PSI Center for Neutron and Muon Sciences

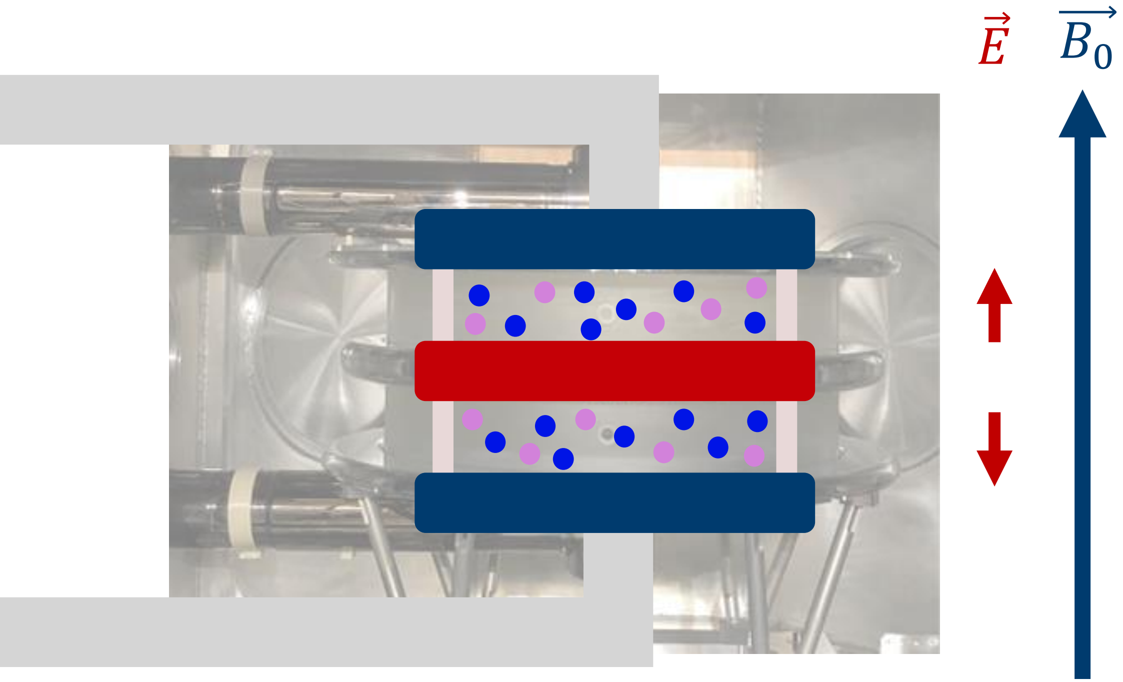
n2EDM

# A high-sensitivity Cesium magnetometer array for the n2EDM experiment

Victoria Kletzl

SPS Annual Meeting, 11 September 2024

# The n2EDM double chamber

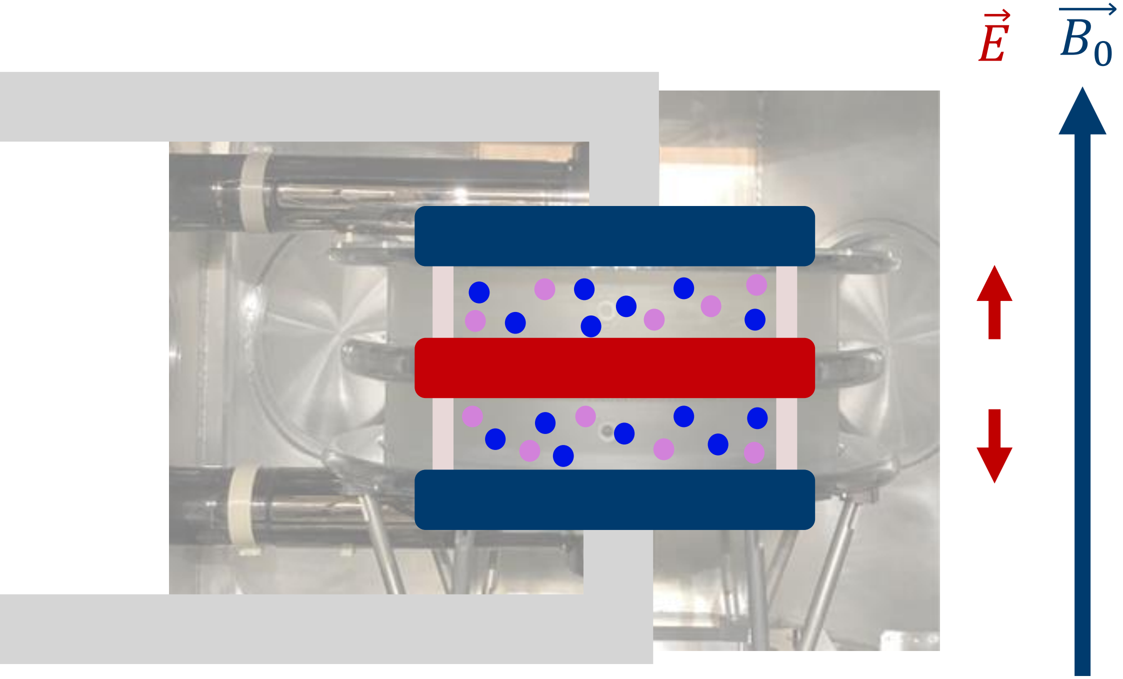


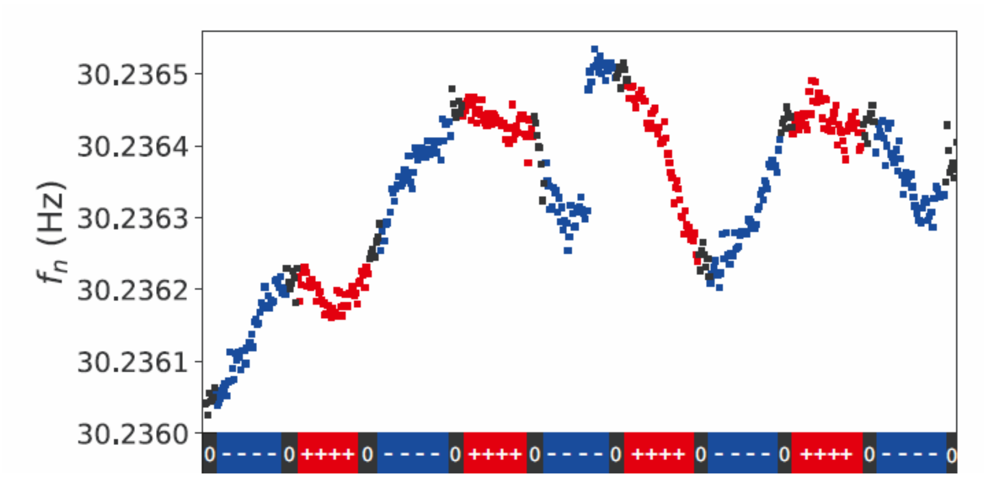

Simultaneous measurement of:

$f_{n,\uparrow\downarrow}$ and $f_{n,\uparrow\uparrow}$

- UCN
- $^{199}$Hg atom

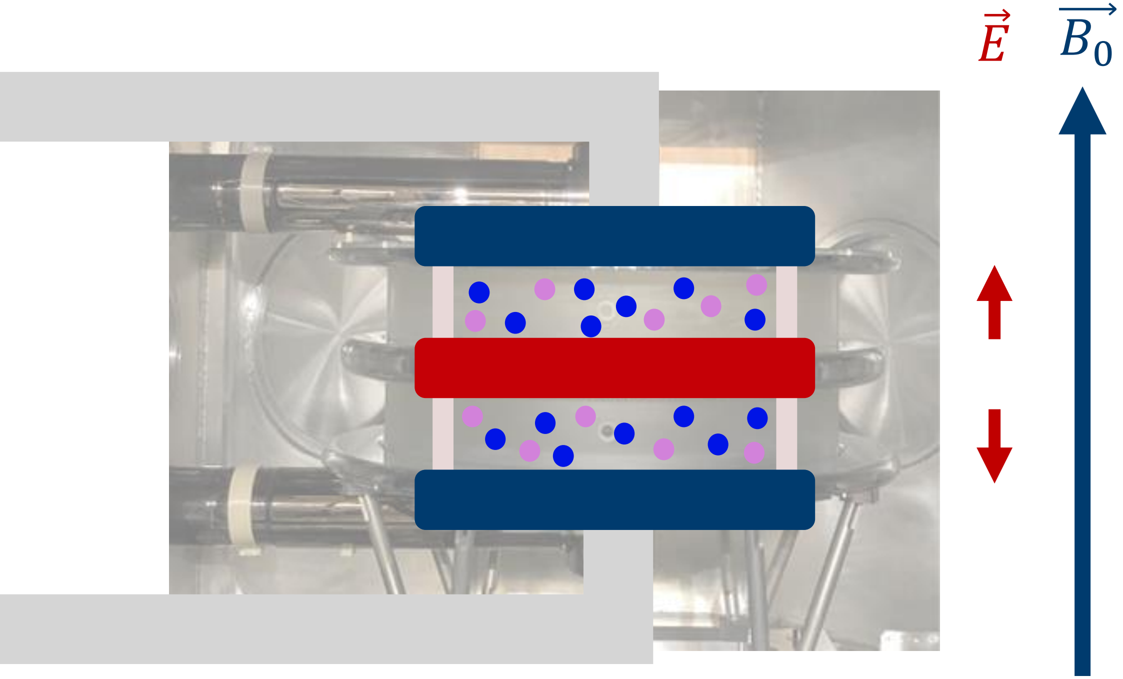
# The n2EDM double chamber




- UCN
- $^{199}$Hg atom

# The n2EDM double chamber




- UCN
- $^{199}$Hg atom

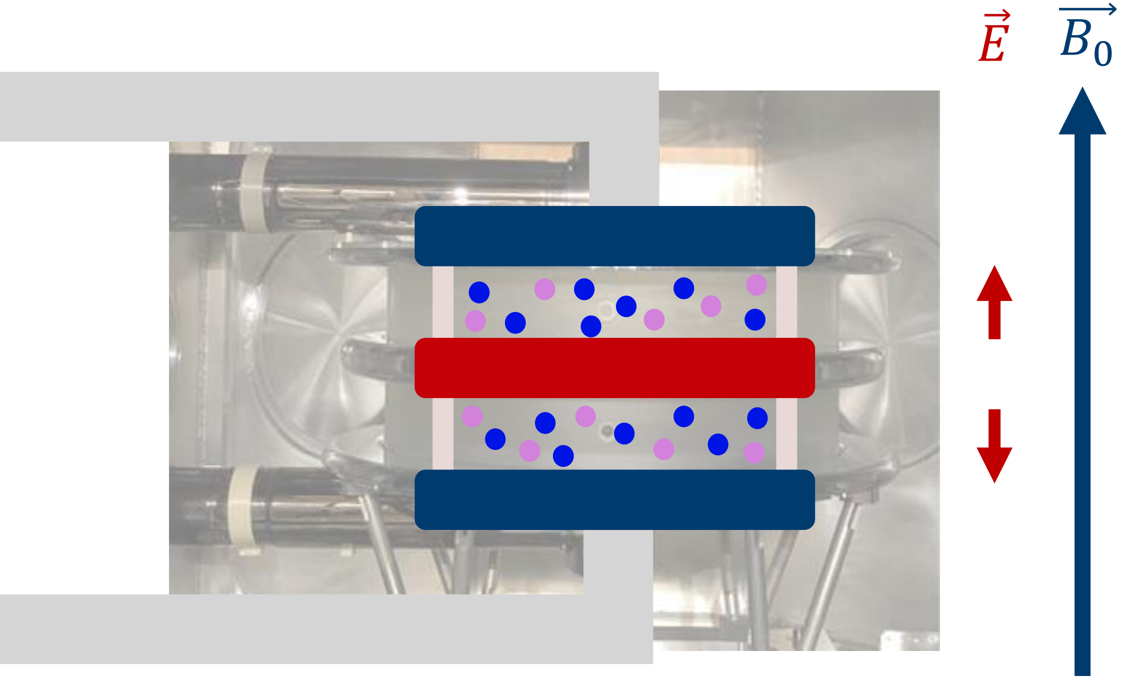
Simultaneous measurement of:

$$f_{n,\uparrow\downarrow} \text{ and } f_{n,\uparrow\uparrow}$$

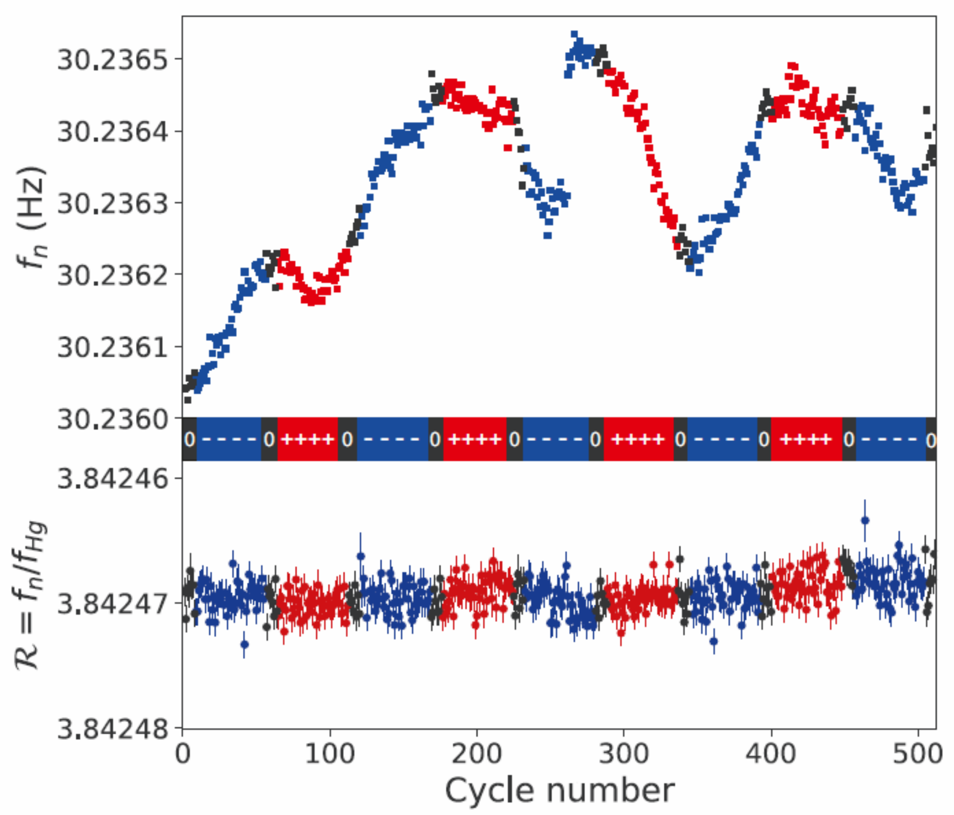
$^{199}$Hg magnetometer allows for cancellation of drifts in $\overrightarrow{B_0}$ via:

$$\mathcal{R} = \frac{f_n}{f_{\mathrm{Hg}}}$$

# The n2EDM double chamber




- UCN
- $^{199}$Hg atom



# The $d^{\text{false}}$ effect

- Special relativity gives a motional magnetic field for particles moving in an electric field :

$$\vec{B}_m = \vec{E} \times \frac{\vec{v}}{c^2}$$

- If $\vec{B}_0 \neq$ uniform → $d^{\text{false}}$ for neutrons and $^{199}$Hg comagnetometer
- $d^{\text{false}}$ for neutrons and Hg are not the same due to different velocities and precession frequencies!

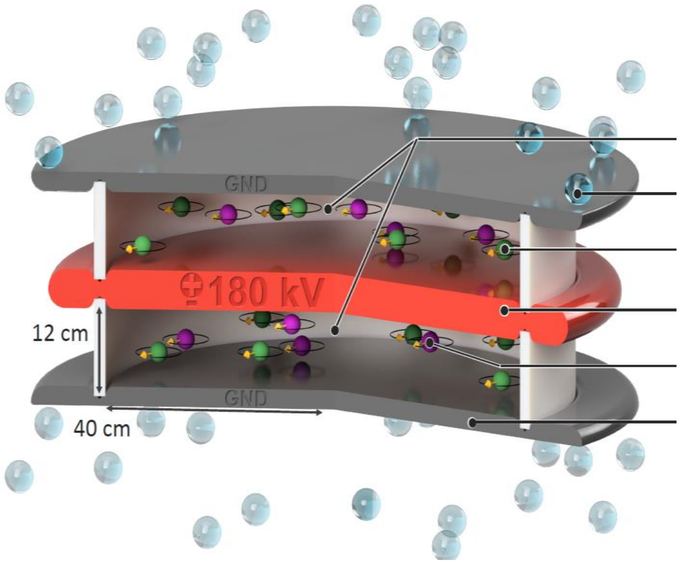
| | Neutrons | $^{199}$Hg |
|---|---|---|
| RMS velocity | few m/s | ≈ 150 m/s |
| Larmor frequency | ≈ 27 Hz | $\gamma_{\text{Hg}} \lvert \vec{B} \rvert \approx 7$ Hz |

# The $d^{\text{false}}$ effect

- The $d_{\text{Hg}}^{\text{false}}$ leads to a shift in the ratio $\mathcal{R} = \frac{f_n}{f_{\text{Hg}}}$

- $d_{\text{Hg}\rightarrow n}^{\text{false}}$ can be of order $10^{-27} e$cm !

- Control magnetic field gradients using an additional magnetometer array

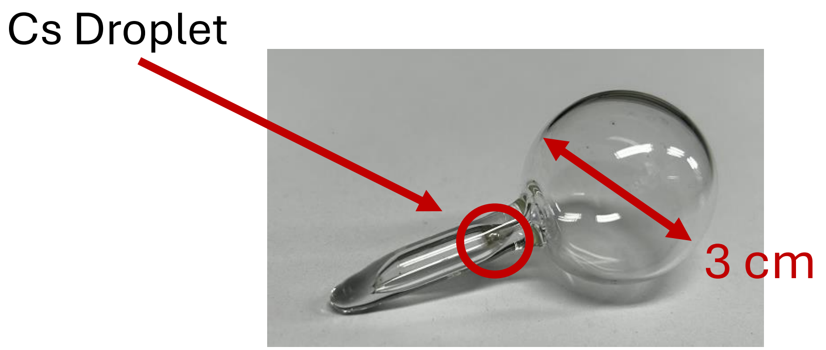


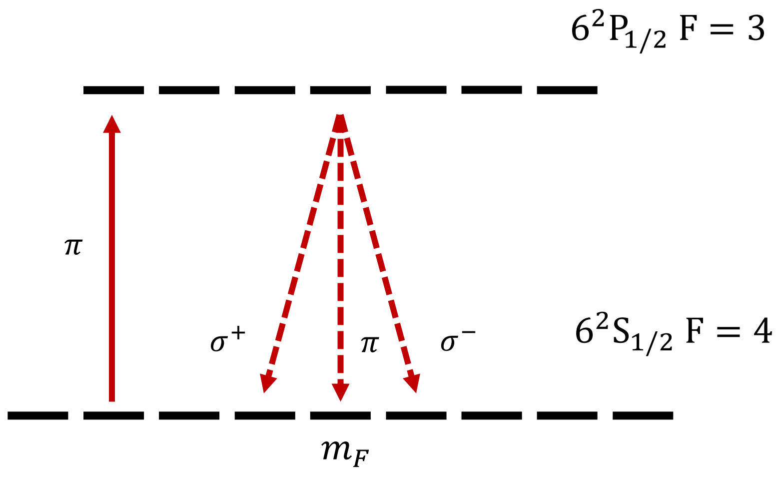

The nEDM collaboration, TDR, 2021,

Gradient control using Cesium magnetometer array!

# Optically pumped magnetometers

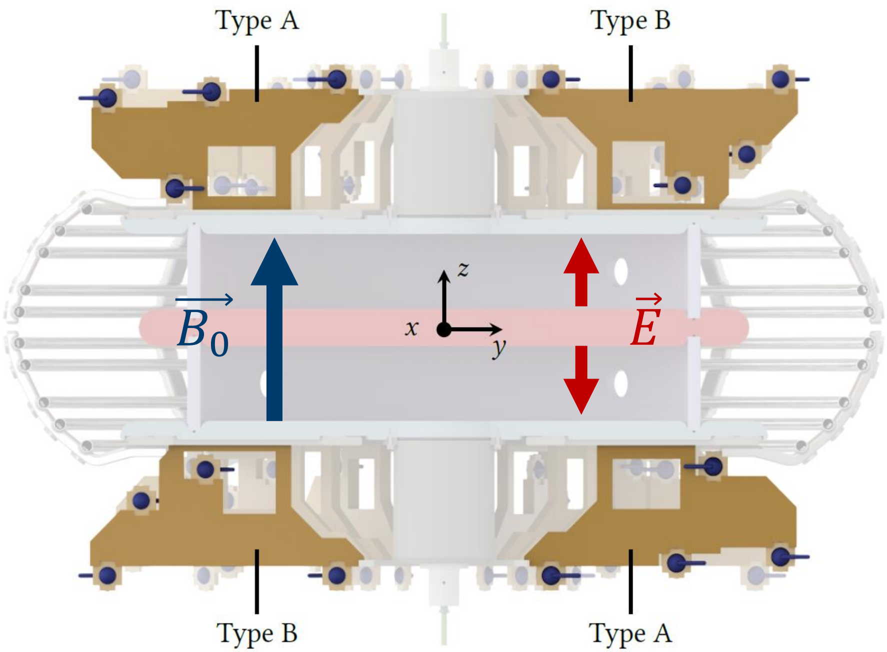
- Wavelength = 894 nm ($D_1$ - line)
- Linear polarization $\pi$
- spin populations in high $|m_F|$ = spin alignment
- Observed precession frequency: $2\omega_L = 7$ kHz



# Cs Magnetometer array @ n2EDM

- Total of 112 Cs cells on 28 plates
  - ➢ higher order gradients
- Placement accuracy: ±0.5 mm
- Relative field accuracy: 5 pT

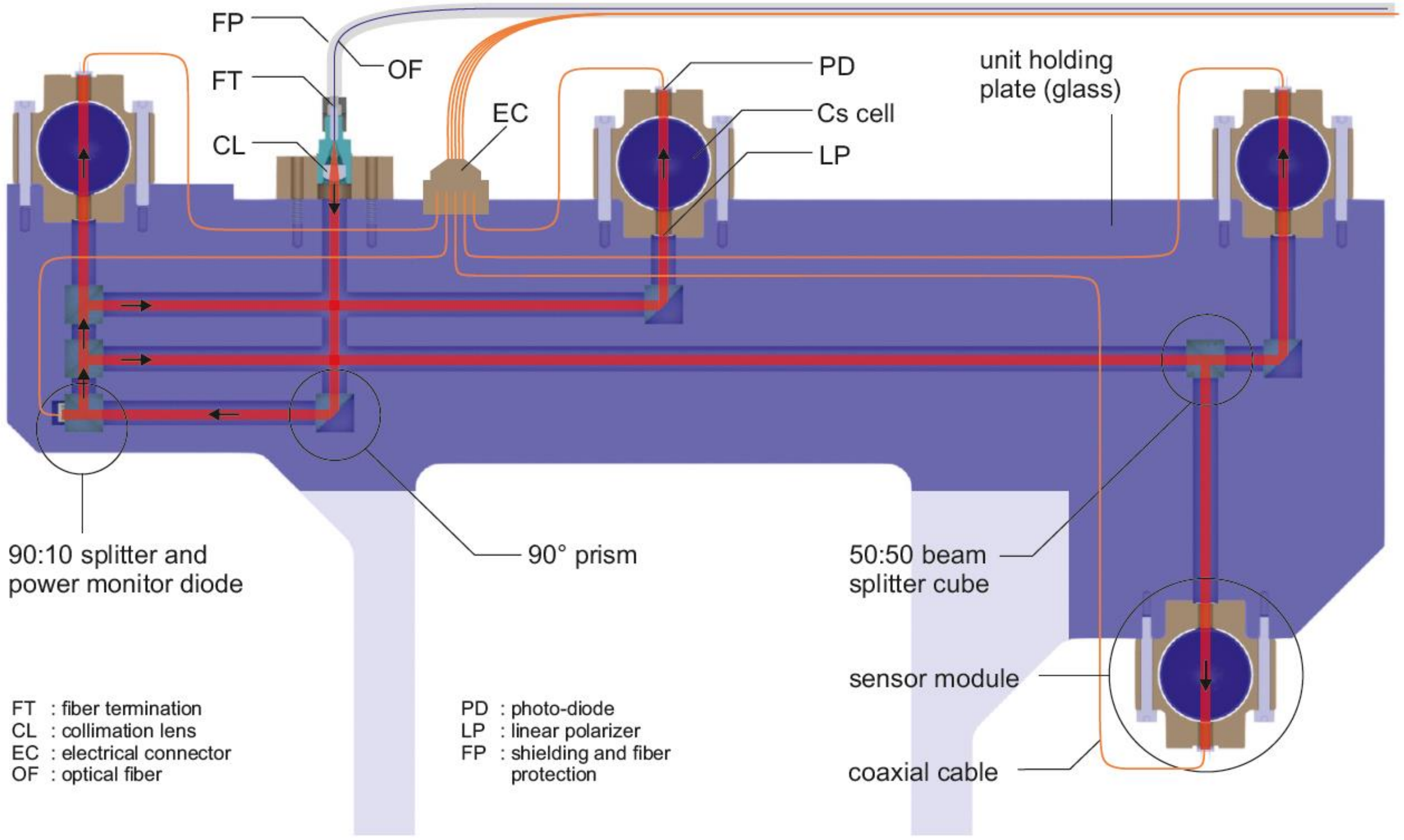



Pais, D., DISS. ETH NO. 27742, 2021.

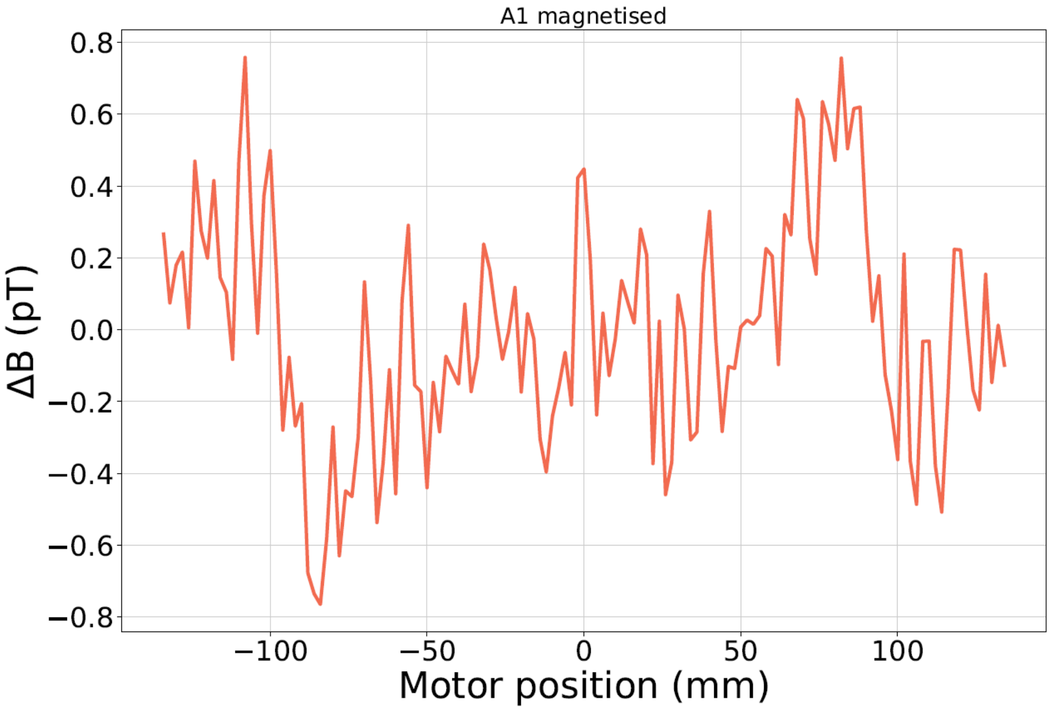
# Single Cs magnetometer plate

Requirements:

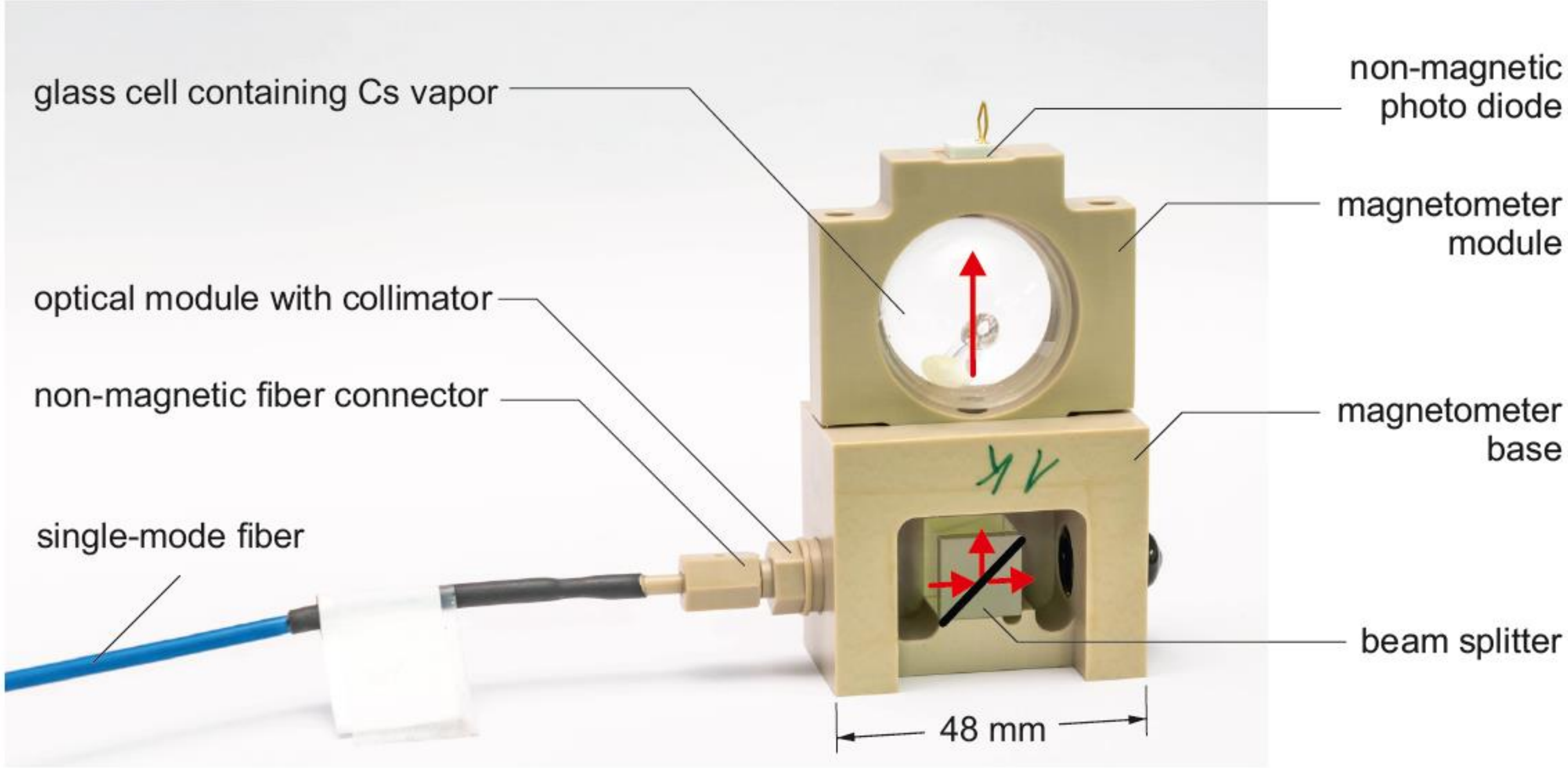
- Non-magnetic
  - ➢ <0.116 $nAm^2$
  - ➢ 5 pT @ 2 cm
- Vacuum compatible



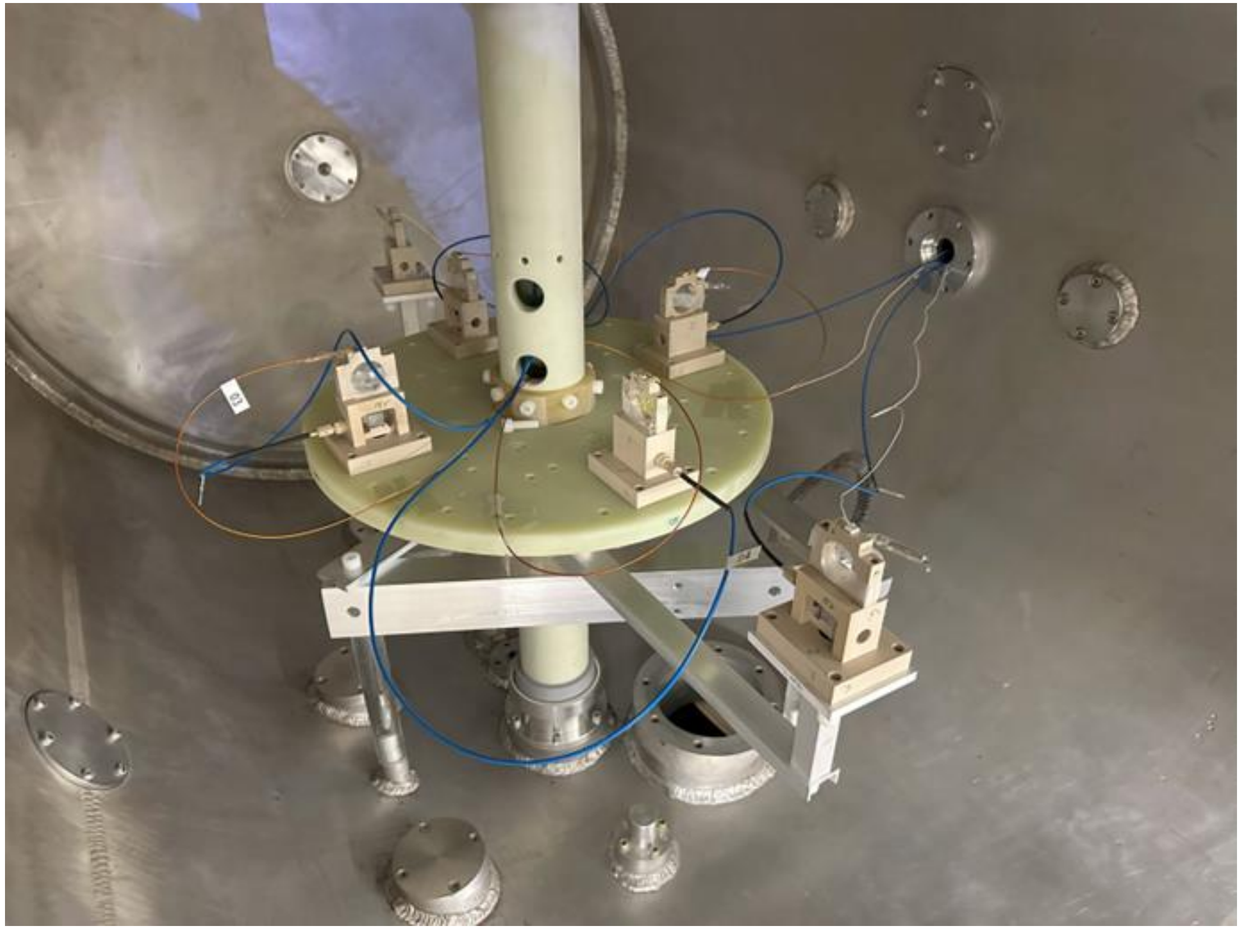
# The solution: MACOR




# Cs magnetometer prototype



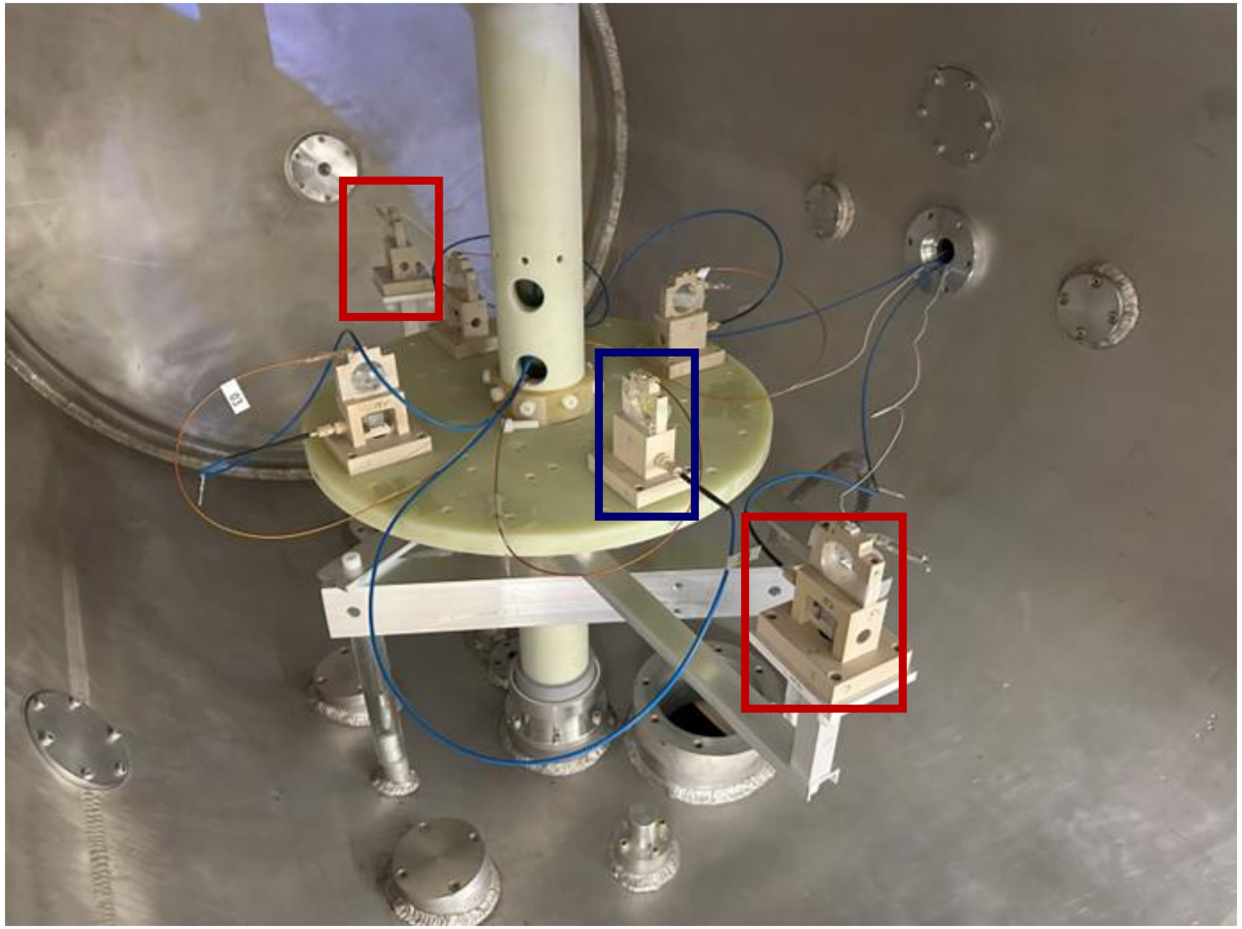
# Testing magnetometric accuracy - setup



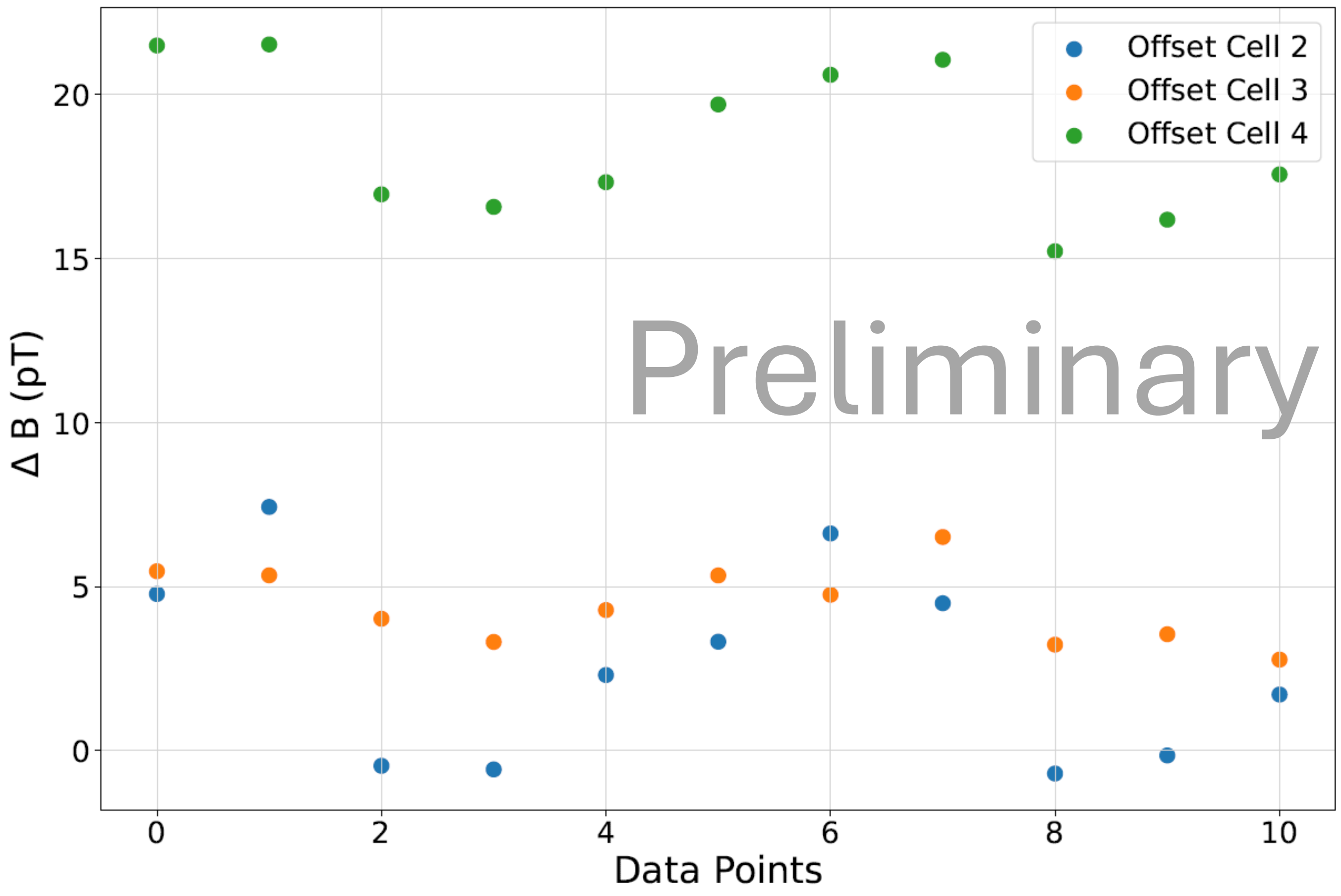
# Testing magnetometric accuracy – measurement scheme

- Use fixed magnetometers to cancel common drift

- Calculate offset to reference cell on rotation table

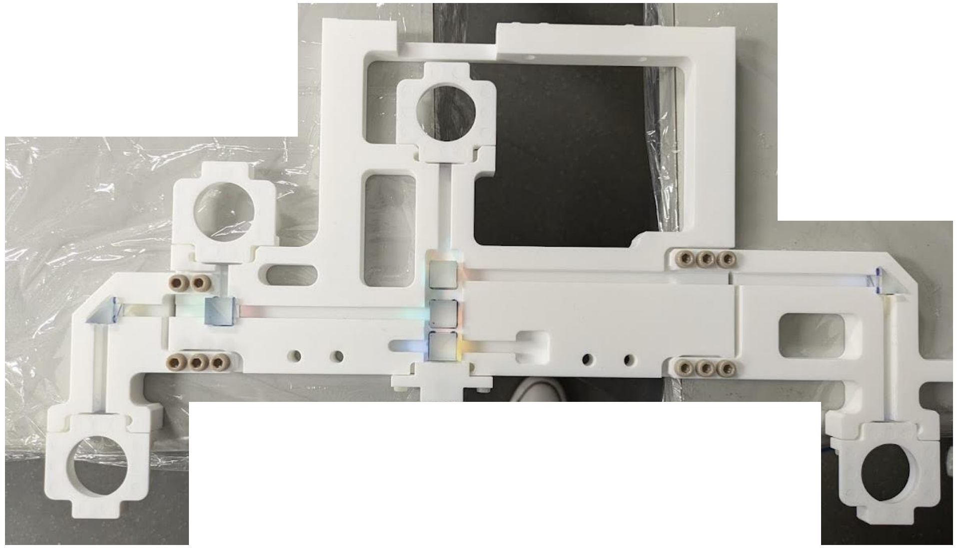


# Determining the magnetometric accuracy



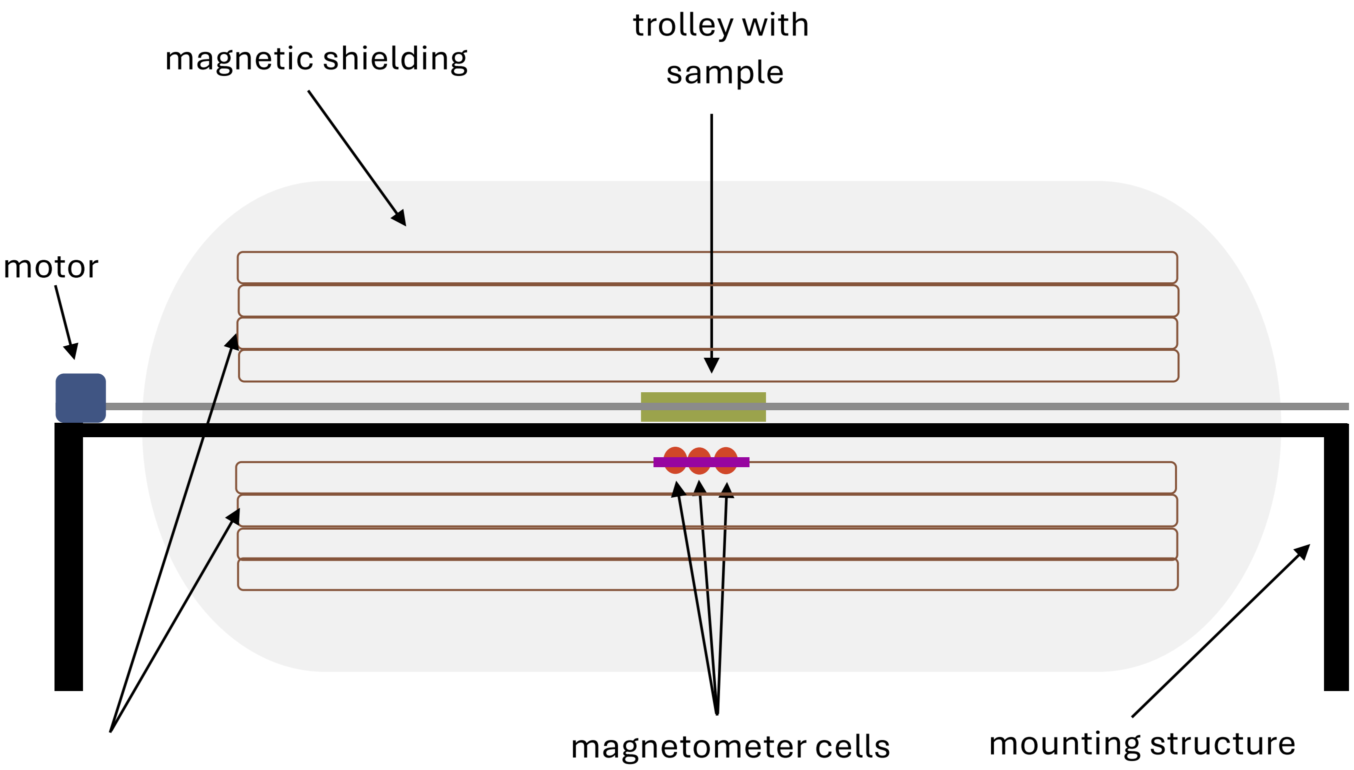
# Conclusion

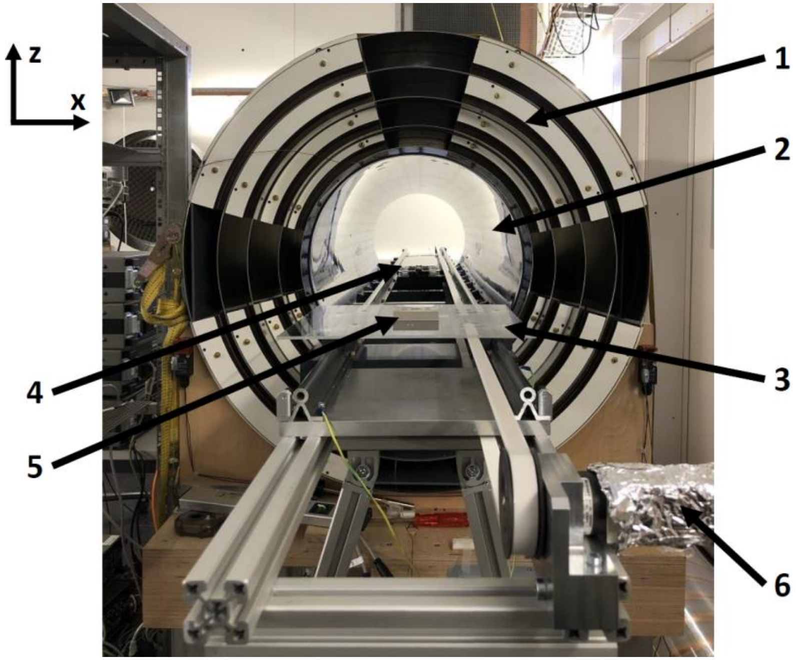
- Required relative accuracy shown for first cells
- Assembly of first prototype array ongoing
- Commissioning runs of prototype in late 2024
- Commissioning of full array in 2025



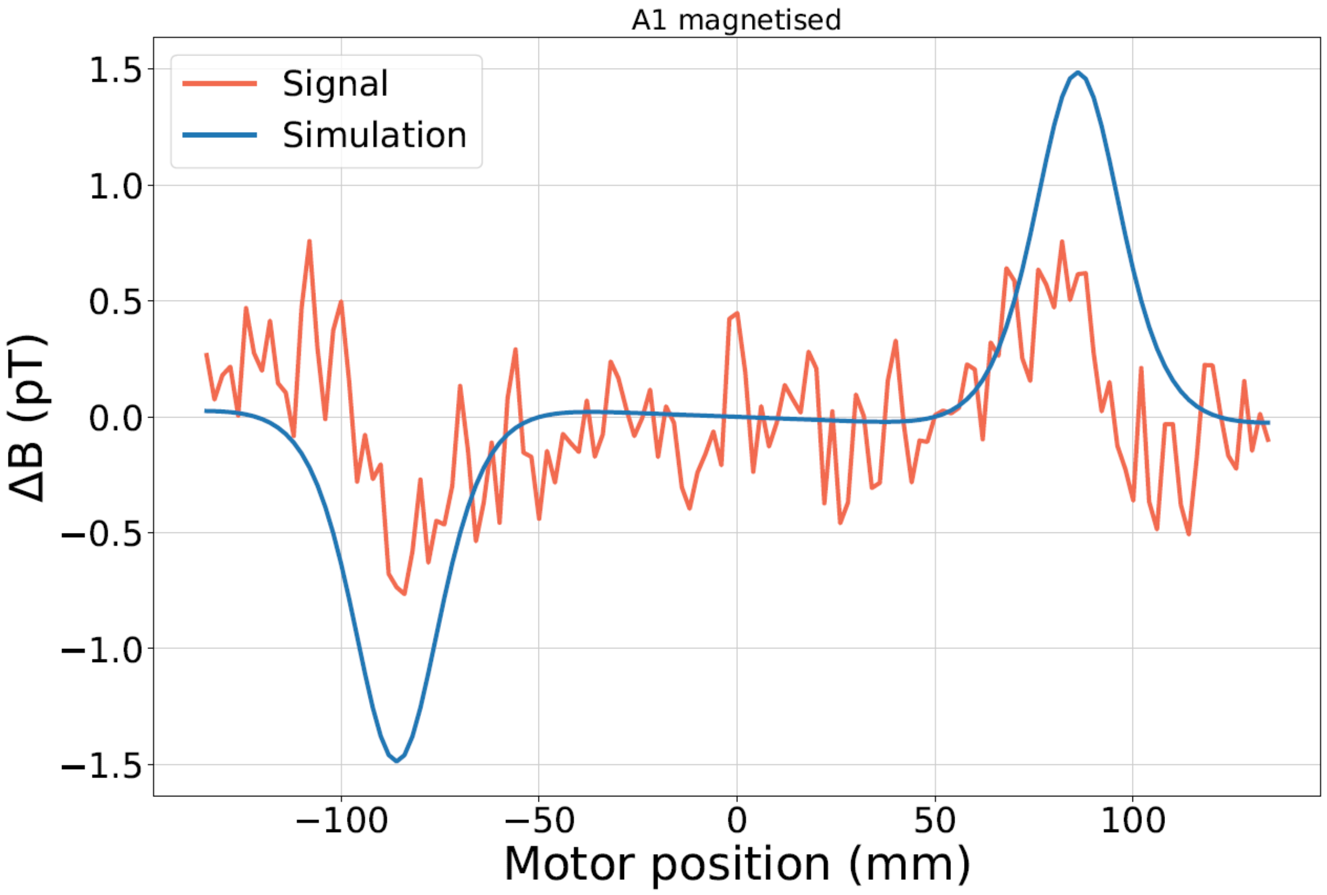
# Back up slides

# Detecting magnetic contamination

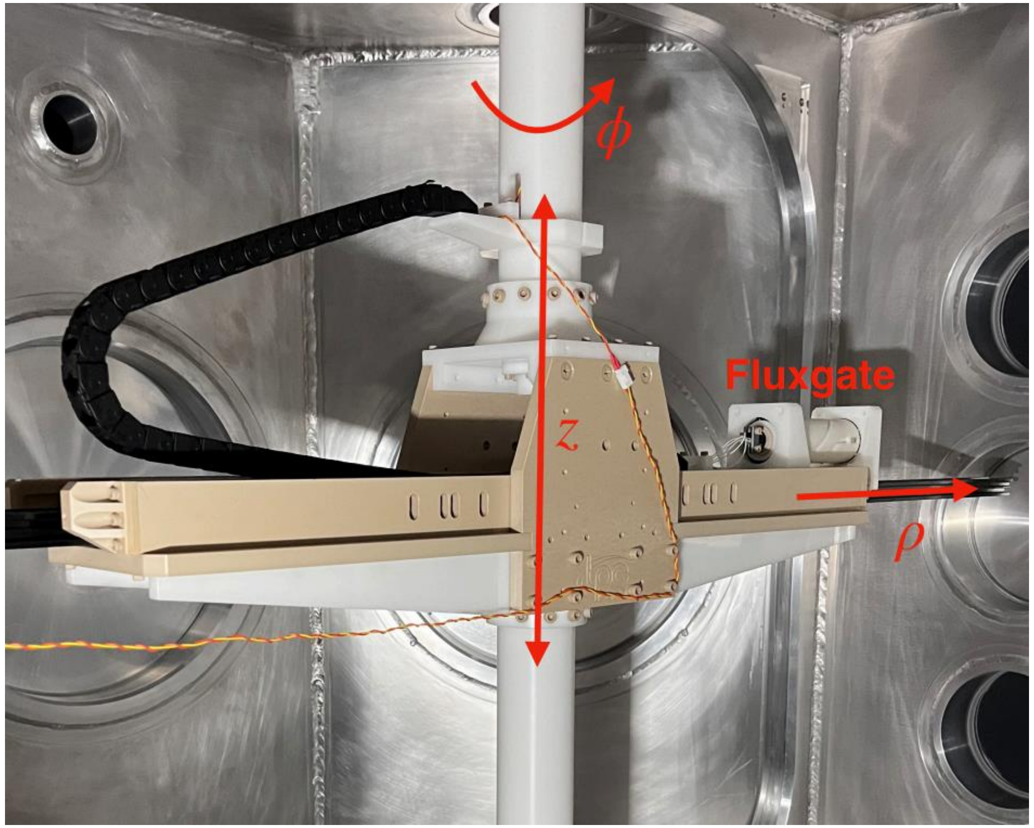


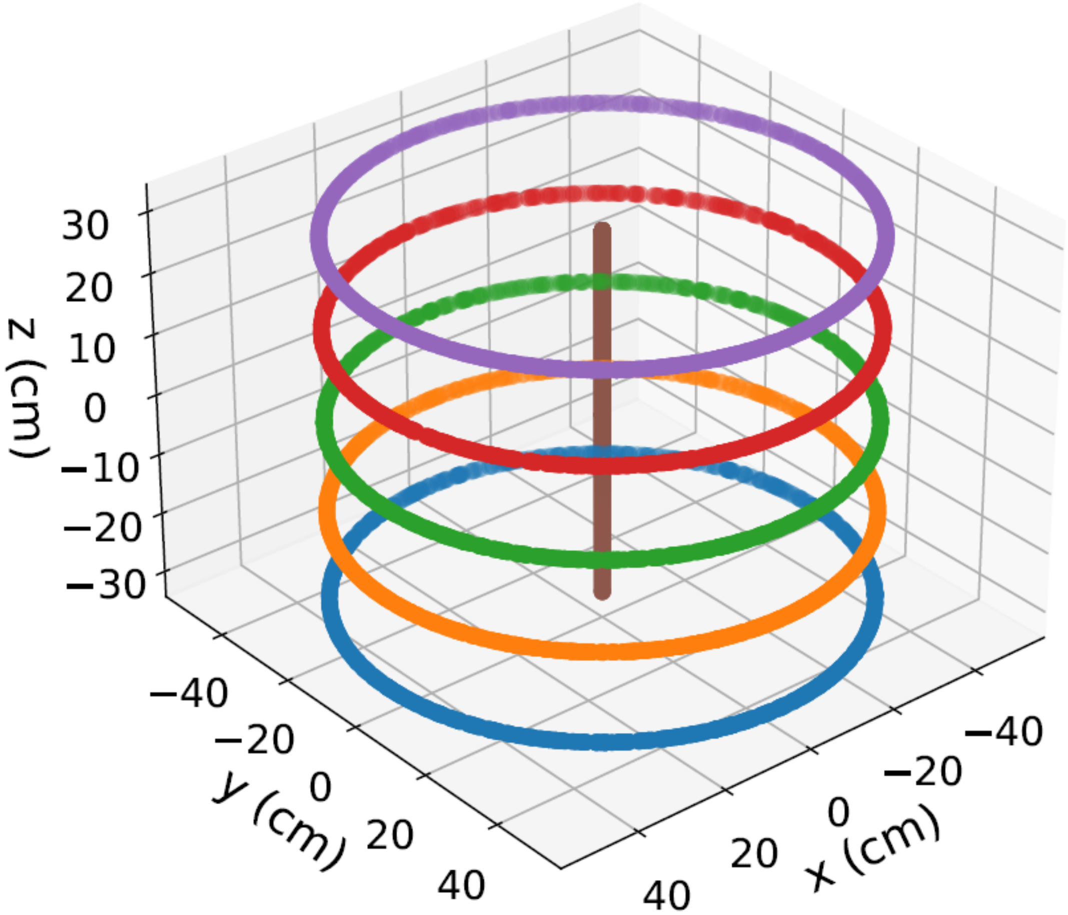



# Expected dipole signal



# Mapping the magnetic field



# Mapping the magnetic field