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Collision energy and system size dependence of J/ψ production in heavy-ion collisions with STAR

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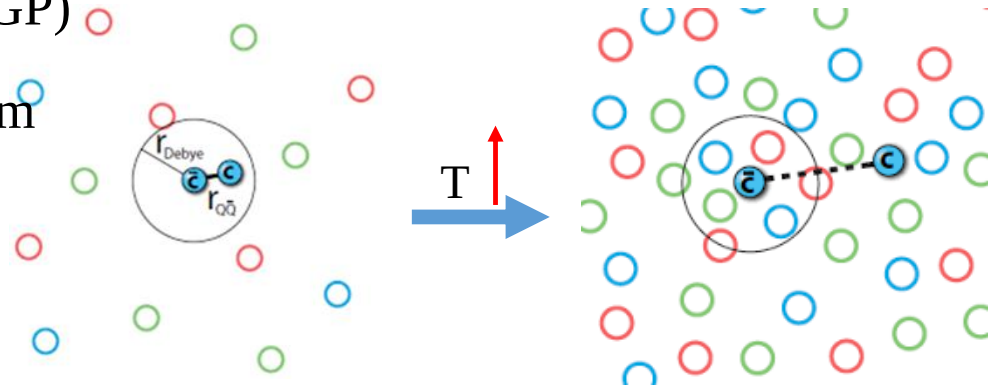
Outline

- Introduction
- Energy dependence of J/ψ production
- System size dependence of J/ψ production
- Summary

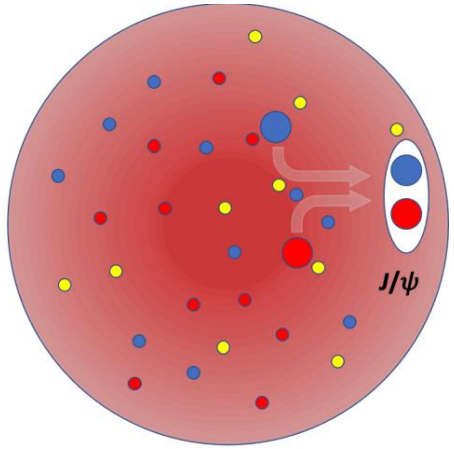
Motivation

- J/ψ provides a good probe to the Quark-Gluon Plasma (QGP)
- Produced via hard scattering, experience the whole medium evolution
- Hot medium effects
  - Dissociation
  - Regeneration
- Cold nuclear matter effects (e.g. nPDF, coherent energy loss, nuclear absorption)
- Other final state effects (e.g. comovers)
- J/ψ nuclear modification factor, R_{AA}, is defined as

$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \times \frac{d^2N_{AA}/dp_T dy}{d^2N_{pp}/dp_T dy}$$

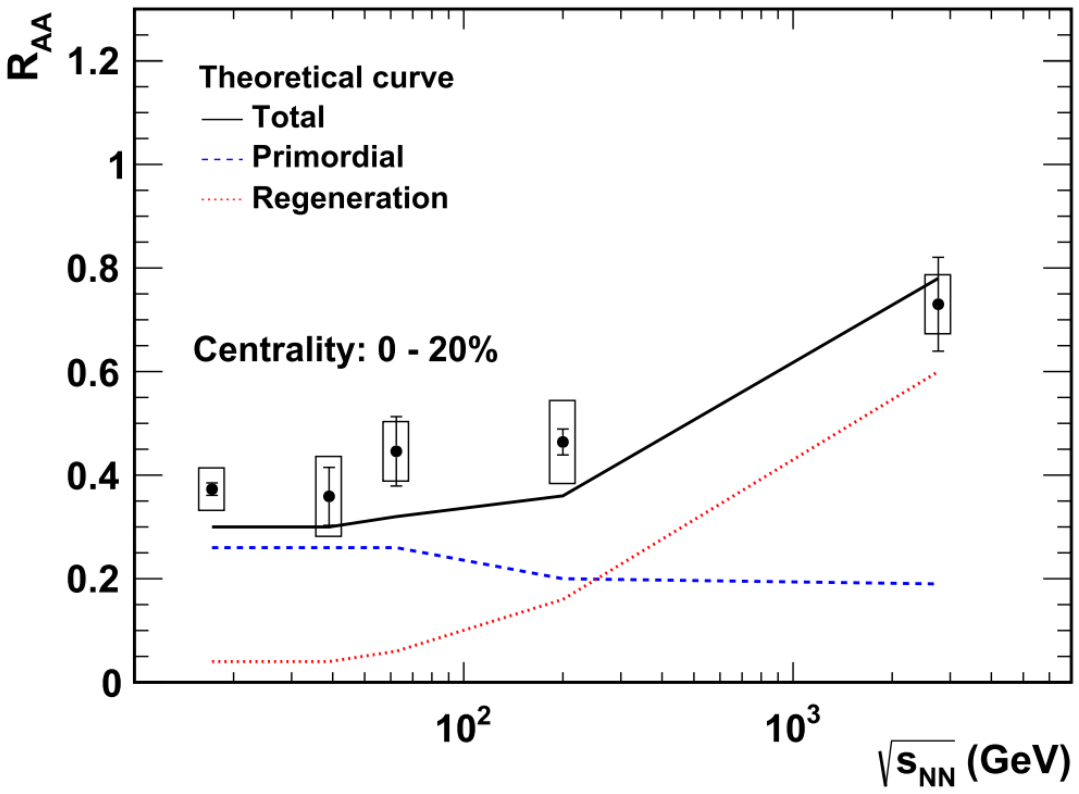


Dissociation



Regeneration

Au+Au collisions at 54.4 GeV



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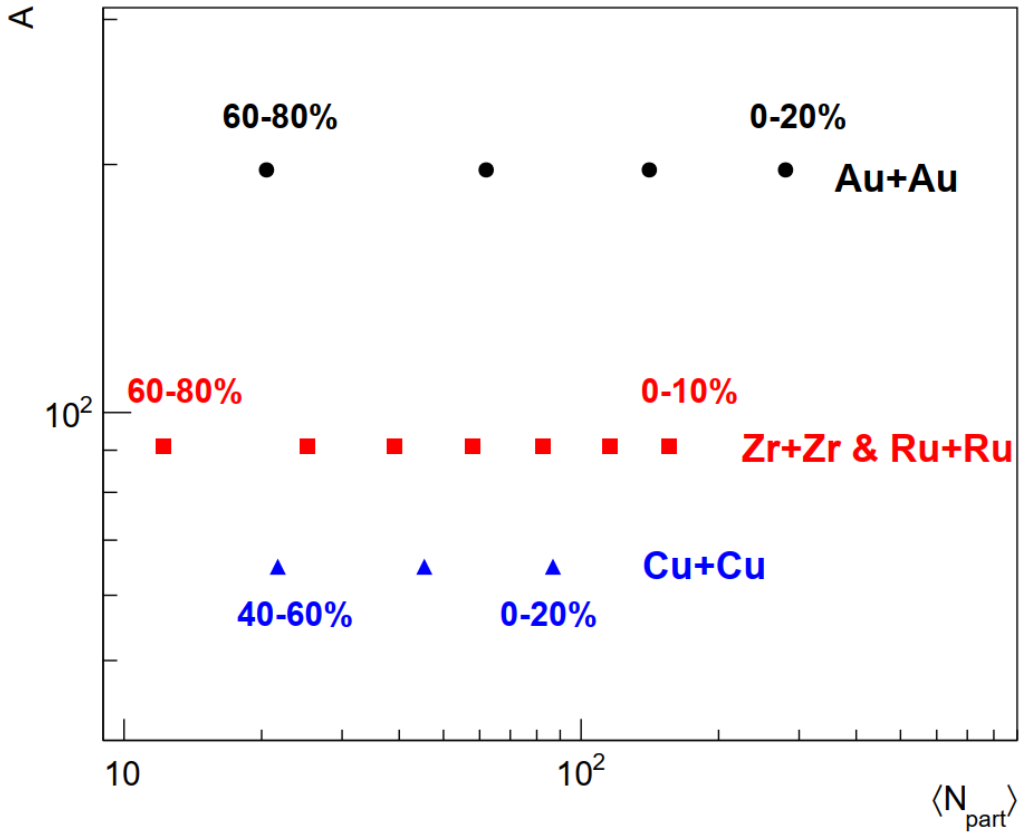
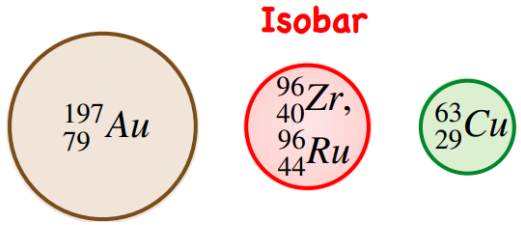
- The J/ψ production has been measured in Au+Au collisions at 39, 62.4 and 200 GeV and in Pb+Pb collisions at 17.2 GeV, 2.76 and 5.02 TeV
- No significant energy dependence of nuclear modification factor within large uncertainties at $\sqrt{S_{NN}} \leq 200$ GeV
- ~ 10x more statistics in 54.4 GeV compared to 62.4 GeV, which will help better understand the energy dependence of J/ψ suppression

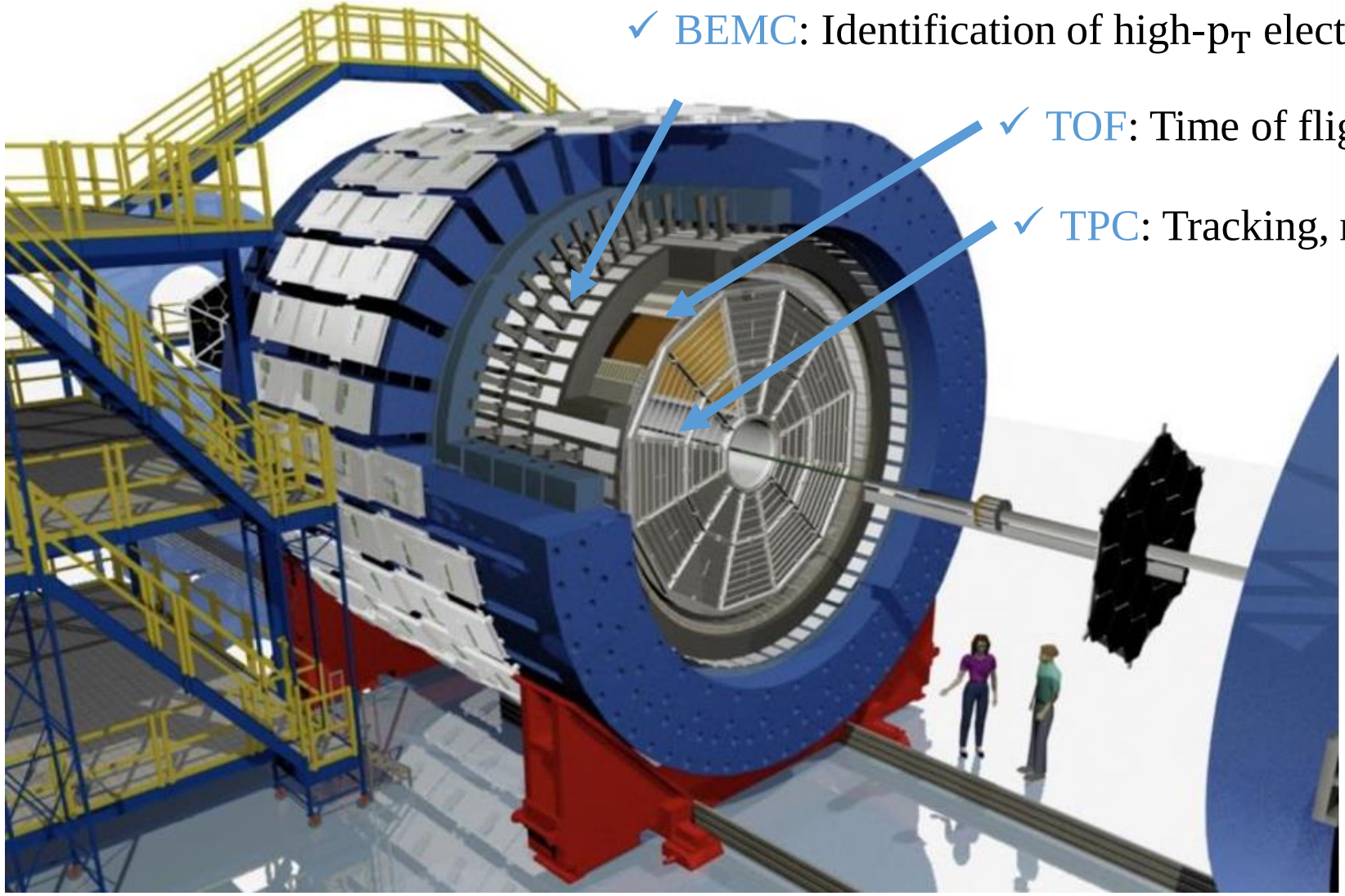
Isobar collisions at 200 GeV





- Large isobar sample ($^{92}_{44}$Ru + $^{92}_{44}$Ru and $^{92}_{40}$Zr + $^{92}_{40}$Zr) collected by STAR
  - ~ 4B good minimum bias events
  - Unique opportunity to measure the spectra with good precision
- $^{92}_{44}$Ru + $^{92}_{44}$Ru and $^{92}_{40}$Zr + $^{92}_{40}$Zr have moderate collisions size
  - Ideal for studying the system size dependence

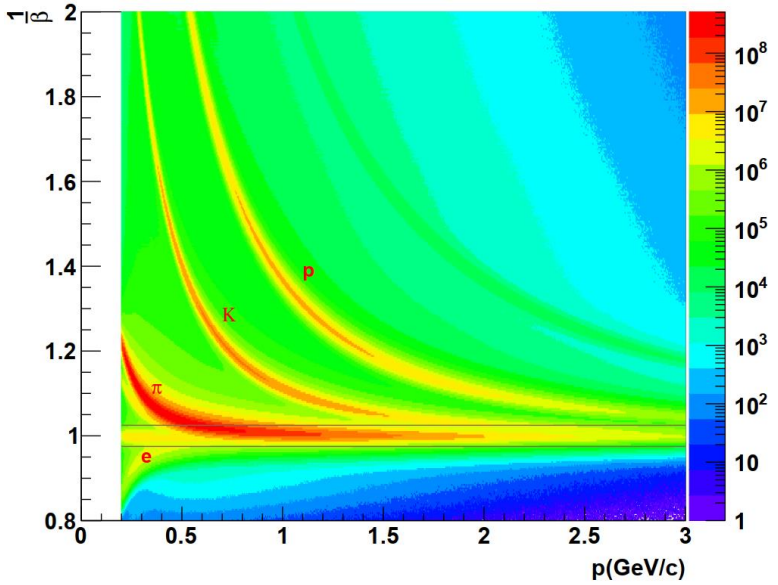
The Solenoidal Tracker At RHIC



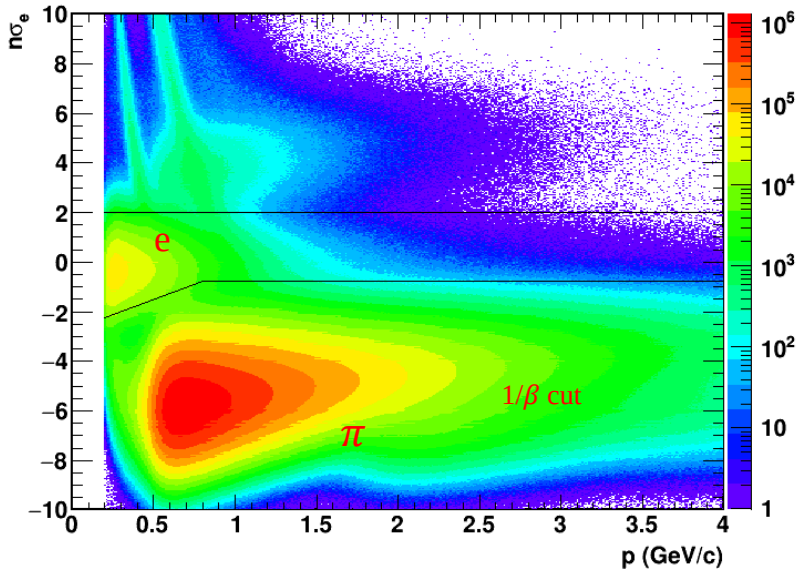
- ✓ BEMC: Identification of high-p_T electrons and triggering
- ✓ TOF: Time of flight, particle identification
- ✓ TPC: Tracking, momentum and energy loss

Electron identification

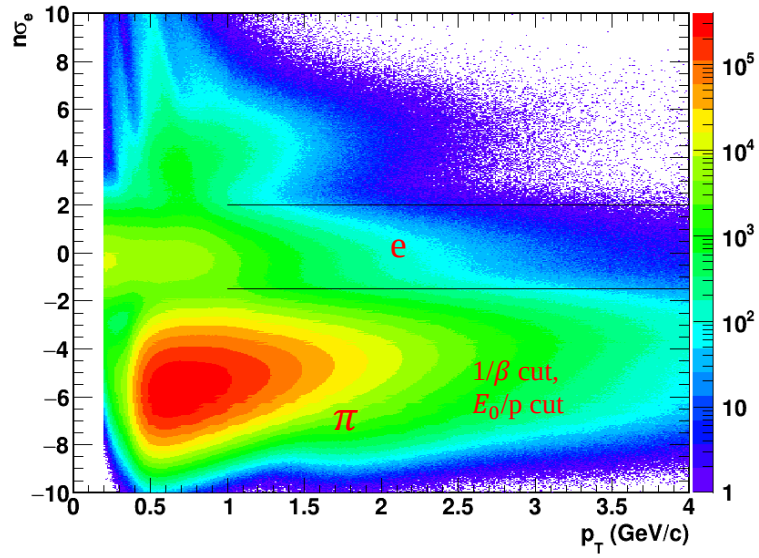
TOF PID



TPC PID after TOF cut



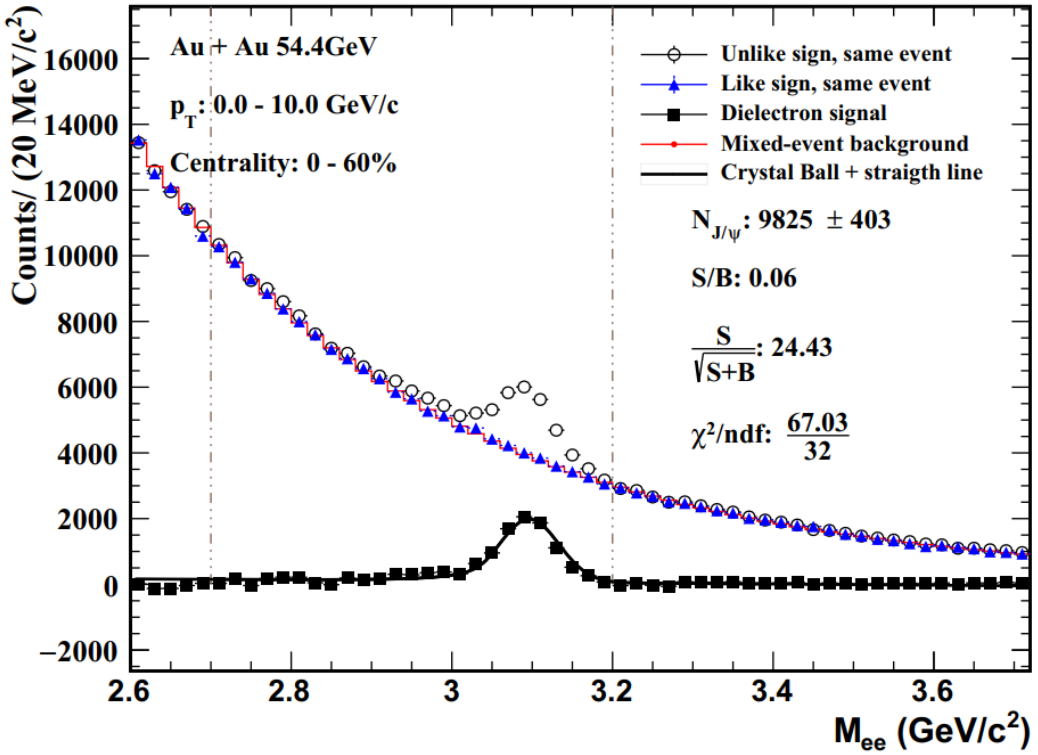
TPC PID after TOF and BEMC cuts



- TPC, TOF, and BEMC used to identify electron

- TPC: $n\sigma_e$
- TOF: $\frac{1}{\beta}$
- BEMC: $\frac{E_0}{p}$

J/ψ signal in Au+Au collisions at 54.4 GeV



- J/ψ raw signal is reconstructed through dielectron channel
- The combinatorial background from mixed-event technique is subtracted
- Residual background described by a linear fit
- Raw counts extracted by bin counting in $2.7 < M_{ee} < 3.2$ GeV/c^2

$\sqrt{s_{NN}}$	39 GeV	54.4 GeV	62.4 GeV	200 GeV
S/B	0.34	0.06	0.19	0.03
Significance	10	24	9	22

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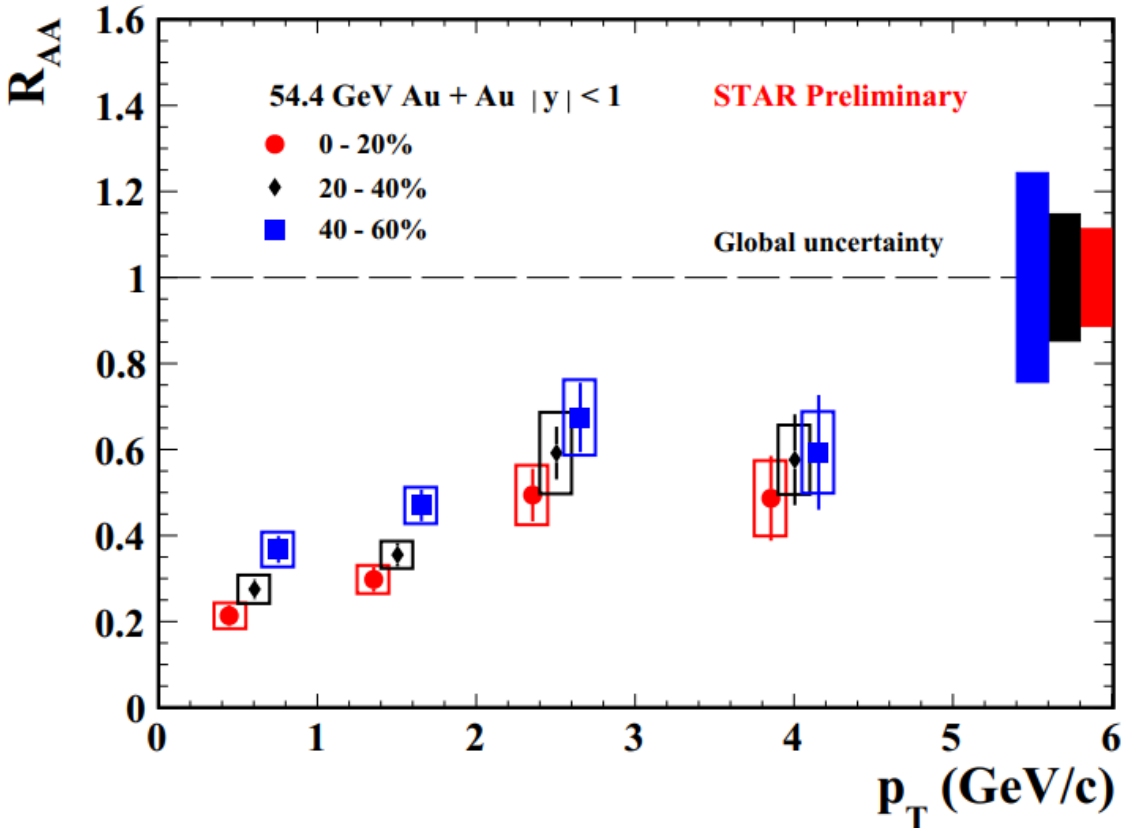
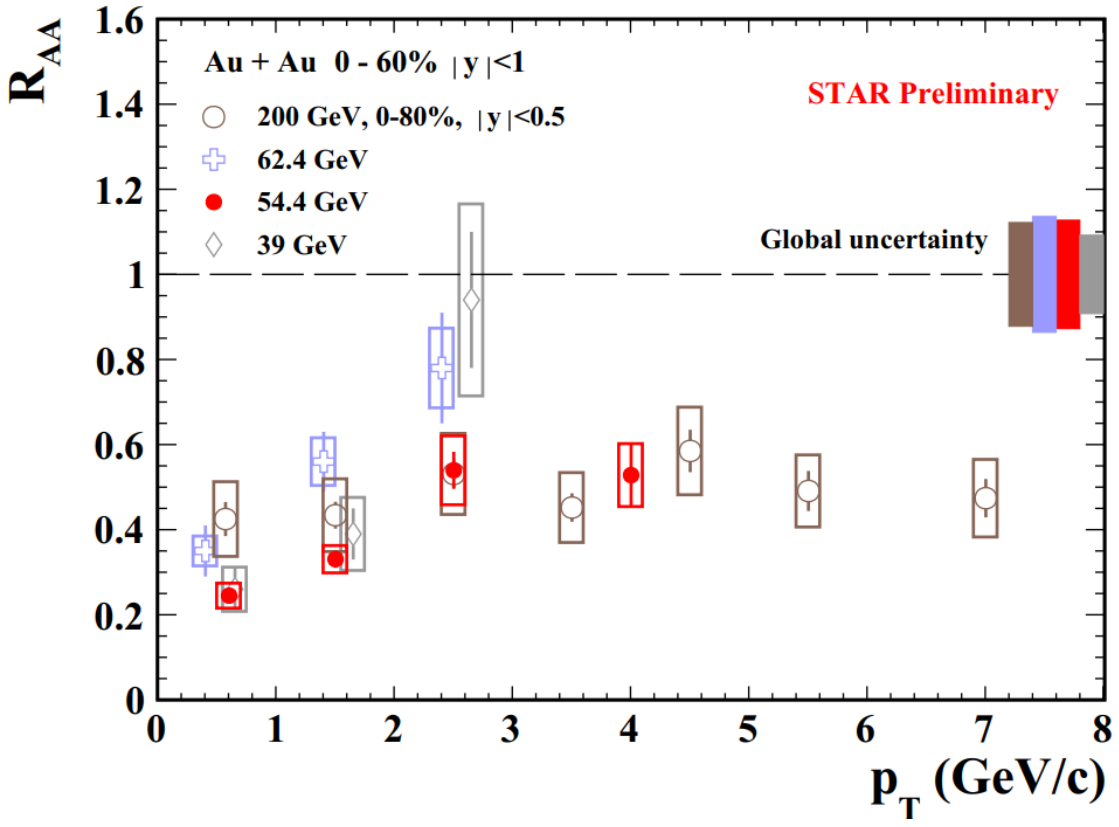
R_{AA} vs p_T in Au+Au collisions

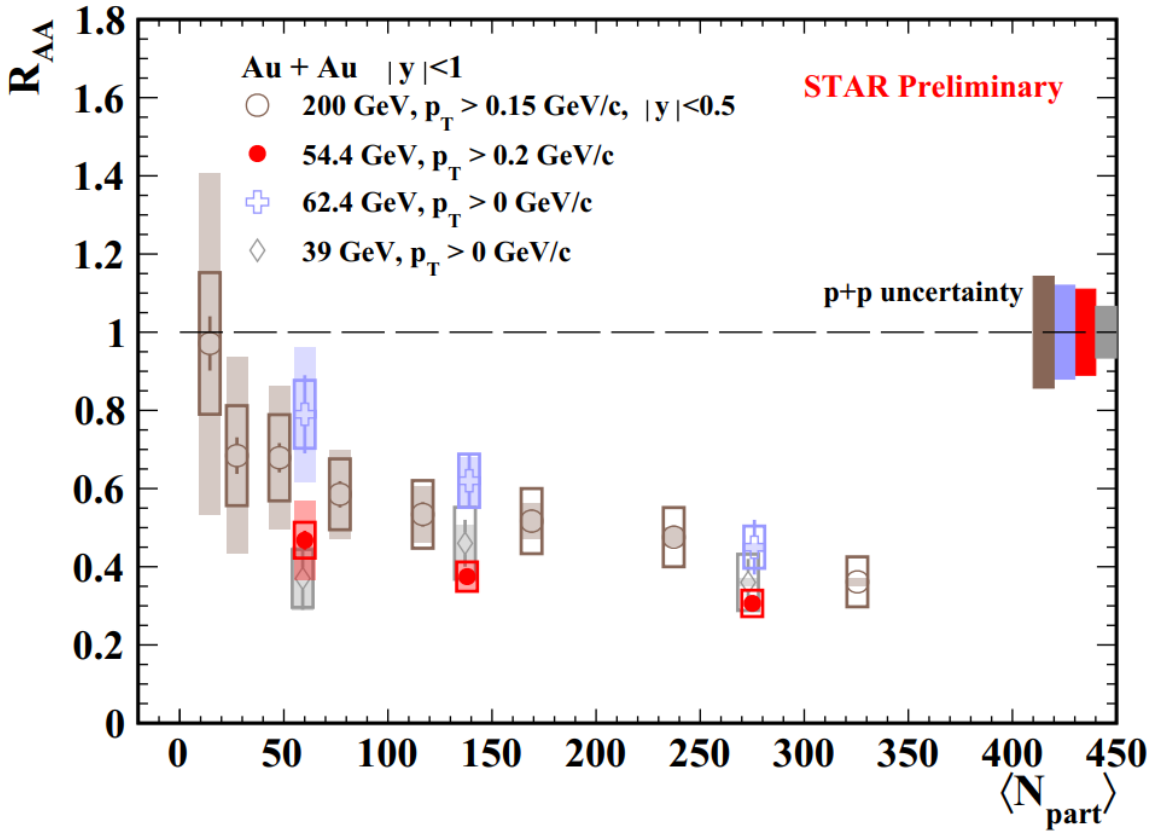


- More suppression towards central collisions



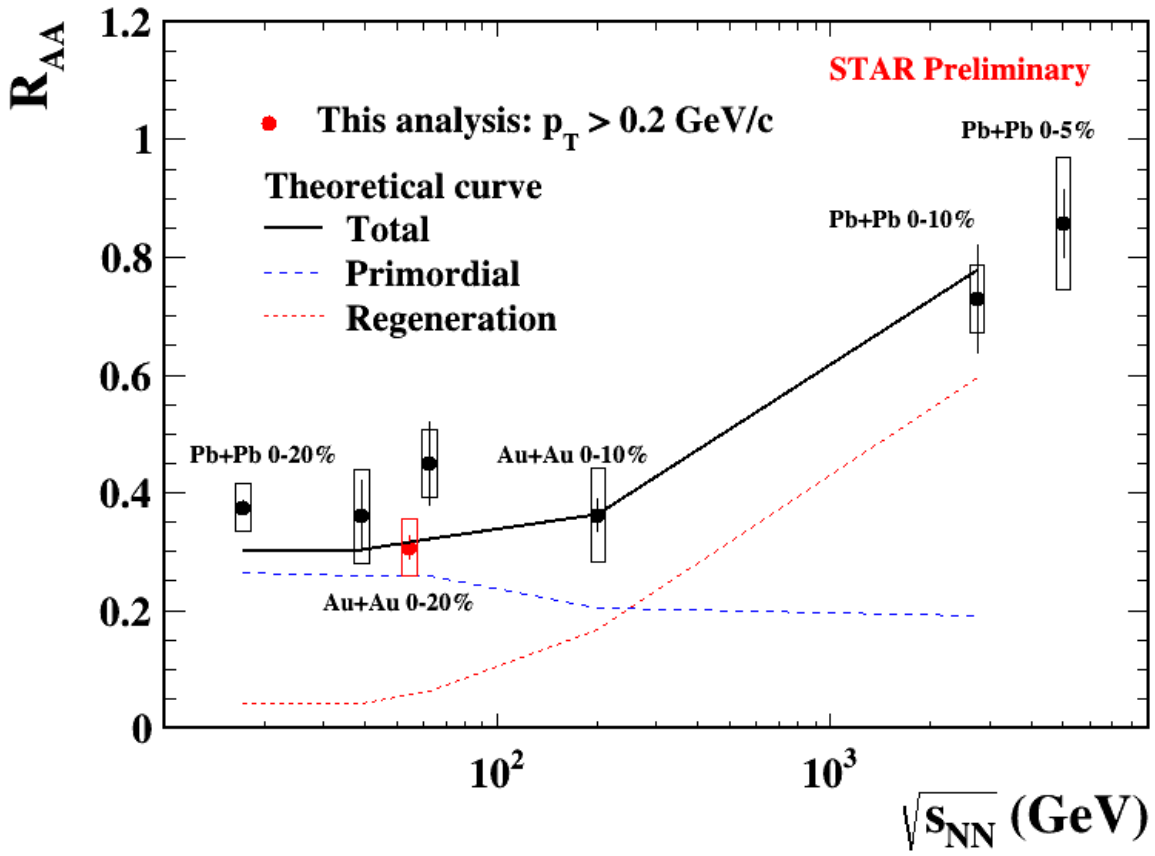
- R_{AA} increases with increasing p_T for 39, 54.4 and 62.4 GeV

R_{AA} vs $\langle N_{part} \rangle$ in Au+Au collisions



- Suppression of J/ψ production is observed in Au+Au collisions at 54.4 GeV with better precision compared to 39 and 62.4 GeV
- No significant energy dependence is observed among 39, 54.4, 62.4 and 200 GeV

R_{AA} vs $\sqrt{s_{NN}}$



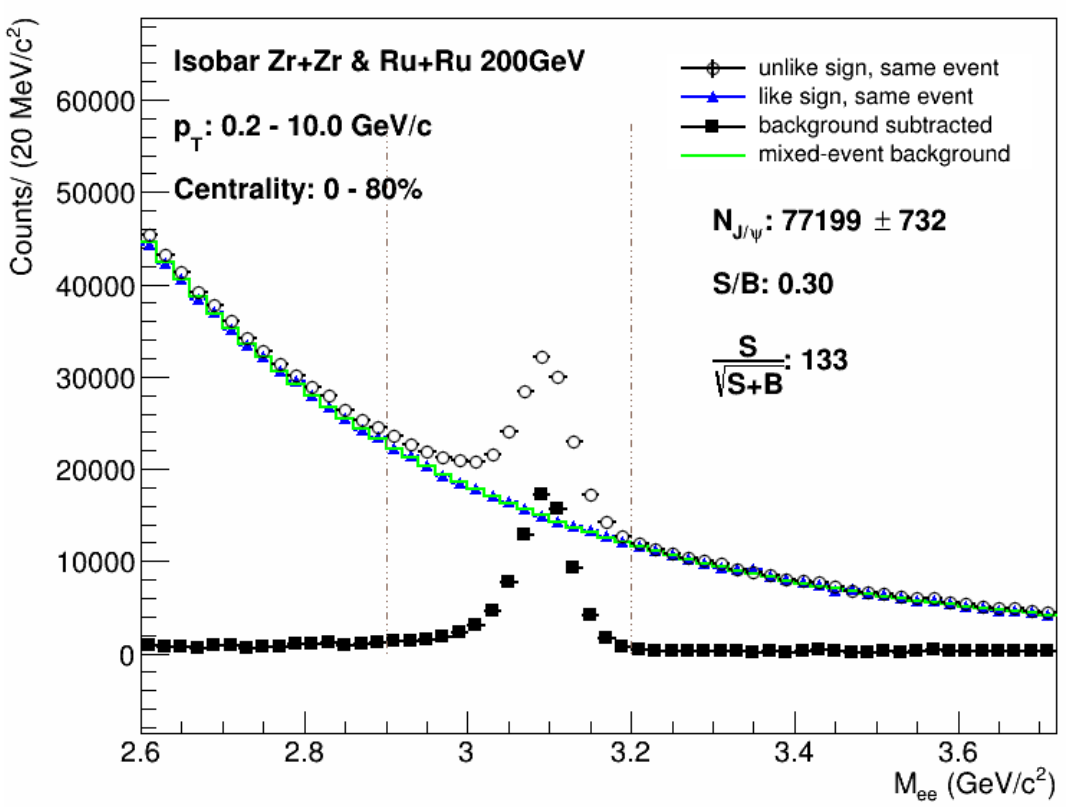
X. Zhao, R. Rapp, Phys. Rev. C 82 (2010) 064905 (private communication).
L. Kluberg, Eur. Phys. J. C 43 (2005) 145.
NA50 Collaboration, Phys. Lett. B 477 (2000) 28.

- 54.4 GeV data follow the trend with improved precision
- No significant energy dependence is observed within uncertainties up to 200 GeV
  - Interplay of dissociation, regeneration and cold nuclear matter effects
- Model calculation is consistent with the observed energy dependence

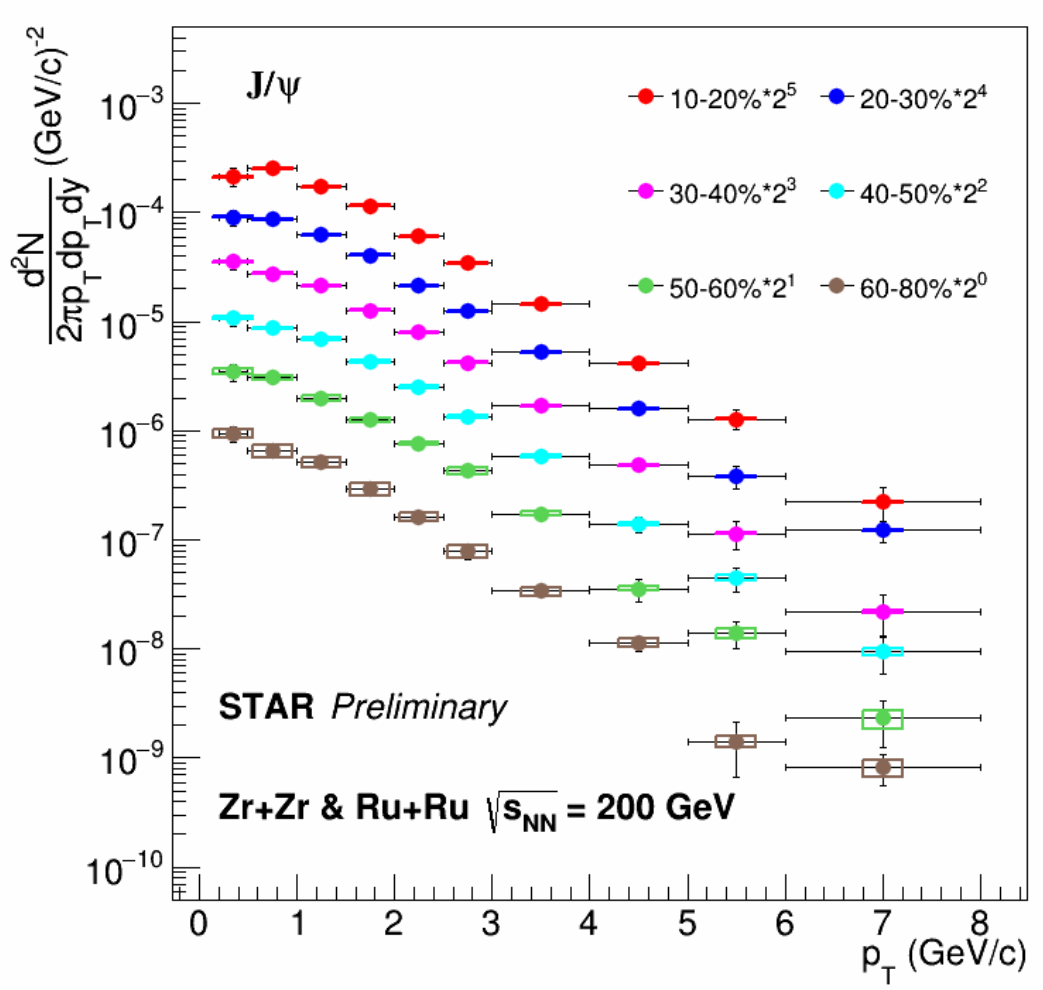
Calculations are for the same system as data points and in 0-20% centrality

ALICE Collaboration, Phys. Lett. B 734 (2014) 314
STAR Collaboration, Phys. Lett. B 771 (2017) 13-20
STAR Collaboration, Phys. Lett. B 797 (2019) 134917
ALICE Collaboration, Nucl. Phys. A 1005 (2021) 121769

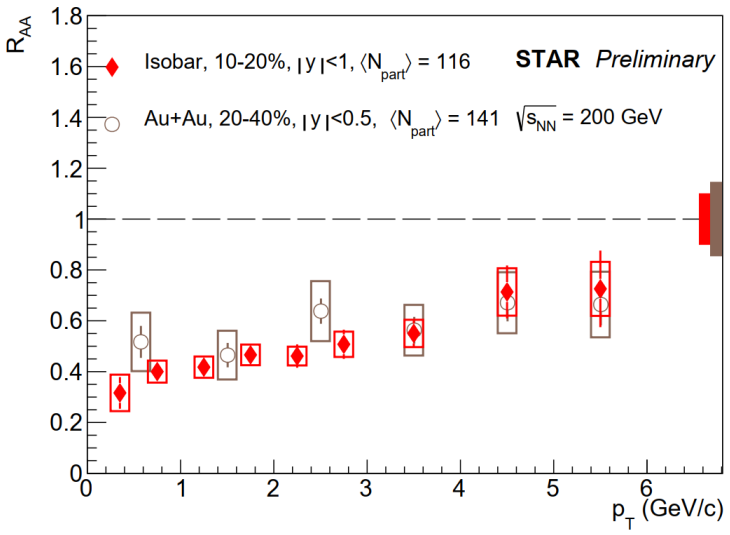
J/ψ signal in isobaric collisions at 200 GeV

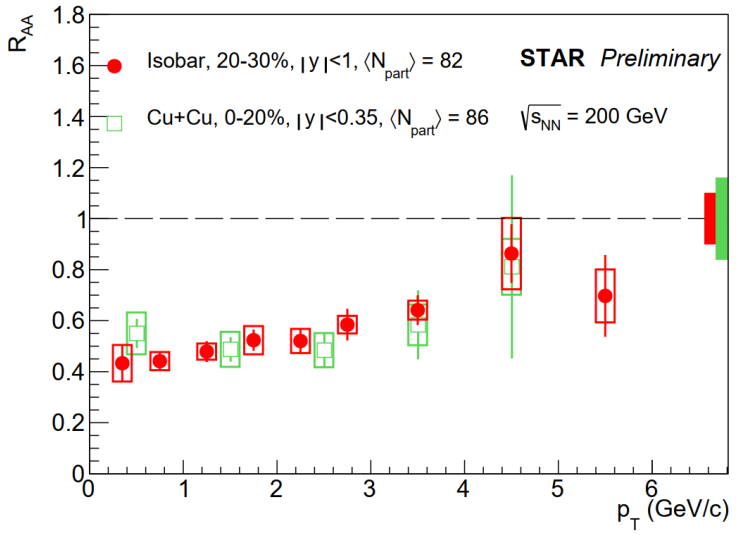


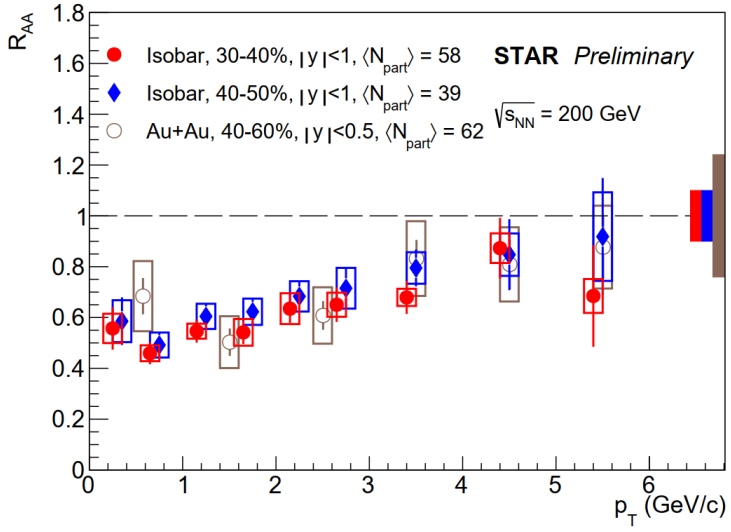
Excellent J/ψ signal

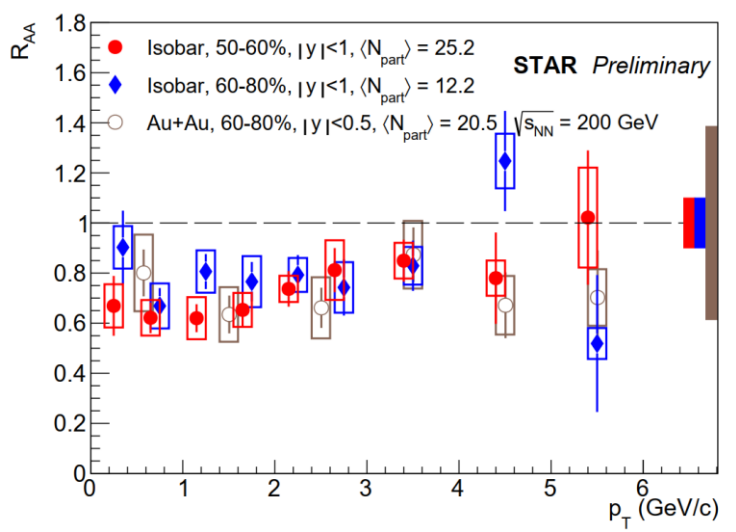


R_{AA} vs p_T in isobaric collisions





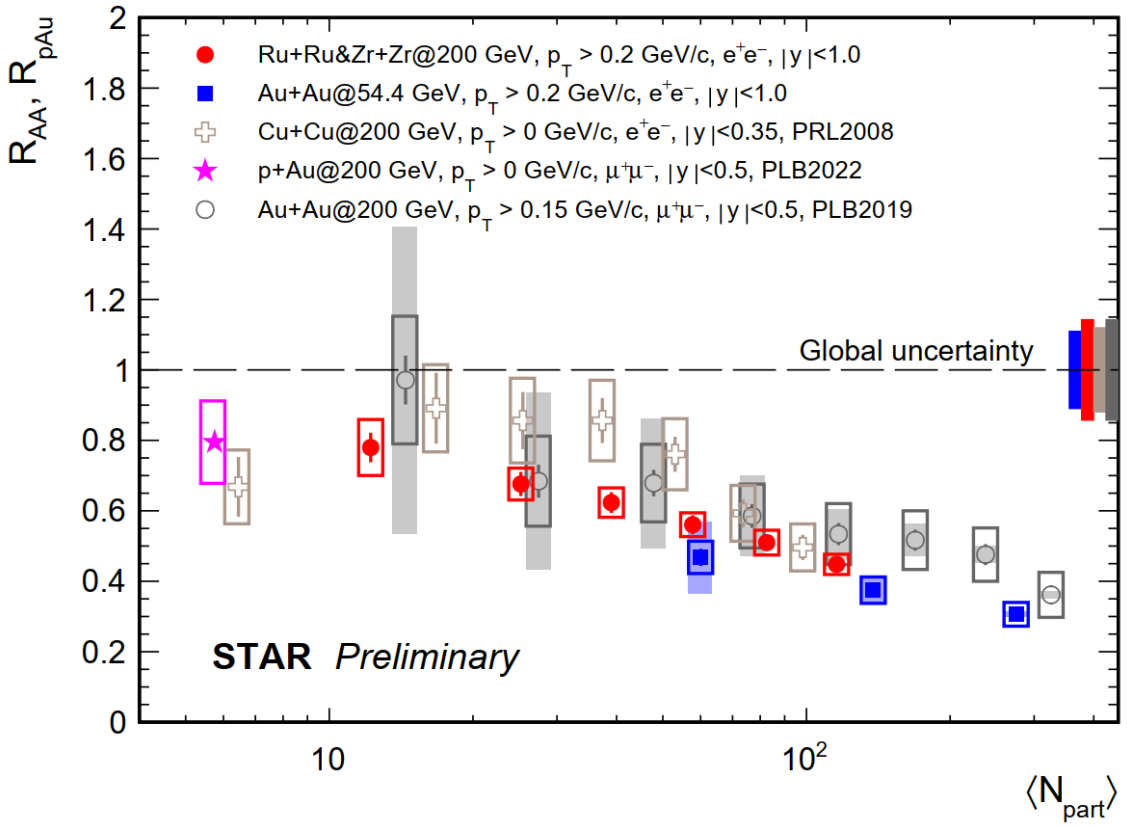




- The R_{AA} as a function of p_T measured in different centralities of isobaric collisions
- Highest precision measurement at RHIC to date
- Significant suppression observed
- Consistent with Au+Au and Cu+Cu results for similar system size

STAR Collaboration, Phys. Lett. B 797 (2019) 134917 PHENIX Collaboration, Phys. Rev. Lett. 101 (2008) 122301

R_{AA} vs $\langle N_{part} \rangle$



- Significant suppression is observed at large N_{part} range
- No significant collision system size and energy dependence at RHIC

Summary

- J/ψ R_{AA} is measured in isobaric collisions at 200 GeV and Au+Au collisions at 54.4 GeV with great precision
- Significant suppressions of J/ψ in central isobaric and Au+Au collisions have been observed
- No significant collision energy and system size dependence of J/ψ R_{AA} for similar $\langle N_{part} \rangle$ at RHIC
  - Interplay of dissociation, regeneration and cold nuclear matter effects