News on the mercury magnetometer for the nEDM experiment at PSI

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on behalf of the nEDM collaboration

Why search for a nEDM?

Obvious but unexplained baryon asymmetry in the Universe:
Where has all the anti-matter gone?

Observed:

$$\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-10}$$

Sakharov 1967:
- B-violation
- C & CP-violation
- thermal non-equilibrium (JETP Lett. 5 (1967) 24)

SM expectation:

$$\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-18}$$

The discovery of a nEDM would indicate a yet unobserved source of CP violation.

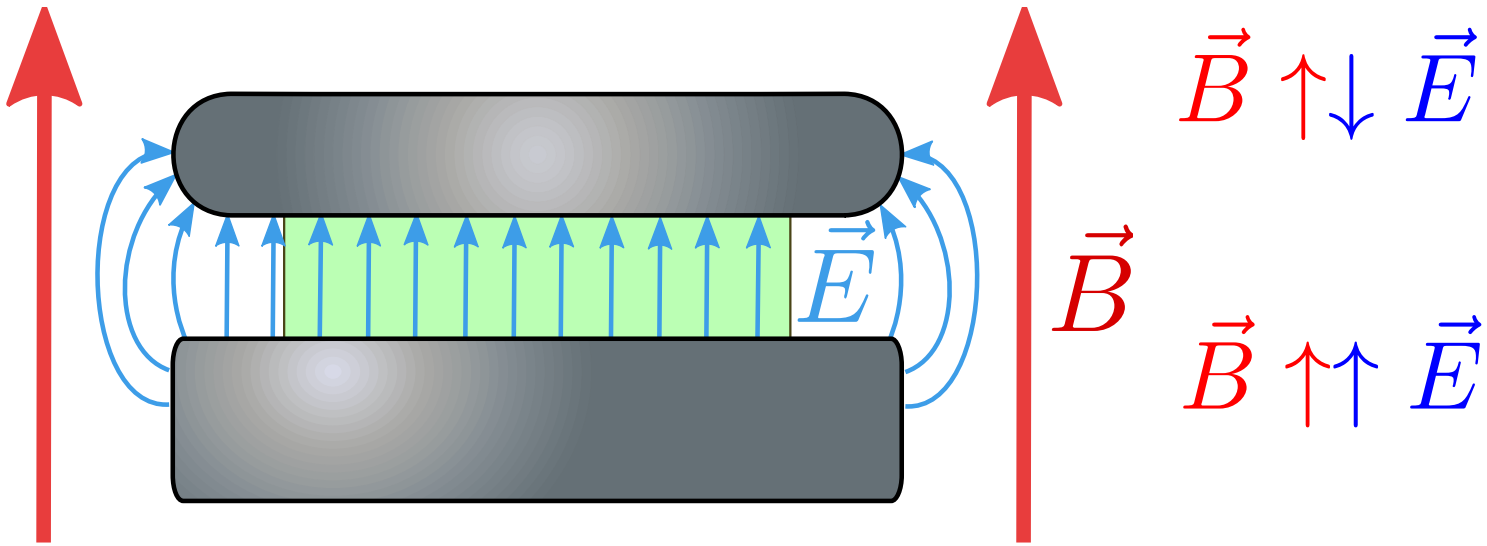
CP violation and nEDM

$$H = -2\left(d\vec{s}\cdot\vec{E} + \mu\vec{s}\cdot\vec{B}\right)$$

A non-zero particle EDM violates *P, T* and, assuming *CPT* conservation, also *CP.*

Search for the electric dipolemoment of the neutron

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



Search for the electric dipolemoment of the neutron

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

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

Major source for systematic effects

Sensitivity requirements

→ Current limit: *C.A.Baker et al., PRL 97 (2006) 131801*

$$\mathbf{d_n < 2.9 \times 10^{-26} e\ cm}$$

→ Sensitivity goal for the nEDM@PSI: 200 days of measuring

$$\mathbf{d_n < 5 \times 10^{-27} e\ cm}$$

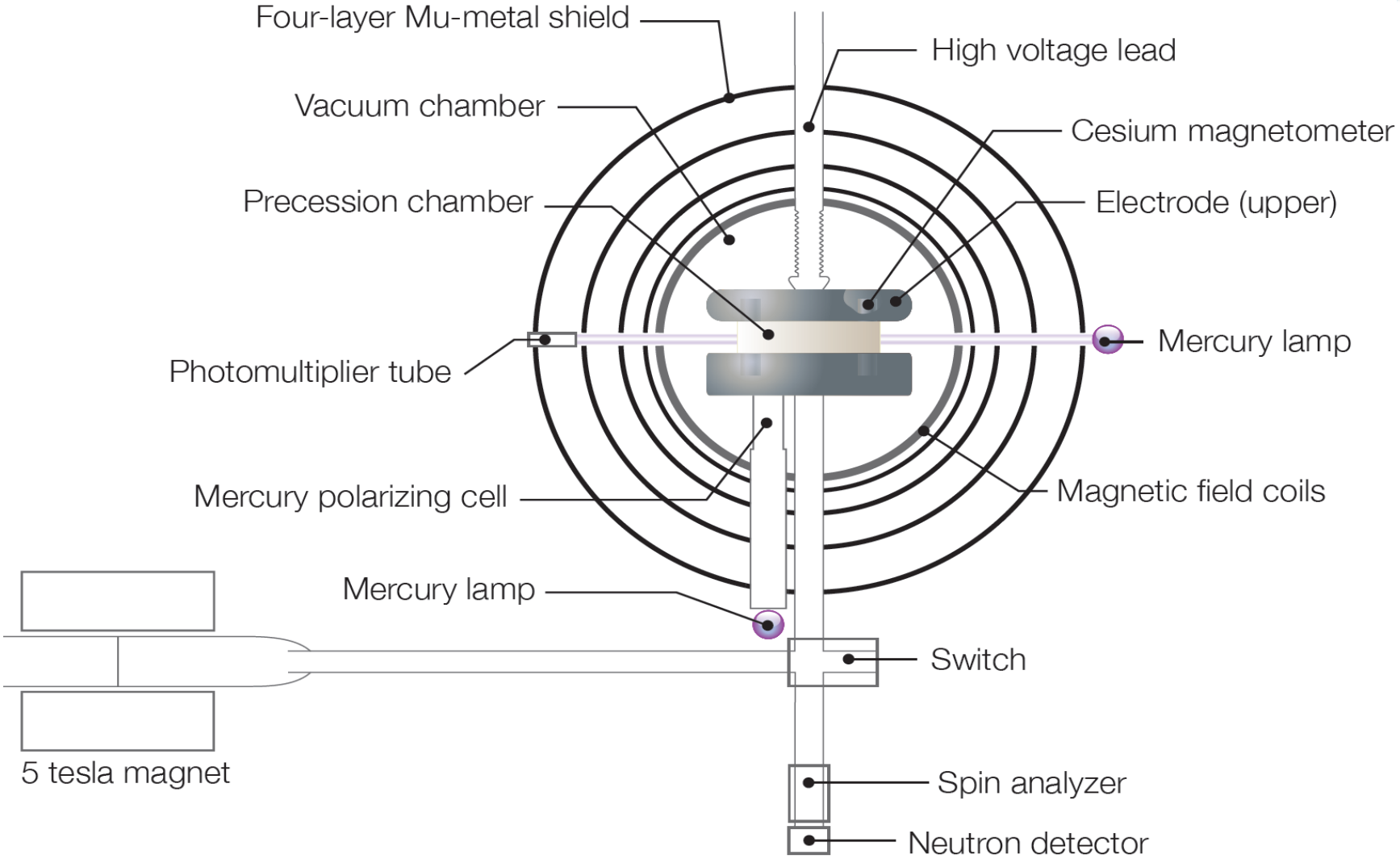
→ Sensitivity goal for our magnetometer:

The uncertainty in a change of the Lamor frequency induced by an magnetic field changes has to be smaller than the frequency change caused by an nEDM

$$\boldsymbol{\sigma(\Delta B) \leq 100 fT}$$

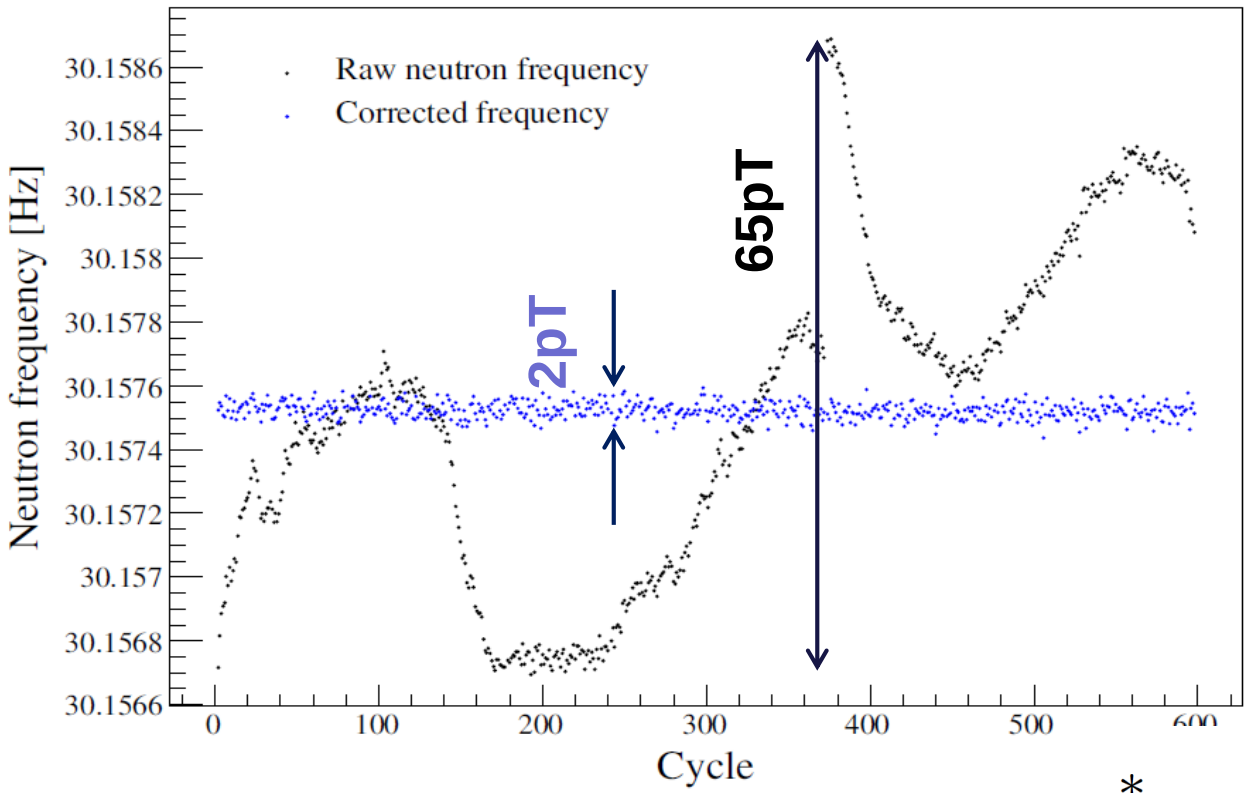
→ And a ten times higher sensitivity goal for n2EDM

The nEDM apparatus



surrounding field compensation

Performance of the Hg-Comagnetometer



$$\nu_n^* = \nu_n + \frac{\gamma_n}{\gamma_{Hg}} \delta\nu_{Hg}$$

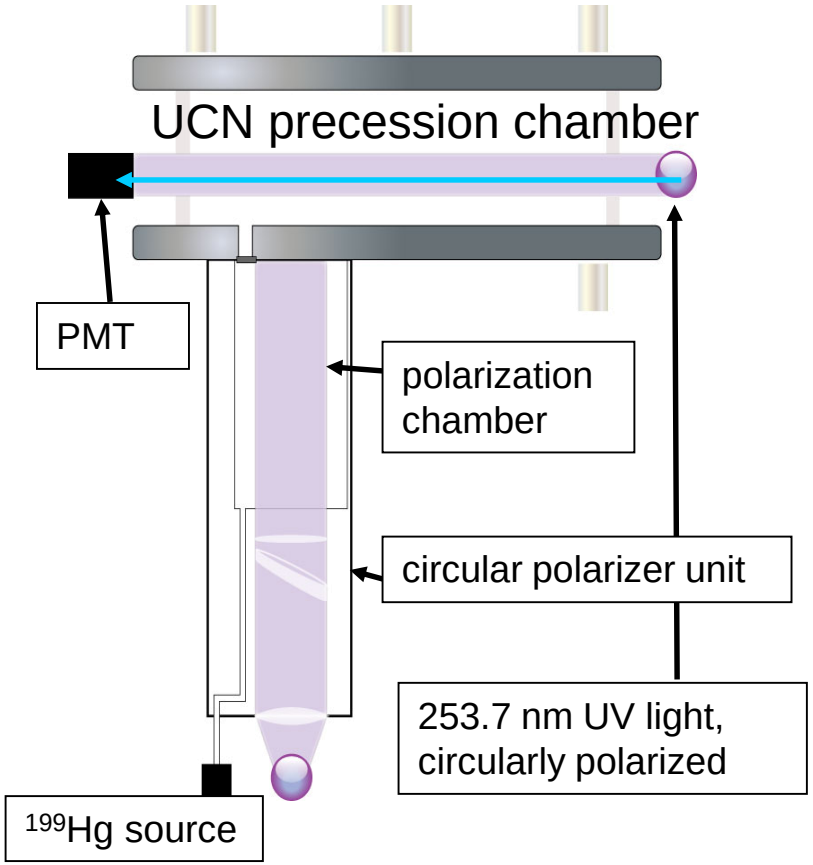
corrected UCN frequency

raw

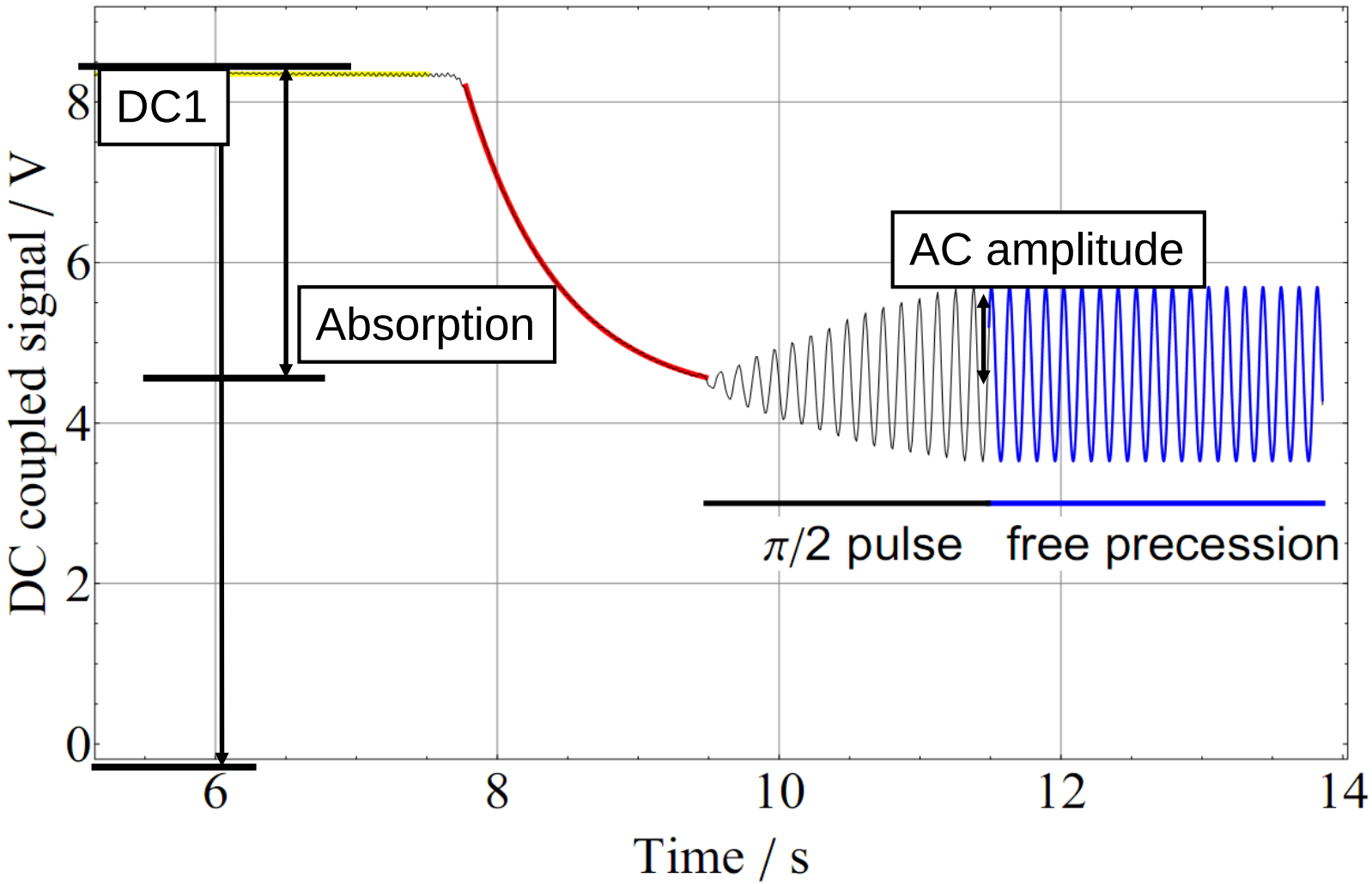
gyromagnetic ratios

Hg-Comagnetometer

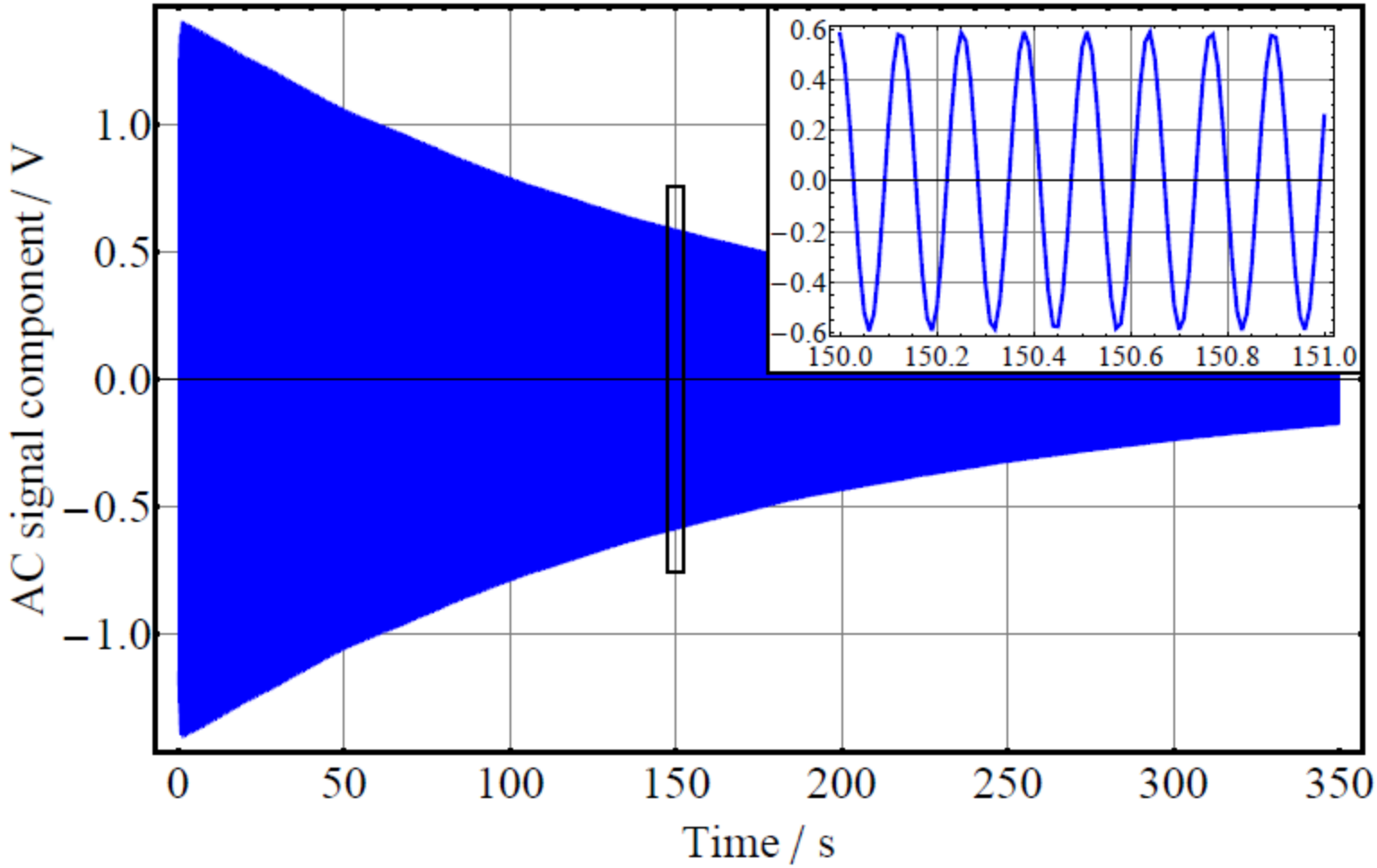
→ Measure residual magnetic field drifts with **optically detected nuclear magnetic resonance (ODMR)**



Hg-Comagnetometer



Hg-Comagnetometer



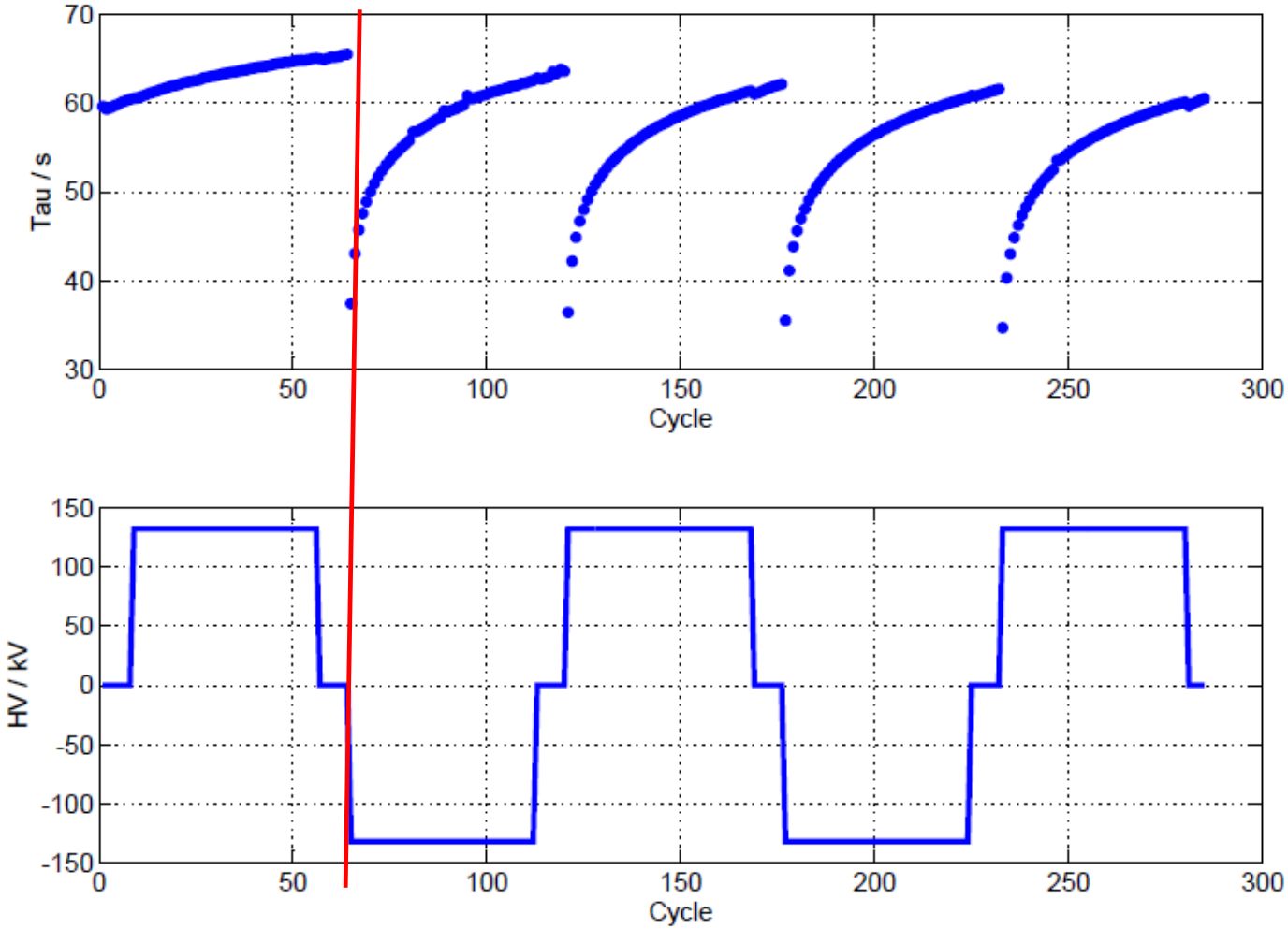
Depolarization rate: dominated by wall collisions

Influence of HV to T2

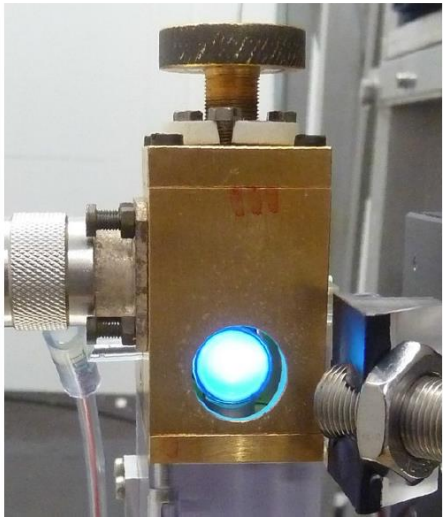
→ Behavior of T2 still not understood completely

Room for improvements

Depolarization Time drops dramatically with each polarity change of the HV



Exchanging the light source



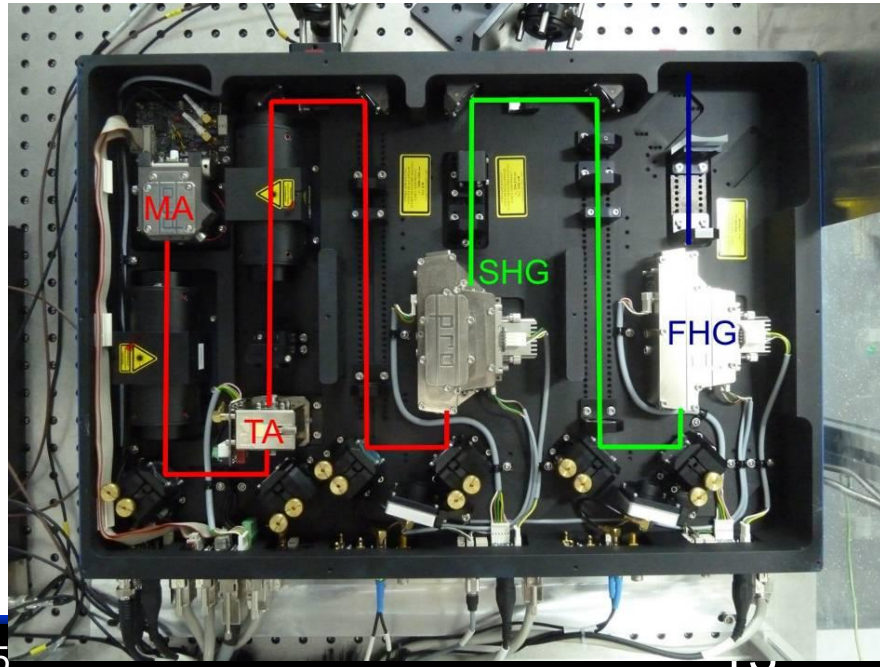
current light sources: ^{204}Hg discharge bulbs
→ Large uncertainty on the output frequency spectrum

- self absorption
- Temperature changes
- Light cannot be focused / collimated
- Emission lines are Doppler-broadend
- …..

Planned light source: UV laser system

FHG (fourth harmonic generator):
IR → Vis → UV

- Higher intensity
- Much lower frequency range of the light



Conclusion

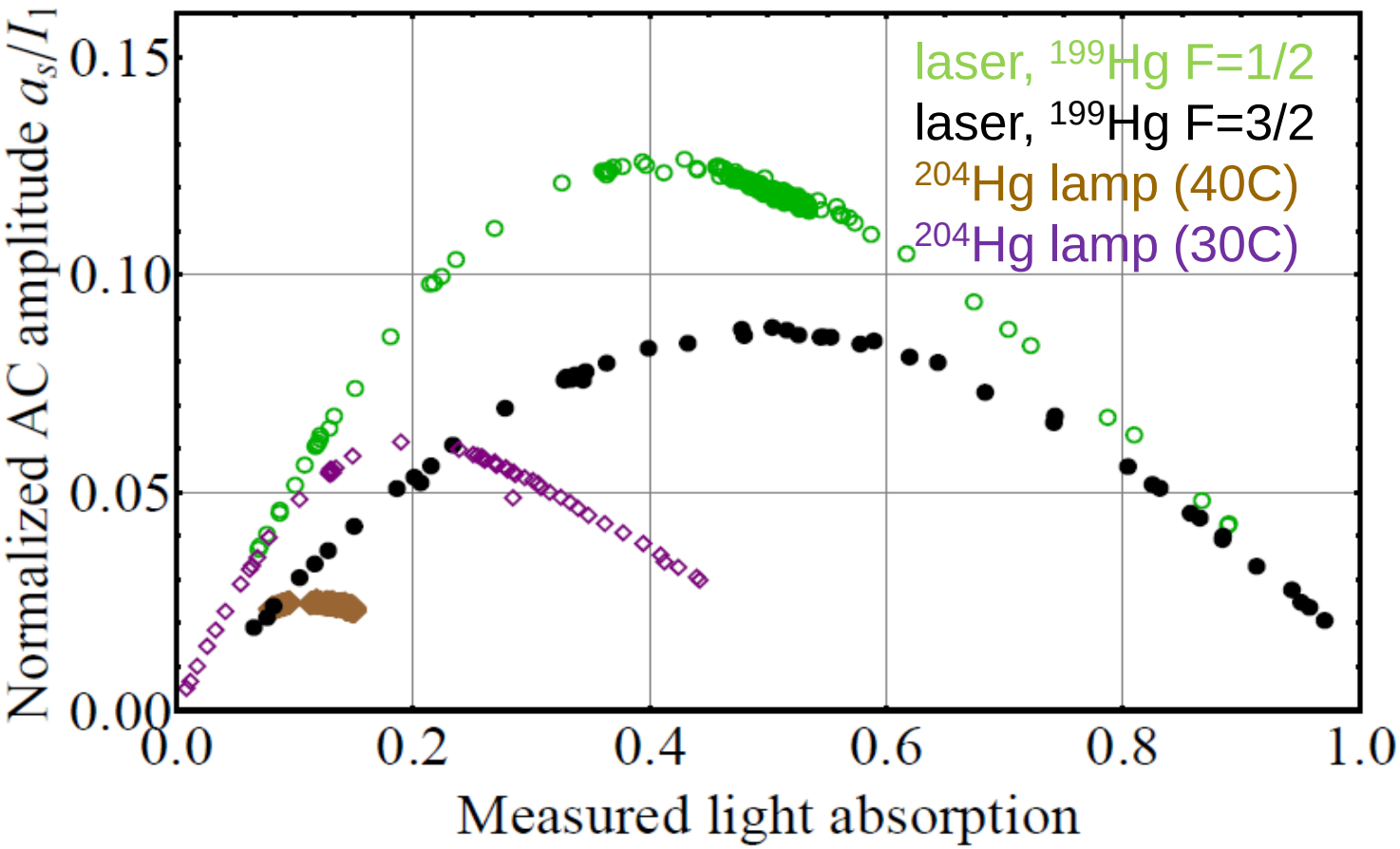
- The nEDM experiment is a very sensitive probe for the SM
- We are taking data at the moment.
- Magnetic field fluctuation are well under control.

- But for the next generation experiment n2EDM we have to improve the performance of the Hg magnetometer.
- Still much room for improvements and not yet understood behavior of the Hg.

Thank you!

tests @ nEDM with laser

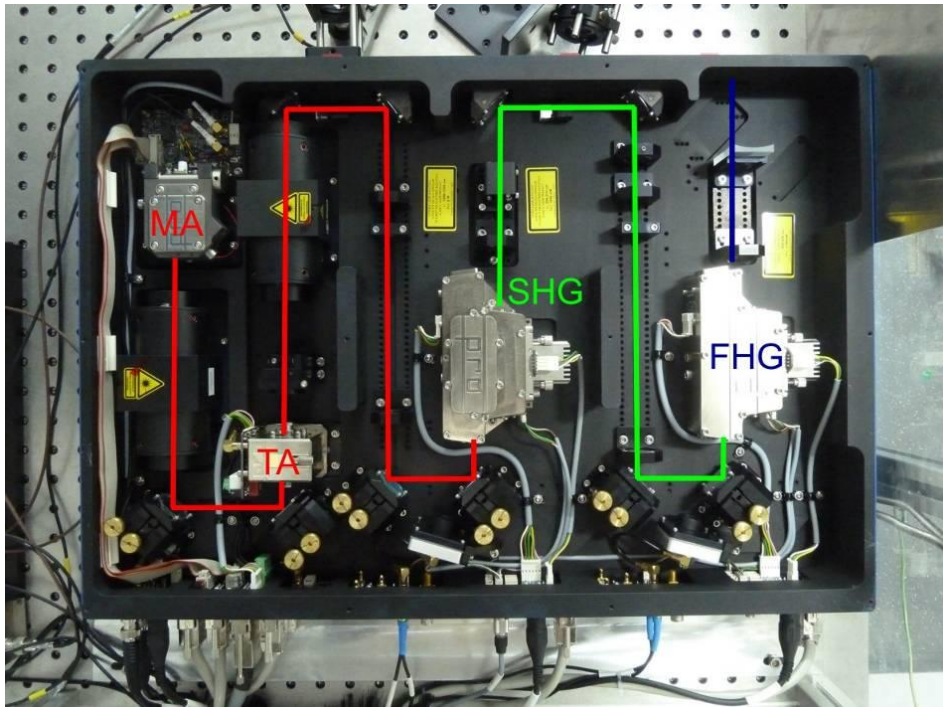
→ transport of the UV laserlight via a 50m multimode fiber from the lab to the experiment (proof of principle)



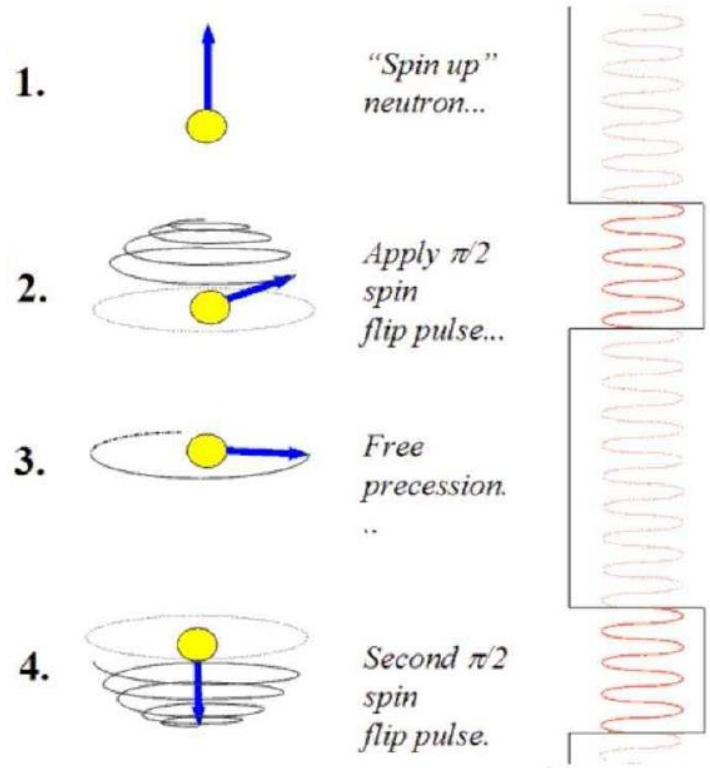
UV laser system

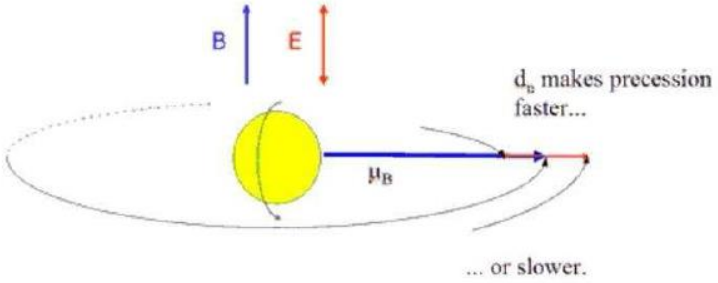
FHG (fourth harmonic generator): IR → Vis → UV

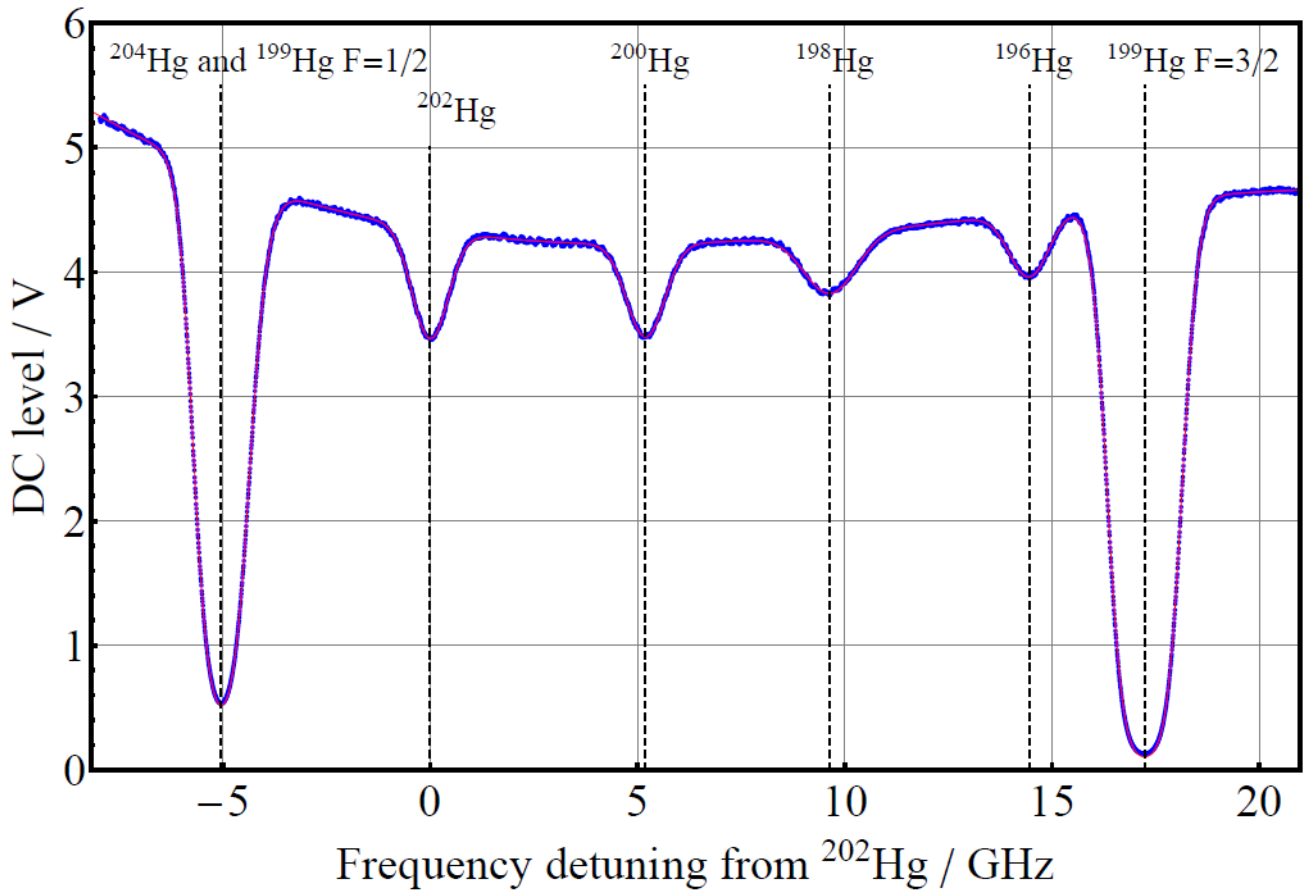
- System from Toptica: 20mW@ 254nm
- Installed in a testlab, 50m away from the nEDM experiment
- Frequency stabilization via Sub-Doppler Dichroic Atomic Vapor Laser Lock (SD-DAVLL)

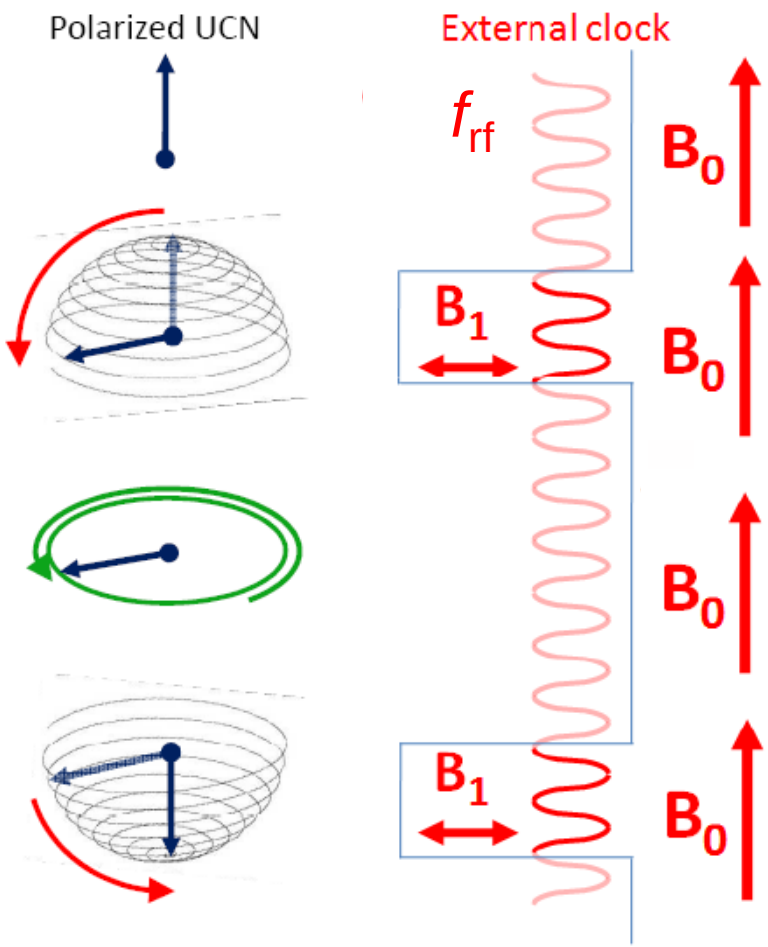


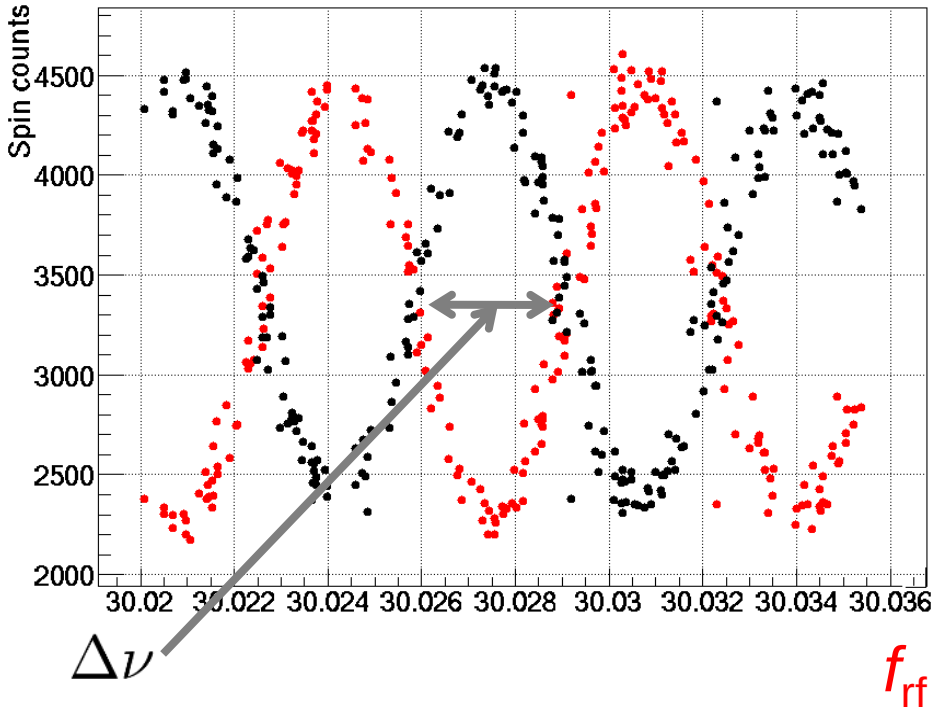
Ramsey's resonance technique






204Hg and 199Hg F=1/2
202Hg
200Hg
198Hg
196Hg
199Hg F=3/2
DC level / V
Frequency detuning from 202Hg / GHz
0
1
2
3
4
5
6
−5
0
5
10
15
20





$$\sigma(f_n) = \frac{\Delta\nu}{\alpha\sqrt{N}\pi}$$