Search for macroscopic spin-dependent forces in the μm – cm range using the PNPI-ILL EDM experiment

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for the PNPI – ILL EDM collaboration

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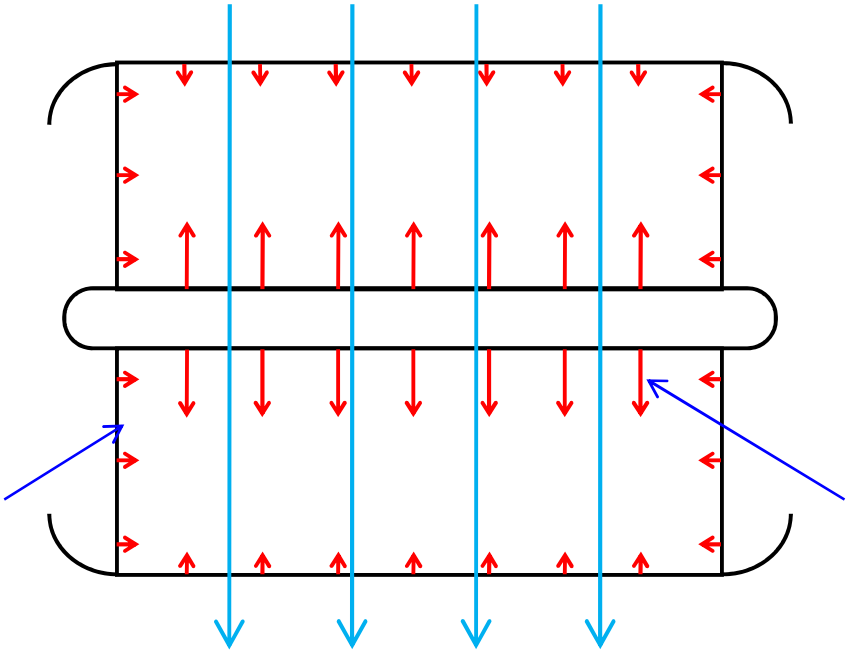
The EDM spectrometer setup at the ILL

Pseudo-magnetic fields in EDM spectrometer



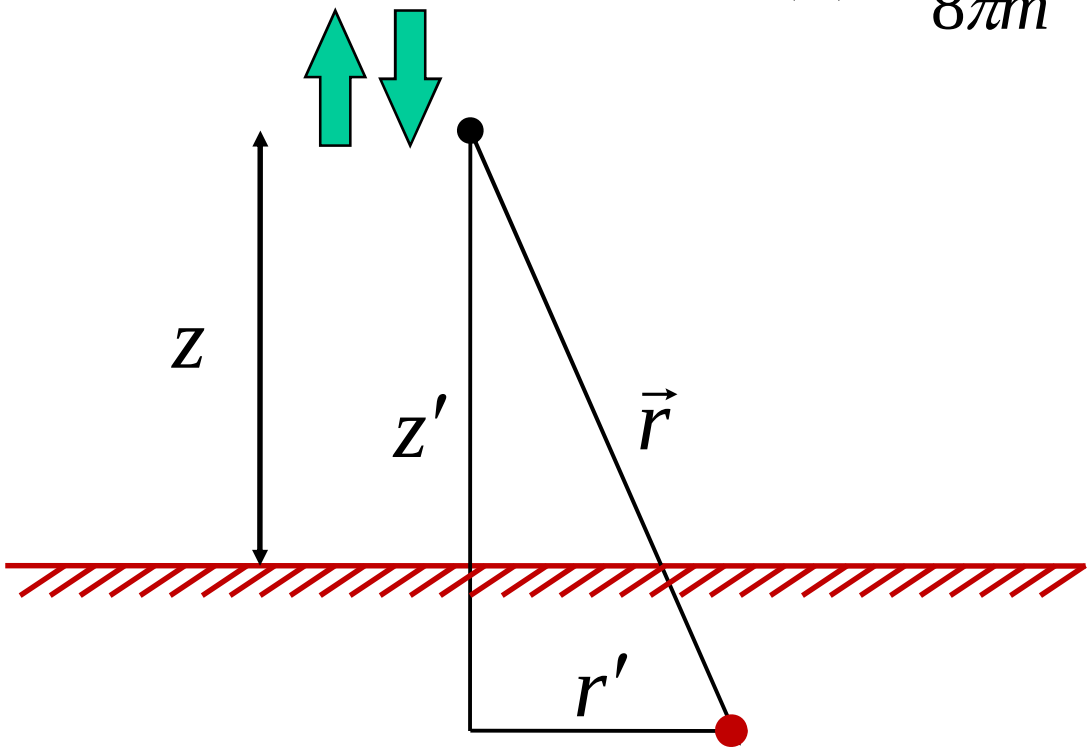
UCN depolarization
on vertical walls

shift of resonance
on horizontal walls

A. Serebrov, arXiv:0902.1056

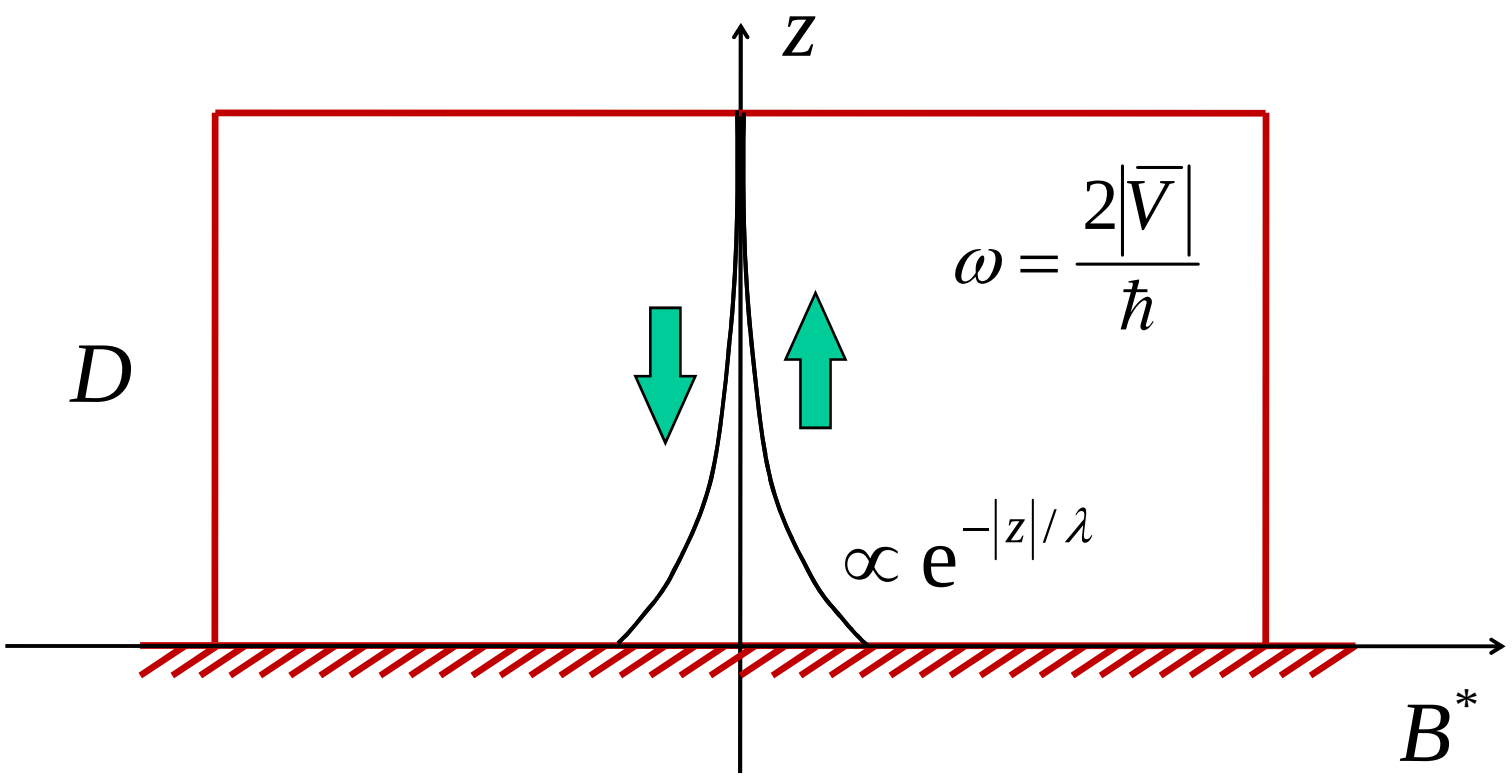
O. Zimmer, arXiv:0810.3215

$$V(\vec{r}) = \frac{\hbar^2}{8\pi m} g_s g_p \left(\frac{1}{\lambda r} + \frac{1}{r^2} \right) \mathrm{e}^{-r/\lambda} [\vec{n} \cdot \vec{\sigma}]$$

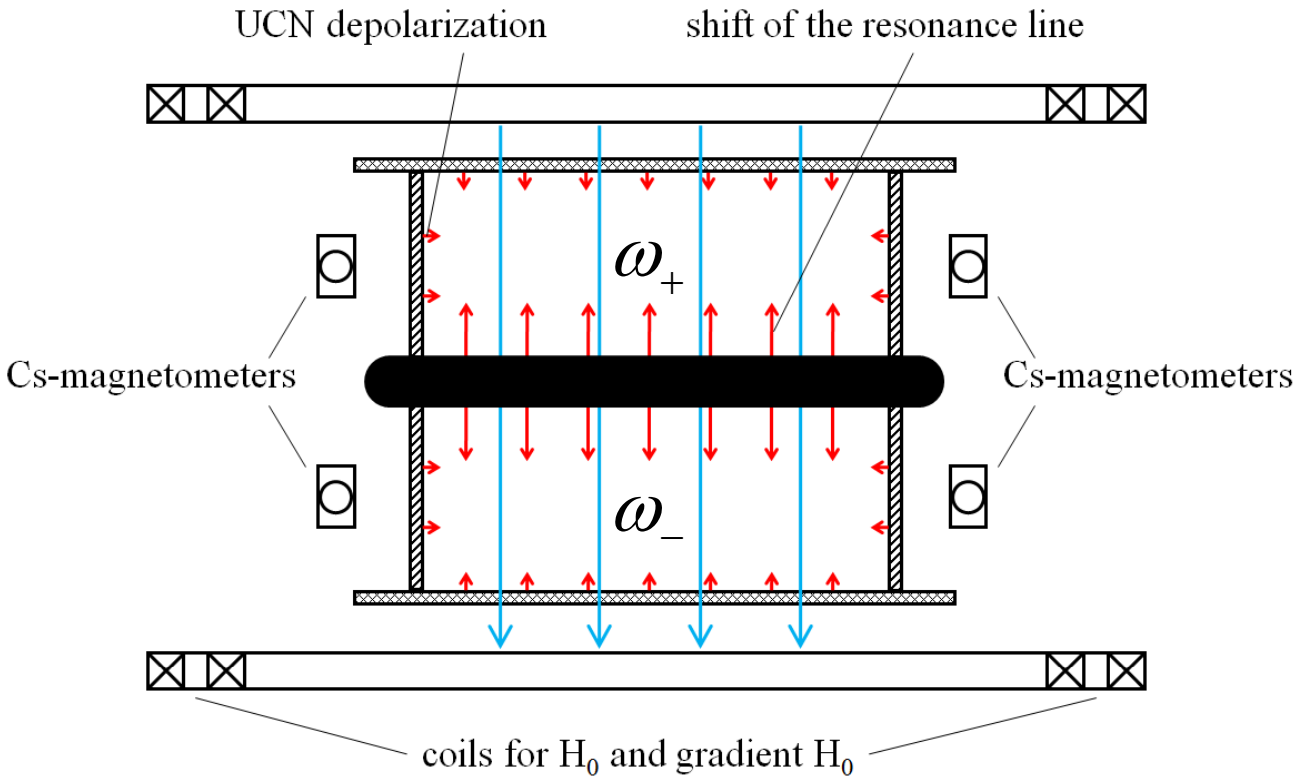


$$\vec{n} = \frac{\vec{r}}{r}$$

$$V(z) = \int_z^\infty \int_0^\infty V(\vec{r}) \mathrm{d}r' \mathrm{d}z' = \frac{\hbar^2}{4m} N g_s g_p \lambda \mathrm{e}^{-|z|/\lambda} \sigma_z$$



$$\bar{V} = \pm\frac{1}{D}\int_0^D V(z)\mathrm{d}z = \pm\frac{\hbar^2}{4m}N\frac{1-e^{-D/\lambda}}{D}g_s g_p \lambda^2$$

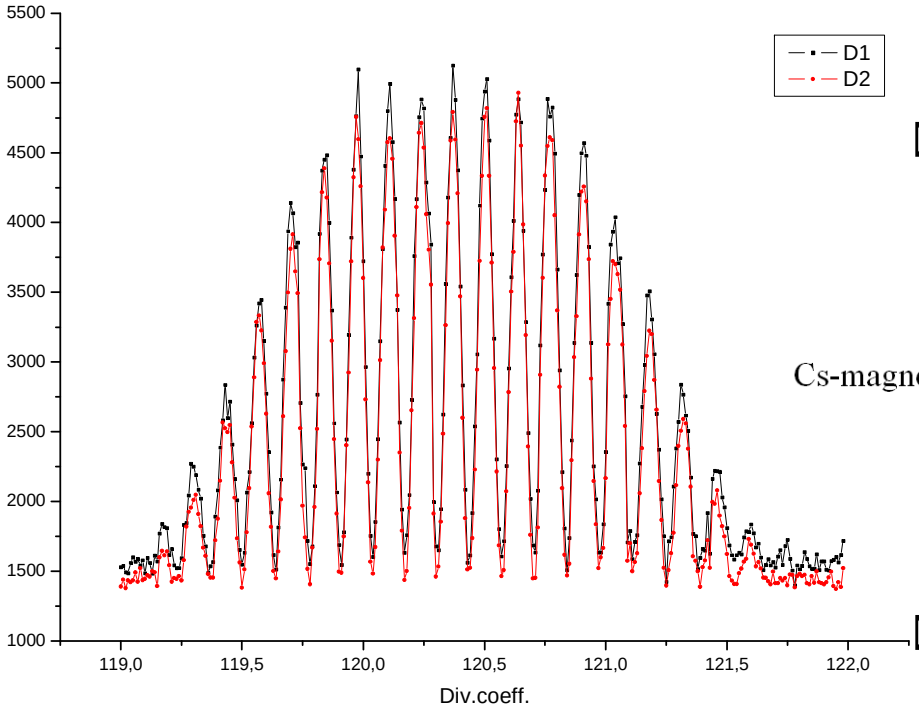


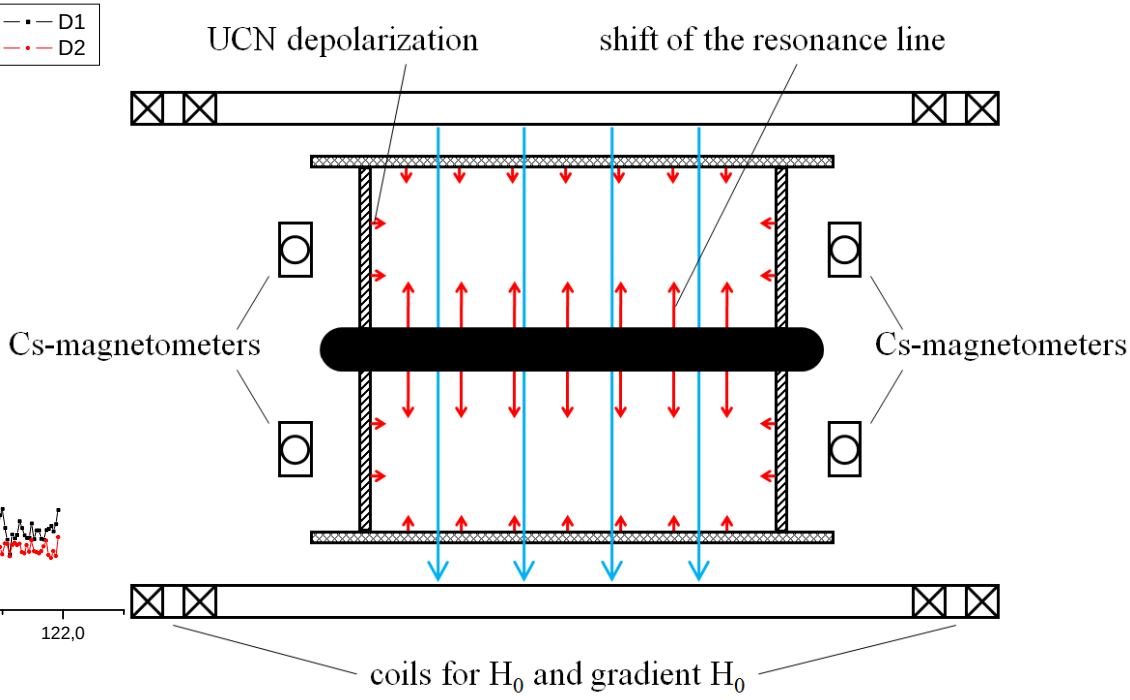
$$\Delta_{\pm}\omega = \omega_+ - \omega_- = \frac{4|\overline{V}|}{\hbar}$$

$$\Delta_{\uparrow\downarrow}\Delta_{\pm}\omega = (\Delta_{\pm}\omega)_{\uparrow} - (\Delta_{\pm}\omega)_{\downarrow} = \frac{8|\overline{V}|}{\hbar}$$

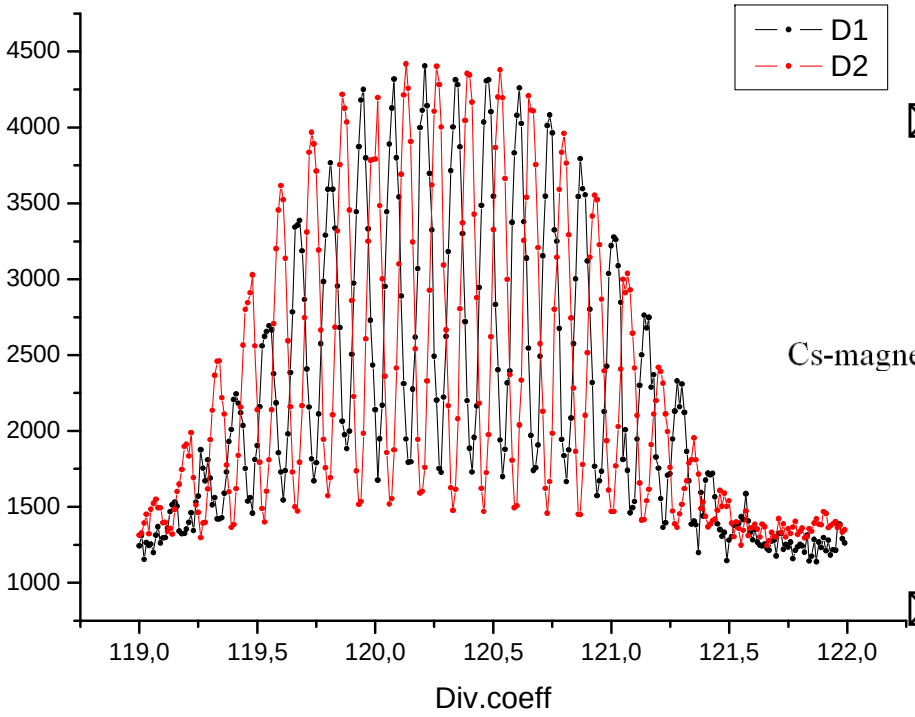
$$\Rightarrow \qquad \Delta\varphi = \frac{8|\overline{V}|}{\hbar}\tau \qquad\qquad g_s g_p \left(\frac{\lambda}{\mathrm{cm}}\right)^2 = 1.04\times10^{-22}\,\Delta\varphi_{\mathrm{Cu}}$$

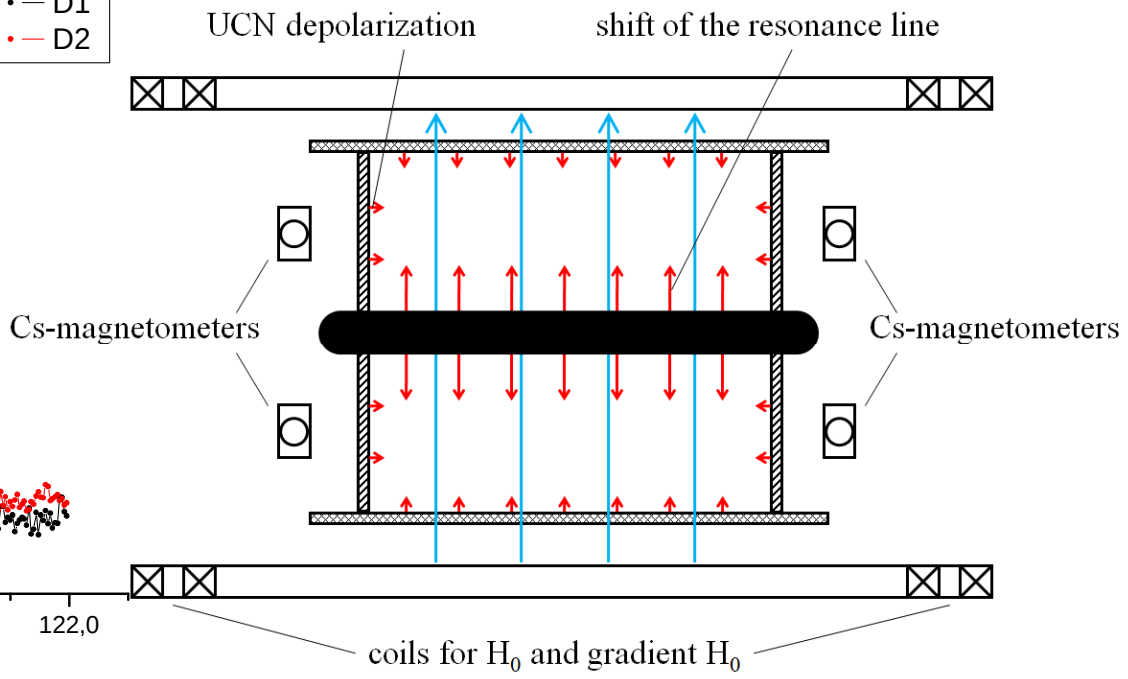
Measurement of Ramsey resonances in the double-chamber EDM spectrometer



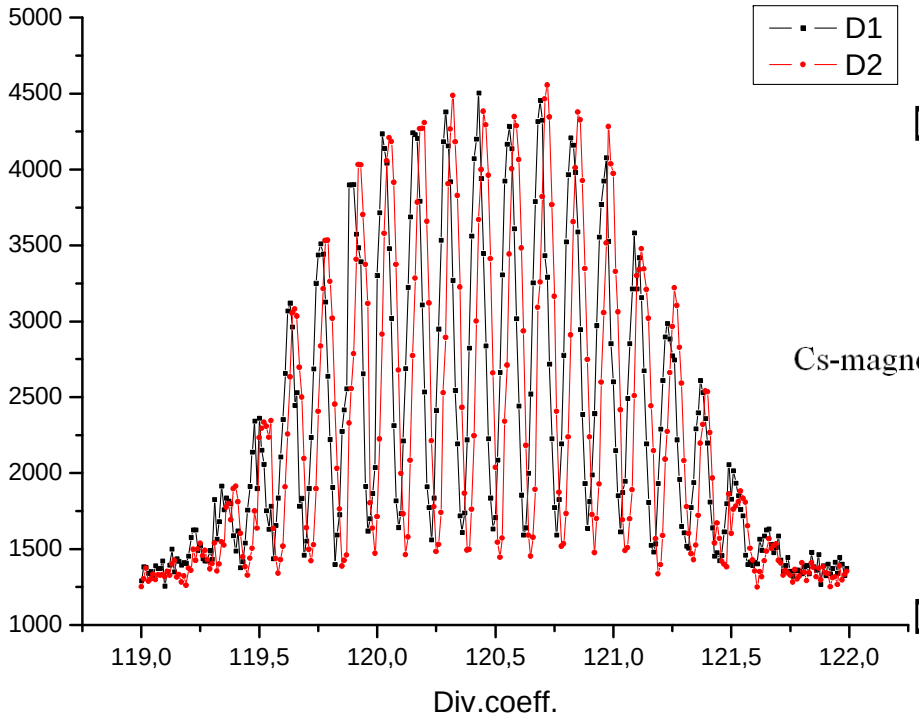


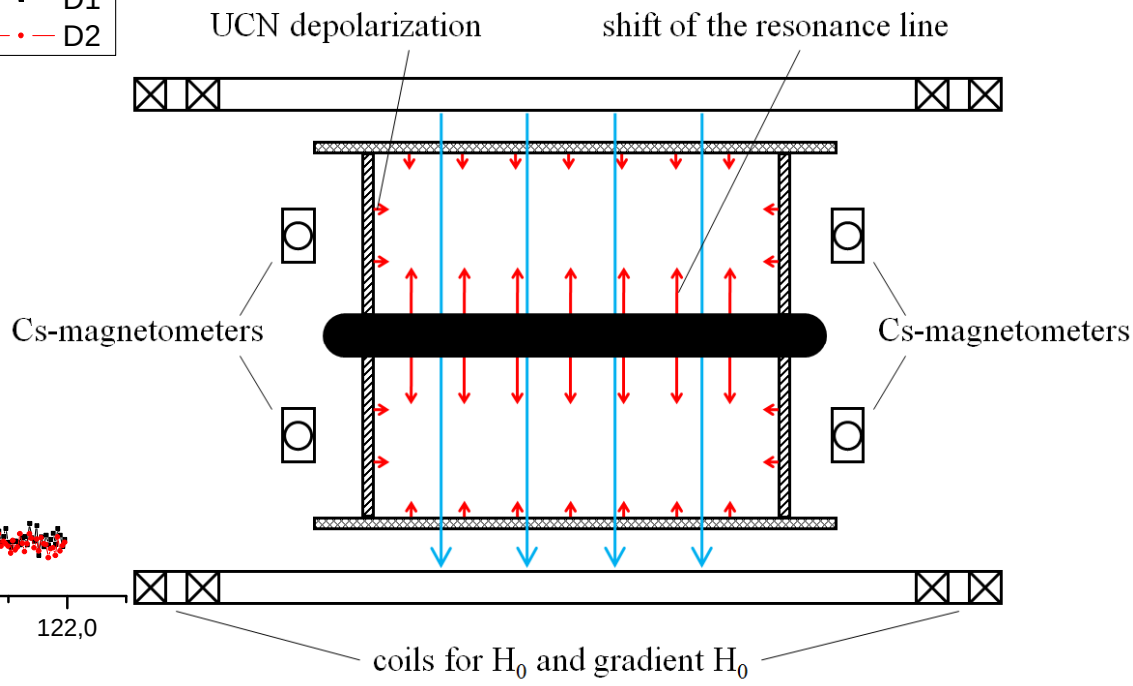
magnetic field down





magnetic field up





magnetic field down again

H_{up}	H_{down}
φ_{up}	φ_{down}
3.5°	
	231.7°
-73.7°	
-27.8°	
29°	
37.9°	
	297°
	300°
231°	
-306.5°	
	-17°
	180°
	180°
-15.23±160.3	195.28±116.76

$\Delta\varphi$ = -210° ± 198°
$\Delta H \sim 1.2 \pm 1.2$ nT

with copper plate:

$$\Delta\varphi_{\mathrm{Cu}} = \left(185^0 \pm 145^0\right) - \left(145^0 \pm 164^0\right) = 40^0 \pm 218^0$$

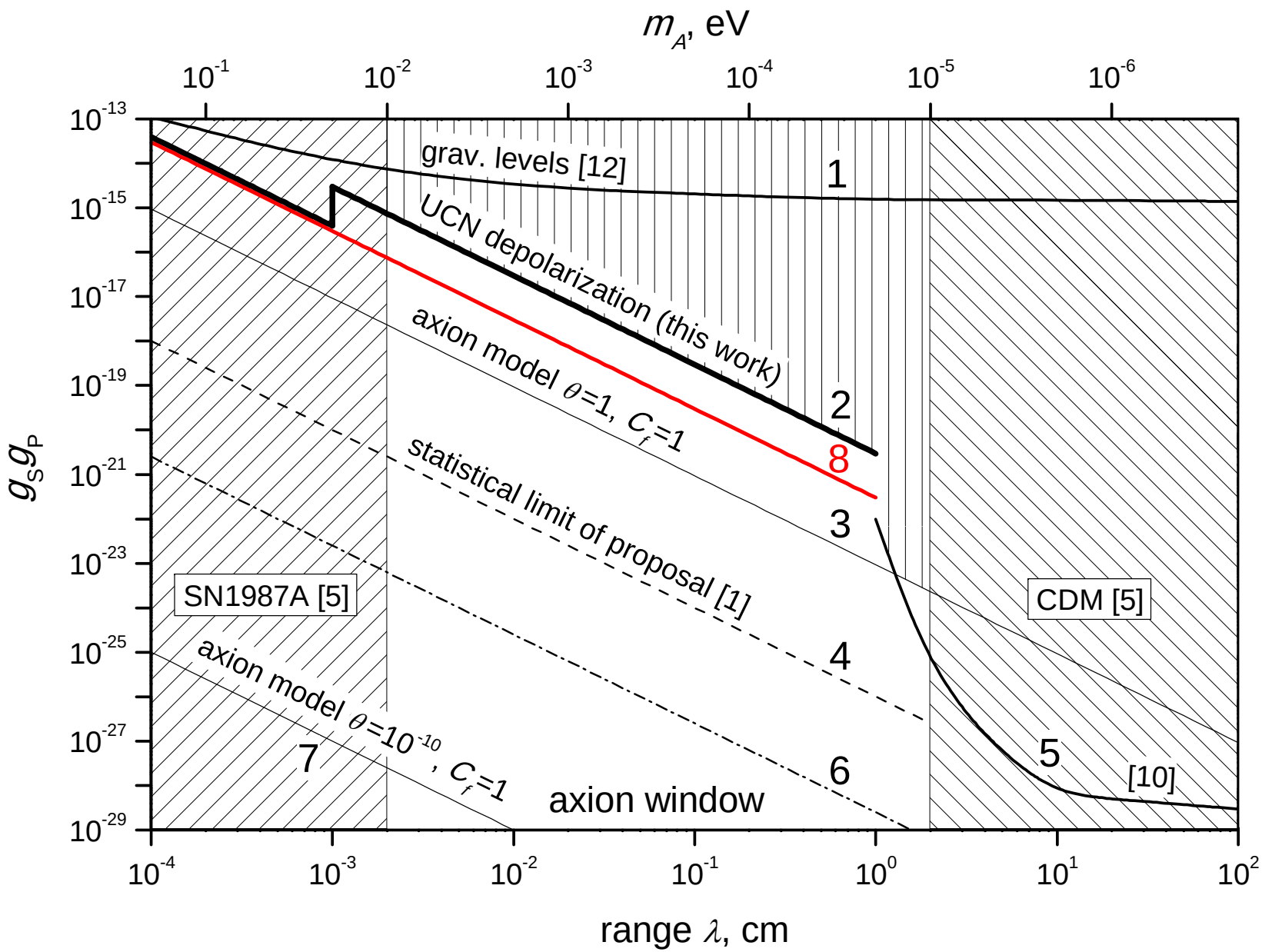
with aluminum plate:

$$\Delta\varphi_{\mathrm{Al}} = \left(-15^0 \pm 160^0\right) - \left(195^0 \pm 117^0\right) = -210^0 \pm 198^0$$

corrected value:

$$\Delta\varphi_{\mathrm{Cu}} - \Delta\varphi_{\mathrm{Al}} = 250^0 \pm 295^0 = (4.36 \pm 5.14)\,\mathrm{rad}$$

$$g_s g_p \left(\frac{\lambda}{\mathrm{cm}}\right)^2 \geq 1.3 \times 10^{-21} \quad (90\%\ \mathrm{c.l.})$$


m_A, eV
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$g_S g_P$
10^{-13}
10^{-15}
10^{-17}
10^{-19}
10^{-21}
10^{-23}
10^{-25}
10^{-27}
10^{-29}
grav. levels [12]
1
UCN depolarization (this work)
2
8
axion model θ=1, C_f=1
3
statistical limit of proposal [1]
4
SN1987A [5]
CDM [5]
5
[10]
axion model $\theta=10^{-10}$, C_f=1
7
6
axion window
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
range λ, cm

Progress planned using the PNPI multi-chamber EDM spectrometer

(no more change of magnetic field direction needed)