Overview and Status of the PanEDM Experiment at ILL

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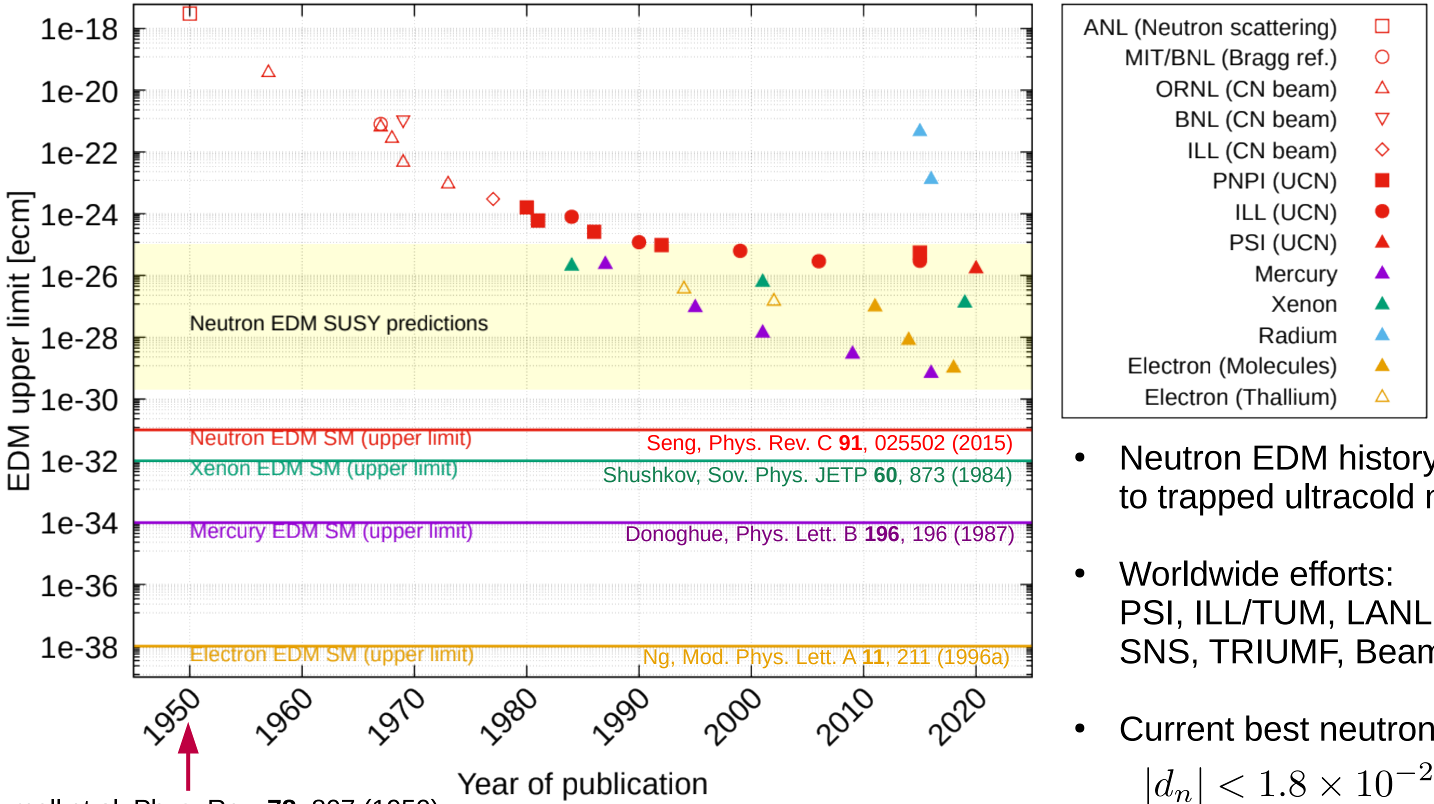
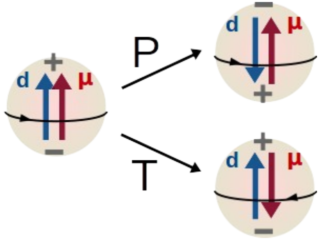
Technische Universität München

PANIC 2021, September 5th 2021

(Neutron) EDM Experiments Overview



Purcell et al, Phys. Rev. **78**, 807 (1950)

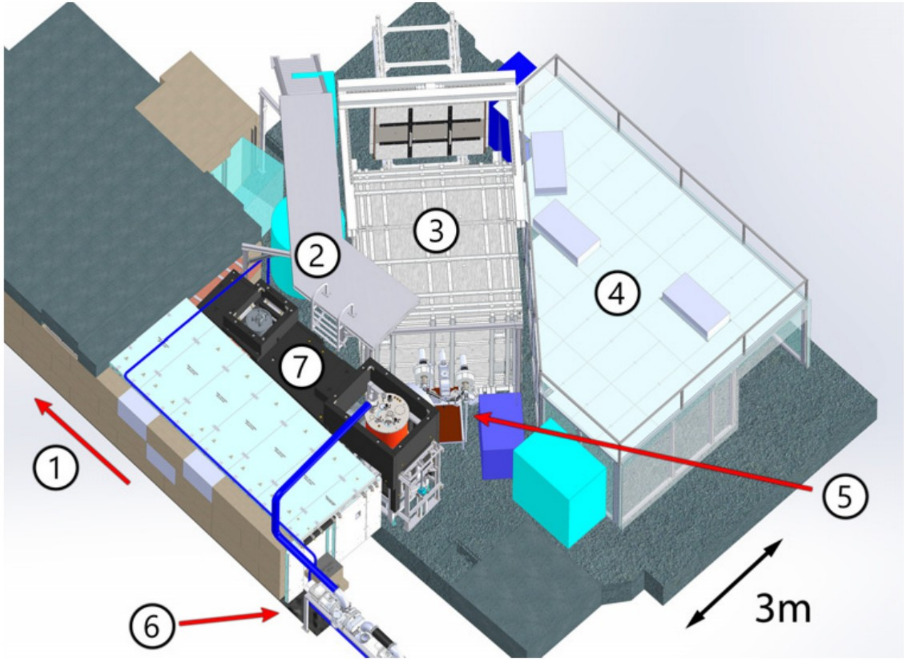


- Neutron EDM history: cold neutron beams to trapped ultracold neutrons (E < 300 neV)
- Worldwide efforts:
  PSI, ILL/TUM, LANL, ILL/PNPI/Gatchina, SNS, TRIUMF, BeamEDM
- Current best neutron EDM limit:

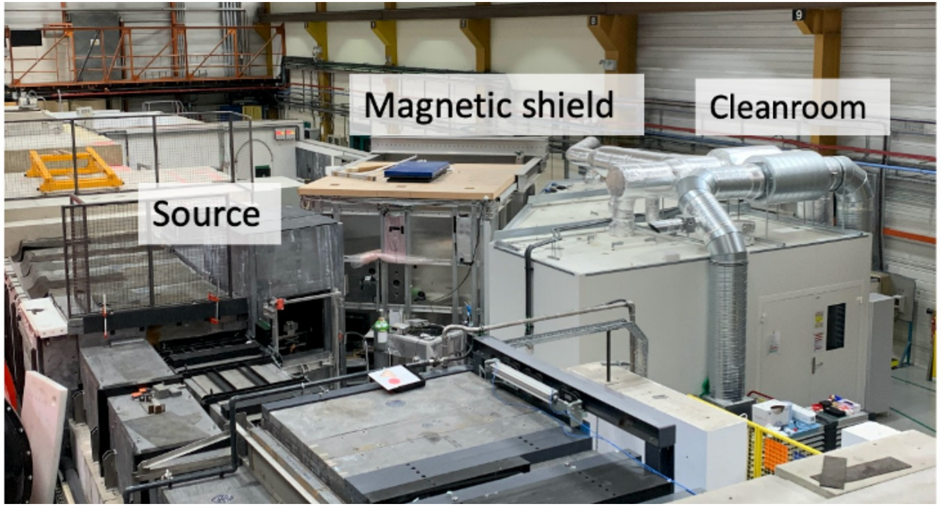
$$|d_n| < 1.8 \times 10^{-26}\, e\mathrm{cm}\,(90\%\,\mathrm{C.L.})$$

Abel et al, Phys. Rev. Lett. **124**, 081803 (2020)

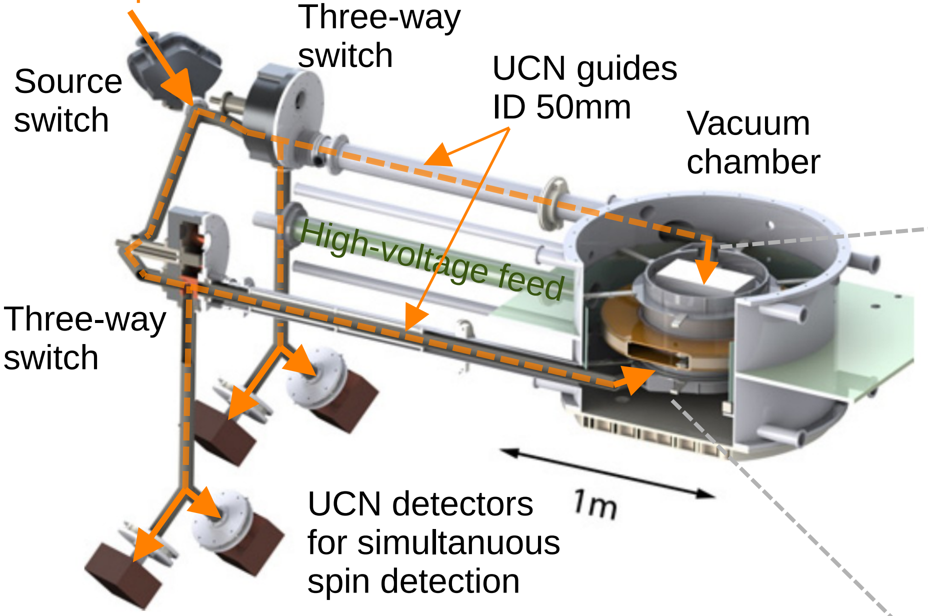
PanEDM at Institute Laue-Langevin, Grenoble



1 Towards ILL reactor (~58 MW, ~150 days/yr)
2 Service platform (now moved)
3 Magnetic shield
4 Cleanroom (atomic magnetometer control)
5 HV, UCN optics and detectors
6 SuperSUN pumping systems (now moved)
7 SuperSUN



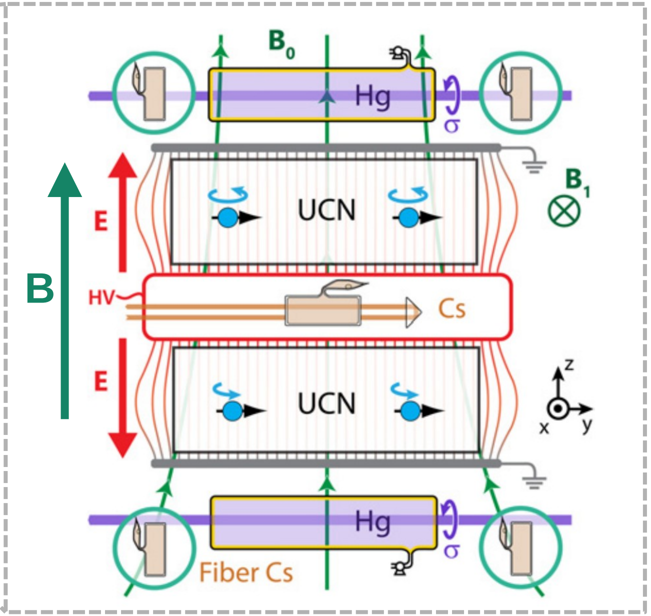
PanEDM overview of central components



PanEDM detection system
Magdalena Pieler
Wednesday, Sept 8th, 14:30

Double cell electrode stack

- central high-voltage electrode (incl internal Cs magnetometer)
- external Cs magnetometers
- external Hg magnetometers



D. Wurm et al, EPJ Web of Conferences 219, 02006 (2019)

PanEDM sensitivity goal

$$\sigma(d_n) \geq \frac{\hbar}{2\alpha E T \sqrt{N}\sqrt{M}}$$

Visibility	$\alpha = 0.85$
El. field	$E = 20\,\mathrm{kV/cm}$
Measurement time	$T \approx 250\,\mathrm{s}$
No. of UCNs	$N^{\mathrm{Phase-I}} \approx 20 \times 10^3$
	$N^{\mathrm{Phase-II}} \approx 480 \times 10^3$
No. of measurements	$M^{\mathrm{day}} \approx 200$

Current best neutron EDM limit:
$|d_n| < 1.8 \times 10^{-26}\, e\mathrm{cm}\,(90\%\,\mathrm{C.L.})$

Abel et al, Phys. Rev. Lett. **124**, 081803 (2020)

SuperSUN	**Phase I**	**Phase II**
Saturated source density [cm^{-3}]	330	1670
Diluted density [cm^{-3}]	63	318
Density in cells [cm^{-3}]	3.9	40
PanEDM Sensitivity [1σ, e cm]		
Per run	5.5×10^{-25}	1.2×10^{-25}
Per day	3.8×10^{-26}	7.9×10^{-27}
Per 100 days	3.8×10^{-27}	7.9×10^{-28}

D. Wurm et al, EPJ Web of Conferences 219, 02006 (2019)

Phase-I
- Temporal magnetic gradient stability
  → no comagnetometer

Phase-II
- UCN source improvements
- Comagnetometer upgrade

Included loss estimates:

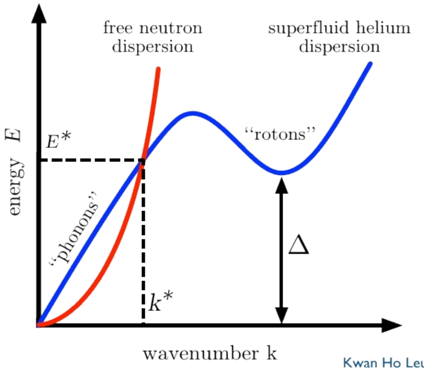
Volume dilution	0.19
Transport efficiency	0.25
Emptying efficiency	0.40
Polarization loss (Phase-I only)	0.50

UCN source: SuperSUN at ILL

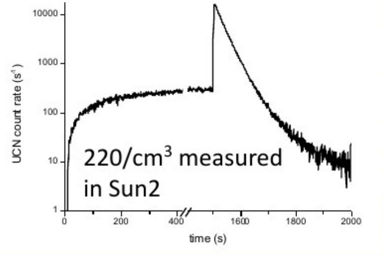
Superthermal UCN conversion from cold neutron beam in superfluid helium
→ Soft spectrum, eg SUN2 spectrum peak at 80 neV (200 s accumulation)

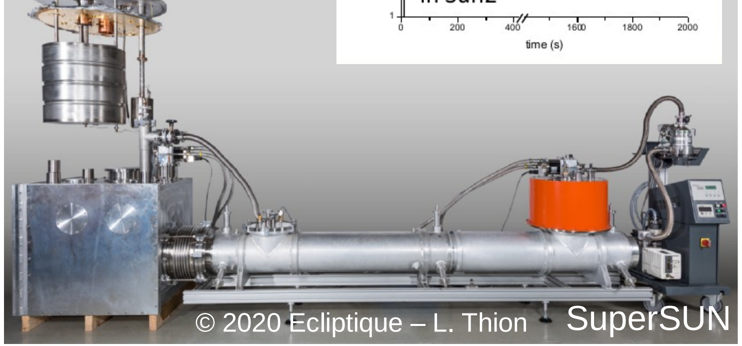
	SUN2	**SuperSUN phase-I**	**SuperSUN phase-II**
Cold neutron beam	monochromatic	brighter, white beam	
Trap	Material walls		Magnetic octupole
Converter volume	4 L	12 L	
Polarization loss	0.5		included
In-situ UCN density	220 cm^{-3}	330 cm^{-3}	1670 cm^{-3}

O. Zimmer et al, Phys. Rev. Lett. 107, **134801** (2011)
O. Zimmer et al, R. Golub, Phys. Rev. C 92, **015501** (2015)
K. Leung et al, Phys. Rev. C 93, **025501** (2016)
D. Wurm et al, EPJ Web of Conferences 219, 02006 (2019)



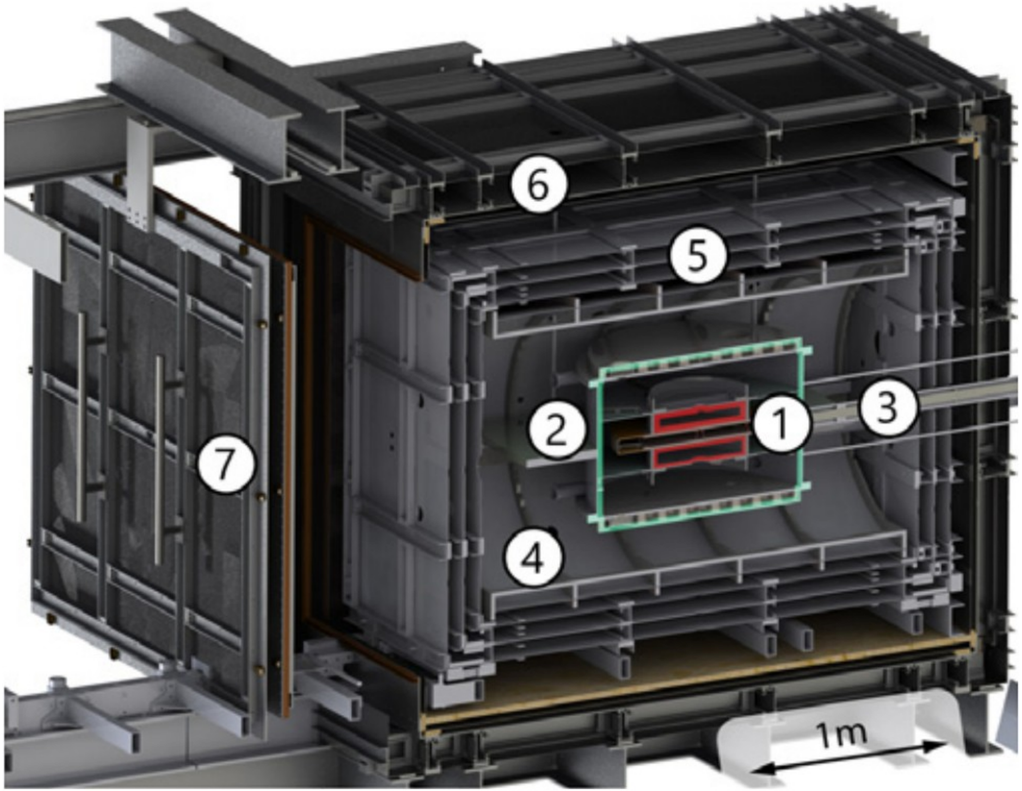
Kwan Ho Leung, PhD,2013





Preparing cooldown for first UCN production using SuperSUN this fall

Magnetic shielding



1 Double cell electrode stack
2 Vacuum chamber
3 High-voltage feed
4 Inner cylindrical shield (incl. B_0, B_1 coils)
5 Three-layer inner magnetic shield
6 Two-layer outer magnetic and RF shield
7 Door

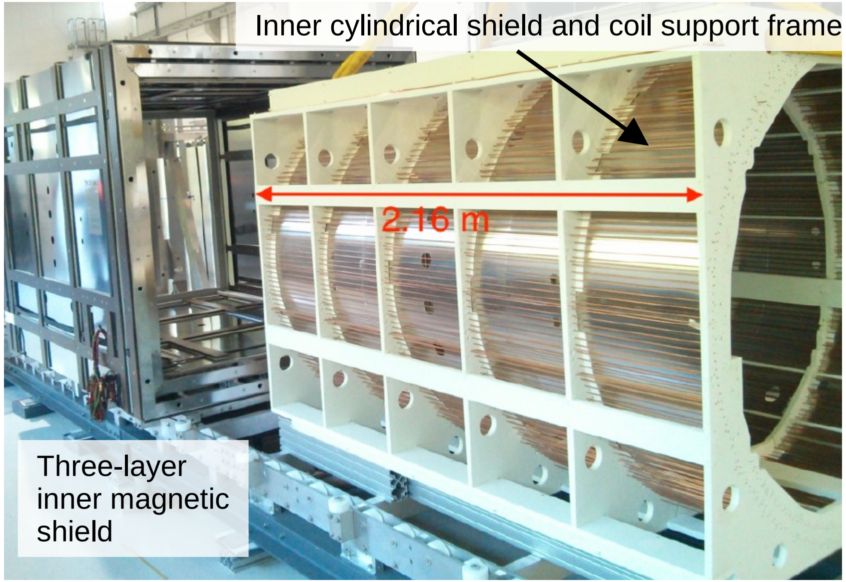
Shielding factor > 6×10^6 @ 1 mHz
Magnetic field drift <10 fT per 250 s
Magnetic field gradient drift <10 fT/m/s

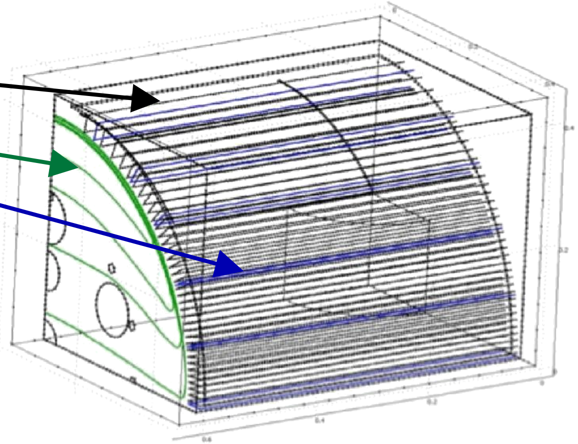
Altarev et al, Rev. Sci. Instr. **85**, 075106 (2014)
Altarev et al, J. Appl. Phys. **117**, 183903 (2015)
T. Lins, PhD thesis, TUM (2016)
S. Stuiber, PhD thesis, TUM (2018)

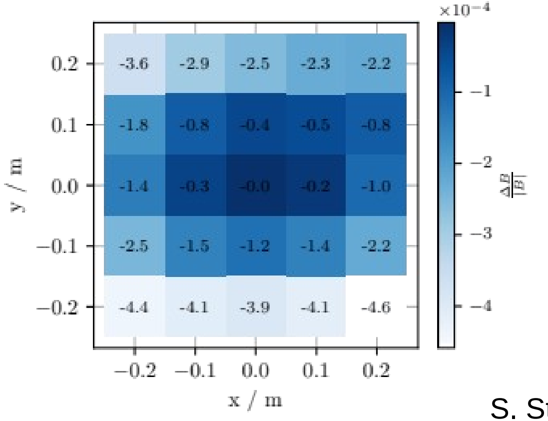
Magnetic field generation: B_0 and B_1 coils

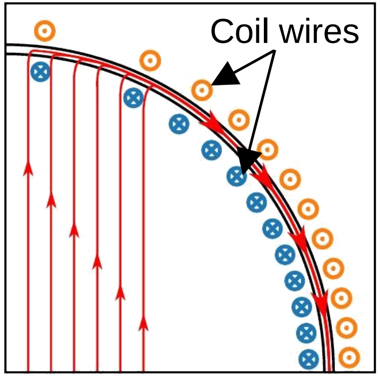
Main coil: Cosine-theta
Trim coils: 21 on end caps
22 on cylinder surface

Measured relative uniformity: 5×10^{-4}





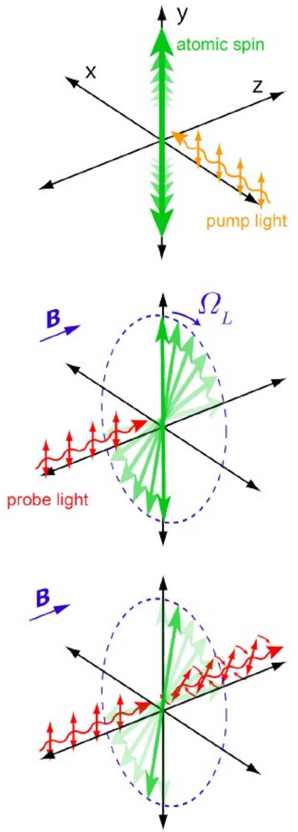




Magnetic field lines return through mu-metal

S. Stuiber, PhD thesis, TUM (2018)

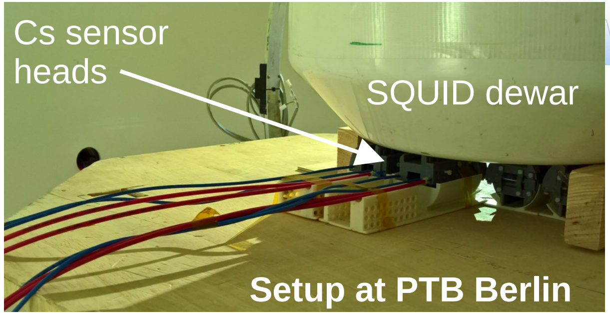
Optical cesium magnetometers

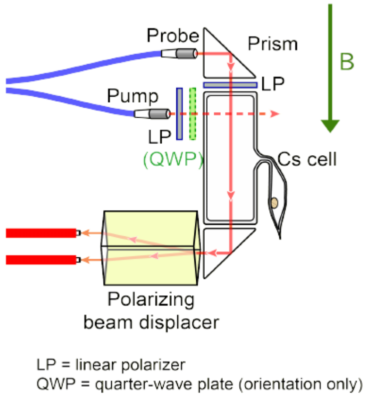


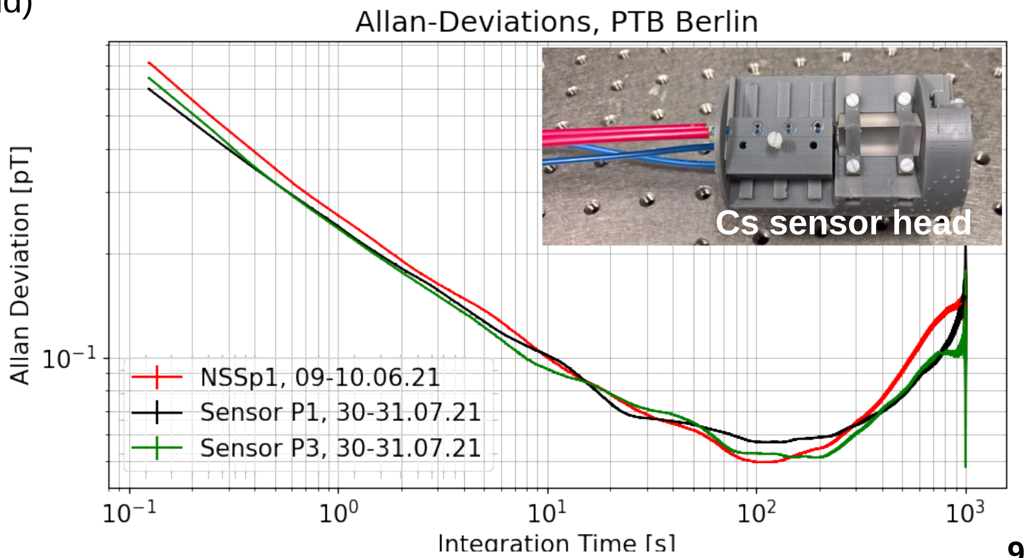
Bell-Bloom type, synchronously pumped NMOR sensor

- all optical, non-magnetic sensor
- fiberized sensors on top and bottom of cell stack
- free-space sensor internal to HV electrode
- 8 kHz bandwith

New sensor head sensitivity <60 fT at 100 s (SQUID-stabilized magnetic field)







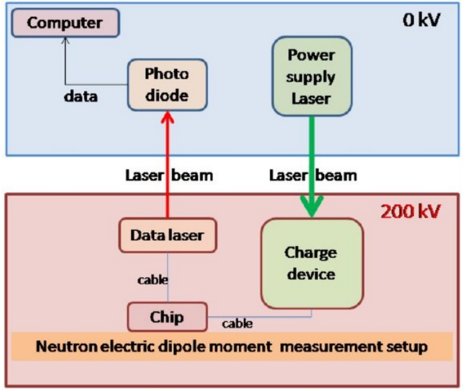
High voltage system

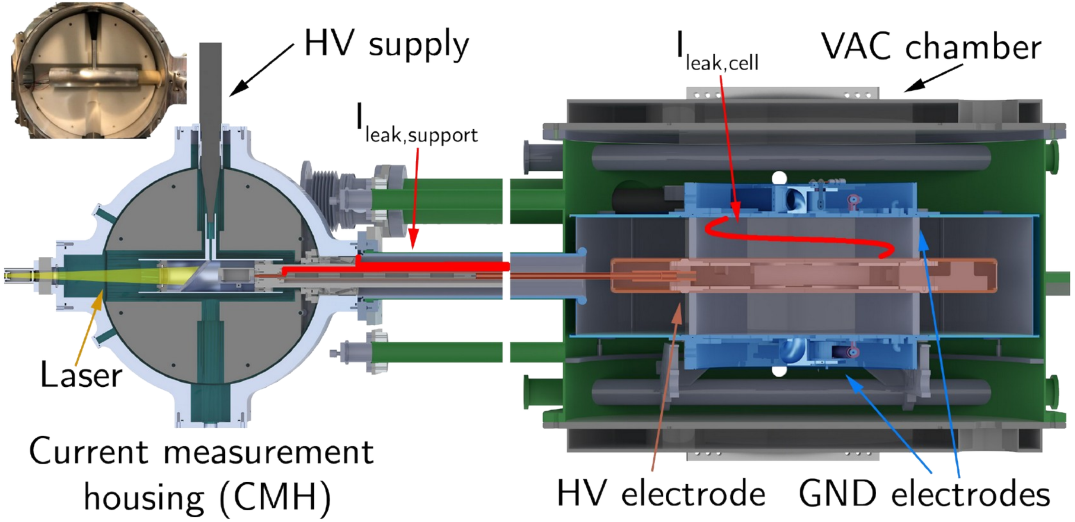
Designed for +/-200 kV → 20 kV/cm

Leakage current generates E-field correlated magnetic field
→ false EDM
Example: 50pA → d_{False} ~1e-27ecm

Current monitoring:

- floating at HV
- optically powered and read-out
- 0.5pA resolution





Final testing ongoing at TUM

Commissioning at ILL in fall/winter 2021

PanEDM status summary

Components built and ready for commissioning:

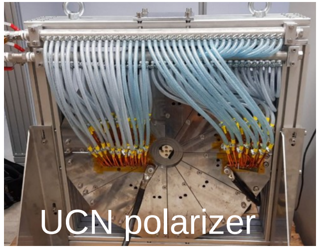
- Source switch
- Two three-way switches
- Polarizer magnet
- EDM cell stack and electrodes
- UCN detectors

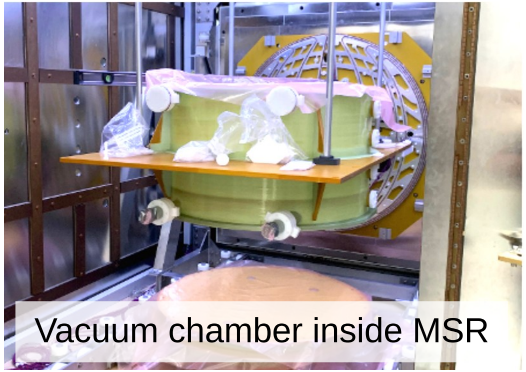
Installation completed at ILL:

- Clean room laser lab
- Magnetic shield
- Vacuum chamber

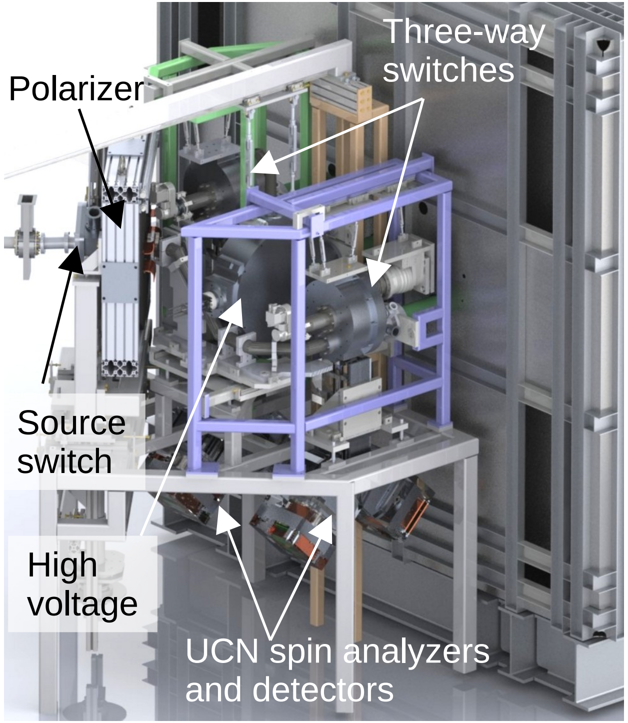
Work in progress at ILL:

- UCN source commissioning (phase I)
- Optical magnetometer setup
- Magnetic field system commissioning
- High-voltage setup and commissioning
- Component tests with UCN


UCN polarizer


Vacuum chamber inside MSR


EDM cell stack test assembly



ILL beamtimes 2021

ILL cycles: Jan-Mar, May-July and **Aug-Oct**

Parallel measurements at SUN2 and SuperSUN

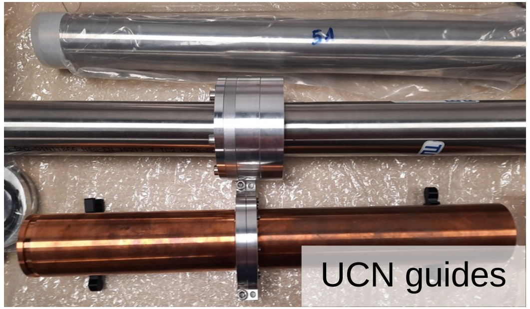
Now ongoing:

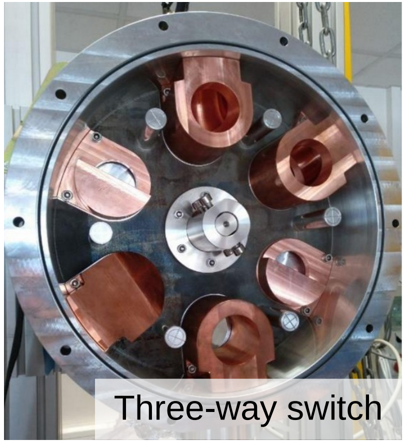
Preparation for cooldown of SuperSUN
- Produce first UCN from SuperSUN
- UCN source comparison (SuperSUN, SUN2)

PanEDM component tests:
- Three-way switch
- Coatings:
  - DLC
  - CYTOP

    τ=311s±9s (296K)
    τ=564s±7s (12K)
- UCN guides

Sunino UCN storage vessel


UCN guides


Three-way switch


DLC coating test vessel

Thank you!

PanEDM Collaboration

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