Initial electromagnetic field dependence of photon-induced production in isobaric collisions at STAR

Kaifeng Shen
(for the STAR collaboration)
State Key Laboratory of Particle Detection and Electronics,
Department of Modern Physics,
University of Science and Technology of China
Motivation and STAR Experiment

$e^+e^-$ Pair Production in Ru+Ru and Zr+Zr Collisions at $\sqrt{s_{NN}} = 200$ GeV at Very Low $p_T$

J/$\psi$ Production in Ru+Ru and Zr+Zr Collisions at $\sqrt{s_{NN}} = 200$ GeV at Very Low $p_T$

Angular Distribution of $e^+e^-$ in Isobaric Collisions

Summary
Photon-induced Production in Peripheral Collisions

- Photon-induced interactions could explain the observed enhancements of $J/\psi$ and $e^+e^-$ production at very low $p_T$.

- The photon-induced production is sensitive to initial EM field:
  - Charge (Z) of the colliding nuclei
  - Collision system

Photon-induced Production in Peripheral Collisions

- The isobaric collisions provide a unique opportunity to test the electromagnetic field dependence

- Comparison between $\text{Ru+Ru}$ and $\text{Zr+Zr}$:
  - Charge (Z)
  - Impact parameter
  - ...

- Comparison between $\text{Au+Au}/\text{U+U}$ and Isobaric collisions:
  - Charge (Z)
  - Impact parameter
  - ...

- • Charge (Z)
- • Collision energy
- • Impact parameter
- • ...

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Kaifeng Shen@SQM2022
The Breit-Wheeler process has been investigated in peripheral and ultraperipheral Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV through $\gamma + \gamma \rightarrow e^+e^-$ process.

- The fourth-order angular modulation, $\cos(4\Delta\phi)$, measured in isobaric collisions.
- Investigate collision system dependence of $\cos(4\Delta\phi)$.

The **Solenoid Tracker At RHIC**

- **BEMC:** $E_0/p$, improves electron purity at high $p_T$
- **TOF:** Time of flight, particle identification
- **TPC:** Tracking, momentum and energy loss
Invariant Mass and Transverse Momentum Distributions of $e^+e^-$

Excesses above hadronic production are observed at low-$p_T$. 

STAR Preliminary

$p_T > 0.2$ GeV/c, $|η^e| < 1$, $|y^{ee}| < 1$
The low-$p_T$ ($p_T < 0.1$ GeV/c) $e^+e^-$ excess and the ratio of excess are shown as function of $N_{part}$

- The excess yields in Ru+Ru collisions are systematically higher than in Zr+Zr collisions
- A constant function is used to fit the ratio and is about $2.4\sigma$ higher than unity
With cocktail subtracted, the yields at low-\( p_T \) are mainly from photon-induced production while the hadronic contributions dominate in intermediate \( p_T \) range.

- The ratio of excess \( e^+ e^- \) yield at low-\( p_T \) (\(< 0.1 \) GeV/c) in the 40-80% centrality is consistent with EPA-QED calculation and \( Z^4 \) scaling.

- The initial EM fields seem to be different.

The charge dependence of the integrated excess yield in the mass region of 0.4-0.76 GeV/c² at low-p_T ( <0.15 GeV/c) in 70-80% centrality.

The excess yields in isobaric collisions are significantly smaller compared to those in Au+Au and U+U collisions, which is an interplay of the differences in charge, impact parameter and form factor.

Charge Dependence of Scaled Excess Yield

- $Z^4$ scaled yield shows clear collision system dependence, likely originating from impact parameter dependence.
- Decreasing trend described the EPA-QED calculation.

The yield spectra are fitted by the Tsallis function at \( p_T \) larger than 0.2 GeV/c, and extrapolated to low-\( p_T \) range.

The data are well described by the fitted curves above 0.2 GeV/c, but show significant enhancements at low-\( p_T \) range.

The \( R_{AA} \) is significantly higher than unity at low-\( p_T \) range.
The collision system dependence ($^{96}_{44}$Ru+$^{96}_{44}$Ru and $^{96}_{40}$Zr+$^{96}_{40}$Zr ) of yield is shown as function of $p_T$

- Inclusive $J/\psi$ production follows $Z^2$ scaling at very low $p_T$
- $\sim 1.7\sigma$ deviation from unity at $p_T < 0.2$ GeV/c
- Hint of different initial EM fields
Collision System Dependence Between Isobar and Au+Au / U+U

- Scale $J/\psi$ excess yields at very low $p_T$ with $Z^2$
- The photo-nuclear production of $J/\psi$ seems to be independent of collision species at a given centrality
- Effects of form factor and impact parameter seem to balance each other

Clear \( \cos(4\Delta \phi) \) signal (~3.6\( \sigma \)) in isobaric collisions: \( |A_{4\Delta \phi}| = 0.47 \pm 0.13 \text{(stat)} \pm 0.05 \text{(sys)} \)

\(~\)\( |A_{4\Delta \phi}| \) predicted by QED-EPA is 0.40

No significant difference between isobaric and Au+Au collisions
Summary

- Enhancements of $J/\psi$ and $e^+e^-$ production at very low $p_T$ have been observed in peripheral isobaric collisions.

- The collision species dependence of photon-induced production have been measured at STAR:
  - The initial EM field seems to be different in peripheral Ru+Ru and Zr+Zr collisions.
  - After taking out the charge difference, the excess yield of $J/\psi$ is mostly independent of collision system, while $e^+e^-$ shows an impact parameter dependence.

- The $\cos(4\Delta\phi)$ signal is prominent (~3.6$\sigma$) in isobaric collisions and no significant difference is observed between isobaric and Au+Au collisions.

Thanks!