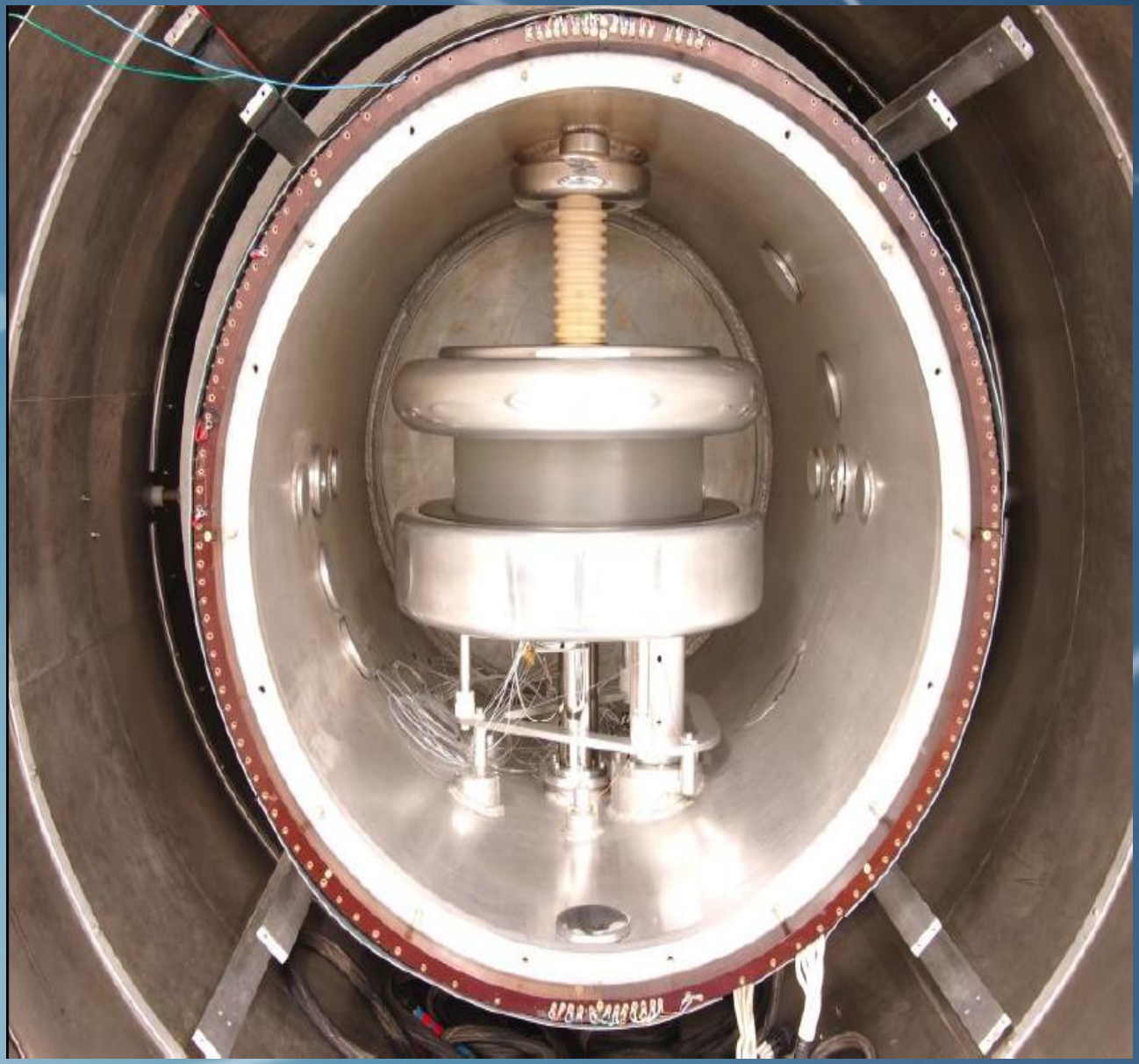
The nEDM experiment at PSI

Prashanth P N
on behalf of
the nEDM
collaboration



The Neutron Electric Dipole Moment

- Why are EDM's interesting?
- How to measure
- nEDM Appartus
- Systematic effect

Baryon Asymmetry

We live in a material world

Sakharov criteria

[JETP Lett. 5 (1967) 24]

- Baryon number violation
- C and CP violation
- Thermal non-equilibrium

There is no evidence of Antimatter;
Where has it gone?

SM expectation

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

[Riotto et al. 1999 Ann.Rev.Nucl.Part.Sci. 49

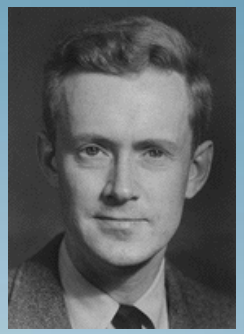
vs.

Observed:

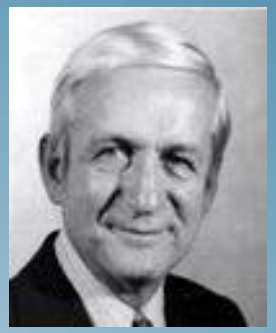
$$\frac{n_B - n_{\bar{B}}}{n_\gamma} \approx 10^{-10}$$

[E. Komatsu et al. 2011 ApJS 192

EDM and CP violation



Edward Purcell



Norman Ramsey

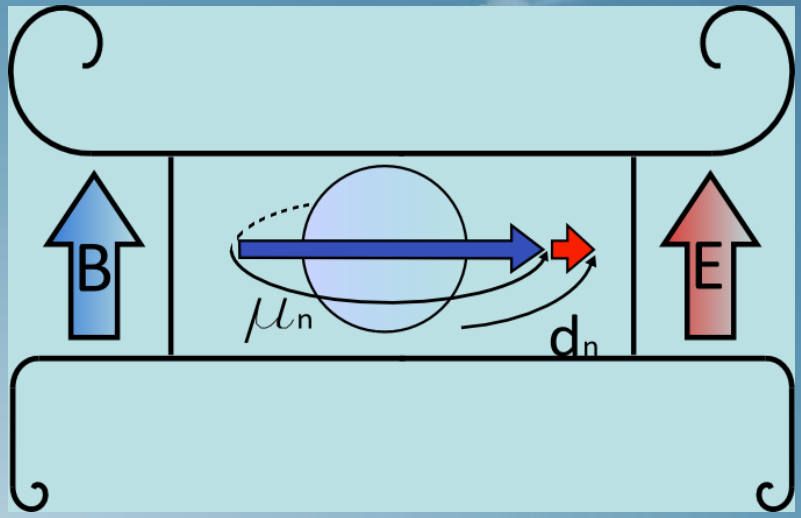
A nonzero particle EDM violates P, T and, assuming CPT conservation, also CP.

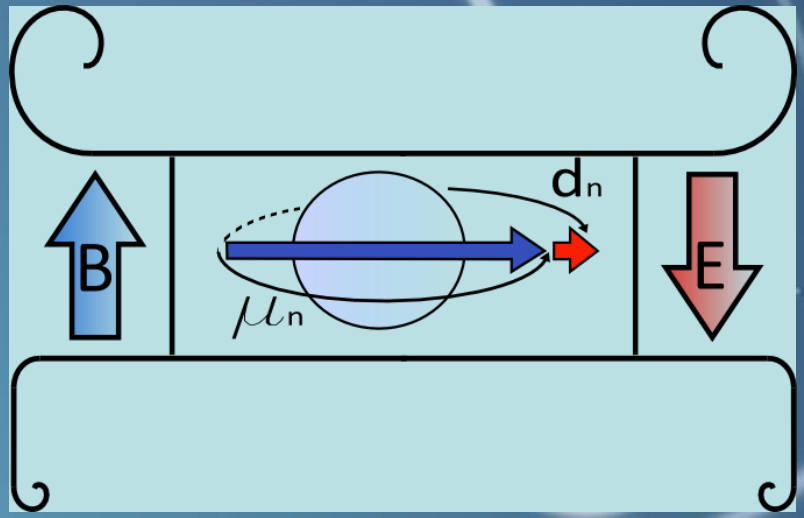
[Purcell and Ramsey, Phys. Rev. 78, 807 (1950)]

"It is generally assumed on the basis of some suggestive theoretical symmetry arguments that nuclei and elementary particle can have no electric dipole moments. It is the purpose of this note to point out that although these theoretical arguments are valid when applied to molecular and atomic moments whose electromagnetic origin is well understood, their extension to nuclei and elementary particles rests on assumptions not yet tested"

The measurement technique

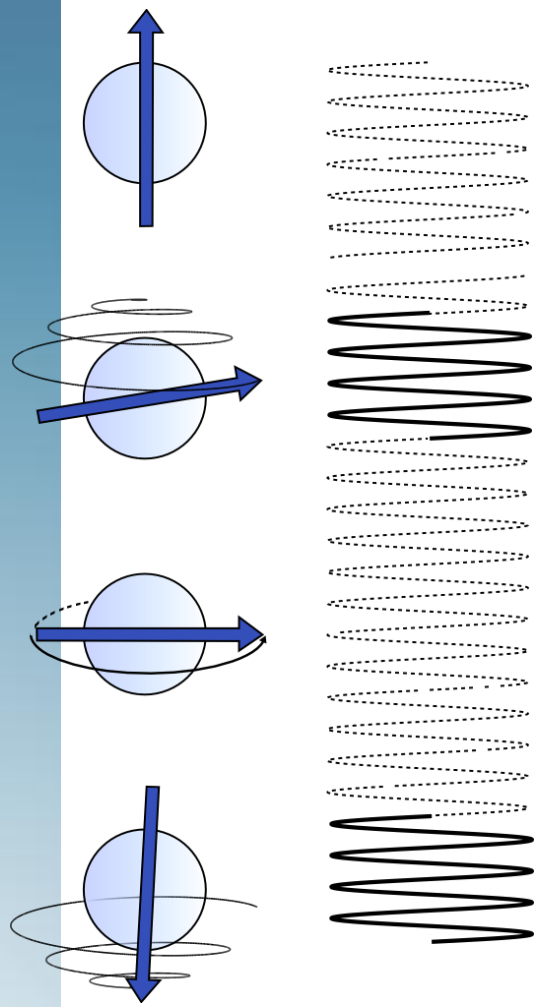
Measure the difference in the Lamor precession frequency of stored ultracold Neutrons (UCN) in parallel and anti-parallel electric and magnetic field configuration.





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

Ramsey method of oscillating field



Neutron clock

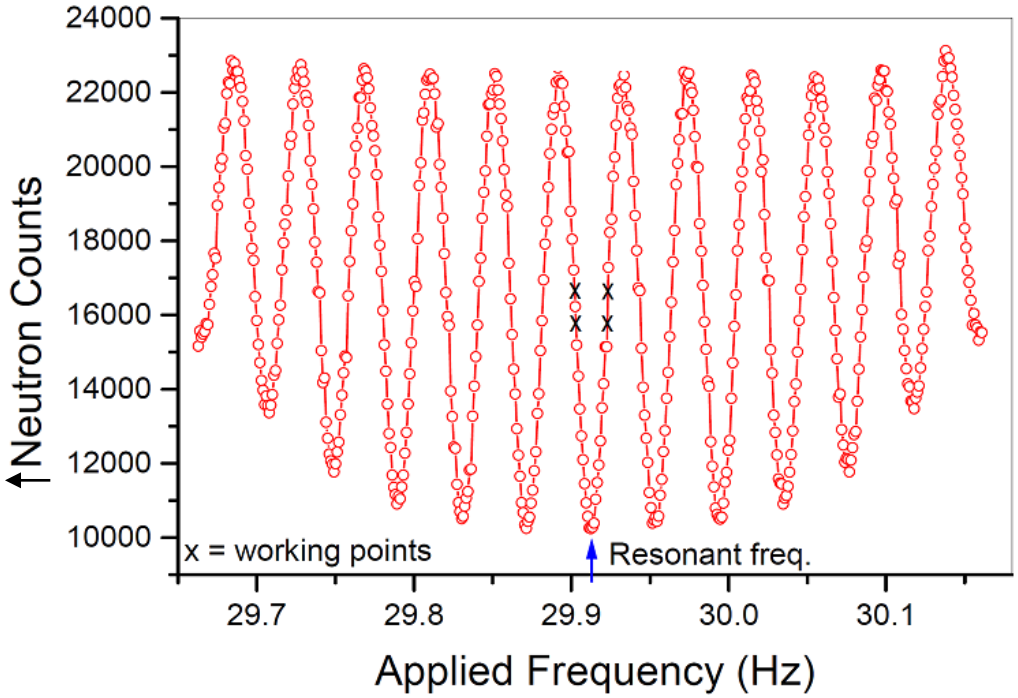
external clock

Spin up neutrons

π/2 flip pulse

Free precession

π/2 flip pulse

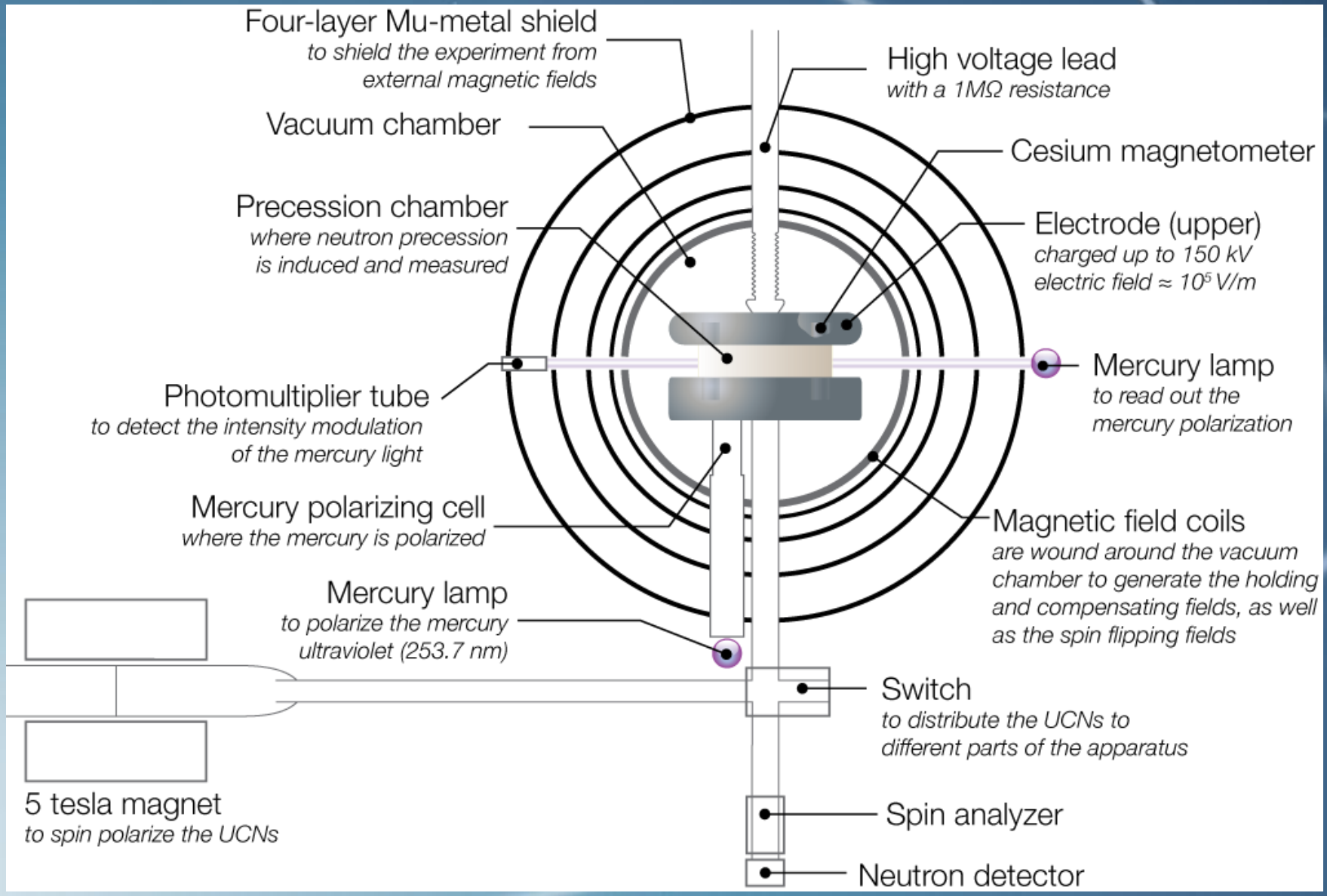


Statistical sensitivity

$$\sigma = \frac{\hbar}{2E\alpha T\sqrt{N}}$$

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

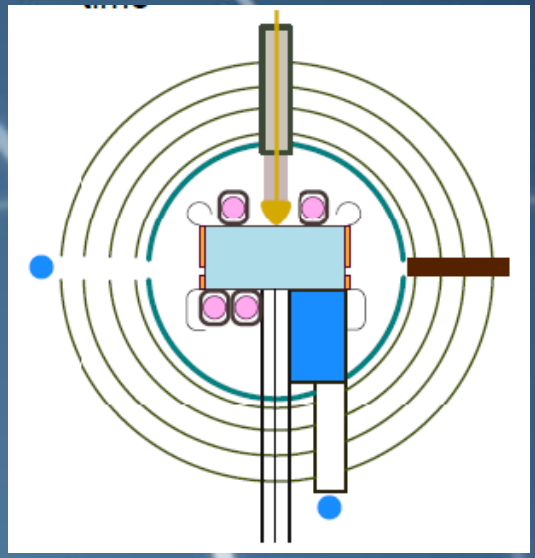
The Apparatus



Systematic effects

Effect	Status (10-27 e.cm)
Leakage Current	0.00±0.05
Uncompensated B Drift	2.9±8.6
vxE UCN	0±0.1
Electric Forces	0 ±0.4
Hg EDM	0.02±0.06
Hg Light Shift	0±0.05
Quadrupole Difference	1.3±2.4
Dipoles	0±3
Total	4.2±9.4

What is Uncompensated



Charging the electrodes could magnetize the shield e.g. close to the HV feed trough => False EDM.

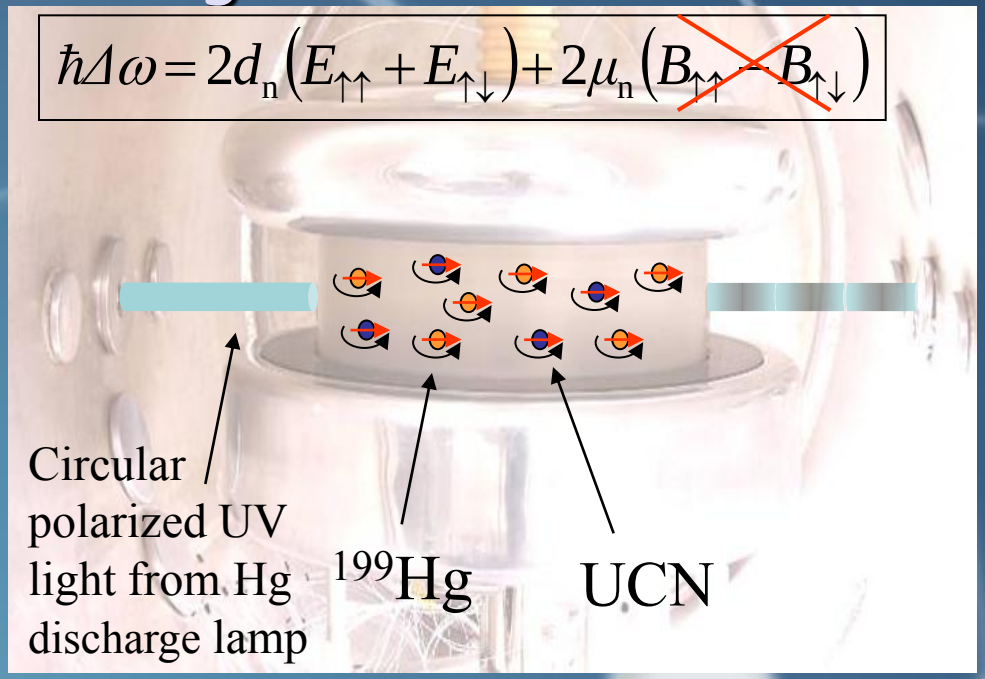
"uncompensated magnetic field drift"

Uncompensated magnetic field drift

Cancelation of magnetic field changes:

Measure online the free precession of polarized 199Hg atoms in the same volume at the same time as the UCN to correct for magnetic field drifts.

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



BUT :

UCN		Hg
$v \approx 3$ m/s	g	$\langle v \rangle \approx 200$ m/s

Difference in the center of mass of UCN and Hg Δh = O(mm).
Any change in the vertical magnetic field gradient will not be Compensated

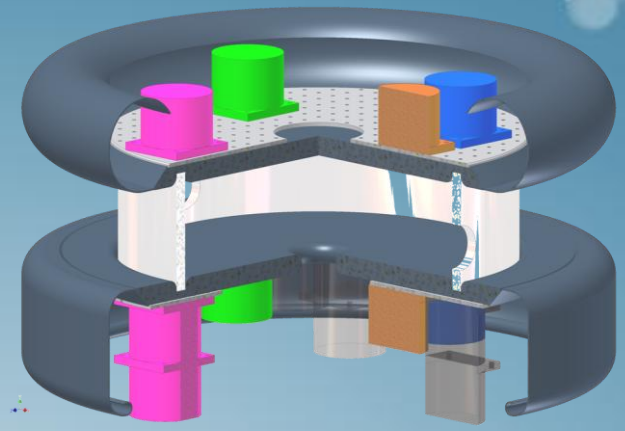
$$f_n = f_{Hg}\frac{\gamma_{Hg}}{\gamma_n}\left(1 + \frac{\partial B}{\partial z}\frac{\Delta h}{B}\right)$$

Uncompensated magnetic field drift

What did RAL Sussex done

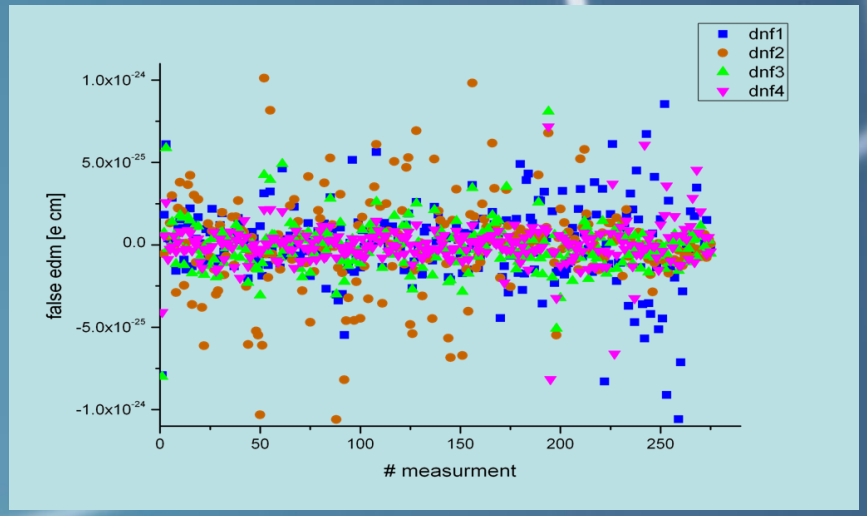
First order effect is compensated by Hg co magnetometer. Gradient fields are only suppressed due to center of mass offset (e.g. h = 0.2 cm)

Additionally we have also Cs magnetometers



In order to study this, the Hg and neutron channels were analyzed independently. The neutrons yielded an EDM signal of $(17 \pm 4) \times 10^{-26} e$ cm; the Hg, once the GP contribution (as calculated from the average $R_a - 1$ at which the data were taken) was subtracted, yielded $(-3.9 \pm 0.8) \times 10^{-26} e$ cm. These results are consistent with a common source of magnetic fluctuations correlated with the HV. We therefore expect the Hg compensation to shield us from this systematic effect to a level of $17 \times 10^{-26}/70 = 2.4 \times 10^{-27} e$ cm.

Baker *et. al.* PRL 97, 131801

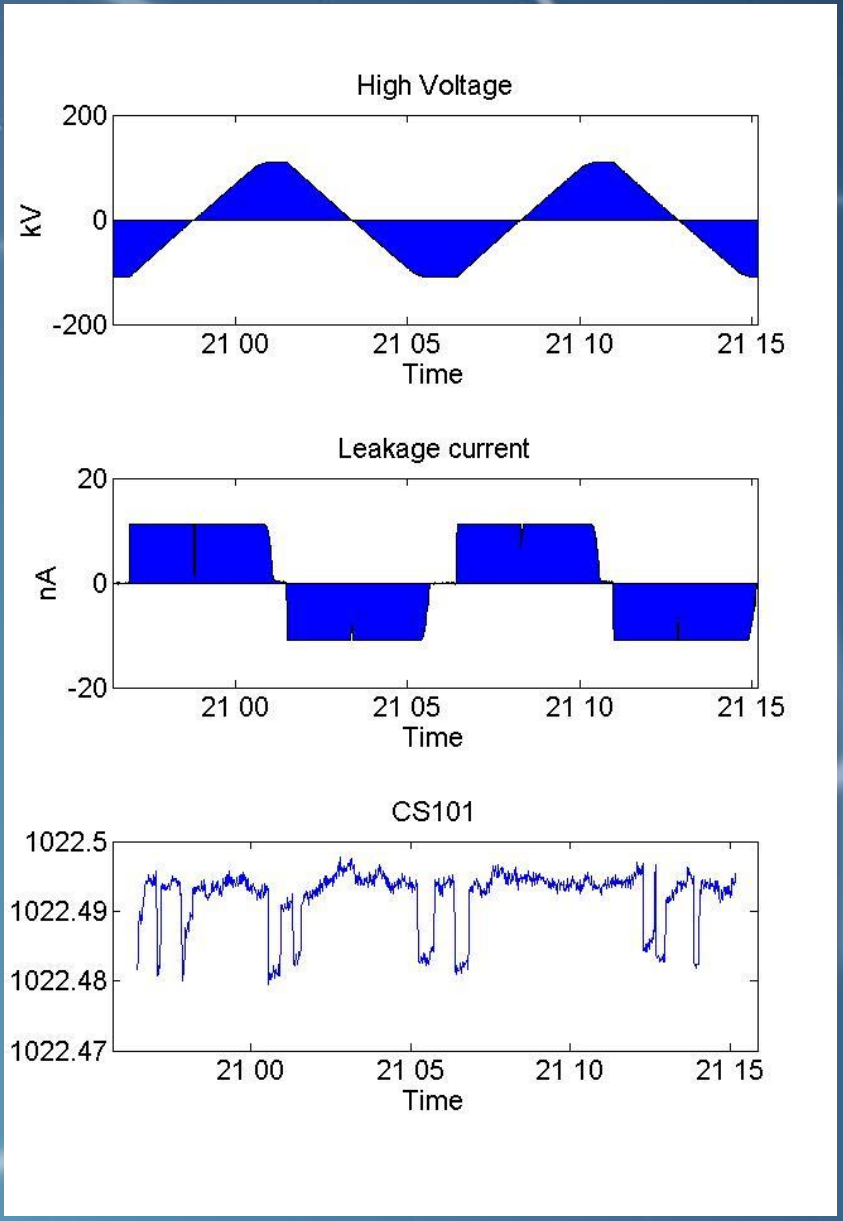


For gradient correlated with electric field changes(e.g. create a magnetization with charging currents) this would result in a EDM like signal!

Use Cs magnetometers to measure the gradient → check for this systematic

How to measure

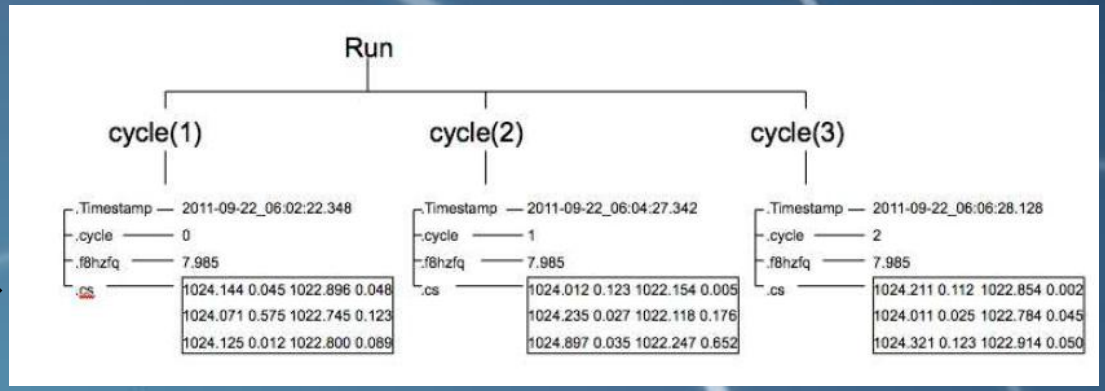
- Ramp high voltage up and down with typical ramping speed
- Use a pattern +--+-++- to be insensitive against linear drifts
- Measure Voltage, Leakage current, and Magnetic field with CS
- Look for a change in the magnetic field (gradient) that is correlated with the electric field



Data Analysis

Read the Data from files ini,meta,HV,CS,leakage etc

Combine it into a structure with matching timestamps



Average Cs to calculate gradients

Calculate gradients (G) and difference of gradients (diffG)

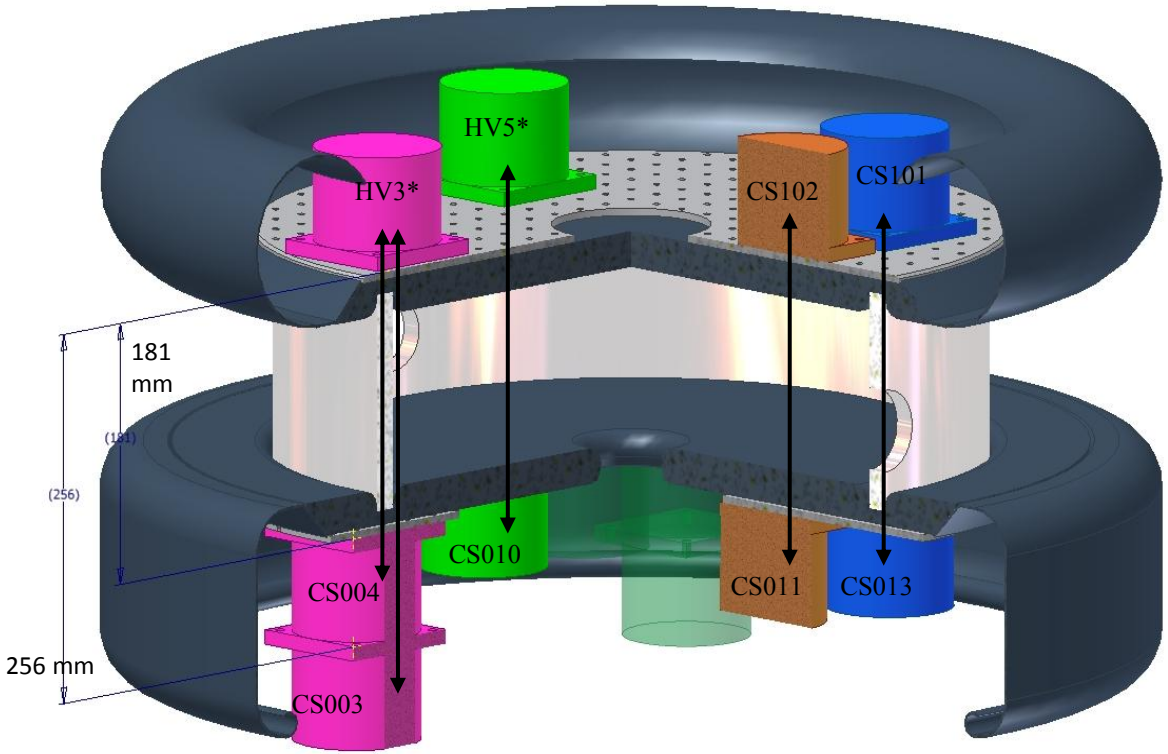
Apply a cut to leakage current bigger 1 nA

Extract false EDM

$$dn_f = \frac{\mu_n \Delta h}{(E^+ - E^-)}(G^+ - G^-)$$

Data Analysis is in Progress

Data Analysis



Summary

2012 already promising, measured UCN related parameters and First set of EDM data taken.

Investigating systematic effects (most are under control)

2013 will be very exciting as we will trying to get the more EDM data for improved Sensitivity

Hopefully brings us one step further in understanding our Universe

Thank you