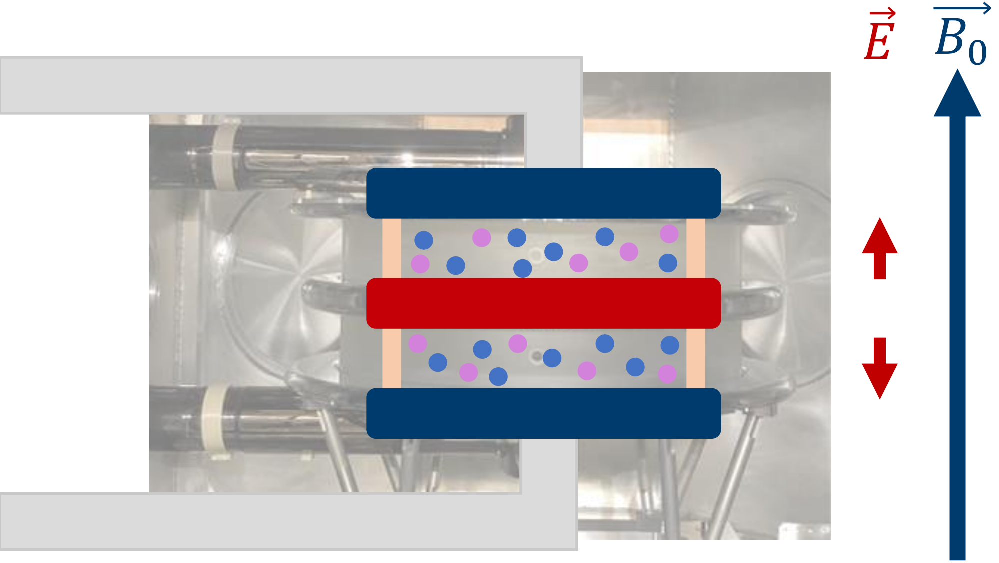
An array of Cs magnetometers for the n2EDM experiment

Victoria Kletzl

On behalf of the nEDM collaboration

nEDM2023 – Santa Fe – 2023/11/07

The n2EDM double chamber



- UCN
- ^{199}Hg atom

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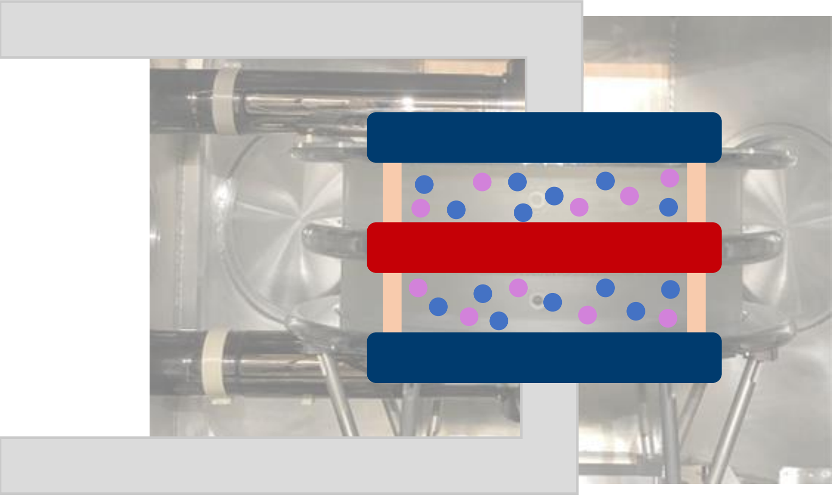

$\vec{E}$ $\overrightarrow{B_0}$

Simultaneous measurement of:

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

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

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

- UCN
- ^{199}Hg atom

The d^{false} effect

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

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- If $\vec{B}_0 \neq$ uniform → d^{false} for neutrons and ^{199}Hg comagnetometer
- d^{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	$\approx 3.8\, \gamma_{\text{Hg}} \lvert\vec{B}\rvert \approx 30$ Hz	$\gamma_{\text{Hg}} \lvert\vec{B}\rvert \approx 8$ Hz

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Pignol & Roccia, Phys. Rev. A85, 042105 (2012).

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- Gradient control using Cesium magnetometer array!

Representing $d_{\mathrm{Hg}\to n}^{\mathrm{false}}$

- $\overrightarrow{B_0}$ can be represented by spherical harmonics

Abel, C. et al., Phys. Rev. A 99, 4 (2019).

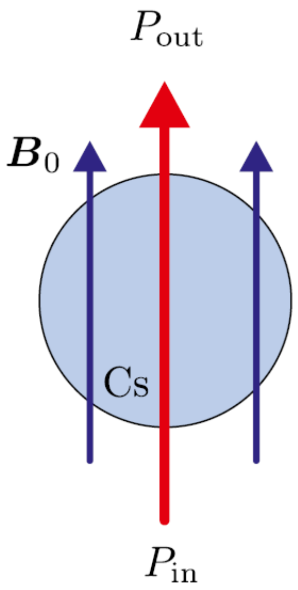
$$d_{\mathrm{Hg}\to n}^{\mathrm{false}} = -\frac{\hbar\left|\gamma_{\mathrm{Hg}}\gamma_n\right|}{2c^2}\sum_{l,m} G_{l,m}\langle\rho\Pi_{\rho,l,m}\rangle$$

Gradients:

$G_{1,0}$ … Hg co-magnetometer

$G_{3,0}$, $G_{5,0}$, $G_{7,0}$ … Cs magnetometer array

The pump-probe-cycle



Z. D. Grujic et al., Eur. Phys. J. D, 69(5), 2015.

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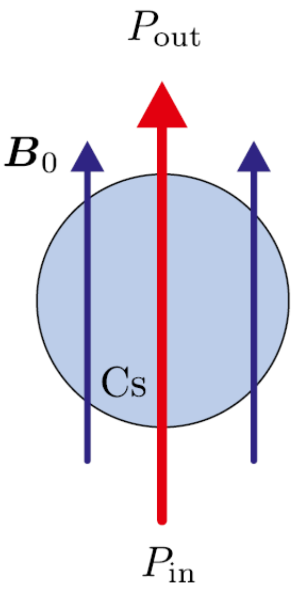

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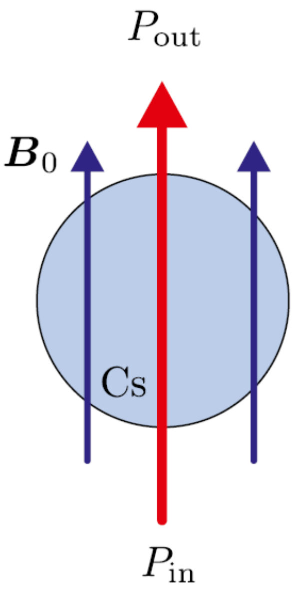

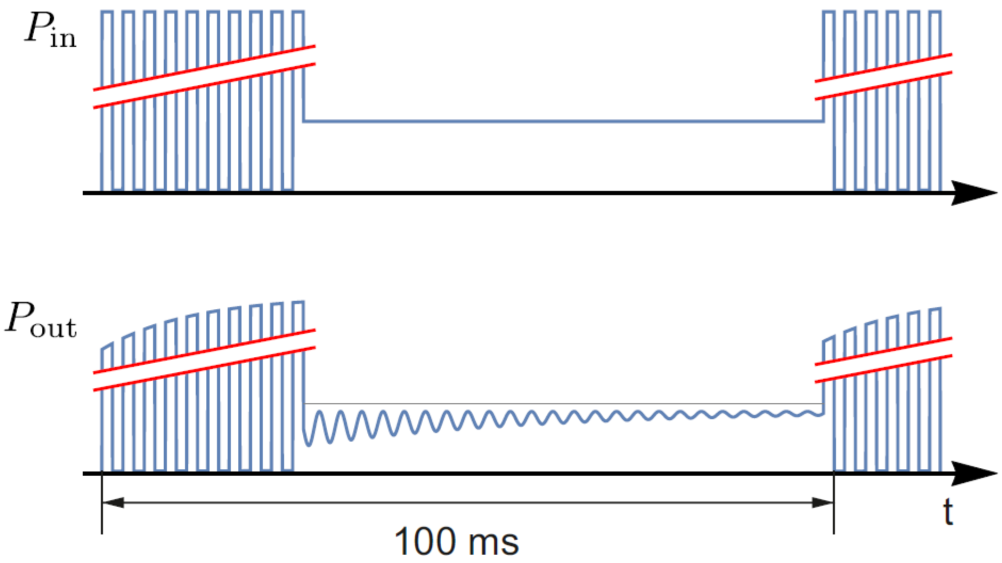

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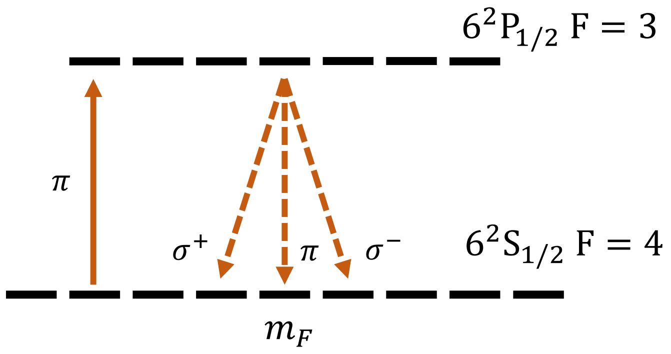
Optical pumping

- Wavelength = 894 nm (D_1 - line)

- Linear polarization π



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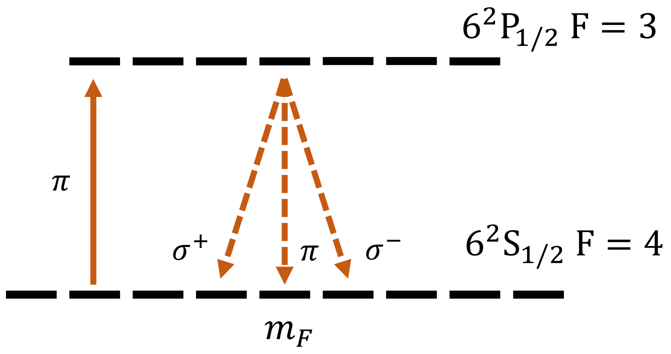

Optical pumping

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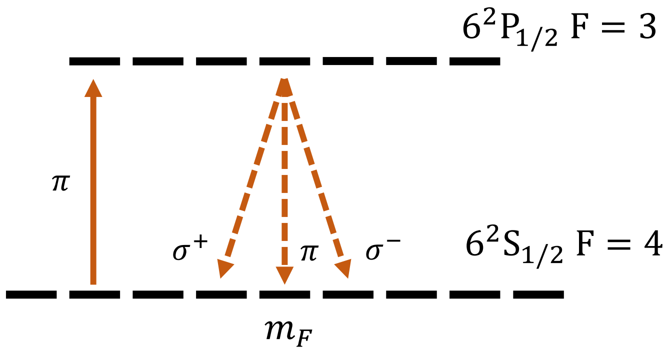
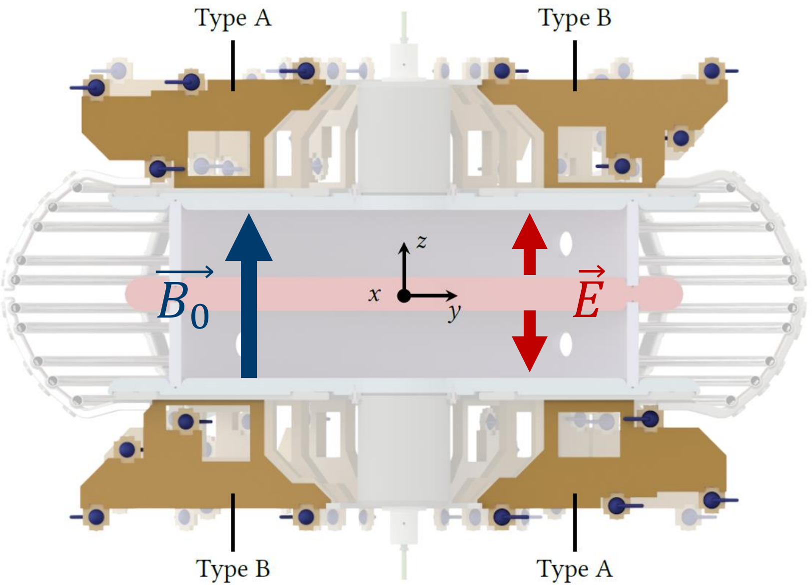
- spin populations in high $|m_F|$
  = spin alignment
- Observed precession frequency:
  $2\omega_L = 7$ kHz



Cs Magnetometer array @ n2EDM

- Total of 112 Cs cells on 28 plates (gradients up to $l \leq 7$)
- Two types of holder geometries
- Placement accuracy: ±0.5 mm
- Magnetometric accuracy: 5 pT



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

Placement and accuracy

- Placement determined with genetic algorithm
- Restriction to unit plates of 4 cells each
- ±0.5 mm is well within our sensitivity goal

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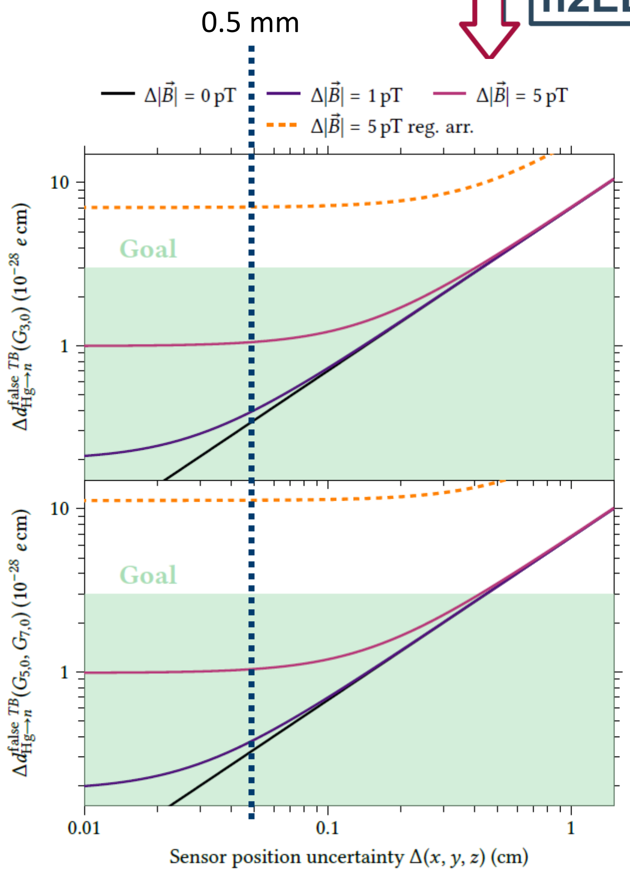
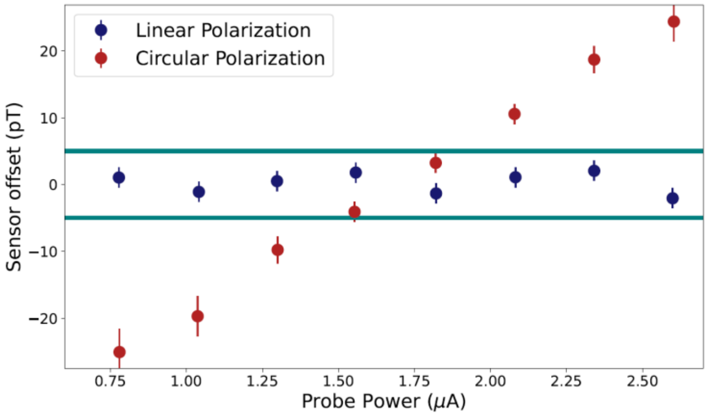


Laser stability and accuracy

- Linear polarisation supresses systematic shifts
  - ➢ Probe power



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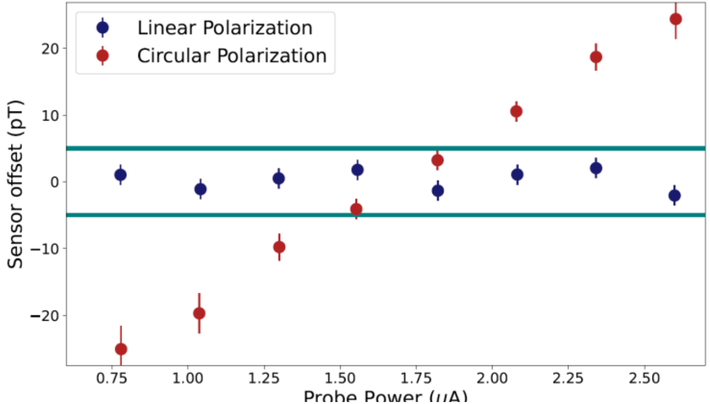
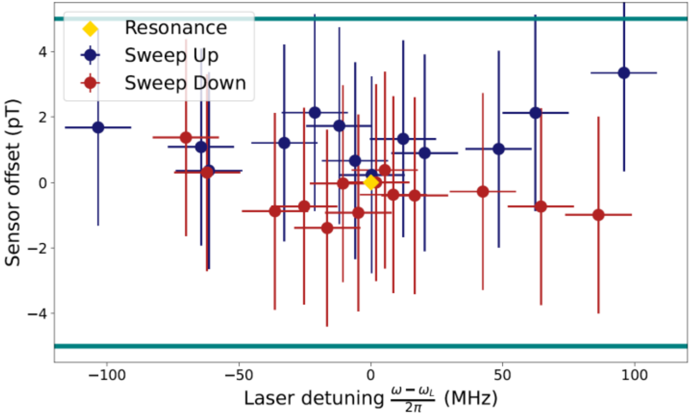
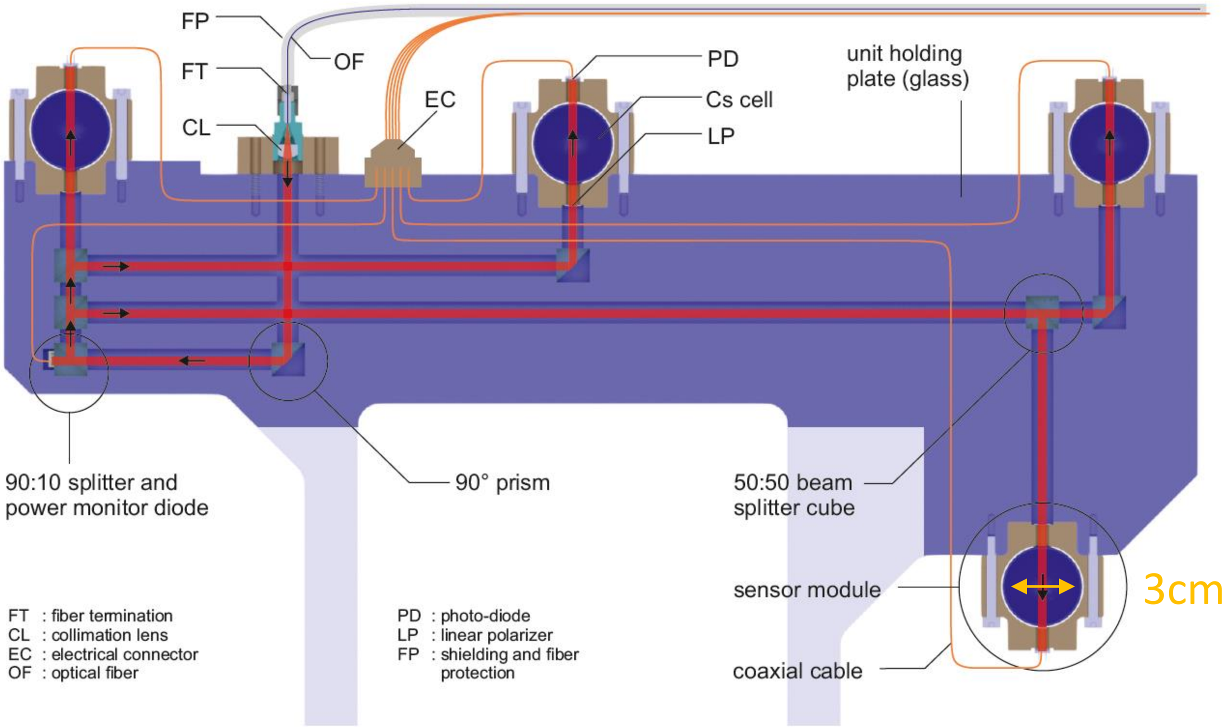


  - ➢ Laser detuning



Single Cs plate



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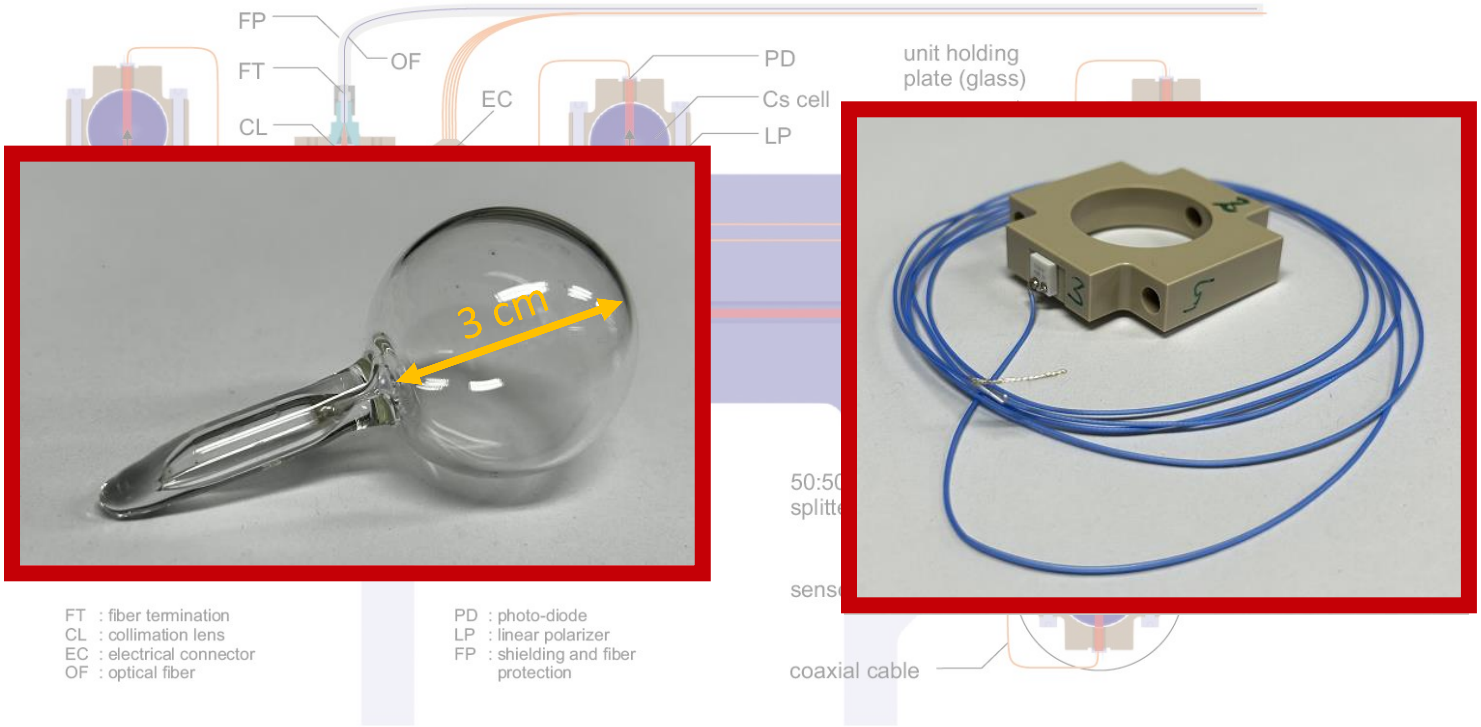
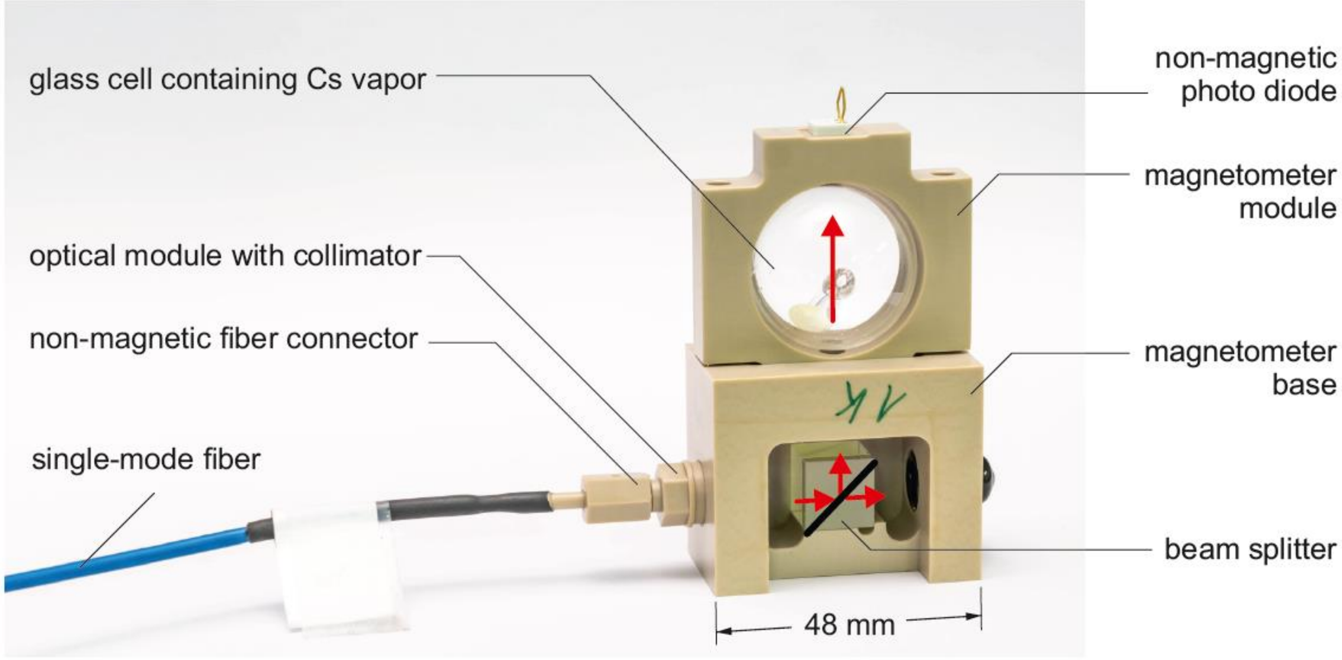
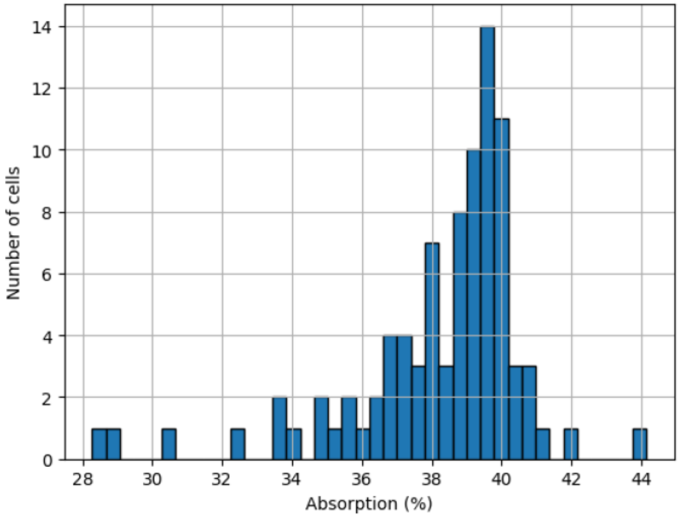


Cs magnetometer prototype



Cell testing

- Laser light absorption:



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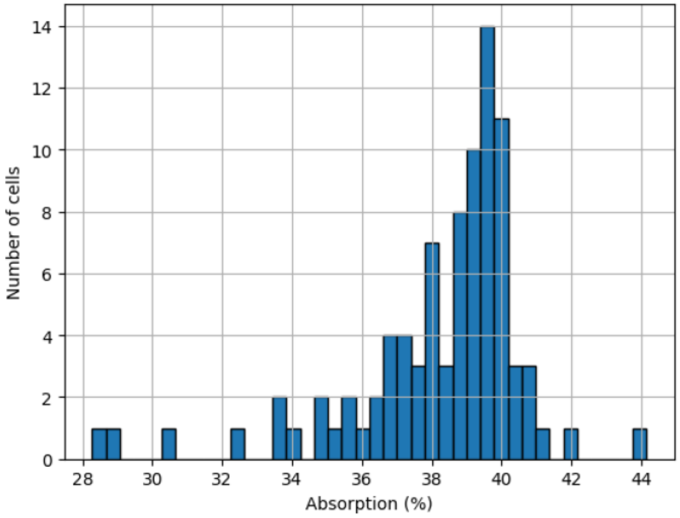
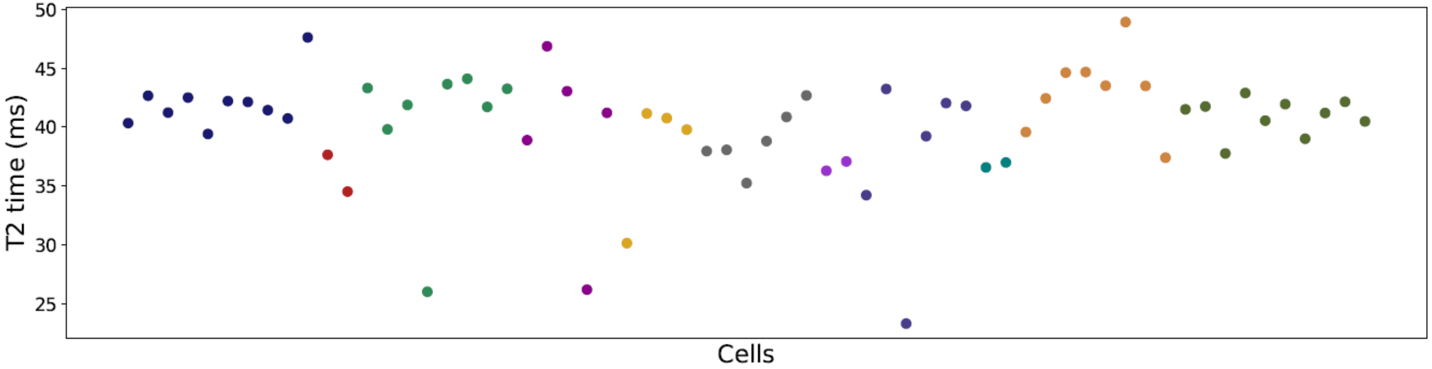
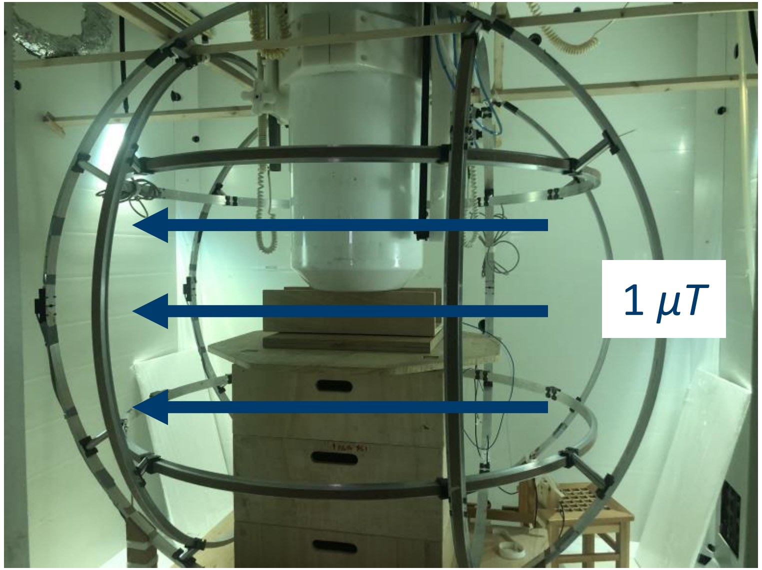


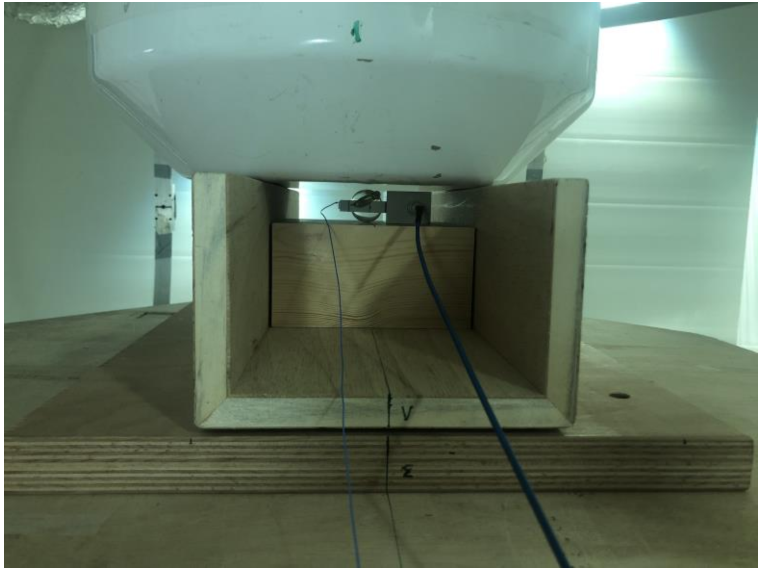
- T2 relaxation time:



Magnetometer stability

- Tested at BMSR-2, PTB Berlin





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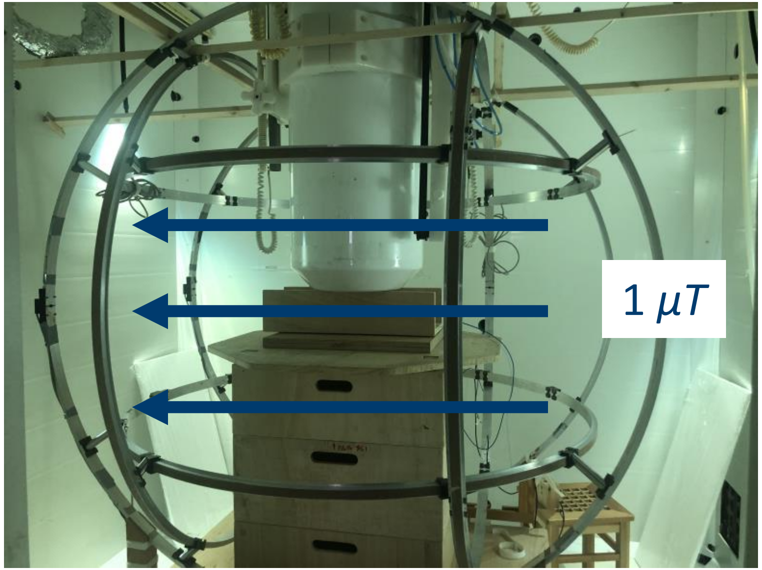
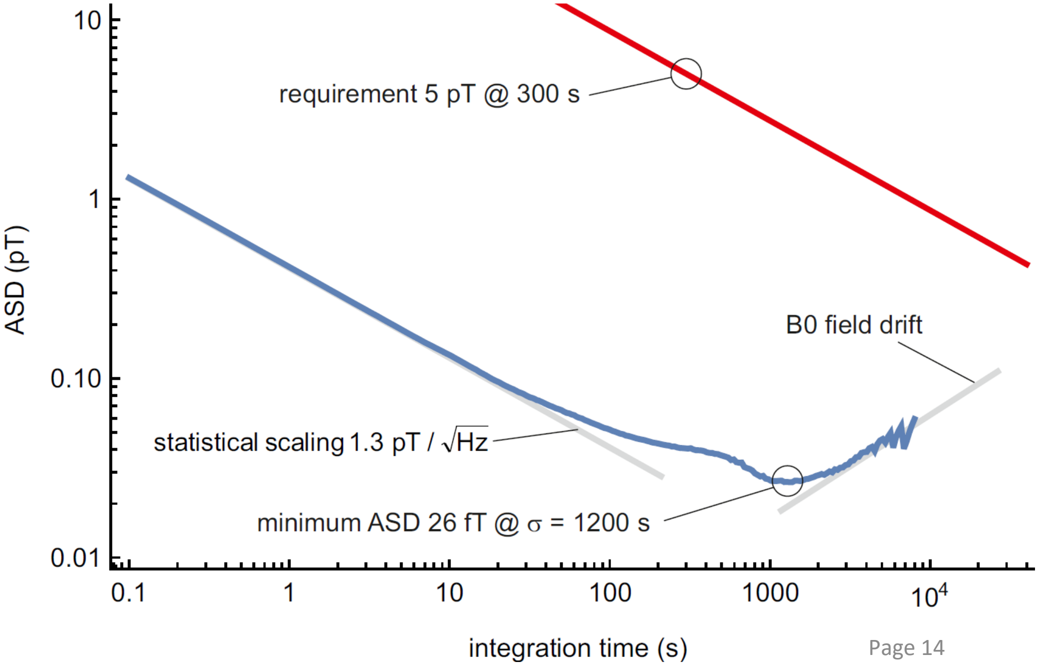
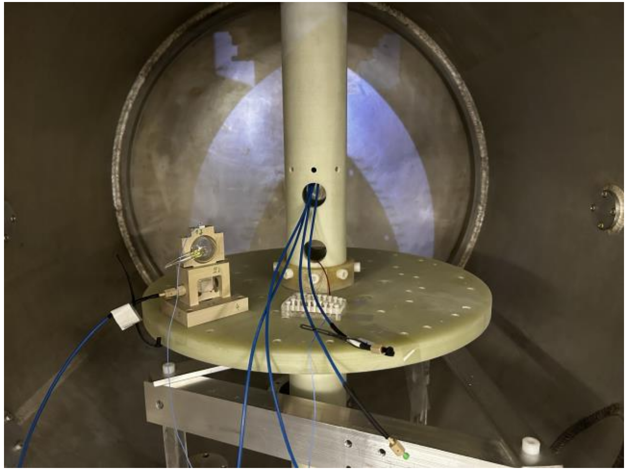




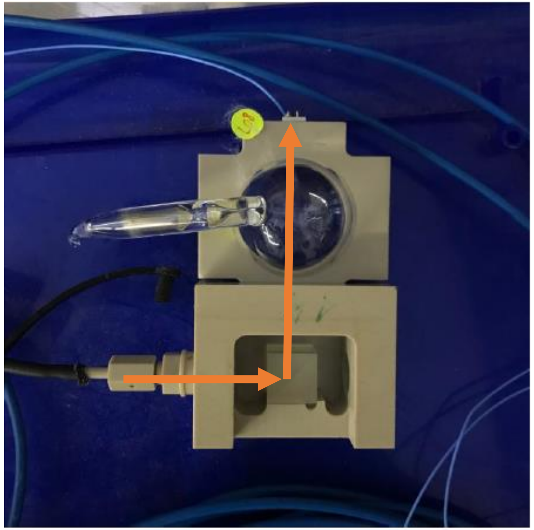
Summary and Outlook

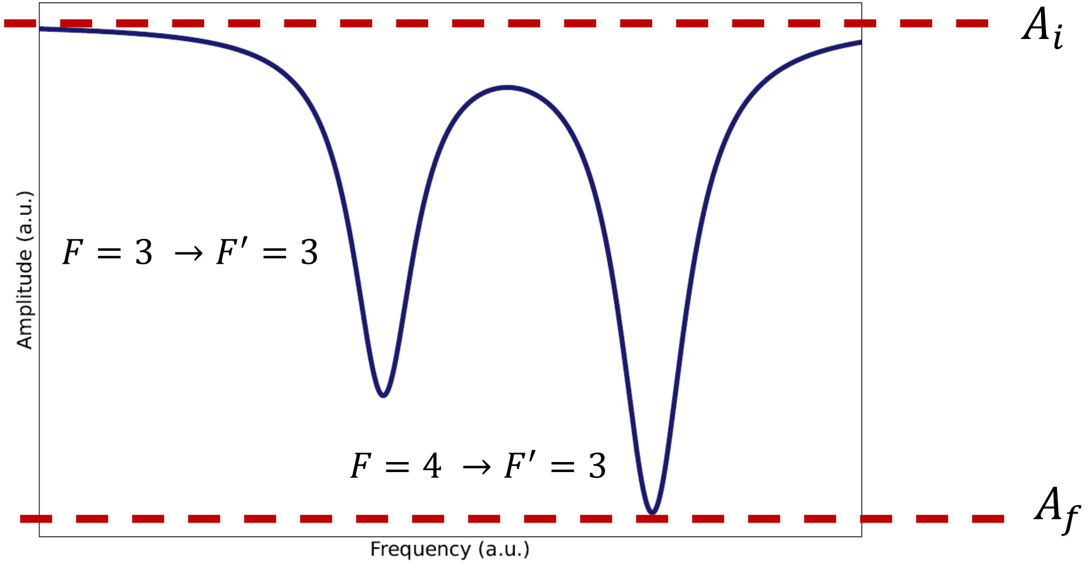
- 112 Cs magnetometers will be used in n2EDM
- Positioning has been optimised
- ~ 60 with optimal characteristics
- To be calibrated for intrinsic offset
- 8 plates (32 cells) to be installed early 2024



Thank you for your attention!

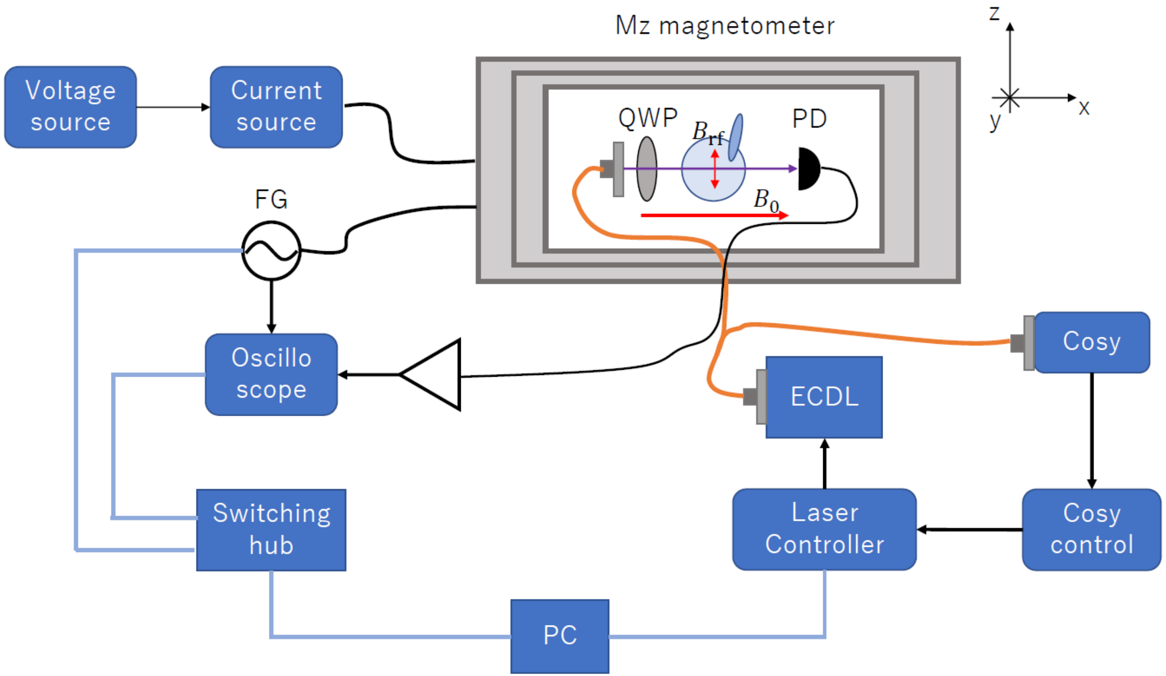
Testing Cs absorption



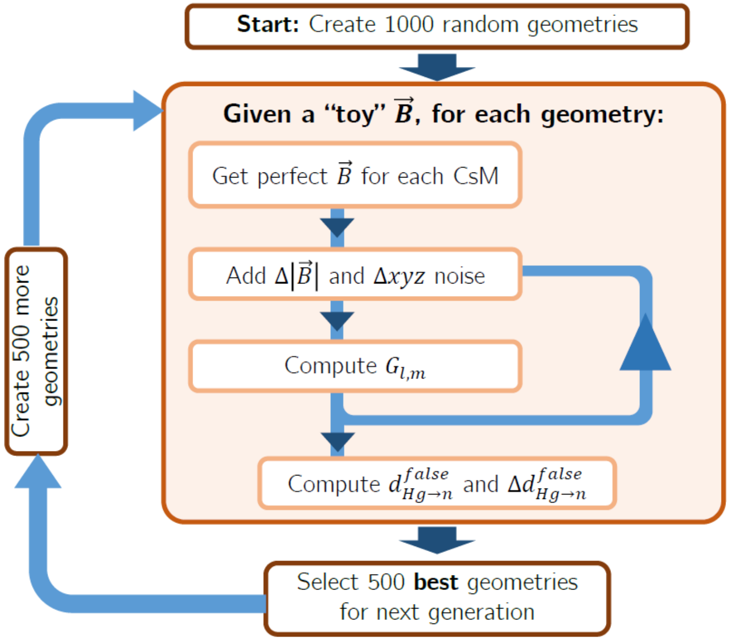


$$I = \frac{(A_i - A_f)}{A_i}$$

Measuring Cs T2 time



The genetic algorithm



Pais, D., nEDM2021 Workshop.