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Entanglement of an Electron-Nuclear Spin Pair in ^{28}Si

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Single-shot, single spin readout allows for strong projective quantum measurements which are used for Bell inequality violations, teleportation, error correction, and many other quantum codes. Very recently, strong projective measurements have become available using a long-lived electron-nuclear donor spin pair in silicon-28. Here we demonstrate Bell/CHSH inequality violations, a proven entanglement witness, using this two spin system. A Bell inequality violation of 2.7(1) conclusively demonstrates on-demand two-spin entanglement, and the $>$ 99% detection efficiency simultaneously closes the detection loophole for this system. Furthermore, we improve upon the destructive electron measurement approach by mapping all Bell inequality observables onto the nuclear spin for high-fidelity quantum non-demolition (QND) measurement. Lastly, we complement the Bell inequality entanglement witness with full two-qubit state tomography complete with QND measurement. Preliminary results con firm a highly entangled state, yielding a fidelity of 98(3)%, concurrence of 0.88(8), and a partial transpose negativity result of -0.46(4). Together these results demonstrate, within a single experiment, the very high initialisation ($>$ 97%), estimated control ($>$ 98%) and measurement ($>$ 99.9%) fidelities in this two-qubit system.