J/ψ Measurements at STAR

Christopher Powell for the STAR Collaboration
Lawrence Berkeley National Laboratory /
University of Cape Town

RHIC & AGS Annual Users' Meeting
Brookhaven National Laboratory
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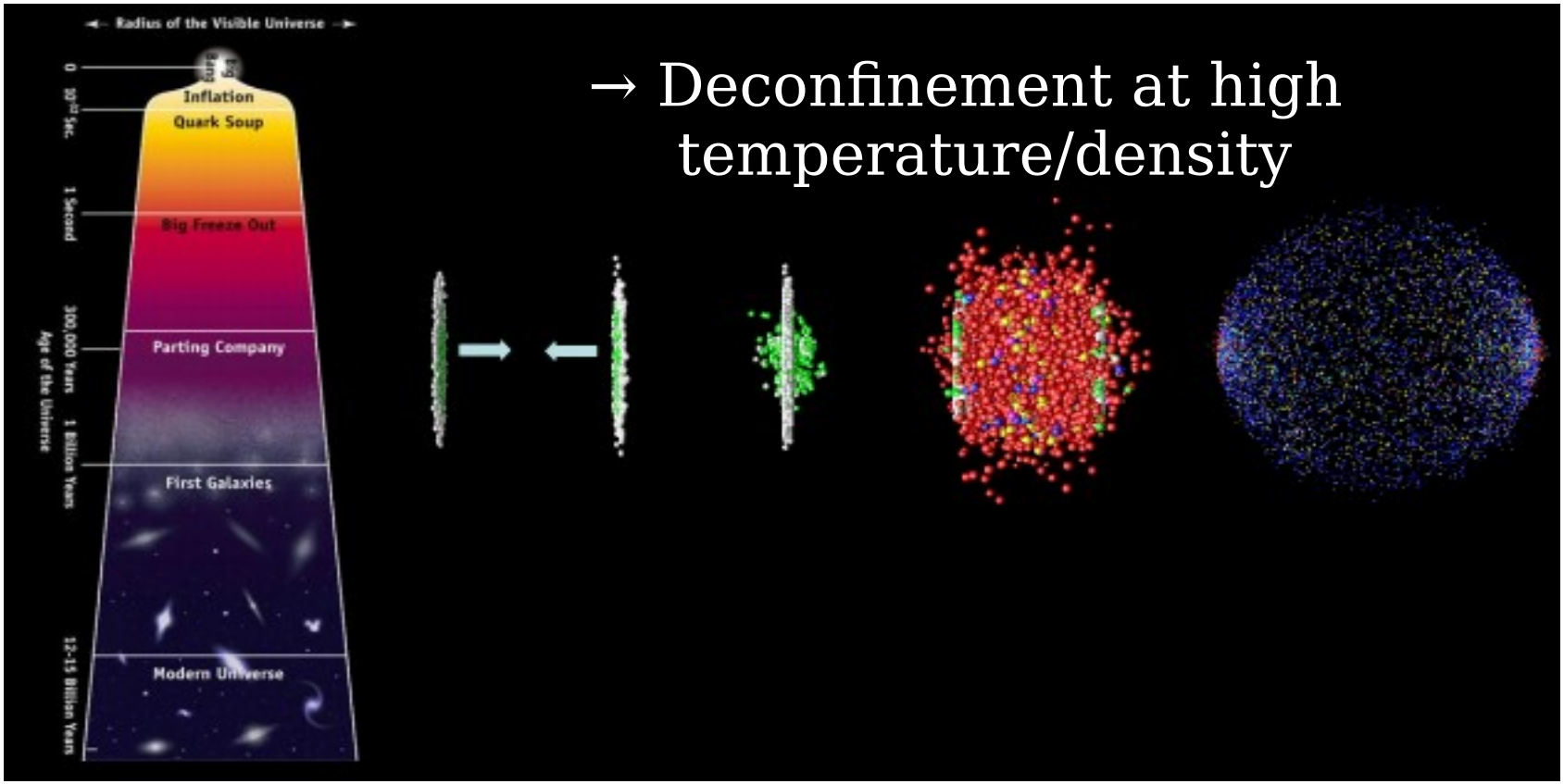
Outline

- Why J/ψ?
- Previous Measurements
- Experiment
- Reconstructing J/ψ
- Results
- Future
- Summary

Why J/ψ?

Relativistic Heavy Ion Collisions



A suppression of J/ψ is expected due to colour screening between the charm and anticharm quarks. **Phys. Lett. 178B (1986) 41*

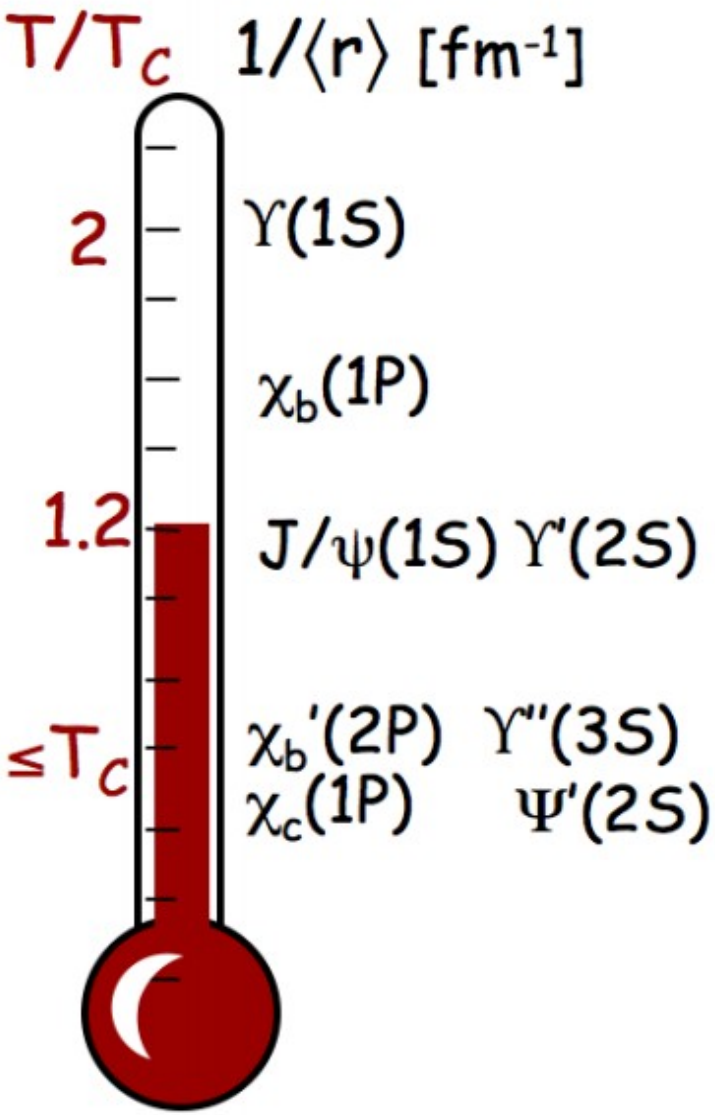
J/ψ as a probe

Charm quarks are heavy ($m_C >> \Lambda_{QCD}$)
→ produced in initial hard scattering

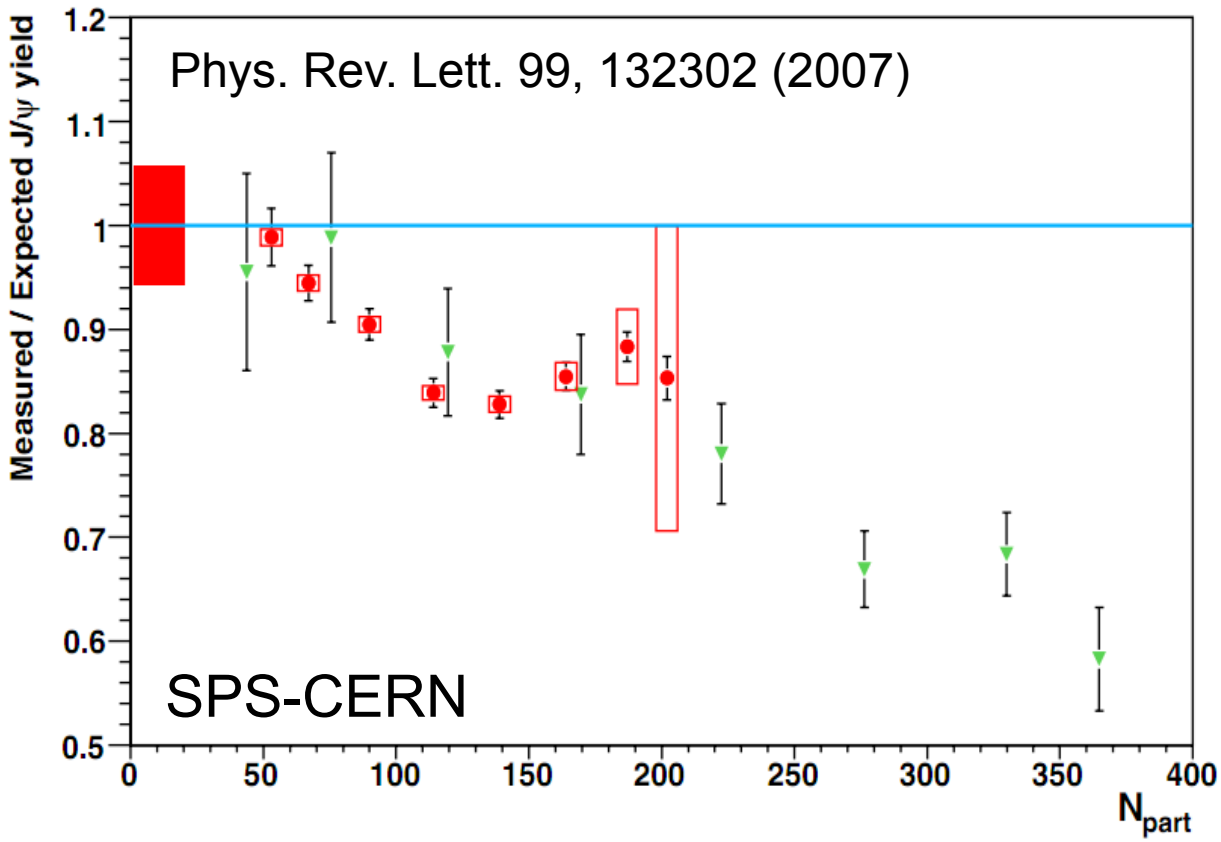
J/ψ as a probe of the dense medium!

Furthermore, we expect a sequential melting of quarkonium states – ***thermometer!***

Eur.Phys.J.C61: 705-710,2009



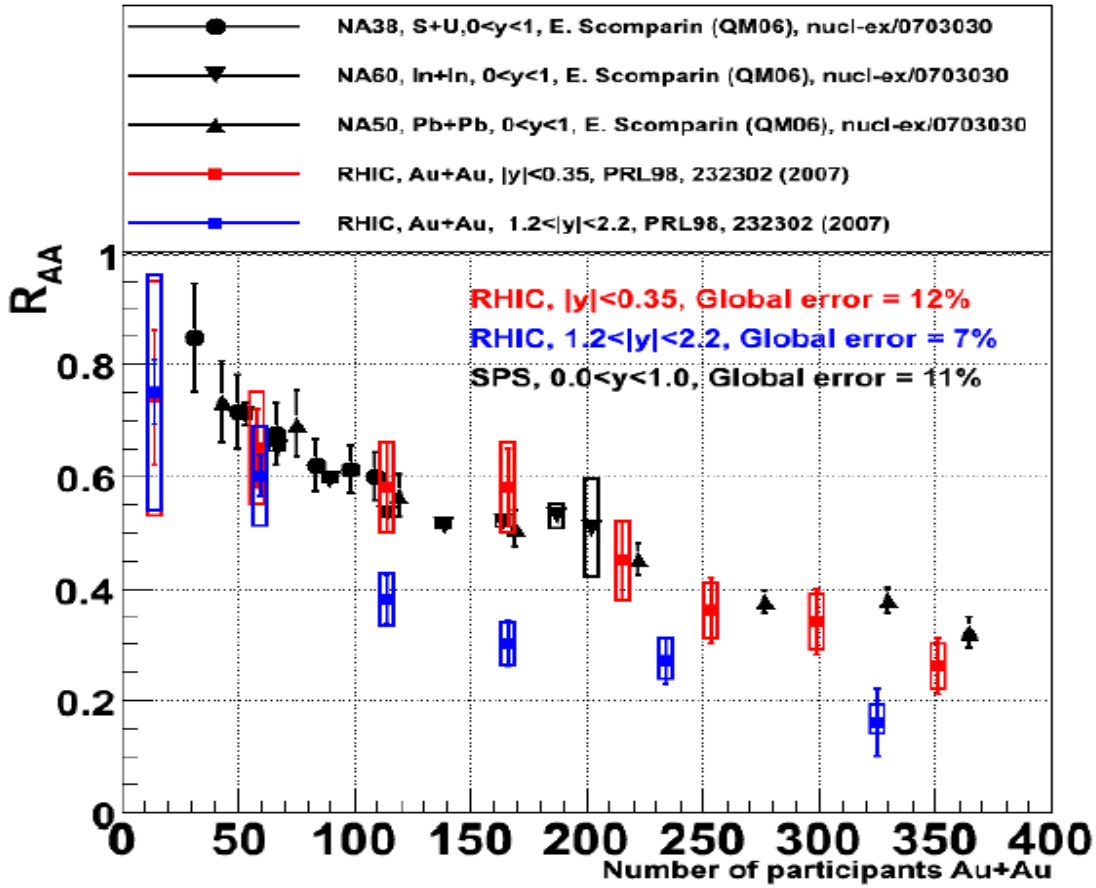
Suppression of J/ψ has been observed



Pb-Pb (NA50, green triangles)
In-In (NA60, red circles)

Suppression of J/ψ has been observed

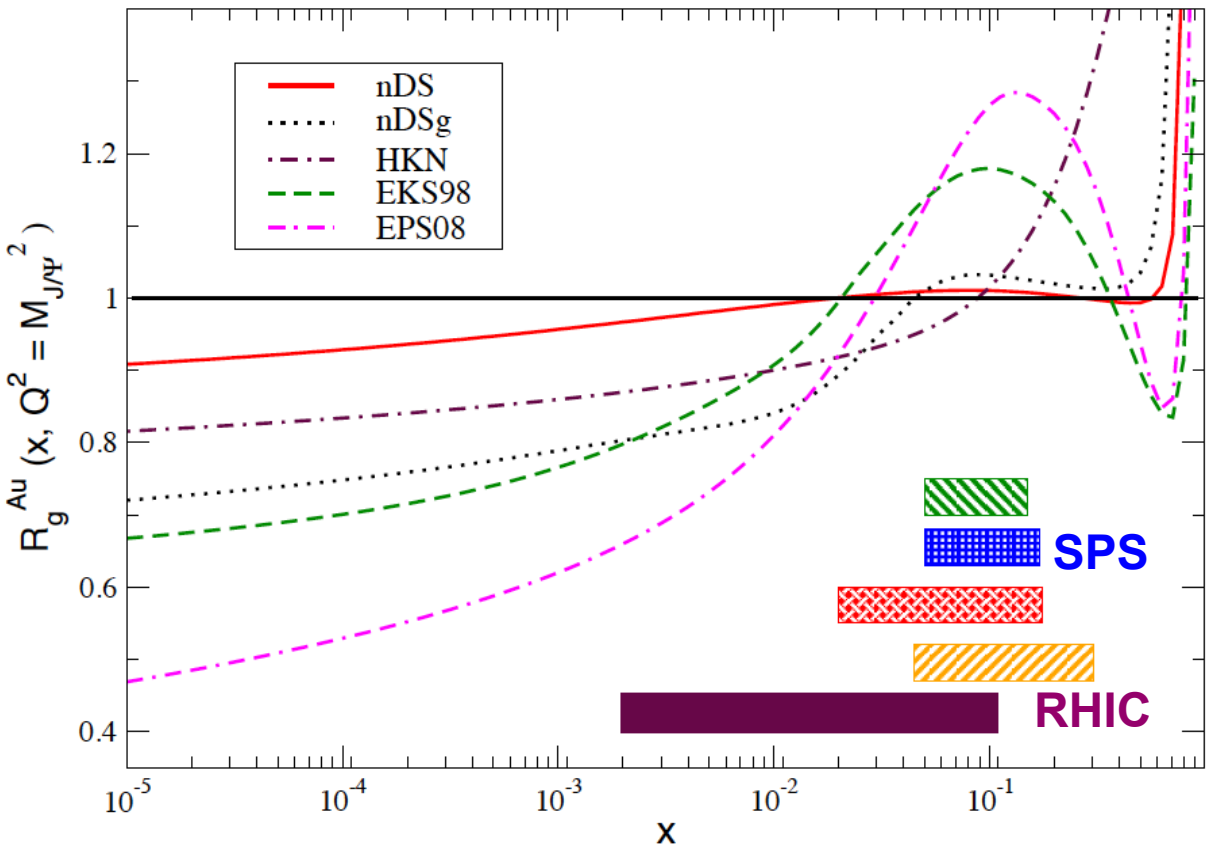
Unexpected similarity between SPS and RHIC energies…



Recombination of $c\bar{c}$ pairs due to increased charm density?
Cold nuclear matter effects (shadowing, nuclear absorption...)?

Cold nuclear matter effects

Shadowing (modification of PDFs within a nucleon)

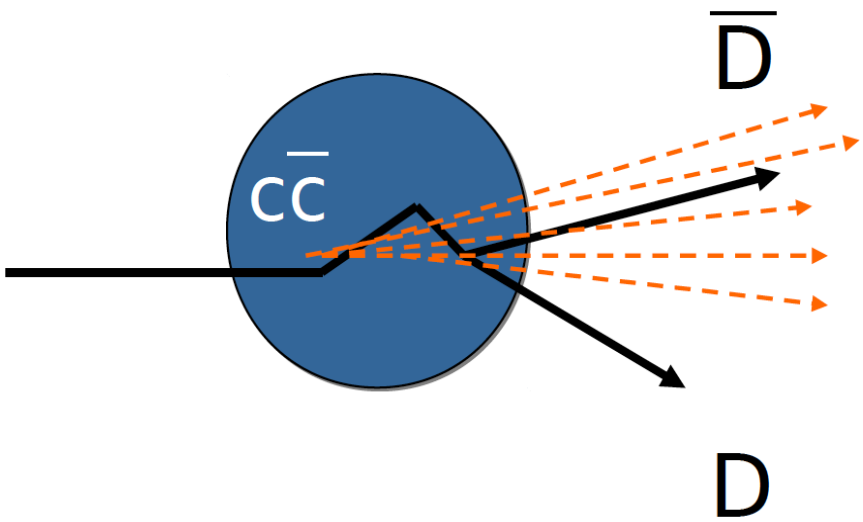


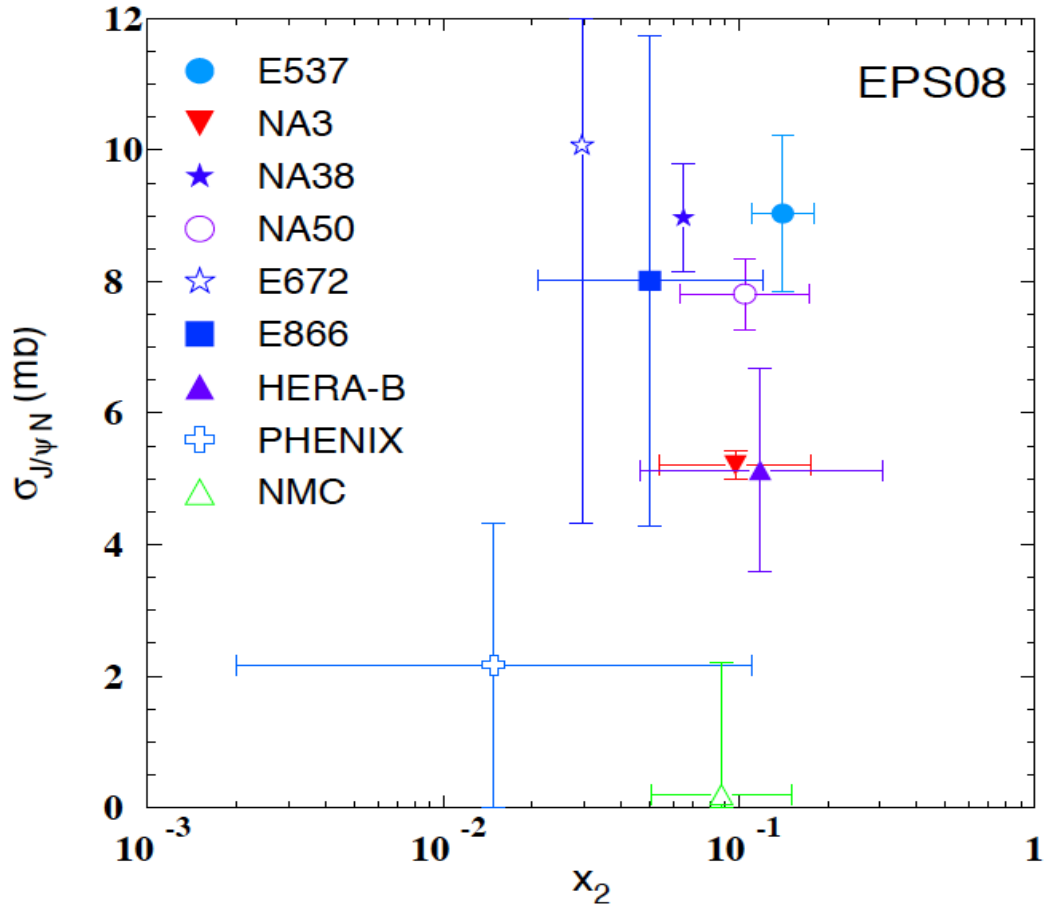
Eur. Phys. J. C61, 847 (2009)

Large uncertainty on model predictions.
Need p+A, d+A to constrain "normal" suppression

Cold nuclear matter effects

Nuclear Absorption





Eur. Phys. J. C61, 847 (2009)

Large uncertainty on model predictions.
Need p+A, d+A to constrain "normal" suppression

Other effects

*QGP (suppression, recombination, co-mover absorption, gluon saturation)
*CNM (shadowing, absorption)

*Feed-down:

· melting of excited states (ψ', χ_c)

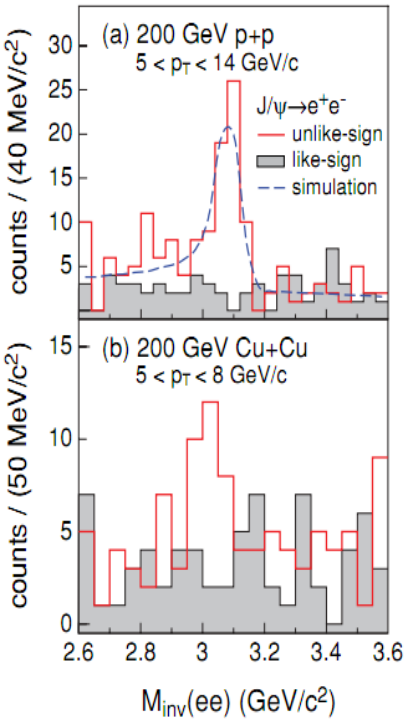
· $B \rightarrow J/\psi$ feed down

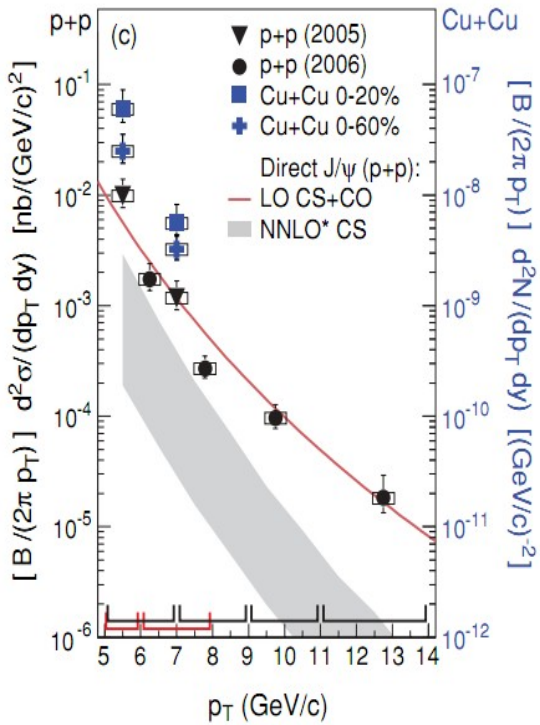
(estimated 30 – 40 % total contribution)
JHEP 0810:004,2008

*Production Mechanism:

· Color Singlet vs Color Octet model

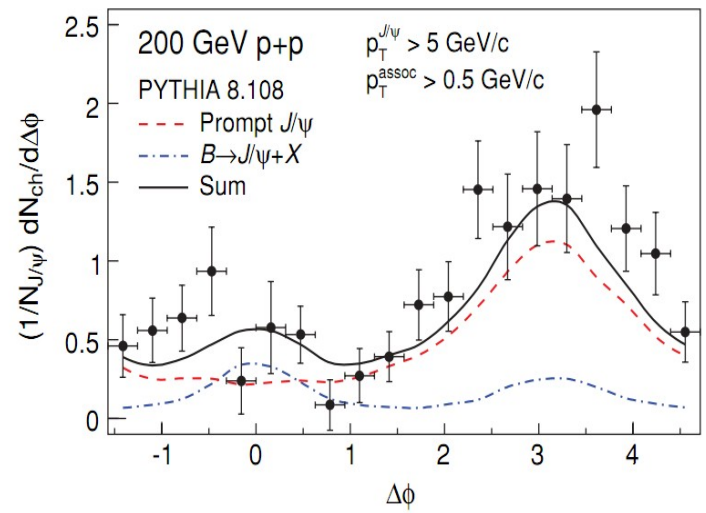
Previous Measurements

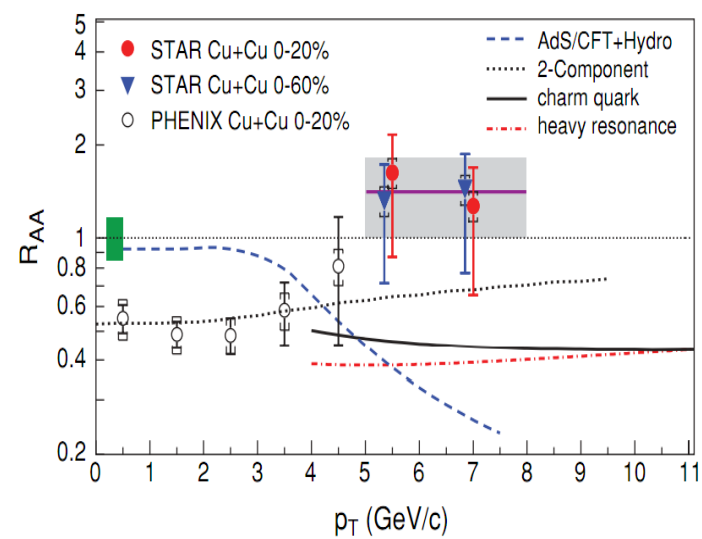




J/ψ in p+p and Cu+Cu @ 200 GeV

Phys.Rev.C80:041902,2009



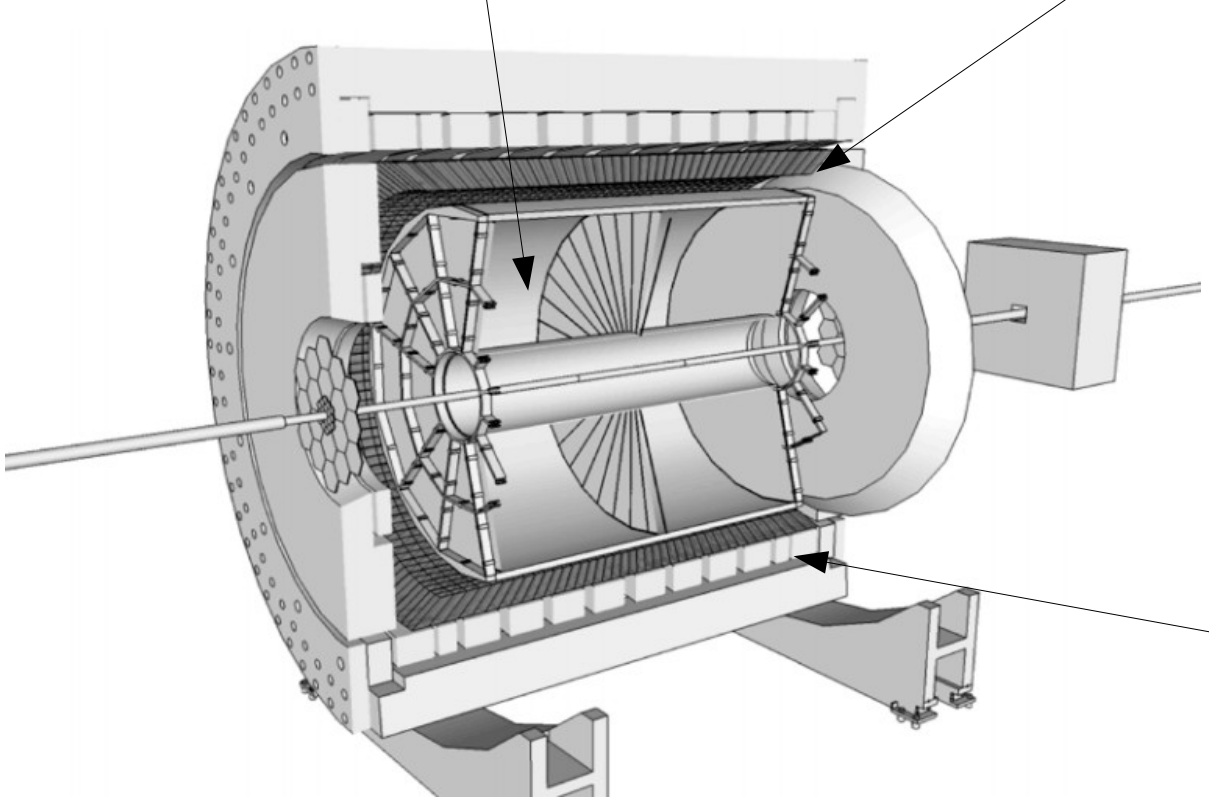


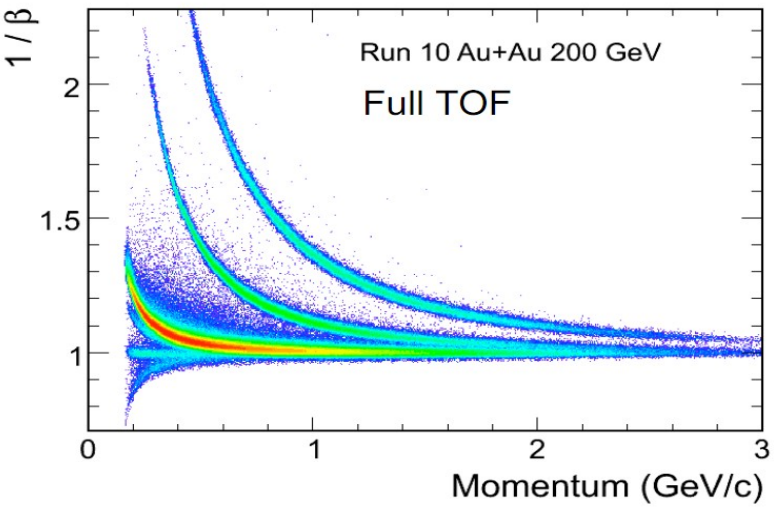
- CO+CS: no room for feed-down.
- NNLO CS: predicts a steeper dependence on pT
- First estimate of B → J/ψ feed-down
- No suppression in Cu+Cu at high-pT

STAR Experiment

TPC:
$|\eta| < 1$, $0 < \varphi < 2\pi$
Tracking → pT, η, φ
dE/dx → PID

BEMC:
$|\eta| < 1$, $0 < \varphi < 2\pi$
Tower $\Delta\eta \times \Delta\varphi = 0.05 \times 0.05$
Energy → E/p ~ 1 (electrons)



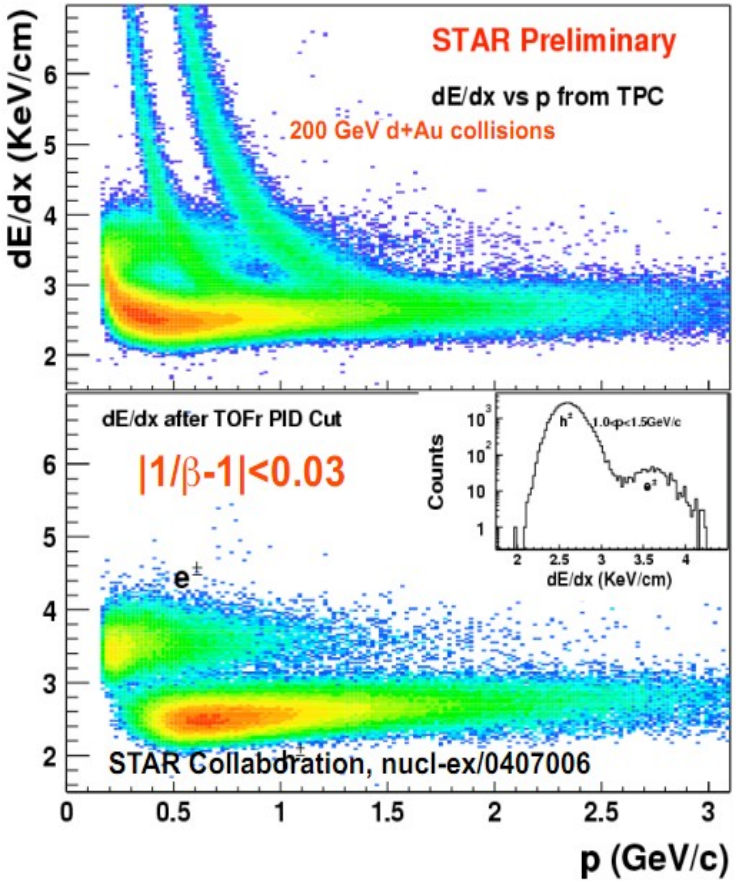


TOF:
$|\eta| < 1$, $0 < \varphi < 2\pi$
Timing res. < 100 ps
1/β → PID

Reconstructing J/ψ

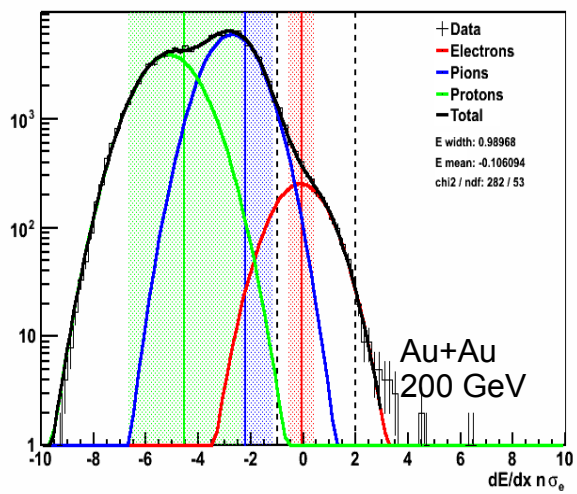
Reconstruction done via the dielectron channel:

$$J/\psi \rightarrow e^{+} + e^{-} \quad (BR = 5.94\ \%)$$

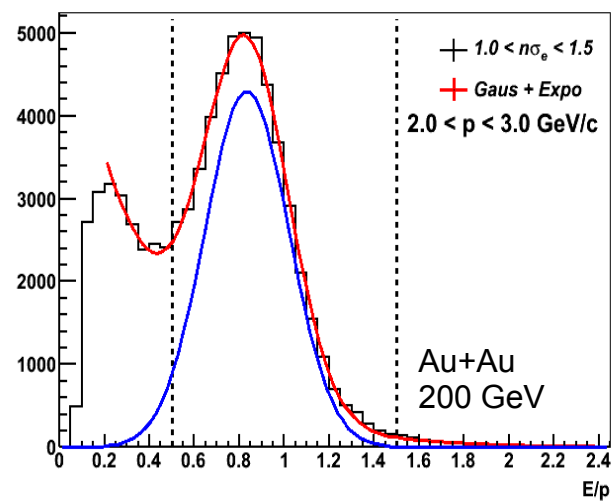


TPC dE/dx	→ select electrons
TOF 1/β	→ separate hadrons
BEMC E_{tow}	→ E/p ~ 1 (electron)

dE/dx (nσe) 5 < p < 6 GeV/c



E/p 2 < p < 3 GeV/c

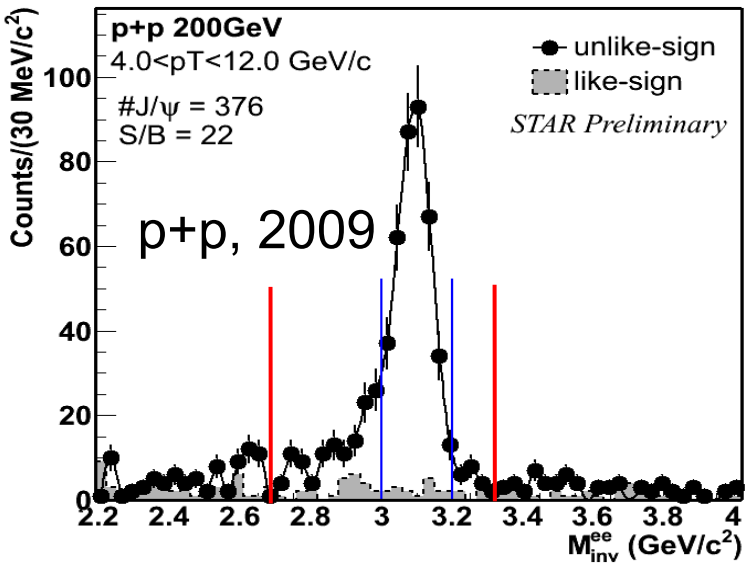


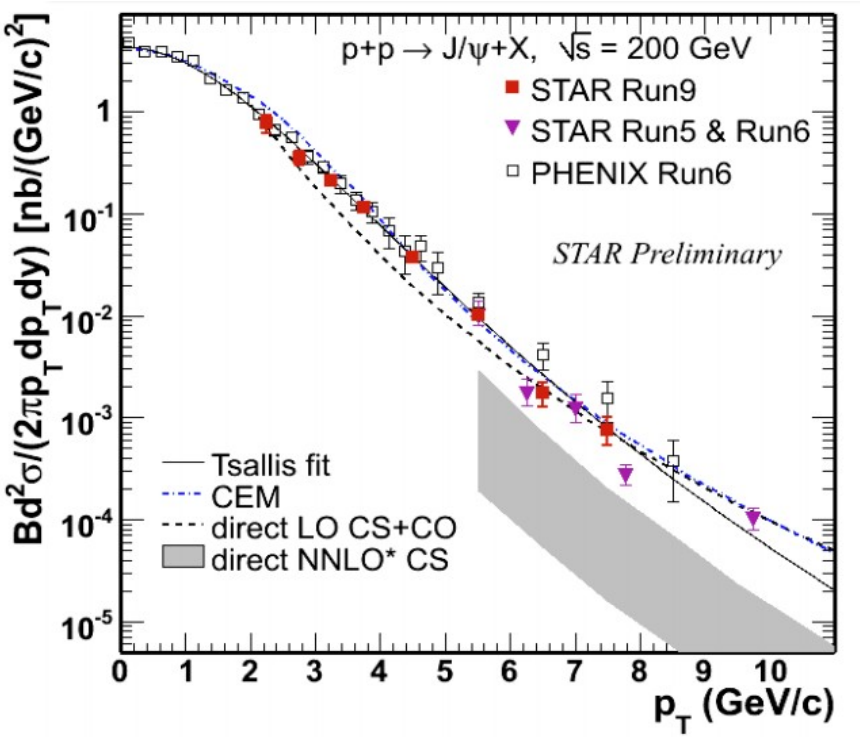
*|1/β-1| < 0.03, match to BEMC

Results

p+p 200 GeV

Production mechanism: high-pT J/ψ





PHENIX: Phys. Rev. D 82, 012001 (2010)
STAR: Phys. Rev. C80, 041902(R) (2009)
Tsallis Blast-Wave model: ZBT *et al.*, arXiv:1101.1912; JPG 37, 085104 (2010)

- Good agreement between STAR and PHENIX
- Color singlet model: direct NNLO still misses the high-p_T part

  P. Artoisenet et al., Phys. Rev. Lett. 101, 152001 (2008), and J.P. Lansberg private communication.
- LO CS+CO: leave no room for feeddown at high p_T

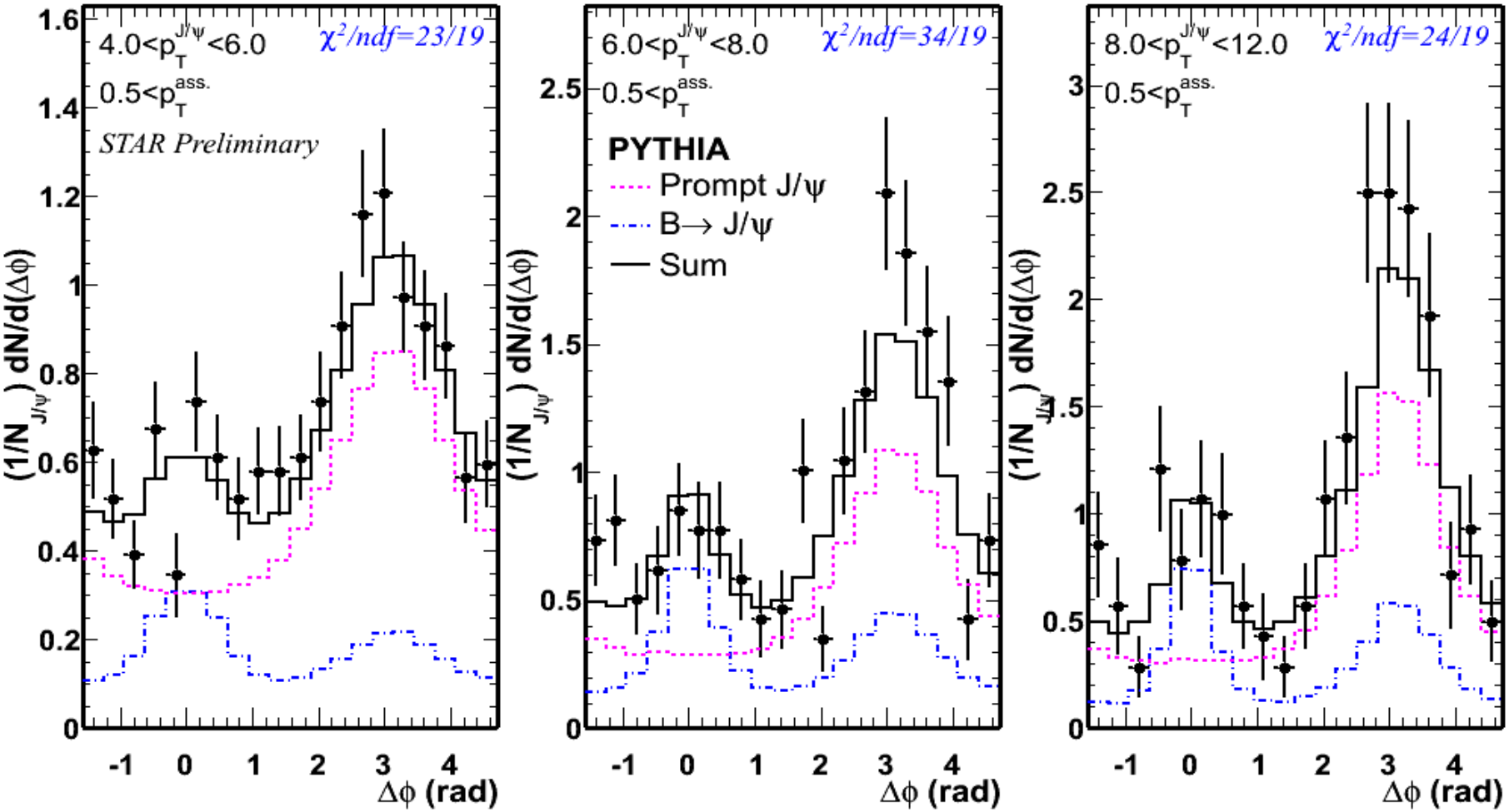
  G. C. Nayak, M. X. Liu, and F. Cooper, Phys. Rev. D68, 034003 (2003), and private communication.
- CEM describes data well

  M. Bedjidian et al., ArXiv: hep-ph/0311048

Results

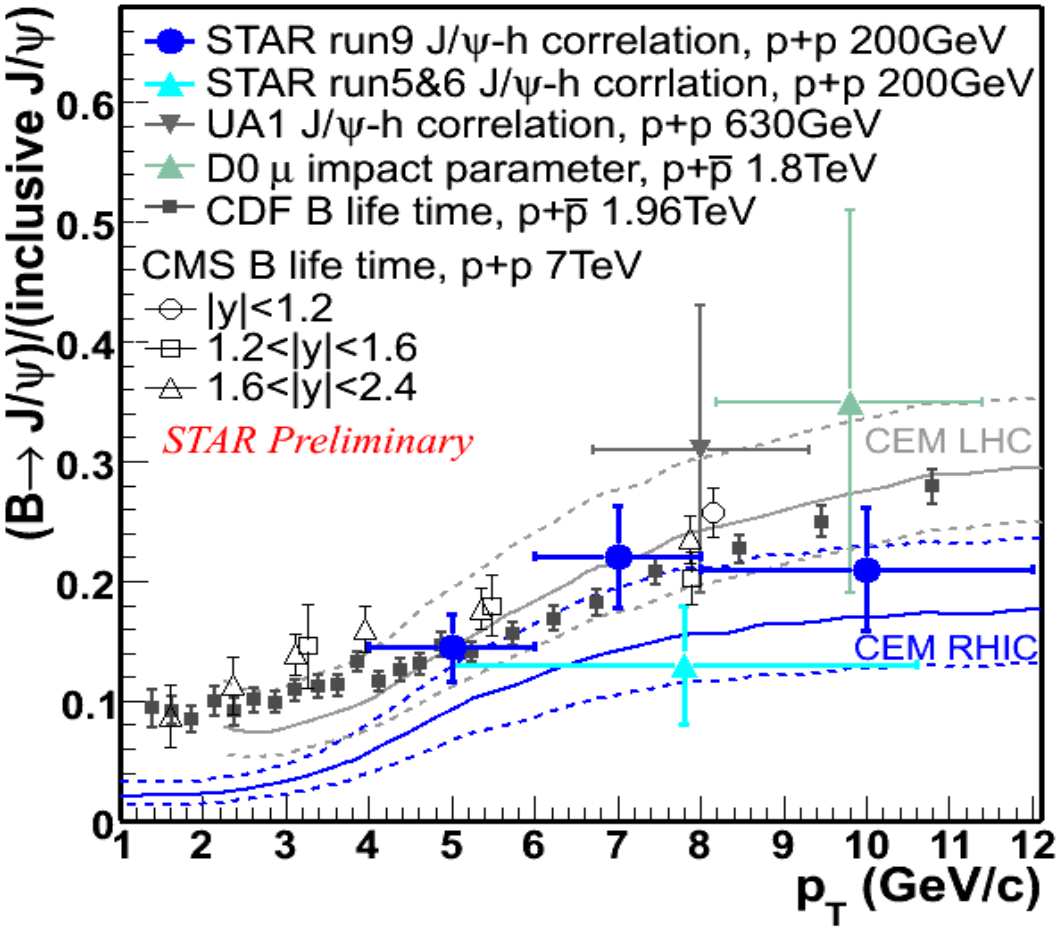
p+p 200 GeV

J/ψ-hadron correlations



Results

p+p 200 GeV



B → J/ψ (inclusive) feed-down

Model based extraction using PYTHIA

*PRC**80**, 041902(R), 2009*
*PLB**200**, 380, 1988*
*PLB**370**, 239, 1996*
*PRD**71**, 032001, 2005*
*EPJC**71**, 1575, 2011*

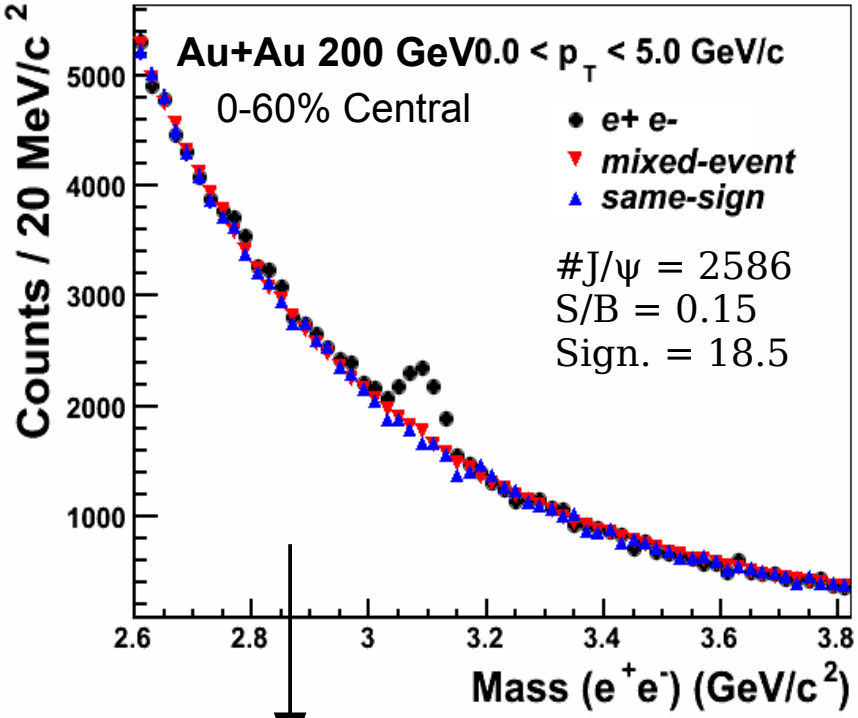
Workshop on Heavy Quark Production in Heavy-ion Collisions, Jan. 6, 2011, Purdue University

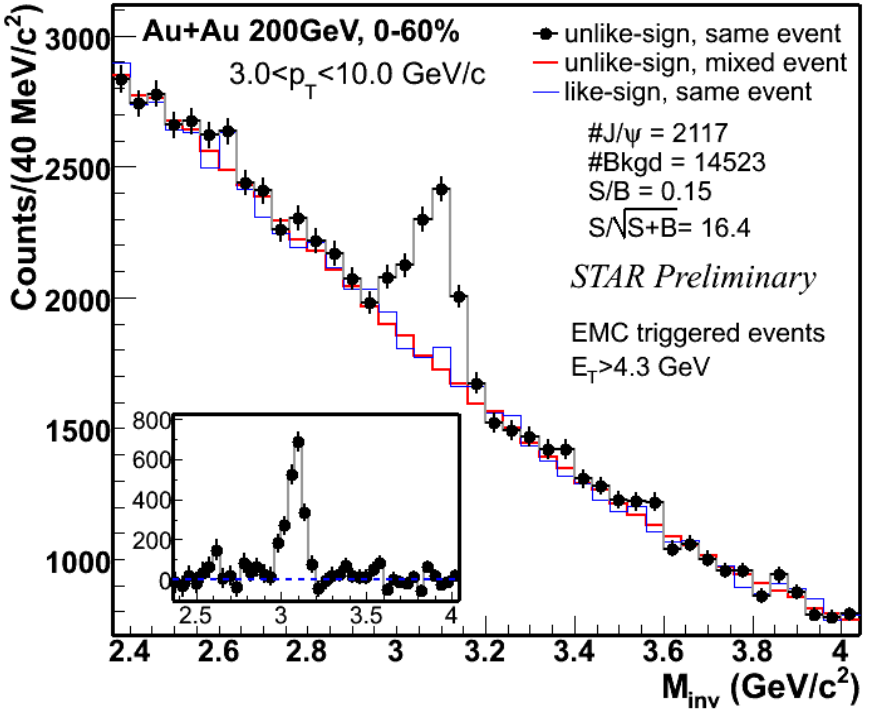
- Extracted from near side J/ψ-h correlation
- Consistent with previous results
- No significant beam energy dependence
- Can be used to constrain B production

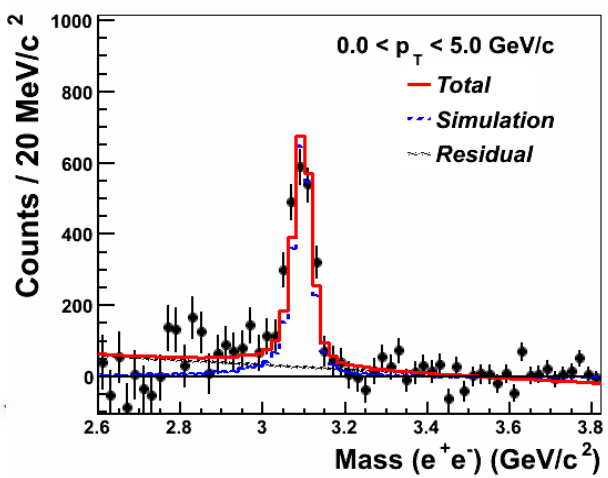
Results

Au+Au 200 GeV

J/ψ Signal





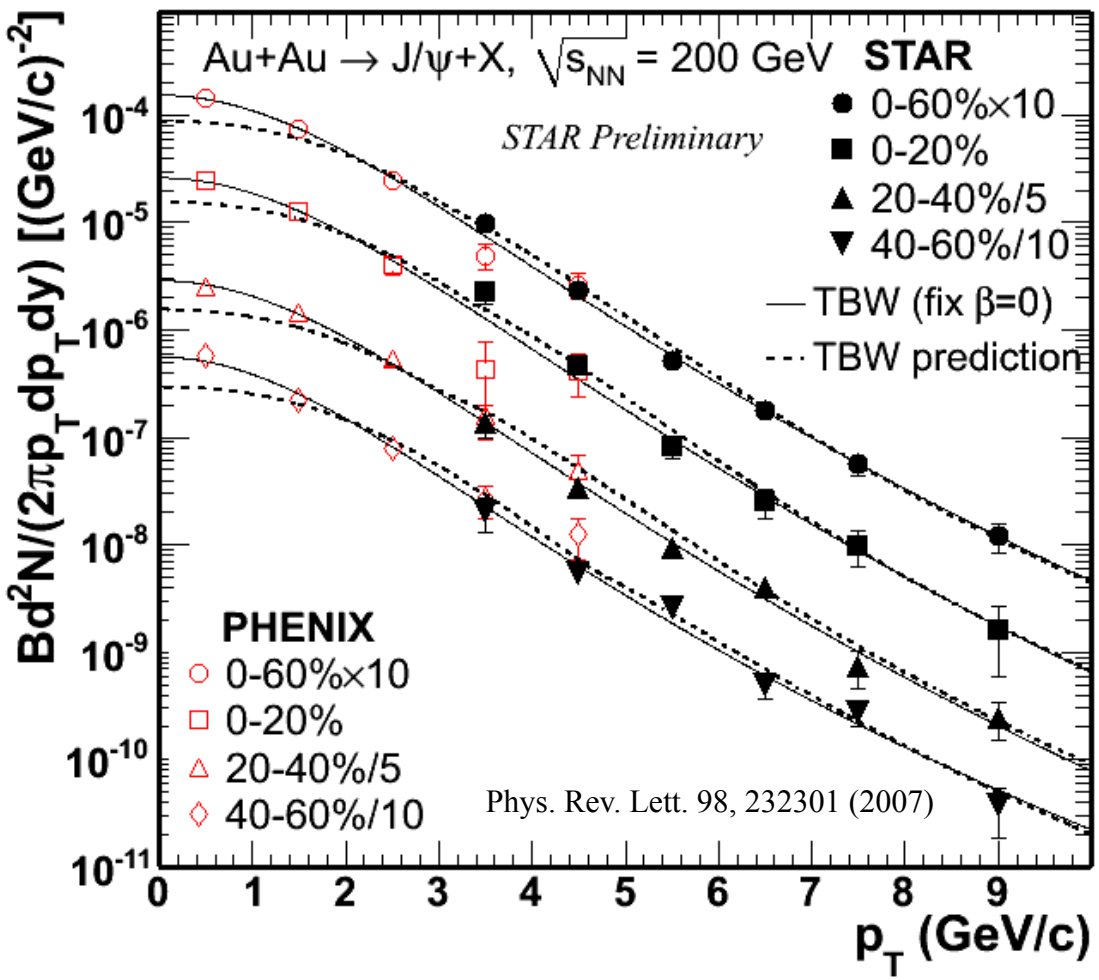


- Significantly reduced material
  → good S/B ~ 1/7
- Clean signal for minimum-bias (left) and high-tower trigger (right) data.

Results

Au+Au 200 GeV

Spectra



· Good agreement between STAR and PHENIX

· J/ψ pT range extended to 0 - 10 GeV/c

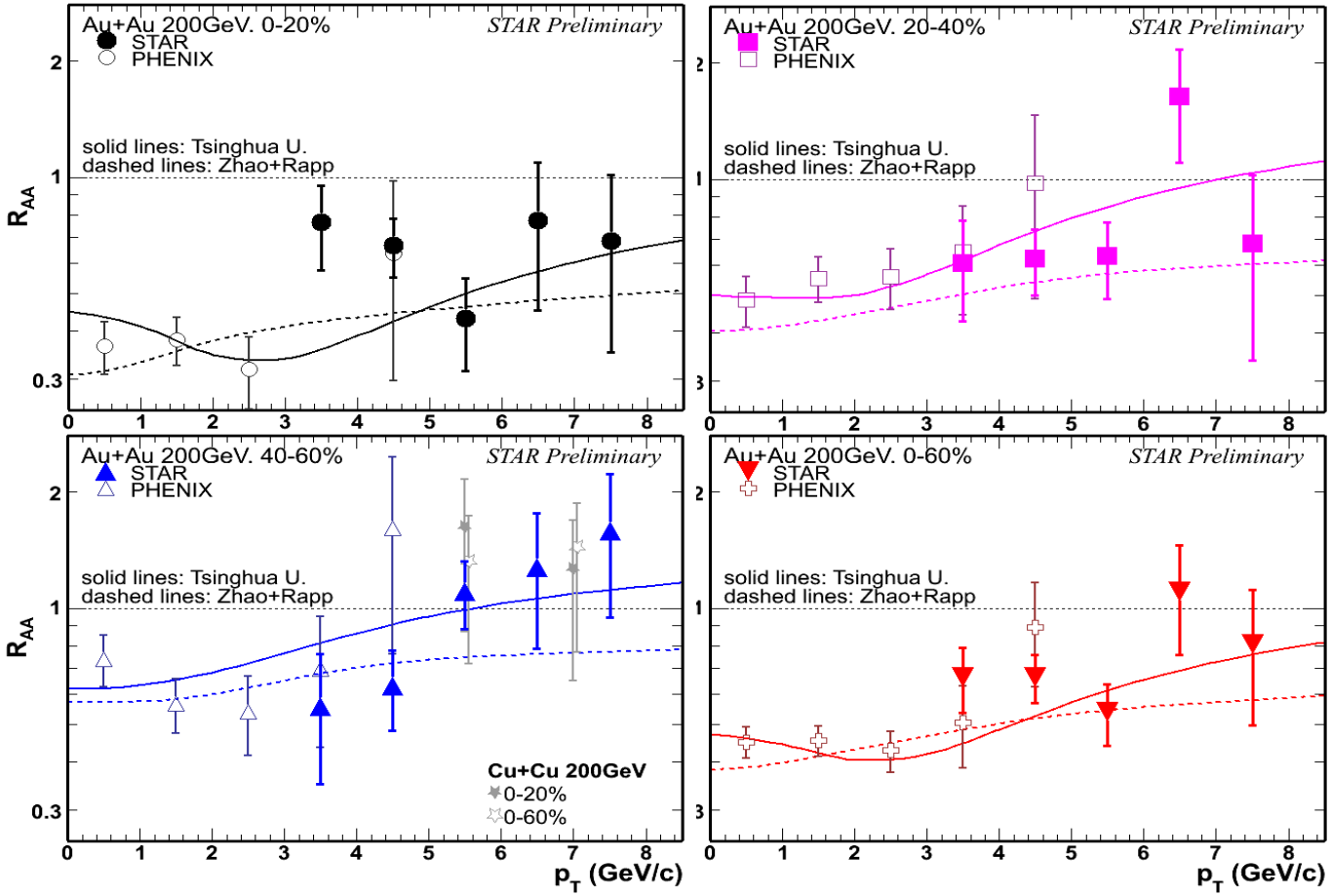
· Softer spectra than light hadron prediction → low-pT regeneration?

Tsallis Blast-Wave model: ZBT *et al.*, arXiv:1101.1912; JPG 37, 085104 (2010)

Results

Au+Au 200 GeV

Nuclear Modification Factor vs. pT



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

Increase from low p_T to high p_T

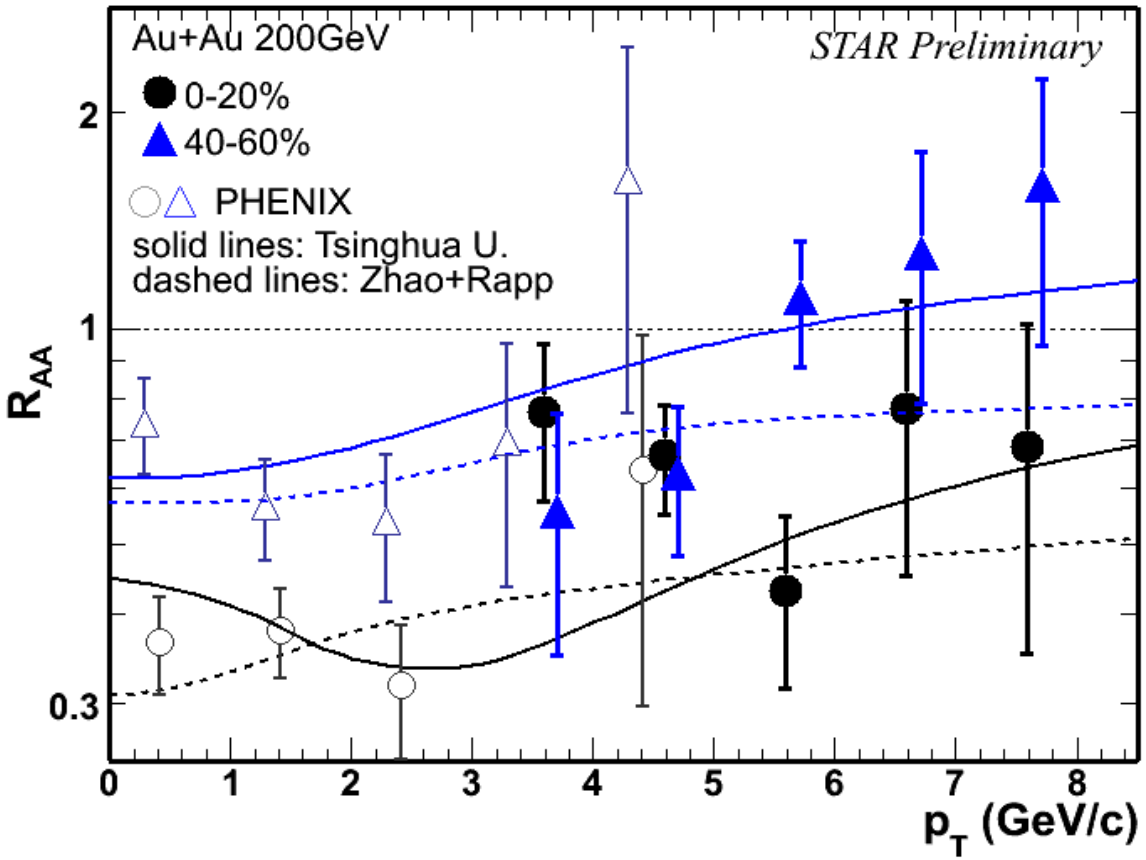
Consistent with unity at high p_T in (semi-) peripheral collisions

More suppression in central than in peripheral even at high p_T

Results

Au+Au 200 GeV

Nuclear Modification Factor vs. pT



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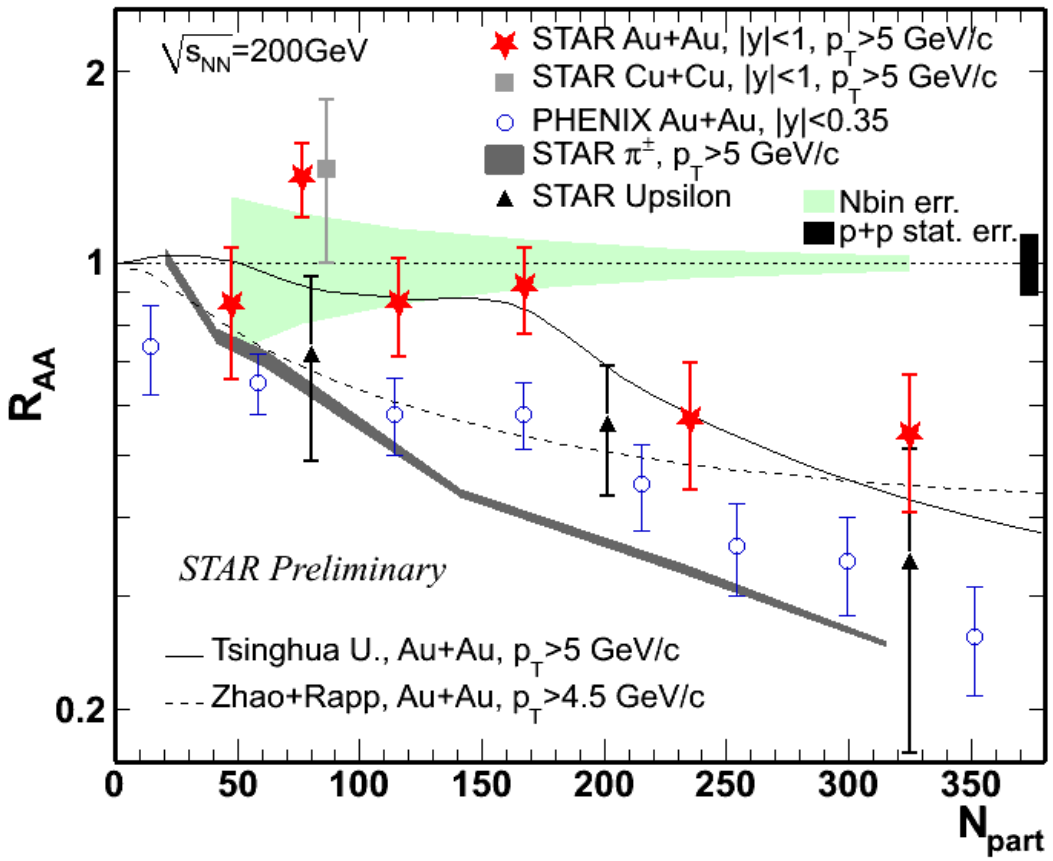
STAR CuCu: PRC80, 014922(R)
PHENIX: PRL98, 232301

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

Results

Au+Au 200 GeV

Nuclear Modification Factor 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: Yichun Xu at QM2009

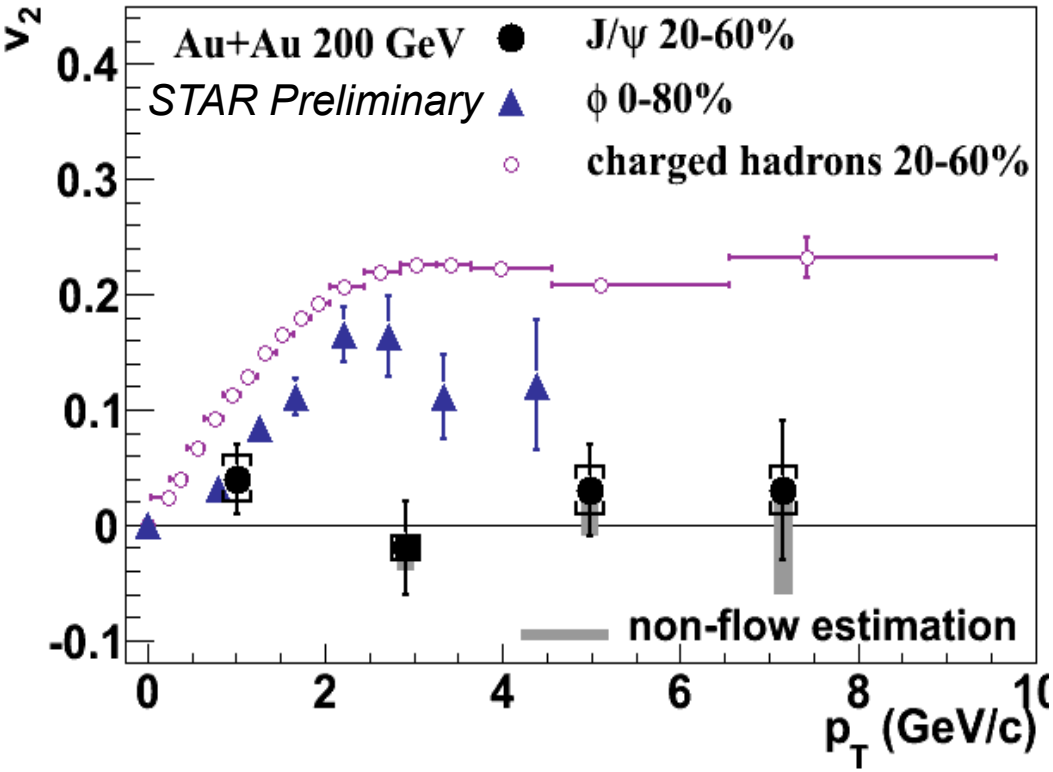
Lower values for low pT across the centrality range.
Suppression in central collisions.
Formation time → system size effect?

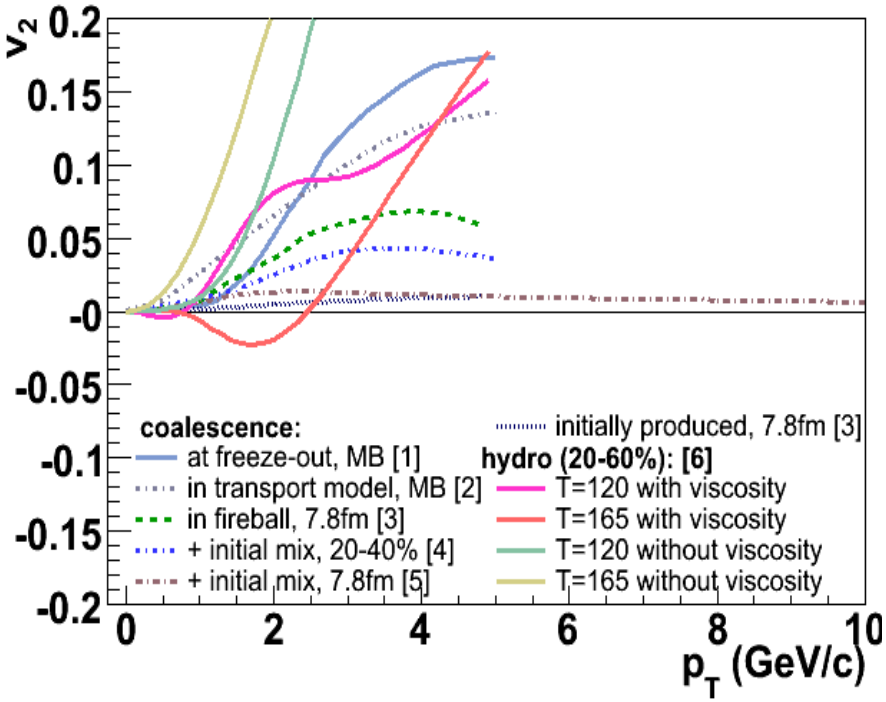
Results

Au+Au 200 GeV

J/ψ Elliptic Flow v_2

[1] V. Greco, C.M. Ko, R. Rapp, PLB 595, 202.
[2] L. Ravagli, R. Rapp, PLB 655, 126.
[3] L. Yan, P. Zhuang, N. Xu, PRL 97, 232301.
[4] X. Zhao, R. Rapp, 24th WWND, 2008.
[5] Y. Liu, N. Xu, P. Zhuang, Nucl. Phy. A, 834, 317.
[6] U. Heinz, C. Shen, priviate communication.

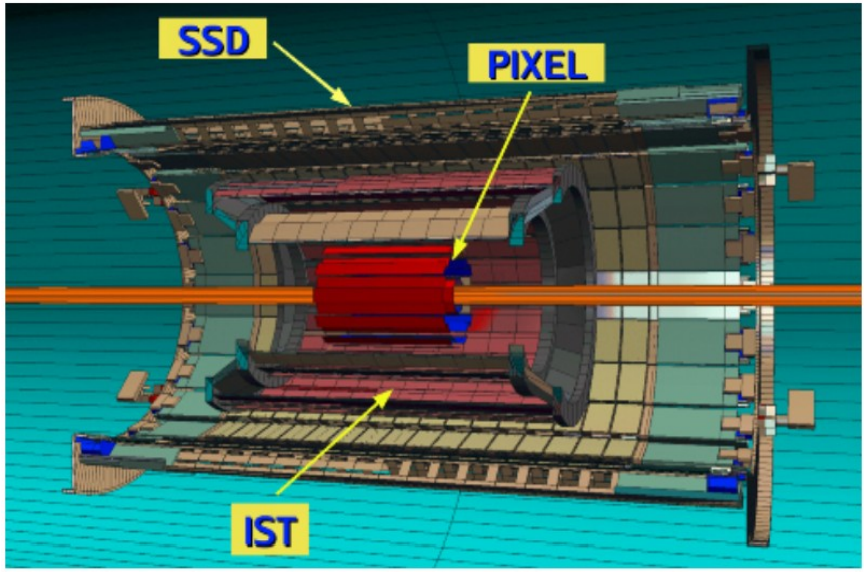




Consistent with zero
Disfavor coalescence from thermalized charm quarks
No regeneration? Regeneration only at low p_T? Charm does not flow?

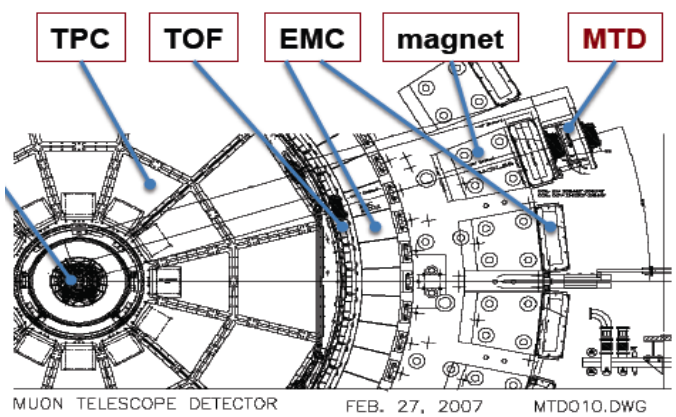
Future

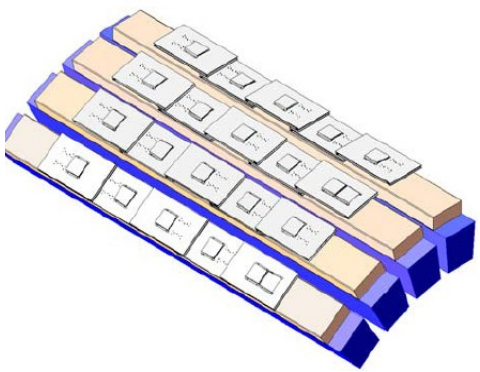
Heavy Flavor Tracker



$|\eta| < 1$, $0 < \varphi < 2\pi$
Pixel and silicon strip detector:
PXL: 2 layers of CMOS pixel detectors (2.5, 8 cm)
IST: low mass silicon strip sensor (14 cm)
SSD: double-sided silicon strip detector (22 cm)
Constrain B feed-down

Muon Telescope Detector





MPRC technology
(similar to TOF)
Acceptance ~ 45% ($|\eta| < 1$)
No photon conversion
Less Dalitz decay
→ J/ψ trigger across pT range in central Au+Au collisions

Summary

In p+p collisions:

Clear J/ψ signal with low material (high S/B)

→ pT spectrum extended up to 14 GeV/c

→ B feed-down from correlation study

In heavy ion collisions:

Suppression of J/ψ in central collisions

→ stronger effect at low pT

No suppression in high-pT Cu+Cu and high pT peripheral Au+Au

J/ψ v_2 is consistent with zero

→ no coalescence of thermalized charm quarks? Initial production favoured?