

Υ Production in Heavy-Ion Collisions from the STAR Experiment

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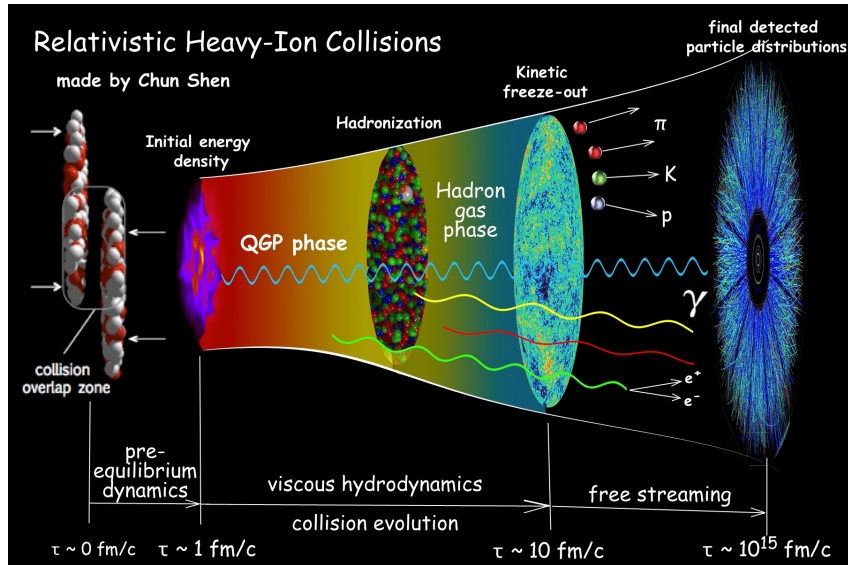
Wuhan

HP2016

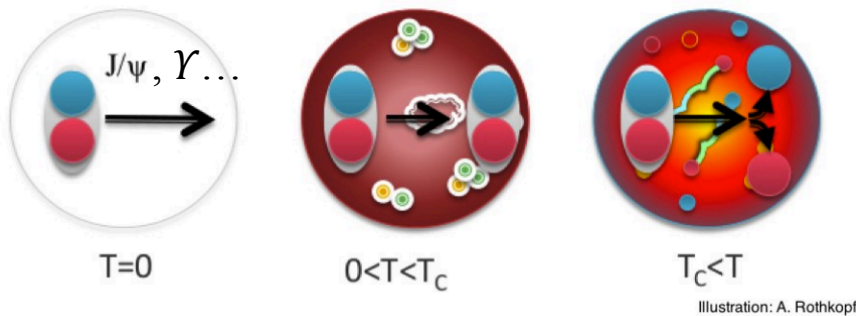
Outline

- **Quarkonia as a probe of QGP**
- **STAR experiment**
- **Υ measurements at STAR**
 - ❑ 2010 Au+Au and 2012 U+U data via di-electron channel
 - ❑ 2014 Au+Au data via di-muon channel (new)
 - ❑ 2015 p+p, p+Au, 2011 + 2014 Au+Au data via di-electron channel (on-going)
- **Summary and Outlook**

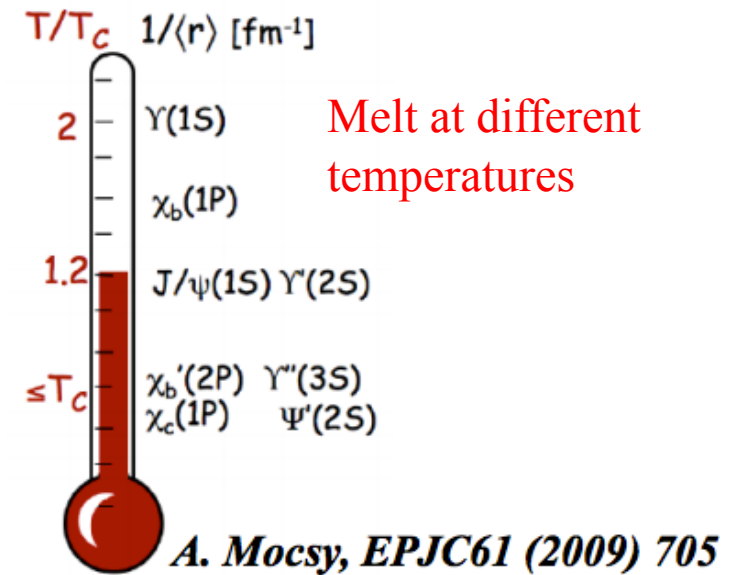
Quarkonia as the thermometer of QGP



QGP can be created and studied in heavy-ion collisions



Quarkonium could melt in the QGP due to the color screening effect ----- T.Matsui and H. Satz(1986)



QGP Thermometer

Υ is a cleaner probe for QGP

Things are never
easy !!

- Complicated contributions to quarkonium suppression:

- Color-screening
- Recombination
- Nuclear PDF
- Co-mover absorption
- Cronin effect
- Feed-down contributions
- ...

- Advantages of bottomonia over charmonia at RHIC:

- Regeneration is negligible

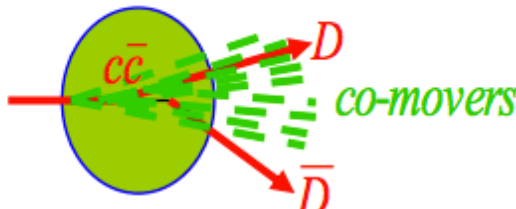
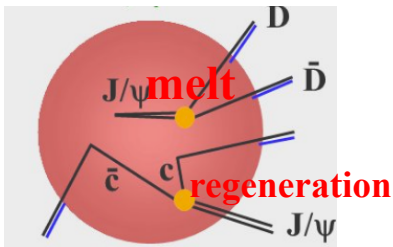
A. Emerick, X. Zhao & R. Rapp Eur.Phys.J. A48 (2012) 72

- Co-mover absorption is negligible

Lin & Ko, PLB 503 104 (2001)

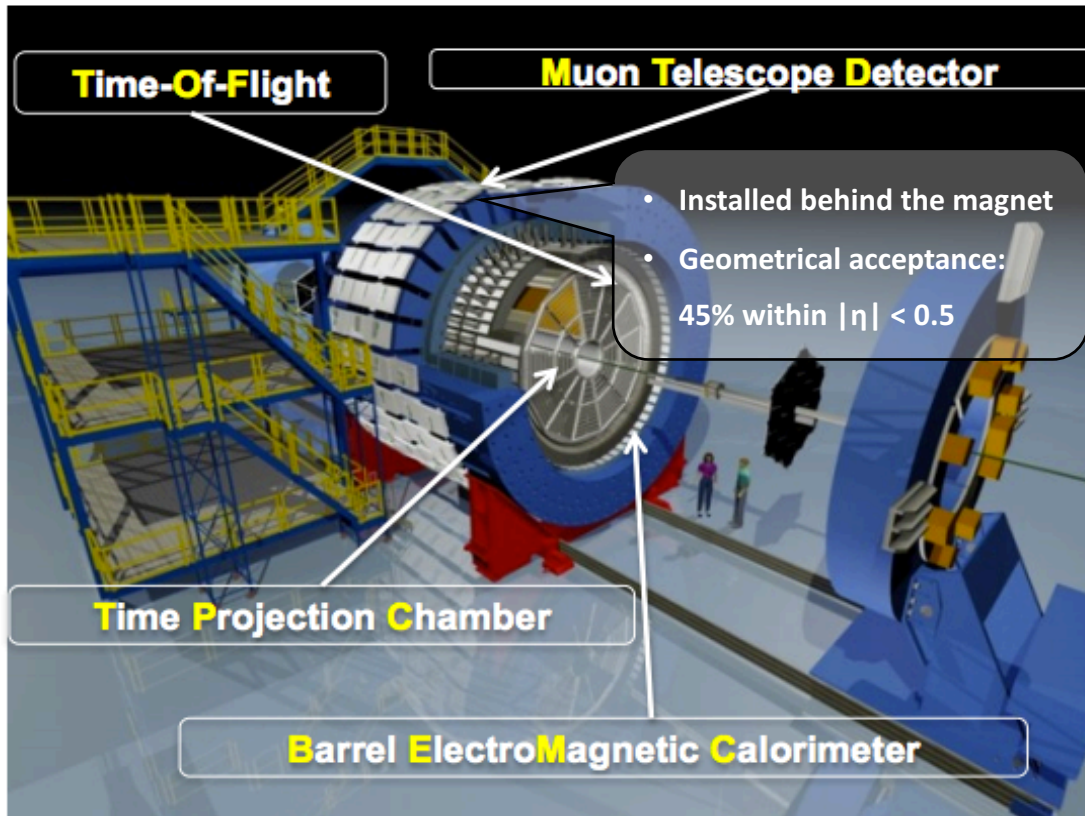
However:

- Feed-down from excited states still exists
- Cold nuclear matter effects
- Lower production rates



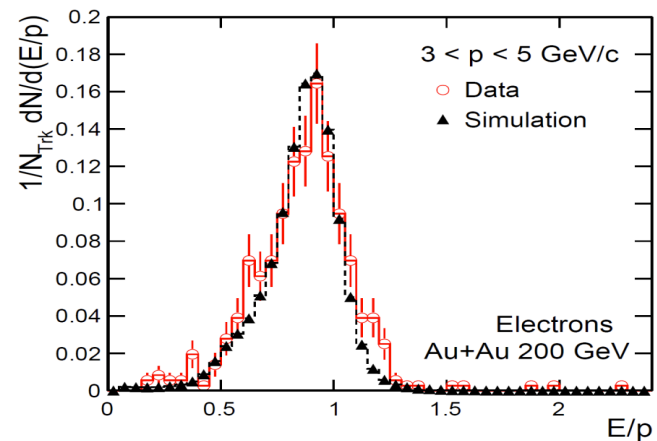
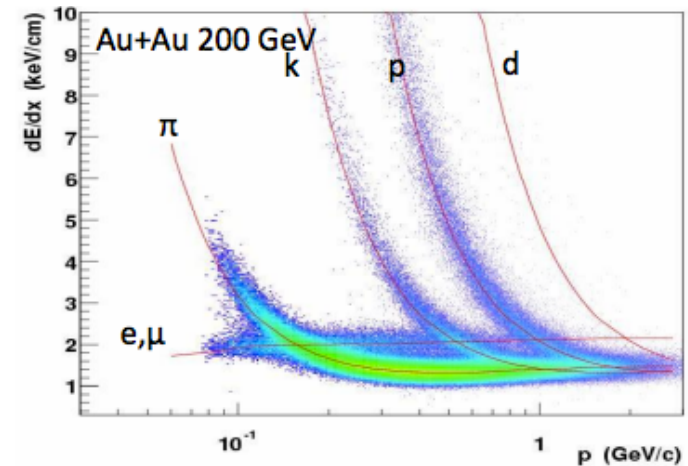
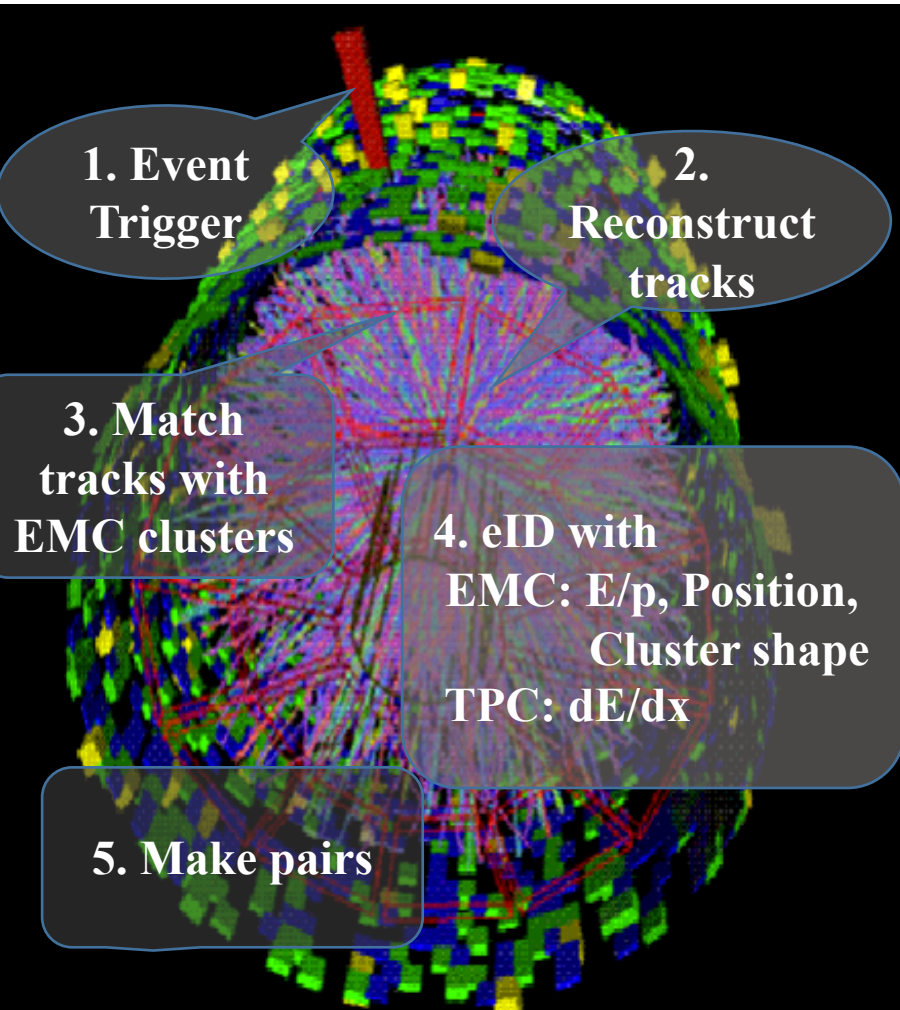
The Solenoidal Tracker At RHIC (STAR)

- Mid-rapidity detector: $|\eta| < 1, 0 < \phi < 2\pi$



- **TPC**: precisely measure momentum and energy loss
- **TOF**: measure time-of-flight
- **BEMC**: trigger on and identify electrons
- **MTD ($|\eta| < 0.5$)**: trigger on and identify muons
 - **Installed 63% in 2013 and 100% in 2014** behind magnet
 - *Precise timing measurement ($\sigma \sim 100$ ps)*
 - *Dimuon trigger for quarkonia*

γ reconstruction via di-electron channel



Υ measurements at STAR

Υ has been measured in di-electron channel for different collision systems at STAR:

- pQCD benchmark and reference:

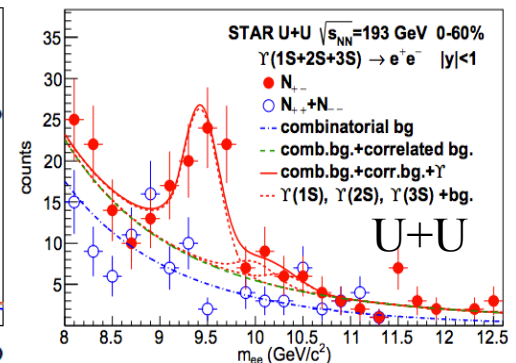
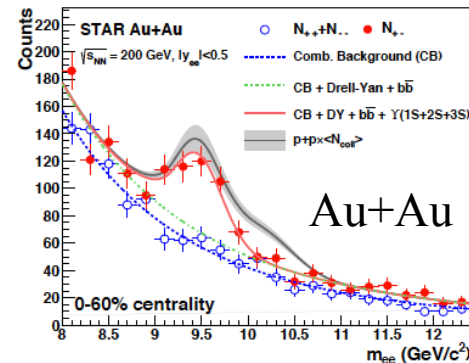
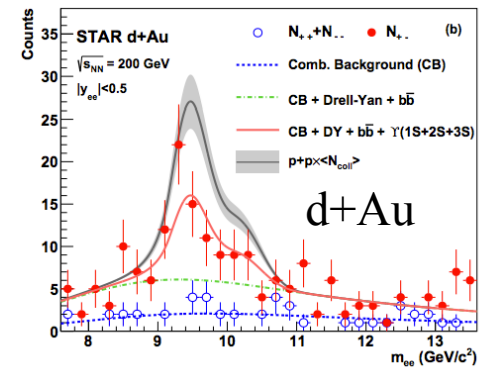
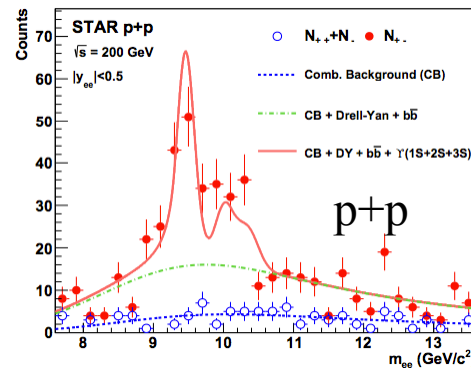
- p+p at $\sqrt{s} = 200 \text{ GeV}$
 - Luminosity = 20.0 pb^{-1}
 - PLB 735 (2014) 127

- Cold nuclear matter effects:

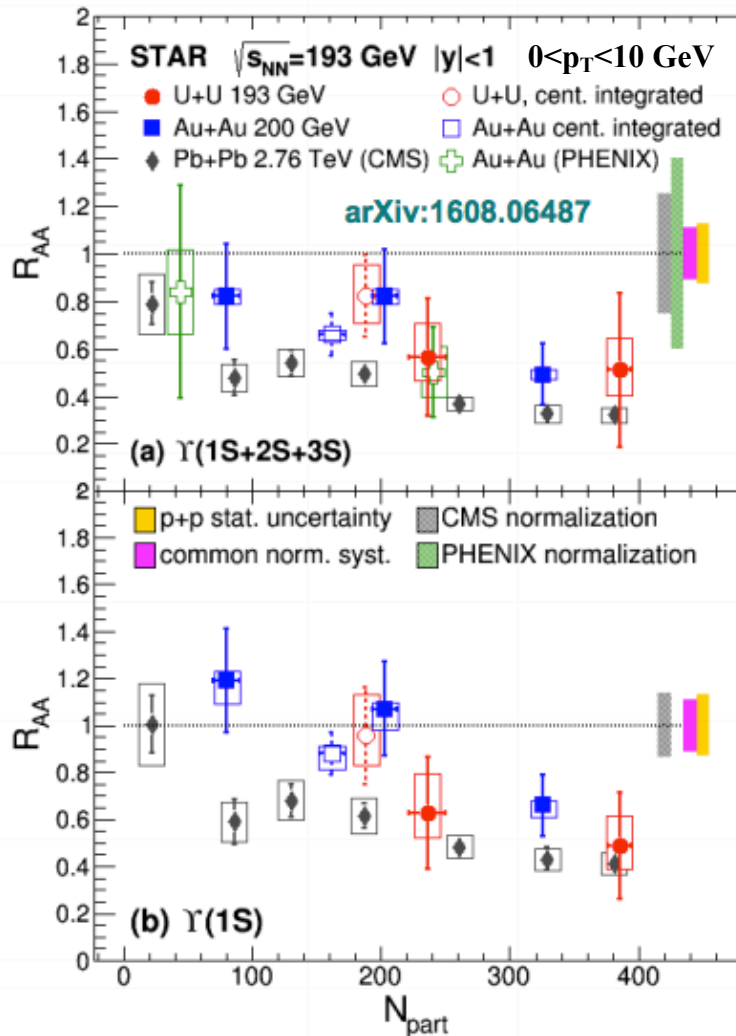
- d+Au at $\sqrt{s_{NN}} = 200 \text{ GeV}$
 - Luminosity = 28.2 nb^{-1}
 - PLB 735 (2014) 127

- Hot nuclear matter effects:

- Au+Au at $\sqrt{s_{NN}} = 200 \text{ GeV}$
 - PLB 735 (2014) 127
 - U+U at $\sqrt{s_{NN}} = 193 \text{ GeV}$
 - arXiv:1608.06487



Υ R_{AA} in Au+Au and U+U collisions



$$R_{AA} = \frac{1}{\frac{\sigma_{AA}}{\sigma_{pp}}} \times \frac{1}{\langle N_{coll} \rangle} \times \frac{B_{ee} \times \left(\frac{d\sigma_{AA}}{dy} \right)^\Upsilon}{B_{ee} \times \left(\frac{d\sigma_{pp}}{dy} \right)^\Upsilon}$$

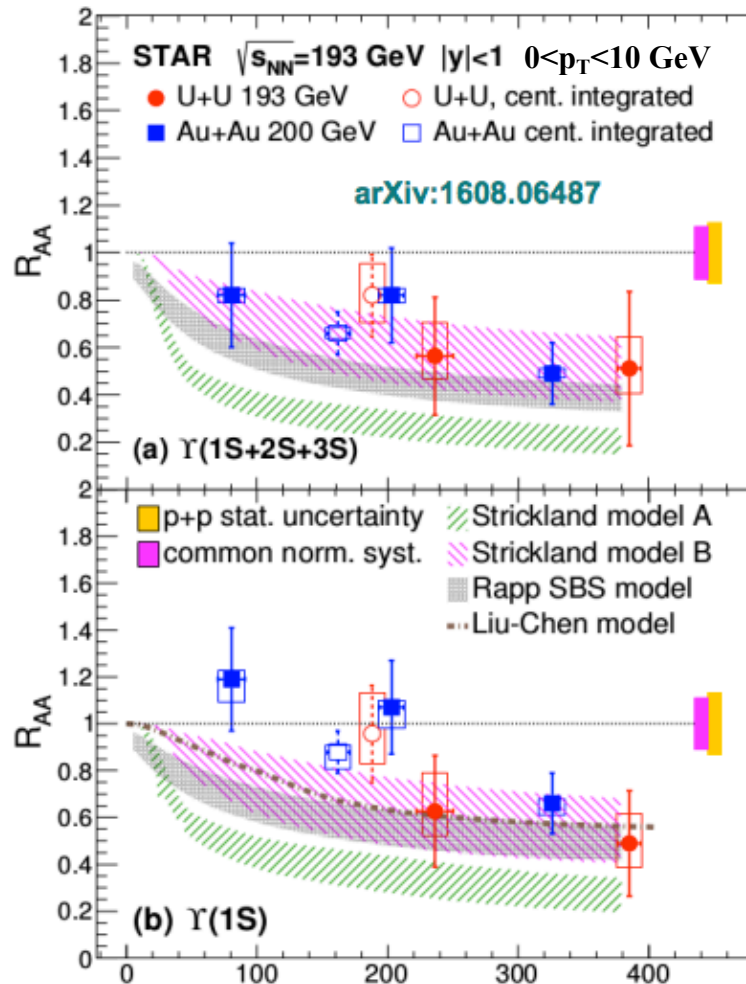
Υ in peripheral collisions:

- No significant suppression

Υ in central collisions:

- In Au+Au: Suppression
- In U+U:
 - Extend the N_{part}
 - Indicative suppression
 - consistent with Au+Au within large uncertainty

Compare with model predictions



Models without CNM effects:

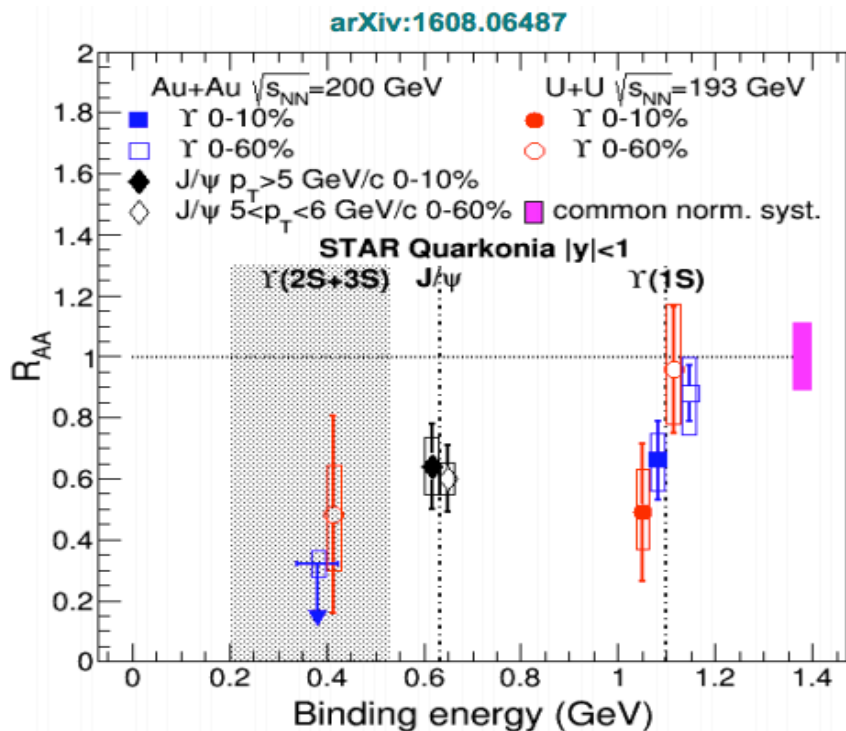
- **Strickland, Bazov:** [Nucl.Phys.A 879,25(2012)]
 - $428 < T < 443$ MeV
 - Hydro-dynamically expanding fire ball
 - Feed down
 - **Model A:** free energy as heavy quark potential
 - **Model B:** internal energy as heavy quark potential
- **Liu, Chen, Xu, Zhuang** [Phys.Lett.B 697, 32(2011)]
 - $T = 340$ MeV
 - Feed down included
 - Only excited states could dissociate

Model with CNM effects:

- **Emerick, Zhao, Rapp SBS model:** [Eur.Phys.J A48, 72 (2012)]
 - $T = 330$ MeV
 - Modified nPDFs
 - Absorption : cross-section $\sigma_{\text{(abs)}}$ 0-3 mb

The internal-energy-based models generally describe the data.

Quarkonium suppression in Au+Au and U+U



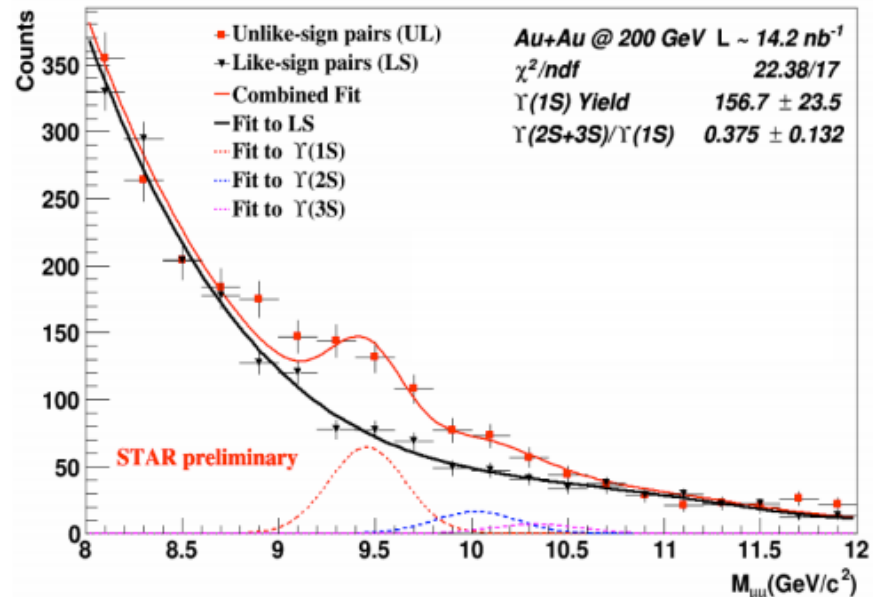
$\Upsilon(1S)$ suppression is similar to high p_T J/ψ in most central collisions

Excited states:
A hint of suppression

More precise measurement is needed!!

Υ in Au+Au from di-muon channel

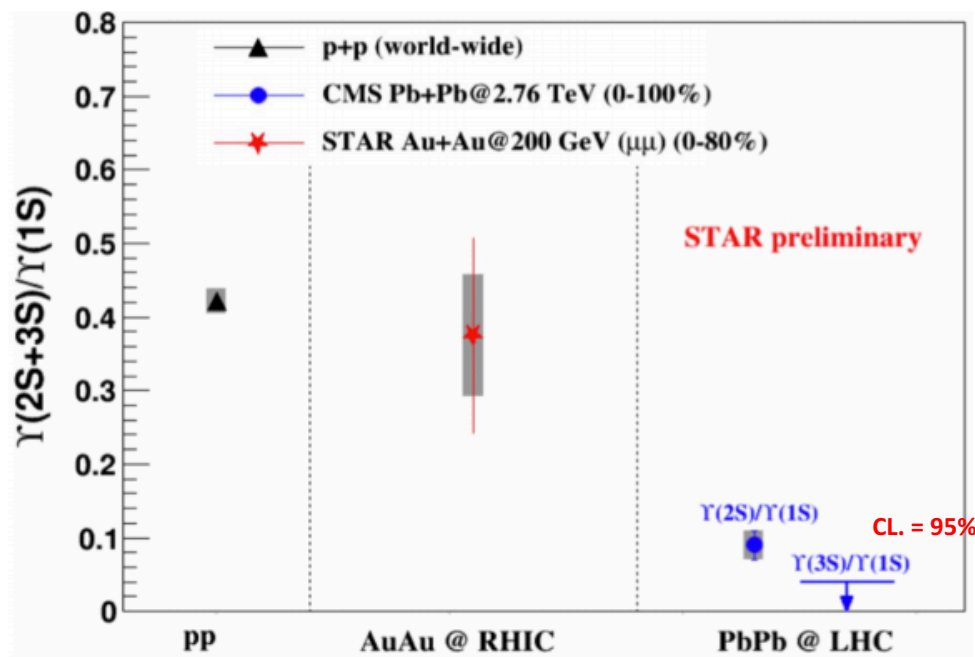
- Υ is reconstructed for the **first time** via di-muon channel in Au+Au at 200 GeV at STAR.
- Better separation of different Υ states.
 - Muons suffer very little Bremsstrahlung radiation



Υ yield extraction:

- Signals: $\Upsilon(1S) + \Upsilon(2S) + \Upsilon(3S)$ Gaussian line shapes from simulation
- Background:
 - Combinatorial background: 5th pol
 - Residual background: Exponential line shape from simulation

Ratio of excited Υ states to the ground state



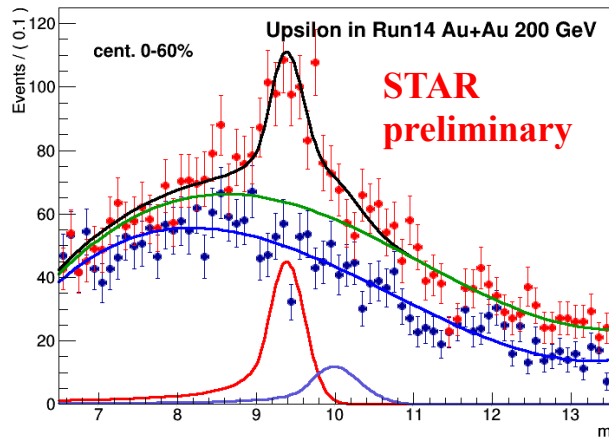
Ratio of $\Upsilon(2S+3S)/\Upsilon(1S)$
at RHIC may have less
suppression than that at
LHC?

World-wide p+p: PRC 88 (2013) 067901
CMS: PRL 109 (2012) 222301
CMS: JHEP 04 (2014) 103

Data taken in 2016 will double the statistics.

On-going analysis of Υ measurements

Upsilon US+LS Fit



Optimization of track quality cuts and the large data taken in 2011 and 2014 may allow the extraction of excited Υ states via the di-electron channel.

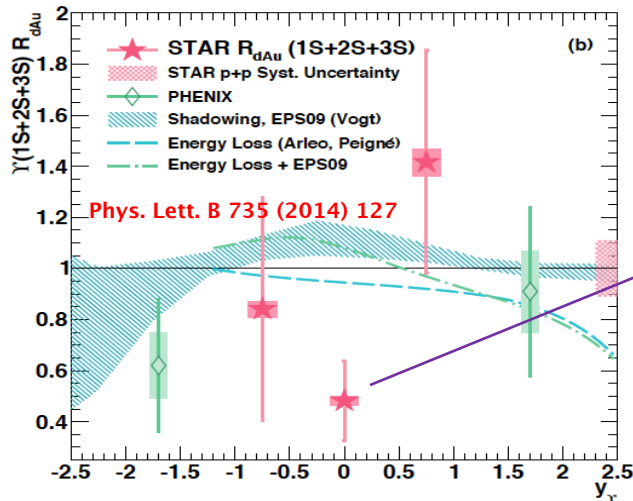
- Run10, Run11 and Run14 results will be combined.

The p+p data recorded in 2015 will have a factor of ~ 5 more Υ than that in 2009 p+p data:

❑ Luminosity = 120 pb^{-1}

❑ A better reference

which is **beyond** the expectation of all existing models.



The p+Au data recorded in 2015 will have a factor of ~ 6 more Υ than that in 2008 d+Au data:

❑ Luminosity = 407 nb^{-1}

❑ Cold nuclear matter effects

Summary and Outlook

- Υ production in **central** Au+Au and U+U collisions shows an indicative suppression
- The **internal-energy-based** models generally describe RHIC data
- Ratio of $\Upsilon(2S+3S) / \Upsilon(1S)$ via the di-muon channel has a **hint** that excited states suffer **less dissociation** at RHIC than at LHC
- Υ measurements from Run15 p+p and p+Au data will provide **better** p+p **reference** and allow better study of the **CNM** effects
- Υ suppression in Au+Au collisions with better precision will improve the understanding of the **hot medium** effect:
 - 1) Run16: di-muon channel
 - 2) Run10+Run11+Run14: di-electron channel

THANK YOU