# Scalable creation of long-lived multipartite entanglement

Ferdinand Schmidt-Kaler[1]

[1] QUANTUM, Johannes Gutenberg Universität Mainz, Germany

We demonstrate the deterministic generation of multipartite entanglement based on scalable methods. Four qubits are encoded in $^{40}Ca^+$, stored in a micro-structured segmented Paul trap. Qubits are sequentially entangled by laser-driven pairwise gate operations. Between these, the qubit register is dynamically reconfigured via ion shuttling operations. We generate a four-ion GHZ state $|\psi\rangle = \frac{1}{\sqrt{2}}|0000\rangle + |1111\rangle)$ with a state fidelity of 94.4(3)% (see Fig. 1) and a storage time of 1.1 seconds [1].

To keep track of phase evolution of qubits shuttled in the inhomogeneous dc magnetic field, we use Bell states of the type $|\uparrow\downarrow\rangle + e^{i\varphi}|\downarrow\uparrow\rangle$ encoded in two $^{40}Ca^+$ ions stored at different locations. Undergoing linear Zeeman effect, the relative phase $\varphi$ serves to measure the magnetic field difference between the constituent locations and we measure this over distances of up to 6.2 mm with accuracies of around 300 fT and sensitivities down to 12 pT/$\sqrt{\text{Hz}}$ at a spatial resolutions down to 10 nm [2].

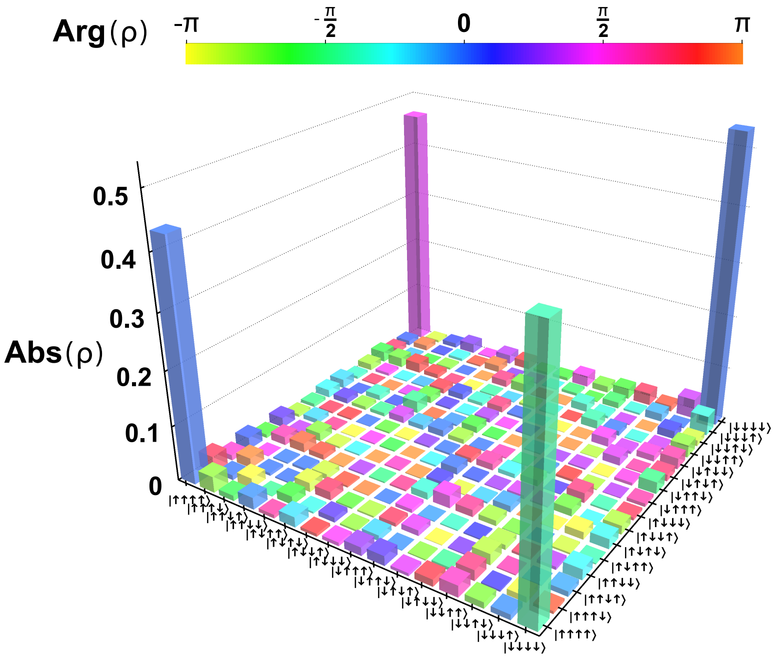


**Figure 1.** Absolut values of the four-ion GHZ state with 94.4(3)% fidelity.

[1] H. Kaufmann, T. Ruster, C. T. Schmiegelow, M. A. Luda, V. Kaushal, J. Schulz, D. von Lindenfels, F. Schmidt-Kaler, U. G. Poschinger, Phys. Rev. Lett. (2017), arXiv:1707.03695.
[2] T. Ruster, H. Kaufmann, M. A. Luda, V. Kaushal, C. T. Schmiegelow, F. Schmidt-Kaler, U. G. Poschinger, Phys. Rev. X 7, 031050 (2017).