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Quantum information and entanglement with top quarks at the LHC

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Entanglement is a key subject in quantum information theory. Due to its genuine relativistic and fundamental nature, high-energy colliders are attractive systems for the experimental study of quantum information theory. We propose the detection of entanglement between the spins of top-antitop quark pairs at the LHC, representing the first proposal of entanglement detection in a pair of quarks, and also the entanglement observation at the highest energy scale so far. We show that entanglement can be observed by direct measurement of the angular separation between the leptons arising from the decay of the top-antitop pair. The detection can be achieved with more than 5 statistical deviations, using the current data recorded at the LHC. In addition, we develop a simple protocol to implement the quantum tomography of the top-antitop pair, providing a new experimental tool to test theoretical predictions for the quantum state of the top-antitop pair. Our work explicitly implements canonical experimental techniques of the quantum information field, paving the way to use high-energy colliders to study quantum information theory.

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