A novel Neutron EDM Search using a Pulsed Beam

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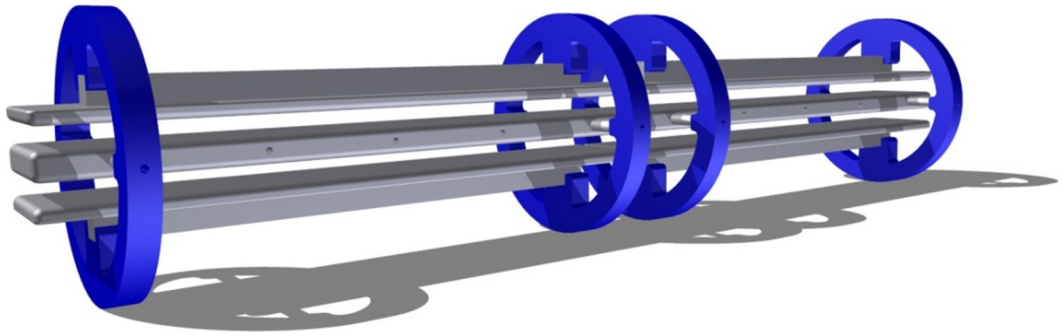
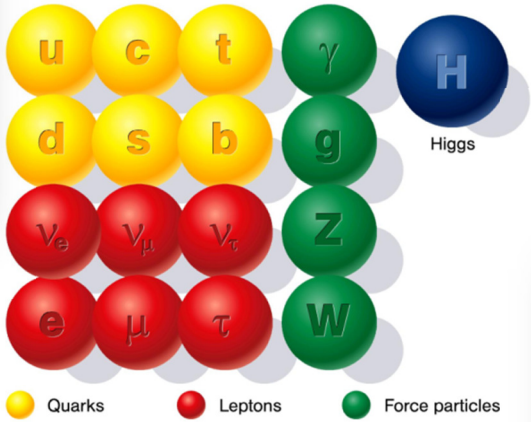
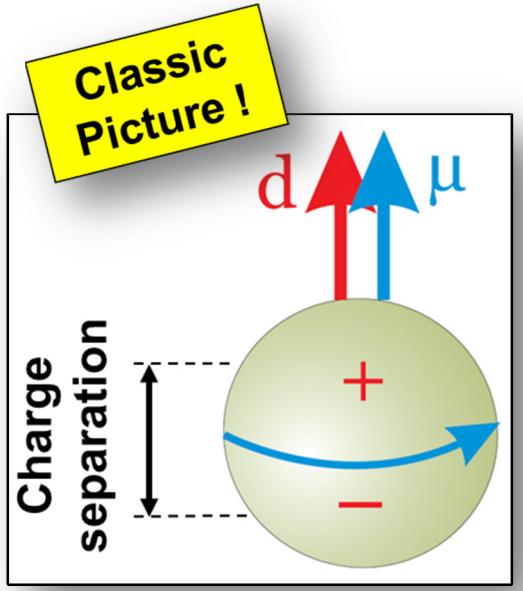


Matter-Antimatter asymmetry in our Universe

Symmetry violation*



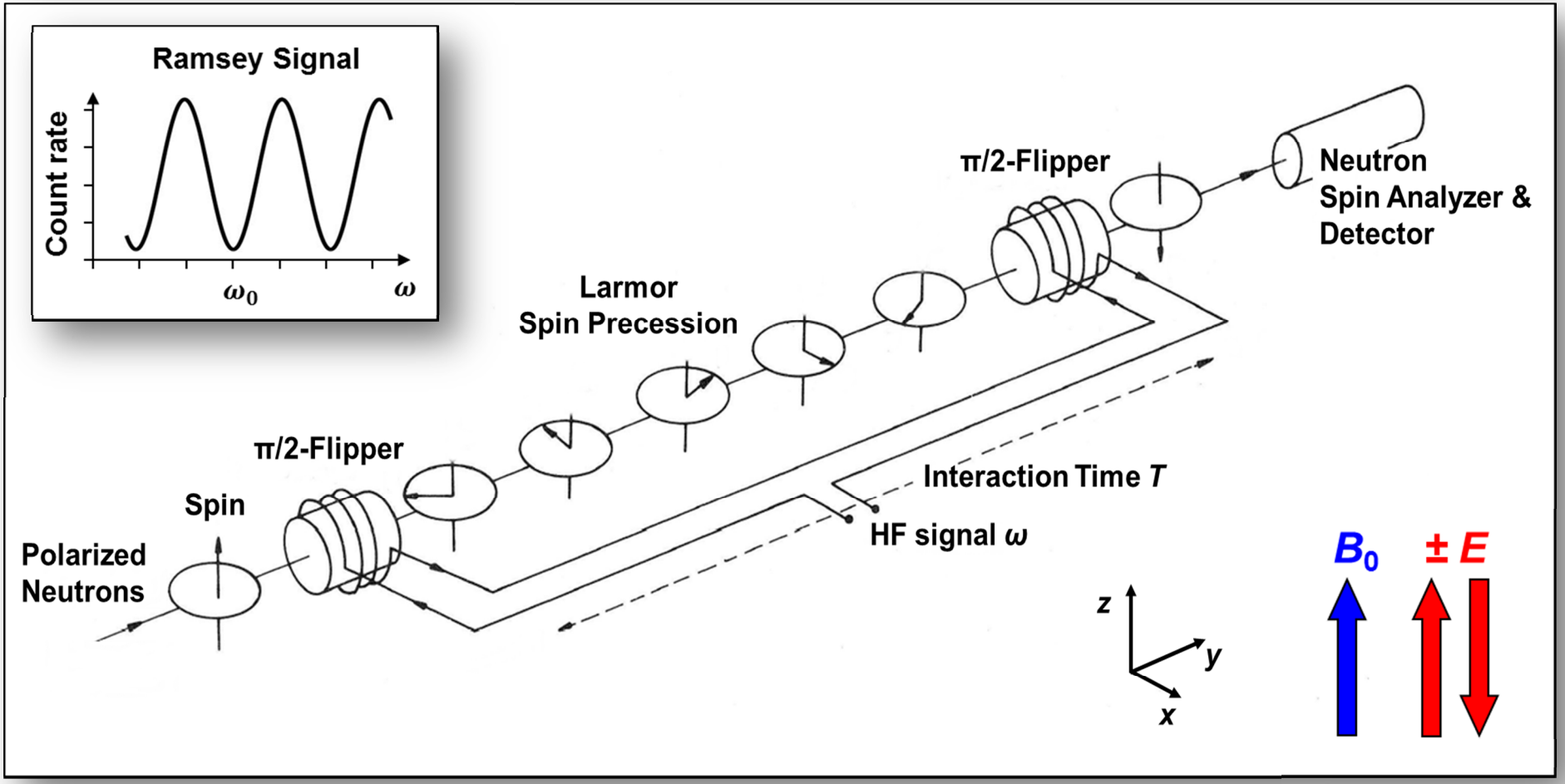
Beyond the SM of Particle Physics



Neutron as an ideal Tool

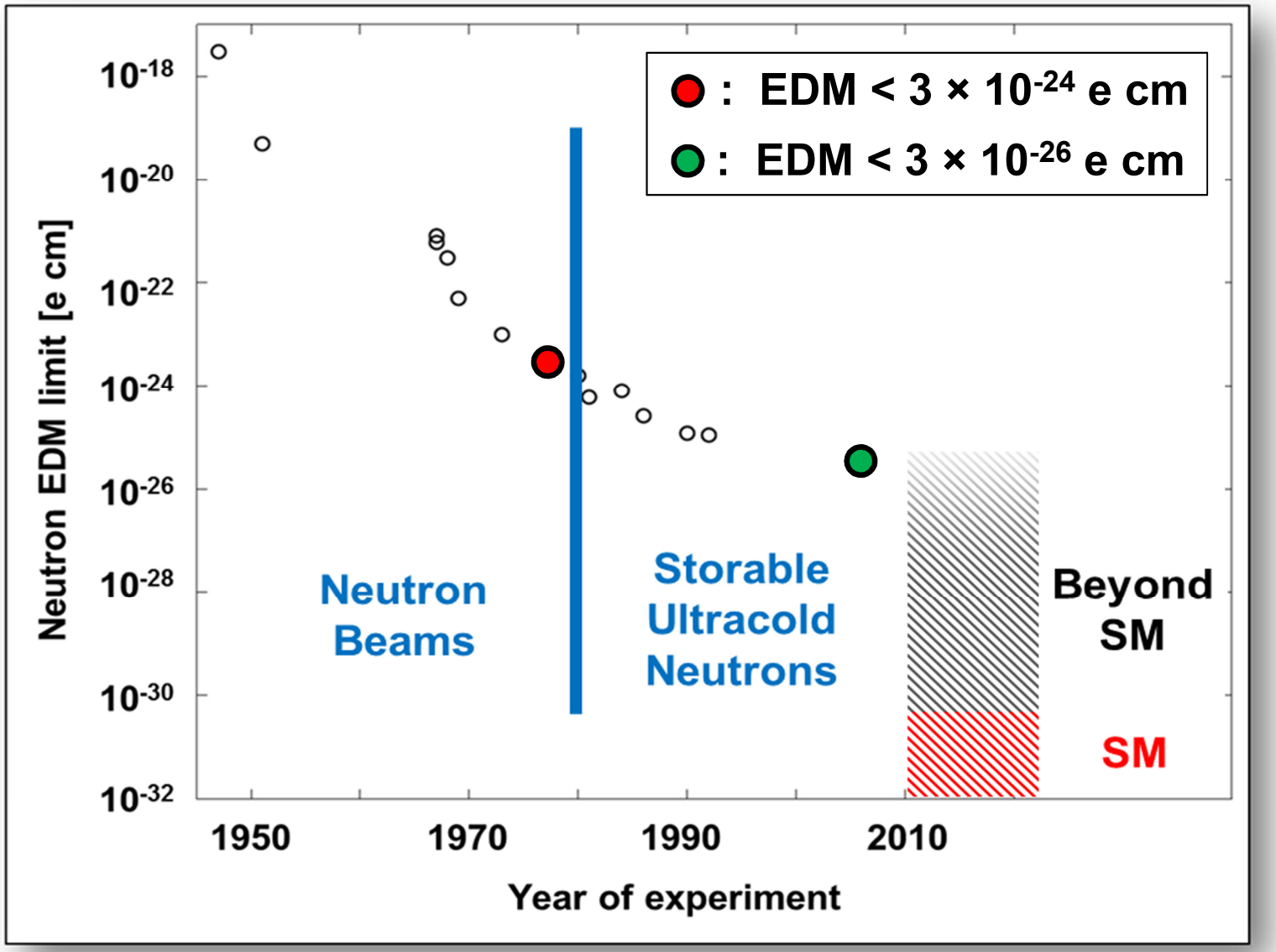
*** Sakharov, JETP Lett. 5, 24 (1967)**

Measurement Principle – Ramsey Technique



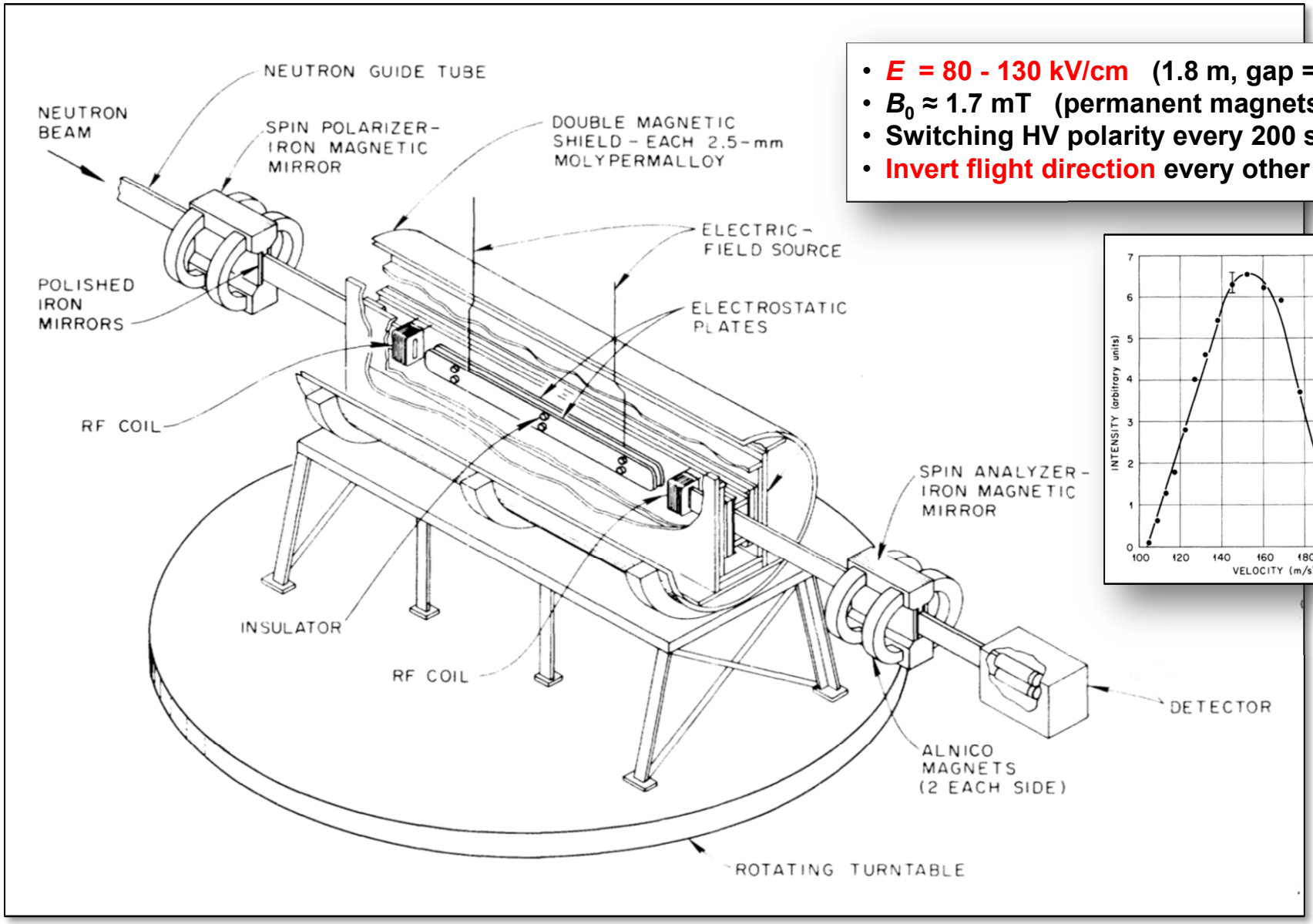
$$\Delta\varphi = (\omega_{\uparrow\uparrow} - \omega_{\uparrow\downarrow}) \cdot T \propto d \cdot E$$

Ramsey, PR 76, 996 (1949), PR 78, 695 (1950)



ALL NEW EXPERIMENTS USE ULTRACOLD NEUTRONS

Neutron EDM Beam Experiment (1977)



- E = 80 - 130 kV/cm (1.8 m, gap = 1 cm)
- $B_0 \approx 1.7$ mT (permanent magnets)
- Switching HV polarity every 200 s
- Invert flight direction every other day

Dress et al., PRD 15, 9 (1977)

Why were EDM Beam Experiments abandoned ?

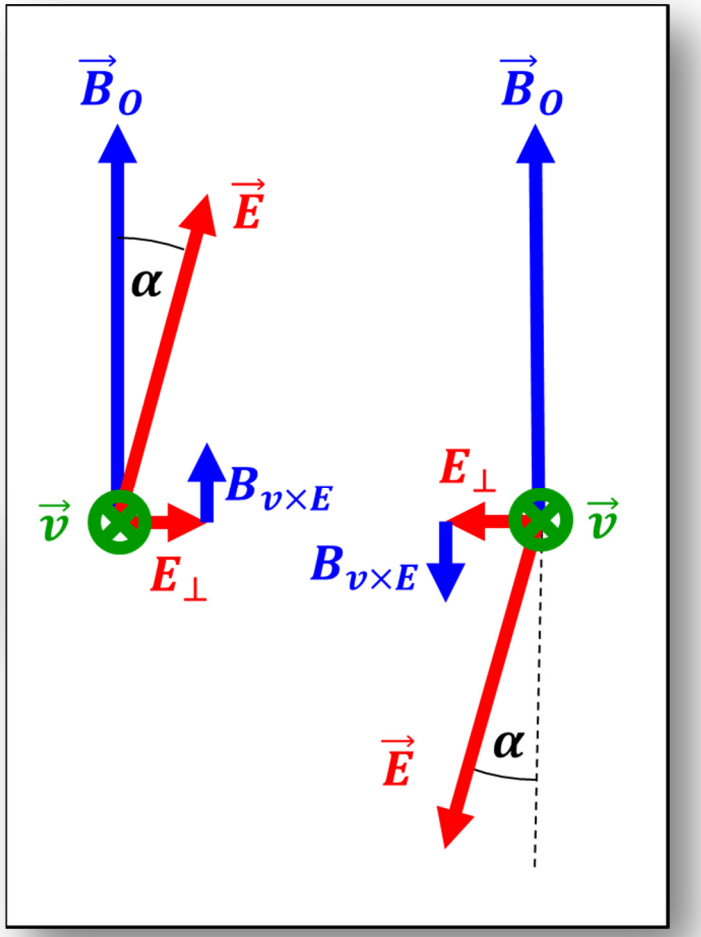
- **v×E – Effect:**

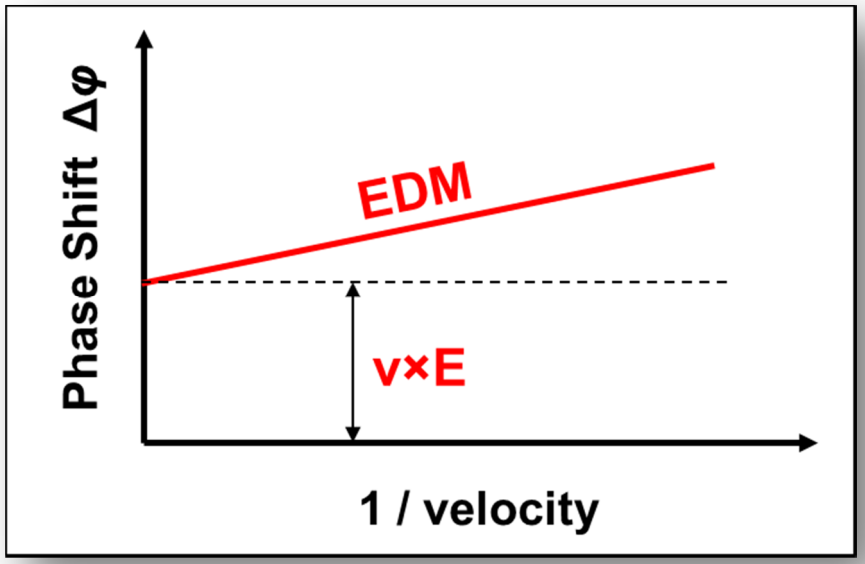
$$\vec{B}_{v\times E} = -\frac{\vec{v}\times\vec{E}}{c^2}$$

- **This can cause a false EDM signal:**

$$d_{\text{false}} \approx 10^{-20}\ \text{e cm} \cdot \sin\alpha \quad \text{for: } v = 100\ \text{m/s}$$

- **The false effect is velocity-dependent, however, the real EDM signal is not !**





Length of experiment

$$\Delta\varphi = \frac{8dE}{\hbar}T + \frac{4\gamma_n EL}{c^2}\sin\alpha$$

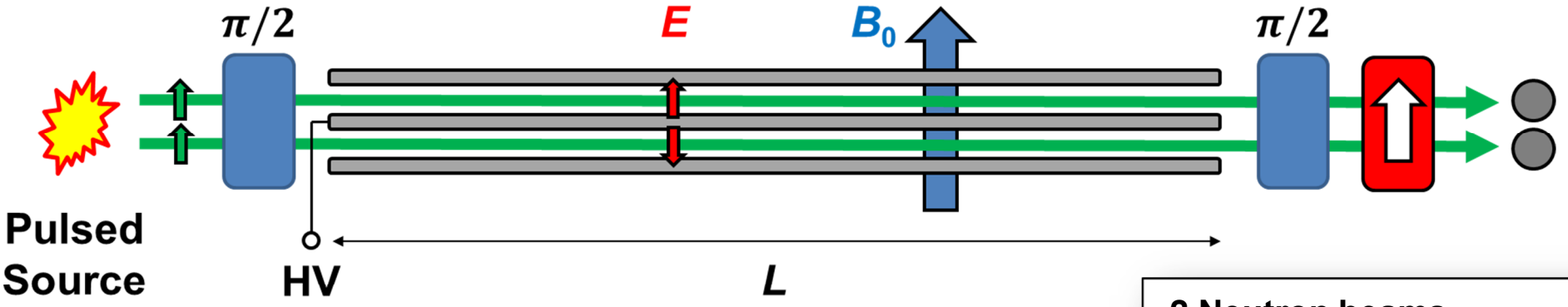
slope = EDM offset = v×E

Concept is ideal for pulsed neutron spallation sources
e.g. the European Spallation Source ESS

Start with proof-of-principle experiments
at Paul Scherrer Institute and Institute Laue-Langevin

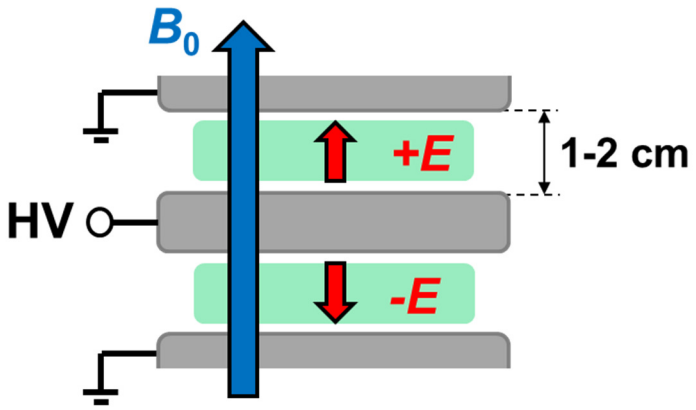
Piegsa, PRC 88, 045502 (2013)

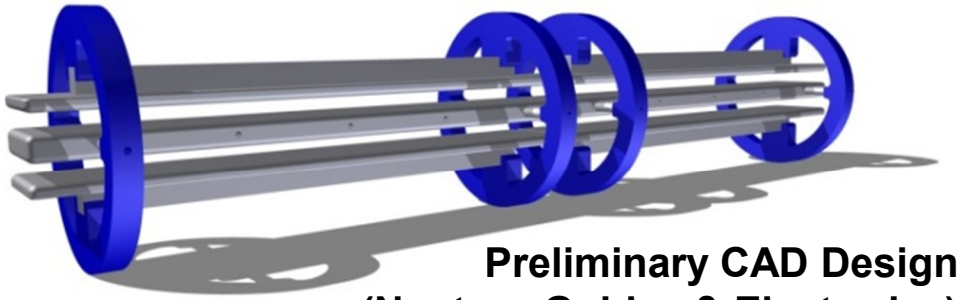
SIDE VIEW



2 Neutron beams
E > 50 kV/cm
B_0 = 200 µT
L = 5 m (proof-of-prin.)
L = 50 m (full-scale)

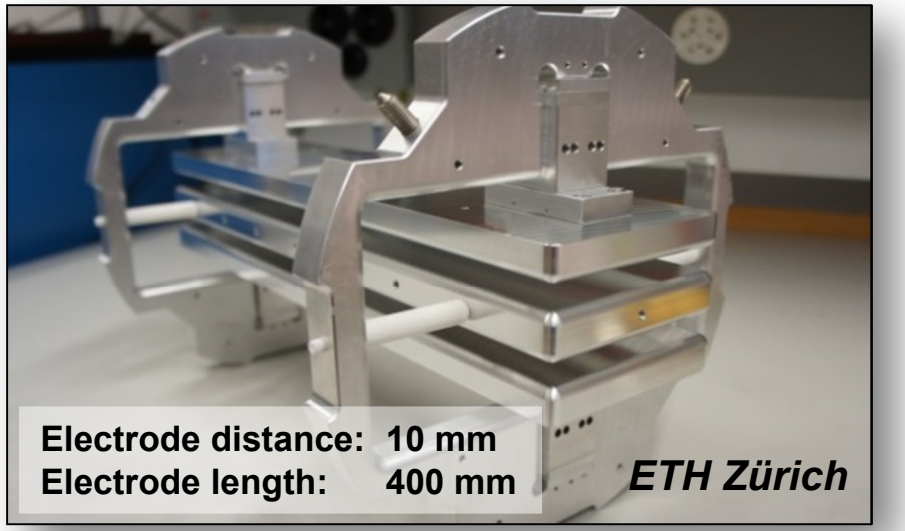
CROSS SECTION



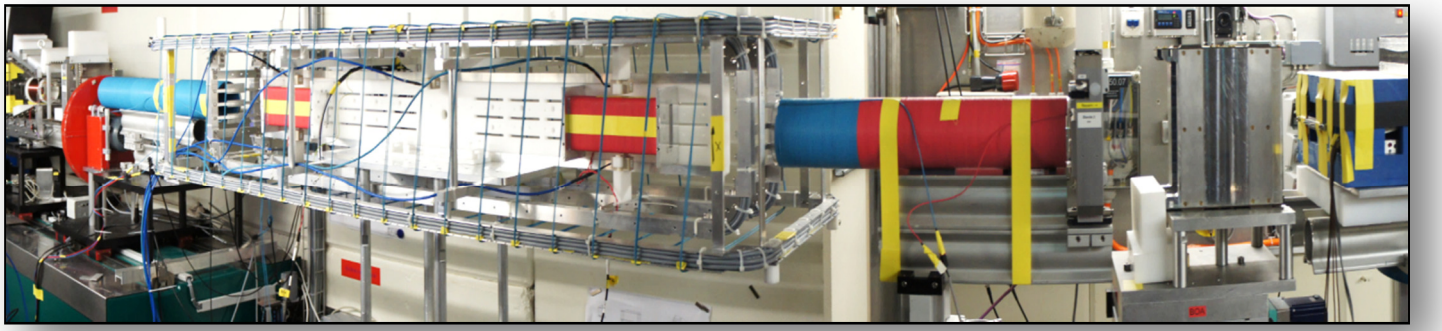


Preliminary CAD Design
(Neutron Guides & Electrodes)

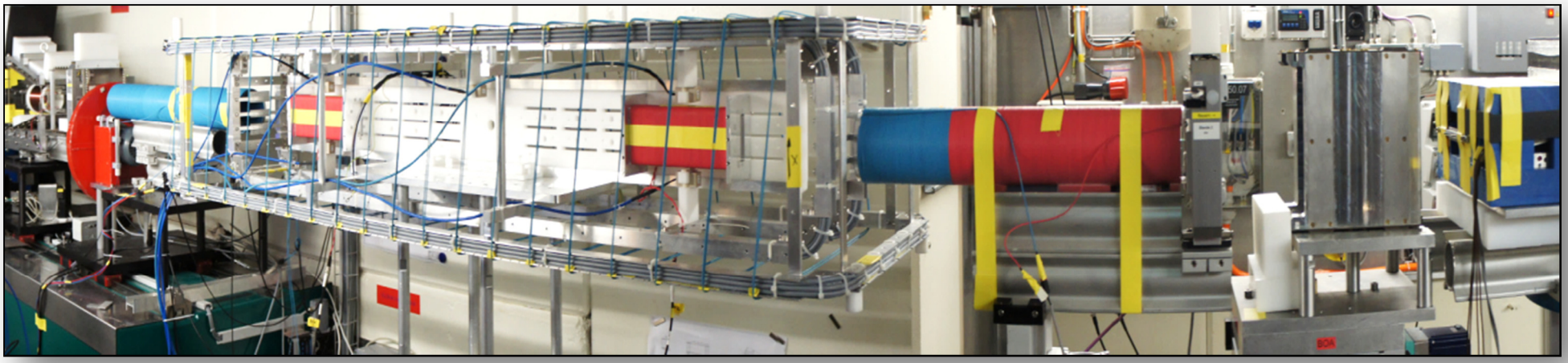
- **High-voltage electrode mock-up**
  - 1:1 scaled test system
  - Reached field of 50 kV/cm

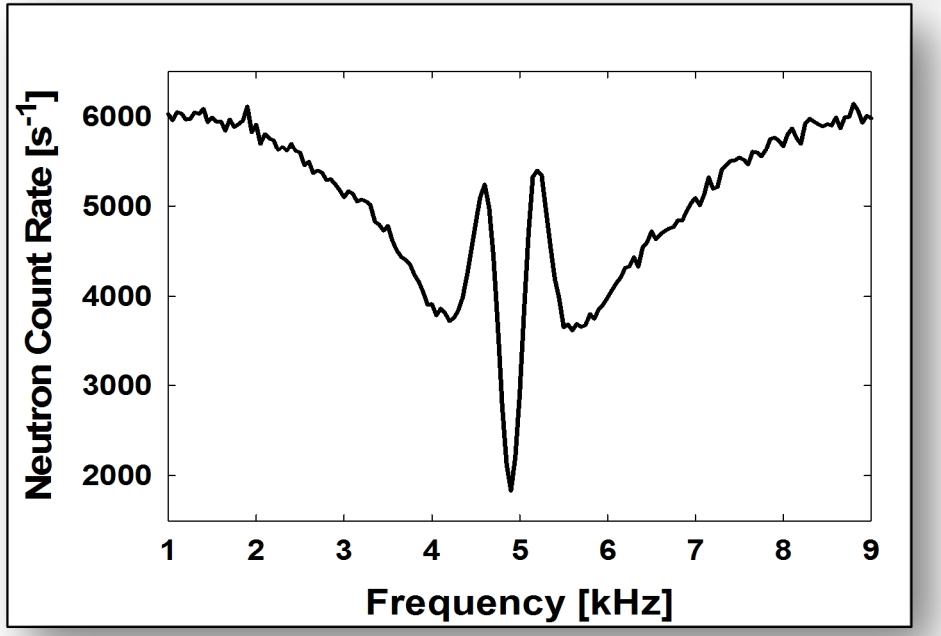


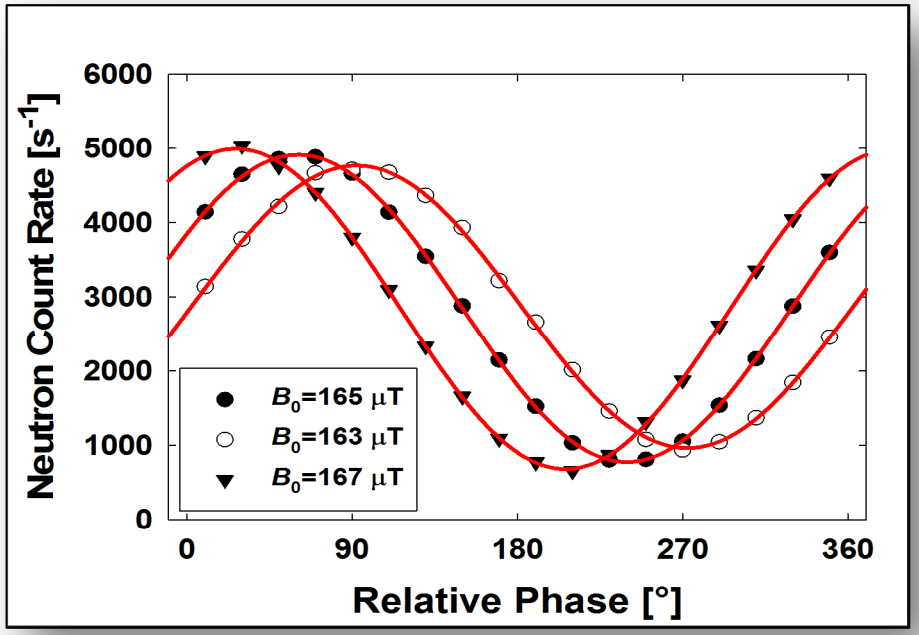
- **Successful beam time with prototype Ramsey apparatus in collaboration with Martin Fertl, Klaus Kirch and Jochen Krempel**



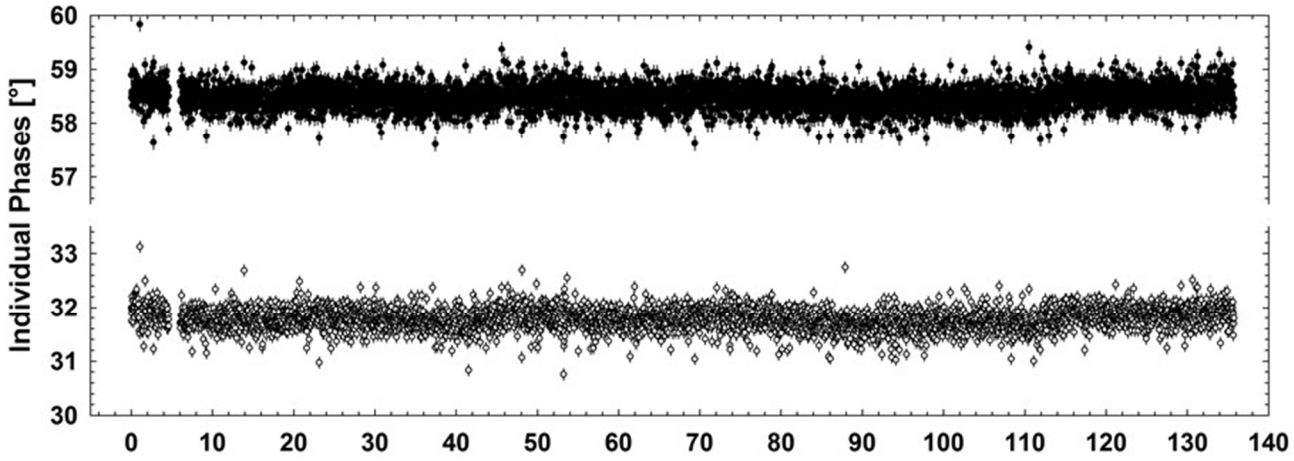
- **Beam time in December 2014 at PSI / SINQ**

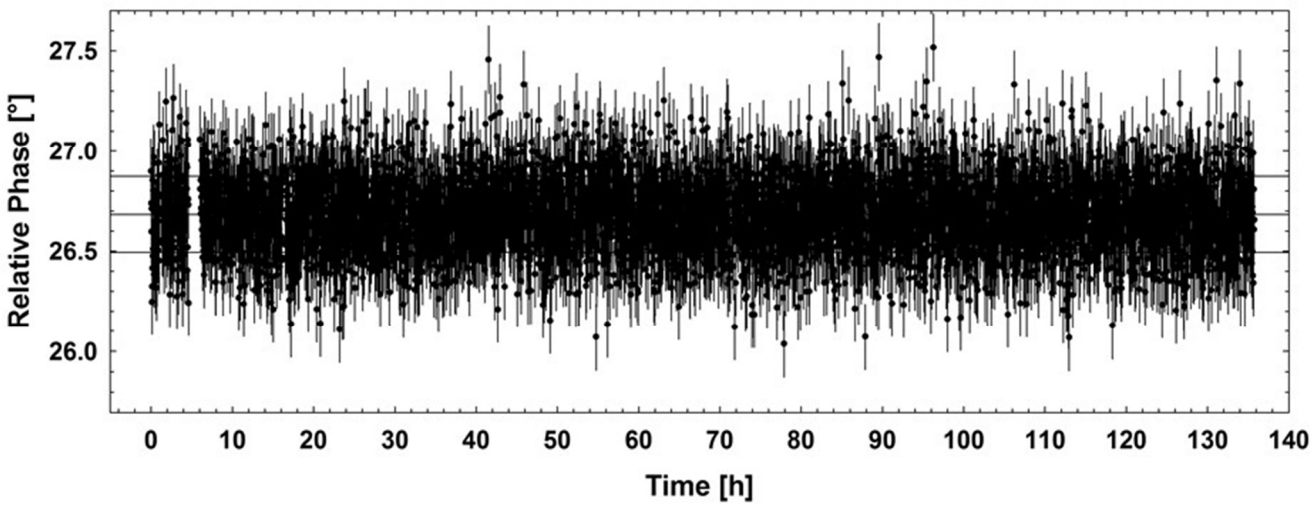




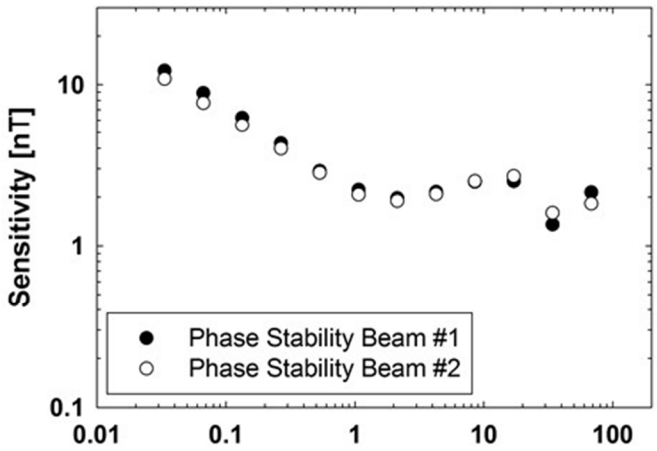


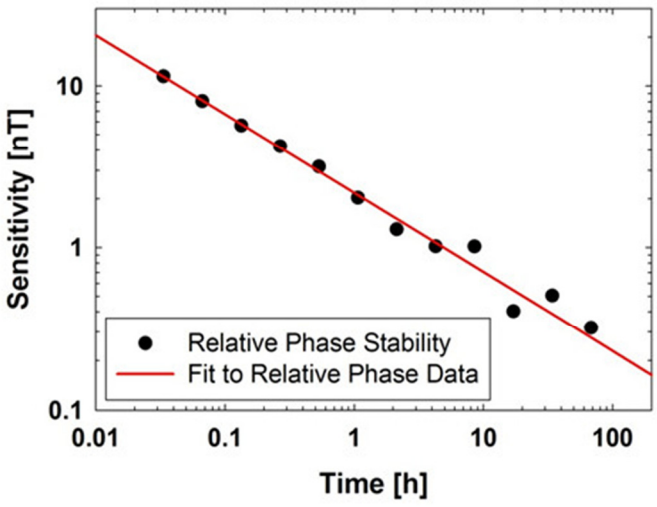
Stability and Sensitivity



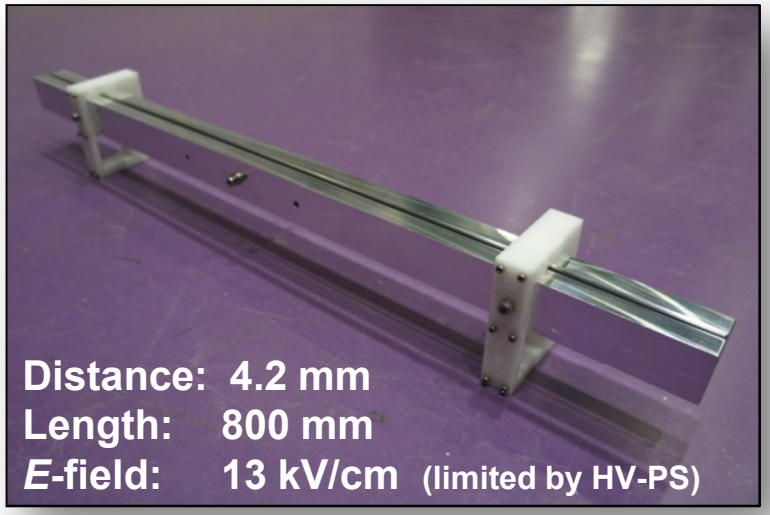


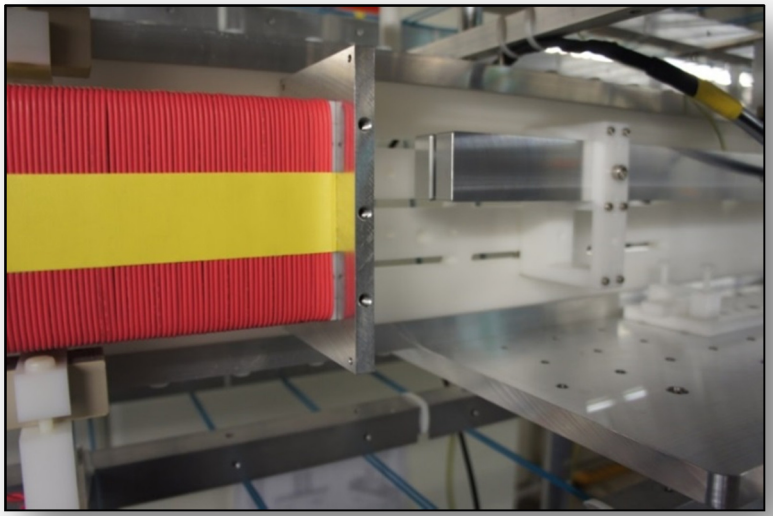
Allan Std Dev Plots



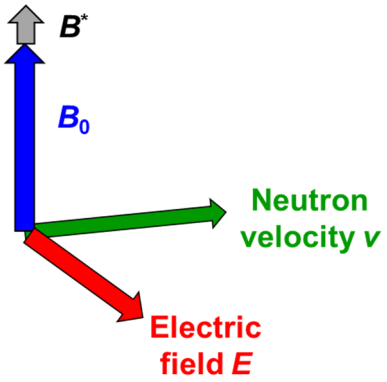


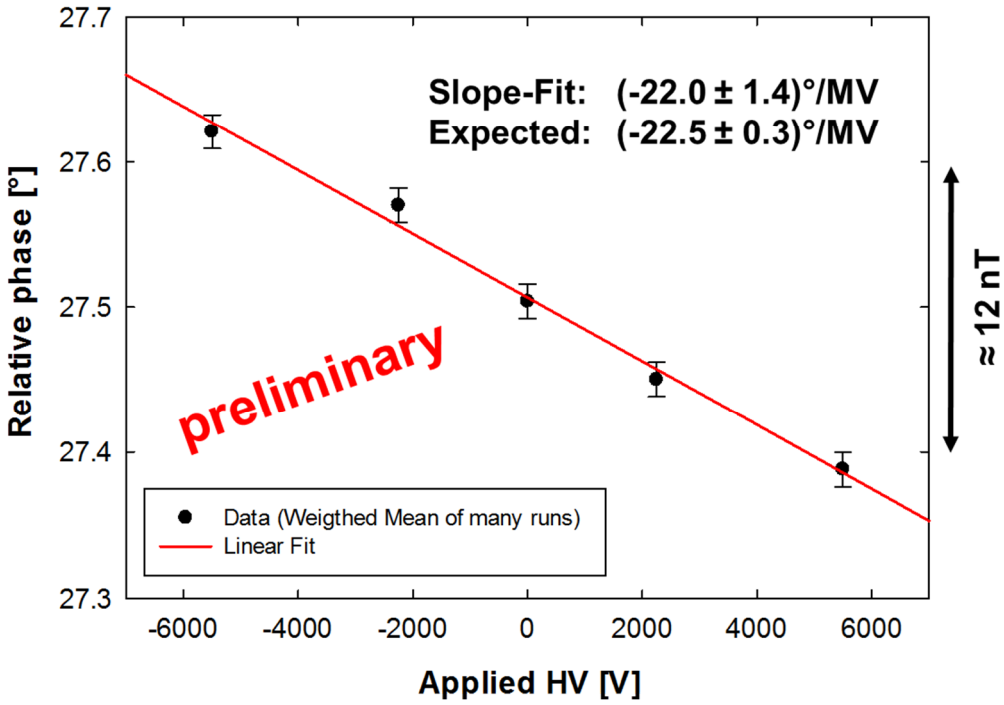
Direct measurement of v×E - Effect



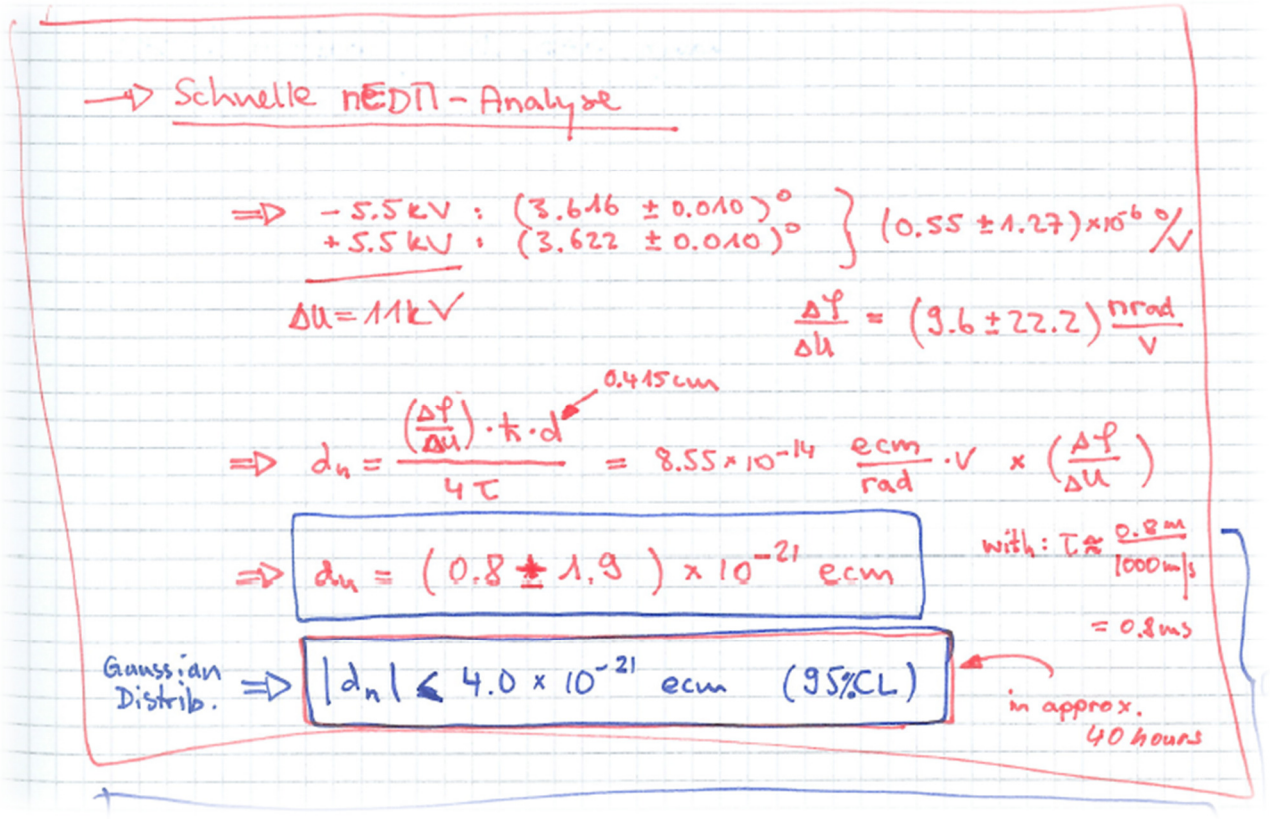


$$\vec{B}^* = -\frac{\vec{v} \times \vec{E}}{c^2}$$





- **Measure neutron EDM by turning B_0 parallel to E-field**



- **Expected statistical EDM sensitivities per day:**

Proof-of-principle at PSI/ILL (5 m)	**~ 10^{-23} e cm**
Full-scale at ESS (50 m)	**~ 10^{-25}..10^{-26} e cm**

- Novel concept of an independent and complementary neutron EDM search – ideal for ESS
- Performed a dedicated measurement of the v×E - Effect with a prototype Ramsey apparatus
- Next years: Realize proof-of-principle experiment and propose viable full-scale experiment

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