QI 14: Quantum Entanglement III

Time: Tuesday 14:00–15:30 Location: HS IX

Invited Talk QI 14.1 Tue 14:00 HS IX

Certification of high-dimensional and multipartite entanglement with imperfect measurements — •Simon Morelli[1], Hayata Yamasaki[2], Marcus Huber[1], and Armin Tavakoli[3] — [1]Atominstitut, Technische Universität Wien, Austria — [2]University of Tokyo, Japan — [3]Lund University, Sweden

Deciding whether an unknown quantum state is entangled is a central challenge in quantum information. The most common approach are entanglement witnesses, where one assumes the state to be close to a known target and then finds suitable measurements that can reveal its entanglement. In principle, this allows for the detection of every entangled state. However, it requires the experimenter to flawlessly perform the stipulated measurements.

We move away from this idealized scenario to the more realistic situation in which measurement devices are not perfectly controlled, but operate with bounded inaccuracy. We formalize this through an operational notion of inaccuracy that can be estimated directly in the laboratory and investigate the impact of measurement errors on standard entanglement detection techniques. To demonstrate the relevance of this approach, we show that small magnitudes of inaccuracy can significantly compromise several renowned entanglement witnesses.

We extend this analysis to the detection of high-dimensional and multipartite entanglement. To support our theoretical findings experimentally, we explicitly construct states that lead to a wrongful detection of high Schmidt number or genuine multipartite entanglement when the inaccuracies in the measurements are not accounted for.

QI 14.2 Tue 14:30 HS IX

Making entanglement witnesses robust to measurement errors — •Elisa Monchietti and Otfried Gühne — Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Walter-Flex-Straße 3, 57068 Siegen, Germany

In recent years, various methods have been developed to characterise entanglement, one of the most widely studied are so-called entanglement witness operators. These are observables with the property that if their expectation value is greater than a predetermined quantity C, we can then ensure that the state is entangled, or that it possesses the type of entanglement that this witness allows us to characterize. In real practice, however, the measurement process is not ideal, and despite sophisticated error mitigation techniques complete elimination of errors due to external factors is not possible. If we assume that the measuring devices are not perfectly aligned, we find states whose result when the entanglement witness is applied is greater than the mentioned constant C, but which do not have the type of entanglement we are looking for, i.e., we obtain false positives. Our general aim is to provide methods to characterise quantum correlations in a more realistic way, considering the role of imprecise measurements. To do so, we study potential correction terms, which can be used to counteract the effects of misalignment and imperfections of measurement devices. First we are going to consider a simple scenario of two qubits, to understand possible correction terms. After this, the idea is to study the multipartite case, to develop a framework for error-robust entanglement witnesses for multiqubit systems.

QI 14.3 Tue 14:45 HS IX

Entanglement between dependent degrees of freedom: Quasi-particle correlations — •Franziska Barkhausen, Laura Ares Santos, Stefan Schumacher, and Jan Sperling — Paderborn University, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, D-33098 Paderborn, Germany

Common notions of entanglement are based on well-separated subsystems with independent degrees of freedom. However, obtaining such independent degrees of freedom is not always possible because of physical constraints leading to dependent degrees of freedom. We theoretically explore the impact of dependent degrees of freedom on quantum entanglement [1]. As an application for interacting light-matter systems, we specifically study quantum correlation features for quasi-particle descriptions in fermion-boson systems in the Jaynes-Cummings model. Non-entangled quasi-particle states can be expressed through projections that act on tensor-product states leading to linear dependencies and states that are non-entangled although they would be entangled when only focusing on the common, independent description. For example, this enables us to construct NOON-type states which are not entangled for dependent degrees of freedom, unlike their counterparts for independent degrees of freedom. Therefore, we provide new insights into the resourcefulness of quantum correlations within the rarely discussed context of dependent degrees of freedom for light-matter links in quantum information applications. [1] F. Barkhausen et al. arXiv:2410.14290, (2024)

QI 14.4 Tue 15:00 HS IX

Quantum particle in the wron box - the perils of finite dimensional approximations — •Felix Fischer, Davide Lonigro, and Daniel Burgarth — FAU Erlangen

When numerically simulating a quantum mechanically system, one usually treats the Hamiltonian as an infinite dimensional matrix given in some basis. Then, one truncates this matrix to some finite dimension and diagonalizes the approximate, finite dimensional Hamiltonians. In general, the spectra of these truncated Hamiltonians do not converge towards the spectra of the original Hamiltonian. We show that this happens in the text book example for a quantum mechanical system - The Particle in a Box. When choosing a boundary agnostic basis, the numerics converge towards the particle in box with Dirichlet boundary conditions - independently of the boundary conditions one aims to simulate. In this talk we outline why these problems arise and show that the numerics always converge to one specific Hamiltonian - the Friedrichs extension of the restriction of the original Hamiltonian onto the finite dimensional span of the basis.

QI 14.5 Tue 15:15 HS IX

Statistical evaluation and optimization of entanglement purification protocols — •Francesco Preti[1,2] and József Zsolt Bernád[1] — [1]Forschungszentrum Juelich, Institute of Quantum Control (PGI-8), D-52425 Juelich, Germany — [2]Institute for Theoretical Physics, University of Cologne, D-50937 Koeln, Germany

Quantitative characterization of two-qubit entanglement purification protocols is introduced. Our approach is based on the concurrence and the hit-and-run algorithm applied to the convex set of all two-qubit states. We demonstrate that pioneering protocols are unable to improve the estimated initial average concurrence of almost uniformly sampled density matrices, however, as it is known, they still generate pairs of qubits in a state that is close to a Bell state. We also develop a more efficient protocol and investigate it numerically together with a recent proposal based on an entan- gling rank-2 projector. Furthermore, we present a class of variational purification protocols with continuous parameters and optimize their output concurrence. These optimized algorithms turn out to surpass former proposals and our protocol by means of not wasting too many entangled states.