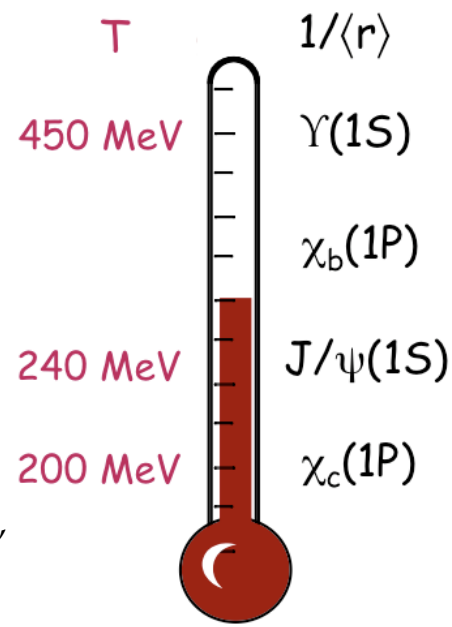
J/ψ and ϒ at STAR

Rosi Reed

For the STAR Collaboration

Quarkonia as a QGP probe

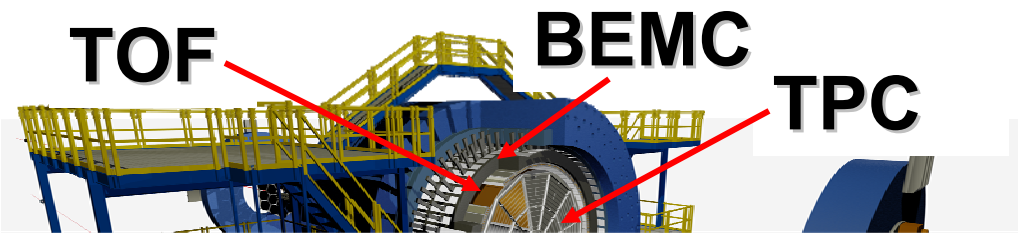
- J/ψ and ϒ Can be great probes but to understand the suppression due to color screening we should quantify
  - Production mechanism
  - Cold Nuclear Matter Effects
  - Hot Nuclear Matter Effects



] A. Mocsy and P.Petreczky, PRL 99, 211602 (2007)

Requires measuring J/ψ and ϒ at a wide range in √s
STAR adds to this effort with its large acceptance + fast trigger

STAR detector and Particle ID



Acceptance

$|\eta|<1$, $0<\phi<2\pi$

Year 2009 72% of full TOF

Year 2010 100% of full TOF

Time Projection Chamber

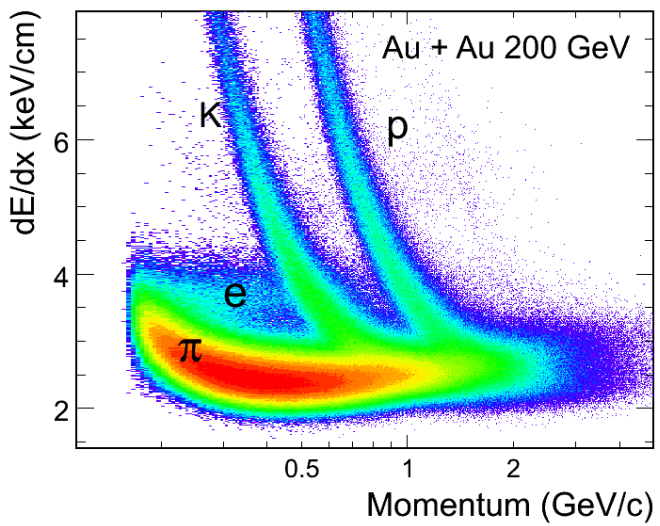
dE/dx, momentum

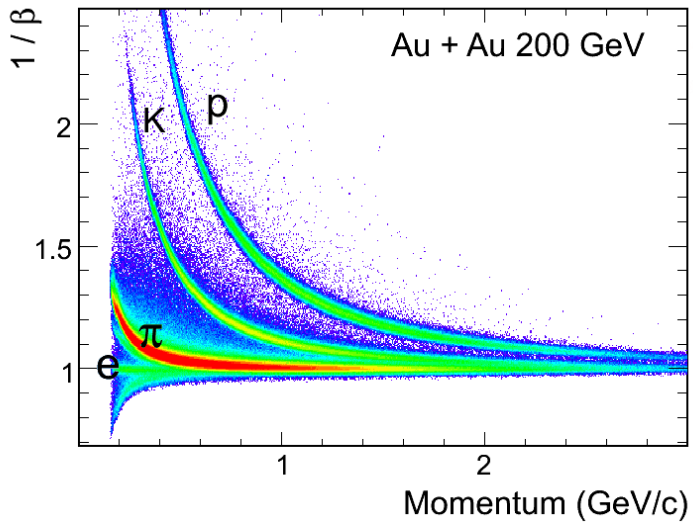
Time Of Flight detector

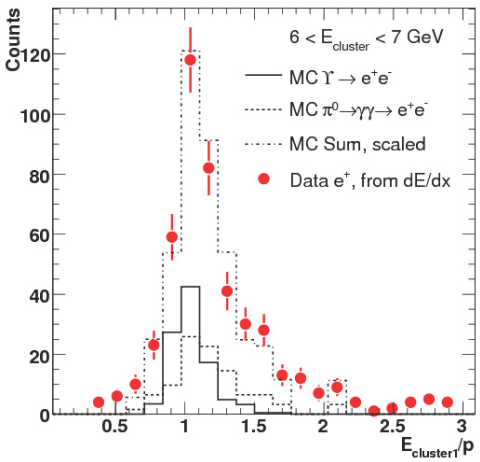
time $1/\beta$

ElectroMagnetic Calorimeter

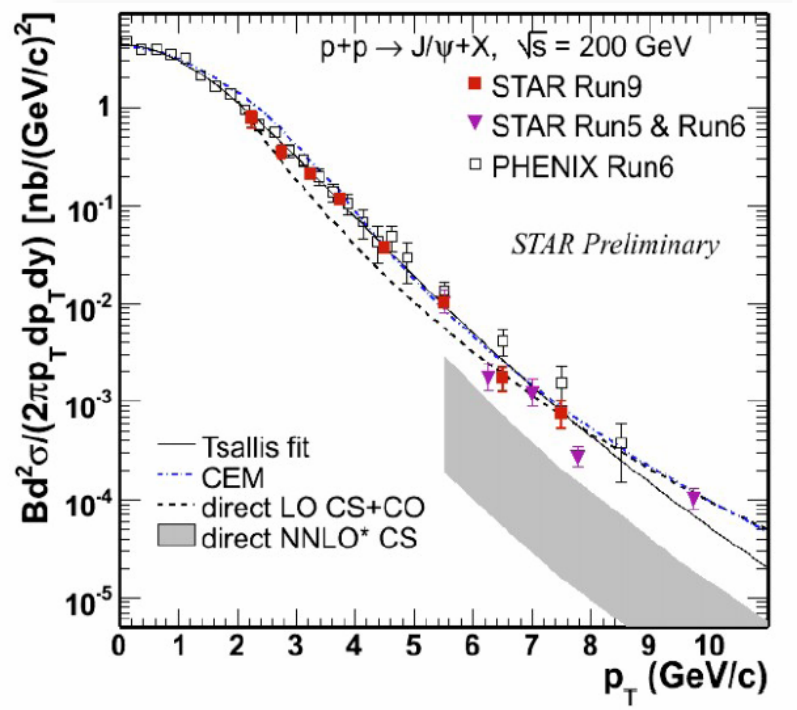
E/p, Trigger

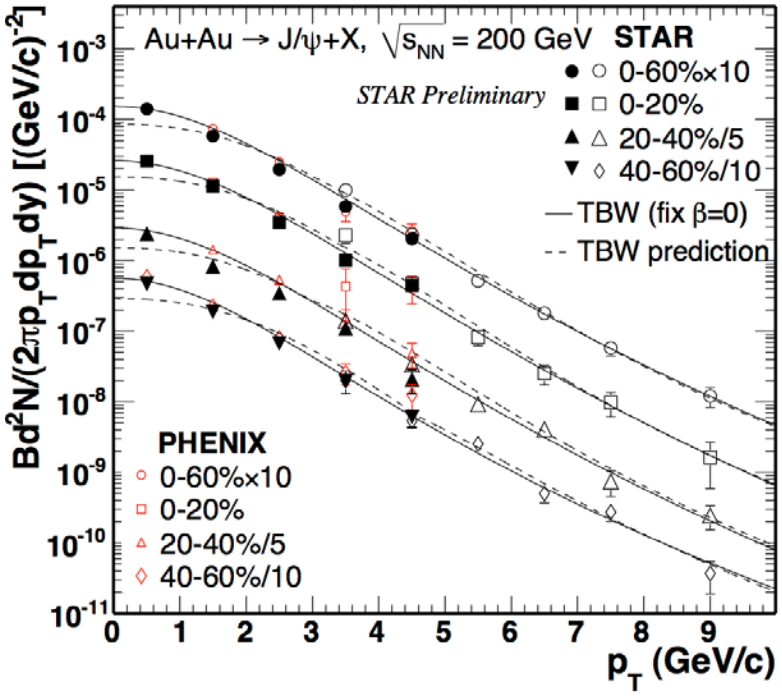






J/ψ spectra

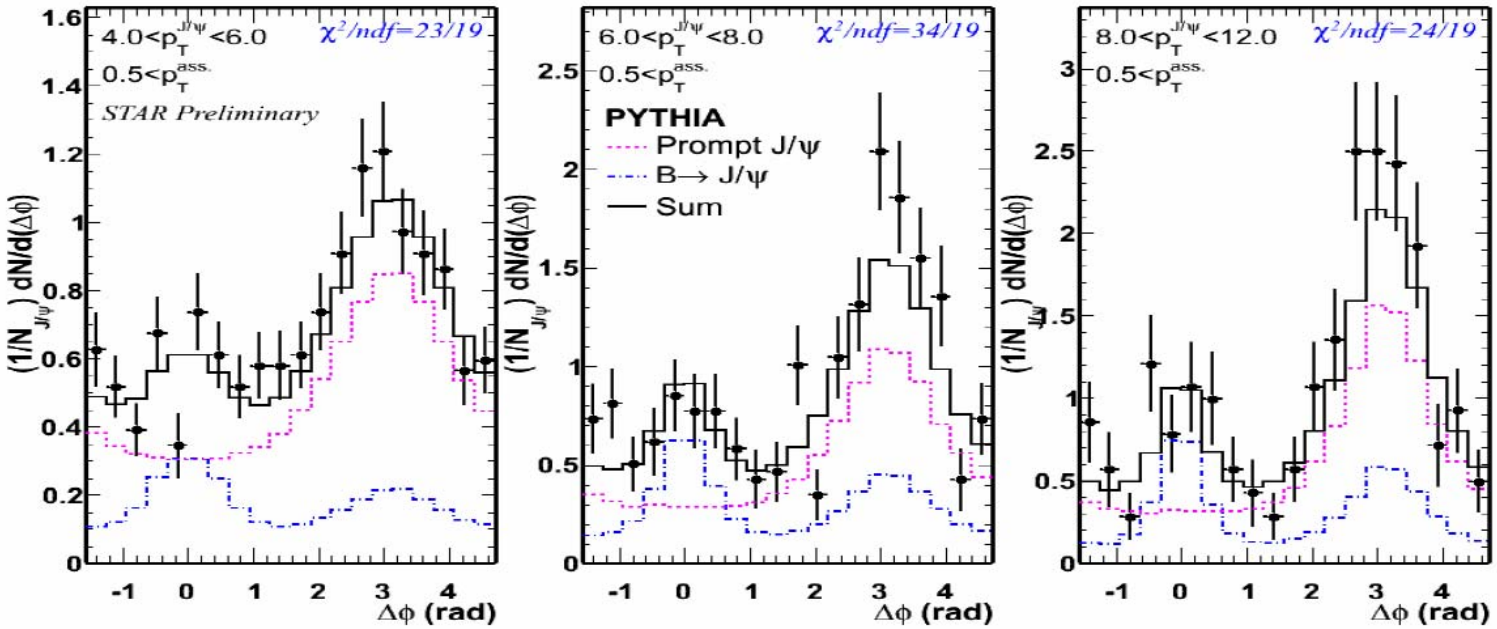




COM prediction (for direct J/ψ only) leaves no room for feed-down
CSM predicts a much steeper trend than our data
CEM seems to describe our data in the large p_T range

Tsallis Blast-Wave model (TBW) describes our data with β = 0
TBW prediction (light hadron parameters) is harder than data
β=0 vs. regeneration?

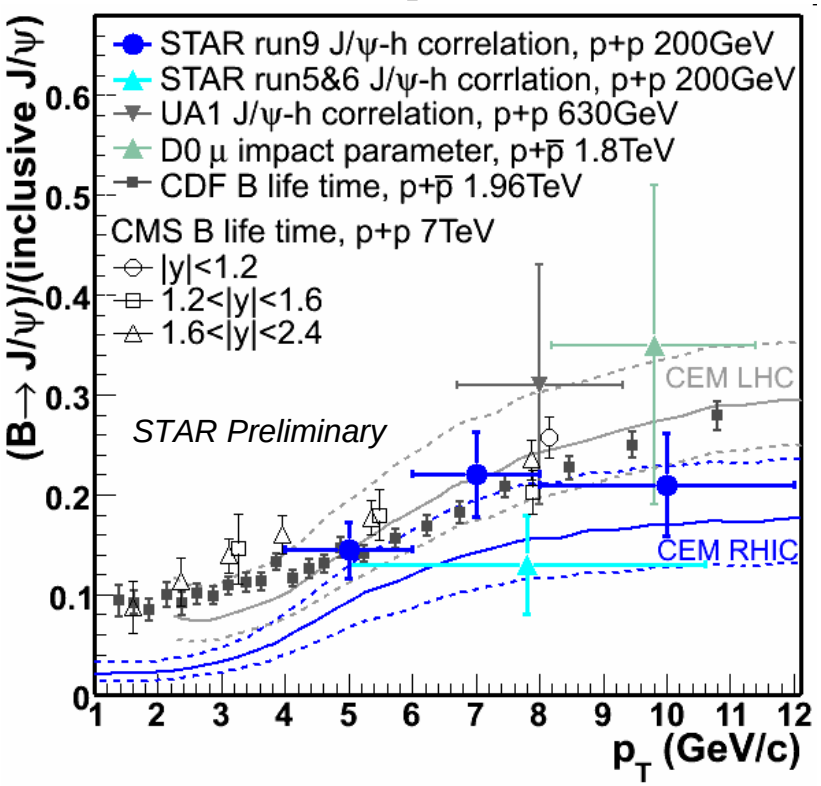
B → J/ψ+X

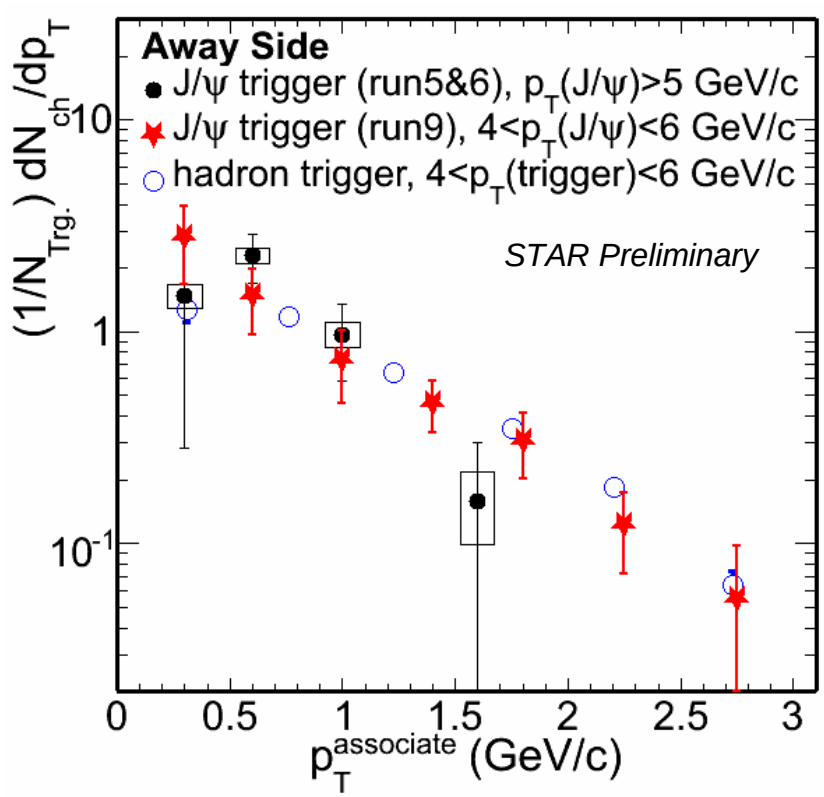


J/ψ-hadron azimuthal correlations are used to separate direct J/ψ from feed-down from B

Pythia simulations of prompt and B→J/ψ azimuthal correlation are fit to the data to determine the relative yield

J/ψ hadron correlations





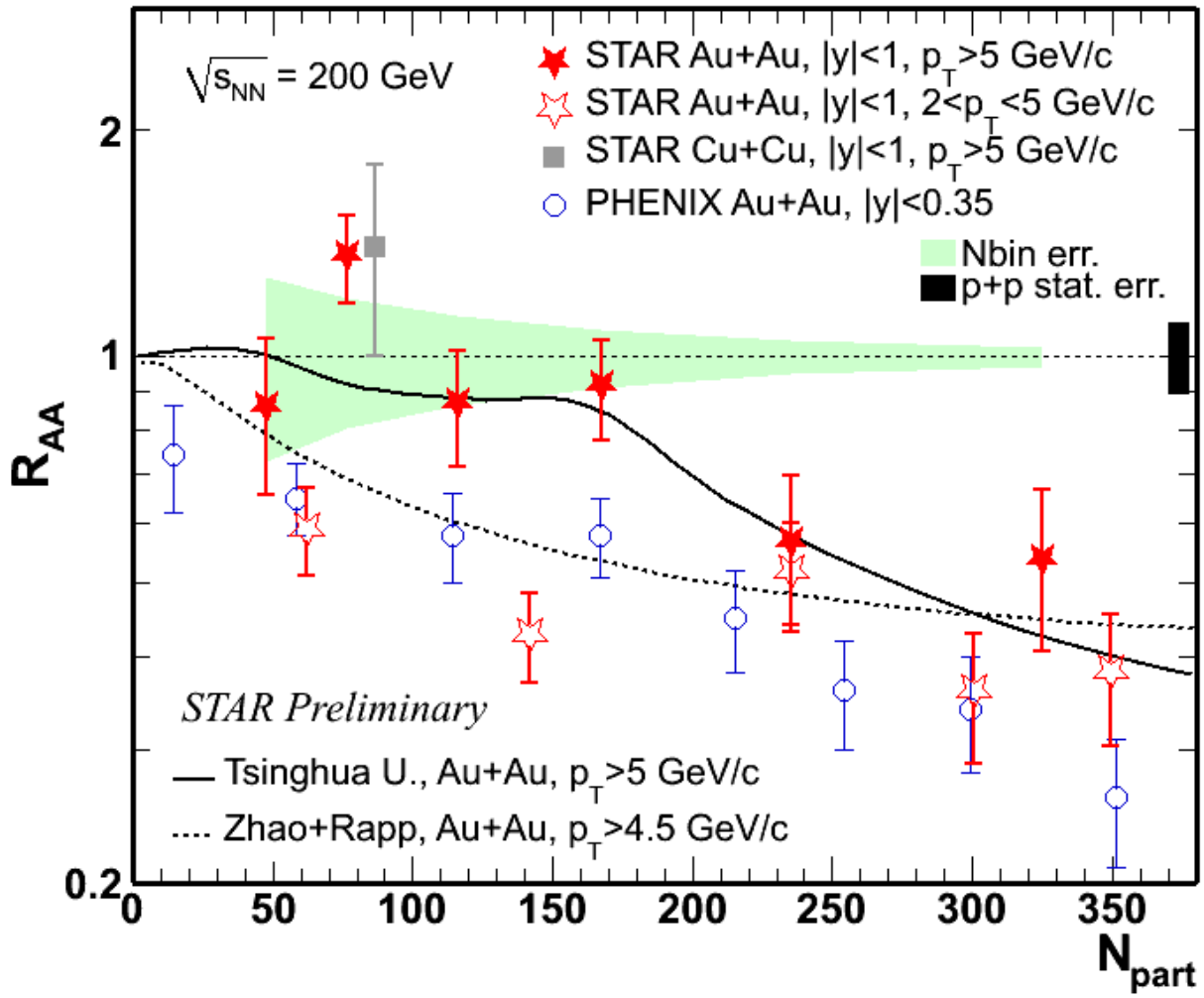
B→ J/ψ+X contributes 10-25% of J/ψ at p_T > 4 GeV/c at 200 GeV

Consistent with the upper boundary of CEM+FONLL calculation

Consistency between hadron spectra indicate associated hadrons are dominantly from light quarks or gluons not heavy quarks

J/ψ R_{AA} vs N_{part}

Tsinghua
Physics Letters B
Volume 678, Issue 1,
6 July 2009,
Pages 72-76

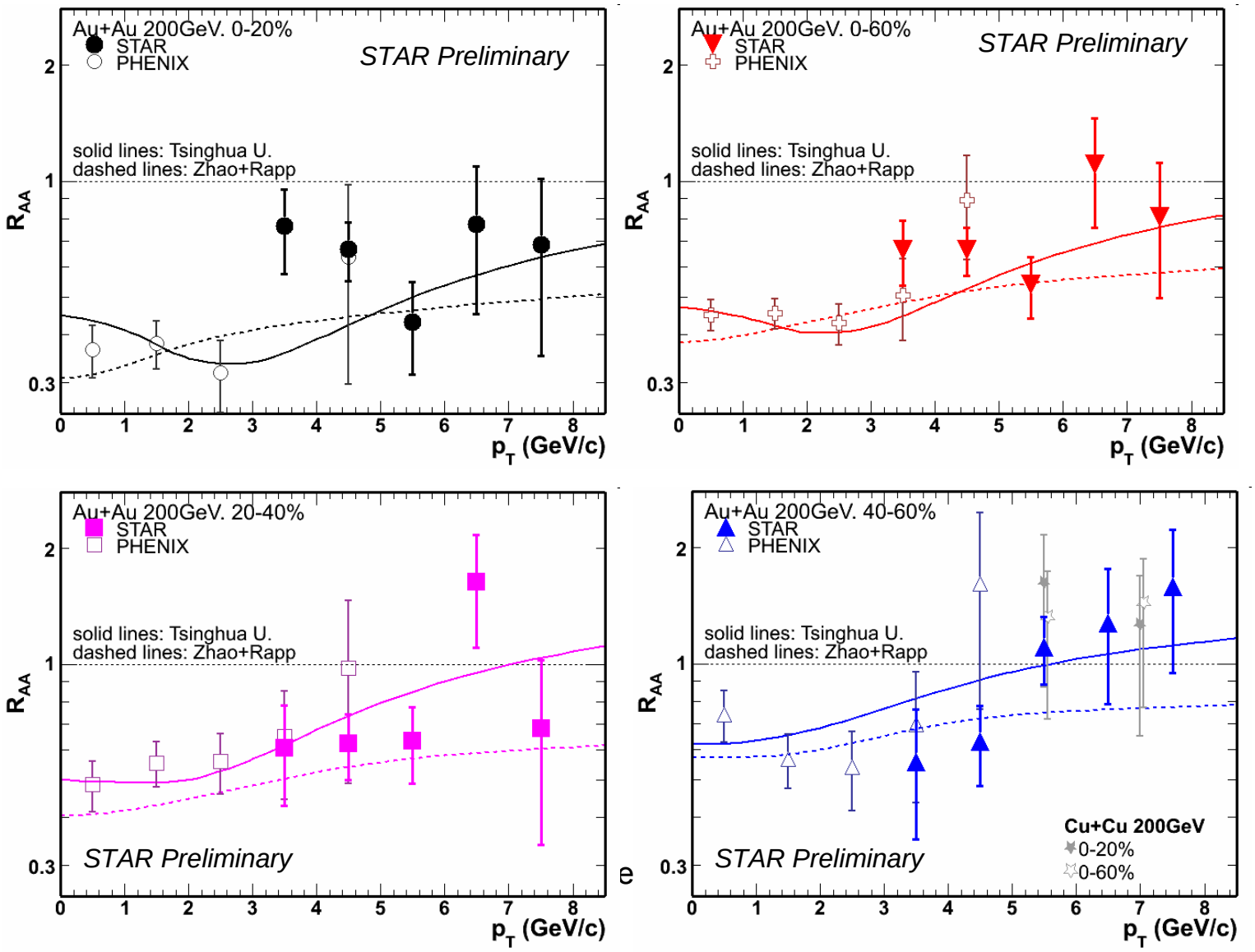


Zhao+Rapp
Phys. Rev. C 82,
064905 (2010)

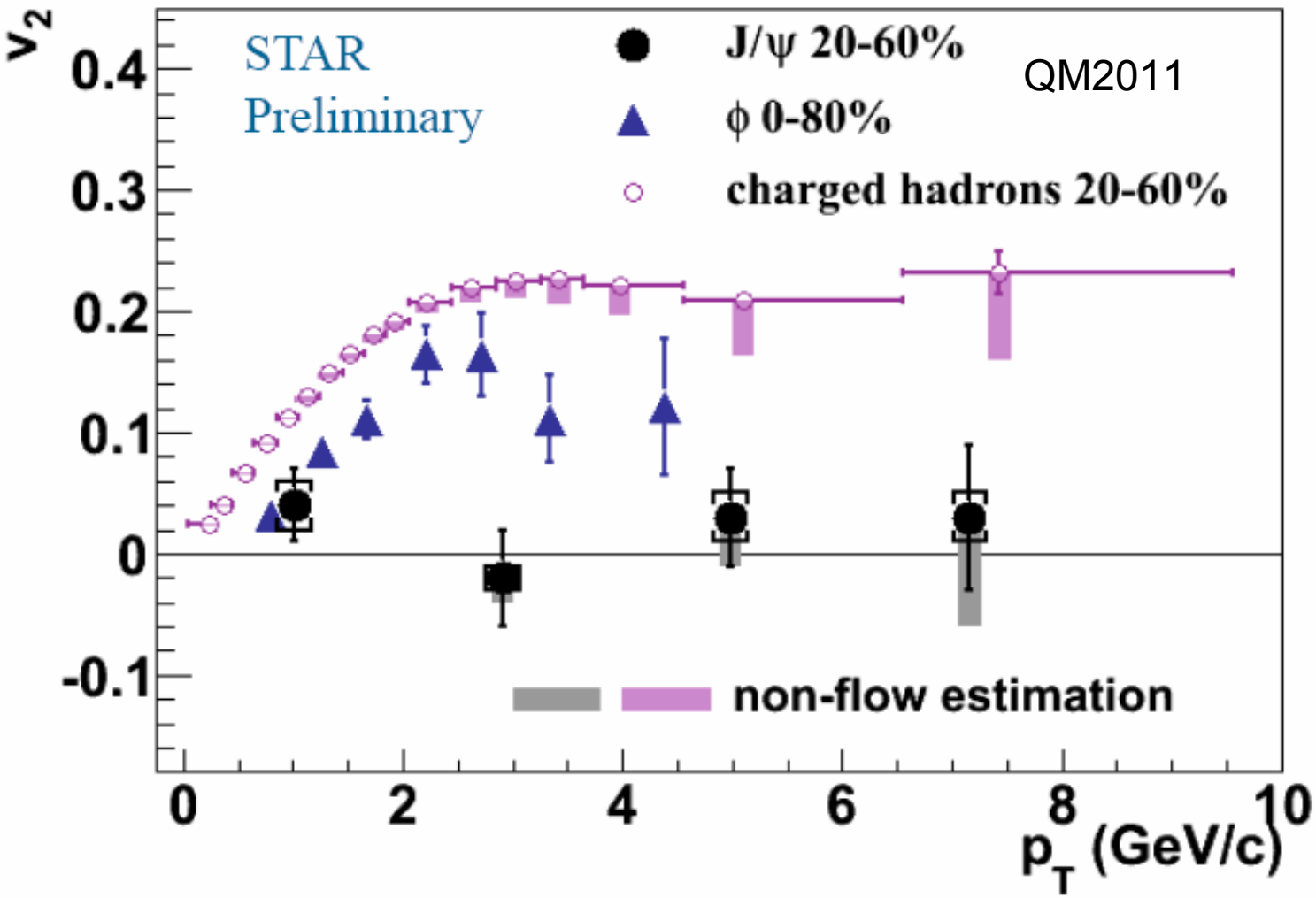
Suppression increases with centrality, decreases with p_T

J/ψ R_{AA} vs p_T and centrality

J/ψ R_{AA} increases with p_T in all centralities



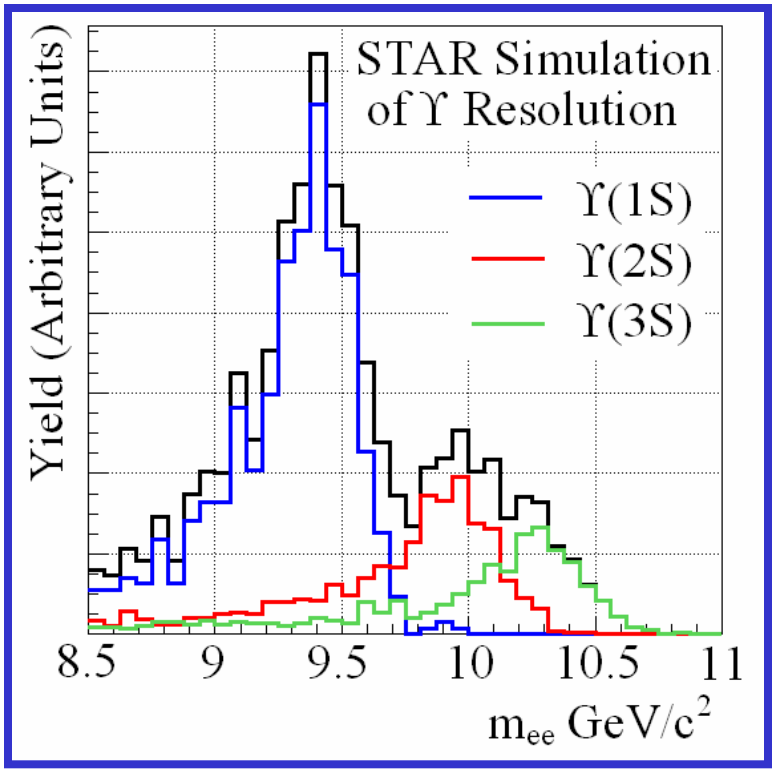
J/ψ v_2 vs p_T



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

Υ at STAR

We have learned much from the J/ψ, what can we learn from Υ?



Decay channel: $\Upsilon \rightarrow e^+e^-$

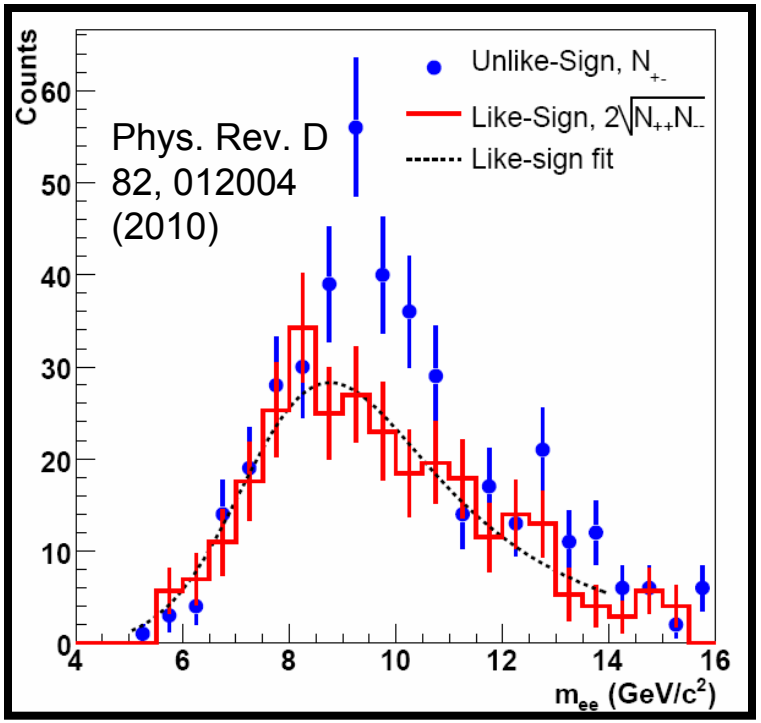
Pros

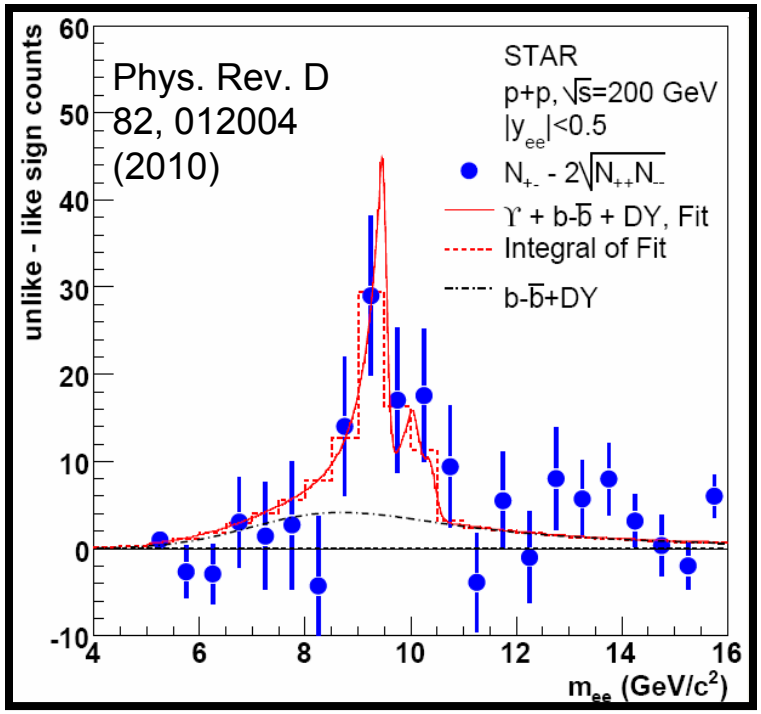
- Small background at M~10 GeV/c^2
- Co-mover absorption is small at 200 GeV
- Recombination negligible at 200 GeV

Cons

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

Υ(1S+2S+3S) cross-section p+p 200 GeV



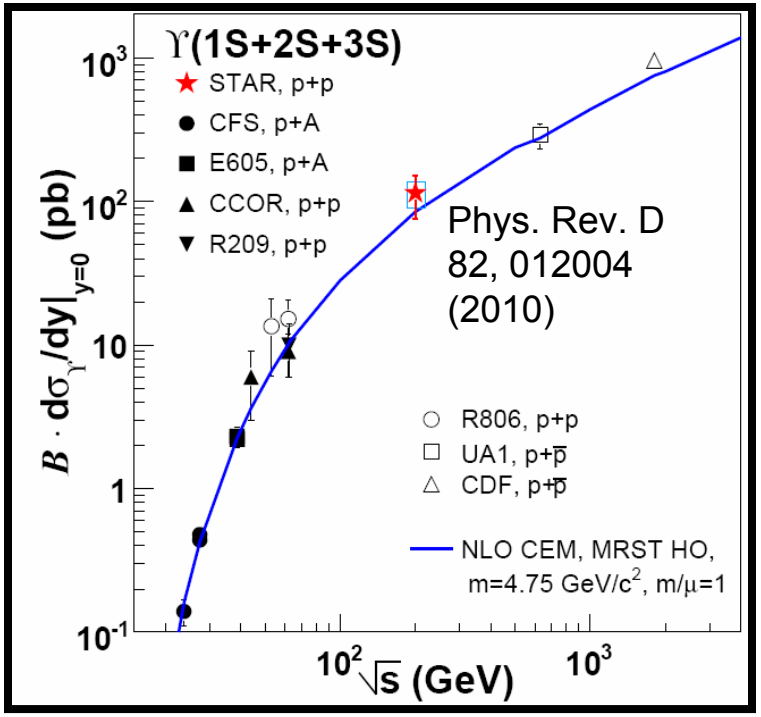


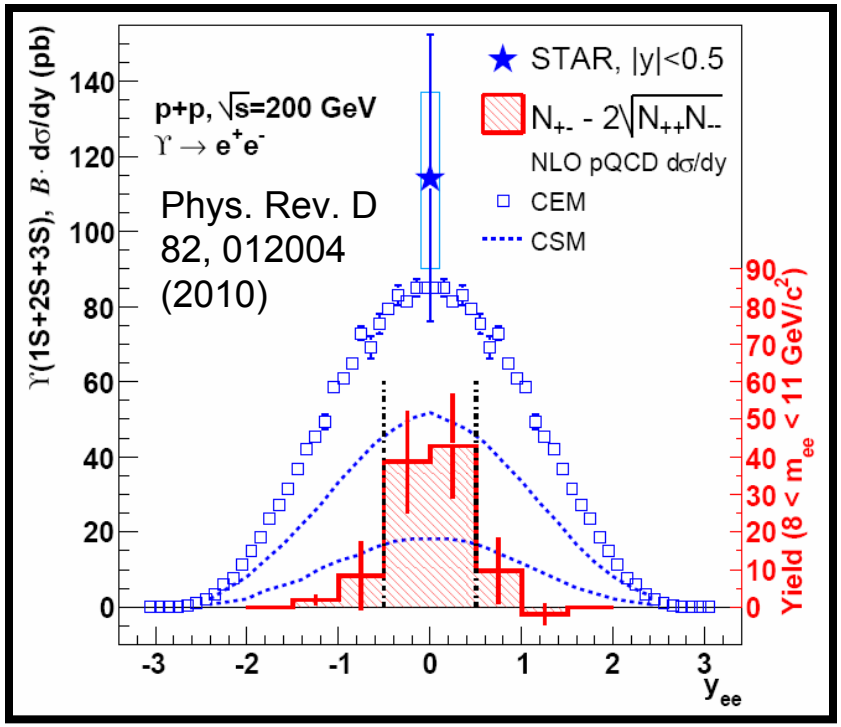
$$\sum_{n=1}^{3} \mathcal{B}(n\mathrm{S}) \times \sigma(n\mathrm{S}) = 114 \pm 38\ ^{+23}_{-24}\ \mathrm{pb}$$

$\mathcal{L}$ = 7.9 ± 0.6 pb^{-1}

N_{Υ}(total)= 67±22(stat.)

ϒ(1S+2S+3S) cross-section

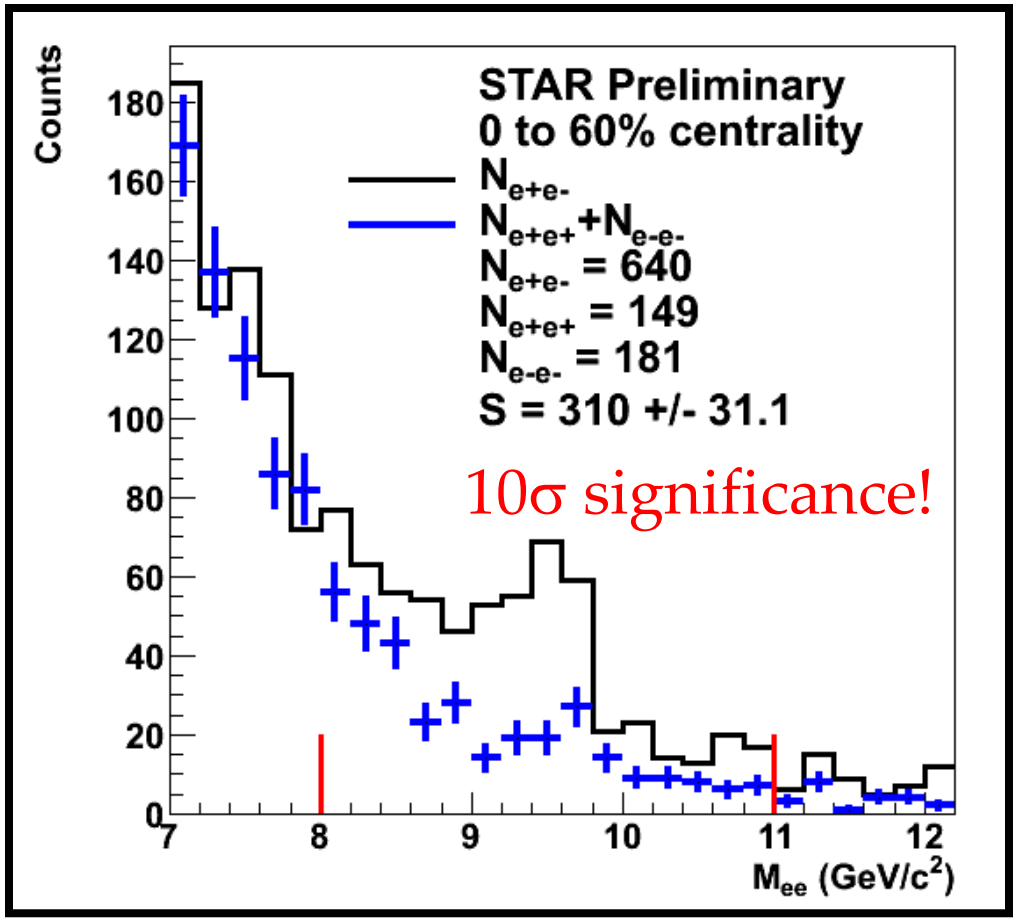




STAR 2006 √s=200 GeV p+p
ϒ+ϒ′+ϒ″→e⁺e⁻ cross section consistent with pQCD and world data trend

Di-electron Yield 0-60% Au+Au

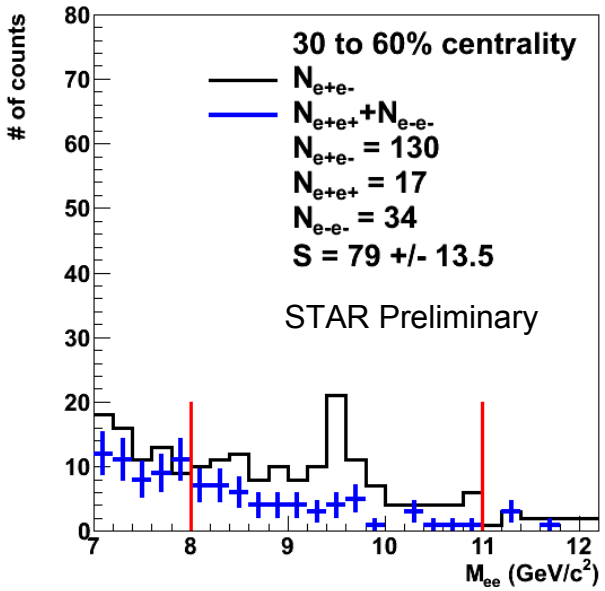
Run 10 Data
# of minimum Bias events= 4.62×10^9
Triggers= 50M

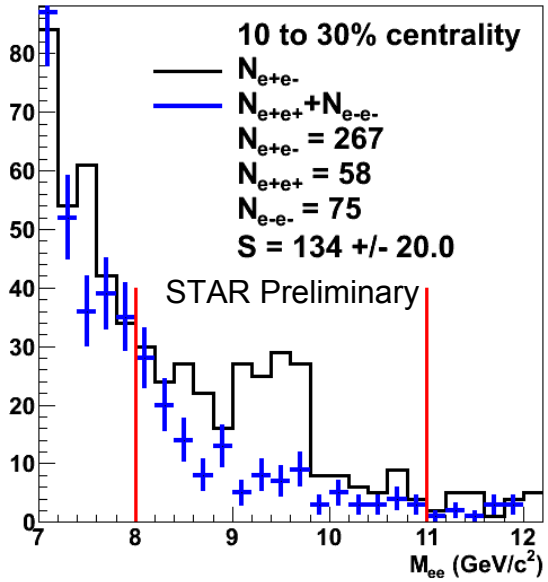


Raw yield of $\Upsilon \rightarrow e^+e^-$ with $|y|<0.5 = 196.6 \pm 35.8$

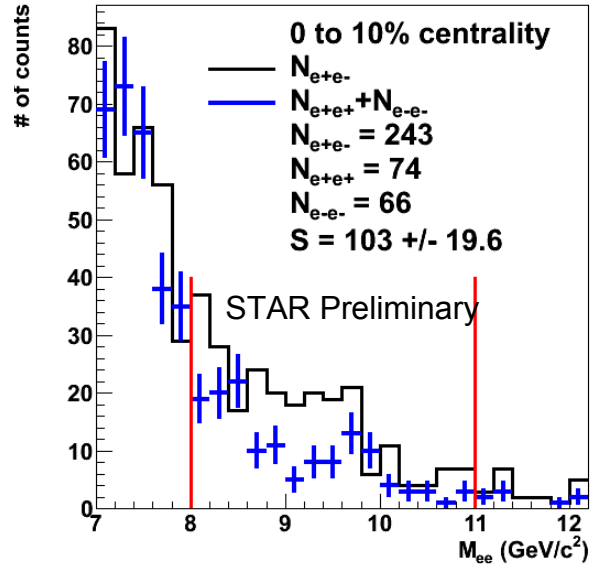
Di-electron Yield by Centrality

Peripheral





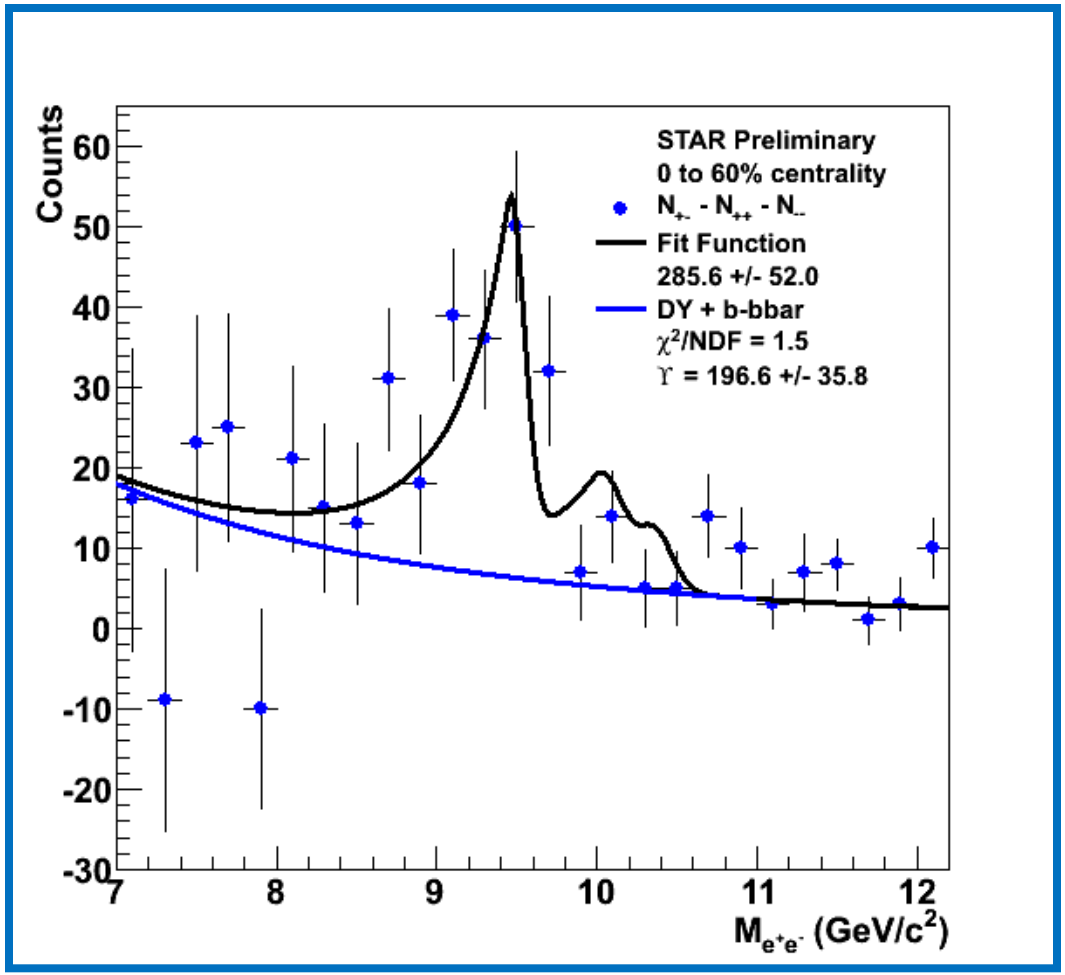
Central



5.9σ 6.7σ 5.3σ

How do we remove the Drell-Yan+$b\bar{b}$ contribution?

Extracting Υ(1S+2S+3S) Yield



Current resolution does not allow for a separation of the 2S+3S states

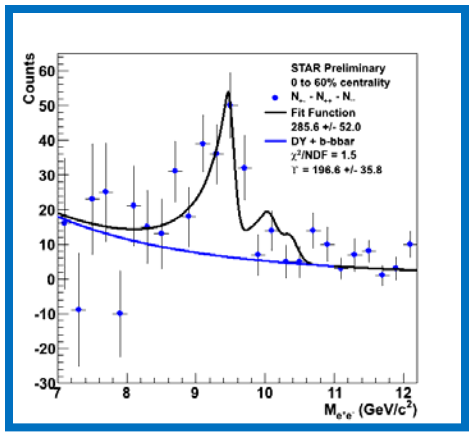
Large theoretical uncertainty in the Drell-Yan and $b\bar{b}$ yield

How do we extract a yield unbiased by our initial suppression assumptions?

$$\text{Drell-Yan}+b\bar{b} = \frac{A}{(1+\frac{m}{m_0})^n}$$

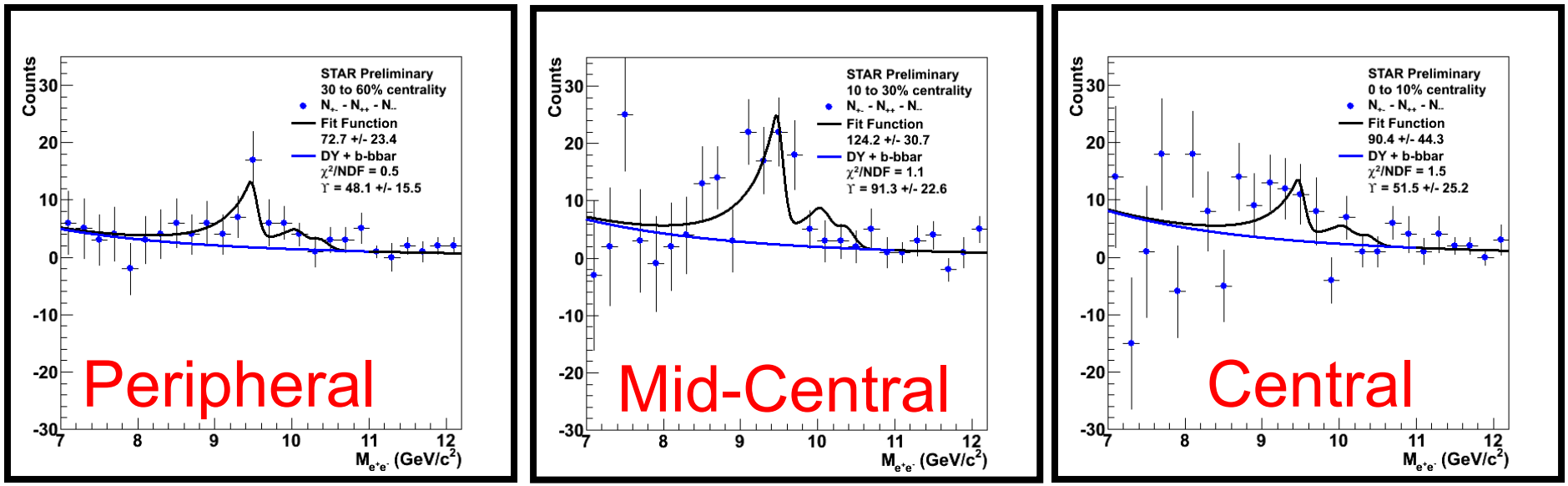
n = 4.59, m_0 = 2.7

Extracting Υ(1S+2S+3S) Yield



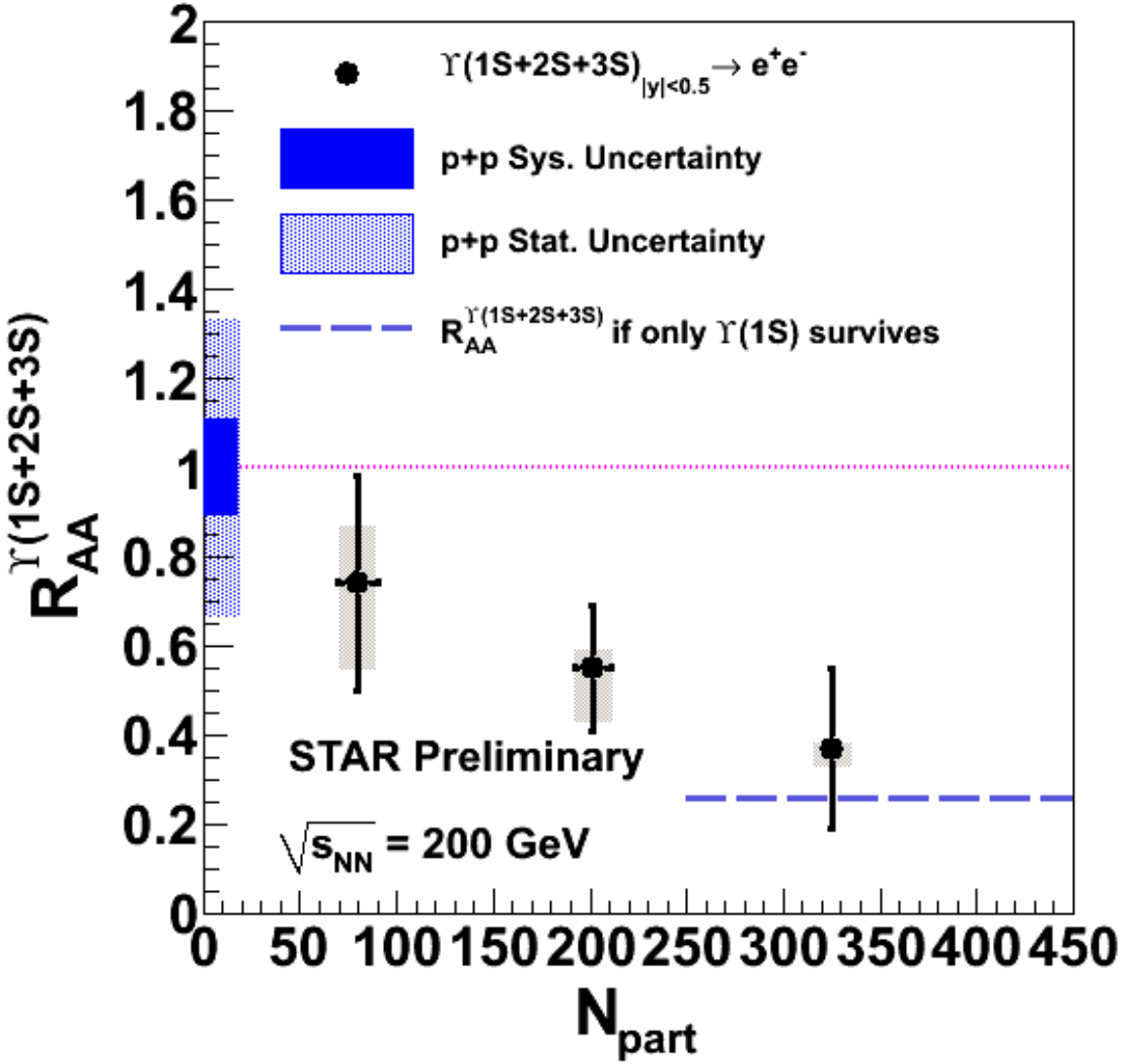
- Fit has 2 free parameters:
  - Yield of Υ(1S+2S+3S)
  - Yield of Drell-Yan + $b\bar{b}$
- Υ yield does **NOT** come from the line-shape!
  - $\Upsilon = N_{+-} - N_{--} - N_{++} - \int DY + b\bar{b}$
  - Υ masses are fixed to PDG Values
  - Ratios of 1S to 2S to 3S fixed to PDG values
  - Other effects come from simulation

ϒ Yield by centrality

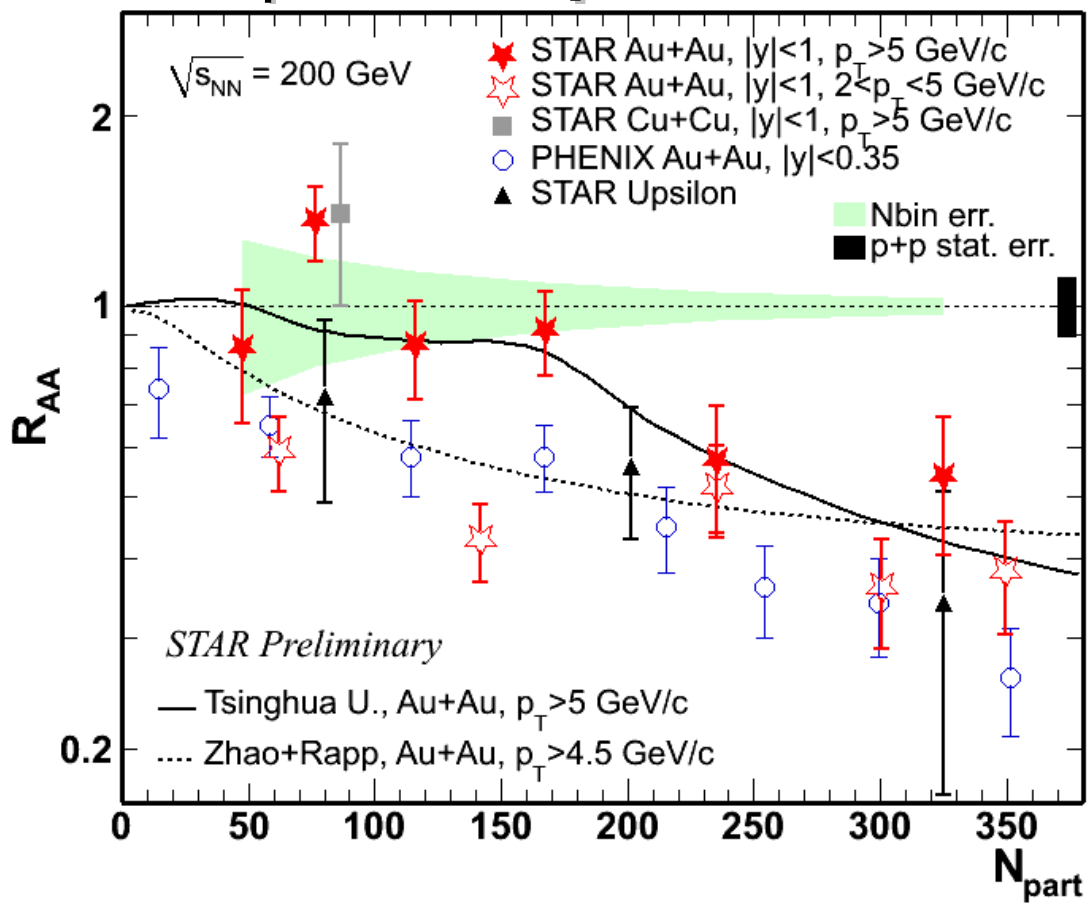


- System uncertainties
  - p+p luminosity and BBC trigger efficiency
  - ϒ Line-shape
  - Drell-Yan and $b\bar{b}$ background

Υ(1S+2S+3S) R_{AA}



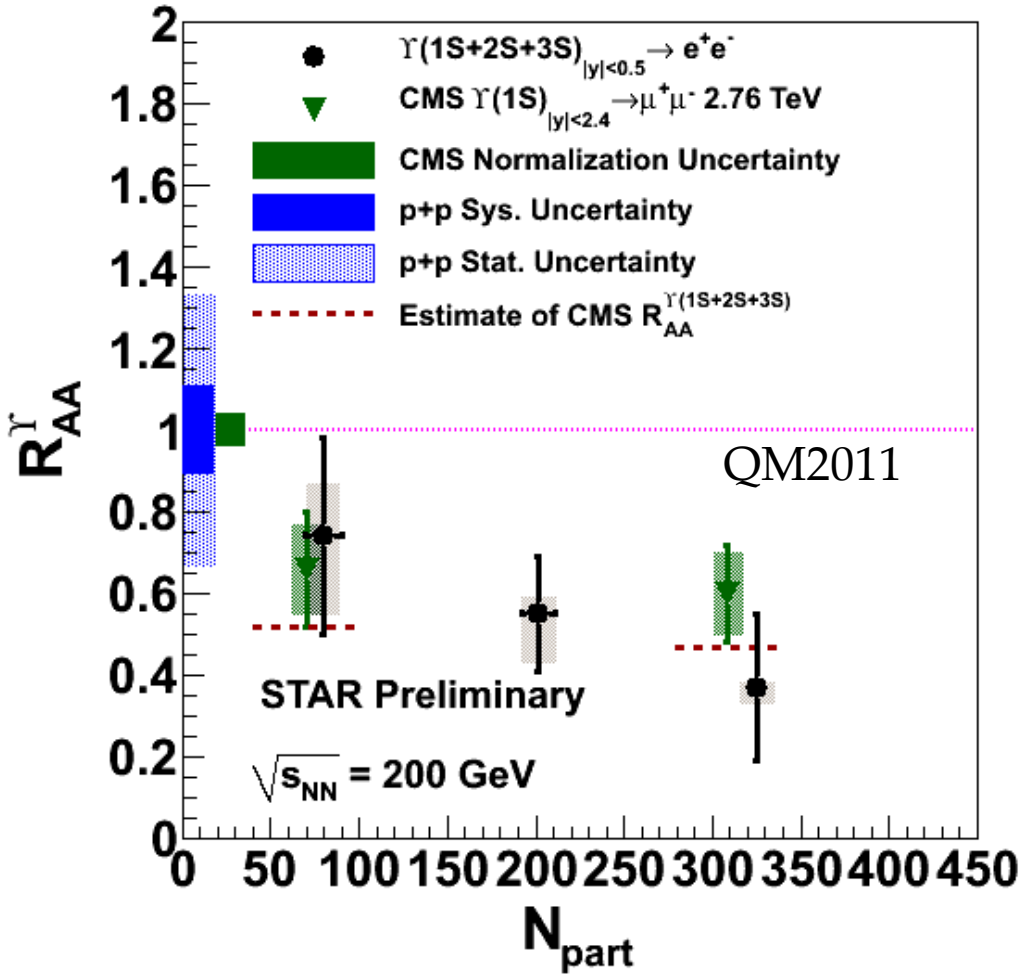
Υ and J/ψ comparison vs N_{part}



Agreement between low pT J/ψ and Υ is interesting

J/ψ and $\Upsilon(2S)$ have similar binding energy, difference in R_{AA} could help understand systematics

Comparison STAR and CMS



STAR data is from 0-60%

|y|<0.5

CMS data is from 0-100%

|y|<2.4

Momentum distributions are different

Results are consistent!

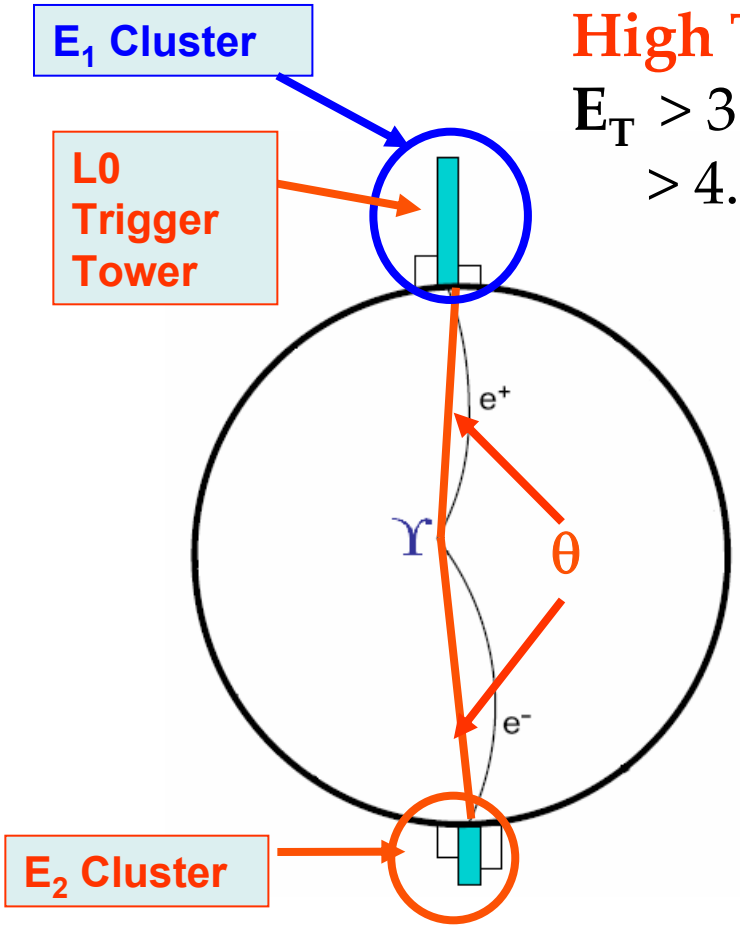
Phys. Rev. Lett. 107, 052302 (2011)
2S+3S/1S suppression

Conclusions

- STAR measured $J/\psi \rightarrow e^+e^-$ and $\Upsilon(1S+2S+3S) \rightarrow e+e-$ at $\sqrt{s_{NN}}$=200 GeV in p+p and Au+Au collisions
- In p+p collisions CEM can describe J/ψ and $\Upsilon(1S+2S+3S)$
- The ratio of $B \rightarrow J/\psi$ to inclusive J/ψ is 10-25% at $p_T > 4$ GeV/c
- Away side spectra from J/ψ-h correlation consistent with h-h
- In Au+Au collisions
  - J/ψ v_2 consistent with zero
  - J/ψ R_{AA} increases with increasing p_T
  - In 20-60% high-p_T J/ψ R_{AA}~1
  - In 0-20% high-p_T J/ψ is significantly suppressed
  - $\Upsilon(1S+2S+3S)$ suppressed in central collisions! 3σ away from $R_{AA} = 1$

Back-up

ϒ Trigger and Analysis



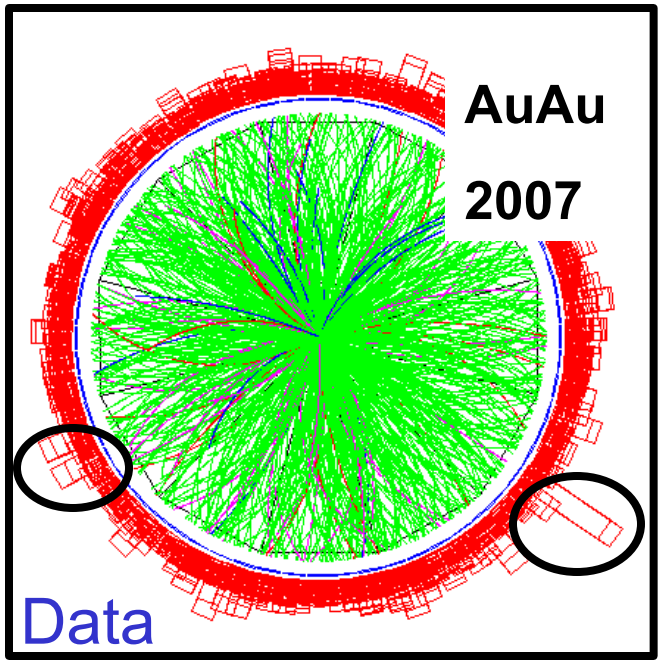
High Tower

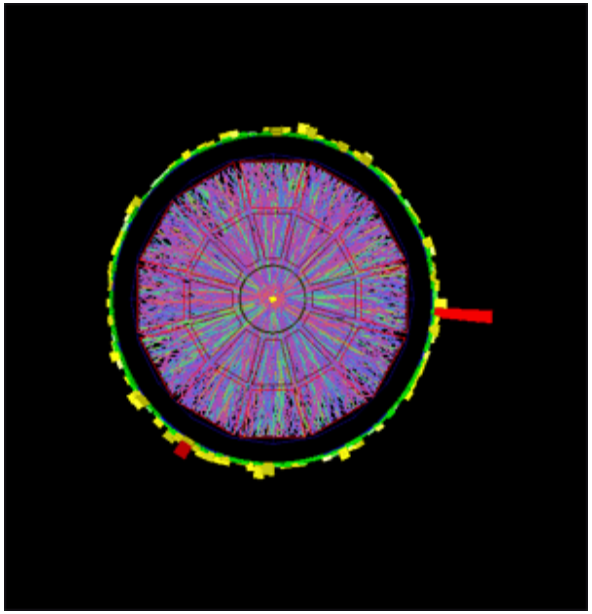
E_T > 3.5 GeV (pp)
> 4.0 GeV (AuAu)

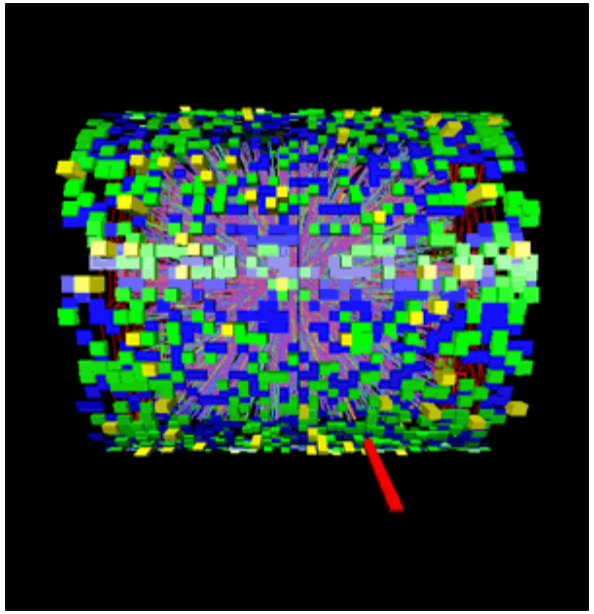
L2 Parameters (pp only)

E_1 Cluster, E_2 Cluster, Cos(θ), Invariant Mass

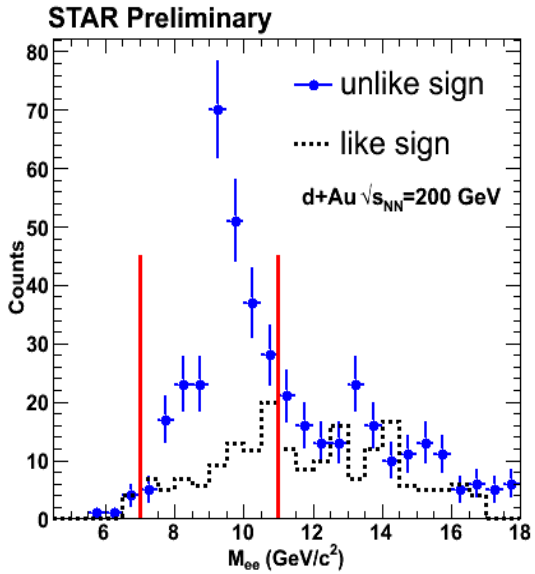
Rejection
~10^5 in pp
Can sample full luminosity

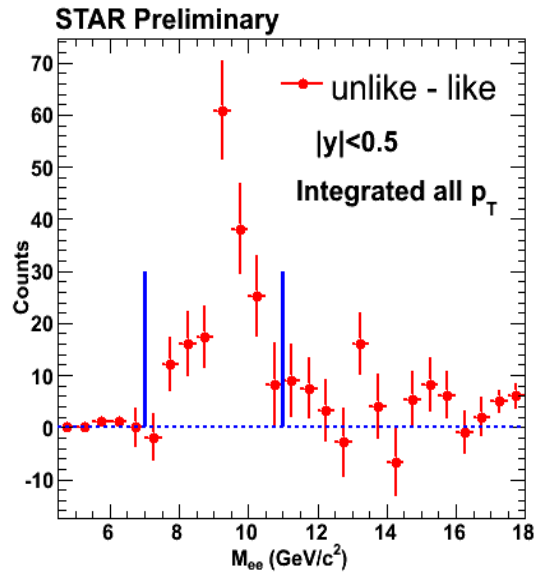


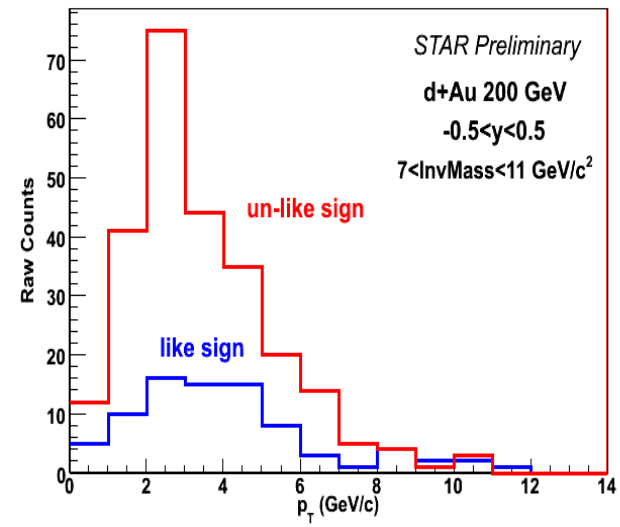




Observed Upsilon Signal





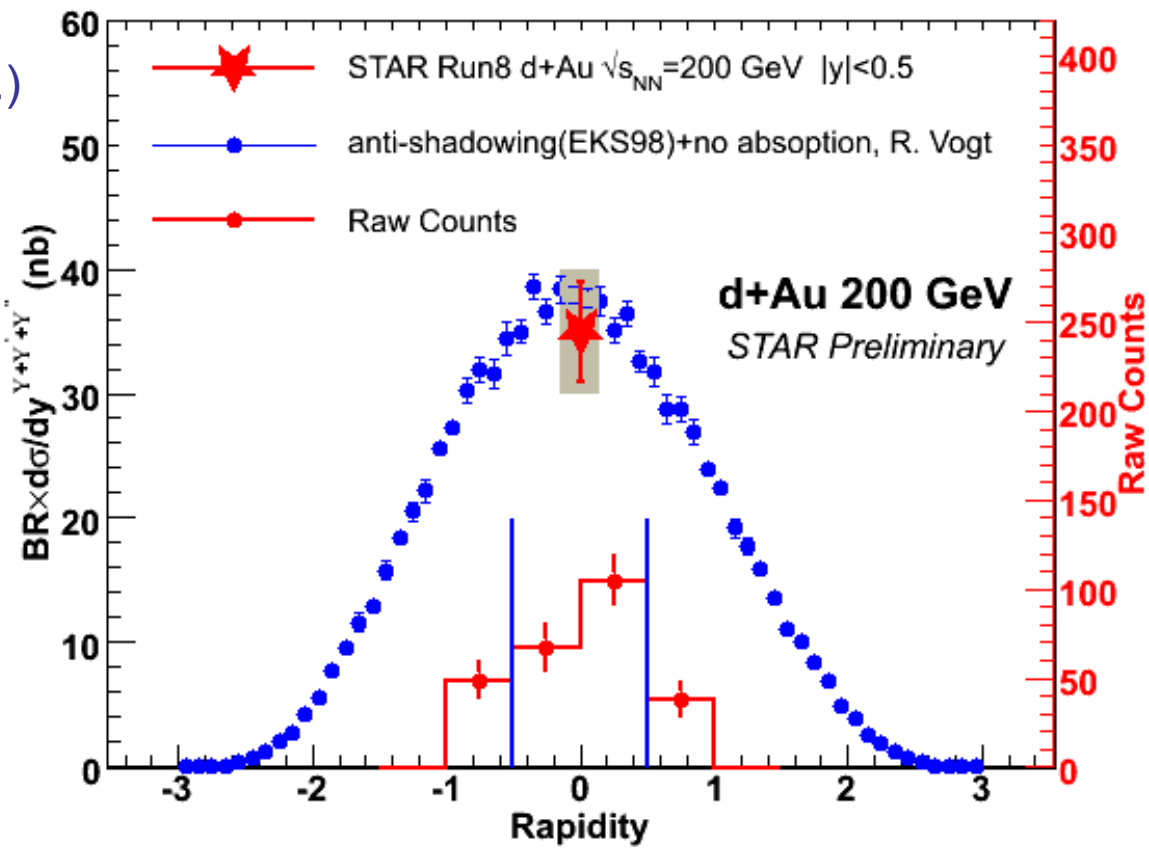


- Signal + Background ⇒ unlike-sign electron pairs
- Background ⇒ like-sign electron pairs
- ϒ(1S+2S+3S) total yield: integrated from 7 to 11 GeV from background-subtracted m_{e+e-} distribution
  - Raw Yield: 172 +/- 20 (stat.)
  - Strong signal (8σ significance)

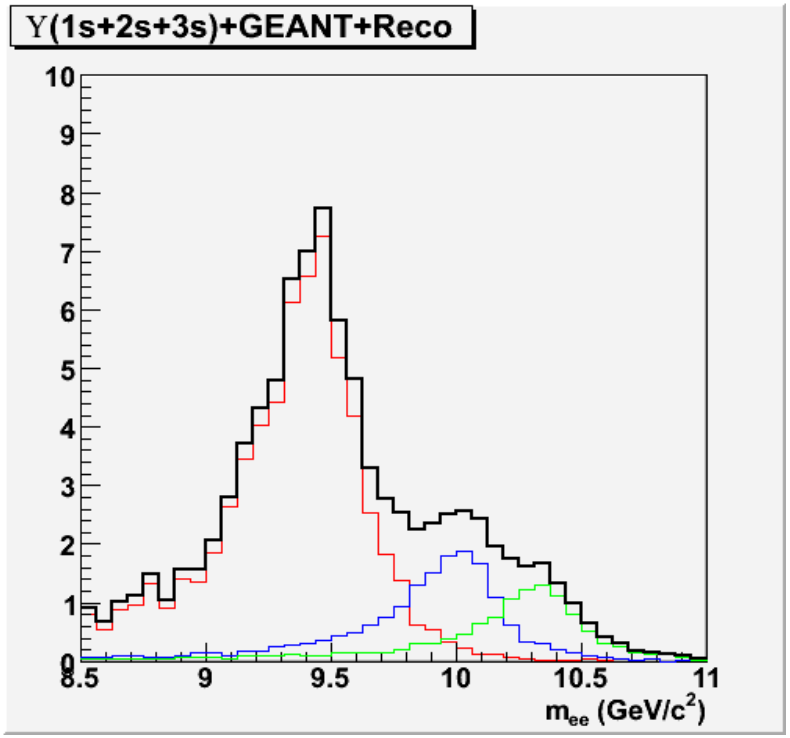
Upsilon d+Au Cross Section

RdAu=0.78±0.28(stat.)±0.20(syst.)

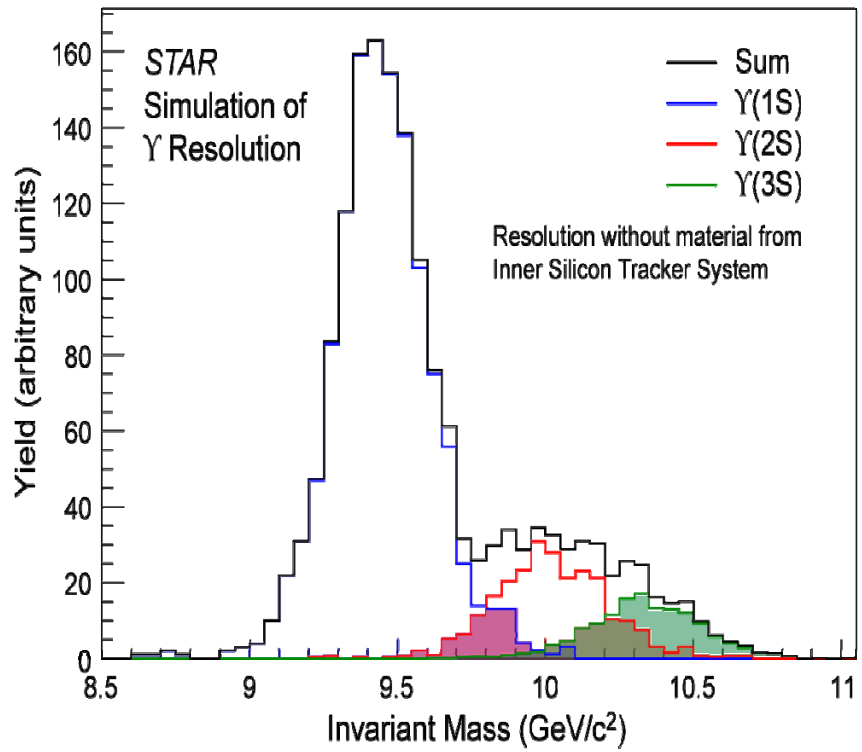
N_Υ	172 ± 20
ε_Υ	0.15 ± 0.02
$\int \mathcal{L} dt$	32 nb^{-1}
dy	1.0



σ=35 ± 4(stat.) ± 5(syst.) nb



With SVT



Without SVT

No Silicon Tracker!

Reduces EM material budget from 0.06 to 0.01 radiation lengths. Removed in Run 8 and beyond.

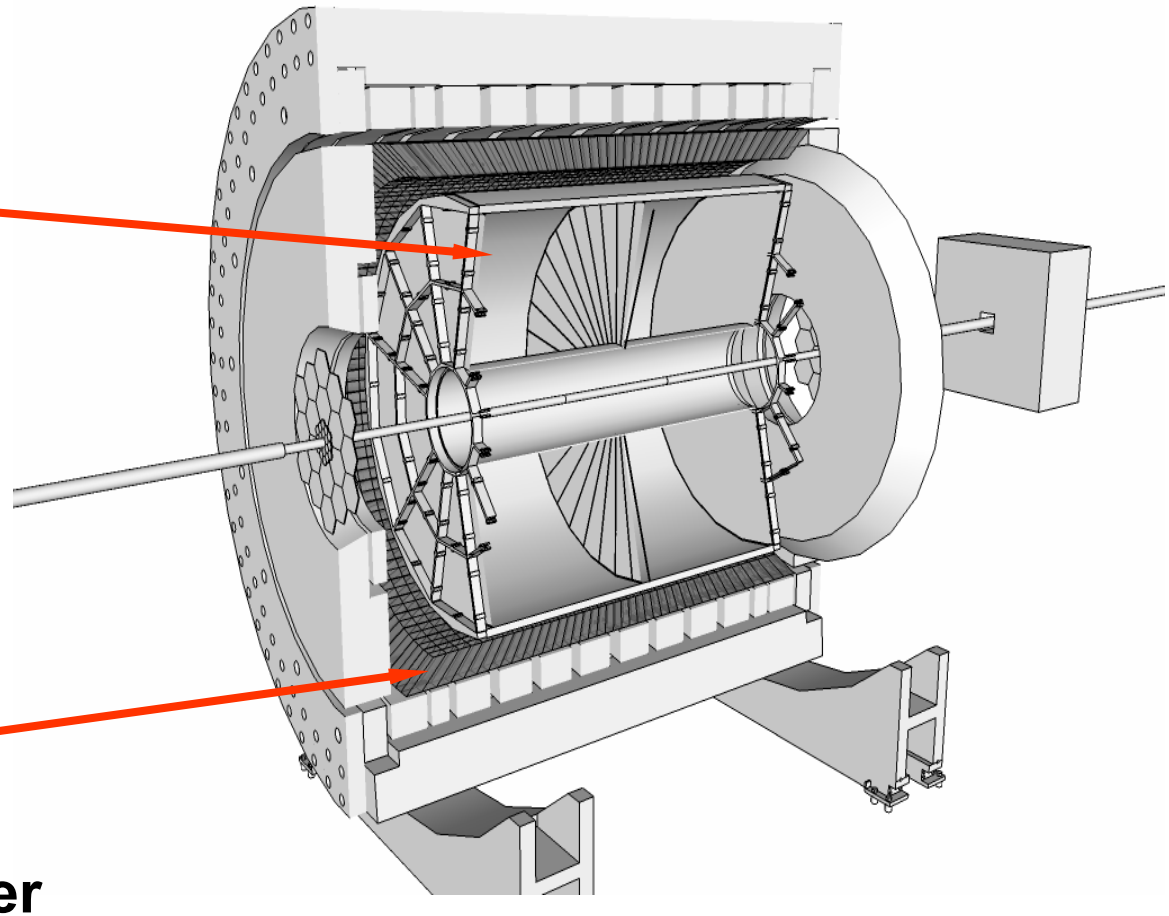
Υ at STAR

TPC

$|\eta| < 1$, $0 < \phi < 2\pi$

Tracking → momentum

dE/dx → electron ID



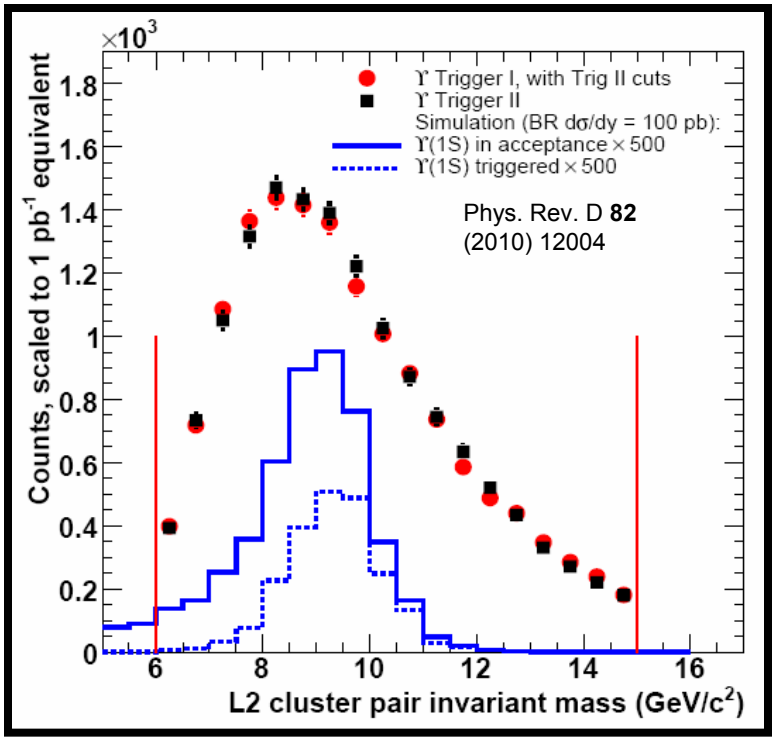
BEMC

$|\eta| < 1$, $0 < \phi < 2\pi$

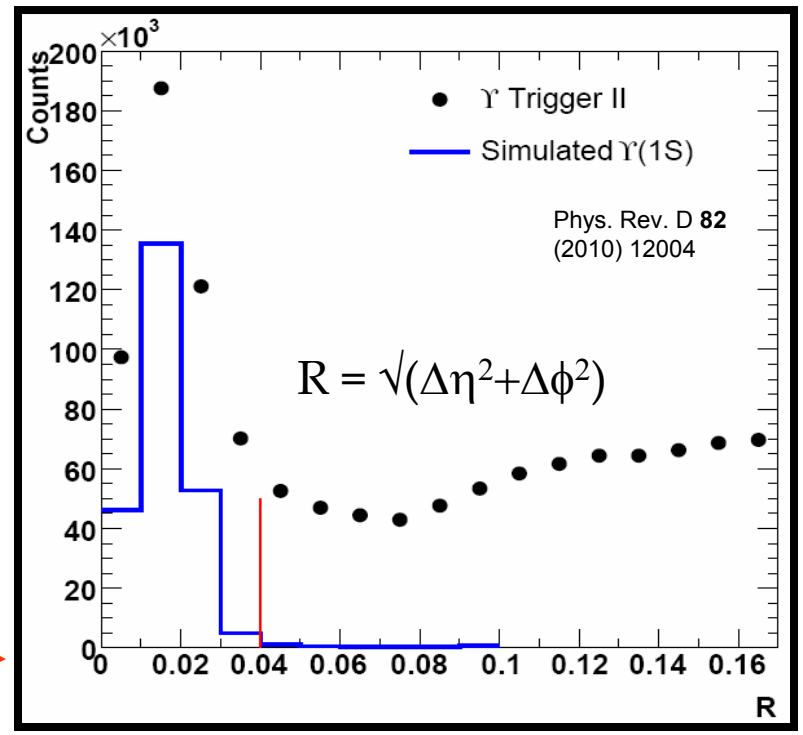
E/p → electron ID

High-energy tower trigger

Analysis Techniques

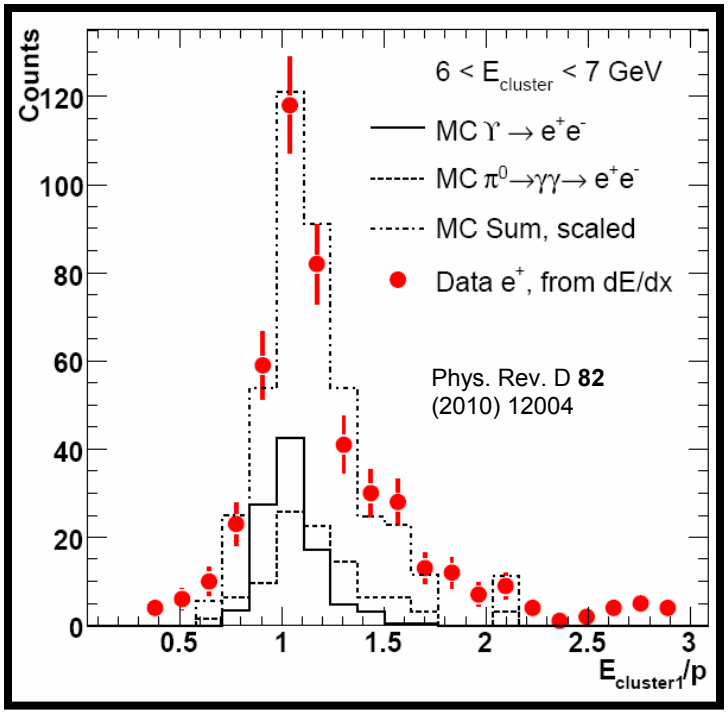


Triggered candidates exceed number of Υ by a factor of ~700 (p+p)

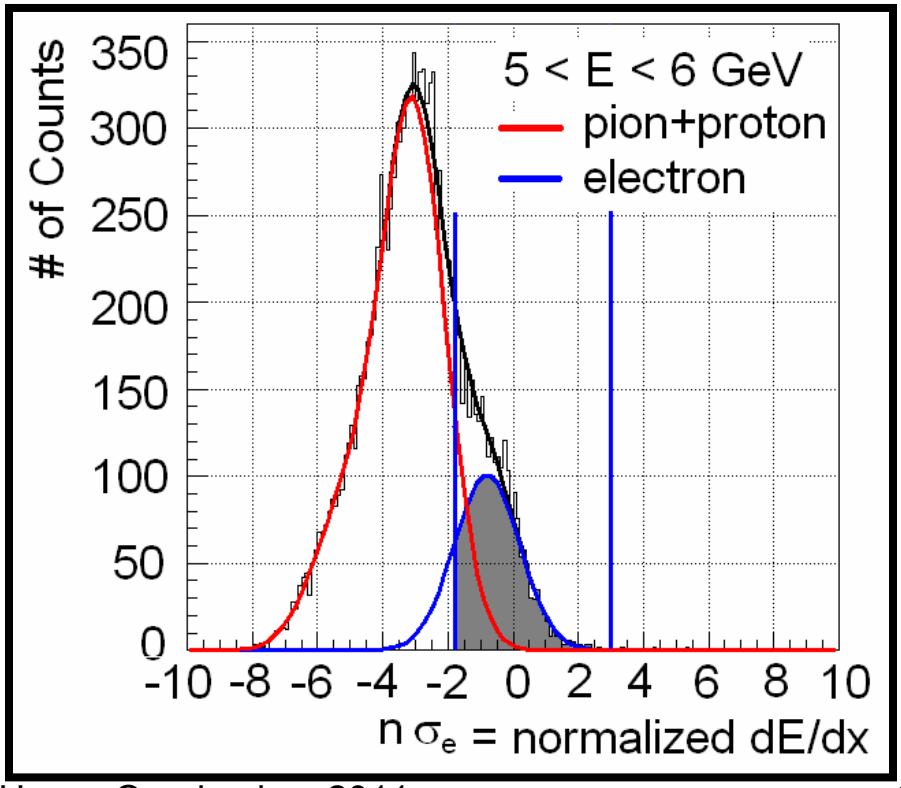


TPC tracks that extrapolate to R=0.04 in η–ϕ to trigger clusters are "matched"

Electron PID



E/p and dE/dx of matched tracks are used to select e^+ and e^- tracks



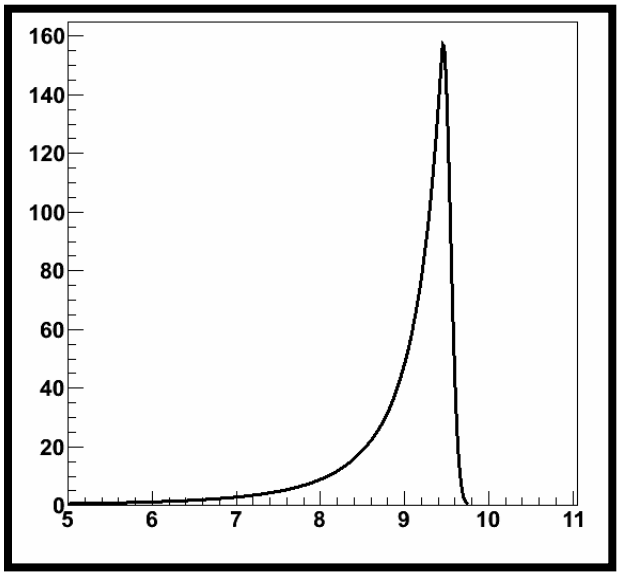
Electron purity is ~98% in p+p for single electron case

Analysis Techniques

Line shape is a crystal function parameterized by a comparison with simulation

$$f(x;\alpha,n,\bar{x},\sigma)=\begin{cases}\exp(-\frac{(x-\bar{x})^2}{2\sigma^2}),\ for\ \frac{x-\bar{x}}{\sigma}>-\alpha\\ A(B-\frac{x-\bar{x}}{\sigma})^{-n},\ for\ \frac{x-\bar{x}}{\sigma}\le-\alpha\end{cases}$$

$$B=\frac{n}{|\alpha|}-|\alpha| \qquad A=(\frac{n}{|\alpha|})^n\exp(-\frac{|\alpha|^2}{2})$$



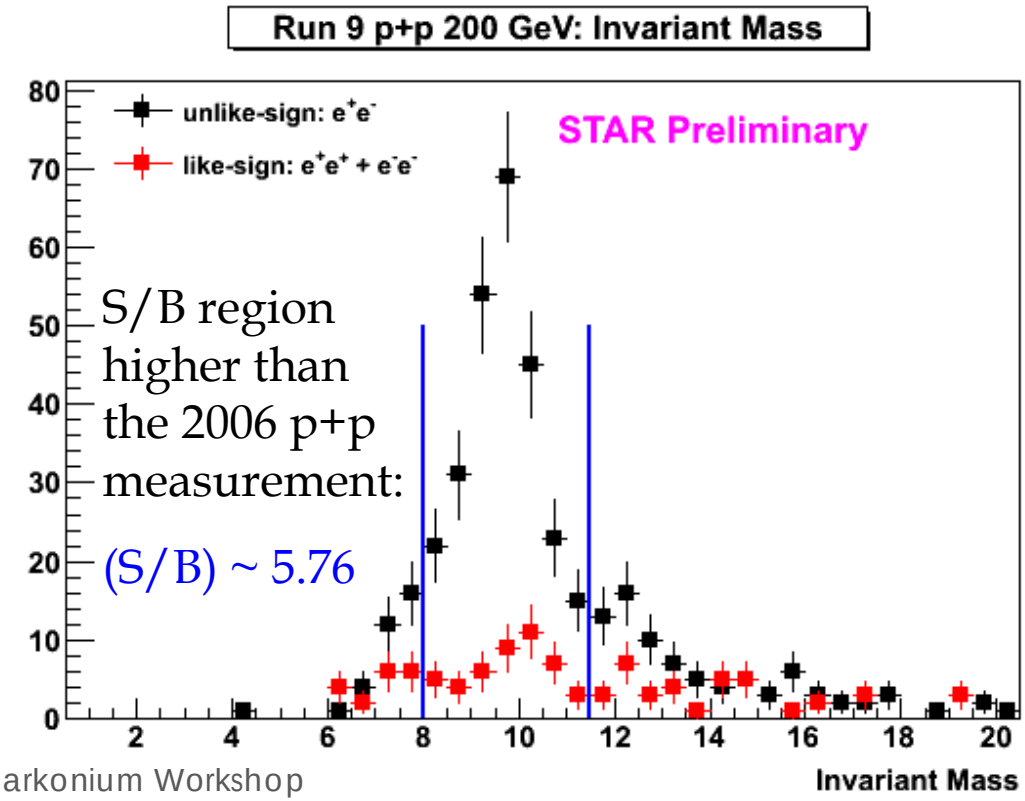
Parameterization of non-Combinatoric background:

Drell-Yan+$b\bar{b}$ = $\frac{A}{(1+\frac{m}{m_0})^n}$

n = 4.59, m_0 = 2.7

Υ(1S+2S+3S) cross-section

New cross-section measurement with ~x3 the statistics to be available shortly



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