TRIUMF Ultra Cold Advanced Neutron Collaboration

Measurements of a Magnetically Shielded Room for a Neutron EDM Experiment

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Overview

In this talk I will:

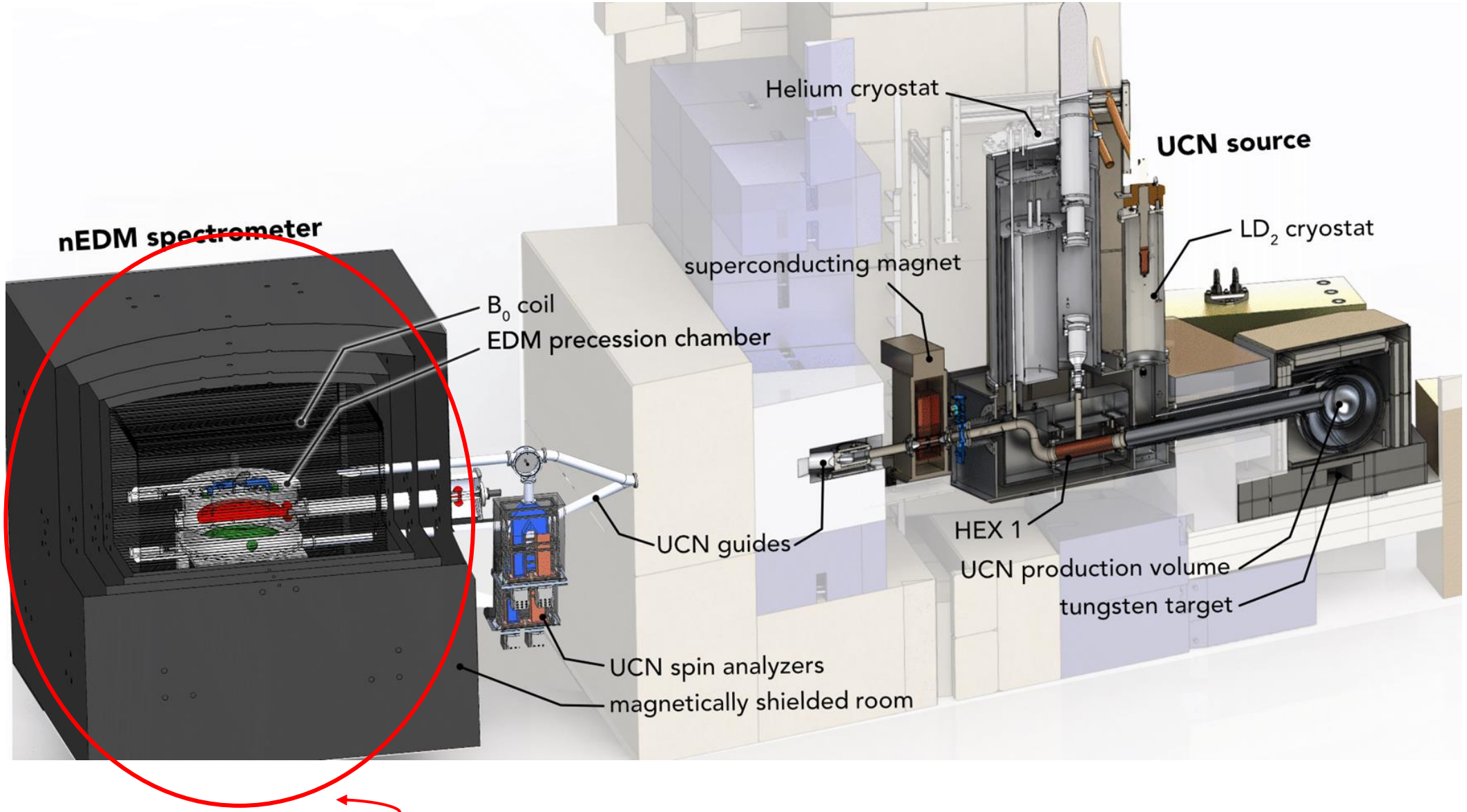
1. Introduce the search for a non-zero neutron electric dipole moment (nEDM) at TRIUMF using ultracold neutrons (UCN)

2. Motivate the need for a magnetically shielded room (MSR), and the required specs for the nEDM measurement

3. Go over magnetically shielded room status: Results of our testing and next steps

The Experiment

- An nEDM measurement searches for new sources of T and CP symmetry violation
- This has implications on new physics scenarios
- Current world best limit is 1.8 *10^{-26} e·cm (90% CL)
- TUCAN aims for 10^{-27} e·cm (factor of 10 improvement)



520 MeV
Cyclotron

My talk lives here

Experimental Technique

ω: precession freq. of neutron
μ_n: neutron magnetic moment
B: magnetic field
E: electric field
d_n: neutron electric dipole moment

- d_n is measured indirectly through the neutron's Larmor spin precession frequency

$$\hbar\omega = 2\mu_n B + 2d_n E$$

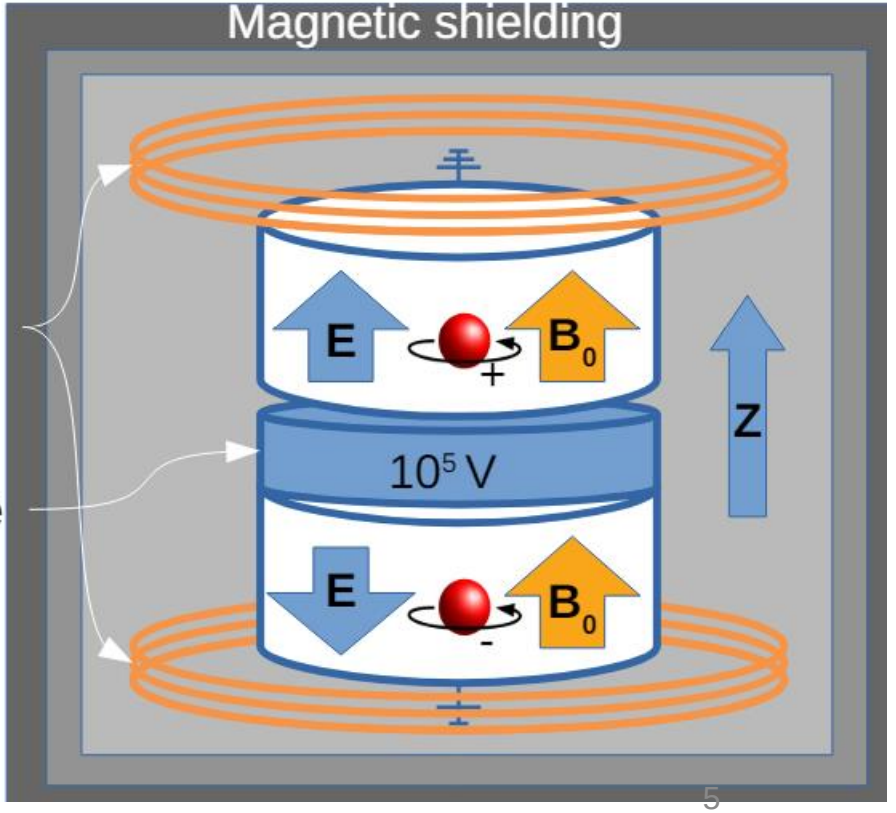
$$\hbar\omega = 2\mu_n B - 2d_n E$$

$$\rightarrow = 0?$$

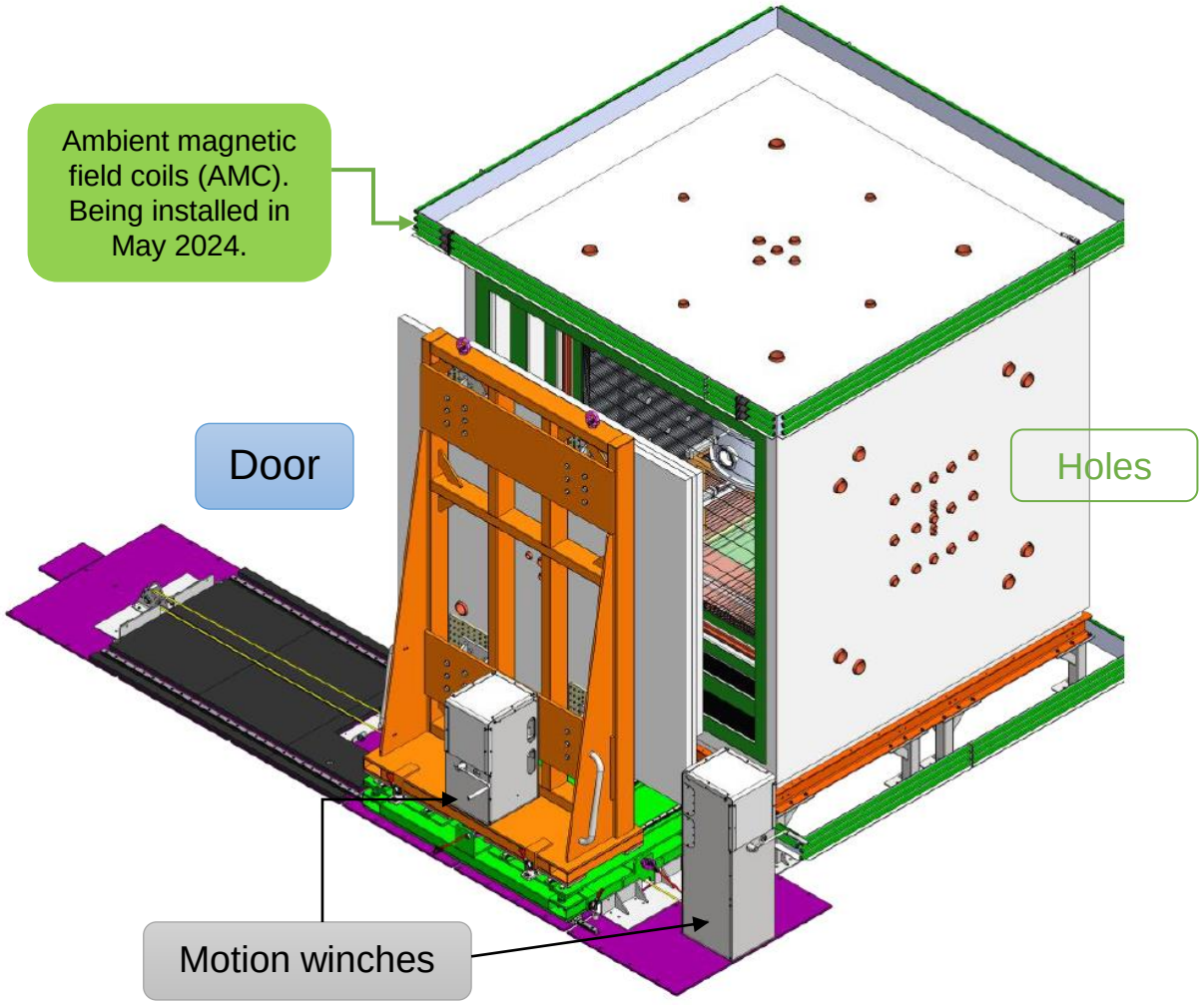
Subtract and we get:

$$d_n = \frac{\hbar(\omega_{\uparrow\uparrow} - \omega_{\uparrow\downarrow})}{4E}$$

→ **B must cancel**



MSR Design



Layer	Thickness	External side length
1- Outer	4 mm (2 x 2 mm)	3.5 m
2	3 mm (2 x 1.5 mm)	3 m
3	3 mm (2 x 1.5 mm)	2.6 m
4 - Cu	8 mm	2.46 m
5 - Inner	2 mm (2 x 1 mm)	2.39 m

$\underline{350\ \mu T\ \text{background field (Cyclotron)}}$
$1\ \mu T$ inner field requirement

MSR Field requirements

- Residual field of < 1 nT within the 1 m^3 central volume .
- Internal gradient must be < 100 pT/m
- 1pT stability over 100s of sec
- To achieve this stability, field inside MSR needs to be around 50,000 times smaller

Measuring the Shielding Factor

- Basic principle:

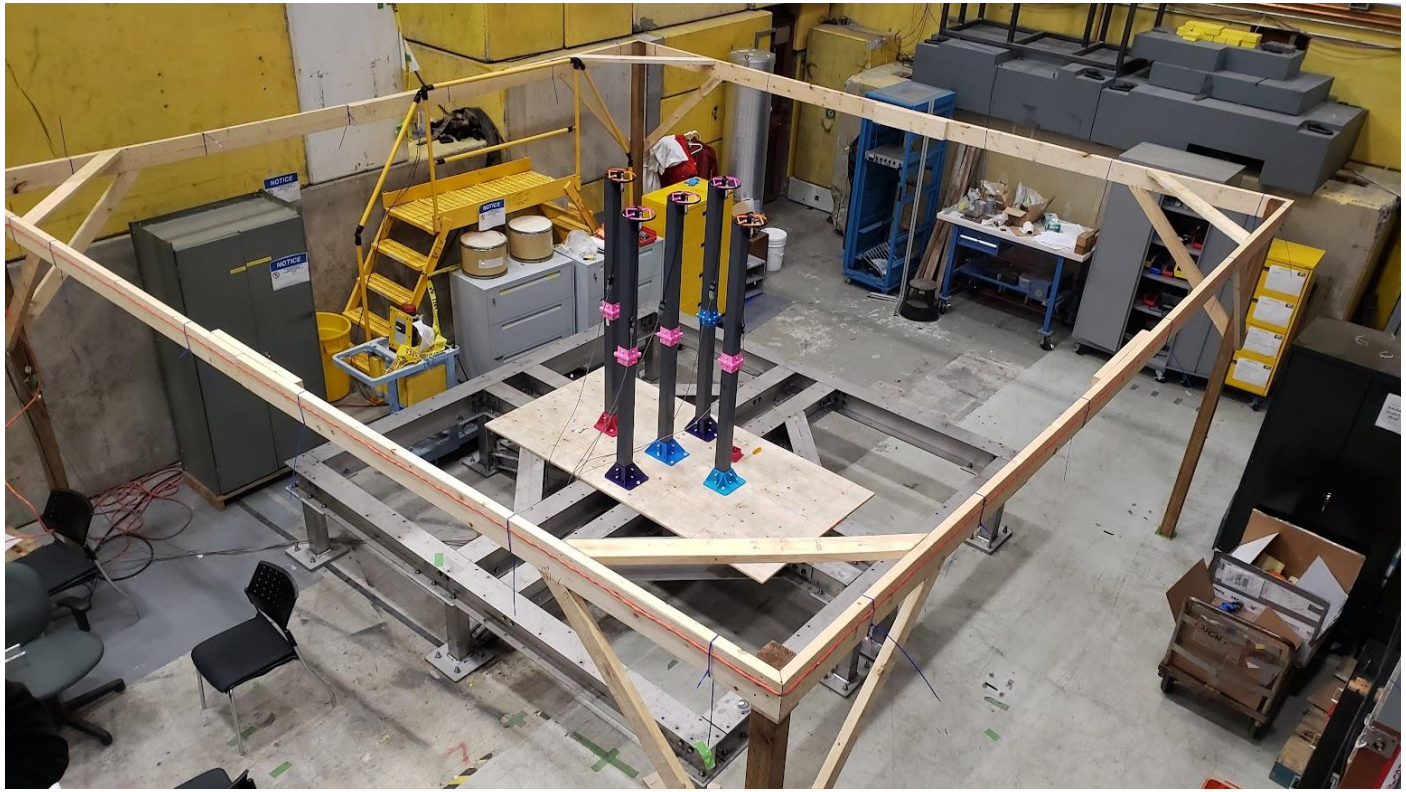
$$SF = \frac{B_{unshielded}}{B_{shielded}}$$

  - We also include several correction factors in this calculation

- We previously measured perturbation coil field to be $18\ \mu T$ (amplitude) AC field at center.

- Example: we measure a field of 18 nT

$$SF = \frac{18\ \times 10^{-6}}{18\ \times 10^{-9}} = 1{,}000$$



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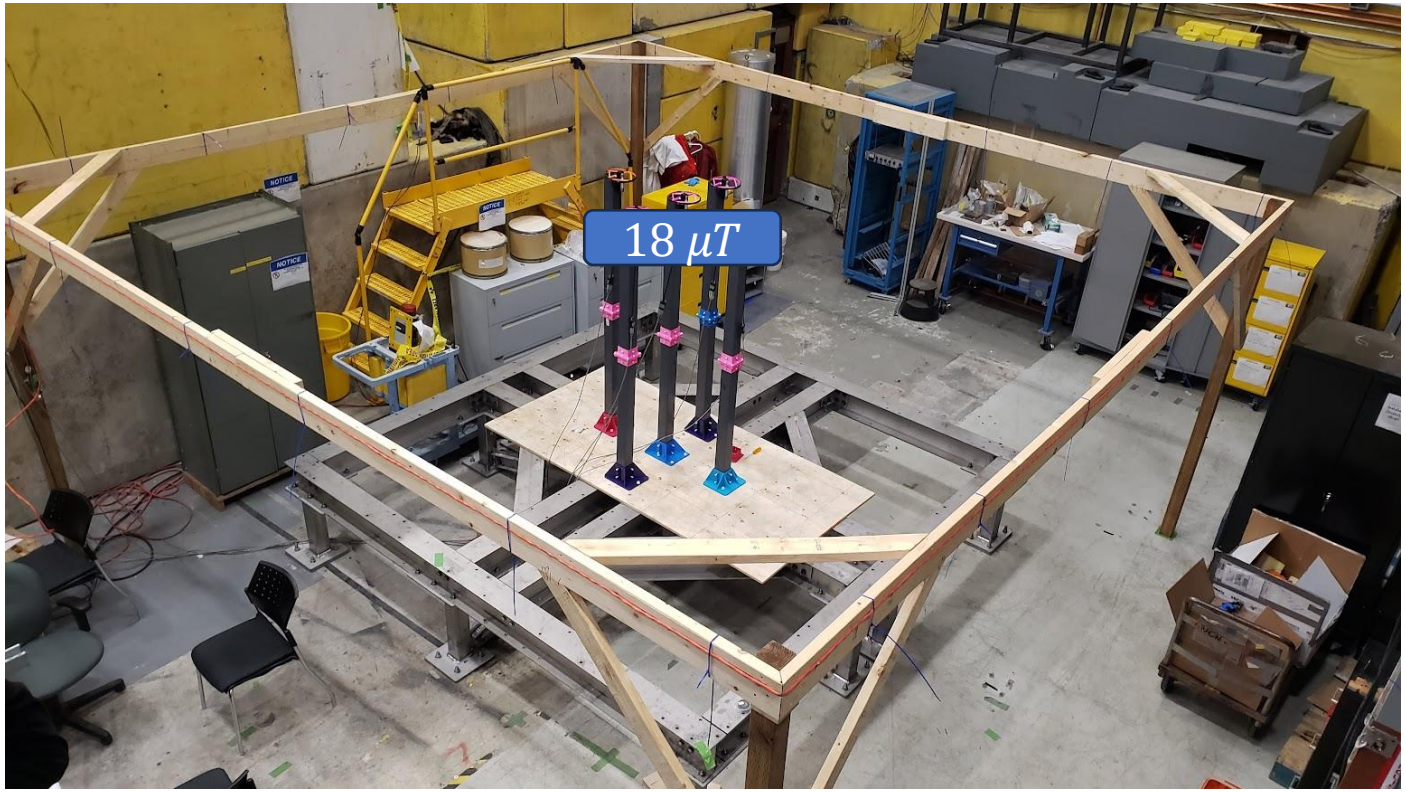

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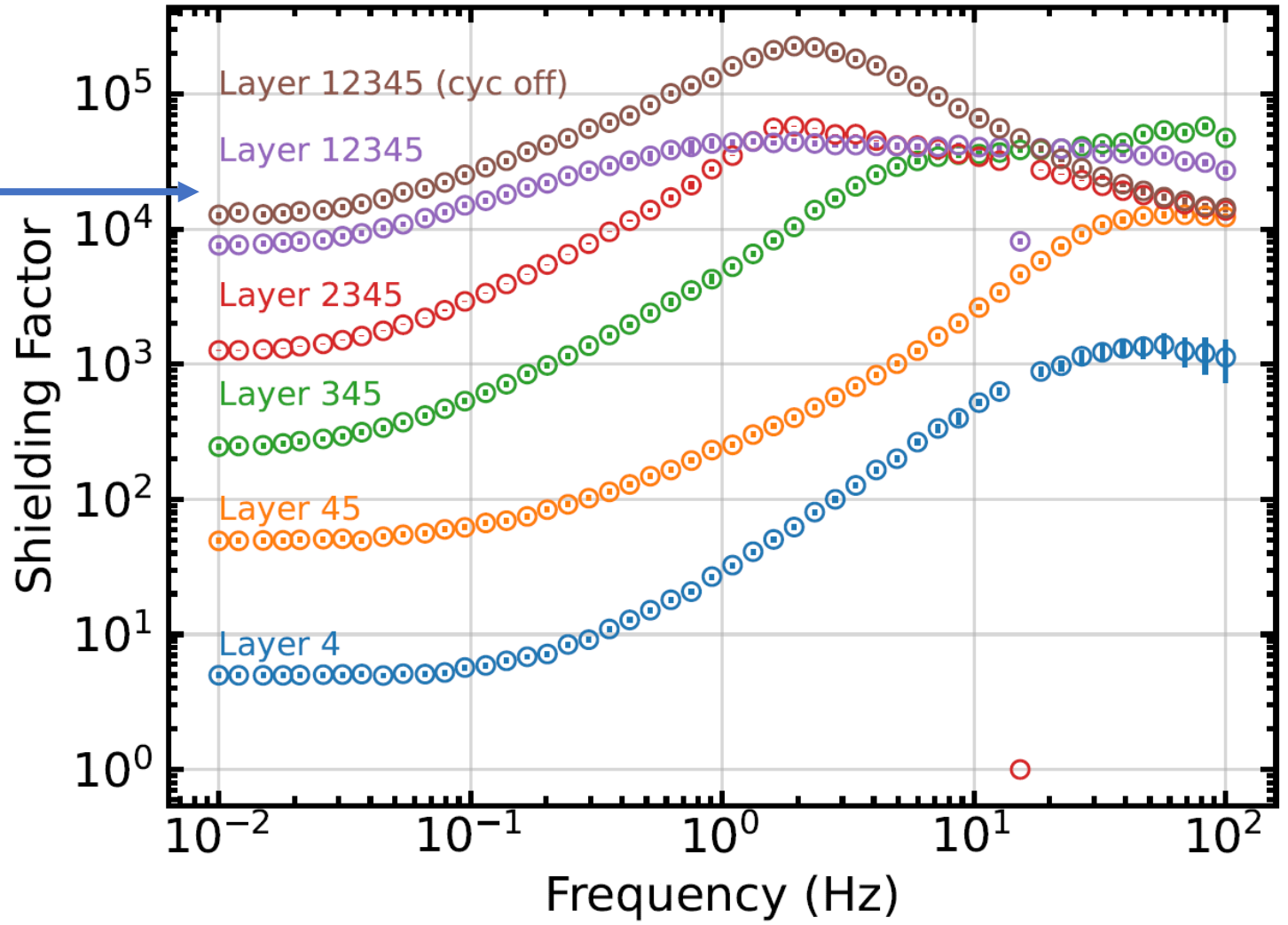
Results

- Internal field: 6 nT
- SF is a factor of 5 smaller than needed
- Simulated SF were all > 100,000 at all frequencies of interest



Cyclotron is ON $\approx 350\ \mu T\ background\ field.$
Cyclotron is OFF $\approx Earth's\ background\ field.$

When in doubt add more layers!

- We believe simulations were too optimistic when guessing the relative permeability of shielding materials
- We are adding an additional inner most mu-metal layer
  - Completion by August 2024
- According to COMSOL simulations, this should improve the SF by around a factor of 10 at low frequencies.
  - Why is this the best course of action?

Conclusion:

- TUCAN is working toward world best 10^{-27} e·cm nEDM measurement at TRIUMF
- We need to improve our magnetic environment i.e. the MSR
- We are adding a 6th mu-metal layer to boost our SF to an acceptable level

Acknowledgements

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