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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

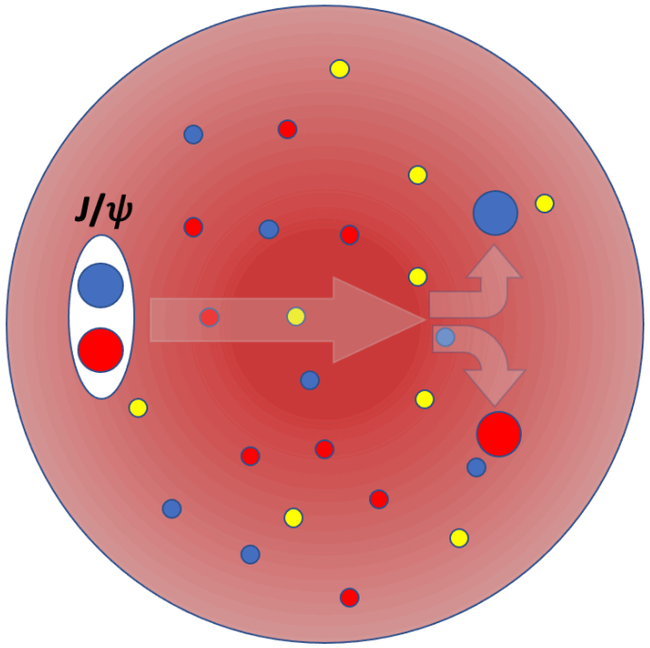
- **Motivation**
- **STAR experiment**
- **J/ψ R_{AA} measurement**
- **J/ψ elliptic flow measurement**
- **Summary**

J/ψ: a key probe to QGP

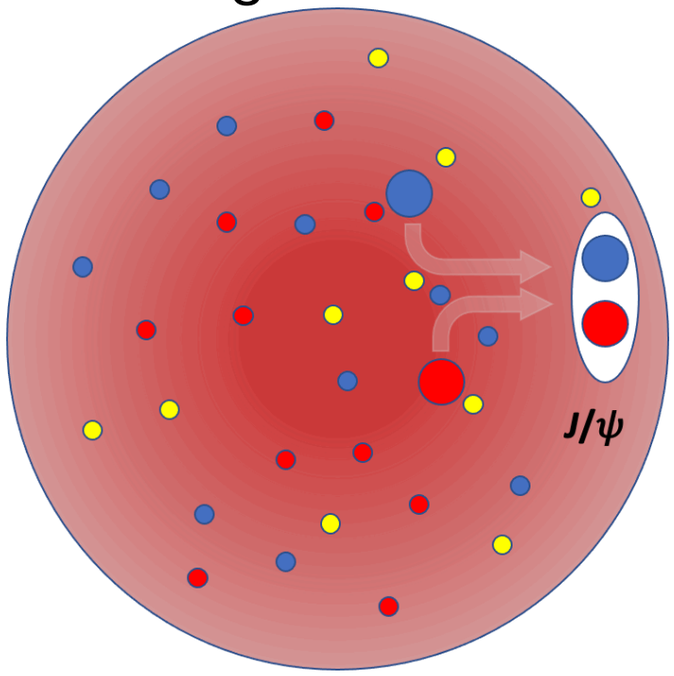
J/ψ is a sensitive probe to study the properties of QGP

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

dissociation



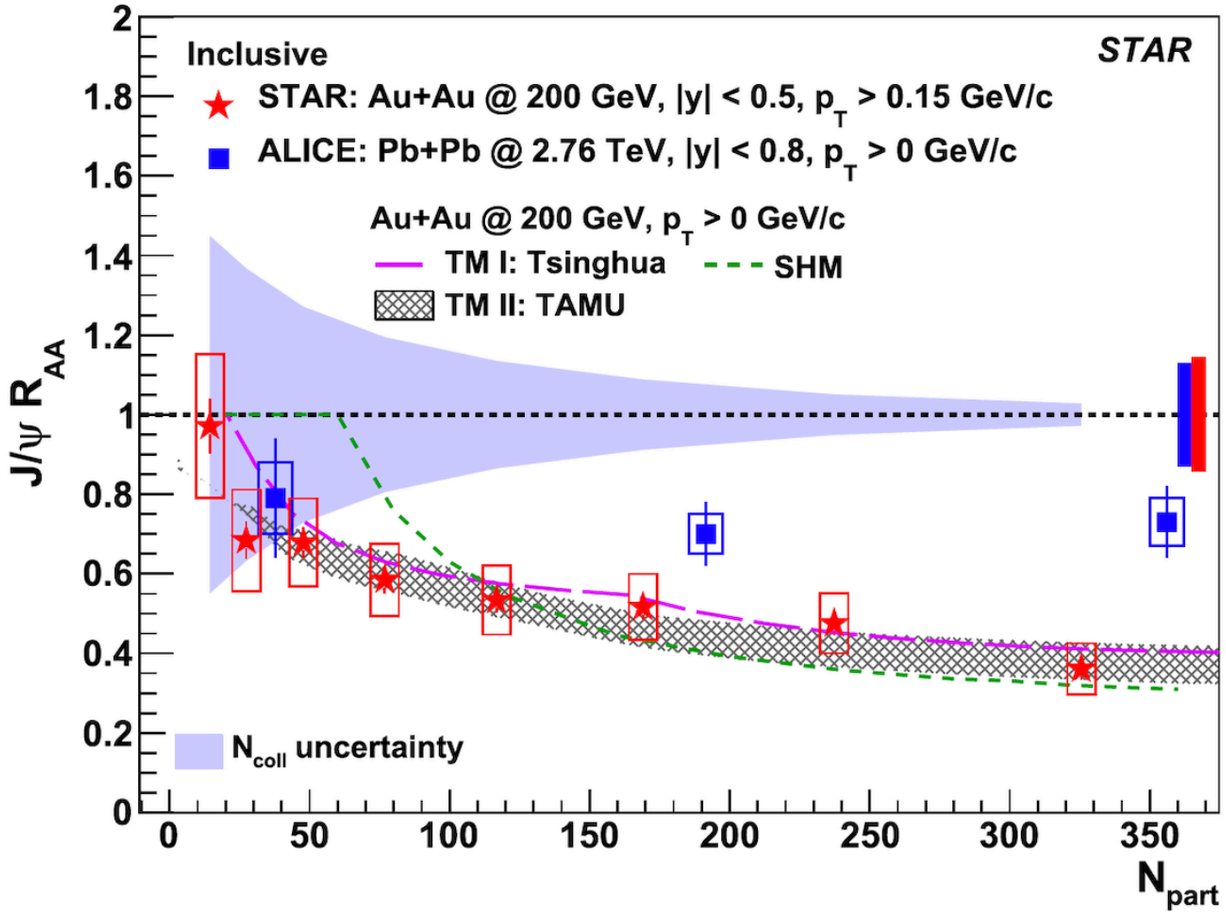
regeneration



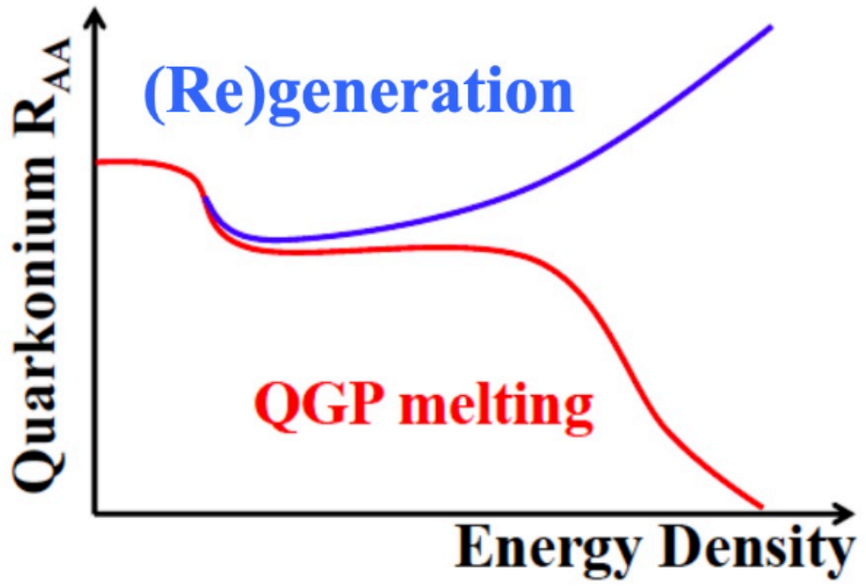
Two key observables:

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

Dissociation vs. Regeneration

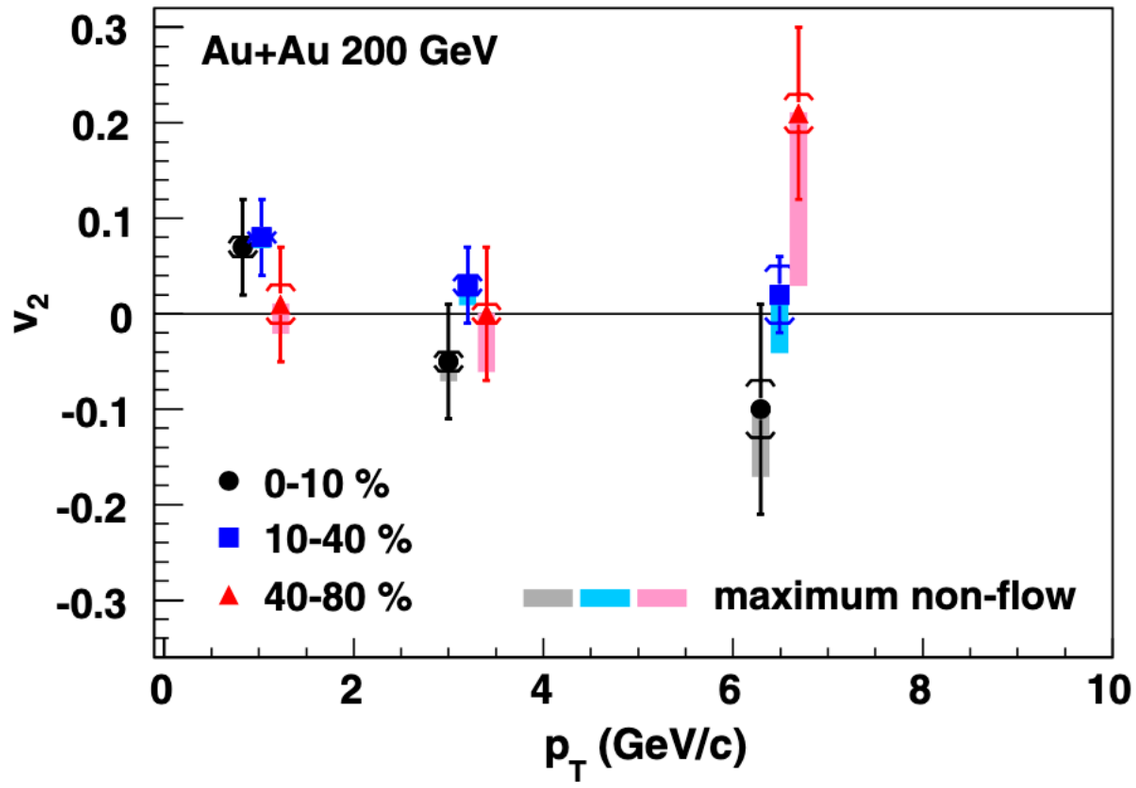


STAR PLB,797 (2019)134917



- Regeneration effect is prominent at LHC energy
- Is it prominent at RHIC top energy and how is it affected by the collision system size?

J/ψ elliptic flow at RHIC

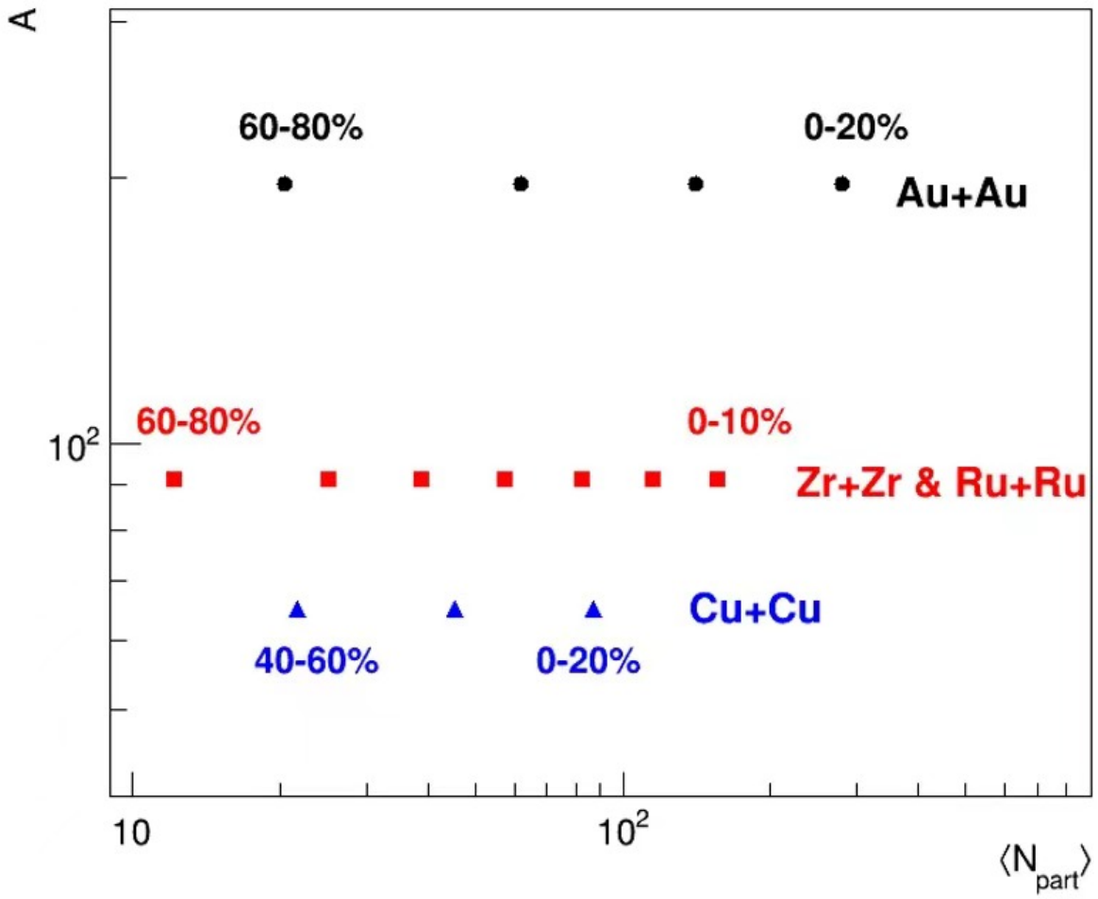


STAR, PRL 111, 052301 (2013)

- J/ψ elliptic flow is consistent with zero but with sizable statistical uncertainties and non-flow contribution in Au+Au measurements
  - Does J/ψ have non zero elliptic flow at RHIC energy?
  - Does it have a system size dependence?
  - Crucial to control non-flow contribution

Isobar collisions

Unique opportunity to measure the J/ψ spectra and v_2 with good precision, and study the system size dependence in isobar collisions ($^{96}_{44}Ru$ + $^{96}_{44}Ru$ and $^{96}_{40}Zr$ + $^{96}_{40}Zr$) at STAR



- A moderate size collision system
  - between Au+Au and Cu+Cu
- Large isobar sample
  - minimum bias (4B)+ high tower triggers
- Event Plane Detector
  - help to reduce non-flow contribution

The Solenoidal Tracker at RHIC

TOF

Identification of low-p_T electrons

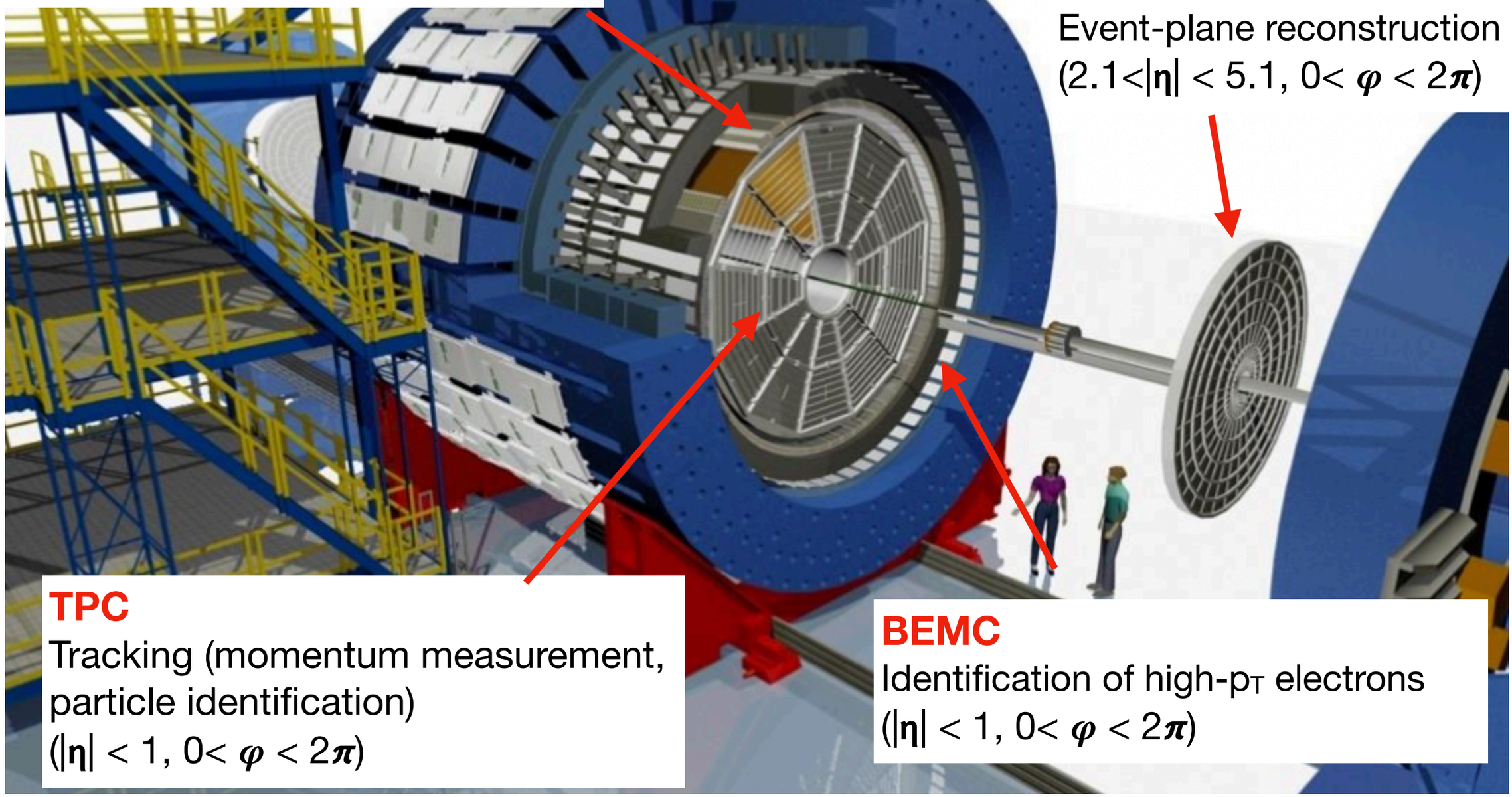
($|\eta| < 1$, $0 < \varphi < 2\pi$)

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

EPD

Event-plane reconstruction

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



TPC

Tracking (momentum measurement, particle identification)

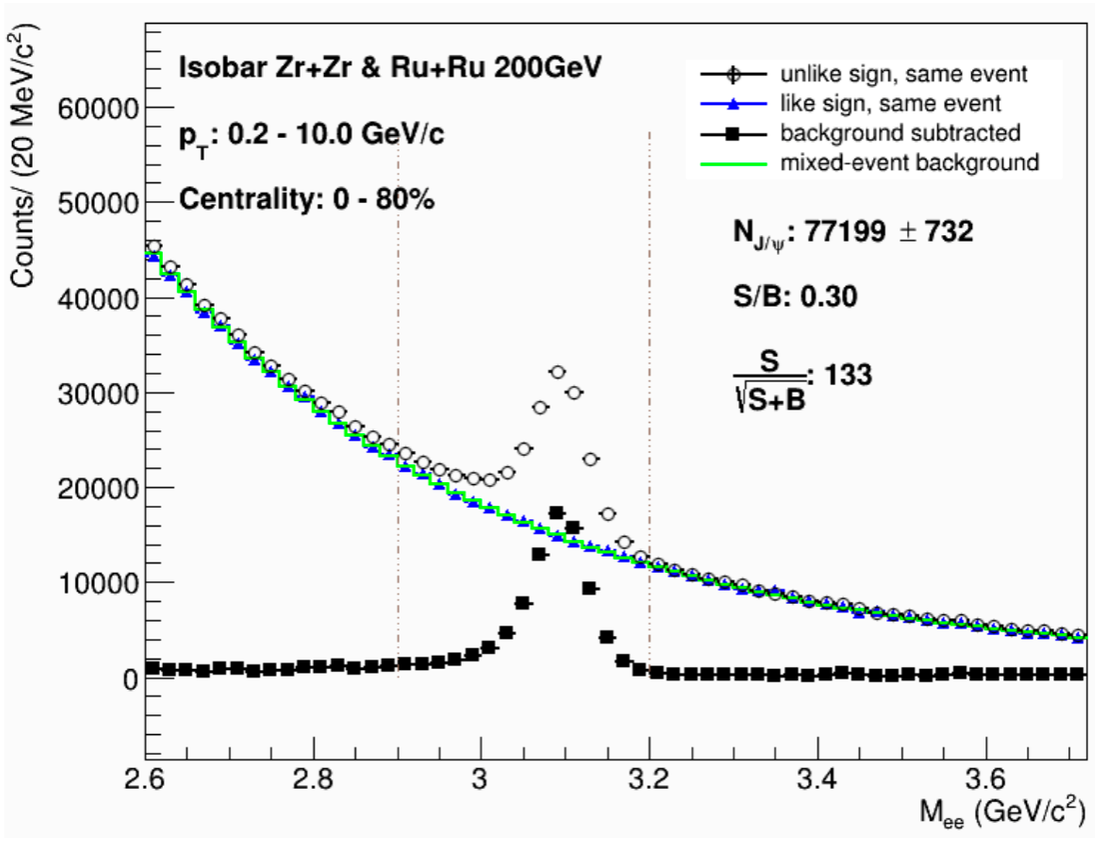
($|\eta| < 1$, $0 < \varphi < 2\pi$)

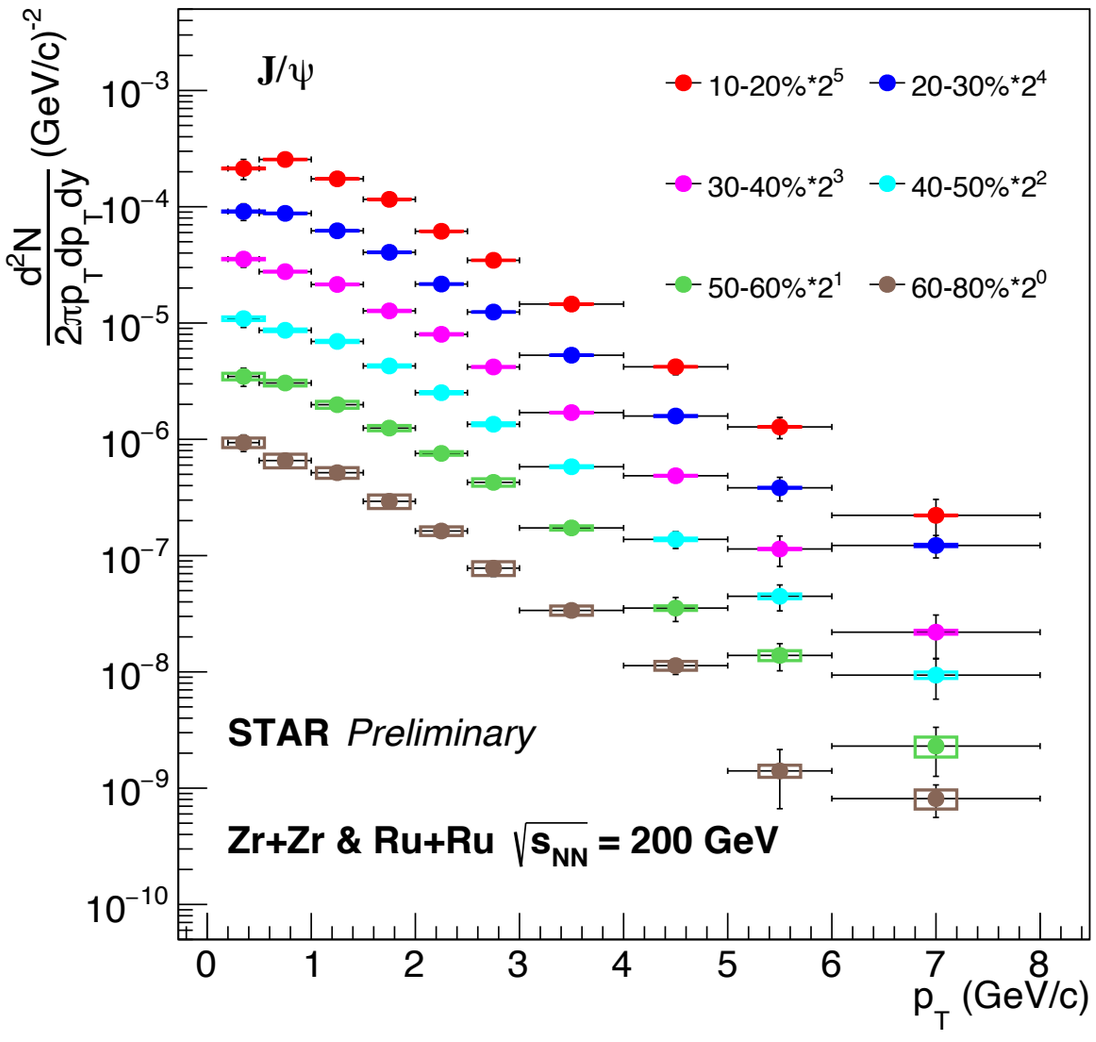
BEMC

Identification of high-p_T electrons

($|\eta| < 1$, $0 < \varphi < 2\pi$)

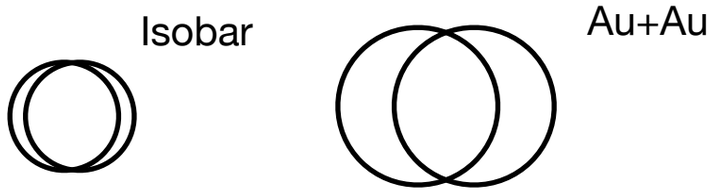
J/ψ reconstruction

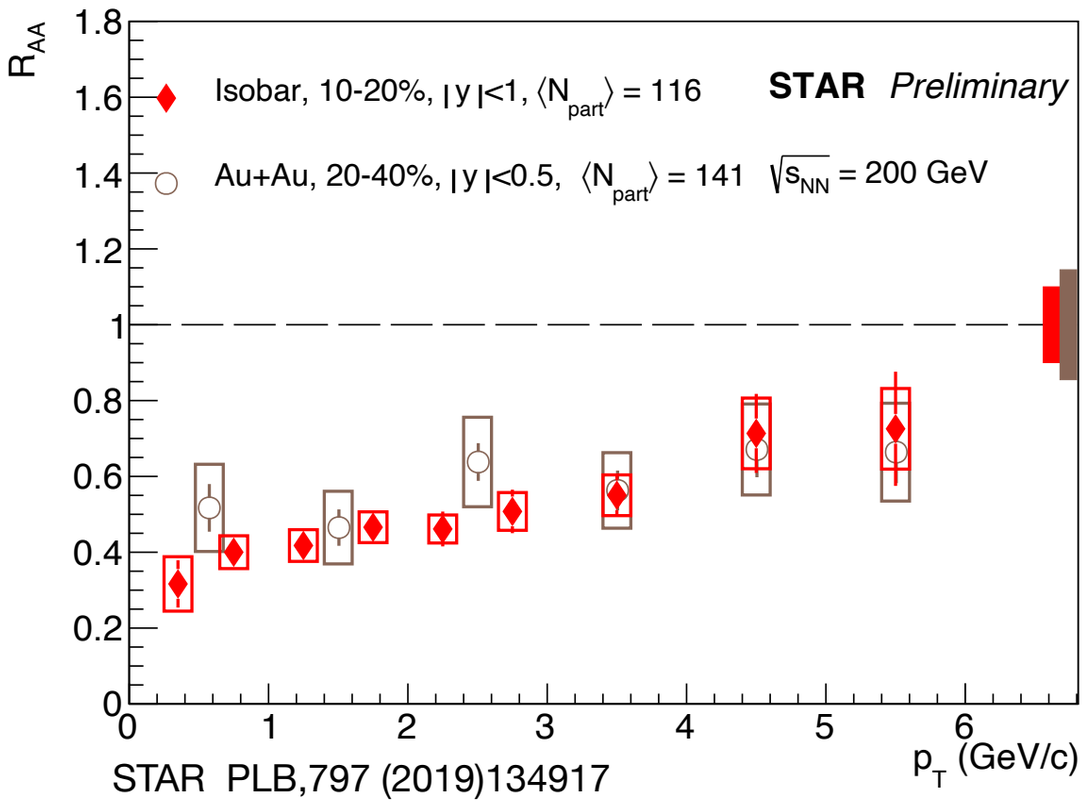


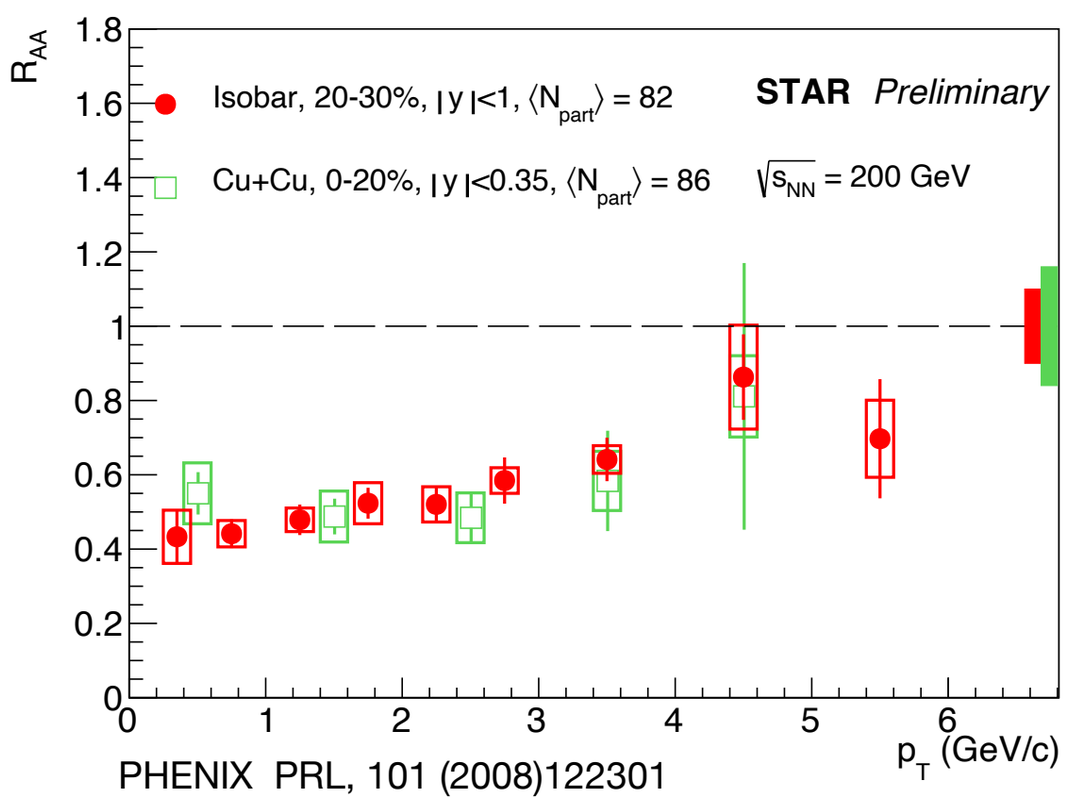


- Largest J/ψ sample at RHIC to date
  - High precision measurement
  - More differential measurements

J/ψ R_{AA} in central collisions

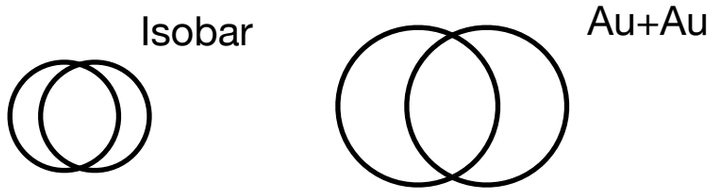


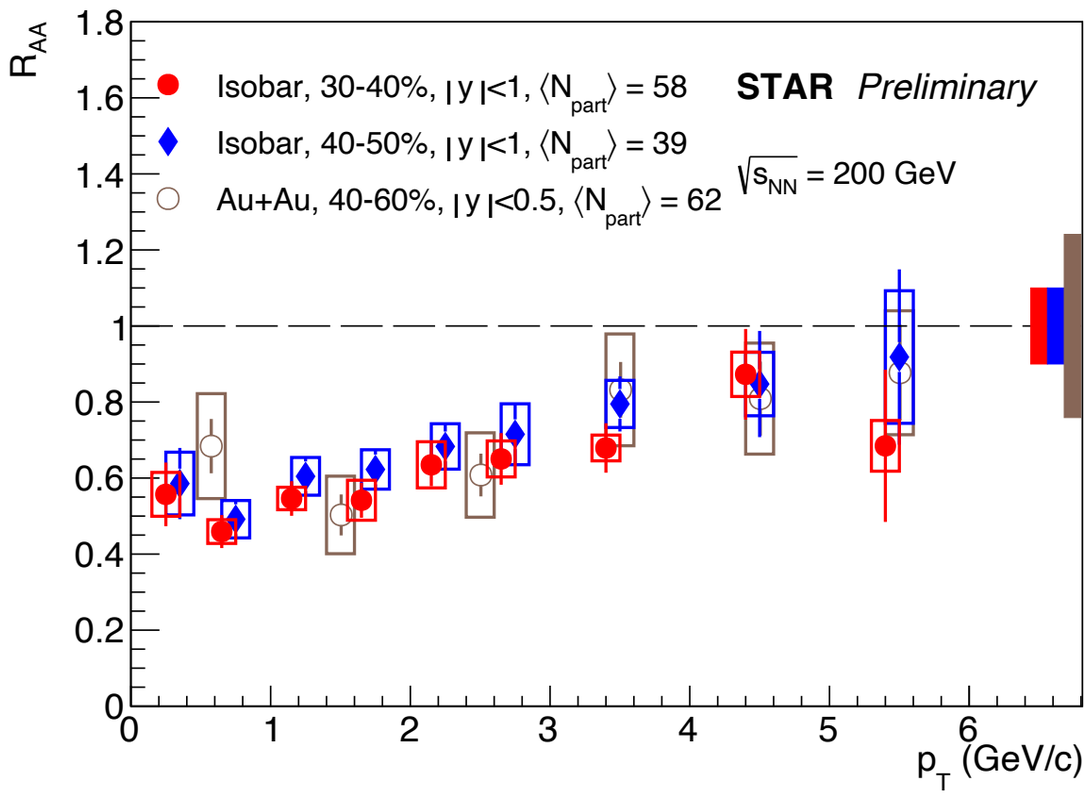


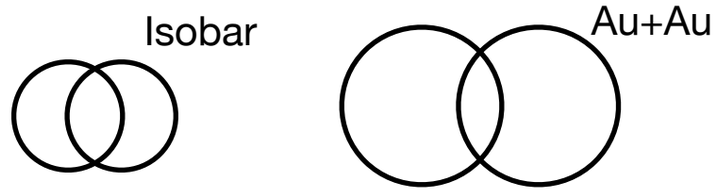


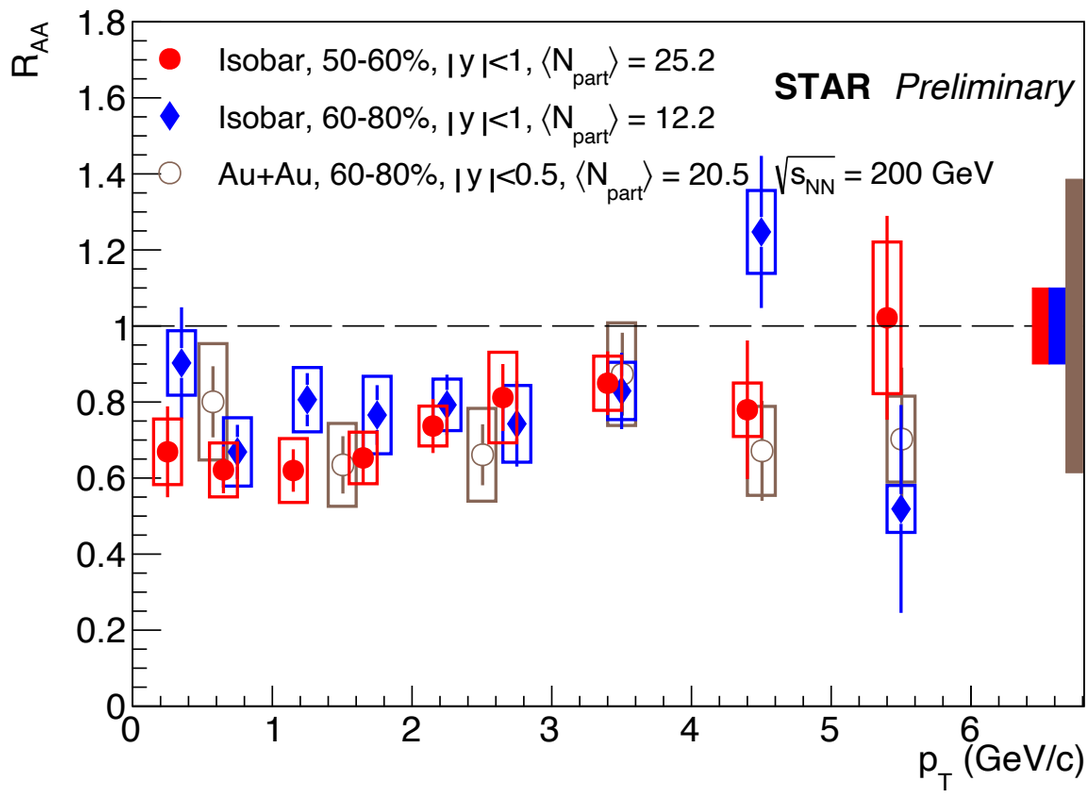
- R_{AA} as a function of transverse momentum in central collisions
  - Significant suppression at all p_T range
  - Similar trend with Au+Au and Cu+Cu results with similar $\langle N_{part} \rangle$
  - No initial geometry dependence is observed

J/ψ R_{AA} in peripheral collisions



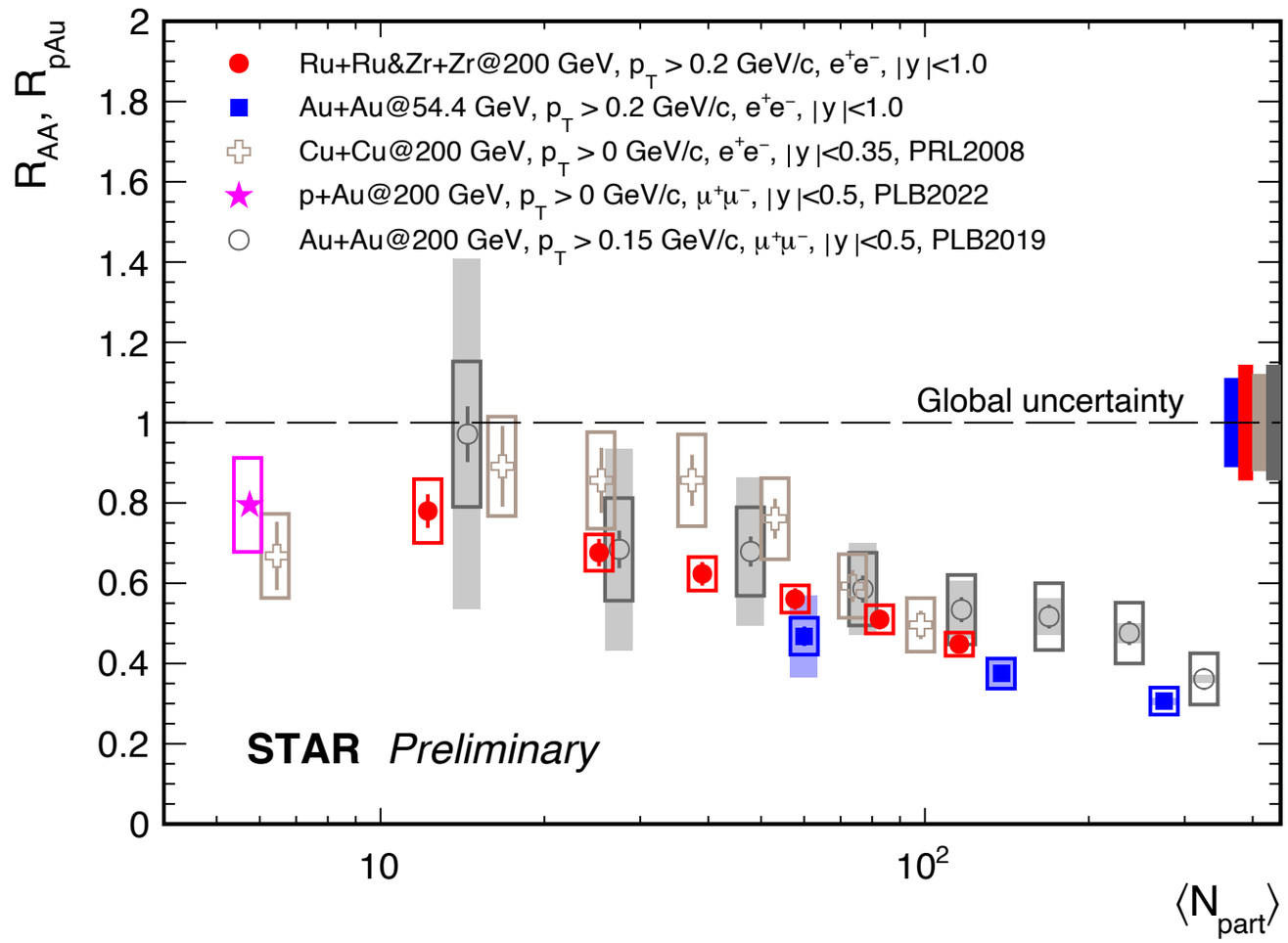






- R_{AA} as a function of transverse momentum in peripheral collisions
  - Significant suppression at low-p_T range (p_T < 4 GeV/c)
  - Similar trend with Au+Au at comparable $\langle N_{part} \rangle$

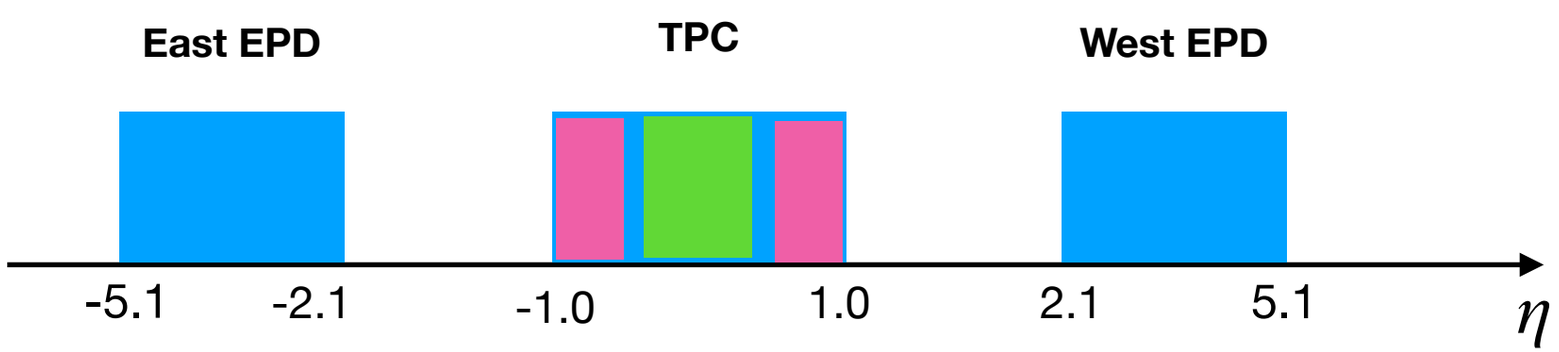
System size dependence



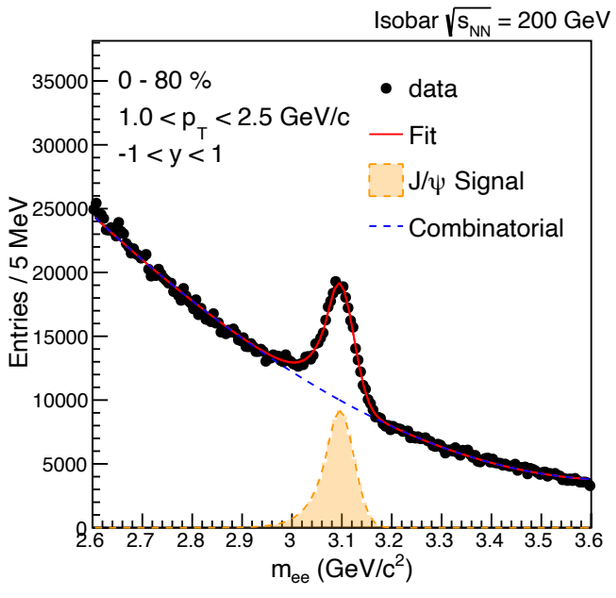
- Highest precision on J/ψ R_{AA} measurement at RHIC energies
- Indication of a universal trend of R_{AA} as a function of $\langle N_{part} \rangle$
  - No significant collision system dependence

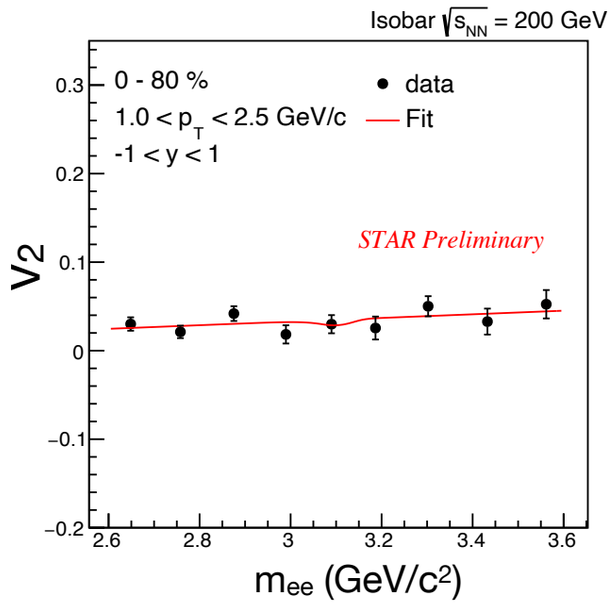
v_2 extraction

Scalar-Product (SP) method:



Large η gap between J/ψ and EPD ➜ limited non-flow contribution to final results





- Crystal-ball function for J/ψ mass distribution
- Polynomial 3 for background mass distribution
- Background v_2: a + b*mass

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

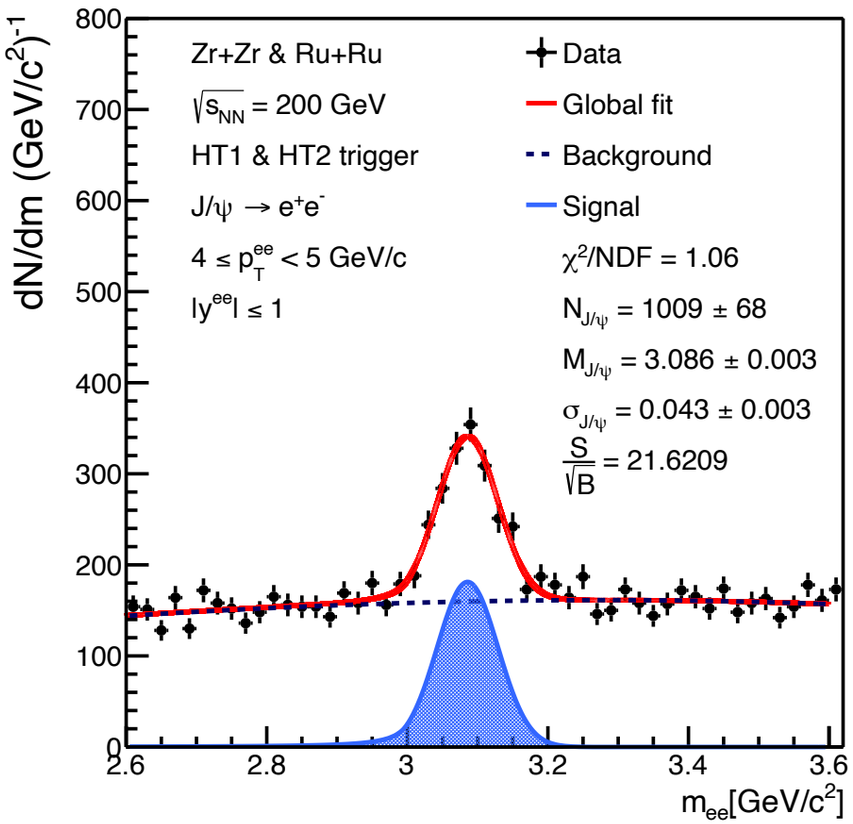
$$f(m_{inv}) = \frac{S(m_{inv})}{S(m_{inv}) + B(m_{inv})}$$

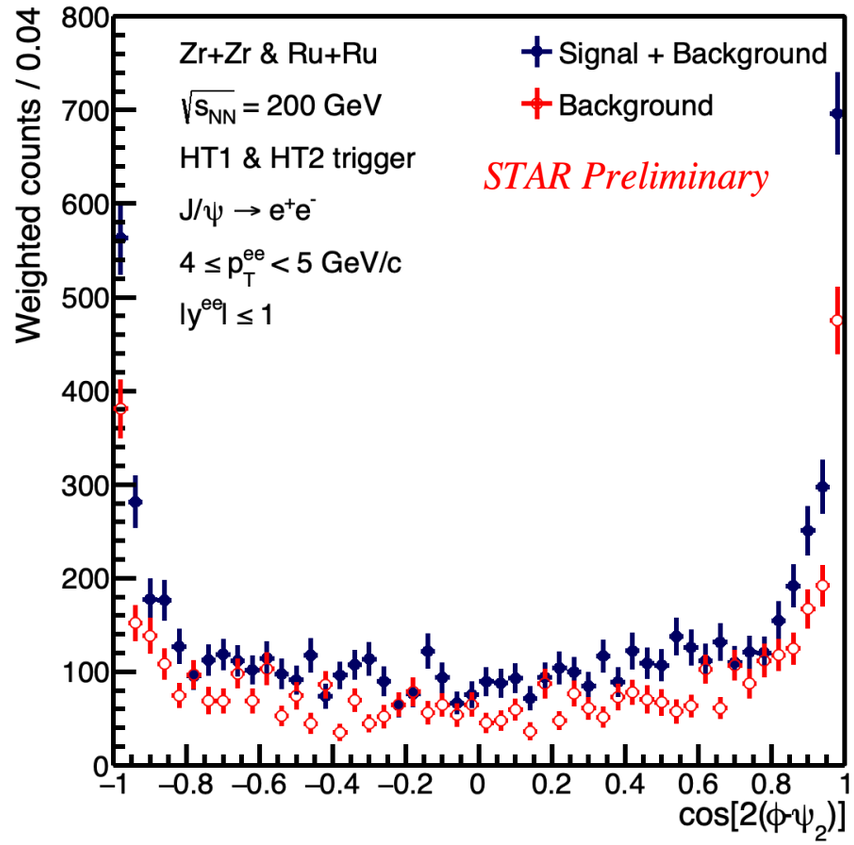
v_2 extraction

TPC Event-Plane (EP) method:

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}(1 + \sum_{n=1}^{\infty} 2v_n cos[n(\phi - \Psi_n)])$$

TPC second-order event plane to estimate the reaction plane

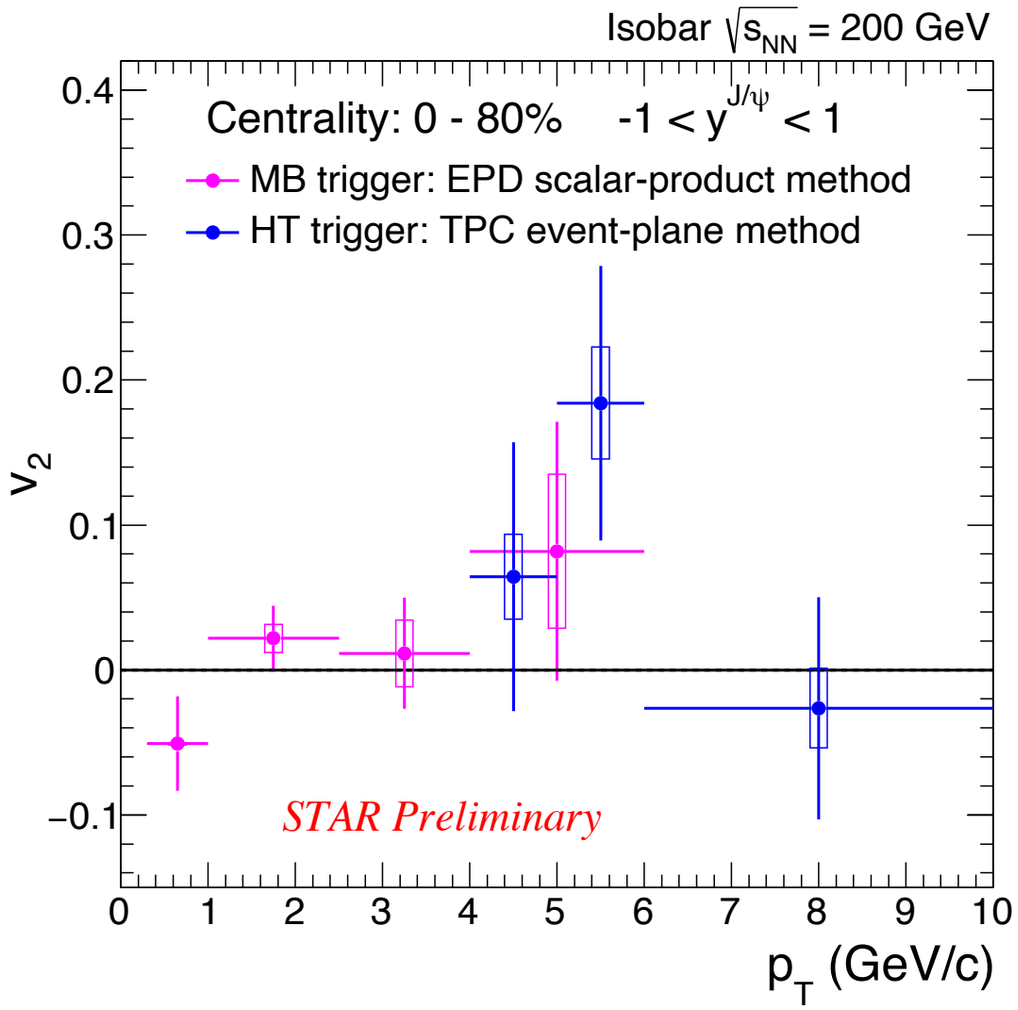


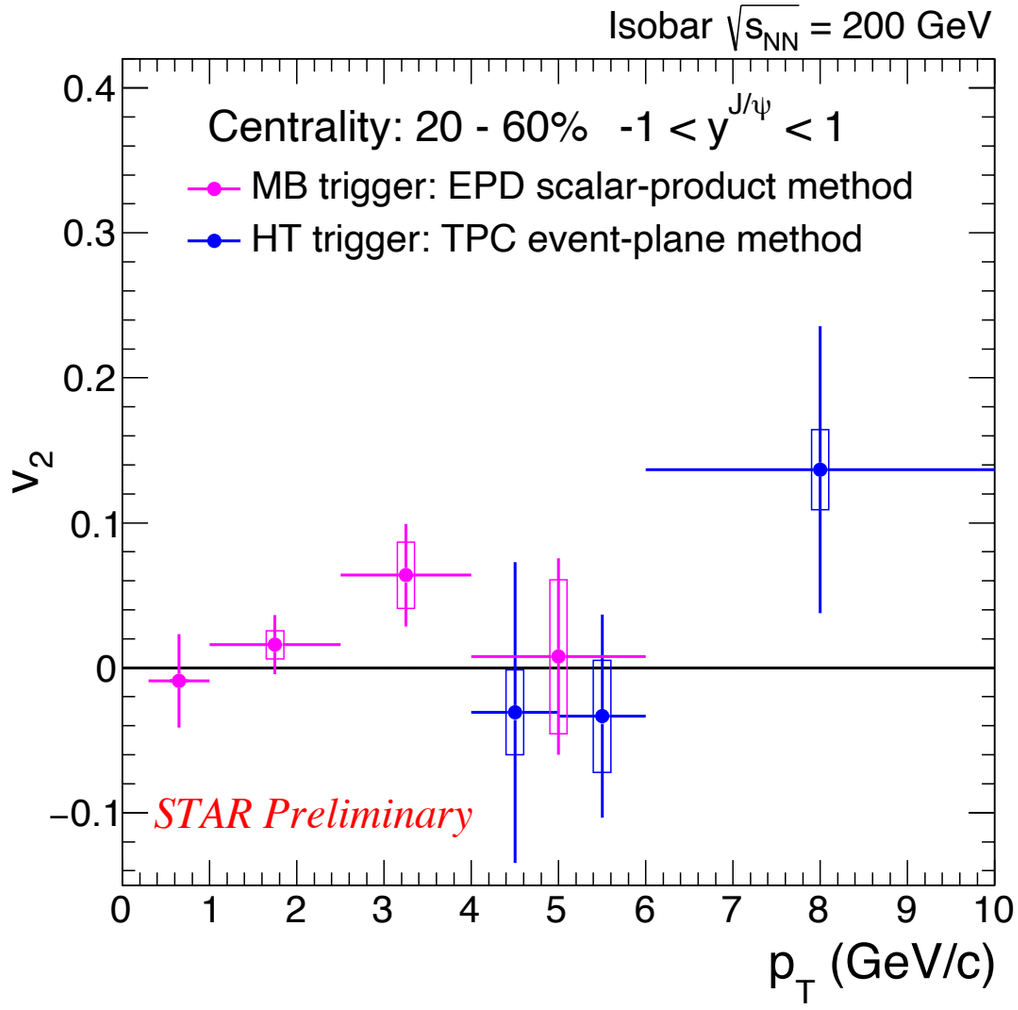


$$v_2^{obs} = \frac{\sum_i cos[2(\phi - \Psi_2)]_{S+B,i} - \sum_j cos[2(\phi - \Psi_2)]_{B,j}}{N_{J/\psi}}$$

$$v_2 = \frac{v_2^{obs}}{\langle cos[2(\Psi_2 - \Psi_r)]\rangle}$$

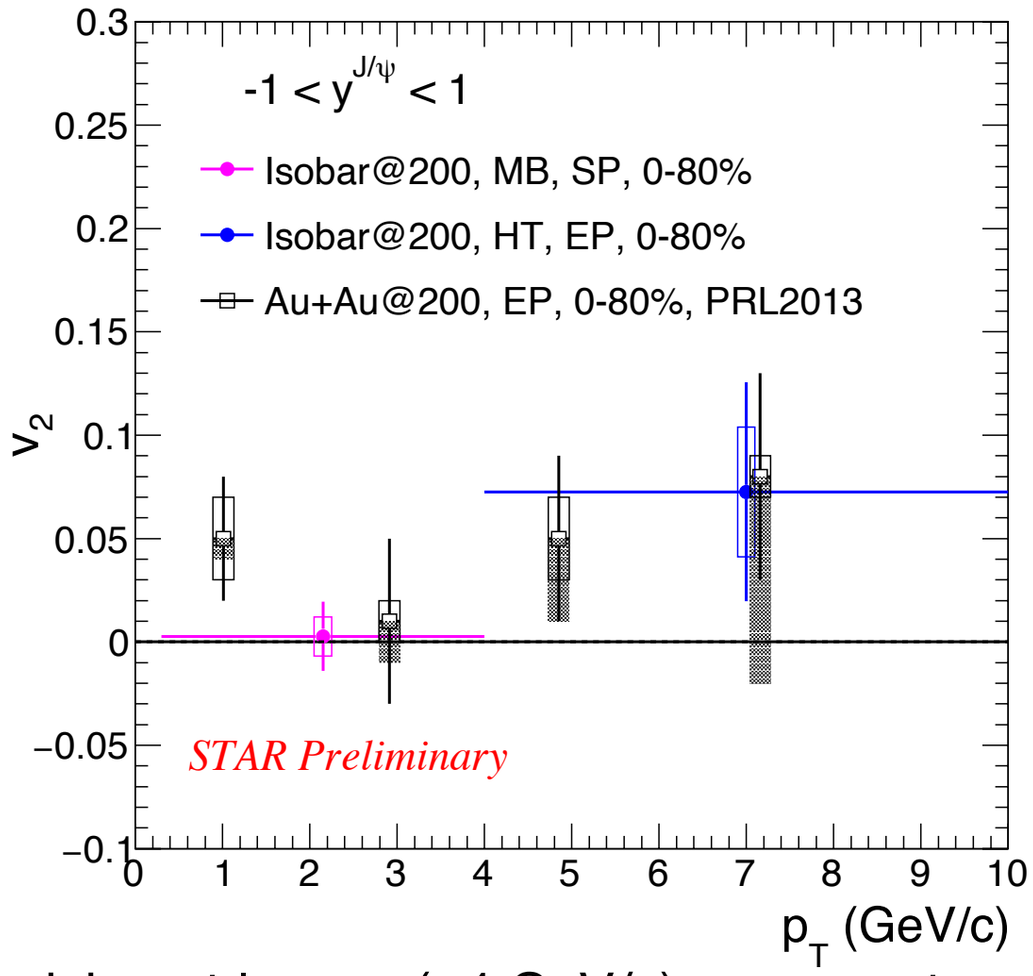
J/ψ elliptic flow





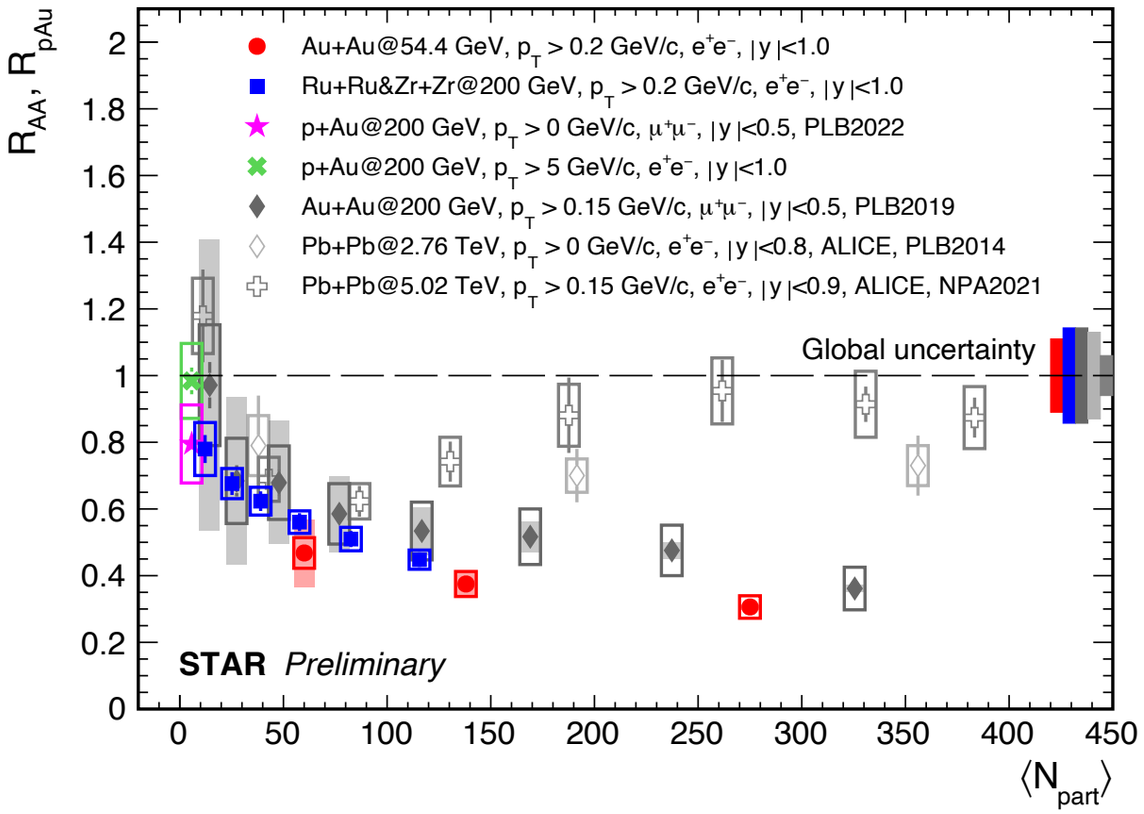
- J/ψ v_2 consistent with zero in both 0-80% and 20-60% centralities
- No significant p_T dependence is seen for J/ψ v_2 with current precision

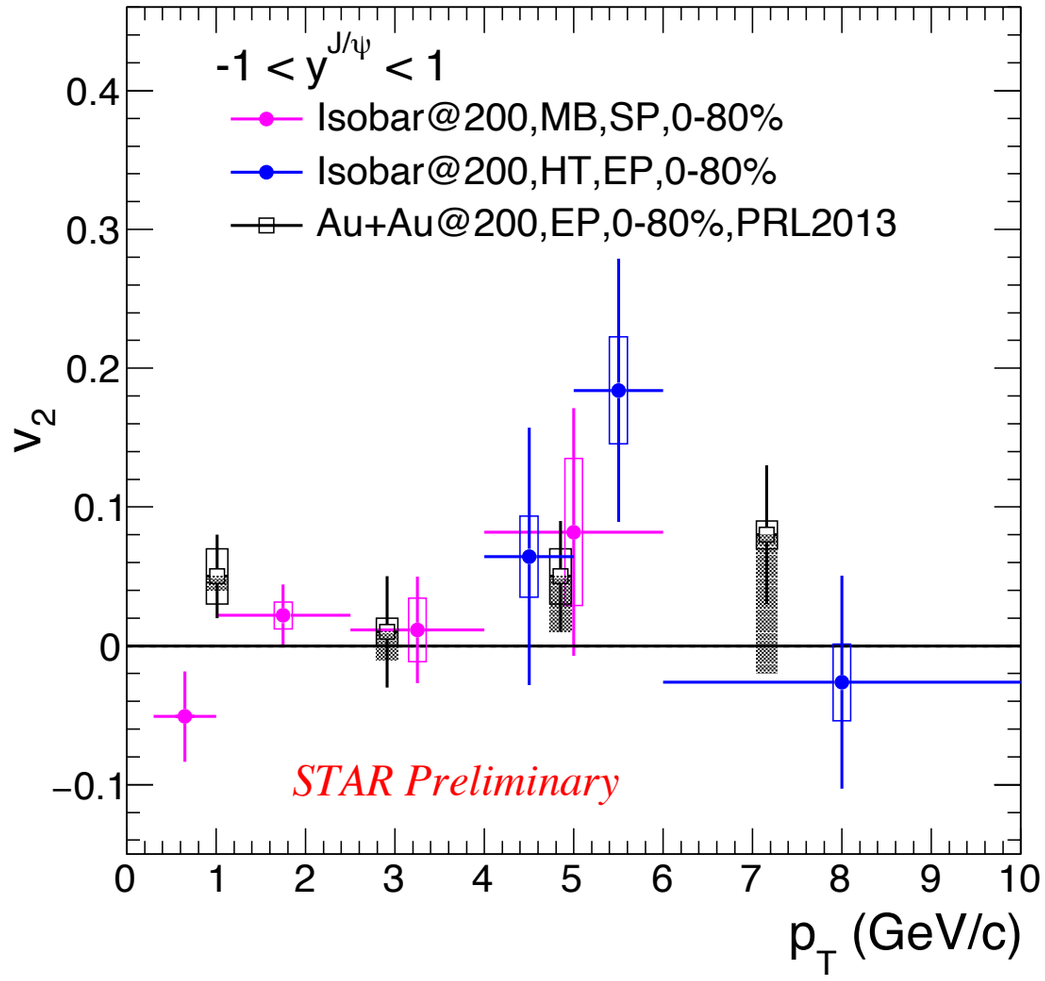
J/ψ elliptic flow



- Improved J/ψ v_2 precision at low-p_T (<4 GeV/c) compare to previous STAR Au+Au results
  - Most precise v_2 measurement to date at RHIC
- The J/ψ v_2 is consistent with 0 at low-p_T range (0.3< p_T < 4 GeV/c)
  - $v_2 = 0.003 \pm 0.017$ (stat.)± 0.010(sys.)
  - Indication of small regeneration effect and/or small charm quark flow

J/ψ v_2 and R_{AA}





- Indication of small regeneration effect in isobar collisions
- The color-screening effect is the dominate hot medium effect that affects J/ψ production at RHIC

Summary

- J/ψ R_{AA} and v_2 measurements in Isobar collisions: most precise in HIC at RHIC so far
  - Significant suppression in R_{AA} is observed, no significant collision system and energy dependence at similar $\langle N_{part} \rangle$
  - v_2 is consistent with zero at 2% precision level at low-p_T range
- Indication of small regeneration effect and the color-screening effect significantly affects the J/ψ production at mid-rapidity in isobar collisions
- Theory inputs are very welcome!!

Thanks!