LA-UR- 02-7090

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Title: NEW SEARCH FOR THE NEUTRON ELECTRIC DIPOLE MOMENT

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Submitted to: Proceedings of the Baryons 2002 Conference:
Jefferson Laboratory, Newport News, VA
March 3-8, 2002

Los Alamos
NATIONAL LABORATORY

Form 836 (8/00)

NEW SEARCH FOR THE NEUTRON ELECTRIC DIPOLE MOMENT

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for the
NEUTRON EDM COLLABORATION

We report on a new experiment to search for the neutron electric dipole moment which has the potential to lower the current limit by a factor of 50 to 100. A unique approach to this measurement is described including the results of recent measurements at LANSCE of the mass diffusion coefficient for ^{3}He in superfluid ^{4}He.

1. Introduction

The possible existence of a nonzero electric dipole moment, EDM, of the neutron is of great fundamental interest in itself 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 T and CP violation and to challenge calculations that propose extensions to the Standard Model[1]. 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.

Searches for the EDM of the neutron date back to a 1957 paper of Purcell and Ramsey[2]. This led to an experiment using a magnetic resonance technique at ORNL, where they established a value[3] of $d_n = -0.1 - 2.4 \times 10^{-20} e$ cm. An MIT/BNL experiment used Bragg scattering of neutrons from a CdS crystal to search for the neutron EDM, and obtained a value[4] of $d_n = 2.4 - 3.9 \times 10^{-22} e$ cm. In the intervening 30 years, a series of measurements with increasing precision have culminated in the current best limit of $d_n < 0.63 \times 10^{-25} e$ cm [90% C.L.] obtained in measurements at the ILL reactor at Grenoble[5]. Thus there has been an impressive reduction with time, of the experimental limit for d_n as illustrated in Fig 1.

2. Measurement Strategy

The new experiment[6], is based on the magnetic resonance technique of rotating magnetic dipole moments in a magnetic field and requires a precision measurement of the neutron precession frequency under the influence of an electric field. The apparatus, shown in Fig. 2, includes two cells that contain neutrons, ^{3}He, and ^{4}He. The strategy[6] features:

a) using a dilute mixture of polarized ^{3}He in superfluid ^{4}He as a working medium for the very high electric field environment;
b) determining in situ the magnetic field experienced by the neutrons, using a direct SQUID measurement of the precession frequency of the ^{3}He magnetic dipoles; and, finally,
c) making a comparison measurement of changes in the precession frequency, under E field reversal, of the neutron and ^{3}He components of the fluid, where the neutral ^{3}He atom does not have an EDM.

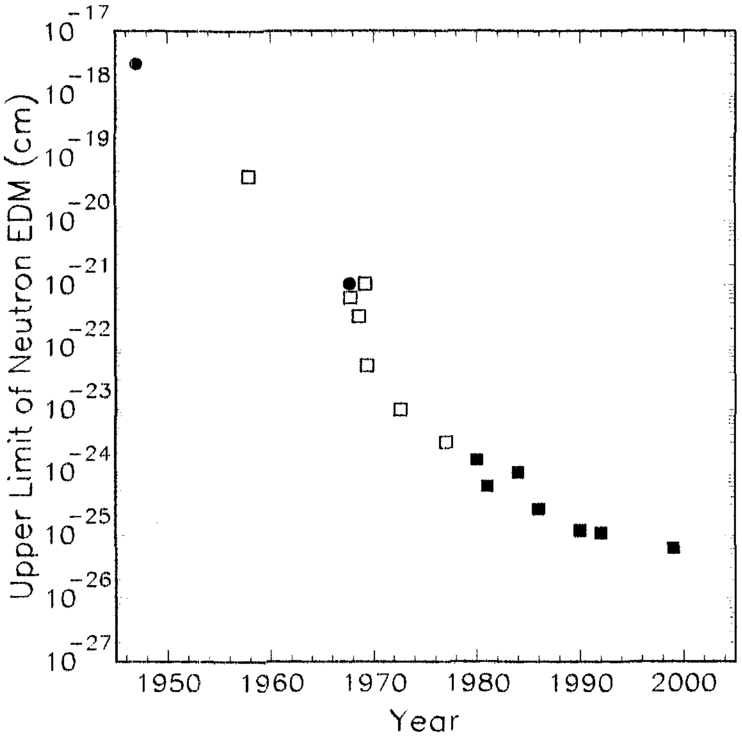

Fig. 1. Upper limits of the neutron EDM plotted as a function of year of publication. The solid circles correspond to neutron scattering experiments. The open squares represent in-flight magnetic resonance measurements, and the solid squares signify UCN magnetic resonance experiments.

Additional features include loading two identical neutron traps with UCNs through a superfluid ^{4}He-phonon recoil process, introducing highly polarized ^{3}He atoms into the trap in order to confirm alignment of the trapped UCN spins, operating the trap at extremely cold temperatures (~300 mK) to minimize UCN losses at the walls, and, finally, detecting the precession frequency difference, independently of the SQUID detectors, by viewing the n-^{3}He absorption reaction with photomultipliers, through the induced ^{4}He scintillation light. The process of validating these techniques and determining their limits is well started.

3. Experimental Apparatus

The technique relies on simultaneous precession of trapped ultra-cold neutrons and ^{3}He atoms in a bath of superfluid ^{4}He at a temperature of ~ 300 mK. The relative precession frequencies of the neutrons and the ^{3}He atoms in a B field, are compared in each of two traps. For one the electric field is parallel to B, for the other, antiparallel.

A schematic of the heart of the experiment in the main cryostat, is shown in Fig. 2. The pair of neutron cells are placed in the gaps between the three electrodes as shown in Fig. 3. The cells consist of two rectangular acrylic tubes, each with dimensions of approximately 7 cm x 10 cm x 50 cm long. The cold neutron beam enters along the long axis of the cell and passes through either deuterated acrylic or deuterated polystyrene windows attached to each end. The beam exits at the rear of the cell and is absorbed outside the cell in a beam stop made from a neutron absorbing material.

The difference in the neutron precession frequency in the two traps (of the order of μHz) is directly proportional to the neutron EDM.

4. ^{3}He Diffusion in ^{4}He

An important technical issue for the EDM measurement is the physics of ^{3}He propagation through the superfluid ^{4}He, where it has both diffusion and ballistic characteristics. These features are very temperature dependent. To clarify this, we used a neutron tomographic technique at flight path 11B at LANSCE[7], to study the spatial and temperature dependence of the ^{3}He density. By irradiating a ^{3}He-superfluid ^{4}He cell with a narrow neutron beam (~2mm) we were able to measure the n-^{3}He absorption yield as a function of position. Specifically we made a study of the changes in density of ^{3}He near a heater as a function of applied heat current and were able to infer, with 20% accuracy, values of the mass diffusion coefficient, D, for ^{3}He in ^{4}He. At temperatures below 0.7 K, D was measured for the first time. At the lowest temperatures, D can be characterized[7] as $D = D_T T^{-7} = (1.6 - 0.2) T^{-7}$ cm^2/sec. We conclude that at

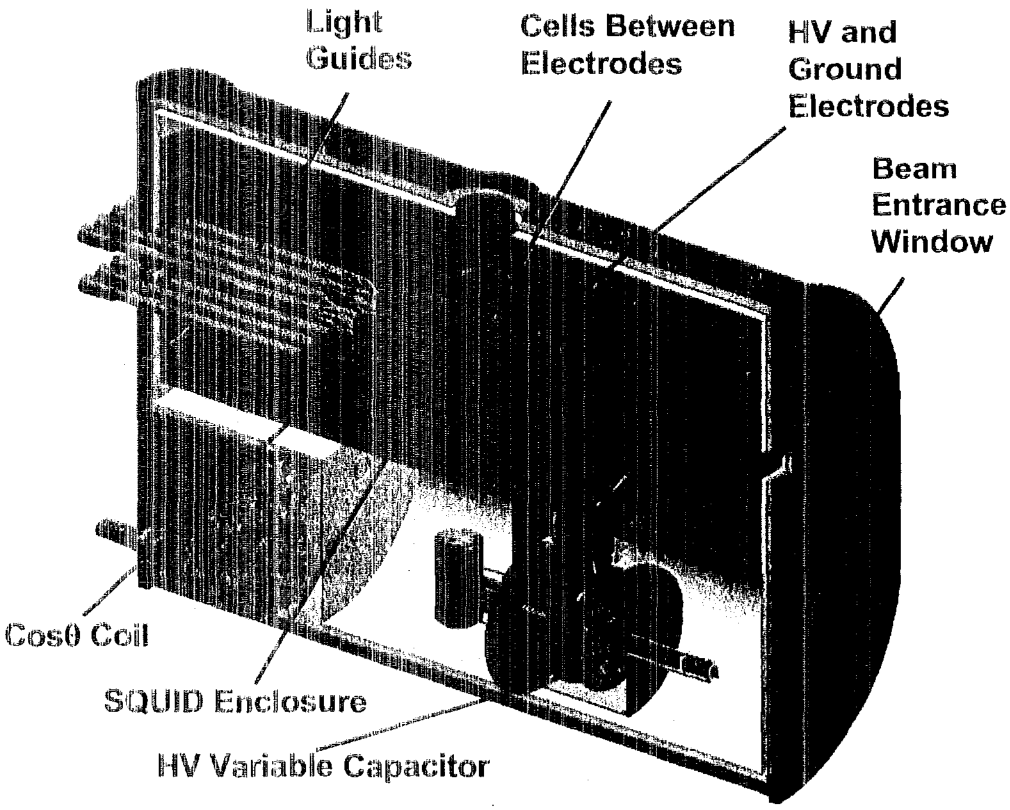

Fig 2. Experimental cryostat. The neutron beam enters from the right. Two neutron cells are between the three electrodes. Scintillation light from the cells is monitored by the light guides and photomultipliers.

temperatures below 0.6 K, ballistic ^{3}He collisions with phonons provide the dominate mechanism for ^{3}He scattering. At the very low temperatures (0.3 K) of the EDM experiment discussed above, the ^{3}He atoms will rapidly traverse the neutron cell as required for an effective co-magnetometer.

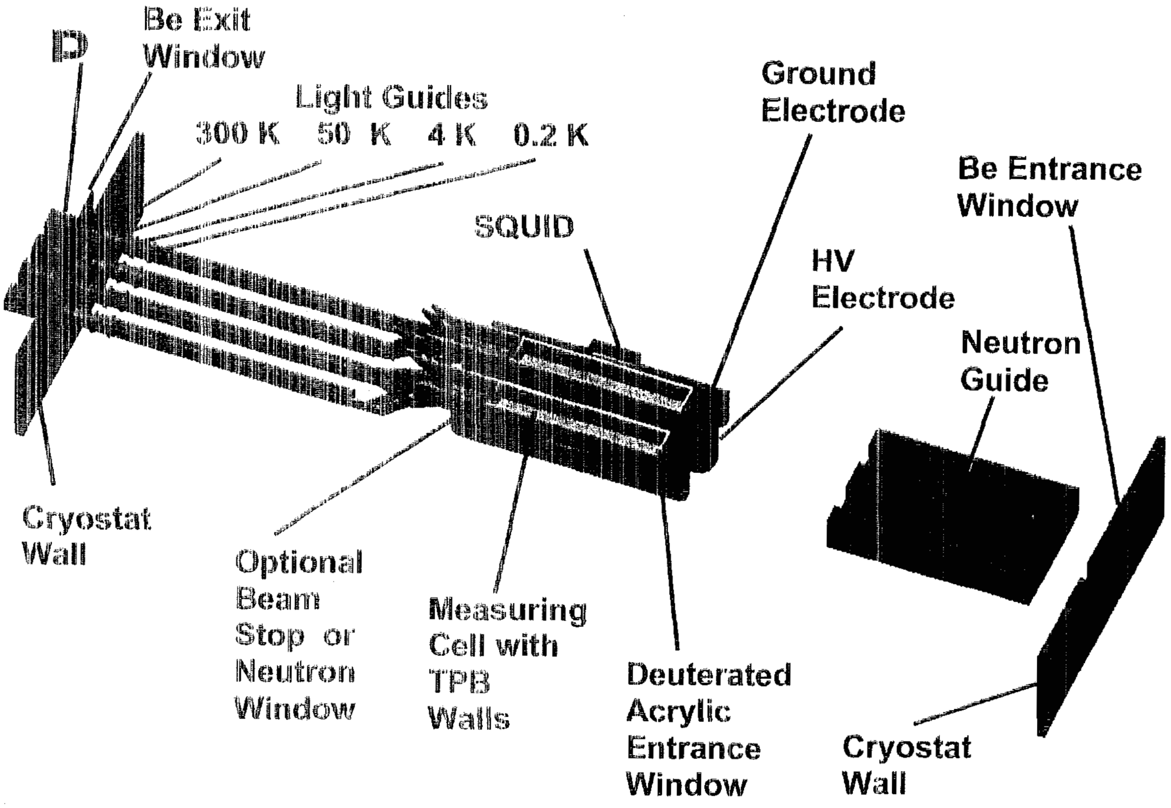

Fig 3 The path of the neutrons through the cryostat. The beam enters from the right. It is about 3.1 m through the cryostat, wall to wall.

The design and construction of this neutron EDM experiment is in progress, for measurements at a new beam line at LANSCE.

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