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High Precision Experiments with Cold and Ultra-Cold Neutrons

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The talk addresses some questions of particle and nuclear physics and concerns the search for possible deviations from the Standard Model (SM) of particle physics with cold and ultra-cold neutrons. The deviations are expected to be the phenomenological outcome of more fundamental theories, unifying all forces induced shortly after the Big Bang.

Precise symmetry tests of various kinds are coming within reach with proposed neutron facilities, where count rates of neutron decay products are increased by a factor 100 compared to best experiments. The goal is neutron beta-decay spectroscopy, where the spectra and angular distributions of the emerging decay particles will be distortion-free on the level of 10^{-4}.

Next, we present a novel direct search strategy with neutrons based on a quantum bouncing ball in the gravity potential of the earth. The aim is a test of Newton’s gravity law with a quantum interference technique, providing a constraint on any possible new interactions on the level of accuracy. Many extensions to the standard model naturally predict deviations from Newton’s law at short distances that should be detectable. If the reason is that some undiscovered dark matter or dark energy particles interact with a neutron, this should result in a measurable energy shift of the observed quantum states. The experiment has the potential to find or exclude these hypothetical particles in full parameter space.

Our goal is insight into the answers to fundamental questions: Firstly, what is dark energy? Is it a cosmological constant, or is it a scalar field such as quintessence or a dynamic quantity whose energy density can vary in time and space? This proposal has – compared to other methods - the unique potential to decide: either to find a signal or rule out certain realizations of quintessence completely. Secondly, what is dark matter? The concept is the detection of very light bosons through the macroscopic forces which they mediate, leading to a deviation from Newton's law at short distances, exactly in the range of this experiment. Thirdly, are the four basic forces – electromagnetism, the weak force, the strong force and gravitation - unified at high energies?