Active magnetic field compensation system for the nEDM experiment at PSI

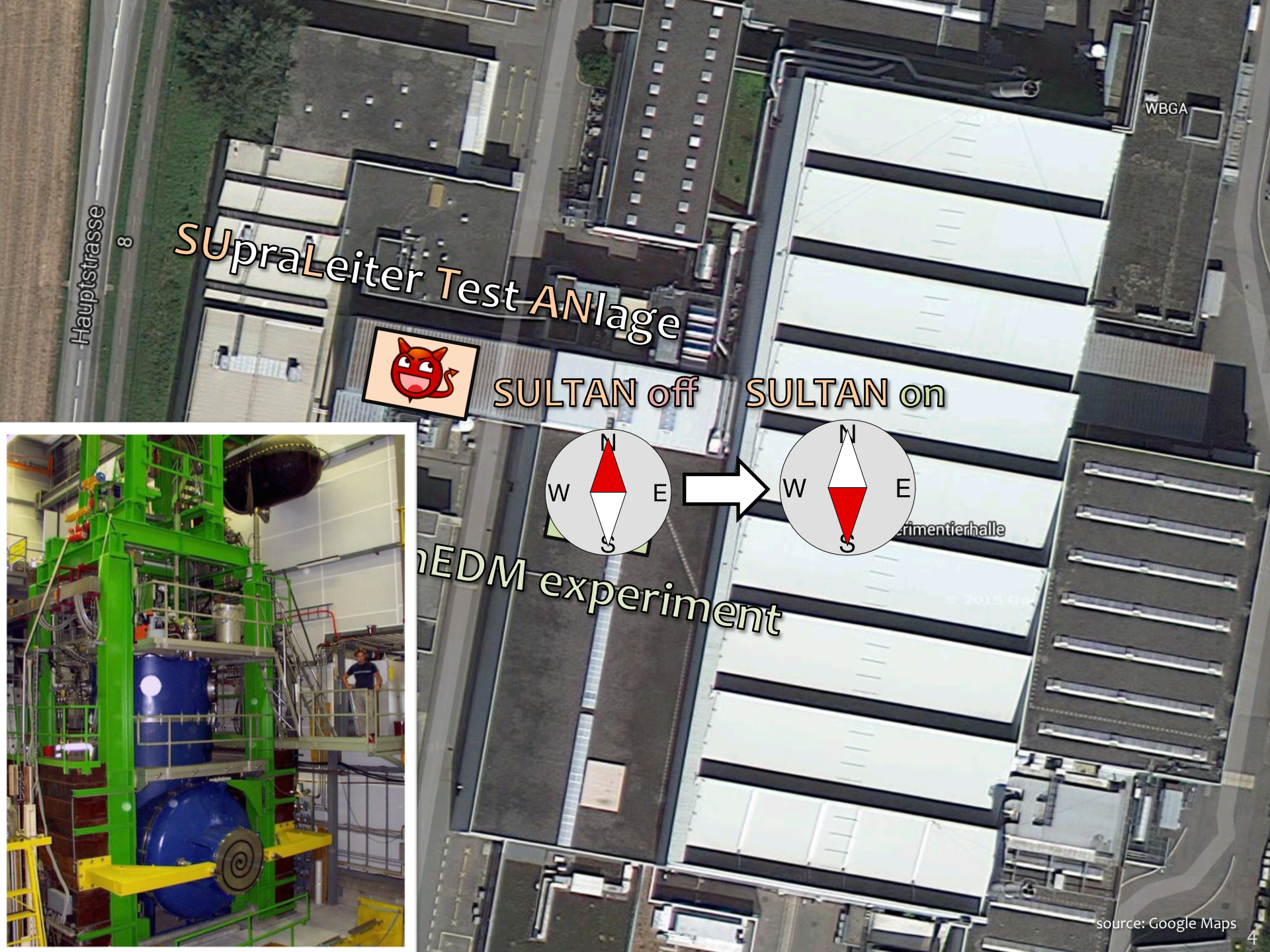
Michał Rawlik

ETH Zürich

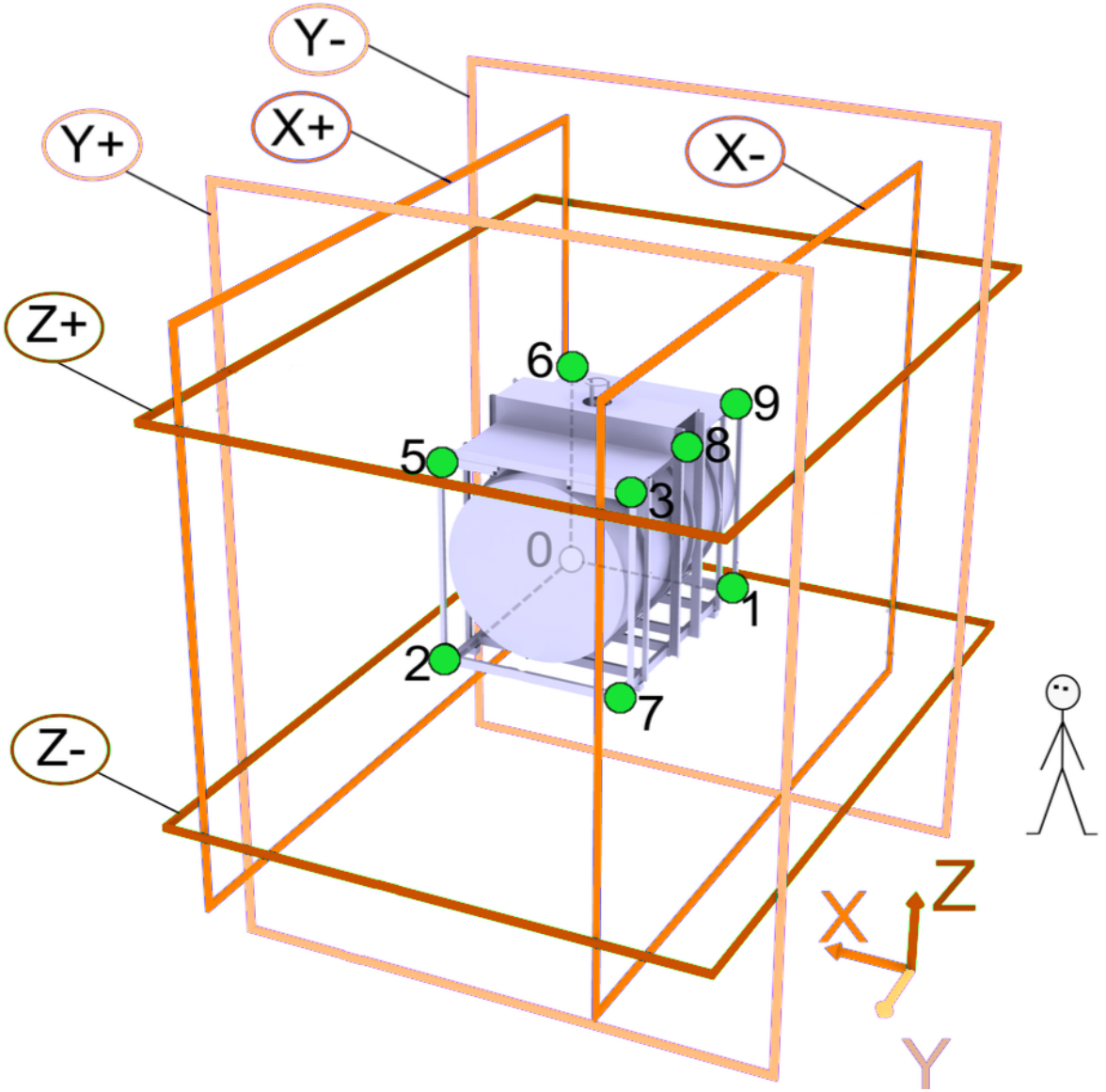
Precision Physics at Low Energy group

source: Google Maps


PSI-West
seen from
a satellite
WBGA
PhD Seminar
Hauptstrasse
8
SUpraLeiter Test ANlage
UltraCold Neutrons source
Experimentierhalle
nEDM experiment
Villigen
24/7 FOOD!
source: Google Maps


Hauptstrasse
8
WBGA
SUpraLeiter Test ANlage
SULTAN off
SULTAN on
N
W
E
S
N
W
E
S
nEDM experiment
source: Google Maps

Active stabilisation

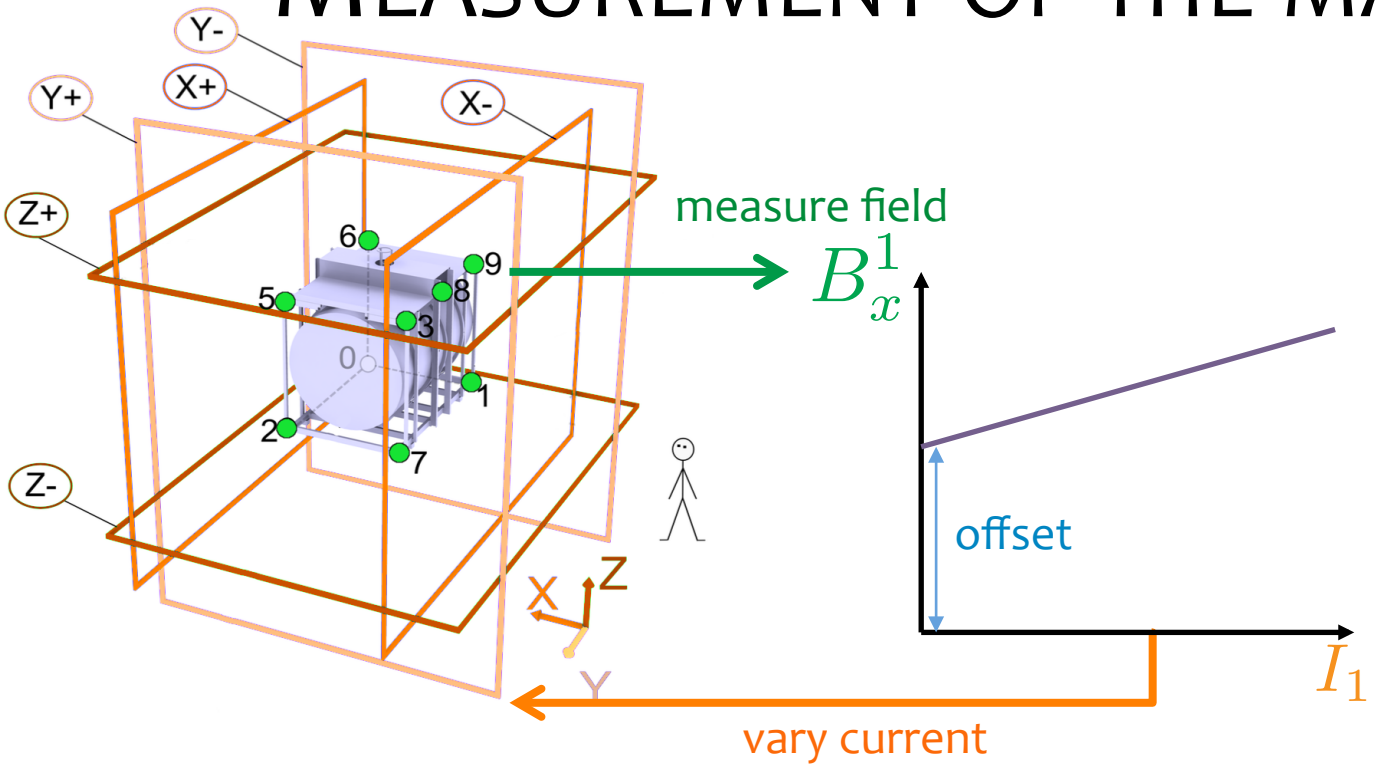


coils

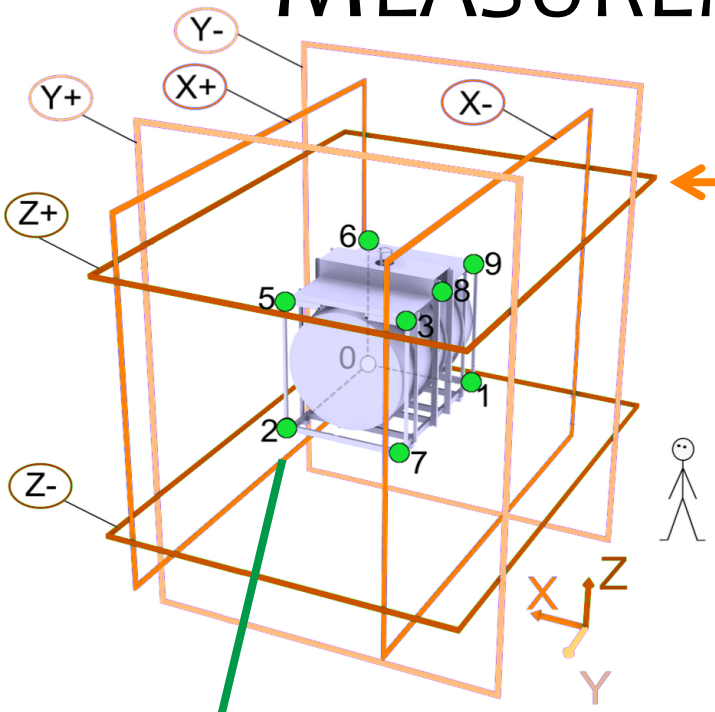
3-axis magnetic field sensors

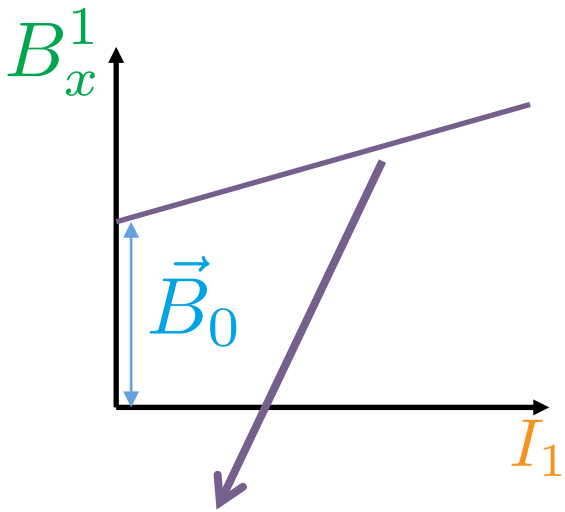
source: PhD thesis of Dr. Beatrice Franke

Measurement of the matrix



Measurement of the matrix





$$\begin{pmatrix} B_x^1 \\ B_y^1 \\ \vdots \end{pmatrix} = \begin{pmatrix} \frac{\partial B_x^1}{\partial I_1} & \frac{\partial B_x^1}{\partial I_2} & \cdots \\ \frac{\partial B_y^1}{\partial I_1} & \frac{\partial B_y^1}{\partial I_2} & \cdots \\ \vdots & \vdots & \ddots \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \\ \vdots \end{pmatrix} + \vec{B}_0$$

$$\vec{B} = M\,\vec{I} + \vec{B}_0$$

We want $\vec{I}$ that makes $\vec{B} = 0$

minimise $\sum_i |\vec{B}_i|$, that is $\sum_i B_i^2$

which is simply a linear least-squares problem

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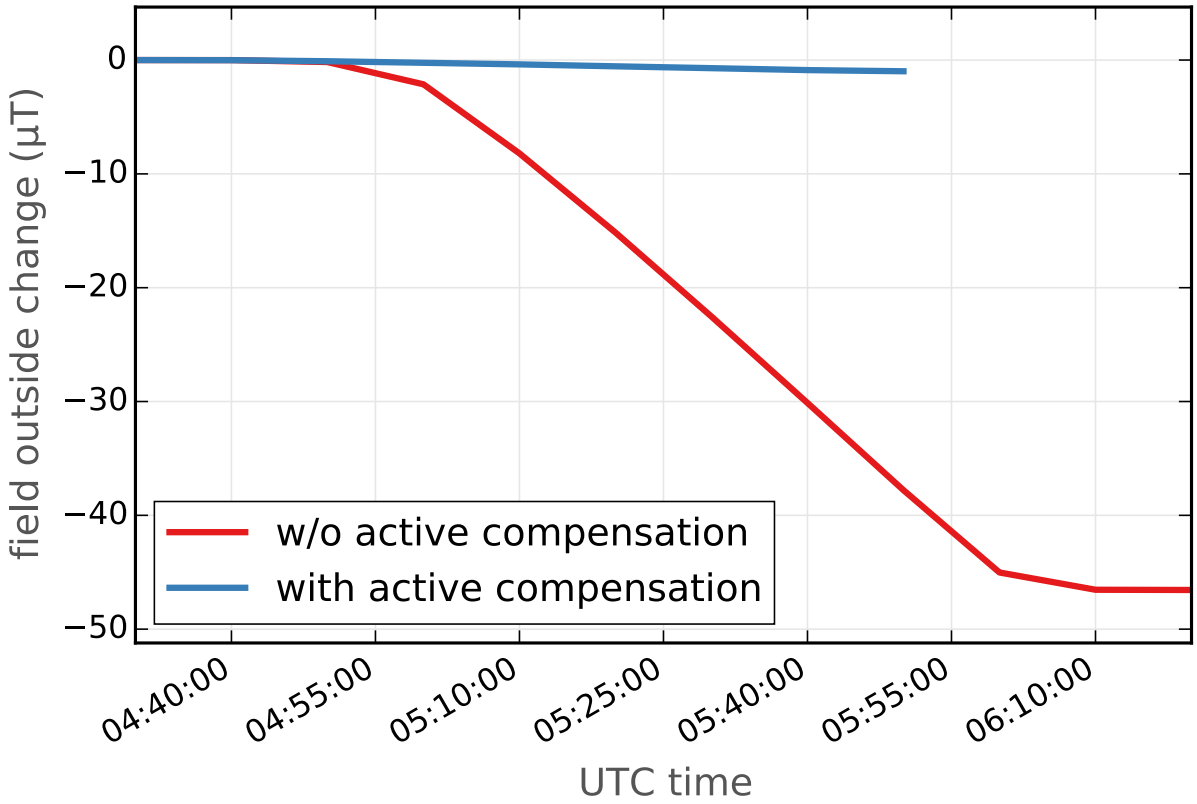
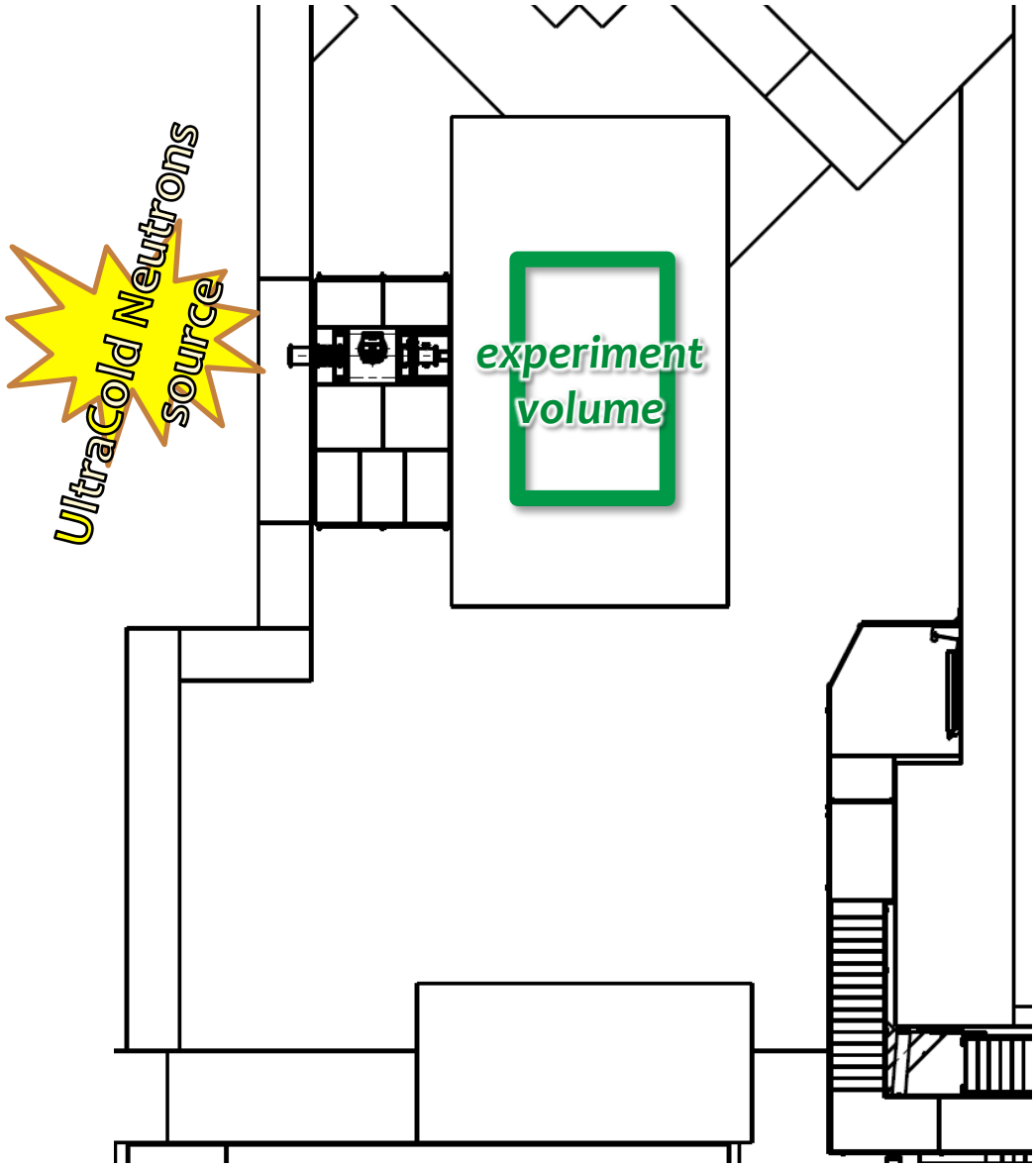
```
in MATLAB syntax: I = M \ (0 - B)
```

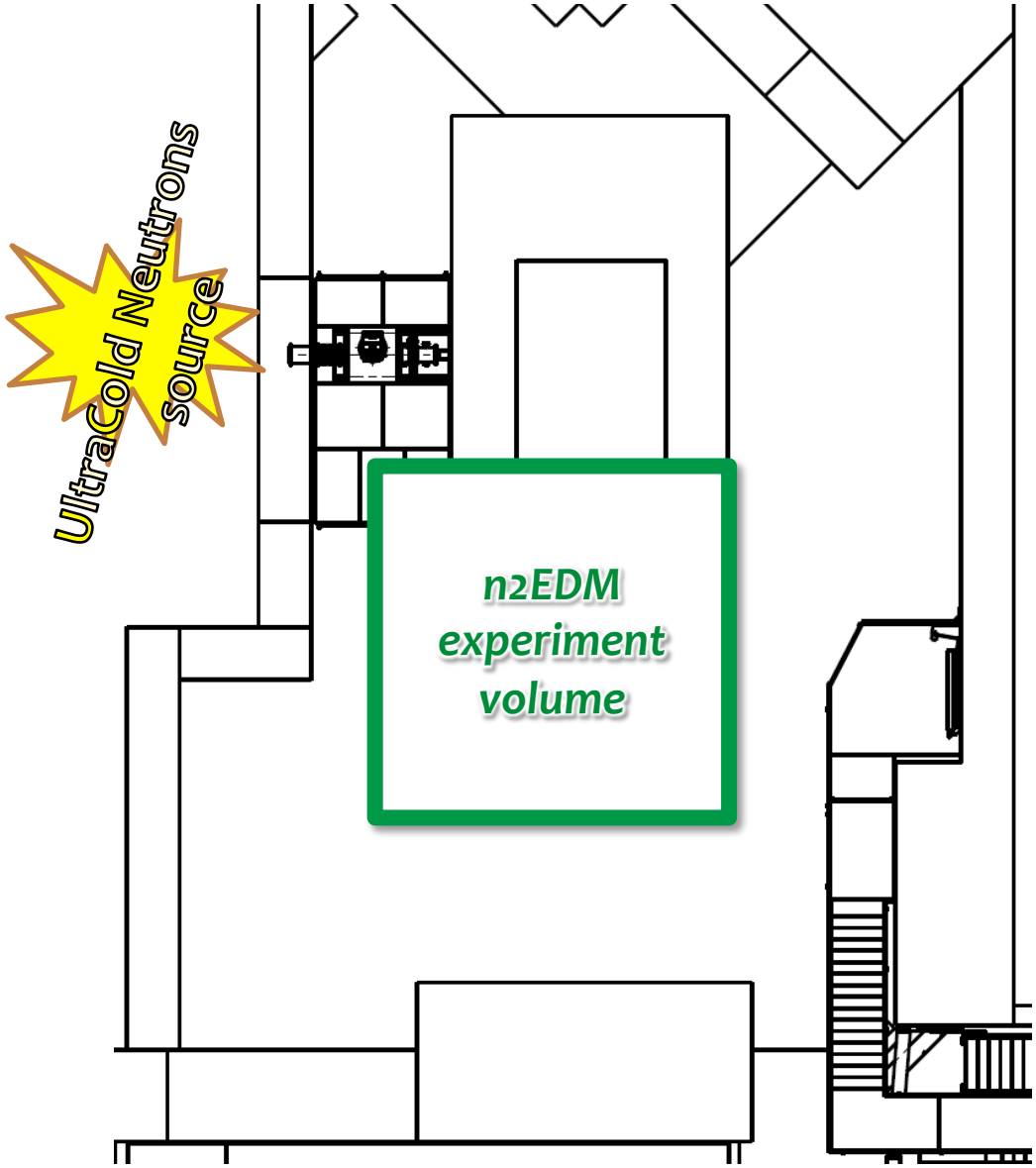
SULTAN MAGNET RAMPING



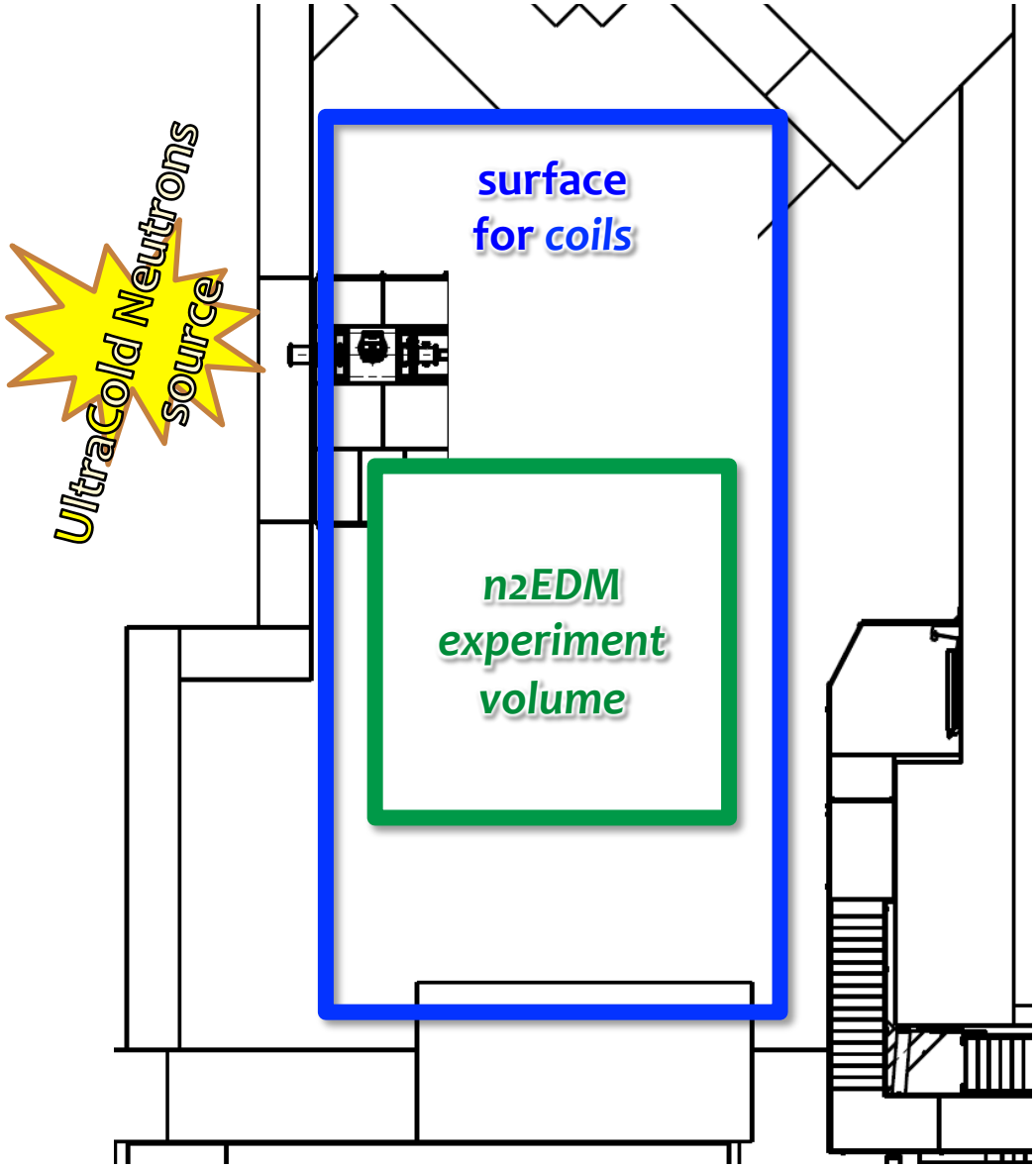
Coil design for n2EDM



Coil design for n2EDM



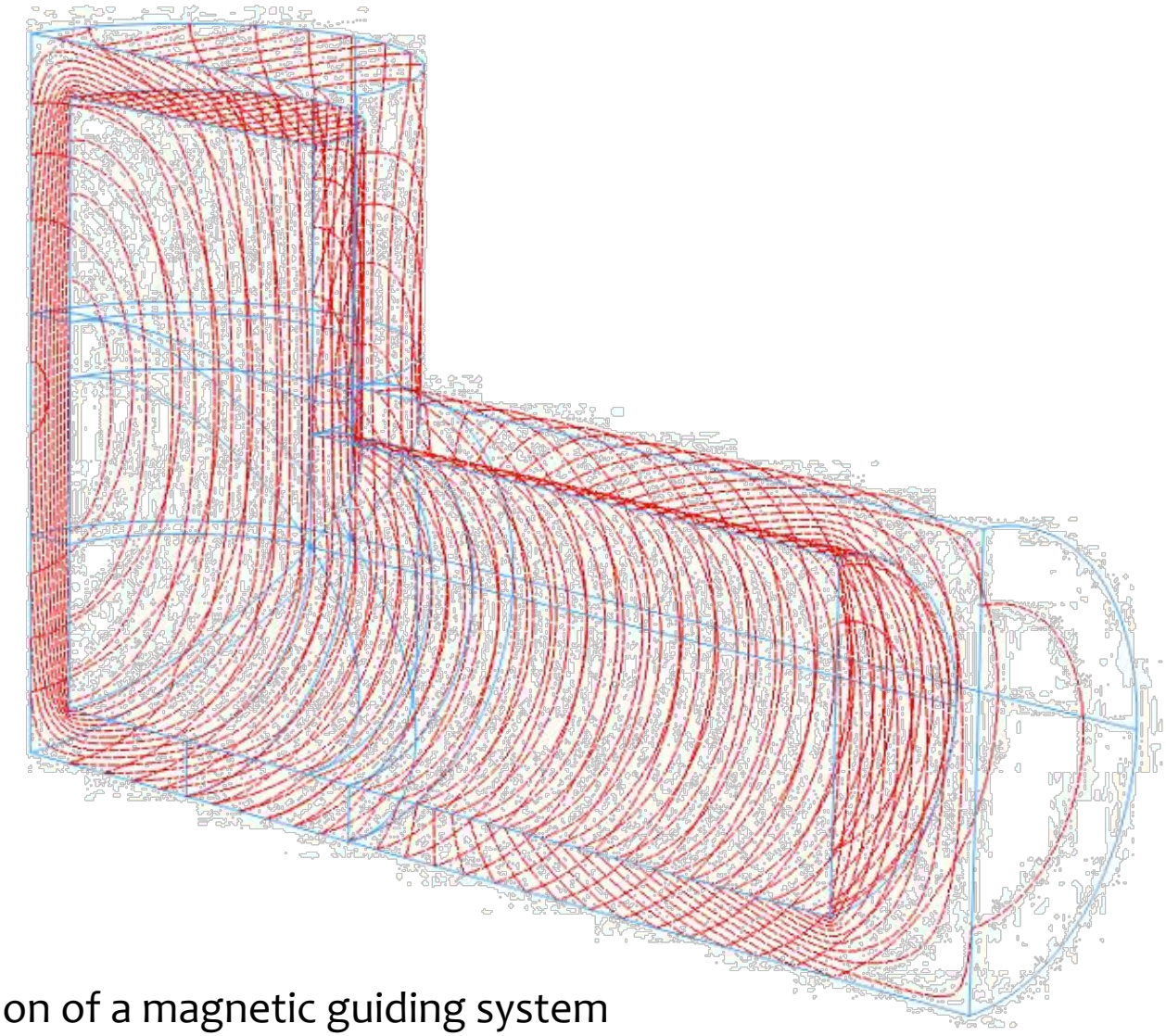
Coil design for n2EDM



Use ***coils*** to bring any homogeneous field down to

< 5%

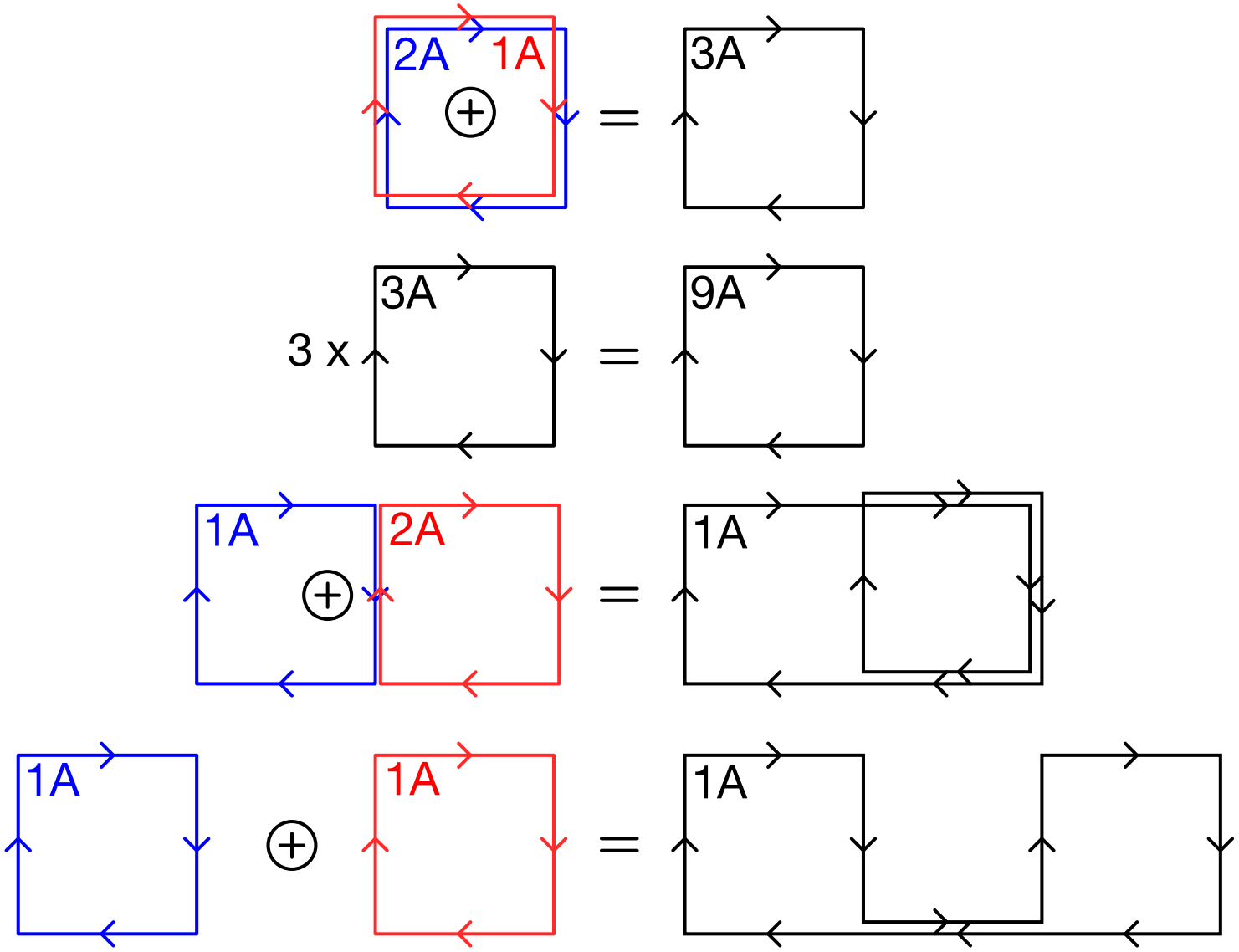
in the whole ***experiment volume***



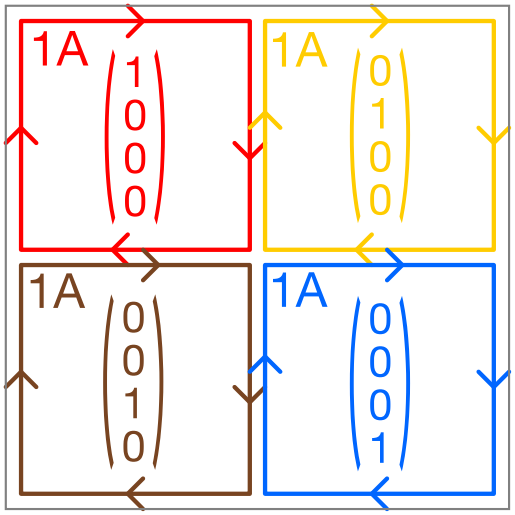
a simulation of a magnetic guiding system

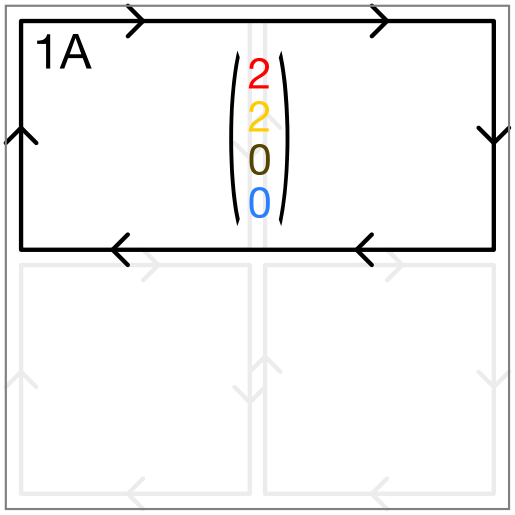
source: Prof. Christopher Crawford

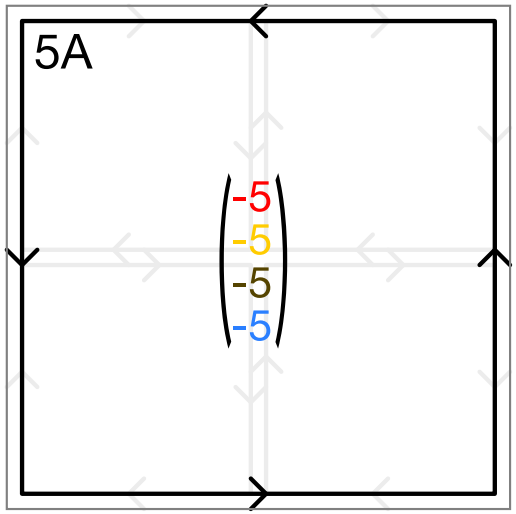
Coil Algebra

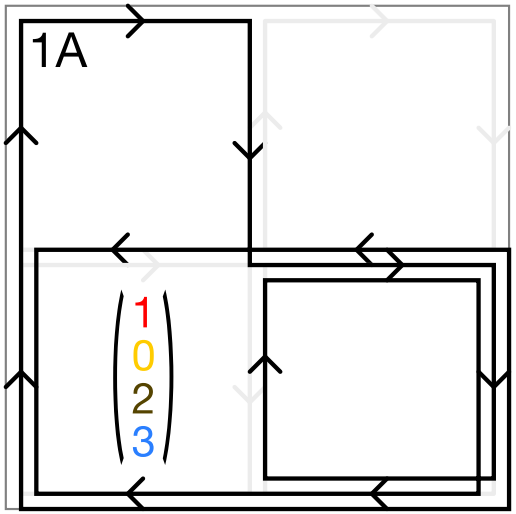


A **BASIS** IN THE SPACE OF POSSIBLE COILS









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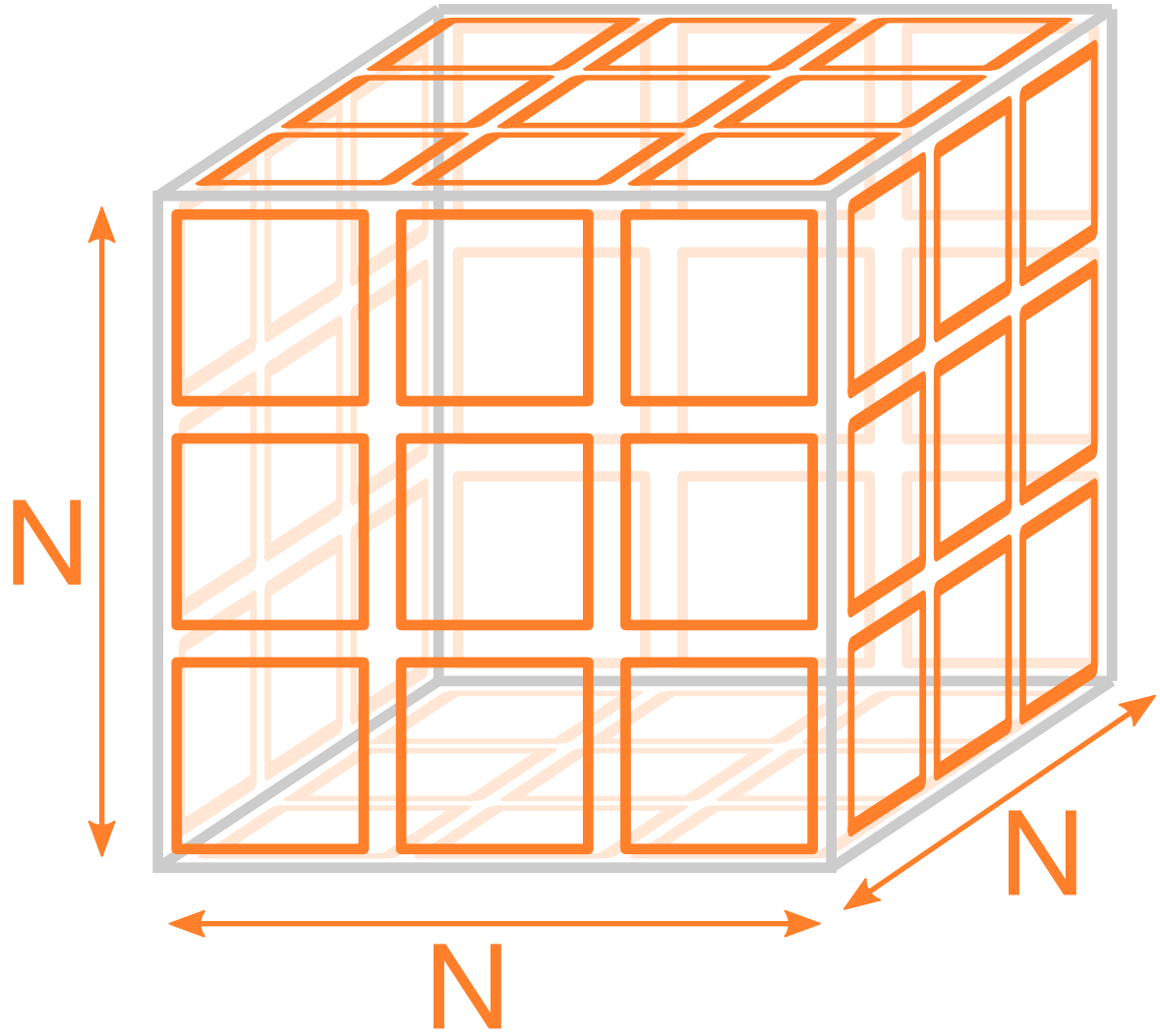
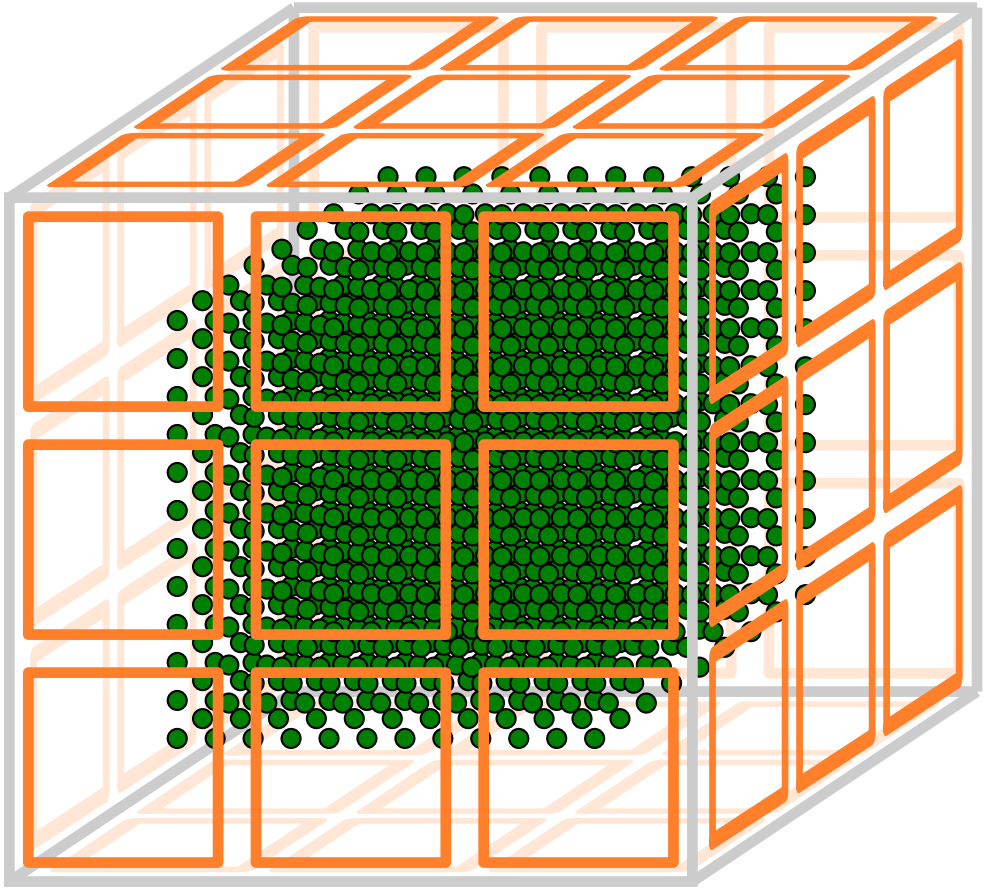


a coil is described with $6N^2-1$ numbers – it is a vector in the coil space

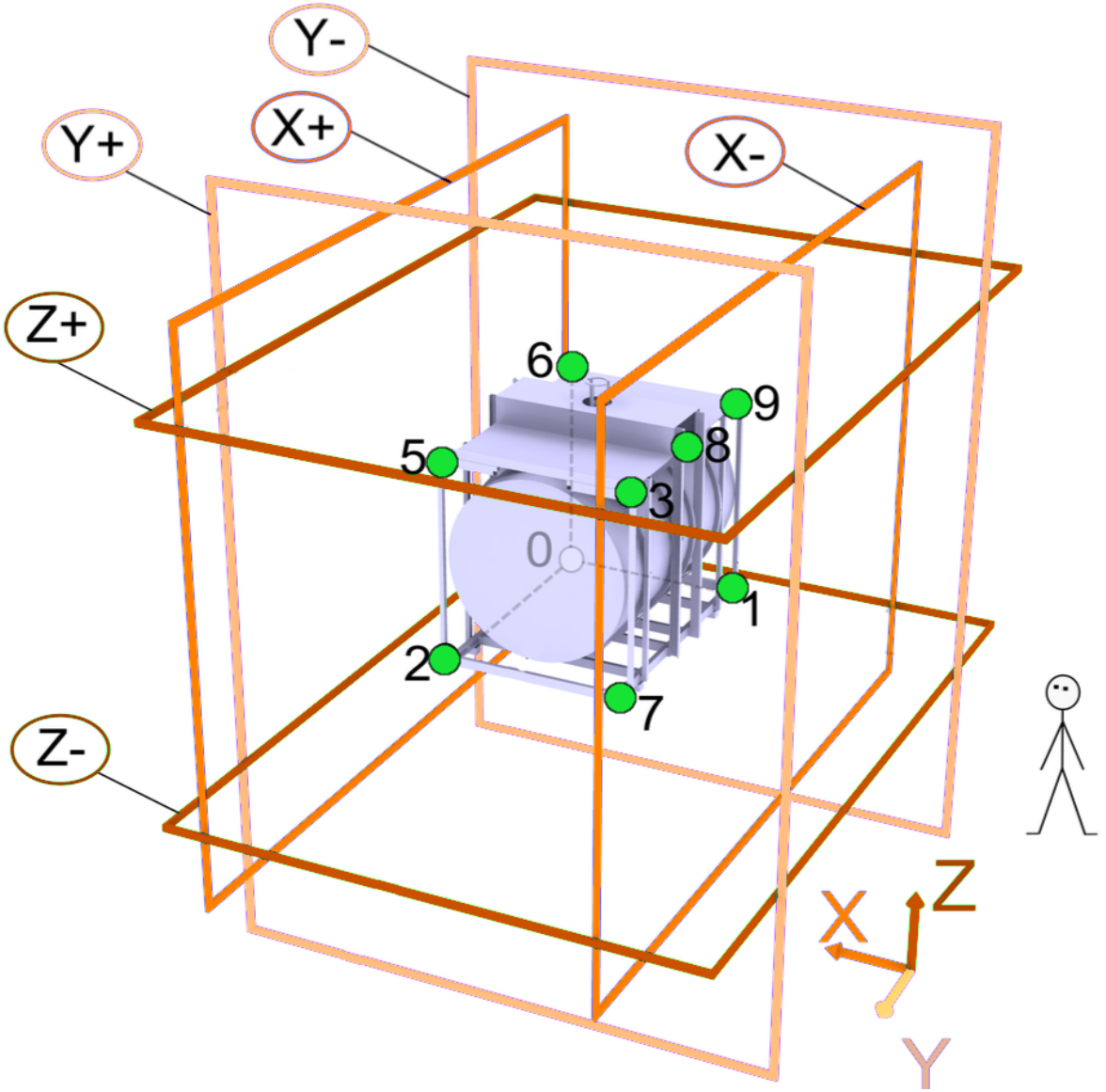
VIRTUAL *SENSORS*

coils

sensors



Active stabilisation



coils

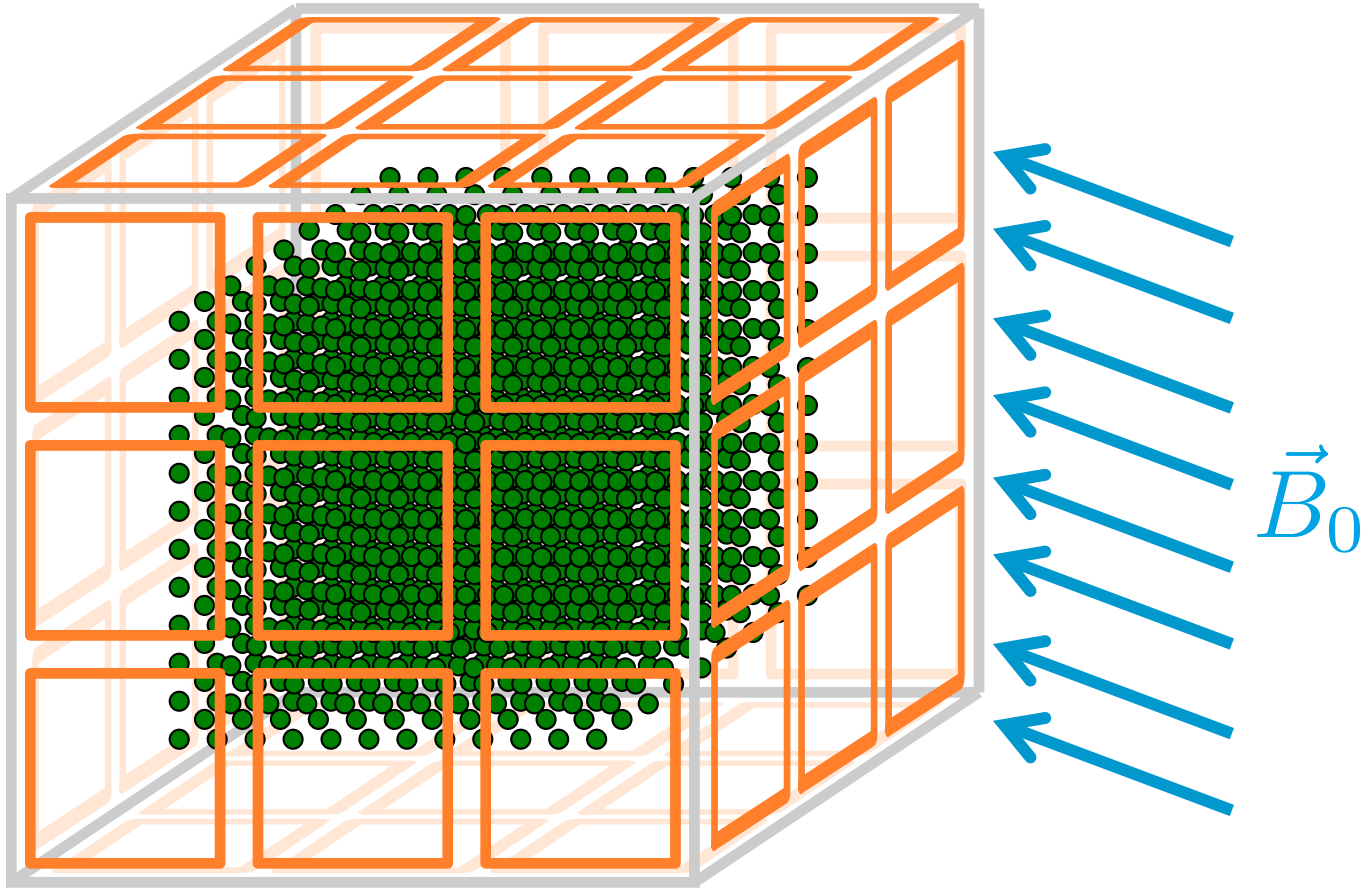
3-axis magnetic field sensors

source: PhD thesis of Dr. Beatrice Franke

The Coil for Given B_0

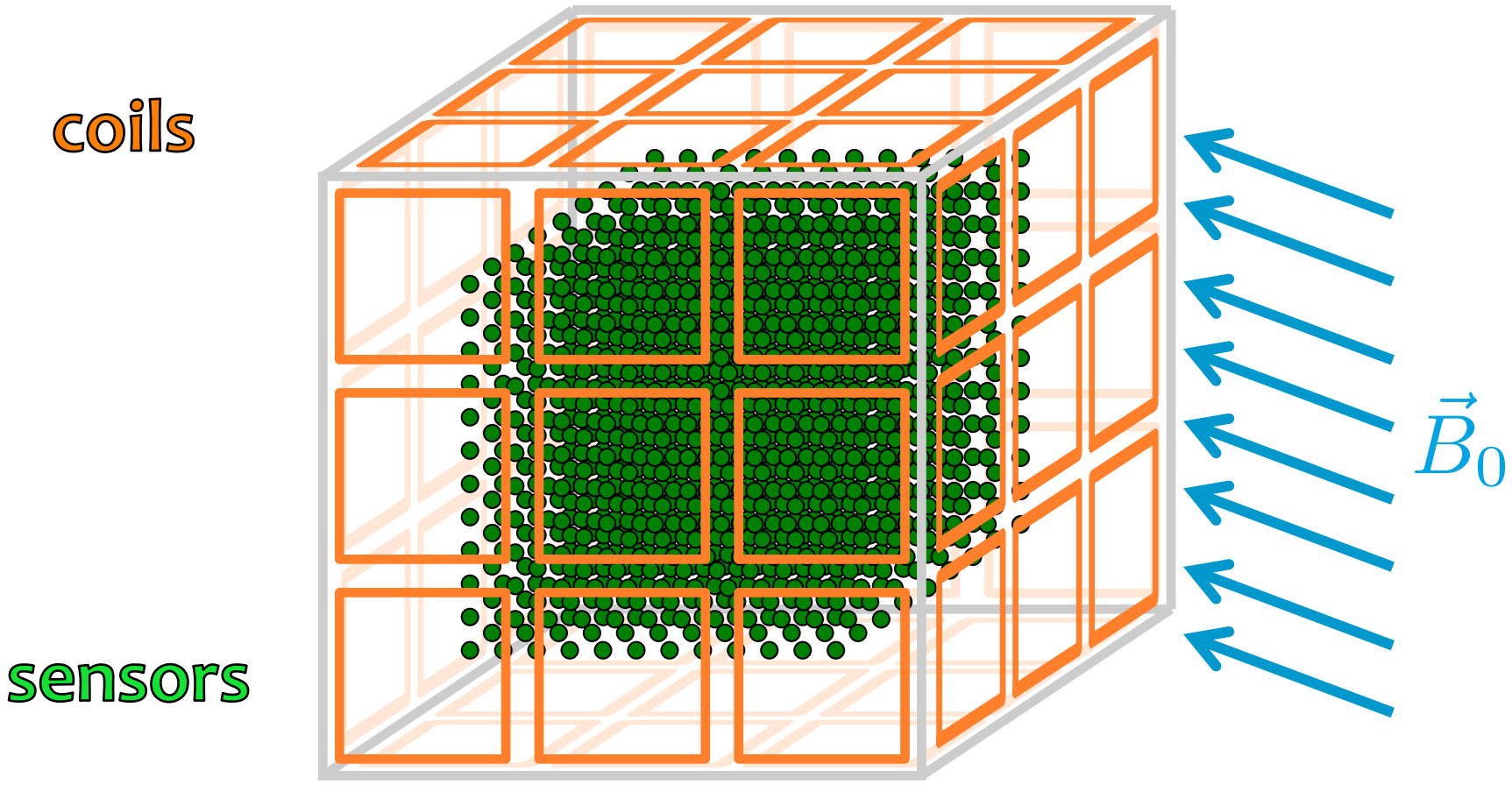
coils

sensors



$$\vec{B} = M\,\vec{I} + \vec{B}_0 \qquad \vec{B} \stackrel{!}{=} 0$$

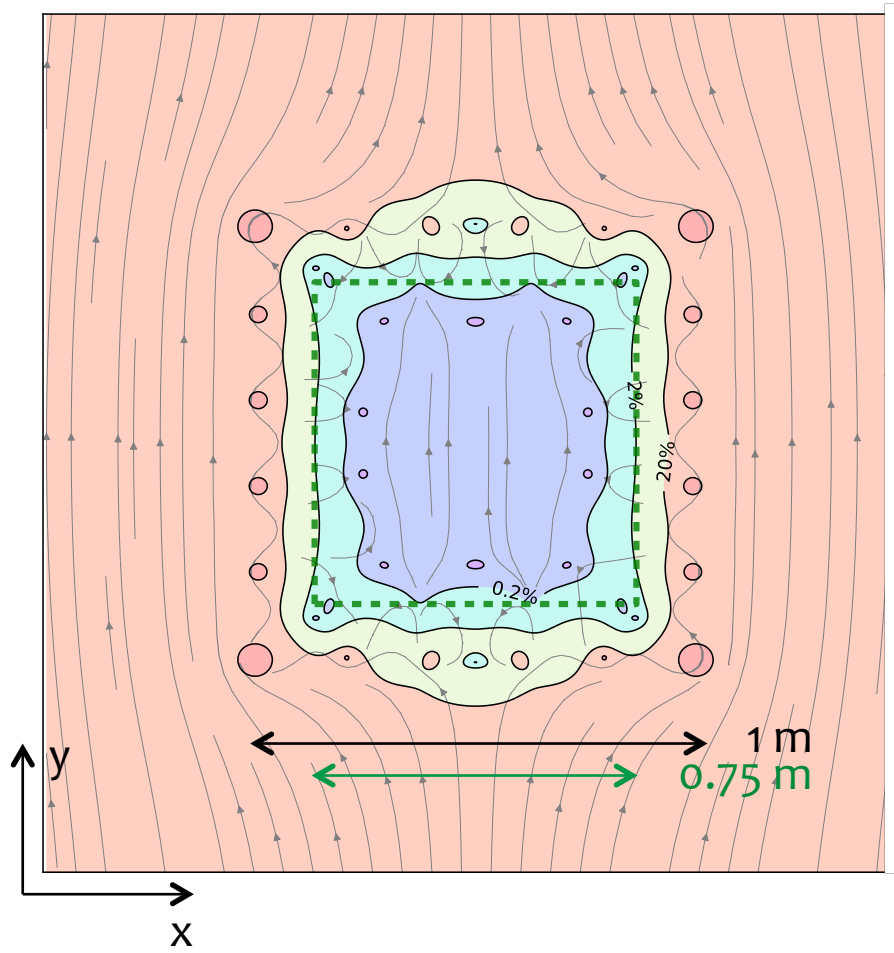
The Coil for Given B_0

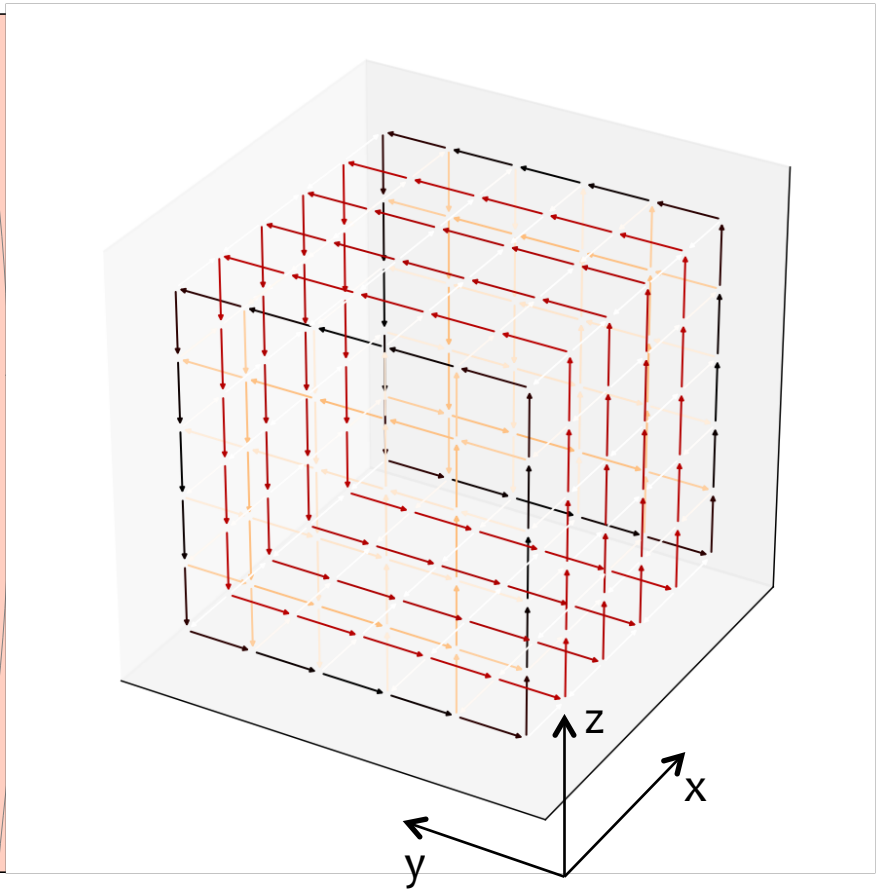


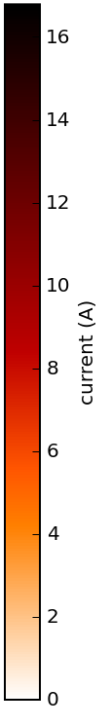

```
in MATLAB syntax: I = M \ (0 - B)
```

B_0 = Homogeneous Field in y

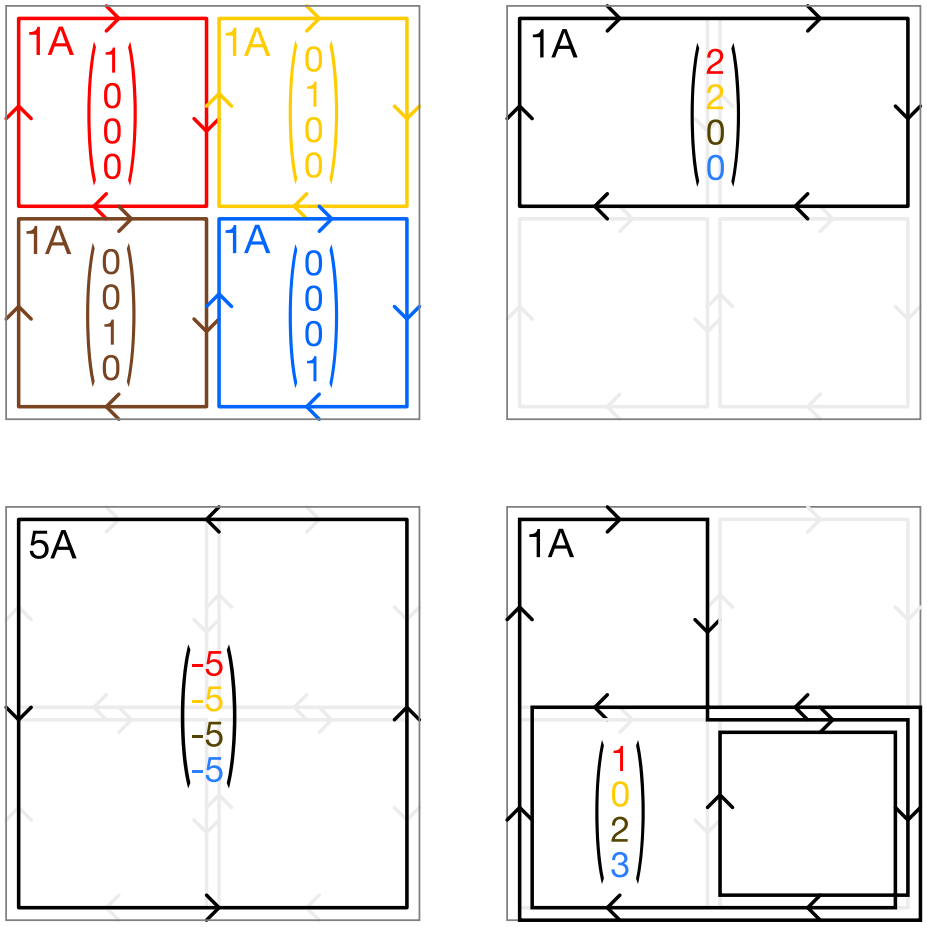
XY-cut in the middle







Wrap-Up

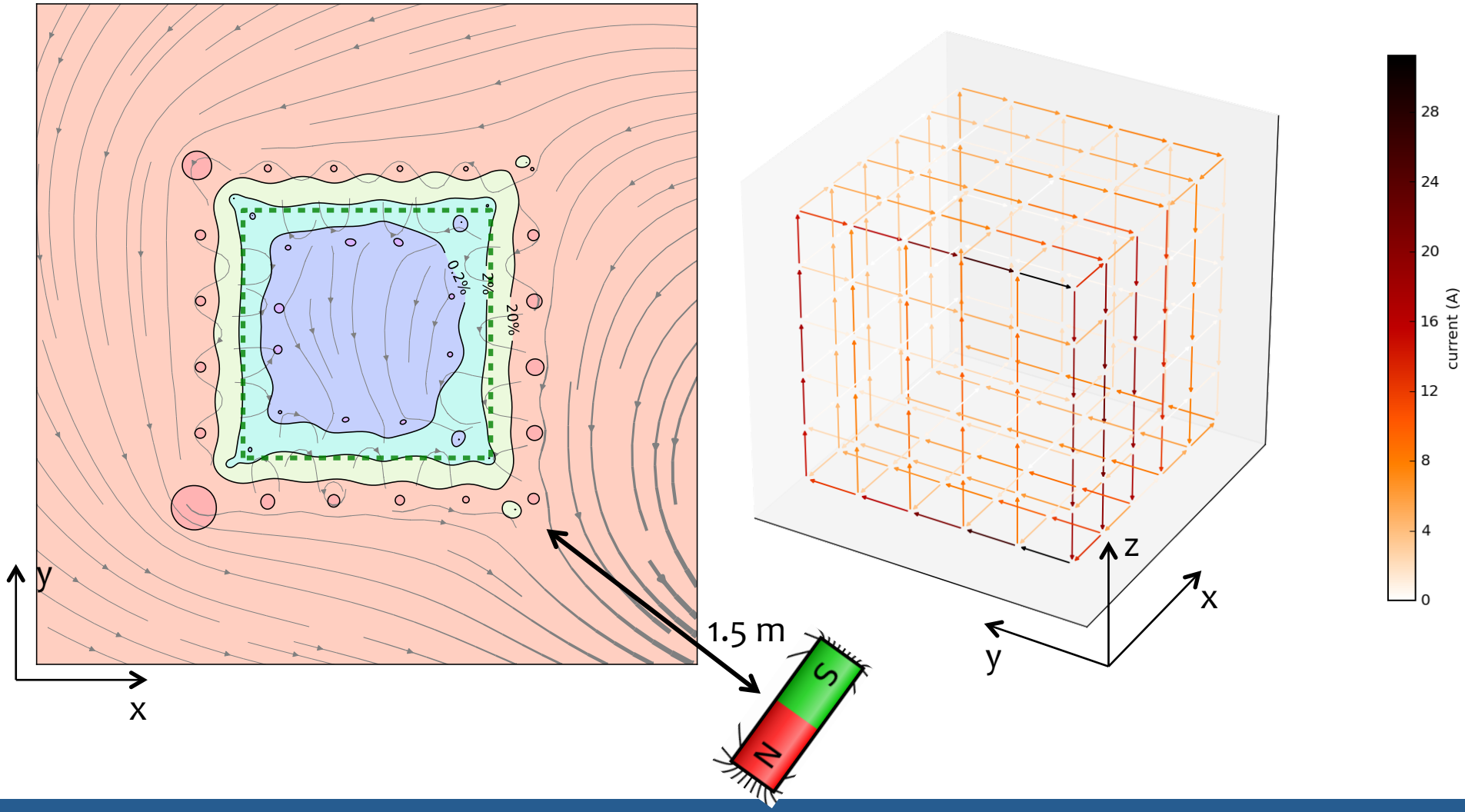



```
I = M \ (0 - B)
```

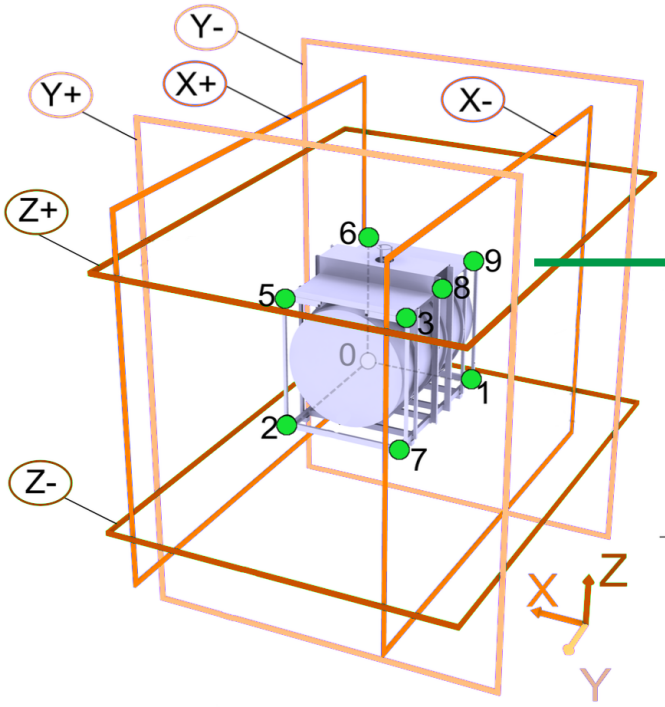
ENJOY THE BARBECUE!

B_0 = Dipole Source 1.5m away

XY-cut in the middle



FEEDBACK



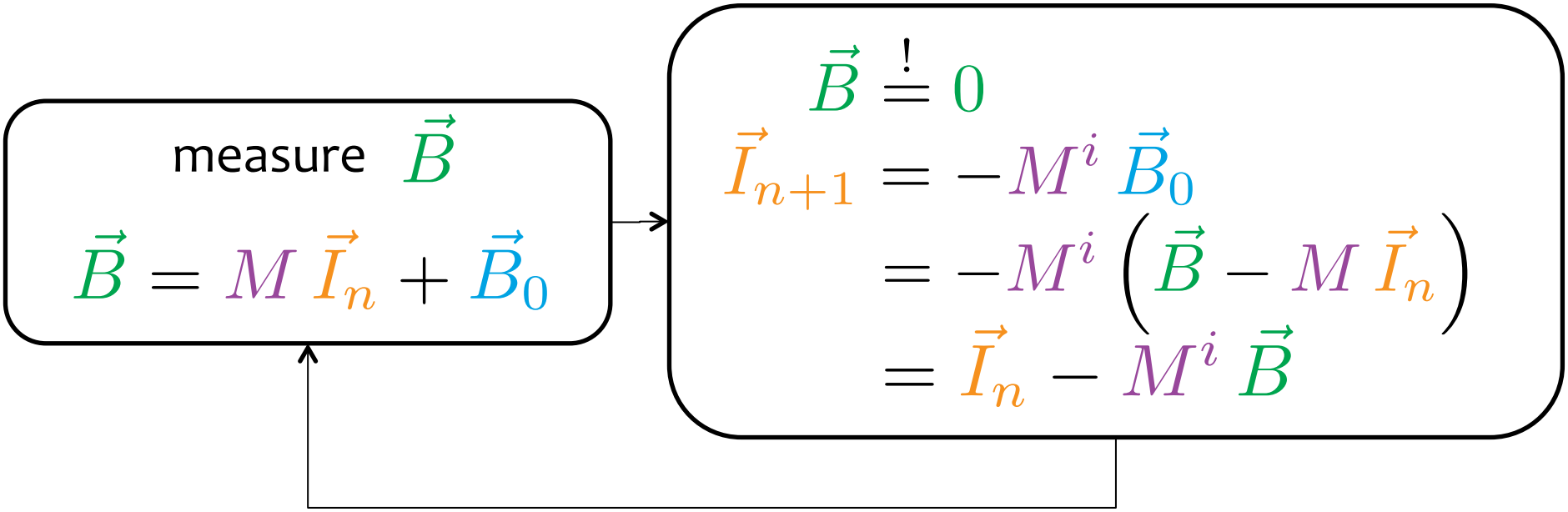
$$? \begin{pmatrix} B_x^1 \\ B_y^1 \\ B_z^1 \\ B_x^2 \\ B_y^2 \\ \vdots \end{pmatrix} + ? = \begin{pmatrix} I_{X+} \\ I_{X-} \\ I_{Y+} \\ I_{Y-} \\ I_{Z+} \\ I_{Z-} \end{pmatrix}$$

Feedback with a Pseudoinverse

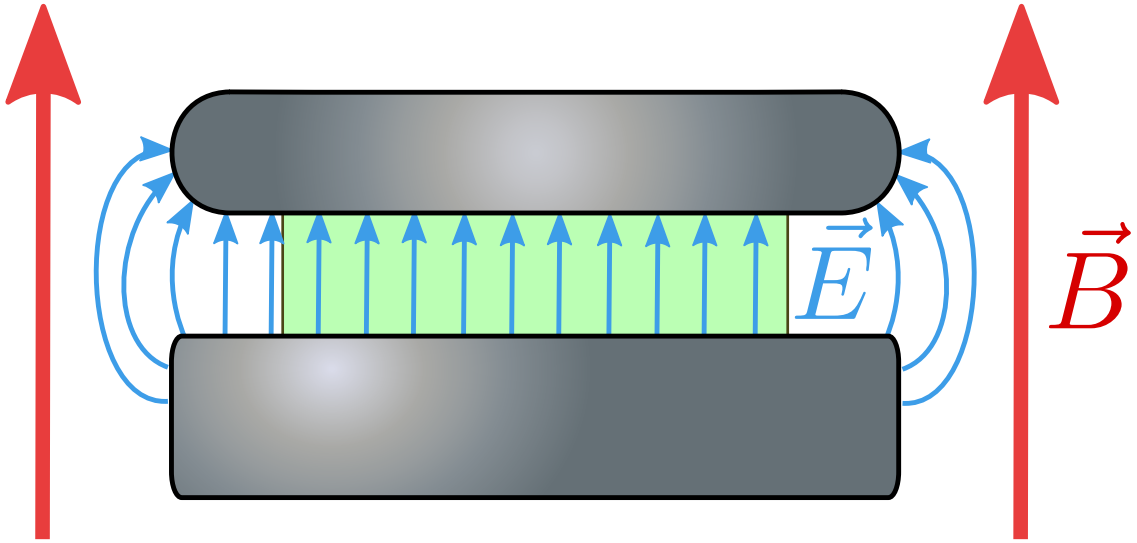
$$\vec{B} = M\,\vec{I} + \vec{B}_0$$

$$\vec{I} = M^i \left(\vec{B} - \vec{B}_0\right)$$

solve `I = M \ (B - B)`
for all `(B - B)`



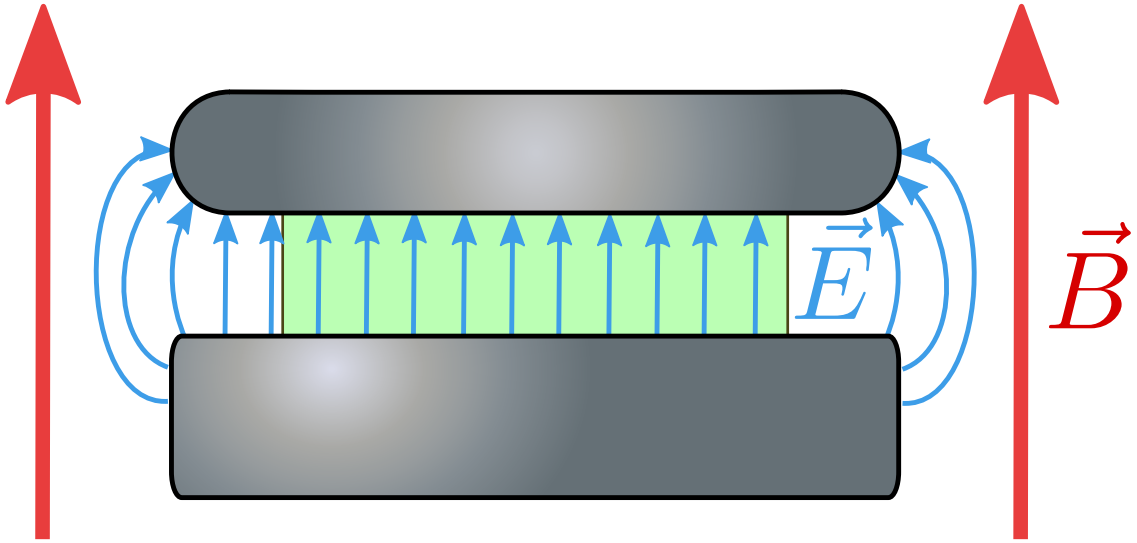
Measurement of the electric dipole moment of the neutron



$$f_n = \frac{2}{h}\left(\vec{\mu}_n \cdot \vec{B} + \vec{d}_n \cdot \vec{E}\right)$$

$\vec{B} \uparrow\uparrow \vec{E}$ $\qquad$ $\vec{B} \uparrow\downarrow \vec{E}$

Measurement of the electric dipole moment of the neutron

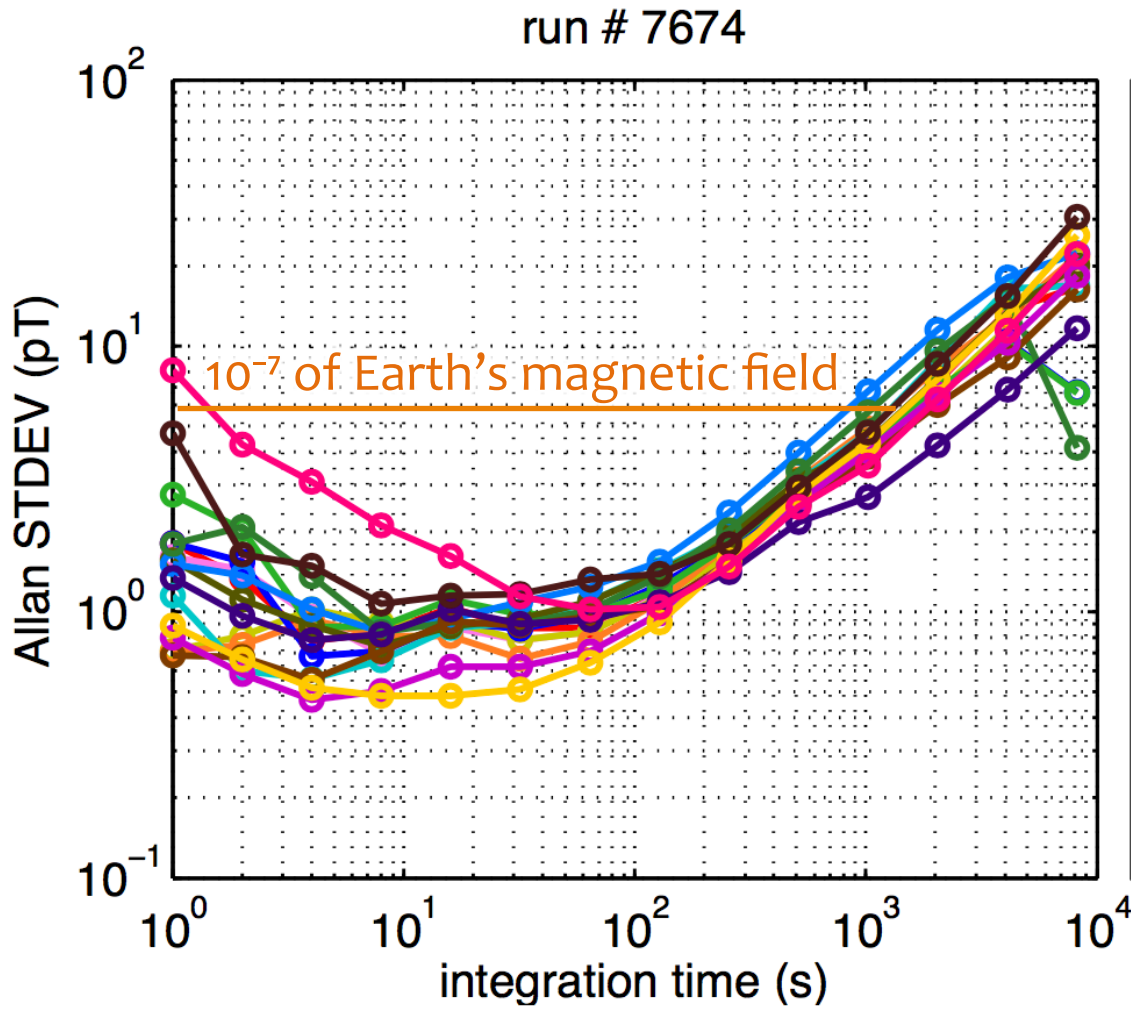


$$d_n = \frac{1}{2E}\left(h\left(f_n^{\uparrow\uparrow} - f_n^{\uparrow\downarrow}\right) + \mu_n\left(B^{\uparrow\uparrow} - B^{\uparrow\downarrow}\right)\right)$$

$$d_n = \frac{1}{2E}\left(h\Delta f_n + \mu_n \Delta B\right)$$

STABILITY OF THE MAGNETIC FIELD

the field is this stable…



… when averaged this long

source: PhD thesis of Dr. Beatrice Franke

Passive magnetic field stabilisation