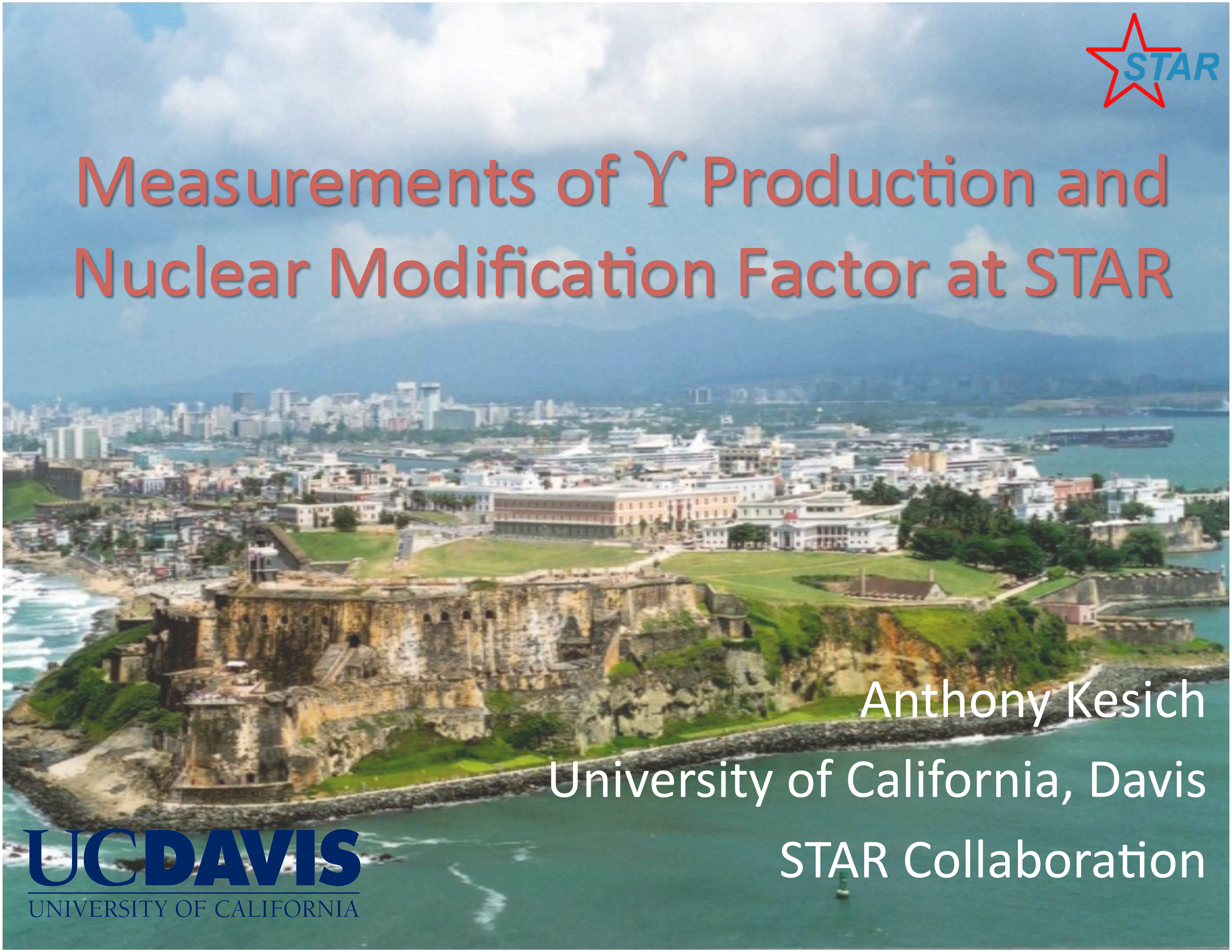
Measurements of Υ Production and Nuclear Modification Factor at STAR



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STAR Collaboration

Outline

- Motivation for measuring Upsilons
- The Solenoidal Tracker At RHIC and its triggers
- Υ production cross section in p+p
- Υ production and CNM effects in d+Au
- Υ Nuclear Modification Factor in Au+Au
- Conclusions

Goal: Quarkonia states in A+A

Charmonia: J/Ψ, Ψ’ , χ_c Bottomonia: ϒ(1S), ϒ(2S), ϒ(3S)

Key Idea: Quarkonia Melt in the plasma

- Color screening of static potential between heavy quarks:
- Suppression of states is determined by T_C and their binding energy
- Lattice QCD: Evaluation of spectral functions ⇒ $T_{melting}$

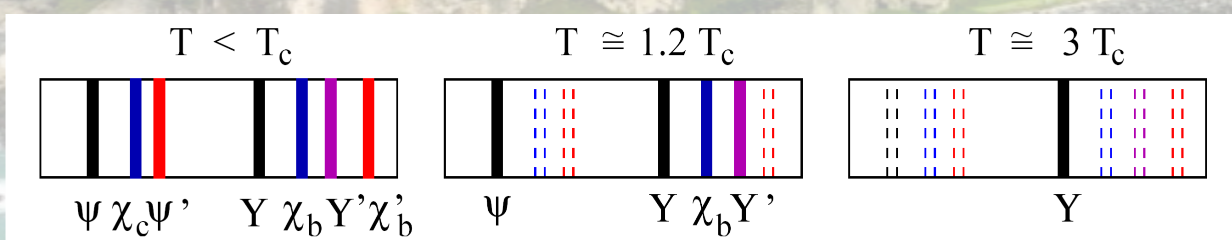
Sequential disappearance of states:

⇒ Color screening ⇒ Deconfinement

⇒ QCD thermometer ⇒ Properties of QGP

When do states melt?

$T_{diss}(\Psi') \approx T_{diss}(\chi_c) < T_{diss}(\Upsilon(3S)) < T_{diss}(J/\Psi) \approx T_{diss}(\Upsilon(2S)) < T_{diss}(\Upsilon(1S))$



H. Satz, HP2006

Measuring the Temperature

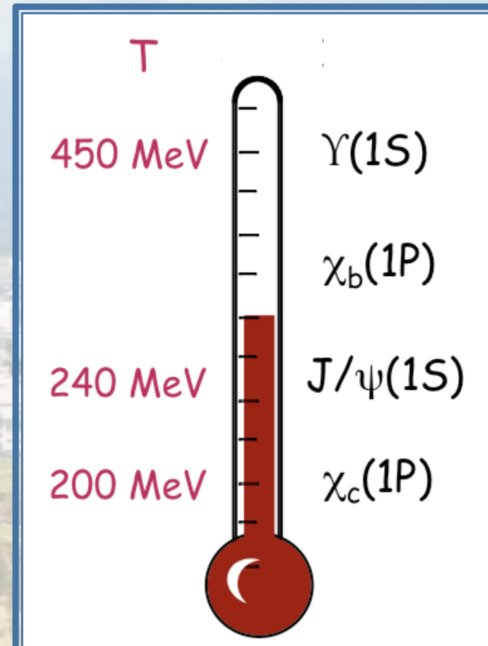
Lattice QCD Calculations:

Dissociation temperatures of quarkonia states

$q\bar{q}$	J/Ψ	χ_c	ψ'	$\Upsilon(1S)$	$\chi_b(1P)$	$\Upsilon(2S)$	$\chi_b(2P)$	$\Upsilon(3S)$
T/T_c	1.10	0.74	0.2	2.31	1.13	1.10	0.83	0.75

S. Digal, P. Petreczky, H. Satz, *hep-ph/0110406*

Quarkonia's suppression pattern
→ **QGP thermometer**



A .Mocsy*, Summer Quarkonium Workshop, BNL, 2011*

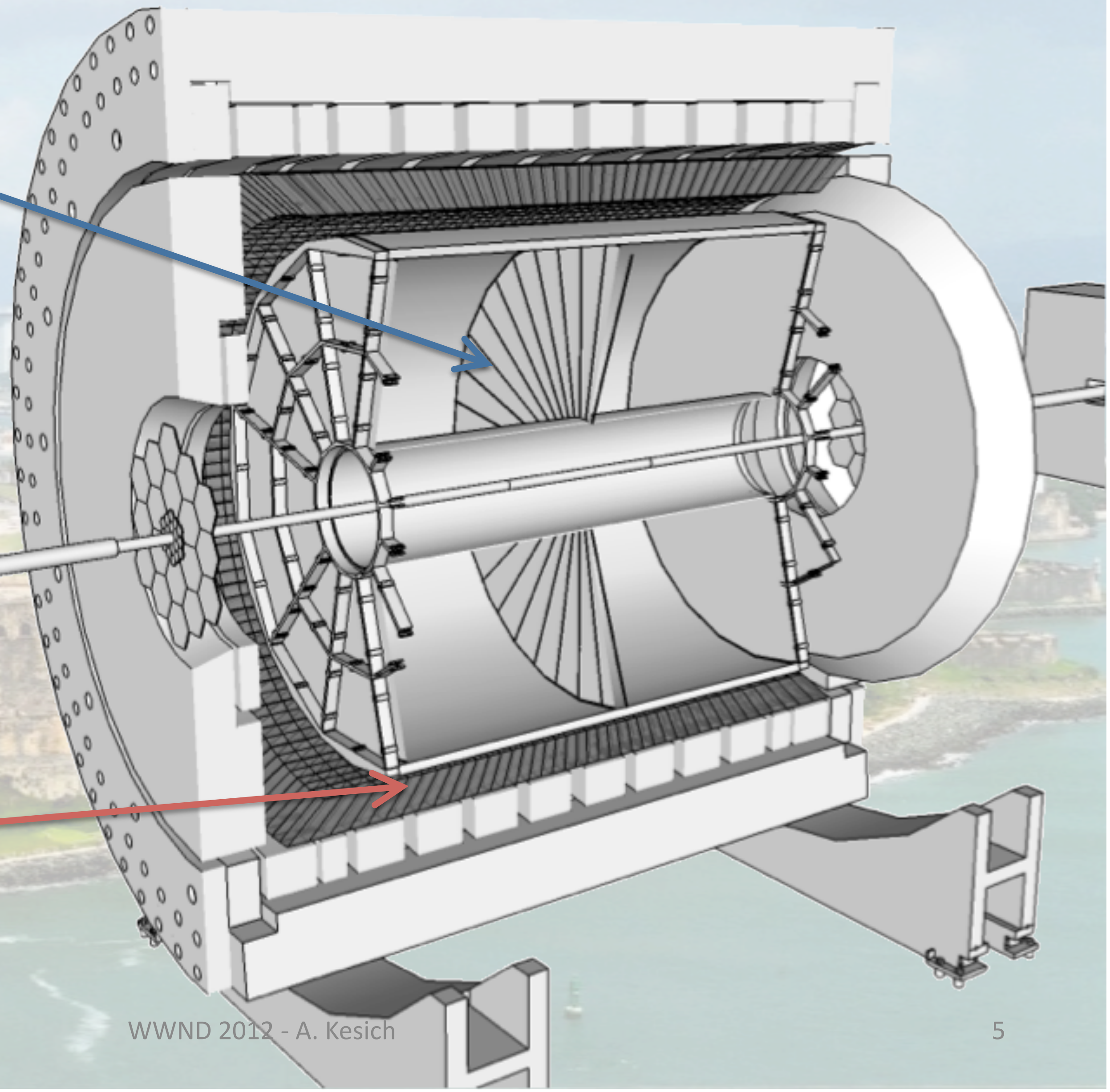
- For Υ production at RHIC
- A cleaner probe compared to J/Ψ
    - co-mover absorption → negligible
    - recombination → negligible
  - d-Au: Cold Nuclear Matter Effects
    - Shadowing / Anti-shadowing at y≈0
- Challenge: low rate, rare probe
  - Large acceptance detector
  - Efficient trigger

- Expectation:
  - Υ(1S) no melting
  - Υ(2S) likely to melt
  - Υ(3S) melts

STAR

Time Projection Chamber

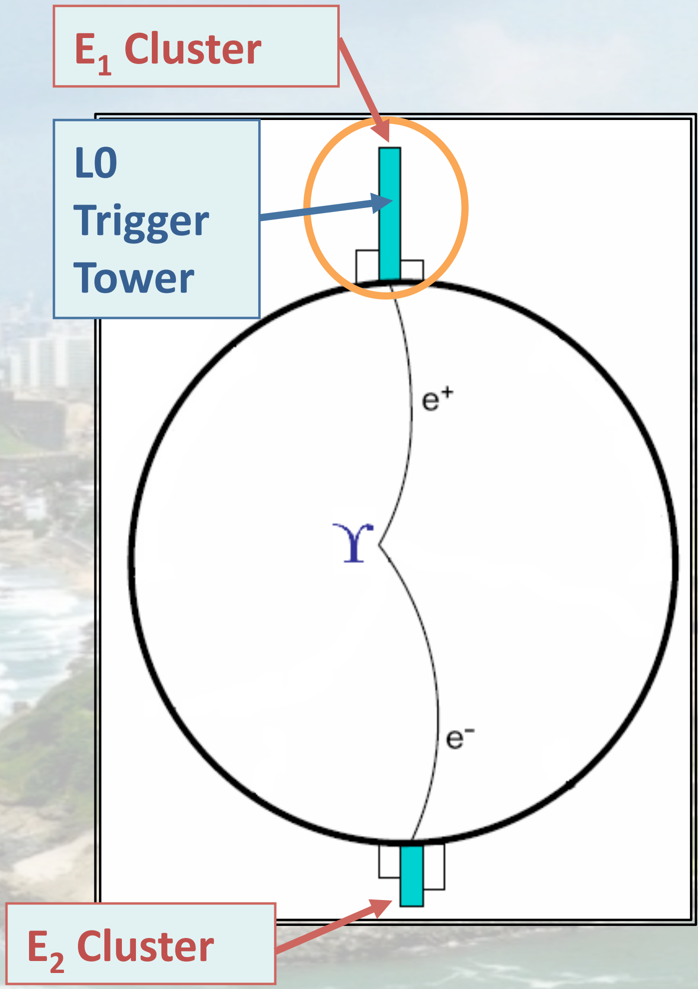
- |η| < 1
- Full ϕ coverage
- Tracking and EID via Ionization



EM Calorimeter

- |η| < 1
- Full ϕ coverage
- Electron ID via E/p
- Event Triggering

Triggering on Υ decays



Level 0 Trigger (p+p,d+Au,Au+Au):

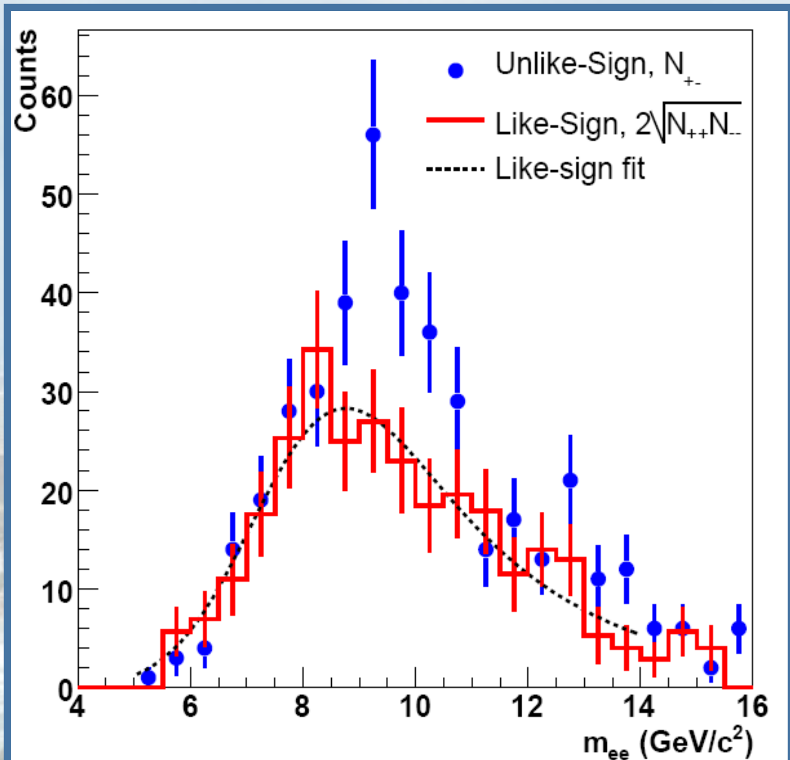
- Hardware-based
- Fires on at least one high tower

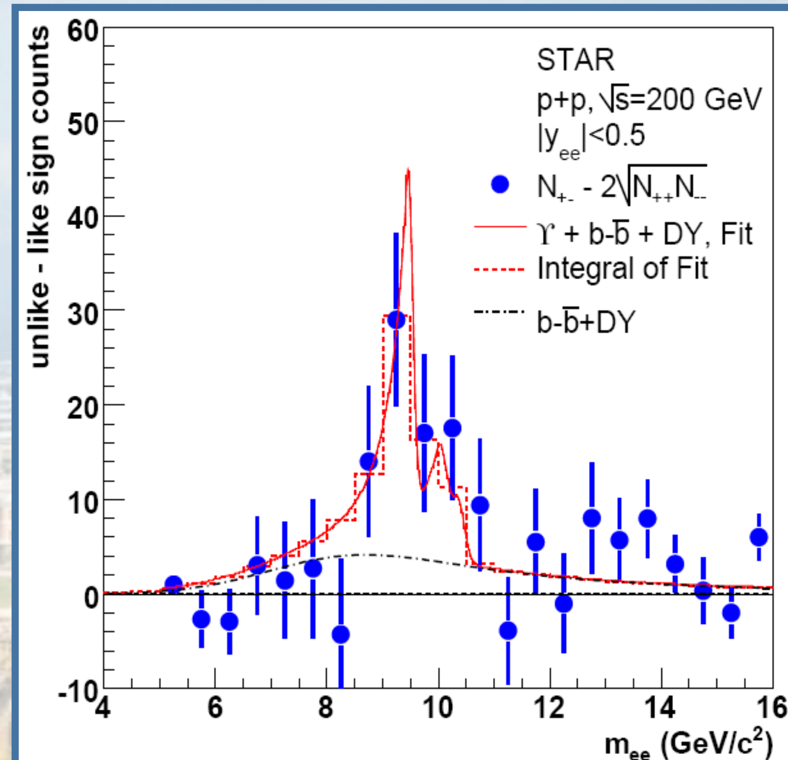
Level 2 Trigger (p+p,d+Au):

- Software-based
- Calculates:
  - Cluster energies
  - Opening angle
  - Mass

High rejection rate allowed us to sample entire luminosity

Υ in p+p 200 GeV



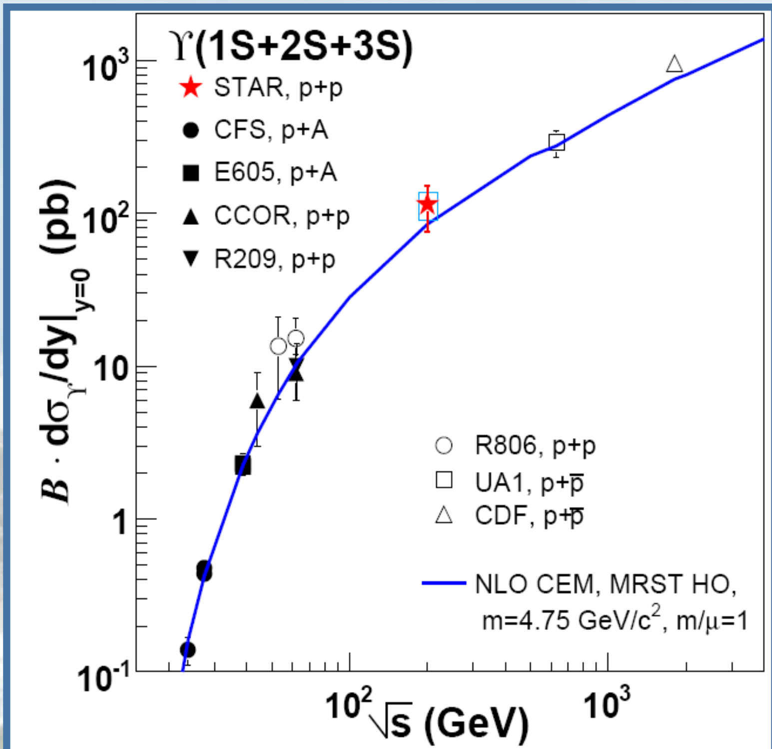


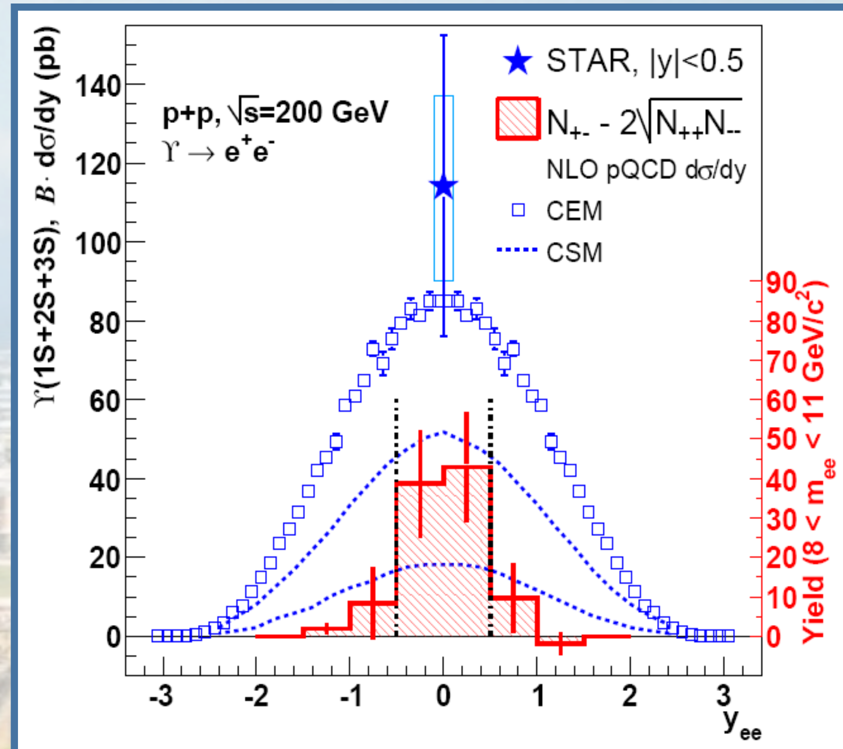
$|y| < 0.5$
$\int L\, dt = 7.9 \pm 0.6$ pb^{-1}
N_{Υ}(total)= 67±22(stat.)

$$\sum_{n=1}^{3} \mathcal{B}(n\mathrm{S}) \times \sigma(n\mathrm{S}) = 114 \pm 38^{+23}_{-24}\,\mathrm{pb}$$

Phys. Rev. D **82** (2010) 12004

Υ in p+p 200 GeV, Comparisons





STAR √s=200 GeV p+p $\Upsilon+\Upsilon'+\Upsilon'' \rightarrow e^+e^-$ cross section consistent with pQCD and world data trend

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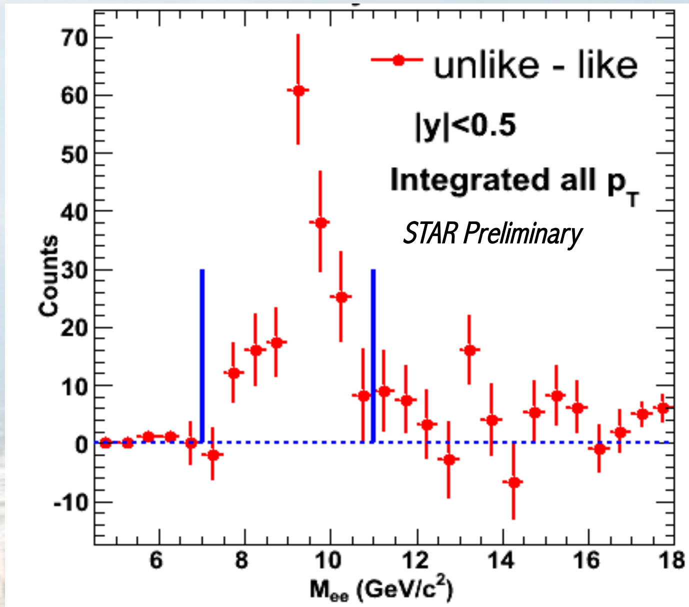
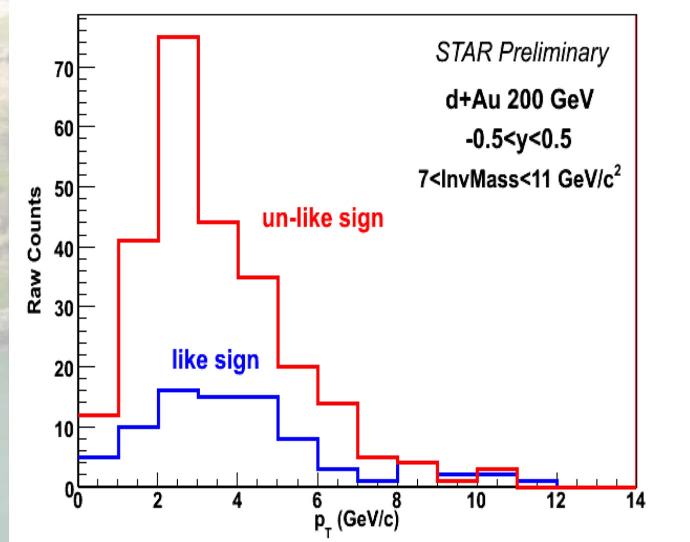
Υ in d+Au 200 GeV

Signal has ~8σ significance
p_T reaches ~ 5 GeV/c

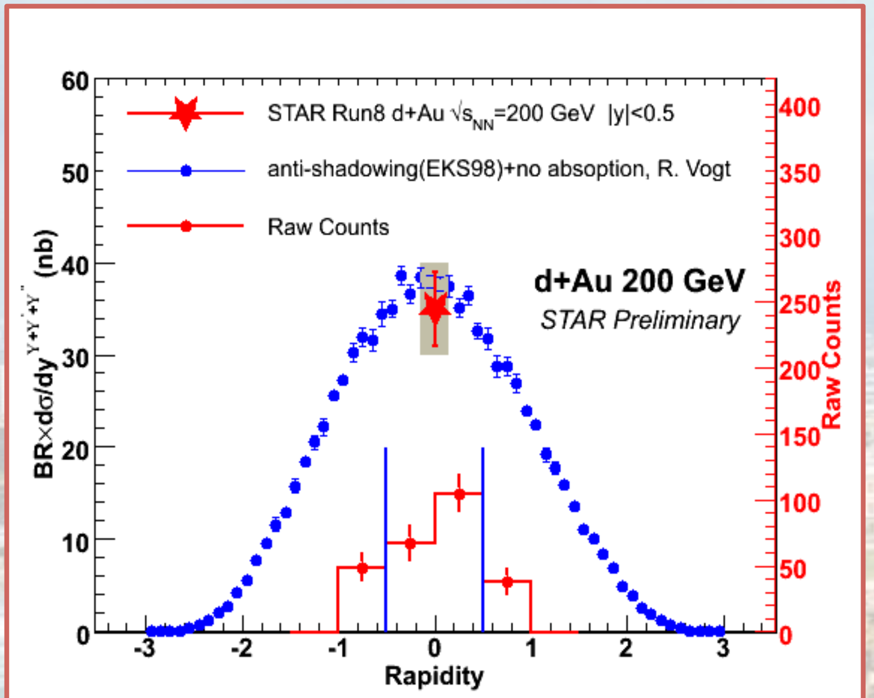
|y| < 0.5
$\int L\, dt = 32.6\ \text{nb}^{-1}$
N_{Υ}(total)= 172 ± 20(stat.)

$$\sum_{n=1}^{3} \mathcal{B}(nS) \times \sigma(nS) = 35 \pm 4 \pm 5\,\text{nb}$$





Υ in d+Au 200 GeV, Comparison



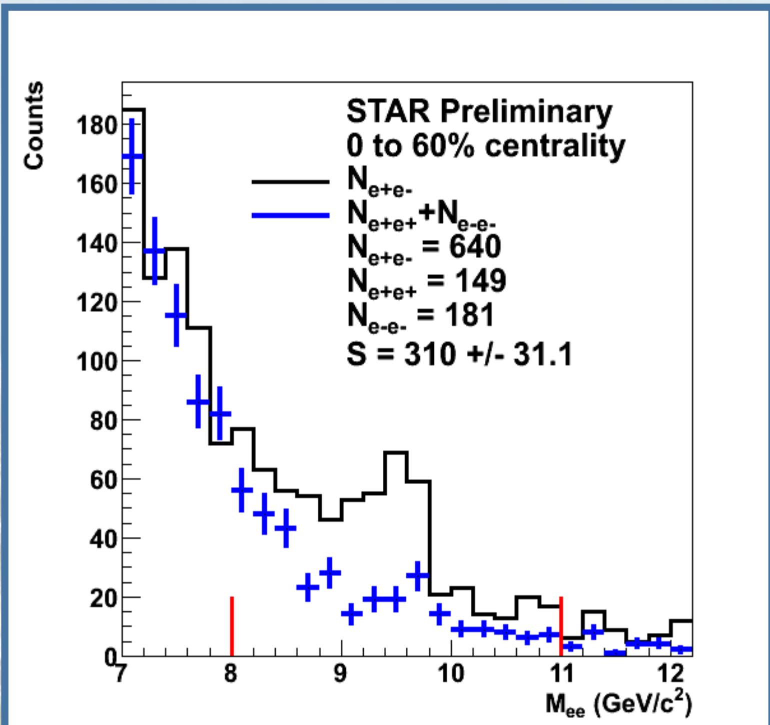
$$R_{dAu} = \frac{1}{N_{bin} \times \frac{\sigma_{dAu}}{\sigma_{pp}}} \times \frac{B_{ee} \times \left(\frac{d\sigma_{dAu}}{dy} \right)_{y=0}^{Y+Y'+Y''}}{B_{ee} \times \left(\frac{d\sigma_{pp}}{dy} \right)_{y=0}^{Y+Y'+Y''}}$$

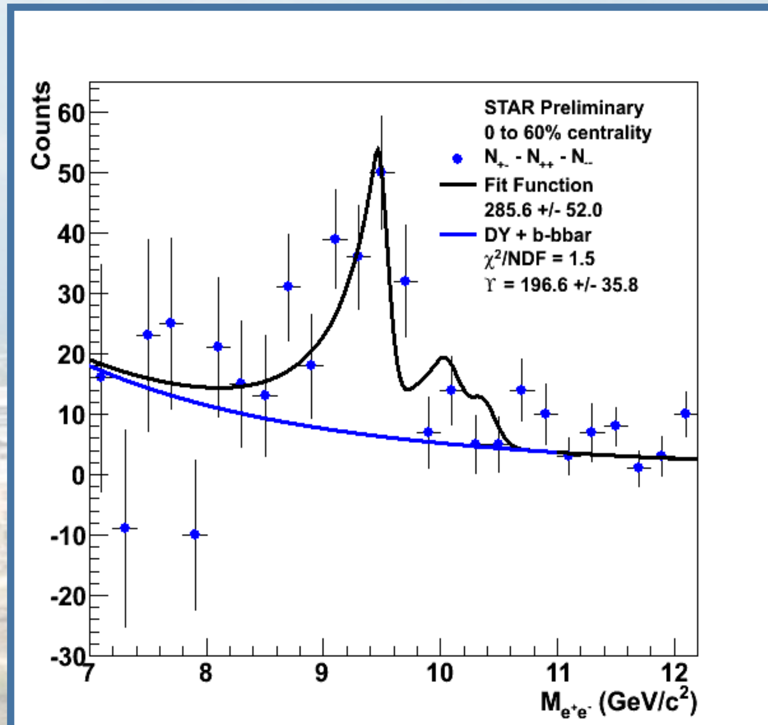
σ_{dAu} = 2.2 b σ_{pp} = 42 mb
N_{bin} = 7.5 ± 4 for minbias dAu

$$R_{dAu} = 0.78 \pm 0.28 \pm 0.20$$

STAR √s=200 GeV d+Au $\Upsilon+\Upsilon'+\Upsilon'' \rightarrow e^+e^-$ cross section consistent with pQCD and minimal shadowing effects

ϒ in Au+Au 200 GeV

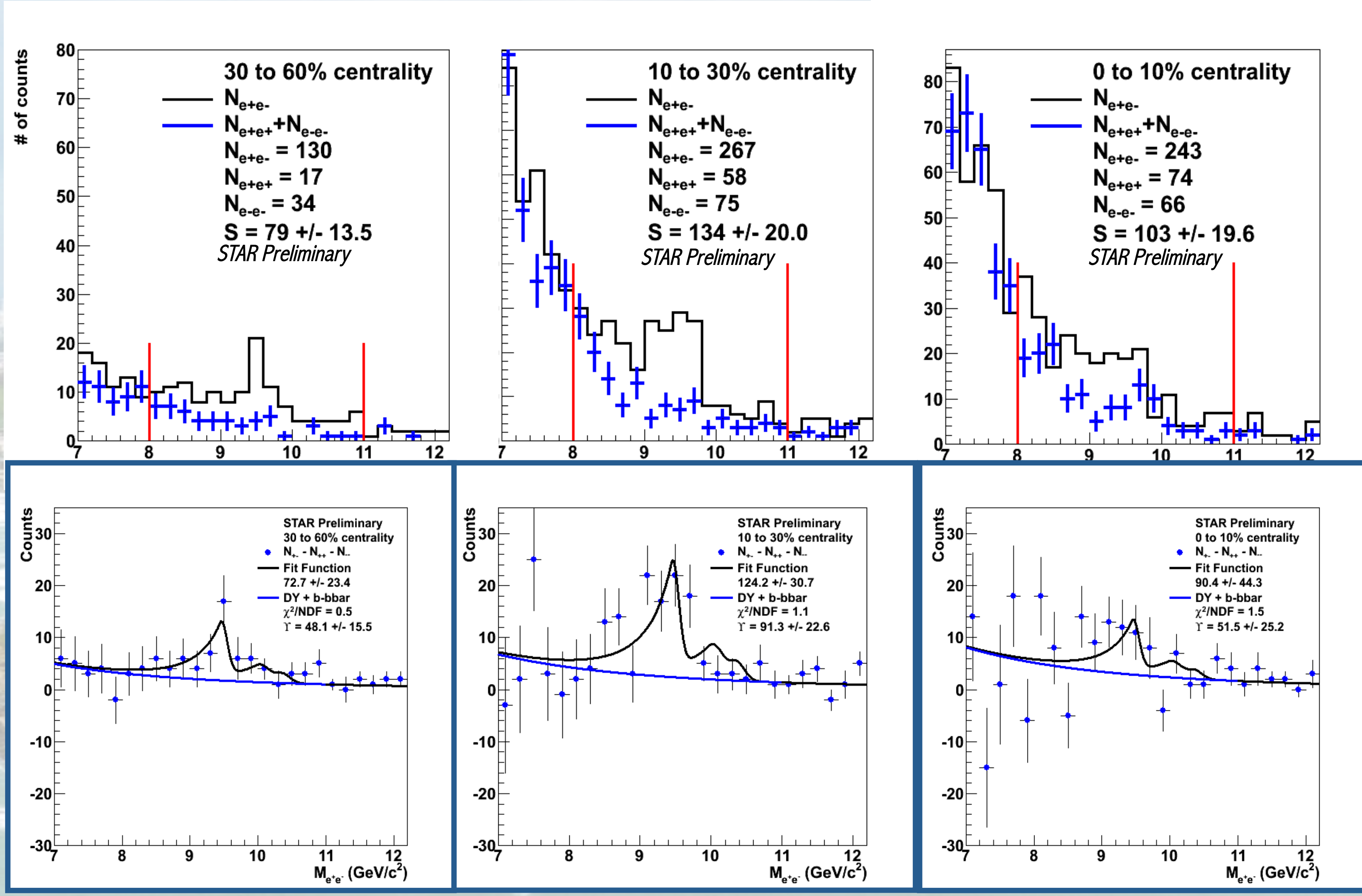




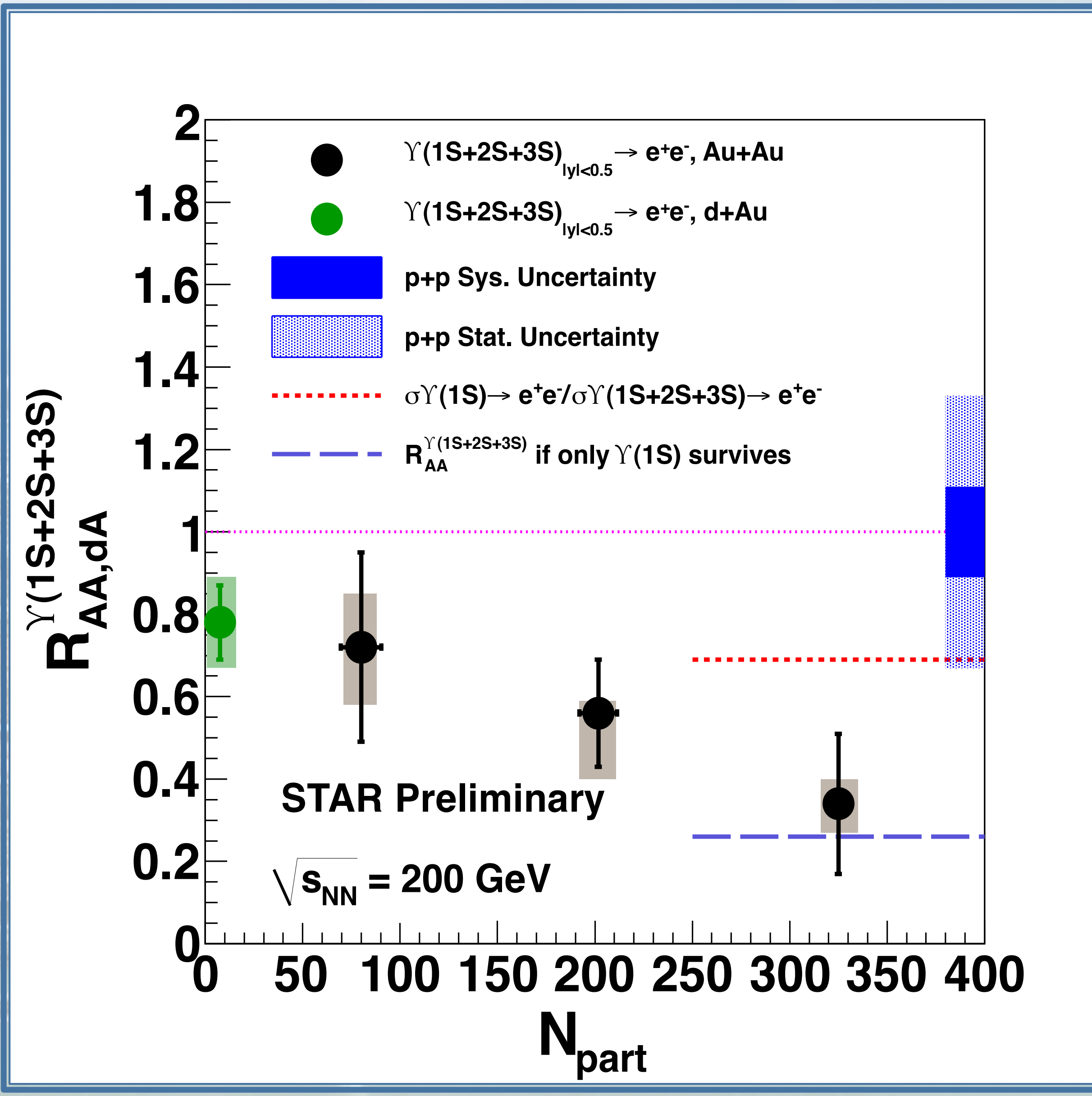
Raw yield of $\Upsilon \rightarrow e^+e^-$ with $|y|<0.5$ = 197 ± 36

$\int L\, dt \approx 1400\ \mu b^{-1}$

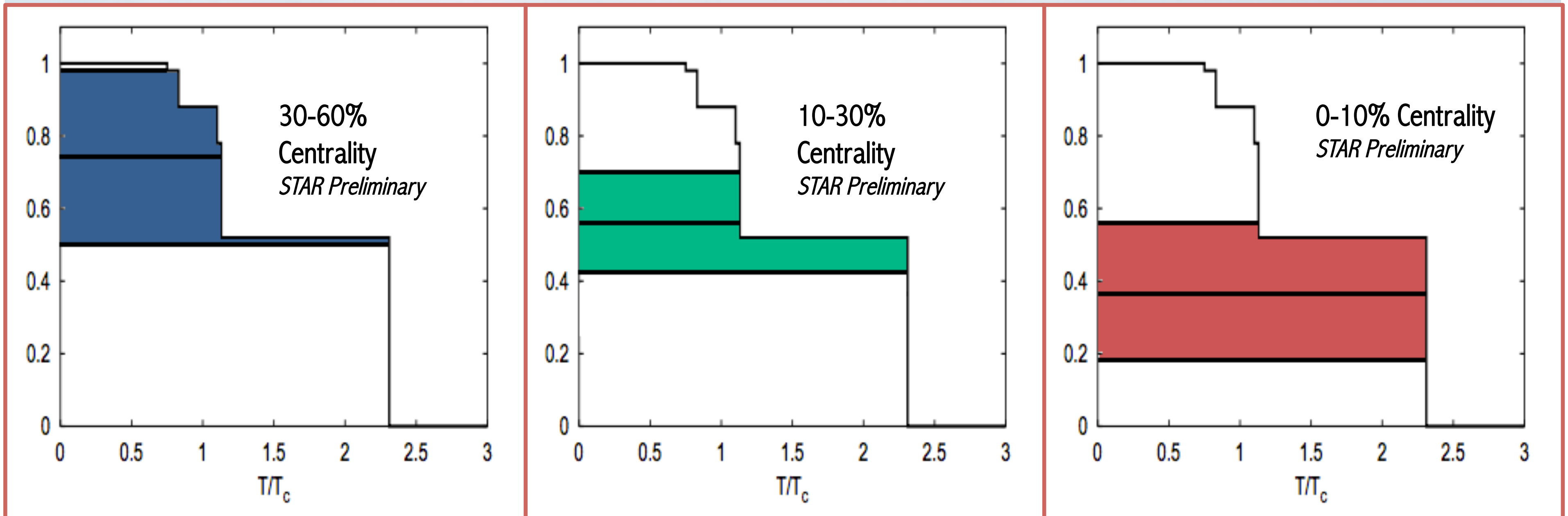
Υ in Au+Au 200 GeV, Centrality



Υ in Au+Au 200 GeV, R_{AA}



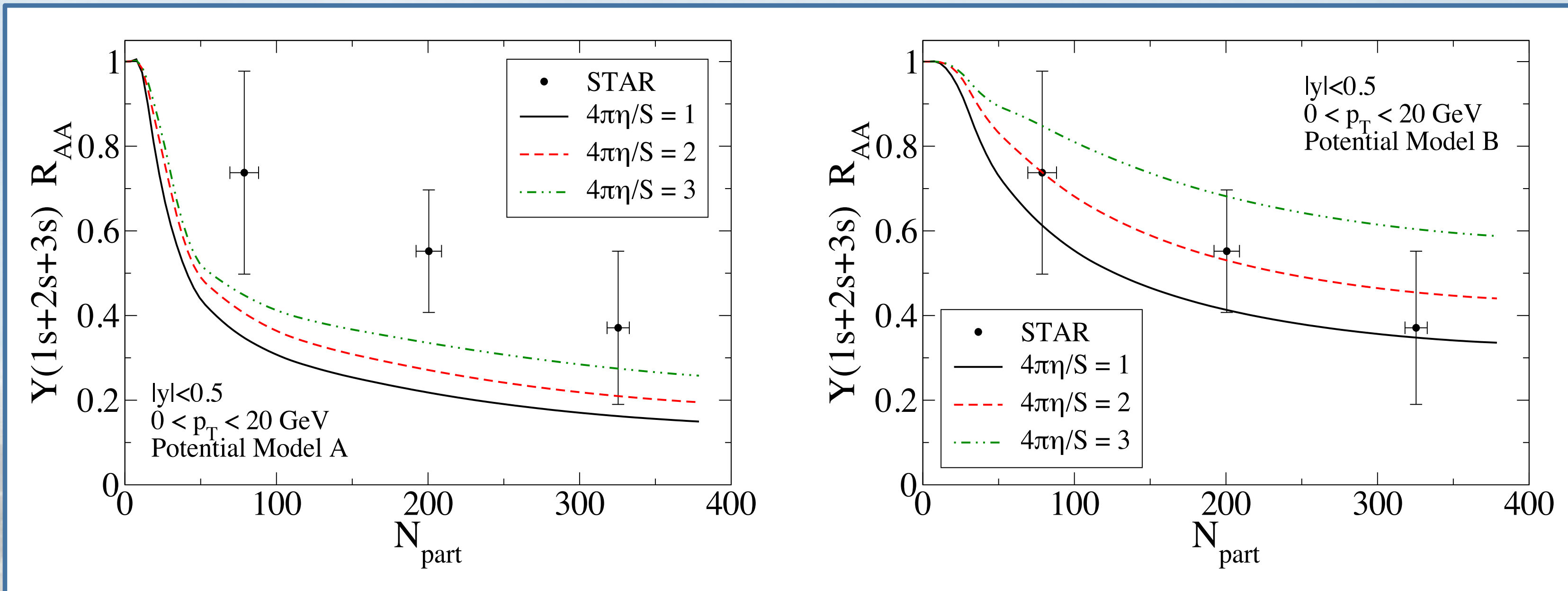
Υ in Au+Au 200 GeV, Comparison



$q\bar{q}$	T/T_c
$\Upsilon(1S)$	2.31
$\chi_b(1P)$	1.13
$\Upsilon(2S)$	1.10
$\chi_b(2P)$	0.83
$\Upsilon(3S)$	0.75

- Lattice-based static model
  - S. Digal, P. Petreczky, and H. Satz, *Phys Rev. D* ***64,094015 (2001)***
- Gives $1.1 \leq T/T_c \leq 2.3$ for most central events
- Consistent with only 1S survival

ϒ in Au+Au 200 GeV, Comparison



- Assumes dynamic system evolution and feed-down
- Model A uses Free Energy
- Model B uses Internal Energy
- The three curves cover a range 428 MeV $\leq T_0 \leq$ 442 MeV
- Clearly, more statistics are needed to reach a conclusion

M. Strickland and D. Bazow, arXiv:1112.2761v4

Conclusions and Outlook

- Measured Υ production in p+p, d+Au, and Au+Au collisions at 200 GeV
- Production in d+Au consistent with binary scaling and cold nuclear matter effects
- Au+Au results consistent with complete 2S+3S suppression in central collisions
- Increased statistics from run 11 will further decrease R_{AA} uncertainties