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

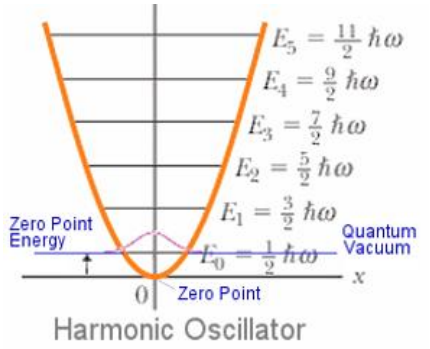
Xin Wu

(for the STAR Collaboration)

University of Science and Technology of China

Motivation

The vacuum is not empty!
→ Zero point energy

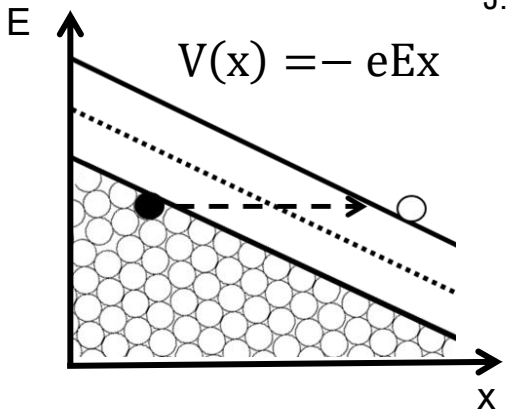


Indirect observables:

Lamb shift
Casimir effect

The Schwinger mechanism

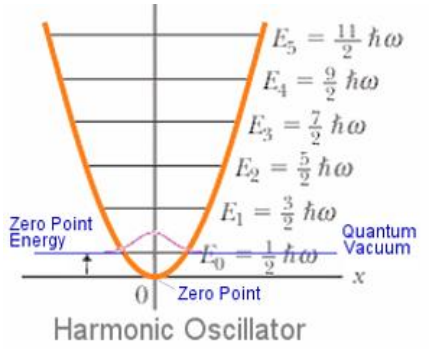
J. Schwinger, PR 82 (1951) 664



Extreme external field to spark the vacuum!

Motivation

The vacuum is not empty!
→ Zero point energy

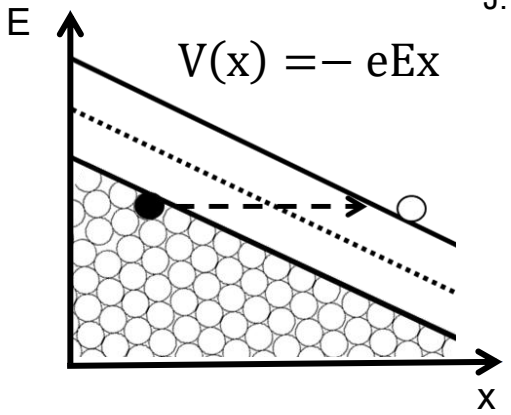


Indirect observables:

Lamb shift
Casimir effect

The Schwinger mechanism

J. Schwinger, PR 82 (1951) 664

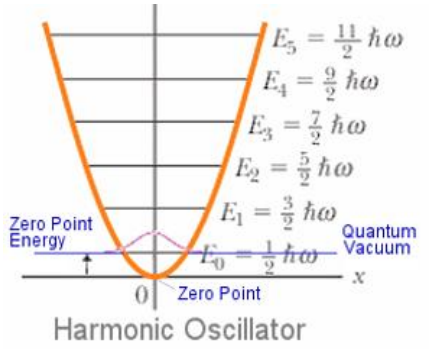


Extreme external field to spark the vacuum!

Can we directly “see” the vacuum quantum fluctuation?

Motivation

The vacuum is not empty!
→ Zero point energy



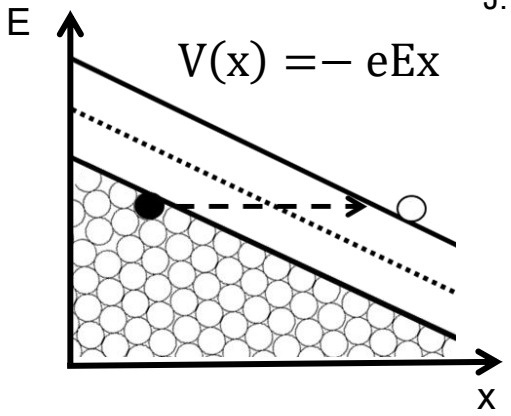
Harmonic Oscillator

Indirect observables:

Lamb shift
Casimir effect

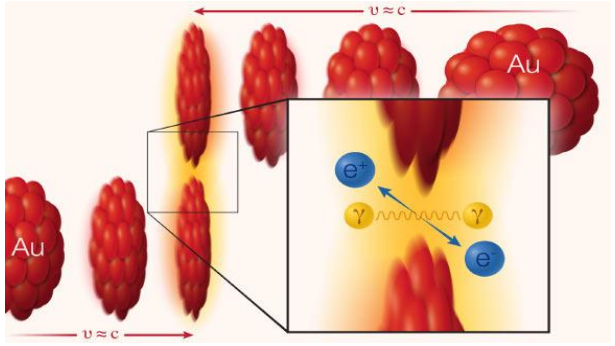
The Schwinger mechanism

J. Schwinger, PR 82 (1951) 664



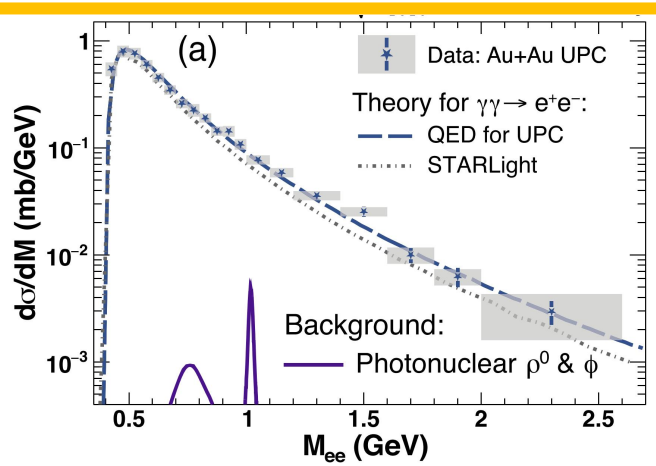
Extreme external field to spark the vacuum!

Can we directly "see" the vacuum quantum fluctuation?



Breit-Wheeler process

Image credit: Brookhaven National Laboratory

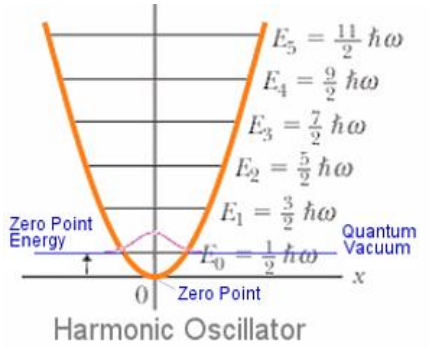


STAR, PRL121 (2018) 132301, PRL127 (2021) 052302

- γγ produce lepton pairs has been measured
- QED theory describe data very well

Motivation

The vacuum is not empty!
→ Zero point energy

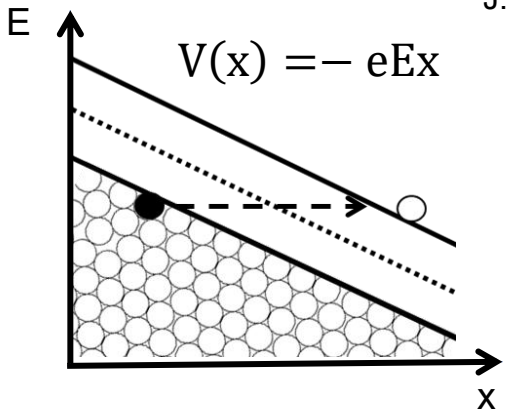


Indirect observables:

Lamb shift
Casimir effect

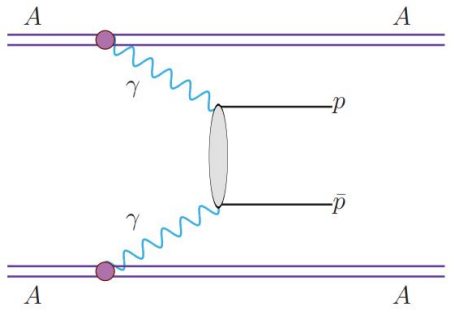
The Schwinger mechanism

J. Schwinger, PR 82 (1951) 664

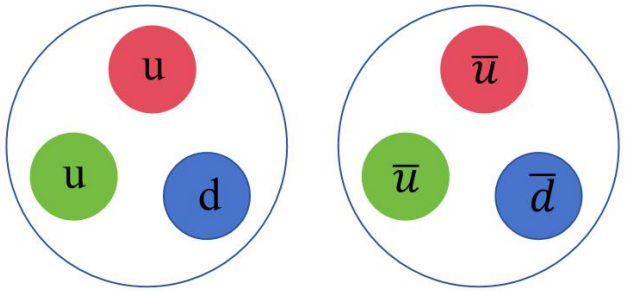


Extreme external field to spark the vacuum!

How about higher-order QED vacuum excitaion?



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

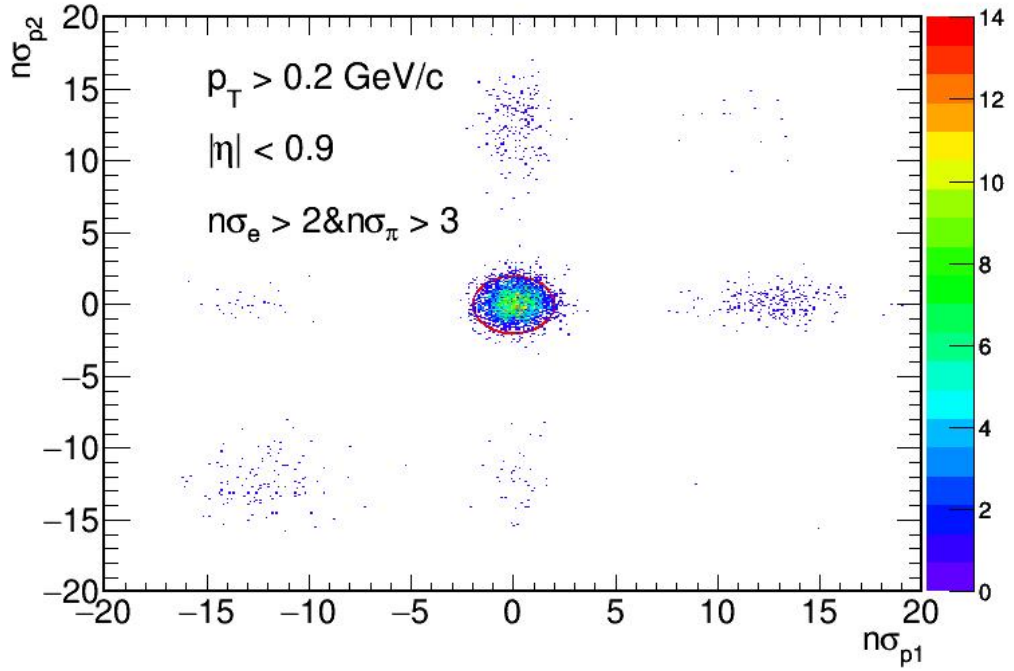


Baryon/Antibaryon: more complex system

- Can γγ produce more complex baryon antibaryon pairs?

Measurement of Proton-anti-proton at STAR

- Dataset: 200 GeV Au+Au taken in 2010, 2011 and 2014
- Ultra-peripheral collisions with Coulomb excitation

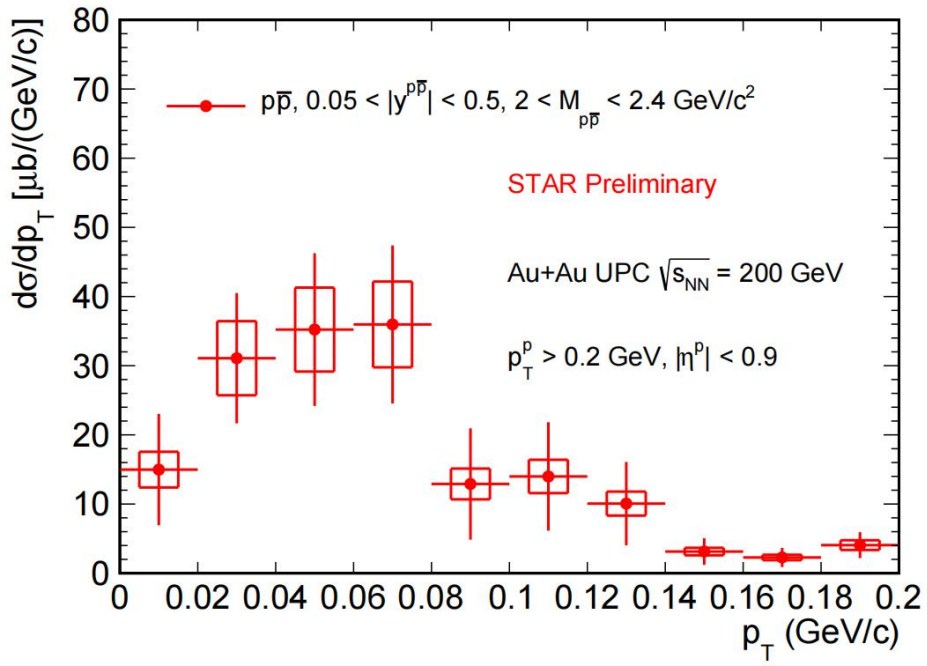


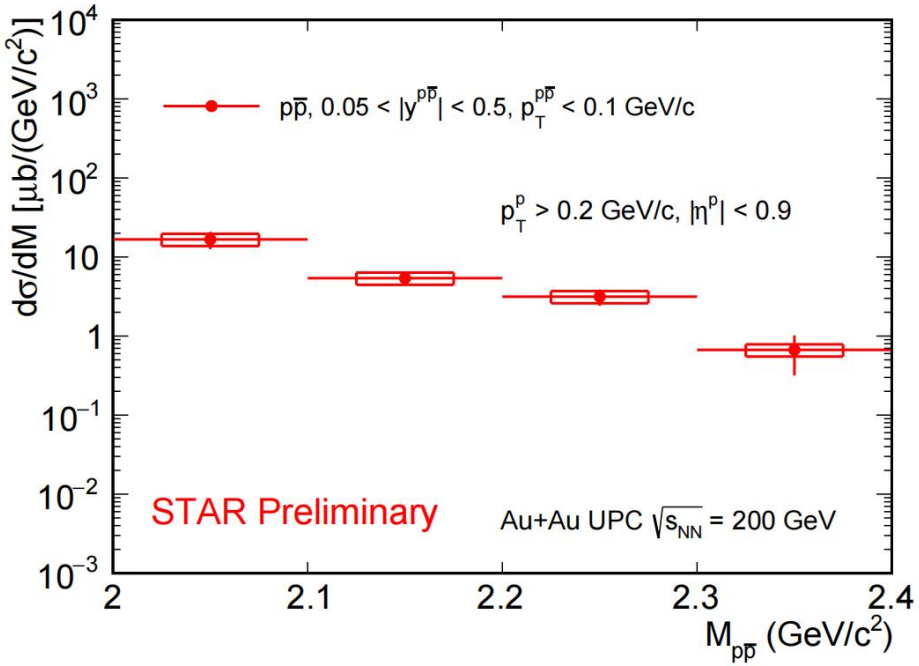
$$n\sigma_x = \frac{1}{\sigma}\log\frac{\langle \mathrm{dE/dx}\rangle^{Measured}}{\langle \mathrm{dE/dx}\rangle_x^{Theory}}$$

$$\chi^2_{p_1p_2} = n\sigma_{p_1}{}^2 + n\sigma_{p_2}{}^2 < 4$$

- Event with only two charged tracks
- Proton identified by Time Projection Chamber

Measurement of Proton-anti-proton at STAR



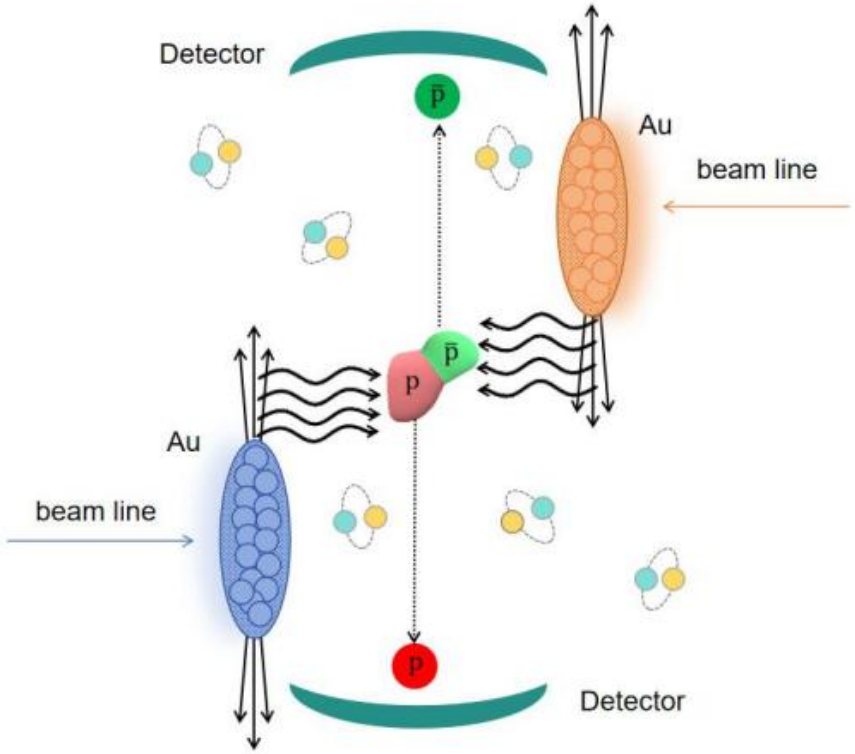


- The $\mathrm{p\bar{p}}$ pairs produced at very low p_{T}
- Decreasing trend from 2 to 2.4 GeV/c²

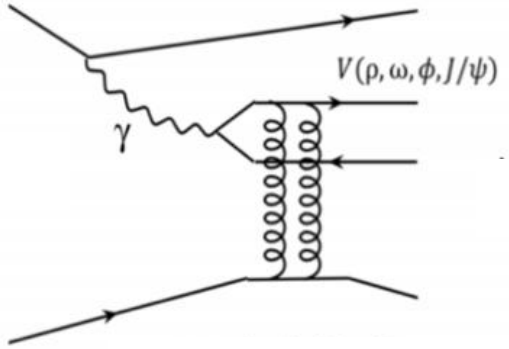
First measurement of baryon-antibaryon production in ultra-peripheral collisions!

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

- Vacuum Excitation



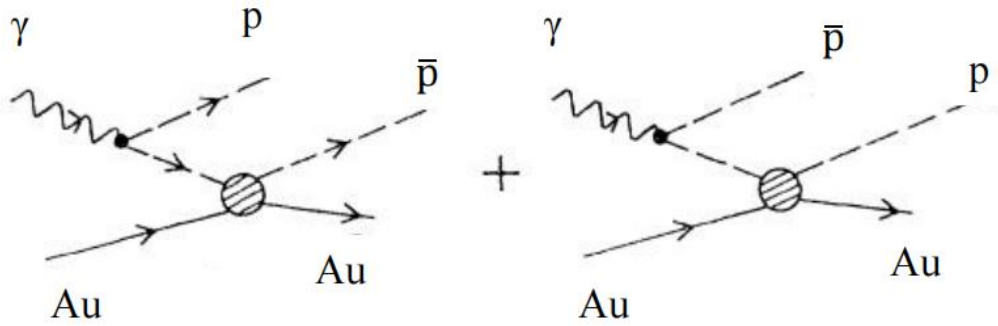
- Background: γA interaction



S. Klein,
ARNPS55 (2005) 271

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

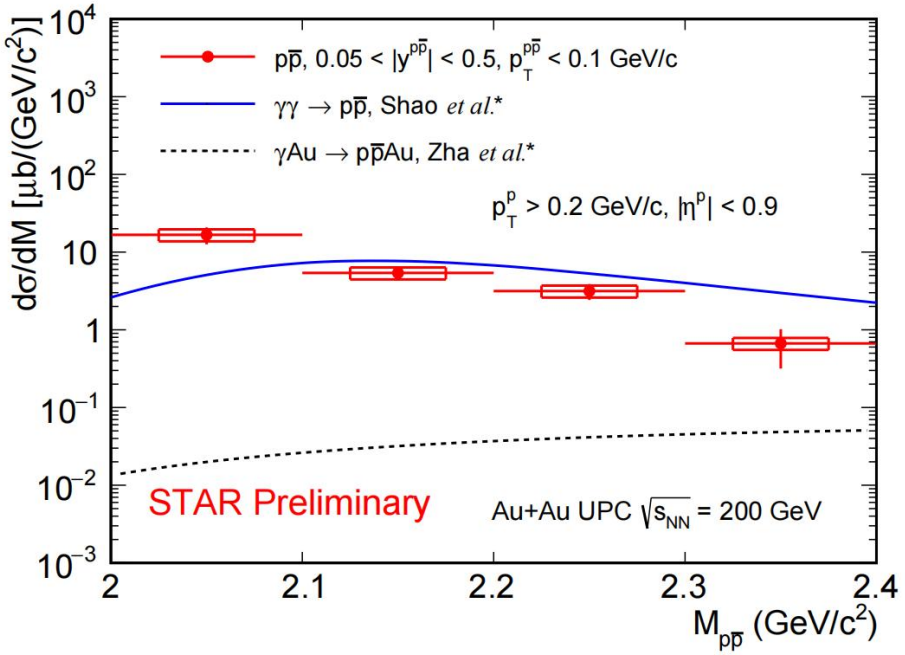
Vector mesons: J/Ψ...



P. Sodding,
PLB19 (1966) 702

Drell-Söding Process

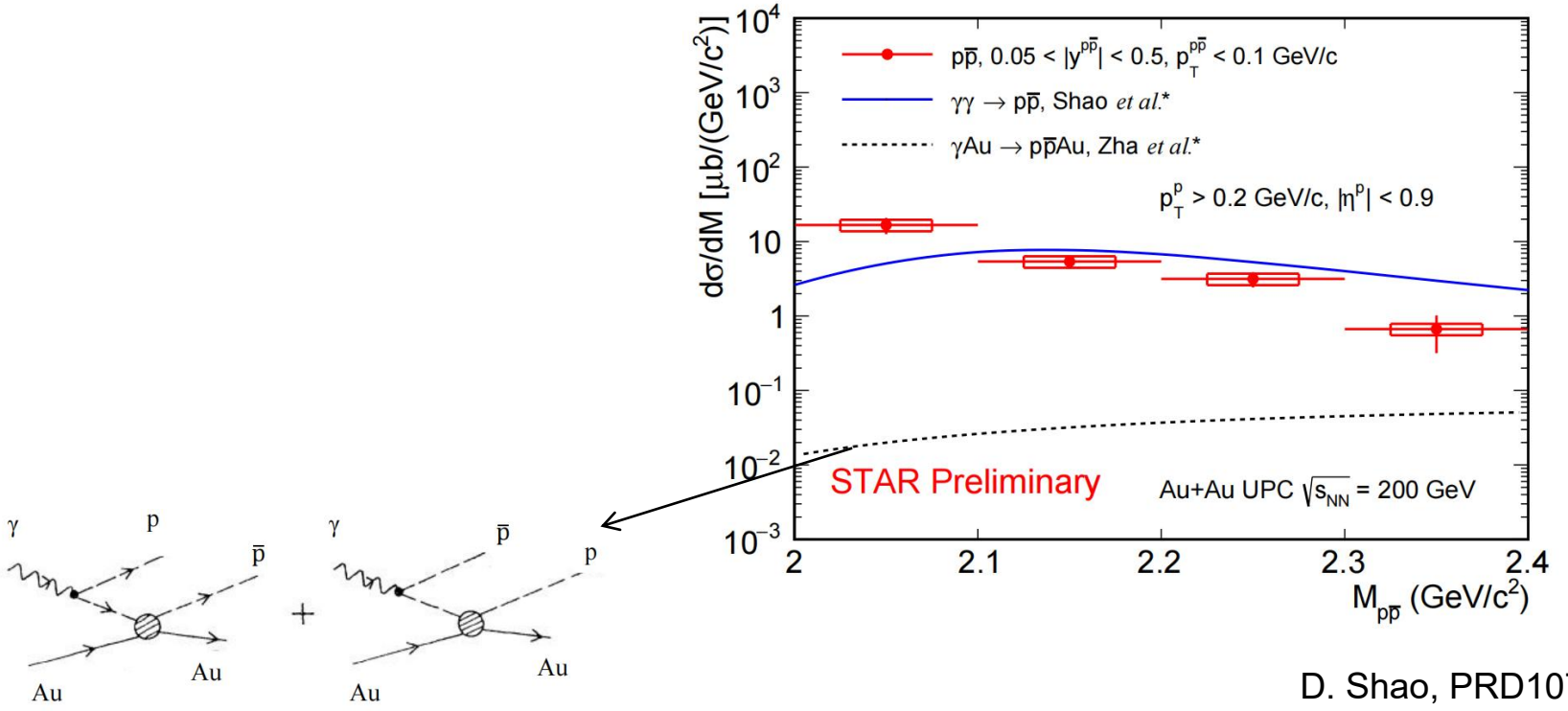
Comparison with Model Calculation



D. Shao, PRD107 (2023) 036020 and private communication
W. Zha, PRC97 (2018) 044910 and private communication

- Drell-Soding process significantly lower than the measurement
- $\gamma\gamma \rightarrow p\bar{p}$ process is consistent to this data

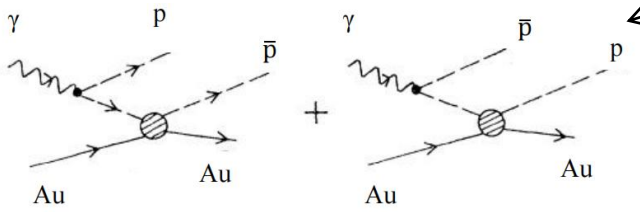
Comparison with Model Calculation

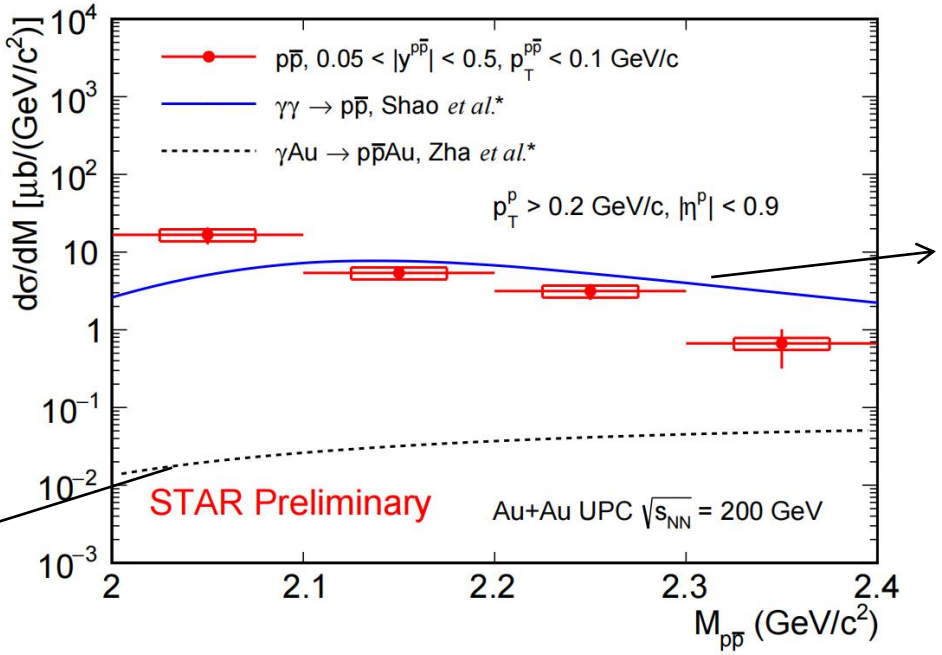


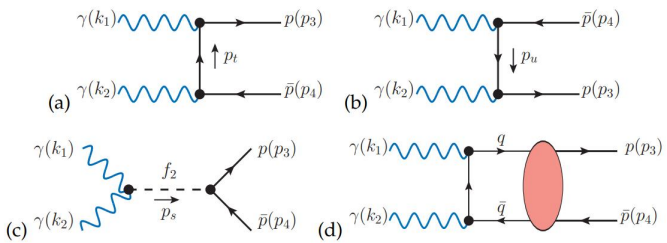
D. Shao, PRD107 (2023) 036020 and private communication
W. Zha, PRC97 (2018) 044910 and private communication

- Drell-Soding process significantly lower than the measurement
- $\gamma\gamma \rightarrow p\bar{p}$ process is consistent to this data

Comparison with Model Calculation



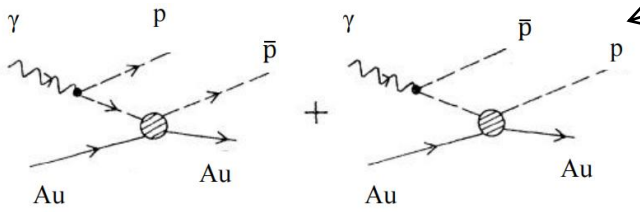


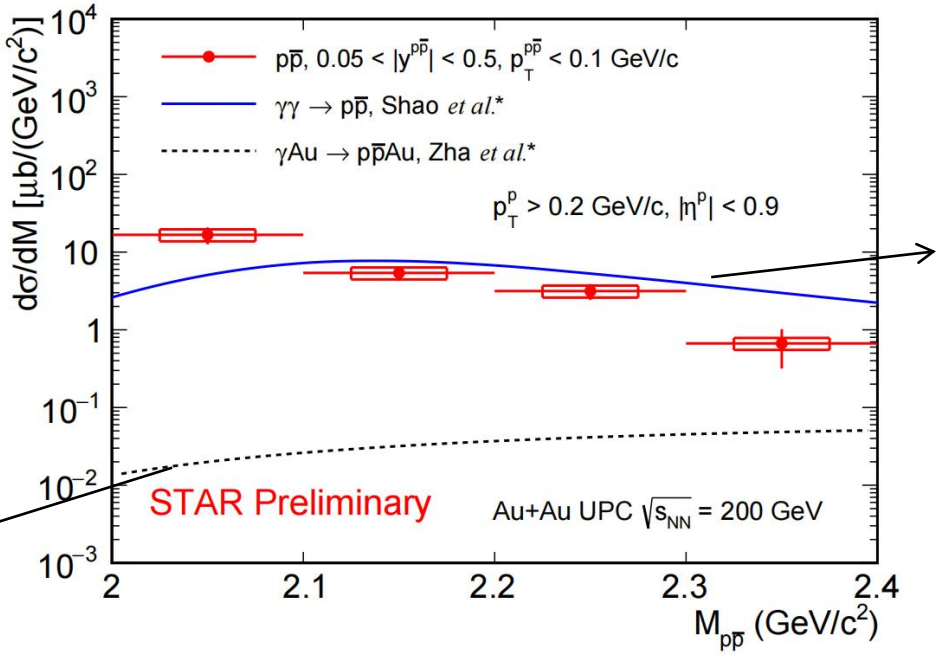


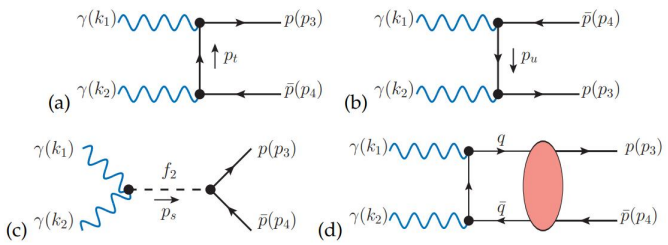
D. Shao, PRD107 (2023) 036020 and private communication
W. Zha, PRC97 (2018) 044910 and private communication

- Drell-Soding process significantly lower than the measurement
- $\gamma\gamma \rightarrow p\bar{p}$ process is consistent to this data

Comparison with Model Calculation







D. Shao, PRD107 (2023) 036020 and private communication
W. Zha, PRC97 (2018) 044910 and private communication

- Drell-Soding process significantly lower than the measurement
- $\gamma\gamma \rightarrow p\bar{p}$ process is consistent to this data

First observation of the $\gamma\gamma$ to $B\bar{B}$ process in heavy ion UPC collisions!

Thank you for your attention!