

A Delayed Choice Quantum Cheshire Cat Experiment with Neutrons

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Abstract

A Quantum Cheshire Cat (QCC) is a quantum mechanical phenomenon invented by Yakir Aharonov [1] and named after its surreal counterpart in Lewis Carroll famous novel "Alice's Adventures in Wonderland ". It was shown, that in quantum mechanical sense the paradoxical situation may arise, where a particle ("the cat") is separated from its property ("the grin"). The proposed experimental setup was for polarized photons in a Mach-Zehnder interferometer and weak measurements on a pre- and post-selected ensemble.

For neutrons a QCC has been realized in a neutron interferometer experiment by Denkmayr et al. 2014 [2]. Weak measurements with certain pre- and post-selection have been employed to explore the neutrons path and magnetic moment and hence the properties of the QCC.

Their experimental scheme can be expanded to realize a delayed choice experiment (a certain type of originally quantum mechanical thought experiments proposed by John Archibald Wheeler [3]). In our case the post-selection is delayed up to a point, where the neutron respectively the QCC has already left the interferometer.

We present the experimental setup, intricacies and results of measurements, that have been carried out at the S18 neutron interferometer at the Institute Laue-Langevin (ILL) in Grenoble France.

References

- [1] Aharonov et al., "Quantum Cheshire Cats." *New Journal of Physics* 15, no. 11 (November 7, 2013): 113015. <https://doi.org/10.1088/1367-2630/15/11/113015>.
- [2] Denkmayr et al., "Observation of a Quantum Cheshire Cat in a Matter-Wave Interferometer Experiment." *Nature Communications* 5 (July 29, 2014): 4492.
- [3] Wheeler, J. A., and Zurek, W. H. *Quantum Theory and Measurement*. Princeton University Press, 1983.