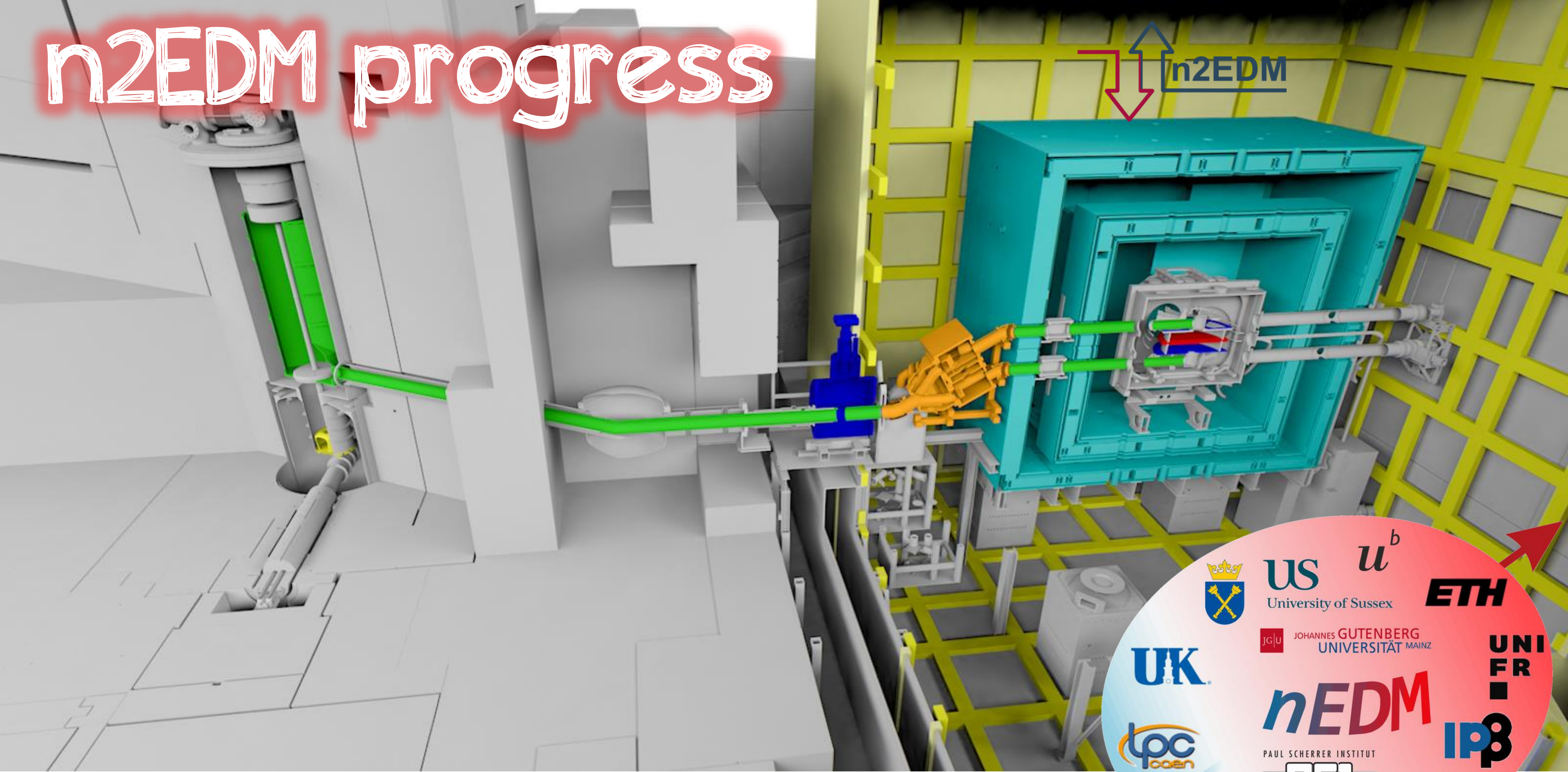
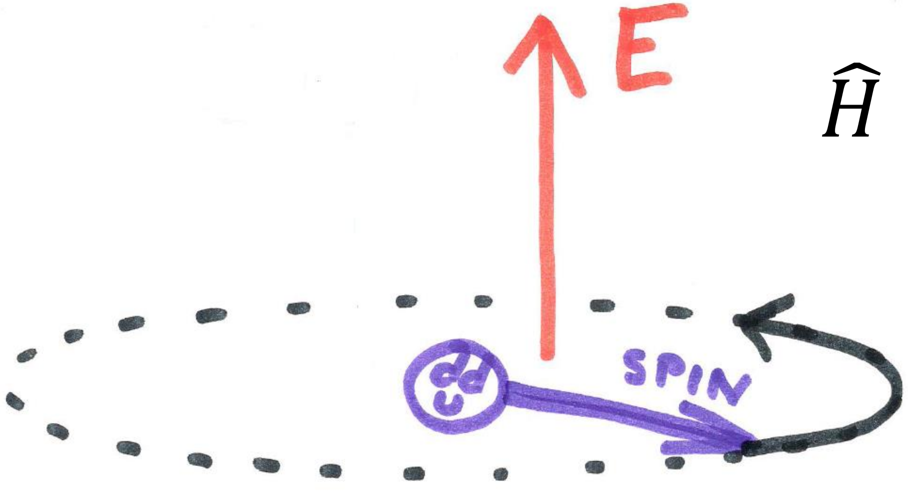
n2EDM progress

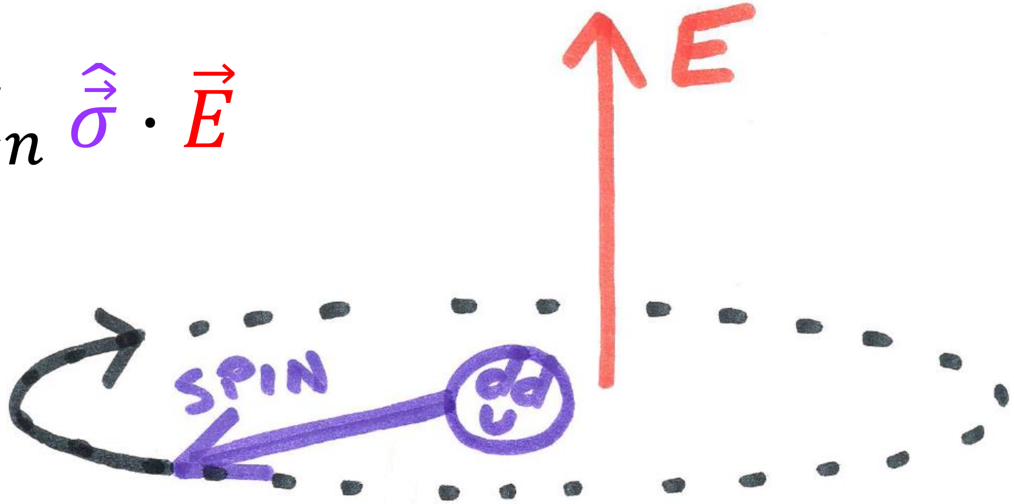


Guillaume Pignol, on behalf of the nEDM collaboration
PSI users' meeting 24.01.2023

EDM: coupling between spin and E-field



$$\hat{H} = -d_n\,\hat{\vec{\sigma}} \cdot \vec{E}$$



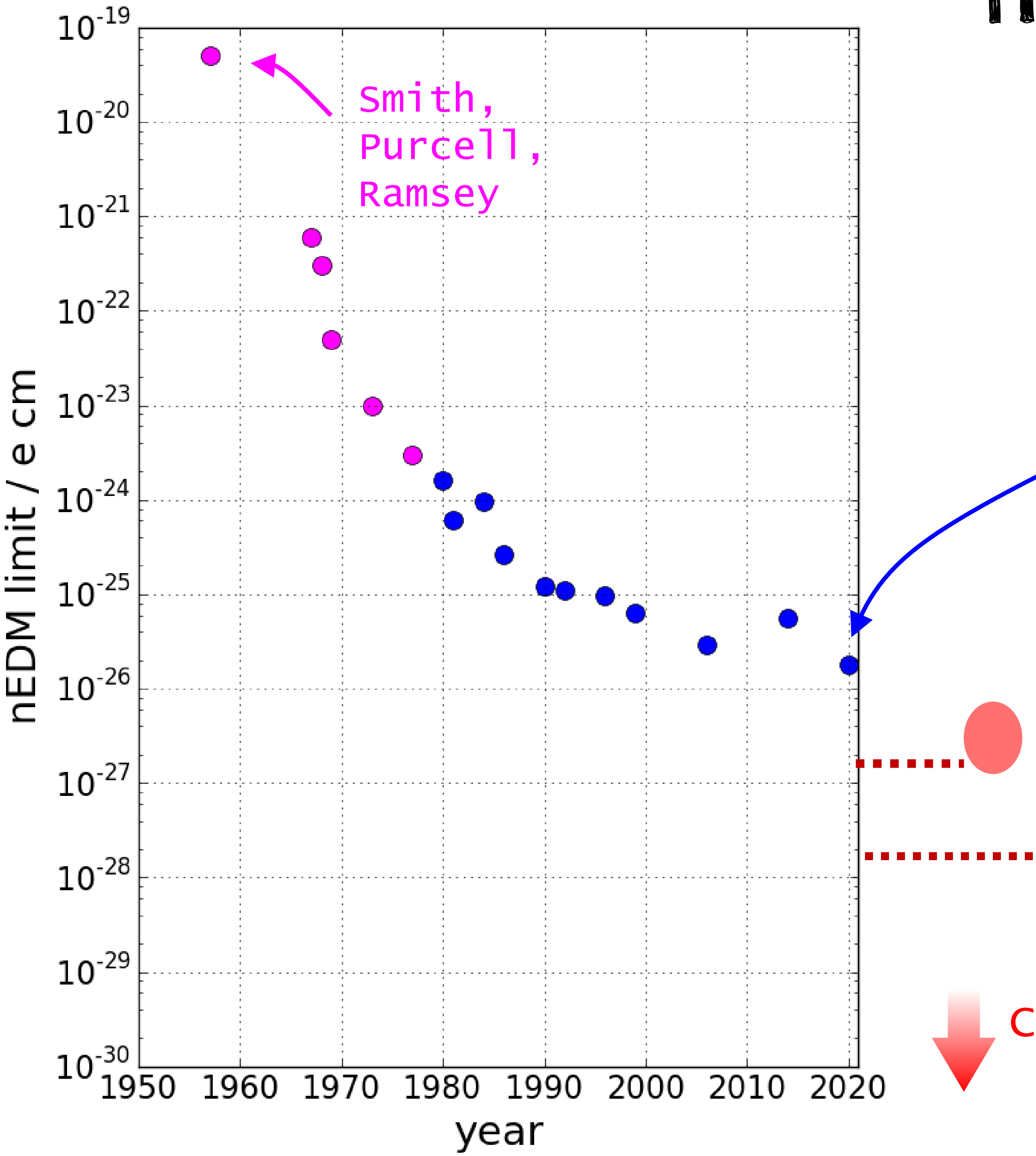
>> PLAY >>

<< REWIND <<

If $d_n \neq 0$ the process and its time reversed version are different.

Violation of T $\xrightarrow{\text{CPT}}$ Violation of CP

The neutron EDM is still zero



Best limit: nEDM @PSI
Abel et al, PRL **124**, 081803 (2020)

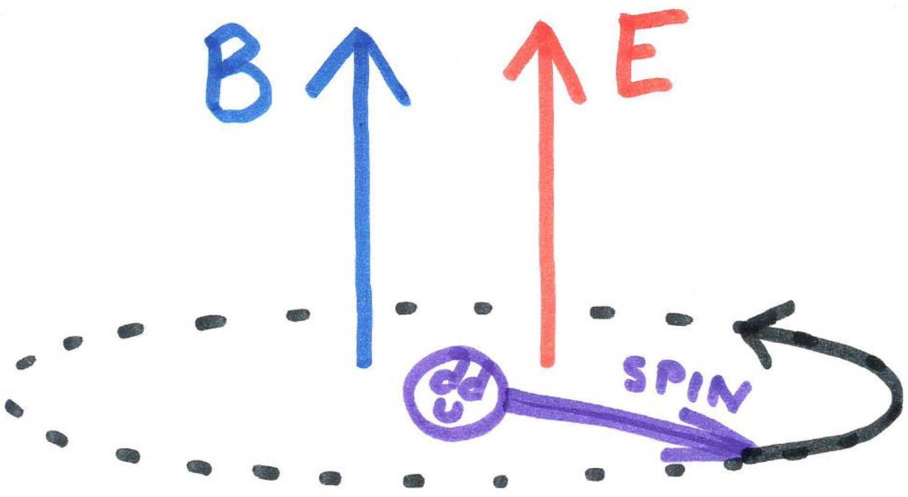
$$|d_n| < 1.8 \times 10^{-26}\, e\ \mathrm{cm}$$

Design sensitivity range of 4 experiments
n2EDM @PSI, panEDM @ILL, LANL EDM, tucan @TRIUMF
under construction now

Design sensitivity EDM@SNS, starting 2028

CKM background uncertain, possibly 10^{-31} e cm

Basics of nEDM measurement



Larmor frequency
$f = 30\ \mathrm{Hz}\ @\ B = 1\ \mu\mathrm{T}$

$$2\pi f = \frac{2\mu_n}{\hbar} B \pm \frac{2d_n}{\hbar} |E|$$

If $d_n = 10^{-26}\ e\ \mathrm{cm}$ and $E = 11\ \mathrm{kV/cm}$
one full turn in a time $\frac{\pi\hbar}{dE} = \mathbf{200\ days}$

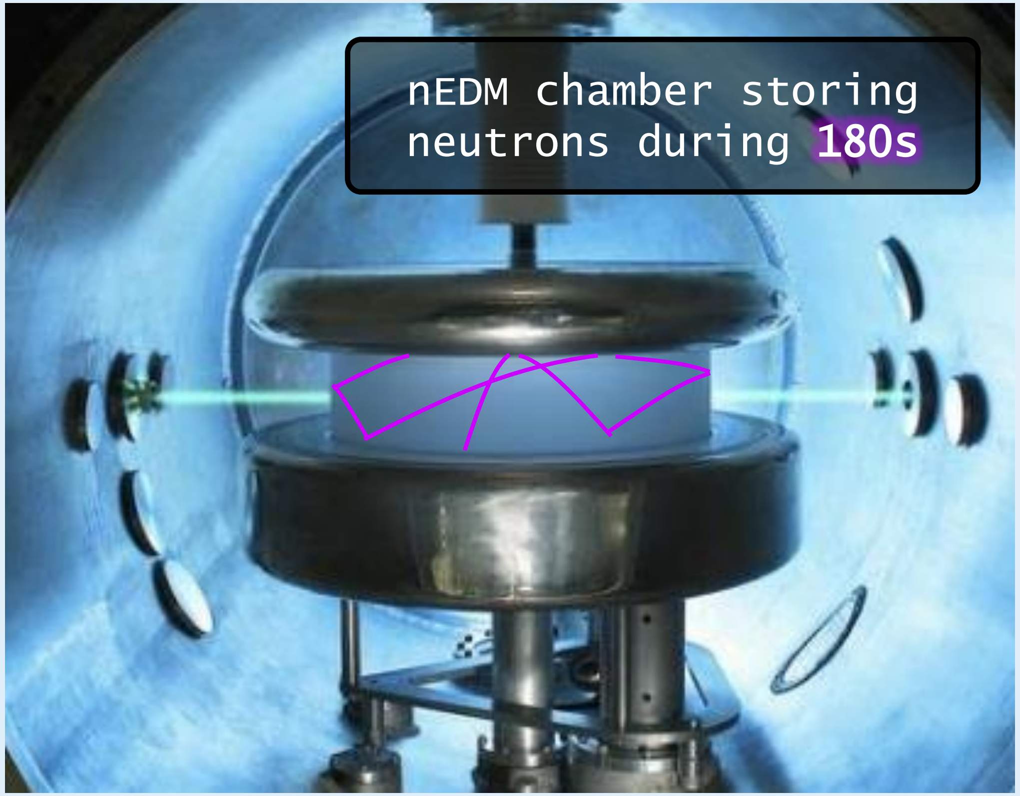
To detect such a minuscule coupling
- Long interaction time
- High intensity/statistics
- Control the magnetic field

- Long interaction time
- High intensity/statistics
- Control the magnetic field

Use big magnetic shielding

Use Ultracold neutrons

Neutrons with velocity <5m/s can undergo total reflection and be stored in material “bottles”



+ Use quantum magnetometry

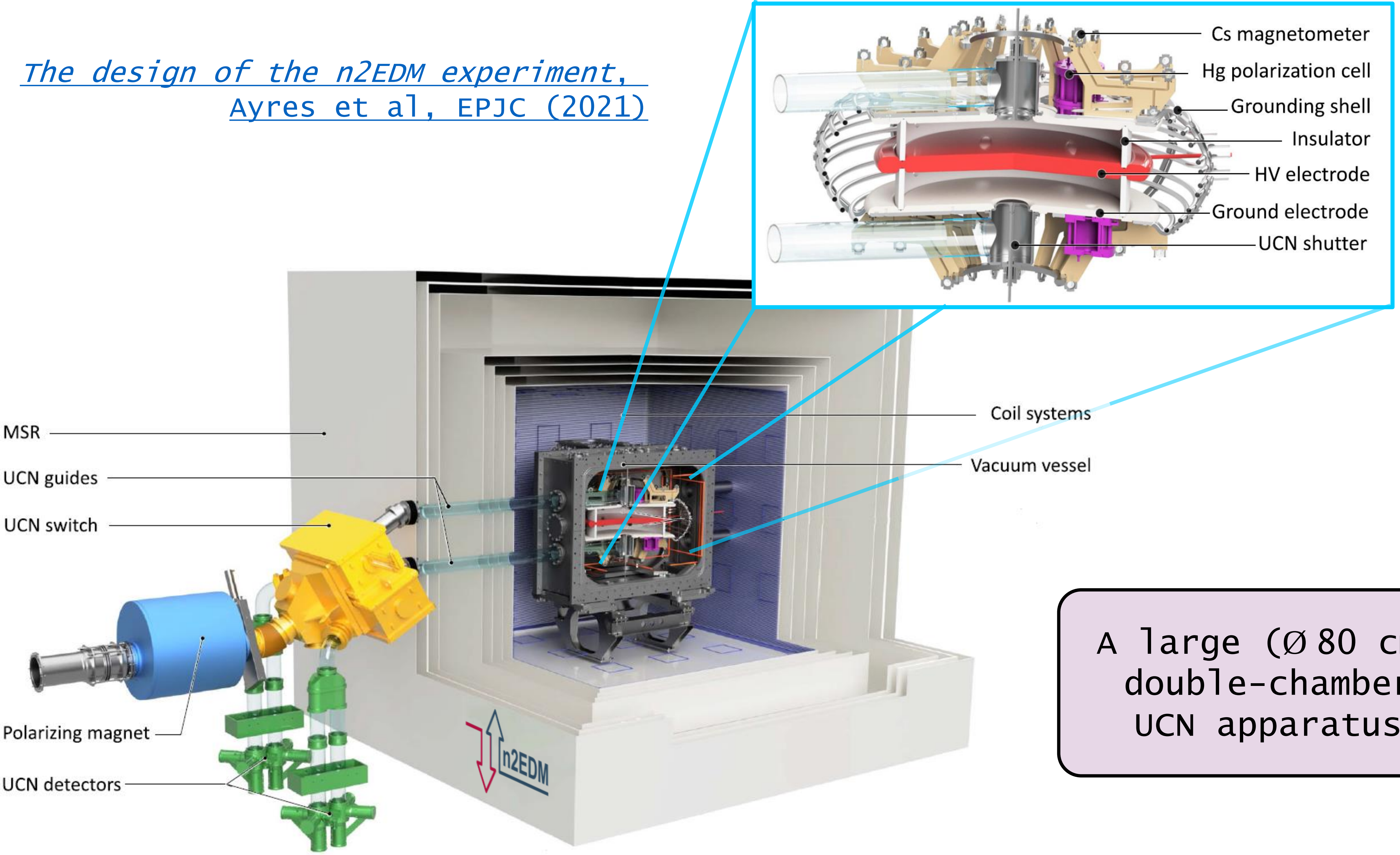
with mercury and cesium atoms

$$d_n = (0.0 \pm 1.1_{\text{stat}} \pm 0.2_{\text{syst}}) \times 10^{-26}\ ecm$$

Limited by the number of UCNs

Uniformity of the B-field

The design of the n2EDM experiment, Ayres et al, EPJC (2021)

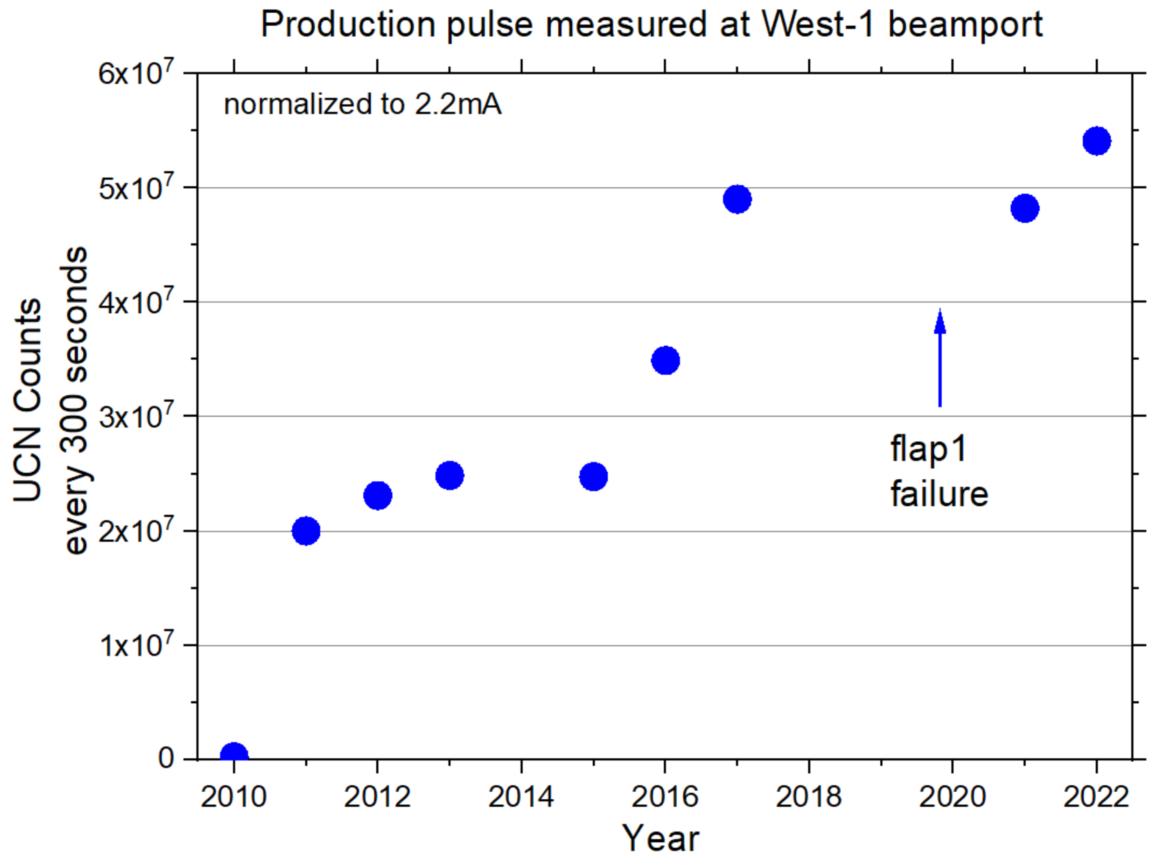


A large (Ø 80 cm) double-chamber UCN apparatus

[The design of the n2EDM experiment, Ayres et al, EPJC (2021)]

Baseline design

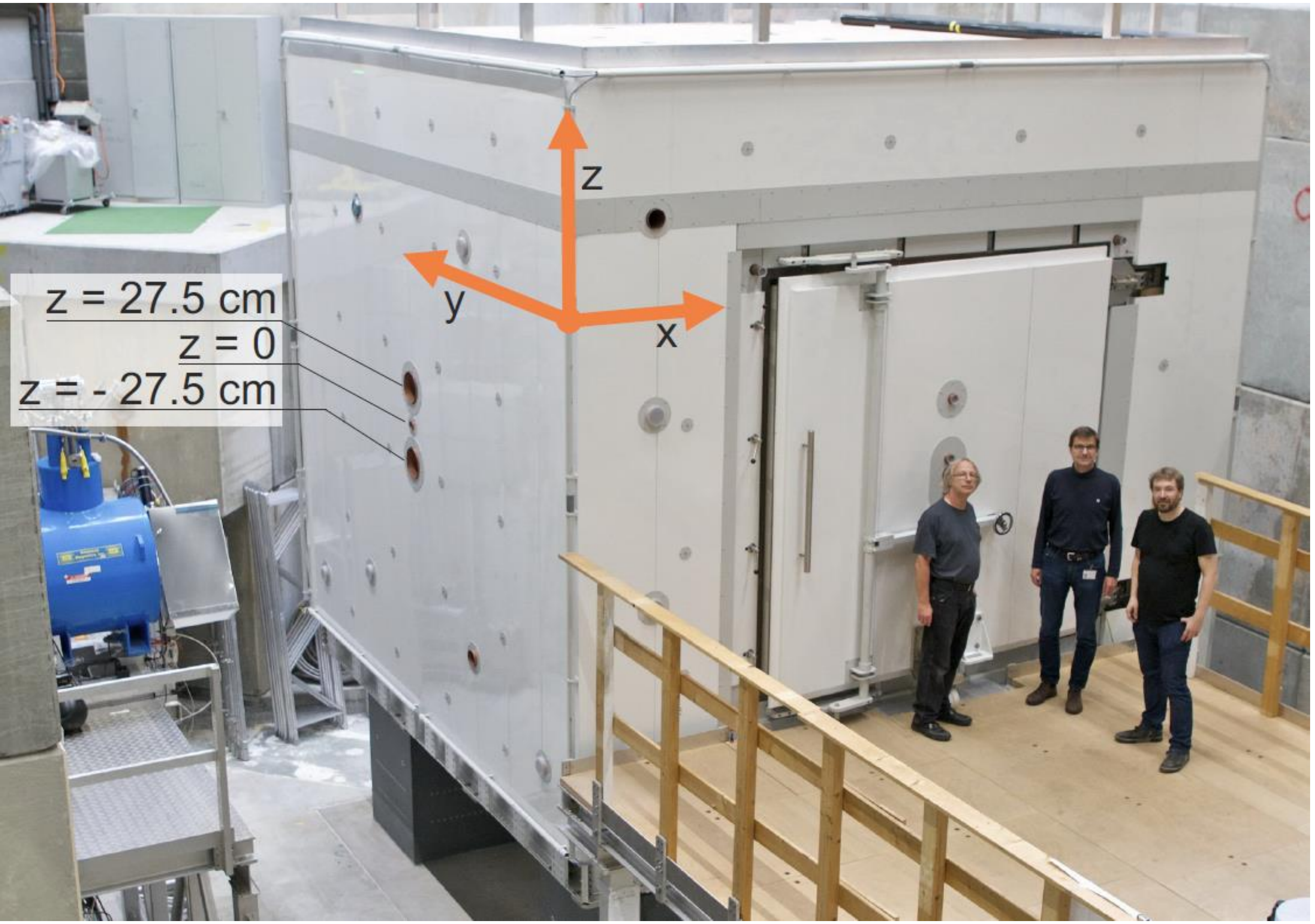
	nEDM 2016	n2EDM
Chamber	DLC and dPS	DLC and dPS
Diameter D	47 cm	80 cm
N (per cycle)	15,000	121,000
T	180 s	180 s
E	11 kV/cm	15 kV/cm
α	0.75	0.8
$\sigma(f_n)$ per cycle	9.6 μHz	3.2 μHz
$\sigma(d_n)$ per day	11×10^{-26} e cm	2.6×10^{-26} e cm
$\sigma(d_n)$ (final)	9.5×10^{-27} e cm	1.1×10^{-27} e cm



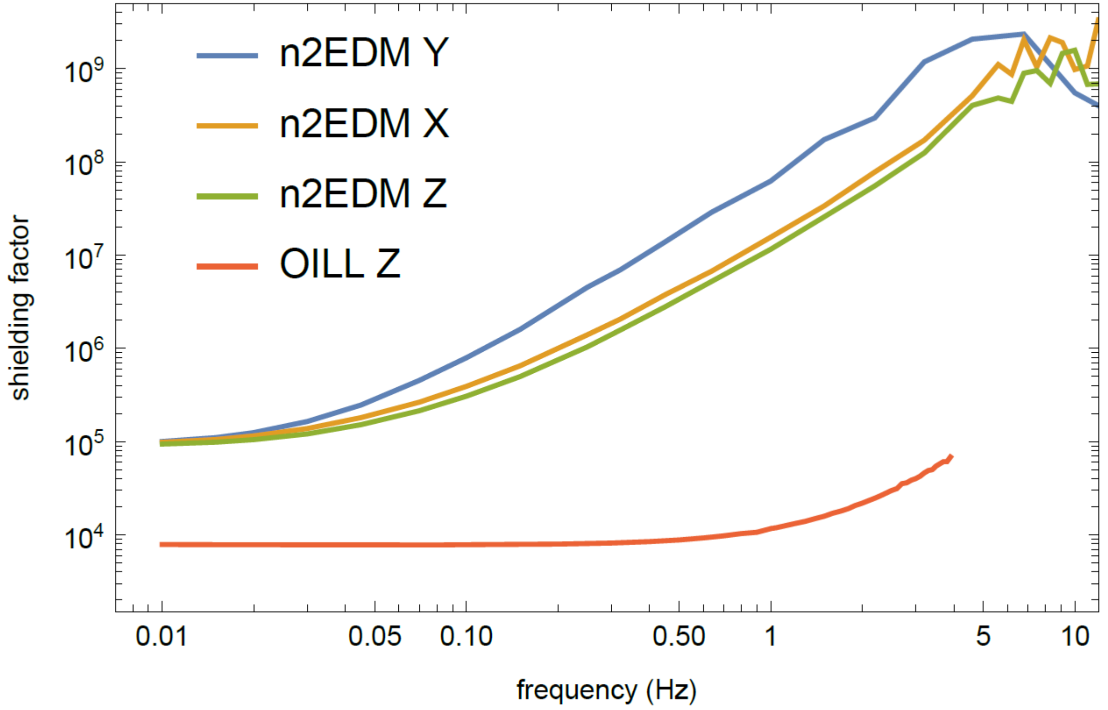
n2EDM designed to improve the sensitivity by factor 10, with 500 data days, based on UCN source performance established in 2016

n2EDM construction Nov 2017 → → → Dec 2019

Commissioning of the n2EDM Magnetically Shielded Room in 2020



- Setup and optimization of the degaussing
- Characterization of the remanent field
- Measurement of the shielding factors

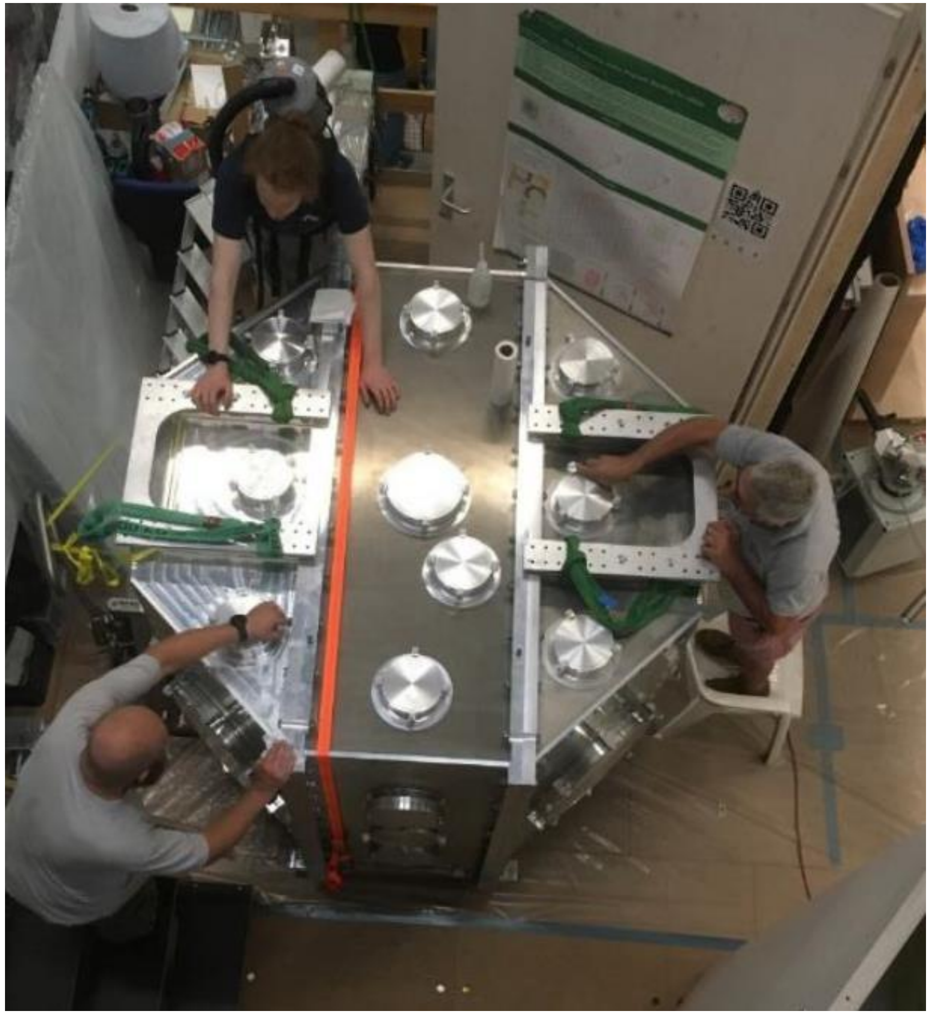


The very large n2EDM magnetically shielded room with an exceptional performance for fundamental physics measurements, Review of Scientific Instruments 93, 095105 (2022)

Active Magnetic Shield built in 2021

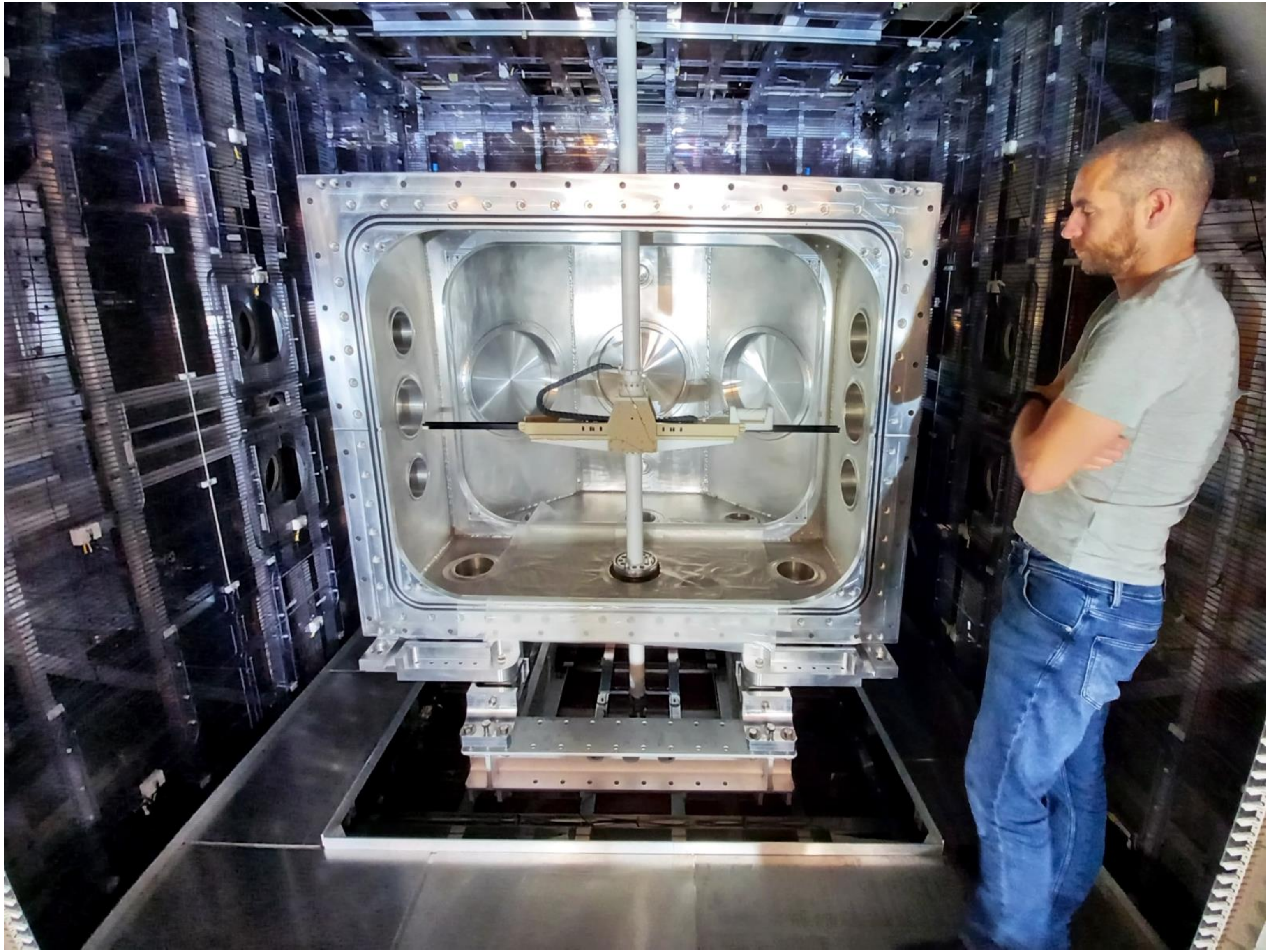
n2EDM in 2021

Installation internal coil system

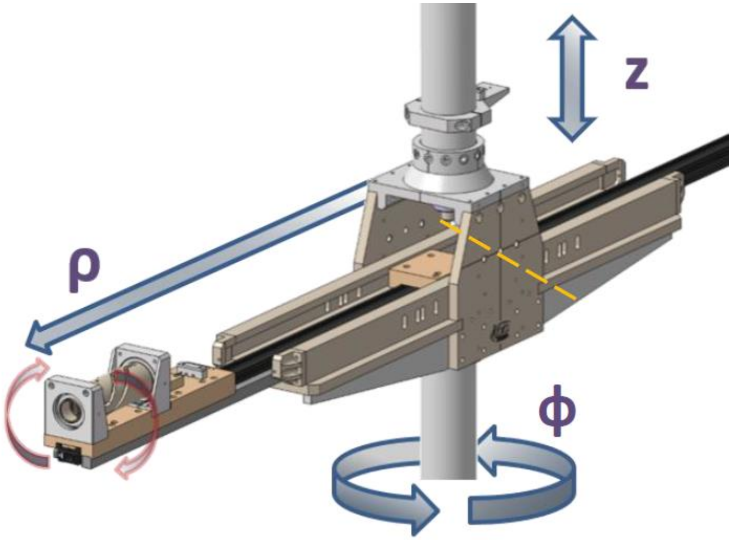


Delivery non-magnetic vacuum vessel

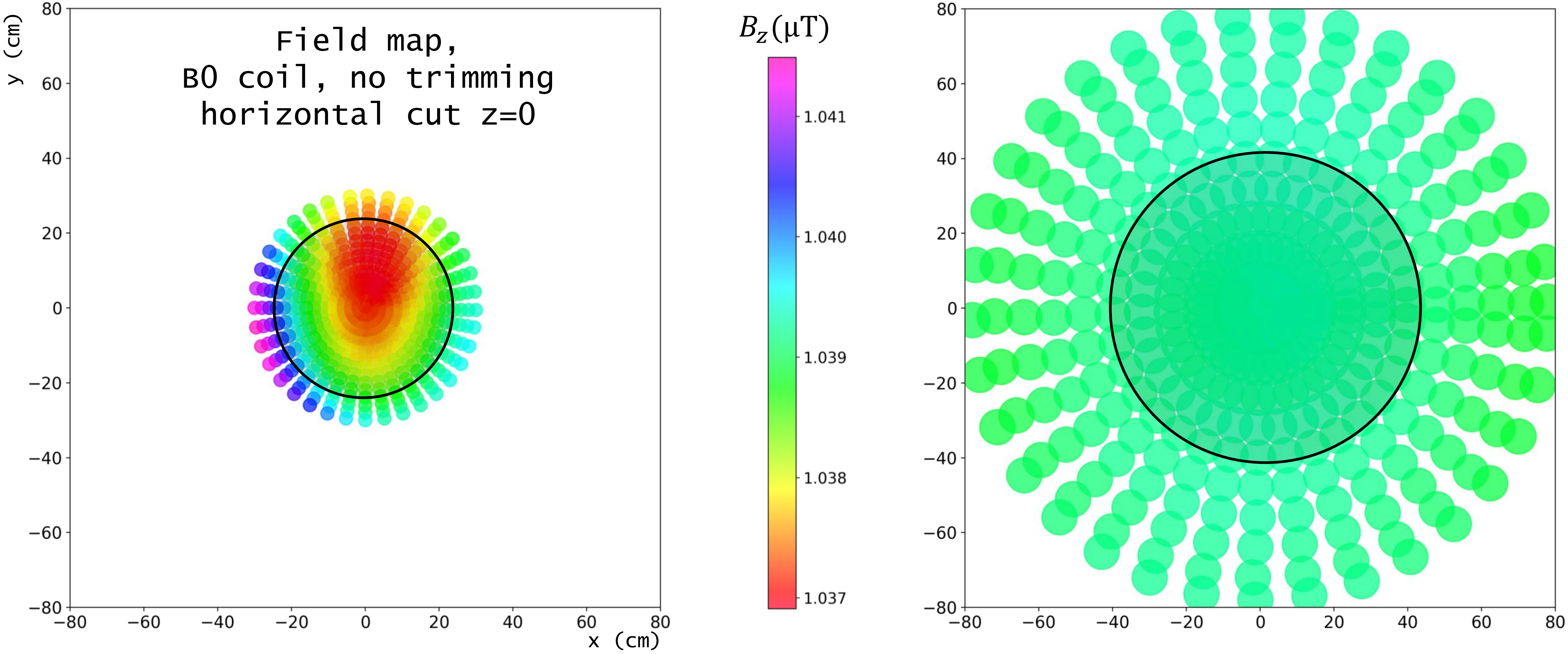
B-field mapping campaign 2022



Installation of the mapper in the empty vacuum vessel



Uniformity of the vertical B-field



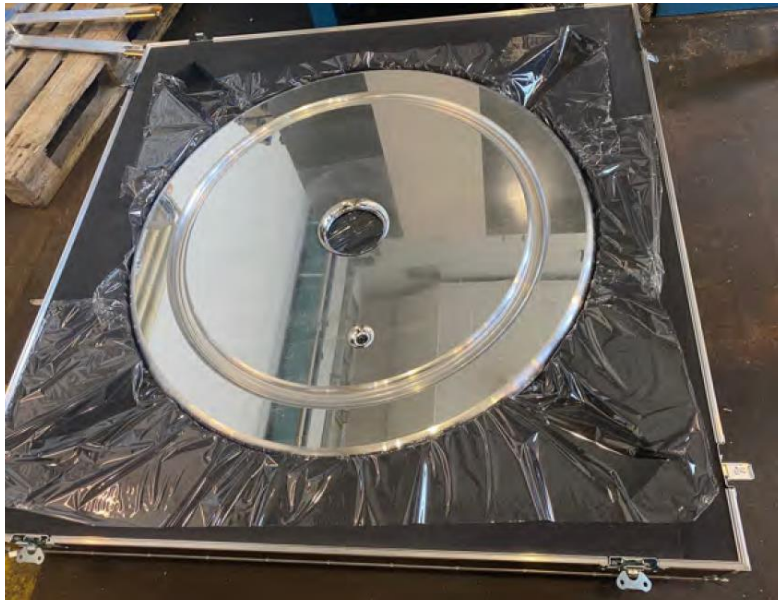
nEDM 2017 $\sigma(B_z) = 860\,\mathrm{pT}$

In the precession chamber Ø 47 cm

n2EDM 2022 $\sigma(B_z) = 60\,\mathrm{pT}$

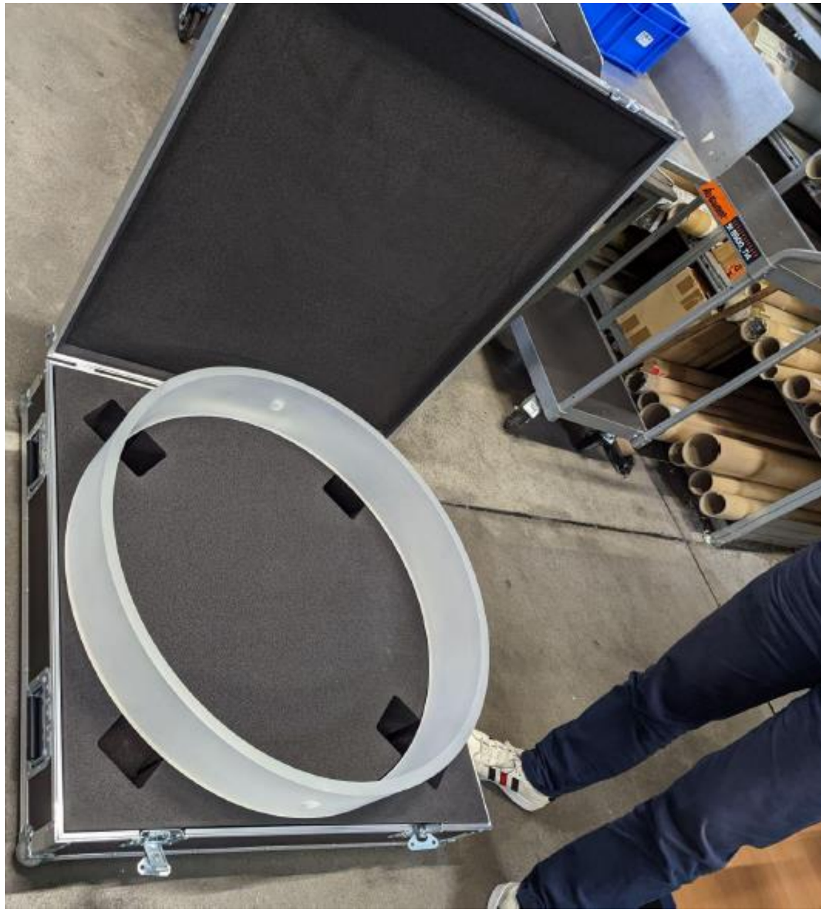
In one chamber Ø 80 cm

Production precession chambers



Ground electrodes

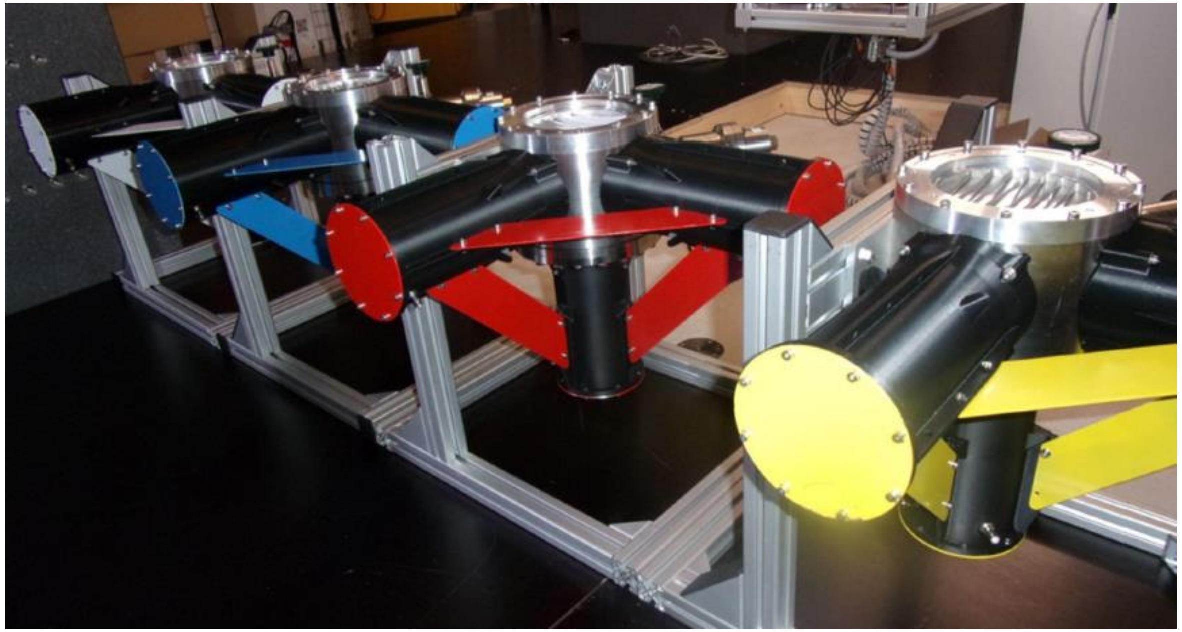
High voltage electrode

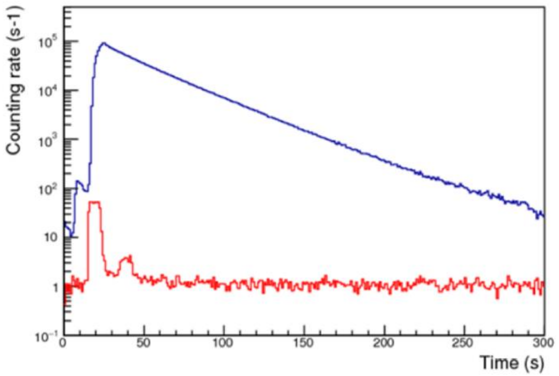


Insulator ring

UCN transport and detection

UCN switch nearly operational





4 UCN detectors operational

Conclusions

n2EDM magnetically operational (MSR+B0)
- Big volume: 6 fold increased /nEDM
- Order of magnitude improved shielding factor
- Order of magnitude improved uniformity

=> Satisfies the requirements => Ready for physics!

Ultracold neutrons
transport, storage, detection:
most of it is ready for installation

Schedule:
n2EDM ready for physics end of 2023