Contribution ID: **3** Type: **not specified**

Bell Inequality Violation of Light Quarks in Back-to-Back Dihadron Pair Production at Lepton Colliders

Saturday, 26 April 2025 11:15 (25 minutes)

Spin correlations between particles produced at colliders provide valuable insights for quantum information studies. While traditional studies of quantum information at colliders are typically limited to massive particles with perturbative decay, we propose an innovative method to explore the Bell inequality in massless quark pair systems by analyzing the azimuthal correlations in back-to-back $\pi^+\pi^-$ dihadron pair production at lepton colliders. Revisiting the Belle data, we have shown the potential to detect Bell inequality violation of light quarks by introducing an additional angular cut, achieving a significance of 2.5 σ even in the worst-case scenario of 100\% correlated systematic uncertainties in each bins. The significance substantially exceeds 5σ when considering uncorrelated systematic uncertainties. Our approach opens avenues for exploring spin quantum information in the non-perturbative aspect and leverages existing data for quantum information research.

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Session Classification: Morning 2