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【701】Weak measurements in neutron interferometry and experimental tests of general uncertainty relations

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Weak measurements [1], introduced more than 30 years ago, underwent a metamorphosis from a theoretical curiosity to a powerful resource for exploring foundations of quantum mechanics, as well as a practical laboratory tool. However, unlike in the original textbook experiment, where an experiment with massive particles is proposed, experimental applications are realized applying photonic systems. We have overcome this gap by developing a new method to weakly measure a massive particle's spin component. Our neutron optical approach is realized by utilizing neutron interferometry, where the neutron's spin is coupled weakly to its spatial degree of freedom [1]. This scheme was then applied to study a new counter-intuitive phenomenon, the so-called quantum Cheshire Cat: If a quantum system is subject to a certain pre- and post-selection, it can behave as if a particle and its property are spatially separated, which is demonstrated in an experimental test [2,3]. State tomography, the usual approach to reconstruct a quantum state, involves a lot of computational post-processing. So in 2011 a novel more direct method was established using weak measurements. Because of this weakness the information gain is very low for each experimental run, so the measurements have to be repeated many times. Our procedure is based on the method established in 2011, without the need of computational post processing, but at the same time uses strong measurements, which makes it possible to determine the quantum state with higher precision and accuracy. We performed a neutron interferometric [4] experiment, but our results are not limited to neutrons, but are in fact completely general. In our latest experiment [5] we investigated the paths taken by neutrons in a three-beam interferometer by means of which-way measurements, realized by a partial energy shift of the neutrons so that faint traces are left along the beam path. Final results give experimental evidence that the (partial) wave functions of the neutrons in each beam path are superimposed and present in multiple locations in the interferometer.

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Authors: Dr SPONAR, Stephan (Atominstitut, TU Wien); LEMMEL, Hartmut (Atominstitut, TU Wien); HASEGAWA, Yuji (Vienna University of Technology)

Presenter: Dr SPONAR, Stephan (Atominstitut, TU Wien)

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