Recent Measurements of Photoproduction Processes at RHIC

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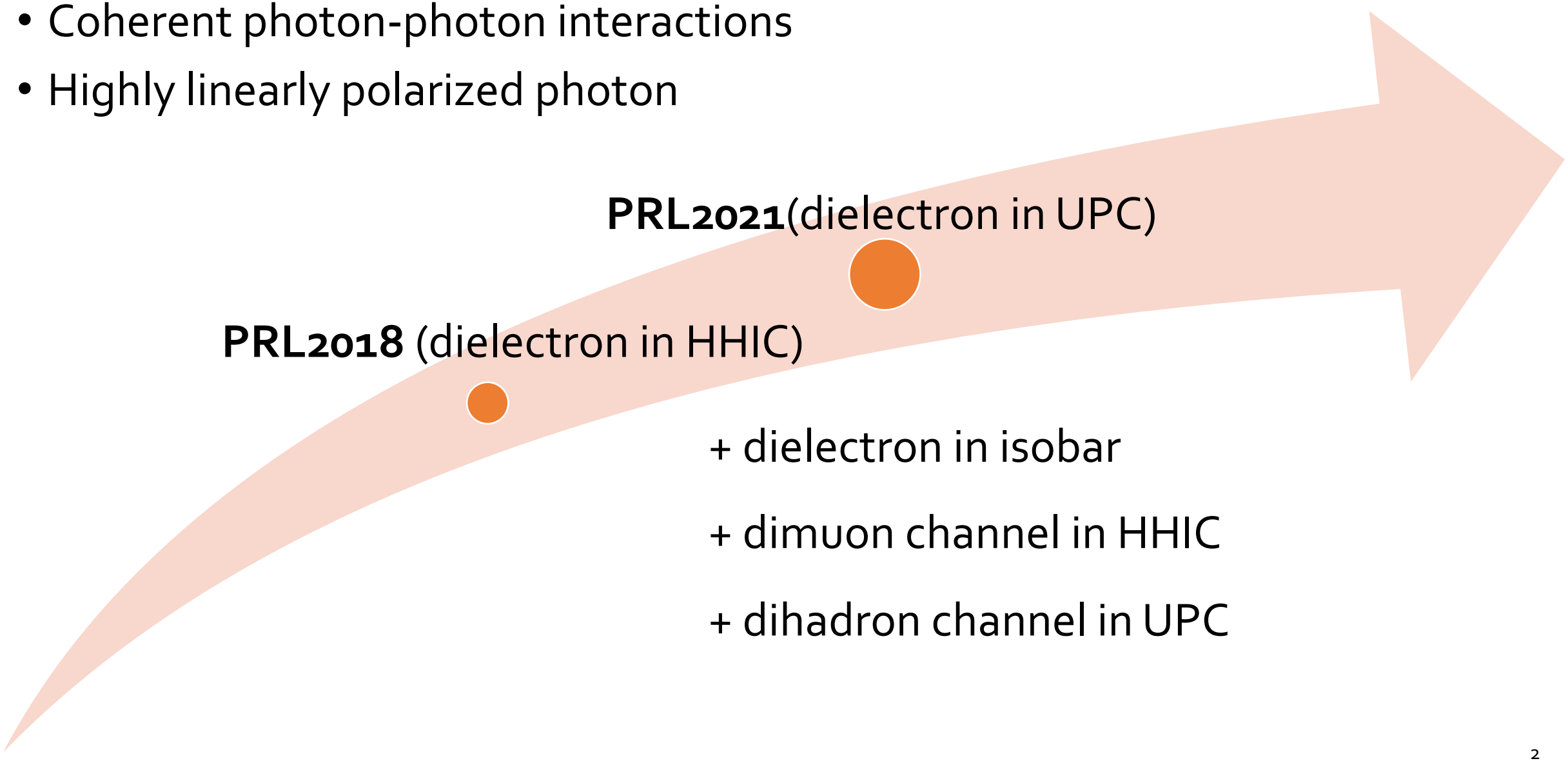
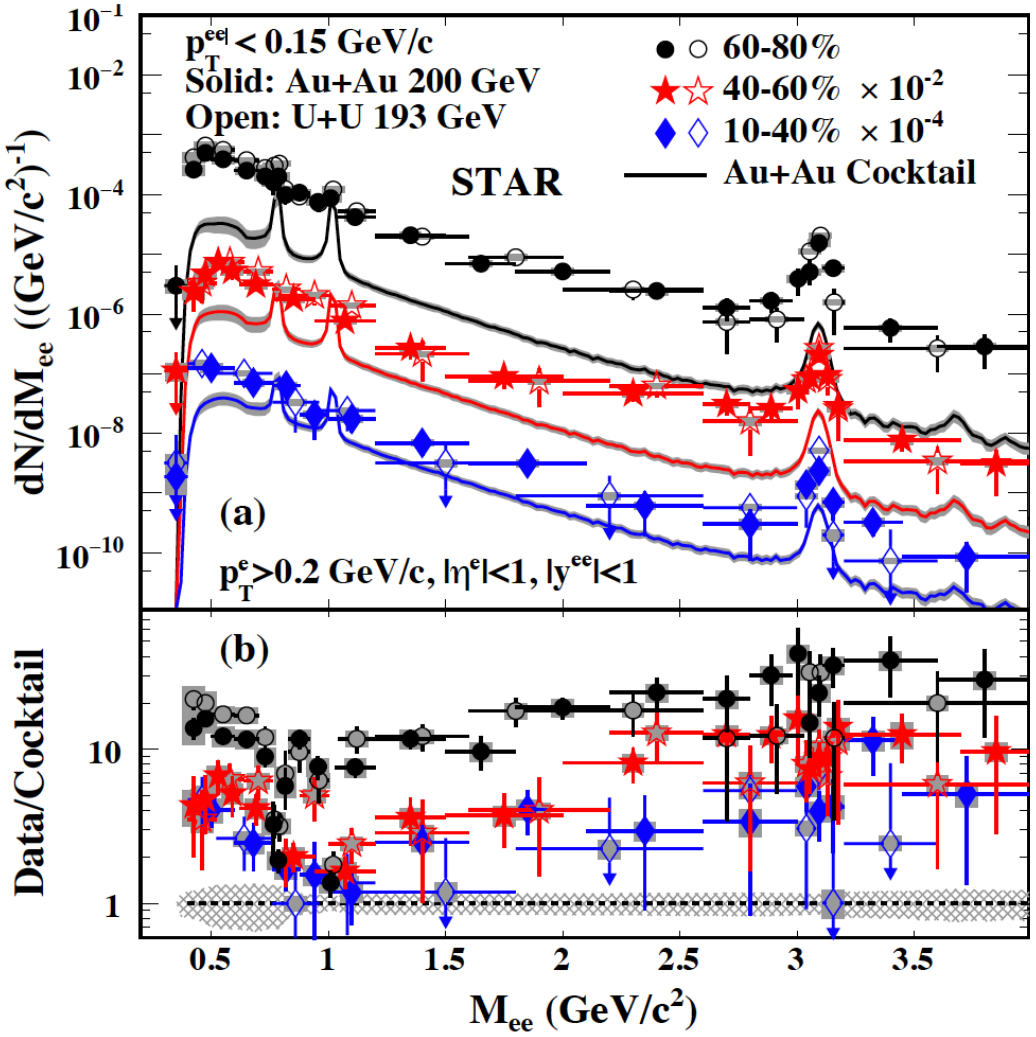
(Polarized) photon-photon interactions

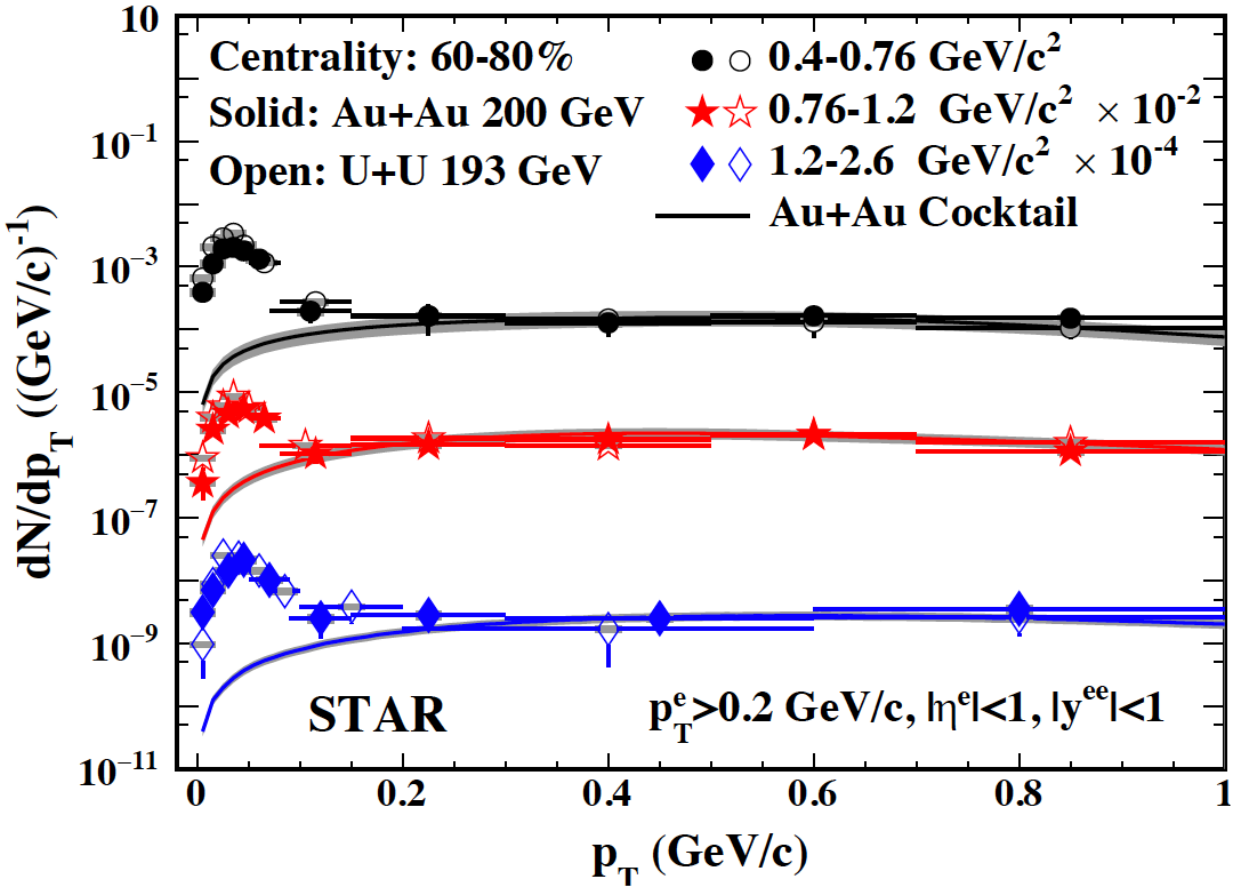
- Coherent photon-photon interactions
- Highly linearly polarized photon



Coherent Low p_T e^+e^- in Au+Au and U+U

STAR, PRL 2018

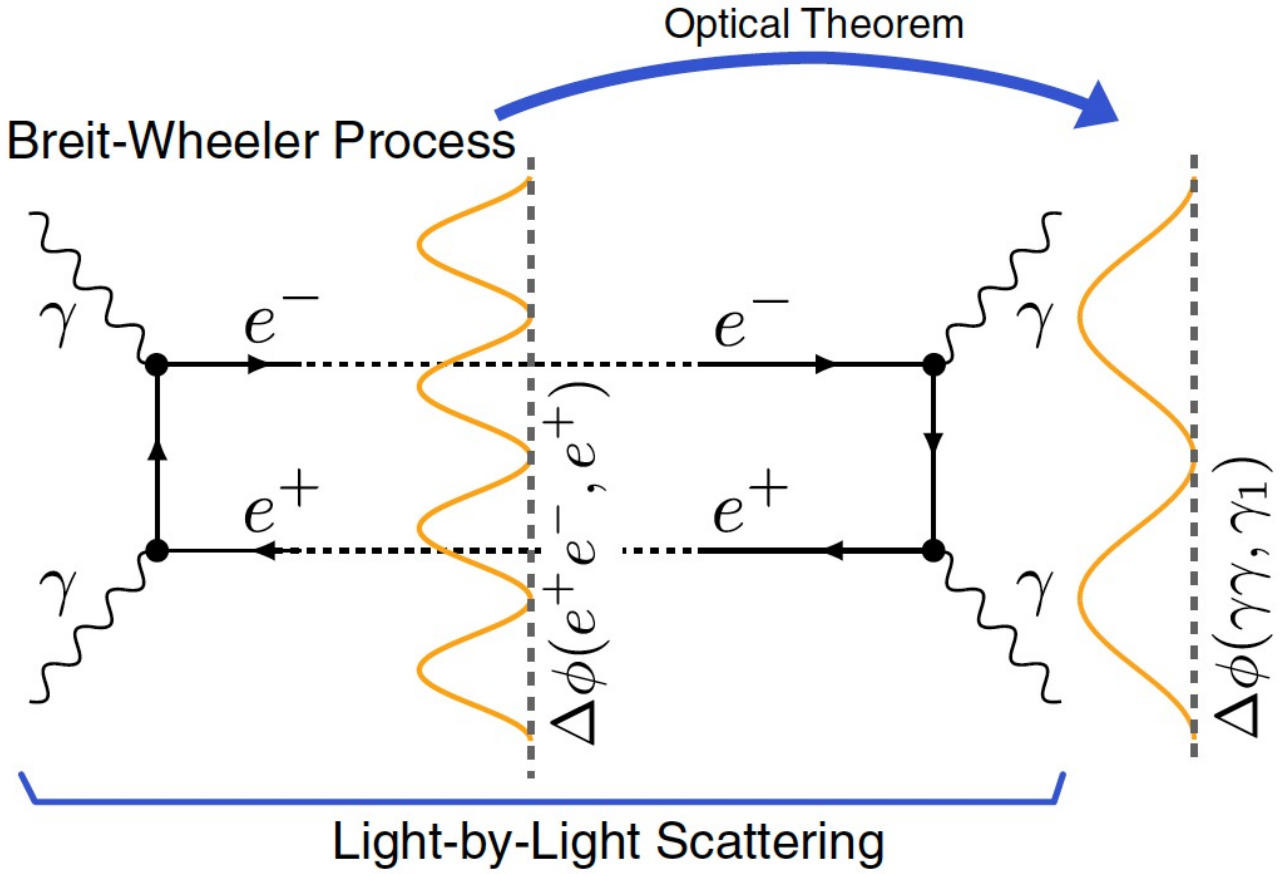


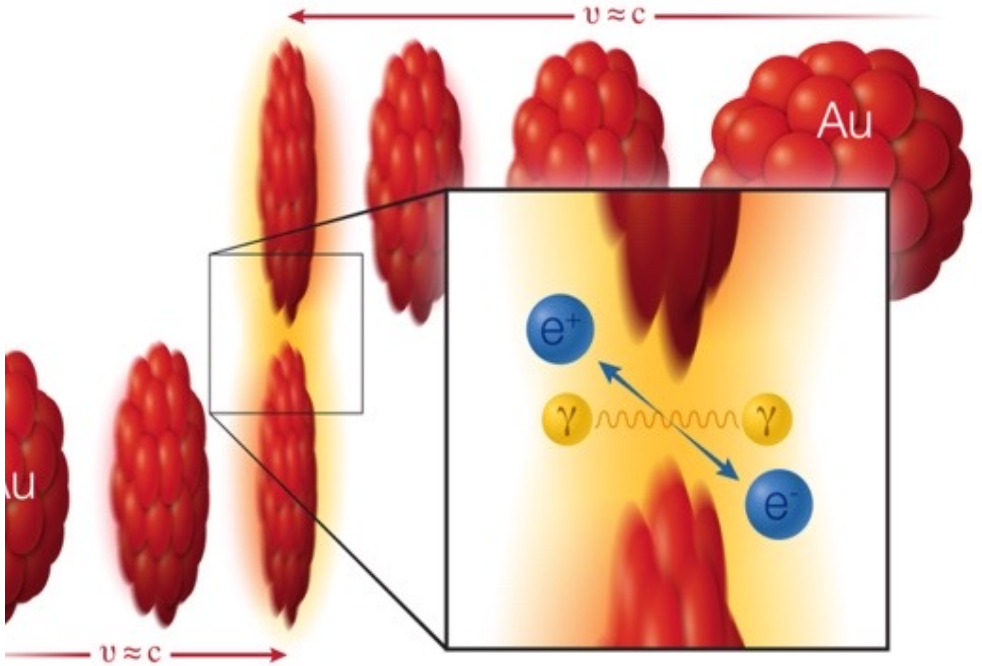


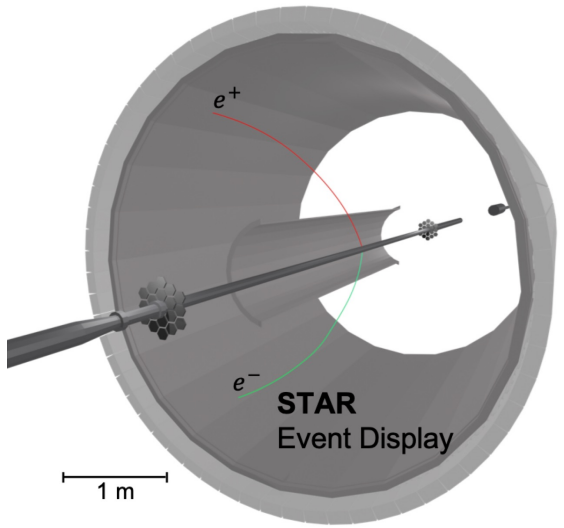
Coherent photon-photon interactions observed in HHIC

Search for Breit-Wheeler Process at RHIC-STAR

STAR, PRL 2021

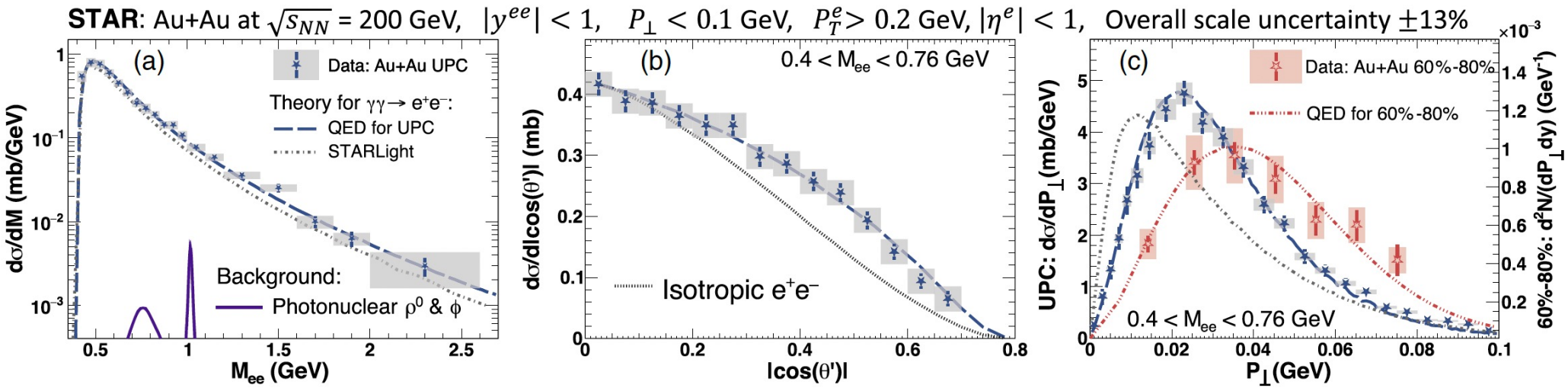


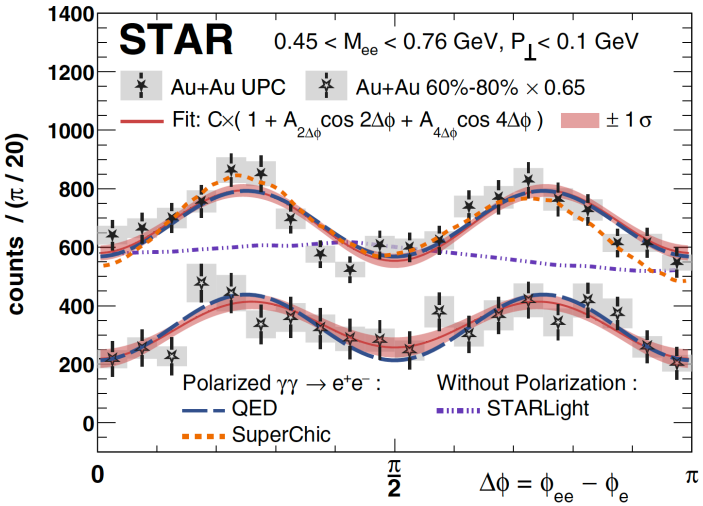




A Feynman diagram for the exclusive Breit-Wheeler process and the related light-by-light scattering process illustrating the unique angular distribution predicted for each process due to the initial photon polarization.

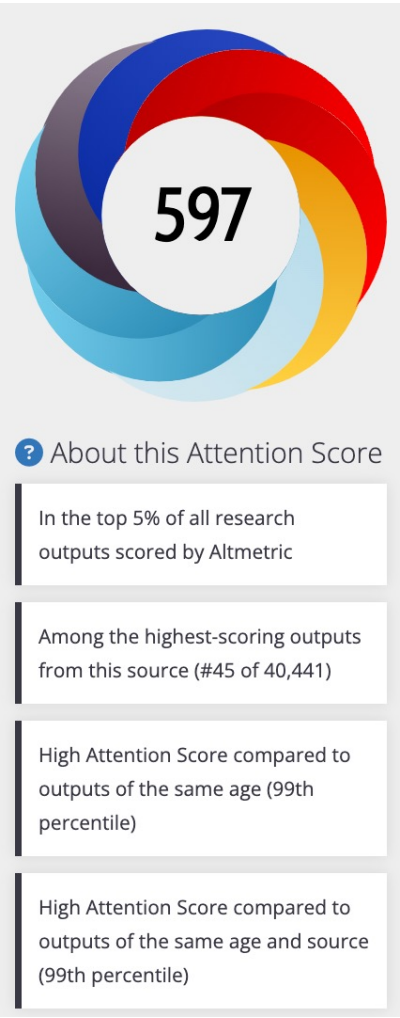
Search for Breit-Wheeler Process at STAR





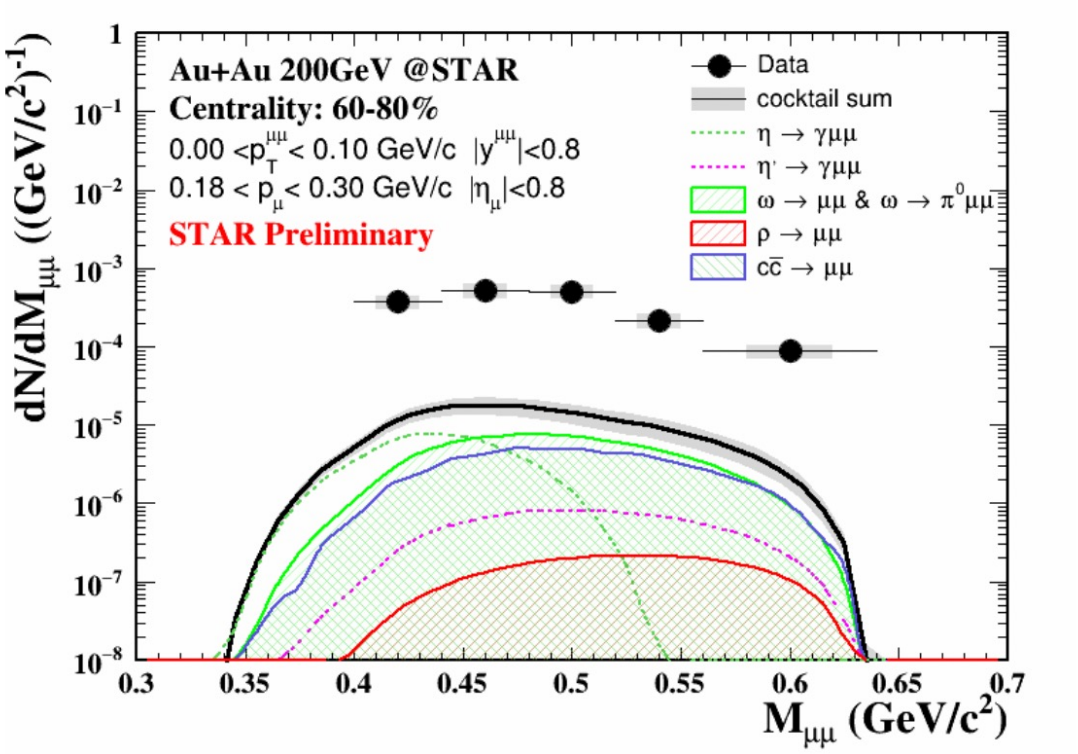
- Observe 6085 exclusive e^+e^- pairs from data collected in 2010
- No vector meson contribution visible
- Energy spectrum
- Photon transverse polarization & spatial distribution

STAR, PRL 2021

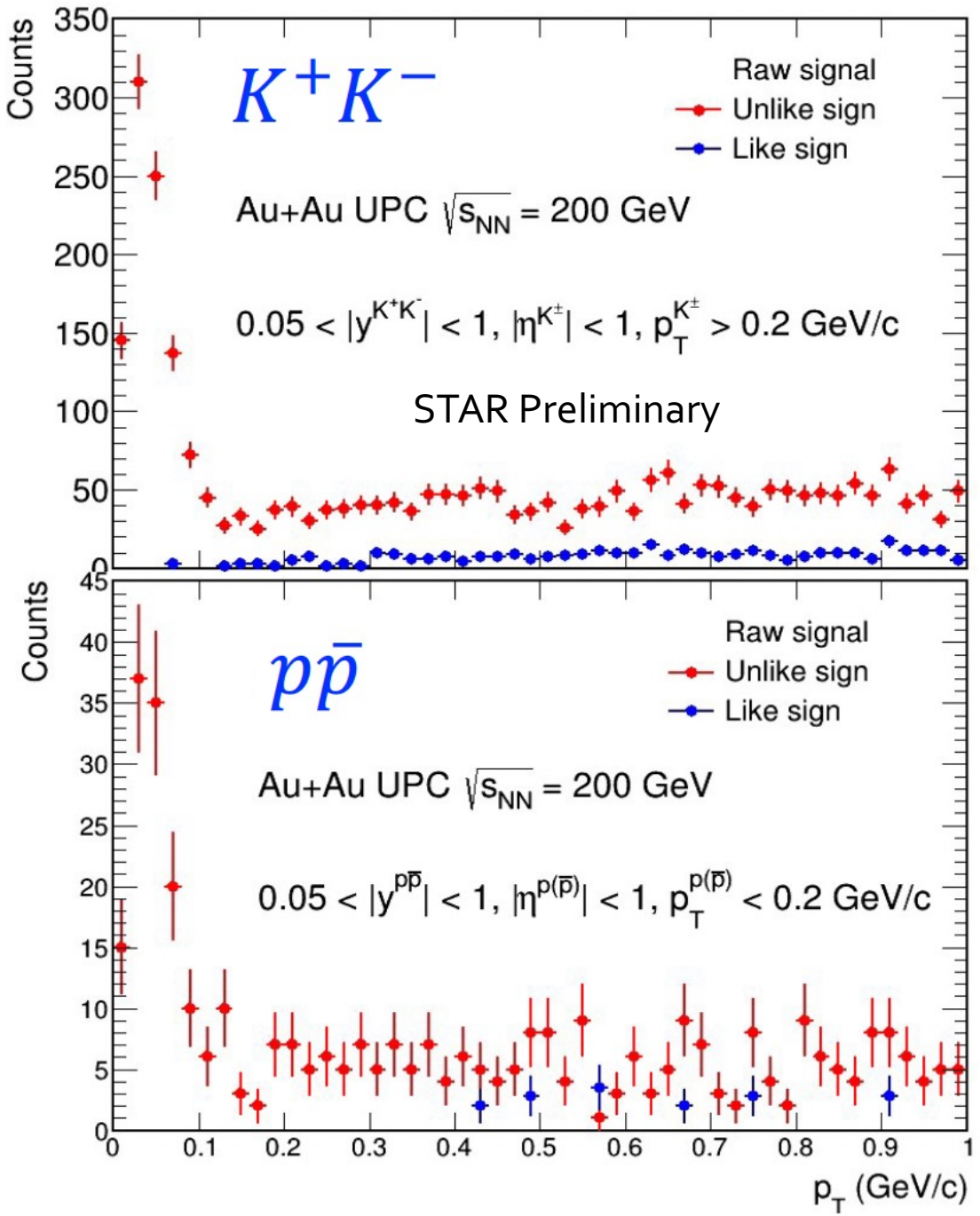


https://www.bnl.gov/newsroom/news.php?a=119023

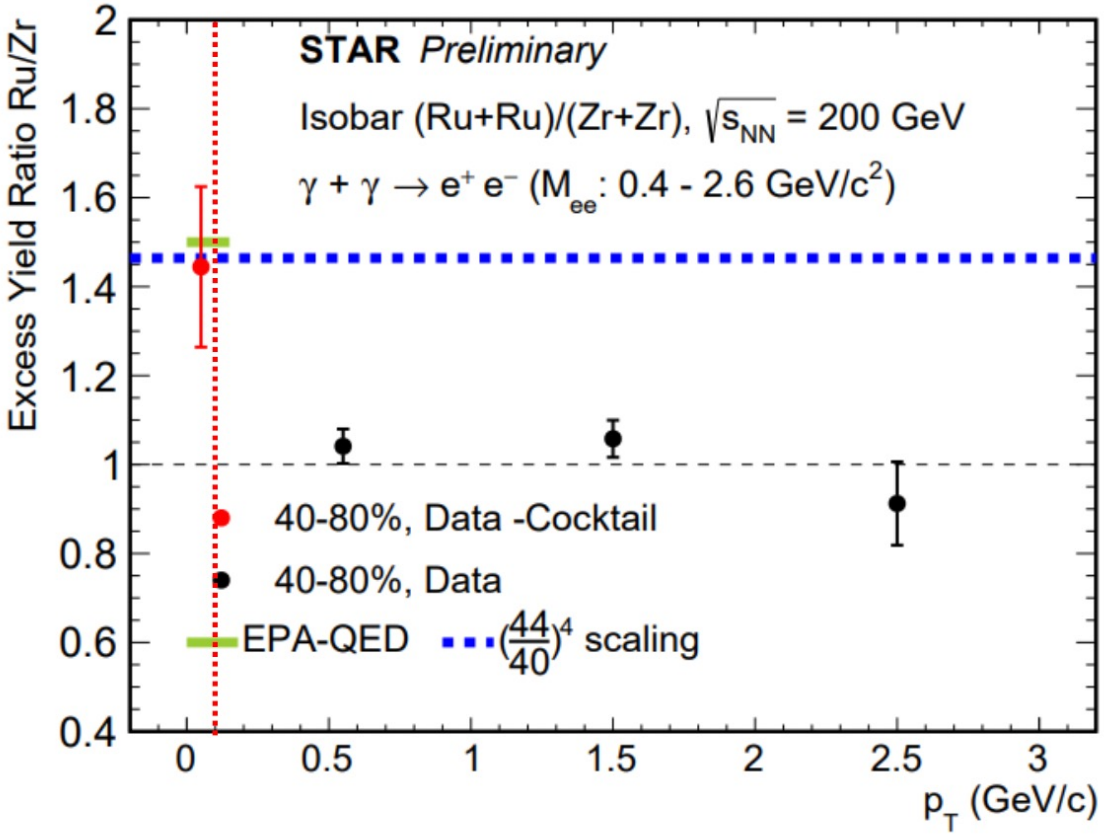
Dimuon and Diharon Channel

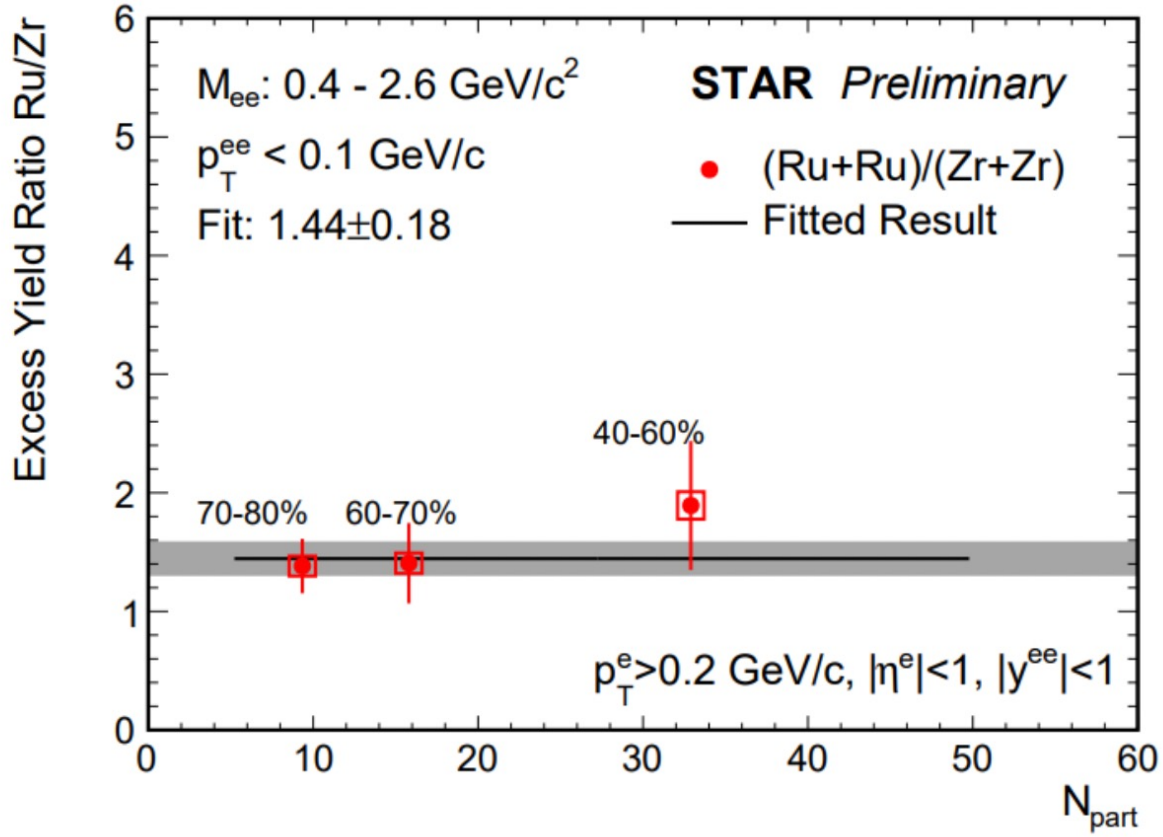


- Both processes have been observed
- QED vacuum excitation



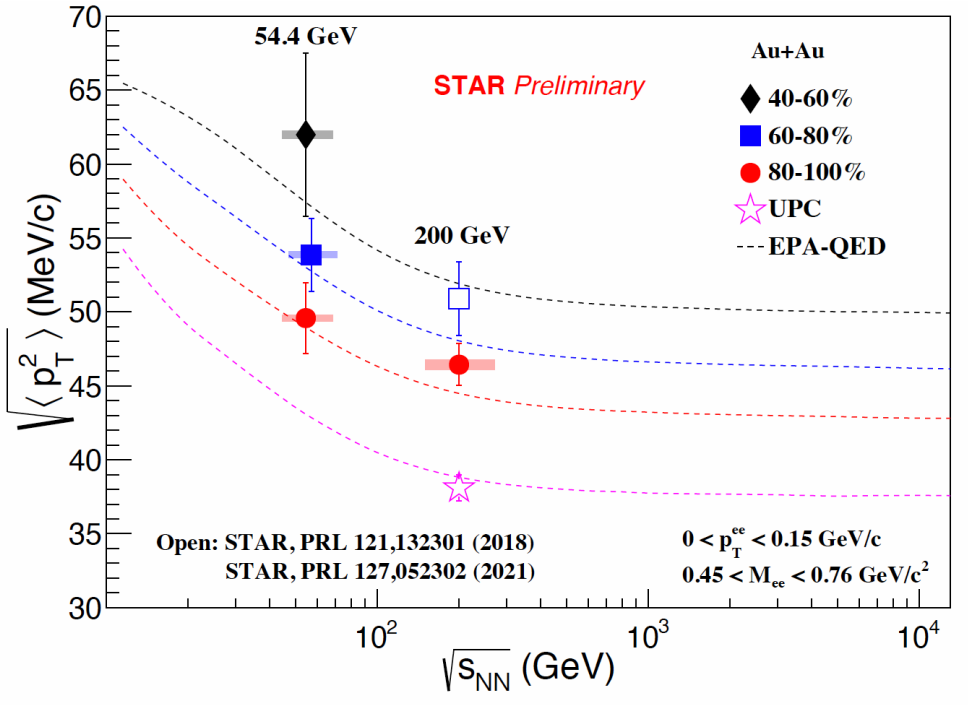
Charge Dependence

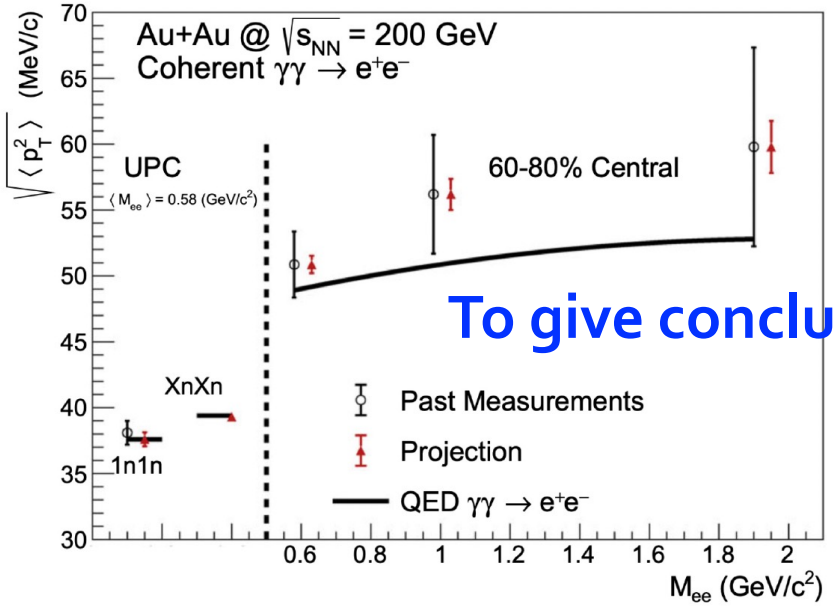




Charge dependence: initial magnetic field dependence

Energy and Centrality Dependence

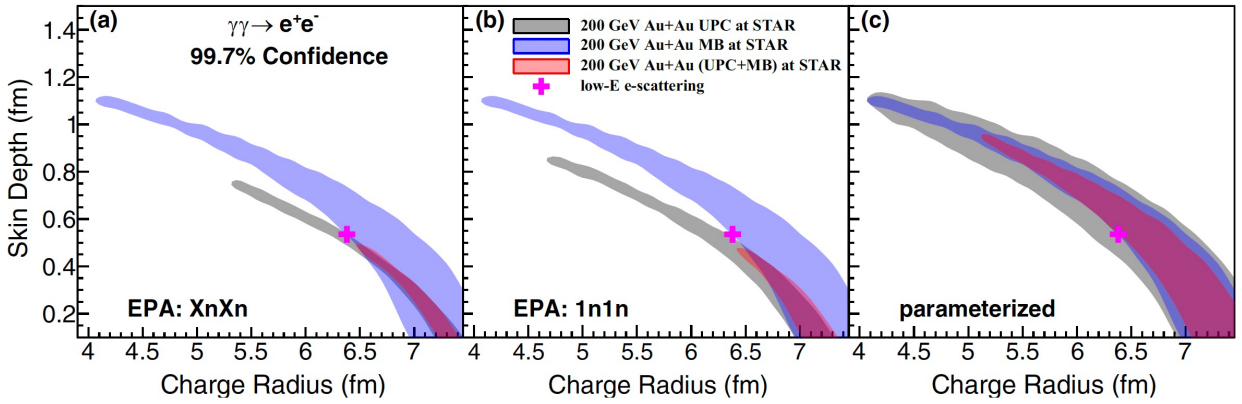




To give conclusion: RHIC Run23-25

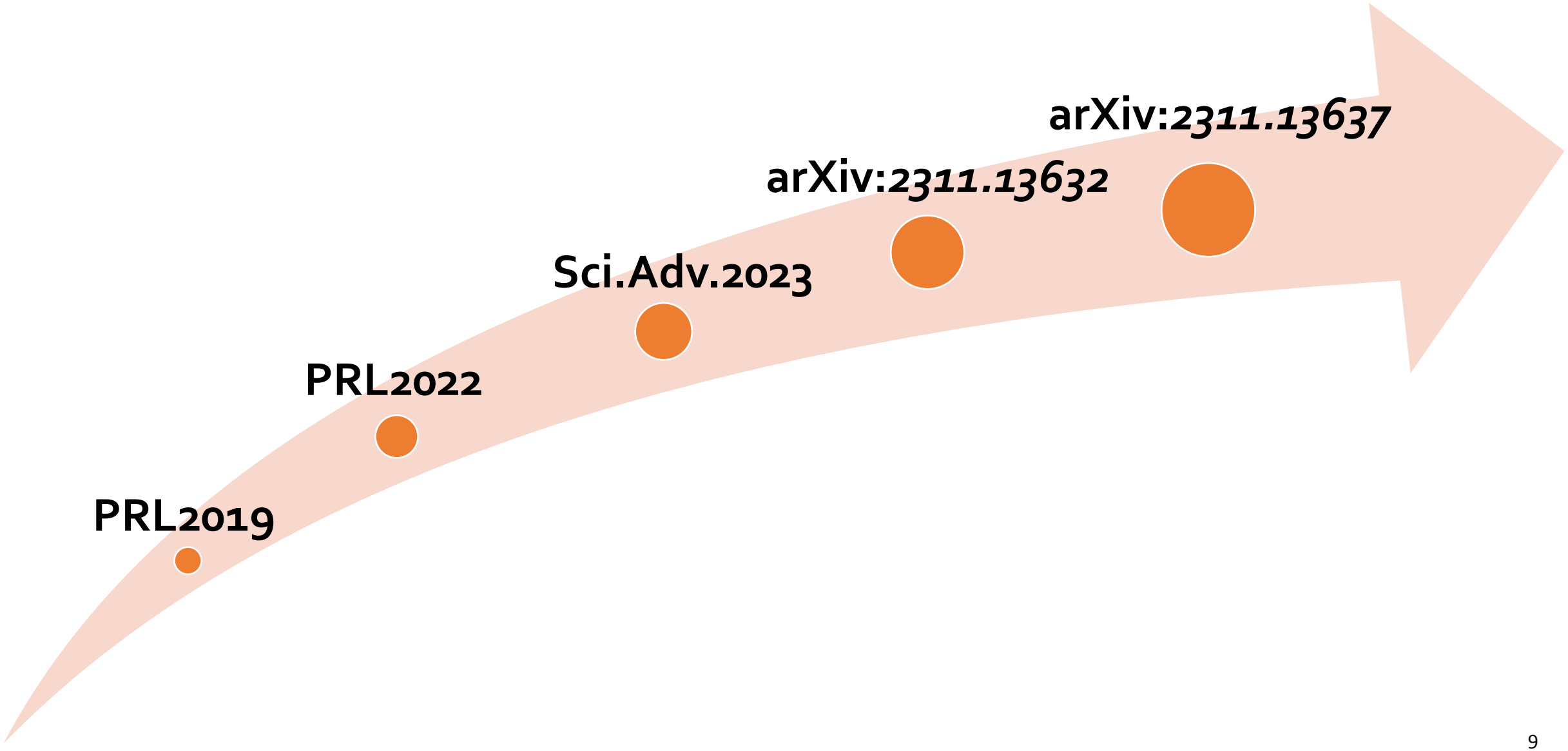
- Centrality dependence:
  b dependence
- Energy dependence:
  (3.7σ compared to 200 GeV QED)
  magnetic effect(1.8σ)?

Constrain charge radius



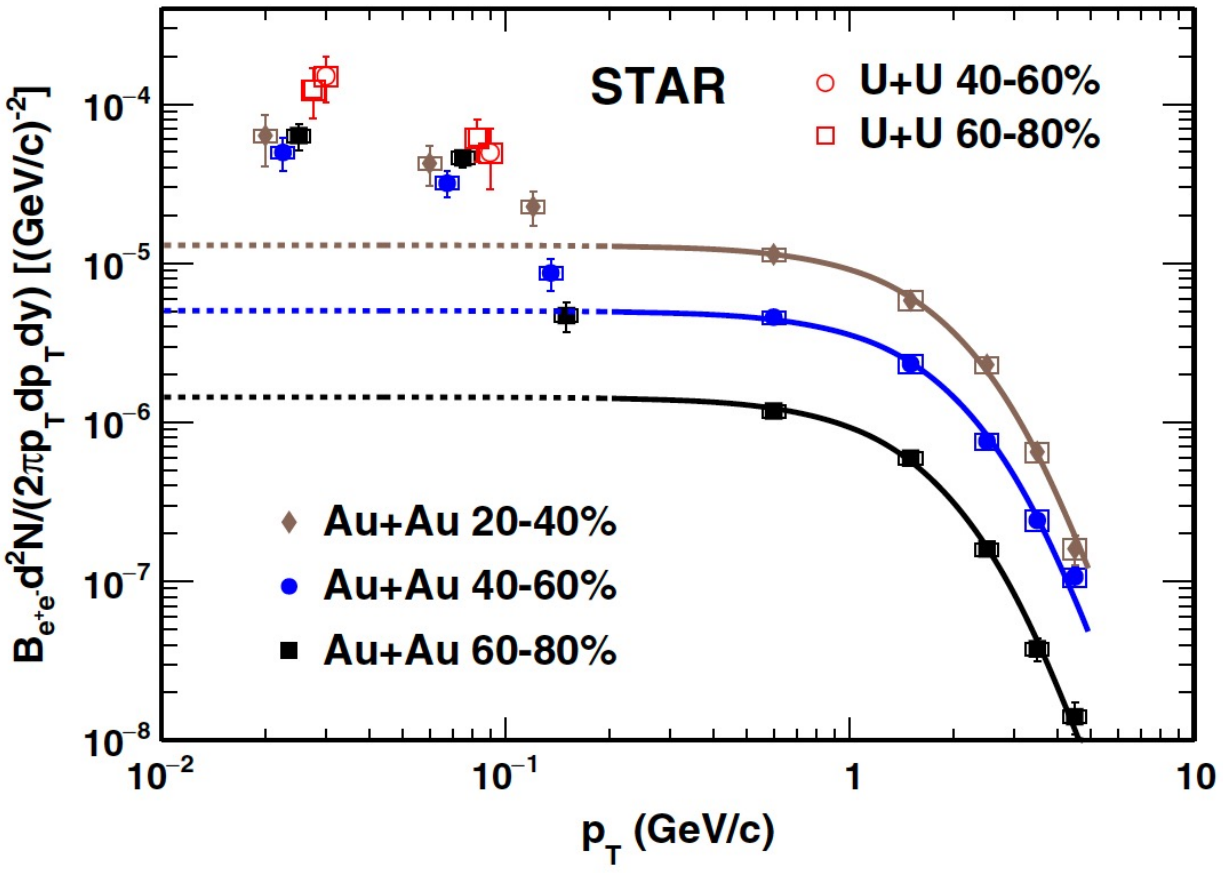
X. Wang, J. Brandenburg, L. Ruan, F. Shao, Z. Xu, C. Yang, W. Zha , PRC 2023

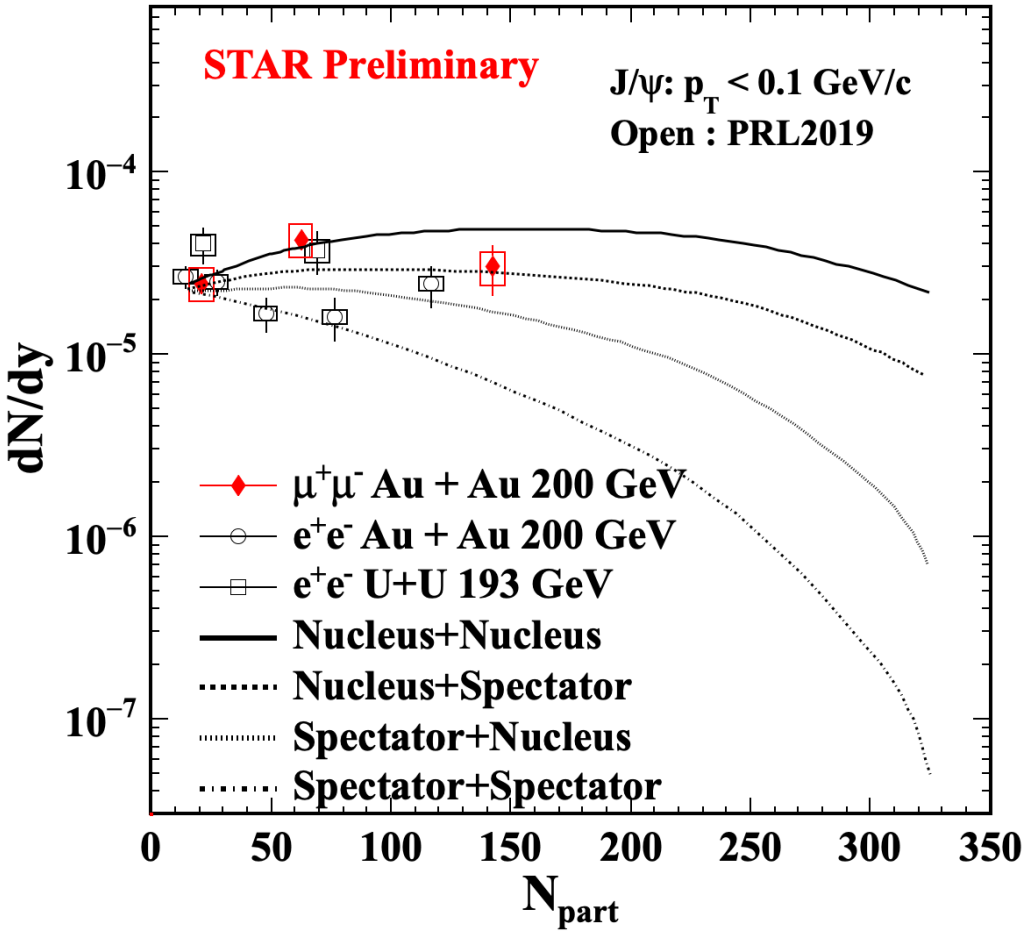
(Polarized) Photon-gluon Interactions



Photon-gluon Collisions

STAR, PRL 2019





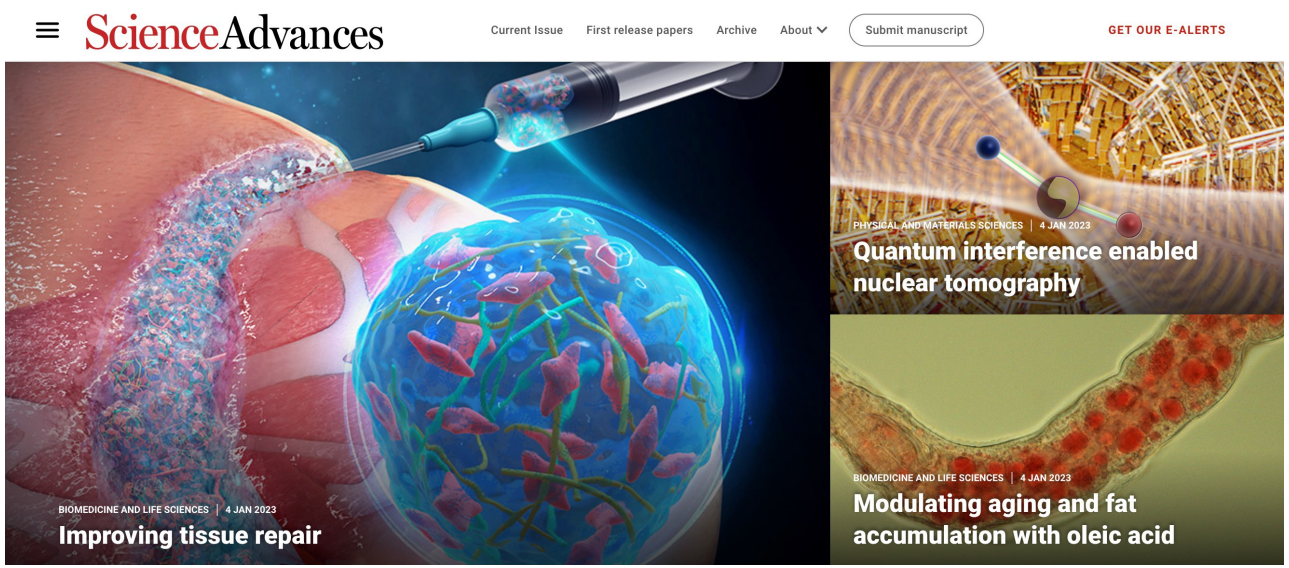
Coherent photon-nuclear interactions observed in HHIC

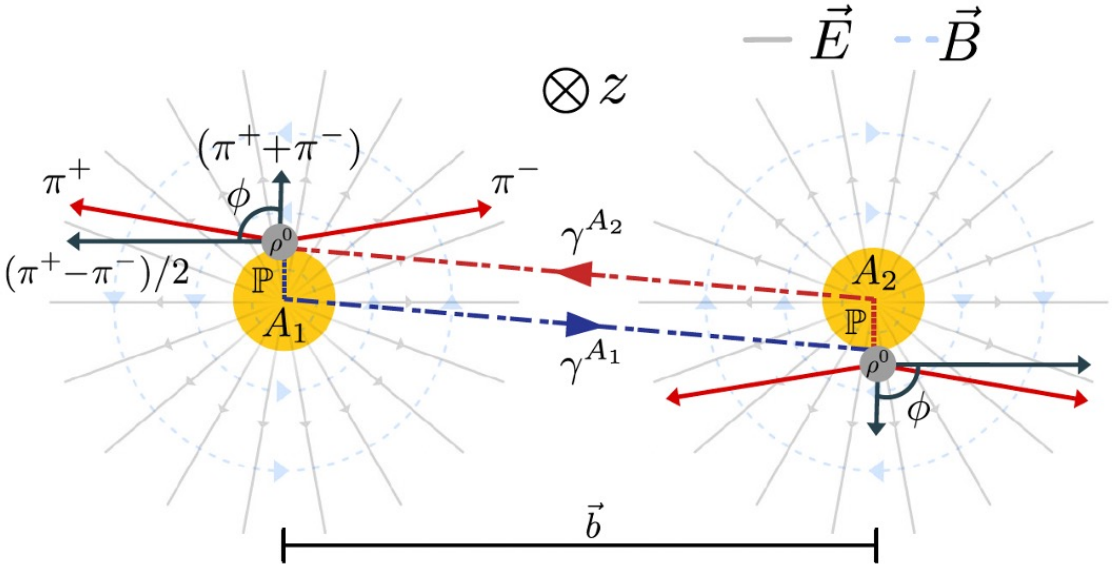
W. Zha, et. al., PRC2018

Photon-gluon collisions in isobar : See Jie Zhao's talk

Linearly polarized photon-gluon collision

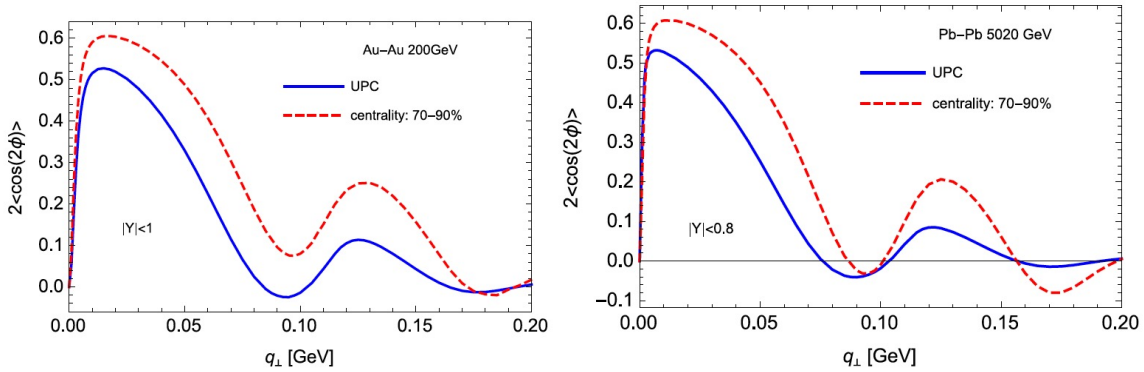
STAR, Sci.Adv. 2023



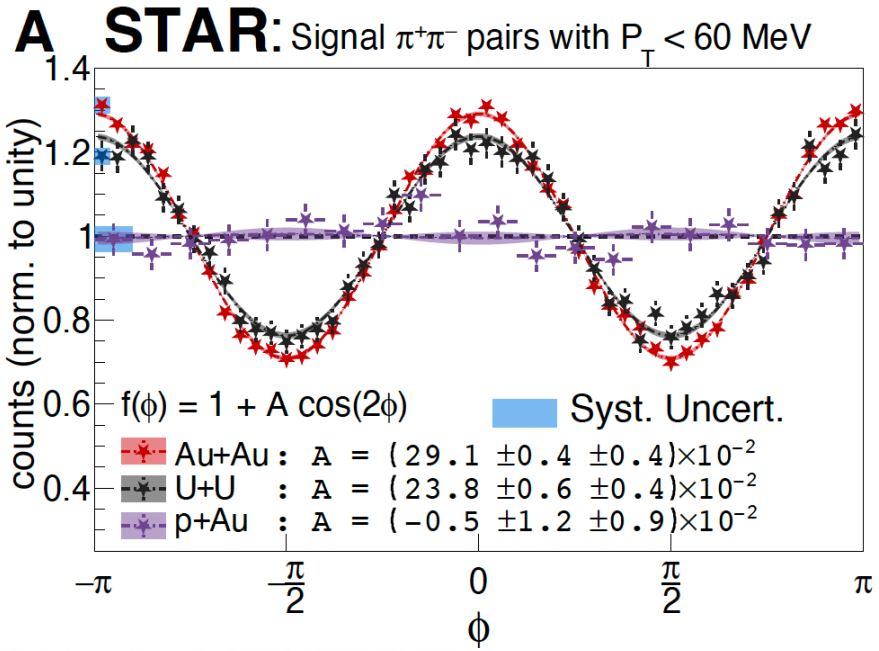


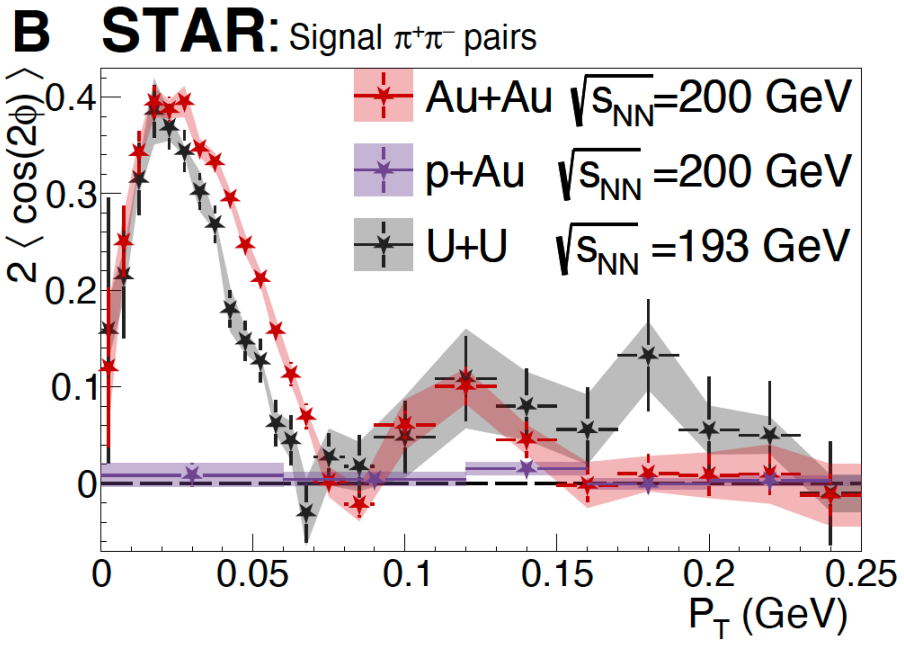
$\cos(2\Delta\phi)$ angular modulation in final state

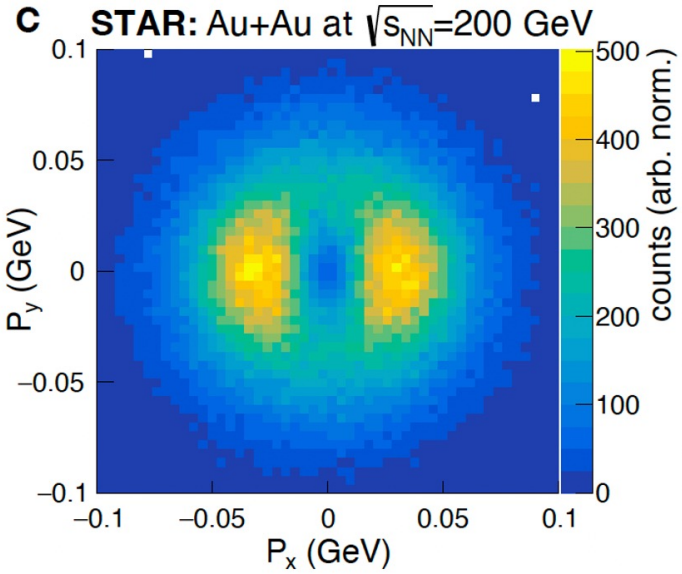
H. Xing, J. Zhou, Y. Zhou et al., JHEP 2020



Angular modulation and interference pattern







- Observed cos $2\Delta\phi$ modulation
- The pattern changes according to the nuclear radius
- Precious enough to study the nuclear structure

STAR, Sci. Adv. 2023

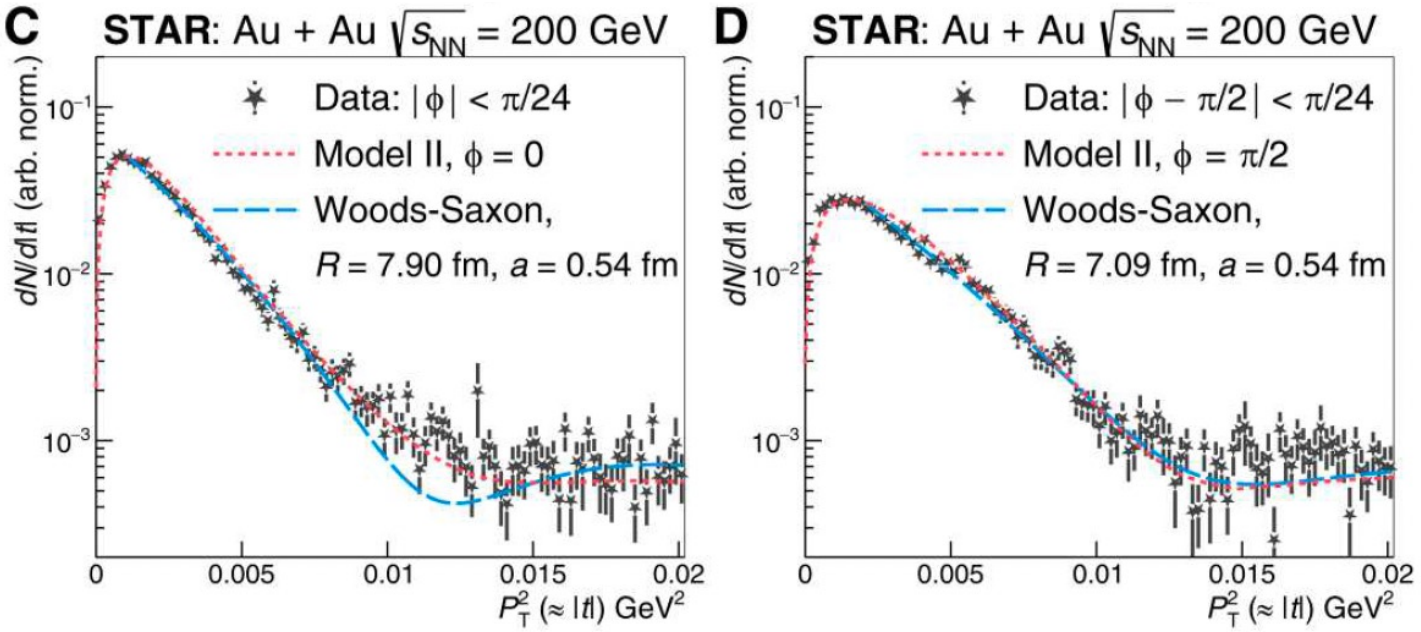
About this Attention Score

In the top 5% of all research outputs scored by Altmetric

High Attention Score compared to outputs of the same age (99th percentile)

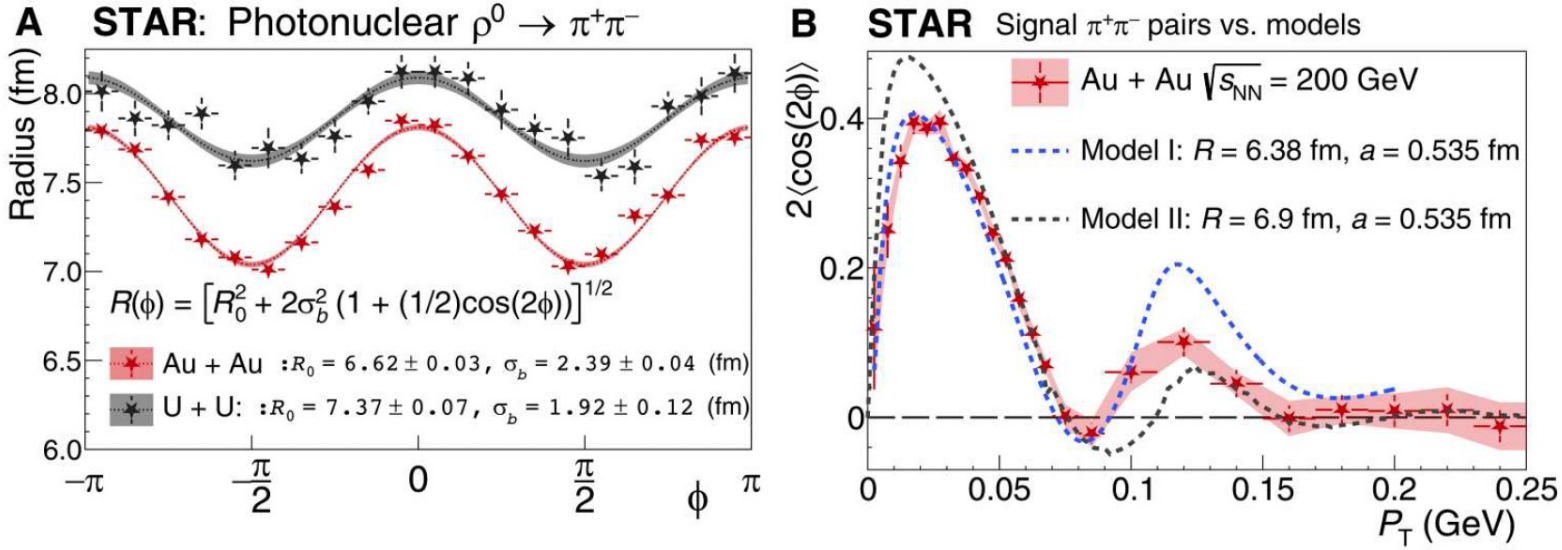
High Attention Score compared to outputs of the same age and source (94th percentile)

Double Slit Experiment at Fermi Scale



STAR, Sci. Adv. 2023

Model I: W. Zha, et al., PRD 2021
Model II: H. Xing, et al., JHEP 2020



The effect from interference in radius extraction can be canceled since we know the modulation behavior

Measure the Neutron Skin

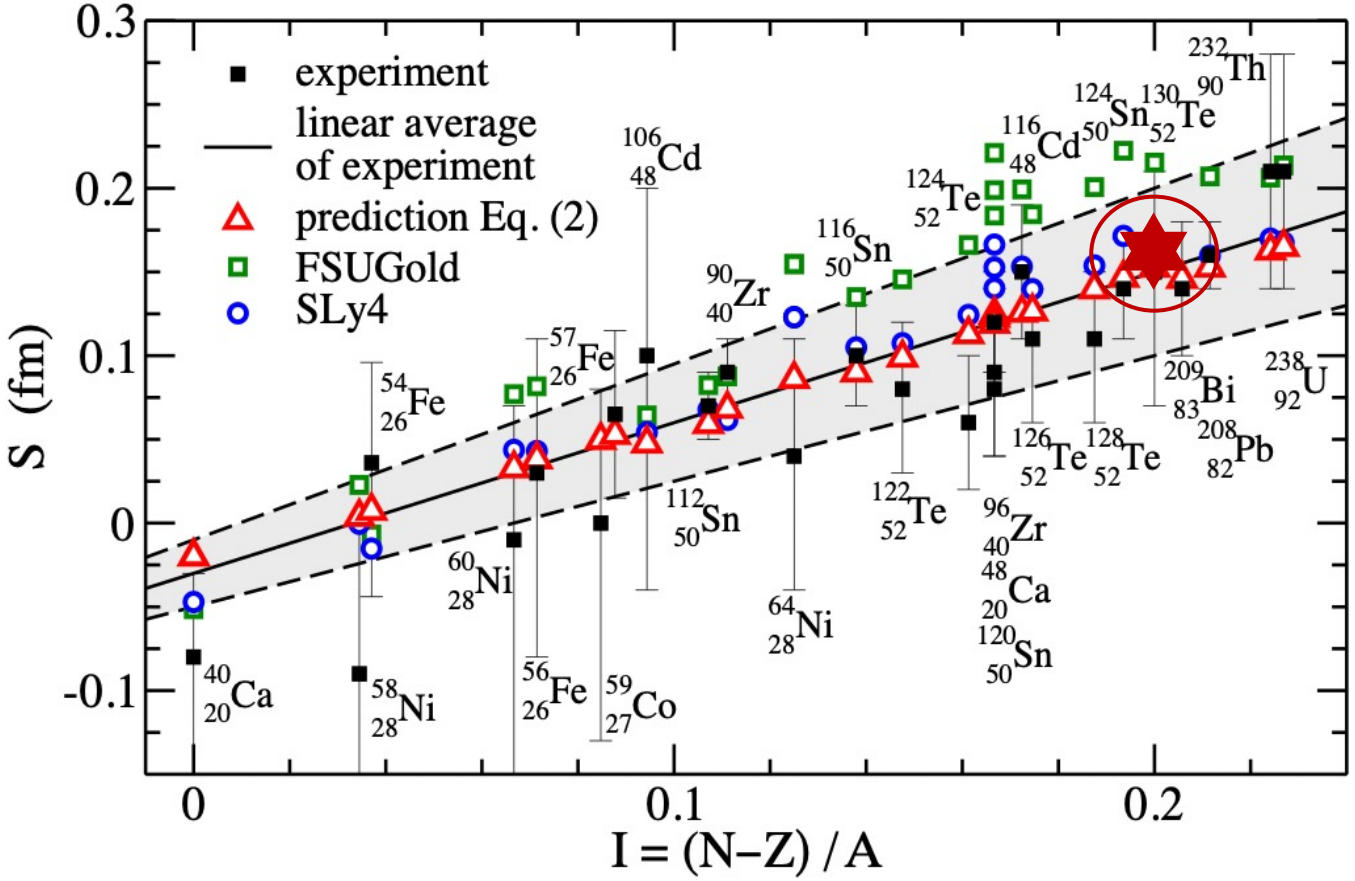
STAR:

S_{197Au} =0.17 ± 0.03 ± 0.08 fm

S_{238U} =0.44 ± 0.05 ± 0.08 fm

Larger radius of U:
indication of the nuclear deformation?

M. Centelles, et al., Phys. Rev. Lett. 102, 122502 (2009)



Rp:

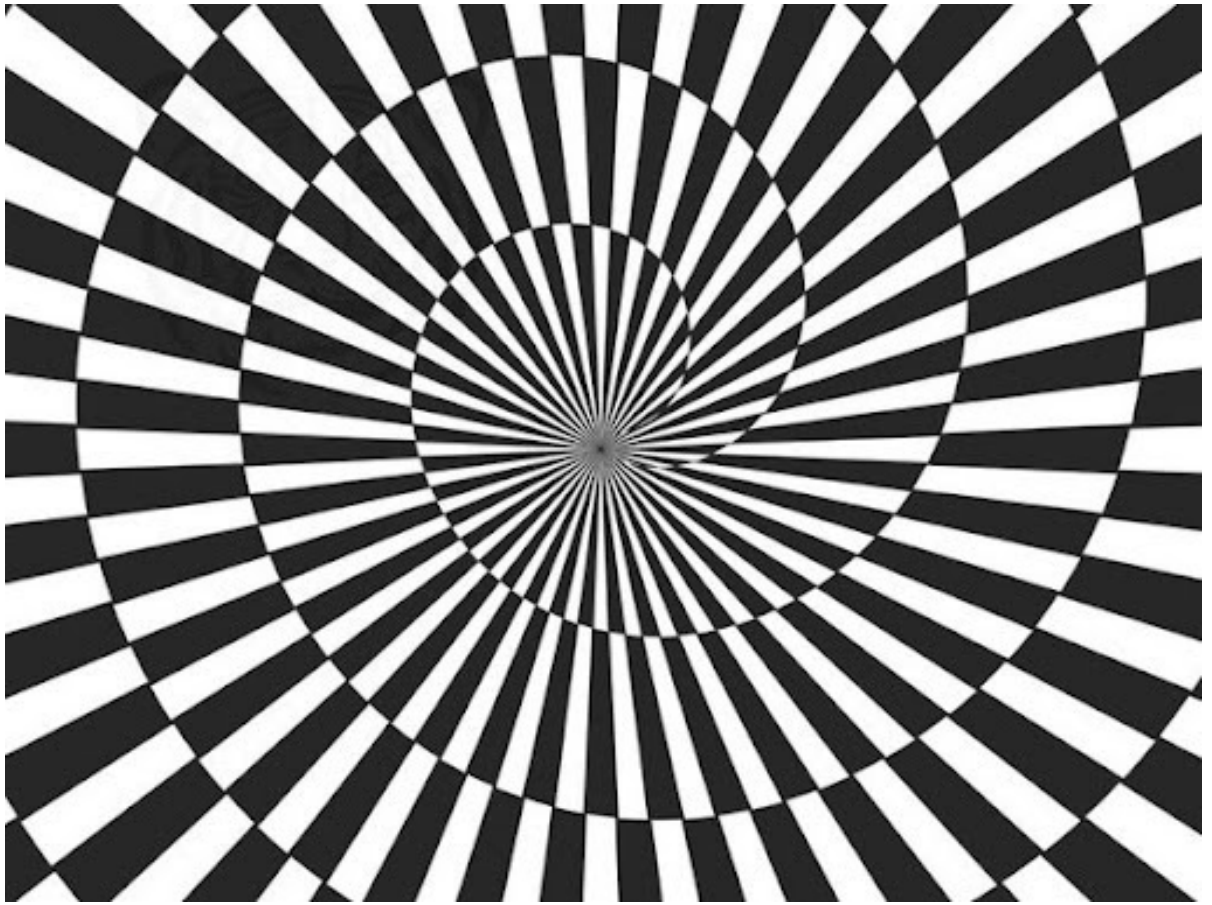
Q. Shou, et al., Phys. Lett. B 2015

H. De Vries, et al., At. Data Nucl. Data Tables 1987

Hot Questions/Discussions in Recent UPC Workshops

- In UPC2023:

How to define Breit-Wheeler process and confirm the measurement of it?

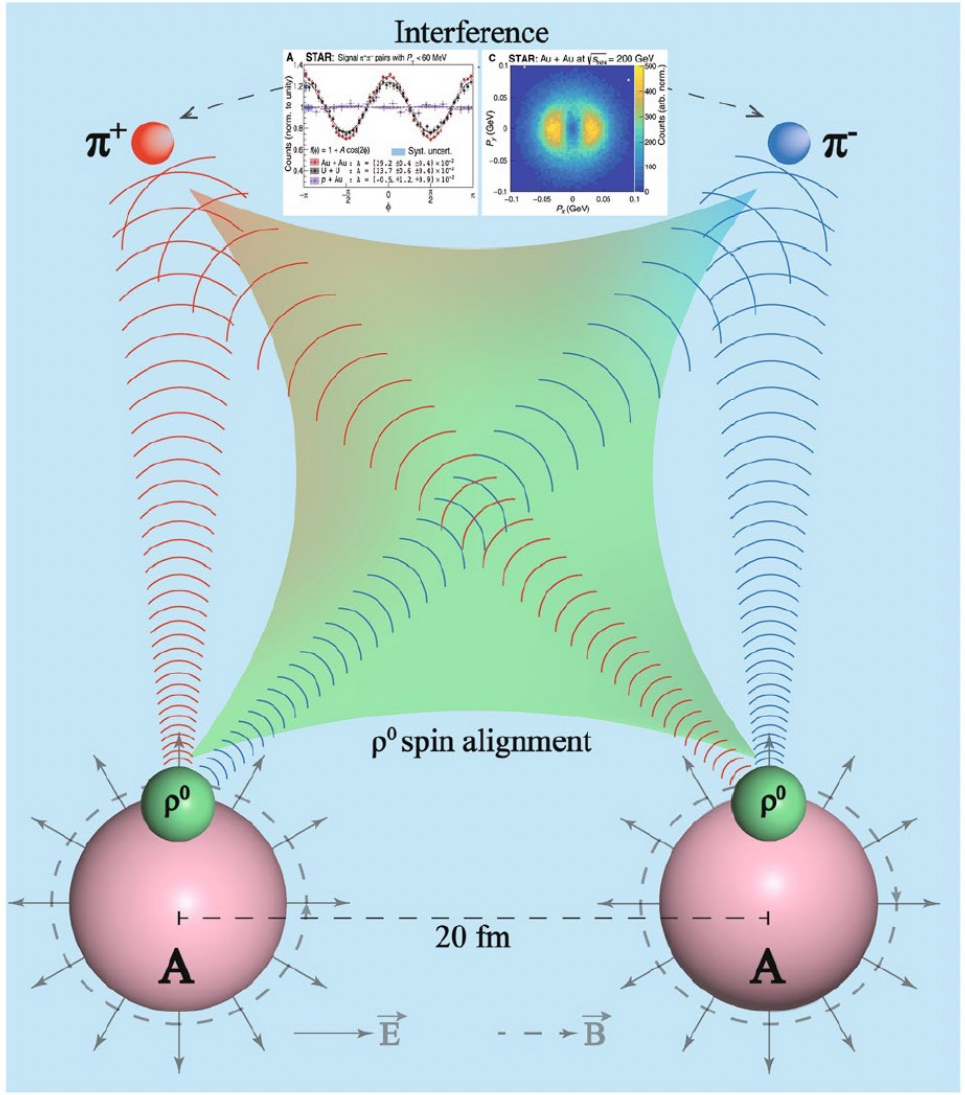


to behave like real photon interactions. The requirement in the center-mass-frame of the heavy-ion collision is that both photons satisfy the following condition:

$$\omega/\gamma \lesssim k_\perp \ll \omega. \qquad (10)$$

Vidovic et al., PRC 1993 *X. Wang PRC 2023*

In UPC2024

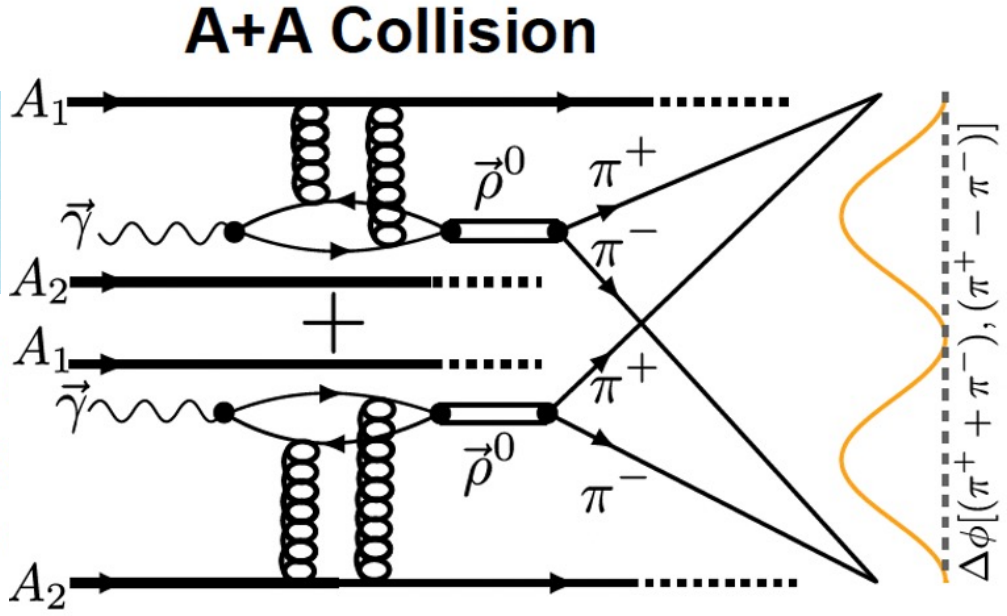


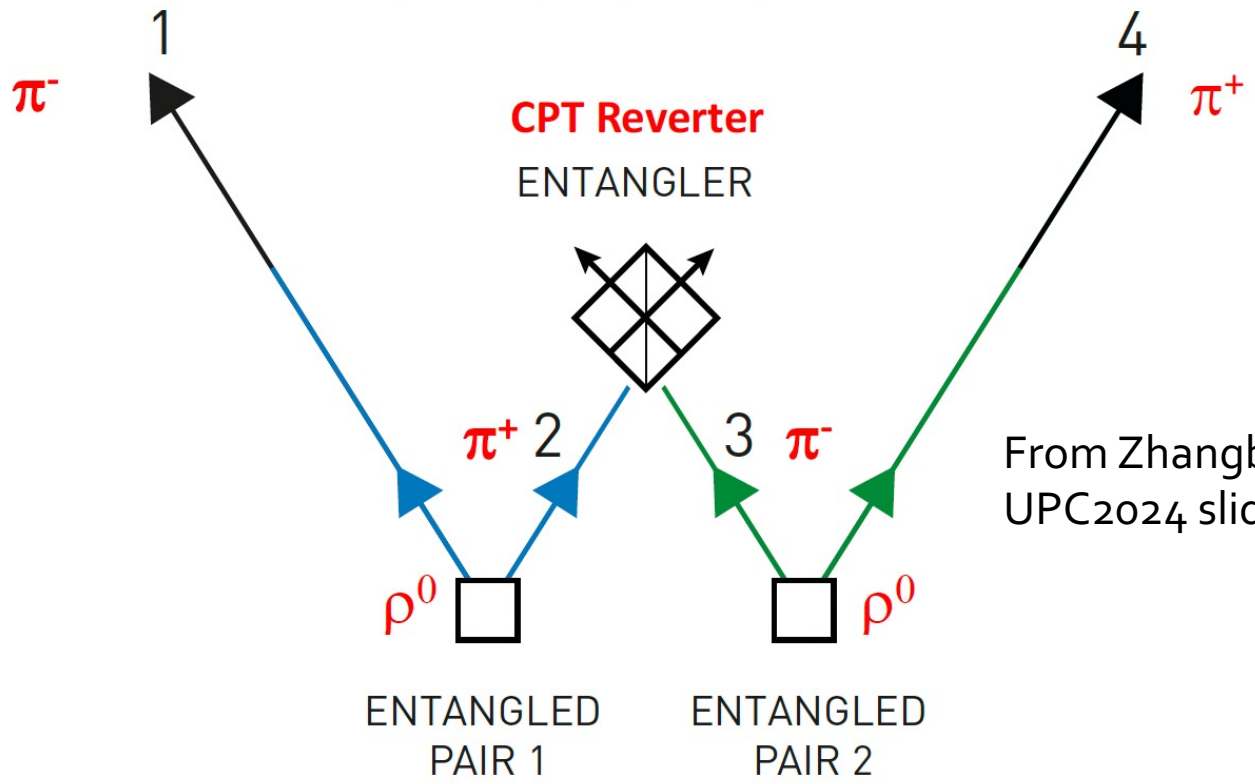
Y. Ma, NST 2023

W. Zha, PRC 2019

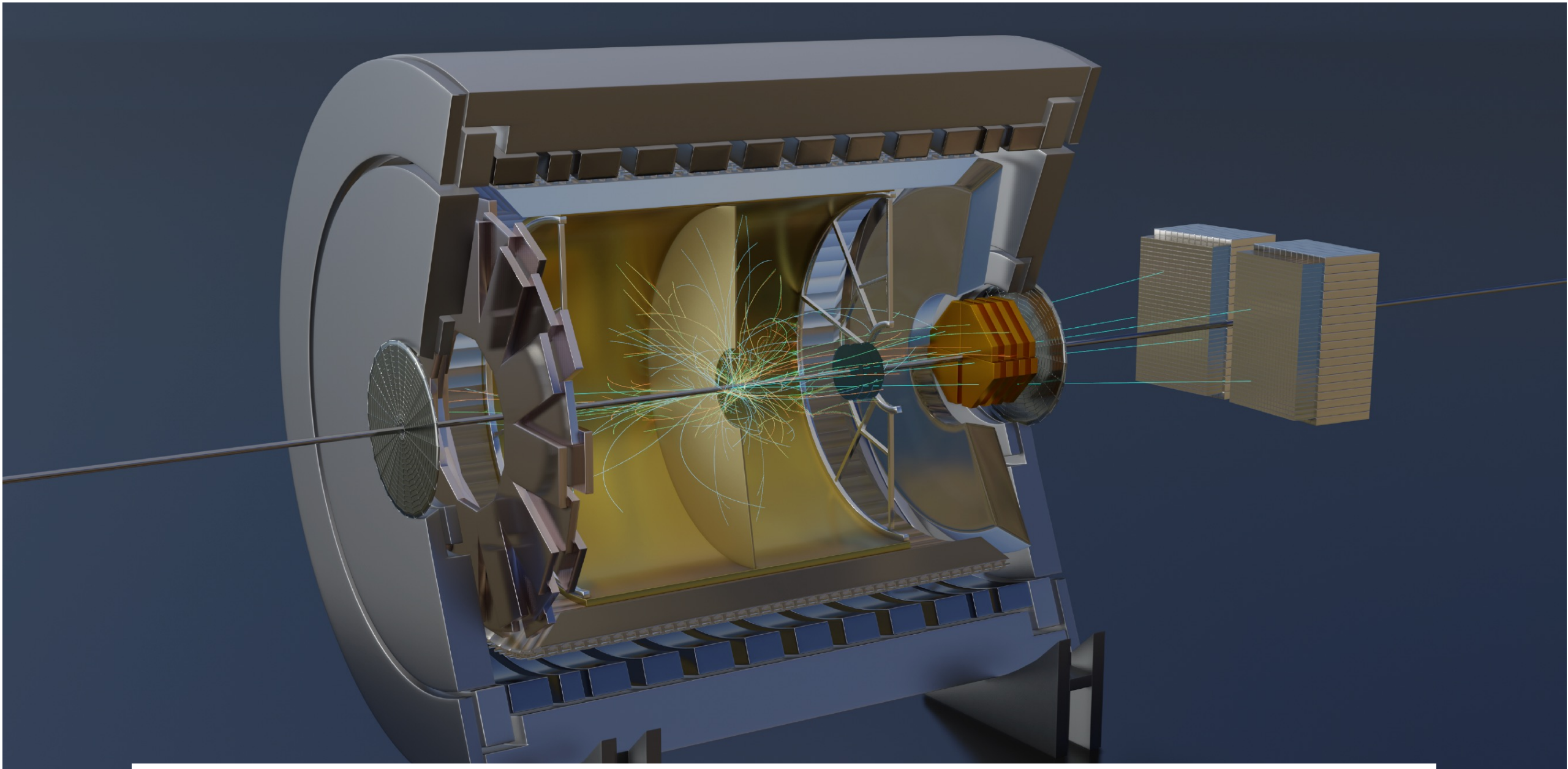
?

A+A Collision





From Zhangbu Xu's UPC2024 slides



Thanks to all of our colleges contributed in
designing, producing and commissioning these nice sub-systems at RHIC-STAR!

Summary

Photoproduction processes – **"unique, penetrating, clean"** probes
Measurements support **highly linearly polarized photons** "move together" with relativistic heavy-ion

$\gamma + \gamma$

- Study fundamental QED process, QED vacuum excitation, higher order effect
- Constrain EM field and nuclear charge distribution
- Search for potential magnetic effect, exotics…

+

$\gamma + A$

- Constrain nuclear gluon distribution
- Measure neutron skin
- Search for quantum entanglement

Current and future opportunities at RHIC

- STAR now at the peak of its performances in resolution, acceptance, DAQ rate…
- RHIC top energy run at Run23 to Run25, large data samples for statistics hunger analysis
- Current BES-II and isobar data provide various chances to study photoproduction processes