Quantum Entanglement Enabled Nuclear Tomography

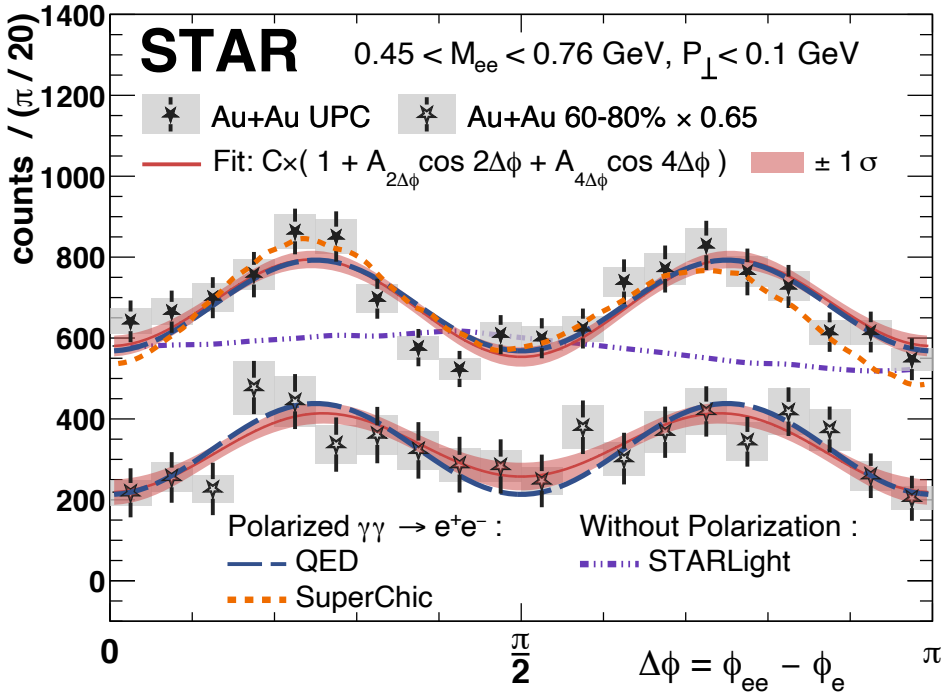
Daniel Brandenburg

September 8th, 2022

@BrookhavenLab

Discoveries with Polarized Photons

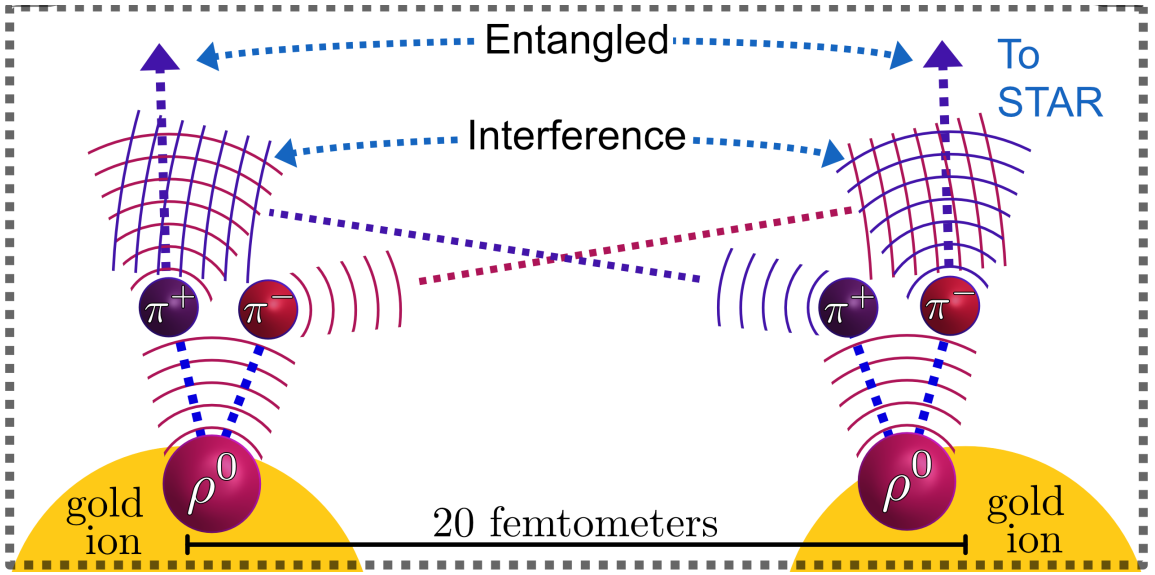
Breit Wheeler process and Vacuum Birefringence



- 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)
PRL 127, 052302 (2021)
EPJA 57, 299, (2021)
PRD 101, 034015 (2020)
PLB 795, 576 (2019)
arXiv:2207.05595

Entanglement enabled intensity interferometry



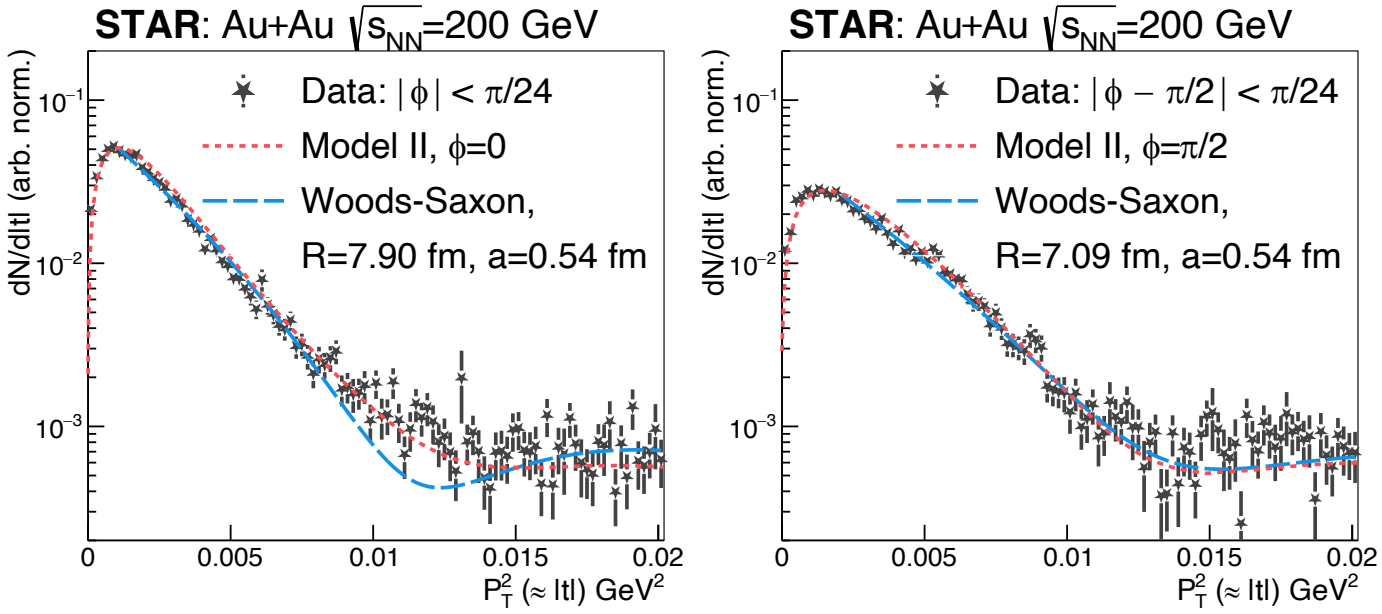
Final-state Interference between **distinguishable** particles

- 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**

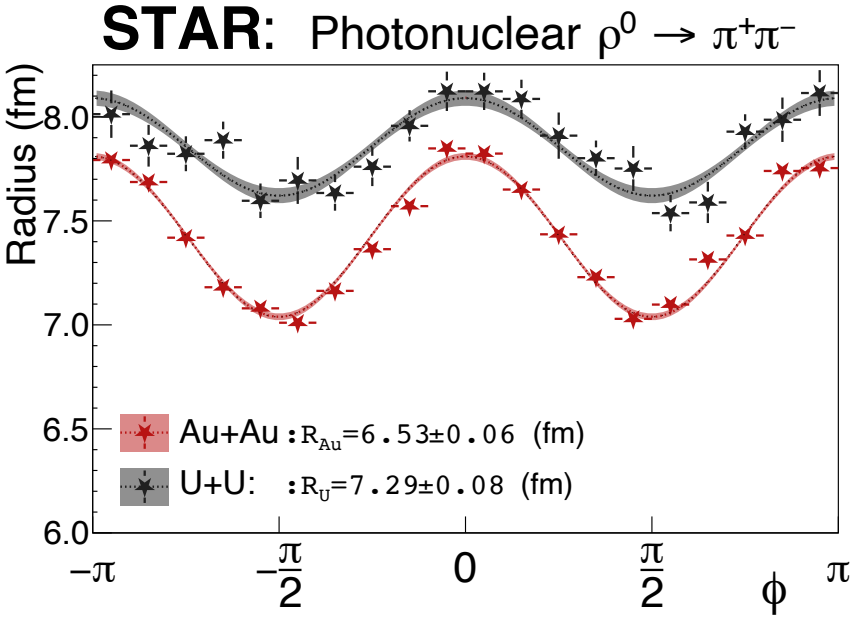
Precision Pb Neutron Skin Measurement at RHIC

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



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

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



Extracted neutron skin (S_A):

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

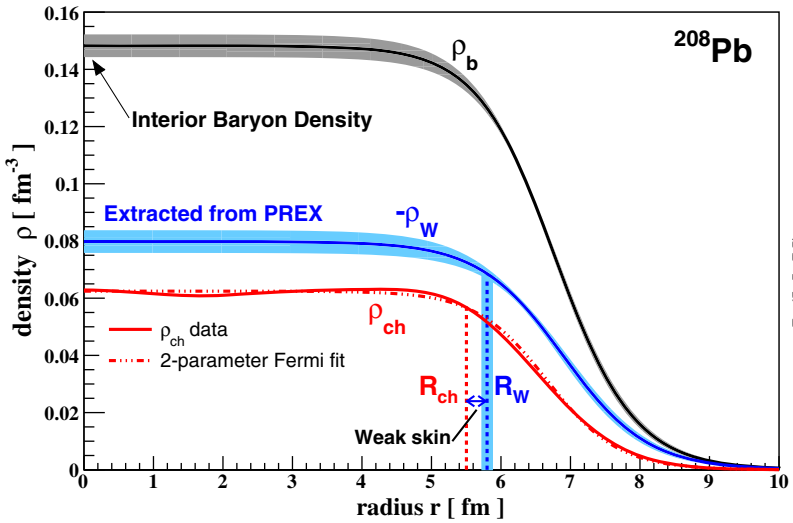
$S_U = 0.44 \pm 0.05(\text{stat.}) \pm 0.08(\text{syst.})$ fm

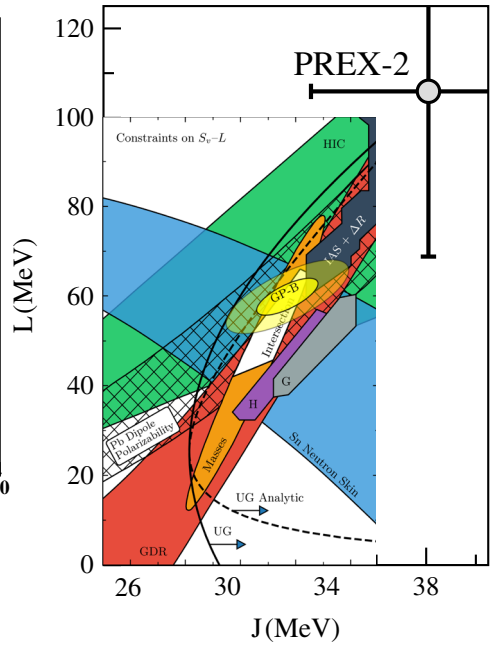
Case for a short Pb+Pb run at RHIC

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

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

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





Phys. Rev. Lett. **126**, 172502 (2021)
Phys. Rev. Lett. **126**, 172503 (2021)

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

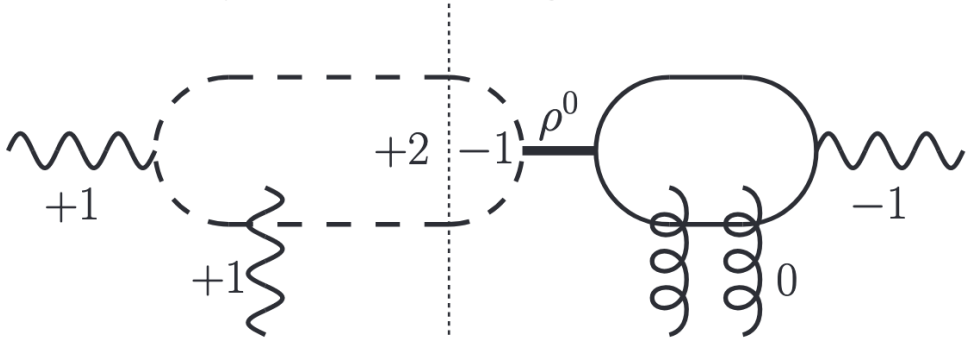
NEW quantum entanglement enabled interference technique provides precision neutron skin measurement at RHIC/LHC at **HIGH ENERGY**

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

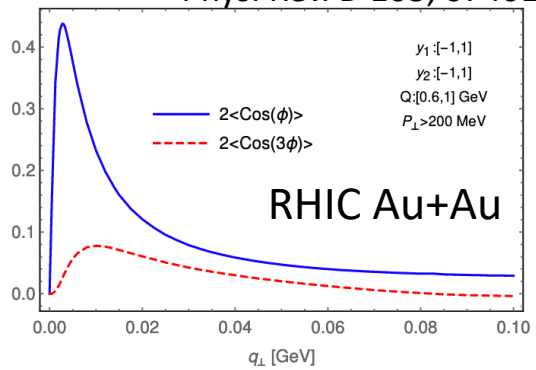
- Precision neutron skin measurement of Pb
- Provides crucial information on initial state of heavy ion collisions
- Complimentary to flow-based nuclear structure measurements (see Jiangyong's presentation)
- Investigate/cross check the higher-than-expected PREX-2 neutron skin result
- Fundamental importance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

Quantum Entanglement and Gluon Tomography

Coulomb-Nuclear Interference to probe entanglement

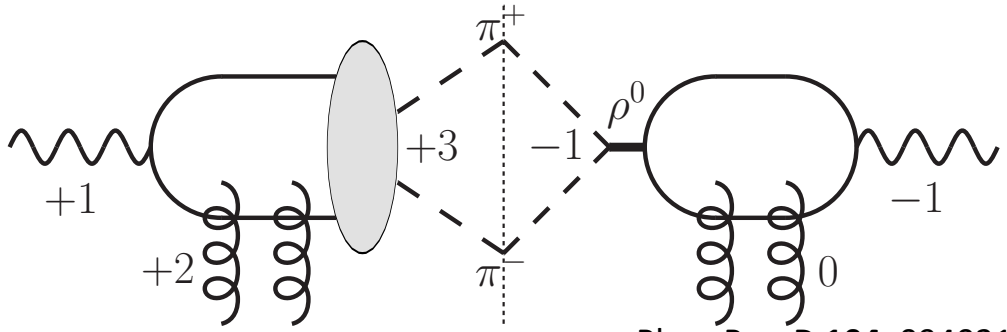


Phys. Rev. D 103, 074013 (2021)

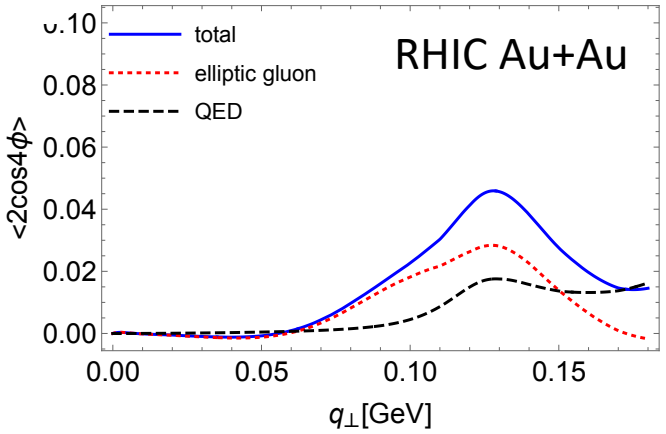


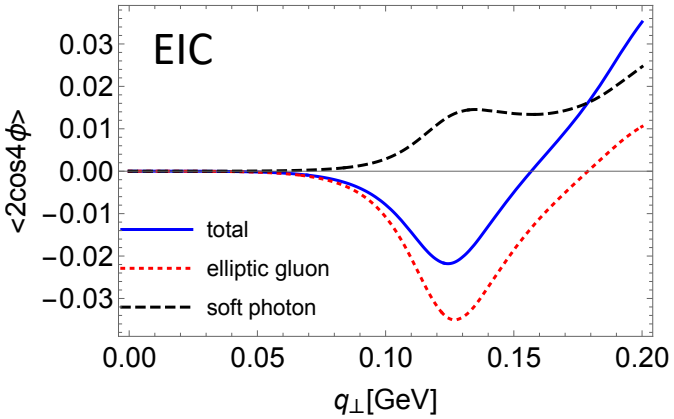
Final state asymmetries due to QED-QCD interference, reveals phase between photon and gluon fields

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