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Spatial entanglement with bosons in optical lattices

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Entanglement is a fundamental resource for quantum information processing, its applications including scalable quantum communication, secure quantum key distribution protocols for cryptography and exponential speedup of quantum algorithms. It occurs naturally in manybody systems at low temperatures: this makes cold atoms good candidates to provide entangled states involving a large number of particles. For realizing and manipulating such states, an essential task is quantifying the actual amount of entanglement contained in the created state before using it for quantum information protocols. However, this task represents a major challenge, as it requires either full state tomography, scaling exponentially in the system size, or the assumption of unverified system characteristics such as its Hamiltonian or temperature.
In this experiment we obtain a quantification of multipartite entanglement from readily accessible measurements – that is time-of-flight atomic density distribution – based on a recent proposal. We directly observe and quantify the multipartite spatial entanglement between the sites of a periodic optical potential (optical lattice) that hosts massive bosonic particles. We characterize its behaviour when crossing the superfluid-Mott insulator transition and when varying temperature, demonstrating the robustness of our method.