The nEDM project at PSI

towards a new measurement of the neutron EDM

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Context and motivation

- Search for new sources of CP-violation
- Assuming CPT invariance: CP-violation = T-violation
- In systems or processes without strangeness, the effects due to the CKM CP-violation are strongly suppressed
  (nEDM < $10^{-(31-33)}$ *e*cm; correlations in beta decay <10^{-10})
- Huge window to search for new physics!
  (without being affected by SM backgrounds)
- EDMs of quantum systems are very sensitive probes

Symmetry properties of permanent EDMs

- observables
  - spin $\boldsymbol{S}$, unit vector $\hat{\boldsymbol{s}}$
  - magnetic dipole moment: $\boldsymbol{\mu} = \mu\,\hat{\boldsymbol{s}}$
  - EDM for elementary QM system: $\boldsymbol{d} = d\,\hat{\boldsymbol{s}}$

- classical dipole interaction

$$H = -(\boldsymbol{d}\cdot\boldsymbol{E} + \boldsymbol{\mu}\cdot\boldsymbol{B}) = -(d\,\boldsymbol{E} + \mu\,\boldsymbol{B})\cdot\hat{\boldsymbol{s}}$$

- transformations under T and P

$\boldsymbol{B}$ and $\hat{\boldsymbol{s}}$ behave identically but not $\boldsymbol{E}$ and $\hat{\boldsymbol{s}}$

if $d \neq 0$: T and P are violated

EDM measurements: achievements and plans

- upper limits have been obtained for:

  $\underline{e}$, μ, τ, p, $\underline{n}$, Λ, atoms, molecules

- new projects and approaches are being considered for:

  e, μ, n, d, radioactive nuclei, atoms

  - very active field !
  - complementary constraints (ex. SUSY phases)

Any new mechanism for CP violation in the light quark sector has in particular to pass the neutron EDM test

General principle to measure an EDM

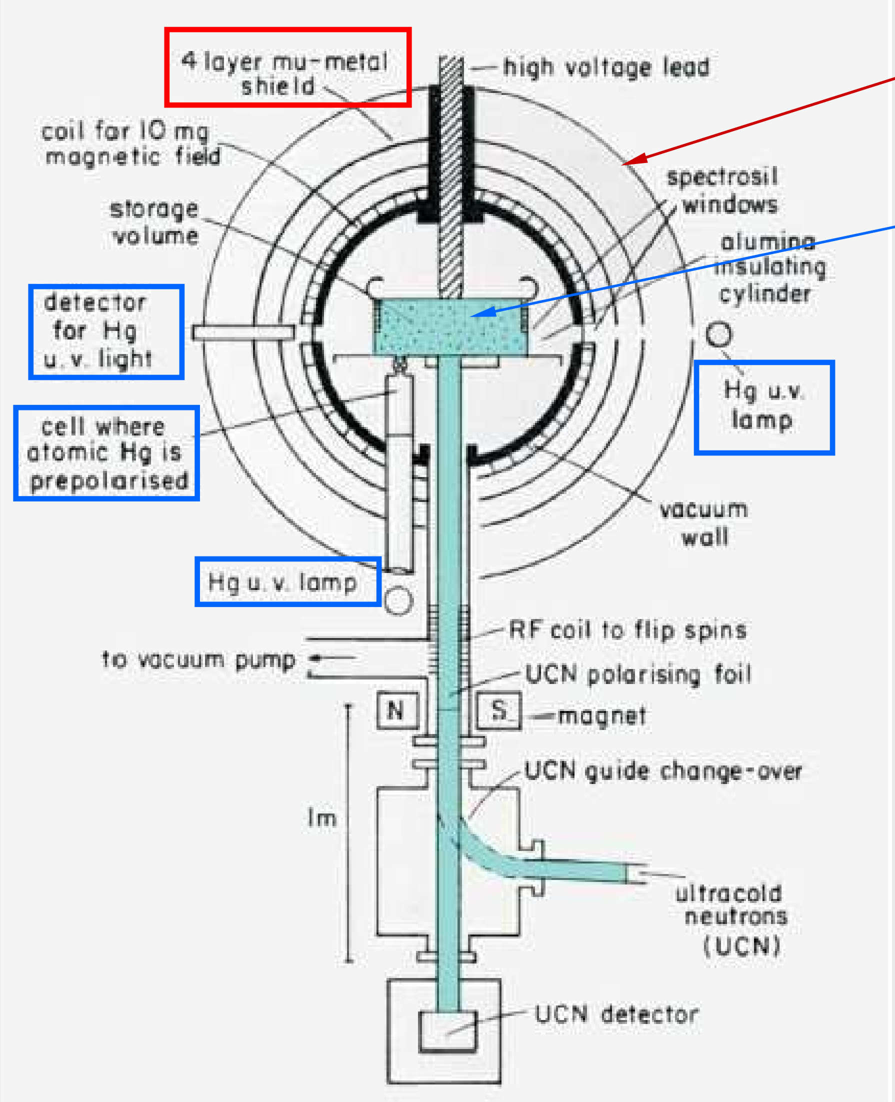
Under electric field inversion:

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

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

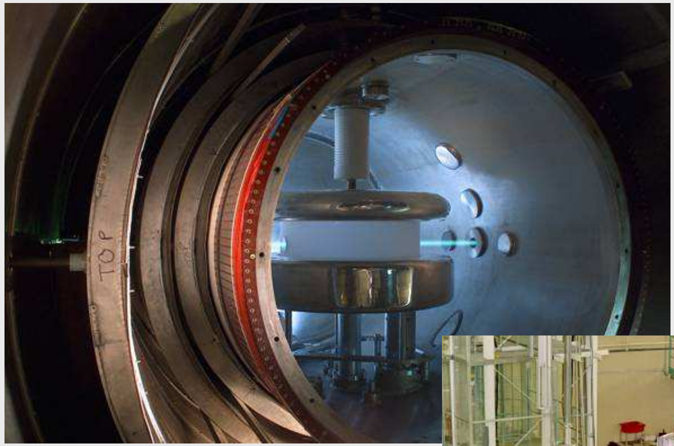
The most sensitive spectrometer

Sussex-RAL-ILL at the PF2 UCN source at ILL-Grenoble

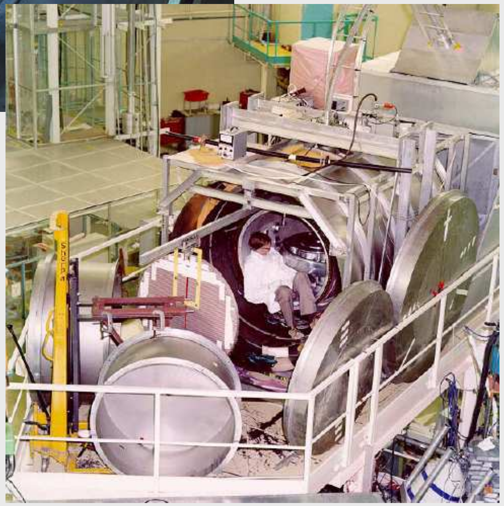


4 layers of passive (μ-metal) shield

Co-habiting ^{199}Hg magnetometer

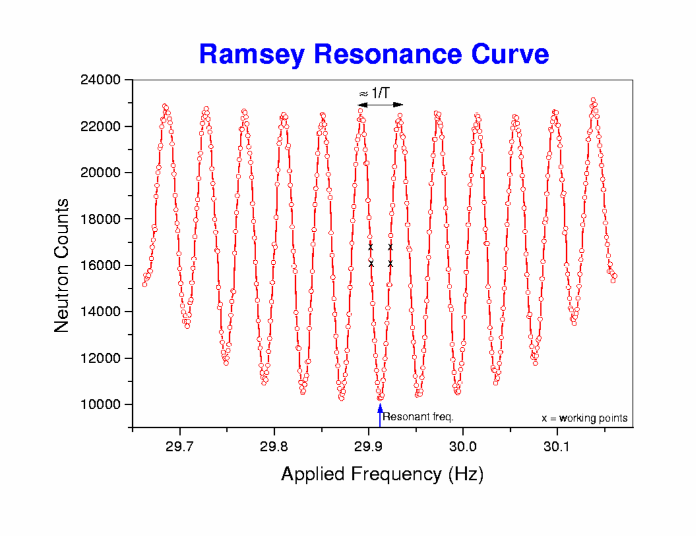


- V = 20 l
- B = 10 mG, ν_L = 30 Hz
- E = 4.5 - 11.0 kV/cm
- T = 120 - 140 s

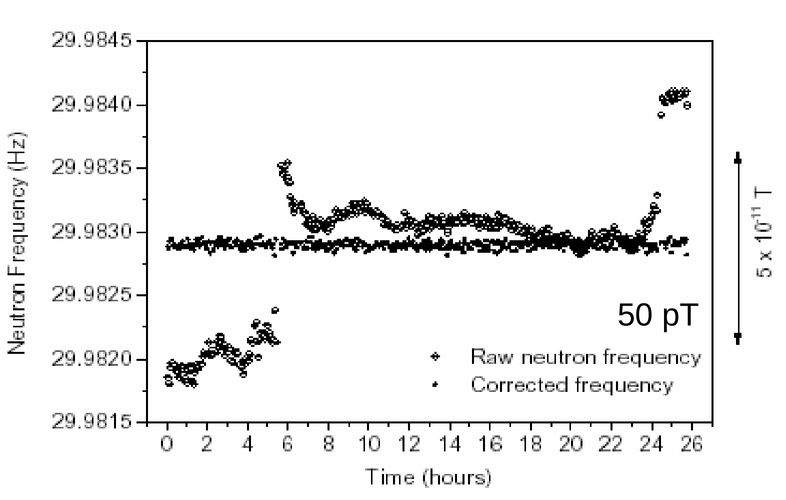


Present nEDM limit

Ramsey resonance technique

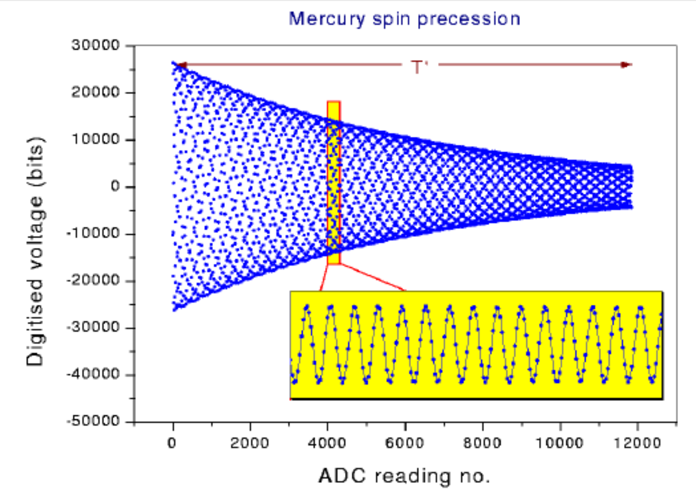


Correction to the neutron precession



50 pT = 500 nG ≈ 10^{-6} x Earth Field

^{199}Hg co-magnetometer $d(^{199}\text{Hg}) < 8.7 \times 10^{-28}$ *e*cm



P.G. Harris *et al.*, PRL **82**(1999)904

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

$| d_n | < 2.9 \times 10^{-26}$ *e*cm (90% CL)

Final Sussex-RAL-ILL result

(limited by statistics)

Our “phase 2” goal

- Install and use the most sensitive EDM spectrometer existing so far (in vacuum-room-temperature)…

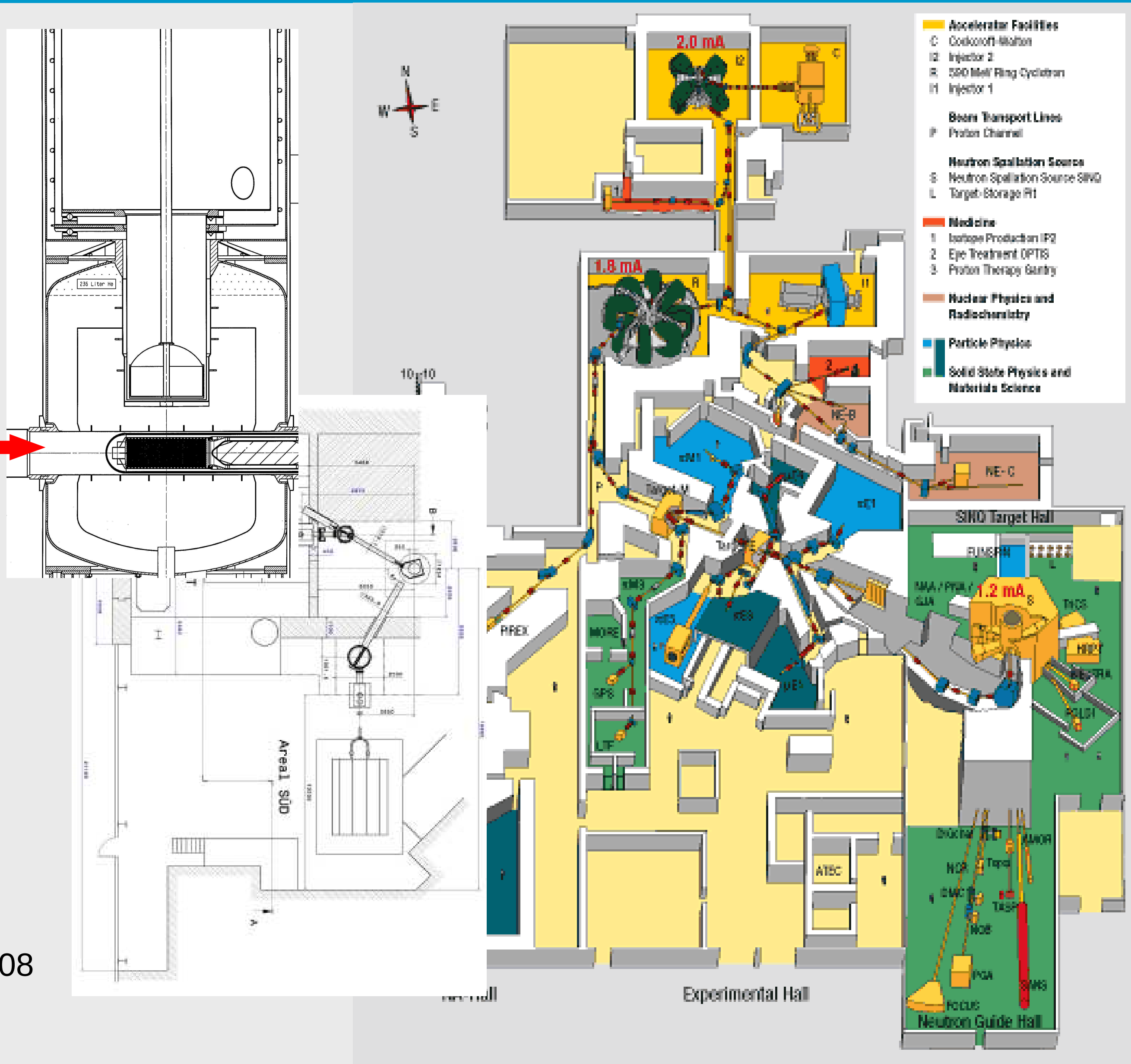
-…at the most intense UCN source in the world (under construction)

  - Move from ILL to PSI planned for end 2008
  - Operate and measure at PSI : 2009-2010
  - Sensitivity goal: $5x10^{-27}$ecm

Spallation UCN source at PSI

UCN
Ultra Cold Neutron Source

- 590 MeV, 2 mA, proton beam
- pulsed (1% duty cycle)
- target: Pb



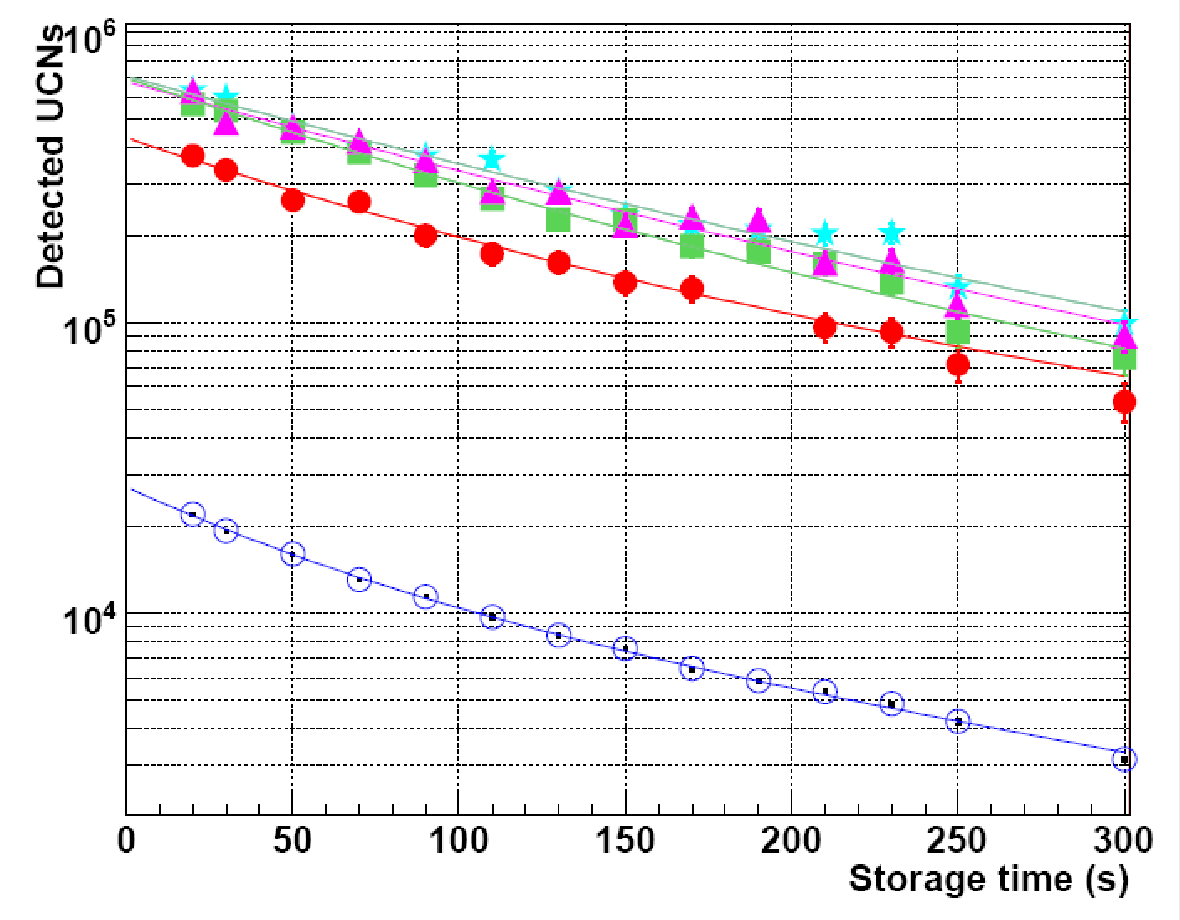
- moderators: D_2O (20-80 K)
- UCN source: SD_2 (30 l, 8K)
- storage volume: 2-3 m^3

- expected density: $\rho > 1000\ /cm^3$
- start operation: autumn-winter 2008

MC simulations and coatings

- required the inclusion of UCN physics into GEANT4 – P. Fierlinger and others, NIMA **552** (2005) 513
- MC simulation tested with UCN data from the Sussex-RAL-ILL spectrometer

Storage time with chamber 1m above beam line



Chamber/Electrode

Spectrometer @ PSI

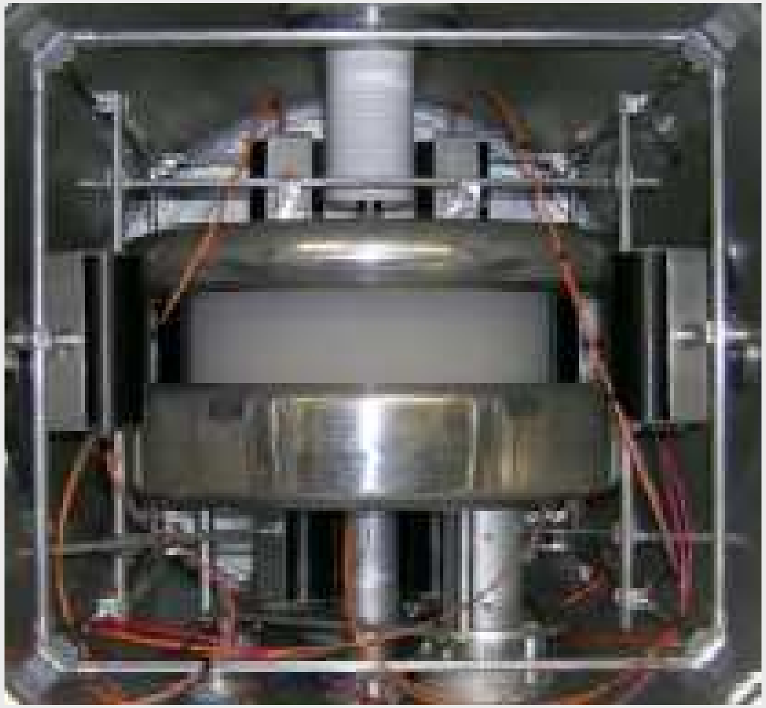
Diam/Diam:	35
Diam/DLC:	33
Si3N4/DLC:	29
Quartz/DLC:	19

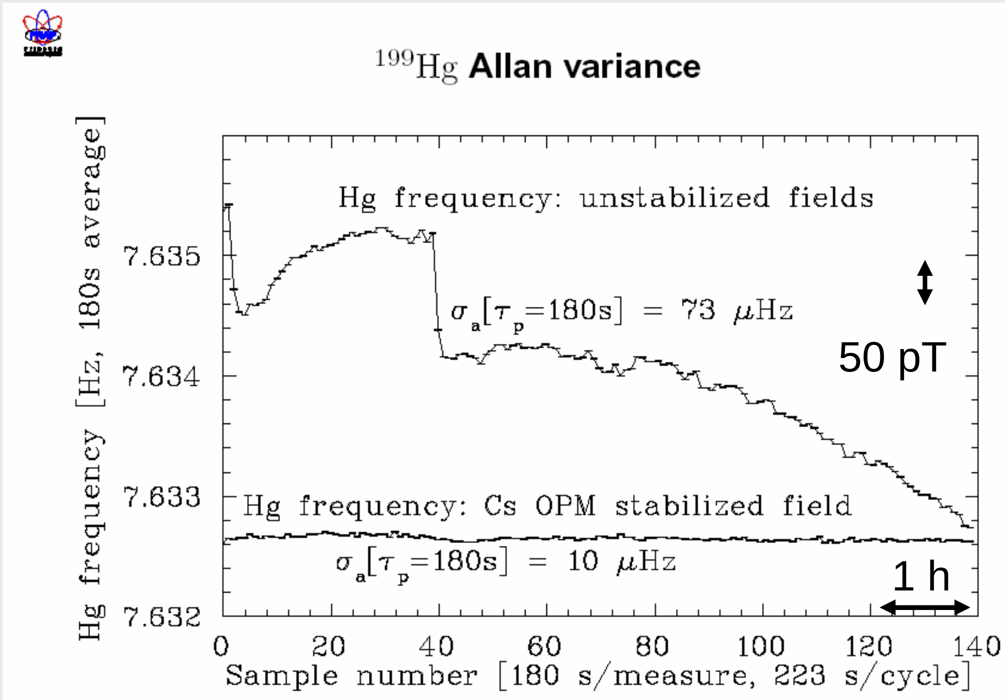
Present system @ ILL

Quartz/DLC:	1

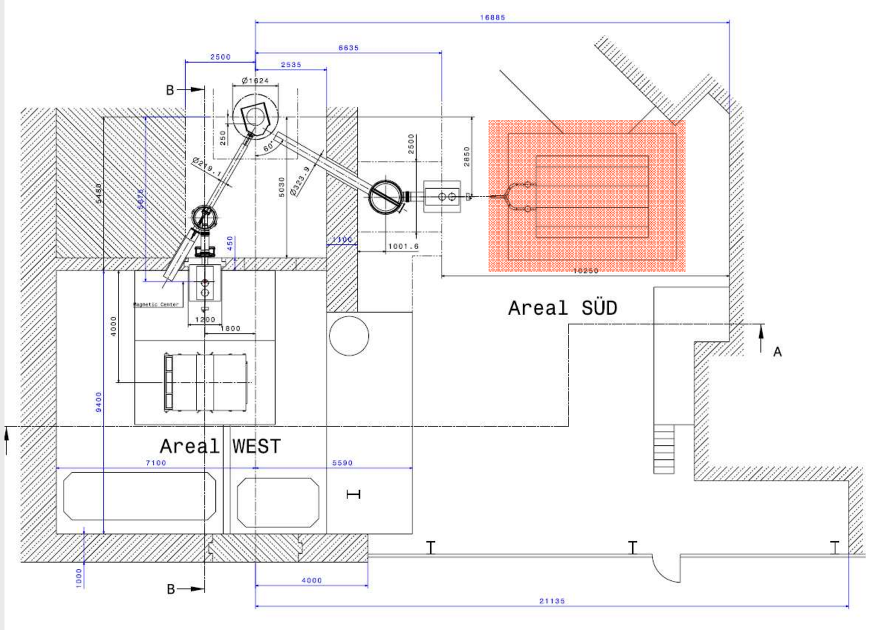
Magnetometry

- operate Cs and Hg magnetometers simultaneously
- use Cs-OPM to stabilize magnetic field
- control with ^{199}Hg precession



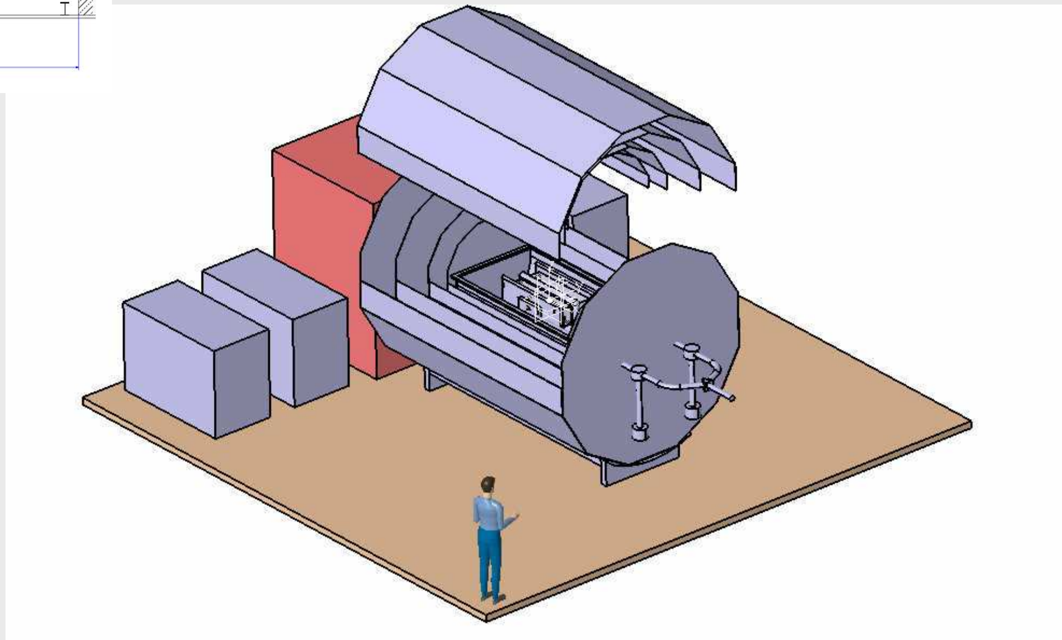


Phase 3: measure with a new spectrometer



- Larger double chamber volume
- Optimized for UCN beam at PSI
- Improved monitoring and stabilization with Cs-OPM
- Additional co-magnetometer (He, Xe)

- Sensitivity goal: 5×10^{-28}ecm



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