

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

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

10 In this talk, we will report first measurements of the differential cross sections of photoproduced
11 J/ψ as functions of rapidity y and $p_T^2 \approx -t$ (up to $2.25 \text{ (GeV}/c)^2$) in Au+Au UPCs at $\sqrt{s_{NN}} =$
12 200 GeV recorded by STAR. The results will be presented for different combinations of neutron
13 emission detected in zero degree calorimeters, which can be used to resolve the photon energy
14 ambiguity. These data provide important constraints for nuclear parton distribution functions and
15 sub-nucleonic shape fluctuations in heavy nuclei in the kinematic range $x_{\text{parton}} \sim 0.015 - 0.03$. We
16 also present the first measurement of the interference pattern for those photoproduced J/ψ . The
17 observation of a positive $\cos(2\Delta\phi)$ modulation in the angular separation between the J/ψ and
18 one of its decay daughters is predicted to be a signature of entanglement between the photon
19 and Pomeron phases. Finally, we will provide an outlook for significantly improved measurements
20 anticipated during the final RHIC runs in 2023-2025.