# Magnetic resonance and coil design for TUCAN EDM experiment

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TRIUMF

TUCAN Collaboration

JSPS

NSERC CRSNG

Research Manitoba

# Introduction

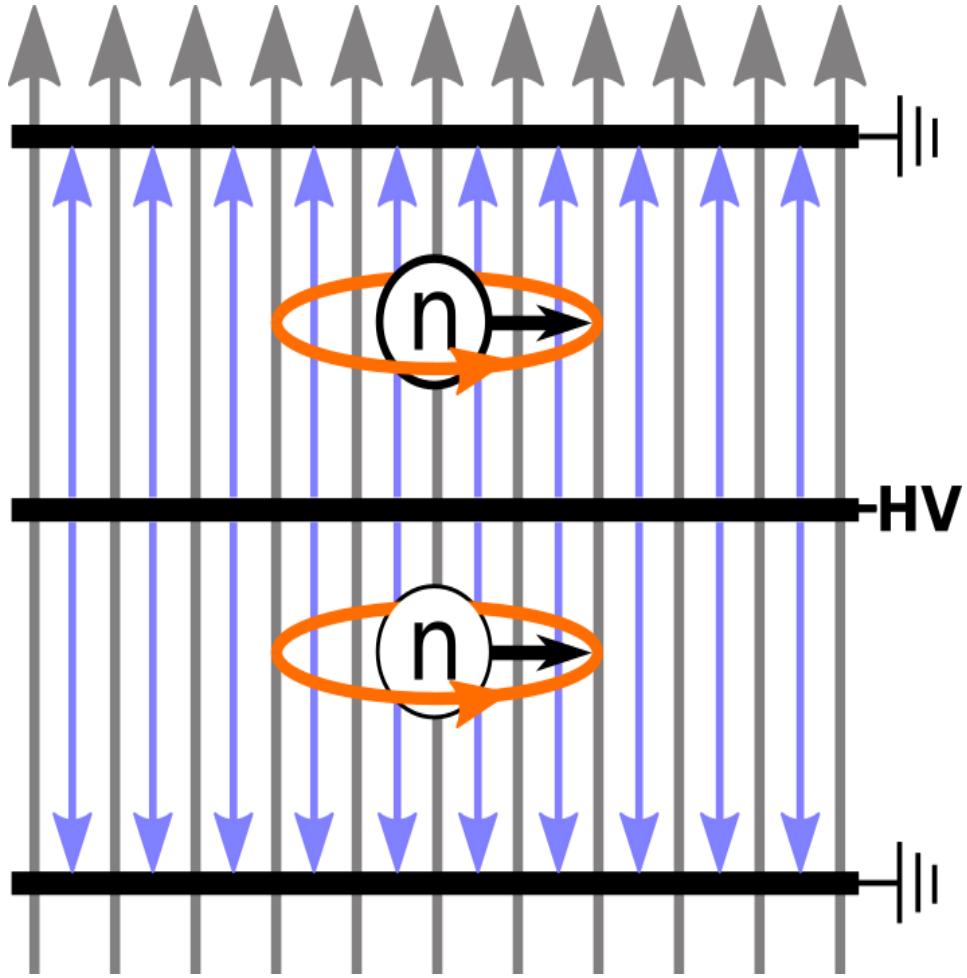
- The TUCAN (TRIUMF Ultracold Advanced Neutron) collaboration aims to make a measurement with an uncertainty of $10^{-27}$e·cm.

- The nEDM is extracted from the spin precession frequency of the neutrons.

- Neutrons travelling through different paths in an inhomogeneous magnetic field will experience instantaneous precession rate changes at different locations.

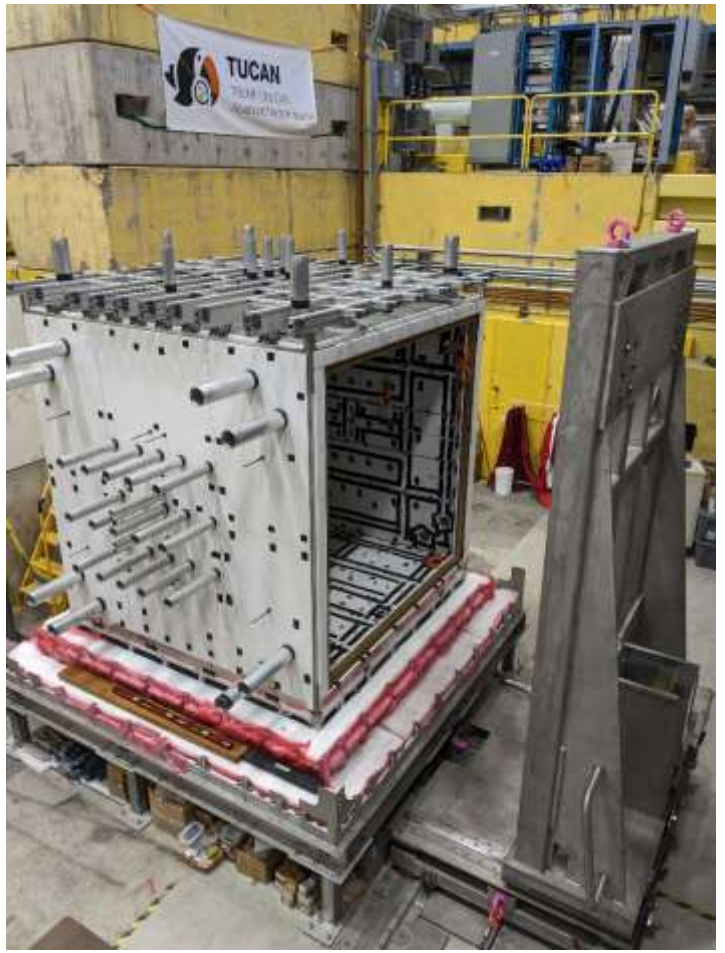
- Magnetic field inhomogeneity depolarizes the neutrons in the cells and contribute to systematic uncertainties

- TUCAN require $\Delta Bz < 140$ pT and $\sigma(Bz) < 40$ pT when measured over the region of the EDM cell(s),within the 1 μT main field.



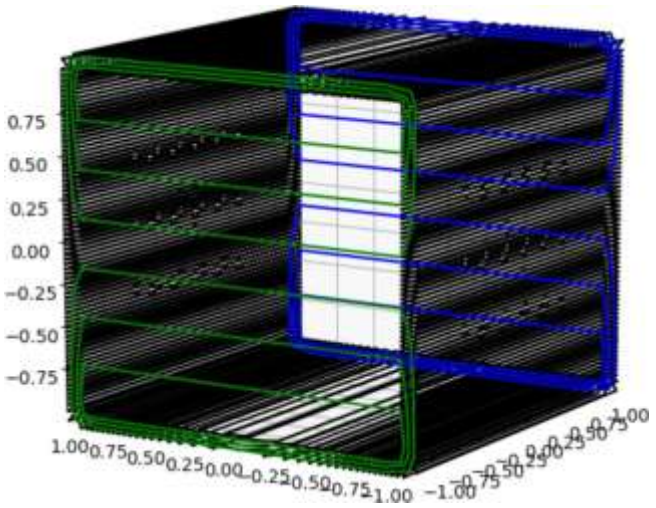
# Coils to correct field inhomogeneties

- **B0 Coil-** Provides the uniform 1μT holding field inside the MSR.
- **nxn coil** -Square coils to cancel arbitrary magnetic gradients in the MSR interior.
- **B1 Coil** -For applying the oscillating field for the π/2 spin flip in the Ramsey method.
- Coils must be constructed inside the MSR in such as way as to provide the required field shapes.
- We are currently working with nxn and Bo coils.

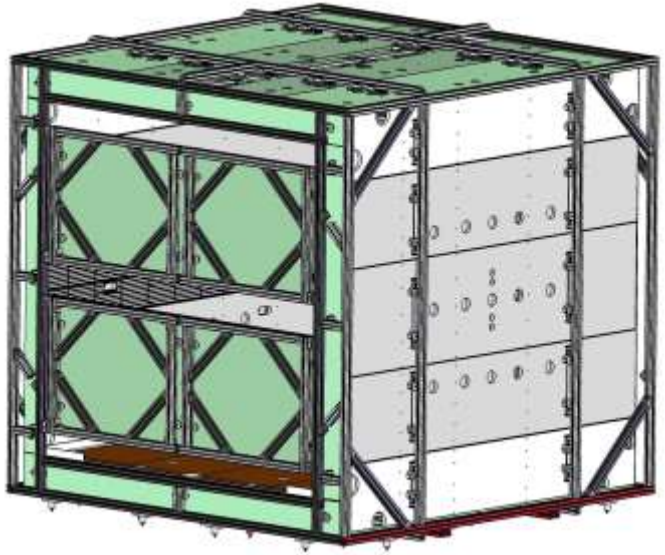


MSR Construction at TRIUMF

# B0 Coil




Simulation of Wire Paths



CAD Model of Coil Frame

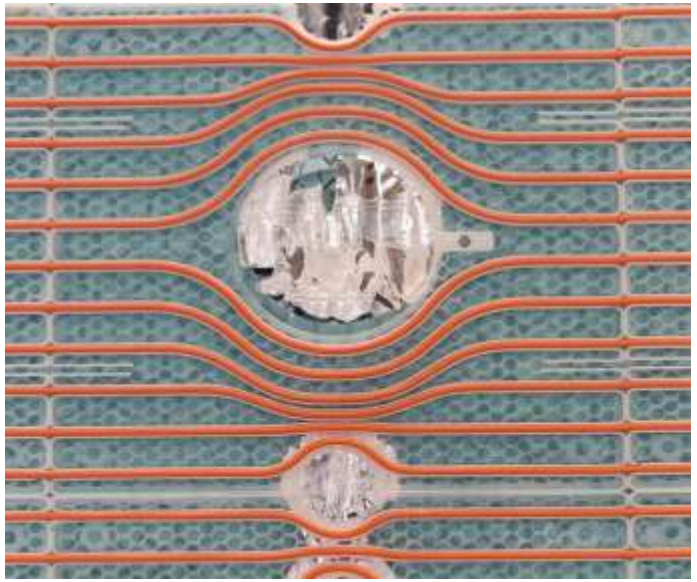
- The purpose of the B0 coil is to provide a uniform 1 $\mu$T magnetic field.
- This field needs to be highly uniform to prevent UCN depolarization and false nEDM signals due to field gradients.
- The coil is designed as a two layer shelf shielded square cosine theta coil.
- The self shielding reduces coupling to the mu-metal of the MSR and should increase stability over time.

Reference:B0coil design by M. McCrea

# B0 Coil Status


↑ Guides on Form

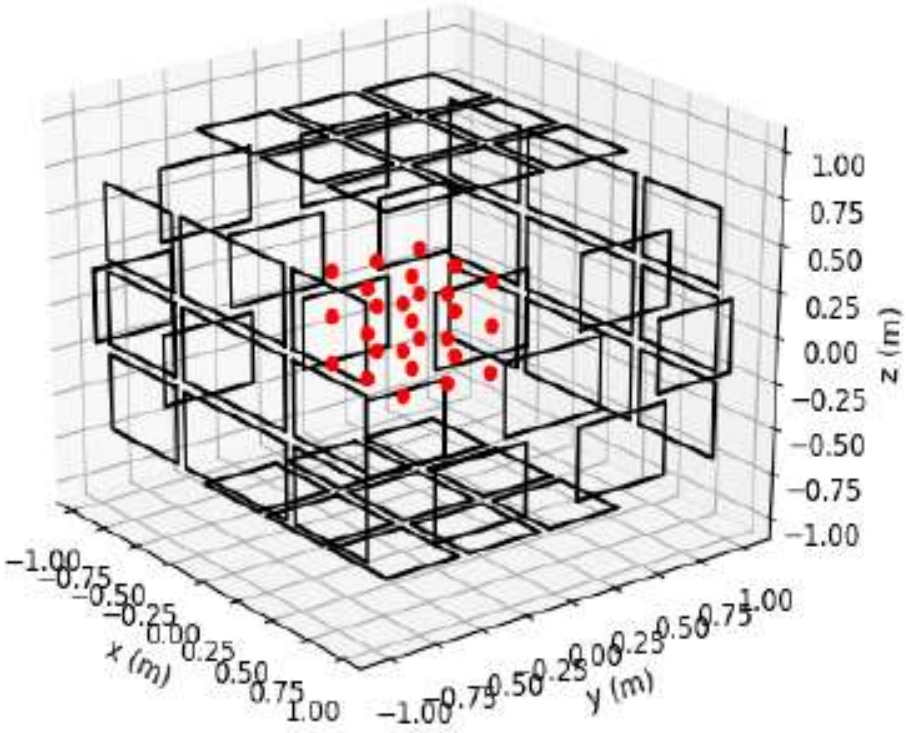
↓guide winding test



- The first frame section with the final design was assembled in 2023/10, and measurements are being examined,initial results show alignment of parts to $0.2 - 0.7$ mm alignment within the 1 mm tolerance.
- The body uses Al ribs separating G10 and Al hex cell sandwiches to make a light weight structure.
- Improvements are being made to the assembly process to increase the accuracy and reduce the assembly time.

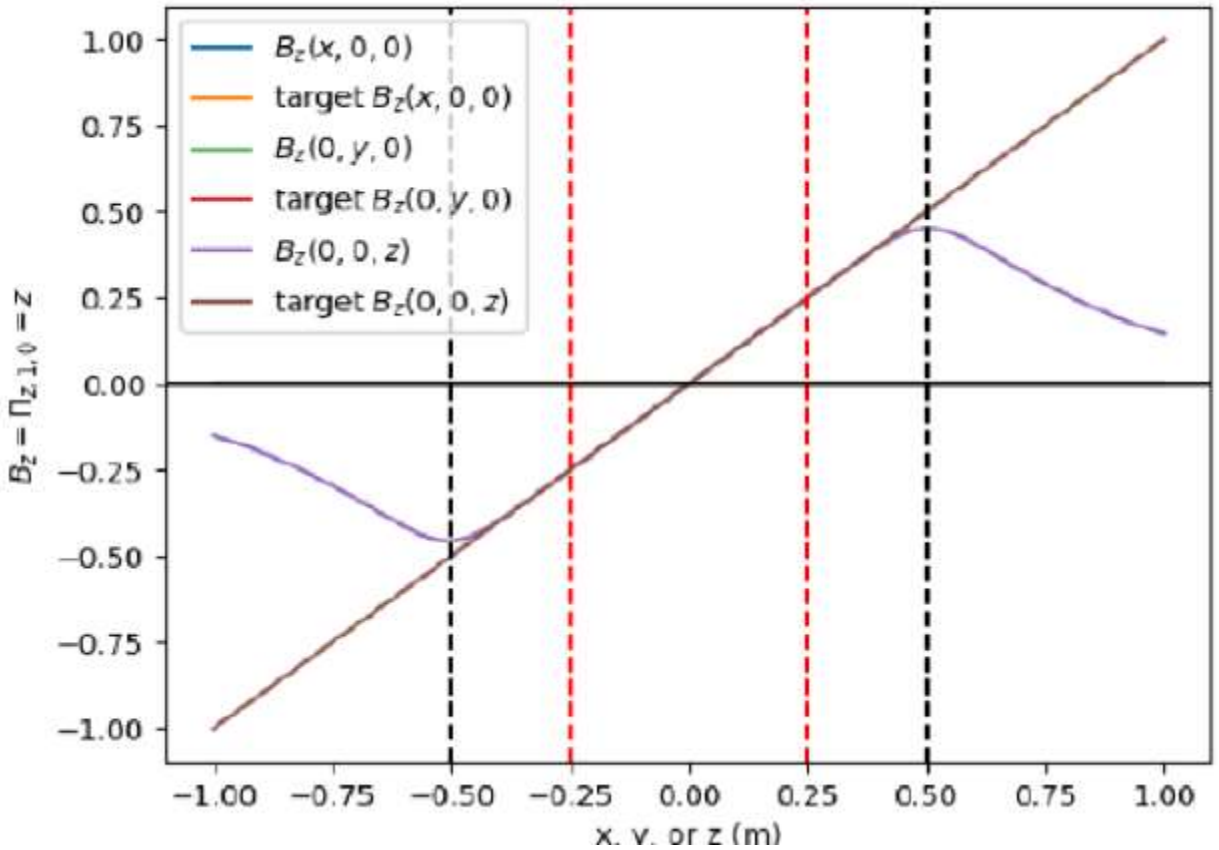
# “nxn” /Shim coils

- Place set of square coils on cubic surface around cells.
- At each of the sensor positions $B_i = \sum_{j=1}^{c} M_{ij} I_j$ or $B=MI$ where $M$ is a matrix
- We can determine the currents to set on each coil to generate a target field using $I_{\text{set}} = M^{-1} B_{\text{target}}$




Example:
9 square coils on 4 faces of a cube + 7 coils on 2 faces = 50 coils
27 sensor positions x 3 axes = 81 sensor axes

# Sample Results

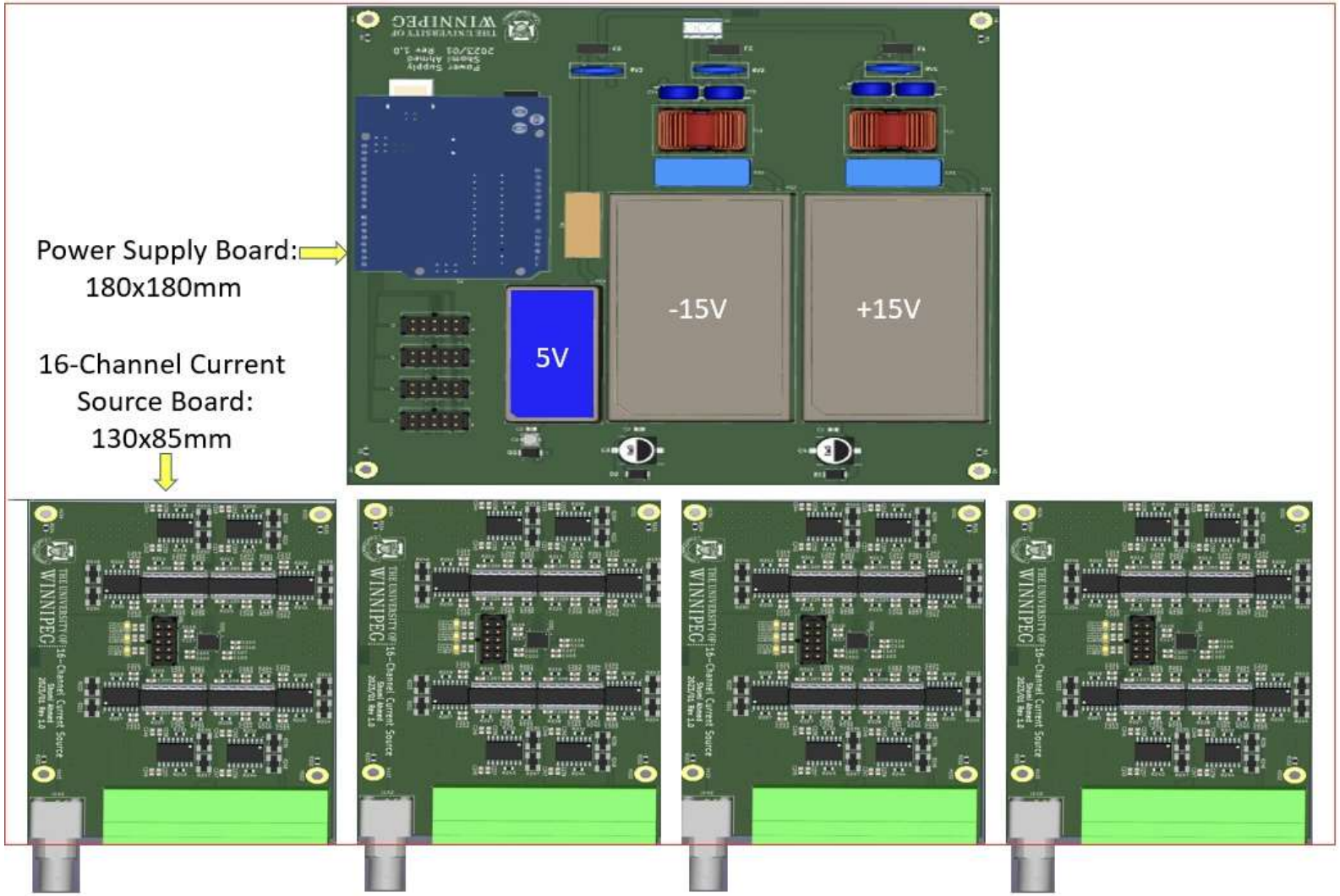



Perfectly linear gradient

- Renormalize applied field (brown) to 3 nT maximum variation over 1 m3 central volume, mimicking expected worst-case homogeneity.
- Residual after field correction is σ(Bz) < 40 pT, averaged over each cell (brown minus purple).
- Results will be better, depending on the actual inhomogeneity of the MSR.

Reference :Square shim coils by J.Martin

# Current Supply For Shim Coils

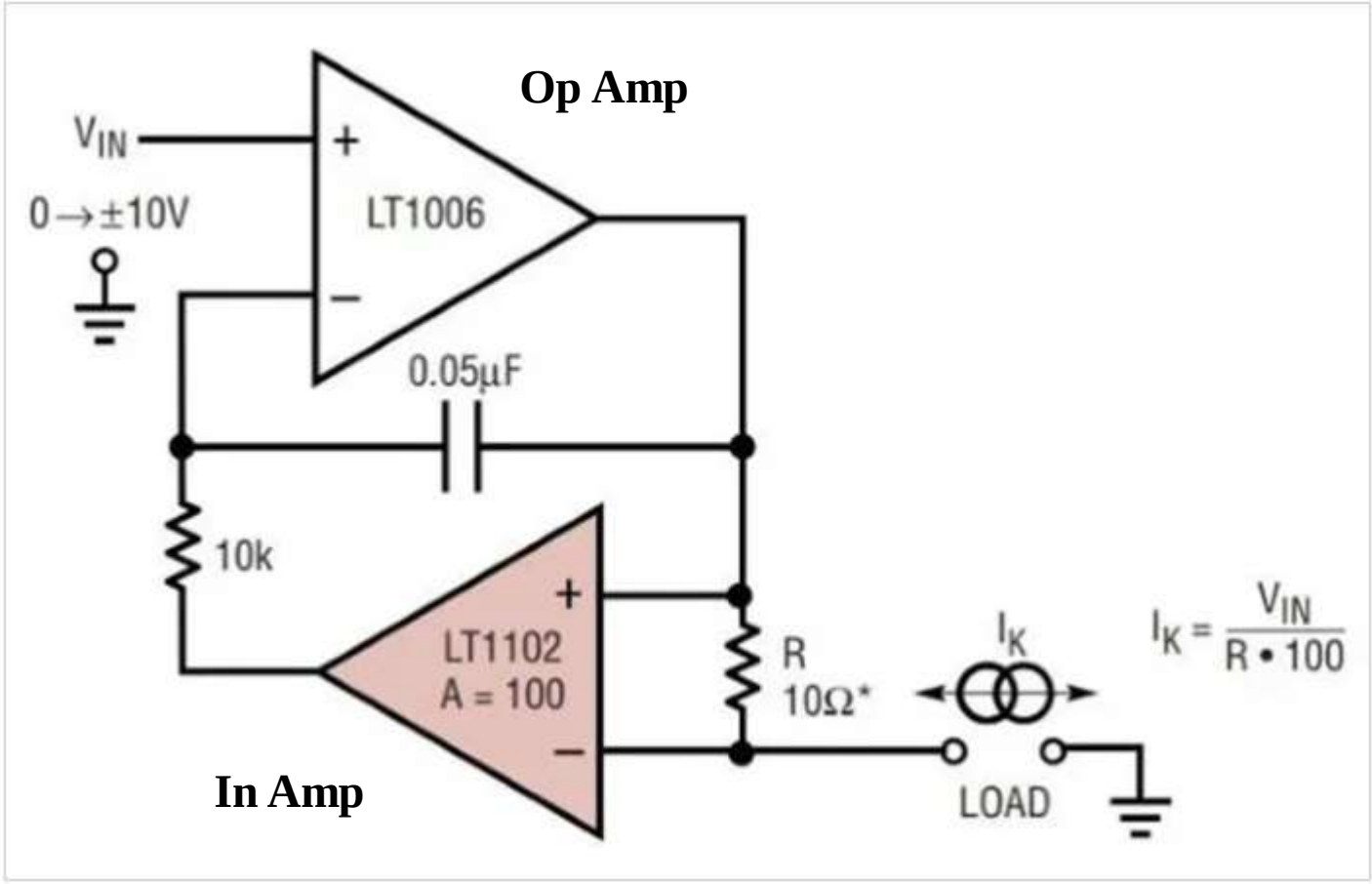



Goal:

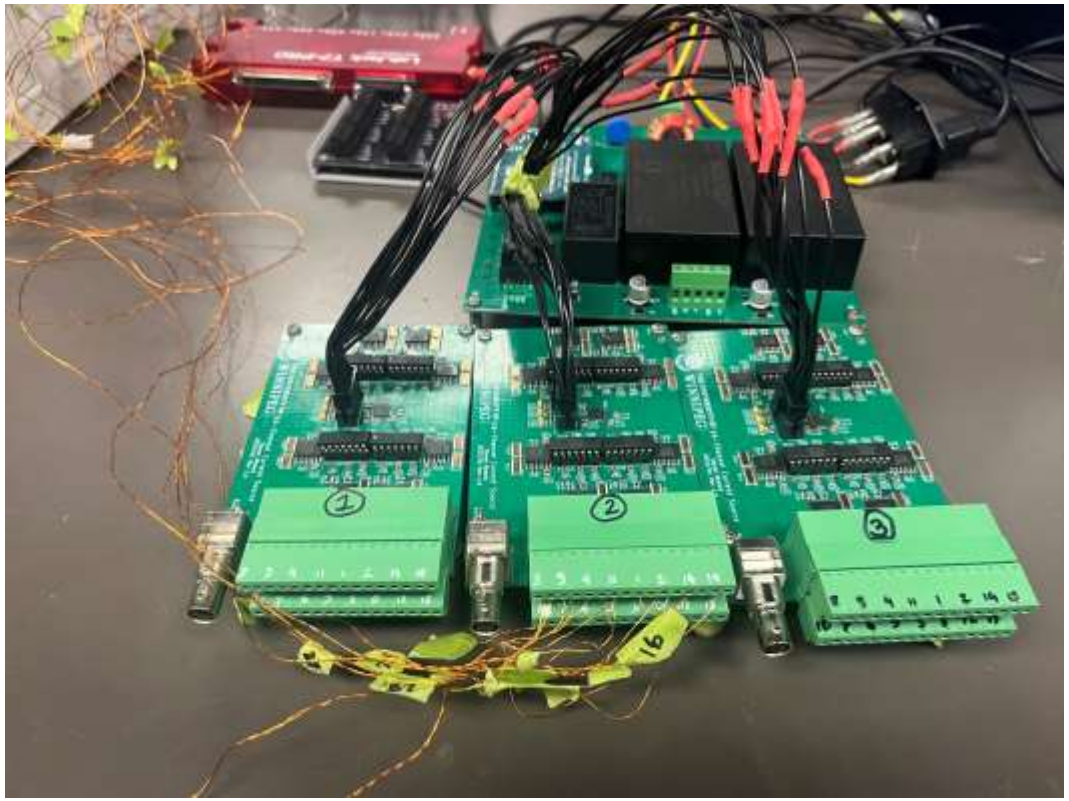
- 64-channel current supply with ±40mA capability
- ± 25 mA would be sufficient, based on simulations of number of bits
  not terribly important
- 4-LTC2668 (16-channel, 16-bit) DACs to supply ±10V to the 64 current sources
- DACs will be controlled by an Arduino Uno

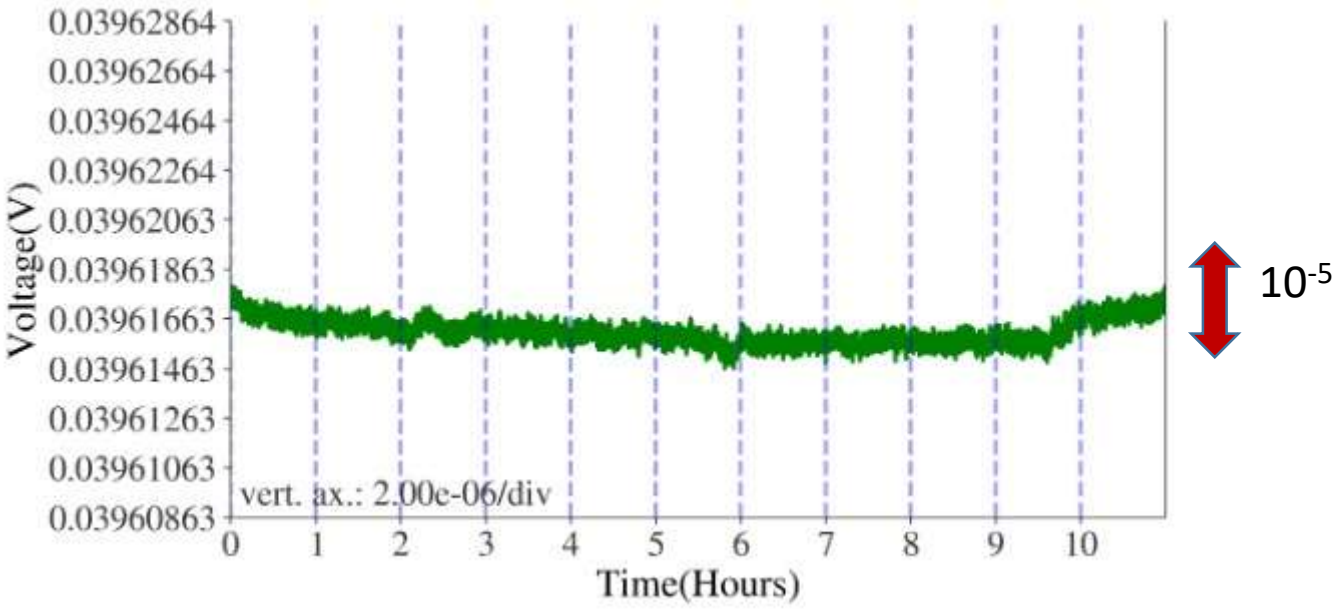
Figure from S.Ahmed

# Voltage Programmable Current Source



# Current supply for shim coils

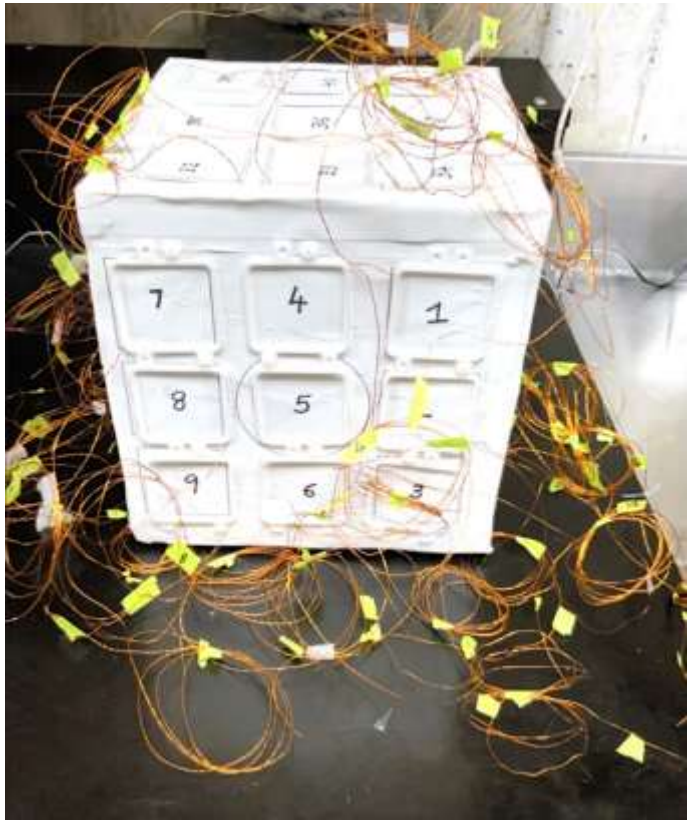





Completed and tested 48-channel prototype at University of Winnipeg

Results from one of the 16 channel current supply.

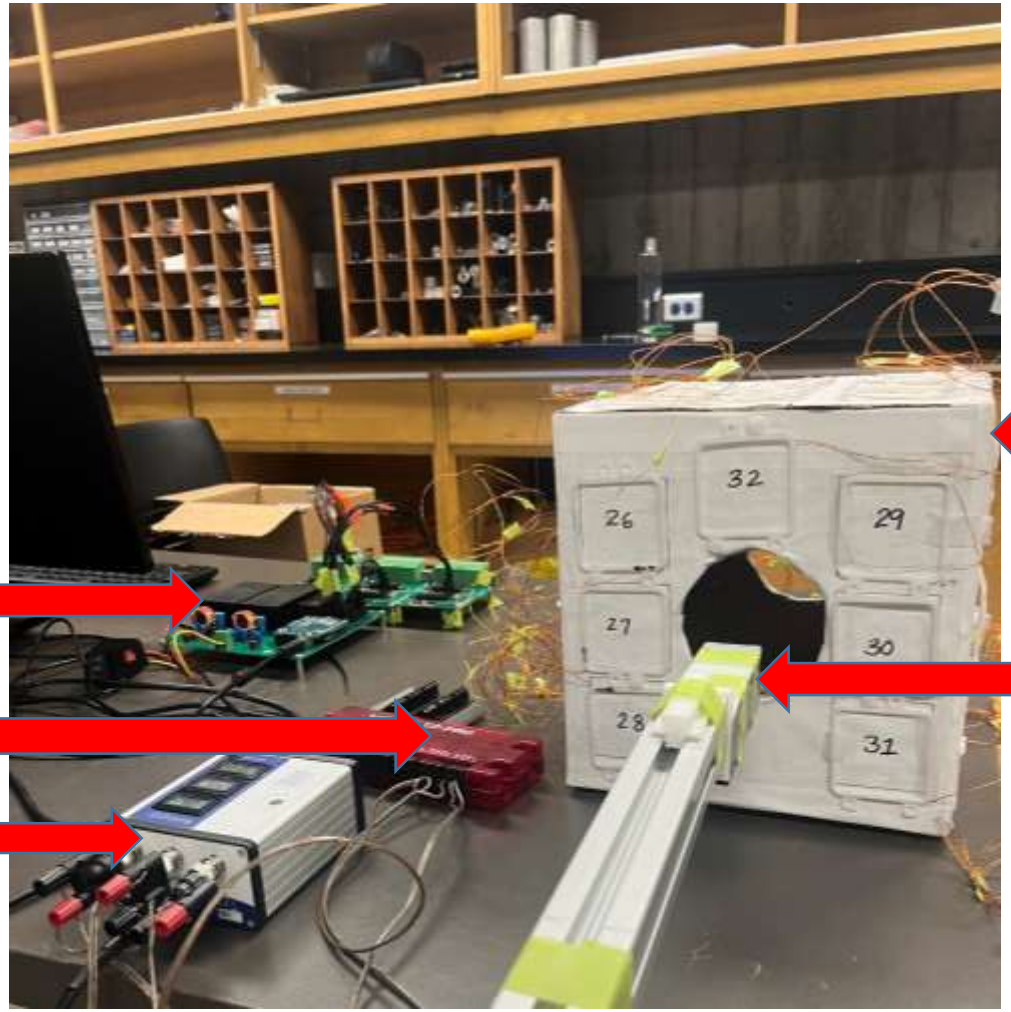
# Shim coil Prototype




Mapper with fluxgate to map the coils

- At University of Winnipeg we are developing a prototype of shim coils and the software to decide what currents to set on the prototype coils that we will use.
- Also working with the field mapper to record magnetic field along three different axis with the help of magnetic field sensor.

# Set Up……




Shim coil prototype

Current supply board

lab jack

SCU

Fluxgate mapper

# Future Work

## B0 Coil

- The next set of parts will be delivered late November and the last set in April 2024.

## Shim Coil

- November 2023: complete 64-channel current source
- December 2023: To complete prototype coils + current source system test.
- May 2024: Installation of shim coil system within B0 coil in MSR

# Conclusion

- nxn shim coil system provides a flexible solution for homogeneous fields.
- Mechanical design concept in preparation.
- Prototype current source tested and scaling up to 64 channels.
- B0 coil is under construction and analysis of measurements and non-contact point map is underway.

# Thank you……..