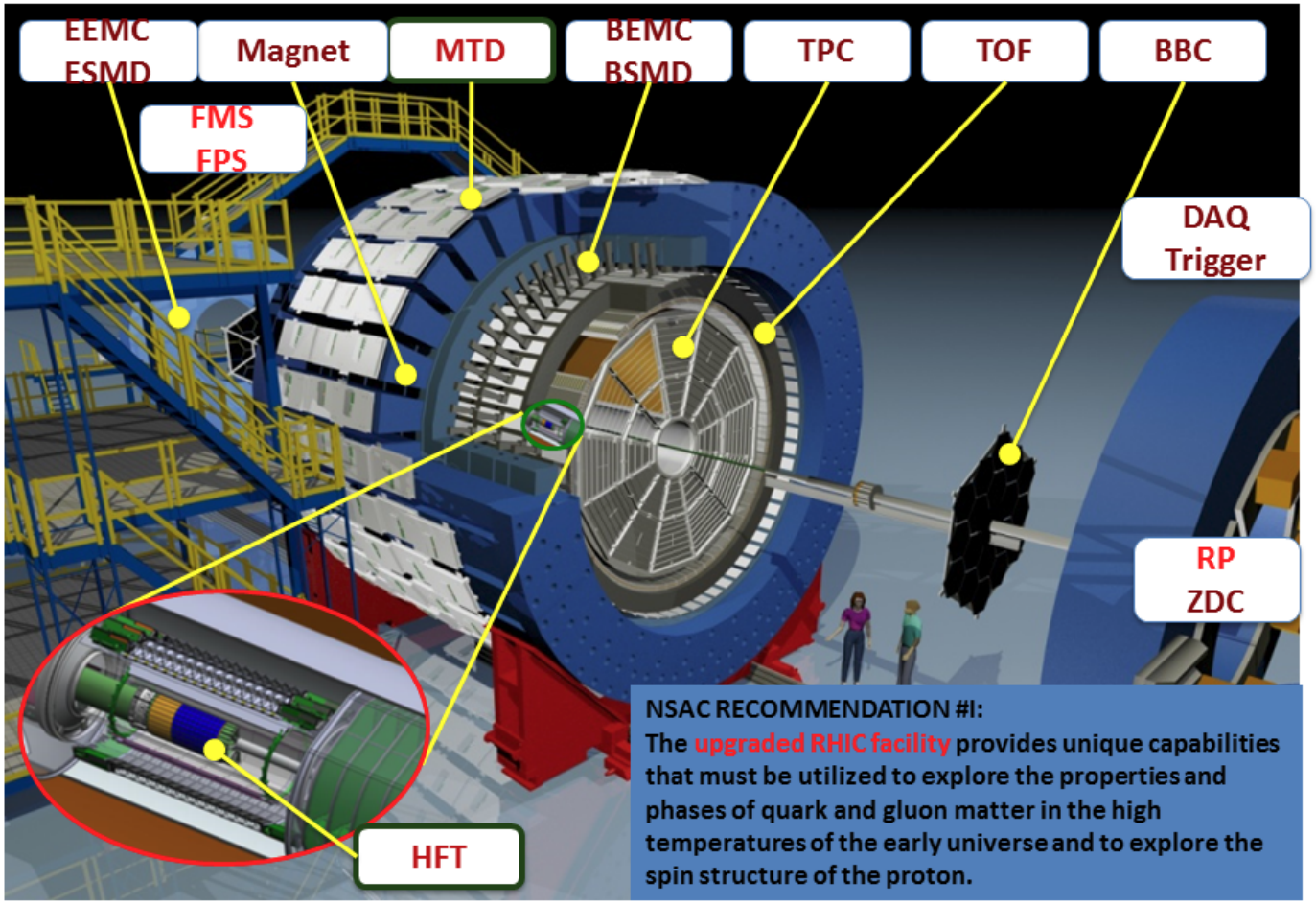
Quarkonium measurements at STAR

Dielectron vs dimuon channel studies

Daniel Kikoła, Warsaw University of Technology

STAR Detector System

15 fully functioning detector systems



X10^3 increases in DAQ rate since 2000, most precise Silicon Detector (HFT)

Main detector: **Time Projection Chamber**

Original Design & goals

- Goal: discovery and study of Quark Gluon Plasma

- large acceptance |y|<1
- full azimuthal coverage
- focus of low-p_T (“bulk”) physics
- excellent two-particle resolution
- low event rate

https://drupal.star.bnl.gov/STAR/book/export/html/7410

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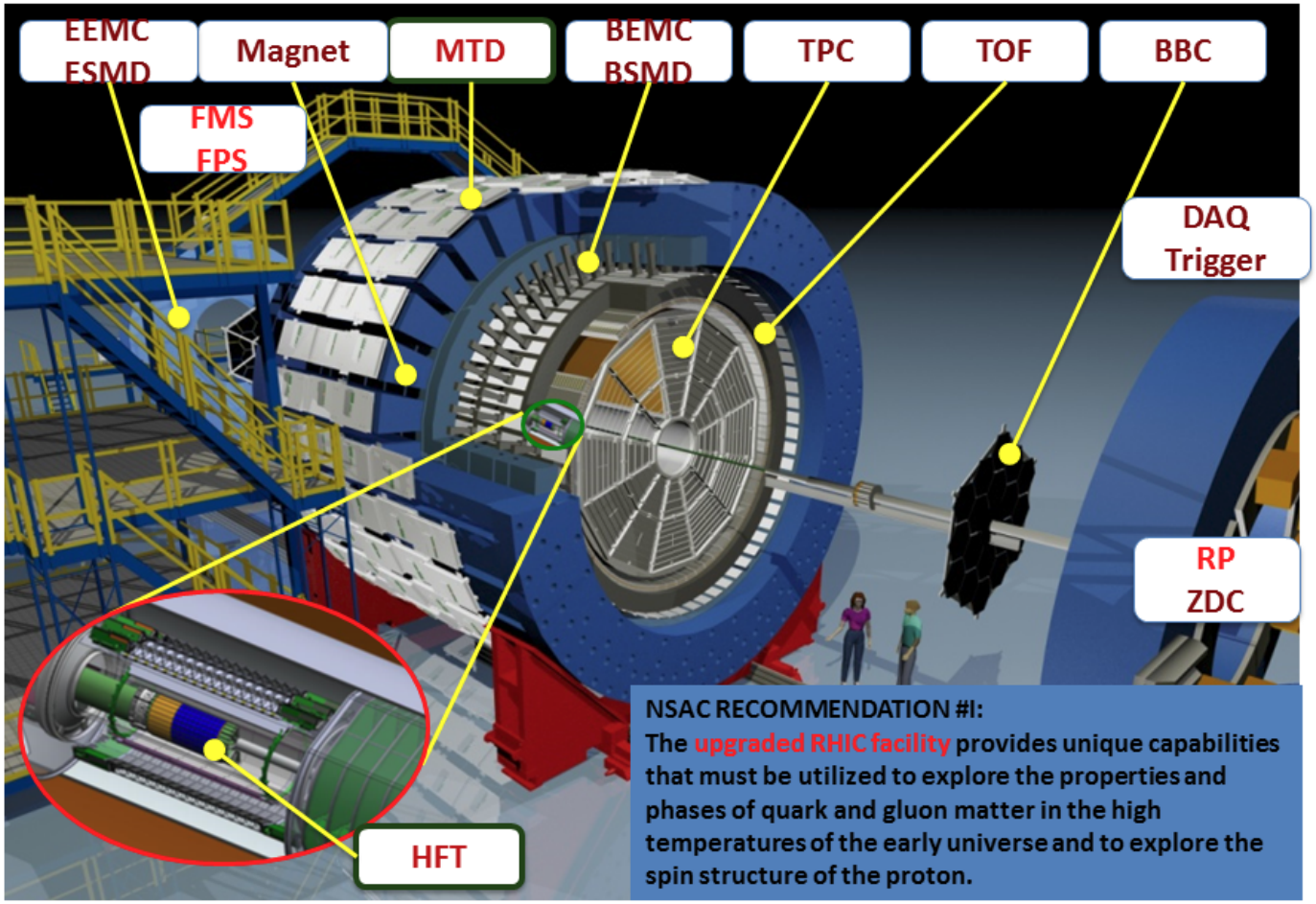


X10^3 increases in DAQ rate since 2000, most precise Silicon Detector (HFT)

Upgrades for **heavy flavor program**

Barre Electromagnetic Calorimeter (BEMC)

- high p_T electrons
- high-p_T J/ψ (via e^+e^-)
- $\Upsilon \rightarrow e^+e^-$

Time of Flight

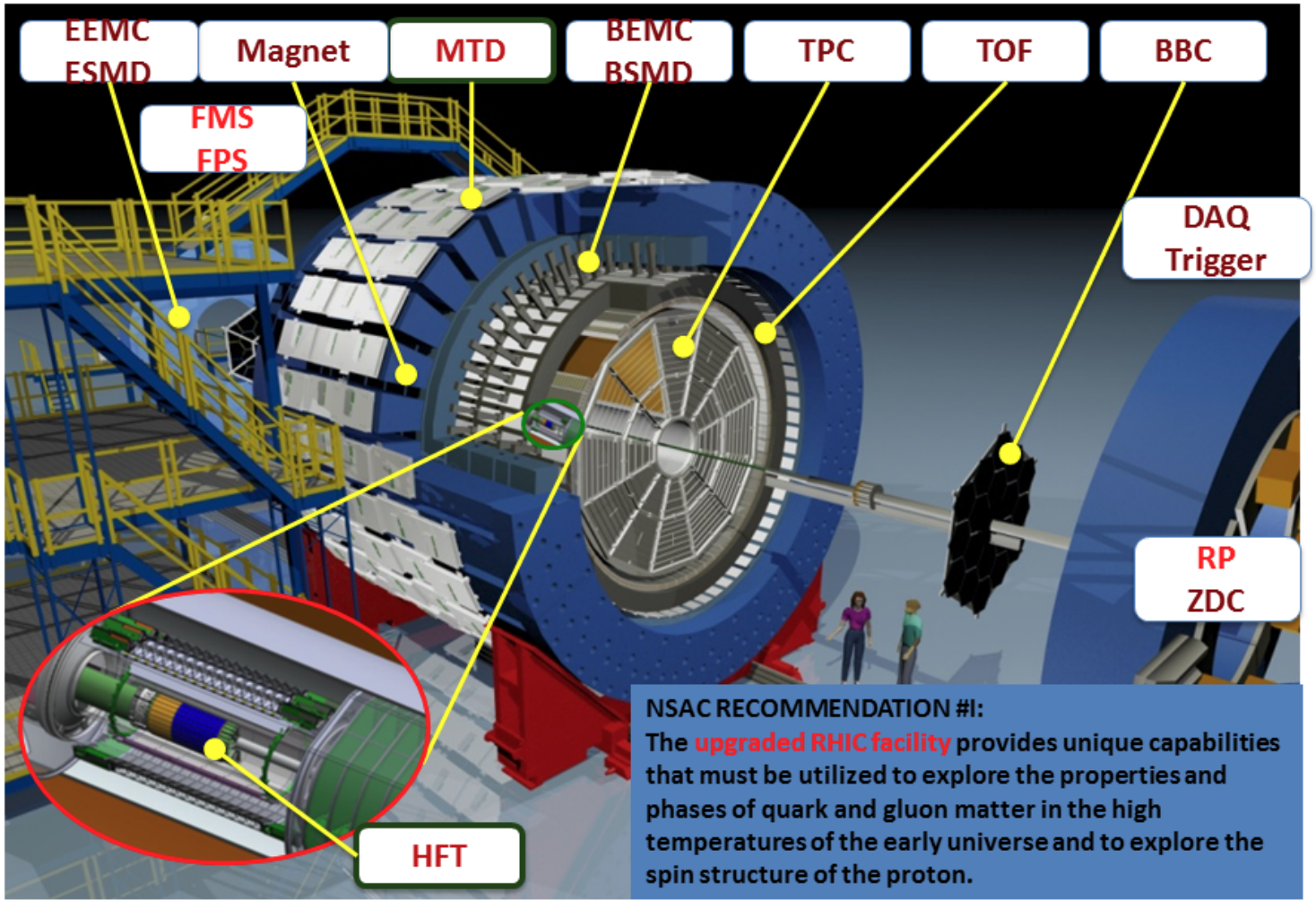
- Low-p_T J/ψ
- Dilepton program

- **Muon Telescope Detector**

https://drupal.star.bnl.gov/STAR/book/export/html/7410

STAR Detector System

15 fully functioning detector systems



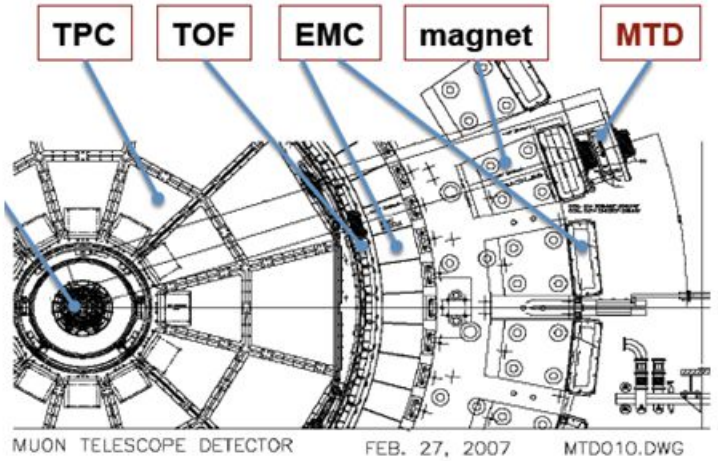
X10^3 increases in DAQ rate since 2000, most precise Silicon Detector (HFT)

Muon Telescope Detector (MTD) added as an upgrade in 2013 to improve detection capabilities at low-p_T J/ψ and ϒ(2S) and ϒ(3S) separation

Goals:

- dimuon trigger capabilities for J/ψ
-improved mass resolution to measure ϒ(2S) and ϒ(3S) separately in heav-ion collisions

Muon Telescope Detector (MTD)



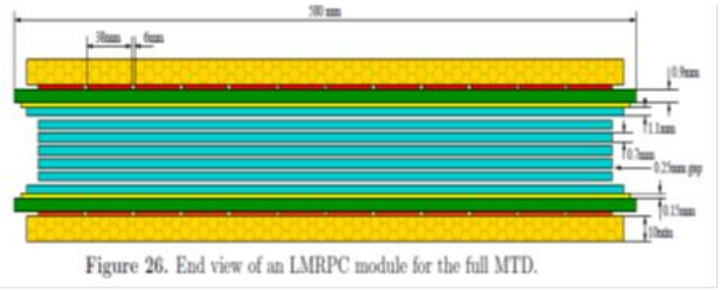
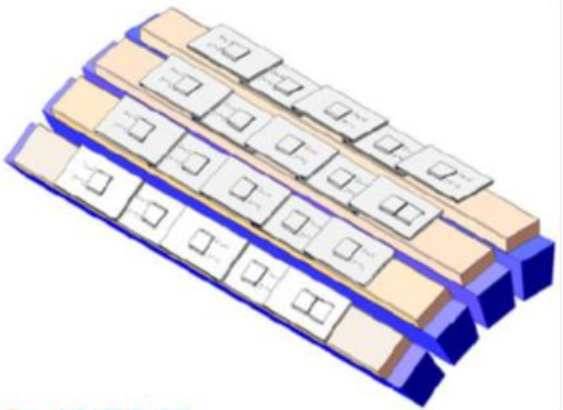


Figure 26. End view of an LMRPC module for the full MTD.

STAR magent used as absorber



A detector with long-MRPCs covers the whole iron bars and leave the gaps in-between uncovered.
Acceptance: $|\eta|<0.5$ and 45% in azimuth

118 modules, 1416 readout strips, 2832 readout channels

Long-MRPC detector technology, HPTDC electronics (same as STAR-TOF)

Nucl.Instrum.Meth.A 762 (2014) 1-6, e-Print: 1402.1078

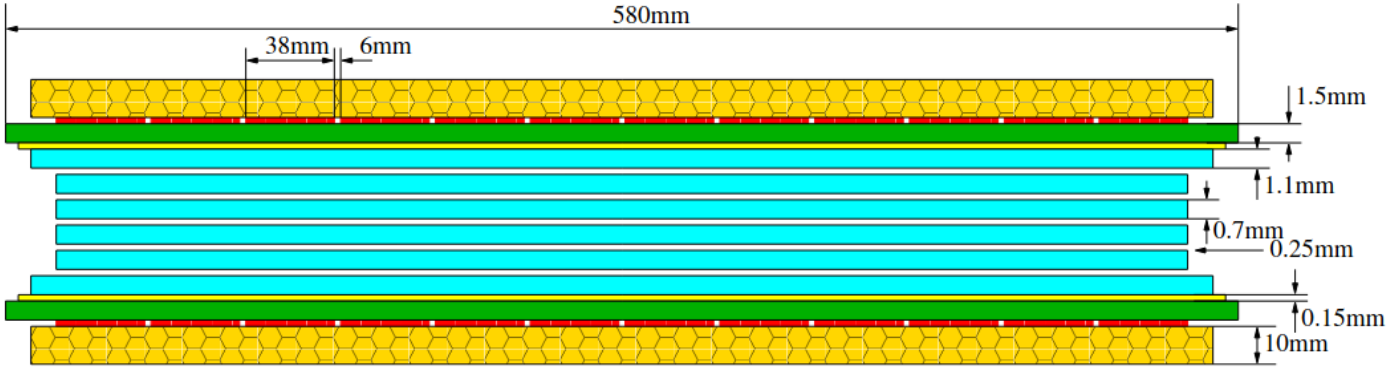


Figure 1: (Color online) Side view of a (type B) MRPC module, honey combs are colored yellow, strips are colored red, PCboards are colored green, mylars are colored light yellow and glasses are colored sky blue. The vertical scale has been expanded for clarity.

The gas mixture used was 95% Freon R-134a and 5% isobutane. The readout electronics were very similar to those implemented in the STAR TOF system.

Muon identification:

TPC dE/dx (selection like for pions)

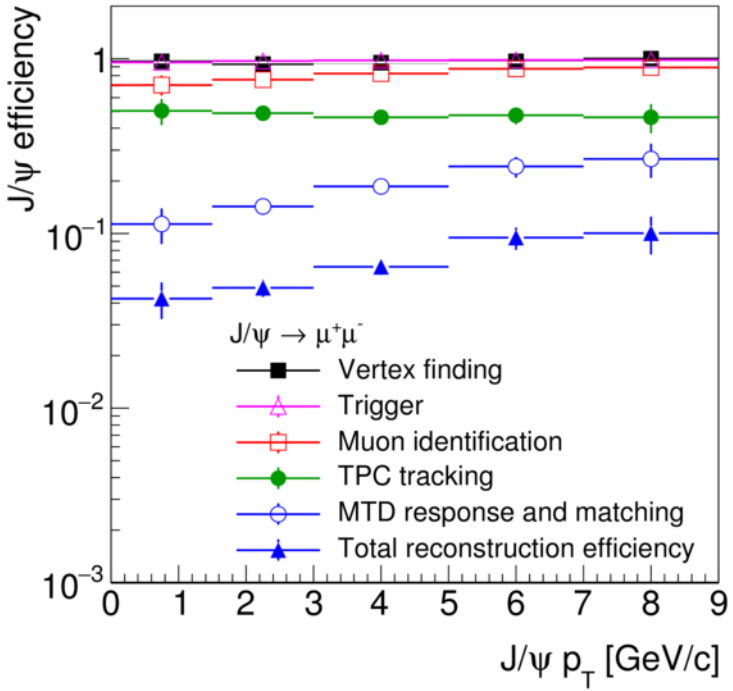
Matching MTD signal with TPC track projection to the MTD plane

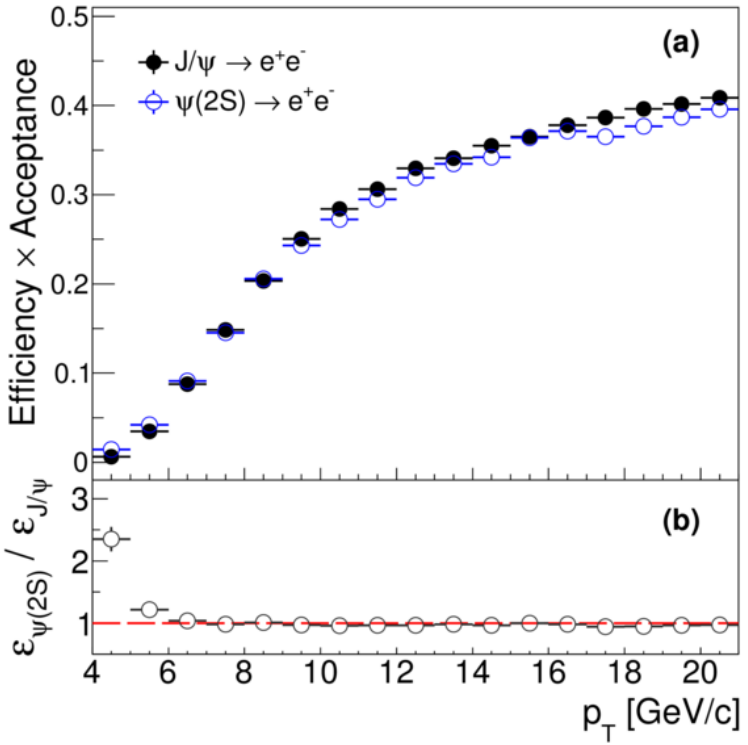
Time-of-Flight

J/ψ: Complementarity of e^+e^- and $\mu^+\mu^-$ channels

BEMC: trigger on high-p_T electron for high-p_T J/ψ and $\Upsilon \rightarrow e^+e^-$

MTD: dimuon trigger





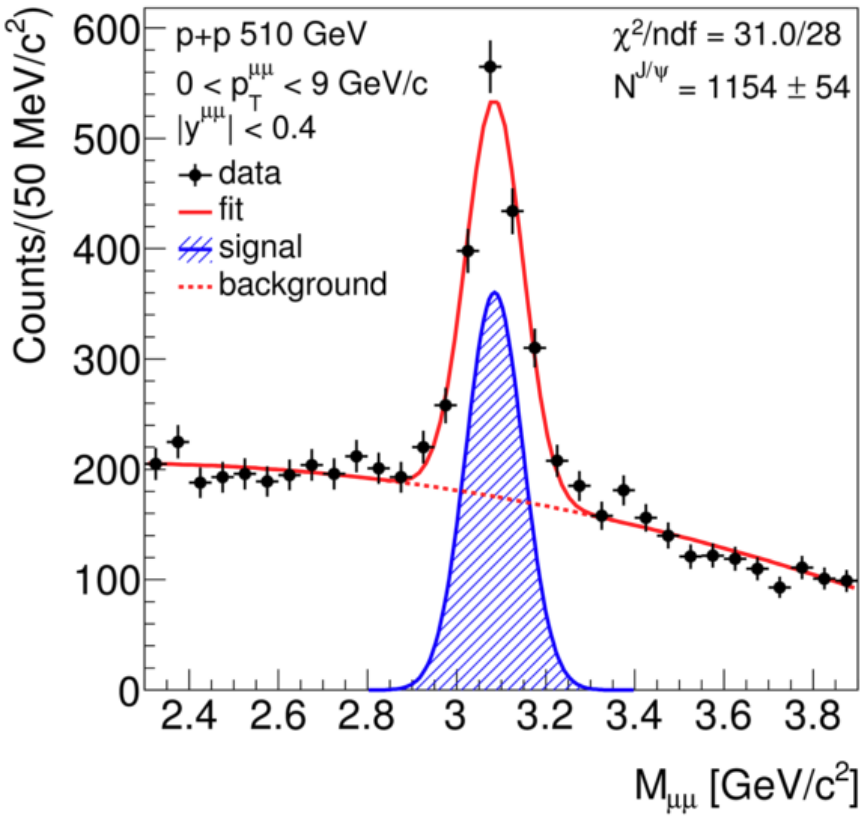
p+p √s = 510 GeV

Phys. Rev. D 100 (2019) 52009

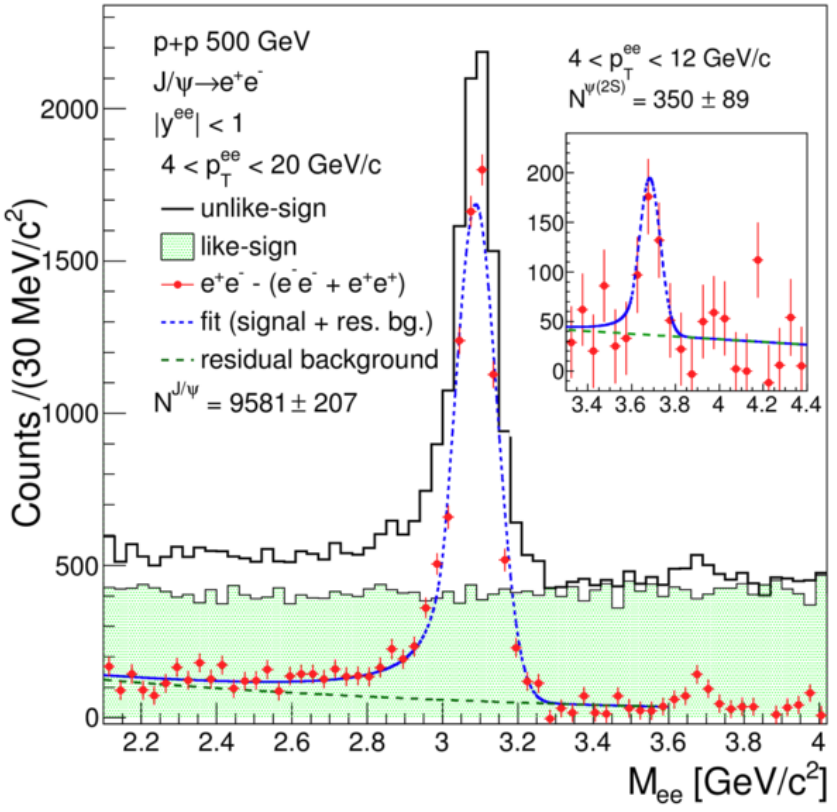
https://drupal.star.bnl.gov/STAR/publications/measurements-transverse-momentum-dependent-cross-sections-jpsi-production-mid-rapidity-

Measurements of the transverse-momentum-dependent cross sections of J/psi production at mid-rapidity in proton+proton collisions at √s = 510 and 500 GeV with the STAR detector, Phys. Rev. D 100 (2019) 52009

Muon detector

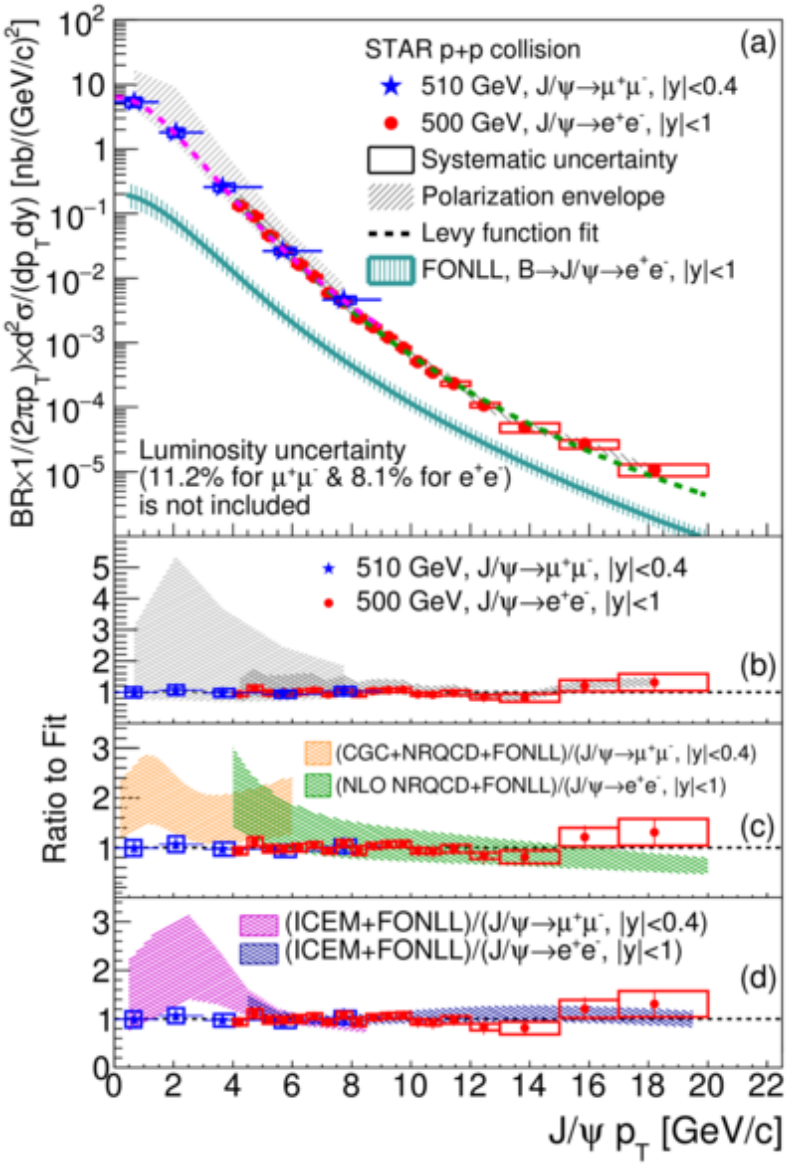


ToF + E-M calorimeter



Measurements of the transverse-momentum-dependent cross sections of J/psi production at mid-rapidity in proton+proton collisions at √s = 510 and 500 GeV with the STAR detector, Phys. Rev. D 100 (2019) 52009

Combined spectrum covers wide p_T range

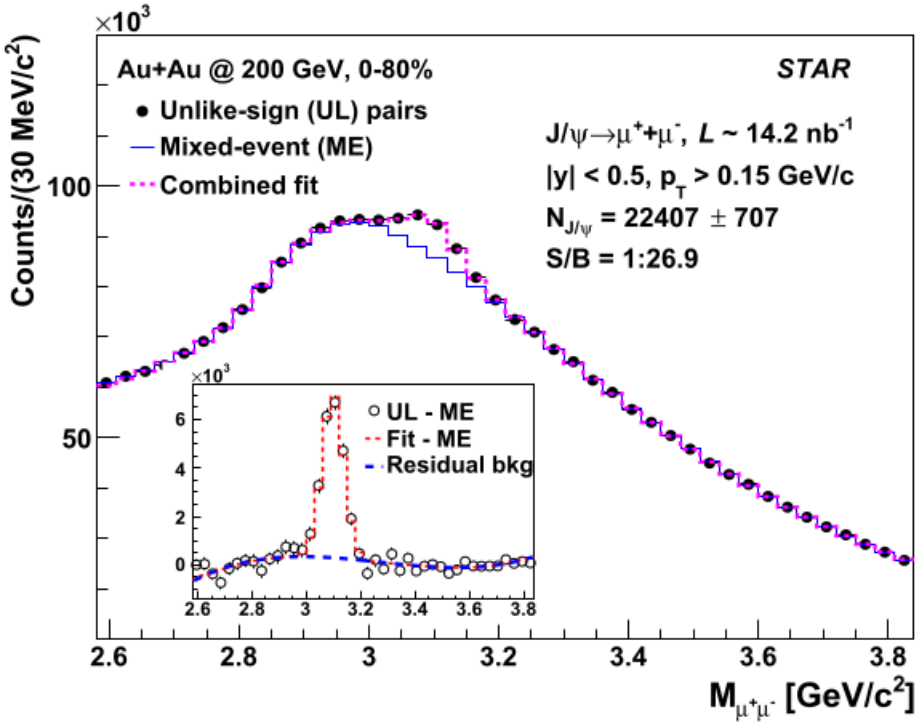


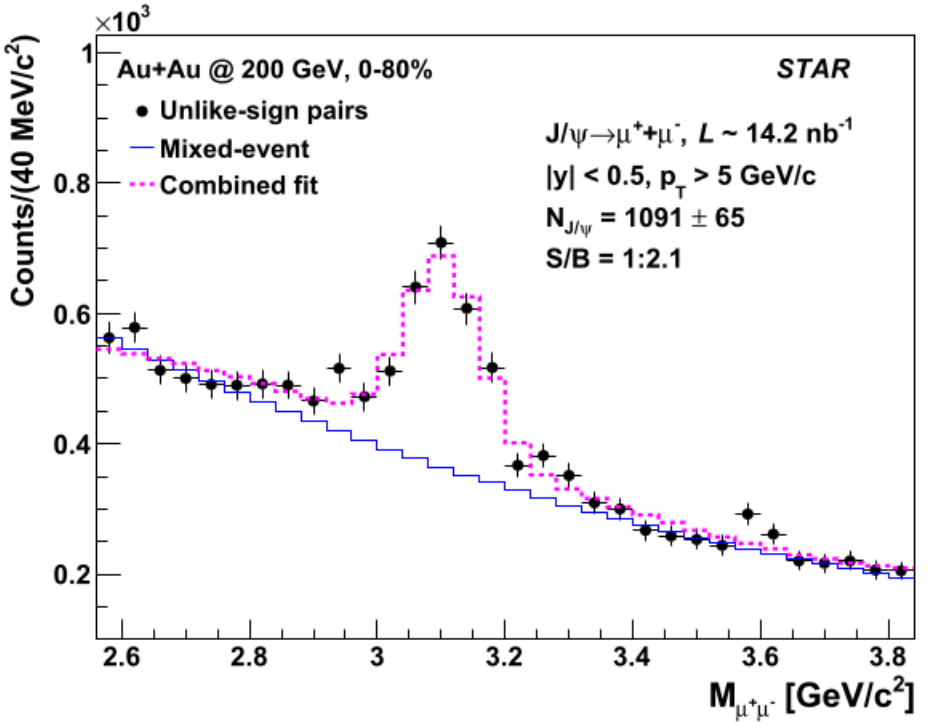
Performance in Au+Au collisions: J/ψ

List of muon PID cuts.

Detector used	Muon PID cuts
TPC	$-1 < n\sigma_{\pi} < 3$
MTD	$\lvert\Delta y\rvert < 2(2.5)\sigma_{\Delta y}$ for p_T <(≥) 3 GeV/c $\lvert\Delta z\rvert < 2(2.5)\sigma_{\Delta z}$ for p_T <(≥) 3 GeV/c $\Delta t_{tof} < 0.75$ ns

Physics Letters B 797 (2019) 134917





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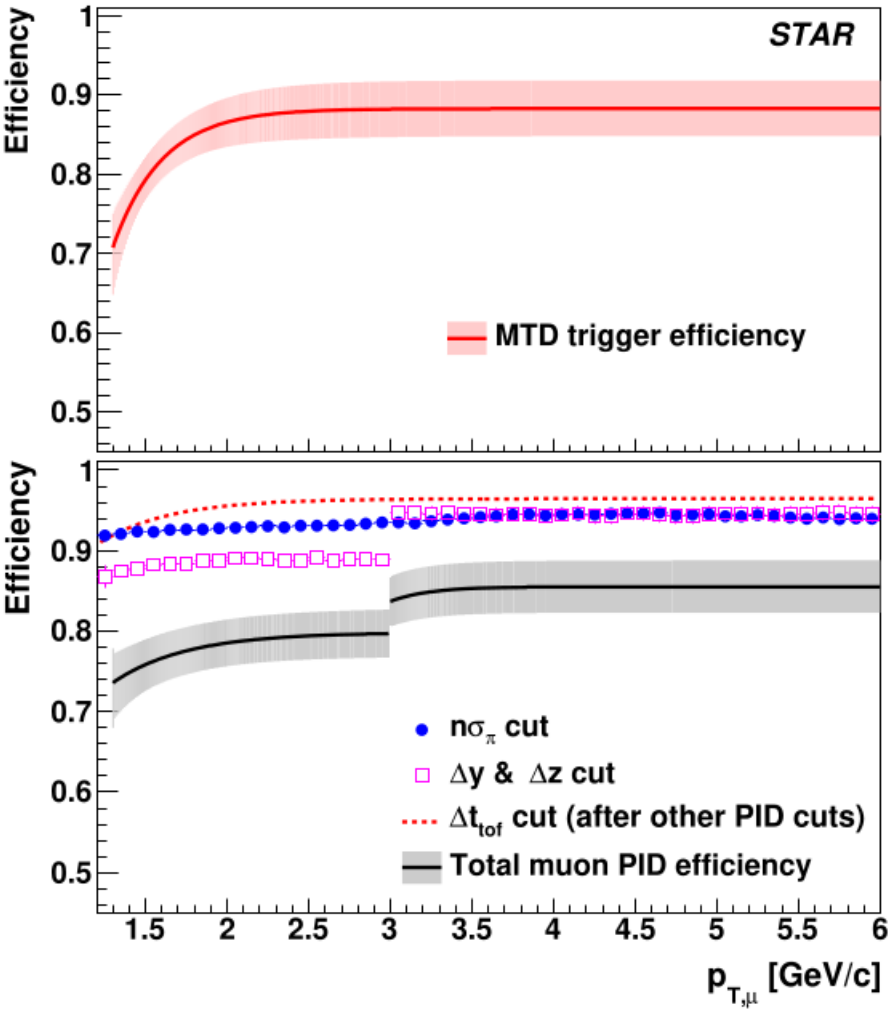

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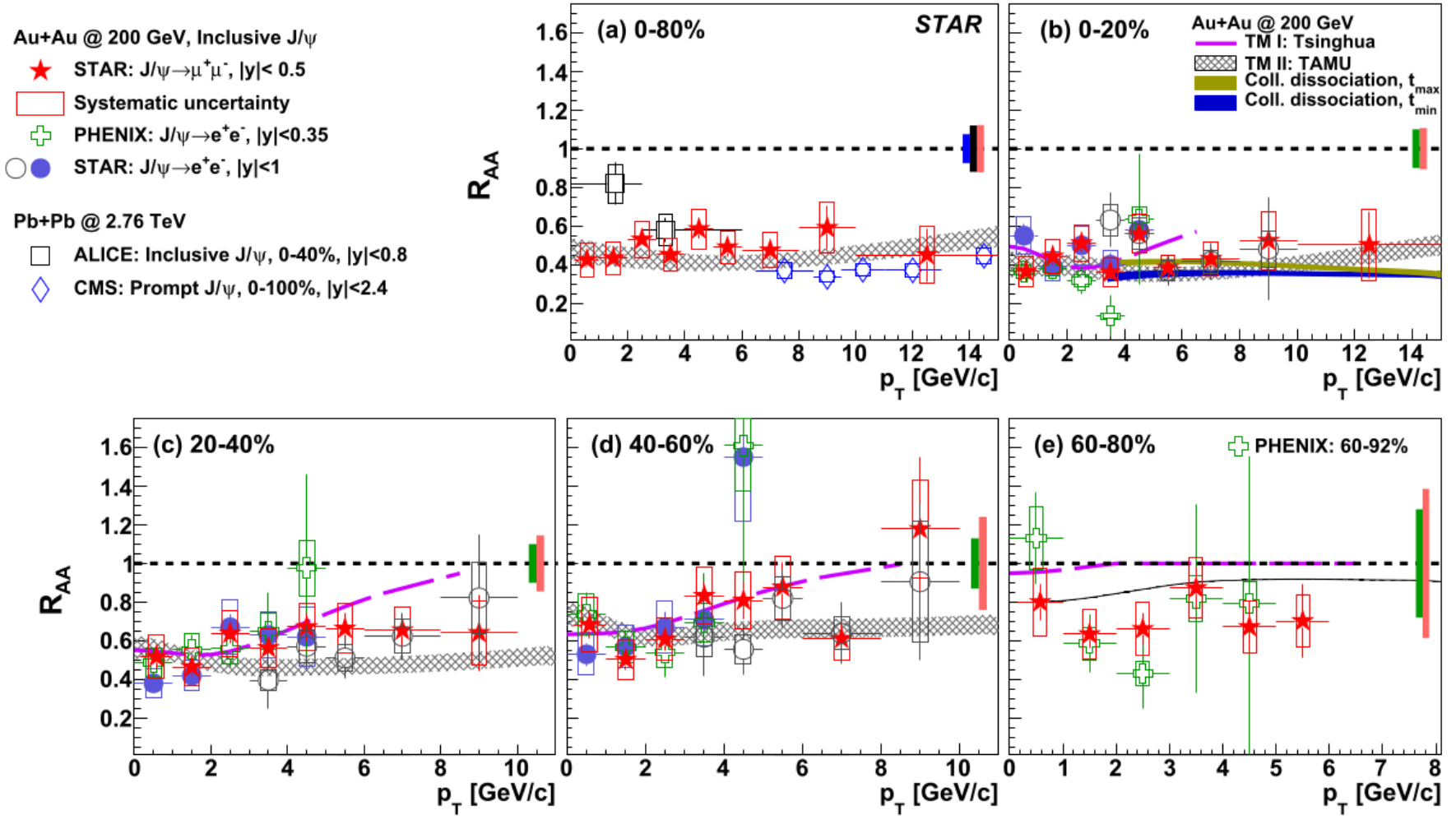
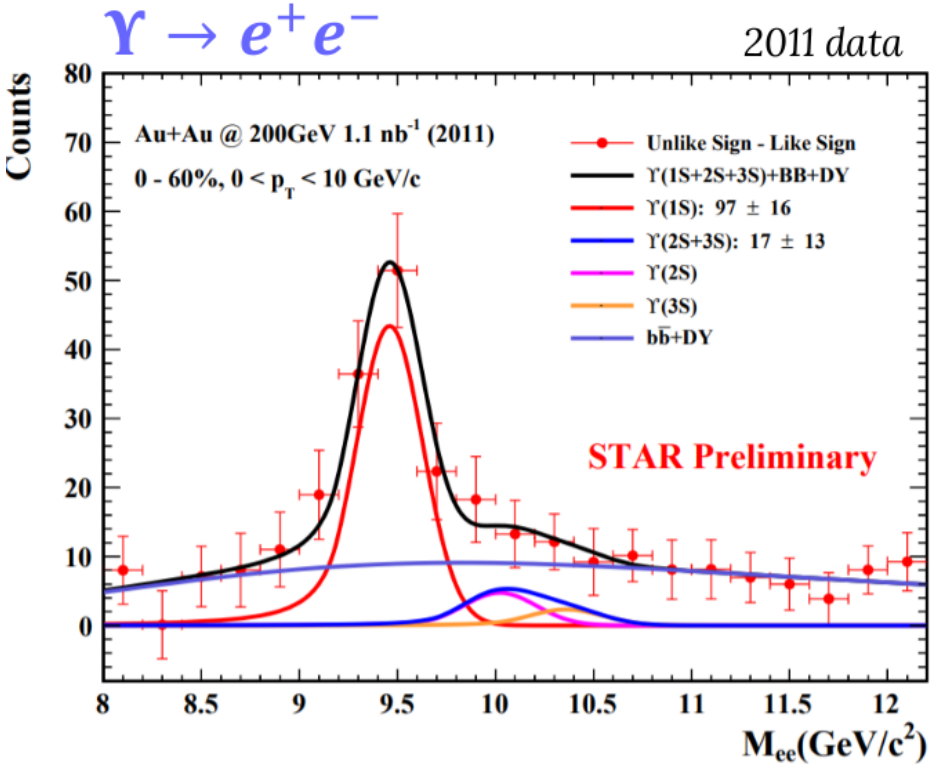
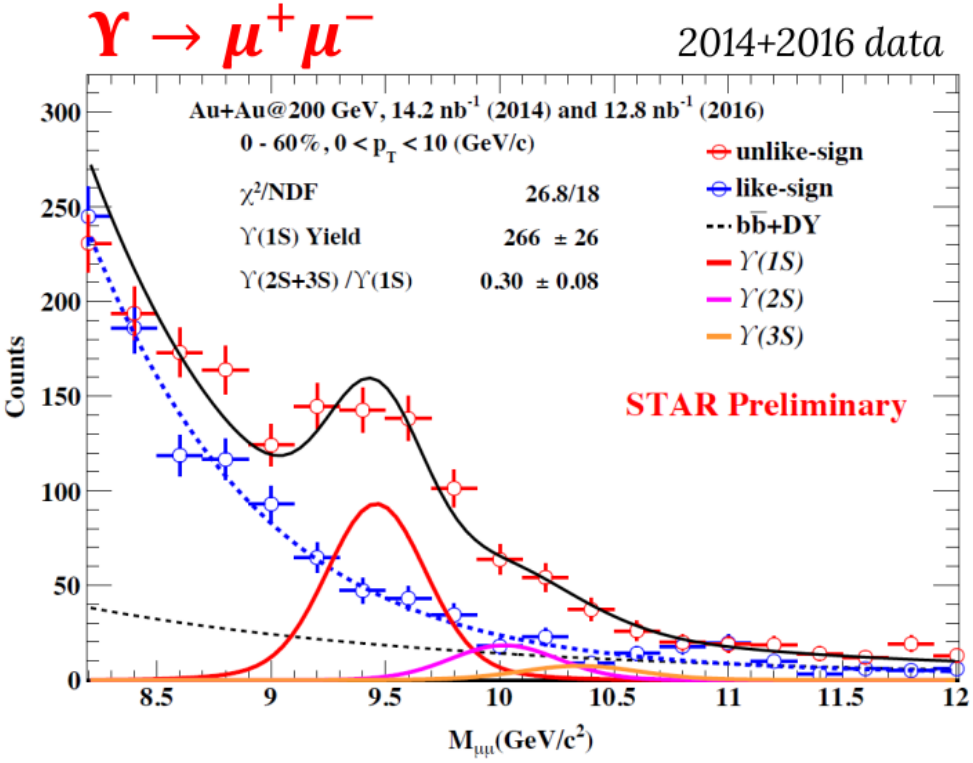


Physics Letters B 797 (2019) 134917

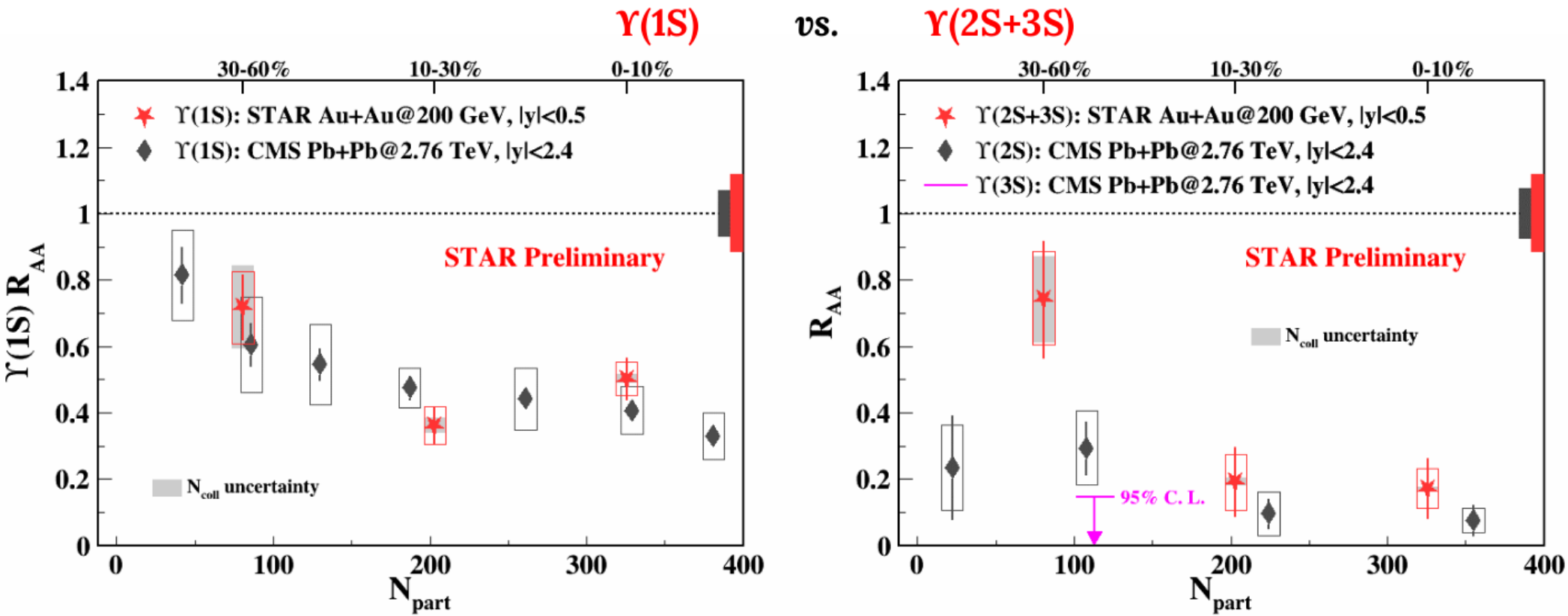
Performance in Au+Au collisions: Υ





O. Matonoha, Hot Quarks 2018

Performance in Au+Au collisions: Υ



O. Matonoha, Hot Quarks 2018

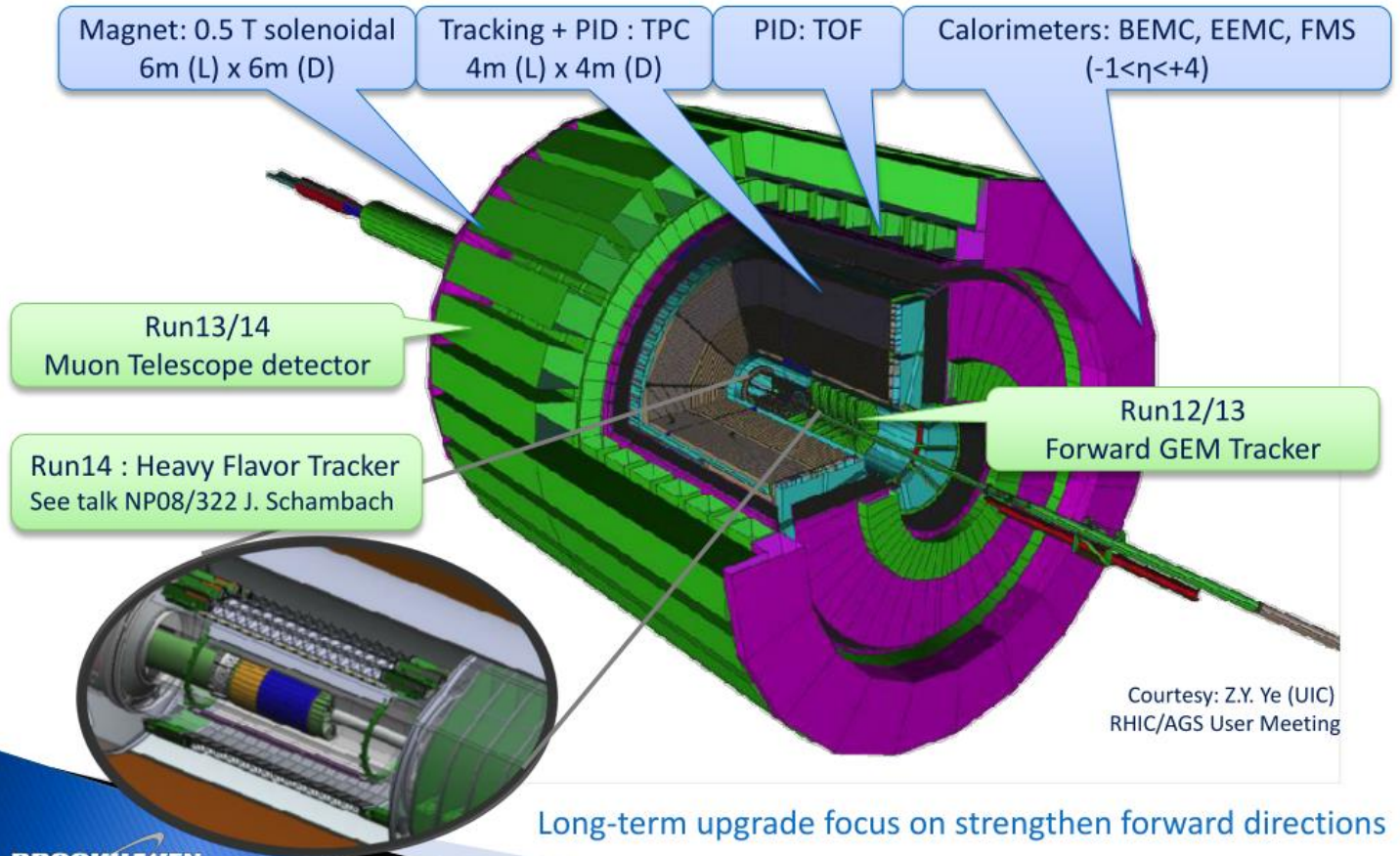
Quarkonium measurement in STAR

- STAR uses e^+e^- and $\mu^+\mu^-$ channels to explore their complementarity and maximize the sampled luminosity

- e^+e^- measurements: TPC + ToF + E-M calorimeter
  - High-p_T J/psi, based on high-energy signal in E-M calorimeter
- $\mu^+\mu^-$ measurements: TPC + Muon detector
  - Low-p_T and mid-rapidity measurements, based on dimuon trigger

Backup

The STAR detector and recent upgrades

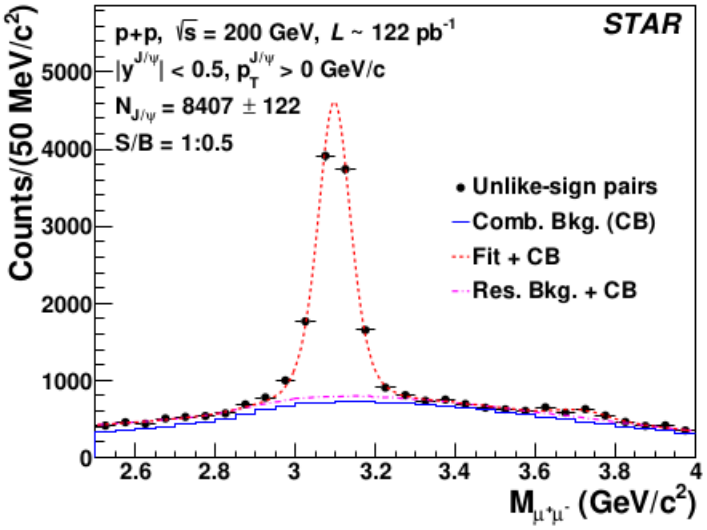


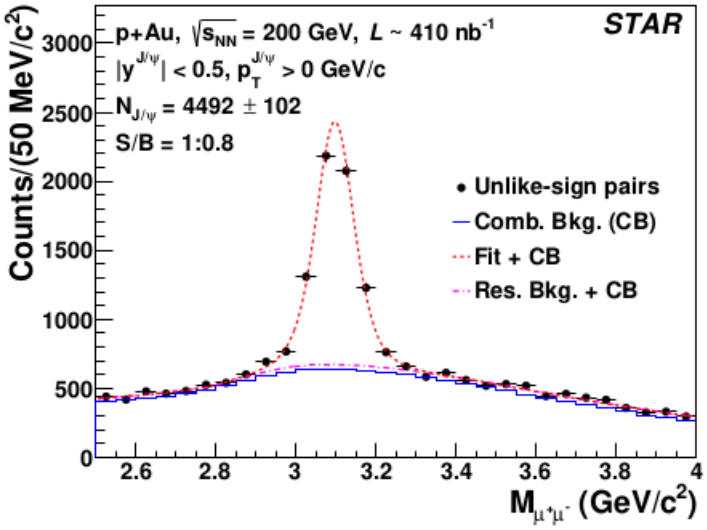
Long-term upgrade focus on strengthen forward directions

Muon Telescope Detector (MTD) added as an upgrade in 2013 to improve detection capabilities at low-p_T J/ψ and ϒ(2S) and ϒ(3S) separation

Performance in p+Au collisions: J/ψ

Phys. Lett. B 825 (2022) 136865





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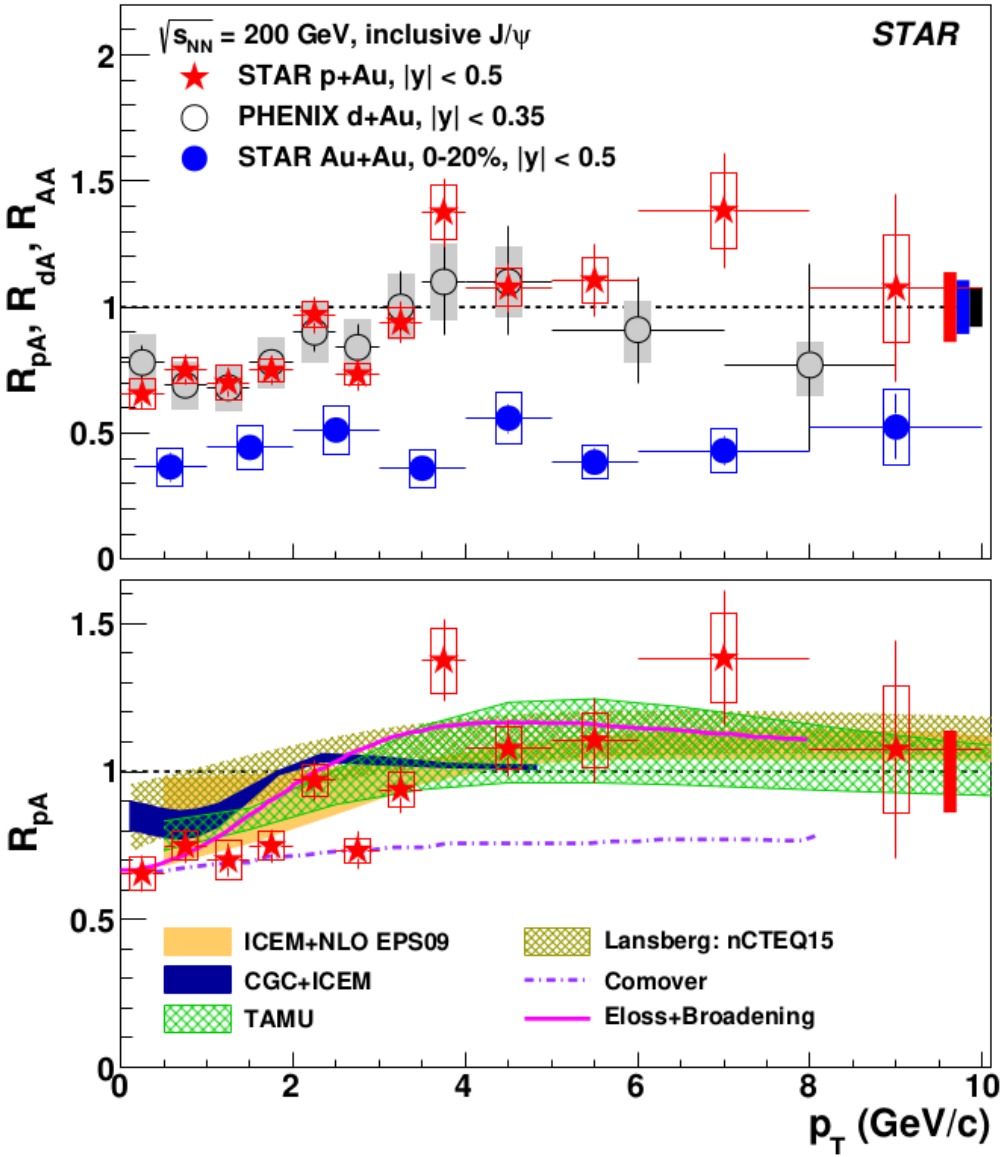
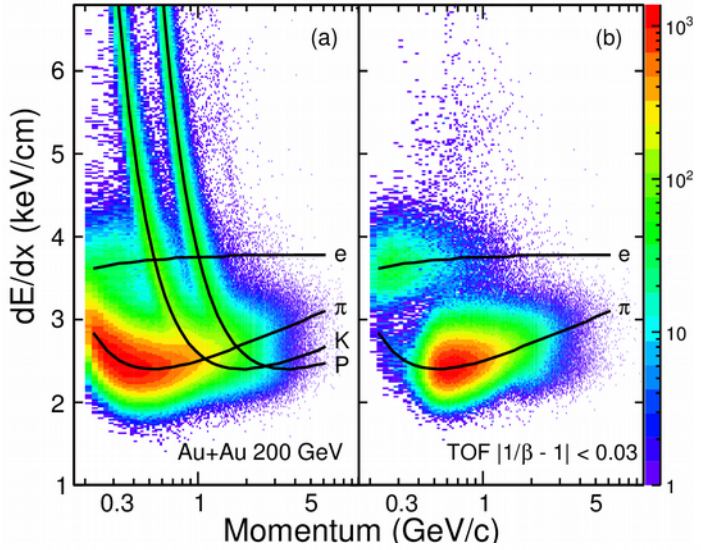
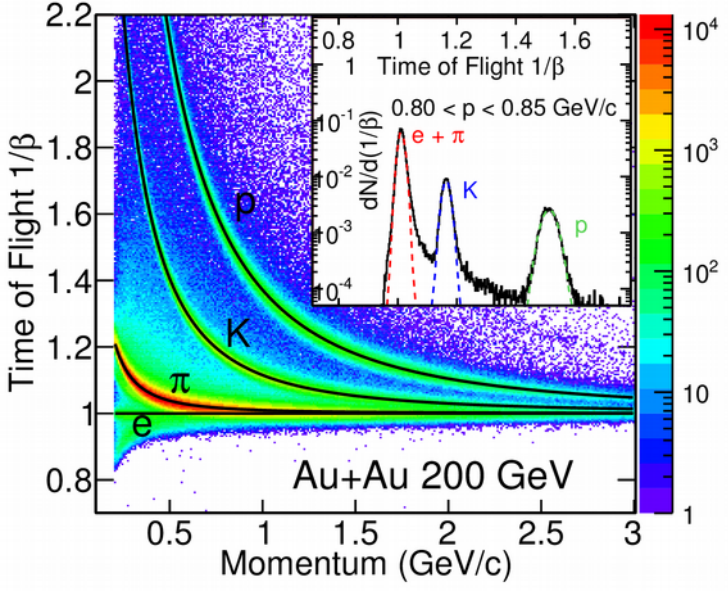


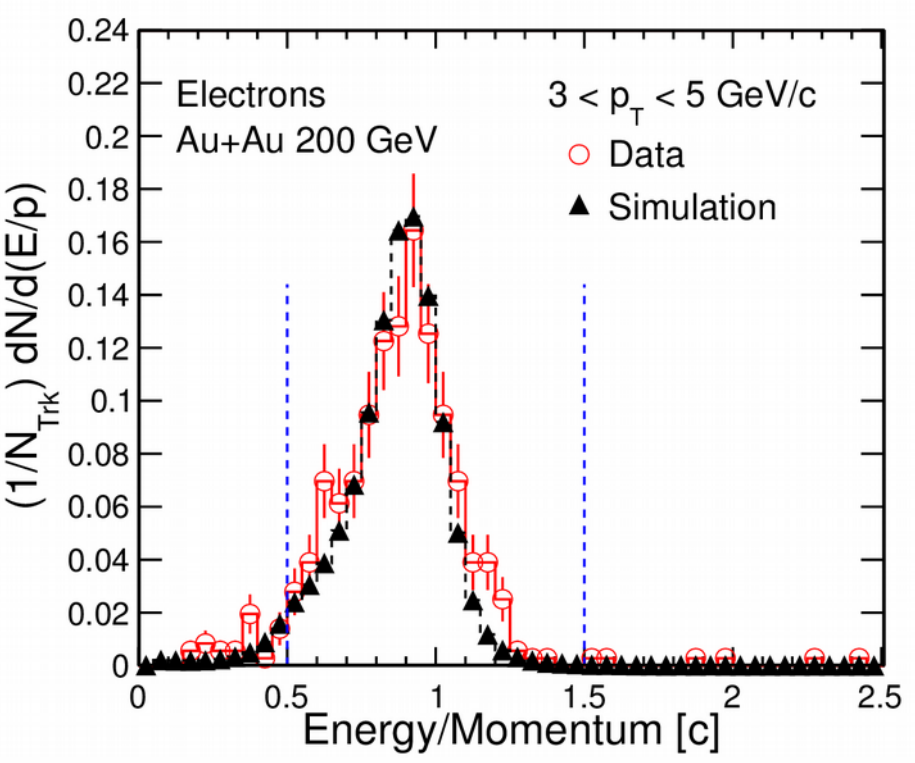
Low-p_T J/psi → e^+e^- in Au+Au 200 GeV

Electron identification

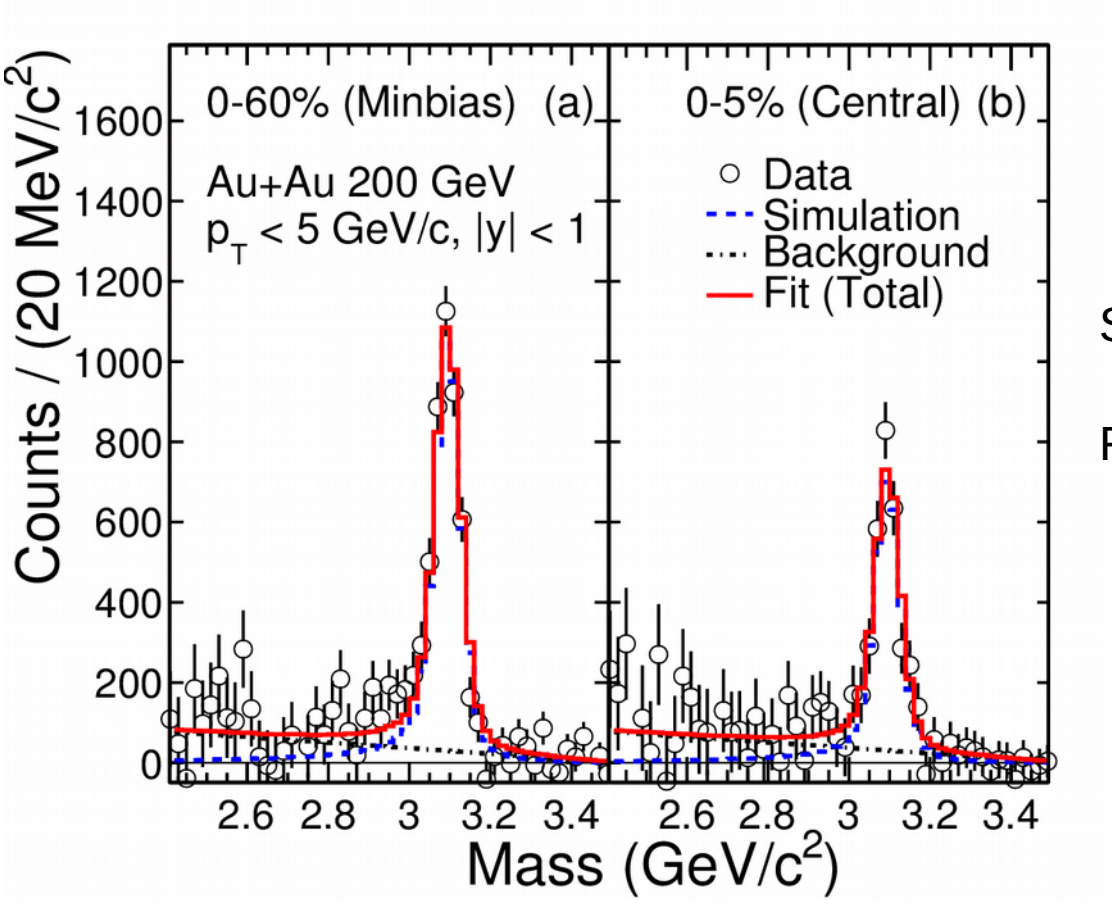
Phys. Rev. C 90 (2014) 24906







Low-p_T J/psi $\rightarrow e^+e^-$ in Au+Au 200 GeV



Phys. Rev. C 90 (2014) 24906

Signal limited to p_T < 5 GeV/c

For R_{AA} : pp baseline from PHENIX (|y|<0.35)

Detection configurations

- $J/\psi \rightarrow e^+e^-$: BR = (5.971 ± 0.032) %
  - $J/\psi \rightarrow e^+e^-\gamma$: BR = (8.8 ± 1.4) × 10^{-3} (intrinsic Bremsstrahlung
- $J/\psi \rightarrow \mu^+\mu^-$: BR = (5.961± 0.033) %

Upsilon:

- BR is the same for e^+e^- and $\mu^+\mu^-$ channels