Updates on TDIS design

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Outline

- Internal review motivation
- Relevant recommendations
- Modifications applied to TDIS design
- Pending issue: risk of UFOs produced by friction of RF fingers against graphite ➔ impact on impedance according to what presented at the internal review
- Questions for impedance team
- Wish list (calculations and measurements) to be agreed with WP2
- Conclusions

Internal review on December 1st 2017

Objectives:

- Validate the technical choices made for the design of the new TDIS in terms of **general mechanical/thermal concept**, **reliability of alignment and control for machine operation**, **exchange in case of failure.**
- Discuss the design by **taking into account the past experience of operation** with the previous generation of TDI and **confirm that the new design addresses the limitations encountered in the past**.
- **Identify possible limitations and critical items** in the current design in terms of **robustness with respect to thermo-mechanical efforts**, **compatibility with machine vacuum, compatibility with impedance requirements and beam quality, possible occurrence of high order RF modes (HOM), possible occurrence of electron cloud.**
- **Propose the tests** to be made on the prototype to validate the design before series production

Reviewers: M. Taborelli, A. Dallocchio, A. Grudiev, V. Kain and S. Sgobba

Recommendations

Full list of recommendations provided by the reviewers*, some brought to modify the mechanical design:

- *" The panel **recommends** a simulation to verify the amount of **energy deposited in the cooling water** as well as in the pipes itself in case of a beam impact on the jaw. The resulting **mechanical stress/strain** (due to possible water pressure instantaneous increase) **on the cooling pipes** should be carefully evaluated."*
- ***"The panel recommends also to carefully verify the energy deposition on the aluminum alloy back stiffeners of the TDIS in case of beam impact** and to evaluate possible permanent plastic deformations with consequent permanent sag of the jaw"*
- *"For the high Z part **Ti-6Al-4V** (Grade 5) **blocks instead of aluminum alloy** would be preferable for mechanical reasons and also for conditioning with respect to e-cloud."*
- *"The benefit of a **copper coating** has to be compared with the risks of damages in case of grazing beam impact (the impact is more likely than for collimators). **The HRMT-35 test, which is already foreseen, will enable a better evaluation of the risk of UFOs and the type of damage on the coating."***

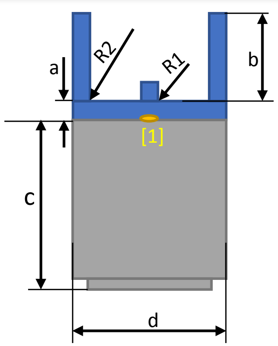
https://indico.cern.ch/event/579995/attachments/1403540/2143469/TDIS_review_form_final_APM.pdf

Updates on TDIS design overview
Thermo-mechanical simulations results

- Jaws design update – Simulations summary

Fluka sim.	Simulation Input						Simulation output (Stiffener)				Remarks
	Material	Tensile Yield strength [MPa]*	Geometry								
			a [mm]	b [mm]	c [mm]	d [mm]	Peak temperature [°C]	Peak stress [MPa]	Peak stresses zones	Safety factor	
TDISv3	Alu 5083	145	8	37.1	54	80	128	> 145	R1	< 1	Original design, high stresses at R1 zone. Plastic deformation expected.
TDISv11	Mo alloy - TZM	515	8	33.5	67	62	227	320	[1] (no rib)	1.61	Current status. Peak stresses below yield strength.

(yellow)	Modification wrt previous case
*	Estimated value @peak temperature

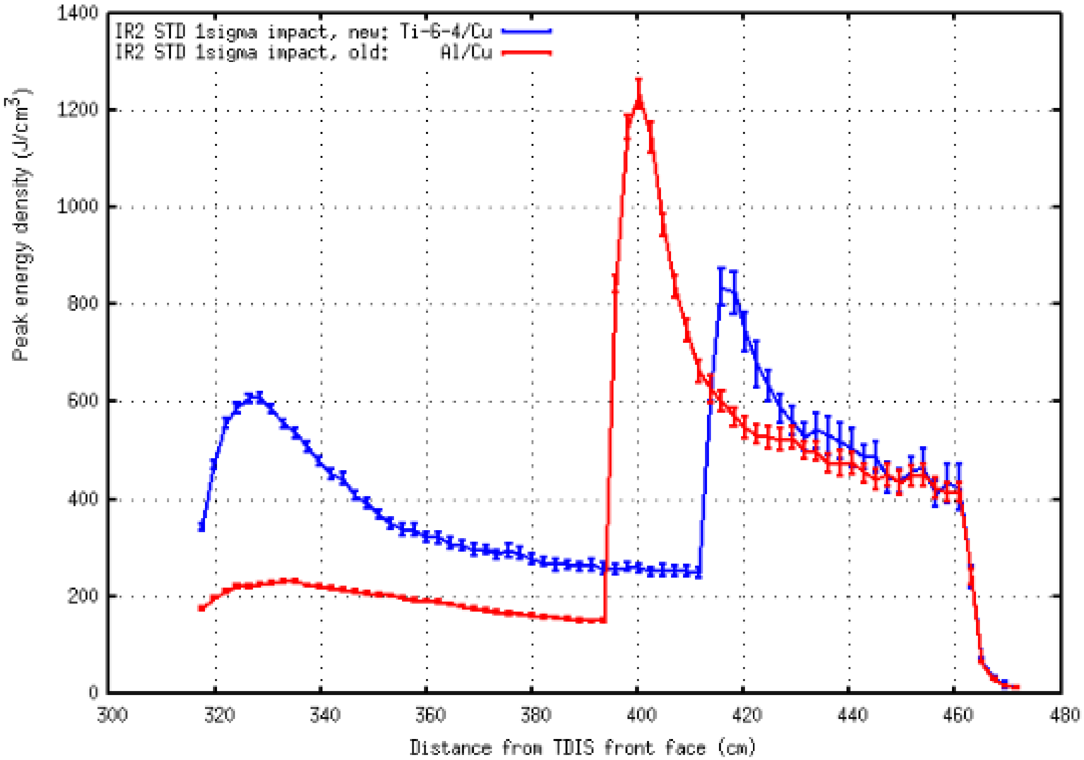


Jaw cross-section sketch
Stiffener + Absorbing block

M.I. Frankl

High-Z Absorbing Blocks

- Peak-Energy deposition in **higher-Z absorber blocks**, **current** and **previous** versions:



- Maximal temperature increase in previous version (Al/Cu): **95 K/360 K**
- Maximal temperature increase in current version (Ti-6-4/Cu): **265 K/245 K**
- Due to possible **misalignment** of the jaws **additional energy deposition** of ~ **15 %** has to be taken into account

Updates on TDIS design overview
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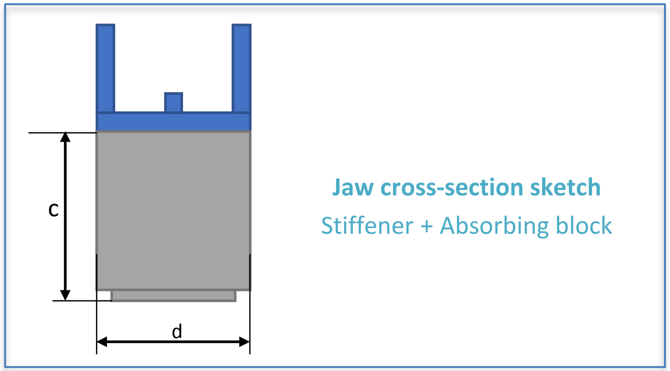
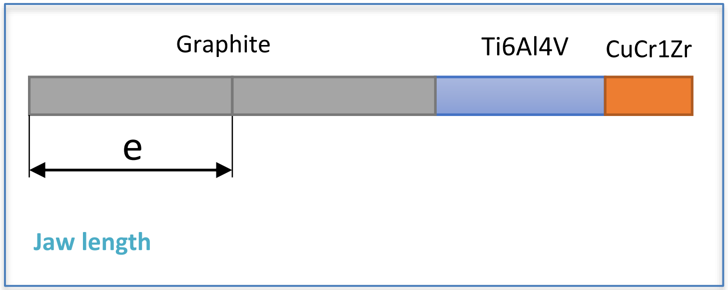
- Jaws design update – Simulations summary

Fluka sim.	Simulation Input					Simulation output (Stiffener)			Remarks
	Material	Tensile Yield strength [MPa]*	Geometry			Peak temperature [°C]	Peak VM stress [MPa]	Safety factor	
			c [mm]	d [mm]	e [mm]				
TDISv3	Alloy 5083	145	54	80	965	143	> 145	< 1	Original design, high stresses in case of grazing impact. Plastic deformation expected.
TDISv11	Ti6Al4V	500	67	62	965	365 (large impact parameter)	273	1.83	Material upgrade. Peak stresses below yield strength.

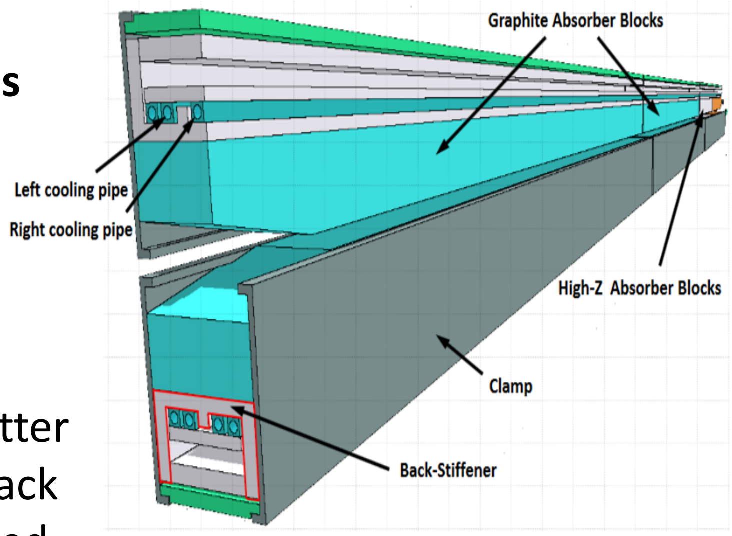
(yellow)	Modification wrt previous case
*	Estimated value @peak temperature

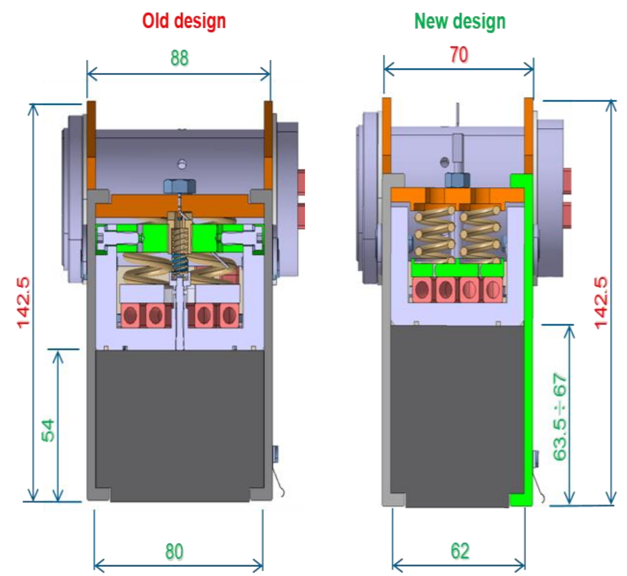




TDIS Modified Design

- **Design modifications** according to **recommendations** ➔ **improve robustness** and **easier integration**
  - Reduced jaw width to allow more space for jaw insertion inside the tank during assembly
  - Increased height of absorber block
  - Different back-stiffener material: TZM Mo-Alloy (high thermal shock resistance, stiffness and better shielding for the cooling pipes. Al 2219 as fall-back solution. Two prototypes, with Al and TZM, tested in parallel in HiRadMat in 2018)
  - Cooling pipe inner diameter decreased from 6mm to 4 mm, pure Cu to improve cooling efficiency
  - Clamps material upgrade (required due to higher energy deposition as result of jaw thinning): Stainless steel → Ti6Al4V
  - Change 3rd jaw material: Al/Cu → Ti6Al4V/CuCrZr
- HRMT-28 tests performed: graphite and 3D CC ➔ both survived (material analysis will follow after cool down)
- HRMT-35 will be performed in week 33: Cu coating

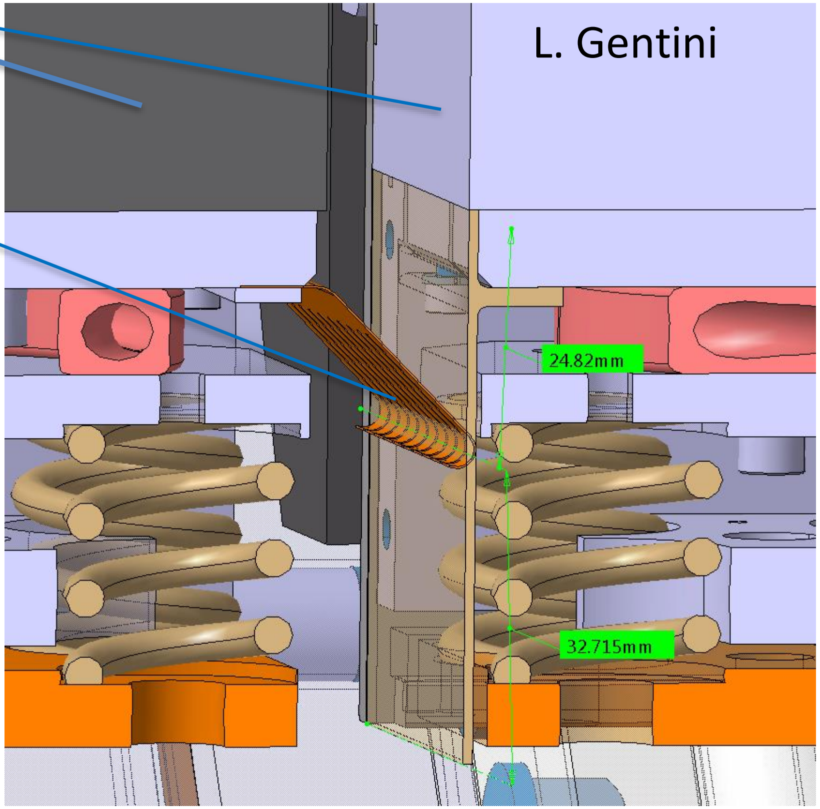




Pending issue.....

Absorber blocks

Longitudinal jaw fingers



The longitudinal jaw fingers are installed behind the absorber blocks. They admit a relative stroke between the jaws in operation of +24mm -32mm, over that:

1- The fingers can slide on the absorber blocks (graphite or Aluminum).

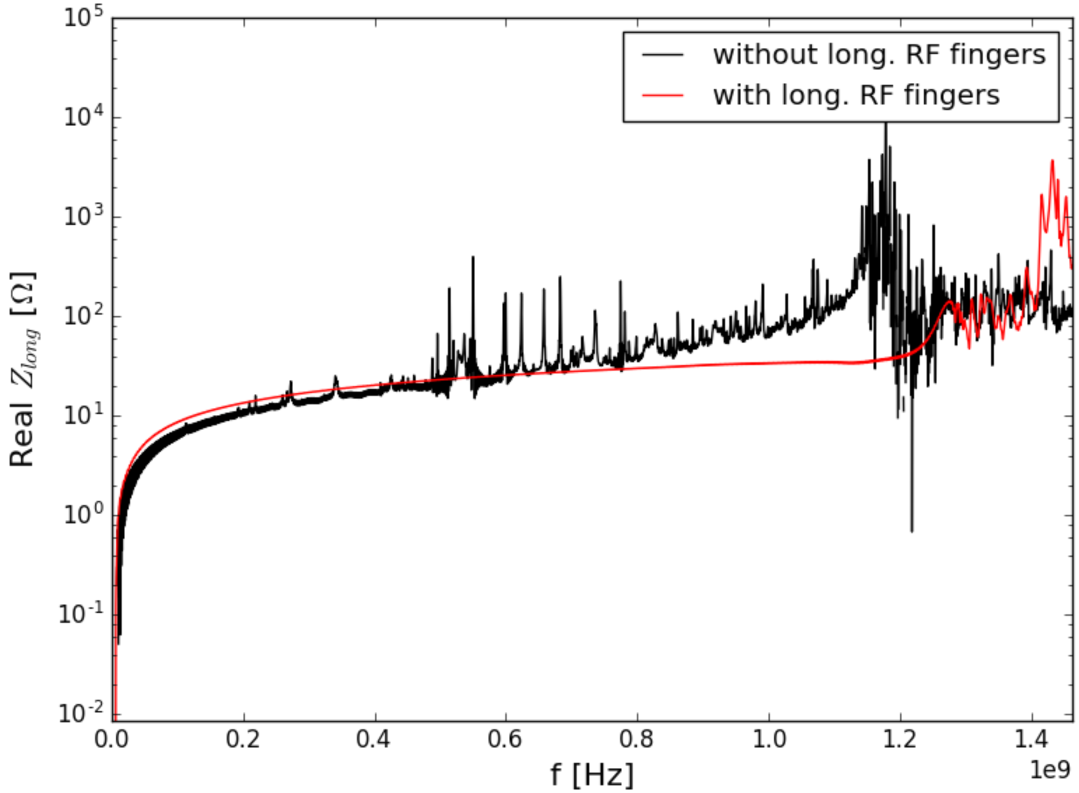
2- We lose contact between the jaws.

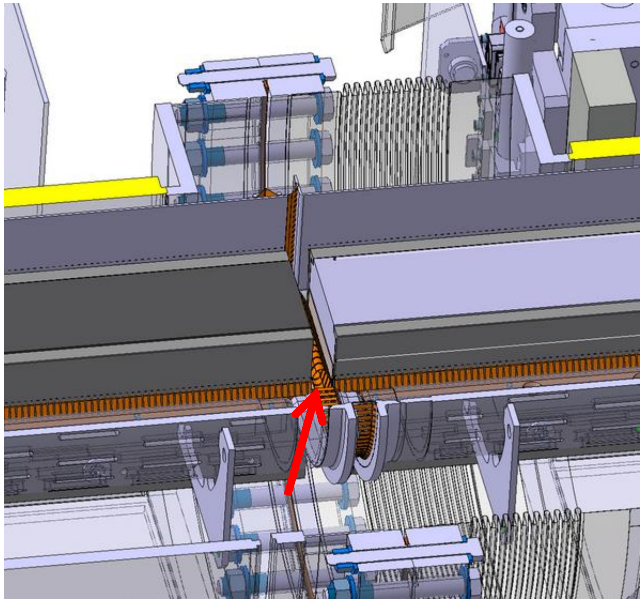
In both cases no finger damage is expected but if fingers touch graphite ➔ dust ➔ UFOs (upper jaw)!

- Additional switches ☒
- HW interlock (need full redesign of control system) ✓
- Add thin Ti sheet between fingers and graphite (being evaluated) ✓✓☒??
- Removing RF fingers between modules (at least from upper jaws) ✓✓☒??

Longitudinal RF fingers

B. Salvant

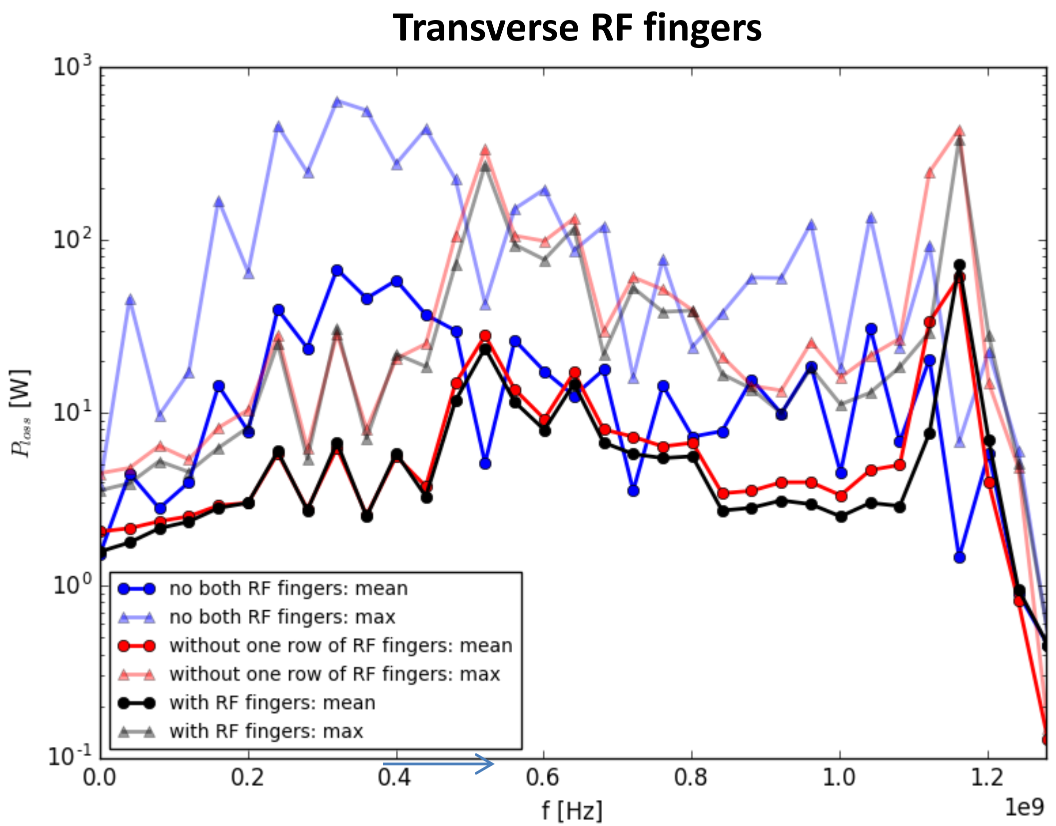




- **RF fingers location optimized** in order to **minimize the field communication with the tank volume** below the jaws (thanks Luca).
- **No visible HOMs in longitudinal impedance below 1.2 GHz** thanks to granted continuity of image current flow.
- **Need to quantify the probability of contact failure of one/some RF fingers**
- **Heat load** left is mainly due to the **resistive wall impedance of the jaw**.

Evaluation of heating from HOMs

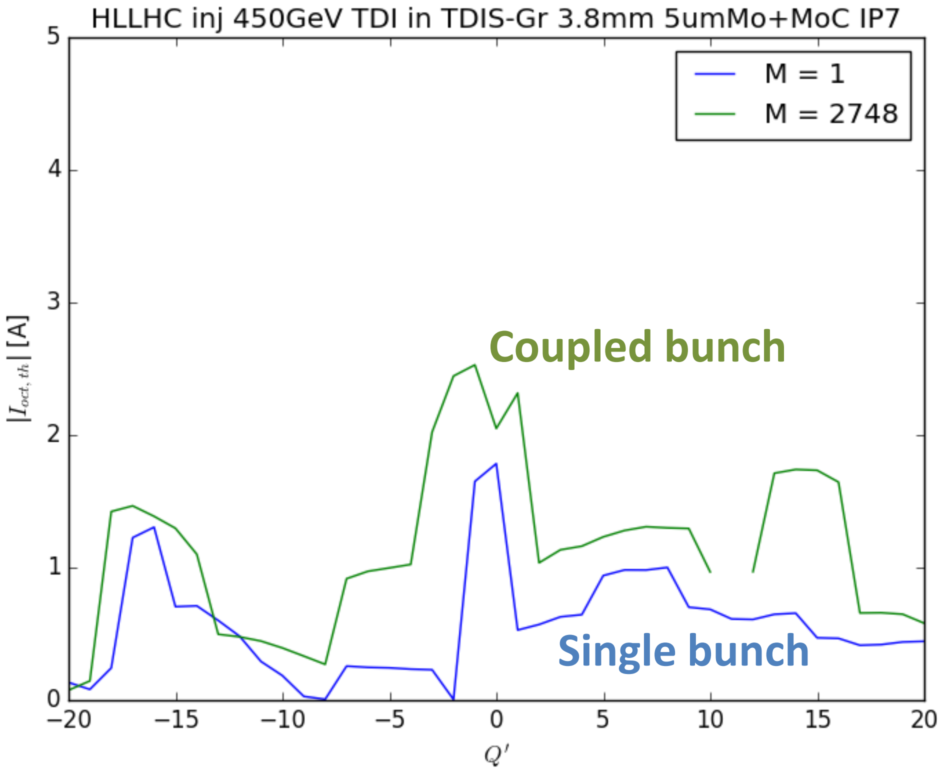
B. Salvant



- On **average** expected **< 100 W** per spectral line.
- **Max values can reach 800 W**
- **Heating** is **distributed** on different elements depending on **different field patterns**.
- **Input needed** on **max allowed power deposited per sensitive elements** in the structure.
- We can then estimate the **probability** an HOM, if present, could be **provoke deformation/damage** on these part of the TDIS.

HL-LHC octupole stability threshold at 450 GeV

B. Salvant & N. Biancacci



Parameters:

- 50 turns damper
- 8.1 cm bunch length
- Gaussian transverse profile
- within
- Injection optics
- HLLHC impedance model with coated IP7 collimators
- TDIS **half gap** of **3.8 mm**
- TDIS jaw in **graphite**

- Assumed **Graphite jaw** and **transverse HOMs as-they-are: statistical simulations to be done to exploit the full impact of HOMs!**
- **10% increase in coupled bunch instability** threshold at injection **due to the HOMs**.
- **Margins for impedance but without ecloud!**
- If **Cu jaws, single bunch threshold 10% lower**, CB may be **unchanged** as it is driven by HOMs.
- **No issues** expected at **flat top** (<0.1% w.r.t. total impedance)

Our Questions

Calculations on TDIS design before internal review define in the worst case a maximum power loss of 800 W (HOM in case of no long. RF fingers) + 676 W (no Cu coating) + 250 W (e-cloud):

- Which range of frequencies do we have to consider?
- Uniform heating?
- Local heating and/or outgassing?
- Other effects like beam instabilities?
- Possible to compensate (improved cooling, pumping, octupoles, transverse damper, etc)?
- For HOM, systematic or sporadic effects?
- Possible to define “absolute” thresholds and safety margins for different aspects?

Wish List for Impedance Calculations and Measurements

- Identification of HOM and sites of power deposition for worst case scenario (reviewers' recommendation) (end 2017)
- Impedance related aspects for (end 2017):
  - New design with RF fingers and Cu coating both jaws (ongoing studies, results will be presented at the next WP14 meeting on August 29th)
  - New design without longitudinal RF fingers and without Cu coating upper jaw only
  - New design without longitudinal RF fingers and without Cu coating both jaws
- Transverse and longitudinal beam coupling impedance measurements with stretched wire test setup on prototype (reviewers' recommendation) (end 2018)
- Possible beam interference on temperature sensors in stretched wire test setup (reviewers' recommendation) (end 2018)

Conclusion

- The mechanical design of the TDIS was modified as a consequence of the identification of weak points after the internal review held in December 2016 ➔ impact on impedance calculations
- Pending issue: eliminate any risk of UFOs production due to melted Cu coating and friction between RF fingers and graphite (other materials?) ➔ several options under investigation between those the removal of the fingers from (at least) the upper jaw
- The design for prototype to be frozen by end 2017 (including impedance studies)
- Tests on prototype (HiRadMat and impedance measurements with stretch wires) within end 2018 ➔ final design before LS2!