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

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Oakland, California

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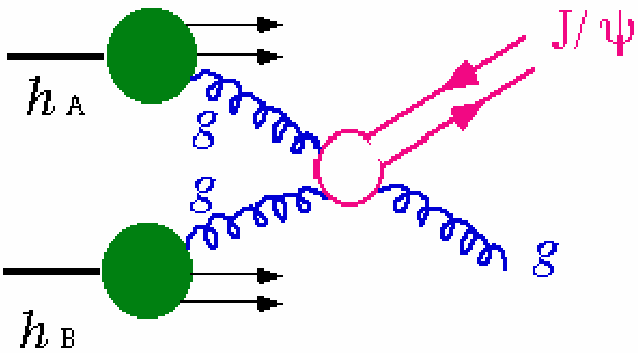
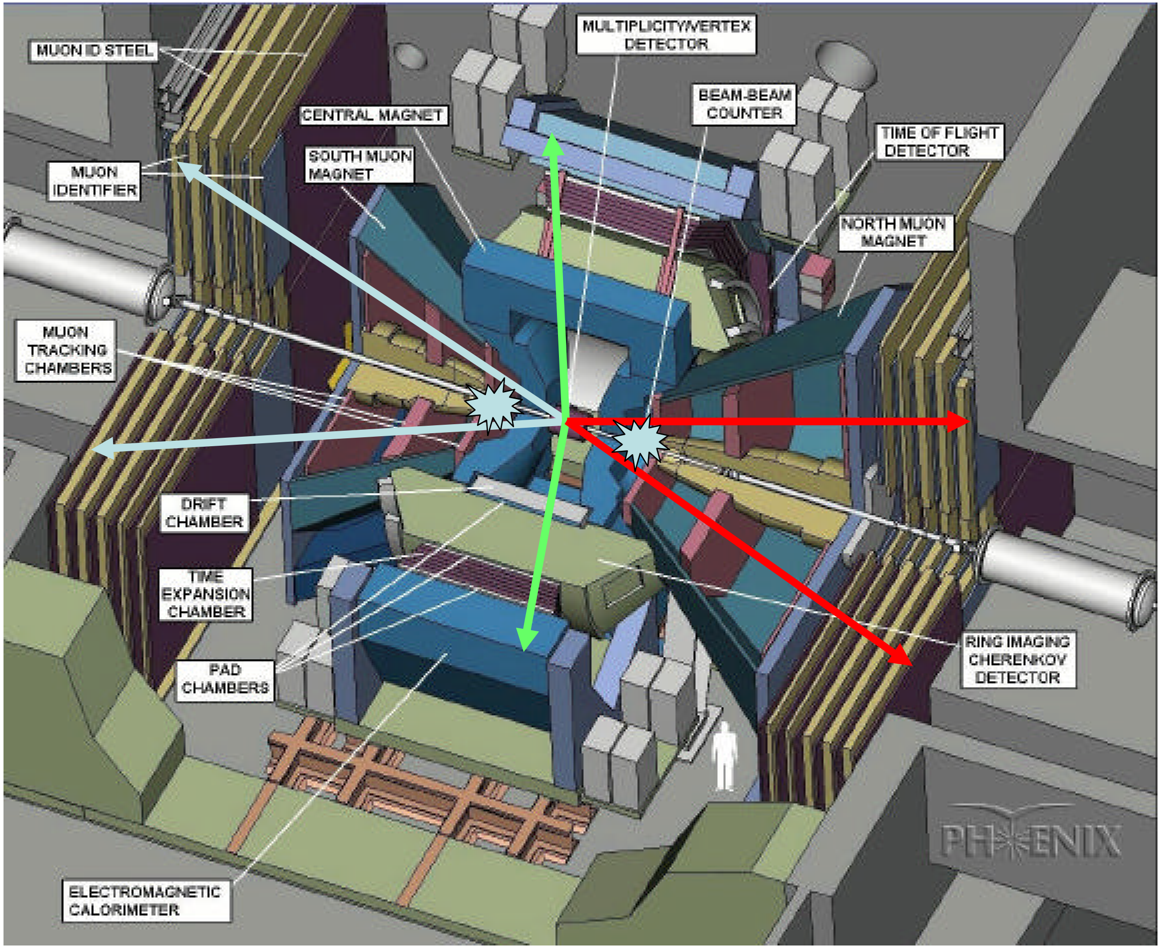
Physics motivation

- 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

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

identified in 2 fwd spectrometers

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

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

Short history of RHIC

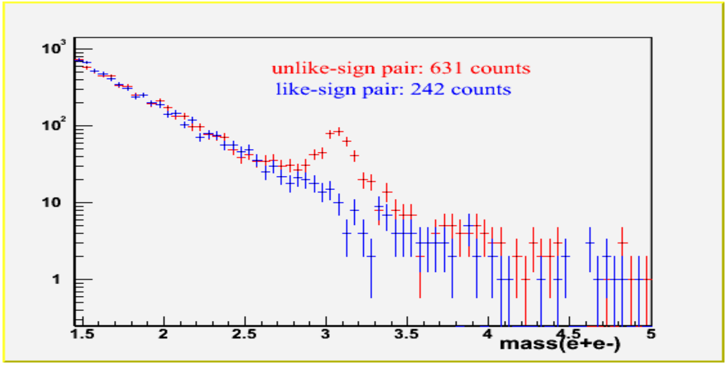
Year	Ions	$\sqrt{s_{NN}}$	Luminosity	Detectors	J/Ψ
2000	Au-Au	130 GeV	1 mb^{-1}	Central (electrons)	0
2001	Au-Au	200 GeV	24 mb^{-1}	Central	13 + 0 [1]
2002	p-p	200 GeV	0.15 pb^{-1}	+ 1 muon arm	46 + 66 [2]
2002	d-Au	200 GeV	2.74 nb^{-1}	Central	300+800+600
2003	p-p	200 GeV	0.35 pb^{-1}	+ 2 muon arms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

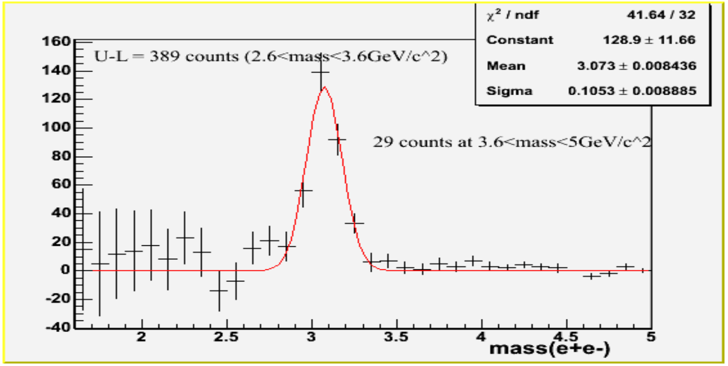
[1] nucl-ex/0305030
[2] hep-ex/0307019

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

Di-electron analysis

Example : dAu sample





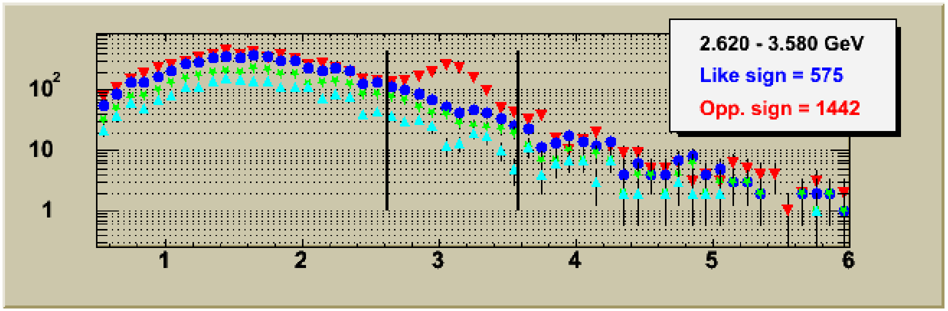
Mass Resolution ~ 100 MeV

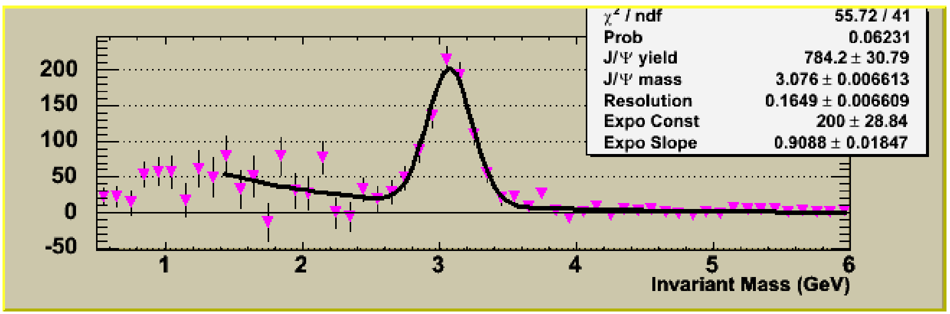
- Identify electron
  - $0.5 < E/p < 1.5$
- Di-electron invariant mass spectra
- Subtract combinatorial background
  - Signal = $N_{+-} - (N_{++} - N_{--})$
- Count J/ψ
- Correct for acceptance and efficiencies

→ Cross section

Di-muon analysis

Example : dAu north sample



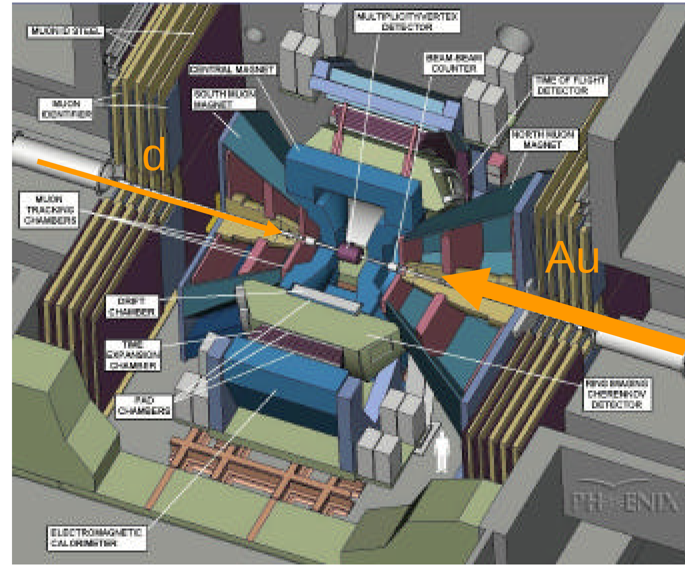


Mass Resolution ~ 150 to 200 MeV

- Identify muons
  - Depth in Identifier
- Di-muon inv. mass spectra
- Subtract combinatorial backgrounds (N_{++} ¹ 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

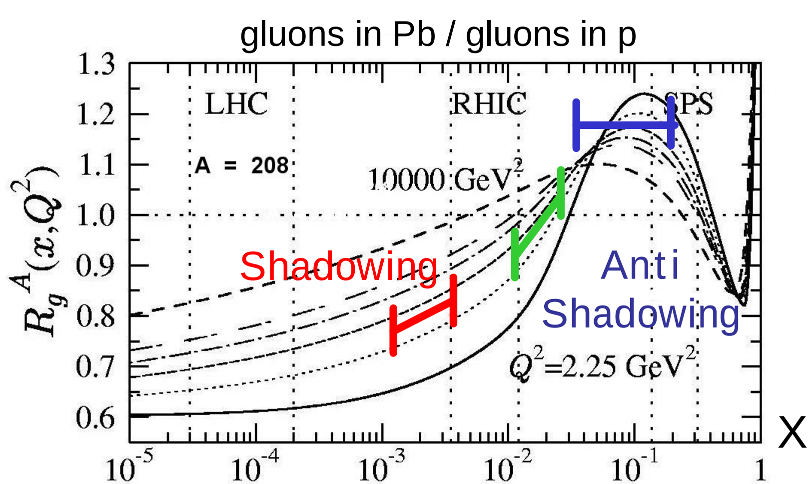
→ Cross section

Deuteron → ← Gold

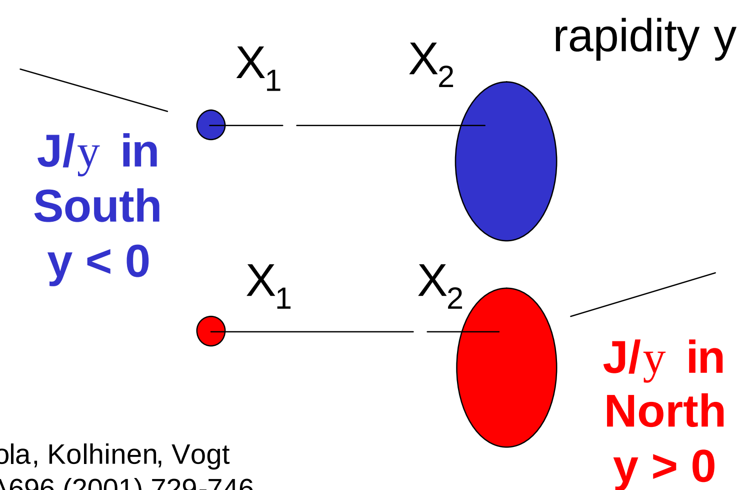


- In PHENIX, J/ψ mostly produced by gluon fusion, and thus sensitive to gluon pdf
- Three rapidity ranges probe different momentum fraction of Au partons
  - South ($y < -1.2$) : large X_2 (in gold) ~ 0.090
  - Central ($y \sim 0$) : intermediate X_2 ~ 0.020
  - North ($y > 1.2$) : small X_2 (in gold)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

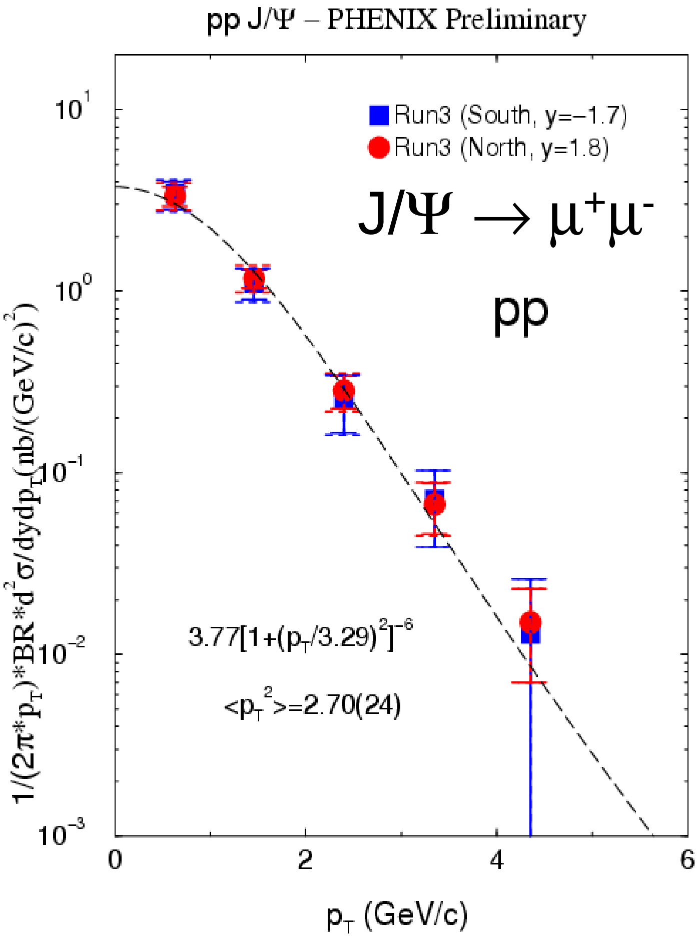
Example of predicted gluon shadowing in d+Au

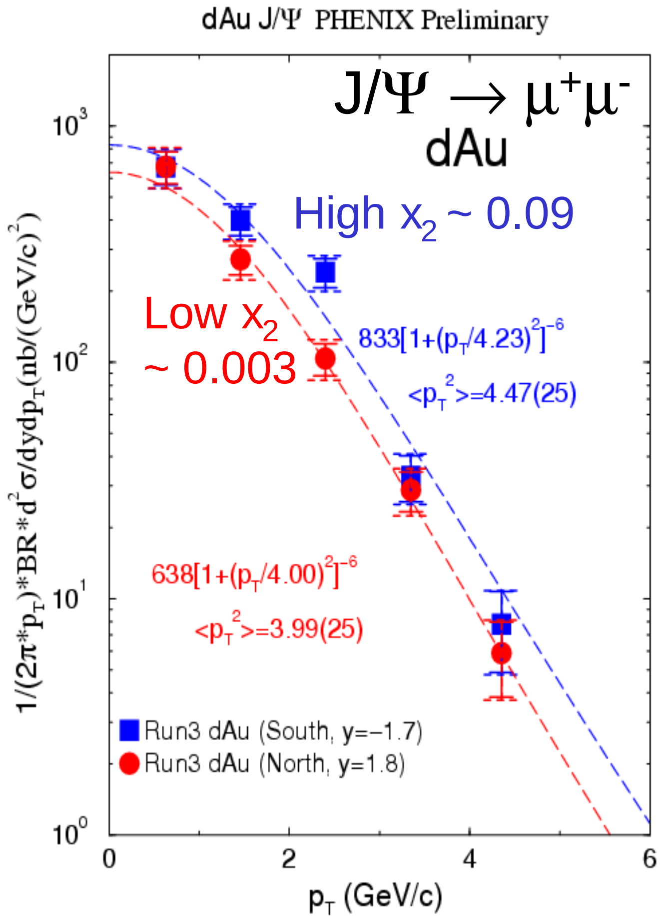


From Eskola, Kolhinen, Vogt Nucl. Phys. A696 (2001) 729-746.



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)

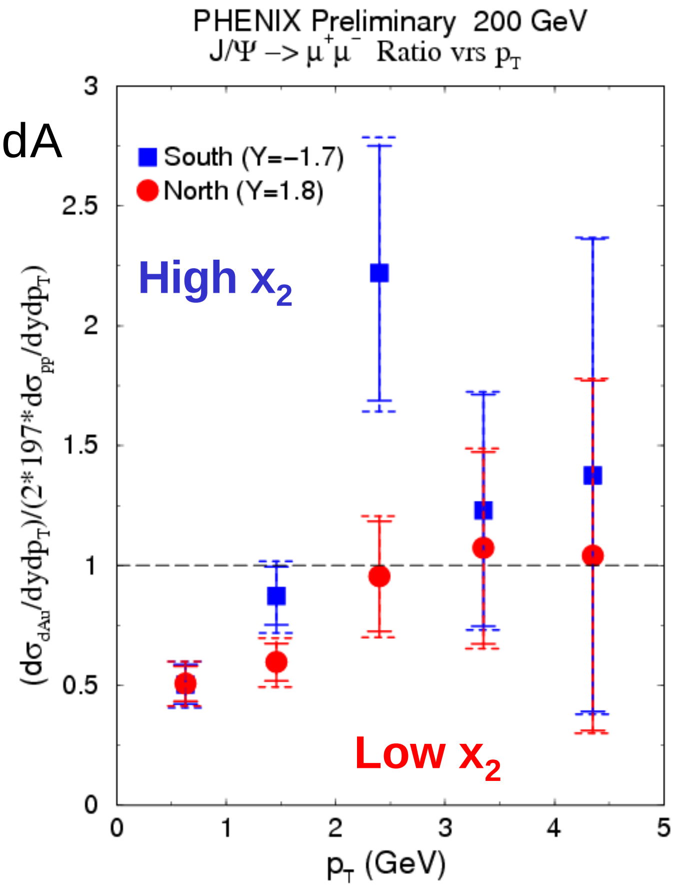
p_T is broadened for dAu

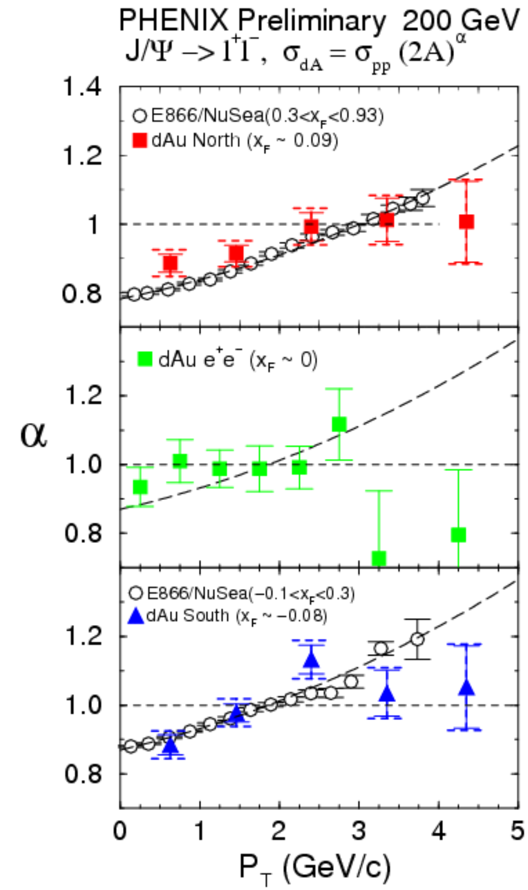
dAu/pp versus p_T

$$R = \sigma_{dA} / 2\times197\times\sigma_{pp}$$

$$\sigma_{dA} = \sigma_{pp}(2\times197)^{\alpha}$$

R_{dA}



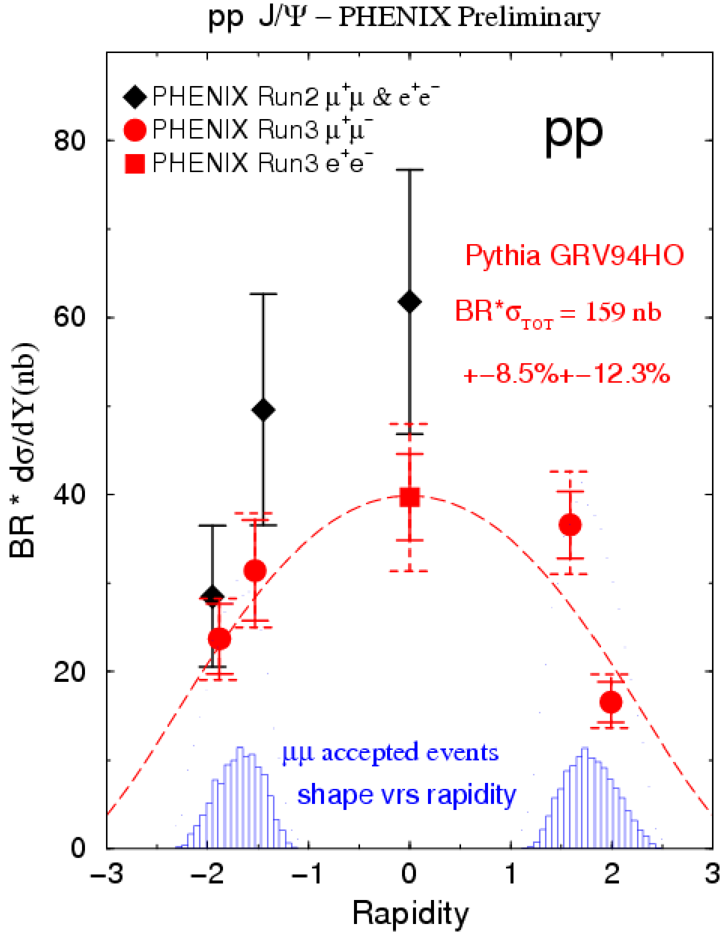


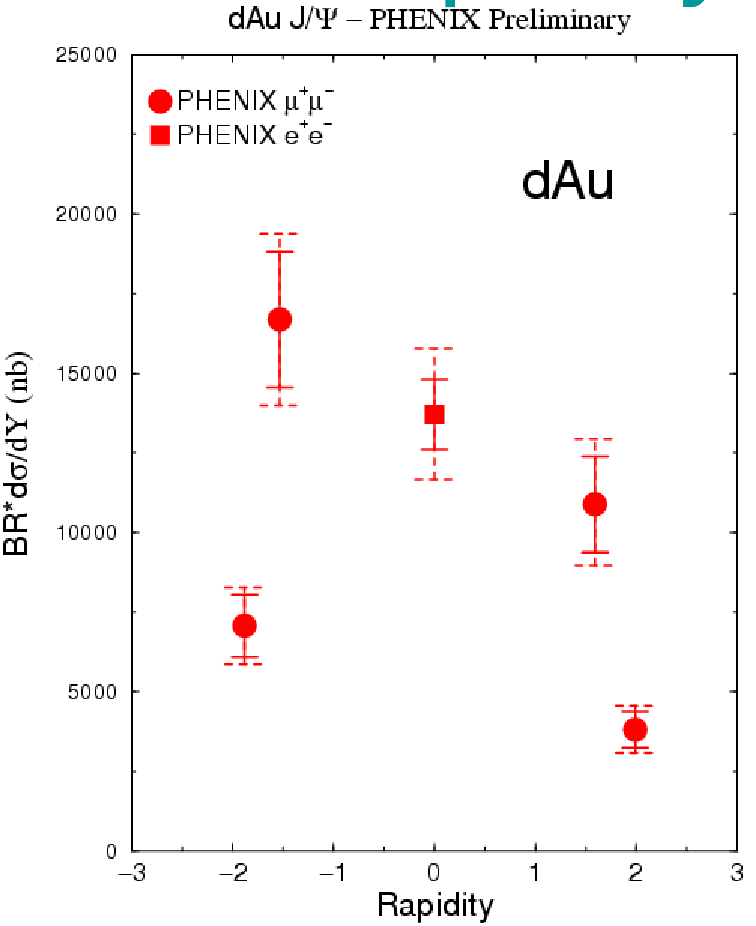
Low x_2 ~ 0.003

High x_2 ~ 0.09

Broadening comparable to lower energy (√s = 39 GeV in E866)

Cross section versus rapidity

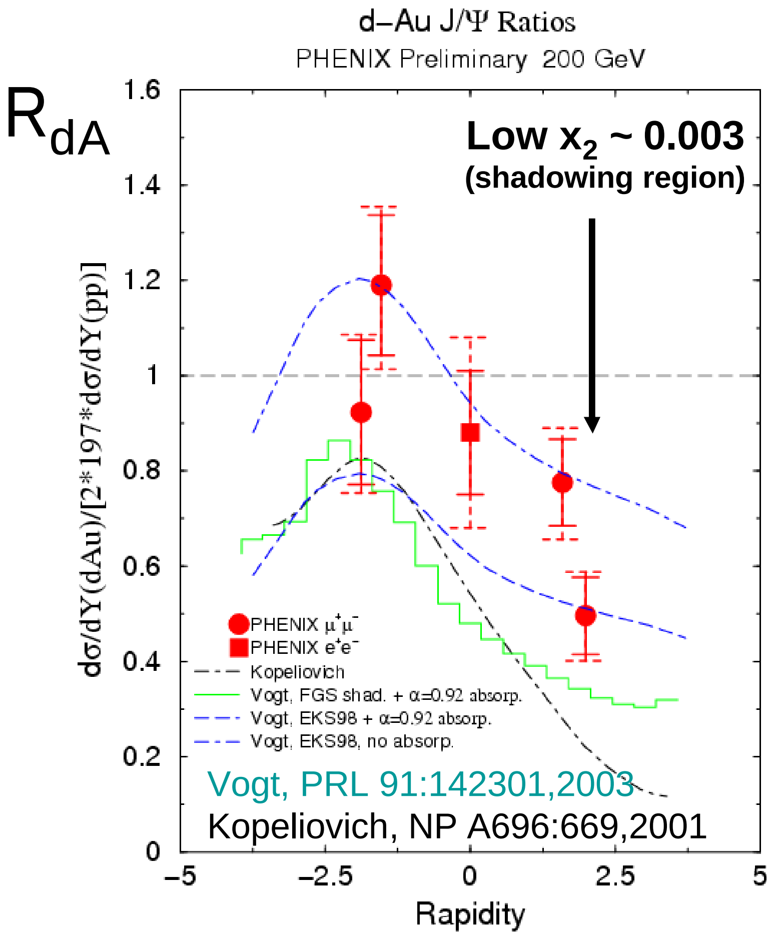


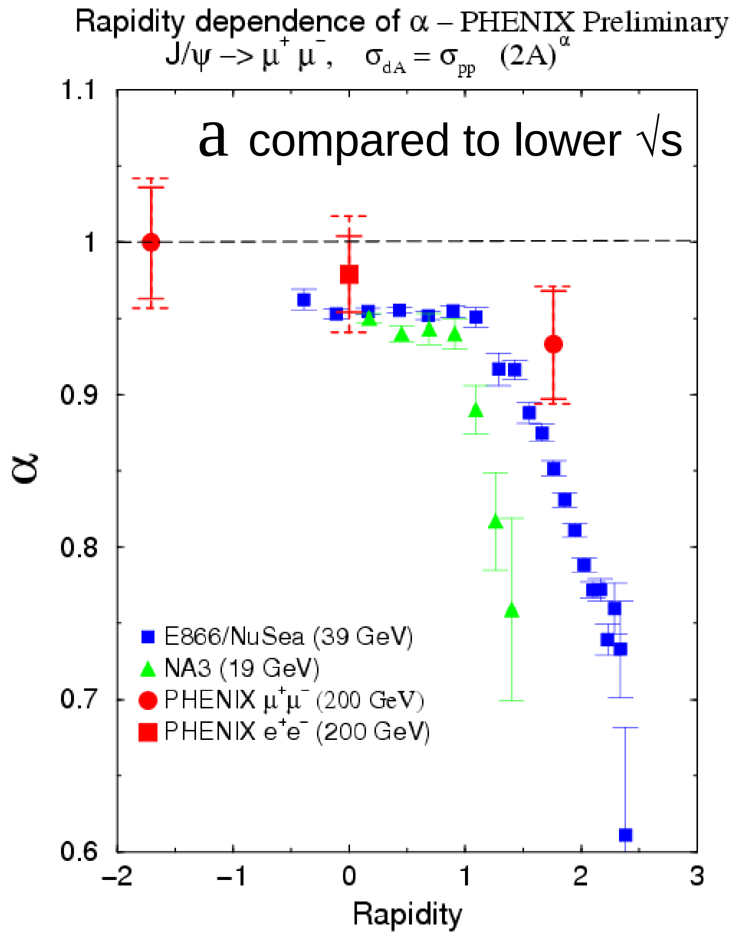


- Total cross section (preliminary)

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

dAu/pp versus rapidity

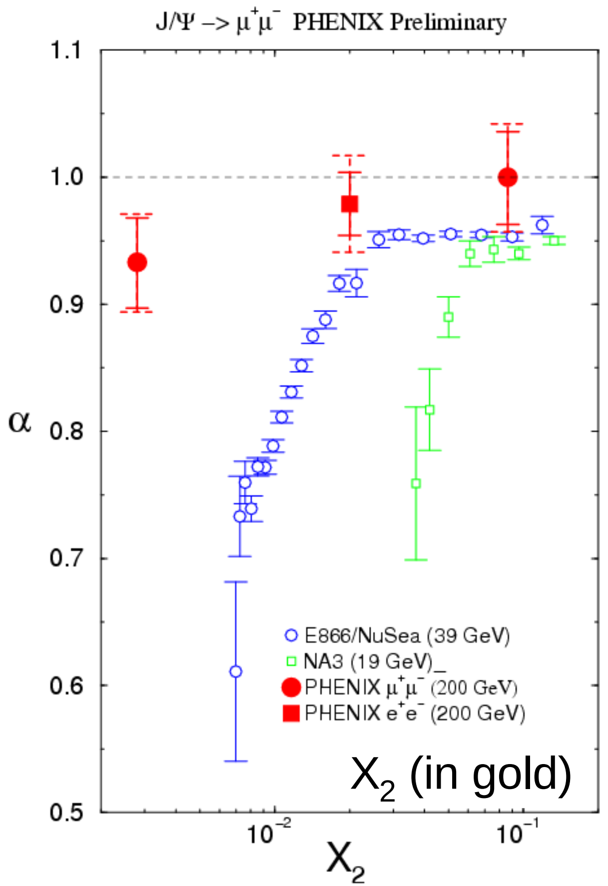


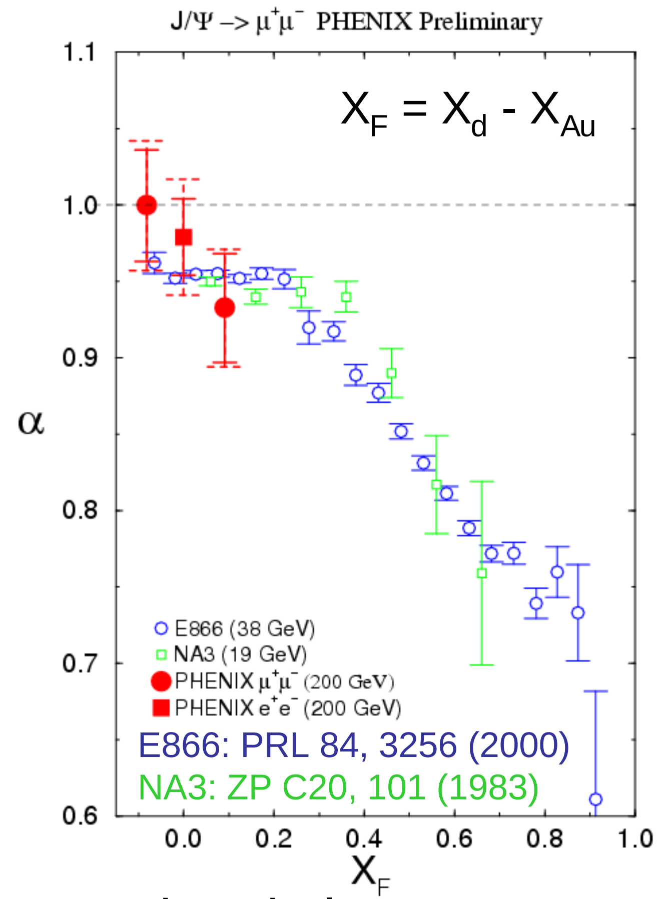


Data favours (weak) shadowing + (weak) absorption ($\alpha > 0.92$)

With limited statistics difficult to disentangle nuclear effects

α versus X compared to lower √s

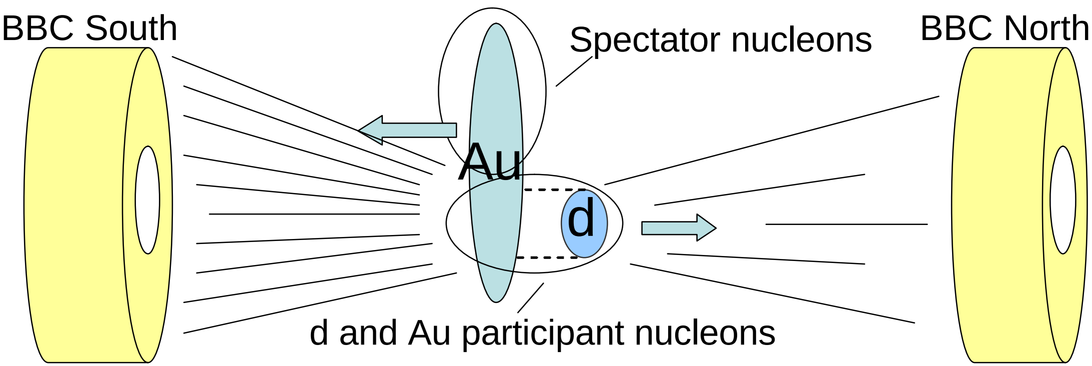




- Not universal versus X_2 : shadowing is not the whole story.
- Same versus X_F for diff √s. Incident parton energy loss ? (high X_d = high X_F)
- Energy loss expected to be weak at RHIC energy.

Centrality analysis

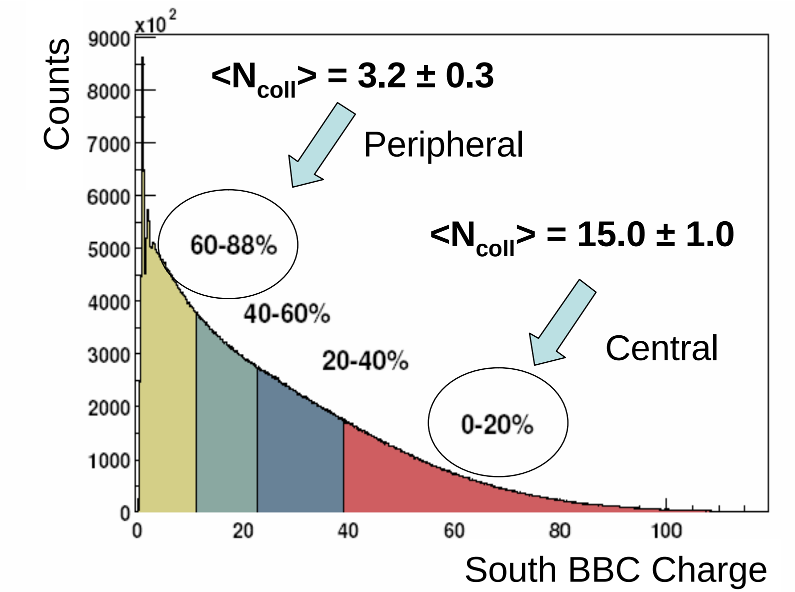
Au breaks up in our south beam counter



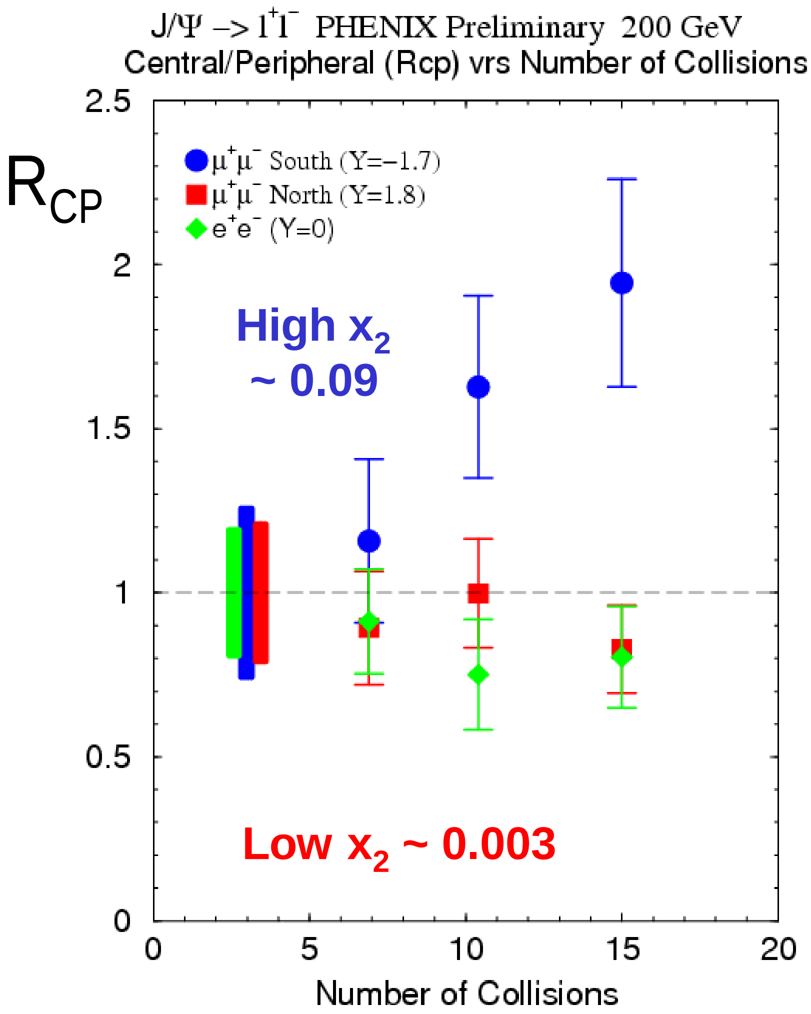
- Define 4 centrality classes
- Relate centrality to $\langle N_{coll} \rangle$

through Glauber computation

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



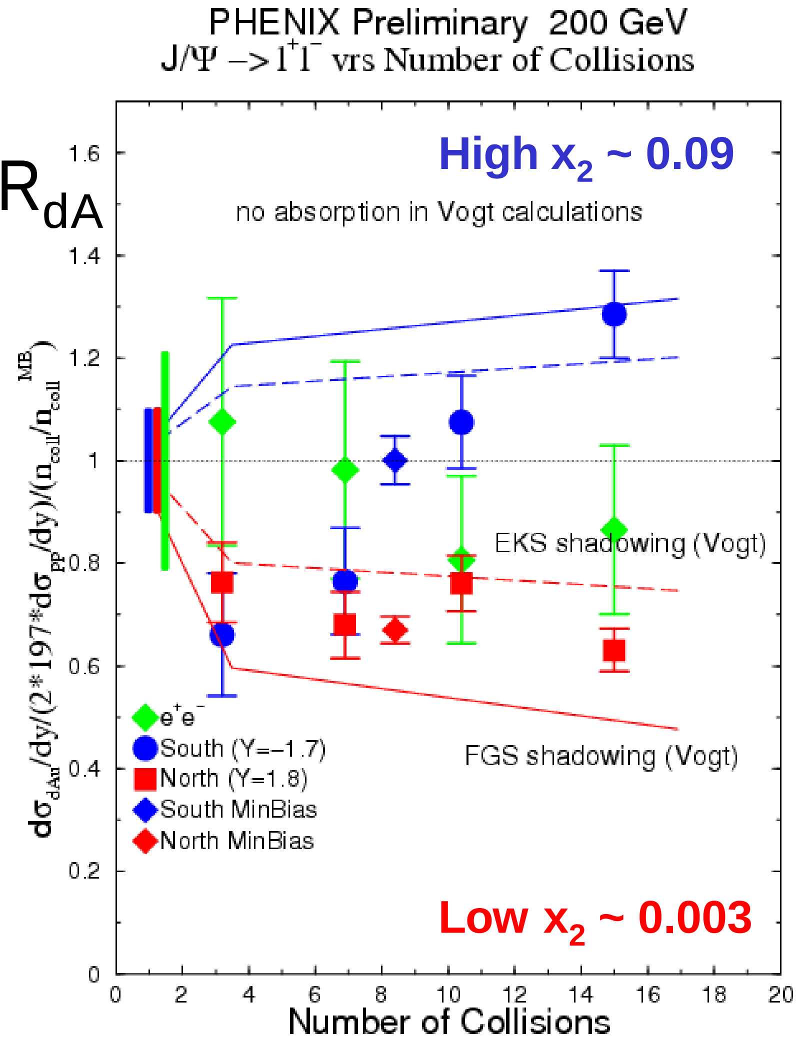
Central/peripheral versus N_{coll}



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

- 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}



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

- 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 Jψ suppression in Au-Au !

PHENIX charmonia related posters

- Jane M. Burward-Hoy: "Centrality Dependence of $J\psi \to \mu^+ \mu^-$ 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 $\chi_c \to J\psi + \gamma$ 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 $J\psi \to e^+e^-$ 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"

PHENIX

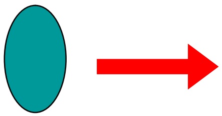
12 Countries; 58 Institutions; 480 Participants*

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, Université 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
	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

Back up slides

Soft physics from Thursday Ming Liu’s talk



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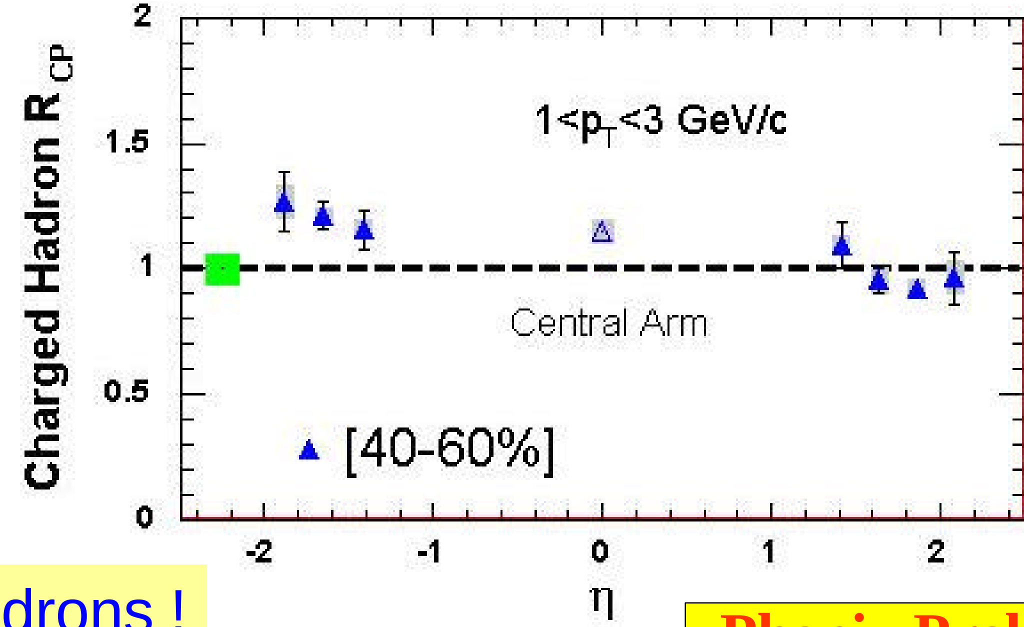
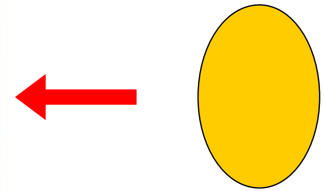
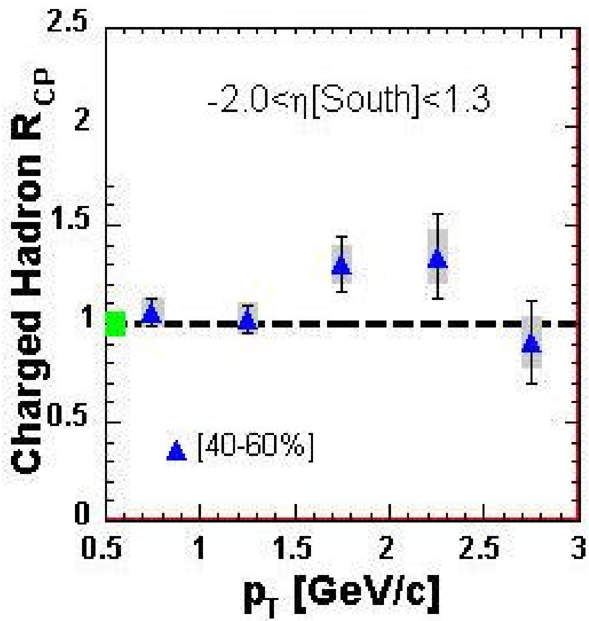


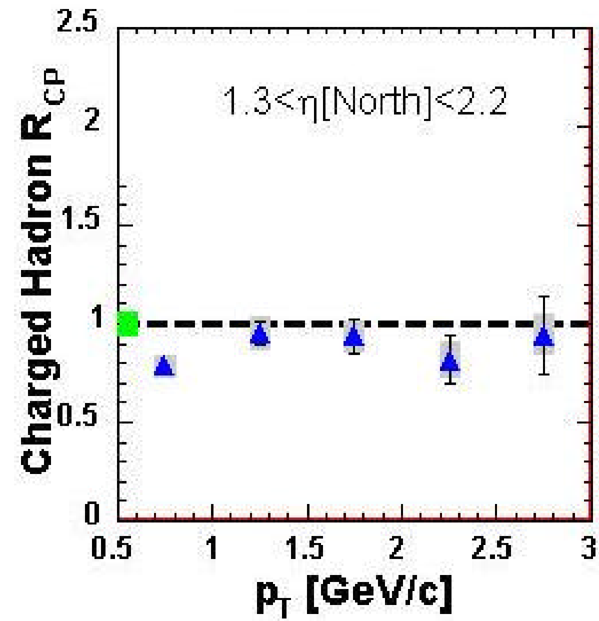


Au

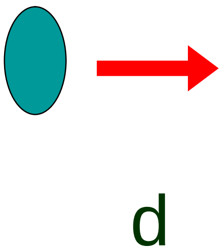
Stopped Hadrons !

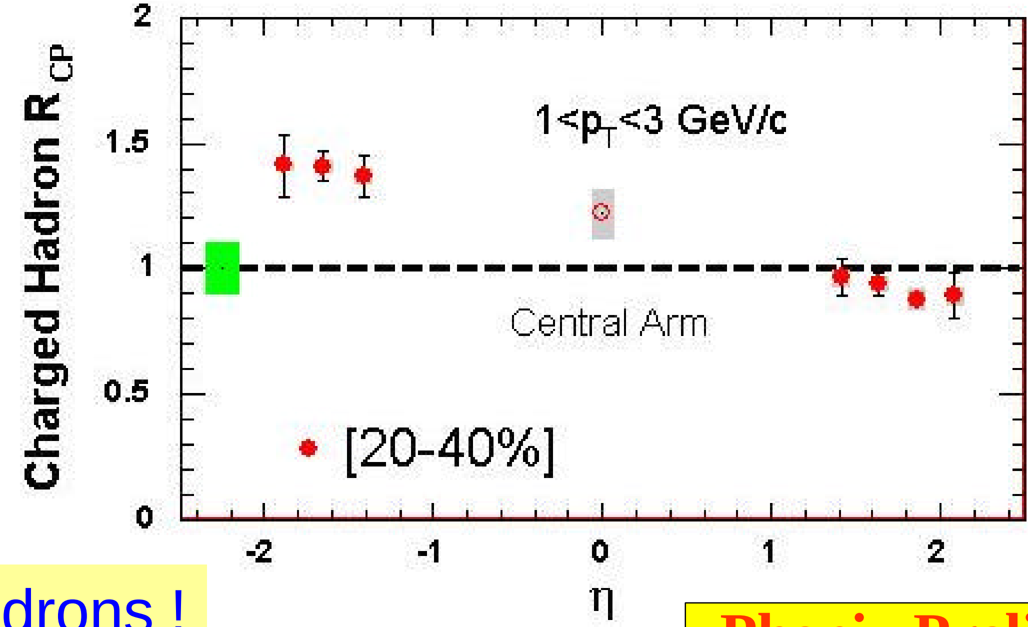
Phenix Preliminary

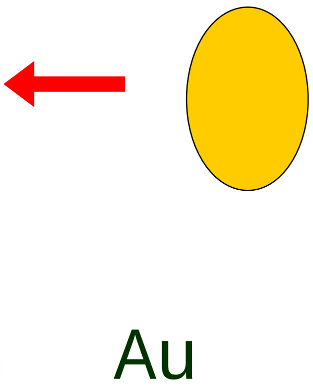




Soft physics from Thursday Ming Liu's talk

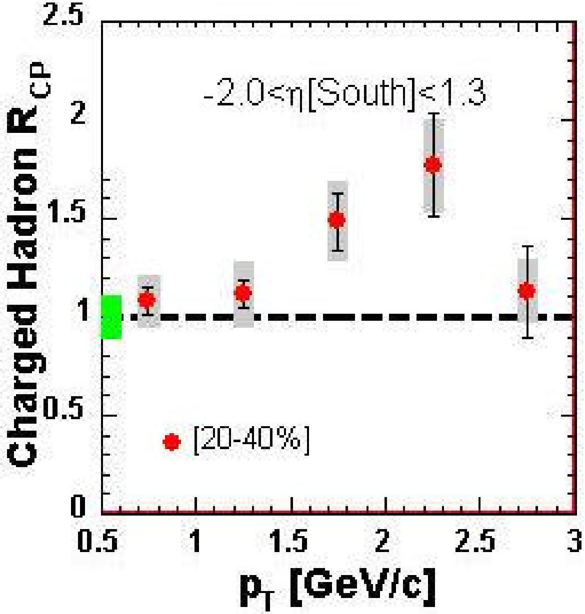


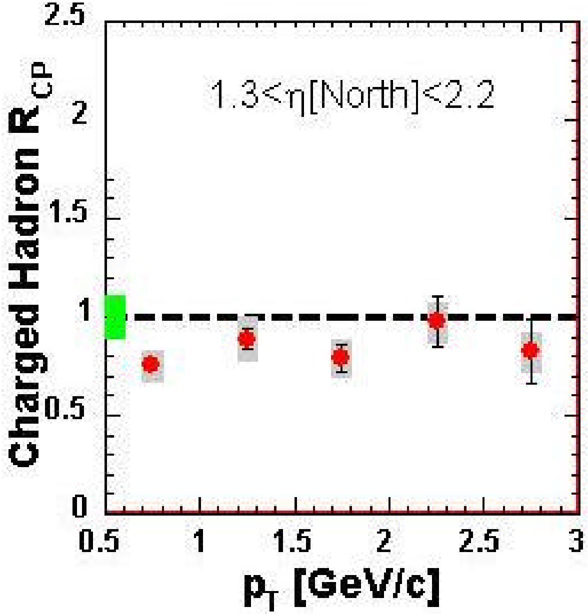




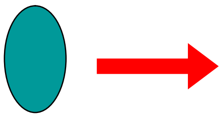
Stopped Hadrons !

Phenix Preliminary





Soft physics from Thursday Ming Liu's talk



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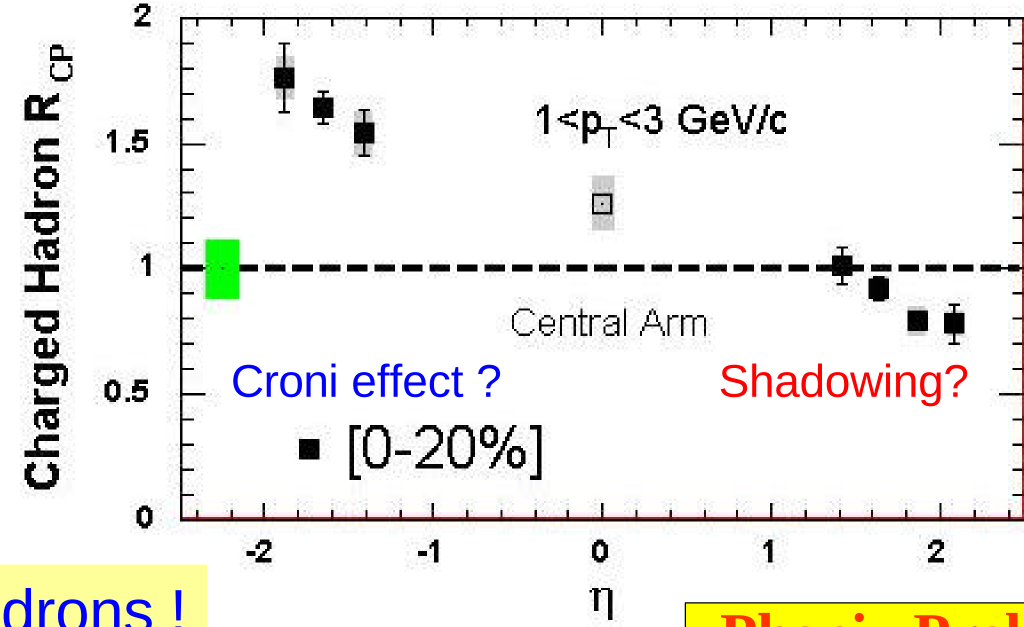
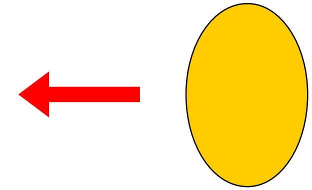
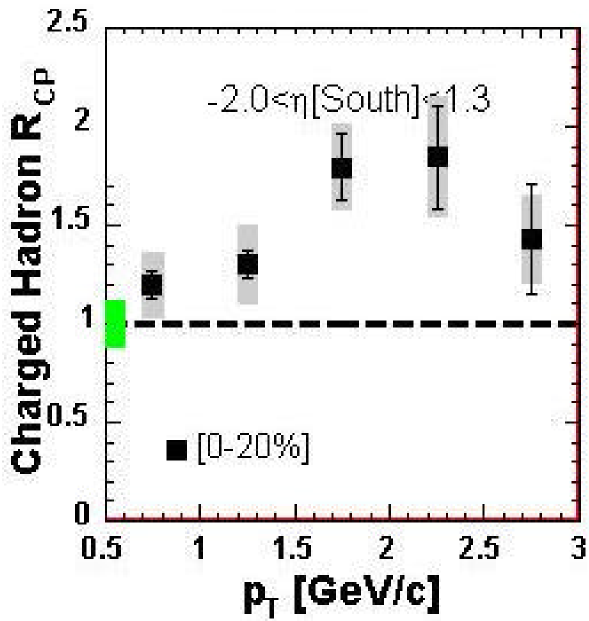


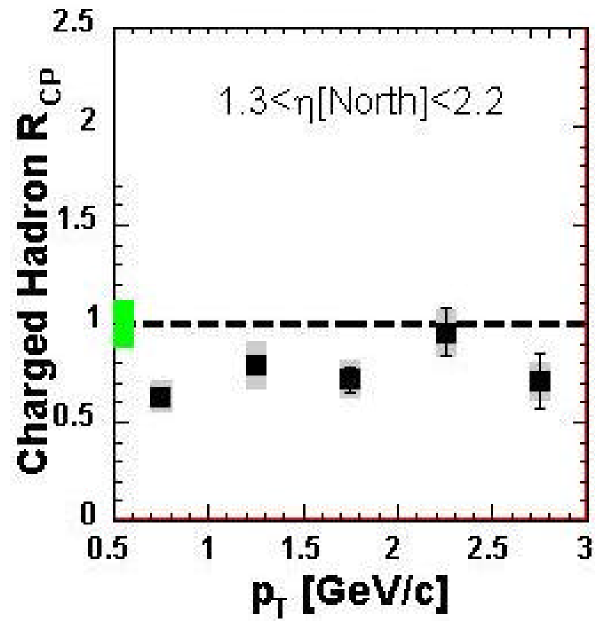


Au

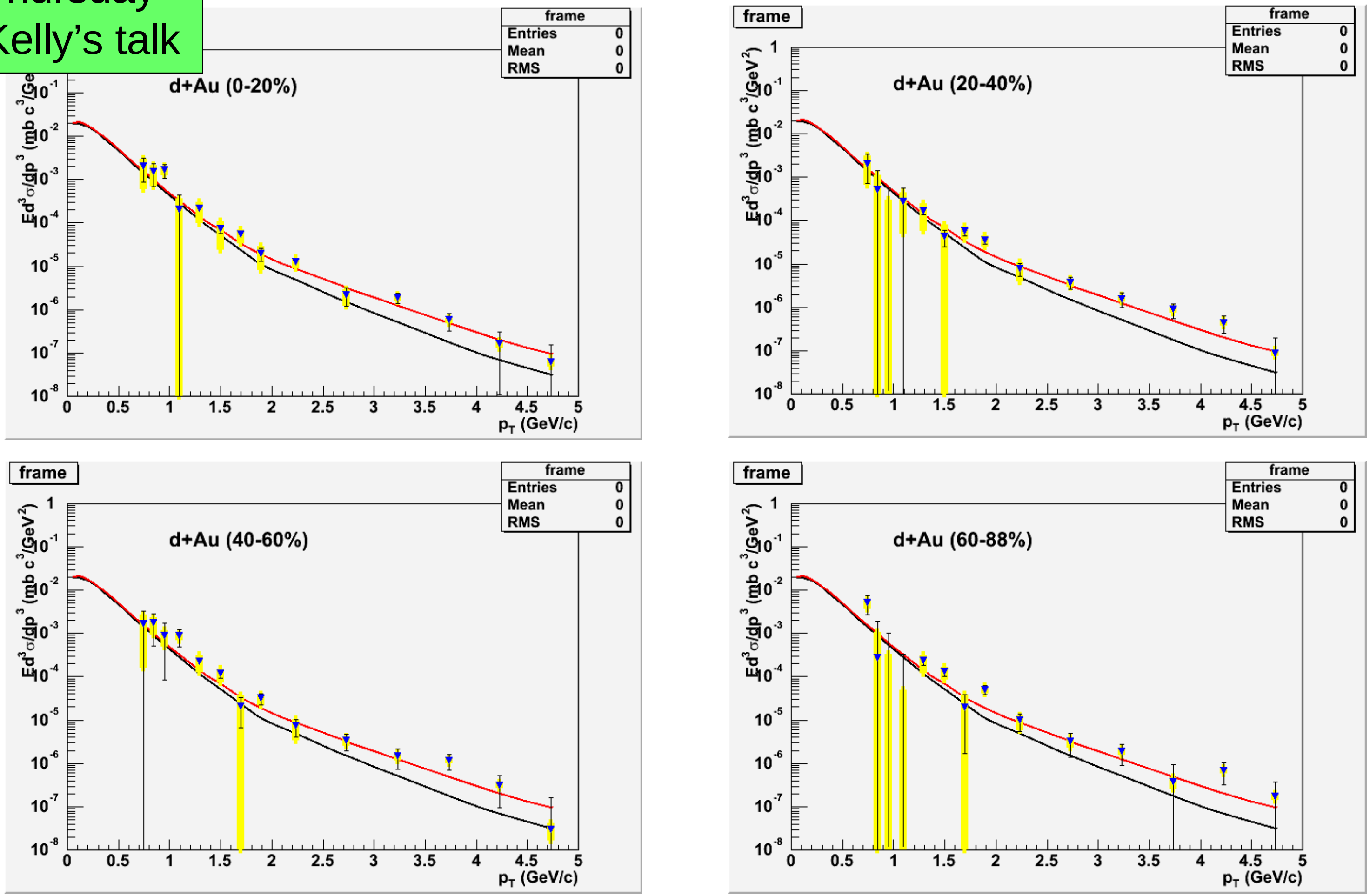
Stopped Hadrons !

Phenix Preliminary



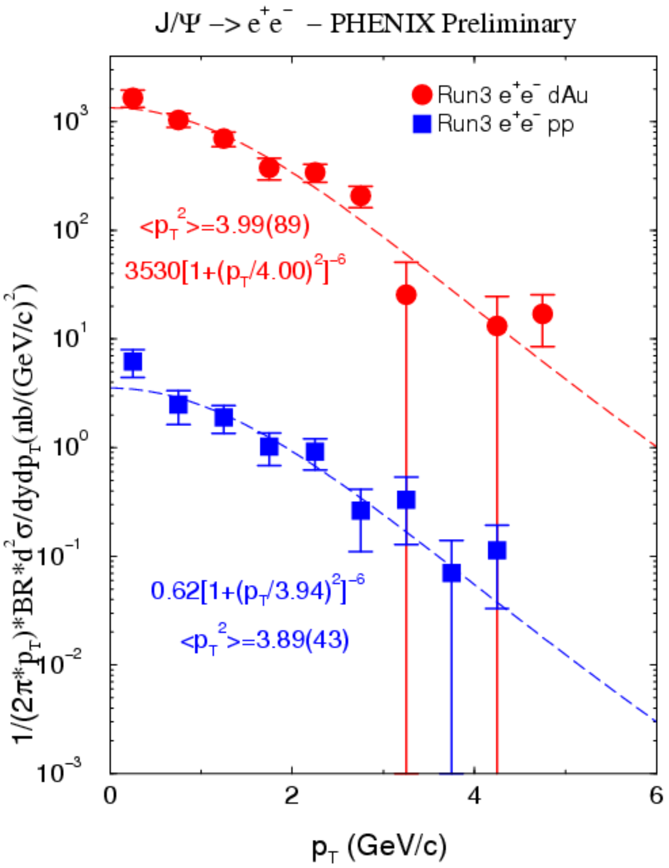


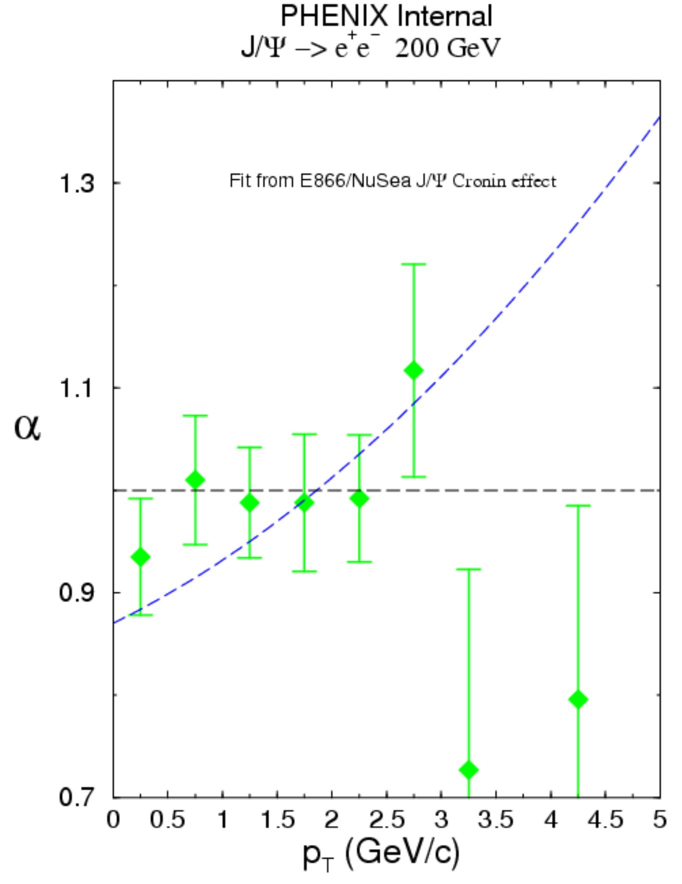
Open charm in dA at mid-rapidity



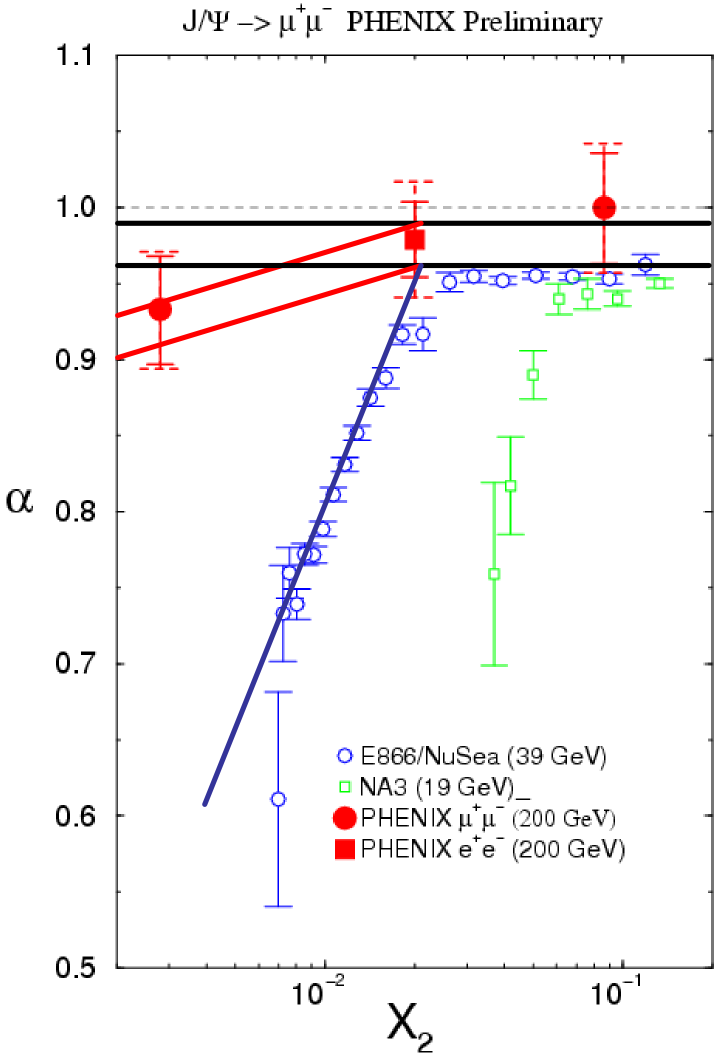
- Similar p_T shape compared to pp data
- No significant centrality dependence seen
- Seems little net nuclear effect on charm production at central rapidity

P_T in dielectrons



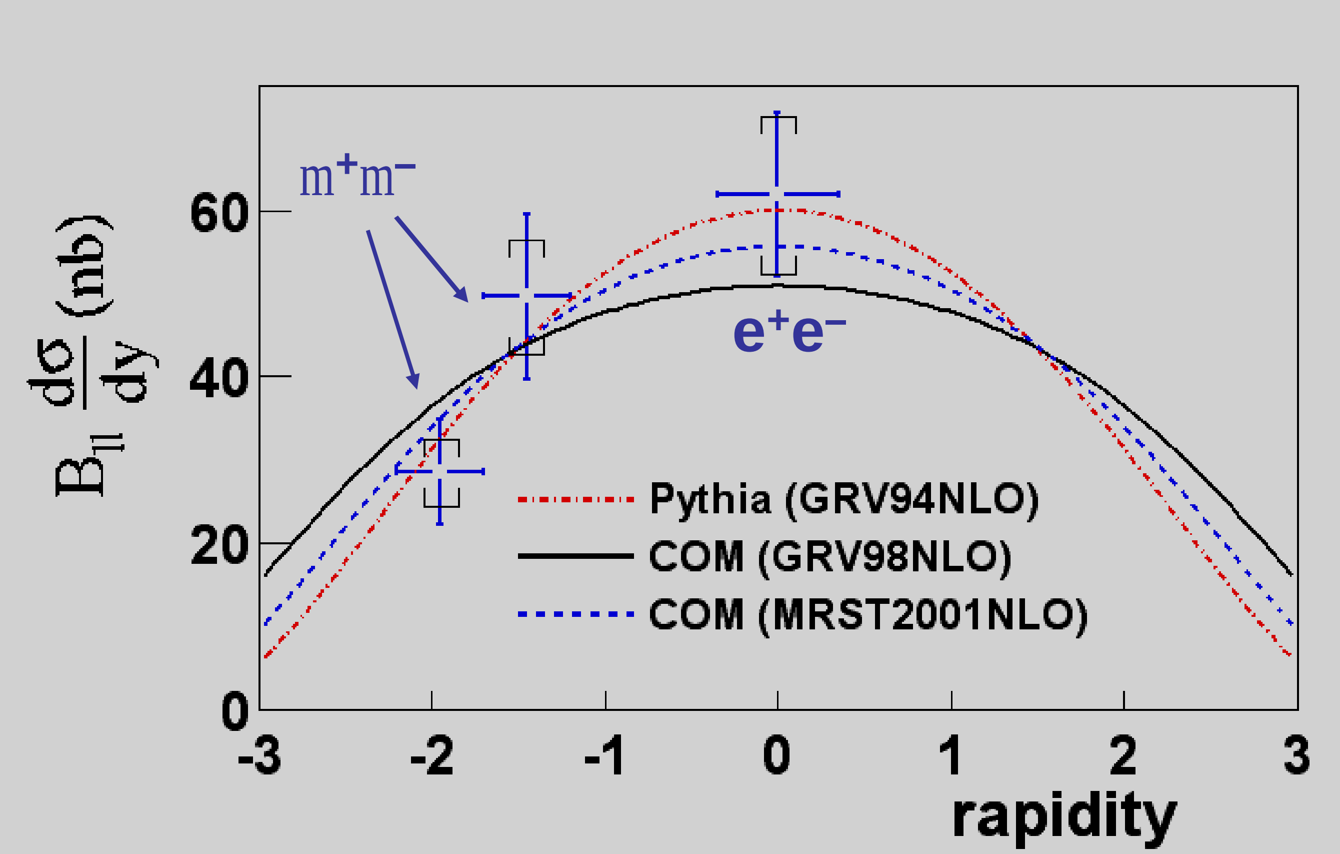


Naive picture



- Less absorption
- Shadowing
- Energy loss

J/Ψ cross section from run 2



Results consistent with shapes from various models and PDF.

Take the PYTHIA shape to extract our cross-section

Error from absolute normalization

Integrated cross-section :

RUN2 234 ± 36 (stat) ± 34 (sys) ± 24(abs) μb

RUN3 159 nb ± 8.5 % (fit) ± 12.3% (abs)

Consistent (1.3 sigma difference)