From Single Pair Measurement of CHSH to Testing Relativistic Independence Through Weak Measurements

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Bell inequalities are one of the cornerstones of quantum foundations and fundamental tools for quantum technologies [1], tied to specific aspects of quantum mechanics, such as quantum non-locality [2], sources of debate in the physicists' community.

Recently, the scientific community worldwide has put much effort towards them, culminating with loophole-free experiments [3-5]. 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. We present here the first single-pair Bell inequality test [6] able to obtain a Bell parameter value for every entangled pair detected. This is made possible by exploiting sequential weak measurements, 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 [9]. 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 and allowing us to exploit this quantum resource for further protocols. We will discuss in detail the possible applications and the impact on Foundations of Quantum Mechanics.

Then, as a further use of sequential weak measurement, we present a test [7] of the relativistic independence proposed in [8].

Finally, the next developments will be presented.

References

[1] M Genovese, Phys. Rep. **413**, 319 (2005)

[2] M Genovese and M Gramegna, Appl. Sci. **9**, 5406 (2019)

[3] B Hensen, H Bernien, A E Dréau, *et al.*, Nature **526**, 682 (2015)

[4] M Giustina, M A M Versteegh, S Wengerowsky, *et al.*, Phys. Rev. Lett. **115**, 250401 (2015)

[5] L Shalm, Phys. Rev. Lett. **115**, 250402 (2015)

[6] S Virzì, E Rebufello, F Atzori, A Avella, F Piacentini, R Lussana, I Cusini, F Madonini, F Villa and M Gramegna, Quantum Sci. Technol. **9**, 045027 (2024)

[7] F Atzori, S Virzì, E Rebufello, *et al.*, Phys. Rev. X Quantum **5**, 040351 (2024)

[8] A Carmi and E Cohen, Sci. Adv. **5**, eaav8370 (2019)

[9] M Genovese and F Piacentini, Phys. Rev. A **111**, 022204 (2024)