# J/ψ Production and Nuclear Effects for d+Au & p+p Collisions in PHENIX at RHIC

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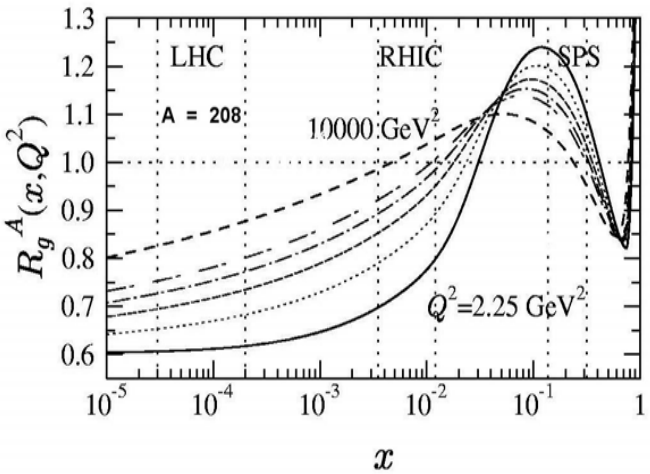
- Physics issues in J/ψ production and nuclear effects
  - production mechanisms
  - shadowing, $p_T$ broadening, absorption, parton energy loss
  - QGP signature?
- PHENIX: di-muons & di-electrons
- J/ψ measurements in dAu and pp collisions with $\mu^+\mu^-$ and $e^+e^-$ pairs in PHENIX
- Expectations for AuAu collisions
- Summary

# Nuclear modification of parton level structure & dynamics

**Modification of parton momentum distributions of nucleons embedded in nuclei**

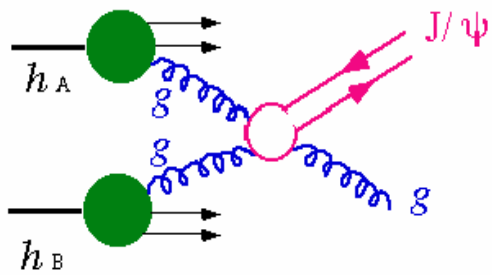
*Eskola, Kolhinen, Vogt hep-ph/0104124*




- e.g. shadowing – depletion of low-momentum partons
- Very low momentum fraction partons have large size, overlap with neighbors, and fuse; thus enhancing the population at higher momenta at the expense of lower momenta
- color glass condensate – specific/fundamental model that gives gluon shadowing in nuclei

**Production of heavy vector mesons, e.g. J/Ψ,Ψ' and ϒ**

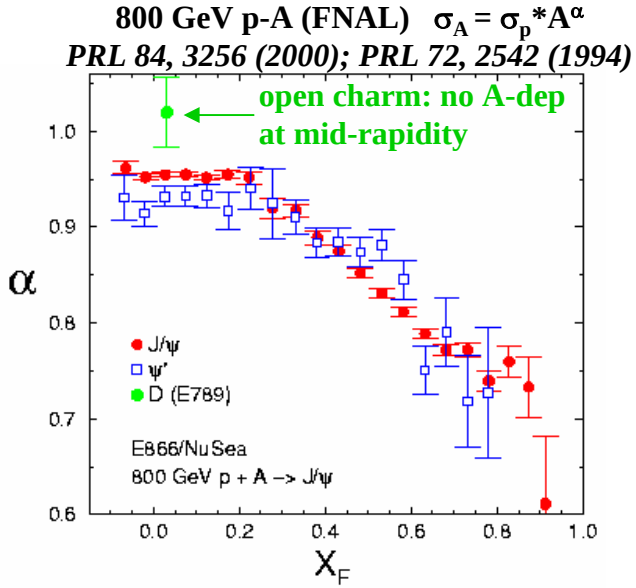
- production: color singlet or octet ccbar?
- hadronization time
- feed-down from higher mass resonances, e.g. $\chi_c$



# Nuclear modification of parton level structure & dynamics II

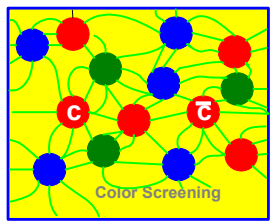
## Nuclear effects on parton "dynamics"

- energy loss of partons as they propagate through nuclei
- and (associated?) multiple scattering effects (Cronin effect)
- absorption of J/ψ on nucleons or co-movers; compared to no-absorption for open charm production

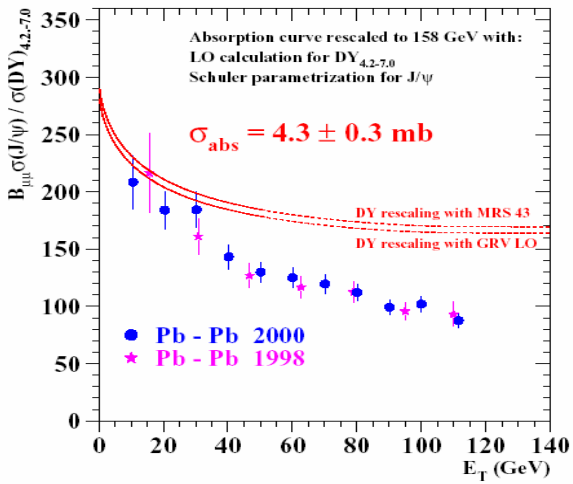



## dAu also baseline for AuAu J/ψ Quark Gluon Plasma (QGP) signature

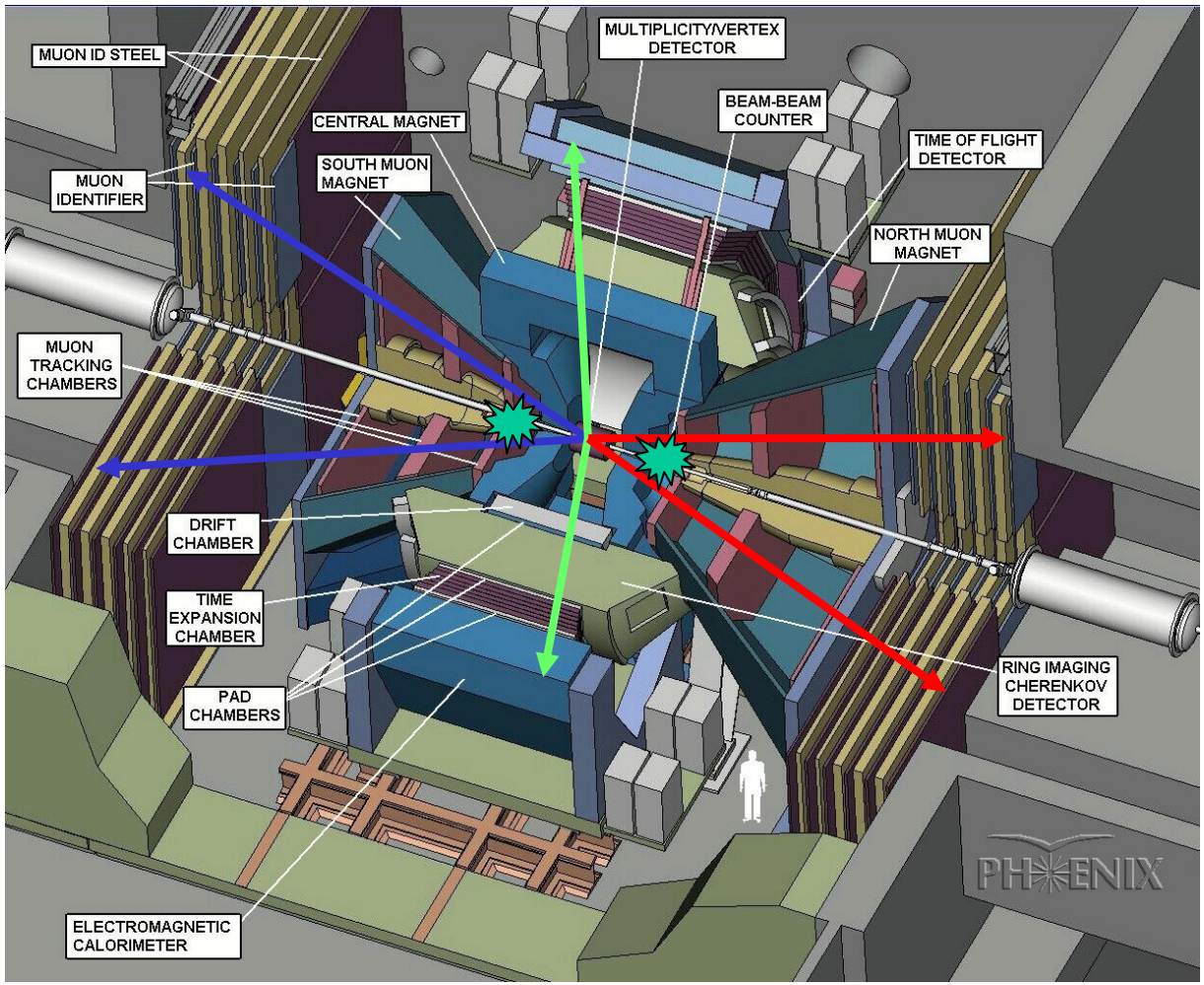
- Debye screening predicted to destroy J/ψ's in a QGP




- but recent charm recombination models might instead cause an enhancement?



# J/ψ's in PHENIX



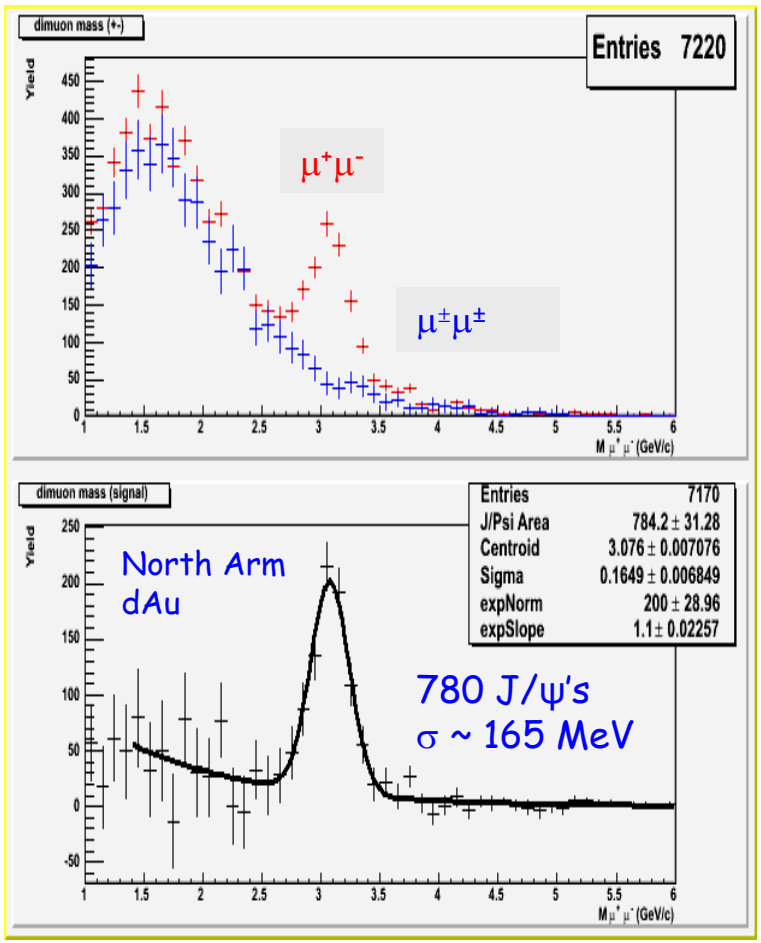

$J/\Psi \rightarrow e^+e^-$
identified in RICH and EMCal
- $|\eta| < 0.35$
- $p > 0.2$ GeV

$J/\Psi \rightarrow \mu^+\mu^-$
identified in 2 fwd spectrometers
- $1.2 < |\eta| < 2.4$
- $p > 2$ GeV

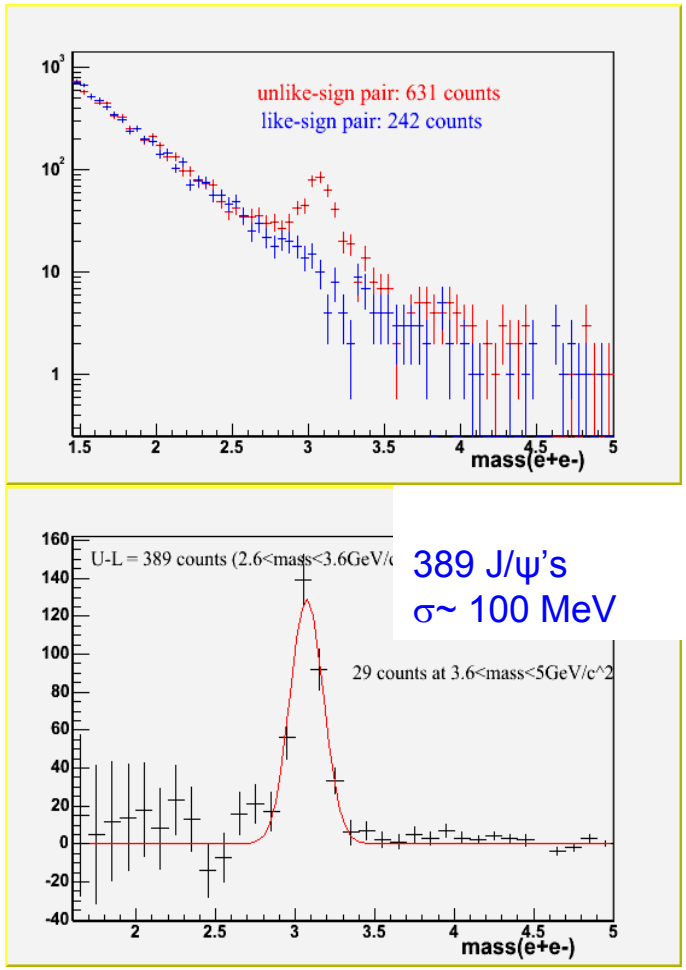
Centrality and vertex given by BBC in $3<|\eta|<3.9$

# J/ψ yields in PHENIX from recent dAu run (2003) at RHIC

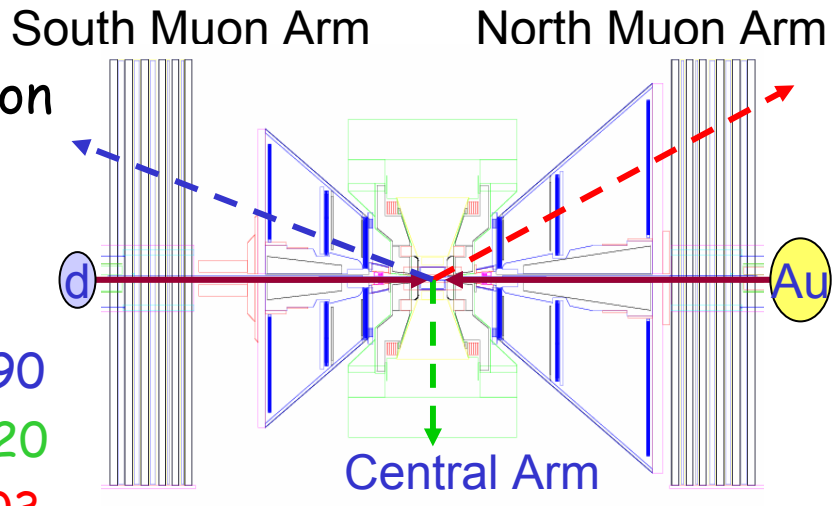
$J/\psi \rightarrow \mu^+\mu^-$ $1.2<|y|<2.4$




$J/\psi \rightarrow e^+e^-$ $|y|<0.35$

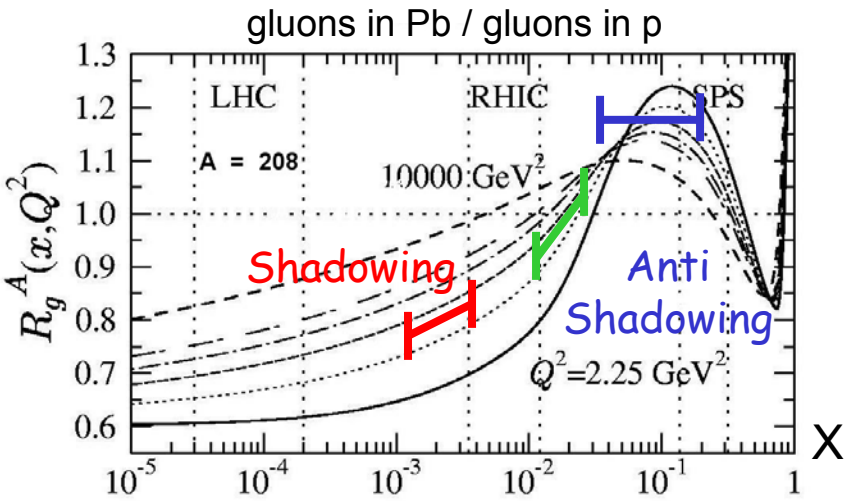


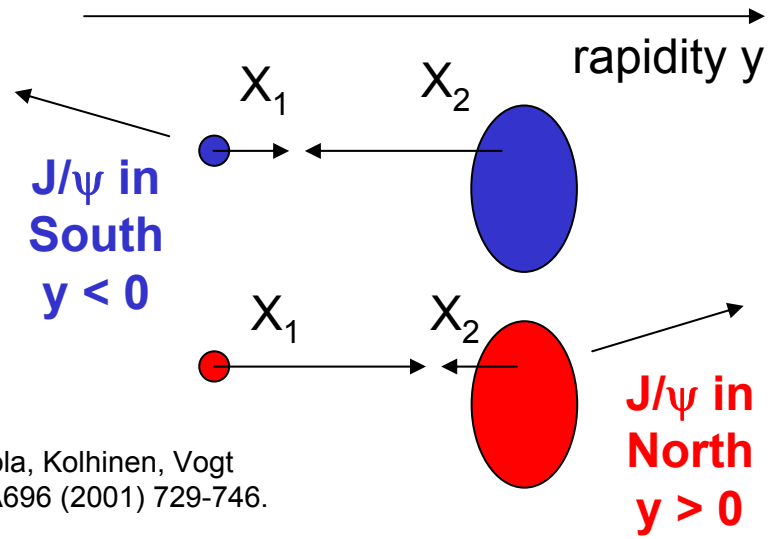
# J/ψ → μ+μ- Analysis for dAu & pp




- In PHENIX, J/ψ mostly produced by gluon fusion, and thus sensitive to gluon pdf
- Three rapidity ranges probe different momentum fractions of Au partons
  - South (y < -1.2) : large $X_2$ (in gold) ~ 0.090
  - Central (y ~ 0) : intermediate $X_2$ ~ 0.020
  - North (y > 1.2) : small $X_2$ (in gold) ~ 0.003

Example of predicted gluon shadowing in d+Au



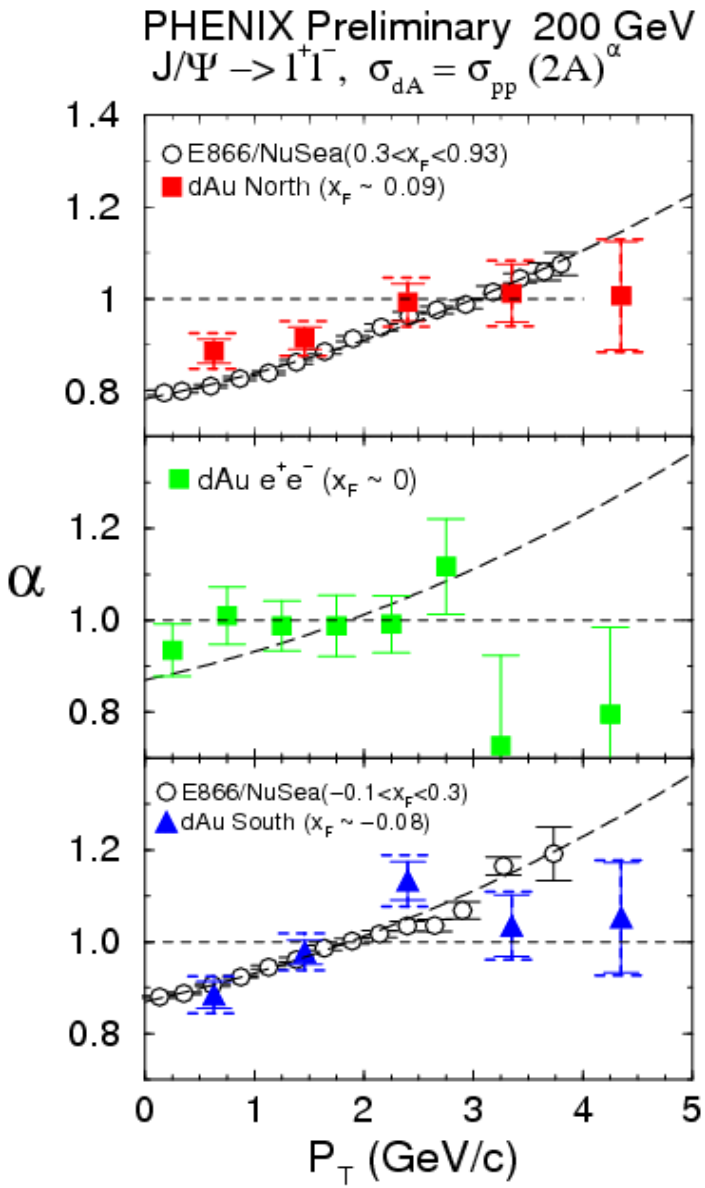




From Eskola, Kolhinen, Vogt
Nucl. Phys. A696 (2001) 729-746.

# dAu/pp versus $p_T$

**$p_T$ broadening comparable to lower energy**
**($\sqrt{s}$ = 39 GeV in E866)**

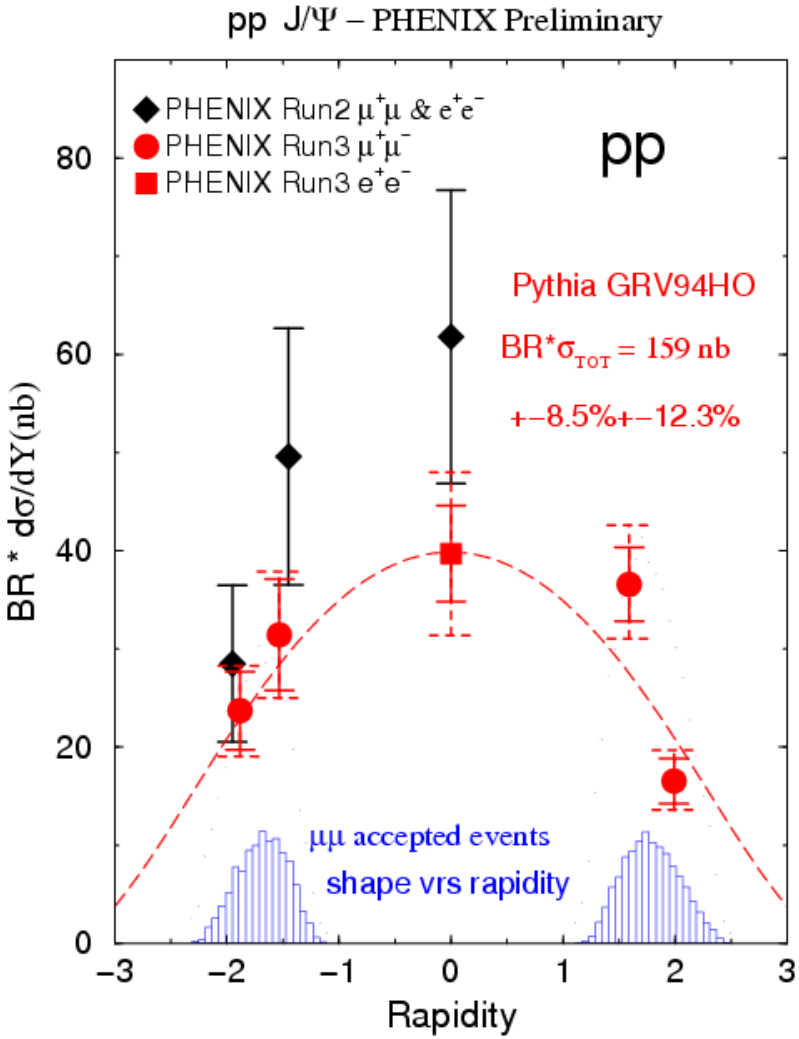
$$\sigma_{dA} = \sigma_{pp}\left(2\times 197\right)^{\alpha}$$

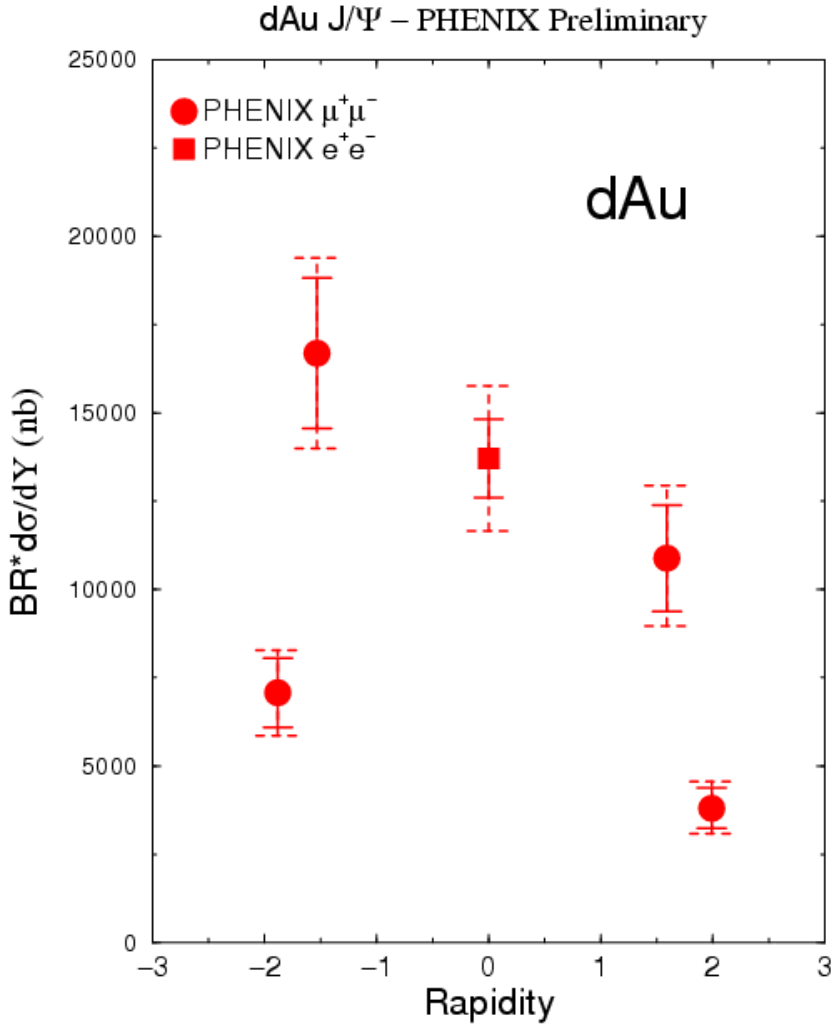



Low $x_2$ ~ 0.003

High $x_2$ ~ 0.09

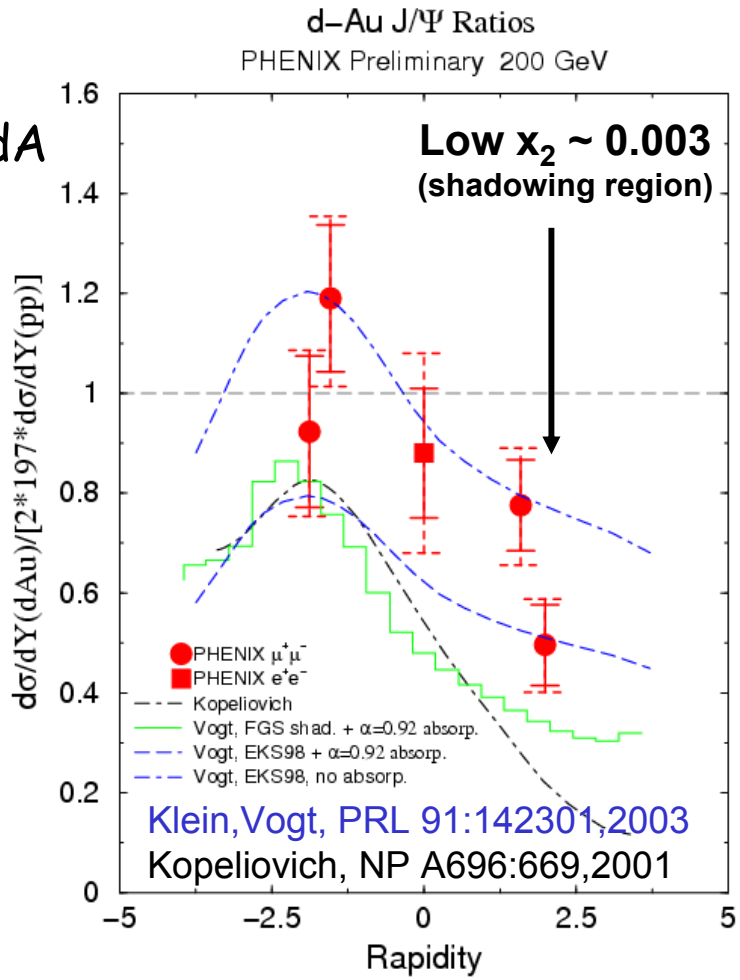
# Cross section versus rapidity

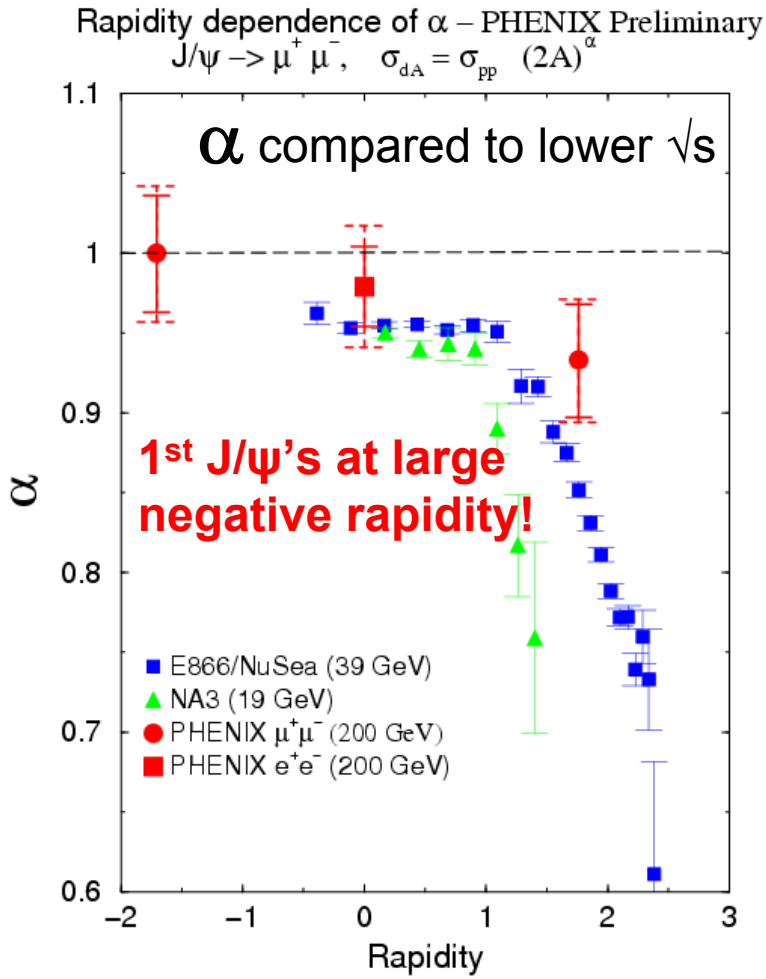



BR $\sigma_{pp}^{J/\psi}$ = 160 nb ± 8.5 % (fit) ± 12.3% (abs) - preliminary

# dAu/pp versus rapidity



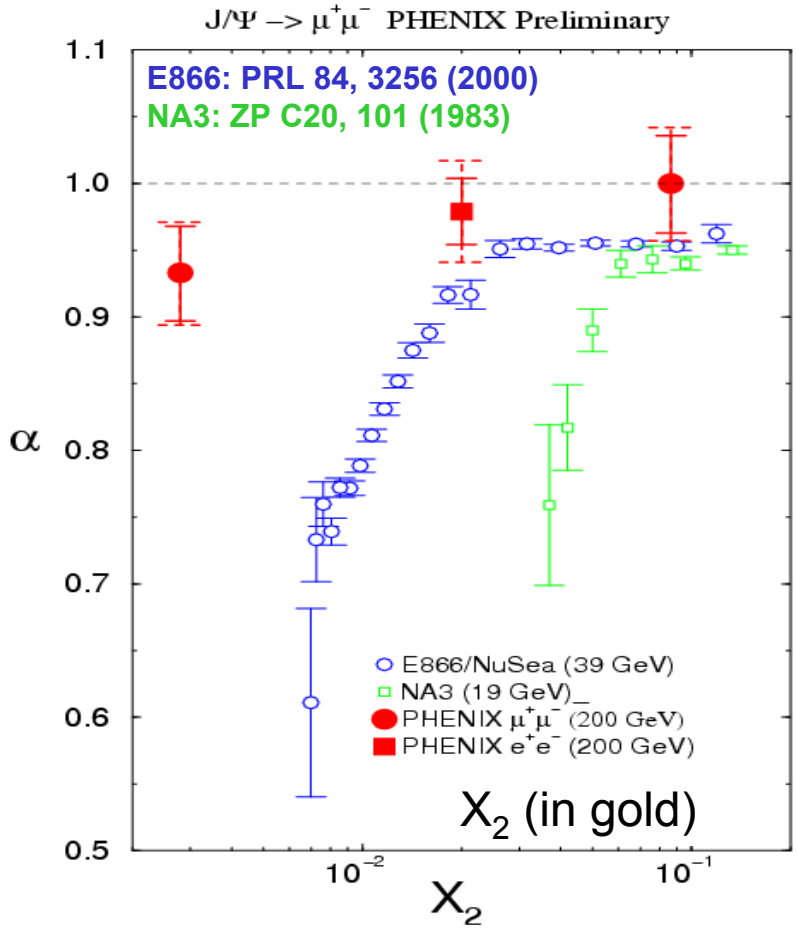

Data favors (weak) shadowing + (weak) absorption ($\alpha$ > 0.92)

With limited statistics difficult to disentangle nuclear effects

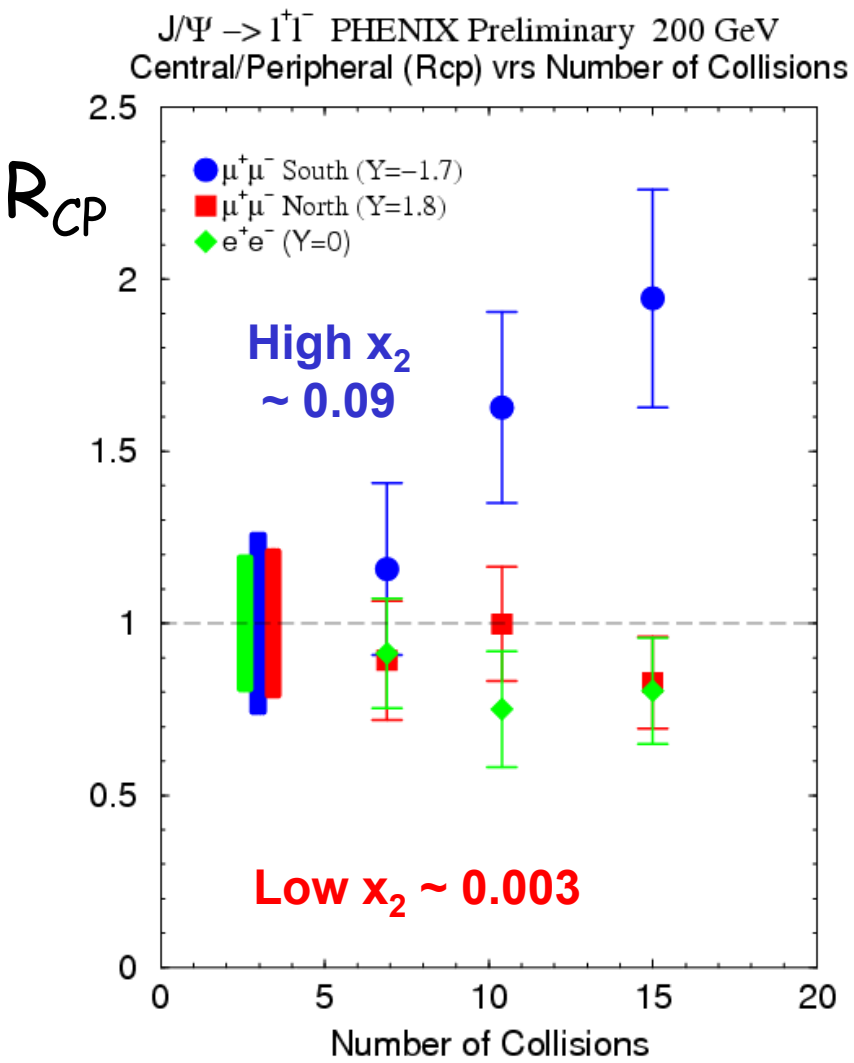
Will need another dAu run! (and more pp data also)

# $\alpha$ versus $x_2(x_{Au})$ compared to lower $\sqrt{s}$

- Not universal versus $X_2$ : shadowing is not the whole story.
- Energy loss expected to be weak at RHIC energy
- But could explain larger suppression seen for lower energy data?



# Central/peripheral versus $N_{coll}$



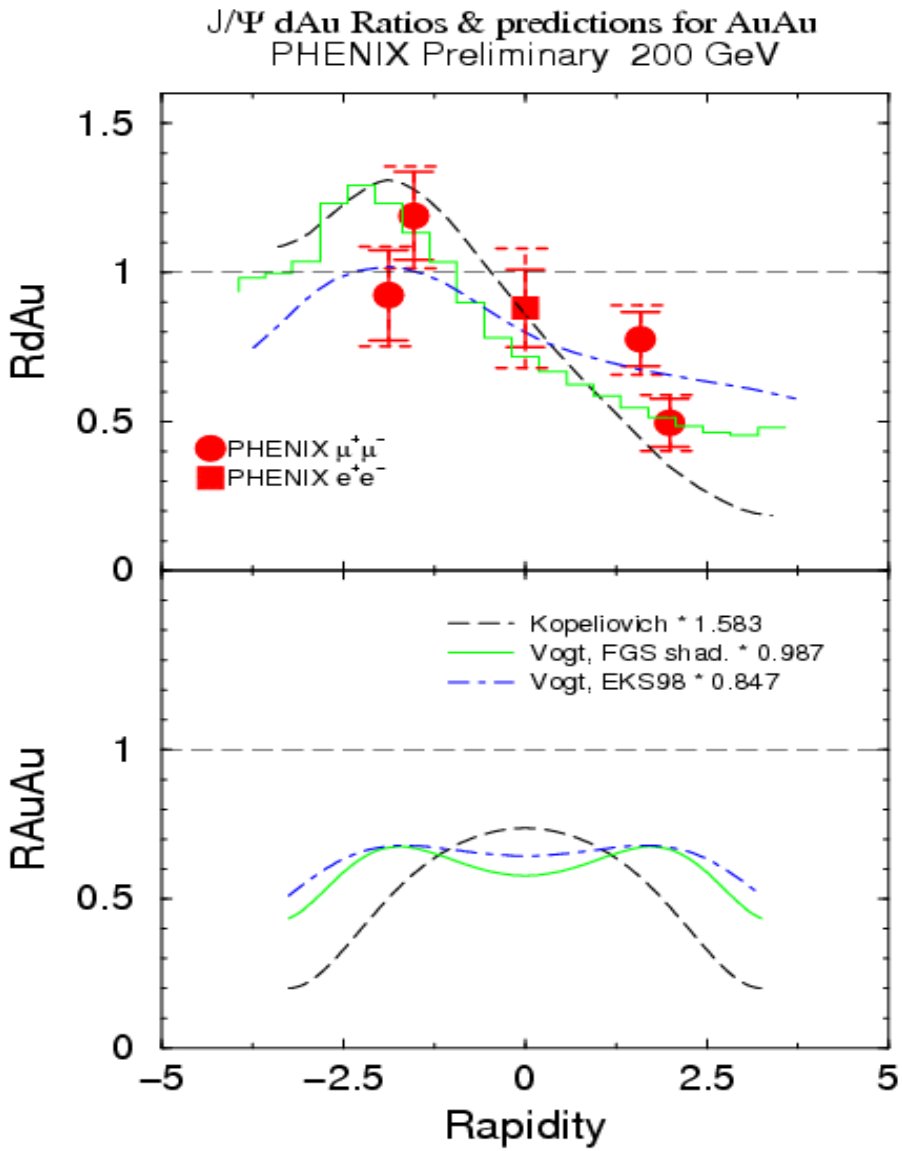

$$R_{cp}(N_{coll}) = \frac{N_{J\psi}^{cent} \times < N_{coll}^{periph} >}{N_{J\psi}^{periph} \times < N_{coll}^{cent} >}$$

- Low and med $x_2$ have small variations
  - Weak nuclear effects
  - Small (shadowing) centrality dependence
- High $x_2$ has a steep rising shape
  - Difficult to see how antishadowing could be so steep when shadowing is not?
  - Effect of being closer to the Au frame ?
  - e.g. final-state effects in Au nucleus remanants?

# Simple expectation for AuAu J/ψ's based on nuclear dependence observed in dAu

- Renormalize model predictions to dAu measurement (top panel).
- Then reverse RdAu and multiply by itself (bottom panel)
- Variations between models not too large at mid-rapidity, but substantial in the large negative or positive rapidity regions. Better models (physics understanding) might help, but a higher statistics dAu baseline, especially in the μμ regions is needed.

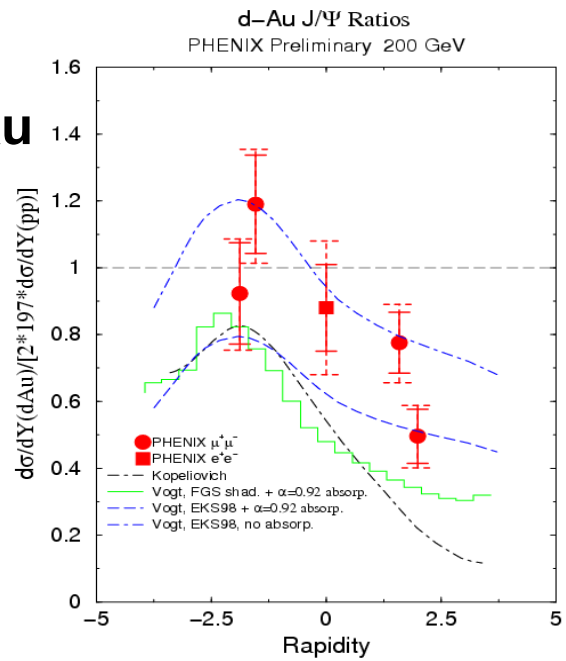
- 2004 AuAu run: (1600 J/ψ)/arm expected for 130 $\mu b^{-1}$
- Challenge of pulling out J/ψ signal in AuAu now being worked!



# Summary

- dAu J/ψ data suggests that gluon shadowing is weak and that absorption is smaller than expectations based on lower energy data; but $p_T$ broadening is very similar to that seen at lower energies
- We will need more J/ψ's to definitively disentangle these effects. Another dAu run with higher luminosity at RHIC is needed.
- Near the Au frame, at negative rapidity, a dramatic centrality dependence in both J/ψ (and hadrons) has been observed and challenges theoretical models
- A modest baseline for the study of J/ψ in AuAu collisions has been obtained. Whether it is adequate will depend on if the AuAu results turn out to be far from simple expectations or not.

**RdAu**



PHENIX

***12 Countries; 58 Institutions; 480 Participants****

| | |
|---|---|
| Brazil | University of São Paulo, São Paulo |
| China | Academia Sinica, Taipei, Taiwan |
| | China Institute of Atomic Energy, Beijing |
| | Peking University, Beijing |
| France | LPC, University de Clermont-Ferrand, Clermont-Ferrand |
| | Dapnia, CEA Saclay, Gif-sur-Yvette |
| | IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, Orsay |
| | LLR, Ecòle Polytechnique, CNRS-IN2P3, Palaiseau |
| | SUBATECH, Ecòle des Mines at Nantes, Nantes |
| Germany | University of Münster, Münster |
| Hungary | Central Research Institute for Physics (KFKI), Budapest |
| | Debrecen University, Debrecen |
| | Eötvös Loránd University (ELTE), Budapest |
| India | Banaras Hindu University, Banaras |
| | Bhabha Atomic Research Centre, Bombay |
| Israel | Weizmann Institute, Rehovot |
| Japan | Center for Nuclear Study, University of Tokyo, Tokyo |
| | Hiroshima University, Higashi-Hiroshima |
| | KEK, Institute for High Energy Physics, Tsukuba |
| | Kyoto University, Kyoto |
| | Nagasaki Institute of Applied Science, Nagasaki |
| | RIKEN, Institute for Physical and Chemical Research, Wako |
| | RIKEN-BNL Research Center, Upton, NY |
| | Rikkyo University, Tokyo, Japan |
| | Tokyo Institute of Technology, Tokyo |
| | University of Tsukuba, Tsukuba |
| | Waseda University, Tokyo |
| S. Korea | Cyclotron Application Laboratory, KAERI, Seoul |
| | Kangnung National University, Kangnung |
| | Korea University, Seoul |
| | Myong Ji University, Yongin City |
| | System Electronics Laboratory, Seoul Nat. University, Seoul |
| | Yonsei University, Seoul |
| Russia | Institute of High Energy Physics, Protovino |
| | Joint Institute for Nuclear Research, Dubna |
| | Kurchatov Institute, Moscow |
| | PNPI, St. Petersburg Nuclear Physics Institute, St. Petersburg |
| | St. Petersburg State Technical University, St. Petersburg |
| Sweden | Lund University, Lund |
| USA | Abilene Christian University, Abilene, TX |
| | Brookhaven National Laboratory, Upton, NY |
| | University of California - Riverside, Riverside, CA |
| | University of Colorado, Boulder, CO |
| | Columbia University, Nevis Laboratories, Irvington, NY |
| | Florida State University, Tallahassee, FL |
| | Florida Technical University, Melbourne, FL |
| | Georgia State University, Atlanta, GA |
| | University of Illinois Urbana Champaign, Urbana-Champaign, IL |
| | Iowa State University and Ames Laboratory, Ames, IA |
| | Los Alamos National Laboratory, Los Alamos, NM |
| | Lawrence Livermore National Laboratory, Livermore, CA |
| | University of New Mexico, Albuquerque, NM |
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| | Oak Ridge National Laboratory, Oak Ridge, TN |
| | University of Tennessee, Knoxville, TN |
| | Vanderbilt University, Nashville, TN |

*as of January 2004