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J/Ψ and open charm measurements at RHIC/PHENIX

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PHENIX

Outline

- Brief PHENIX Experiment and Physics intro
- Selected results;

  Open Charm :

  - Au-Au and p-p

    single electron results

  Charmonium :

  - J/Ψ in dAu collisions

    Shadowing, nuclear effects

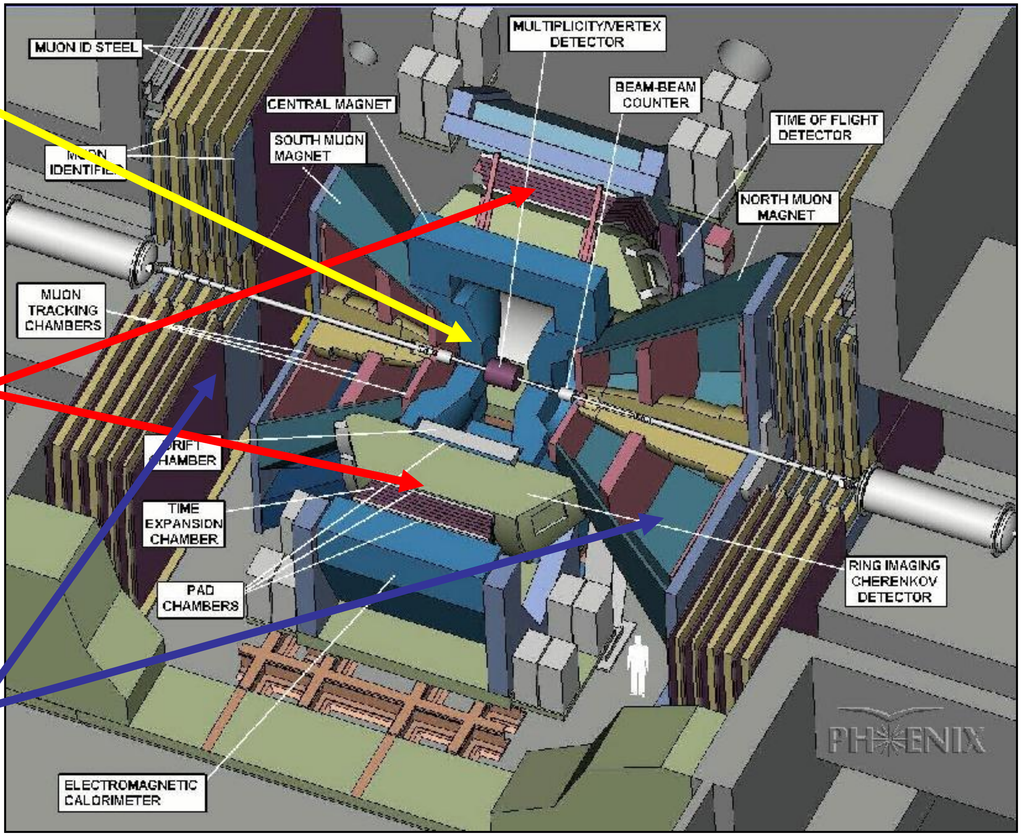
- Summary and Outlook

PHENIX

Event characterization detectors in middle

Two central arms for measuring hadrons, photons and electrons

Two forward arms for measuring muons



electrons: central arms

electron measurement in range:

$|\eta| \leq 0.35$

$p \geq 0.2$ GeV/c

muons: forward arms

muon measurement in range:

$1.2 < |\eta| < 2.4$

$p \geq 2$ GeV/c

Measure Open Charm via Electrons

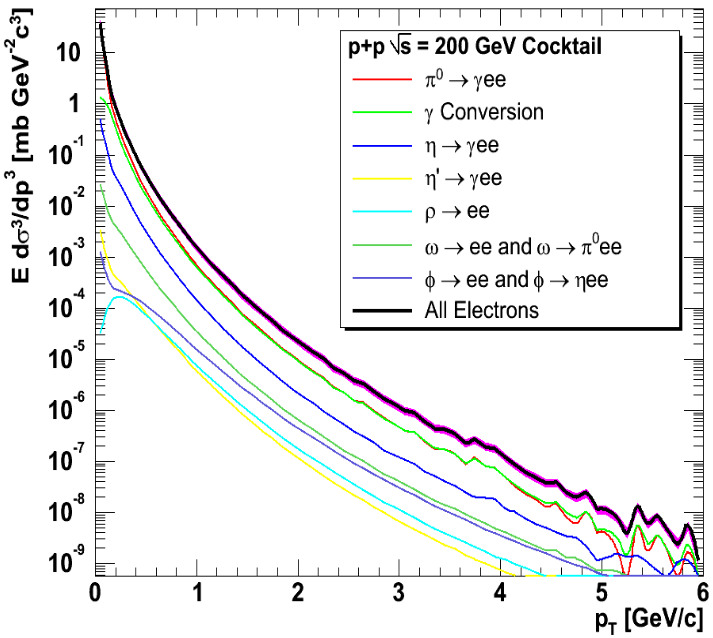
Open charm and bottom can be measured via semi-leptonic decay.

PHENIX measures inclusive electron spectra at mid-rapidity.

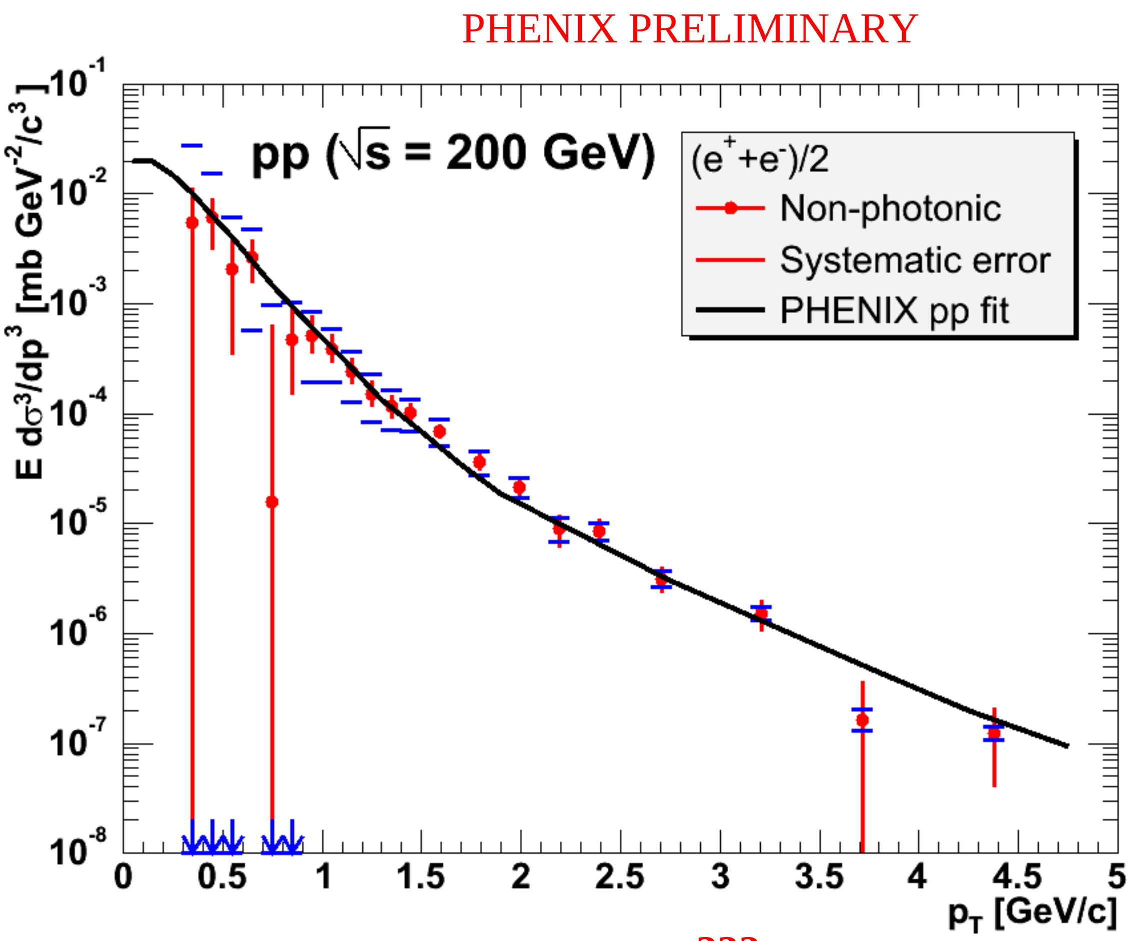
The physics we are interested in is the "non-photonic" electrons, which we define as what's left over after we subtract the following:

- π^0 Dalitz,
- γ conversions
- η Dalitz,
- light vector meson decays

cocktail



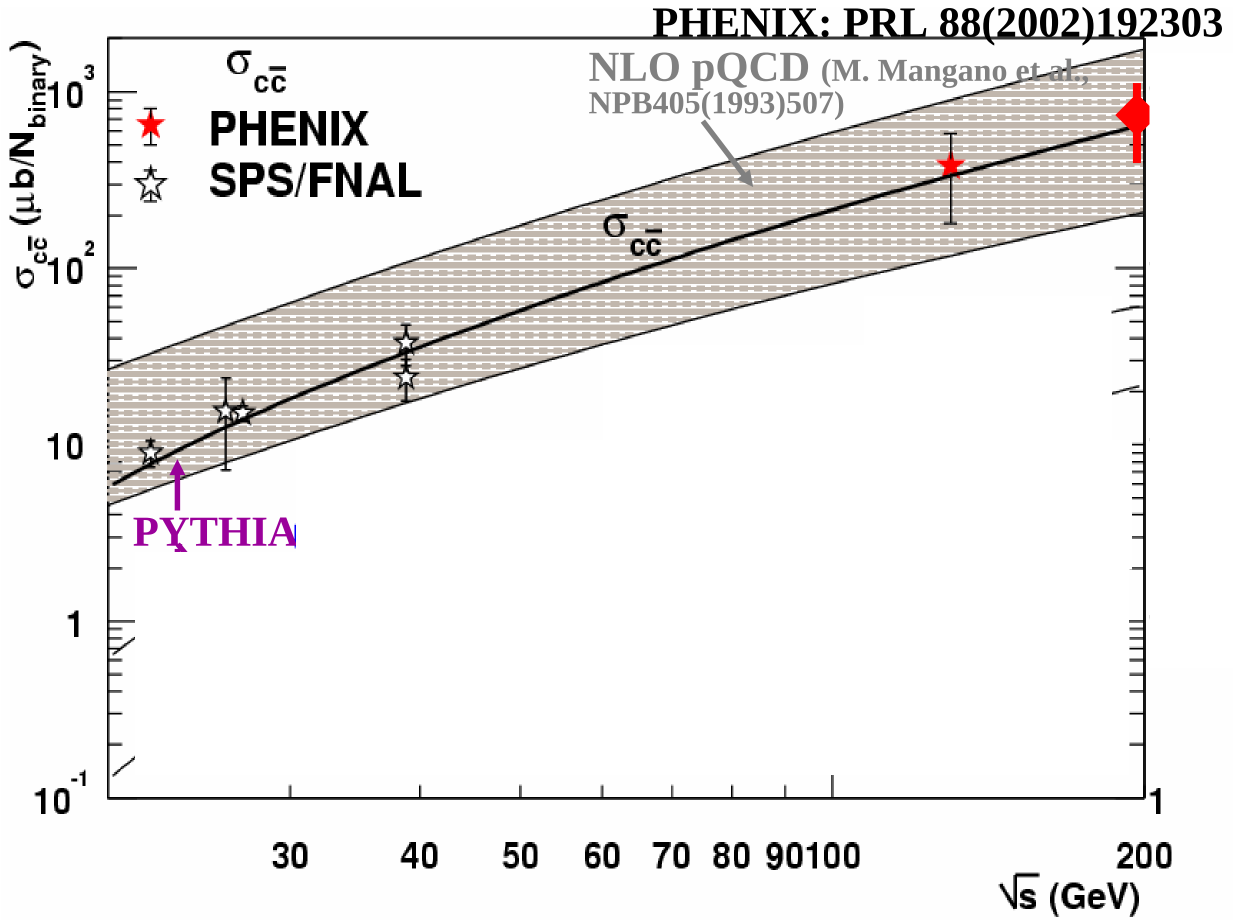
PHENIX Non-Photonic Single Electron Spectra
pp @ $\sqrt{s}$ = 200 GeV



$$\sigma_{c\bar{c}} = 709\mu b \pm 85(\text{stat})\,^{+332}_{-281}\,(\text{sys})$$

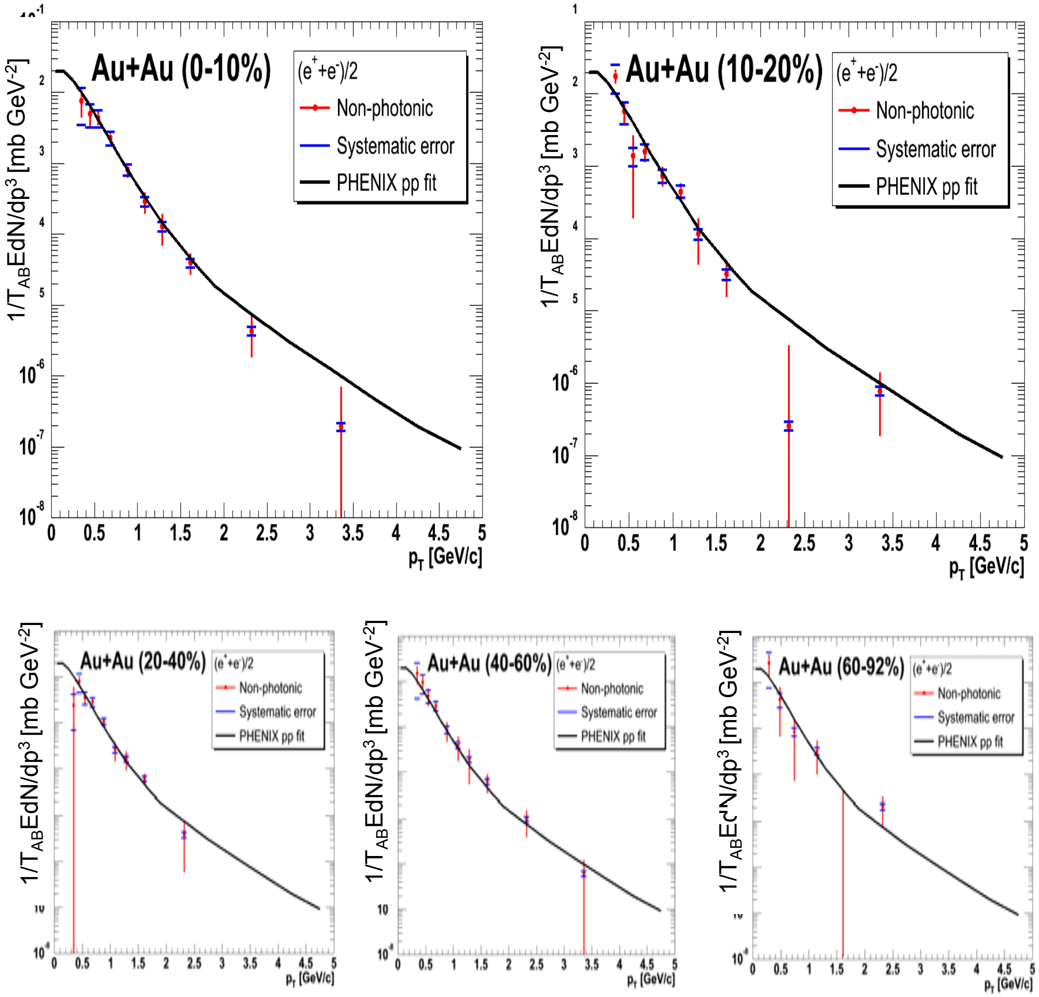
Can use ***measured*** p-p result for A-A comparisons!

PHENIX Non-Photonic Single Electron Spectra



PHENIX data is consistent with the prediction of NLO pQCD calculation and PYTHIA prediction!

PHENIX Non-Photonic Single Electron Spectra
Au-Au @ $\sqrt{s}$ = 200 GeV



To quantify centrality dependence, perform fit to

$dN/dy = A\, N_{coll}^{\alpha}$

All α values are consistent with 1, in measured p_T range:

$0.8 < p_T < 4.0$ (GeV/c)

At 90 % C.L. :

$0.906 < \alpha < 1.042$

- Data seems to scale with N_{coll} in all the centrality bins!

N_{cc}/T_{AA} = 644±59(stat) ±150(sys) μb [info on initial state]

J/Ψ Production

p-p : study of production mechanism and cross sections

Color evaporation model, Color singlet model, Color octet model

Polarization, Rapidity dependence (electron and muon channels)

Production of J/Ψ, Ψ',.. states

Base line for pA and AA

p(d)-A : study of "normal nuclear effects": shadowing and energy loss

Nuclear dependence of σ(J/Ψ): A^{α} or σ_{abs} (nuclear absorption)

Base line for AA

A-A : study of "medium effect" in high density matter

J/Ψ suppression : signature of QGP (Matsui/Satz)

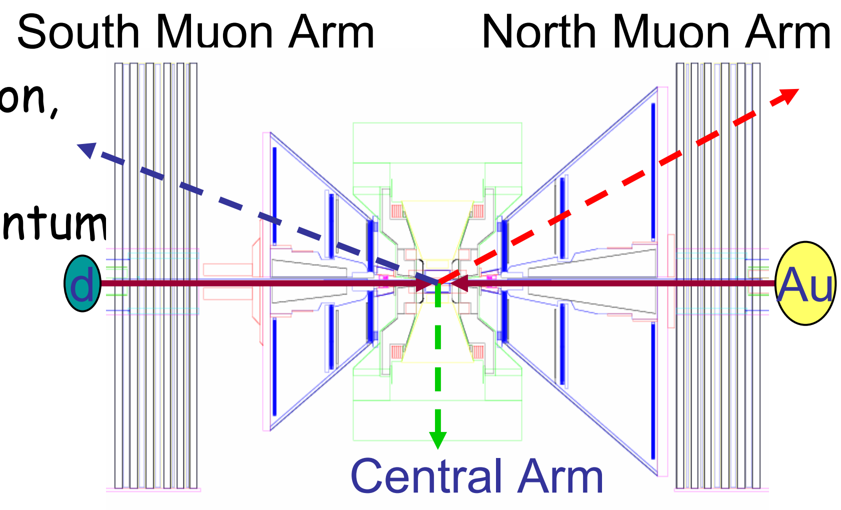
J/Ψ formation by c quark coalescence at RHIC/LHC ?

Comparisons between various collision species are very important.

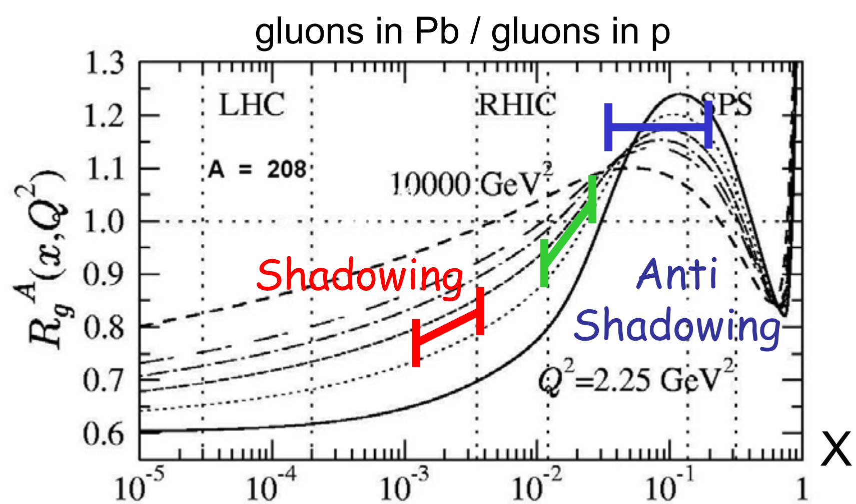
Studies done via both dielectron and dimuon channels in PHENIX.

$J/\Psi \rightarrow \mu^+\mu^-/e^+e^-$ for dAu & pp

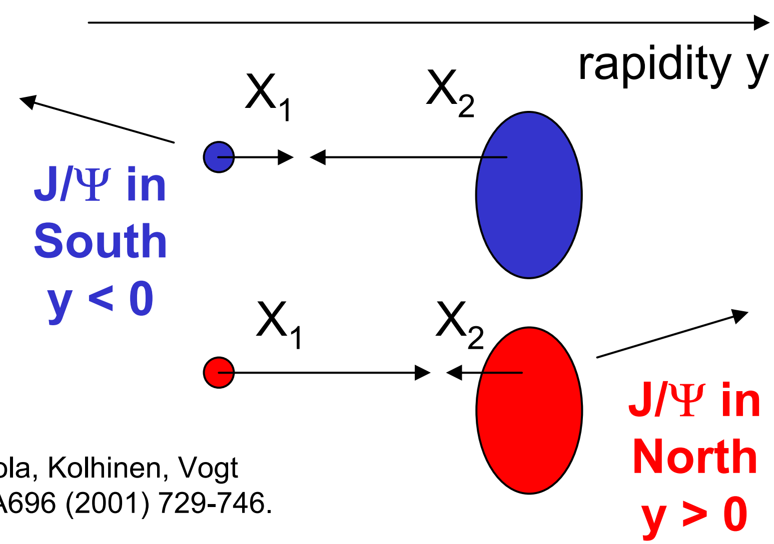
- At RHIC, J/Ψ mostly produced by gluon fusion, and thus sensitive to gluon pdf
- Three rapidity ranges probe different momentum fractions of Au partons
  - South ($y < -1.2$) : large X_2 (in gold) ~ 0.09
  - Central ($y \sim 0$) : intermediate X_2 ~ 0.02
  - North ($y > 1.2$) : small X_2 (in gold) ~ 0.003



Example of predicted gluon shadowing in d+Au

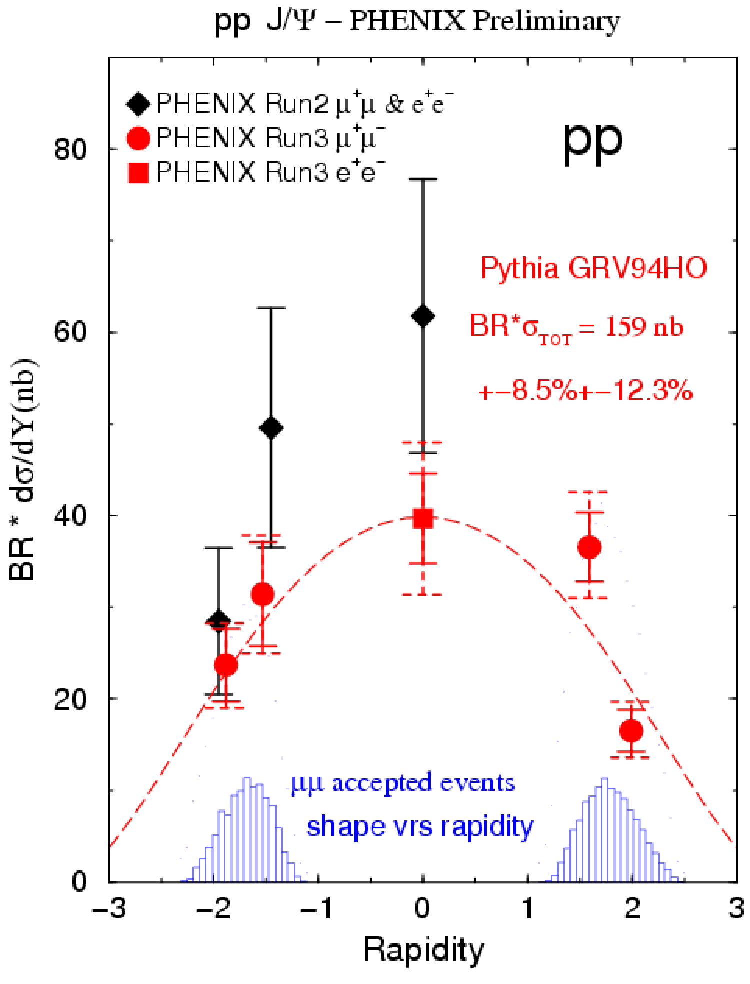


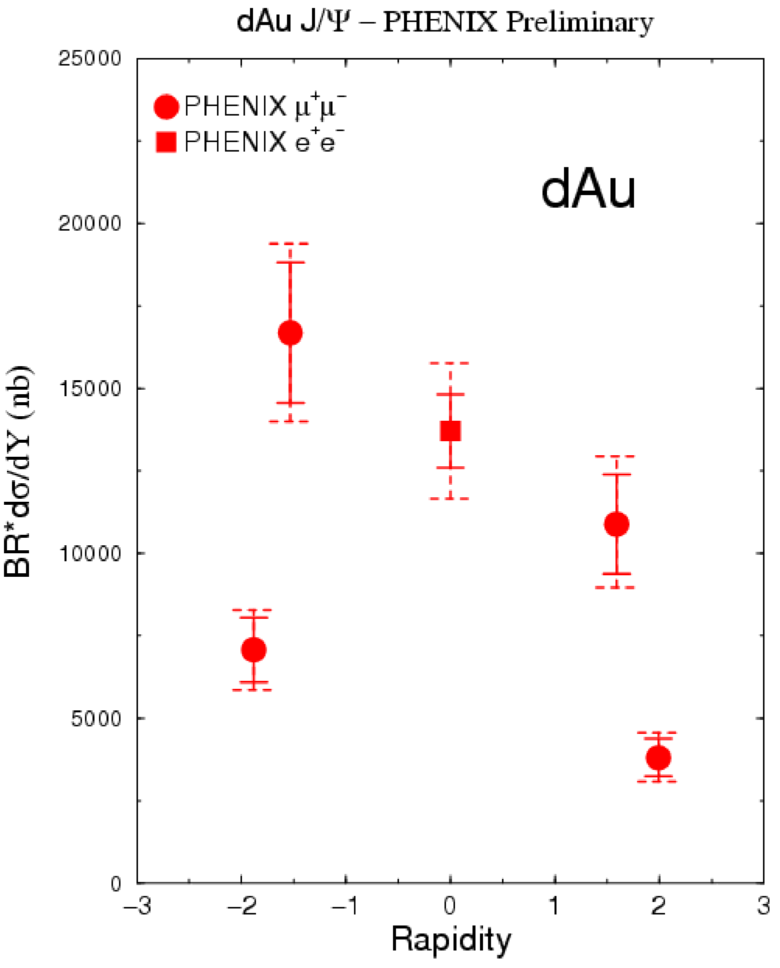
From Eskola, Kolhinen, Vogt
Nucl. Phys. A696 (2001) 729-746.



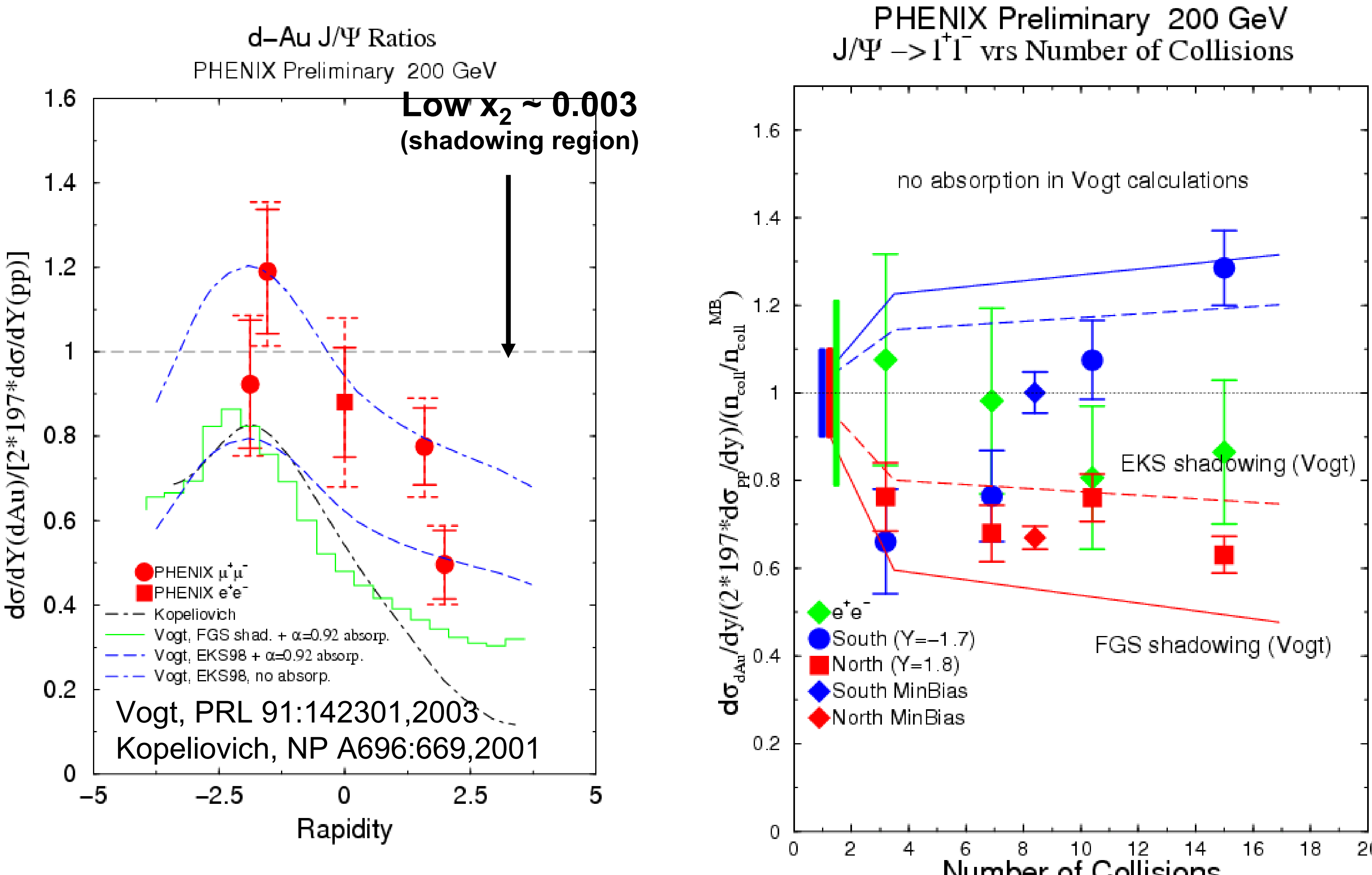
J/Ψ Rapidity Distribution

In RUN3, we accumulated ~300nb^{-1} p-p and ~3nb^{-1} d-Au collisions.





Gluon Shadowing and Nuclear Absorption



Data favor weak shadowing and weak nuclear absorption effect.

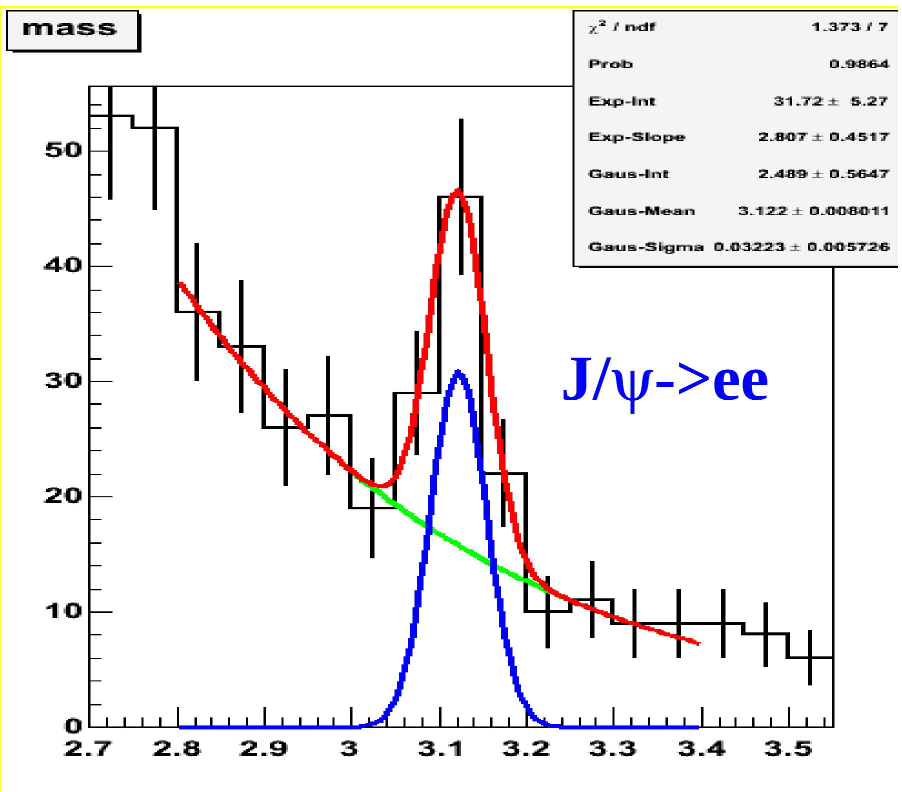
Steep rise of R_{dA} with increasing N_{coll} at large X_2.

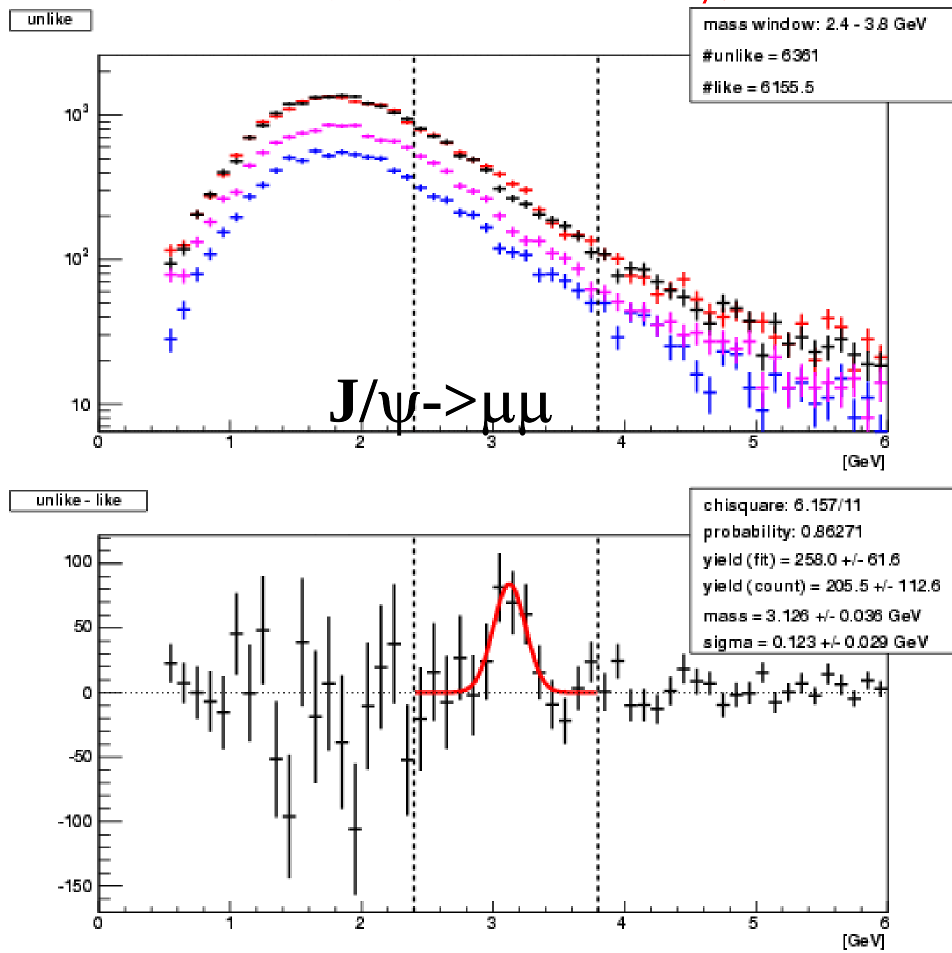
Need more data to distinguish different models.

J/Ψ Signal in RUN4 Au-Au Collisions

RUN4 was mainly a long Au-Au run to be able to really study e.g. J/Ψ:
PHENIX recorded **~240μb^{-1}** Au-Au collisions.

We see signals from a small portion of filtered AuAu data already.





Summary and Outlook

- Open Charm:

  - Ncoll scaling has been observed for non-photonic single electron production in p-p, d-Au and Au-Au collisions.

  * Distinguish different scenarios of charm quark energy loss in medium require more statistics. Much more clear answer expected in RUN4 data.

- Charmonium:

  - Weak shadowing and absorption has been observed in both central and forward region for J/Ψ production. A modest baseline for Au-Au J/Ψ has been established.

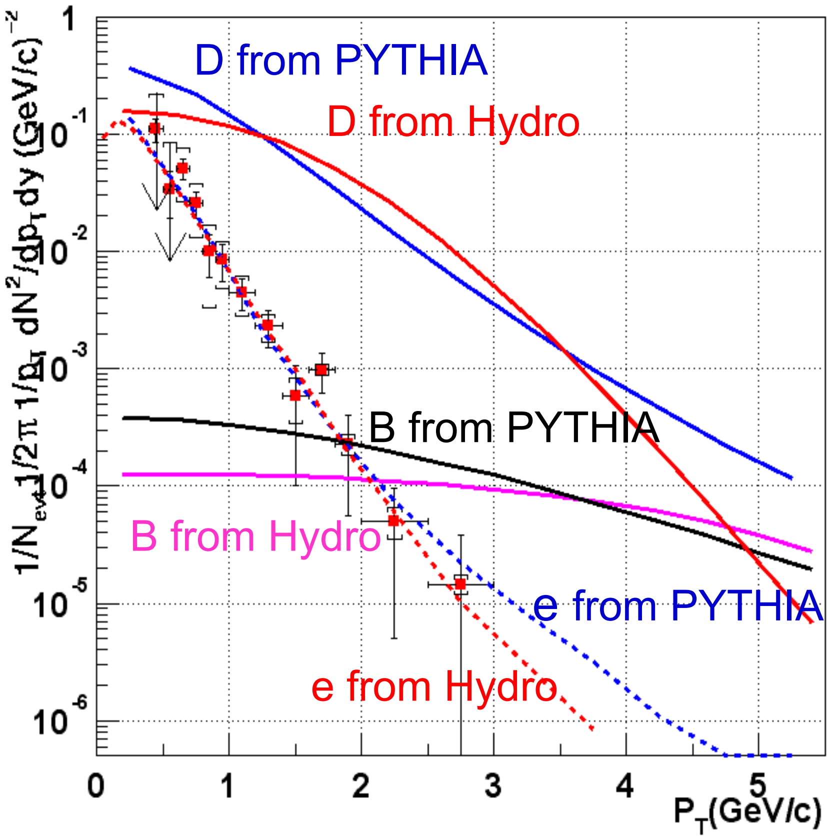
  * RUN4 has accumulated ~50 times more data (than RUN2) and we already see clear J/Ψ signals!

Look forward to future runs with high luminosity where also studies for different collision species and with varying energy can be made.

Extra slides

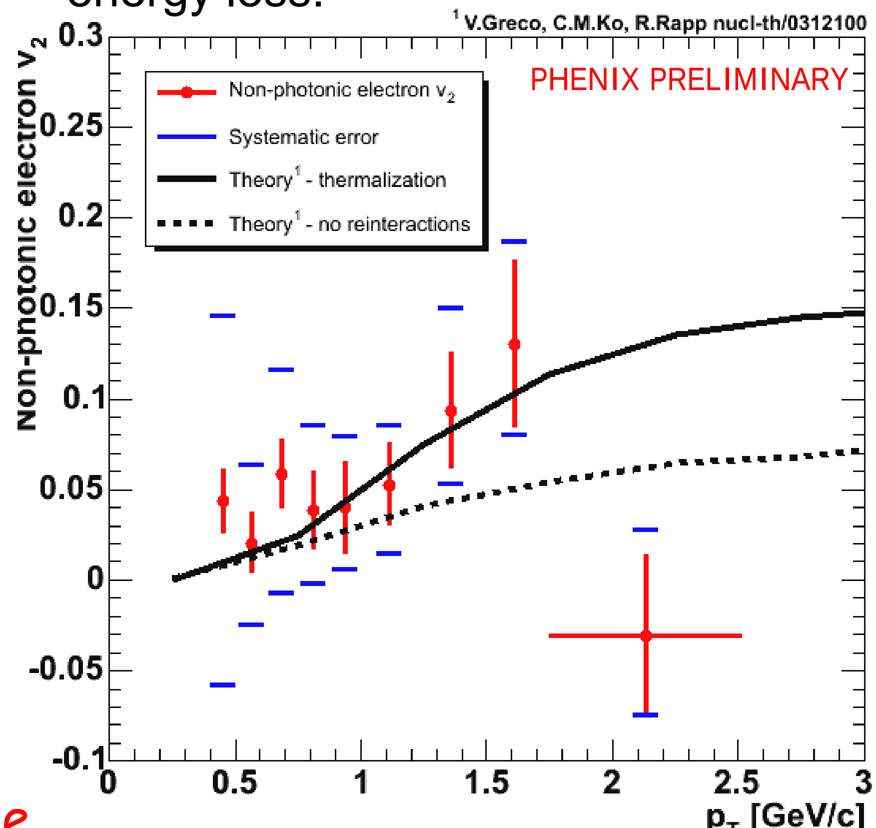
Charm in the Medium

130 GeV Au+Au (0-10%)



S. Batsouli, S.Kelly, M.Gyulassy, J.Nagle)
Phys.Lett. B557 (2003) 26-32

Scaling with N_{coll} seems to indicate little energy loss, but Hydro can also describe spectra.. Charm quark v2 is expected to be zero if there is no energy loss.



Data favor maximal flow scenario at the level of one sigma

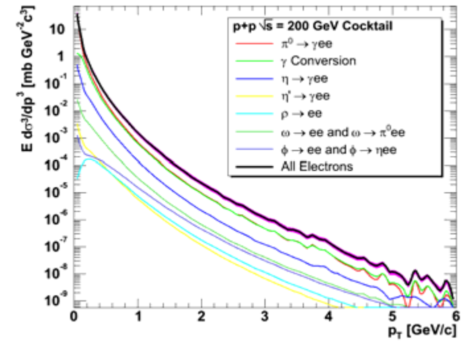
PHENIX expects to have much more clear answer from RUN4 data.

Subtracting Photonic Electrons

Cocktail subtraction method

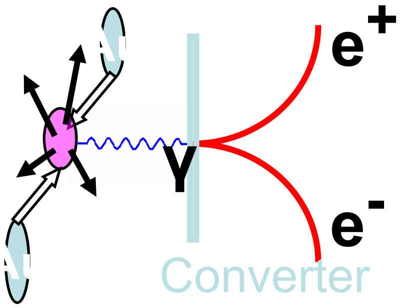
Includes conversion of photons from hadron decays in material, Dalitz decays of light mesons ($\pi^0, \eta, \omega, \eta, \phi$)

cocktail



Converter method

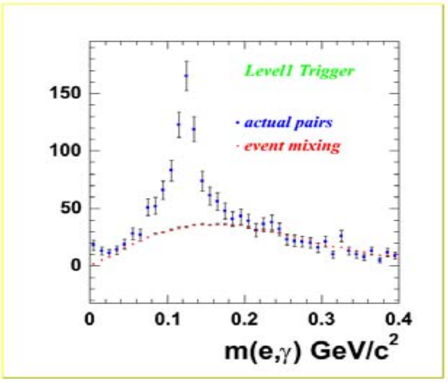
Comparison of $e^{+/-}$ spectra with and without converter allows separation of photonic and non-photonic sources of single electrons.



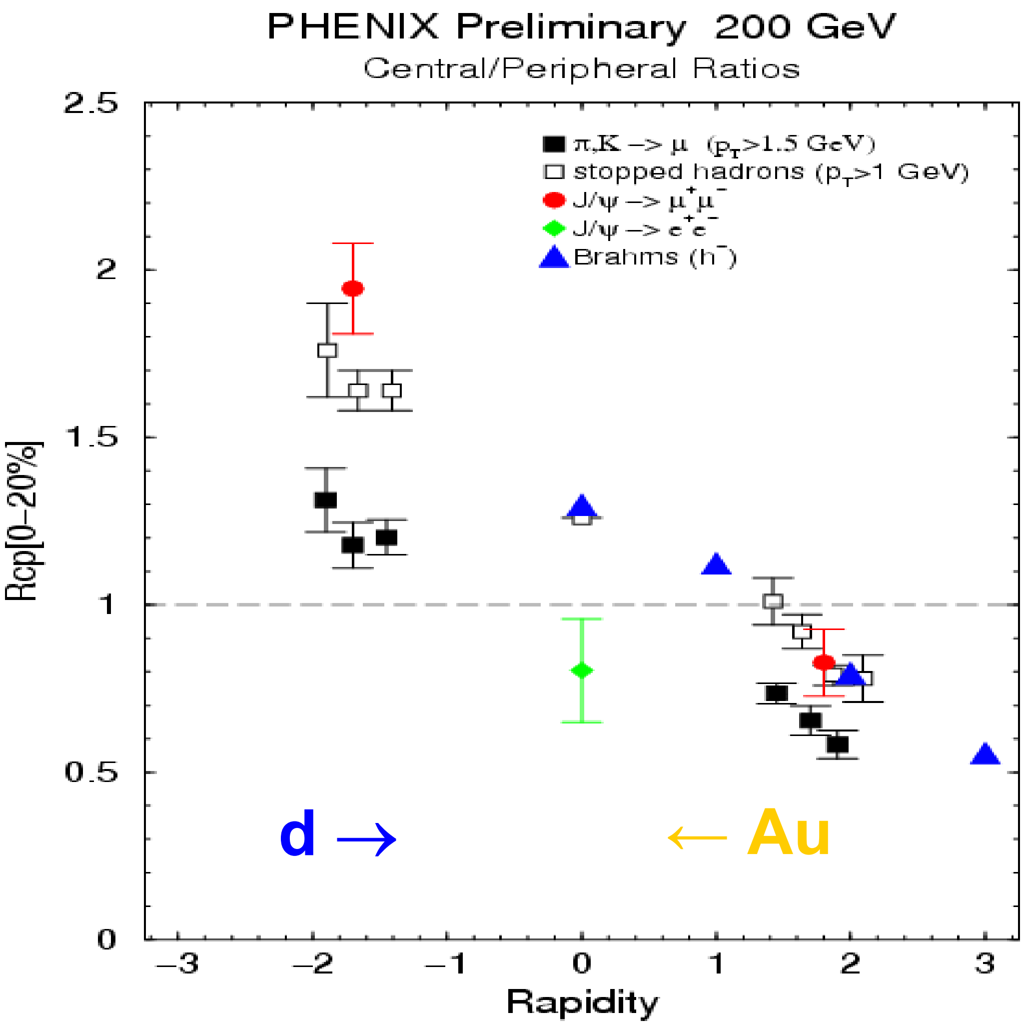
Direct measurement via γ-e coincidences

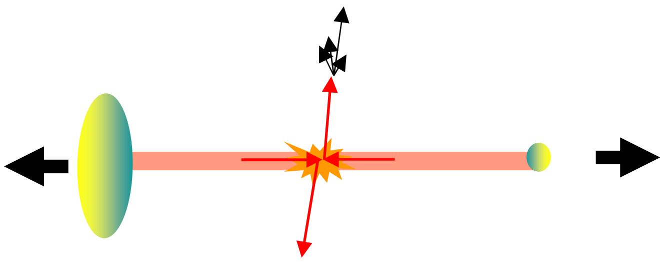
Yield of γ-e in vicinity of π η mass with mixed event subtraction.

γ-e invariant mass



R_{CP} @ QM04



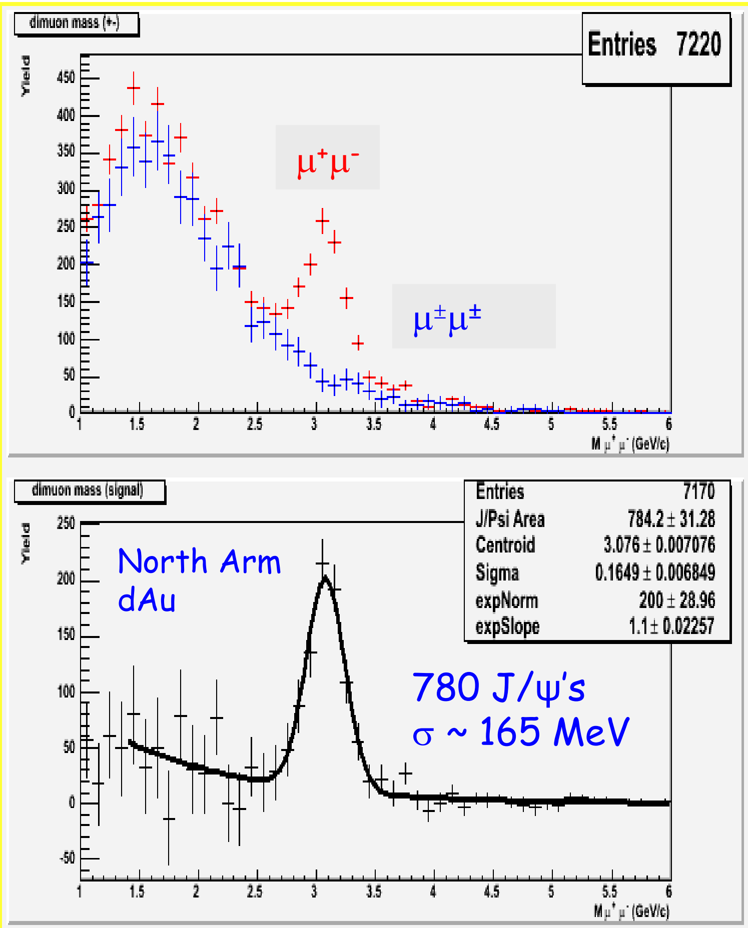


$$R_{CP} = \frac{dN^{central} / dydp_T / < N_{coll} >}{dN^{60-88\%} / dydp_T / < N_{coll} >}$$

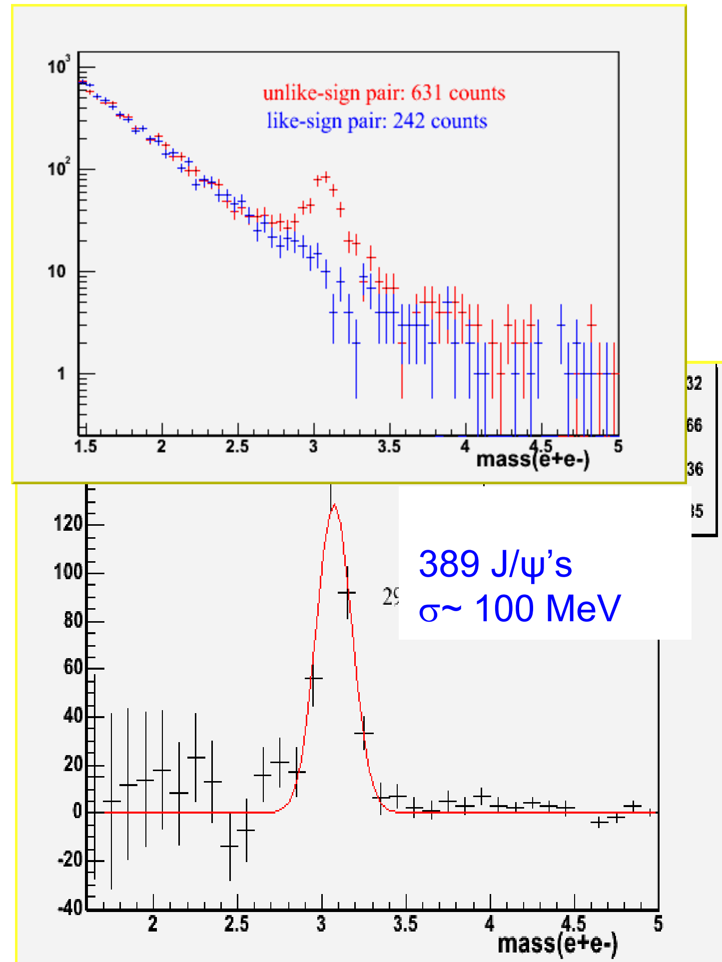
(00-20%)/(60-88%)

J/Ψ → μ+μ-/e+e- for dAu

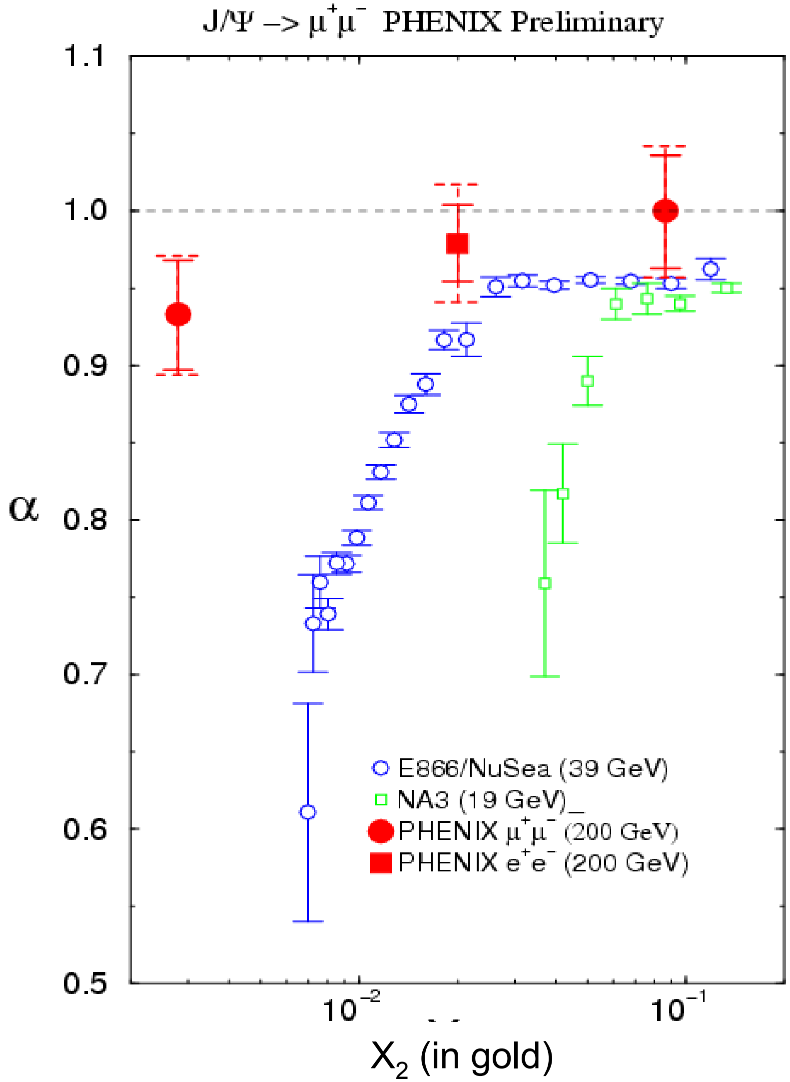
J/ψ → μ+μ-   1.2<|y|<2.4



J/ψ → e+e- |y|<0.35



Initial State Energy Loss?



- Energy loss expected to be weaker with increasing √s

(*B. Kopeliovich et al., Nuclear Physics A696(2001)669-714*)

The speculation is:

- Energy loss dominant at SPS
- Energy loss is less at E866 energy
- Energy loss negligible at RHIC

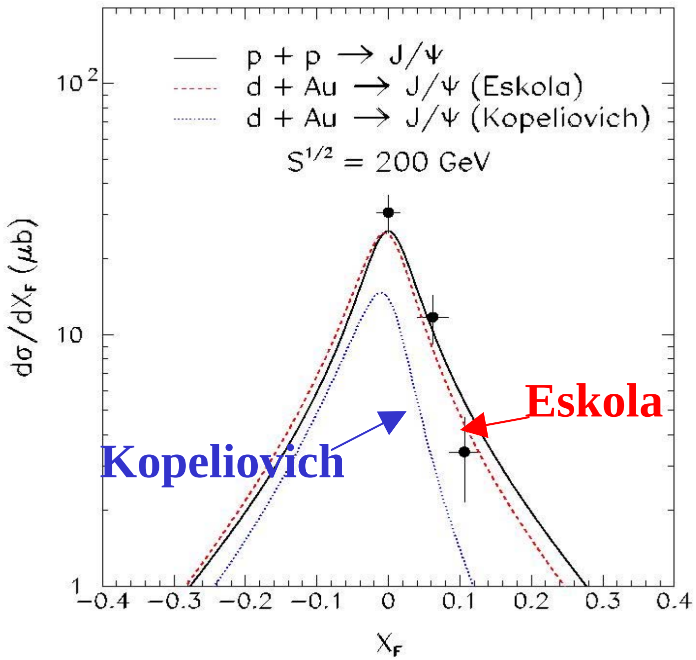
Kinematics

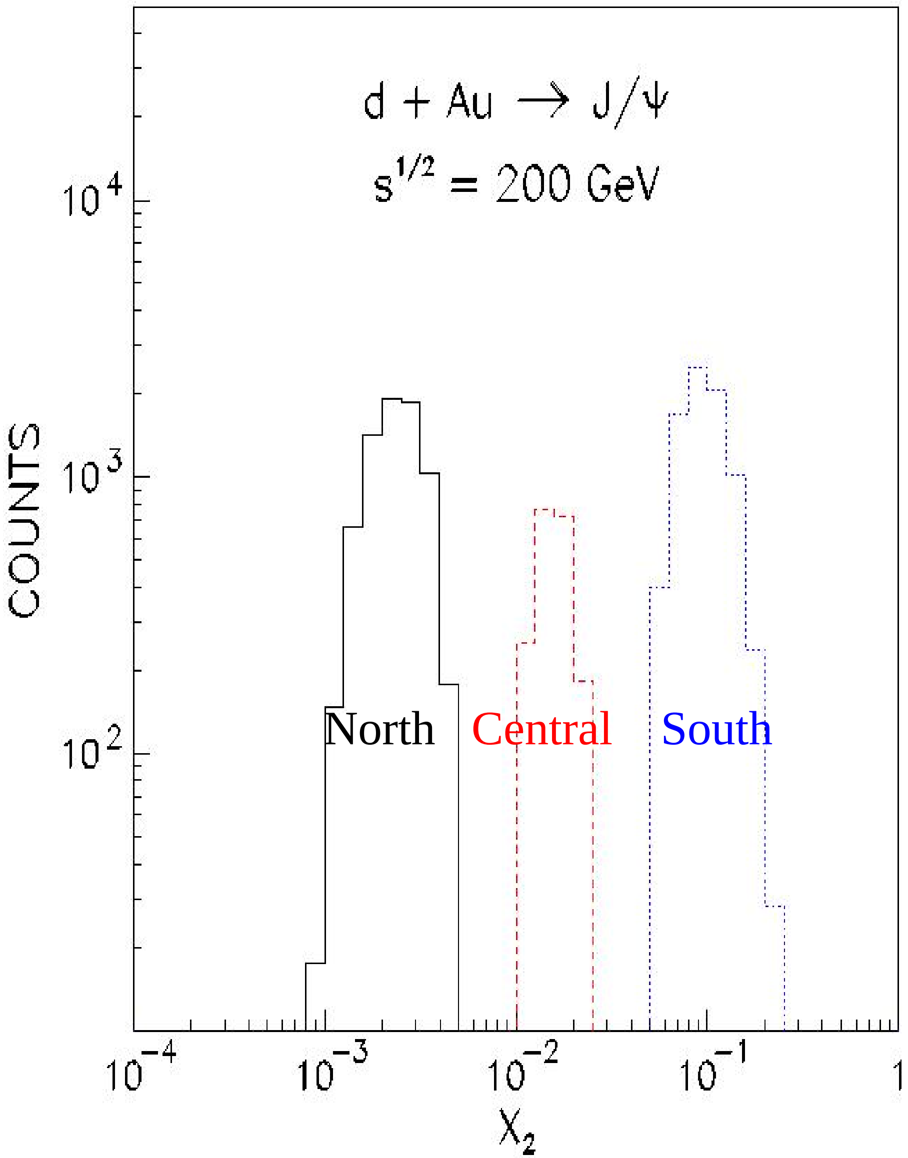
$x_F = 2*p_z/sqrt(s)$.

$\tau = m^2/s$,

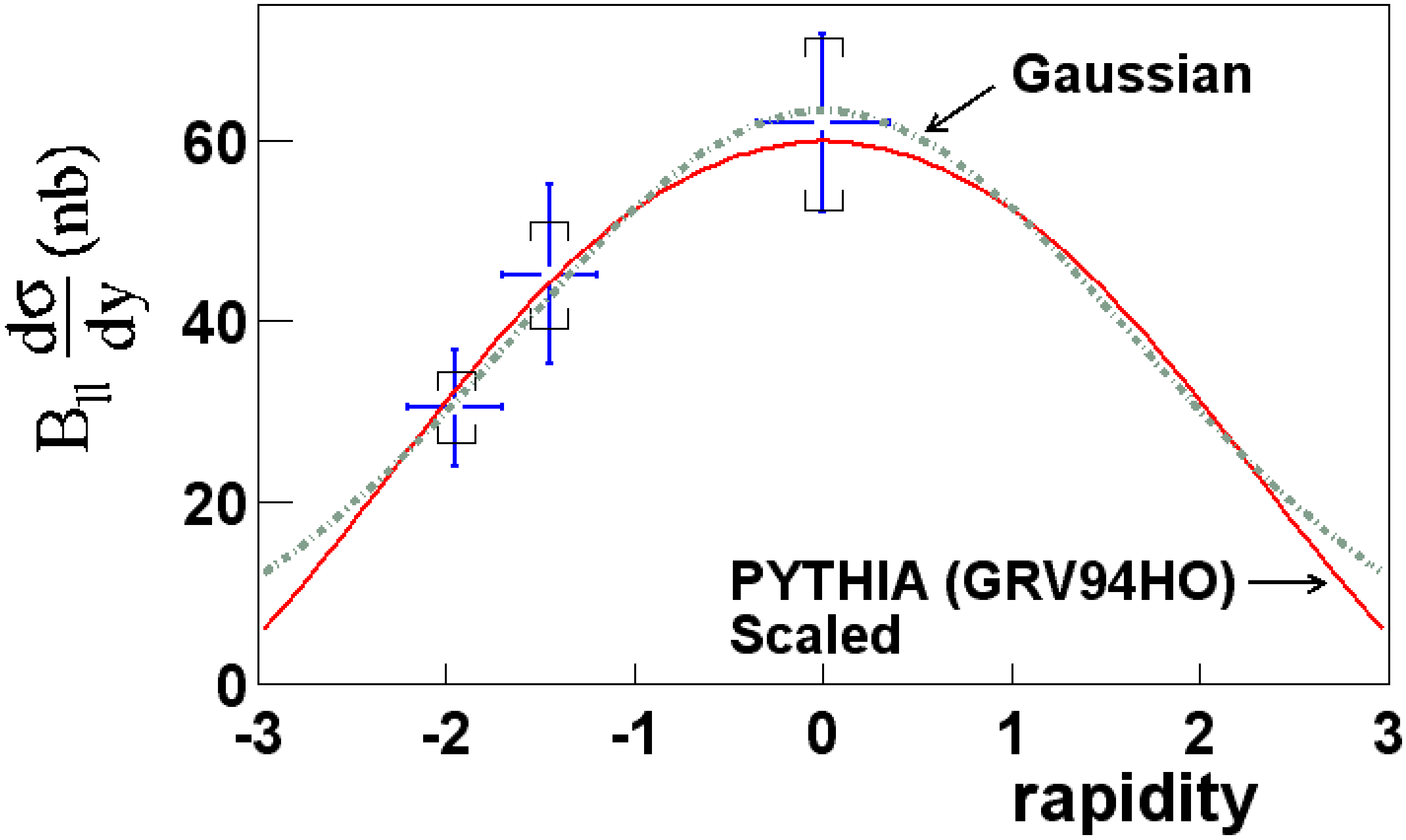
$x_1 = 1/2*(x_F+sqrt(x_F{}^2+4*\tau))$;

$x_2 = x_1 - x_F$





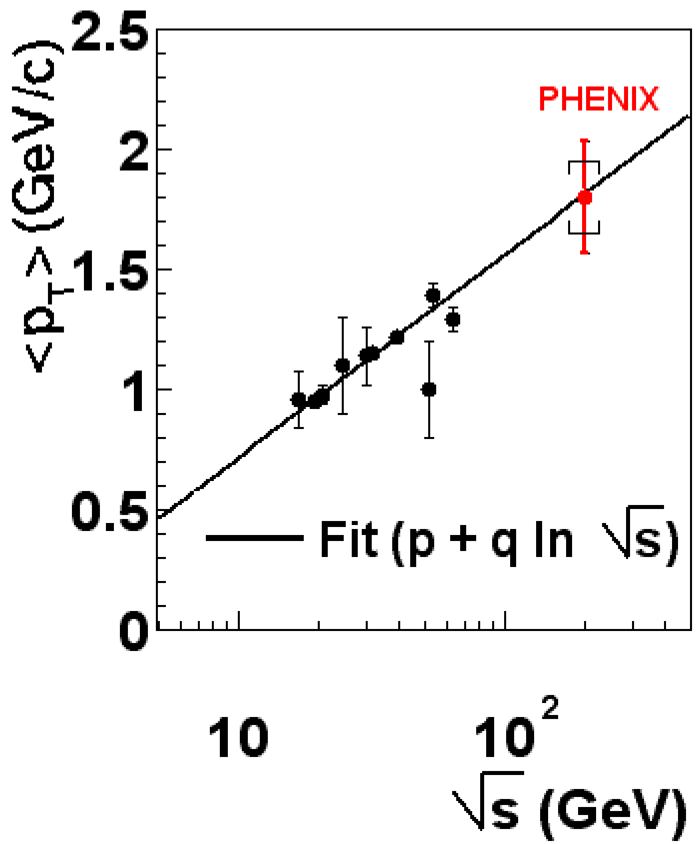
Rapidity Distribution

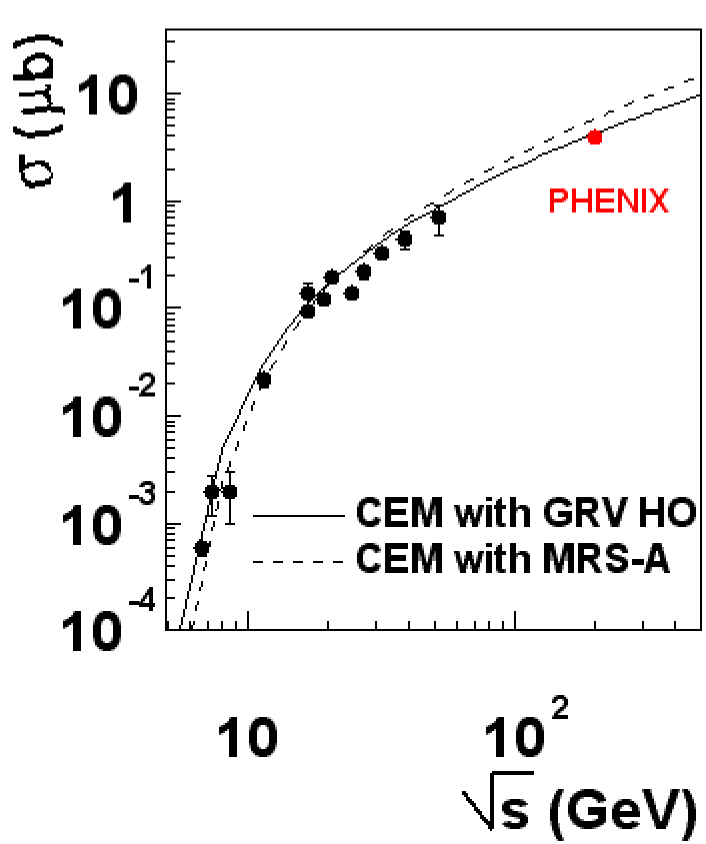


Integrated cross-section : 3.98 ± 0.62 (stat) ± 0.56 (sys) ± 0.41(abs) μb

Estimated B decay feed down contribution : < 4% (@ 200 GeV)

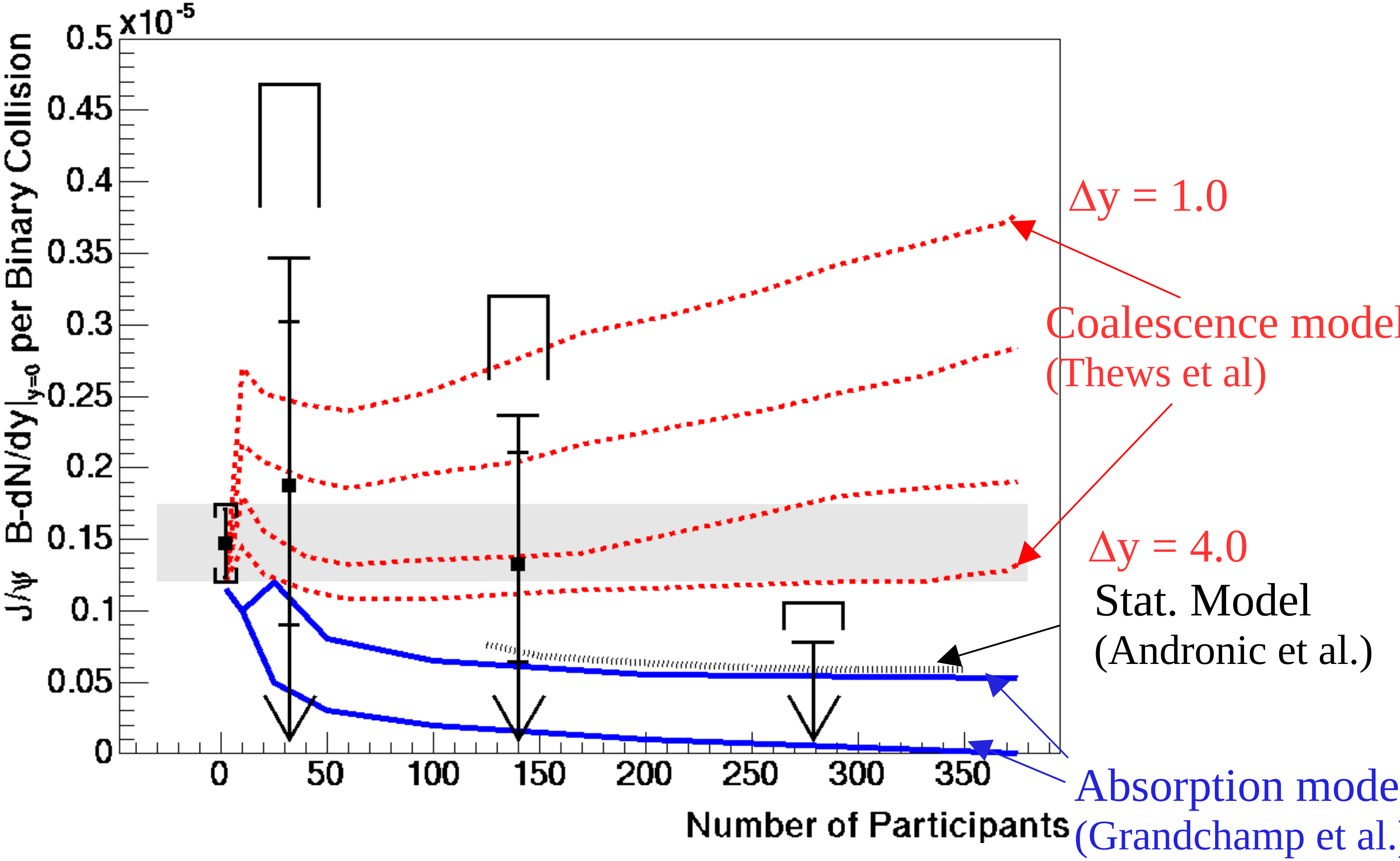
Comparisons with other Experiments





Phenomenological fit for average p_T; p = 0.531, q= 0.188
Cross-section well described by e.g. Color Evaporation Model.

Model Comparisons



Disfavor models with enhancement relative to binary collision scaling. Cannot discriminate between models that lead to suppression relative to binary collision scaling.

RHIC History

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 62 GeV	~240 ub^{-1} ~9 ub^{-1}	Central + 2 muon arms	? ?

[1] nucl-ex/0305030, Phys. Rev. C 69, 014901 (2004).
[2] hep-ex/0307019, Phys. Rev. Lett. 92, 051802 (2004)

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

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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

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University of Colorado, Boulder, CO
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Iowa State University and Ames Laboratory, Ames, IA
Los Alamos National Laboratory, Los Alamos, NM
Lawrence Livermore National Laboratory, Livermore, CA
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Vanderbilt University, Nashville, TN

*as of January 2004