Low-p_T e^+e^- pair production in Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV at STAR

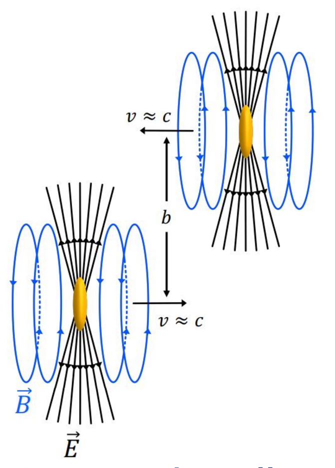
Xiaofeng Wang *for the STAR Collaboration*

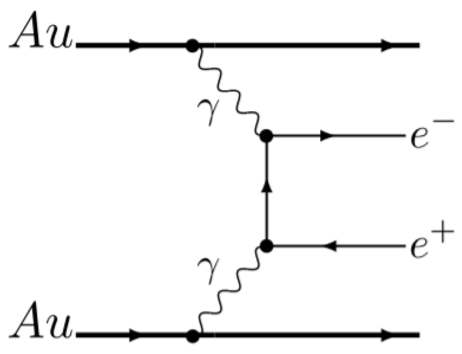
Institute of Frontier and Interdisciplinary Science, Shandong University, Shandong, China
School of Physics and Physical Engineering, Qufu Normal University, Shandong, China
xwang1@rcf.rhic.bnl.gov

Abstract

In high-energy heavy-ion collisions, strong electromagnetic fields arising from the Lorentz-contraction of large amounts of charge in nuclei generate a large flux of high-energy quasi-real photons. Dielectrons can be produced via the interaction of these photons. Dielectron production from photon-photon scattering is distinctly peaked at very low transverse momentum (p_T < 0.15 GeV/c). Traditionally these photon-photon processes were expected to exist only in Ultra-Peripheral Collisions (UPC). However, it has been recently realized that even in peripheral collisions, the dielectron production at very low transverse momentum mainly originates from the two photon interactions, which provides a possible tool to directly measure the giant magnetic field created in heavy-ion collisions.
In this presentation, we will present measurements of dielectron production at low transverse momentum in peripheral (80-100%) Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV at STAR.

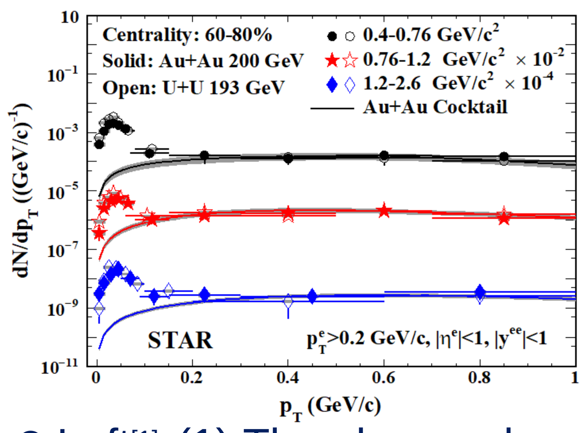
Motivation

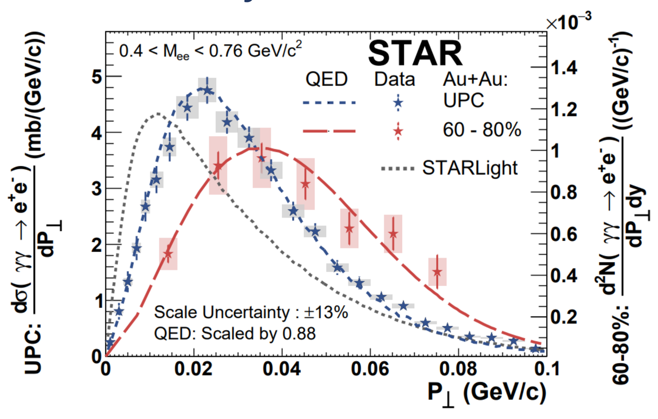




- Equivalent Photon Approximation (EPA): In a specific phase space, EM fields can be quantized as a flux of quasi-real photons
- Quasi-real photons ∝ Z^2

- Conventionally studied in ultraperipheral collisions (UPC) -> Can the photon-induced interactions also occur in hadronic heavy-ion collisions?

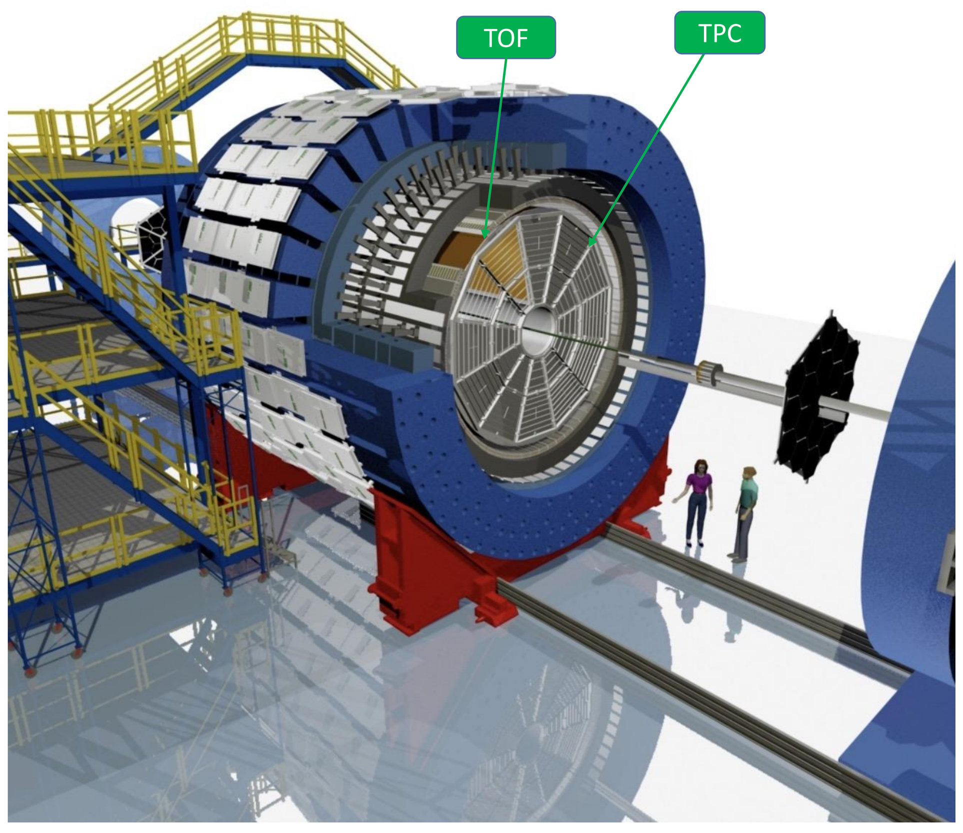




$\sqrt{\langle p_T^2\rangle}$ (MeV/c)	UPC Au+Au	60-80% Au+Au
Measured	38.1±0.9	50.9±2.5
QED	37.6	48.5

- Left[1] (1) The observed excess is found to concentrate below $p_T \approx$ 0.15GeV/c
  Evidence of photon interactions in hadronic heavy ion collisions.
- Right[2] (1) Leading order QED calculation of $\gamma\gamma \rightarrow e^+e^-$ describes both spectra ($\pm 1\sigma$)
  (2) On table: STAR observes **4.8σ** difference between UPC and 60-80% Au+Au collisions
  (3) Proposed as a probe of trapped magnetic field or Coulomb scattering in QGP
  Di-electron measurement at the centrality of 80-100% can serve as a bridge between HIC and UPC $\gamma\gamma \rightarrow e^+e^-$ process

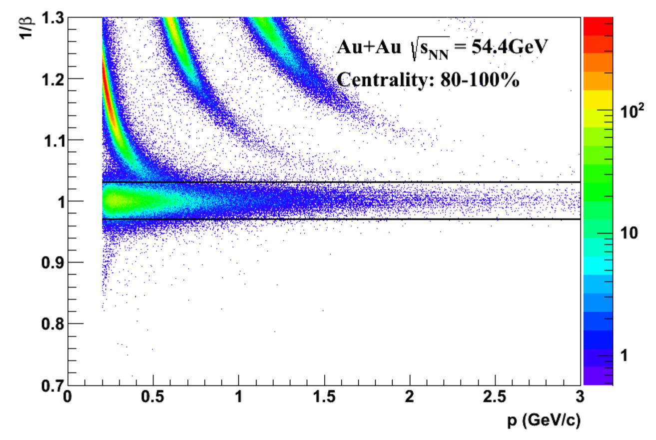
STAR detector

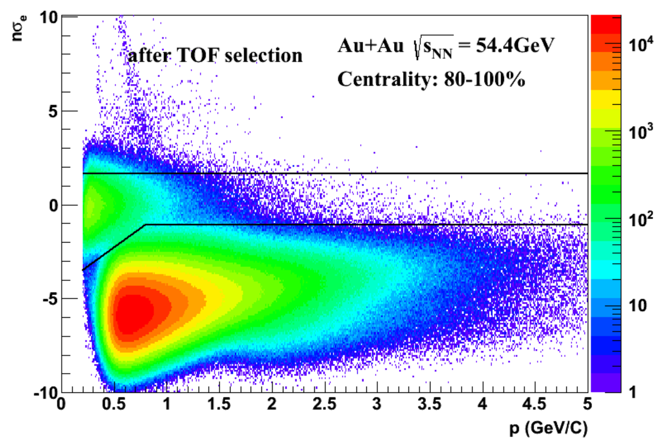


Time Projection Chamber:
- $|\eta|$ < 1,full azimuth
- momentum
- PID via energy loss

Time Of Flight:
- $|\eta|$ < 0.9,full azimuth
- PID via particle velocity

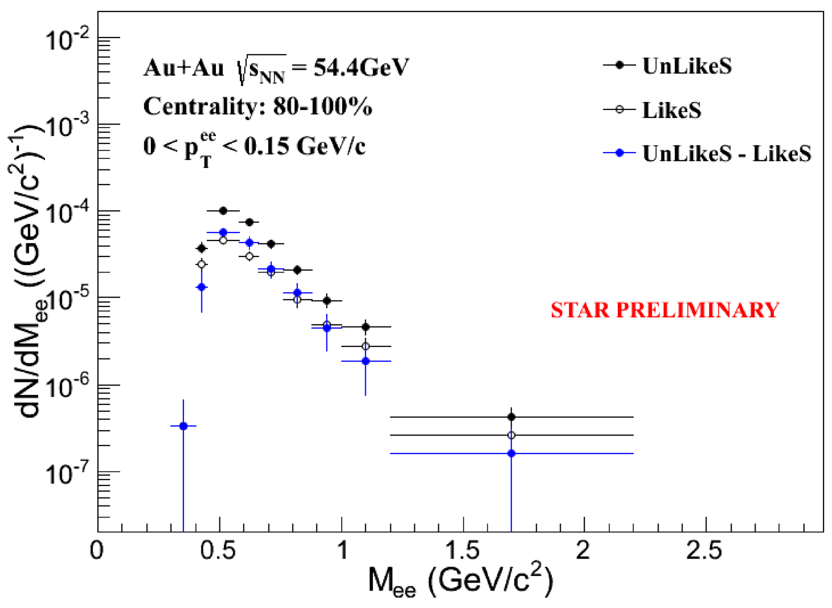
Electron Identification

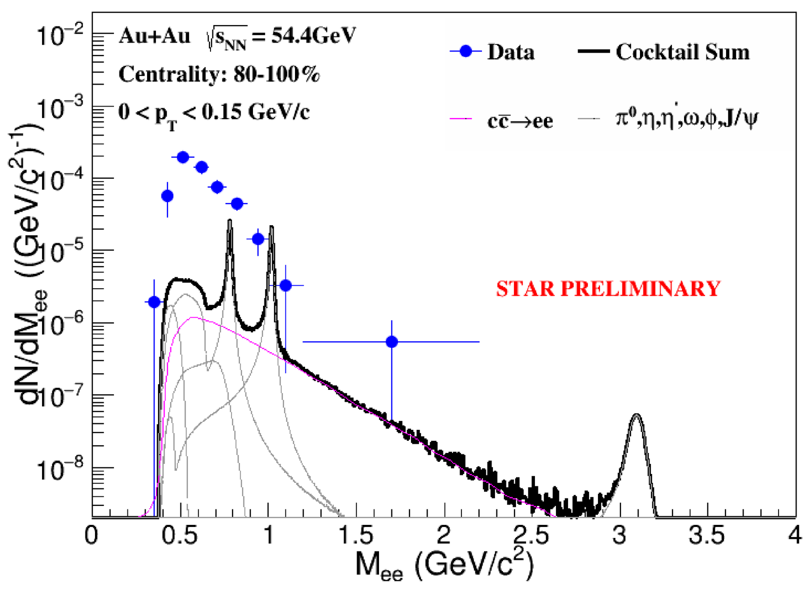




- Excellent electron identification capability with the information from TPC and TOF
- High electron purity (95% in $n\sigma_e$ non-overlapping area) sample with STAR PID

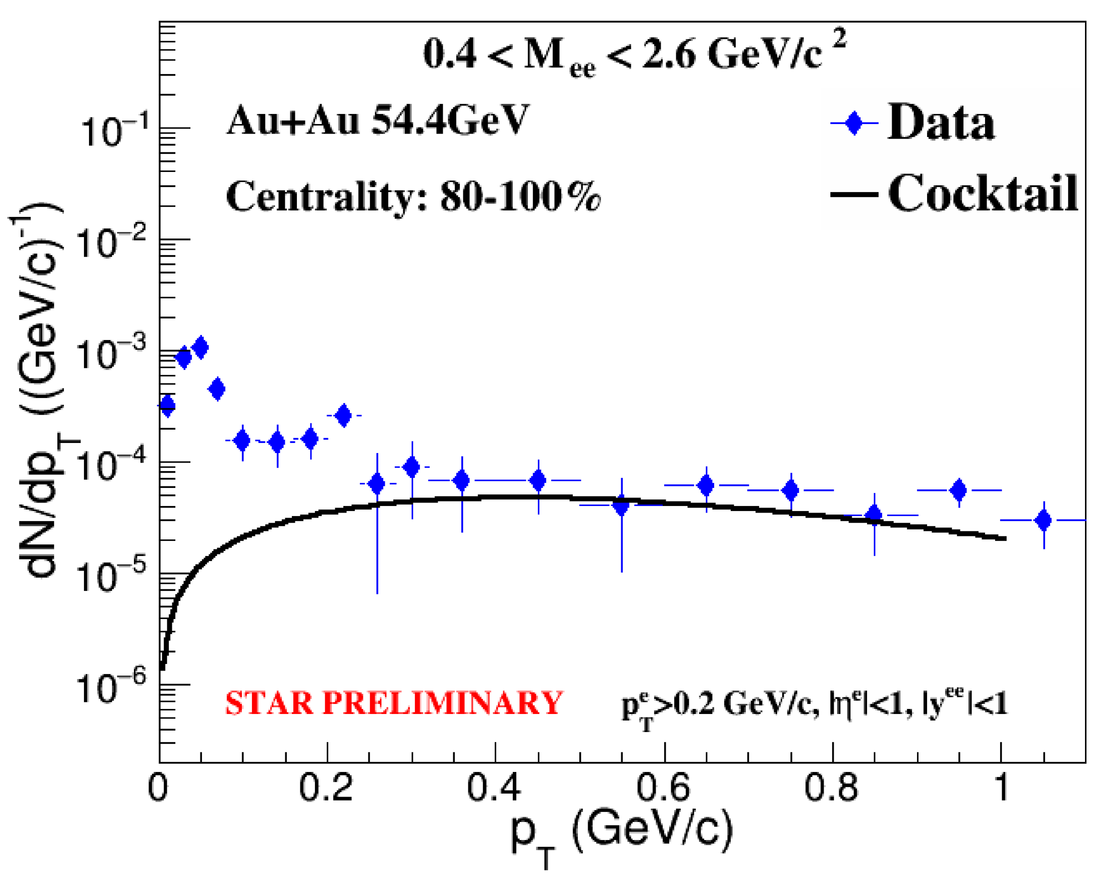
Mass Distribution in Low-p_T





- First di-electron measurement at the centrality of 80-100% at $\sqrt{s_{NN}}$ = 54.4 GeV at STAR
- Significant enhanced di-electron yield compared to hadronic cocktail
- No vector meson is observed ⟶ forbidden for real photons with helicity ± 1

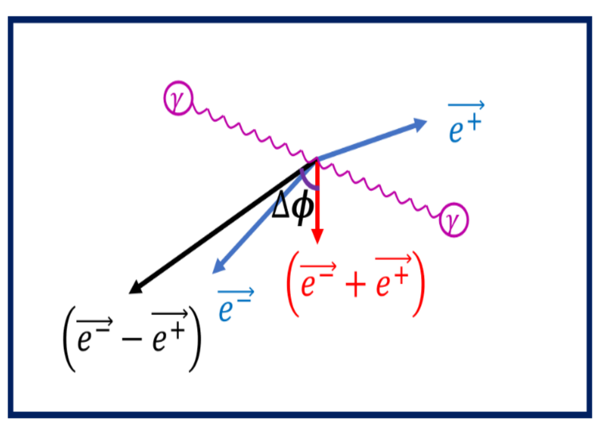
p_T Distribution



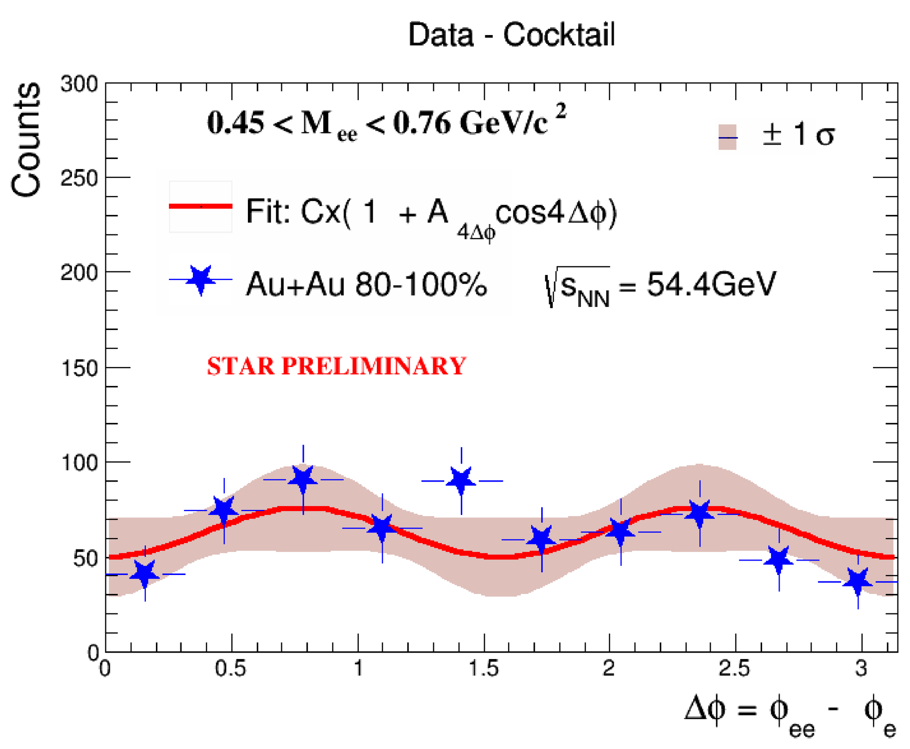
- Observed excess is concentrated below 0.2 GeV/c in 80-100% compared to the cocktail
- Similar p_T distribution of e^+e^- pairs to those of Au+Au at $\sqrt{s_{NN}}$ = 200 GeV/c 60-80% centrality
- ✓ Indication of $\gamma\gamma \rightarrow e^+e^-$ production

$\cos(4\Delta\phi)$ Modulations

- Lorentz contraction of EM fields → Quasi-real photons should be linearly polarized ($\vec{E} \perp \vec{B} \perp \vec{k}$)
- Recently realized, there are $\cos(4\Delta\phi)$ modulations in polarized $\gamma\gamma \rightarrow e^+e^-$ [3]



Quantity	Value	χ^2/ndf
C	62.5 ± 5.3	8.9/8
$-A_{4\Delta\phi}$(%)	20.8 ± 11.8	



- Indication of $\cos(4\Delta\phi)$ modulations in linearly polarized $\gamma\gamma \rightarrow e^+e^-$ process with a significance of 1.76σ (systematics needs to be studied)
  ✓ More statistics are needed to confirm the trend

Summary

- First di-electron measurement in 80-100% central Au+Au collisions at $\sqrt{s_{NN}}$ = 54.4 GeV at STAR
  ✓ Indication of $\gamma\gamma \rightarrow e^+e^-$ process
- The very low-p_T di-electron mass spectra are significantly higher than hadronic cocktail and the p_T distribution is similar to 60-80% Au+Au 200 GeV results
  ✓ Bridge between HIC and UPC $\gamma\gamma \rightarrow e^+e^-$ process
- Indication of $\cos(4\Delta\phi)$ modulations in linearly polarized $\gamma\gamma \rightarrow e^+e^-$ process, but more precise measurement is needed to improve the significance

Outlook

- Systematic uncertainty at the centrality of 80-100% at $\sqrt{s_{NN}}$ = 54.4 GeV will be studied

References

[1] Adam J *et al.* (STAR) 2018 *Phys. Rev. Lett. 121 132301*
[2] Adam J *et al.* (STAR) 2019 arXiv : 1910.12400
[3] C. Li, J. Zhou, Y.-j. Zhou. (2019) Phys. Lett. B 795, 576

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