Compensation of Magnetic Fields at the the TRIUMF nEDM Experiment

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Thanks To:
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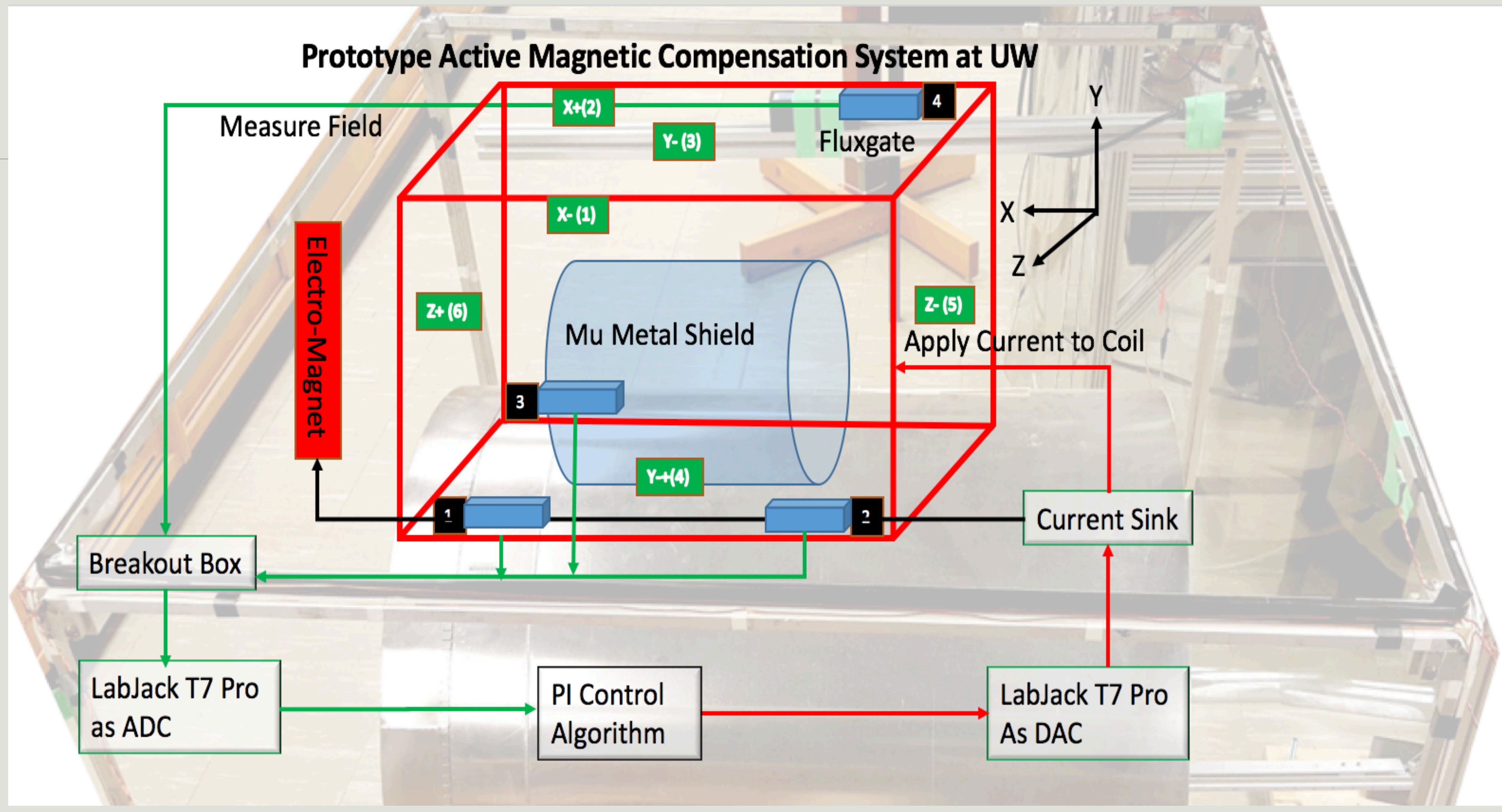
MOTIVATION

- Annihilation of anti-matter from the universe is a long standing mystery which can be explained by CP violation [1]. Extensions to the Standard Model predict new sources of CP violation, in turn generating a neutron Electric Dipole Moment (nEDM) to be 10^{-26} to 10^{-28} e-cm . So, a search for a non-zero nEDM represents a search for new physics that violates CP symmetry.
- The current best upper limit set by Sussex/RAL/ILL nEDM experiment is 3.0×10^{-26} e-cm [2]. The nEDM experiment at TRIUMF is aiming at the 10^{-27} e-cm sensitivity level.
- We are developing the world's highest density source of UCN . The experiment requires a very stable (<~pT) and homogeneous (<~nT/m) magnetic field (B0) within the measurement cell.
- I am involved in the development of active magnetic shielding to stabilize the external magnetic field by compensation coils.

PROTOTYPE SETUP



OBJECTIVES

Fig. 1: Magnetic Field Compensation System

Active Shield Goals-

- Stability of field surrounding Magnetic Shielded Room (MSR) ≤ 100 nT.
- Reduce 400 μT background (avoid saturation).
- Ability to open the door without magnetizing internal layers.

METHODS

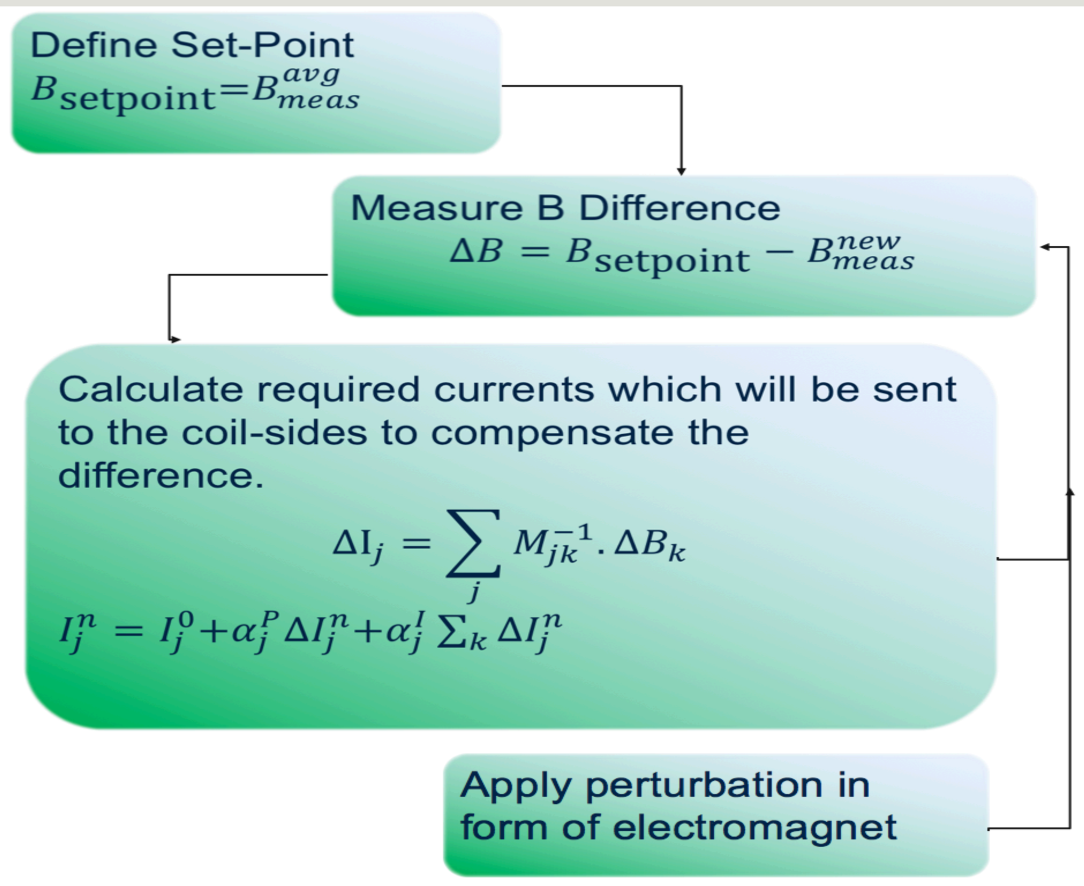


Fig. 2: Flow chart of the whole process. Here, M (nT/A) is the matrix of proportionality factors.

MATRIX OF PROPORTIONALITY FACTORS

Problem

- Wildly varying currents and poor control away from sensor positions.
- Inverse of non-square matrix.

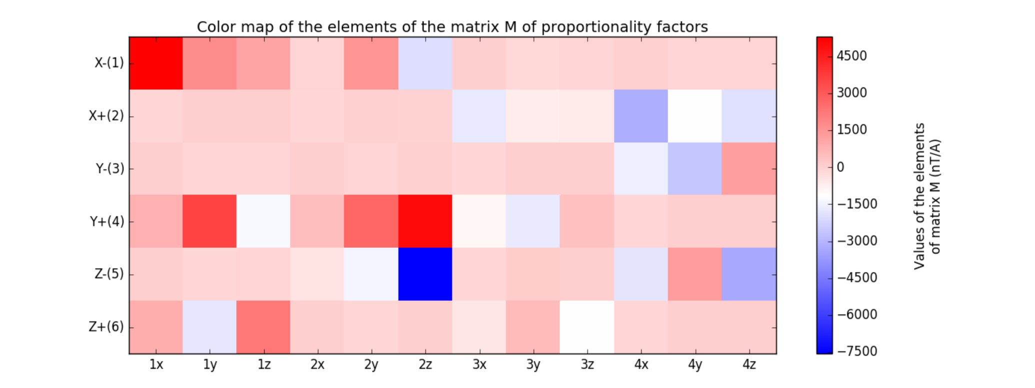


Fig. 3: Color map of M (nT/A).

Solution[3]

- Use pseudoinverse with Tikhonov regularization.
  - ✓ Regularization Parameter, r
    - r $\to -\infty$ means non regularized (big current fluctuations).
    - r $\to +\infty$ means $M^{-1} \to 0$ (no control).

Monte Carlo Method to Find M^{-1}

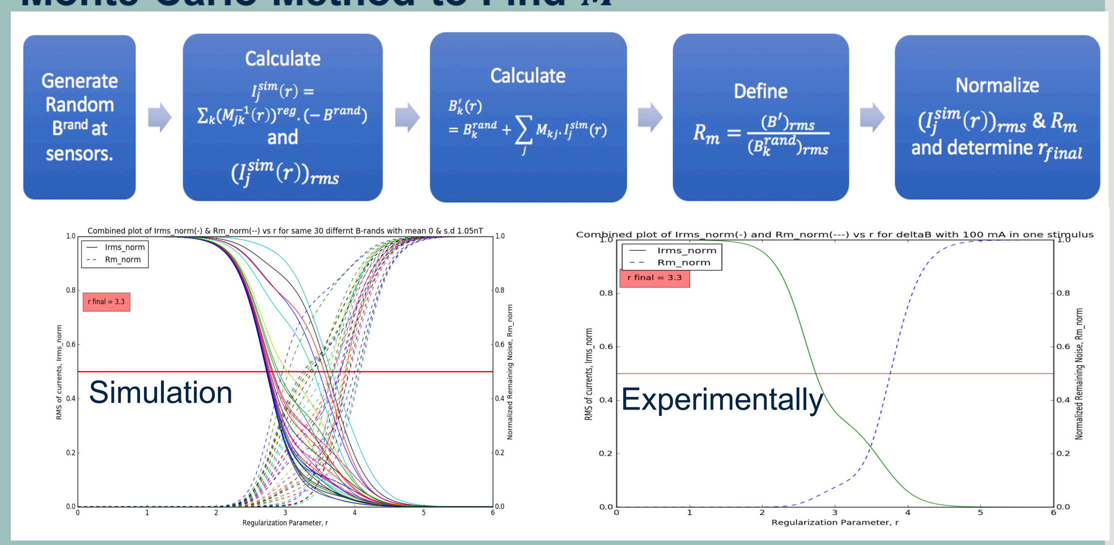


Fig. 4: Simulated values to generate r (left) and right graphs shows same result for one stimulus experimentally.

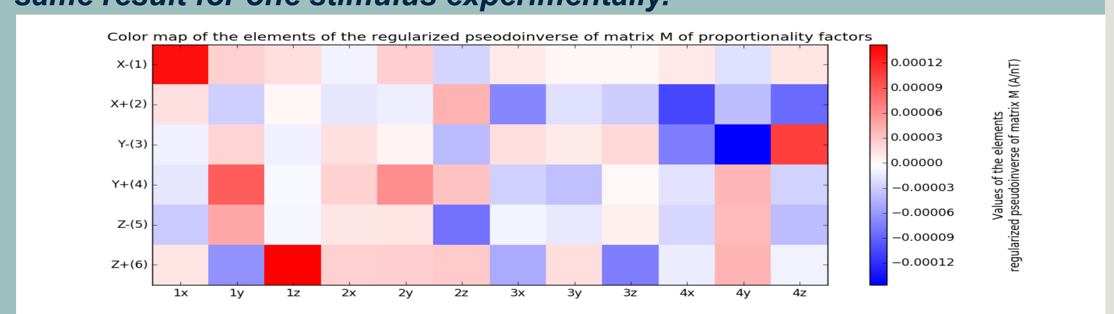


Fig. 5: Color map of regularized pseudoinverse M^{-1} (A/nT) after getting 'r'.

RESULTS

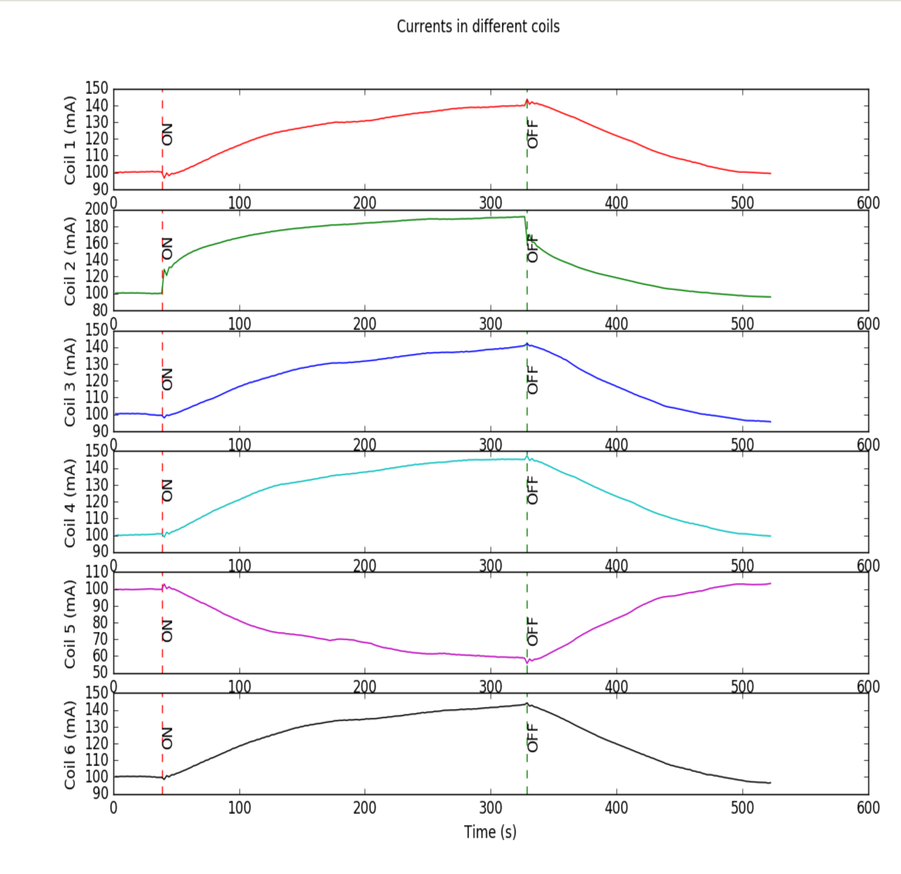


Fig. 6: Currents in different coils. ON & OFF indicates the status of the electromagnet.

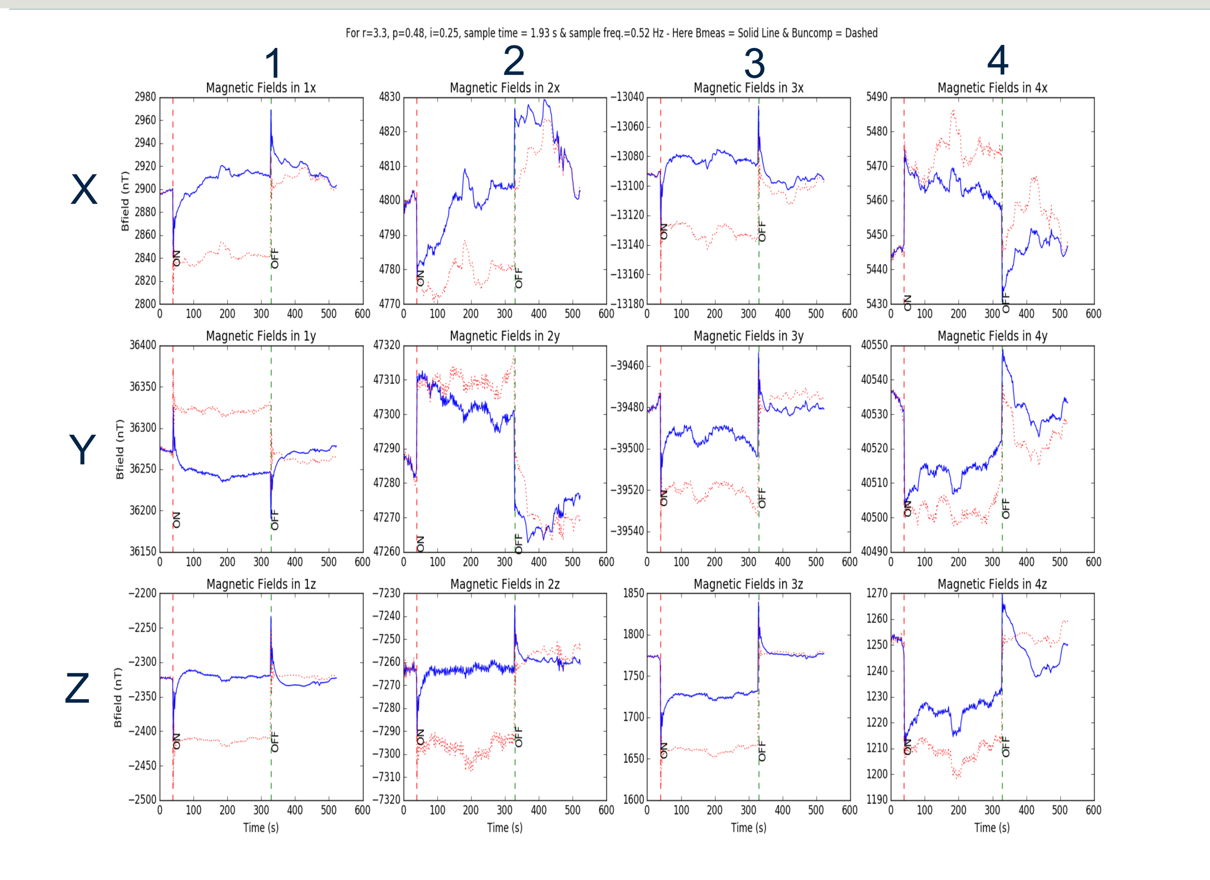


Fig. 7: Magnetic fields over times in different sensor positions. Here, Bmeasured=Solid Line (Blue) and Buncompensated = Dashed (Red).

RESULTS (CONTD.)

- Allan Deviation, $\sigma_{ADEV} = \sqrt{\frac{1}{2} < (y_{n+1} - y_n)^2 >}$
  - y_n - n^{th} average over τ.
- Shielding Factor , $S_k(\tau) = \frac{\sigma_{ADEV}(B^{uncomp}_k)}{\sigma_{ADEV}(B^{meas}_k)}$

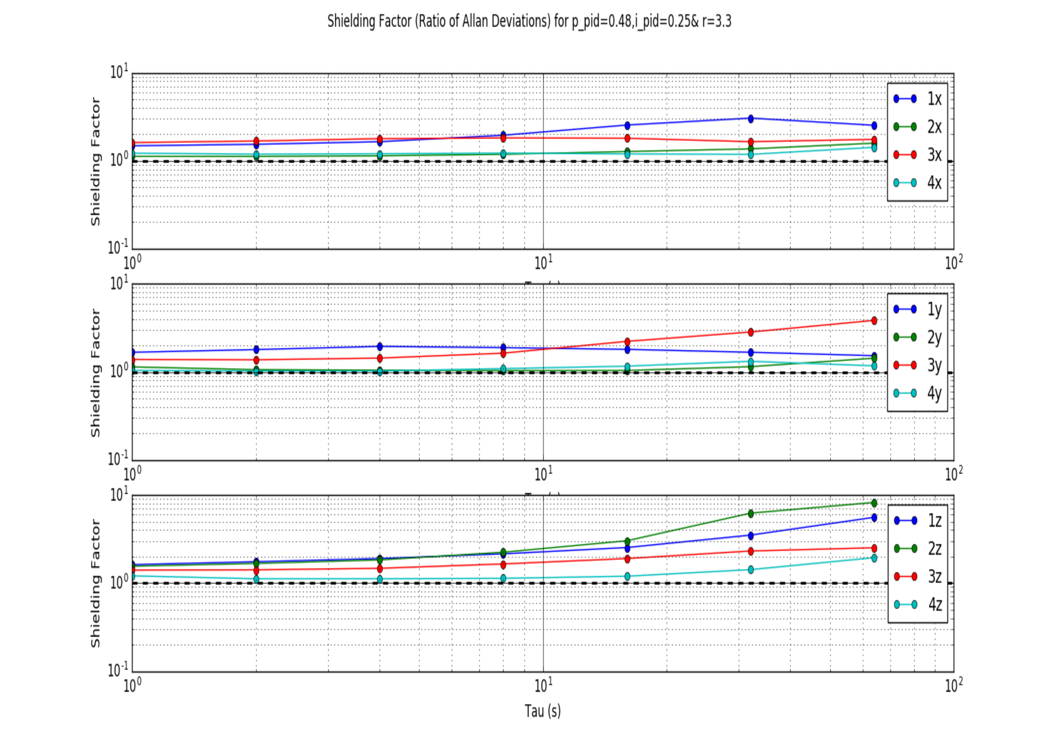


Fig. 8: Shielding factor in different sensor positions. Shielding factor greater than one indicates success. So, on that note, our results are success.

DISCUSSION

- We are planning on optimize the system to get best results out of it.
- The steps that we are considering-
  - Find the best tuning process.
  - Build an analog filter and increase the sampling frequency rate.
  - Find the best positions of the fluxgates.
- Finally, the optimized system will be compared with a simulated result.

CONCLUSIONS

- Non-zero nEDM tests T-symmetry, new physics violating CP symmetry.
- TRIUMF nEDM sensitivity 10^{-27} e-cm.
- nEDM experiment requires very stable (< pT) and homogeneous (< nT/m) magnetic field.
- Need suitable active magnetic compensation system.
- Protoype system at UW gives reasonable level of compensation.
- We are working on to have better result.

REFERENCES

1. V.Barger et al. Phys.Lett. B 566 , 8(2003).
2. J. M. Pendlebury et al.Phys. Rev. D 92, 092003(2015).
3. B. Franke, Doctoral Theses, ETH-Zürich (2013).