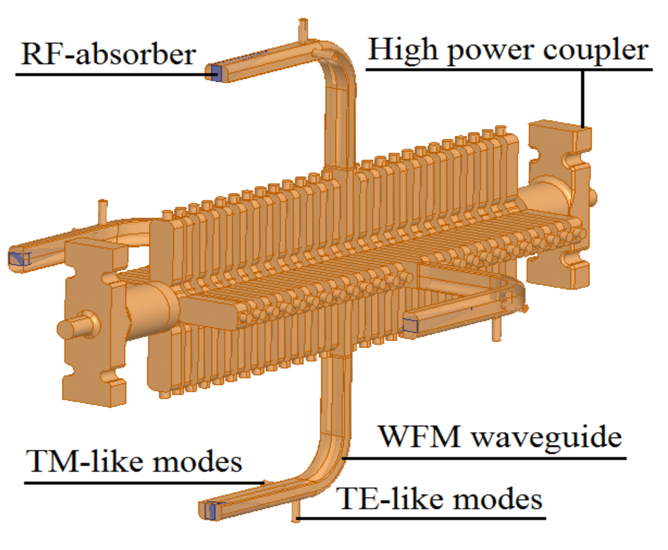
PROGRESS ON WIRE-BASED TRAVELING-WAVE STRUCTURE ALIGNMENT

To reach a high accelerating gradient of **100 MV/m**, the CLIC project under study at CERN uses a 23 cm long tapered normal-conducting **travelling wave Accelerating Structure (AS)** operating at **12 GHz**. To preserve beam emittance at the 1 nm vertical-size collision point, **7 µm accuracy** is required in the pre-alignment of the AS wrt the supporting girder. We have developed a dedicated test bench where a wire is used to materialize the electromagnetic axis in the AS and serves as a reference to fiducialise the structure in the accurate environment of a 3D Coordinate Measuring Machine (CMM). Our simulations have shown that a **resolution of 1 µm** is possible using a calibrated VNA. The recent experimental results and improvements will be presented and discussed.

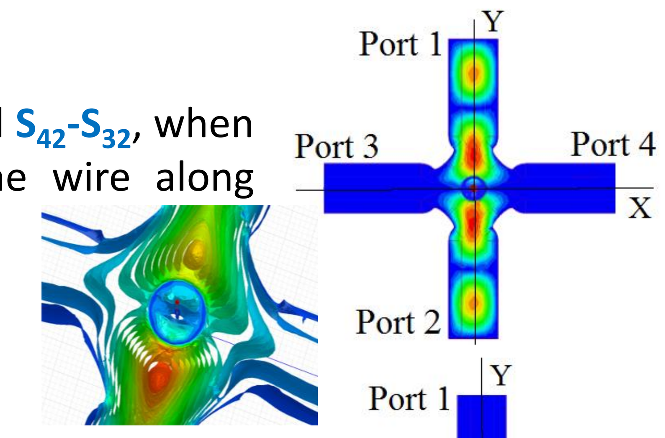
Methodology



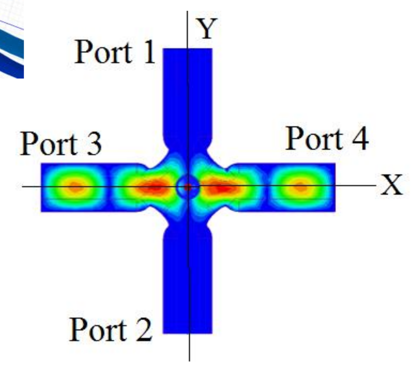
Accelerating Structure

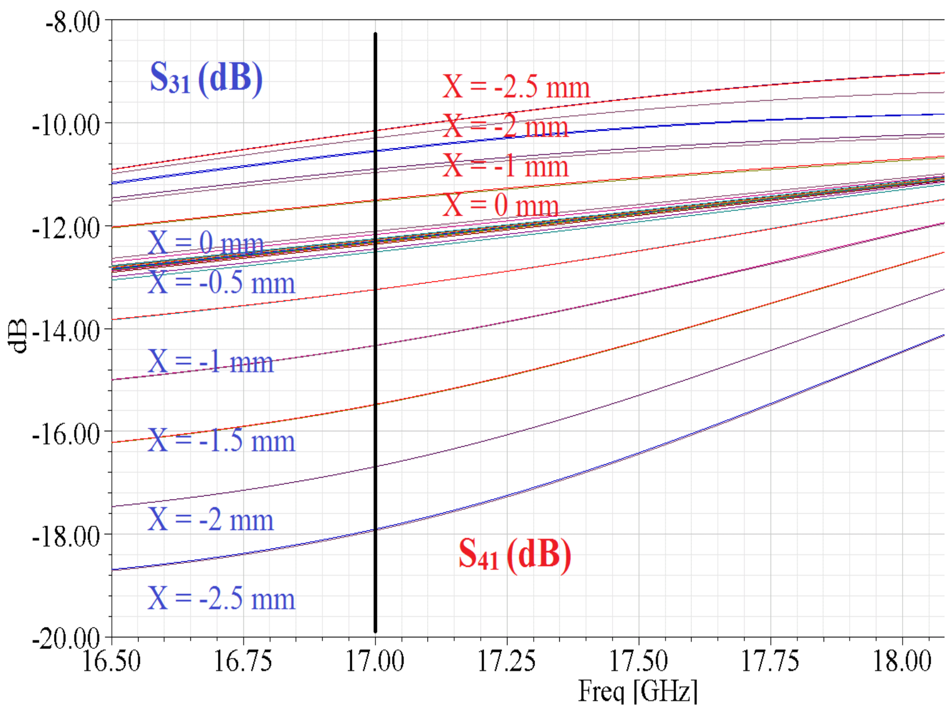
1) The first **dipole mode** is excited with a Vector Network Analyzer (VNA) through the WFM in the middle cell.
2) A 0.1 mm diameter **fixed stretched** Be-Cu **wire** inside the AS perturbs the electromagnetic field by changing transmitted and reflected power signals between the RF pick- ups.
3) We change the position of the wire to **minimize** the perturbation.
4) We define this position as the **electromagnetic axes** in the AS and use the wire as a reference to fiducialise the structure in an accurate environment of a 3D Coordinate Measuring Machine (CMM).

S_{41}-S_{31} and S_{42}-S_{32}, when moving the wire along the X axis.



S_{14}-S_{24} and S_{13}-S_{23}, when moving the wire along the Y axis.



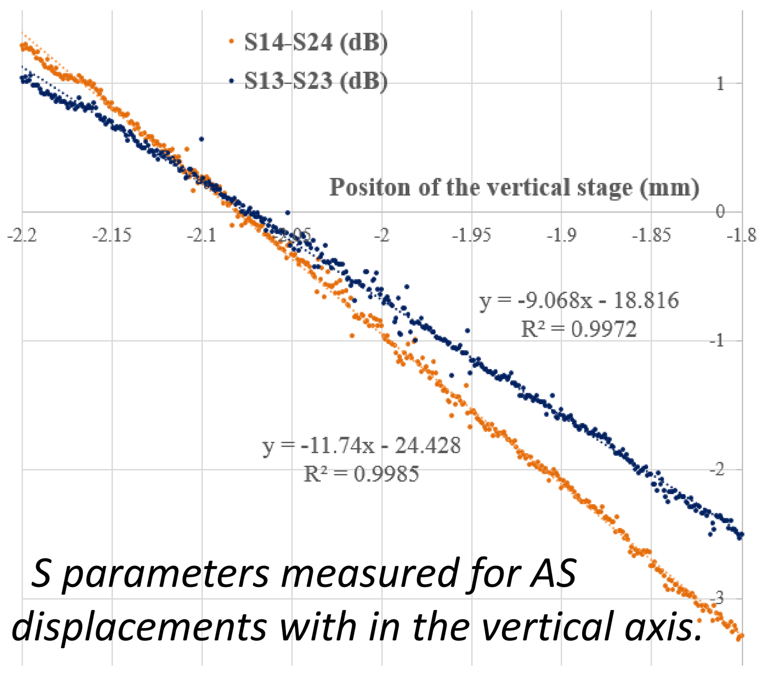


S parameters for different wire displacements.

Algorithm for experimental measurements

Random Y position. AS displacements in X	S_{41}-S_{31} S_{42}-S_{32}
Linear fit of the measurements. chose X_0 with better R^2 value	X_0 @ port1 X_0 @ port2
Fix X at X_0 position. AS displacements in Y	S_{14}-S_{24} S_{13}-S_{23}
Linear fit of the measurements. chose Y_0 with better R^2 value	Y_0 @ port3 Y_0 @ port4

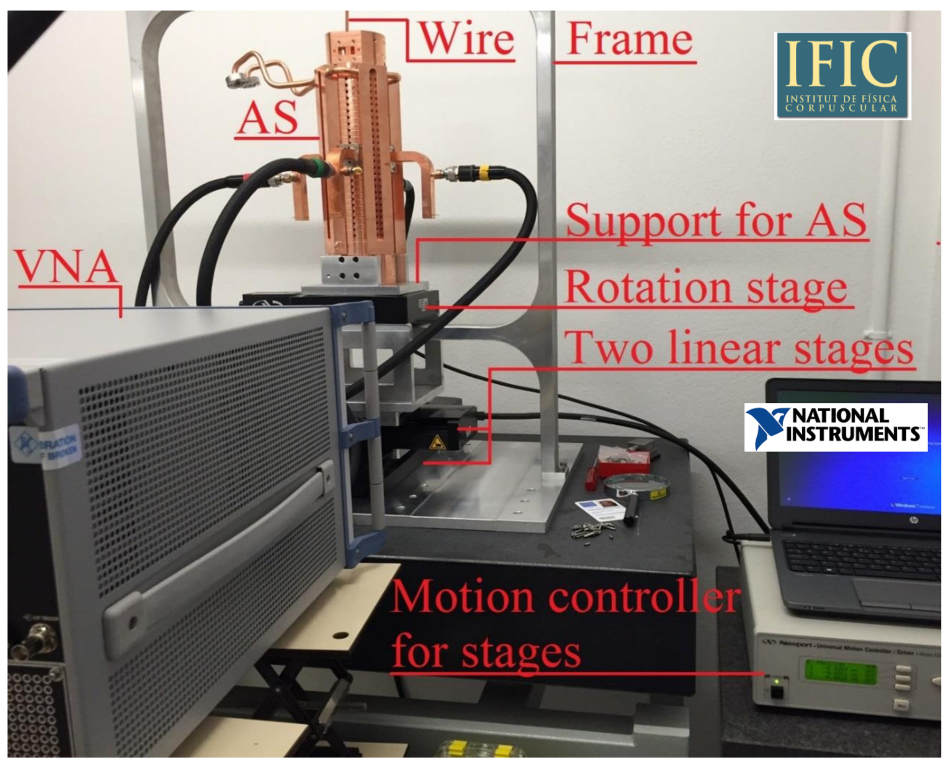
N iterations, until both X and Y converge



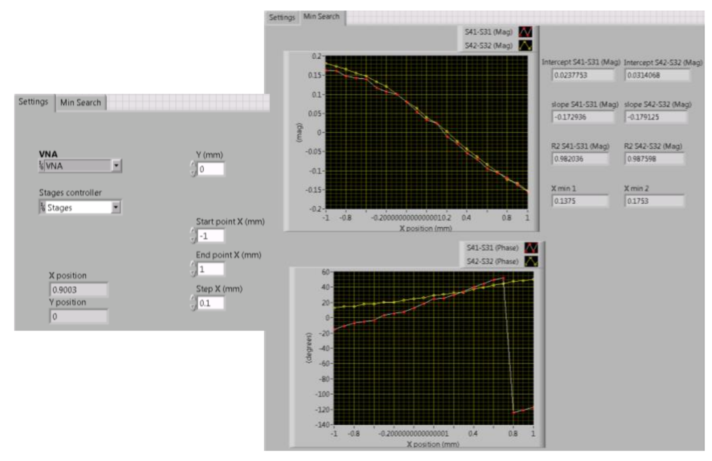
S parameters measured for AS displacements with in the vertical axis.

The line **crosses zero** at the positon of the electromagnetic center of he AS.
The **slope** represents the sensitivity of our measurements to the displacement of the wire.

Experimental Set-Up

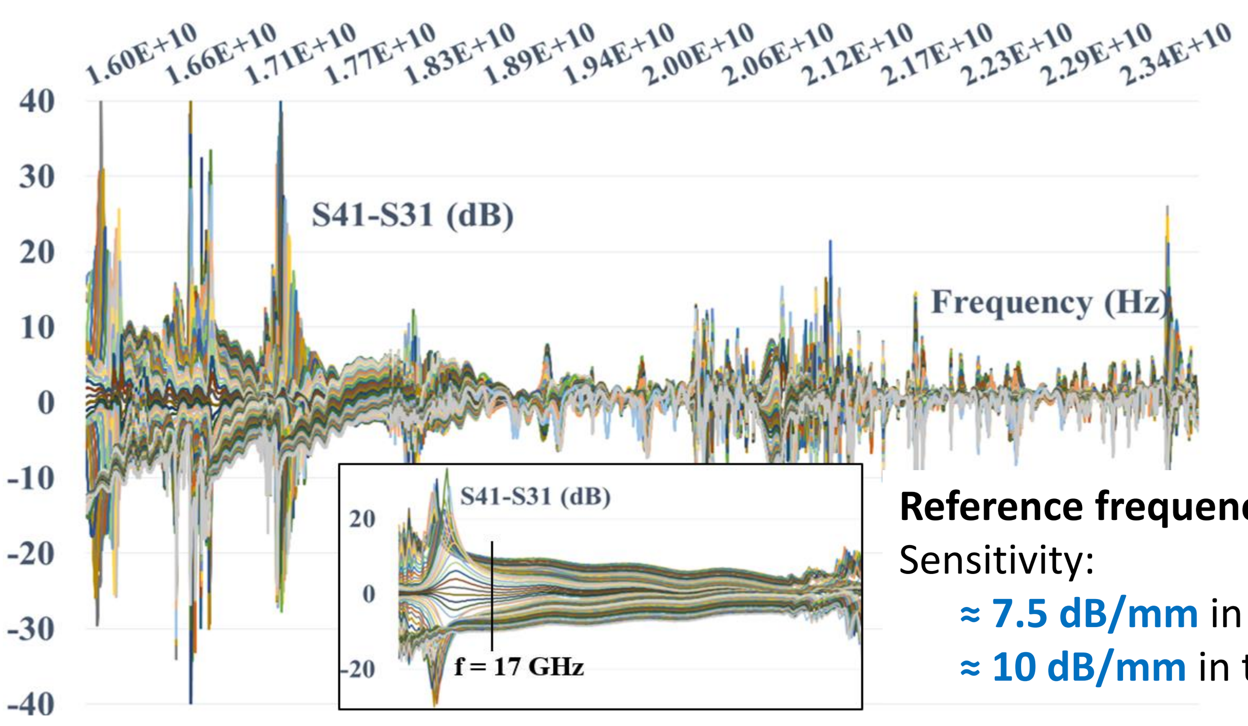


VNA: 4 ports, 10 MHz – 24 GHz.
Rotation stage: Accuracy = 0.012º
Resolution = 0.0005º
Linear stages: Accuracy = 4 µm over 100 mm
Motion controller: Resolution = 0.1 µm



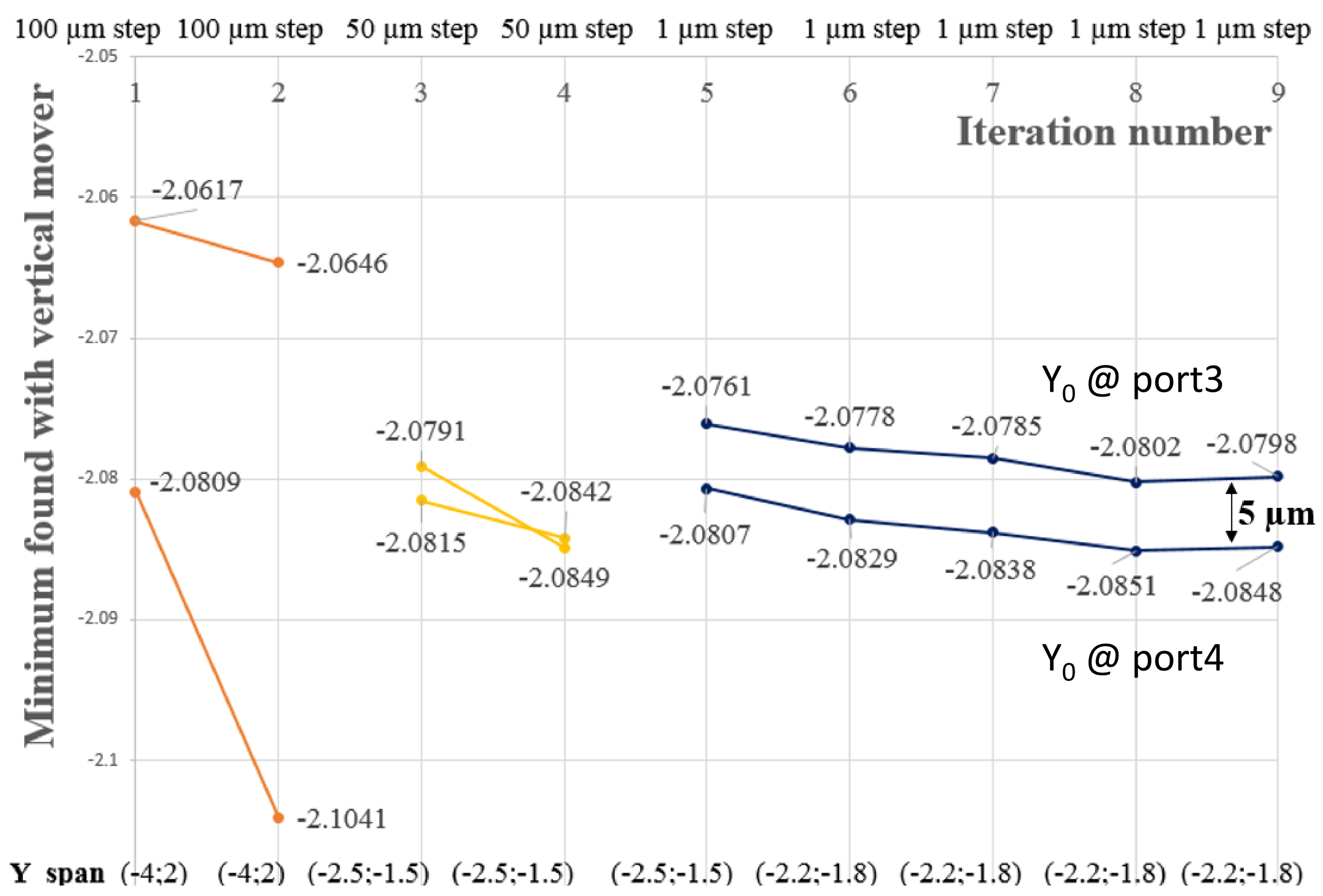
LabVIEW user platform for automatic measurements.

Experimental results using WFM signals



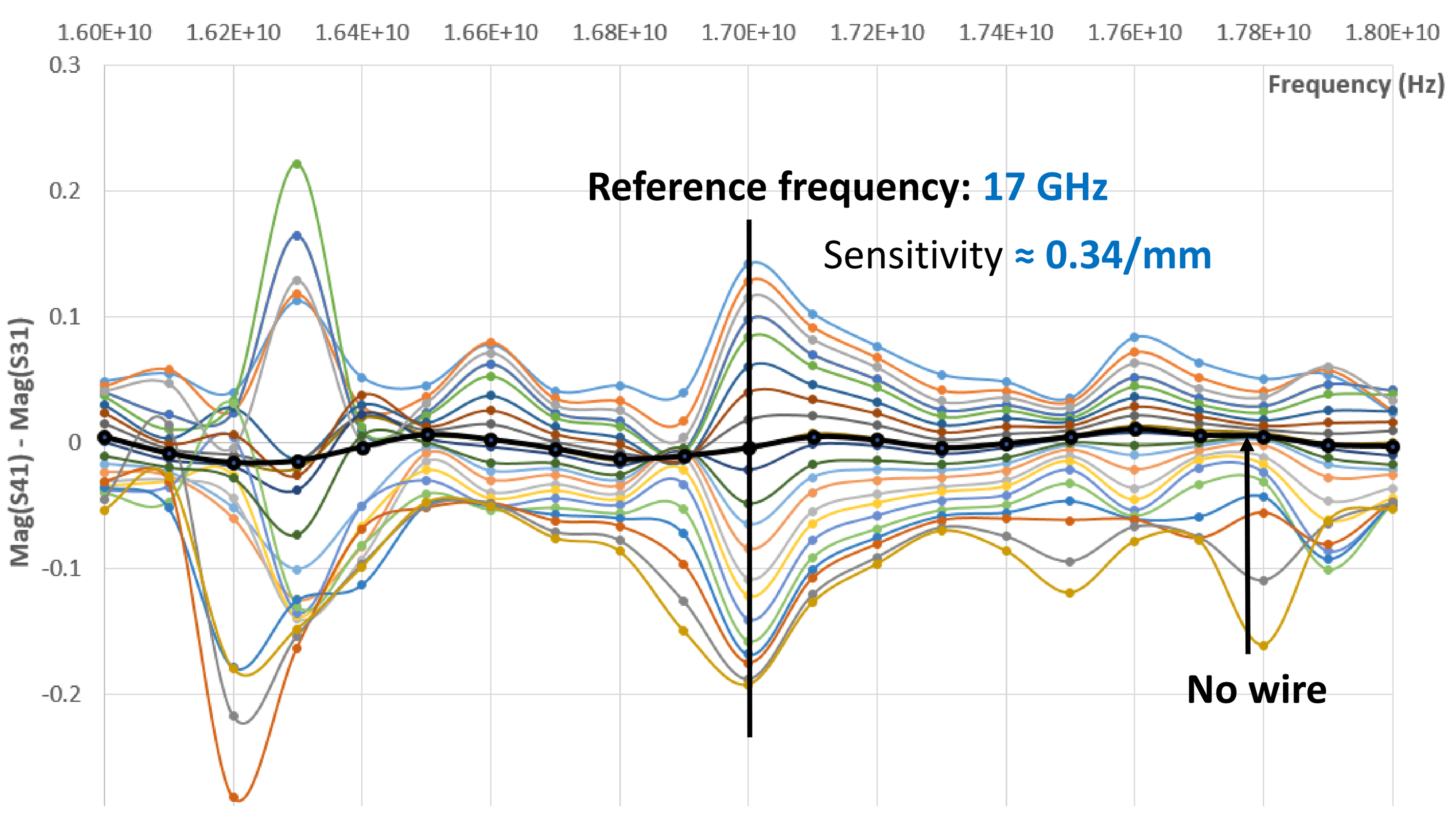
Reference frequency: **17 GHz**
Sensitivity:
≈ **7.5 dB/mm** in the X axis
≈ **10 dB/mm** in the Y axis

S_{41}-S_{31} (dB) with respect to the frequency for different positions of the wire inside the AS. No calibration of the VNA performed.



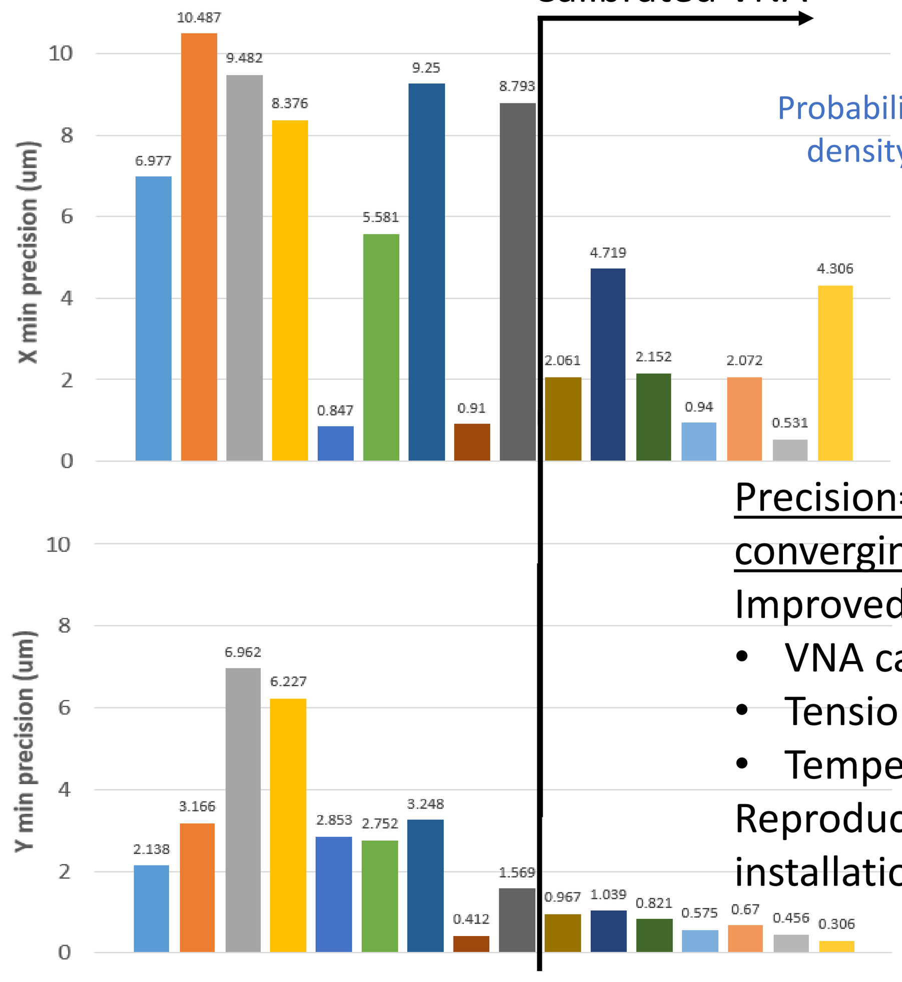
After the first interactions, the centre as measured by each port **converges** into a unique value. However, we find a different value for the centre when using different ports.
Lack of matching between the WFM and the structure? Indeed, these ports were designed to extract HOM power and not to input RF signals.
Also, the sensitivity is different depending on the port and in the horizontal and vertical plane. The difference is an estimation of our accuracy: 18 µm in the horizontal plane and 5 µm in the vertical plane.
Solution: **new tapered transitions** with low reflection coefficient to recover the symmetry. We confirm by simulations that sensitivity depends on the position in the other axes and it converges when approaching the centre.

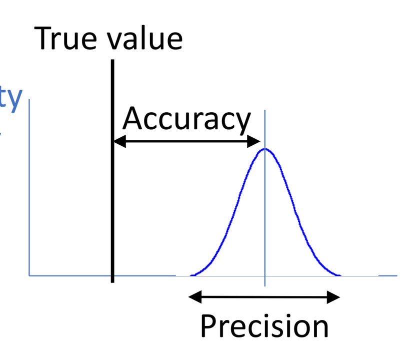
Experimental results using tapered solution



Linear magnitude of S_{41}-S_{31} (dB) with respect to the frequency for different positions of the wire inside the AS with calibrated VNA.

Calibrated VNA

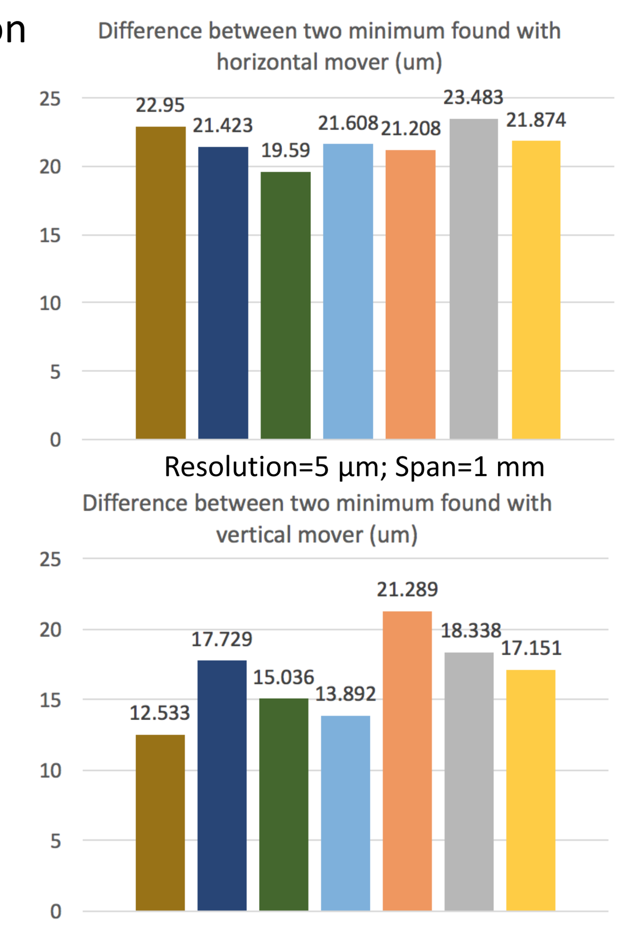




Precision=standard deviation of converging measurements.
Improved and affected by:
- VNA calibration.
- Tension of the wire.
- Temperature: 0.5 µm/0.1º

Reproducibility will be improved with the installation of the wire-positioning system.

Accuracy=difference between the measurements coming from opposite ports. Can be improved by reducing resolution



Conclusions

We have proven that we can locate the centre of the electromagnetic field inside the middle cell of the structure with a stretched wire and a VNA using two different measurements with similar results: accuracy > 20 µm and precision between 1 µm to 5µm for vertical and horizontal plane. Tapered transitions have been designed and manufactured with low reflection coefficient which should allow us to recover the symmetry. However, asymmetry is still present between ports and between planes. We have identified main sources of random errors: temperature and tension. Future developments will aim to investigate the effect of the relative tilt between the structure and the wire as well as assessing reproducibility. We plan to study cell to cell alignment using the pumping holes at the end of the waveguides in each cell. In order to reference the electromagnetic axis with respect to the outside fiducials of the structure we need to implement a wire positioning system which will allow to precisely locate in space the wire with the help of a CMM or other metrological equipment. This system is currently under fabrication and will be implemented in the next months.

Authors: N. Galindo Munoz*, N. Catalan Lasheras, CERN, Geneva, Switzerland
A. Faus Golfe, IFIC, Valencia, Spain and LAL, Paris, France
*natalia.galindo.munhoz@cern.ch

PACMAN is founded under the European Union's 7th Framework Program
Marie Curie Actions, grant PITN-GA-2013-606839
http://pacman.web.cern.ch/