ϒ production in STAR

HOT QUARKS 2008

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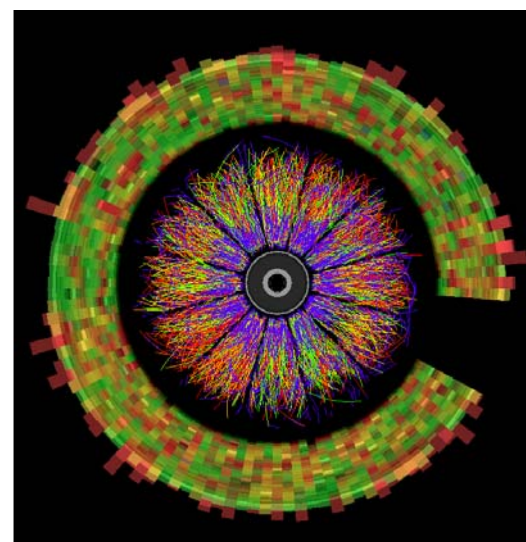
(For the **STAR Collaboration**)



Quarkonia and the concept of suppression

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

Heavy quarks carry information of early stage of collisions:

- Charm and bottom quarks are massive.
- Formation takes place only early in the collision.

Proposed Signature of De-confinement :

Color screening of static potential between heavy quarks:

J/ψ suppression: Matsui and Satz, *Phys. Lett. B* **178** (1986) 416

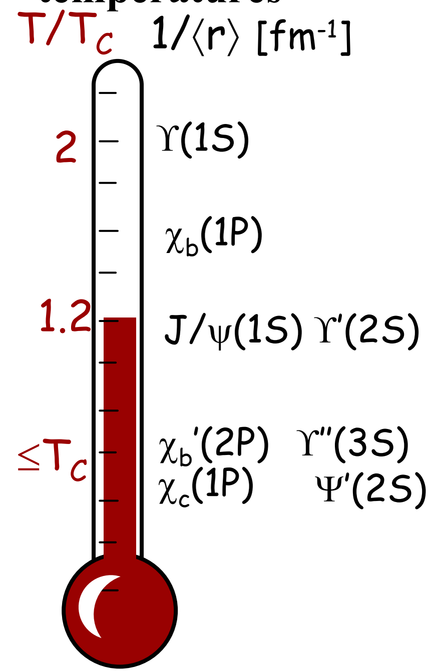
Suppression determined by T_C and binding energy

Lattice QCD: Evaluation of spectral functions ⇒ $T_{melting}$

De-confinement → Color screening → heavy quarkonia states “dissolved”

state	χ_c	ψ'	J/ψ	Υ'	χ_b	Υ
T_{dis}	$\leq T_c$	$\leq T_c$	$1.2T_c$	$1.2T_c$	$1.3T_c$	$2T_c$

Upper limit melting temperatures



The QGP thermometer

(courtesy: **A .Mocsy**, 417th WE-Heraeus-Seminar,2008)

models based on potential with largest possible binding ⇒ most bound states melt by $1.3T_c$ .Upsilon (1S) survives until $2T_c$.

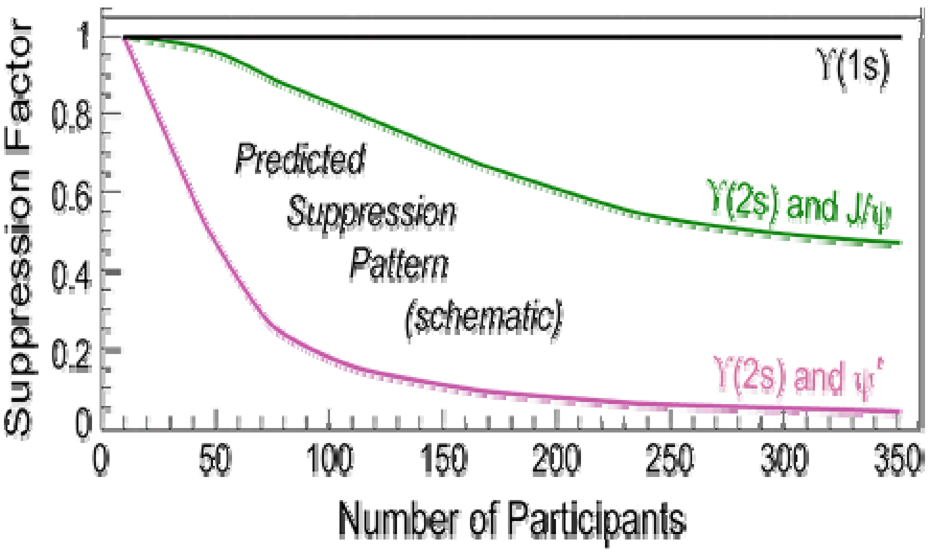
Lattice results are consistent with quarkonium melting.

Suppression pattern ⇒ **thermometer** of QCD matter.

Υ states in RHIC

Υ (1S), Υ '(2S), Υ''(3S)

- Υ(1S) perhaps not melting at RHIC $\Rightarrow$ standard candle (reference)
- Υ'(2S) likely to melt at RHIC (analogous to J/ψ)
- Υ''(3S) melts at RHIC (analogous to ψ')



Pros

- co-mover absorption is very small (C.M.Ko PLB 503, 104)
- recombination negligible at RHIC ($\sigma_{bb} << \sigma_{cc}$)
- STAR has efficient Υ trigger and large acceptance

Cons

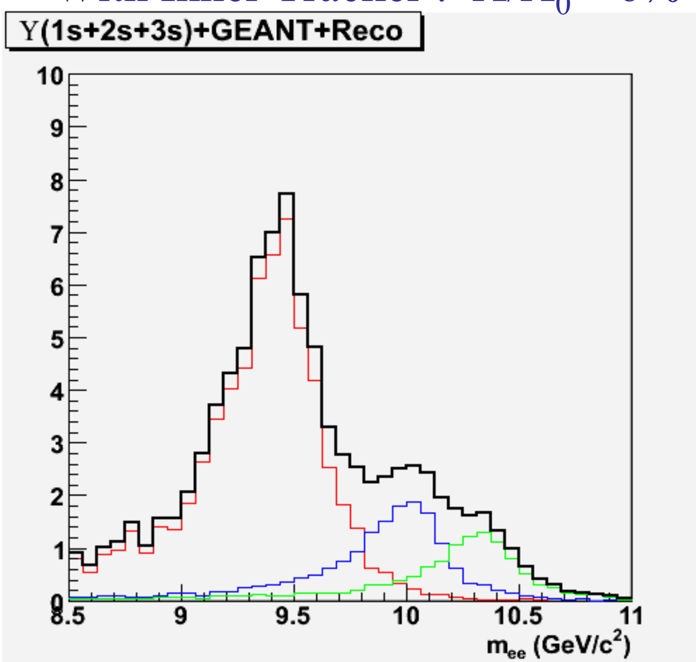
- extremely low rate 10^{-9}/minimum-bias pp interaction
- need good resolution to separate the three S-states

Υ measurements at RHIC $\Rightarrow$ challenge to understand such rare probes

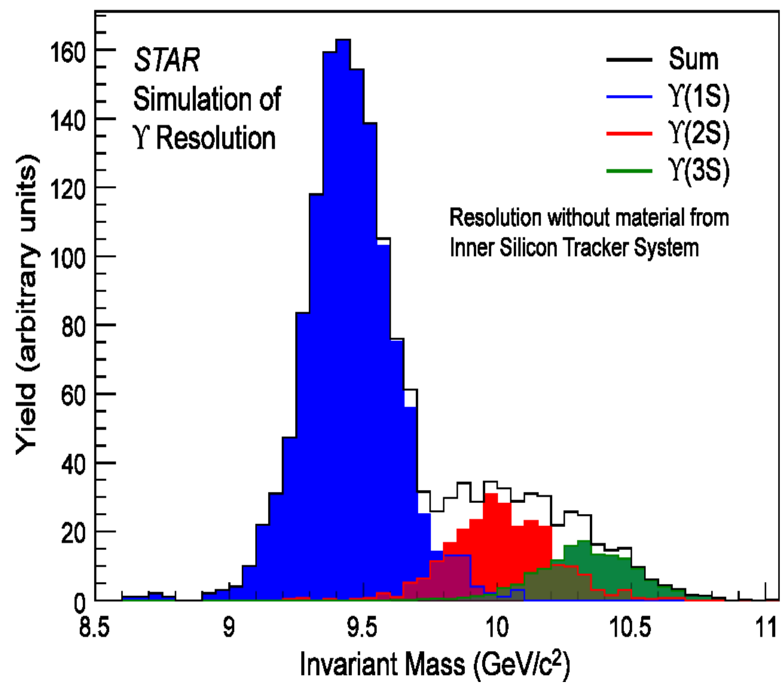
STAR Υ Mass Resolution

- STAR detector is able to resolve individual states of Υ, albeit Bremsstrahlung
- With current low statistics, yield is extracted from combined Υ(1S+2S+3S) states
- FWHM ~ 400 MeV/c^2

With Inner Tracker : $X/X_0 \sim 6\%$

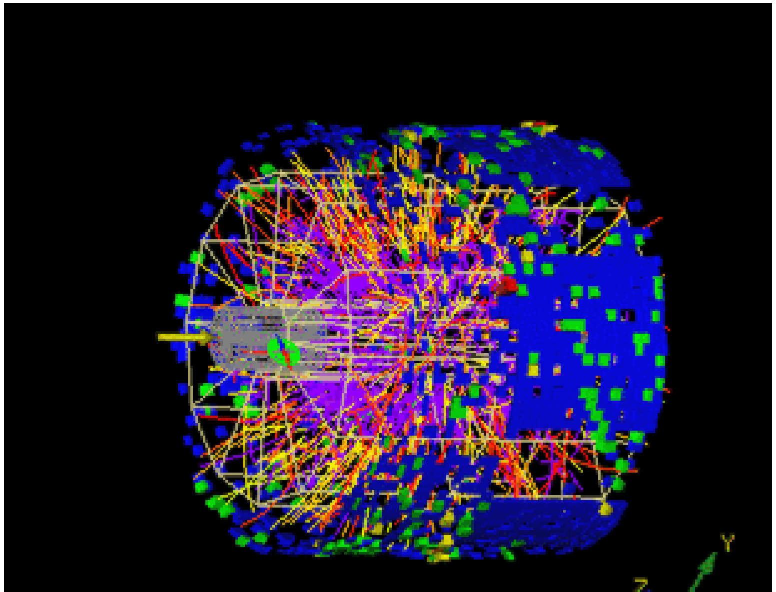


W/o Inner Tracker : Low X/X_0

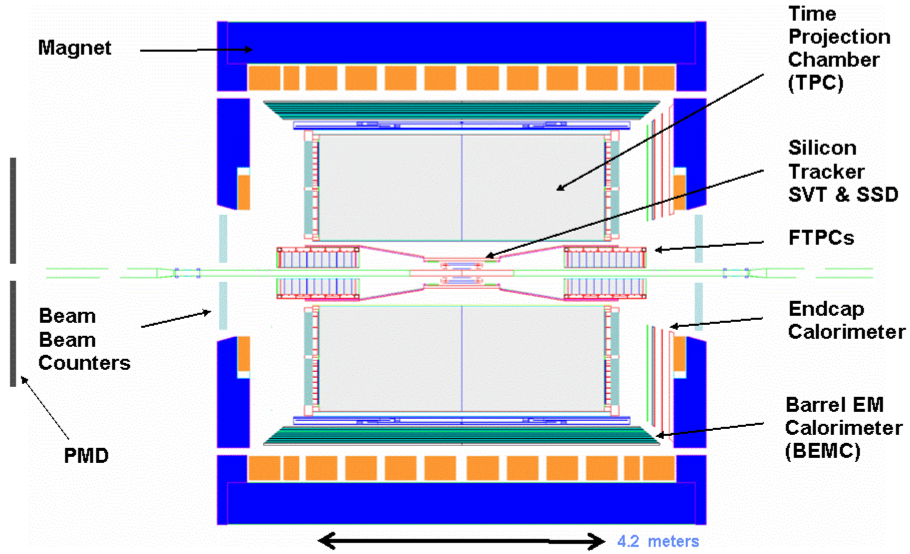


Current ongoing analysis without inner tracker for Run-8 d+Au !!

STAR Detectors used for ϒ measurements



Au+Au ϒ Event in STAR Trigger.



BEMC

- Acceptance: $|\eta| < 1$, $0 < \phi < 2\pi$
- High-energy tower trigger ⇒ enhance high-p_T sample
- Essential for quarkonia triggers

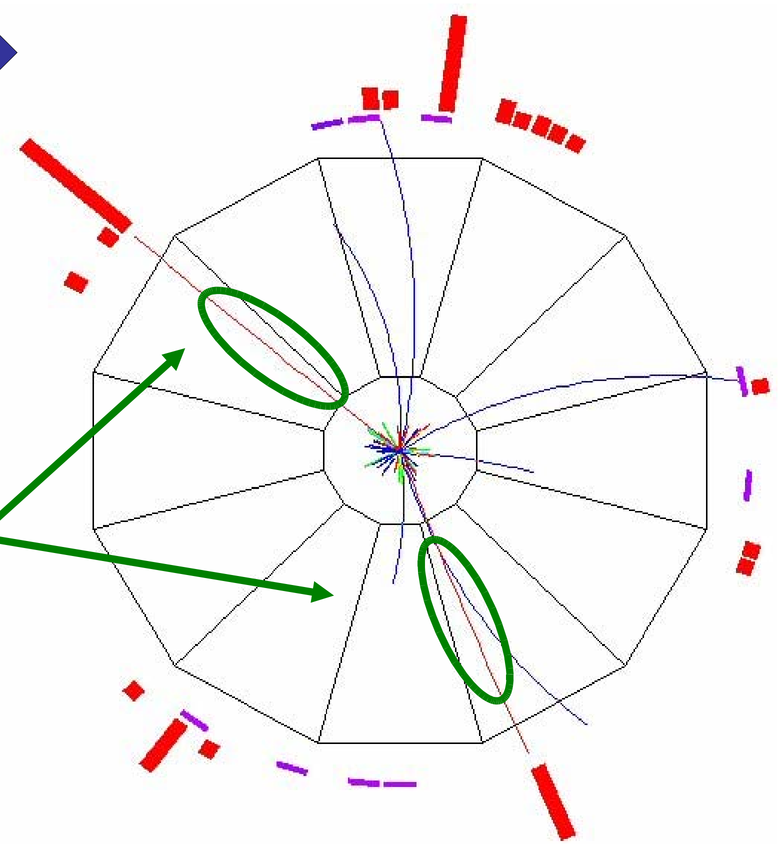
ϒ trigger → enhances electrons

- Use TPC for charged tracks selection
- Use BEMC for hadron rejection
- Electrons identified by dE/dx ionization energy loss in TPC
- Select tracks with TPC, match to BEMC towers above 3 GeV

STAR Υ Trigger (p+p 200 GeV in Run 6)

Sample Υ-triggered Event

- $\Upsilon \rightarrow e^+e^-$
- $m_{ee} = 9.5$ GeV/c^2
- $\cos\theta = -0.67$
- $E_1 = 5.6$ GeV
- $E_2 = 3.4$ GeV

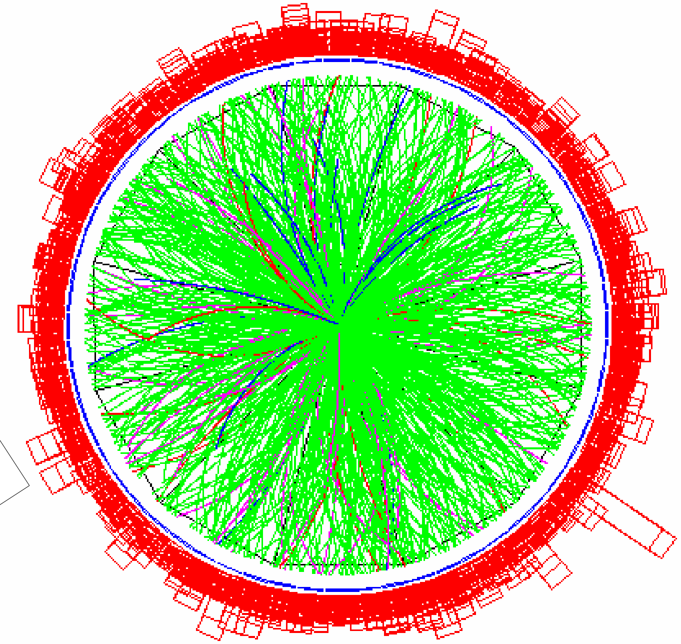


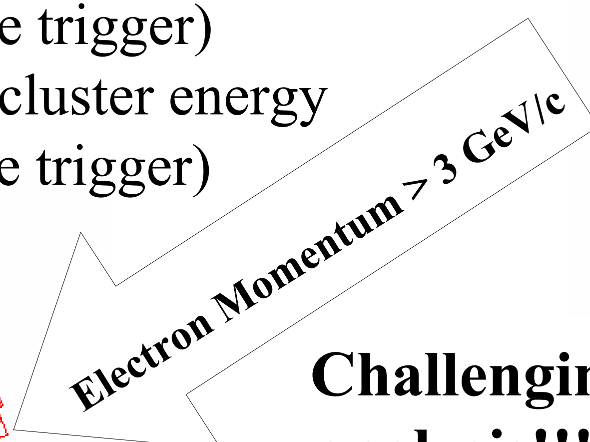
- Full BEMC acceptance $|\eta|<1$ in run 6
- Integrated luminosity ≈ 9 pb^{-1} in run 6

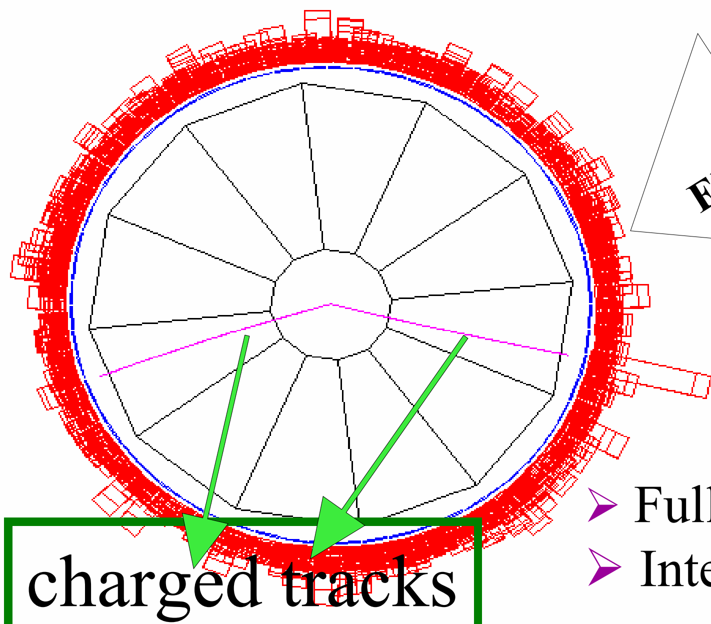
STAR Υ Trigger (Au+Au 200 GeV in Run 7)

Sample Υ-triggered Event

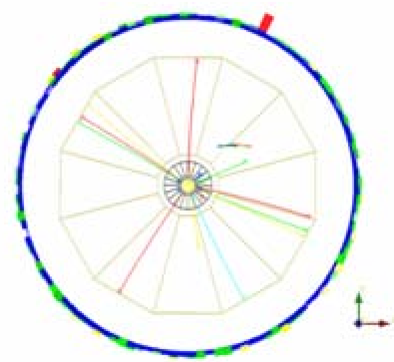
- $\Upsilon \rightarrow e^+e^-$
- mee = 9.5 GeV/c^2 (offline mass)
- cosθ = -0.77(offline opening angle)
- E_1 = 6.6 GeV (online cluster energy hardware trigger)
- E_2 = 3.2 GeV (online cluster energy software trigger)





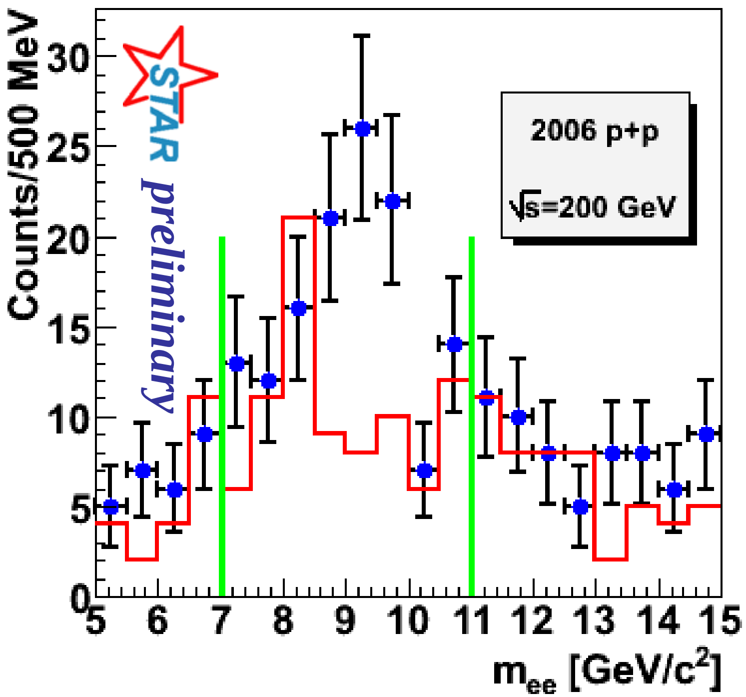


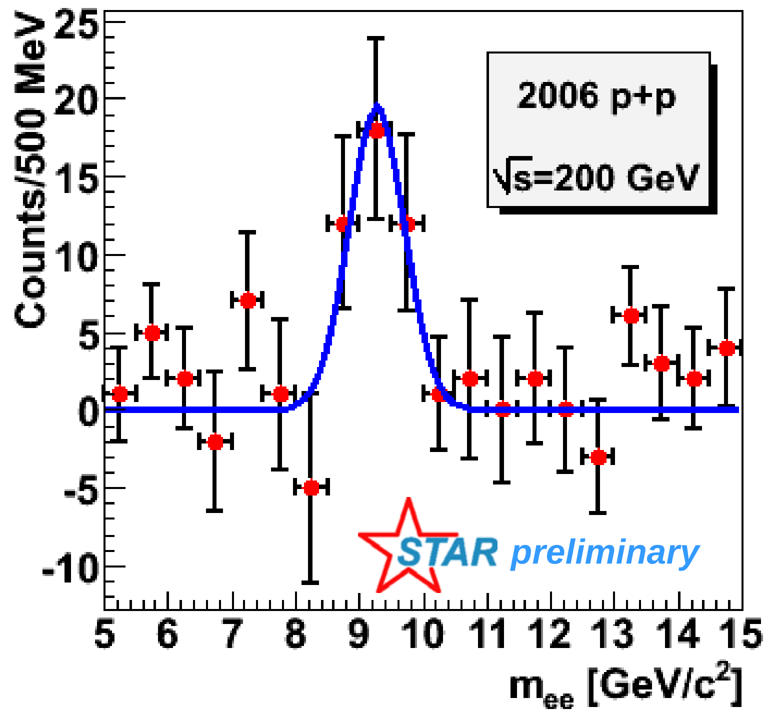
Challenging analysis!!!!!



- Full BEMC acceptance |η|<1 in Run 7
- Integrated luminosity ≈ 300 μb^{-1} in Run 7

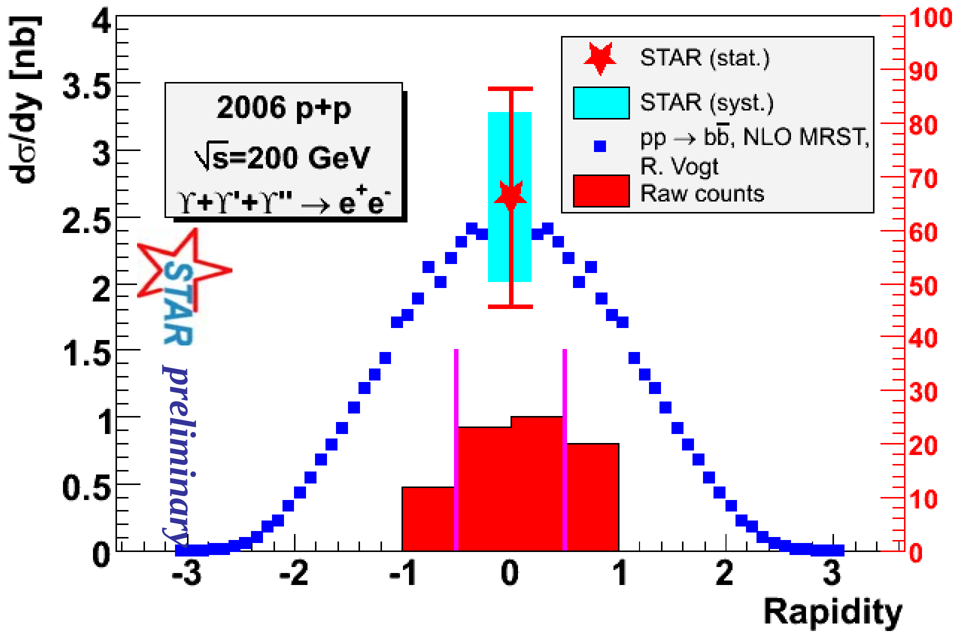
Υs in Run 6 p+p at $\sqrt{s}$=200 GeV: Invariant Mass

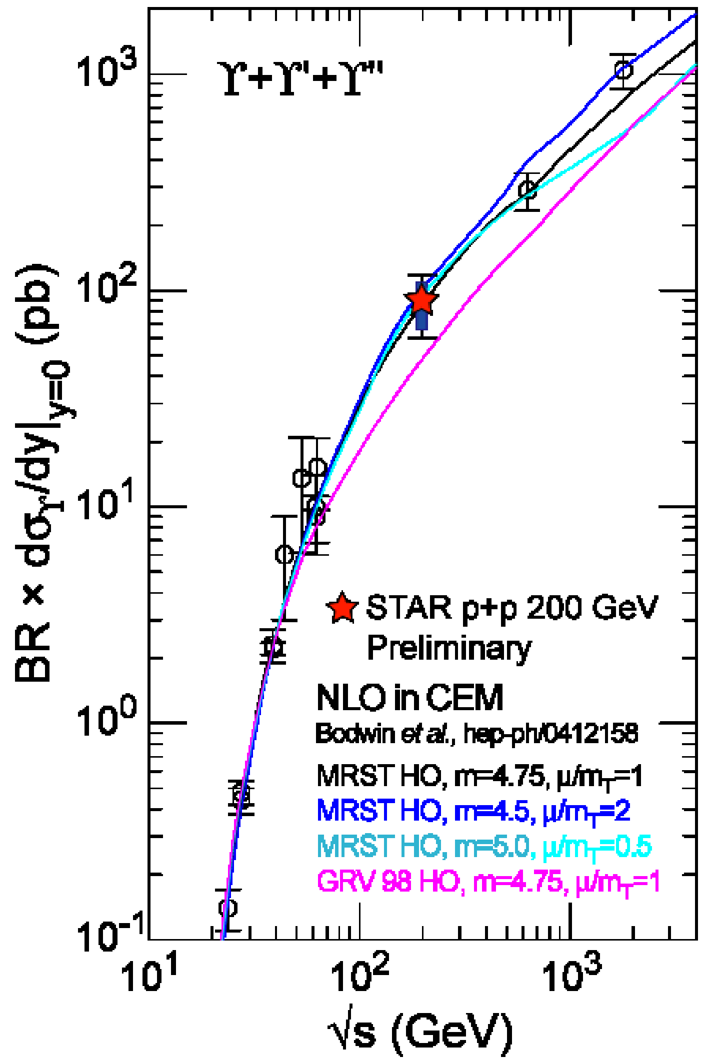




- **Signal + Background** ⇒ unlike-sign electron pairs
- **Background** ⇒ like-sign electron pairs
- **Υ(1S+2S+3S) total yield** : integrated from 7 to 11 GeV from **background-subtracted** m_{ee} distribution
- Peak width consistent with expected mass resolution
- Significance of signal is 3σ
- *Note:* Contribution from Drell-Yan (~9%) ignored

STAR Υ *vs.* Theory and World Data





STAR 2006 $\sqrt{s}$ = 200 GeV p+p

$\Upsilon+\Upsilon'+\Upsilon'' \rightarrow e^+e^-$ cross section **consistent** with **pQCD** and **world data.**

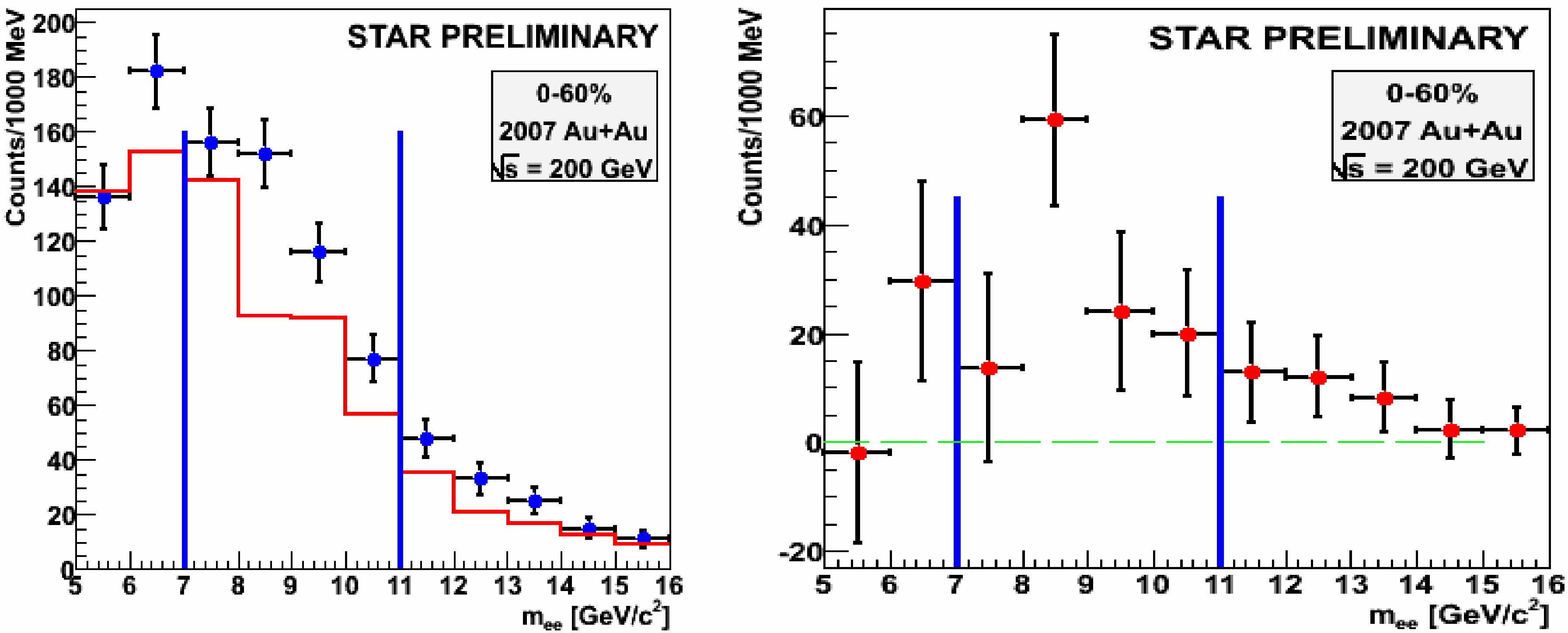
Υs in Au+Au at $\sqrt{s_{NN}}$ = 200 GeV (Run 7)

First **Rough Look**: Using identical cuts as in p+p analysis.

Pros : allows "apples-to-apples" comparison with p+p.

Cons : not optimal for Au+Au

– larger background, different trigger thresholds



$\mathbf{R_{AA}}$: Upper Limit $\Rightarrow R_{AA} < 1.3$ at 90% CL

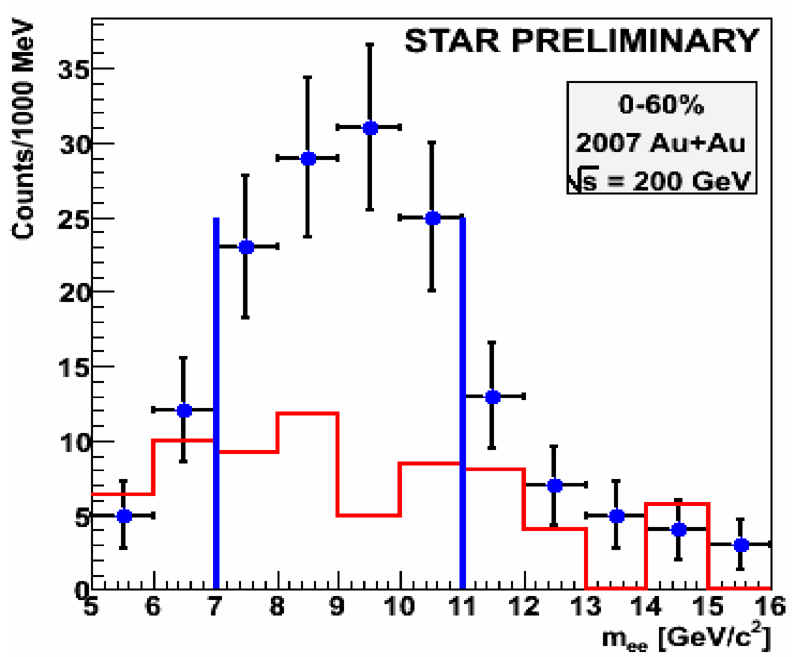
ϒs in Au+Au at $\sqrt{s_{NN}}$ = 200 GeV (Run 7)

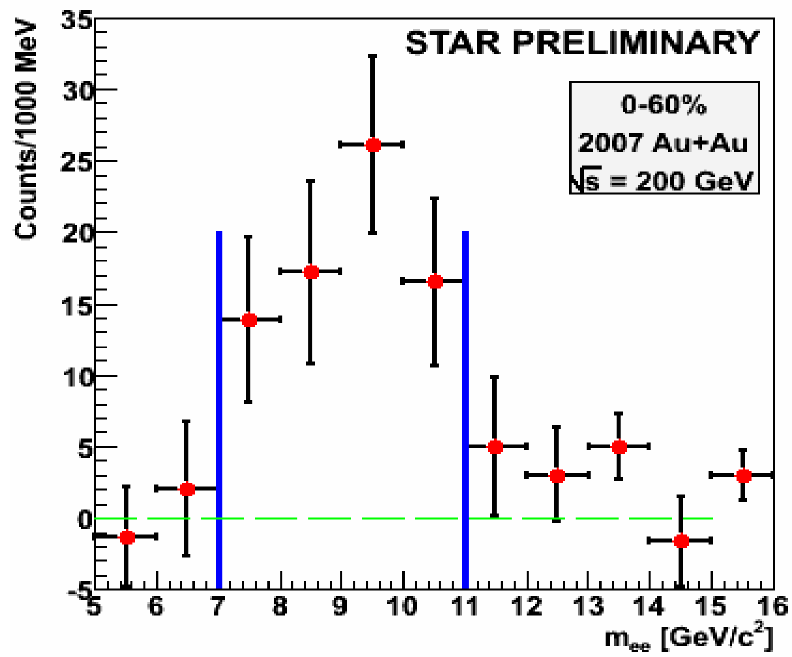
***Improved* Analysis:**

Pros : improved EMC-track-trigger handling

⇒ strong signal and enhanced S/B (~ factor of 5!)

Trigger efficiency and systematic checks are in progress.



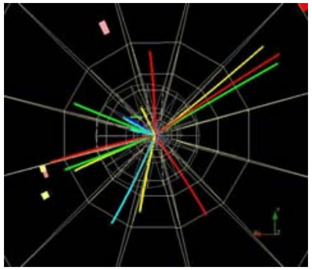


- Strong 4σ signal.
- **First measurement of ϒ in nucleus-nucleus collisions ever.**
- R_{AA} measurement in progress.

Summary and Outlook

- Full BEMC + trigger $\Rightarrow$ quarkonium program in STAR
- **Run 6**: mid-rapidity measurement of $\Upsilon(1S+2S+3S) \rightarrow e^+e^-$ cross section at RHIC in p+p collisions at $\sqrt{s}$ = 200 GeV
- $BR_{ee} \times (d\sigma/dy)_{y=0}$ = 91±28(stat.)±22(syst.) pb
- STAR Υ in p+p measurement is consistent with pQCD and world data

- **Run 7**: We have the **first** proof-of-principle Υ measurement results in heavy ion collisions for 200 GeV Au+Au
- Strong signal
- Soon : R_{AA} of Υ



- **Run 8**: measurement in d+Au , ongoing analysis!
- Absolute cross-section in p+p, d+Au, and Au+Au.