Considerations for a caesium magnetometer array for the n2EDM experiment

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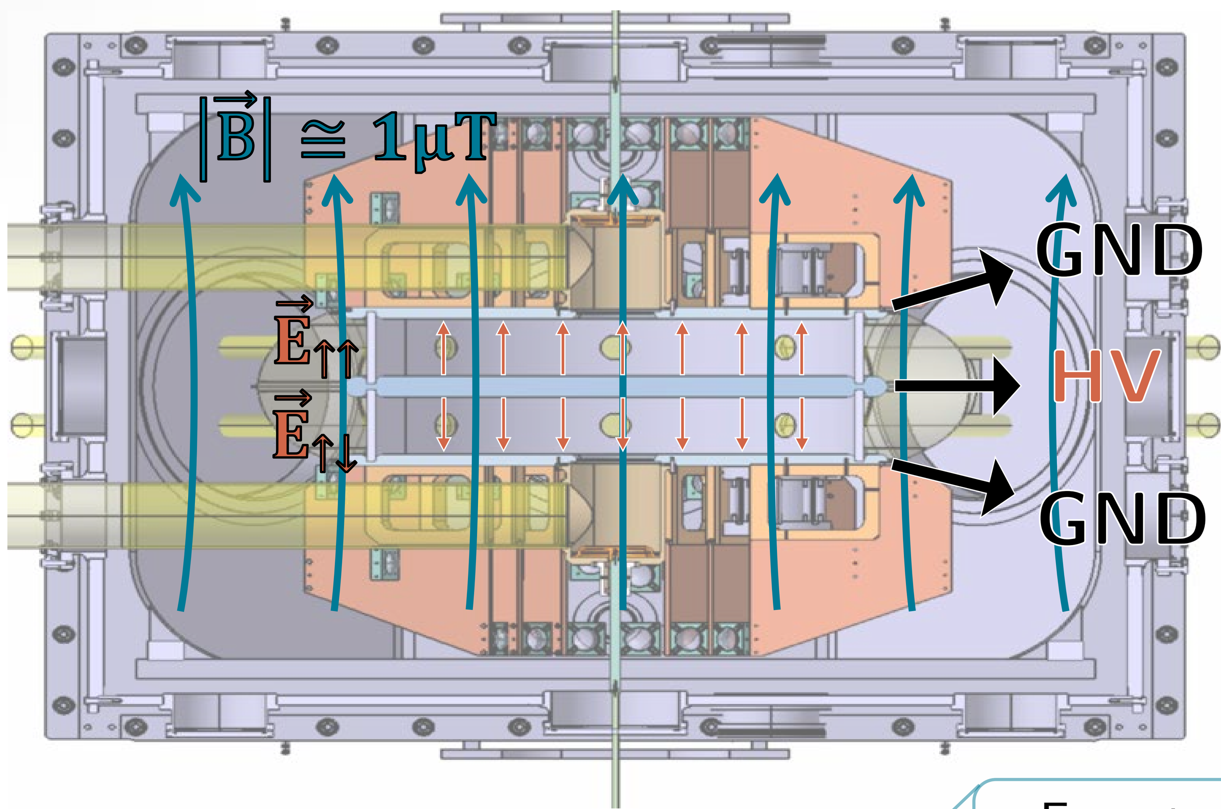
The n2EDM experiment

The apparatus consists in two identical chambers, where the spins of ultra cold neutrons (UCN) precess in the following configuration of electric and magnetic fields, with frequencies $\omega_{n,\uparrow\uparrow}$ and $\omega_{n,\uparrow\downarrow}$[1].



A neutron electric dipole moment

$$d_n = \frac{\hbar}{4E}(\omega_{n,\uparrow\uparrow} - \omega_{n,\uparrow\downarrow}) \qquad (1)$$

may then provide insight into the baryon asymmetry of the universe, as a source of CP violation, and into new physics [2].

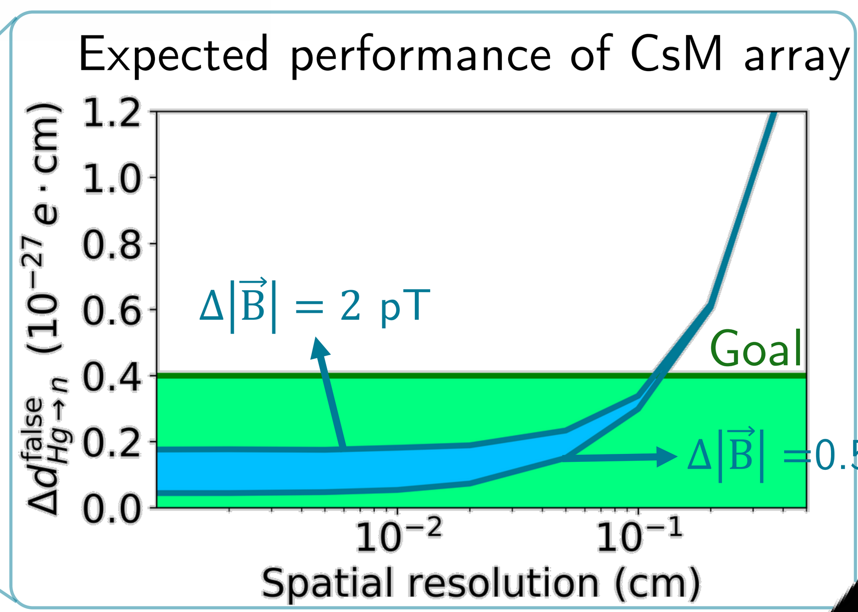
Problem

A mercury comagnetometer (HgM), samples the same volume as the UCN. Its reading compensates the effect of $\vec{B}$ fluctuations on $\omega_{n,\uparrow\uparrow}$ and $\omega_{n,\uparrow\downarrow}$

… but …

this correction leads to a systematic shift of Eq. 1 by $d^{false}_{Hg\to n}$ (Eq. 3) [3,4], since

$$|\langle\vec{B}\rangle| - \langle|\vec{B}|\rangle = \frac{\omega_{Hg}}{\gamma_{Hg}} - \frac{\omega_n}{\gamma_n} \neq 0 \qquad (2)$$



Solution to $d^{false}_{Hg\to n}$

An array of caesium magnetometers (CsM) with an optimised geometry, allows the calculation the magnetic field gradients $G_{l,m}$ [4] and of

$$d^{false}_{Hg\to n} = -\frac{\hbar\gamma_n\gamma_{Hg}}{2c^2}\sum_{l=1}^{\infty} G_{l,m=0}\langle\rho\Pi^{\rho}_{l,m=0}\rangle, \qquad (3)$$

with the goal of

$$\Delta d^{false}_{Hg\to n} \leq 4\times 10^{-28}\ e\cdot cm.$$

This is based on the assumption that

$$\sum_{l=1}^{\infty} G_{l,m=0}\langle\rho\Pi^{\rho}_{l,m=0}\rangle = \langle xB_x + yB_y\rangle. \quad (4)$$

Why ^{133}Cs?

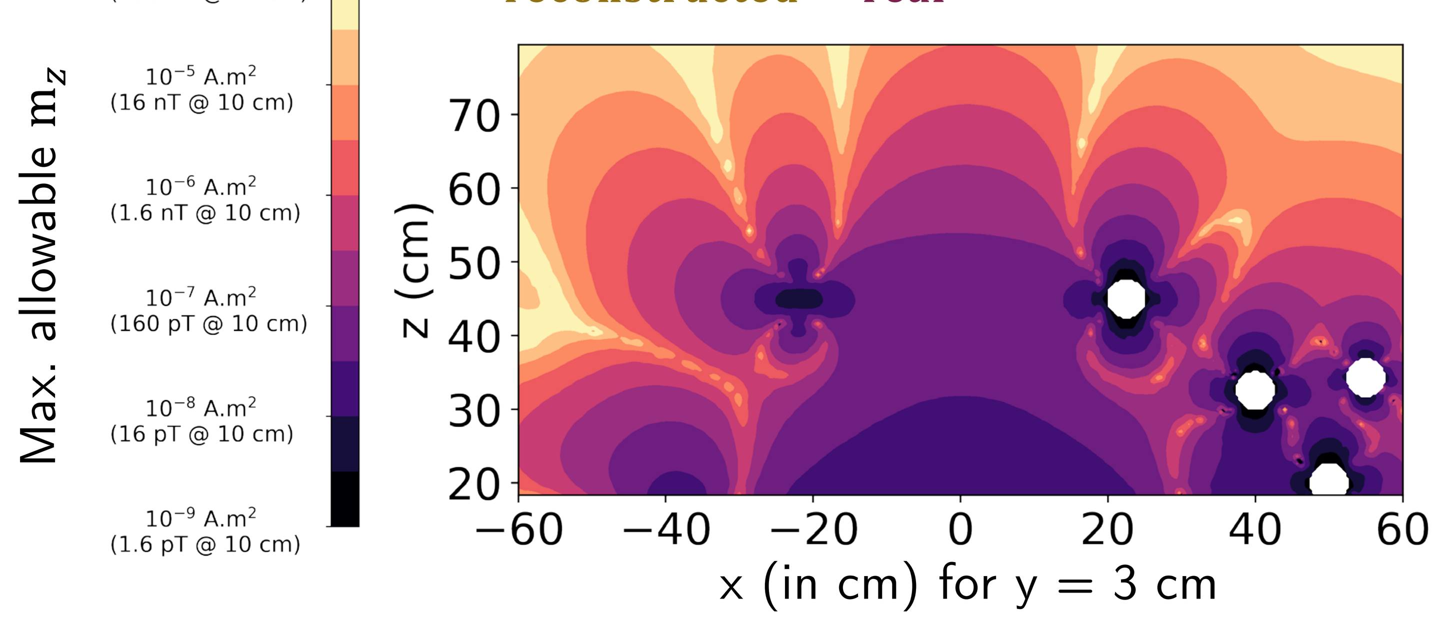
- Saturated vapour at room temperature
- Well resolved hyperfine levels
- No need for buffer gas
  - 30 ms T2 time assured by anti-relaxation coating

Magnetic contaminants

The inevitable contamination of magnetic dipoles (e.g. magnetisable dust, screws, etc.) in the n2EDM experiment dictates that

$$\underbrace{-\frac{\hbar\gamma_n\gamma_{Hg}}{2c^2}\langle xB_x + yB_y\rangle}_{d^{false}_{real}} \neq \underbrace{-\frac{\hbar\gamma_n\gamma_{Hg}}{2c^2}\sum_{l=1}^{\infty} G_{l,m=0}\langle\rho\Pi^{\rho}_{l,m=0}\rangle}_{d^{false}_{reconstructed}}$$

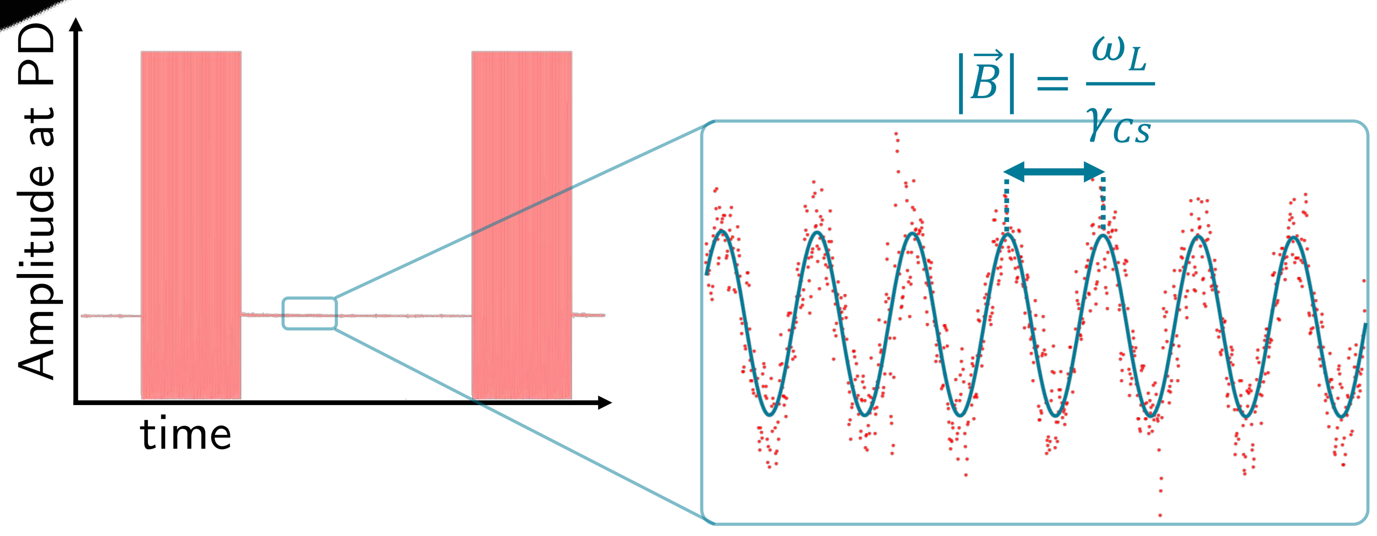
$$|d^{false}_{reconstructed} - d^{false}_{real}| \leq 4\times 10^{-29} e\cdot cm$$



Such a map of the whole volume gives the limit of the allowable dipole strengths m_z, below which their effect on the CsM array's performance is negligible.

CsM characteristics

The chosen sensor measures $|\vec{B}|$ and is of Bell-Bloom type [5,6]. Amplitude modulated and linearly polarised light resonant on the appropripriate electronic transition during the pumping regime leads to the precession of the aligned spin ensemble. A typical signal recorded by a photodiode (PD) looks like:



References

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