The Neutron Beam EDM Experiment

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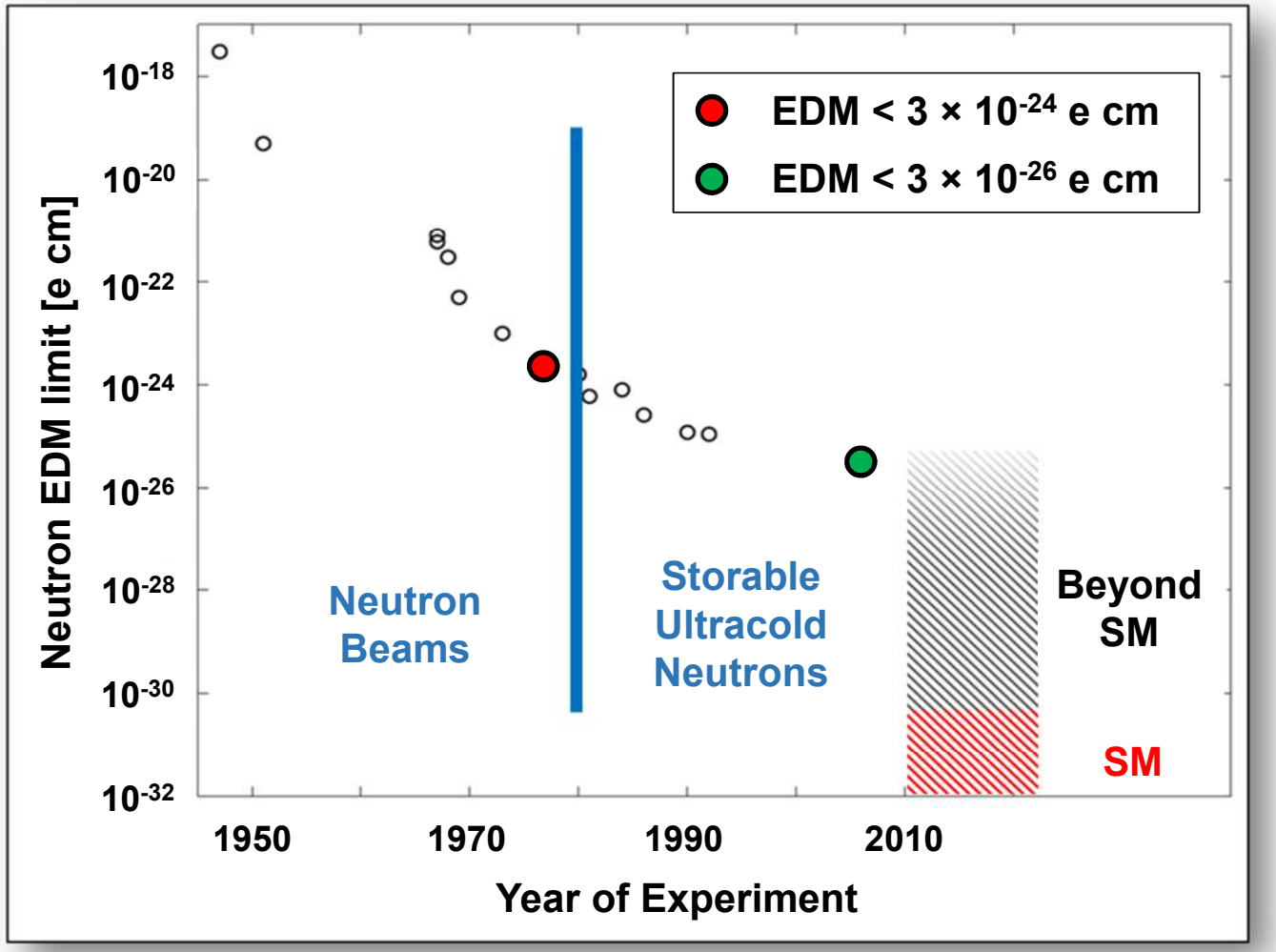
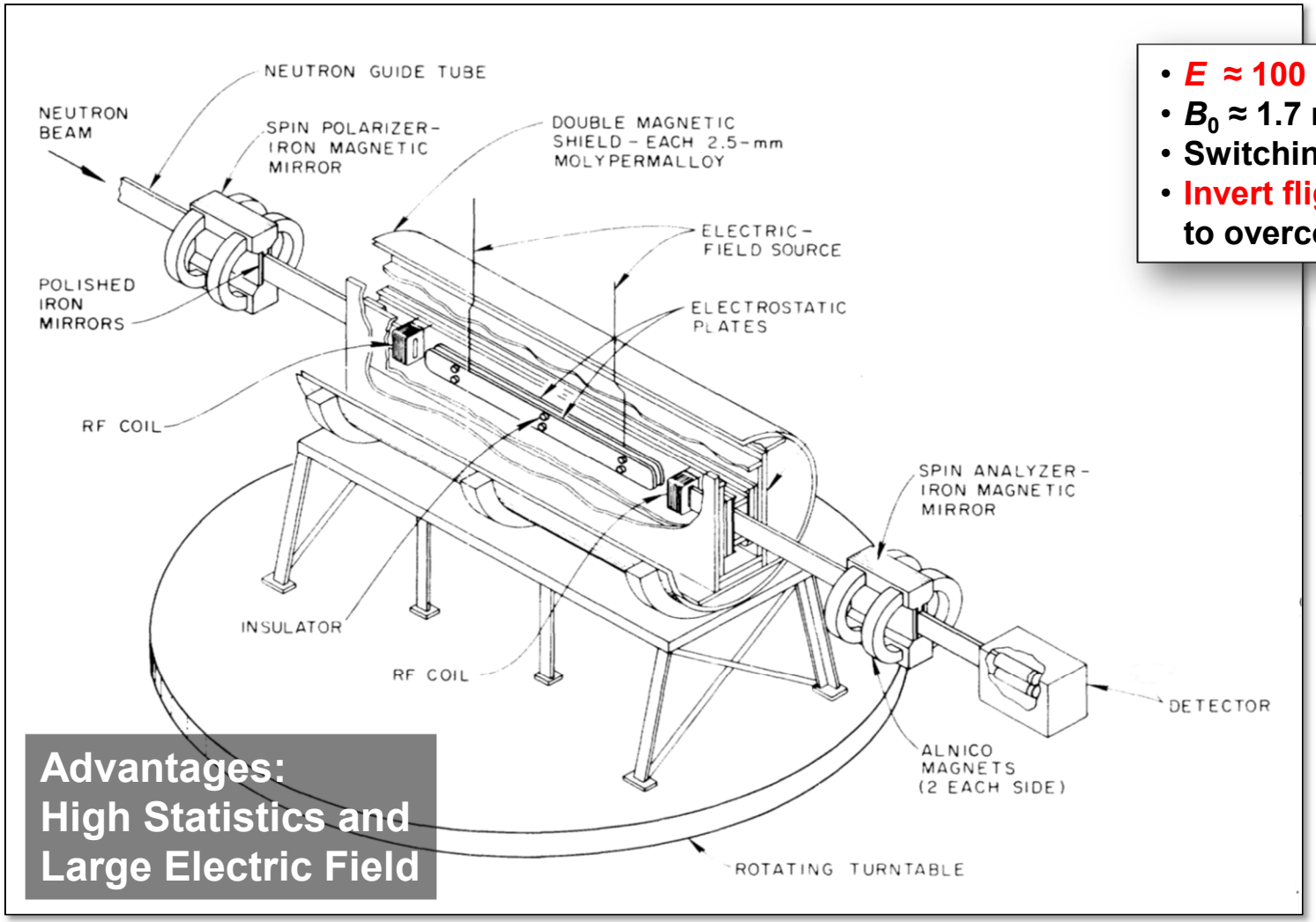
Situation and Perspective

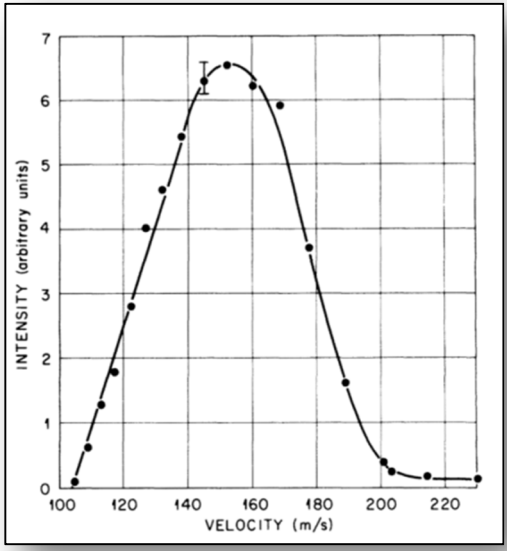


Neutron Beam EDM Experiment (1977)



Advantages:
High Statistics and Large Electric Field

- $E \approx 100$ 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 to overcome systematic $v \times E$-effect



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

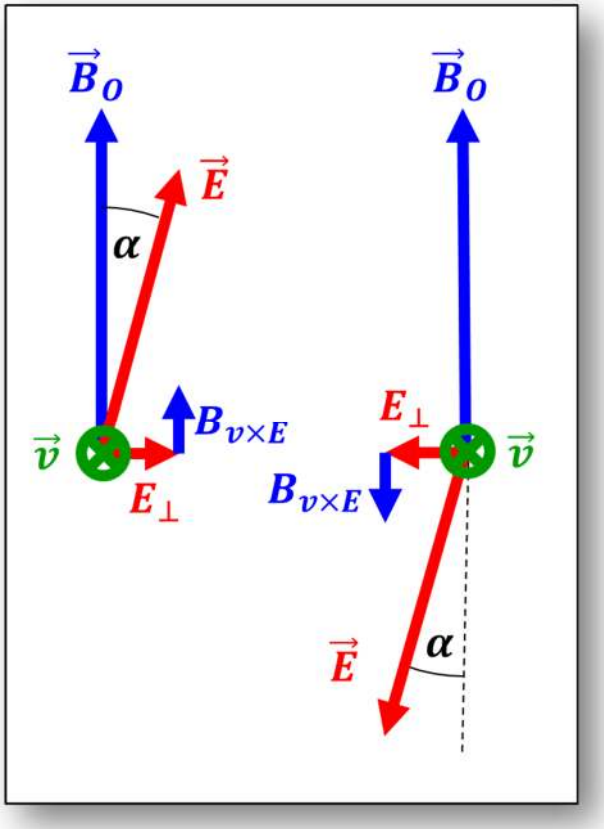
Why were Beam EDM Experiments abandoned ?

- **v×E – effect:** $$\vec{B}_{v\times E} = -\frac{\vec{v}\times\vec{E}}{c^2}$$

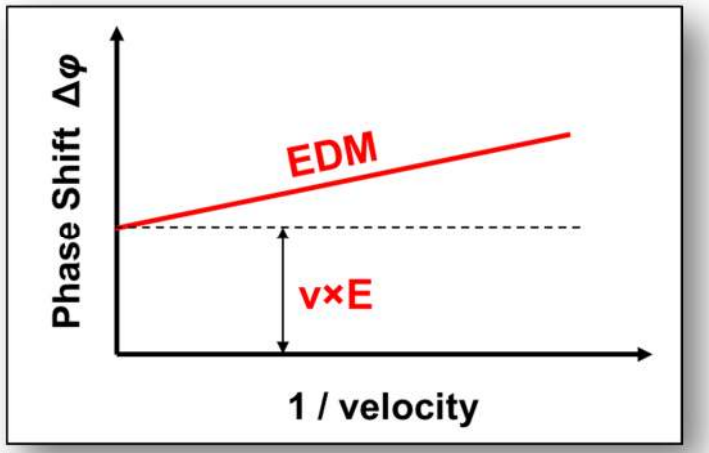
- **This can cause a false EDM signal:**

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

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



Novel Neutron Beam EDM Concept



Length of experiment

$$\Delta\varphi = \frac{8 d_n E}{\hbar} T + \frac{4 \gamma_n E L}{c^2} \sin\alpha$$

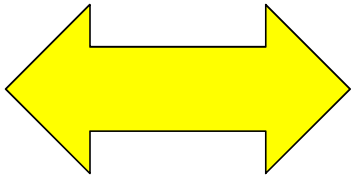
slope = EDM offset = v×E

- **Concept is ideal for pulsed neutron spallation sources**
  e.g. at the European Spallation Source (ESS)
- **Start with proof-of-principle experiments**
  at Paul Scherrer Institute and Institute Laue-Langevin

Piegsa, PRC 88, 045502 (2013)

$$\sigma(d_n) \propto \frac{1}{ET\sqrt{N}}$$

BEAM



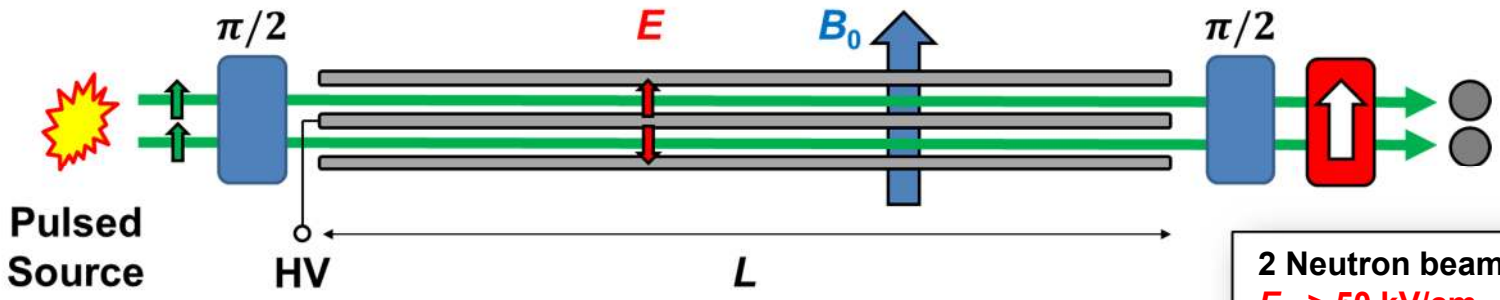
UCN

E = 100 kV/cm
N ≈ 100 MHz (ESS)
T ≈ 100 ms (50 m)

E = 10 kV/cm
N = 14'000 / 300 s ≈ 50 Hz
T = 130 s (storage)

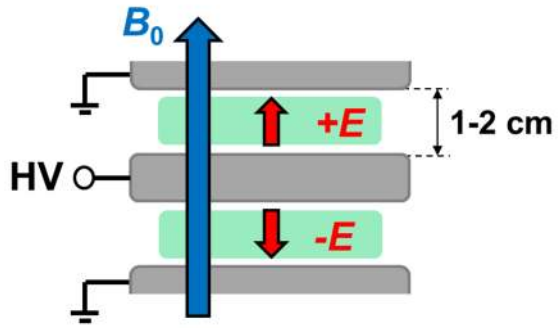
Baker et al., PRL 97, 131801 (2006)
Pendlebury et al., PRD 92, 092004 (2015)

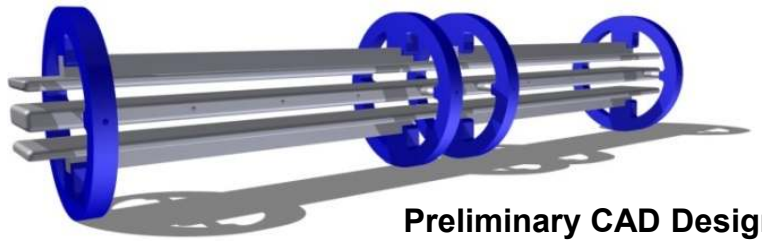
SIDE VIEW



2 Neutron beams
E > 50 kV/cm
B_0 = 100 μT
L = 5 m (proof-of-prin.)
L = 50 m (full-scale)

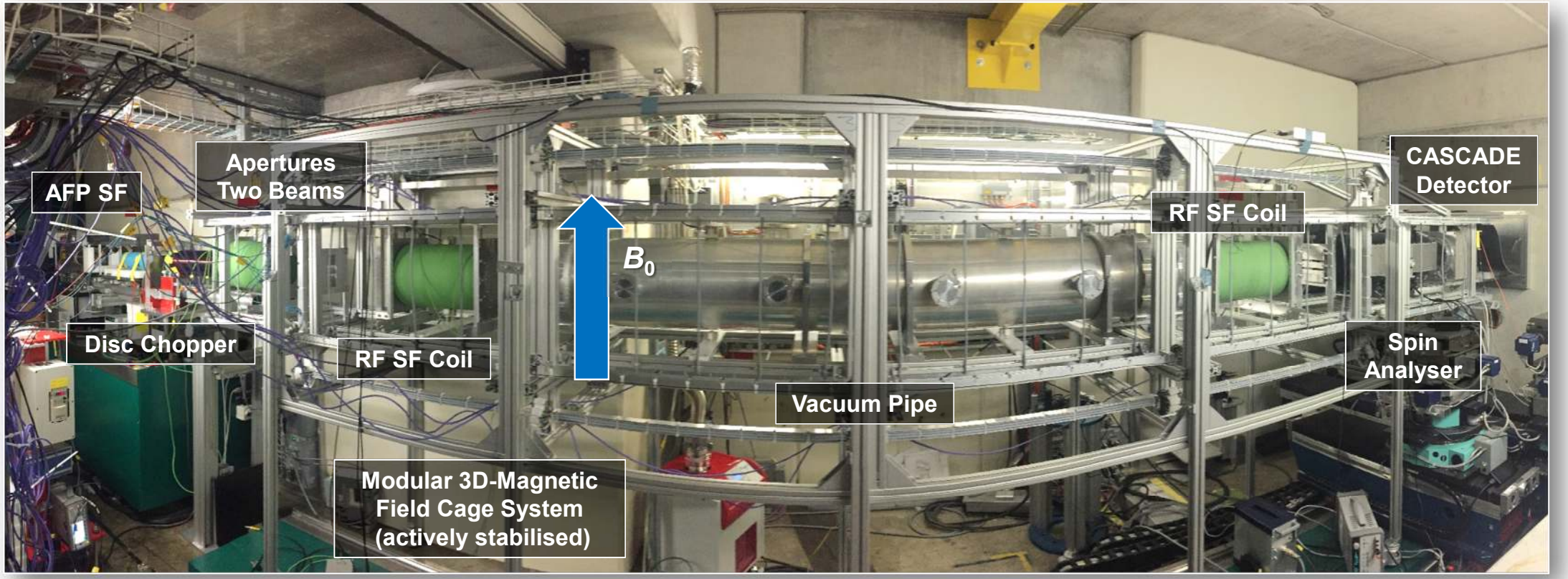
CROSS SECTION





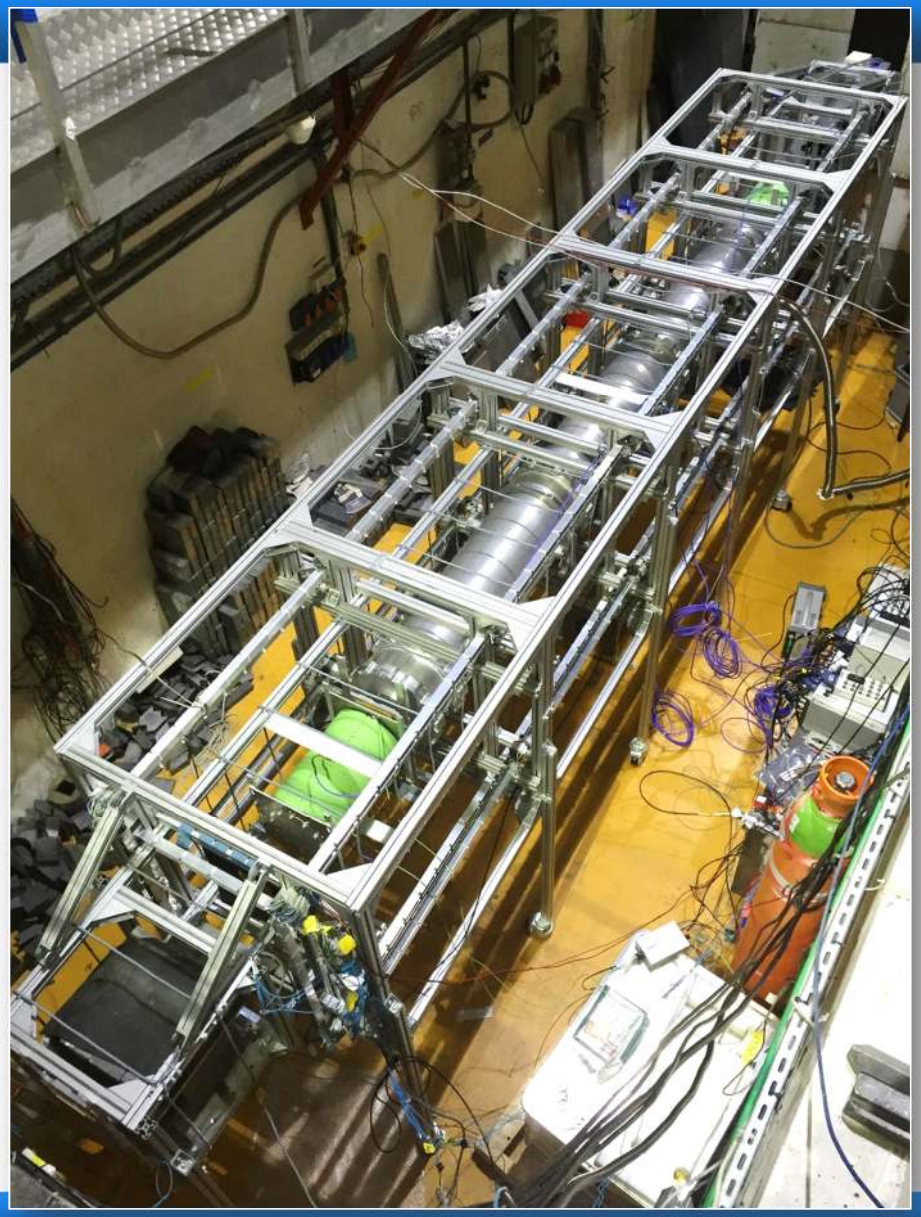
Preliminary CAD Design
(Neutron Guides & Electrodes)

Beam Time at BOA / PSI (Sept./Oct. 2018)

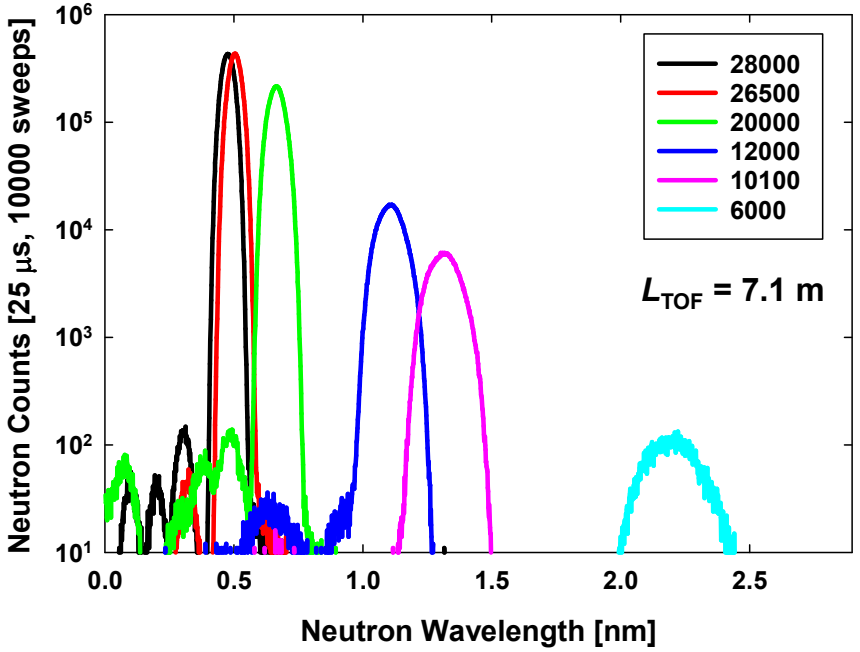


Polarised and White Cold Neutron Beam

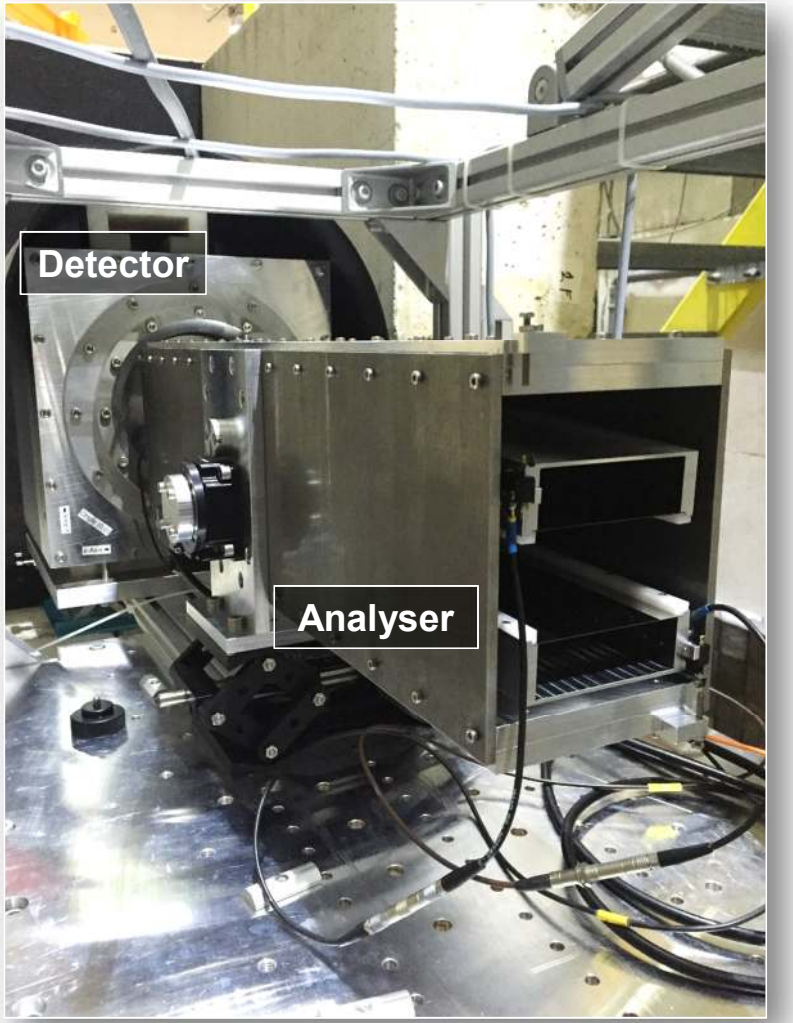
Beam Time at PF1b / ILL (March 2018)

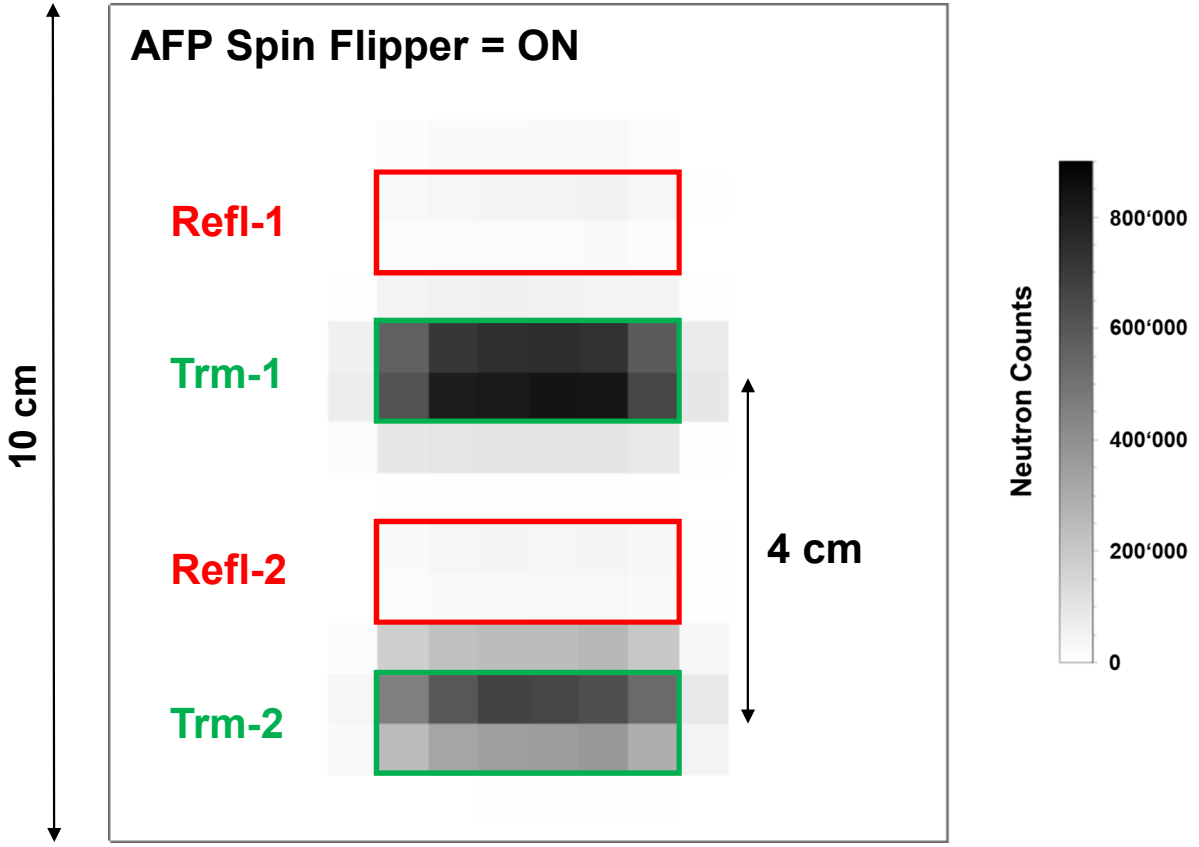


Polarised and Monochromatic (Selector) Neutron Beam



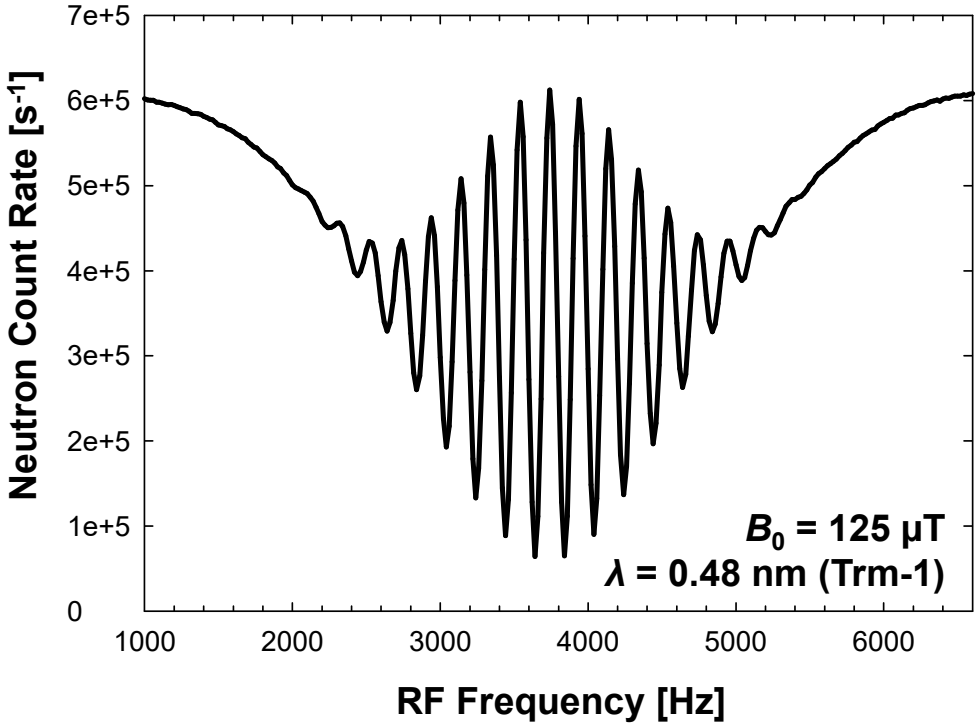
Spin Analyser and Detector



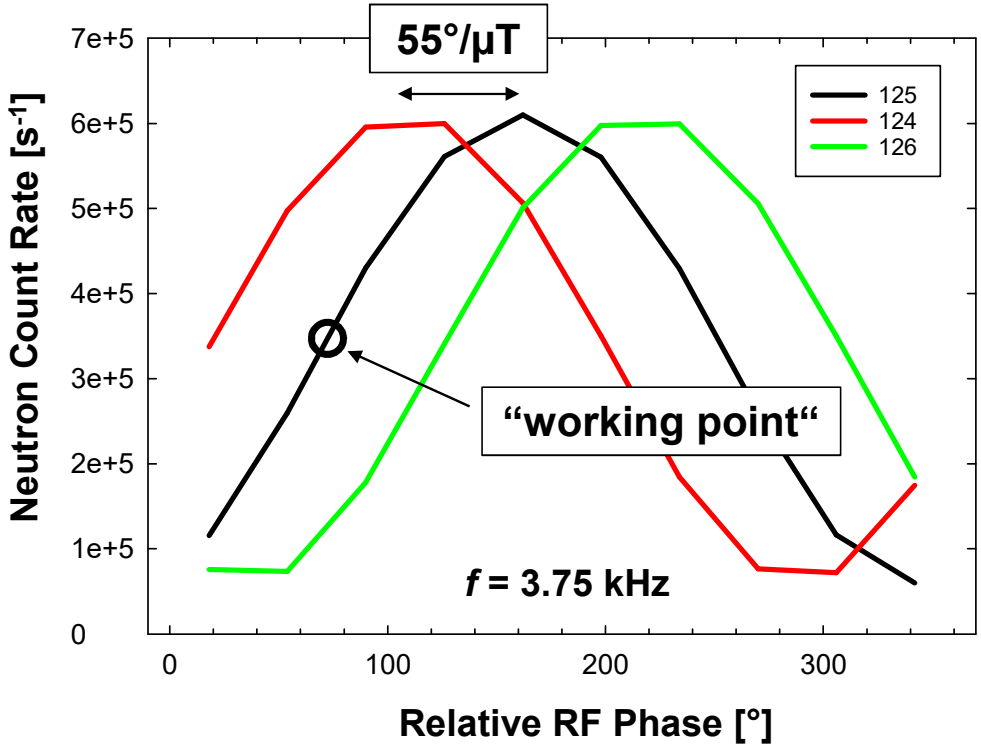


Two beams/Four beam spots each with 3×1 cm²
16×16 Pixels, Pixel-Size = 6×6 mm²
Exposure time: 10 sec (at λ = 0.48 nm)
FeSi supermirror *m* = 5 (*SwissNeutronics*)

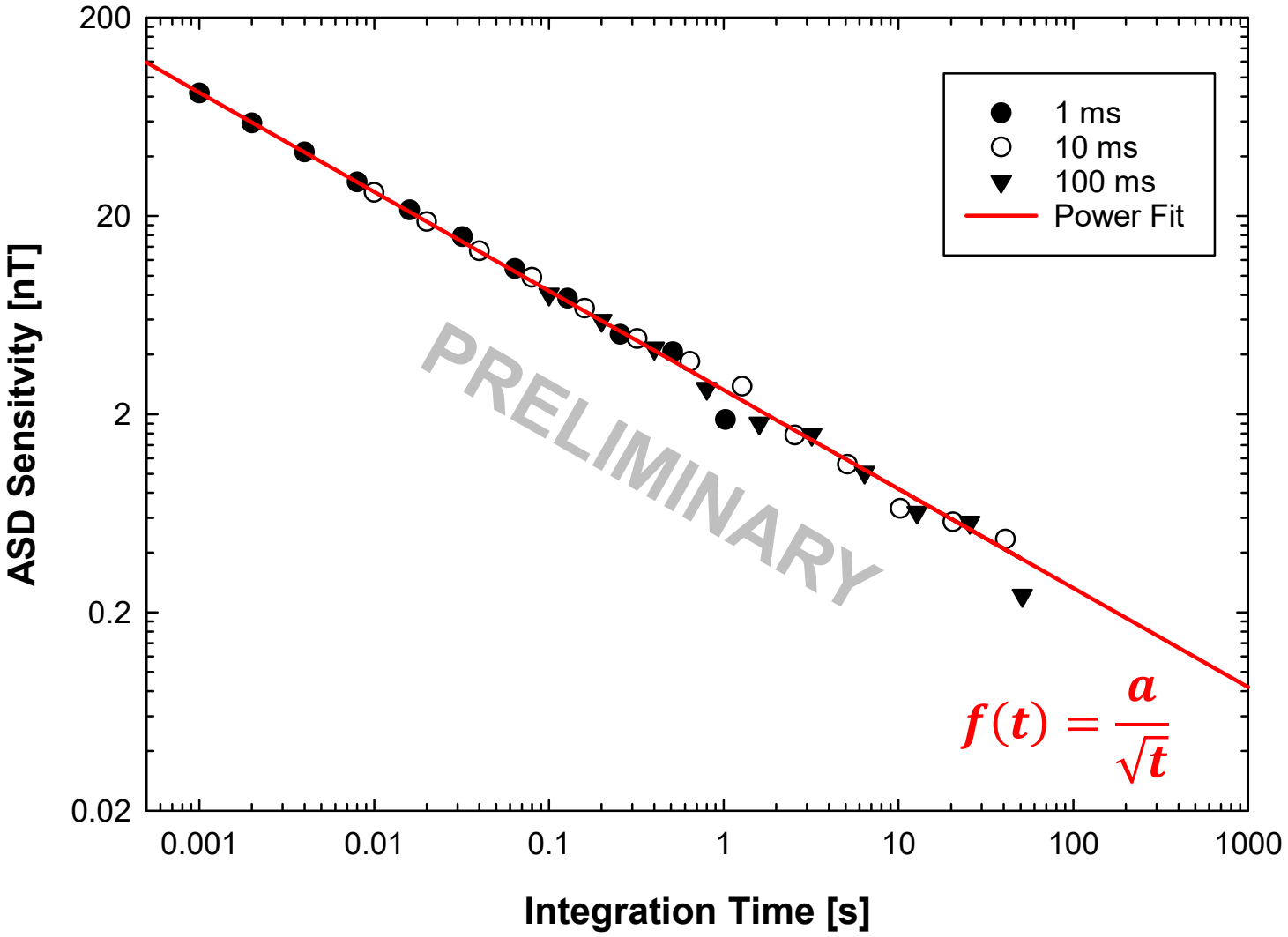
“Classic Ramsey“



“Phase Ramsey“



Ramsey Apparatus Sensitivity

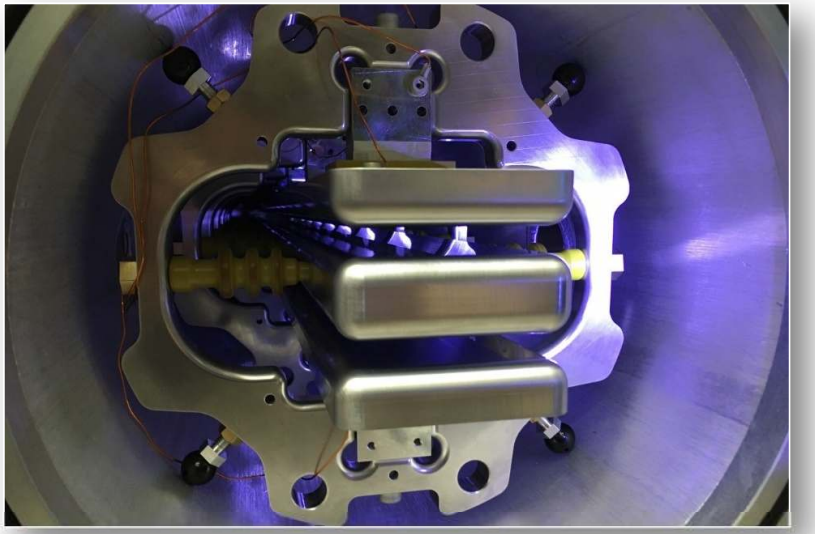


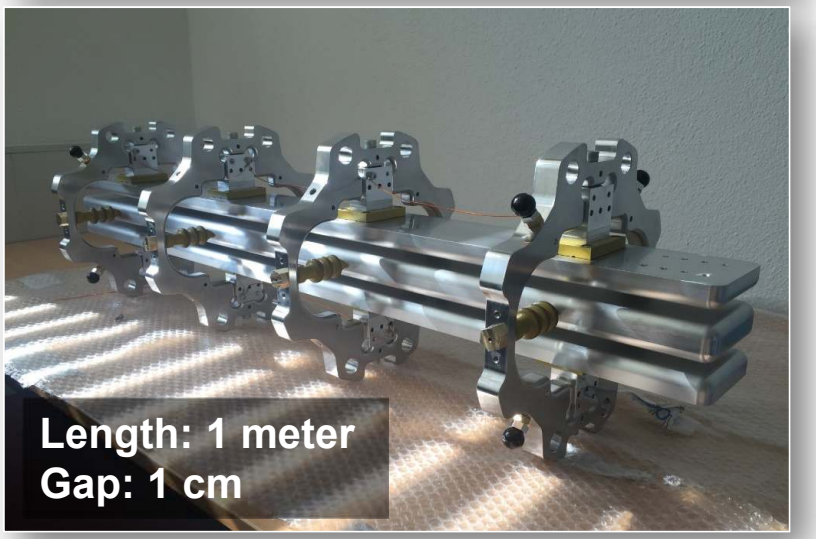
$$a \approx 2\ \mathrm{nT}/\sqrt{\mathrm{Hz}}$$

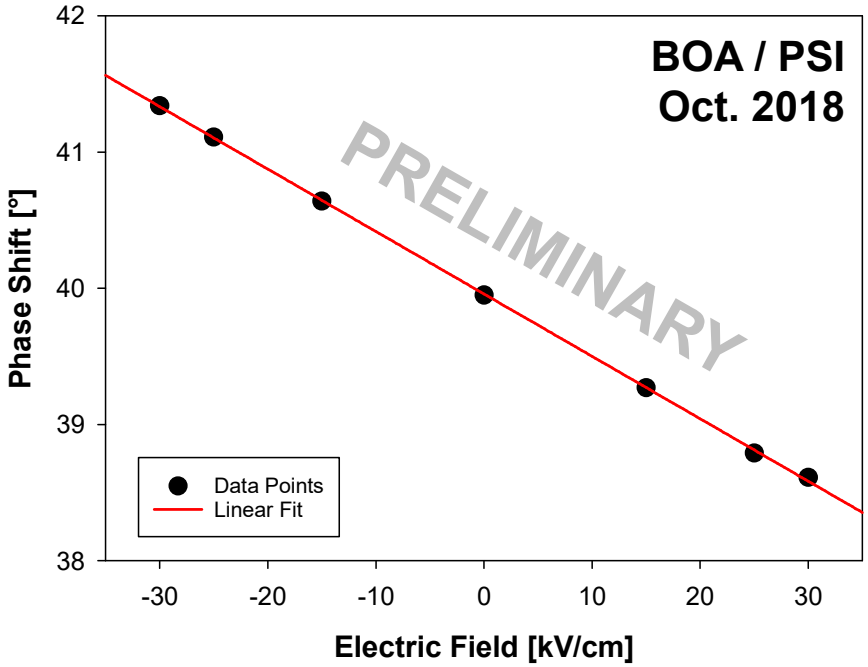
3×10^{-24} e cm (per day)

with: L = 3 m, v = 800 m/s, E = 100 kV/cm

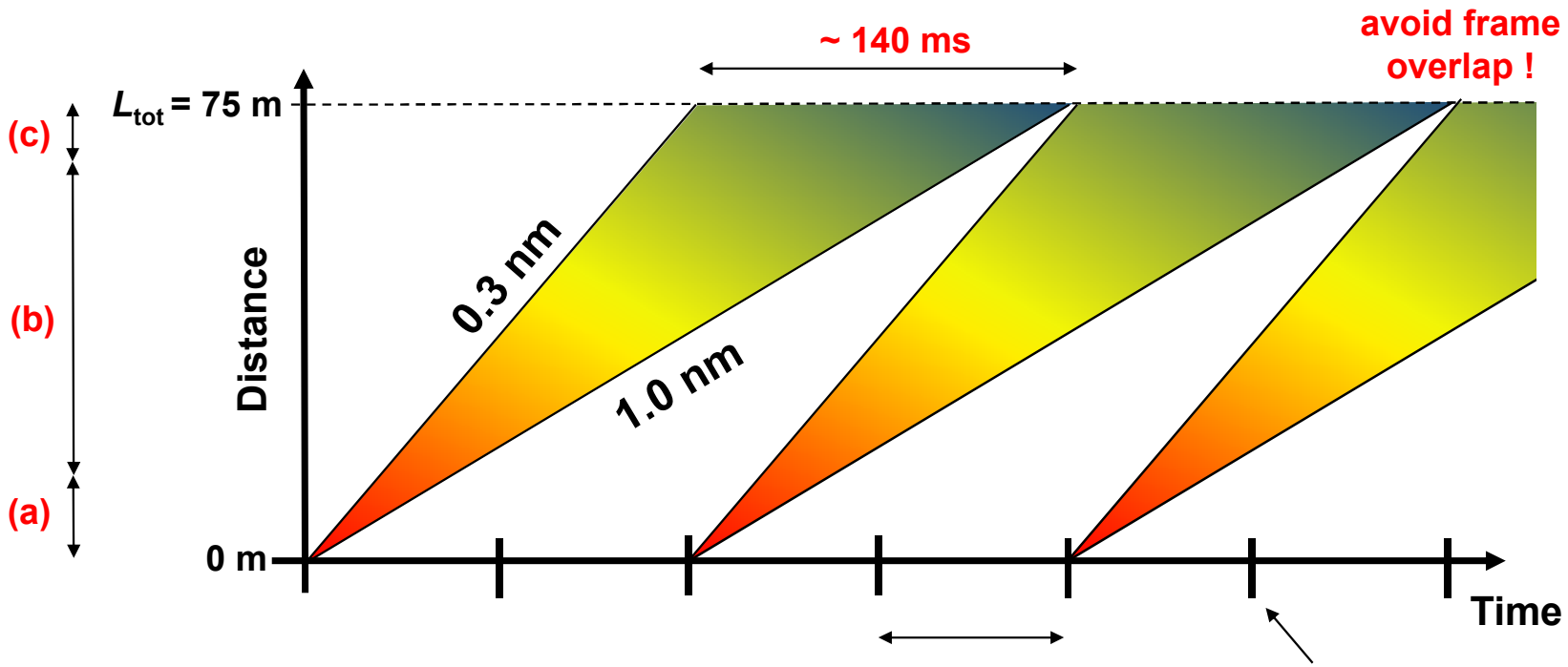
Electrodes and v×E-Effect







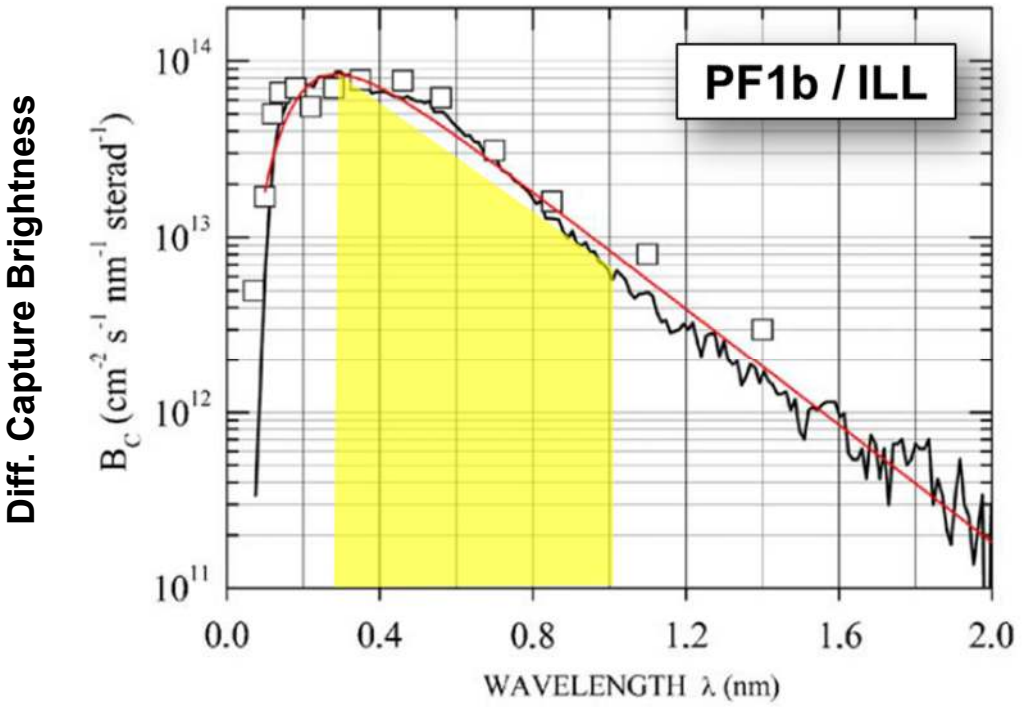
- **Direct measurement of *E*-field seen by neutrons**
- **Maximum v×E-effect (with $B \perp E$): 30 kV/cm, 1000 m/s → 30 nT**



(a) Beam extraction & preparation
(b) Ramsey precession region (L ~ 50 m)
(c) Spin analysis & detector

Optimization ongoing …

Particle Brightness at PF1b (ILL)

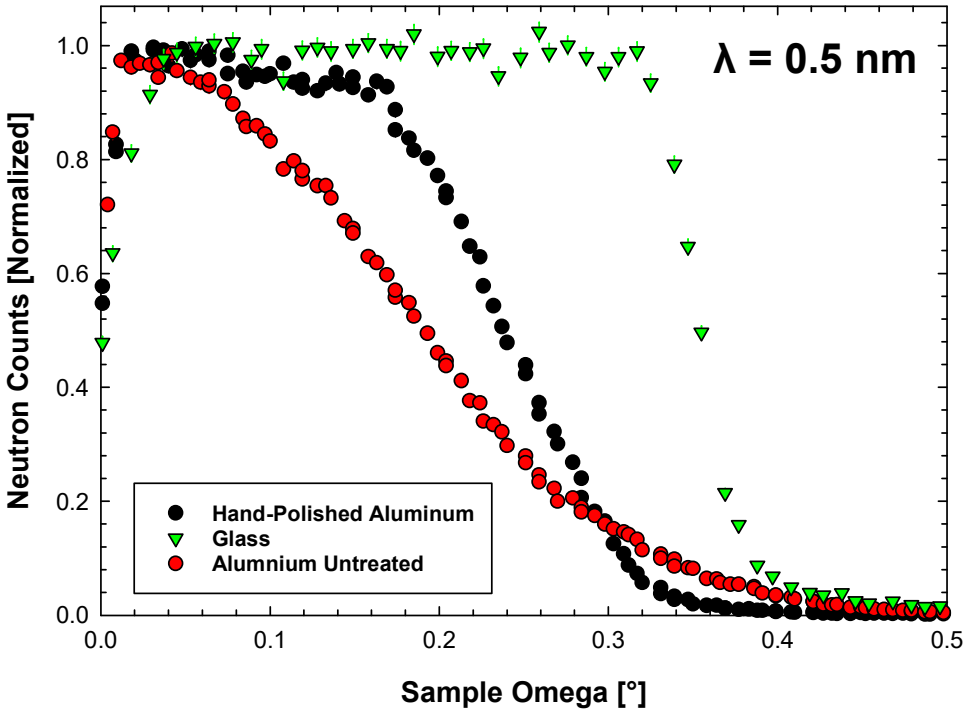


$$B_P = \int_{0.3}^{1.0} \frac{\lambda_0}{\lambda} \frac{\partial B_C}{\partial \lambda} d\lambda \quad \Rightarrow \quad B_P \approx 1.5 \times 10^{13} \text{ cm}^{-2}\text{s}^{-1}\text{sterad}^{-1}$$

with: $\lambda_0 = 0.18$ nm

Abele et al., NIM A 562, 407 (2006)

Reflectometry of Electrodes

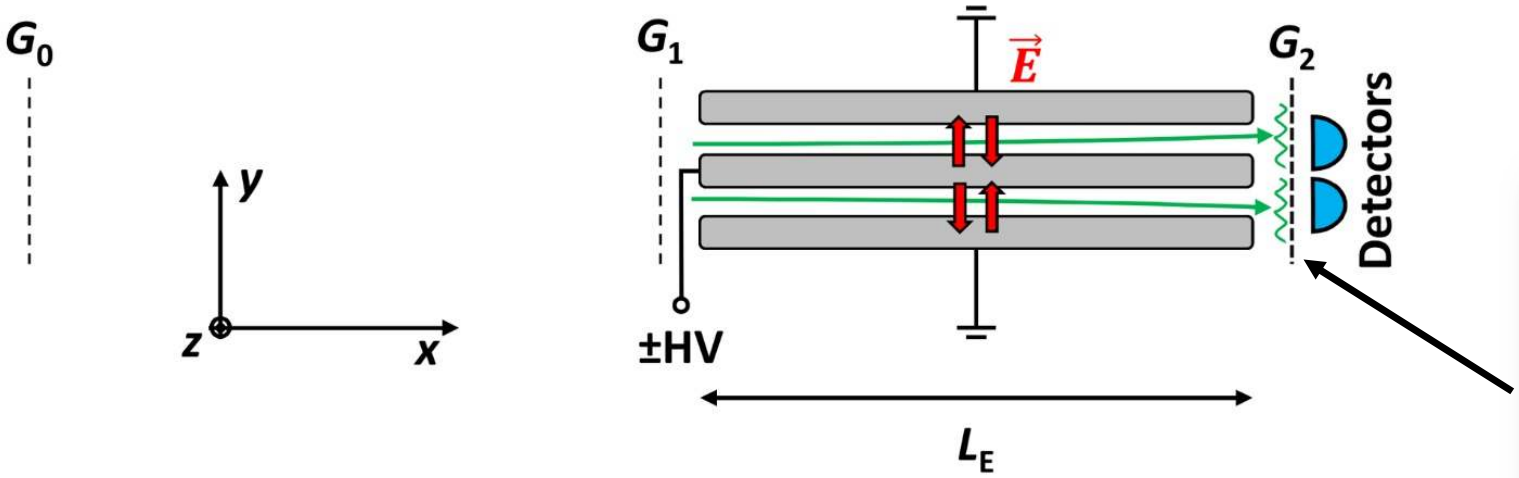


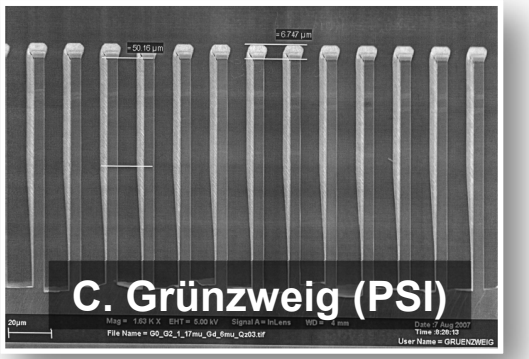
Absorbing Electrodes: 20 mm / 75 m → 0.015° (max. vertical divergence)

Guiding Electrodes: about 0.15° @ 0.5 nm (only polished aluminum)

- Data analysis is ongoing
- Proposal for beam time at ILL in 2019:
  - Improved magnetic stability / homogeneity
  - Perform first EDM measurements
  - Search for Dark Matter Axions

    compare: Abel et al., PRX 7, 041034 (2017)
- Future: Full-scale experiment at the ESS (ANNI)
- And a new project …





- **Measurement of neutron electric charge**
- **Grating interferometer in TOF-mode**
- **Ideal for ESS pulse structure and ANNI beam line**
- **L_E = 5 m, E = 100 kV/cm – improvement by factor 100 possible**

Piegsa, PRC 98, 045503 (2018)

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Thank you for your attention !