TRIUMF

Upcoming MSR Publication and Current Status

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2026-02-19

TUCAN
TRIUMF Ultracold Advanced Neutron Collaboration

Discovery, accelerated

Overview

→ We finished the room... a while ago
→ Paper scope:
  → Requirements, design, and construction
  → Shielding factor
  → Preliminary residual field and gradients
  → Use existing data only
→ Email for comments sent after this meeting

> "Review of Scientific Instruments (RSI) publishes novel advancements in scientific instrumentation, apparatuses, techniques of experimental measurement, and related mathematical analysis."

https://pubs.aip.org/aip/rsi

Requirements and Design

Central $1\,\text{m}^3$ performance requirements:

- $\rightarrow$ $\geq 10^5$ shielding factor at $0.01\,\text{Hz}$
- $\rightarrow$ Residual fields $<1\,\text{nT}$
- $\rightarrow$ Stable to the pT level over minutes
- $\rightarrow$ Internal field gradients $<100\,\text{pT/m}$

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Design philosophy

- → As many mu-metal layers as possible with the maximum inter-layer spacing
- → Mirror all ports into the room
- → Each layer individually degaussable
- → Door robust against misalignment

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Layer	**Thickness**		**Material**	**Side Length**
1-outer	$4\,\mathrm{mm}$	$(2 \times 2.0\,\mathrm{mm})$	mu-metal	$3500\,\mathrm{mm}$
2	$3\,\mathrm{mm}$	$(2 \times 1.5\,\mathrm{mm})$	mu-metal	$3000\,\mathrm{mm}$
3	$3\,\mathrm{mm}$	$(2 \times 1.5\,\mathrm{mm})$	mu-metal	$2600\,\mathrm{mm}$
4	$6 - 12\,\mathrm{mm}$	$(1 - 2 \times 6.0\,\mathrm{mm})$	copper	$2550\,\mathrm{mm}$
5	$2\,\mathrm{mm}$	$(2 \times 1.0\,\mathrm{mm})$	mu-metal	$2400\,\mathrm{mm}$
6-inner	$2.4\,\mathrm{mm}$	$(2 \times 1.2\,\mathrm{mm})$	mu-metal	$2250\,\mathrm{mm}$

Construction

- → Engineering and installation by Magnetic Shields Ltd.
- → Jan 2023 - Aug 2024
  - → Base frame
  - → Floor (all layers)
  - → Layer 4 (copper)
  - → Door (all layers)
  - → Layers 5, 3, 2, 1, 6
- → Shielding factor measured after each layer installed
- → For the most part, things went smoothly

MSR prior to layer 3 installation

Construction Issues

- → MSR “mispositioned” by ~ 30 cm eastward
- → Strongback base plate deformation
- → Initial poor performance
- → Unreliable degaussing connections at door
- → Electrical short between L3 and L4
- → Door crank cable fray

MSR prior to layer 3 installation

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- $\rightarrow$ MSR "mispositioned" by $\sim 30\,\text{cm}$ eastward $\rightarrow$ UCN guide path adjusted
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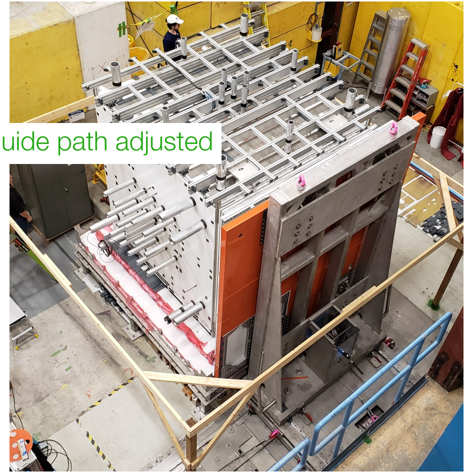

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→ Door crank cable fray → regular maintenance needed

MSR prior to layer 3 installation

Shielding Factor

$$S = \left(\frac{B^u_{\text{ext}}}{B^s_{\text{ext}}}\right) \underbrace{\left(\frac{B^s_{\text{ref}}}{B^u_{\text{ref}}}\right)\left(\frac{I^s_{\text{ext}}}{I^u_{\text{ext}}}\right)\left(\frac{I^u_{\text{ref}}}{I^s_{\text{ref}}}\right)}_{\text{corrections}}$$

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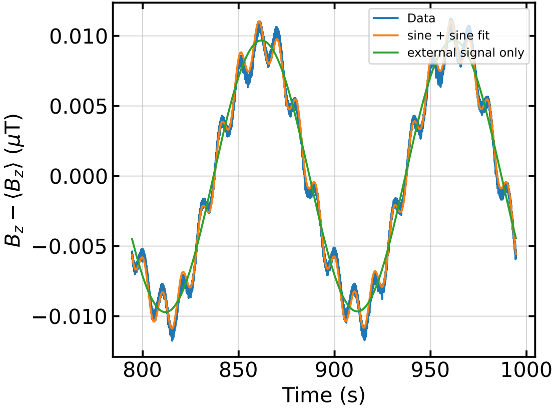
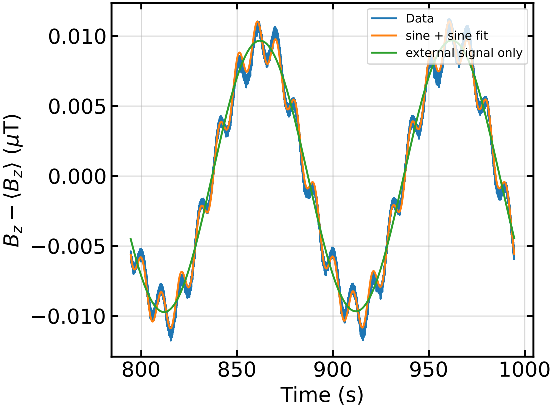


Raw data with fits at 0.01 Hz, measured with fluxgate

Shielding Factor

→ Measure with fluxgate (QuSpin for L6)

→ Use least-squares fit (lock-in amplifier for L6)



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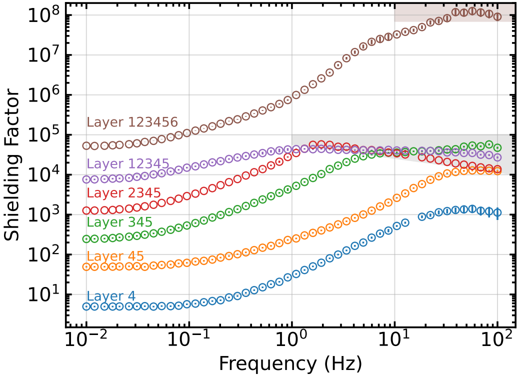
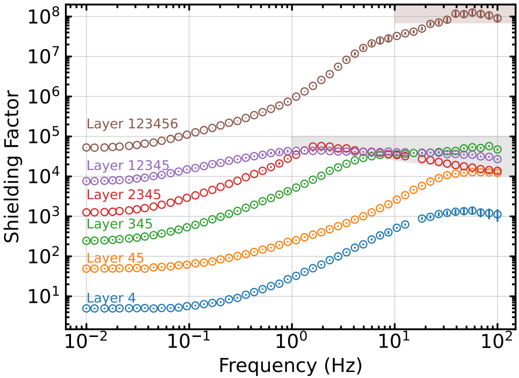


Shielding factor at end of each layer installation

Shielding Factor

Shielding factor at 0.01 Hz, 36 µT peak-peak, cyclotron on:

Layers completed	Shielding Factor	Improvement (S_i/S_{i-1})
4	5	
45	49	9.8
345	245	5
2345	1263	5.2
12345	7592	6
123456	$58\,200$	7



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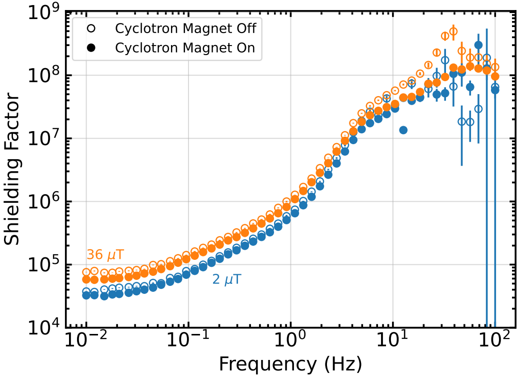
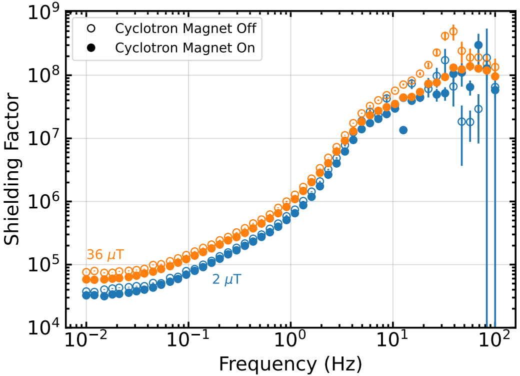


Shielding factor at peak-peak external fields of $36\,\mu T$ and $2\,\mu T$

Shielding Factor

Shielding factor at 0.01 Hz:

Cyclotron	$B_{pp} = 2\,\mu T$	$B_{pp} = 36\,\mu T$
On	$32\,500 \pm 200$	$58\,200 \pm 500$
Off	$37\,500 \pm 400$	$75\,900 \pm 500$



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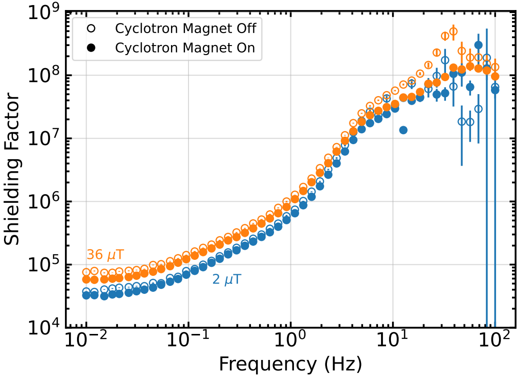

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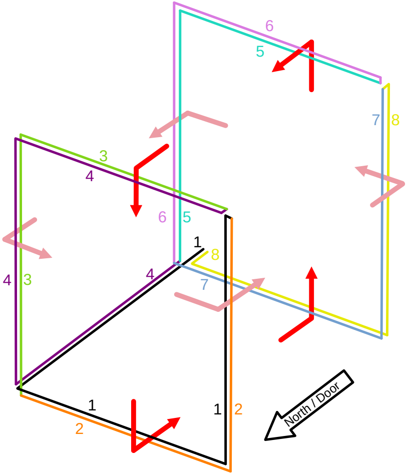
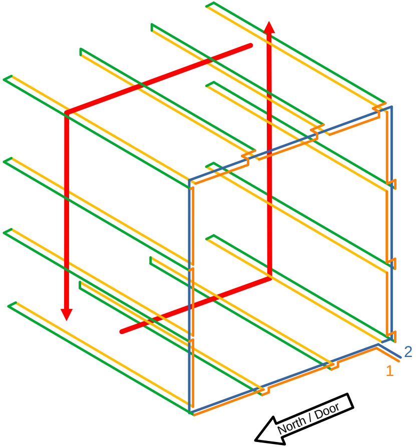
Degaussing Coils



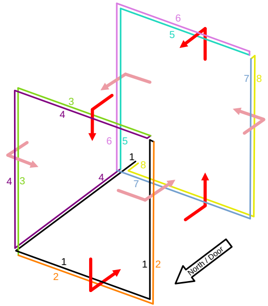
Edge “L” coils

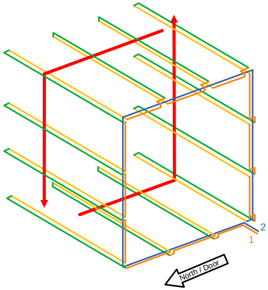


Distributed toroidal coils

Degaussing Coils

Layer	Primary Coil Set	Secondary Coil Set
1	Edge “L” (reconfigurable)	
2	Edge “L”	
3	Edge “L”	
5	Distributed “L”	Edge toroidal $\times 3$
6	Distributed toroidal $\times 2$	Edge toroidal $\times 3$

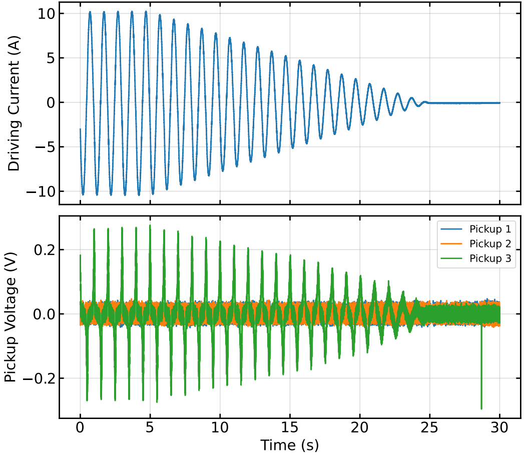




Degaussing Procedure

At $1\,\text{Hz}$, maximum amplitude, timing structure for each layer:

- $\rightarrow$ Ramp to max amp: $5\,\text{s}$
- $\rightarrow$ Hold max amp: $10\,\text{s}$
- $\rightarrow$ Linear amp ramp down: $60\,\text{s}$
- $\rightarrow$ Hold zero amplitude: $2\,\text{s}$



Example driving sequence (different time structure)

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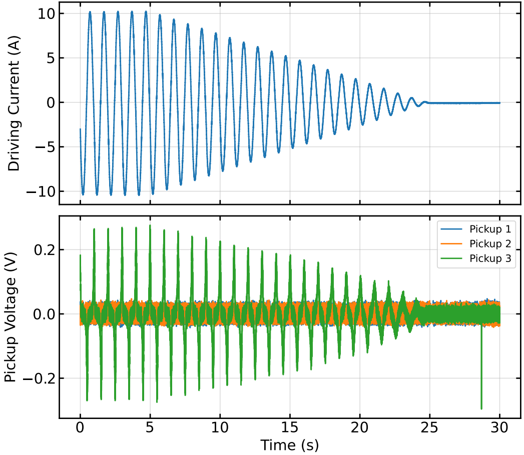
Layer pattern:

- $\rightarrow$ Outwards: L6, L5, L3, L2, L1
- $\rightarrow$ Inwards: L2, L3, L5
- $\rightarrow$ Connect Isolation transformer, switch to 3 Hz, 120 s ramp down, half max amplitude
- $\rightarrow$ L6



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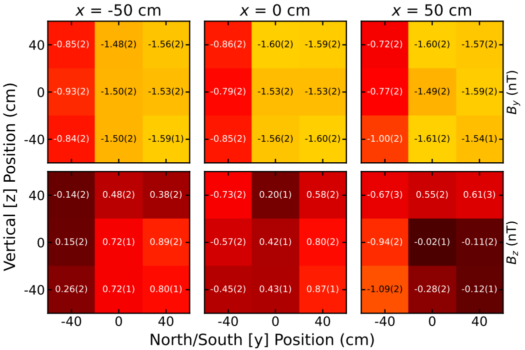
Residual Fields

→ Used QuSpin taped to a stick, flipping at each point

→ Above requirement of 1 nT, but not by much

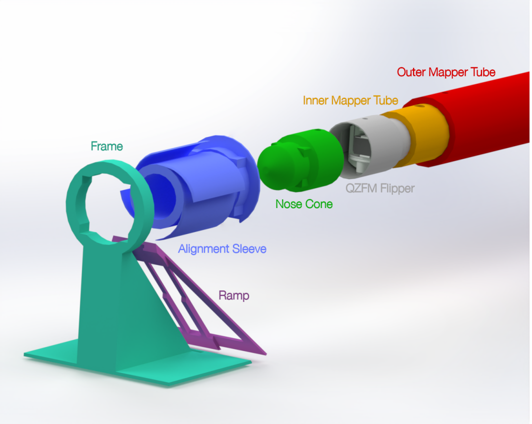
→ With cyclotron on



Residual fields measurable through the west wall, with cyclotron field on and simple degaussing procedure

Residual Fields

- → Used QuSpin taped to a stick, flipping at each point
- → Above requirement of $1\,\mathrm{nT}$, but not by much
- → With cyclotron on
- → We have a better stick now, should repeat for future publication
- → Repeat with cyclotron off

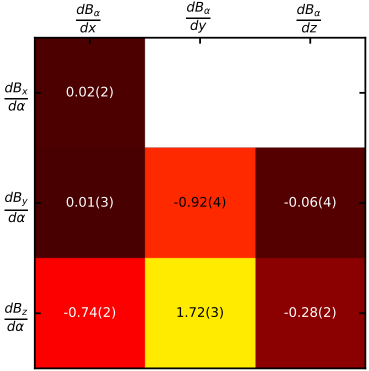


New mapper stick with 2 axis rotation and fixed positions / angles

Field Gradient

Calculated only $G_{0,m}$ for room center position:

- → Above requirement of $0.1\,\mathrm{nT/m}$
- → Missing two points (incalculable from what we have)
- → Higher order gradients, at more positions possible with better maps



$G_{0,m}$ at room center in nT/m.

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Most metrics don't meet requirement:

- $\to$ Shielding factor at $0.01\,\mathrm{Hz}$, $2\,\mu\mathrm{T}$ too low:
  $4 \times 10^4 < 10^5$
- $\to$ Residual field max a little too high:
  $1.6\,\mathrm{nT} > 1\,\mathrm{nT}$
- $\to$ Gradient max at room center much too high:
  $1.7\,\mathrm{nT} > 0.1\,\mathrm{nT}$

Residual fields and gradients can likely be improved upon.

Draft to be sent out soon

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