Very low-p_T J/ψ production in Au+Au collisions at $\sqrt{S_{NN}}$ = 200 GeV and U+U collisions at $\sqrt{S_{NN}}$ = 193 GeV at STAR

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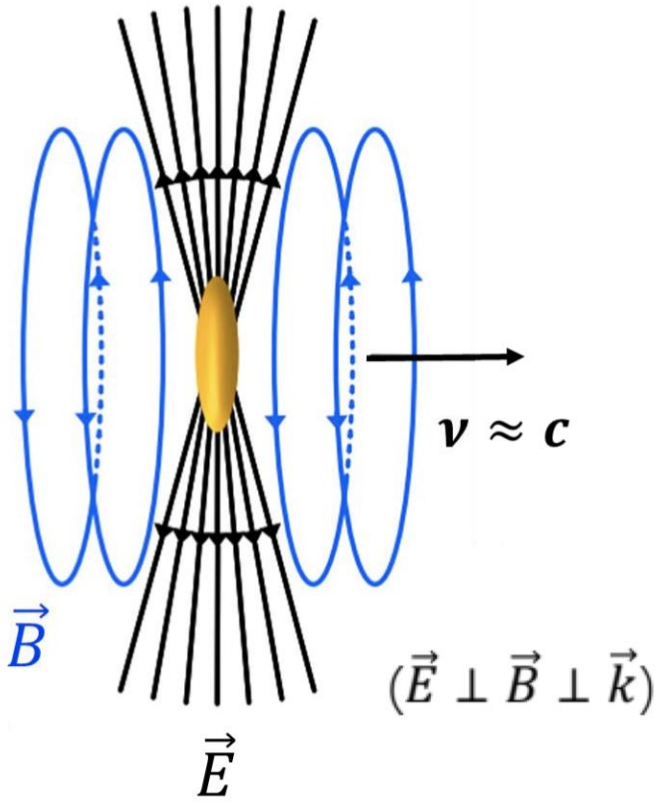
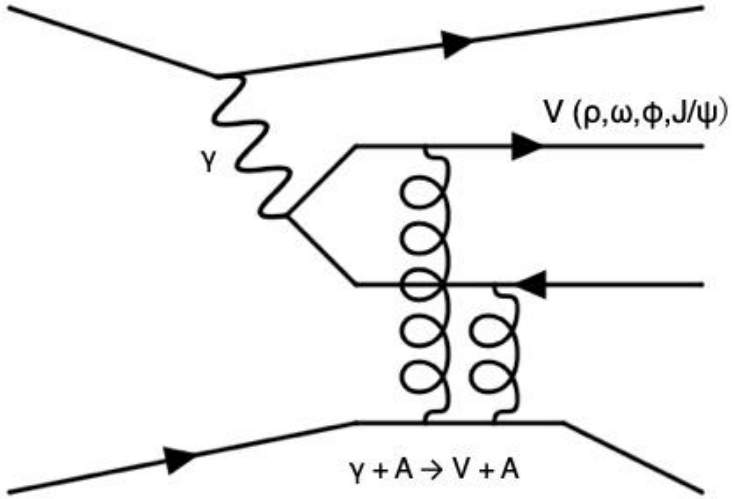
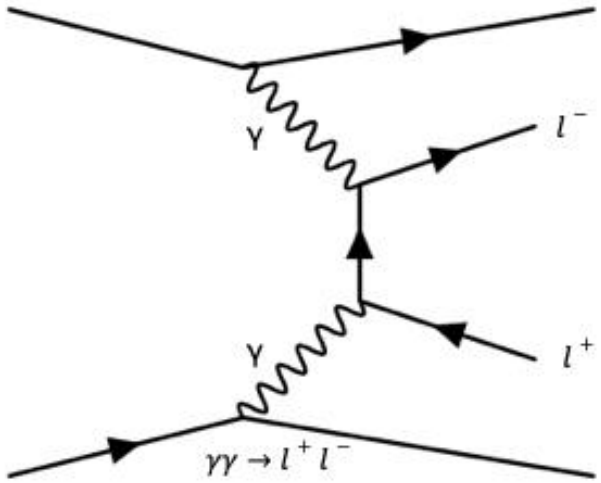
Photon-induced process





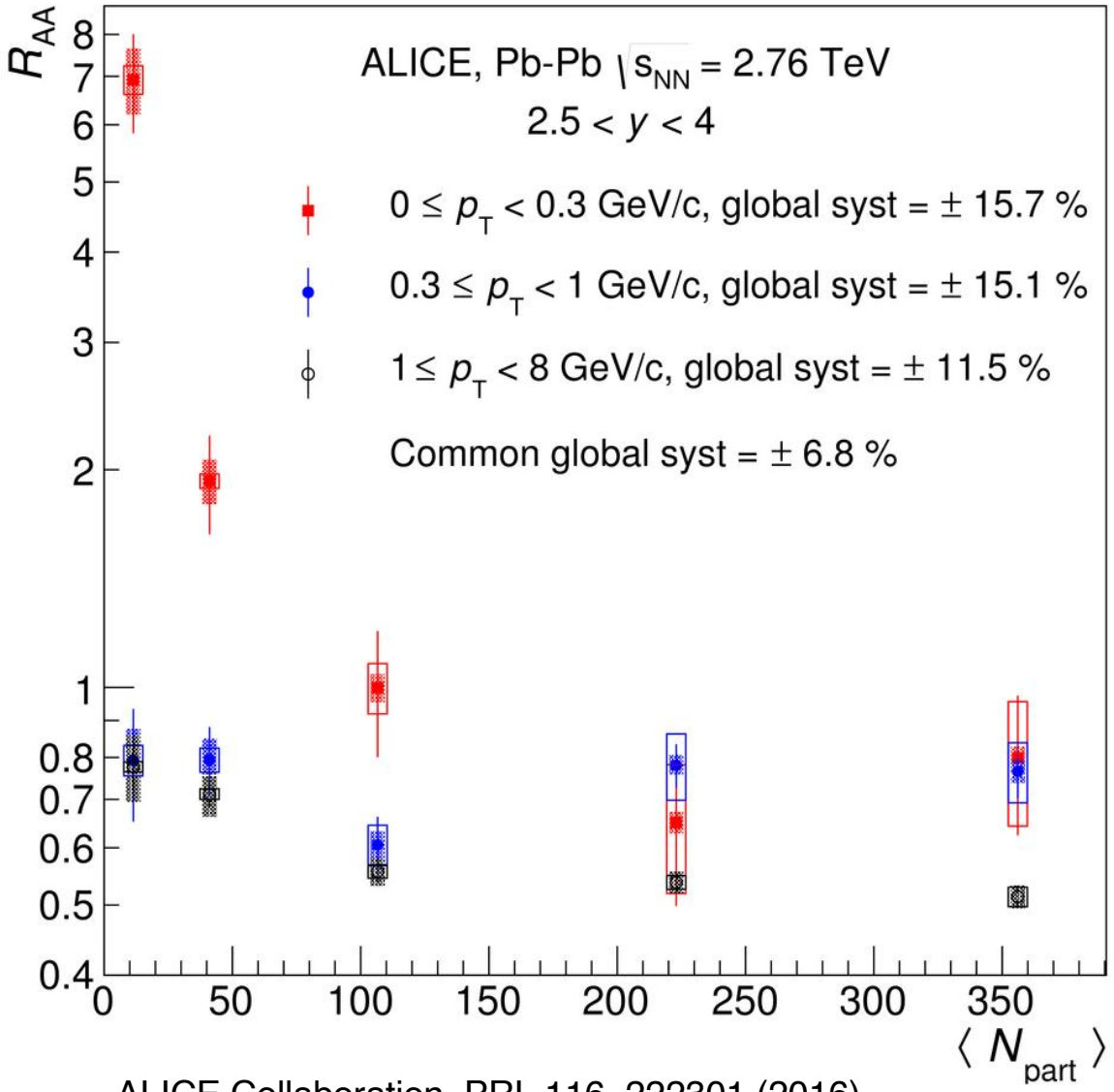


- Boosted nuclei generate intense electromagnetic fields.
- Weizsacker-Williams equivalent photon approximation (EPA):
  - In a specific phase space, transverse EM fields can be quantized as a flux of real photons.

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

- Large quasi-real photon flux $\propto Z^2$
- Studied in detail for Ultra-Peripheral Collisions (UPC)

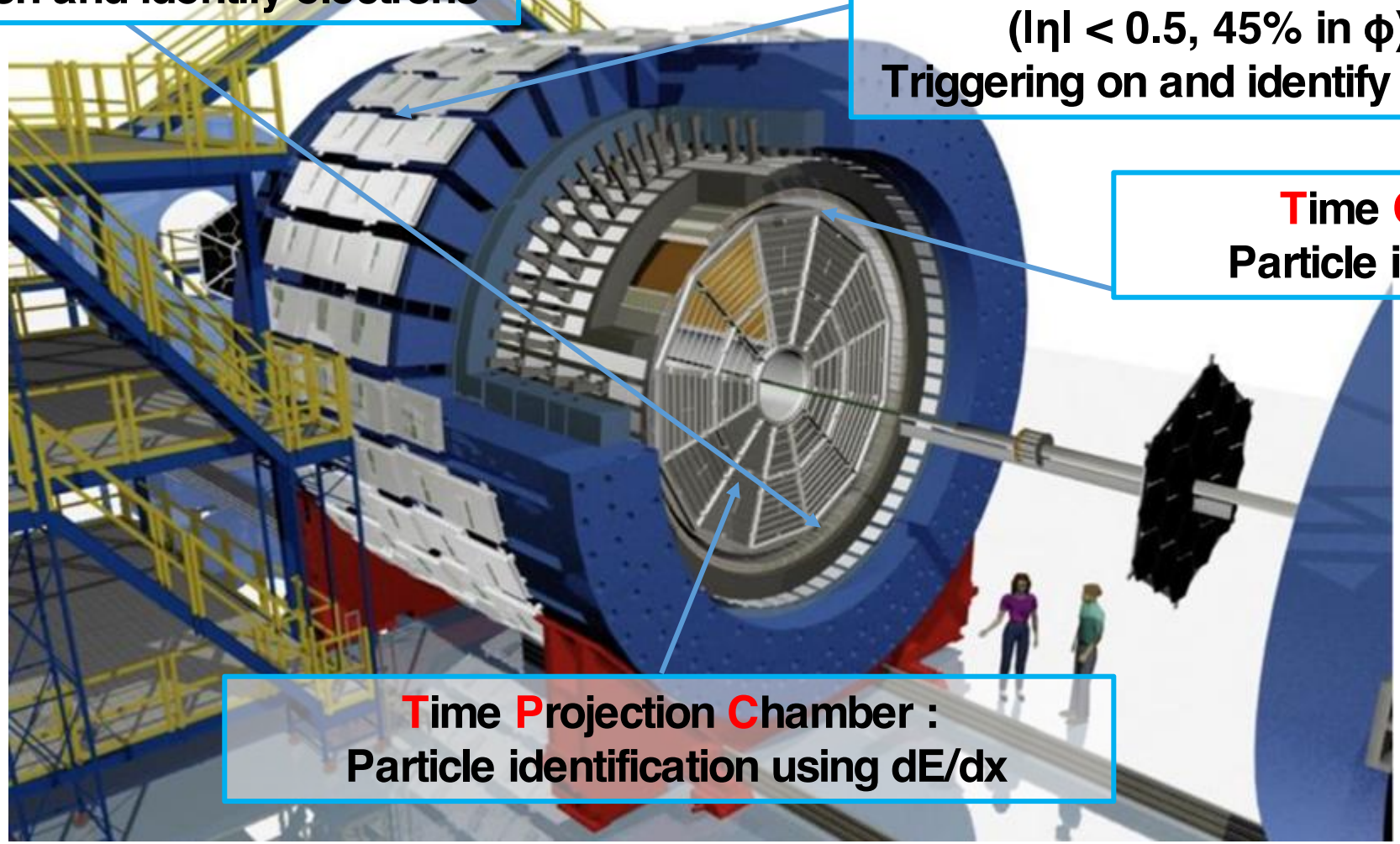
Excess of J/ψ production with nuclear overlap



ALICE Collaboration, PRL 116, 222301 (2016)

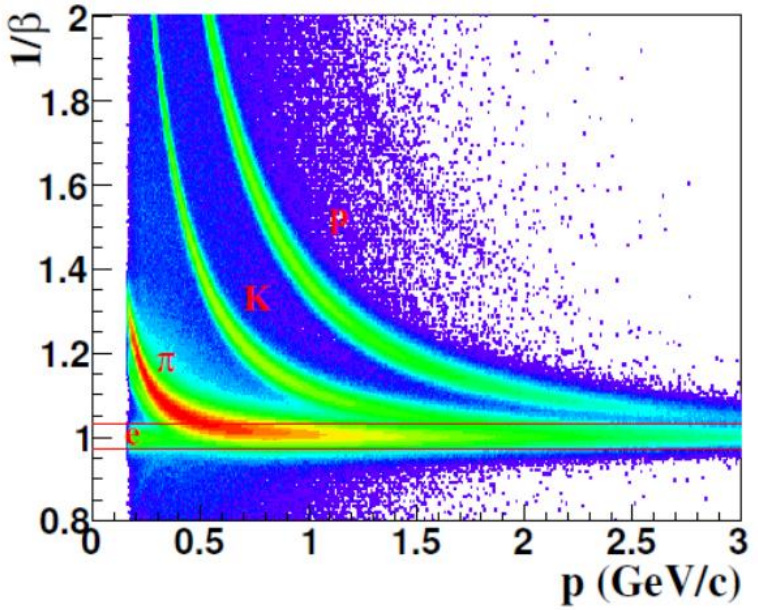
- Significant enhancements of J/ψ production at very low p_T (below ~ 0.3 GeV/c) for peripheral collisions (50–90%).
- Can not be explained by hadronic production modified by medium effects.
- May originate from coherent photon induced interaction.
- Measurements of J/ψ yield at very low p_T in hadronic collisions (Au+Au and U+U) can provide further evidence, and study the properties of the excess.
  - ➢ p_T, centrality and system size dependence of the excess; t distribution.
  - ➢ Dielectron and dimuon channel

The Solenoidal Tracker At RHIC (STAR)

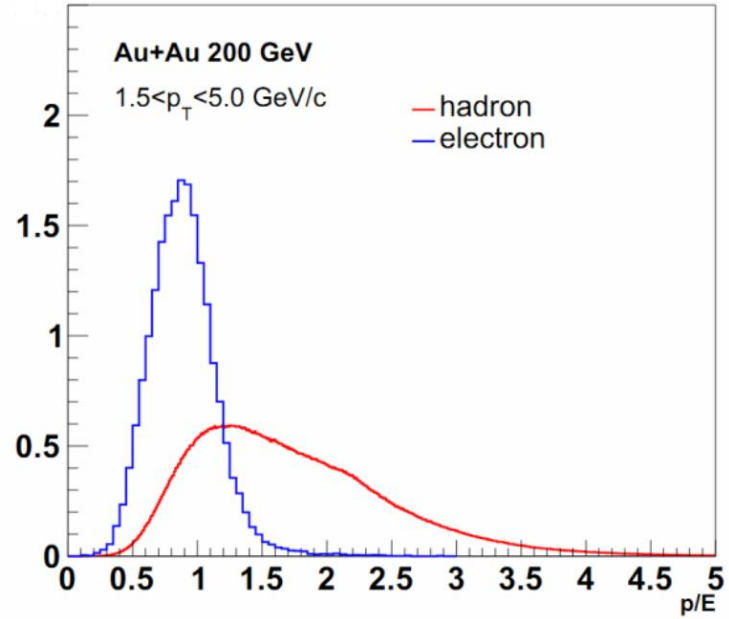


J/ψ→e⁺e⁻ electron identification

- Data set: 2010&2011 Au+Au 200 GeV, 720M
  2012 U+U 200 GeV, 270M

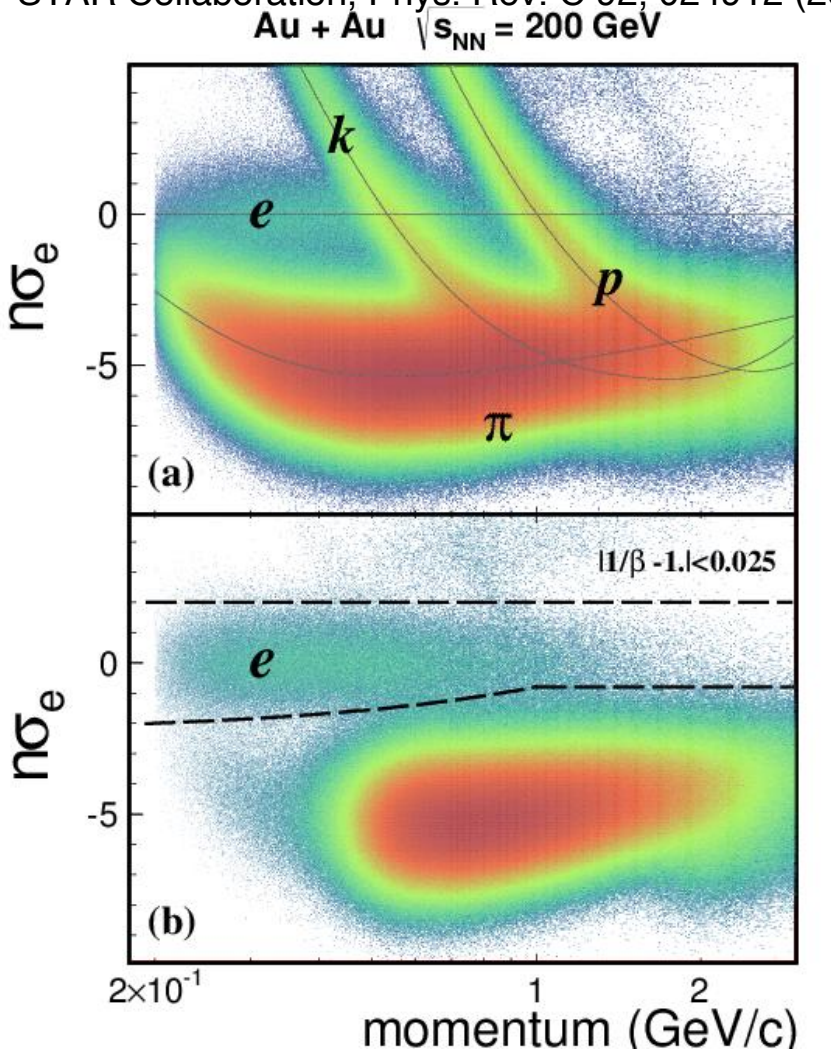


1/β distribution for electrons and hadrons from TOF



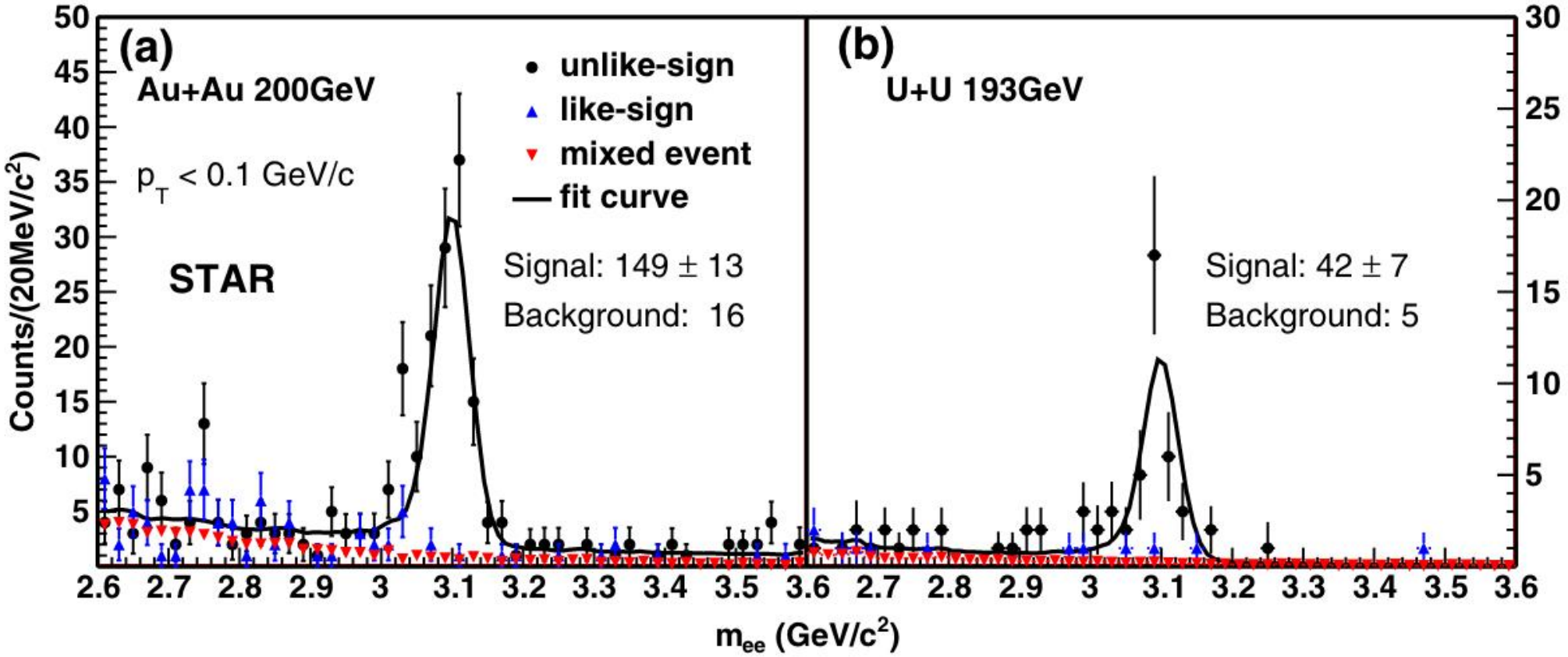
p/E distribution for electrons and hadrons from BEMC

STAR Collaboration, Phys. Rev. C 92, 024912 (2015)



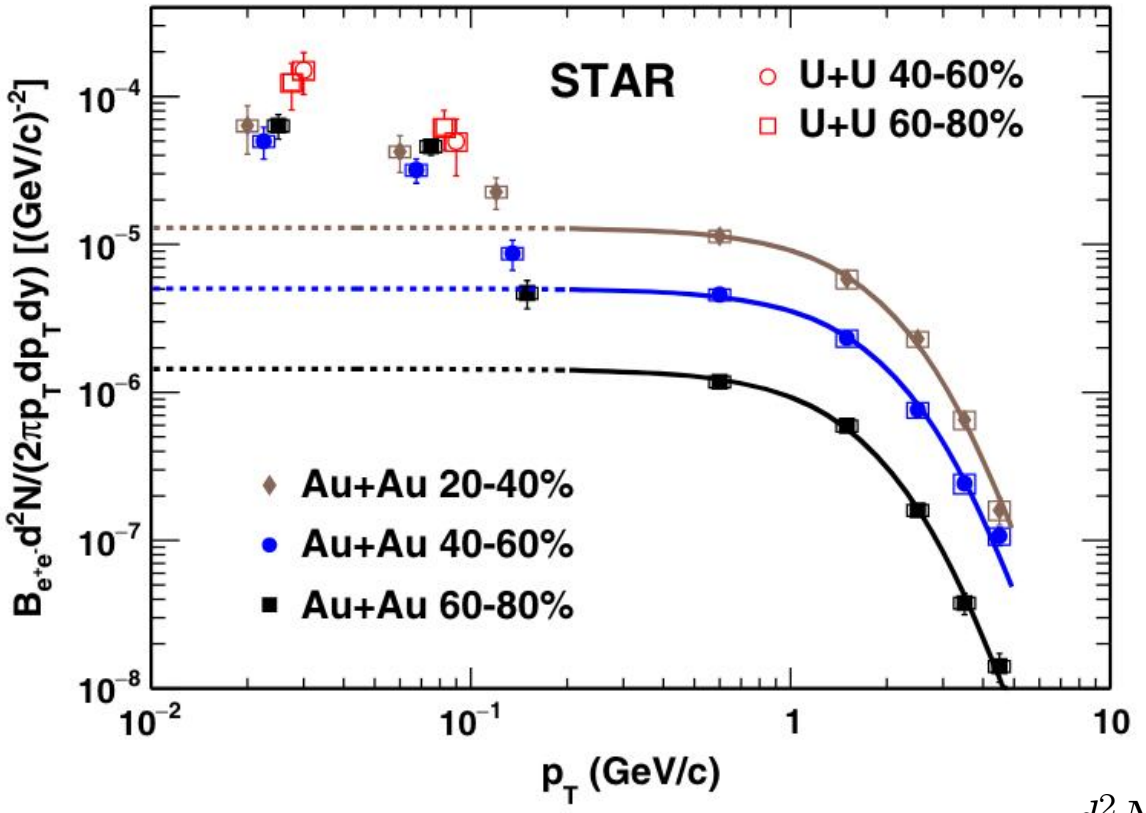
Normalized dE/dx ($n\sigma_e$) distribution before and after TOF cuts

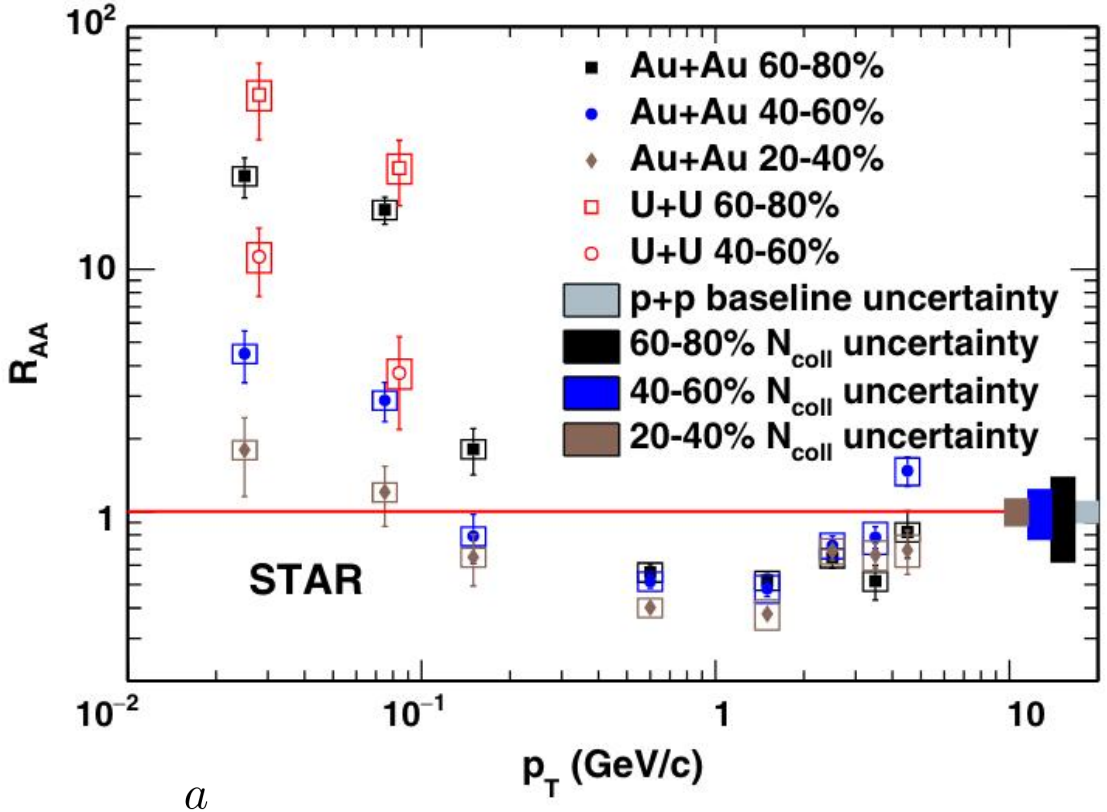
J/ψ→e⁺e⁻ signal extraction



- 40-80% centrality.
- The raw signal is obtained from bin counting in the mass range 2.9–3.2 GeV/c^2 after subtraction of the mixed event combinatorial background.

J/ψ→e⁺e⁻ invariant yield and R_{AA}

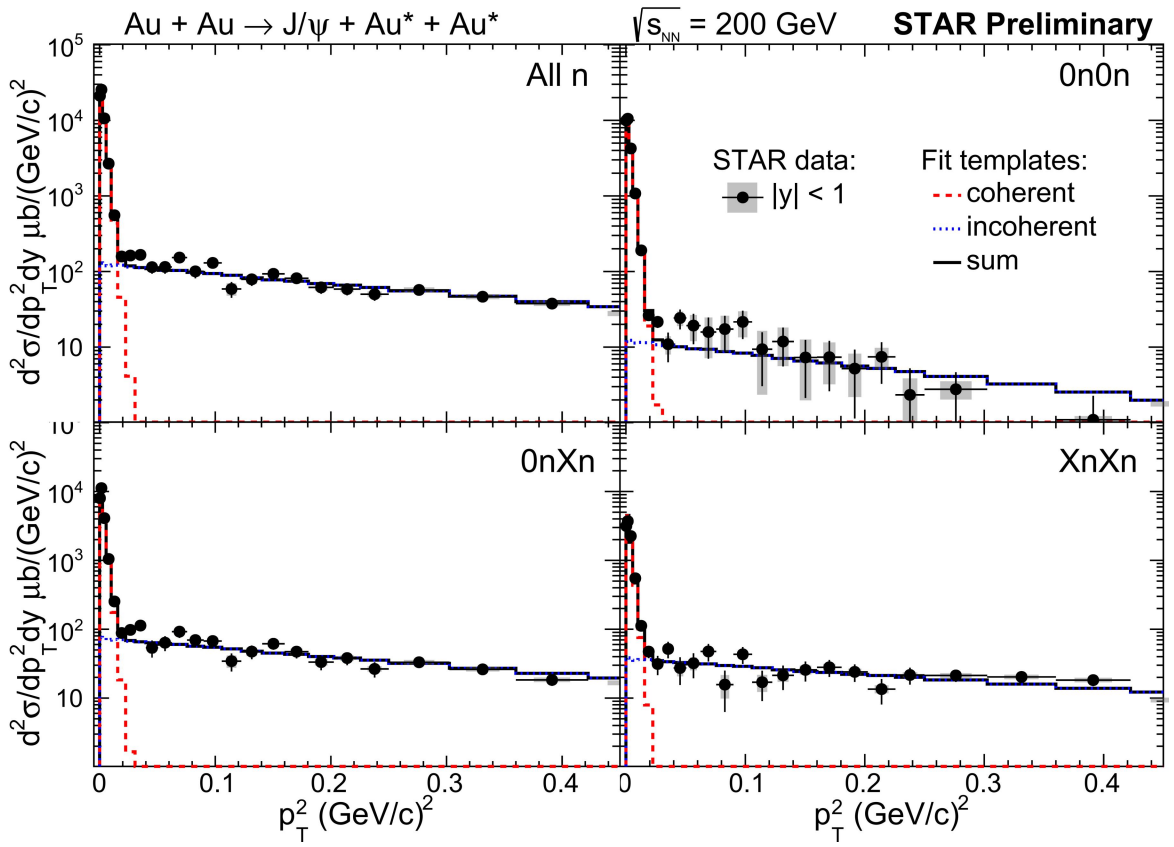




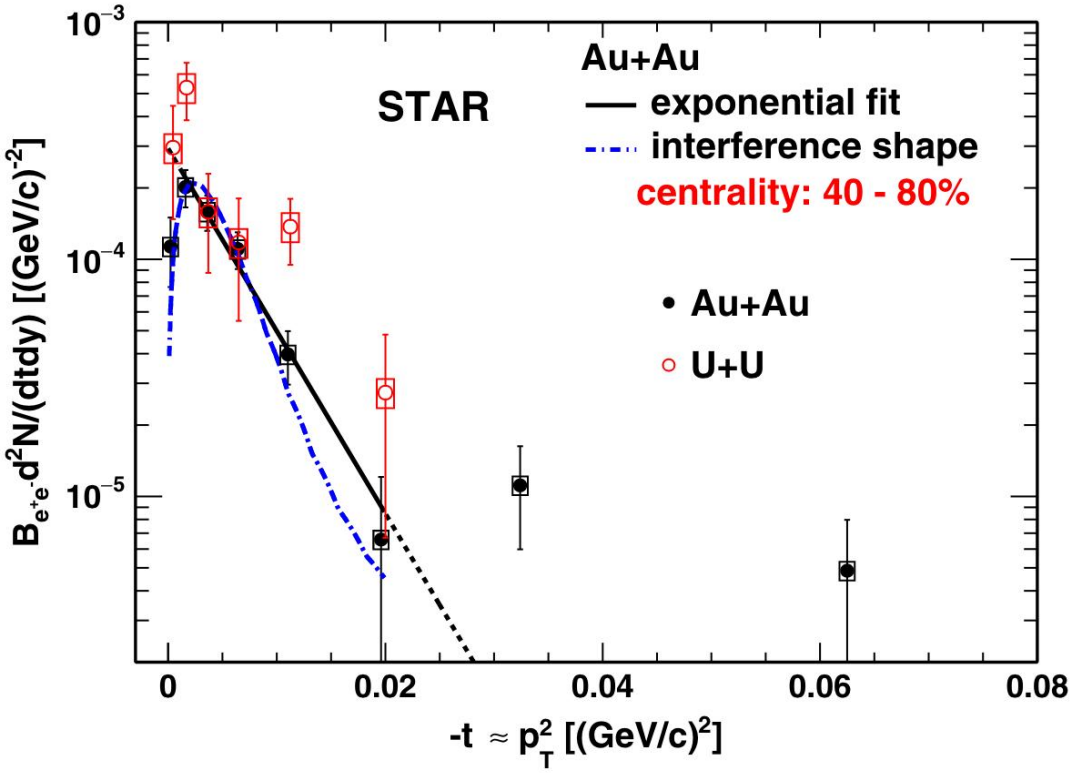
Function to describe hadronic production: $\frac{d^2N}{2\pi p_T dp_T dy} = \frac{a}{(1+b^2p_T^2)^n}$

- Significant enhancement of J/ψ yield at $p_T < 0.2$ GeV/c is observed for peripheral collisions (40-80%)
- The yield of J/ψ at very low p_T in Au+Au is similar to that in U+U within uncertainties.

J/ψ→e⁺e⁻ dN/dt distribution

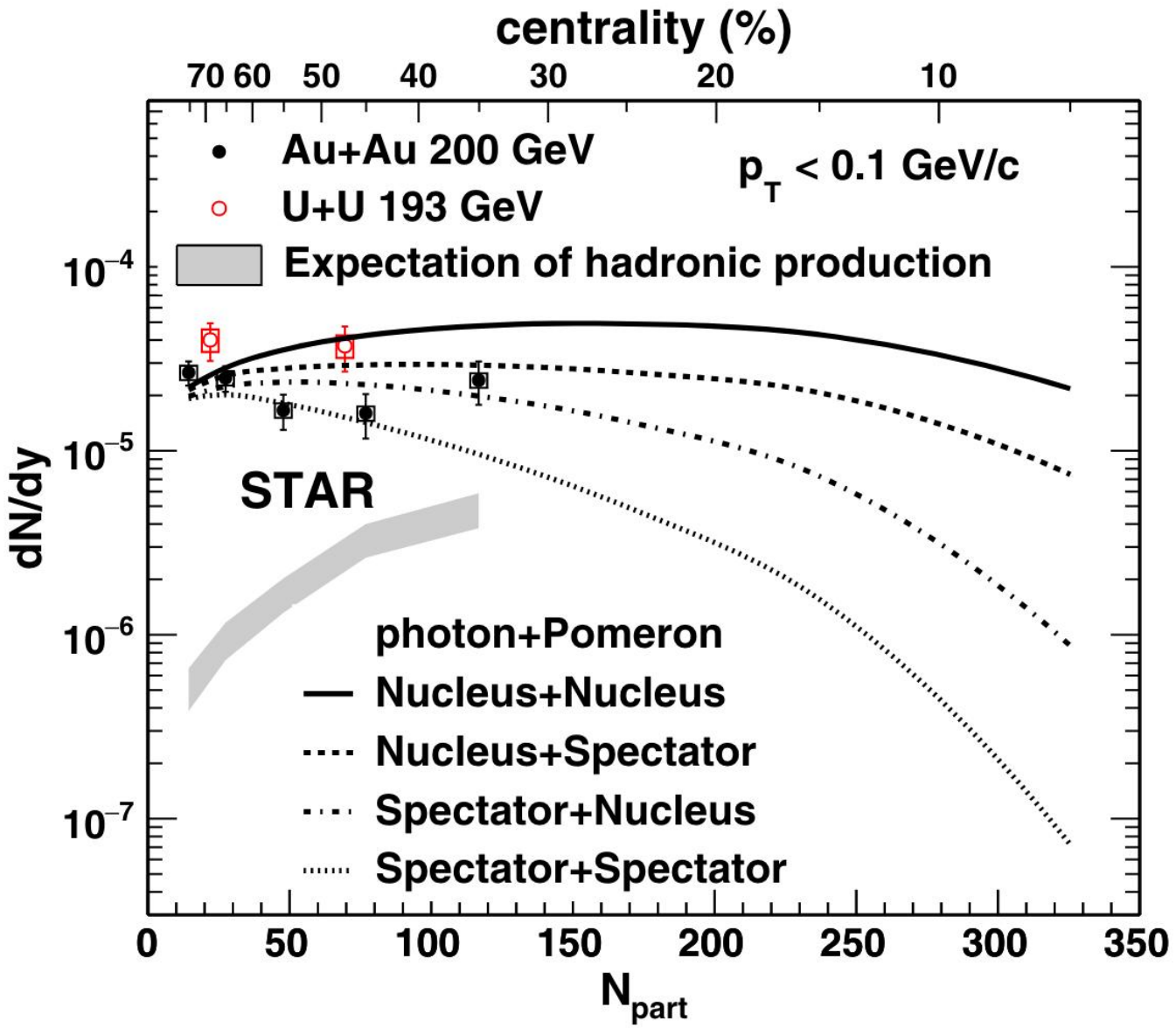


J/ψ as a function of the momentum transfer squared ($t \approx p_T^2$) from STAR UPC measurements.



- ✓ Similar structure to that in UPC case.
- ✓ Indication of interference.
- ✓ The slope from the exponential fit reflects the size and shape of target:
  - ➢ 177 ± 23 $(GeV/c)^{-2}$, consistent with that expected for an Au nucleus [199 $(GeV/c)^{-2}$] within uncertainties.

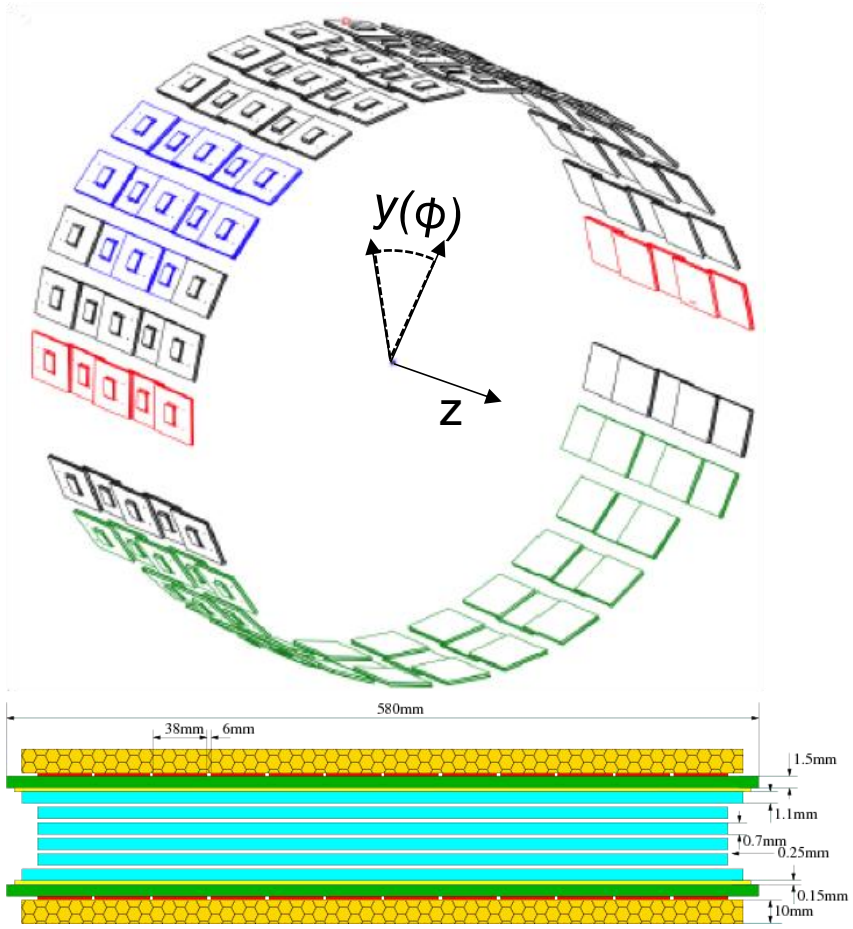
J/ψ→e⁺e⁻ excess yield versus centrality



- No significant centrality dependence of the excess yield.
- Consider four configurations for photon emitter + Pomeron emitter:
  - All four scenarios can describe the data points in 60-80% centrality.
  - Data points favor the nucleus + spectator or spectator + nucleus scenarios in semicentral collisions.

J/ψ→μ⁺μ⁻ muon identification

- Data set: 2014 Au+Au 200 GeV, 1101M



MTD system:

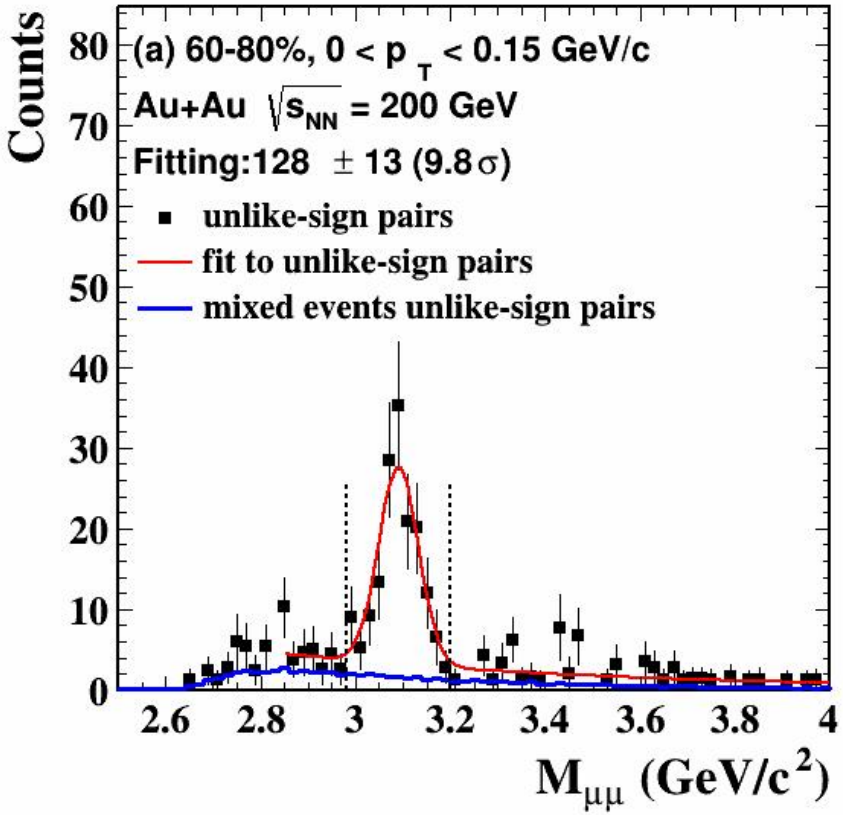
- Fully installed in 2014, behind the magnet (~ 5 interaction length)
- p_T threshold for MTD ~ 1.2 GeV/c
- Precise timing measurement (σ ~ 100 ps)
  - Arrival time: Δtof cut
- Intrinsic spatial resolution (~ 1 cm)
  - Hit position: Δy and Δz cuts

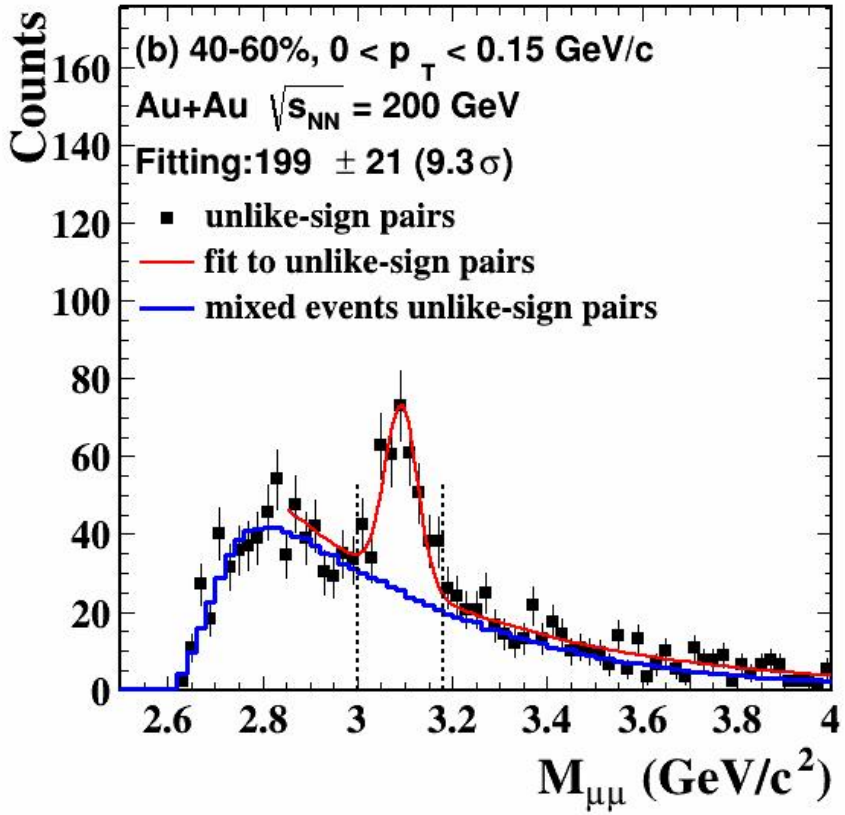
TPC:

- Measure energy loss
- dE/dx cut: muons are expected to lose about 0.5σ more energy compared to pions; $-1 < n\sigma_{\pi} < 3$

MTD system provides the capability of muon pair measurement in J/ψ mass region

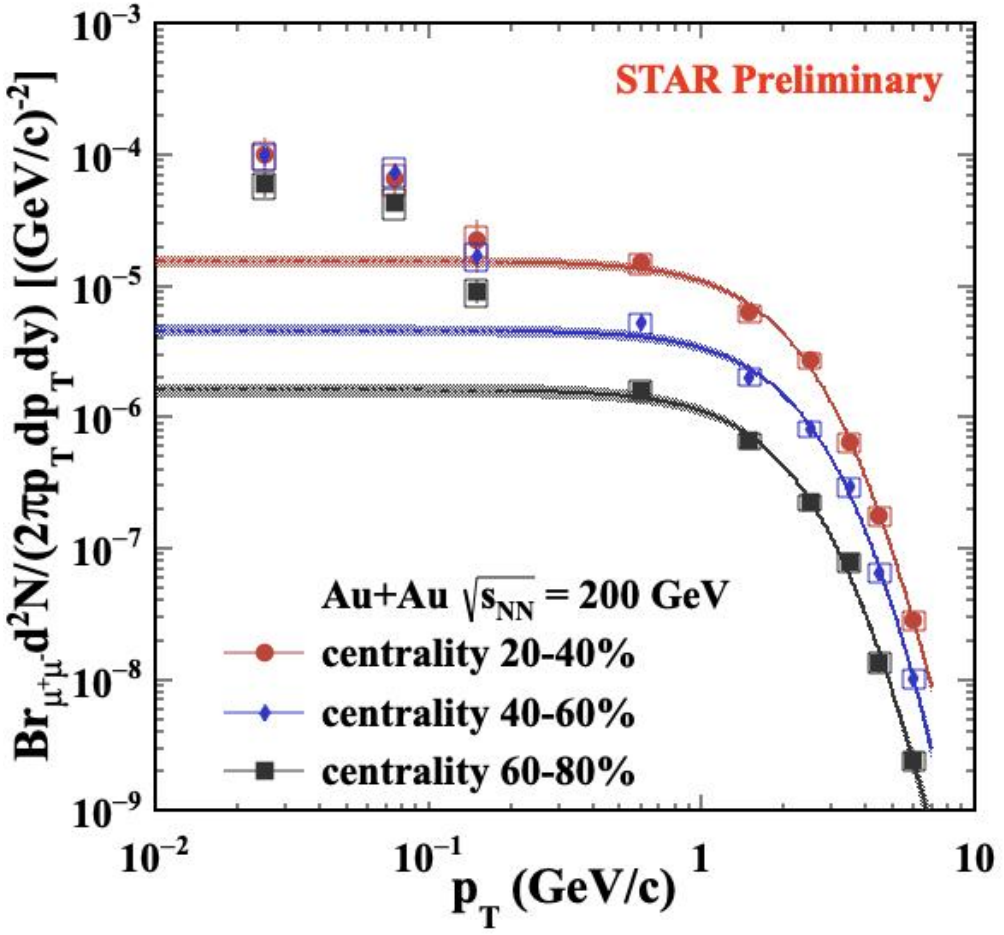
J/ψ→μ⁺μ⁻ signal extraction

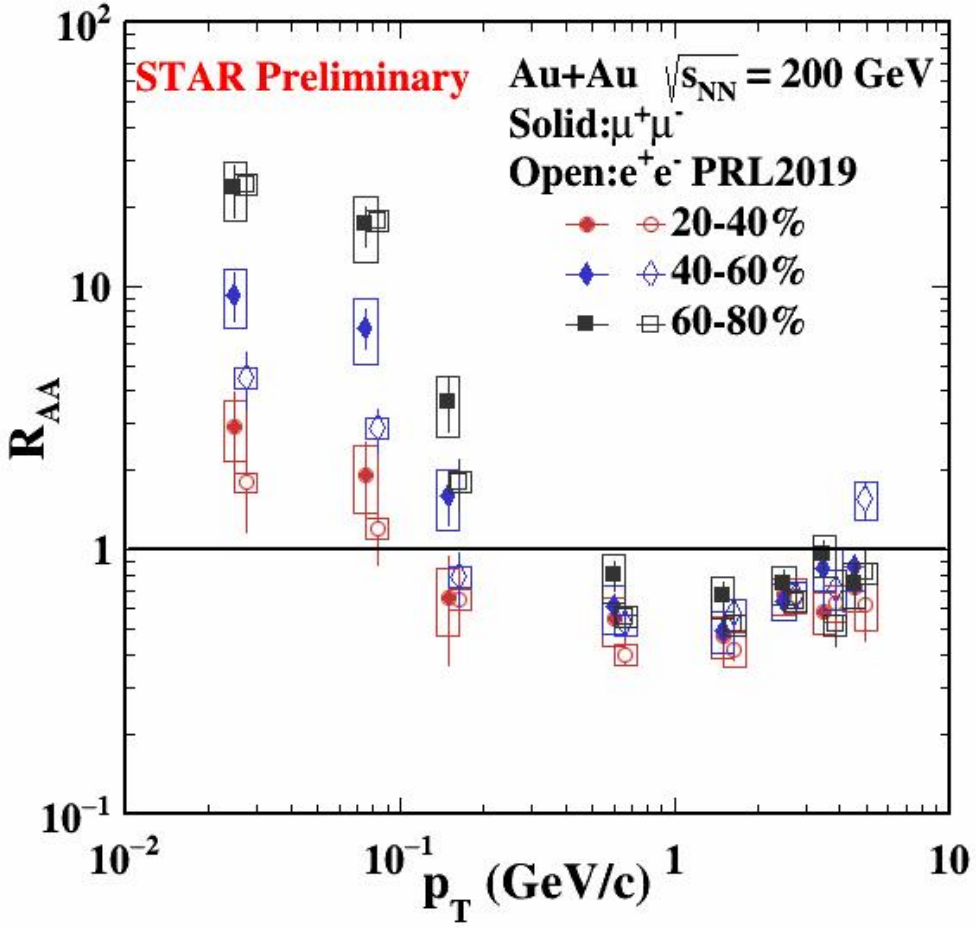




- Muon pair mass distributions in $0 < p_T < 0.15$ GeV/c in 40-60% and 60-80% centralities.
- The raw signal is obtained from the combined fit of signal, mixed event combinatorial background and residual background using the Maximum Likelihood (ML) method.

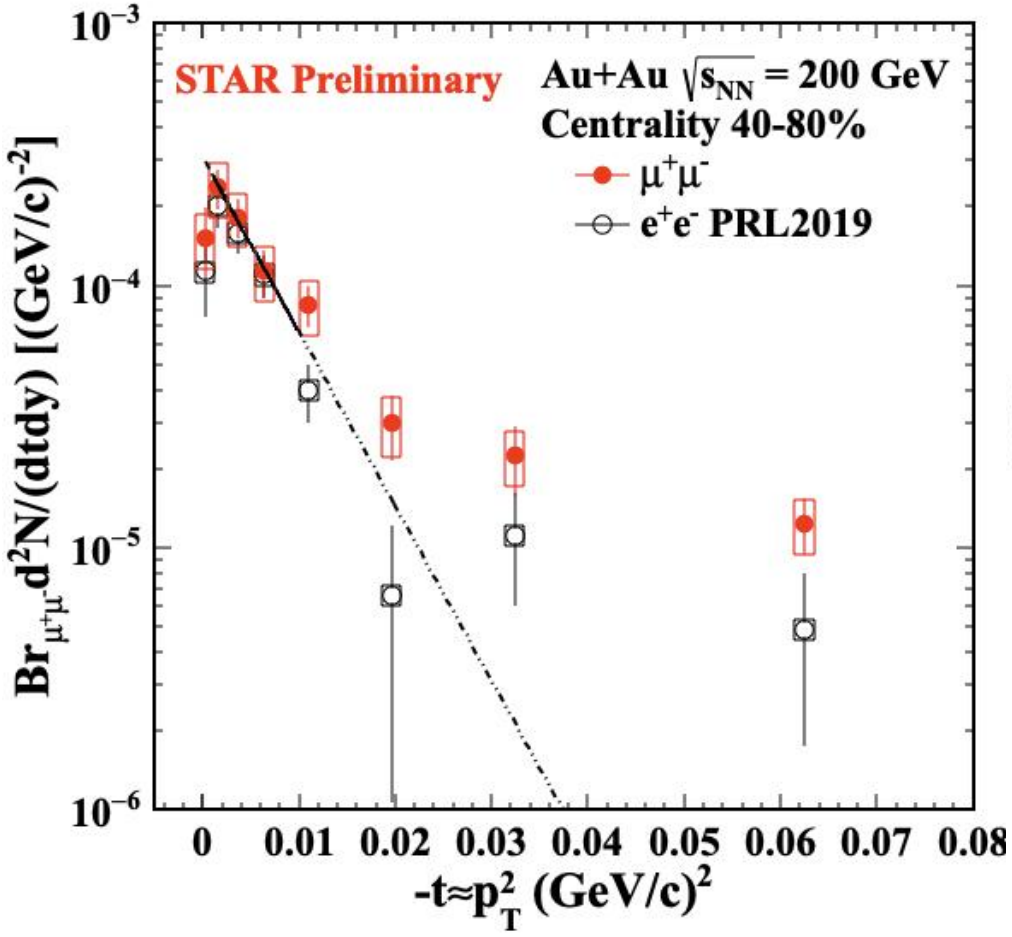
$J/\psi \rightarrow \mu^+\mu^-$ invariant yield and R_{AA}



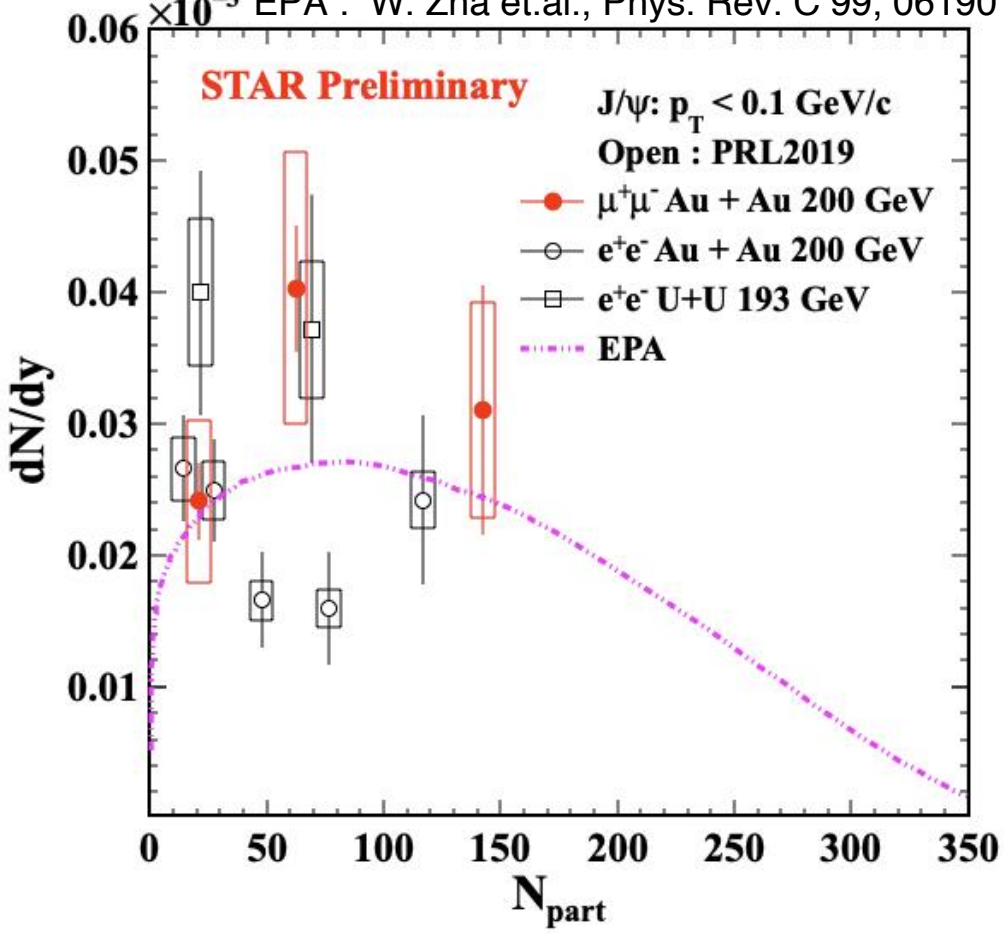


- A large enhancement of the J/ψ yield at low p_T in peripheral collisions.
- Consistent with dielectron channel results.

J/ψ→μ⁺μ⁻ t distribution and excess yield



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



- The slope parameter is 153 ± 55 (GeV/c)$^{-2}$, consistent with the e^+e^- channel results.
- Excess yield consistent with equivalent photon approximation (EPA) calculation (Nucleus+Spectator scenario).

Summary

- Significant excess of J/ψ yield at very low p_T (0-0.2 GeV/c) is observed for peripheral collisions (40-80%) via both dielectron channel and dimuon channel.

- The excess trend shows no significant centrality dependence within uncertainties, which is beyond the expectation from hadronic production.

- The EPA calculations can describe data, indicating the enhancements at very low p_T originate from photon-induced interactions.

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Thank you !