# Single-pair measurement of the Bell parameter

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In 1965, J. S. Bell turned a philosophical debate into a physical experiment capable of extracting the true nature of correlations within physical systems [1], opening several research fields spanning from quantum mechanics foundations [2][3][4] to quantum technologies [5]. However, with projective measurements the wavefunction collapse and Heisenberg uncertainty principle forbid performing, on the same quantum system, all the measurements needed for evaluating the entire Bell parameter. Conversely, here we present a method for estimating the entire Bell parameter from each entangled pair while preserving the entanglement [6]. Such method relies on weak measurements [7], where a tiny coupling between the observed system and the measurement device allows estimating the observables of interest while preventing the state from collapsing: one can therefore measure incompatible observables in sequence on the same quantum state, extracting all the correlations needed to evaluate the full Bell parameter from each entangled pair. Overall, we achieve a strong (6 standard deviations) Bell inequality violation while leaving the quantum state almost unaltered, as demonstrated by tomographic reconstruction of the quantum state before and after the (weak) measurement process. This way, our experiment provides new insights into understanding the foundations of quantum mechanics, like the concept of counterfactual definiteness [8]. Moreover, after the entanglement certification process, the entanglement remains available for other quantum foundations experiments or quantum technology protocols.

## References

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