

# Testing nonlocality over 12.4 km of underground fiber with universal time-bin qubit analyzers

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We experimentally demonstrate that the nonlocal nature of time-bin entangled photonic qubits persists when one or two qubits of the pair are converted to polarization qubits. This is possible by implementing a novel Universal Time-Bin Qubit Analyzer (UTBA), which, for the first time, allows analyzing time-bin qubits in any basis. We reveal the nonlocal nature of the emitted light by violating the Clauser-Horne-Shimony-Holt inequality with measurement bases exploring all the dimensions of the Bloch sphere. Moreover, we conducted experiments where one qubit is transmitted over a 12.4 km underground fiber link and demonstrate the suitability of our scheme for use in a real-world setting. The resulting entanglement can also be interpreted as hybrid entanglement between different types of degrees of freedom of two physical systems, which could prove useful in large scale, heterogeneous quantum networks. This work opens new possibilities for testing nonlocality and for implementing new quantum communication protocols with time-bin entanglement.

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