Reentrant cavity resonator for low intensities proton beam measurements

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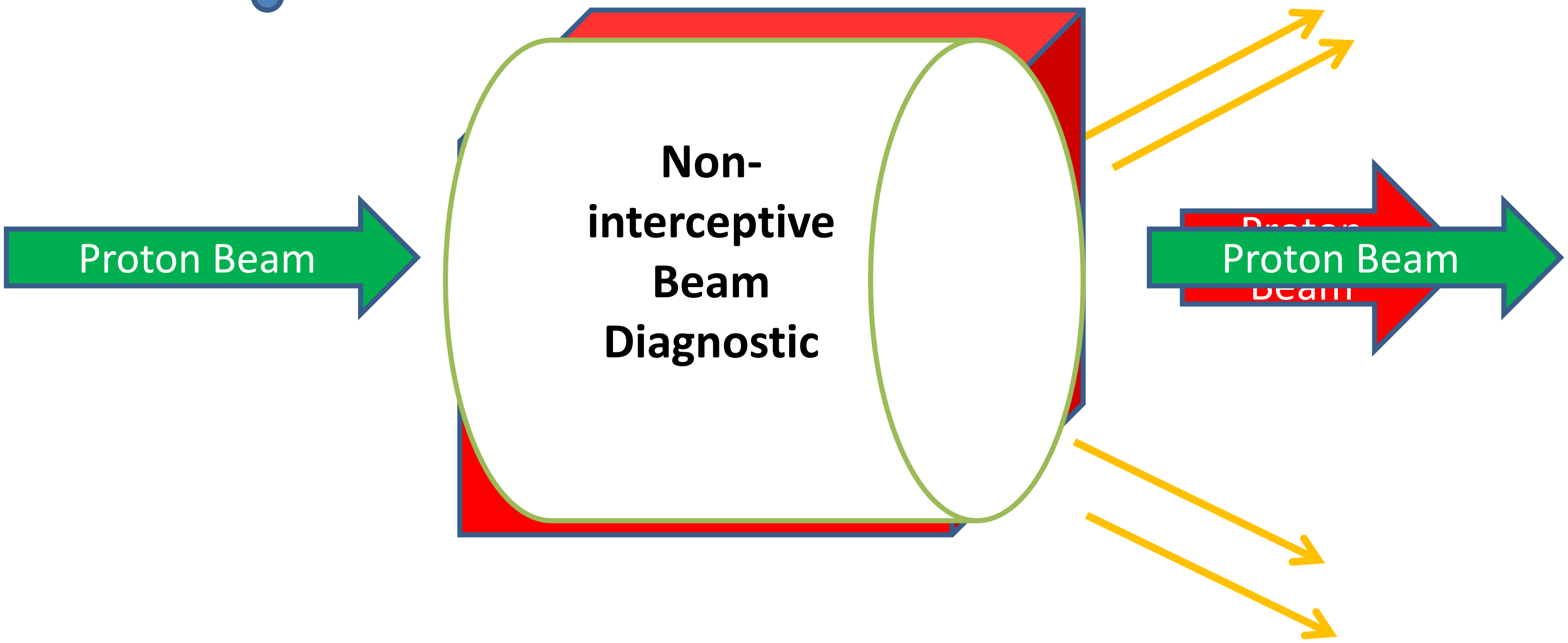
Project Start Date: 01/01/2017

Contents

Beam Parameters	Value
Repetition Rate	72.85 MHz
RMS Bunch Length	2 ns
Beam Intensity of Interest	1 – 800 nA
Resonator Frequency	145.7 MHz

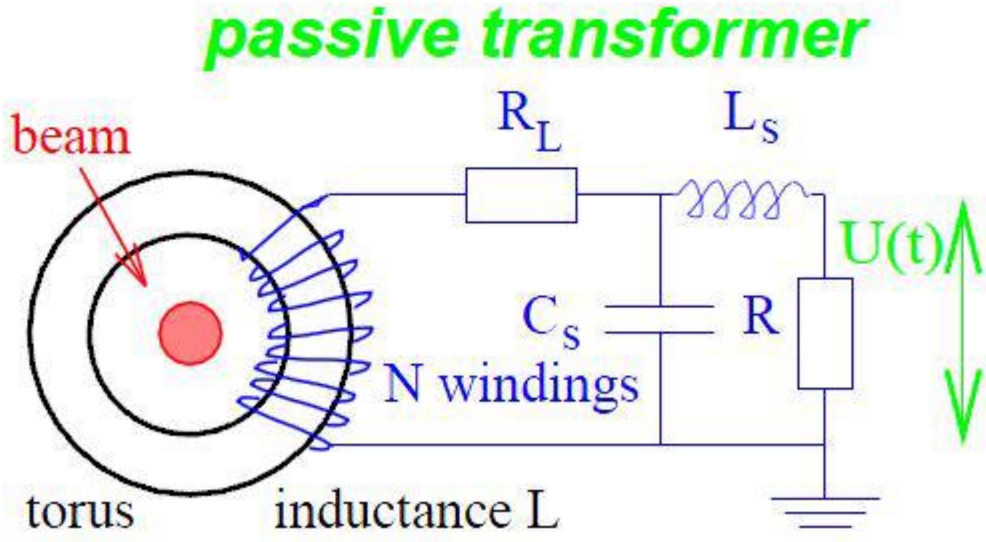
RF based Measurement of Ultra Low charges



Comparison of Diagnostics

Passive Transformer

- Short pulsed beams
- Low number of windings
- Low stray capacitance
- High permeability metal shielding

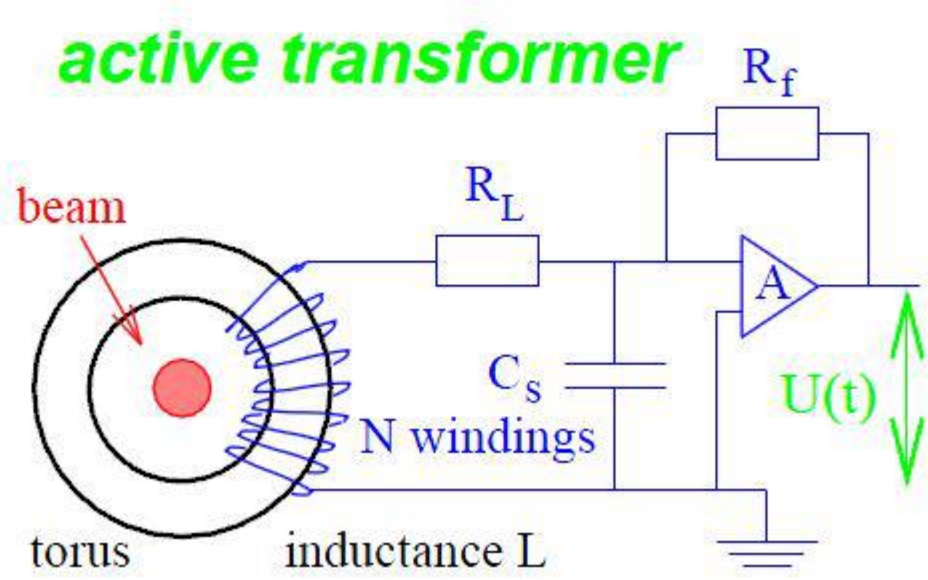


P. Forck, *Lecture Notes on Beam Instrumentation and Diagnostics*. 2011.

Comparison of Diagnostics

Active Transformer

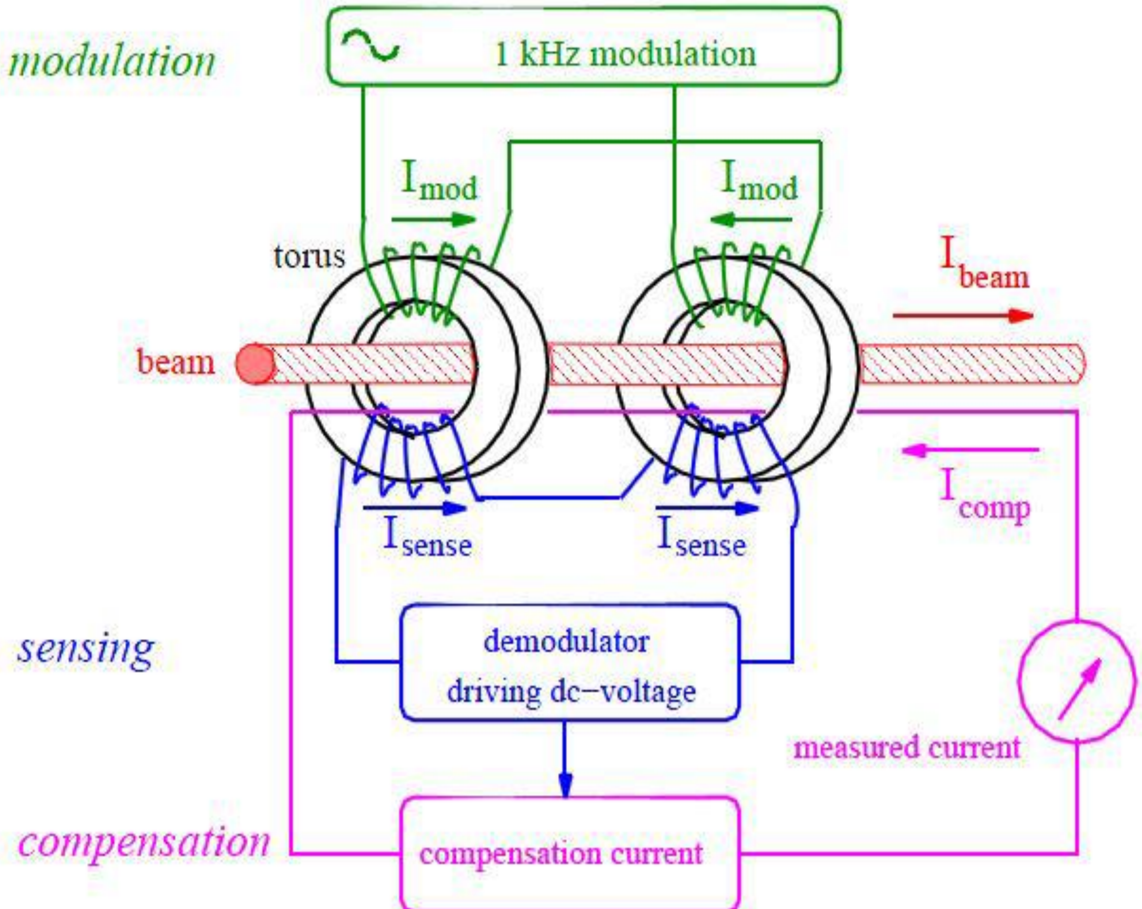
- Operational amplifier with feedback resistor
- Higher sensitivity
- Low bandwidth
- High permeability torus



P. Forck, *Lecture Notes on Beam Instrumentation and Diagnostics*. 2011.

DC Transformer

- DC beam current
- High sensitivity
- High SNR
- Complex realization
- Typical resolution 1 µA

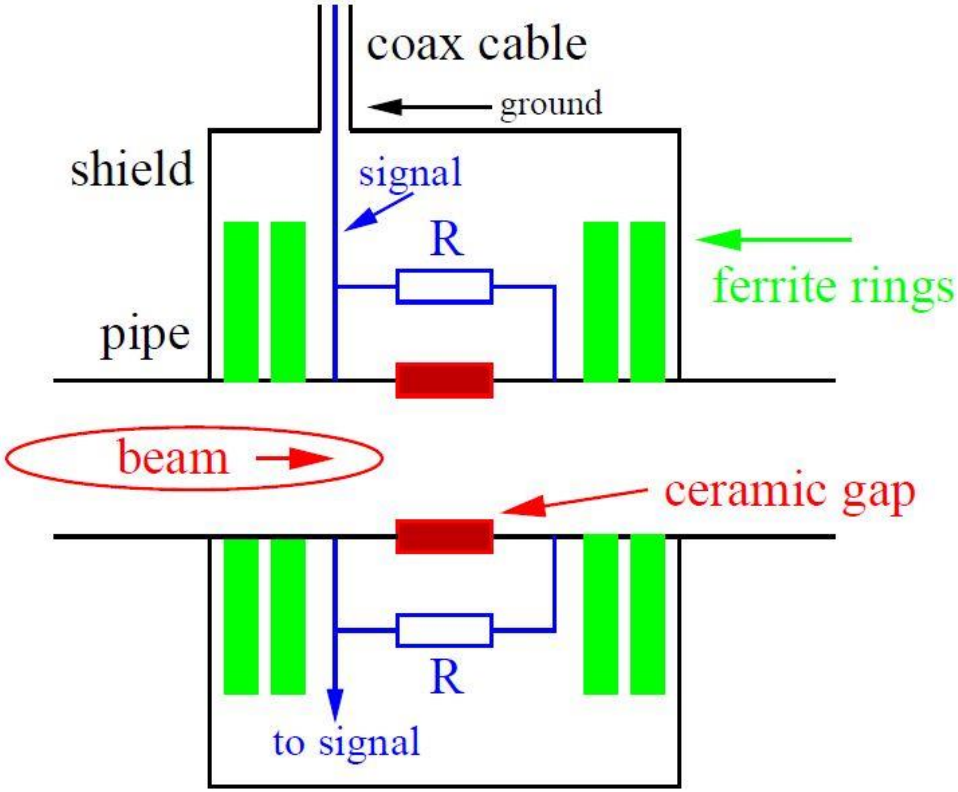


P. Forck, *Lecture Notes on Beam Instrumentation and Diagnostics*. 2011.

Comparison of Diagnostics

Resistive WCM

- Bunch structure observation
- Emittance measurement
- Shielding
- Rarely used
- Thermal noise
- Coupling impedance
- Beam instability

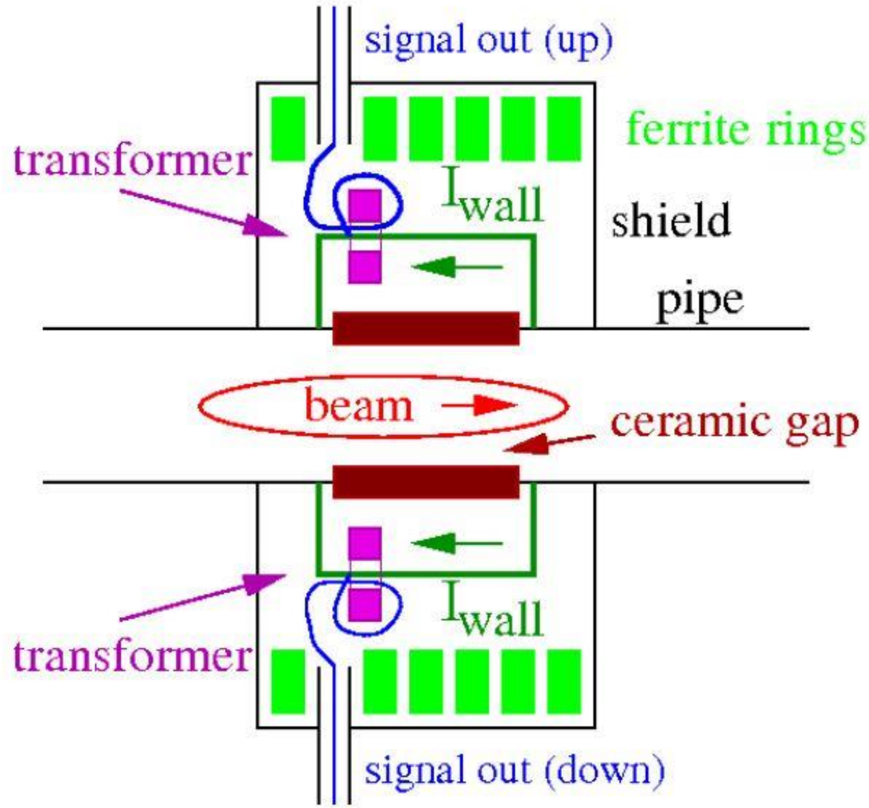


P. Forck, *Lecture Notes on Beam Instrumentation and Diagnostics*. 2011.

Comparison of Diagnostics

Inductive WCM

- Azimuthal image current distribution
- Positional sensitivity
- Large bandwidth
- Installation is outside beam pipe
- Easy accessibility

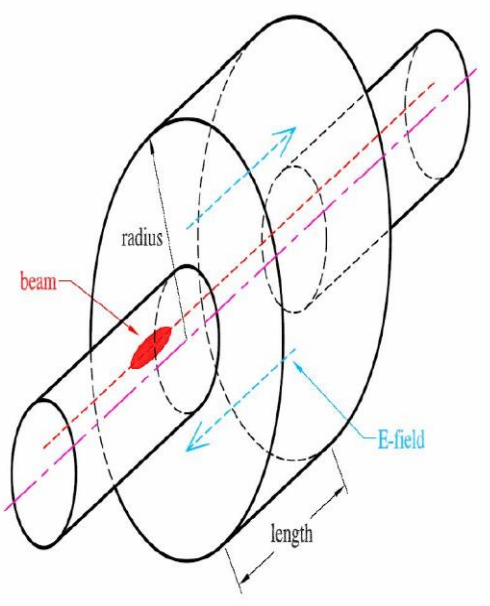


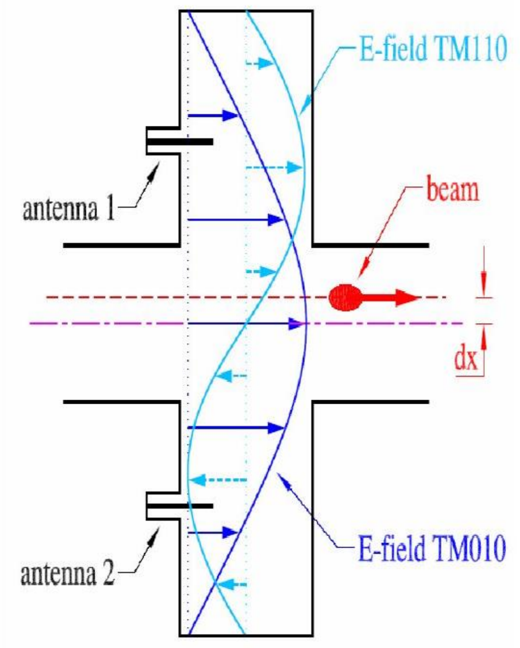
P. Forck, *Lecture Notes on Beam Instrumentation and Diagnostics*. 2011.

Comparison of Diagnostics

Pillbox

- Short pulse and single pulse
- Superior signal sensitivity
- Size limitations
- Mode contamination



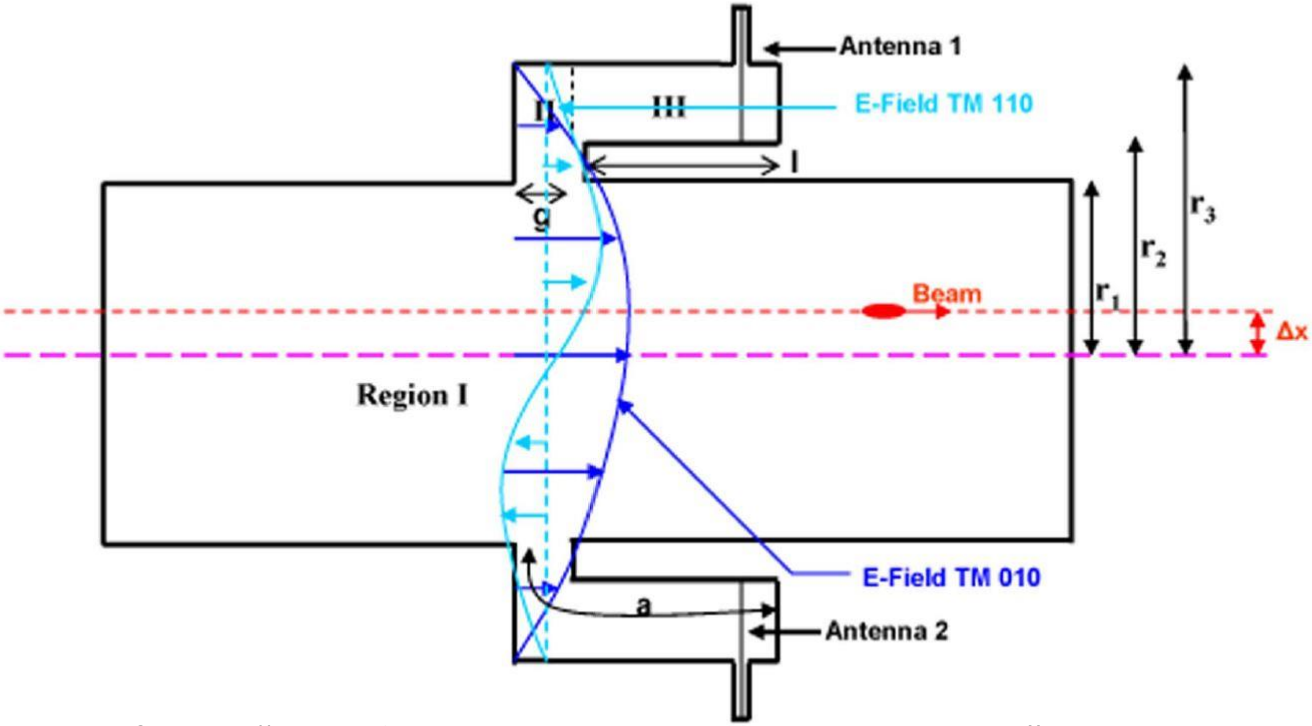


R. Lorenz, "Cavity beam position monitors," pp. 53–73, 1998.

Comparison of Diagnostics

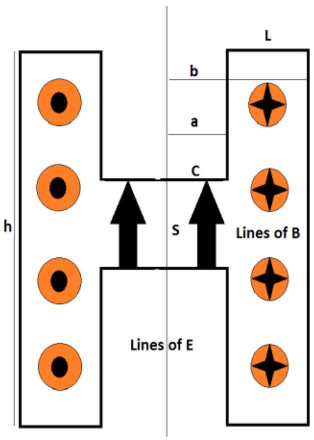
Reentrant

- Proven cryogenic and cleanroom compatability
- Smaller size
- Lower Q
- Better damping
- Good linearity
- Radial symmetry

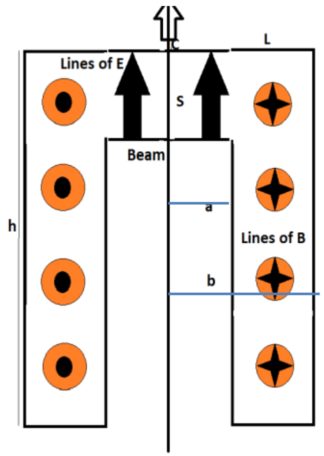


H. S. M. Gasior, R. Jones, T. Lefevre, "Introduction to Beam Instrumentation," 2013.

Principle of Operation



Concept from Feynman Lectures



our Scenario

$$\omega_o = 1/\sqrt{LC} \qquad f = \frac{1}{2\pi\sqrt{LC}}$$

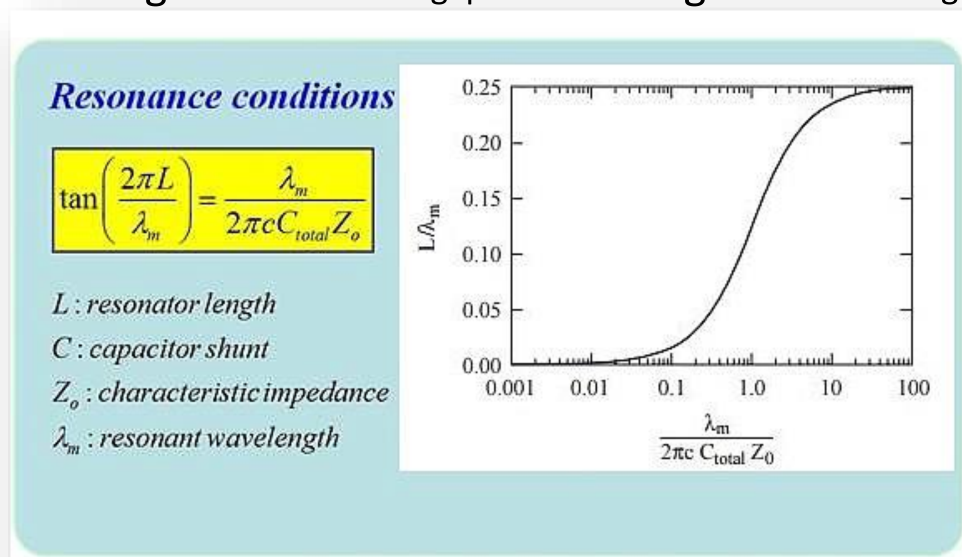
$$C_c = 2\pi\varepsilon_o / \ln\frac{b}{a}$$

Increasing a increases C_{gap}. Increasing S reduces C_{gap}

$$L_c = \frac{\mu_o}{2\pi}\ln\frac{b}{a}$$

$$C_{gap} = \varepsilon_o \frac{\pi a^2}{s}$$

$$f = \frac{1}{2\pi}\left[L_c(C_c + C_{gap})\right]^{-0.5}$$



“Microwave Phase Modulators for Smoothing by Spectral Dispersion,” *LLE Rev.*, vol. 68, pp. 192–208, 1996.

ANSYS HFSS Simulation

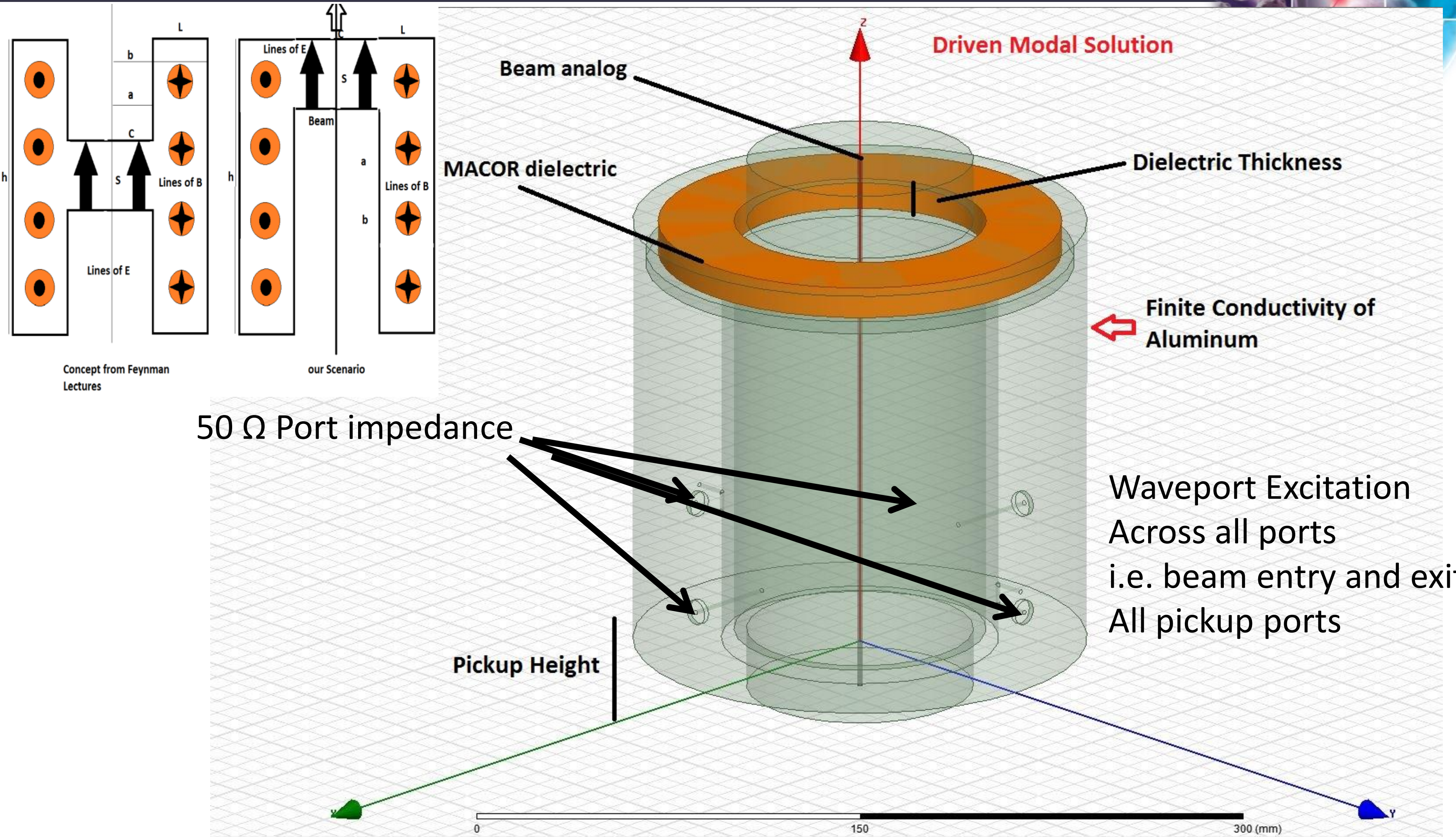
Parametric Model
- Design Modeler
- Boundaries
- Excitations

Analysis
- Solution Setup
- Frequency Sweep

Mesh Conditions
- Adaptive Mesh
- Convergence

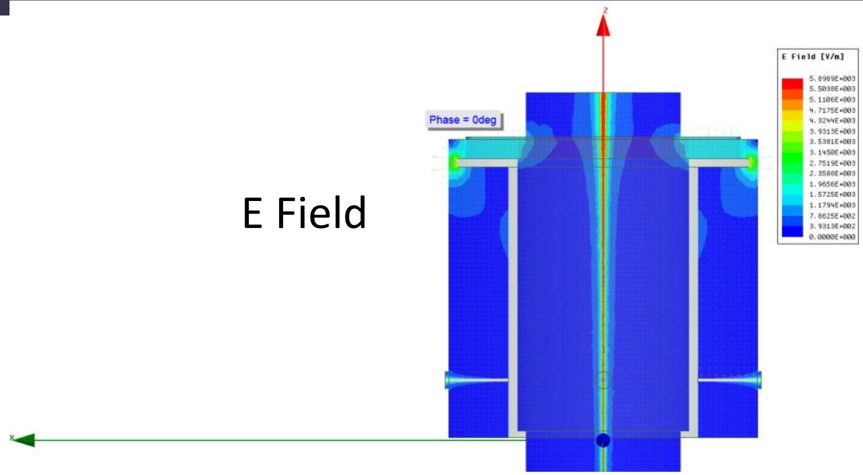
Results & Post-Processing
- 2D reports
- Fields plot

ANSYS HFSS Simulation

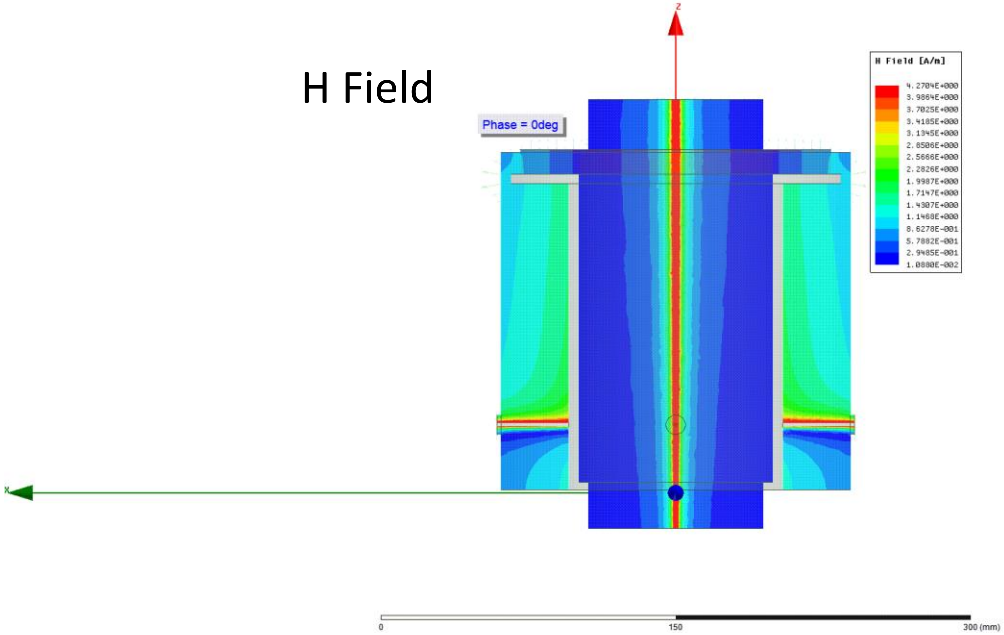


ANSYS HFSS Simulation

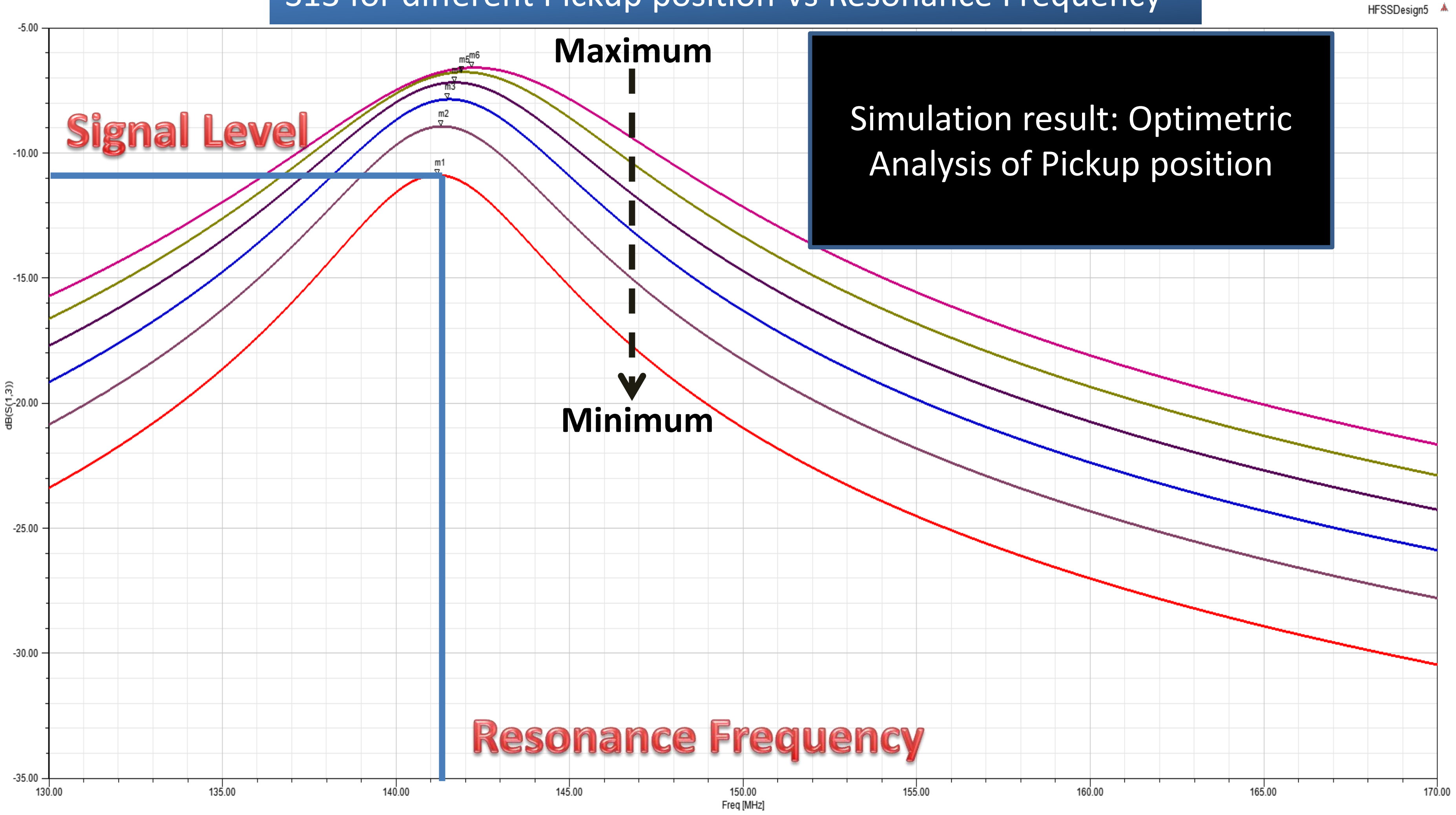
E Field



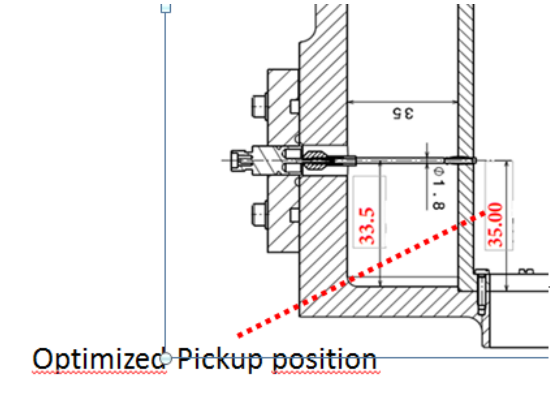
H Field

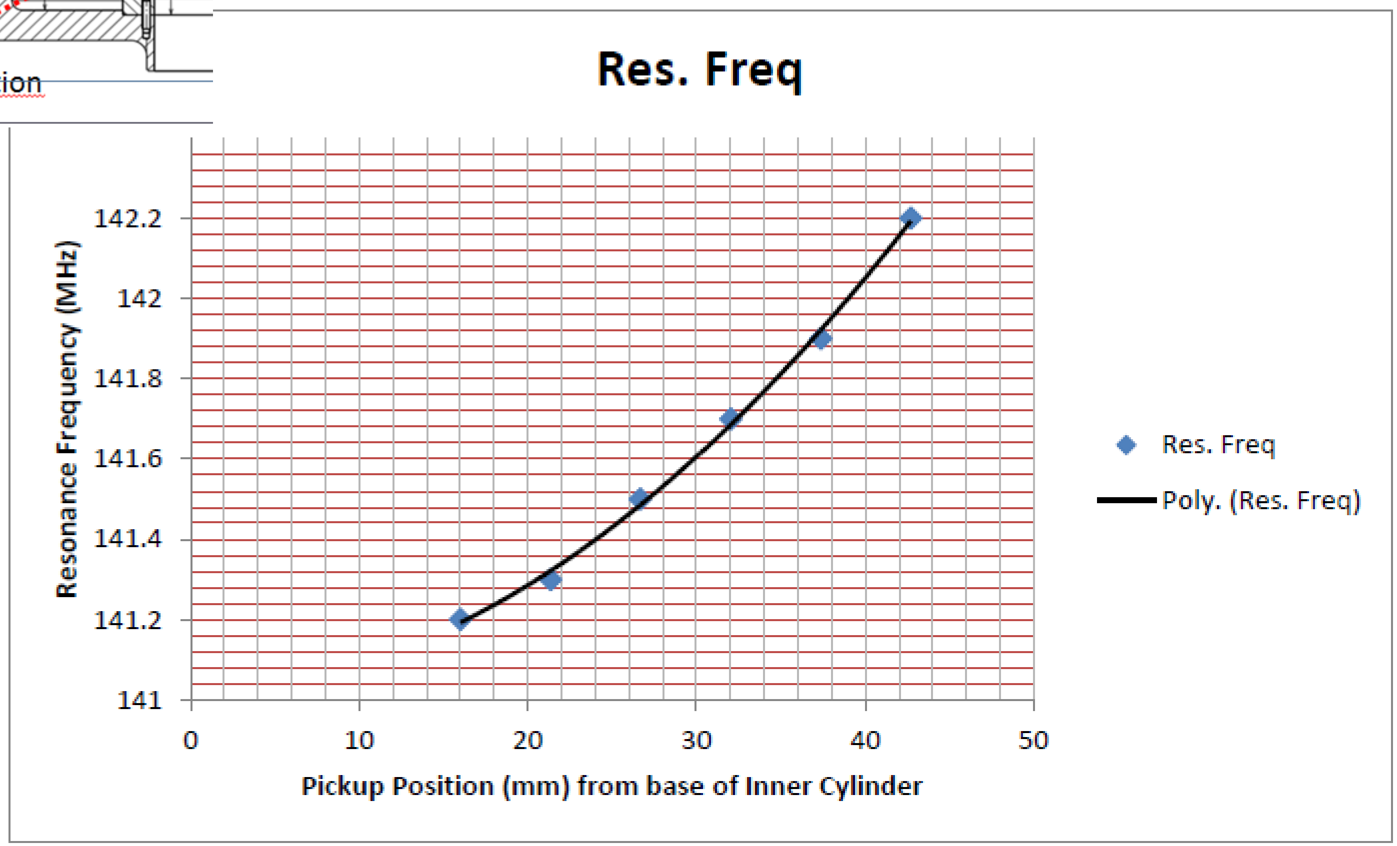


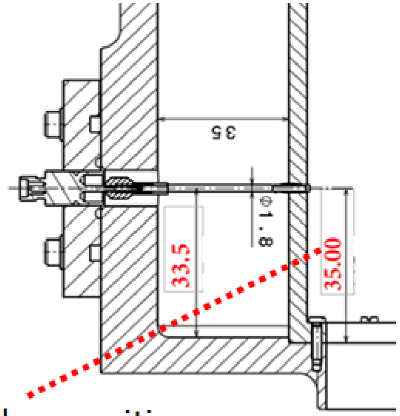
S13 for different Pickup position Vs Resonance Frequency



Resonance Frequency Vs Pickup Position



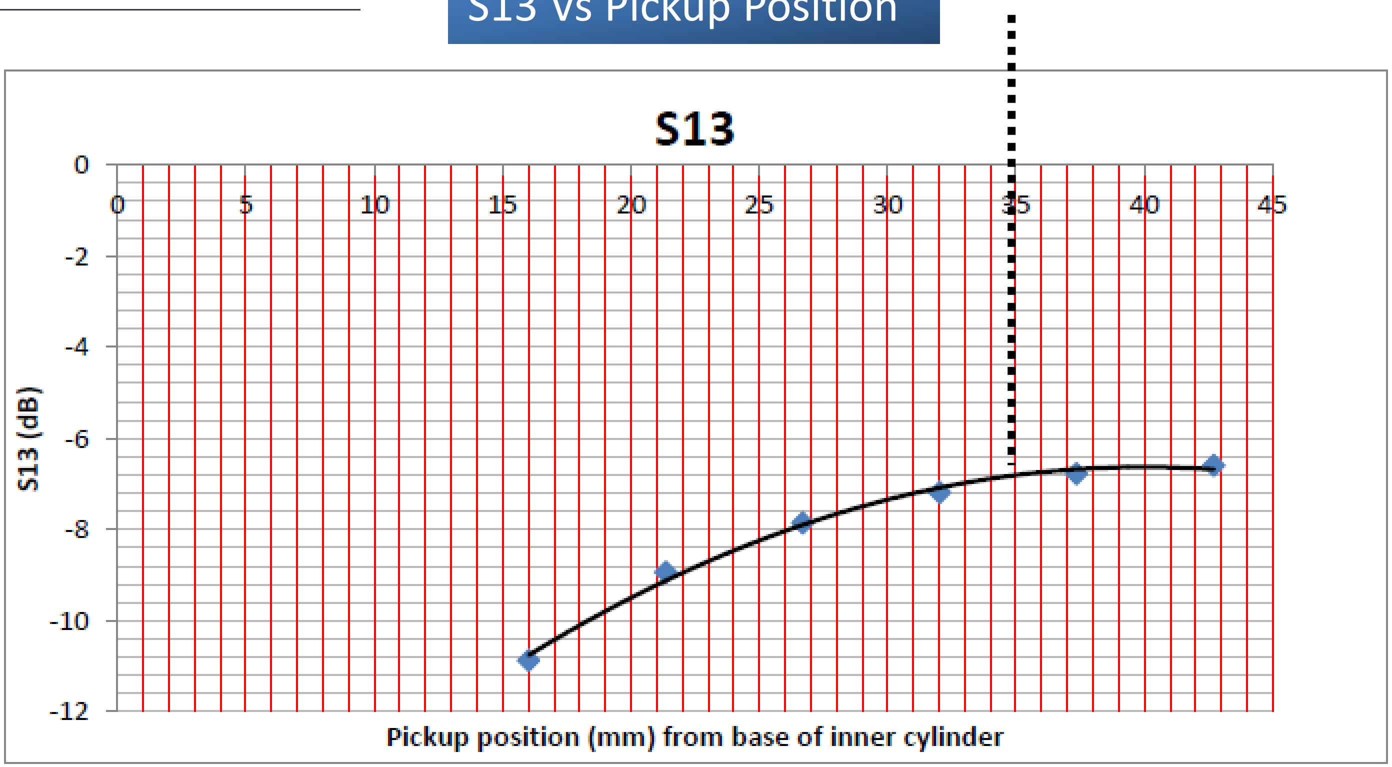




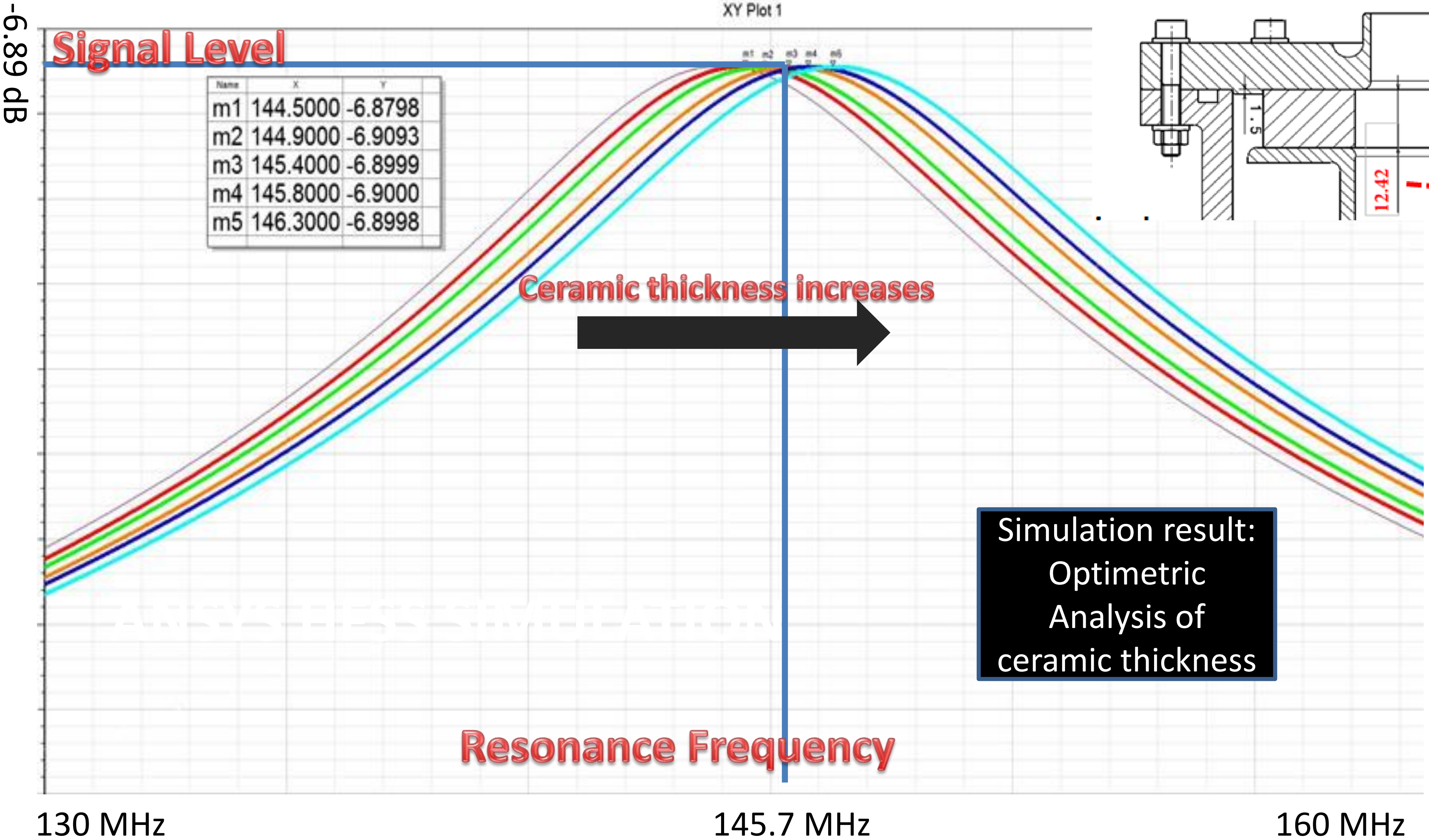
Optimized Pickup position

Pickup position 35 mm chosen

S13 Vs Pickup Position



S13 for Ceramic Thickness Vs Resonance Frequency

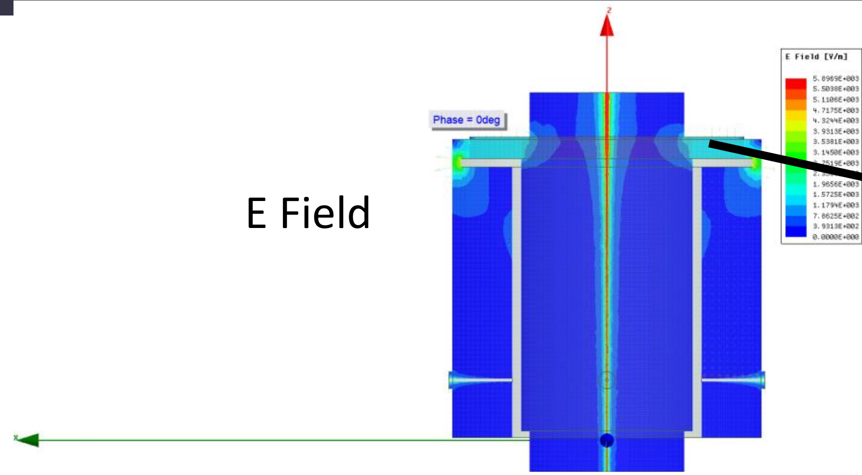


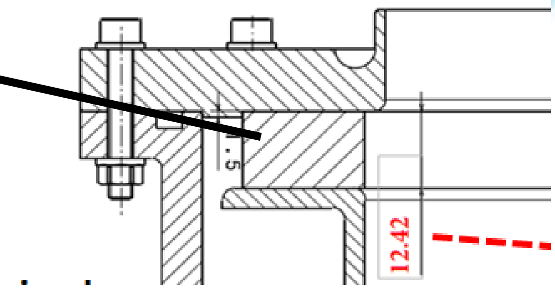
Name	X	Y
m1	144.5000	-6.8798
m2	144.9000	-6.9093
m3	145.4000	-6.8999
m4	145.8000	-6.9000
m5	146.3000	-6.8998

Simulation result: Optimetric Analysis of ceramic thickness

ANSYS HFSS Simulation

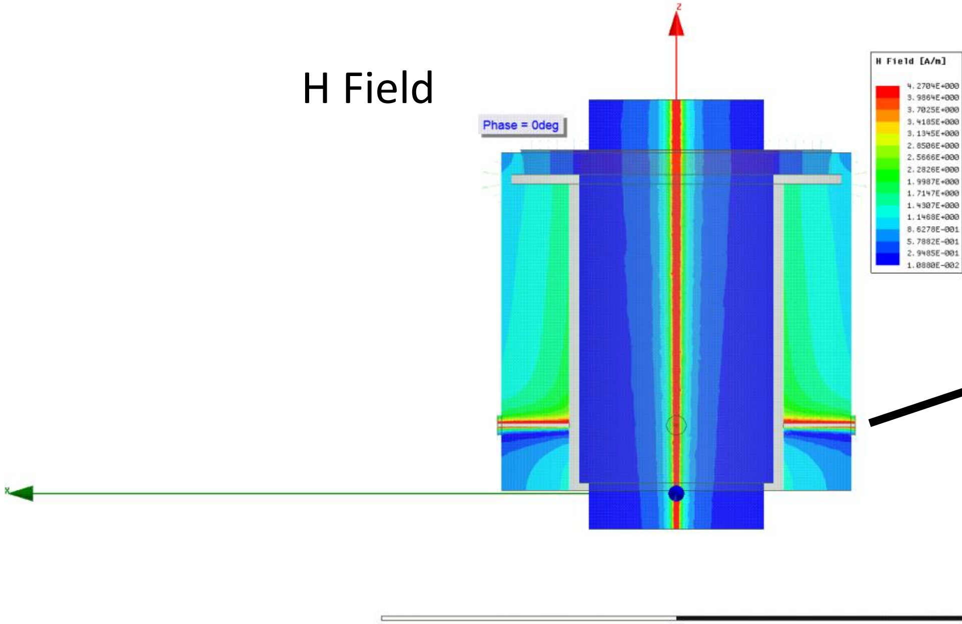
E Field

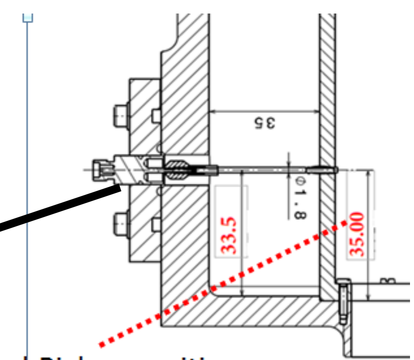




Resonance Frequency

H Field



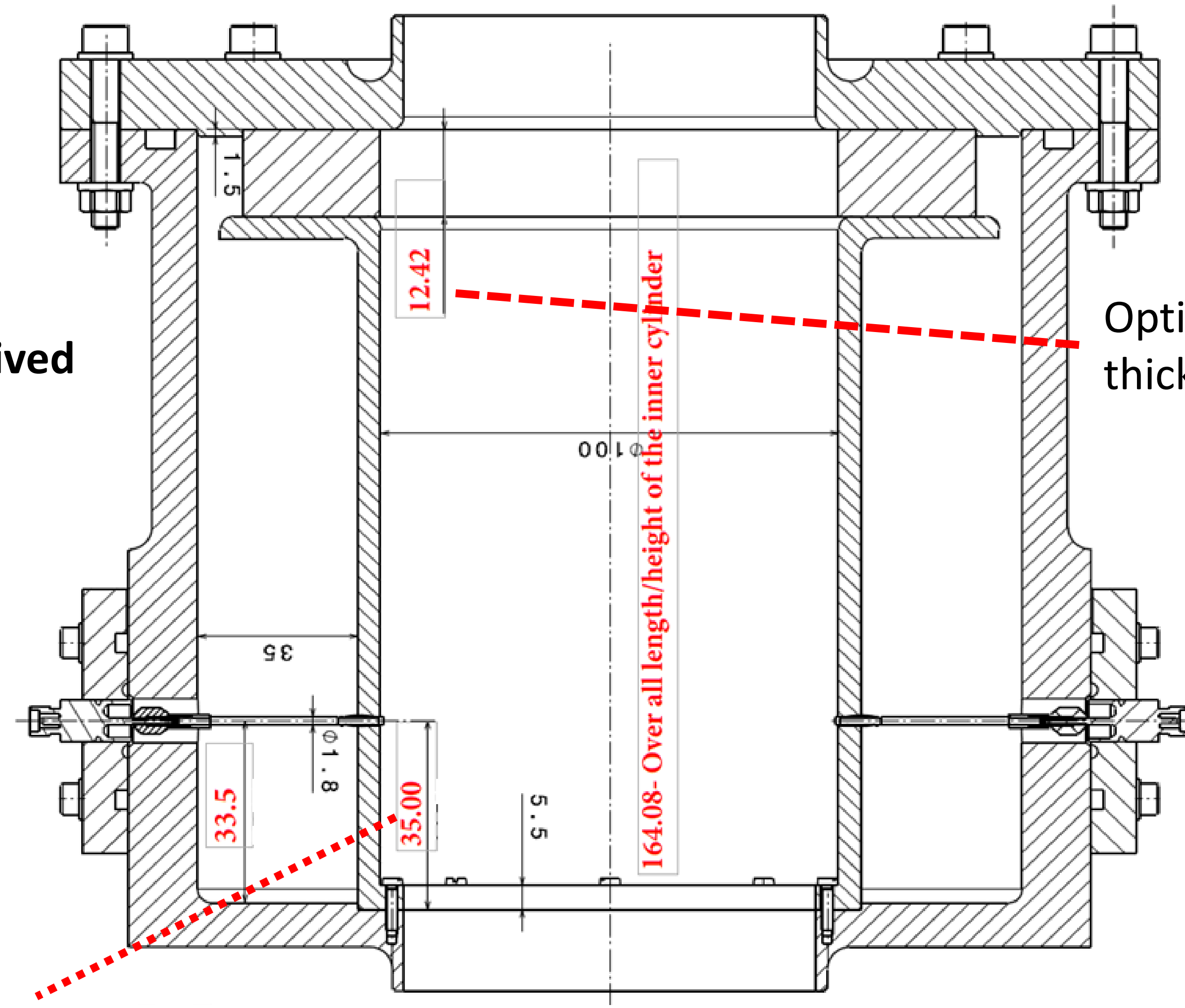


Optimized Pickup position

Signal Level

Mechanical Prototype

Dimensions derived from HFSS

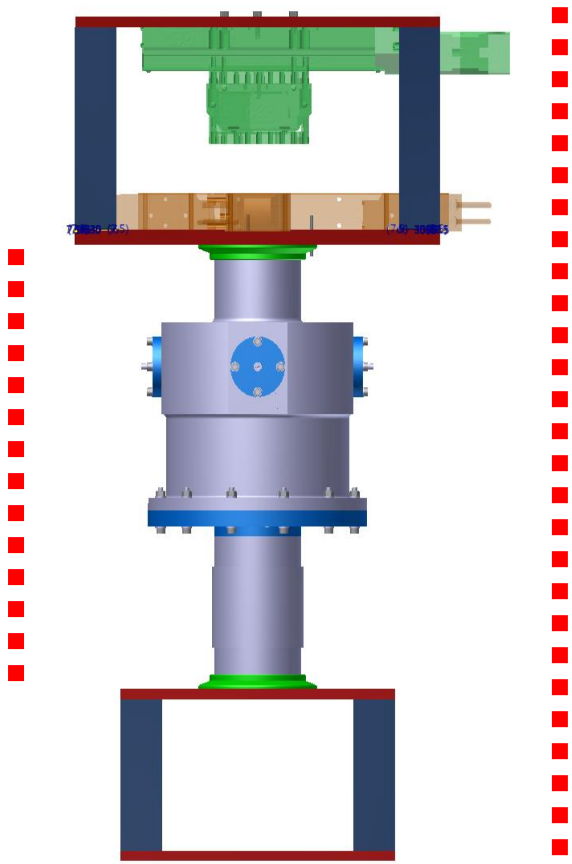


Optimized Ceramic thickness

Optimized Pickup position

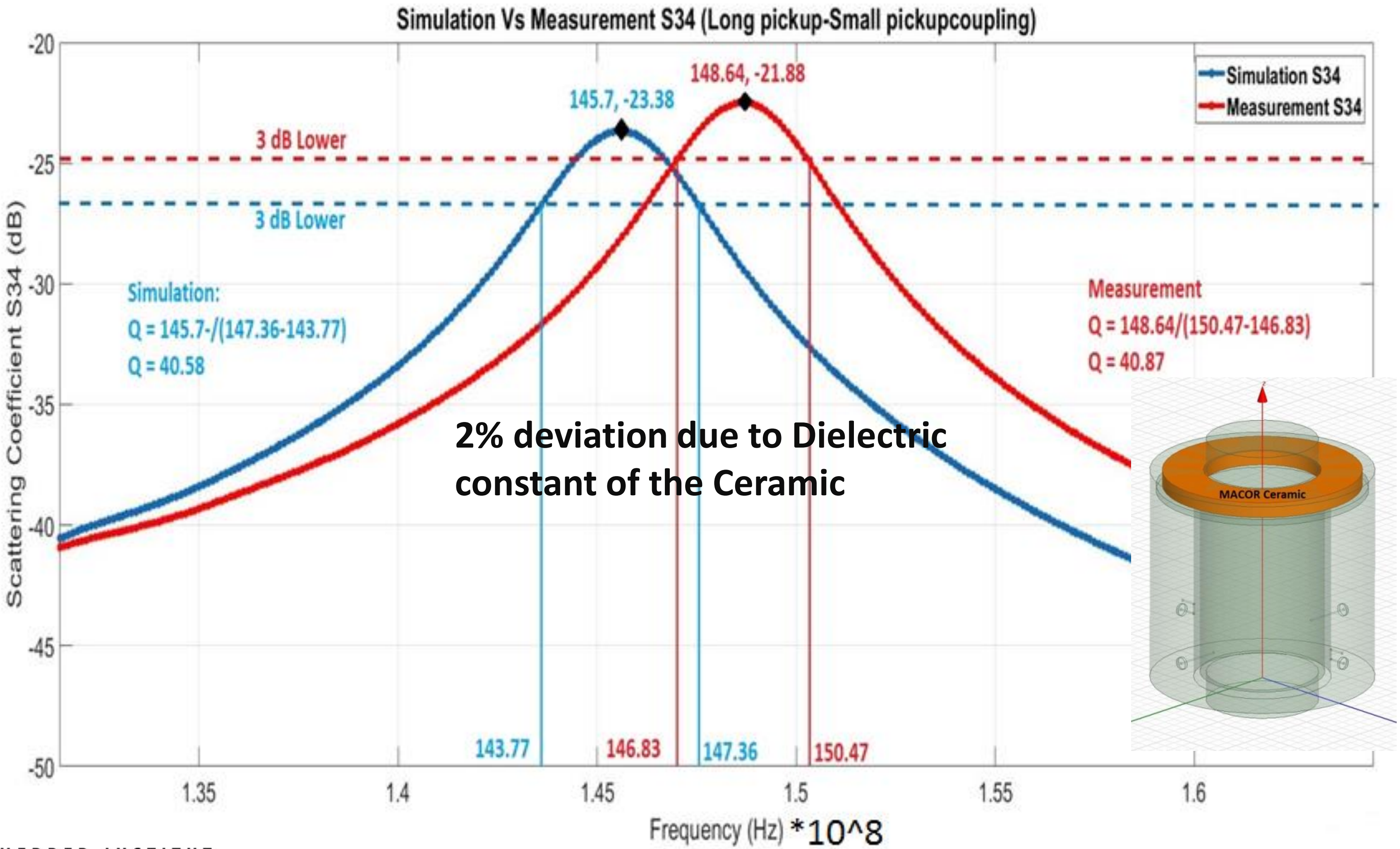
Test Bench Design

45 cm (approx)



85 cm (approx)

Simulation Vs Measurement



2% deviation due to Dielectric constant of the Ceramic

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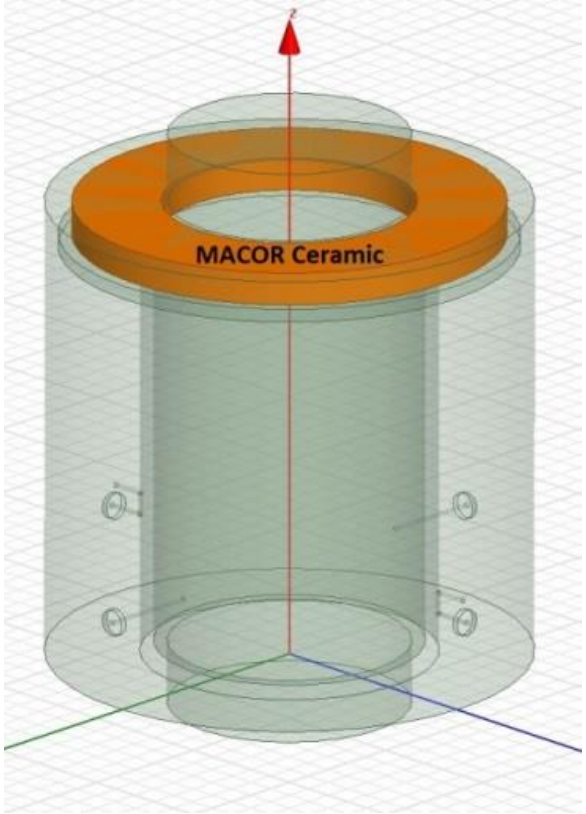
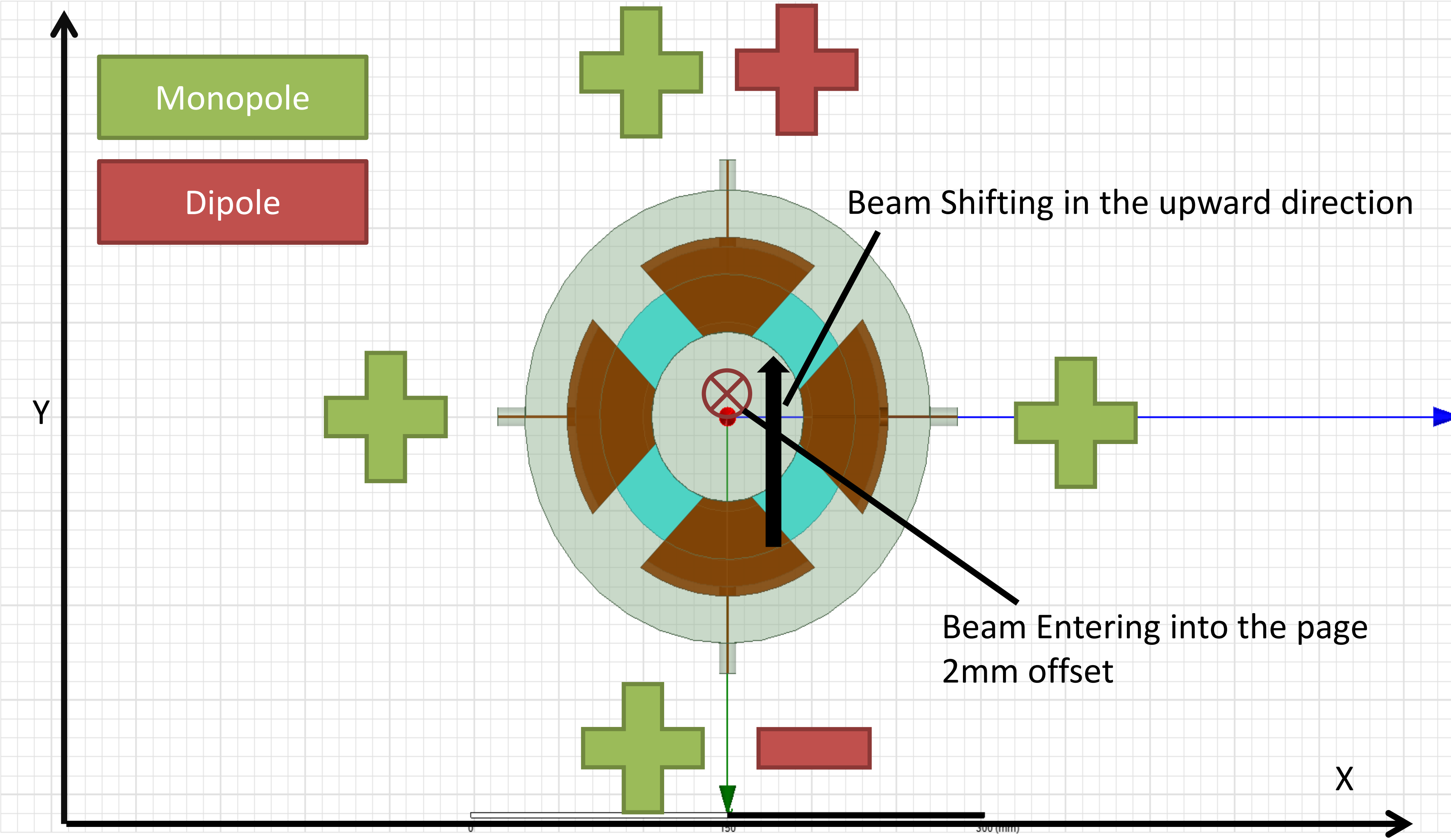
Status of BCM

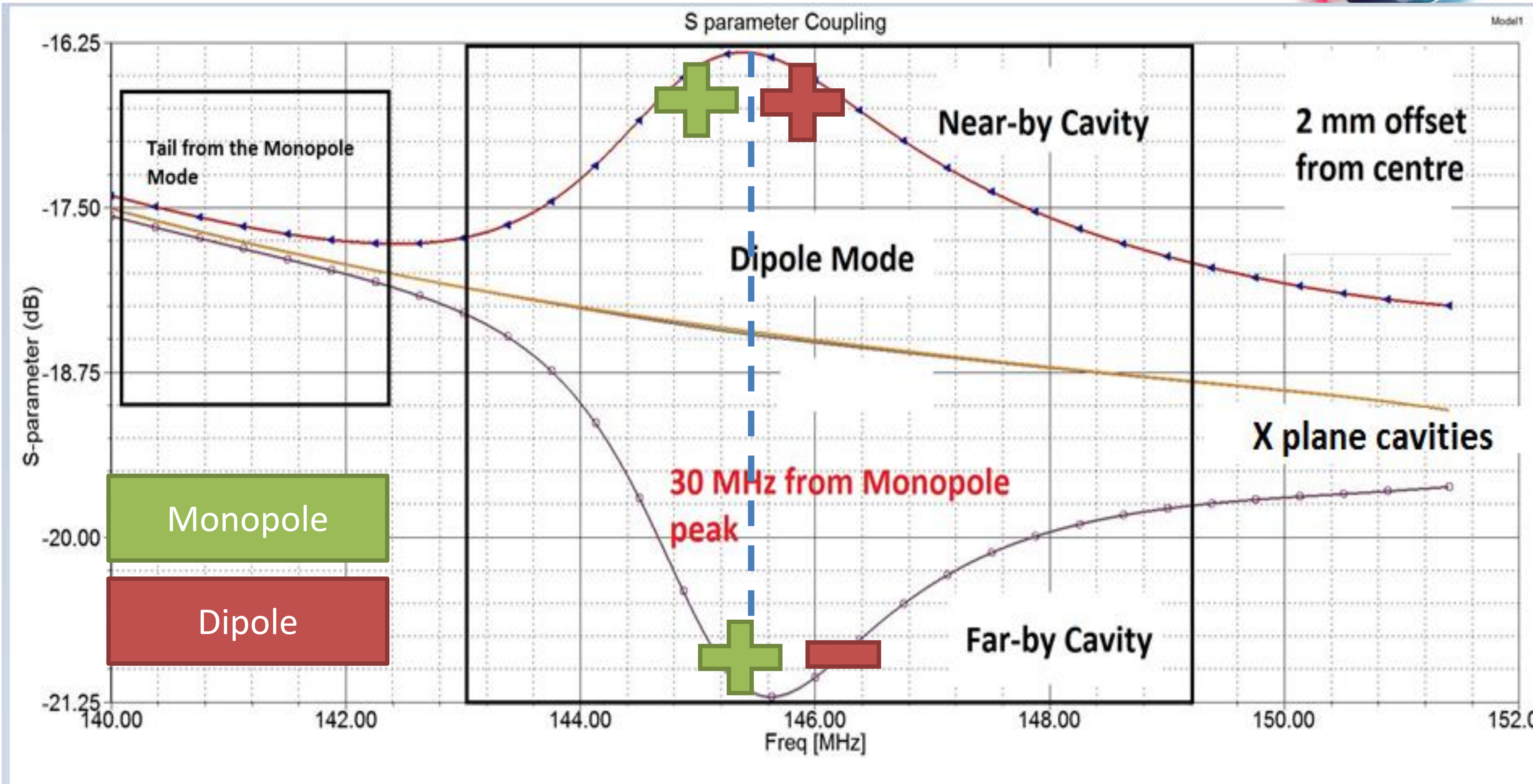
- The prototype built and characterized
- Simulation Vs Test bench measurement good agreement
- Deviation from Simulation investigated
- Frequency dependent dielectric constant of MACOR
- Install in the beam line in the coming weeks



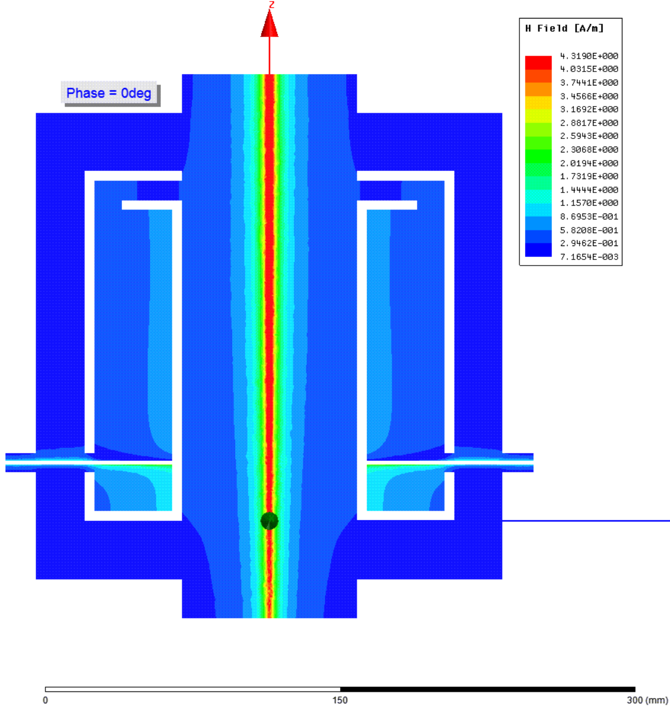
Reentrant BPM



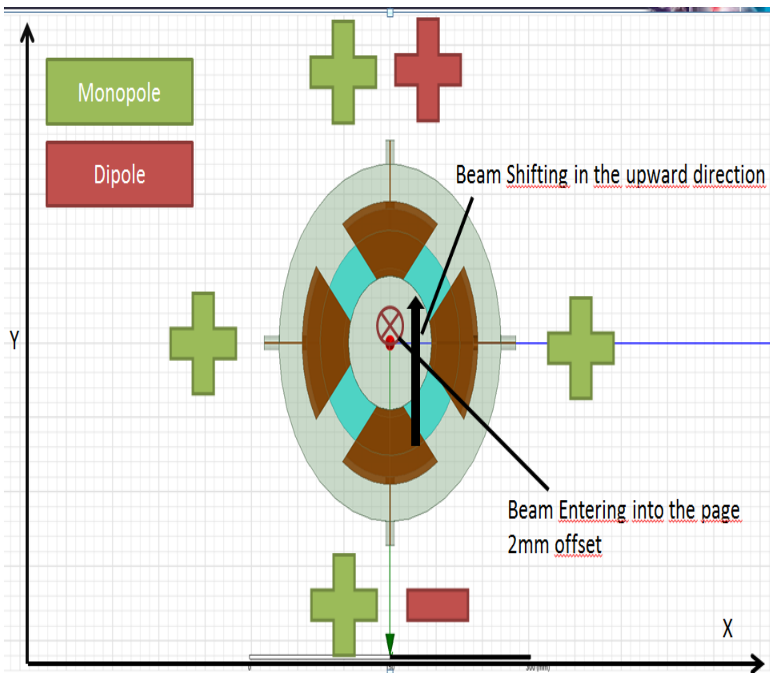
Reentrant BPM



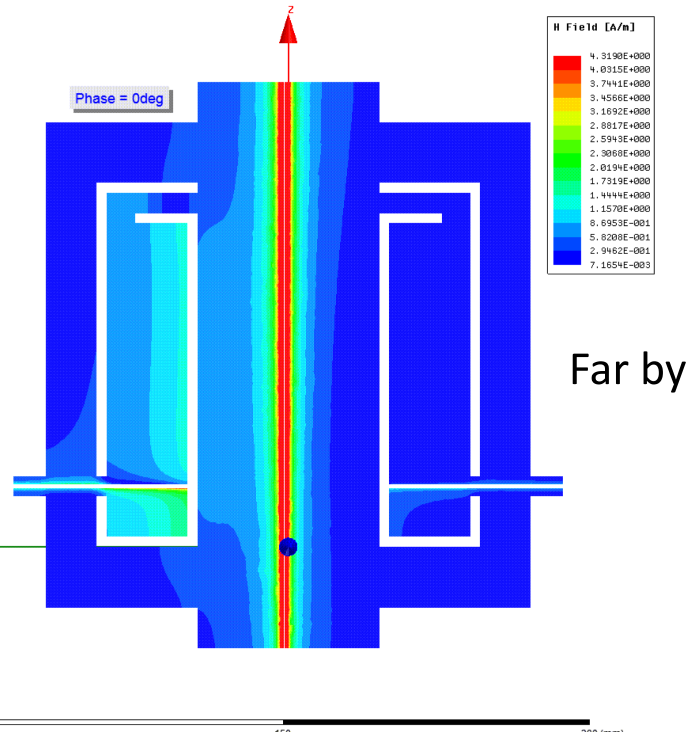
2 mm offset in Y plane.
X plane cavities see no difference in induced fields
Y plane cavities see considerable difference in induced fields



X direction



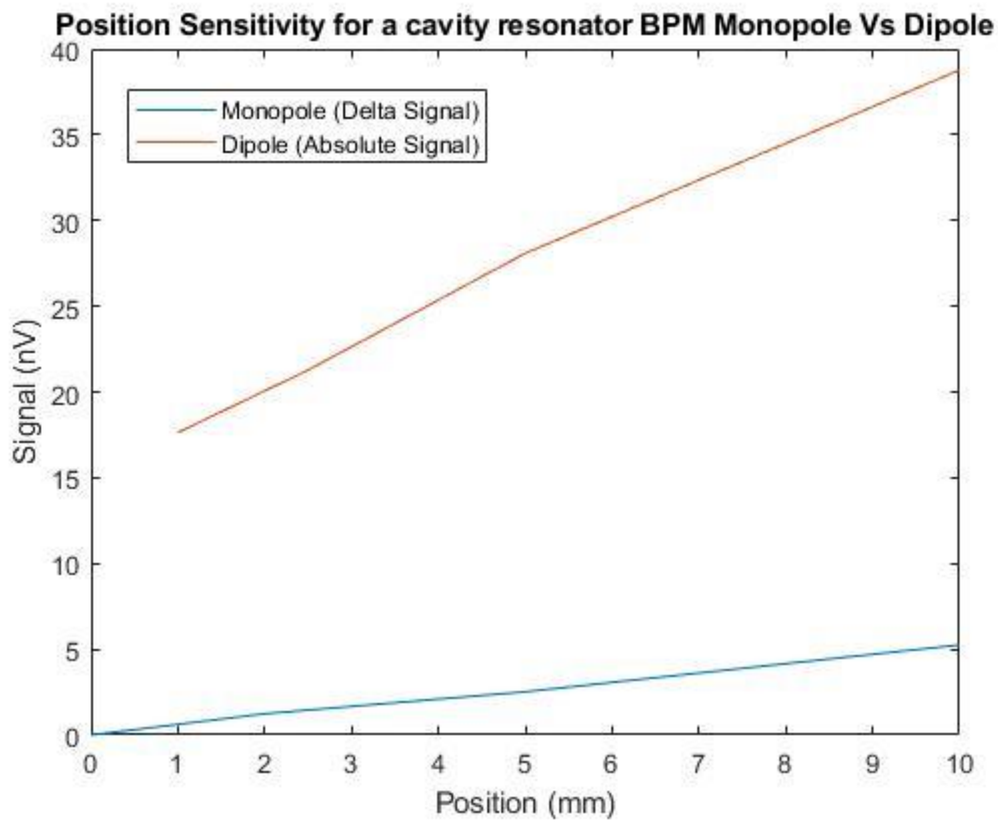
Near by



Far by

Y Direction

First Observations



Future Works

- BPM prototype middle of July, 2018
- BPM Test bench measurement
- Fine-tuning of Prototype

Thank You

Questions???

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 675265