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The neutron Electric Dipole Moment experiment – exploring the low-energy precision frontier

Geza Zsigmond on behalf of the nEDM Collaboration

Europhysics Conference on HEP, Grenoble, July 21-27 2011

The Neutron EDM Collaboration

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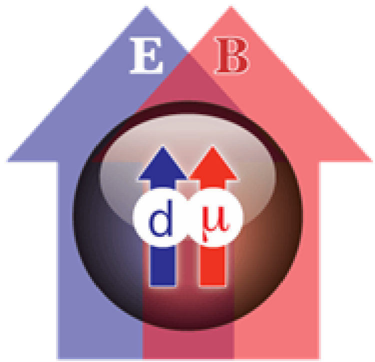
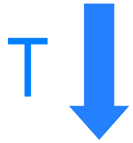
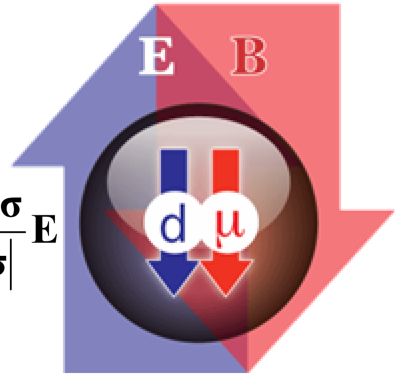
EDM a probe for CP violation

$$H = -\mu \frac{\boldsymbol{\sigma}}{|\boldsymbol{\sigma}|}\mathbf{B} - d\frac{\boldsymbol{\sigma}}{|\boldsymbol{\sigma}|}\mathbf{E}$$





$$H' = -\mu \frac{-\boldsymbol{\sigma}}{|\boldsymbol{\sigma}|}(-\mathbf{B}) - d\frac{-\boldsymbol{\sigma}}{|\boldsymbol{\sigma}|}\mathbf{E}$$



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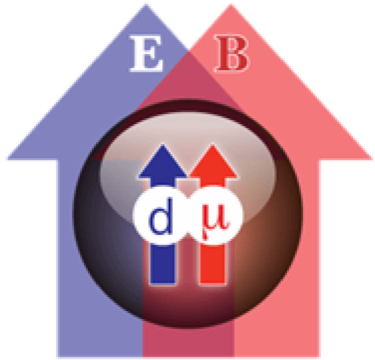

A nonzero particle EDM violates T, P and, assuming CPT conservation, also CP.

T

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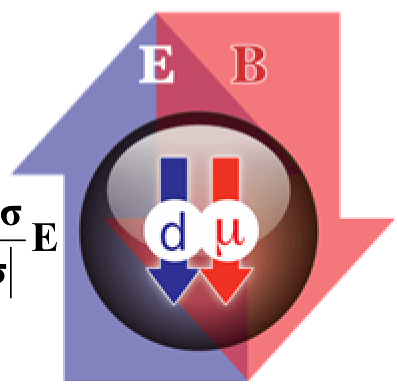

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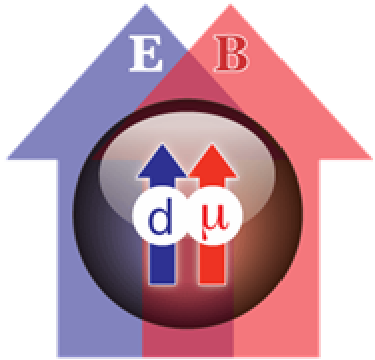

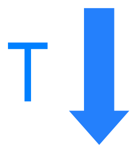

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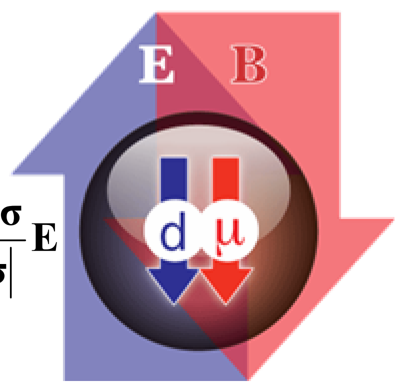
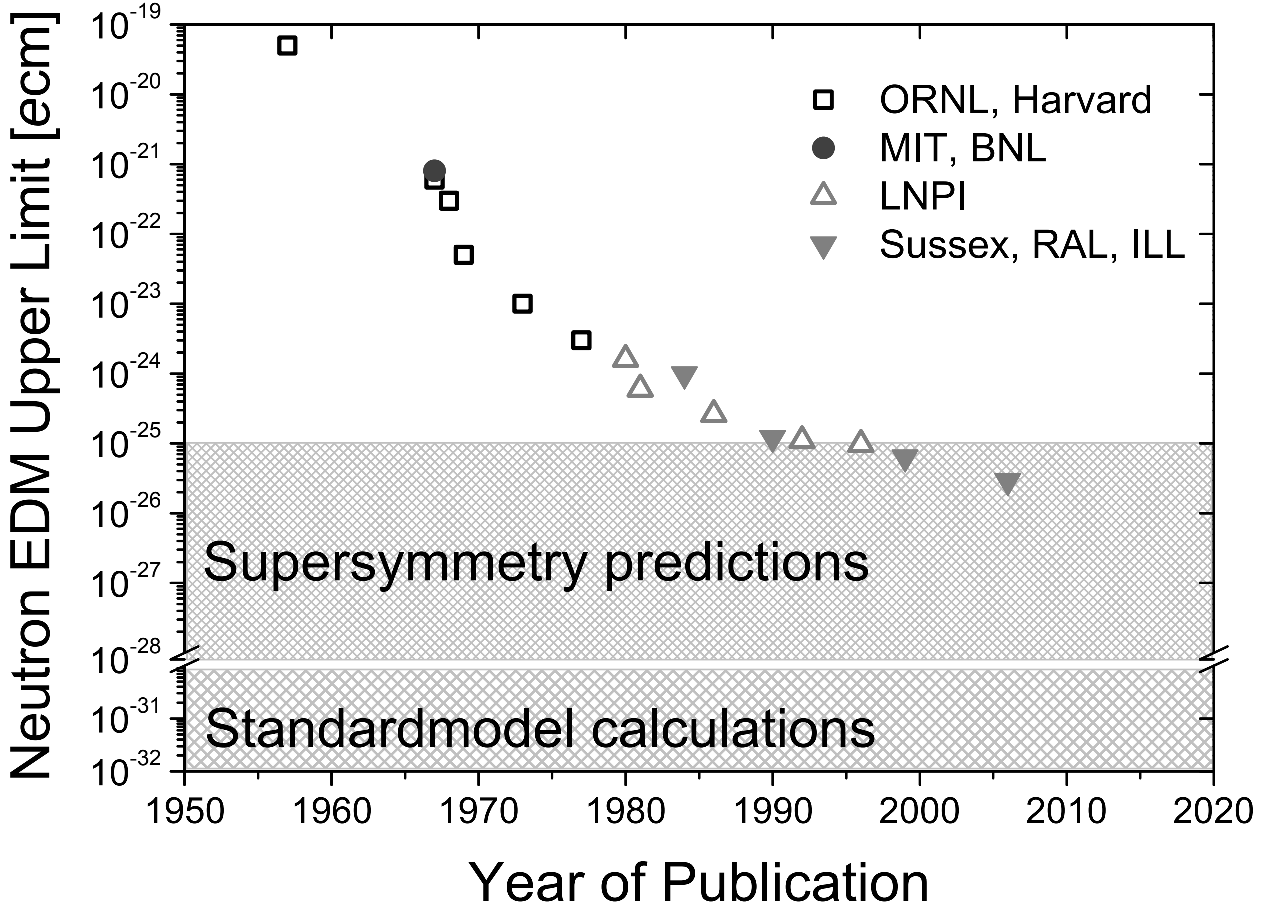


A nonzero particle EDM violates T, P and, assuming CPT conservation, also CP.

→ CP violation might help to explain matter/anti-matter asymmetry (BAU)

→ Excellent probe for physics beyond the Standard Model

Previous neutron EDM searches

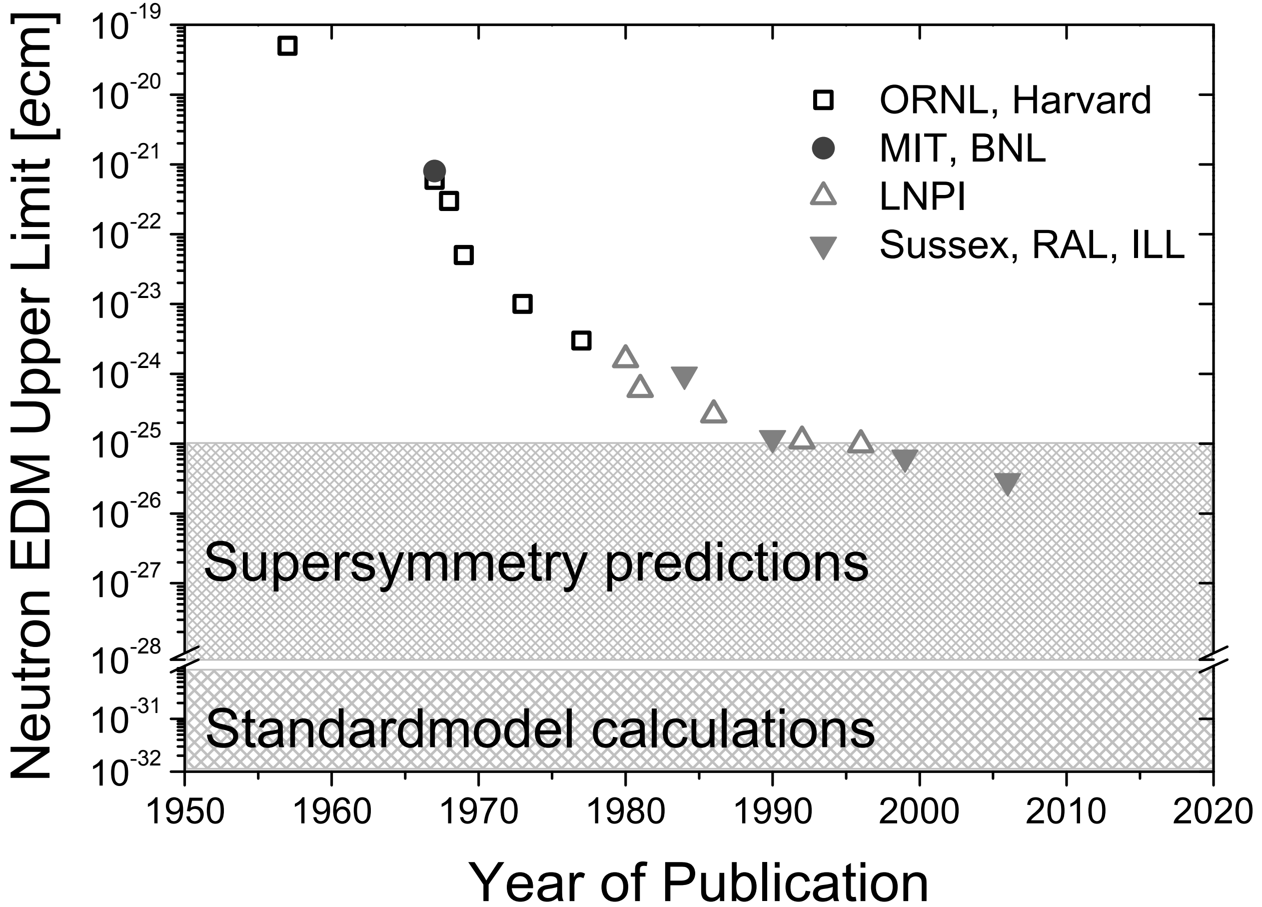


Sussex-RAL-ILL

$|d_n| < 2.9 \times 10^{-26}$ e cm (90% C.L.)

C.A.Baker et al., PRL 97 (2006) 131801

Previous neutron EDM searches



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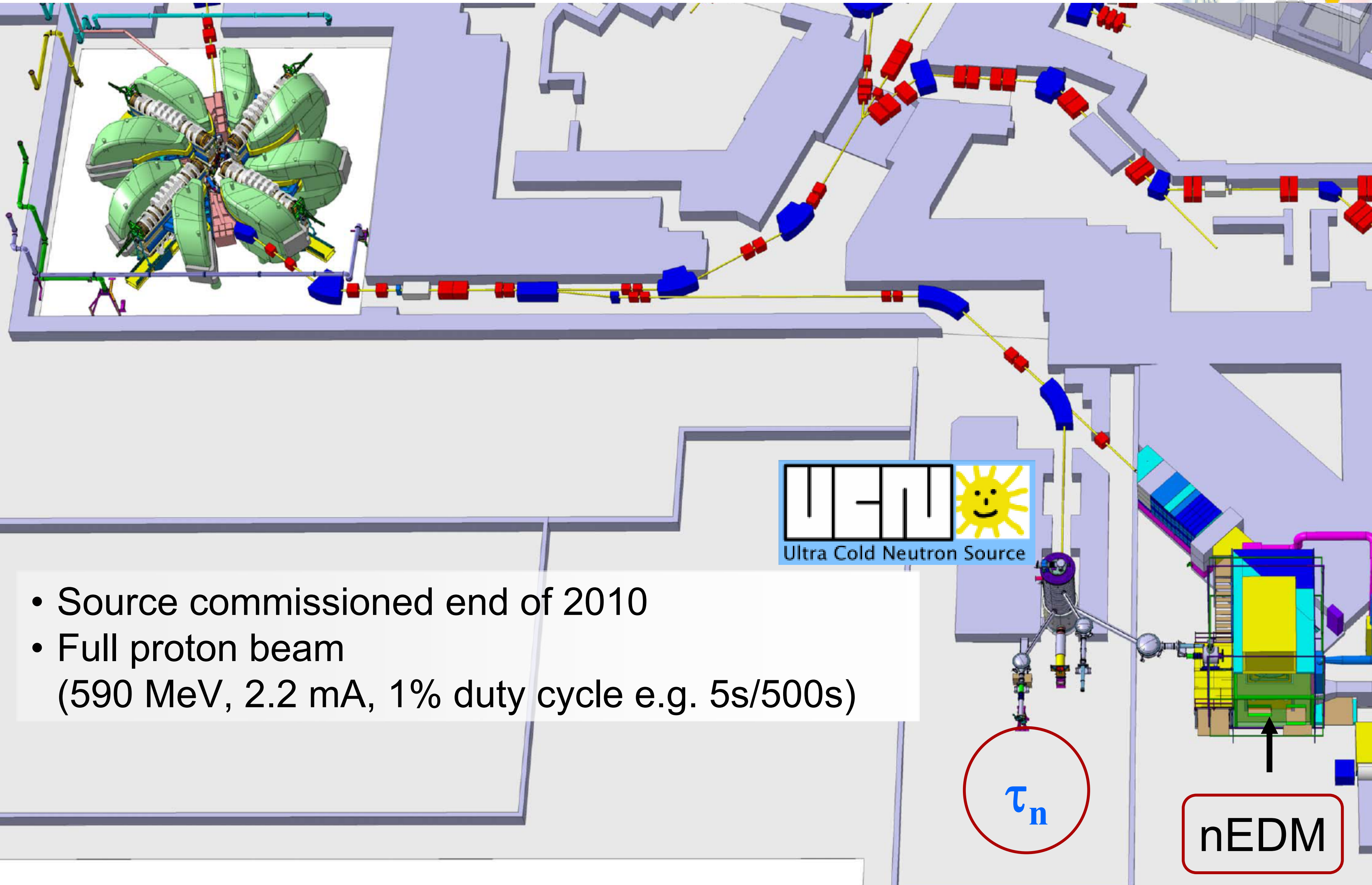
Goal nEDM Collaboration at PSI:

2012-2013: $|d_n| < 5 \times 10^{-27}$ e cm (95% C.L.)

Final (n2EDM): $|d_n| < 5 \times 10^{-28}$ e cm (95% C.L.)

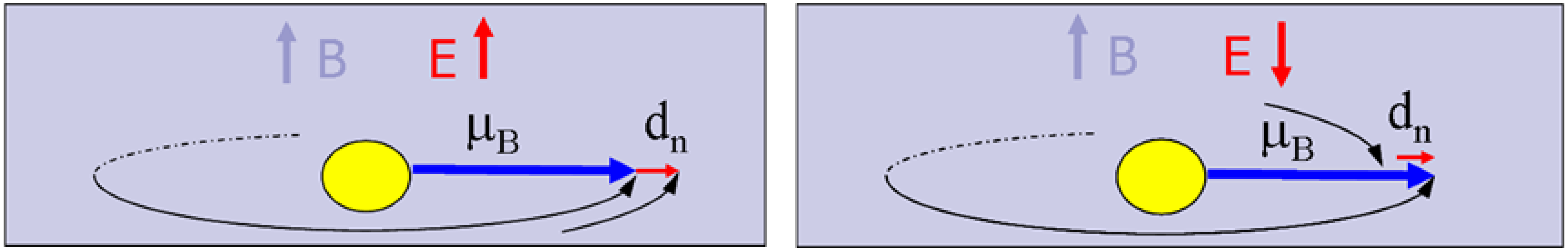
UCN beamlines at PSI



- Source commissioned end of 2010
- Full proton beam
  (590 MeV, 2.2 mA, 1% duty cycle e.g. 5s/500s)

Experiment principle

Difference of UCN precession frequencies in parallel/anti-parallel **B** and **E** fields:



$$h\Delta\nu = 2d_n\left(E_{\uparrow\uparrow} + E_{\uparrow\downarrow}\right) + 2\mu_n\left(B_{\uparrow\uparrow} - B_{\uparrow\downarrow}\right)$$

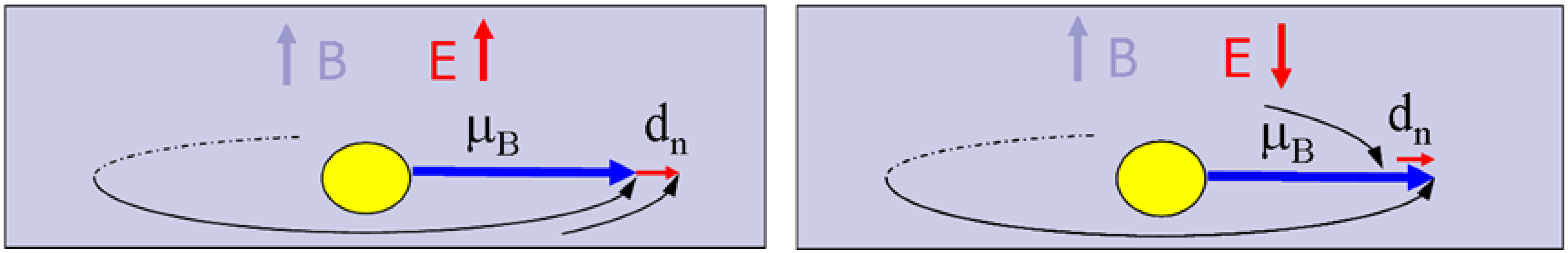
for $\sigma_{d_n} < 10^{-26}$ e cm → σ_ν < 60 nHz at 30 Hz

PAUL SCHERRER INSTITUT PSI

Experiment principle

ETH LPSC PTB nEDM LEUVEN

Difference of UCN precession frequencies in parallel/anti-parallel **B** and **E** fields:

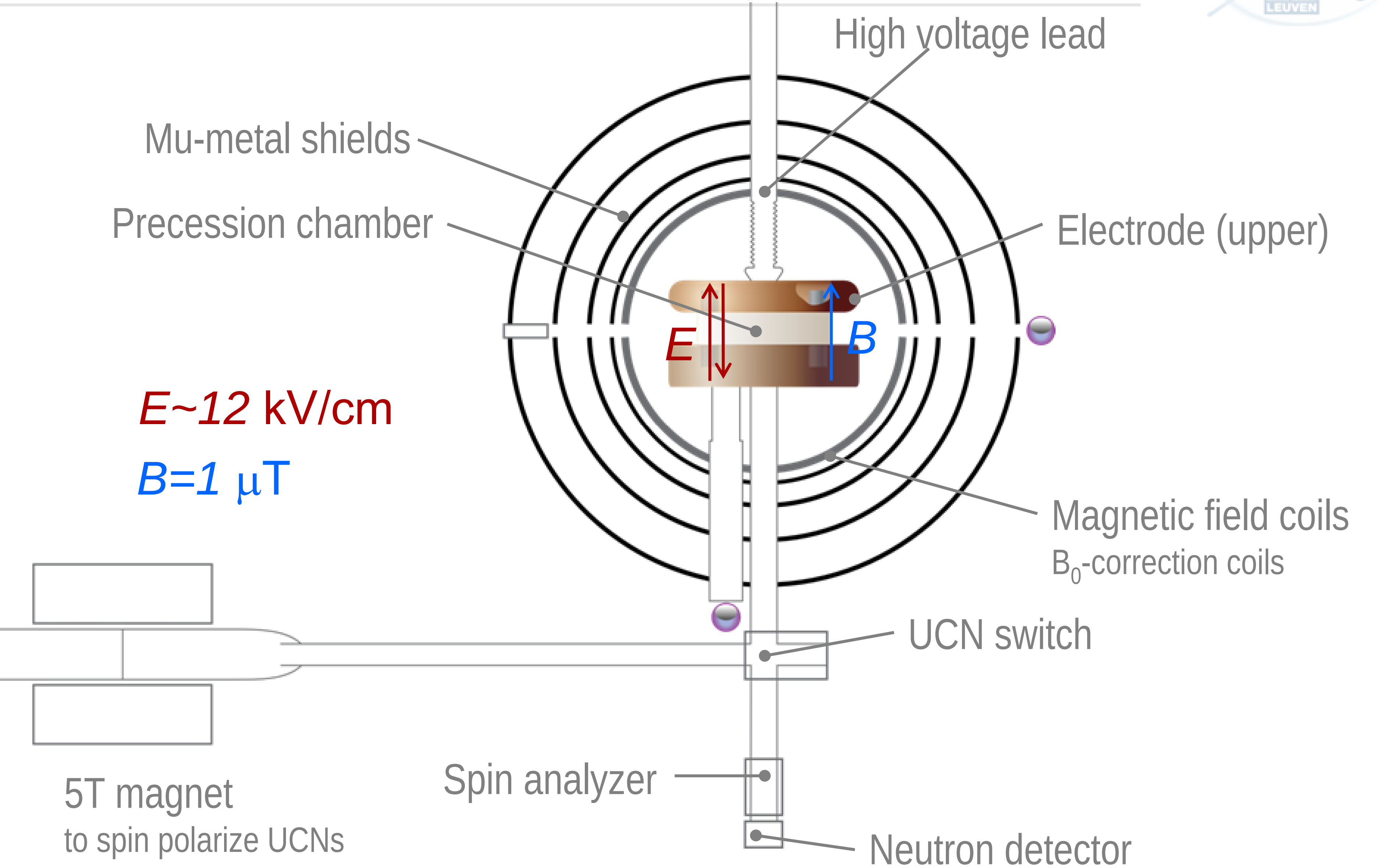


$$h\Delta\nu = 2d_{\mathrm{n}}\left(E_{\uparrow\uparrow}+E_{\uparrow\downarrow}\right)+2\mu_{\mathrm{n}}\cancel{\left(B_{\uparrow\uparrow}-B_{\uparrow\downarrow}\right)}$$

for $\sigma_{d_n} < 10^{-26}$ e cm → $\sigma_\nu <$ 60 nHz at 30 Hz

***New:* Improved magnetometry – ^{199}Hg + Cs magnetometers**

Apparatus – main parts



The Ramsey technique

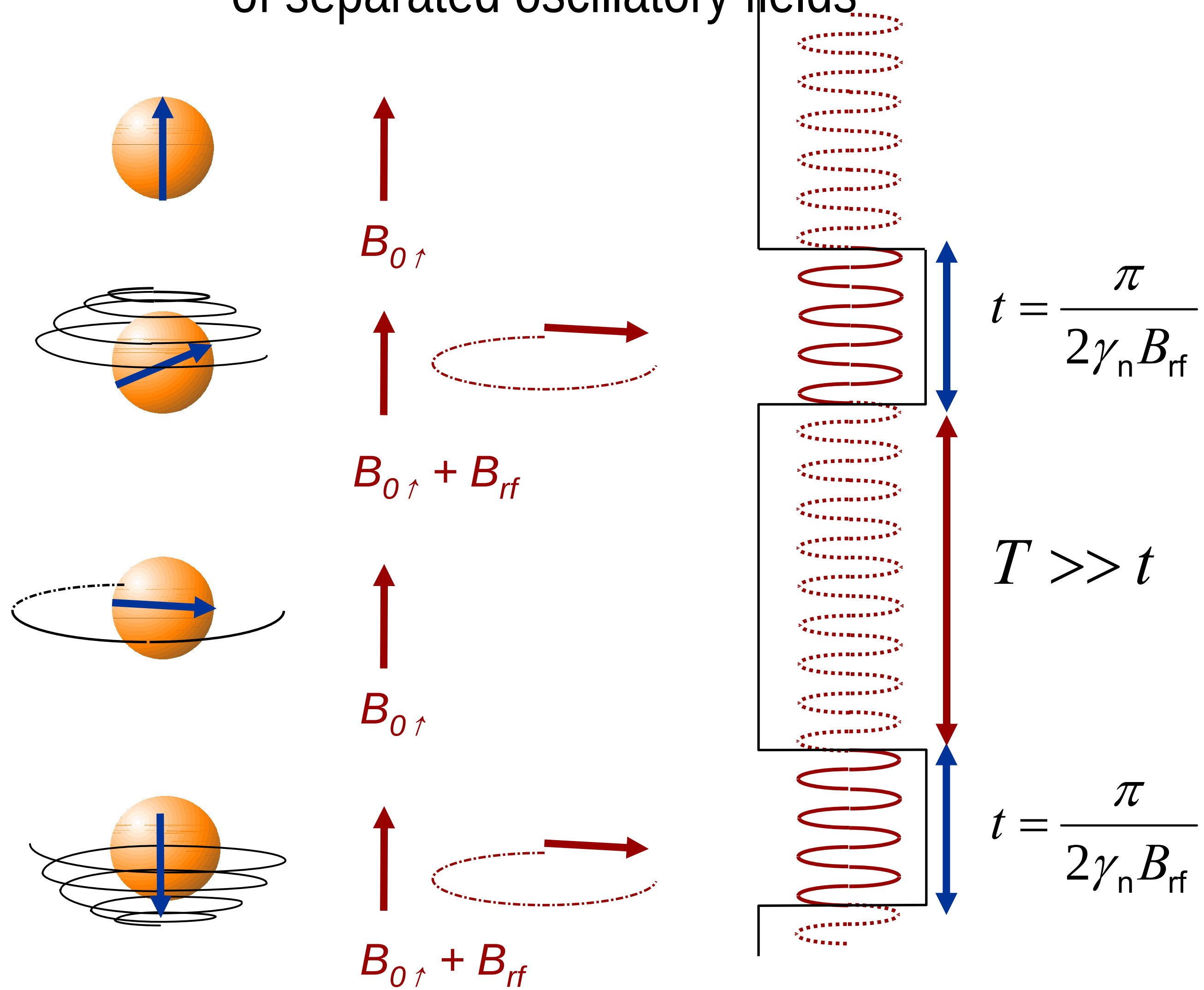
of separated oscillatory fields

"Spin up" neutron...

Apply $\pi/2$ spin flip pulse...

Free precession at ω_L

Second $\pi/2$ spin flip pulse.



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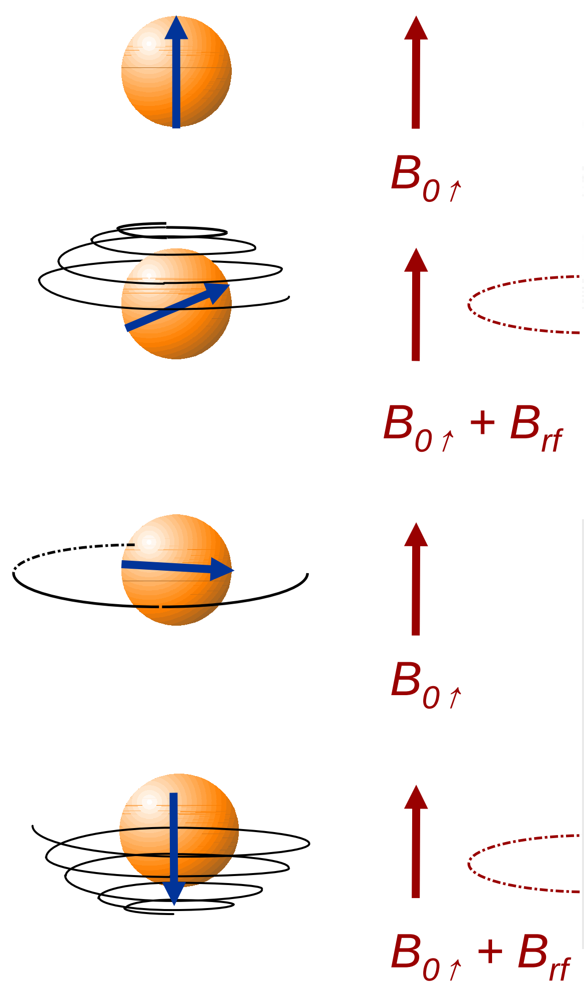
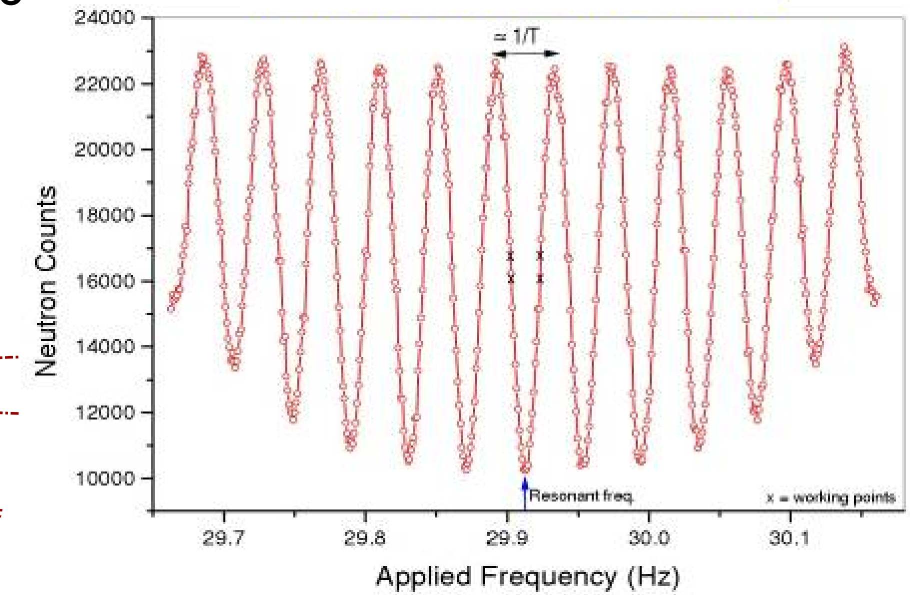


Ramsey resonance curve



Sensitivity: $$\sigma(d_n) = \frac{\hbar}{2\alpha E T\sqrt{N}}$$

α	Visibility of resonance
E	Electric field strength
T	Time of free precession
N	Number of neutrons

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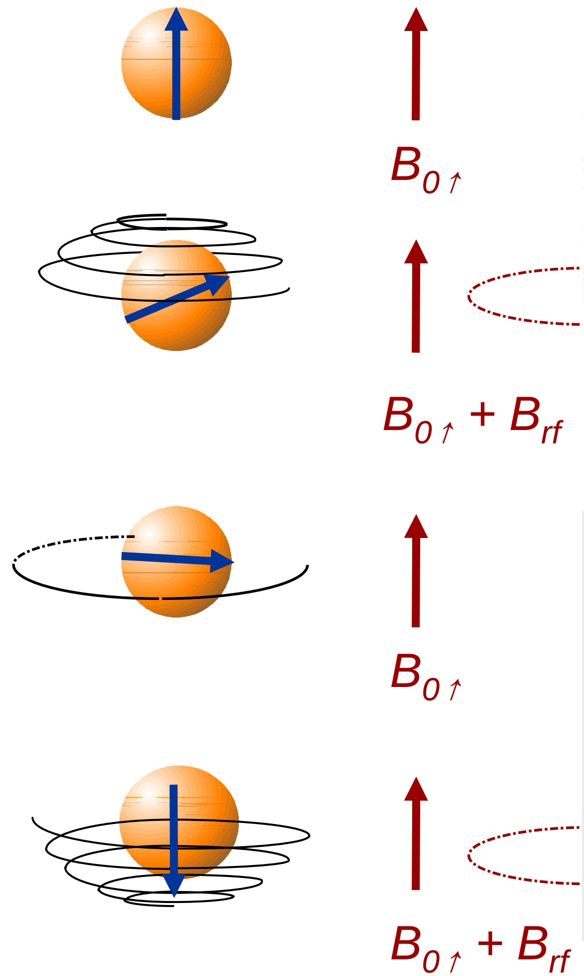
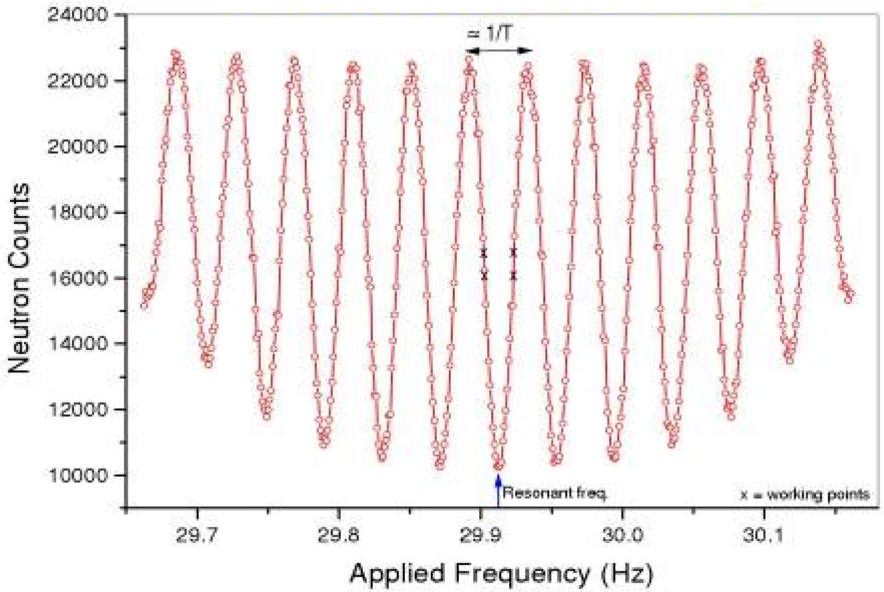


Ramsey resonance curve



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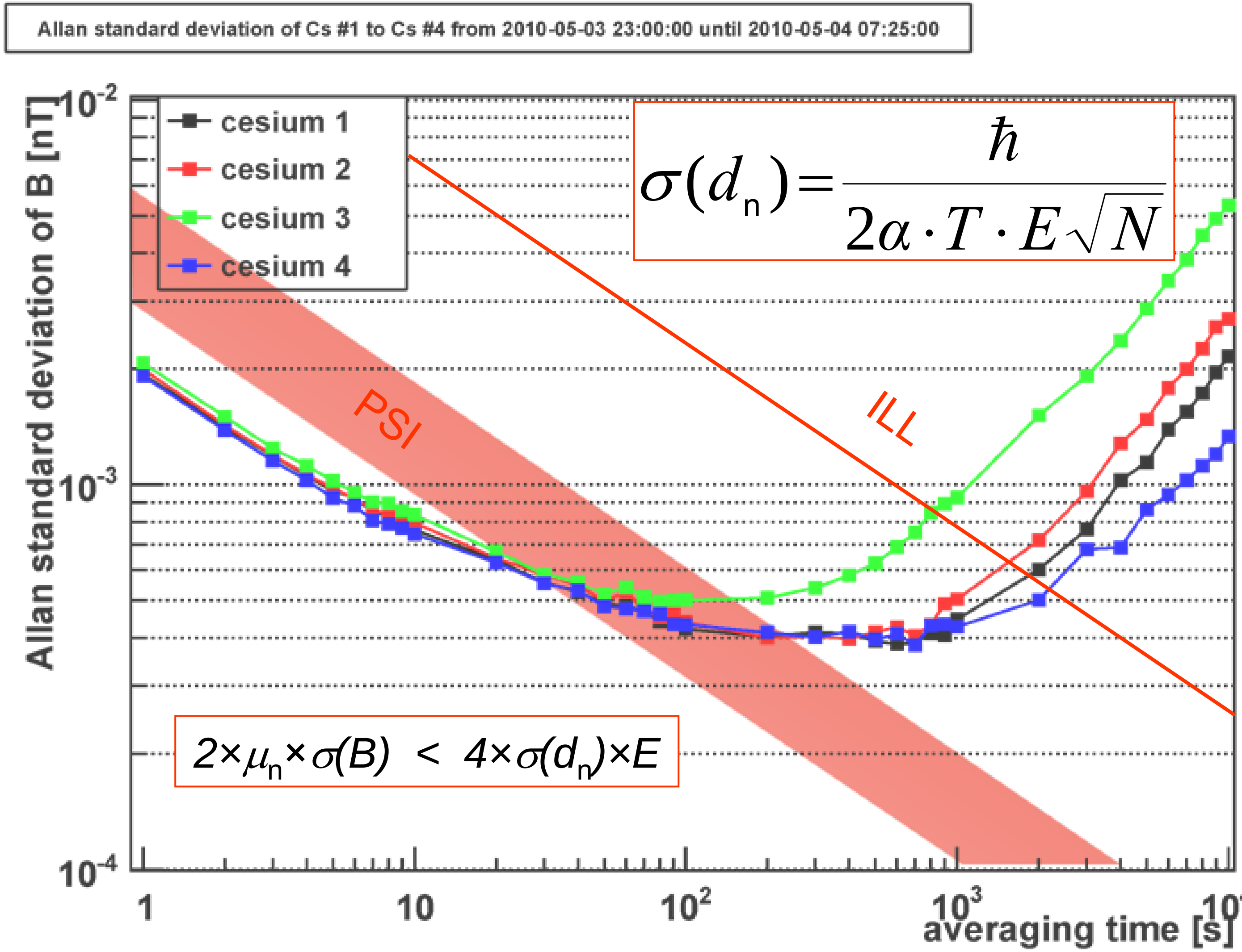
25x more at PSI

nEDM systematic effects

Effect	Shift (Bak06) [10^{-27} *e* cm]	σ (Bak06) [10^{-27} *e* cm]	σ (goal at PSI) [10^{-27} *e* cm]
Cavity dipole	-5.6	2.00	**0.10**
Other dipole fields	0.0	6.00	**0.40**
Quadrupole difference	-1.3	2.00	**0.60**
v×E translational	0.0	0.03	0.03
v×E rotational	0.0	1.00	**0.10**
Second-order v×E	0.0	0.02	0.02
νHg light shift (geo phase)	3.5	0.80	**0.40**
νHg light shift (direct)	0.0	0.20	0.20
Uncompensated B drift	0.0	2.40	**0.90**
Hg atom EDM	-0.4	0.30	**0.06**
Electric forces	0.0	0.40	0.40
Leakage currents	0.0	0.10	0.10
ac fields	0.0	0.01	0.01
Total	-3.8	7.2	**1.4**

C. A. Baker et al., Phys. Rev. Lett 97 (2006) 131801

Magnetic field stability



Prepared for data taking

Thermal stabilization

Surrounding mag. field compensation

Prepared for data taking

Thermal stabilization

Surrounding mag. field compensation

Superconducting magnet polarizer

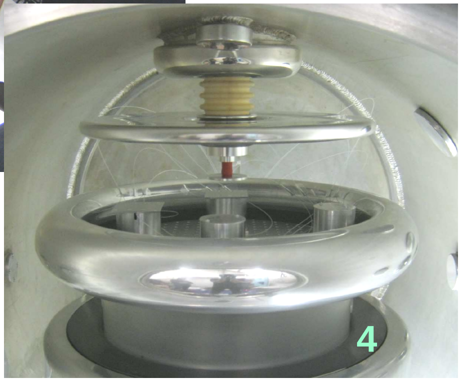
Prepared for data taking

Thermal stabilization

Surrounding mag. field compensation

UCN precession chamber
HV electrodes
Mu-metal shields

Cs-Magnetometers



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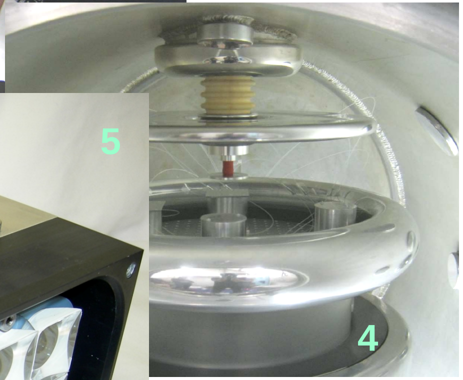

Superconducting magnet polarizer

High rate UCN detection system

Outlook 2011- 2013

- UCN source at PSI commissioned 2010
  25× more UCN/cycle than at ILL
- Main systematic effects reduced by improved magnetometry
- First nEDM data this year (50 nights)

$$d_n = (\,?\pm 6_{\text{stat}} \pm\ 4_{\text{sys}})\times 10^{-27}\, e\cdot\text{cm}$$

- Further improvements on sys. effects in winter 2011-2012 when PSI accelerator shut-down
- In 2012-2013 – 200 nights of data taking

$$d_n = (\,?\pm 3_{\text{stat}} \pm\ 1.4_{\text{sys}})\times 10^{-27}\, e\cdot\text{cm}$$

Previous: Baker et al. '06 $d_n = (+2\ \pm\ 15_{\text{stat}} \pm\ 7_{\text{sys}})\times 10^{-27}\, e\cdot\text{cm}$