



An active magnetic shield for the n2EDM experiment

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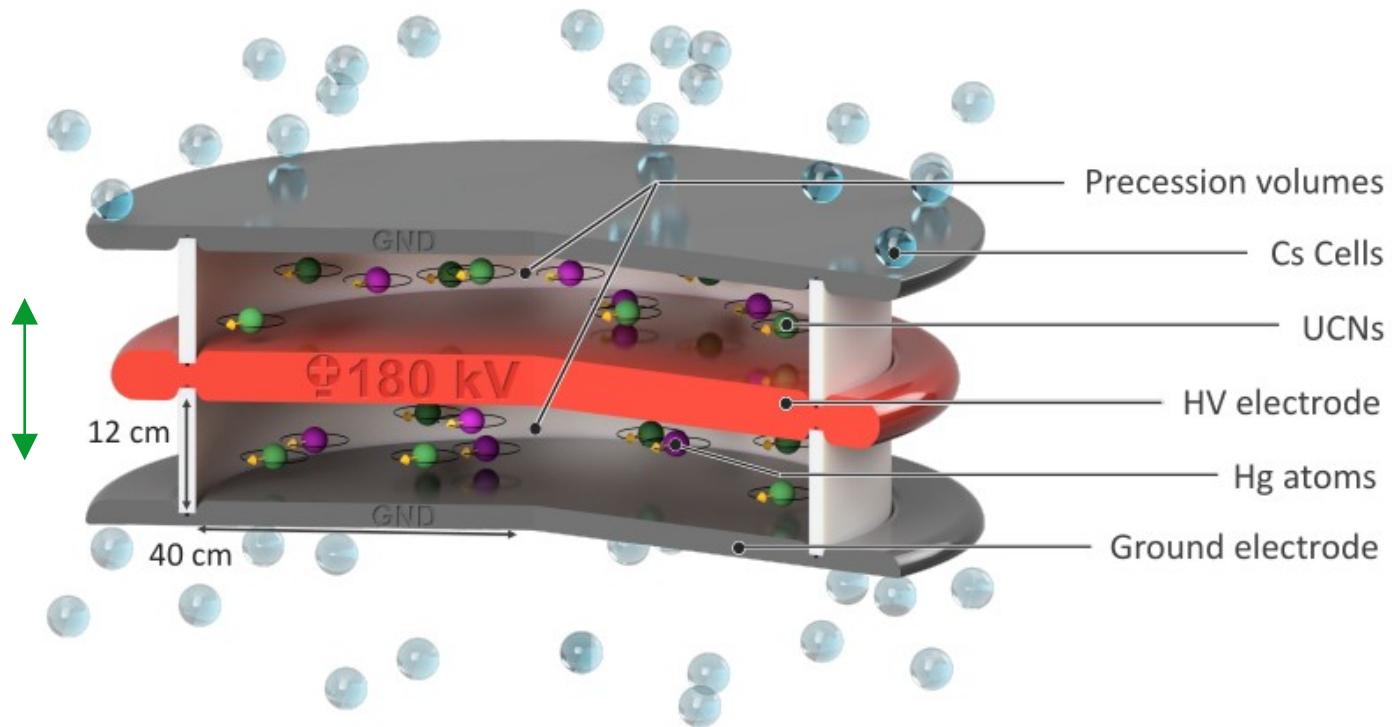
Requirements

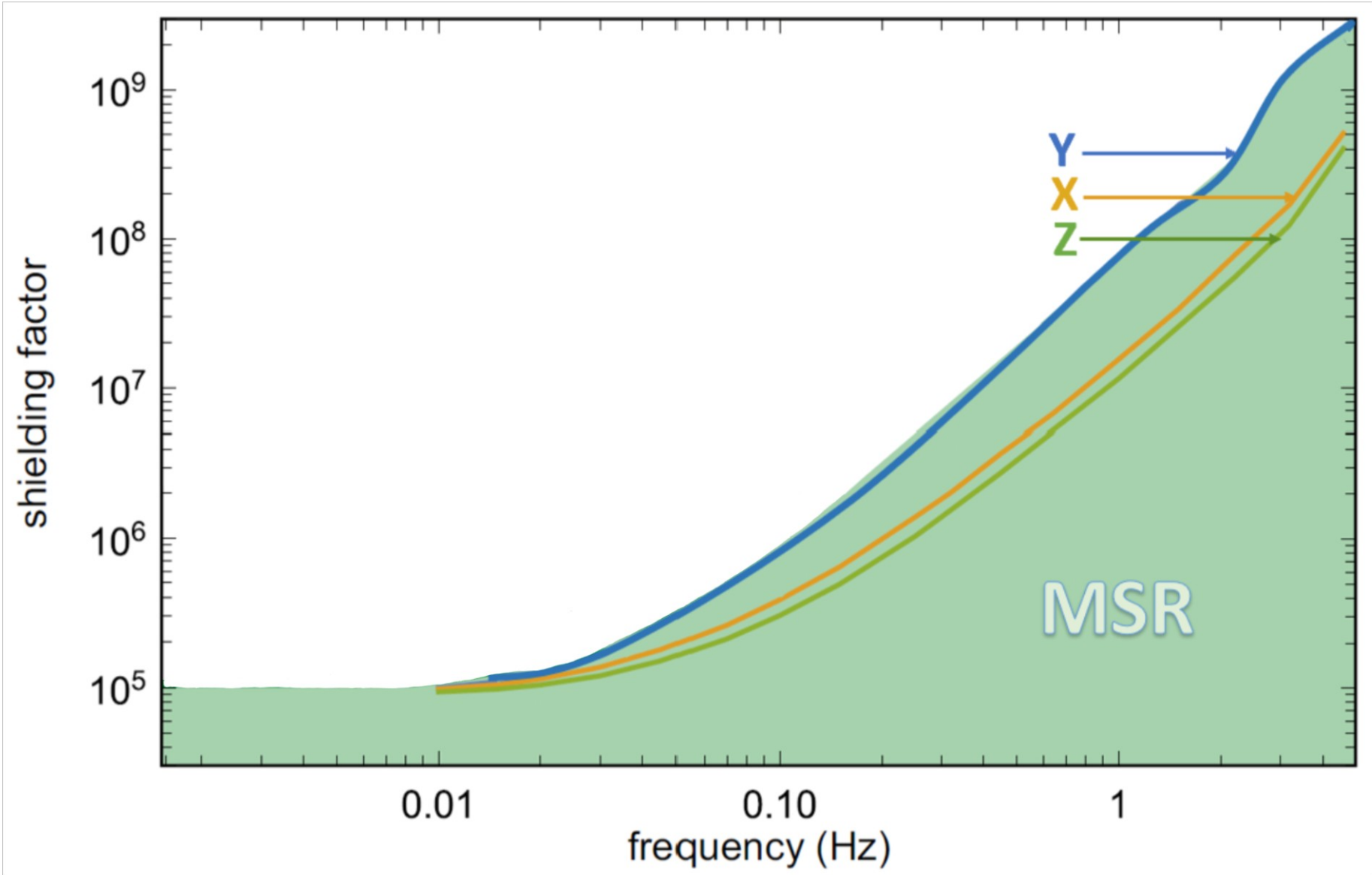
- Internal B-field difference: $< 10 \text{ pT}$
→ **MSR**

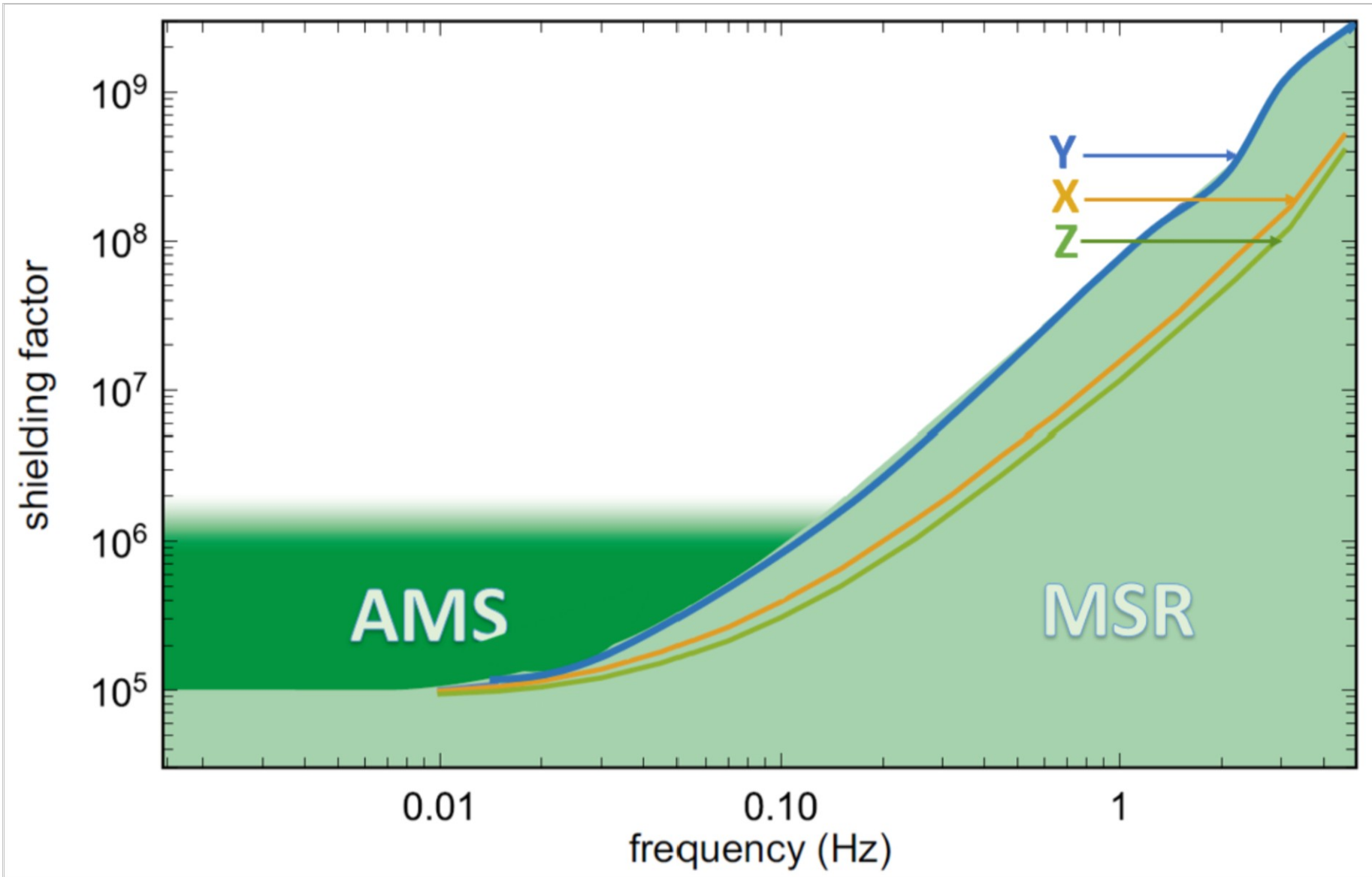
- External Field $\sim 10 \mu\text{T}$

Outside disturbance: $\sim 100 \mu\text{T}$

⇒ shielding factor 10^6

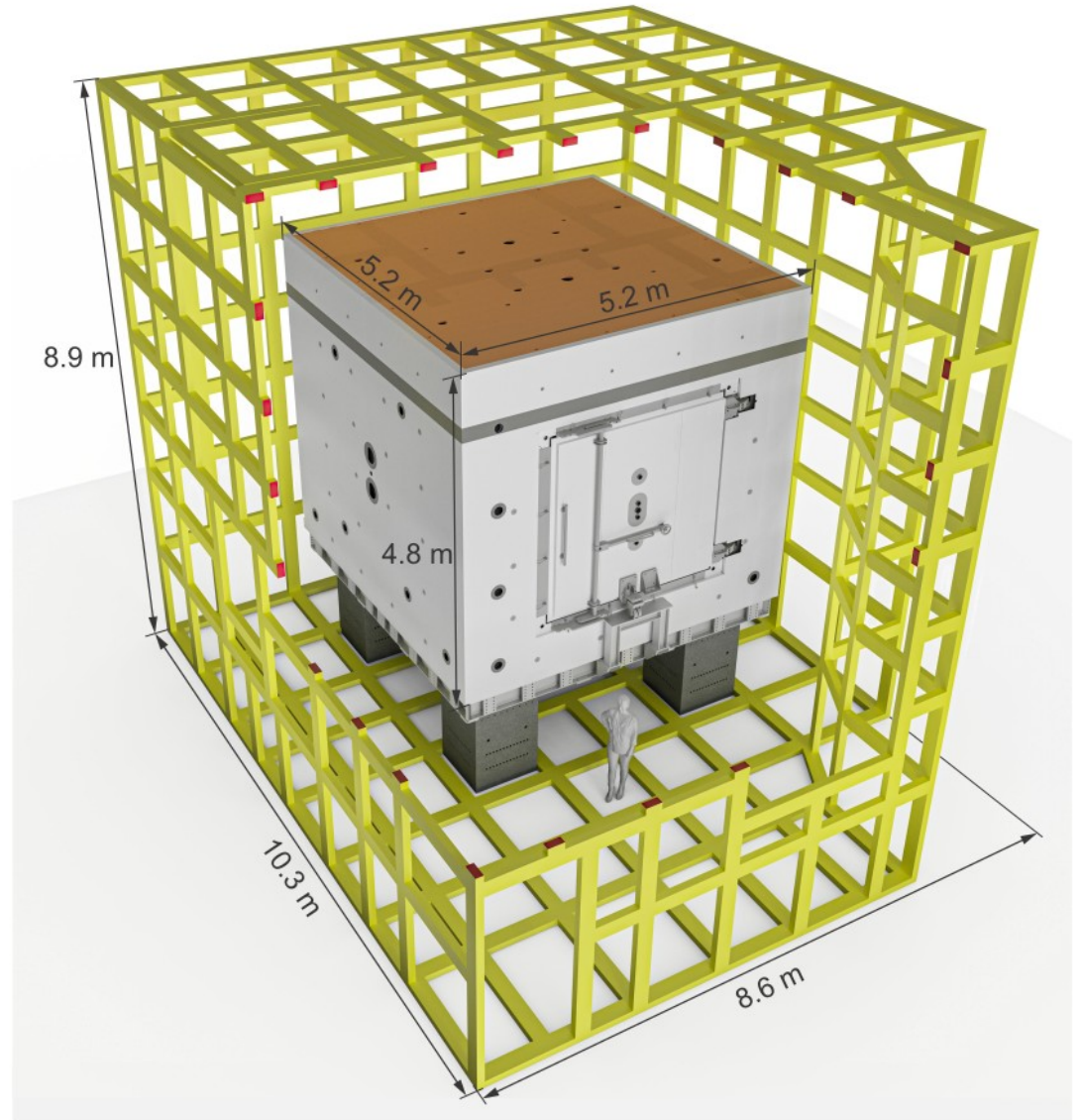






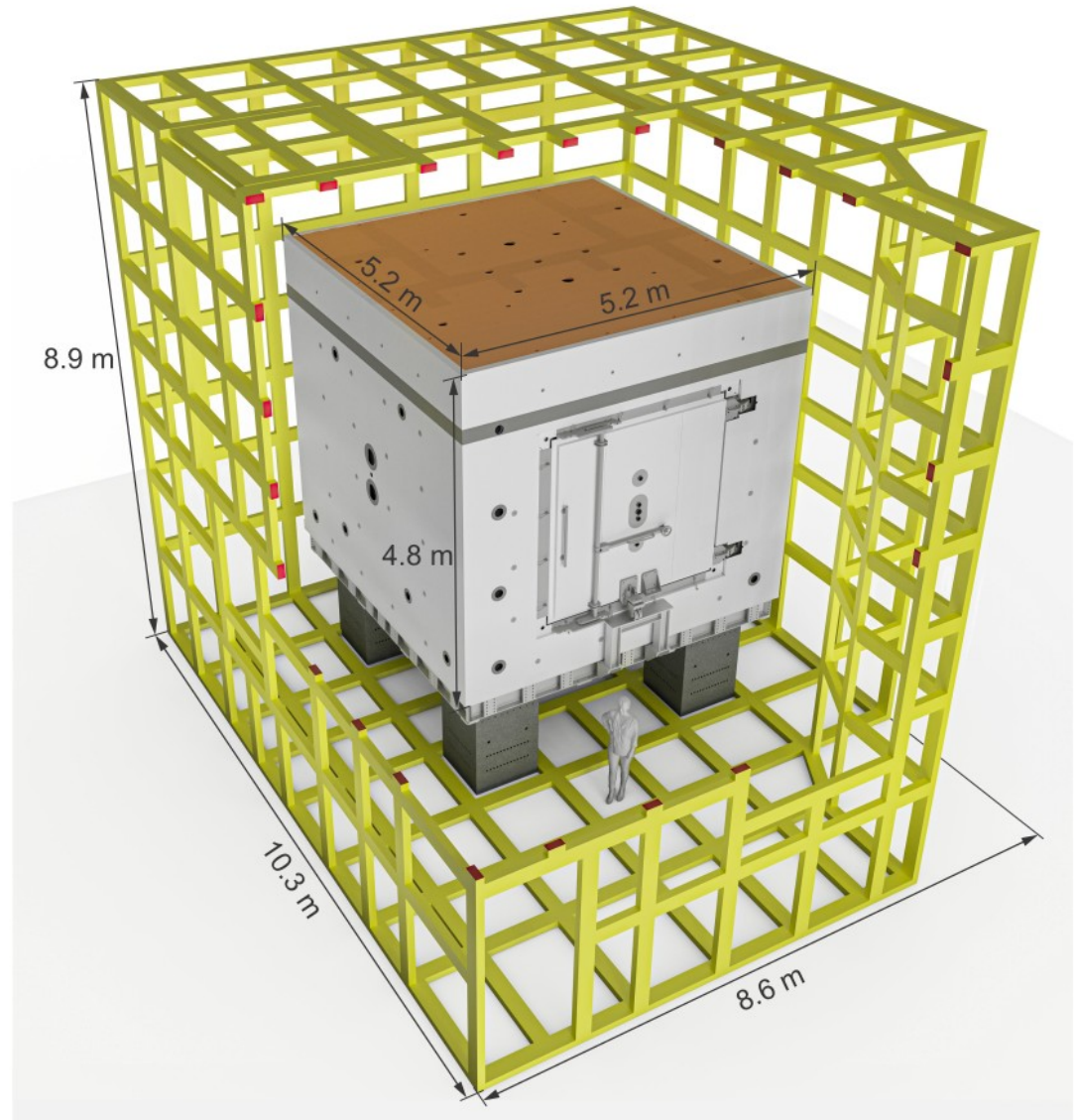
Active Magnetic shielding

- Based on **sensors** around the experiment
- Coils generate a **magnetic** field
- To **compensate** external sources

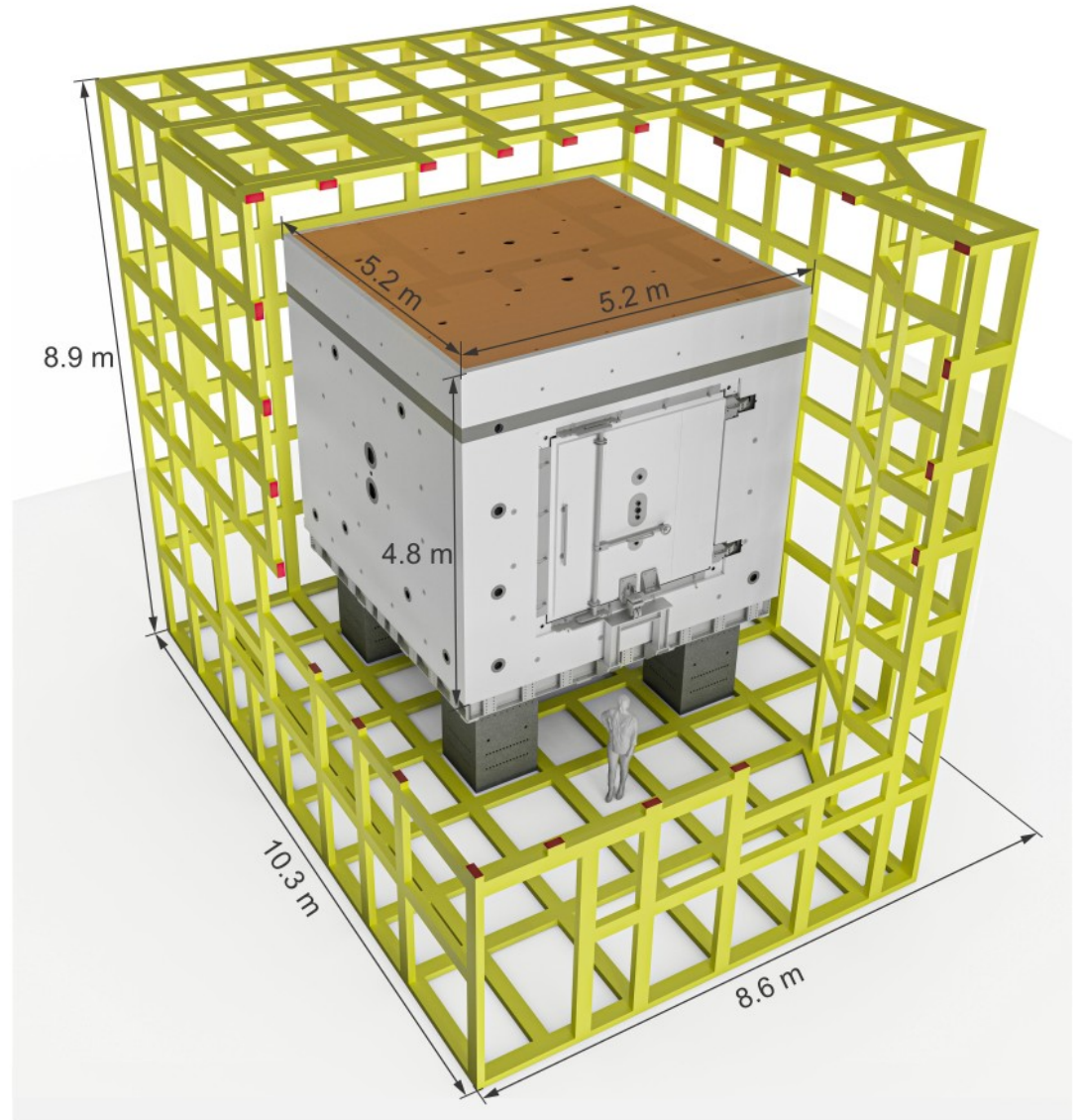


Active Magnetic shielding

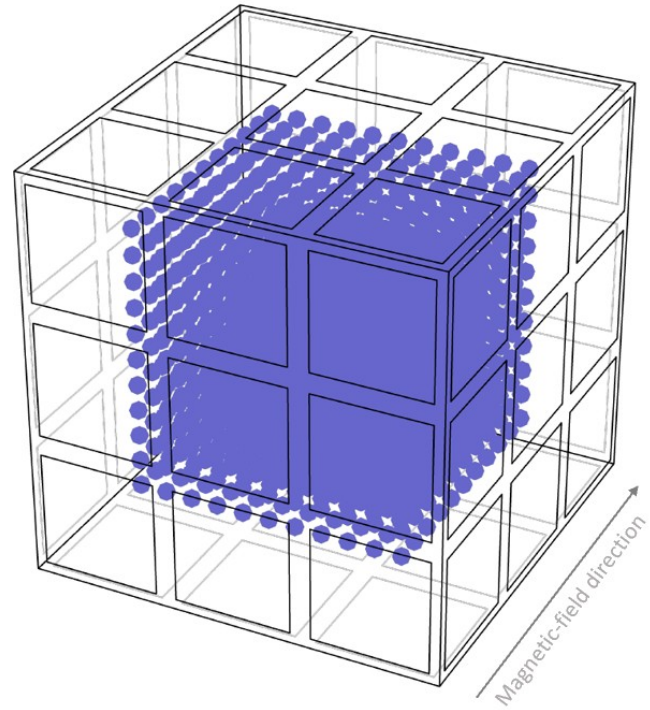
Solenoids!



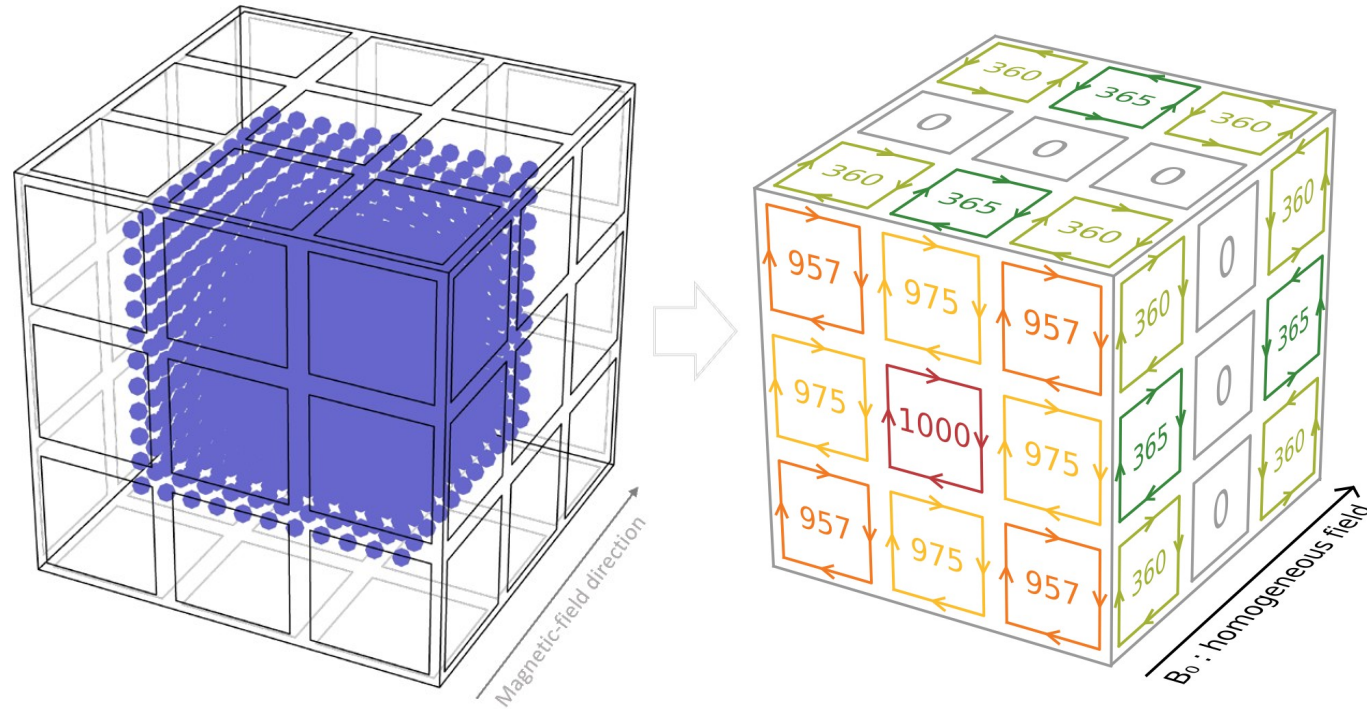
Active Magnetic shielding



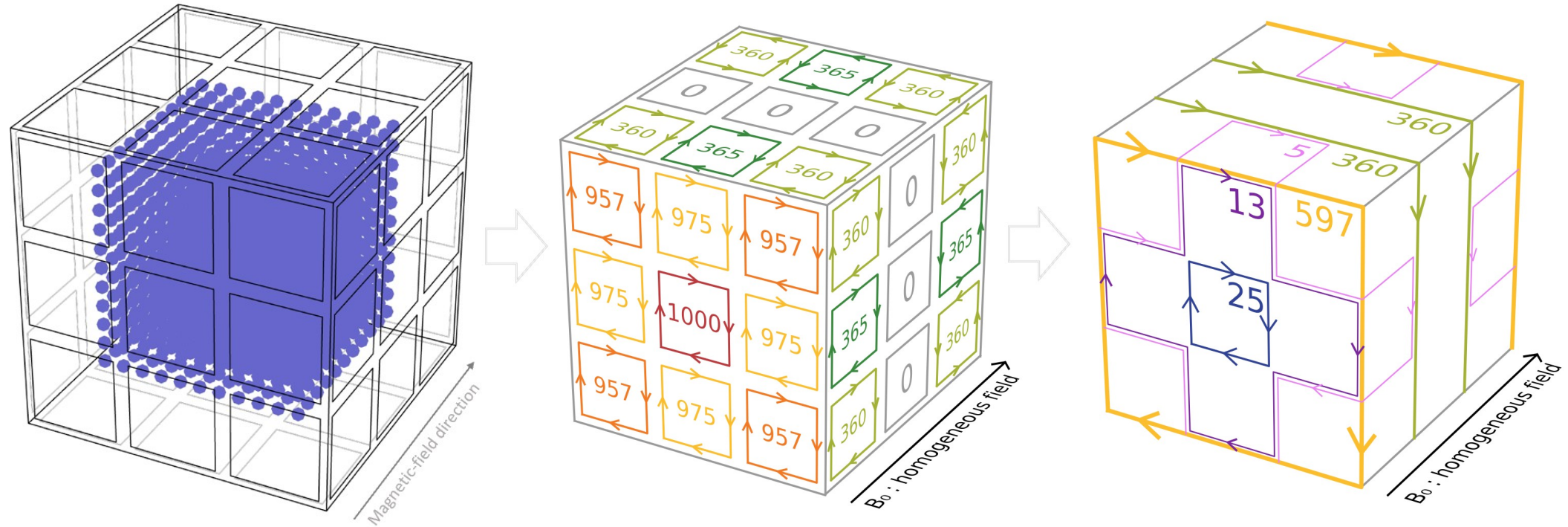
Method of simple coil design



Method of simple coil design

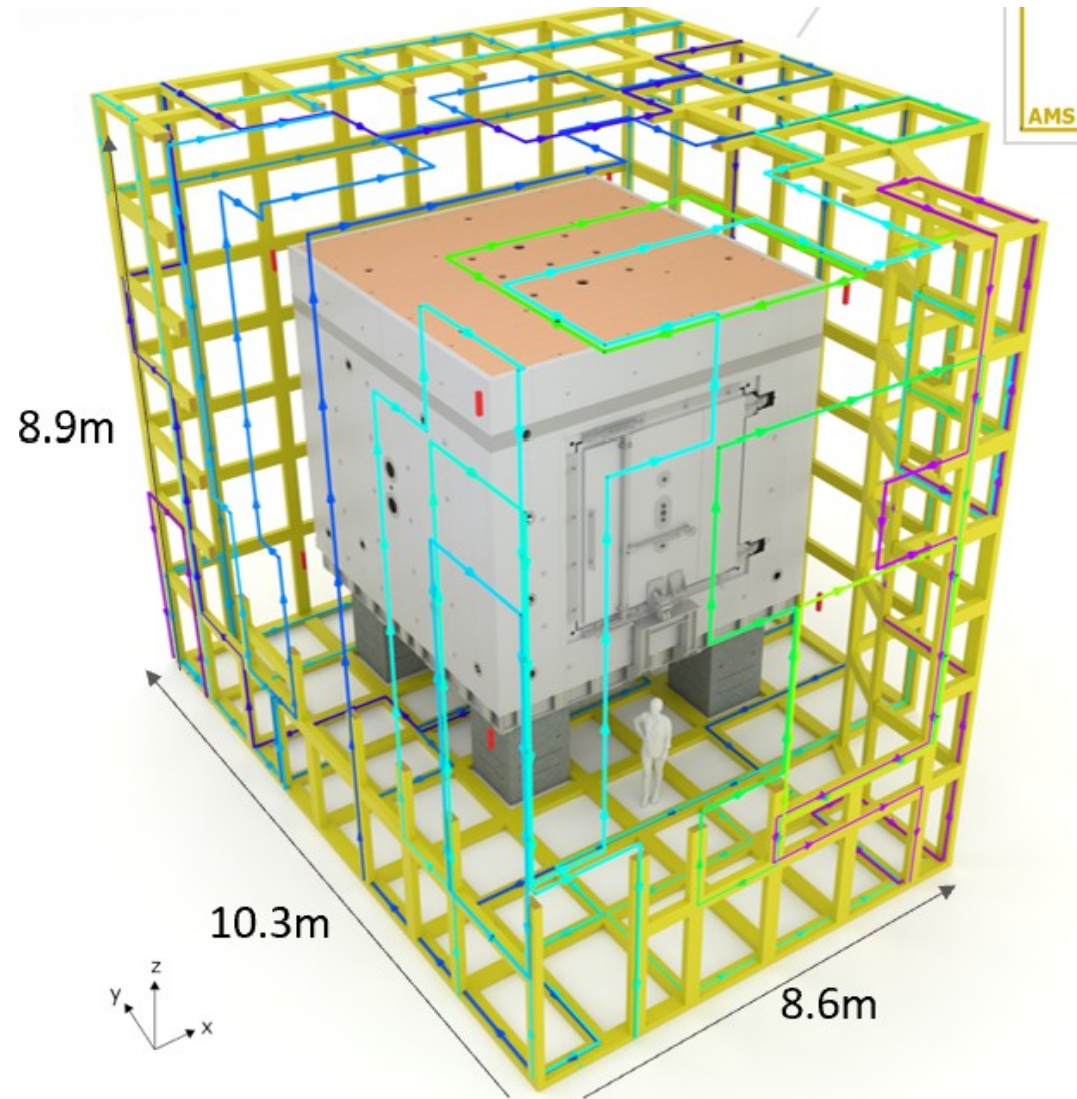


Method of simple coil design



Add simple loops in series to obtain a coil

- 3 homogeneous coils
- 5 gradient coils
- $\pm 50\mu T$ field strength
- > 55 km cable!





Active feedback control

$$B = B_0 + MI$$

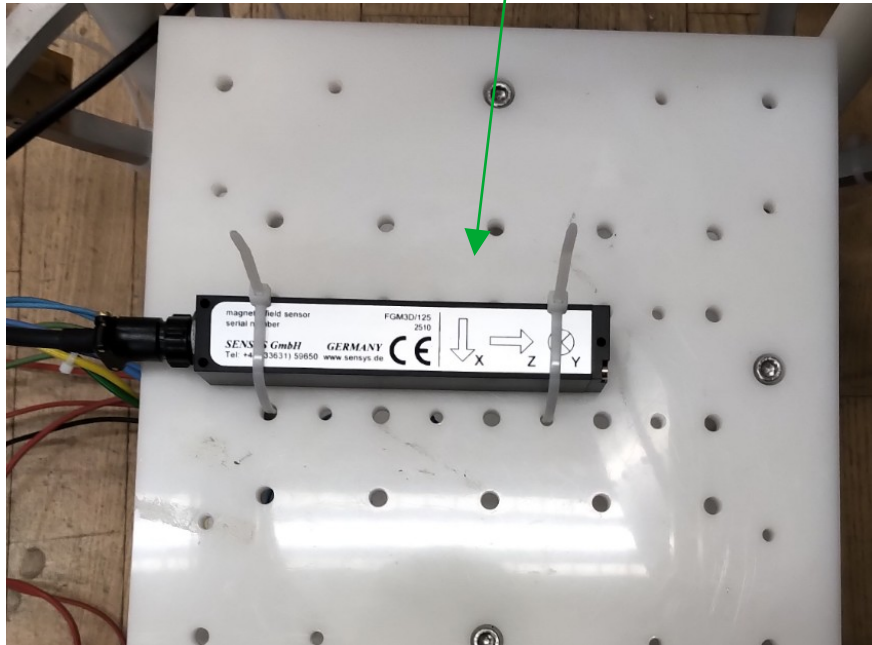
The diagram illustrates the equation $B = B_0 + MI$. Three blue arrows point from text labels to the variables in the equation: one from 'measured field' to B , one from 'background field' to B_0 , and one from 'coil currents' to I .

Active feedback control

$$B = B_0 + MI$$

measured field \rightarrow B \leftarrow coil currents

B_0 \leftarrow background field

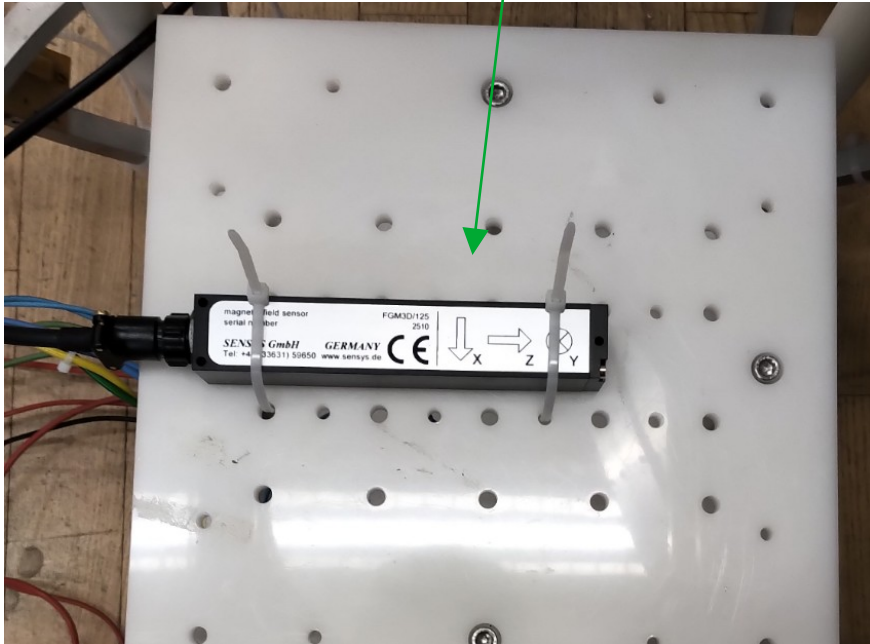


Active feedback control

$$B = B_0 + MI$$

measured field \rightarrow B \leftarrow coil currents

B_0 \leftarrow background field



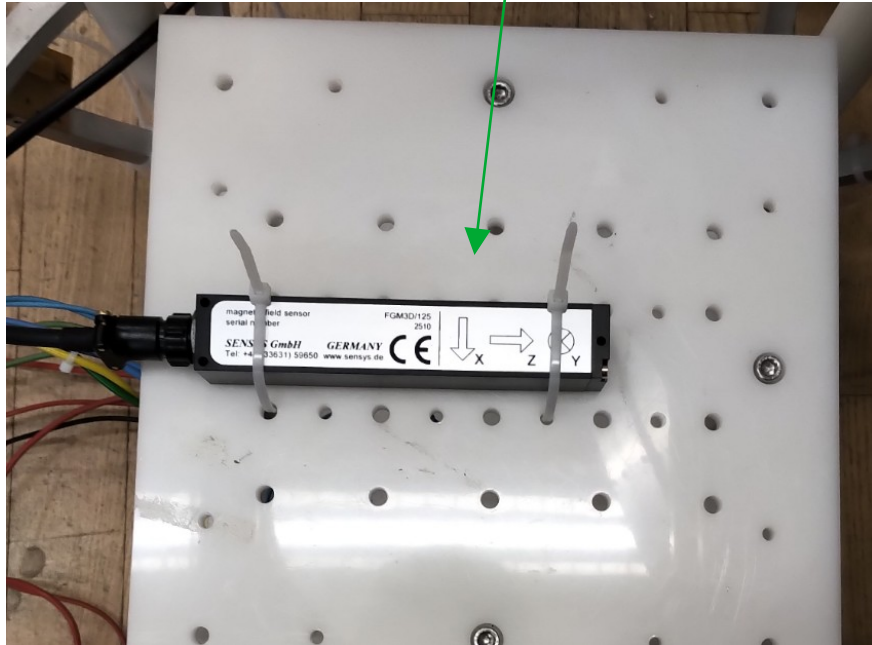
8 Fluxgates \rightarrow 3 magnetic sensors per fluxgate

Goal: maximise information!

Active feedback control

$$B = B_0 + MI$$

measured field \rightarrow B \leftarrow coil currents
 \uparrow background field



8 Fluxgates \rightarrow 3 magnetic sensors per fluxgate

Goal: maximise information!

Sensor positioning

$$B = B_0 + MI$$

$$\begin{array}{c} \text{24} \\ \text{sensors} \end{array} \downarrow \begin{pmatrix} B_{1x} \\ B_{1y} \\ B_{1z} \\ \vdots \\ B_{8z} \end{pmatrix} = \begin{pmatrix} B_{0,1x} \\ B_{0,1y} \\ B_{0,1z} \\ \vdots \\ B_{0,8z} \end{pmatrix} + \begin{pmatrix} M_{11x} & M_{21x} & \dots & M_{81x} \\ M_{11y} & M_{21y} & \dots & M_{81y} \\ M_{11z} & M_{21z} & \dots & M_{81z} \\ \vdots & \vdots & \ddots & \vdots \\ M_{18z} & M_{28z} & \dots & M_{88z} \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \\ \vdots \\ I_8 \end{pmatrix} \downarrow \begin{array}{c} \text{8 coils} \end{array}$$

Sensor positioning

$$B = B_0 + MI$$

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- Each sensor contributes one row of M
- All sensor contribute equal amount of information

Sensor positioning

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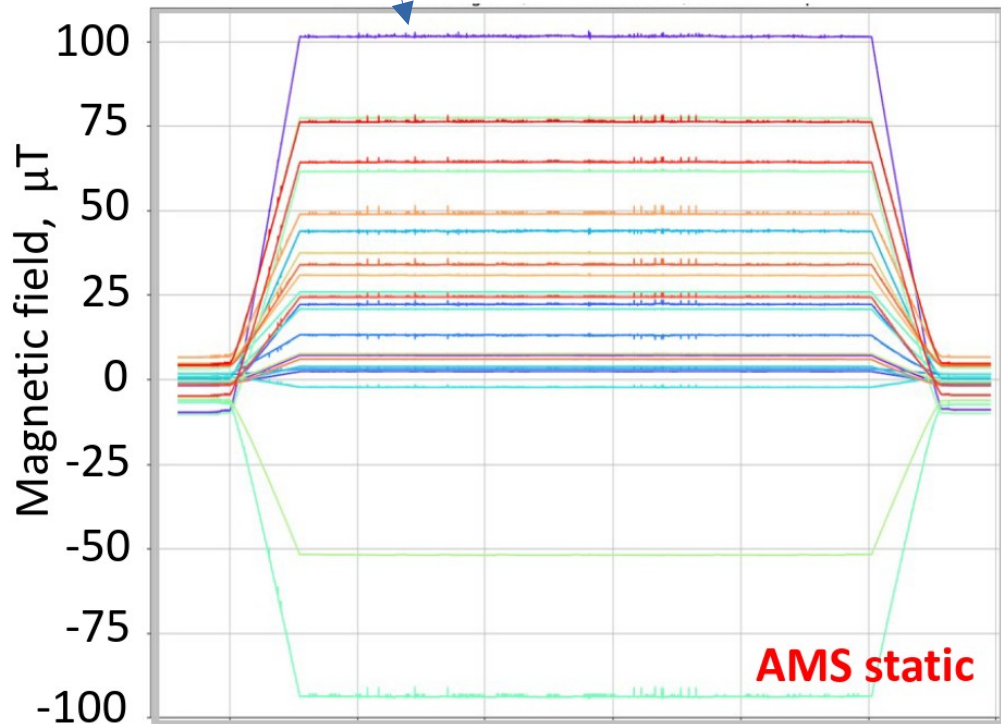
⇒ optimise for condition number of M → gradient descent method

Performance

SULTAN ramp

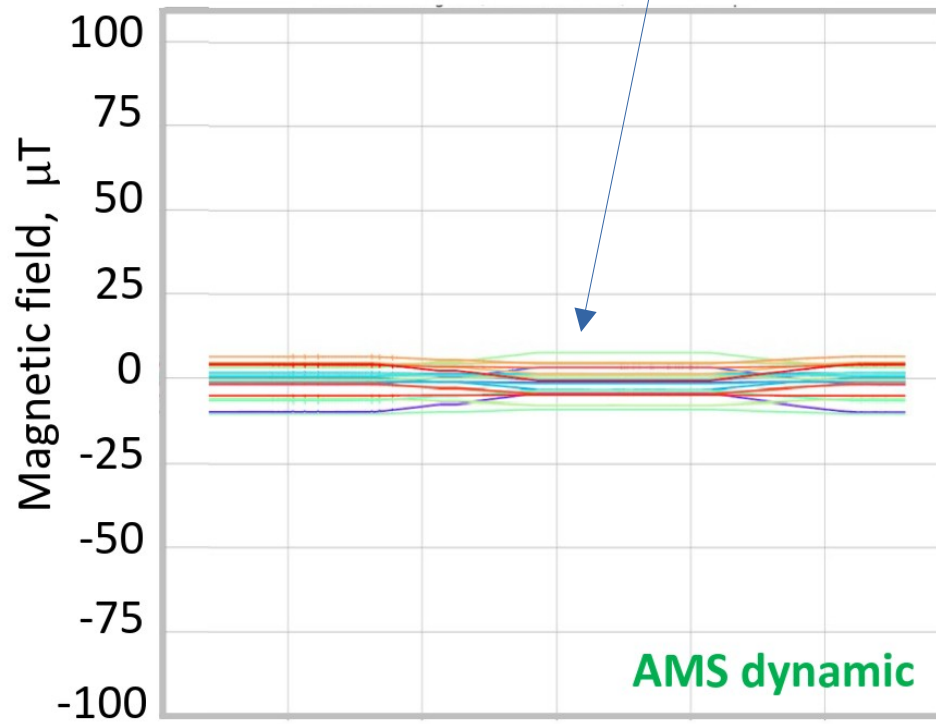


Fluxgate readings outside the MSR



SULTAN ramp

$\sim 10 \mu\text{T}$!



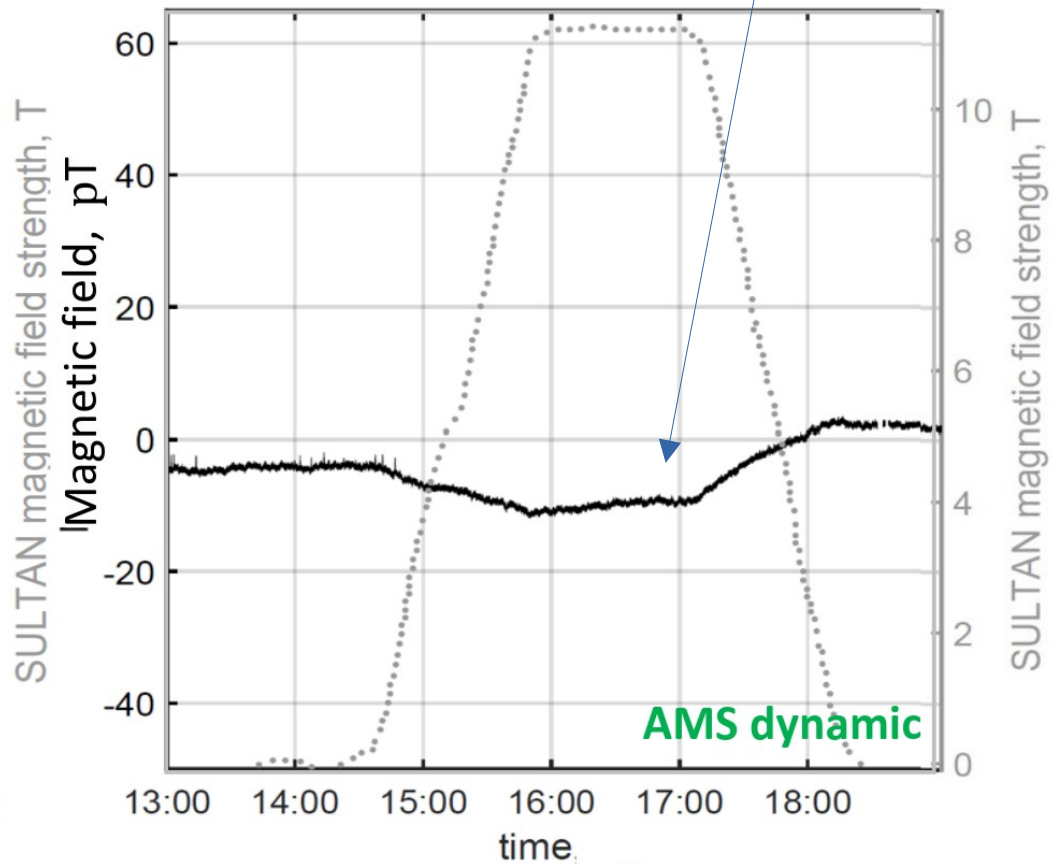
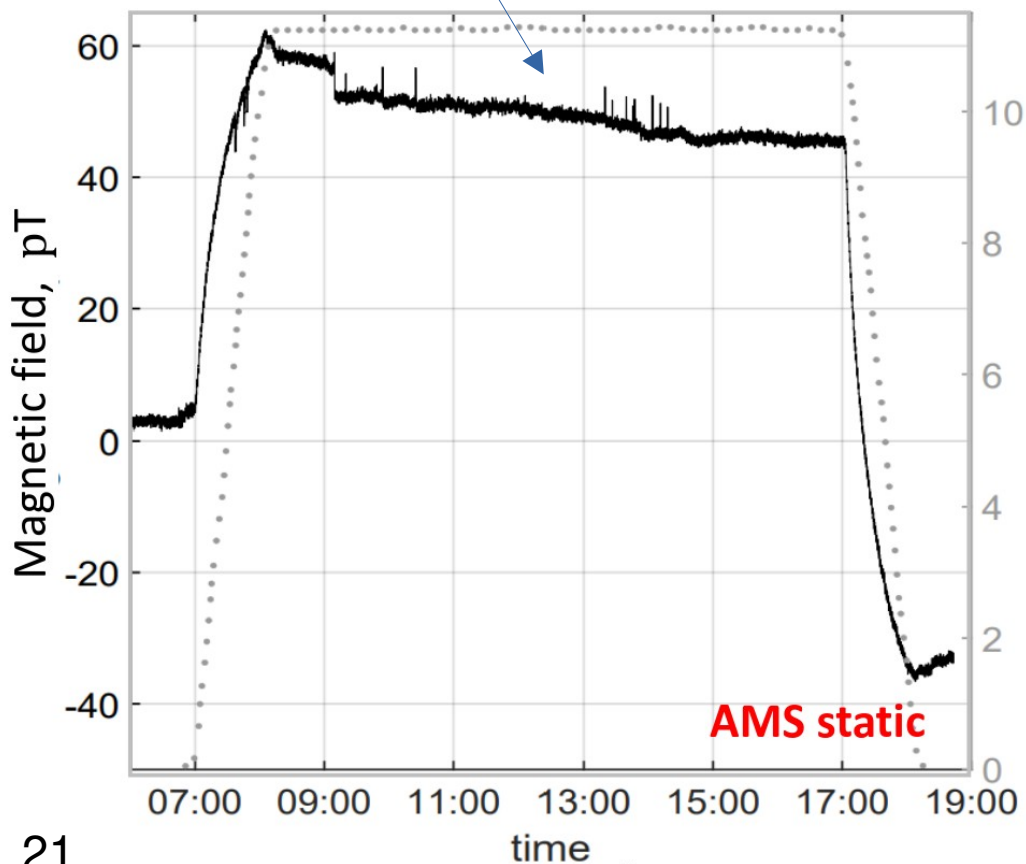
Performance

SULTAN ramp

< 10 pT!

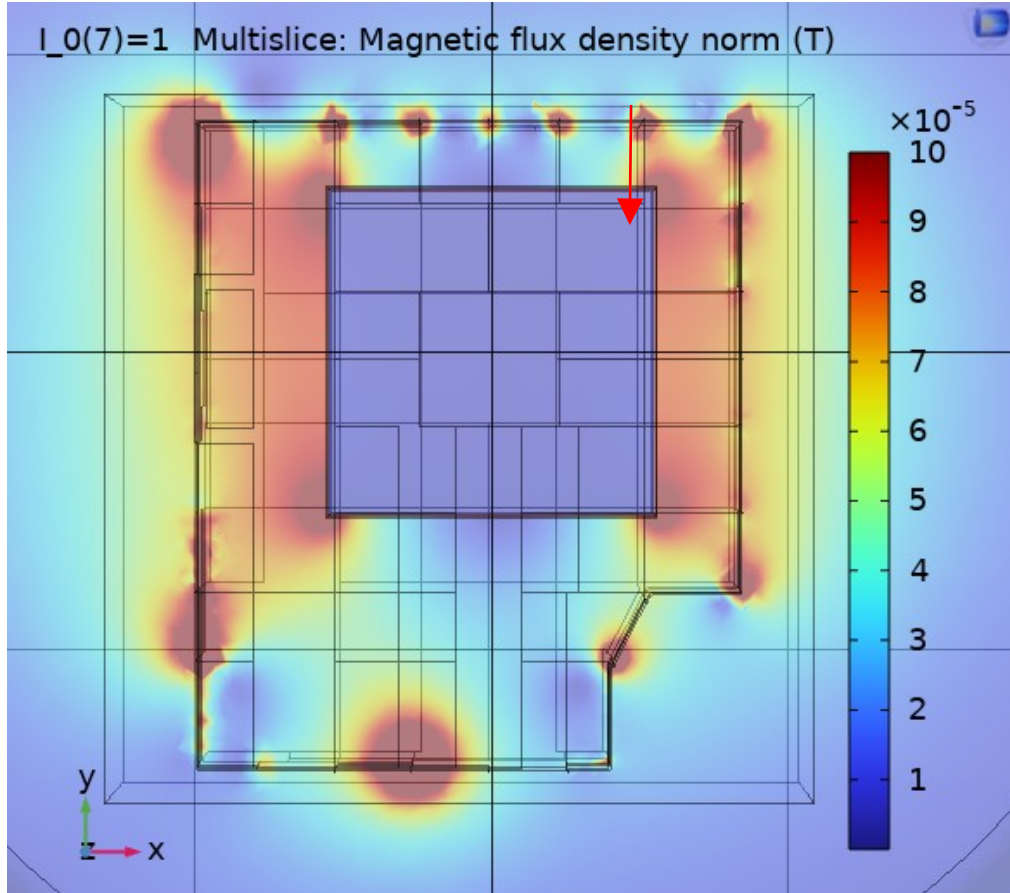
QuSpin readings inside the vacuum tank

SULTAN ramp



New simulations unveiled!

Full COMSOL
simulations of
AMS + MSR!



Better
understanding of
system!

New sensor
optimisation
algorithm!

Better performance?

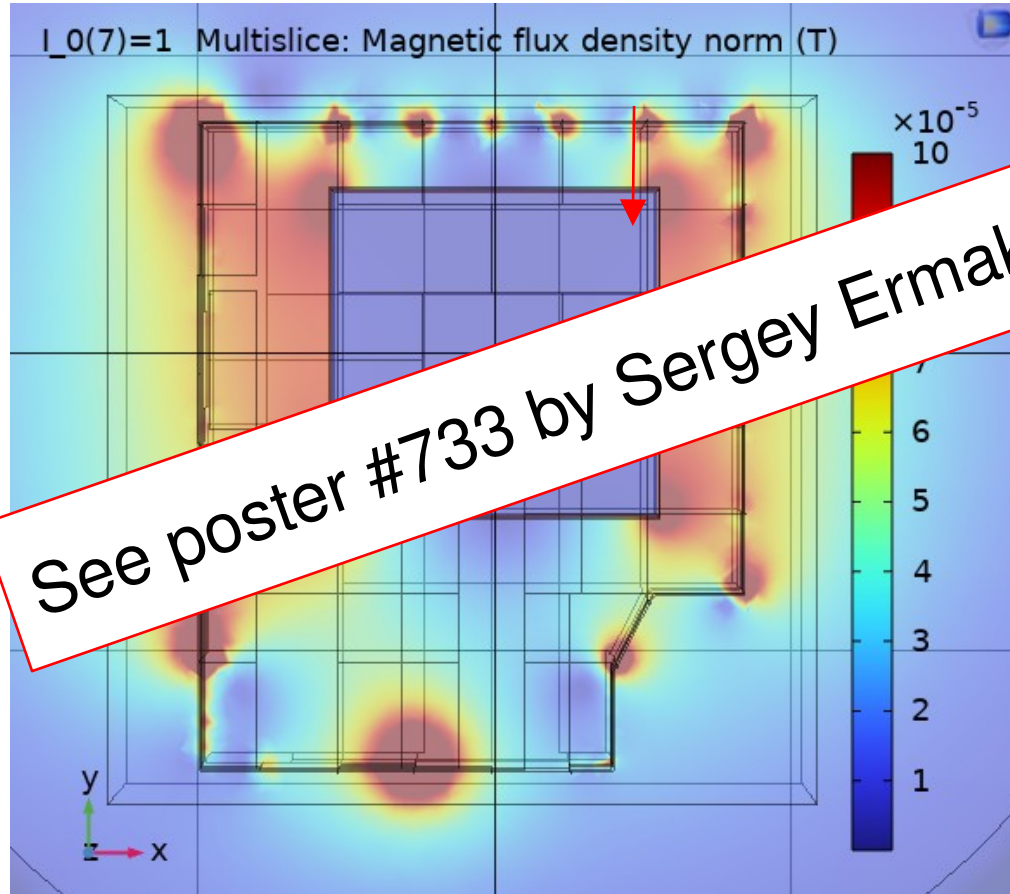
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WOW



See poster #733 by Sergey Ermakov!

Better
understanding of
system!

New sensor
optimisation
algorithm!

Better performance?

Thank you for your attention.

References: [arXiv:2307.07588](https://arxiv.org/abs/2307.07588)