Device-independent entanglement depth witness from two-body correlators

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Some subset of entanglement present correlations which are strong enough as to violate a Bell inequality, which manifests non-local correlations. We consider the characterization of many-body systems by making use of such non-local correlations. In general, multipartite Bell inequalities are hard to treat from both computational and experimental points of view. However, in [1] researchers presented Bell inequalities involving only one- and two-body correlation functions and constrained by symmetry. Such Bell inequalities have been proven to be experimentally feasible resulting in the detection of Bell correlations in a Bose-Einstein condensate of 480 particles reported in [2].

Furthermore, we have recently shown in [3,4] that the non-local correlations detected by such Bell inequalities can be used to characterize the amount of entanglement present on a many-body system. In particular we use them to construct a Device-Independent Witness of Entanglement Depth (DIWED). That is, a witness that certifies how many particles are genuinely entangled without relying on assumptions on the system nor on the measurements performed. As illustrated in (fig. 1), one ends up with a hierarchy of bounds whose violation provides certification of the depth of entanglement.

Finally, in recent unpublished advances, we are using the presented toolset in order to look at the role of non-local correlations near quantum critical points and how non-local correlations can be used to characterize such situations.

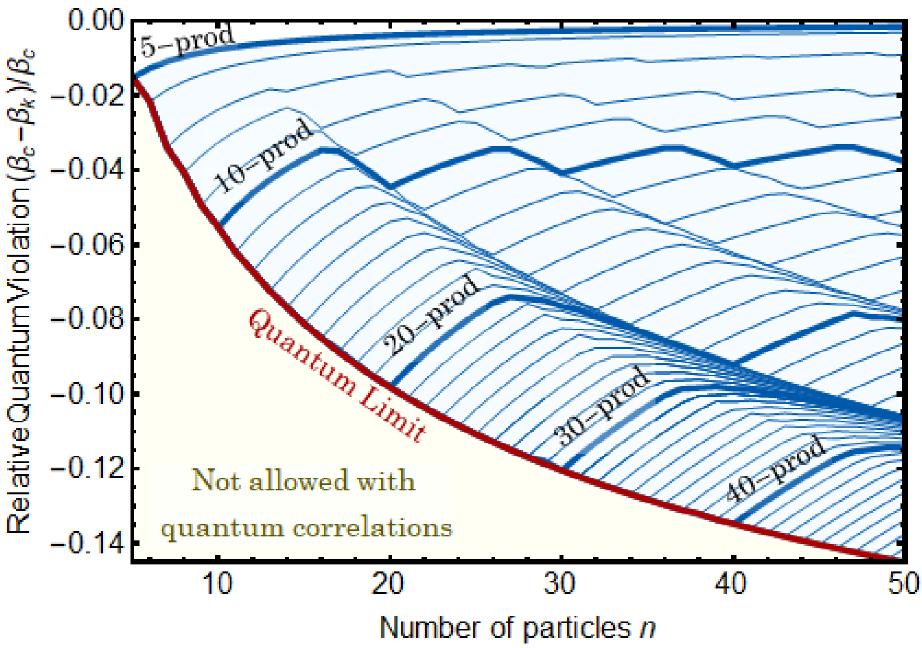

Figure 1. Example of DIWED bounds that can be achieved out of a 2-body Permutation Invariant Bell inequality. Each line represents a *k*-producible bound, the violation of which assures that at least *k*+1 particles are entangled.

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[2] R. Schmied, J-D. Bancal, B. Allard, M. Fadel, V. Scarani, P. Treutlein and N. Sangouard, *Bell correlations in a Bose-Einstein condensate,* Science, **352**, 6284 (2016).

[3] A. Aloy, J. Tura, F. Baccari, A. Acín, M. Lewenstein and R. Augusiak, *Device-independent witness of entanglement depth from two-body correlators,* arXiv, 1807.06027 (2018).

[4] J. Tura, A. Aloy, F. Baccari, A. Acín, M. Lewenstein and R. Augusiak, *Optimization of device-independent witnesses of entanglement depth from two-body correlators,* arXiv, 1903.09533 (2019).