

STUDY OF THE ELECTRICAL CENTER OF A RESONANT CAVITY BEAM POSITION MONITOR (RF-BPM) AND ITS INTEGRATION WITH THE A MAIN BEAM QUADRUPOLE FOR ALIGNMENT PURPOSES

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Outline

□ The Ph.D. research

- CLIC experiment
- PACMAN project
- BPM-MBQ alignment module
- BPM stretched-wire measurements
- Electromagnetic offset fiducialization

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The CLIC experiment at CERN



What is CLIC?

The **Compact Linear Collider (CLIC)** study is an international collaboration working on a concept for a machine to collide electrons and positrons at energies up to 3TeV.

The objective:

Achieve the **highest number of collisions** at a nano-metric beam size

By means of...

The **pre-alignment** between the accelerator components in the micrometric regime and control the beam misalignment with a nanometric stabilization system

The CLIC experiment at CERN



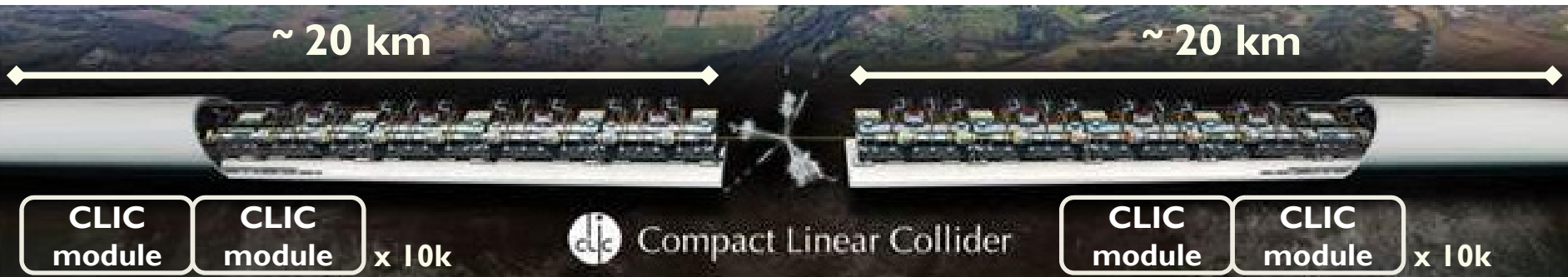
Parameter	Symbol	Unit	Stage 1	Stage 2	Stage 3
Centre-of-mass energy	\sqrt{s}	GeV	500	1400	3000
Repetition frequency	f_{rep}	Hz	50	50	50
Number of bunches per train	n_b		354	312	312
Bunch separation	Δt	ns	0.5	0.5	0.5
Accelerating gradient	G	MV/m	80	80/100	100
Total luminosity	\mathcal{L}	$10^{34} \text{ cm}^{-2}\text{s}^{-1}$	2.3	3.2	5.9
Luminosity above 99% of \sqrt{s}	$\mathcal{L}_{0.01}$	$10^{34} \text{ cm}^{-2}\text{s}^{-1}$	1.4	1.3	2
Main tunnel length		km	13.2	27.2	48.3
Charge per bunch	N	10^9	6.8	3.7	3.7
Bunch length	σ_z	μm	72	44	44
IP beam size	σ_x/σ_y	nm	200/2.6	$\sim 60/1.5$	$\sim 40/1$
Normalised emittance (end of linac)	ϵ_x/ϵ_y	nm	2350/20	660/20	660/20
Normalised emittance (IP)	ϵ_x/ϵ_y	nm	2400/25	—	—
Estimated power consumption	P_{wall}	MW	272	364	589

Emittance preservation is a key issue!

Large scale accelerators

Sub- μm beam size

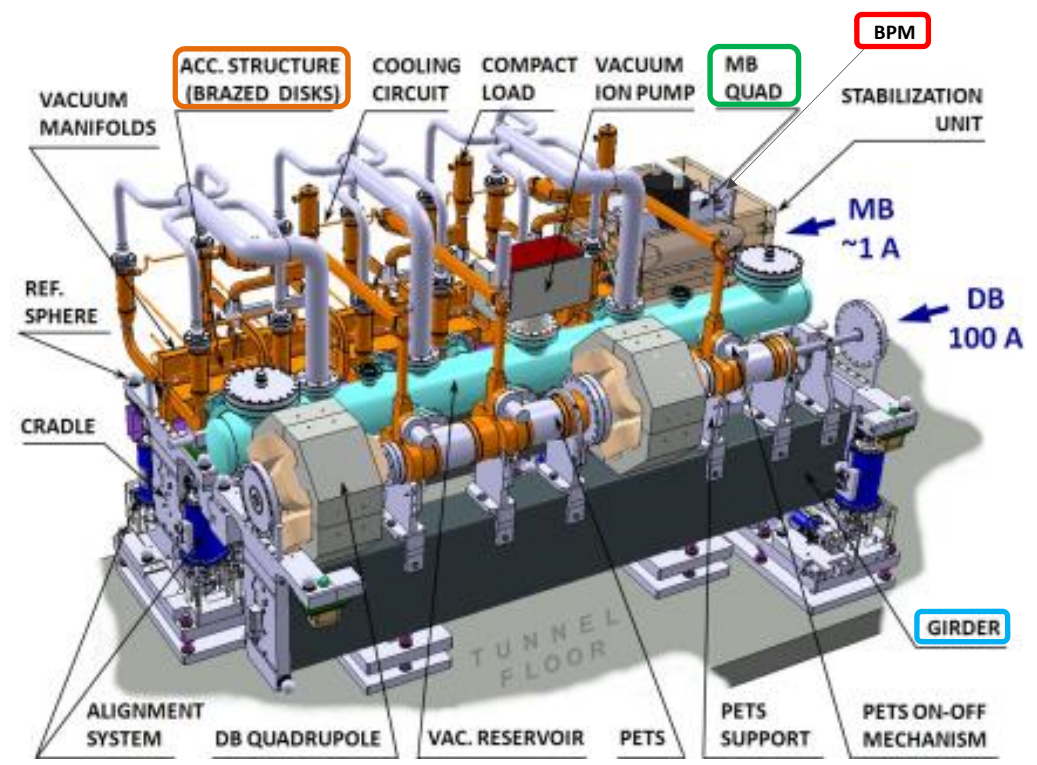
CLIC modules and pre-alignment



Accelerating structure
Normal conducting cavity



Main Beam Quadrupole



Beam Position Monitor (BPM)



Alignment on a common girder

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Why PACMAN?



CLIC alignment strategy

- **Fiducialisation of the components**
- **Pre-alignment of the components on the girder (module)**
- Module-module alignment into the tunnel

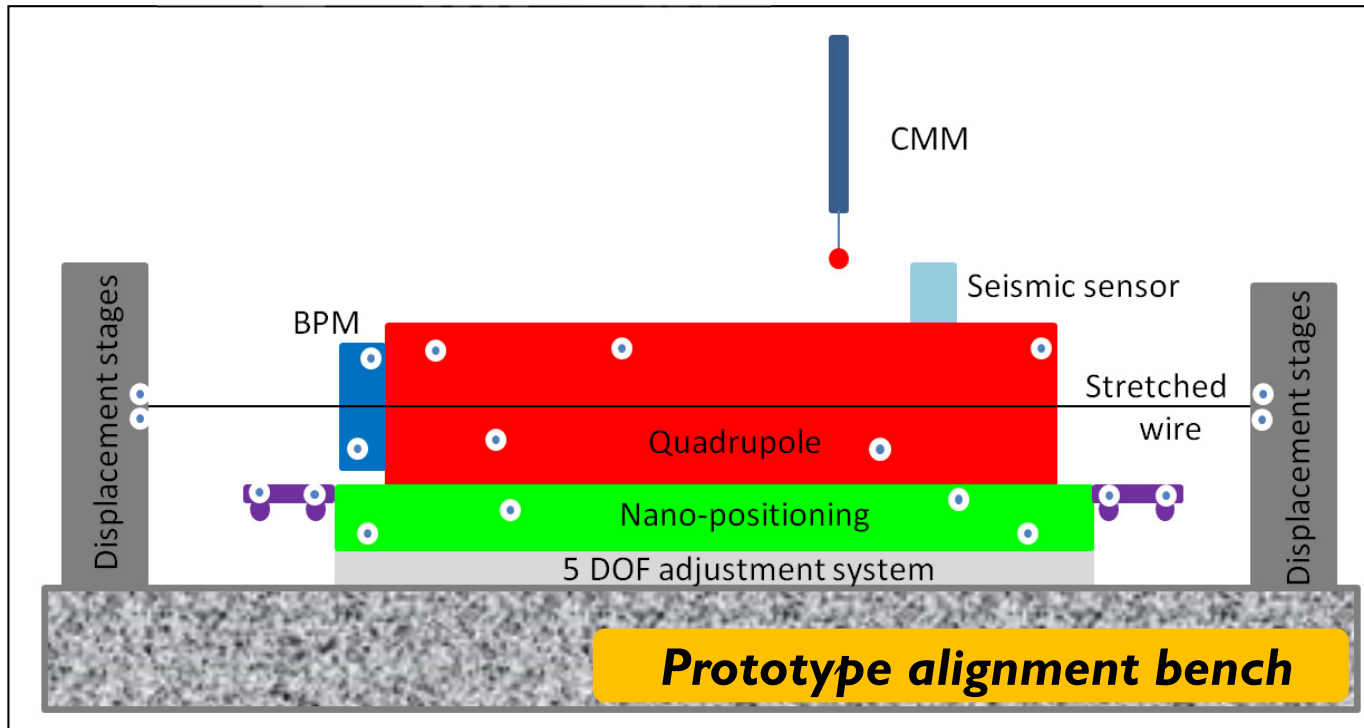
PACMAN

Particle Accelerator Components' Metrology and Alignment to the Nanometre scale

Goal

Wire-based methodology to realize the **pre-alignment**

The PACMAN project



PACMAN Key activities:

- Integration, ultra-high precision engineering and manufacturing;
- **Magnetic measurements** with the vibrating wire technique;
- Determination of the electromagnetic center of the **BPM and RF structure** using a stretched-wire;
- **Absolute methods of measurements:** new measuring head for coordinate measuring machine; (CMM). Or combination of laser scanner (FSI) and micro-triangulation measurements as alternatives;
- Improve **seismic sensors** and study ground motion;
- **Nano-positioning** of the quadrupole magnet and the BPM.

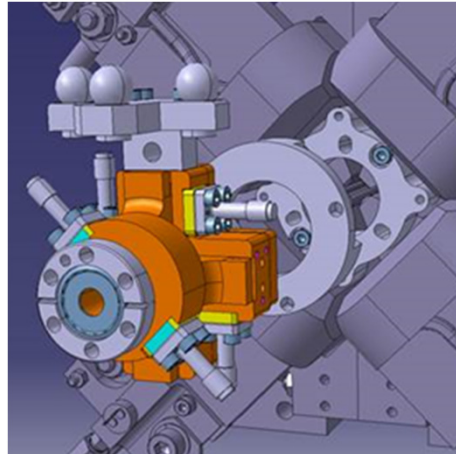
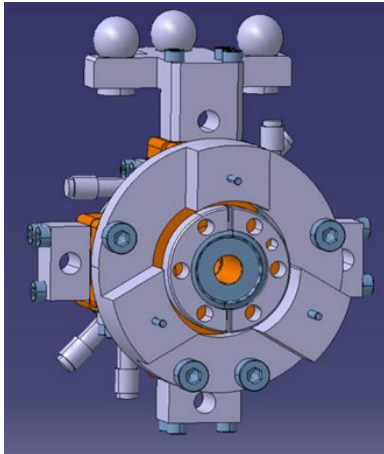
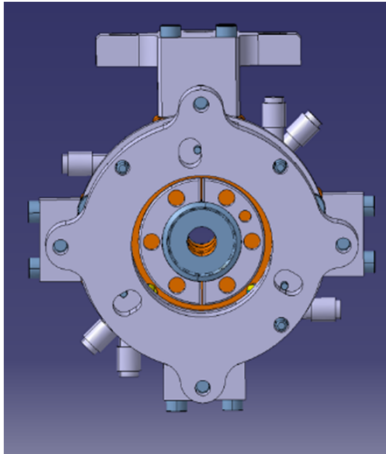
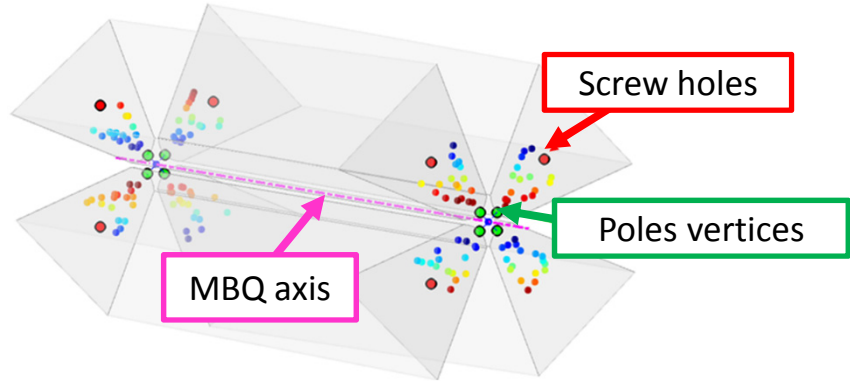
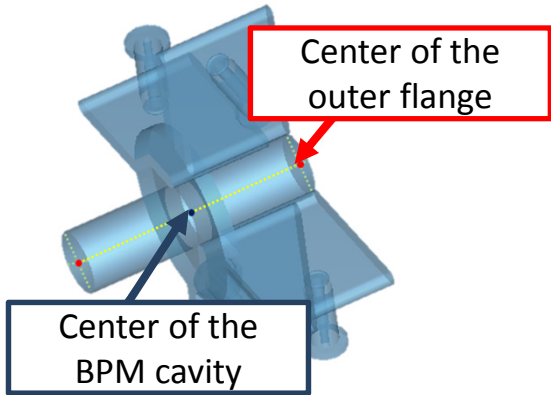
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BPM-MBQ Integration

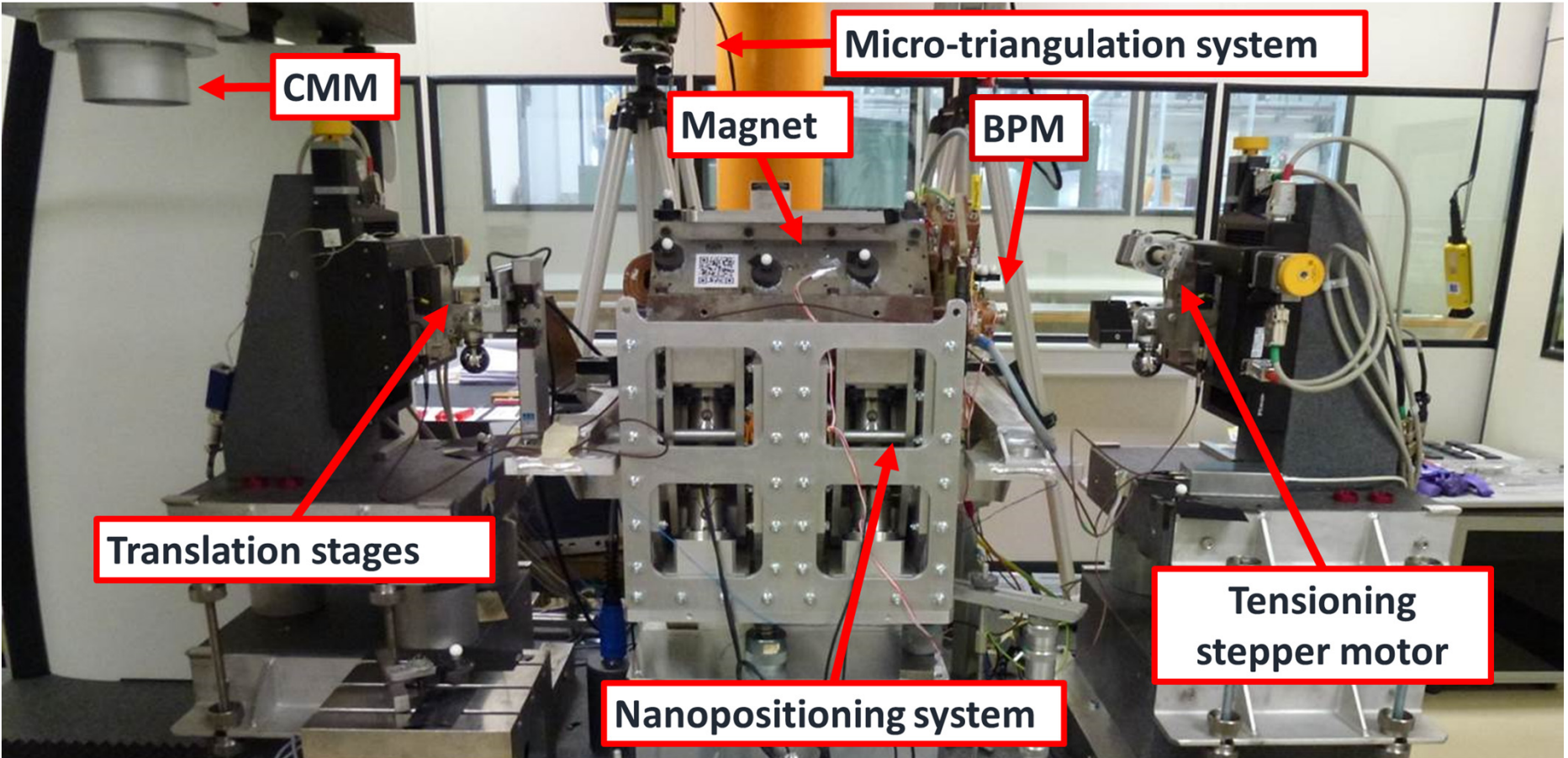
Mechanical Integration



Two complementary mechanical parts to attach the **BPM** and the **MBQ** were designed and manufactured. The former attached to the quadrupole has three concentric ellipses that center the mechanical axis of the quadrupole; the latter interfaces the BPM through three pins matching the slotted holes on the complementary part.

BPM-MBQ Fiducialization

Electromagnetic offset



The centers of the quadrupole and the BPM are located using respectively **vibrating and stretched wire measurements methodologies**

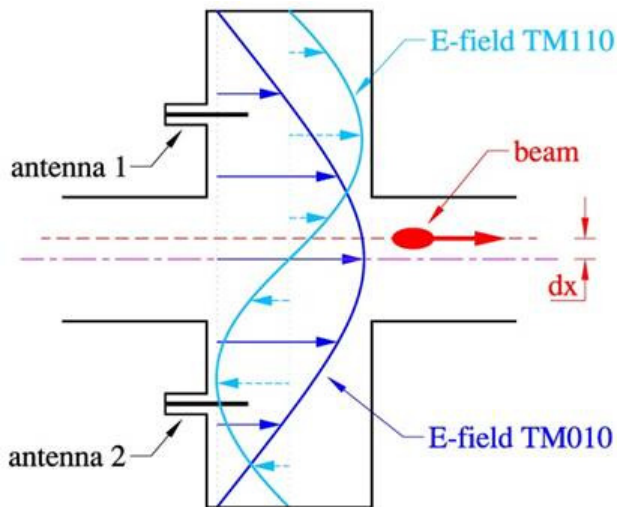
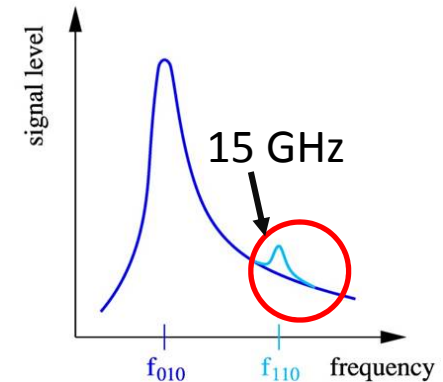
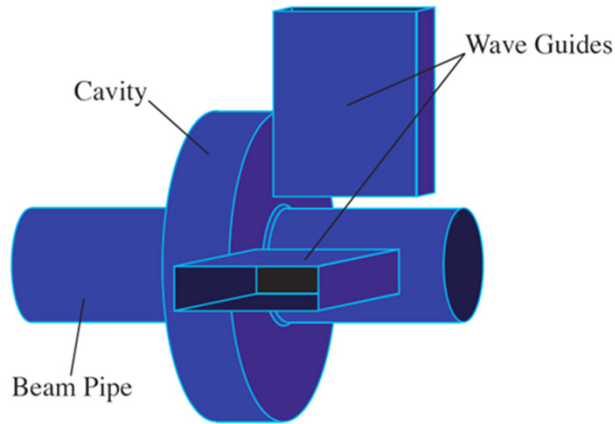
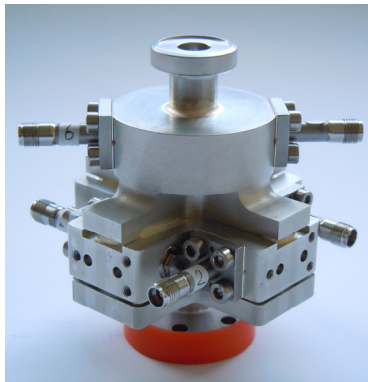
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Cavity RF-BPMs

The Cavity RF BPM is not excited by external sources, but by the beam itself.

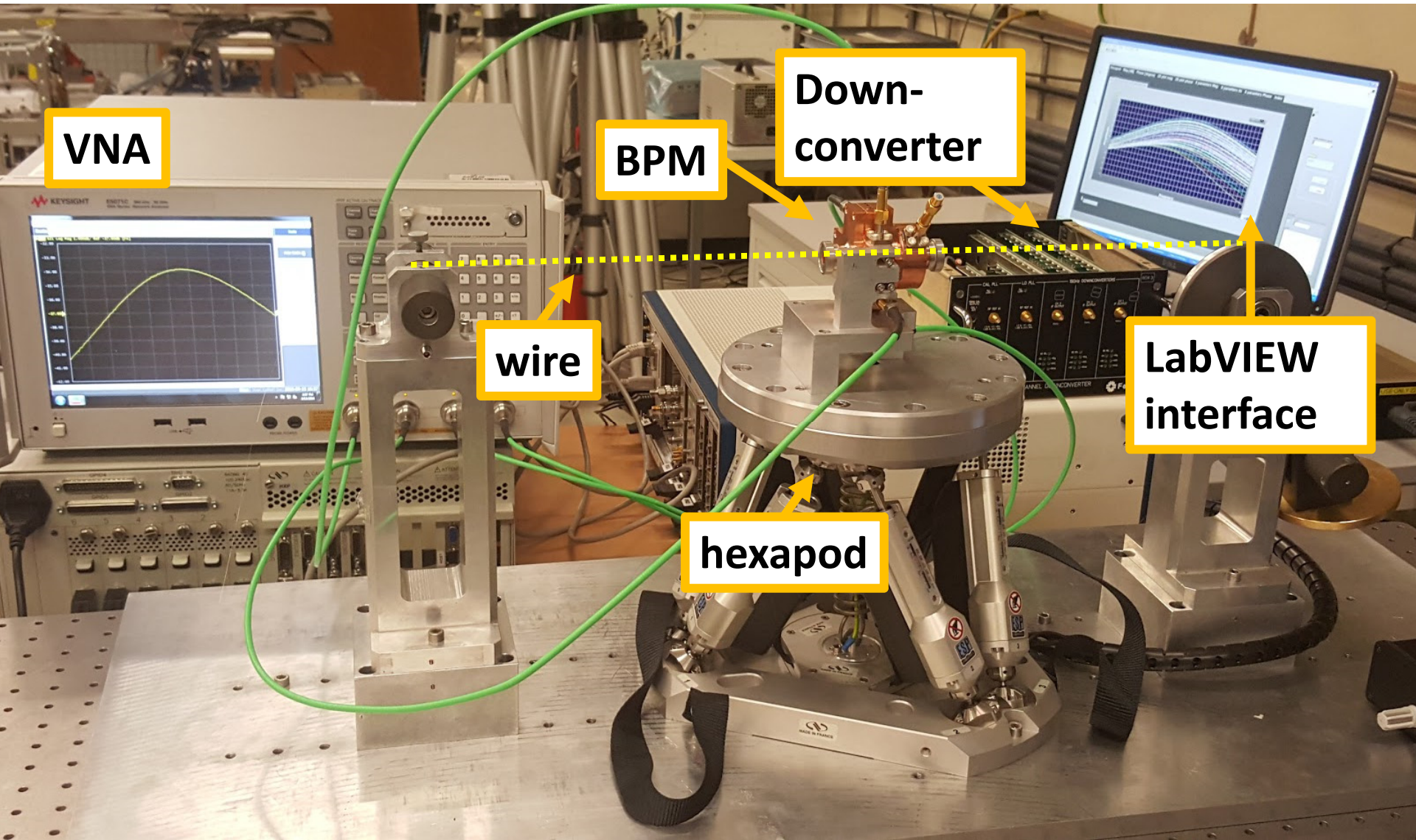


If the dipole mode (TM110) is discriminated, the beam displacement around the cavity's center is **proportional** to the transverse component of the electric field.

Dipole mode

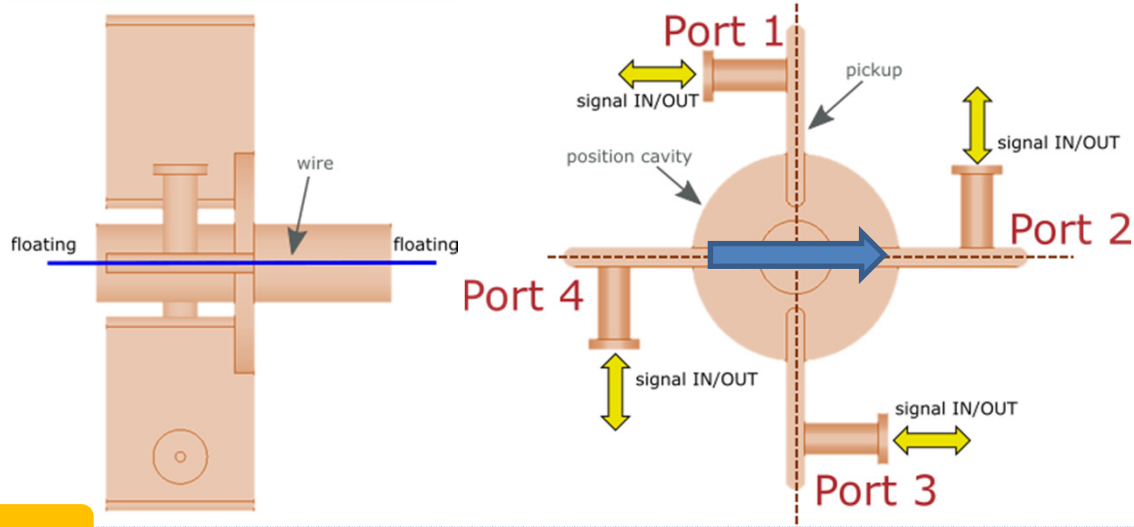
$$V_{out} \propto p$$

BPM Test Bench

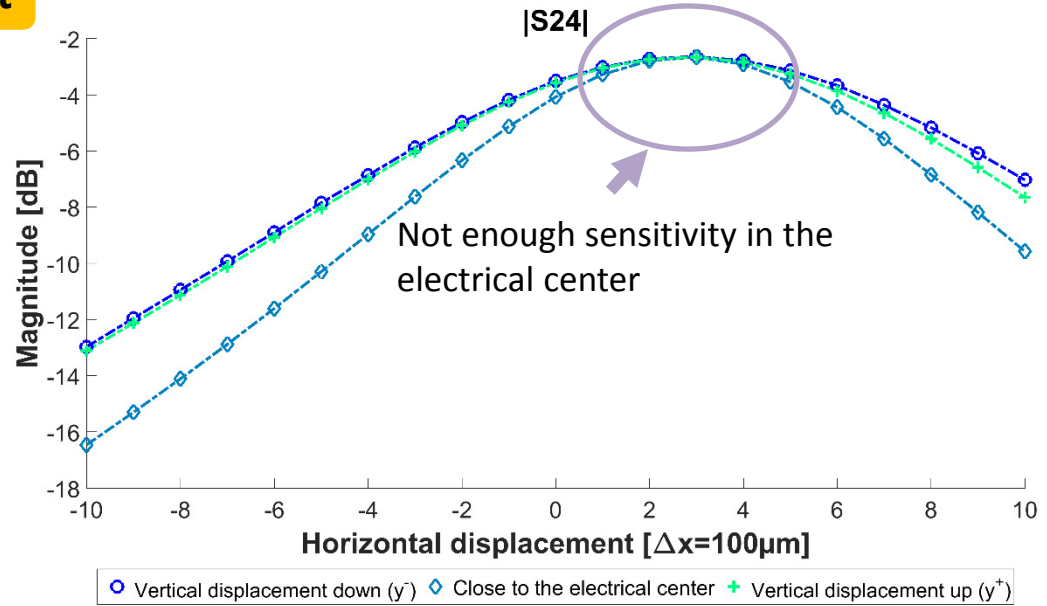
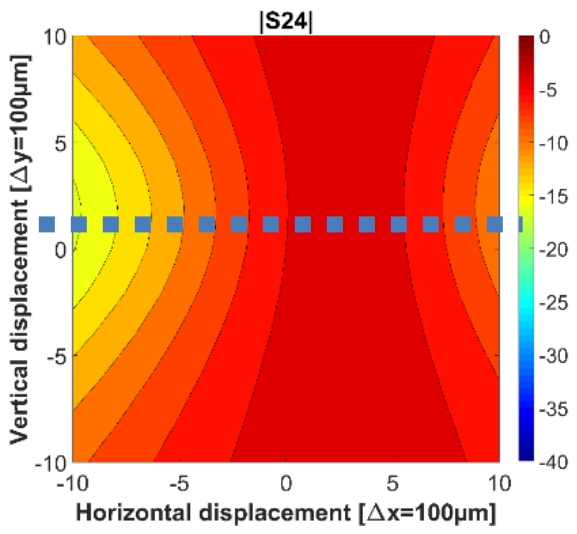


Magnitude analysis - Horizontal

- S-paramters investigation:
- Magnitude analysis
 - Horizontal place

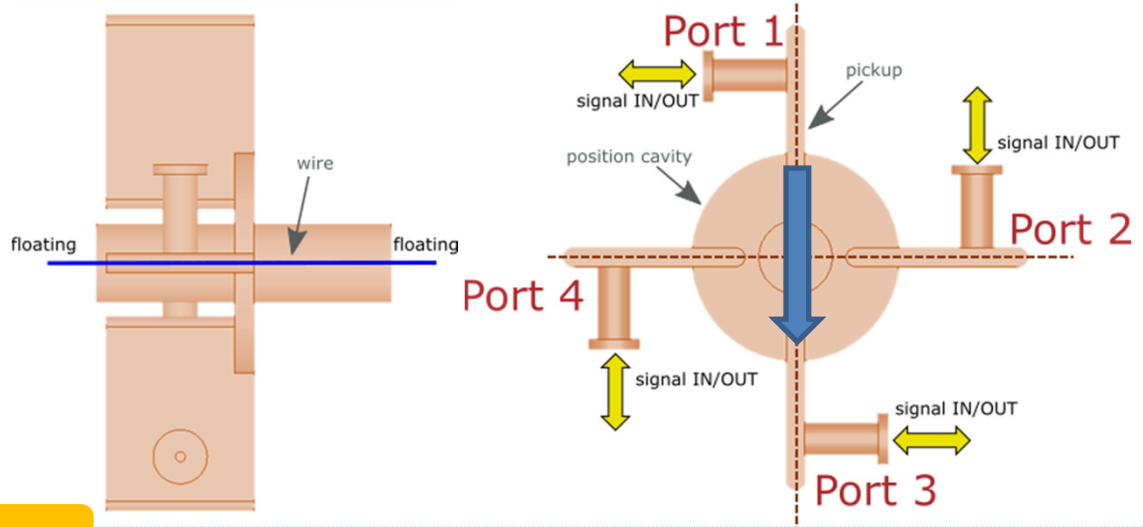


Opposite ports - magnitude argument

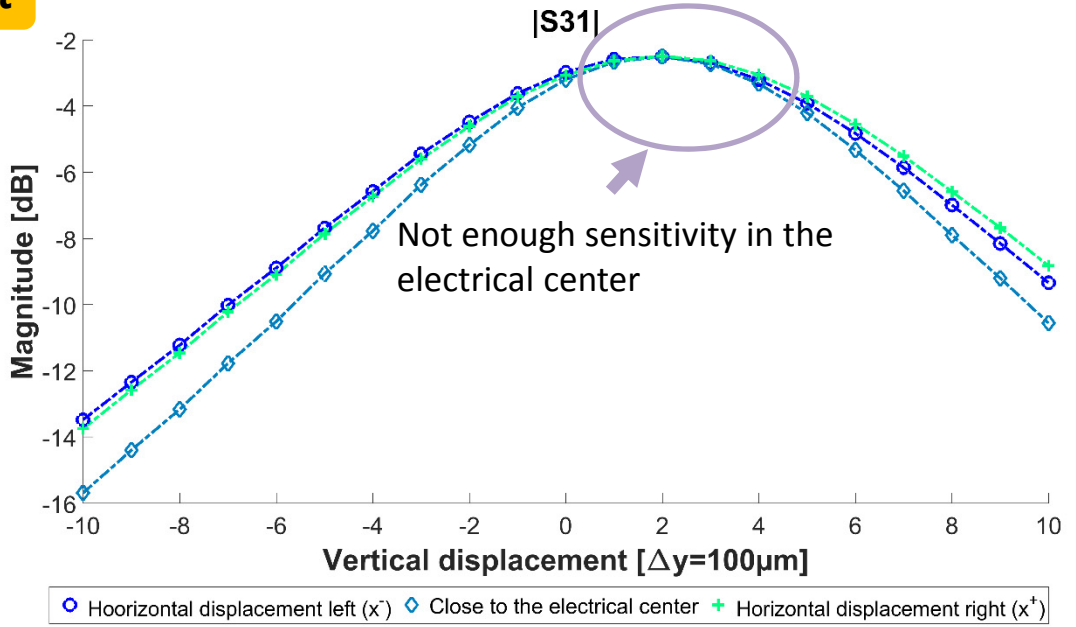
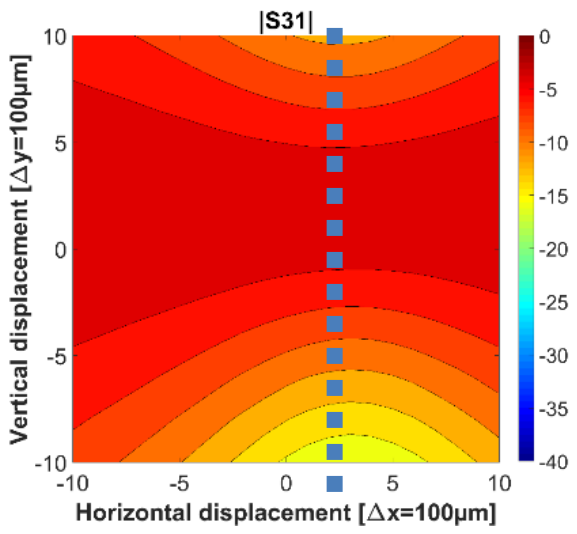


Magnitude analysis - Vertical

- S-paramters investigation:
- Magnitude analysis
 - Vertical place



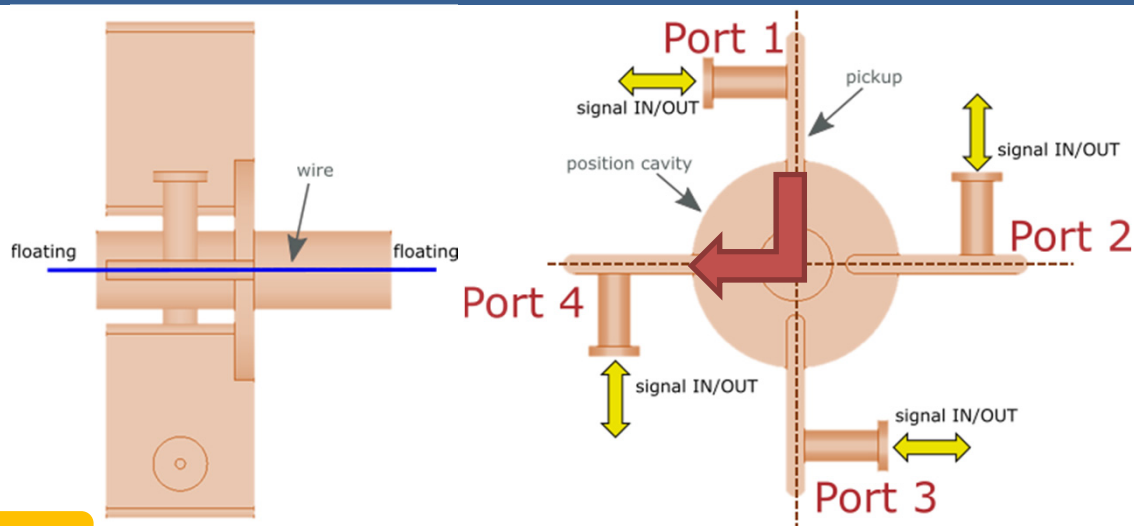
Opposite ports - magnitude argument



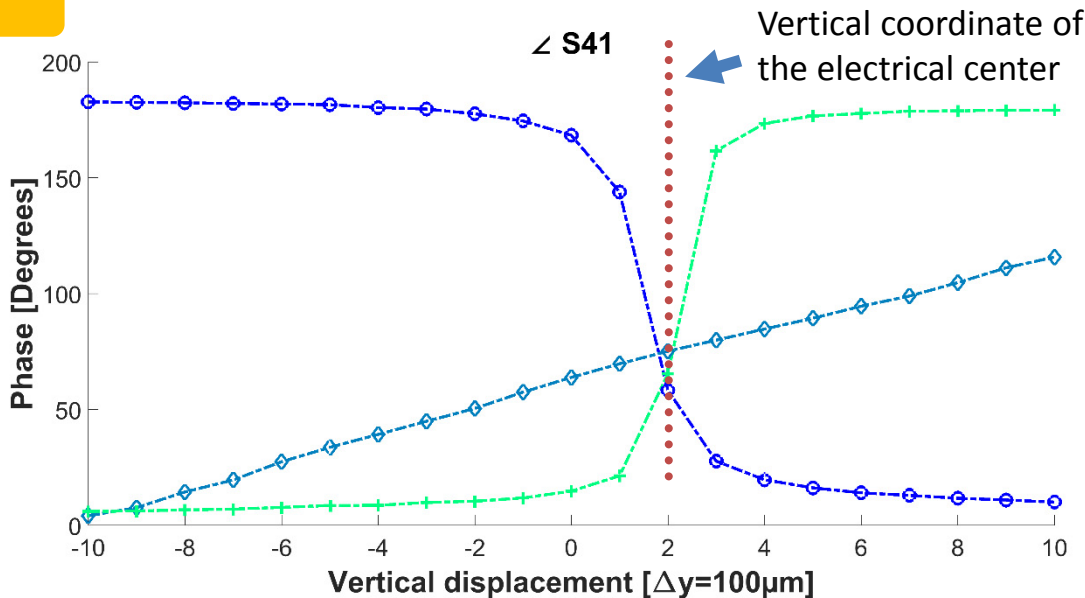
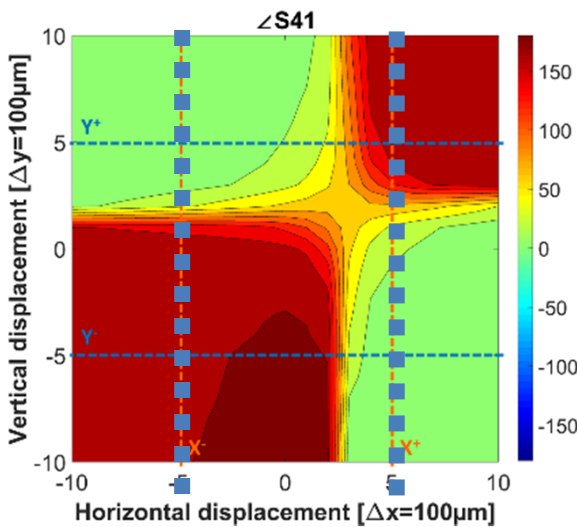
Phase analysis

S-paramters investigation:

- Phase analysis
- Cross-section
- Vertical plane



Adjacent ports - phase argument

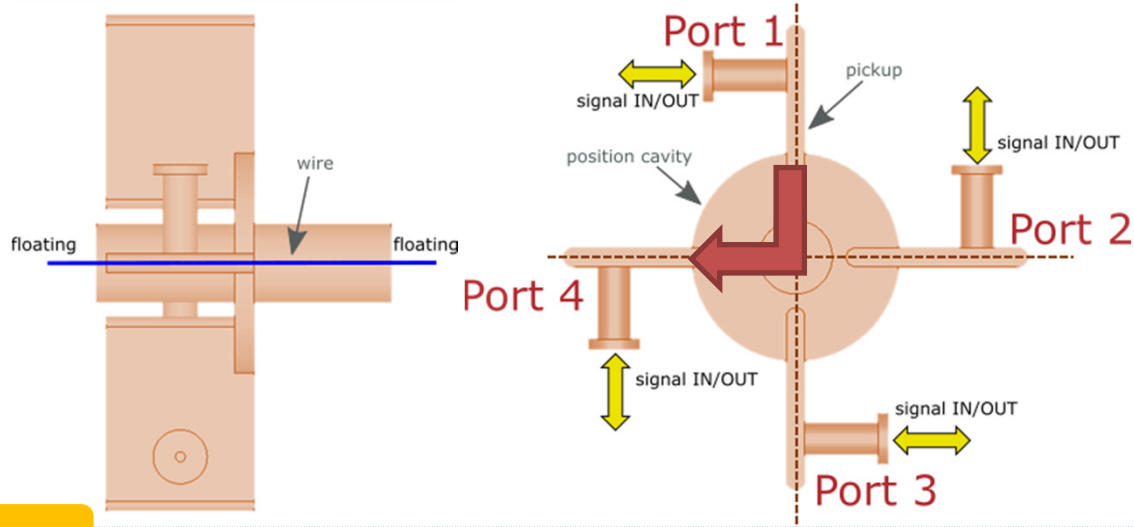


○ Horizontal displacement left (x^-) ◇ Close to the electrical center + Horizontal displacement right (x^+)

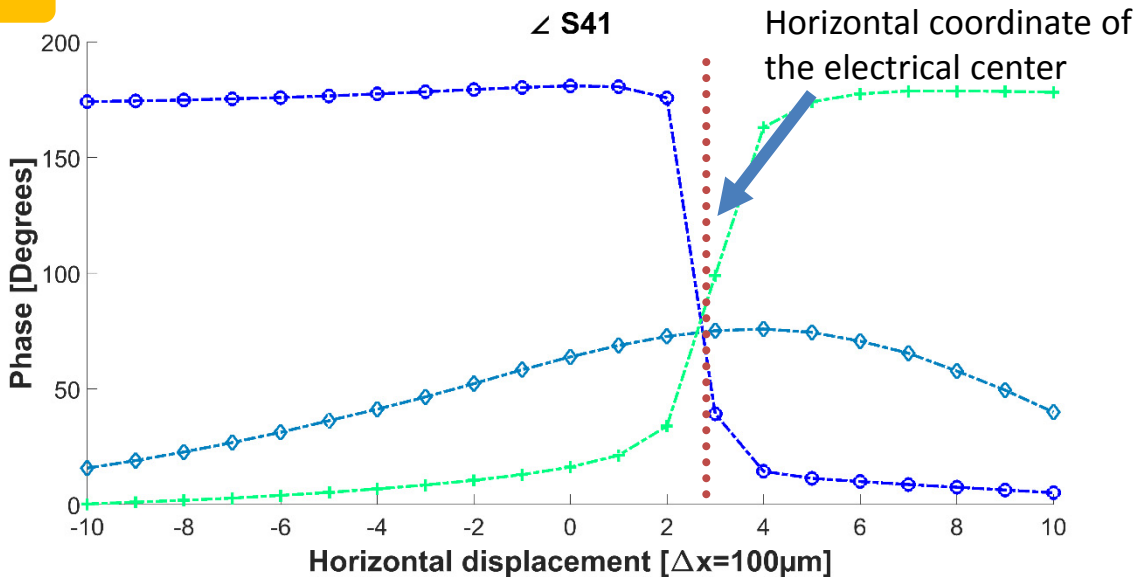
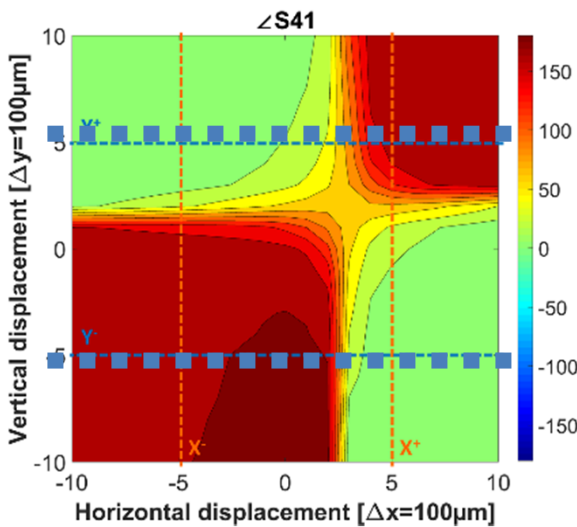
Phase analysis

S-paramters investigation:

- Phase analysis
- Cross-section
- Horizontal plane



Adjacent ports - phase argument



○ Vertical displacement down (y^-) ◇ Close to the electrical center + Vertical displacement up (y^+)

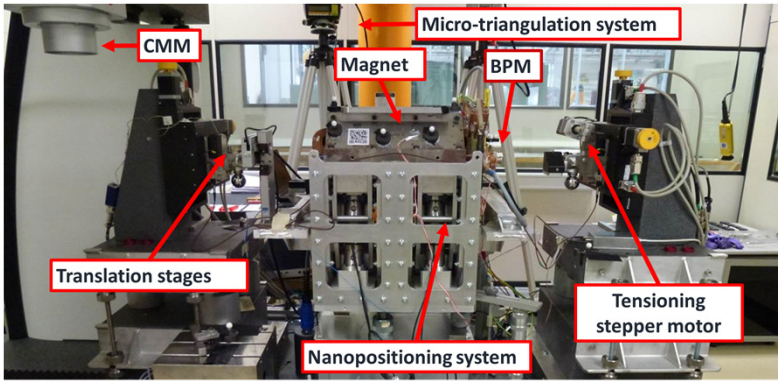
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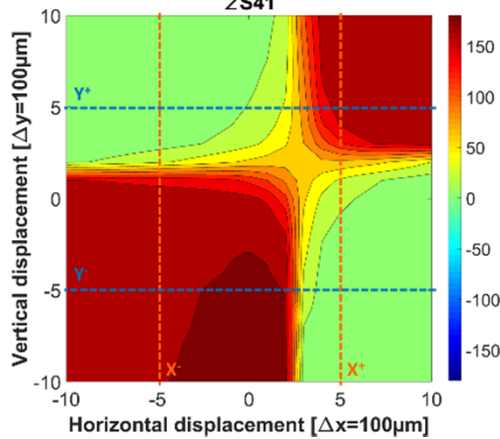
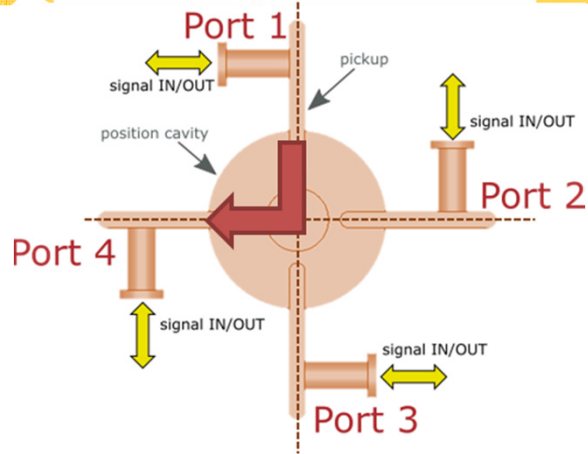
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BPM measurements on the module

MBQ-BPM assembly



S-parameters – adjacent ports - Phase



Magnetic to electrical centers offset

Magnetic center of the quadrupole: vibrating-wire analysis

Metrology fiducialization

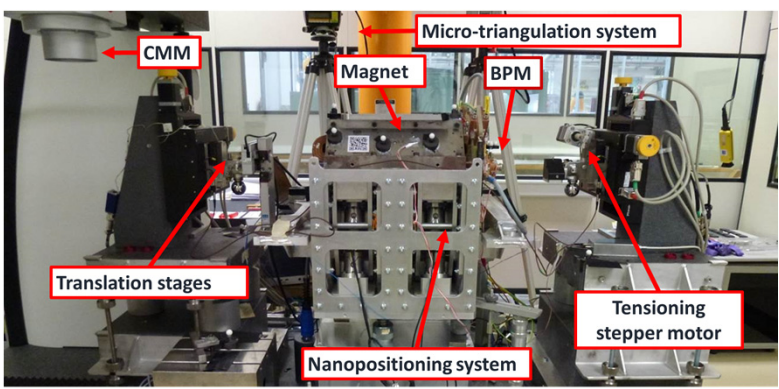
Electrical center of the BPM: stretched-wire analysis

Metrology fiducialization

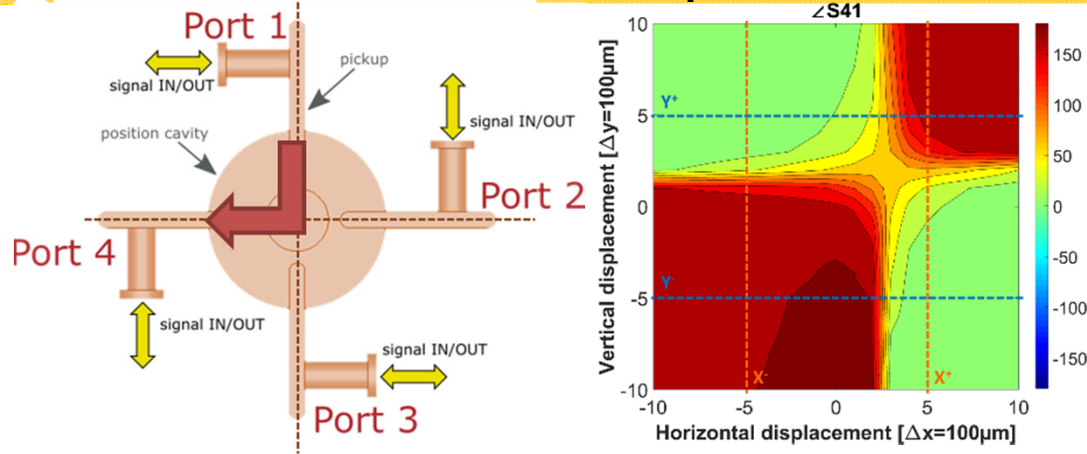


BPM measurements on the module

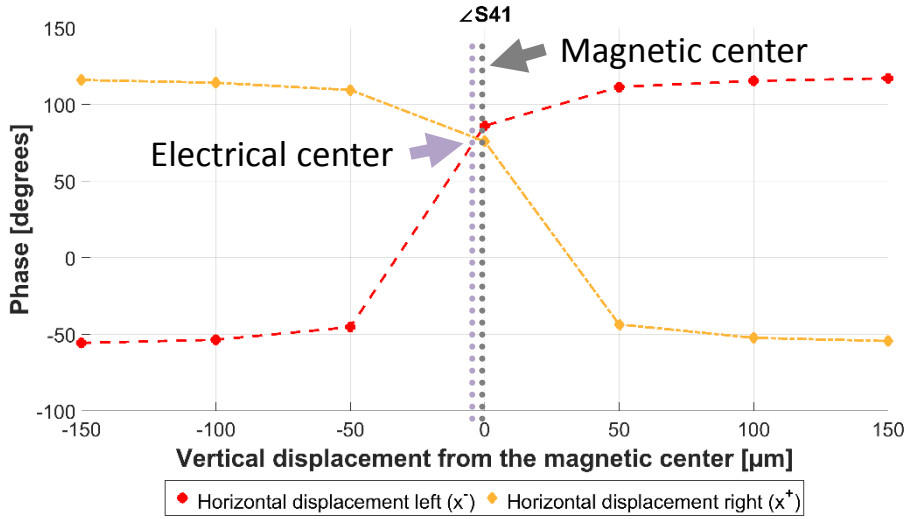
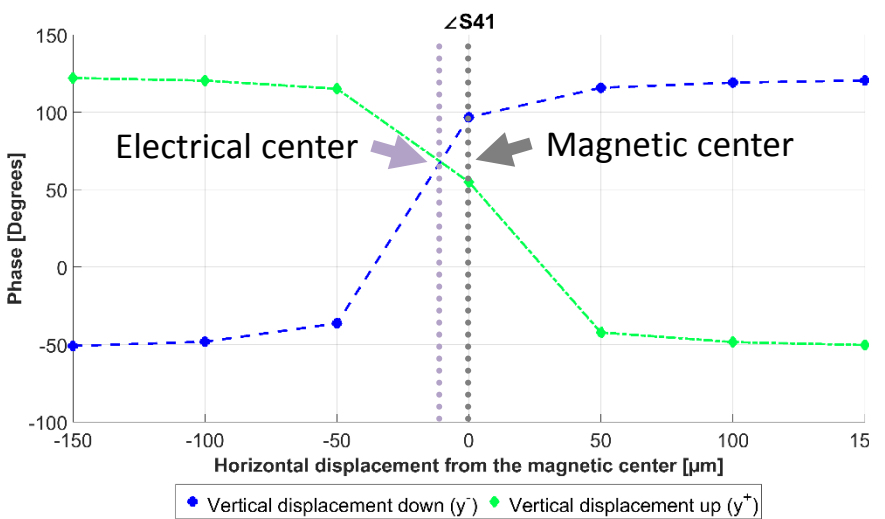
MBQ-BPM assembly



S-parameters – adjacent ports - Phase



Magnetic to electrical centers offset



< 10 μm on the horizontal axis

< 5 μm on the vertical axis

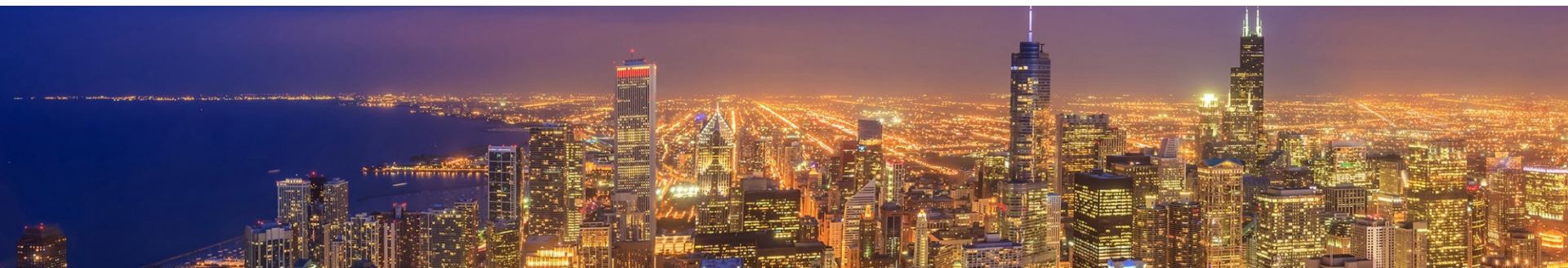
Conclusions

- The PACMAN pre-aligned module was assembled
- **First electromagnetic measurements show the electromagnetic offset in a few micrometers range**
- Further measurements are on-going toward a more precise characterization

PACMAN



Particle Accelerator Components' Metrology and Alignment to the Nanometre scale



Thank You