Detection of Genuine Multipartite Entanglement Without Any Reference Frames

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Abstract

Under a number of experimental conditions, especially for communication in multiparty quantum networks, the relative measurement directions fluctuate and are hard to calibrate. Yet, even with absolutely random measurements one can still gain information about the state and its entanglement. Here we extend previous attempts and perform numerical as well as experimental analysis of the performance of the method. From detailed distributions of measurement outcomes and their correlations different types of multipartite entanglement are identified making our method useful for entanglement verification in the presence of noise.

Entangled particles exhibit quantum correlations over arbitrary long distances in time and space which cannot be mimicked by local realistic models. A variety of schemes for experimentally characterizing quantum states have been devised. However, these are often experimentally demanding in terms of stability and insensitivity against noise. Standard methods such as state tomography and Bell tests will fail to reliably detect quantum correlations in the presence of unknown local perturbations to the measuring apparatus, as consecutive measurements must be co-ordinated via a shared choice of measurement basis, i.e. a shared reference frame. So called reference frame independent schemes overcome this difficulty [1,2], however, even these schemes fail when the choice of local measurement setting is not repeatable.

Several recent papers theoretically address detection of quantum entanglement in the last and most unrestricted scenario [3,4,5]. Here we extent these results gaining information about the entanglement structure of the state. We experimentally implement reference free, random measurements on multi-qubit states from different entanglement classes and detect distributions of measured correlations. We provide theoretical witnesses of genuine multipartite entanglement that are solely based on easily deducible second moments of the observed distributions. Even more information about the entanglement class of a multiparty state can be obtained from the analysis of higher order moments of full and marginal distributions as we will analyse from our data.

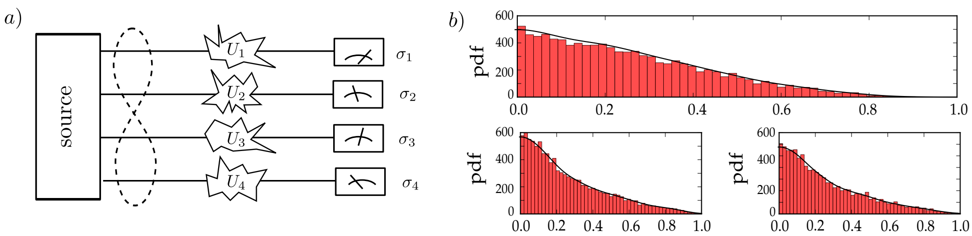

Figure 1: a) Concept of the random measurement scheme without reference frames. A source produces a state of four particles on which unknown rotations act on. All parties perform measurements in (Haar-)randomly chosen bases. b) Experimental results for four qubit GHZ state, full and marginal correlations.

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