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Low-p_T $\mu^+\mu^-$ production in Au+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV at STAR

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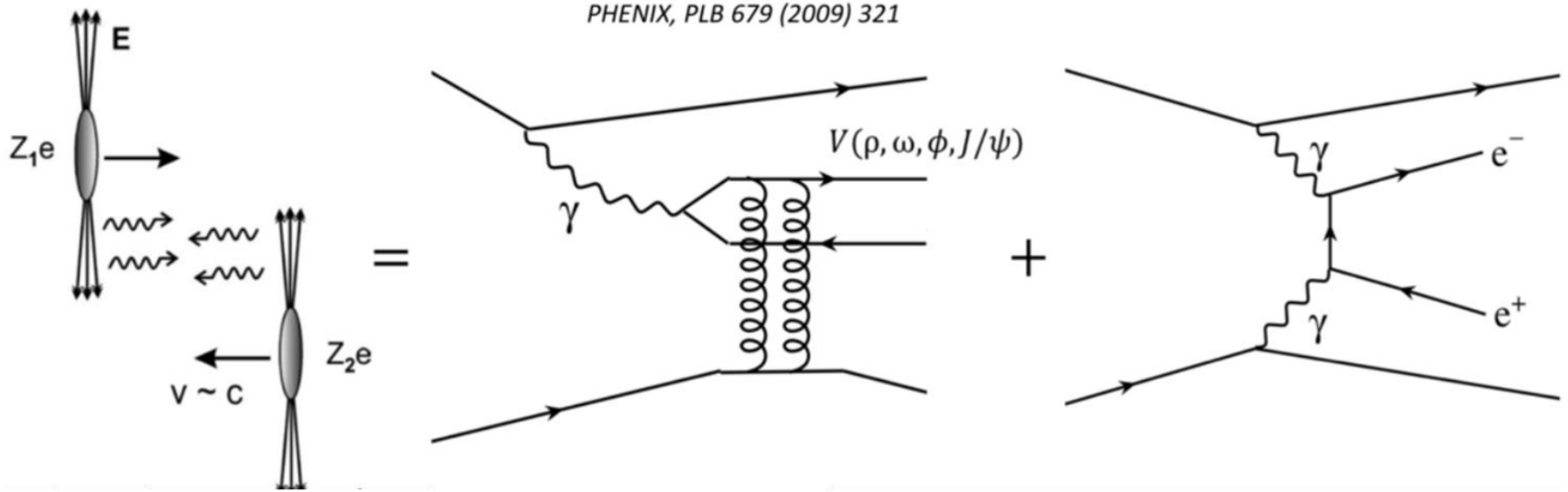
第6届中国LHC物理工作会议

The 6th China LHC Physics Workshop

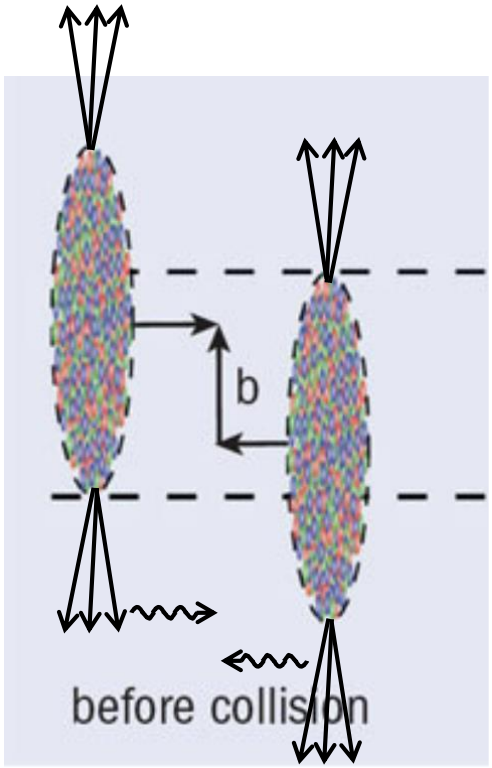
Dileptons from photon interactions

C. A. Bertulani et al., Ann. Rev. Nucl. Part. Sci. 55 (2005) 271
PHENIX, PLB 679 (2009) 321

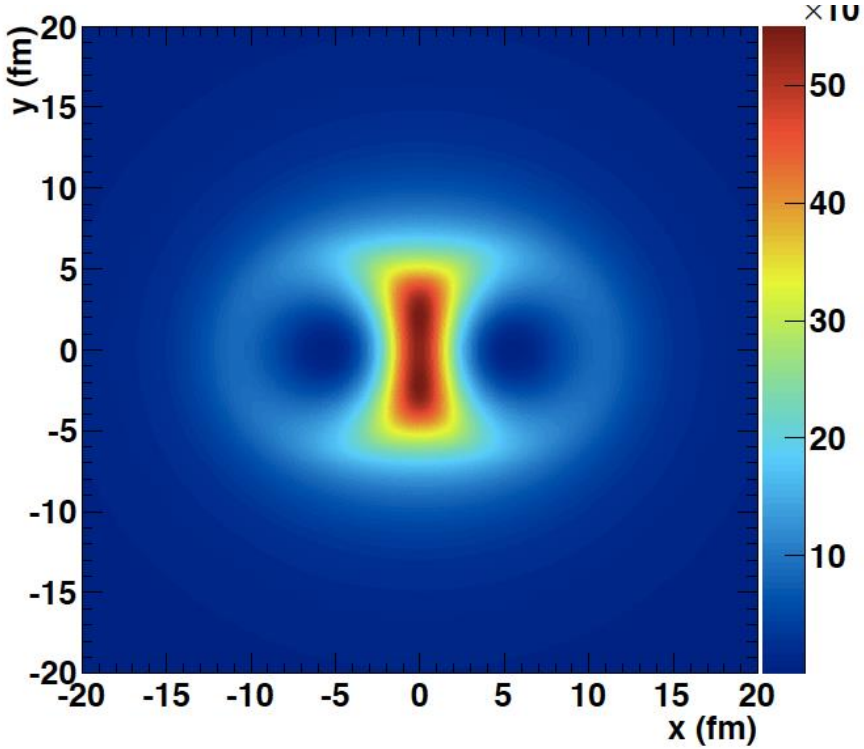


- Large quasi-real photon flux $\propto Z^2$
- Photon interactions
  - photon-photon interaction (dilepton...) $\propto Z^4$ —— distinctly peaked at low p_T
  - photon-nuclear interaction (vector mesons) $\propto Z^2$
    - ✓ Coherent: photon interacts with the whole nucleus
    - ✓ Incoherent: photon interacts with nucleon or parton individually
- Conventionally only studied in ultra-peripheral collisions (b>$2R_A$,UPCs) to keep coherence condition

Photons in hadronic heavy-ion collisions



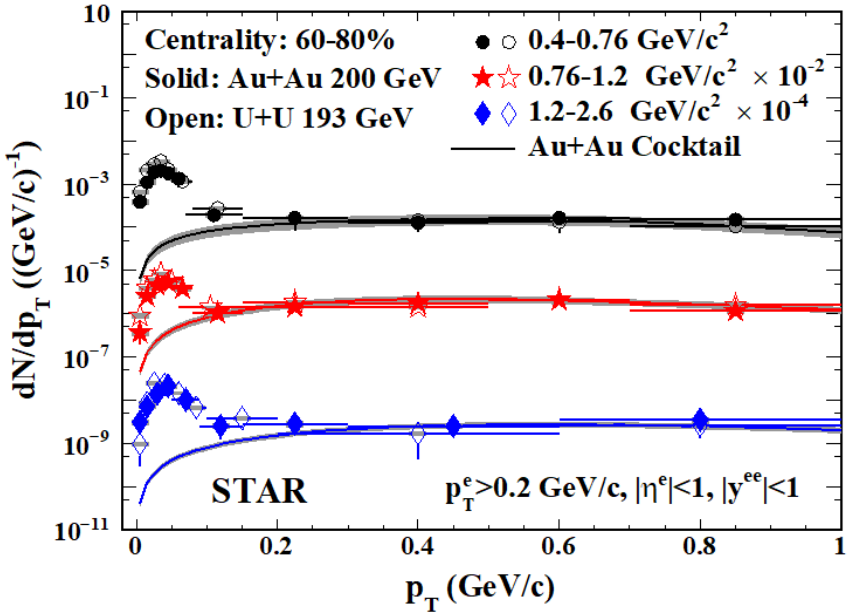
Example of dilepton spatial distributions at z=0 in 50-60% Au+Au collisions



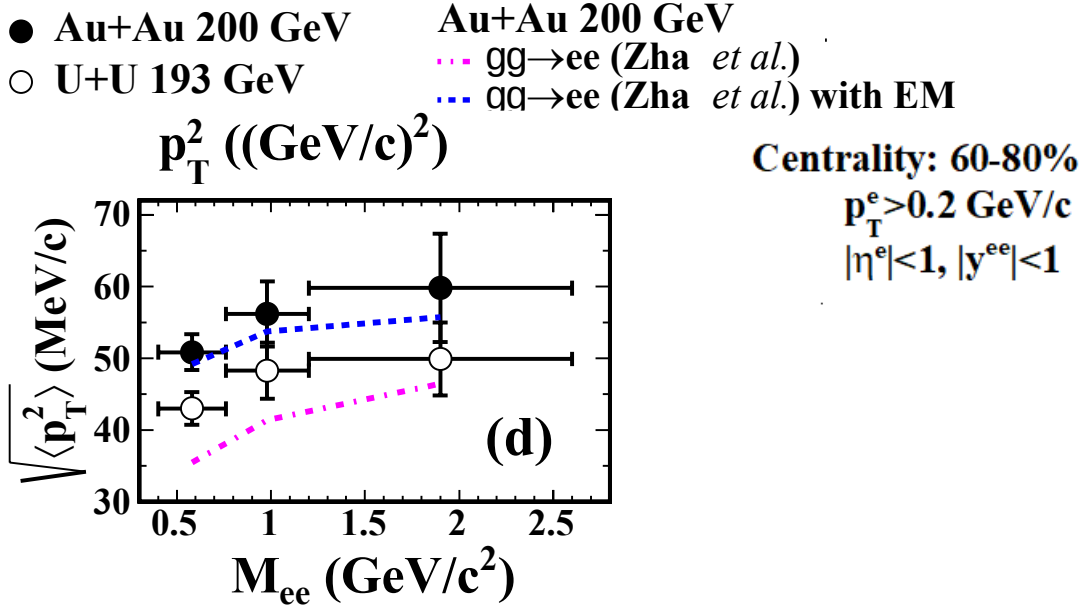
W. M. Zha et al., Phys. Lett. B 781 (2018) 182

- Photons interact at the very beginning.
- The dileptons can bring the information from the nuclear overlap region.

Photoproduction with nuclear overlap



STAR, Phys. Rev. Lett. 121 (2018) 132301

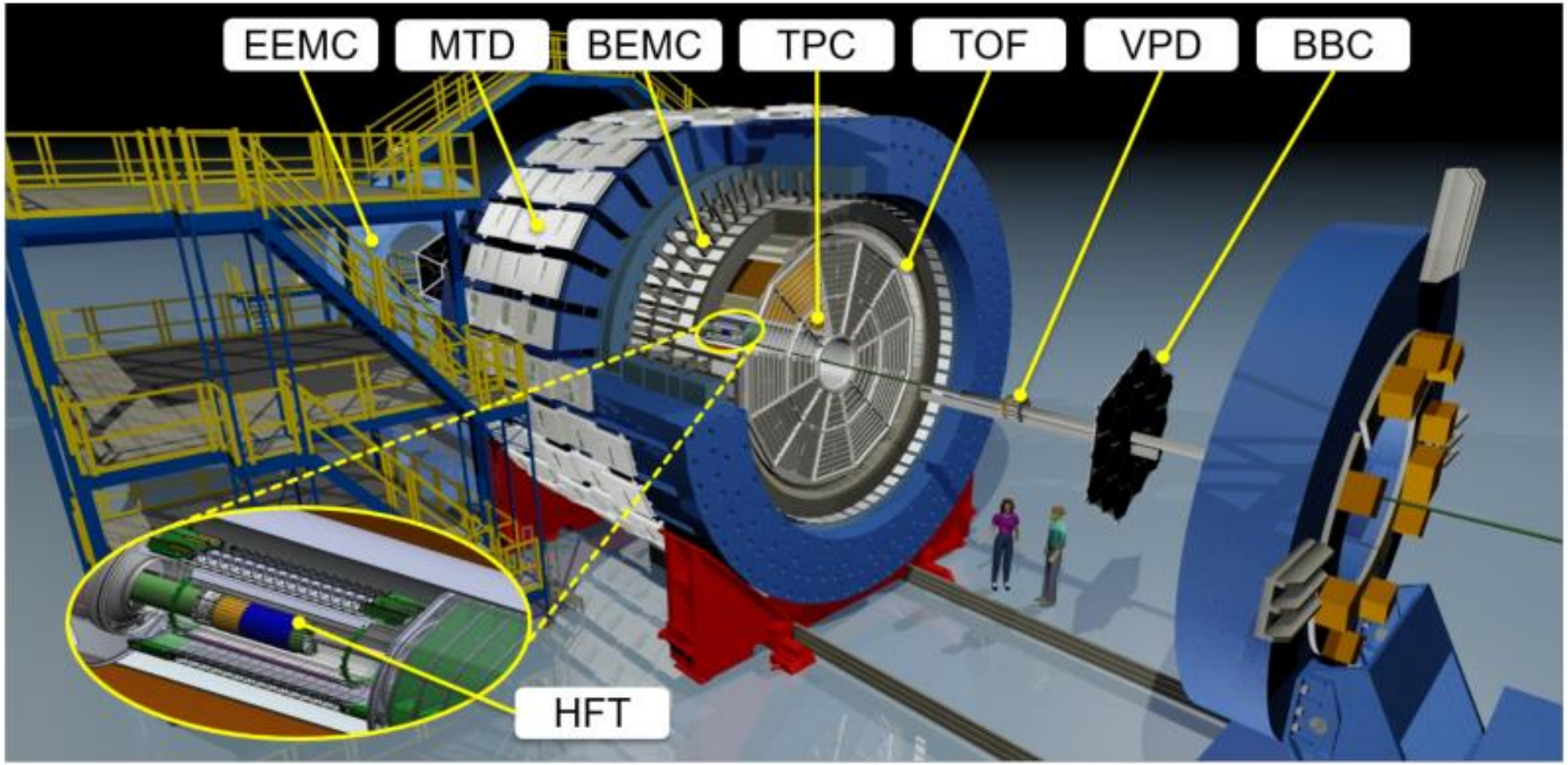


STAR, Phys. Rev. Lett. 121 (2018) 132301

W.M. Zha et al., Phys. Lett. B 800 (2020) 135089

- Excess e^+e^- pair p_T distribution concentrates below $p_T \sim 0.15$ GeV/c.
  - Evidence of photon interactions in hadronic heavy ion collisions.
- The observed p_T^2 broadening is consistent with QED calculations. Possible additional broadening is also proposed as a probe of a trapped magnetic field or of Coulomb scattering in a QGP.
- Low-p_T muon pairs production measurements provide a complementary channel and will help to further improve our understanding of photon-induced processes.

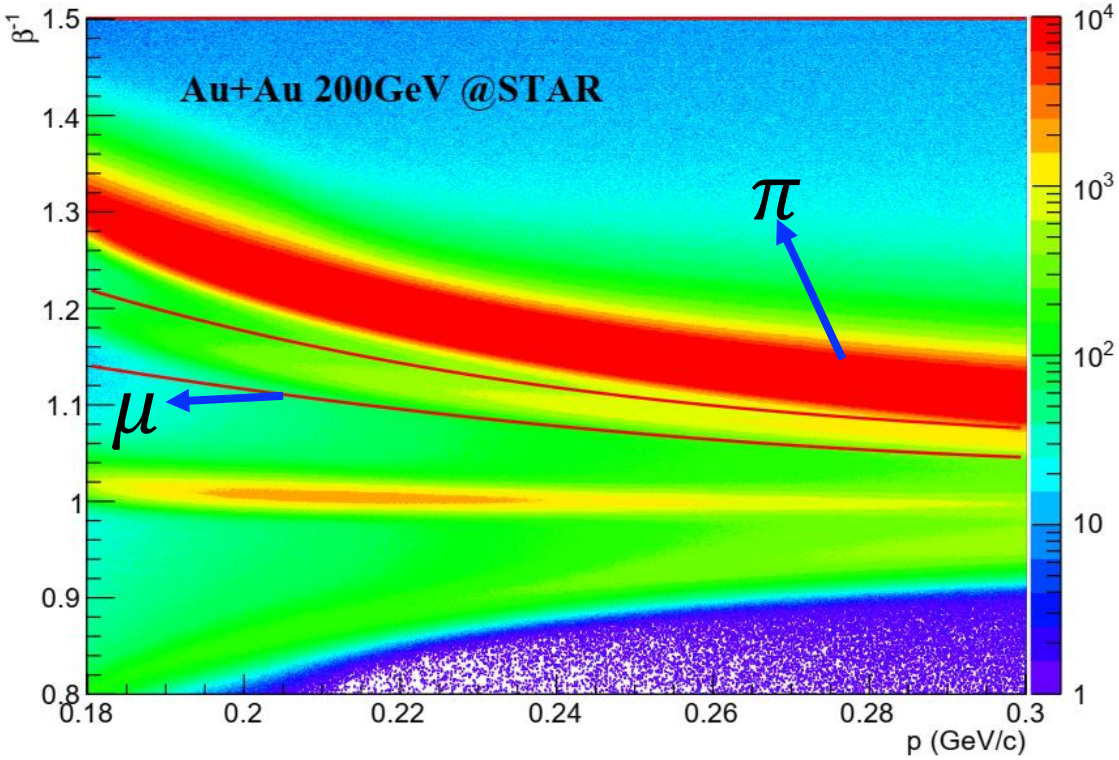
The Solenoidal Tracker At RHIC (STAR)



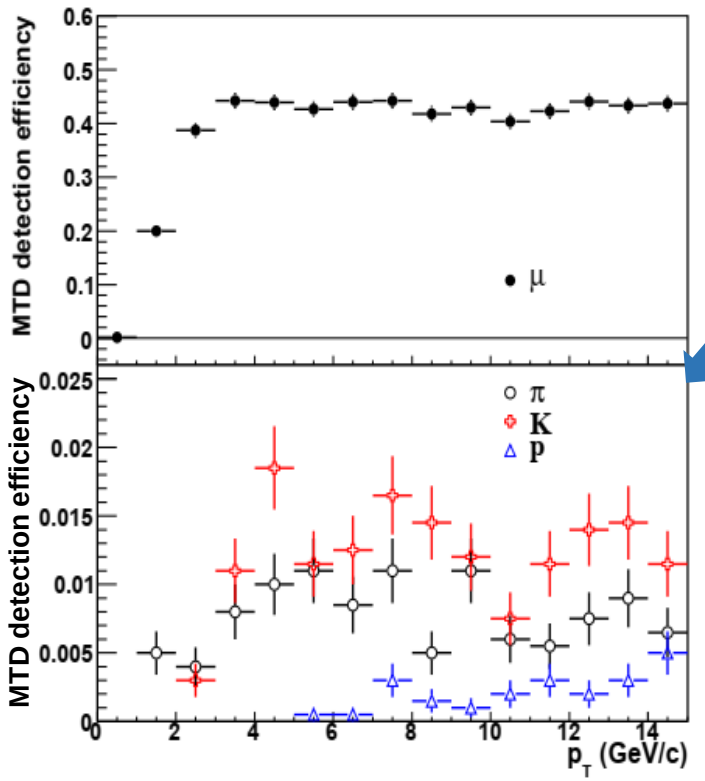
- Time Projection Chamber: tracking, momenta, and PID
- Time of Flight: PID by velocity
- Muon Telescope Detector: trigger on and identify muons

Muon identification

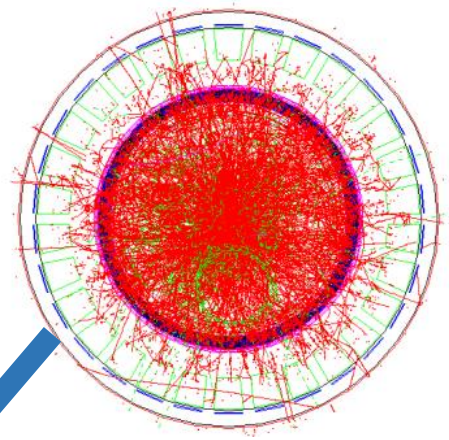
PID@TOF



PID@MTD



STAR, J. Phys. G **36** (2009) 095001

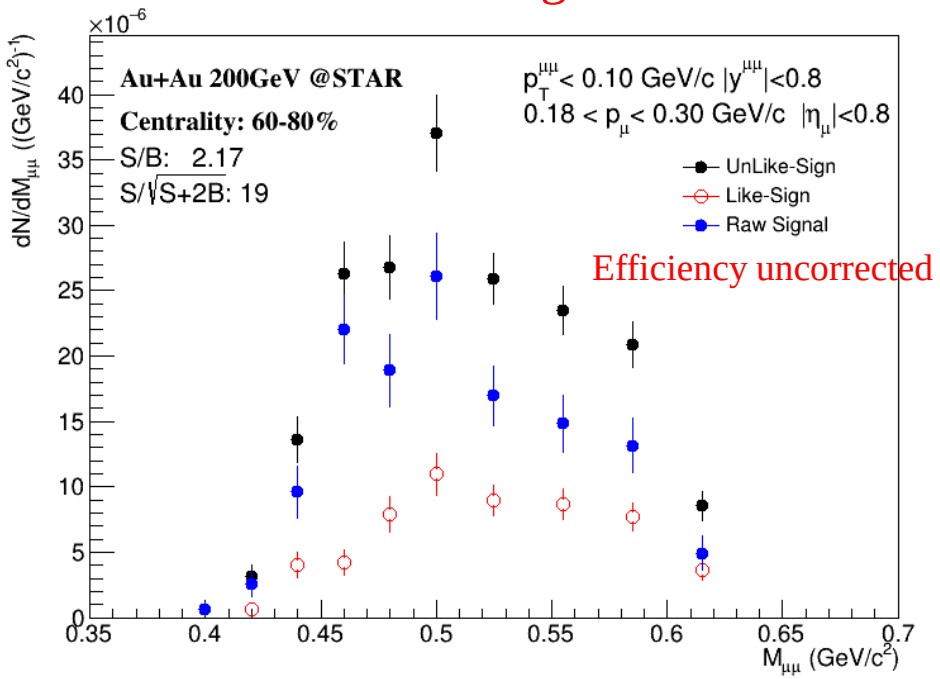


Significantly suppress pion with MTD

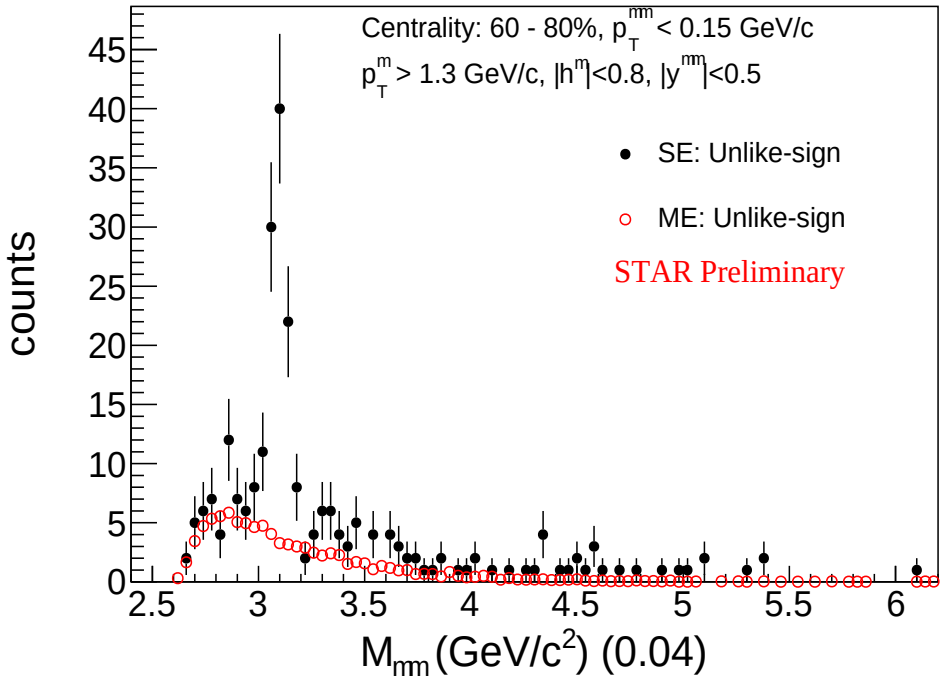
- Muon can be identified at low p_T by using TOF.
- Muon can be identified at high p_T by using MTD.

Invariant mass spectrum

Low mass region

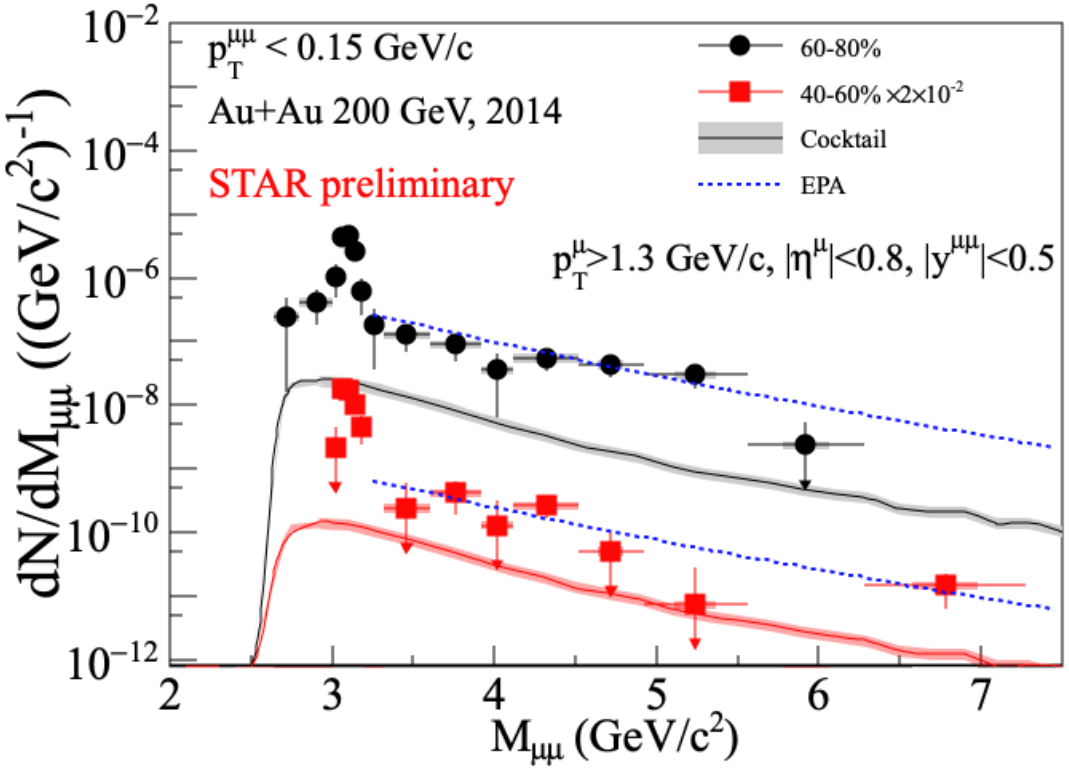


High mass region



- The $\mu^+\mu^-$ invariant mass distribution at very low p_T in peripheral collisions.
  - Low mass region ($0.40 < M_{\mu\mu} < 0.64$ GeV/c^2) using TOF.
  - High mass region ($M_{\mu\mu} > 3.2$ GeV/c^2) using MTD.

Invariant mass spectra in high mass region



- Significant enhancement with respect to the cocktail in 60-80% centrality collisions.
- Consistent with the theoretical calculation.

Calculations based on Equivalent Photon Approximation (EPA) method.

- Weizsacker–Williams method to estimate photon flux.
- Use Woods-Saxon charge distribution in nucleus for photon flux estimation.
- Photon is treated as real.
- Consider dilepton production insides nucleus.

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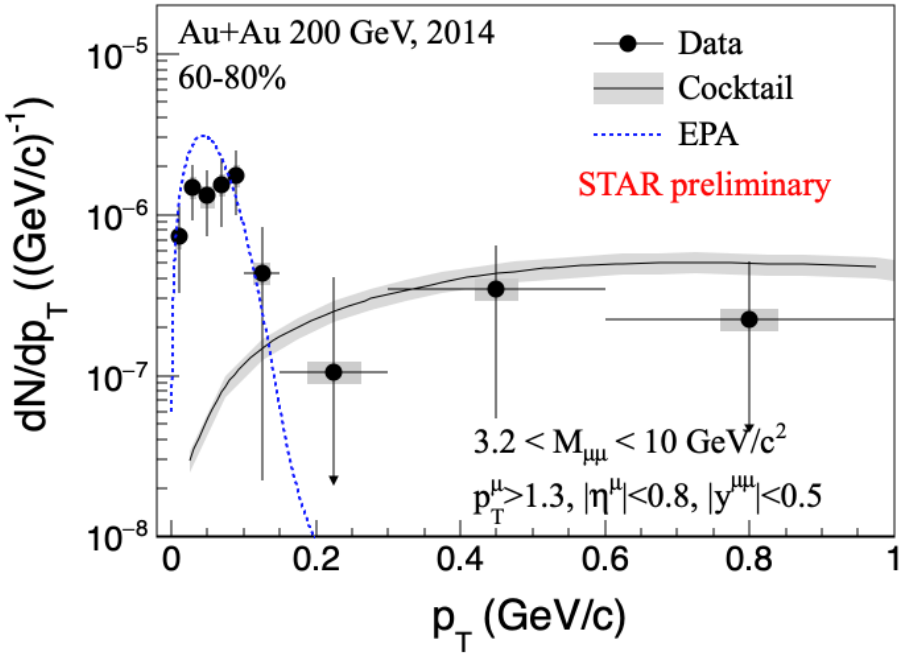
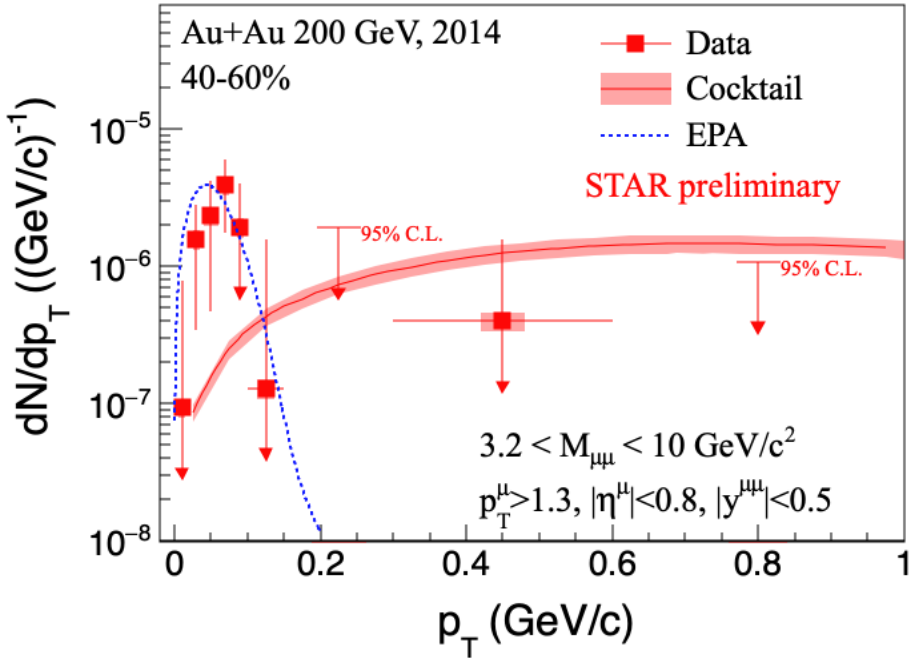
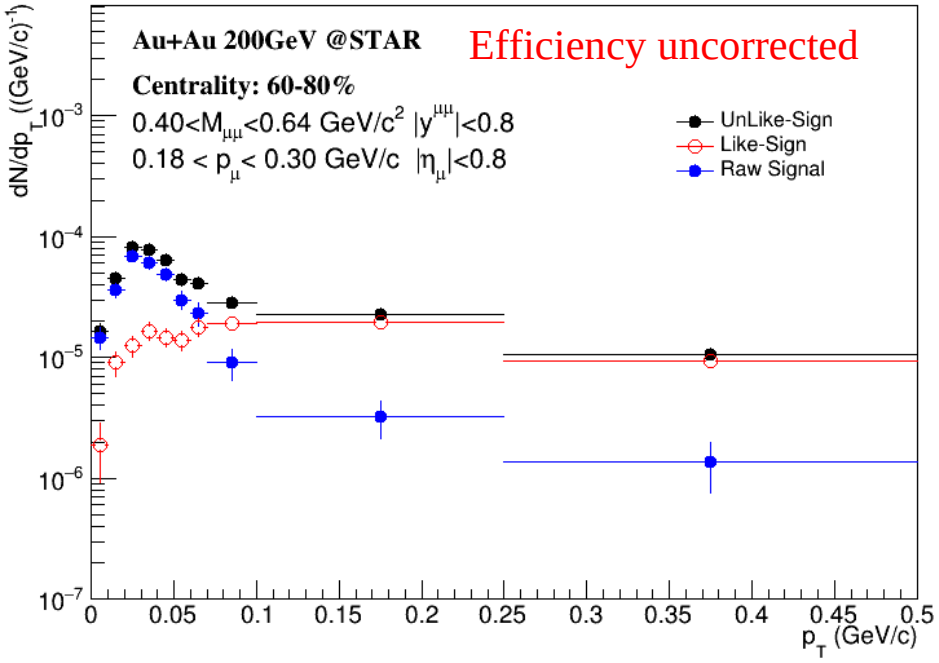
p_T distributions in high mass region

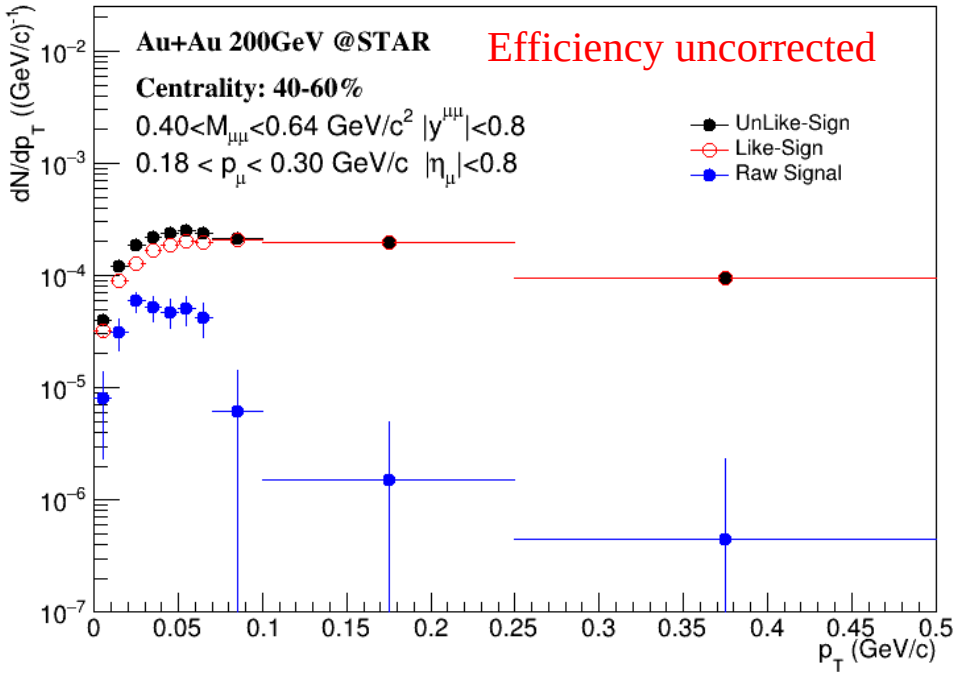




- Excesses concentrate below $p_T \approx 0.15$ GeV/c.
- Data are consistent with hadronic expectation when $p_T > 0.15$ GeV/c.
- Theoretical calculation is compatible with data.

p_T distribution in low mass region





- Excesses concentrate below $p_T \approx 0.15$ GeV/c.
  - Similar shape to e^+e^- and high mass $\mu^+\mu^-$ measurements.
  - Indication of photon interactions in hadronic heavy ion collisions.
  - Efficiency correction and cocktail simulation are ongoing.

Summary

- A significant $\mu^+\mu^-$ enhancement relative to the cocktail is observed at very low p_T in peripheral Au+Au collisions at 200 GeV.

  In high mass Region ($M_{\mu\mu} > 3.2$ GeV/c^2):

  - Excess was entirely observed below $p_T \approx 0.15$ GeV/c.
  - Compatible with the theoretical calculation.

  In low mass Region ($0.40 < M_{\mu\mu} < 0.64$ GeV/c^2):

  - Excess was entirely observed below $p_T \approx 0.15$ GeV/c.
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- Outlook

  - Search for cos4Δϕ angular distribution which is related to vacuum birefringence. ——STAR, arXiv : 1910.12400

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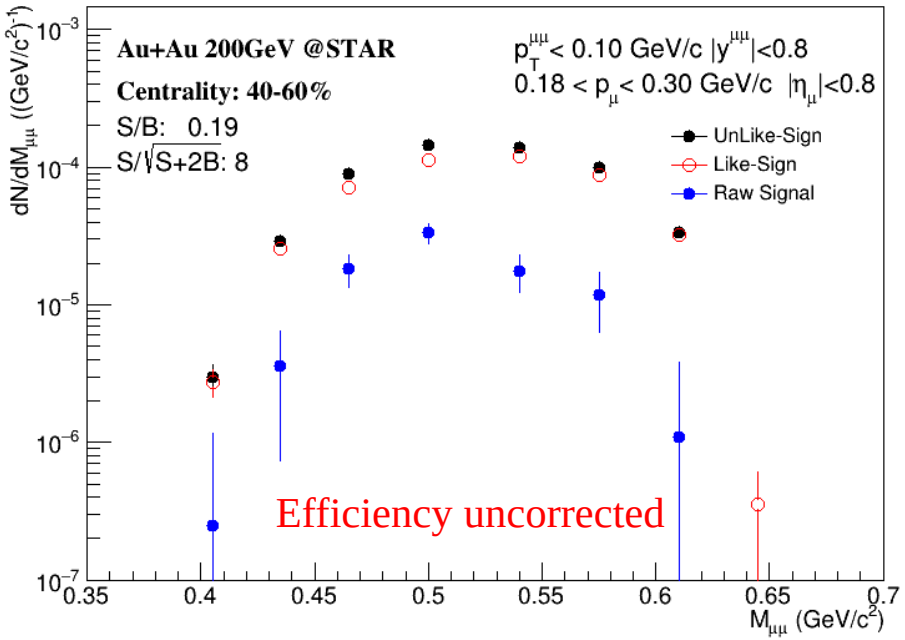
Thank you!

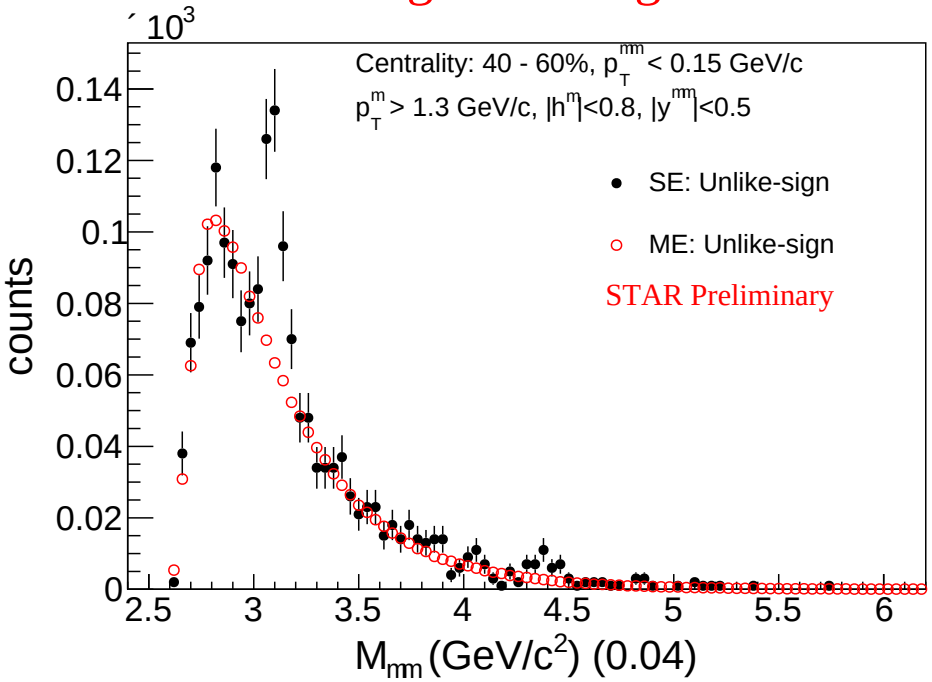
Back up

Invariant mass spectrum (40-60%)

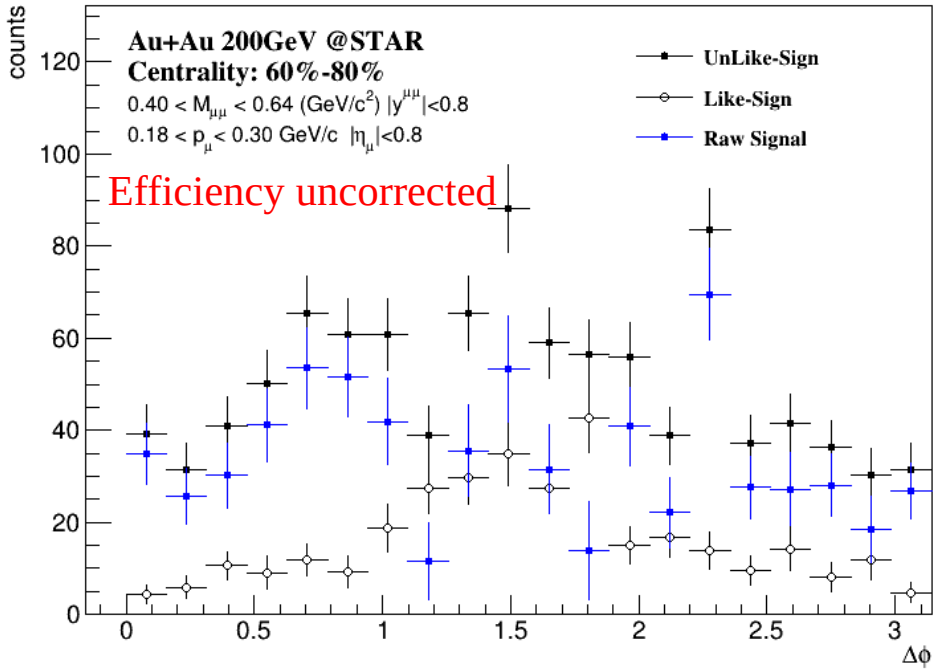
Low mass region



High mass region



Outlook—— $\Delta\phi$ distribution (60-80%)



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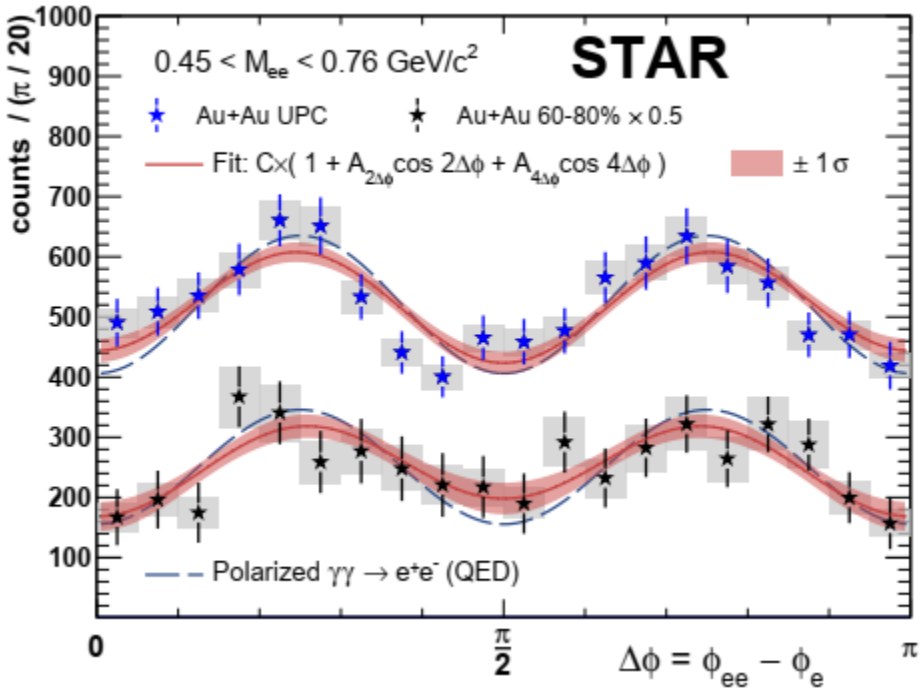

- Theory predicts that the linearly polarized photon-photon collisions will lead to a $cos4\Delta\phi$ angular distribution which can be identified as vacuum birefringence.
- The previous observation of dielectron production is in agreement with theoretical predictions.
- Dimuon channel provides a new channel to study the Breit-Wheeler process.