Victoria Kletzl :: Paul Scherrer Institute :: on behalf of the nEDM collaboration

The n2EDM experiment – A high-sensitivity search for physics beyond the Standard Model

SPS/ÖPG Joint Meeting 2023 – Universität Basel

n2EDM

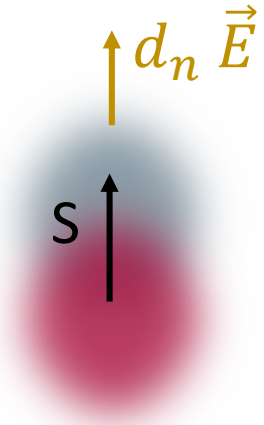
Neutron

2nd generation

Electric **D**ipole **M**oment

What is an EDM?

- Separation of charges ⟶ d_n



$$\hat{H} = -\mu_n \frac{\vec{S}}{S} \cdot \vec{B} - d_n \frac{\vec{S}}{S} \cdot \vec{E}$$

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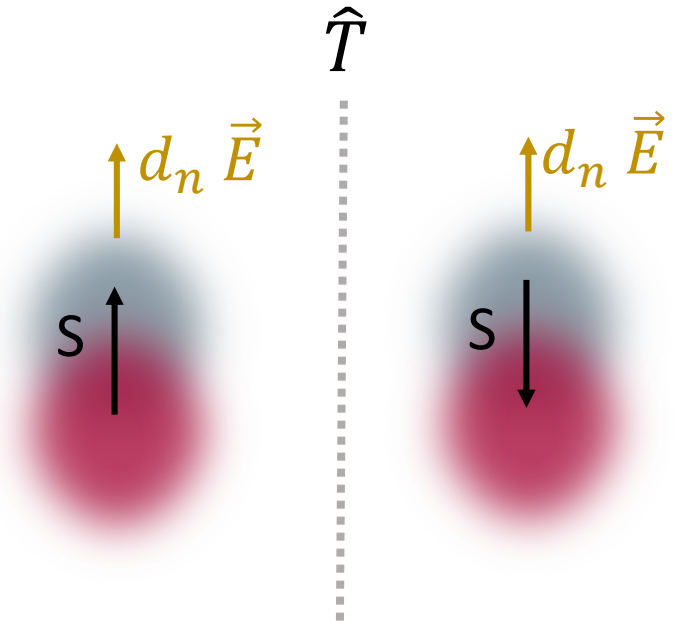

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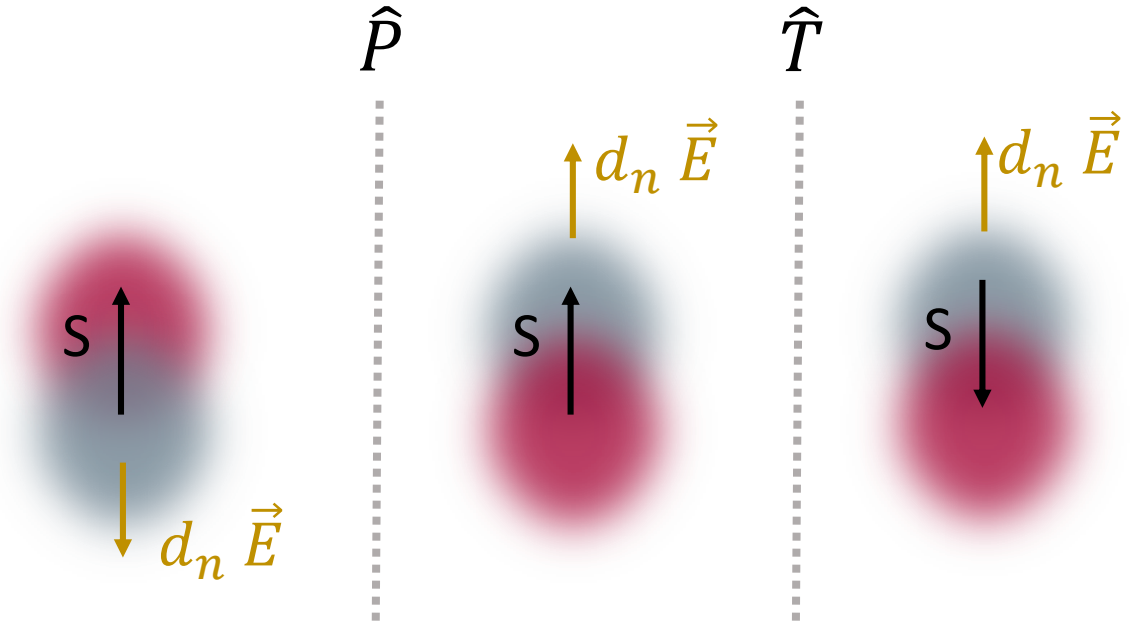
What is an EDM?

- Separation of charges ⟶ d_n
- $d_n \neq 0$ ⟶ CP violation



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Search for the nEDM

- $d_{n,SM} \sim 10^{-32}\ e$ cm

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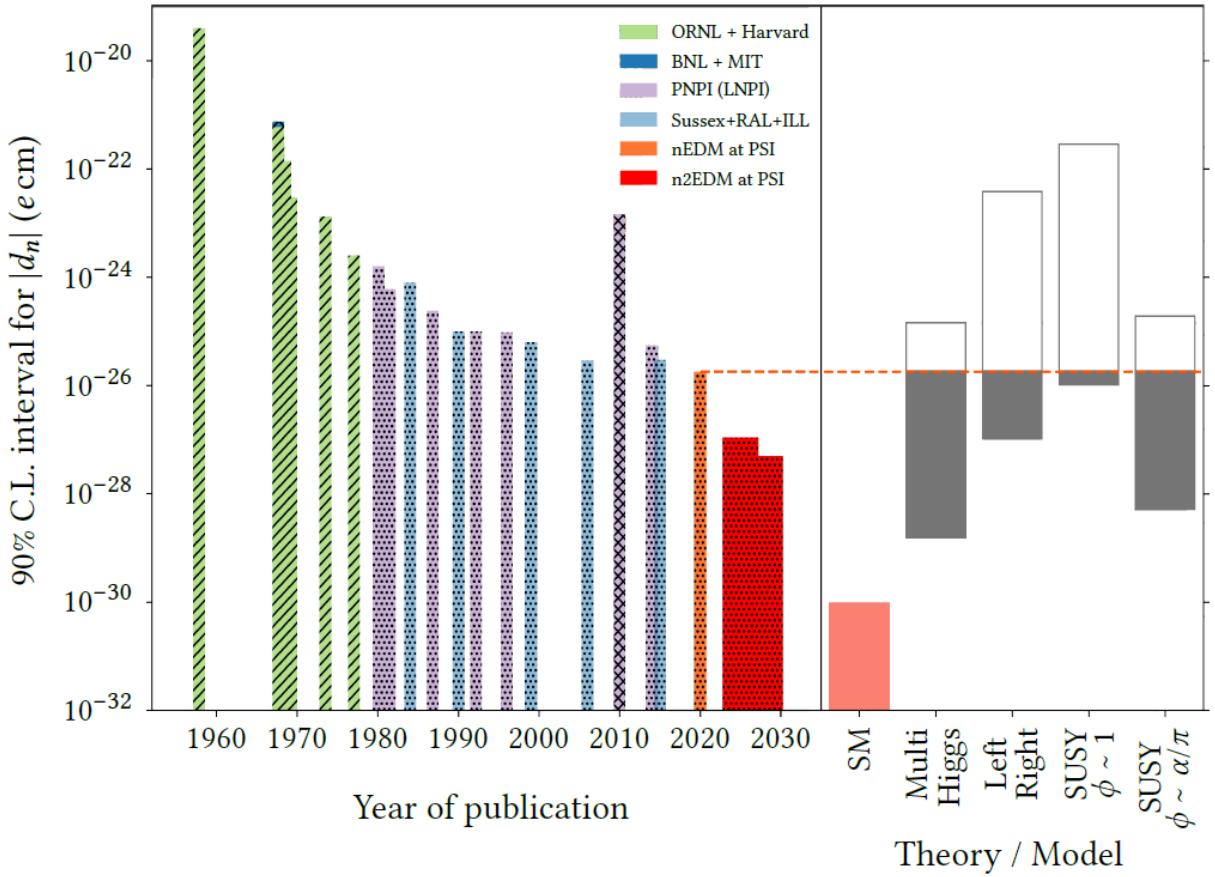
New Physics!



How to detect an EDM?

- Measure neutron precession frequency:

$$hf_L = d_n E$$

- BUT:

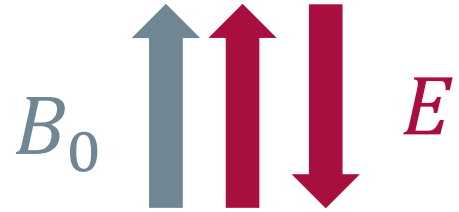
$$f_L \approx 7\ \mathrm{nHz}$$

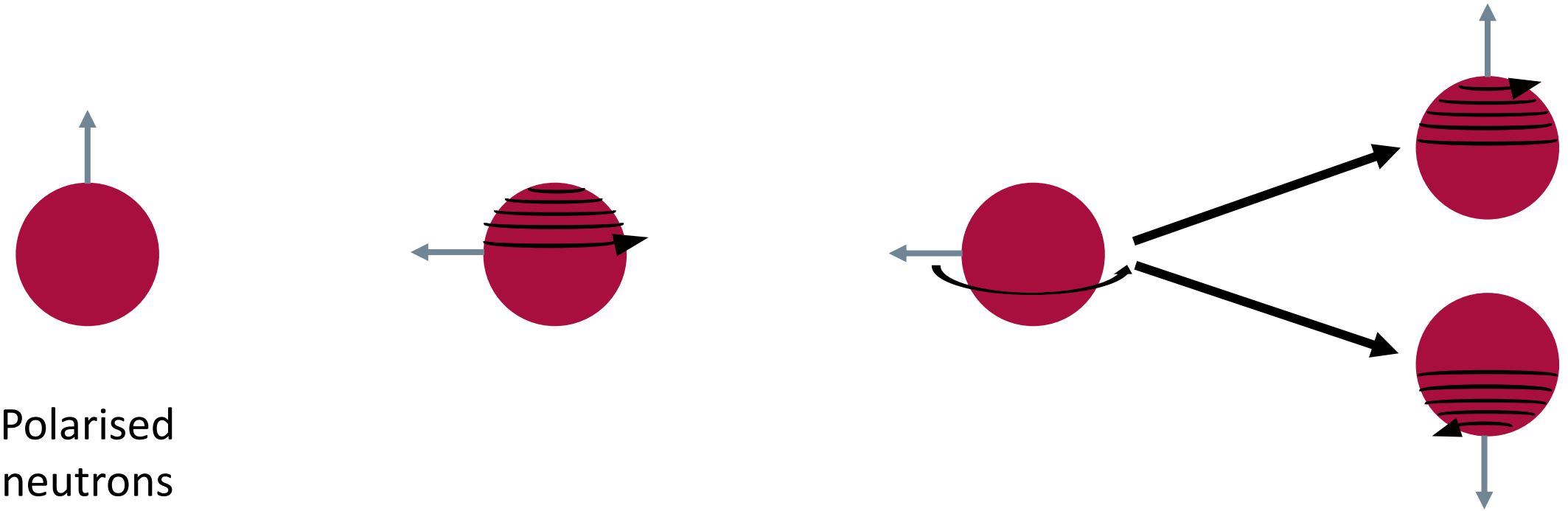
How to detect an EDM?
Use the magnetic moment!

- neutron's magnetic moment μ
- Apply magnetic field B_0
- Observe Larmor precession

$$hf_L = 2(\underbrace{\mu B_0}_{\approx 30\text{Hz}} \pm \underbrace{d_n E}_{\approx 7\text{ nHz}})$$

How to detect an EDM: Ramsey's method





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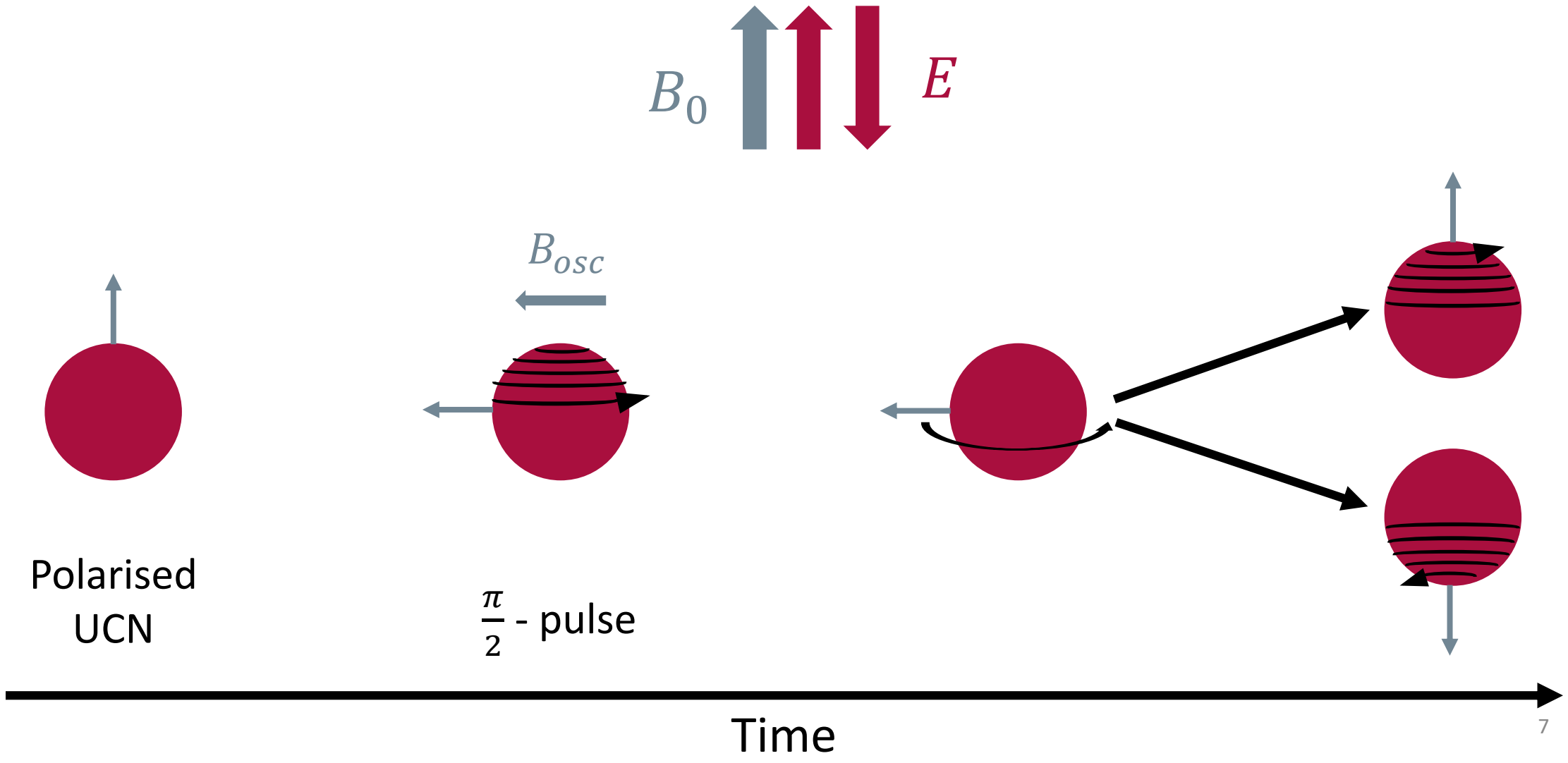

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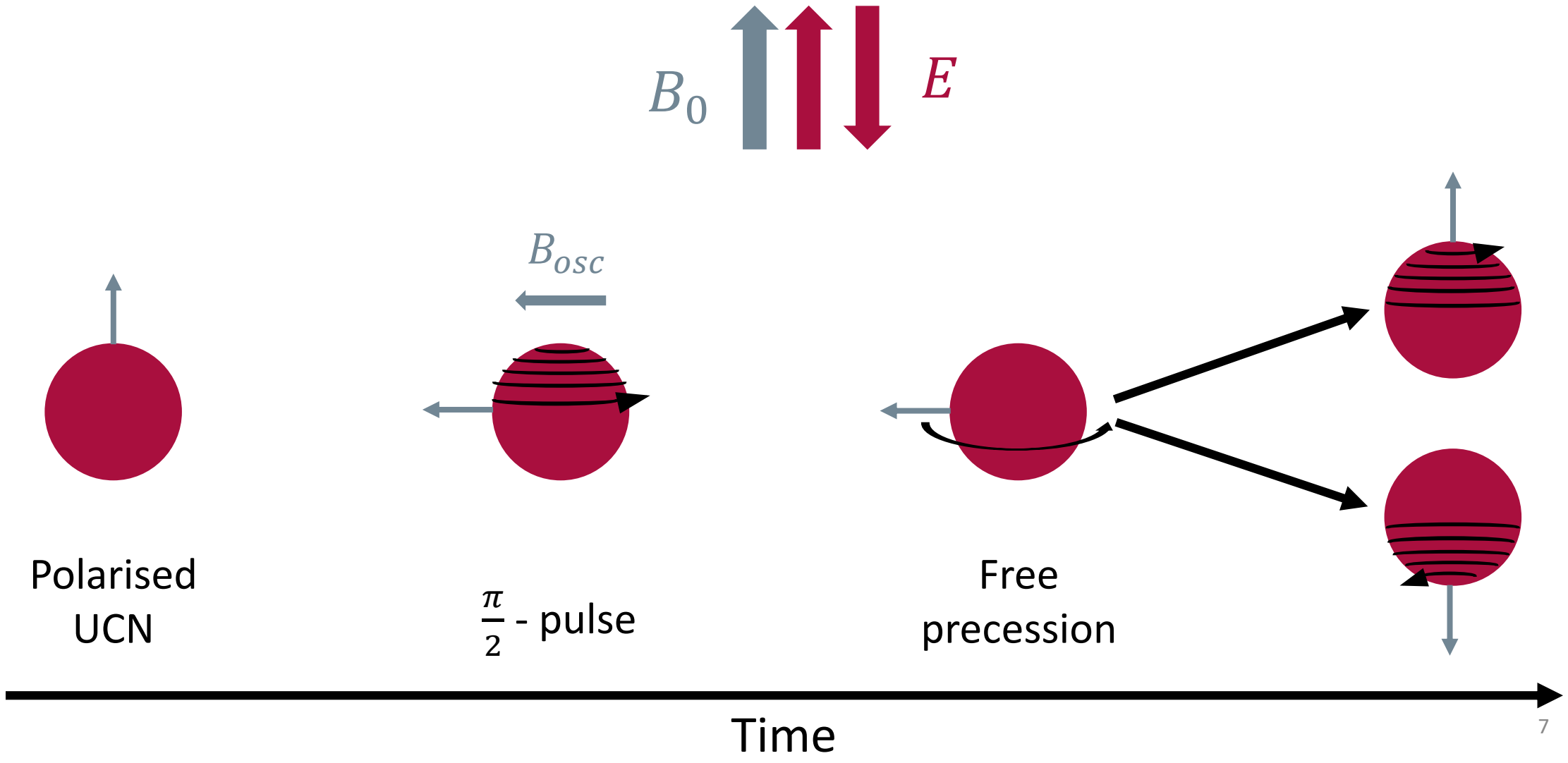

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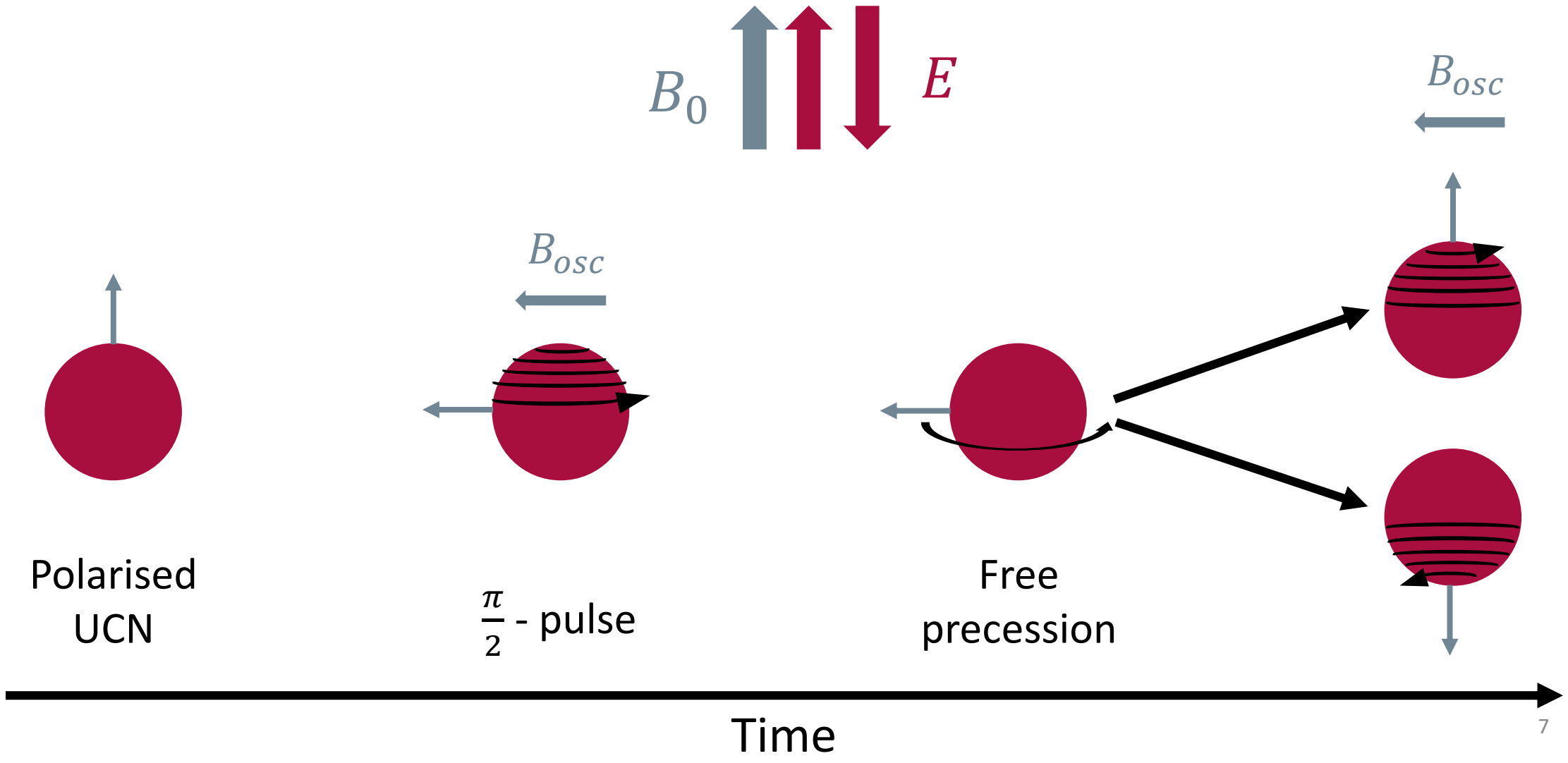
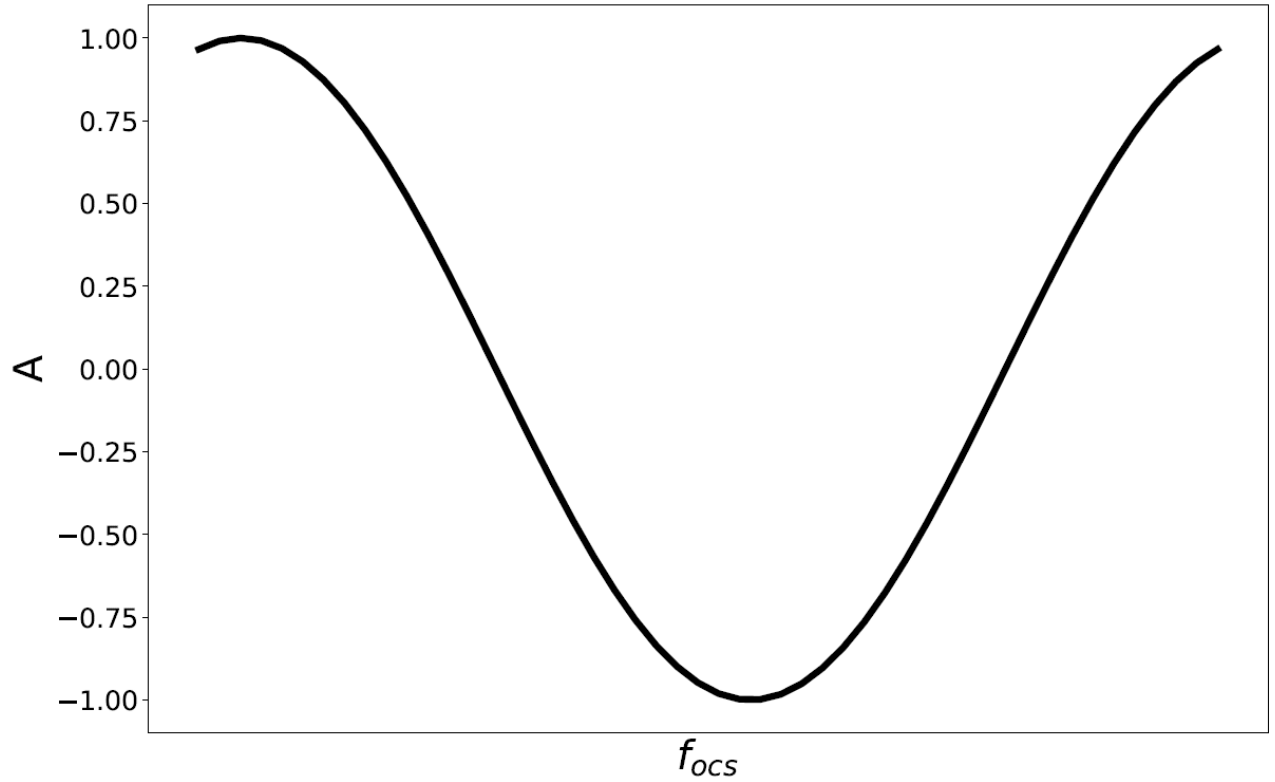


How to detect an EDM: Ramsey's method

$$A(f_{osc}) = \frac{(N_\uparrow - N_\downarrow)}{(N_\uparrow + N_\downarrow)}$$



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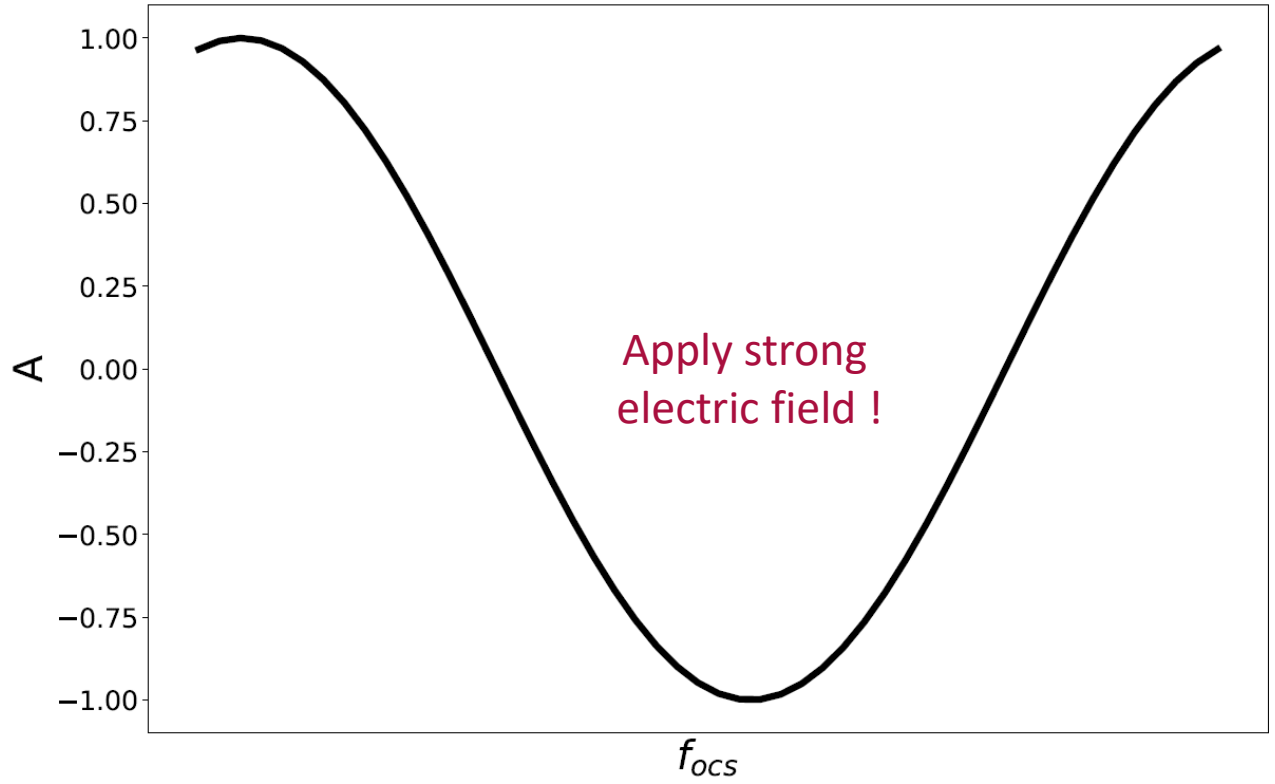

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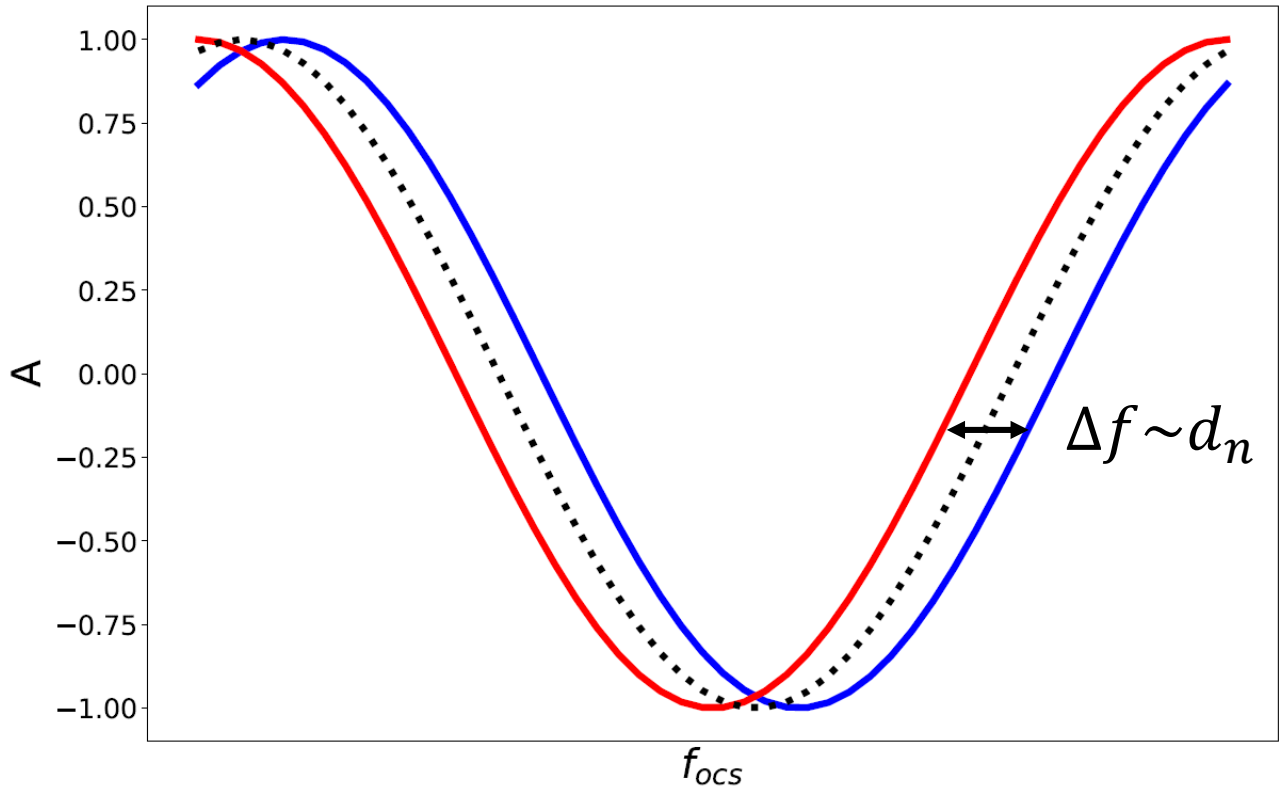


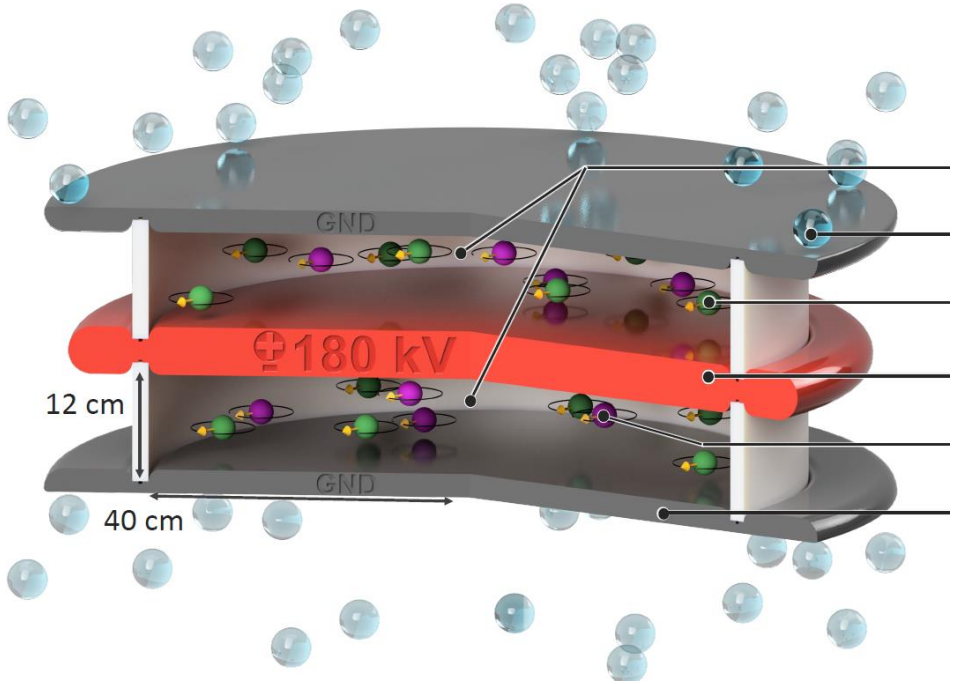
Requirements for nEDM experiments with high sensitivity:

- Neutrons!
- High electric field
- Spin dependent neutron detection
- Precisely known and controlled magnetic fields

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

Neutrons @ n2EDM

- Neutrons!



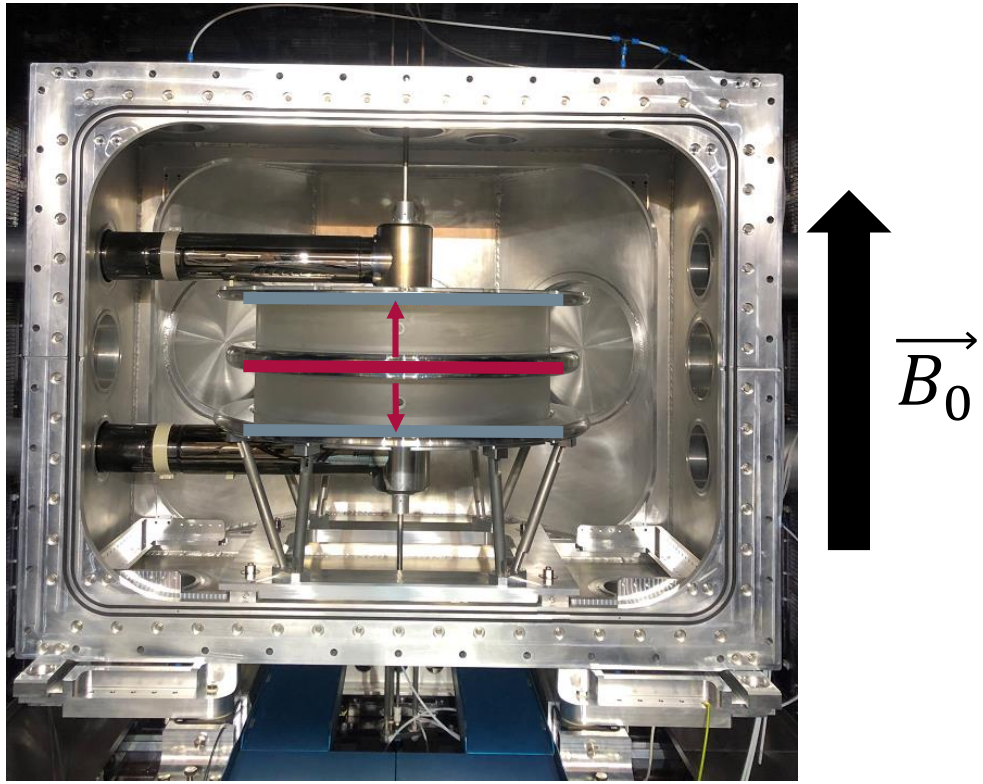
C. Doorenbos
15:00

- Ultracold neutrons (UCN)
- Produced via spallation + cooling
- < 300 neV
- 5 m/s
- Reflected off materials (storage possible!)

Electric field @ n2EDm

- High electric field + 2 orientations

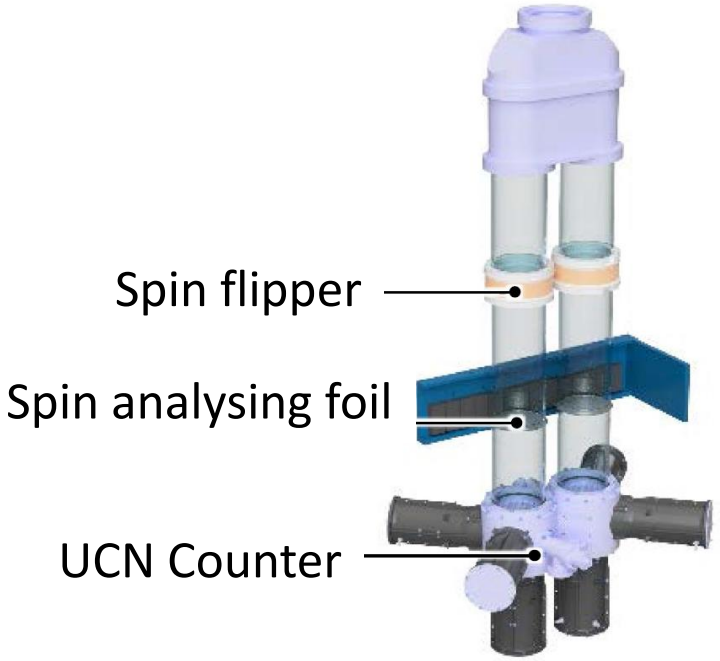
GND
HV
GND



- 1 HV electrode (± 180kV)
- 2 ground electrodes

Neutron detectors @n2EDM

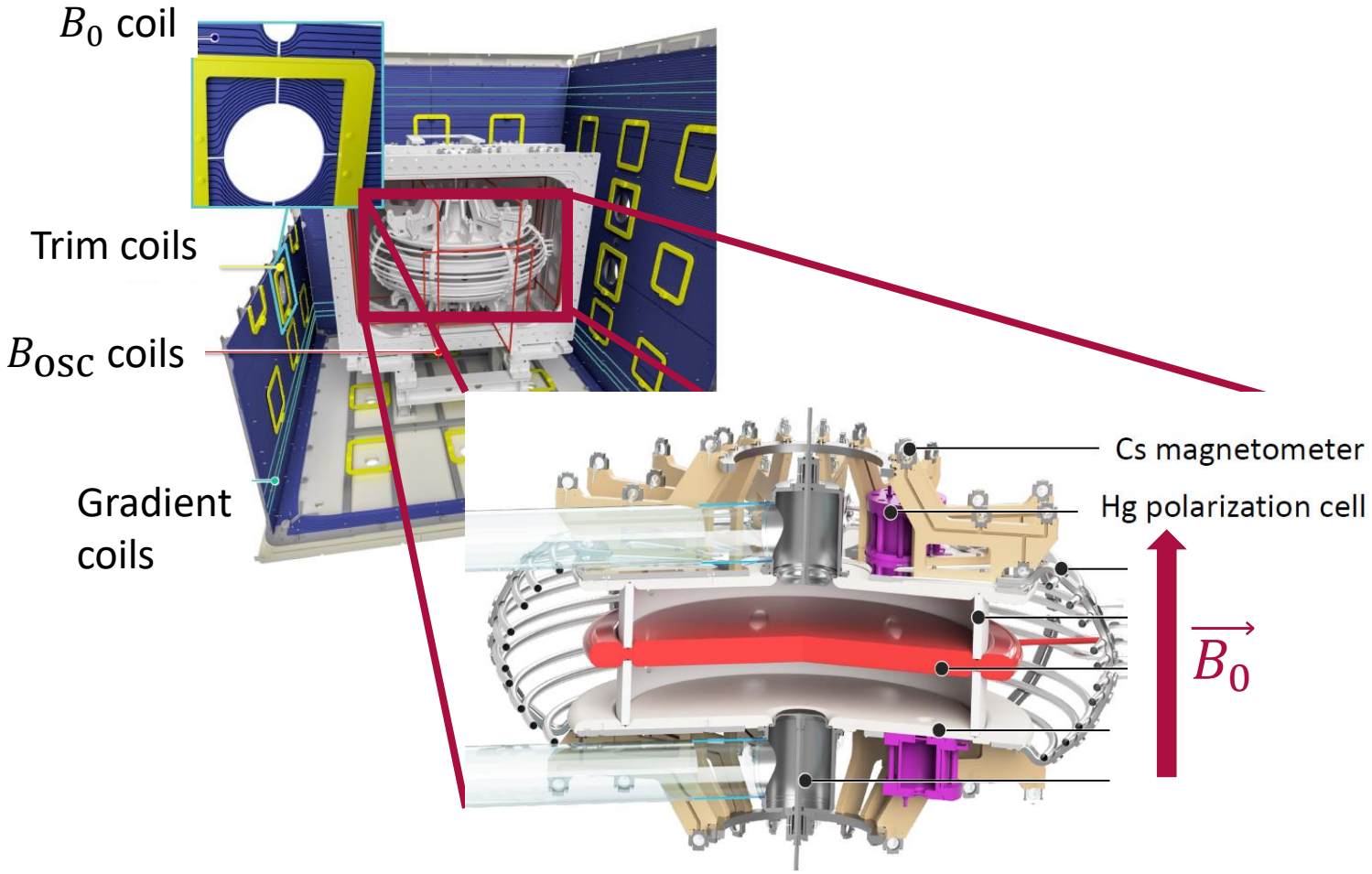
- Spin dependent neutron detection



- 2 Detectors per chamber
  1. Spin Up
  2. Spin Down
- Gaseous detector
- Capture neutrons:
  $\mathrm{n} + {}^{3}\mathrm{He} \rightarrow \mathrm{p} + {}^{3}_{0}\mathrm{H}$
- Scintillation in CF_4

Magnetic field @ n2EDM

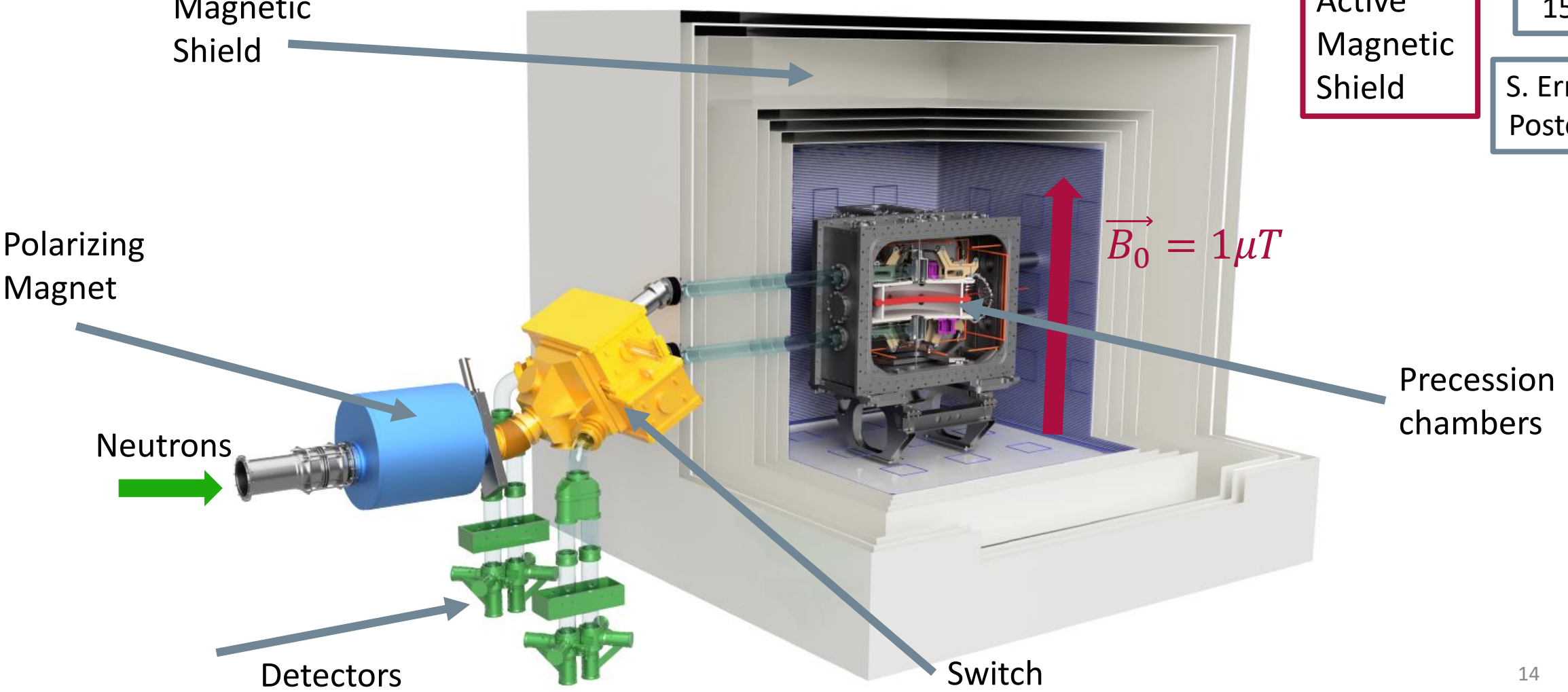
- Precisely known and controlled magnetic fields



- Passive magnetic shield
- Active magnetic shield
- B_0 coil + 56 trim coils
- 2 Magnetometry systems
  1. Hg co-magnetometer
  2. Cs array

W. Chen 14:45

The n2EDM experiment



Active Magnetic Shield

N. Ziehl 15:15

S. Ermakov Poster 733

Exciting times!

Exciting times!

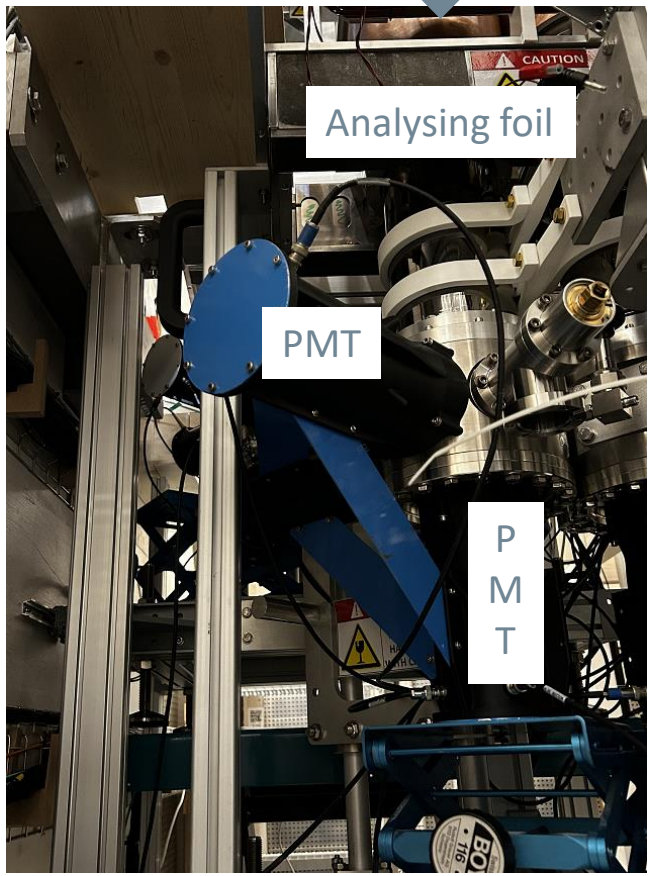
Top Detector 1

Top Detector 2

Exciting times!

Top Detector 1

Top Detector 2



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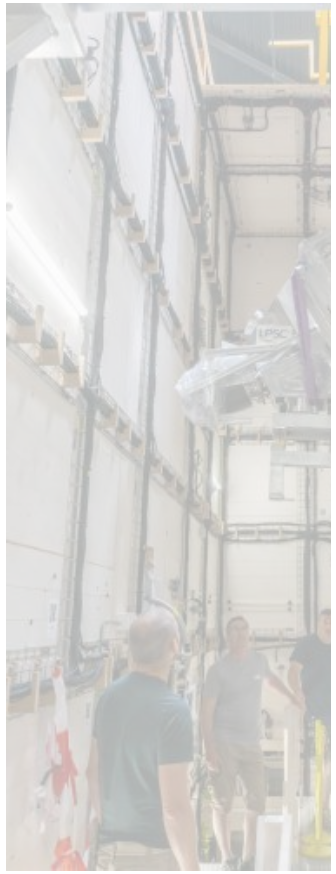
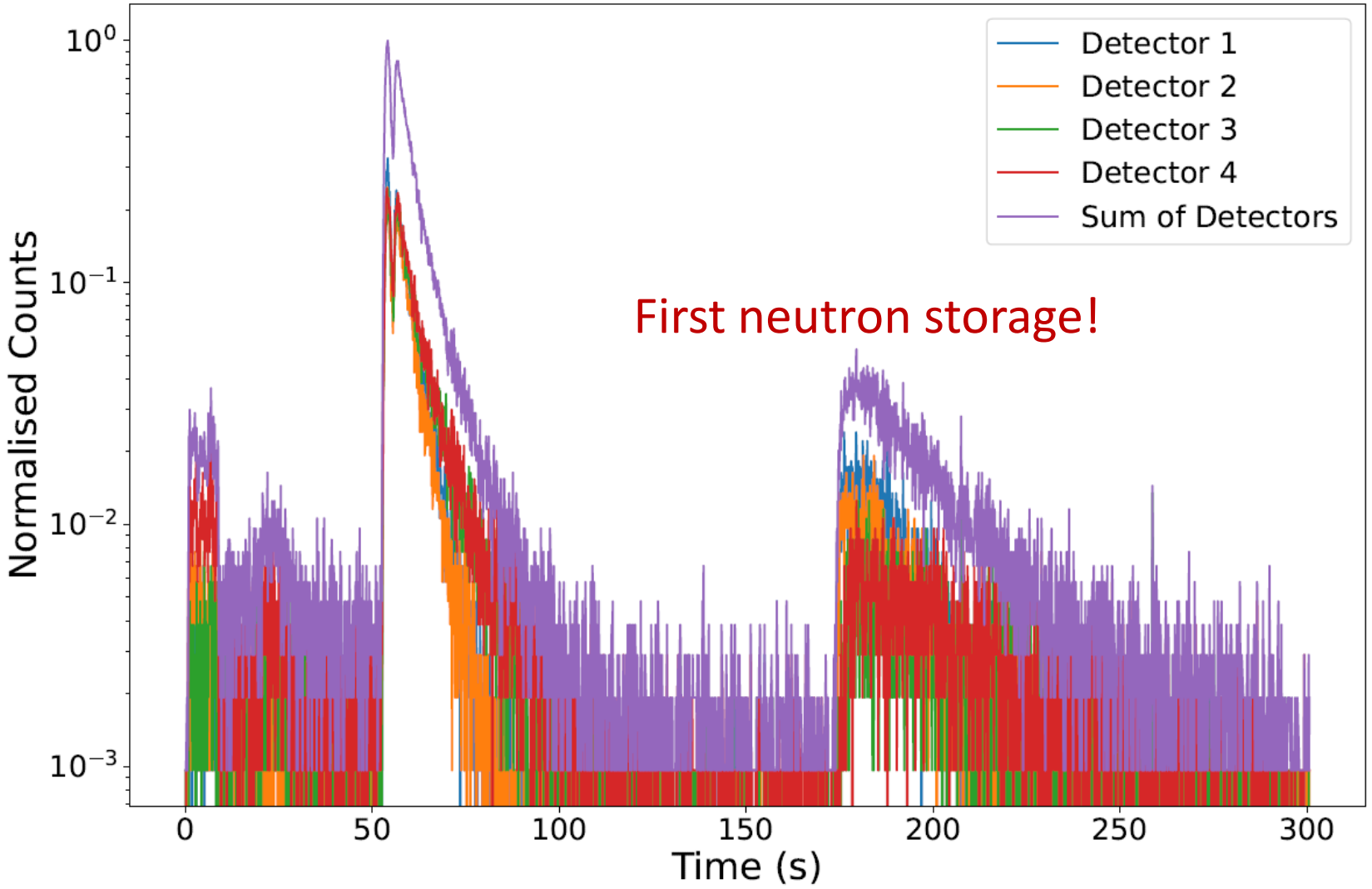
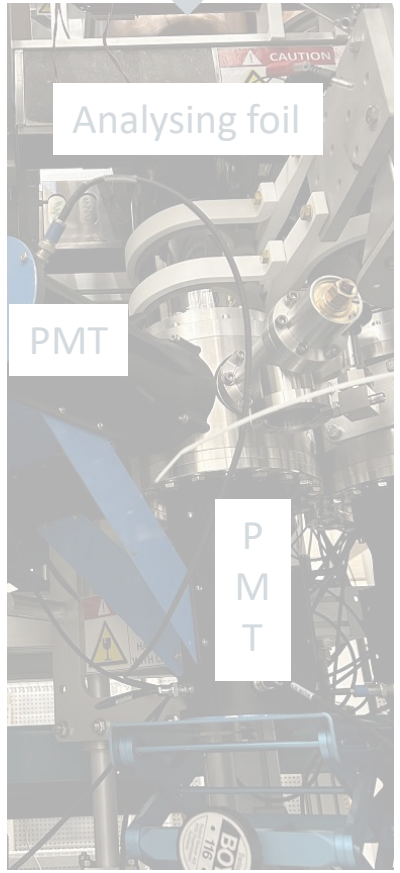
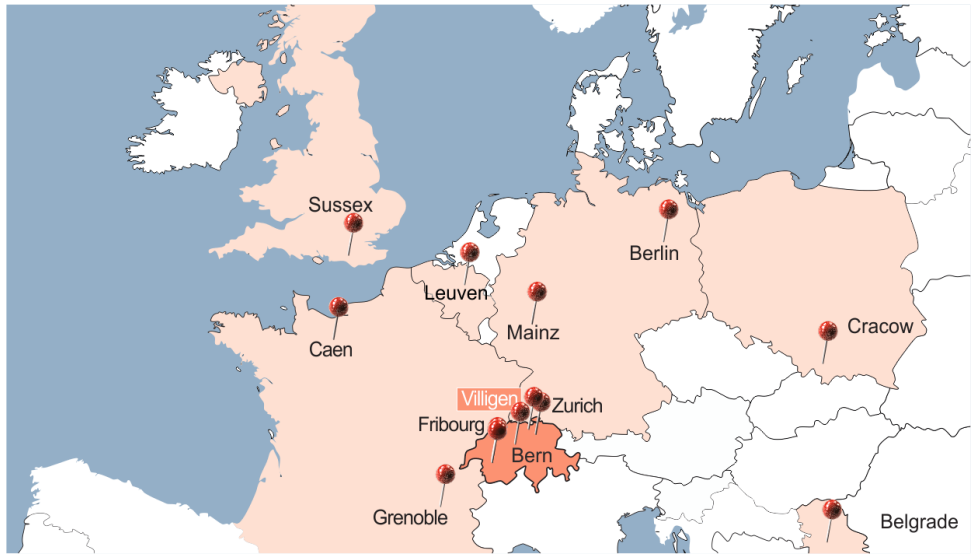






Thank you for your attention!

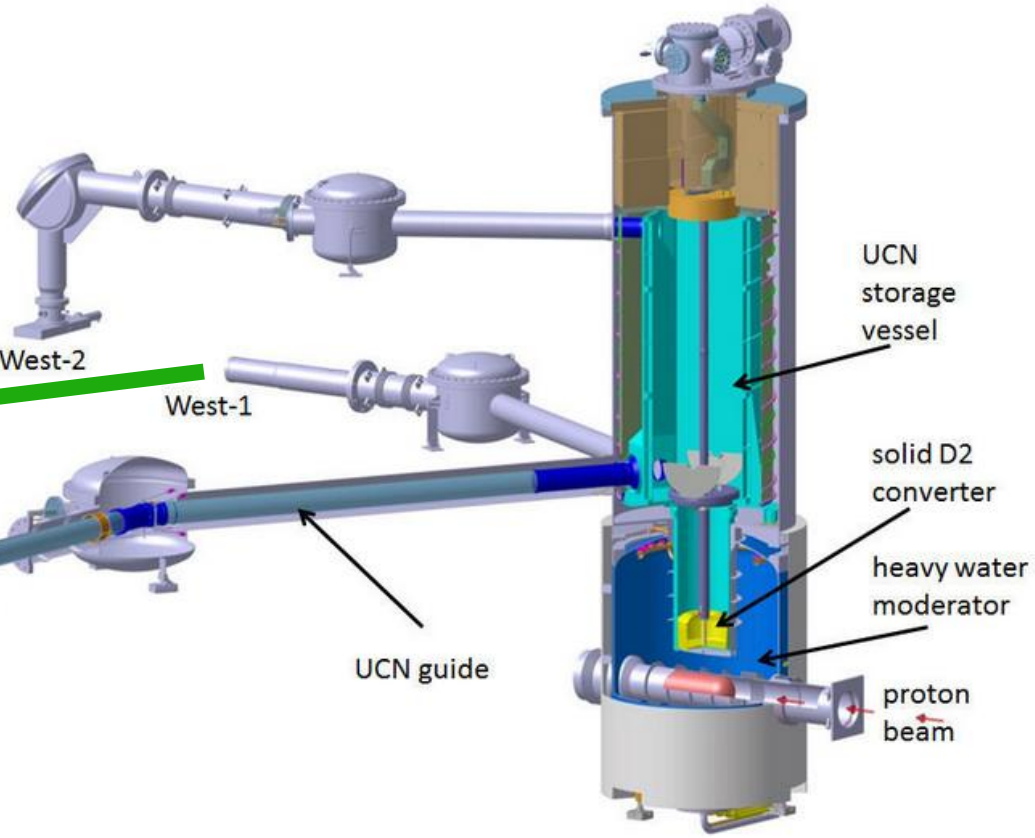


Additional Material

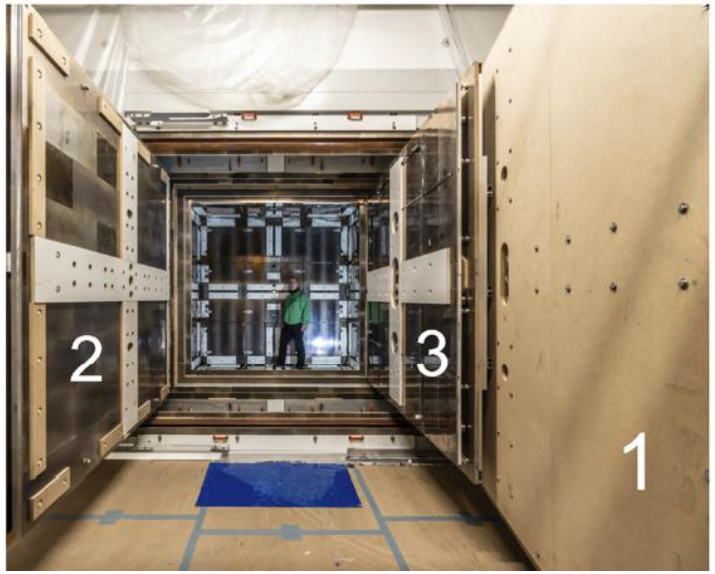
The UCN source @ PSI

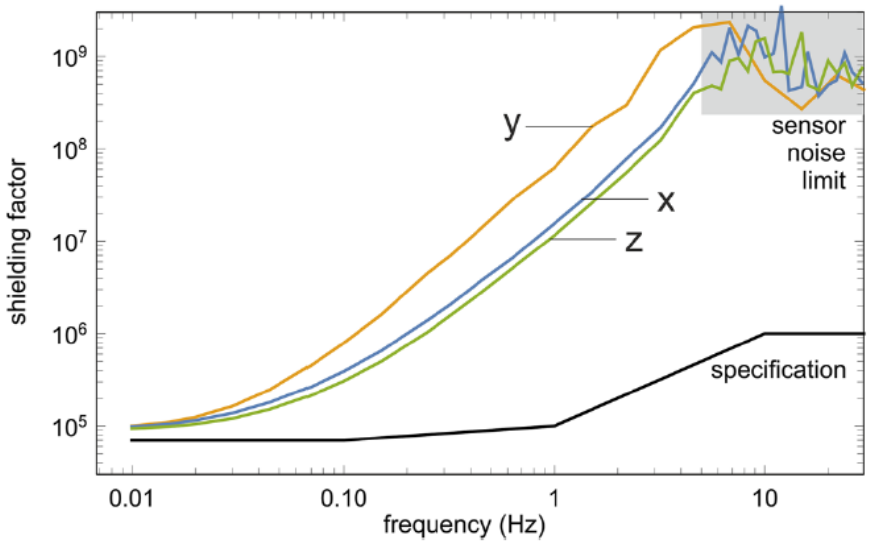
τSPECT
Dieter A. Ries 15:30

n2EDM
Cornelis Doorenbos 15:00



Magnetically shielded room





Systematic effects

- We actually look at a ratio of frequencies!

$$\mathcal{R} = \frac{f_n}{f_{Hg}} = \left|\frac{\gamma_n}{\gamma_{Hg}}\right| (1 + \delta_{elec} + \delta_{mag} + \delta_{other})$$

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$\delta_{EDM}^{true} + \delta_{EDM}^{false} + \delta_{quadratic}$

$\delta_{grav} + \delta_T$

False EDM effect

- Special relativity gives a motional magnetic field for particles moving in an electric field :

$$\vec{B}_m = \vec{E} \times \frac{\vec{v}}{c^2}$$

- If $\vec{B}_0 \neq$ uniform → d^{false} for neutrons and Hg comagnetometer

- d^{false} for neutrons and Hg are not the same due to different velocities and precession frequencies!

- This leads to Hg induced false nEDM [3]:

$$d^{false}_{n \leftarrow Hg} = -\left|\frac{\gamma_n}{\gamma_{Hg}}\right| d^{false}_{Hg}$$

- Gradient fields can be monitored and corrected, except if localized (e.g. dipole contaminations)!

Gravitational shift

- Systematic effects due to magnetic field non-uniformities:

$$\delta_{mag} = \delta_{grav} + \delta_T$$

- δ_{grav} (*gravitational shift)*: Mercury and neutrons do not sample the same volume

- δ_T *(transverse shift)*: residual magnetic fields → fluctuating magnetic field for moving particles
  - ➢Intrinsic depolarization
  - ➢Shift in Larmor frequency