Upsilon suppression studies in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV in the STAR experiment

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- Quarkonia as a probe of QGP
- Quarkonium production modifications
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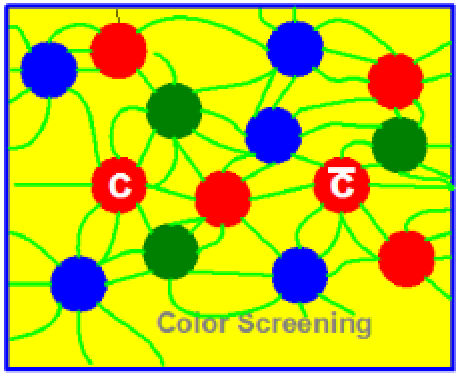
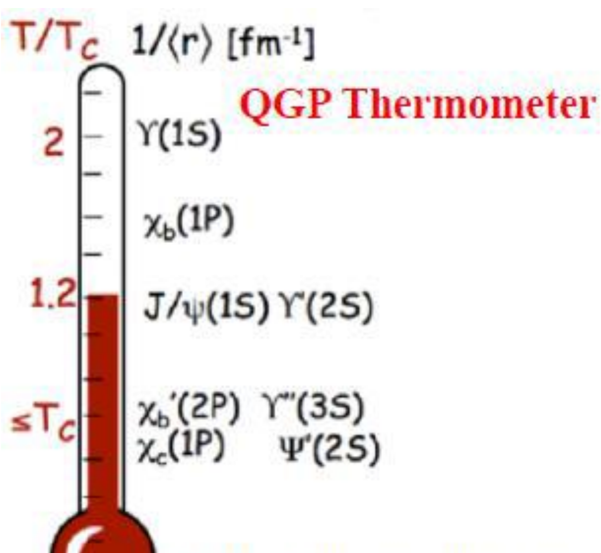
Quark-gluon Plasma

- deconfined state of strongly interacting matter as result of color screening
- only in high energy densities → nuclei collisions
- Color screening
  - medium (quarks and gluons) after collision is dense enough to screen binding between quarks and causes dissociation of the state
  - Debye screening length $r_D \sim 1/T$
  - $r_{state} > r_D \rightarrow$ dissociation
- transition from confined to deconfined phase takes place at $T_c \approx 170$ MeV – QGP creation



Quarkonia as a probe of QGP

- quarkonia – J/Ψ , Υ
- quarkonia are usually created before QGP – they live through whole collision
- different excited states have different radii → they melt at different temperatures and can serve as „thermometer“

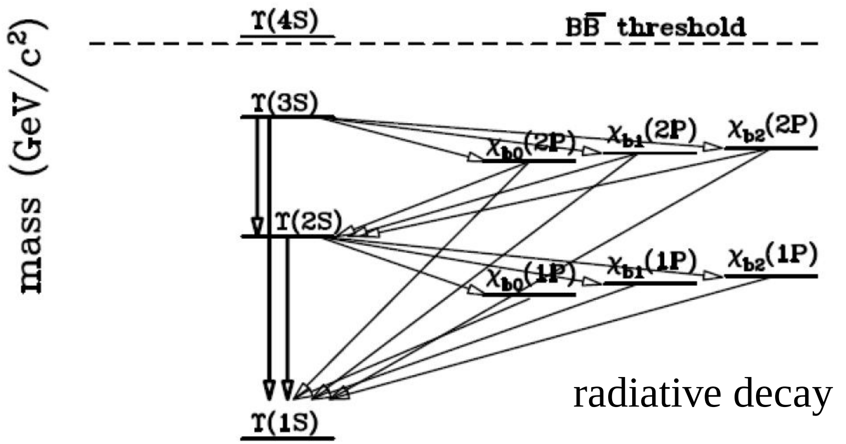


[A.Mocsy, EPJ C61 (2009) 705]

Illustration: A. Rothkopf

Quarkonium production modifications

- suppression as a result of dissociation in QGP
- Quarkonium recombination
  - coalescence of randomly encountered quark and anti-quark in QGP
- Interaction with co-movers
  - quarkonium is broken-up in interactions with co-moving hadrons → suppression due to collisions
- Feed-down effects
  - part (40%) of observed quarkonia originates from decays of excited states



radiative decay

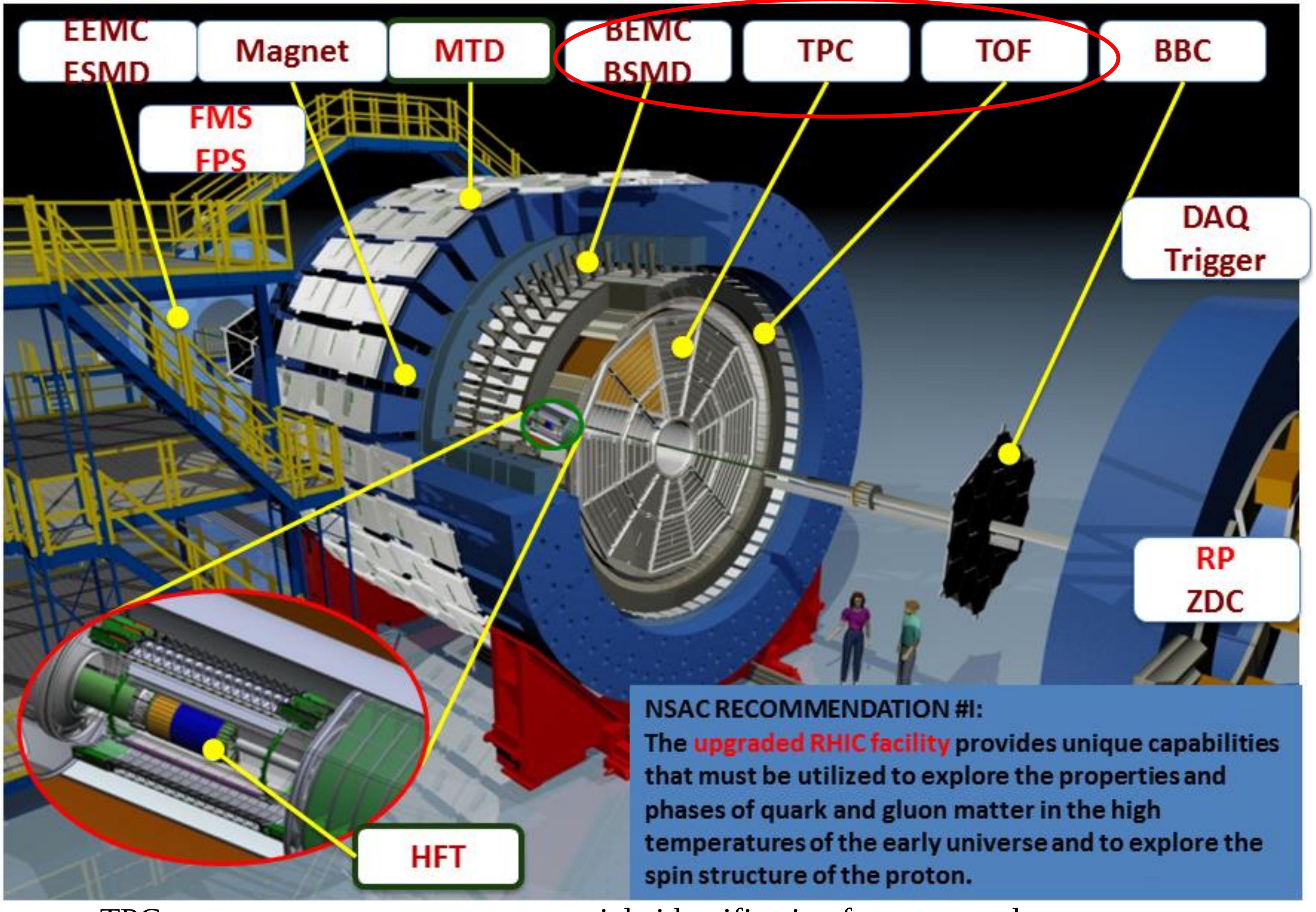
hadronic decay

Quarkonium production modifications

- Cold Nuclear Matter Effects
  - they do not originate in QGP
  - they contribute to measured suppression in addition to QGP effects
  - are studied in p+A collisions – colliding system considered too small to create QGP
  - Shadowing – modification of a parton distribution in a bound nucleon compared to a free nucleon
  - Cronin Effect – proton‘s partons gain transverse momentum in a series of parton collisions before a final hard collision
  - Nuclear Absorption – quarkonium dissociation by interaction with nuclear matter
- suppression is measured by calculating nuclear modification factor R_{AB}

$$R_{AB}(p_T) = \frac{dN^{AB}/dp_T}{\langle N_{coll}\rangle dN^{pp}/dp_T}$$

- $R_{AB} > 1$: enhancement
- $R_{AB} < 1$: suppression in A+B



TPC – momentum measurement, particle identification from energy loss

TOF – particle identification from time of flight

BEMC – electron detection→ quarkonia

MTD – muon detection→ quarkonia

Advantages of STAR

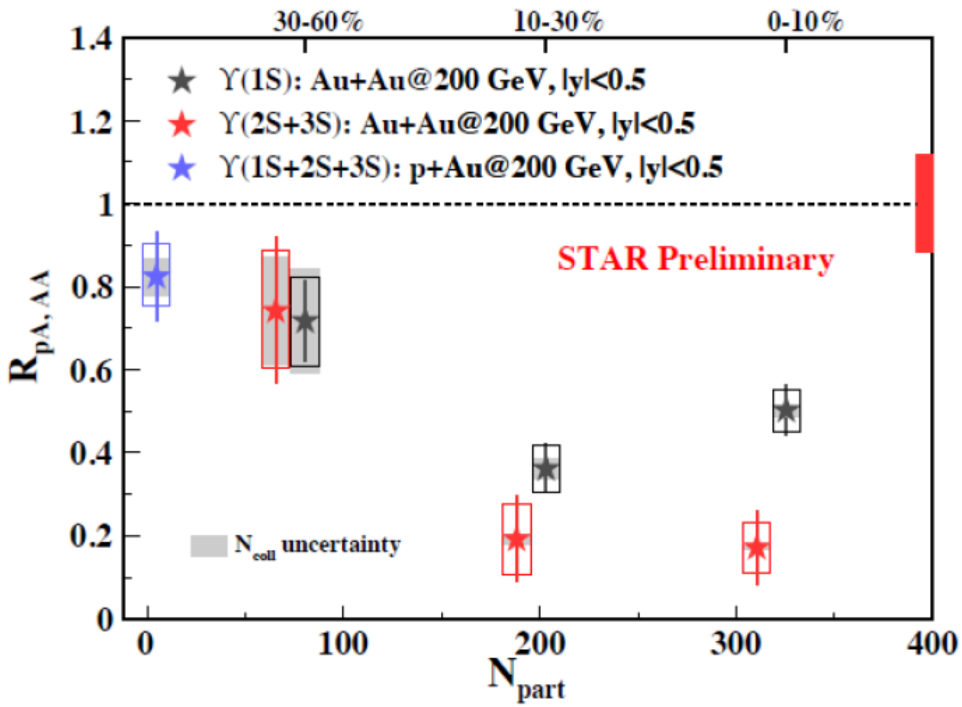
- RHIC operates at $\sqrt{s_{NN}} = 200\ \text{GeV}$ - less than LHC
- large acceptance $|\eta| < 1$, $0 < \varphi < 2\pi$
- Υ is clean probe
  - production of Υ is not influenced by B meson feed-down, unlike J/ψ
  - recombination and co-mover absorption can be neglected

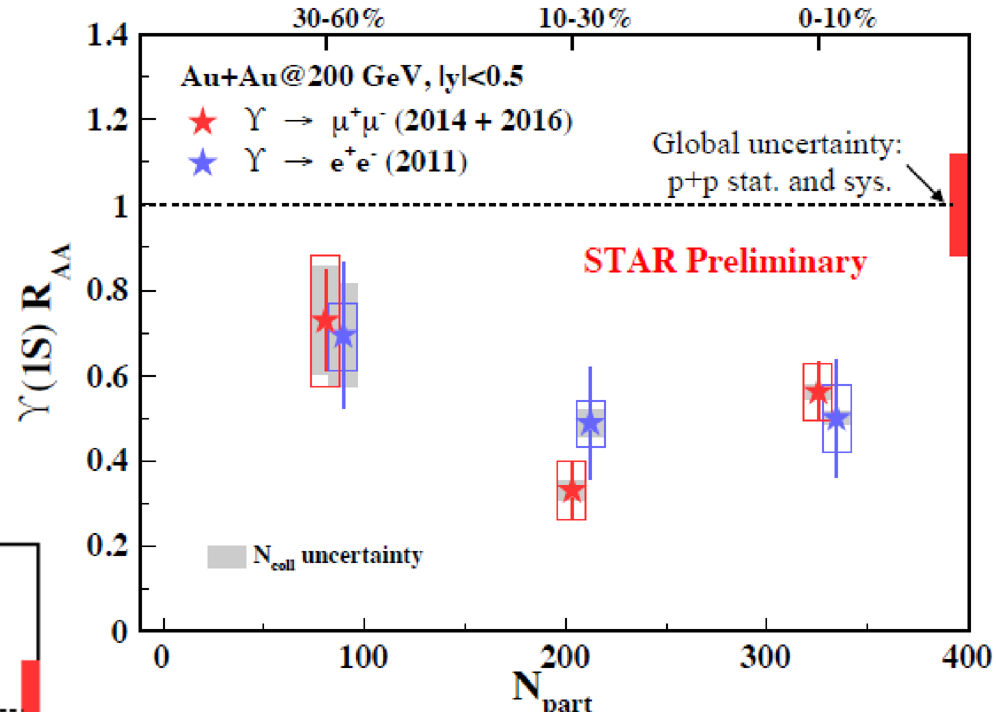
A. Emerick, X. Zhao, R. Rapp, EPJ A48 (2012) 72
Z. Lin, C. Ko, PLB 503 (2001) 104

Recent STAR Au+Au results

- suppression of ϒ in Au+Au →
- suppression in p+Au (CNM) less than in central Au+Au (QGP)

↓

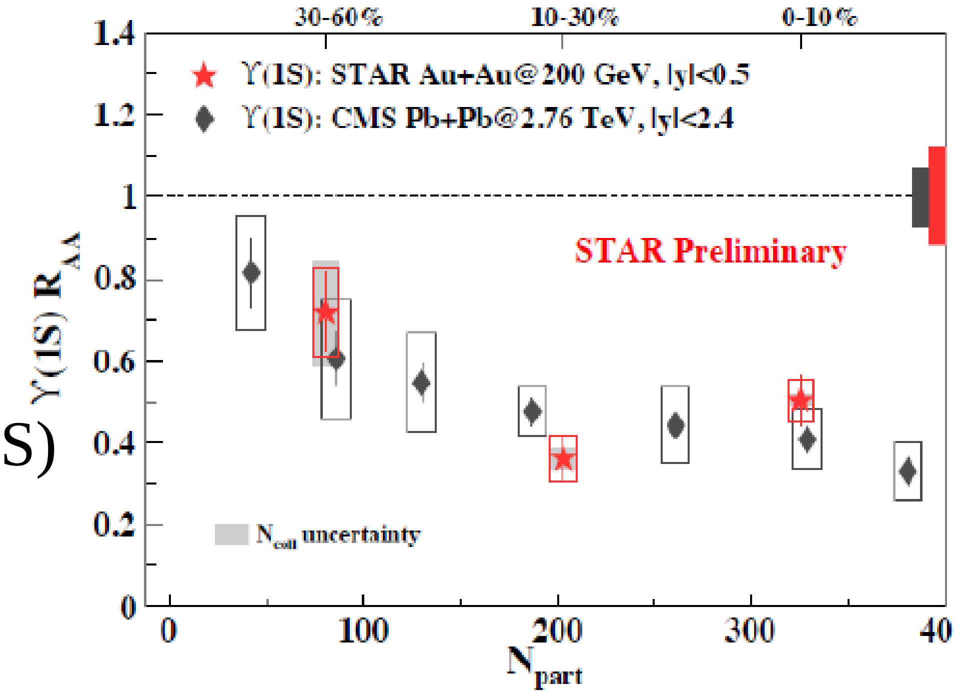




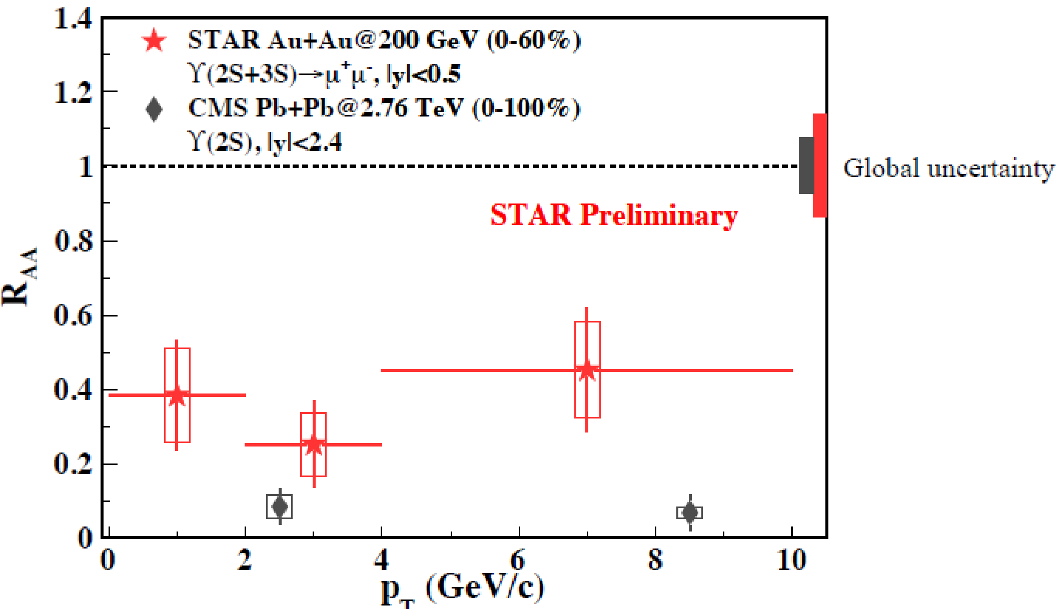
Pengfei Wang, QM 2018

Recent STAR Au+Au results

- suppression of Υ(1S) is the same at LHC and RHIC energies →
- suppression is constant in p_T, indication of less suppression of Υ(2S+3S) at RHIC than Υ(2S) at LHC ↓



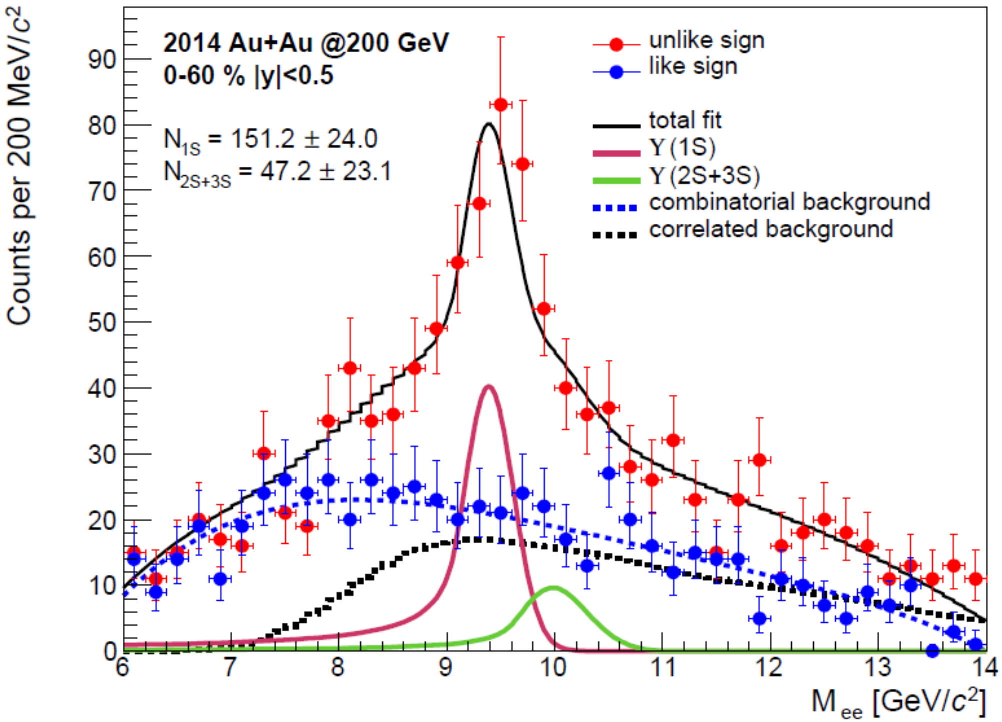
Pengfei Wang, QM 2018



[CMS: PLB 770, 357 (2017)]

My work

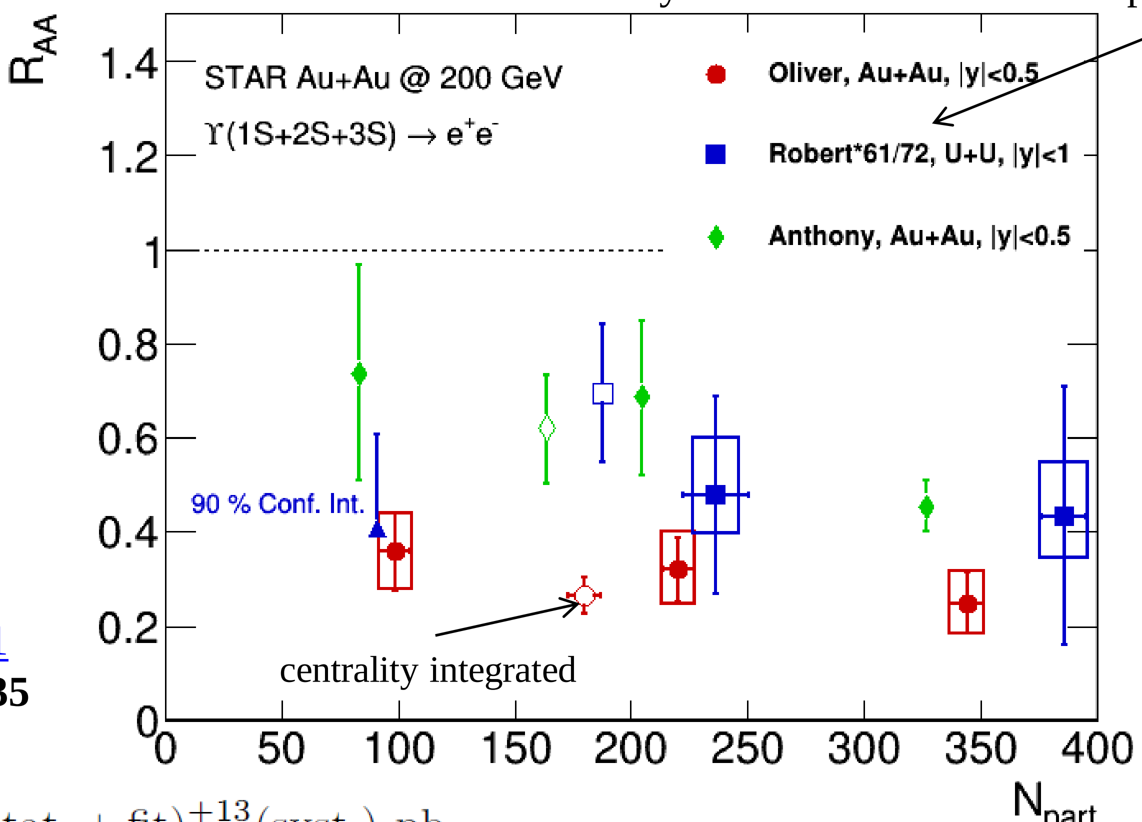
- Υ suppression study in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV via dielectron channel
- data sample recorded by STAR during 2014 run
  - 4x higher integrated luminosity than previous studies ($4nb^{-1}$) $\rightarrow$ high precision results
- Oliver saw too small signal
- new data sample produced without HFT tracking
- different tracking algorithm STICA



My work

- all data are divided in two datasets: lowmid (45.7%) and high luminosity
- 1) comparison of present results – Olivers‘ are more suppressed

to rescale the results by the same cross section in pp



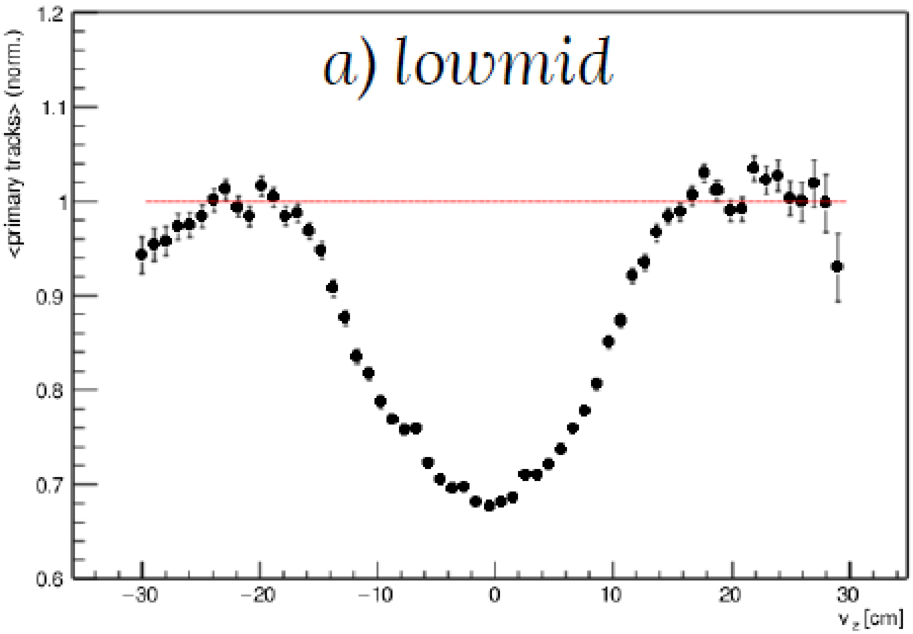
centrality integrated

Robert Vertesi: arXiv:1611.06531
Anthony Keisch: Phys. Lett. B **735** (2014) 127

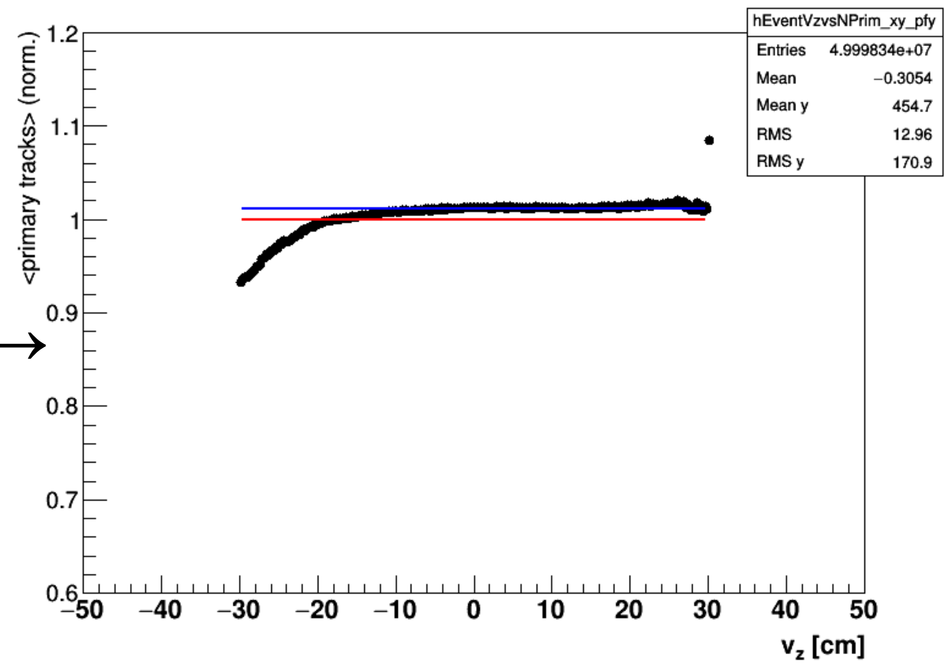
$$B_{ee} \times d\sigma/dy|_{|y|<1} = 61 \pm 8(\mathrm{stat.} + \mathrm{fit})^{+13}_{-12}(\mathrm{syst.})\ \mathrm{pb}$$

My work

- 2) plots for primary tracks |p| ≠ 0
- dip caused by HFT disappeared using new data sample



Oliver‘s result with HFT



without HFT

Au+Au 2014 200 GeV
Production: P17 lowmid
Library SL18b
Trigger: BHT2*VPDMB-30

My work – used cuts

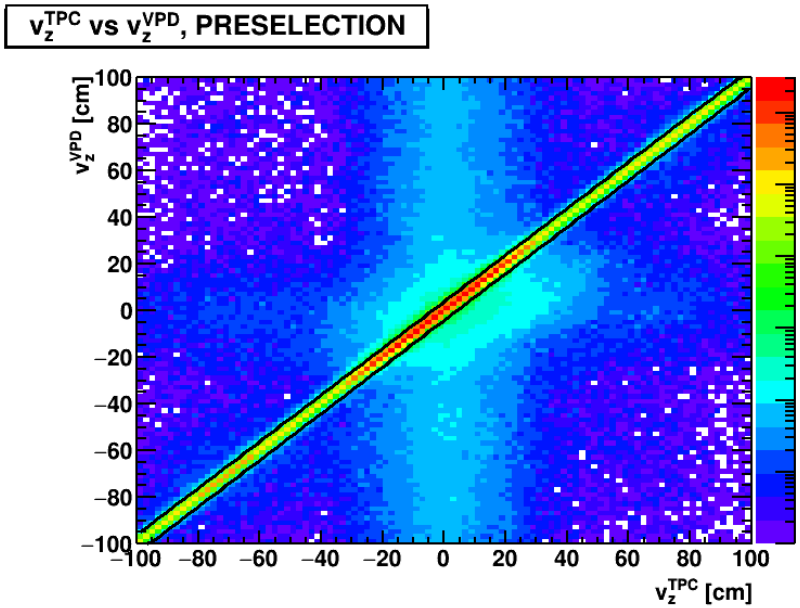
- $|v_z^{TPC}| < 30$ cm, $|v_z^{TPC} - v_z^{VPD}| < 4$ cm
- ○ nHitsFit ≥ 20
- nHitsFit/nHitsMax ≥ 0.52
- nHitsDedx ≥ 10
- $-1.5 \leq n\sigma_e \leq 3$
- $|\eta| \leq 1$
- $|p| \geq 3.5$ GeV
- DCA ≤ 0.75 cm
- $0.75 \leq E/|p| \leq 1.5$
- $E \geq 0.1$ GeV
- $R < 0.025$ cm

Oliver:
nHitsFit ≥ 25
$|y| \leq 0.5$

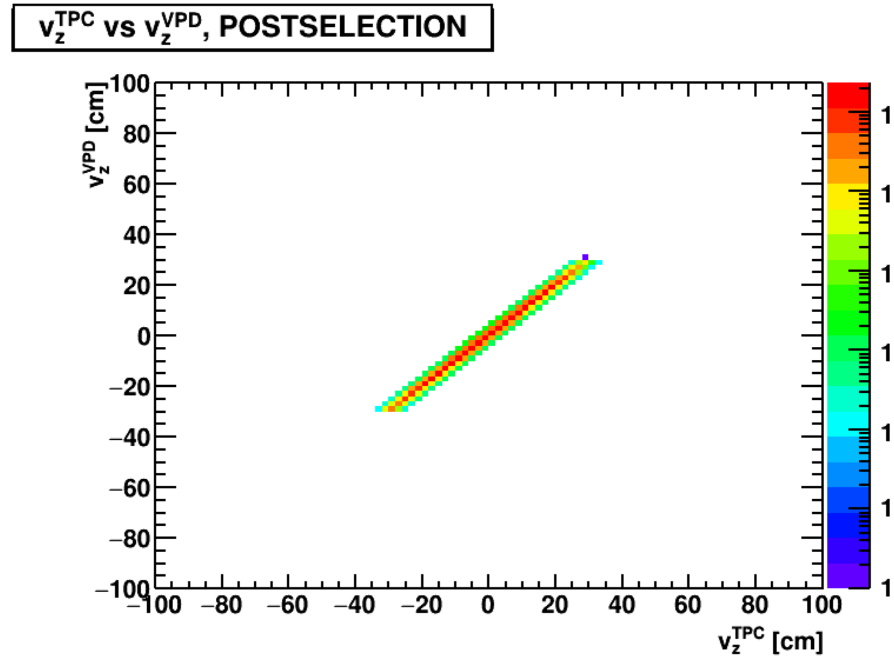
Pair cuts:

- $p \geq 4.5$ GeV for at least one daughter
- ○ $|y| \leq 1$ for a daughter pair
- $p_T \leq 10$ GeV for a daughter pair

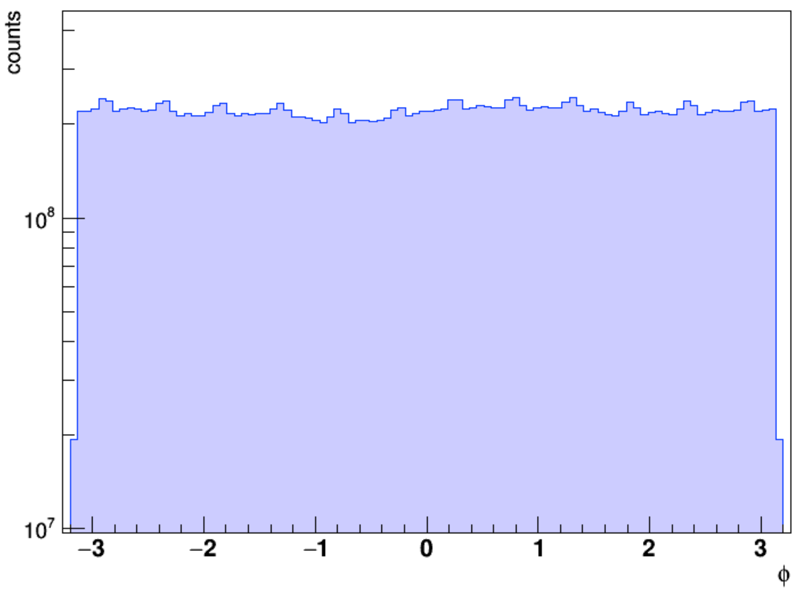
My work



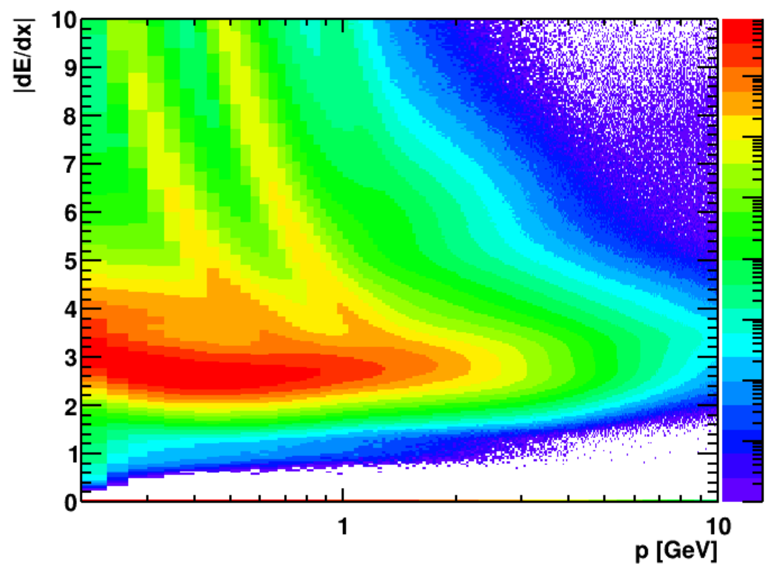
v_z^{TPC} vs v_z^{VPD}, PRESELECTION
v_z^{VPD} [cm]
v_z^{TPC} [cm]
100
80
60
40
20
0
−20
−40
−60
−80
−100
10^6
10^5
10^4
10^3
10^2
10
1



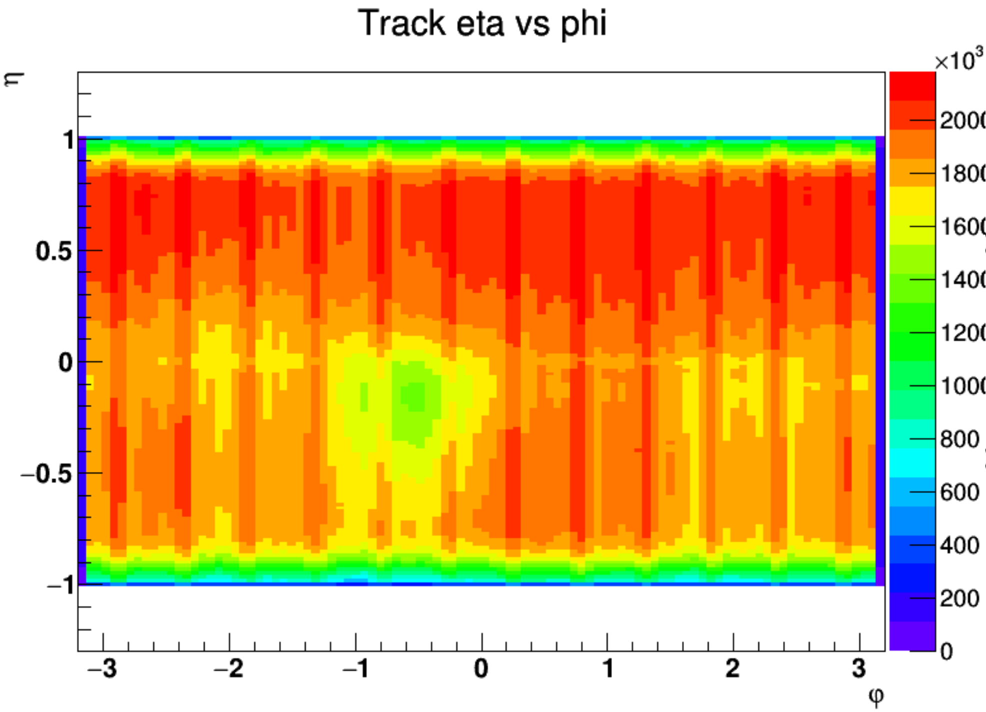
v_z^{TPC} vs v_z^{VPD}, POSTSELECTION
v_z^{VPD} [cm]
v_z^{TPC} [cm]
100
80
60
40
20
0
−20
−40
−60
−80
−100
10^6
10^5
10^4
10^3
10^2
10
1

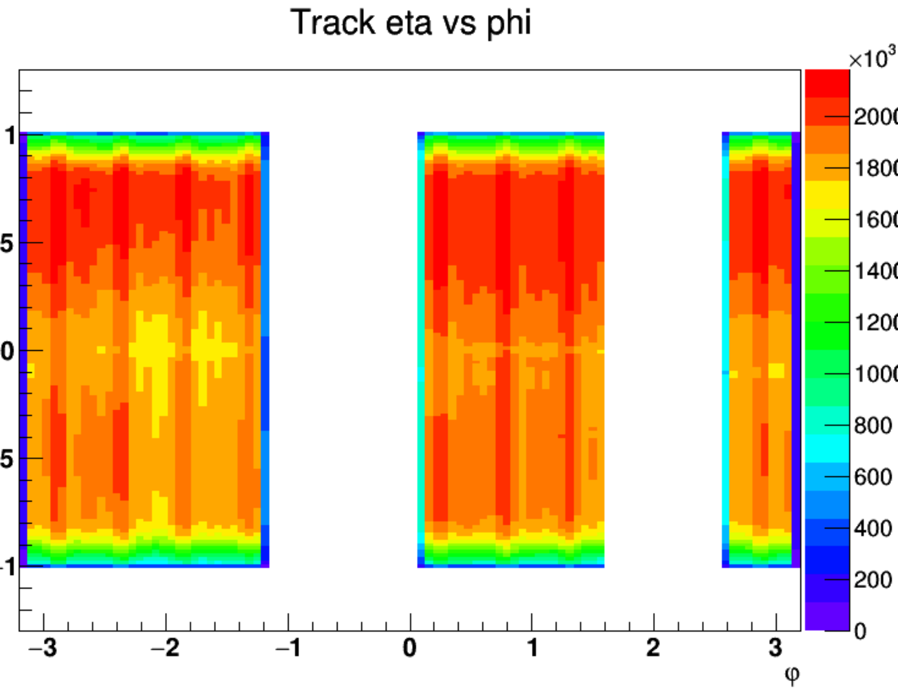


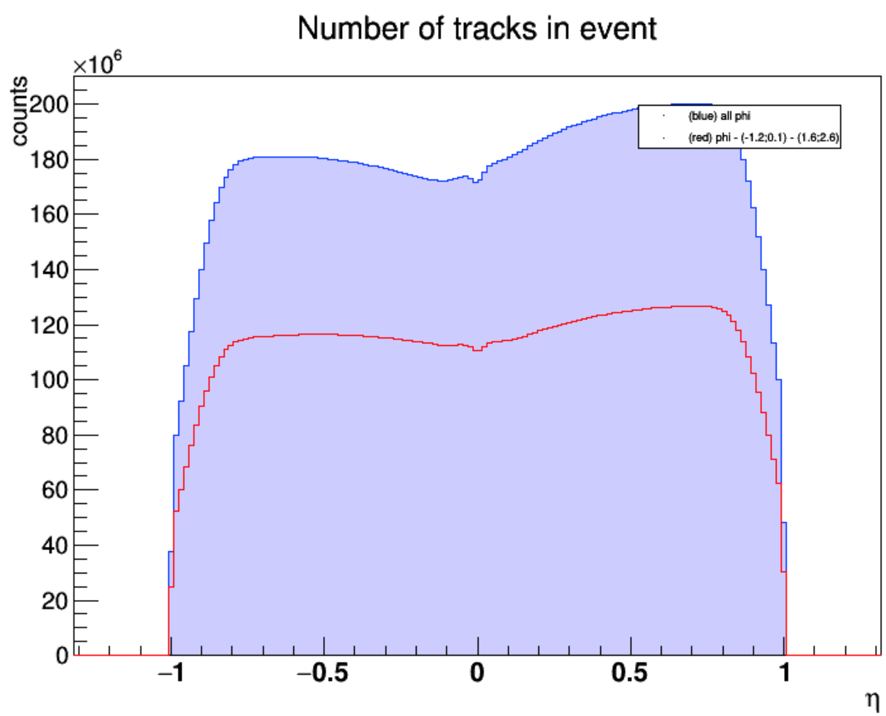
counts
10^8
10^7
−3
−2
−1
0
1
2
3
ϕ



|dE/dx|
p [GeV]
10
9
8
7
6
5
4
3
2
1
0
10^7
10^6
10^5
10^4
10^3
10^2
10
1

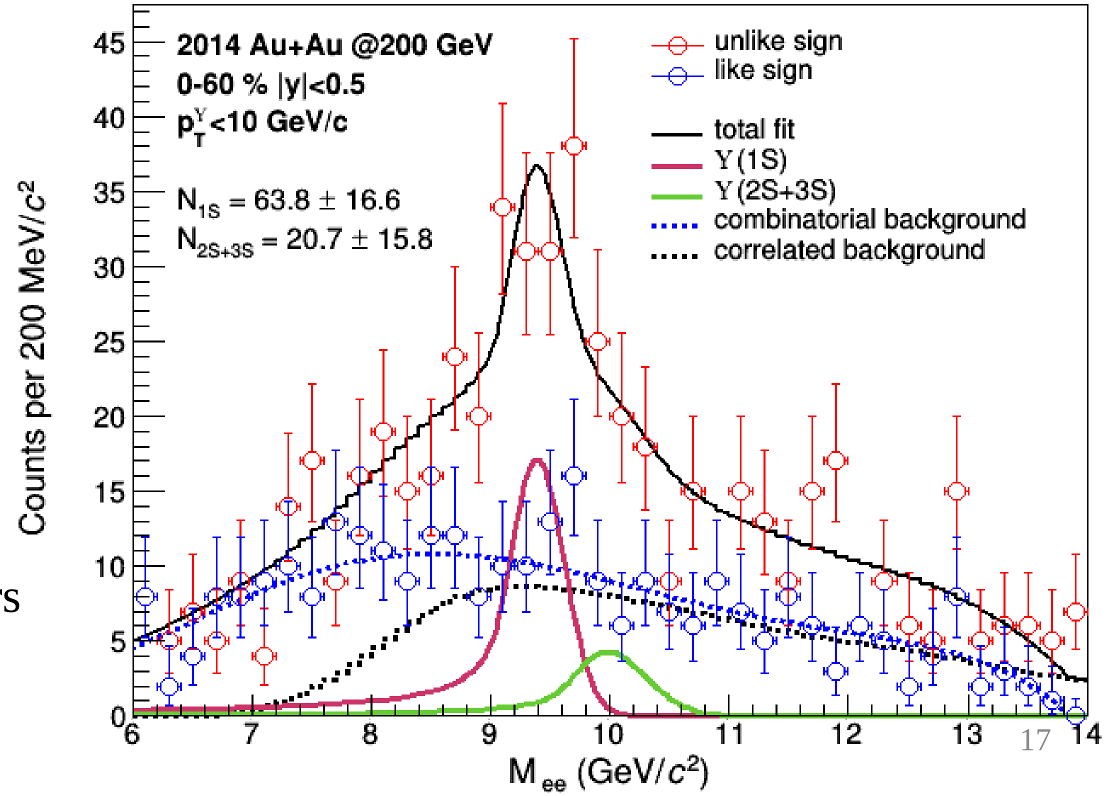

Track eta vs phi
η
φ
×10^3


Track eta vs phi
φ
×10^3


Number of tracks in event
counts
×10^6
η
(blue) all phi
(red) phi - (-1.2;0.1) - (1.6;2.6)

My work

- lowmid and high luminosity dataset use different libraries → currently I test new version of code suitable for both library versions
- for now, signal obtained only for lowmid luminosity dataset



Total fit to unlike sign:
- like sign - third-order Chebychev polynomial
- correlated bg – MC simulation
- 3 Crystal Ball functions – parameters from embbeding
- no Drell-Yan

Outlook

- finish unified code and combine lowmid and high luminosity
- reproduce the Υ yield obtained by Oliver and cross check it
- check efficiency calculation

Summary

- quarkonia can be used to study properties of the QGP created in heavy-ion collisions
- at RHIC we can neglect some production effects
- continue work to obtain preliminary status

Thank you for your attention