Supported in part by
U.S. DEPARTMENT OF ENERGY | Office of Science

Baryon-antibaryon Production in Au+Au Ultra-Peripheral Collisions at RHIC

Xin Wu

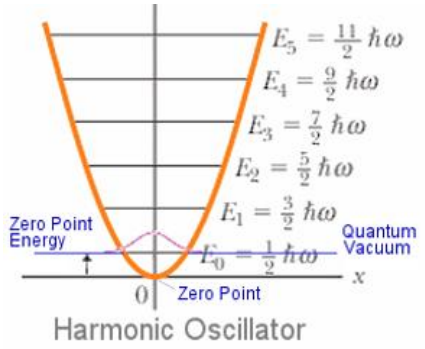
(for the STAR Collaboration)

University of Science and Technology of China

SQM2024
The 21st International Conference on Strangeness in Quark Matter
3-7 June 2024, Strasbourg, France

Motivation

The vacuum is not empty!
→ Zero point energy

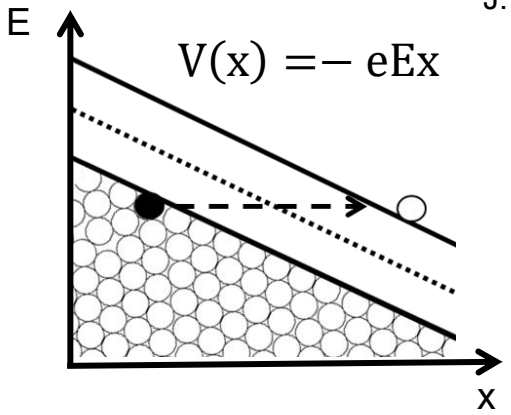


Indirect observables:

Lamb shift
Casimir effect

The Schwinger mechanism

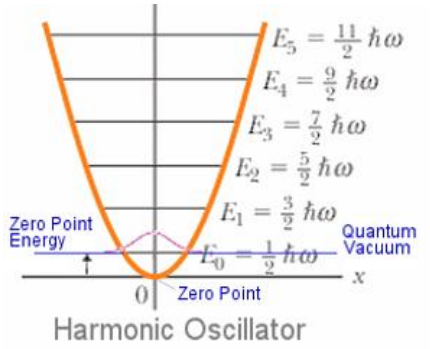
J. Schwinger, PR 82 (1951) 664



Extreme external field to spark the vacuum!

Motivation

The vacuum is not empty!
→ Zero point energy

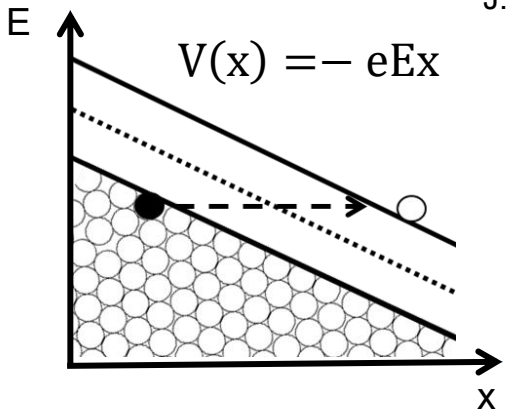


Indirect observables:

Lamb shift
Casimir effect

The Schwinger mechanism

J. Schwinger, PR 82 (1951) 664

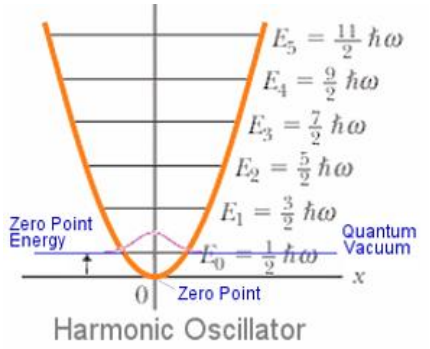


Extreme external field to spark the vacuum!

Can we directly “see” the vacuum quantum fluctuation?

Motivation

The vacuum is not empty!
→ Zero point energy



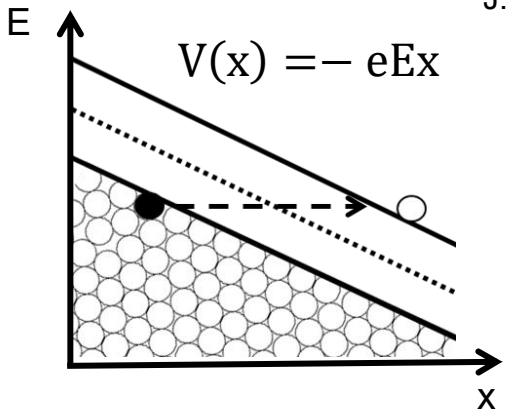
Harmonic Oscillator

Indirect observables:

Lamb shift
Casimir effect

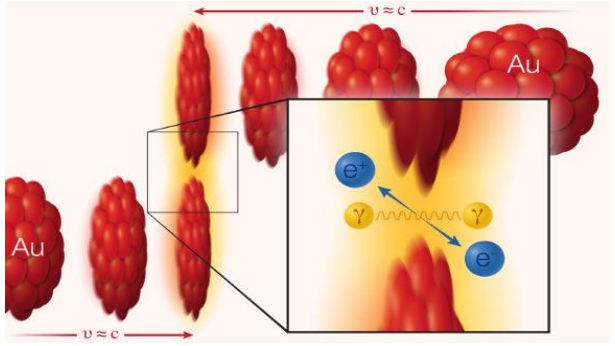
The Schwinger mechanism

J. Schwinger, PR 82 (1951) 664



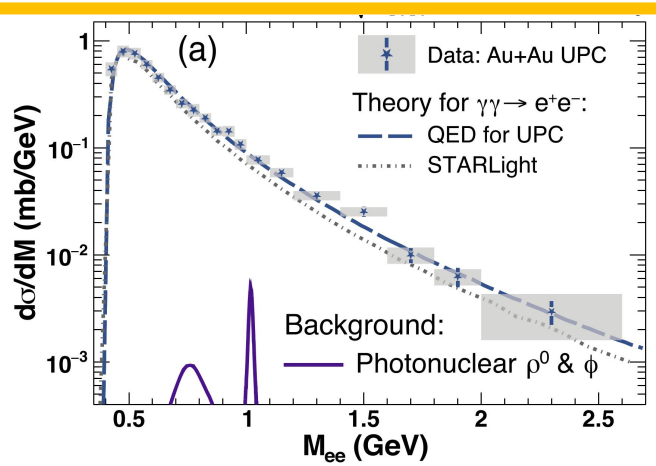
Extreme external field to spark the vacuum!

Can we directly "see" the vacuum quantum fluctuation?



Breit-Wheeler process

Image credit: Brookhaven National Laboratory

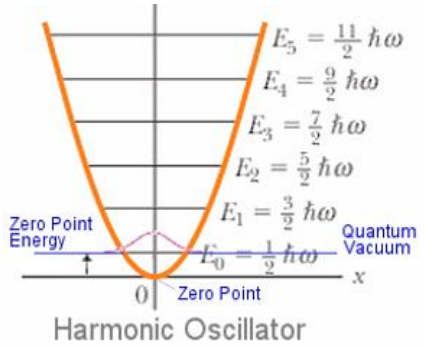


STAR, PRL121 (2018) 132301, PRL127 (2021) 052302

- $\gamma\gamma \rightarrow l^+l^-$ has been measured
- QED theory describes data very well

Motivation

The vacuum is not empty!
→ Zero point energy

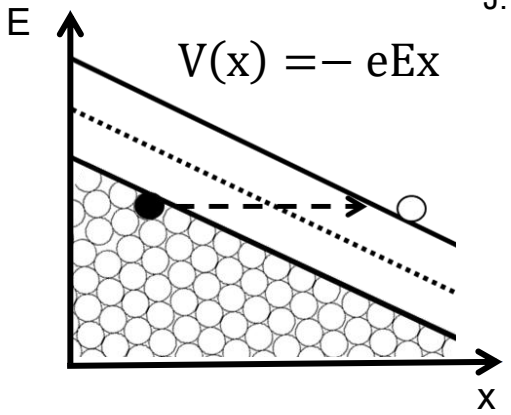


Indirect observables:

Lamb shift
Casimir effect

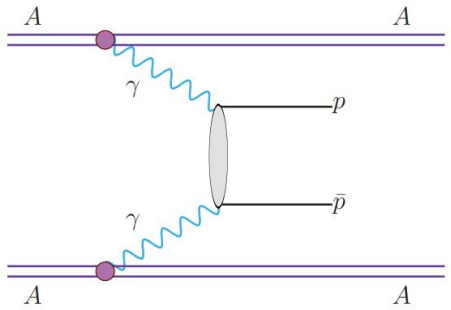
The Schwinger mechanism

J. Schwinger, PR 82 (1951) 664

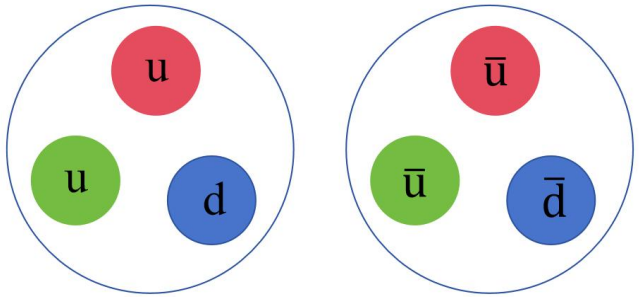


Extreme external field to spark the vacuum!

How about higher-order QED vacuum excitation?



M. Kłusek-Gawenda et al., PRD107 (2023) 036020

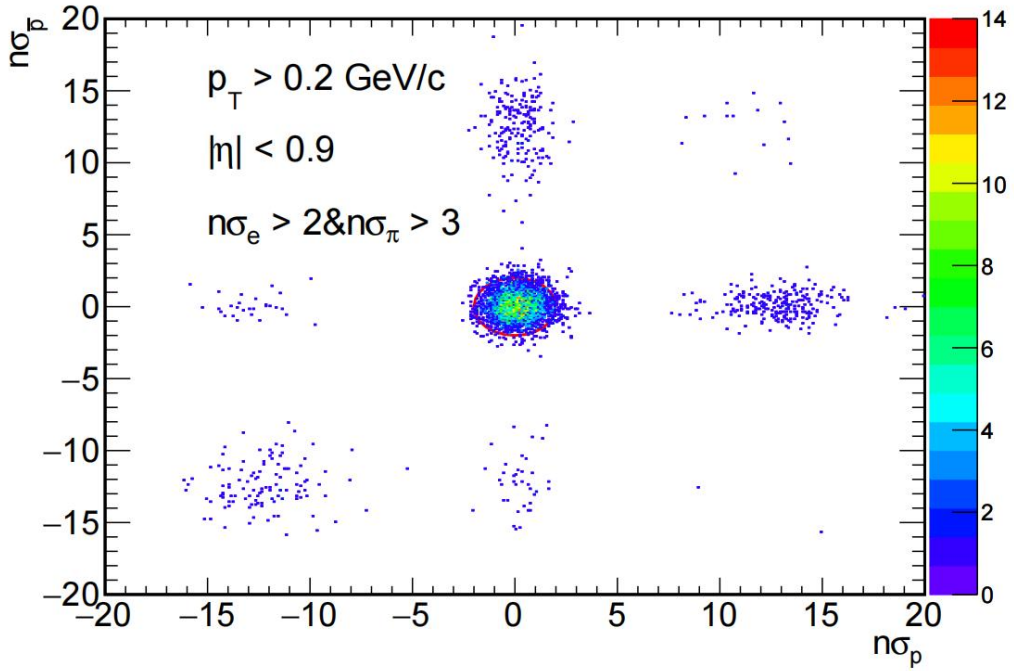


Baryon/Antibaryon: more complex system

- Can γγ produce more complex baryon antibaryon pairs?

Measure Proton-antiproton Pair Production in UPCs

- Dataset: Au+Au ultra-peripheral collisions (UPCs) at $\sqrt{s_{\mathrm{NN}}}$ = 200 GeV taken in 2010, 2011 and 2014

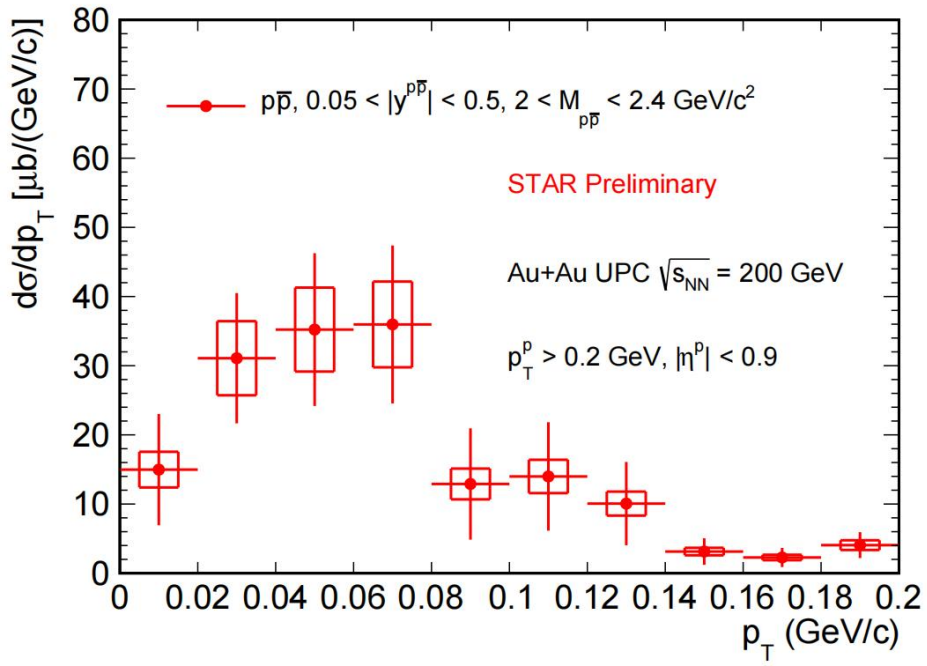


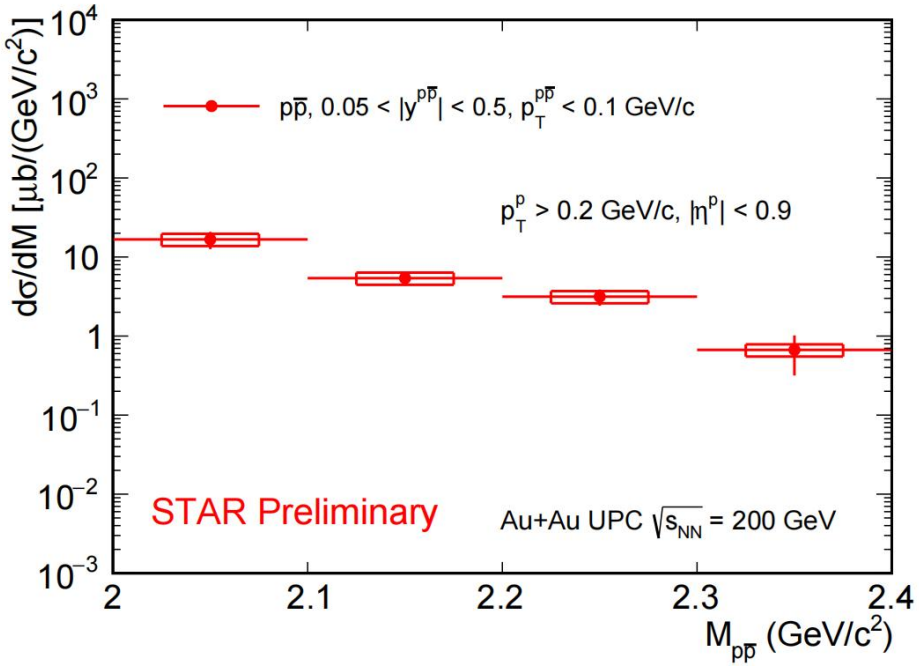
$$n\sigma_x = \frac{1}{\sigma}\log\frac{\langle \mathrm{dE/dx}\rangle^{Measured}}{\langle \mathrm{dE/dx}\rangle_x^{Theory}}$$

$$\chi^2_{p\bar{p}} = n\sigma_p{}^2 + n\sigma_{\bar{p}}{}^2 < 4$$

- Coincidence between two ZDCs
- Events with only two charged tracks
- Protons and antiprotons identified by Time Projection Chamber

Measure Proton-antiproton Pair Production in UPCs



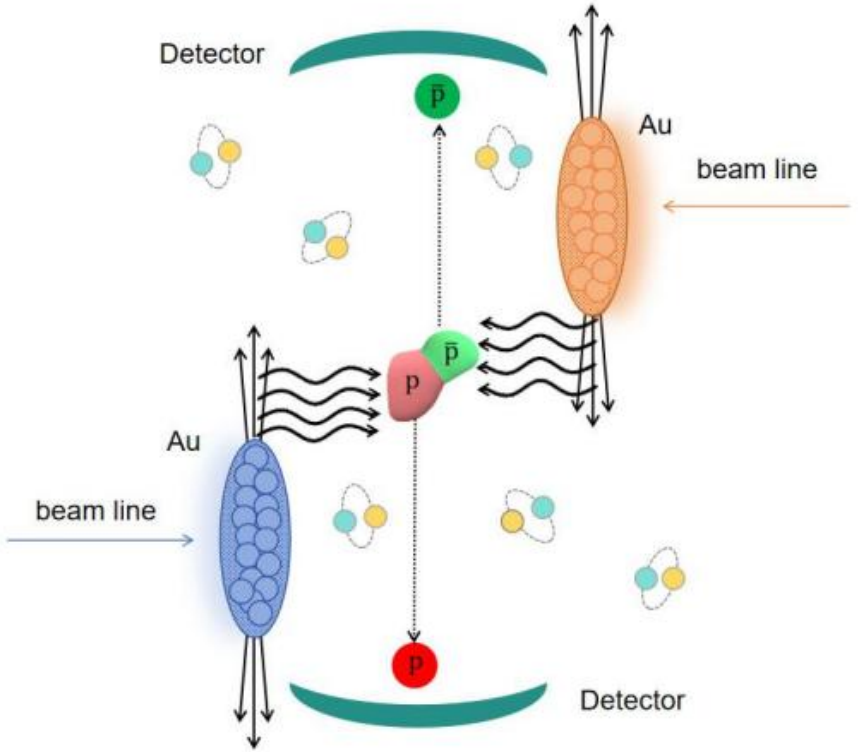


- The $p\bar{p}$ pairs produced at very low p_T
- Decreasing trend from 2 to 2.4 GeV/c²

First measurement of baryon-antibaryon pair production in UPCs!

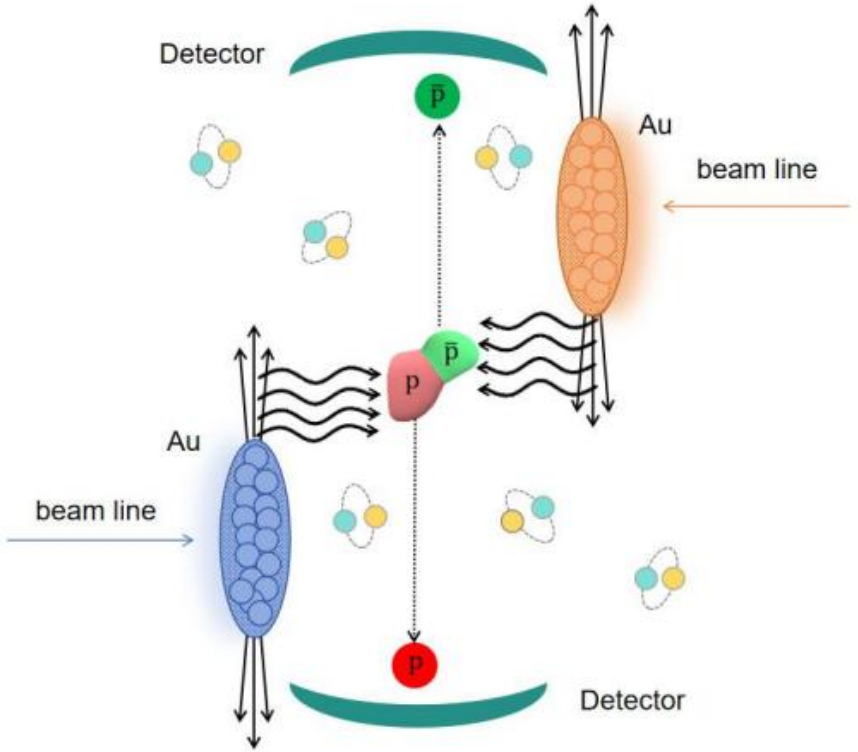
Low-p_{T} $\mathrm{p\bar{p}}$ Production Mechanism

- Vacuum Excitation

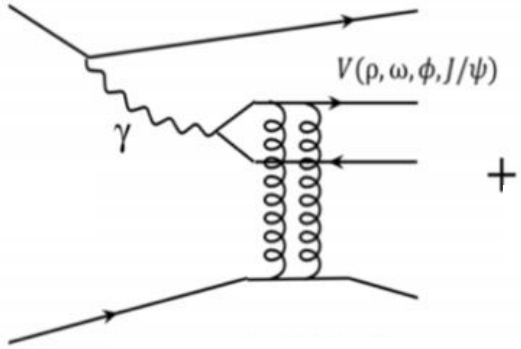


Low-p_T $p\bar{p}$ Production Mechanism

- Vacuum Excitation



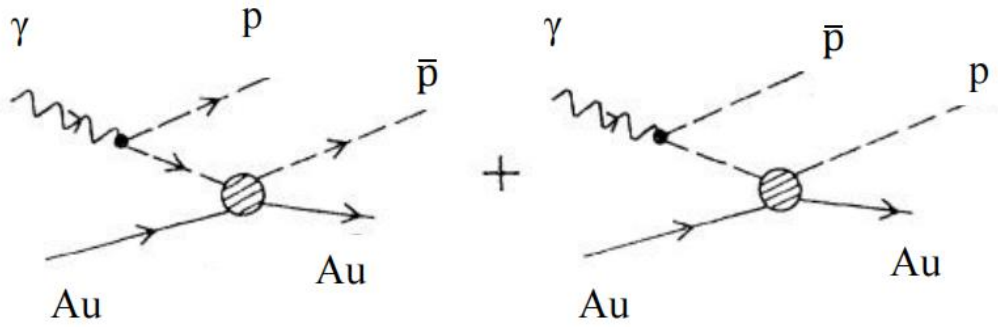
- Background: γA interaction



S. Klein,
ARNPS55 (2005) 271

$$\gamma + \mathrm{Au} \rightarrow \mathrm{V} + \mathrm{Au} \rightarrow \mathrm{p\bar{p}X} + \mathrm{Au}$$

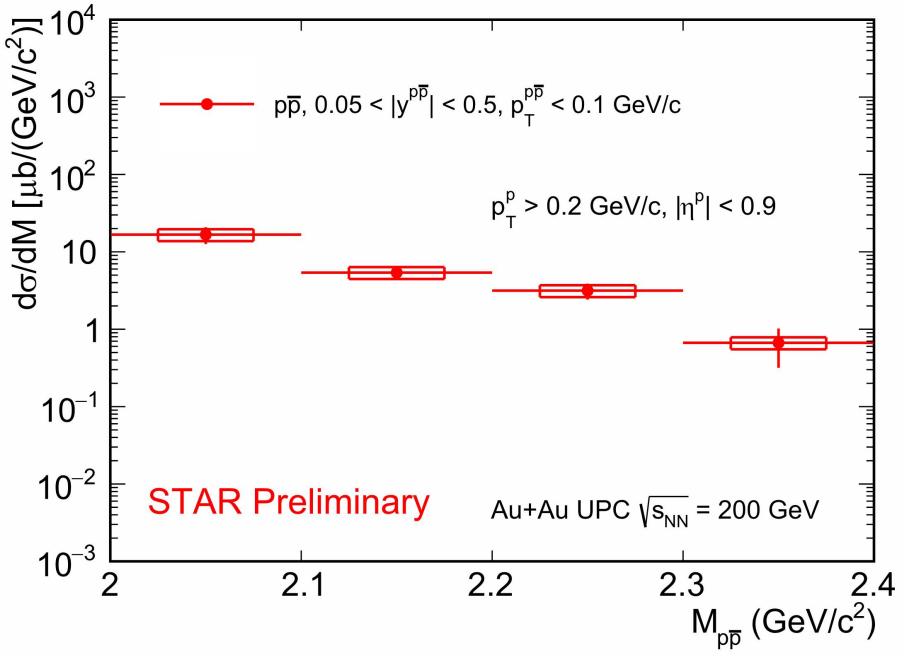
Vector mesons: J/Ψ...



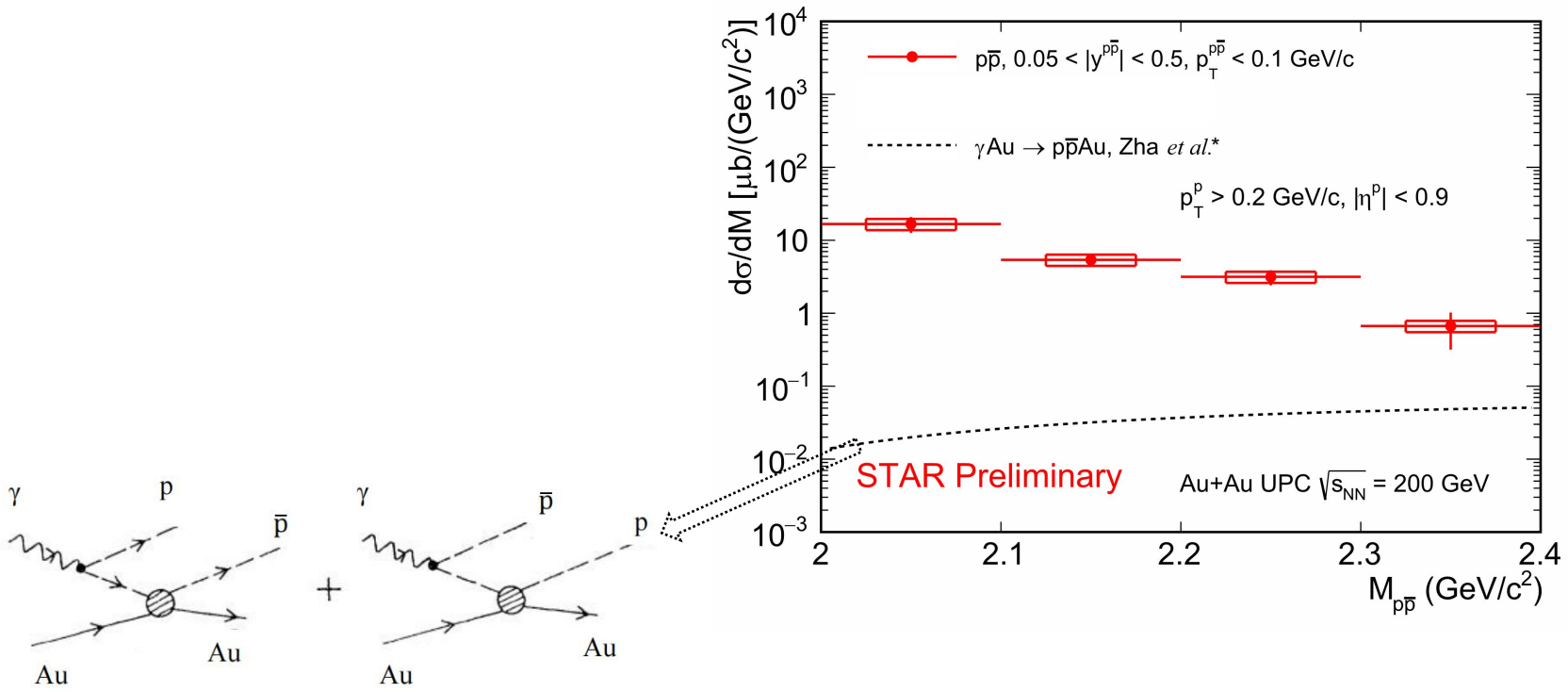
P. Sodding,
PLB19 (1966) 702

Drell-Söding Process

Comparison with Model Calculation



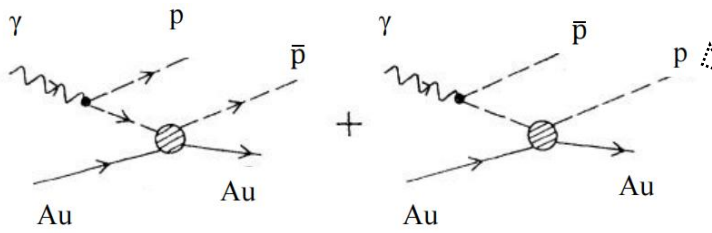
Comparison with Model Calculation

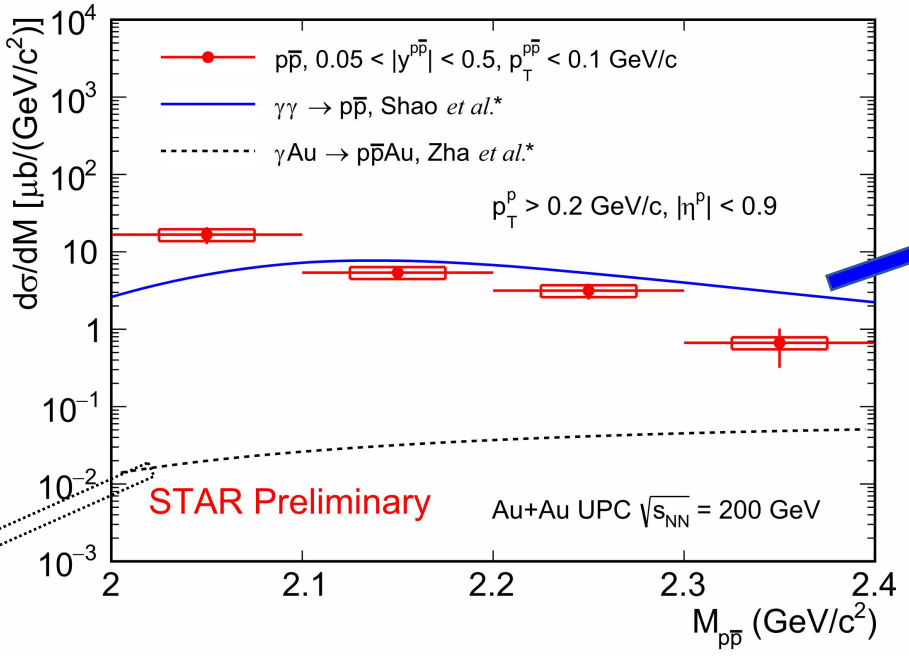


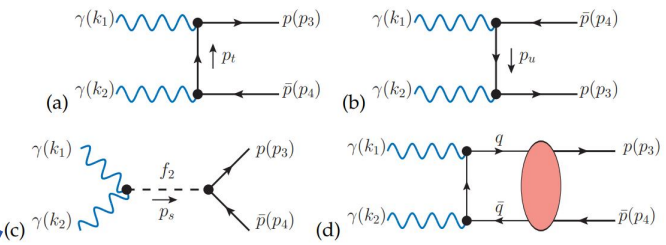
W. Zha et al., PRC97 (2018) 044910 and private communication

- Drell-Soding process significantly lower than the measurement

Comparison with Model Calculation





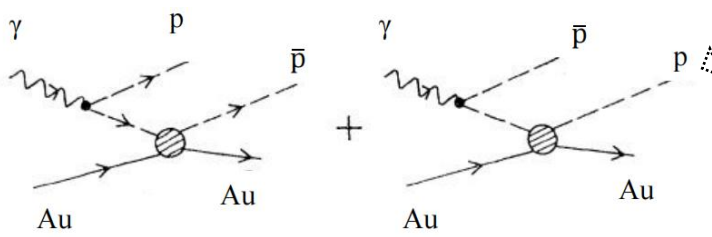


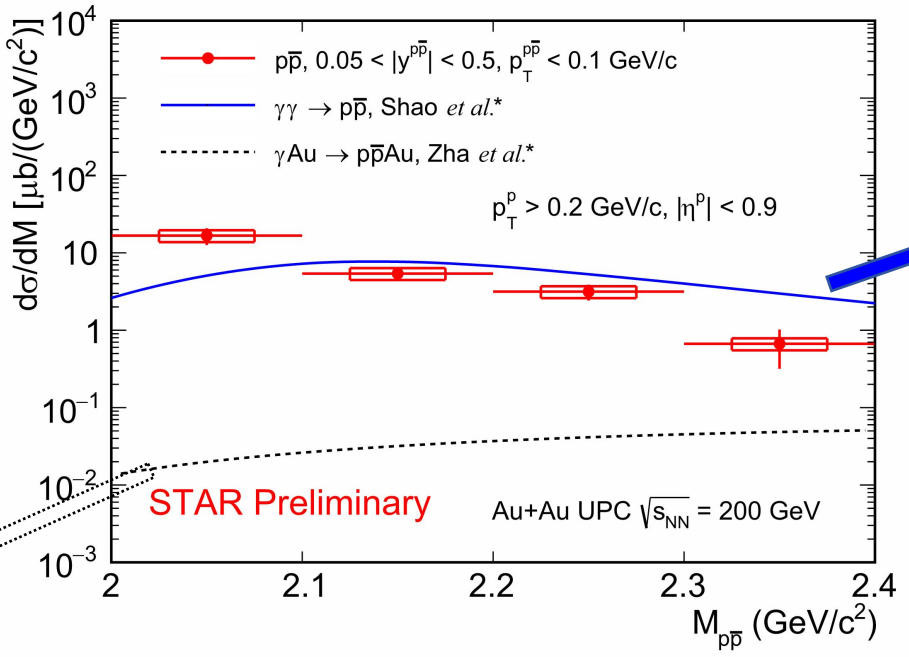
D. Shao et al., PRD107 (2023) 036020 and private communication

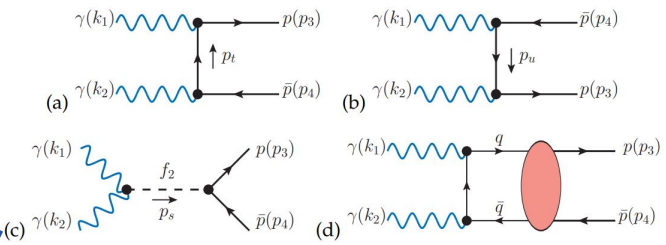
W. Zha et al., PRC97 (2018) 044910 and private communication

- Drell-Soding process significantly lower than the measurement
- $\gamma\gamma \rightarrow p\bar{p}$ process more consistent with the data

Comparison with Model Calculation







D. Shao et al., PRD107 (2023) 036020 and private communication

W. Zha et al., PRC97 (2018) 044910 and private communication

- Drell-Soding process significantly lower than the measurement
- $\gamma\gamma \rightarrow p\bar{p}$ process more consistent with the data

First observation of the $\gamma\gamma \rightarrow$ baryon-antibaryon process in heavy-ion UPCs!

Thank you for your attention!