Recent results on quarkonium production at RHIC-STAR

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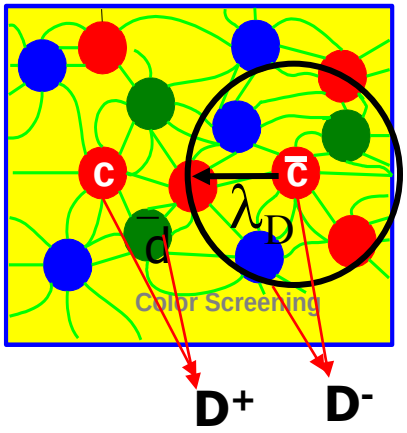
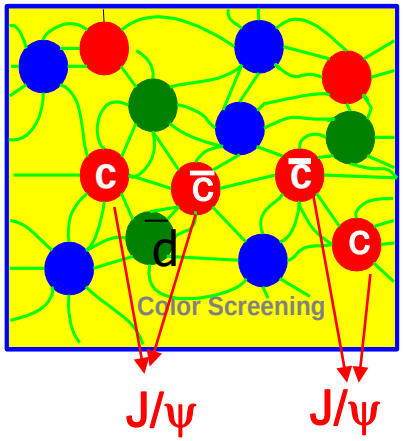
Quarkonium as a sensitive probe of QGP

Hot Nuclear Matter effects:

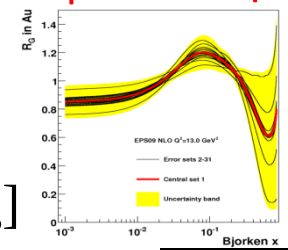
- **Color-screening**
- **Recombination of uncorrelated c and cbar**

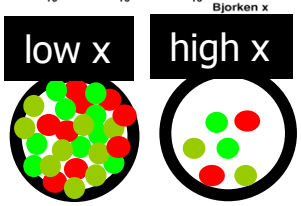


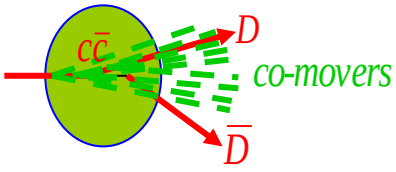


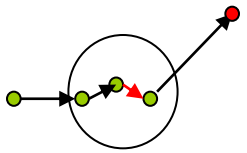
Cold Nuclear Matter (CNM) effects:

- Nuclear absorption
- PDF modification in nucleus [(anti)-shadowing]
- Cronin effect
- Gluon saturation
- …

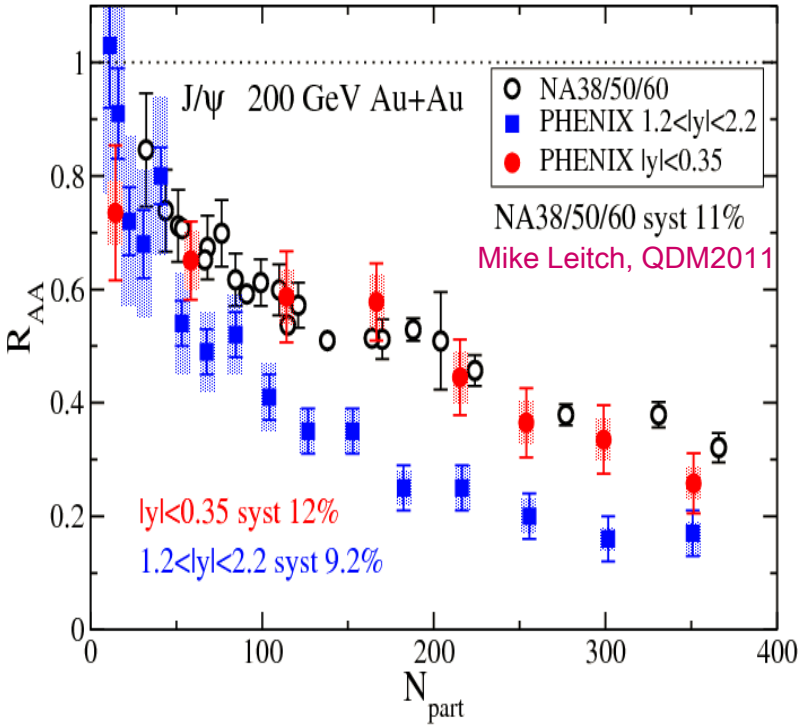


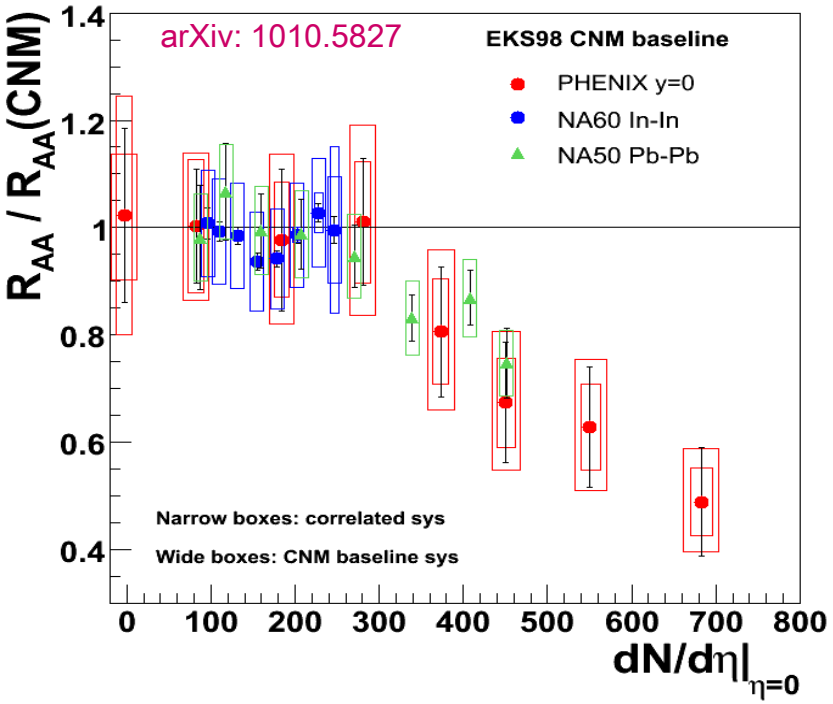






Low-p_T J/ψ suppression at RHIC





Similar anomalous suppression

Mid-rapidity:

Similar suppression as SPS

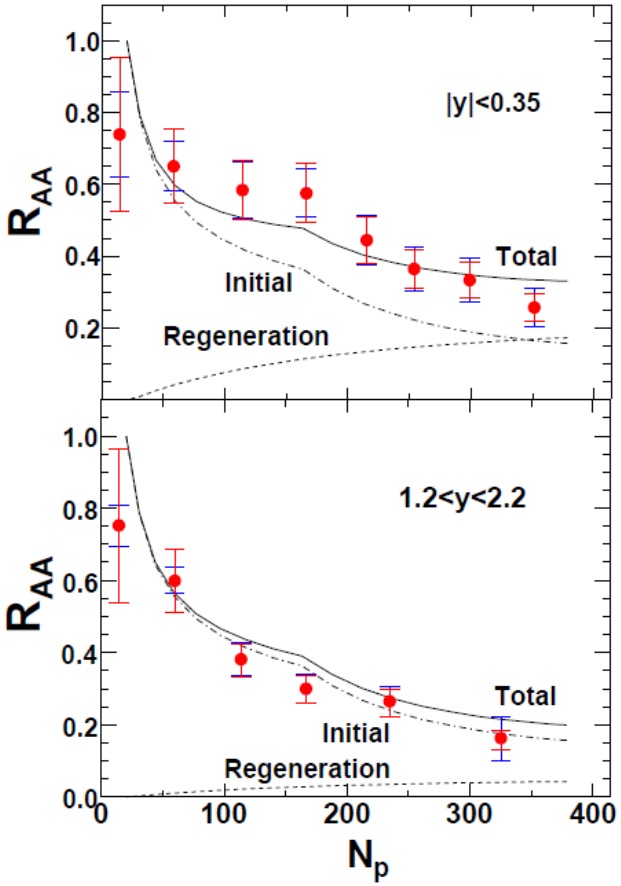
Forward rapidity:

More suppression than in mid-rapidity

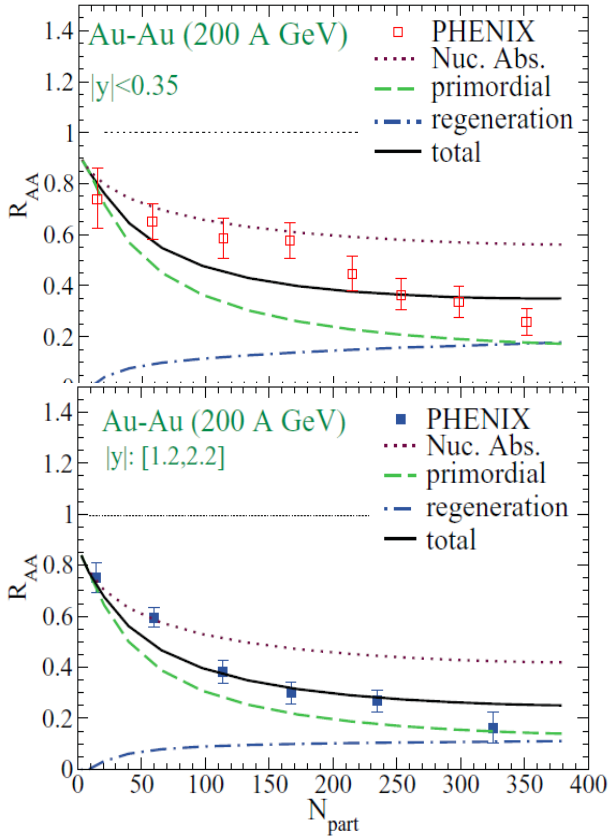
Two Puzzles!!

Color-screening vs. Regeneration

Z. Qu, Y., N. Xu, P. Zhuang, NPA830, 335c (2009)

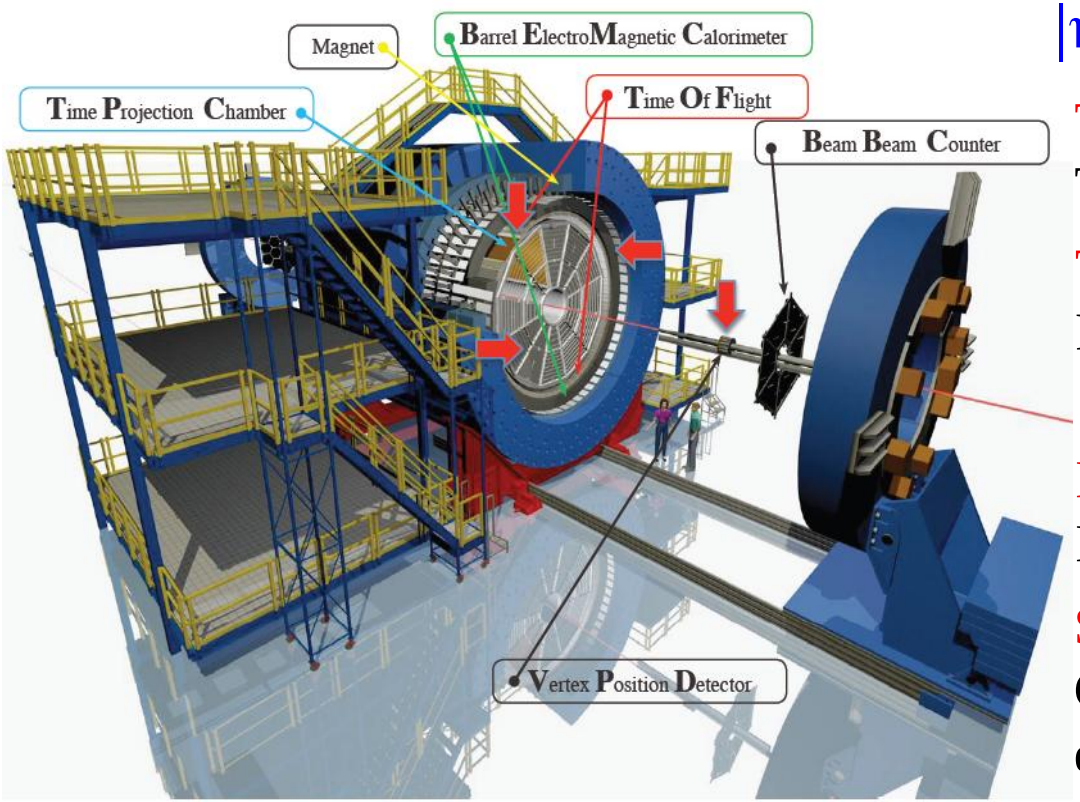


X. Zhao, R. Rapp, PRC82, 064905 (2010)



- Theoretical calculations describe J/ψ suppression at SPS and RHIC top energy.
- Interplay of CNM, Color-screening and Regeneration effects. → **Complicated!**
- **Vary the relative contributions and test?** **and/or** **Isolate some effect?**

STAR Detector for Quarkonium



$|\eta|<1$, full azimuthal coverage

Time Projection Chamber (TPC):
Tracking, $\vec{p}$, dE/dx

Time Of Flight (TOF):
Reject slow hadrons

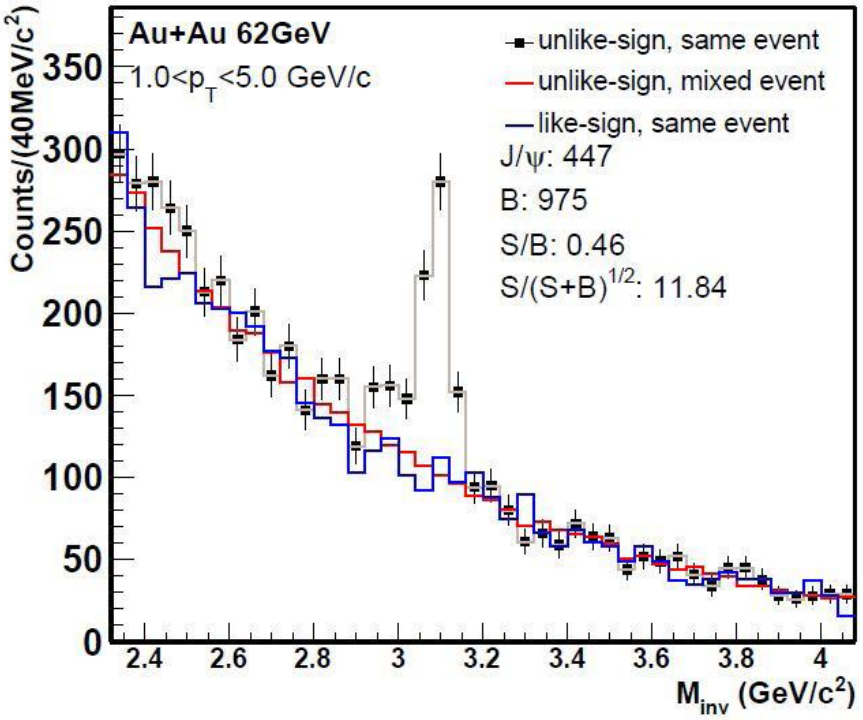
Electromagnetic Calorimeter (EMC):
Deposited energy, fast trigger

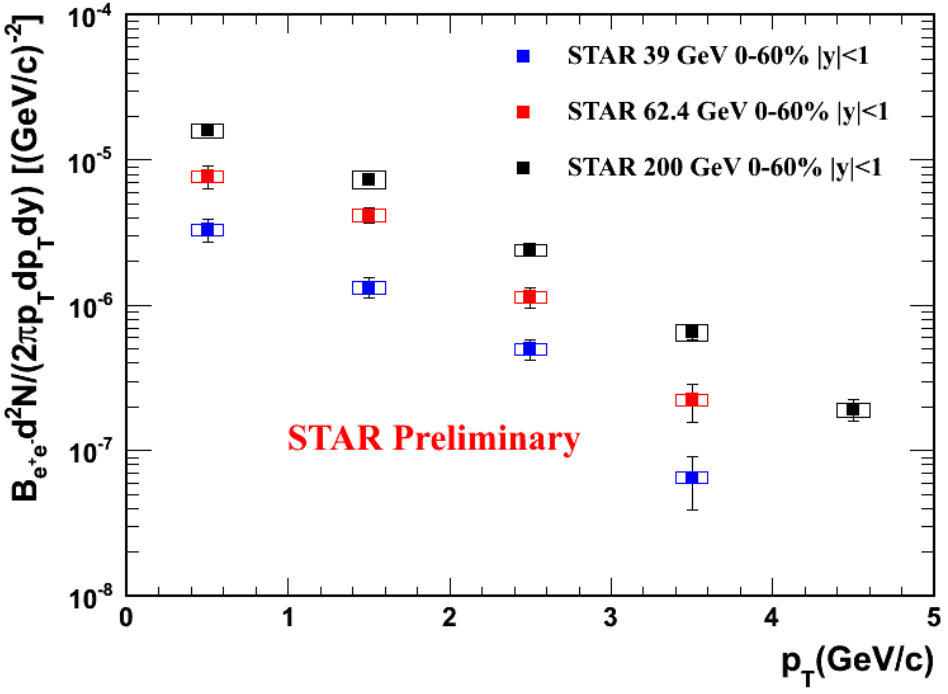
Shower Maximum Detector (SMD):
Cluster size and position
e/h seperation

Installing a large area muon detector (Muon Telescope Detector) at mid-rapidity.
It significantly improves (compare to dielectron channel):

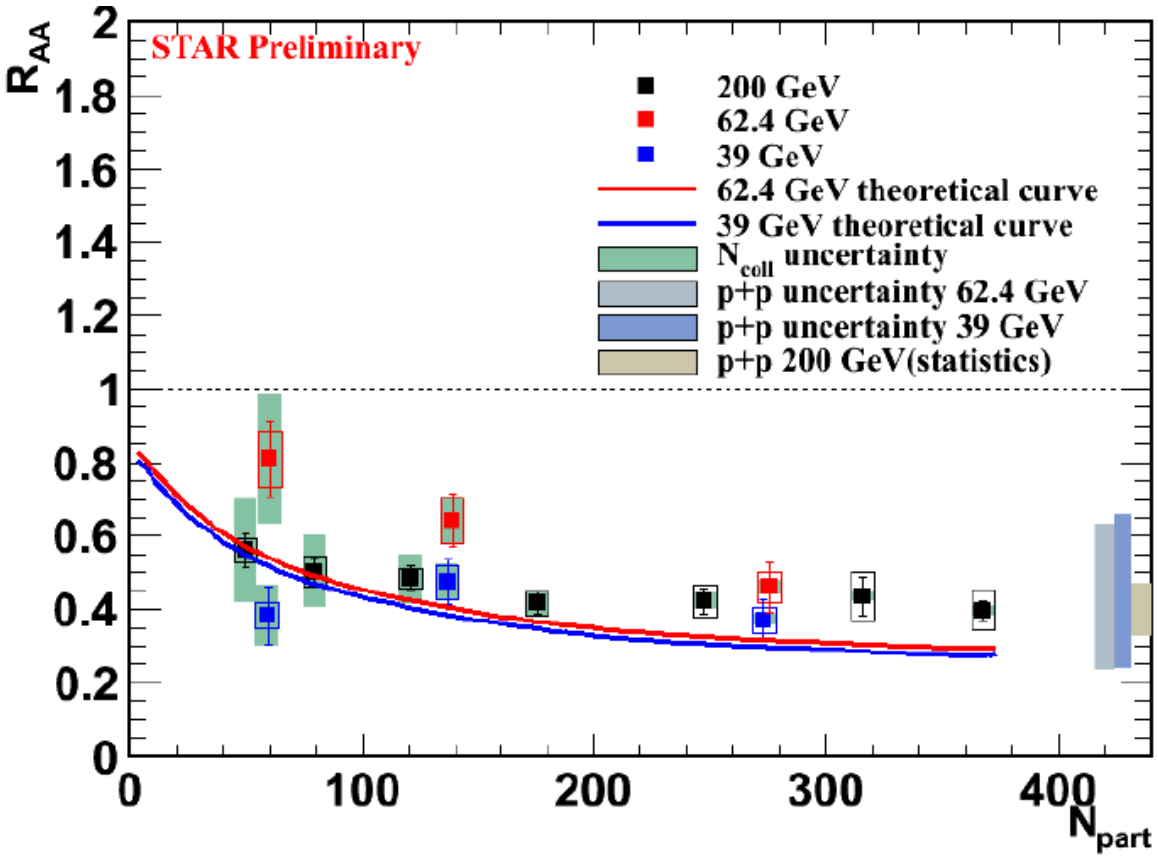
- Trigger capability
- Signal-to-background ratio
- Mass resolution

J/ψ at RHIC low energy





J/ψ suppression at RHIC low energy



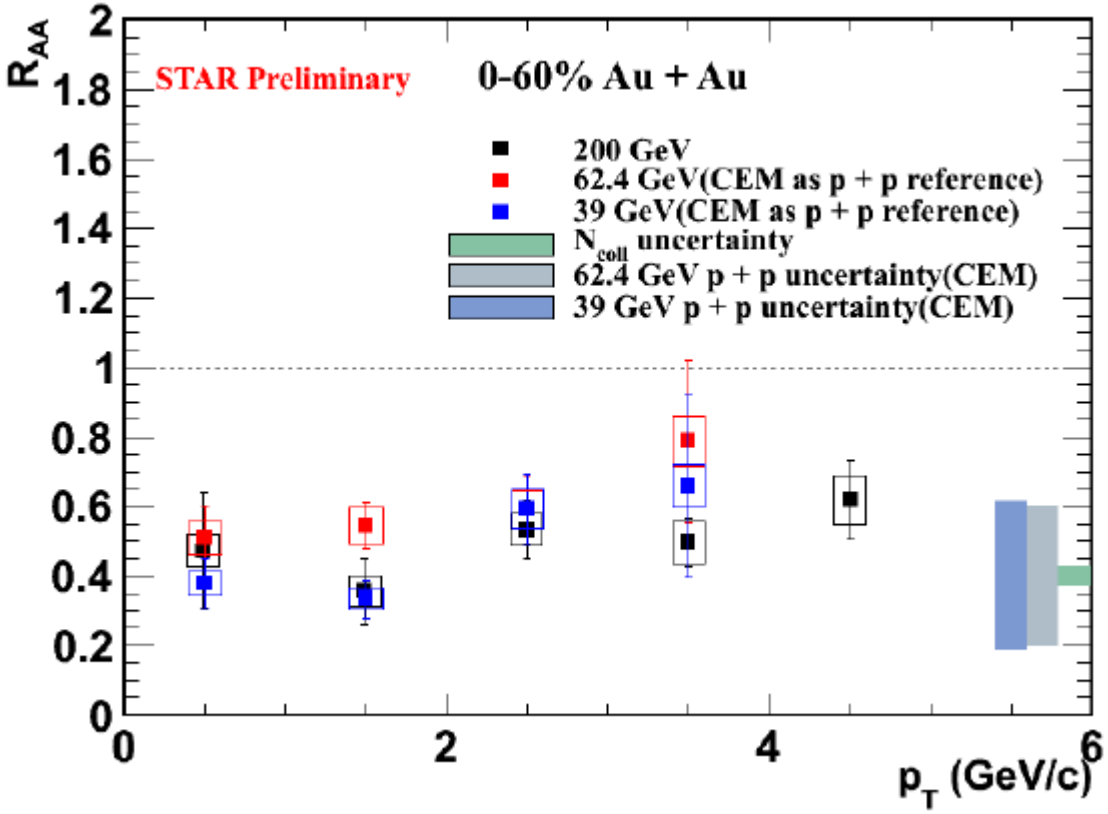
p+p references for 39 and 62 GeV: CEM
R. Nelson, R. Vogt et al, PRC87, 014908 (2013)

Theoretical curves:
Xingbo Zhao, Ralf Rapp PRC82, 064905 (2010)

Similar suppression from 39 – 200 GeV

Consistent with theoretical calculation.

J/ψ suppression at RHIC low energy



p+p references for 39 and 62 GeV: CEM
R. Nelson, R. Vogt et al, PRC87, 014908 (2013)

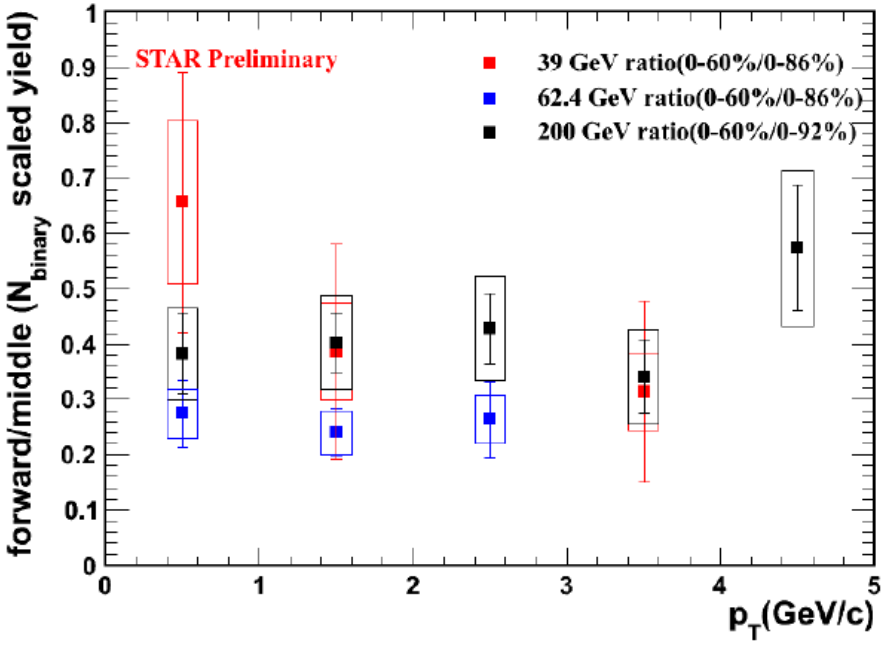
Strong suppression at low-p_T.

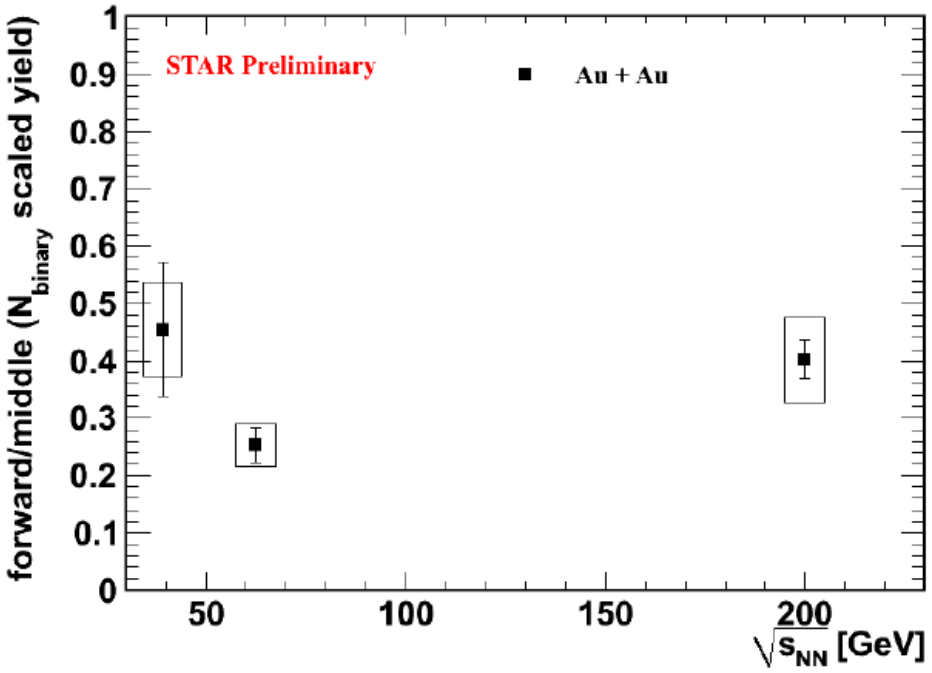
No significant beam-energy dependence.

Forward/mid-rapidity

Mid-rapidity: |y|<1 STAR

Forward rapidity: 1.2<|y|<2.2 PHENIX PRC86, 064901 (2012)



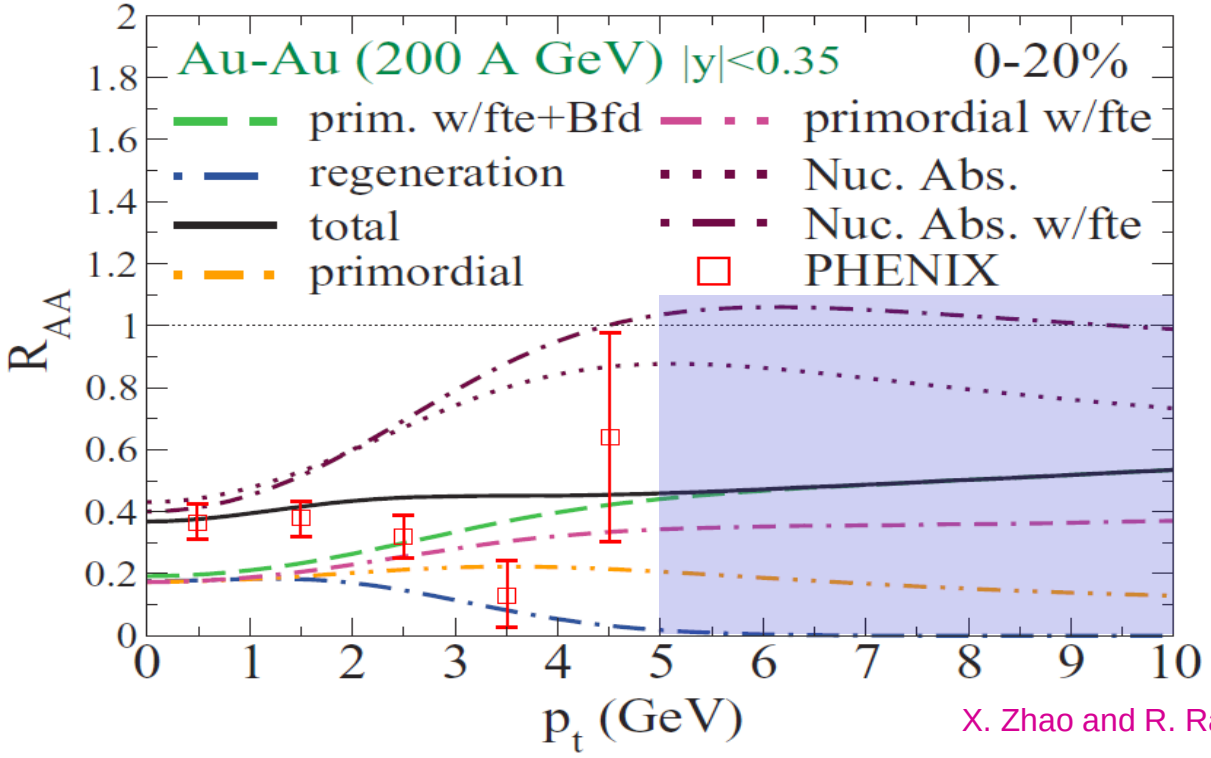


No significant p_T dependence at all of the beam energies.

No significant beam energy dependence.

High-p_T J/ψ provides a cleaner probe

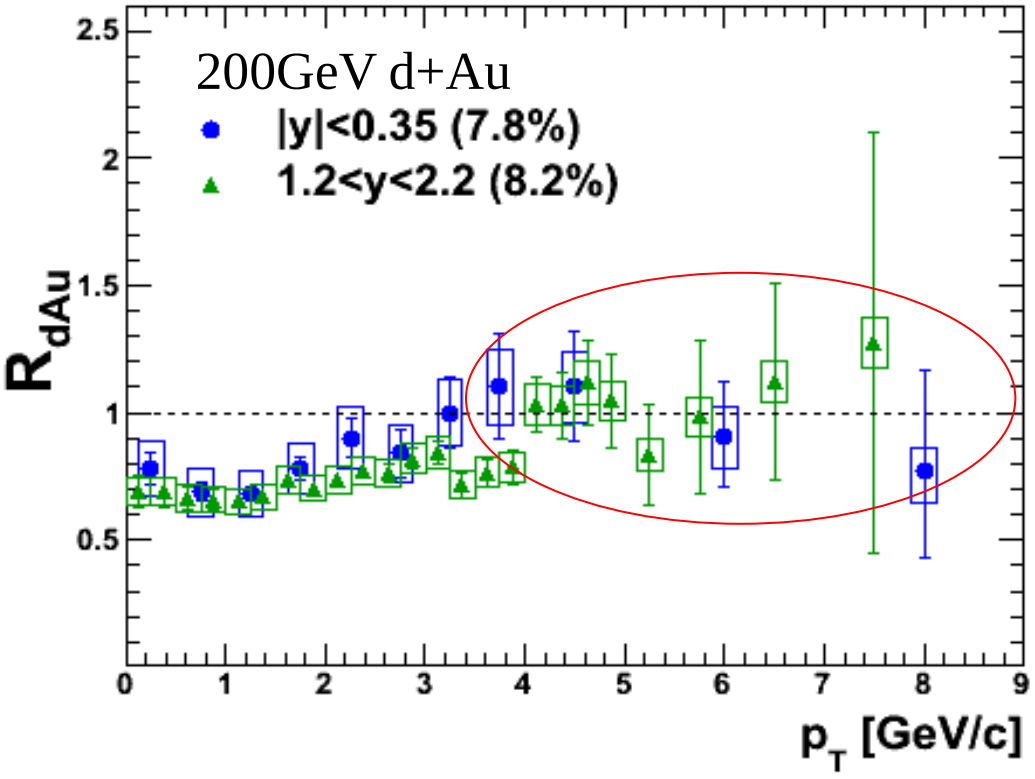
- Regeneration only affect low p_T
- Nuclear absorption with lifetime effect (CNM effects)
  R_{AA}~0.4 at low p_T, increase to unity at 5 GeV/c



X. Zhao and R. Rapp, PRC82, 064905

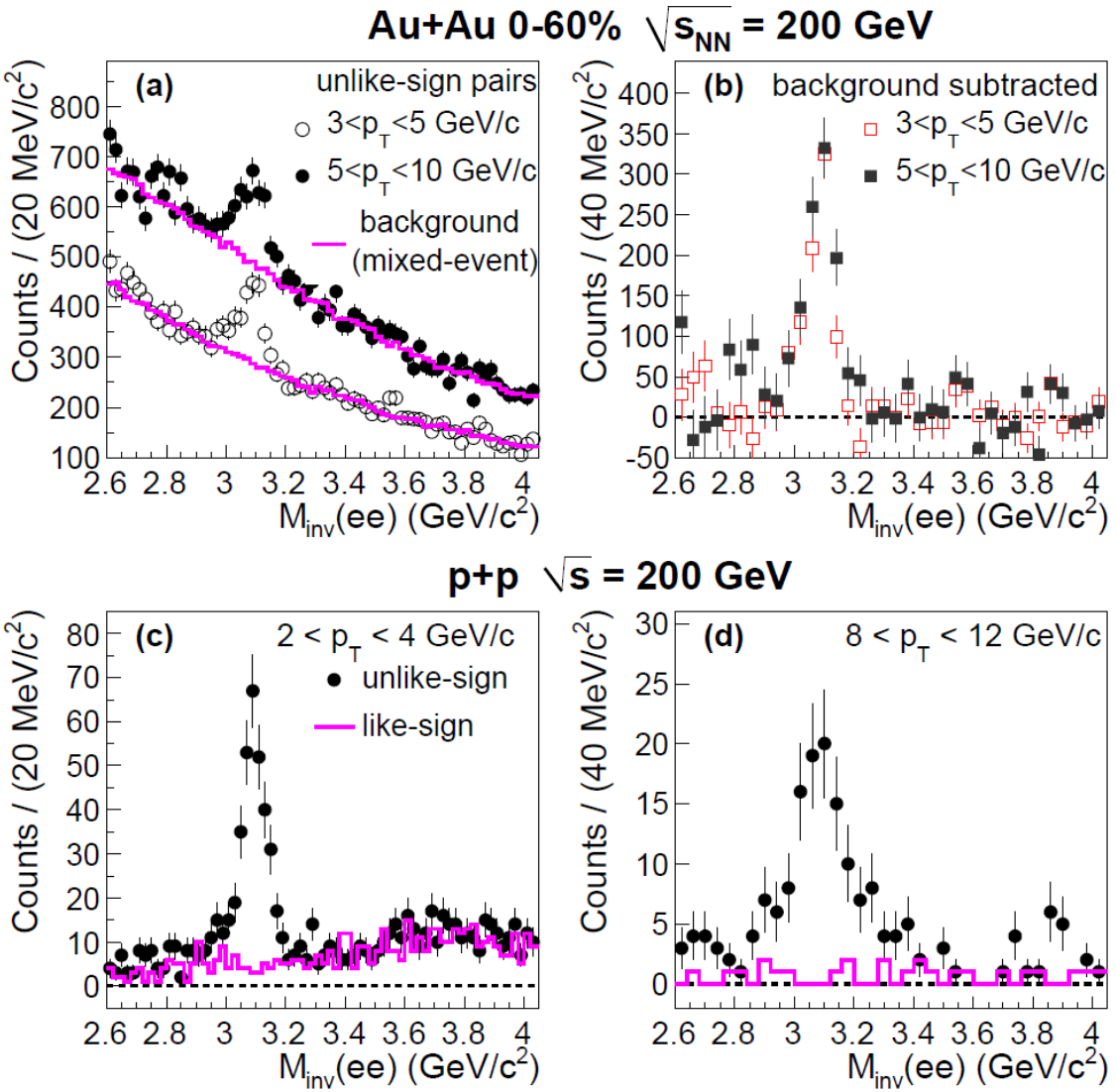
High-p_T J/ψ provides a cleaner probe

- R_{AA} increase to unity at p_T>4 GeV/c in d+Au collisions
  CNM effects are negligible at high-p_T



PHENIX, arXiv:1204.0777

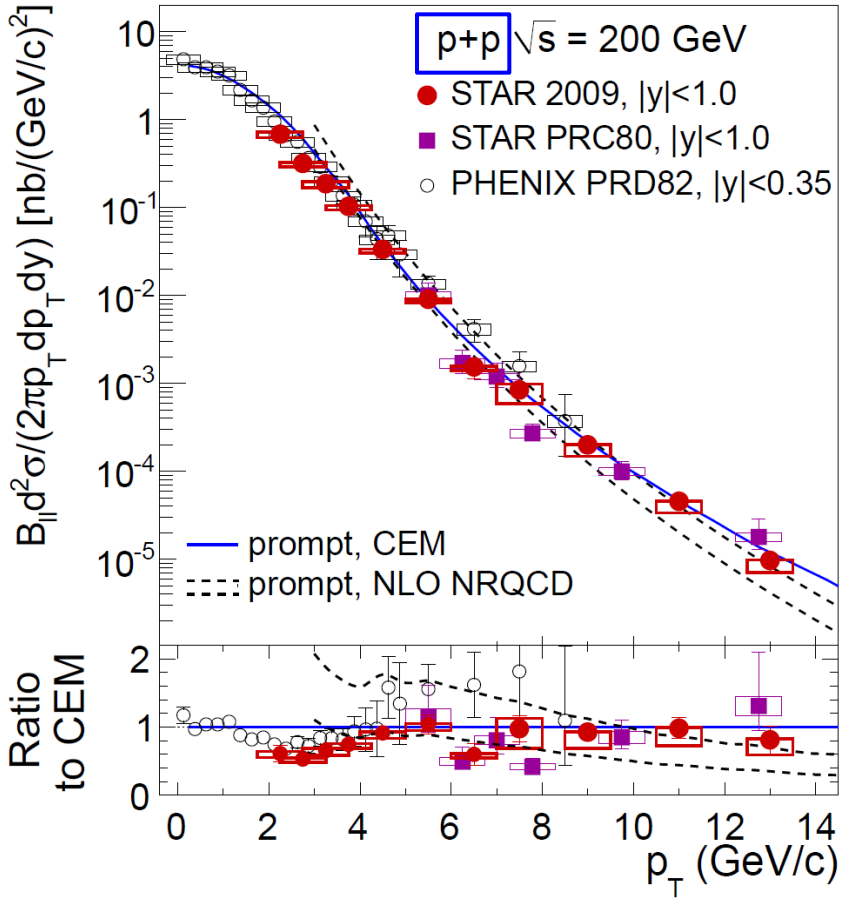
High-p_T J/ψ signals at STAR



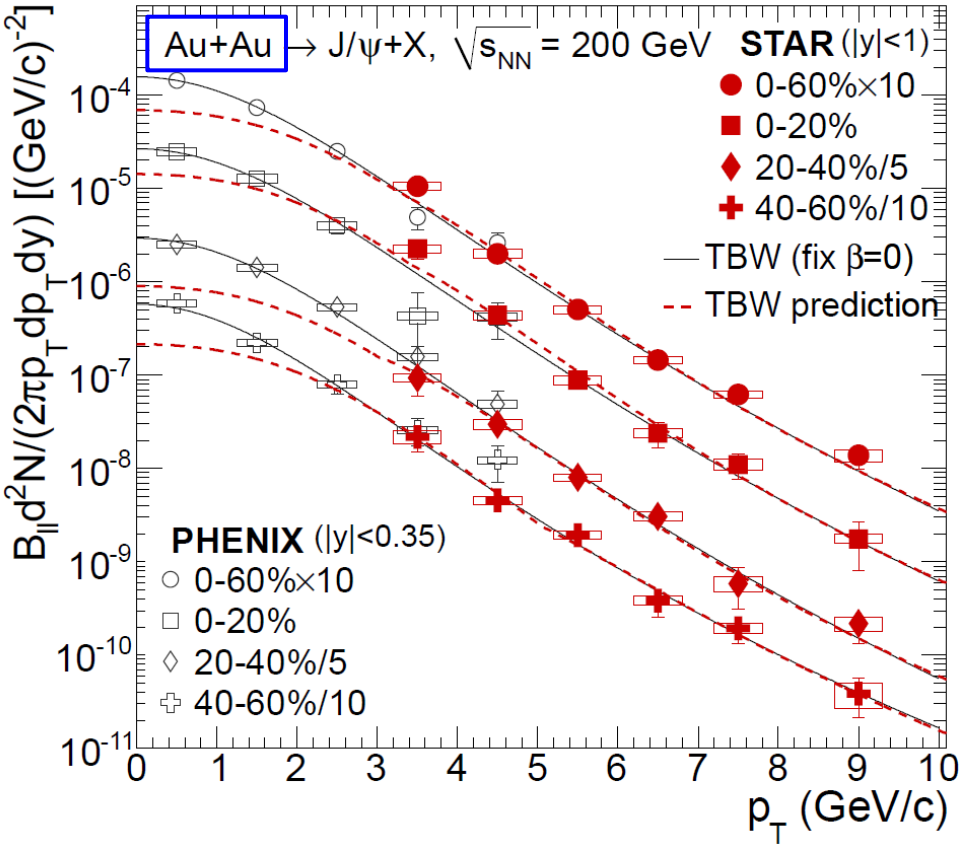
With TOF

STAR,
PLB 722, 55 (2013)

p_T spectra



PHENIX: PRD 82, 012001 (2010); PRL98, 232301 (2007)
STAR: PRC80, 041902(R) (2009), PLB722, 55 (2013)

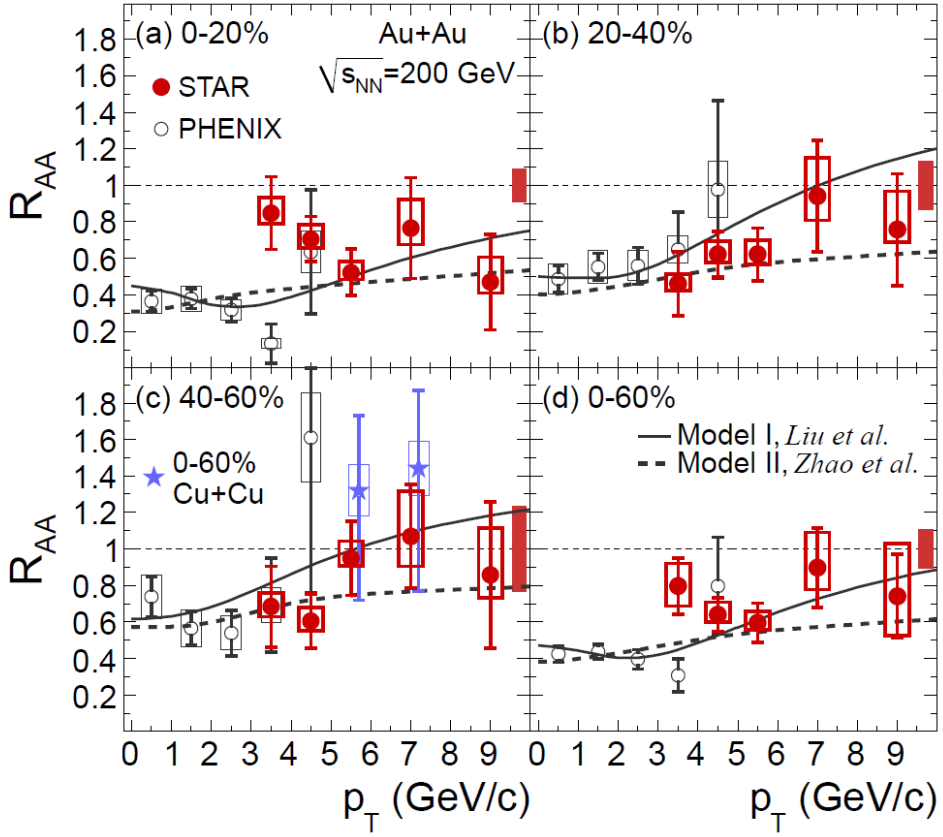


Y.-Q. Ma, K. Wang, and K.-T. Chao, Phys. Rev. D84, 114001 (2011), and private communication

M. Bedjidian et al., hep-ph/0311048, and R. Vogt private communication

Tsallis Blast-Wave model: ZBT *et al.*, CPL 30, 031201 (2013); JPG 37, 085104 (2010)

R_{AA} vs. p_T



STAR CuCu: PRC80, 014922(R)
PHENIX: PRL98, 232301

Yunpeng Liu, Zhen Qu, Nu Xu and Pengfei Zhuang, PLB 678:72 (2009) and private comminication

Xingbo Zhao and Ralf Rapp, PRC 82,064905(2010) and private communication

STAR,
PLB 722, 55 (2013)

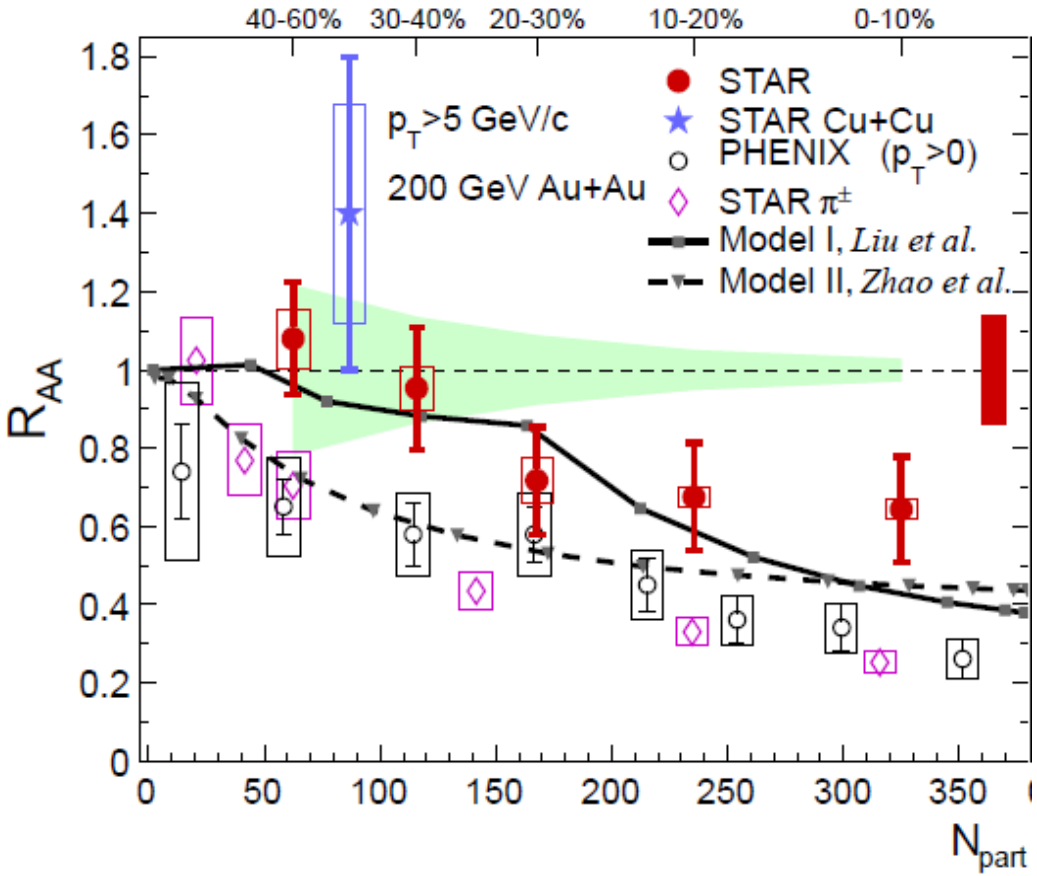
First high-p_T J/ψ suppression measurement in Au+Au collisions at RHIC

Increase from low p_T to high p_T

Consistent with unity at high p_T in (semi-) peripheral collisions

More suppression in central than in peripheral even at high p_T

R_{AA} vs. Centrality



Yunpeng Liu, Zhen Qu, Nu Xu and Pengfei Zhuang, PLB 678:72 (2009) and private comminication

Xingbo Zhao and Ralf Rapp, PRC 82,064905(2010) and private communication

STAR Pion: PRL108, 072302 (2012)

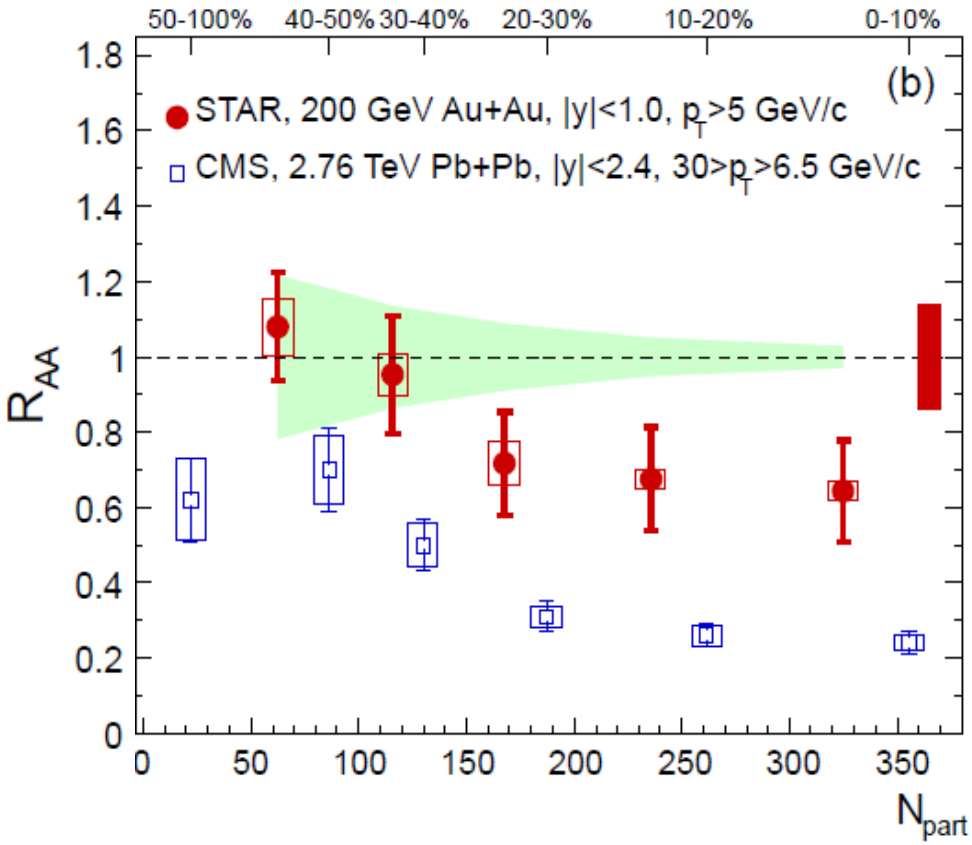
STAR,
PLB 722, 55 (2013)

Significant suppression in central Au+Au collisions for high-p_T J/ψ → **QGP?**

Different from high-p_T pions and low-p_T J/ψ

Consistent with models including QGP suppression and regeneration

Compare to LHC



STAR,
PLB 722, 55 (2013)

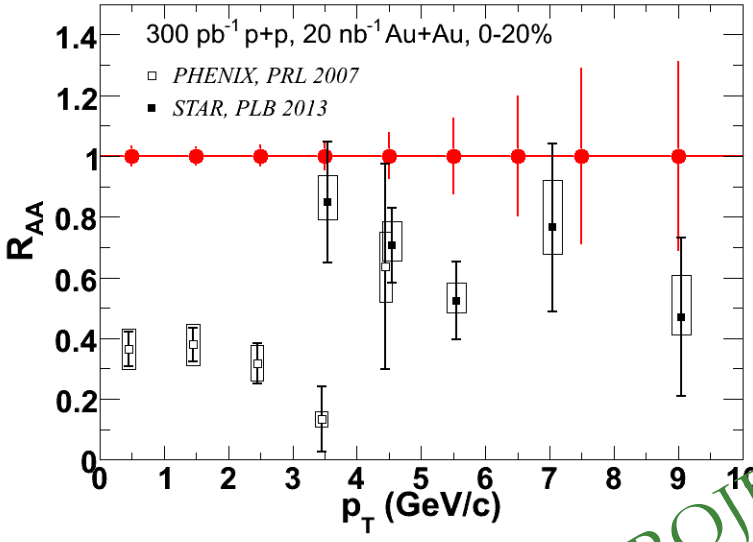
CMS, JHEP 1205, 063 (2012)

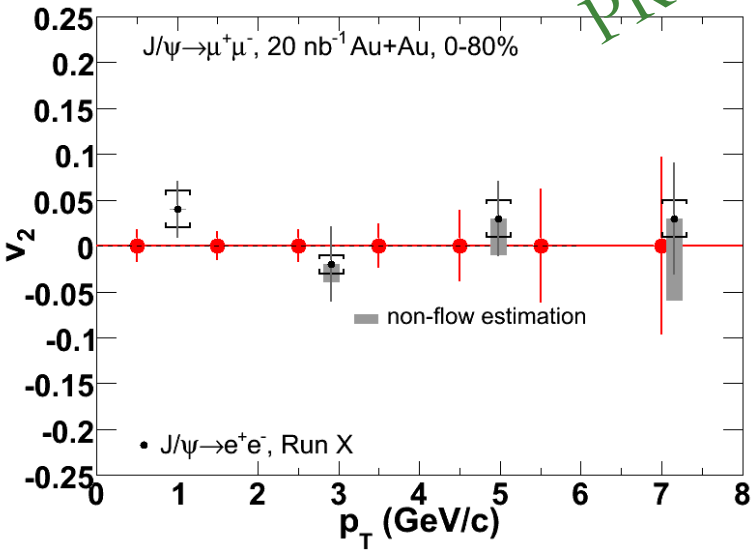
More suppression at LHC than at RHIC

Similar central-to-peripheral ratio

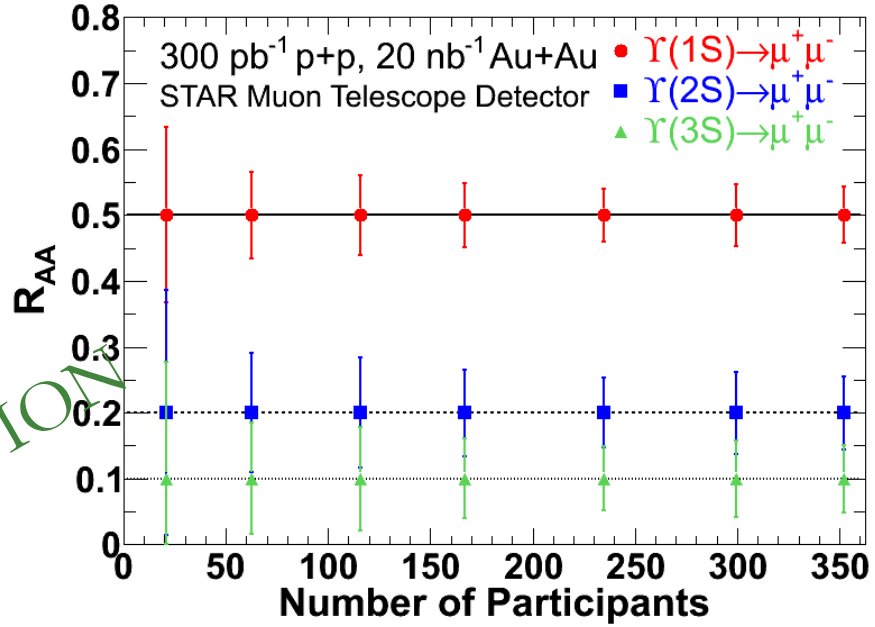
Stronger shadowing effect at LHC? (much lower x)

Future quarkonium measurement with MTD





PROJECTION



MTD: Improves statistical uncertainty

As well as systematic uncertainty

MTD+HFT: B→J/ψ, J/ψ-D …

Summary

• J/ψ suppression measurement extended to lower beam-energy and high p_T at RHIC.

• Centrality and p_T dependence of low-p_T J/ψ R_{AA} is similar in 39, 62 and 200 GeV Au+Au collisions.

• First measurement of high-p_T J/ψ suppression in Au+Au collisions at RHIC.

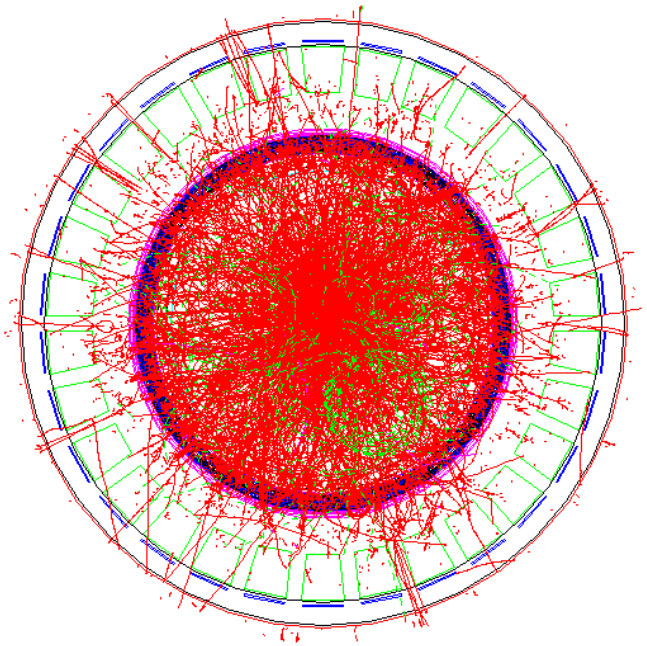
  • With less complication of CNM and regeneration effects.

  • Significant suppression at p_T>5 GeV/c → Color-screening effect?

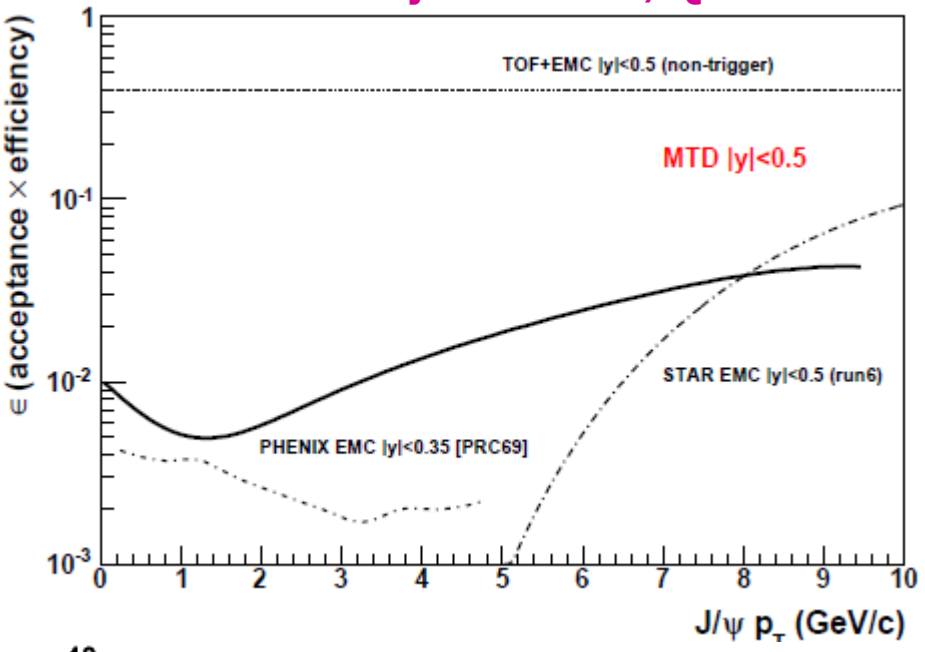
• Beam-energy and p_T dependent R_{AA} can be consistently described by the models including CNM, QGP suppression and Regeneration.

Thanks!

Muon Telescope Detector (MTD)



Lijuan Ruan, QM2011



Advantages over electrons

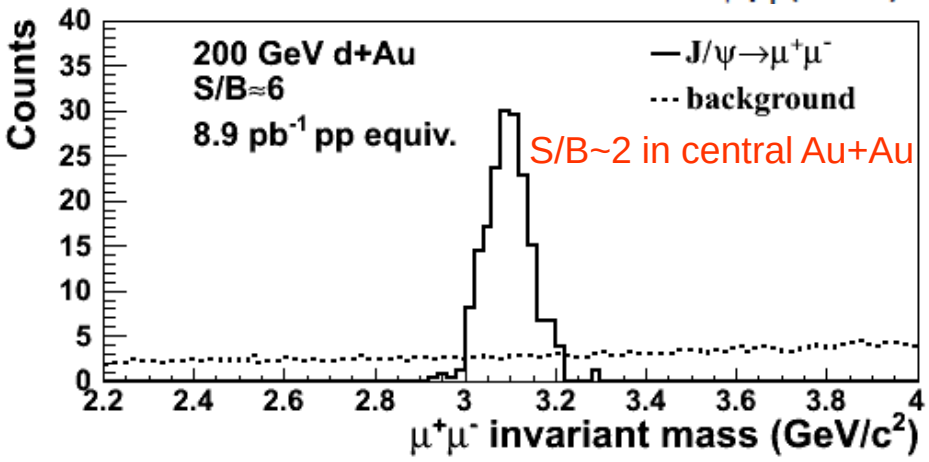
no γ conversion

much less Dalitz decay contribution

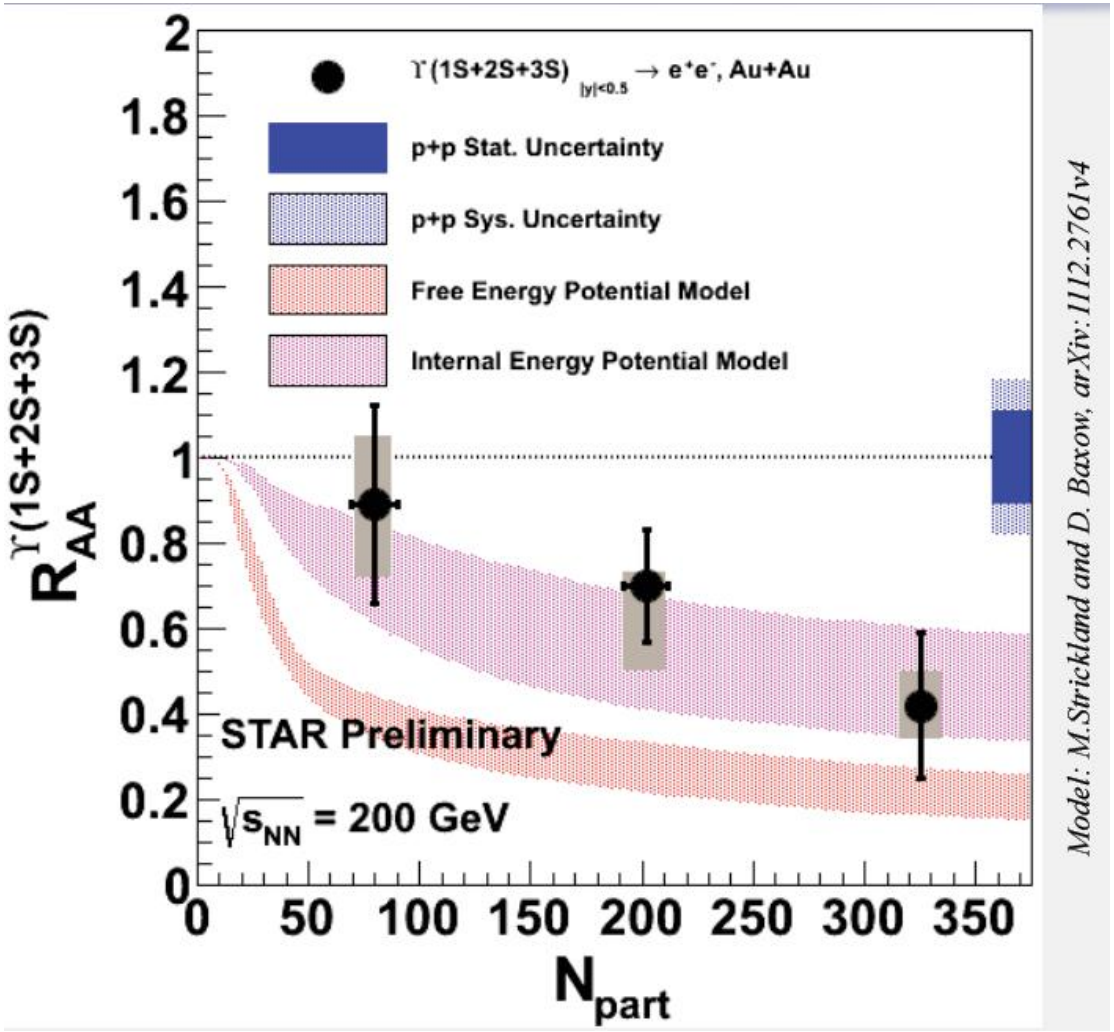
less affected by radiative losses in the materials

Trigger capability for low to high p_T J/ψ in central Au+Au collisions

High μ/hadron enhancement

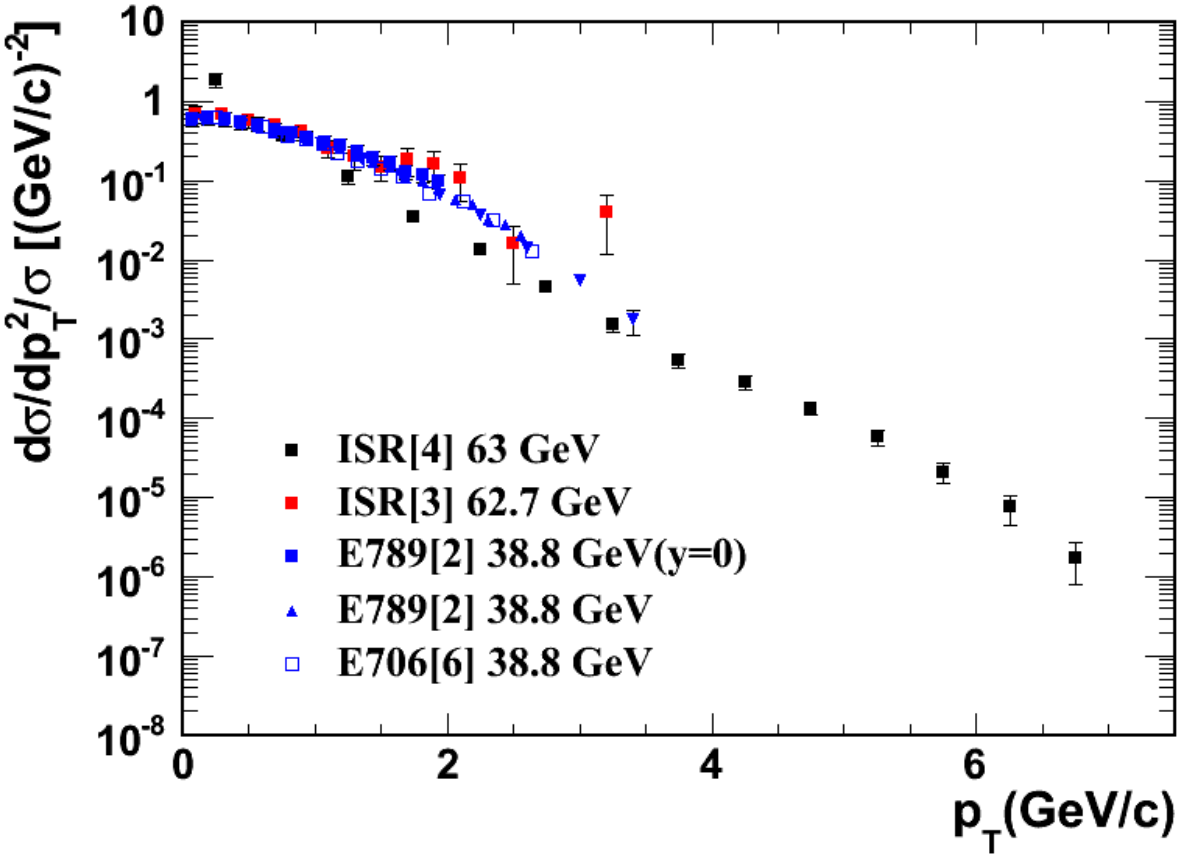


Upsilon at STAR

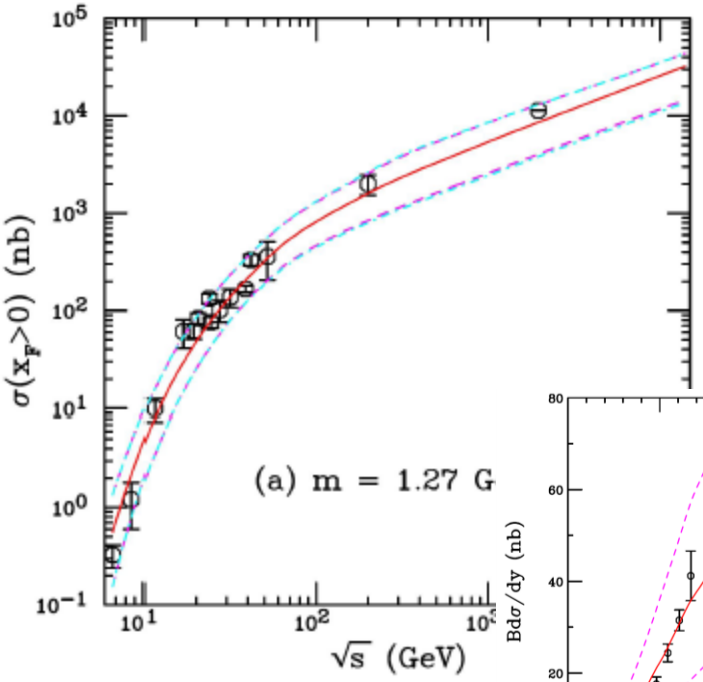


- recombination can be neglected at RHIC
- Final state co-mover absorption is small.
- More suppression in more central collisions
- Consistent with prediction from a model requiring strong 2S and complete 3S suppression.

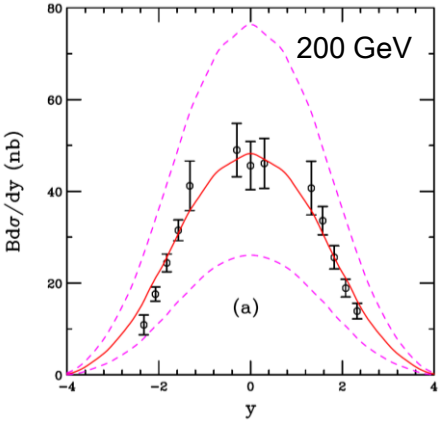
Reference for R_{AA} calculation

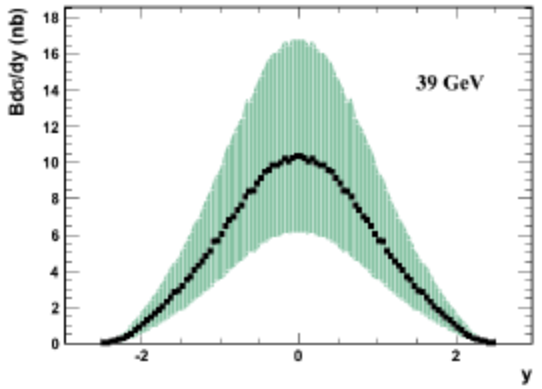


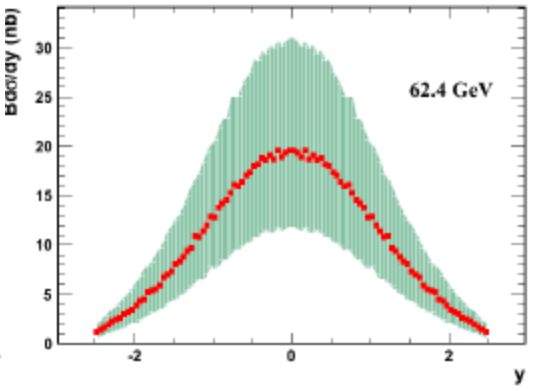
p + p reference from CEM calculation



R. Nelson, R. Vogt et al, arXiv:1210.4610v1



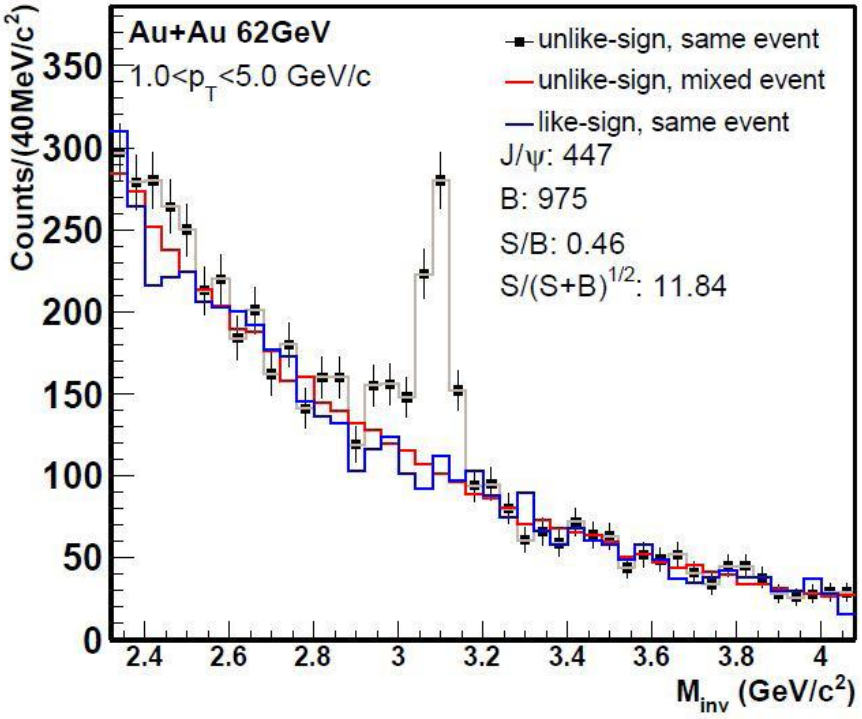


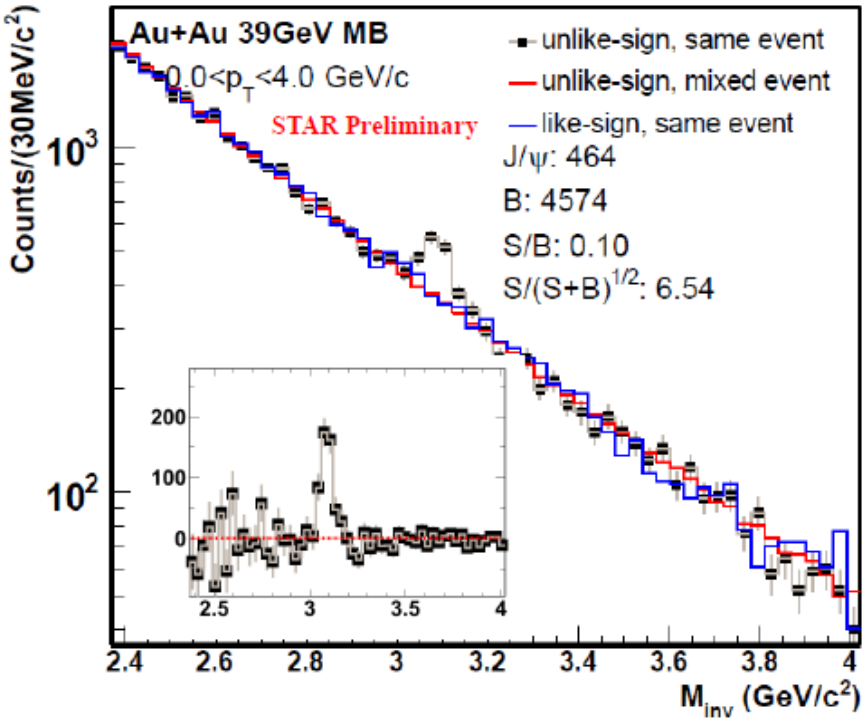


39 GeV: $Bd\sigma/dy = 8.7^{+5.6}_{-3.5}$ nb ($|y|<1.0$) $Bd\sigma/dy = 2.3^{+1.5}_{-1.0}$ nb ($1.2<|y|<2.2$)

62.4 GeV: $Bd\sigma/dy = 17.1^{+9.9}_{-7.0}$ nb ($|y|<1.0$) $Bd\sigma/dy = 6.1^{+3.8}_{-2.6}$ nb ($1.2<|y|<2.2$)

J/ψ signal at RHIC low energy





J/ψ spectra at RHIC low energy