The TUCAN Magnetics Lab (and how it's important for the nEDM)

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Why we care about the neutron electric dipole moment (nEDM)

Many theories beyond the Standard Model addressing open questions in physics, such as the mater-antimatter asymmetry problem, predict in a non-zero **neutron electric dipole moment (nEDM)**.

Measurements of the nEDM place strict constraints on theoretical models. The **TRIUMF Ultra Cold Advanced Neutron (TUCAN)** Collaboration aims at searching for the nEDM with a sensitivity of 10^{-27} ecm.

How the experiment works

The experiment fundamentals borrow from nuclear magnetic resonance (NMR). Spin polarized neutrons are exposed to magnetic and electric fields, and their precession frequency ν_n is given by

$$\nu_n = \gamma_n B_0 + d_n E$$

Where d_n is the nEDM, γ_n is the gyromagnetic ratio and E is the electric field. The magnetics lab is developing tools to measure the magnetic field, B_0, and its inhomogeneities. This is crucial for the control of systematic effects.

In the TUCAN Magnetics lab we pursue important R&D related to magnetic field measurement and manipulation. These developments are critical for the advancement of the expertise about magnetic field control within the TUCAN collaboration.

The Gradiometer

The Gradiometer allows for precise measurement of small-scale magnetic fields created by various potentially magnetized components, such as screws and fasteners. This device is essential to the minimization of stray magnetic fields within the EDM cell setup.

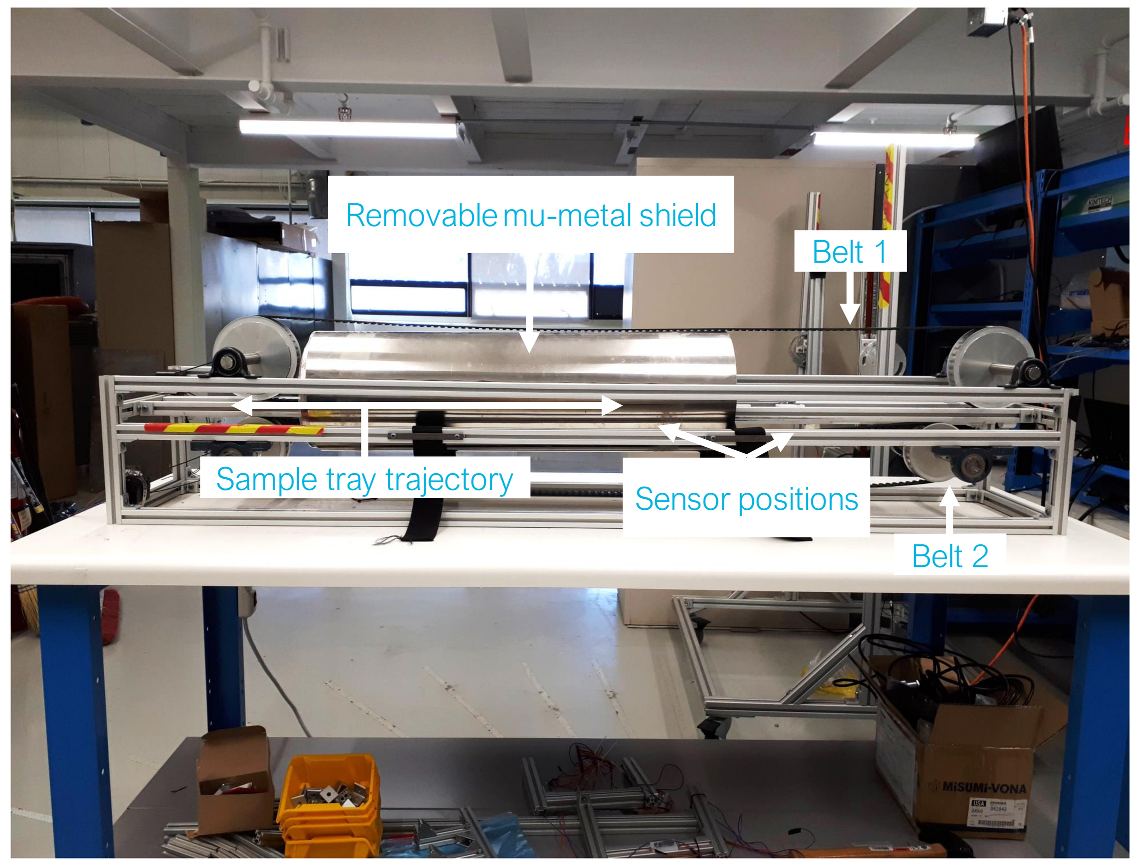

Figure 1: The Gradiometer in the Magnetics Lab used to test items to be used in the nEDM experiment.

Working Principle

The device consists of a long rail system with two belts, which are pulled through a cylinder of mu-metal, useful for magnetic shielding. One of the belts carries a fluxgate magnetometer which measures the magnetic field on 3 axes. The second belt carries a tray with the potentially magnetized object for measurement. A second fluxgate is stationary inside the shield.

For this system, it is important that the cart be moved smoothly through the system at a constant speed, such that position of the cart can be properly understood with respect to the magnetic flux measured. This is facilitated by stepper motors controlled by a Raspberry Pi, and easily operated from the user-friendly GUI.

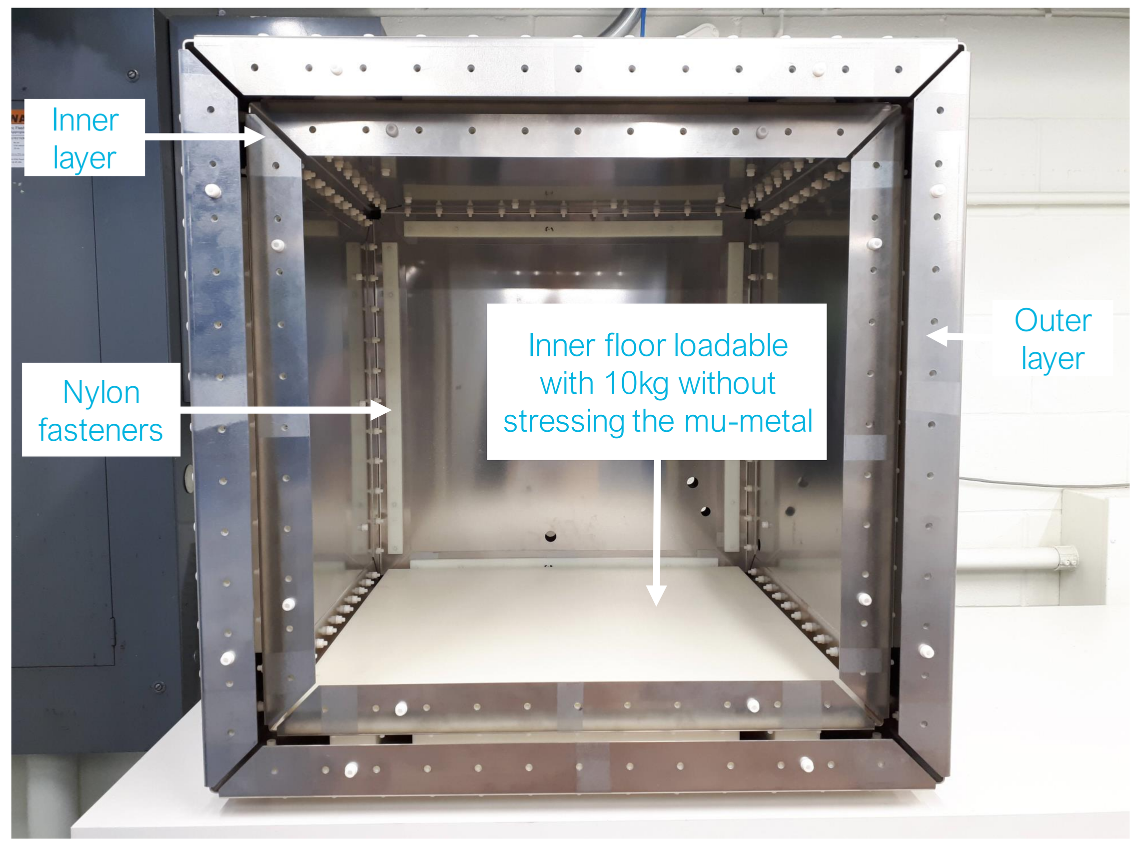

Figure 2: The magnetically shielded box shown here with one panel open for access.

Small-Scale Magnetically Shielded Box

The Shielded Box is a 29"x29" box assembled from two layers of mu-metal inside which a magnetic field mapper robot will be installed for testing. The mapper will be used in the magnetically shielded room (MSR) of the main nEDM experiment to map the magnetic field in 3D with high precision, and thus it needs to be tested in the small-scale box first.

Figure 5: 3D printed custom fluxgate stand to be used in the Gradiometer shielding factor measurement.

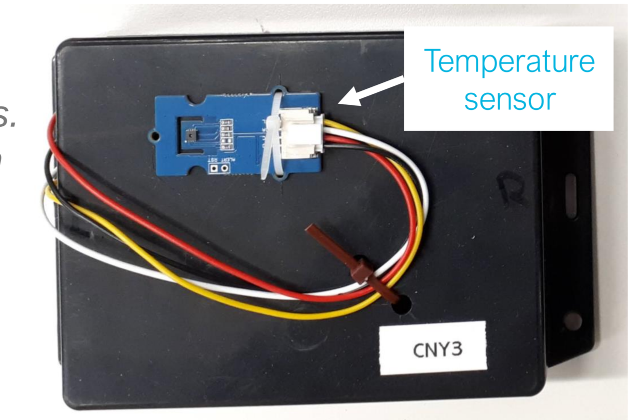

Figure 3: One of the Canaries. The temperature sensor is on top of the case and is connected to an Arduino board inside.

The Canaries

The Canaries are wireless temperature sensors built in house that will monitor the ambient temperature around the MSR to be located in the TRIUMF's Meson Hall. The nEDM experiment will take place inside the MSR. The stability of the magnetic field depends on temperature, and therefore it is important to have accurate knowledge of the temperature to improve the control over the magnetic field.

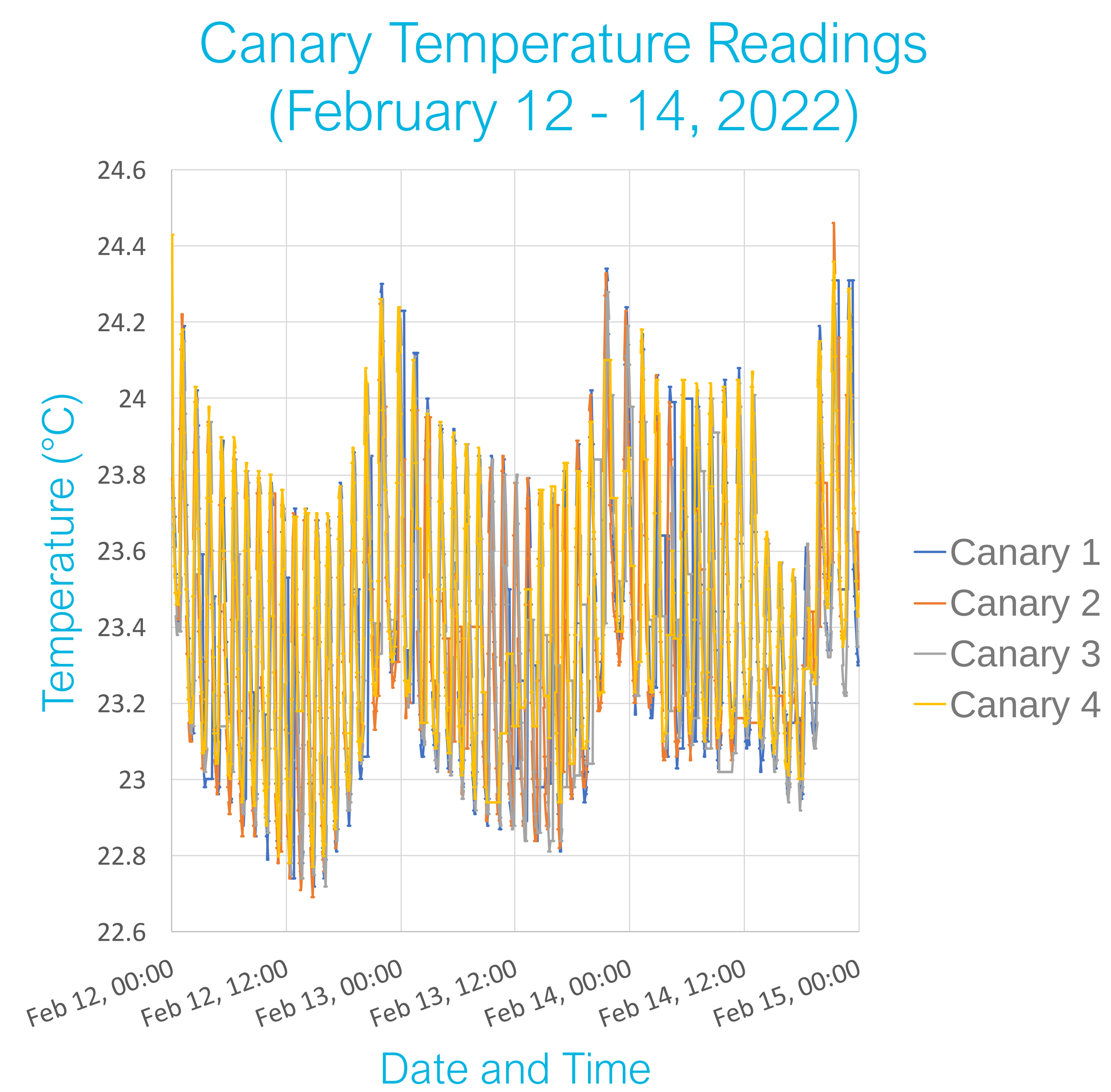

Figure 4: Temperature data from the four Canary sensors from February 12 to 14, 2022 taken in the Magnetics Lab. The sensors show consistent readings within $\pm 0.1°C$. The short-term fluctuations are probably due to the AC, while the changes on the 12-24h scale are due to day/night.

Next Steps

Next, we will measure the shielding factor of the mu-metal shield of the Gradiometer and that of the Shielded Box. This will be done by generating a magnetic field with a coil and measuring it with a fluxgate inside and outside the shield.

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