Measurements of J/ψ production in Ru+Ru and Zr+Zr collisions at $\sqrt{s_{NN}}$ = 200 GeV from STAR experiment

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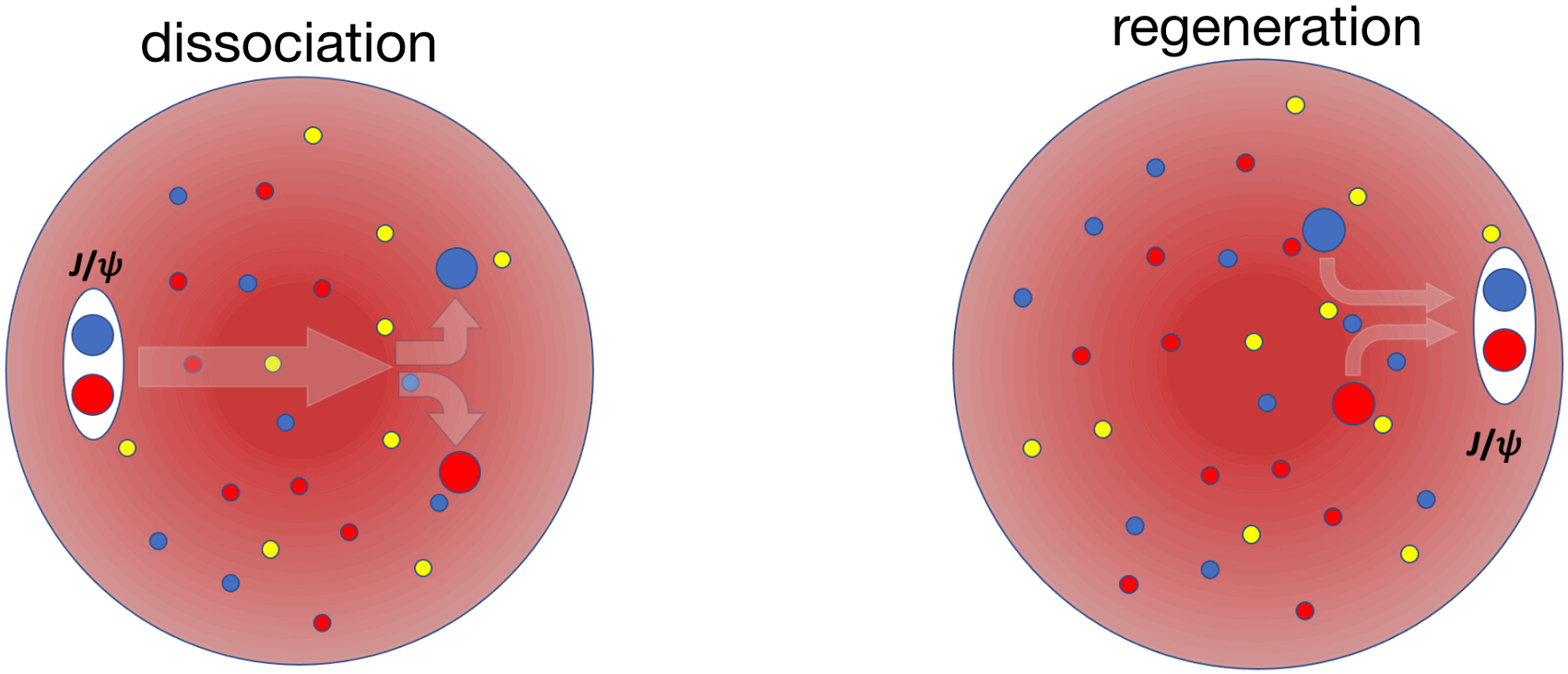
Outline

- **Motivation**
- **STAR experiment**
- **J/ψ R_{AA} measurement**
- **J/ψ elliptic flow measurement**
- **Summary**

Motivation

J/ψ is a sensitive probe to study the properties of QGP

- heavy mass (m_c = ~1.5 GeV/c^2) ➜ early creation
- long lifetime



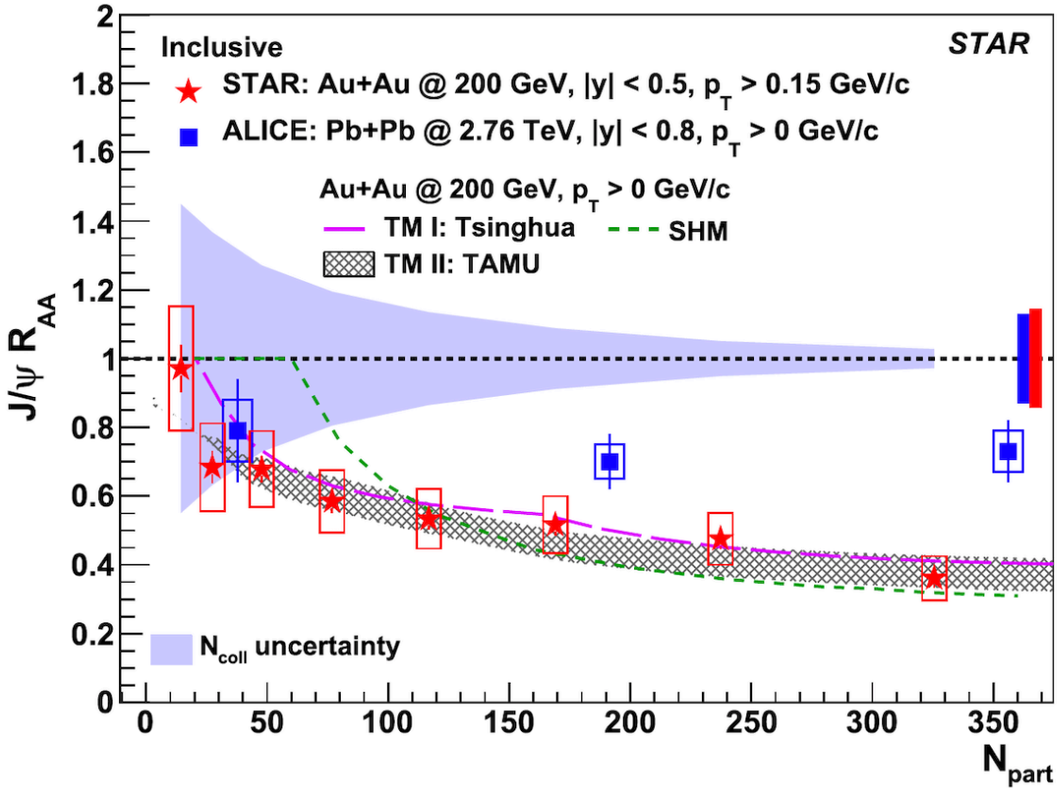
Two key observables to probe properties of QGP:

- J/ψ R_{AA} ➜ dissociation and regeneration
- J/ψ v_2 ➜ charm quark thermalization and regeneration

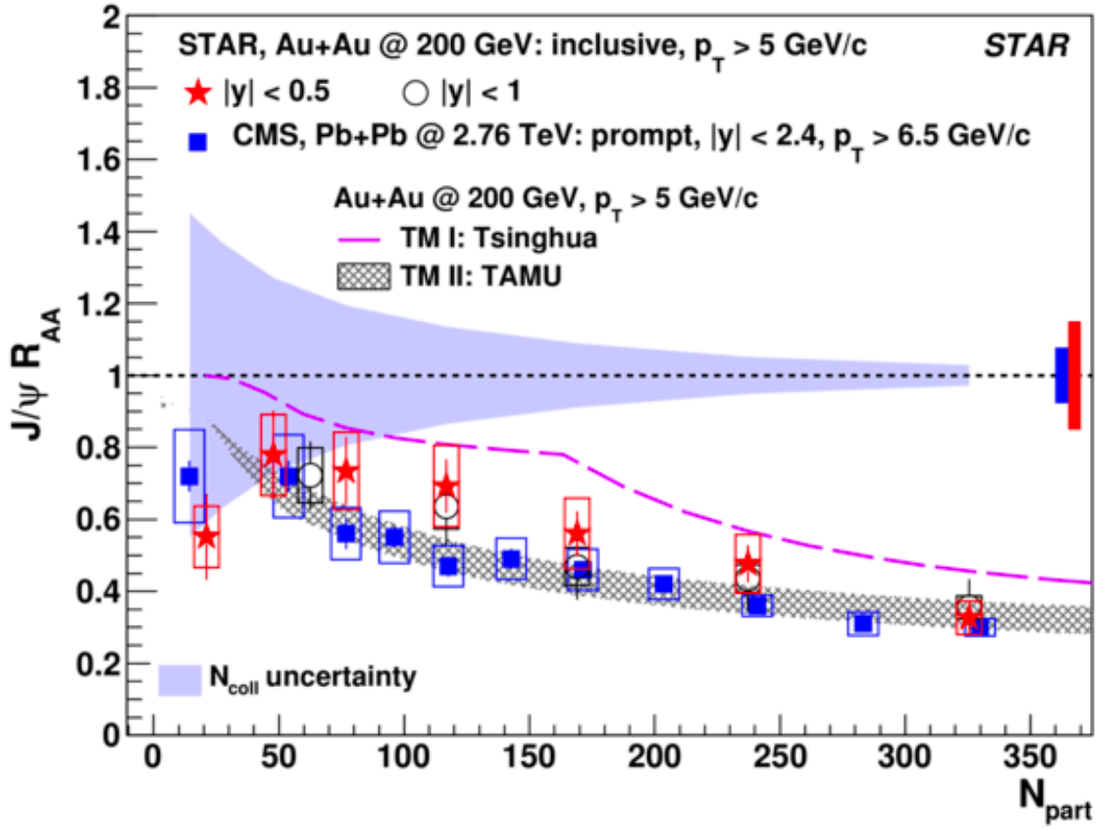
System size dependence

Motivation-I

p_T > 0 GeV/c



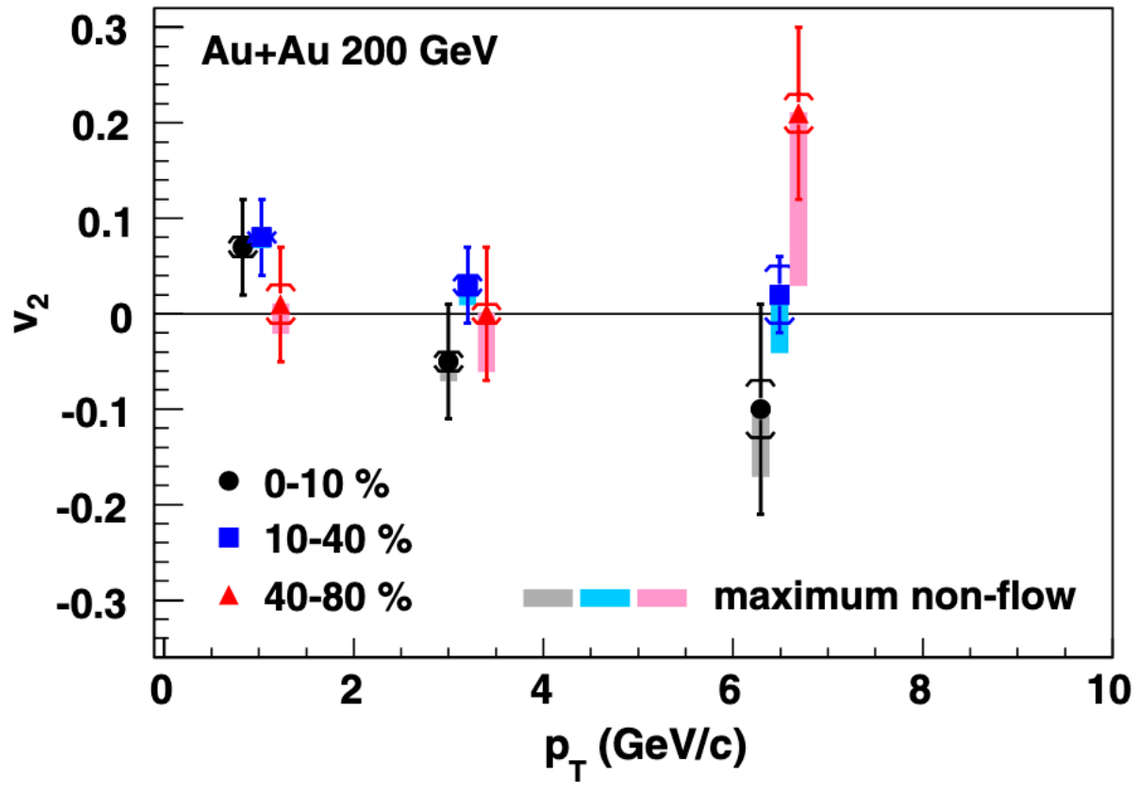
p_T > 5 GeV/c



STAR PLB,797 (2019)134917

- Regeneration effect is important at LHC energy
- Does it important at RHIC top energy and How it affect by the collision system size?

Motivation-II

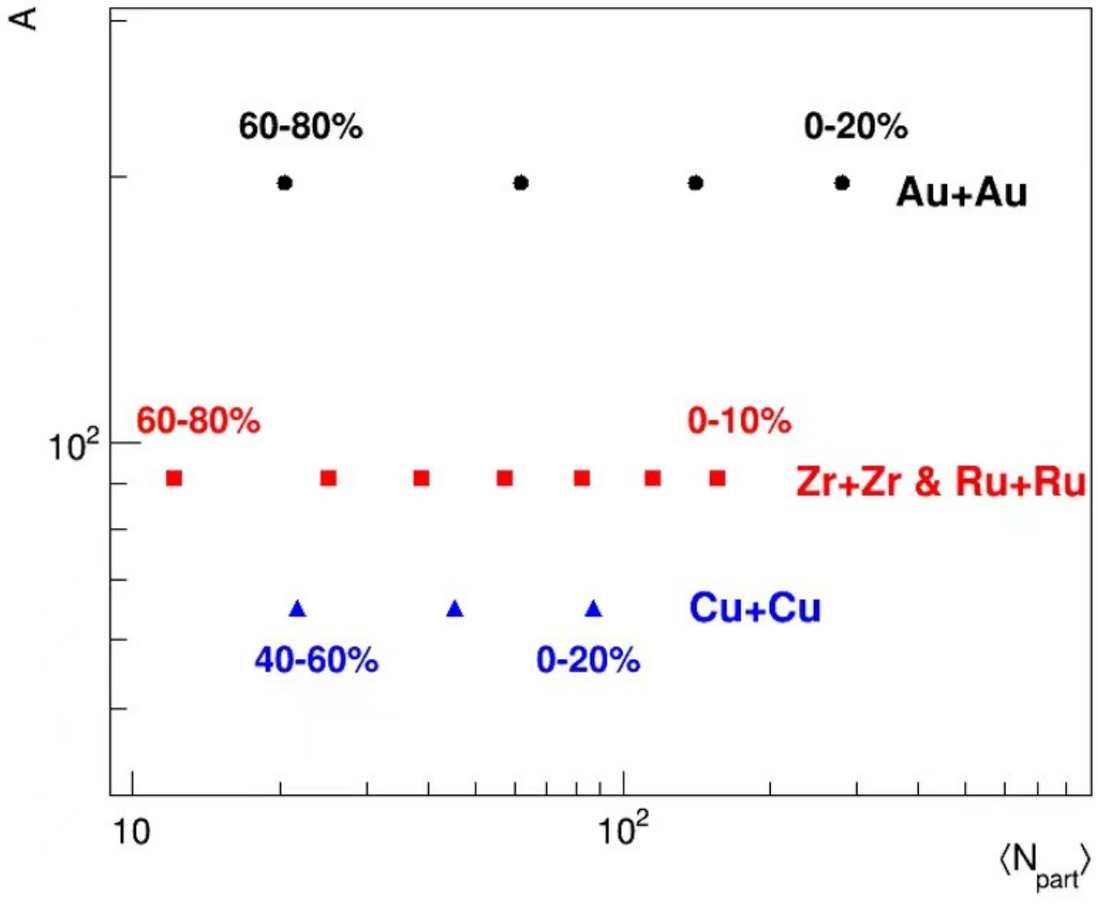


STAR, PRL 111, 052301 (2013)

- J/ψ elliptic flow is consistent with zero but with sizable statistical uncertainties and non-flow contribution in Au+Au system
  - Does J/ψ have non zero elliptic flow at RHIC energy?
- How J/ψ elliptic flow be established from small to large collision system?
  - crucial to control non-flow contribution at small collision system

Isobar collisions

Unique opportunity to measure the J/ψ spectra and v2 precisely, and study the system size dependence in isobar collisions ($^{92}_{44}Ru$ + $^{92}_{44}Ru$ and $^{92}_{40}Zr$ + $^{92}_{40}Zr$) at STAR



- A moderate size collision system
  - between Au+Au and Cu+Cu system
- Large isobar collisions sample
  - ~4B good minimum bias
- Event Plane Detector
  - help to pin-down non-flow contribution

The Solenoidal Tracker at RHIC

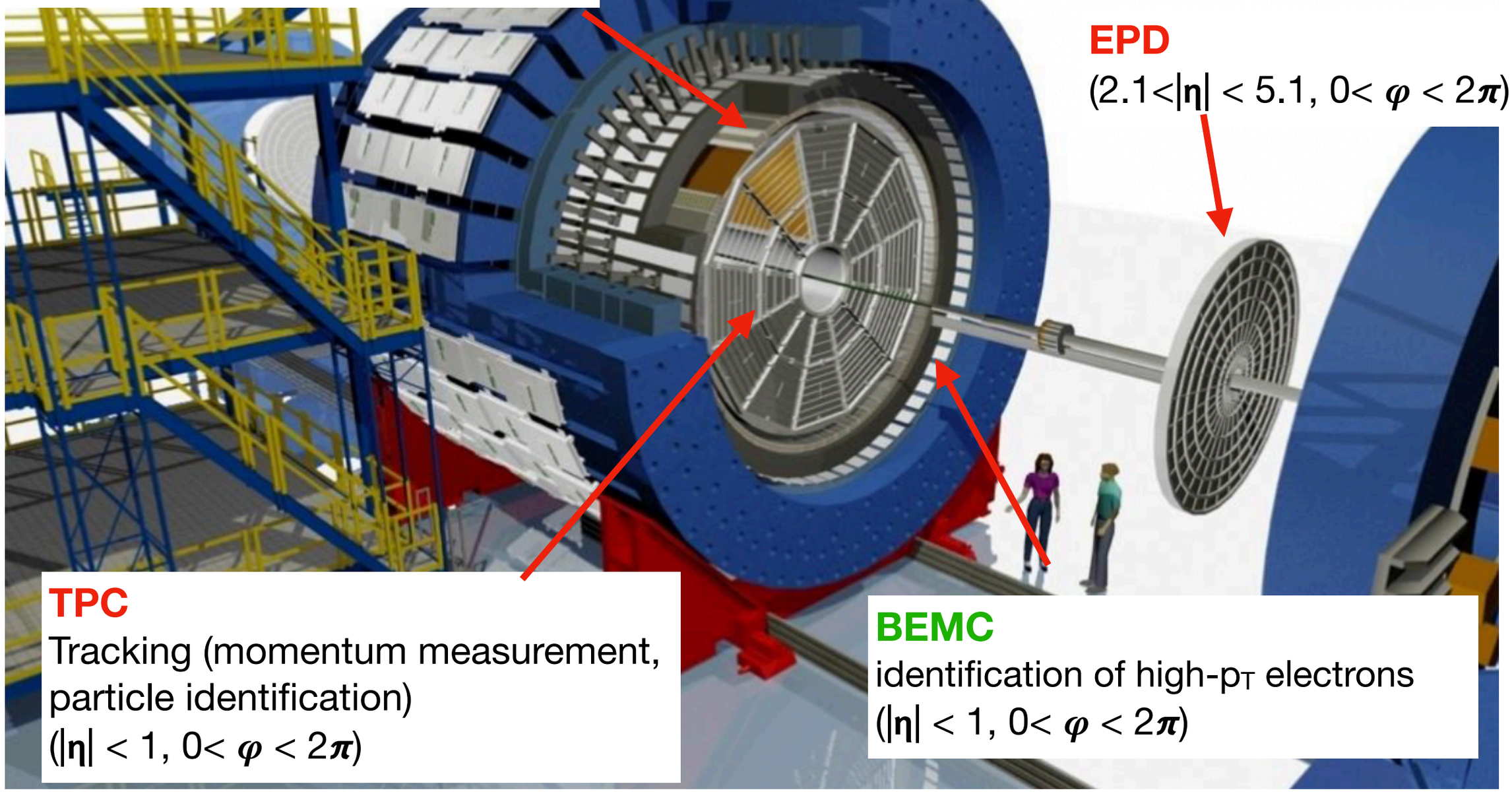
TOF

identification of low-p_T electrons
($|\eta| < 1$, $0 < \varphi < 2\pi$)

$J/\psi \rightarrow e^+ + e^-$

EPD

($2.1 < |\eta| < 5.1$, $0 < \varphi < 2\pi$)



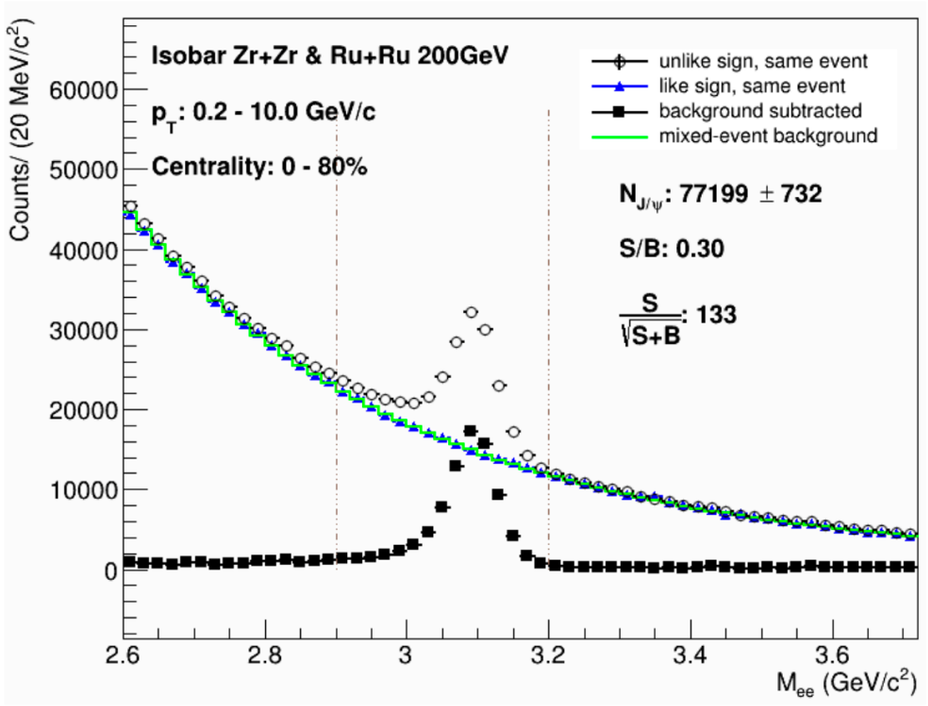
TPC

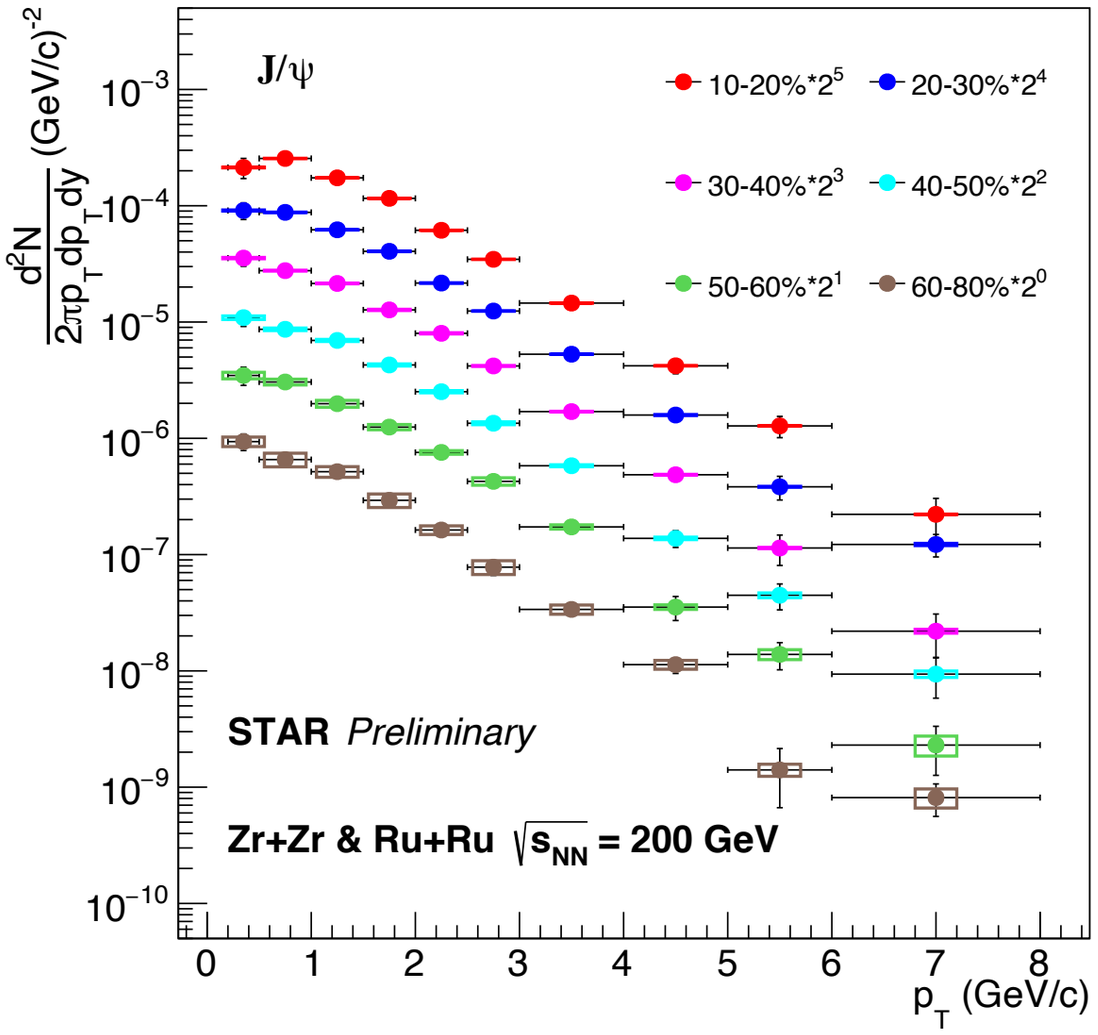
Tracking (momentum measurement, particle identification)
($|\eta| < 1$, $0 < \varphi < 2\pi$)

BEMC

identification of high-p_T electrons
($|\eta| < 1$, $0 < \varphi < 2\pi$)

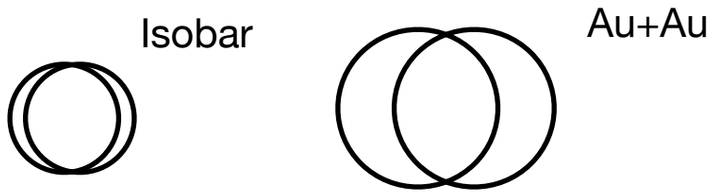
J/ψ reconstruction

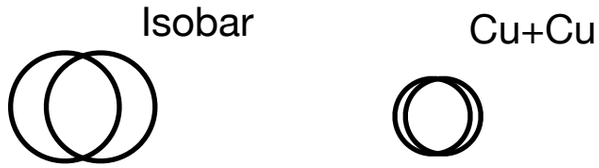


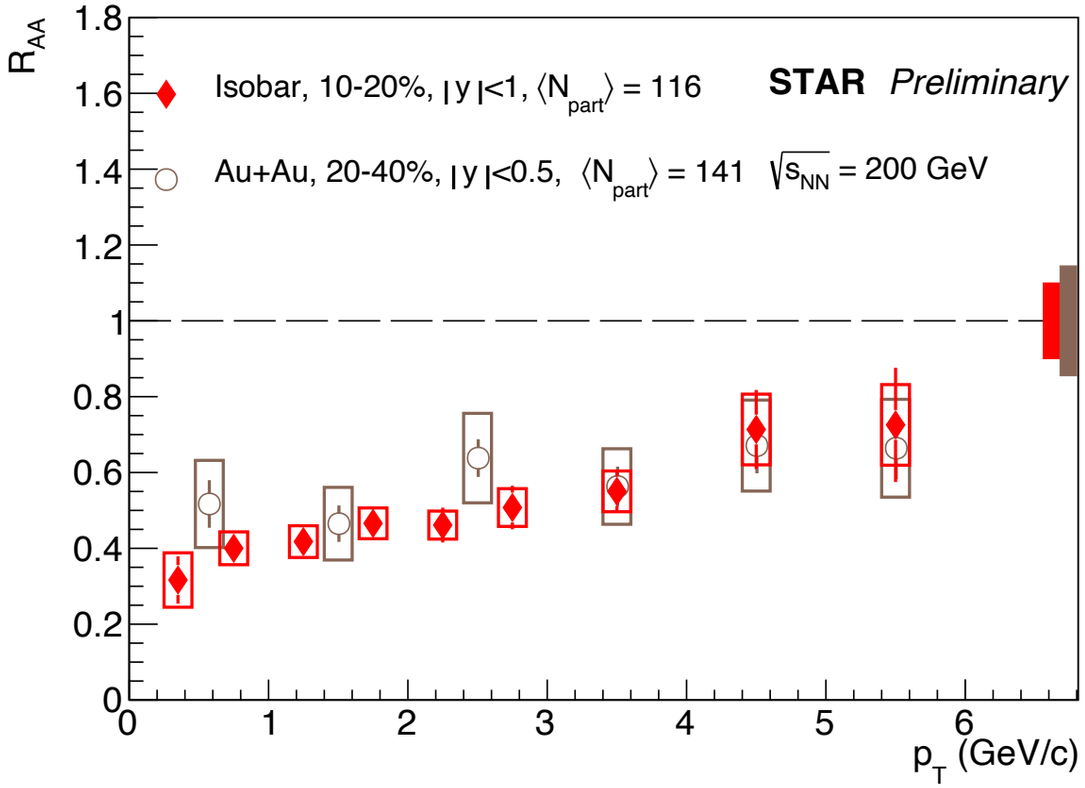


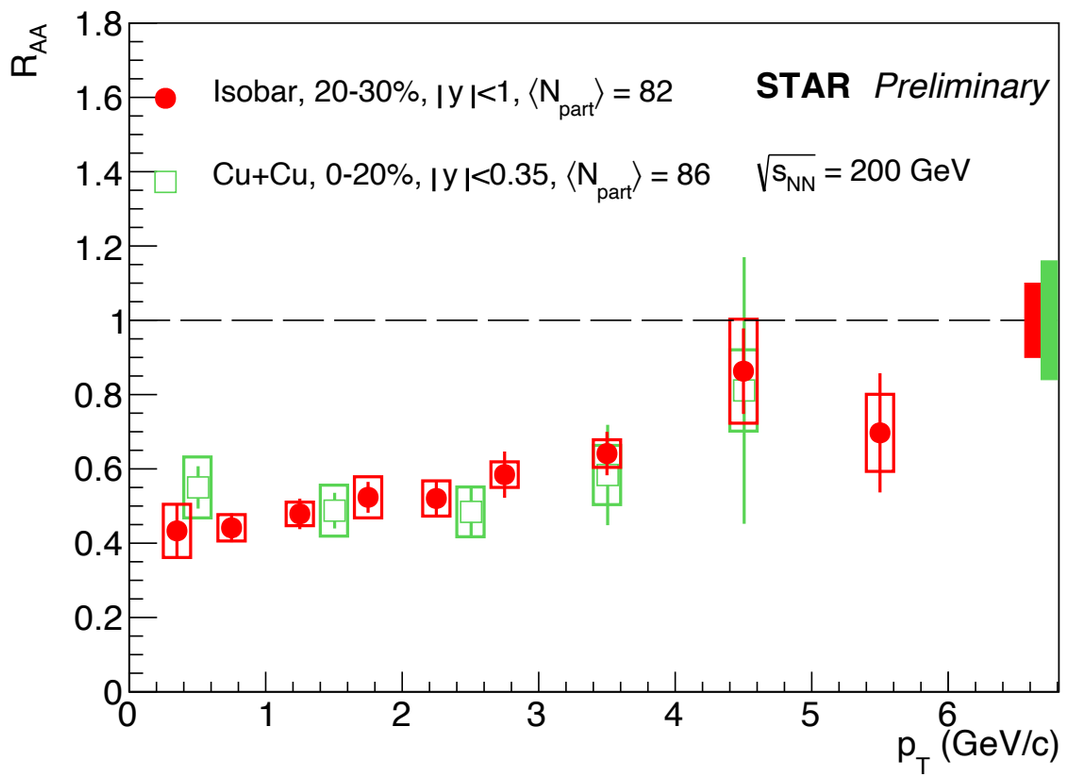
- Largest J/ψ sample at RHIC to data
  - Highest precision measurement
  - More differential measurement simultaneously

Nuclear modification factors



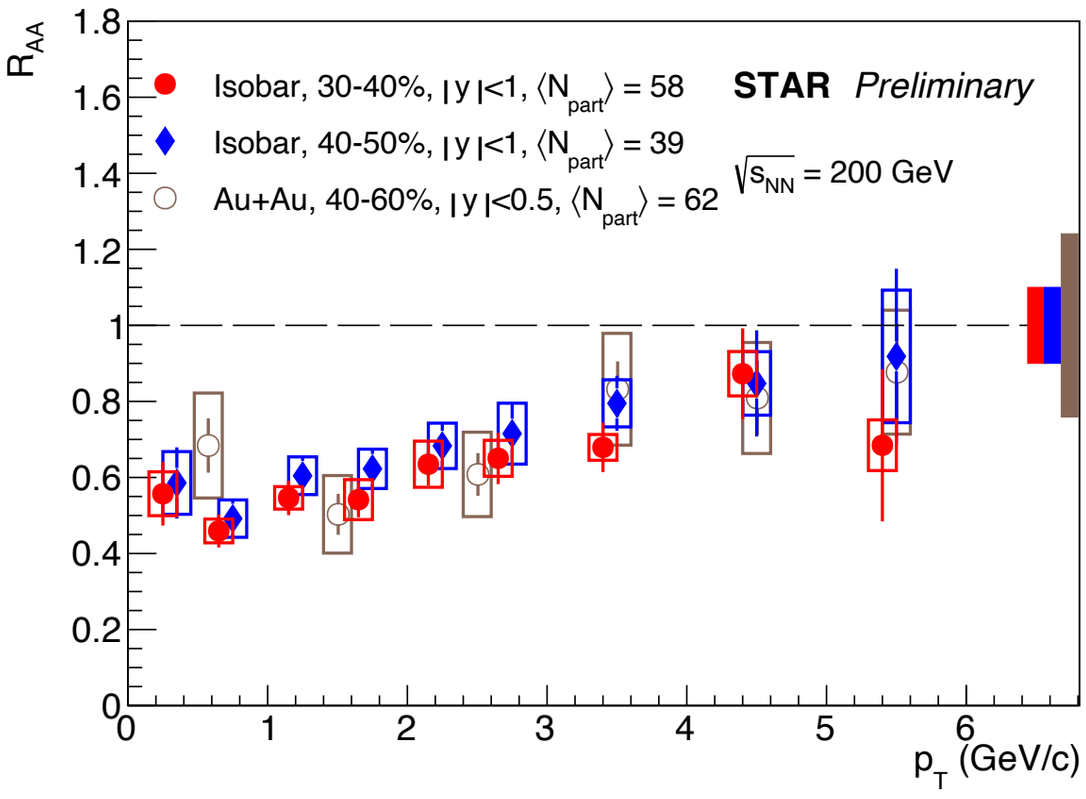


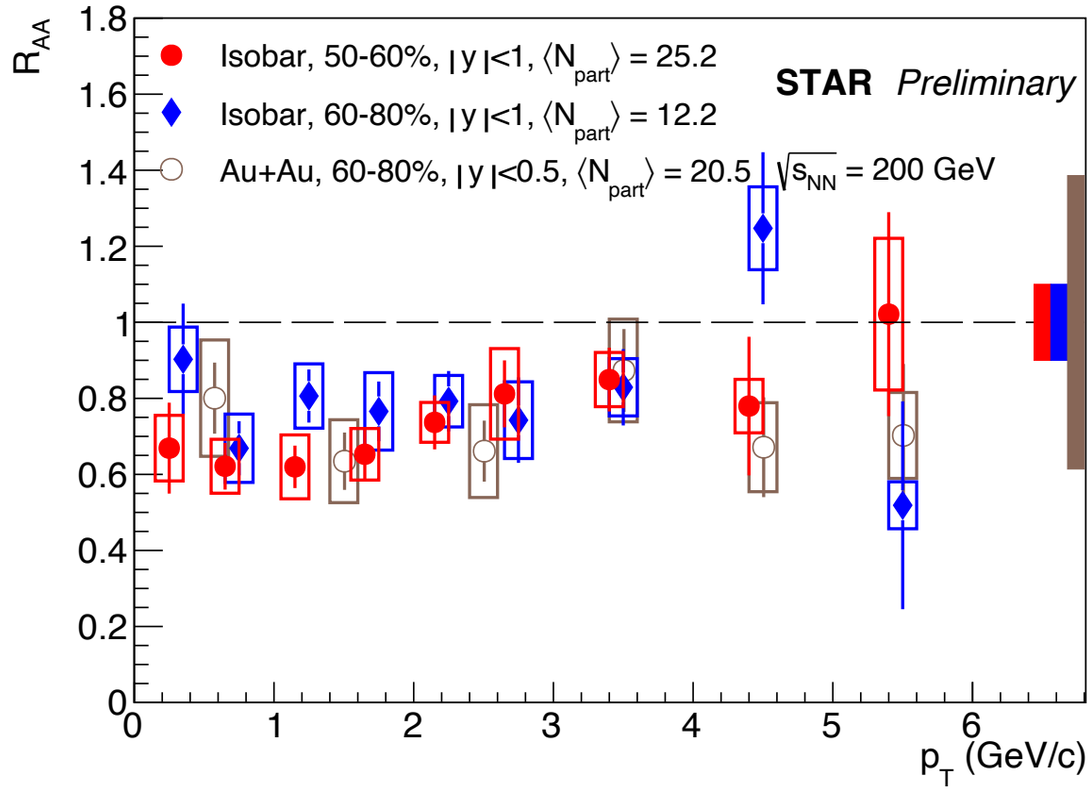




- R_{AA} as a function of transverse momentum in central collisions
  - Significant suppression at all p_T range
  - Similar trend with Au+Au and Cu+Cu results with similar system size
  - No initial geometry dependence were shown

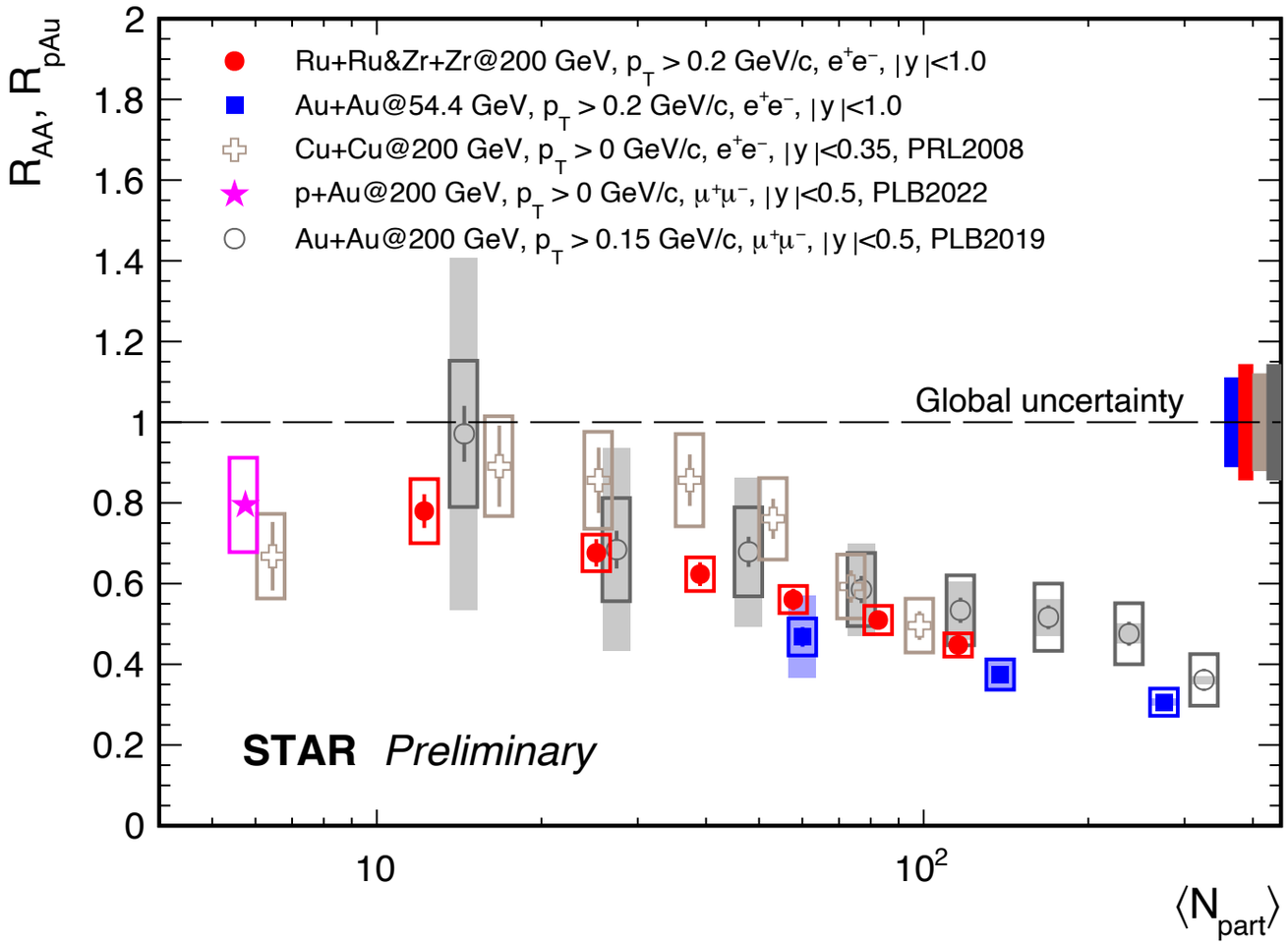
Nuclear modification factors





- R_{AA} as a function of transverse momentum in peripheral collisions
  - Significant suppression at low-p_T range (p_T < 4 GeV/c)
  - Similar trend with comparable system size

System size dependence

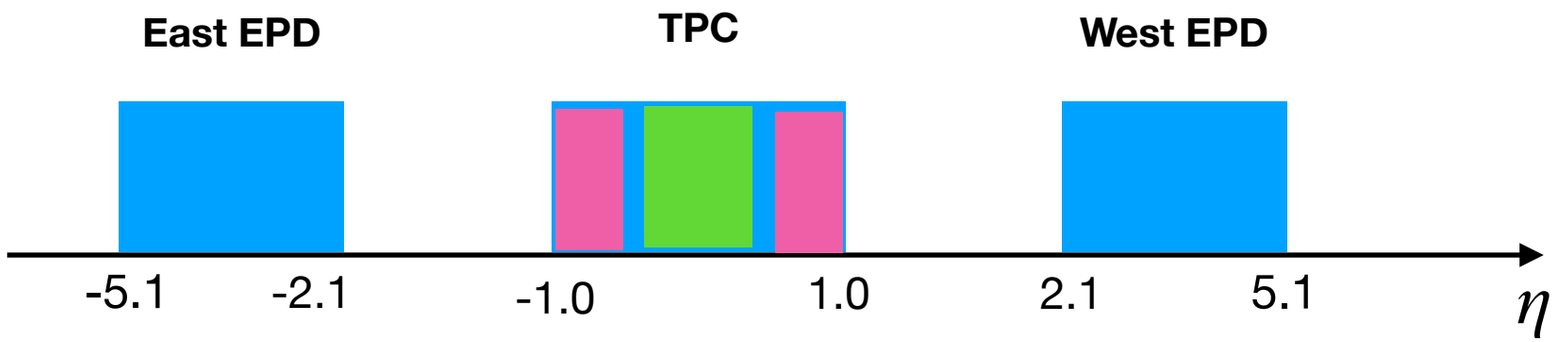


- An universal trend of R_{AA} as a function of $\langle N_{part} \rangle$
  - No obvious initial system size dependence
  - No clear collision energy dependence at RHIC

v_2 extraction

Scalar-Product (SP) method:

- EPD (West+East)
- West TPC and East TPC with a η gap of 0.9



$$v_2^{obs} = \frac{< Q_{2,POI} Q^*_{2,EPD} >}{\sqrt{\frac{< Q_{2,EPD} Q^*_{2,TPCW} > < Q_{2,EPD} Q^*_{2,TPCE} >}{< Q_{2,TPCW} Q^*_{2,TPCE} >}}} = \frac{< Q_{2,POI} Q^*_{2,EPD} >}{\sqrt{\frac{< Q_{2,EPD} Q^*_{2,TPCW} > < Q_{2,EPD} Q^*_{2,TPCE} >}{< Q_{2,TPCW} Q^*_{2,TPCE} >}}}$$

Large η gap between J/ψ and EPD to minimize auto-correlation

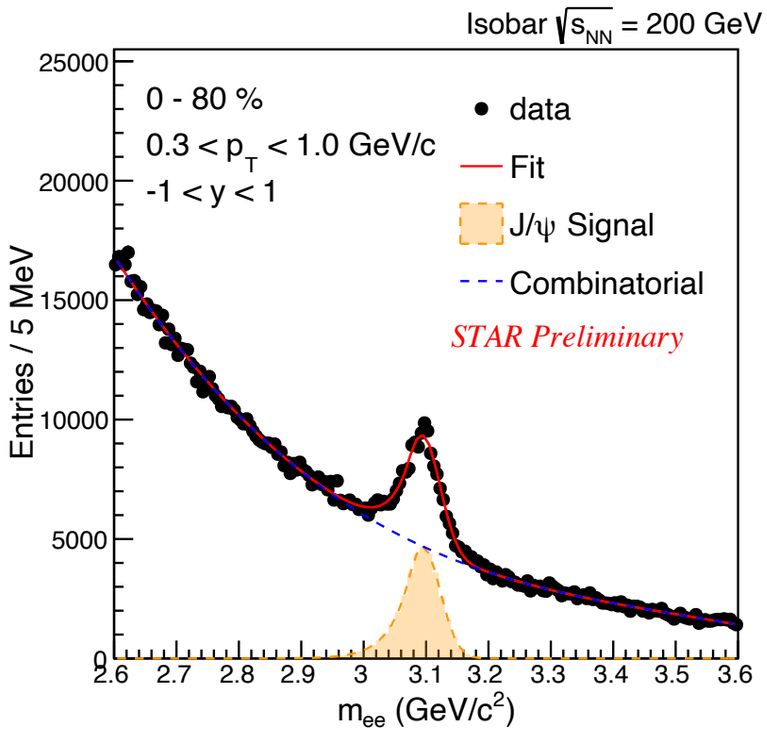
➜ limited non-flow contribution to final results

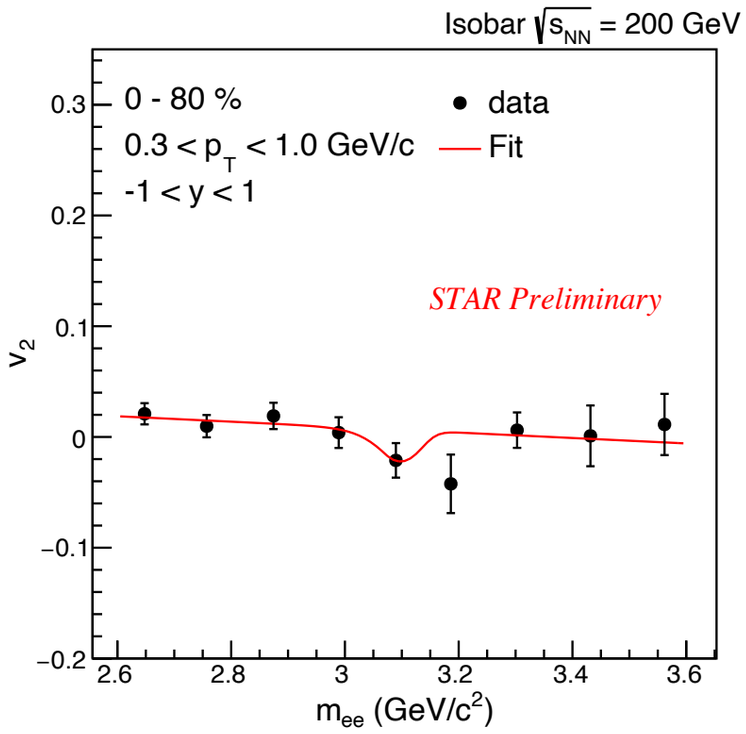
J/ψ elliptic flow

- Crystal-ball function for J/ψ mass distribution
- Polynomial 3 for combinatorial background mass distribution
- Combinatorial background v2: a + b*mass

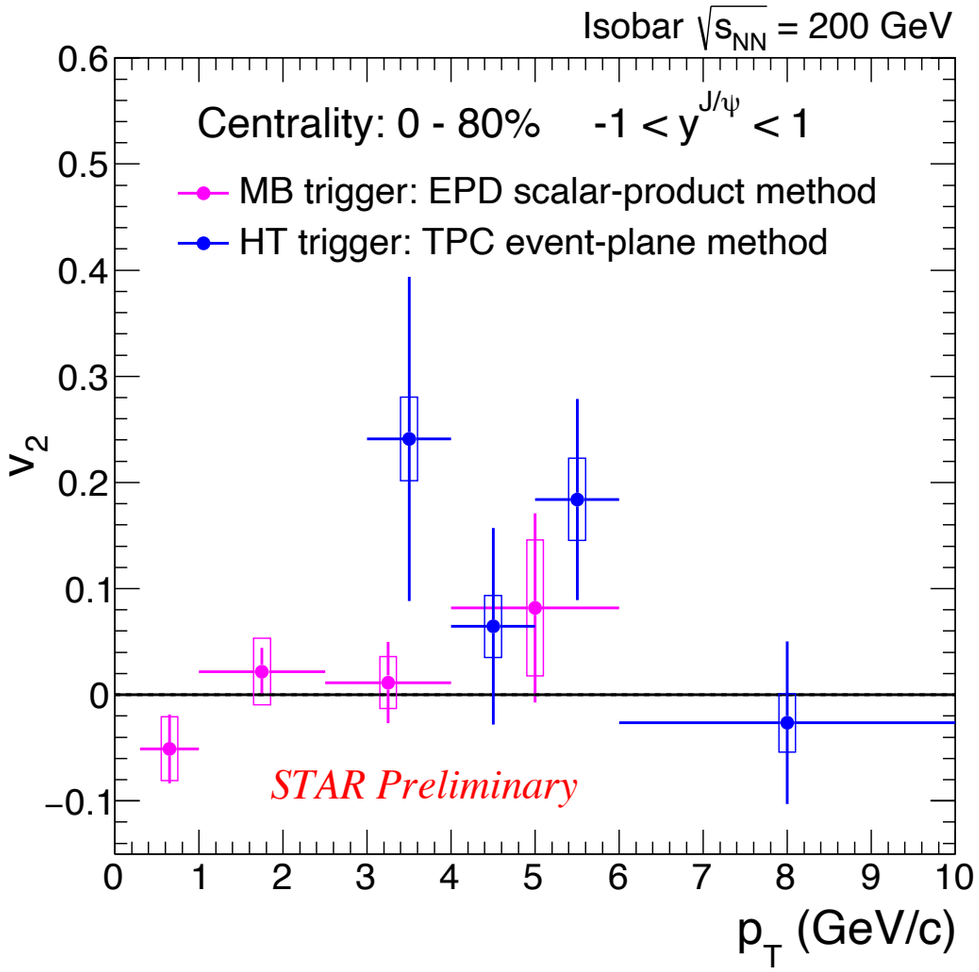
$$v_2^{S+B}(m_{inv}) = f(m_{inv})v_2^S + [1 - f(m_{inv})]v_2^B(m_{inv})$$

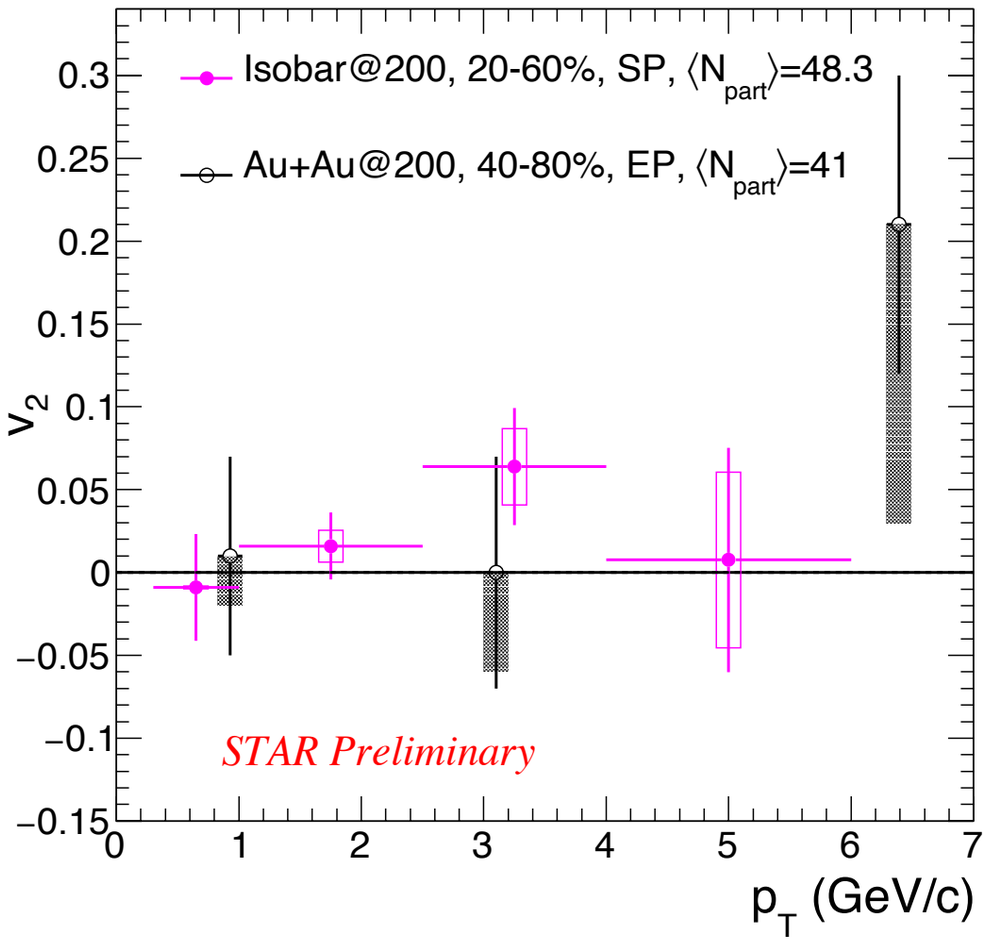
$$f(m_{inv}) = \frac{S(m_{inv})}{S(m_{inv}) + B(m_{inv})}$$





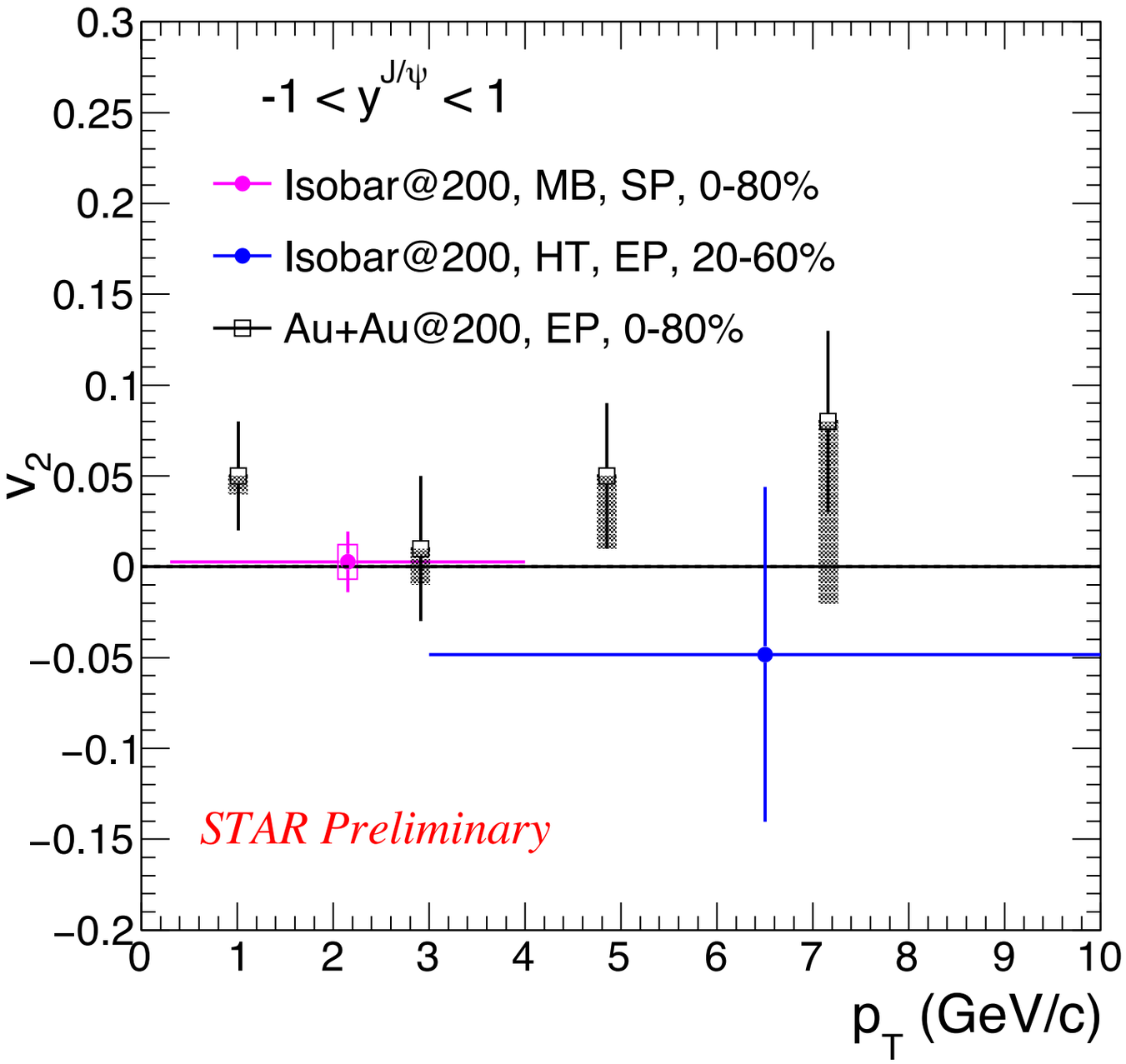
J/ψ elliptic flow





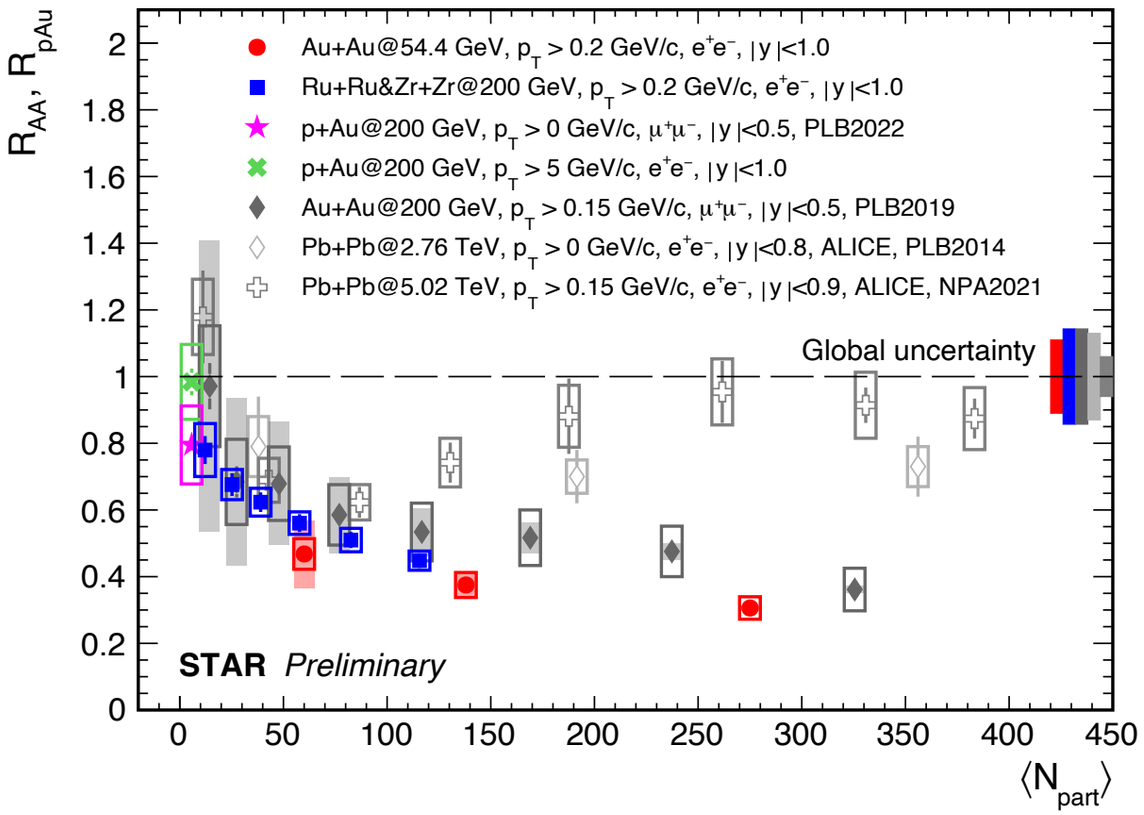
- J/ψ v_2 is consistent with zero in isobar collision
- Significant non-flow suppression by using scalar-product method at similar collision system

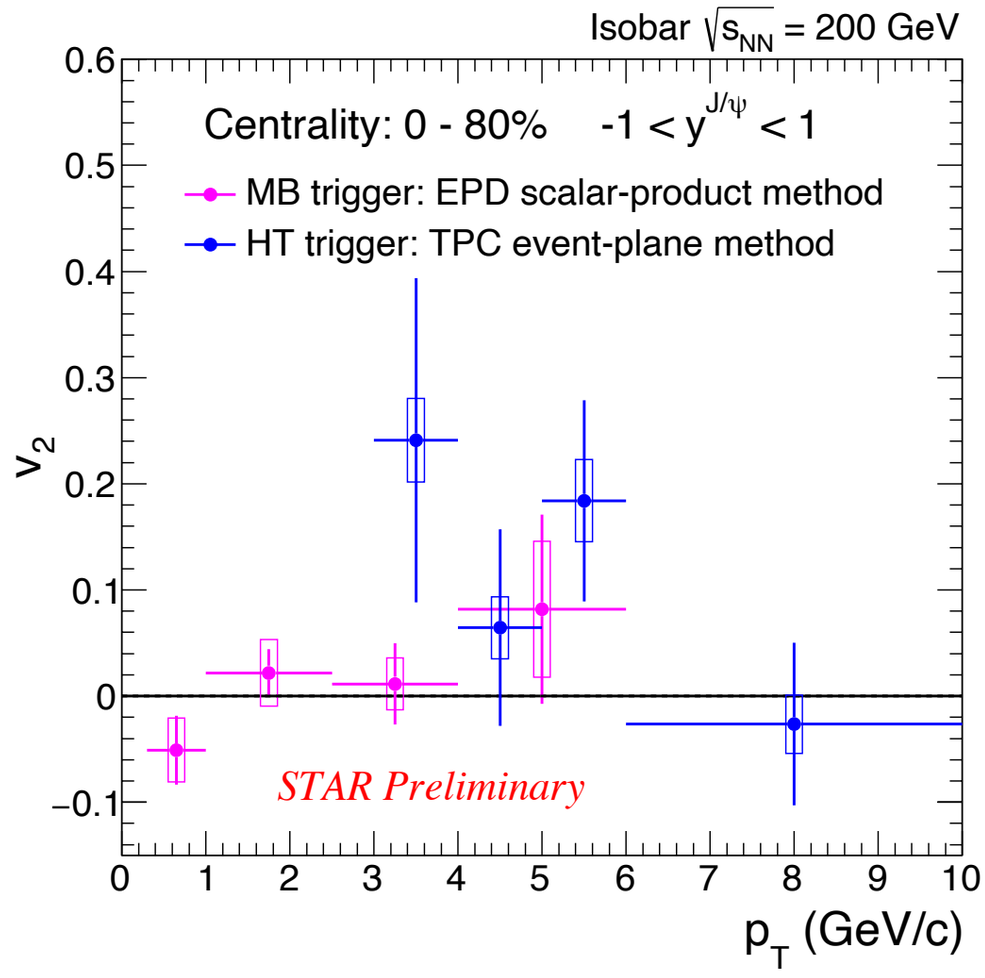
J/ψ elliptic flow



- The J/ψ v_2 is consistent with 0 at low-p_T range (0.3< p_T < 4 GeV/c)
  - $v_2 = 0.0027 \pm 0.017$ (stat.) ± 0.0095(sys.)
- Improved J/ψ v_2 precision compare to STAR Au+Au results
  - Most precise measurement to data at RHIC

J/ψ v_2 and R_{AA}





- The regeneration effect is small in isobar collisions
- The color-screening effect is the dominated hot medium effect that affecting J/ψ production at RHIC

Summary

- Most precise J/ψ v_2 and R_{AA} measurement in HIC at RHIC so far
  - v_2 is consistent with zero at 2% precision level at low-p_T range
  - Significant suppression is observed, no obvious system size and energy dependence at RHIC

- The regeneration effect is small and the color-screening effect dominated the J/ψ production at mid-rapidity in isobar collisions

- Theory inputs are very welcome!!

Thanks!