The Neutron EDM Collaboration

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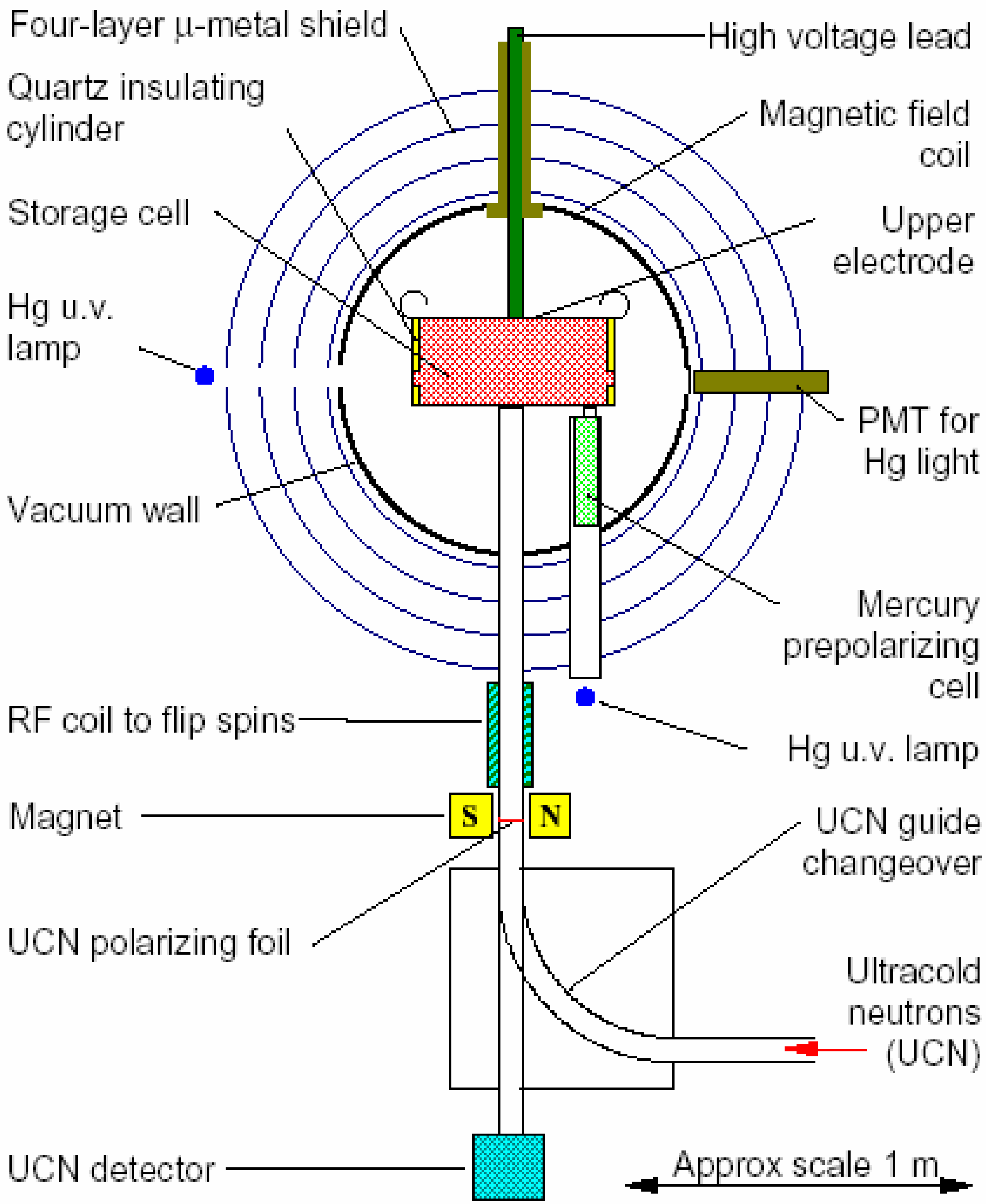
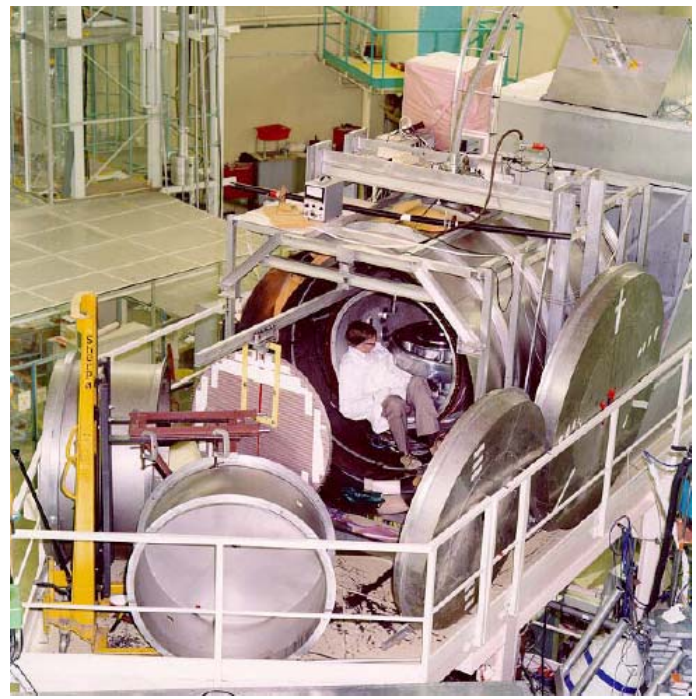


Context: OILL

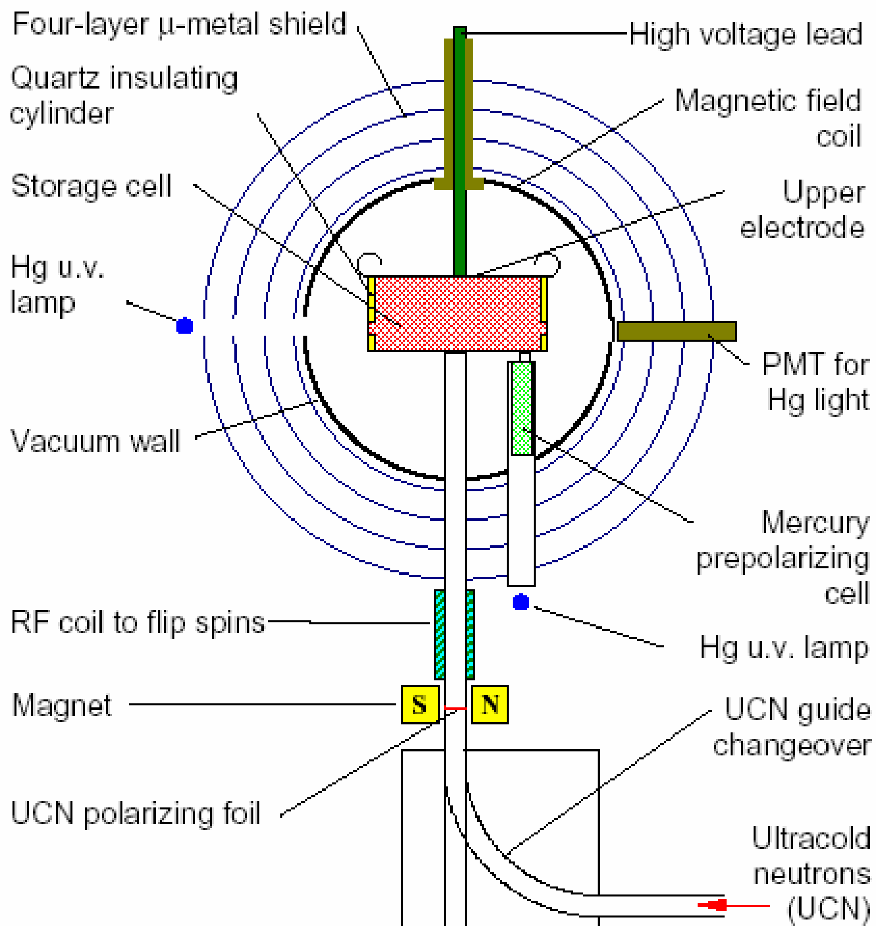
Sussex-RAL-ILL experiment

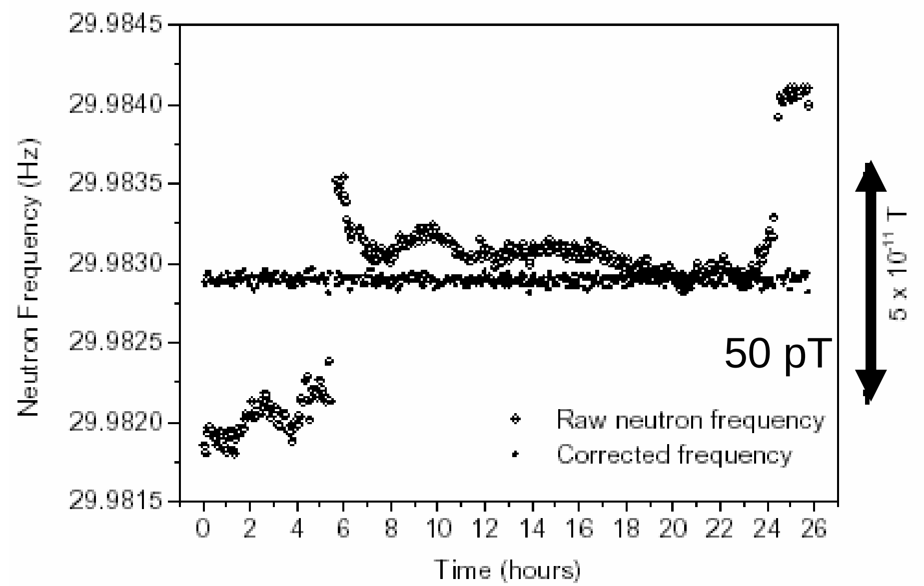
$d_n < 2.9 \times 10^{-26}$ e cm

C. A. Baker et al., PRL 97 (2006) 131801
P. G. Harris et al., PRL 82 (1999) 904



Context

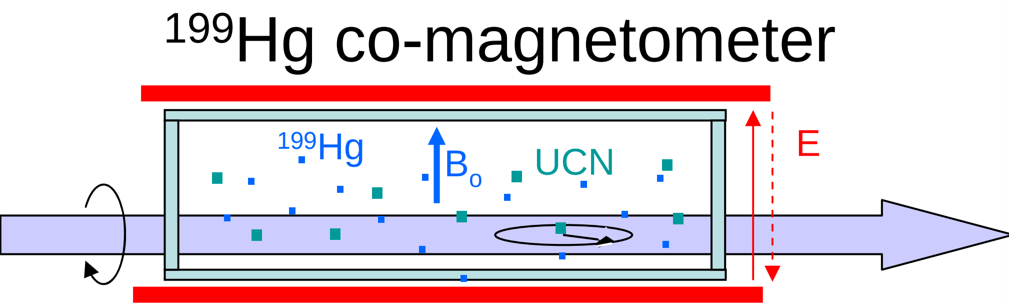


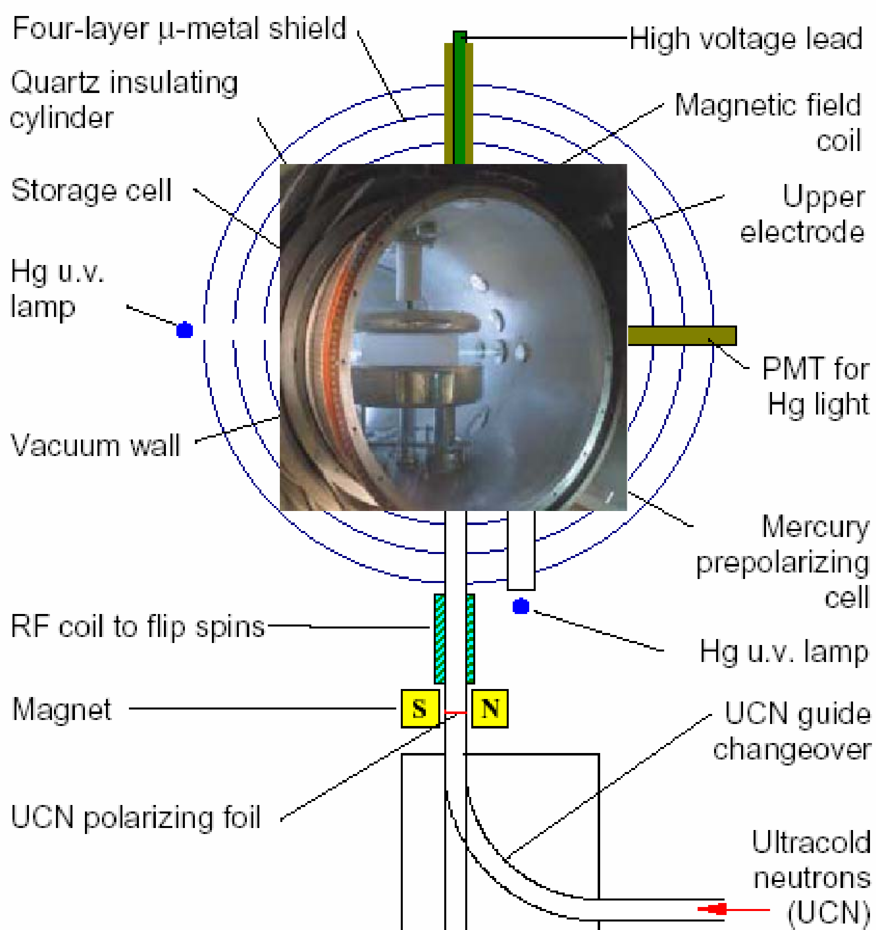


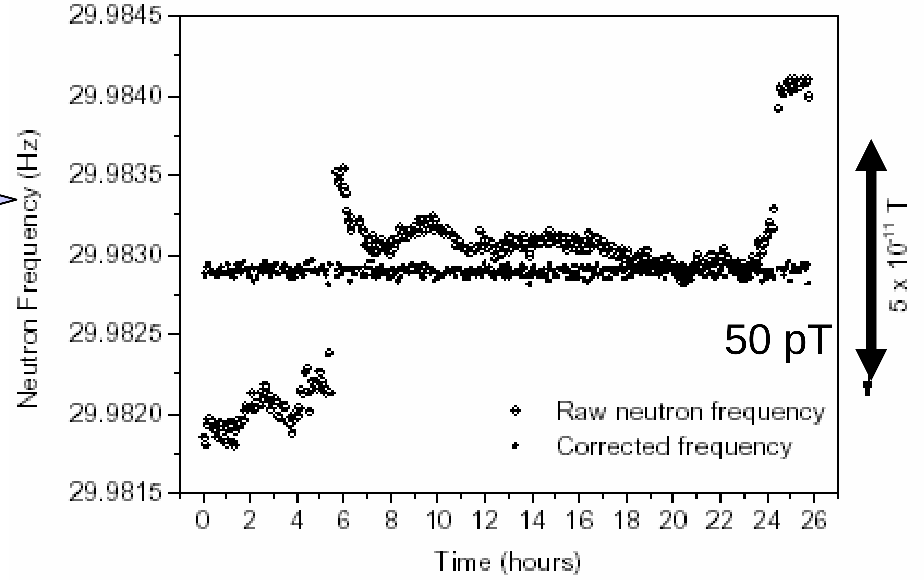
$$h\nu^{+} = 2\,(\mu_n B + d_n E)$$
$$h\nu^{-} = 2\,(\mu_n B - d_n E)$$

$$h\Delta\nu = 4\,d_n\,E$$

Context







K.Green et al., NIM A 404 (1998) 381
P. G. Harris et al., PRL 82 (1999) 904

J.M.Pendlebury et al., PR A 70 (2004) 032102
S.K.Lamoreaux and R.Golub, PR A 71 (2005) 032104
P.G.Harris and J.M.Pendlebury, PR A 73 (2006) 014101
C.A.Baker et al., PRL 97 (2006) 131801

For progress, need to improve sensitivity and systematics, especially UCN performance and magnetic field control

Our Strategy

Optimize (proven)
in-vacuum,
room-temperature
technique

Strategy

- Phase I:
  - Operate and improve OILL@ILL (-2008)
  - Move of OILL in 2008 (approved by RAL/Sussex)
  - Design of n2EDM, related R&D
- Phase II:
  - Operate OILL@PSI (2009-2010)
  - Sensitivity goal: 5×10^{-27}ecm
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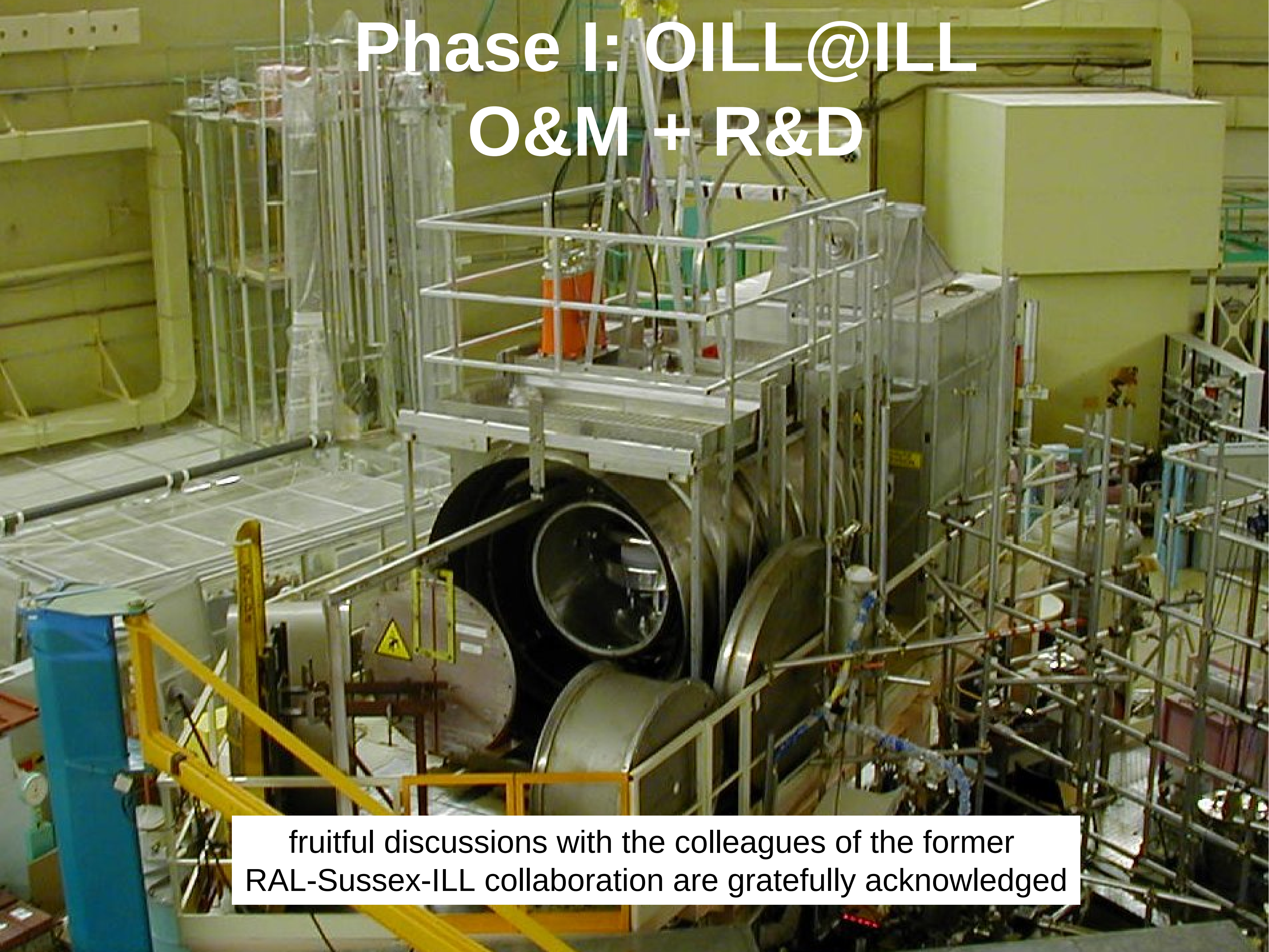
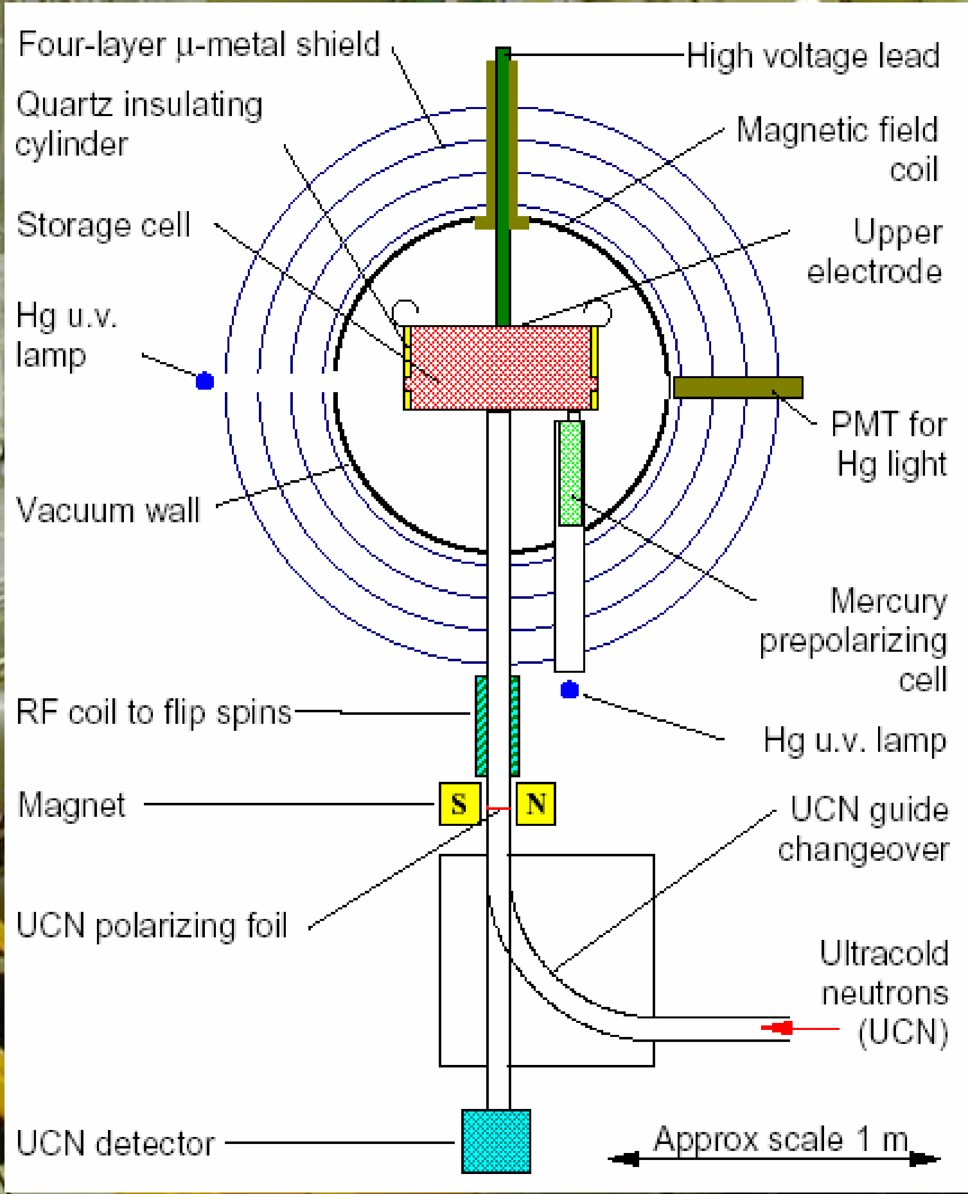
Optimize in-vacuum, room-temperature technique

Phase I: OILL@ILL
O&M + R&D

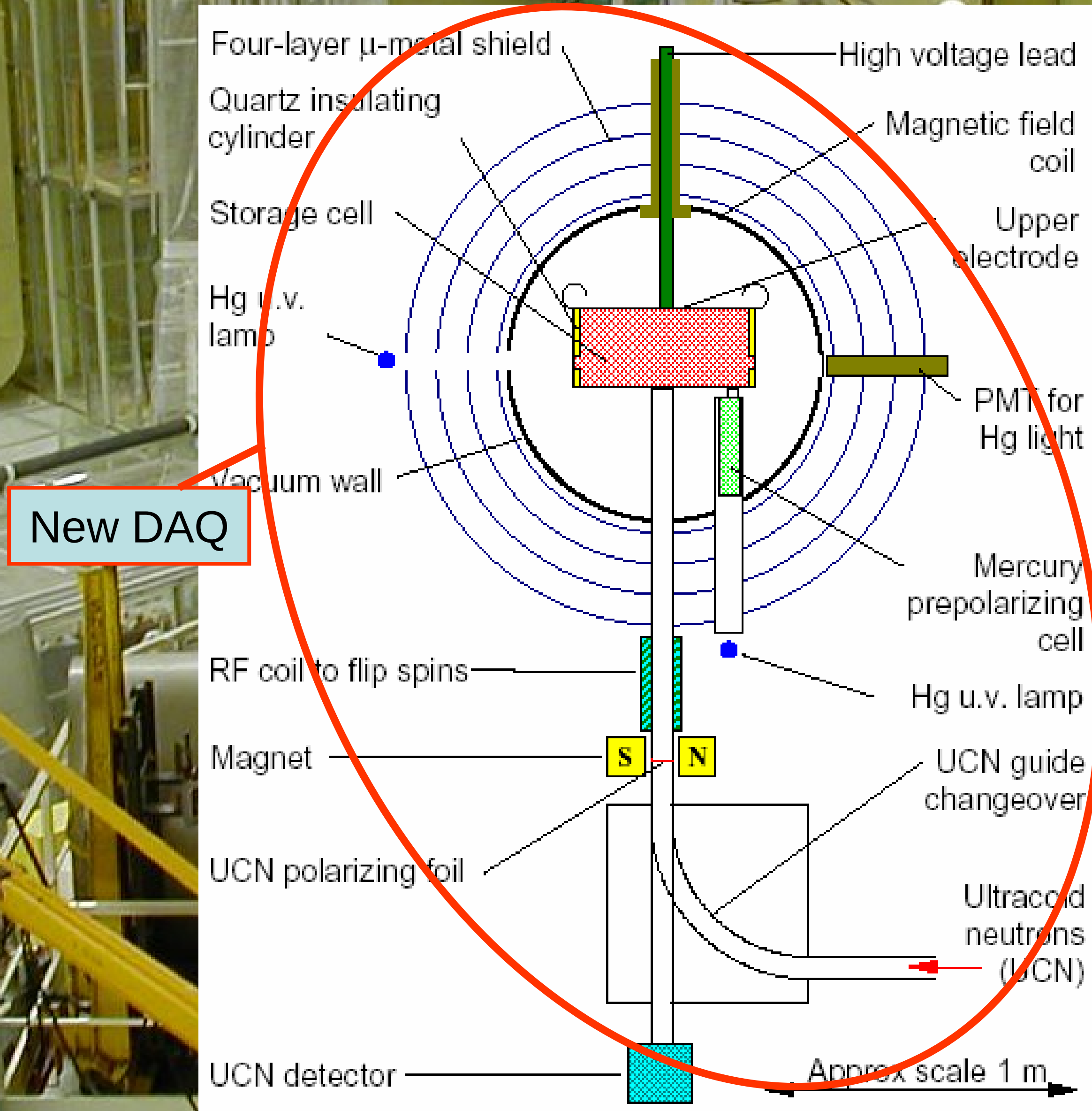


fruitful discussions with the colleagues of the former
RAL-Sussex-ILL collaboration are gratefully acknowledged

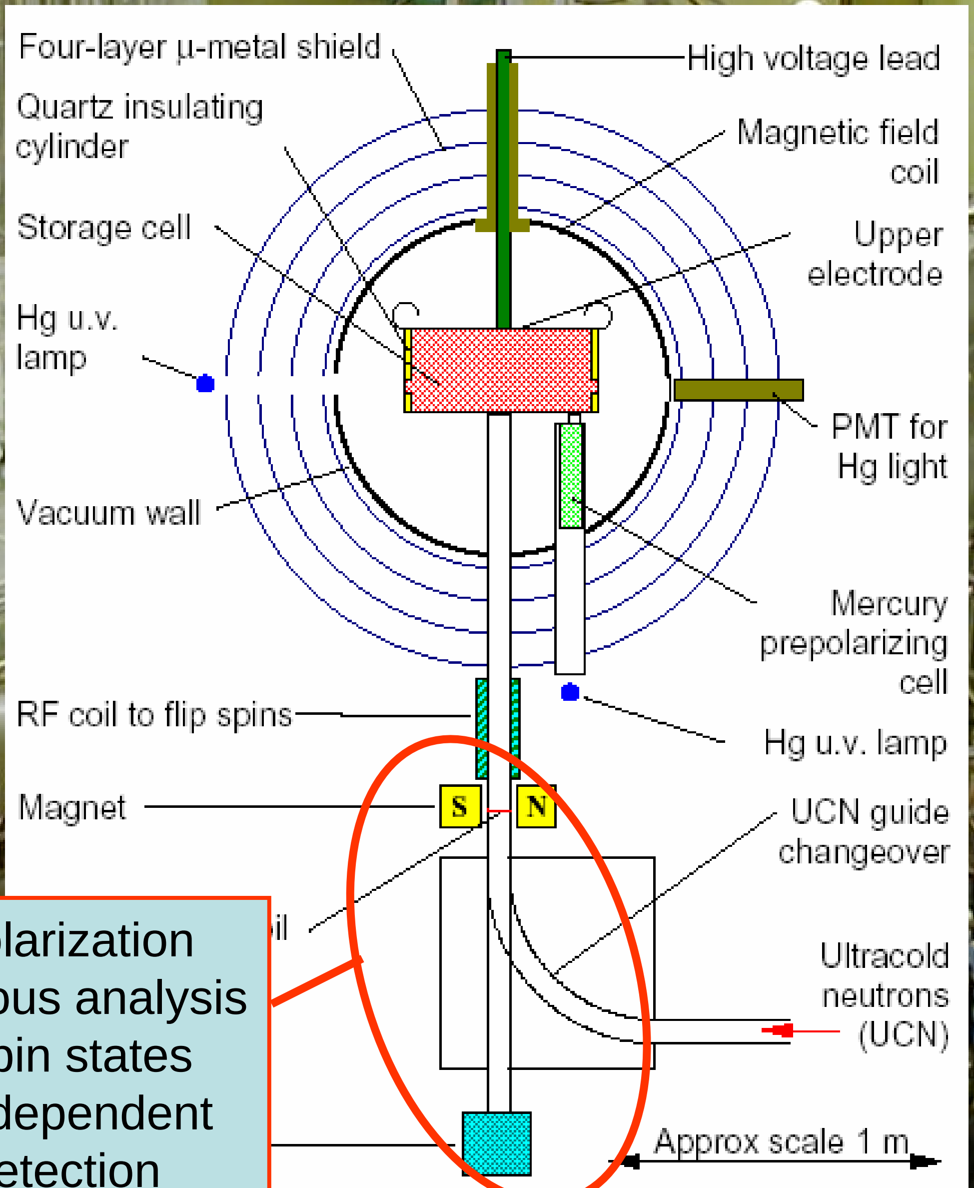
Phase I: OILL@ILL, O&M + R&D



Phase I: OILL@ILL, O&M + R&D



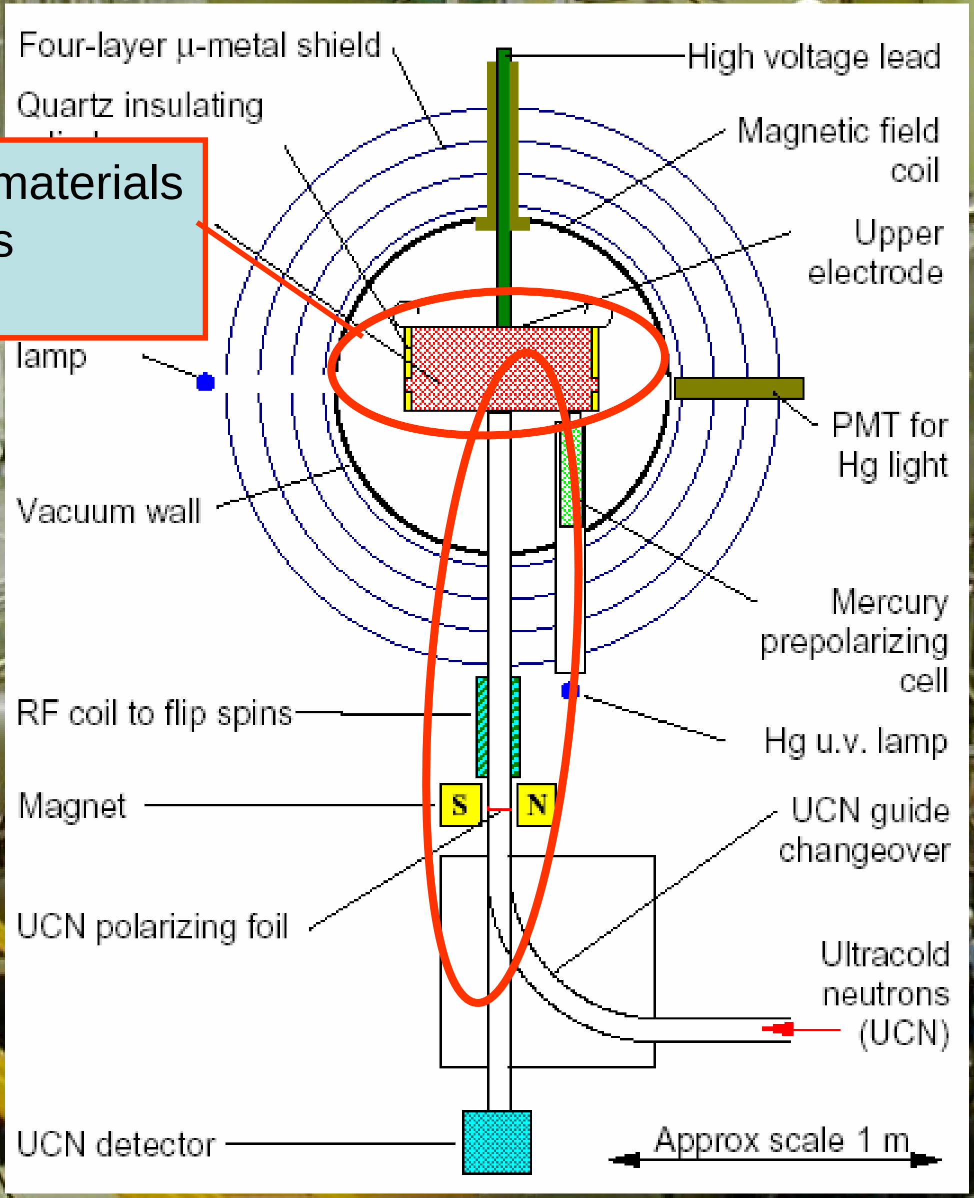
Phase I: OILL@ILL, O&M + R&D



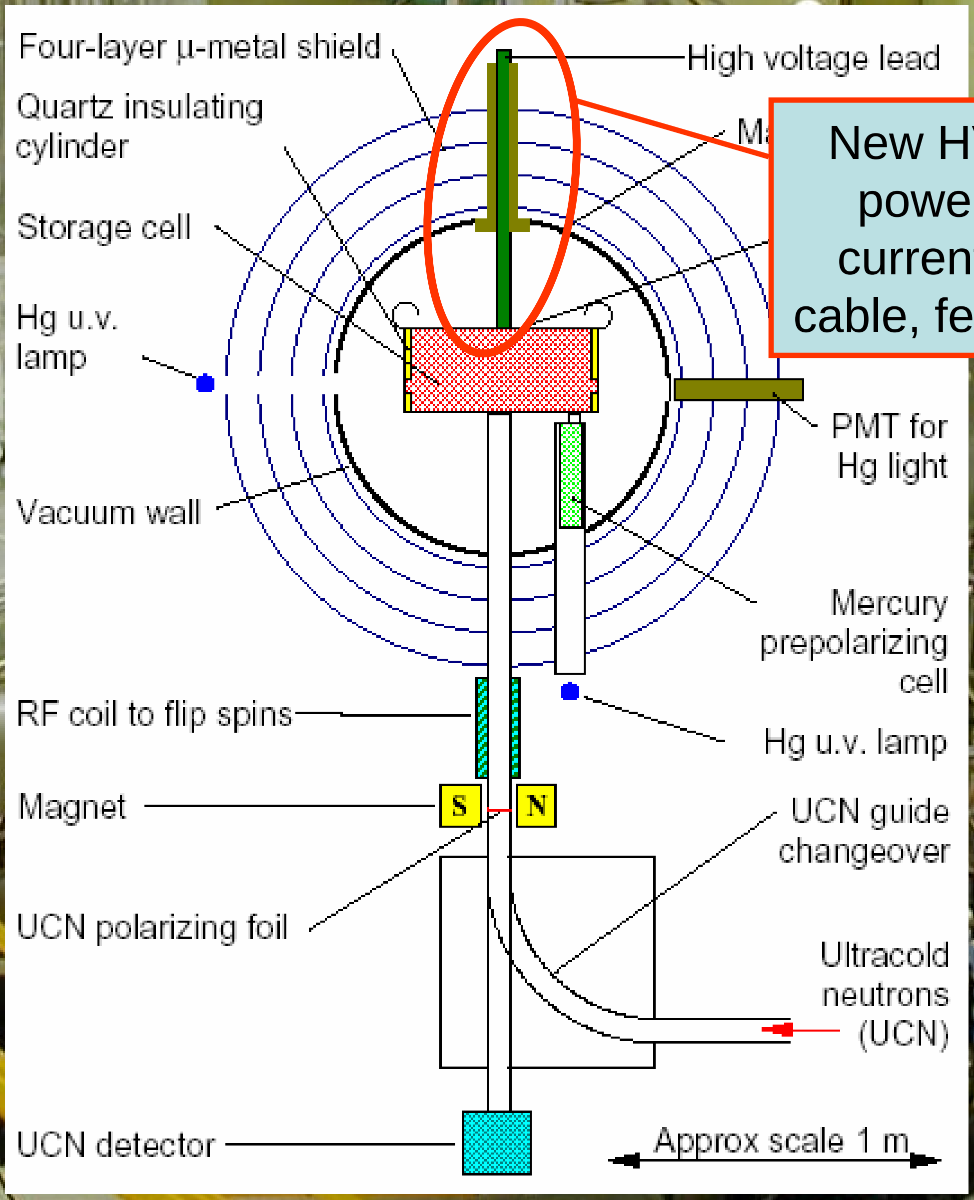
- UCN polarization
- simultaneous analysis of both spin states
- velocity dependent UCN detection

Phase I: OILL@ILL, O&M + R&D

- New chamber materials
  - Shutters
  - Guides

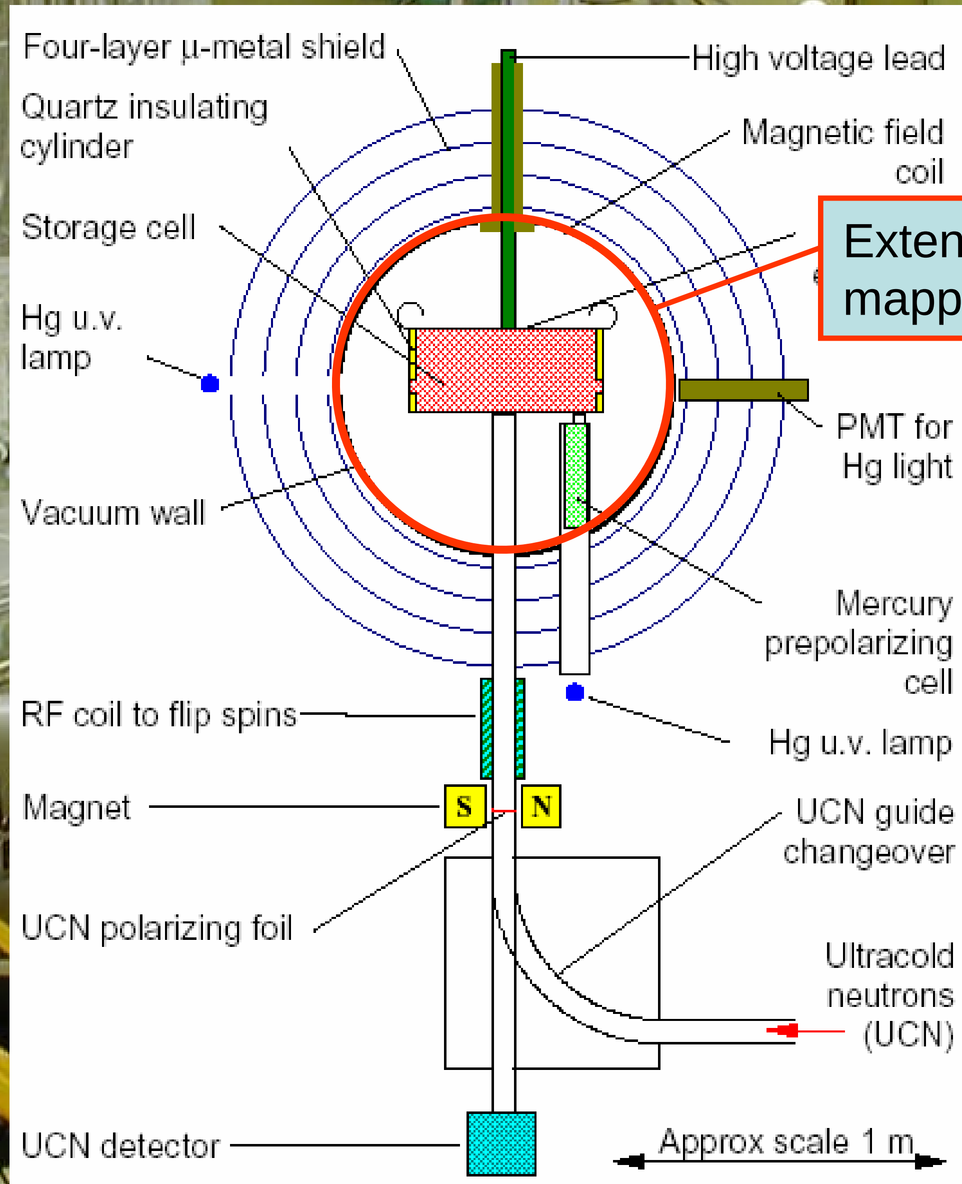


Phase I: OILL@ILL, O&M + R&D



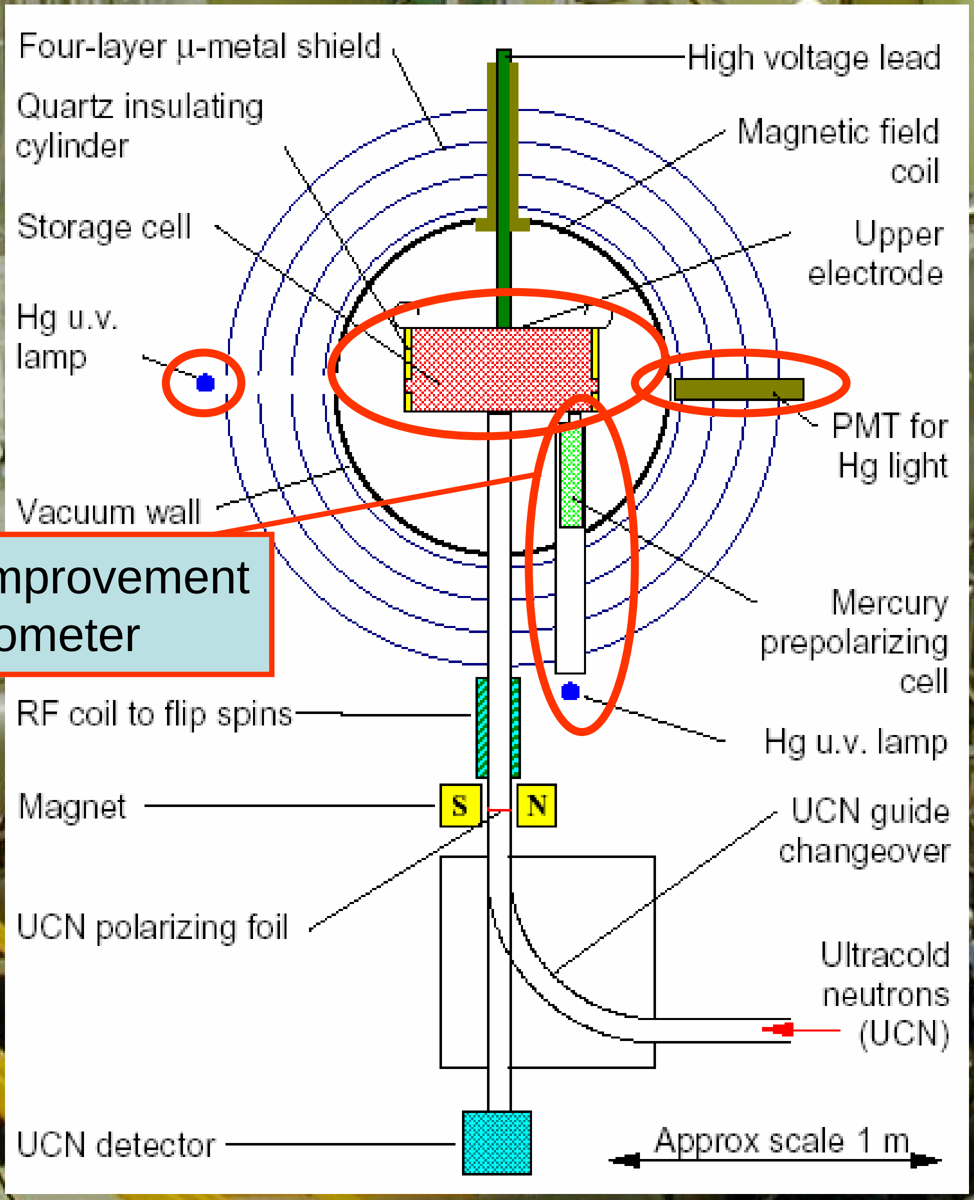
New HV system, power supply, current monitor, cable, feed through

Phase I: OILL@ILL, O&M + R&D



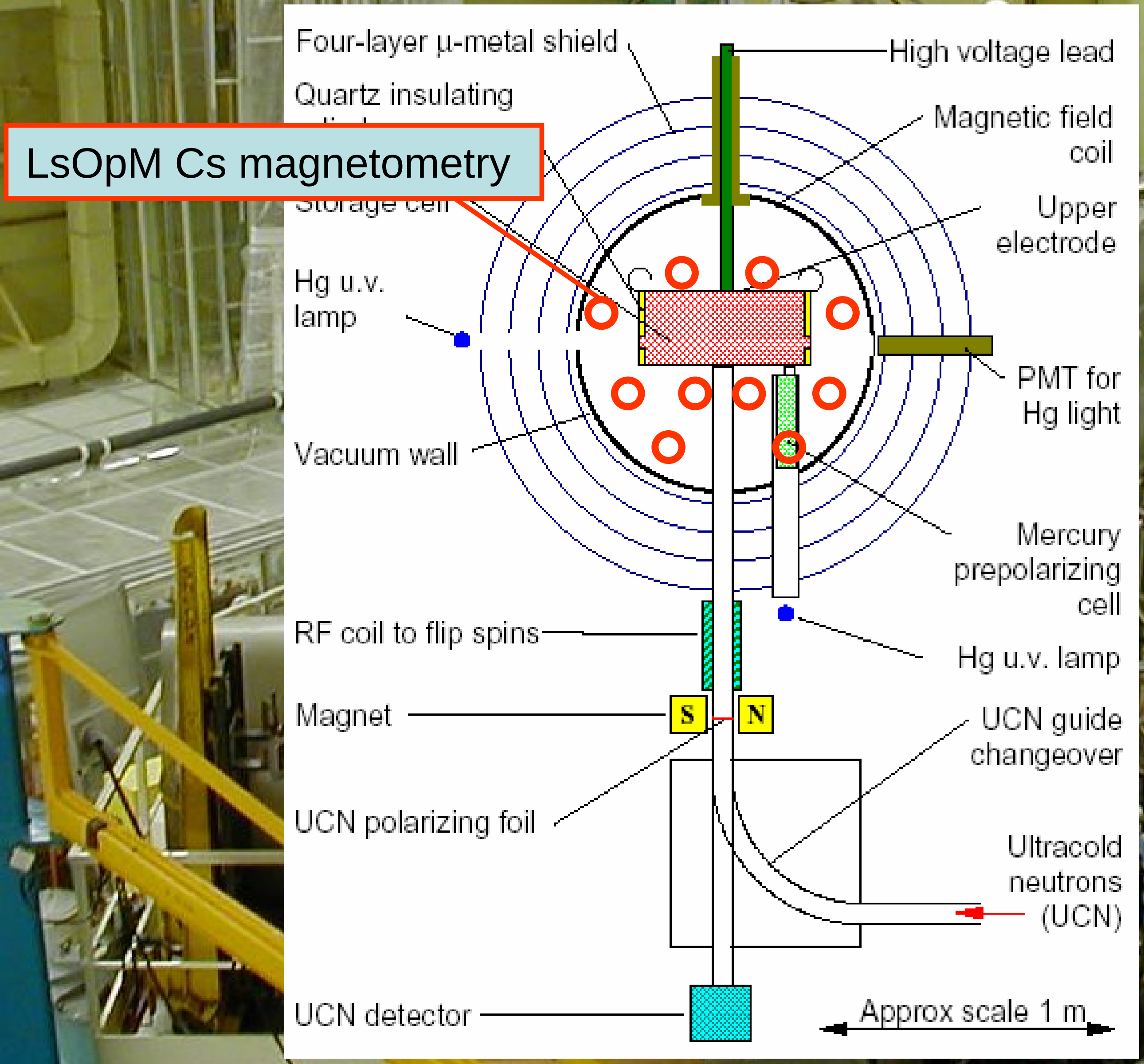
Extensive magnetic field mapping and calculation

Phase I: OILL@ILL, O&M + R&D



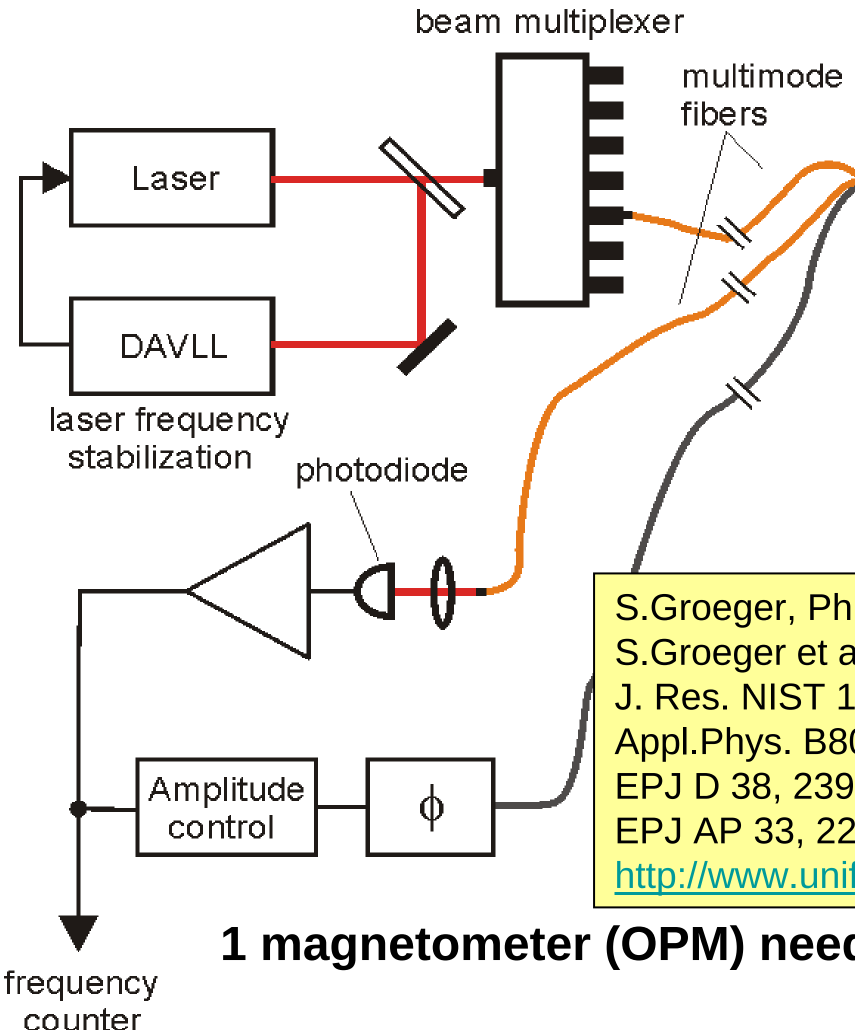
Hg magnetometer improvement
2nd co-magnetometer

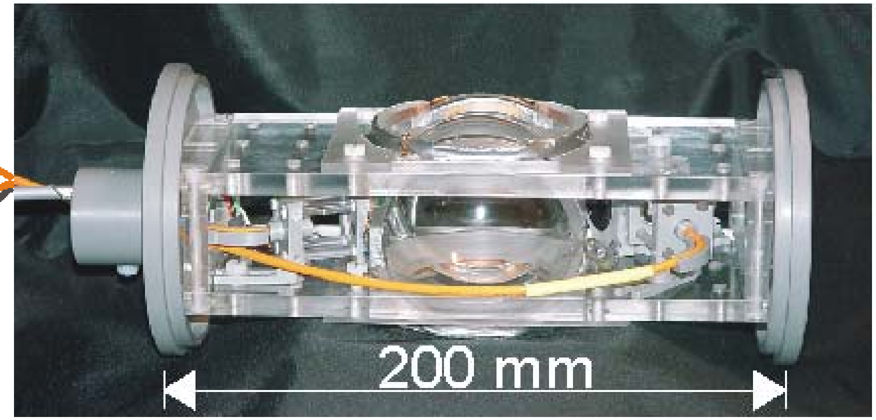
Phase I: OILL@ILL, O&M + R&D



External magnetometry with

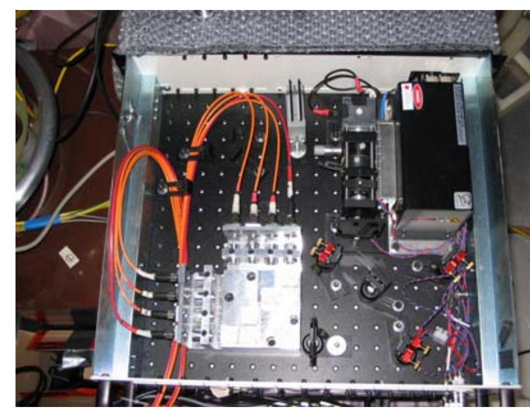
Self-oscillating laser-pumped Cs magnetometers





- non-magnetic sensor head
- Larmor frequency: 3.5 kHz @ 1 μT

S.Groeger, PhD thesis, UniFr, 2005
S.Groeger et al.,
J. Res. NIST 110, 179 (2005),
Appl.Phys. B80, 645 (2005),
EPJ D 38, 239 (2006),
EPJ AP 33, 221 (2006)
http://www.unifr.ch/physics/frap/



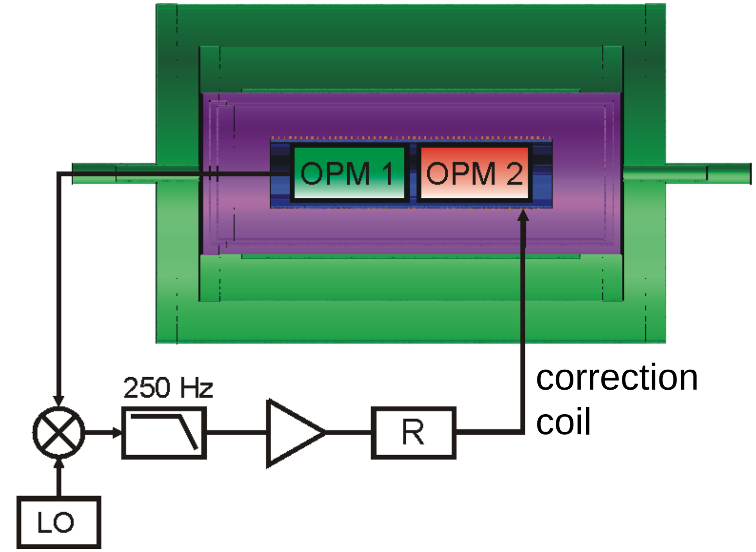
1 magnetometer (OPM) needs 25 μW

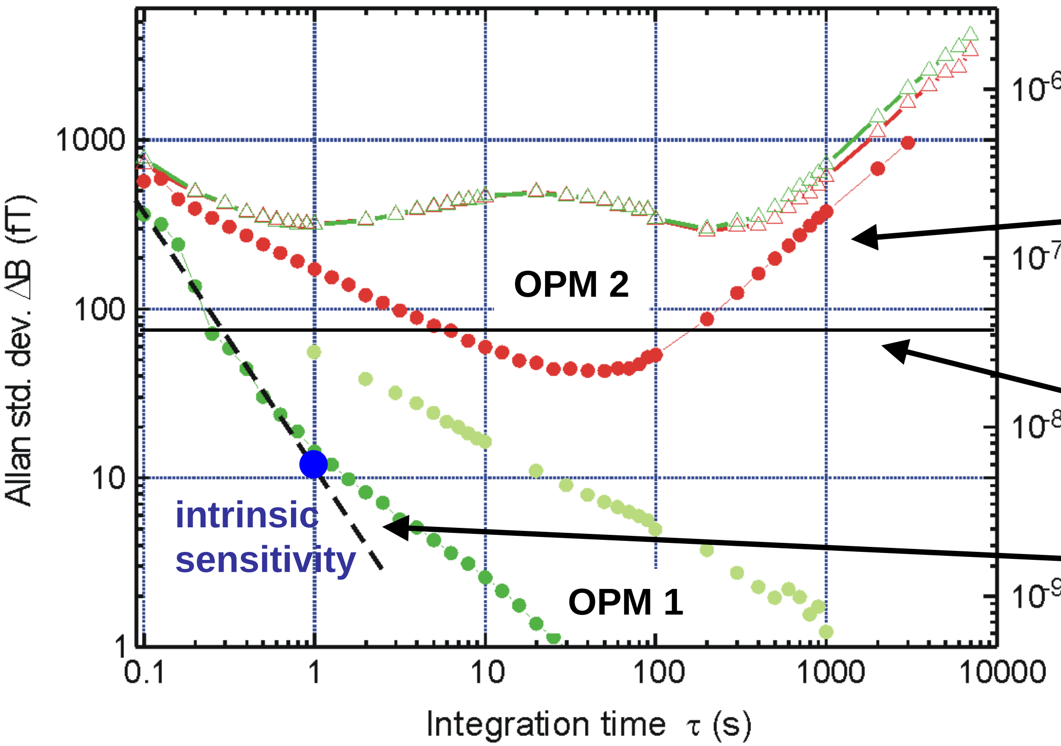
1 laser delivers >10 mW

→ **1 laser = many sensors**

Active field stabilization

Simple field stabilization coils give order of magnitude improvement at 100 s. Gradient correction of the same order can be expected.



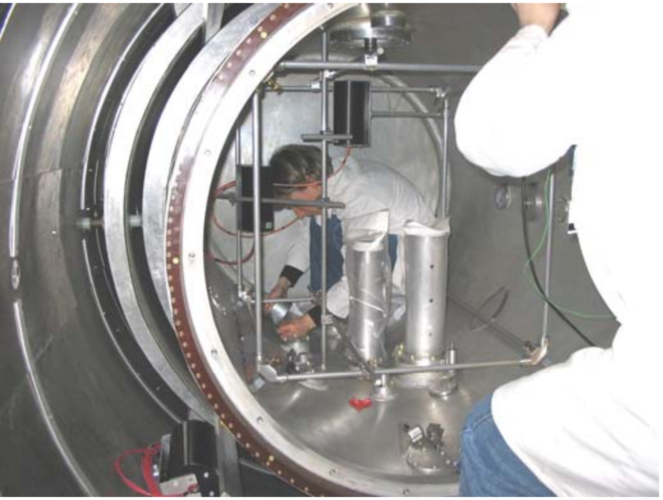


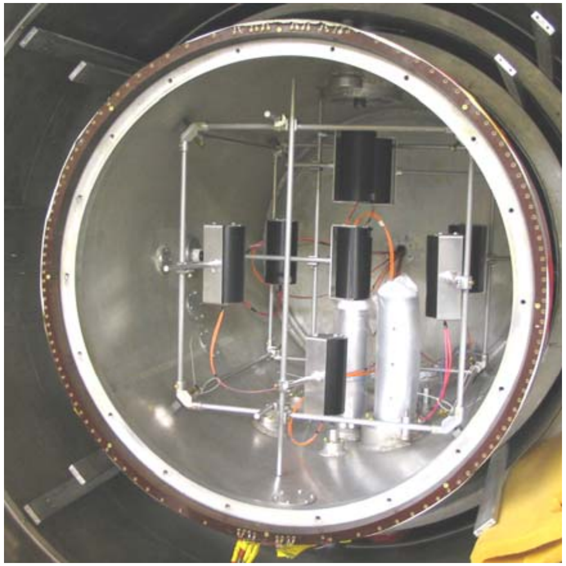
gradient fluctuations

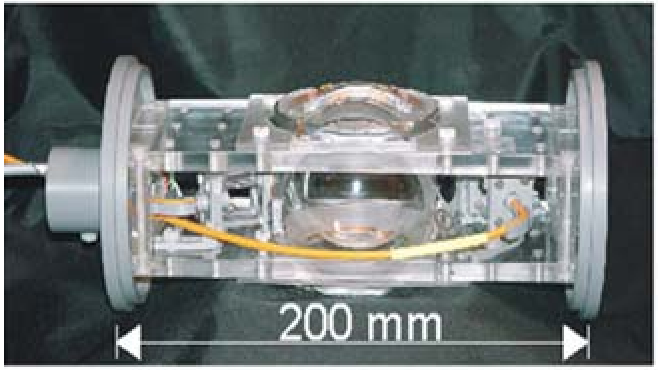
field stability for ~10^{-27} e cm

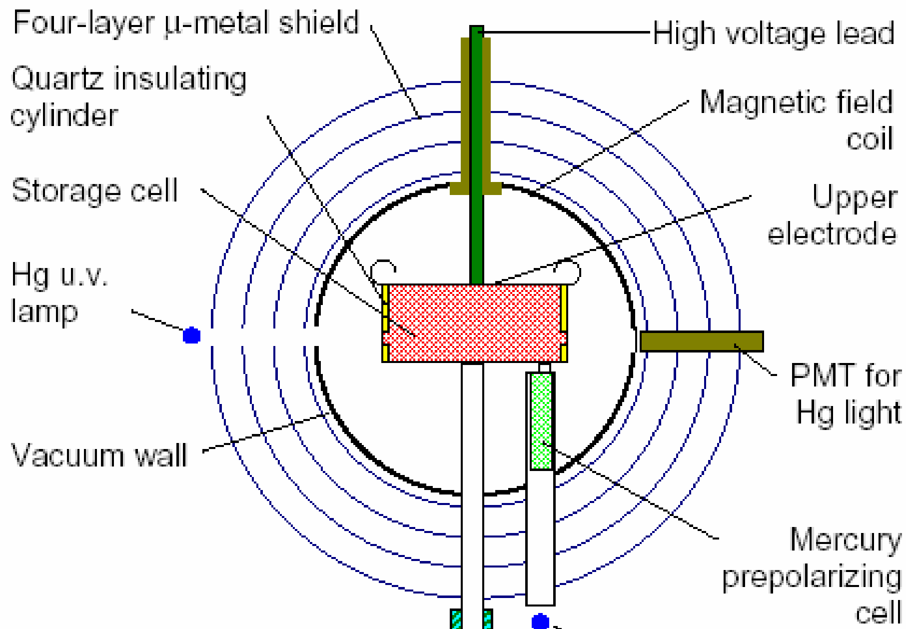
Cramér-Rao limit: ~ $\tau^{-3/2}$

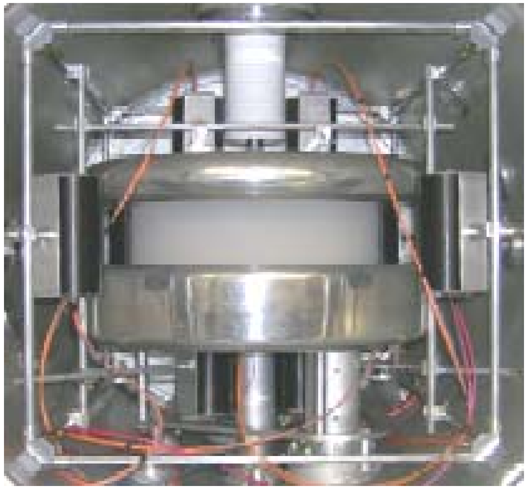
Cs magnetometers in EDM



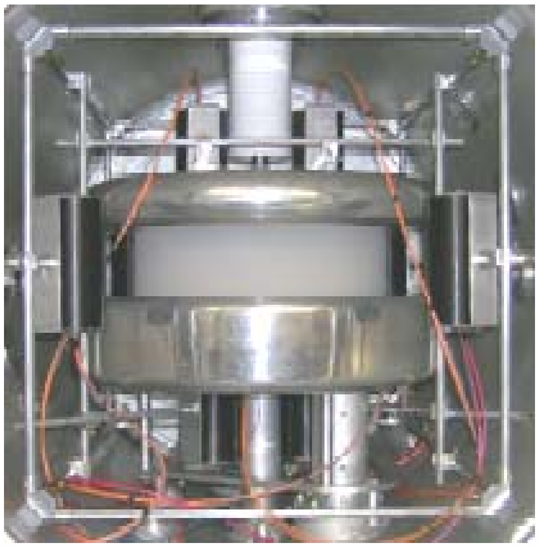




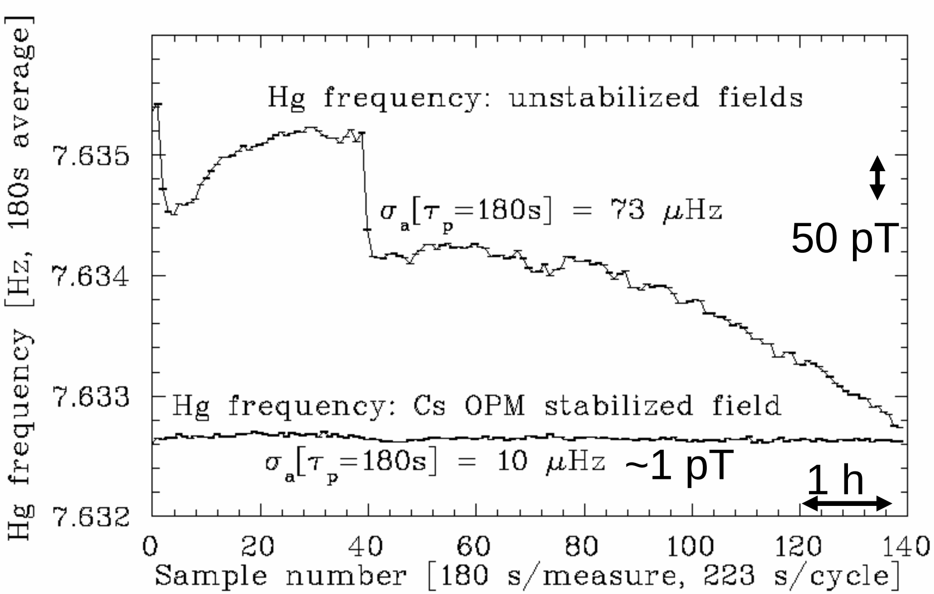


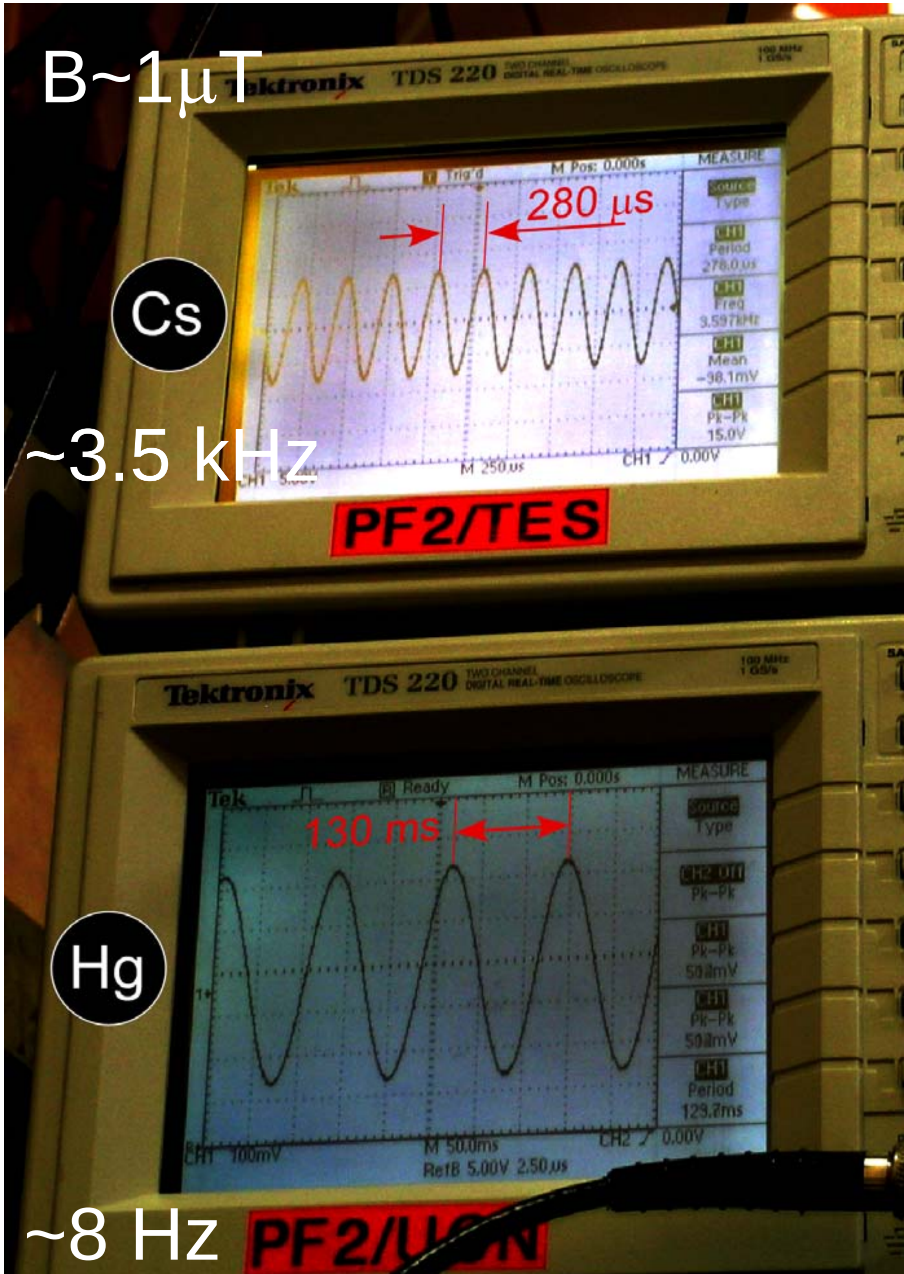


Operating Cs and Hg simultaneously



^{199}Hg **Allan variance**



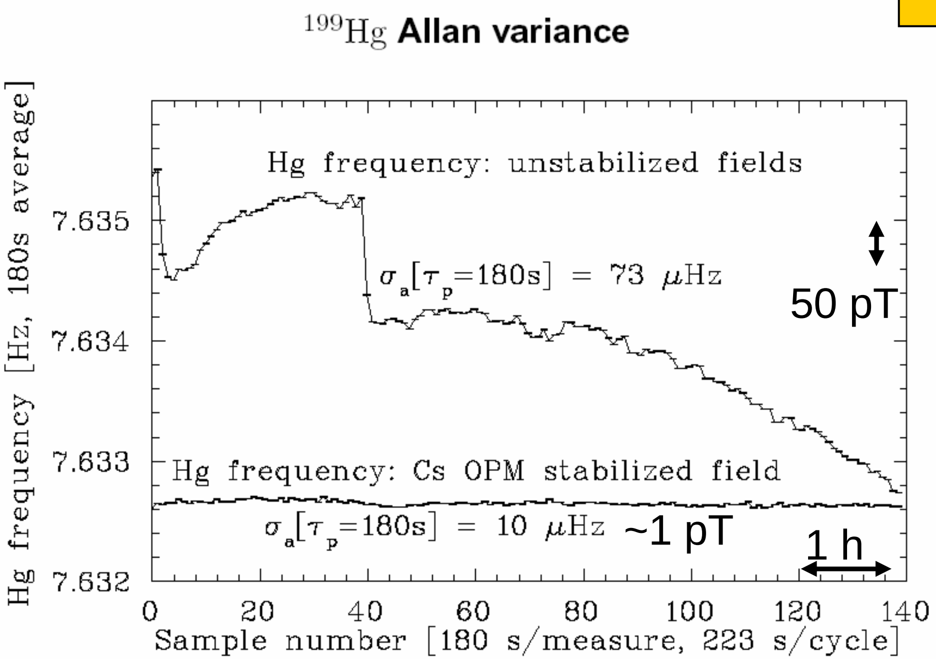


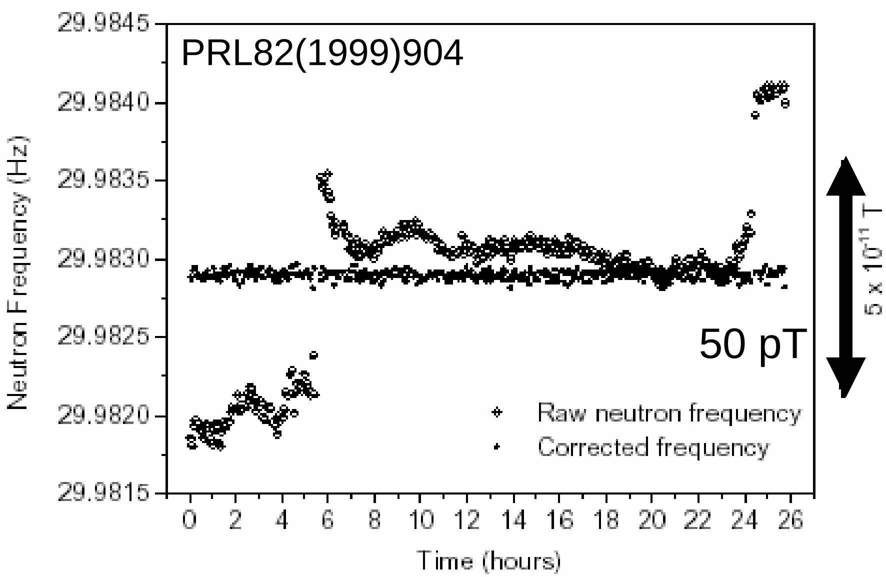
Operating Cs and Hg simultaneously

Active B-field stabilization in EDM with Cs-magnetometer works.*

P. Knowles et al. 2005

* Caveat: Level D instability since 2006





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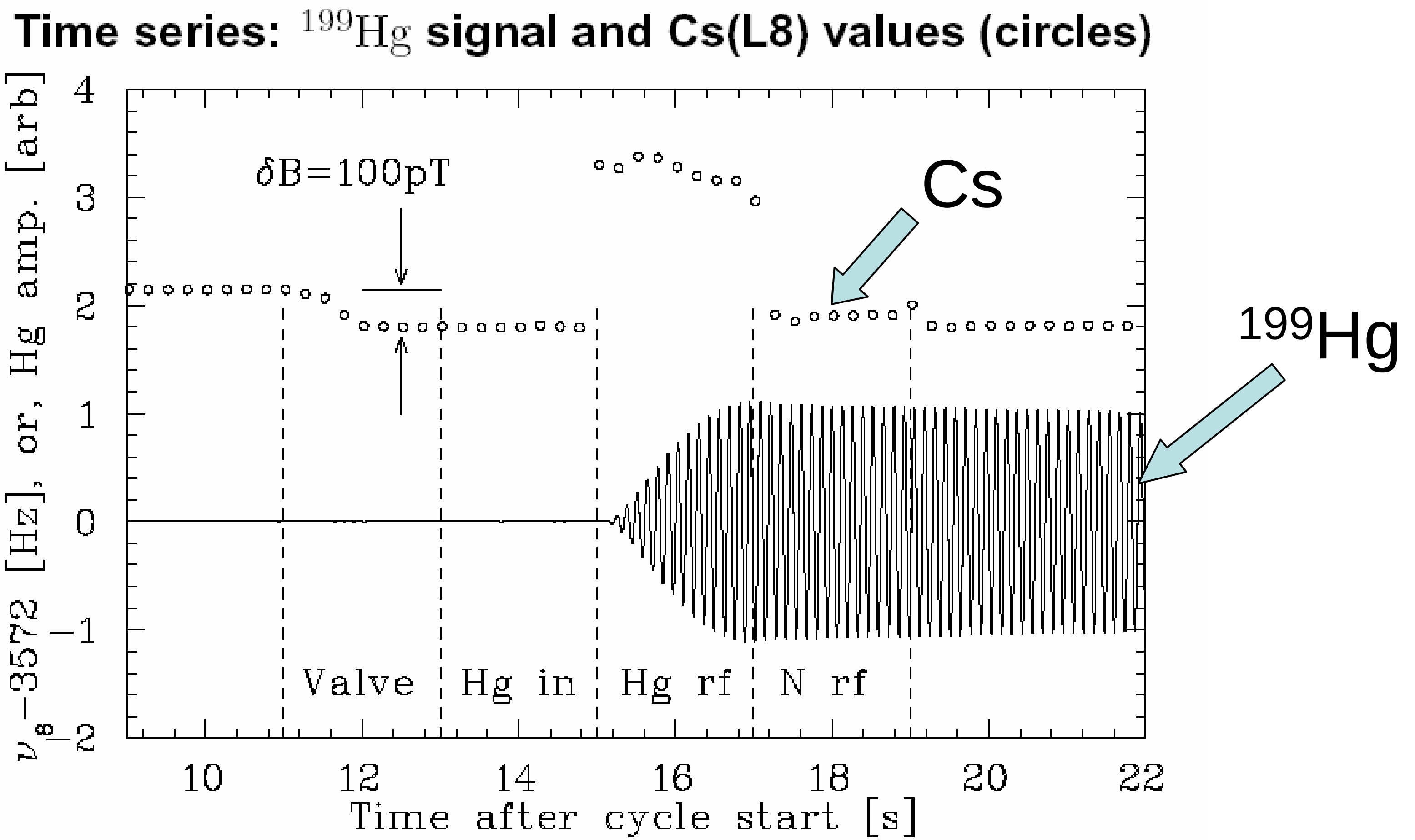
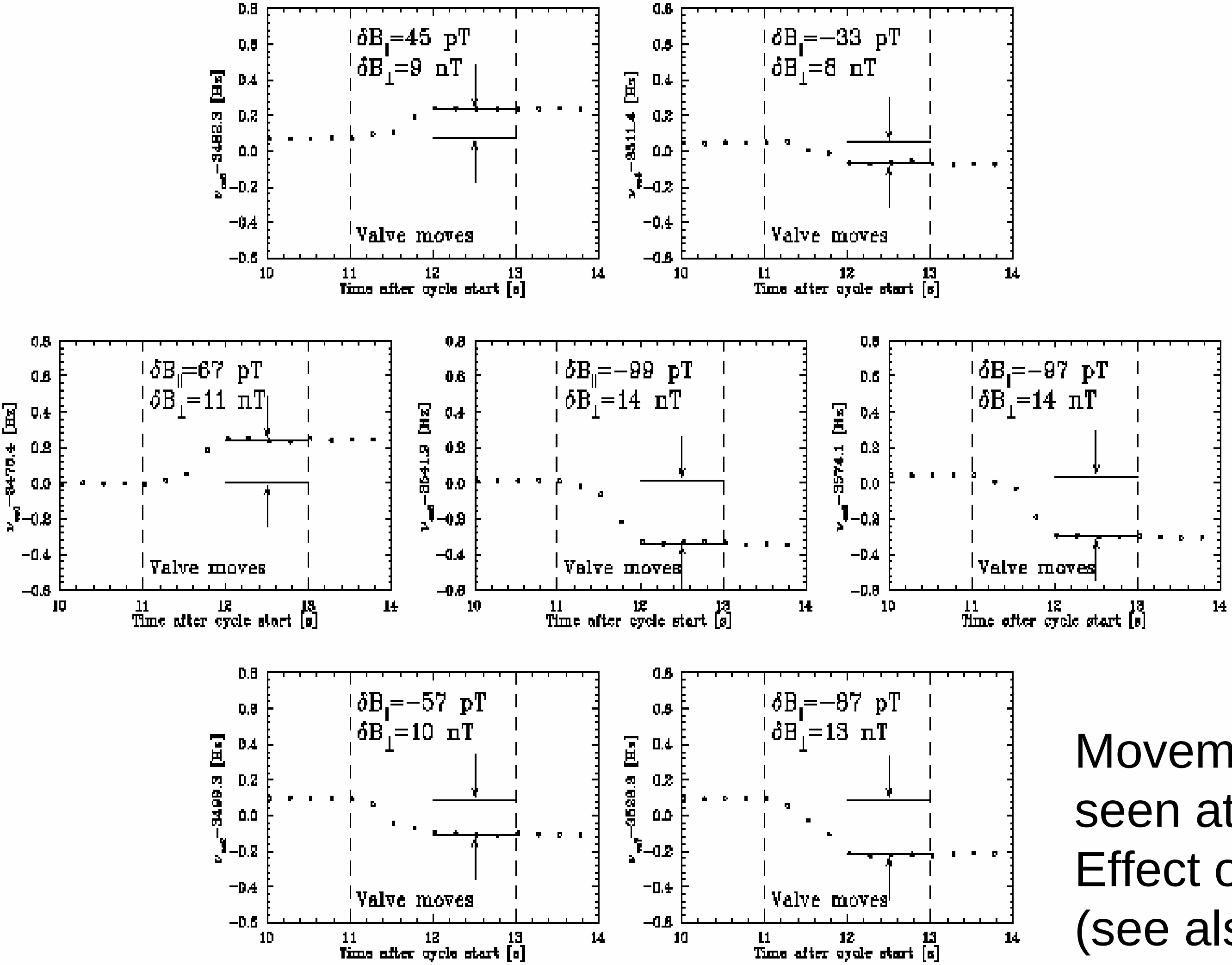
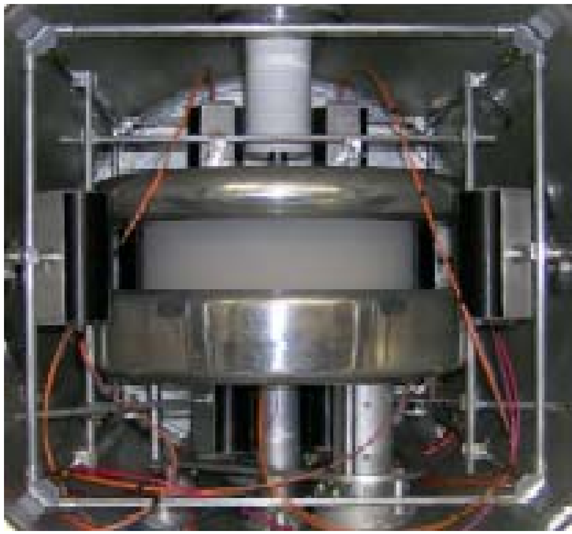
A new dimension in diagnostics ...



280 GB of data under analysis at FRAP

A new dimension in diagnostics ...

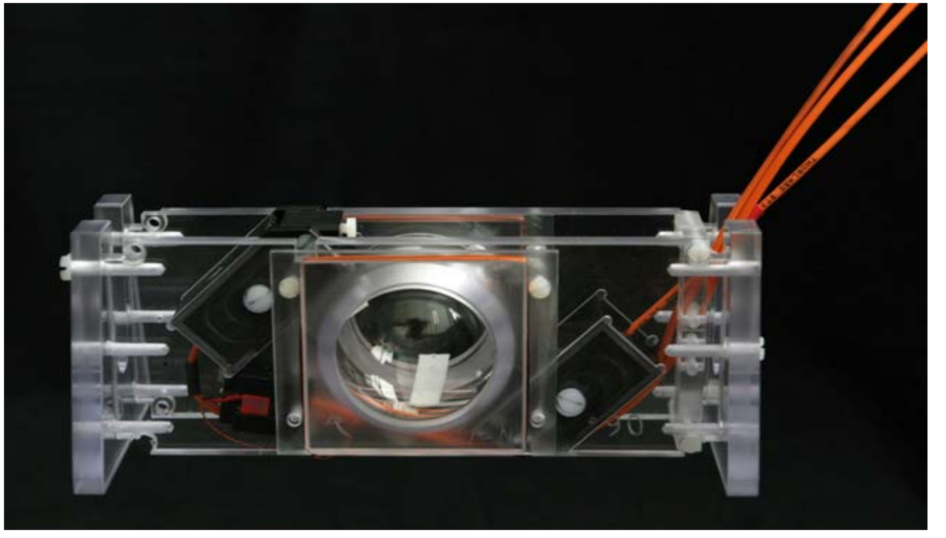




Movement of the UCN shutter seen at different locations: Effect of a magnetic impurity (see also PRL97(2006)131801)

2006: Vacuum & HV compatible Cs-OPM

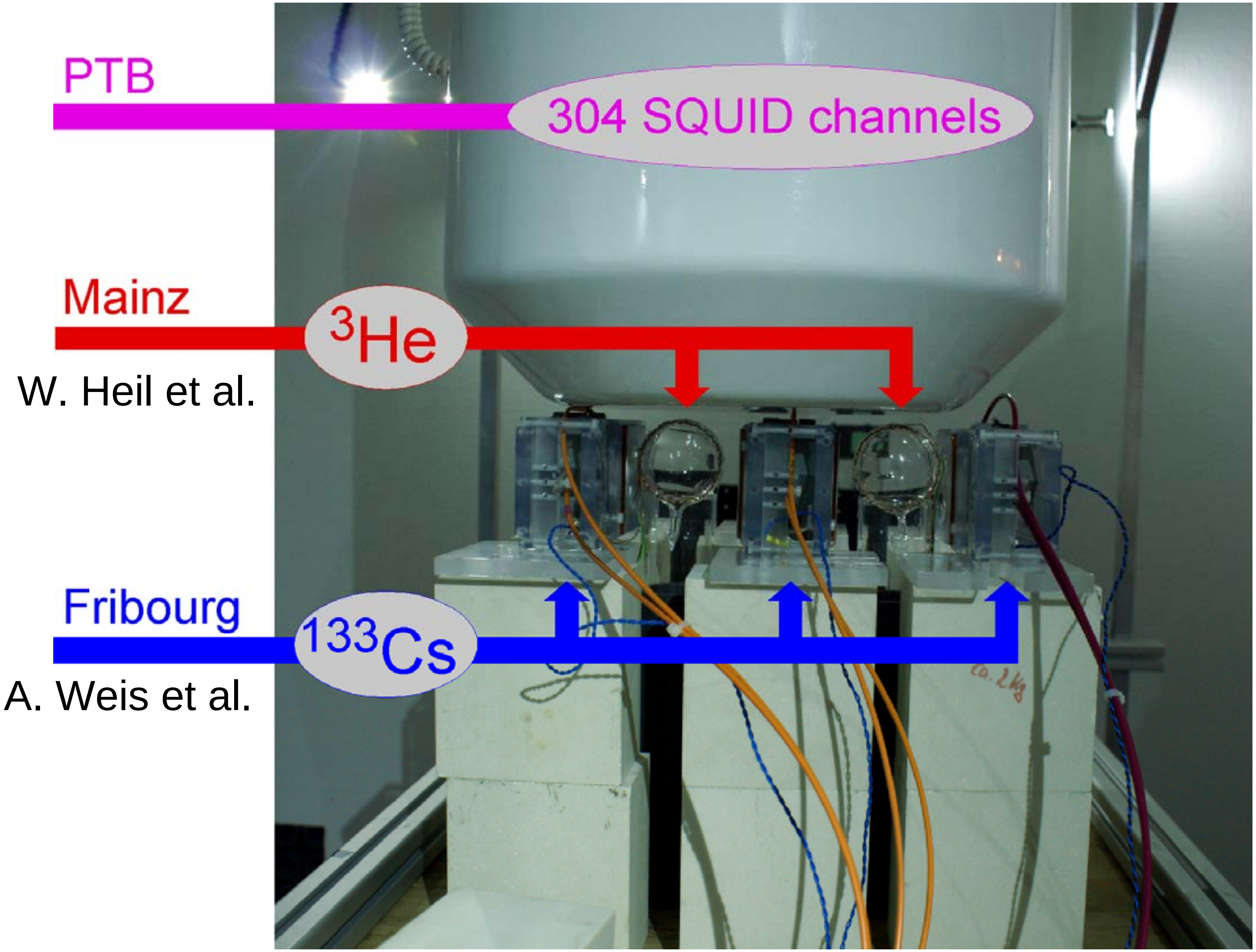
- Polycarbonate: nonmagnetic and vacuum compatible
- Optocoupling for HV
- Successful operation at ILL
  - in vacuum
  - at 30 kV



External Cs magnetometry

- Superstable current source (<10^{-8})
- Many (vector) CsM for monitoring B field
- Stabilize magnetic field and gradients
- But:
  external magnetometry not sensitive enough to leakage currents and magnetic wall impurities
- ^{3}He (^{129}Xe) magnetometry :
  – read by Cs-OPM (PTB)
  – forced (Cs) versus free (He)
  – co-magnetometry (He, Xe)

Magnetometer comparisons ongoing



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Co-co-magnetometry

- Potential co-magnetometer candidates:

  ^{199}Hg (7.7 Hz/μT), ^{129}Xe (-11.8 Hz/μT), ^{3}He (-32.4 Hz/μT)

- Geometrical phase induced false effect:

  (Pendlebury et al., PRA70(2004)032102)

  $d_{af,atom} \sim \gamma^2 R^2\, dB_z/dz$ $\quad$ $d_{af,n} \sim \langle v^2_{ucn} \rangle B_z^{-2}\, dB_z/dz$

- Example: B_z=1μT, dB_z/dz=1nT/m

$d_{af,n} \sim 10^{-27}$e cm

$d_{af,Hg} \sim 13 \times d_{af,n}$

$d_{af,Xe} \sim 2 \times d_{af,Hg}$

$d_{af,He} \sim 18 \times d_{af,Hg}$

Two null results for atomic co-magnetometers could prove the stability of the B-field magnitude **and** the absence of gradients

Strategy

- Phase I:
  - Operate and improve OILL@ILL (-2008)
  - Move of OILL in 2008 (approved by RAL/Sussex)
  - Design of n2EDM, related R&D
- Phase II:
  - Operate OILL@PSI (2009-2010)
  - Sensitivity goal: 5×10^{-27} ecm
  - Setup of n2EDM, continued R&D
- Phase III:
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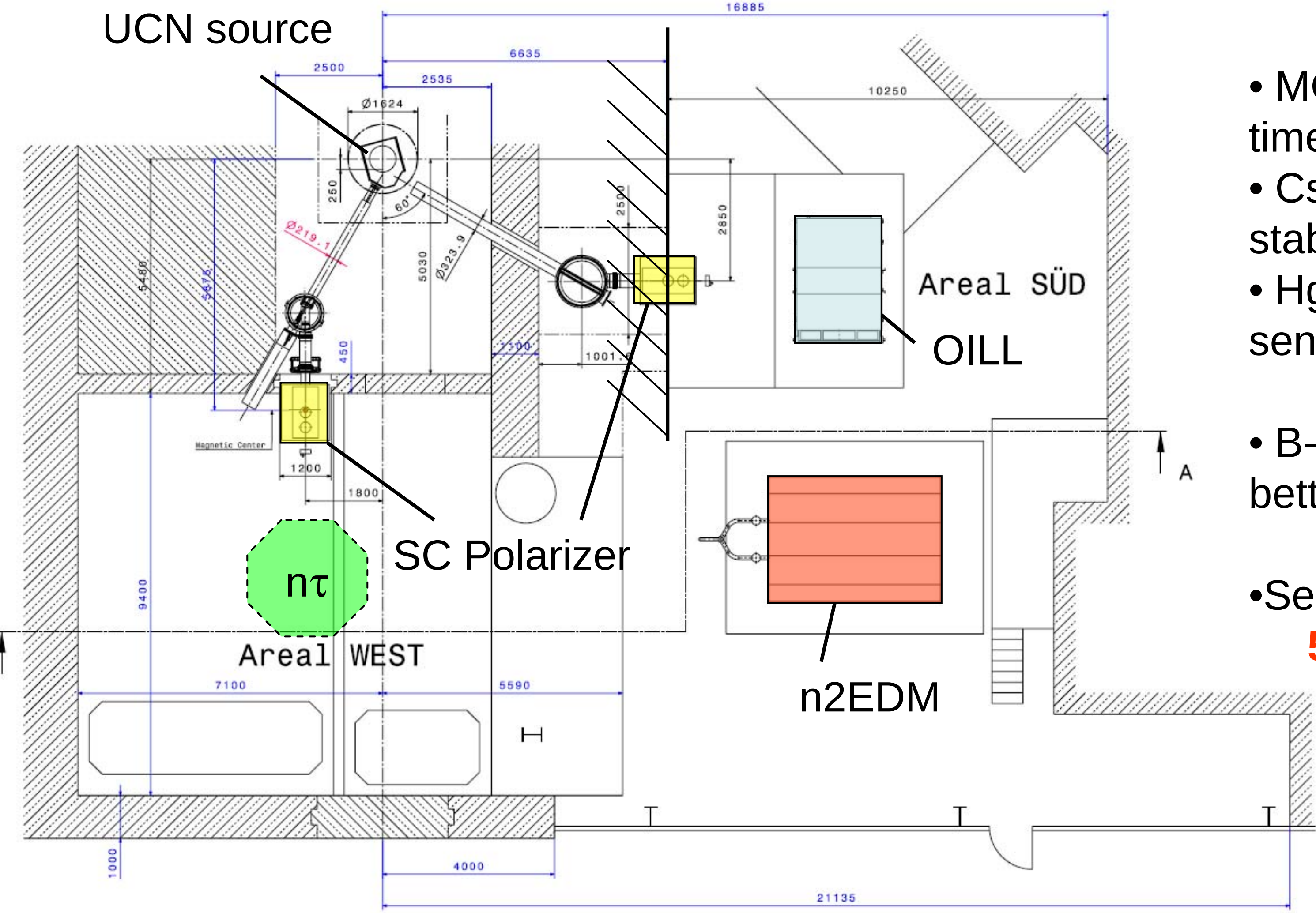
Phase II: OILL@PSI

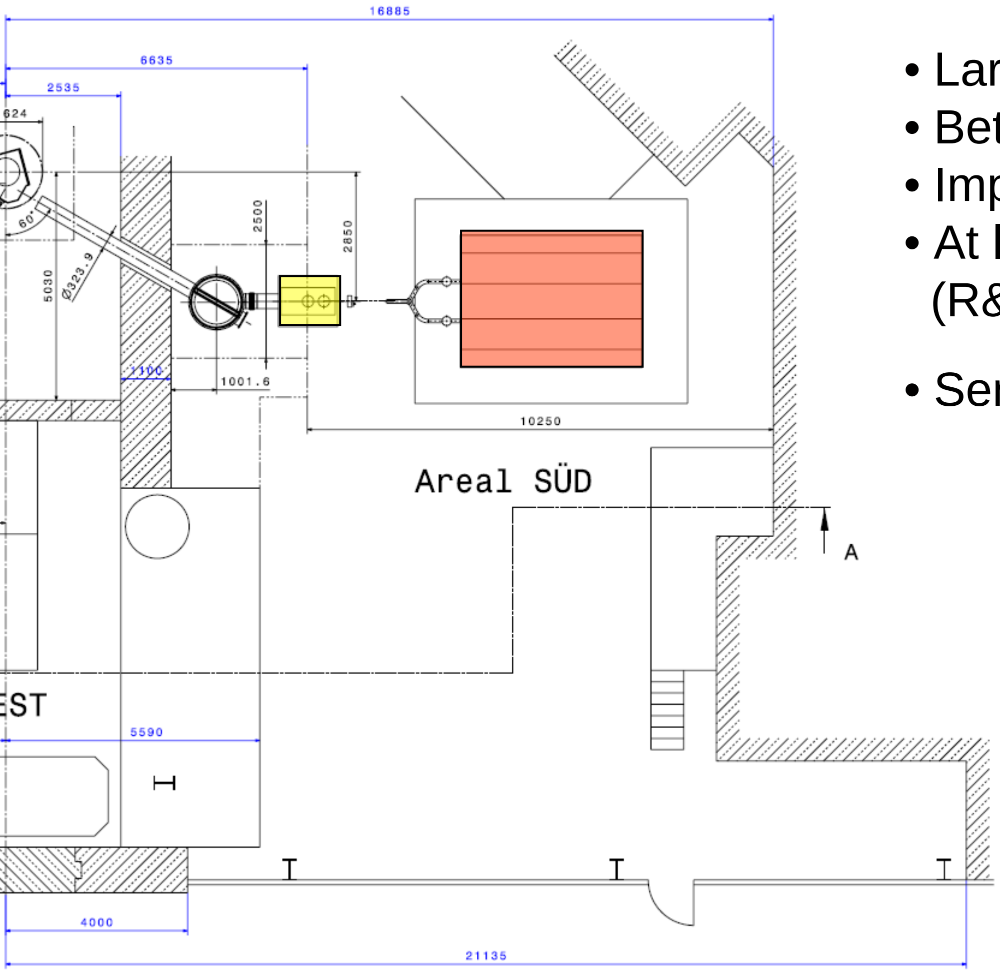


- MC predicts ~25 times higher statistics
- CsM monitoring and stabilization of the field
- HgM with improved sensitivity

- B-field control to better 100fT/100s

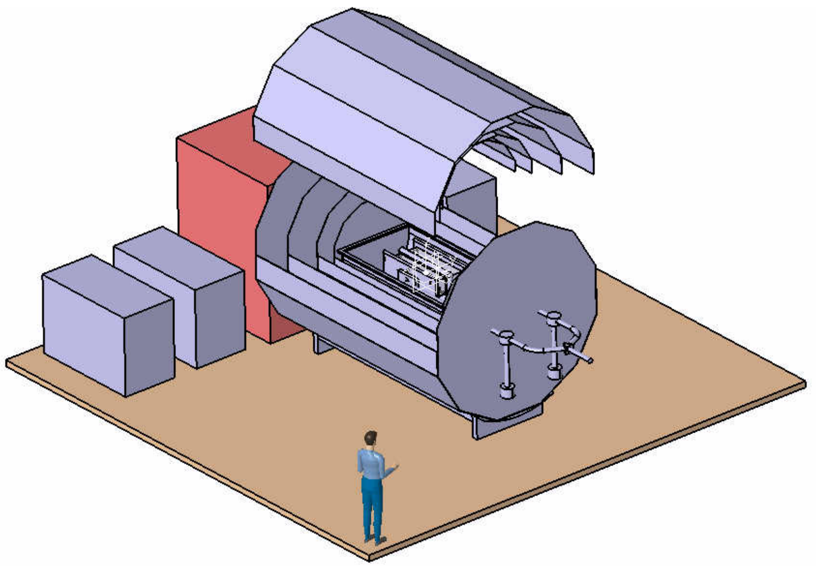
- Sensitivity goal: **5×10^{-27}ecm**

Phase III: n2EDM@PSI



- Large double chamber volume
- Better adaption to UCN beam
- Improved CsM monitoring and stabilization
- At least one co-magnetometer (R&D on Hg, He, Xe)

- Sensitivity goal: **5x10^{-28}ecm**



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nEDM - Conclusion & Outlook

- Phase I:
  - OILL@ILL (-2008)
  - Move of OILL in 2008 (approved by RAL/Sussex)
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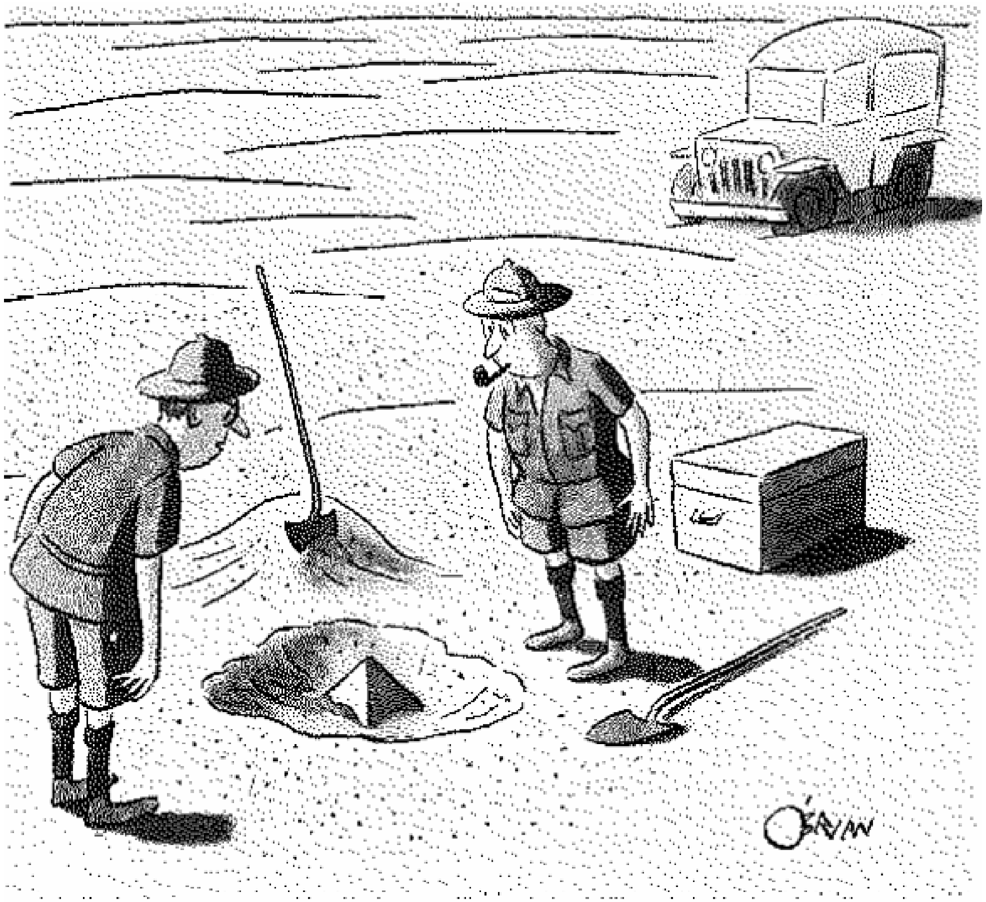

"This could be the discovery of the century. Depending, of course, on how far down it goes."

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