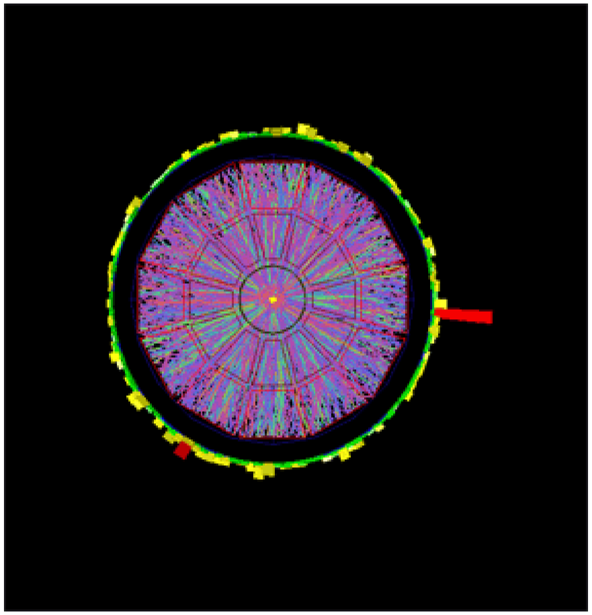
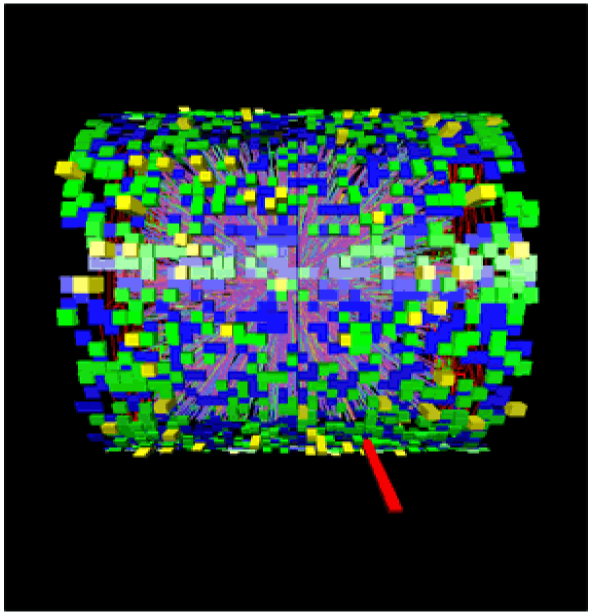
ϒ production in p+p, d+Au, Au+Au collisions at 200 GeV in STAR





Rosi Reed
UC Davis
For the STAR Collaboration

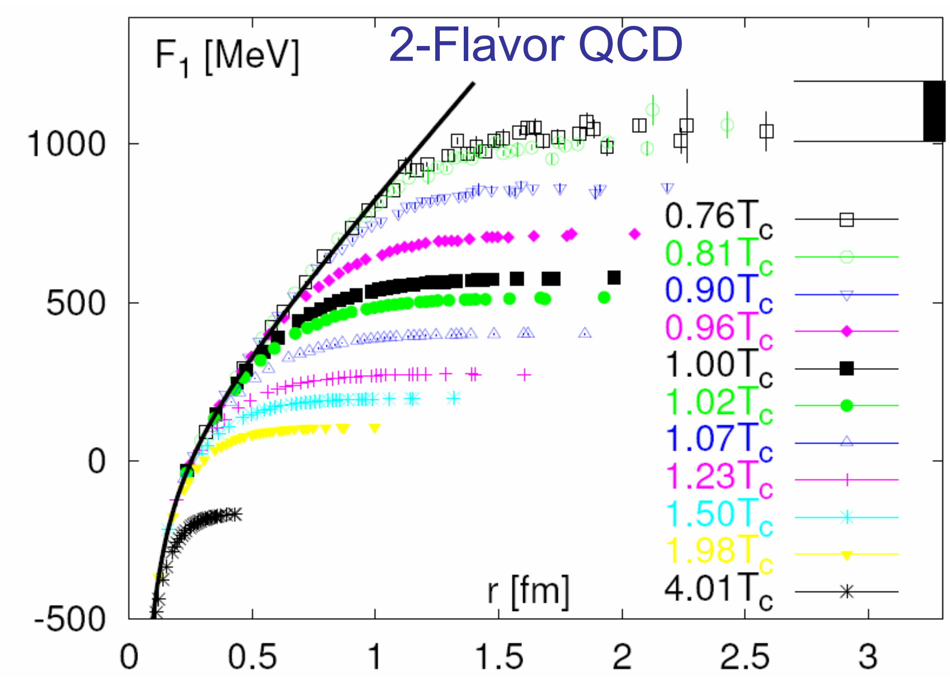
Outline

- Motivations
- Measuring Υ
- STAR detectors and the Υ trigger
- Υ measurements
  - p+p
  - d+Au
  - Au+Au
- Summary/Outlook

Motivations

- Suppression of quarkonia is predicted to be a QGP signature *Matsui T and Satz H 1986 Phys.Lett.B178:416,1986*
  - Quarkonia = heavy quark+anti-quark meson ($b\bar{b}$,$c\bar{c}$)
- 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

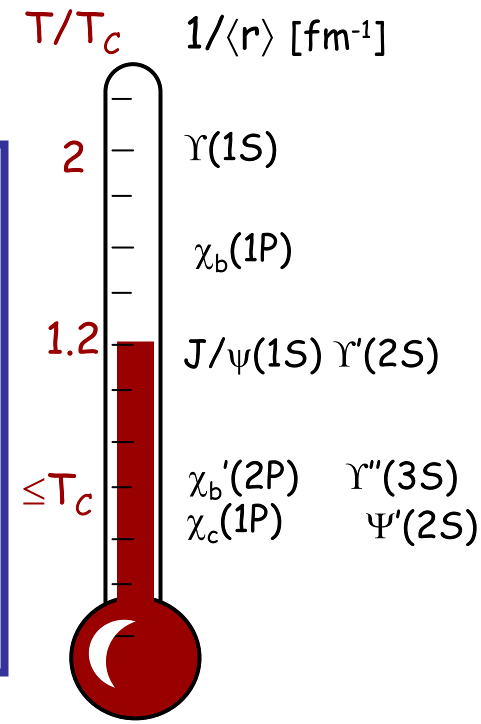
Sequential disappearance of states:

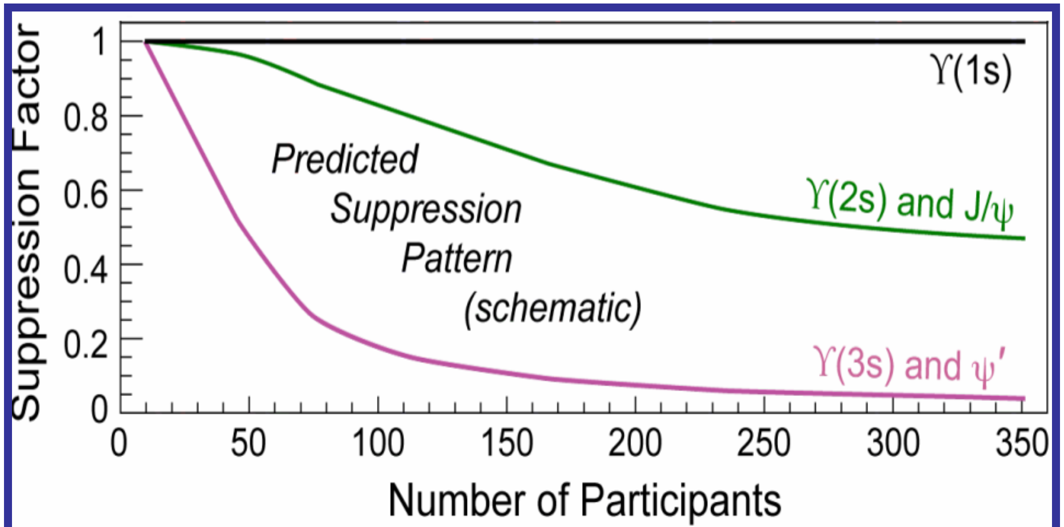
⇒Color screening ⇒ Deconfinement

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

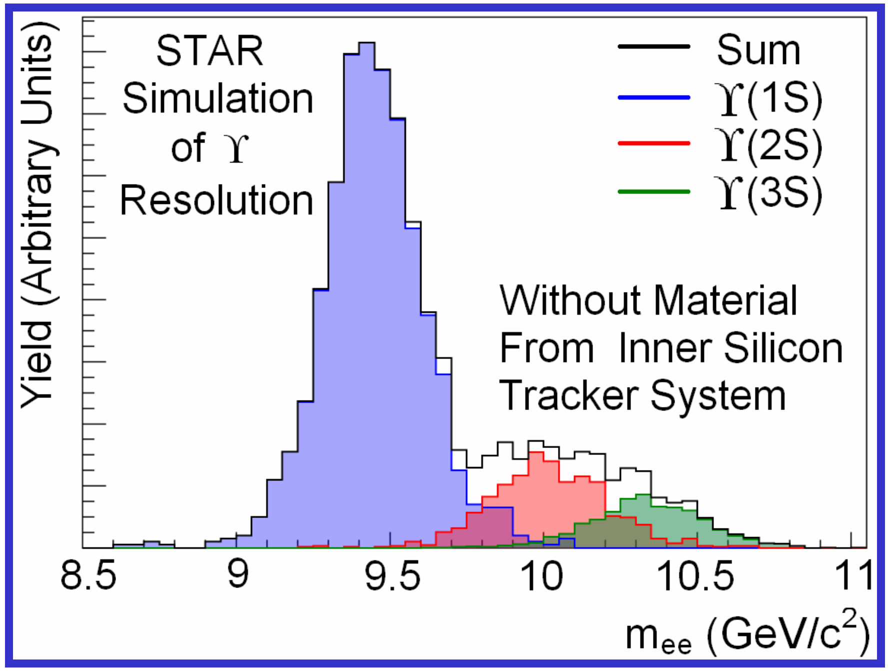
Υ(1S) does not melt

Υ(2S) is likely to melt

Υ(3S) will melt

Measuring Υ at STAR

- Υ quark content is $b\bar{b}$
- Decay channel: $\Upsilon \rightarrow e^{+}e^{-}$
  - $m_{\Upsilon(1S)}$=9.46 GeV/c^2
  - $m_{\Upsilon(2S)}$=10.02 GeV/c^2
  - $m_{\Upsilon(3S)}$=10.35 GeV/c^2



  - unlike-sign electron pairs → Signal + Background
  - like-sign electron pairs → Background
- Drell-Yan (DY) and uncorrelated $b\bar{b}$ pairs also contribute to $e^{+}e^{-}$ mass spectrum S.D. Drell and T.-M. Yan, PRL 25, 316 (1970)
  - DY is $q\bar{q} \rightarrow \gamma^{*} \rightarrow e^{+}e^{-}$

Measuring Υ Pros and Cons

Pros

- Efficient trigger - works in p+p up to central A+A
- Large acceptance at $|y|<0.5$
- Small background at M~10 GeV/c^2
- Co-mover absorption is small

  Z.W. Lin and C.M Ko PLB 503:104 (2001)
- Recombination negligible at RHIC

  Zhao and Rapp, PLB 664, 253 (2008)

Cons

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

STAR Detectors

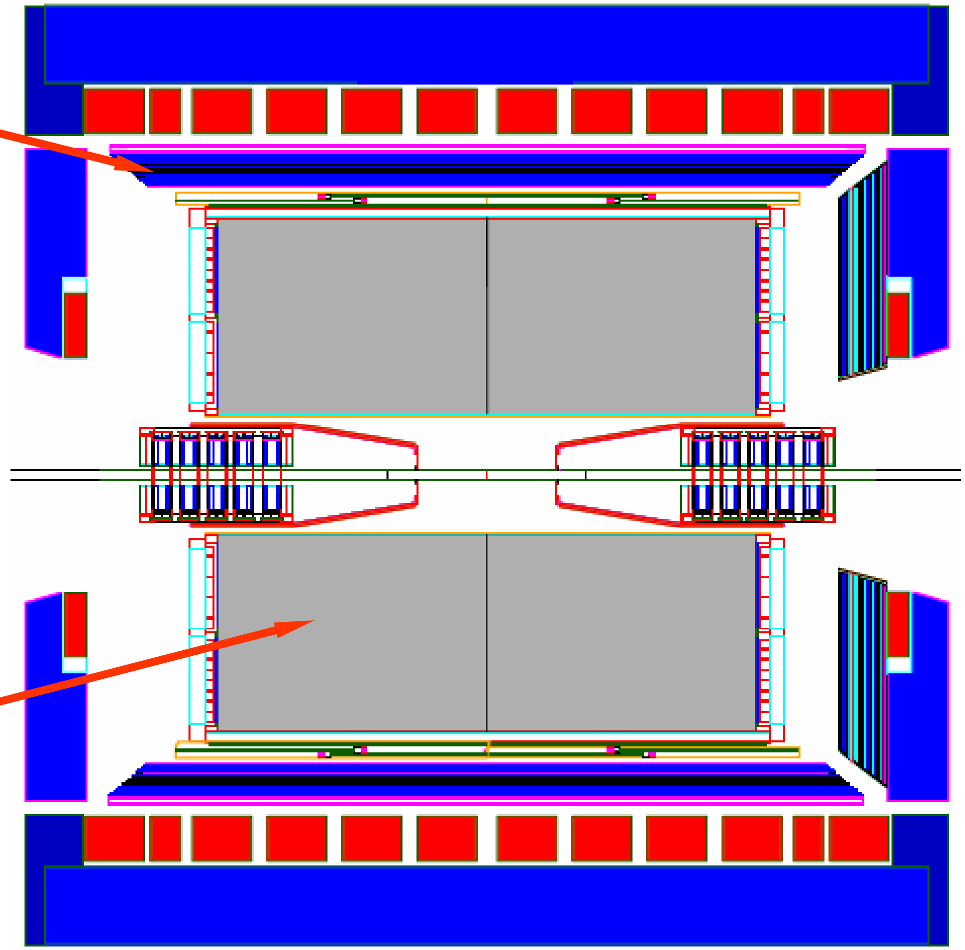
BEMC

$|\eta| < 1$

$0 < \phi < 2\pi$

E/p → electron ID

High-energy tower trigger



TPC

$|\eta| < 1$

$0 < \phi < 2\pi$

Tracking → momentum

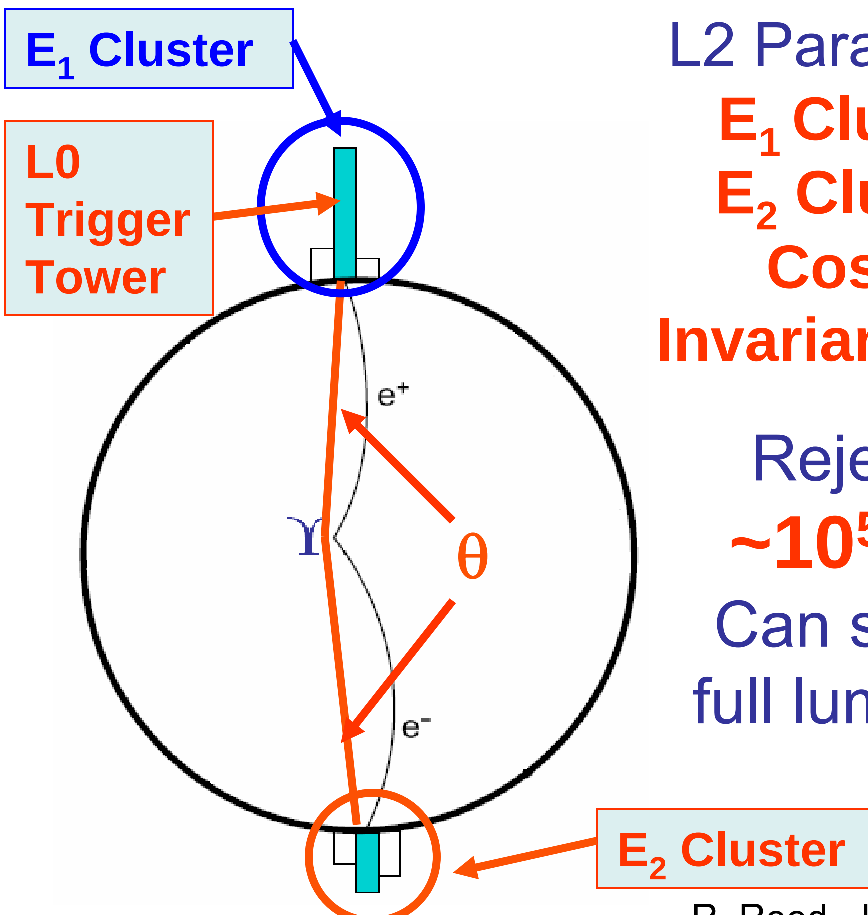
ionization energy loss → electron ID

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,

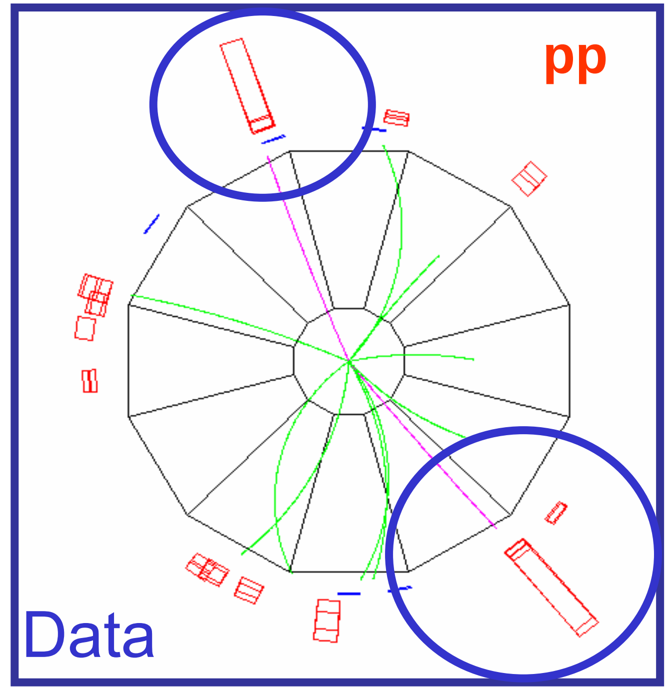
Cos(θ),

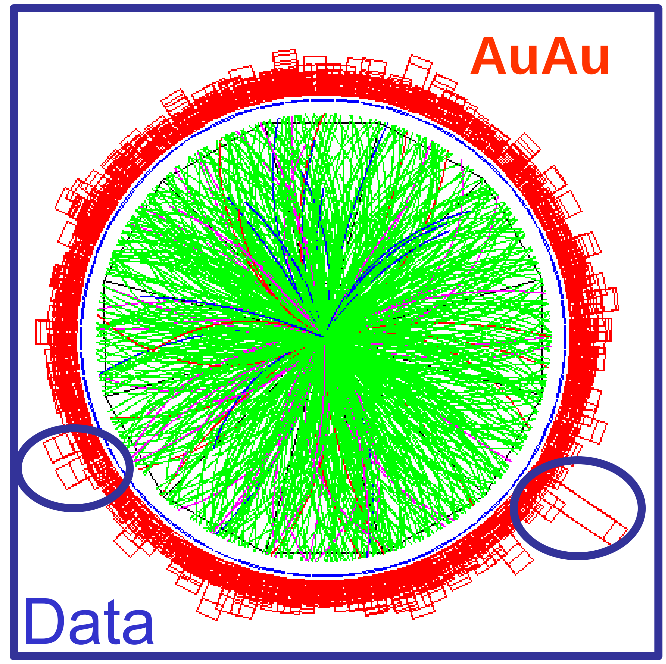
Invariant Mass

Rejection

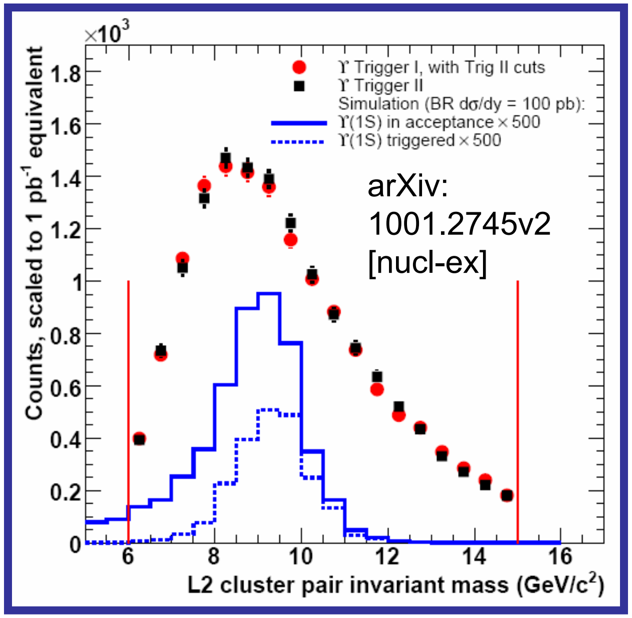
~10^5 in pp

Can sample full luminosity

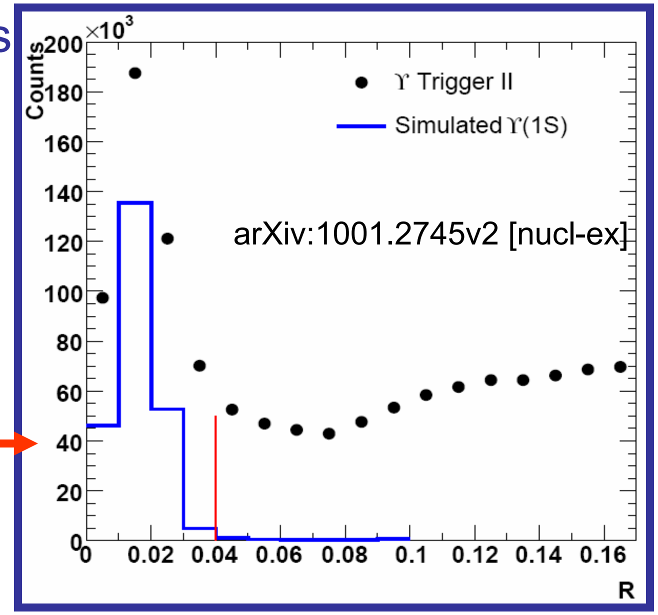




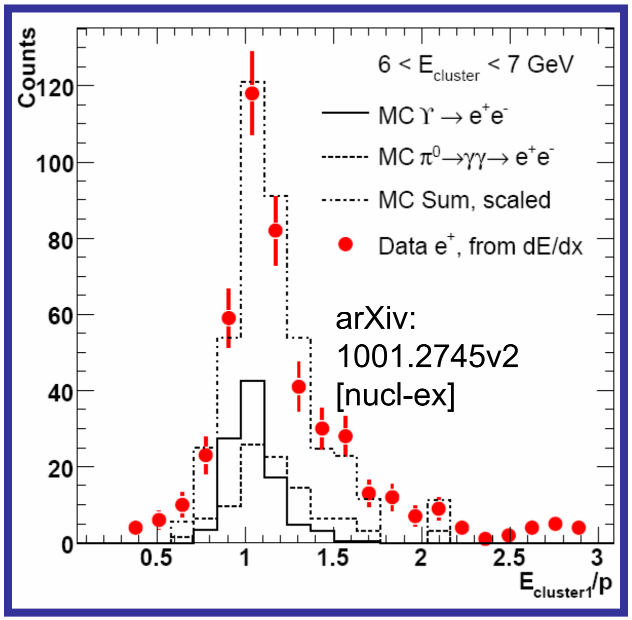
Analysis Techniques



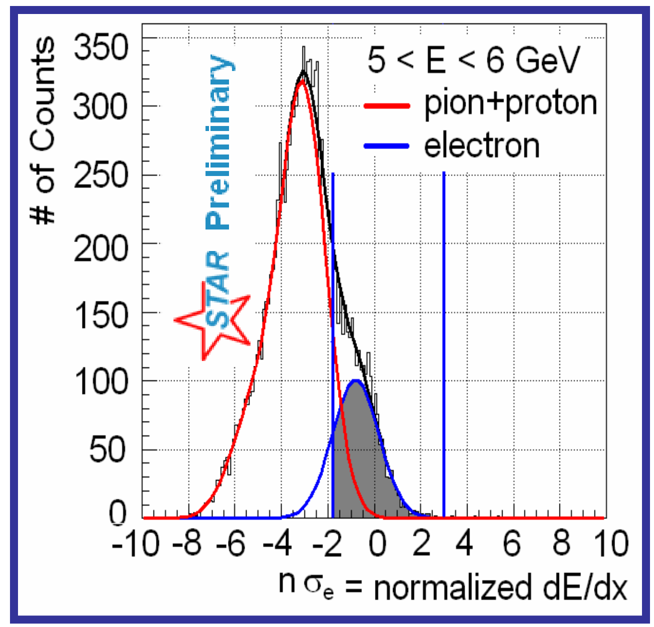
Triggered candidates exceed number of Υ by a factor of ~700 (p+p)



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



Analysis Techniques

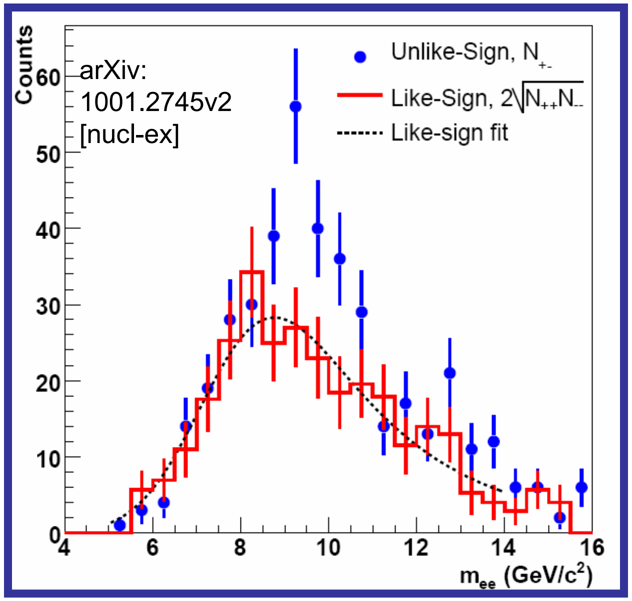
Track pairs combined into:

$e^+e^- = N_{+-}$ = Signal + Background

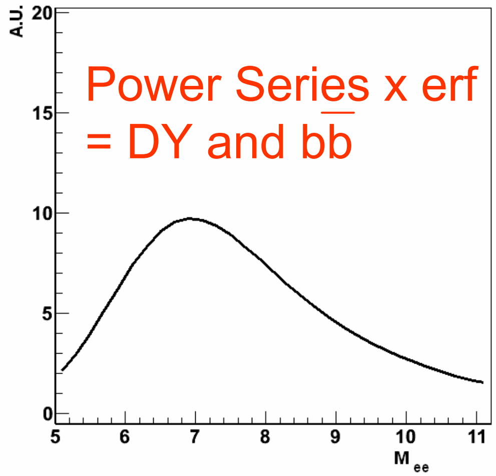
$e^-e^-, e^+e^+ = N_{--}, N_{++}$ = Background

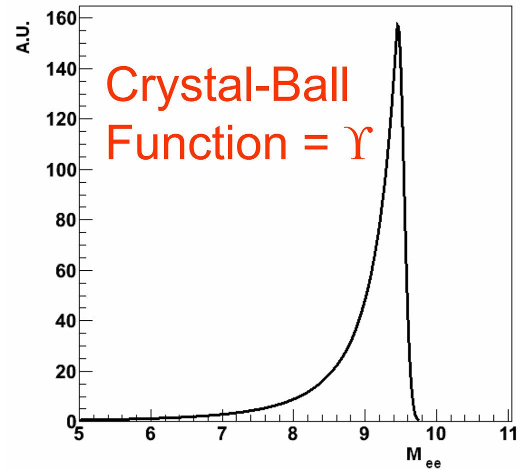
Inv. Mass is calculated giving the yield:

$S = N_{+-} - 2\sqrt{N_{--}N_{++}}$



Yield of $b\bar{b}$ and Drell-Yan determined by fitting S with 3 Crystal Ball functions for the Υ(1S+2S+3S) states and power series multiplied by an erf functions for Drell-Yan and $b\bar{b}$

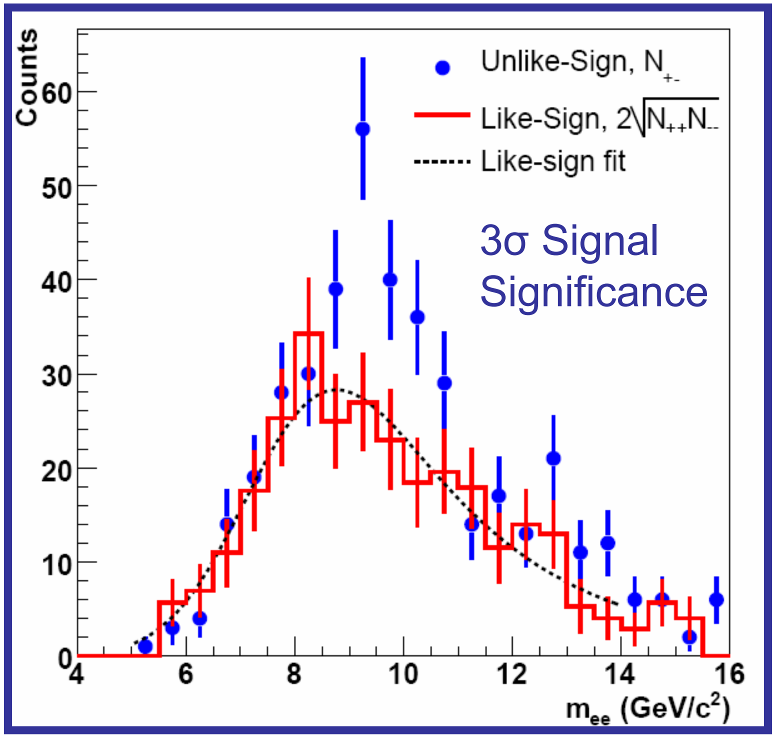




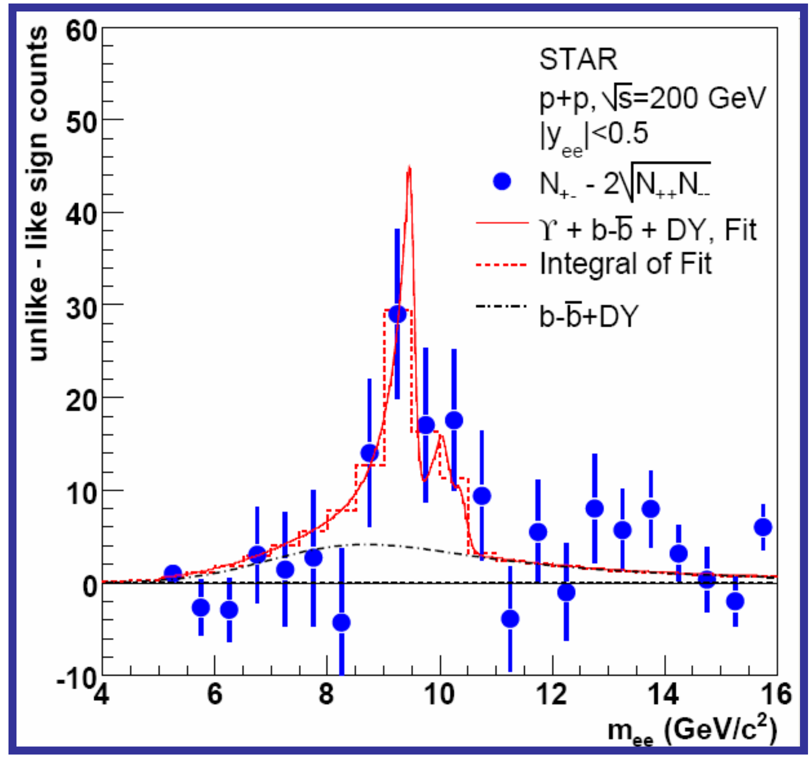
$\Upsilon = S - b\bar{b} - DY$

Υ in p+p 200 GeV

arXiv:1001.2745v2 [nucl-ex]



arXiv:1001.2745v2 [nucl-ex]



$\mathcal{L} = 7.9 \pm 0.6\ \text{pb}^{-1}$

$N_{\Upsilon}(8<m<11)$ = S - DY-bb = 61±20(stat.)

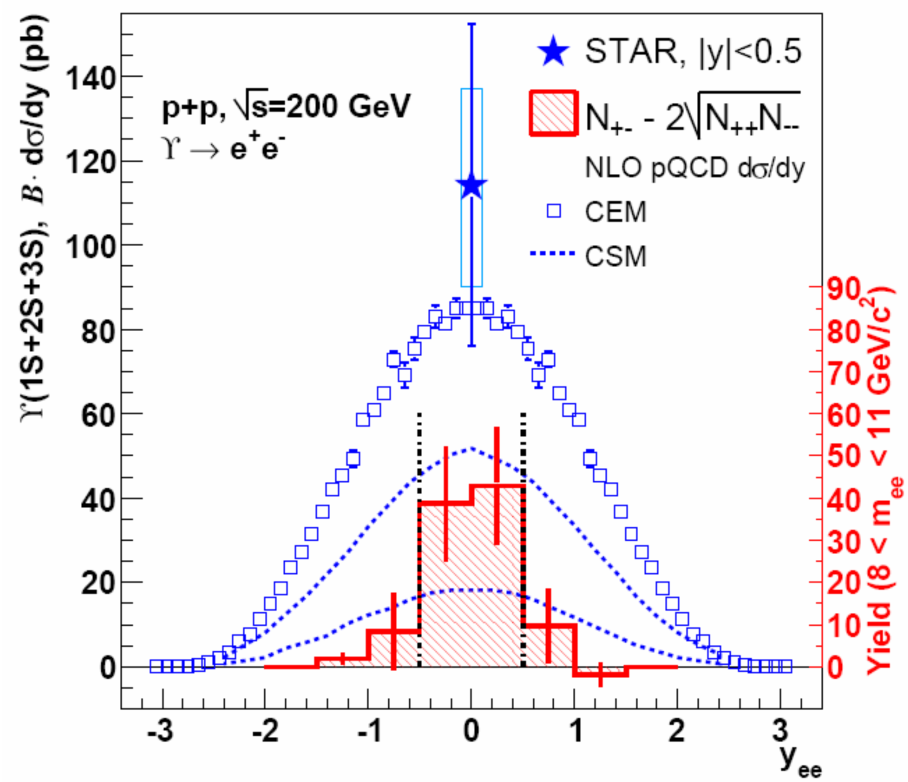
N_{Υ}(total)= 67±22(stat.)

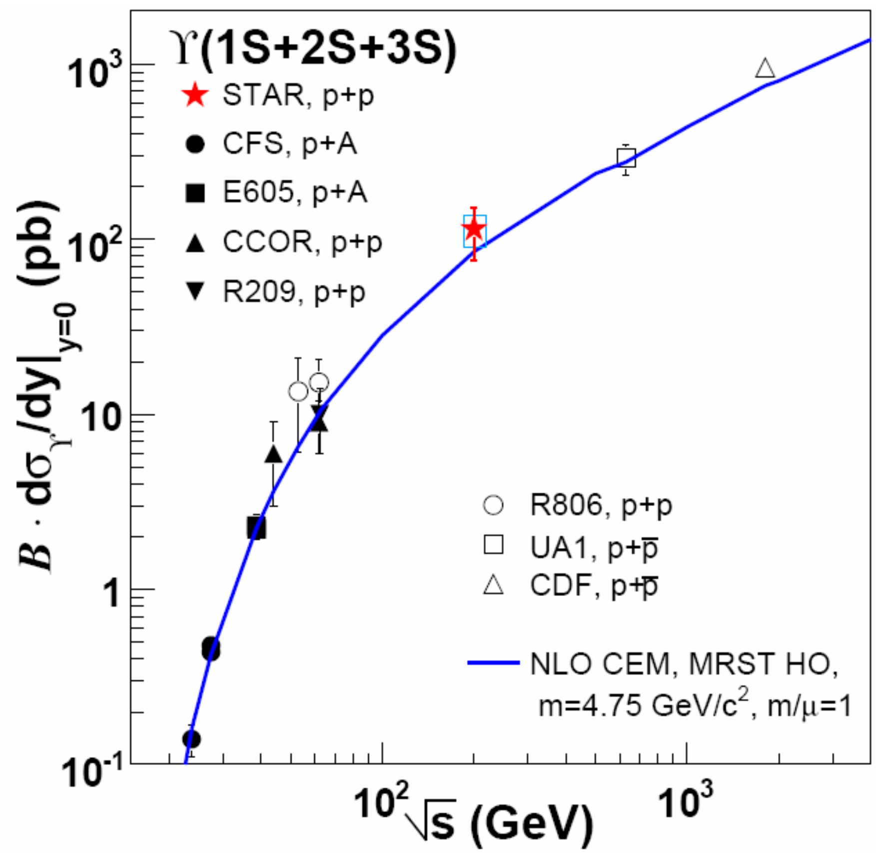
$$\sum_{n=1}^{3} B(nS)\times\sigma(nS) = \frac{N_{\Upsilon}}{dy\times\varepsilon_{\Upsilon}\times\int \mathcal{L}dt}$$

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

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

STAR ϒ *vs.* theory and world data



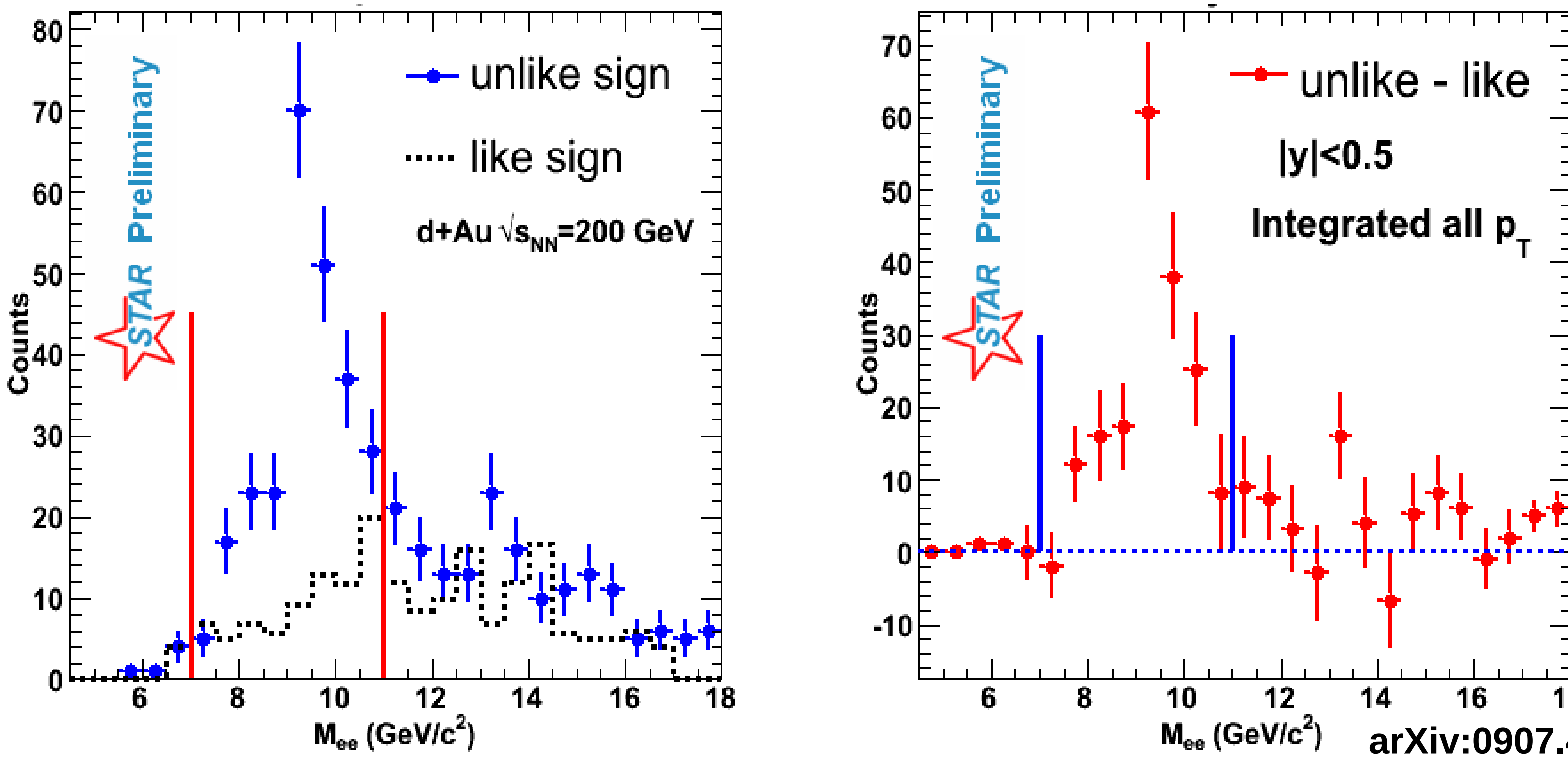


$$\sum_{n=1}^{3} \mathcal{B}(nS) \times \sigma(nS) = 114 \pm 38\ ^{+23}_{-24}\ \text{pb}$$

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

QM 2009

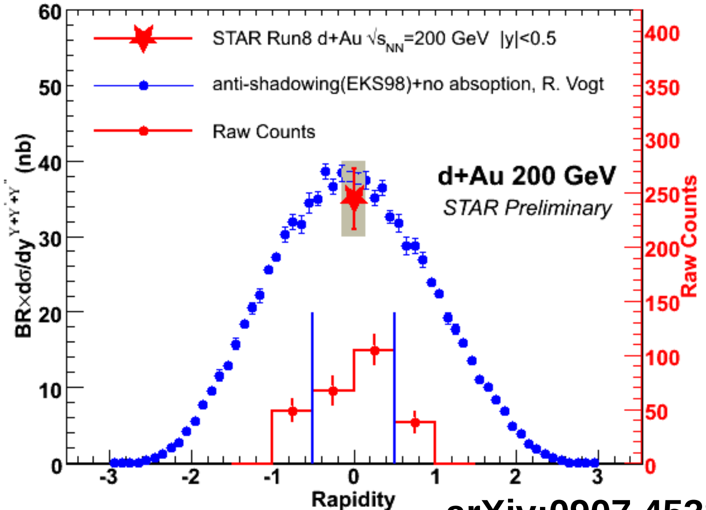


arXiv:0907.4538

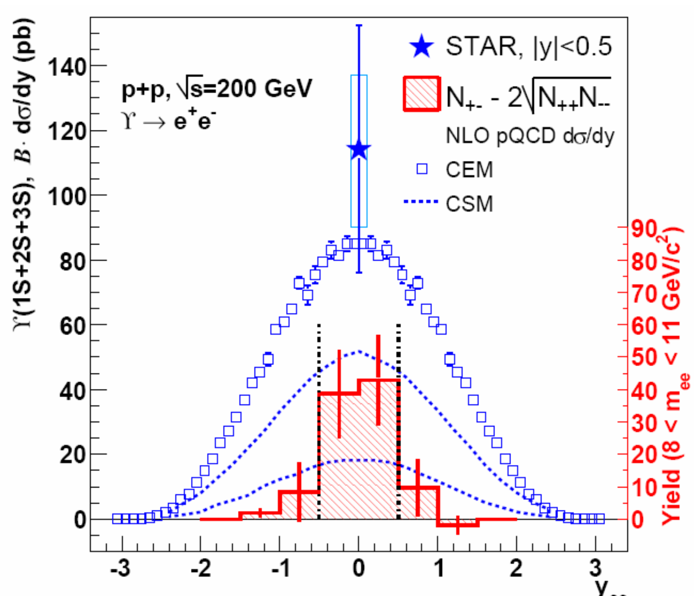
- ϒ(1S+2S+3S) raw yield (7<m<11) = 172 ± 20 (stat.)
  - Strong signal (8σ significance)

$$B_{ee} \times \left(\frac{d\sigma}{dy} \right)_{y=0}^{Y+Y'+Y''} = 35 \pm 4(\text{stat.}) \pm 5(\text{sys.}) \quad \text{nb}$$

Nuclear modification factor



arXiv:0907.4538



arXiv:1001.2745v2 [nucl-ex]

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

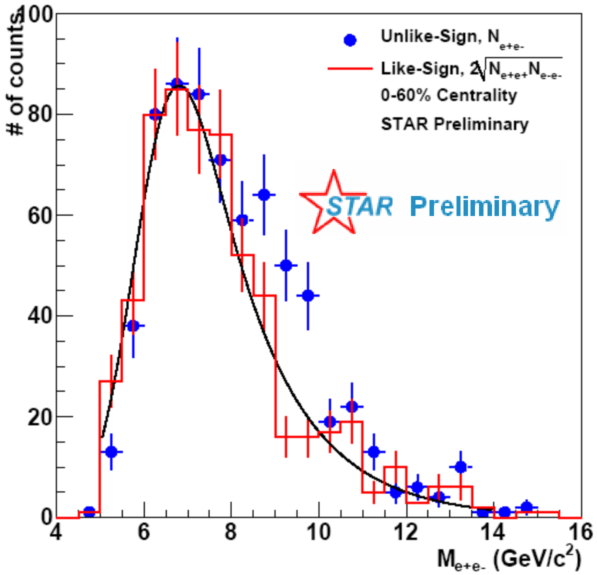
σ_{pp} = 42 mb σ_{dAu} = 2.2 b

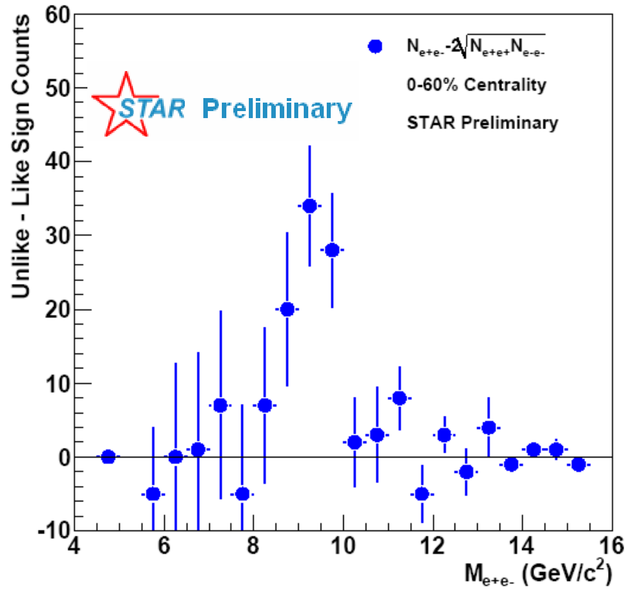
N_{bin} = 7.5 ± 0.4 for Minbias dAu

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

Consistent with N_{bin} scaling
Cold Nuclear Matter effects (Shadowing) are not large.

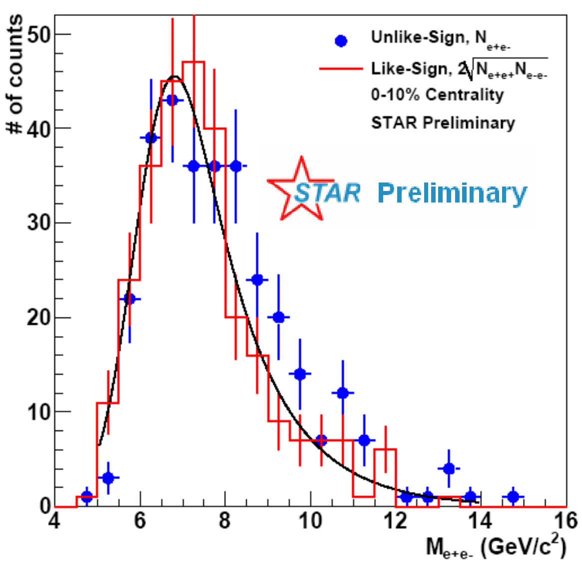
ϒ in Au+Au 200 GeV

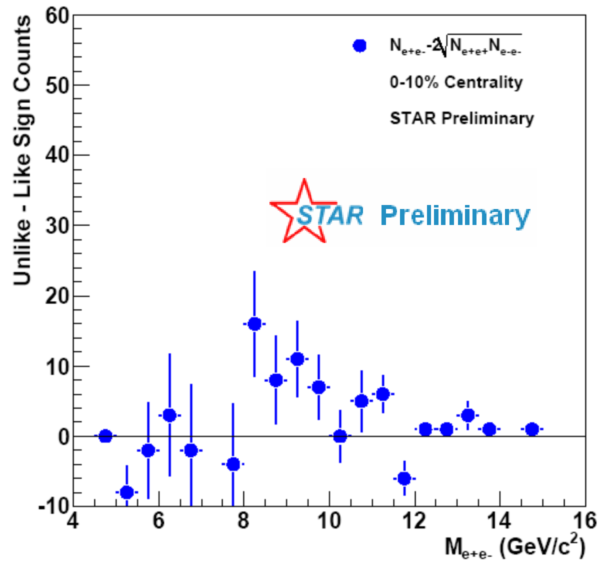




8<m<11 GeV/c^2
$\mathcal{L}$ = 496 μb^{-1}

0-60%
4.6σ significance
95 Signal counts



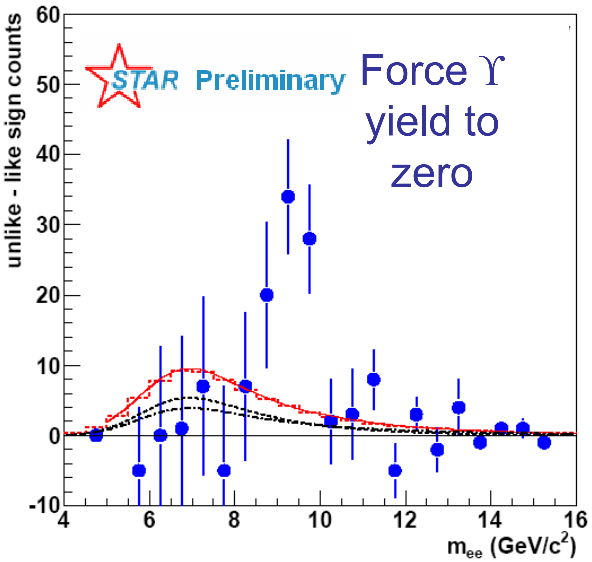


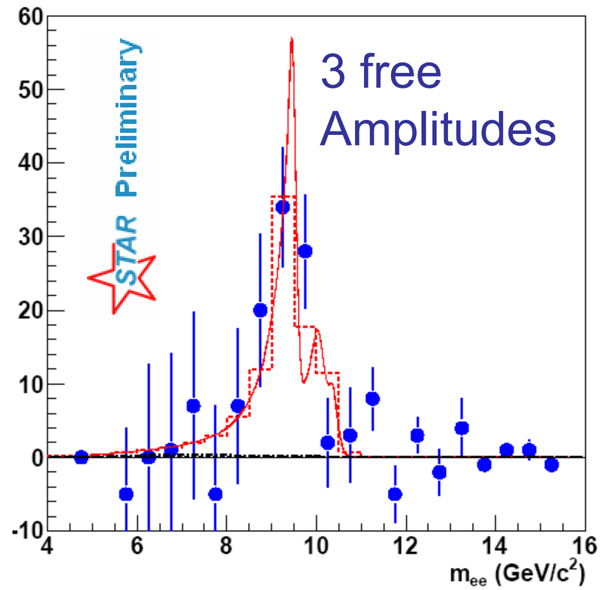
0-10%
3.5σ significance
47 Signal counts

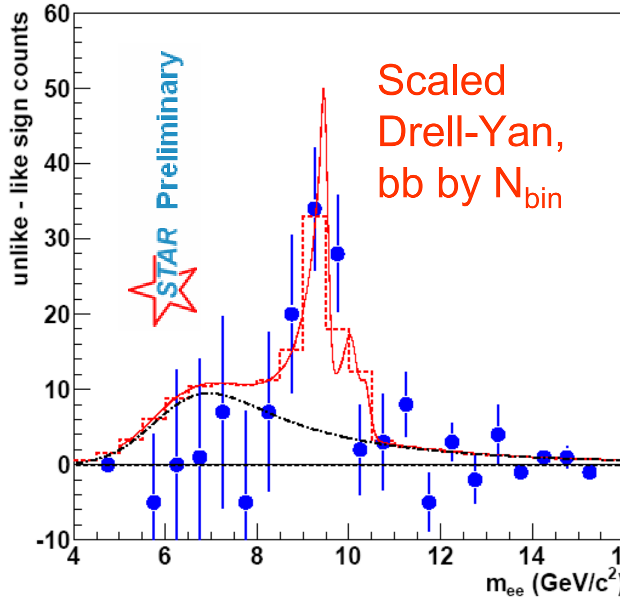
Includes ϒ,
Drell-Yan + $b\bar{b}$

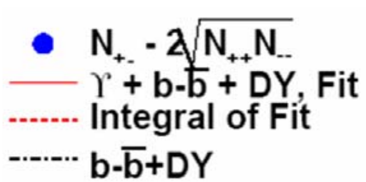
Υ Yield Extraction Scenarios 0-60% Centrality

- $\Upsilon(1S+2S+3S) = S - DY - b\bar{b}$
  - Amplitudes of DY and bb depend on fit with Υ function
    - The form of the Υ function depends on suppression assumption
    - Yields of Drell-Yan and bb in p+p have a large uncertainty





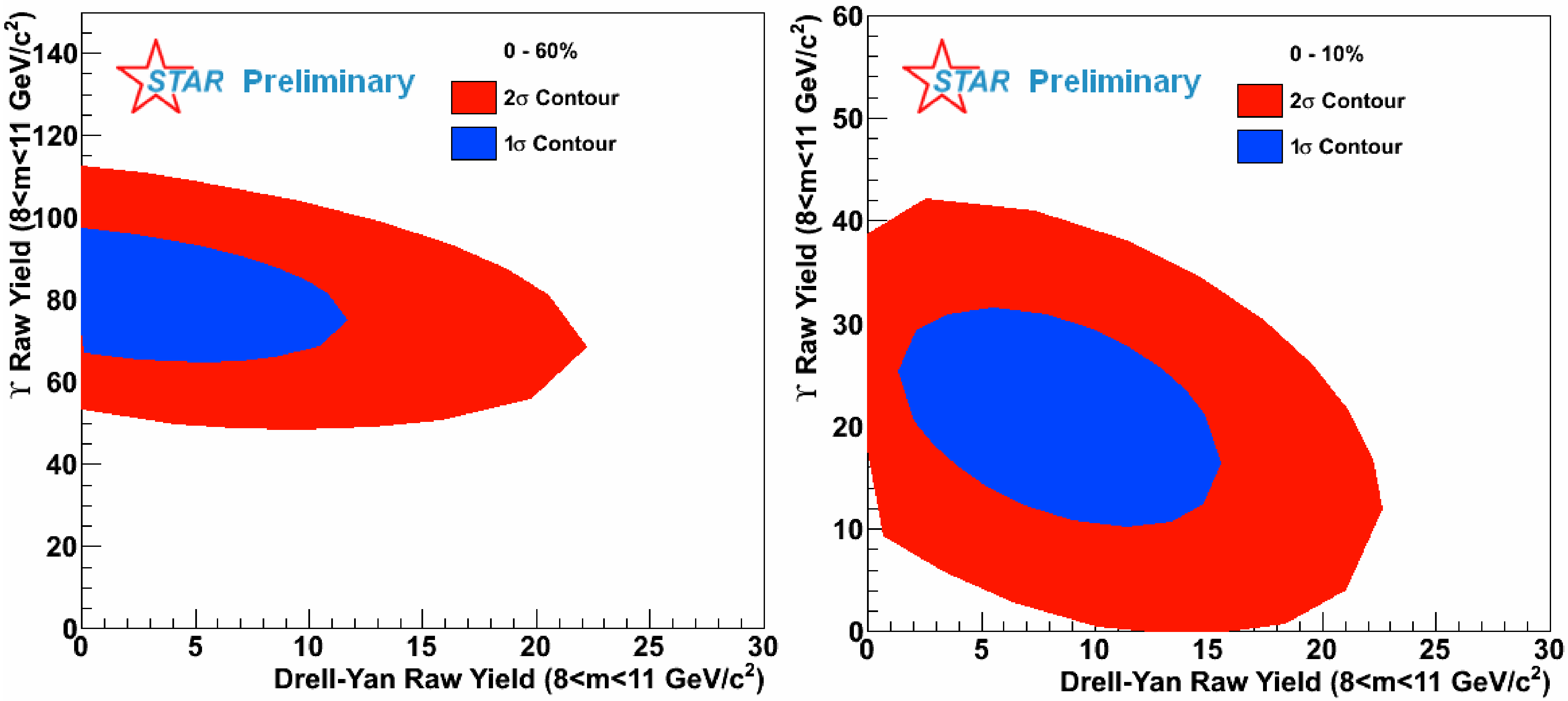




Raw Yield: $\Upsilon = 87 \pm 18$
$DY+b\bar{b} = 3.5 \pm 11$

Raw Yield: $\Upsilon = 66 \pm 15$
$DY+b\bar{b} = 27$

Υ, Drell-Yan and $b\bar{b}$ in Au+Au



Correlations between yields adds to systematic uncertainties when extracting the Υ yield

Summary and Outlook

- measured $\Upsilon(1S+2S+3S) \rightarrow e^+e^-$ cross-section at $\sqrt{s}$=200 GeV, $|y|<0.5$
  - p+p (from $\mathcal{L}$ = 7.9 pb^{-1})
    - Consistent with CEM model
    - Does not exclude CSM model
    - Consistent with the world trend

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

  - d+Au (from $\mathcal{L}$ = 33 nb^{-1})
    - R_{dAu} = 0.78±0.28±0.20
    - Follows Binary Scaling
  - Au+Au (from $\mathcal{L}$ = 496 μb^{-1})
    - In central 0-60% - 4σ Signal significance
    - Systematic uncertainty and Drell-Yan bb analysis in progress
- Addition of ~20 pb^{-1} more p+p statistics
  - will improve R_{dA}
  - reduced uncertainty in Drell-Yan and bb yield
- Addition of 1.4 nb^{-1} more Au+Au statistics may allow us to resolve the $\Upsilon(1S)$ to $\Upsilon(2S+3S)$ states

Back-up

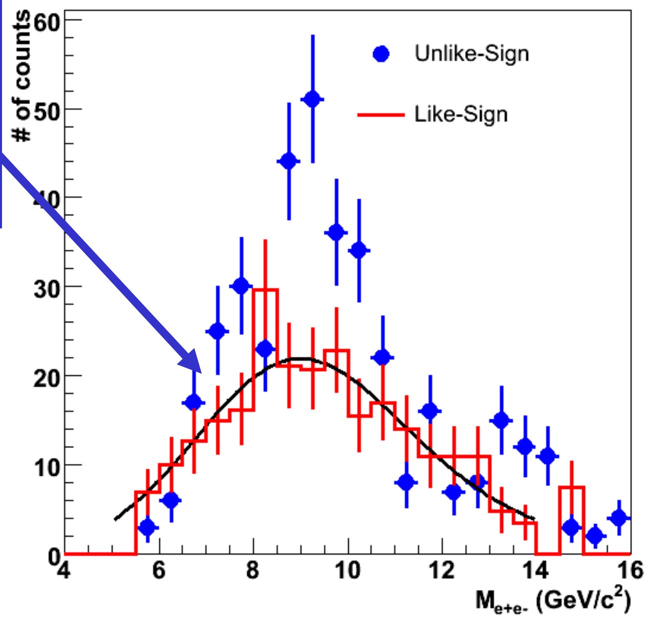
$b\bar{b}$ contribution from PYTHIA 8 + Drell-Yan

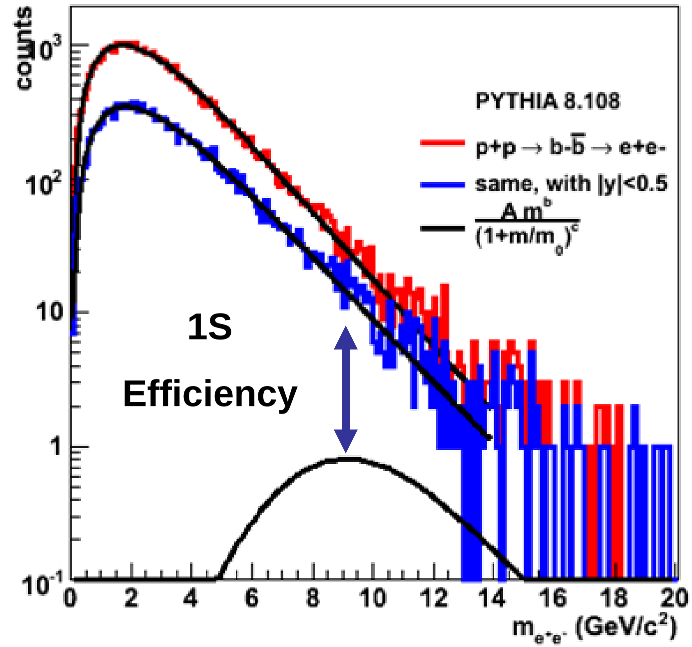
Like-sign background from data parameterizes trigger effects

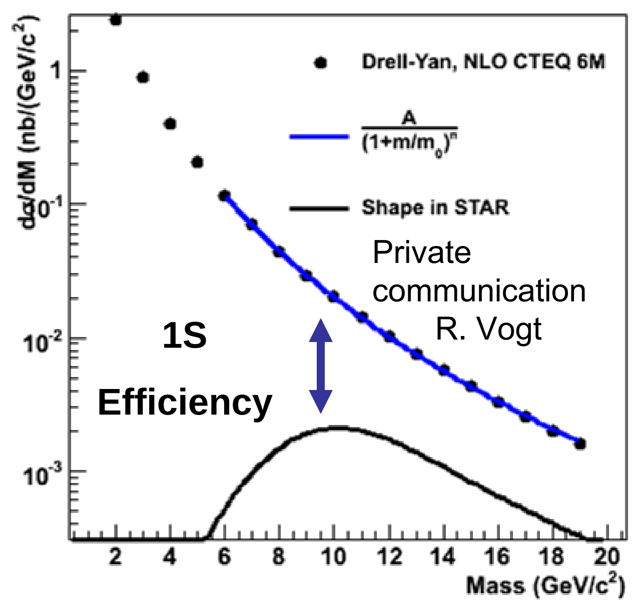
$$\frac{erf\left(\frac{m - m_0}{\sigma} + 1\right)}{2}$$

m_0 α trigger threshold = 8.1 +/- 0.7 GeV/c^2

σ = width due to finite detector resolution = 1.8+/- 0.4 GeV/c^2





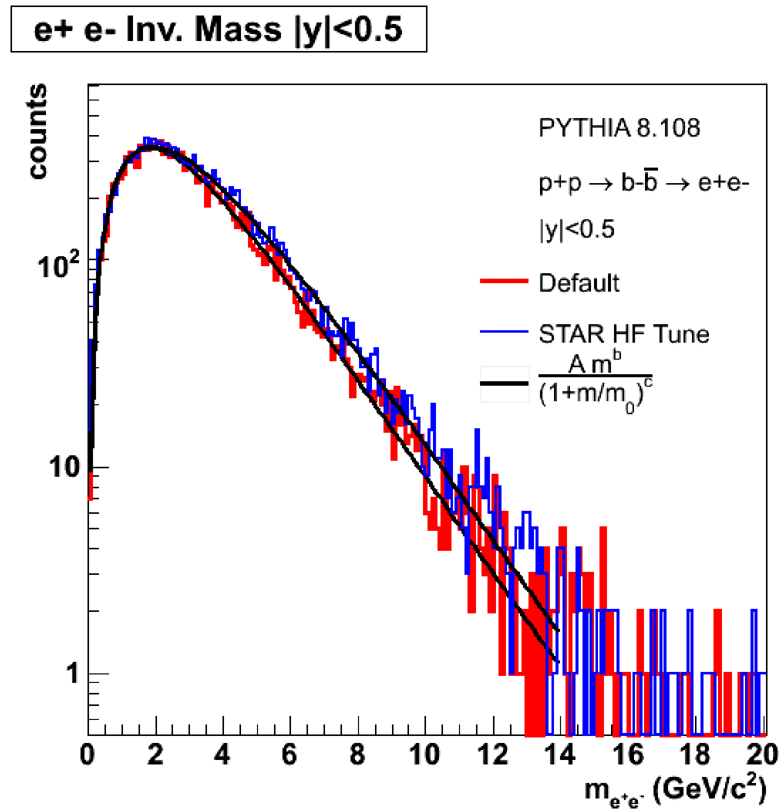


Exponentials from PYTHIA and Drell-Yan are multiplied by erf function to convolute background with detector effects

\# $b\bar{b}$ counts in region 8 – 11 GeV/c^2 = 15

\# Drell-Yan count in 8 – 11 GeV/c^2 = 25

Updates: Using STAR HF Tune



- Pythia 8.108
- Changes from defaults
  - m=4.3 GeV/c2
    - 4.8 GeV/c2 Default
  - PDF : MRSTMCal.LHgrid
    - CTEQ5L default
  - Renormalization scale

From HF Tune:
- b-bbar cross section : 1.02 ub
- into e+e- : 7.7 nb
- into e+e-, 8<m<11 : 212 pb
- e+e-, 8<m<11, |y|<0.5: 47 pb

From Default Pythia 8:
- b-bbar cross section : 0.83 ub
- into e+e- : 6.5 nb
- into e+e-, 8<m<11 : 135 pb
- e+e-, 8<m<11, |y|<0.5: 24 pb