

S. Roccia, on behalf of the nEDM collaboration at PSI



# Search for the nEDM at the Paul Scherrer Institute





UNIVERSITÉ  
PARIS  
SUD

Comprendre le monde,  
construire l'avenir®

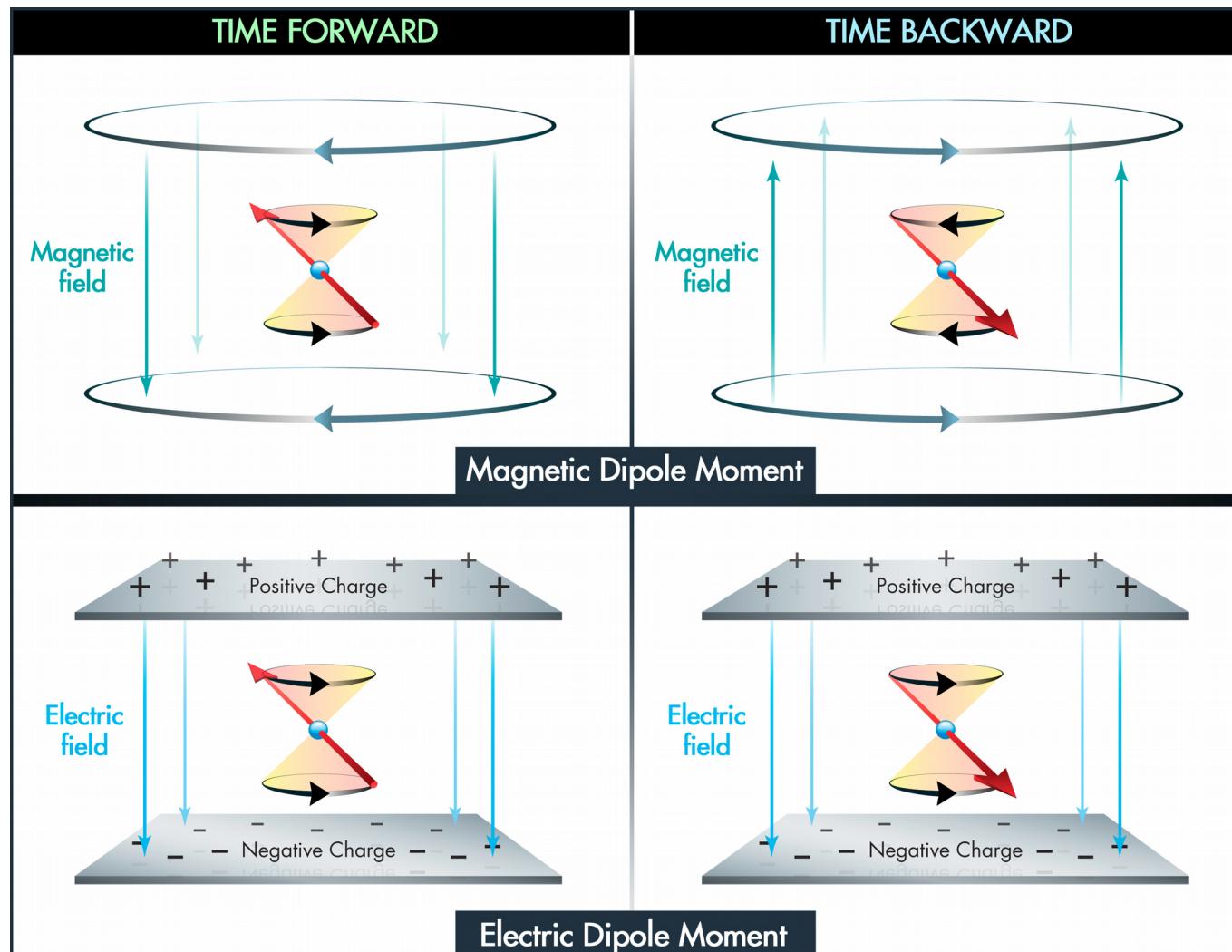
- nEDM
- n2EDM

$u^b$

Welcome University of Bern

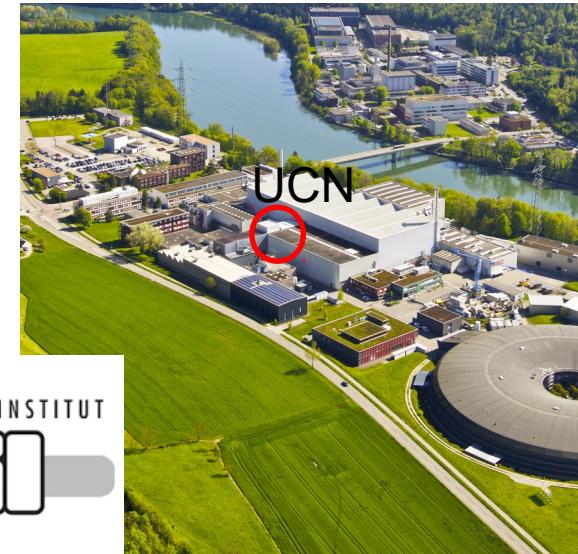
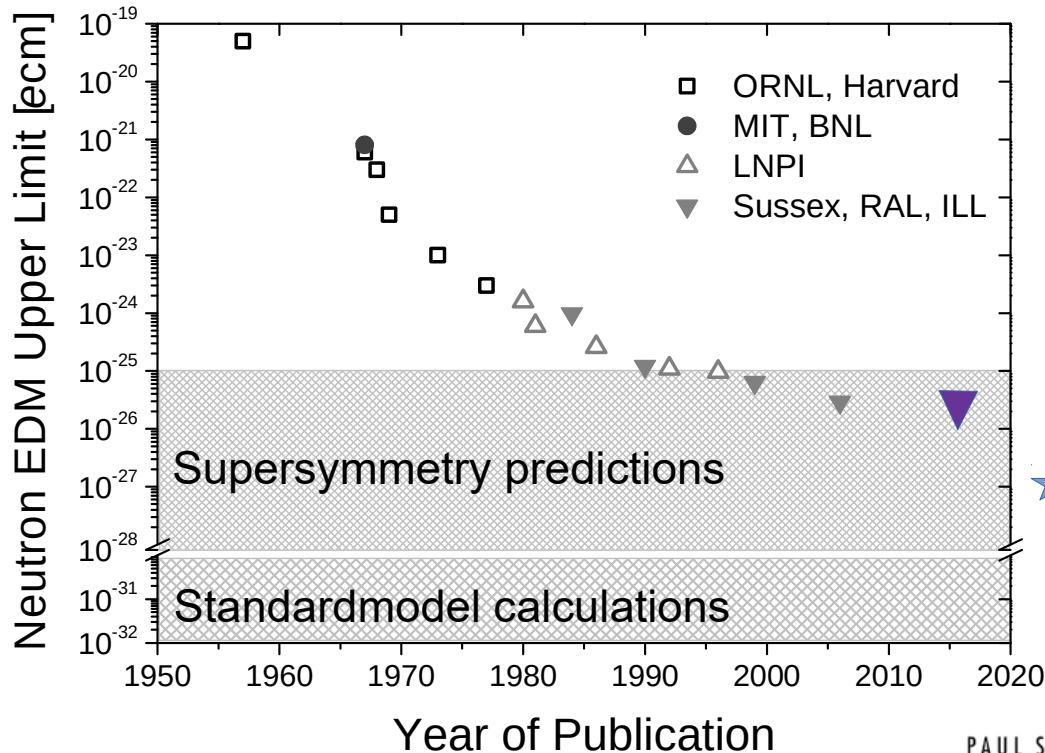


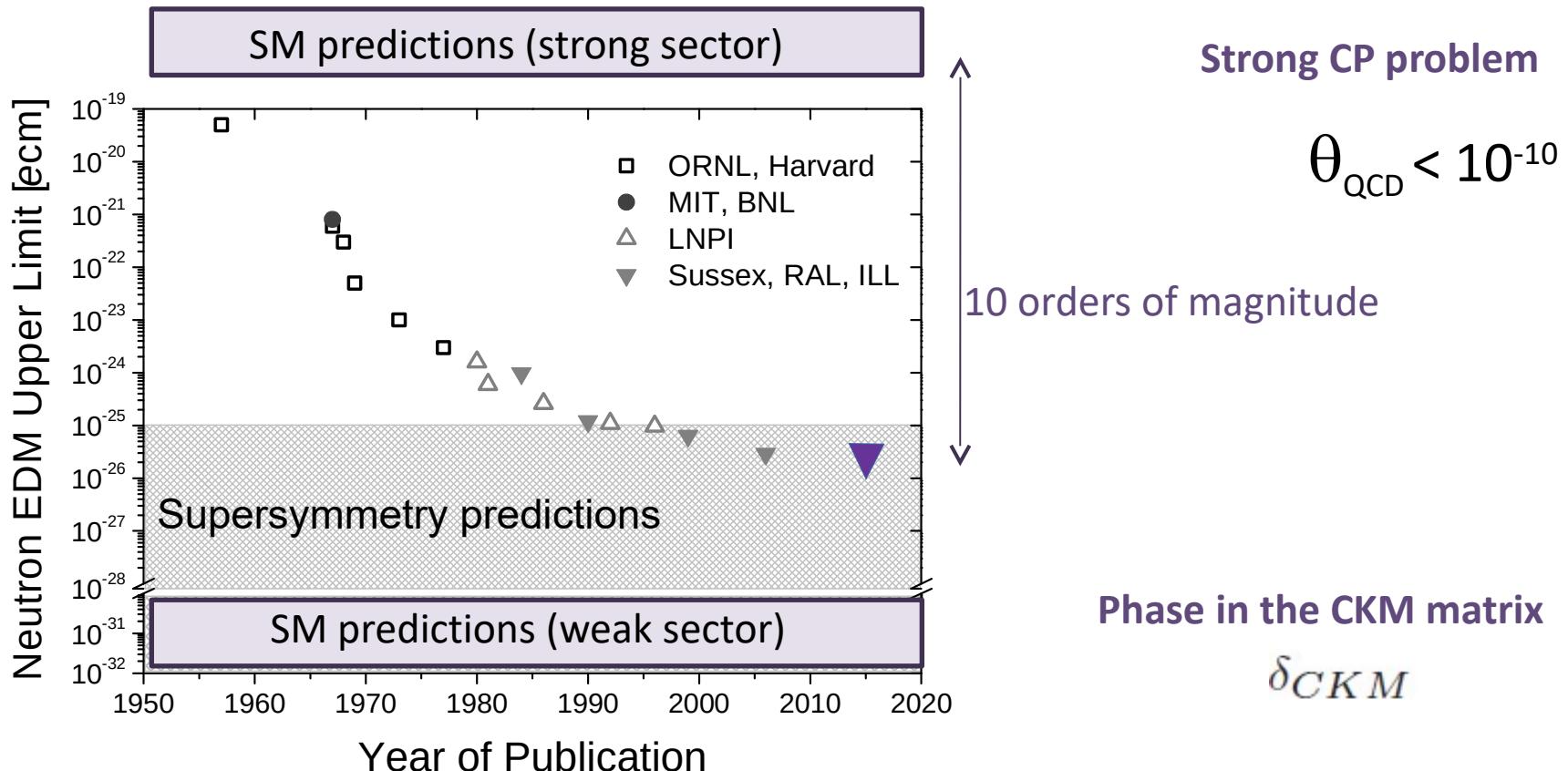
The nEDM collaboration

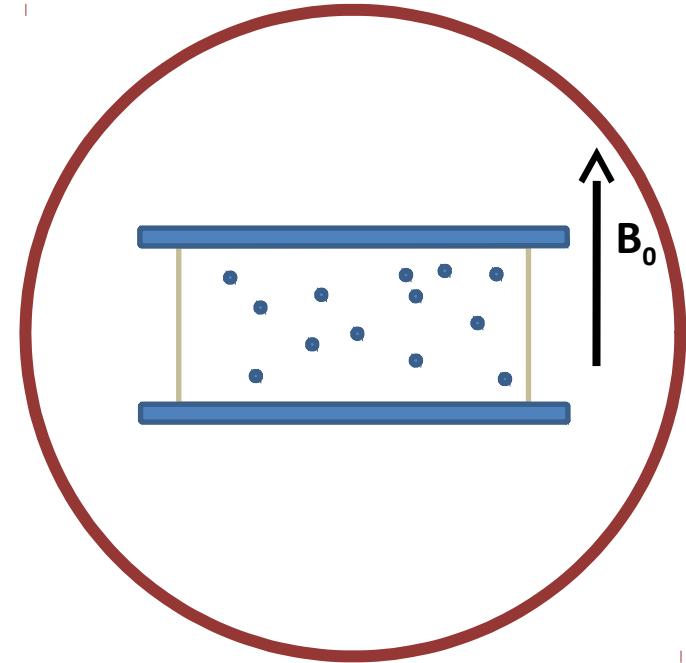
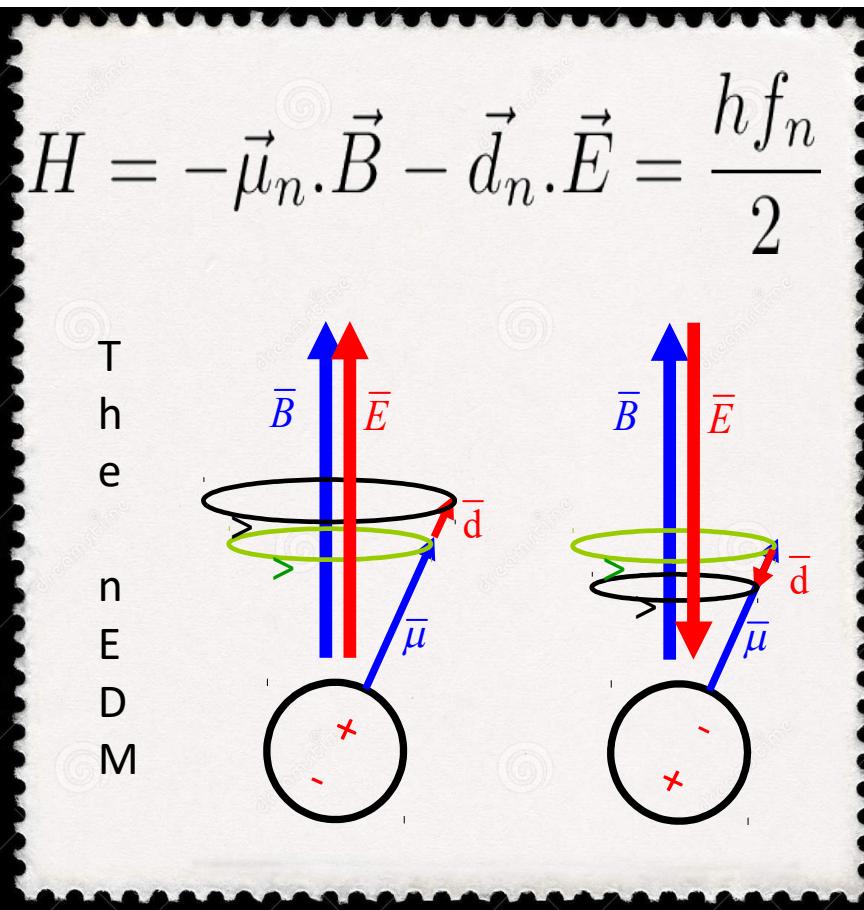


$$H = -\vec{\mu} \cdot \vec{B} - \vec{d} \cdot \vec{E}$$

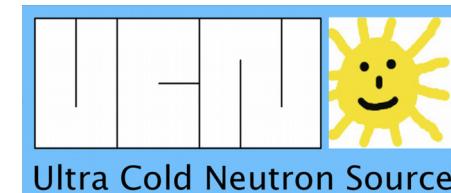
A nonzero particle EDM violates **T**, **P** and, assuming **CPT** conservation, also **CP**.







Neutrons reflected for all incidence angles: UCNs



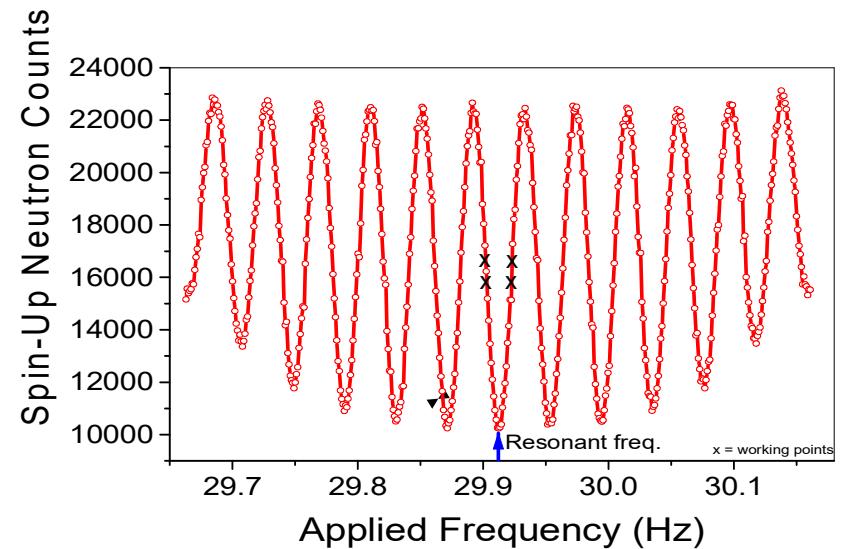
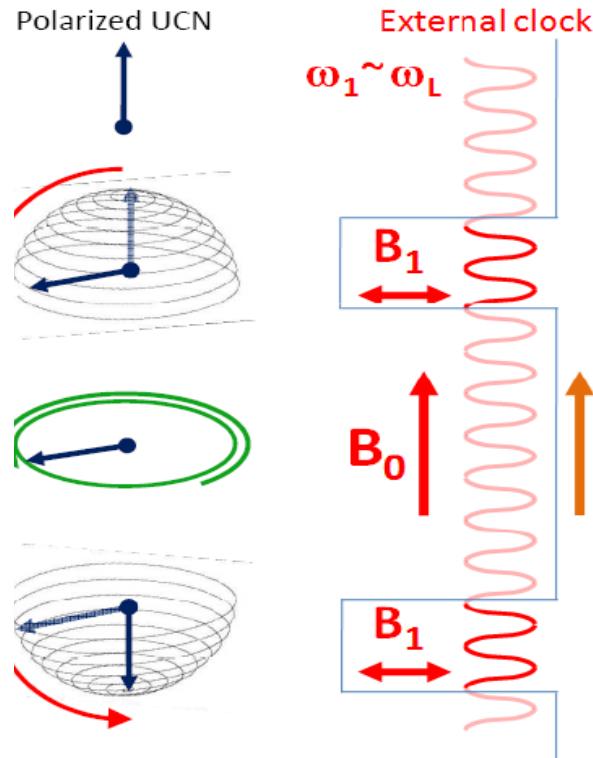
$$\lambda_n \approx 800 \text{ \AA};$$

$$v_n \approx 5 \text{ m/s};$$

$$T_n \approx 2 \text{ mK};$$

$$E_n \approx 130 \text{ neV}$$

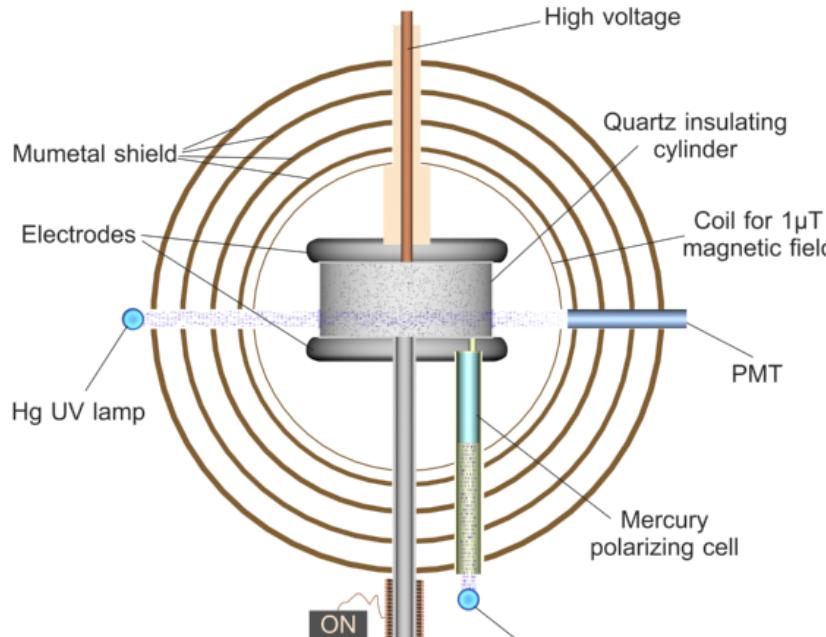
## The Ramsey's method of separated oscillating fields



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

## First limitation ..... Magnetic field fluctuations

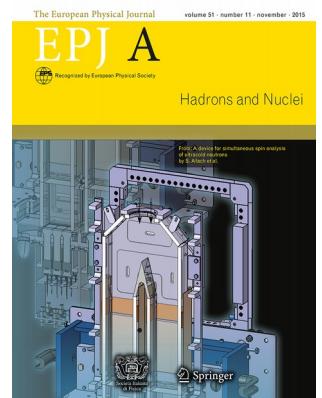
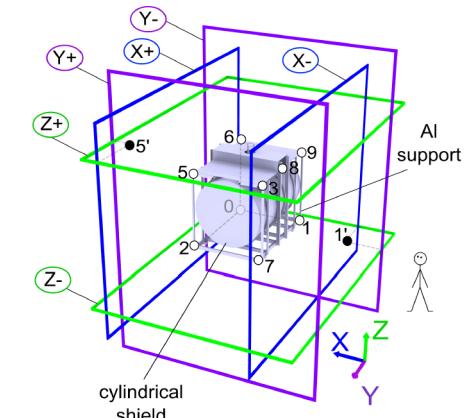
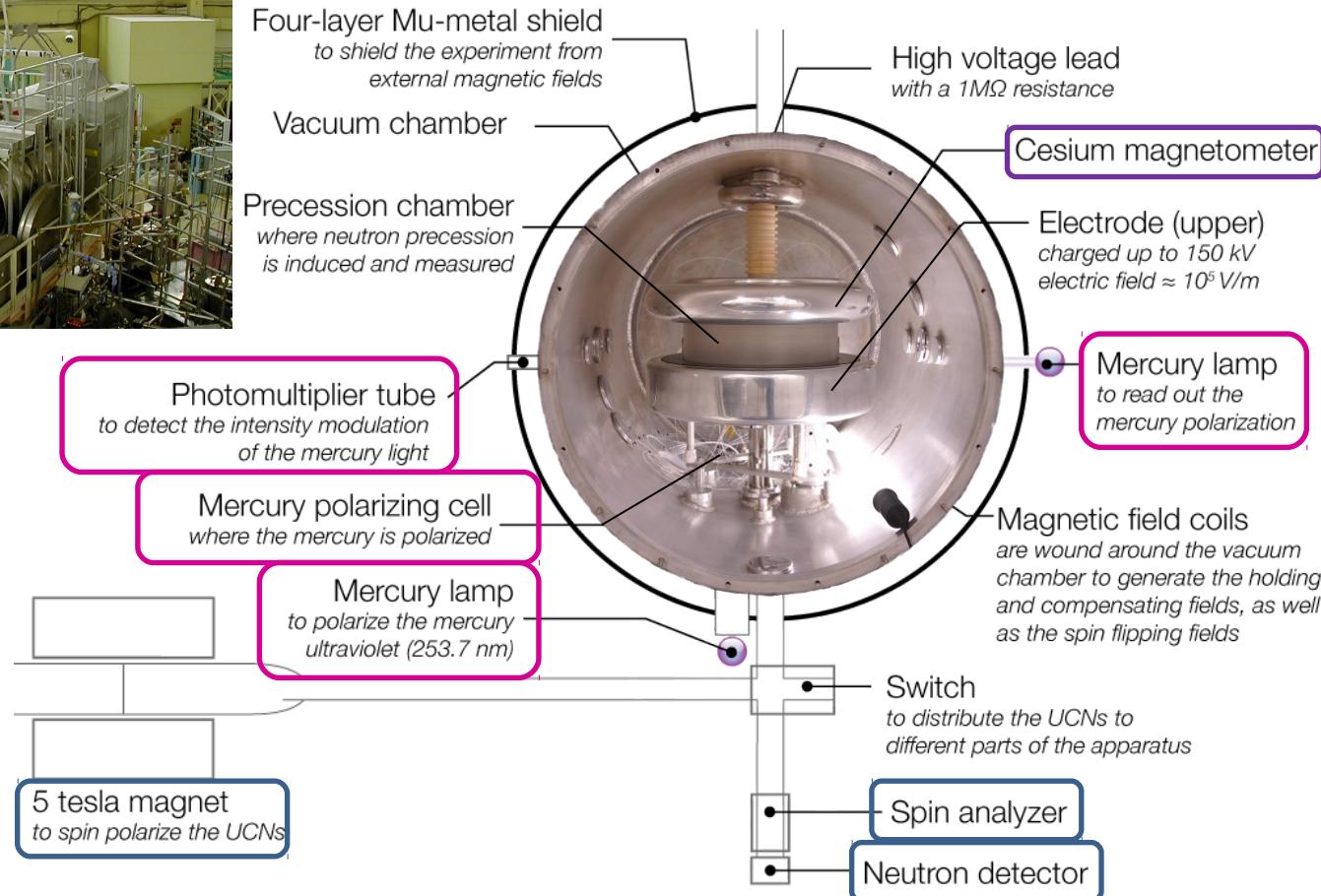
$$\begin{aligned}
 h f_n (\uparrow\uparrow) &= 2 \vec{\mu}_n \cdot \vec{B}(\uparrow\uparrow) \\
 h f_n (\uparrow\downarrow) &= 2 \vec{\mu}_n \cdot \vec{B}(\uparrow\downarrow) \\
 \hline
 h(f_n (\uparrow\uparrow) - f_n (\uparrow\downarrow)) &= 2 \vec{\mu}_n \cdot (\vec{B}(\uparrow\uparrow) - \vec{B}(\uparrow\downarrow)) \\
 &\quad - 2 \vec{d}_n \cdot (\vec{E}(\uparrow\uparrow) + \vec{E}(\uparrow\downarrow))
 \end{aligned}$$



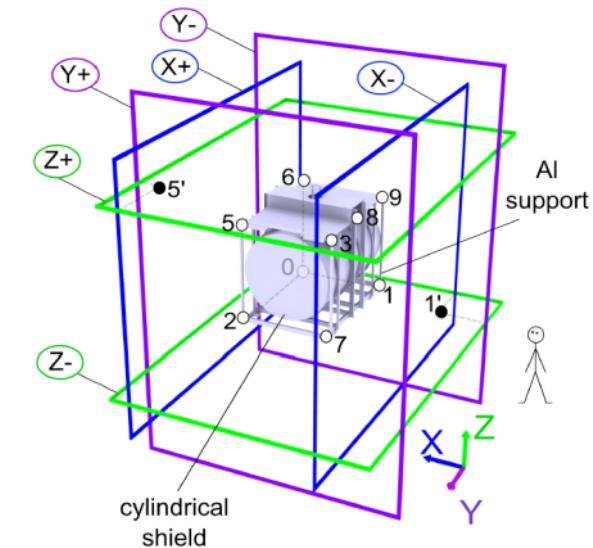
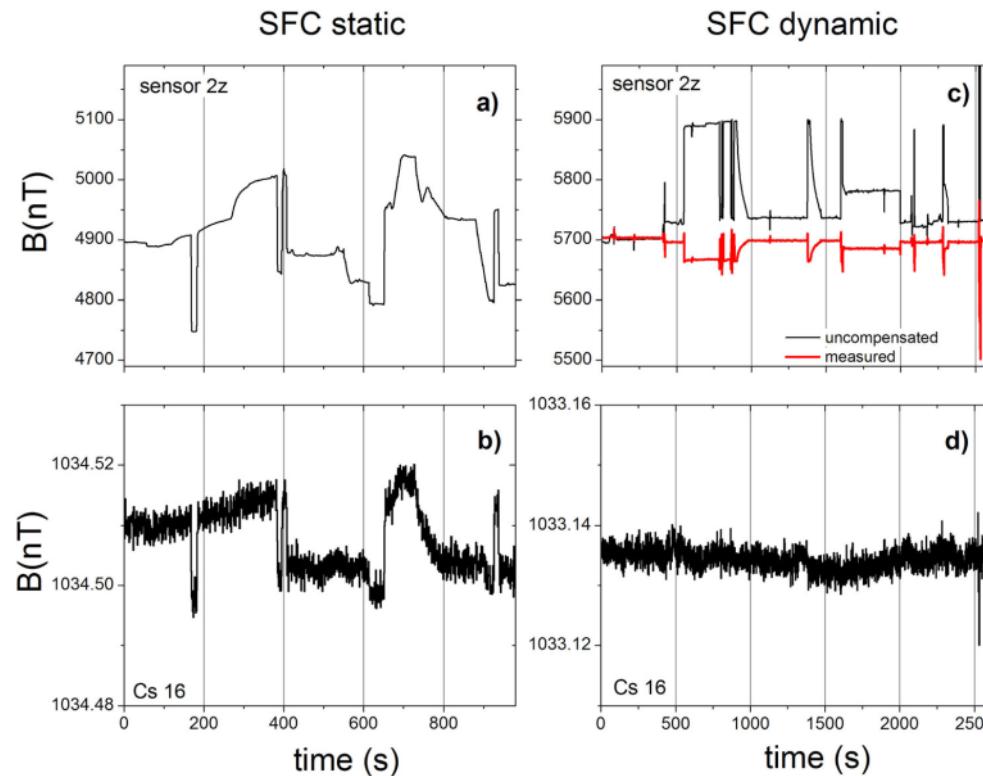
Mercury co-magnetometer (1998)

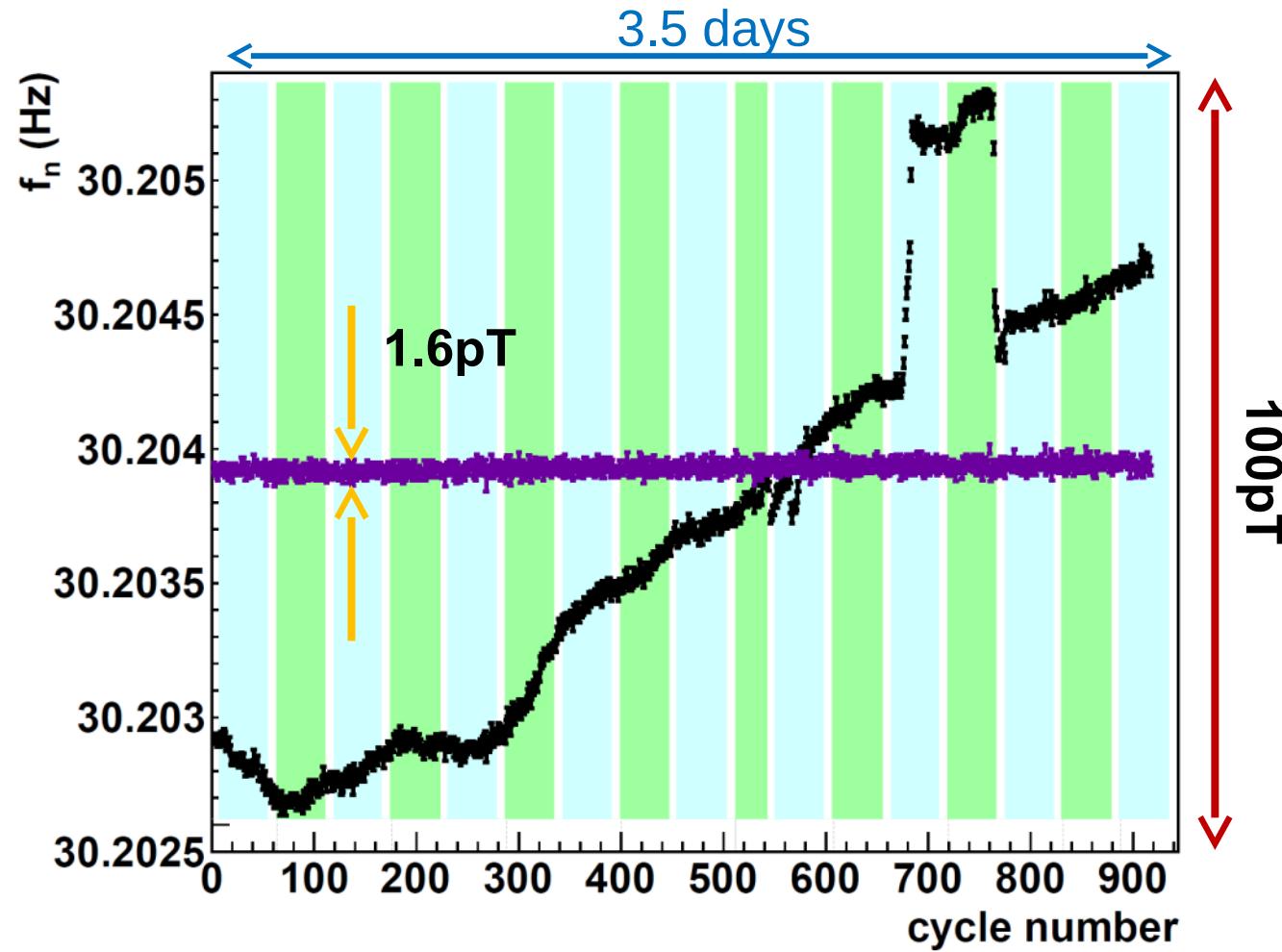
$$R = \frac{f_n}{f_{Hg}} = \frac{\gamma_n B_n}{\gamma_{Hg} B_{Hg}} = \frac{\gamma_n}{\gamma_{Hg}}$$

Cesium magnetometer array (2009)

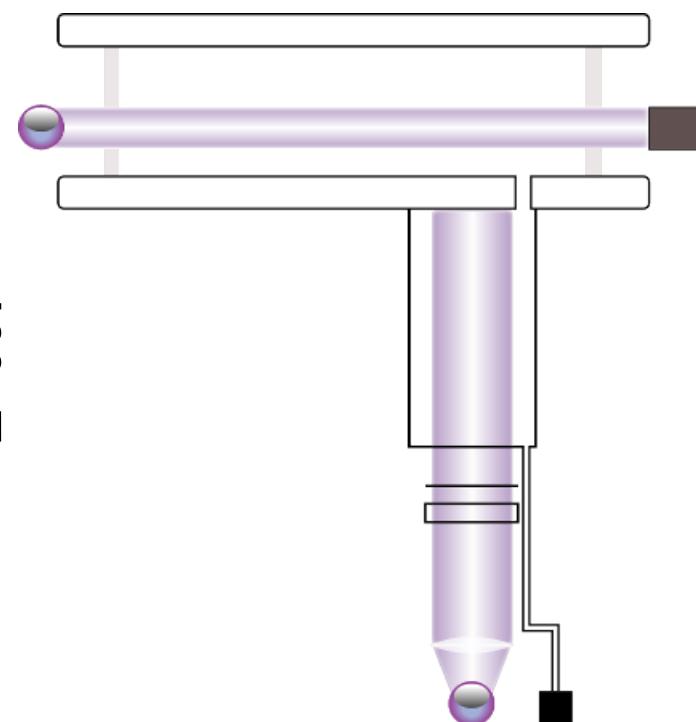


- Excellent stability  
(dynamic SFC & 4 layer magnetic shield)
- Stability (AD) @400s:  $\sim <400\text{fT}$

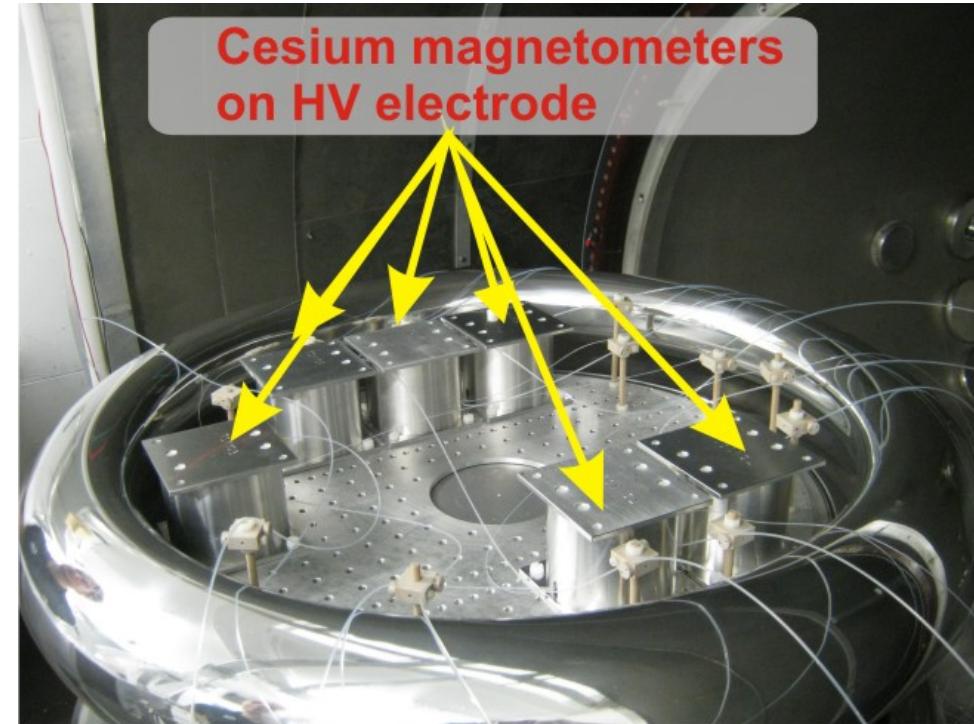
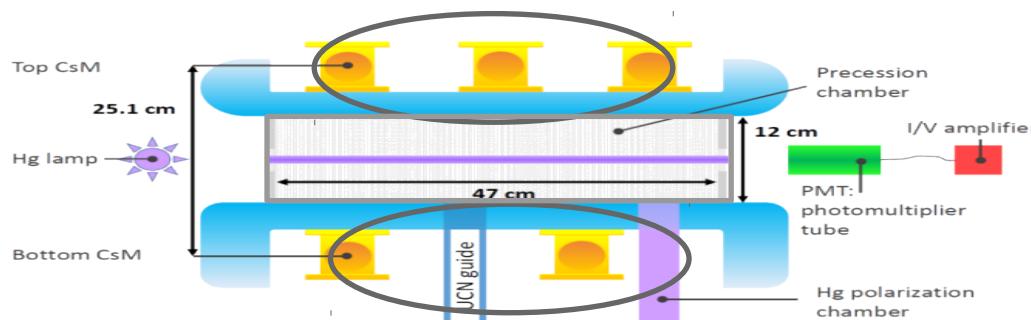




The Hg co-magnetometer



Monitoring of the vertical gradient  
Homogenisation of the magnetic field



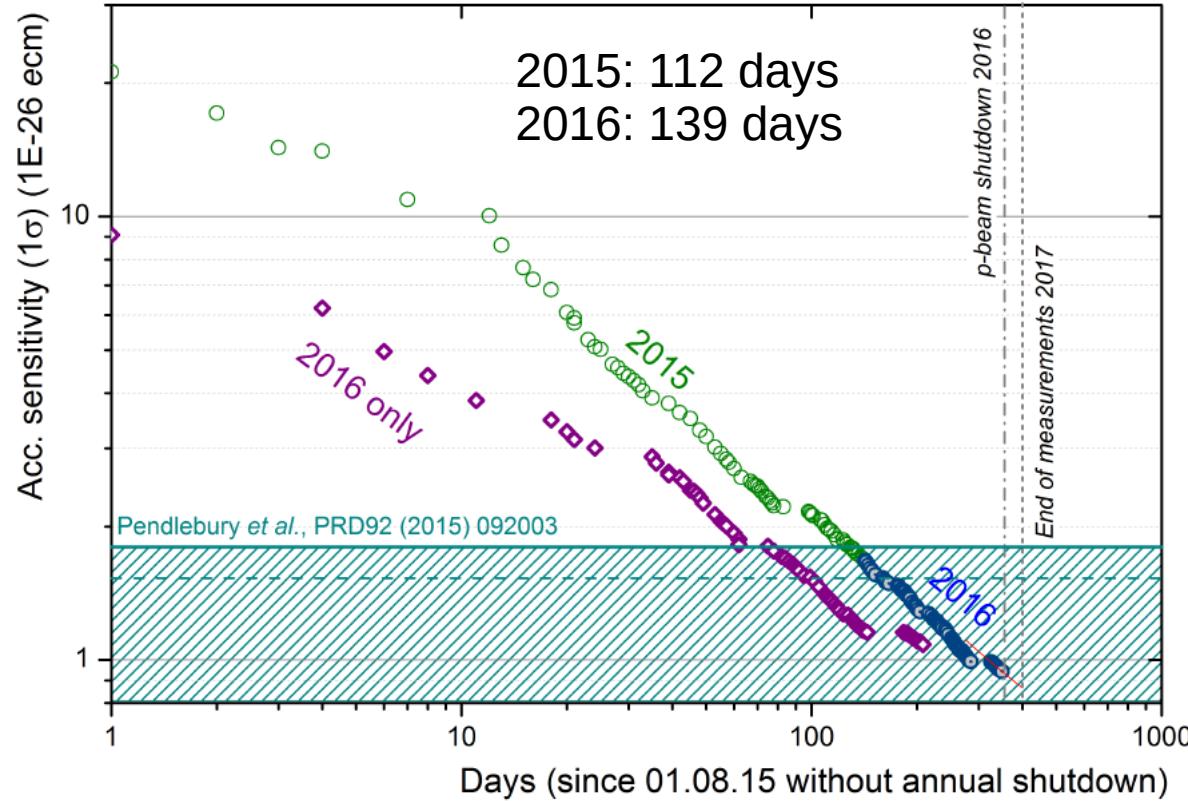
	nEDM@ILL 2006	nEDM@PSI 2016
Chamber	1	1
Diameter (cm)	47	47
Neutron/cycle	14 000	15 000
E(kV/cm)	8.3	11 (15)
T(s)	130	180
$\alpha$	0.45 (0.6)	0.75 (0.80)
Sens/day(e.cm)	$30 \times 10^{-26}$	$11 \times 10^{-26}$

Statistical sensitivity

$$\sigma(d_n) = \frac{\hbar}{2\alpha ET\sqrt{N}}$$

Pushing the limit of the technique  
at room temperature

World record for sensitivity



Accumulated raw sensitivity

2015:  $1.7 \times 10^{-26}$  ecm

2016:  $1.1 \times 10^{-26}$  ecm

Total:  $0.94 \times 10^{-26}$  ecm

(values from simple fit)

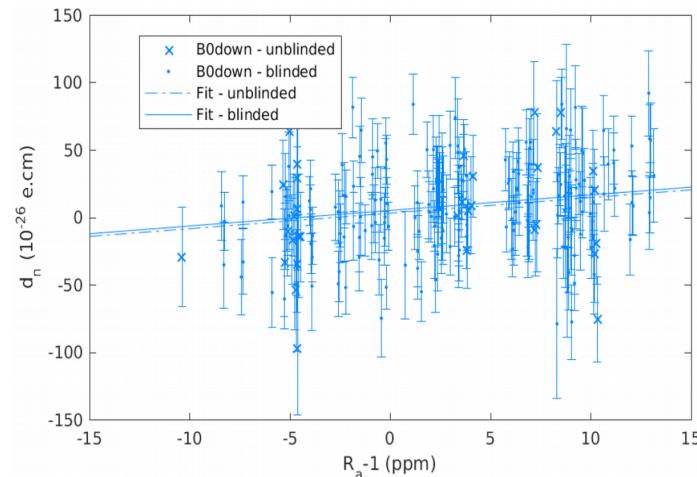
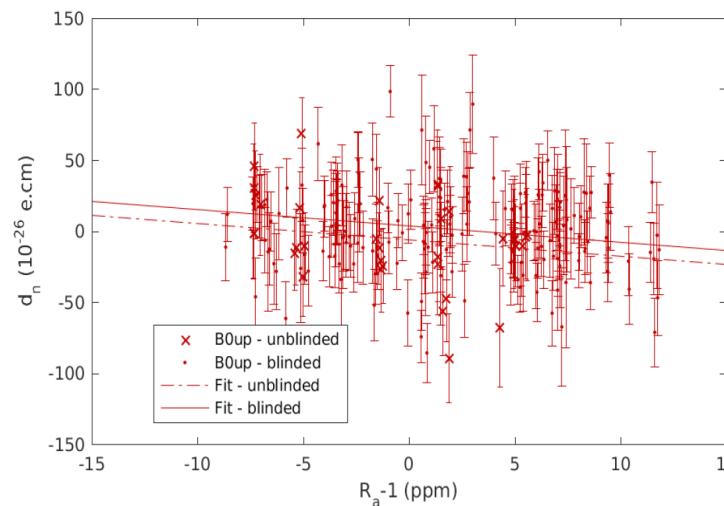
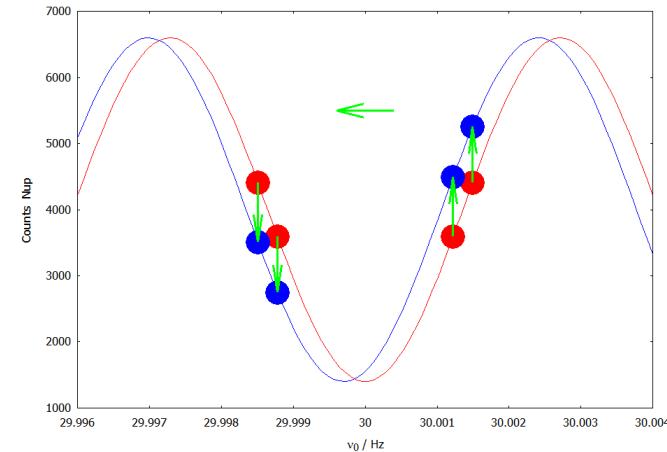
2016 : 1.5 % of available pulses missed

On-going analysis (preliminary)

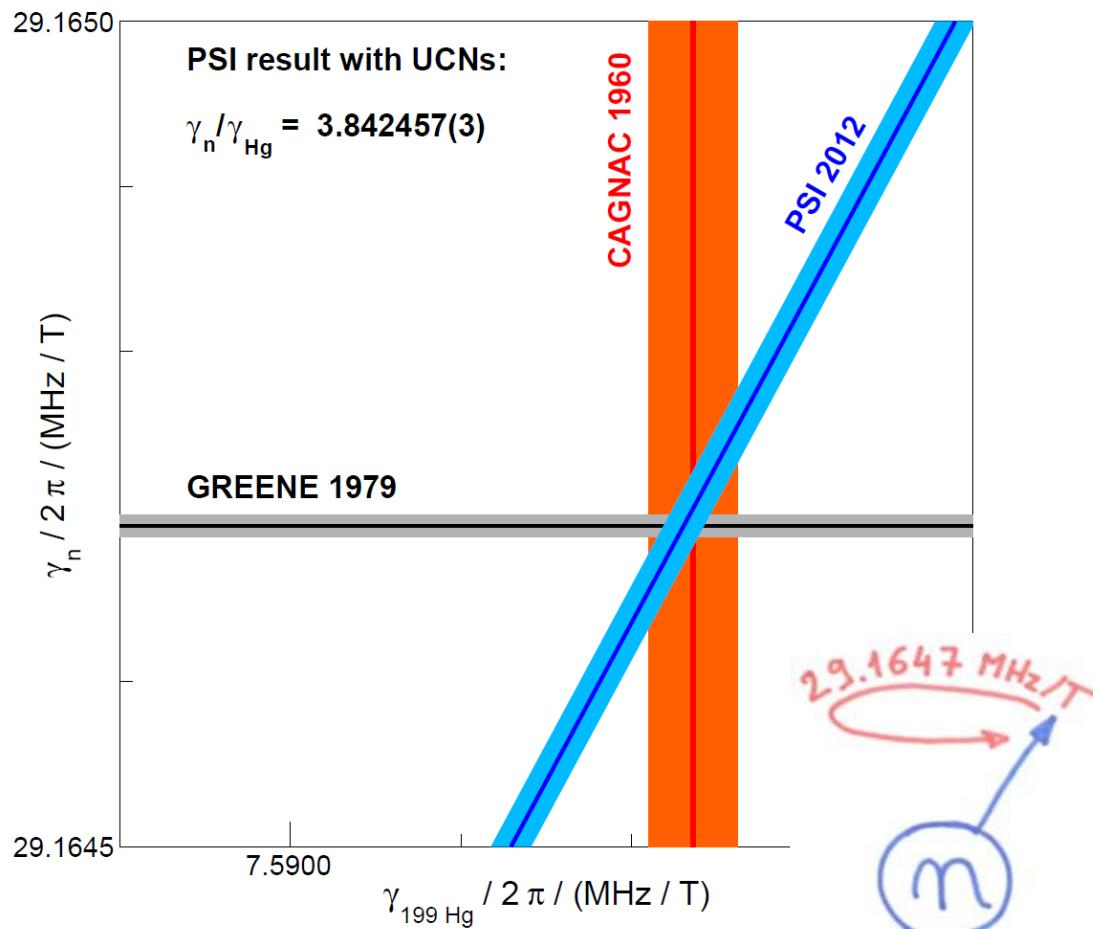
- Blinded data
- 2 analysis teams (East/West)

Demonstrated sensitivity  
after analysis (2015-2016)

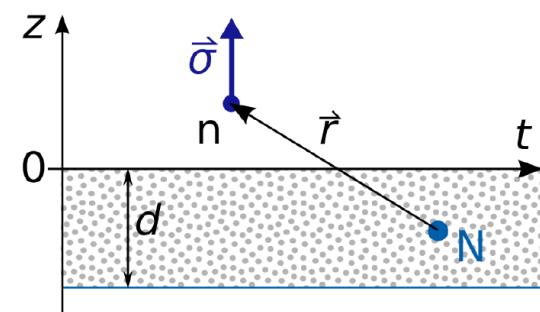
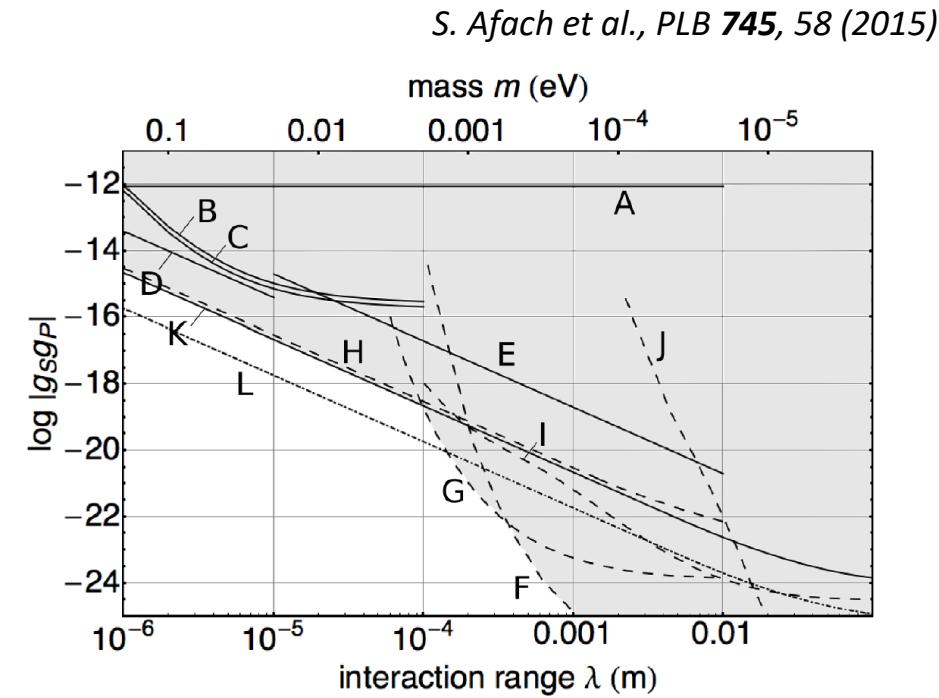
$$1.15 \times 10^{-26} e \cdot \text{cm}$$



Unblinded $d_n$ : $-1.28 \pm 3.85 \times 10^{-26} e \cdot \text{cm}$
Blinded $d_n$ : $4.63 \pm 1.22 \times 10^{-26} e \cdot \text{cm}$
$h: 0.40 \pm 0.07 \text{ cm}$
$\chi^2/\text{DoF}: 708/464, \text{ p-value: } 2.02\text{e-12}$



S. Afach et al., PLB 739, 128 (2014)

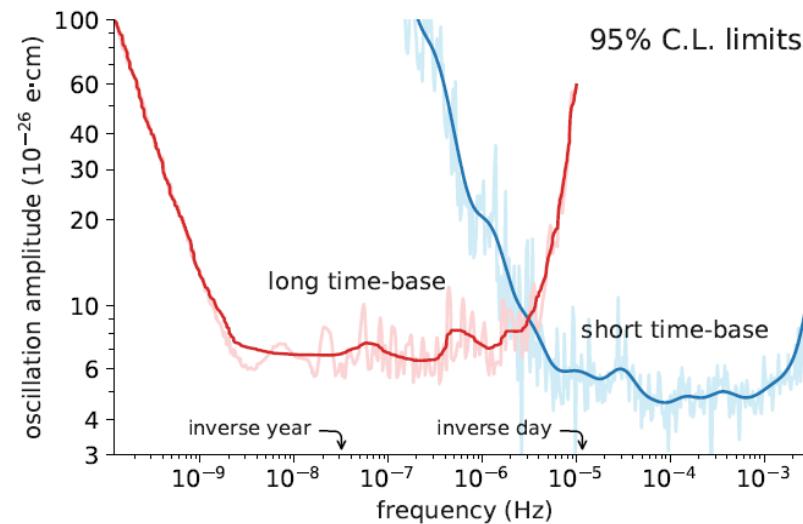


## Search for axion-like dark matter through nuclear spin precession in electric and magnetic fields

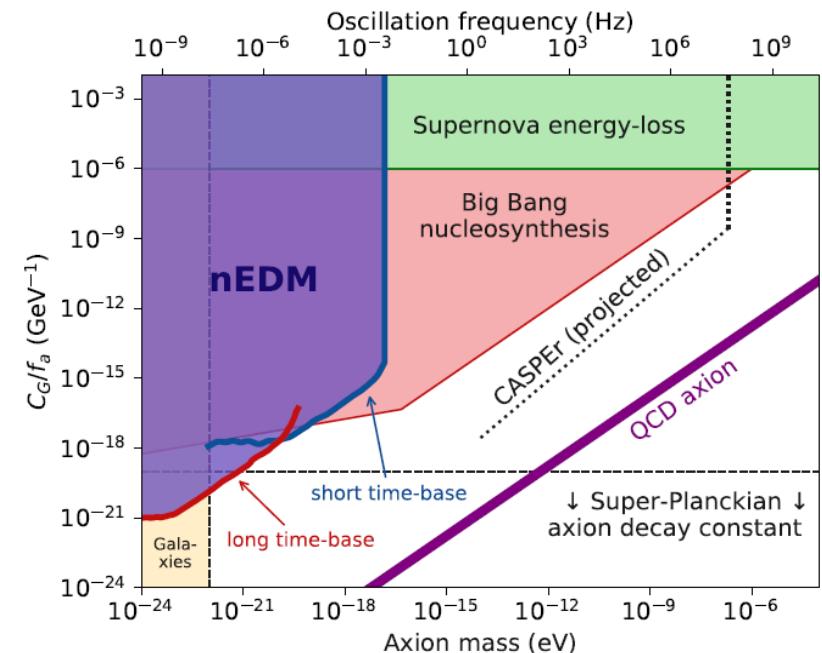
C. Abel et al. (RAL-Sussex\_ILL collab. + PSI collab + King's College London)

Physical Review X 7, 041034 (2017)

$$d_n(t) \approx +2.4 \times 10^{-16} \frac{C_G a_0}{f_a} \cos(m_a t) e \cdot \text{cm}.$$

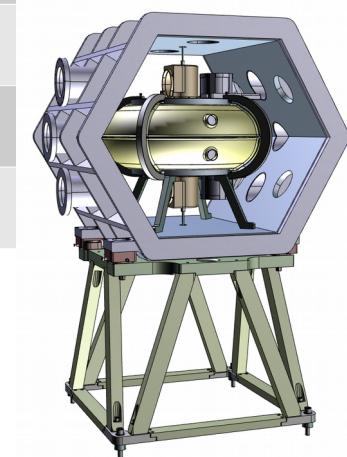
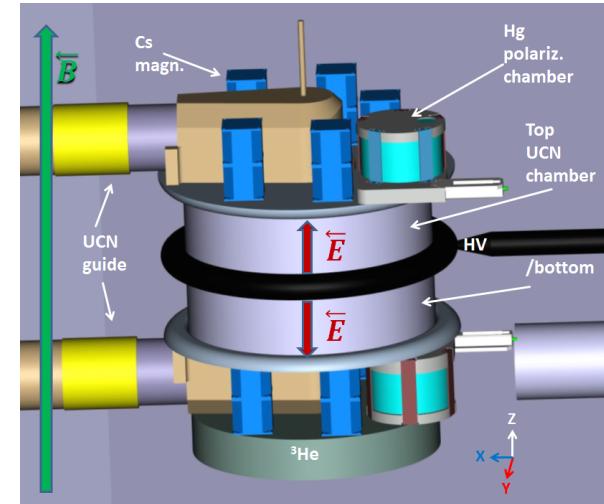


ILL data: long data taking

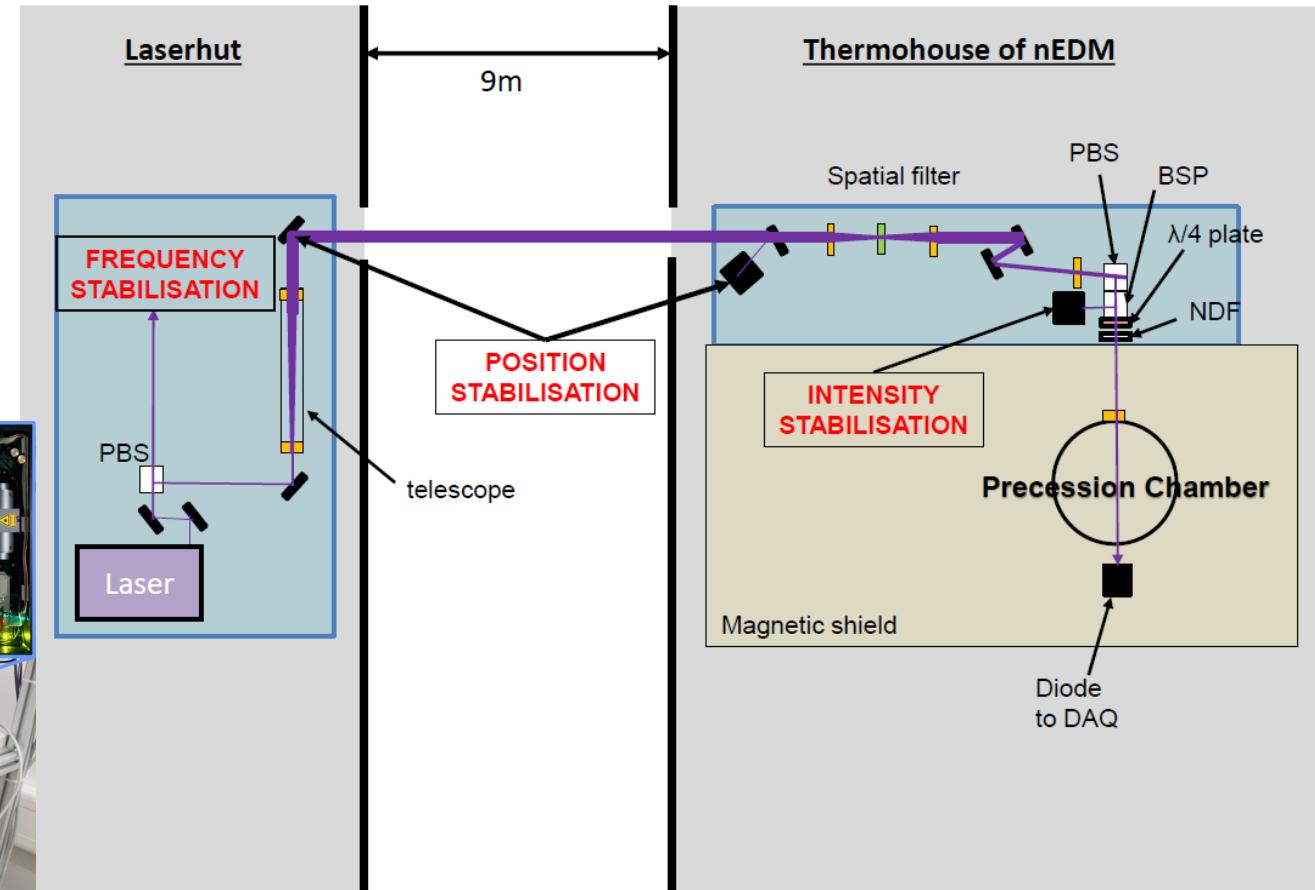
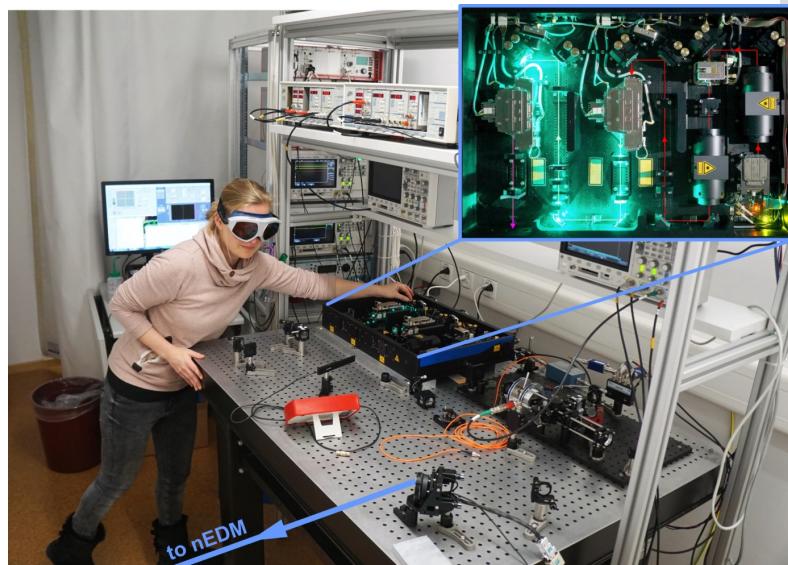


PSI data: high sensitivity  
Still blinded

	nEDM@ILL 2006	nEDM@PSI 2016	n2EDM@PSI 2020
Chamber	1	1	2
Diameter (cm)	47	47	100
Neutron/cycle	14 000	15 000	400 000
E(kV/cm)	8.3	11 (15)	15
T(s)	130	180	180
$\alpha$	0.45 (0.6)	0.75 (0.80)	0.8
Sens/day(e.cm)	$30*10^{-26}$	$11*10^{-26}$	$1.4*10^{-26}$
Sens (500 days)	$1.3*10^{-26}$	$5.0*10^{-27}$	$6.4*10^{-28}$

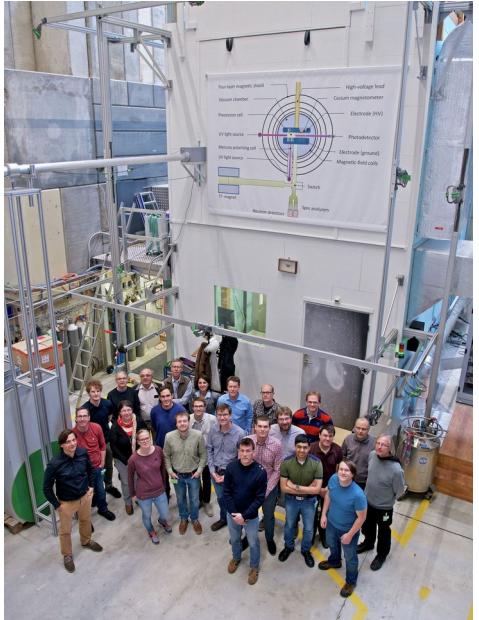


Hg co-magnetometer  
nEDM sensitivity: 50-70 fT (35 fT)  
n2EDM requirements: 26 fT

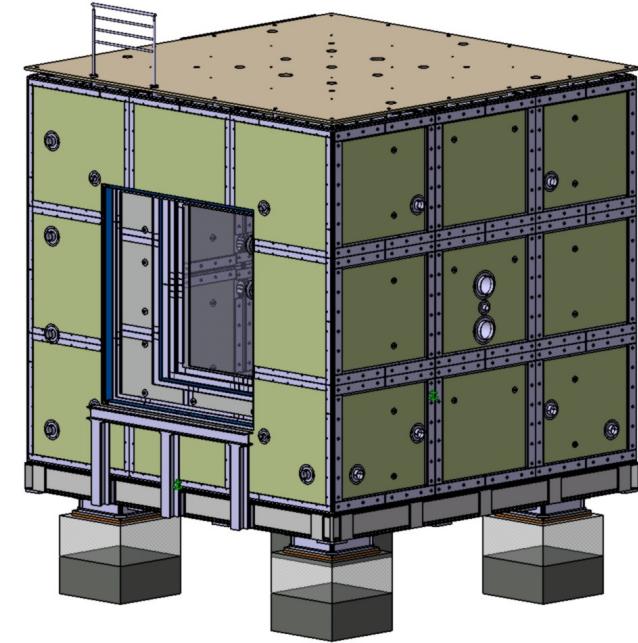


Demonstrated sensitivity: 8 fT  
Used for nEDM data taking in 2017

# 2017: Hard work in the UCN hall

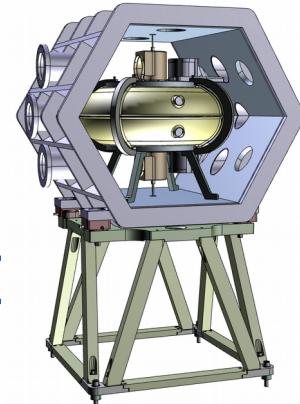


2017: removing of  
the OILL  
spectrometer



March 2018 installation of the shielded  
room

- n2EDM R&D efforts merged into one concept design
- Highly based on demonstrated techniques
- Shielded room expected in 2018



- nEDM operated with high efficiency and world-record sensitivity
- Systematic effect studies reanalysis of 2006 data
- More data in 2017 for by products



Thanks  
Merci