0.0.1 Systematic Studies for the nEDM Experiment at the PULSTAR UCN Facility

R. Golub, H. Gao, D.G. Haase, P.R. Huffman, A. Merizalde, C.M. Swank, Q. Ye, *TUNL*; A. Hawari, E. Korobkina, *NC State University Nuclear Engineering Department, Raleigh, NC*; S.K. Lamoreaux, *Yale University*; the nedm collaboration

We are developing an apparatus based on our existing dilution refrigerator and cryostat that will allow tests using a single full-size measurement cell (without an E field) of key systematic effects for the neutron EDM experiment. These tests will primarily focus on studies relating to demonstrating and quantifying the double magnetic resonance technique using polarized ^{3}He-UCN.

Because of the complexity and long cooling cycle of the full neutron EDM apparatus, a program at TUNL is being developed with the primary goal of significantly reducing the commissioning time of the nEDM apparatus. Measurements performed during the commissioning of the main apparatus will be costly and time-consuming so we are developing an auxiliary apparatus where one can perform tests on a single full size measuring cell containing all the features of the final experiment except for the electric field. The design of the apparatus will be based on our existing dilution refrigerator and cryostat.

The primary objectives of the design of the apparatus are as follows:

- A standing set-up to allow measuring UCN storage time, ^{3}He depolarization time, and ultraviolet scintillation detection efficiency of the nEDM measurement cells prior to installation in the main apparatus at ORNL.
- Studies and development of the operating procedures related to optimizing the techniques for observing double resonance effects in the UCN - ^{3}He system. This will include studies aimed at optimizing the procedures for critical spin dressing and techniques for minimizing and measuring the 'false edm' systematic error.
- The system will also serve as a stand-by test bed for studies of various new types of systematic errors that may be proposed as the experiment is underway.

As such, a general schematic showing the key components of the apparatus was developed and is shown in Fig. 1.

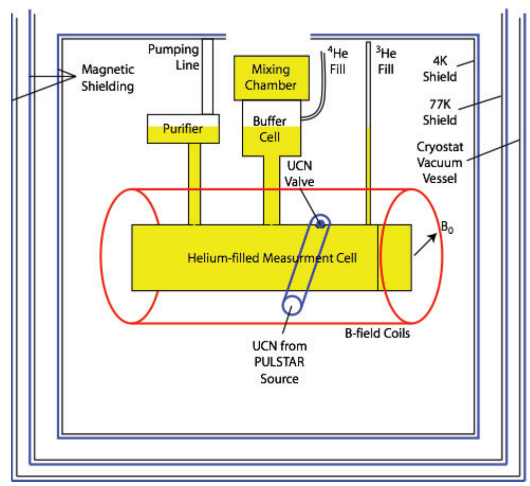

Figure 1: (Color online) Schematic of the proposed apparatus showing the key components.

The measurement cell will be suspended from the bottom of a buffer cell connected to the mixing chamber of the dilution refrigerator. The long axis of the cell will be horizontal and enclosed in a set of cylinders containing the magnetic field coils and a ferromagnetic (Metglass) shield. Additional magnetic shielding will be mounted on the 4 K and 77 K cryostat heat shields and the vacuum vessel itself. These are all coaxial cylinders with horizontal axes. The cell will be cooled by a combination of gold plated copper wires and ^{4}He-filled acrylic tubes. The nEDM cells have only one opening used to admit polarized ^{3}He, so in our setup this will be used for the UCN as well. There will be an entrance chamber that will fasten to the cell using the features supplied for fixing the valve and transport pipe in the main apparatus. The ^{4}He and polarized ^{3}He will enter this chamber through a small holes. The chamber will be filled with ^{4}He and sealed by a thin foil window which will transmit UCN from the PULSTAR UCN source. The ^{3}He transport pipe will widen into an evaporation chamber.

The ^{3}He will be polarized using the same setup previously used in the studies of ^{3}He wall depolarization and geometric phase effects. As turn around time for measurements using ^{3}He is limited by the polarization time, we will have several hours to remove the depolarized ^{3}He. For the more detailed studies of the ^{3}He-UCN spin dynamics the ^{3}He will enter and leave by means of a dedicated 1 mm hole. This will not impact the UCN storage time. There will be a small evaporating chamber connected to the hole so that the depolarized ^{3}He can be pumped away. The UCN will enter through a thin window to confine the ^{4}He liquid and a UCN valve.

Two quantities set the size of the apparatus, the measurement cell and magnetic field coils. The measurement cell has been specified by the collaboration to be rectangular with inner dimensions of $7x10x30$ cm^3. The measurements require a uniform magnetic field across the cell region, so the diameter of the magnetic field coil must be large enough to accommodate the uniform field region. Our initial estimate based on field calculations using a $\cos\theta$ winding geometry suggest that the diameter of the coil will need to be approximately 50 cm and the length about 1.5 m. Based on these dimensions, a preliminary design for the cryostat has been developed and is shown in Fig. 2.

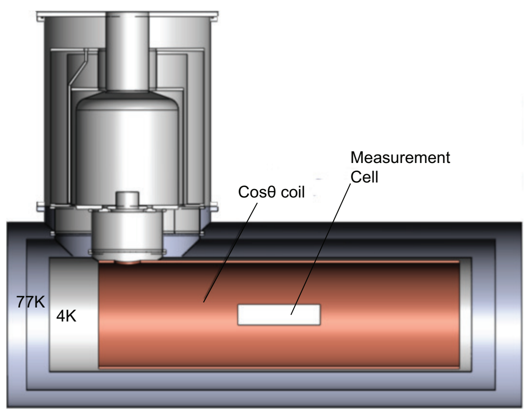

Figure 2: (Color online) Model of the cryostat for the systematic effects apparatus. The length of the apparatus is approximately 2 m.

The physics program will begin with the commissioning of the ^{3}He transport features and measure wall relaxation rates for the ^{3}He. This work could be done 'off-line' before the apparatus is installed at the PULSTAR source. The work would continue with studies of the ^{3}He trajectory correlation functions.

The same program would then be carried out with UCN alone. We would then introduce UCN and ^{3}He into the cell together and start to use the scintillation detection to study the critical dressing and its behavior as a function of the operating parameters. Experiments to study the pseudomagnetic field interaction and possible new schemes for double resonance will then be undertaken.

The primary questions we envision addressing with this apparatus are as follows:

- UCN storage and depolarization studies to optimize cell materials and fabrication techniques.
- Test bed for new cell designs and trouble shooting cells that don't work in main apparatus
- Measure scintillations due to relative ^{3}He-UCN precession.
- Demonstrate the concept of critical dressing through the observation of a constant scintillation rate.
- Detection of ^{3}He pseudomagnetic field.
- Study techniques for reversing the ^{3}He and UCN spins, $\sigma(^3\mathrm{He})$ and $\sigma(\mathrm{UCN})$, and the magnetic field B_0.
- Measurement of the "trajectory correlation function" for systematic error characterization.
- Develop techniques for NMR imaging of ^{3}He.

This program of studies will occur in parallel with the construction and commissioning of the nEDM apparatus. We estimate that the entire program will last 4-5 years.