Bottonium Measurements at Midrapidity at the STAR Experiment

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Why Bottonium?

Investigate the properties of the Quark- Gluon Plasma (Au+Au collisions)

✓Color screening→ Deconfinement Phys. Lett. B 178, 416(1986)

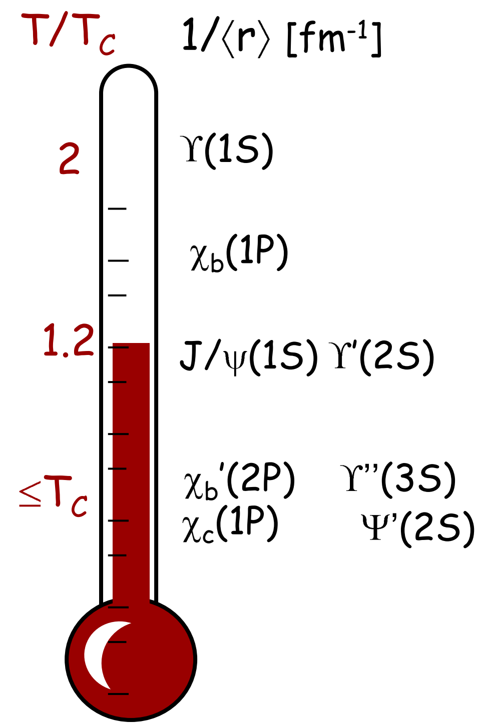
Υ(nS) is a differential probe: sequential disappearance of states

Expectation at 200 GeV: Υ(1S) not melt

Υ(2S) may melt, Υ(3S) will melt, J/ψ family will melt

QCD thermometer → QGP properties

Phys. Rev. Lett. 99, 211602 (2007), Phys. Rev. D 77, 014501 (2008)



p+p (baseline)

- Understanding the production mechanisms of Quarkonia

- **NRQCD, Color Octet Model (COM)** PRD51, 1125(1995)
- **Color Singlet Model (CSM)** PLB102, 364(1981)
  - CSM w/ s-channel cut PRL100, 032006(2008)
- **Color Evaporation Model (CEM)** PLB67,217(1977)
- **3g-pQCD** Eur.Phys.J.C39,163(2005)

➢Models have difficulties to reproduce quarkonia x-sections, pt, and polarizations simultaneously.

Why Bottonium?

STAR

d+Au (Cold Nuclear Matter-CNM effect)

- ✓ **Initial state energy loss**
- ✓ **gluon shadowing**
- ✓ **Cronin**
- ✓ **nuclear absorption**

p+p, d+Au, Au+Au

❖ **Feed-down contributions from higher states represent other source of uncertainty to the x-section measurements.**

Bottonium vs. Charmonium

- Significant feed-down from higher $c\bar{c}$ states and B meson decays compared to $b\bar{b}$.
- Cleaner probe of high-temperature color screening

Co-mover absorption is very small Phys. Lett. B 503, 104 (2001)

Recombination negligible at RHIC ($\sigma_{b\bar{b}} \approx 1.9\ \mu b << \sigma_{c\bar{c}}$)
Phys. Rev. Lett. 95, 122001 (2005)

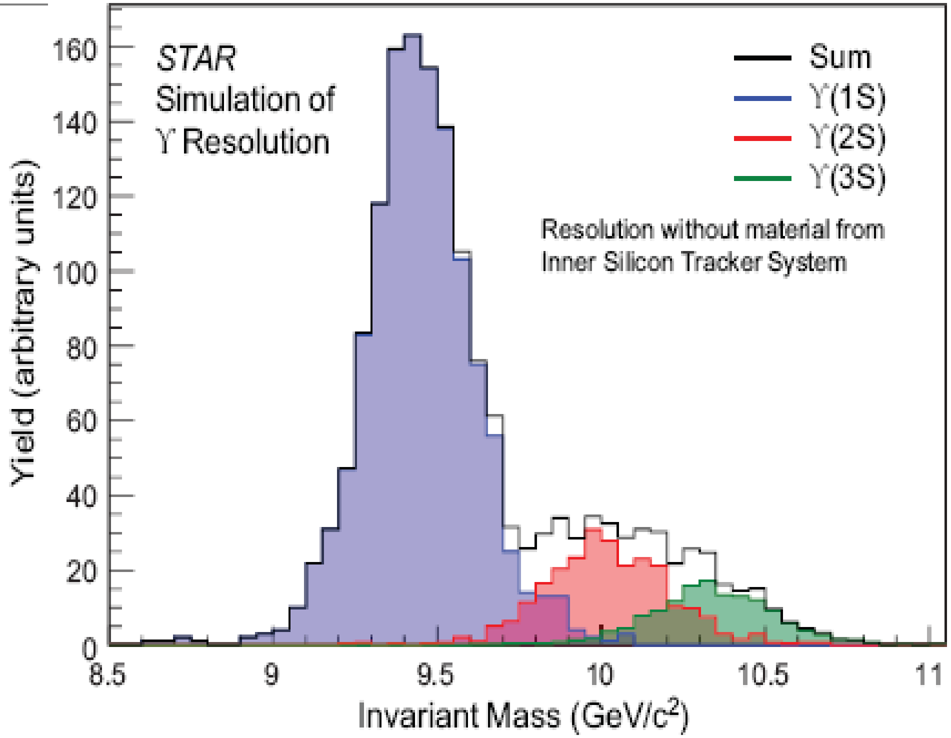
Practical issues with Bottonium measurements

Branching fractions for $\Upsilon(nS) \rightarrow e^+e^-$ Phys. Lett. B 667, 1 (2008)

Υ state	$\mathcal{B}$ (%)	σ (nb)
Υ(1S)	2.38±0.11	6.60
Υ(2S)	1.91±0.16	2.18
Υ(3S)	2.18±0.21	1.32

σ_{total} at $\sqrt{s}$ = 200 GeV (NLO CEM model)

Phys. Rept. 462, 125 (2008)



- Extremely low rate:

10^{-9} /minimum bias pp interaction

3 orders of magnitude smaller than $\sigma_{J/\psi}$

- Υ(1S+2S+3S) separation require high resolution

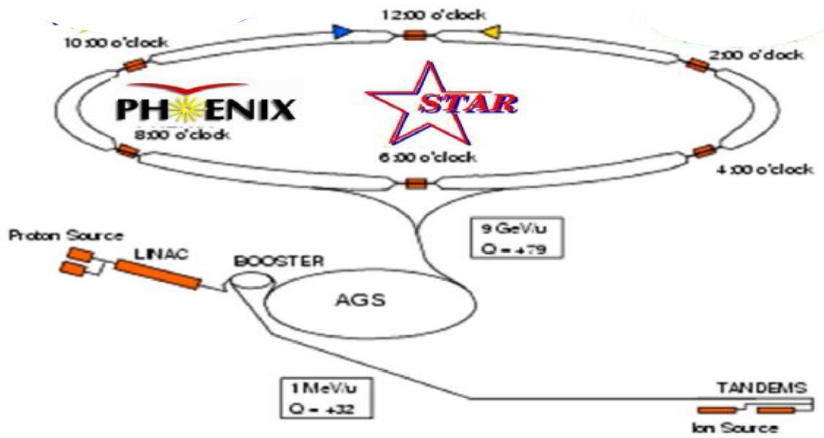
➢ With less radiation lengths (w/o inner tracker detectors) It is possible to separate The three states at STAR.

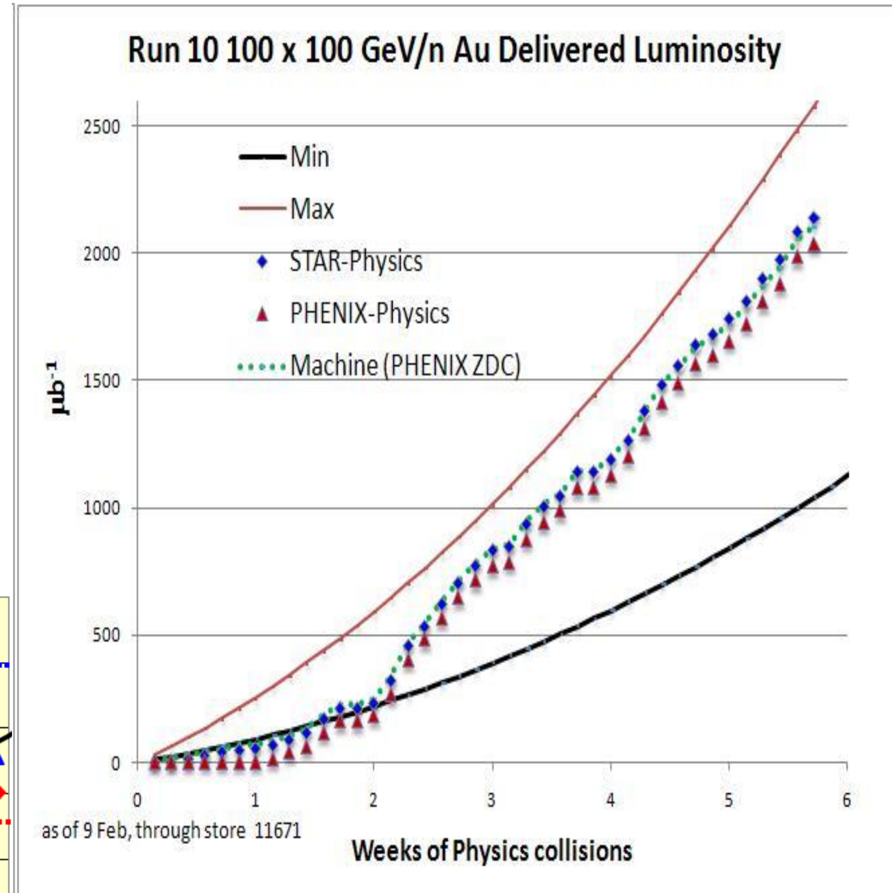
Run2006 p+p 200GeV
Run2007 Au+Au 200GeV } more x_0

Run2008 d+Au 200GeV, Run2009 p+p 200GeV, Run2010 Au+Au 200GeV ⟶ less x_0

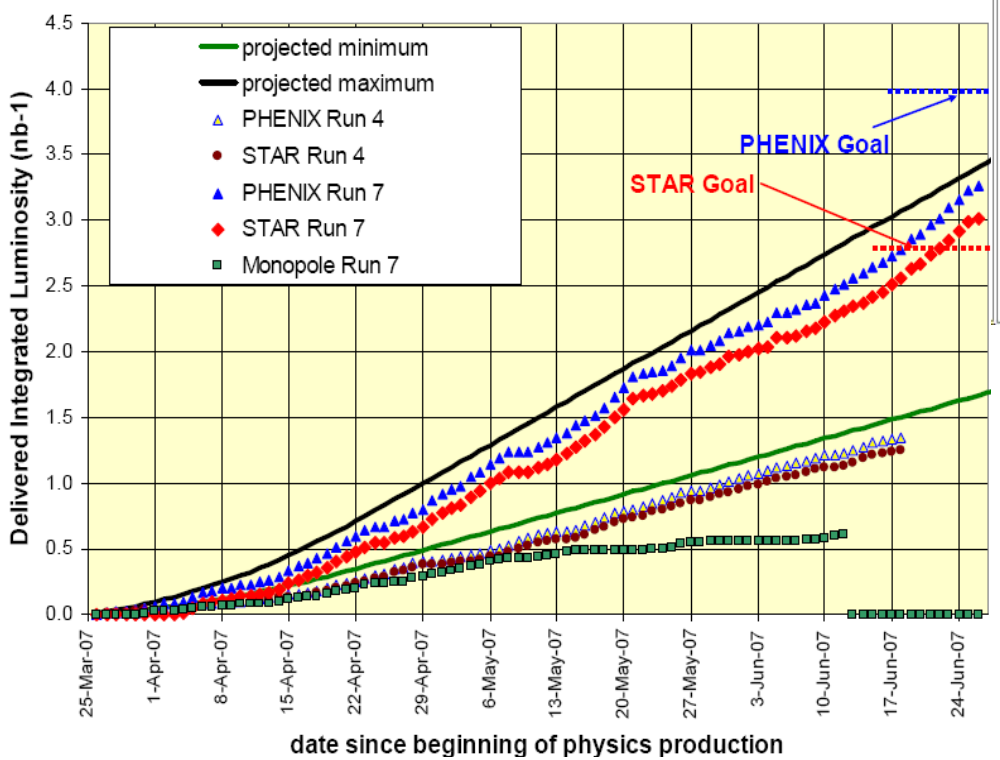
Needed: high luminosity, and acceptance, efficient triggers in p+p up to central Au+Au

RHiC machine





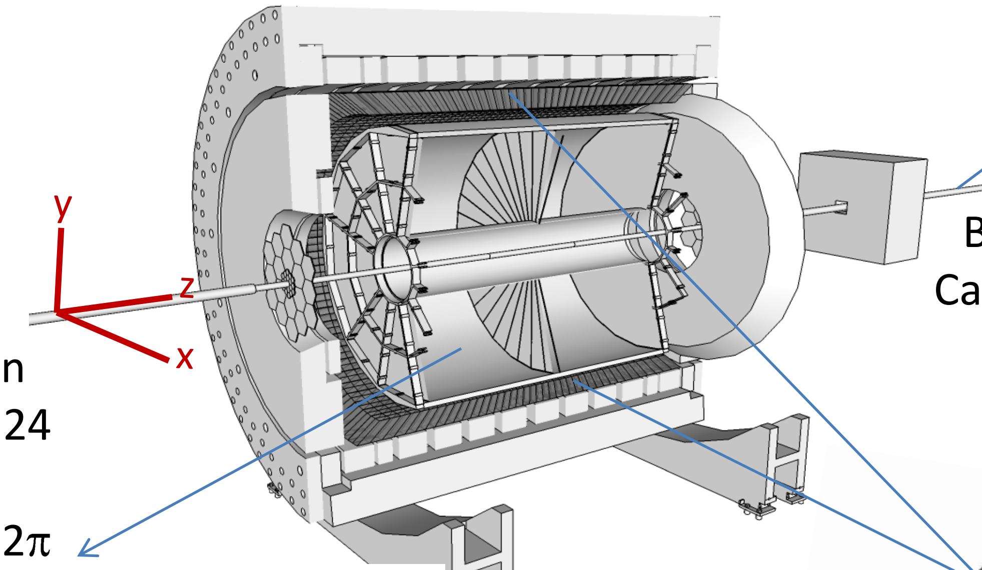
Run 7 100 GeV/n Au-Au Luminosity (final)



- Stochastic cooling
- DAQ upgrade

- As of Feb, 9th the integrated luminosity is approximately doubled.

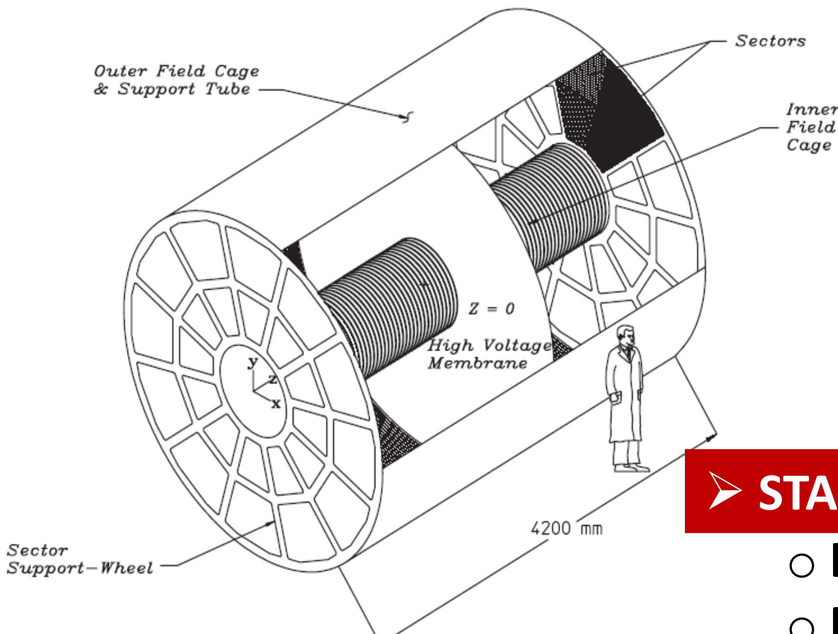
STAR detector

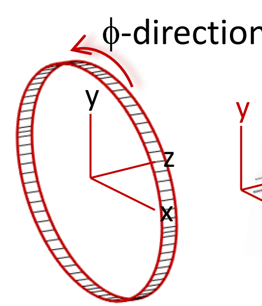


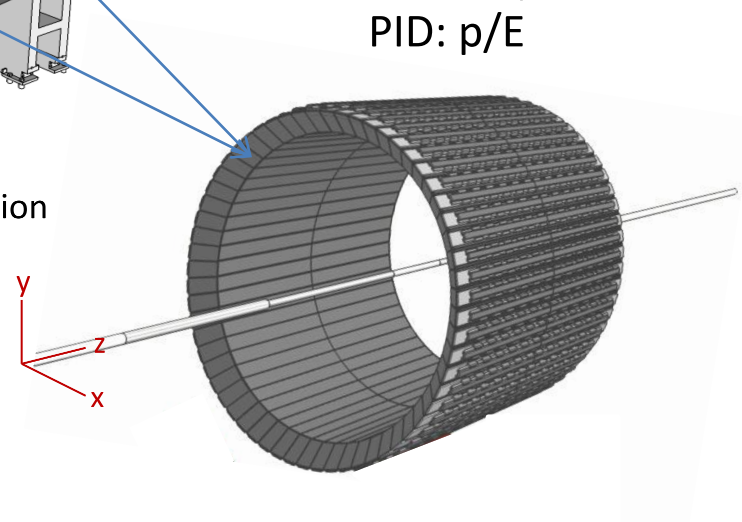
Beam line

Time Projection Chamber TPC – 24 sectors
$|\eta| < 1$, $0 < \phi < 2\pi$

Barrel Electromagnetic Calorimeter BEMC – 4800 towers
$|\eta| < 1$, $0 < \phi < 2\pi$
PID: p/E







- **STAR is well-suited detector to measure $\Upsilon \to e^+e^-$**
  - **Large acceptance**
  - **Efficient trigger**

STAR Υ Online & Offline analysis

➢ Online:

Trigger components: Select events with at least one candidate satisfies

○Fast Hardware trigger – L0

▪E_T (tower) > $E_{threshold}$

○Software trigger – L2

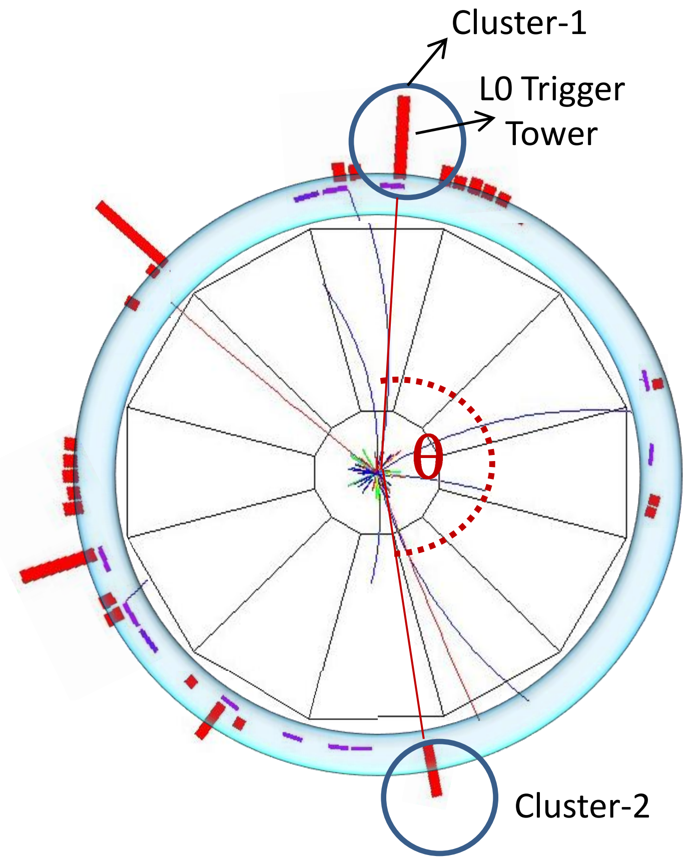
▪Forms clusters: $E_{cluster-1} > E_{threshold-1}$, $E_{cluster-2} > E_{threshold-2}$

▪Calculates cos θ,

▪Calculates $m_{cluster-1cluster-2} = \sqrt{2E_{cluster-1} * E_{cluster-2}(1-\cos\theta)}$

is $m_{cluster-1cluster-2} > m_{threshold}$?

Issue decision within ~ 5 ms for the slow detectors to continue/abort data-acquisition processes.



BEMC: Track-blind

➢ Offline:

Match TPC tracks to triggered towers

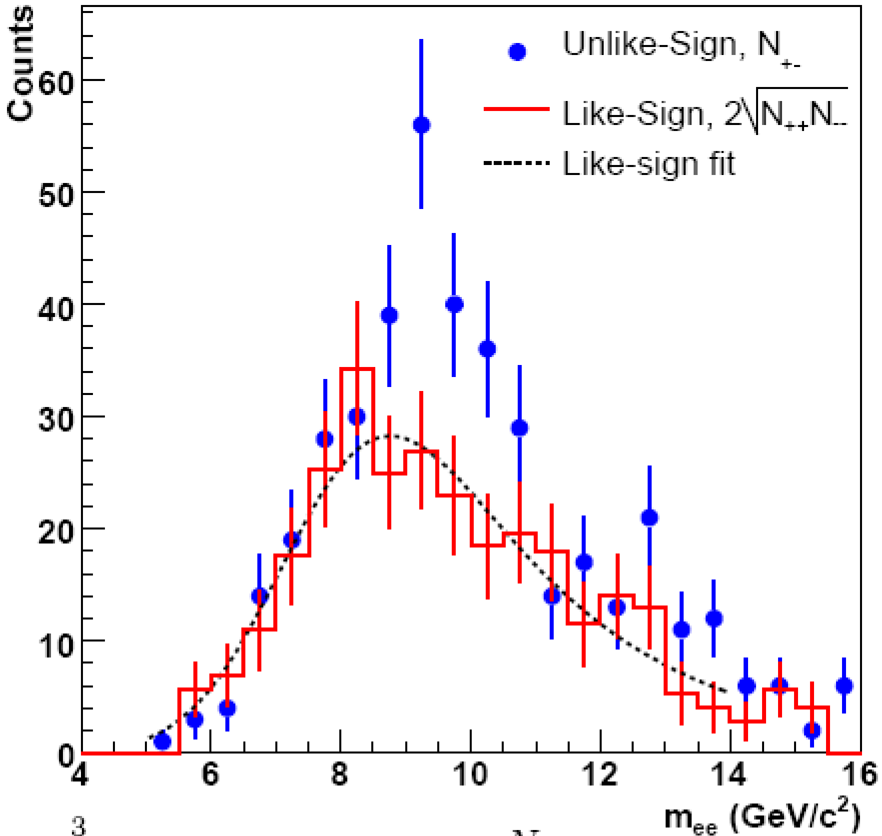
p+p @200 GeV e-Print: nucl-ex 1001.2745

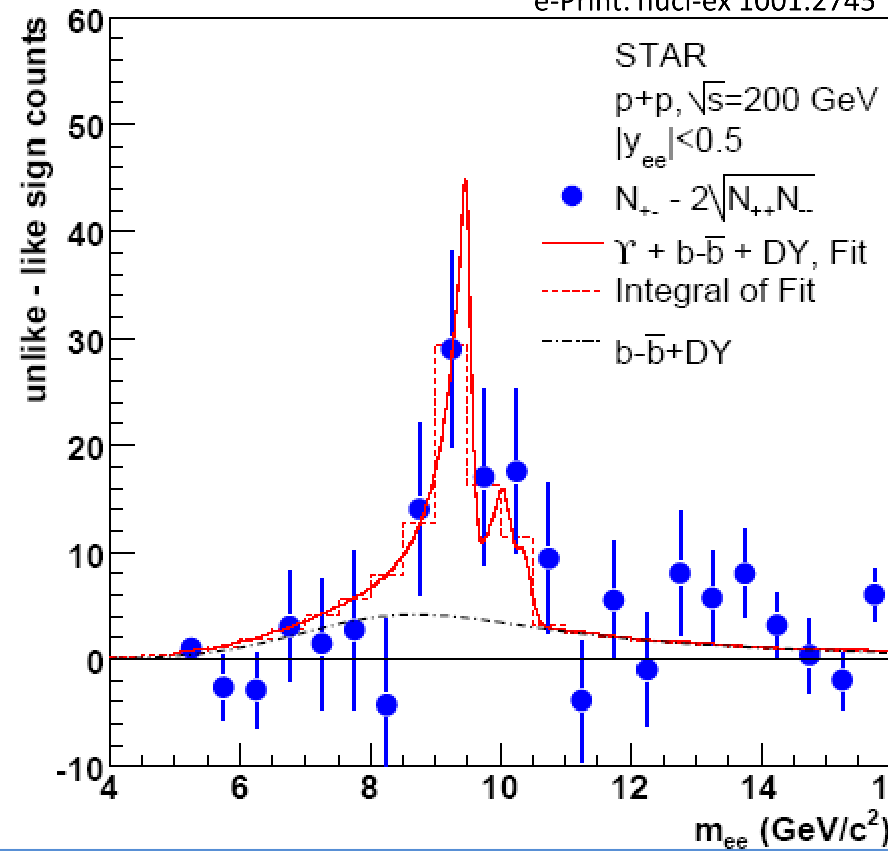
Geom., trigger, and tracking efficiency for reconstructing $\Upsilon \to e^+e^-$ in STAR at $|y_\Upsilon| < 0.5$

Quantity	Value
ϵ_{geo}	0.57
$\epsilon_{geo} \times \epsilon_{L0}$	0.25
$\epsilon_{geo} \times \epsilon_{L0} \times \epsilon_{L2}$	0.21
$\epsilon_{geo} \times \epsilon_{L0} \times \epsilon_{L2} \times \epsilon_{track} \times \epsilon_{R}$	0.13
$\epsilon_{geo} \times \epsilon_{L0} \times \epsilon_{L2} \times \epsilon_{track} \times \epsilon_{R}$ (1S+2S+3S)	0.14

First $\sigma_{\Upsilon(nS)}$ *measurements in p+p @ 200 GeV*

$\int \mathcal{L} dt = 7.9\ pb^{-1}$ of p+p (2006)





$$\sum_{n=1}^{3} \mathcal{B}(nS) \times \sigma(nS) = \frac{N}{\Delta y \times \epsilon \times \mathcal{L}},$$

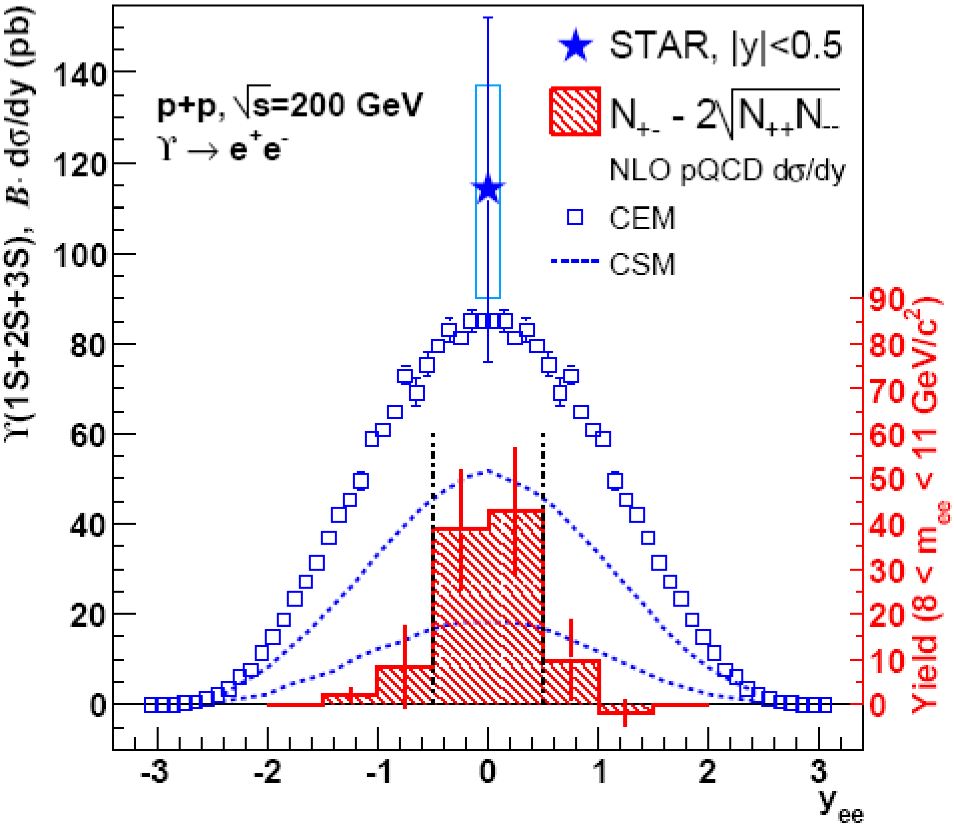
$$\left(\sigma_{\mathrm{DY}} + \sigma_{b\text{-}\bar{b}}\right)\Big|_{|y|<0.5,\ 8<m<11\ \mathrm{GeV}/c^2} = 38 \pm 24\ \mathrm{pb}$$

$$\epsilon = \epsilon_{\mathrm{geo}} \times \epsilon_{\mathrm{vertex}} \times \epsilon_{\mathrm{L0}} \times \epsilon_{\mathrm{L2}} \times \epsilon_{\mathrm{TPC}} \times \epsilon_{R} \times \epsilon_{dE/dx} \times \epsilon_{E/p}$$

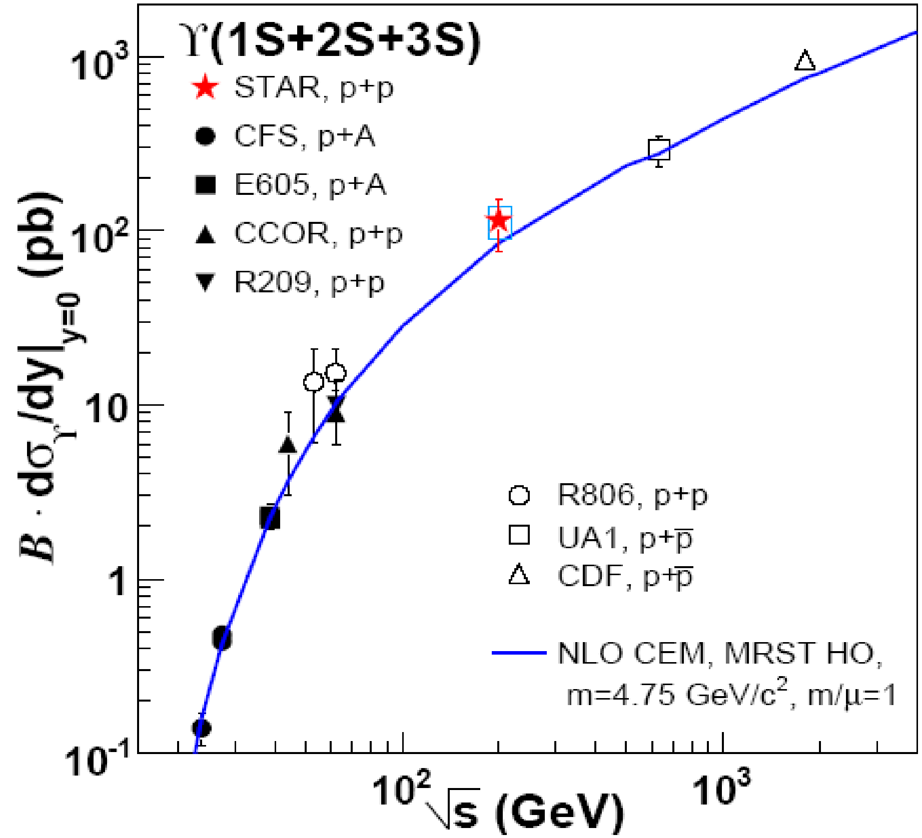
$$\sum_{n=1}^{3} \mathcal{B}(nS) \times \sigma(nS) = 114 \pm 38\ ^{+23}_{-24}\ \mathrm{pb}$$

$\sigma_{\Upsilon(nS)}$ *measurements vs. theory and world data*

e-Print: nucl-ex 1001.2745



e-Print: nucl-ex 1001.2745



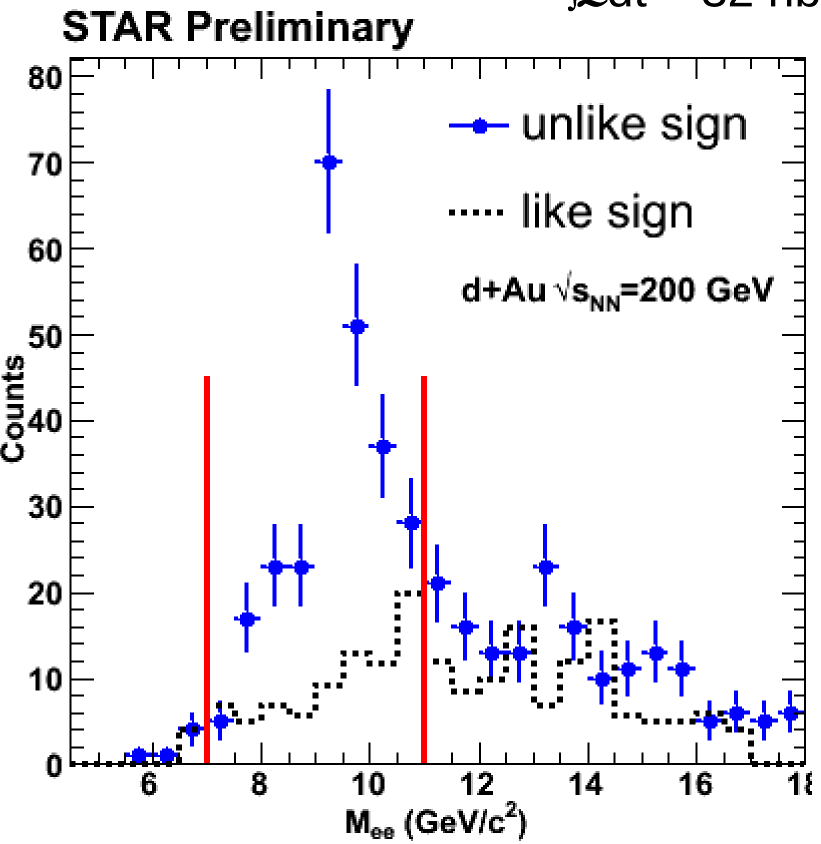
STAR $\sigma_{\Upsilon(nS)}$ in p+p at 200 GeV at midrapidity |y| < 0.5 is:

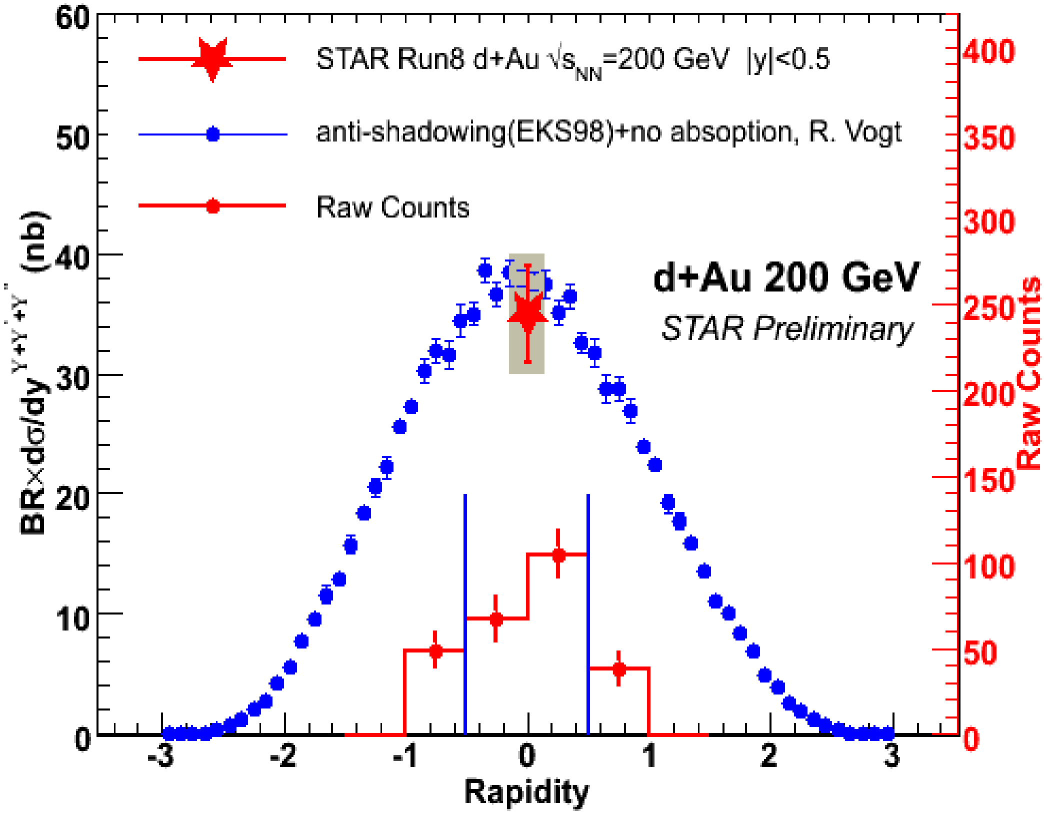
- ➢ in agreement with CEM at NLO,
- ➢ inconsistent with CSM (2σ effect),
- ➢consistent with world data trend.

STAR Preliminary Υ measurements in d+Au @ 200 GeV

$\int \mathcal{L}dt = 32\ nb^{-1} \approx 12.5\ pb^{-1}$ (p+p)

(H. Liu, QM 2009) nucle-ex 0907.4538





$$BR \times \left(\frac{d\sigma}{dy}\right)_{y=0}^{\Upsilon(1S+2S+3S)} = 35 \pm 4(stat.) \pm 5(sys.)\ \text{nb.}$$

STAR preliminary $\sigma_{\Upsilon(nS)}$ in d+Au at 200 GeV at midrapidity |y| < 0.5 is:

- consistent w/ CEM calculations at NLO including anti-shadowing.

$$R_{dAu} = \frac{dN^{dAu}/dy}{\langle n_{coll}^{dAu} \rangle dN^{pp}/dy}$$

$$R_{dAu} = 0.98 \pm 0.32(stat.) \pm 0.28(sys.)$$

CNM effects are not large, need more p+p statistics in order to quantify the effect.

Summary and Outlook

STAR

- $|y|<0.5$ preliminary meas. of $\Upsilon+\Upsilon'+\Upsilon''\rightarrow e^+e^-$ cross-section at $\sqrt{s}$=200 GeV
  - p+p 3σ Signal Significance with

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

    - in agreement with CEM at NLO,
    - inconsistent with CSM (2σ effect),
    - consistent with world data trend.

    Report the combined continuum cross-section of (Drell-Yan+b-$\bar{b}$->e^+e^-)

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

  - d+Au 8σ Signal Significance with

$$BR \times \left(\frac{d\sigma}{dy}\right)^{\Upsilon(1S+2S+3S)}_{y=0} = 35 \pm 4(stat.) \pm 5(sys.) \text{ nb.}$$

    - consistent w/ CEM calculations at NLO including anti-shadowing.

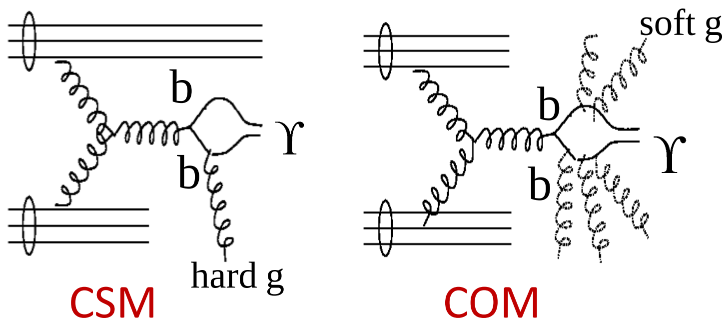
$$R_{dAu} = 0.98 \pm 0.32(stat.) \pm 0.28(sys.).$$

    - Follows Binary Scaling (in 200 GeV dAu collisions)

- Large luminosity at RHIC and full azimuth acceptance at the STAR experiment enable these measurements. Expect reduced uncertainties from further analysis and future runs, 20 pb^{-1} of p+p (2009) with low x_0 vs. 7.9 pb^{-1} (2006).

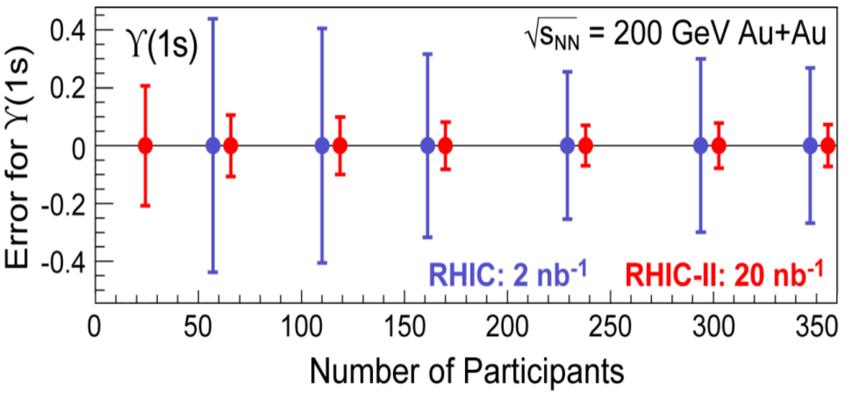
Summary and Outlook

- ϒ-hadron correlations and polarization measurements of ϒ are underway.



- ϒ Cross-section result in Au+Au Run (2007) is coming soon

Projection for statistical uncertainties in ϒ(1S) measurements.



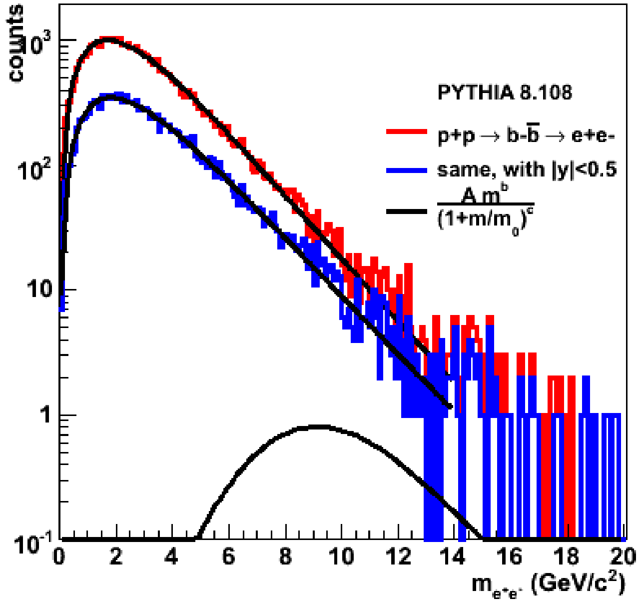
- Muon Telescope Detector (MTD), one of STAR upgrades, will enhance its capability for the quarkonia measurements.
  - online trigger enhancement factor: 10-50

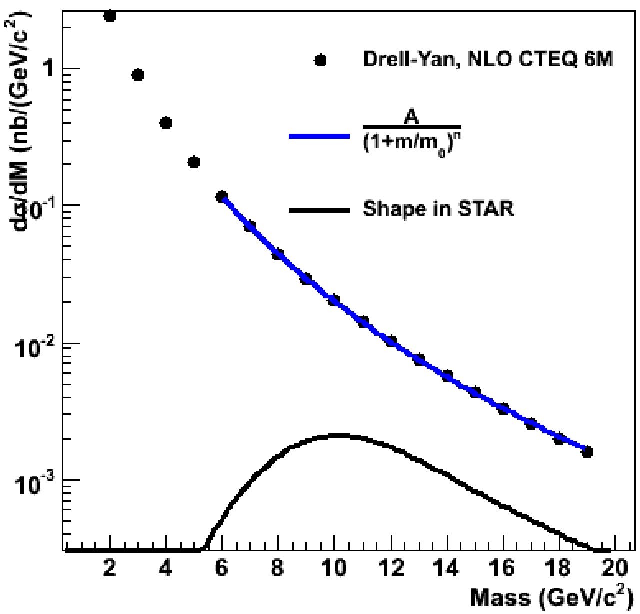
Backup slides

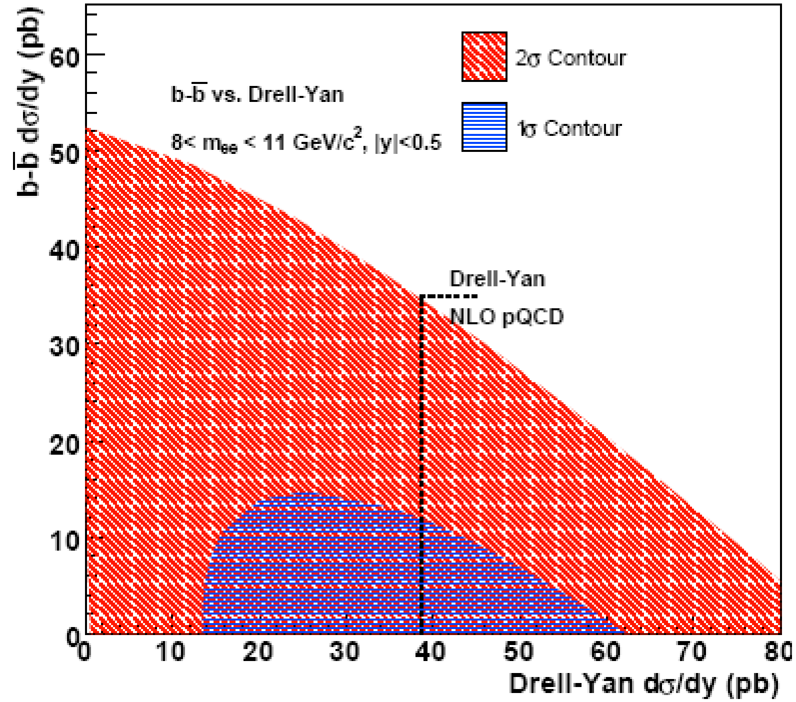
Systematic uncertainties on the measurements of σ_Υ

Quantity	Value	Syst. uncertainty on $d\sigma/dy$ (%)
$N_{+-} - 2\sqrt{N_{++}N_{--}}$	82.7	$^{+0}_{-9}$
$\mathcal{L}$	7.9 pb^{-1}	± 7
ϵ_{BBC}	0.87	± 9
ϵ_{geo}	0.57	$^{+3.0}_{-1.7}$
$\epsilon_{\mathrm{vertex}}$	0.96	± 1.0
ϵ_{L0}	0.43	$^{+7.5}_{-5.9}$
ϵ_{L2}	0.85	$^{+0.7}_{-0.2}$
ϵ_{TPC}	0.85^2	$2 \times \pm 5.8$
ϵ_R	0.93^2	$2 \times ^{+1.1}_{-0.2}$
$\epsilon_{dE/dx}$	0.84^2	$2 \times \pm 2.4$
$\epsilon_{E/p}$	0.93^2	$2 \times \pm 3.0$
Combined		$^{+22.8}_{-24.1}$

Drell-Yan and b-$\bar{b}$ continuum contributions







✓ Obtaining the expected shape from b$\bar{b}$ simulation PHYTIA and Drell-Yan (NLO pQCD).

✓ The continuum cross sections determined by a combined fit to bg. subtracted data.