# PHENIX J/Ψ Measurements at $\sqrt{s}$ = 200A GeV

**Wei Xie**
*UC. RiverSide*
For PHENIX Collaboration

# Outline

- ∀ Motivation of $J/\psi$ measurement.
- ∀ PHENIX ability to measure $J/\psi$
- ∀ PHENIX $J/\psi$ results in RUN2002
- ∀ Status of ongoing analysis
- ∀ PHENIX readiness to study $J/\psi$ in d-Au collision

# Motivation

**When Quark-Gluon plasma (QGP) is formed:**

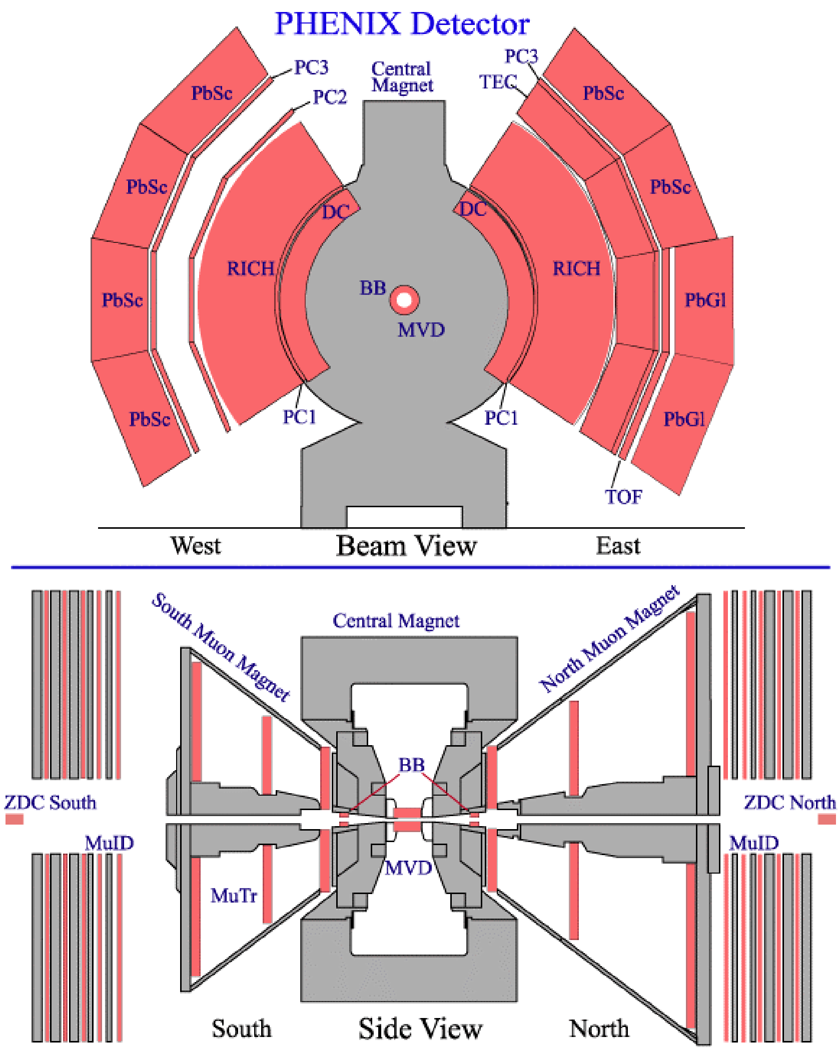
Color screening will lead to suppression of charmonium production in heavy ion collisions.

More recent predictions of increased J/Ψ production at RHIC from recombination..

**A promising signal for the observation of QGP**

# PHENIX Ability to Measure J/ψ

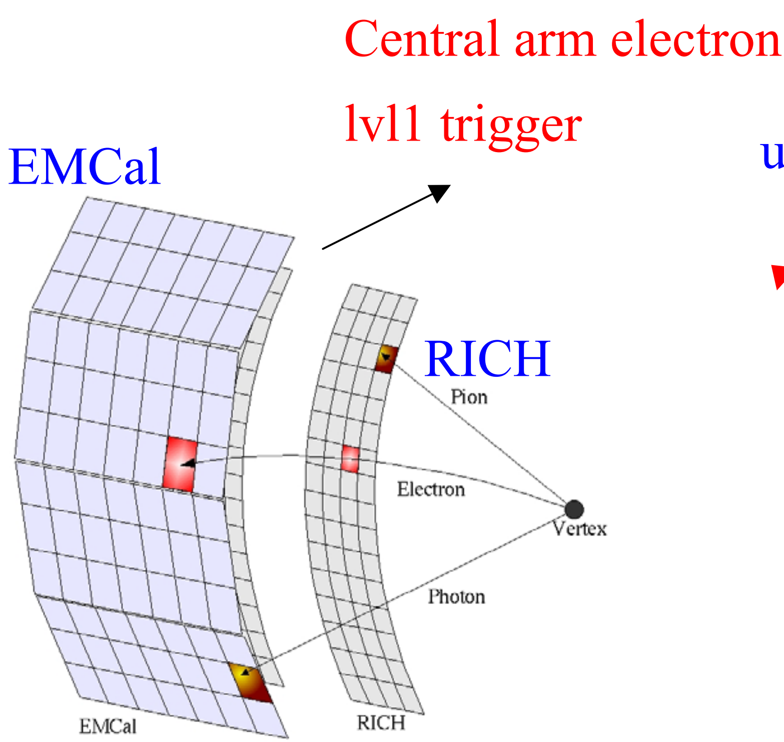
## -- electron and muon measurenent

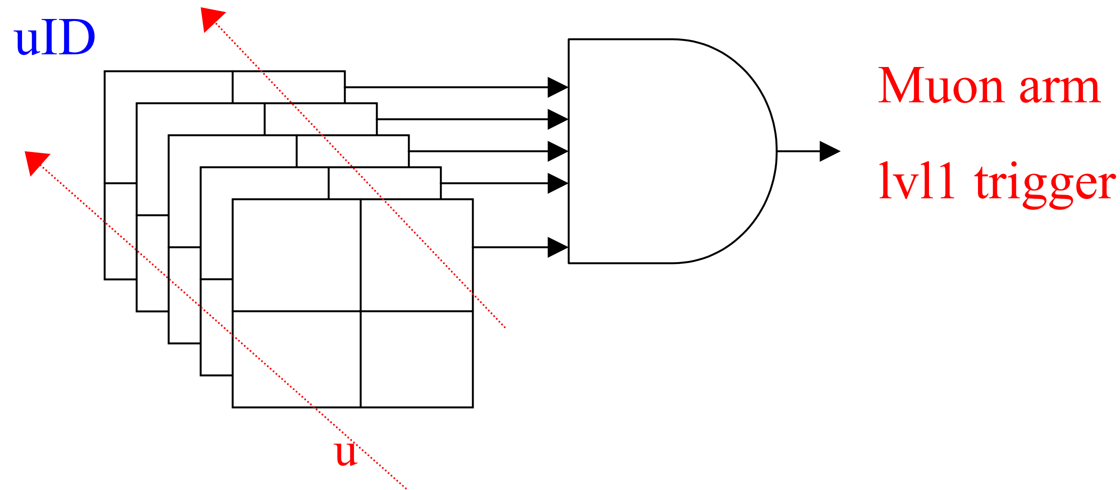



- ∀ high resolution tracking and momentum measurement from Drift chamber.
- ∀ Good electron identification from Ring Imaging Cherenkov detector (RICH) and Electromagnetic Calorimeter (EMCal).
- ∀ Good momentum resolution and muon identification from μID and μTrk.

# PHENIX Ability to Measure J/Psi

## *-- Level-1 and Level-2 triggers*



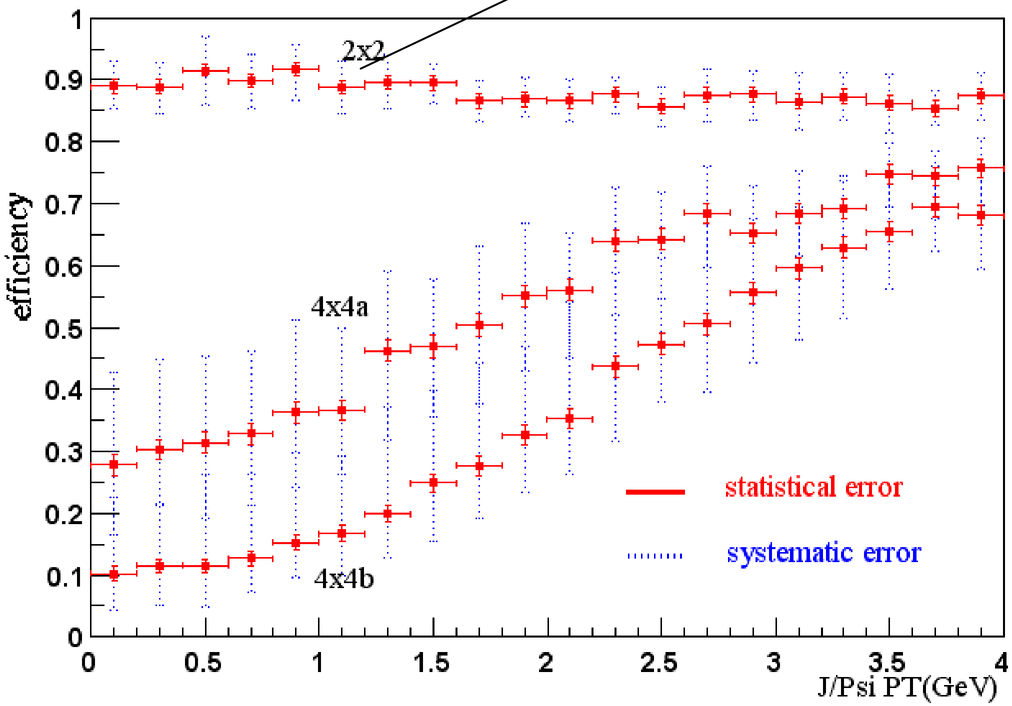




*** Software level-2 trigger enables us to further select Interesting events.**

# J/ψ to lepton pairs in RUN2002 p-p collision

*(I). Central Arm J/Psi Trigger performance*

J/ψ trigger = minimum bias&2x2 pmt "tile"




Minimum Bias Trigger (+ offline vertex cut)

$BB \geq 1$ and $|Z| \leq 35$ cm

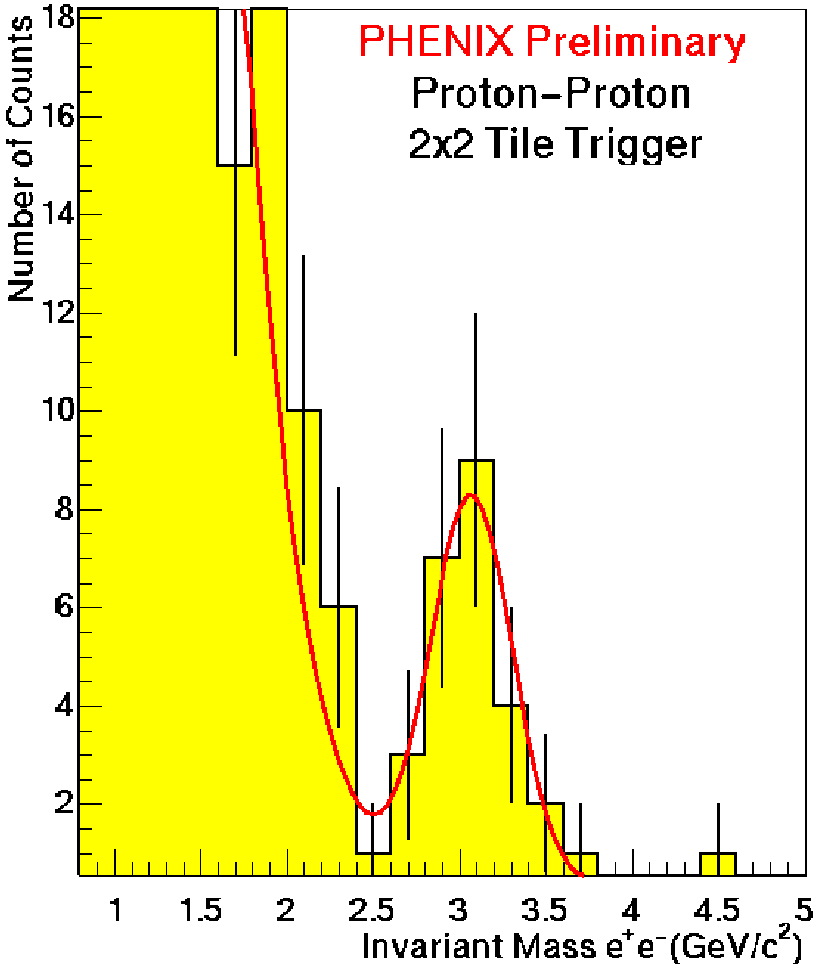
where $BB \geq 1$ means at least one hit in each Beam-Beam counter is required .

2x2 Level 1 Trigger: EMCal > 700 MeV in any 2x2 PMT "tile" ie. we use a single electron trigger with a 700 MeV threshold as our J/Ψ trigger.

Only 2x2 trigger is used in QM analysis. In the final analysis, we also benefit from the 4x4 trigger.

# J/ψ to lepton pairs in RUN2002 p-p collision

*(II). Signal in electron channel*



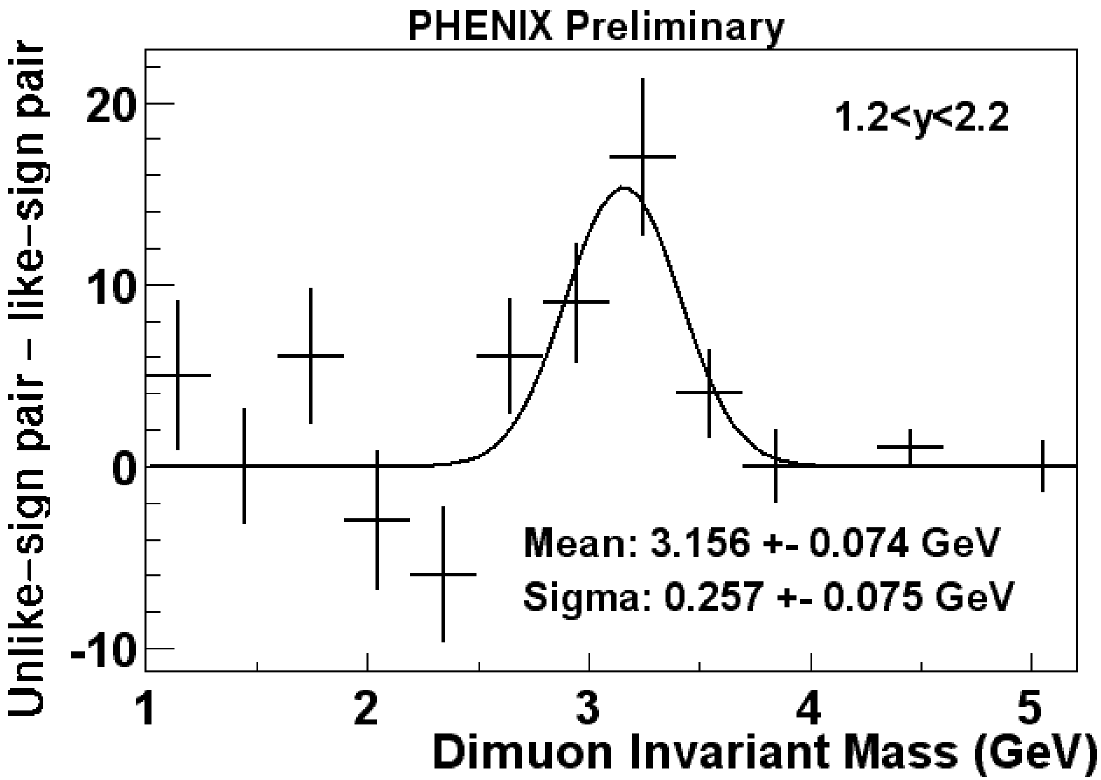

QM2002 result.

Only 2x2 pmt "tile" trigger is used for the analysis.

Total sampled minimum-bias events 48 $nb^{-1}$ (1.0x10^9)

**$N_{J/\Psi}$ = 24 ± 6 (stat) ± 4 (sys)**
**Bdσ/dy = 52 ± 13 (stat) ± 18 (sys) nb**

# J/ψ to lepton pairs in RUN2002 p-p collision
## *(III). Signal in Muon channel*




QM2002 results

J/Ψ trigger = minimum bias & level 1
Muon level-1 trigger efficiency is 62%

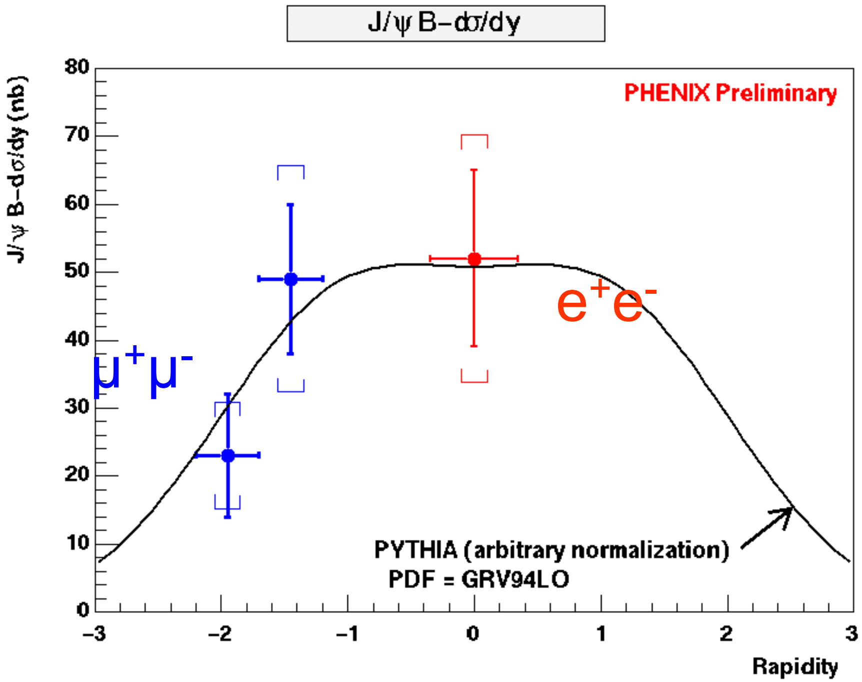
Total sample minimum-bias events:
81 $nb^{-1}$ (1.7x10^9)

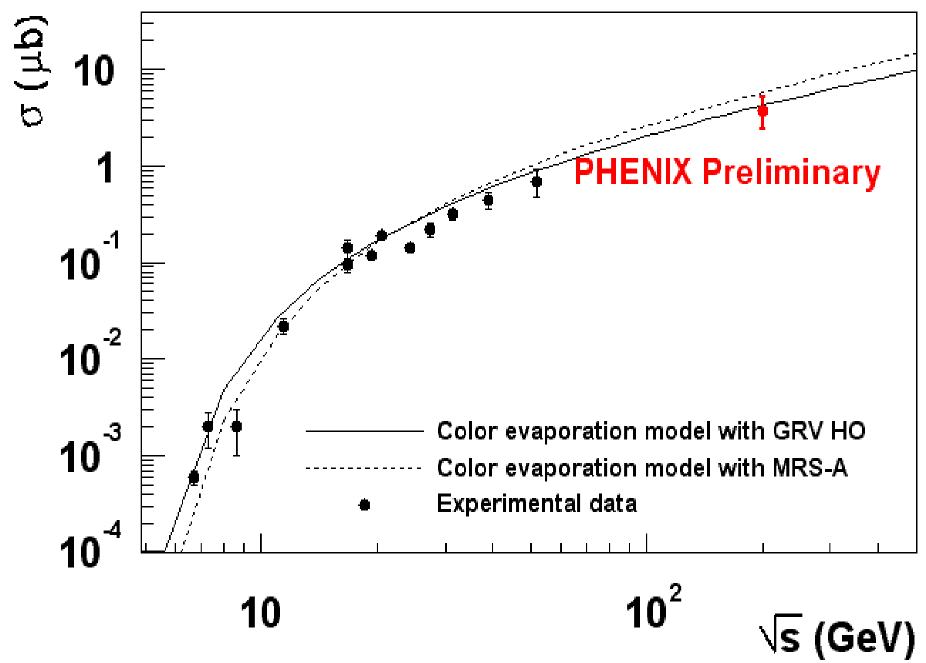
**1.2 < y < 1.7 $N_{J/\Psi}$ = 26 ± 6 ± 2.6 (sys)**
**B dσ/dy = 49 ± 11 ± 14 (sys) nb**

**1.7 < y < 2.2 $N_{J/\Psi}$ = 10 ± 4 ± 1.0 (sys)**
**B dσ/dy = 23 ± 9 ± 7 (sys) nb**

# J/ψ to lepton pairs in RUN2002 p-p collision

## *(IV) J/ψ rapidity distribution and total cross section*



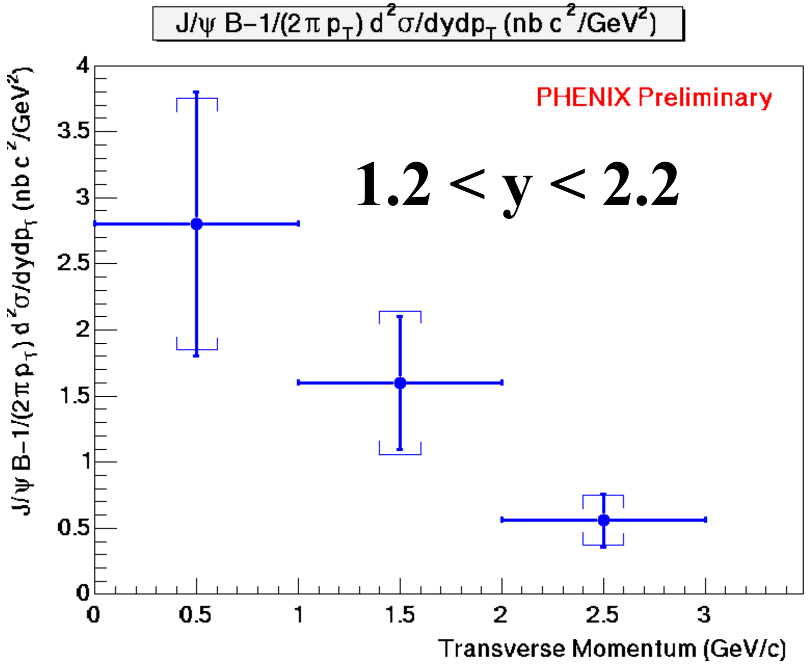

Br (J/ψ→$l^+l^-$) σ (p+p→J/ψX)
= 226 ± 36 (stat.) ± 79 (sys.) nb

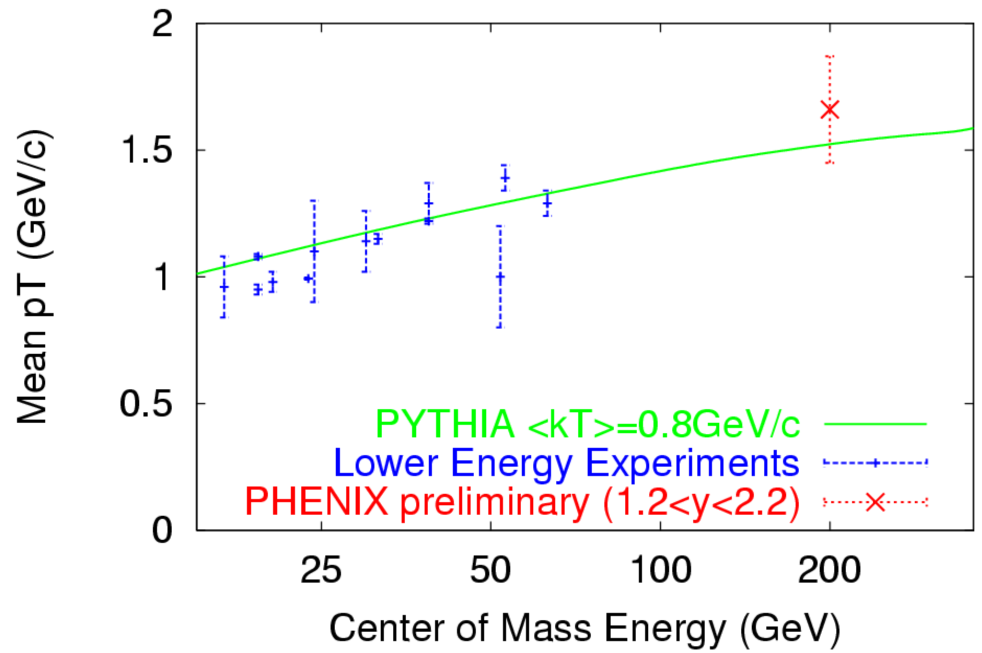
σ (p+p→J/ψX)
= 3.8 ± 0.6 (stat.) ± 1.3 (sys.) μb

- Our result agrees with the color evaporation model prediction at √s=200 GeV
- Reference data for Au+Au

# J/ψ to lepton pairs in RUN2002 p-p collision

## *(IV) J/ψ* Transverse Momentum Distribution




- Our result of $\langle p_T \rangle$ is slightly higher than lower energy experiments
- Our result is consistent with PYTHIA prediction including $\langle k_T \rangle$ tuned to reproduce $\langle p_T \rangle$ and $p_T$ spectrum of E672/E706 experiments at $\sqrt{s} = 39$ GeV (Phys. Rev. D62, 012001)

# J/ψ to Electron Pairs in RUN2002 Au-Au Collision

## *(I). J/ψ Trigger*

J/Ψ trigger = minimum bias & level 2

Minimum Bias Trigger (+ offline vertex cut)

$BB \geq 2$ and $|Z| < 30$ cm

where $BB \geq 2$ means at least two hits in each Beam-Beam counter required .

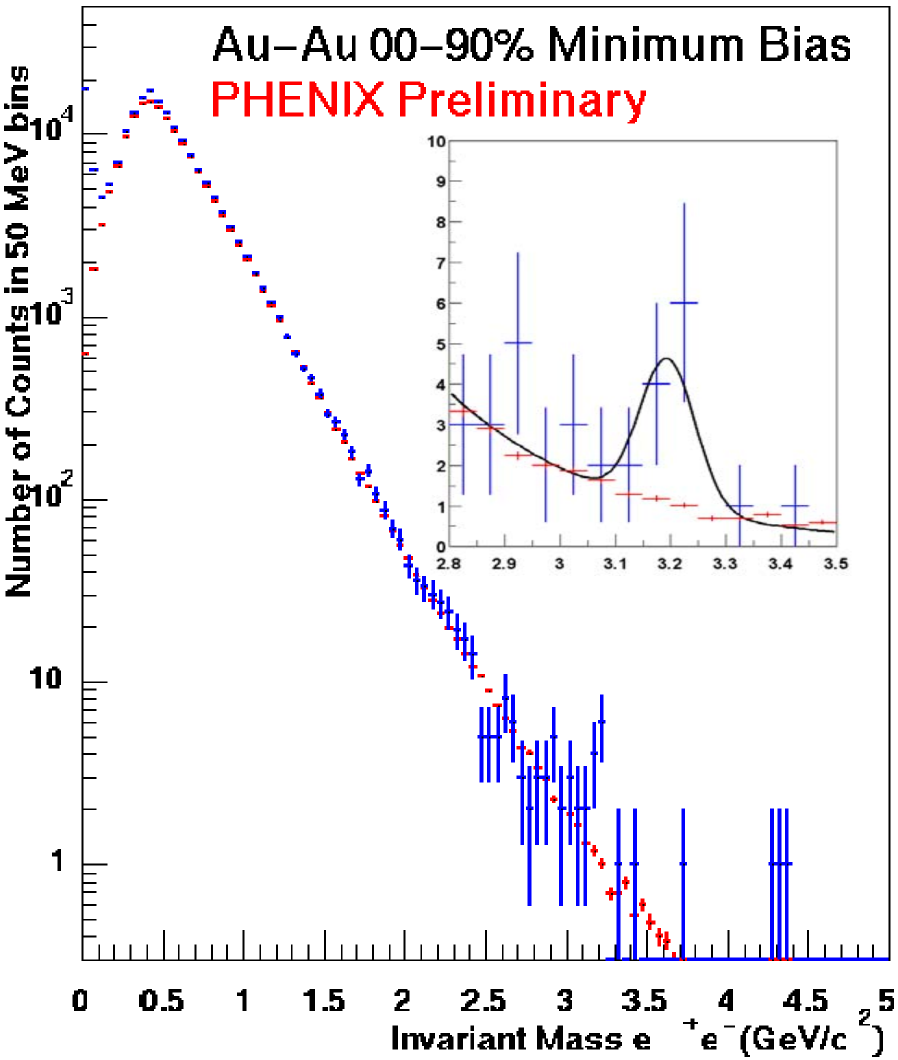
Level 2 Trigger

Loose RICH/EmCal match to get electron candidates
Require $\geq$ 300 MeV in EMCal for electron candidates
Require a confirming hit in Pad Chamber 3
Calculate invariant mass of all electron pairs
Require invariant mass $\geq$ 2.2 GeV/c

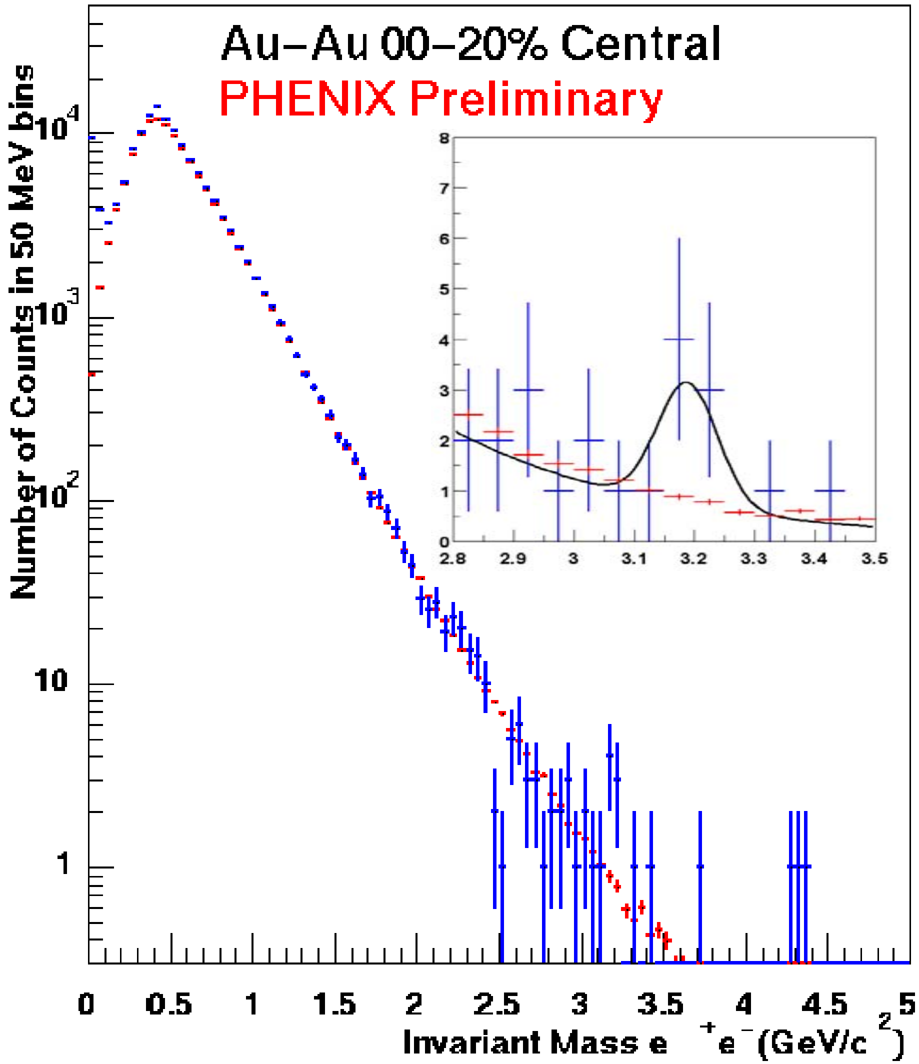
# J/ψ to Electron Pairs in RUN2002 Au-Au Collision

## *(II). J/ψ Signal*

$N_{J/\Psi} = 10.8 \pm 3.2$ (stat) $+ 3.8 - 2.8$ (sys)

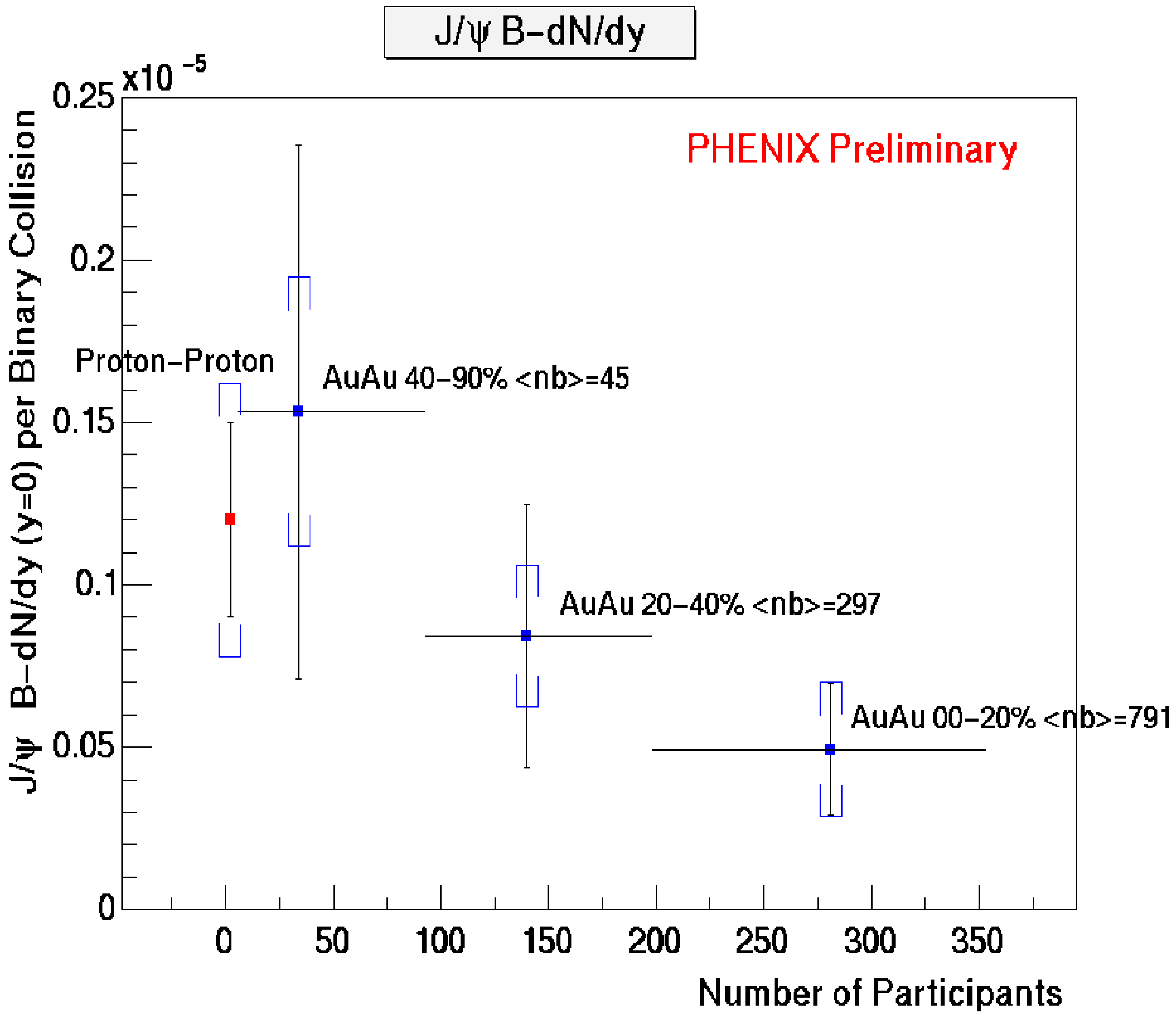



$N_{J/\Psi} = 5.9 \pm 2.4$ (stat) $\pm 0.7$ (sys)



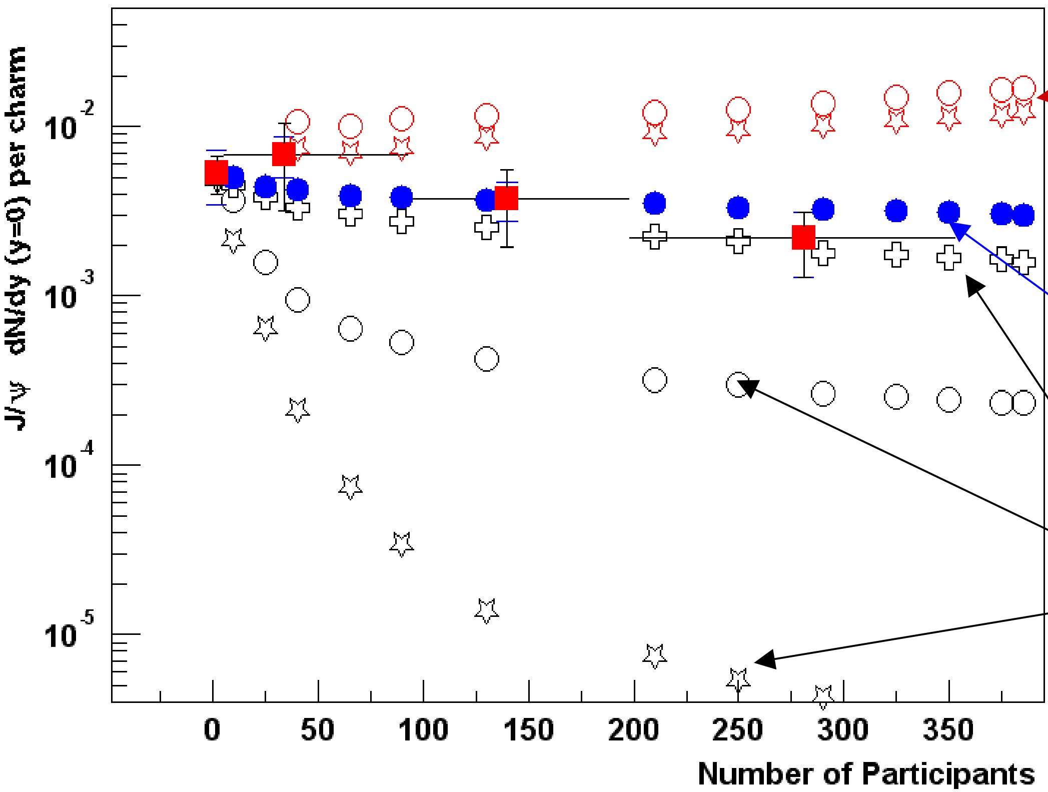
# J/ψ to Electron Pairs in RUN2002 Au-Au Collision

## *(III). Centrality Dependence*



# Comparison with Models

PHENIX J/ψ pp data normalized to the model for most peripheral collisions.




Calculation including coalescence. Assumes thermal distribution of all cc with approximately 10 cc per central event.

Normal nuclear absorption only

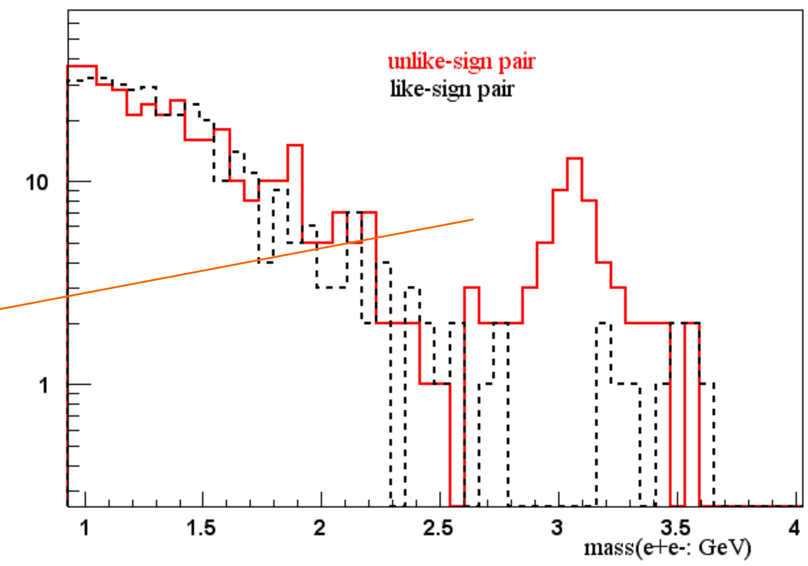
**Calculation with only suppression from plasma with different temperatures**

Coalescence model can not explain PHENIX data. They used a very narrow rapidity distribution compared to the PHENIX measurement

# Ongoing Analysis

**Electron pairs in p-p collision:**

Analysis of J/Ψ pt distribution in central arm using improved tracking and all level-1 triggered events is almost finished. We gain nearly a factor of two signals




**Muon pairs in p-p collision:**

re-do the analysis with improved tracking efficiency and optimised software. We gain about 70% more J/ψ.

**Au-Au collision**:

Additional data from level-2 trigger event will double yields

# We Need Results from p-A

To probe QGP via A-A collision, we need to understand nuclear effect through p-A collisions.

Normal nuclear absorption

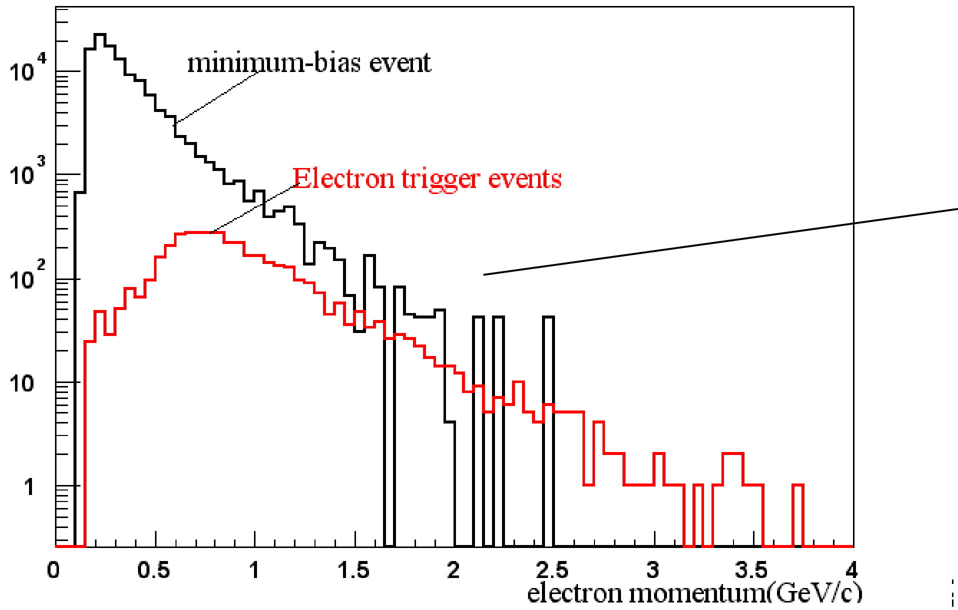
Gluon shadowing. Important for RHIC experiment, i.e. $x \sim 10^{-2}$.

Some conventional models[*]claim to be able to explain existing $J/\psi$ suppression results.

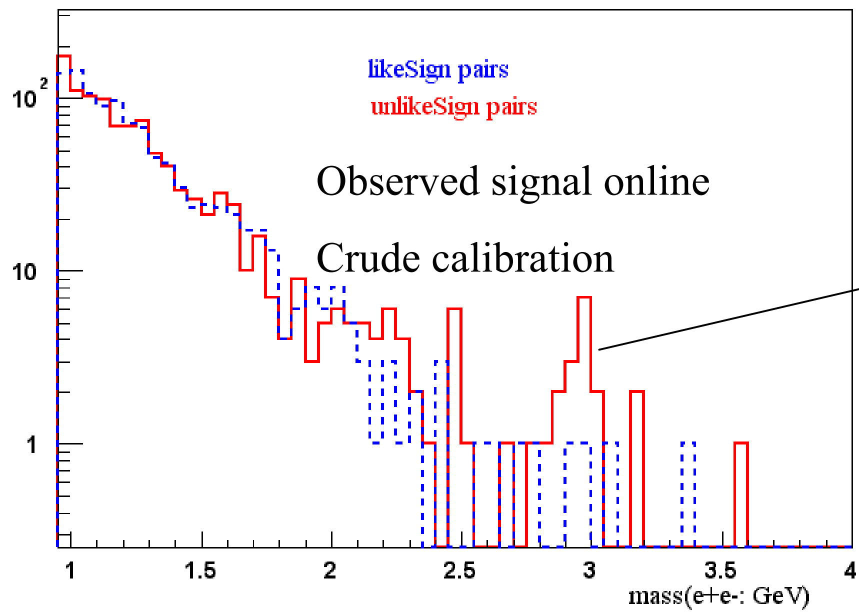
We need to measure the effect.

* A.K. Chaudhuri, 88(2001)232302

# Activities in RUN3 d-Au Collision




PHENIX has a working level-1 electron trigger from the combination of EMCal and RICH.




PHENIX has seen J/ψ signal in d-Au collisions and expects to get a few thousands J/ψ at the end of the run.

# Summary

PHENIX has measured J/Ψ yields at $\sqrt{s}$ = 200A GeV for:

pp -> ee and AuAu -> ee in $-0.35 < \eta < +0.35$

pp -> μμ in $1.2 < \eta < 2.4$

Final results from more detailed analysis will come out very soon.

PHENIX is accumulating data from run2003 200A GeV d-Au collisions to get more J/y.

We also expect to have much more p-p data in RUN3

**Backup Slide**

# Calculating p-p → J/Ψ → ee Yields

$$B_{ee}\, d\sigma/dy_{|y=0} = \frac{N_{J/\Psi}^{true}\ \sigma_{inelastic}}{N_{events}^{true}\ A\ \varepsilon\ dy}$$

$A\ \varepsilon$ = acceptance Δ (J/Ψ reconstruction eff. Δ level 1 trigger eff.)

$A\ \varepsilon\ dy$ = 0.0128 ± 17.5% (sys)

$N_{J/\Psi}^{true} = N_{J/\Psi}^{measured}$/( J/Ψ fraction sampled by MB trigger )

$= N_{J/\Psi}^{measured}$/( 0.75 ± 0.11 (sys) )

$N_{events}^{true} = N_{events}^{measured}$/(fraction of 42 mb sampled by MB trigger )

$= N_{events}^{measured}$/( 0.51 ± 0.10 (sys) )

$N_{events}^{measured}$ = (BBCLL1≥1, |Z|≤35 cm) Δ level 1 = 1.037 Δ $10^9$

**Combined systematic = 35%**

# Calculating p-p $\rightarrow J/\Psi \rightarrow \mu\mu$ Yields

$$B_{\mu\mu}\, d\sigma/dy_{|y=0} = \frac{N_{J/\Psi}^{true}\ \sigma_{inelastic}}{N_{events}^{true}\ dy\ A\ \varepsilon}$$

$N_{J/\Psi}^{true} = N_{J/\Psi}^{measured}$/( $J/\Psi$ fraction sampled by MB trigger )

$= N_{J/\Psi}^{measured}/(\ 0.75 \pm 0.11$ (sys) )

$N_{events}^{true} = N_{events}^{measured}$/(fraction of 42 mb sampled by MB trig )

$= N_{events}^{measured}/(\ 0.51 \pm 0.10$ (sys) )

$N_{events}^{measured}$ = (BBLL1$\geq$1 with $|Z|<38$ cm) $\Delta$ level 1 = $1.72 \pm 0.09 \times 10^9$

$A\ \varepsilon$ = acceptance $\Delta$ ($J/\Psi$ reconstruction eff. $\Delta$ level 1 trigger eff.)

$A\ \varepsilon\ \Delta\ (0.75 + 0.11)$ $= 0.0131 \pm 3\% \pm 19\%$ for $y = 1.45$, $dy = 0.5$

$= 0.0108 \pm 3\% \pm 19\%$ for $y = 1.95$, $dy = 0.5$

Combined systematic on $B_{\mu\mu}\, d\sigma/dy = 29\%$

# $J/\Psi \rightarrow ee$ Analysis for Au Au Data

$$B_{ee}\, d\sigma/dy_{|y=0} = \frac{N_{J/\Psi}^{true}\ \sigma_{inelastic}}{N_{events}^{true}\ A\ \varepsilon\ dy}$$

dy A ε = acceptance Δ J/Ψ reconstruction eff. Δ centrality dependence

dy A ε = 0.00407 ± 0.0009 Δ 0.65 ± 0.07 (00-20%)
0.76 ± 0.08 (20-40%)
0.86 ± 0.09 (40-90%)

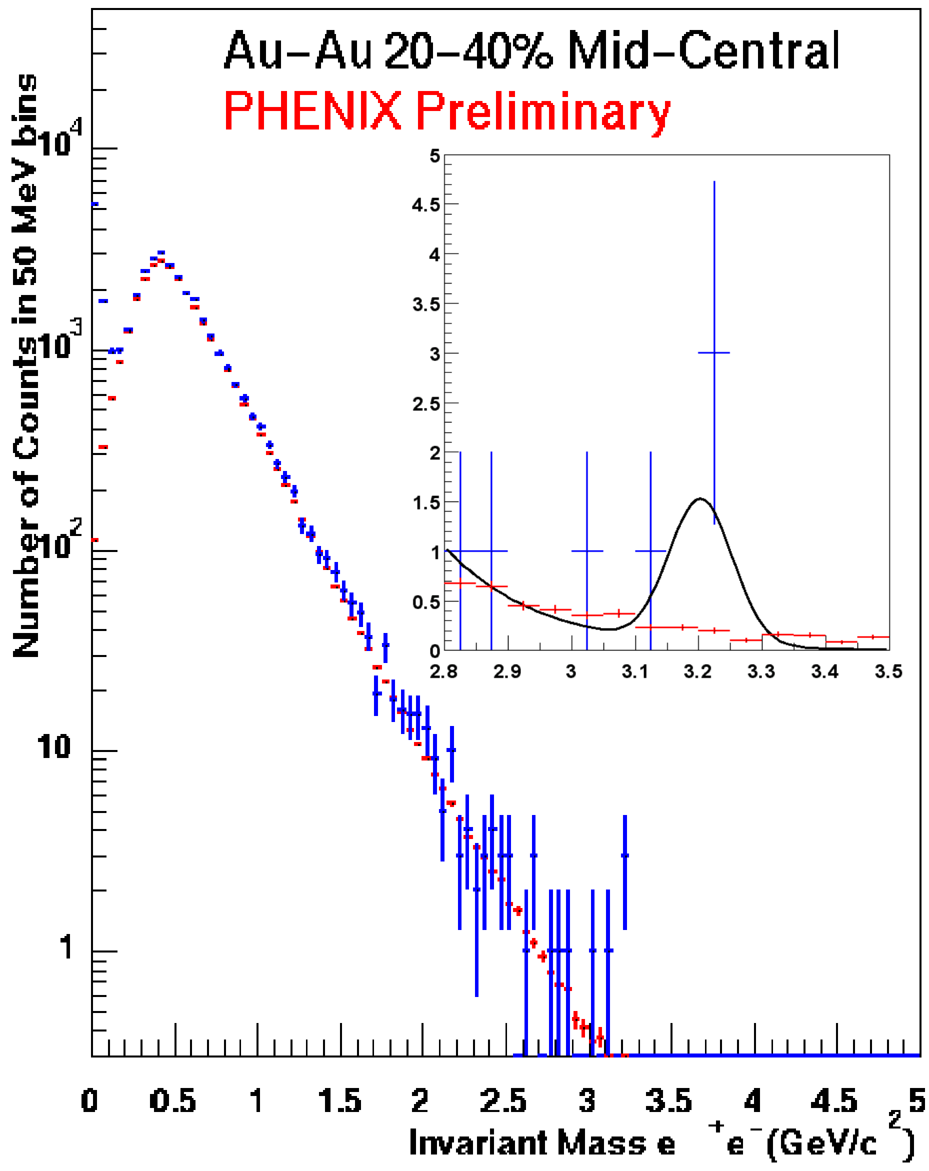
$N_{J/\Psi}^{true} = N_{J/\Psi}^{measured}$ (within 0-90% centrality)

$N_{events}^{true} = N_{events}^{measured}$ = minbias events in the centrality bin
= 25,902,950 Δ (centrality bin width in %) / 90%

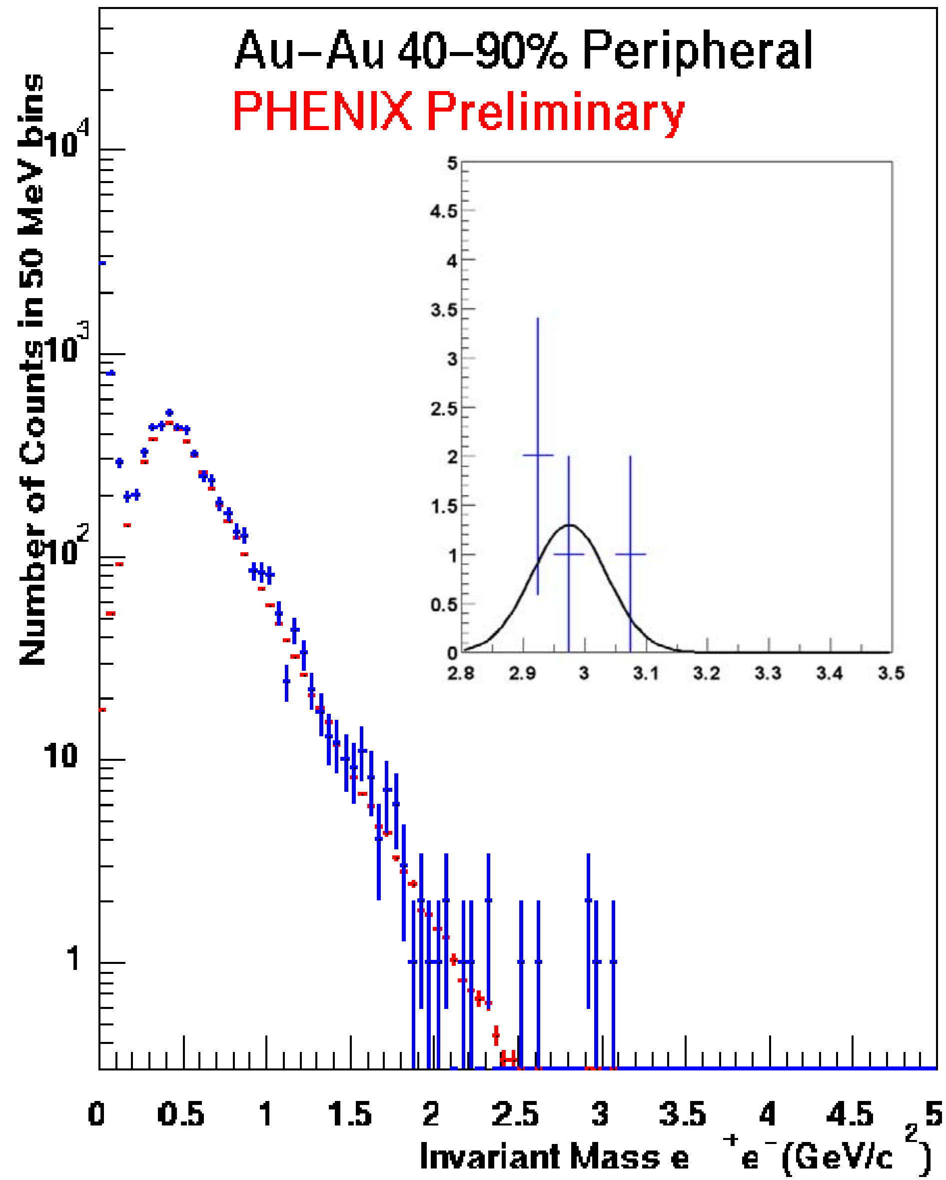
$N_{J/\Psi}^{measured}$ extracted using 7 different fitting procedures to establish systematic errors

# Au-Au → ee Invariant Mass Spectra

$N_{J/\Psi} = 4.5 \pm 2.1\ (stat) \pm 0.5\ (sys)$




$N_{J/\Psi} = 3.5 \pm 1.9\ (stat) \pm 0.5\ (sys)$



# Prediction from Kopeliovich, et al

At RHIC the energy-loss correction is gone, but gluon shadowing is expected to be a tremendous effect.

$$R(x_f) = \frac{d\sigma^A / dx_f}{A \cdot \left( d\sigma^N / dx_f \right)} = A^{\alpha(x_f)}$$

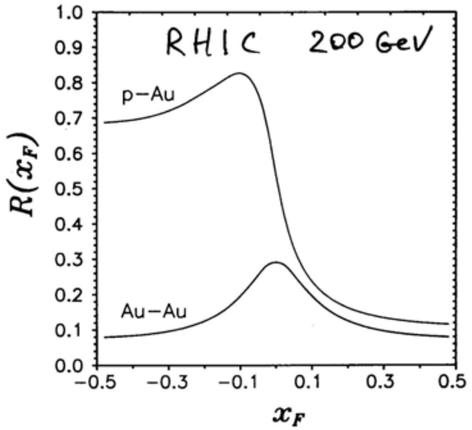



Figure 11: *Nuclear suppression of $J/\Psi$ production in proton-gold collisions at $\sqrt{s} = 200\,GeV$ as function of $x_F$ (the upper curve) and in gold-gold collisions (bottom curve). Effects of quark and gluon shadowing and gluon antishadowing are included.*

# PHENIX RUN Plan

| | |
|---|---|
| RUN1: | 1$\mu b^{-1}$ |
| RUN2: | 24$\mu b^{-1}$ Au-Au<br>130 $nb^{-1}$ p-p |
| RUN3: | 1 $pb^{-1}$ p-p<br>10 $nb^{-1}$ d-Au |
| RUN4: | 264-770 $\mu b^{-1}$ Au-Au<br>1-8 $pb^{-1}$ p-p |