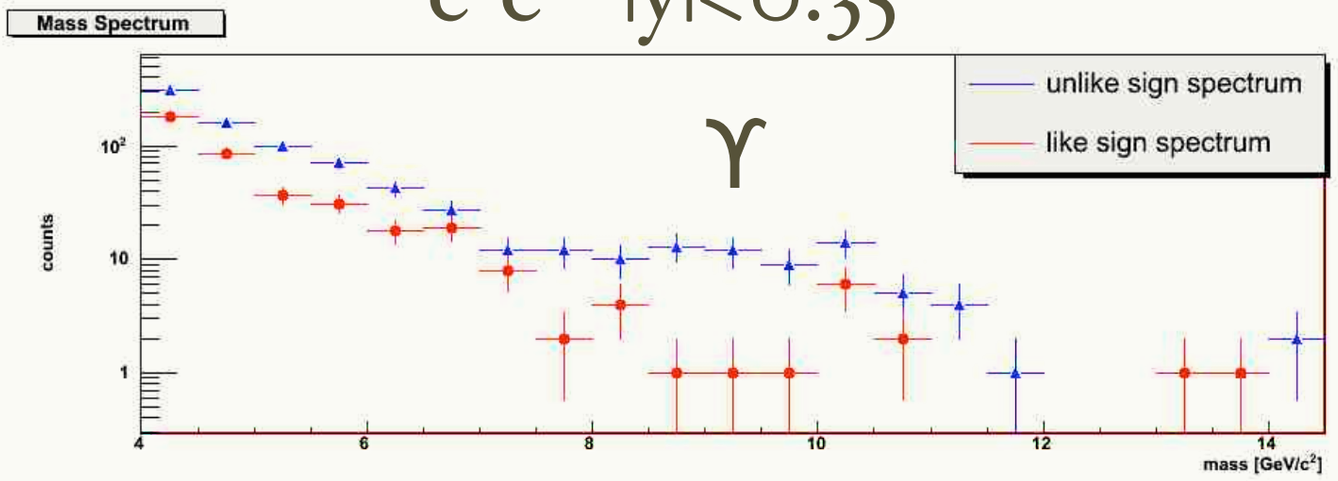
Upcoming fits to R_{dA} can better constrain $\sigma_{breakup}$.

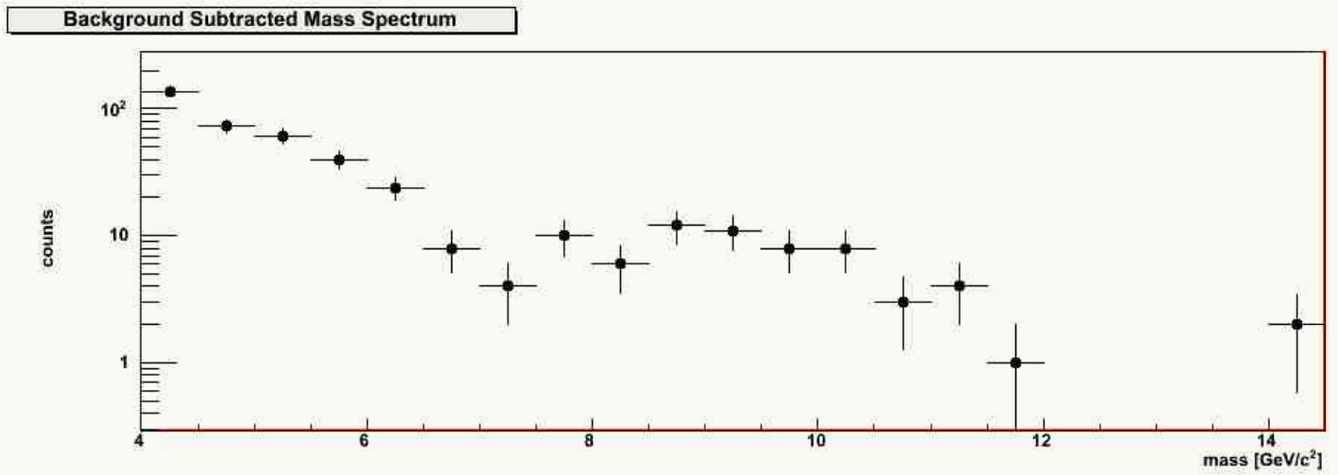
Curves: R. Vogt - private communication

See D. McGlinchey's poster

Upcoming new results from d+Au data



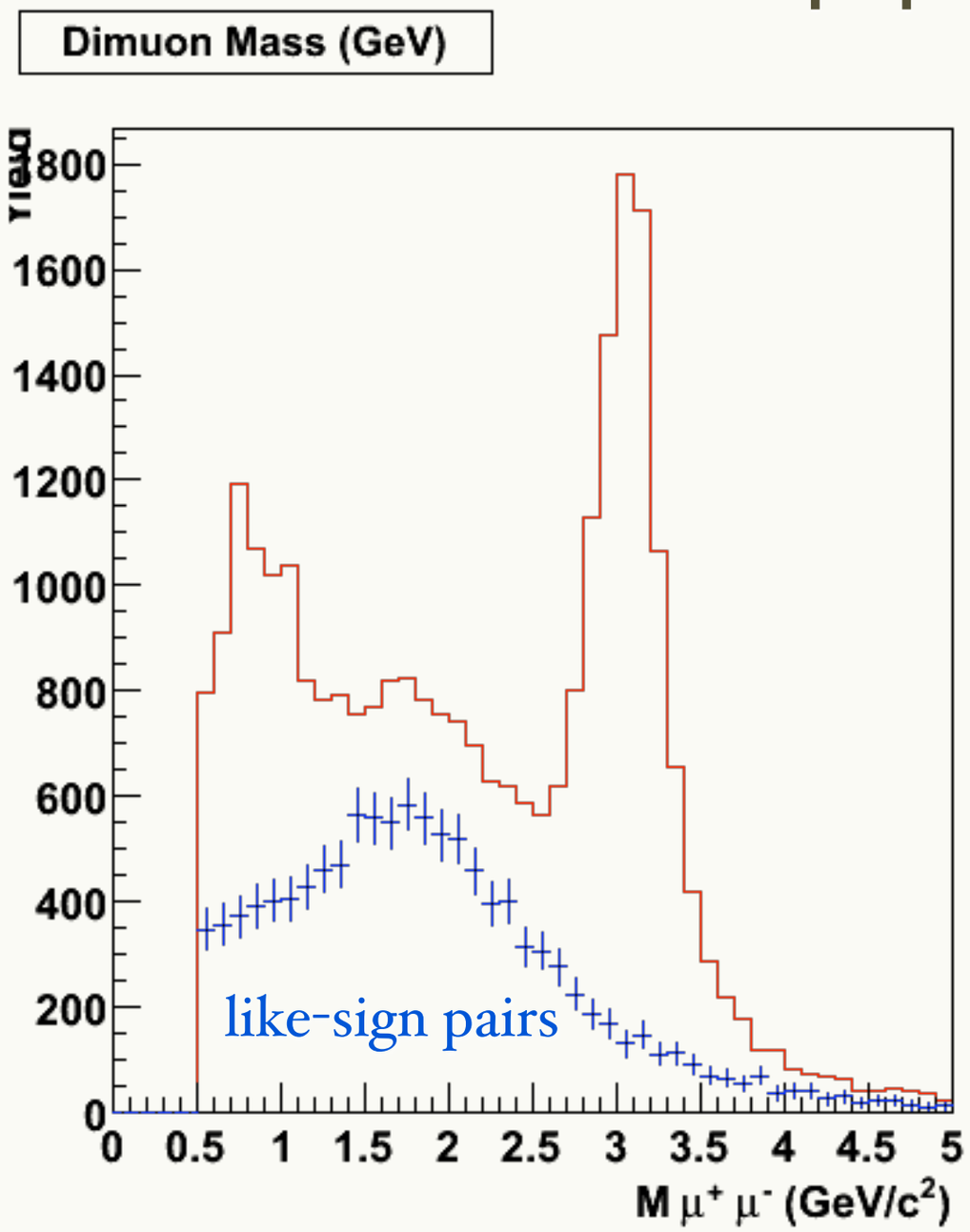


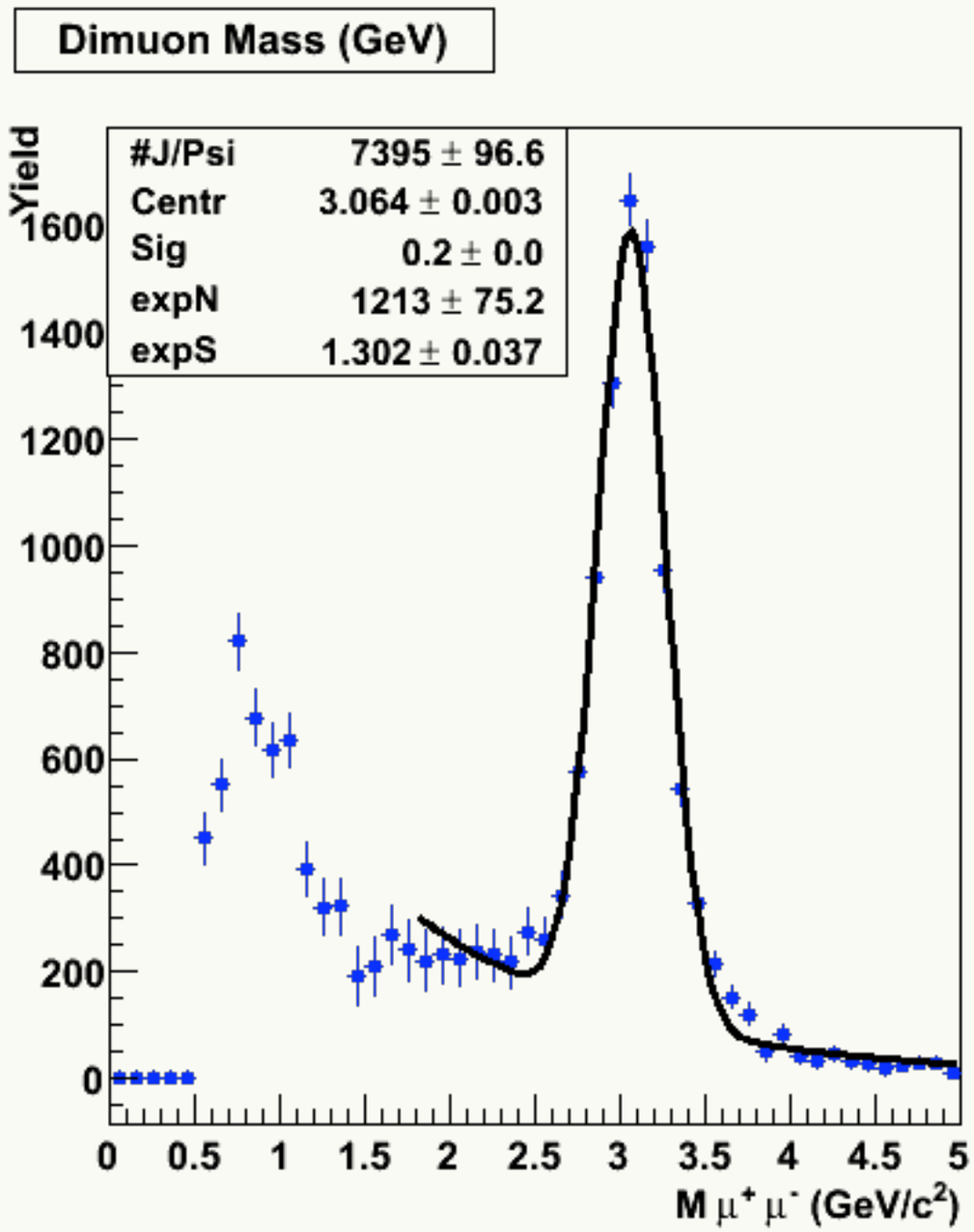


Measurement of other quarkonia states in the new d+Au data will provide a better picture of Cold Nuclear Matter effects and perhaps help in the understanding the production mechanism.

and 500 GeV run

$\mu^+\mu^-$ 1.2<|y|<2.2





Data from the the last 72 hours. Still counting...

Outlook

- PHENIX has measured different quarkonium states in p+p and d+Au in different rapidity regions

- New data from 2006 p+p collisions agree with our published results and is better described by CSM with s-channel contribution (Lansberg CSM)

- ψ' / J/ψ ratio has no strong p_T and energy dependence

- first measurement of J/ψ polarization agrees with CSM s-channel contribution at mid-rapidity and still consistent with CEM. Waiting for COM and 3-gluon fusion predictions at our p_T range

- brand new preliminary J/ψ R_{cp} measurement in d+Au has smaller statistical and systematic uncertainties and can better constrain the cold nuclear matter effect estimations

- upcoming modification factors of heavier quarkonium states in d+Au will also contribute to disentangle the production and medium effects