

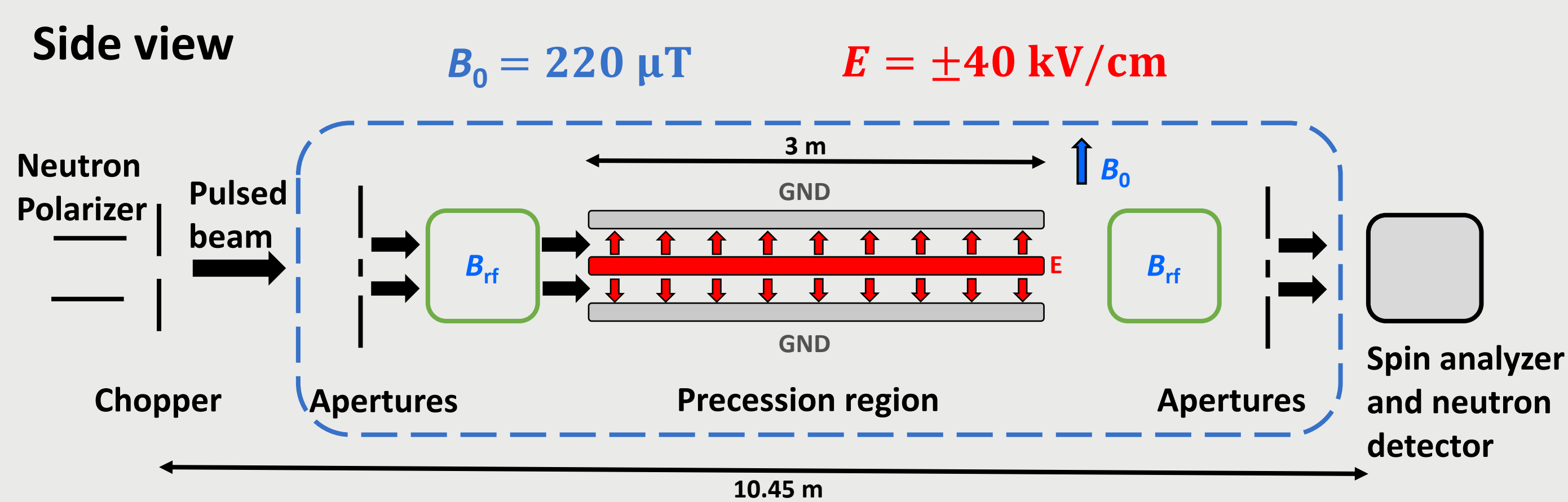
A beam experiment to search for the neutron electric dipole moment

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Abstract

The neutron Electric Dipole Moment (EDM) has attracted interest as a promising channel for finding new physics for a long time. The **Beam EDM** experiment aims to measure the neutron EDM using the time-of-flight technique with a pulsed cold neutron beam which allows to distinguish between time dependent and time independent effects such as the EDM. Thanks to this, it is possible to overcome the previous systematic limitation of neutron beam experiments, the relativistic effect. The results from the data taking campaign with a proof-of-principle apparatus at the Institut Laue-Langevin are presented.

Schematics of the experiment



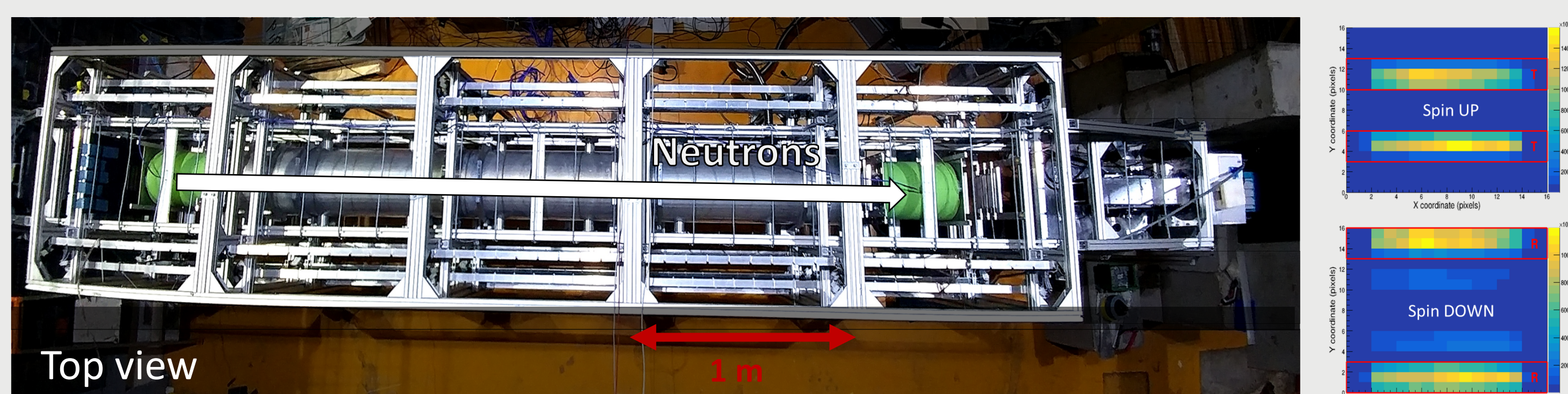
$$\text{Spin precession frequency: } \omega_n = \gamma_n B_0 + \gamma_n \frac{v E \sin \alpha}{c^2} \pm \frac{2d_n}{\hbar} E$$

$$\text{Acquired phase: } \phi_n = \omega_n t \longrightarrow \Delta\phi_n = (\omega_n^{\uparrow} - \omega_n^{\downarrow}) \cdot t \propto d_n E$$

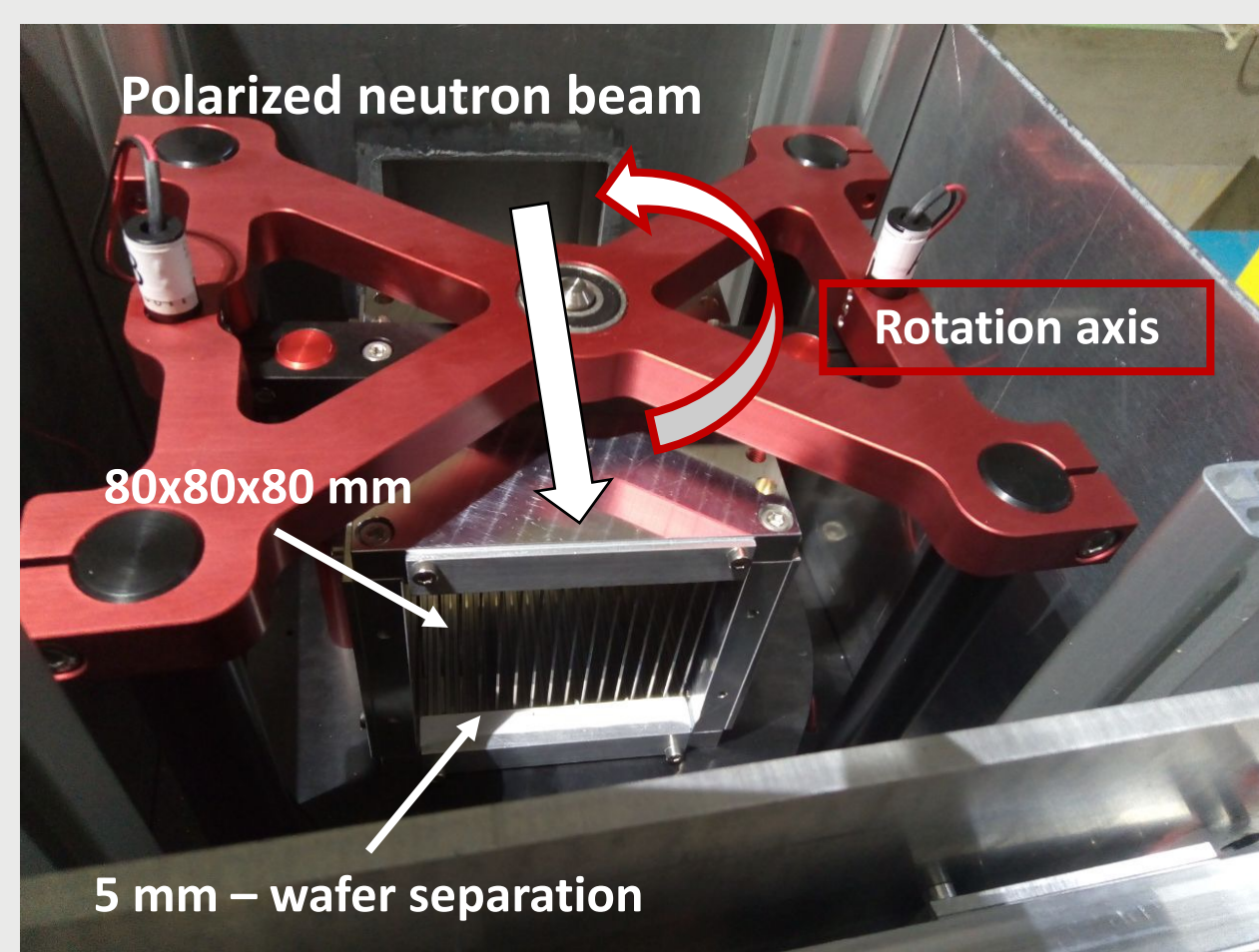
Experiment at PF1b (ILL)

- Combination of the Ramsey's **separated oscillatory field method** and the **time-of-flight technique** applied to a polarized cold neutron beam.
- Two beam method allows simultaneous measurement of both electric field configurations $B_0 \uparrow E \uparrow$ and $B_0 \uparrow E \downarrow$
- Extract Asymmetry for each beam by means of the spin analyzer and pixel detector :

$$\text{Asymmetry} = \frac{N^T - N^R}{N^T + N^R}$$



Apparatus details

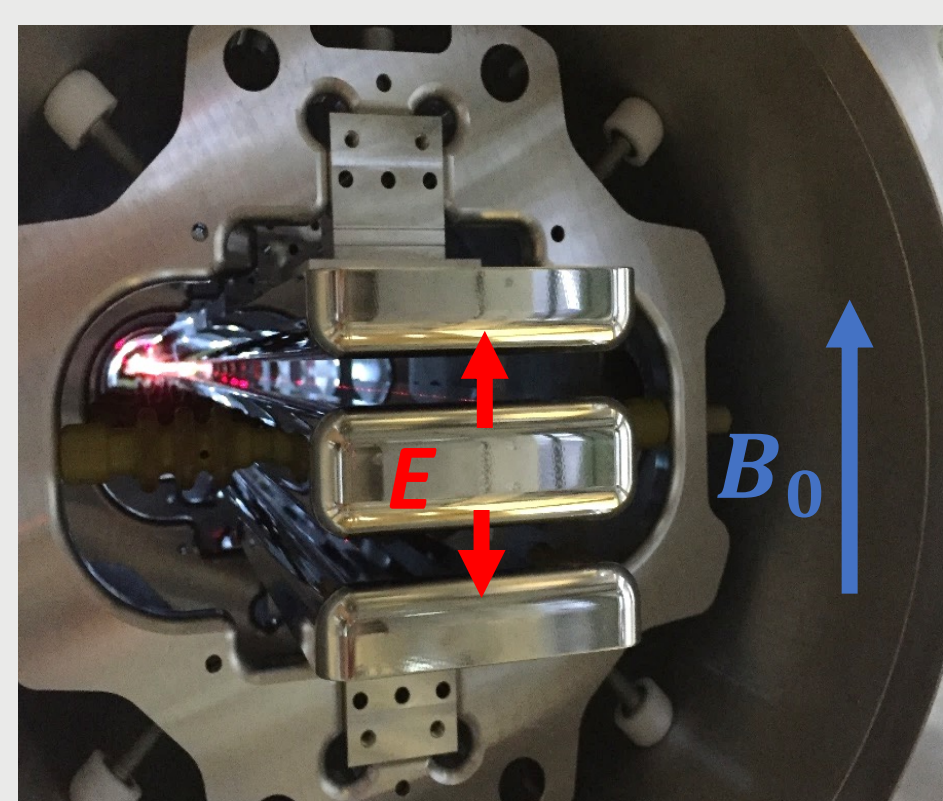


Chopper:

- Fermi chopper with Soller-slit type collimator
- 40 Si-wafers with sputtered Gd-Ti
- Rotation frequency 9.5 Hz
- Duty cycle 1.2%
- Adjustable apertures at the beam entrance/exit

Electrodes:

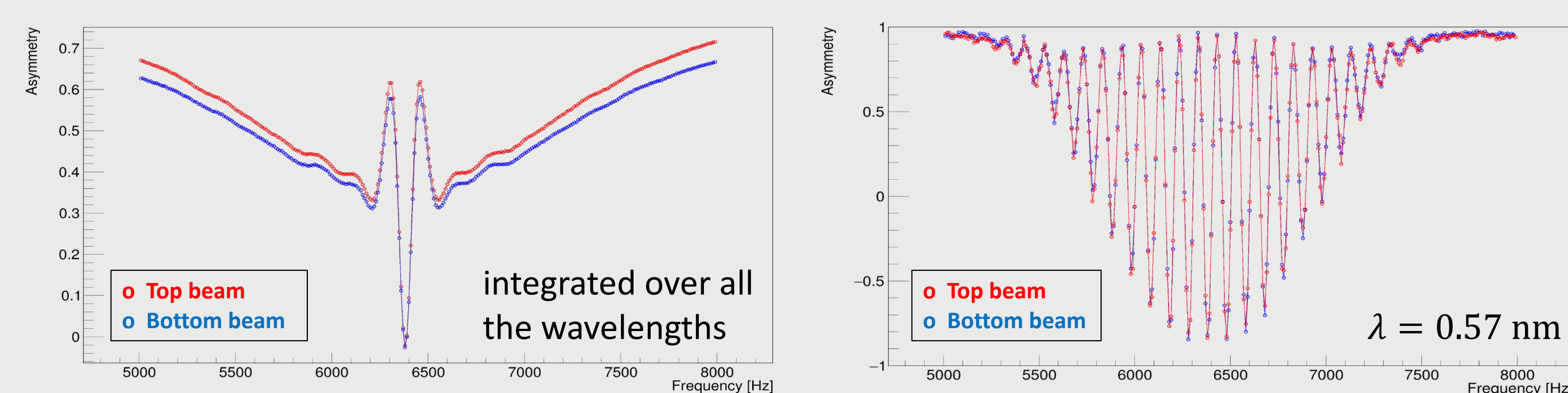
- Two ground electrodes and one HV electrode made of aluminum
- Three stacks 1 m long each connected with brass pins
- 1 cm separation between HV and ground electrodes



Classic Ramsey technique

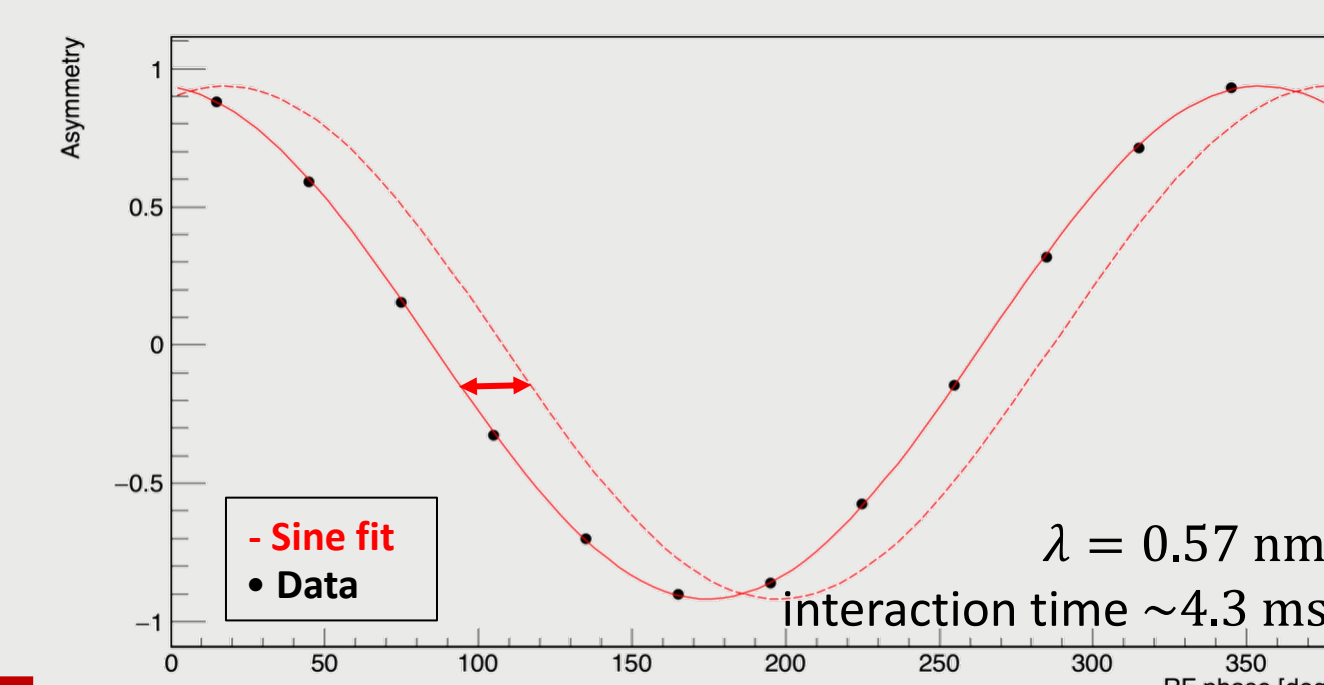
The Ramsey technique is applied using a pulsed beam of cold neutrons. The measurement is performed with a simultaneous scan of the two B_{rf} magnetic oscillating fields frequency. The same resonance is obtained for both beams: **6380 Hz** at $B_0 = 220 \mu\text{T}$.

The plot on the left shows the Ramsey pattern for a white beam, while the plot on the right shows the same pattern for one single wavelength of the time-of-flight spectrum.

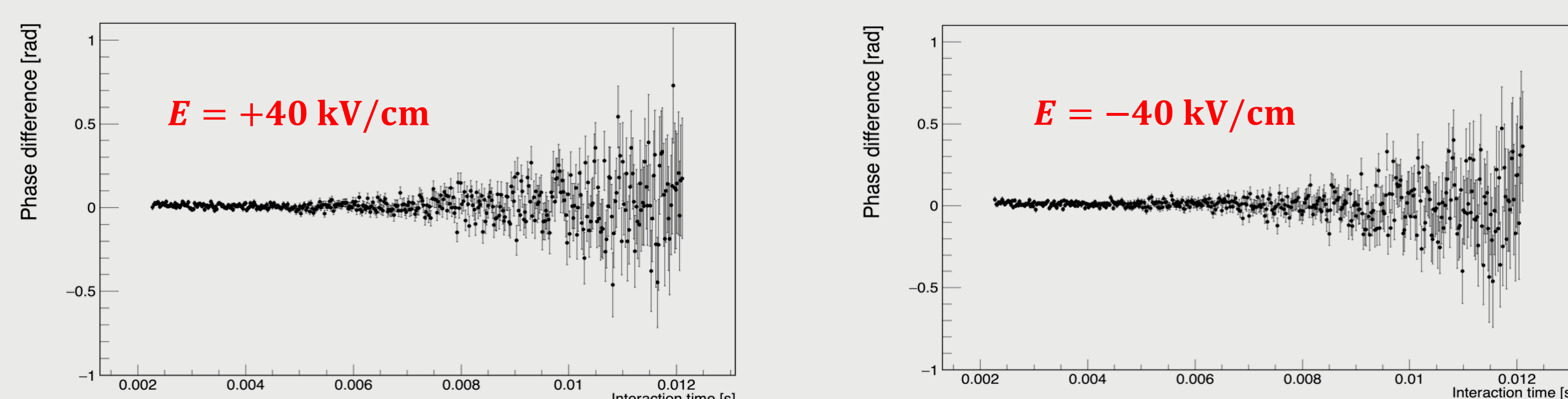


EDM measurement

A phase measurement is performed by changing the relative phase between the two RF signals. The Asymmetry is then calculated for each phase and with a sinusoidal fit the phase is extracted for each wavelength and for both beams. A non-zero EDM would induce a phase shift when an electric field is applied.

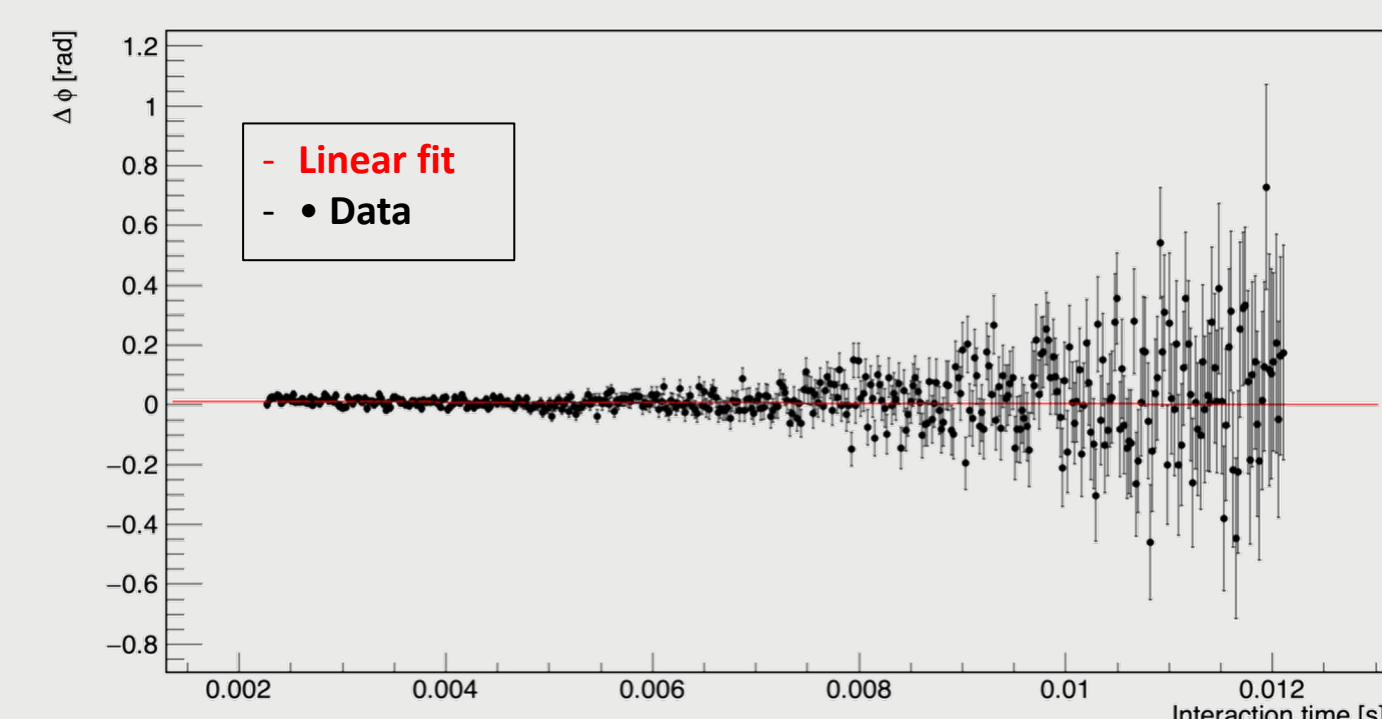


The **phase difference TOP-BOTTOM** is calculated for each measurement and opposite electric field polarities are applied $E = \pm 40 \text{ kV/cm}$



Phase difference between two measurements and linear fit:

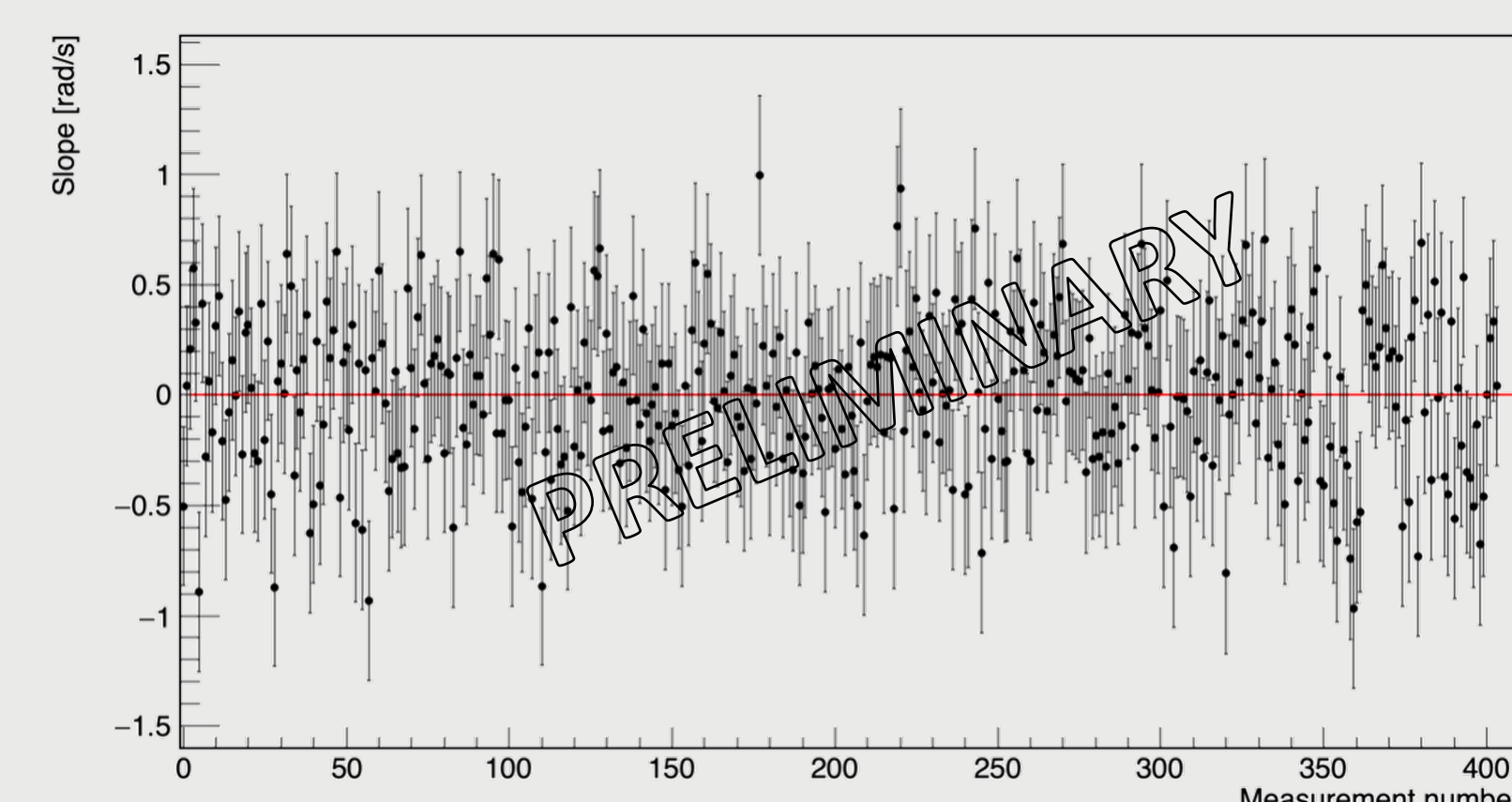
$$\Delta\phi = m \cdot t + 4\gamma_n \frac{E \sin \alpha}{c^2} \text{ where } m \propto d_n \cdot E$$



EDM result and conclusions

- Performed 24h EDM measurement
- Mean slope: $m = (0.022 \pm 0.018) \frac{\text{rad}}{\text{s}}$
- Extract neutron EDM uncertainty:

$$\sigma(d_n) \sim 4 \cdot 10^{-23} e \cdot \text{cm}$$



- First EDM measurement and result with the **Beam EDM** proof-of-principle apparatus
- Perform McStas simulations for the final experiment intended for the European Spallation Source