Very low-p_T di-muon production in peripheral Au+Au collisions at $\sqrt{S_{NN}}$ = 200 GeV at STAR

Ziyang Li (*for the STAR Collaboration)*

State Key Laboratory of Particle Detection and Electronics,

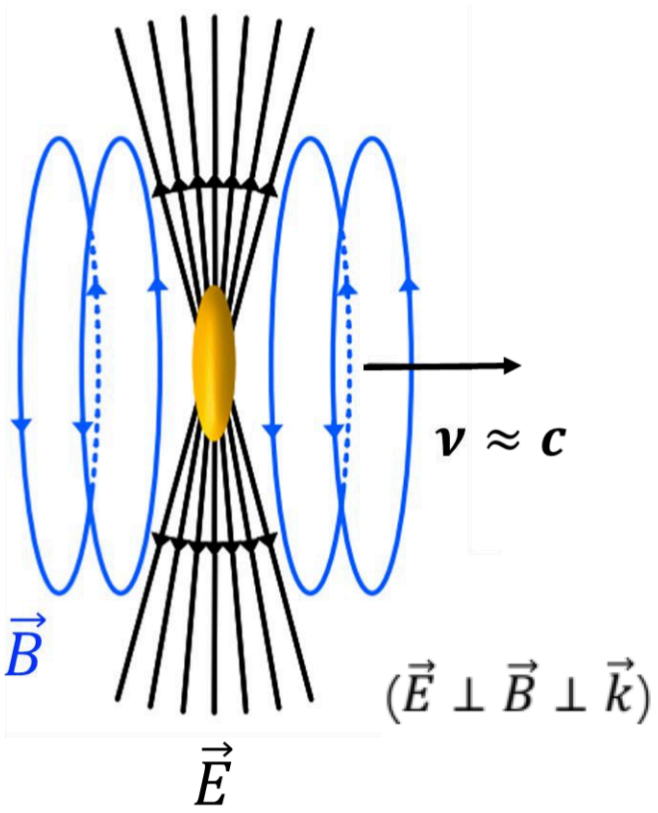
Department of Modern Physics,

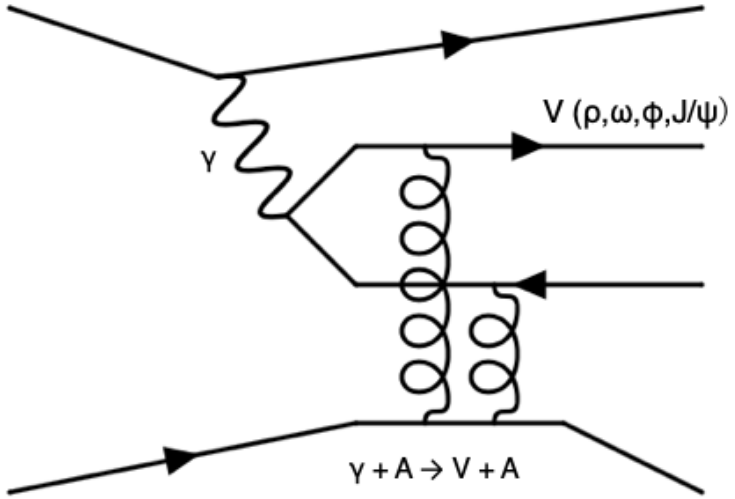
University of Science and Technology of China

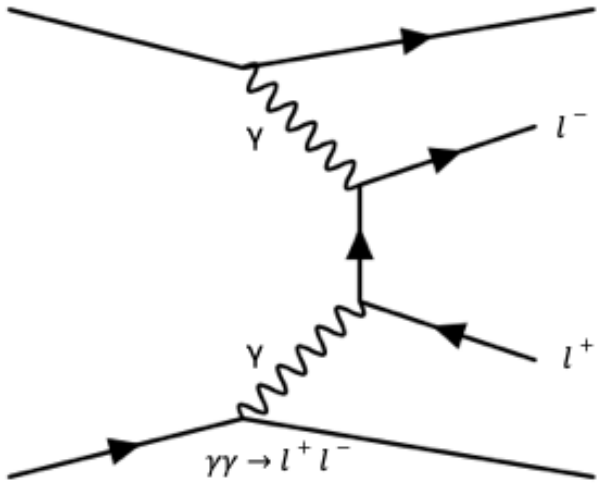
Supported in part by the

U.S. DEPARTMENT OF ENERGY | Office of Science

Photon-induced process







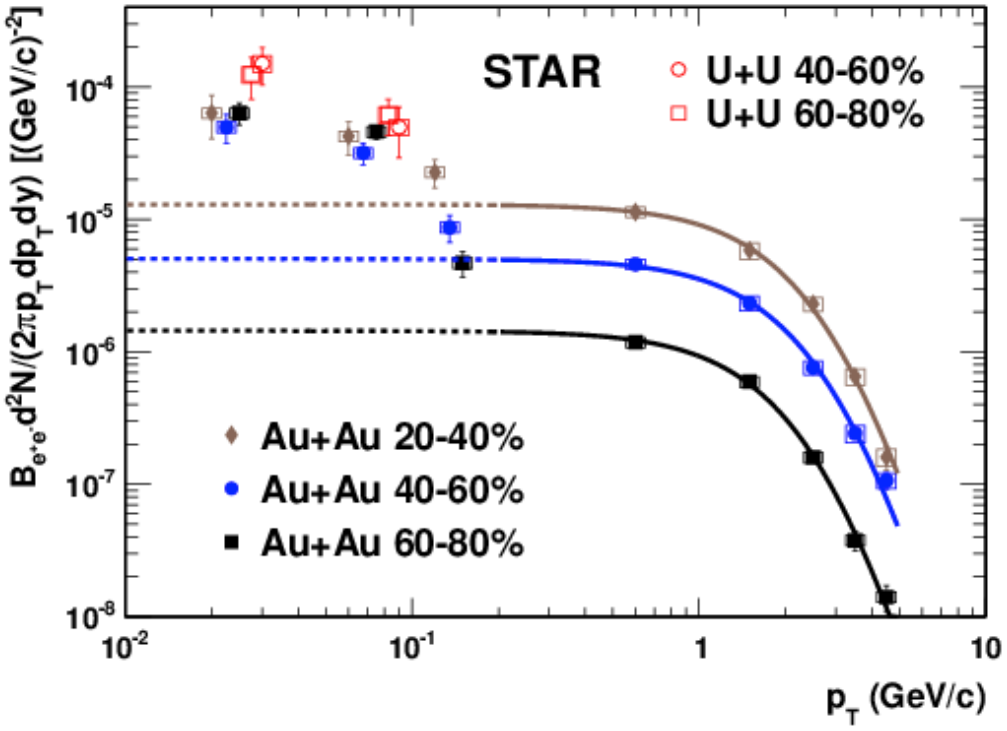
- Boosted nuclei generate intense electromagnetic fields.
- Weizsacker-Williams equivalent photon approximation (EPA):
  - In a specific phase space, transverse EM fields can be quantized as a flux of real photons.

$$n \propto \vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B} \approx |\vec{E}|^2 \approx |\vec{B}|^2$$

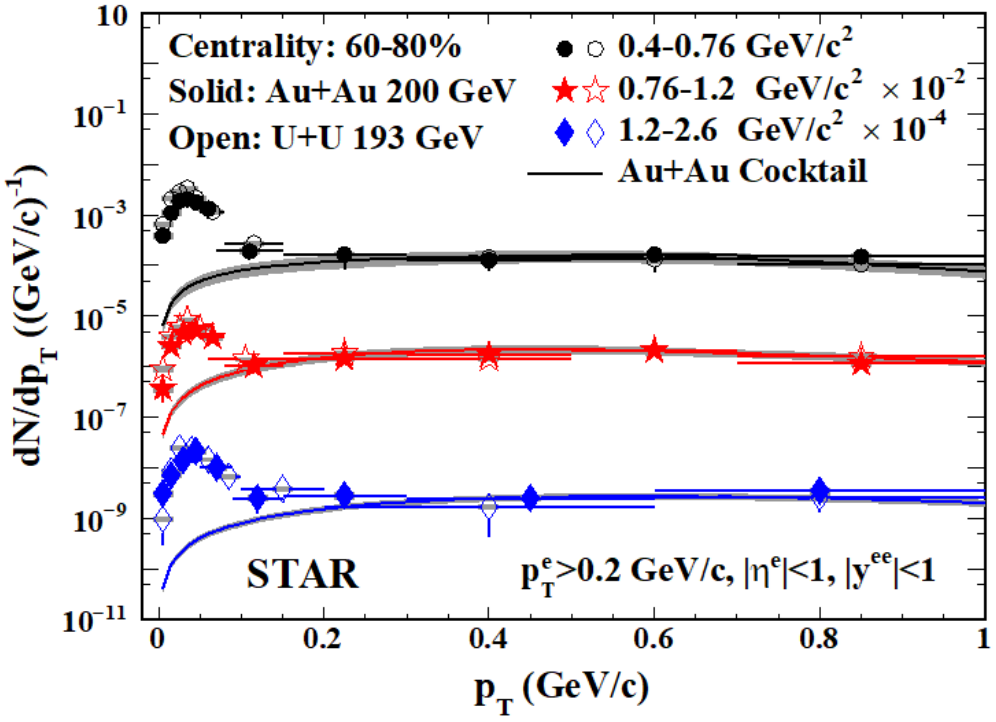
- Large quasi-real photon flux $\propto Z^2$

Photoproduction with nuclear overlap

$J/\psi \to e^+e^-$ STAR: Phys. Rev. Lett. 123, 132302 (2019)

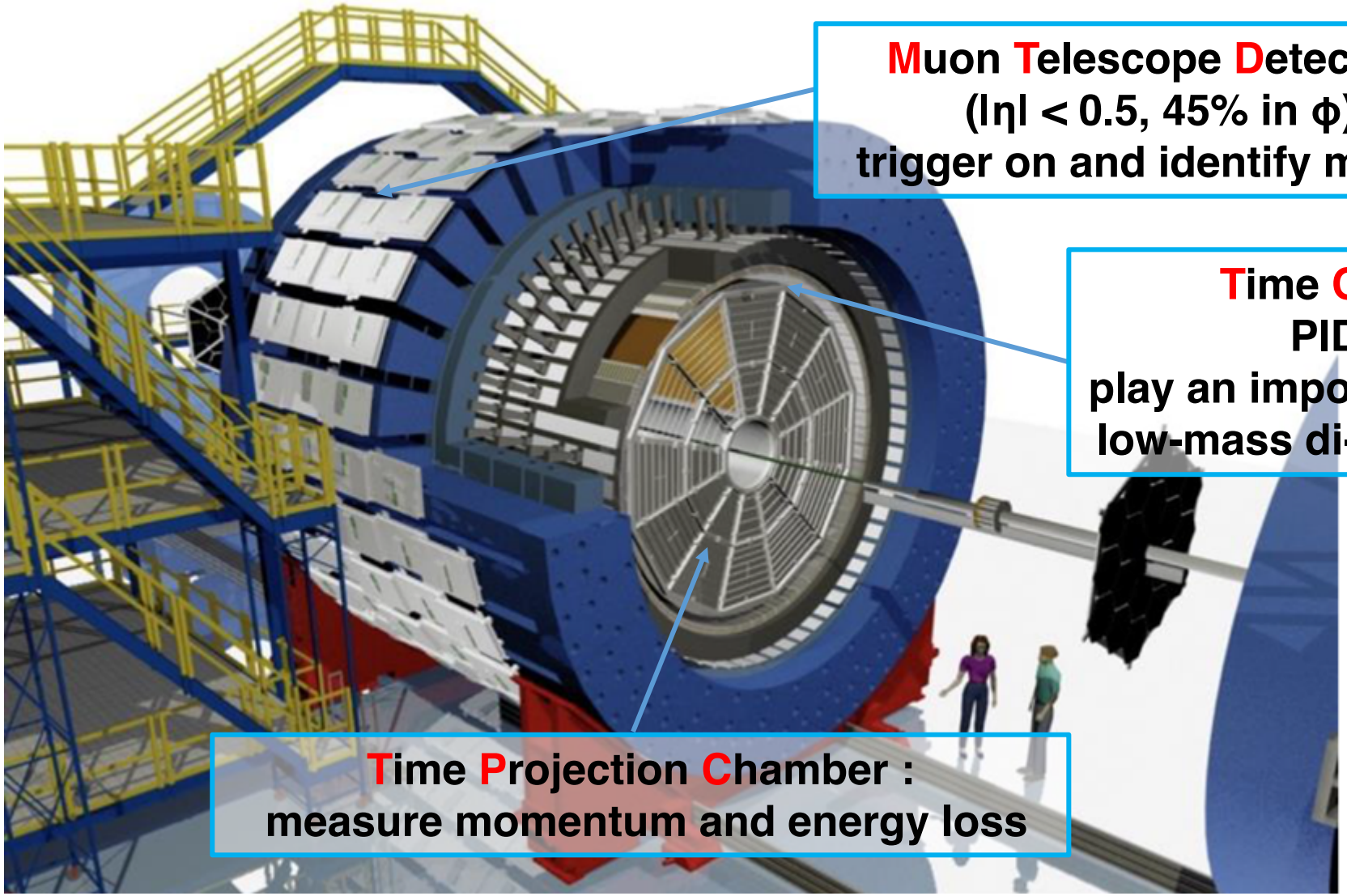


e^+e^- pairs STAR: Phys. Rev. Lett. 121, 132301 (2018)



- Significant enhancements of J/ψ and dielectron pair production at very low p_T (below ~ 0.2 GeV/c).
- Evidence of photon interactions in hadronic heavy ion collisions.
- Dimuon channel measurements provide additional statistics and will help to further improve our understanding of photoproduction processes.

The Solenoidal Tracker At RHIC (STAR)



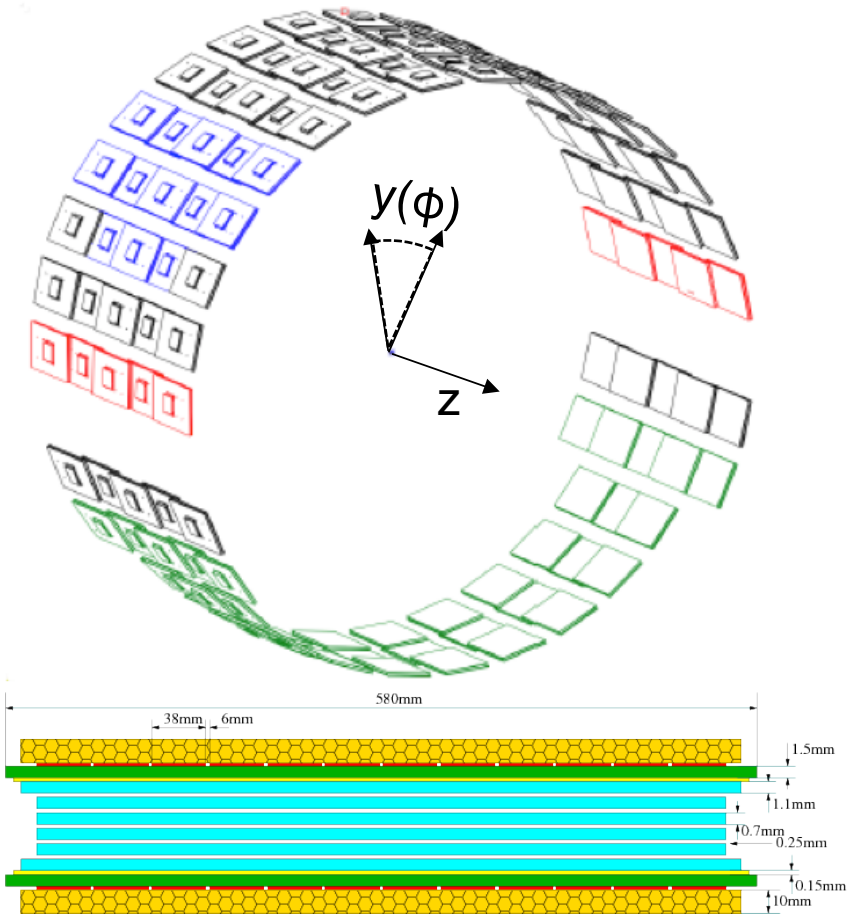
Muon Telescope Detector :
(|η| < 0.5, 45% in ϕ)
trigger on and identify muons

Time Of Flight :
PID (1/β)
play an important role in the low-mass di-muon analysis

Time Projection Chamber :
measure momentum and energy loss

Muon PID in high momentum region

- Data set: 2014 Au+Au 200 GeV, full luminosity ~ 14.2 nb^{-1}



MTD system:

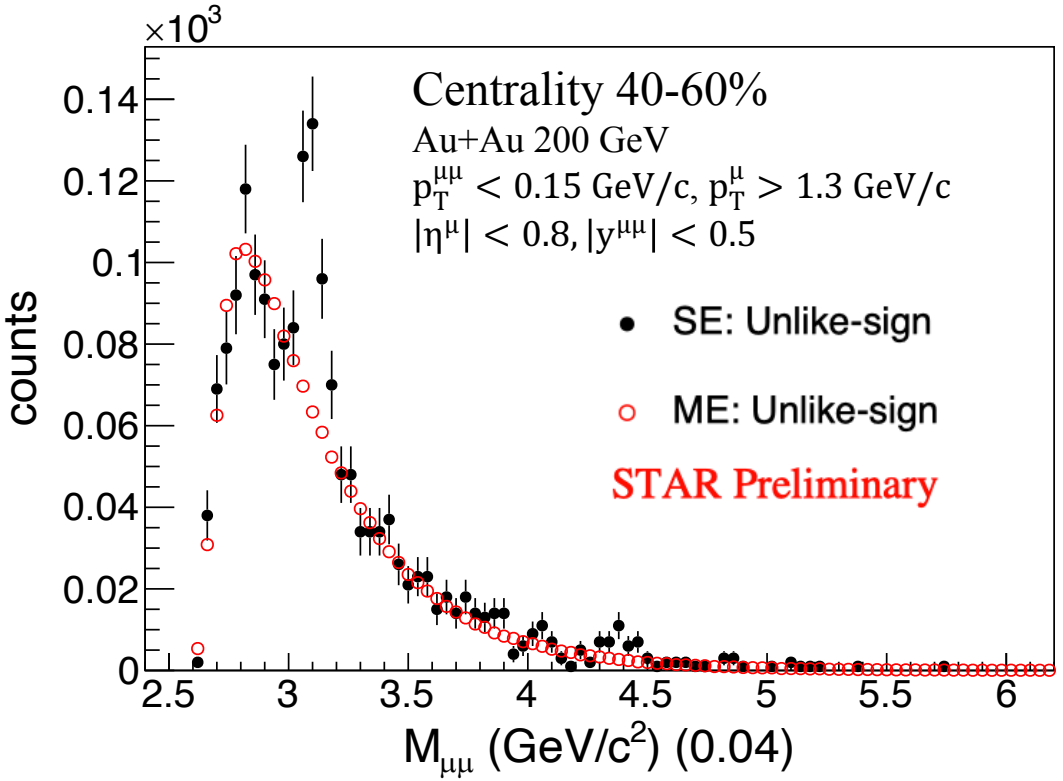
- Fully installed in 2014, behind the magnet (~ 5 interaction length)
- p_T threshold for MTD ~ 1.2 GeV/c
- Precise timing measurement (σ ~ 100 ps)
  - Arrival time: Δtof cut
- Intrinsic spatial resolution (~ 1 cm)
  - Hit position: Δy and Δz cuts

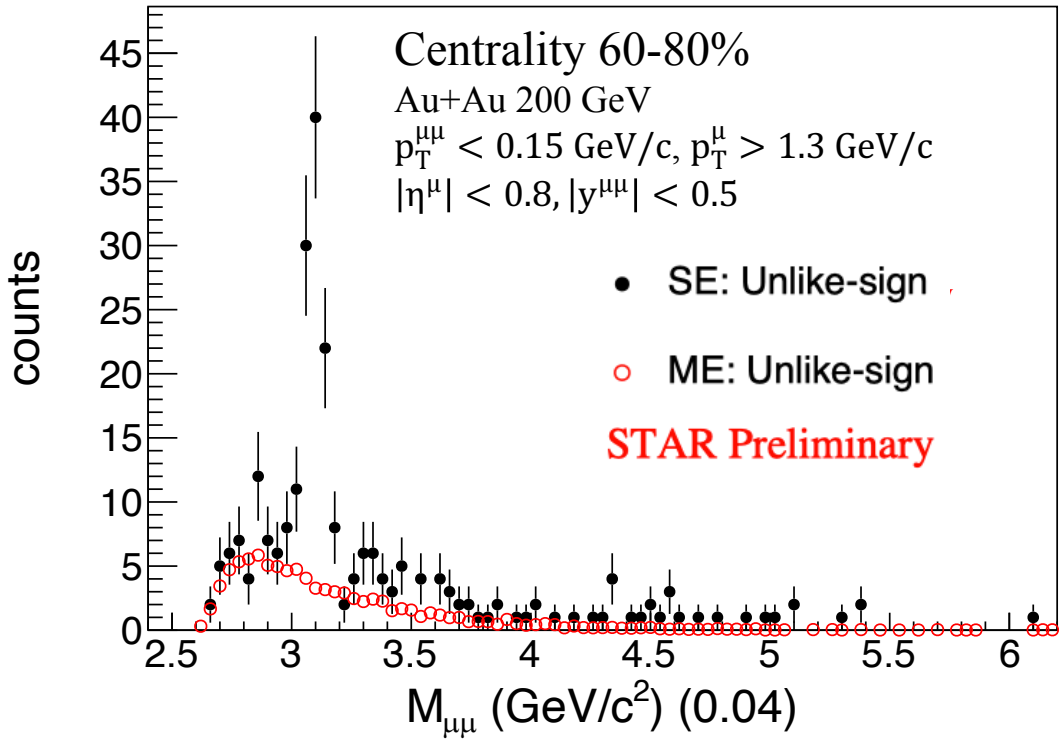
TPC:

- Measure energy loss
- dE/dx cut: muons are expected to lose about 0.5σ more energy compared to pions; $-1 < n\sigma_{\pi} < 3$

MTD system provides the capability of muon pair measurement in the high mass region

Signal extraction

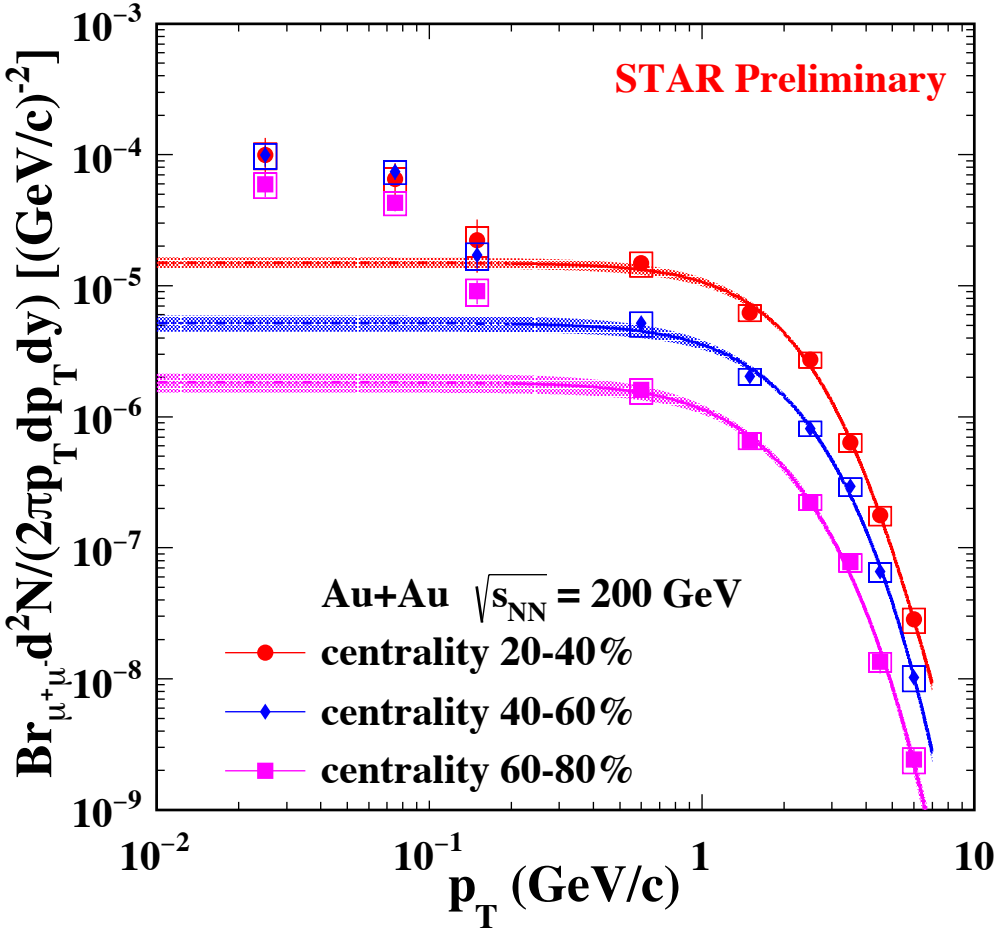


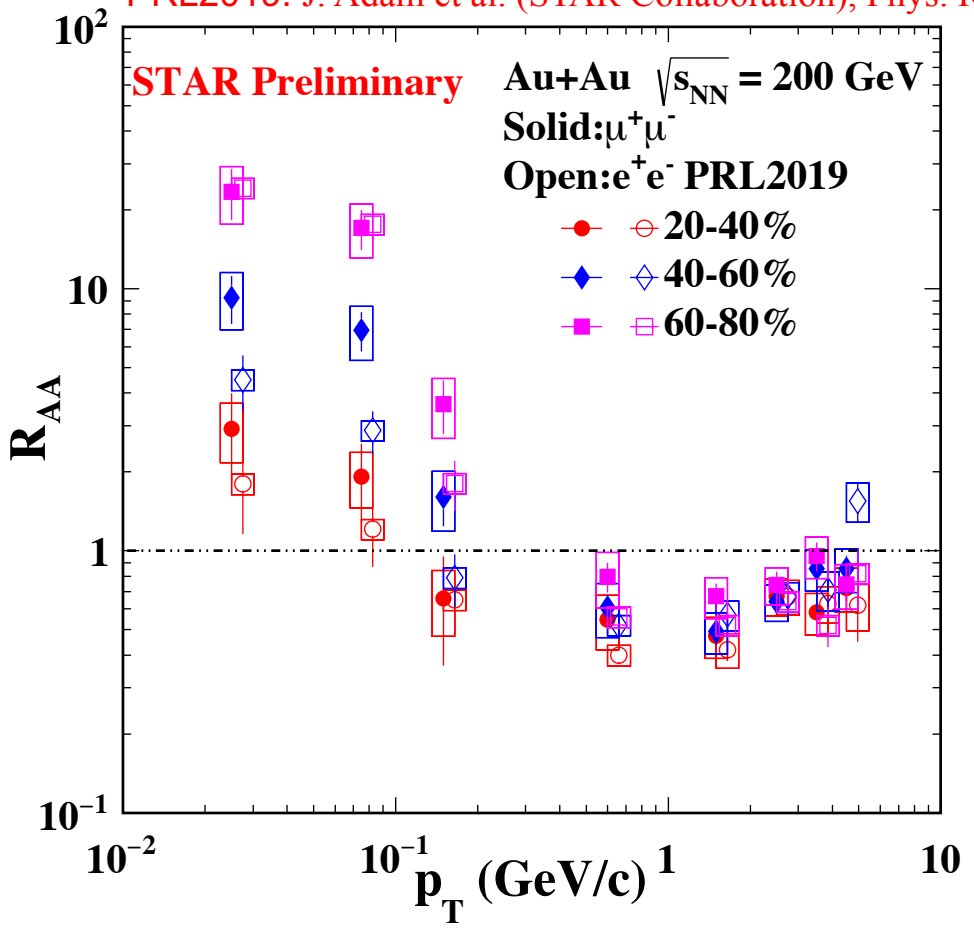


- The $\mu^+\mu^-$ invariant mass distributions for $p_T < 0.15$ GeV/c in peripheral collisions
- The mixed-event technique is used to estimate the combinatorial background
- Focus on the J/ψ ($2.9 < M_{\mu\mu} < 3.2$ GeV/c^2) and high mass region ($3.2 < M_{\mu\mu} < 10$ GeV/c^2)

J/ψ : Invariant yield and R_{AA}

PRL2019: J. Adam et al. (STAR Collaboration), Phys. Rev. Lett. 123, 132302

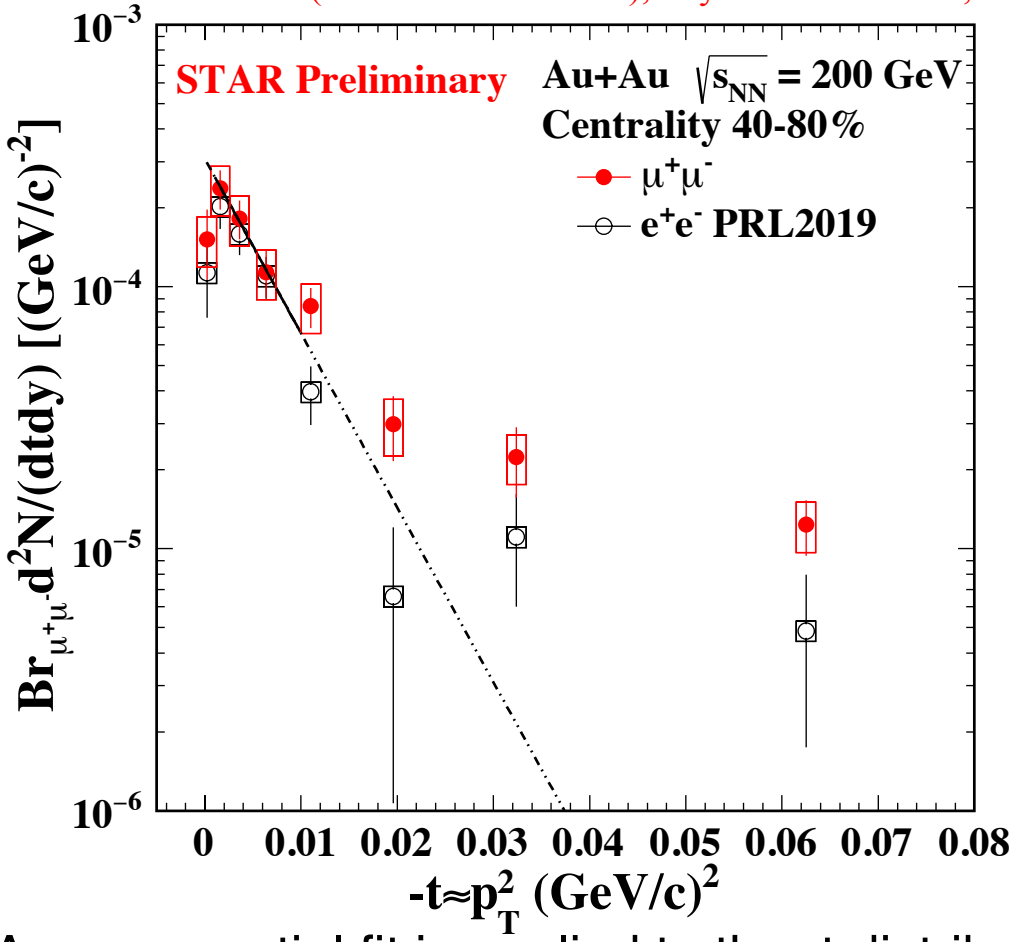




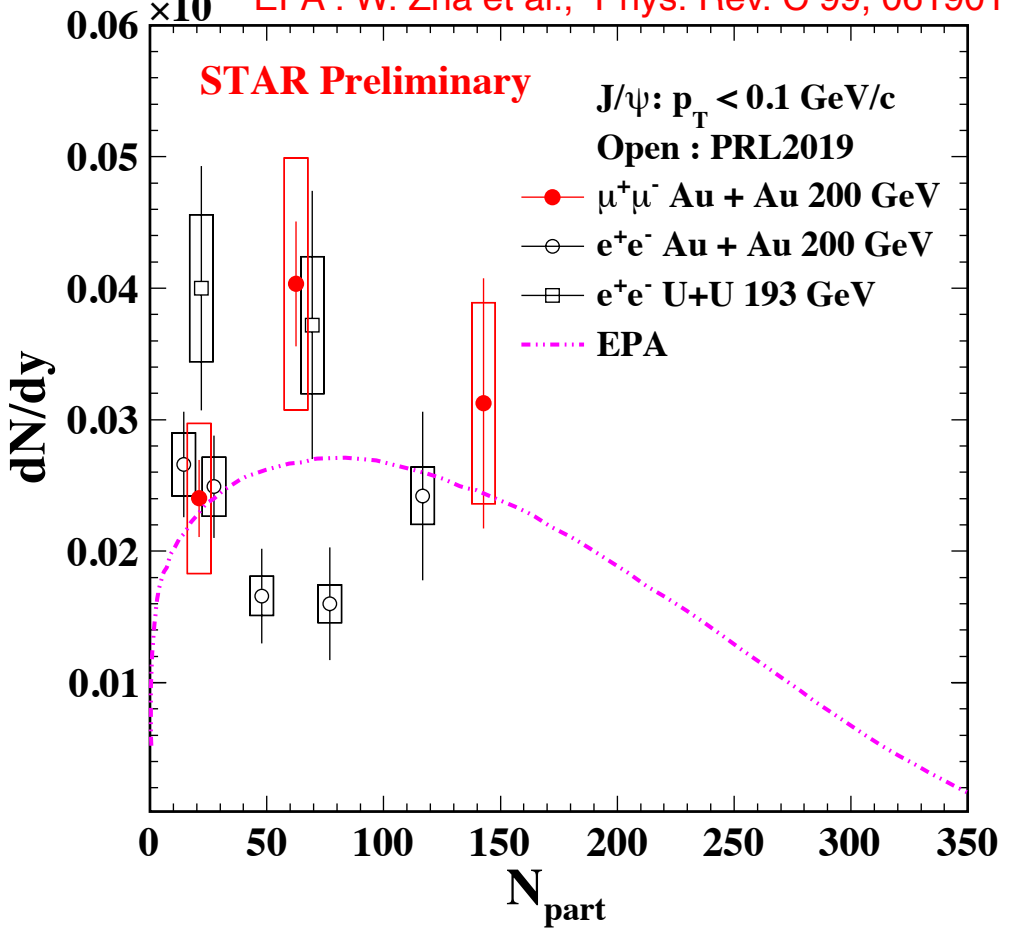
- Significant enhancement at $p_T < 0.2$ GeV/c is observed for J/ψ production with respect to the extrapolation of fit to data for $p_T > 0.2$ GeV/c. Reflected in a large enhancement of R_{AA} above unity.

J/ψ : p_T^2 distribution and excess yield

PRL2019: J. Adam et al. (STAR Collaboration), Phys. Rev. Lett. 123, 132302



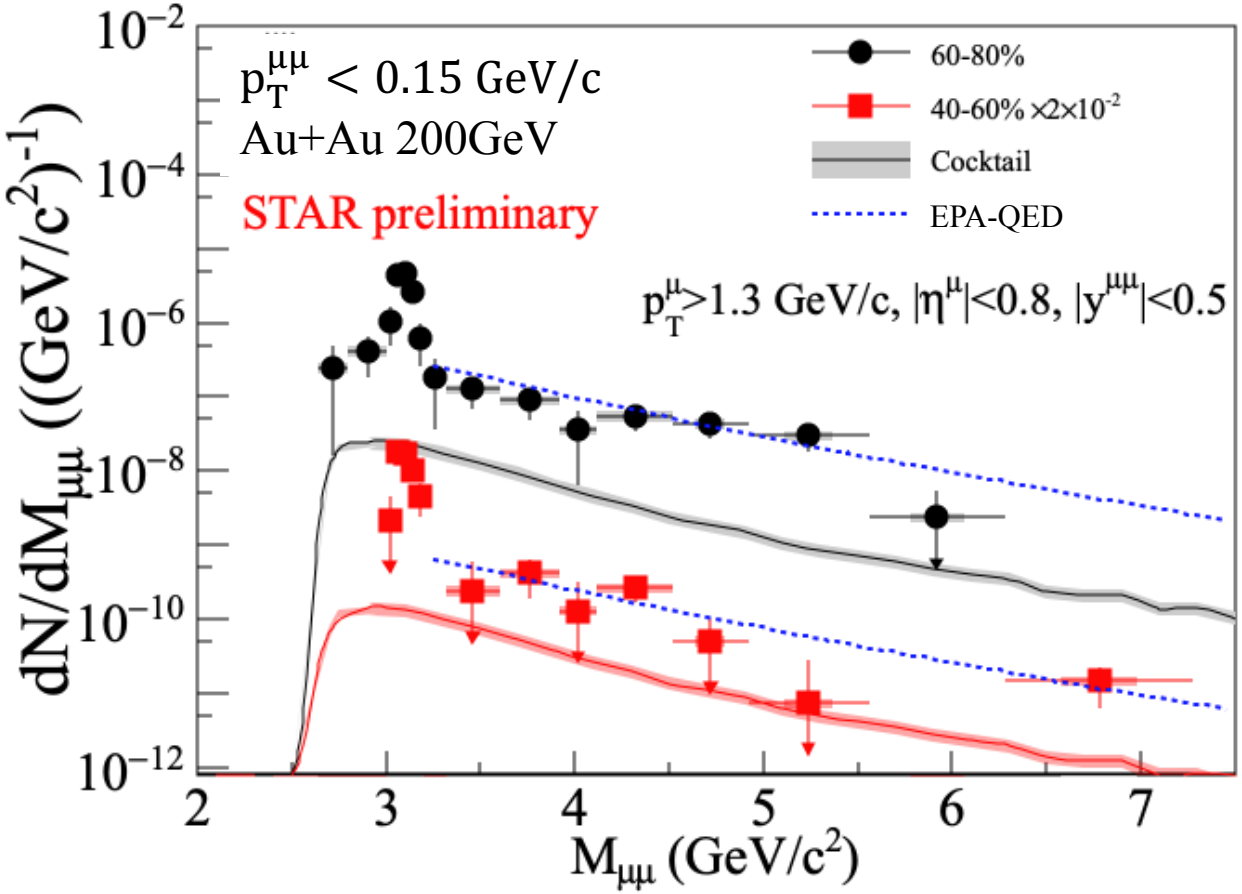
EPA : W. Zha et al., Phys. Rev. C 99, 061901 (2019)



- An exponential fit is applied to the -t distribution, and the slope parameter is 153 ± 55 (GeV/c)$^{-2}$, consistent with that expected for an Au nucleus [199 (GeV/c)$^{-2}$] within uncertainties. The slope parameter is 177 ± 23 (GeV/c)$^{-2}$ from the e^+e^- channel.
- Excess yield consistent with equivalent photon approximation (EPA) calculation.

High mass $\mu^+\mu^-$: Invariant mass spectra

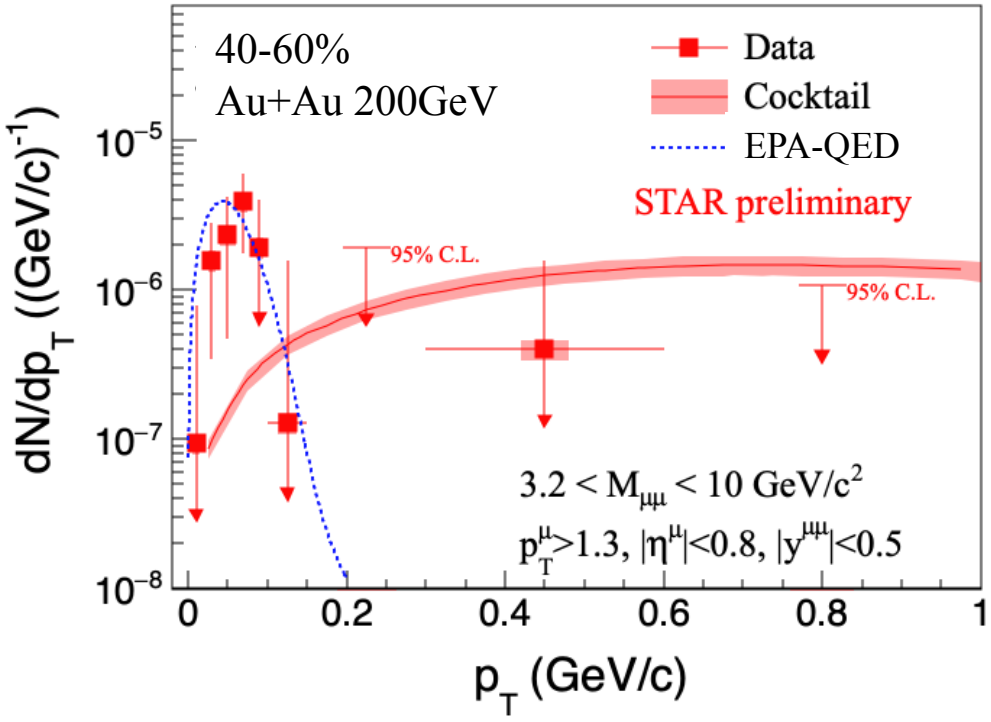
EPA -QED： W. Zha et al., Phys. Lett. B 800, 135089 (2020)

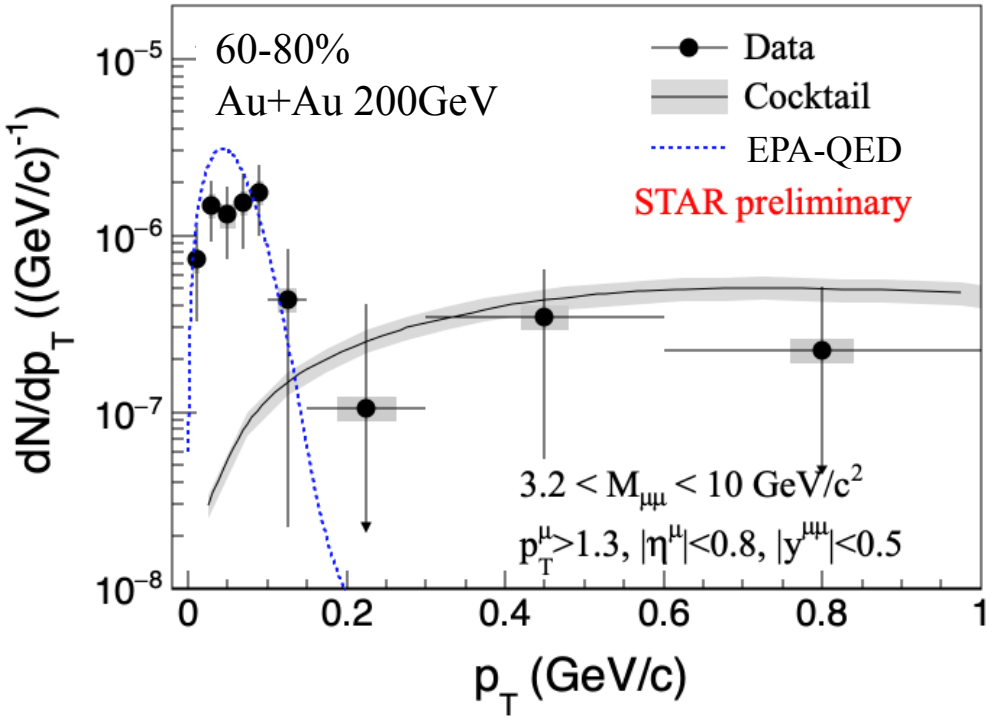


- Significant enhancement with respect to the cocktail in 60-80% centrality.
  - Indication of enhancement in 40-60% centrality
- Consistent with the theoretical calculation.

High mass $\mu^+\mu^-$: p_T distributions

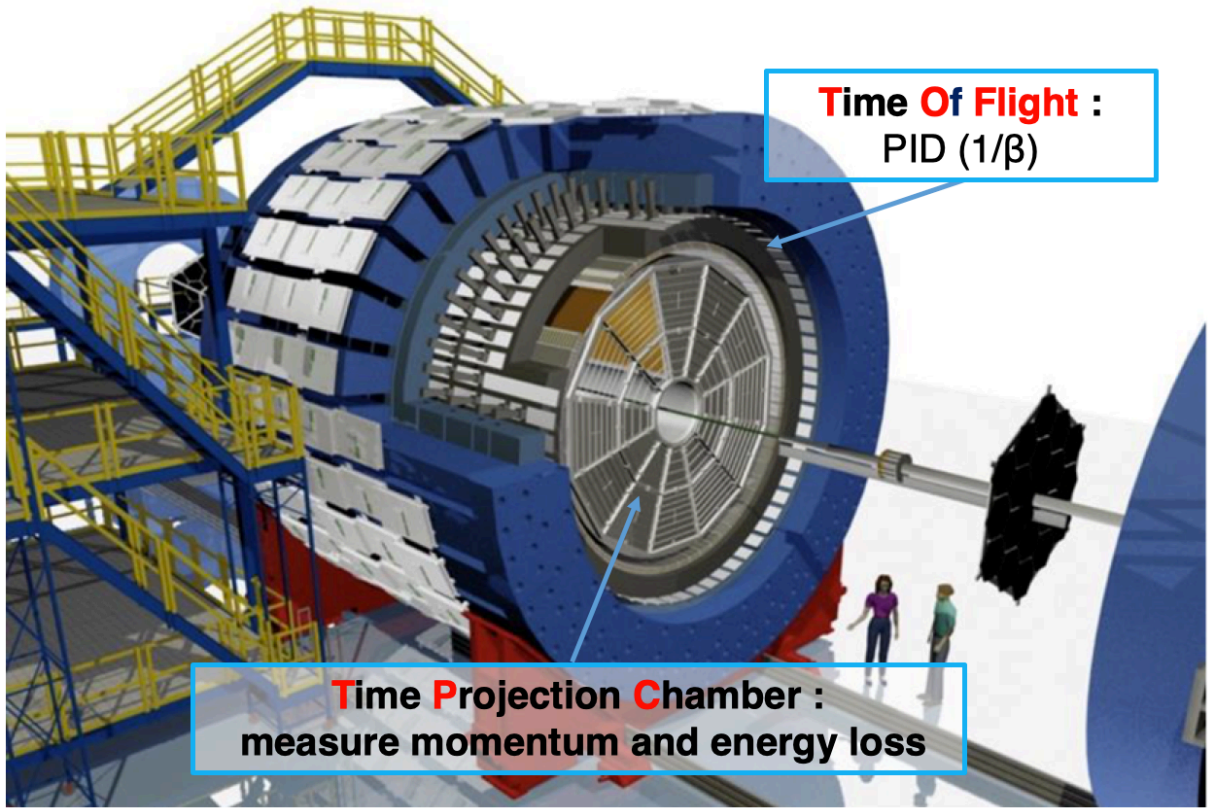
EPA -QED： W. Zha et al., Phys. Lett. B 800, 135089 (2020)



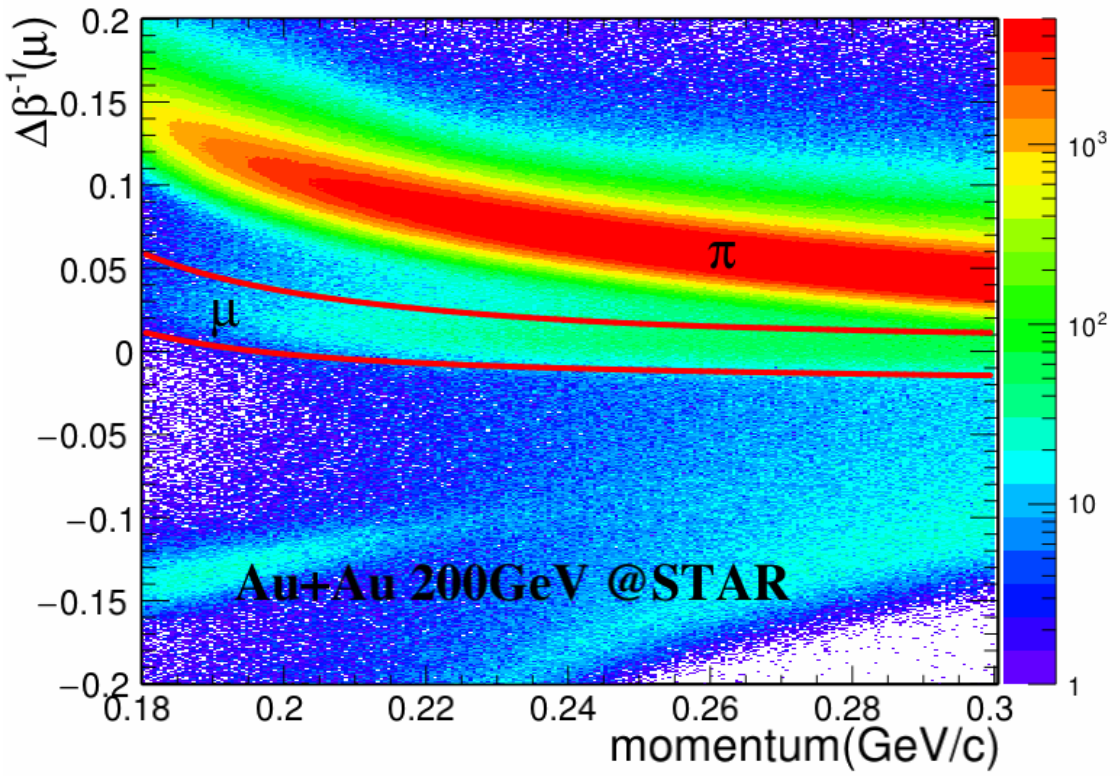


- Excesses concentrate below $p_T \sim 0.1$ GeV/c.
- Data are consistent with hadronic expectation when $p_T > 0.1$ GeV/c.
- EPA-QED calculations are compatible with data.

Muon PID in low momentum region



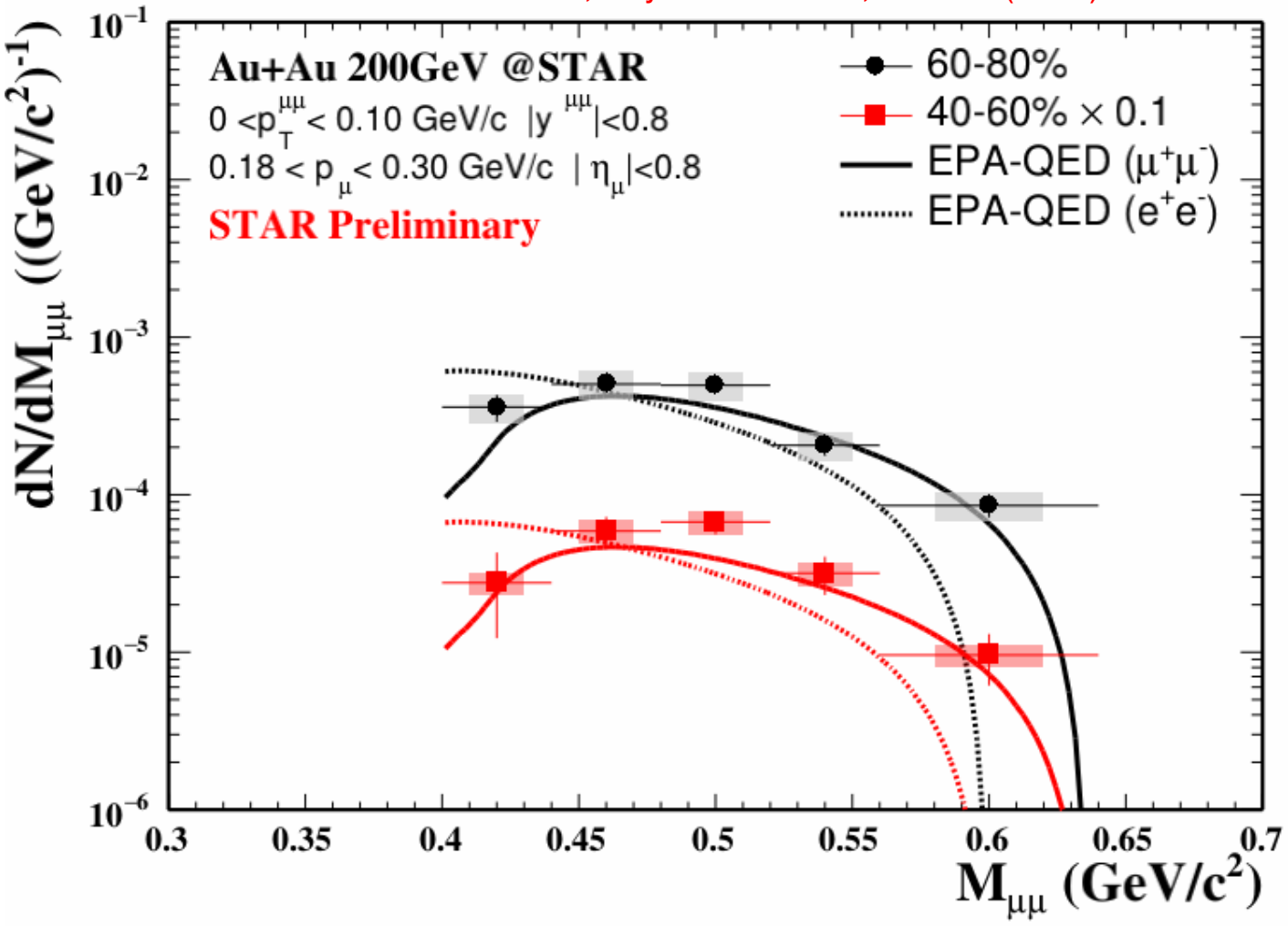
PID cut by TOF



- TPC+TOF : dimuon measurement in low mass region

Low mass $\mu^+\mu^-$: Invariant mass spectra

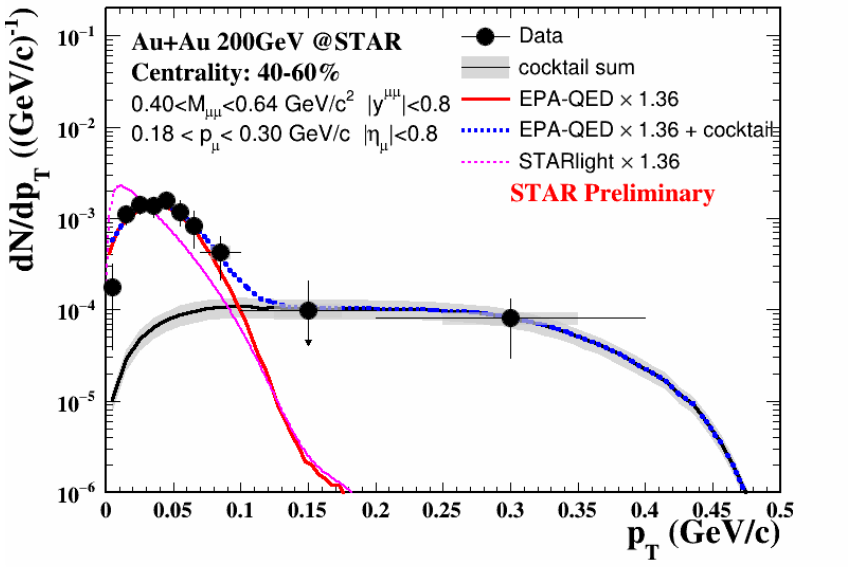
EPA -QED : W. Zha et al., Phys. Lett. B 800, 135089 (2020)

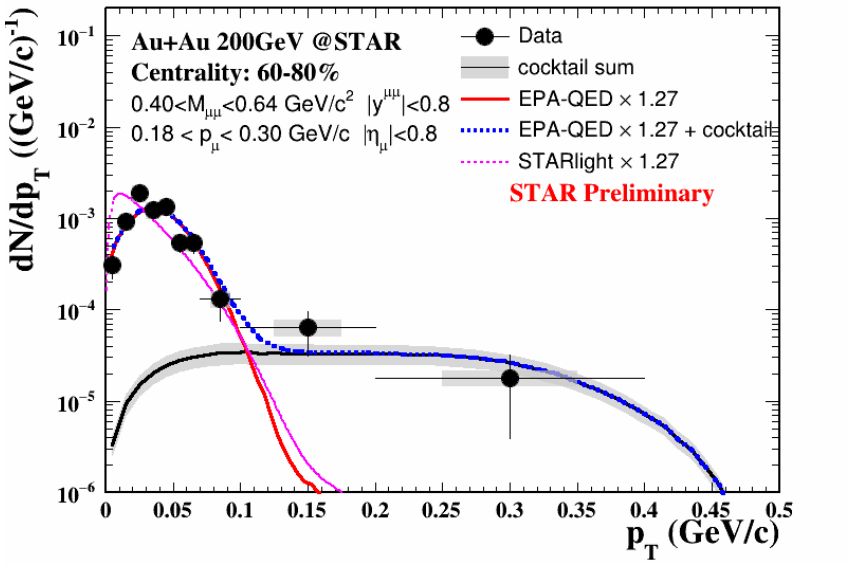


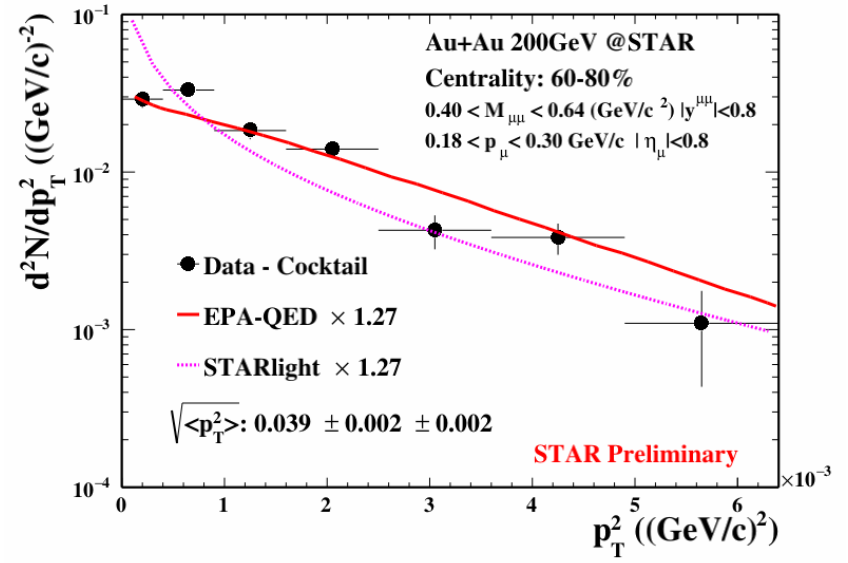
- Excesses (Data - Cocktail) are extracted.
- Consistent with the EPA-QED calculations in different centralities.

Low mass $\mu^+\mu^-$: p_T and t distributions

EPA -QED : W. Zha et al., Phys. Lett. B 800, 135089 (2020)







- Excesses concentrate below $p_T \approx 0.1$ GeV/c
- Data in favor of EPA-QED calculation over STARlight.
- The $\sqrt{< p_T^2 >}$ is consistent with the EPA-QED calculation over STARlight.

Summary

- First measurement of di-muon production in low and high mass range at very low p_T.

- Significant J/ψ and $\mu^+\mu^-$ enhancements are observed at very low p_T in peripheral Au+Au collisions at 200 GeV.

- Compatible with the theoretical calculations with EPA.

Summary

- First measurement of di-muon production in low and high mass range at very low p_T.

- Significant J/ψ and $\mu^+\mu^-$ enhancements are observed at very low p_T in peripheral Au+Au collisions at 200 GeV.

- Compatible with the theoretical calculations with EPA.

Thank you !