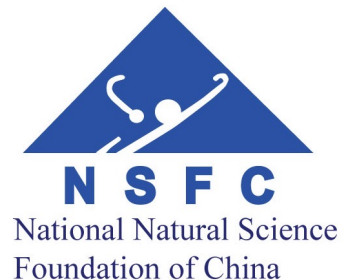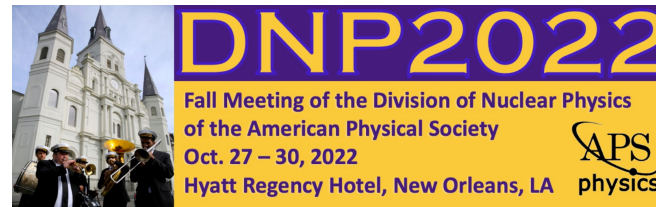# Measurements of the Collision Energy Dependence of the Polarized $\gamma\gamma \to e^+e^-$ Process in Peripheral Au+Au Collisions with the STAR Detector

Xiaofeng Wang (王晓凤)
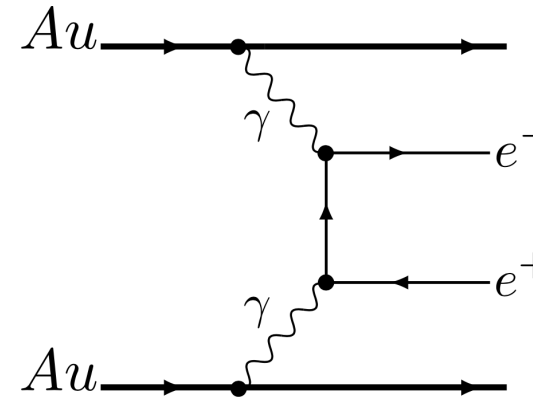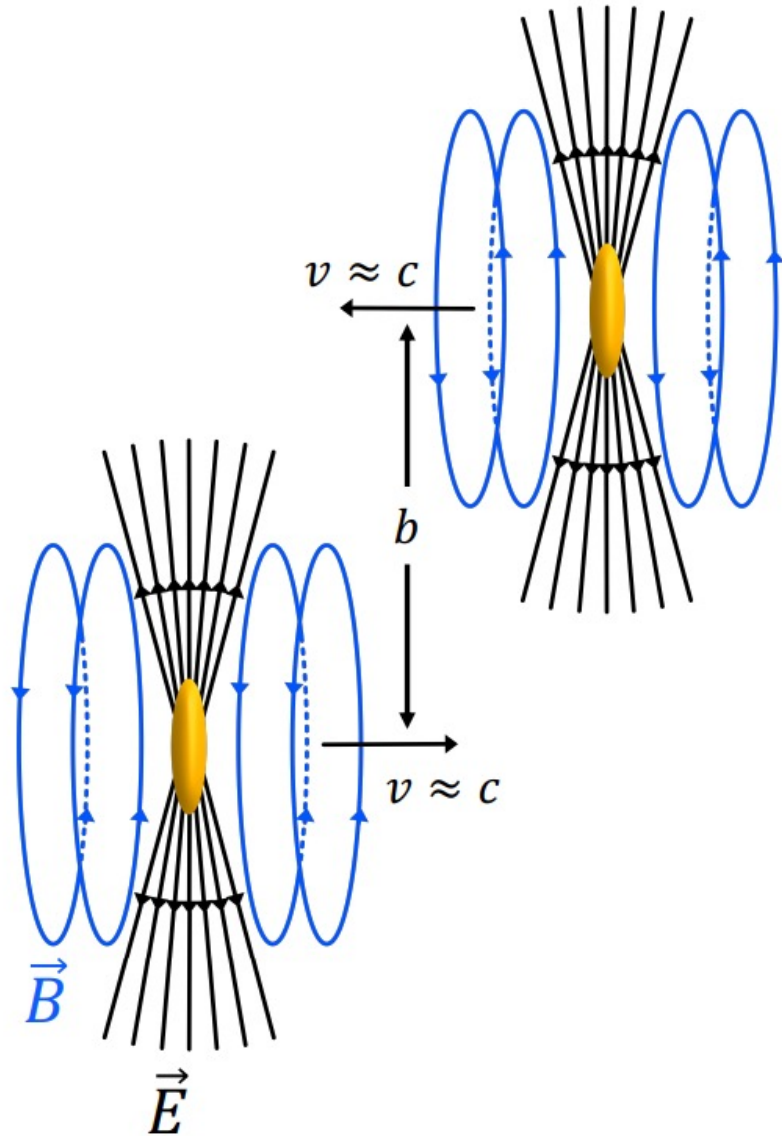
For the STAR Collaboration
Shandong University (山东大学)

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APS physics

NSFC
National Natural Science
Foundation of China

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

- Ultra-relativistic charged nuclei produce highly Lorentz-contracted electromagnetic fields (EM)

- Equivalent Photon Approximation (EPA): EM fields → a flux of **quasi-real photons**

  Weizsäcker, C. F. v. Zeitschrift für Physik 88 (1934): 612

- 1934 Breit & Wheeler : "Collision of two Light Quanta"

  G. Breit and J. A. Wheeler. *Physical Review* 46 (1934): 1087

- High photon density from highly charged nuclei ($\propto Z^2$)

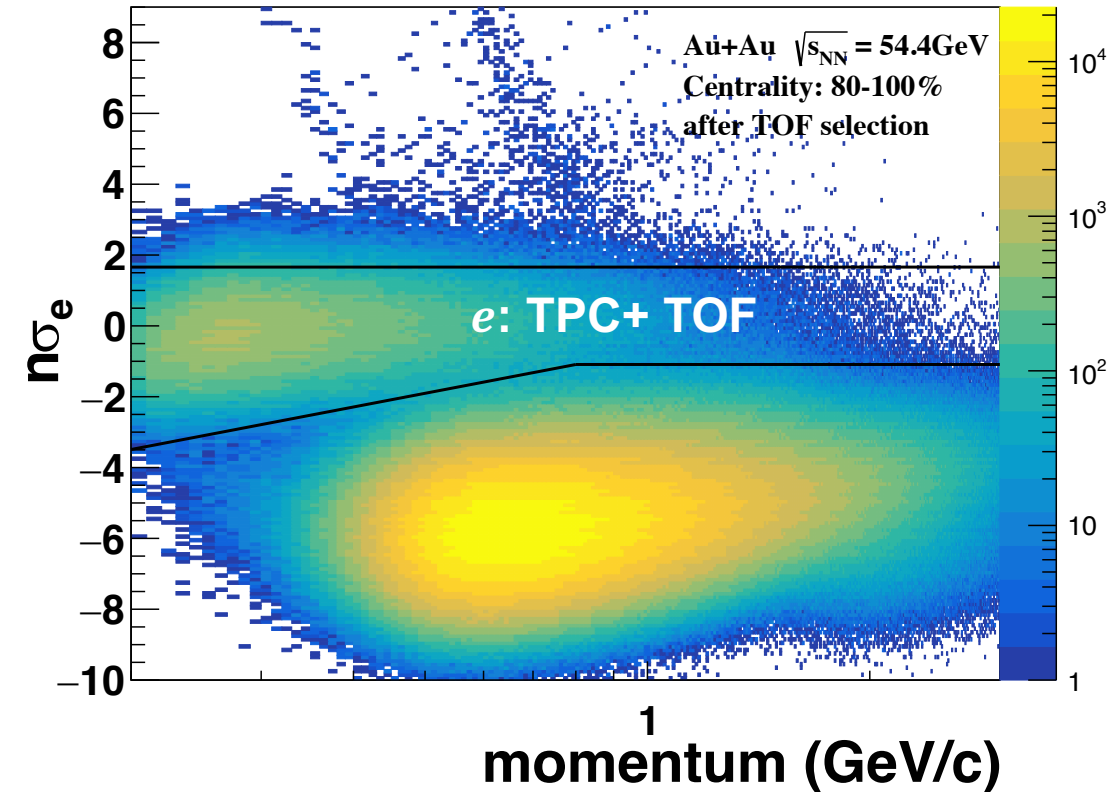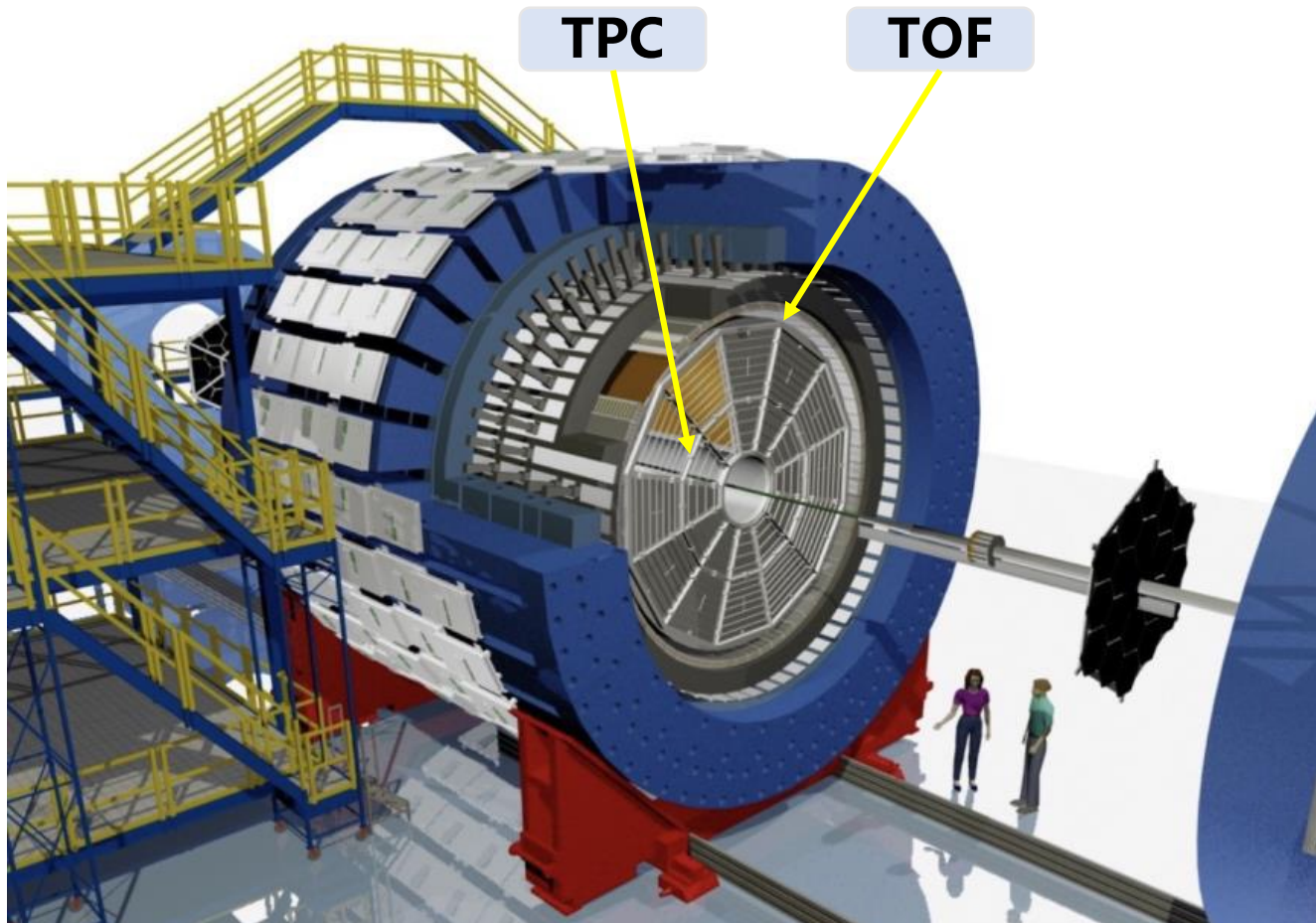# $\gamma\gamma \rightarrow e^+e^-$ in Peripheral Collisions

STAR: Phys.Rev.Lett. 121, 132301 (2018)
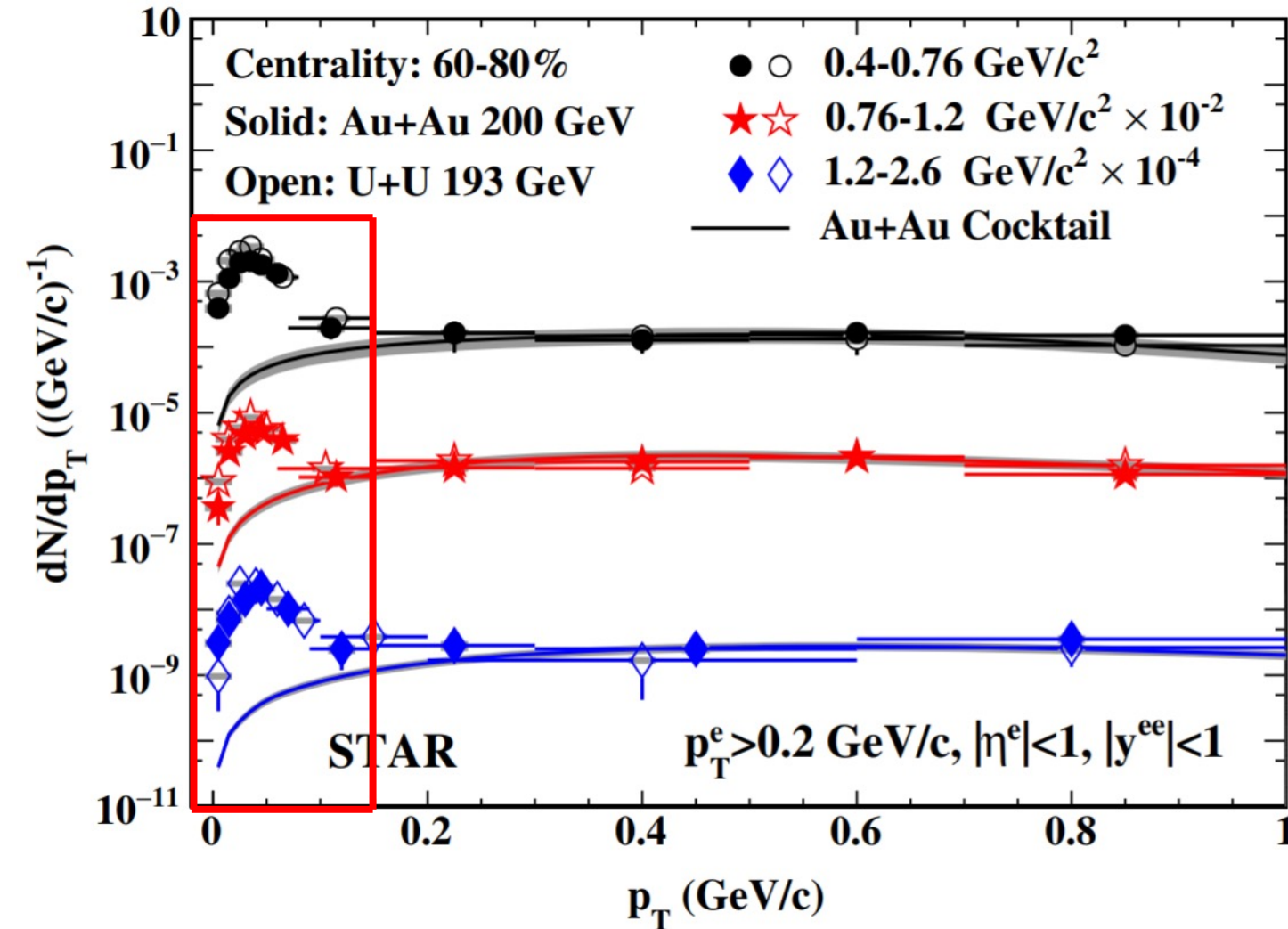
Observation of $\gamma\gamma \rightarrow e^+e^-$ in hadronic heavy ion collisions at STAR

**Energy dependence?
Centrality dependence?**

The Solenoid Tracker At RHIC (STAR) and PID

TPC

TOF

Au+Au $\sqrt{s_{NN}}$ = 54.4GeV
Centrality: 80-100%
after TOF selection

e: TPC+ TOF

$n\sigma_e$

momentum (GeV/c)

Time **P**rojection **C**hamber (**TPC**): momentum and energy loss

Time **O**f **F**light (**TOF**): flight time

Transverse Momentum Distribution

(a) STAR *Preliminary* Au+Au $\sqrt{s_{NN}}$ = 54.4 GeV Centrality: 40-60%

Cocktail
EPA-QED
EPA-QED + Cocktail

(b) STAR *Preliminary* Au+Au $\sqrt{s_{NN}}$ = 54.4 GeV Centrality: 60-80%

$0.4 < M_{ee} < 2.6$ GeV/c^2
$p_T^e > 0.2$ GeV/c, $|\eta^e| < 1$, $|y^{ee}| < 1$

(c) STAR *Preliminary* Au+Au $\sqrt{s_{NN}}$ = 54.4 GeV Centrality: 80-100%

(d) STAR *Preliminary* Au+Au $\sqrt{s_{NN}}$ = 200 GeV Centrality: 80-100%

dN/dp_T ((GeV/c)$^{-1}$)

p_T (GeV/c)

EPA-QED: W. Zha et al, Phys.Lett.B 800 (2020) 135089
X. Wang et al, arxiv:2207.05595

Excesses above hadronic production are observed at low-p_T

Lowest order EPA-QED predictions are consistent with observed excesses

Energy dependence
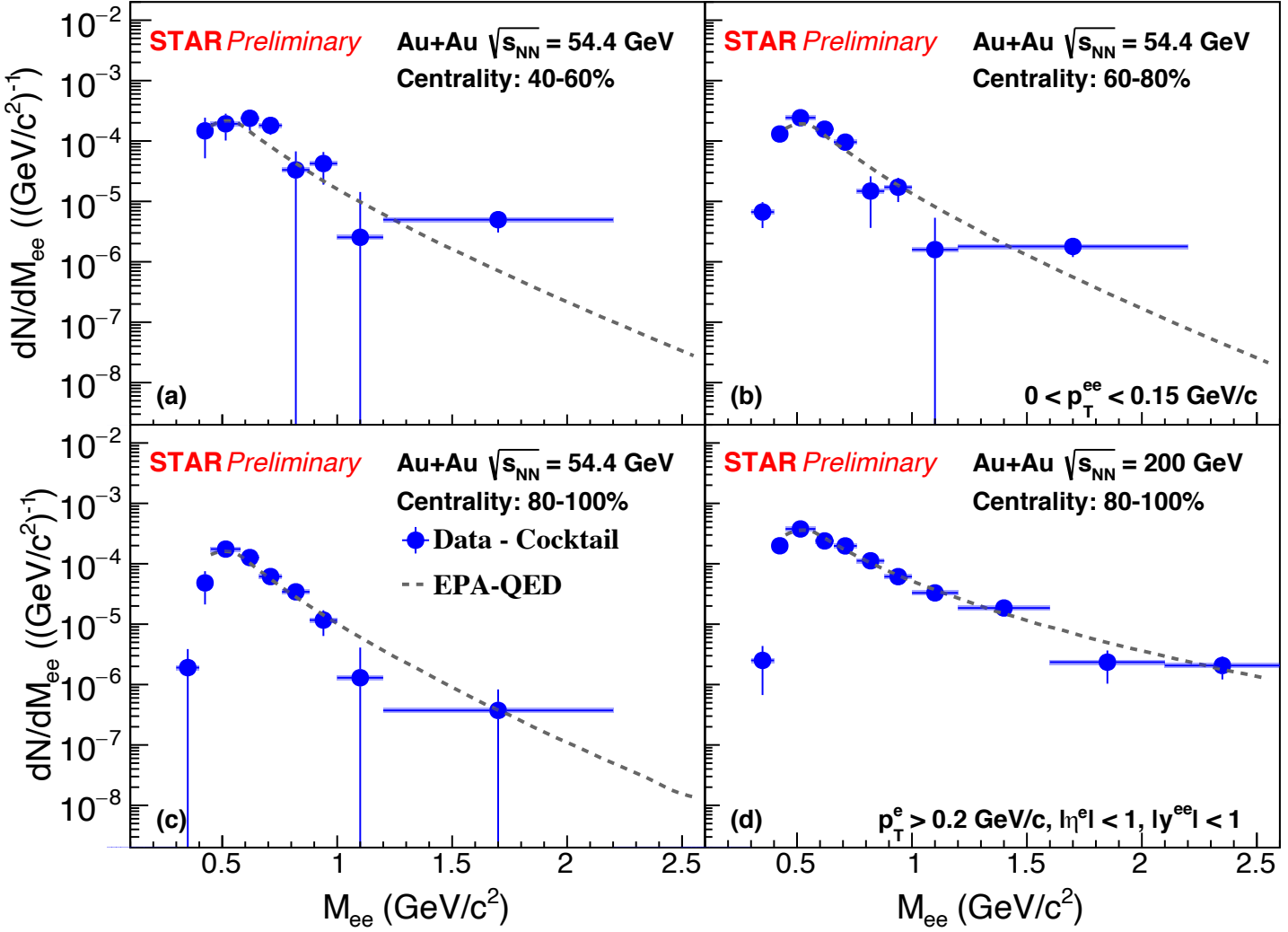54.4 GeV, 200 GeV

Centrality dependence
40-60%, 60-80%, 80-100%

Invariant Mass Distribution at Low-p_T

Excesses (Data - Cocktail) are extracted

No vector meson observed
($\gamma\gamma$ ⟶✕⟶ vector meson)

Excesses are well described by lowest order EPA-QED predictions

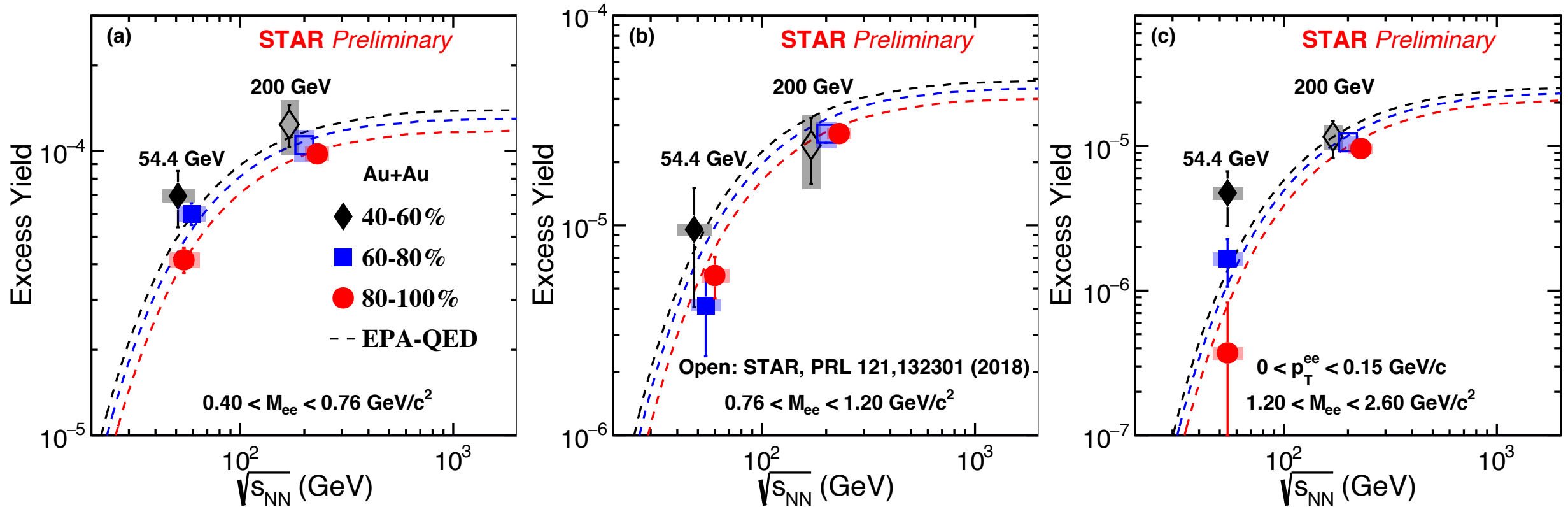EPA-QED: W. Zha et al, Phys.Lett.B 800 (2020) 135089
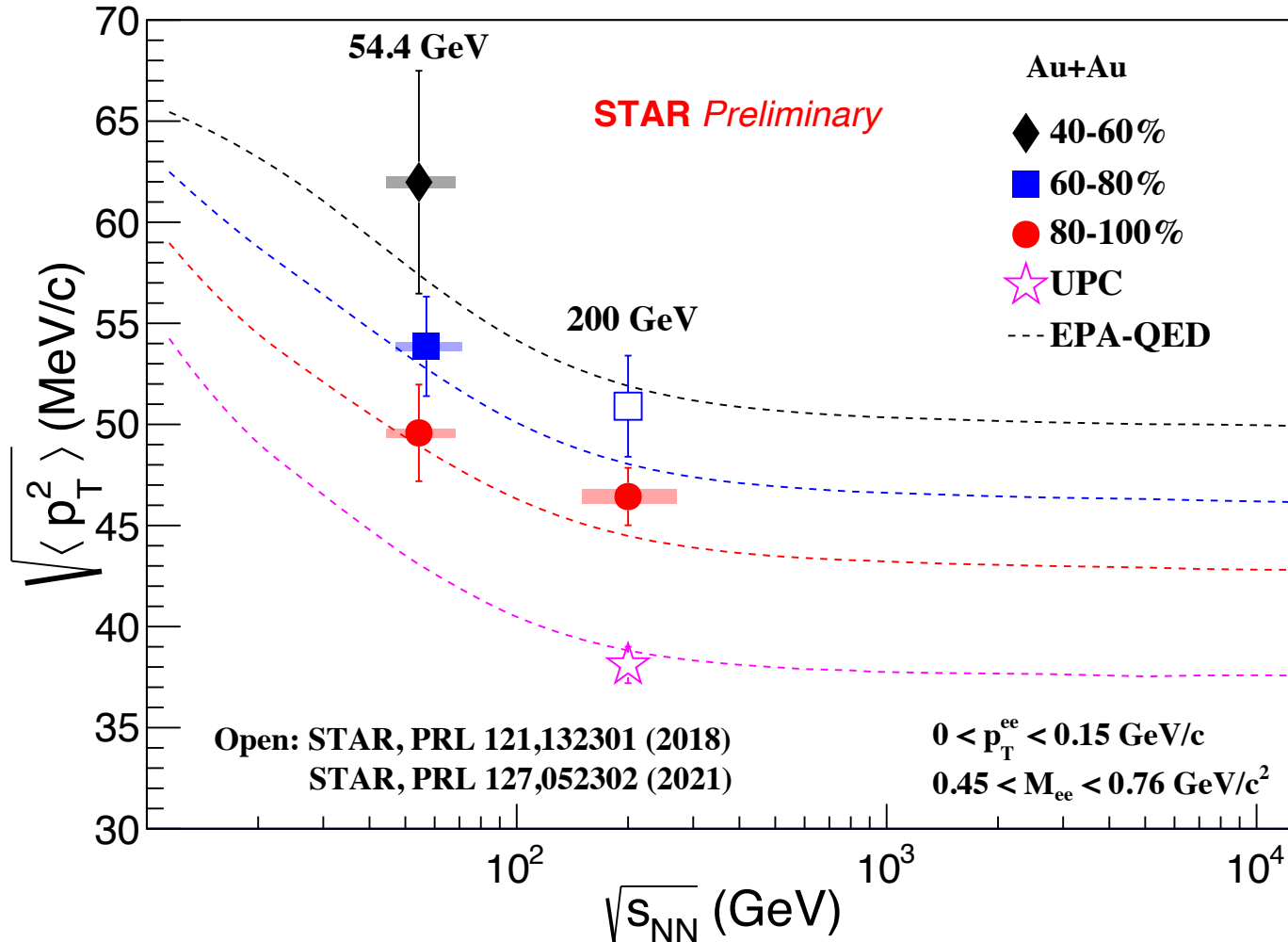X. Wang et al, arxiv:2207.05595

Energy Dependence of Excess Yield

Excess yield increase with beam energy

EPA-QED predicts similar energy dependence

Energy and Centrality Dependence of $\sqrt{\langle p_T^2 \rangle}$

EPA-QED: W. Zha et al, Phys.Lett.B 800 (2020) 135089
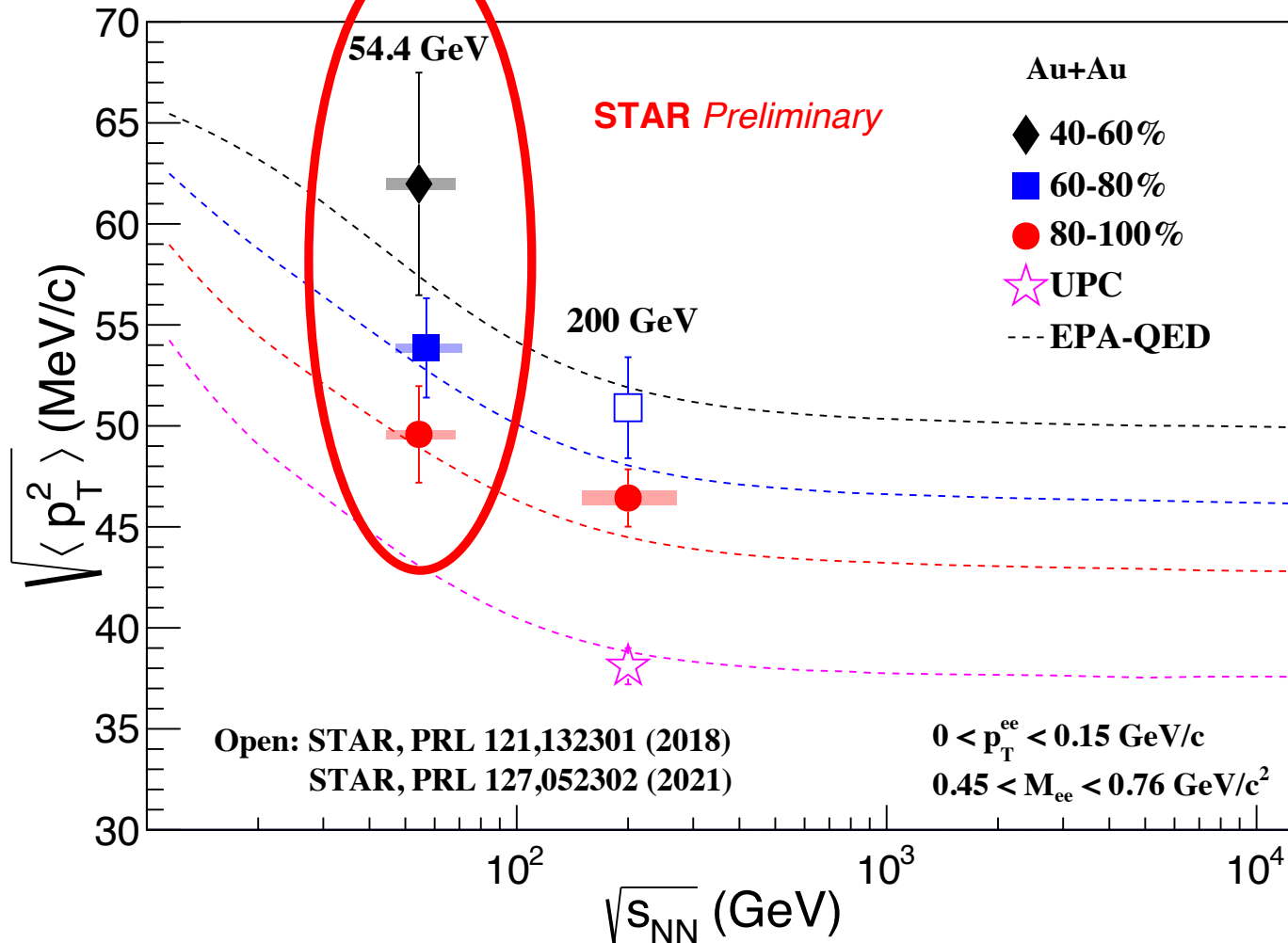X. Wang et al, arxiv:2207.05595

$\sqrt{\langle p_T^2 \rangle}$ is sensitive to p_T broadening

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$\sqrt{\langle p_T^2 \rangle}$ is sensitive to p_T broadening

$\sqrt{\langle p_T^2 \rangle}$ **decreases from semi-peripheral to peripheral collisions**

Initial state effect: Impact parameter dependence

EPA-QED: W. Zha et al, Phys.Lett.B 800 (2020) 135089
X. Wang et al, arxiv:2207.05595

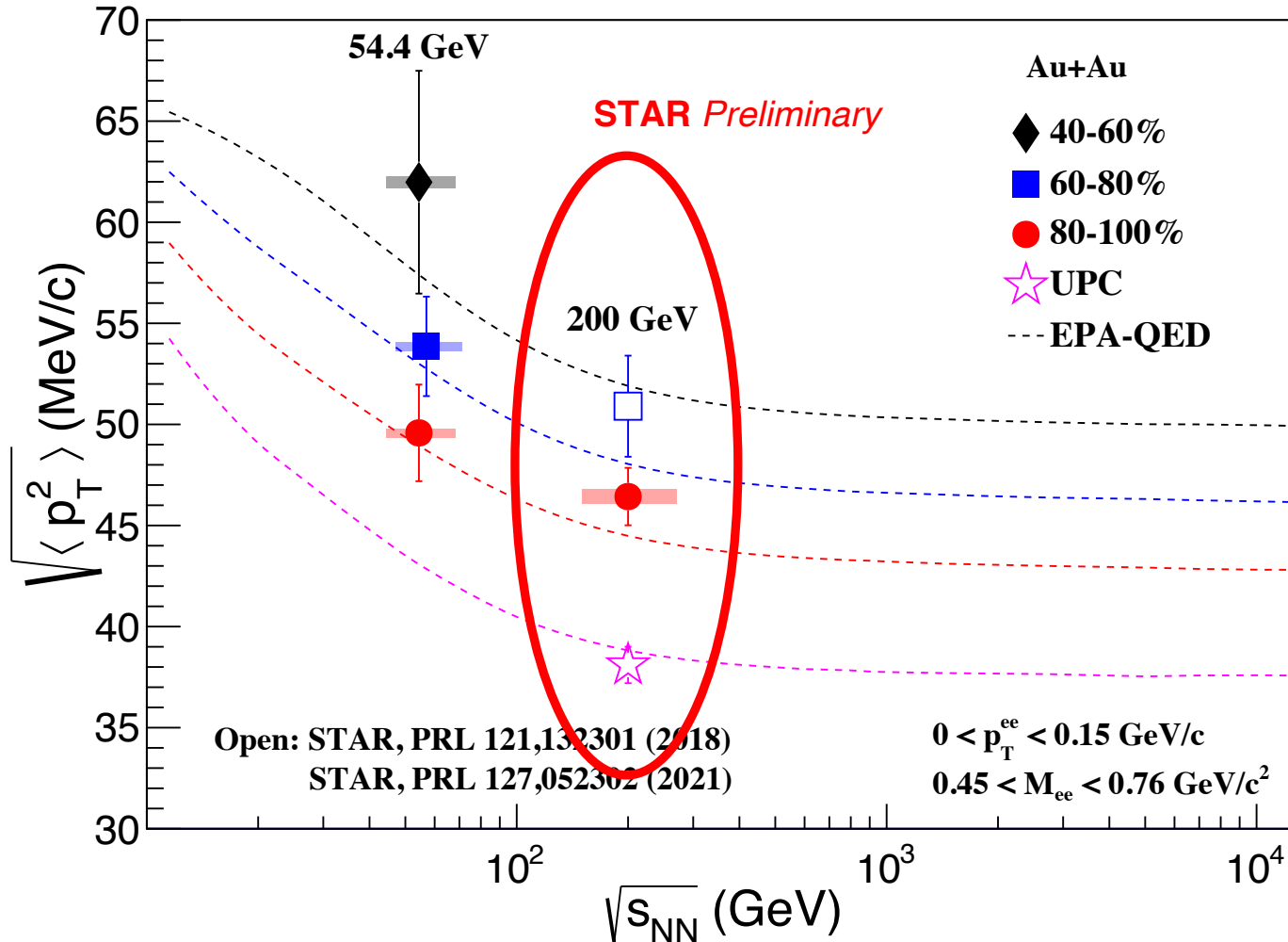$\sqrt{\langle p_T^2 \rangle}$ is sensitive to p_T broadening

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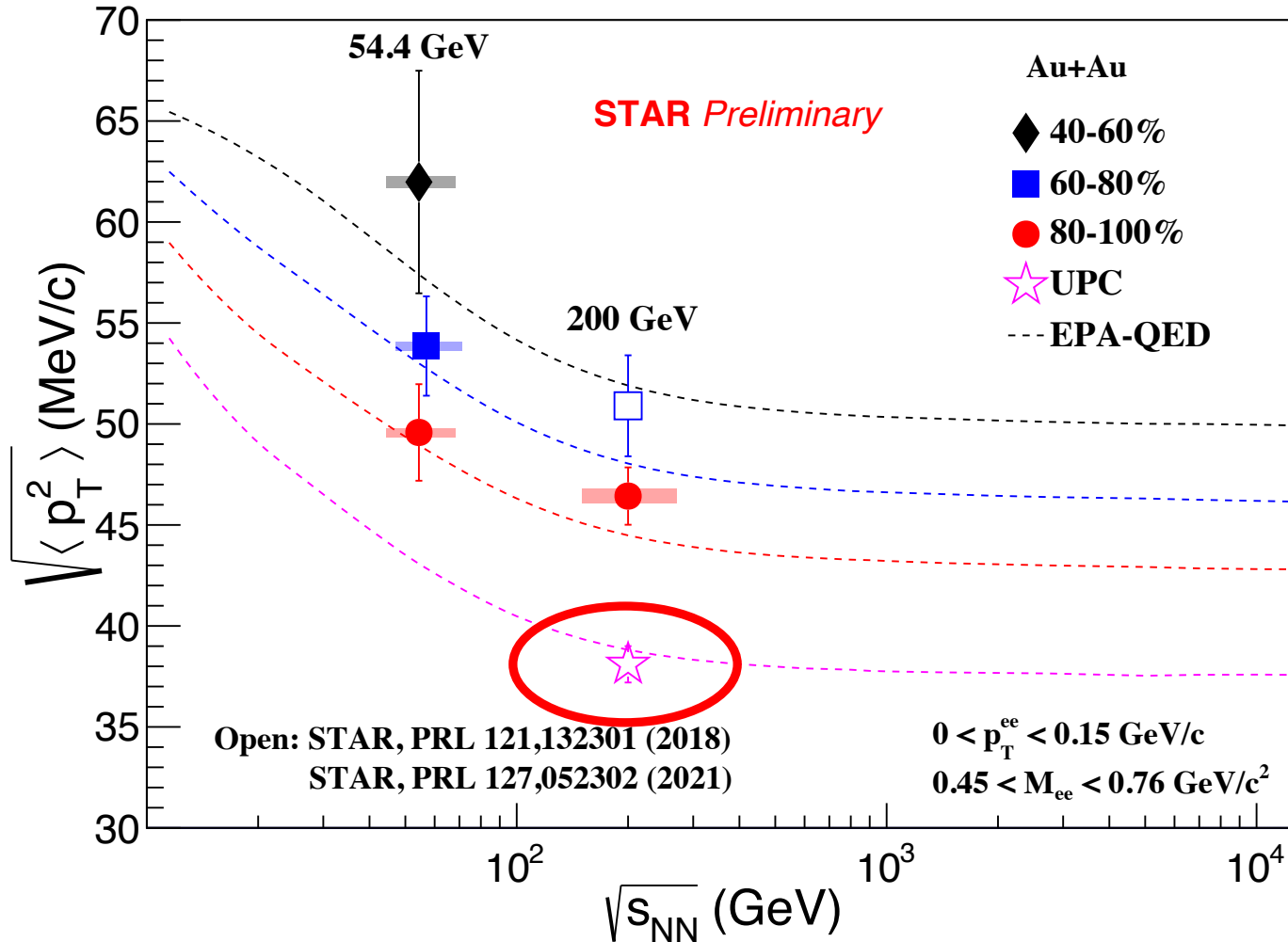$\sqrt{\langle p_T^2 \rangle}$ is sensitive to p_T broadening

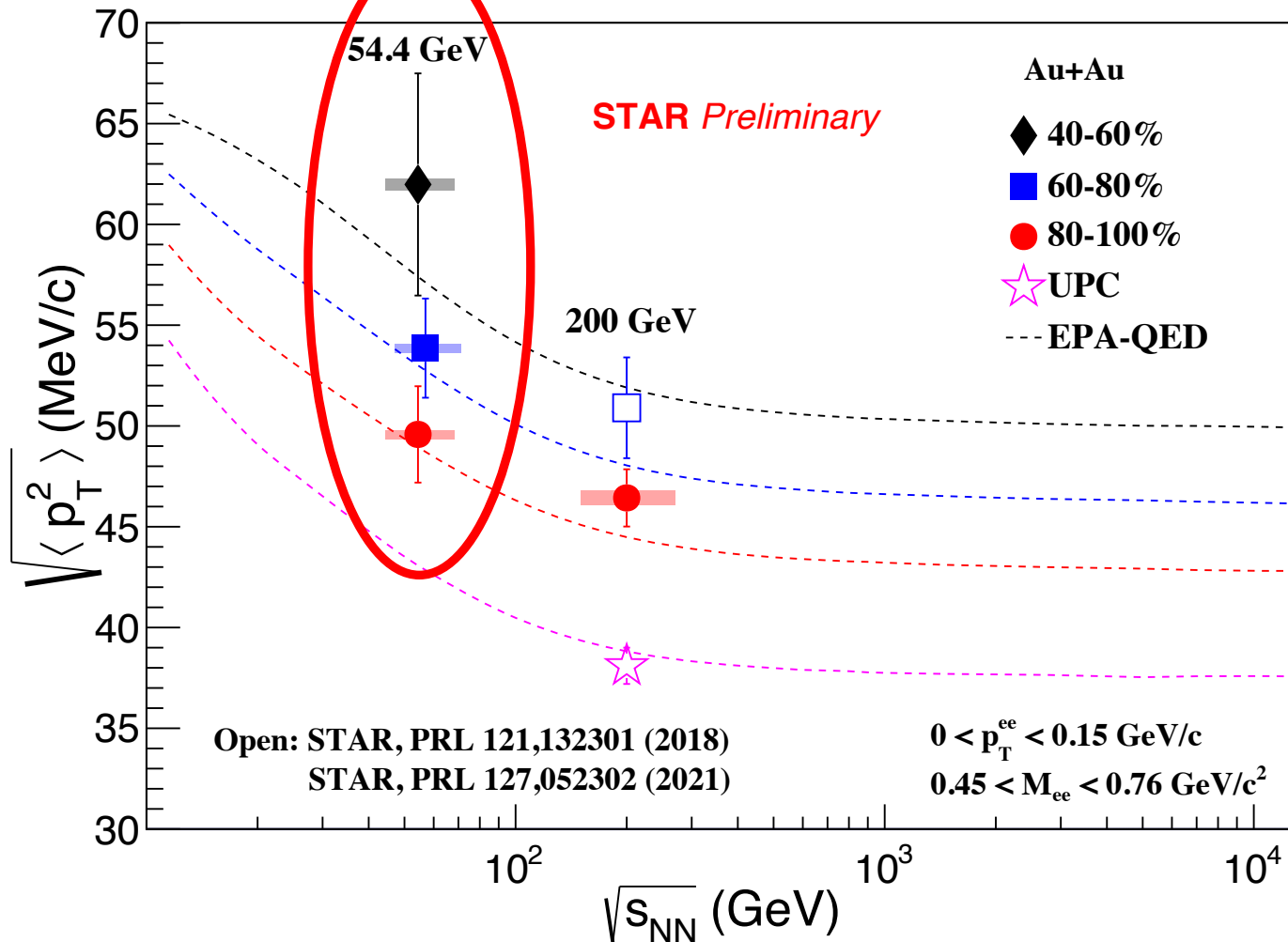$\sqrt{\langle p_T^2 \rangle}$ **decreases from semi-peripheral to peripheral collisions**

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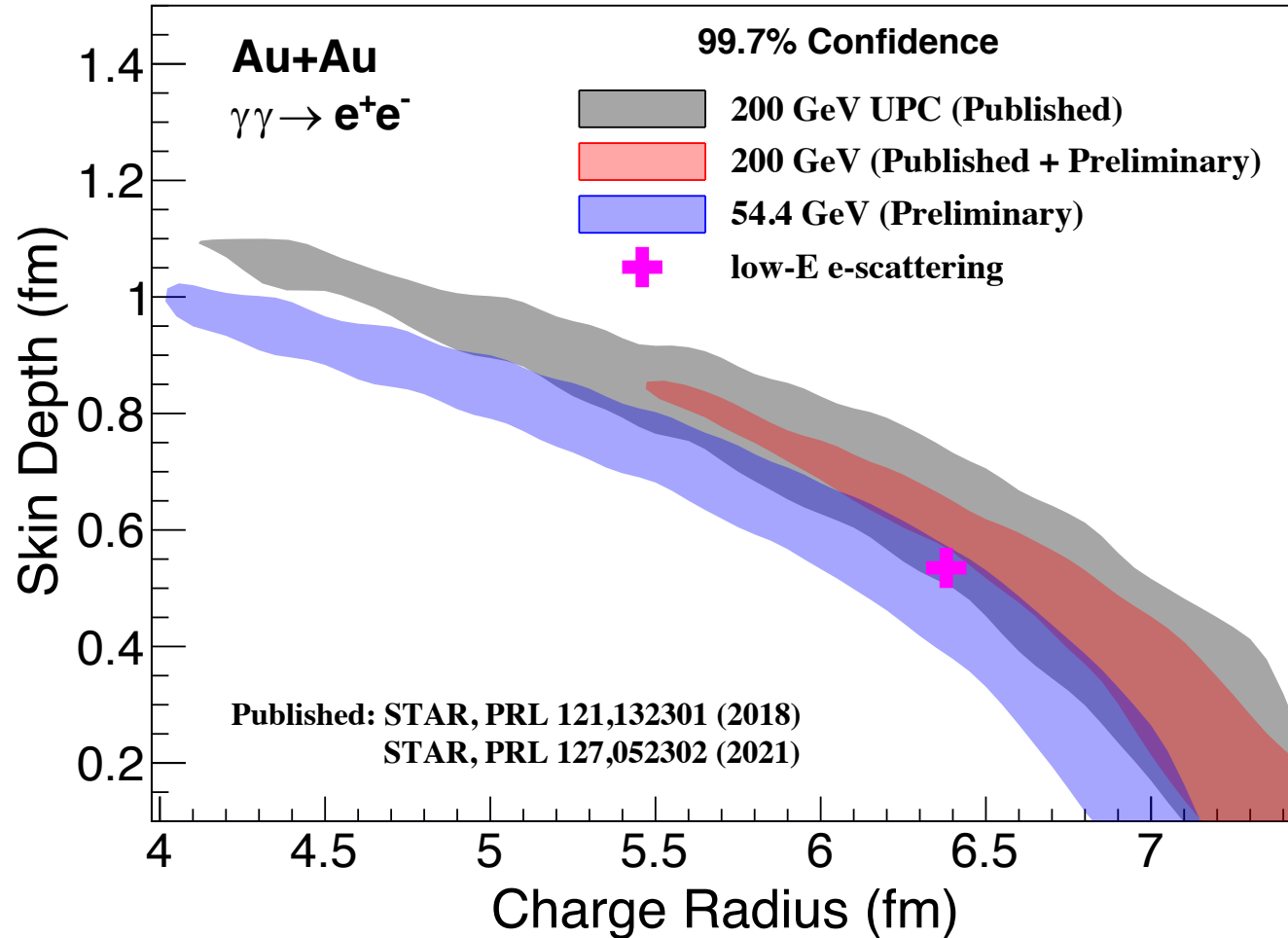
Initial state effect: Impact parameter dependence

Energy dependence and possible final state effect (3.7σ compared to 200 GeV QED)

Application: Constrain Charge Distribution

$\gamma\gamma \to e^+e^-$ **can be used to constrain nucleus charge distribution at RHIC energy**

STAR data compared to EPA-QED

Low energy scattering: R=6.38 fm, d=0.535 fm

R. C. Barrett and D. F. Jackson, Nuclear Sizes and Structure (Oxford University Press, 1977)

200 GeV vs 54.4 GeV: maybe due to energy dependence of charge distribution

Low-energy vs RHIC 200 GeV (3σ difference): maybe due to energy dependence of charge distribution and/or final state effect

Summary

- Beam energy and centrality dependences of $\gamma\gamma \to e^+e^-$ have been measured at STAR

  - ✓ Excess yield: Increases with beam energy

  - ✓ $\sqrt{\langle p_T^2 \rangle}$: Decreases with increasing impact parameter

  - ✓ $\sqrt{\langle p_T^2 \rangle}$: **Energy dependence and possible final state effect** (3.7σ compared to 200 GeV QED)

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Thanks for your attention!