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Exclusive J/ψ Photoproduction and Entanglement-Enabled Spin Interference in Ultra-Peripheral Collisions at STAR

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In ultra-peripheral collisions (UPCs), exclusive vector meson photoproduction, e.g., ρ^0 and J/ψ, has been considered one of the most sensitive probes to the gluon structure in heavy nuclei. Recently, it was discovered that the linear polarization of the photons involved in these processes can enable measurements of the nuclear geometry through the so-called entanglement-enabled spin interference with the ρ^0 meson. However, the possibility that the interference can happen at the level of vector mesons cannot be falsified using ρ^0 data. The longer lifetime and non-localized wave function of J/ψ at the time of its decay would not result in an interference pattern similar to the ρ^0 unless the entanglement occurs between the photon and the Pomeron phases emitted from each nucleus, providing an opportunity to study the source of the entanglement.

In this talk, we will report first measurements of the differential cross sections of photoproduced J/ψ as functions of rapidity y and $p_T^2 \approx -t$ (up to 2.25 $(\mathrm{GeV/c})^2$) in Au+Au UPCs at $\sqrt{s_{\mathrm{NN}}} = 200$ GeV recorded by STAR. The results will be presented for different combinations of neutron emission detected in zero degree calorimeters, which can be used to resolve the photon energy ambiguity. These data provide important constraints for nuclear parton distribution functions and sub-nucleonic shape fluctuations in heavy nuclei in the kinematic range $x_{\mathrm{parton}} \sim 0.015 - 0.03$.
We also present the first measurement of the interference pattern for those photoproduced J/ψ. The observation of a positive $\cos(2\Delta\phi)$ modulation in the angular separation between the J/ψ and one of its decay daughters is predicted to be a signature of entanglement between the photon and Pomeron phases. Finally, we will provide an outlook for significantly improved measurements anticipated during the final RHIC runs in 2023-2025.

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