Measurements of Y and very low p_{T} J/ψ production in Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV at STAR

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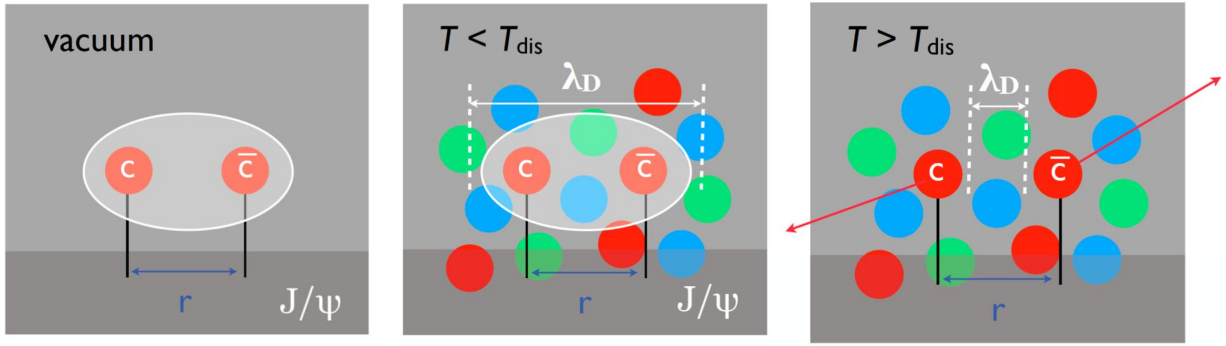
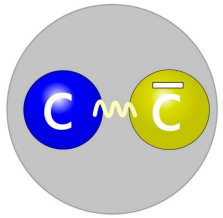
Quarkonium

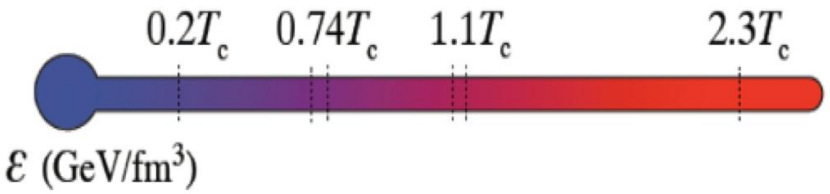
- Early creation: heavy quarks created in initial hard scattering, experience the entire evolution of the QGP.
- Dissociation: suppression of quarkonium yield, direct evidence of the QGP formation.
- Regeneration: compete with dissociation.
- Other effects: feed-down, Cold Nuclear Matter effects (nPDF, Nuclear absorption…), etc.

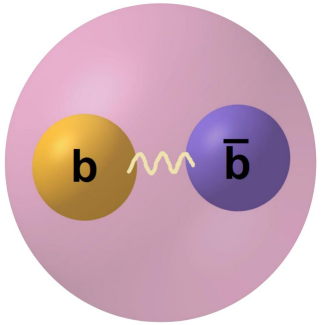


$$r_{q\bar{q}} \sim 1/E_{binding} > r_D \sim 1/T$$

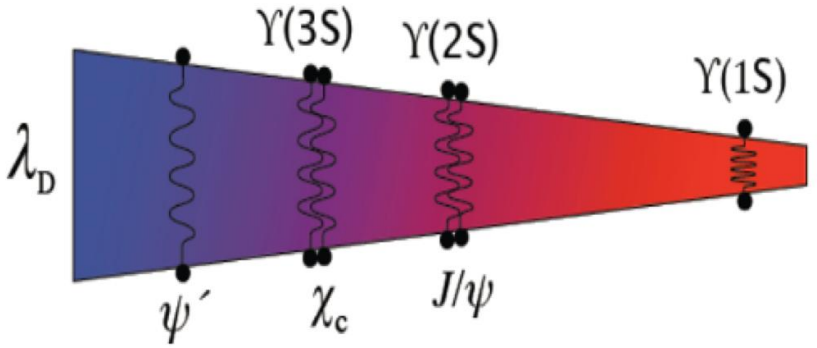


- Larger production cross section

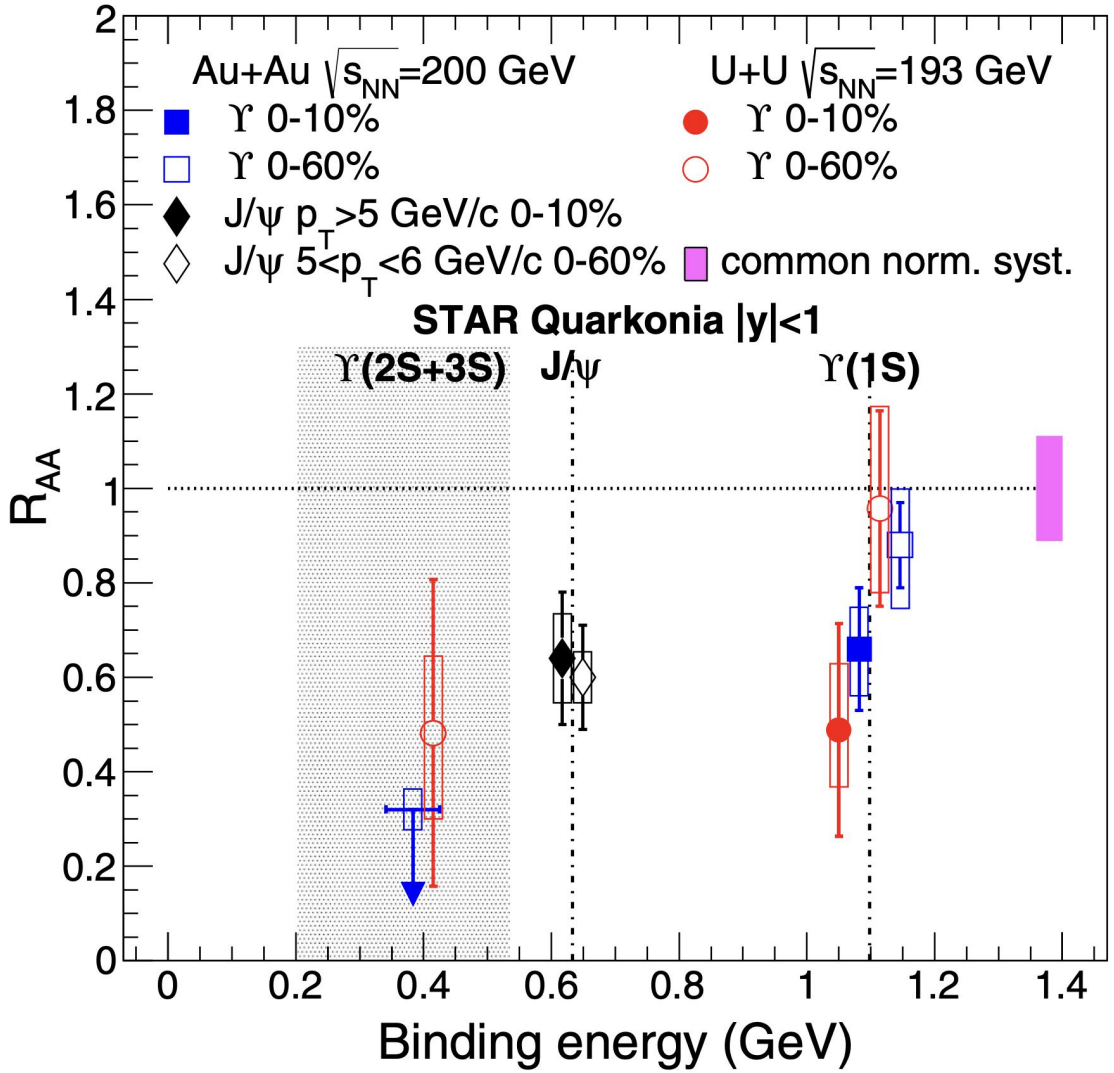




- Negligible regeneration
- Compared to charmonia, bottomonia are cleaner probes



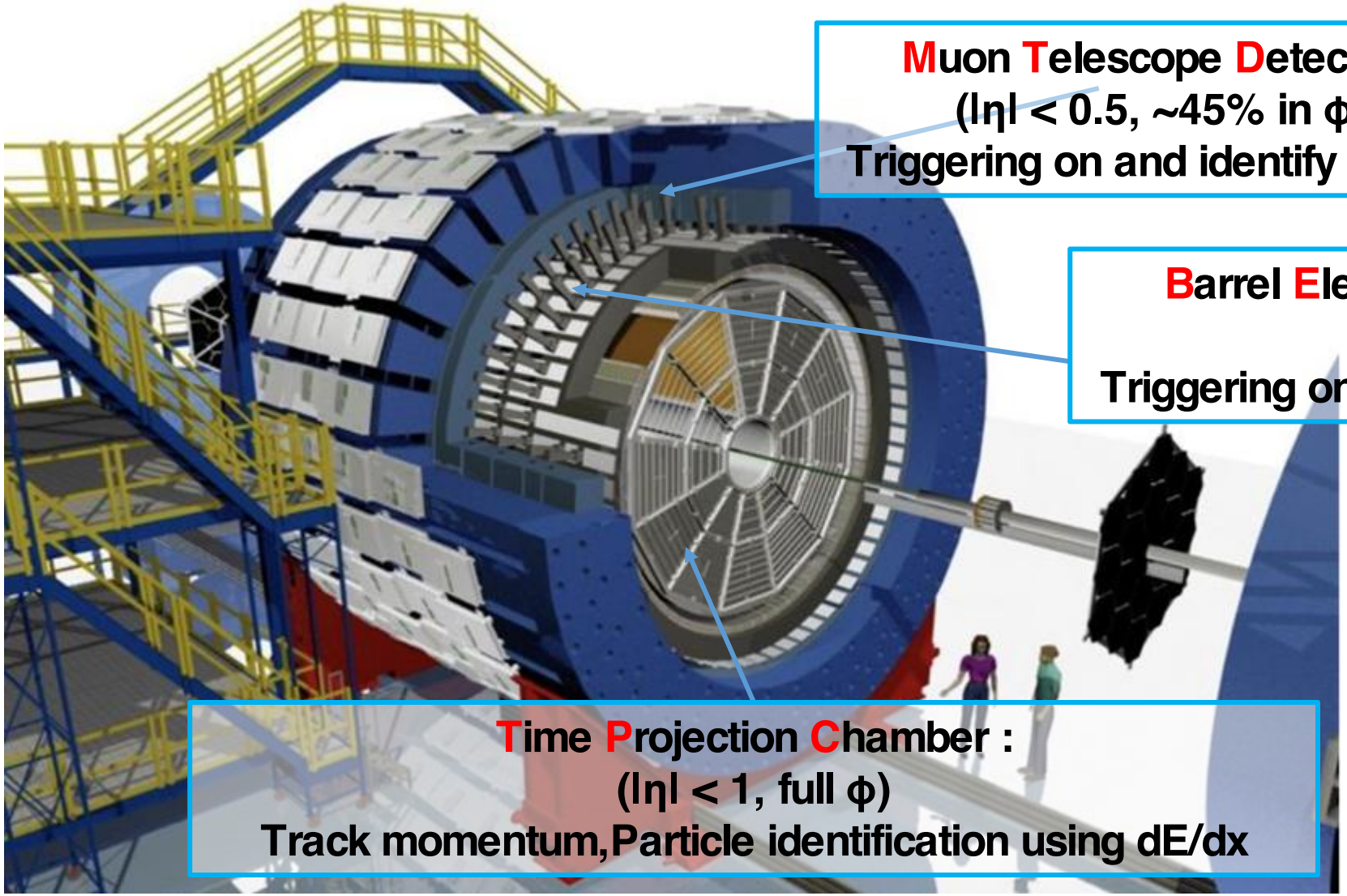
Quarkonium sequential suppression



STAR, Phys. Lett. B 735 (2014) 127–37.
STAR, Phys. Rev. C 94 (2016) 064904.

- Hint of stronger suppression for Y(2S+3S) compared to Y(1S)
  - ➢ Significance less than 1.5σ
- Differential measurements with improved precision are crucially needed.

STAR detector

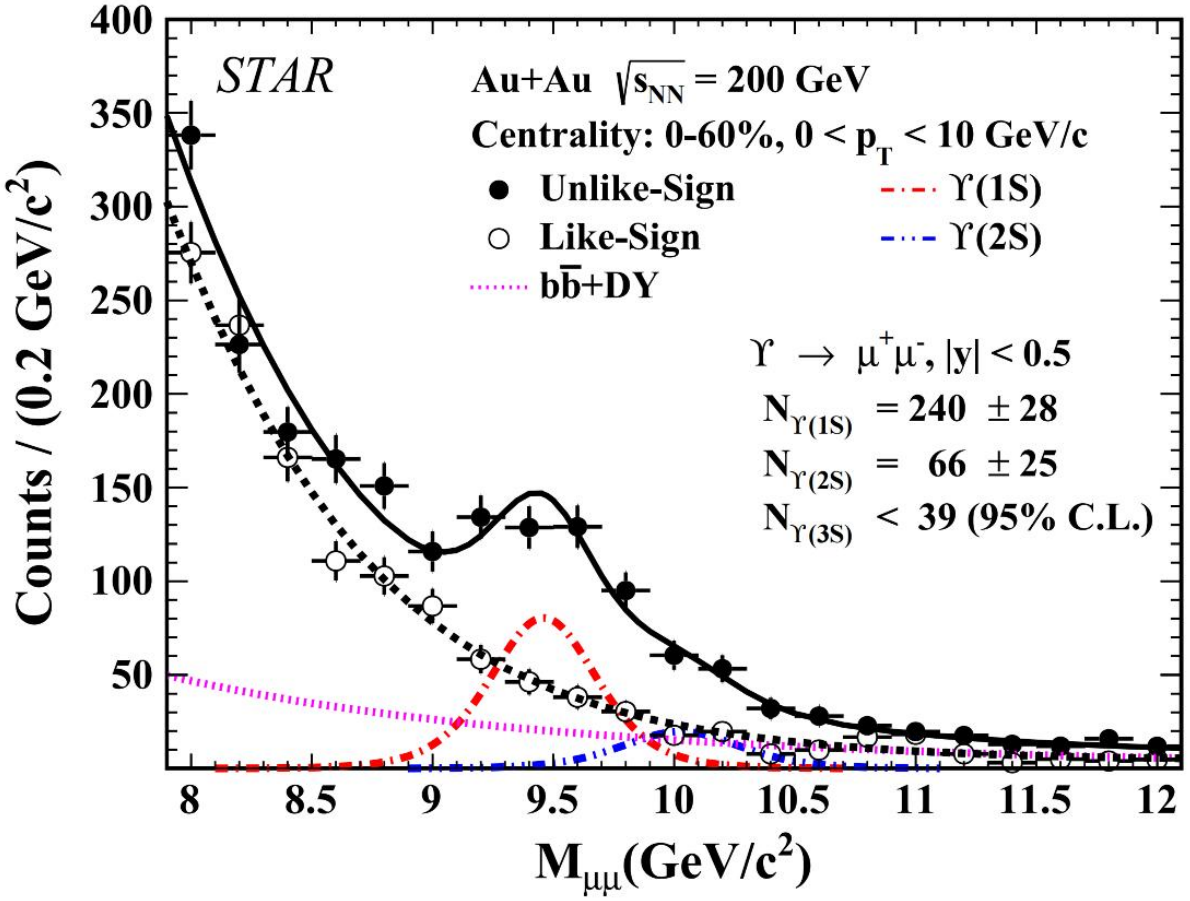


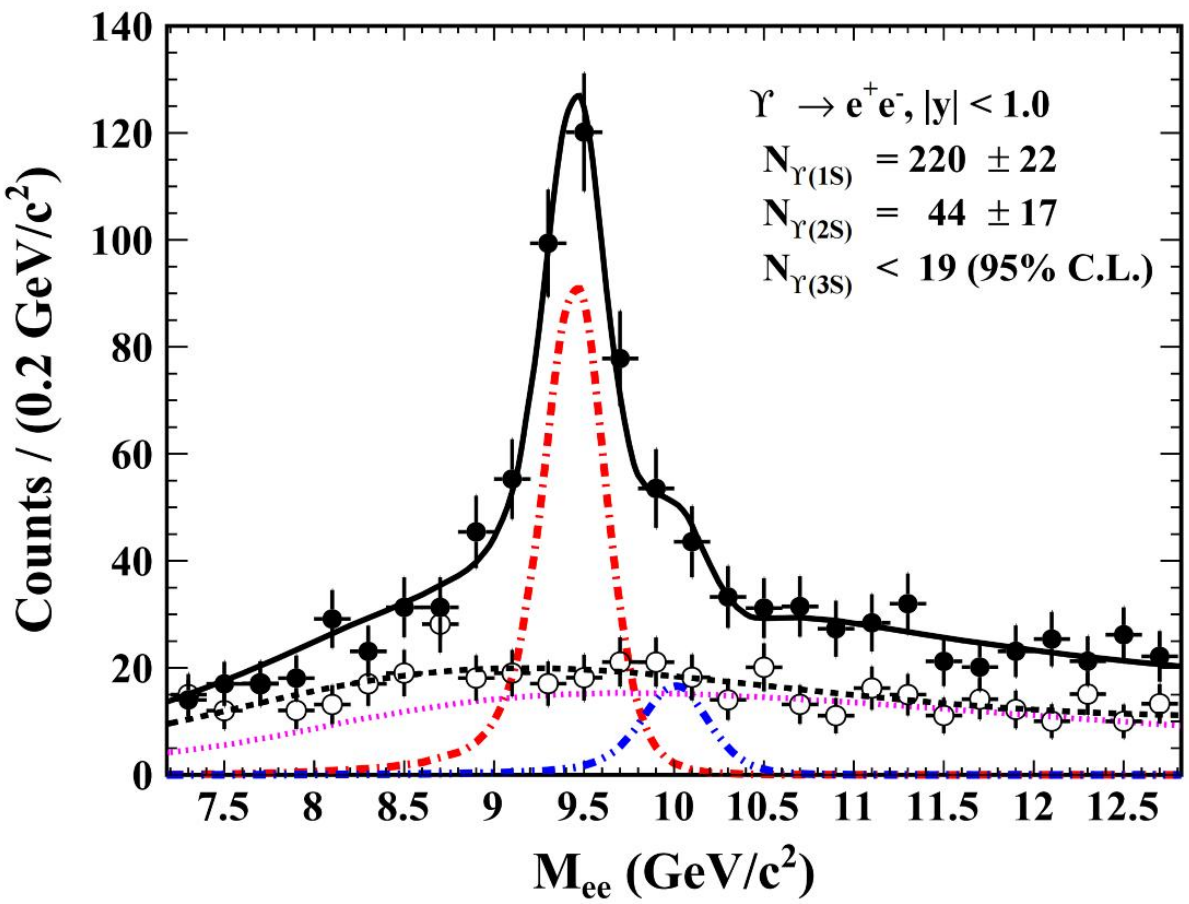
Muon Telescope Detector :
(|η| < 0.5, ~45% in ϕ)
Triggering on and identify muons

Barrel Electro Magnetic Calorimeter:
(|η| < 1, full ϕ)
Triggering on and identify high-p_T electrons

Time Projection Chamber :
(|η| < 1, full ϕ)
Track momentum,Particle identification using dE/dx

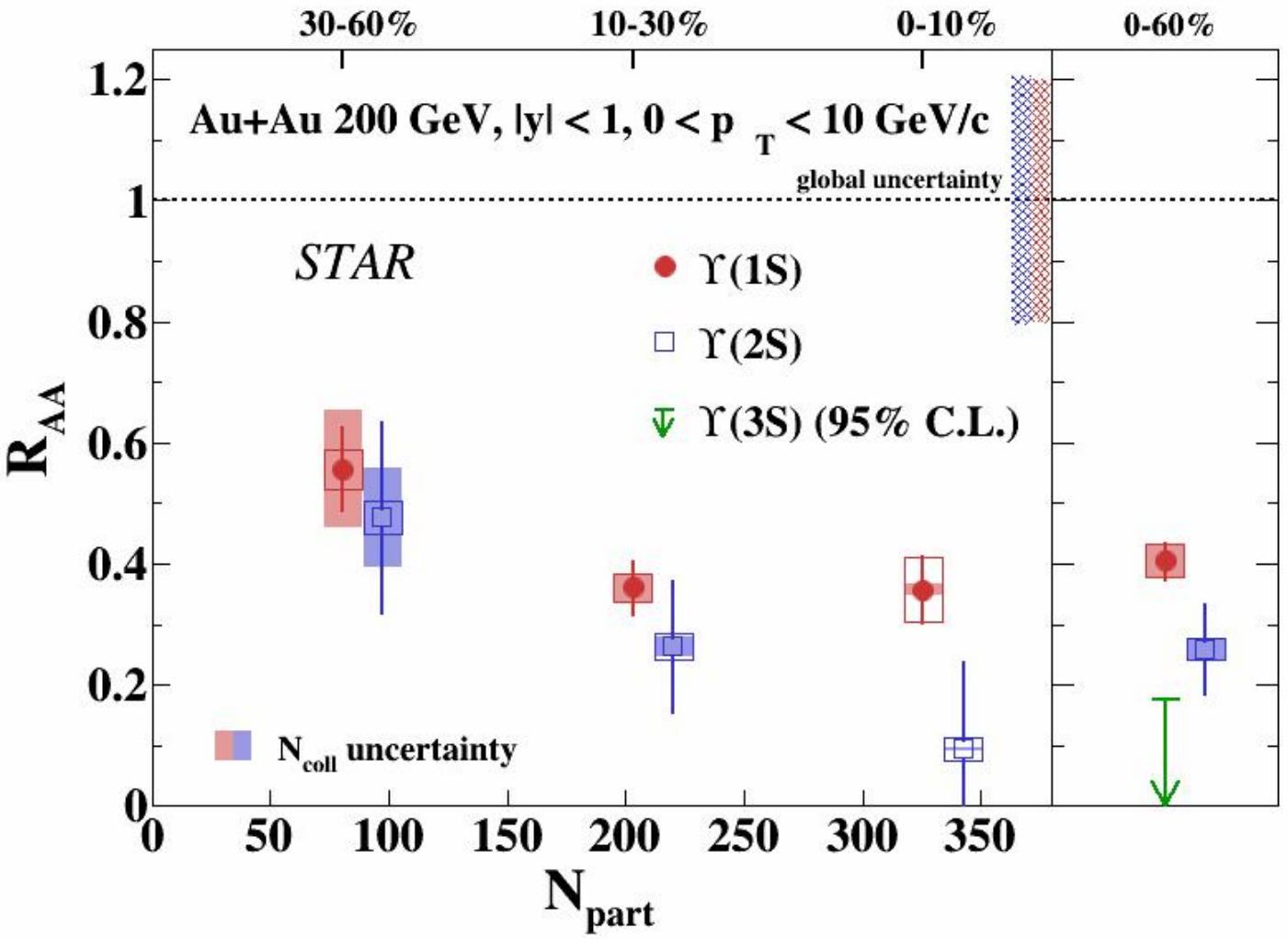
Signal extraction





- Unbinned maximum-likelihood simultaneous fit to unlike-sign and like-sign mass distributions
  - Template of each Y state: embedding sample
  - Residual background ($b\bar{b}$+ Drell-Yan): Pythia 6
  - Combinatorial background: modeled with exponential function

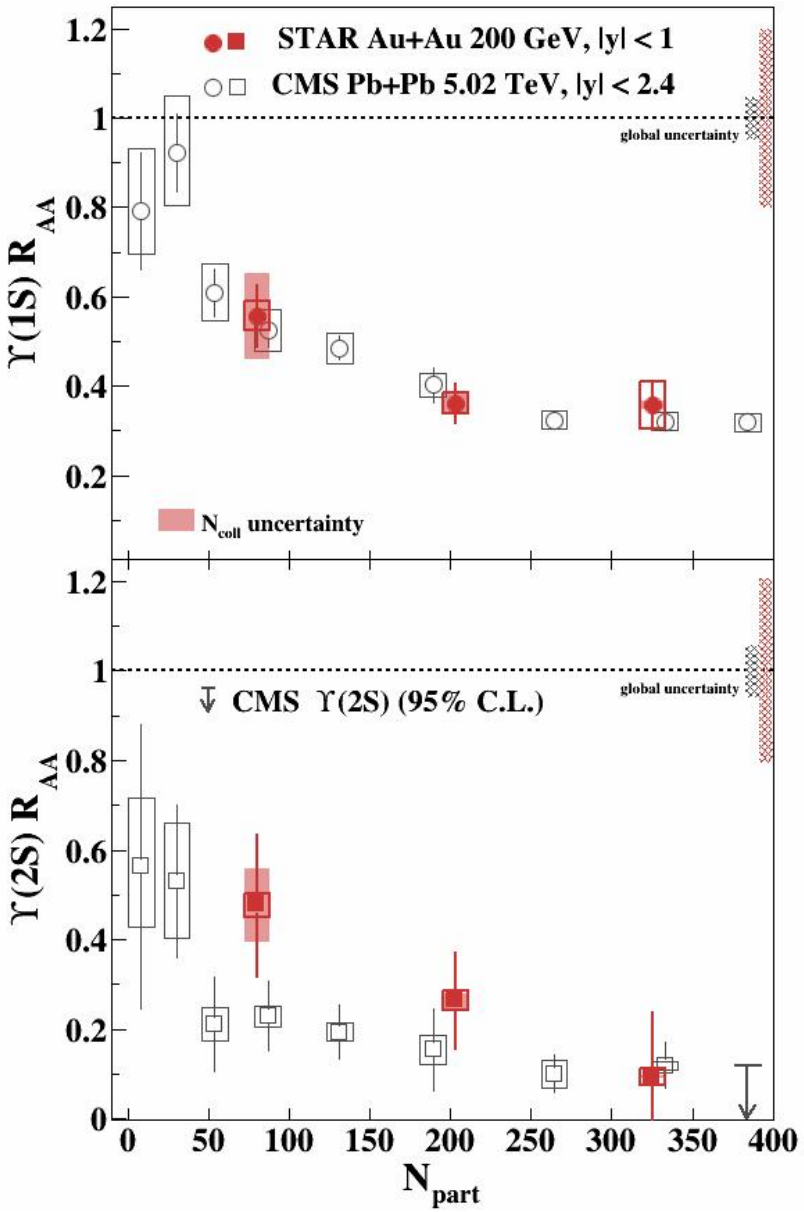
Centrality dependence of R_{AA}

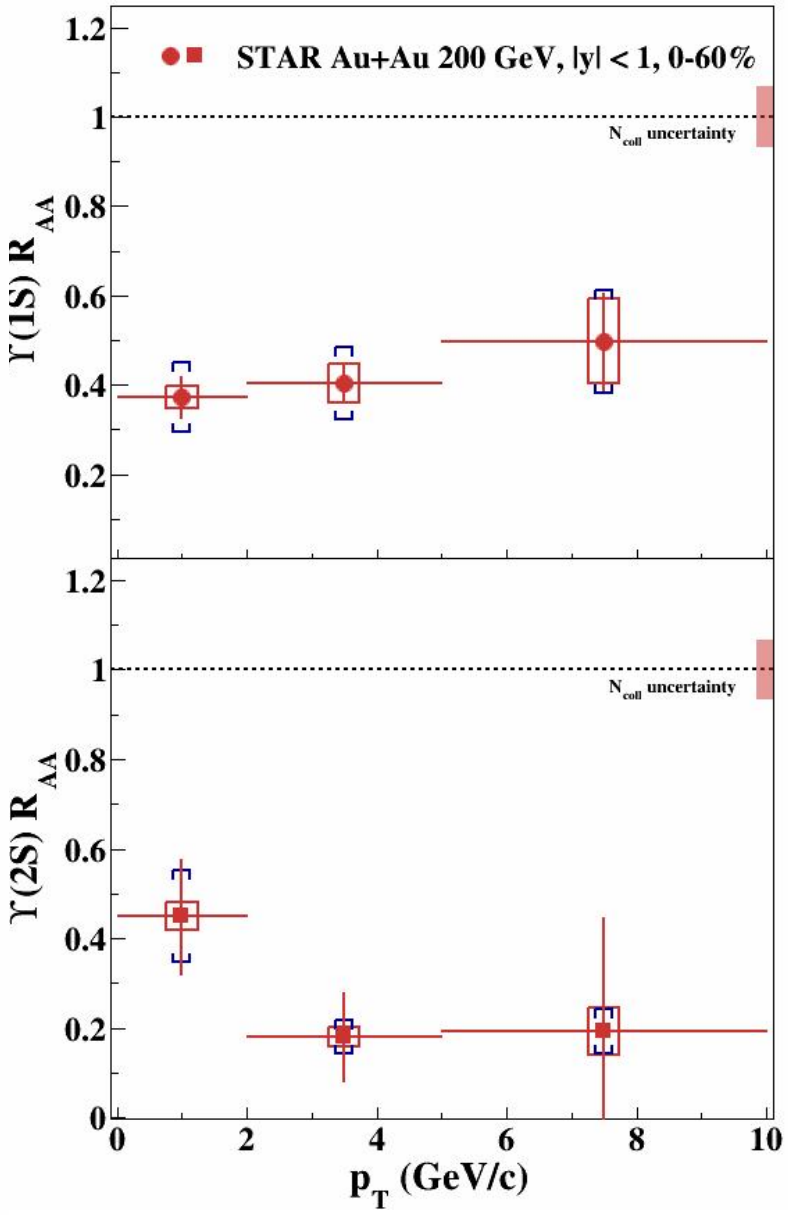


STAR, Phys. Rev. Lett. 130 (2023) 112301

- Significant suppression for different Y states is observed
- Suppression gradually increase towards central collisions
- The results are consistent with sequential suppression pattern

Comparison with LHC results

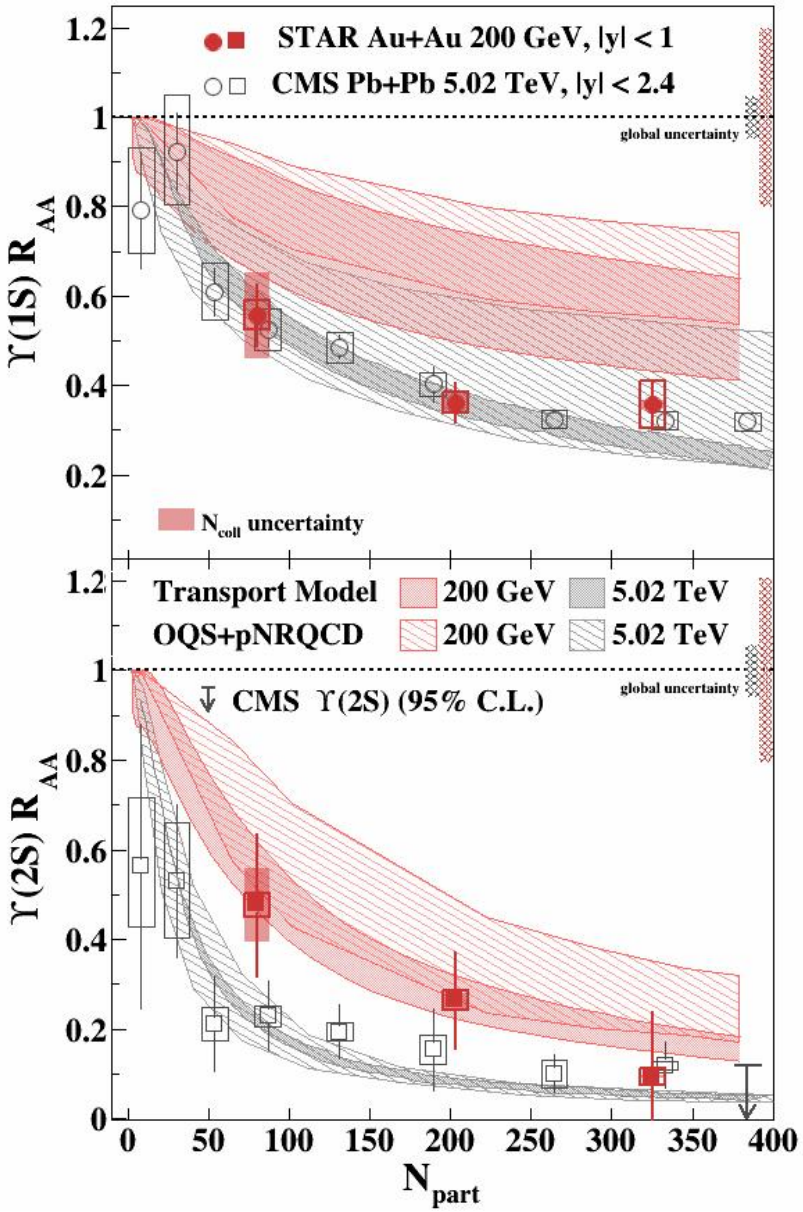


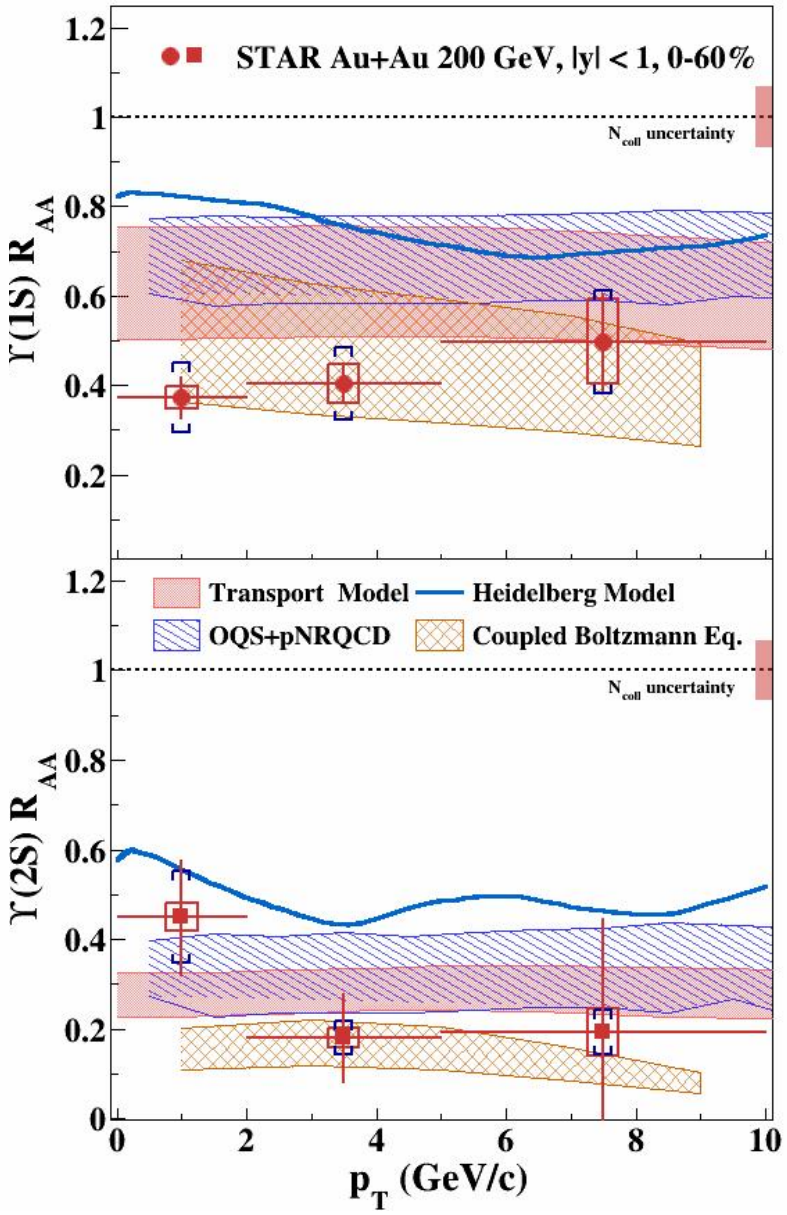


- Υ(1S) exhibits a similar magnitude of suppression at the LHC and RHIC collision energies
- Hint of less suppression of Υ(2S) at RHIC in peripheral collisions
- No significant p_T dependence is observed

CMS, Phys. Lett. B 790 (2019) 270–93

Comparison with models





- OQS+pNRQCD: dissociation + regeneration + feed-down

JHEP 05 (2021) 136. arXiv 2205.10289 (2022).

- Transport model: dissociation + regeneration + feed-down + CNM

X. Du et al. Phys. Rev. C 96 (2017) 054901.

- Coupled Boltzmann equations: elastic and inelastic scatterings + correlated regeneration + CNM

X. Yao et al. JHEP 01 (2021) 046.

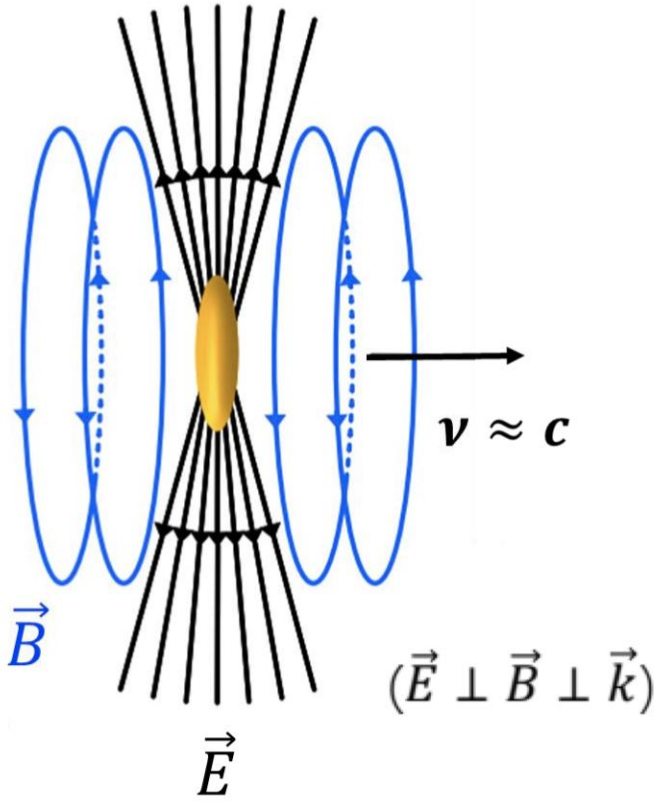
- Heidelberg model: gluon-induced dissociation + feed-down.

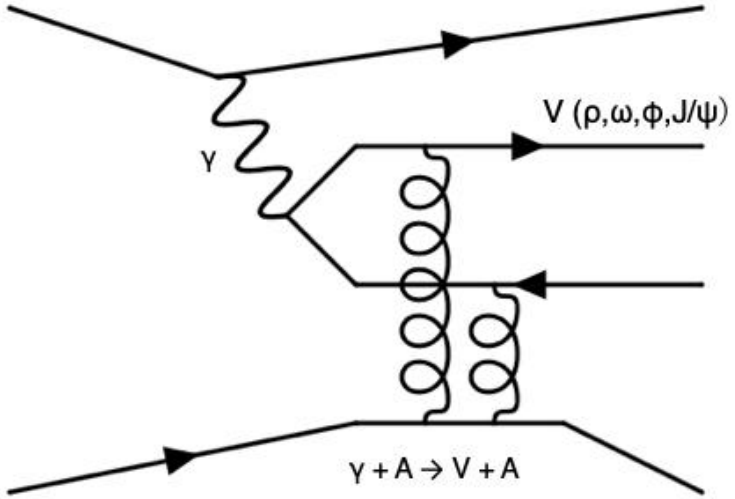
J. Hoelck et al. Phys.Rev. C 95 (2017) 024905

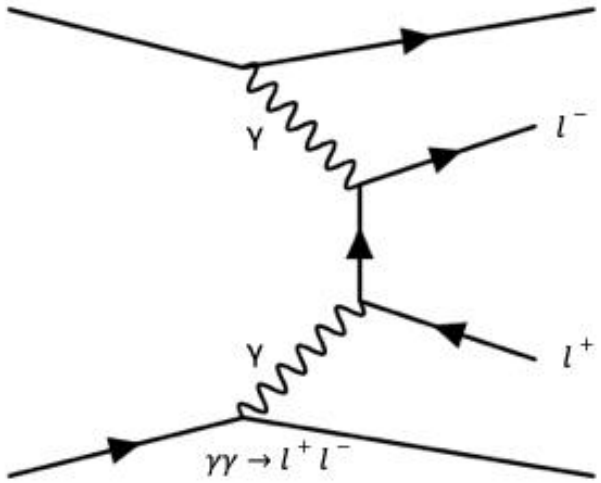
Part #2

Measurements of very low p_{T} J/ψ via dimuon decay channel

Photon-induced process







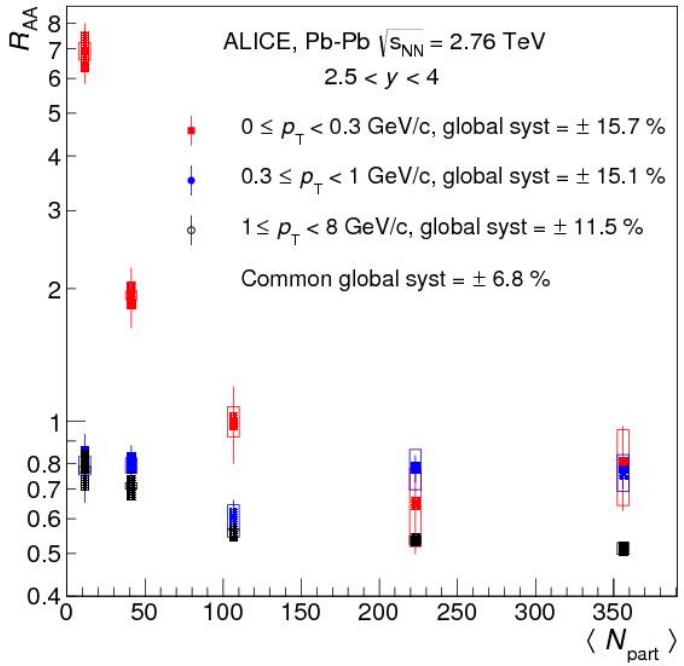
- Boosted nuclei generate intense electromagnetic fields
- Weizsacker-Williams equivalent photon approximation (EPA):
  - In a specific phase space, transverse EM fields can be quantized as a flux of real photons

$$n \propto \vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B} \approx |\vec{E}|^2 \approx |\vec{B}|^2$$

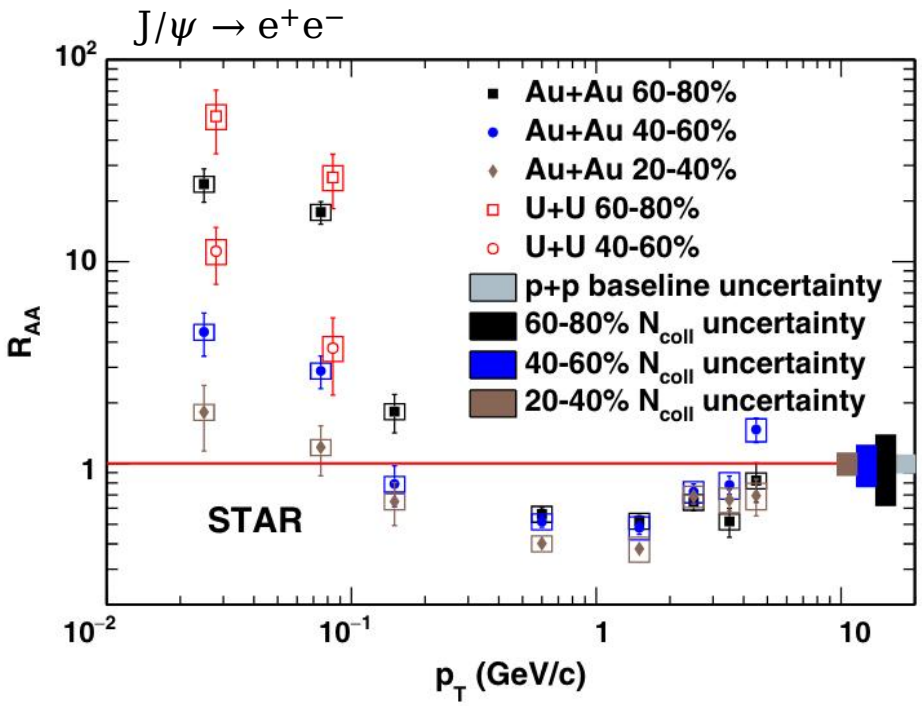
- Large quasi-real photon flux $\propto Z^2$

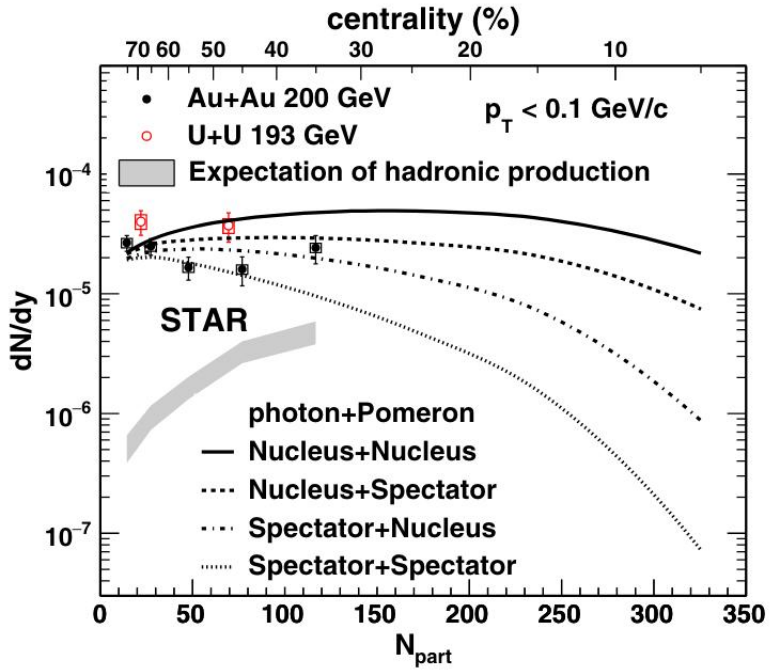
Photon production with nuclear overlap

- Significant enhancements of the J/ψ production at very low p_T observed by the ALICE and STAR collaboration in peripheral collisions.
  - Weaker centrality dependence.
  - Consistent with coherent photon-nucleus interactions.



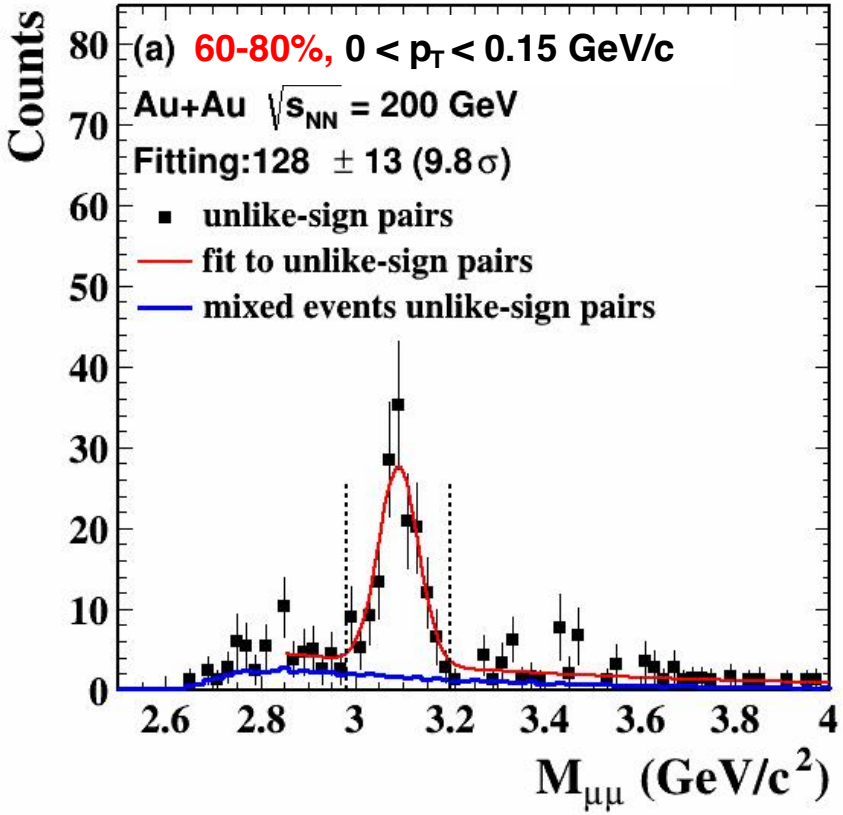
ALICE, Phys. Rev. Lett. 116, 222301 (2016).

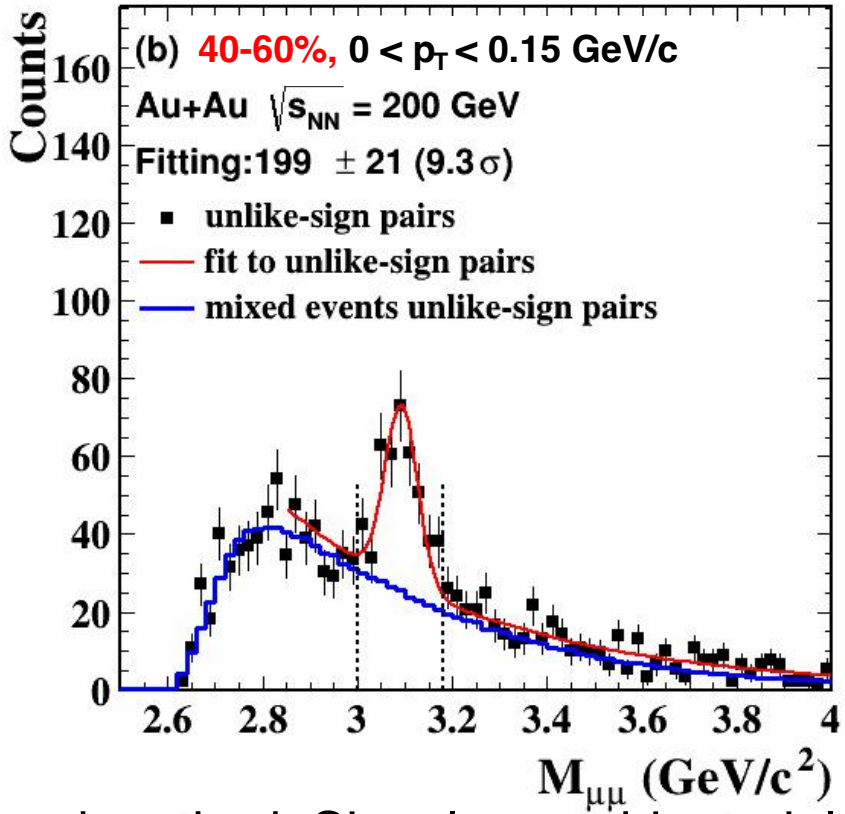




STAR, Phys. Rev. Lett. 123, 132302 (2019).

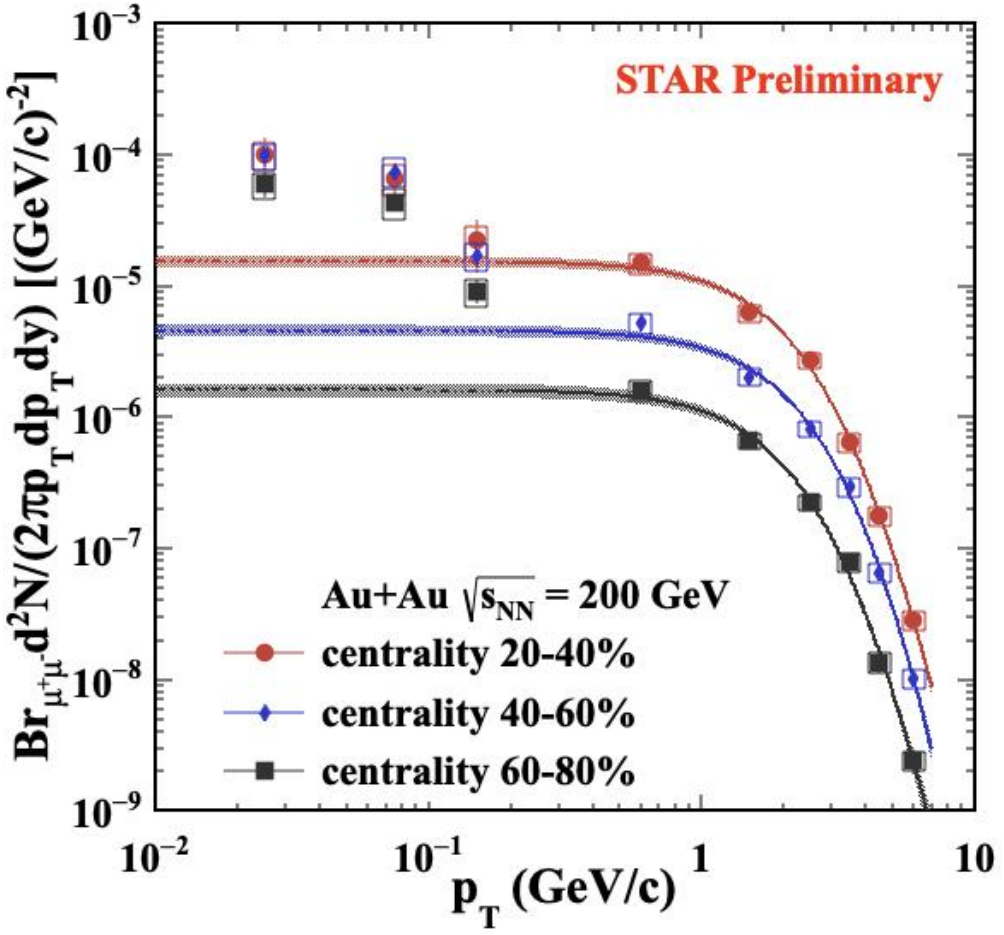
J/ψ→μ⁺μ⁻ signal extraction

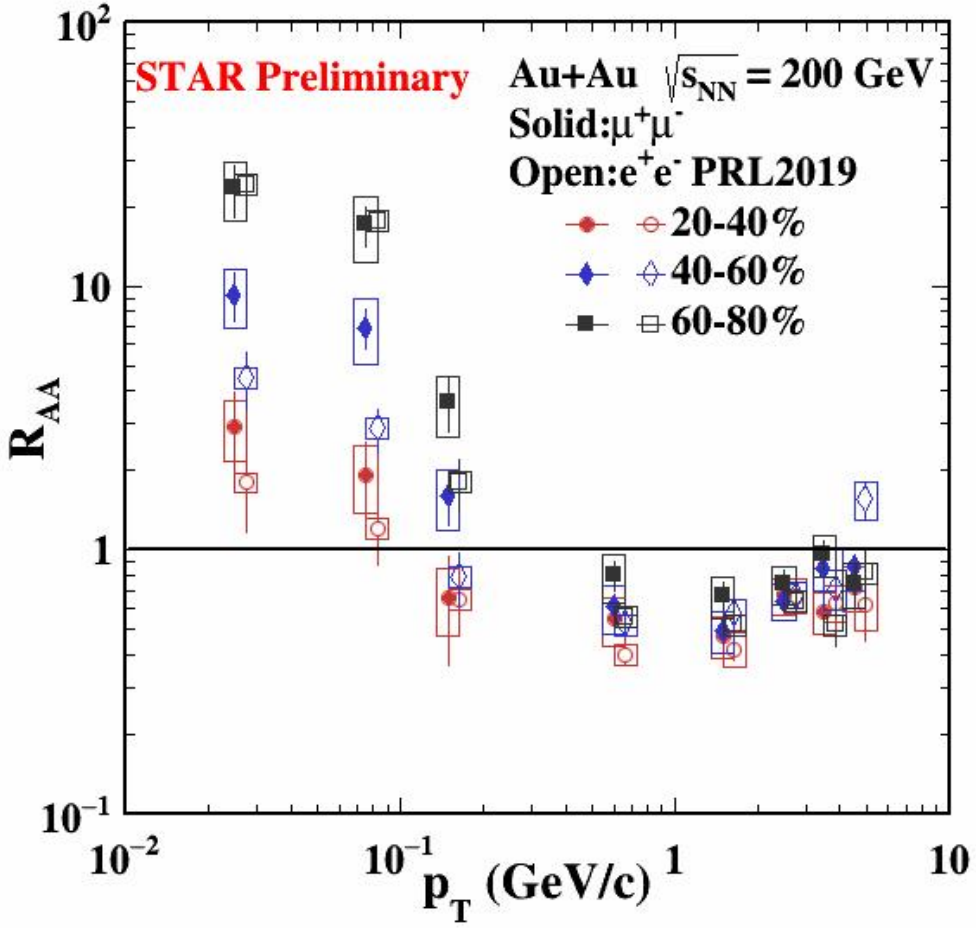




- Fit unlike sign distribution with maximum likelihood method: Signal + combinatorial background + residual background.
- Template of J/ψ: embedding sample
- Residual background: exponential function
- Combinatorial Background: mixed event technique

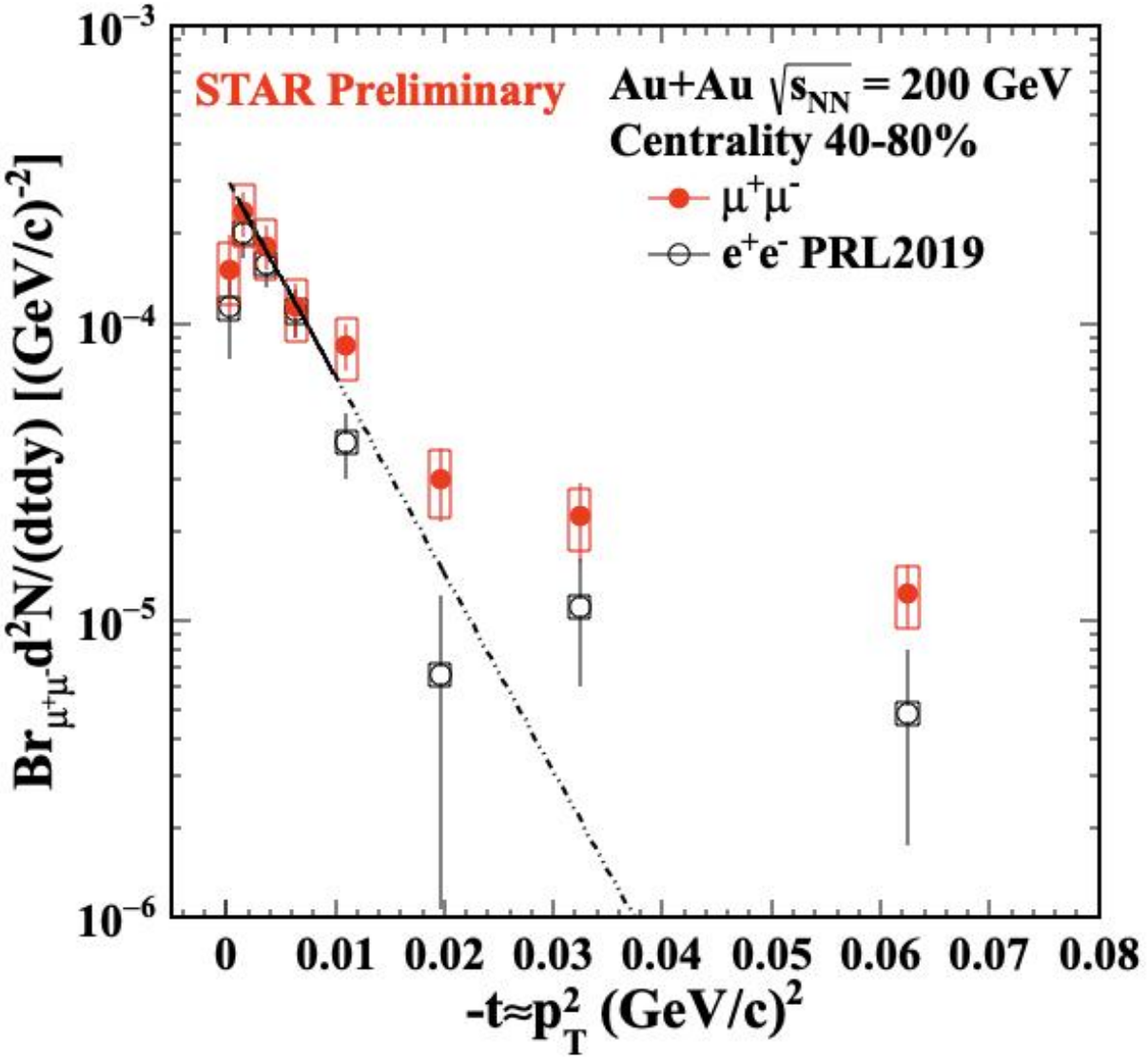
J/ψ→μ⁺μ⁻ invariant yield and R_{AA}





- A large enhancement of the J/ψ yield at low p_T in peripheral collisions
- Show same trend with dielectron channel results

J/ψ→μ⁺μ⁻ t distribution

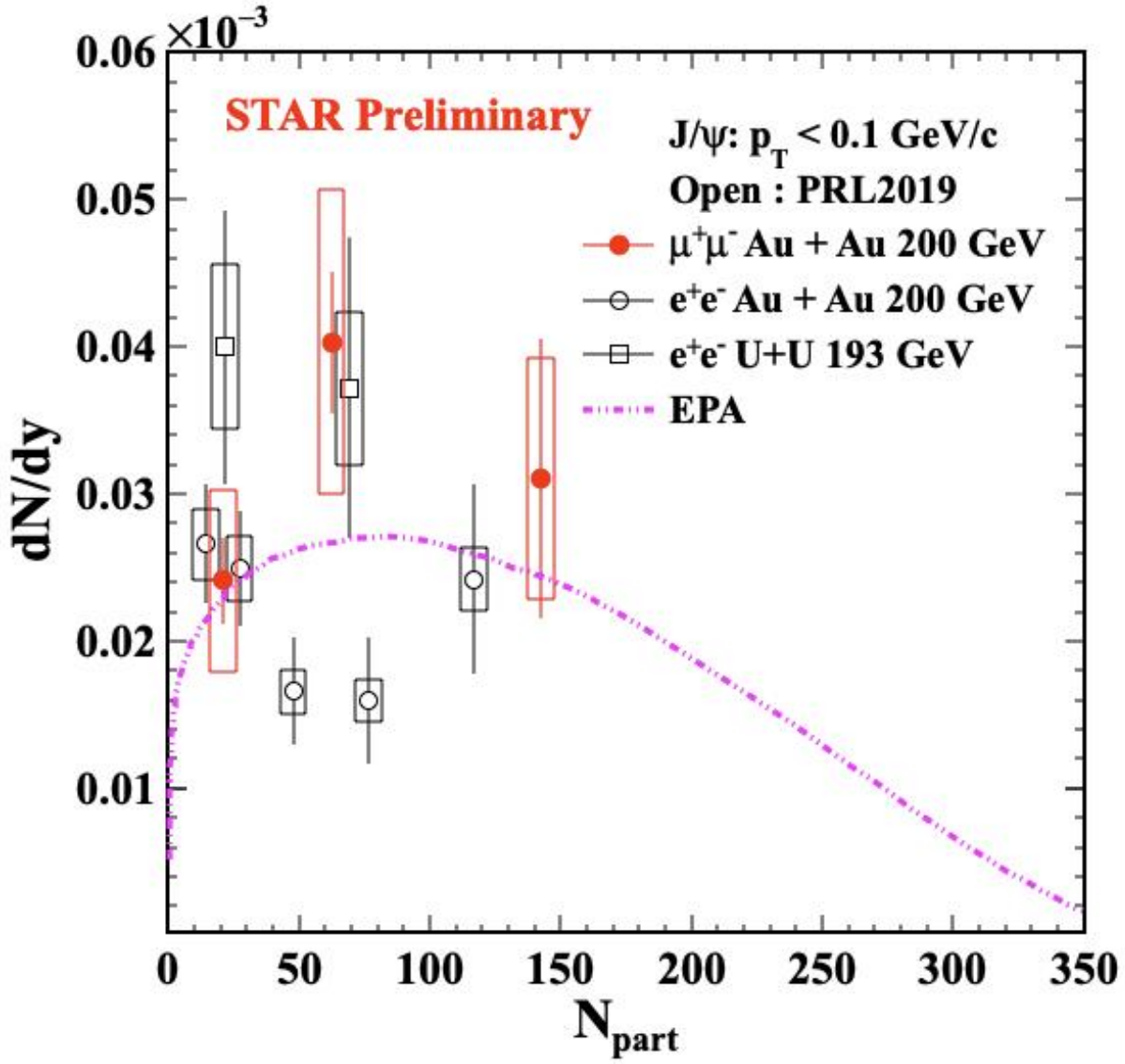


- The expected hadronic contributions are subtracted.
- Resembling the structure observed for J/ψ in Au+Au UPC at 200 GeV [1].
- The slope parameter is 153 ± 55 $(GeV/c)^{-2}$, consistent with the e^+e^- channel results, 177 ± 23 $(GeV/c)^{-2}$
- The first data point is significantly lower than the extrapolation of the exponential fit
  - Indication of interference

[1] STAR, Phys. Rev. C 110, 014911 (2024)

J/ψ→μ⁺μ⁻ excess yield

EPA： W. Zha et.al., Phys. Rev. C 99, 061901 (2019)



- No obvious centrality dependence
- Excess yield consistent with equivalent photon approximation (EPA) calculation
  - In EPA calculation, the photon emitter is the whole nucleus and the Pomeron emitter is spectator nucleons

Summary

- **Different Υ states are measured separately in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV.**
  - Υ(1S) has a similar magnitude of suppression as observed in LHC Pb+Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV.
  - No signficant p_T dependence is observed.
  - Different model calculations consistent with data within the uncertainties.

- **Measured very low p_T J/ψ production via the dimuon channel.**
  - Significant J/ψ enhancements at very low p_T are observed.
  - The EPA-QED calculations can describe data, indicating the enhancements at very low p_T originate from photon-induced interactions.

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Thank you !