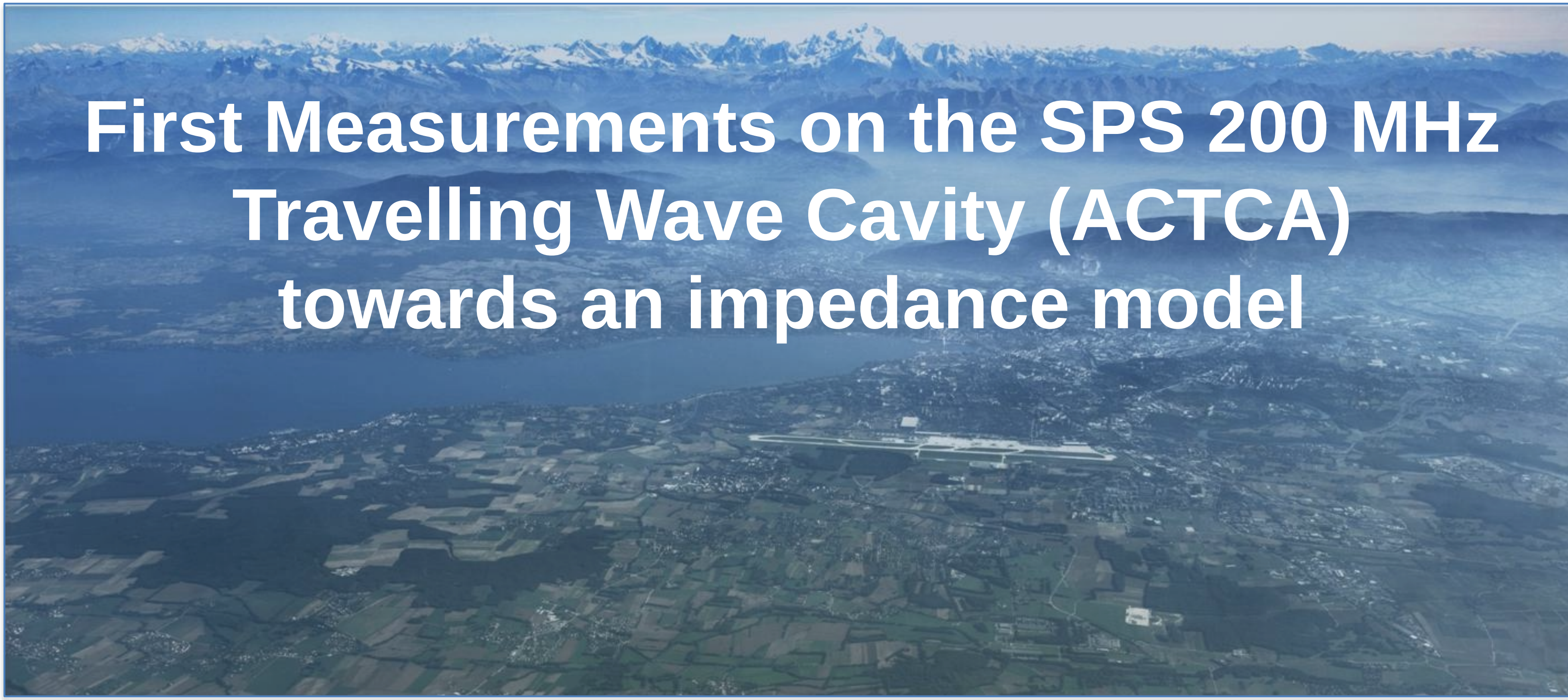
LHC Injectors Upgrade

First Measurements on the SPS 200 MHz Travelling Wave Cavity (ACTCA) towards an impedance model



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LIU-SPS

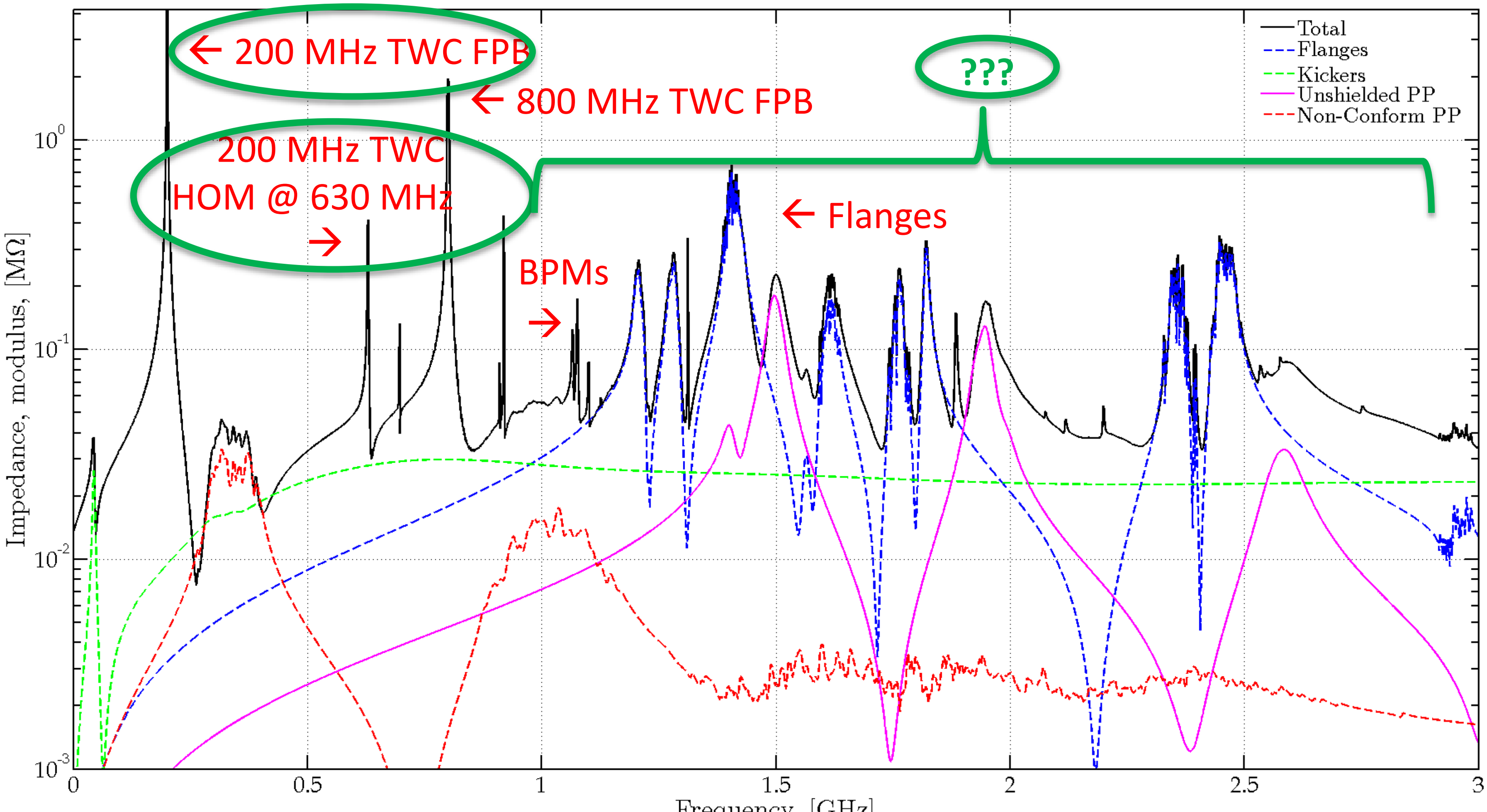
16/04/2015

Outline

- Longitudinal impedance model of the SPS
- Measurement setup & method
- Fundamental pass band: Results
- Higher Order Modes: Results
- 1.4 GHz band
- Conclusions

Longitudinal impedance model of the SPS

Why do we need this?



Courtesy: J.B. Ghini

Measurement setup & method

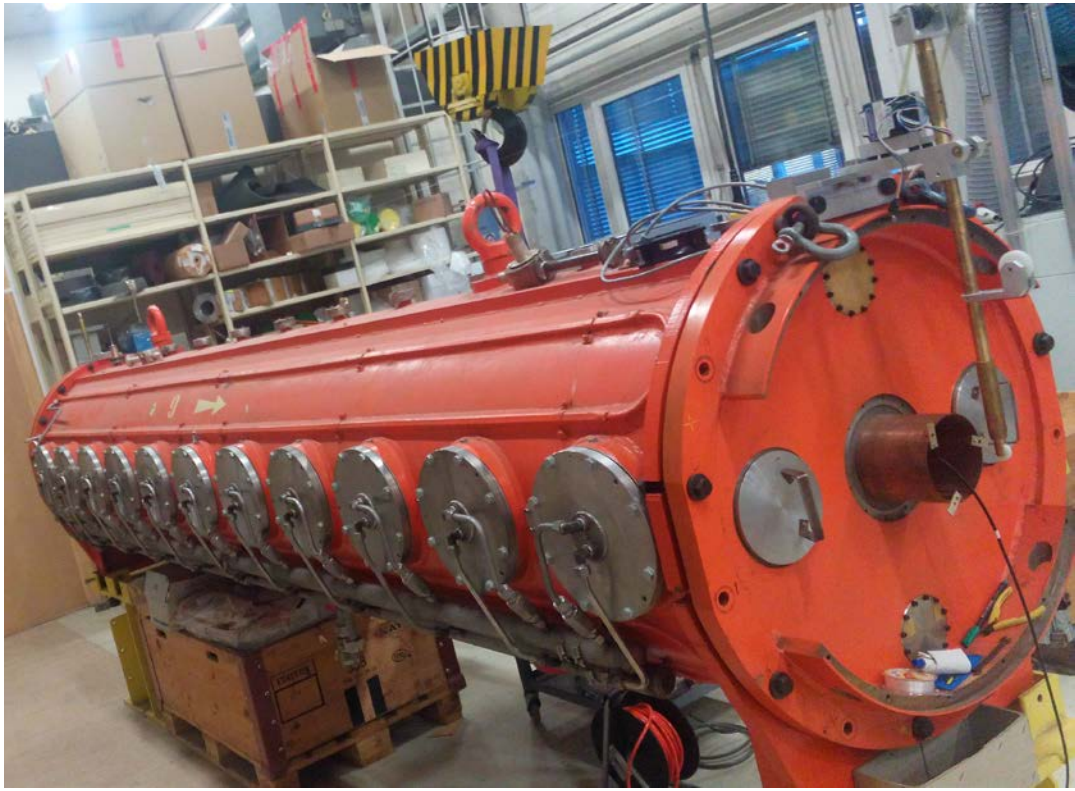
SPS 200 MHz TWC in the ring:

- 4 to 5 sections / cavity system

Test device: One section

- 4.114 m long
- 11 drift tubes
- No power couplers
- No HOM couplers
- Short circuited

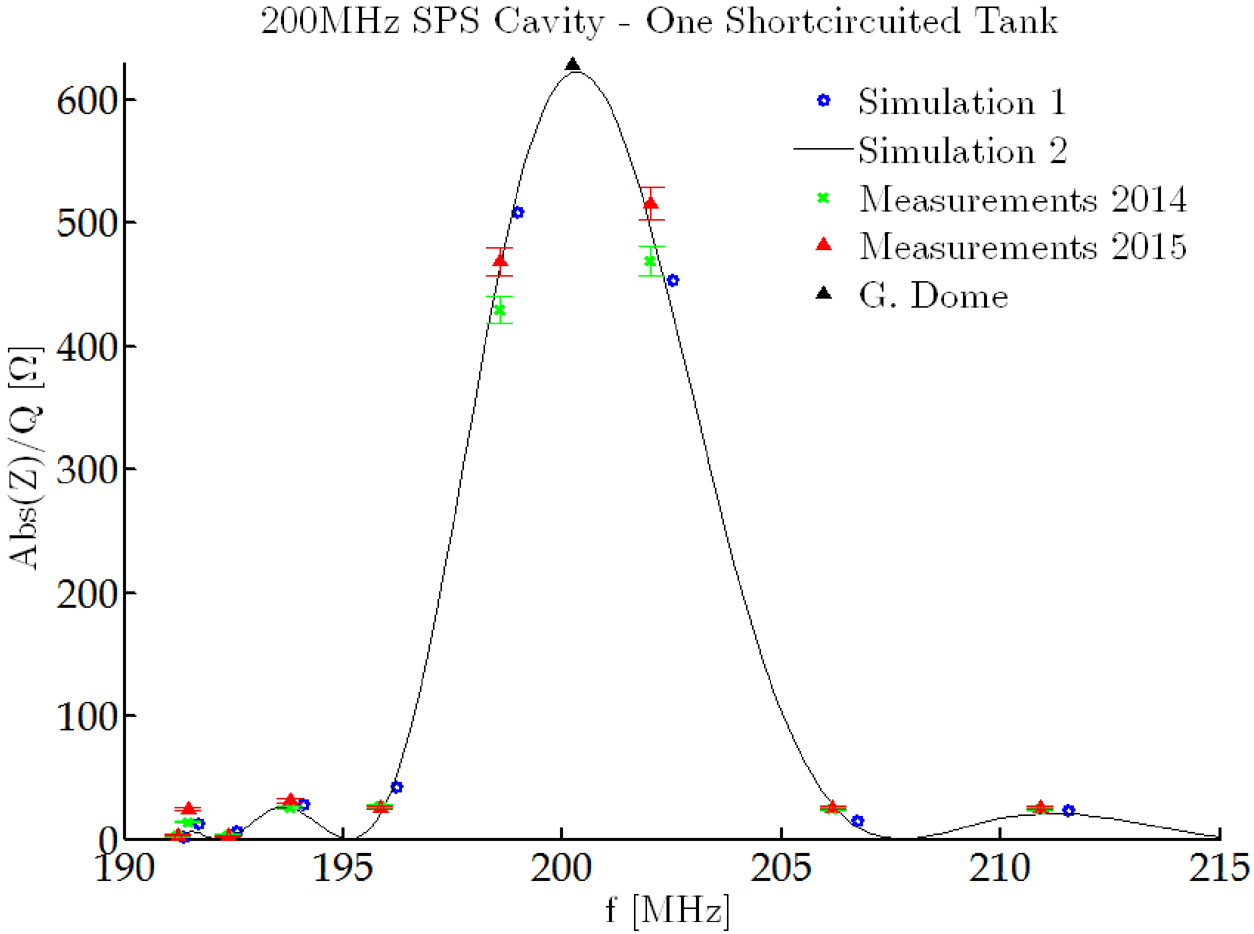
→ Standing wave measurements



Measurement setup & method

What we're after:

Fundamental pass band model with HOMs of the SPS 200 MHz TWC



Measurement setup & method

- Goal: Obtain longitudinal impedance of SPS 200 MHz TWC
- Method: Bead-pull measurements
- Main concept: Introducing a conductor / dielectric / ferromagnetic into a resonator → Frequency change (Perturbation theory).

$$\frac{\Delta f}{f_0} = \frac{\iiint_{V_{bead}} (\vec{E}_1.\vec{D}_0 - \vec{E}_0.\vec{D}_1 - \vec{H}_1.\vec{B}_0 + \vec{H}_0.\vec{B}_1)\, dv}{\iiint_V (\vec{E}_0.\vec{D}_1 - \vec{H}_0.\vec{B}_1)\, dv}$$

Assumptions:
- Homogeneous bead ($\vec{D}$, $\vec{B} \rightarrow \vec{E}$, $\vec{H}$, ε,µ)
- Small perturbation
- Small bead: $\vec{E}$, $\vec{H}$ constant within
- $\vec{E}$, $\vec{H}$ outside bead: unchanged
- <u>Only E_z sensitive</u>: metallic + needle shape bead

$\rightarrow \frac{\Delta f}{f_0} \approx \frac{1}{W_0}(K_1 \varepsilon_0 |E_z|^2)$ with K_1 a constant related to the bead dimensions, $W0$ the total time averaged mean stored energy in the cavity.

F. Caspers, G. Dôme, CERN-SPS 85-46

Measurement setup & method

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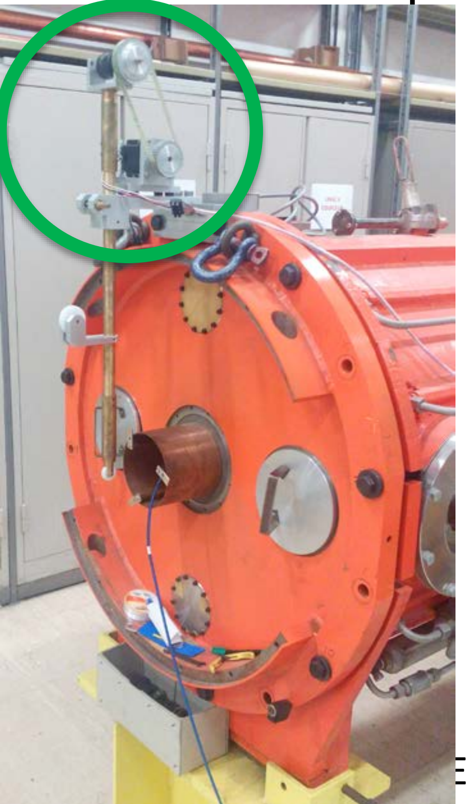


$\frac{\Delta f_0}{f_0}(z) \sim \frac{|E_z(z)|^2}{\sqrt{W}}$ → Excite with f_0 + move bead & measure Δf_0

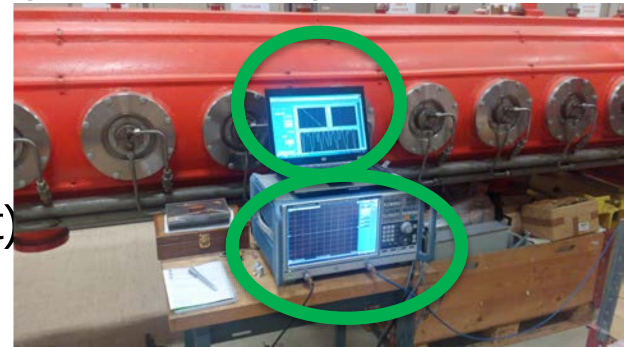
→ In practice: easier

S_{21} (or S_{11}) → transmission phase shift $\Delta\varphi$

$$\frac{\Delta f_0}{f_0} \approx \frac{1}{2Q_L}\tan(\Delta\varphi)$$

→ Semi-automated (single f_0)

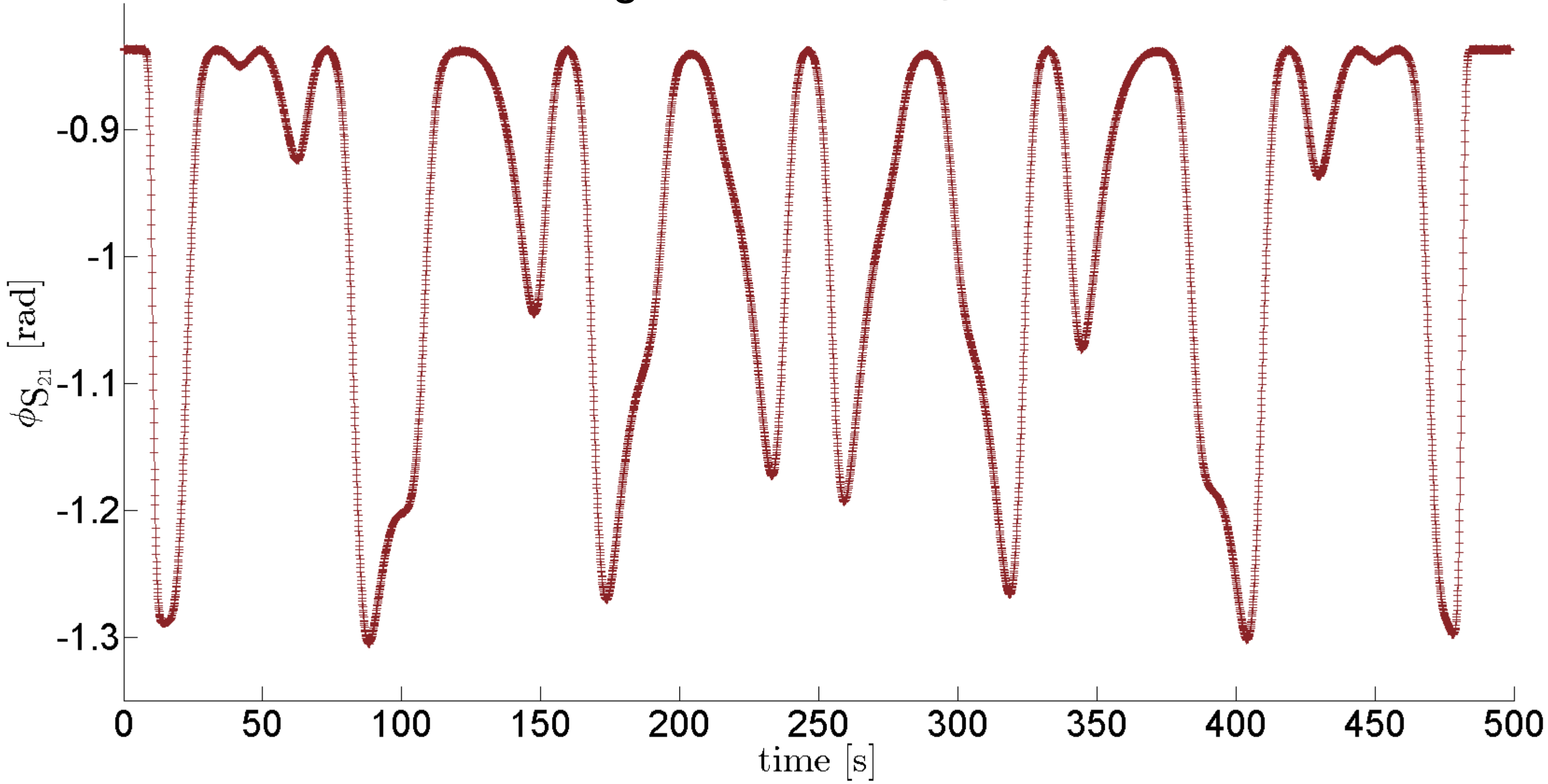
(motor + VNA + acquisition soft)



ERN-SPS 85-46

Measurement setup & method

Typical transmission measurement for a needle moving in the SPS 200 MHz TWC in standing wave mode @ 202 MHz

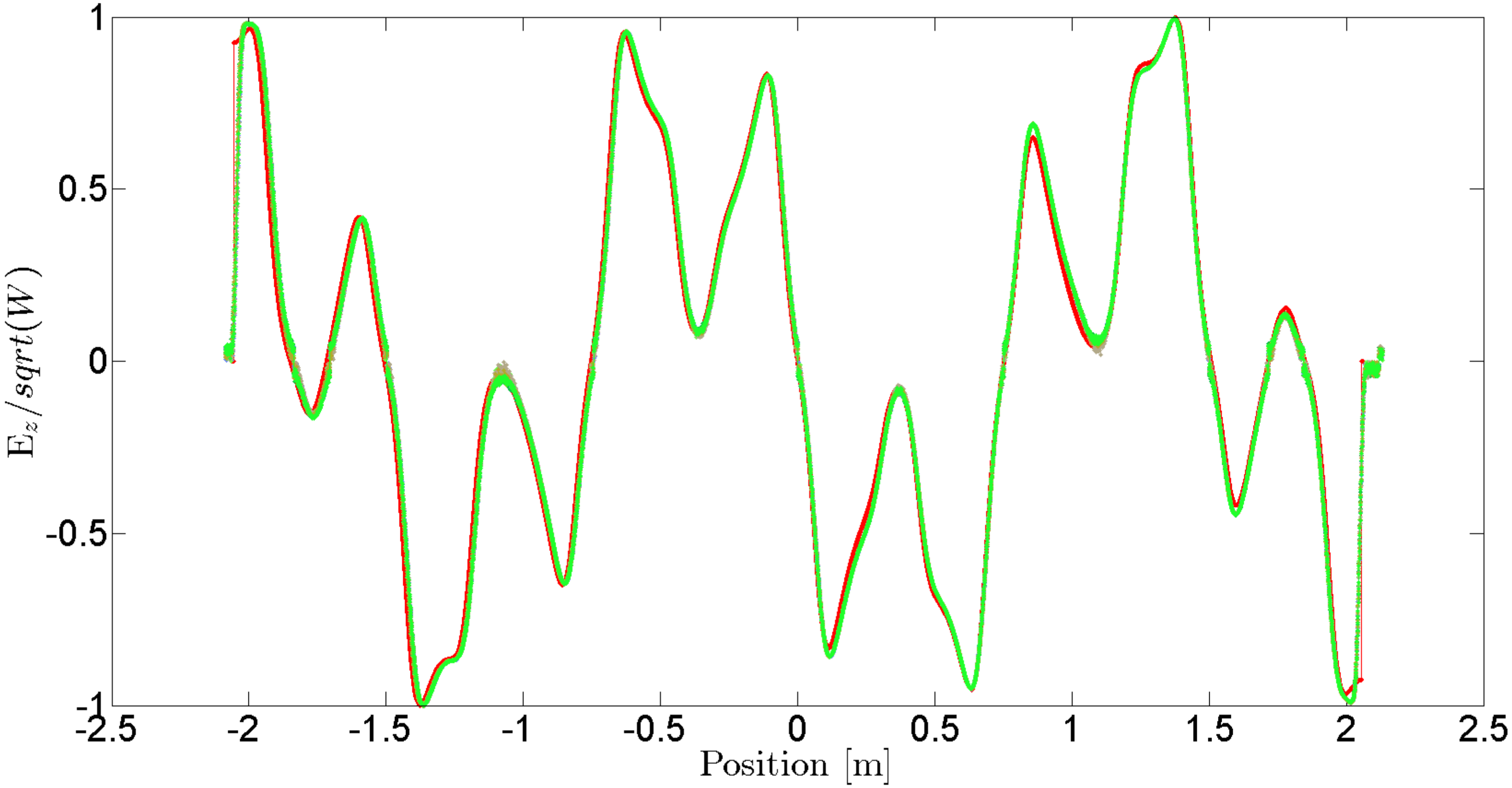


Very accurate E_z measurement → R/Q , but time consuming

Measurement setup & method

Typical Result: SPS 200 MHz TWC FPB @ 202 MHz

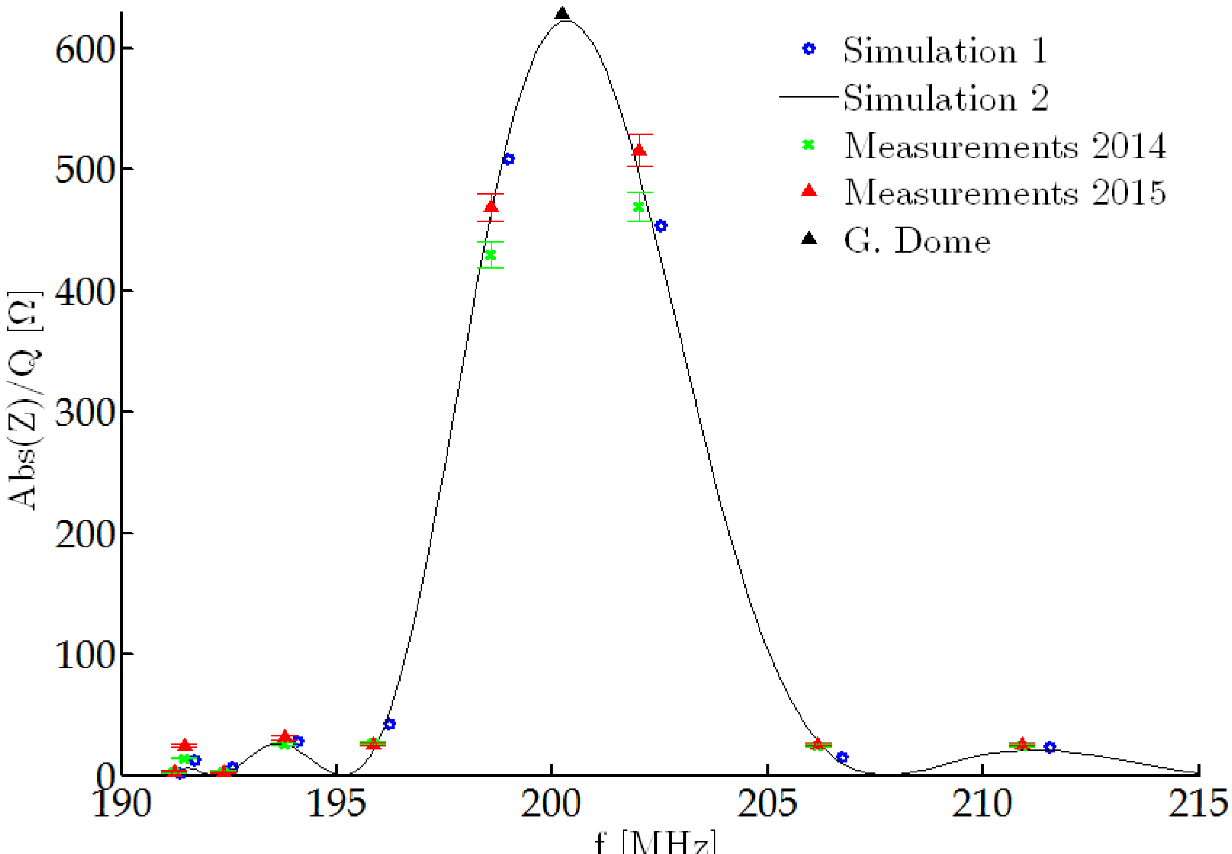
Simulation vs. measurement: E_z along cavity section



Fundamental pass band: Results

Fundamental pass band of the SPS 200 MHz TWC

- 11 modes in standing wave measurements ↔ 25 MHz pass band: 192 MHz – 217 MHz in travelling wave operation
- High R/Q: 198.6 MHz and 202.0 MHz



Higher Order Modes: Results

SPS 200 MHz TWC:

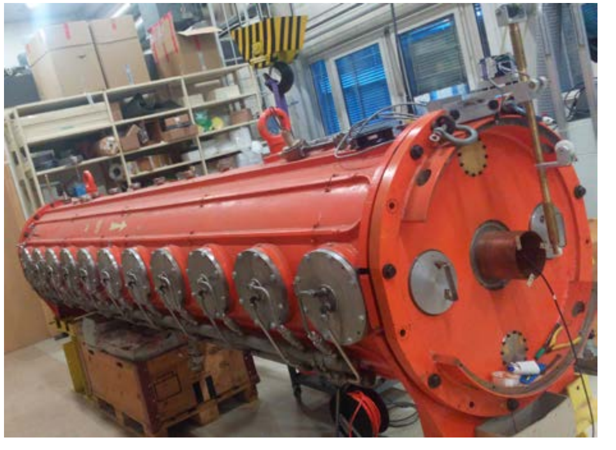
- Current impedance model (TWC) →
- HOM coupler @ 628 MHz (Longit. mode)
- HOM coupler @ 939 MHz (Transv. mode)
- HOM coupler @ 460 MHz (Transv. mode)

f [MHz]	Z [kΩ]
200 (4-cav)	1752
200 (5-cav)	2760
629 (both)	388

Measurement situation SPS 200 MHz TWC :

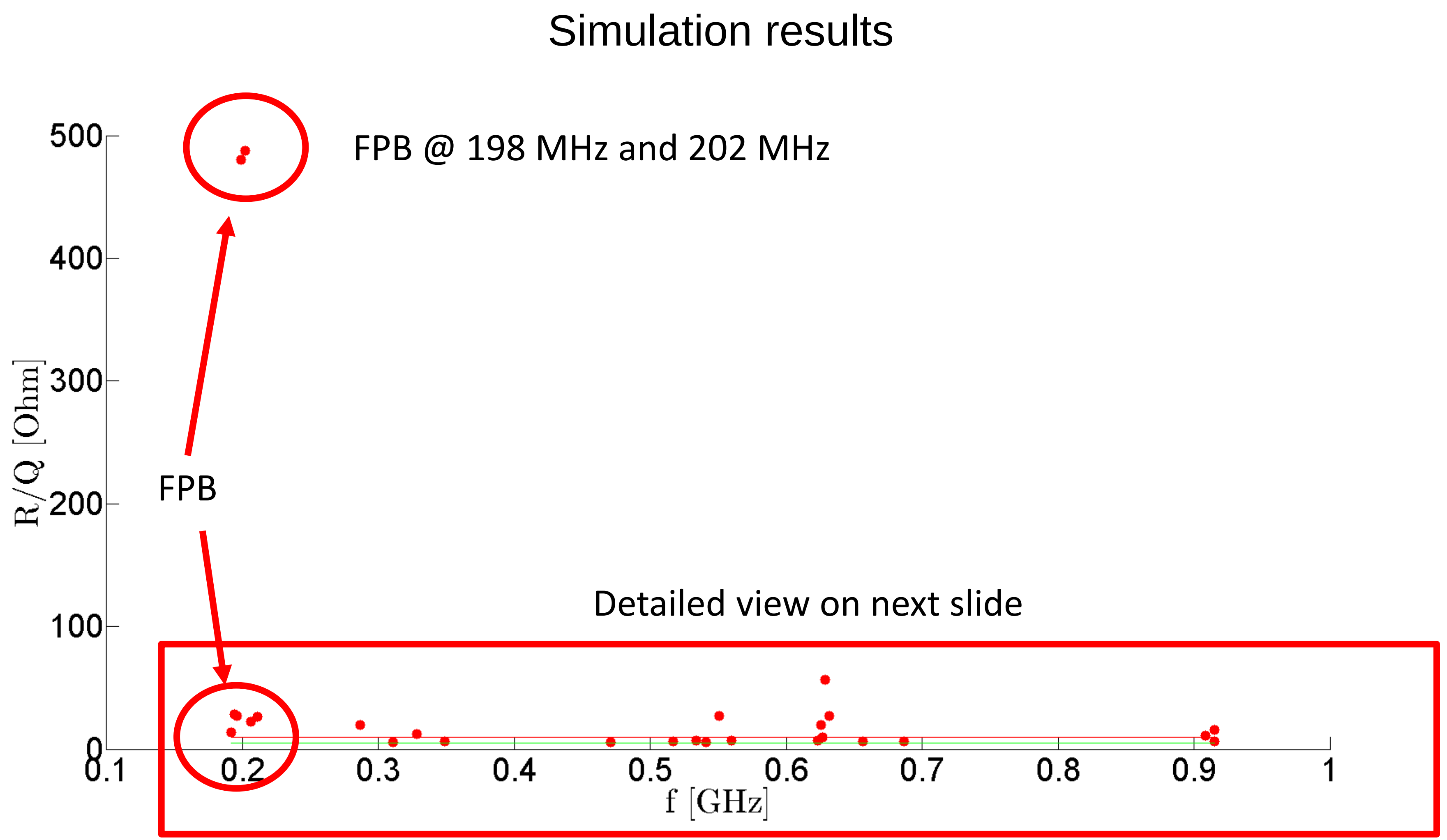
! Remember !

- Single 4m section
- No FPC
- No HOM couplers
- Short circuited

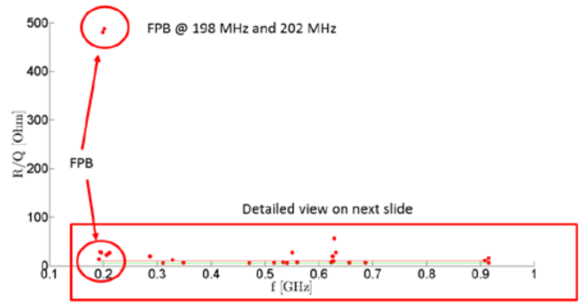


Higher Order Modes: Results

SPS 200 MHz TWC

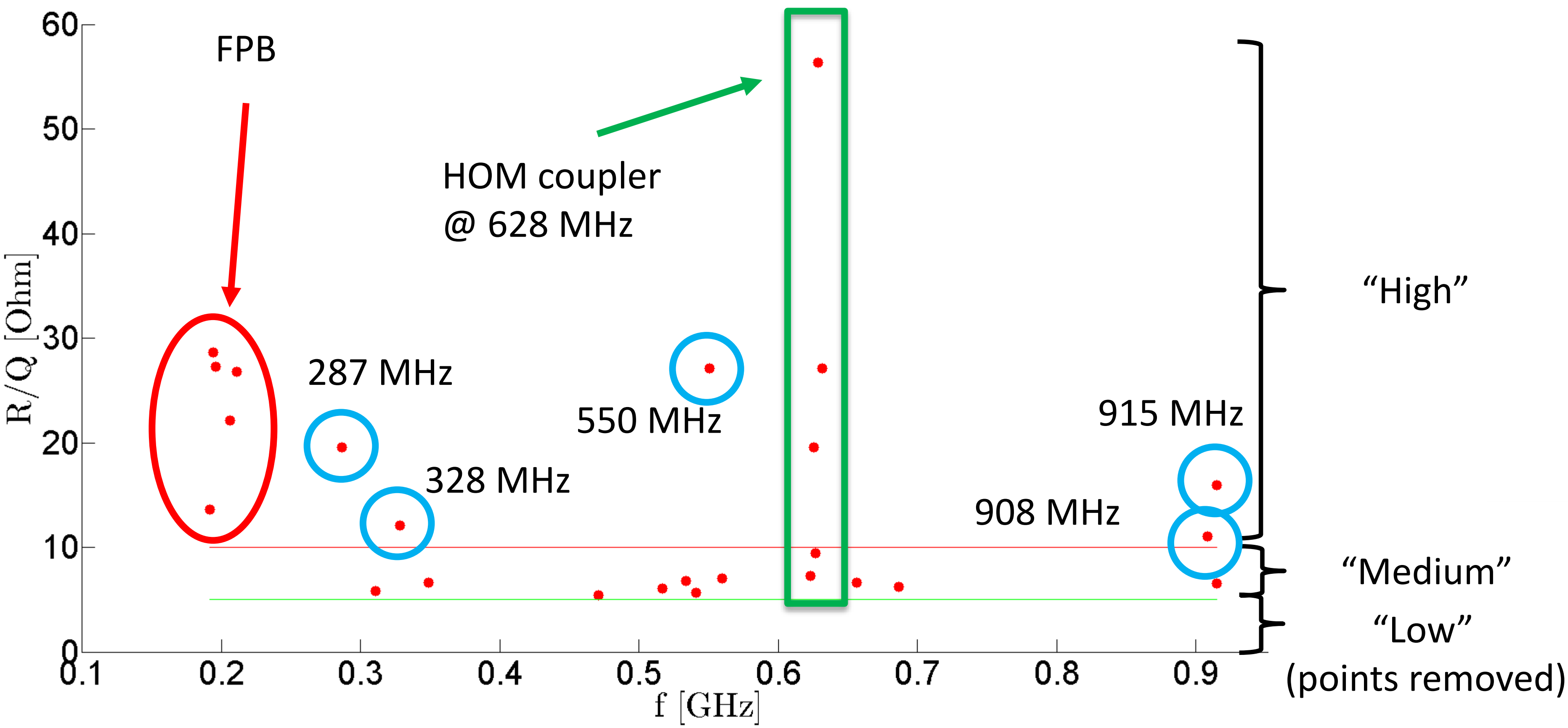


Higher Order Modes: Results



SPS 200 MHz TWC

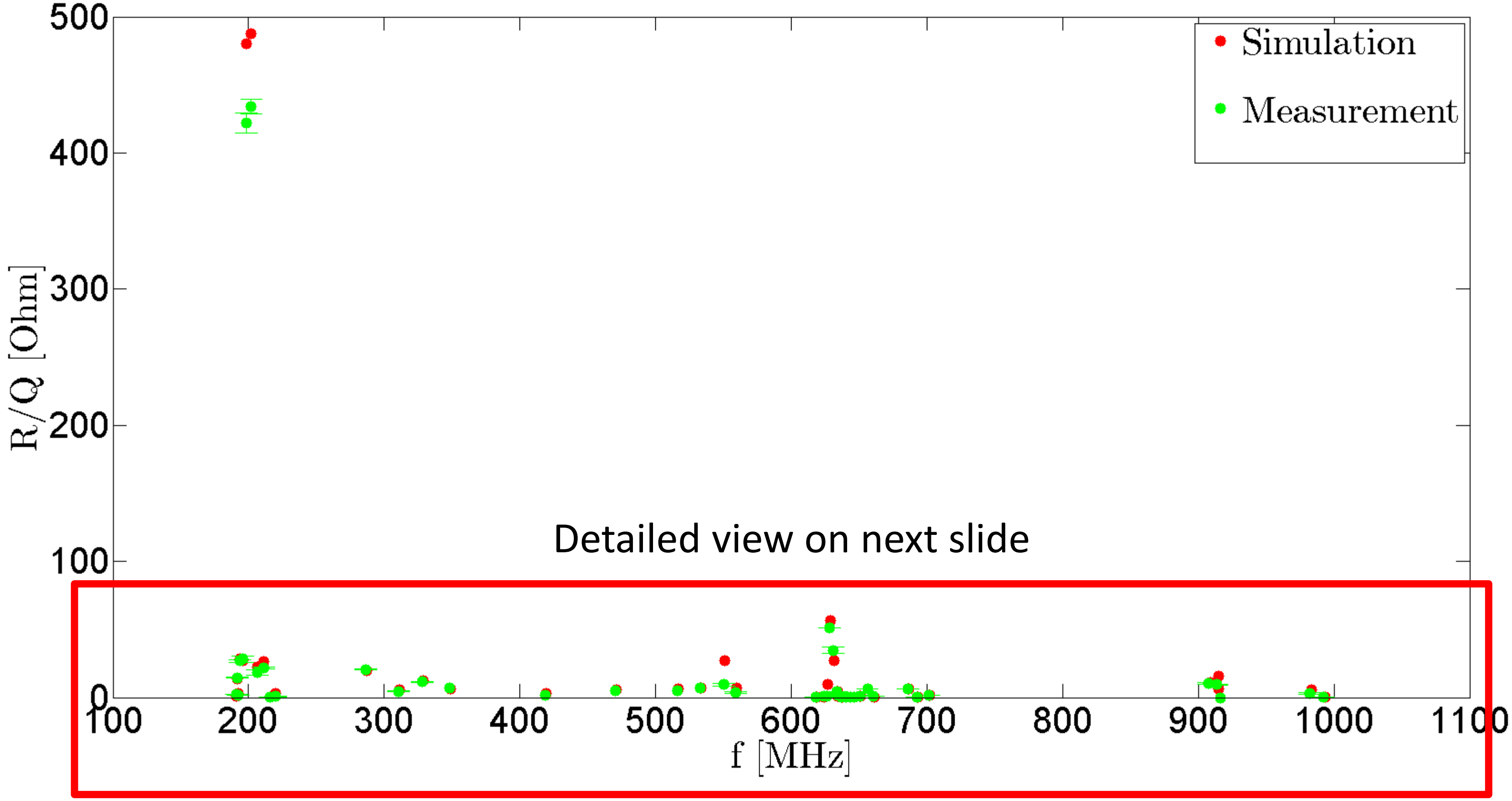
Simulation results



Higher Order Modes: Results

SPS 200 MHz TWC

Simulations vs. measurements: comparison



Higher Order Modes: Results

SPS 200 MHz TWC

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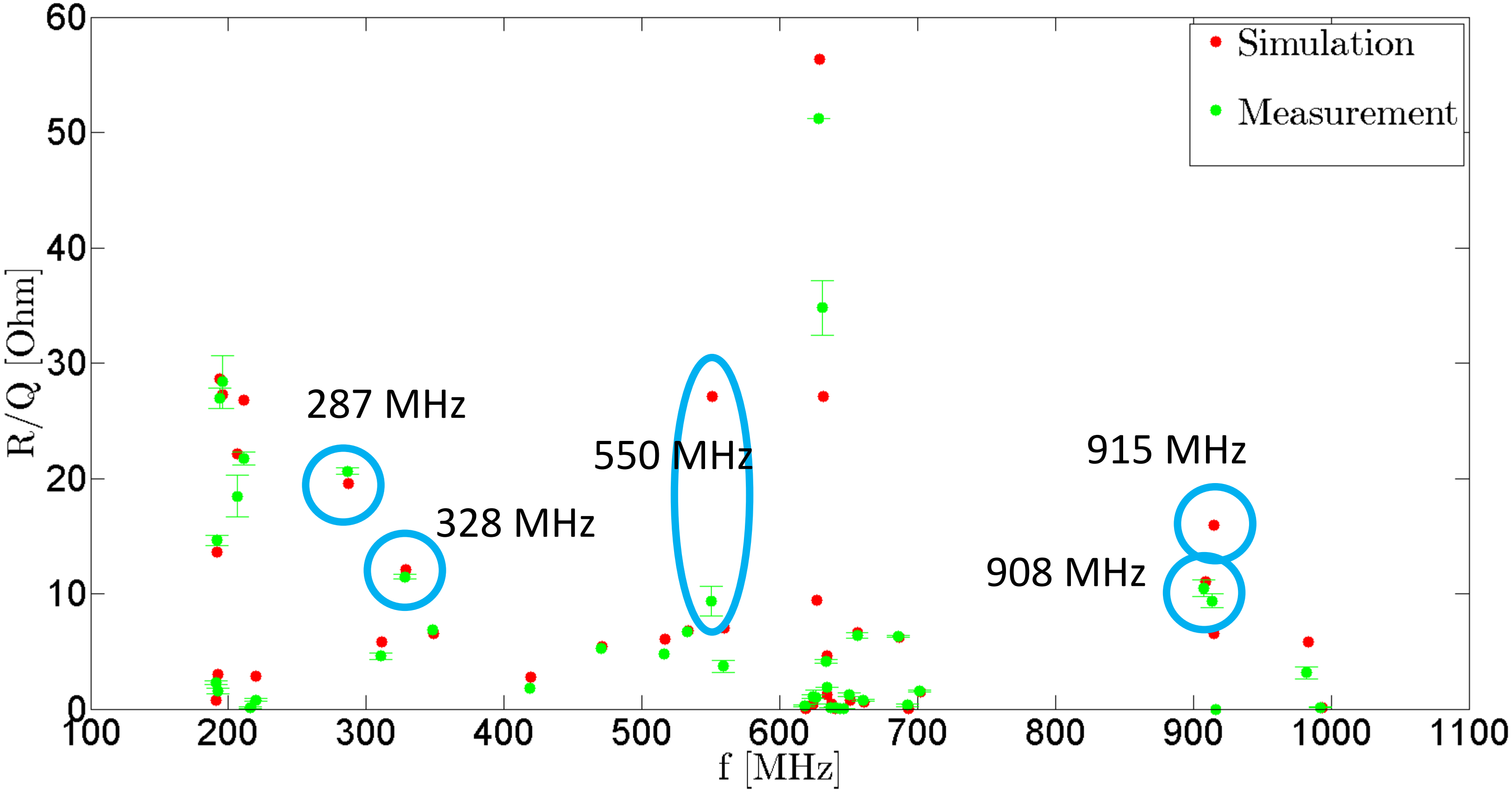
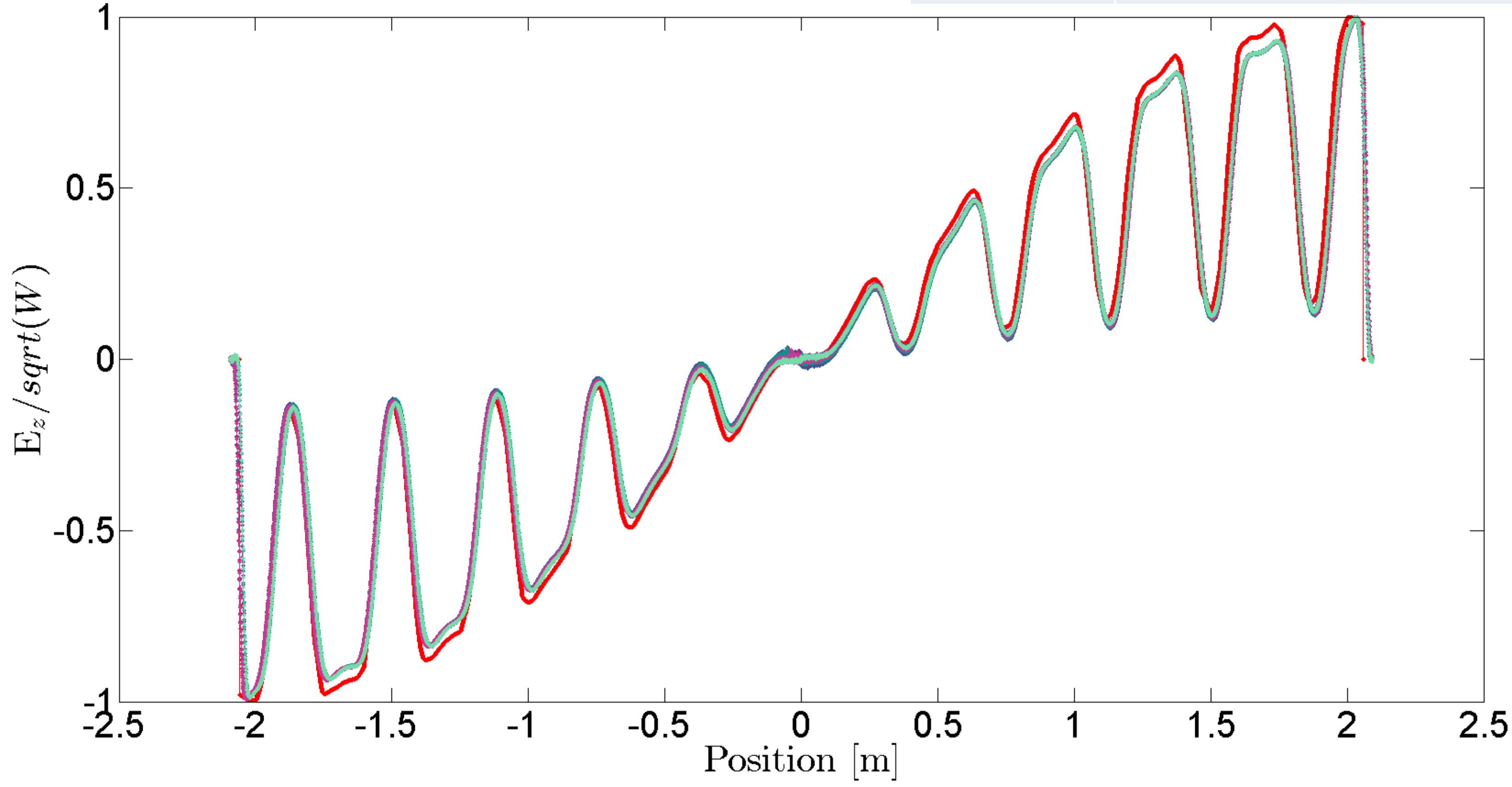


Higher Order Modes: Results

SPS 200 MHz TWC

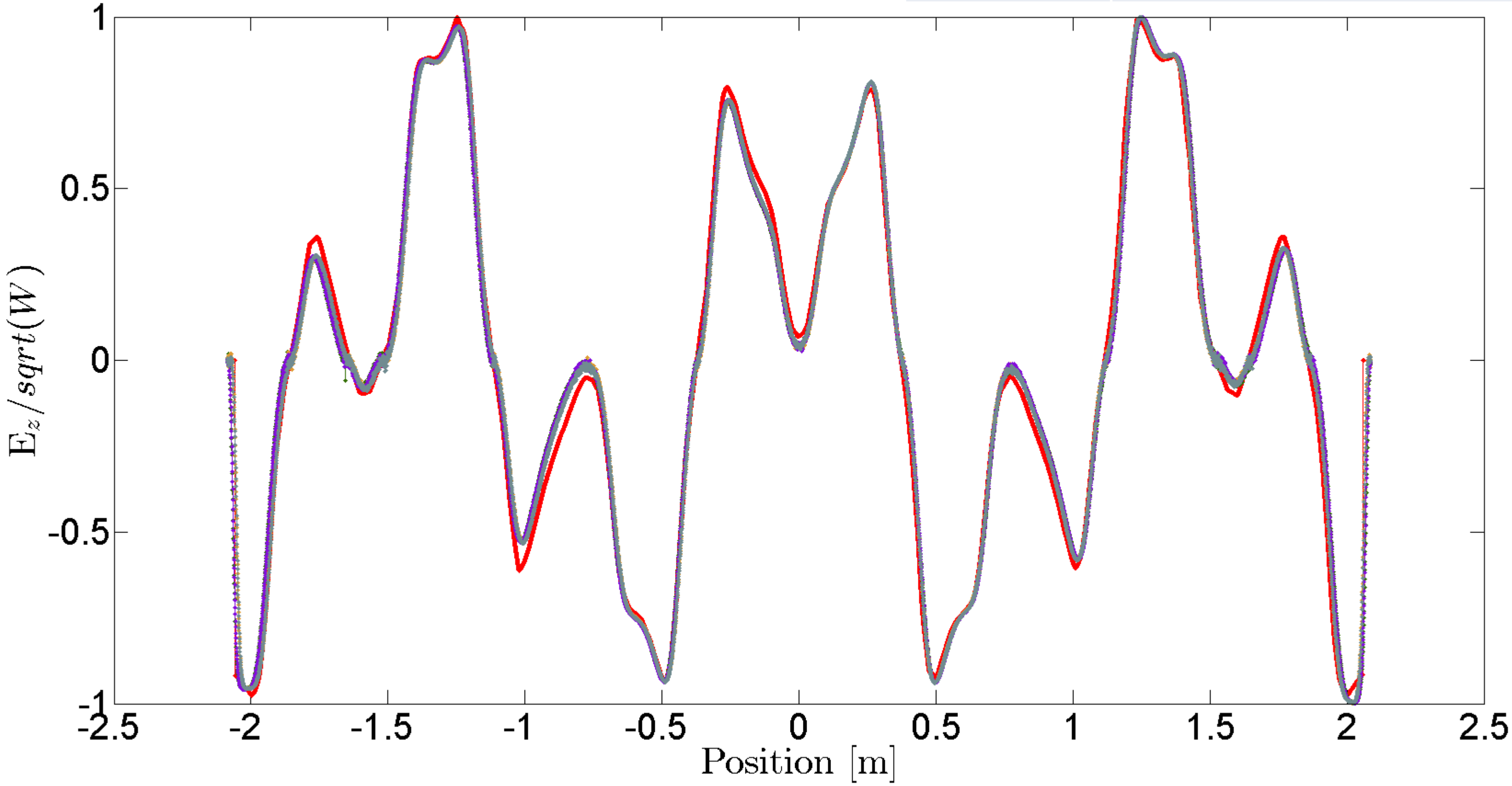
	Simulation	Measurement
f [MHz]	287	
Δϕ [°]	32	
R/Q [Ω]	19.6	20.6
Q	25013	



Higher Order Modes: Results

SPS 200 MHz TWC

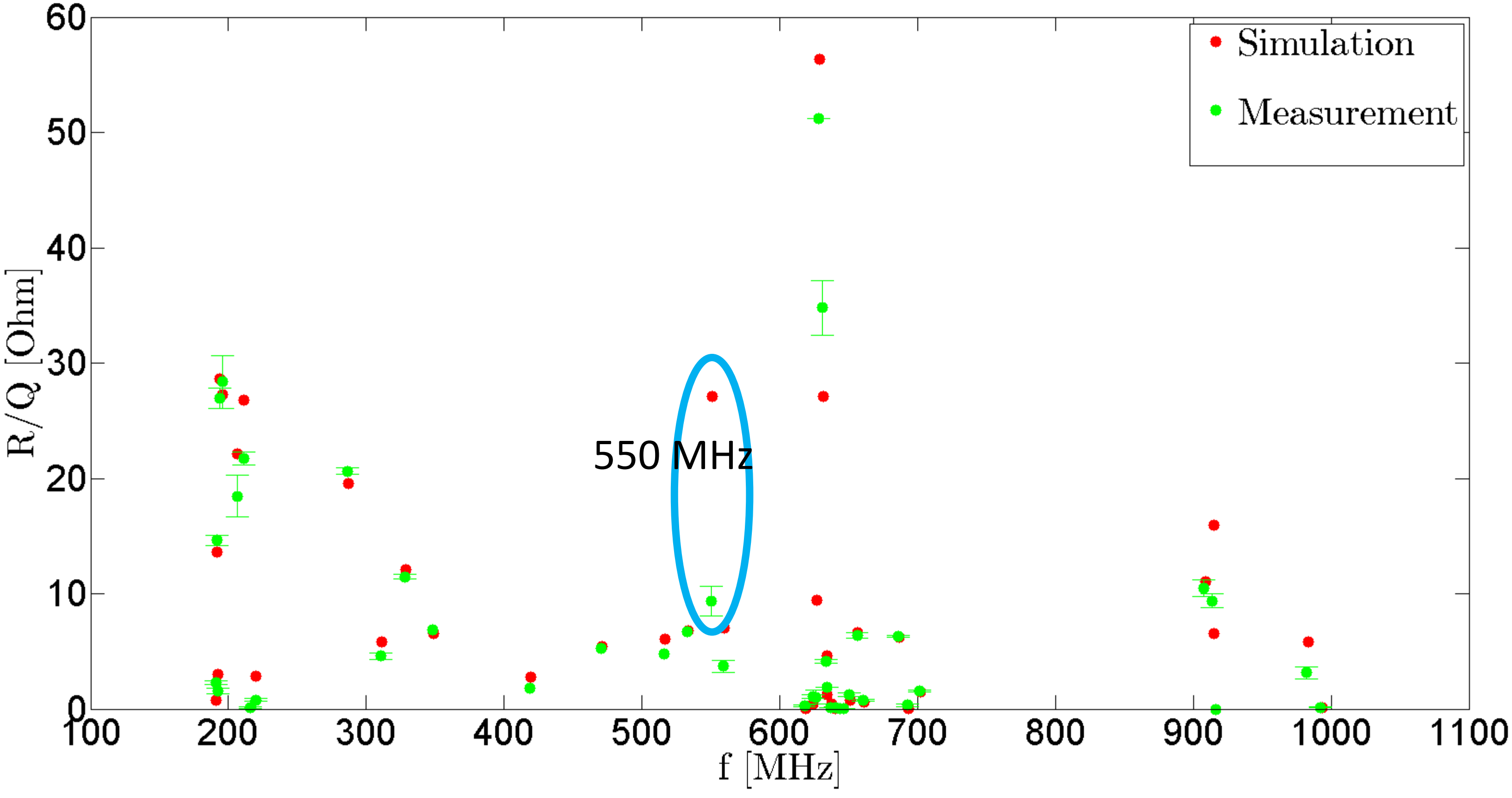
	Simulation	Measurement
f [MHz]	328	
Δϕ [°]	25	
R/Q [Ω]	12.0	11.5
Q	28666	



Higher Order Modes: Results

SPS 200 MHz TWC

Simulations vs. measurements: comparison

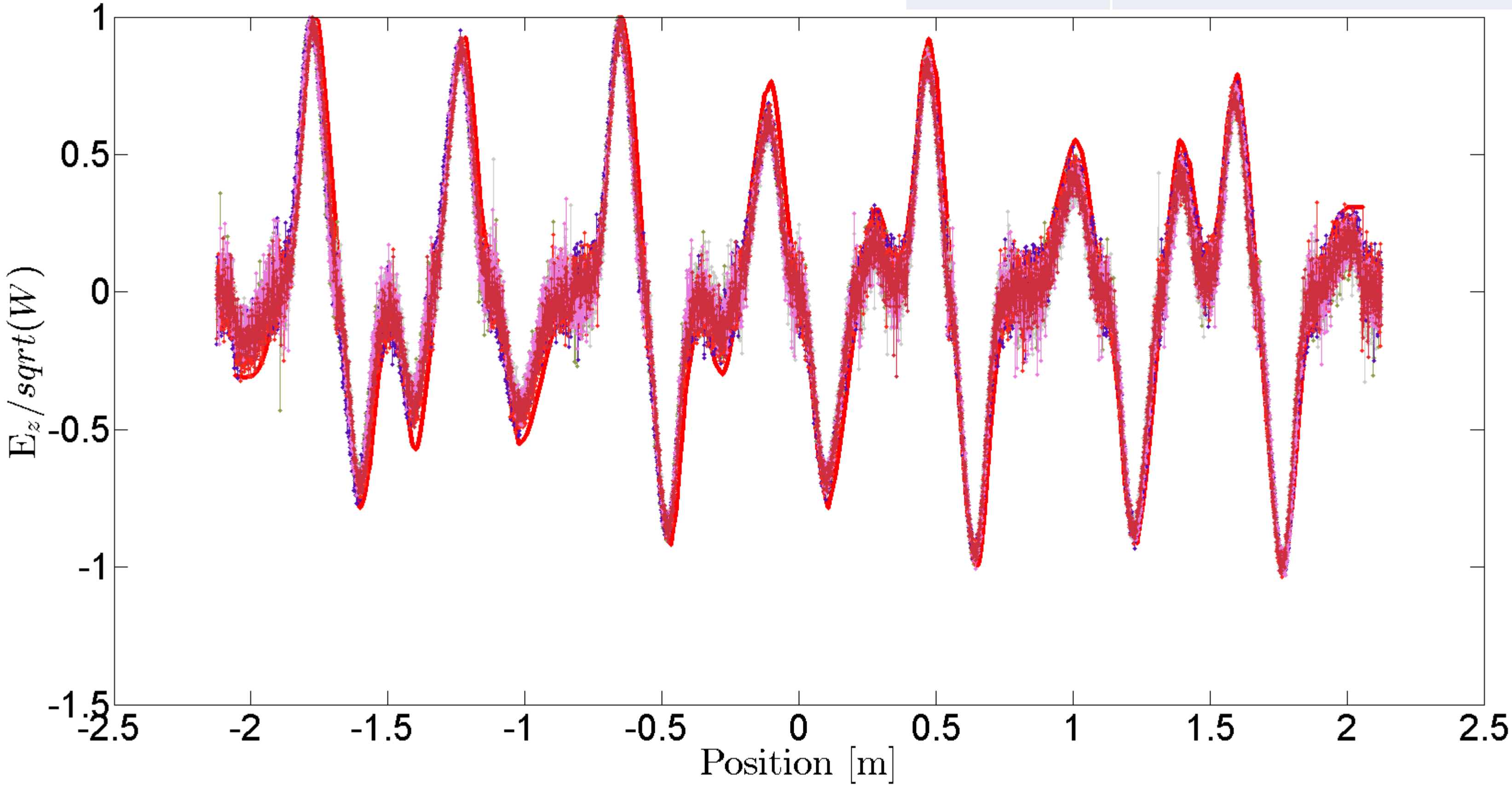


Higher Order Modes: Results

SPS 200 MHz TWC

	Simulation	Measurement
f [MHz]	550	
Δϕ [°]	6	
R/Q [Ω]	27	9.4
Q	40492	

Noisy data: Small Δϕ, to be improved

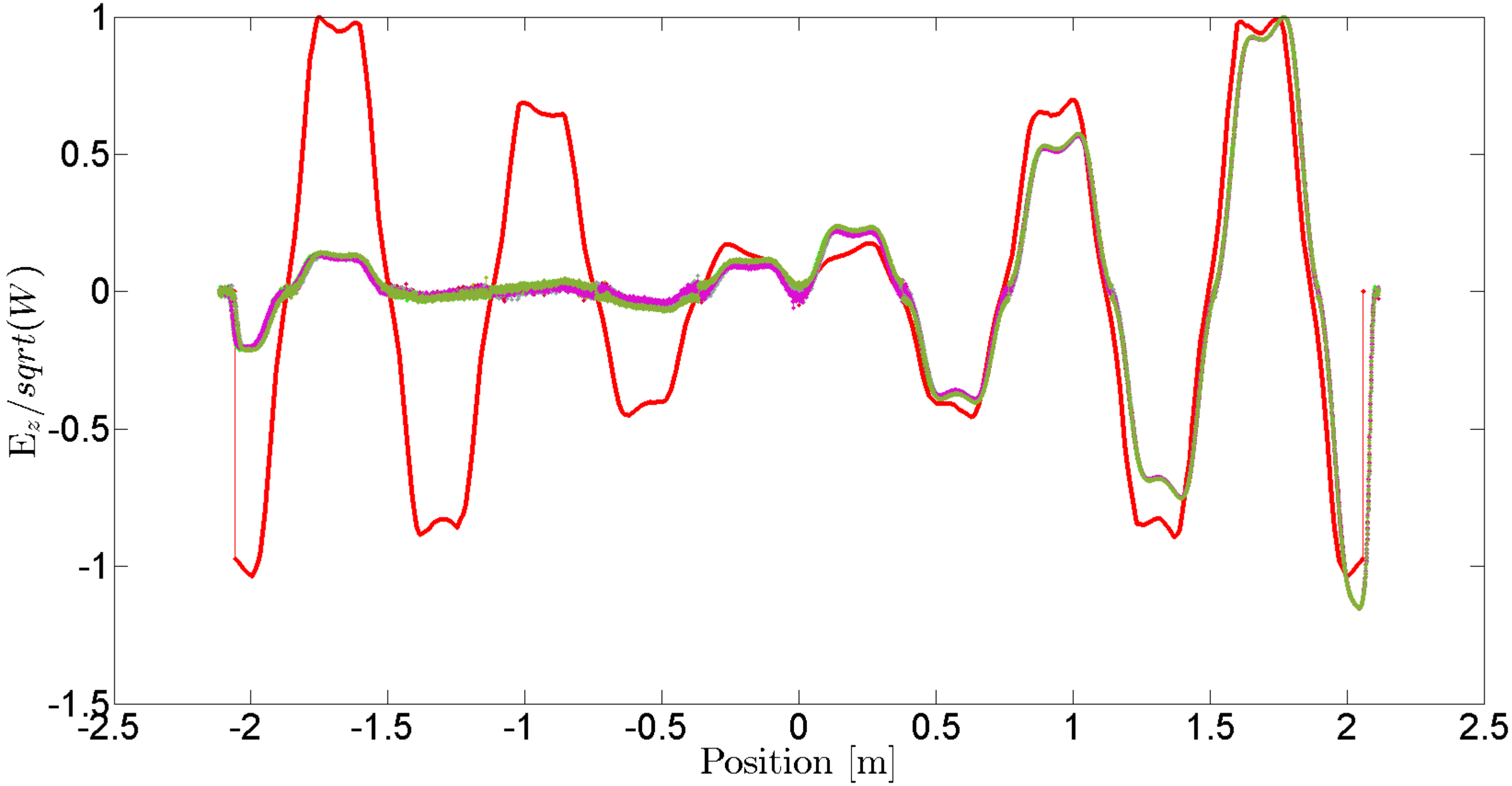


Higher Order Modes: Results

	Simulation	Measurement
f [MHz]	622	
Δϕ [°]	30	
R/Q [Ω]	7.2	??
Q	16356	

Other reasons for mismatch:

- Noisy data
- Asymmetry: Intrinsic to cavity or… ?

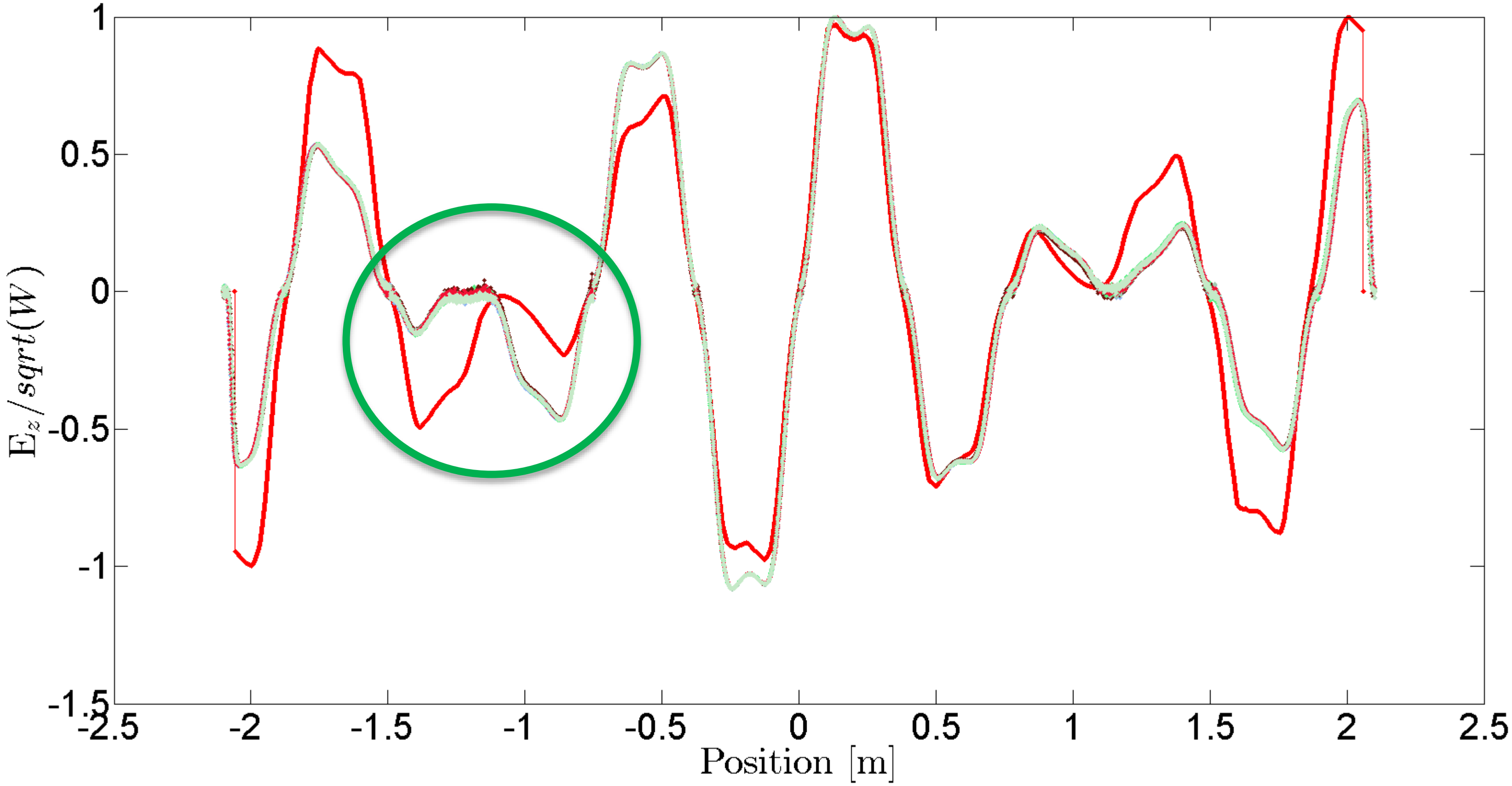


Higher Order Modes: Results

	Simulation	Measurement
f [MHz]	624	
Δϕ [°]	18	
R/Q [Ω]	0.5	1.1
Q	18418	

Other reasons for mismatch:

- Noisy data
- Asymmetry
- Local mismatch (= reality)

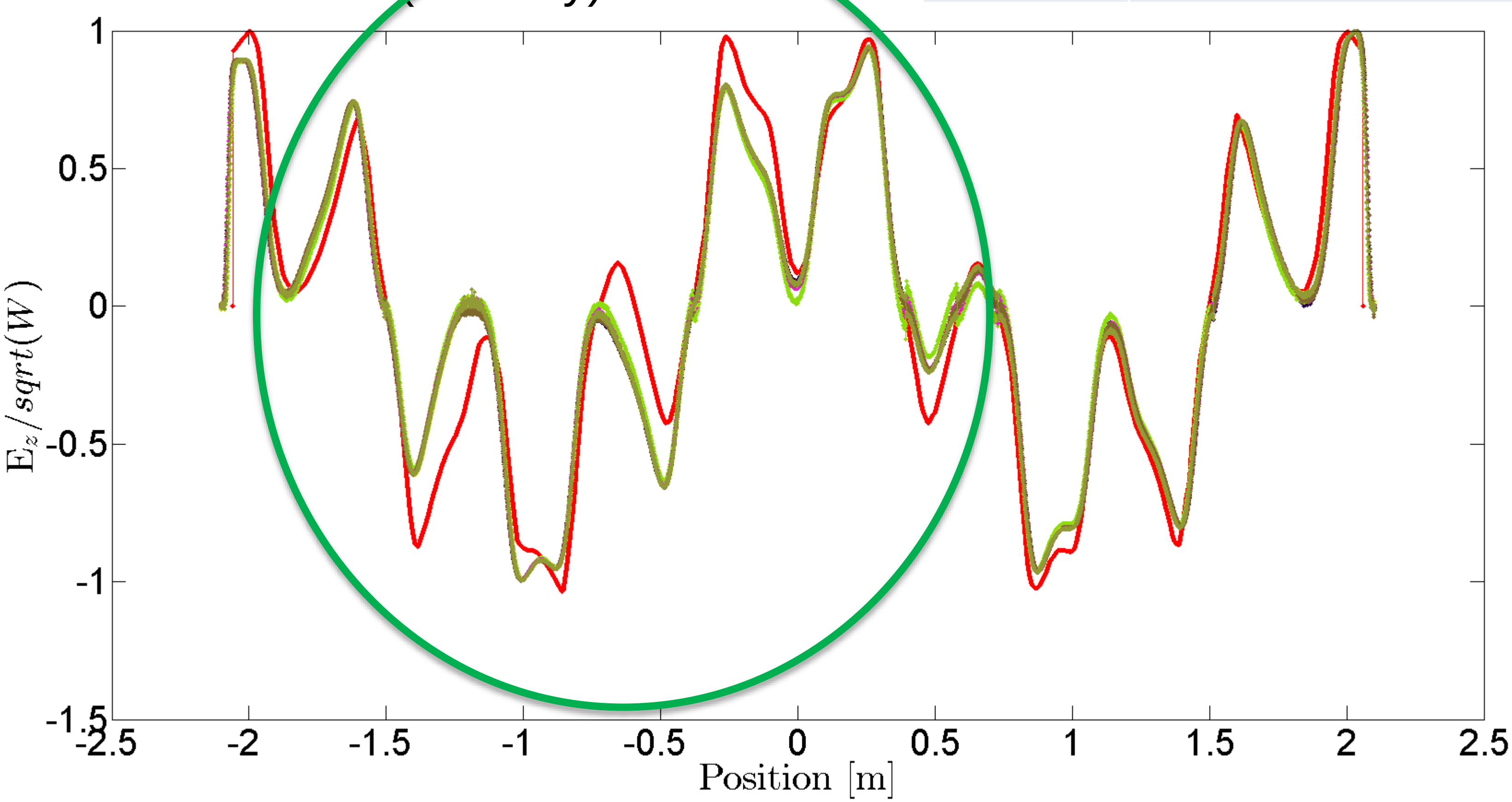


Higher Order Modes: Results

	Simulation	Measurement
f [MHz]	631	
Δϕ [°]	10	
R/Q [Ω]	27.1	34.8
Q	19519	

Other reasons for mismatch:

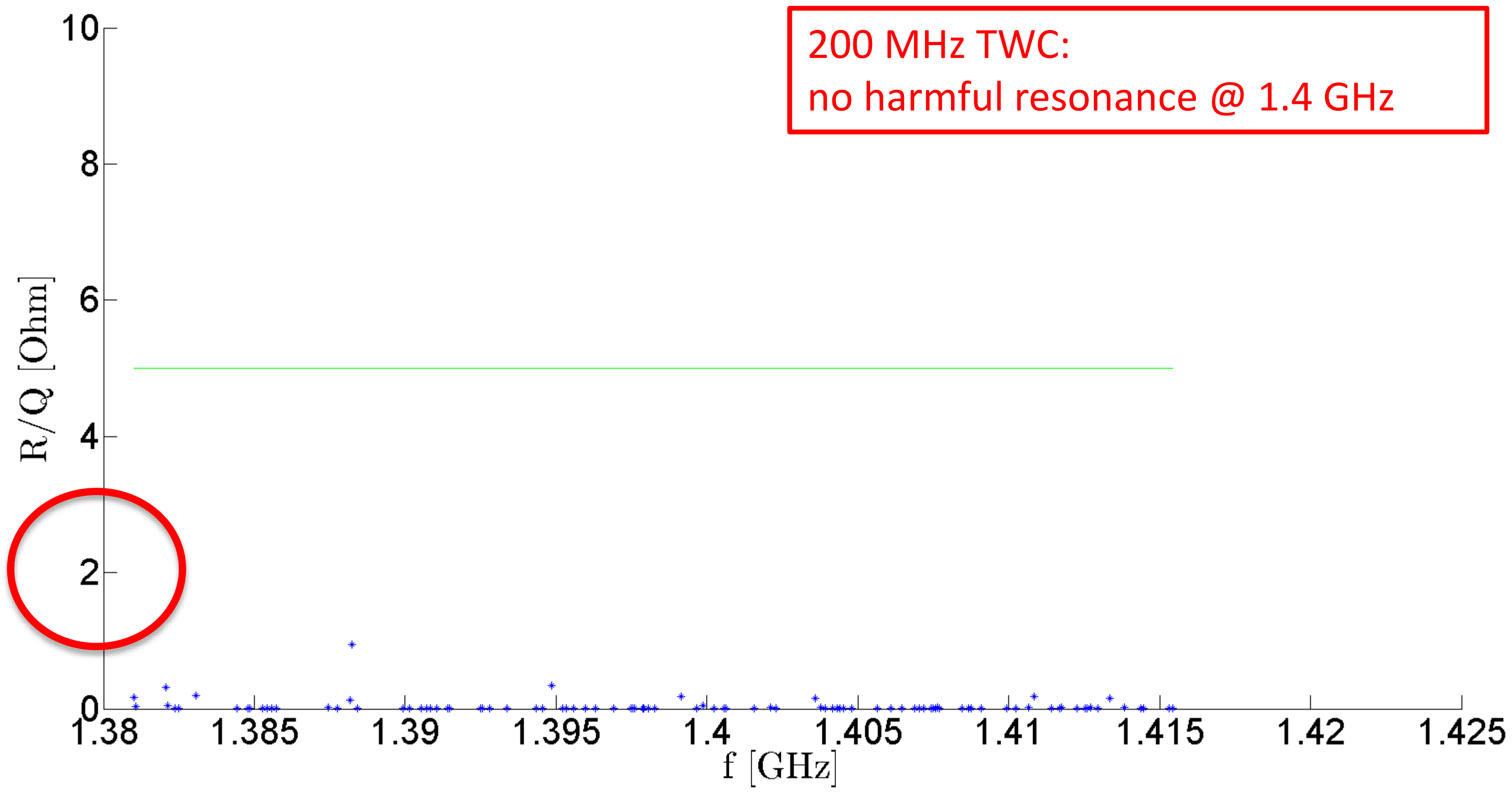
- Noisy data
- Asymmetry
- Local mismatch (= reality)



1.4 GHz band

1.4 GHz band: Longit. modes

Simulation ↔ Measurements: Noisy, but no indications



Conclusions

SPS 200 MHz TWC impedance measurements

- Fundamental pass band: 11 modes, 25 MHz bandwidth
  - Good agreement sim. – meas.

- HOM: Overall good agreement sim. – meas.
  - Documented HOMs:
    - 628 MHz
  - Additional identified HOMs in standing wave:
    - 287 MHz
    - 328 MHz
    - 550 MHz
    - 908 MHz
    - 915 MHz

To be investigated in-depth
(TW, FPC and HOM couplers in place…)

- No indications of harmful longit. modes at 1.4 GHz