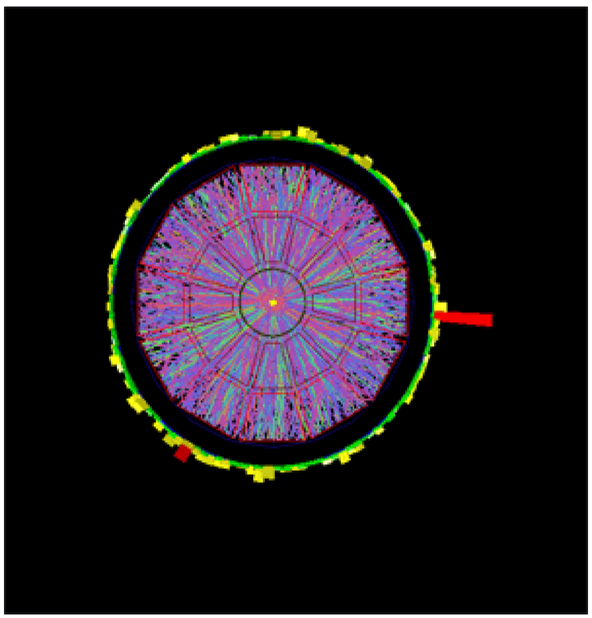
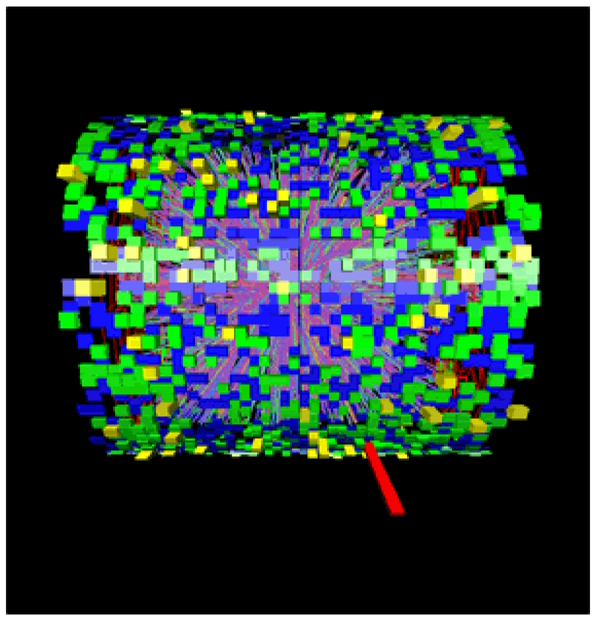
Υ production in p+p, d+Au, Au+Au collisions at 200 GeV in STAR





Rosi Reed

UC Davis

For the STAR Collaboration

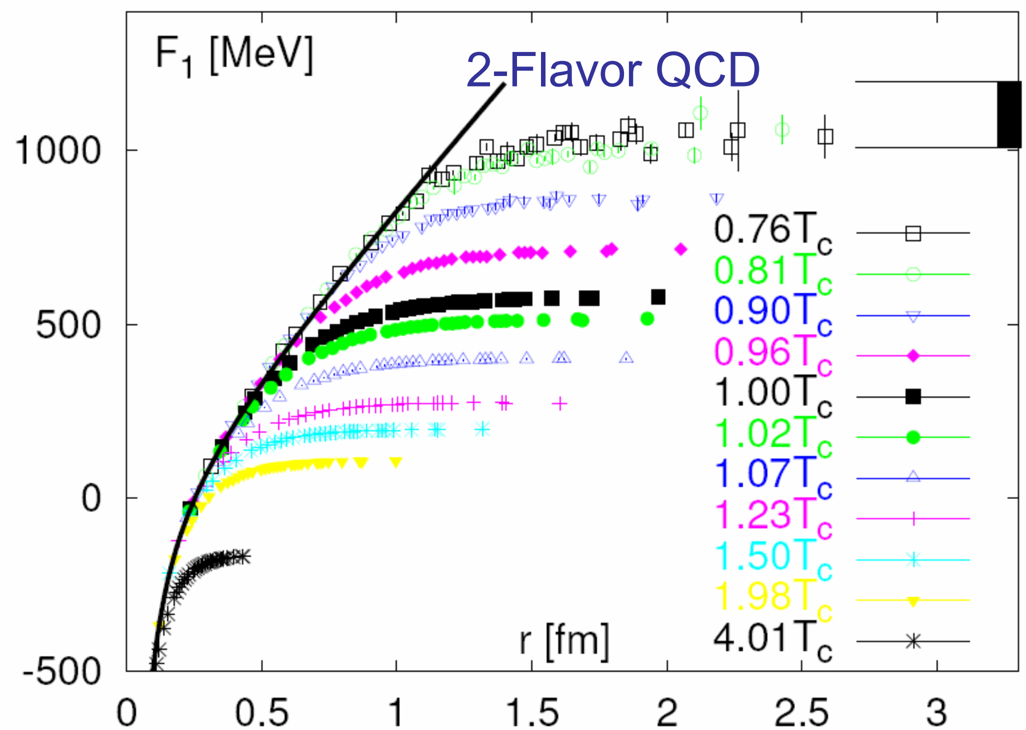
Outline

- Motivations
- Measuring Υ
- STAR detectors and the Υ trigger
- Υ measurements
  - p+p
  - d+Au
  - Au+Au 0-60% and 0-10% Centrality
    - Yield
    - R_{AA}
- Summary/Outlook

Motivations

- Suppression of quarkonia is predicted to be a QGP signature *Matsui T and Satz H 1986 Phys.Lett.B178:416,1986*
- b+c quarks are produced early in the collision
  - Makes them an excellent probe
- Quantifying suppression requires:
  - Baseline p+p measurement
  - Measurement of cold nuclear matter effects
    - d+Au collisions

O.Kaczmarek, F. Zantow, Phys. Rev. D71 (2005) 114510



Motivations

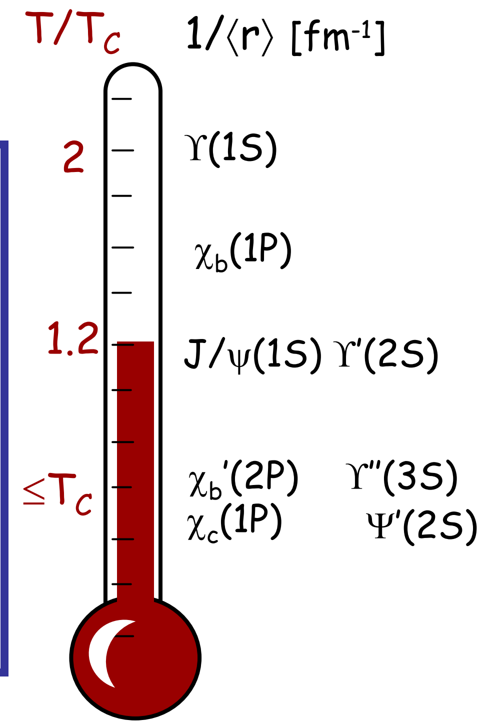
Sequential disappearance of states:

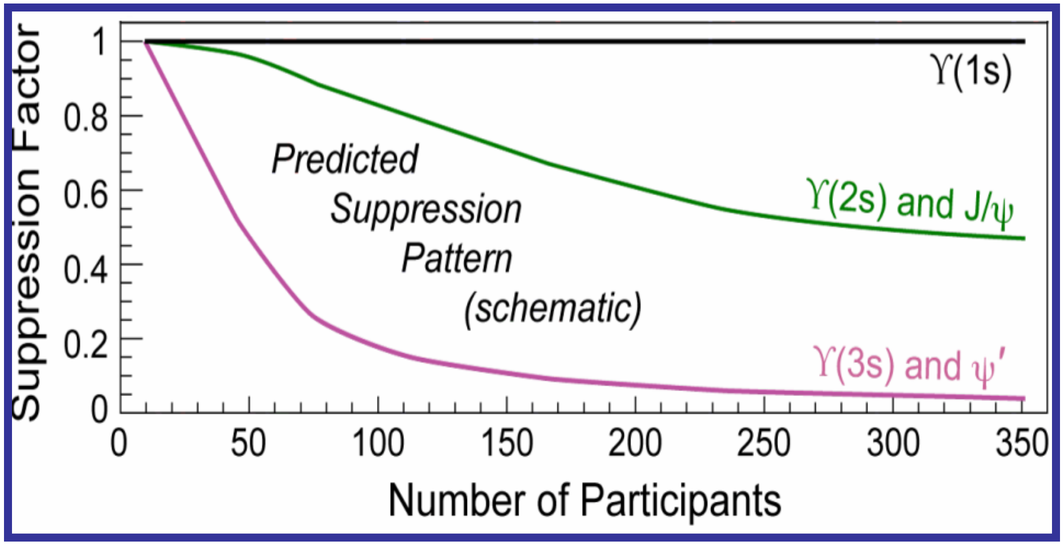
⇒Color screening ⇒ Deconfinement

Matsui T and Satz H 1986 Phys.Lett.B178:416,1986

⇒QCD thermometer ⇒ QGP Properties

A. Mocsy and P. Petreczky PRD 77 014501 (2008)





A .Mocsy, 417th WE-Heraeus-Seminar,2008
A. Mocsy and P.Petreczky, PRL 99, 211602 (2007)

Expectation at 200 GeV

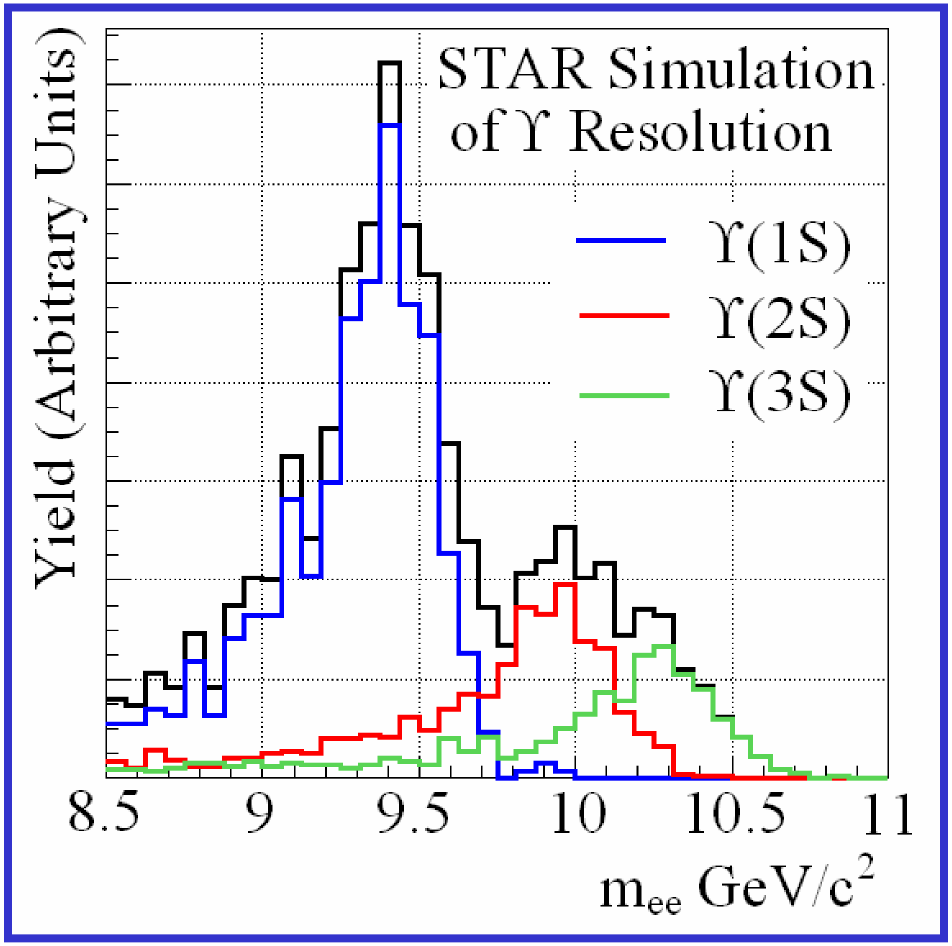
Υ(1S) does not melt

Υ(2S) is likely to melt

Υ(3S) will melt

Measuring Υ at STAR

- Decay channel
  - $\Upsilon \rightarrow e^+e^-$
- Pros
  - Small background at M~10 GeV/c^2
  - Co-mover absorption is small
  - Recombination negligible at RHIC



- Cons
  - Low rate of 10^{-9} per minbias pp interaction
  - Good resolution needed to separate 3 S-states

STAR Detectors

BEMC

$|\eta| < 1$

$0 < \phi < 2\pi$

E/p → electron ID

High-energy tower trigger

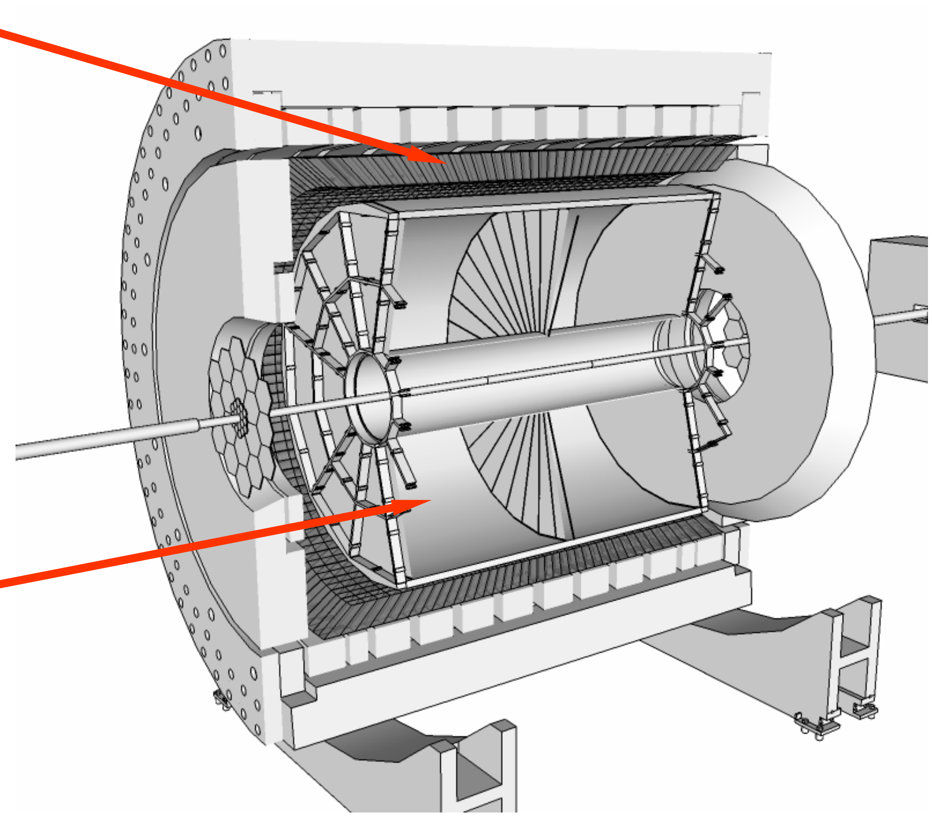
TPC

$|\eta| < 1$

$0 < \phi < 2\pi$

Tracking → momentum

ionization energy loss → electron ID

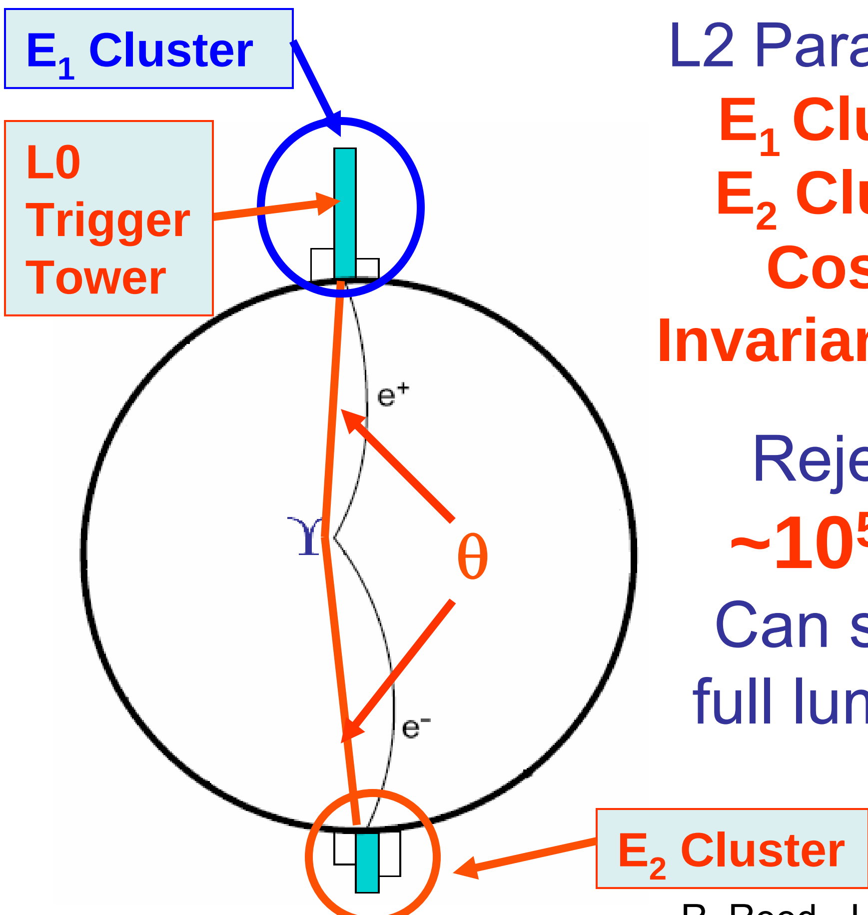


STAR Υ Trigger

L0 Parameters pp 2006 (dAu,AuAu)

High Tower E_T > 3.5 GeV (4.0 GeV)

Trigger Patch E_T > 4.3 GeV (NA)



L2 Parameters

E_1 Cluster,

E_2 Cluster,

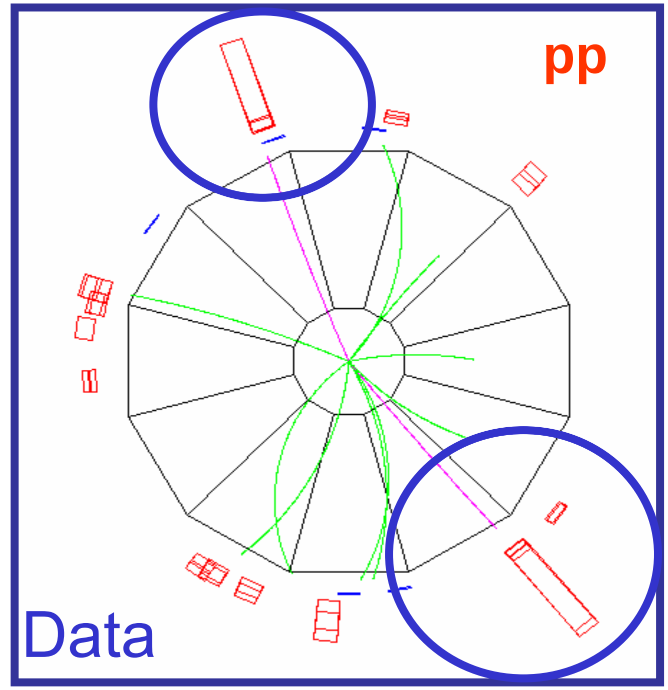
Cos(θ),

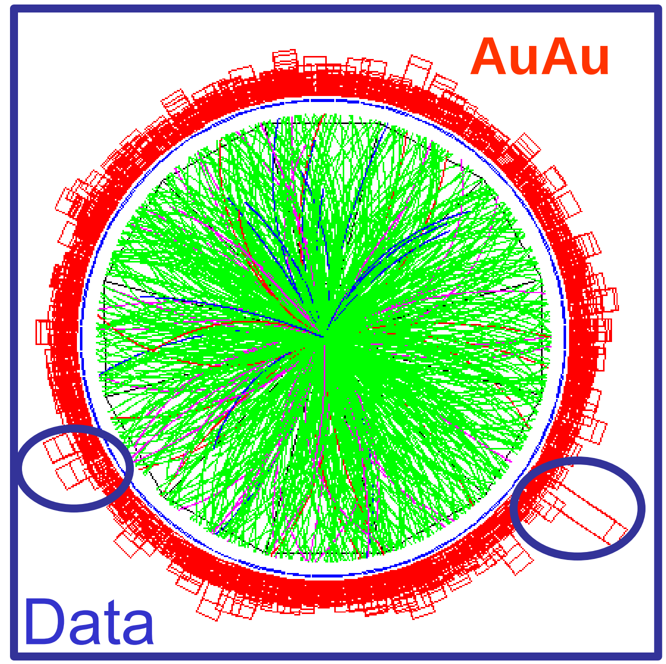
Invariant Mass

Rejection

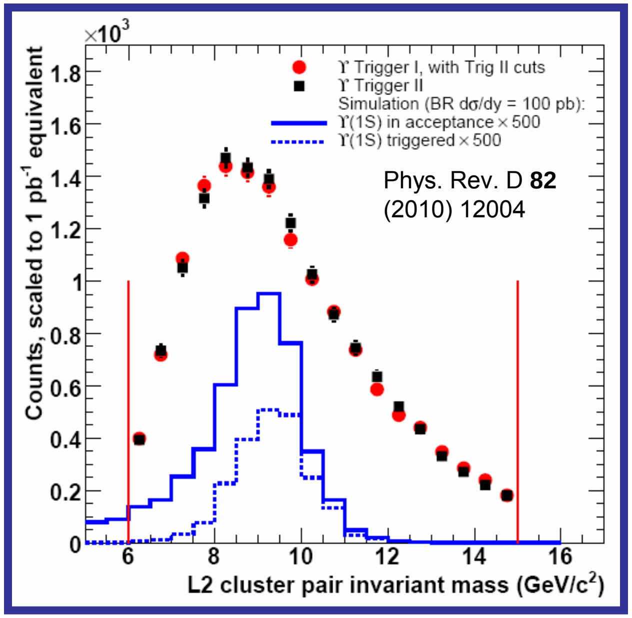
~10^5 in pp

Can sample full luminosity

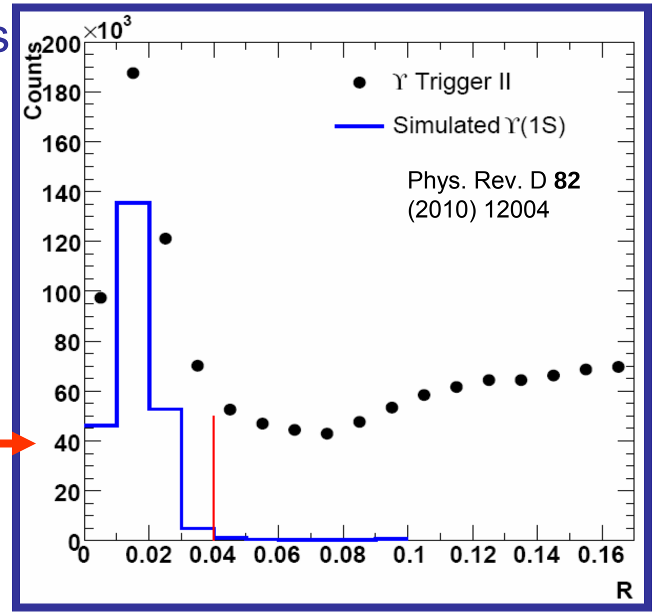




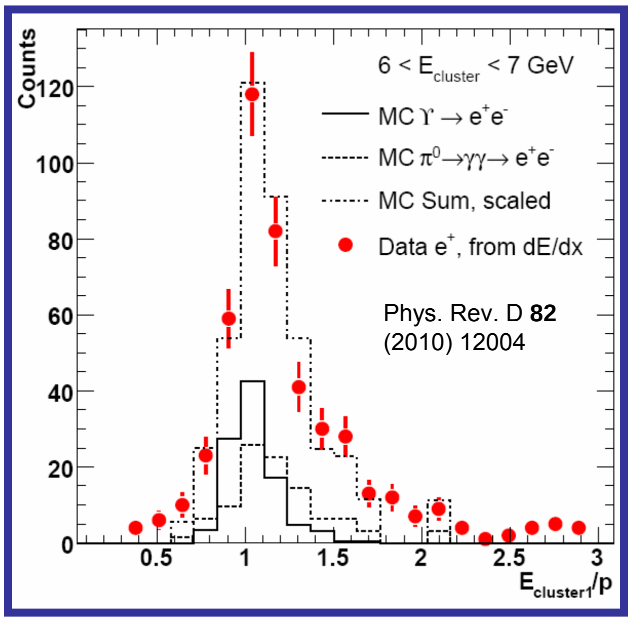
Analysis Techniques



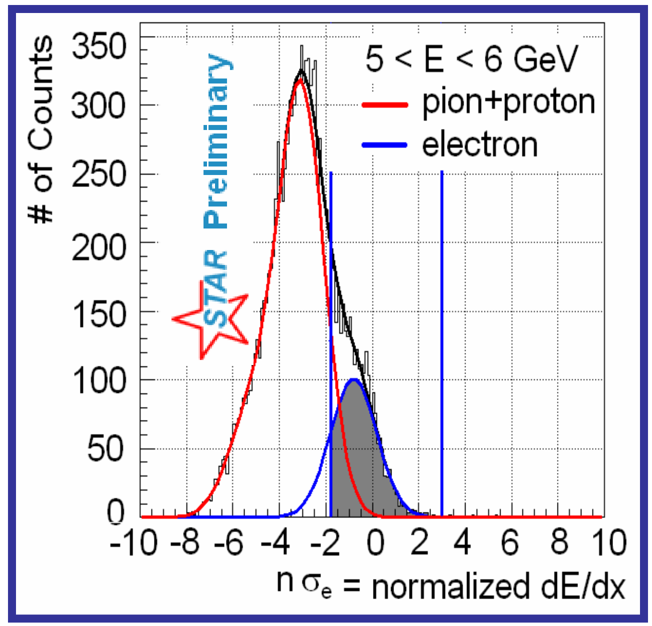
Triggered candidates exceed number of Υ by a factor of ~700 (p+p)



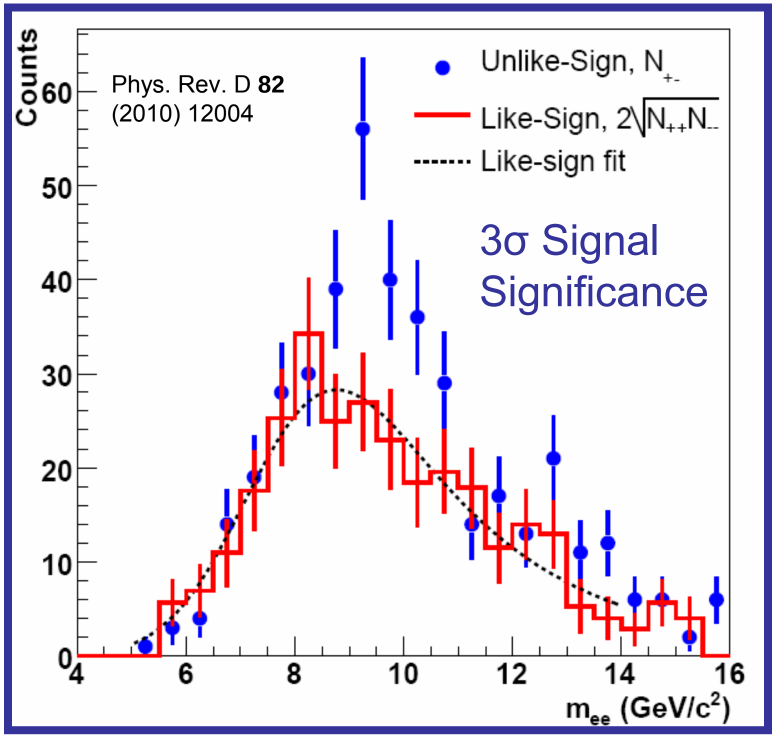
TPC tracks that extrapolate to R=0.04 in $\eta-\phi$ to trigger clusters are "matched"

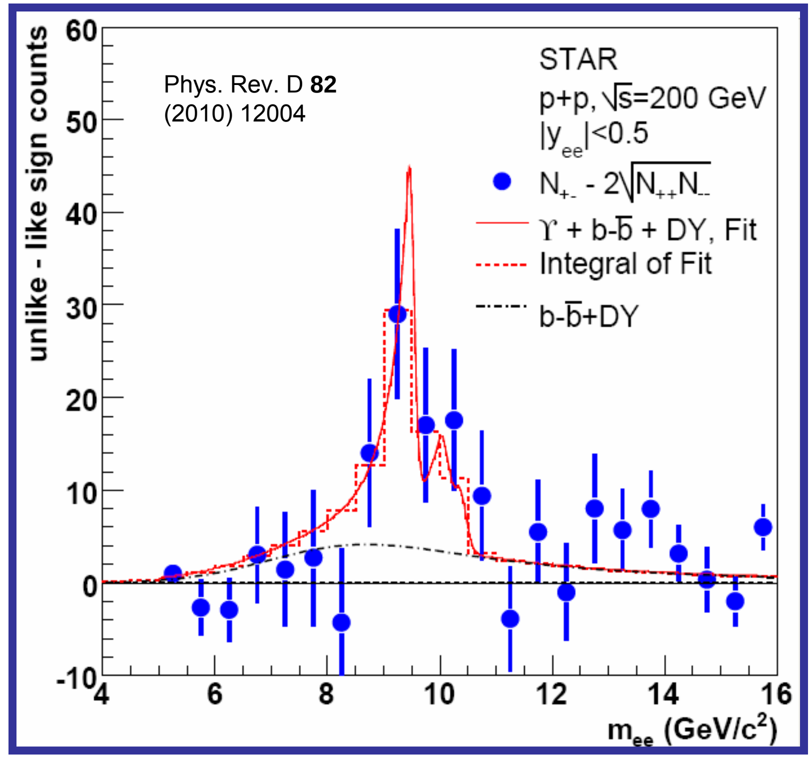


E/p and $n\sigma_e$ of matched tracks are used to select e^+ and e^- tracks



Υ in p+p 200 GeV





$\mathcal{L}$ = 7.9 ± 0.6 pb^{-1}

N_Υ(8<m<11) = S - DY-bb = 61±20(stat.)

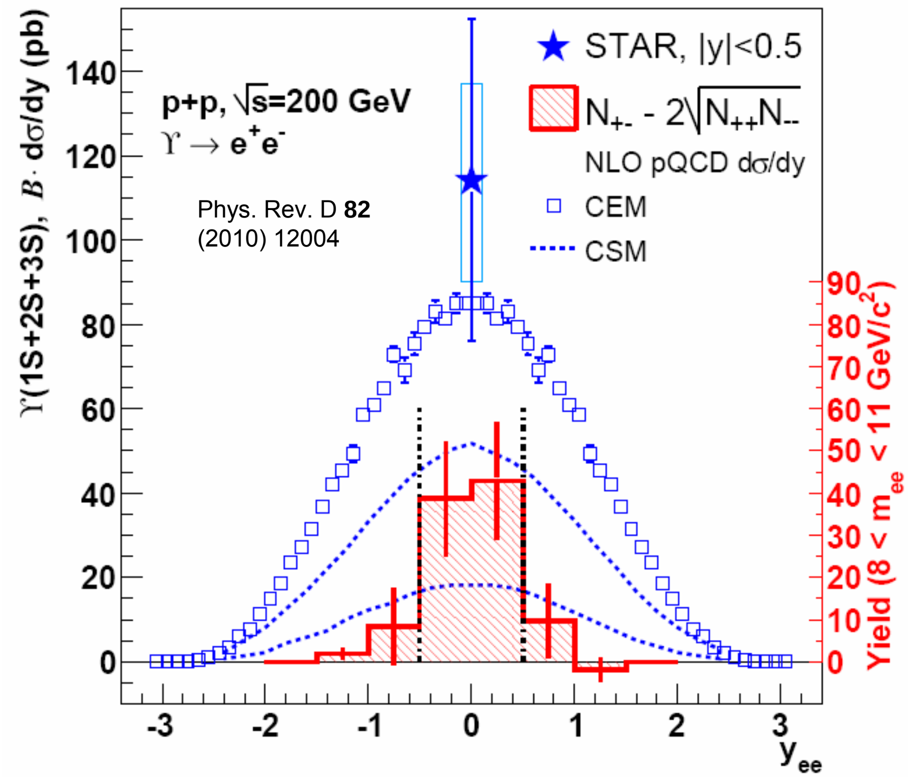
N_Υ(total)= 67±22(stat.)

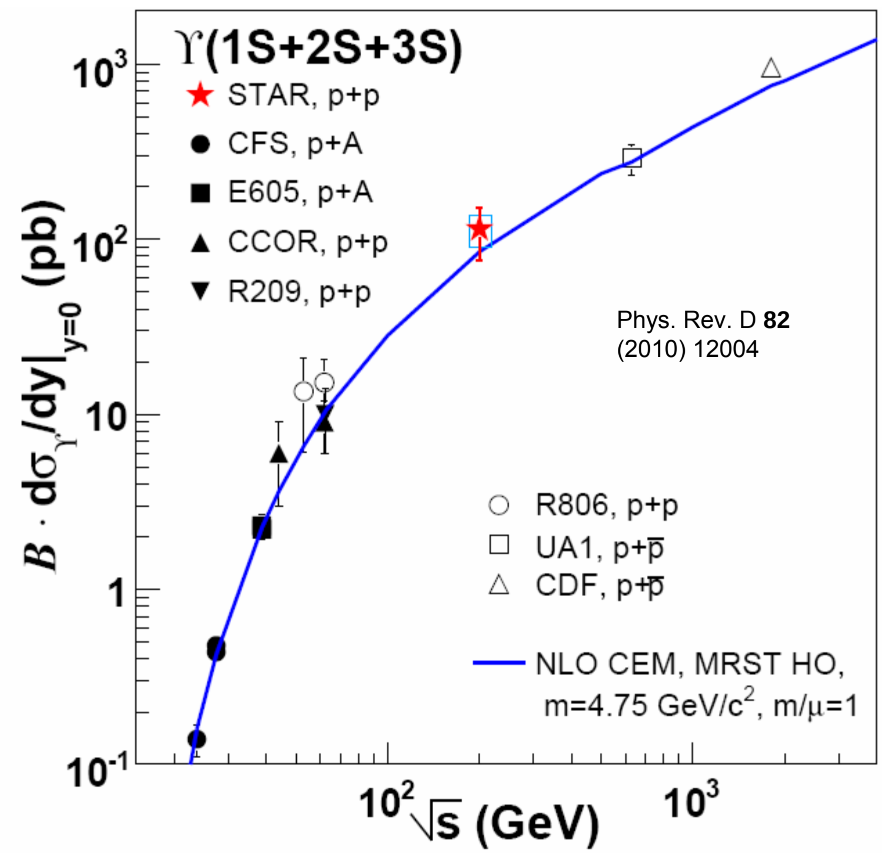
$$\sum_{n=1}^{3} B(nS)\times\sigma(nS) = \frac{N_\Upsilon}{dy\times\varepsilon_\Upsilon\times\int\mathcal{L}dt}$$

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

$$\left(\sigma_{DY}+\sigma_{b\bar{b}}\right)_{|y|<0.5,\, 8<m_{ee}<11\,\text{GeV/c}^2} = 38\pm 24\ \text{pb}$$

STAR ϒ *vs.* theory and world data

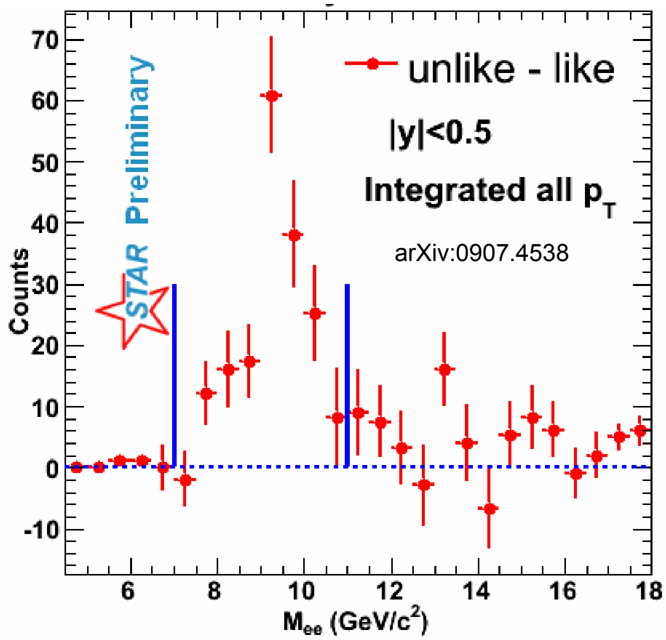


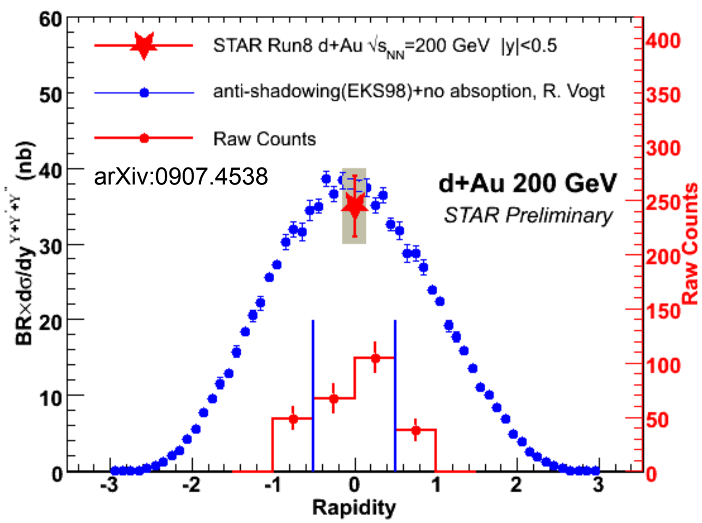


$$\sum_{n=1}^{3} \mathcal{B}(nS) \times \sigma(nS) = 114 \pm 38 \,^{+23}_{-24} \text{ pb}$$

STAR 2006 √s=200 GeV p+p ϒ+ϒ′+ϒ″→e⁺e⁻ cross section consistent with pQCD and world data trend

Υ in d+Au 200 GeV





Υ(1S+2S+3S)+DY+$b\bar{b}$ raw yield (7<m<11) = 172 ± 20 (stat.)

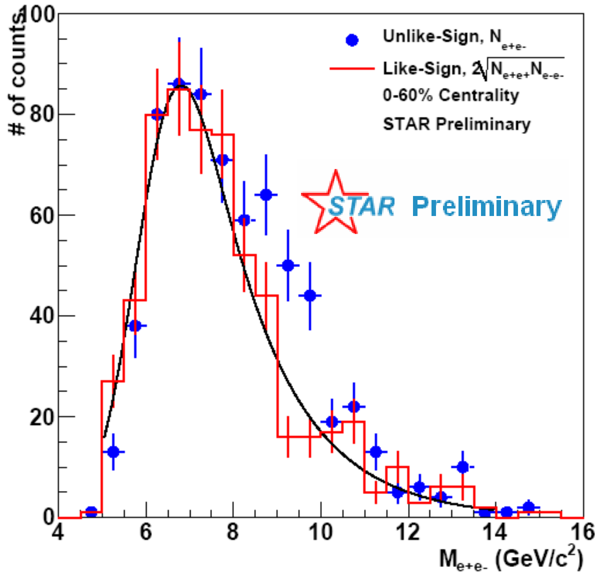
Strong signal (8σ significance)

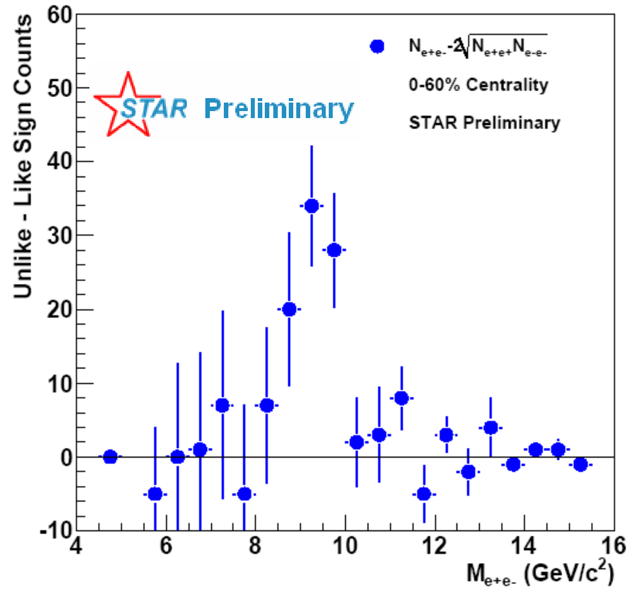
$$R_{dA} = 0.78 \pm 0.28(stat) \pm 0.20(sys)$$

Consistent with N_{bin} scaling

Confirms theory calculation that Cold Nuclear Matter effects (Shadowing) are not large.

ϒ in Au+Au 200 GeV





Year 2007

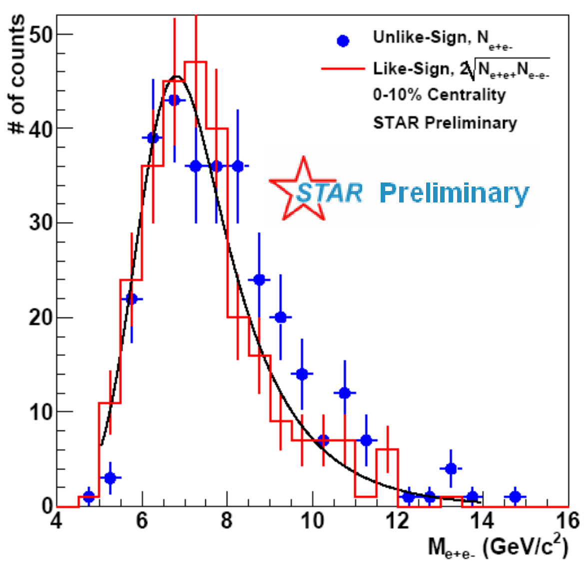
$8<m<11$ GeV/c^2

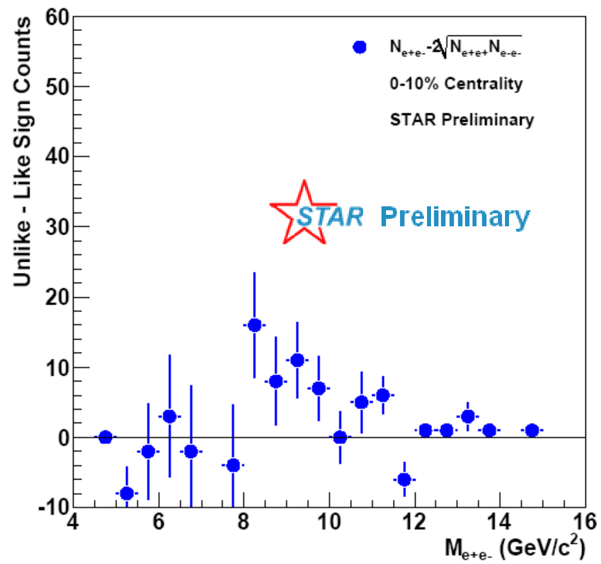
0-60%

4.6σ significance

95 Signal counts

1.11×10^9 events





0-10%

3.5σ significance

47 Signal counts

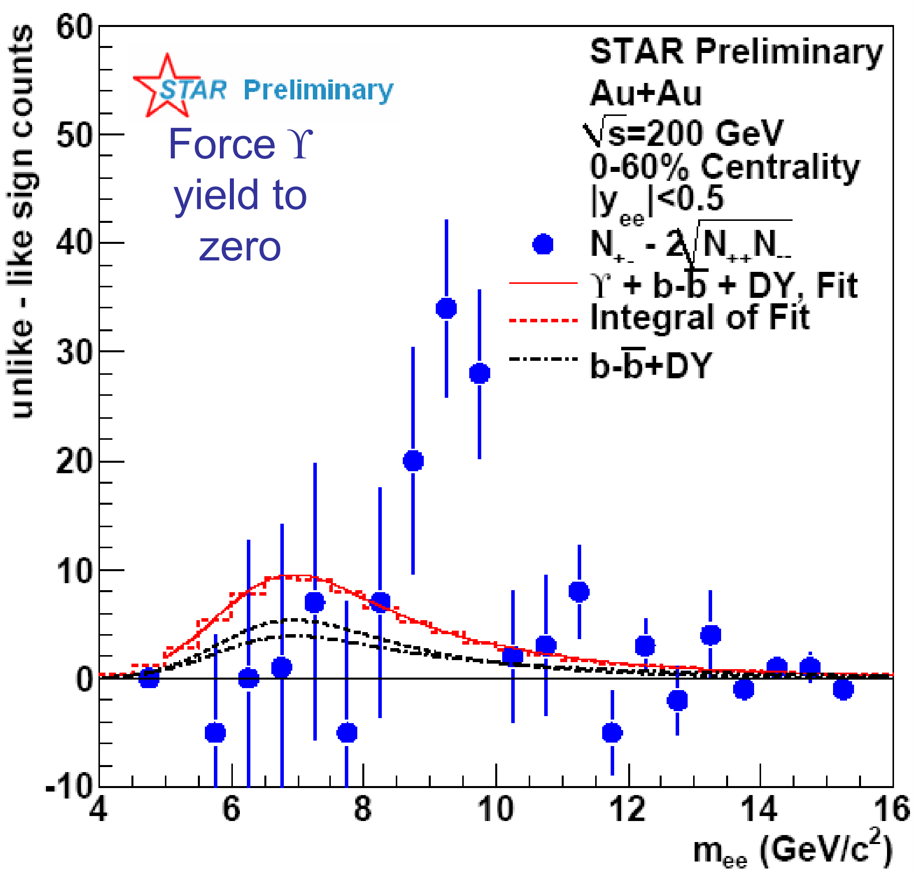
1.78×10^8 events

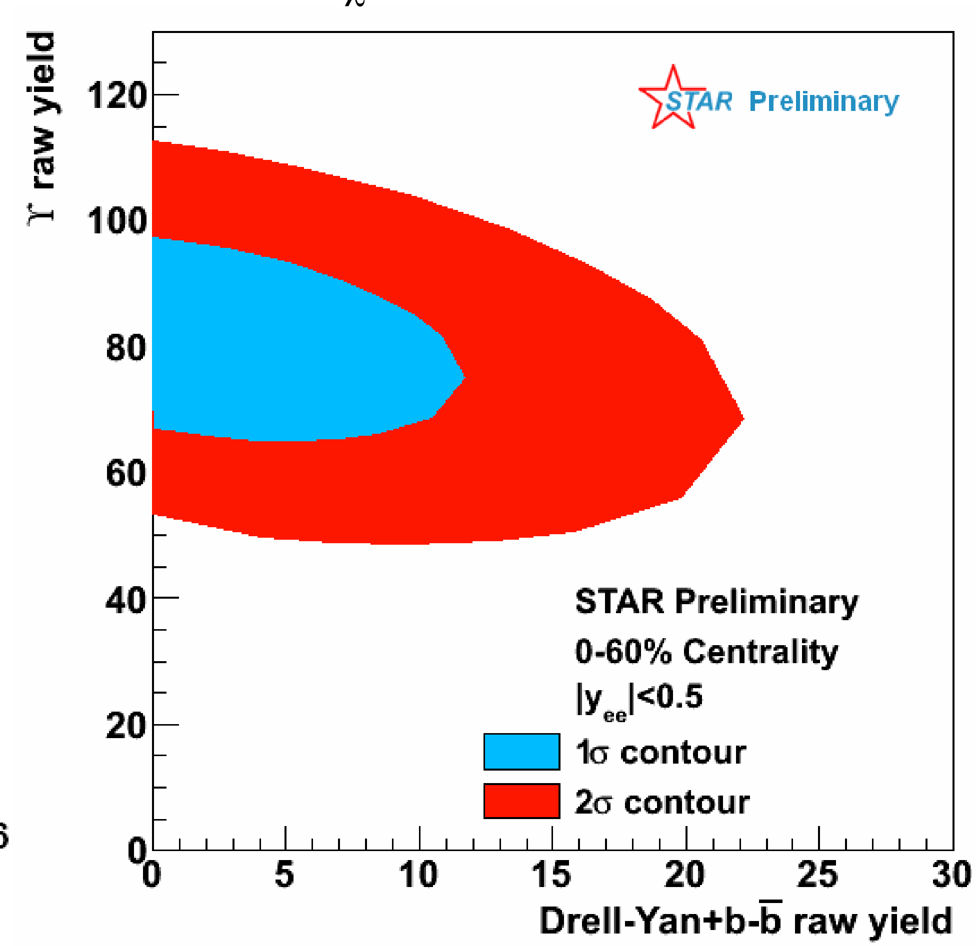
Includes ϒ, Drell-Yan + $b\bar{b}$

Υ Yield Extraction 0-60% Centrality

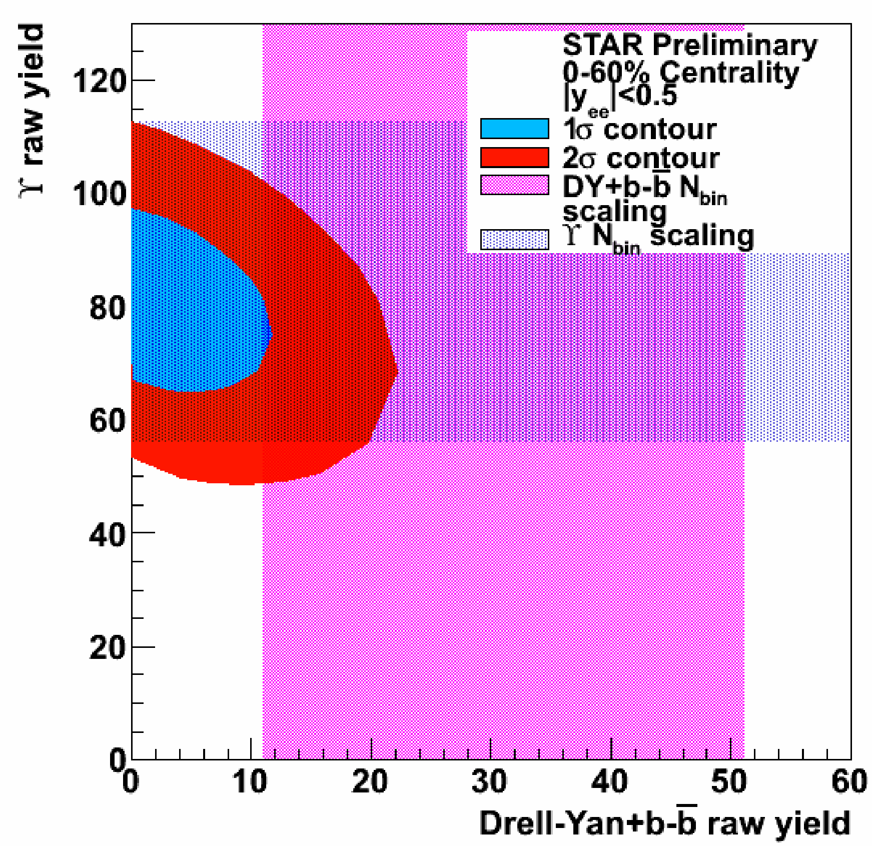
- Do we see Υ(1S+2S+3S) in 0-60% centrality?
  - Yes!

Raw yield of 0 is many sigma away from minimum χ^2



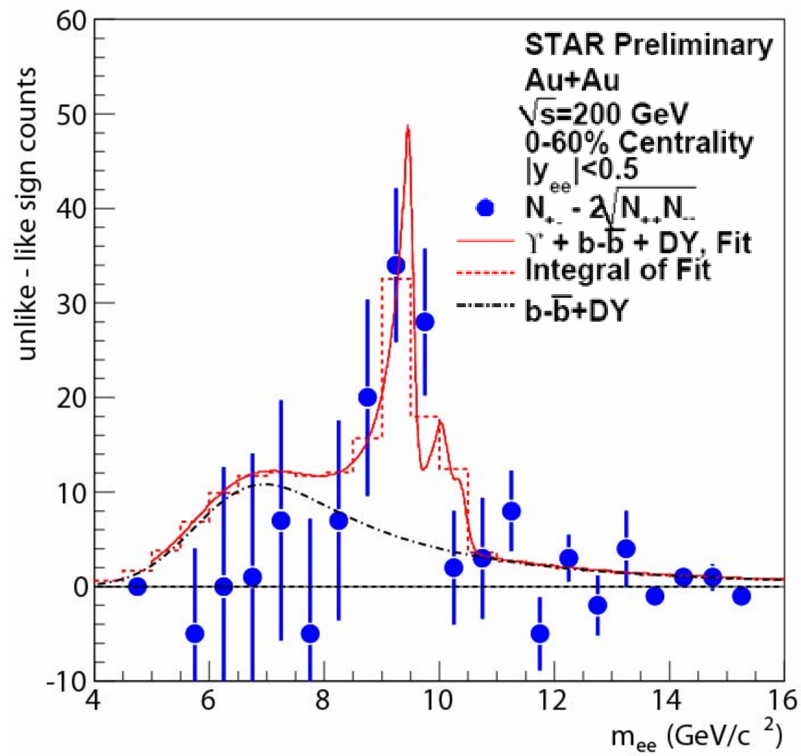


Υ Yield Extraction 0-60% Centrality



Scaling p+p results for Υ and DY + $b\bar{b}$ gives us colored rectangles

R_{AA} Υ(1S+2S+3S)+DY+$b\bar{b}$ of 1 would be at the center of the intersection between the two rectangles

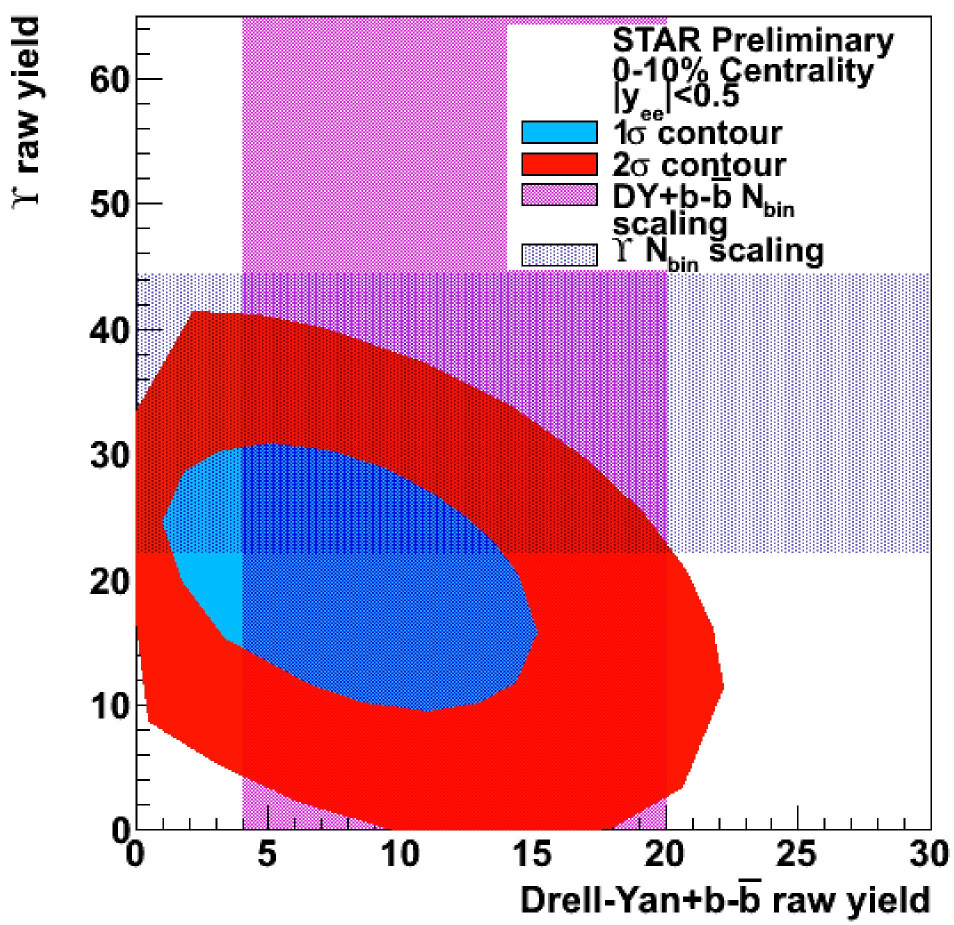


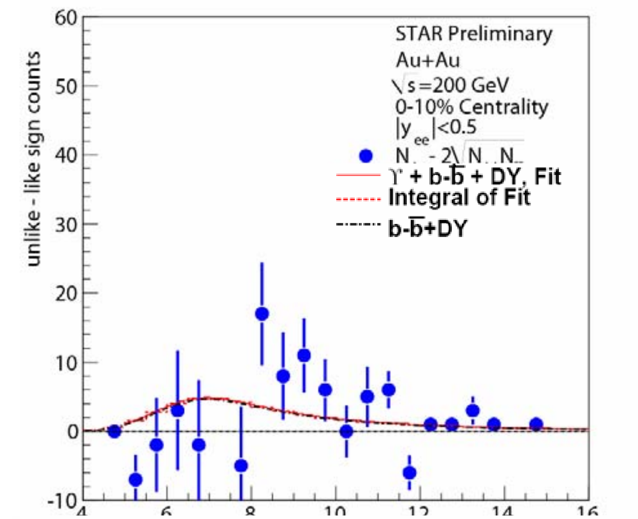
Υ yield determined by:

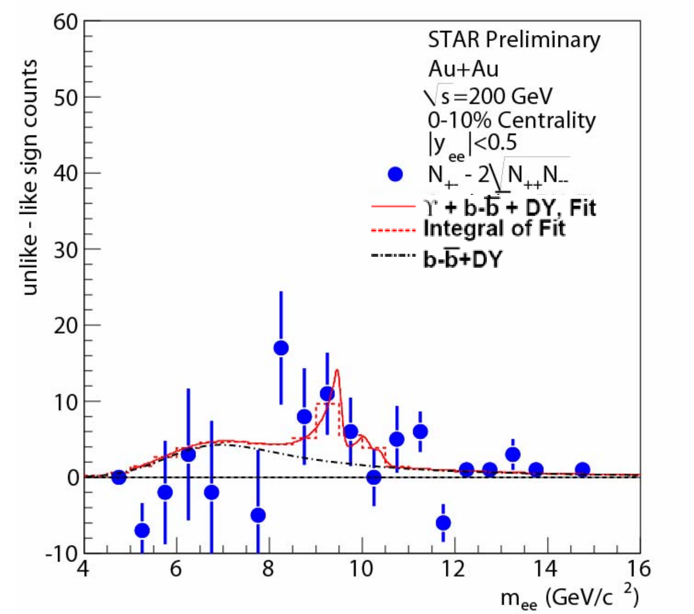
Υ(8.5<m<11 GeV/c²) = $N_{+-} - 2\sqrt{N_{++}N_{--}} - \int DY+b\bar{b}$

=64±16(stat)±25(sys)

ϒ Yield Extraction 0-10% Centrality







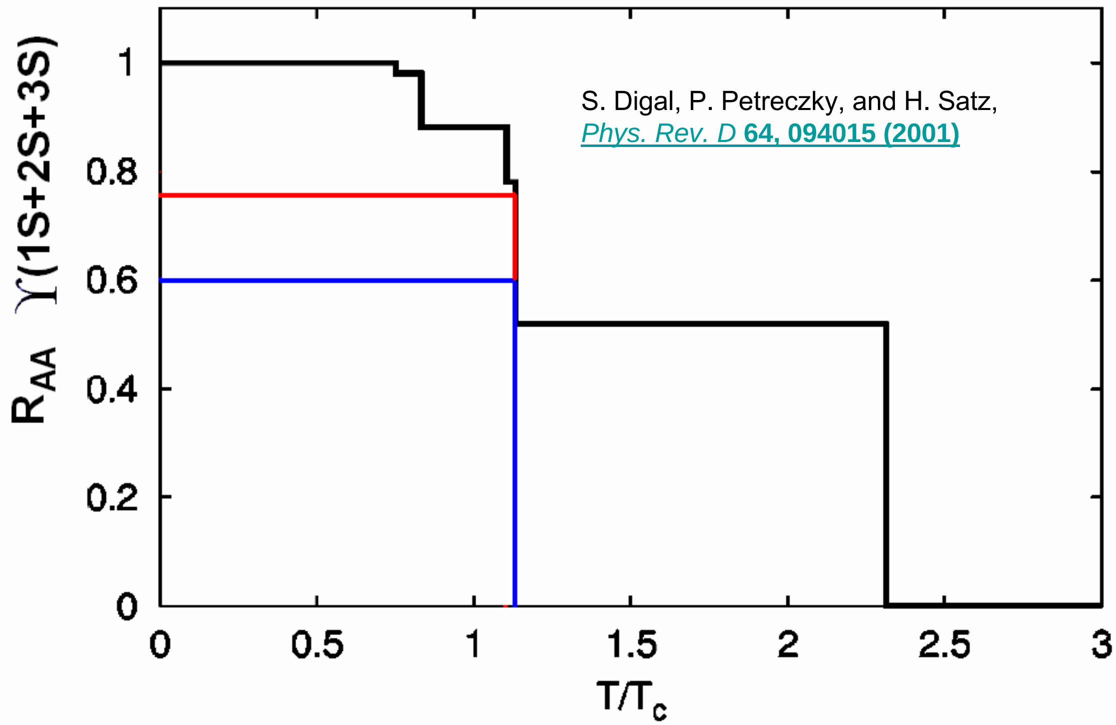
Unlike the 0-60%, ϒ of 0 is only 2σ away

ϒ(8.5<m<11GeV/c^2) =21±11(stat) ± 11(sys)

Lattice QCD R_{AA} comparison

- 0-60%= 0.78±0.32(stat) ± 0.22(sys,Au+Au) ±0.09(sys,p+p)
- 0-10%= 0.63±0.44(stat) ± 0.29(sys,Au+Au) ±0.07(sys,p+p)

$q\bar{q}$	T/T_c
J/Ψ	1.10
$\chi_c(1P)$	0.74
$\psi(2S)$	0.1–0.2
$\Upsilon(1S)$	2.31
$\chi_b(1P)$	1.13
$\Upsilon(2S)$	1.10
$\chi_b(2P)$	0.83
$\Upsilon(3S)$	0.75



Lattice QCD R_{AA} comparison

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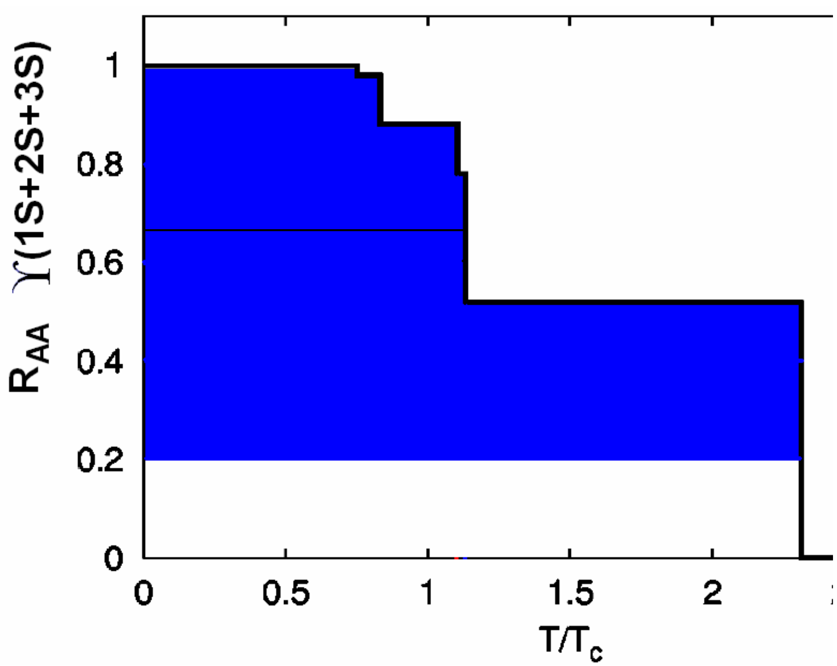
$q\bar{q}$	T/T_c
$\Upsilon(1S)$	2.31
$\chi_b(1P)$	1.13
$\Upsilon(2S)$	1.10
$\chi_b(2P)$	0.83
$\Upsilon(3S)$	0.75

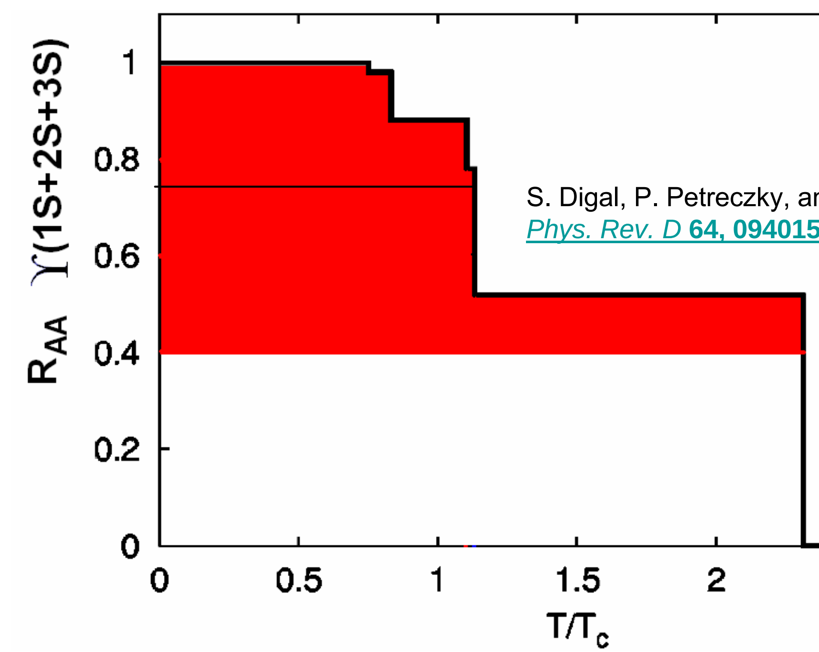
$0 < T/T_c < 2.31$

$0 < T/T_c < 2.31$

More statistics are needed!

Center points: $T/T_c = 1.13$ and $T/T_c = 1.13$





S. Digal, P. Petreczky, and H. Satz, *Phys. Rev. D* **64, 094015 (2001)**

Summary and Outlook

- Measured ϒ(1S+2S+3S)→e^+e^- at $\sqrt{s}$=200 GeV, |y|<0.5
  - p+p (from $\mathcal{L}$ = 7.9 pb^{-1})
  - d+Au (from $\mathcal{L}$ ~ 32 nb^{-1})
    - Follows Binary Scaling

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

$$R_{dA} = 0.78 \pm 0.28(stat) \pm 0.20(sys)$$

  - Au+Au (from $\mathcal{L}$ ~ 0.3 nb^{-1})
    - ϒ observed in heavy ion collisions

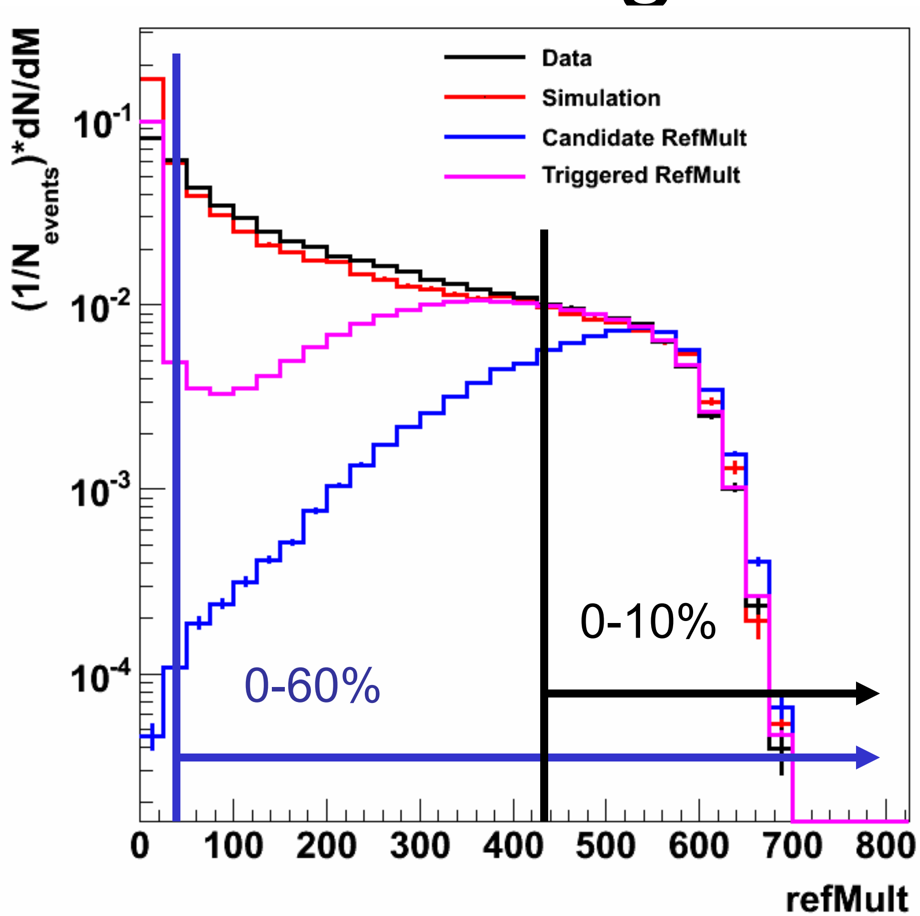
$$R_{AA}(0-60\%) = 0.78 \pm 0.32(stat) \pm 0.22(sys, Au+Au) \pm 0.09(sys, p+p)$$

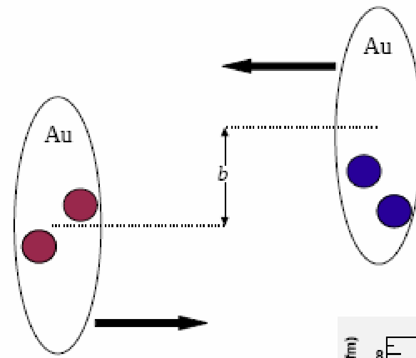
$$R_{AA}(0-10\%) = 0.63 \pm 0.44(stat) \pm 0.29(sys, Au+Au) \pm 0.07(sys, p+p)$$

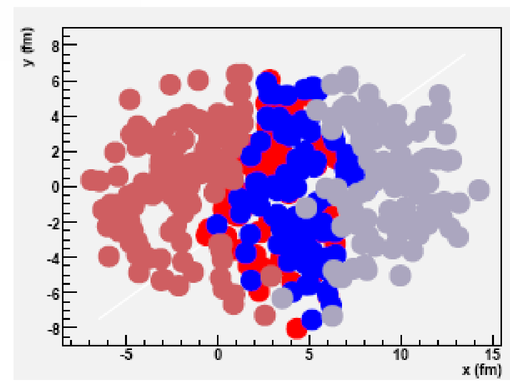
- Addition of ~20 pb^{-1} more p+p statistics from 2009 and 1.4 nb^{-1} more Au+Au statistics from 2010

Back-up

Measuring ϒ in Au+Au: Centrality







Glauber Model calculation allows us to calculate both refMult versus centrality and number of binary collisions (N_{bin})

refMult → Charged particle multiplicity

Data = minimum bias collisions

Trigger = ϒ triggered event with no event selection

Candidate = events with 2 matched tracks with a high probability of being an electron