

Lepton pair photoproduction in Ultra-peripheral and peripheral heavy ion collisions

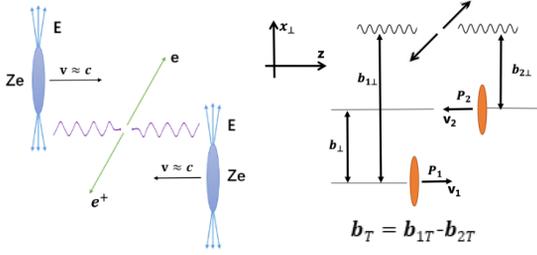
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Abstract

The lepton pair production in ultra-peripheral and peripheral collisions is studied in the classical field approximation. We derive a general form of the cross section in terms of photon distributions which depend on the transverse momentum and coordinate based on the wave packet form of nuclear wave functions. Such a general form of the cross section in the classical field approximation contains the results of the generalized equivalent photon approximation (EPA) as well as the corrections beyond EPA in the Born approximation. By rewriting the general form of the cross section in light-cone coordinates, we find a good connection with the transverse momentum dependent distribution factorization formalism in the Born approximation. Our numerical results are consistent with current experimental data.

Introduction



According to the equivalent photon approximation (EPA) or the Weizsacker-Williams method, strong electromagnetic fields generated by fast moving nucleus can be treated as the quasi-real photons. Recently, the lepton pair production through the fusion of two quasi-real photons, named Breit-Wheeler process, in ultra-peripheral collisions (UPC) has drawn broad interest. The process may provide a baseline for the medium effects in peripheral collisions (PC) and has been measured by STAR, ATLAS and CMS Collaboration.

Several theoretical methods are available to describe the lepton pair production in UPC. A widely used method is the EPA, however, EPA fails to describe the experimental data due to missing the essential information of transverse momentum and polarization of photons. To understand the experimental results, the generalized EPA (gEPA) or the calculations based on QED models in the background field approaches, the transverse momentum dependent (TMD) parton distribution functions as well as the photon Wigner functions factorization formalism were introduced.

In this work, we will derive a general form of the cross section based on wave-packet nuclear wave functions, which incorporates photon distributions with the dependence on the transverse momentum and coordinate. The cross sections in (g)EPA and the TMD formalism can be derived from the general form.

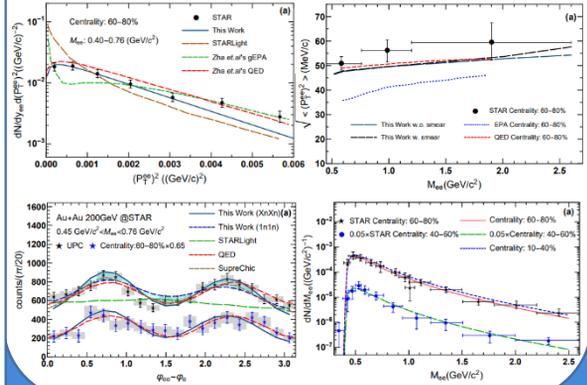
Theoretical method

In order to describe collisions at fixed impact parameters, we need to assume the wave functions of colliding nuclei to be wave packets. After a long calculation, we have derived the differential cross section for the photoproduction in a compact form,

$$\begin{aligned} \frac{d\sigma}{d^3k_1 d^3k_2} = & \frac{1}{32(2\pi)^6 E_{k_1} E_{k_2}} \int d^2b_T d^2b_{1T} d^2b_{2T} \int d^4p_1 d^4p_2 \\ & \times \delta^2(b_T - b_{1T} + b_{2T}) (2\pi)^4 \delta^4(p_1 + p_2 - k_1 - k_2) \\ & \times \int \frac{d^2P_{(1+1)T}}{(2\pi)^2} \frac{d^2P_{(2+2)T}}{(2\pi)^2} \frac{1}{v\sqrt{E_{p_1} E_{p_2} E_{p_1'} E_{p_2'}}} \\ & \times G^2 \left[(P_{1T}^z - P_{A1T}^z)^2 \right] \phi_T(P_{1T}) \phi_T(P_{2T}) \phi_T^*(P_{1T}') \phi_T^*(P_{2T}') \\ & \times S_{\sigma\mu}(p_1, b_{1T}) S_{\rho\nu}(p_2, b_{2T}) \\ & \times \sum_{\text{spin of } i\bar{i}} L^{\mu\nu}(p_1, p_2, k_1, k_2) L'^{\sigma\rho}(p_1', p_2', k_1, k_2) \end{aligned}$$

To handle the non-perturbative Wigner functions, $S_{\sigma\mu}(p_1, b_{1T})$, for photons we have adopted the classical field approximation for the cross section. In the ultra-relativistic limit, our result will reduce to the gEPA.

Numerical results



Summary

A general form of the lepton pair photoproduction cross section was derived in terms of photon Wigner functions based on the wave packet form of nuclear wave functions.

The transverse momentum and polarization information of the photon are important for understanding the experimental data.

Some high order corrections such as Sudakov factor need to be considered.

References:

- [1] R.-j. Wang, S. Pu, and Q. Wang, Phys. Rev. D 104, 056011 (2021).
- [2] R.-j. Wang, S. Lin, S. Pu, Y.-f. Zhang, and Q. Wang, in preparation.