PanEDM central components

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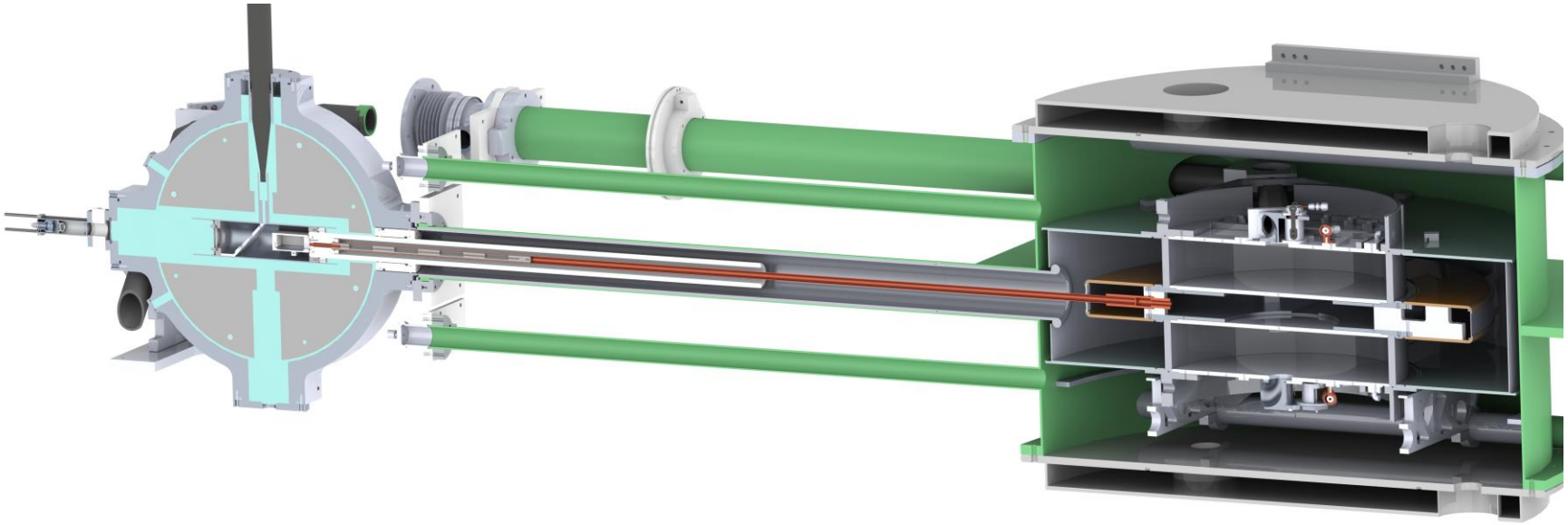
International Workshop on Searches for a
Neutron Electric Dipole Moment
February 16th 2021

Central components

- Major changes going from FRM2 to SuperSUN
  - Guides with small volumes but good transport behaviour
  - ID50 instead of ID90
- Reduce number of components
  - Everything is magnetic, outgasses, fails eventually
- Keep B_0 small
  - Technial issues expected at larger fields

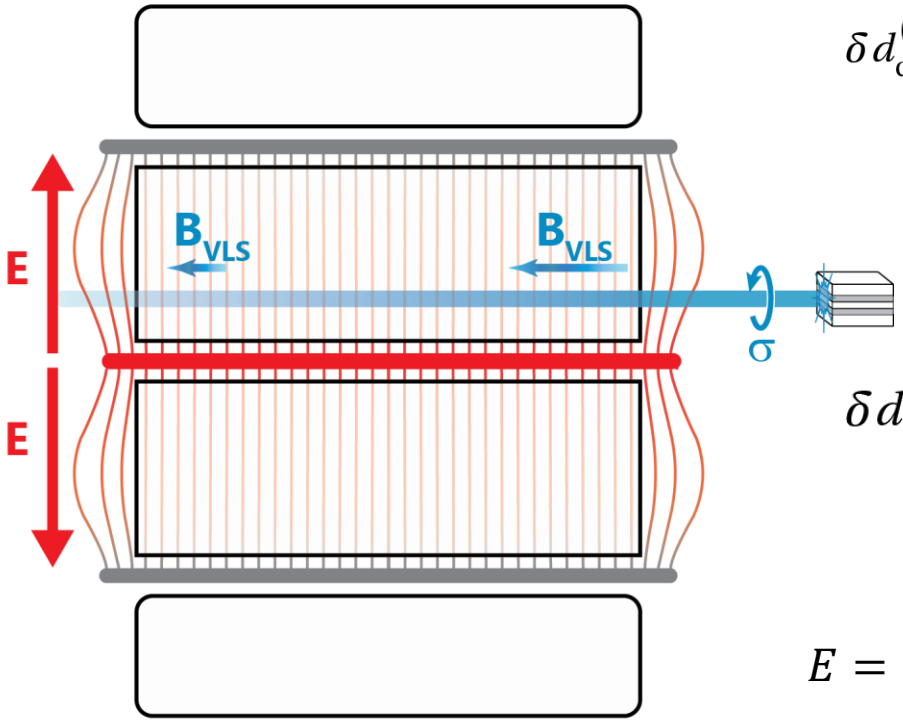


Co-magnetometer arguments

- Spatially averaged field
- Co-magnetometer is main source of systematic issues
  - And a strong source of understanding systematic effects!
  ‘
- Co-magnetometer installation possible if need in phase II

- Charging currents:
  - Magnetization effects mainly elastic
  - Current in wires, not in bulk
- HV breakdowns:
  - Spark monitoring bandwidth issue
- Knowledge of magnetic contamination sufficient for phase I
  - precision component mapping, upper limits for thermal currents, vibrational effects

Examples for Hg systematics



$$\mathbf{B}_v = \frac{\mathbf{E} \times \mathbf{v}}{c^2} \qquad \boldsymbol{B}_{xy} = \boldsymbol{B}_{VLS}(x)$$

Direct vector light shift

$$\delta d^{(1)}_{\mathrm{dVLS,n}}(\Delta\nu_L) = 3.6 \cdot 10^{-28} \frac{e\,\mathrm{cm}}{\mathrm{MHz{\cdot}mrad}} \cdot \Delta\nu_L \cdot \alpha.$$

$\Delta\nu_L$ Detuning from no-light shift point
α missalingment from xy-plane

Light shift geometric phase

$$\delta d_{LSGP} = -1.7 \times 10^{-29}\, e\,\mathrm{cm\,MHz}^{-1} \cdot \Delta\nu.$$

$\Delta\nu$ Detuning from no-LS point

$$E = \pm 20 \frac{kV}{cm} \rightarrow \Delta\nu = 1.328 \pm 0.024\ MHz$$

$$\delta\, d_{LSGP,DC\ Stark\ (uncomp.)} = 2.2 \times 10^{-29} e\ cm$$

$$\omega_{xy}^2 = \left(\frac{\partial B_{0z}}{\partial z}\frac{\boldsymbol{r}}{2}\right)^2 + \left(\frac{\boldsymbol{E}\times\boldsymbol{v}}{c^2}\right)^2 + 2\frac{\partial B_{0z}}{\partial z}\frac{\boldsymbol{r}}{2}\cdot\frac{\boldsymbol{E}\times\boldsymbol{v}}{c^2}$$

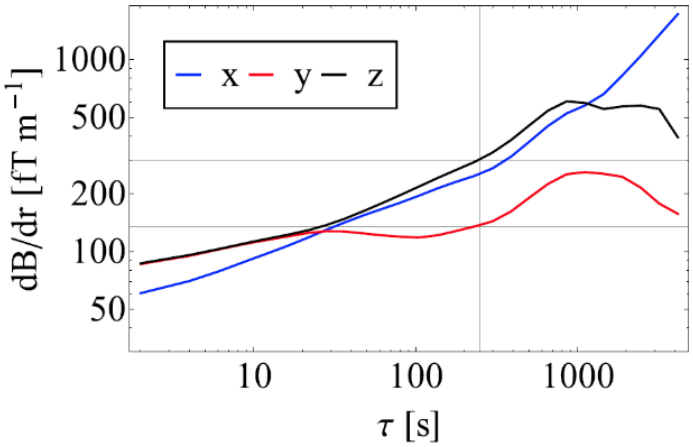
Bernd Taubenheim, 2017

B gradient monitoring

- 8 Cs magnetometer are placed 45 cm off stack center
- 2 Hg magnetometers

  4fT differential sensitivity between EDM cell positions

$$\omega_{xy}^2 = \ldots. + 2\frac{\partial B_{0z}}{\partial z}\frac{\boldsymbol{r}}{2}\cdot\frac{\boldsymbol{E}\times\boldsymbol{v}}{c^2} + \ldots$$



SQUID reported gradient drift inside shield without cylinder layer (additional 9x improvement)

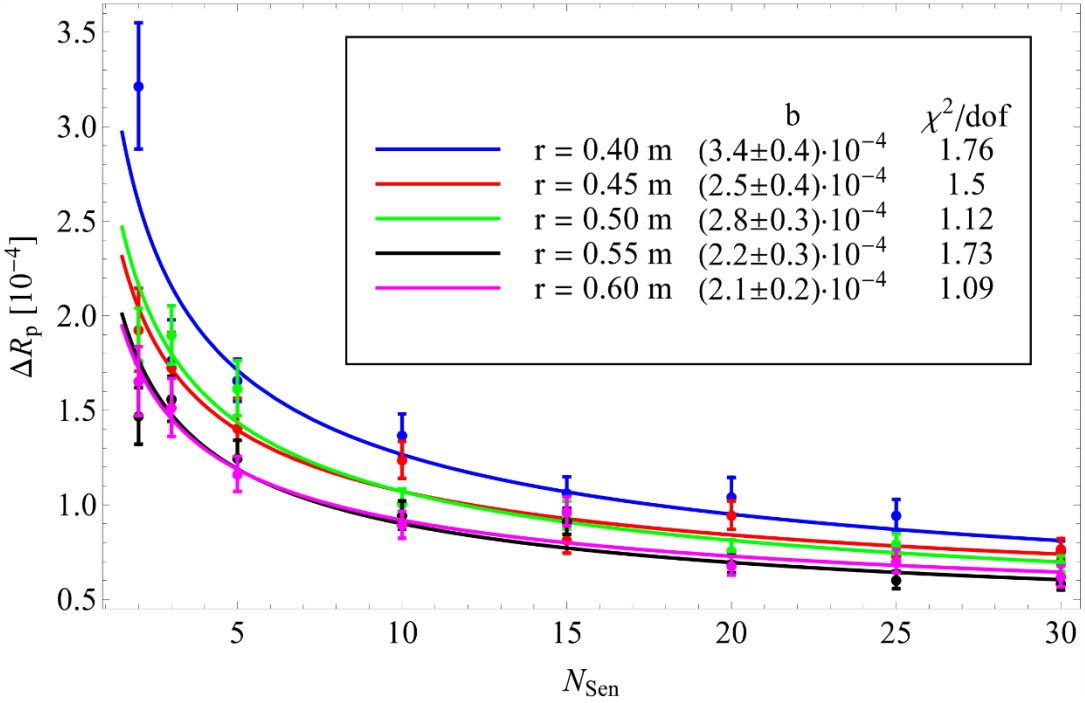
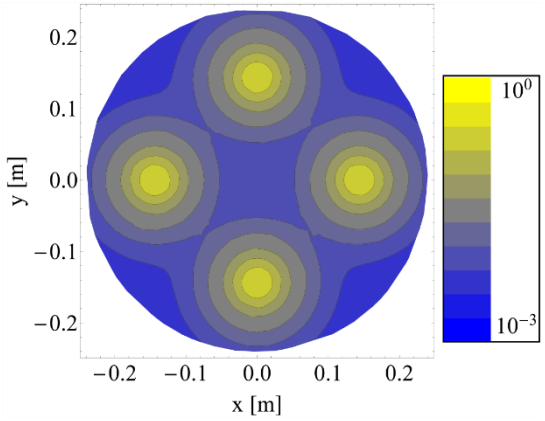


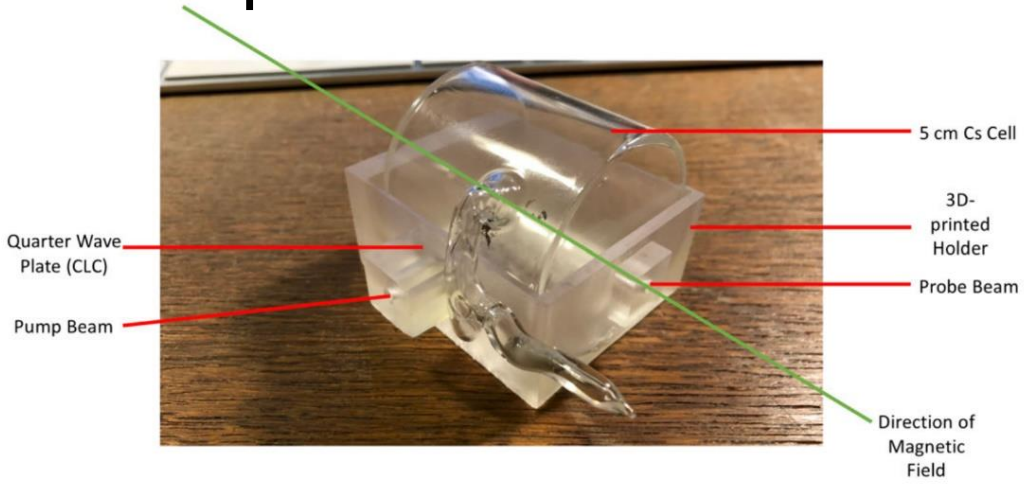
Figure 2.8.: Field reconstruction quality for gradient fields of 100 pT/cm as a function of distance r to the center and the number of sensors. The solid lines are $b/\sqrt{N_{sen}}$ fits to the data. The choice for the $1/\sqrt{N_{Sen}}$ functionality is based on the expected statistical behavior. The error bars are determined by the standard deviation spread of the simulation results for different magnetometer arrays.

Tobias Lins, 2016

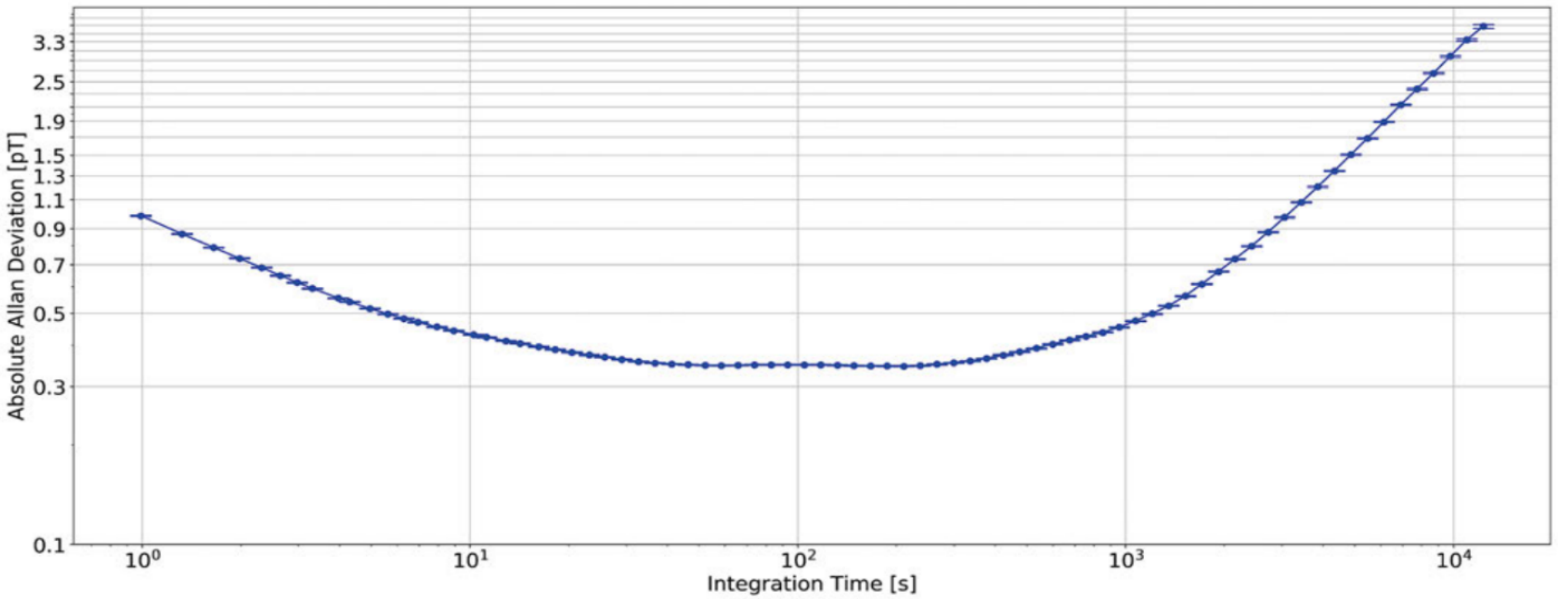
Cs HV sensor – Dipole detection



Tobias Lins, 2016

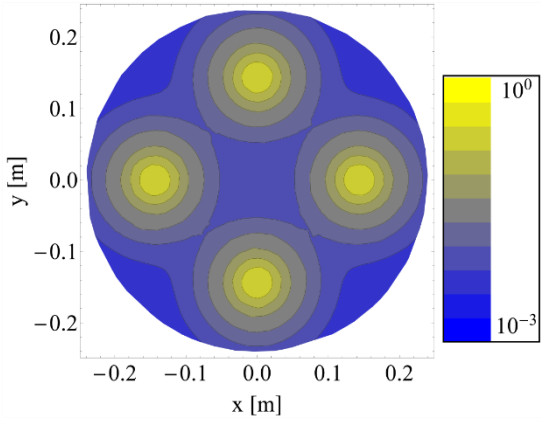


Michael Sturm, Martin Rosner, 2019



Currently not sensitive enough for dipole reconstruction, only HV discharge veto

Cs HV sensor – Dipole detection



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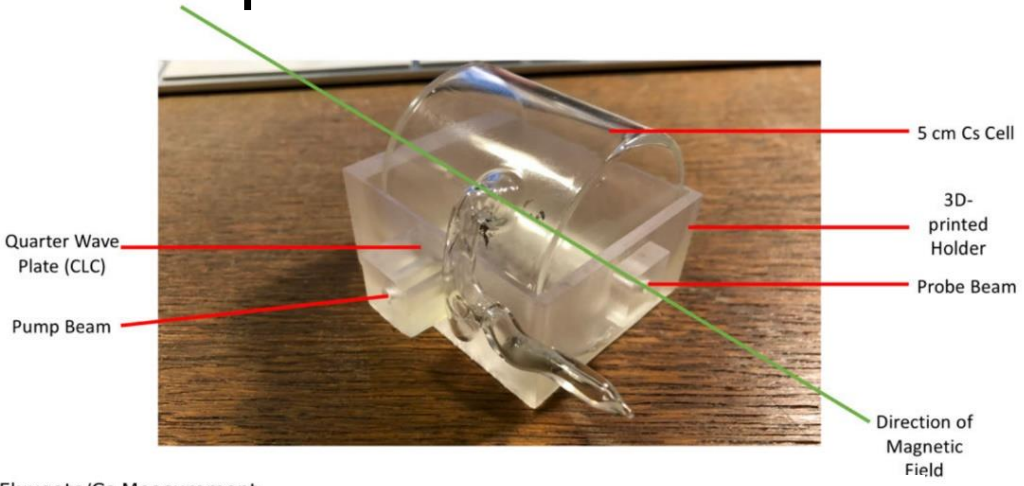
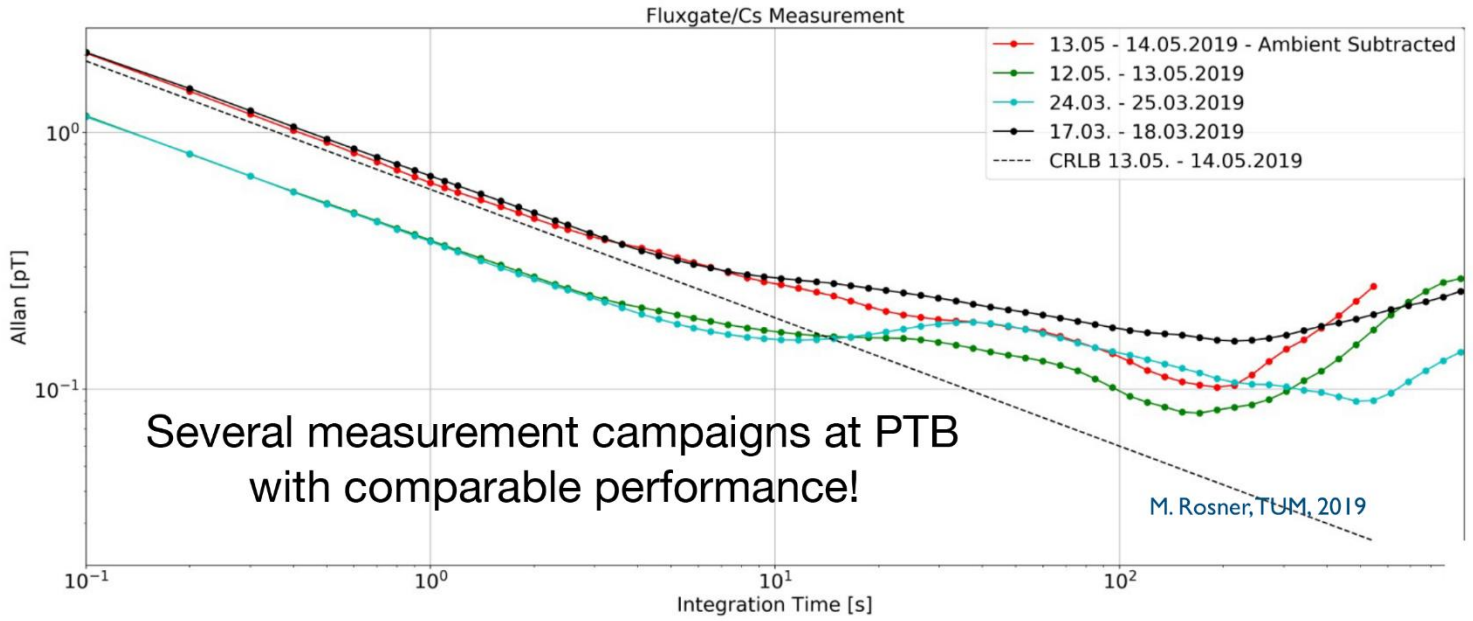
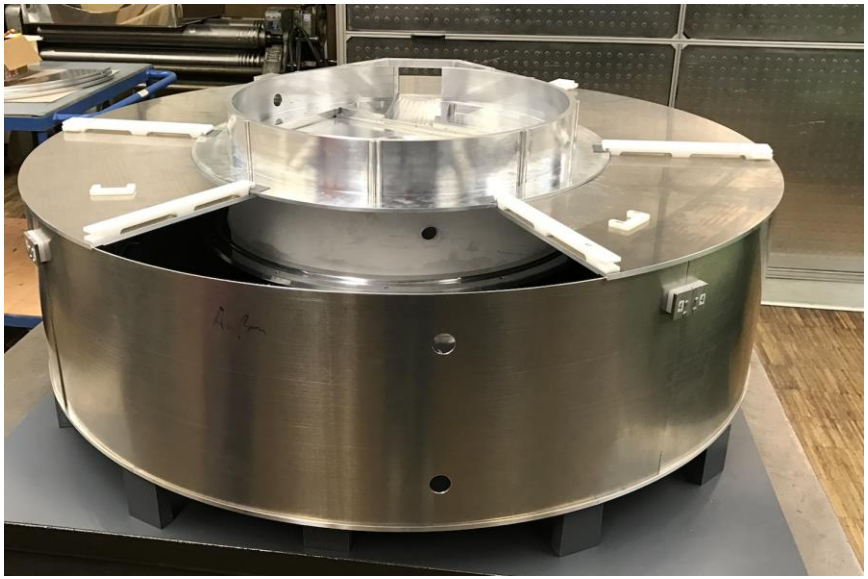


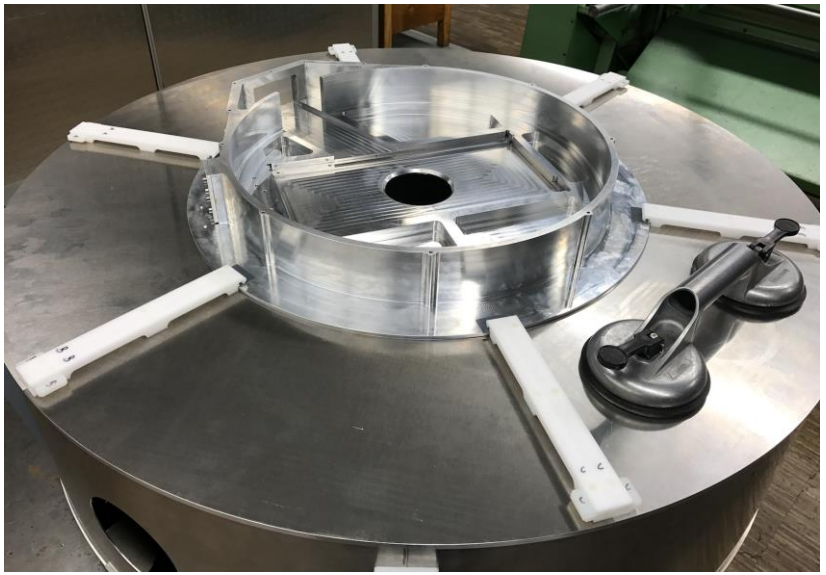
Michael Sturm, Martin Rosner, 2019



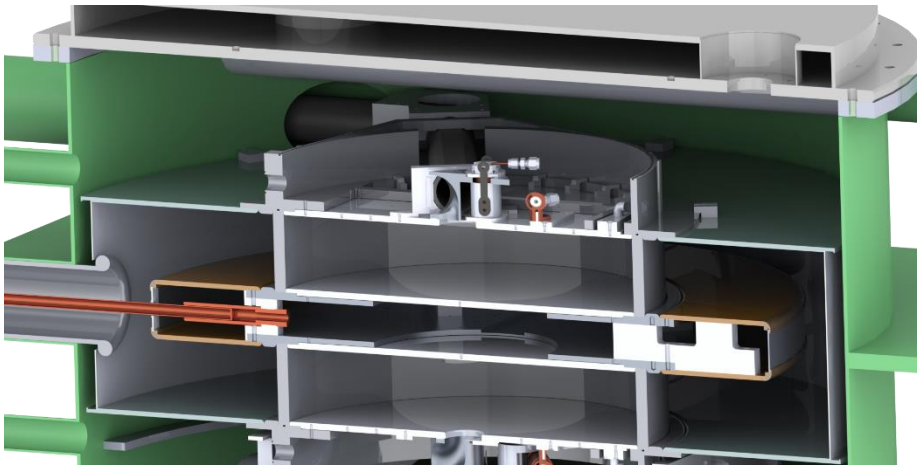
Fiberized sensor performance

Central component test assembly



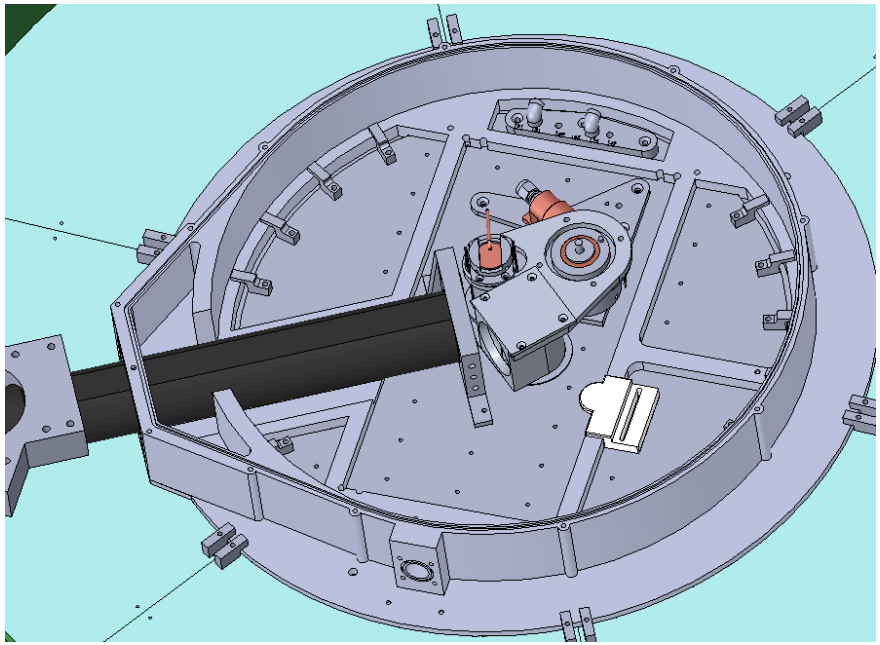


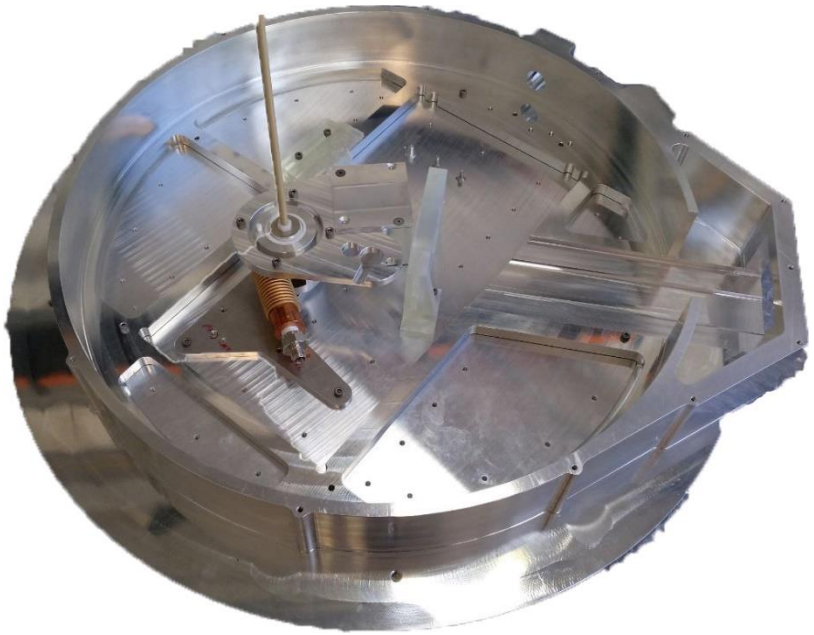
Cells and GND electrode test assembly (2016)



GND electrode details

- Two way pneumatic movement
  - Vertical actuator seals cell
  - Rotational movement exchanges seal with guide adapter
- Third generation currently being commissioned

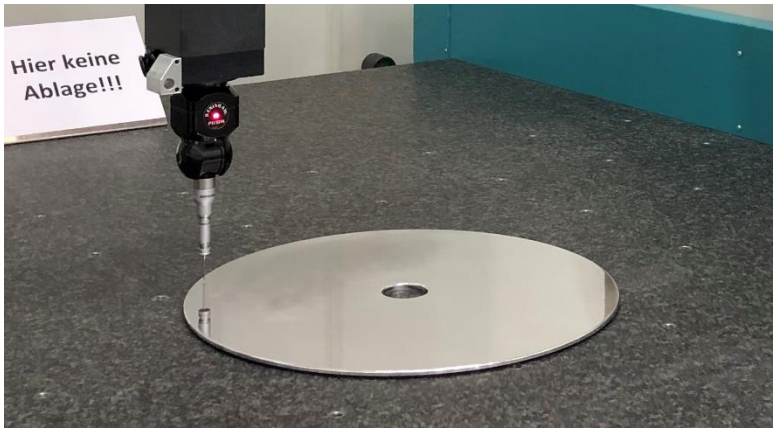




Note: Removeable electrode

Electrode Iterations

- Initial coating strategy: NiMo 85/15
- HV spark could change local metallurgy
  - permanent local dipole on electrode
- Flatness and Stability separated:
  - Highly smooth and flat electrode on stable support
- Coating of large pieces difficult



Substrate (1st iteration)

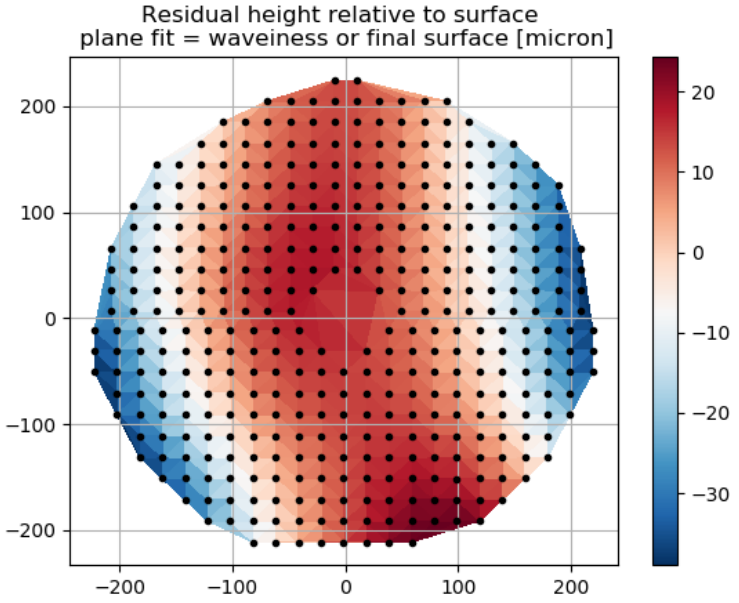
GND Electrode Structure

Electrode Iterations

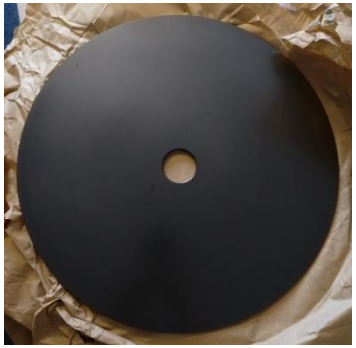
- Substrate discs currently in 3rd iteration
- Parallel development of coating options:
  - 500nm DLC in low-temperature CVD with standard / deuterated precursor
  - CYTOP

    Talk by Tom Neulinger
  - dPE
  - (small) crystalline diamond on silica substrates
- Mounting of substrate on structure main source of deformation

  Substrate attached symmetrical on outer edge
- Aluminium substrates not suitable for phase II



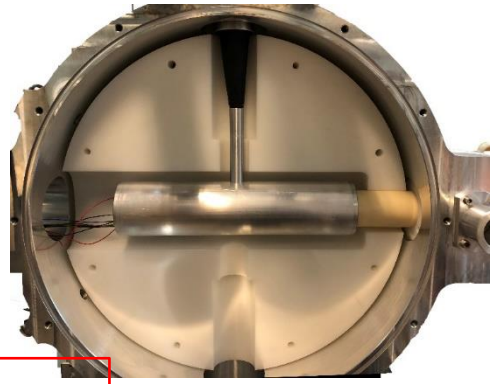
Shape survey for 2nd iteration
Substrate (aluminium with „deuterated“ DLC)



2nd iteration
with DLC

3rd iteration
(to be measured)

HV System



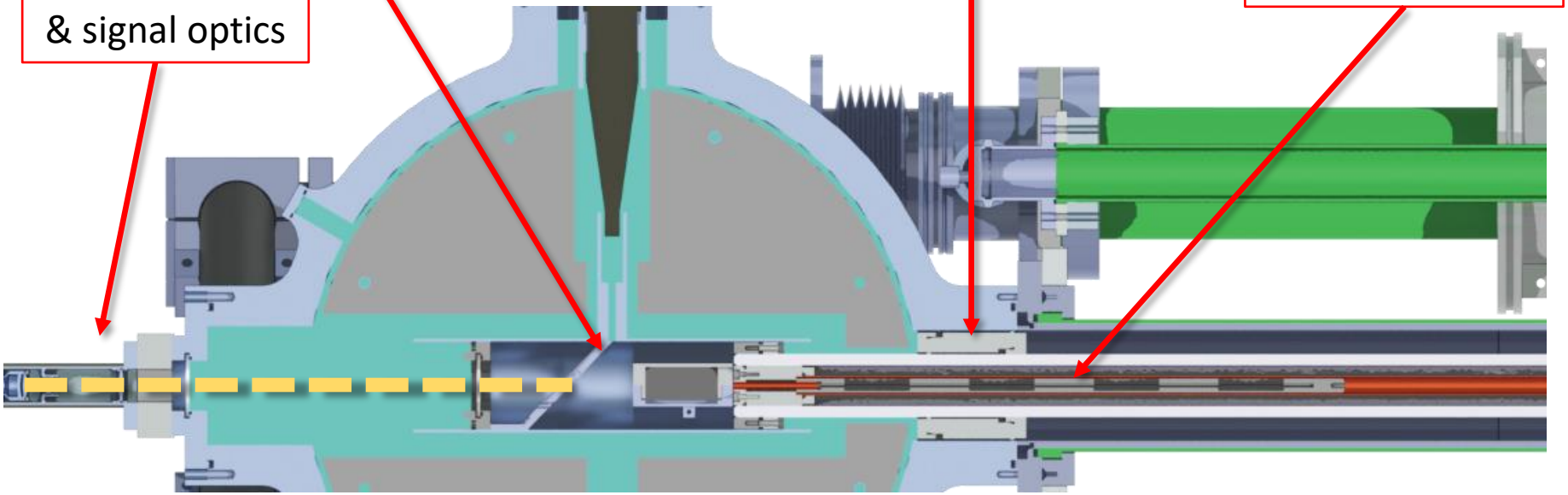
HV supply stable
<1*10^{-4} in 8h @ 200kV
ripple: 2*10^{-5} (0-10MHz)

Floating, laser powered
leakage current electronics

Only contact prior to leakage
current monitor:
quartz isolator

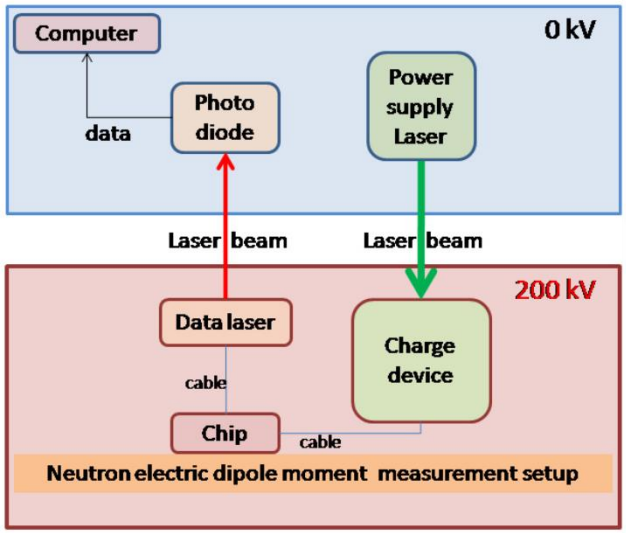
Inline resistor
chain

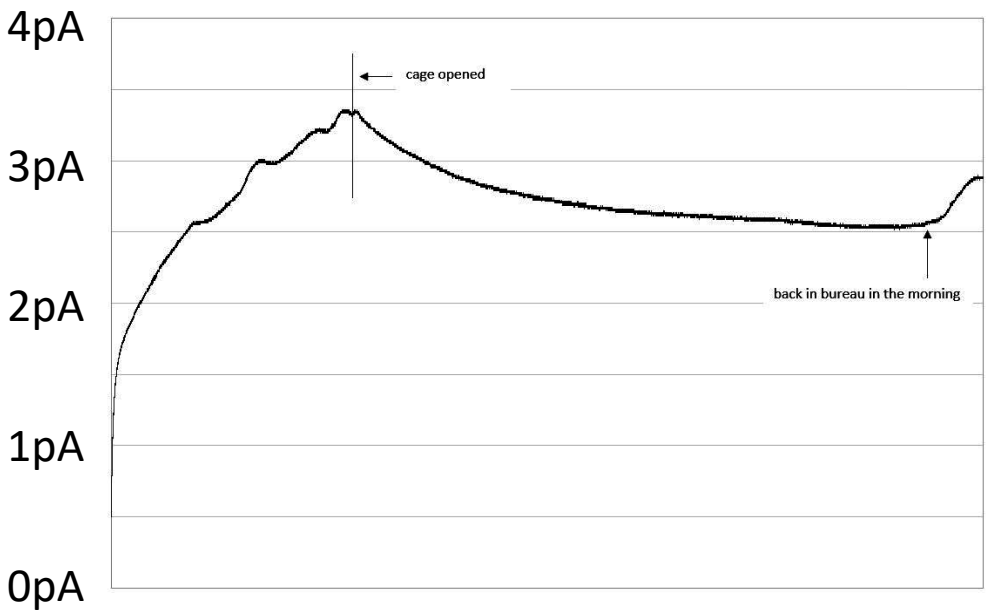
Power laser
& signal optics



HV and Leakage Current

- Figure of merit: 50pA
  1e-27 ecm false effect for simple current model: loop
- 0.5pA resolution @ 1Hz
  - Matched with system bandwidth





Baseline drift 24h

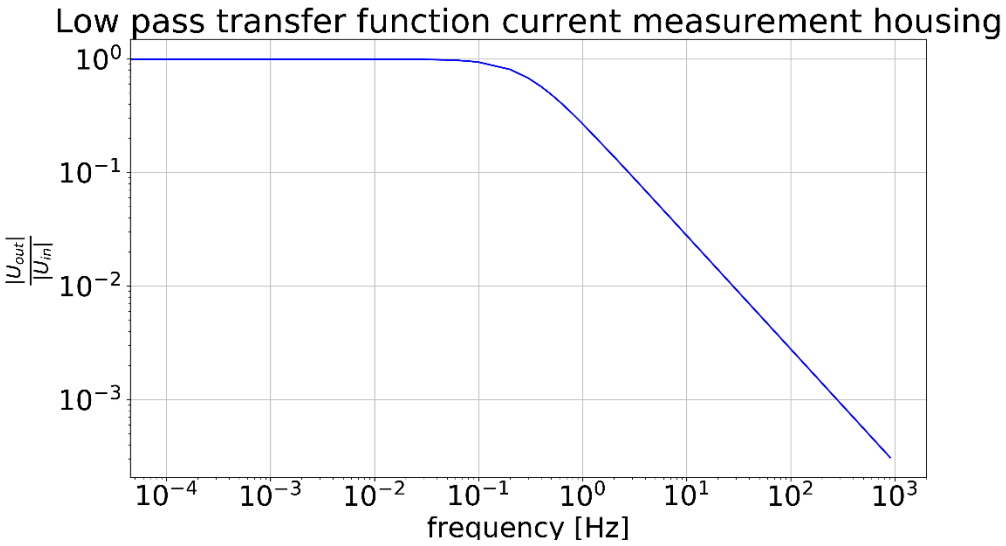
Petra Müschenborn, 2018

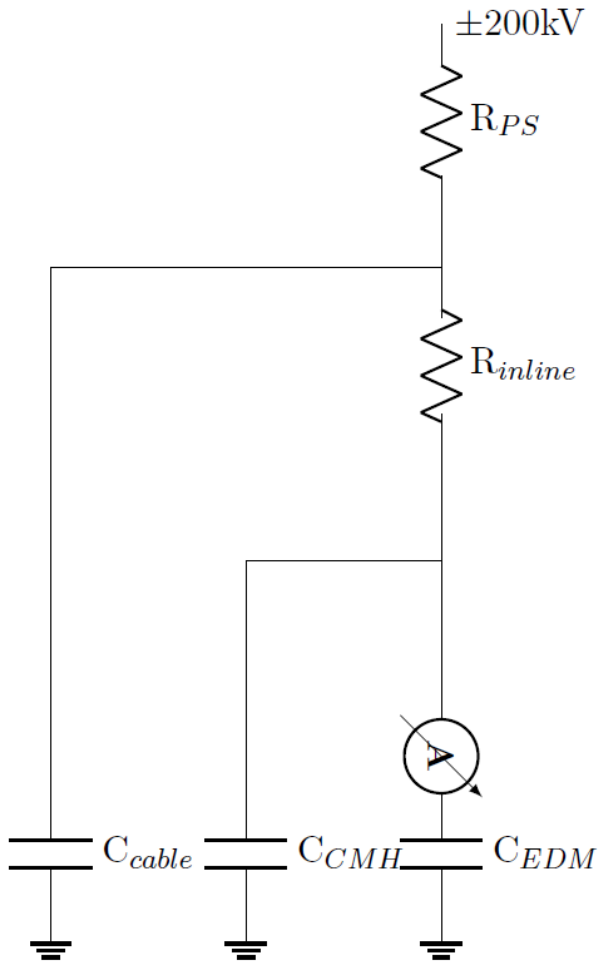
HV peculiarities

- Leakage current measurement: bandwidth limited

  RF damping!

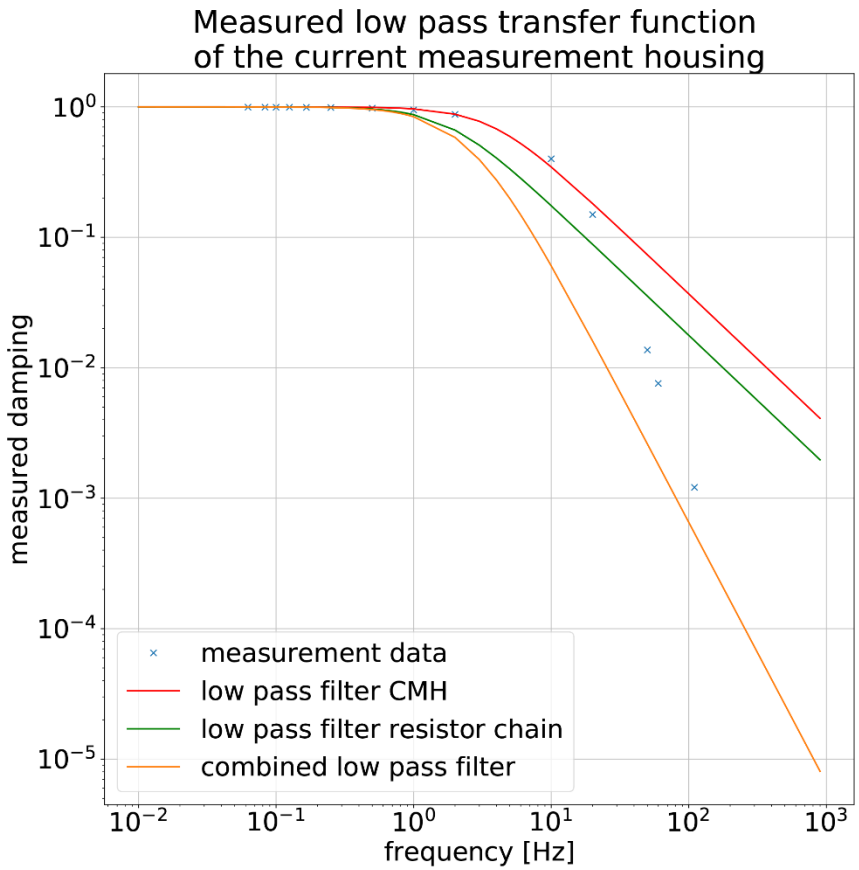
- All possible leakage currents are collected on the HV side
- We can (in principle) distinguish between upper and lower chamber



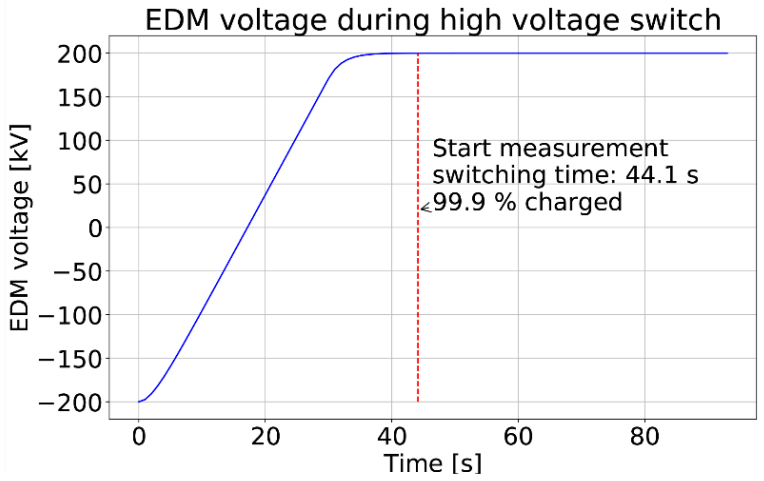


Lucas Hopf, 2020

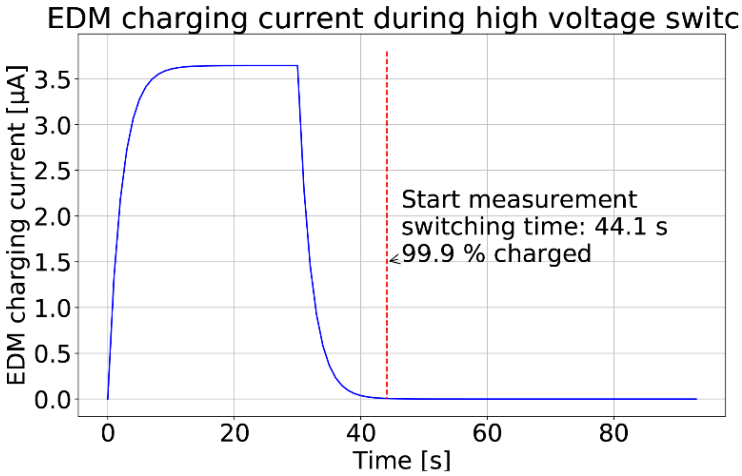
HV and leakage current



Test with HV setup and 1GOhm



(a) Simulated voltage at the EDM cells during the high voltage switch.

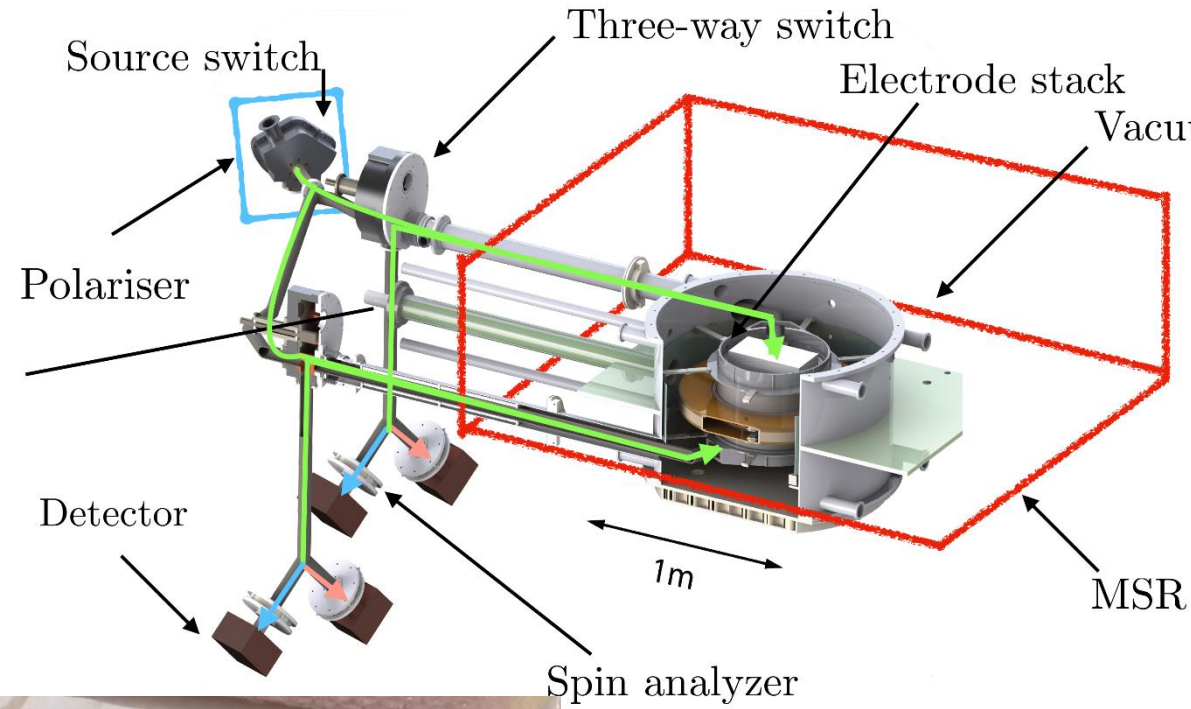


(b) Simulated charging current during the high voltage switch.

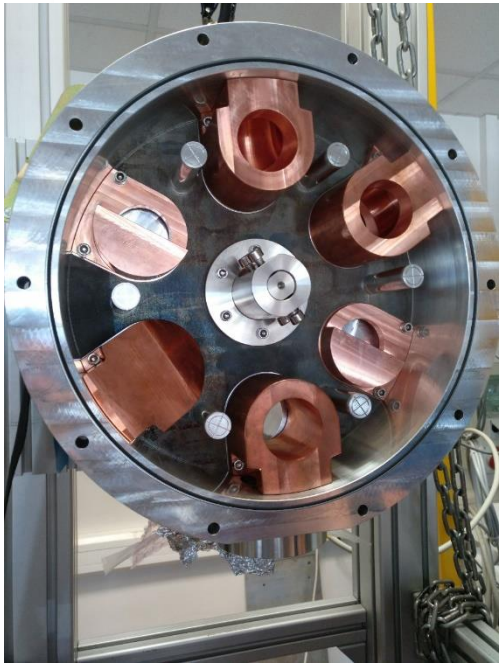
Lucas Hopf, 2020

Quick reminder

Installation at ILL
(Phase I)

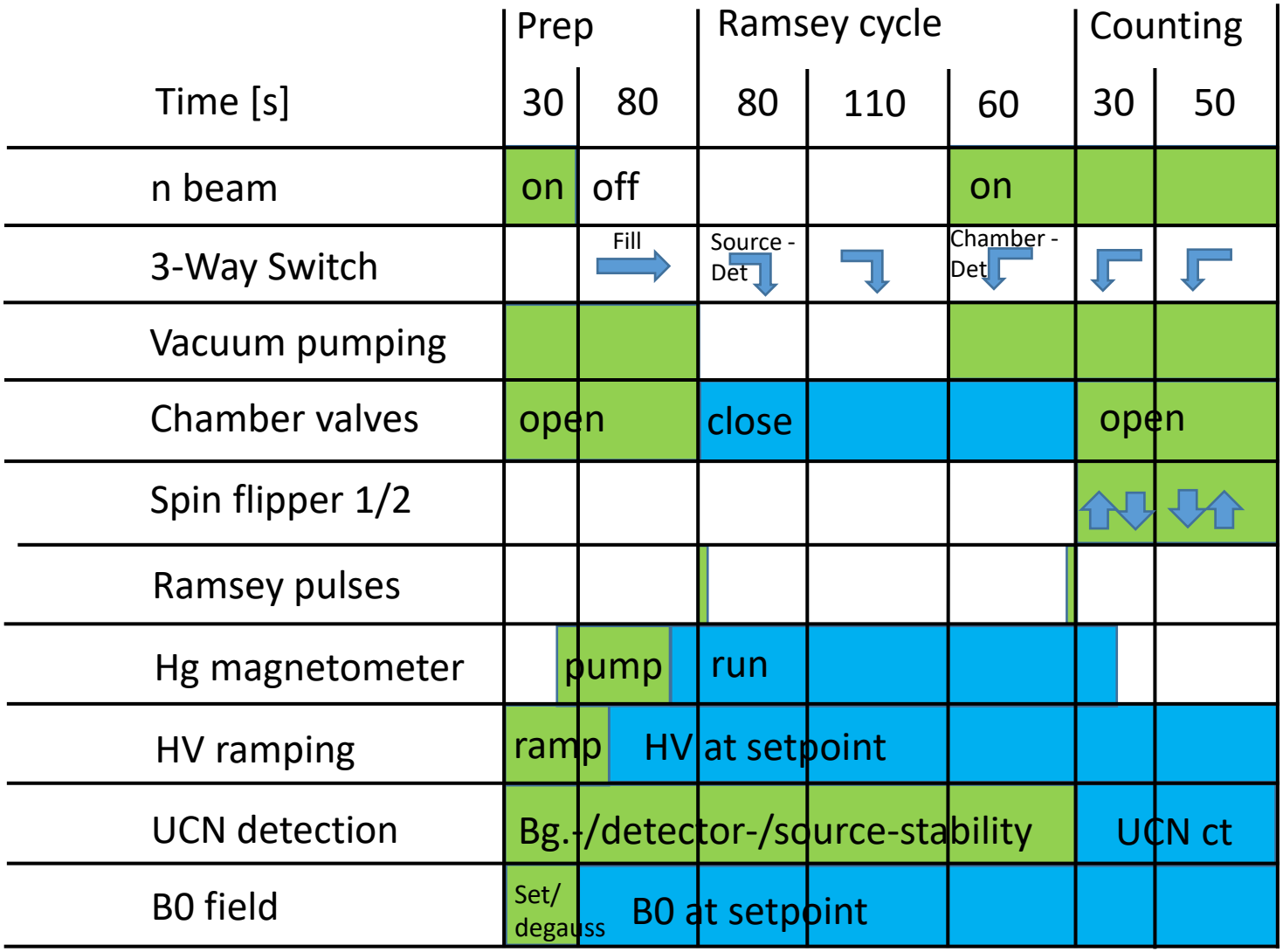


2 of 20 NiMo coated guide sections



Three-way switch with copper diverters

Operation sequence



Summary

- Central components of panEDM reworked for SuperSUN
- Electrodes split into structure and substrate to aid development of various materials and coatings
- HV system with floating leakage current is approaching completion

Next steps:

- Production of missing parts spring 2021
- Assembly of central components in place with mapping of parts spring/summer 2021