J/Ψ Production and Nuclear Effects for d+Au and p+p Collisions in PHENIX

Raphaël Granier de Cassagnac
LLR – Ecole polytechnique, France
for the PHENIX collaboration

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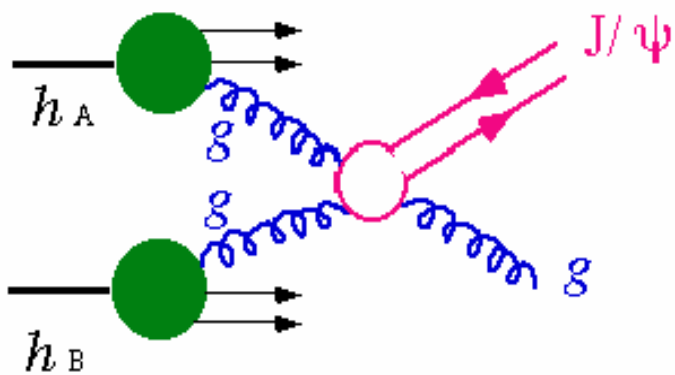
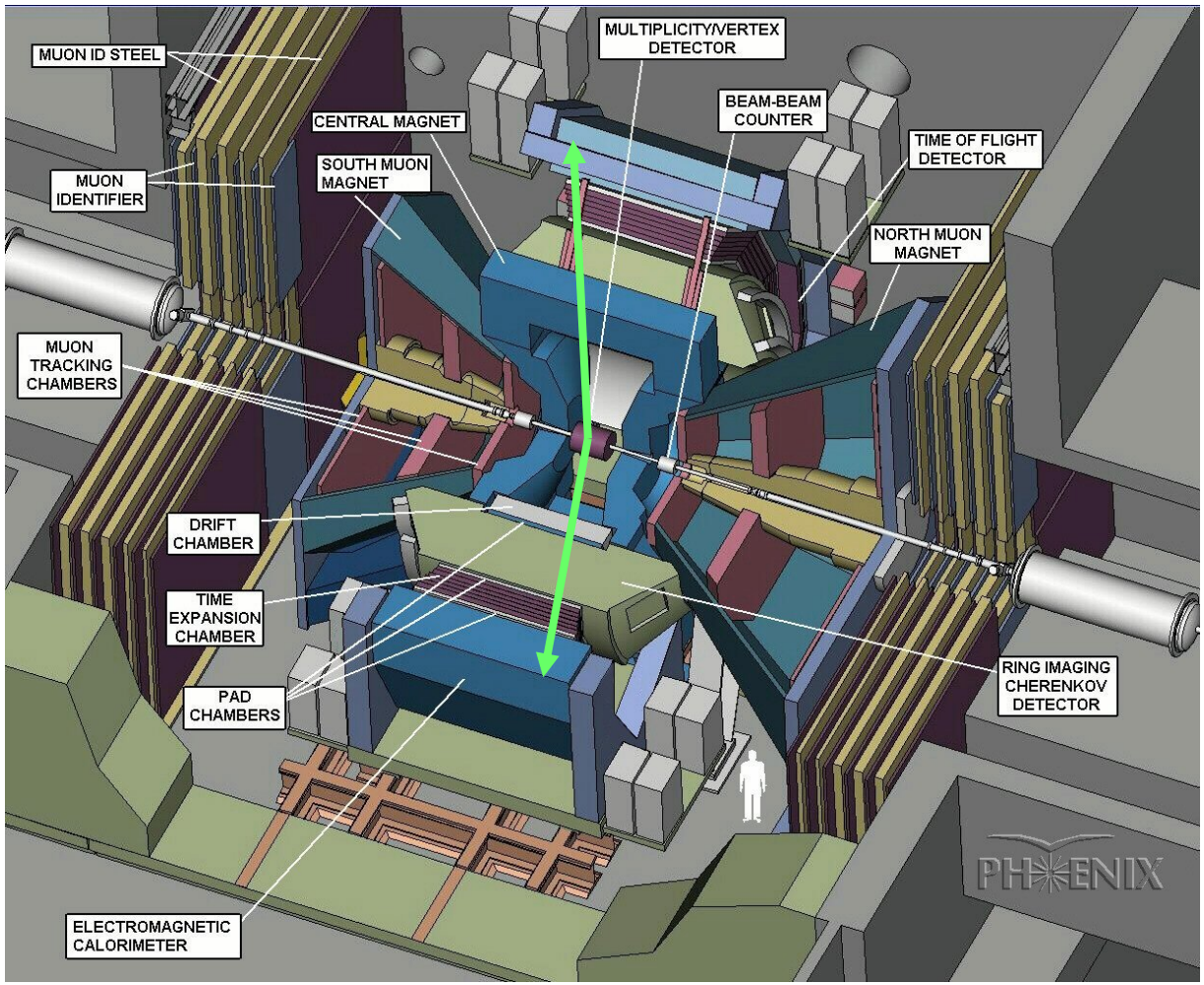
Physics motivation

- Goal: disentangle normal nuclear effects
  - Antishadowing & Shadowing (gluon saturation ?)
  - Energy loss of initial parton
  - p_T broadening (Cronin effect)
  - J/ψ (or $c\bar{c}$) absorption



- Tool: d+Au collisions
  - over a broad range of p_T, rapidity and centrality.
- Interests:
  - Intrinsically probes interesting nuclear effects
  - Baseline for Au+Au: Why do J/ψ disappear / appear ?

How does PHENIX see the J/Ψ ?



$J/\Psi \rightarrow e^+e^-$
identified in RICH and EMCal

- $|\eta| < 0.35$
- $p > 0.2$ GeV

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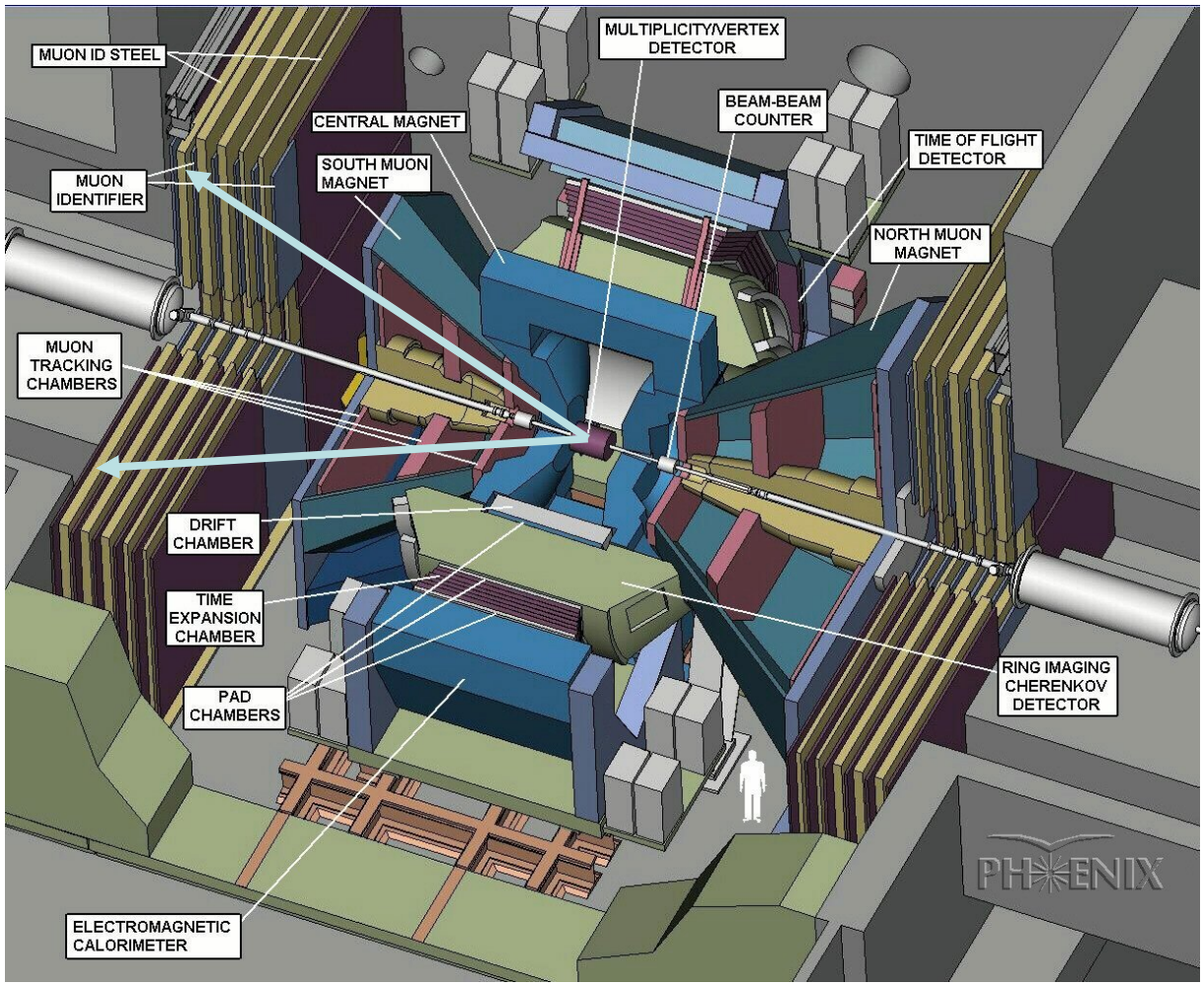

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$J/\Psi \rightarrow \mu^+\mu^-$

identified in 2 fwd spectrometers

- $1.2 < |\eta| < 2.4$
- $p > 2$ GeV

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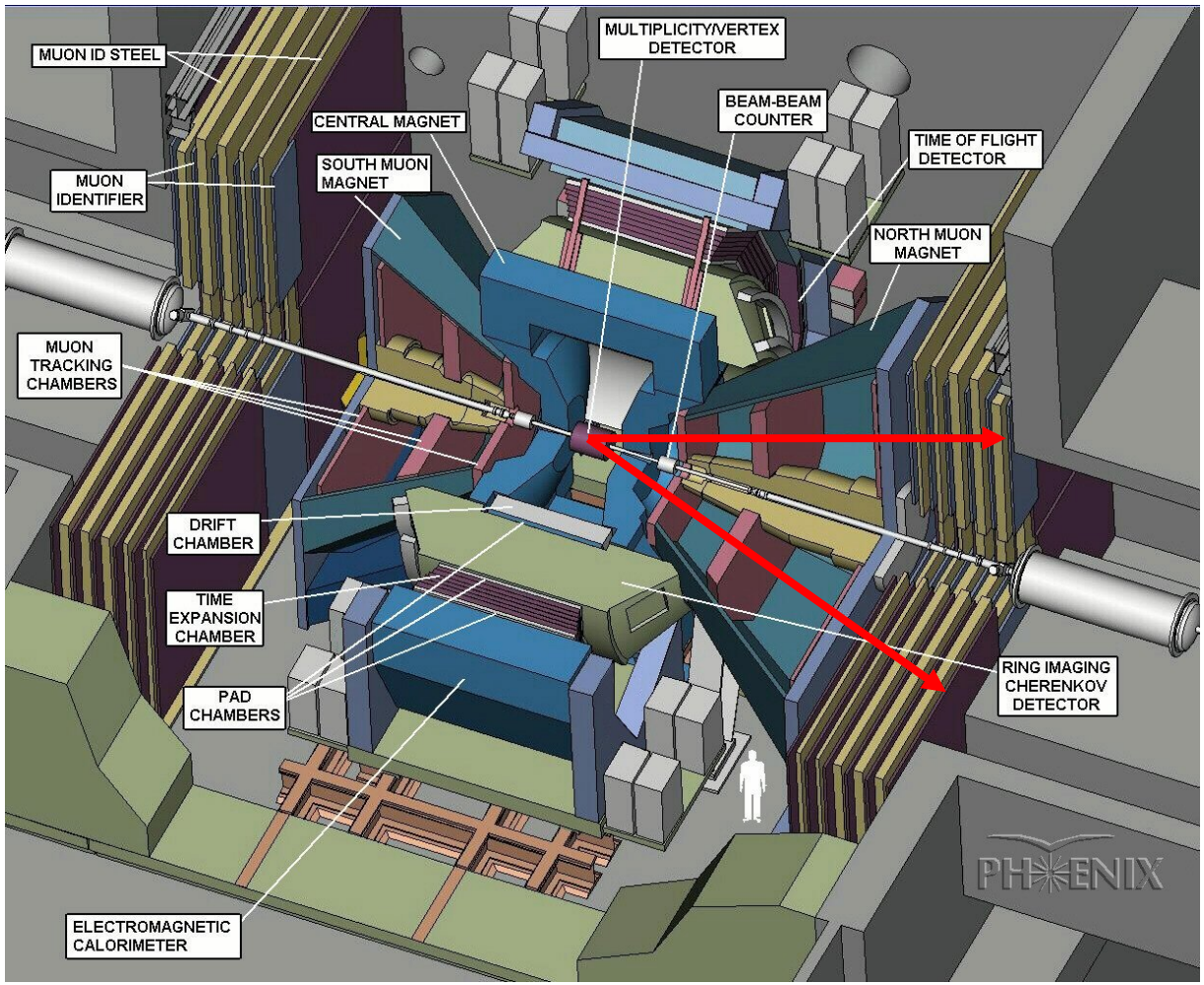

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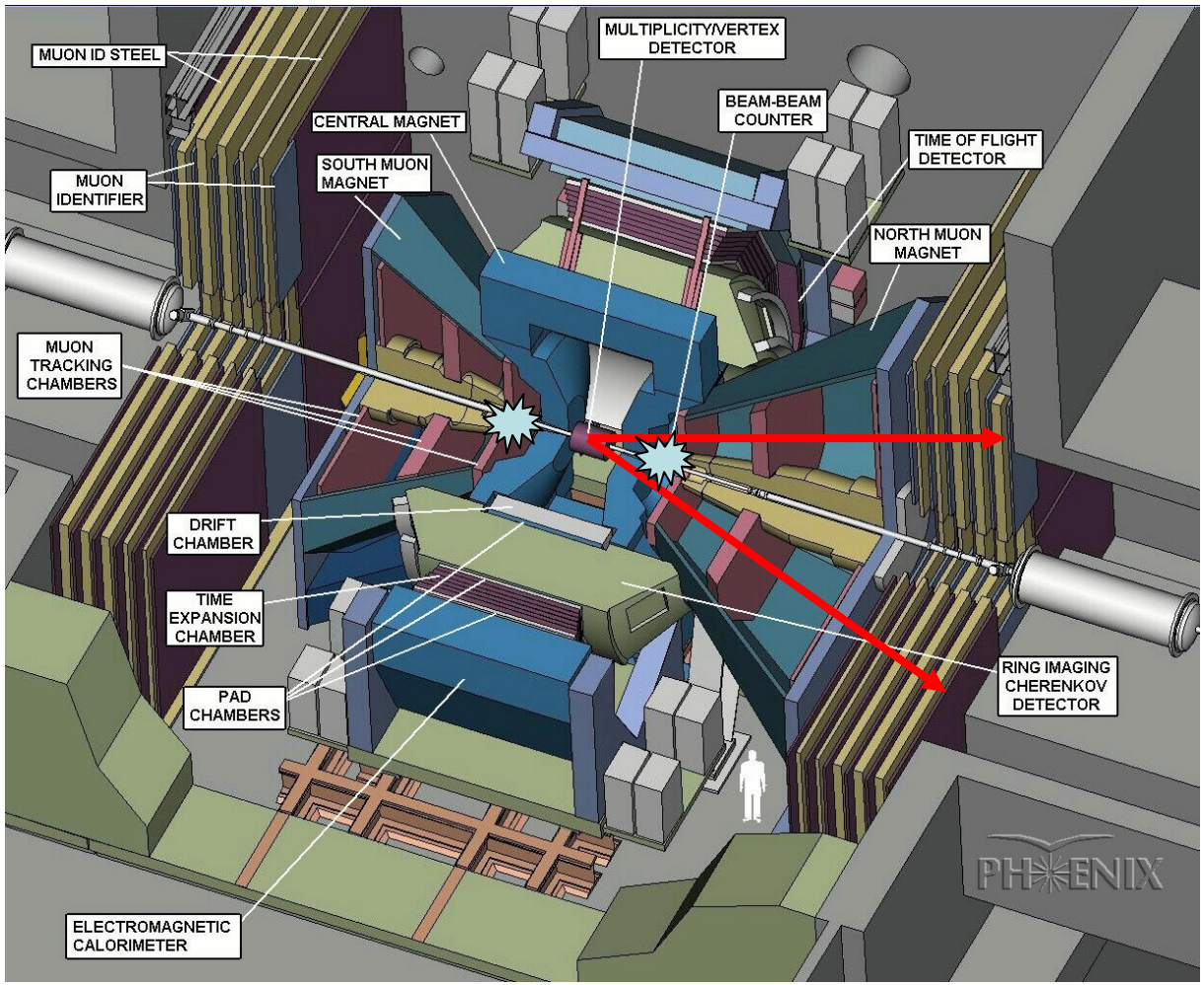

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Centrality and vertex given by BBC in $3<|\eta|<3.9$

Short history of RHIC

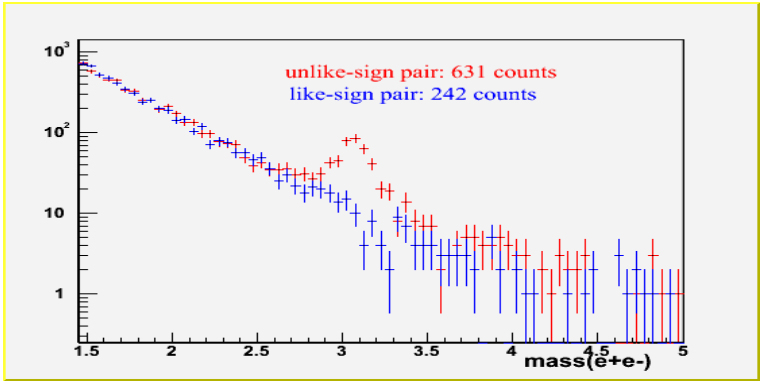
Year	Ions	$\sqrt{s_{NN}}$	Luminosity	Detectors	J/Ψ
2000	Au-Au	130 GeV	1 μb^{-1}	Central (electrons)	0
2001 2002	Au-Au p-p	200 GeV 200 GeV	24 μb^{-1} 0.15 pb^{-1}	Central + 1 muon arm	13 + 0 [1] 46 + 66 [2]
2002 2003	d-Au p-p	200 GeV 200 GeV	2.74 nb^{-1} 0.35 pb^{-1}	Central + 2 muon arms	300+800+600 100+300+120
2004	Au-Au	200 GeV	300 nb^{-1} ?	! taking data !	~400+2x1600 ?

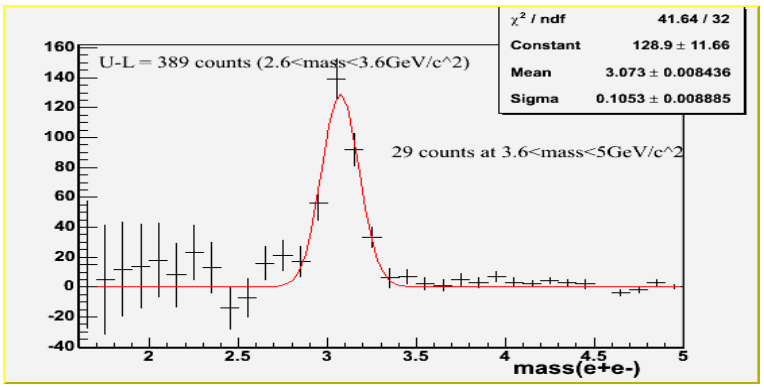
[1] nucl-ex/0305030
[2] hep-ex/0307019

All data shown are from the run 3 and results are PHENIX preliminary !

Di-electron analysis

Example : dAu sample





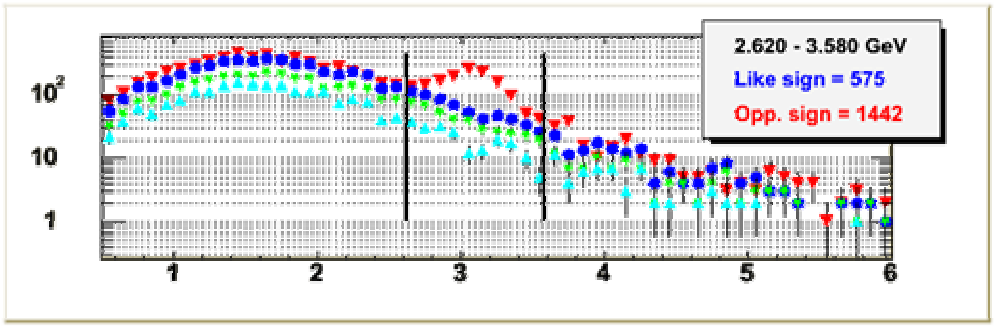
Mass Resolution ~ 100 MeV

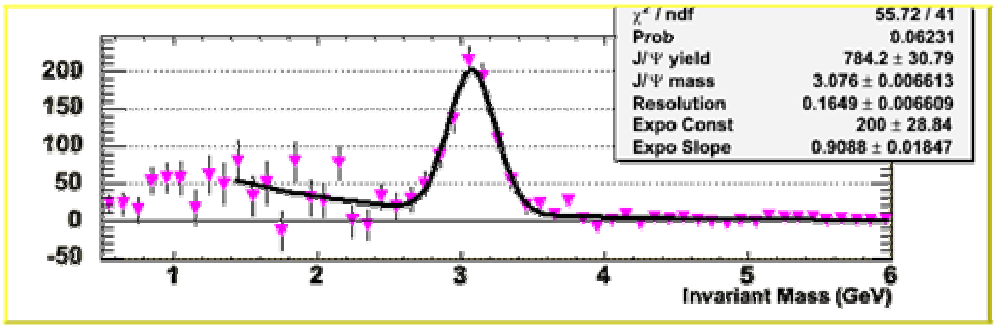
- Identify electron
  - $0.5 < E/p < 1.5$
- Di-electron invariant mass spectra
- Subtract combinatorial background
  - Signal = $N_{+-} - (N_{++} - N_{--})$
- Count J/ψ
- Correct for acceptance and efficiencies

$\rightarrow$ Cross section

Di-muon analysis

Example : dAu north sample





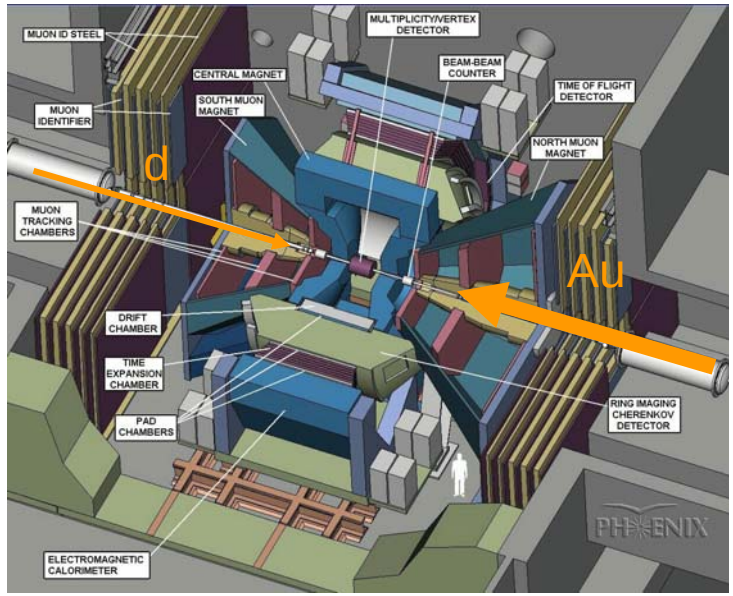
Mass Resolution ~ 150 to 200 MeV

- Identify muons
  - Depth in Identifier
- Di-muon inv. mass spectra
- Subtract combinatorial backgrounds ($N_{++} \neq N_{--}$)
  - Signal = $N_{+-} - 2\sqrt{(N_{++})(N_{--})}$
- Work in progress to quantify physical backgrounds :
  - Open charm & beauty,
  - Drell-Yan,
  - A hint of ψ'
- For now: fit gauss J/ψ+exp bg
- Correct for acceptance and efficiencies

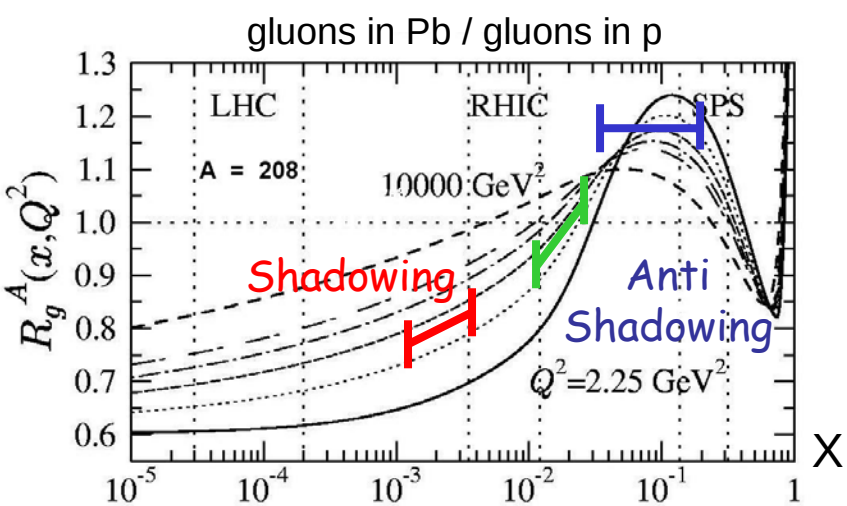
→ Cross section

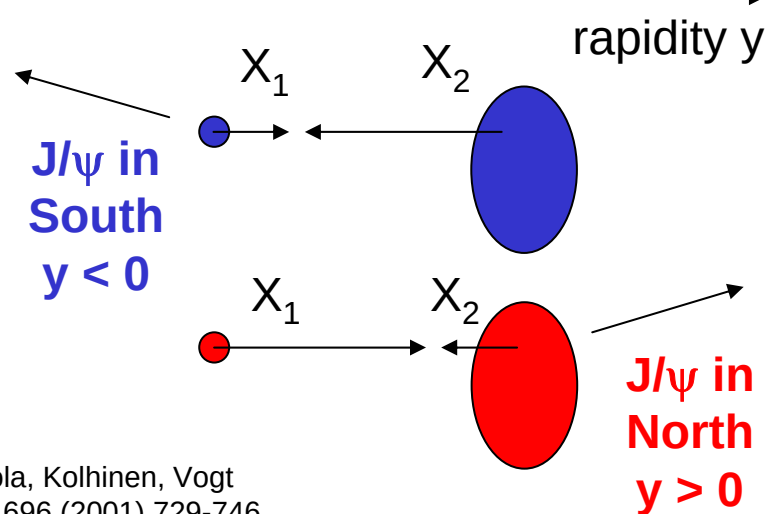
Deuteron → ← Gold

- In PHENIX, J/ψ mostly produced by gluon fusion, and thus sensitive to gluon pdf
- Three rapidity ranges probe different momentum fraction 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



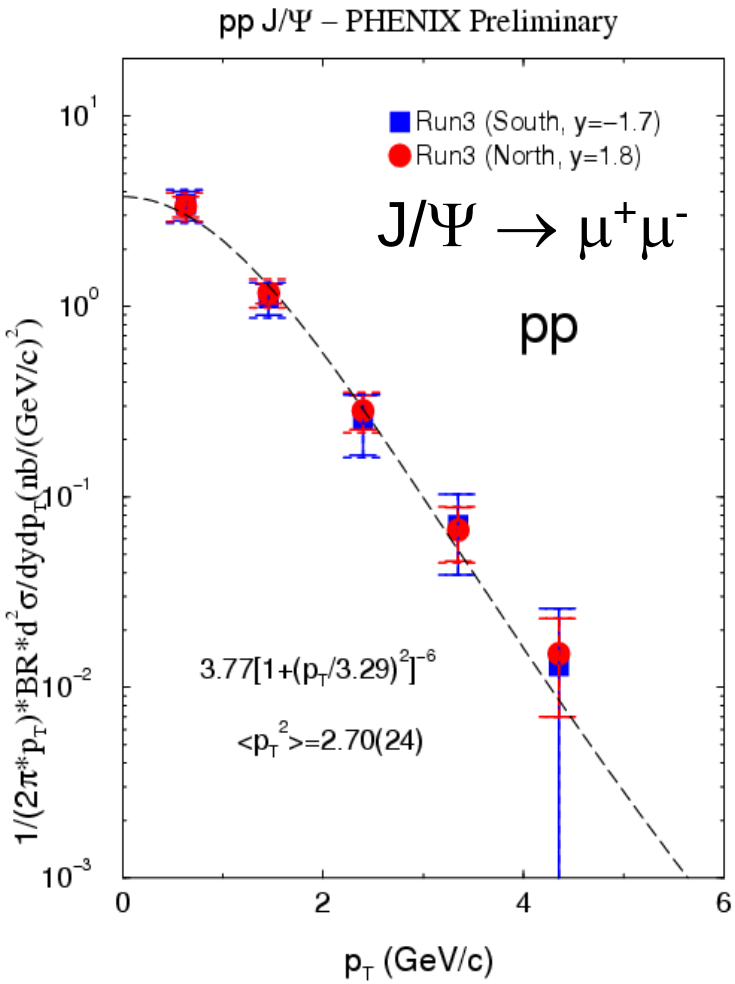
<u>Example of predicted gluon shadowing in d+Au</u>

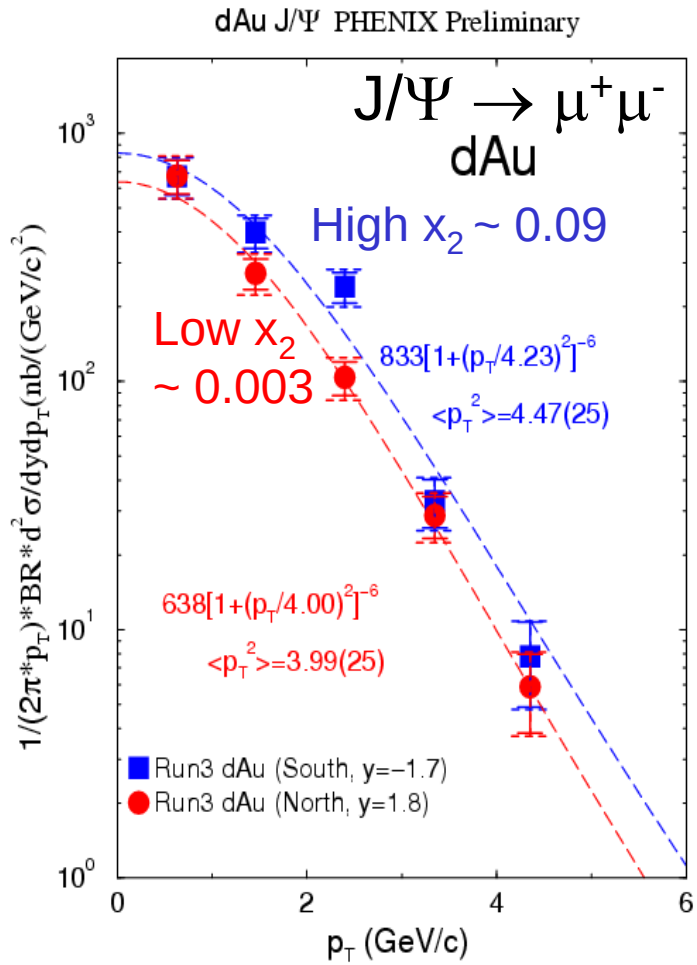




From Eskola, Kolhinen, Vogt
Nucl. Phys. A696 (2001) 729-746.

Cross section versus p_T





$\Delta\langle p_T^2\rangle =$

$\langle p_T^2\rangle_{dAu} - \langle p_T^2\rangle_{pp}$

1.77 ± 0.35 GeV^2

1.29 ± 0.35 GeV^2

(preliminary)

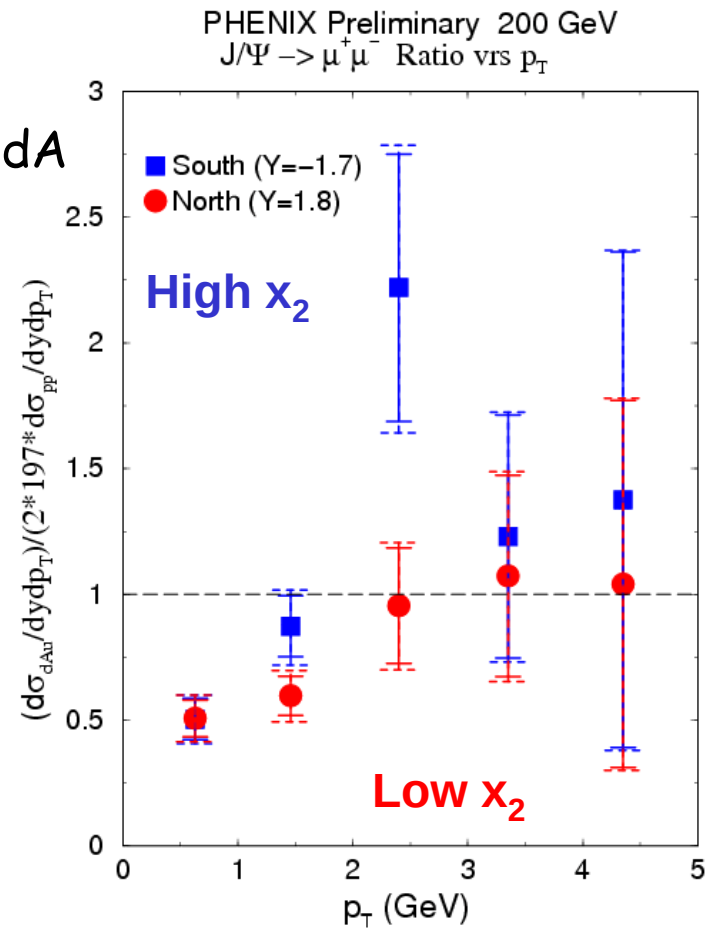
p_T is broadened for dAu

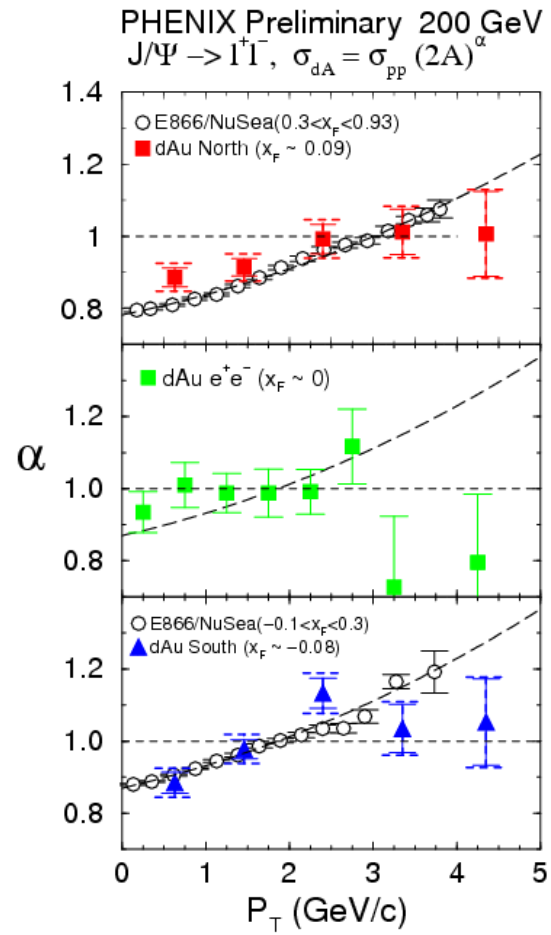
dAu/pp versus p_T

$$R = \sigma_{dA} / 2 \times 197 \times \sigma_{pp}$$

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

R_{dA}



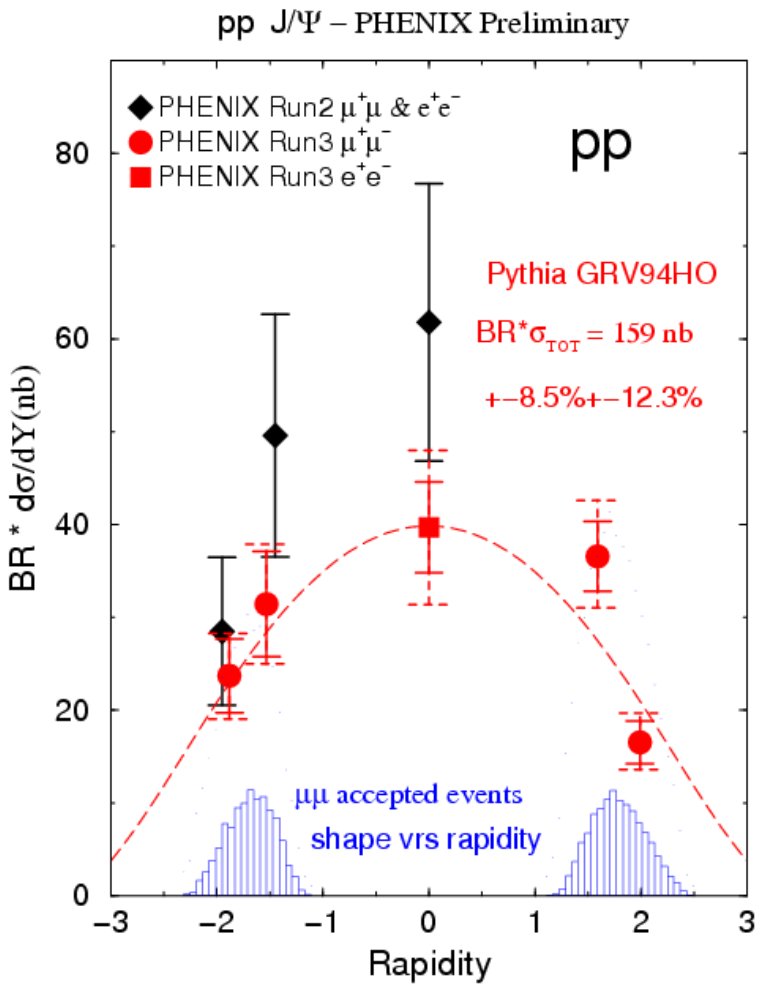


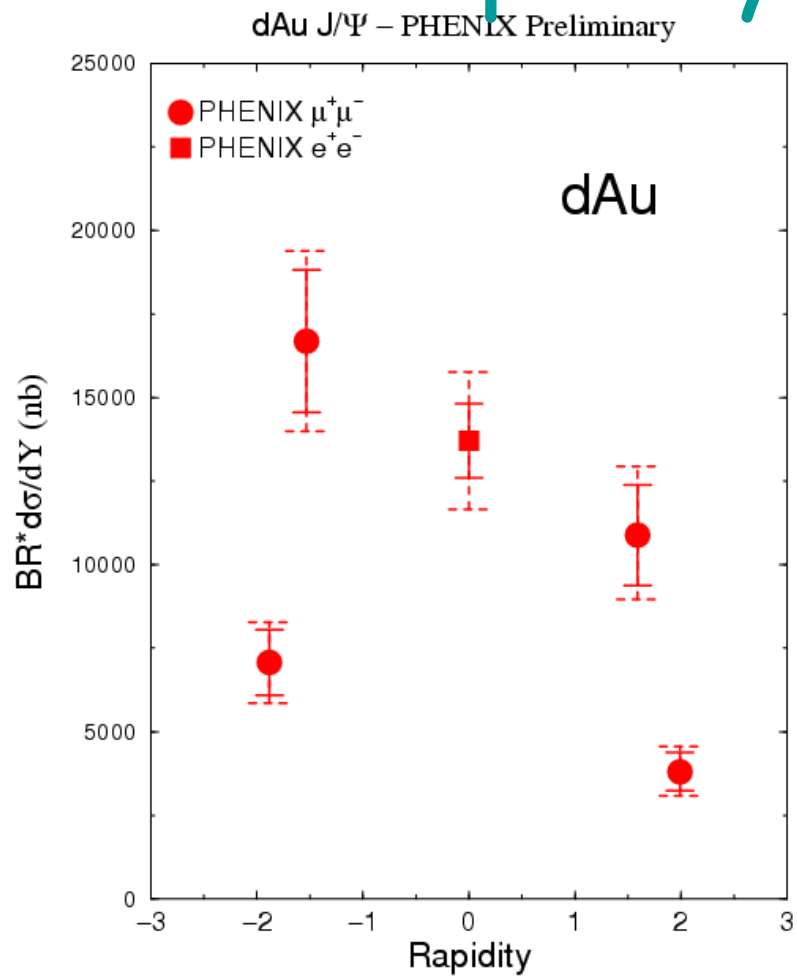
Low x_2 ~ 0.003

High x_2 ~ 0.09

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

Cross section versus rapidity

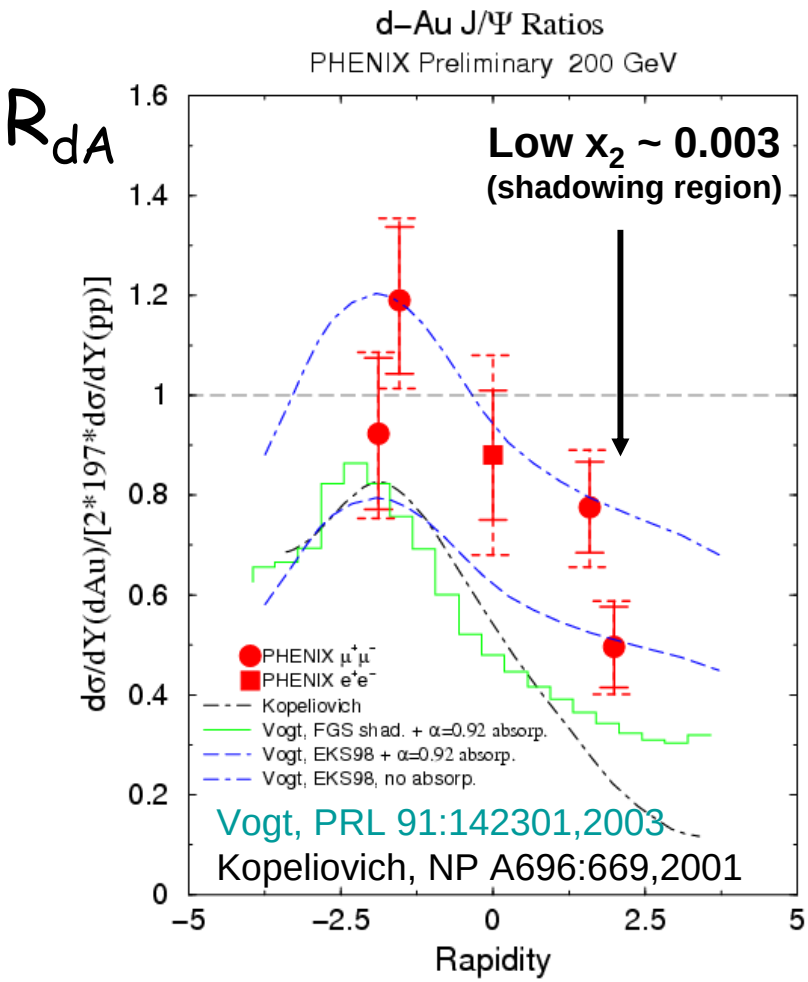


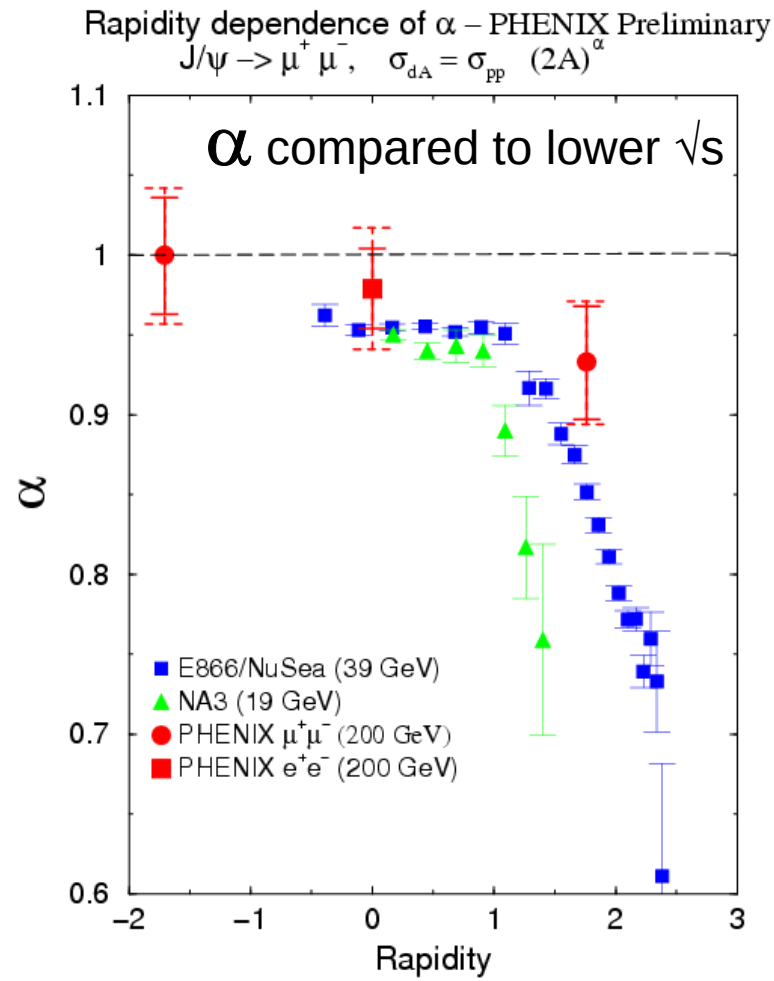


- Total cross section (preliminary)

$$BR\ \sigma_{pp}^{J\psi} = 159\ nb \pm 8.5\ \%\ (fit) \pm 12.3\%\ (abs)$$

dAu/pp versus rapidity

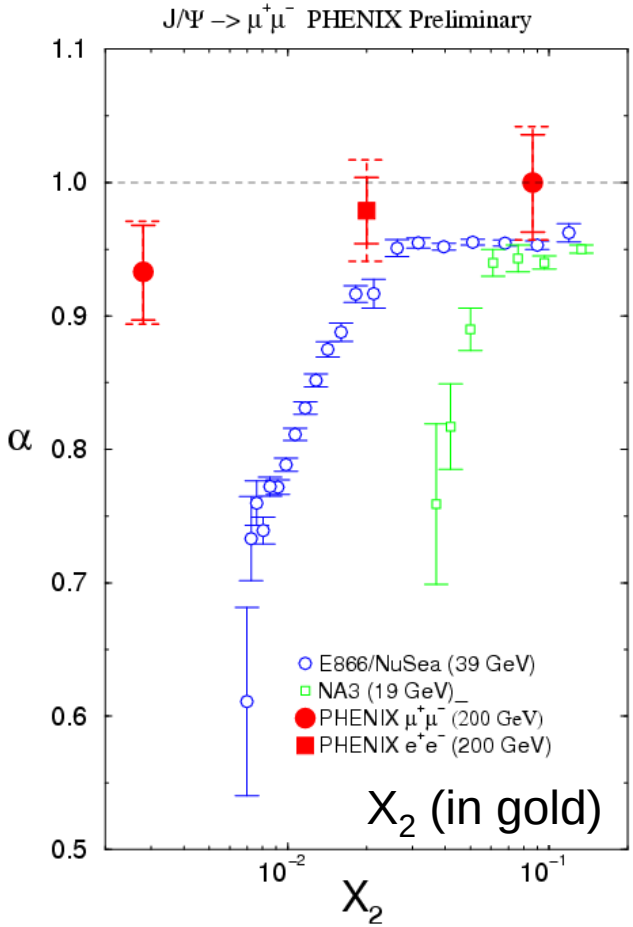


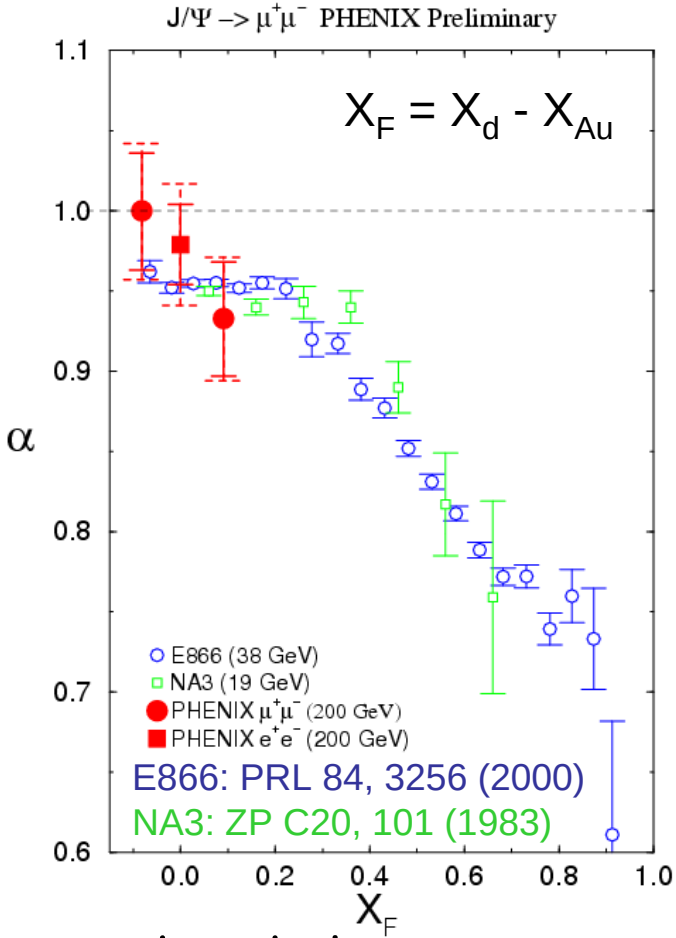


Data favours (weak) shadowing + (weak) absorption (α > 0.92)

With limited statistics difficult to disentangle nuclear effects

α versus X compared to lower √s

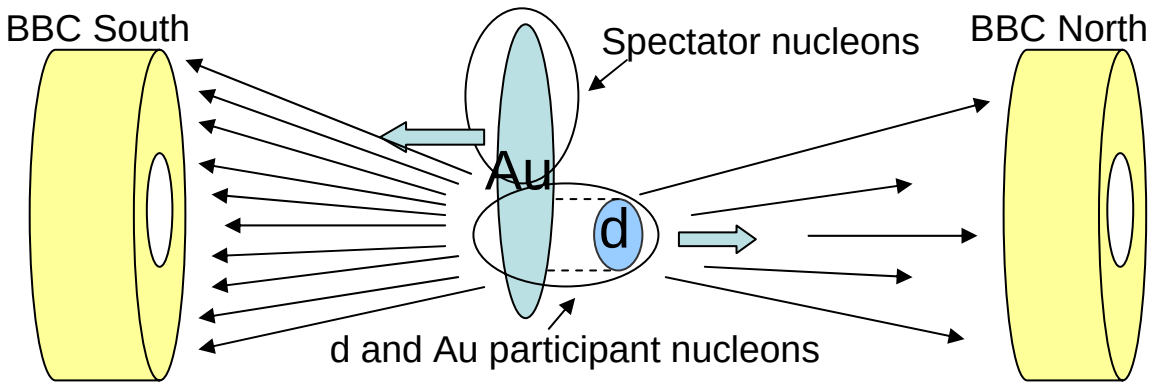




- Not universal versus X_2 : shadowing is not the whole story.
- Same versus X_F for diff √s. Incident parton energy loss ? (high X_d = high X_F)
- Energy loss expected to be weak at RHIC energy.

Centrality analysis

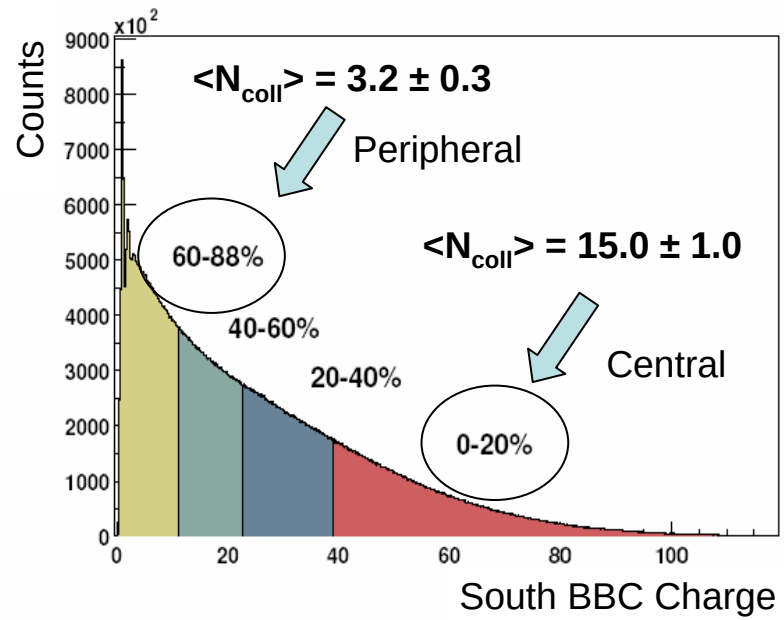
Au breaks up in our south beam counter



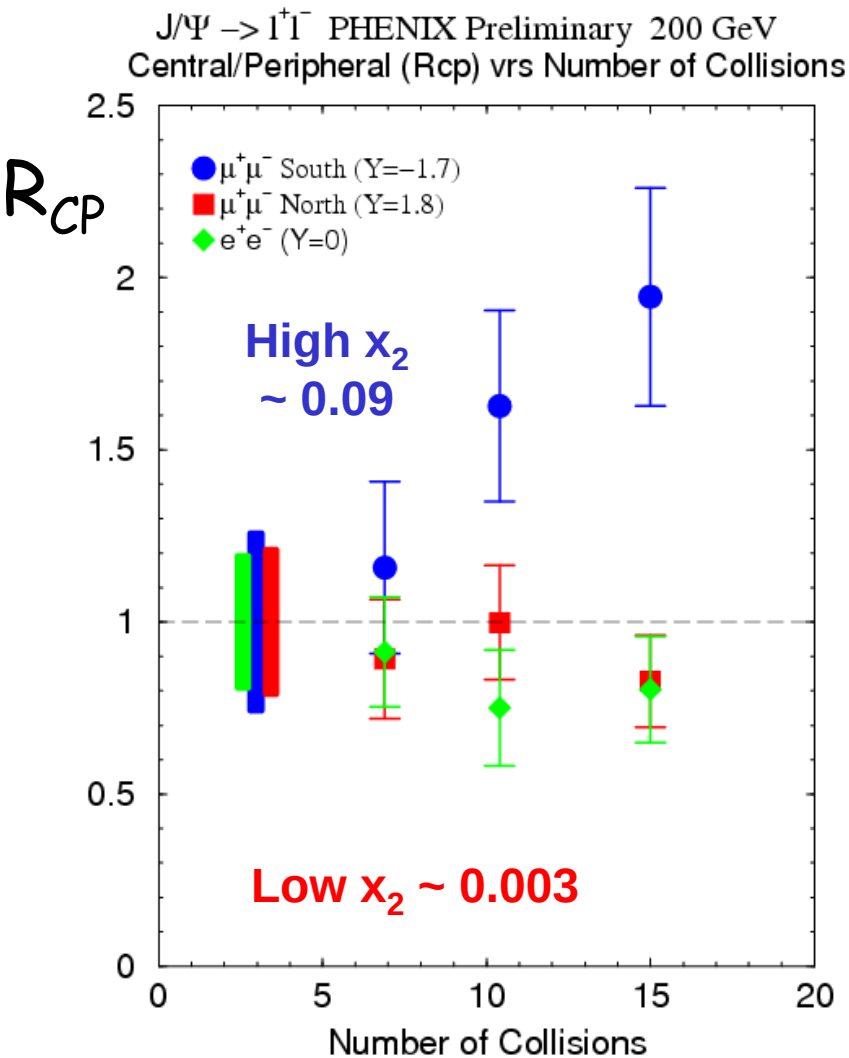
- Define 4 centrality classes
- Relate centrality to $\langle N_{coll} \rangle$

through Glauber computation

- $\langle N_{coll}^{MB} \rangle = 8.4 \pm 0.7$



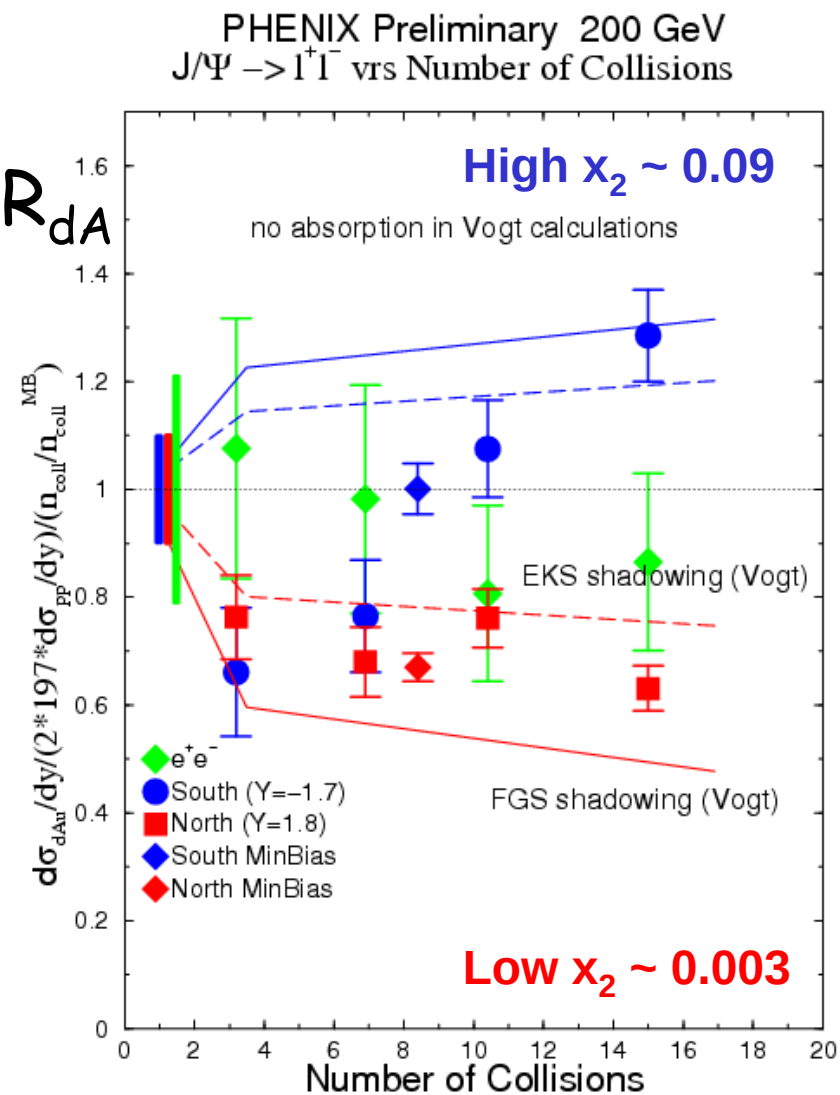
Central/peripheral versus N_{coll}



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

- Low and med x_2 have small variations
  - Weak nuclear effects
  - Small shadowing centrality dependence
- High x_2 has a steep rising shape
  - How can antishadowing be so steep ?

dAu / pp versus N_{coll}



$$R = \frac{\sigma_{dA} \times < N_{coll}^{MB} >}{2 \times 197 \times \sigma_{pp} \times < N_{coll} >}$$

- Low x_2 shape consistent with shadowing models
- High x_2 shape steeper than corresponding antishadowing…
  - What could it be ?
  - Effect of being closer to the Au frame ?

Conclusion & perspectives

- We have seen small nuclear effects !
  - Weak shadowing
  - Smaller absorption than expected ($\alpha > 0.92$)
  - p_T broadening similar to lower energies
  - Something above antishadowing ?
    - Rising RdA versus centrality at high x_2 ($y < -1.2$)
- Difficult to disentangle given statistics
  - Need more luminosity !
- But, no large nuclear effect !
  - Good news to see $J\psi$ suppression in Au-Au !

J/ψ supporters

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

12 Countries; 58 Institutions; 480 Participants*

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
New Mexico State University, Las Cruces, NM
Dept. of Chemistry, Stony Brook Univ., Stony Brook, NY
Dept. Phys. and Astronomy, Stony Brook Univ., Stony Brook, NY
Oak Ridge National Laboratory, Oak Ridge, TN
University of Tennessee, Knoxville, TN
Vanderbilt University, Nashville, TN

***as of January 2004**

PHENIX charmonia related posters

- Jane M. Burward-Hoy: "Centrality Dependence of $J\psi \rightarrow \mu^+ \mu^-$ in High-Energy d+Au Collisions"
- Xiaorong Wang: "$J\psi$ Polarization Study for d Au collisions at RHIC"
- DongJo Kim: "$J\psi$ production in p+p collisions at $\sqrt{s}$ = 200 GeV with the PHENIX experiment at RHIC"
- Alexandre Lebedev: "Measurement of $\chi_c \rightarrow J\psi + \gamma$ in dAu Collisions at RHIC/PHENIX"
- Gobinda Mishra: "Study of $J\psi$ polarization in p+p collisions at $\sqrt{s_{NN}}$ = 200 GeV with PHENIX experiment at RHIC"
- Kyoichiro Ozawa: "Measurements of $J\psi \rightarrow e^+e^-$ in Au-Au collisions at $\sqrt{s}$ = 200 GeV"
- David Silvermyr: "First observation of the ψ' at RHIC - Techniques for fitting dimuon spectra in d-Au collisions at $\sqrt{s_{NN}}$ = 200 GeV"