A New Search for the Neutron Electric Dipole Moment

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The possible existence of a nonzero electric dipole moment (EDM) of the neutron is of great fundamental interest and directly impacts our understanding of the nature of electro-weak and strong interactions. The experimental search for this moment has the potential to reveal new sources of time reversal (*T*) and charge conservation and parity (*CP*) violation and to challenge calculations that propose extensions to the Standard Model (SM). In addition, the small value for the neutron EDM continues to raise the issue of why the strength of the *CP*-violating terms in the strong Lagrangian are so small. This result seems to suggest the existence of a new fundamental symmetry that blocks the strong *CP*-violating processes. In addition, the discovery of new *CP*-violating process may contribute to unraveling the mystery of the observed matter-antimatter asymmetry in the Universe.

After thirty years, a series of measurements of increasing precision have culminated in the current best limit of $d_n < 3 \times 10^{-26}$ e·cm (90% C.L.) obtained in measurements at the Institute Laue-Langevin (ILL) reactor at Grenoble. The goal of the current experiment is to significantly improve the measurement sensitivity to the neutron EDM over what is reported in the literature.

The SM prediction for the nEDM is at the 10^{-31} e·cm level, below the reach of current measurements by six orders of magnitude. There are many proposed models of the electro-weak interaction that are extensions beyond the SM and that raise the predicted value of the nEDM by up to seven orders of magnitude. Some of these are already excluded by the current limit on the nEDM. The proposed experiment has the potential to reduce the acceptable range for predictions by two orders of magnitude and to provide a significant challenge to these extensions to the SM.

This experiment is based on a technique to measure the electric dipole moment of the neutron (nEDM) that is qualitatively different from the strategies adopted in previous measurements. The overall method adopted here is to form a three-component fluid of neutrons and ^{3}He atoms dissolved in a bath of superfluid ^{4}He at ~0.5 K. Both the neutron and ^{3}He magnetic dipoles can be made to precess in the plane perpendicular to a weak, external magnetic field. The measurement of the nEDM comes from a precision measurement of the difference in the precession frequencies of the neutrons and the ^{3}He atoms, as modified when a strong electric field parallel or antiparallel to the magnetic field is activated.

The figure of merit for nEDM experiments varies as $E_0\sqrt{N}\tau$. The neutrons decay, implying that the measurement must be repeated many times. E_0 is the magnitude of the electric field, N is the number of neutrons in the cell during a single measurement and τ is the duration of each measurement. The improvement factor for this experiment results from the possibility of an increased electric field (a factor of ~5) due to the excellent dielectric properties of superfluid ^{4}He, an increase in total number of ultracold neutons (UCNs) stored (~100 fold improvement that leads to factor of 10 gain in sensitivity) and an increased storage time (~5 times, which produces a factor of 2 in sensitivity) due to the low temperature of the walls. With the proposed experiment, an EDM limit of 10^{-28} e·cm is possible; the use of ^{3}He as a volume comagnetometer is crucial to the elimination of the magnetic-field systematics.

The physics goals of this experiment are timely and of unquestioned importance to modern theories of electro-weak and strong interactions. This experiment offers an intriguing opportunity to measure a quantity of fundamental significance.