Beam Position Monitors for Storage Rings

Falastine Abusaif

Juelich Forschungszentrum/IKP-2/On Behalf of JEDI Collaboration

June 4th, 2018

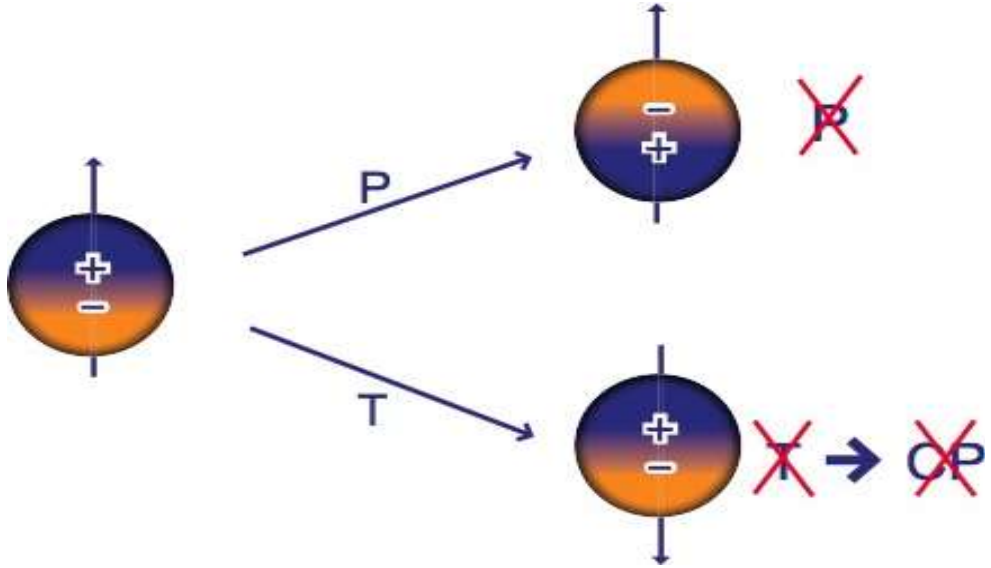
Our existence in the universe!

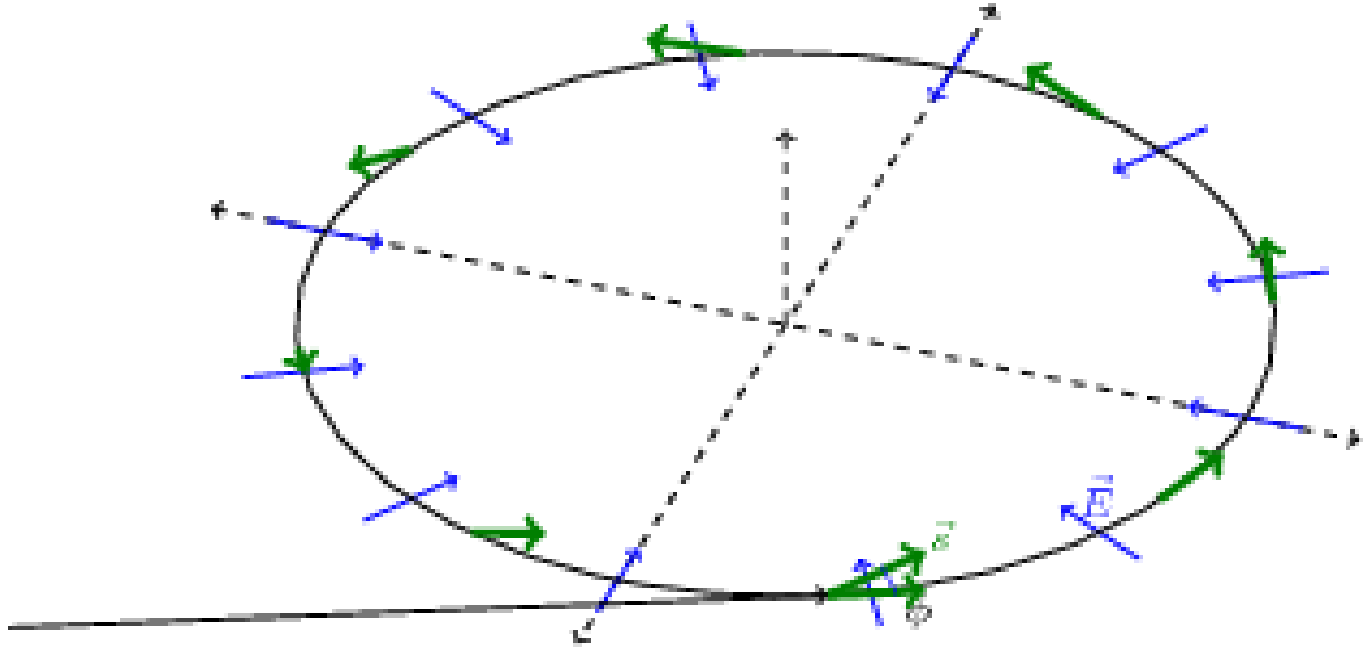
$\eta \sim 6*10^{-10}$!

CP **violation could answer !**

JÜLICH Forschungszentrum

Why electric dipole moment in particular?





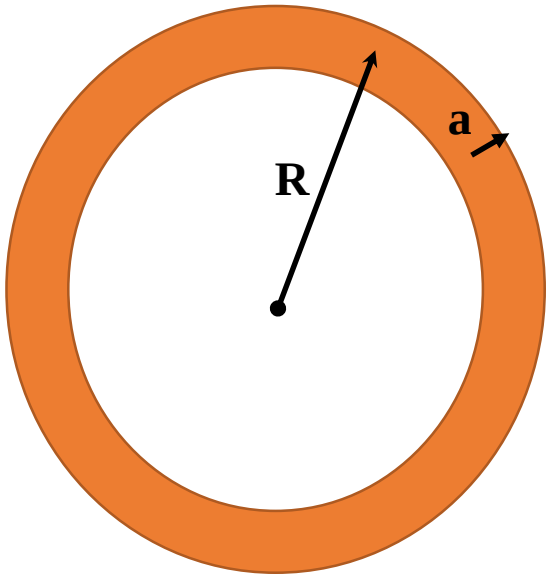
$$\frac{d\vec{s}}{dt} \propto d.\vec{E} \times \vec{S}$$

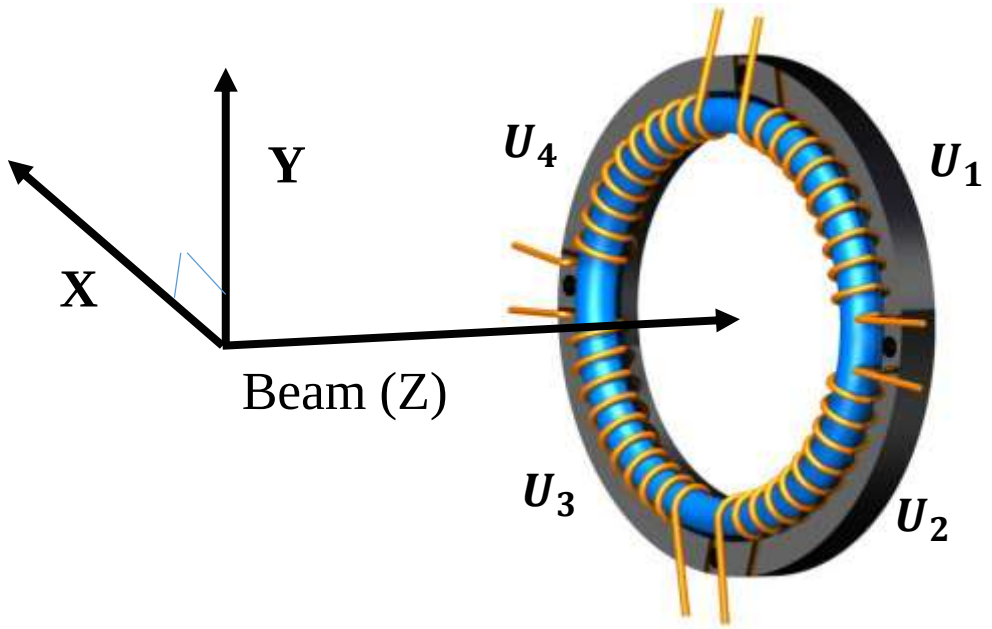
JÜLICH Forschungszentrum

Importance of BPM's

- Small EDM signal
- Beam center of mass
  - Longitudinal shape of the bunch
- Beam closed orbit

Theoretical background





* $\frac{\Delta U_{hor}}{\sum_{i=1}^{4} U_i} = \frac{(U_1 + U_2) - (U_3 + U_4)}{\sum_{i=1}^{4} U_i}$

* $\frac{\Delta U_{ver}}{\sum_{i=1}^{4} U_i} = \frac{(U_1 + U_4) - (U_3 + U_2)}{\sum_{i=1}^{4} U_i}$

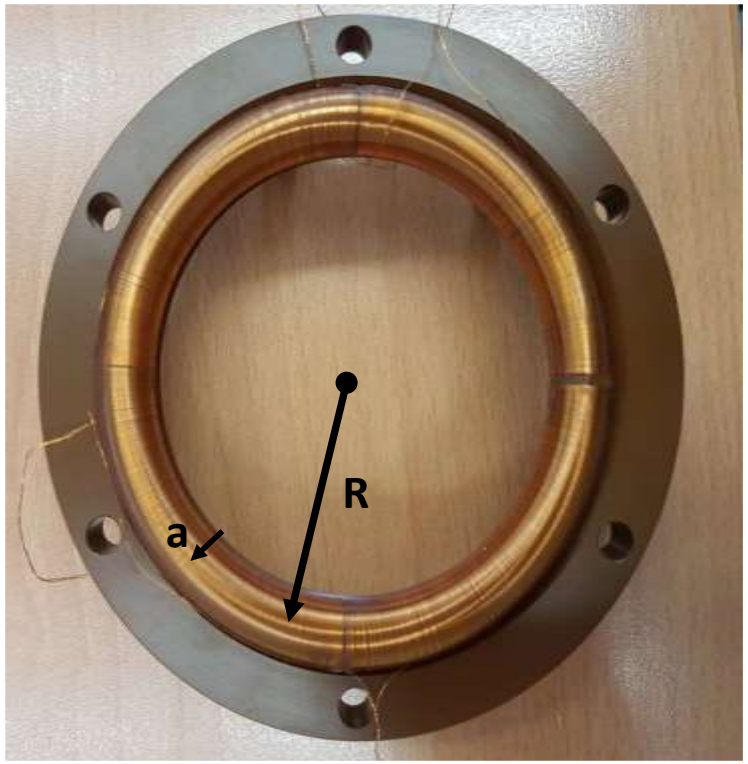
* $$\frac{\Delta U_{hor}}{\sum_{i=1}^{4} U_i} = c_1 x - c_2\left(x^3 - 3y^2 x\right) + c_3\left(x^5 - 10y^2 x^3 + 5y^4 x\right) + \ldots$$

* $$\frac{\Delta U_{ver}}{\sum_{i=1}^{4} U_i} = c_1 y - c_2\left(y^3 - 3x^2 y\right) + c_3\left(y^5 - 10x^2 y^3 + 5x^4 y\right) + \ldots$$

Construction

Winding process

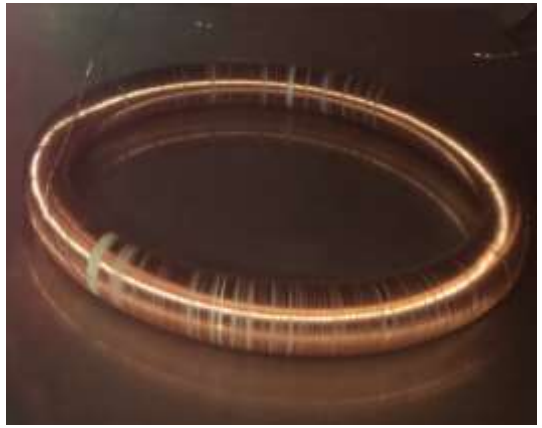
$R = 58.6\ mm$
$\mathrm{a} = 6.4\ \mathrm{mm}$



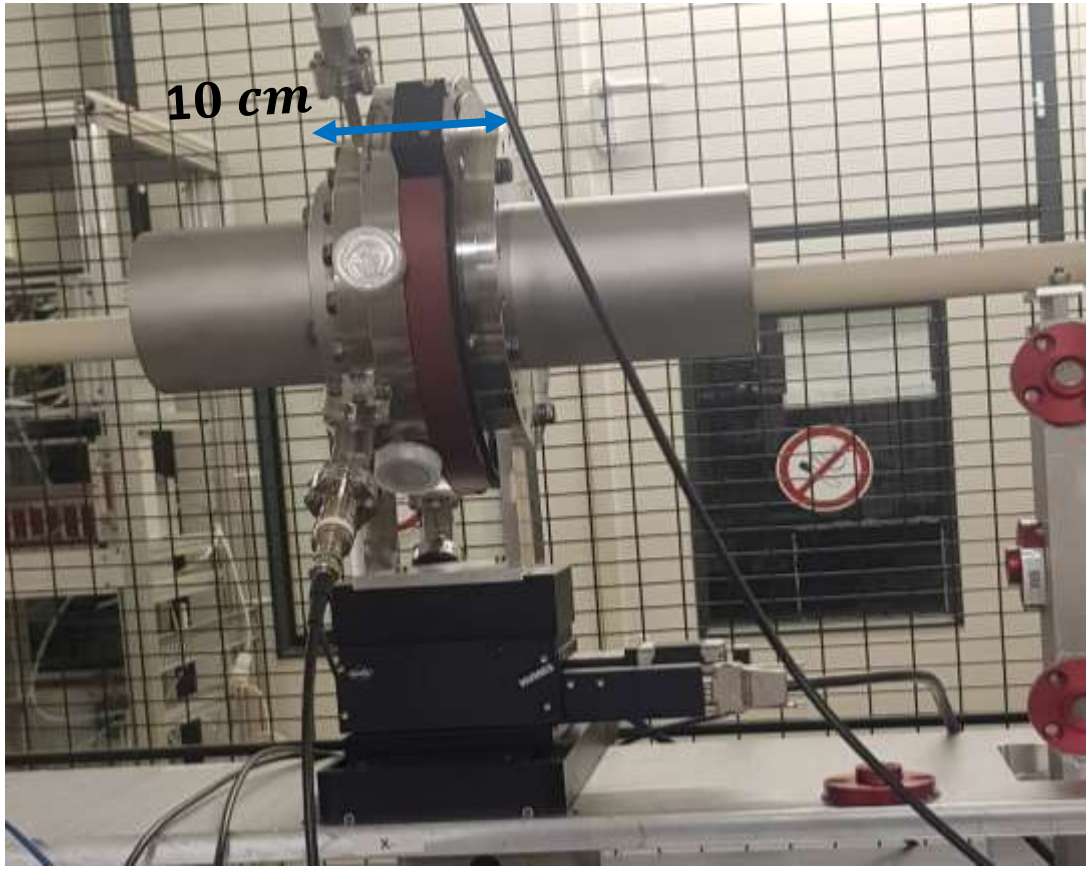
$R = 40\ mm$
$\mathrm{a} = 5\ \mathrm{mm}$

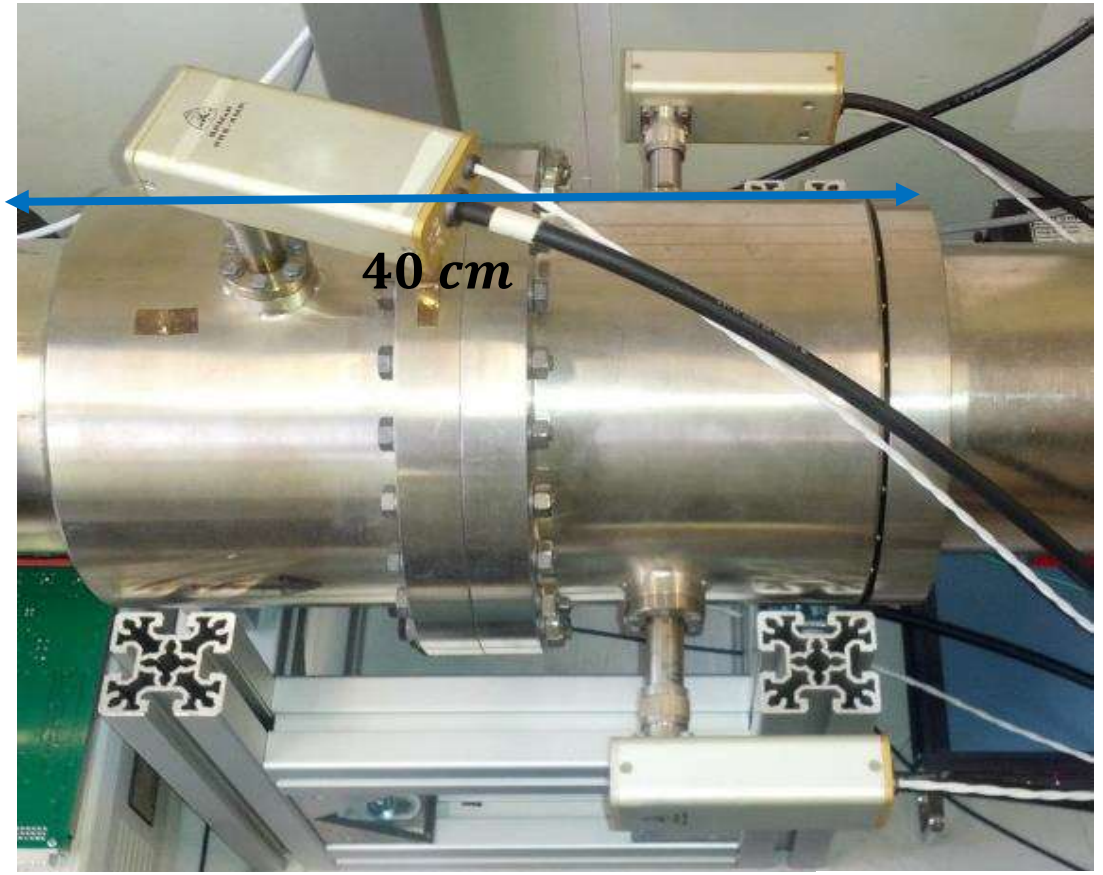
JÜLICH Forschungszentrum

Assembly work



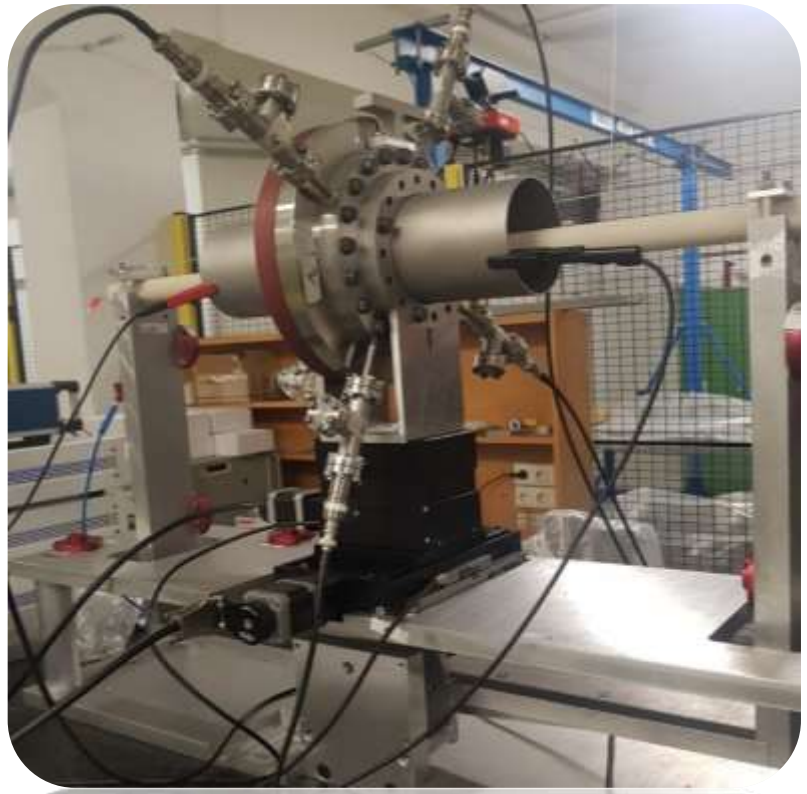
Reduction in size





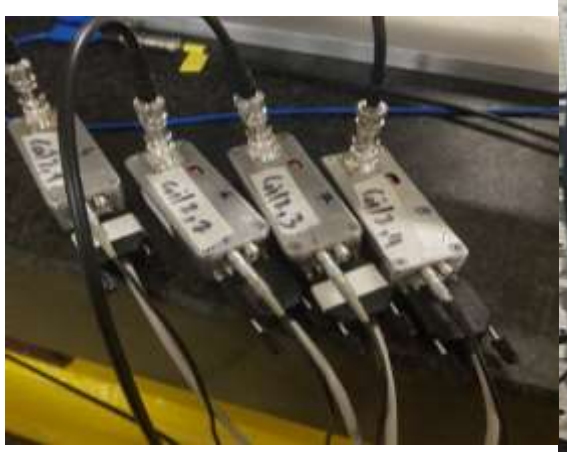
JÜLICH Forschungszentrum

Position test

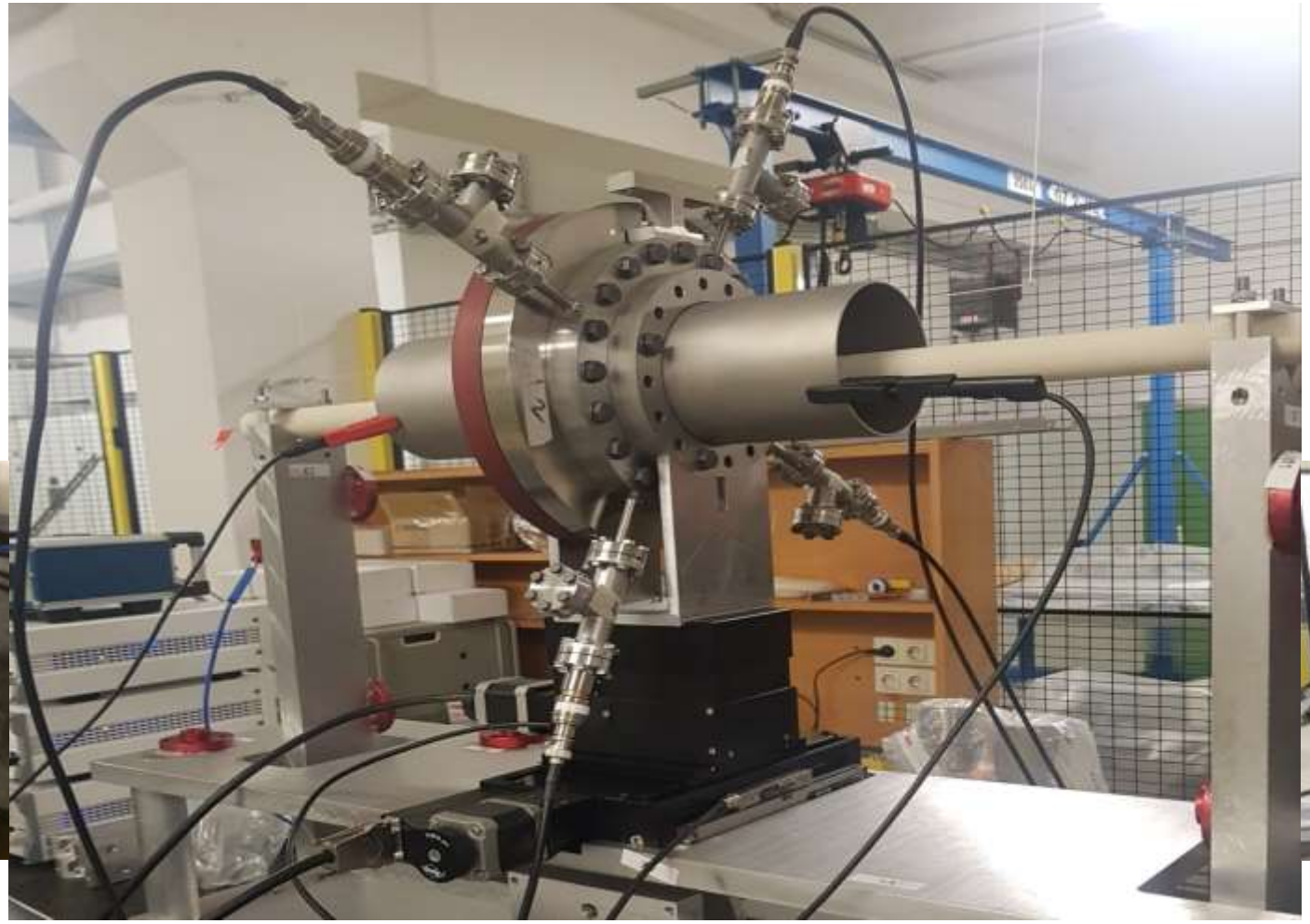


JÜLICH Forschungszentrum

Calibration test



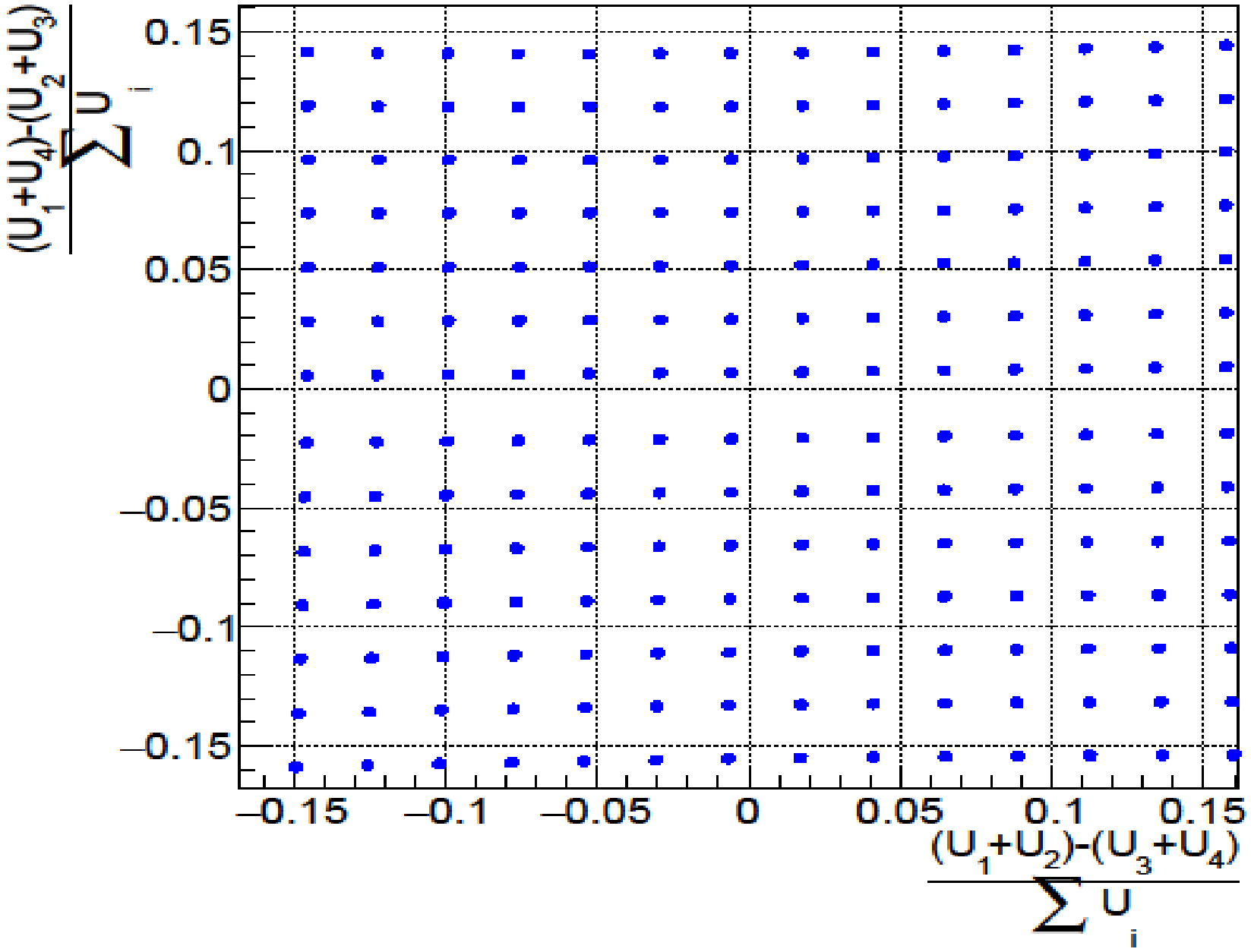
Pre-amplifiers



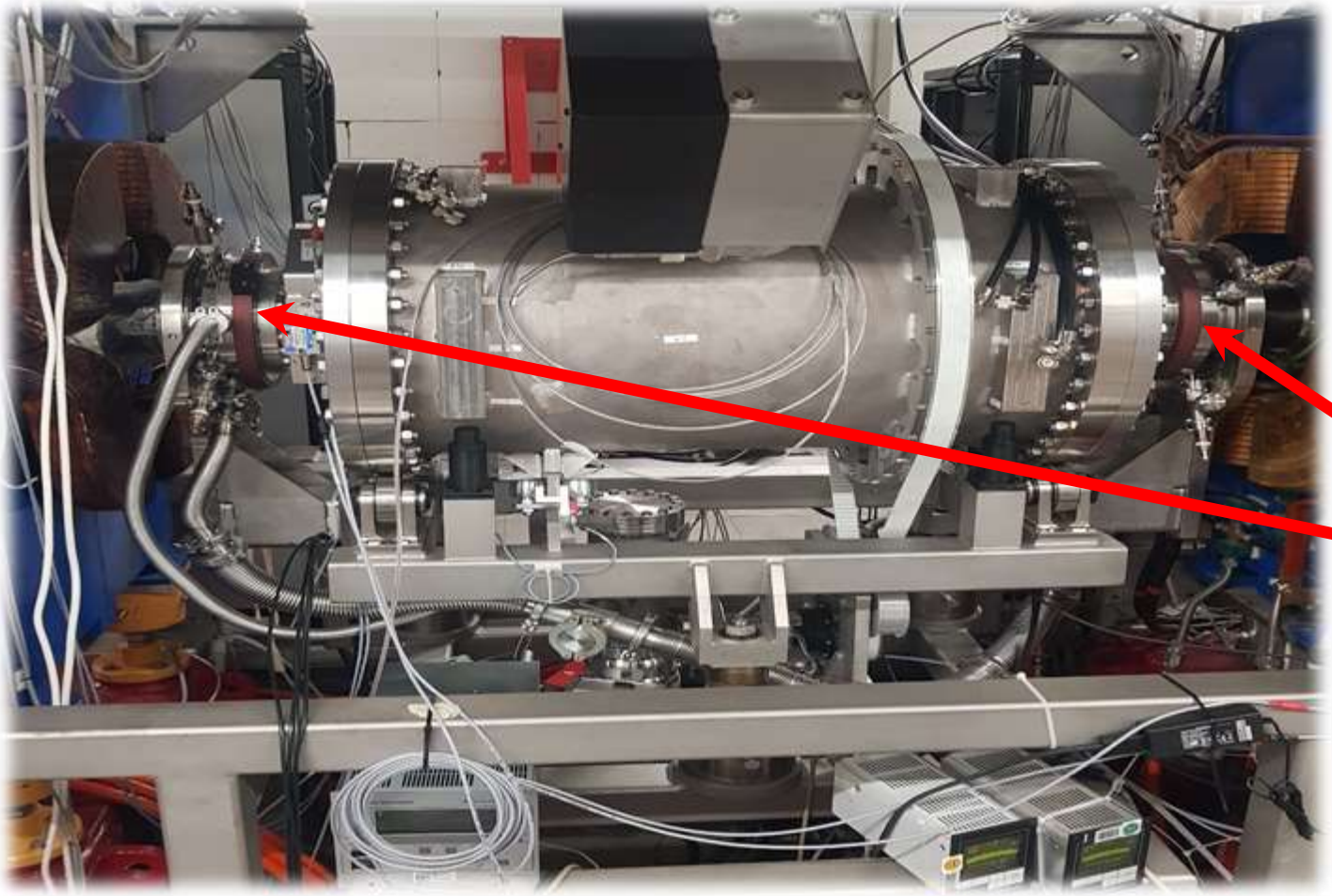
Lock-in amplifiers

JÜLICH Forschungszentrum

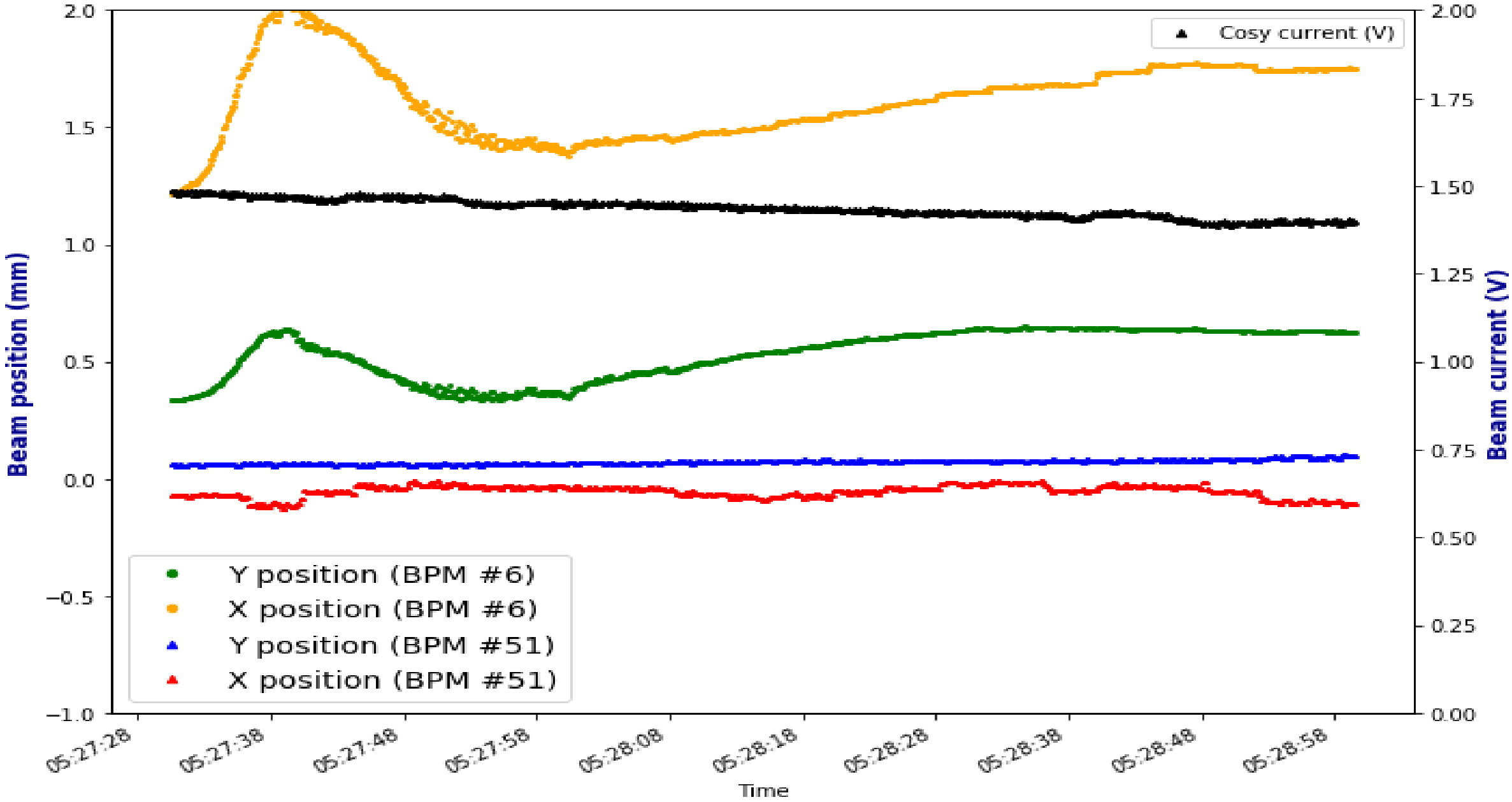
Vertical and horizontal voltage ratios



Installation

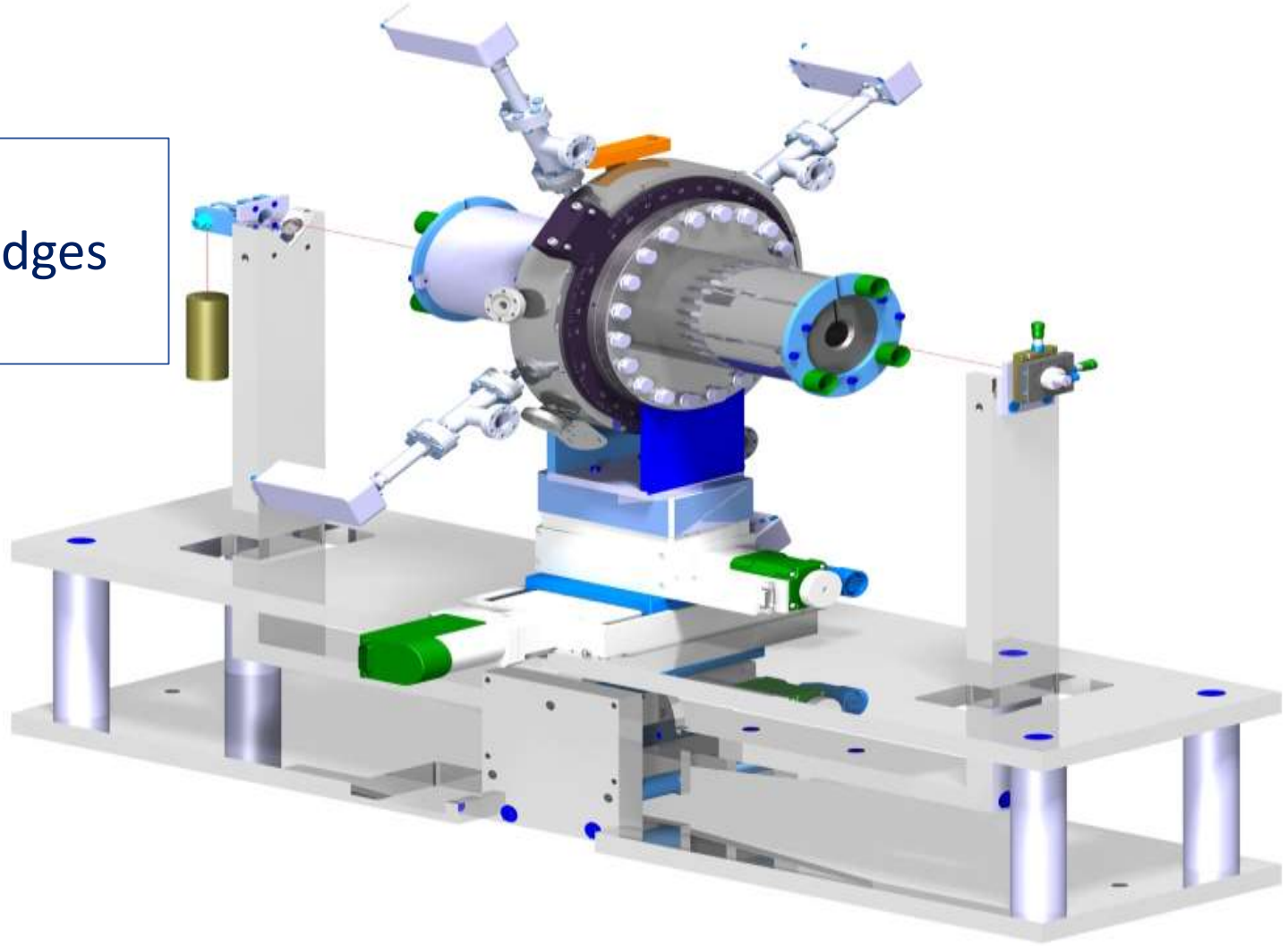


JÜLICH Forschungszentrum


Cosy current (V)
Beam position (mm)
Beam current (V)
Y position (BPM #6)
X position (BPM #6)
Y position (BPM #51)
X position (BPM #51)
Time
05:27:28
05:27:38
05:27:48
05:27:58
05:28:08
05:28:18
05:28:28
05:28:38
05:28:48
05:28:58

Future upgrades

More precise positions:
With the addition of some knife edges around the wire

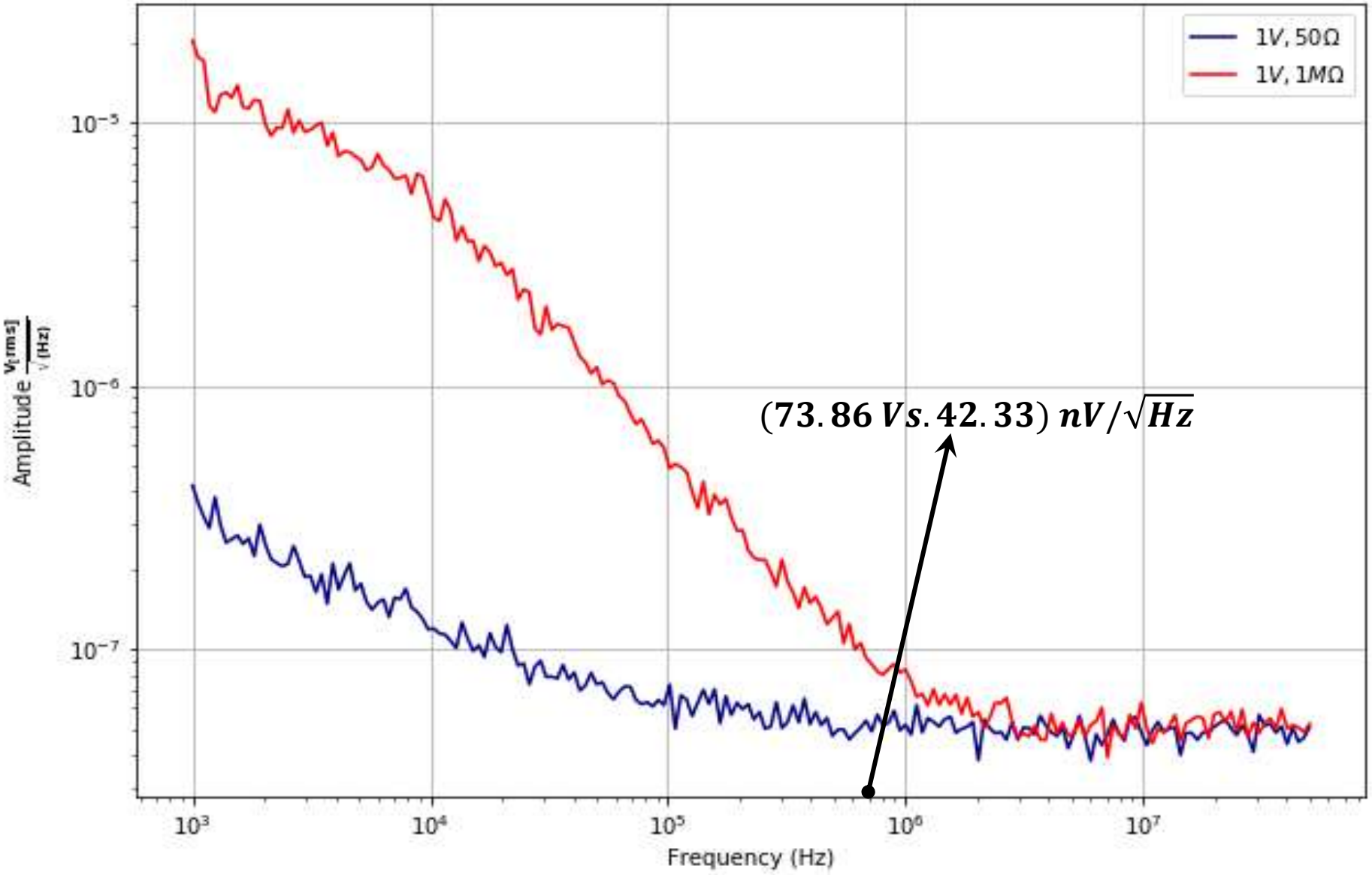


JÜLICH Forschungszentrum

Controlling Noise sources in the experiment:

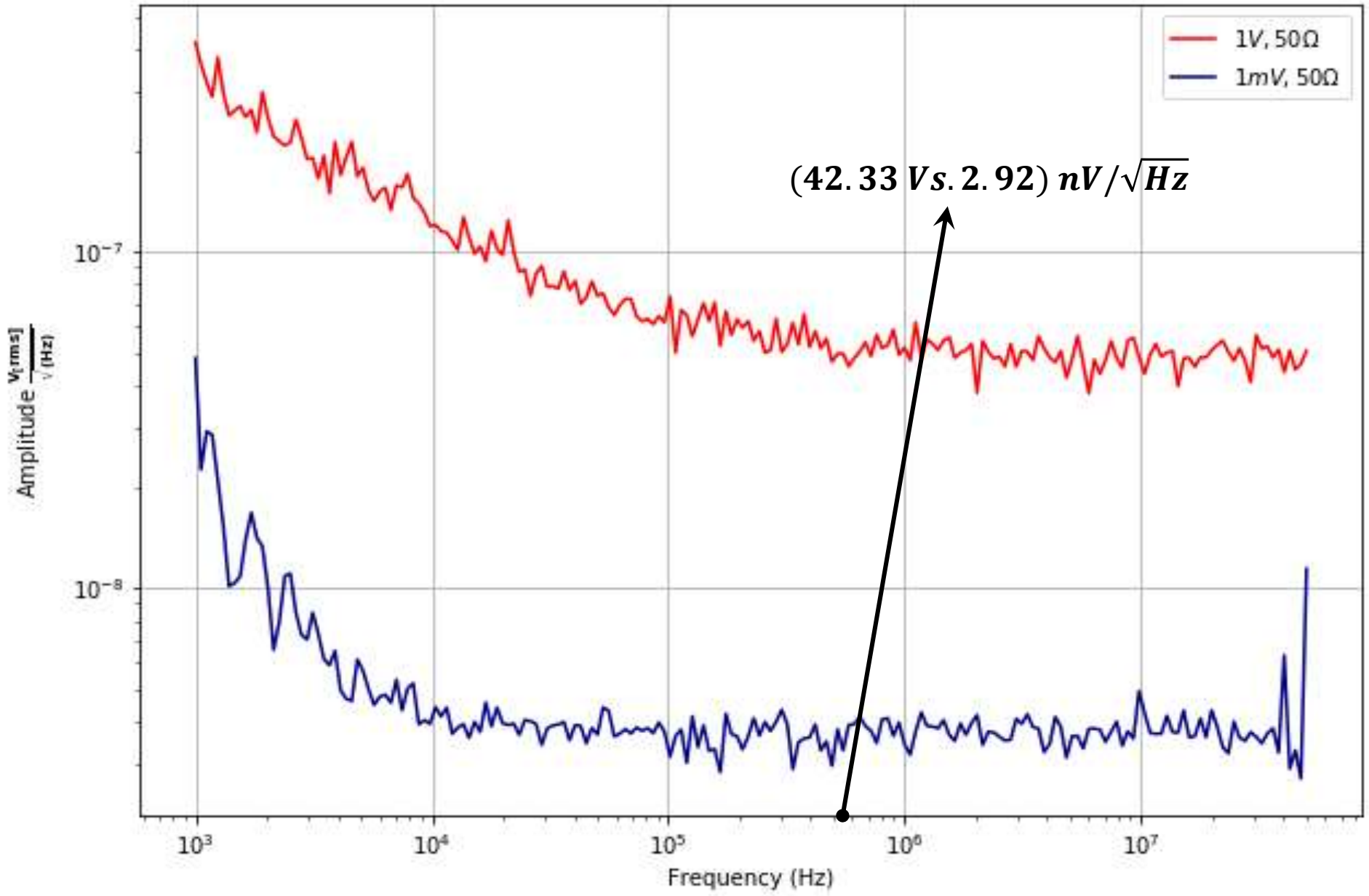
- Know potential sources
- Measure/calculate the noise
- Suppress/minimize the noise

Measured noise at high and low input impedances of the lock-in amplifier



JÜLICH Forschungszentrum

Measured noise at high and low input voltage ranges in the lock-in amplifier



JÜLICH Forschungszentrum

Not only the lock-in amplifier…

The pre-amplifier also produces noise:

- Current noise $1.62\ nA/\sqrt{Hz} - 1.67\ pA/\sqrt{Hz} \sim 446\ nV/\sqrt{Hz} - 462\ nV/\sqrt{Hz}$
- Voltage noise $7.69\ nV/\sqrt{Hz} - 508.28\ nV/\sqrt{Hz}$
- Conventional pre-amplifier produces voltage noise $(18.0 - 20.11)\ nV/\sqrt{Hz}$

More reliable Signal:

- Control the current strength at the test-stand **(0.1 – 1.0 mA)**
- Modify the algorithm in the Epics to avoid giving position readouts when there is no beam!

Summary

- Rogowski coil BPM's are highly sensitive and compact devices
- Currently, the greatest goal is to have a perfectly produced, tested, and calibrated coils with zero issues
- In the final prototype ring, we would have several of such monitors for distinct experimental purposes

Coil parameters

R = 58.625 mm
a = 6.375 mm
n = 434
s = 150 µm
Material: PEEK

Sensitivities:

- $c_1 = \frac{2}{\pi\sqrt{R^2-a^2}}$

$= 0.01092 mm^{-1}$

- $c_2 = \frac{Ra^2}{3\pi\left(R^2-a^2\right)^{\frac{5}{2}}\left(R-\sqrt{R^2-a^2}\right)}$

$= 1.0817 \times 10^{-6} mm^{-3}$

- $c_3 = \frac{Ra^2(4R^2+3a^2)}{20\pi\left(R^2-a^2\right)^{\frac{9}{2}}\left(R-\sqrt{R^2-a^2}\right)}$

$= 1.9511 \times 10^{-10} mm^{-5}$

Calibration parameters

- $x_{off} = 3.67\ mm$
- $y_{off} = 6.31\ mm$
- $\emptyset = 1.9°$
- $g_2 = 93\%$
- $g_3 = 77\%$
- $g_4 = 79\%$
- $s_1 = 2.13$