Quarkonia Production at STAR

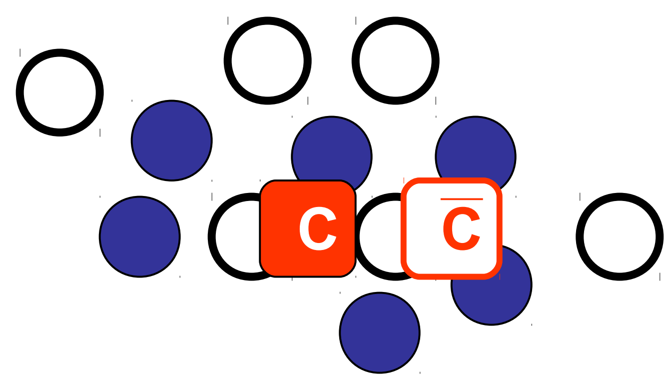
Daniel Kikoła for the STAR collaboration

Purdue University

Matsui & Satz (1986):

Quark-Gluon Plasma

= J/ψ production suppression



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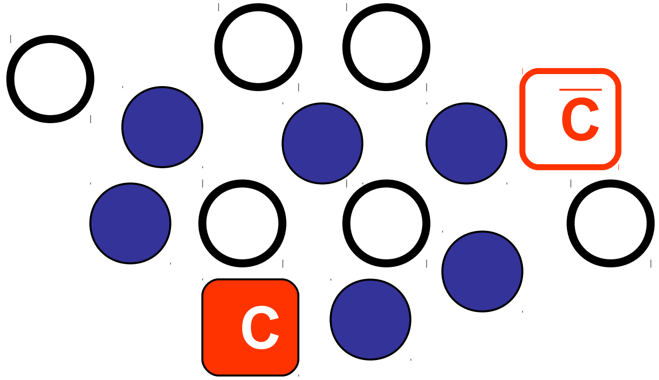

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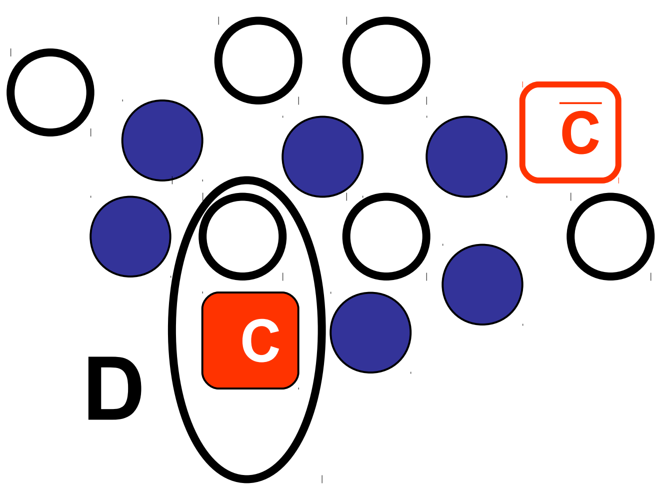
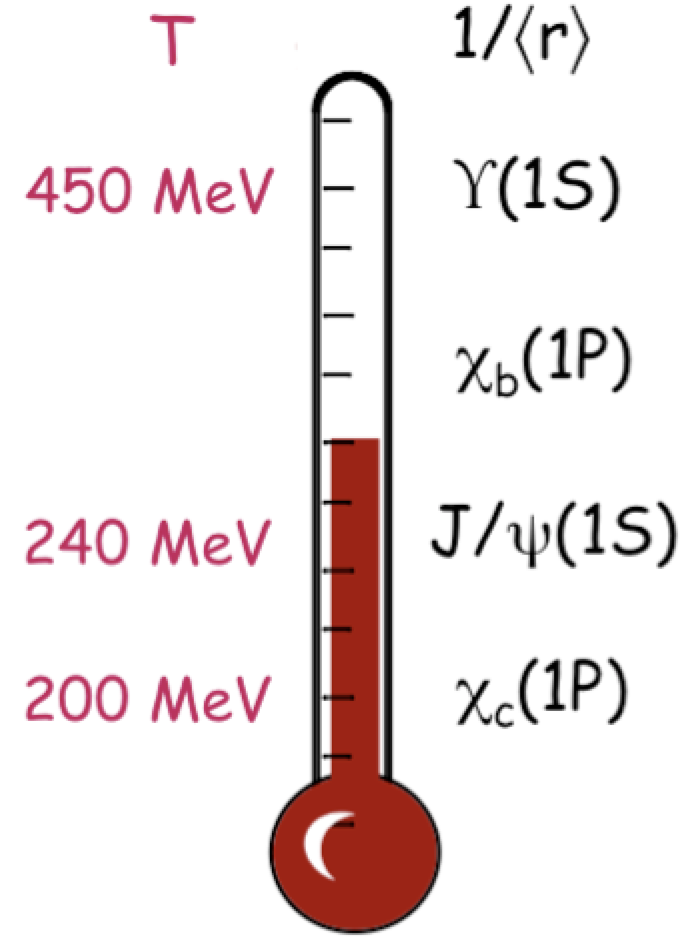


Sequential melting

→ Temperature of QGP



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

Complications

“Normal” suppression

- shadowing
- nuclear absorption

...

Effects in QGP

- secondary production via recombination
- dissociation by gluons, energy loss

…

How to disentangle

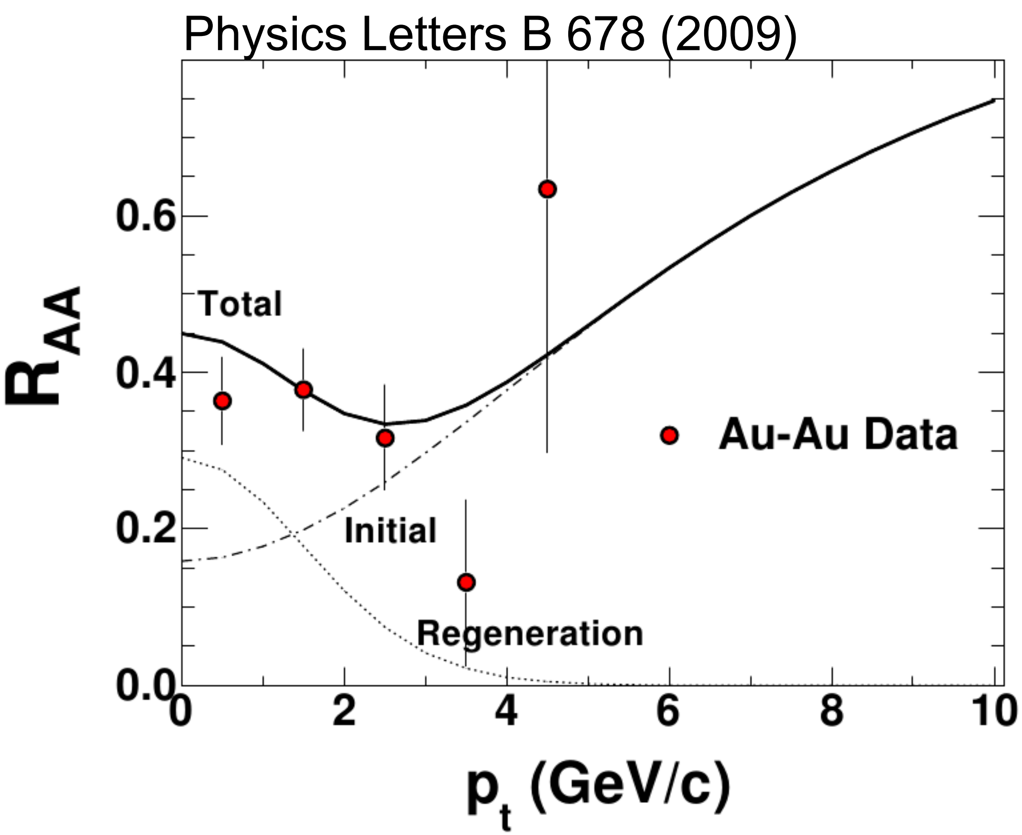
Color screening vs recombination vs CNM ?

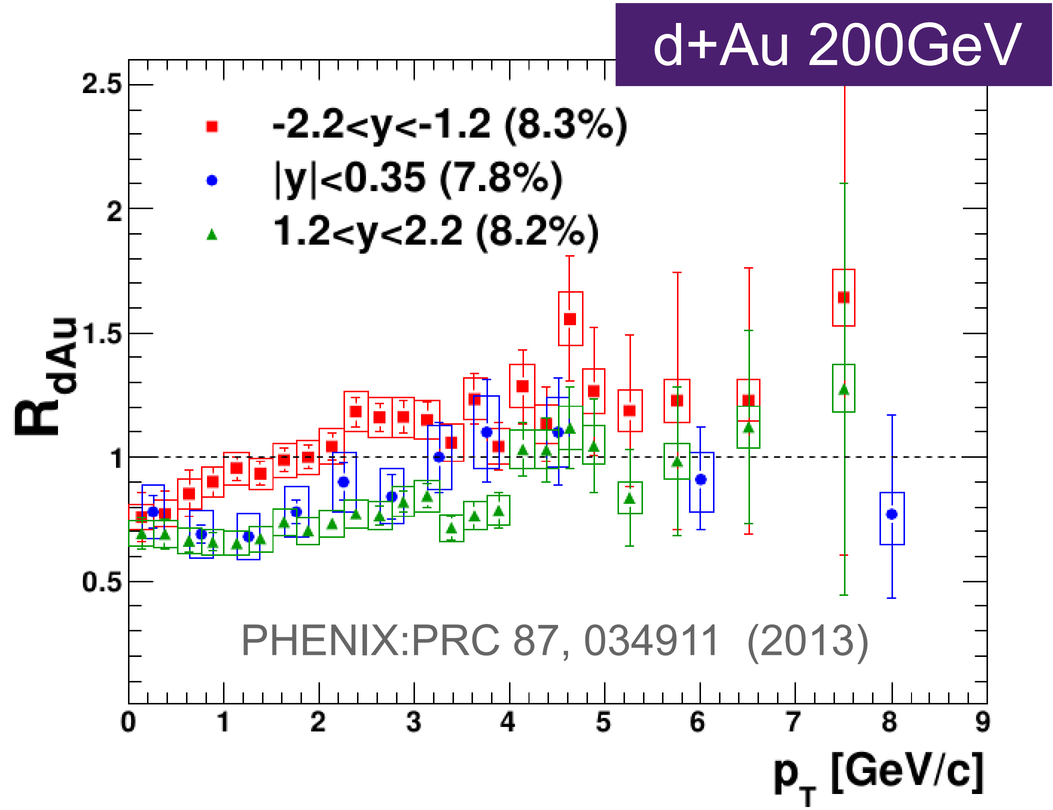
- Vary relative contributions

  → J/ψ production vs energy

- "Simplify" the problem
  - high-p_T J/ψ

High-p_T J/ψ





Recombination and CNM small at high-p_T

→ direct access to QGP effects at $p_T > 4$ GeV

How to disentangle

Color screening vs recombination vs CNM ?

- Vary relative contributions

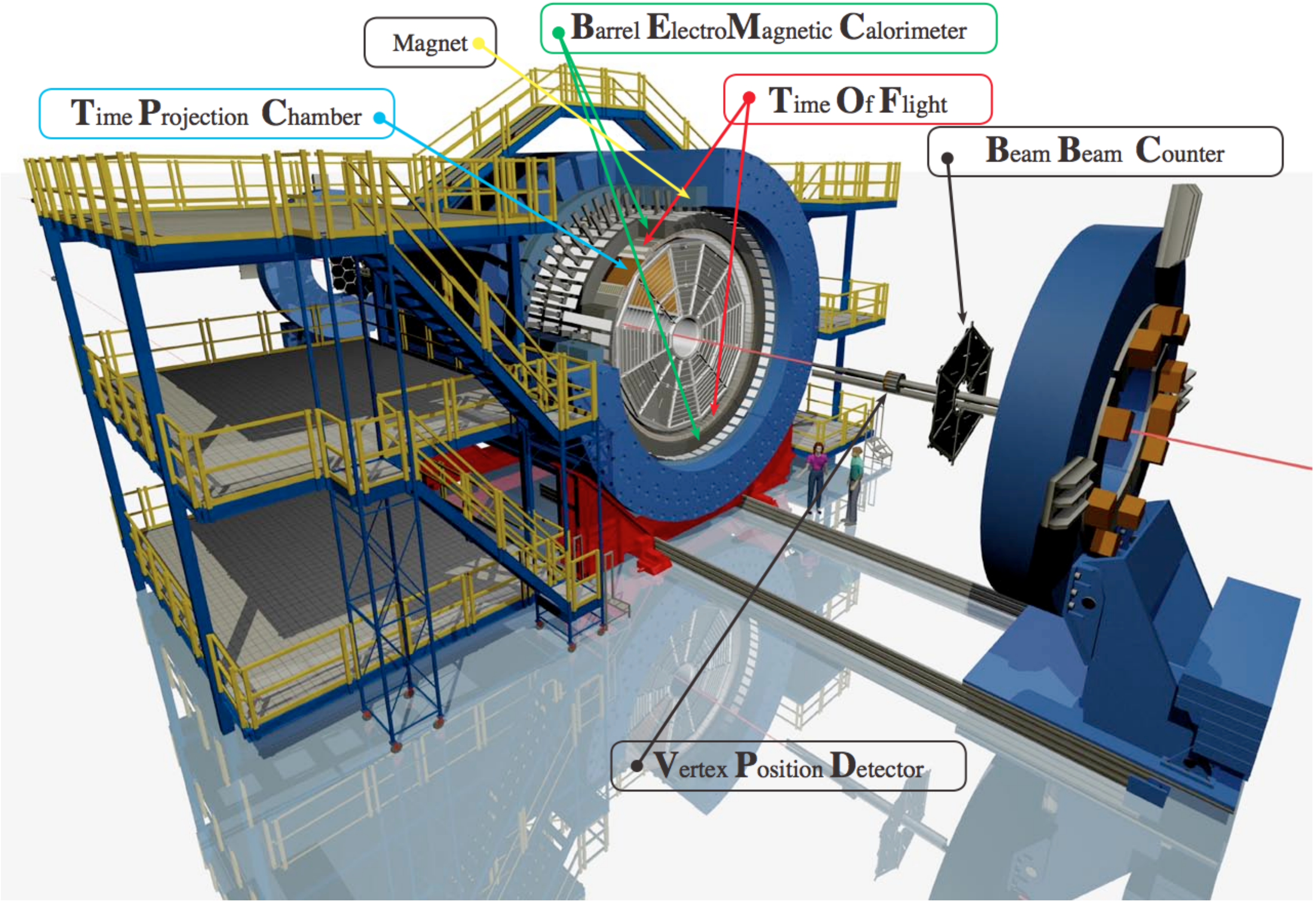
  → J/ψ production vs energy

- "Simplify" the problem
  - high-p_T J/ψ → small recombination and CNM
  - ϒ → negligible co-mover abs. and recombination,

    → less affected by nuclear absorption and shadowing compared to J/ψ at RHIC

The STAR detector

Solenoidal **T**racker **A**t **R**HIC : $-1 < \eta < 1, 0 < \phi < 2\pi$



VPD: minimum bias trigger.

TPC: PID via dE/dx, tracking

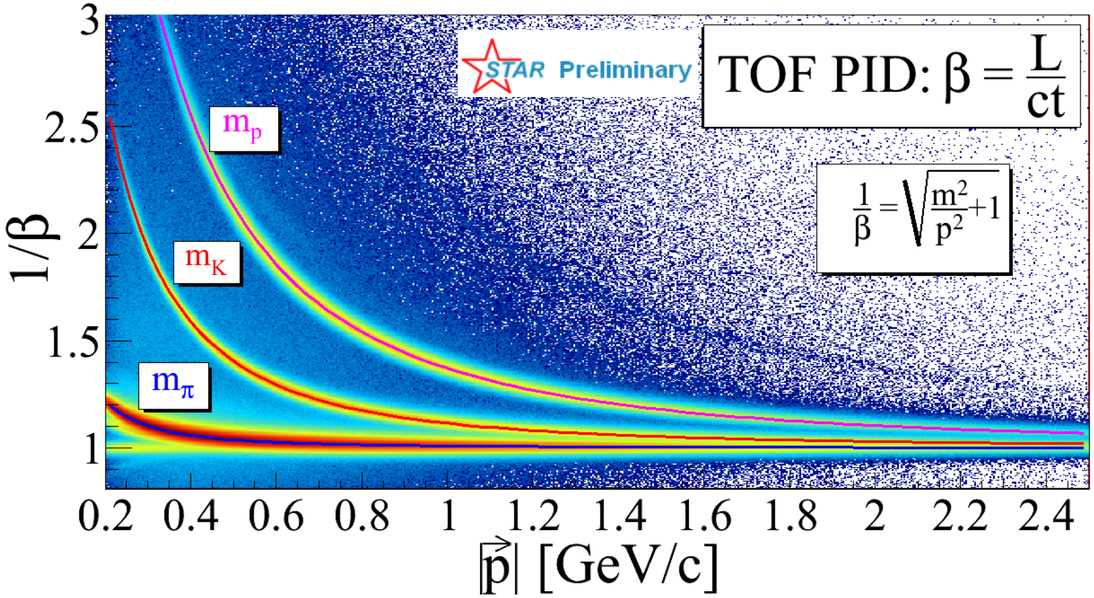
TOF: PID.

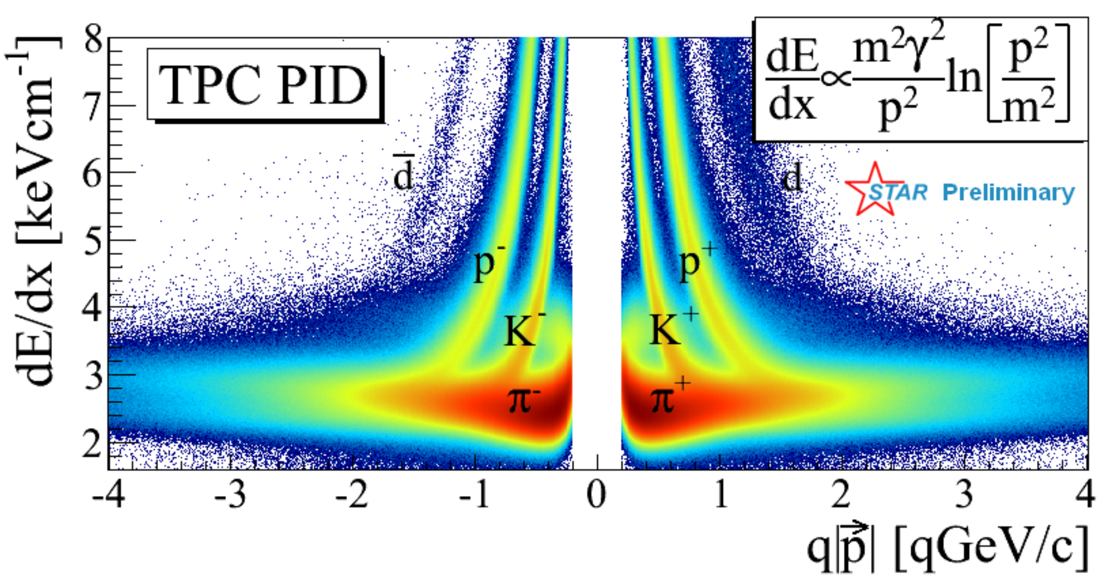
BEMC: PID via E/p, fast online trigger

$J/\psi \to e+e-$

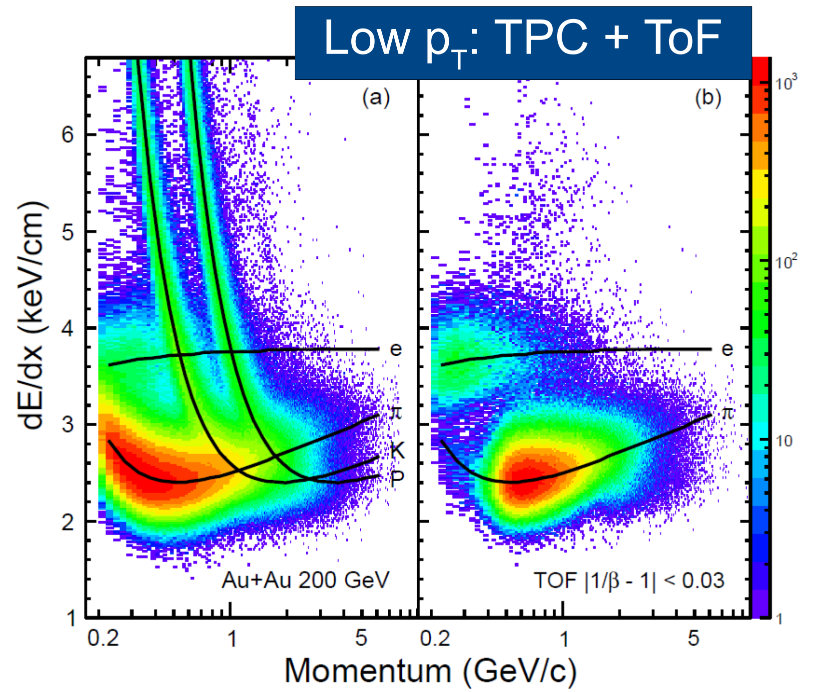
$\Upsilon \to e+e-$

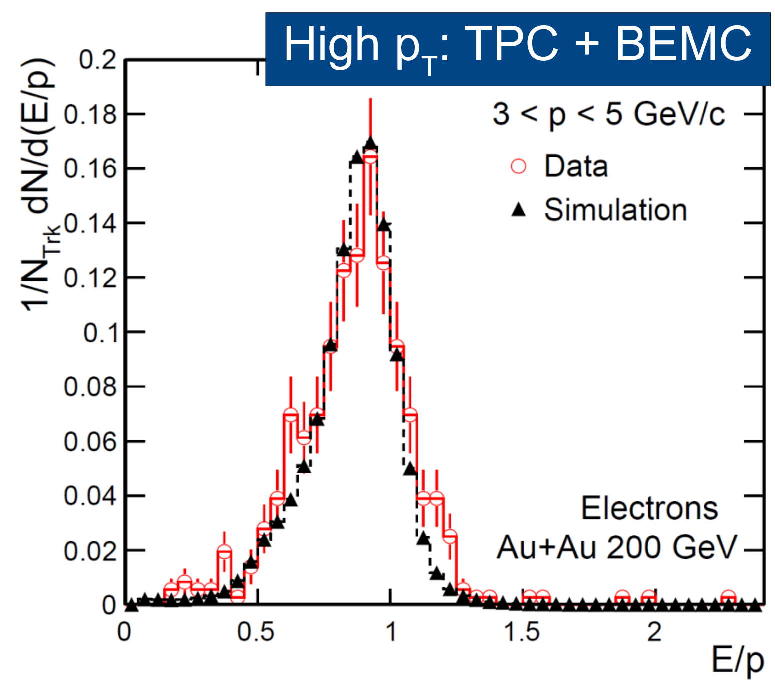
Particle Identification at STAR





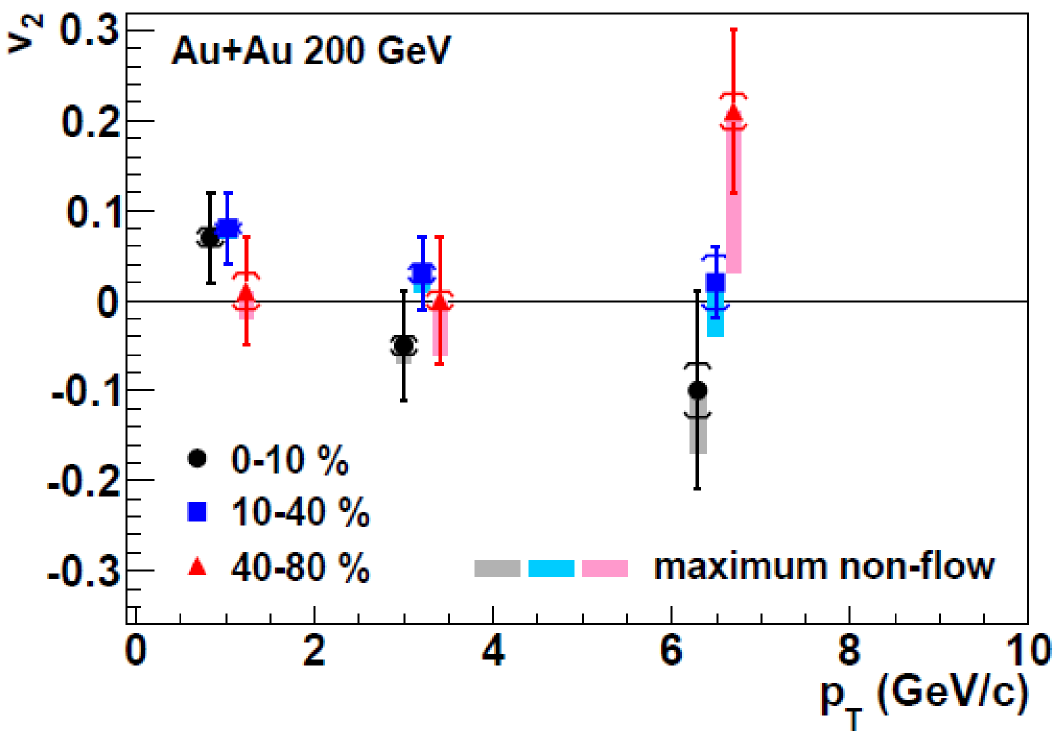
Electron Identification

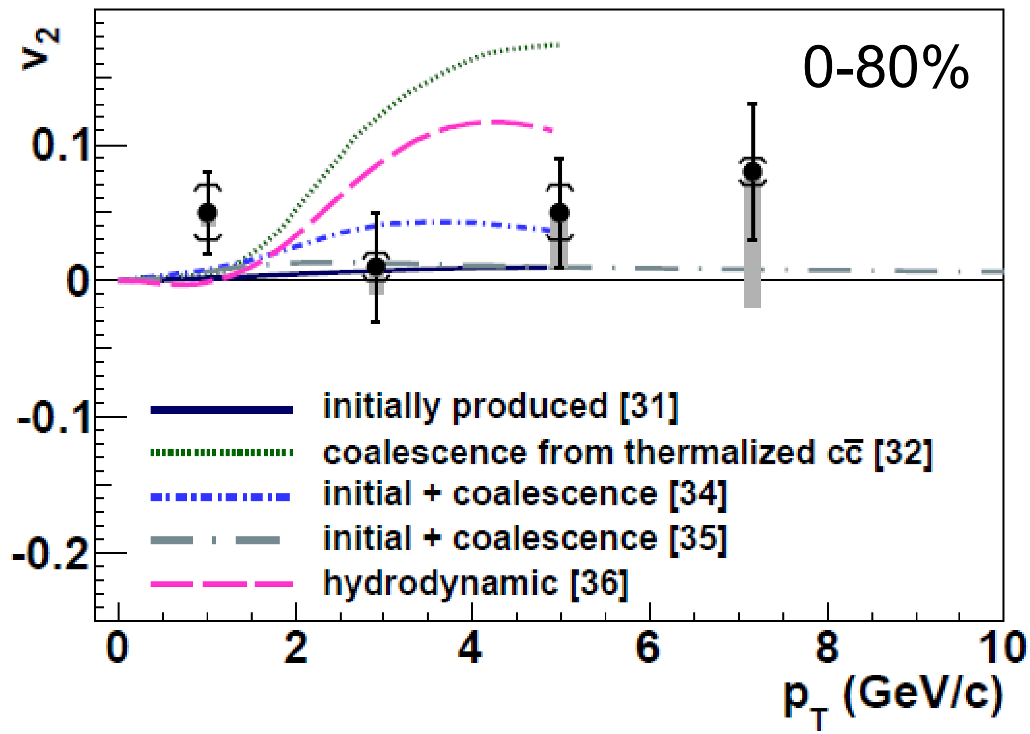




J/ψ

J/ψ elliptic flow





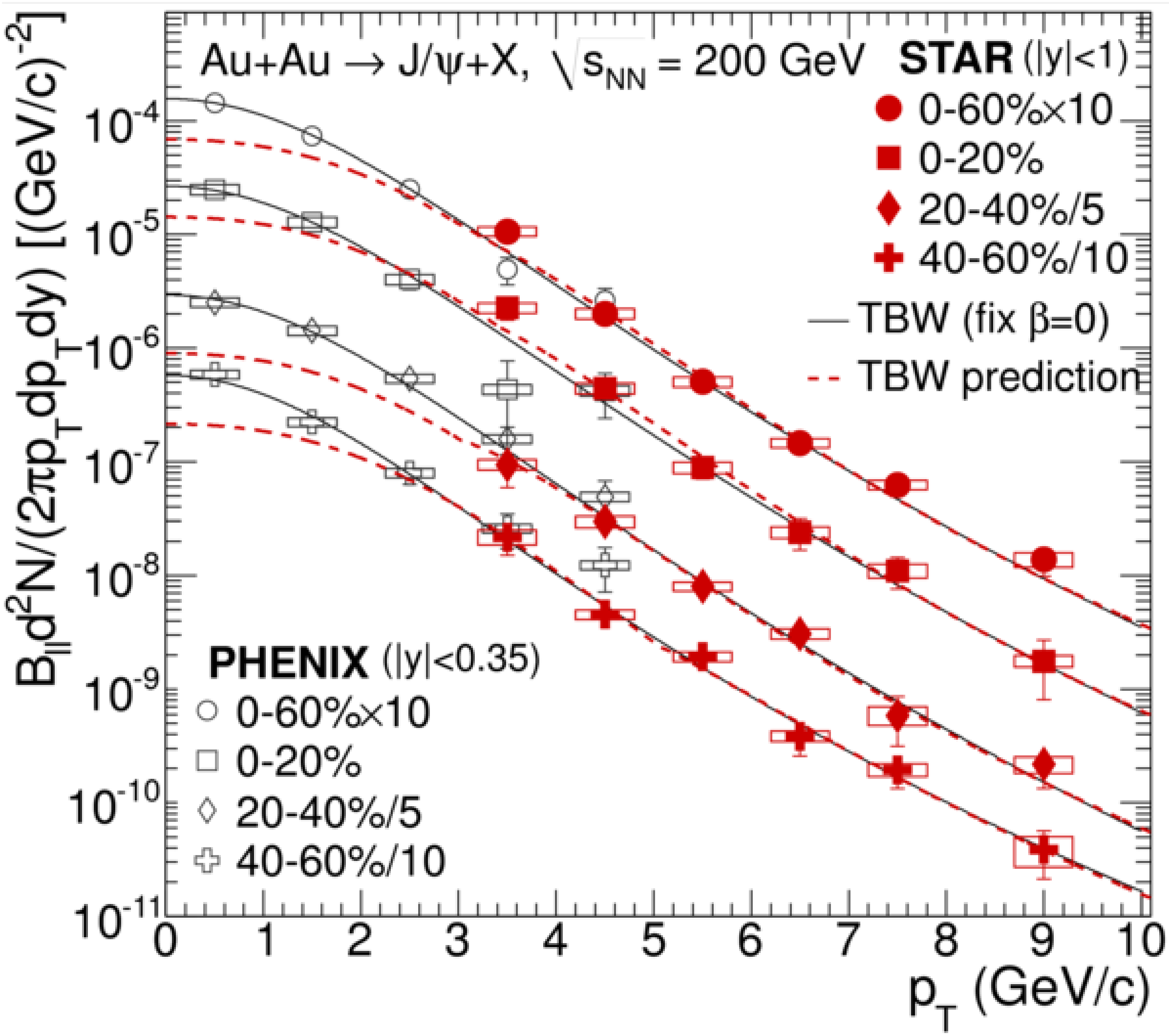
ArXiv:1212.3304,
PRL in press

J/ψ v_2 sensitive to production mechanism

J/ψ v_2 consistent with 0 at p_T>2 GeV

→ J/ψ <u>is not</u> dominantly produced by coalescence from thermalized c,$\bar{c}$ quarks

High-p_T J/ψ



Phys. Lett. B 722 (2013) 55

p_T spectra softer than expected based on TBW fit to light hadron

→ small radial flow?

→ significant regeneration component at low-p_T?

Tsallis Blast-Wave model: CPL 30, 031201 (2013);
JPG 37, 085104 (2010)

High-p_T J/ψ

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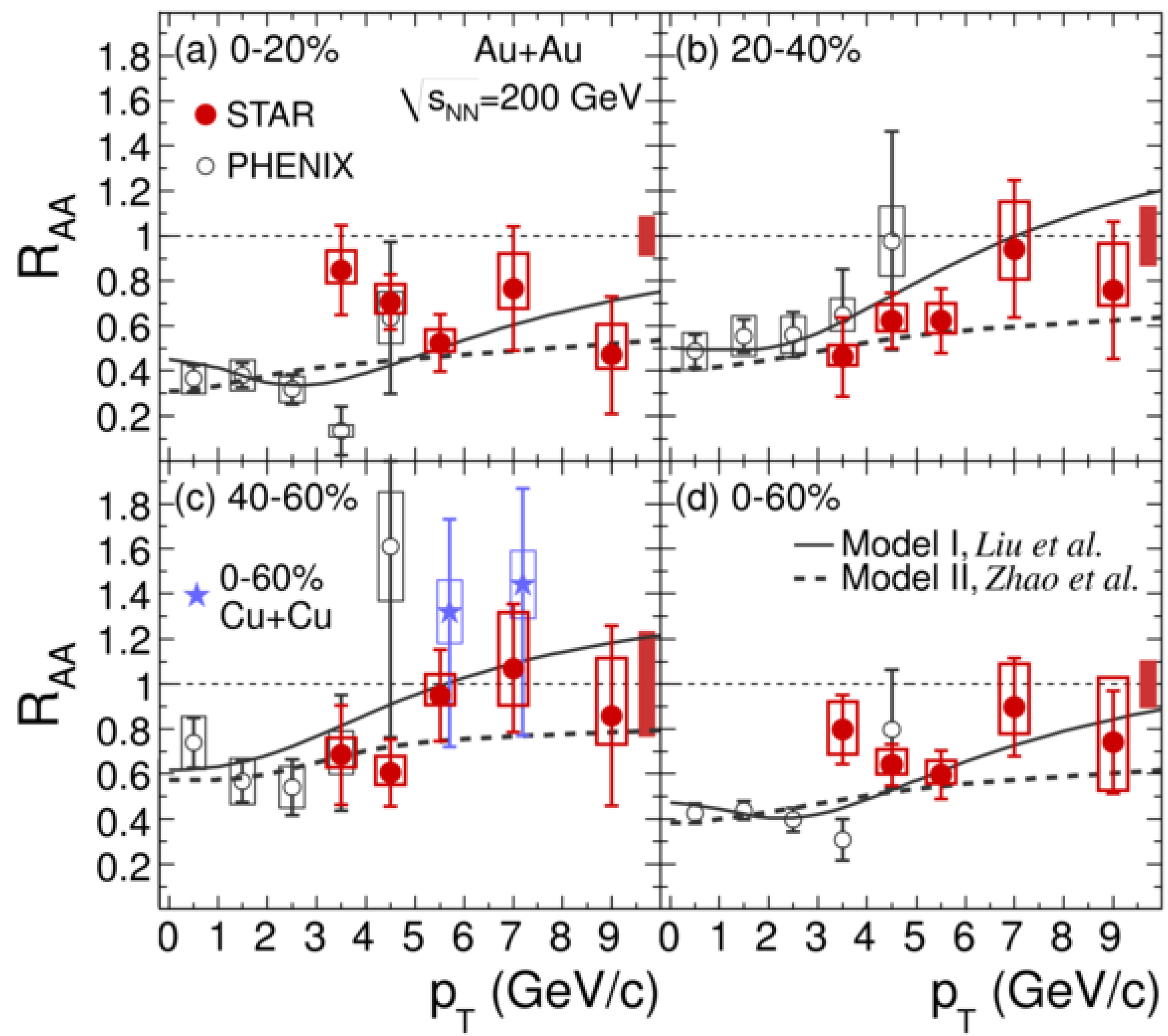
Suppression decrease with p_T

R_{AA} consistent with unity at high p_T in peripheral collisions

Larger suppression in central than in peripheral collisions

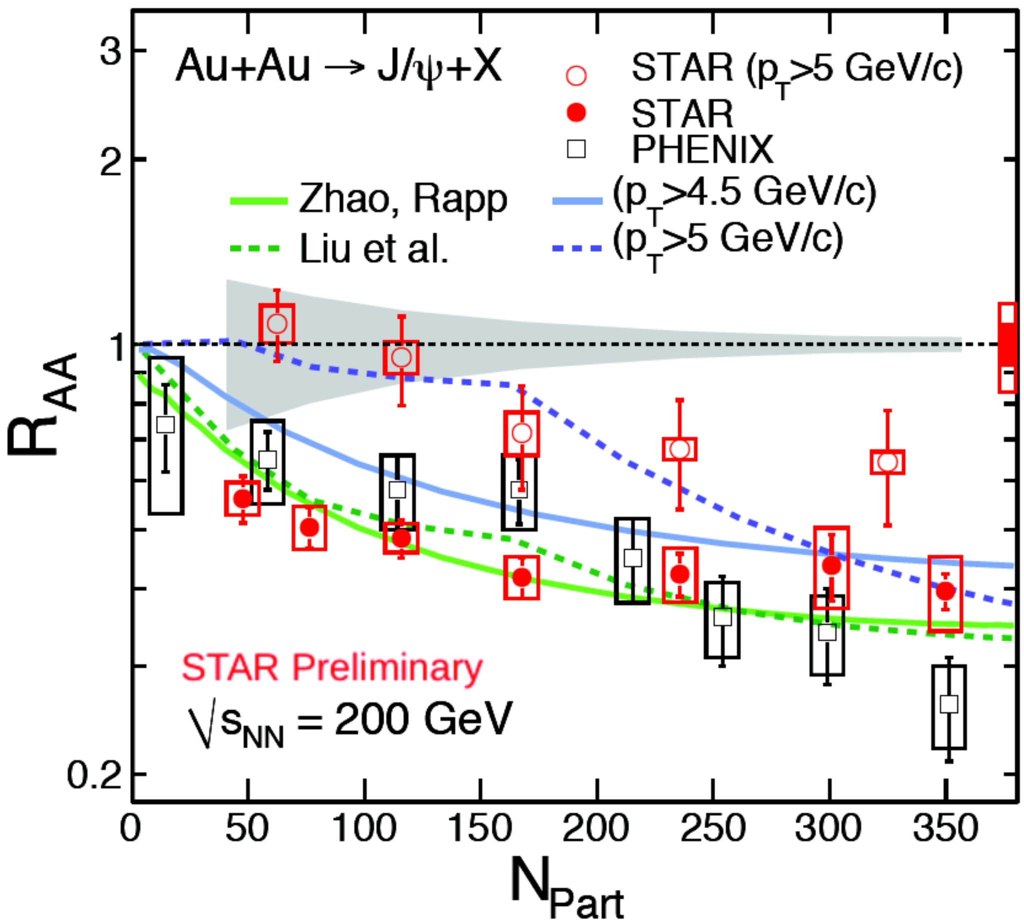
Suppression at high p_T (p_T >5 GeV) in central events



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

R_{AA} vs centrality



High-p_T J/ψ **suppressed** in central collisions

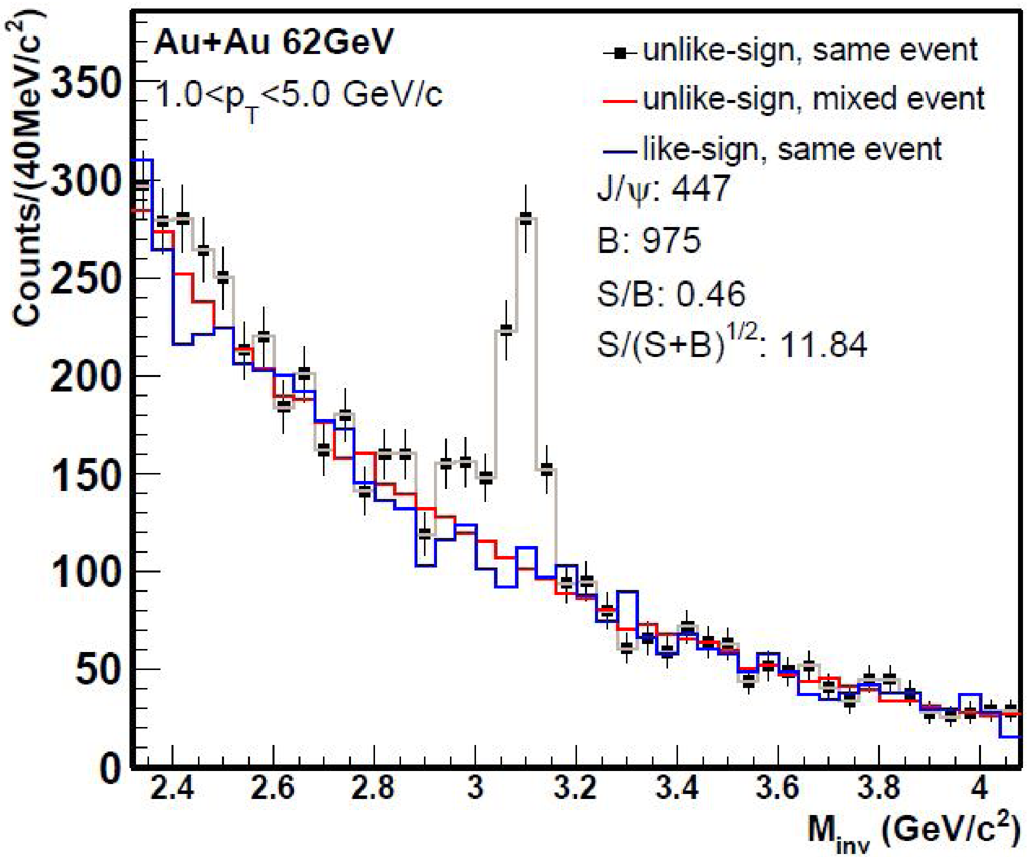
→ **clearly QGP effect**

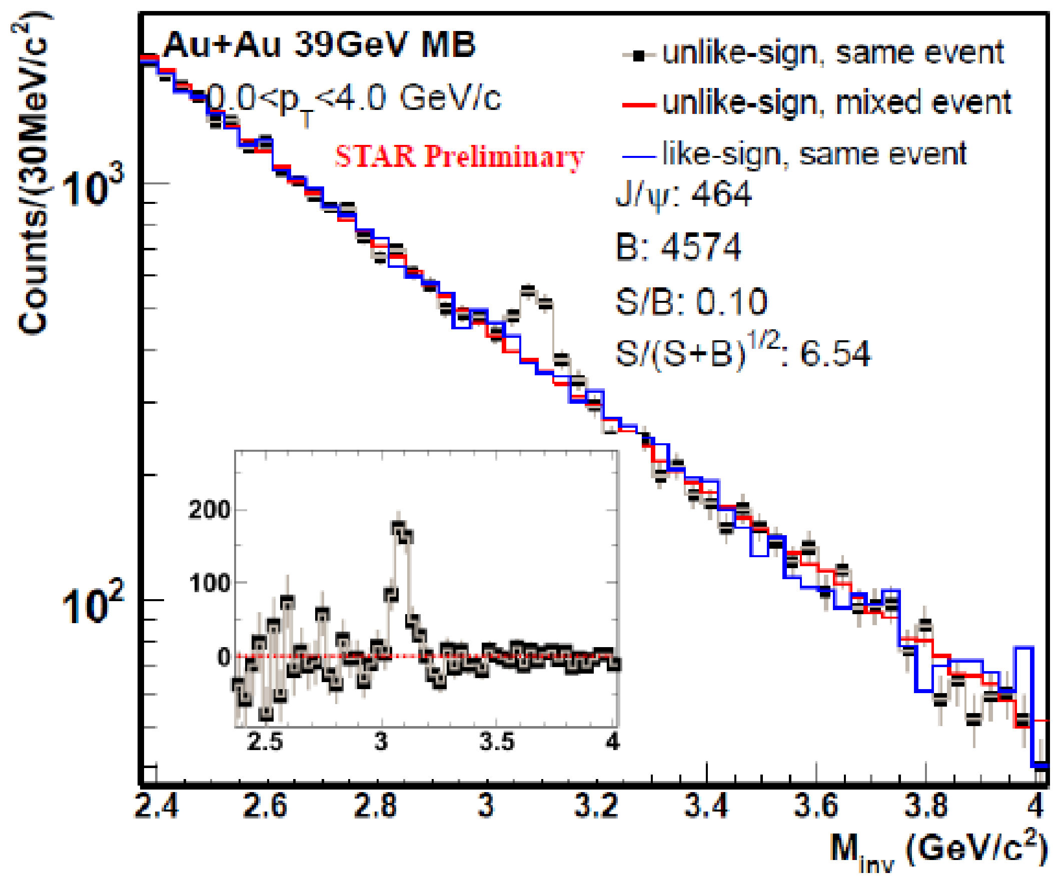
Suppression systematically **smaller at high p_T** in all centralities

Low-p_T data agrees with models including color screening and regeneration effects

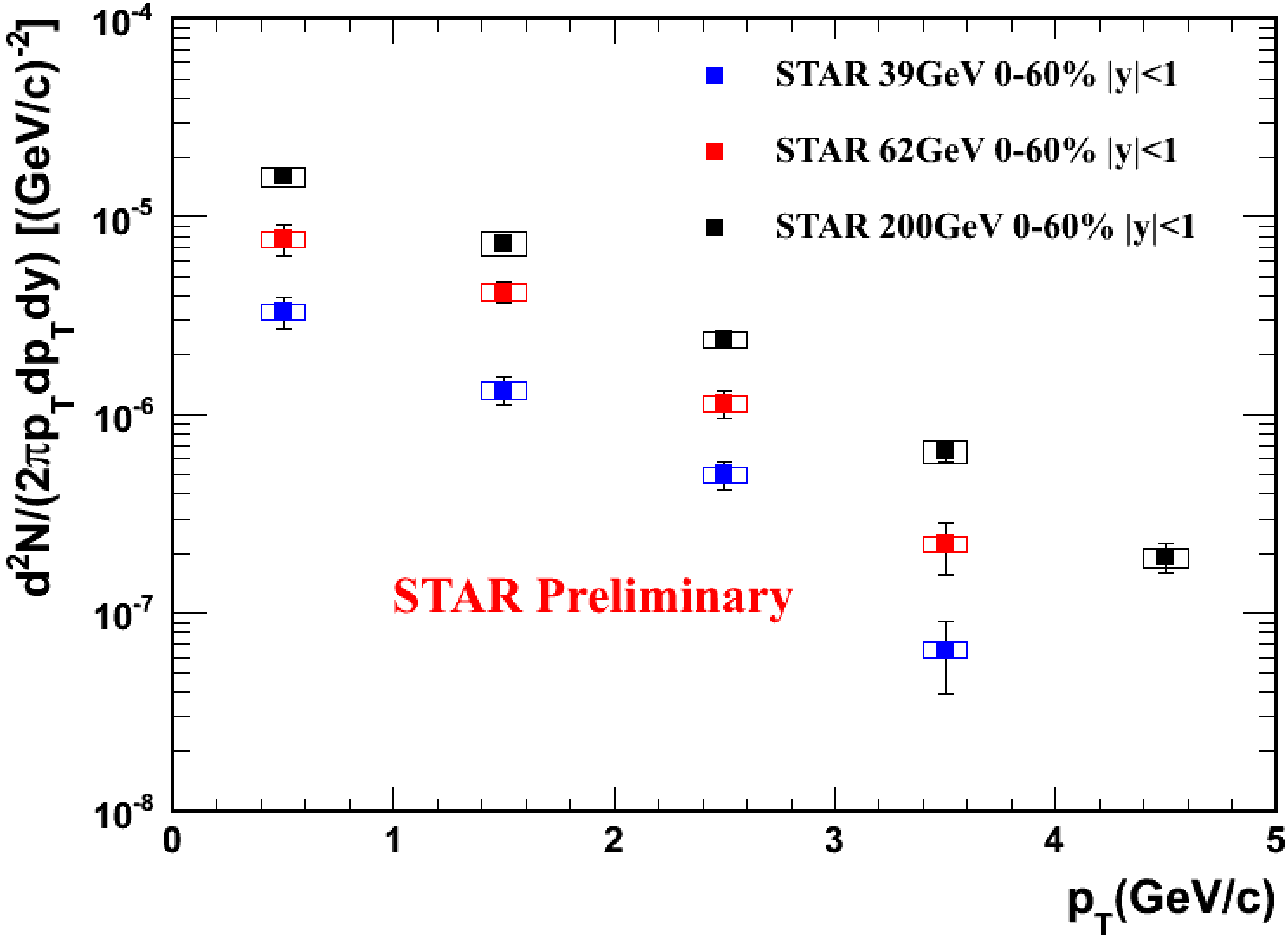
J/ψ production vs energy

J/ψ signal at 39 and 62 GeV

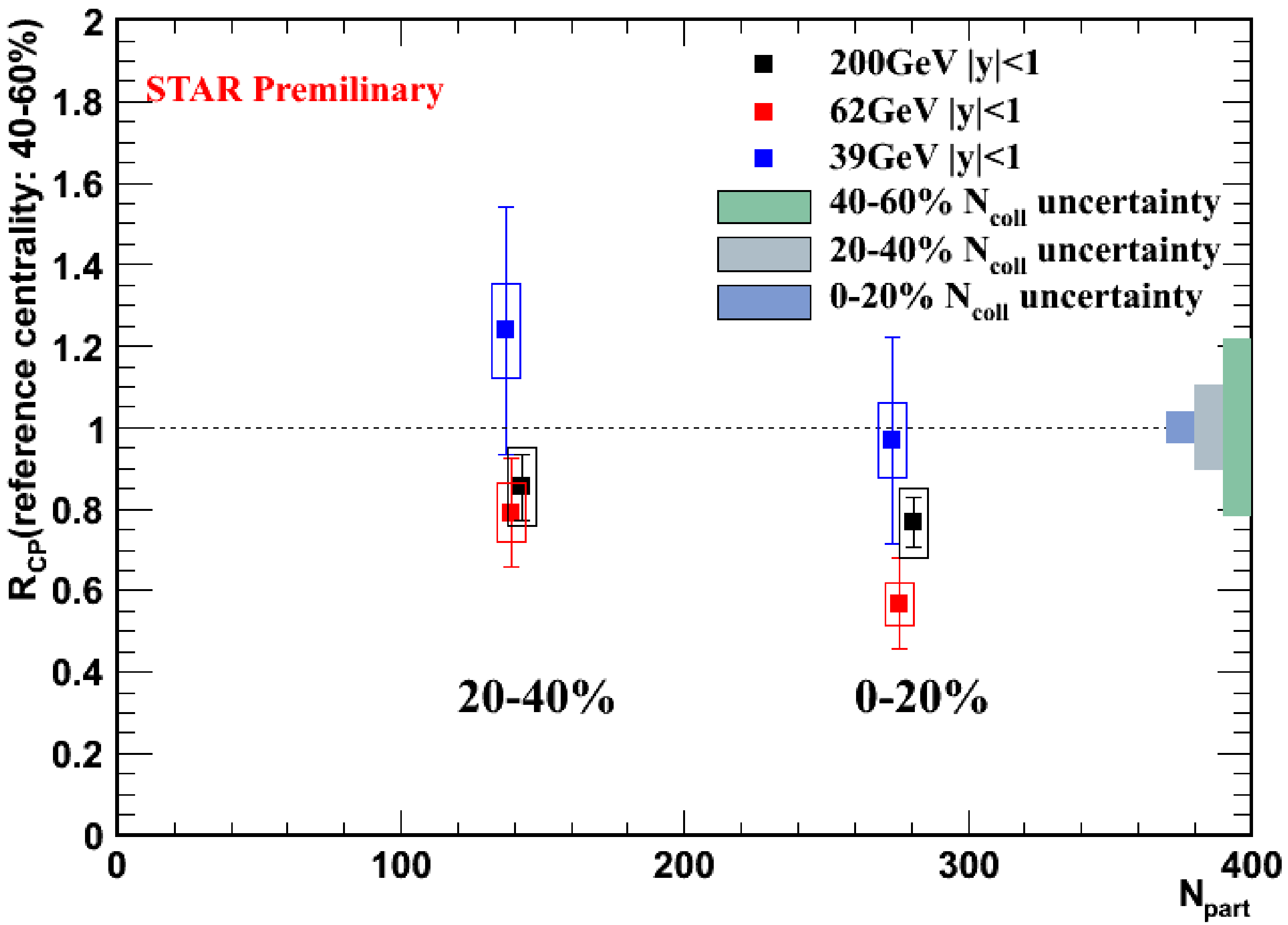




J/ψ p_T spectra in Au+Au 39, 62 and 200 GeV



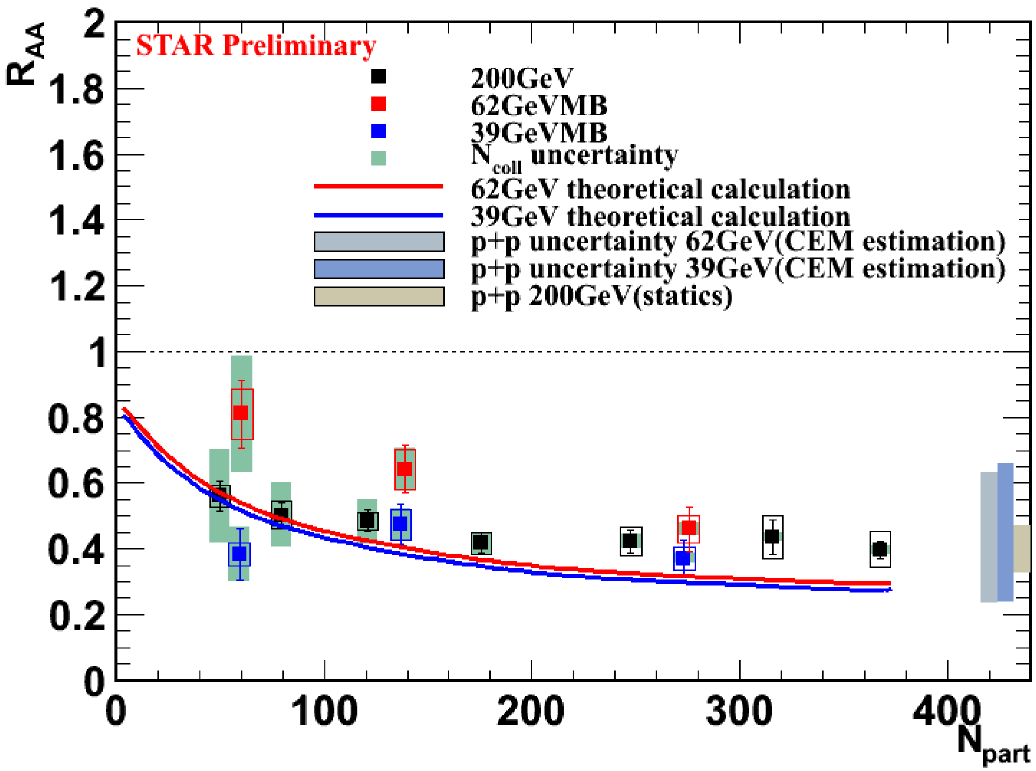
Suppression vs energy (R_{cp})

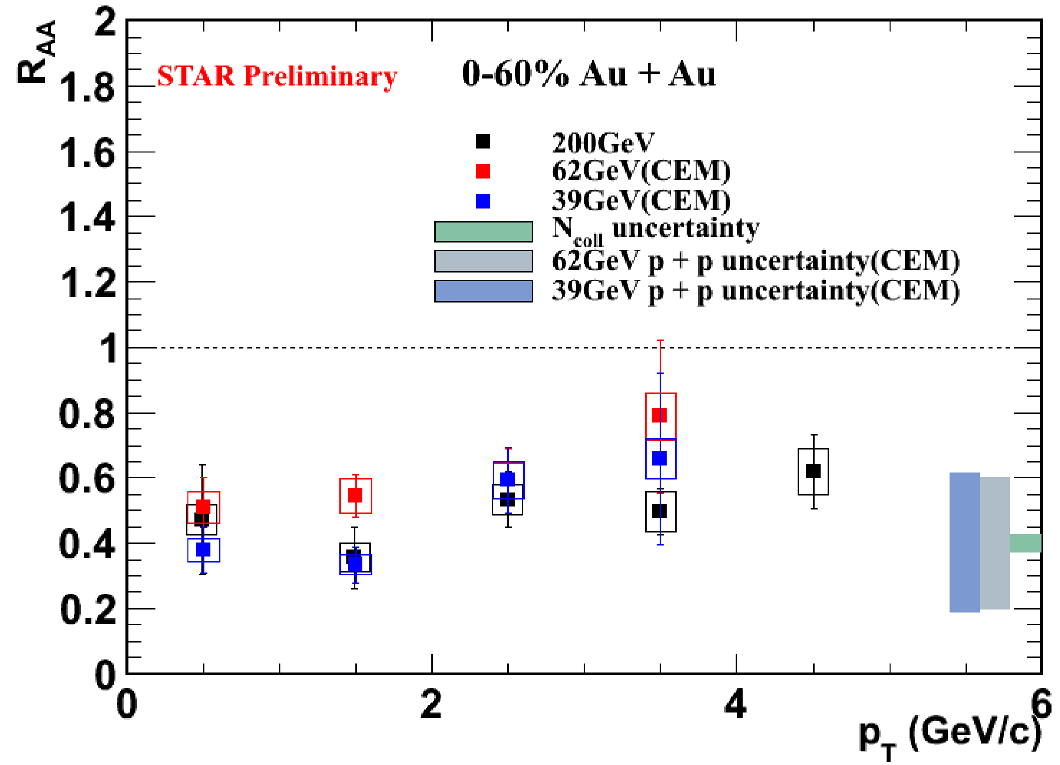


Significant suppression in central collisions at 62 GeV, similar as at 200 GeV

Suppression vs centrality and p_T

Model: Zhao, Rapp Phys Rev C.82.064905





Significant suppression at 39 and 62 GeV, similar as at 200 GeV

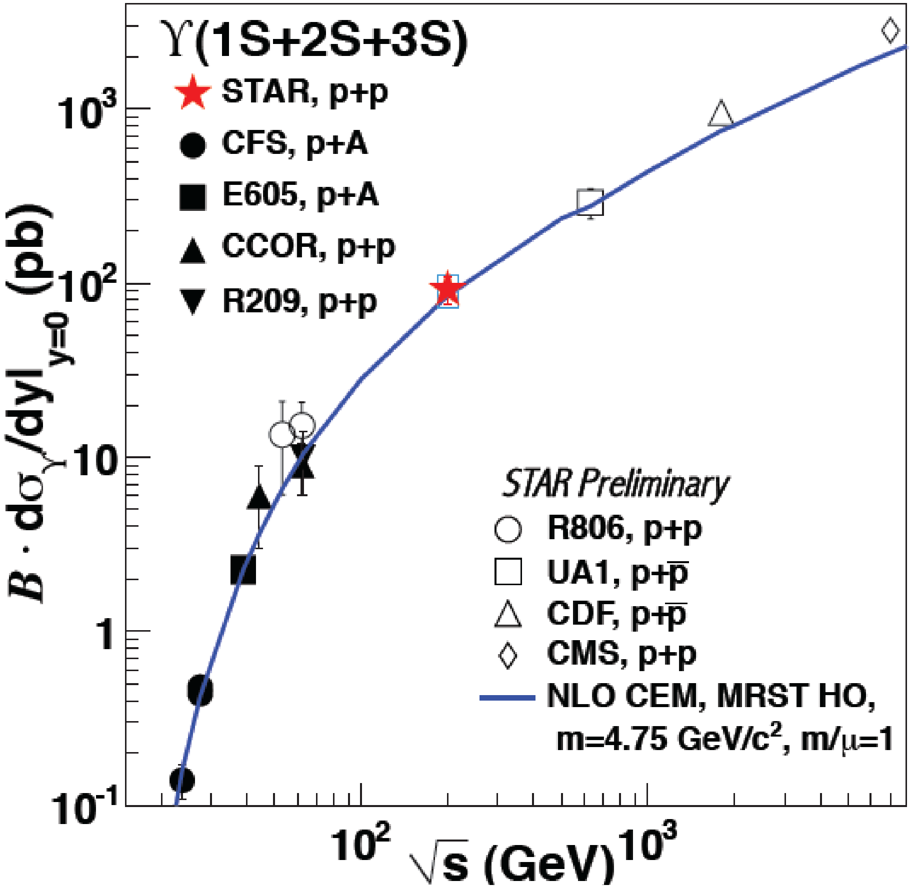
Model with two main components (direct suppression and regeneration) consistent with data.

39 and 62 GeV p+p reference: Color Evaporation Model (CEM)

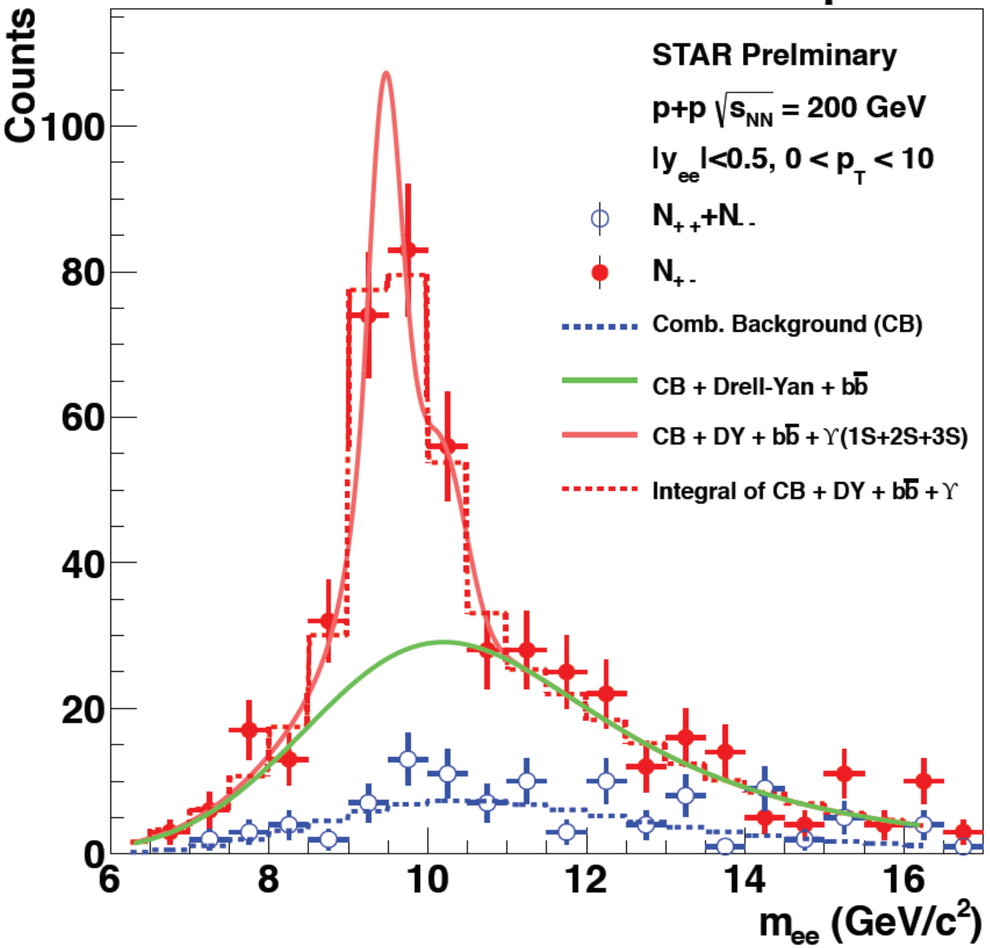
Upsilon

Υ production in p+p 200 GeV

New, high-statistics p+p baseline for R_{AA}



2009, $\int L\,dt = 19.7\ \mathrm{pb}^{-1}$



Υ(1S+2S+3S) in Au+Au 200 GeV

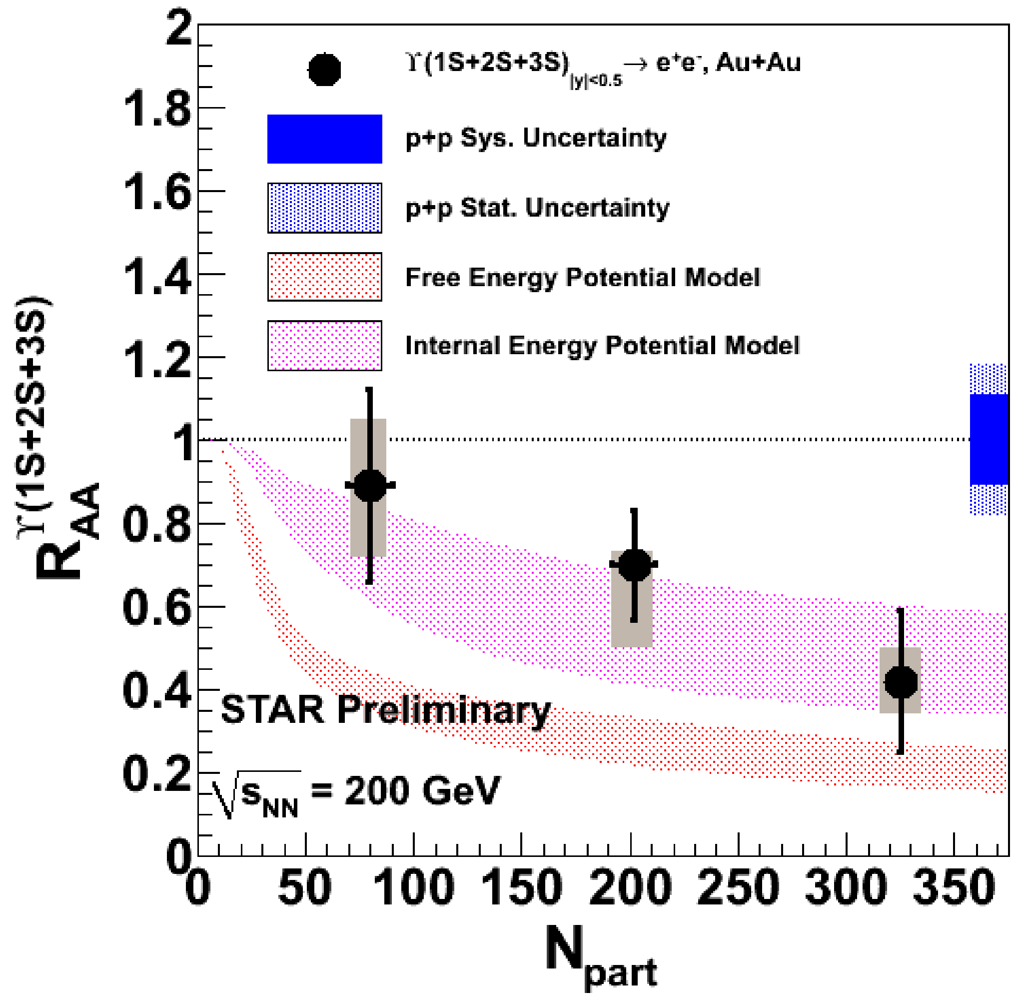
Suppression getting **stronger** with **centrality**

Data consistent with model which assumes **complete 2S and 3S suppression**

Model (Strickland et al)

→ dynamic model with fireball expansion and feed-down

→ assumes T_0 of 428-442 MeV and $1/4\pi < \eta/S < 3/4\pi$



Strickland et al., PRL 107, 132301 (2011).

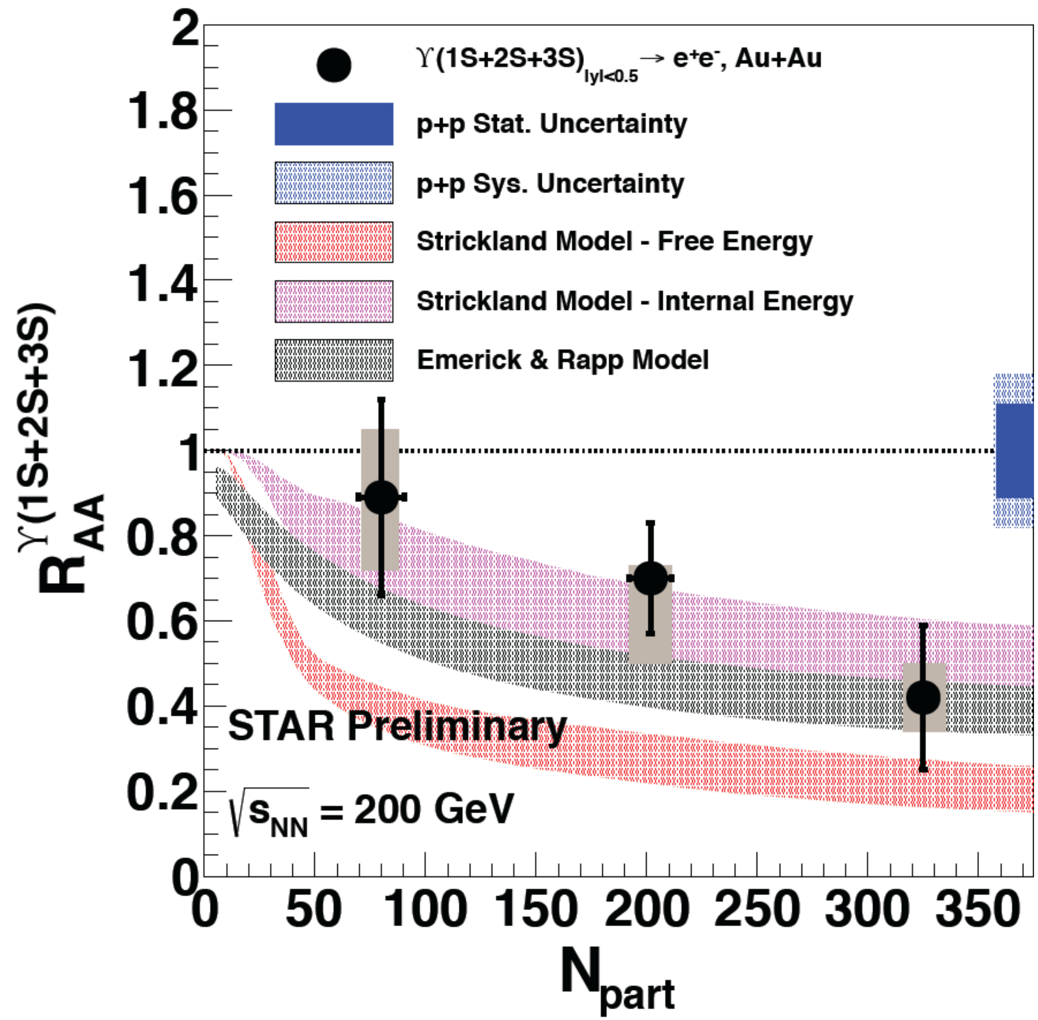
Υ(1S+2S+3S) in Au+Au 200 GeV

<u>Rapp et al.:</u>

kinetic rate-equation approach in a thermal QGP background, two scenarios:

→ Binding energy of the decreases with T (Weak Binding, shown)

→ Suppression due to gluo-dissociation of Upsilon (Strong Binding, not shown)



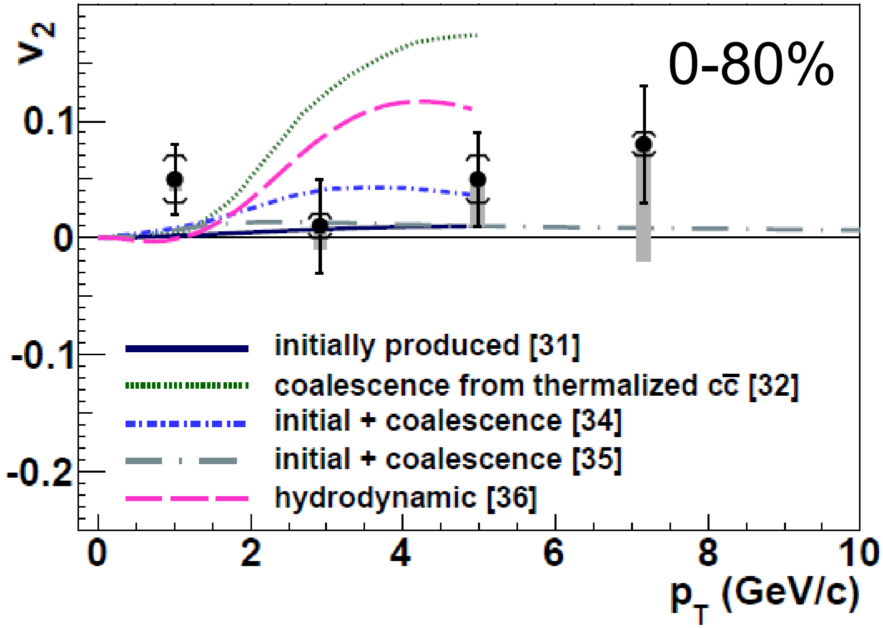
Rapp et al., EPJ A 48 (2012) 72

Summary

- Significant J/ψ suppression at **high-p_T** → clear signal of QGP effects
- J/ψ suppression at lower energies (39 and 62 GeV) similar as at 200 GeV
- Υ(1S+2S+3S) suppression increases with centrality
- Data consistent with a model with complete 2S and 3S suppression.

Backup

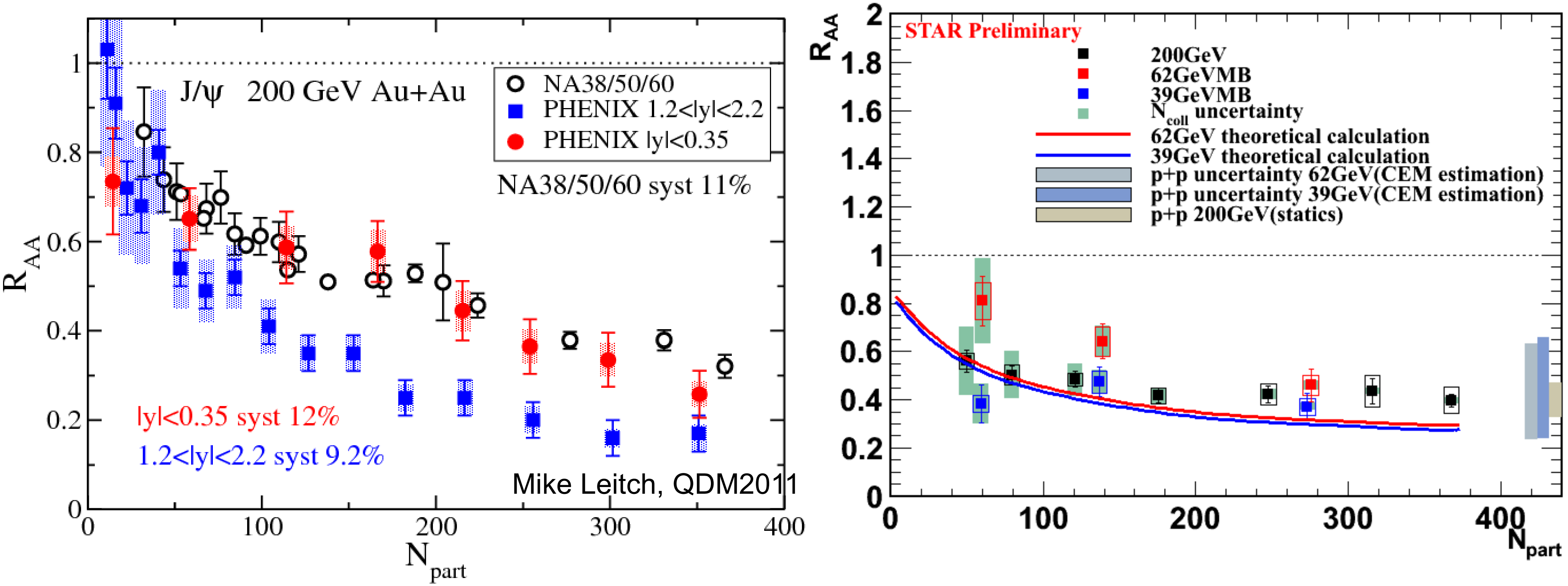
J/ψ elliptic flow



theoretical calculation	χ^2/NDF	p-value
initially produced [31]	2.6 / 3	4.6×10^{-1}
coalescence from thermalized $c\bar{c}$ [32]	16.2 / 3	1.0×10^{-3}
initial + coalescence [34]	2.0 / 3	5.8×10^{-1}
initial + coalescence [35]	4.2 / 4	3.8×10^{-1}
hydrodynamic [36]	7.0 / 3	7.2×10^{-2}

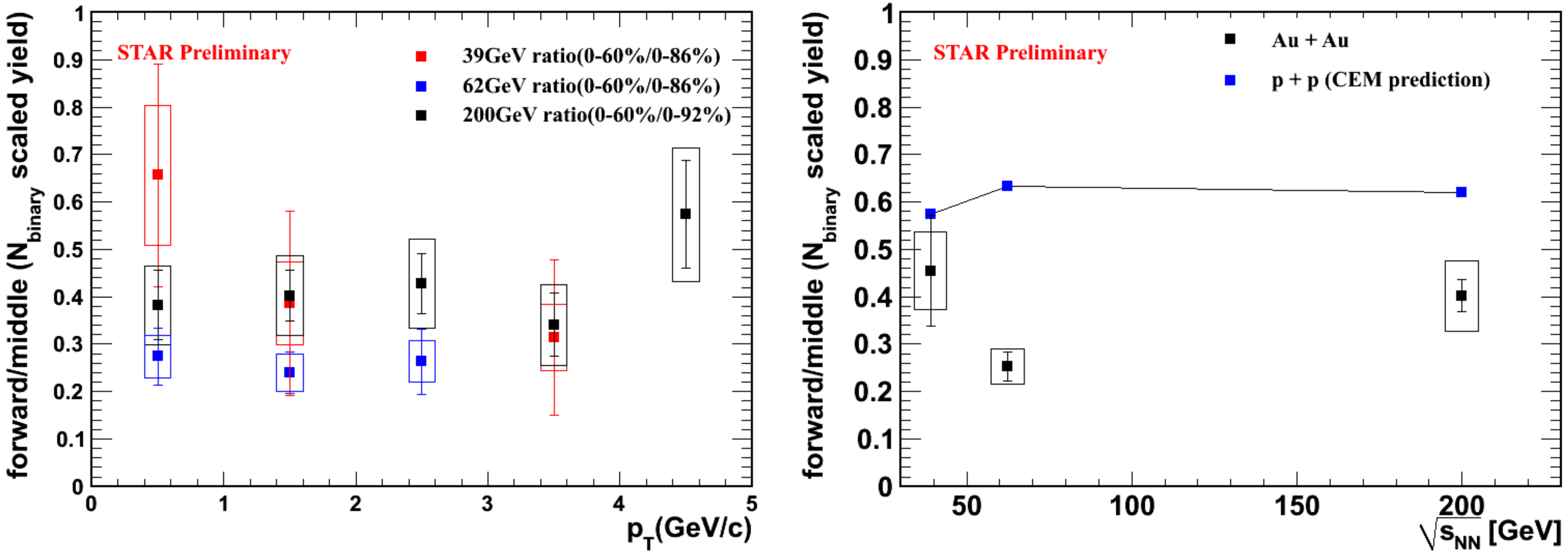
J/ψ v_2 disfavor the scenario that J/ψ with pT > 2 GeV/c are produced dominantly by coalescence from (anti-)charm quarks which are thermalized and flow with the medium.

J/psi suppression: RHIC vs SPS



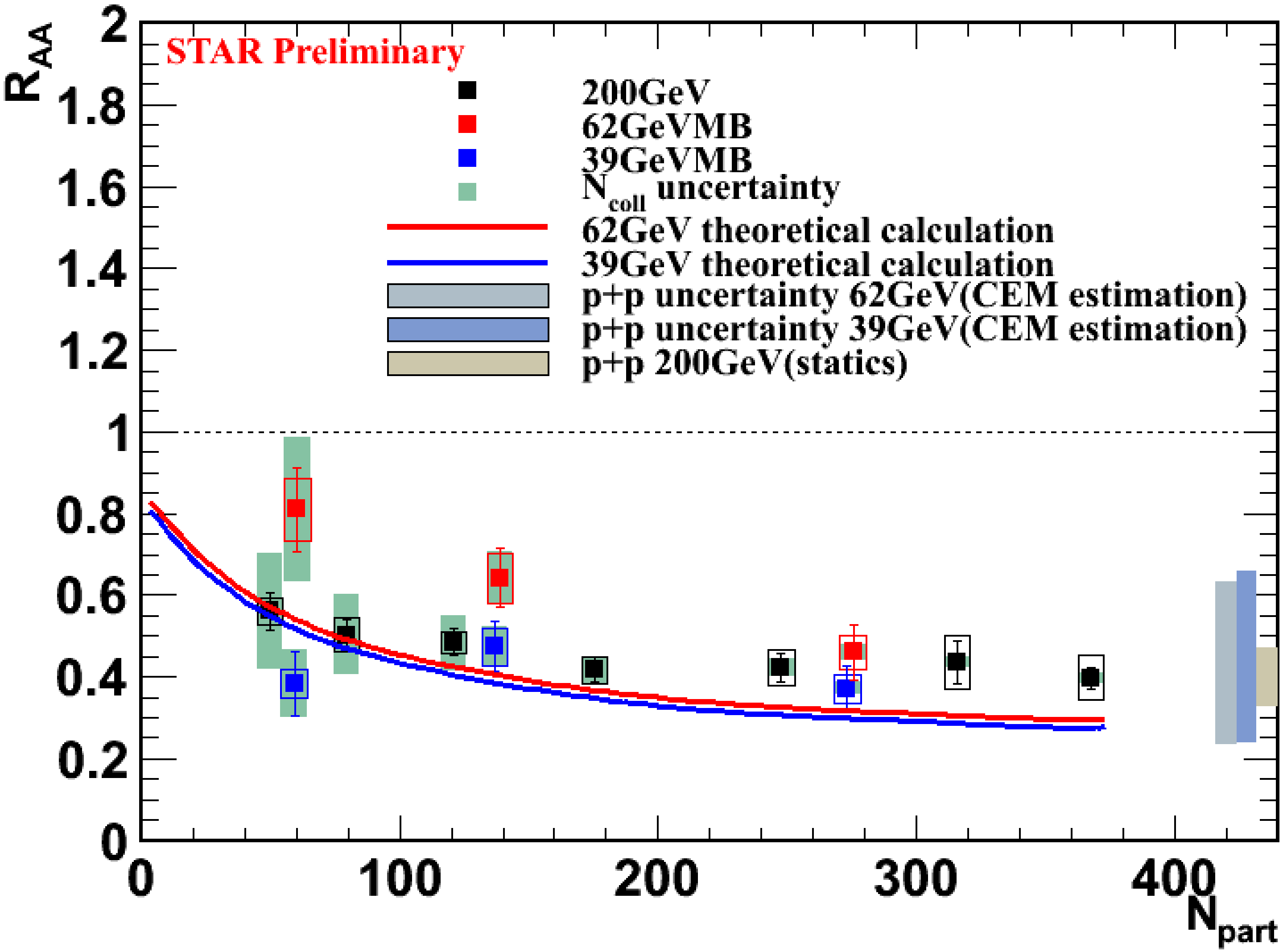
Similar J/psi suppression at SPS (17.3 GeV) and RHIC (200, 62, 39 GeV)

J/psi production: forward/midrapidity ratio

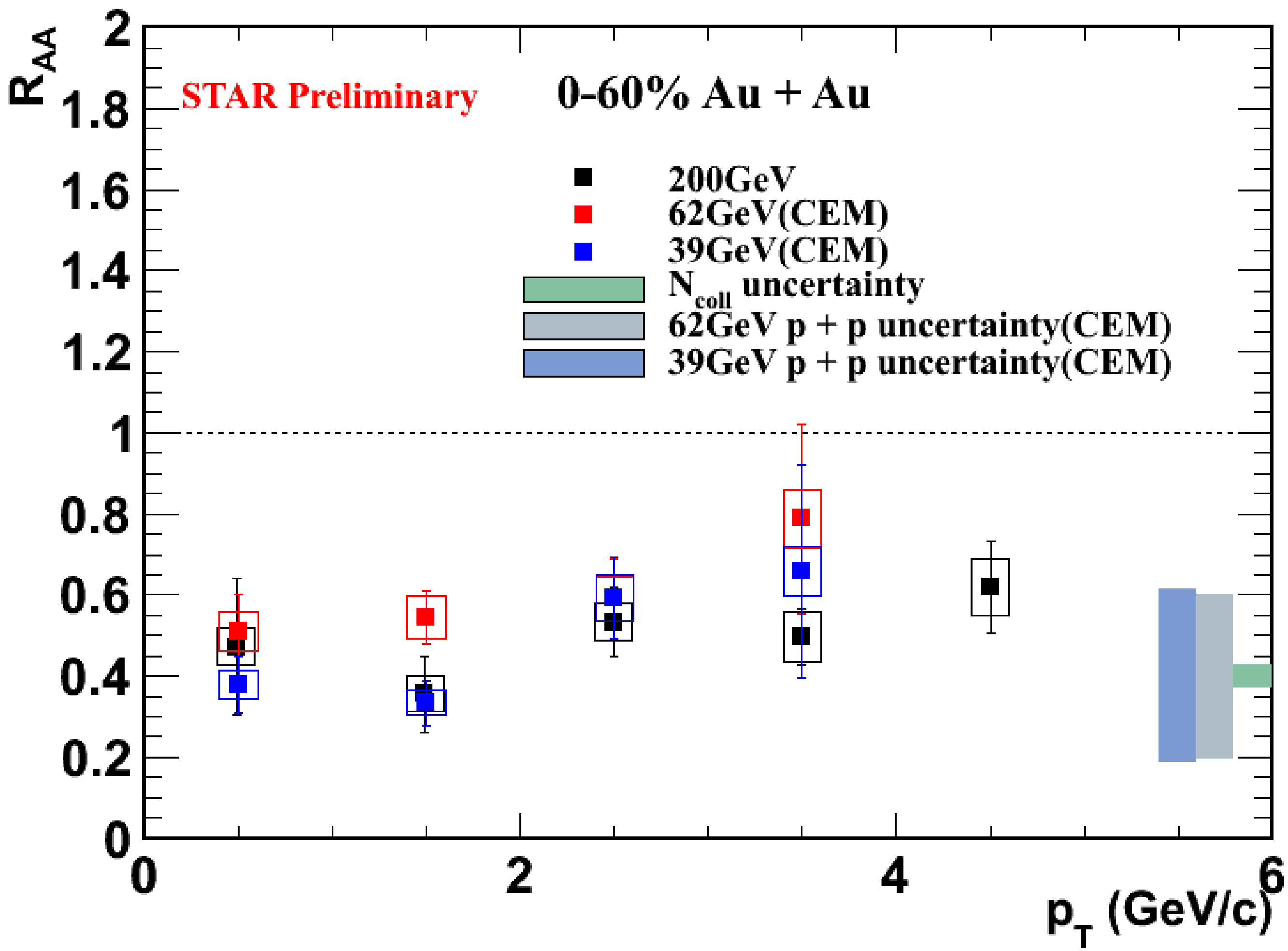


No significant energy and p_T dependence

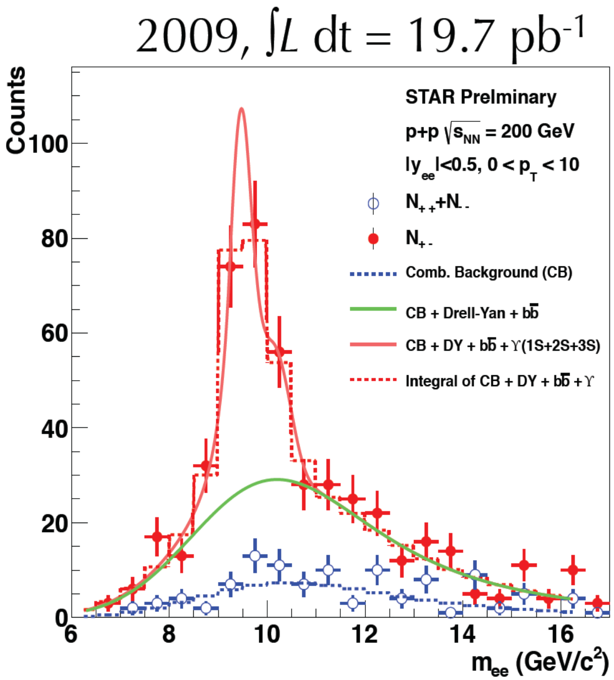
R_{AA} vs centrality

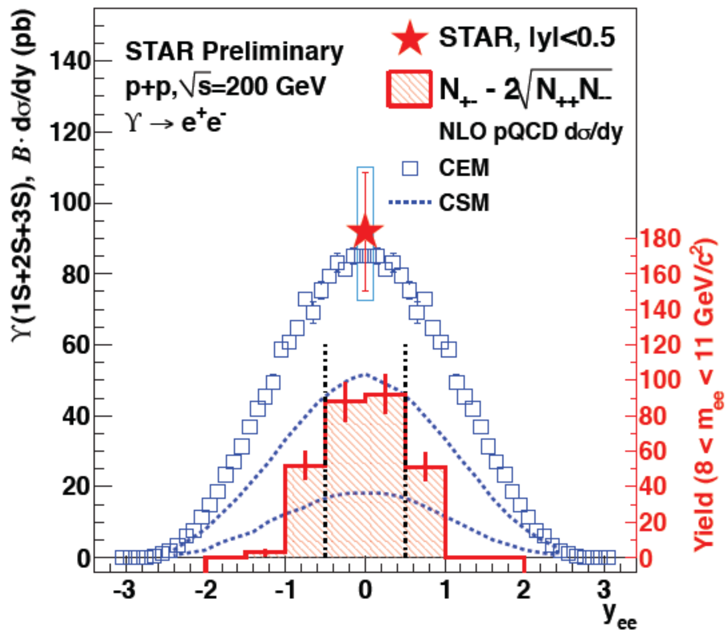


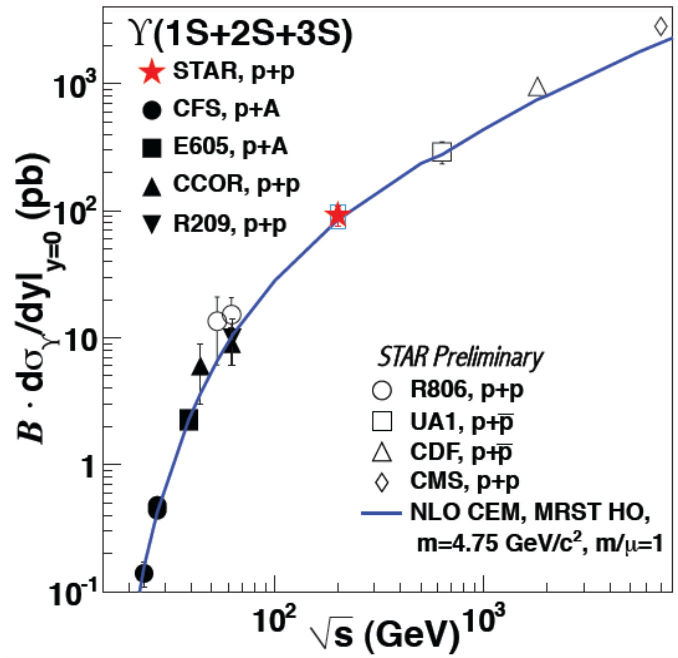
R_{AA} vs p_T


STAR Preliminary
0-60% Au + Au
200GeV
62GeV(CEM)
39GeV(CEM)
N$_{coll}$ uncertainty
62GeV p + p uncertainty(CEM)
39GeV p + p uncertainty(CEM)
R$_{AA}$
p$_T$ (GeV/c)

Upsilon p+p reference at 200 GeV







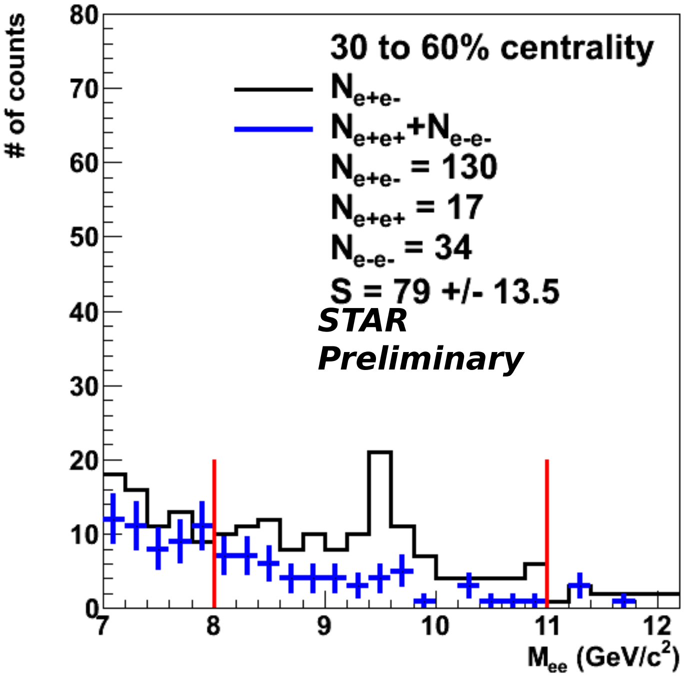
Cross section: consistent with pQCD and world data trend

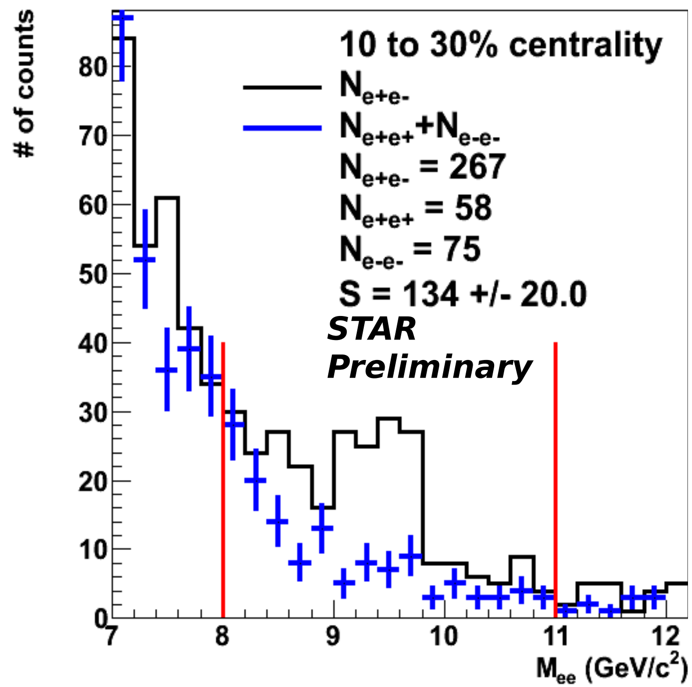
$\int L\, dt = 19.7$ pb-1

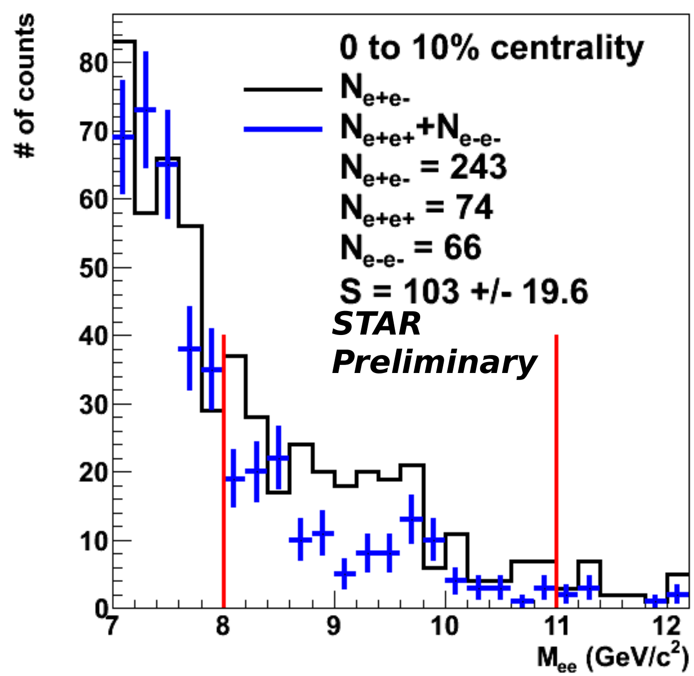
NϒY(total)= 145±26(stat.)

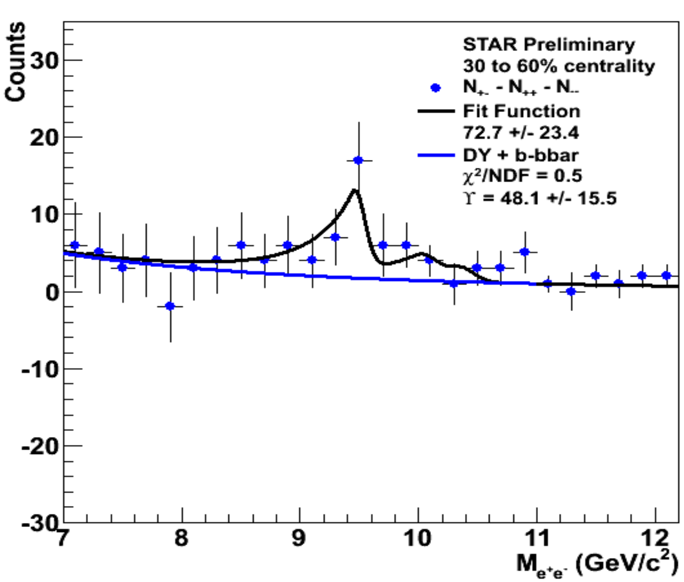
$$\sum_{n=1}^{3} \mathcal{B}(nS) \times \sigma(nS) = 91.8 \pm 16.6 \pm 19 \text{ pb}$$

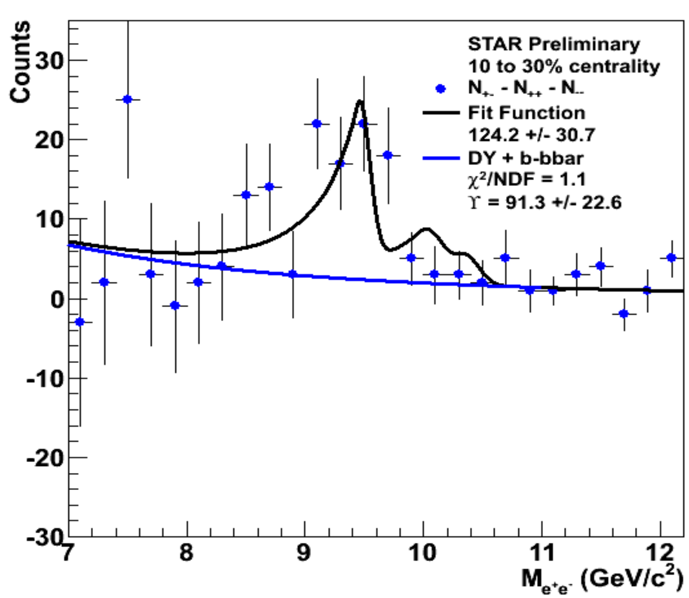
Upsilon in Au+Au 200 GeV

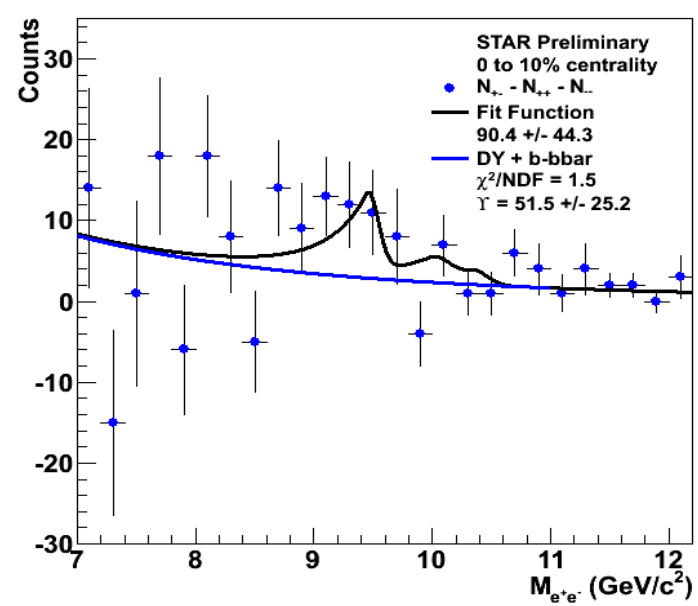




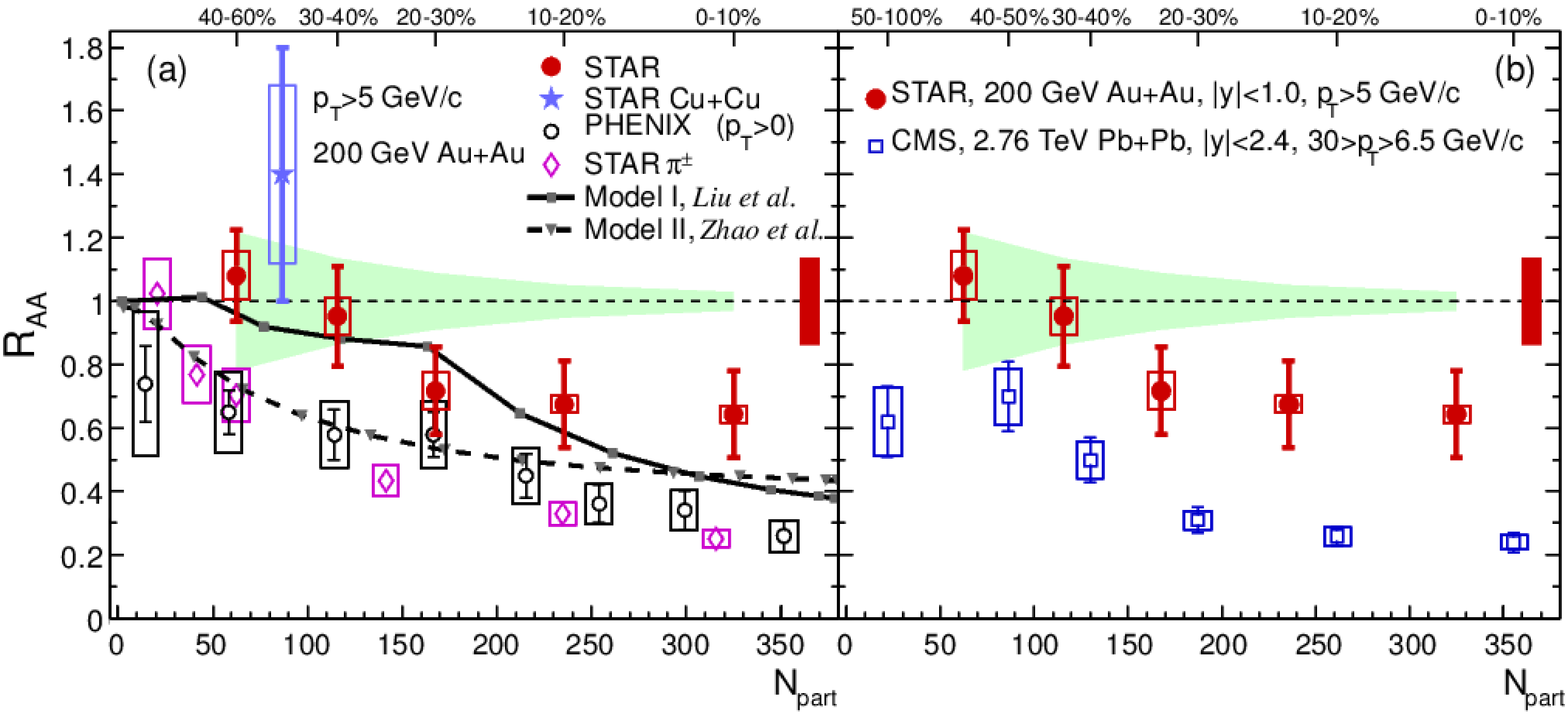






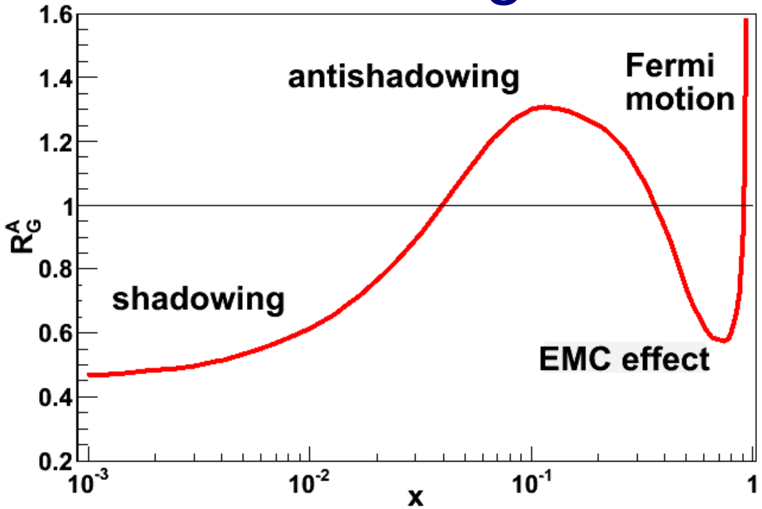


High-p_T J/ψ: RHIC vs LHC

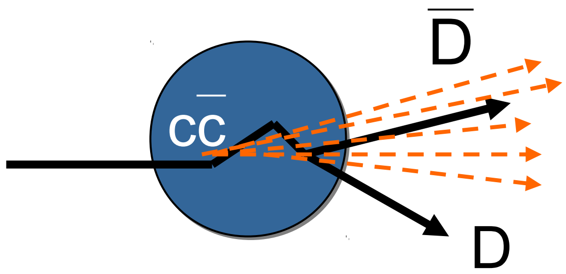


"Normal" suppression

Shadowing



Nuclear absorption



Co-mover absorption
Cronin effect
Gluon saturation
...