Measurements of the Upsilon Meson Production in Au+Au Collisions at $\sqrt{s_{NN}}$ = 200 GeV by the STAR Experiment

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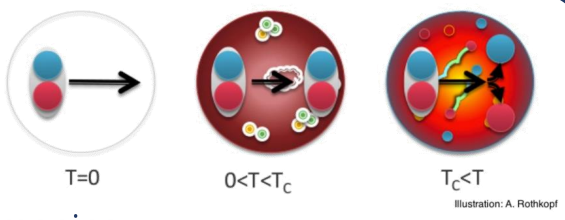
Abstract

In ultra-relativistic heavy-ion collisions, creation of a novel state of matter, the quark-gluon plasma (QGP), has been observed. This hot, dense, and short-lived medium of deconfined quarks and gluons is experimentally very challenging to study. Suppressed production of heavy quarkonia, caused by colour screening of the binding force, has been viewed as a direct evidence of the QGP formation. Moreover, different quarkonium states are expected to dissociate at different temperatures, which can be used to constrain the properties of the medium. In this poster, we present recent measurements of the ϒ production in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV via the di-lepton channel by the STAR experiment at RHIC. At RHIC energies, other phenomena influencing the quarkonium production, such as the regeneration and co-mover absorption, are expected to have little or no effect for the bottomonium family, which makes it a cleaner probe compared to the J/ψ meson.

Motivation

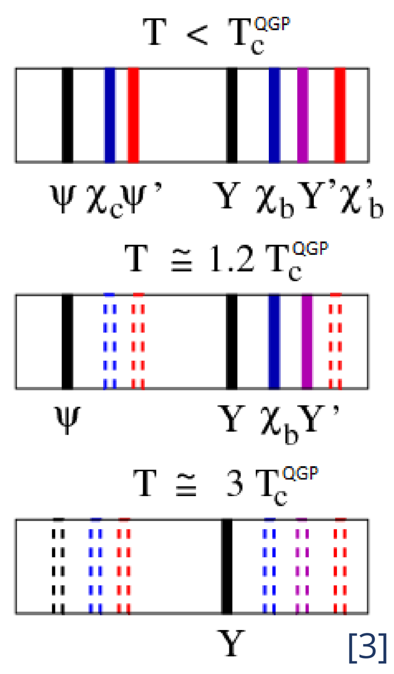


- **Quarkonium as a QGP thermometer**
  - A quarkonium is expected to dissociate by the colour screening effect in the hot medium if the Debye screening length becomes smaller than its radius:

    $$r_{Debye} < r_{Q\bar{Q}}\ ,\quad r_{Debye} \propto T^{-1}$$
  - This dissociation is dependent on the $\bar{Q}Q$ binding energy

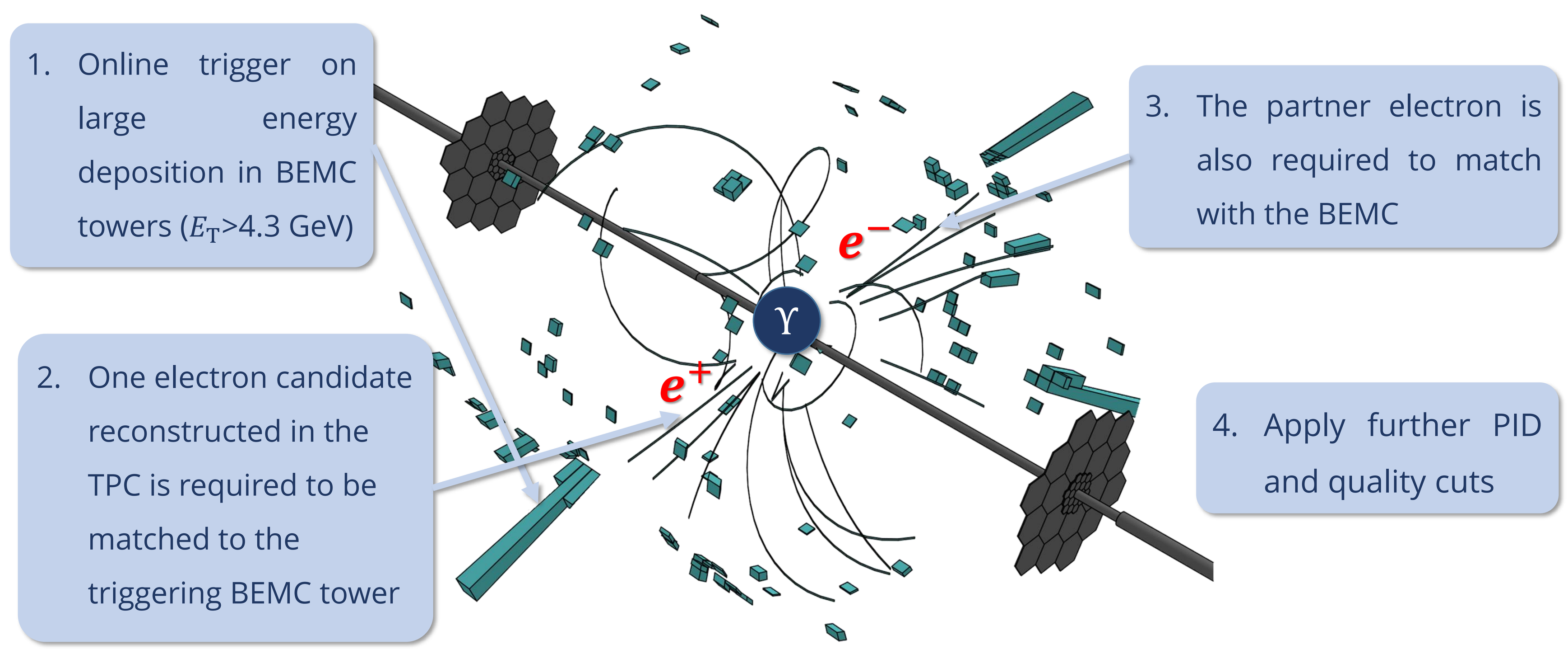
    → ***Different $\bar{Q}Q$ states melt at different temperatures***
- **Upsilons at RHIC**
  - Due to the low $b\bar{b}$ cross-section, the ϒ's receive relatively small contribution from regeneration by statistical recombination [1]
  - Certain Cold Nuclear Matter (CNM) effects, such as the absorption by co-moving hadrons, are also predicted to be small [2]

    → ***Much cleaner probe of the screening effect than the J/ψ***



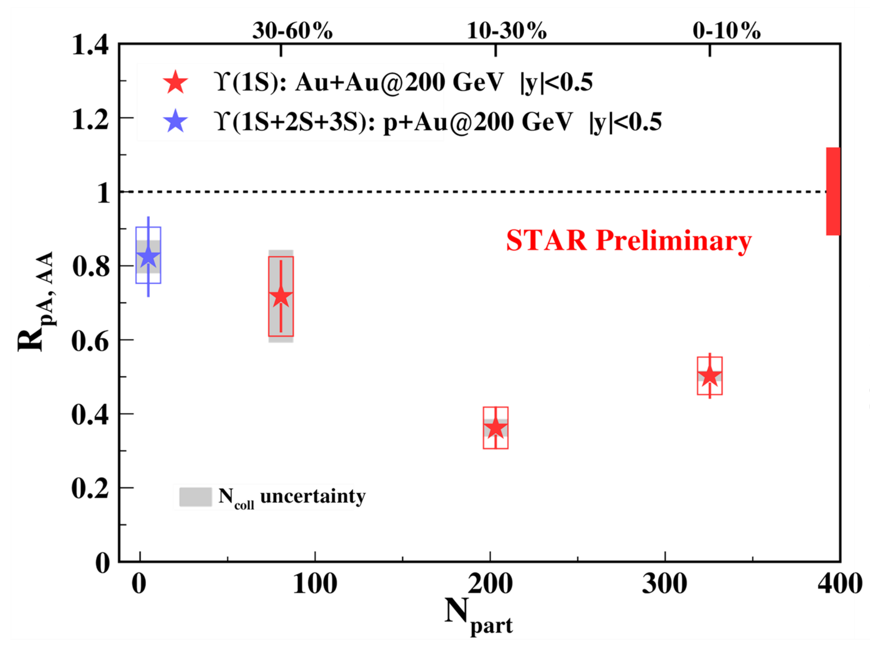
Dataset and Upsilon Reconstruction

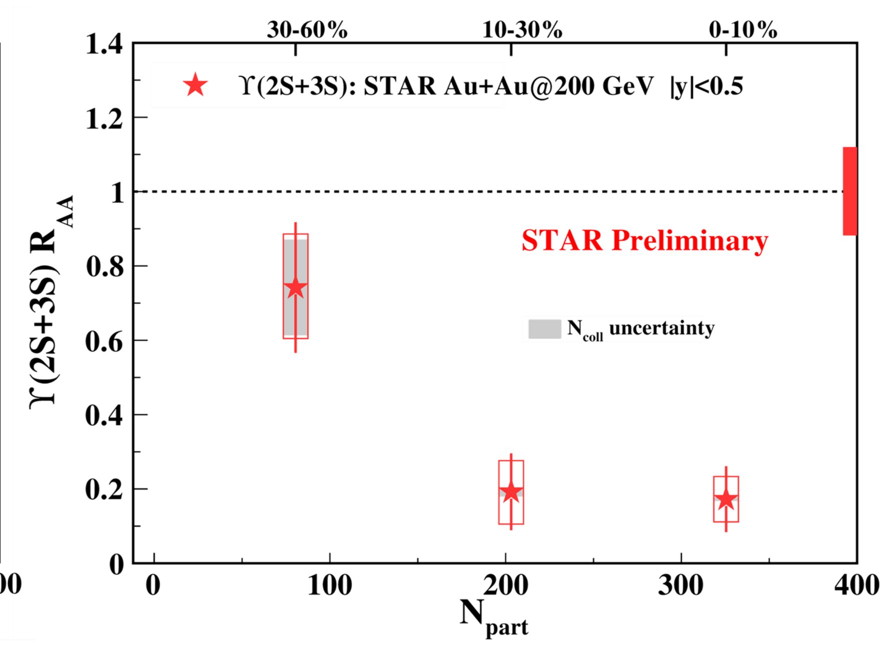
- **Di-electron decay channel** is used to reconstruct the ϒ ($BR_{\Upsilon(1S)\to ee}$ = 2.38%)
- Data from Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV taken in 2014
- ϒ's were measured at $|y| < 0.5$ with primary tracks of $p > 3.5$ GeV/c; $|\eta| < 1.0$; $0.75 < E/p < 1.5$; $-1.5 < n\sigma^{dE/dx}_{electron} < 3.0$



Recent Results from STAR

- STAR measurements, combining di-electron (2011) and di-muon (2014+2016) channels:

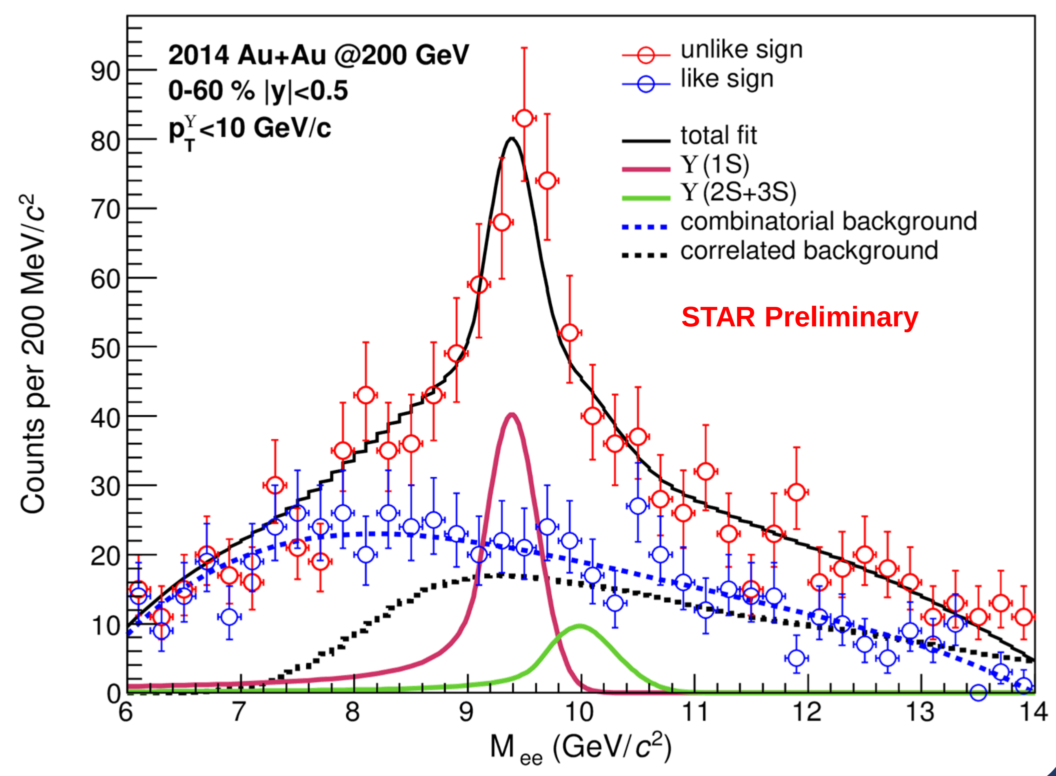




- At RHIC, inclusive ϒ(1S) is suppressed with: $R_{AA}\big|^{0-10\%}_{|y|<0.5} = 0.50 \pm 0.06\,(stat.) \pm 0.05\,(syst.)$
- ϒ(2S+3S) seem to be more suppresed than ϒ(1S) in central collisions, consistent with the phenomenon of sequential melting, with: $R_{AA}\big|^{0-10\%}_{|y|<0.5} = 0.17 \pm 0.09\,(stat.) \pm 0.06\,(syst.)$

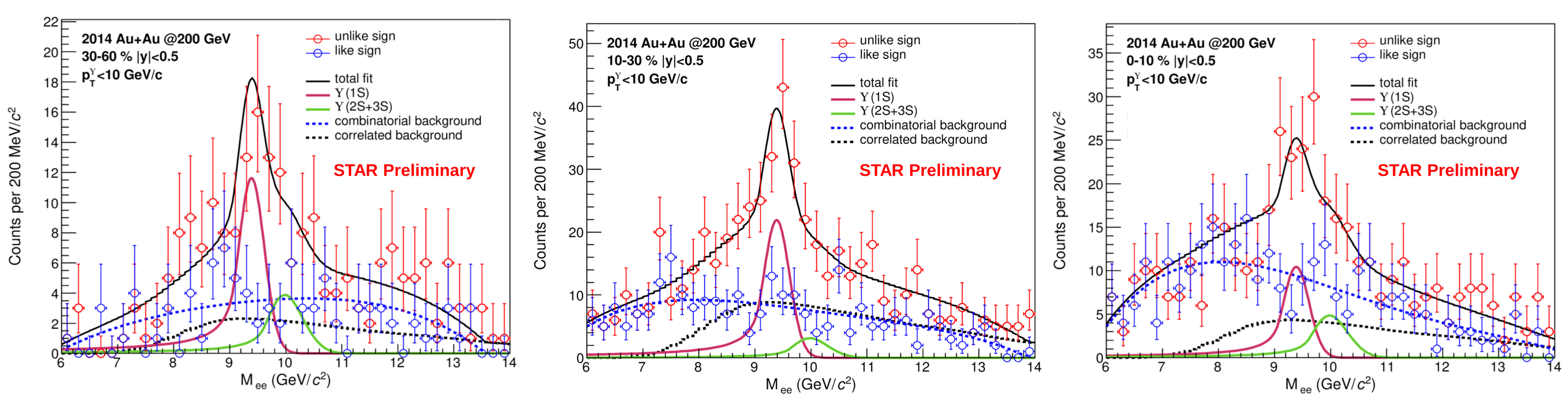
Raw Yield Extraction

- **Raw signal yield is extracted** using unbinned likelihood fit of the ***unlike-sign*** e^+e^- invariant mass spectrum
  - Combinatorial background estimated from the ***like-sign*** combinations
  - ***ϒ(1S)*** and ***ϒ(2S+3S)*** templates obtained from simulations incorporating full detector response
  - Shape of the correlated ***di-electron background***, mainly coming from $B\bar{B}$ decay and Drell-Yan, is determined from PYTHIA



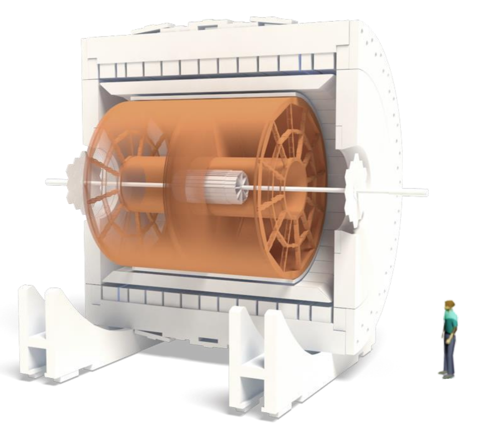
Centrality Dependence

- ϒ raw yields were obtained at $|y| < 0.5$, in 30–60%, 10–30%, and 0–10% centralities

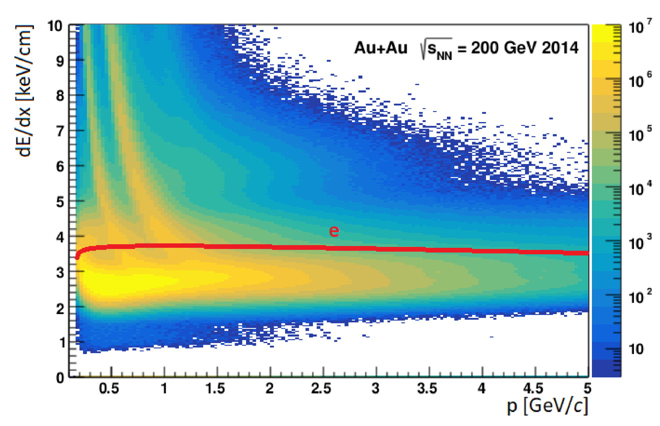


Experimental Setup

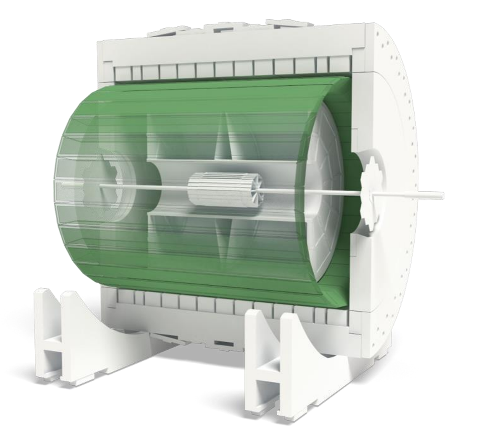
- **Solenoidal Tracker At RHIC (STAR)** is a detector designed for studying heavy-ion collisions, located in Brookhaven National Laboratory, USA. It has excellent particle identification (PID) capability and full azimuthal coverage. Most of the sub-detectors are immersed in a 0.5 T magnetic field.
- To measure the scarce ϒ's in the di-electron channel, we utilise mainly two STAR sub-detectors:
- **Time Projection Chamber (TPC)**



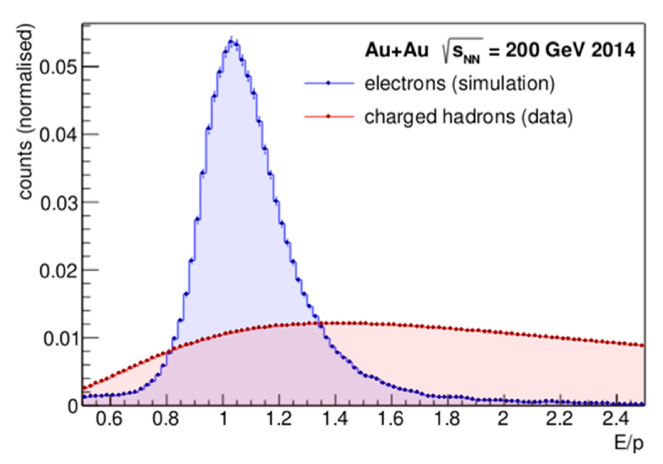
  - mid-rapidity coverage $|\eta| < 1.0$
  - tracking and momentum measurement
  - PID via ionisation energy loss dE/dx



- **Barrel Electromagnetic Calorimeter (BEMC)**



  - trigger on high-p_T electrons
  - electron identification via ratio of deposited energy to momentum



Summary

- Raw yields of ϒ(1S) and ϒ(2S+3S) were extracted in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV from di-electron invariant mass spectrum using the 2014 data
- Calculation of R_{AA} is currently in progress

References

[1] A. Emerick, X. Zhao, R. Rapp, Eu. Phys. Jour. A **48**, 72 (2012).
[2] Z. Lin and C. Ko, Phys. Lett. B **503**, 104 (2001).
[3] H. Satz, Int. J. Mod. Phys. A **28**, 1330043 (2013).

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