Measurements of $J/\psi \rightarrow e^+e^-$ in Au+Au collisions at $\sqrt{s_{NN}}$=200 GeV by PHENIX at RHIC

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Outline

- Physics Motivation
- PHENIX Detectors
- Data analysis
- Signal Counting
- Invariant Yield per binary collision
- R_{AA} and theoretical models
- Invariant pT distribution
- Summary and Outlook

Physics Motivation

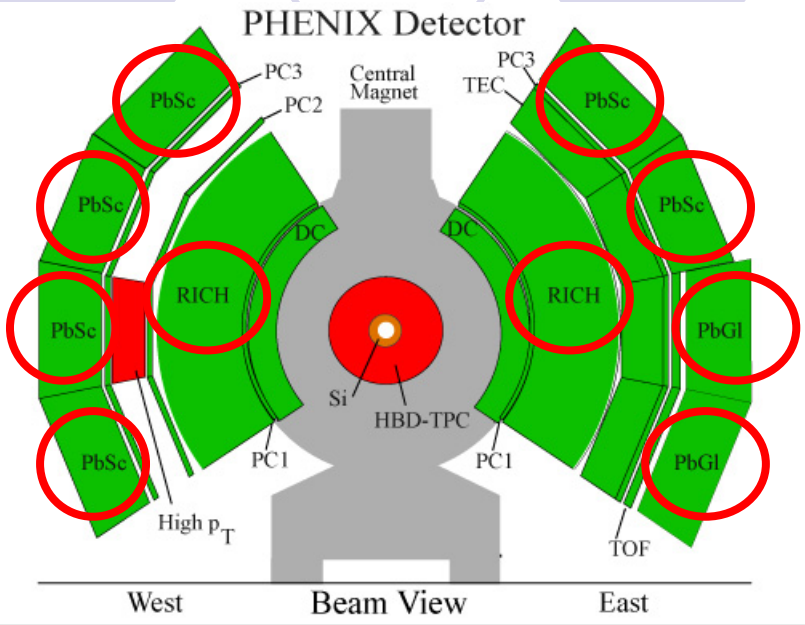
- Study the properties of hot and dense medium created by Heavy-Ion Collisions.
  - T, ε, ρ, dof, collective behavior, deconfinement,,,,

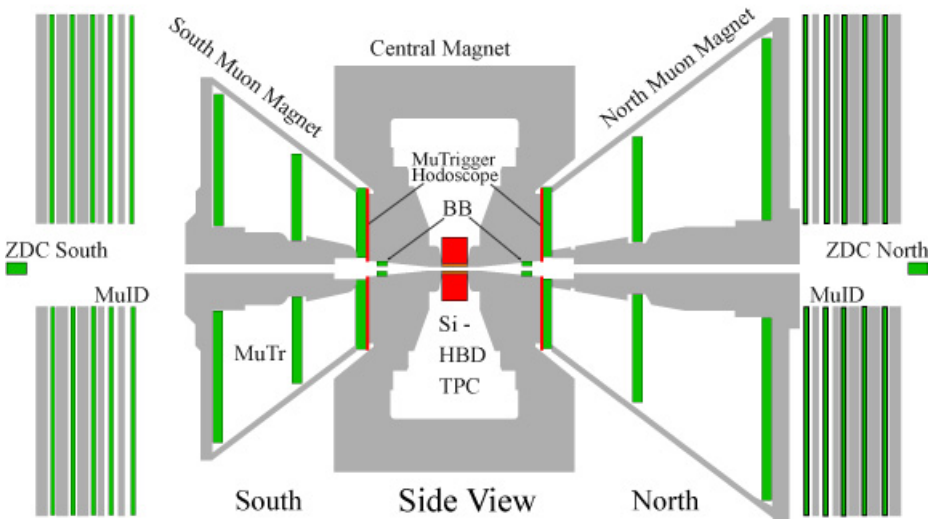
- J/ψ measurement in Heavy-Ion Collisions
  - Suppression by Debye Color Screening
    - Probe of de-confinement T. Mastui and H. Satz . PLB. 178 (1986) 416
    - Survive up to 2 *Tc* from recent lattice calculations
  - Enhancement by the recombination of uncorrelated $c\bar{c}$ pairs
    - QGP phase + statistical coalescence at hadronization
  - Non-QGP effects
    - Gluon shadowing
    - Nuclear absorption
    - Comover scattering

PHENIX d+Au J/ψ results show the nuclear absorption cross section is order1-3 mb. [nucl-ex/0507032]

PHENIX Experiment

- BBC, ZDC
  - centrality
  - z-vertex
- DC, PC1
  - momentum
- RICH
  - Electron ID
- EMCal (PbGl, PbSc)
  - Energy
  - Track Matching





Data analysis

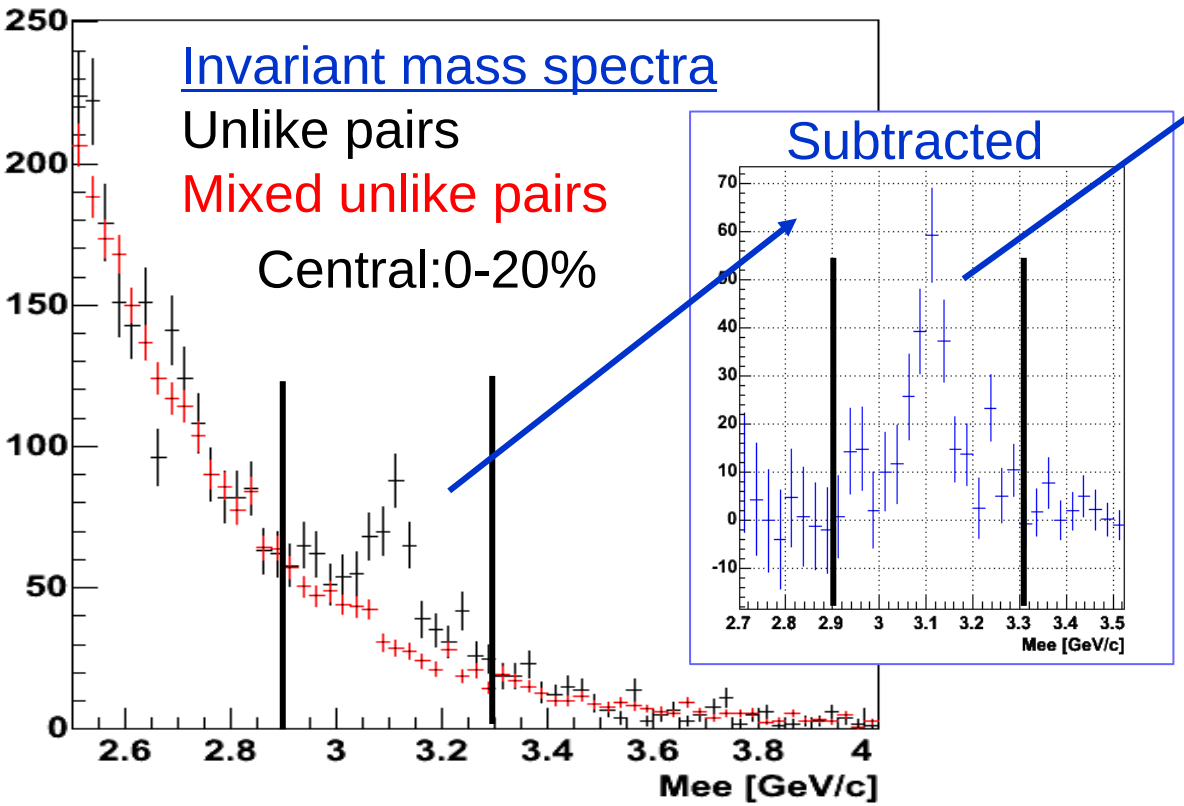
- Invariant Yield

$$B\frac{dN}{dy} = \frac{N_{J/\psi}}{N_{evt}} \times \frac{1}{\Delta y} \times \frac{1}{\epsilon_{acc} \times \epsilon_{eff} \times \epsilon_{run-by-run} \times \epsilon_{embed}}$$

- Centrality selection → N_{evt}
- Signal Counting of J/ψ → $N_{J/\psi}$
  - $e^+ e^-$ Invariant mass
  - subtract combinatorial background
- Correction factors
  - single J/ψ detection efficiency → $\varepsilon_{acc} \times \varepsilon_{eff}$
  - centrality dependence → ε_{embed}
  - Run-by-Run fluctuation of detector acceptance → $\varepsilon_{run\text{-}by\text{-}run}$

Signal counting of J/ψ

- Analyzed 760 M Minimum Bias Data
- $N_{J/\psi} = N_{ee} - N_{mixed_ee}$ (2.9 <Mee<3.3 GeV)
  - Event mixing method was used.



$N_{J/\psi}$ is counted in this mass range.

Centrality vs. $N_{J/\psi}$

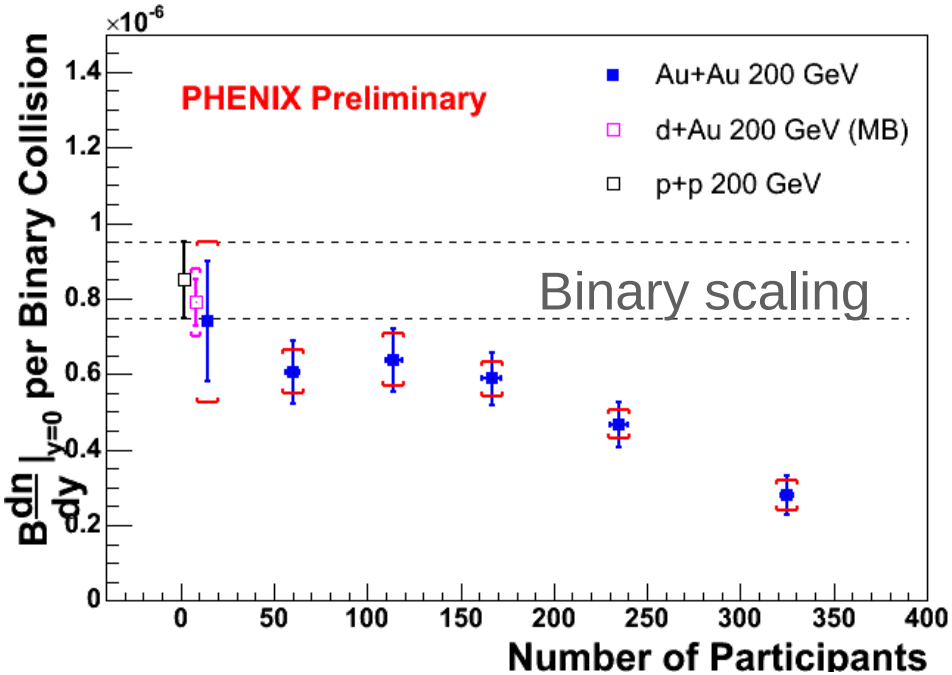
Centrality	$N_{J/\psi}$
0-10%	145.4 +- 25.3
10-20%	155.1 +- 19.2
20-30%	124.2 +- 14.7
30-40%	87.9 +- 11.1
40-60%	70.1 +- 9.6
60-92%	26.7 +- 5.4

Invariant Yield per binary collisions

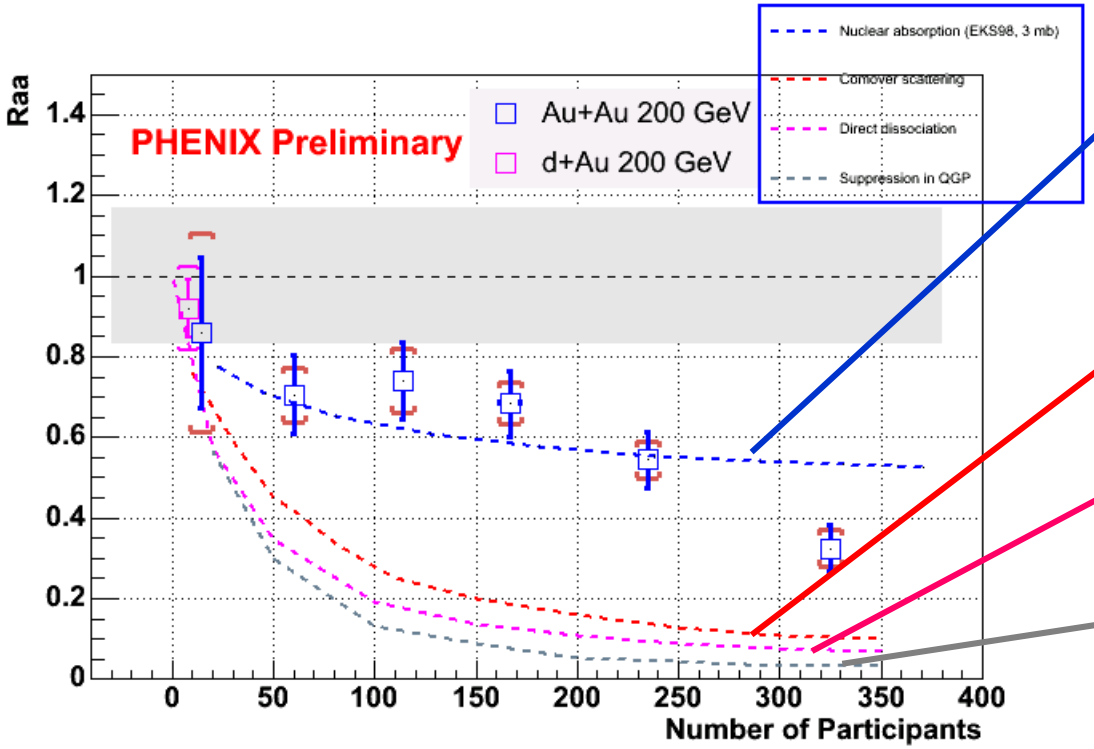
- BdN/dy per binary collisions (N_{binary})
  - 6 centrality bins. (0-10/10-20/20-30/30-40/40-60/60-92%)
  - N_{binary} from Glauber calculation. (PRL. 91. 072301)
- Comparison to p+p & d+Au results. (nucl-ex/0507032)
  - (0.86 +- 0.10) x10^{-6} (p+p), (0.79 +- 0.06) x 10^{-6} in d+Au
- J/ψ yield is suppressed.
  - For more central collisions
  - Factor 3 of suppression

  for most central collisions.

  0-10%: (0.279 +- 0.05)x10^{-6}



R_{AA} and theoretical models



Nuclear absorption + Shadowing (EKS98)

σ_{abs} = 3.0 mb

R. Vogt nucl-th/0507027

Comover scattering

Capella et.al. hep-ph/0505032

Direct dissociation

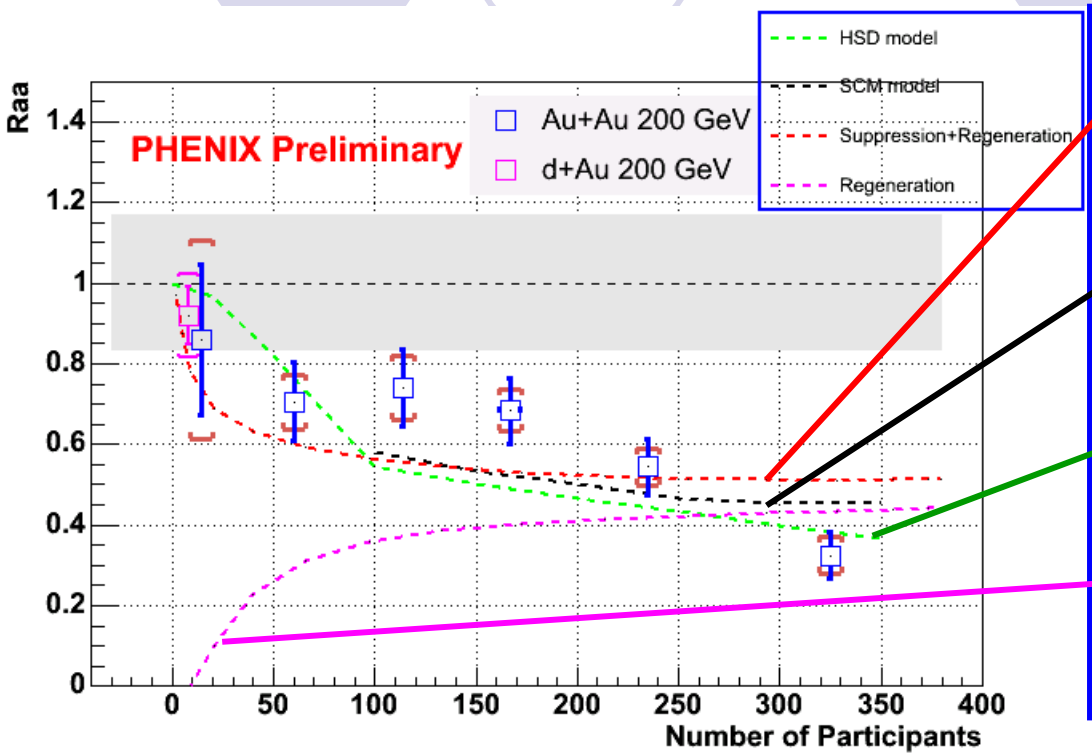
Grandchamp et.al. hep-ph/0306077

Suppression in QGP

Kostyuk et.al. hep-ph/0305277

- Consistent with nuclear absorption + shadowing (σ_{abs} ~ 3.0 mb) for centrality > 10% but Beyond the suppression for centrality 0-10%
  - σ_{abs} ~ 3.0 mb seems to be high in d+Au data.
  - σ_{abs} ~ 1.0 mb describes better d+Au results.
- Comover, direct dissociation and suppression in QGP over-predict the suppression

R_{AA} and theoretical models



Suppression & Regeneration

Grandchamp et.al. hep-ph/0306077
private communication

Statistic Coalescence

Kostyuk et.al. hep-ph/0305277

Hadron-String Dynamics

Bratkovskaya et.al. nucl-th/0402042

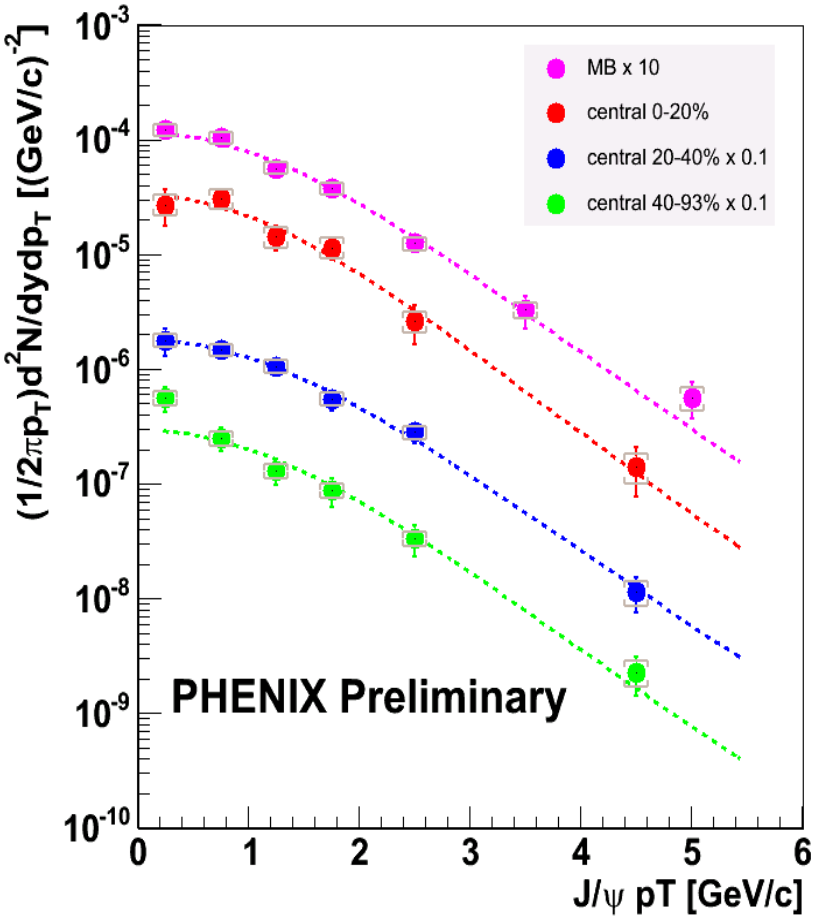
Regeneration

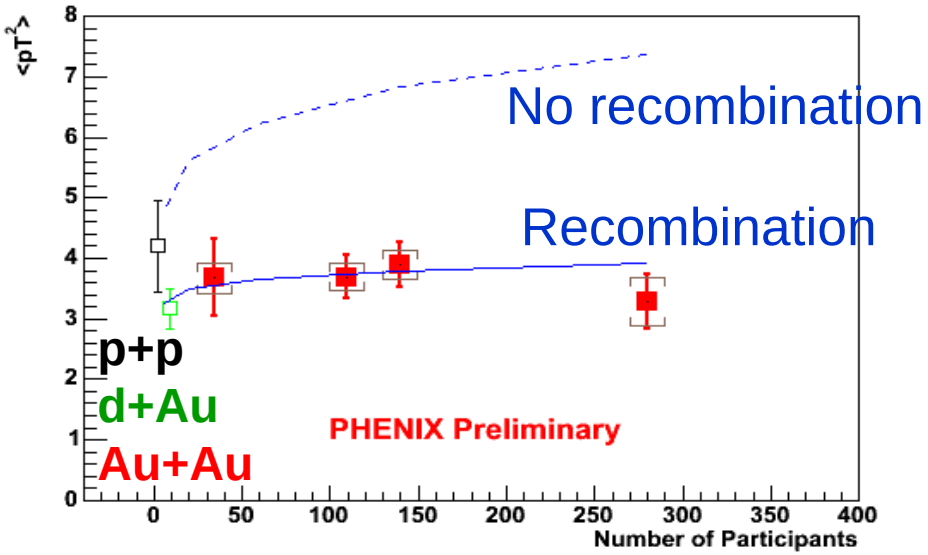
Grandchamp et.al. hep-ph/0306077
private communication

- Suppression + various recombination Models.
- Better matching with data points (at most central collisions) compared to the only suppression models.
- At RHIC (energy): Recombination compensates stronger QGP screening?

Invariant p_T distribution

- Extraction of $<p_T^2>$ by fitting with $p0(1+(p_T/p1)^2)^{-6}$
- Key to understand the recombination of J/ψ.





R.L. Thews et. al. nucl-th/0505055

- No clear centrality dependence.
- Indication of recombination?
- Need to understand with rapidity dependence, charm production (pT etc).

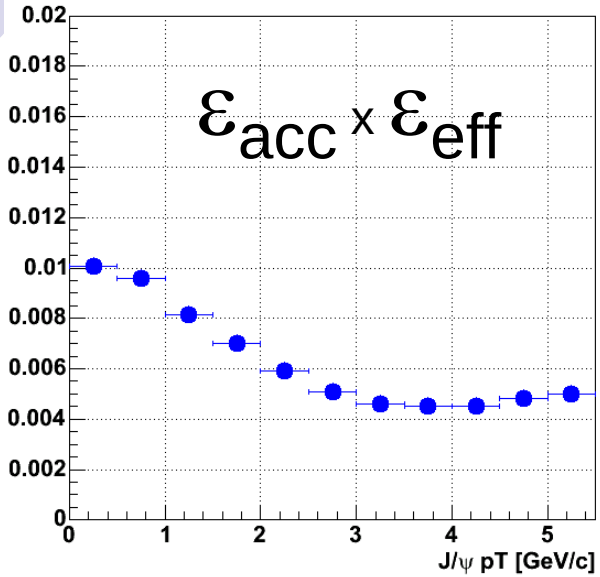
Summary and Outlook

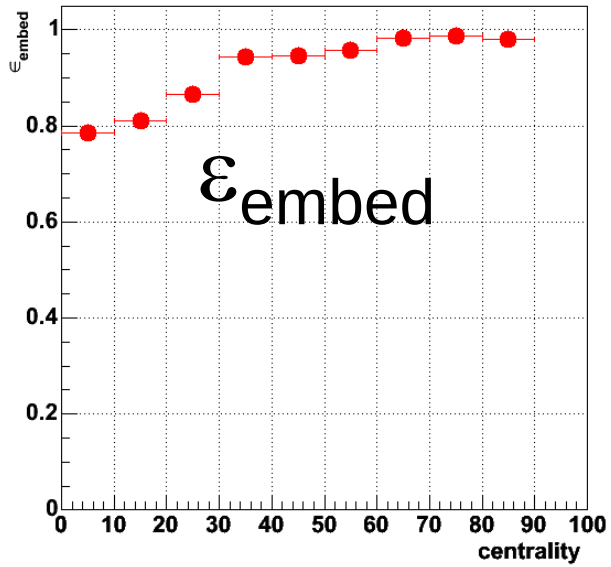
- Analyzed 760 M events (MB) of Au+Au collisions.
- Extracted Invariant yield per binary collisions
  - Factor 3 suppression for most central collisions.
- R_{AA} was compared to theoretical models.
  - Consistent with normal nuclear absorption (σ_{abs} ~3.0) for >10% central
  - Suppression beyond nuclear absorption for 0-10% central.
  - Comover and QGP suppression over-predict the suppression.
  - Suppression + Recombination model matches better compared to the models with suppression-only.
- Extracted J/ψ p_T distribution.
  - No clear centrality dependence . Recombination?
- Need to understand our data with:
  - d+Au results (but more statistic needed!)
  - Rapidity dependence (→Muon arm), Nuclear dependence (→Cu+Cu)
  - Charm production [thermalization, p_T, rapidity] (→single e, single μ)

Backup slides

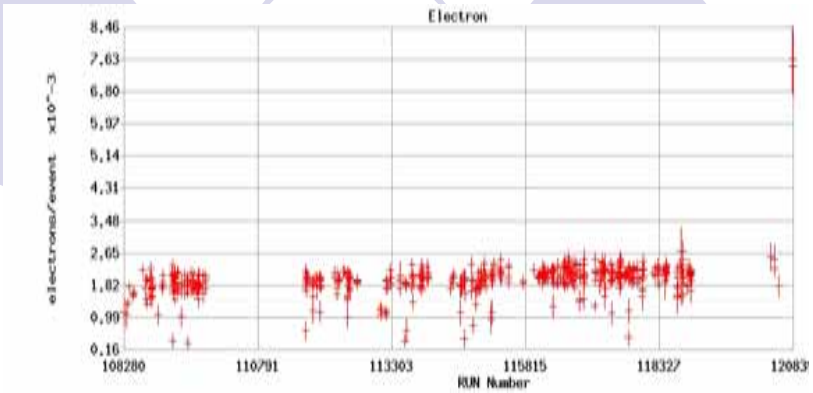
Correction factors

- Single J/ψ detection efficiency
  - Full GEANT simulation of PHENIX detector
  - Same reconstruction code as used for real data
- Embedding efficiency
  - Centrality dependent efficiency
  - Simulated single J/ψ → e+e- events were merged into real data.
- Run-by-Run efficiency
  - Evaluated by the yield of electron
  - Represent the normalization factor to the acceptance used in simulation

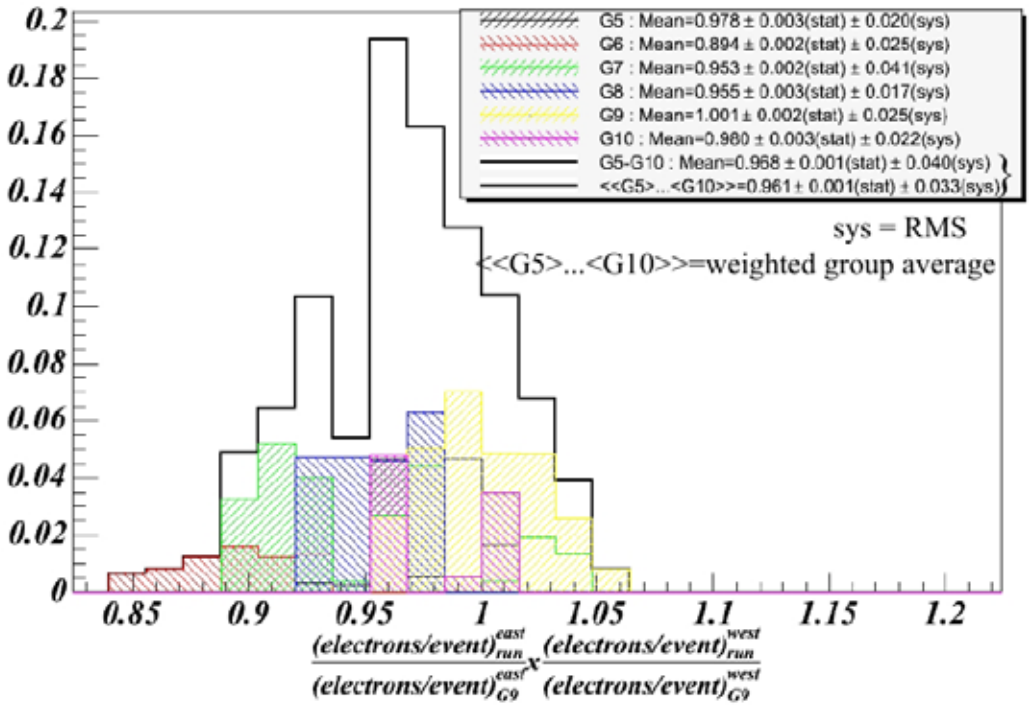




Correction factors
-- run-by-run efficiency



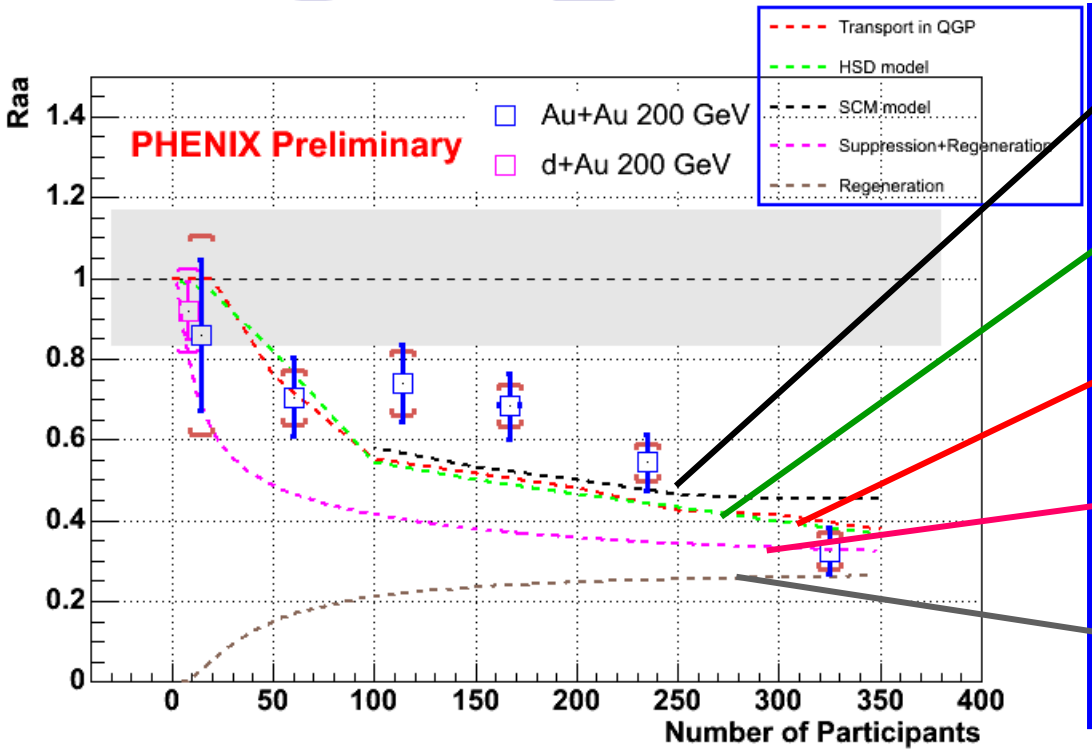
- From Electron QA
  - Fluctuation of $<(Ne/Nevt)_{East} x (Ne/Nevt)_{West}>$
- Relative to G9



- RMS is assigned to systematic error.

- Run-by-Run efficiency :
  0.968 +- 0.001 (stat)
  +- 0.040(sys) [pro.59]
  1.002 +- 0.004 (stat)
  +- 0.016(sys) [pro.66]

R_{AA} and theoretical models



Statistic Coalescence
Kostyuk et.al. hep-ph/0305277

Hadron-String Dynamics
Bratkovskaya et.al. nucl-th/0402042

Transport in QGP
Zhu et.al. nucl-th/0411093

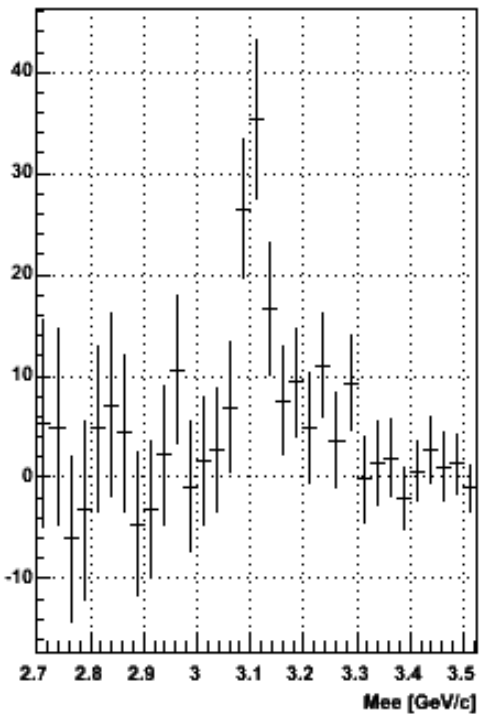
Suppression & Regeneration
Grandchamp et.al. hep-ph/0306077

Regeneration

- Models using suppression + various regeneration mechanisms.
- Better matching with data points (at most central collisions)
- At RHIC: Recombination compensates stronger QGP screening?
- Energy density and gluon density at RHIC should be much higher (2-3 times) !?

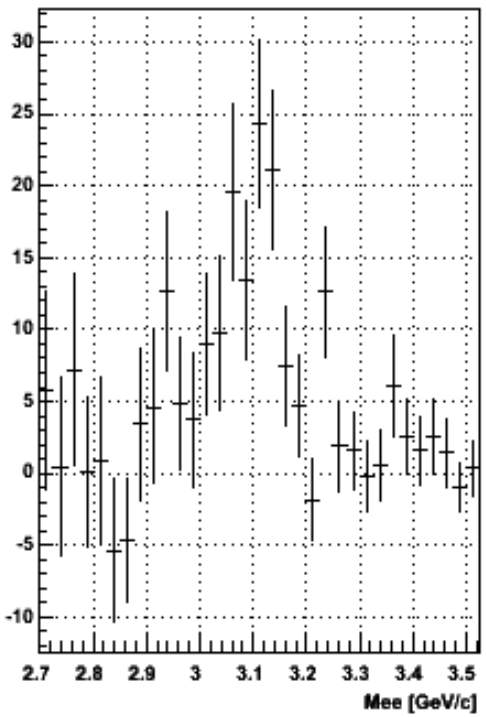
Subtracted Mass distribution (0-10%, 10-20%, 0-20%)

0-10%



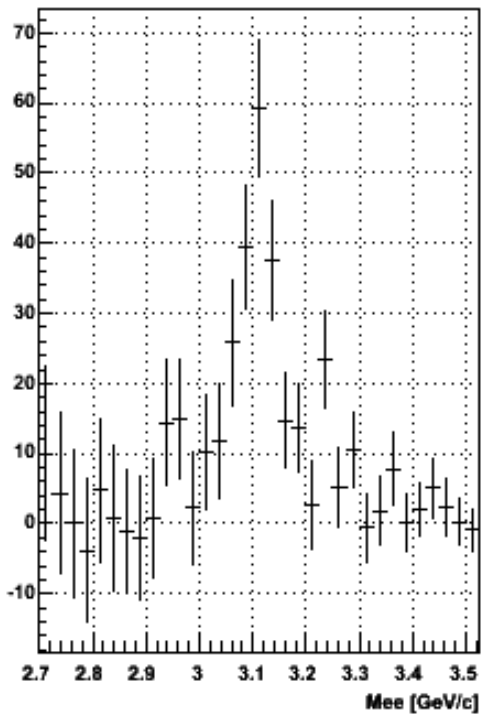
145.4 +- 25.3

10-20%



155.1 +- 19.2

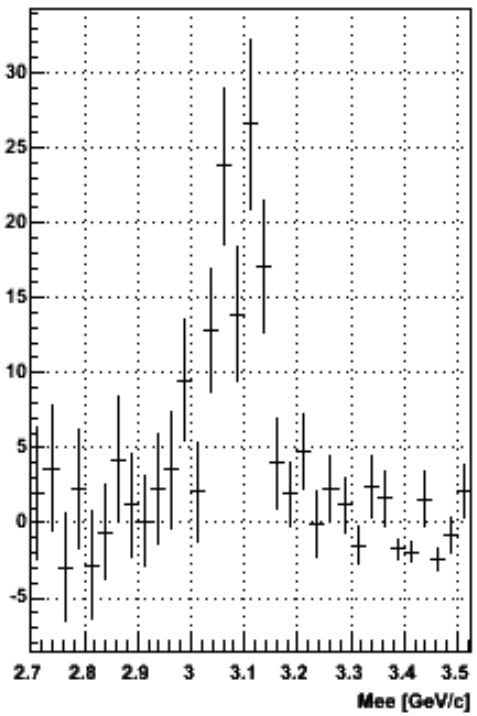
0-20%



292.7 +- 31.9

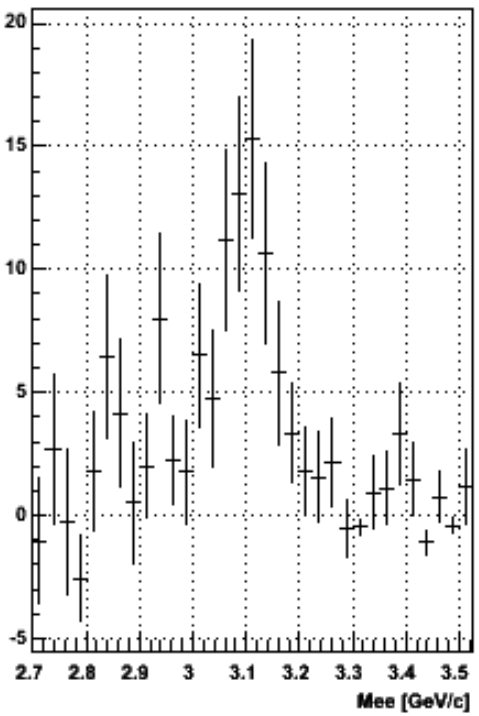
Subtracted Mass distribution (20-30%, 30-40%, 20-40%)

20-30%



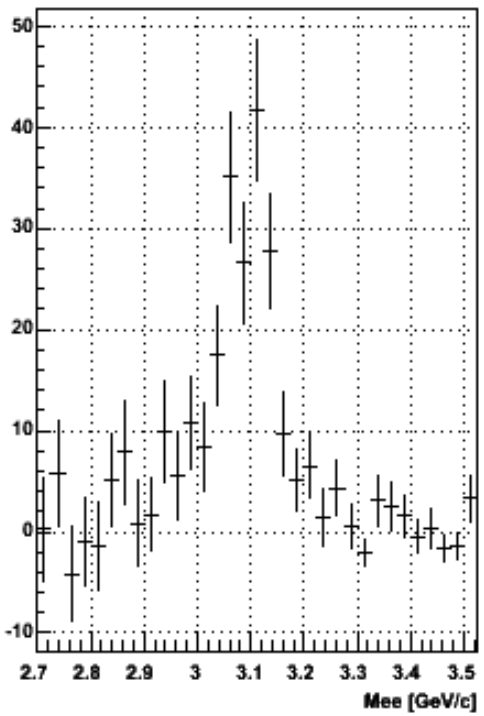
124.2 +- 14.7

30-40%



87.9 +- 11.1

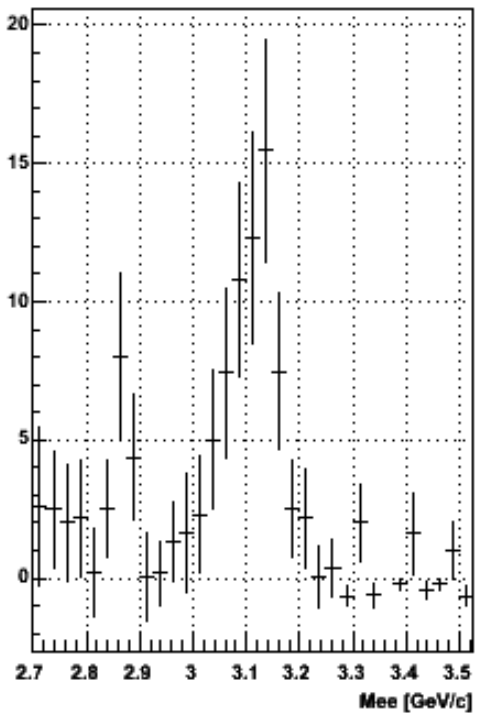
20-40%



209.0 +- 18.5

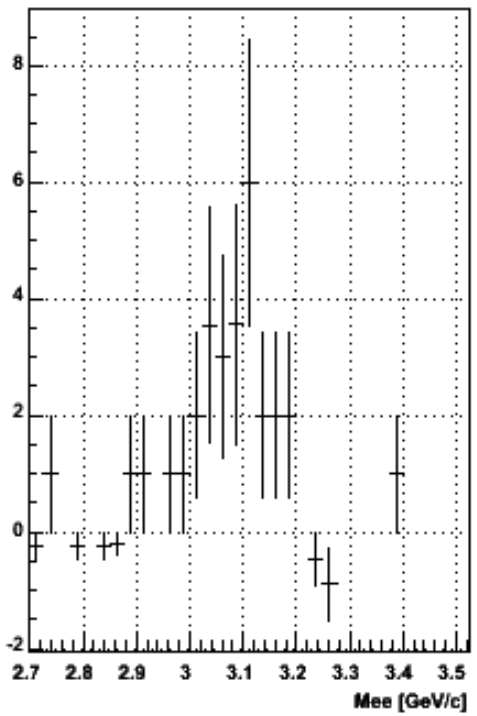
Subtracted Mass distribution (40-60%, 60-92%, 40-92%)

40-60%



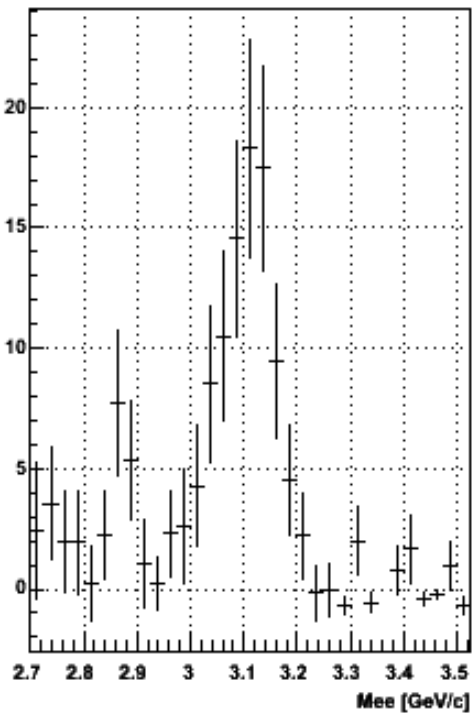
70.1 +- 9.6

60-92%



26.7 +- 5.4

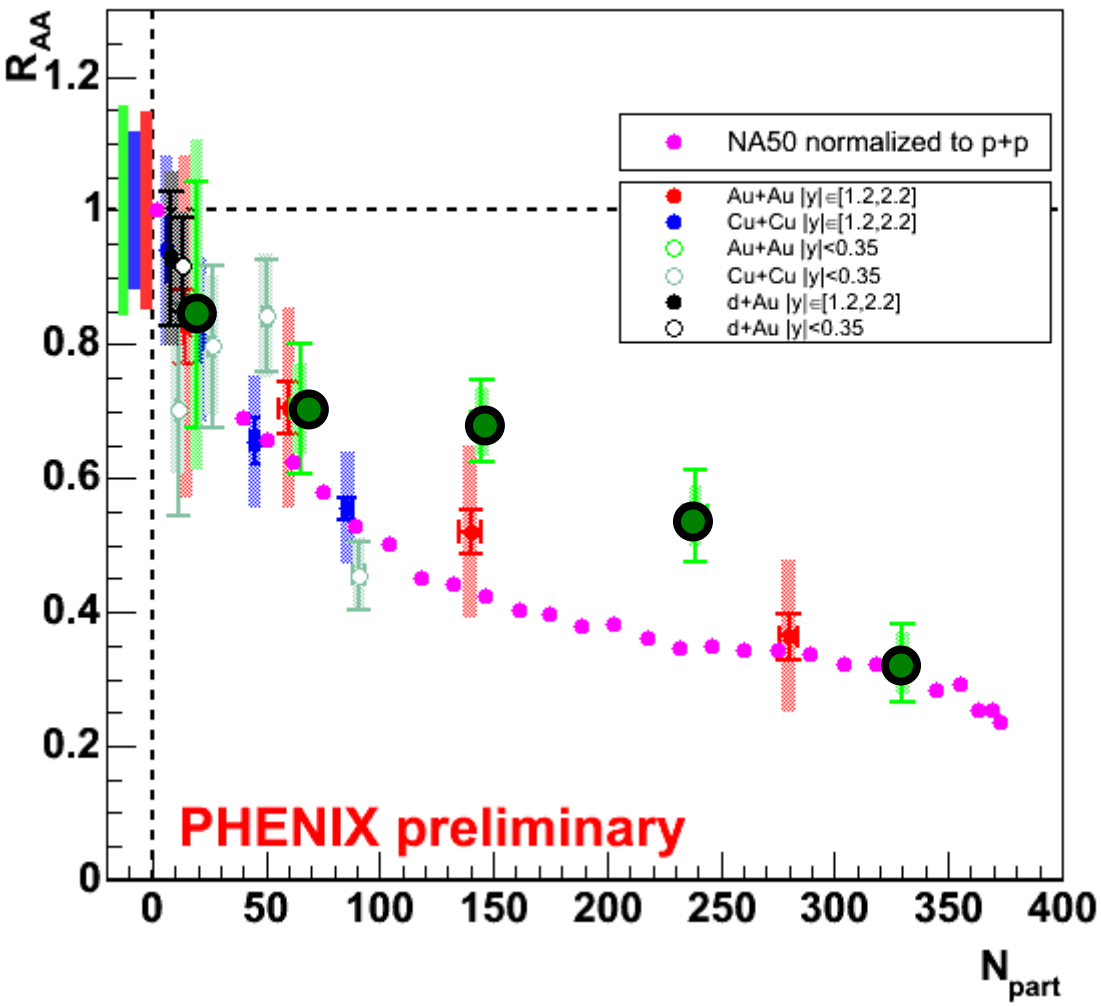
40-92%



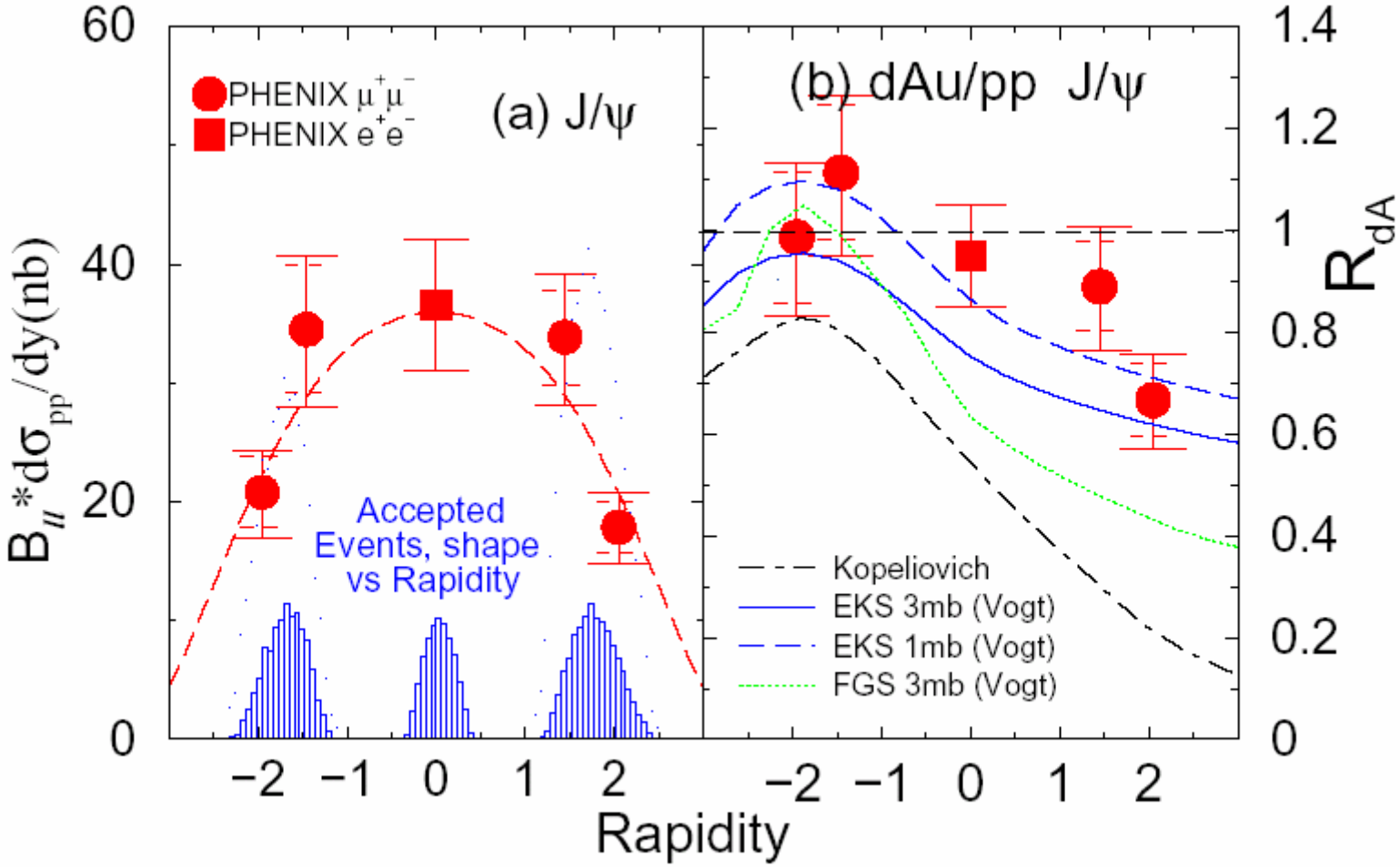
97.8 +- 11.0

Comparison of $BdN/dy/N_{binary}$ to NA50

J/ψ nuclear modification factor R_{AA}



J/ψ d+Au results



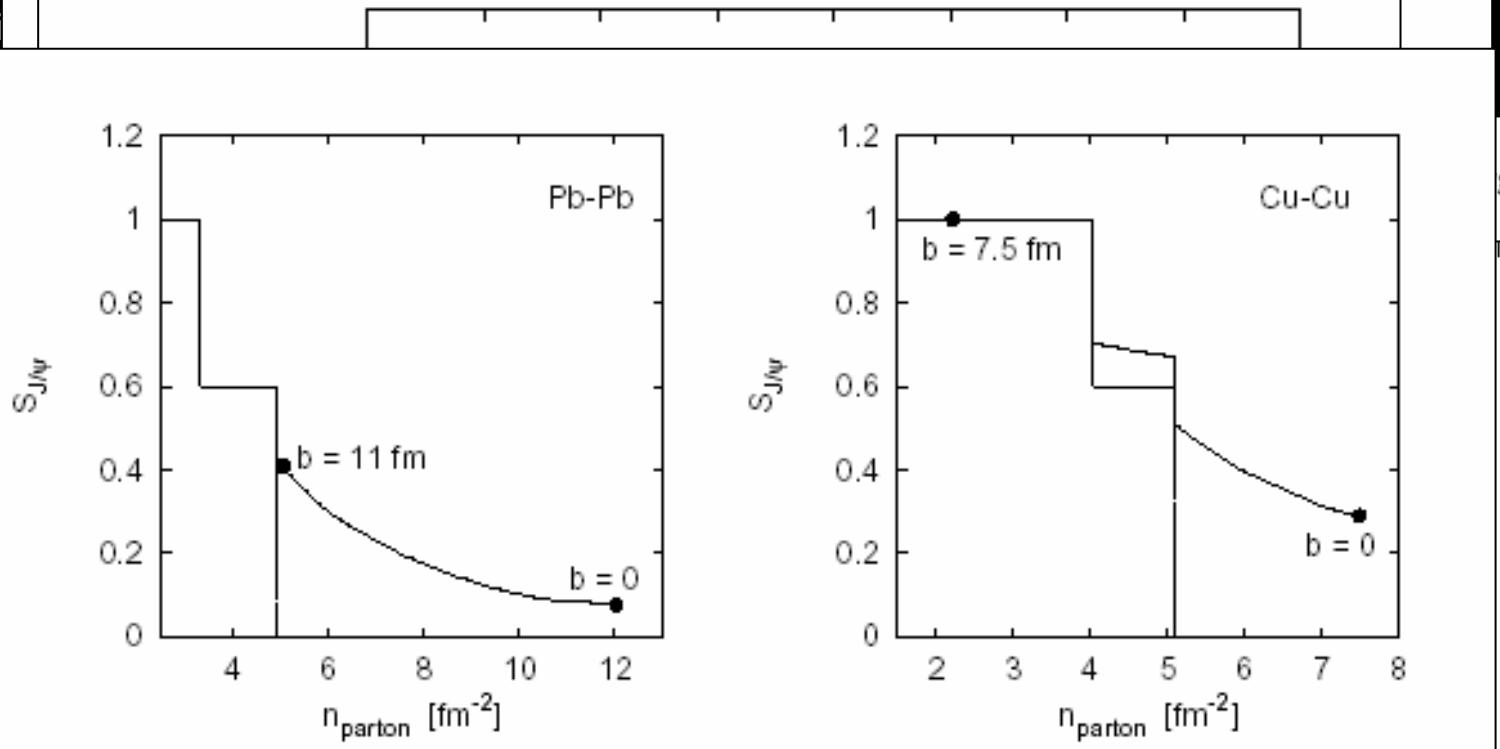


Figure 8. The J/ψ survival probability as function of the parton density for $Pb-Pb$ (left) and for $Cu-Cu$ (right) collisions at RHIC energy; the dotted line corresponds to a medium of uniform parton density, the solid line to collisions with parton densities determined by the profiles of the colliding nuclei.