SQM2022
The 20th International Conference on Strangeness in Quark Matter
13-17 June 2022 Busan, Republic of Korea

Supported in part by
U.S. DEPARTMENT OF ENERGY | Office of Science

Initial electromagnetic field dependence of photon-induced production in isobaric collisions at STAR

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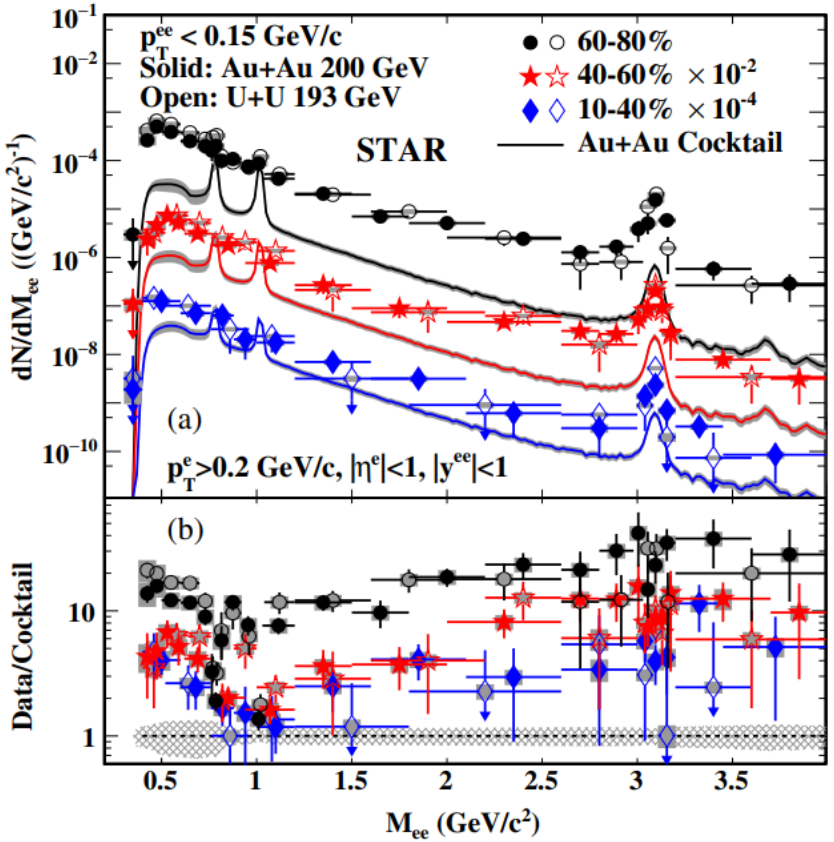
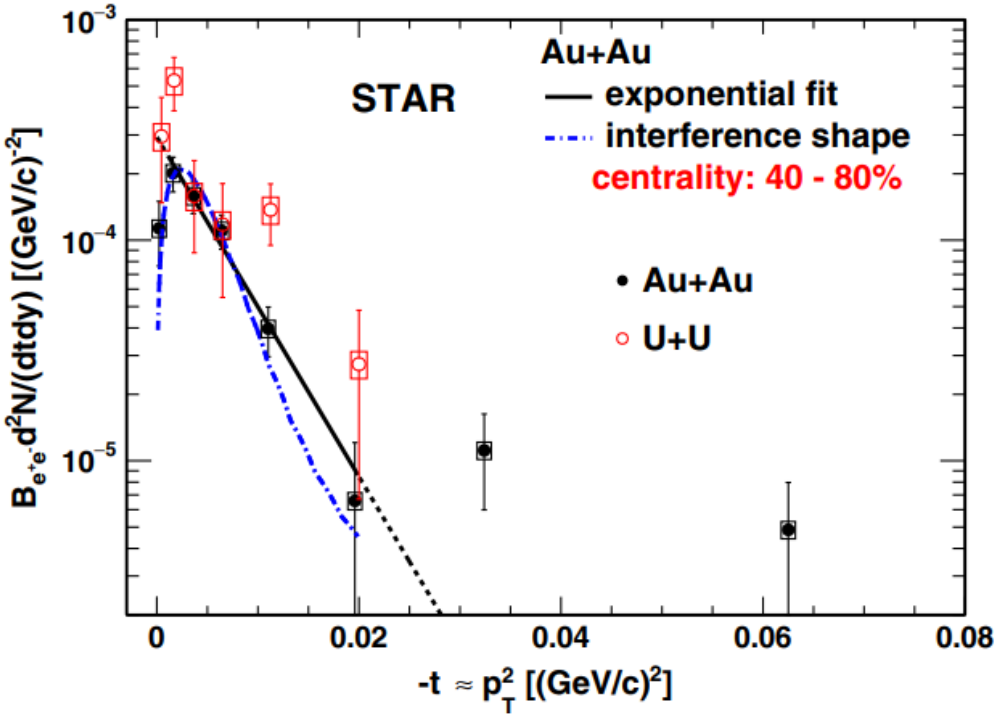
Outline

- Motivation and STAR Experiment
- e^+e^- Pair Production in Ru+Ru and Zr+Zr Collisions at $\sqrt{s_{NN}}$ = 200 GeV at Very Low p_T
- J/ψ Production in Ru+Ru and Zr+Zr Collisions at $\sqrt{s_{NN}}$ = 200 GeV at Very Low p_T
- Angular Distribution of e^+e^- in Isobaric Collisions
- Summary

Photon-induced Production in Peripheral Collisions



- Photon-induced interactions could explain the observed enhancements of J/ψ and e^+e^- production at very low p_T



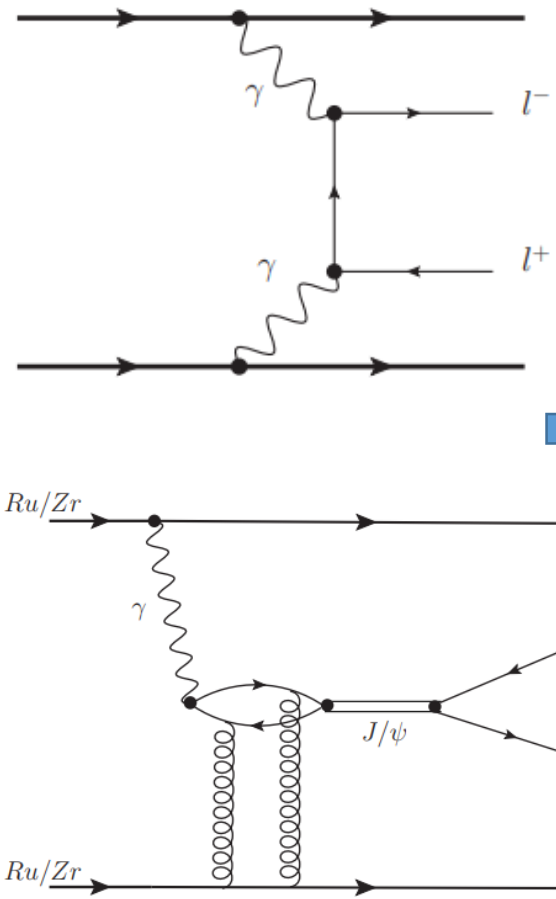
- The photon-induced production is sensitive to initial EM field:
  - Charge (Z) of the colliding nuclei
  - Collision system

J.Adam et al. (STAR) Phys. Rev. Lett. 121 (2018) 132301

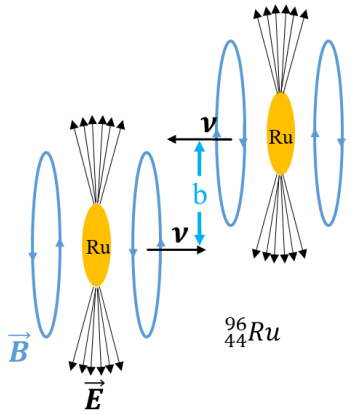
J.Adam et al. (STAR) Phys. Rev. Lett. 123 (2019) 132302.

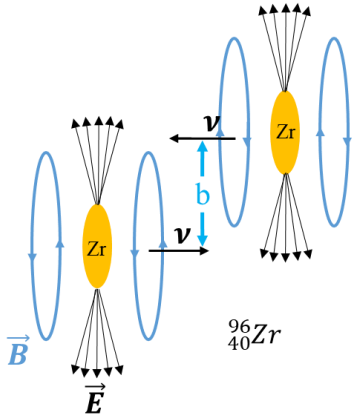
Photon-induced Production in Peripheral Collisions

- The isobaric collisions provide a unique opportunity to test the electromagnetic field dependence



- Charge (Z)
- Collision energy
- Impact parameter
- …

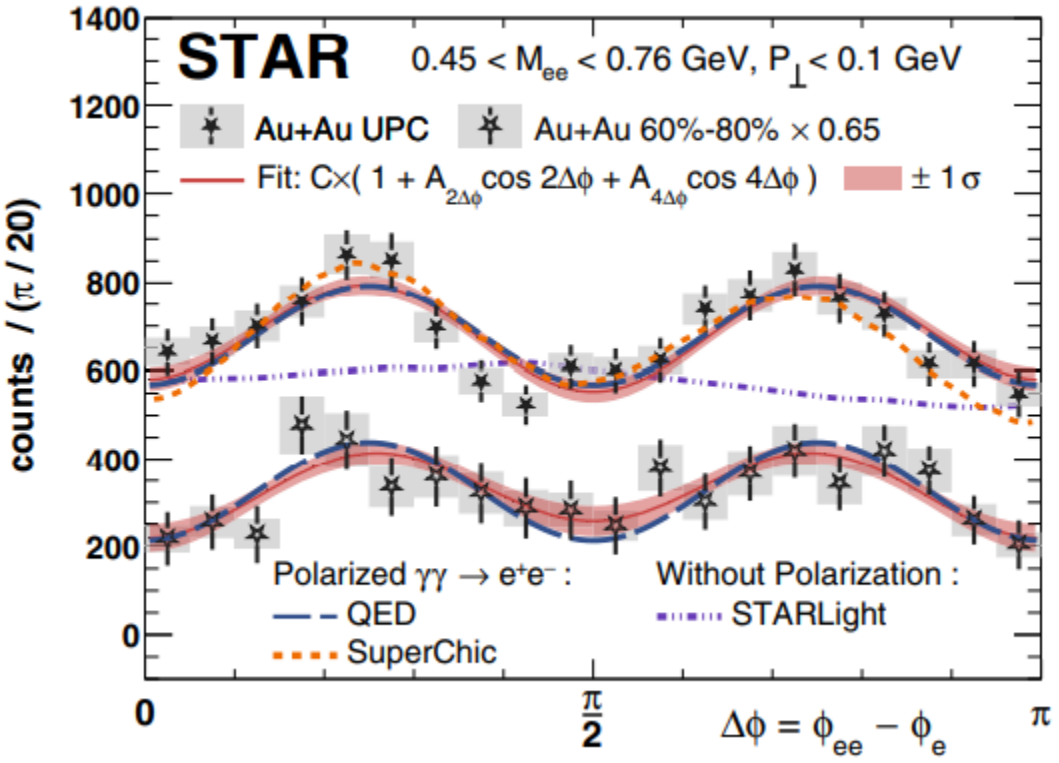




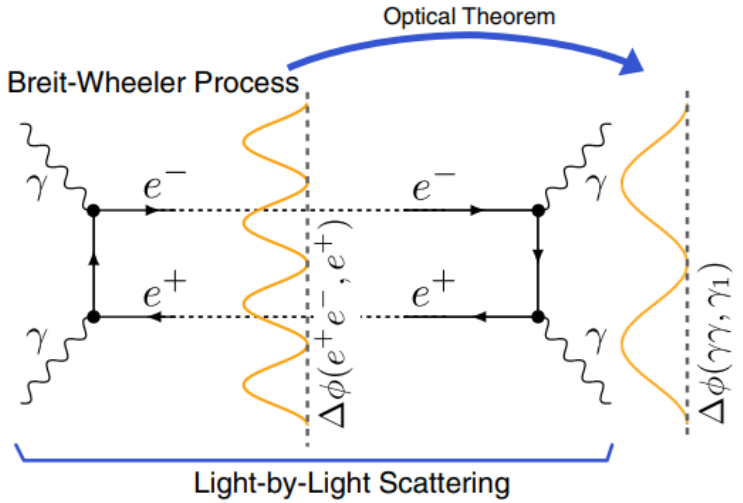
- Comparison between Ru+Ru and Zr+Zr:
  - Charge (Z)
- Comparison between Au+Au/U+U and Isobaric collisions:
  - Charge (Z)
  - Impact parameter
  - …

Photon-induced Production in Peripheral Collisions

- The Breit-Wheeler process has been investigated in peripheral and ultraperipheral Au+Au collisions at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV through $\gamma + \gamma \rightarrow e^+e^-$ process

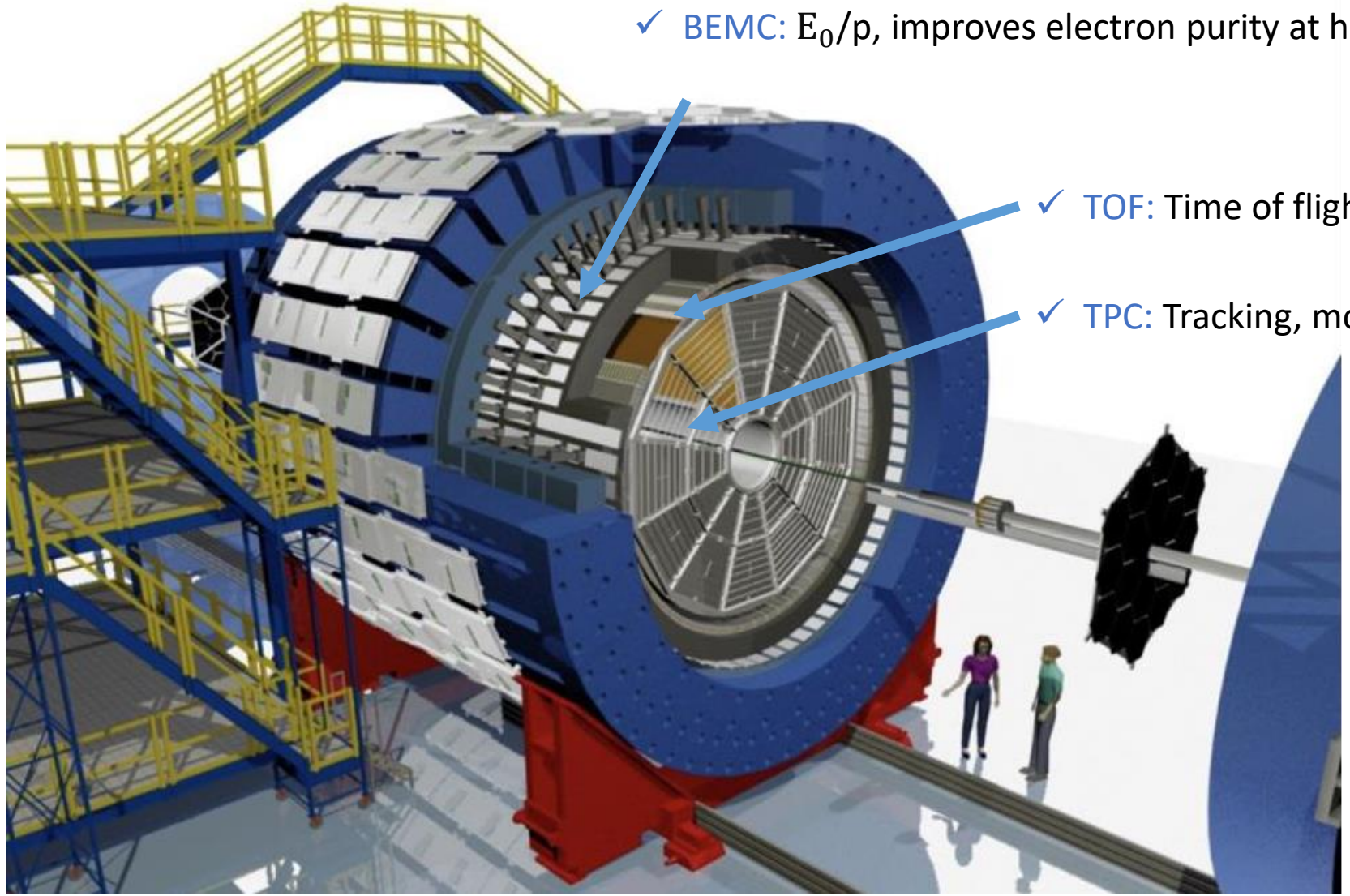


J.Adam et al. (STAR) Phys. Rev. Lett. 127 (2021) 052302



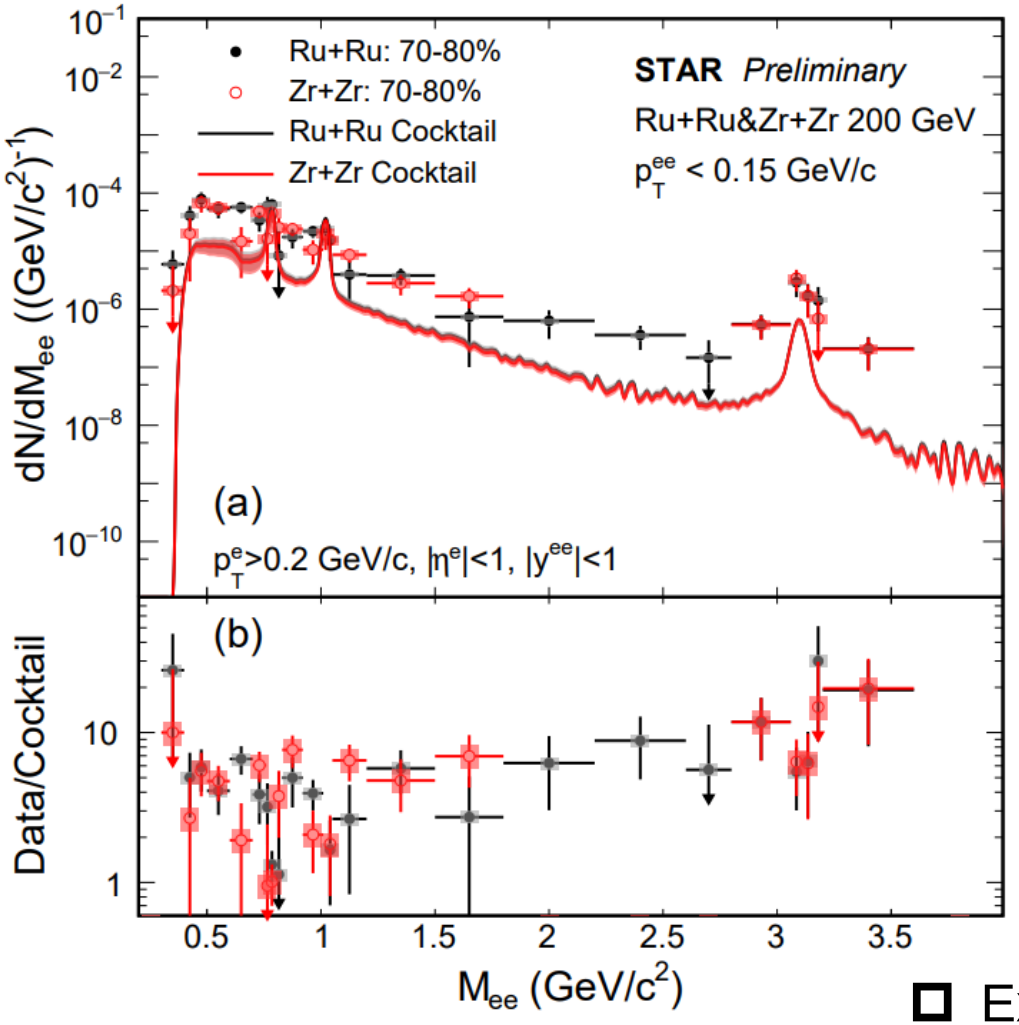
- The fourth-order angular modulation, cos(4Δϕ), measured in isobaric collisions
- Investigate collision system dependence of cos(4Δϕ)

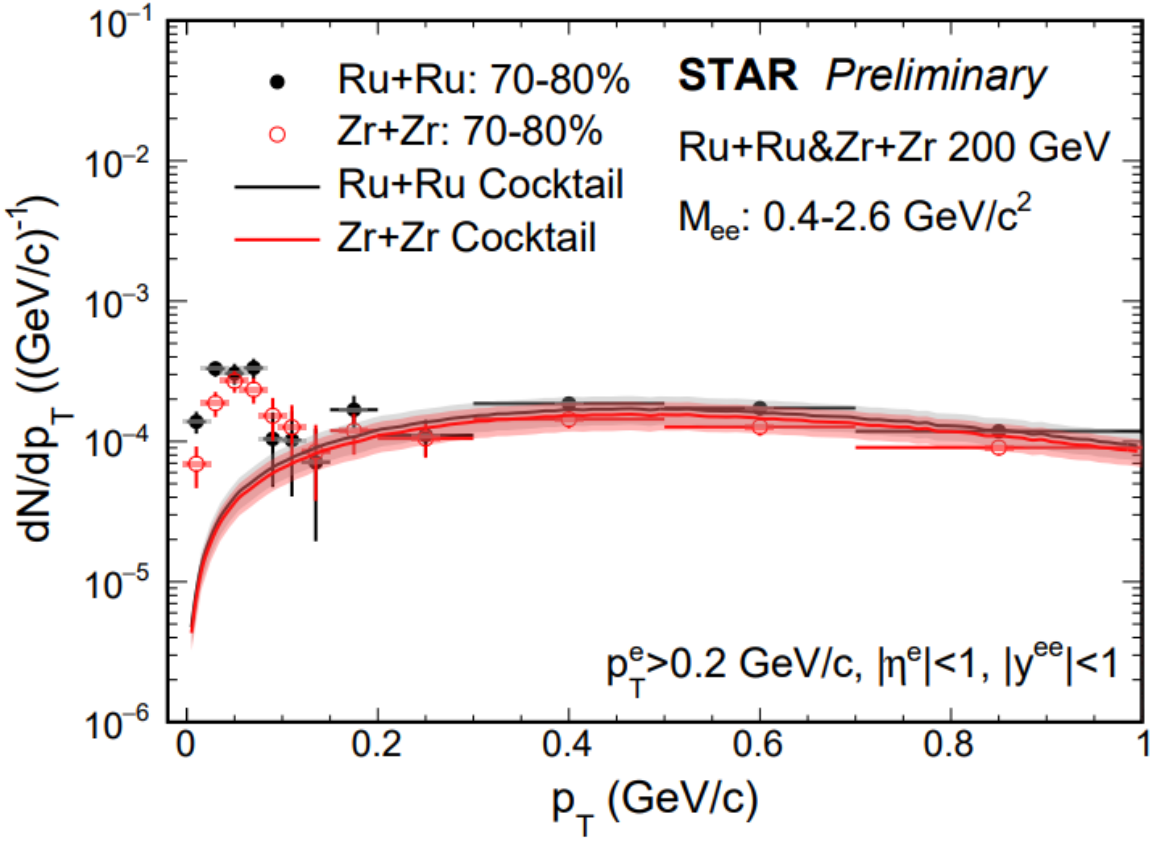
The Solenoid Tracker At RHIC



- ✓ BEMC: E_0/p, improves electron purity at high p_T
- ✓ TOF: Time of flight, particle identification
- ✓ TPC: Tracking, momentum and energy loss

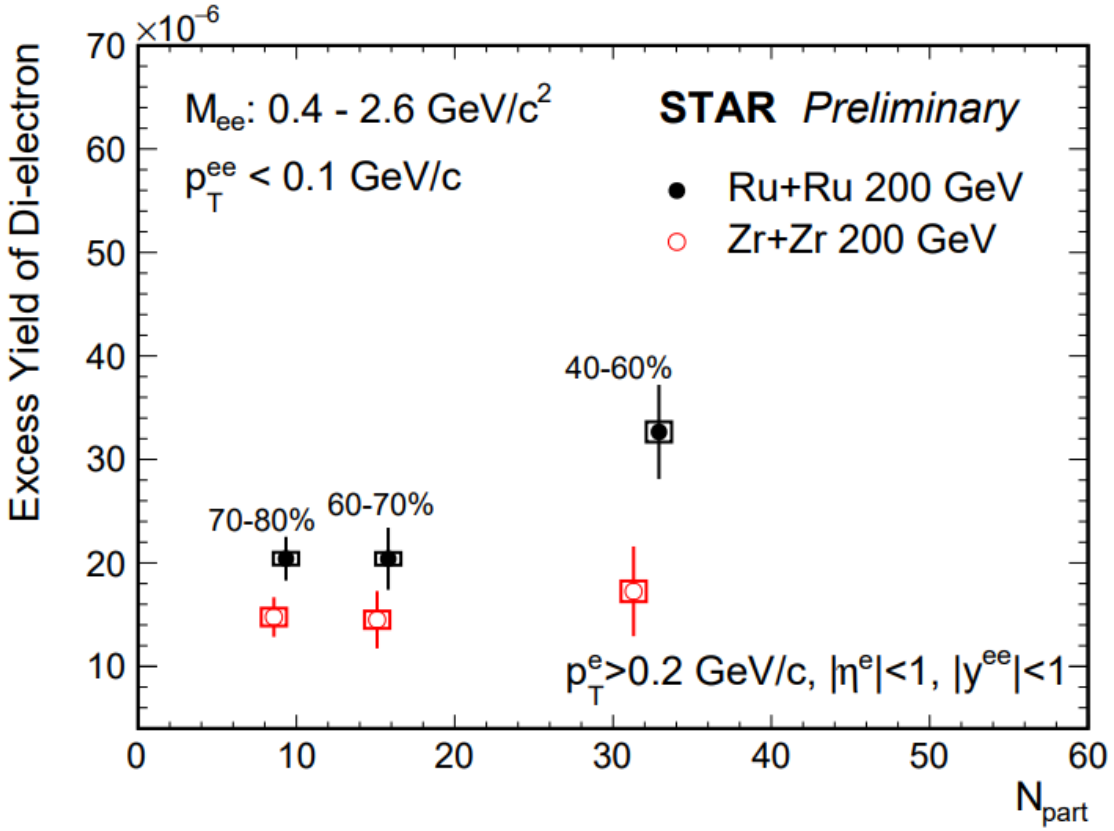
Invariant Mass and Transverse Momentum Distributions of e^+e^-

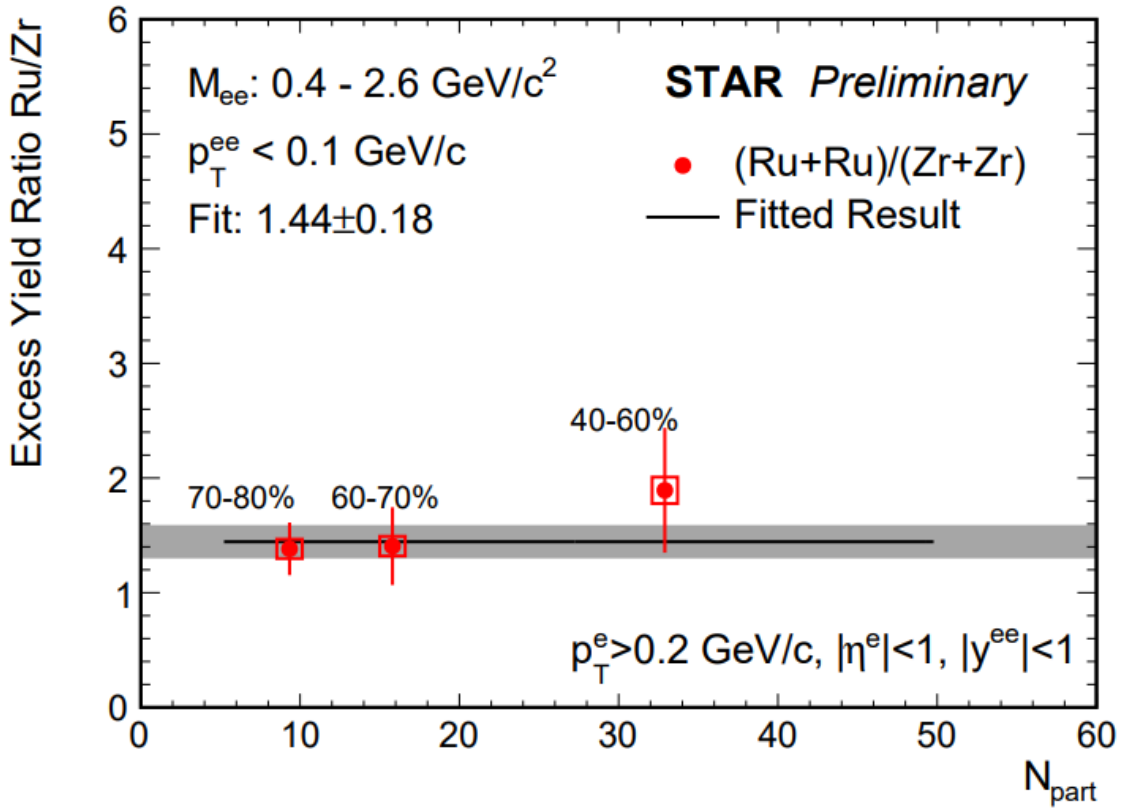




- Excesses above hadronic production are observed at low-p_T

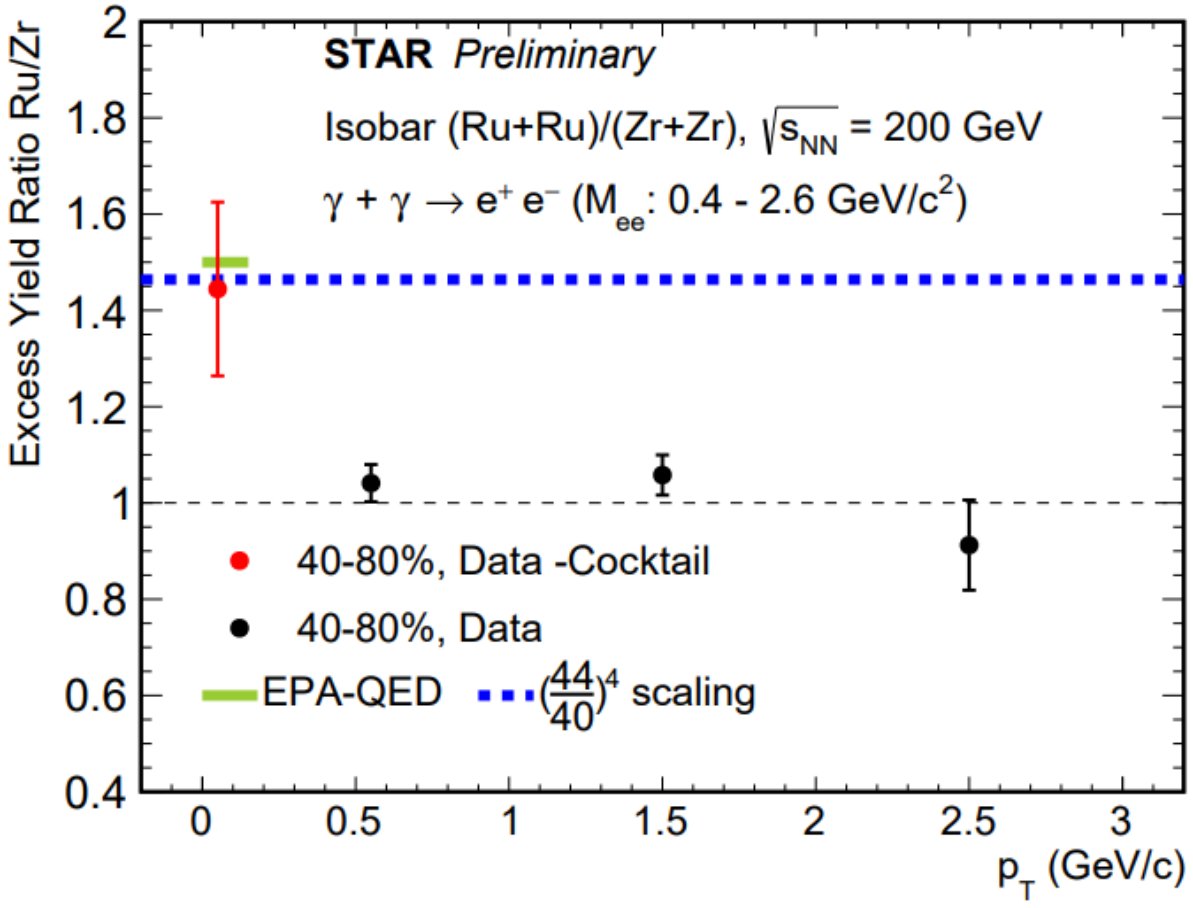
Centrality Dependence of Excess Yield





- The low-p_T (p_T < 0.1 GeV/c) e^+e^- excess and the ratio of excess are shown as function of $\mathrm{N_{part}}$
- The excess yields in Ru+Ru collisions are systematically higher than in Zr+Zr collisions
- A constant function is used to fit the ratio and is about 2.4σ higher than unity

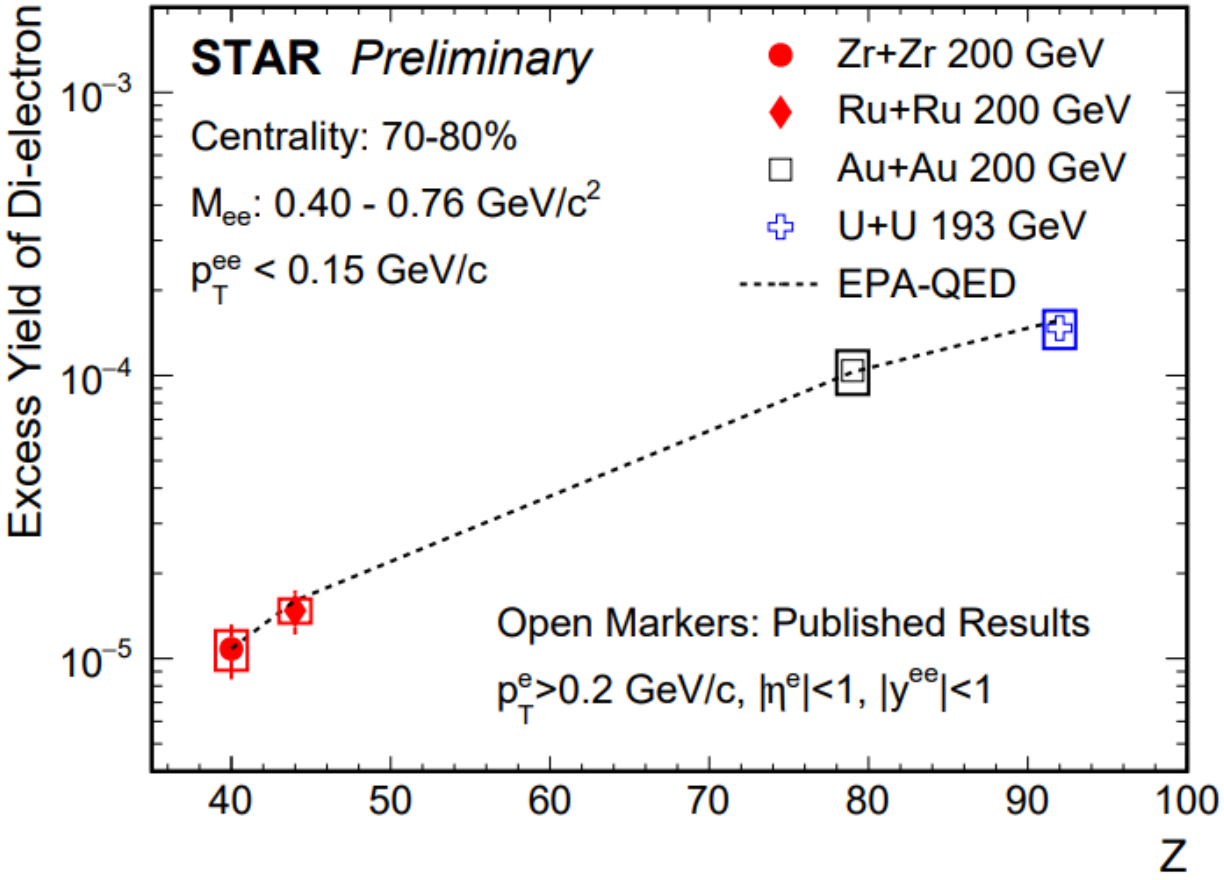
Excess Yield Ratio Between Isobaric Collisions



W. Zha et al, Phys. Lett. B 789 (2019) 238-242

- With cocktail subtracted, the yields at low-p_T are mainly from photon-induced production while the hadronic contributions dominate in intermediate p_T range
- The ratio of excess e^+e^- yield at low-p_T (< 0.1 GeV/c) in the 40-80% centrality is consistent with EPA-QED calculation and Z^4 scaling
- The initial EM fields seem to be different

Charge Dependence of Excess Yield



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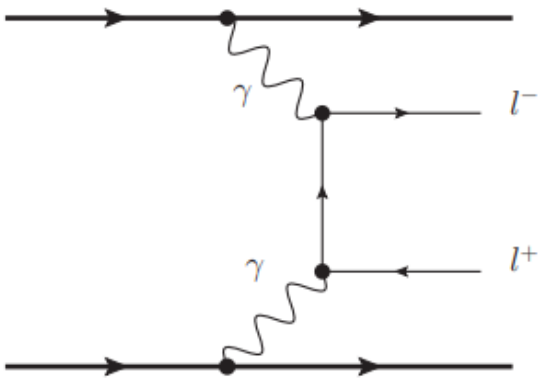
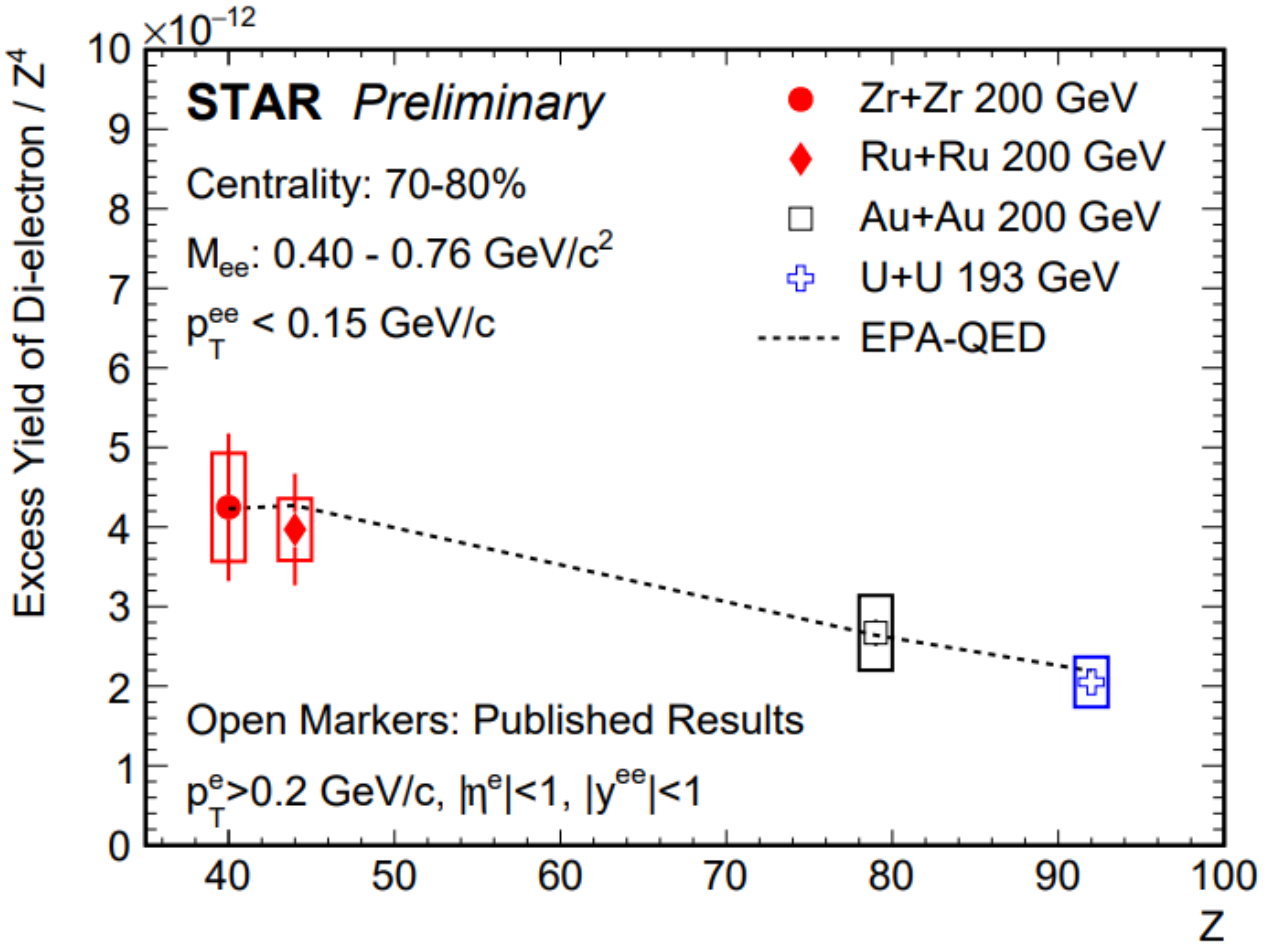


$\gamma + \gamma \rightarrow e^+e^-$

- The charge dependence of the integrated excess yield in the mass region of 0.4-0.76 GeV/c^2 at low-p_T (<0.15 GeV/c) in 70-80% centrality
- The excess yields in isobaric collisions are significantly smaller compared to those in Au+Au and U+U collisions, which is an interplay of the differences in charge, impact parameter and form factor

Charge Dependence of Scaled Excess Yield



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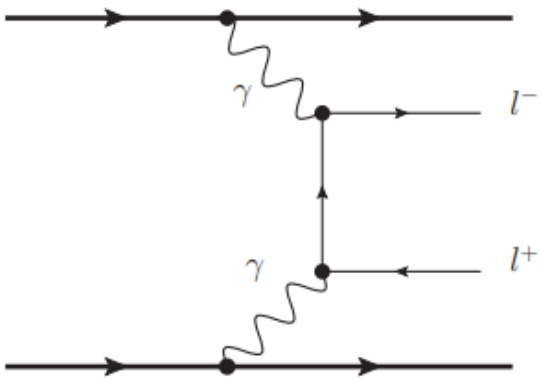
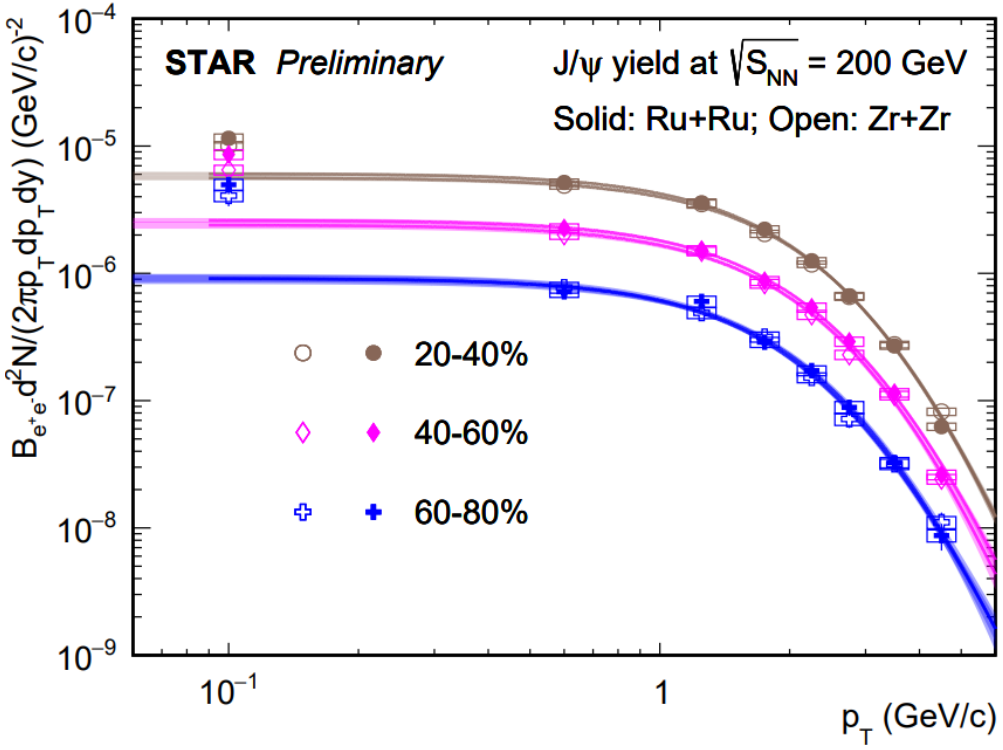
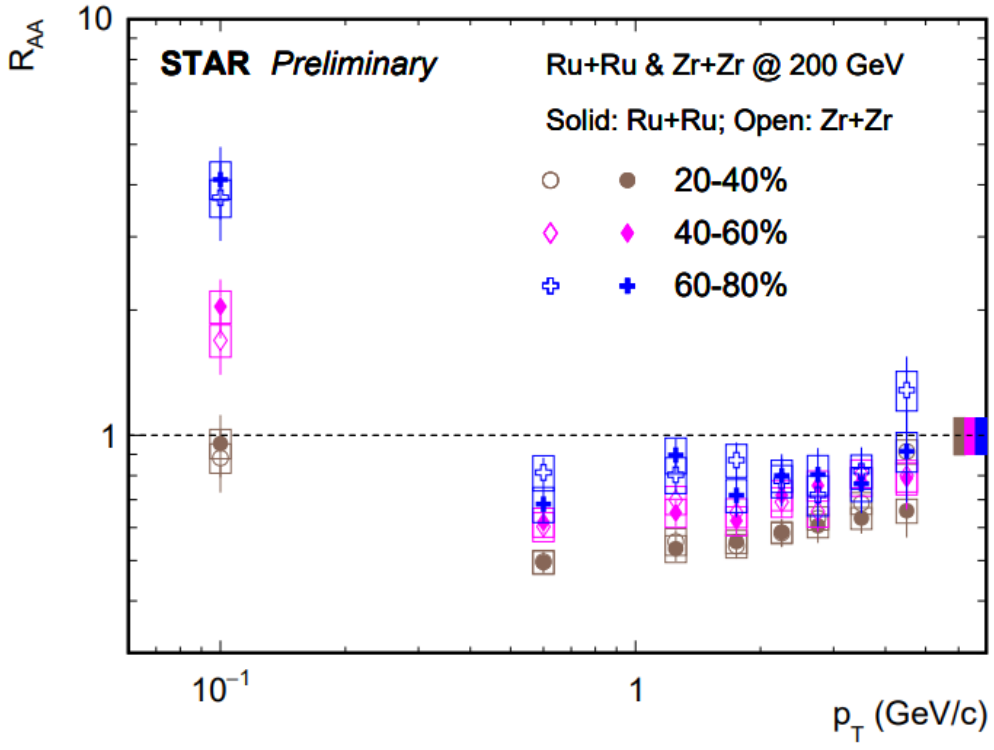


$\gamma + \gamma \rightarrow e^+e^-$

- Z^4 scaled yield shows clear collision system dependence, likely originating from impact parameter dependence
- Decreasing trend described the EPA-QED calculation

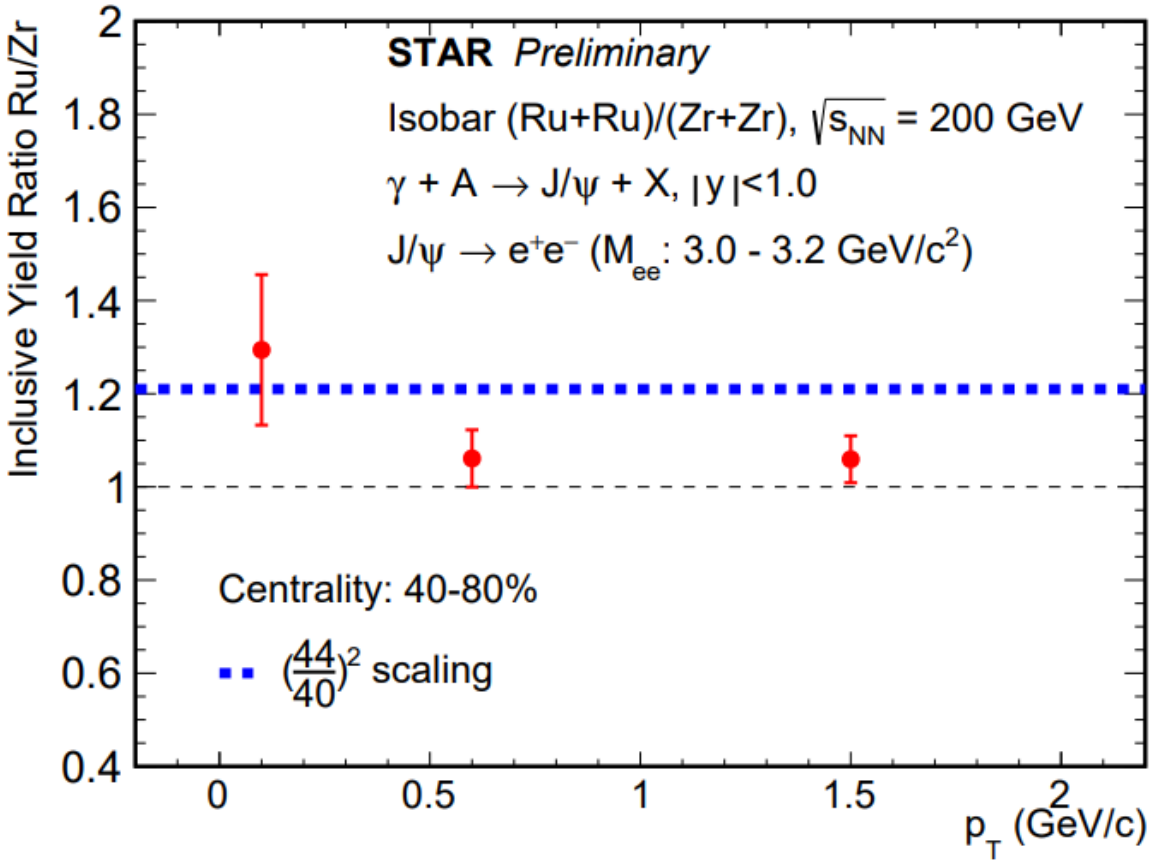
Invariant Yield and Nuclear Modification Factor of J/ψ





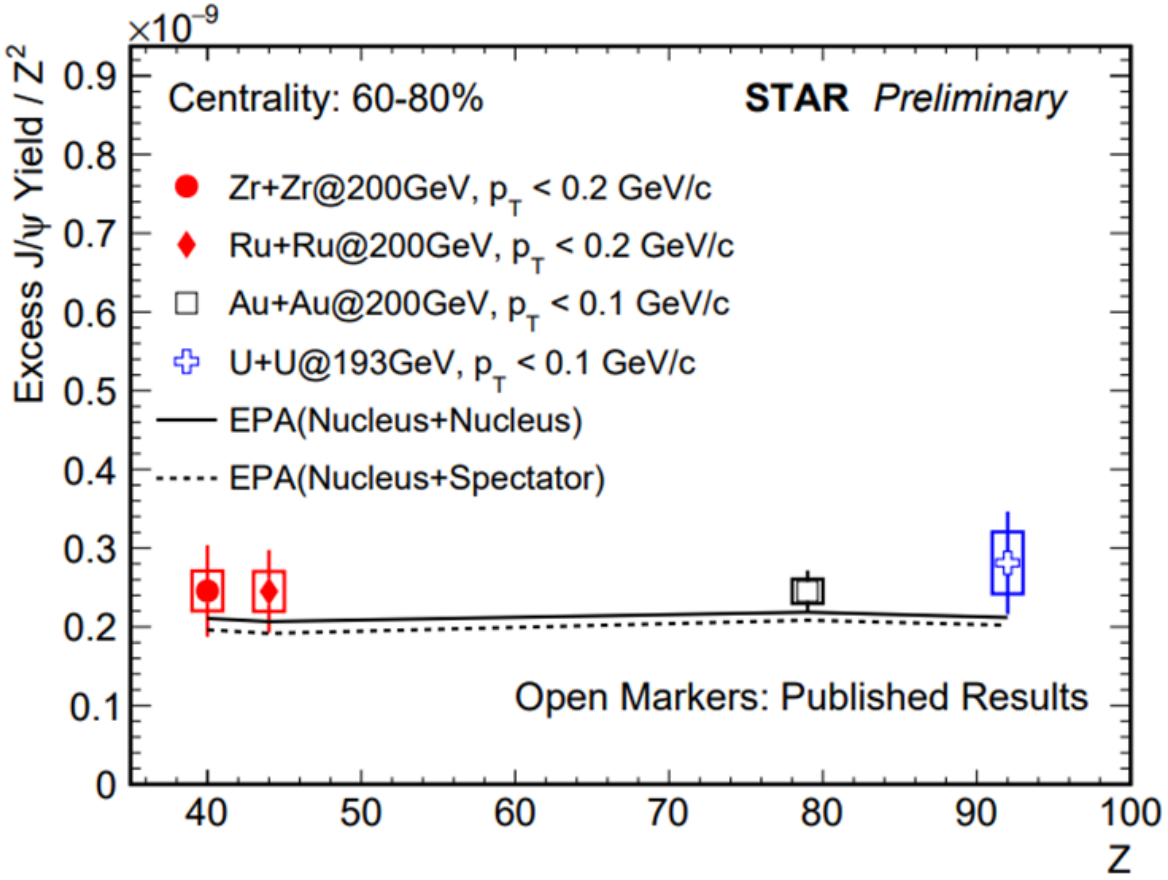
- The yield spectra are fitted by the Tsallis function at p_T larger than 0.2 GeV/c, and extrapolated to low-p_T range
- The data are well described by the fitted curves above 0.2 GeV/c, but show significant enhancements at low-p_T range
- The R_{AA} is significantly higher than unity at low-p_T range

Ratio of J/ψ Yields Between Isobaric Collisions



- The collision system dependence ($^{96}_{44}Ru+^{96}_{44}Ru$ and $^{96}_{40}Zr+^{96}_{40}Zr$) of yield is shown as function of p_T
  - Inclusive J/ψ production follows Z^2 scaling at very low p_T
  - ~1.7σ deviation from unity at p_T < 0.2 GeV/c
  - Hint of different initial EM fields

Collision System Dependence Between Isobar and Au+Au / U+U



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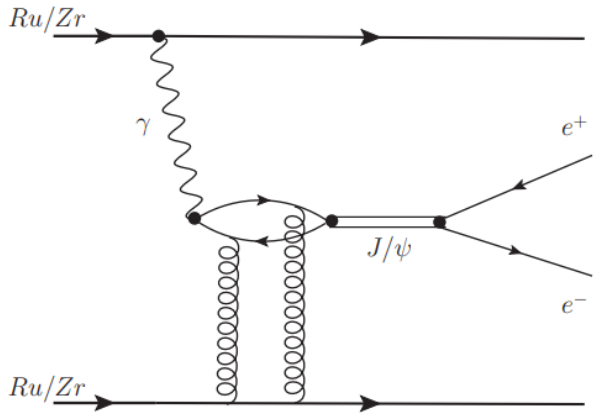
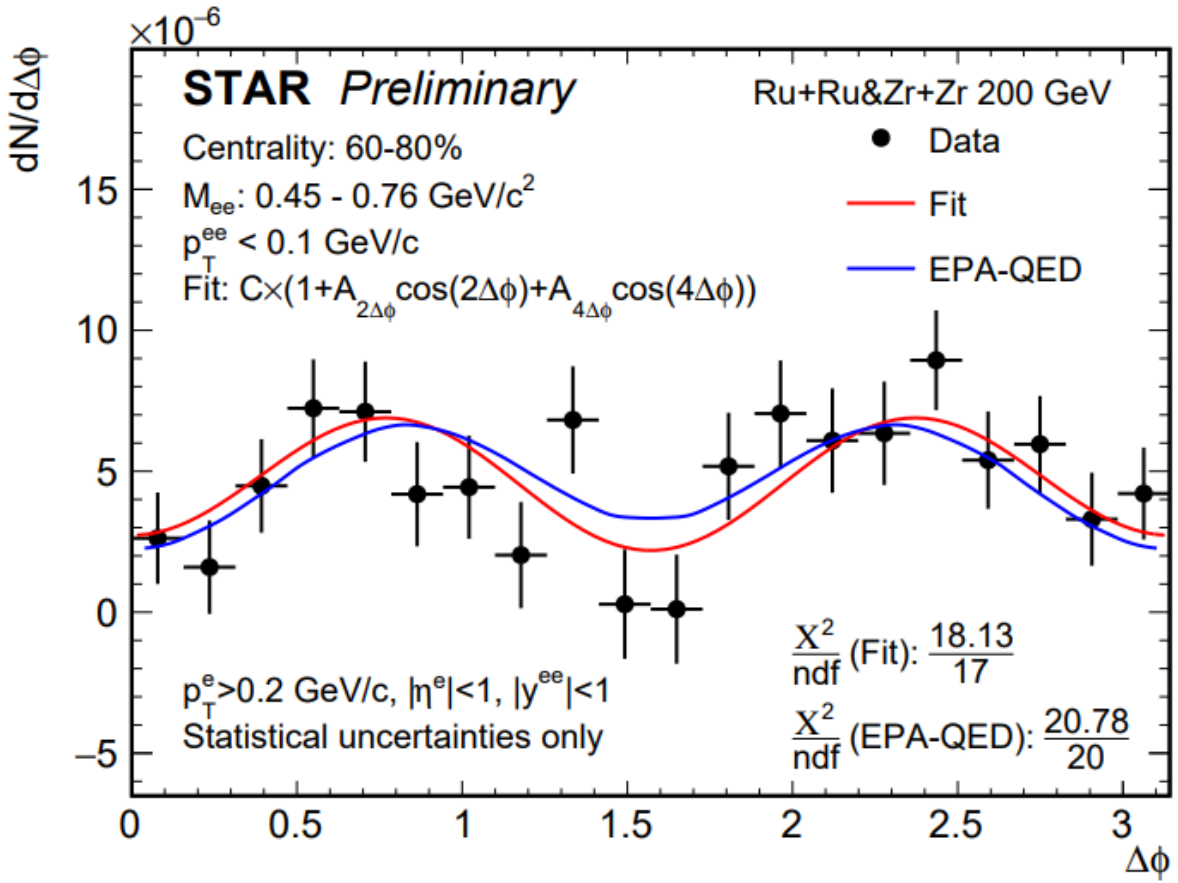
W. Zha et al. Phys. Rev. C 97, 044910 (2018)



$\gamma + \mathrm{A} \rightarrow J/\psi + \mathrm{A}$

- Scale J/ψ excess yields at very low p_T with Z^2
- The photo-nuclear production of J/ψ seems to be independent of collision species at a given centrality
- Effects of form factor and impact parameter seem to balance each other

cos(4Δϕ) Modulation in Isobaric Collisions



	$\lvert A_{4\Delta\phi}\rvert$ (%)	$\lvert A_{2\Delta\phi}\rvert$ (%)
Isobar(60-80%)	47±13(stat)	6±12(stat)
Au+Au(60-80%)	27±6	6±6

- Clear cos(4Δϕ) signal (~3.6σ) in isobaric collisions: $\lvert A_{4\Delta\phi}\rvert$ = 0.47±0.13(stat)±0.05(sys)
  - $\lvert A_{4\Delta\phi}\rvert$ predicted by QED-EPA is 0.40
- No significant difference between isobaric and Au+Au collisions

Summary

- Enhancements of J/ψ and e^+e^- production at very low p_T have been observed in peripheral isobaric collisions
- The collision species dependence of photon-induced production have been measured at STAR
  - The initial EM field seems to be different in peripheral Ru+Ru and Zr+Zr collisions
  - After taking out the charge difference, the excess yield of J/ψ is mostly independent of collision system, while e^+e^- shows an impact parameter dependence
- The cos(4$\Delta\phi$) signal is prominent (~3.6σ) in isobaric collisions and no significant difference is observed between isobaric and Au+Au collisions

Thanks !