

Experimental prospects for quantum decoherence measurements at colliders

martes, 20 de octubre de 2026 13:10 (20)

Quantum entanglement is one of the defining features of quantum mechanics. In high-energy colliders, quantum properties are experimentally accessible, the most important example being top quark pair production at the LHC. This channel led to the discovery of spin entanglement in 2024 [1-2].

In this work [3], we study how energetic final-state radiation modifies the spin entanglement of fermion-antifermion pairs, and demonstrate that it can lead to measurable decoherence. The study is performed at parton level using simulations computed with MadGraph5_aMC@NLO, using $t\bar{t}g$ and $\tau^+\tau^-\gamma$ production processes. The spin density matrix is reconstructed as a function of the FSR energy.

We conclude that a statistically significant observation of decoherence can be obtained with current data in associated $pp \rightarrow t\bar{t}g$ production at the LHC and in $e^+e^- \rightarrow \tau^+\tau^-\gamma$ production at Belle II. Future electron-positron colliders operating well above the $t\bar{t}g$ production threshold or at the Z pole, respectively, could further enable differential measurements of quantum entanglement as a function of the FSR energy.

[1] ATLAS Collaboration. Nature 633, 542 (2024).

[2] CMS Collaboration. PRD 110, 112016 (2024).

[3] Aoude et. al. arXiv:2604.16268v3. Submitted to PRL.

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Clasificación de la sesión : Theory and analysis