Exploring the spin structure of the Pomeron through quantum entanglement

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Quantum Chromodynamics (QCD) describes the strong interactions amongst the quarks and gluons that are the building blocks of visible matter. In QCD at short distances, color-charged quarks and gluons interact by the exchange of colored gluons. However it is known that the cross sections for high energy scattering are dominated by a colorless compound state of gluons (and possibly quarks) which has no yet conserved quantity associated - it has the ``quantum numbers" of the vacuum. This is the **Pomeron** and despite all the advances in QCD to date, we know very little about it. Though the Pomeron is colorless, it is not a robust particle like a meson or a baryon and conjectures that it is a glueball are unsubstantiated. Nevertheless, a good deal of high energy scattering can, at least qualitatively, be understood through the mechanism of "*Pomeron exchange*", explaining in particular the structure of multi-particle production events with so-called rapidity gaps - where no particles are produced in some region of a particle detector.

Recently there has been considerable discussion whether data points to a tensor structure of Pomeron exchange as opposed to vector exchange as previously assumed. Our LDRD will bring a novel tool to investigate the spin structure of the Pomeron by utilizing the entanglement enabled quantum interference discovered by the STAR Collaboration [1] in photon-Pomoron interactions. This effect leads to quantum interference between non-identical particles (recently also discussed in quantum optics [2]) providing a unique window into the spin structure of the Pomeron. Our work will investigate this quantum interference effect more deeply by exploring if it turns off at short impact parameters comparable to the wavefunction of the rho meson produced in photon-Pomeron interactions.

Our theory-experiment collaborative work will analyze the polarized proton-proton collision data recorded in 2022 thereby taking full advantage of DOE investment to advance an underappreciated aspect of the data. Further our work will advance the emerging synergy between high energy nuclear physics and quantum information science (QIS) allowing us to ask questions about quantum phenomena accessible previously only to tabletop experiments at much lower energies. The role of QIS in EIC physics is only beginning to be explored and the study (real and virtual) of photon-Pomeron exchanges has the potential to put it on a firm basis.

[1] STAR Collaboration, *Science Advances*, 4 Jan 2023 Vol 9, Issue 1
[2] J. Cotler, F. Wilczek, V. Borish, Entanglement enabled intensity interferometry of different wavelengths of light. Ann. Phys. 424, 168346 (2021).