Impact of fingers removal on TDIS impedance

N.Biancacci, G.Mazzacano, E.Métral, B.Salvant

WP2 , 10-08-2017

Acknowledgements:
G.Arduini, D.Carbajo Perez, L.Gentini, A. P. Marcone and all the colleagues who helped at the TDIS review.

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 (see HBn coating issues on TDI in 2015)

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.**

At the TDIS review on 01/12/2016 an overview of the TDIS impact on impedance together with impedance reduction recommendations where given. → **"TDIS v1.0" for us**

Main recommendation concerning fingers were:

- **Heating**
  - HOM heating can be drastically reduced with longitudinal and lateral RF fingers: **recommended**
  - In case of no or bad contacts, the heat load can be as bad as ~800 W depending on the mode.
  - To be checked if sensitive equipment can sustain it and with which probability it may happen.
  - Needed input from mechanical design on the elements sensitive to power deposition.
  - Power loss between 600 -800 W for Graphite or 3D Carbon jaws
  - Power loss between < 100 W for Copper coating: recommended

Introduction

On **12/05/2017** a **change of the main TDIS jaw dimension was communicated to the impedance team. The width of the absorbing jaws was shortened from 80 to 62mm** → **"TDIS v2.0" for us**

The change in jaw width is being addressed by the impedance team: model available since **end of May**.

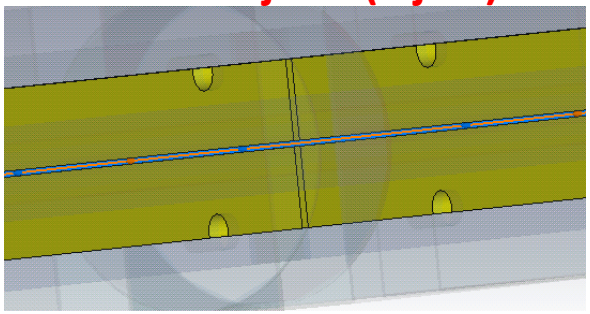
On **02/08/2017**, Antonio made a request to study the possibility of **removing the fingers between contiguous jaws (longitudinal fingers)**

In this presentation **we summarize the impact on impedance and beam stability** of removing the longitudinal fingers **focusing on the HOMs** that are introduced. We give **only a rough estimate of the HOM impact (as was not foreseen for the simulations!)**

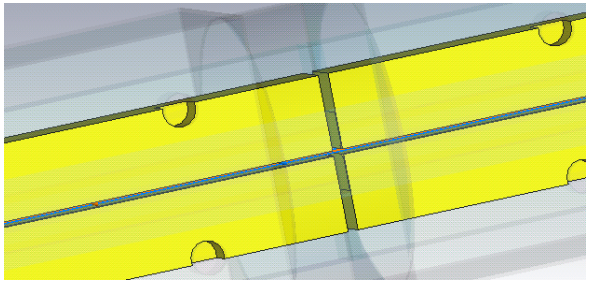
Due to the **complexity of the device and the number of HOMs** introduced a **detailed analysis is needed for the TDIS updated model**.

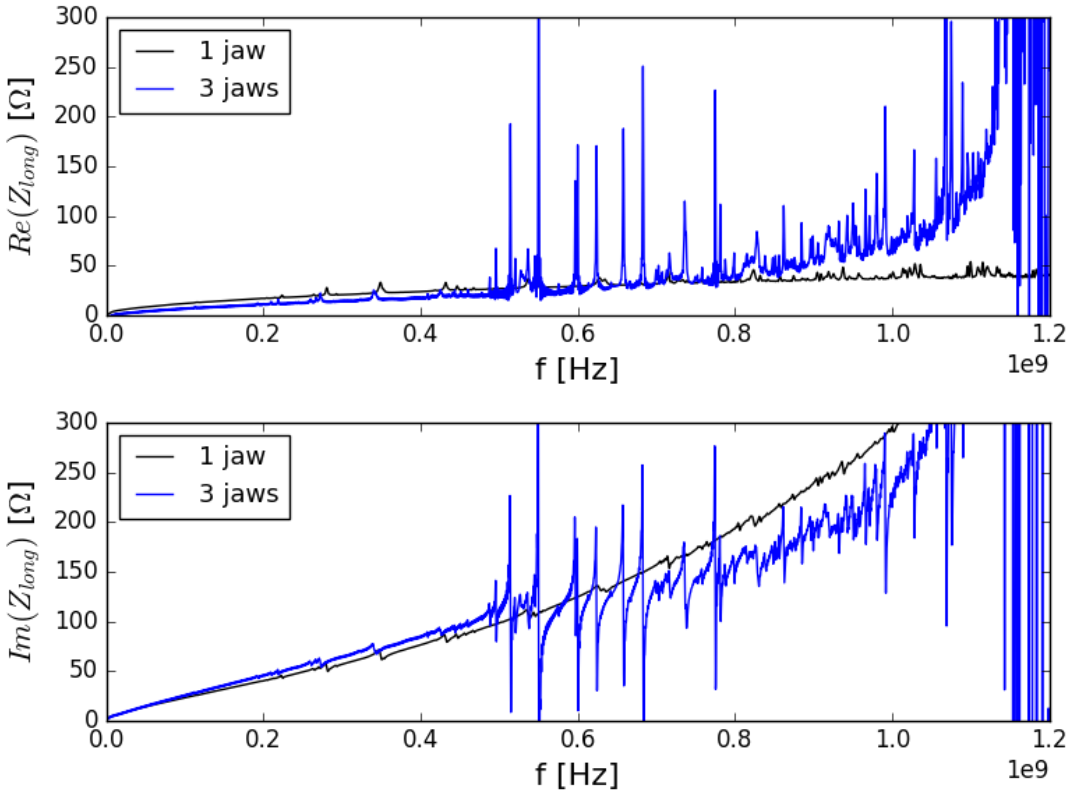
Effect of jaw segmentation (TDI → TDIS v1.0)

Connected jaws (1 jaw)



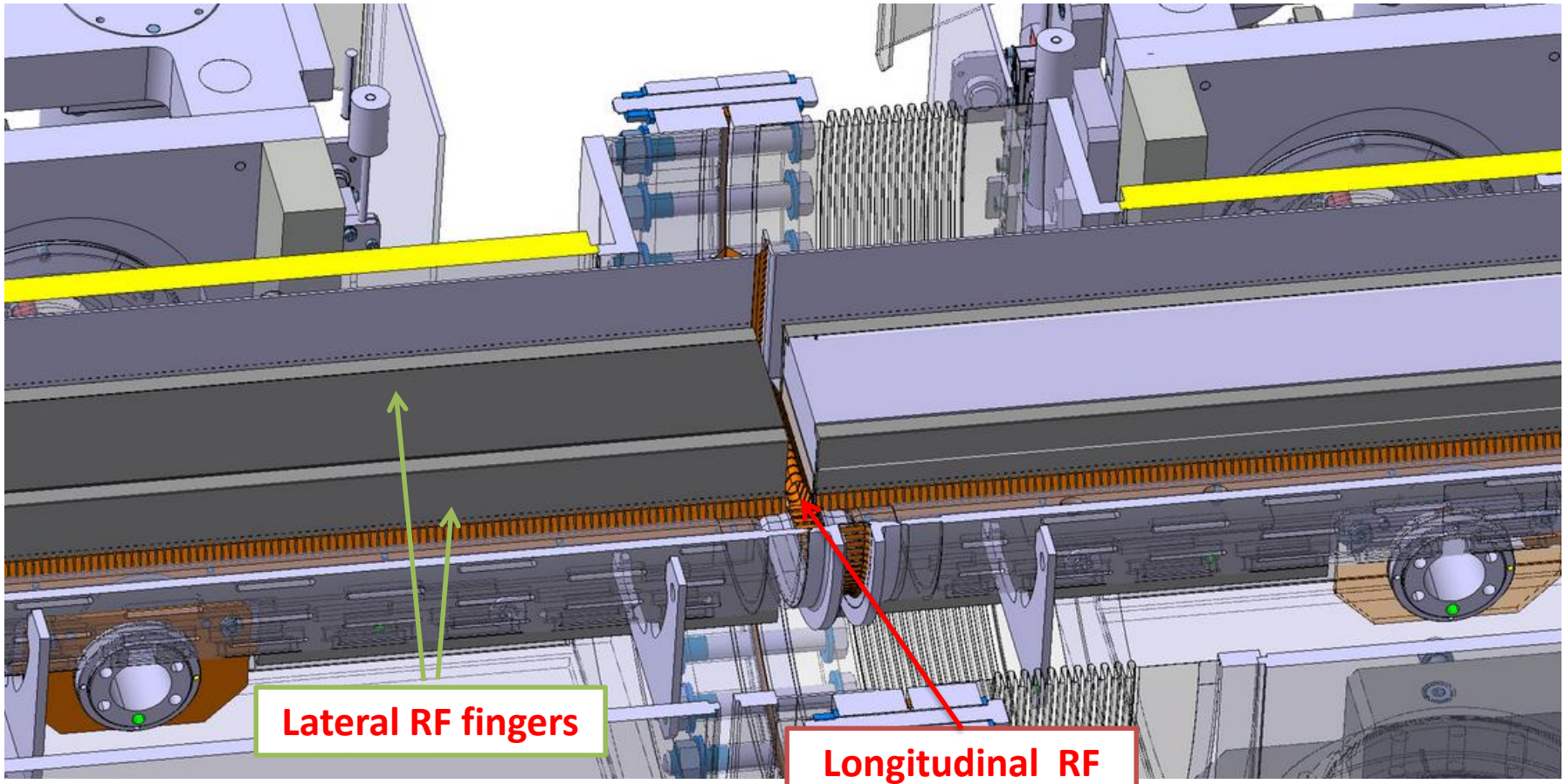
Segmented jaws (3 jaws)



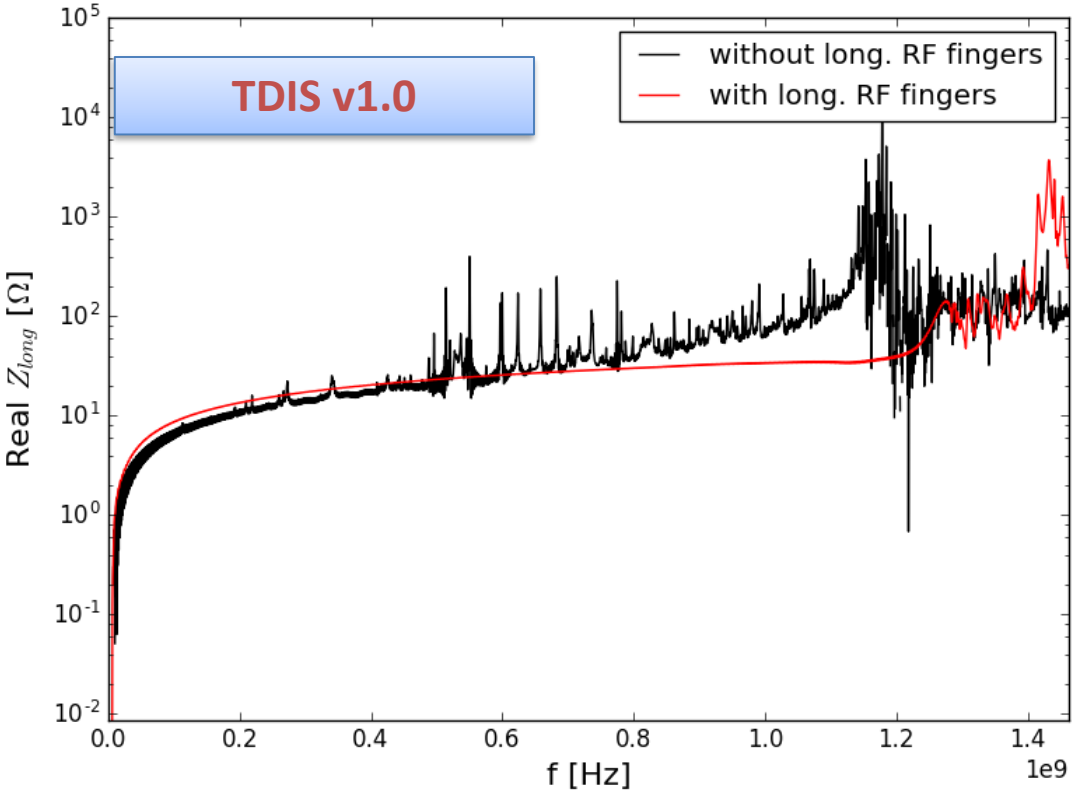


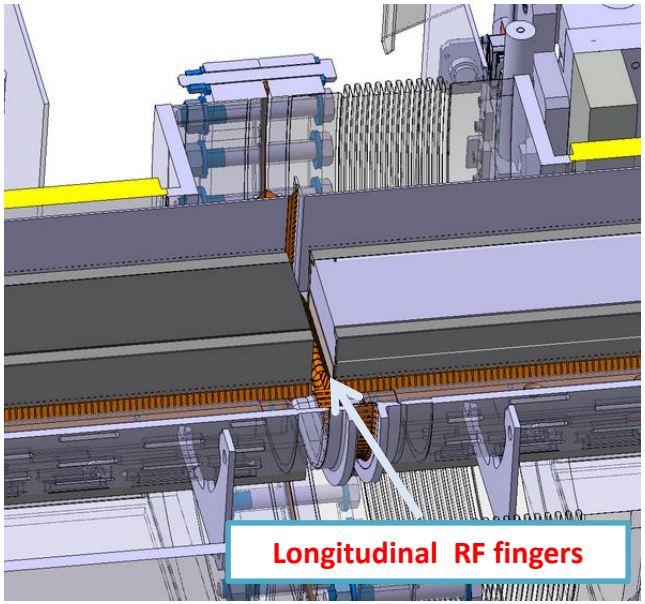
- **Removing the jaw connection introduces a large amount of HOMs!**
- A **detailed quantification** of the effect on heating and stability **needs heavy amount of Eigenmode simulations.**
- **Rough estimates given in the following.**

RF fingers in the TDIS design



Effect of longitudinal fingers on impedance

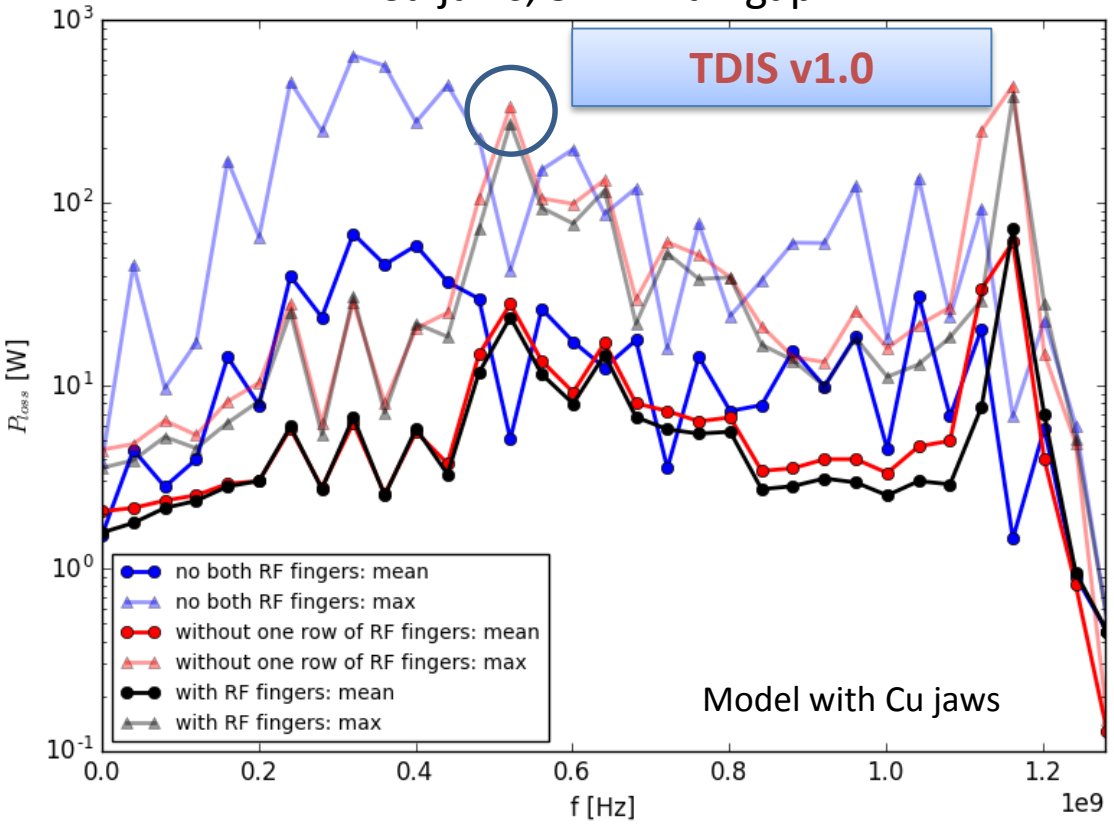


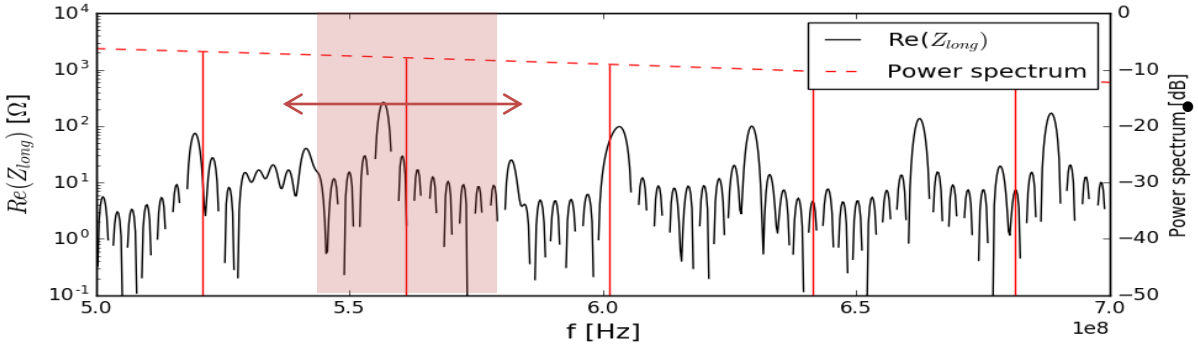


- **No visible HOMs in longitudinal impedance below 1.2 GHz** if granted continuity of image current flow with longitudinal RF fingers.

Effect of fingers removal on heating

Cu jaws, 5mm half gap

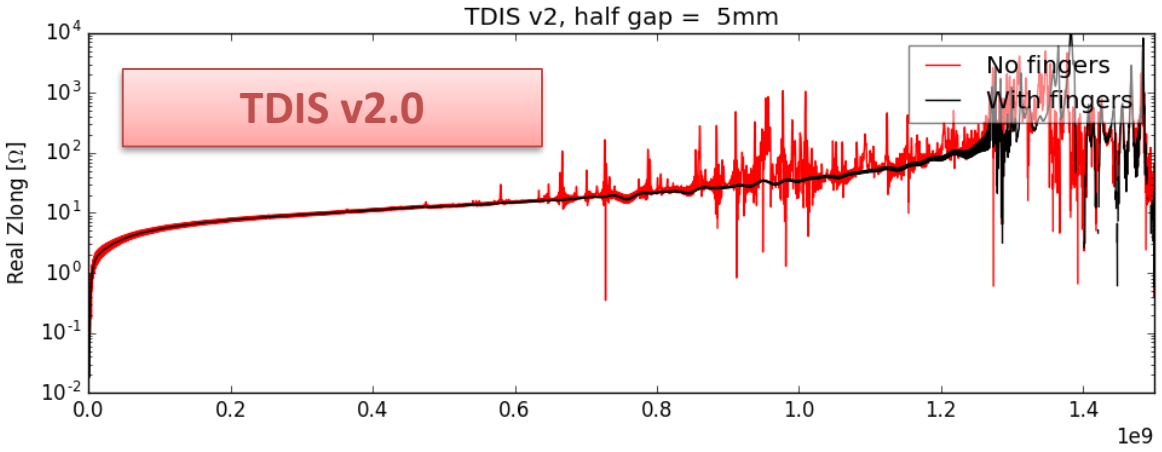


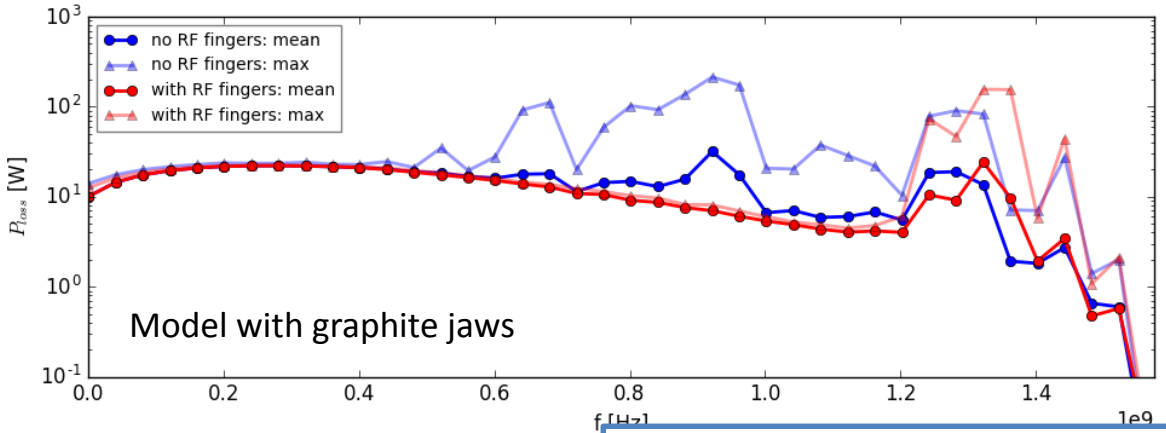


- HOMs are introduced removing the longitudinal fingers and/or lateral ones.
- Black curve shows impact with **no longitudinal RF** finger but **with lateral RF fingers**.
- Heating from HOM evaluated with statistical approach (+/- 20MHz uncertainty)
- **300 W** max power dissipated around 500MHz (may change on the updated model of the TDIS and with Eigenmode analysis)

Summing all the HOMs is not a priori correct as we should check where the heat is deposited.

Effect of fingers removal on heating





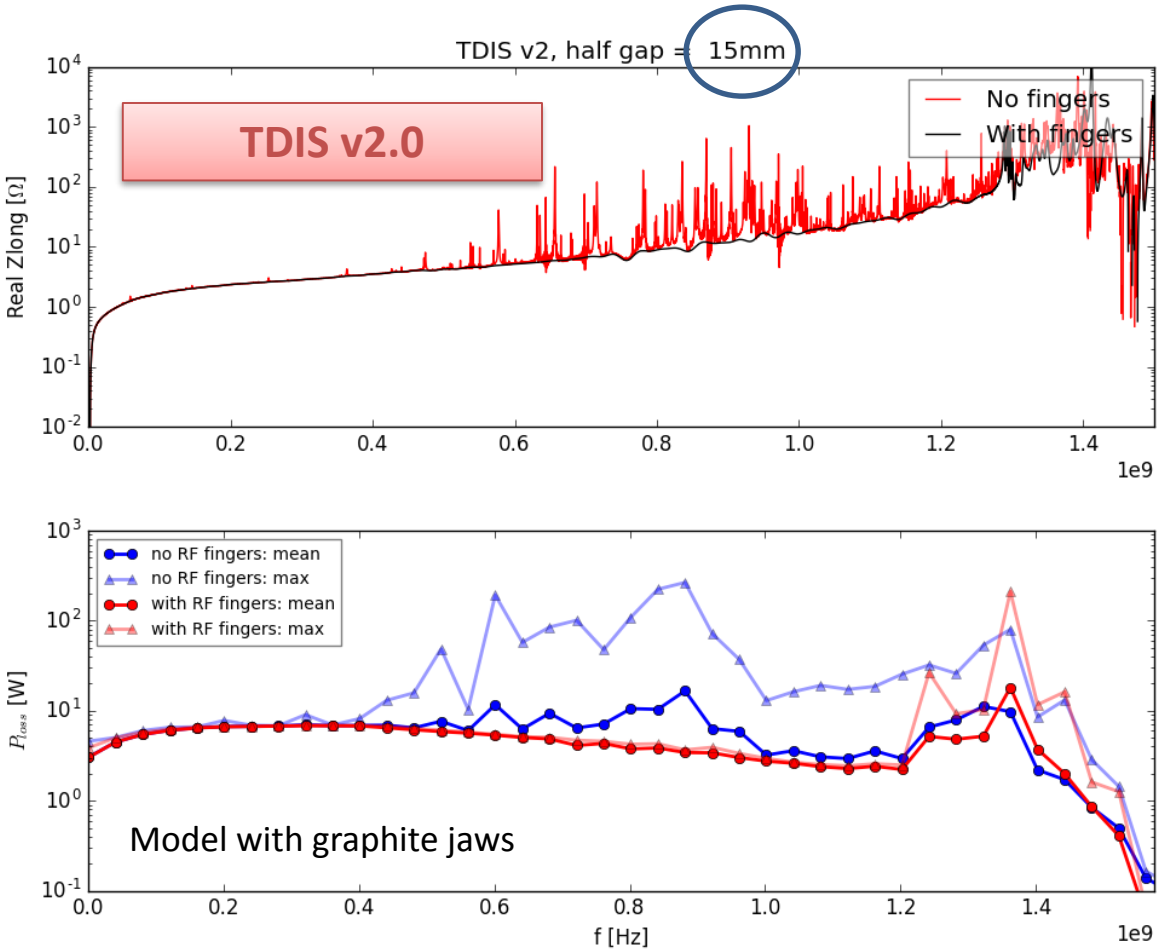
- **Simulations being updated by G.Mazzacano on TDIS v2.0**
- Strong fingers effect on longitudinal impedance confirmed.
- **Few 100 W** at max per HOM around 800 MHz.
- **Dependence on gap not straightforward**, need to check in detail.

Preliminary simulations fr

CST 2socket	Running	CERN\gmazzaca	0%	8/10/2017 2:05:46 AM
CST 2socket	Running	CERN\gmazzaca	0%	8/10/2017 2:04:52 AM
CST 2socket	Finished	CERN\gmazzaca	100%	8/10/2017 1:46:02 AM
CST 2socket	Finished	CERN\gmazzaca	100%	8/10/2017 1:45:39 AM
CST 2socket	Running	CERN\gmazzaca	0%	8/10/2017 1:45:07 AM

Many thanks for all this work ☺

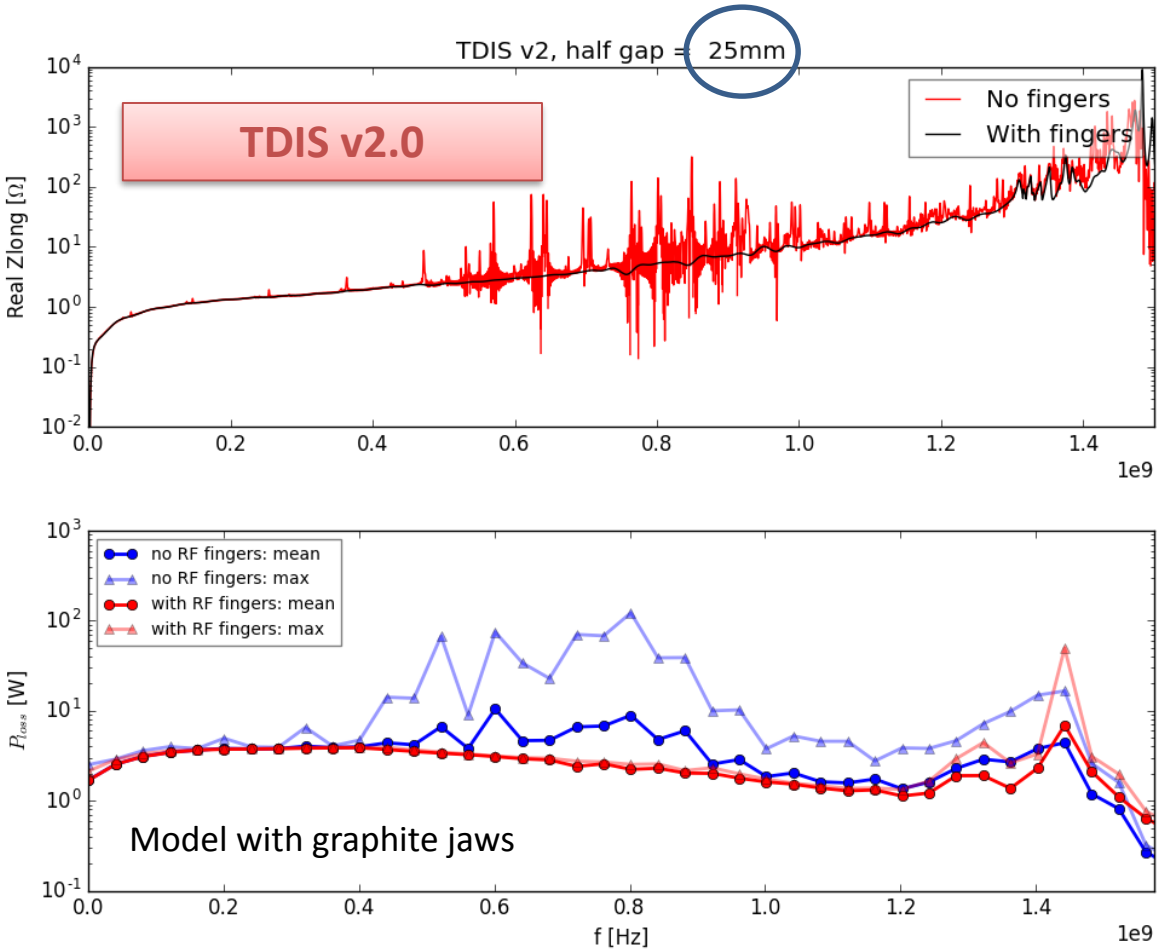
Effect of fingers removal on heating



Preliminary simulations from G.Mazzacano

- **Simulations being updated by G.Mazzacano on TDIS v2.0**
- Strong fingers effect on longitudinal impedance confirmed.
- **Few 100 W** at max per HOM around 800 MHz.
- **Dependence on gap not straightforward**, need to check in detail.

Effect of fingers removal on heating



Preliminary simulations from G.Mazzacano

- **Simulations being updated by G.Mazzacano on TDIS v2.0**
- Strong fingers effect on longitudinal impedance confirmed.
- **Few 100 W** at max per HOM around 800 MHz.
- **Dependence on gap not straightforward**, need to check in detail.

Comments on HOMs evaluation

- The heating calculated so far **might be underestimated** as it is inferred with **time domain Wakefield simulations.**

- If the longitudinal fingers are removed, we need to **study in details the HOMs with Eigenmode simulations** and **check Q-factor and shunt impedance to refine the heating probability calculations.**

- **The impact of filling pattern** should be as well addressed (F.Giordano, B.Salvant)

- **Local power loss:** HOMs can heat different locations.
  - What are the **heat load tolerances on the TDIS components**?
  - Can we foresee any **vacuum issue**?
  - Do we have **someone to check it with thermo-mechanical simulations**? Some expertise presented by L.Teofili on impedance meeting 14-07-2017.
  - Should we foresee an **intermediate step between impedance calculations and design validation** to account for **local heat deposition effect studies**? The impedance team can can provide the power loss maps.

- **Transverse stability: Eigenmode simulations** are as well needed to assess the impact on **coupled bunch** (mainly shunt impedance R of the modes) and **single bunch** (R/Q) from each HOM.

Timescale for impedance studies

Finalization of the impedance and beam stability impact estimates on updated TDIS :

Impedance calculations: broadband estimation, shunt impedance, Q factor HOM by HOM, especially without RF fingers in both longitudinal and transverse plane.	**~20 days**	**1-2 people**
Beam stability /heating calculations: DELPHI / filling pattern simulations at injection and flat top.	**~10 days**	**2 people**

Prototype measurements:

Long./Transverse impedance wire measurements in circulating and injection positions at different gaps..	**~10 days**	**3 people from ABP + 1 helping from EN-STI**
HOM characterization with probe/loop at different gaps.		
Broadband impedance with resonant wire method.		
Device exceptionally long: need to allocate enough time (see issue with TCSPM wire measurements)		

Additional measurements:

If required: EM coupling on temperature probes	**~2 days**	**To be checked**

Conclusions and outlook

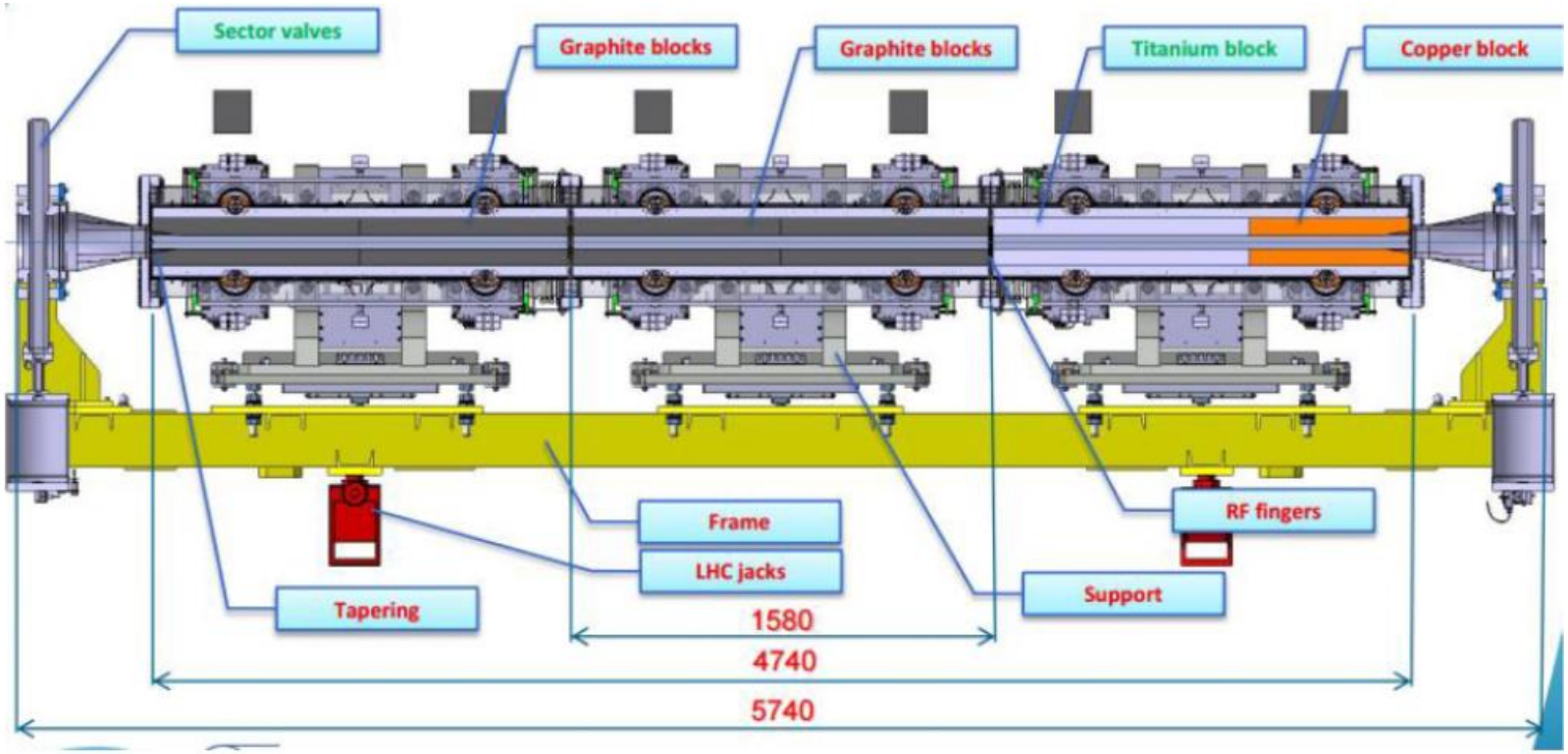
- Impedance and instability studies on TDIS
  - **Transition from TDIS v1.0 to TDIS v2.0 still under study.**
  - Preliminary results **confirm detrimental effect of removal of longitudinal RF fingers.**
  - Order of **few 100W** dissipated for strongest HOM.
  - Need to assess the impact also with thermo-mechanical simulations and on vacuum.
  - **Need to do careful analysis HOM by HOM with Eigenmode Solver.**
  - Impact on **transverse stability being investigated**.

- Timescale requested:
  - **Impedance studies:** 20 days – 2 people
  - **Instability studies:** 10 days -2 people
  - **Prototype measurements:** 10 days – 3 people from ABP + 1 from EN-STI
  - Additional measurements: 2+ days depending on item and people availability.

Key dates and **milestones for design revisions and prototyping needed** to plan well ahead all this work!

Thanks for your attention!

Backup



- green: changed
- red: same as before