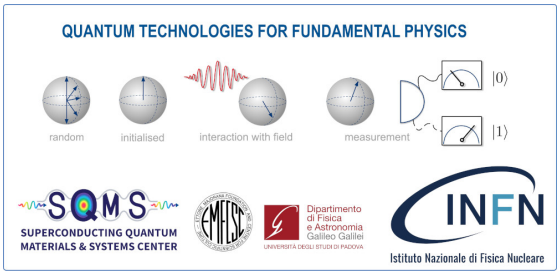

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Experimental measurement of the Bell parameter with a Single entangled pair

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Bell inequalities are one of the cornerstones of quantum foundations and fundamental tools for quantum technologies.
Recently, the scientific community worldwide has put a lot of effort towards them, which culminated with loophole-free experiments [1]. Nonetheless, none of the experimental tests so far was able to extract information on the whole inequality from each entangled pair, since the wave function collapse forbids performing, on the same quantum state, all the measurements needed for estimating the entire Bell parameter.
After a general introduction to quantum optics experiments addressing fundamental issues, we present here the first single-pair Bell inequality test able to obtain a Bell parameter value for every entangled pair detected [2]. This is made possible by exploiting sequential weak measurements [3], allowing to perform non-commuting measurements in sequence on the same state, on each entangled particle. Such a feature not only grants unprecedented measurement capability, but also removes the need to choose between different measurement bases, intrinsically eliminating the counterfactual definiteness hypothesis.
We also demonstrate how, after the Bell parameter measurement, the pair under test still presents a noteworthy amount of entanglement, providing evidence of the absence of the wave function collapse. This, on the one hand, provides new insights into the concept of quantum measurement and, on the other hand, allows us to exploit this quantum resource for further protocols.

[1] https://plato.stanford.edu/entries/bell-theorem/
[2] Salvatore Virzì, Enrico Rebufello, Francesco Atzori, Alessio Avella, Fabrizio Piacentini, Rudi Lussana, Iris Cusini, Francesca Madonini, Federica Villa, Marco Gramegna, Eliahu Cohen, Ivo Pietro Degiovanni, Marco Genovese arXiv:2303.04787
[3] F. Piacentini, et al.; Phys. Rev. Lett. 117 (2016) 170402

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