



Discovery of the Breit-Wheeler process and Quantum Entanglement Enabled Nuclear Tomography

Daniel Brandenburg, Zhangbu Xu

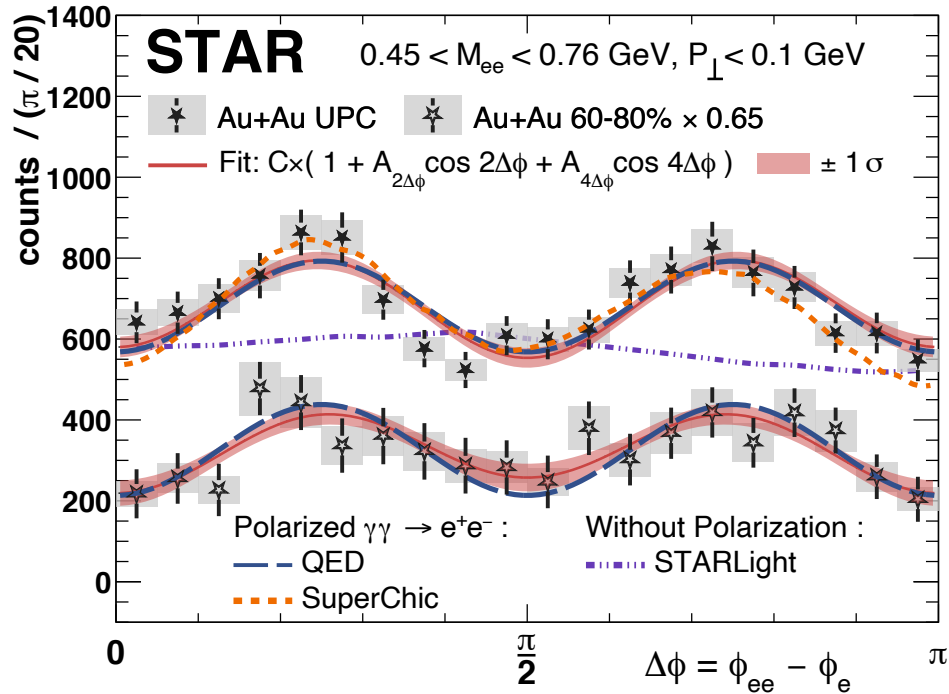
September 25th, 2022



@BrookhavenLab

Discoveries with Polarized Photons

Breit Wheeler process and Vacuum Birefringence



- Vacuum birefringence leads to a $\cos 4\phi$ in the e^+e^- from the Breit-Wheeler process
- Sensitive to charge distribution within nuclei at high-energy
- Precision source of linearly polarized photons

PRL 121, 132301 (2018)

PRD 101, 034015 (2020)

PRL 127, 052302 (2021)

PLB 795, 576 (2019)

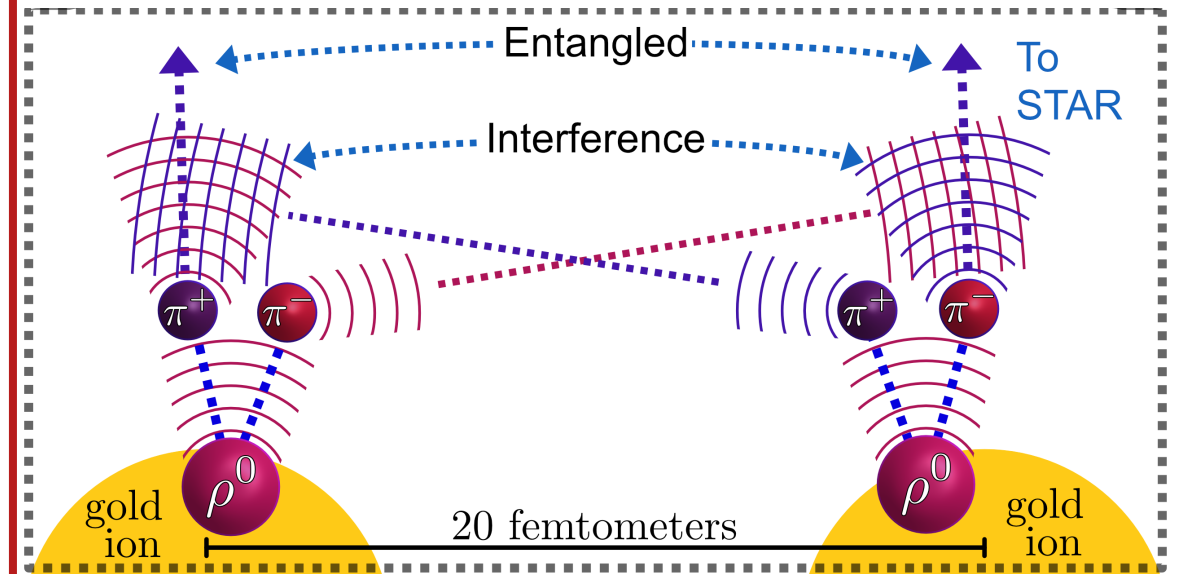
EPJA 57, 299, (2021)

arXiv:2207.05595

September 8th, 2022

Daniel Brandenburg

Entanglement enabled intensity interferometry



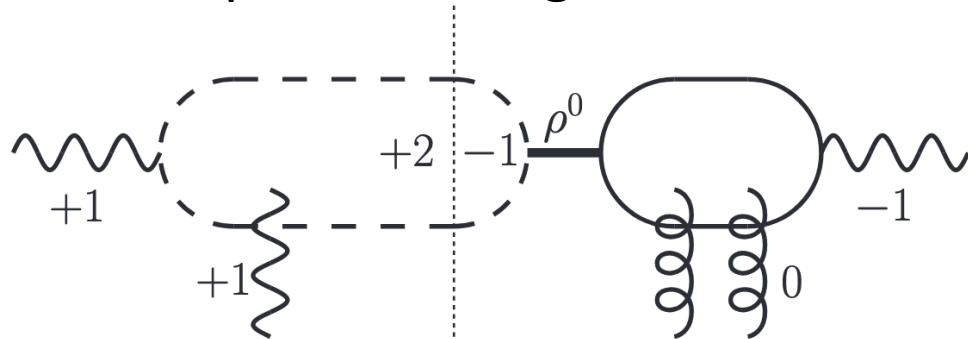
Final-state Interference between **distinguishable** particles

- Resolves a 20-year puzzle in diffractive photonuclear measurements

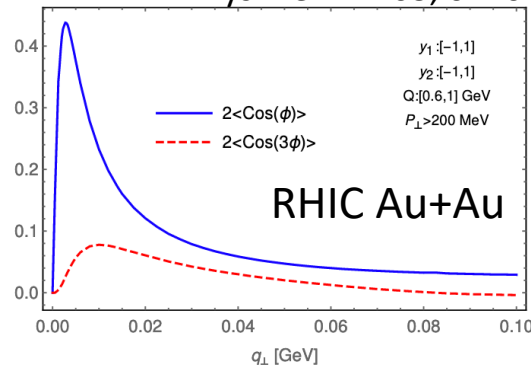
Calibrated source of linearly polarized photons provides a **precision probe of gluon distribution within heavy nuclei**

Quantum Entanglement and Gluon Tomography

Coulomb-Nuclear Interference to probe entanglement



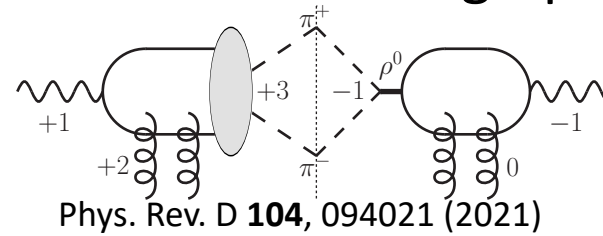
Phys. Rev. D 103, 074013 (2021)



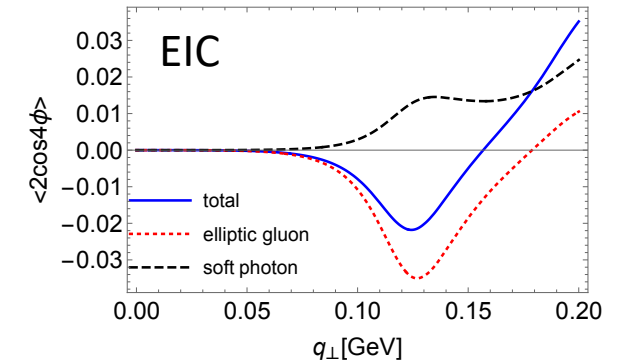
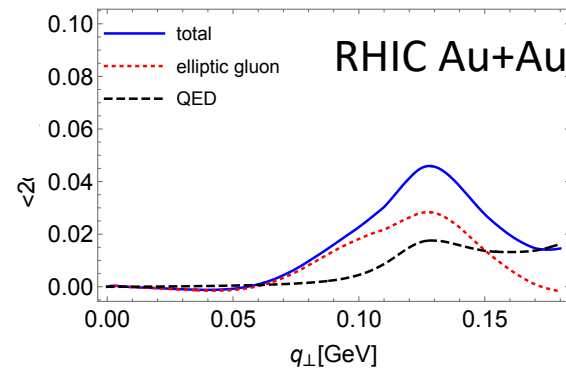
Final state asymmetries due to QED-QCD interference, reveals phase between photon and gluon fields, and possible entanglement

September 8th, 2022

Gluon tomography at RHIC and EIC



Phys. Rev. D 104, 094021 (2021)



Clear signature of elliptic gluon distribution within nuclei.
Complimentary measurements at RHIC and EIC needed

LRP Message:

The discovery of the Breit-Wheeler process in heavy ion collisions marks a milestone in QED and has led to the discovery of entanglement enabled quantum interference of non-identical particles which enables precise tomography of gluon distributions at RHIC and the future EIC.

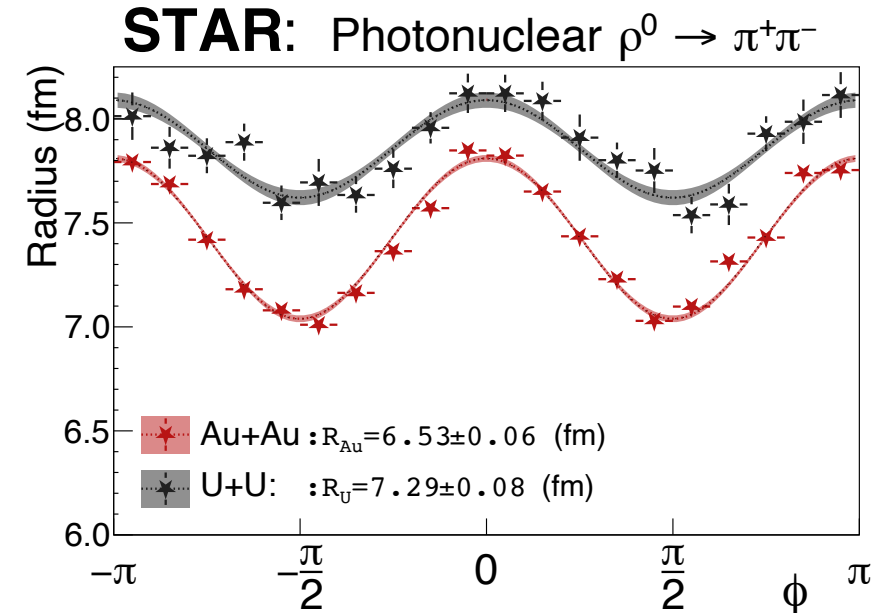
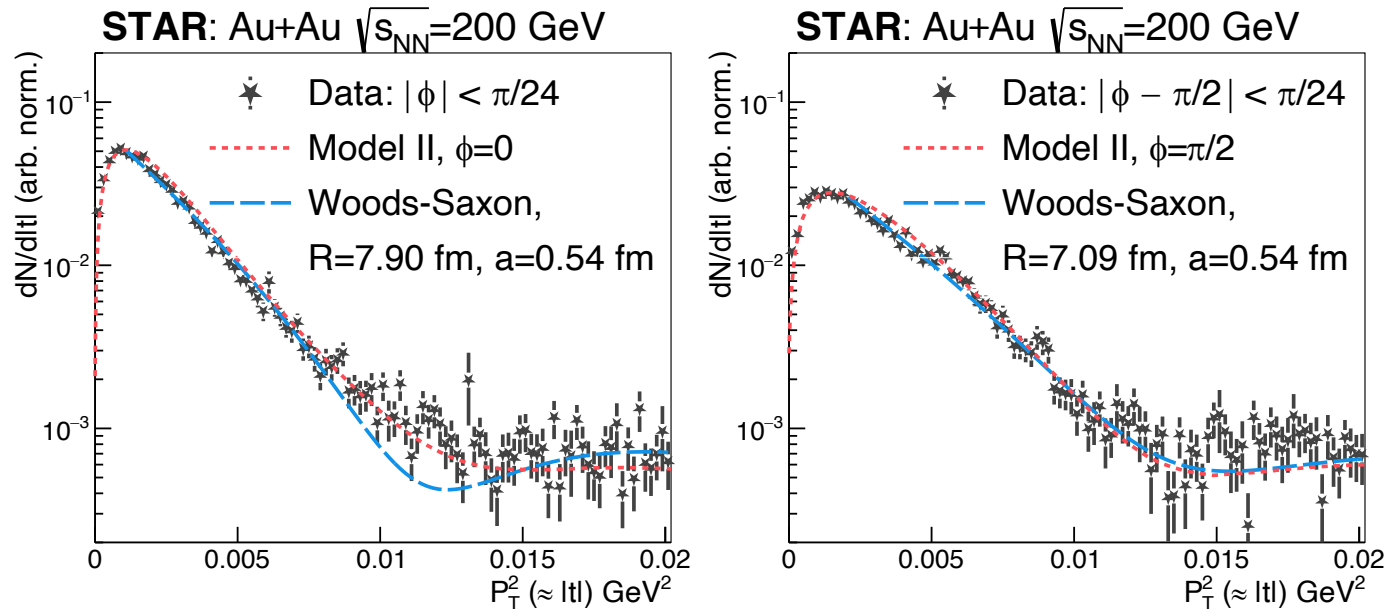
Daniel Brandenburg

EXTRA

Precision Pb Neutron Skin Measurement at RHIC

Interference effect causes apparent increase of nuclear size. For 20 years, extracted radius appeared ~ 1 fm too large

Precision measurement of ^{197}Au and ^{238}U mass radii via interference effect in diffractive photonuclear production



- Direct measurement of the radius (R) and skin depth (a) with small uncertainty
- Compliments the flow-based nuclear structure measurements (See Jianguo's talk)

Extracted neutron skin (S_A):

$$S_{Au} = 0.17 \pm 0.03(\text{stat.}) \pm 0.08(\text{syst.}) \text{ fm}$$

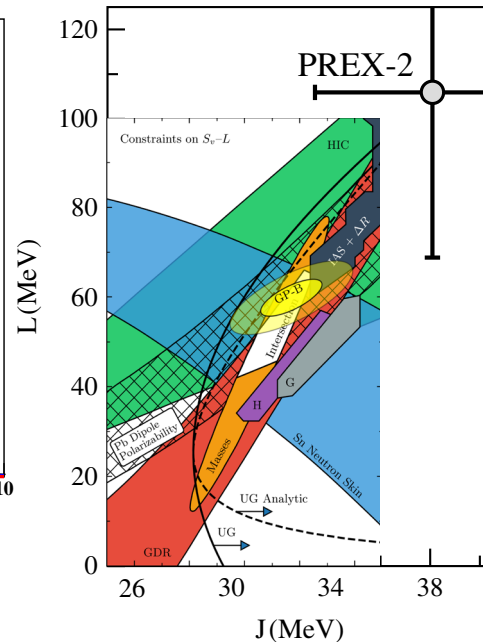
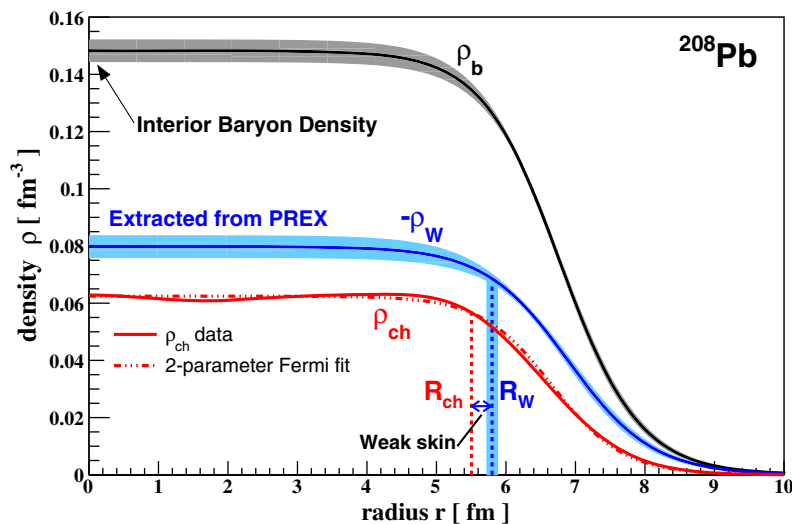
$$S_U = 0.44 \pm 0.05(\text{stat.}) \pm 0.08(\text{syst.}) \text{ fm}$$

Case for a short Pb+Pb run at RHIC

PREX-2 neutron skin measurement for ^{208}Pb

$$S_{\text{Pb}} = 0.283 \pm 0.071 \text{ fm}$$

Tension between PREX-2 measurement and other measurements / theoretical models



All past neutron skin measurements at **LOW ENERGY**

NEW quantum entanglement enabled interference technique provides precision neutron skin measurement at RHIC/LHC at **HIGH ENERGY**

~Two weeks of Pb+Pb at RHIC in 2023:

- Precision neutron skin measurement of Pb
- Provides crucial information on initial state of heavy ion collisions
- Complimentary to flow-based nuclear structure measurements (see Jiangyong's presentation)
- Investigate/cross check the higher-than-expected PREX-2 neutron skin result
- Fundamental importance for nuclear physics

Phys. Rev. Lett. **126**, 172502 (2021)

Phys. Rev. Lett. **126**, 172503 (2021)