Search for a Neutron Electric Dipole Moment at the SNS

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The discovery of a neutron EDM (Electric Dipole Moment) above the Standard Model background, which lies about five orders-of-magnitude below the present limits, would be first evidence for a new type of time-reversal violation (and, hence, CP violation via the CPT theorem). Experiments have searched for an EDM of the neutron for over six decades. During this time the sensitivity has increased by nearly eight orders-of-magnitude. The failure to observe an EDM has severely constrained many different versions of beyond-Standard-Model physics - including minimal supersymmetry (e.g. MSSM). The present best limit on the neutron EDM comes from the ILL experiment [1] that obtained $d_n < 2.9 \times 10^{-26}$ e-cm at the 90% confidence level. A number of new experiments are being pursued attempting to improve this sensitivity by nearly two orders-of-magnitude. While an observation of a neutron EDM in this range would have profound impact on our understanding of fundamental interactions, an improved limit would provide stringent limits on possible new physics even with data from the LHC [2].

The goal of the nEDM experiment, to be carried out at the Spallation Neutron Source (SNS), is to achieve a sensitivity $< 4 \times 10^{-28}$ e-cm. A conceptual design of the experiment is shown in Fig. 1. A value (or limit) for the neutron EDM will be extracted from the difference between neutron spin precession frequencies for parallel and anti-parallel magnetic ($\sim$ 30 mGauss) and electric ($\sim$ 70 kV/cm) fields. This experiment, based on Ref. [3], uses a novel polarized ^{3}He co-magnetometer and will detect the neutron precession via the spin-dependent neutron capture on ^{3}He. The capture signal is observed via scintillation light produced from the ionization in liquid helium of the energetic proton and triton produced in the reaction. Since the EDM of ^{3}He is strongly suppressed by electron screening in the atom it can be used as a sensitive magnetic field monitor. High densities of trapped ultra-cold neutrons are produced via phonon production in superfluid ^{4}He which can also support large electric fields. This technique allows for a number of independent checks on systematics including:

1. Studies of the temperature dependence of false EDM signals in the ^{3}He
2. Measurement of the ^{3}He precession frequency via Superconducting QUantum Interference Devices (SQUID), and
3. Cancellation of magnetic field fluctuations by matching the effective gyromagnetic for neutrons and ^{3}He with an additional RF field ("spin dressing" of both species [3]).

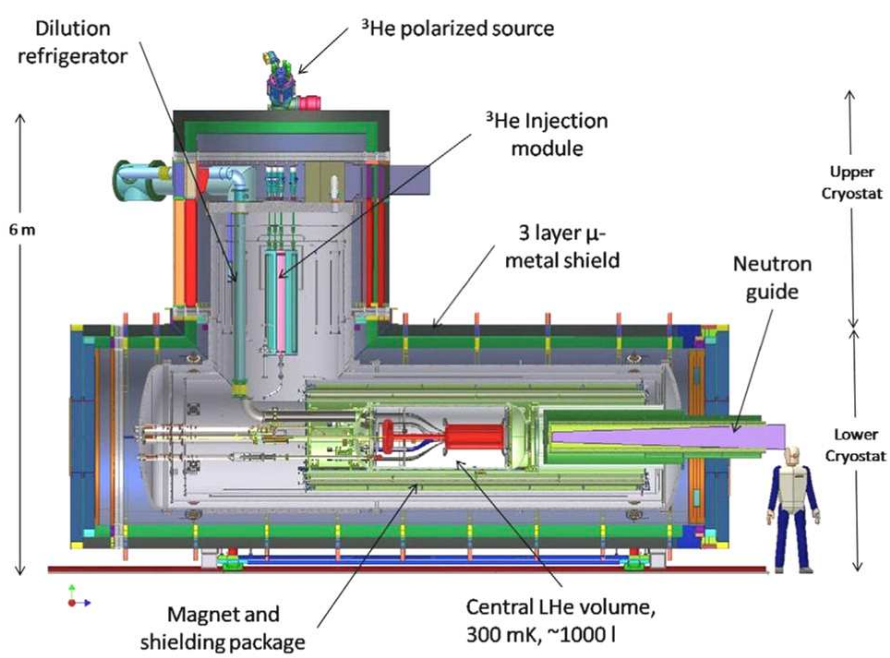

Fig. 1. Schematic diagram of the nEDM apparatus.

The collaboration is continuing to address critical R&D developments in preparation for construction of a full experiment. Key issues being addressed include:

1. Maximum electric field strength for large-scale electrodes made of appropriate materials in superfluid helium below a temperature of 1 K.
2. Magnetic field uniformity for a large-scale magnetic coil and a Pb superconducting magnetic shield.
3. Understanding of polarized ^{3}He injection and transport in the superfluid.
4. Estimation of the detected light signal from the scintillation in superfluid helium.
5. Development of coated measurement cells that preserve neutron and ^{3}He polarization along with neutron storage time.

The experiment will be installed at the FNPB (Fundamental Neutron Physics Beamline) at the SNS and construction is likely to take at least five years, followed by hardware commissioning and data taking. Thus first results could be anticipated by the end of the decade.

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[3] R. Golub and S. Lamoreaux, Phys. Rep. 237, 1 (1994).