Impact of fingers removal on TDIs Impedance

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INTRODUCTION

The LHC TDI is one of the most important contributors to the LHC machine impedance at injection. Being 3.8mm close to the beam, may have critical impact if impedance is not minimized or non conformities are found

From TDI to TDIs 1.0

A new TDI design has been proposed for HL-LHC, the TDIS, segmented in 3 tanks in order to:

- Improve mechanical reliability.
- Allow module exchangeability.

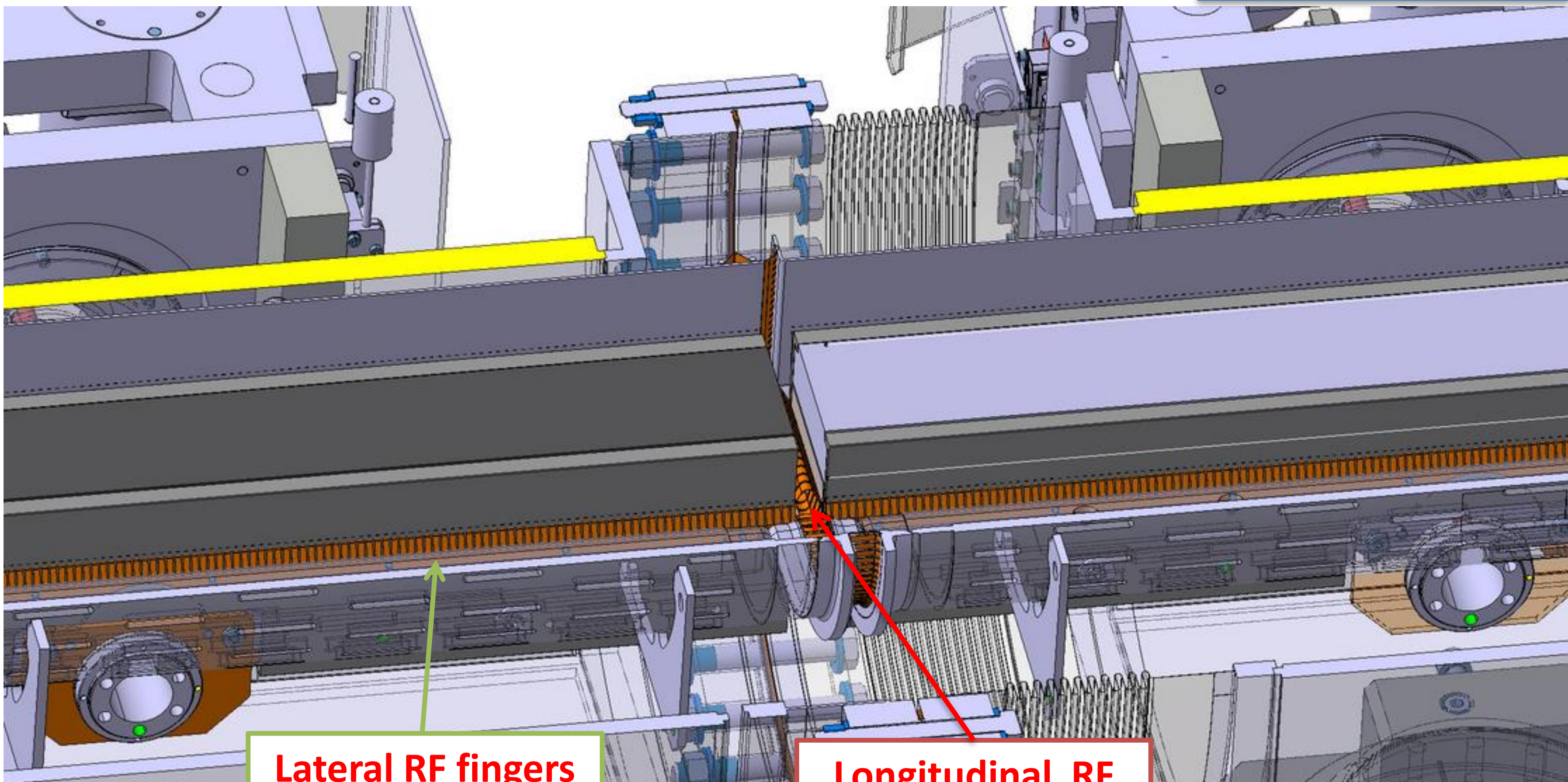
From TDIs 1.0 to TDIs 2.0

On 12/05/2017 different changes of the main TDIS jaw dimensions were communicated to the impedance team. This has been done :

"- To allow for more space for the insertion of the jaws into the tank.

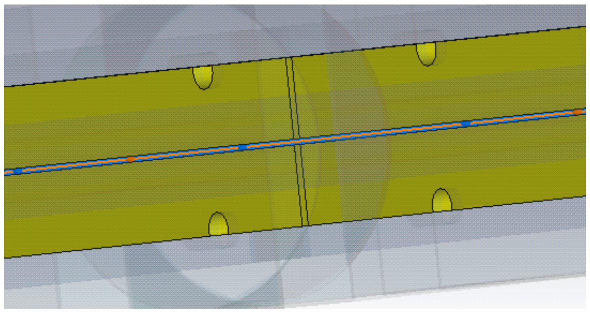
- To make the back stiffener narrower: now it is made out of TZM instead of aluminum (for strength reasons), which makes it much more expensive and also (due to the higher density) much heavier. By reducing the width of the stiffener we save quite some weight and cost".

FROM TDI TO TDIS 1.0 (jaw segmentation):

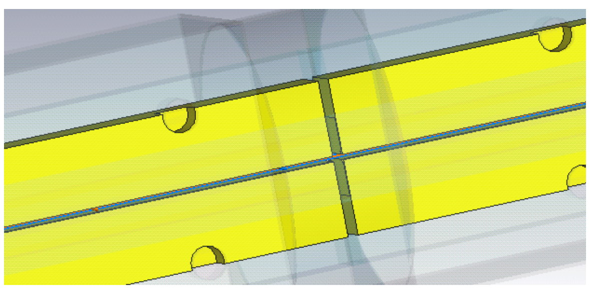


FROM TDI TO TDIS 1.0 (jaw segmentation):

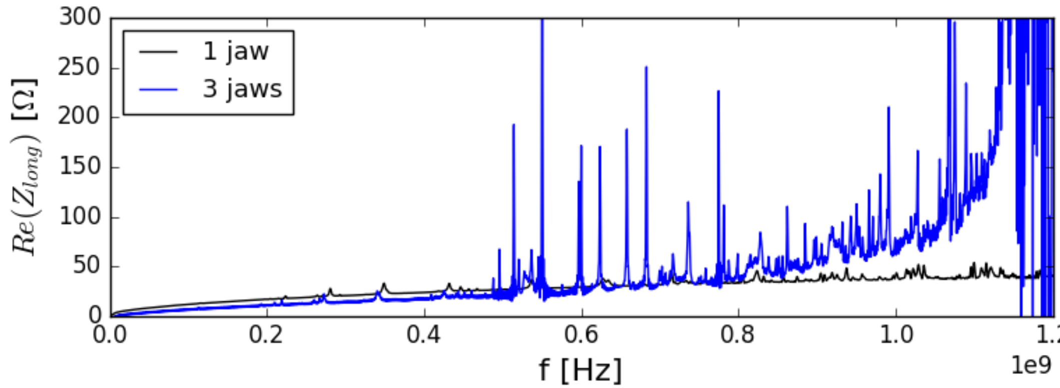
Connected jaws (1 jaw)

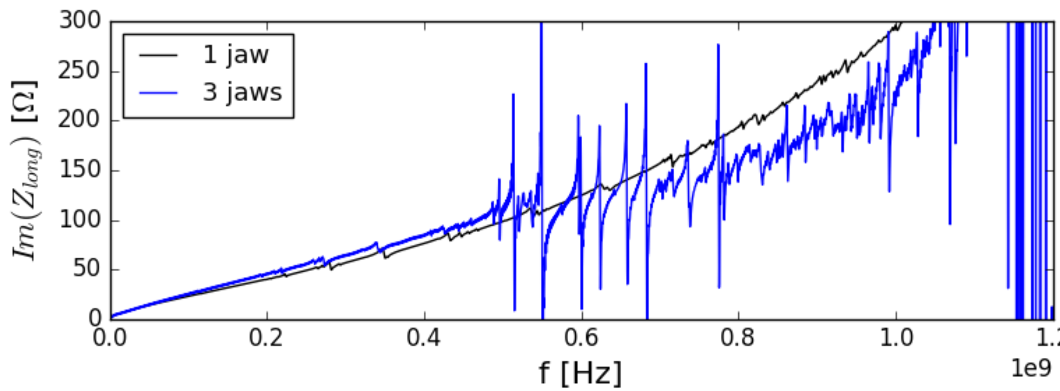


Segmented jaws (3 jaws)



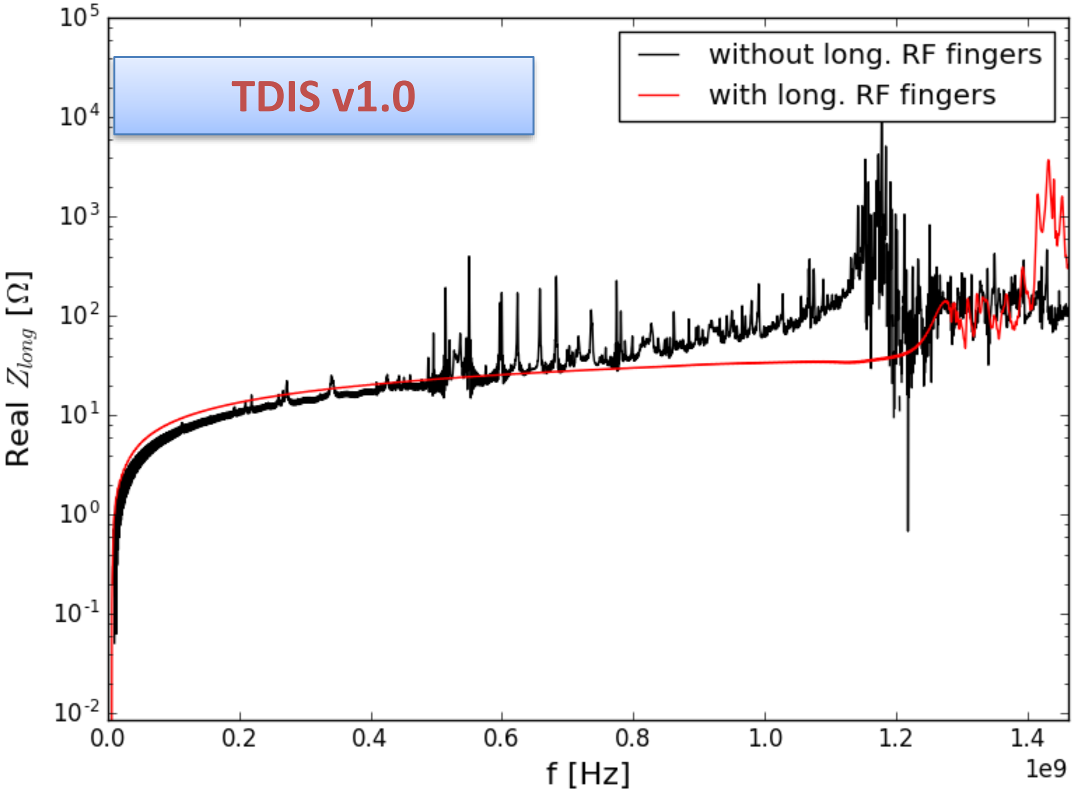
TDIS v1.0

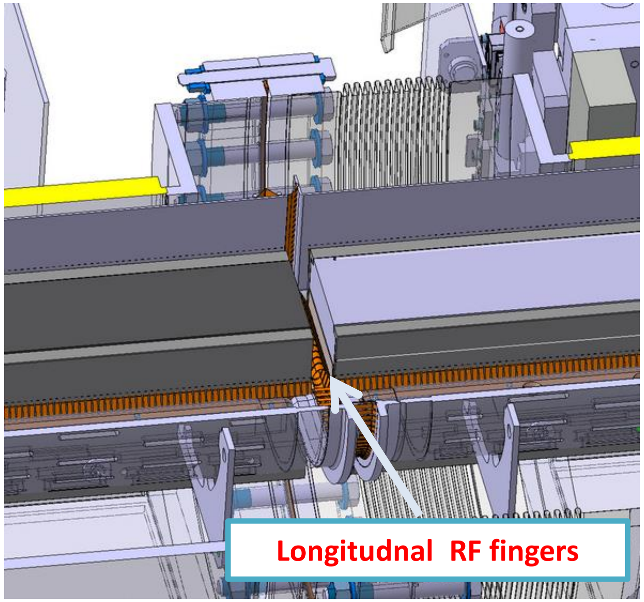




→ Removing the jaw connection introduced a large amount of HOMs!

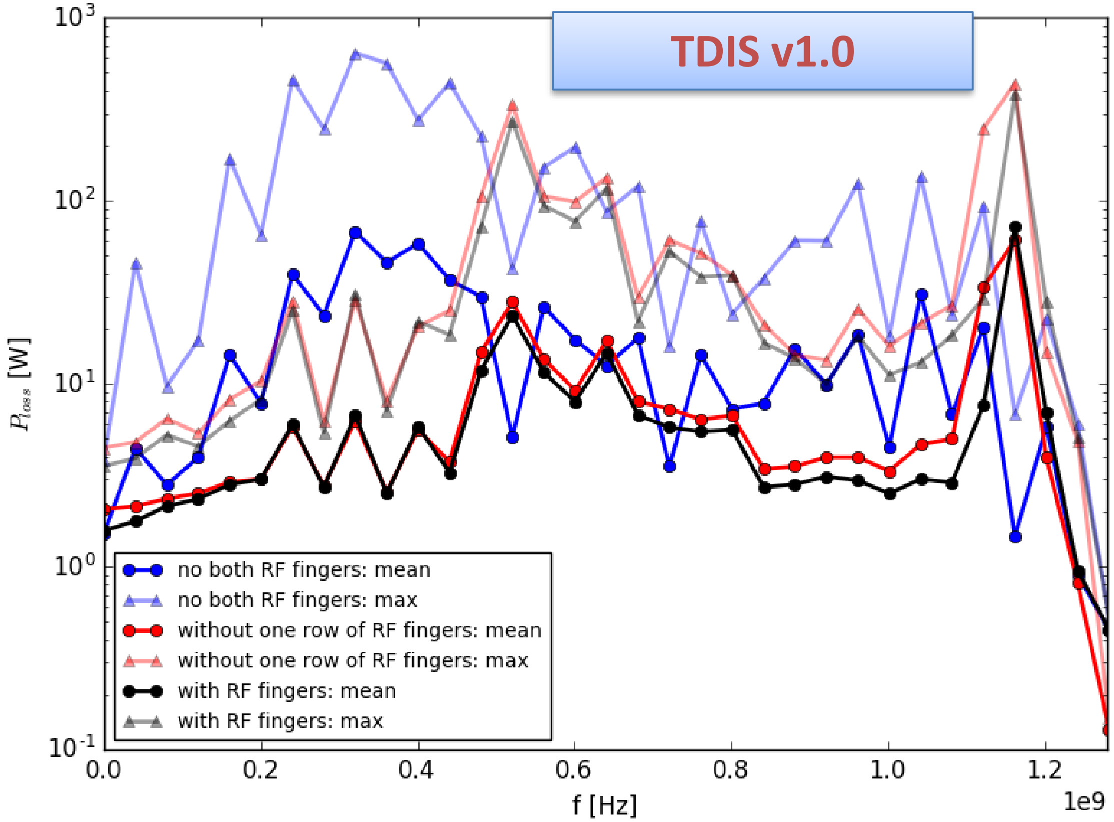
FROM TDI TO TDIS 1.0 (jaw segmentation):



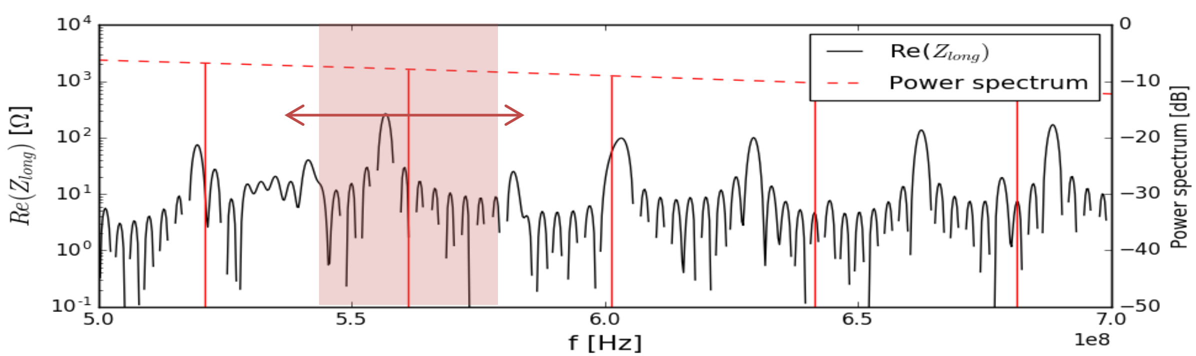


→ No visible HOMs in longitudinal impedance below 1.2 GHz with longitudinal fingers

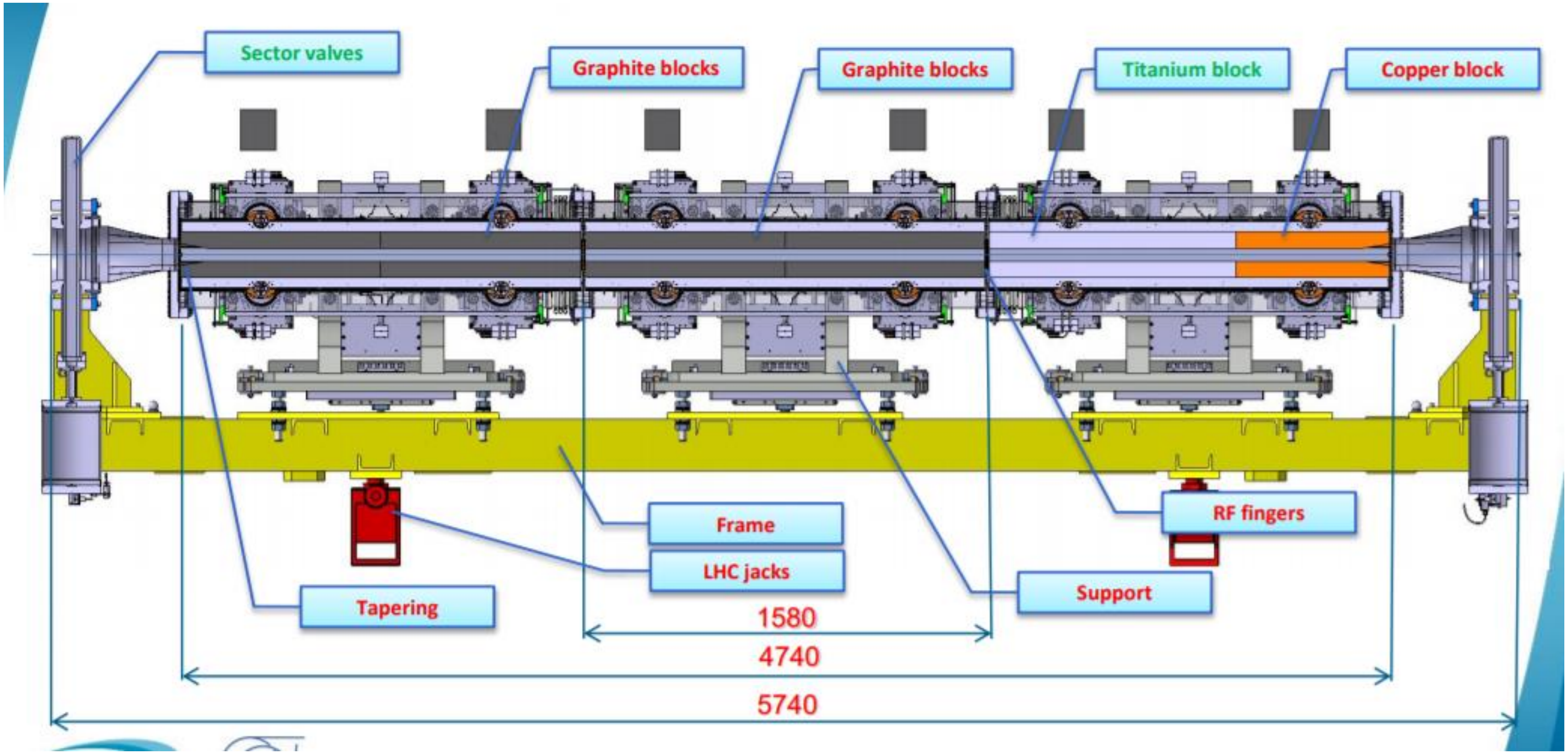
FROM TDI TO TDIS 1.0 (jaw segmentation):



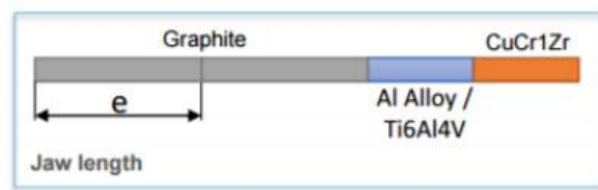
- HOMs are introduced removing the longitudinal fingers
- Heating from HOM evaluated with statistical approach (+/- 20MHz uncertainty) depending on the filling pattern
- **300 W** max power dissipated computed with losses calculation in time domain



FROM TDIS 1.0 TO TDIS 2.0:



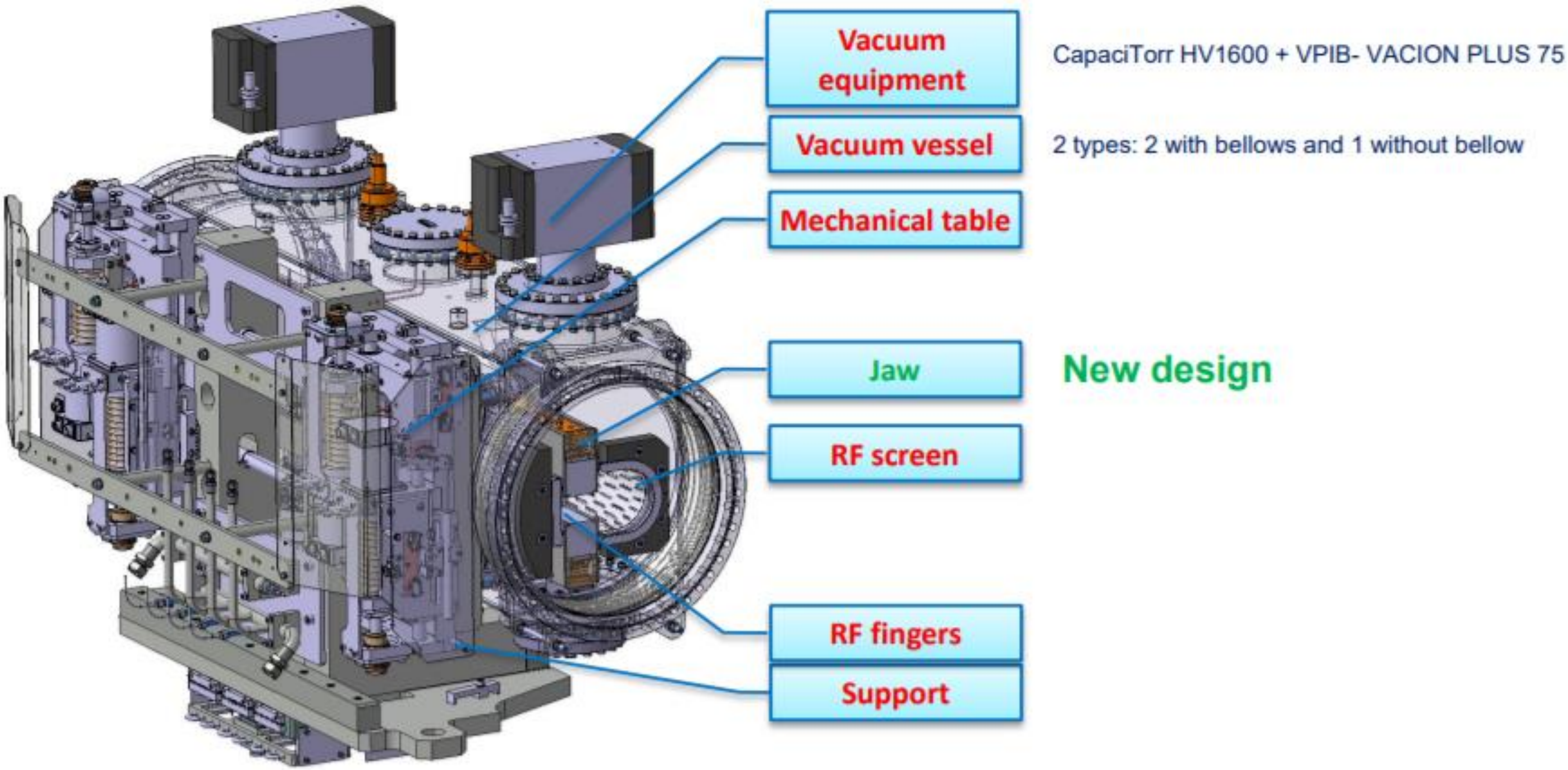
- green: changed
- red: same as before



New material in here!

https://indico.cern.ch/event/632532/ Updates on detailed TDIS mechanical design, L.Gentini

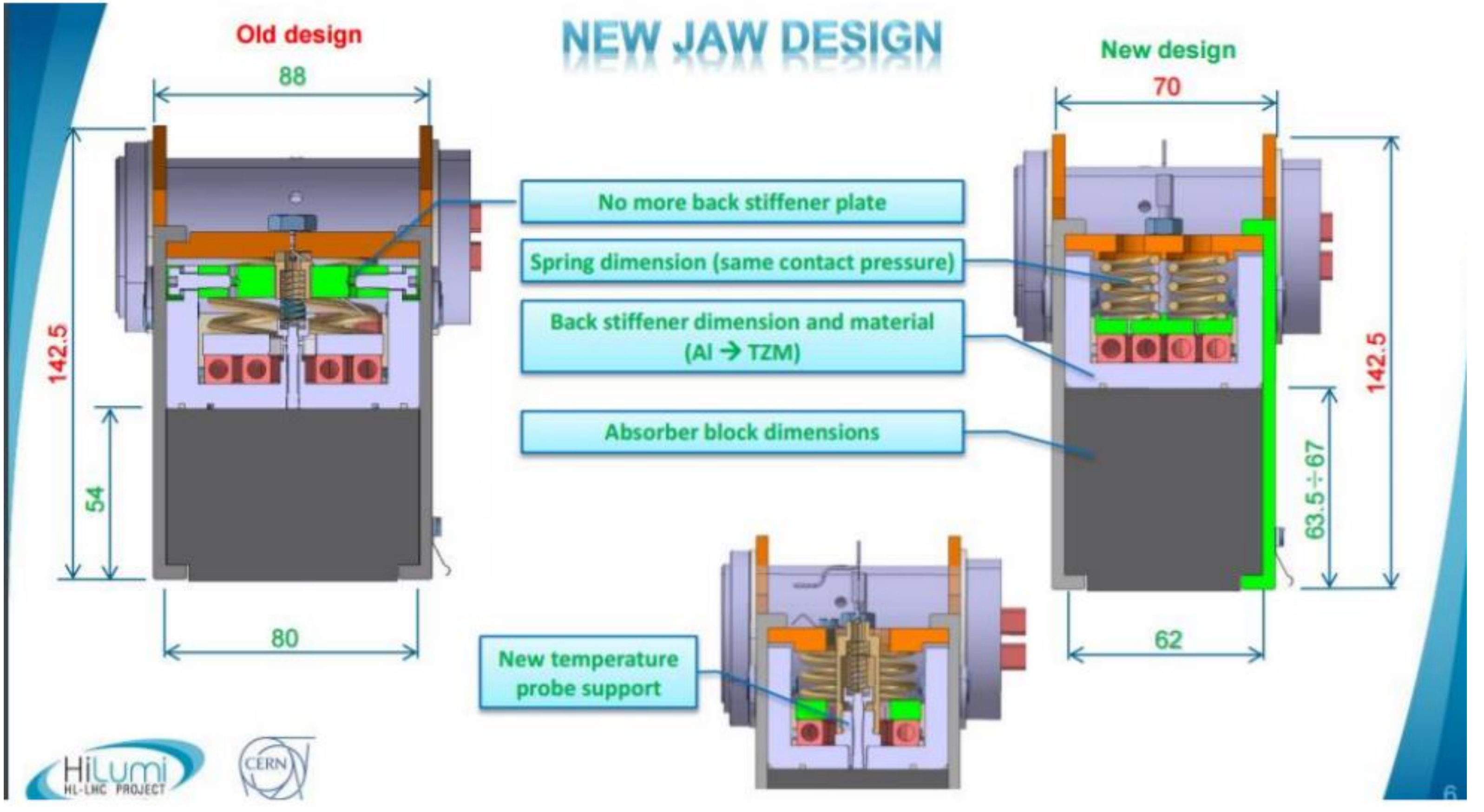
FROM TDIS 1.0 TO TDIS 2.0:



The jaws design was upgraded to a new one

https://indico.cern.ch/event/632532/ Updates on detailed TDIS mechanical design, L.Gentini

FROM TDIS 1.0 TO TDIS 2.0:

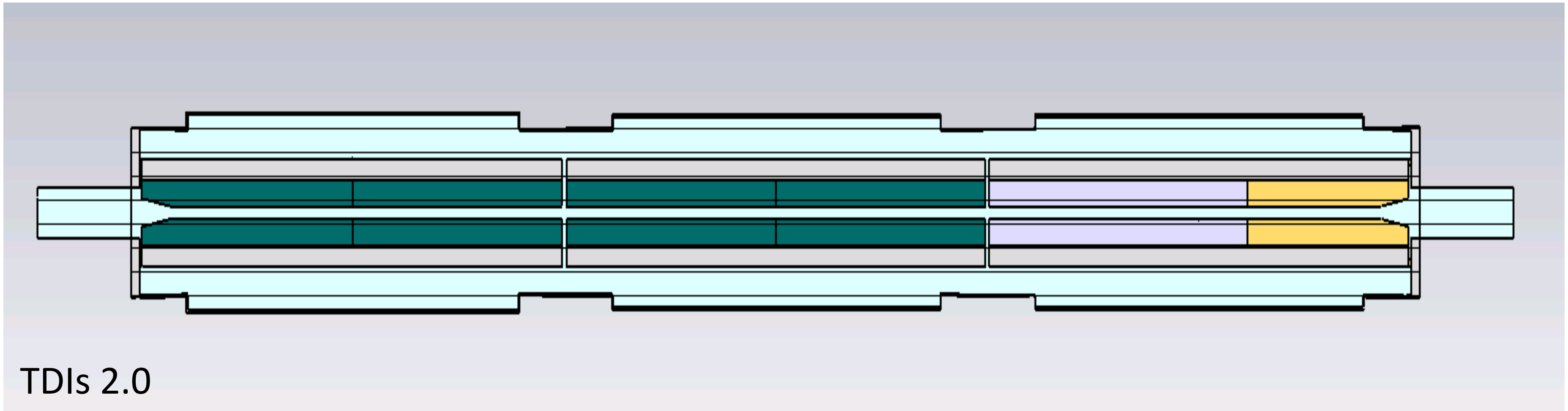


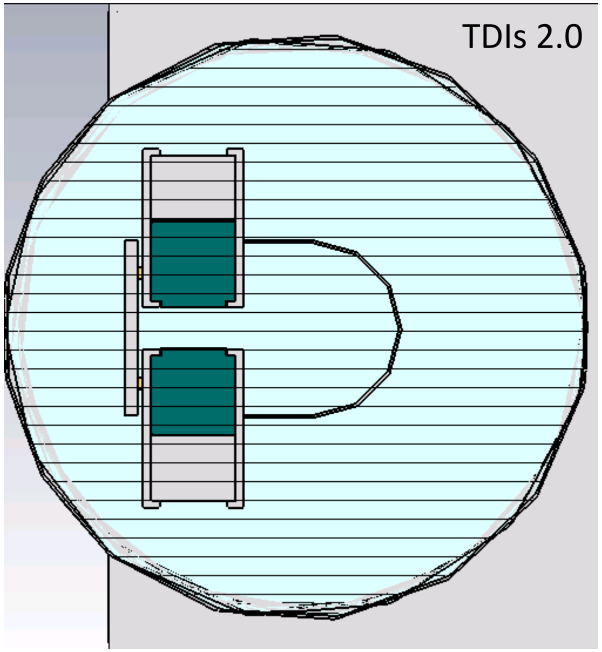
- → Width changed from 80mm to 62mm
- → Height changed from 54mm to 65mm

Significant changes from an impedance point of view

https://indico.cern.ch/event/632532/ Updates on detailed TDIS mechanical design, L.Gentini

FROM TDIS 1.0 TO TDIS 2.0:





Original model from Cern Repository

Imported with SmarTeam

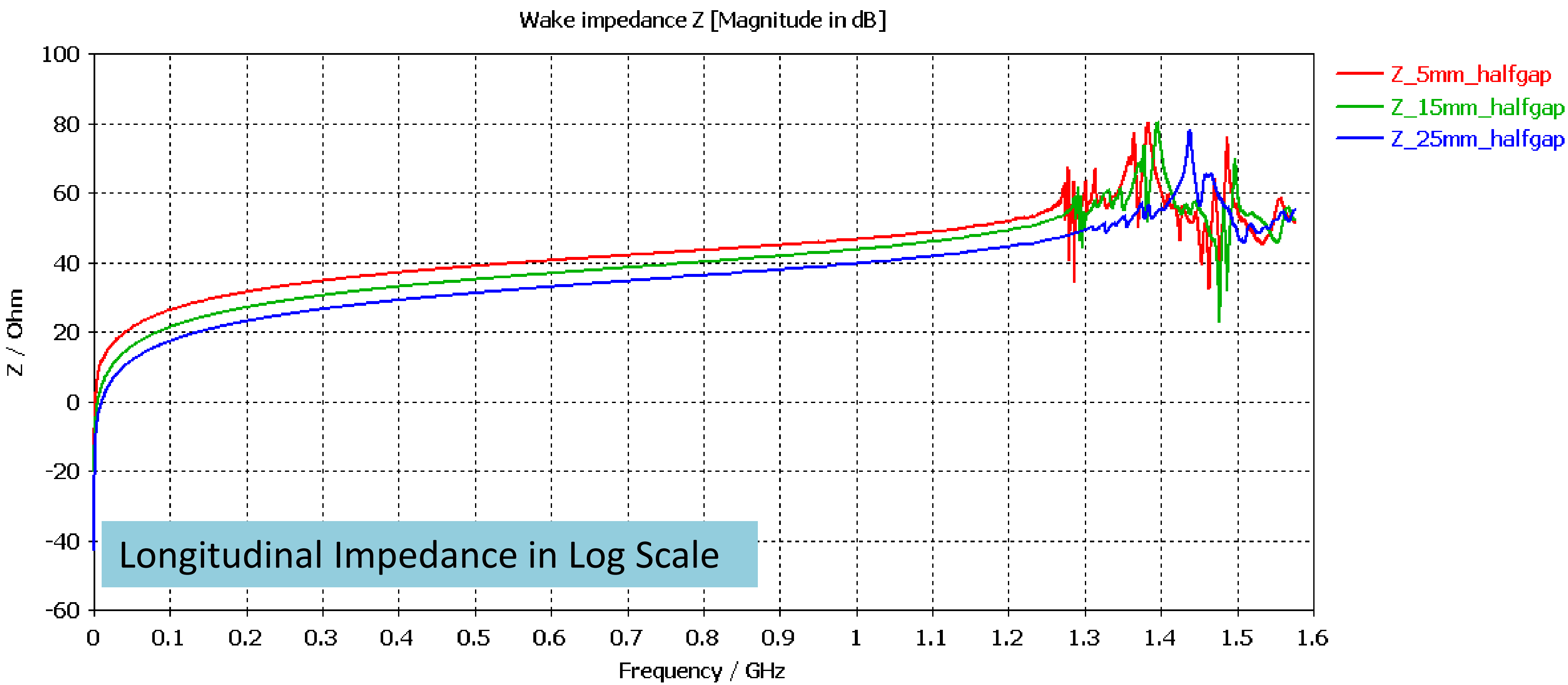
Simplified in CST

→ All the features not relevant for the impedance calculations were removed

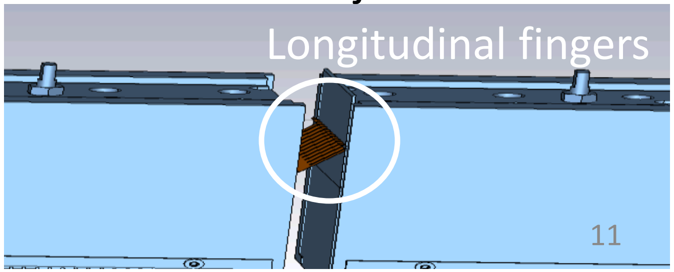
→ All the original materials were preserved: Jaws made of graphite, Titanium and Copper, tank made of steel

TDIS 2.0 Impedance Analysis

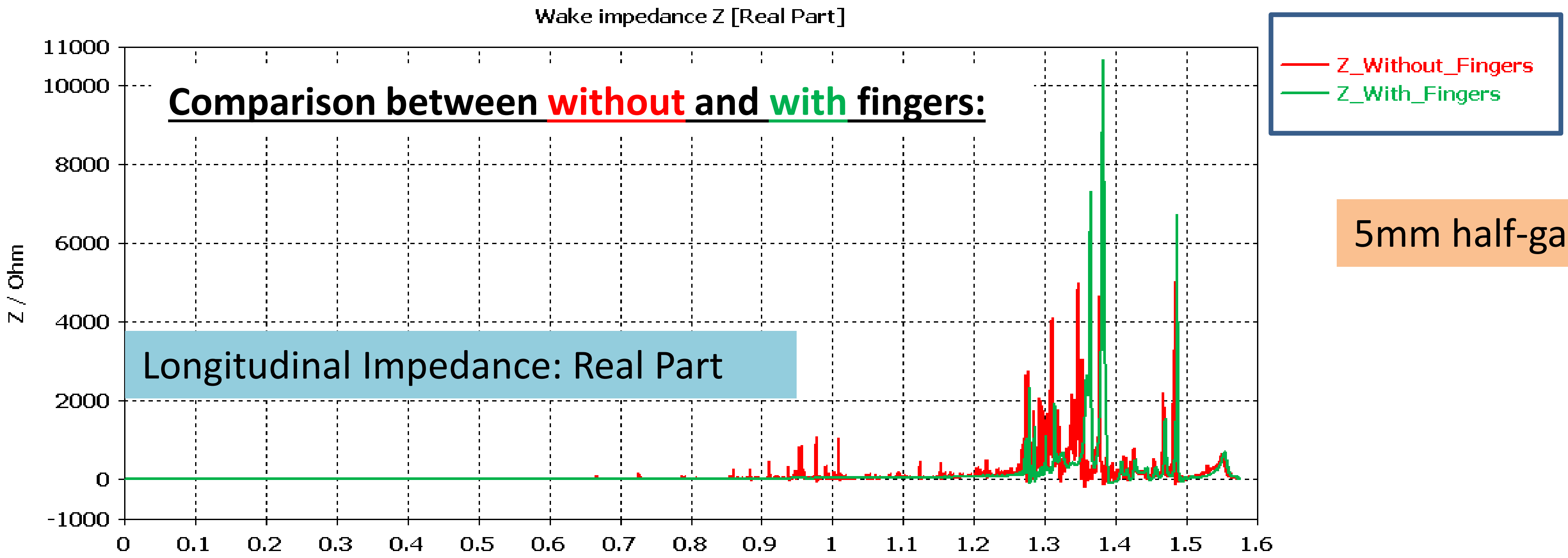
Results with longitudinal fingers:



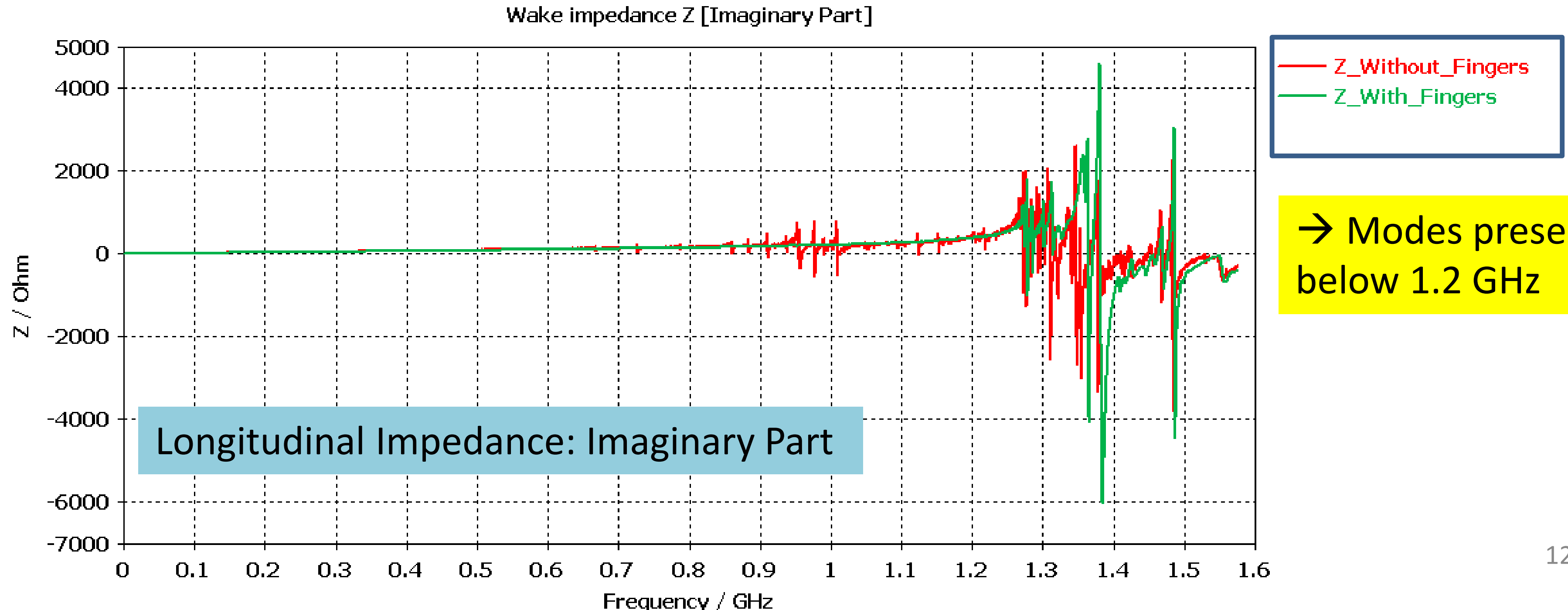
- Absence of resonant modes below 1.2 GHz (as the TDIs 1.0)
- Visible contribution to broadband impedance given by the three different jaws materials (Graphite, Titanium and Copper)
- Broadband Impedance decreasing for larger apertures



TDIS 2.0 Impedance Analysis

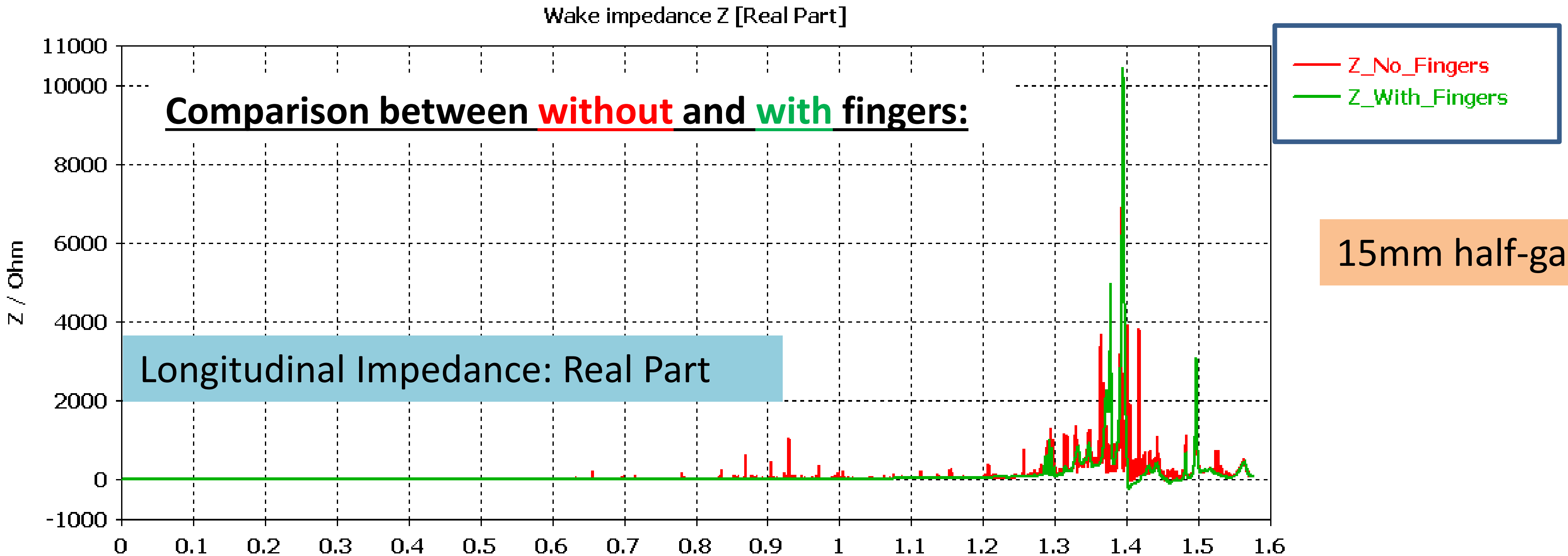


5mm half-gap

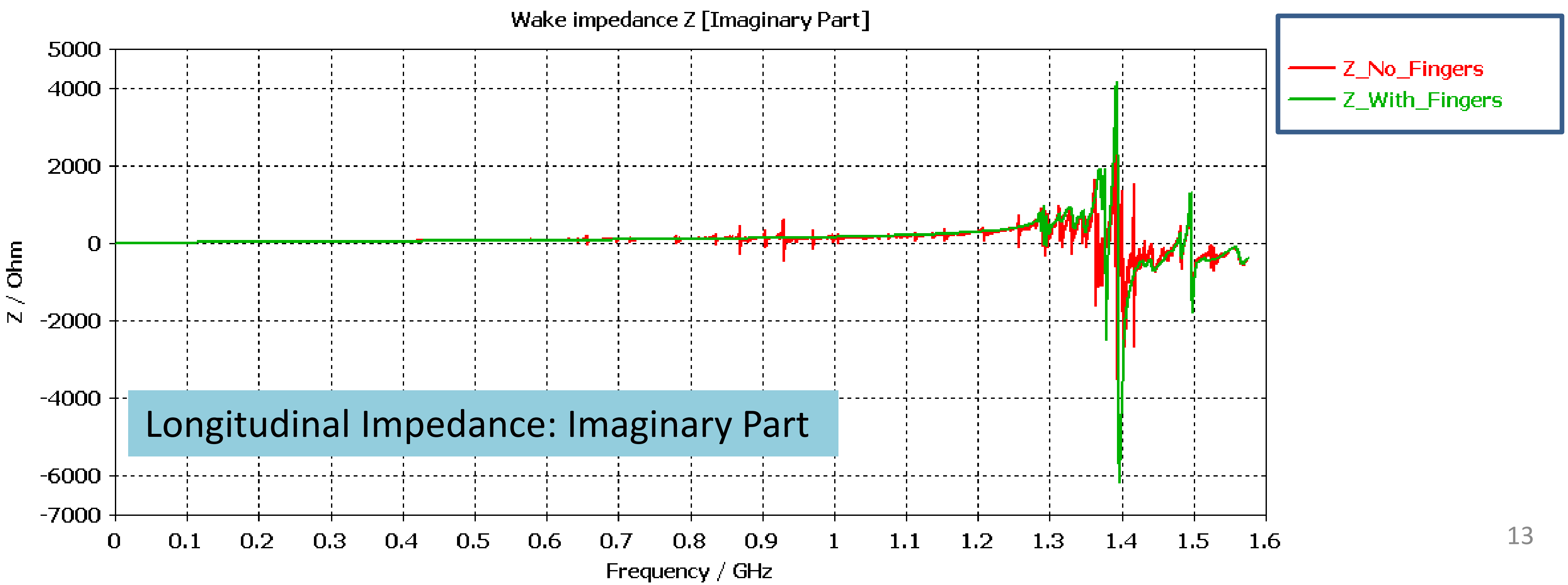


→ Modes present below 1.2 GHz

TDIS 2.0 Impedance Analysis

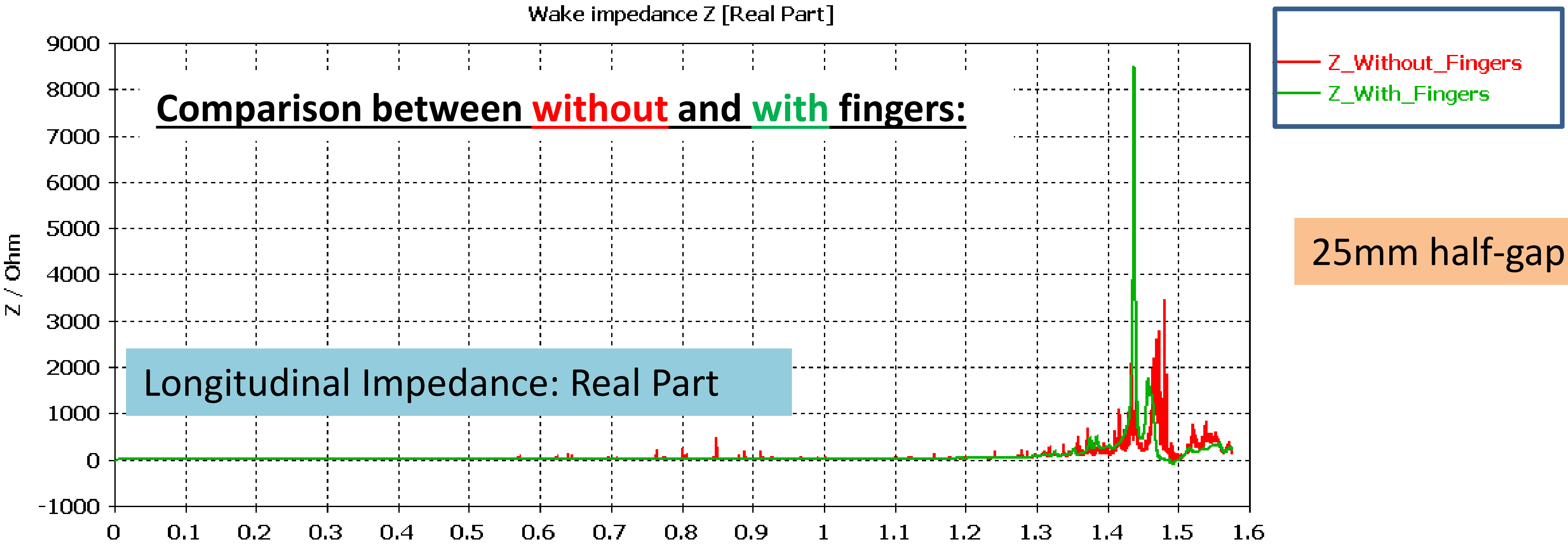


15mm half-gap

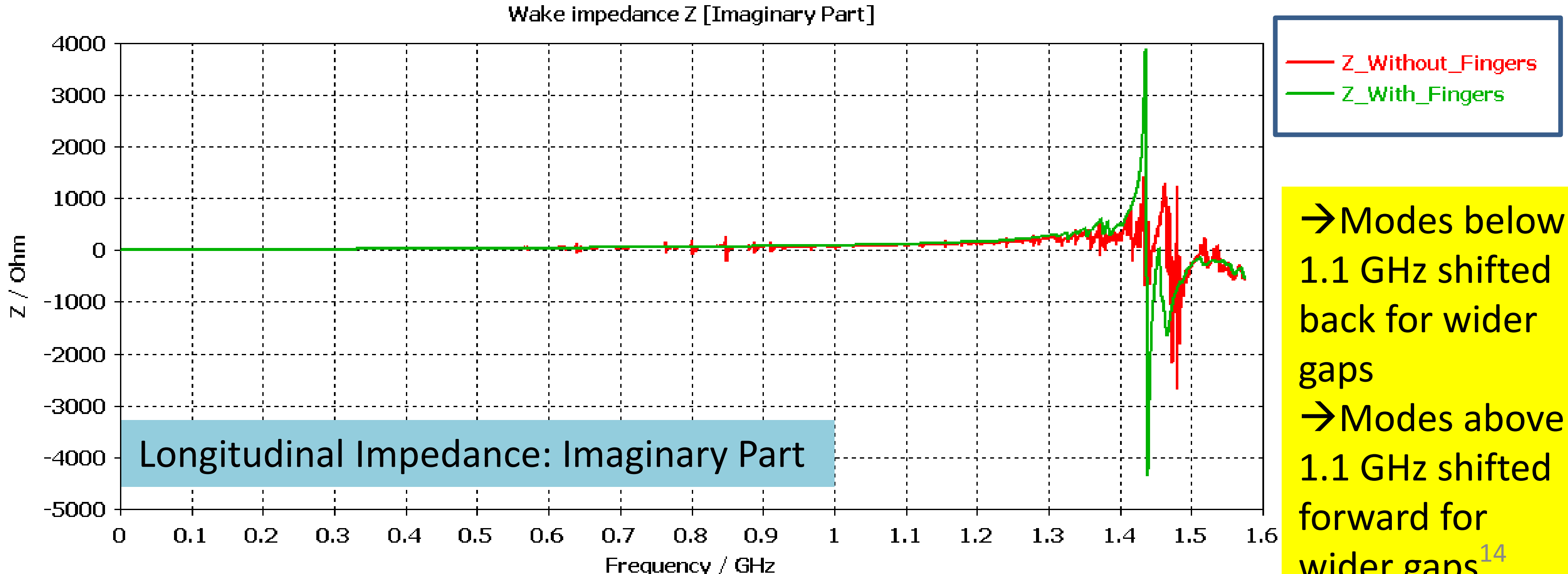


TDIS 2.0 Impedance Analysis

Comparison between without and with fingers:



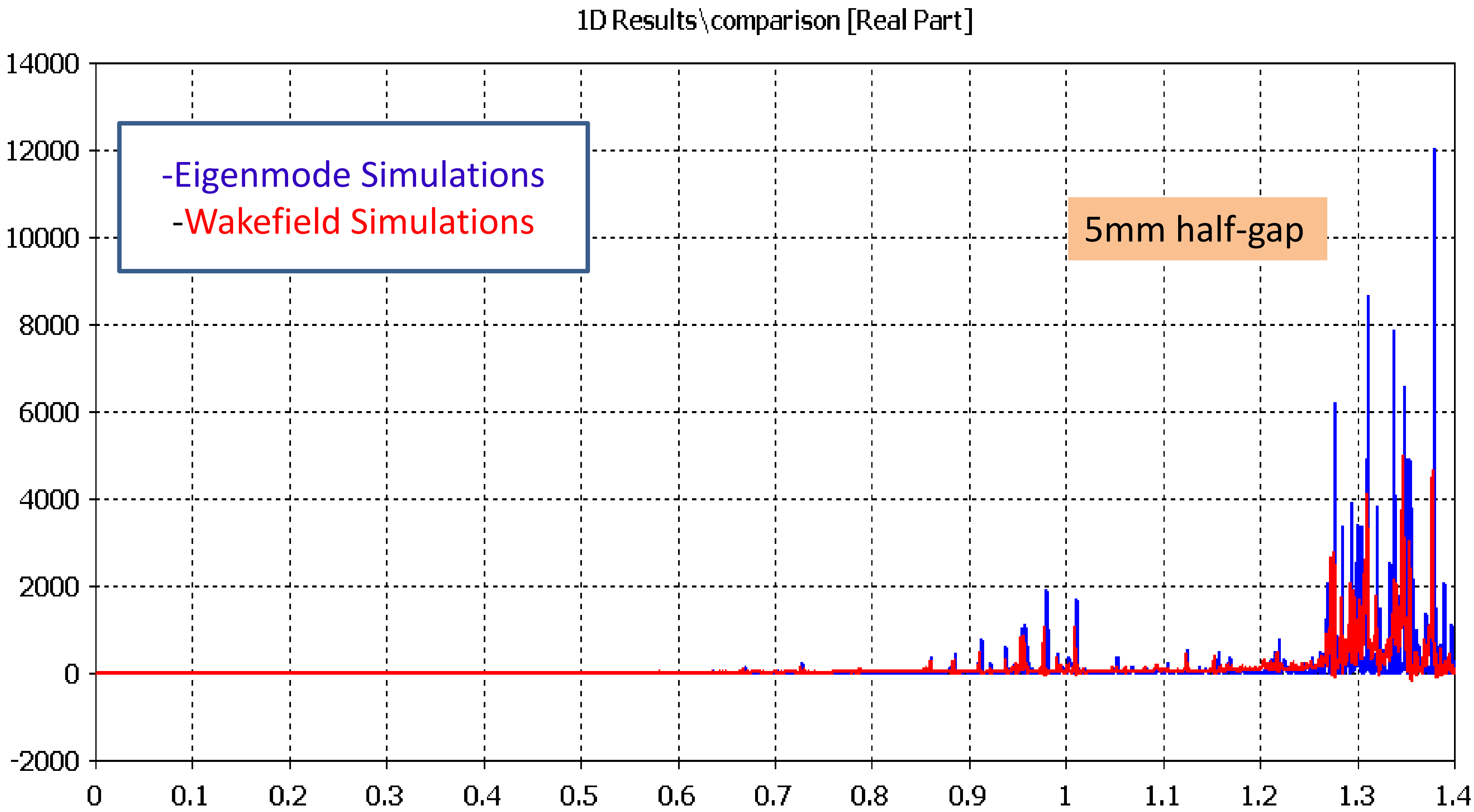
25mm half-gap



→Modes below 1.1 GHz shifted back for wider gaps

→Modes above 1.1 GHz shifted forward for wider gaps

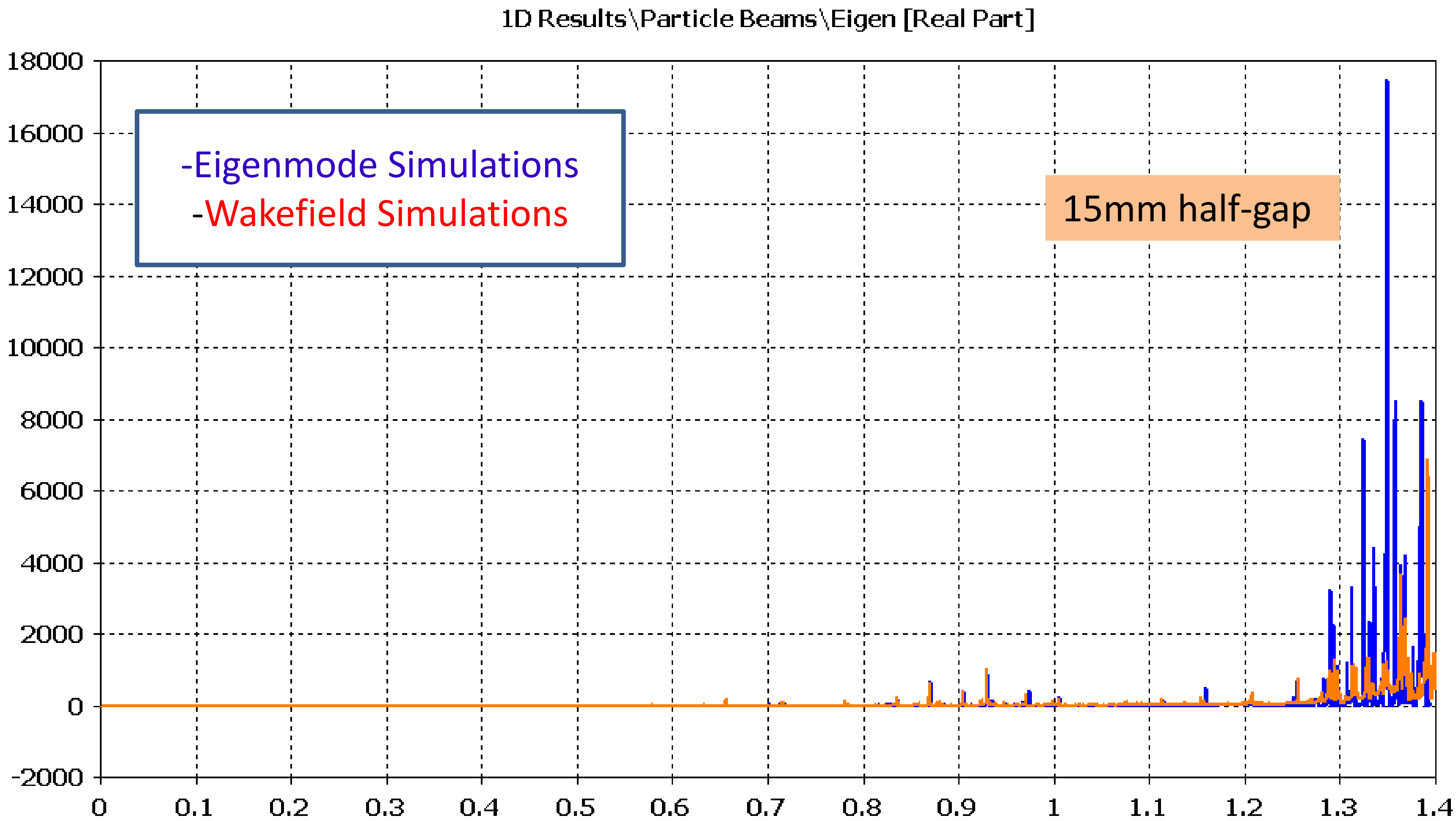
Matching with Eigenmode Simulations:



→ 800 modes computed for each half-gap, very long execution time

→ Good agreement between Eigenmode and Wakefield simulations for 5mm half-gap

Matching with Eigenmode Simulations:



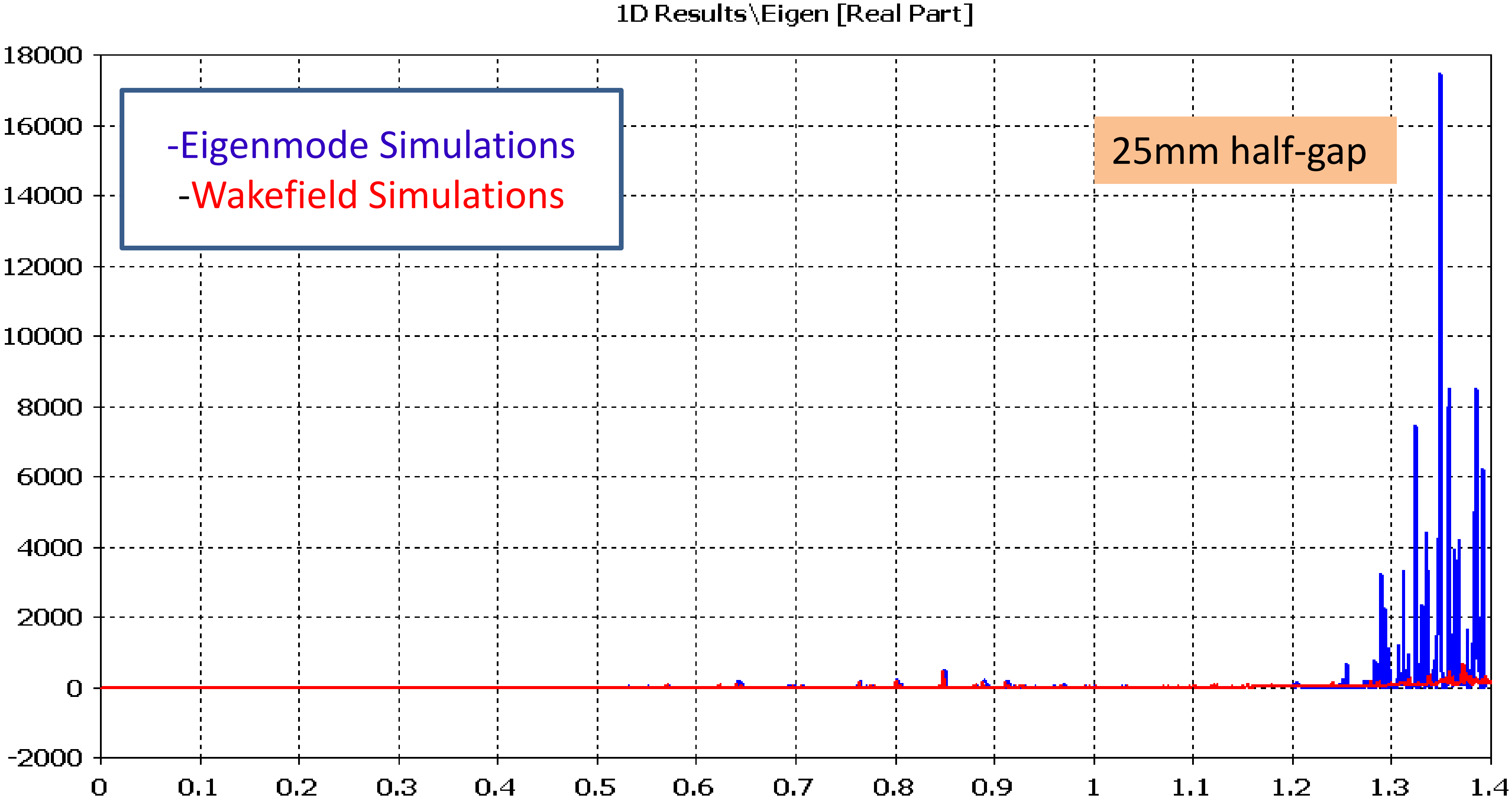
→ Good agreement below 1.25 GHz

→ Only frequency matching above 1.25 GHz, Amplitude non totally agreeing

→ Wake not totally decaying, too long wakelength required

TDIS 2.0 Impedance Analysis

Matching with Eigenmode Simulations:



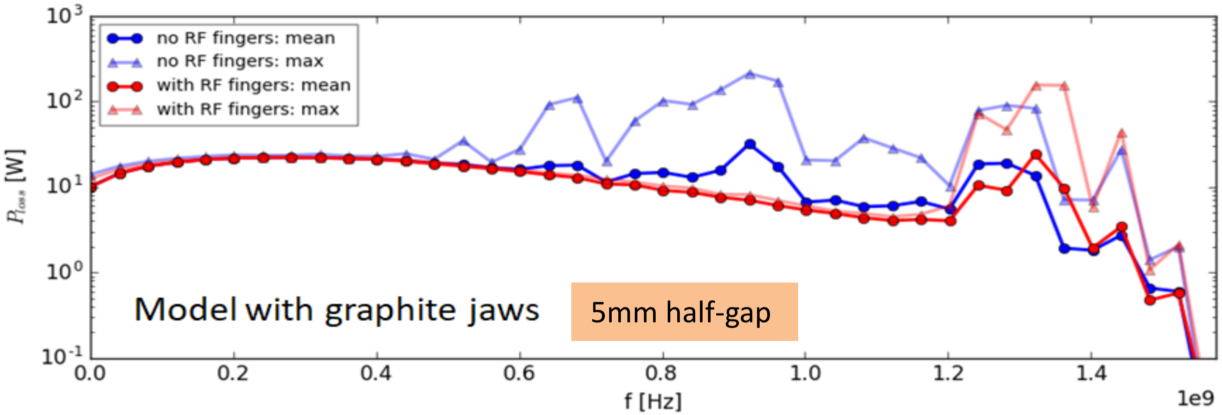
→ Good agreement below 1.3 GHz

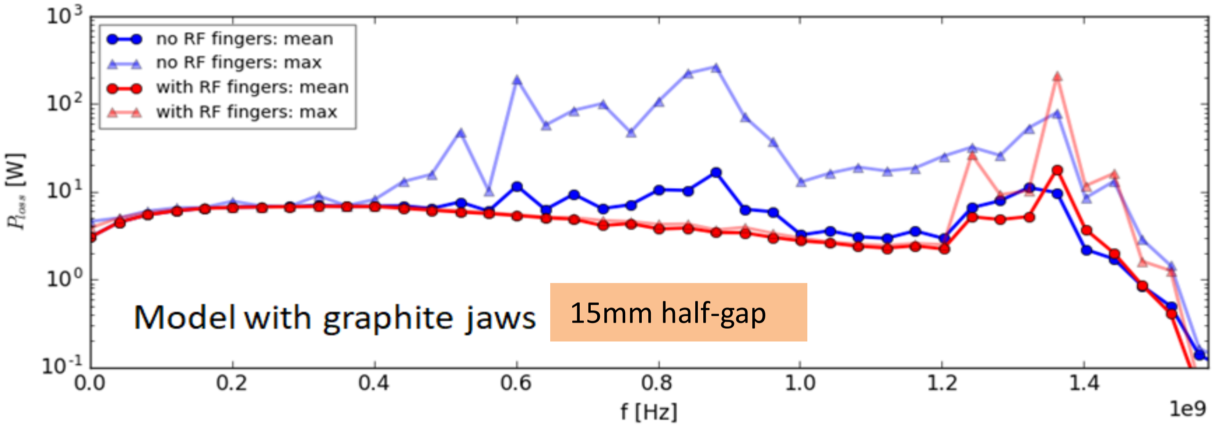
→ Only frequency matching above 1.3 GHz, Amplitude non totally agreeing

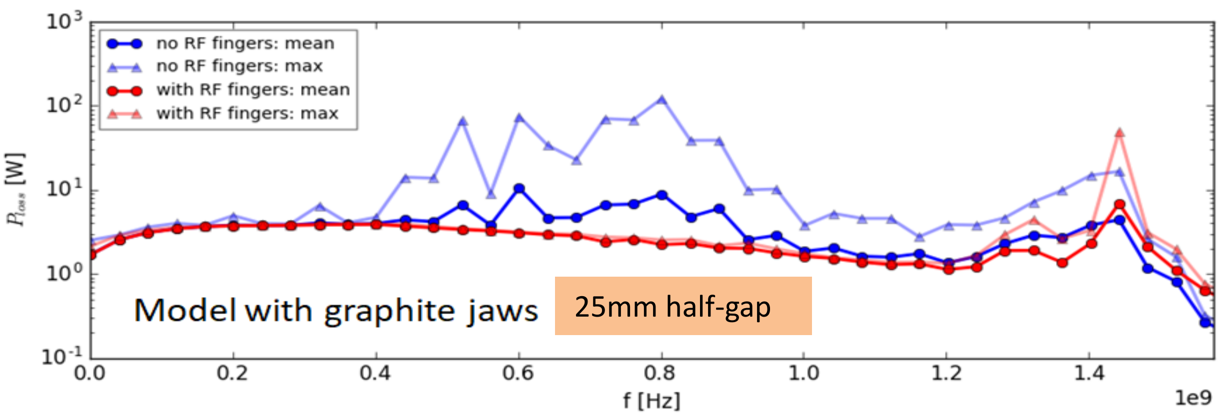
It is linked to:

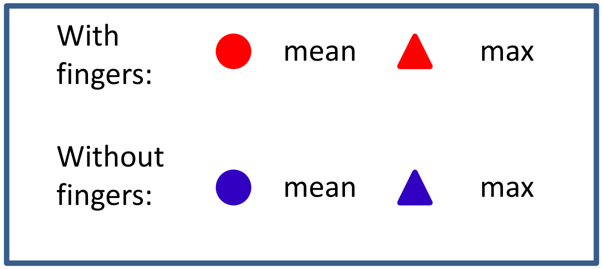
damping effect reduced for wider gaps → Q increasing → really long wake

Losses from Wake Field Simulations :







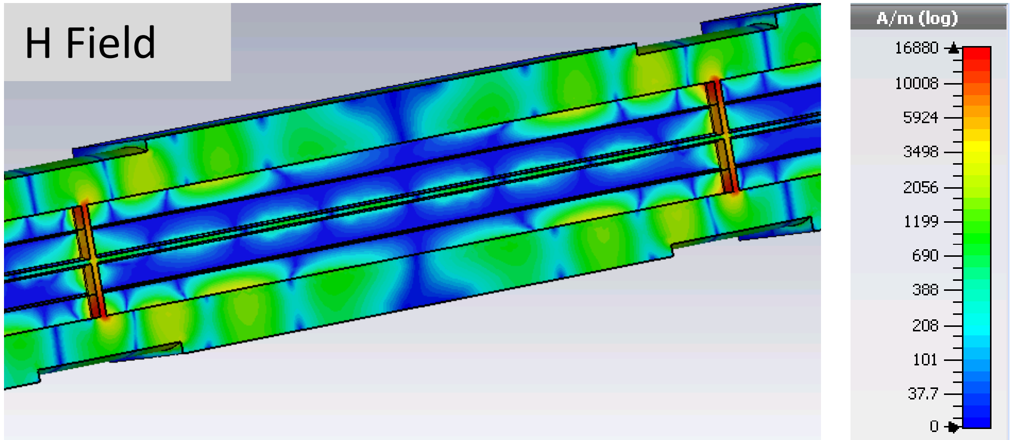


→ **100 W** of power dissipated at most per HOM in the region around 800 MHz.

→ Consistent losses below 1.2 GHz detected in the scenario without longitudinal fingers

→ Heating from HOM evaluated with statistical approach (+/- 20MHz uncertainty) depending on the filling pattern

Losses from Eigenmode Simulations : Ideal filling Pattern



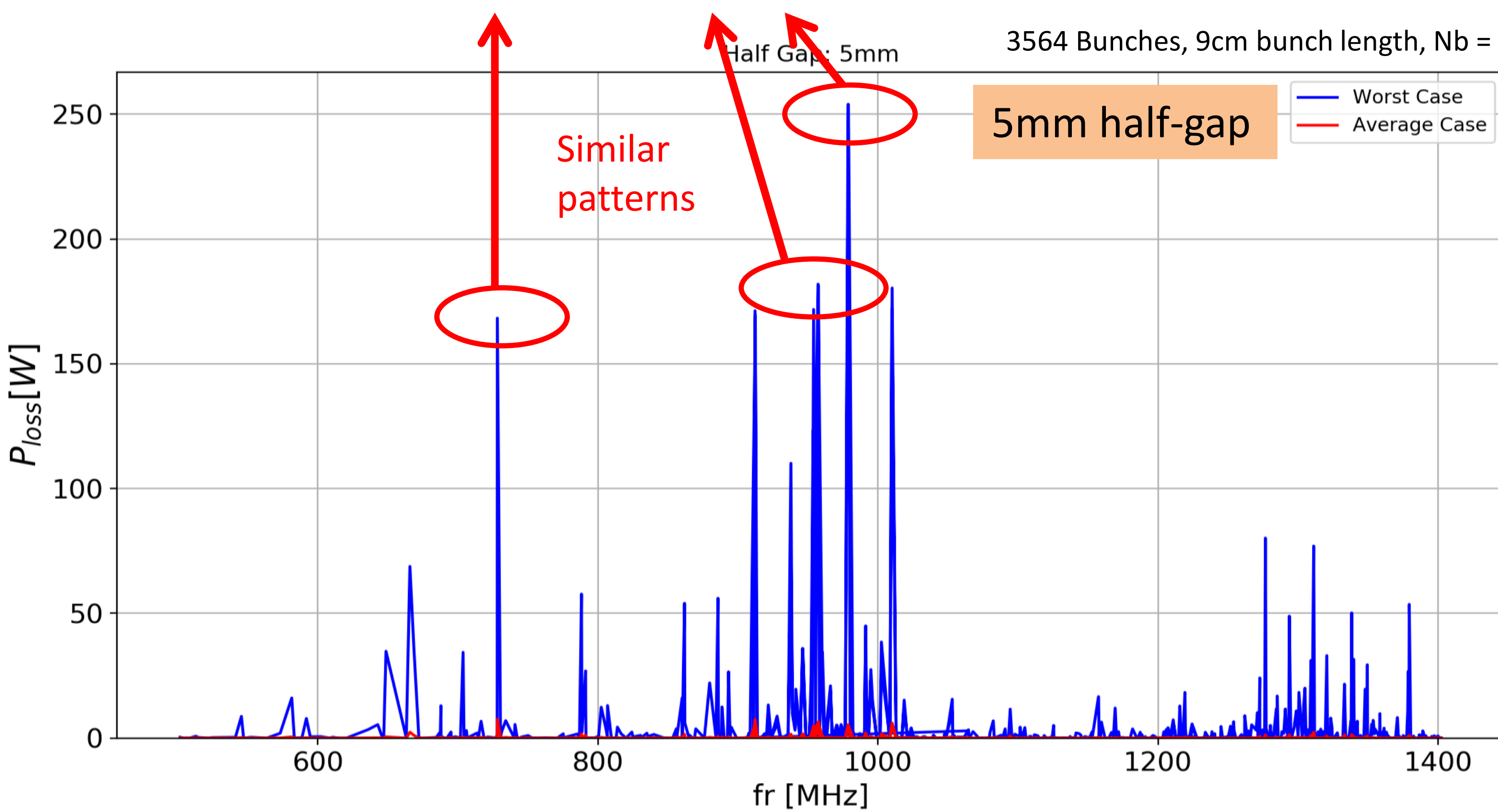
Worst Case

- 250W peak of power loss at 978 MHz
- Many other losses around 160W

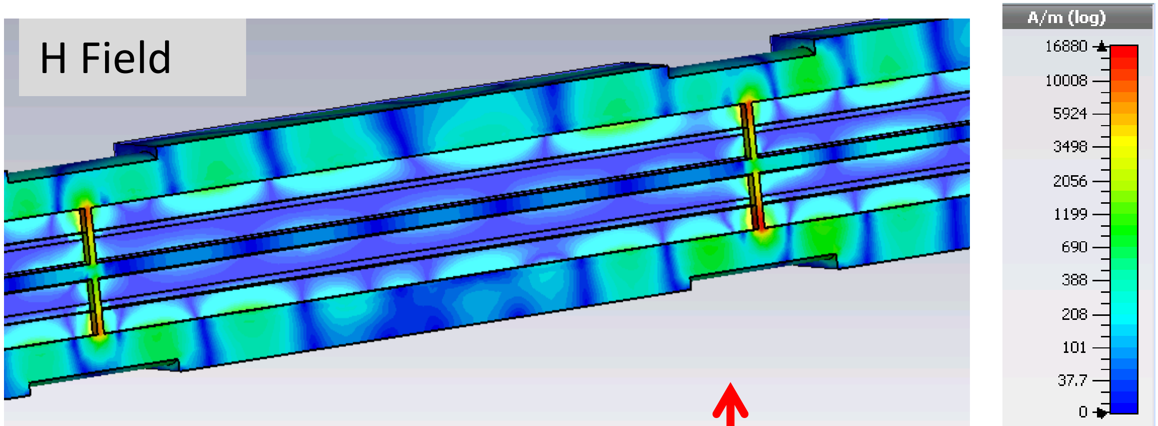
Average case

- Non critical contribution

3564 Bunches, 9cm bunch length, Nb = 2.3e11



Losses from Eigenmode Simulations : Ideal filling Pattern



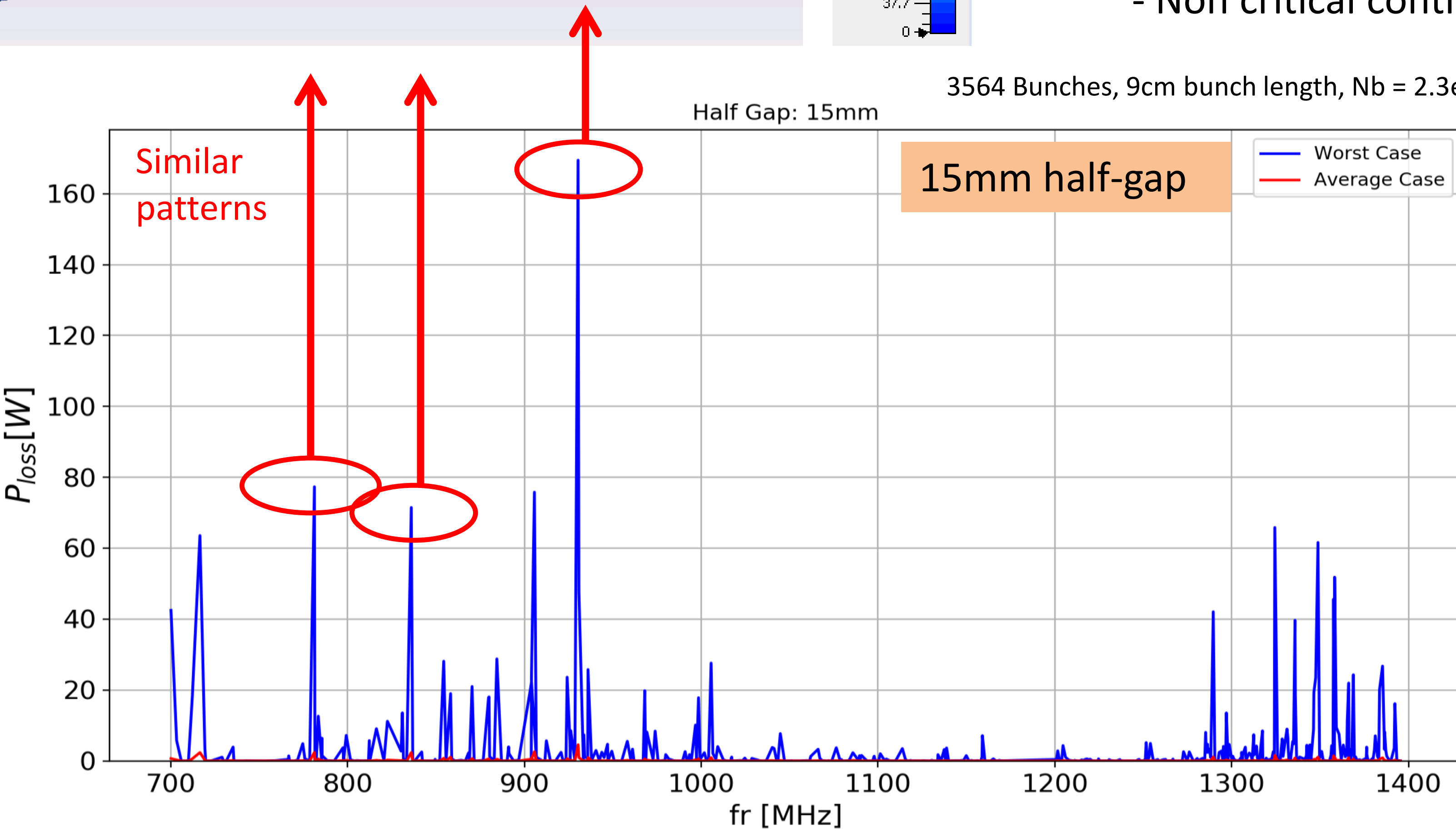
Worst Case

- 170W peak of power loss at 930 MHz
- Many other losses around 80W

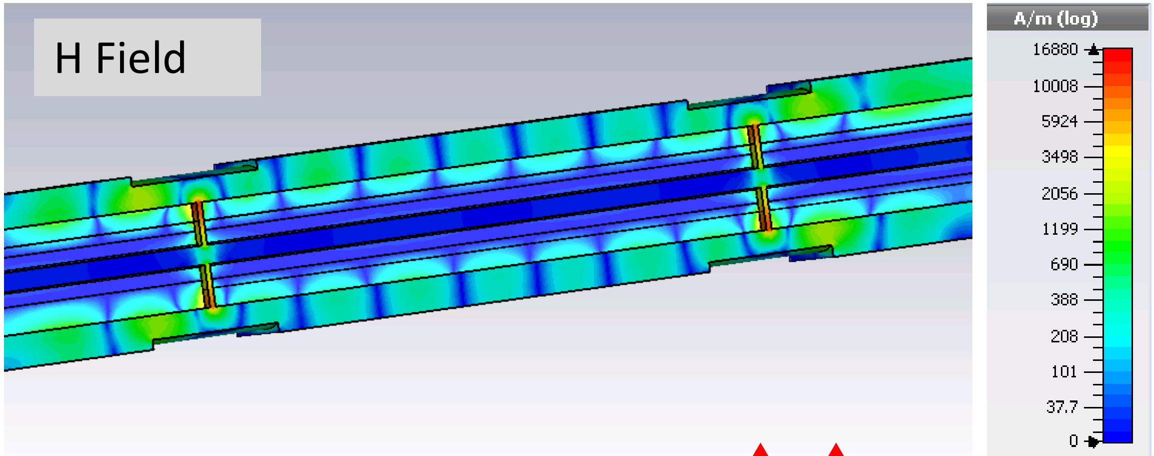
Average case

- Non critical contribution

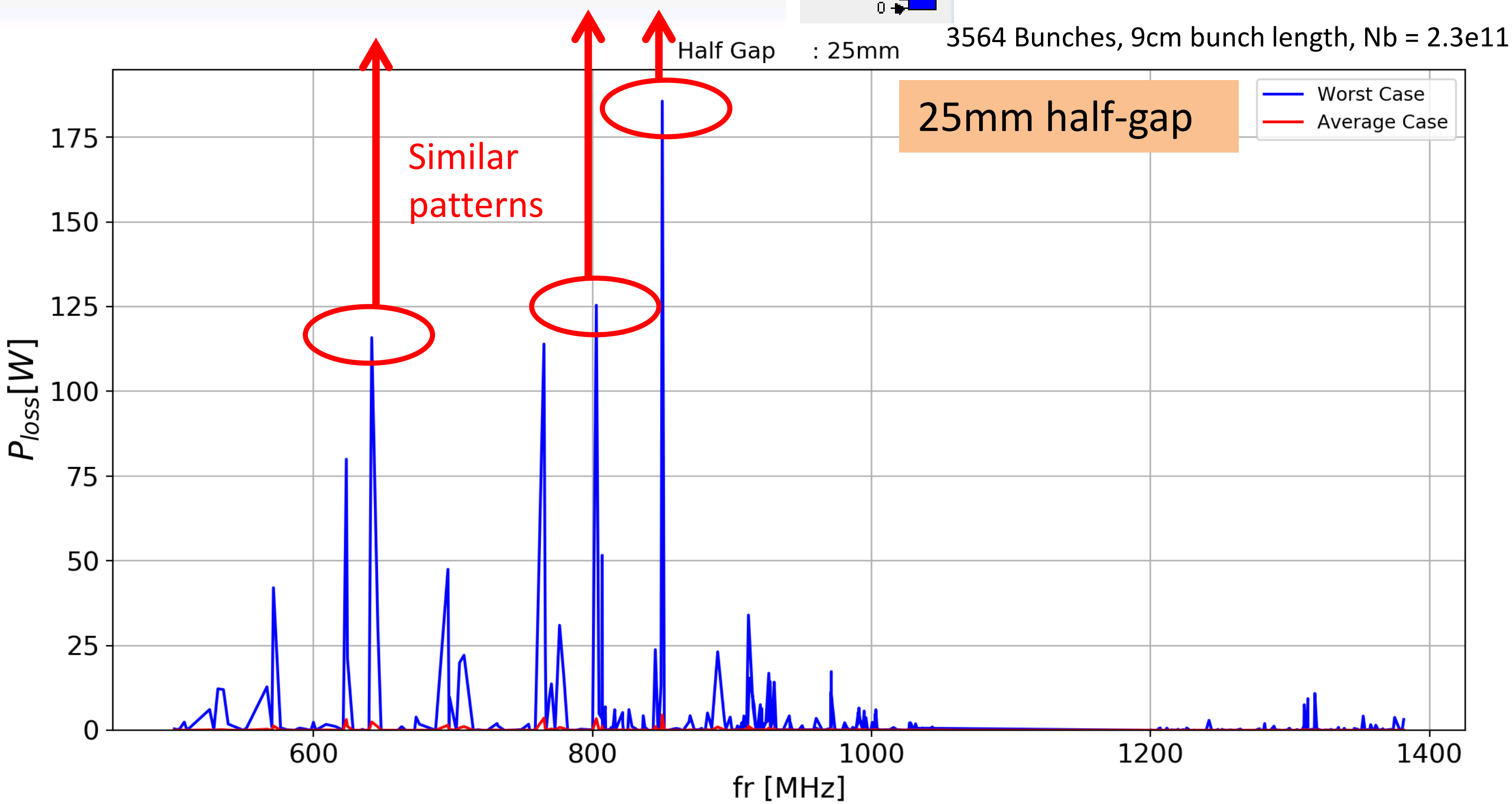
3564 Bunches, 9cm bunch length, Nb = 2.3e11



Losses from Eigenmode Simulations : Ideal filling Pattern



- **Worst Case**
  - 175W peak of power loss at 830 MHz
  - Many other losses around 120W
- **Average case**
  - Non critical contribution



Losses from Eigenmode Simulations : Real filling Pattern

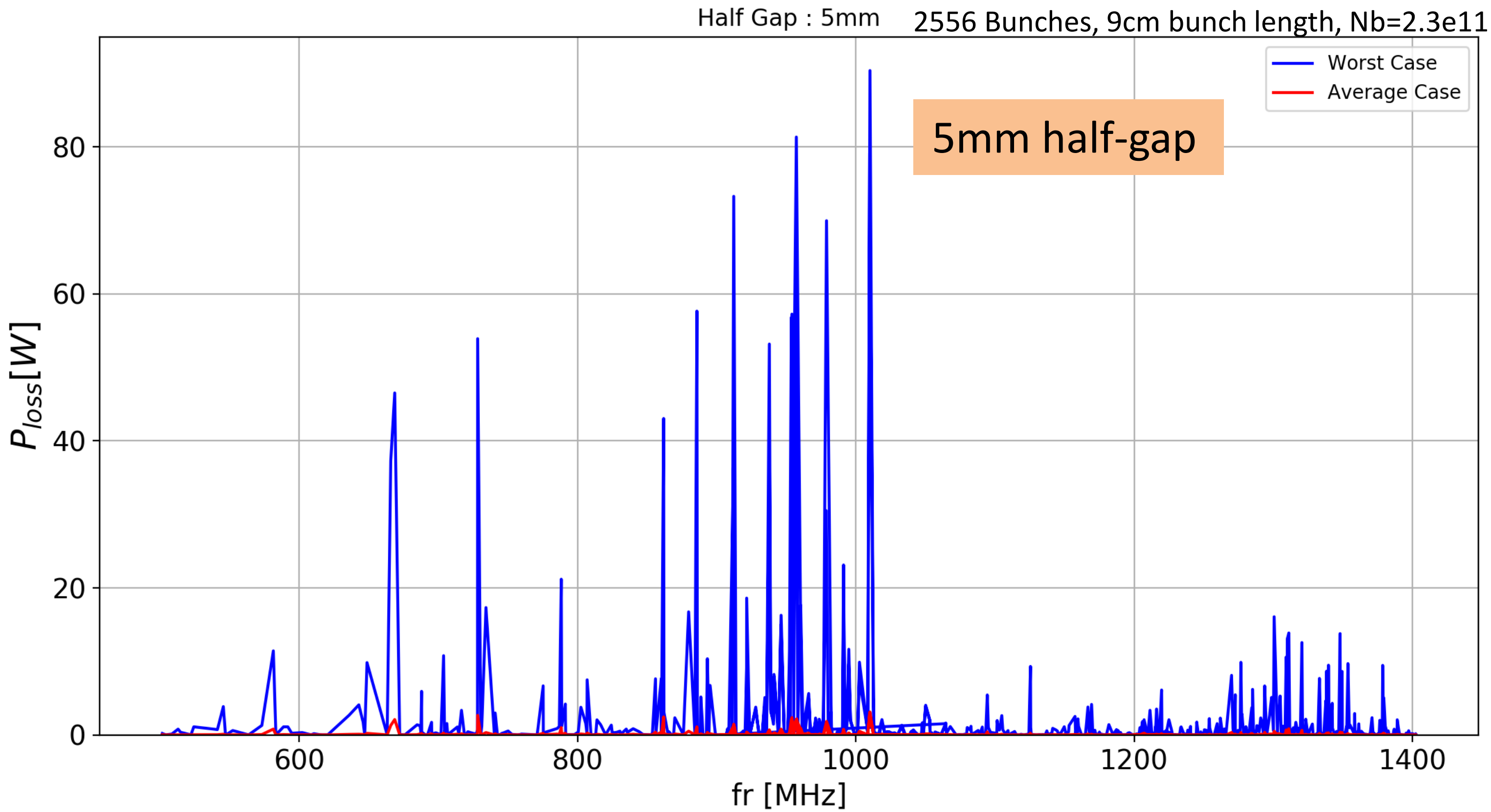
→ Same resonant modes contributing to losses in both ideal and real filling schemes

Worst Case

- 90W peak of power loss at 978 MHz
- Many other losses around 60W

Average case

- Non critical contribution



Losses from Eigenmode Simulations : Real filling Pattern

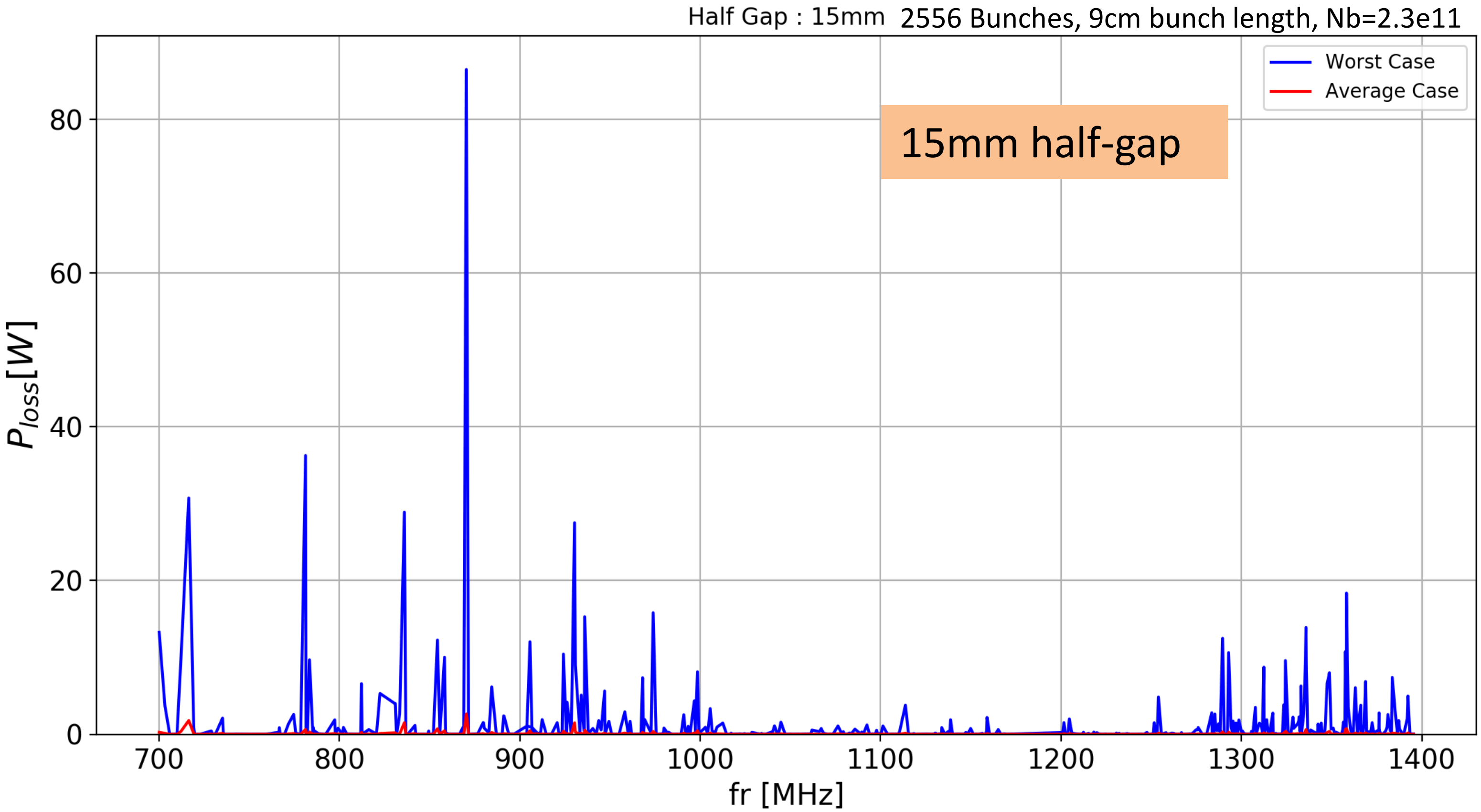
→ Same resonant modes contributing to losses in both ideal and real filling schemes

Worst Case

- 84W peak of power loss at 870 MHz
- Many other losses around 25W

Average case

- Non critical contribution



Losses from Eigenmode Simulations : Real filling Pattern

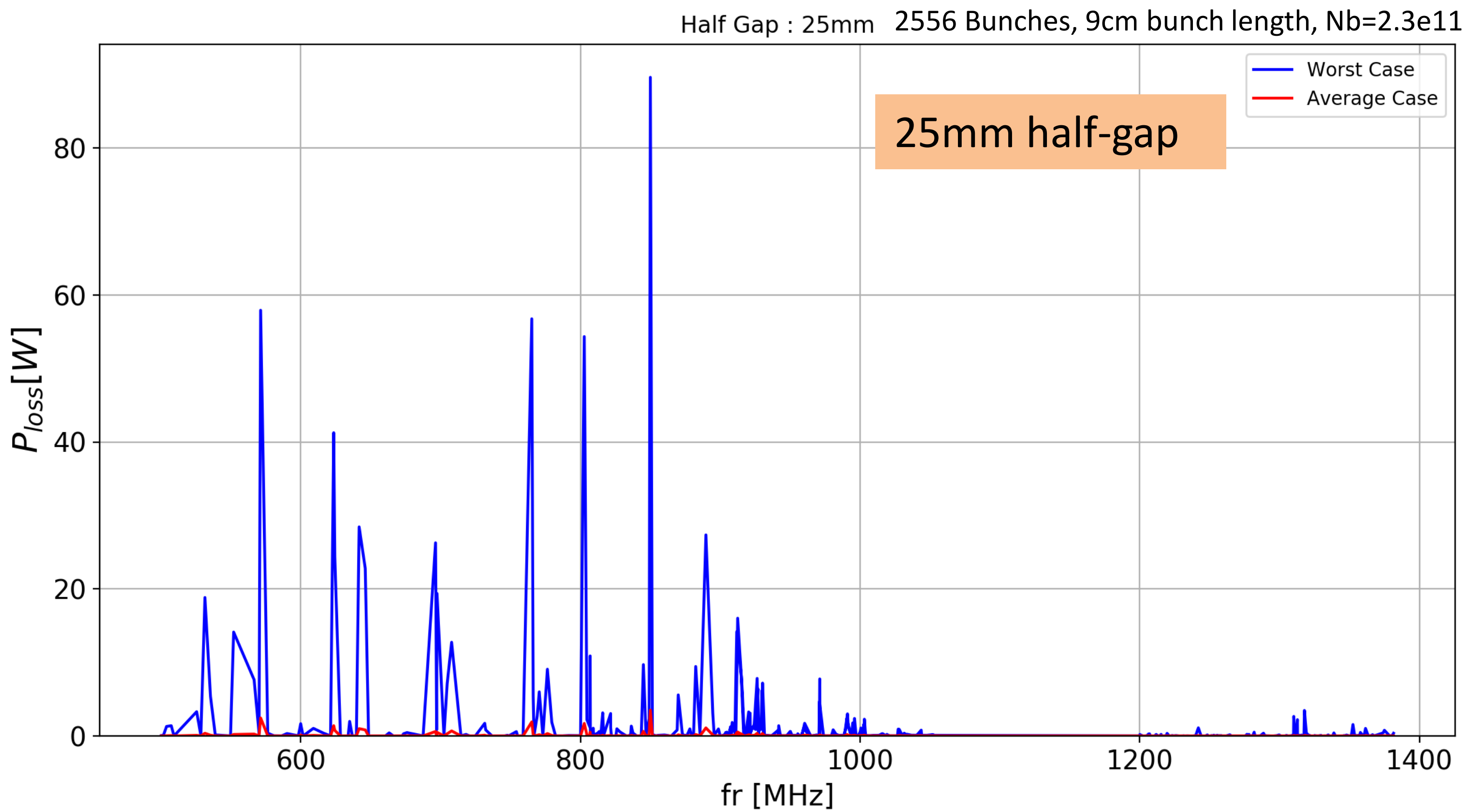
→ Same resonant modes contributing to losses in both ideal and real filling schemes

Worst Case

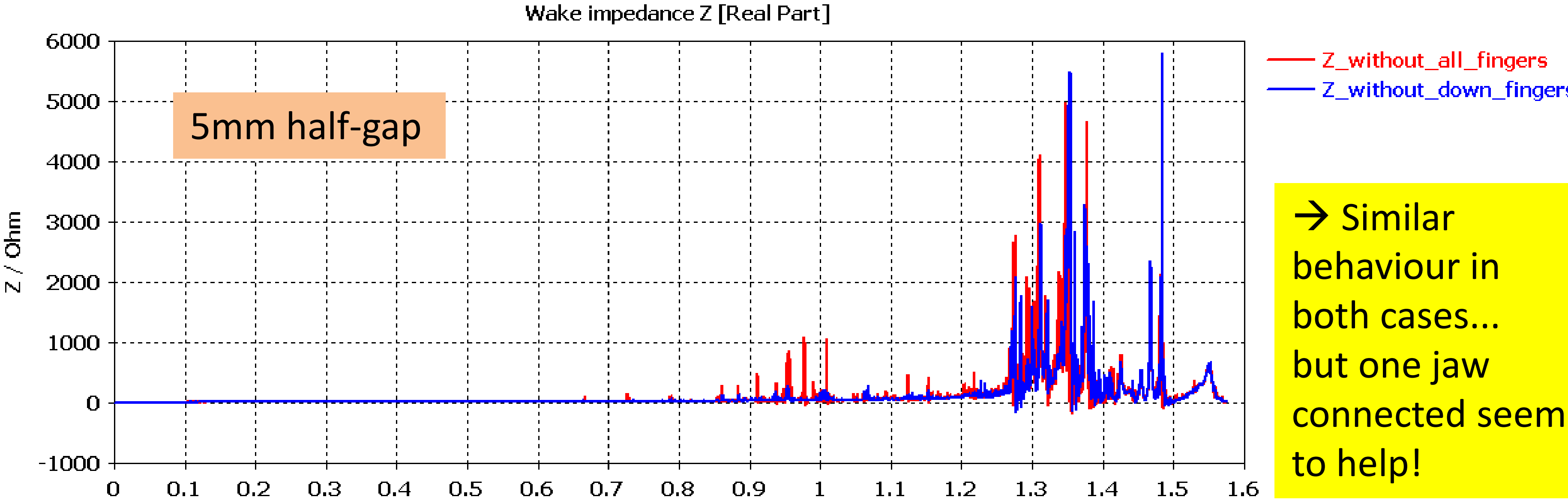
- 85W peak of power loss at 630 and 830 MHz
- Many other losses around 60W

Average case

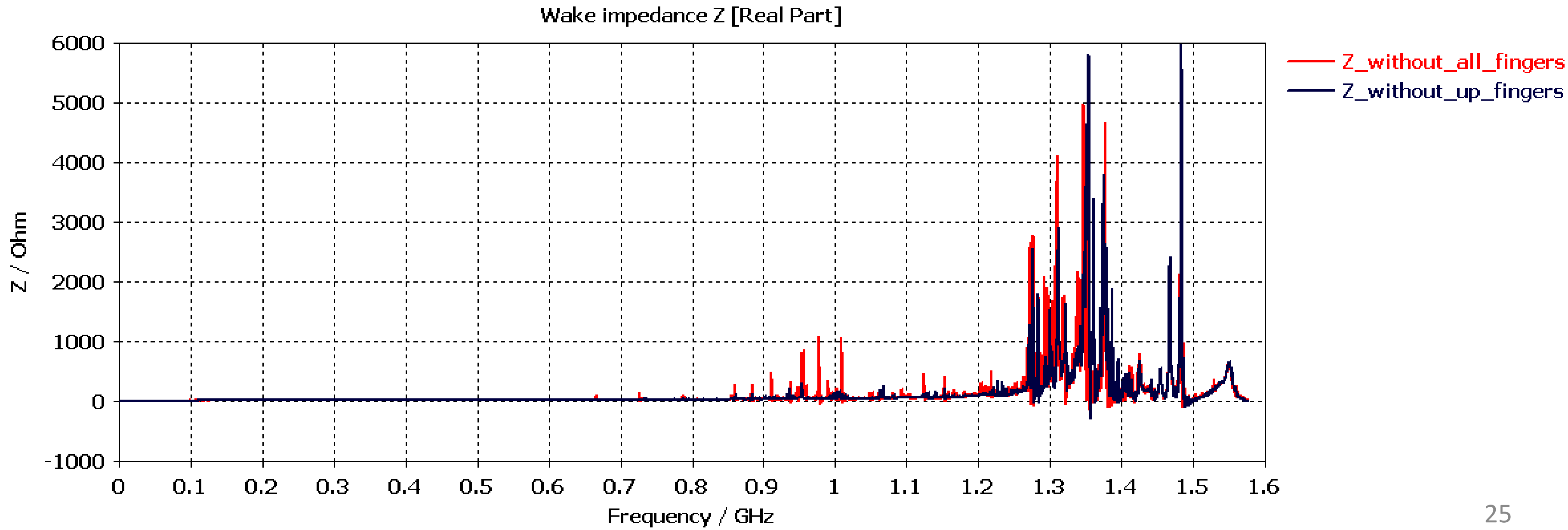
- Non critical contribution



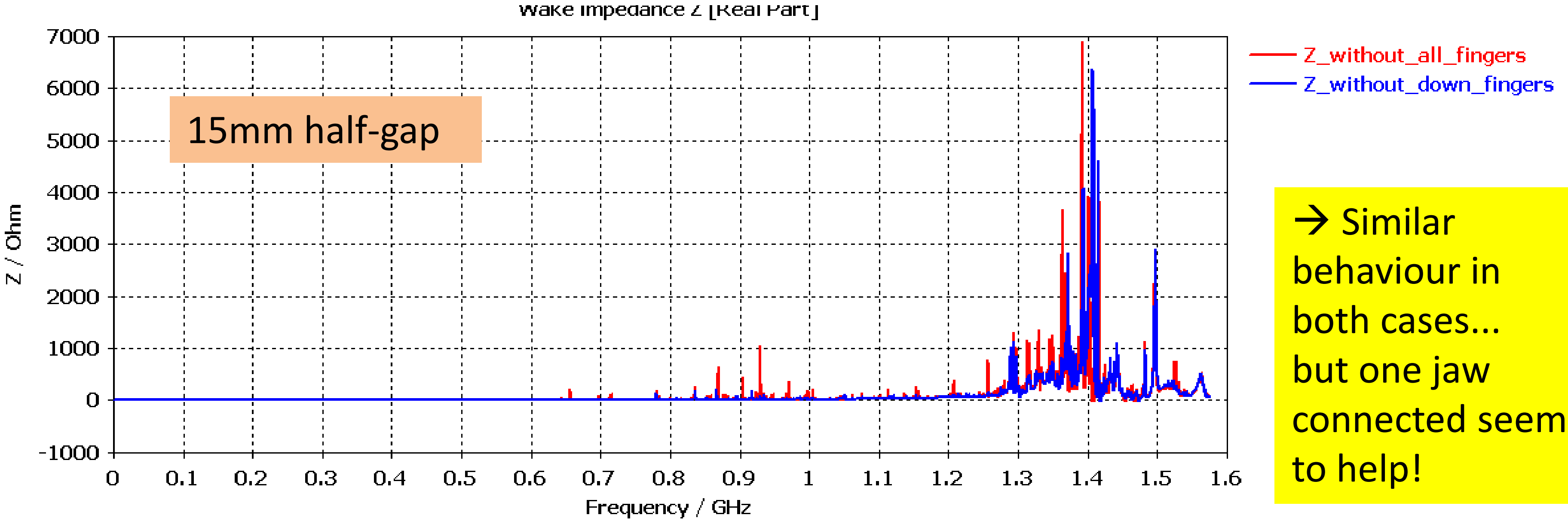
Comparison between without all fingers, without fingers down and without fingers up:



→ Similar behaviour in both cases… but one jaw connected seems to help!



Comparison between without all fingers, without fingers down and without fingers up:



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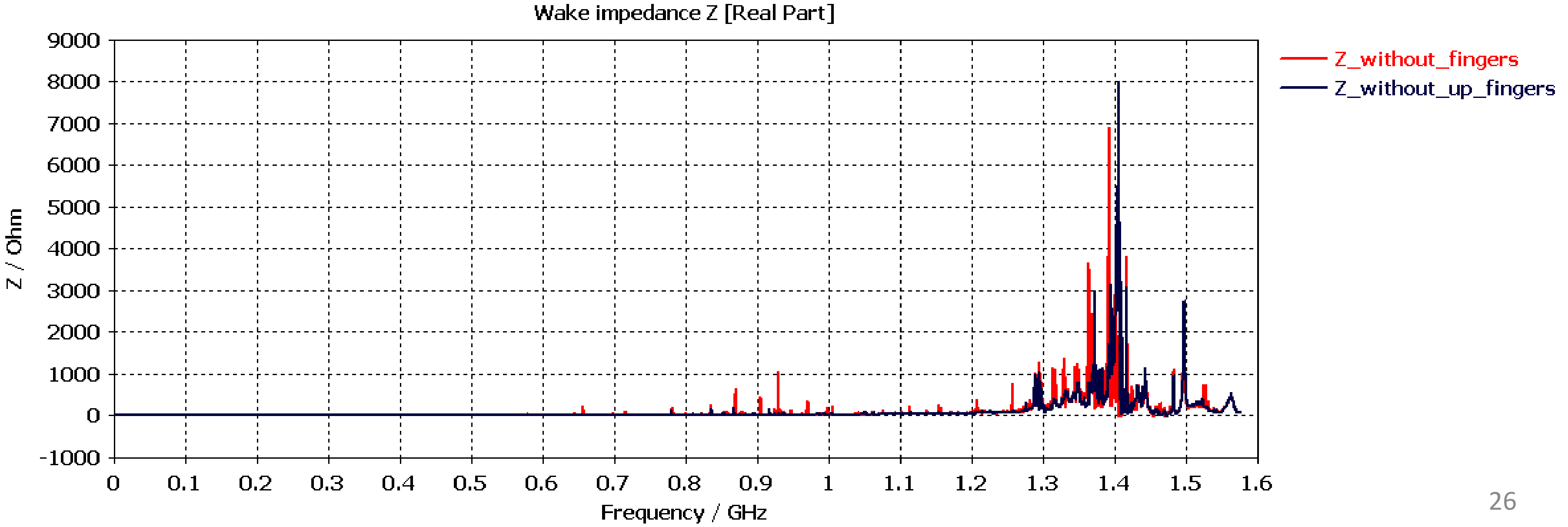
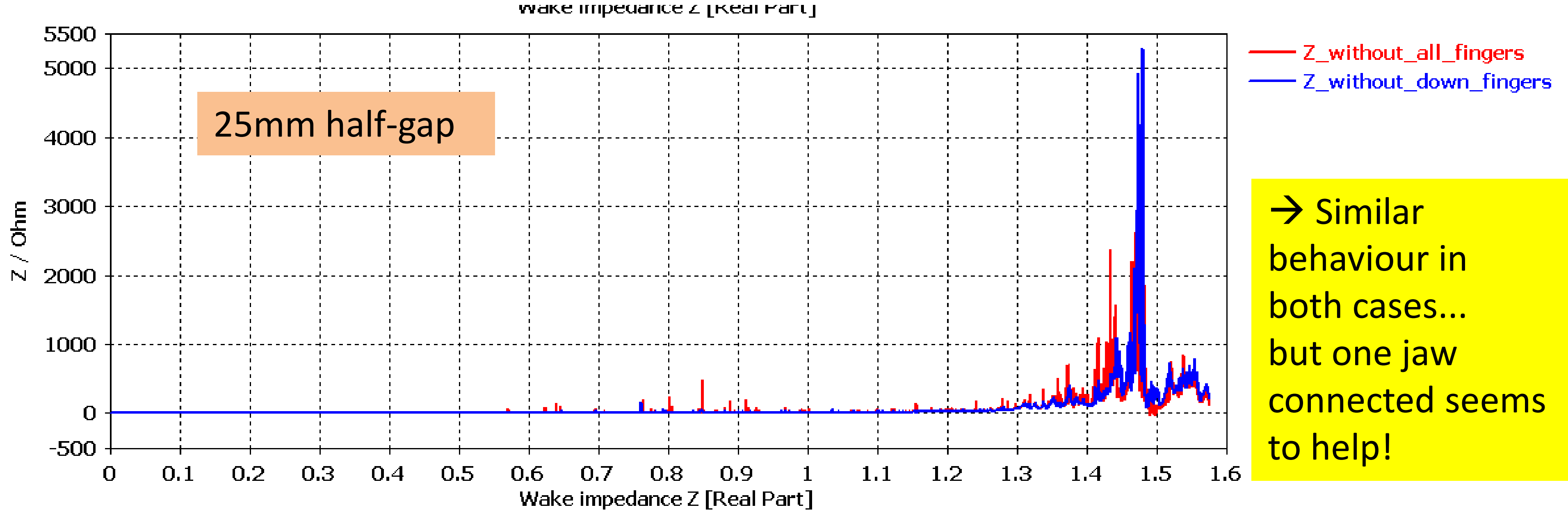


Comparison between without all fingers, without down fingers and without up fingers:



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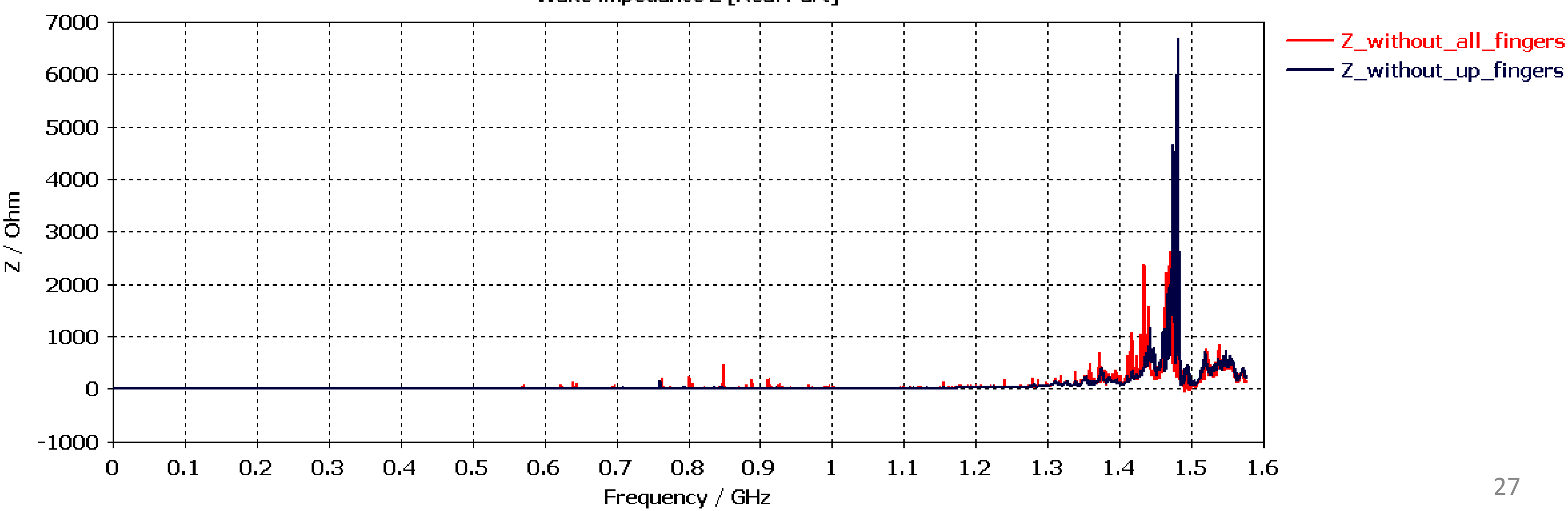

CONCLUSIONS

→ Impact on broadband longitudinal Impedance similar for TDIS 1.0 and TDIs 2.0

→ Shunt Impedance of resonant modes increasing for wider gaps

→ Many resonant modes introduced by removing the longitudinal fingers connecting different tanks, which could lead to:

- up to 250 W dissipated between the gap and the rest of the tank in ideal filling scheme.
- up to 30 W dissipated between the gap and the rest of the tank in real filling scheme.

→ Partial HOM screening when applying finger only on one jaw

→ Losses in worst case scenario generally decreasing for wider gaps

NEXT STEPS

→ Analyze the impact of fingers missing scenario on transverse Impedance (If requested)

→ Fix the discrepancy above 1.3 GHz between Wake and Eigen Simulations (ongoing)

→ Investigate also with Eigenmode the case in which just down\up fingers are removed

→Analyze the impact of heating distribution for the most relevant modes (to be agreed with EN/STI)

THANK YOU FOR YOUR TIME