LHC & HL-LHC impedance models

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Acknowledgements: R. Bruce, F. Carra, R. de Maria, N. Kos, A. Mereghetti.

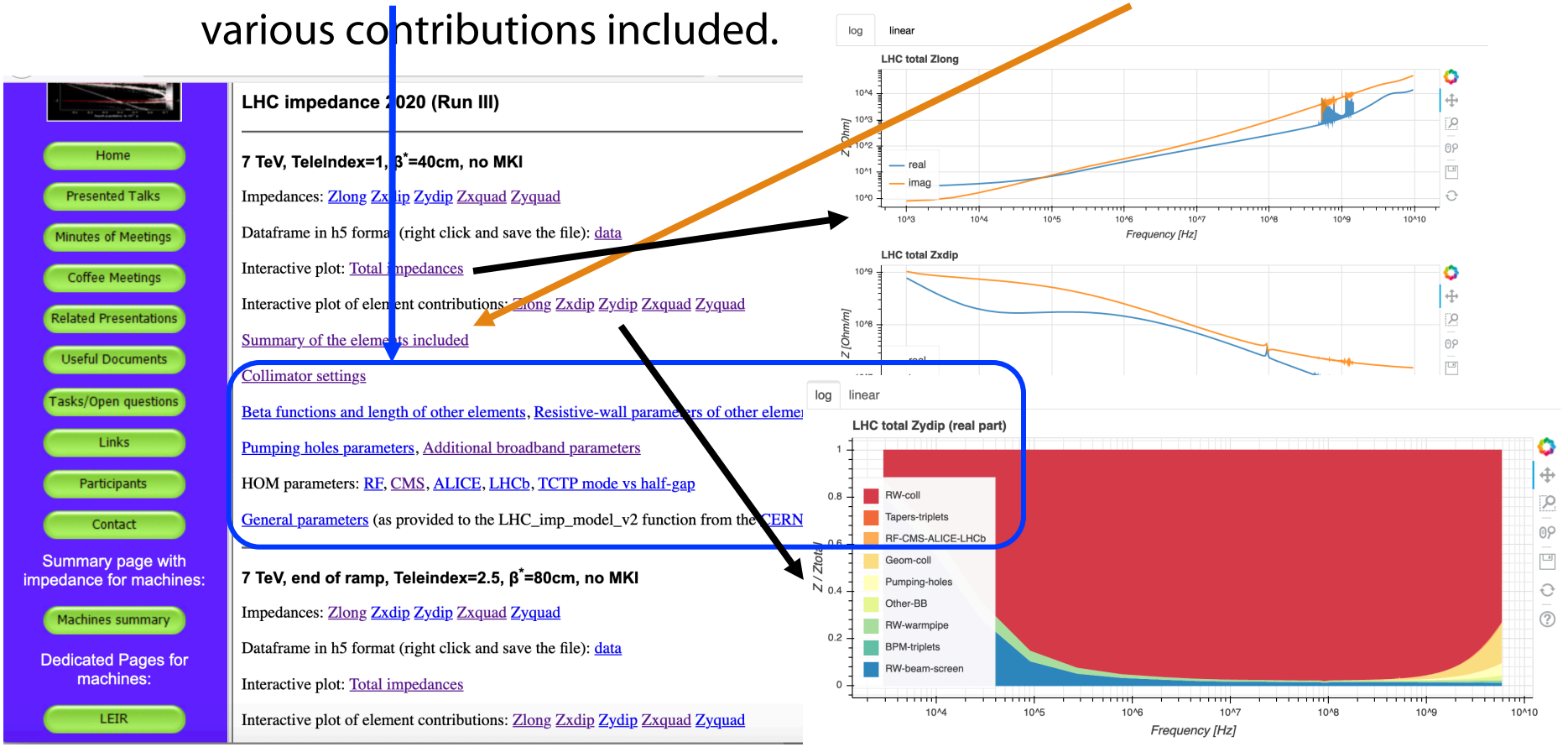
LHC impedance model – Run III

- The main LS2 planned modifications that can affect impedance at top energy, are in the model:
  - ✓ Low-impedance collimator upgrade (jaws of 2 TCPs and 4 TCSs in IR7 replaced by Mo-graphite ones, Mo-coated for the TCSs),
  - ✓ Addition of TCLD absorber (tungsten) in IR7,
  - ✓ Beta functions in the arcs and triplets,
  - ✓ Partial update of TDI (no more coating for first block).
- Planned modifications that are not yet in the model (thanks to **B. Salvant**): :
  - ✘ New MKI cool (now could be put in model – implemented by **D. Amorim**)
  - ✘ Updated tapers of coll. (could be put in model – implemention **S. Antipov**),
  - ✘ experimental chamber upgrades (CMS, ALICE, LHCb),
  - ✘ fully updated TDIS (geometric and resistive-wall),
  - ✘ TCLD in IR2 (will stay in parking for the proton run),
  - ✘ VELO and SMOG2 (LHCb),
  - ✘ in-situ aC-coating in Q5 and Q6 (beam screens of stand-alones),
  - ✘ new BGC (negligible) and potential new beam instrumentation.

LHC impedance model – Run III

The model is on-line, with interactive plots (thanks **N. Biancacci**!)

- Various variants (optics & collimator settings)
- All parameters and settings are provided, and an explanation of the various contributions included.



LHC Run III – Collimator settings

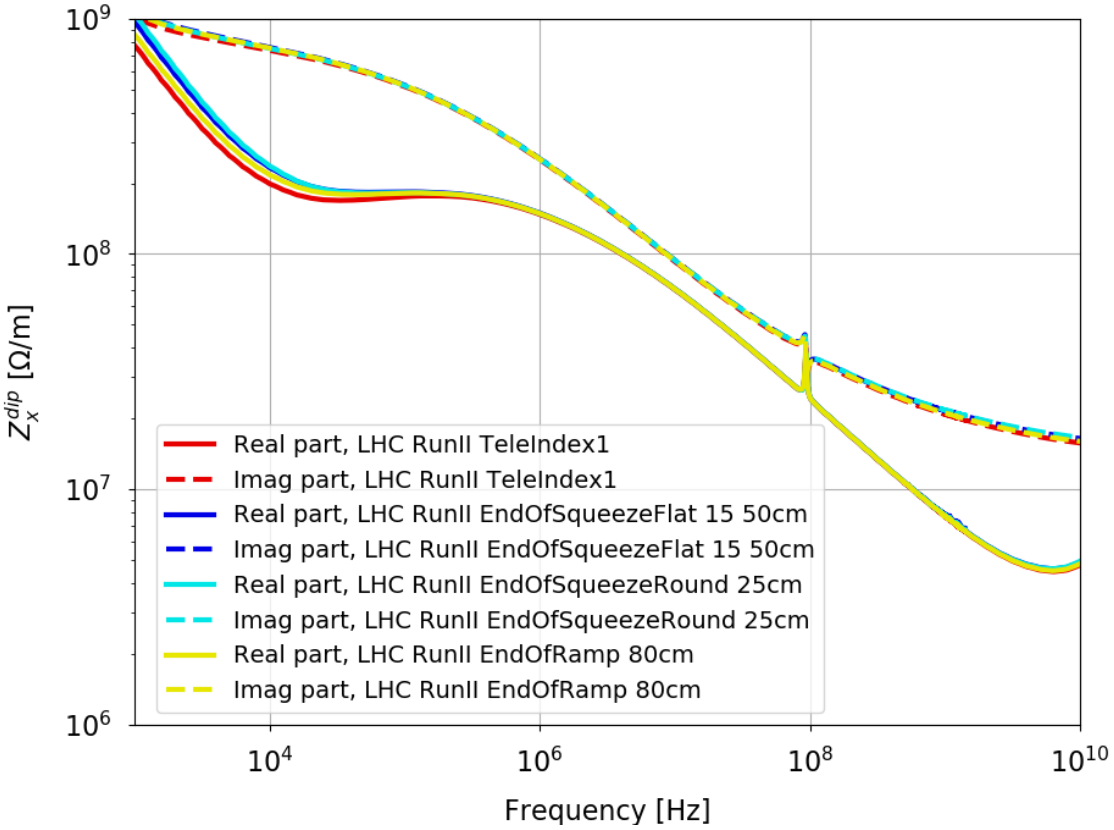
- Two scenarios for the collimator settings (expressed in "collimator" σ, i.e. computed with $\varepsilon = 3.5$ mm.mrad):

	« Relaxed » as in HL-LHC baseline	« Tight » as in LHC Run II
TCP/TCS/TCLA(D) IR7	5.7 / 7.7 / 10.7 (14)	5 / 6.5 / 10 (10)
TCP/TCS/TCLA IR3	15 / 18 / 20	15 / 18 / 20
TCDQ/TCS IR6	8.5	7.3
TCT IR1/5	8.8	7.8
TCL (IR1/5) Q4/Q5/Q6	20.5	15 / 15 / parking
TCT IR2/8	37 / 15	37 / 15

Note: IR2 injection protection collimators are always in parking position.

LHC Run III – Impact of optics

Transverse impedance is weighted by β function at the location of impedance

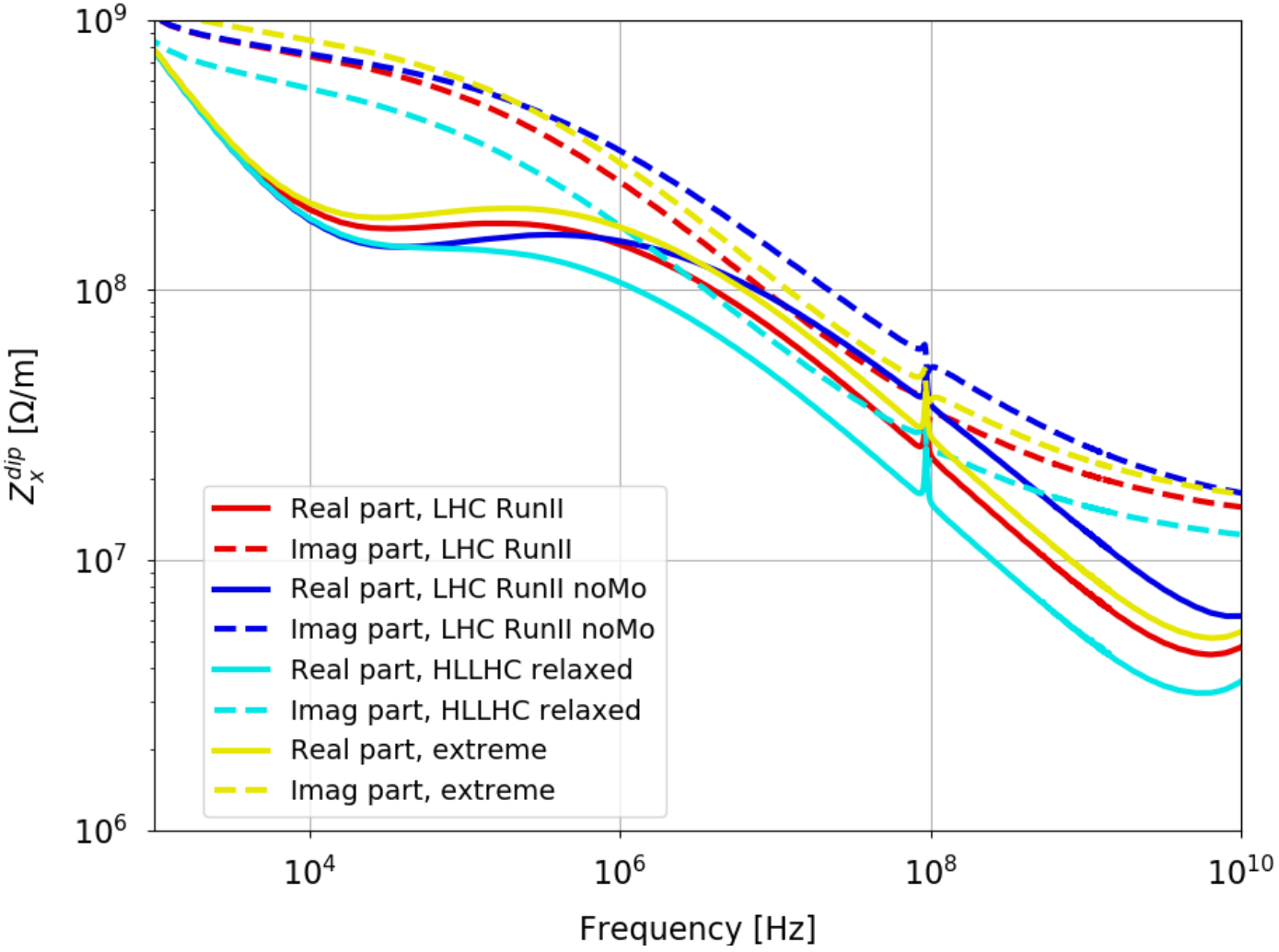


- β^* varies from 15cm to 80 cm
- Telescopic Index from 1 to 4
- x plane (similar in y)

⇒ Impact of optics on impedance only at low frequencies

LHC Run III – Impact of collimator settings

Hor. impedance for various collimator scenario (some very hypothetical):

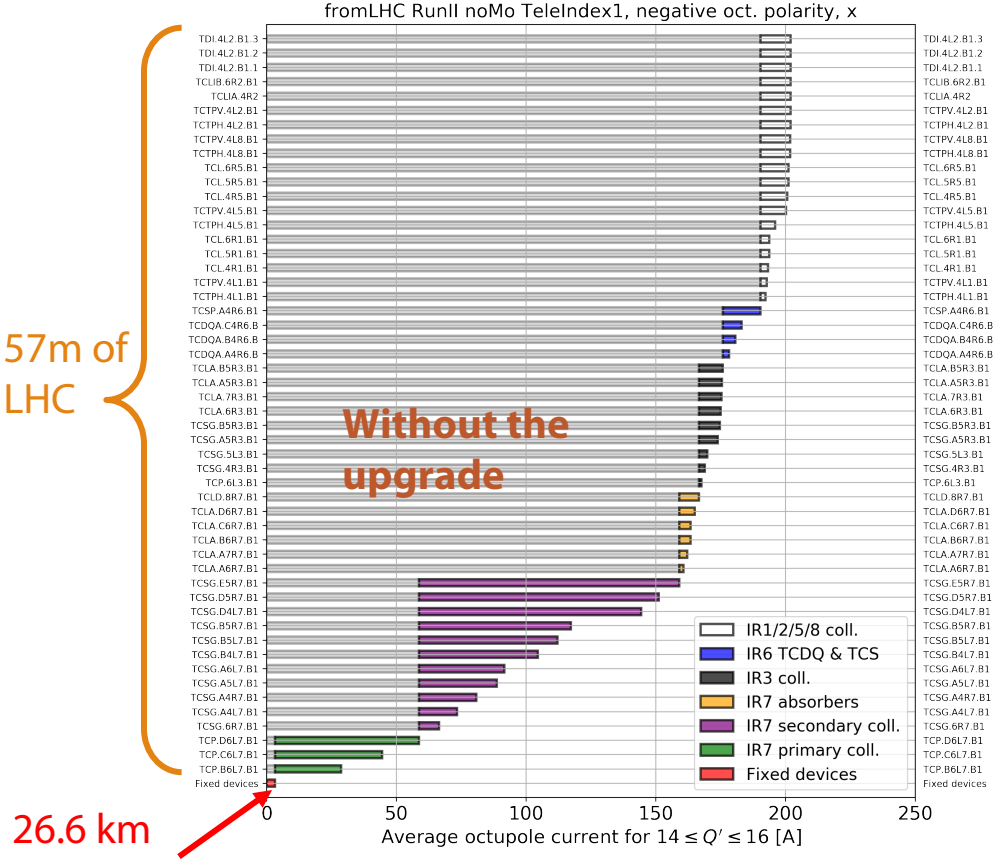


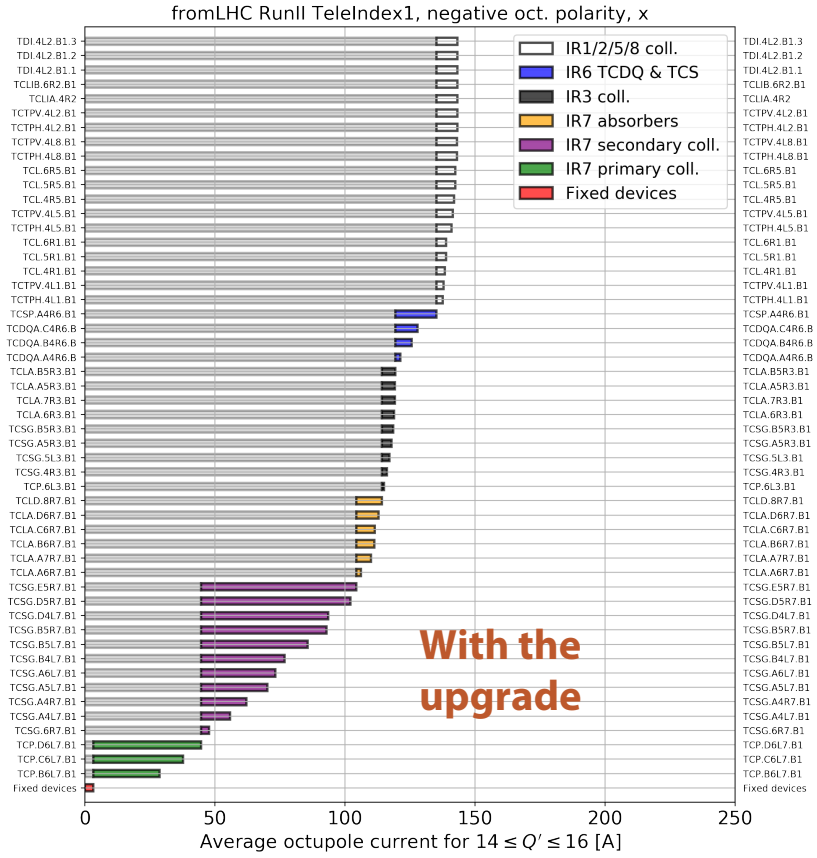
We gain a lot thanks to the collimator upgrade

LHC RunII settings are clearly more critical than the HL-LHC relaxed ones

LHC Run III – Contributions to the impedance

Adding incrementally each of the devices present in the impedance model, beginning with unmovable ones (beam screens, pipe, pumping holes, cavities, etc.), one can get an idea of the contribution of each element to the total octupole threshold:





⇒ Clear impact of the upgrade in IR7

HL-LHC impedance model

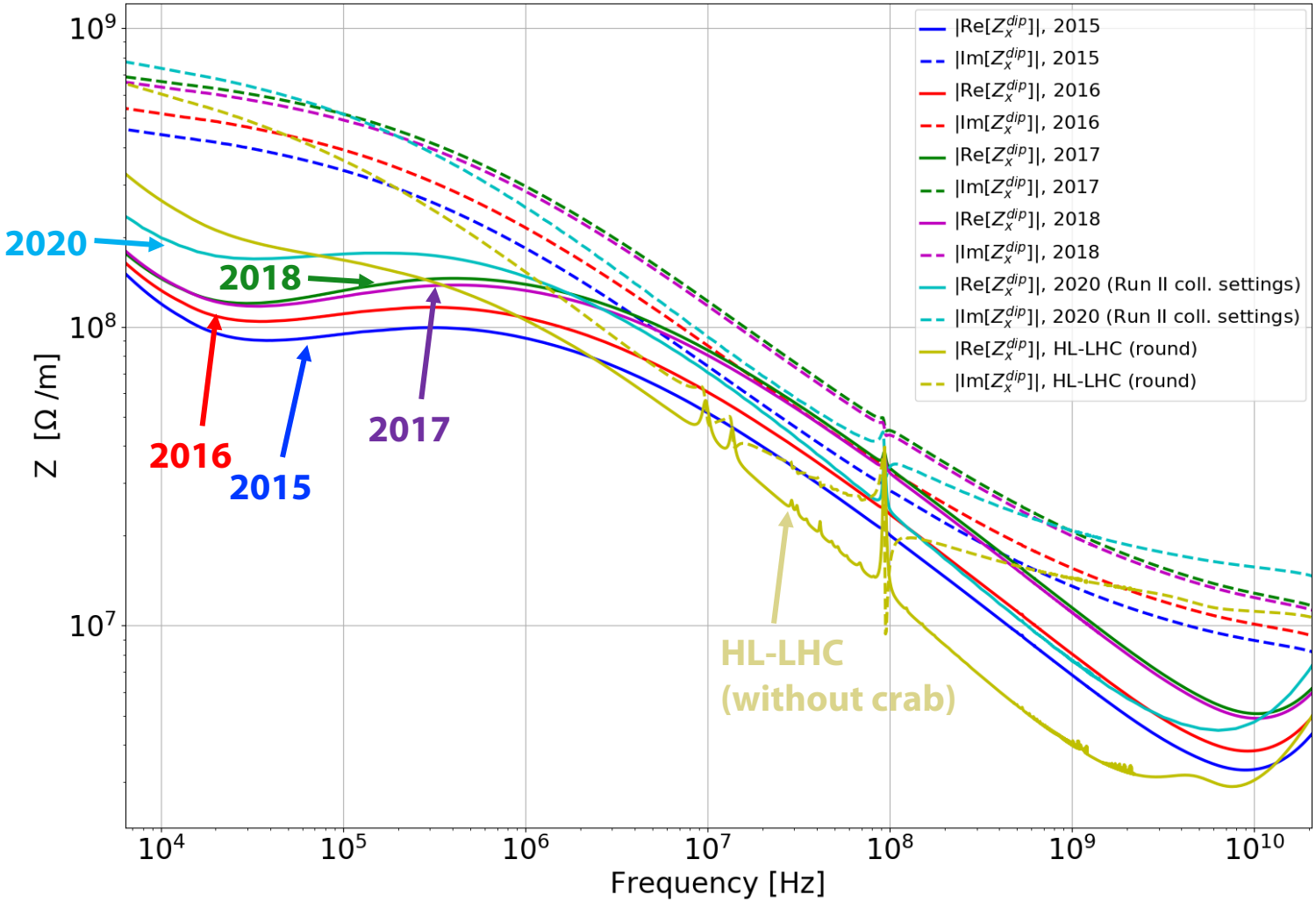
- Changes w.r.t. the LHC **model** (Run III), that are **included** in the HL model:
  - ✓ Collimator ~full upgrade (jaws of 2 TCPs and all but 2 TCSs in IR7 replaced by Mo-graphite ones, Mo-coated for the TCSs); some TCTs in Cu-coated copper-diamond,
  - ✓ Updated collimator tapers (implemented by **S. Antipov**),
  - ✓ Beta functions in the arcs and triplets (optics v1.4),
  - ✓ TDIS (with graphite, Ti_6Al_4V and CuCr1Zr),
  - ✓ New MKI-cool – 4 of them (implemented by **D. Amorim**),
  - ✓ New octogonal beam screens in triplets, with up-to-date dimensions, aC-coating, 75K copper, pumping holes and welds (rough estimate for the welds),
  - ✓ Updated experimental chambers (ATLAS & CMS),
  - ✓ Tapers and BPMs in the triplets region,
  - ✓ Crab cavities (although not yet included on the web impedances).

HL-LHC impedance model

- Modifications that are not yet in the model:
  - ✘ Y-chamber (negligible) and VELO,
  - ✘ experimental chambers ALICE and LHCb, possibly also CMS,
  - ✘ updated longitudinal weld factor computation in the triplets beam screens,
  - ✘ deformable RF-fingers (ongoing work),
  - ✘ new instrumentation,
  - ✘ possible aC-coating in some sectors,
  - ✘ possible collimators in IR1 & 5, and updated design of all tertiaries and TCLs,
  - ✘ crab cavities HOMs as measured in real cavities,
  - ✘ electron lens and crystal collimators (recently added to baseline),
  - ✘ new roman pots,
  - ✘ "SMOG3" in LHCb.

HL-LHC & LHC impedance models: a retrospective

- Putting on the same plot all impedances currently on the web, for LHC & HL-LHC:



Dipolar horizontal

HL-LHC & LHC model: remaining issues

- Some remaining general issues have to be clarified for both models:
  - ✓ Collimator geometric design: now tapers are well taken into account, but an HOM is "blindly" applied to all TCTs and TCSP in IR6.
    ⟶ What about all possible geometries: TCTX, TCL, etc.?
  - ✓ Cut-off frequency for broadband resonator impedance: now set to 50 GHz.
    ⟶ put back a more physical value (5 GHz)? Or change the broadband model?
  - ✓ Some inconsistencies between impedance and wake (geometry of collimators, pumping holes longitudinal impedance, weld factor).

- On the technical side: re-implement fully the models using the impedance toolbox, following-up on the work of **D. Amorim**
  ⟶ technical student coming for a year in June.

Backup slides

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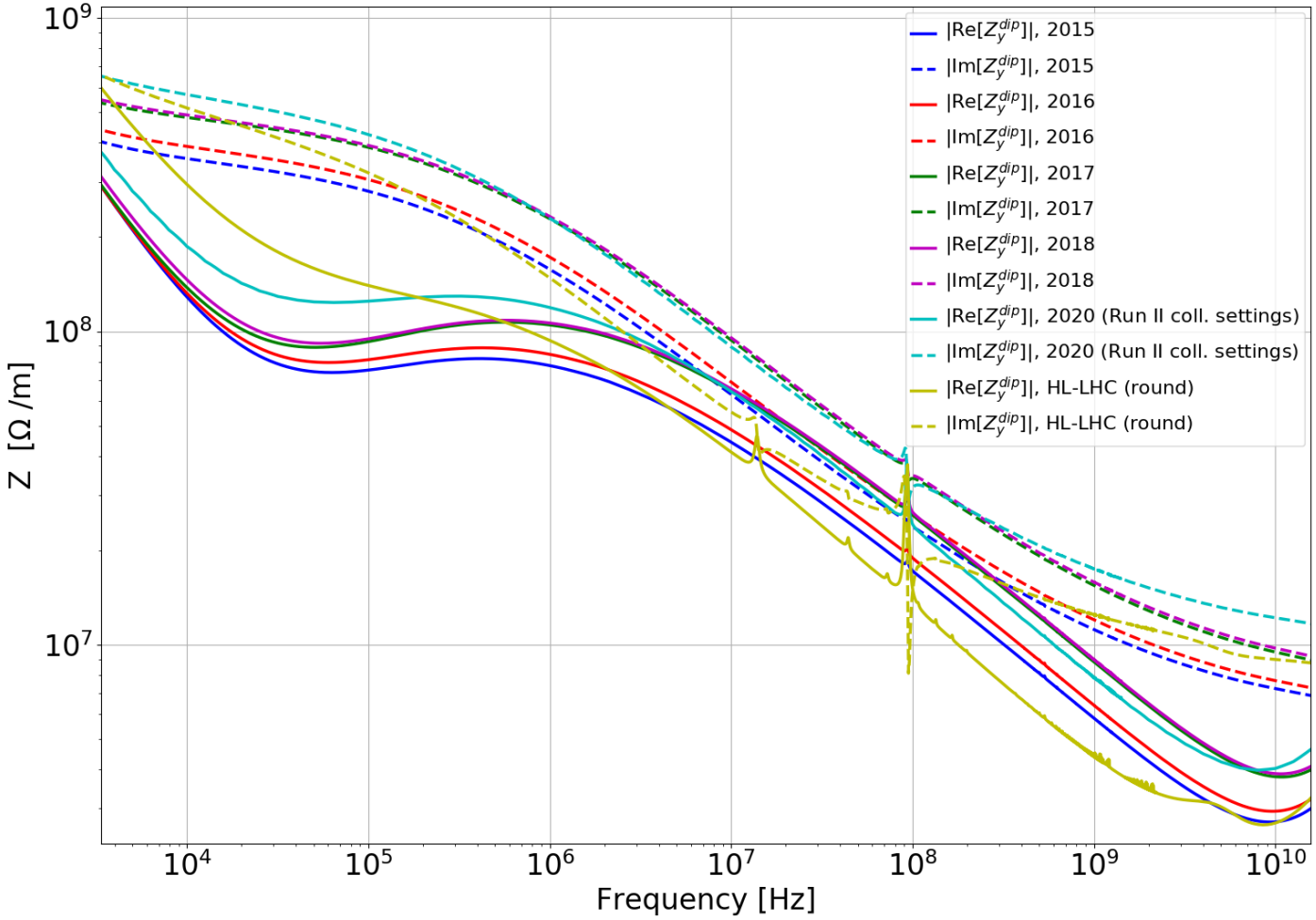

Dipolar vertical

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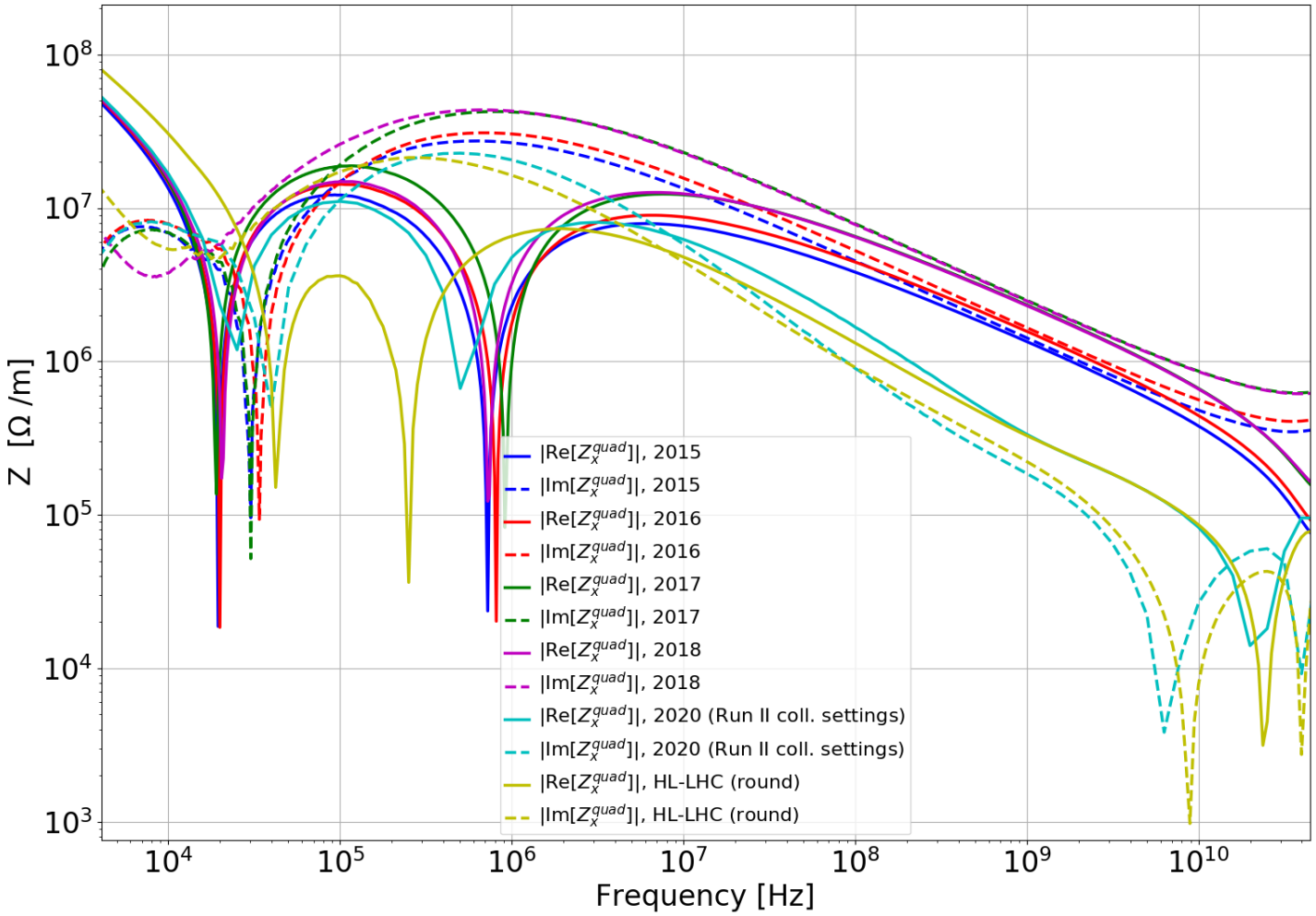

Quadrupolar horizontal

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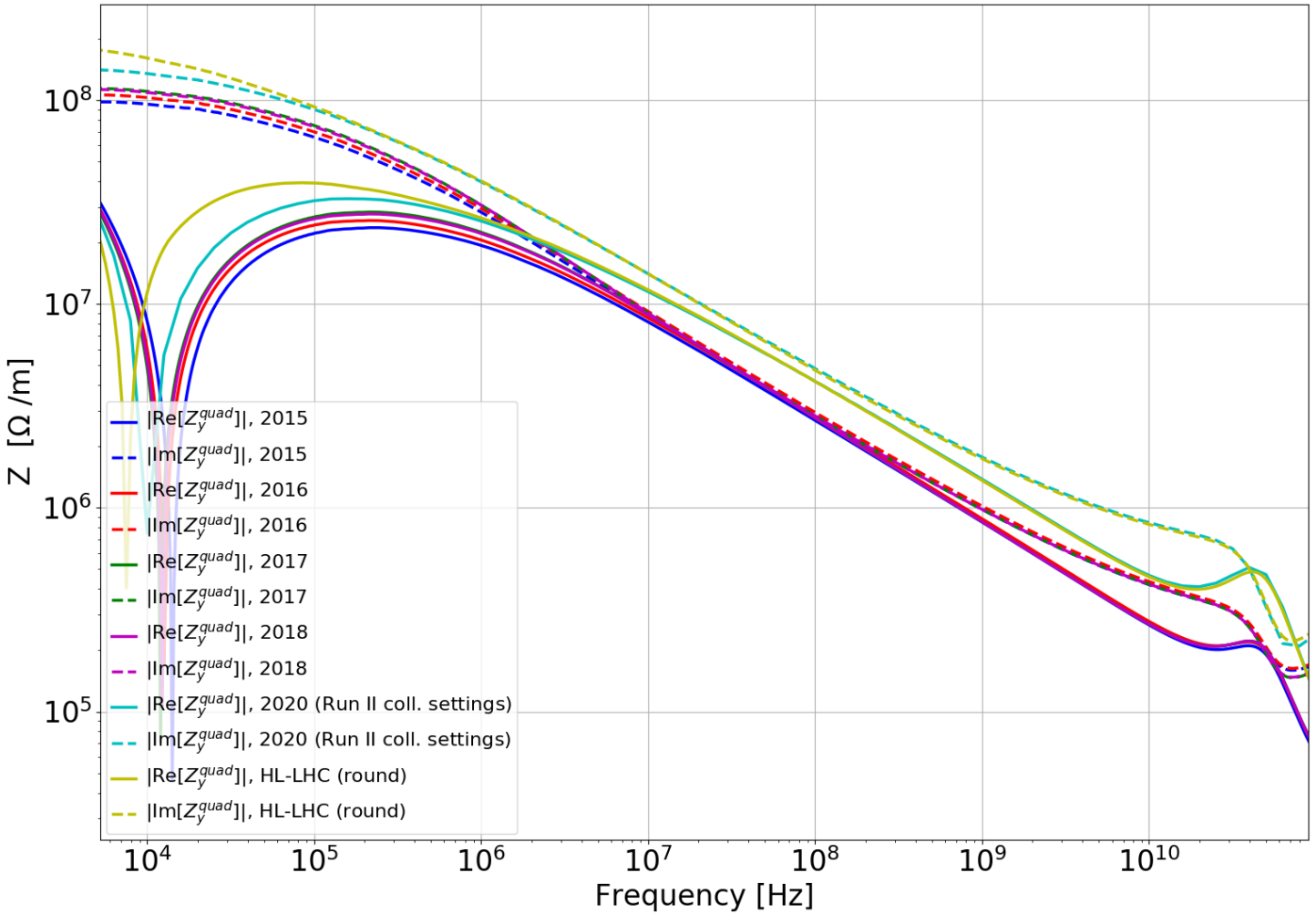

Quadrupolar vertical

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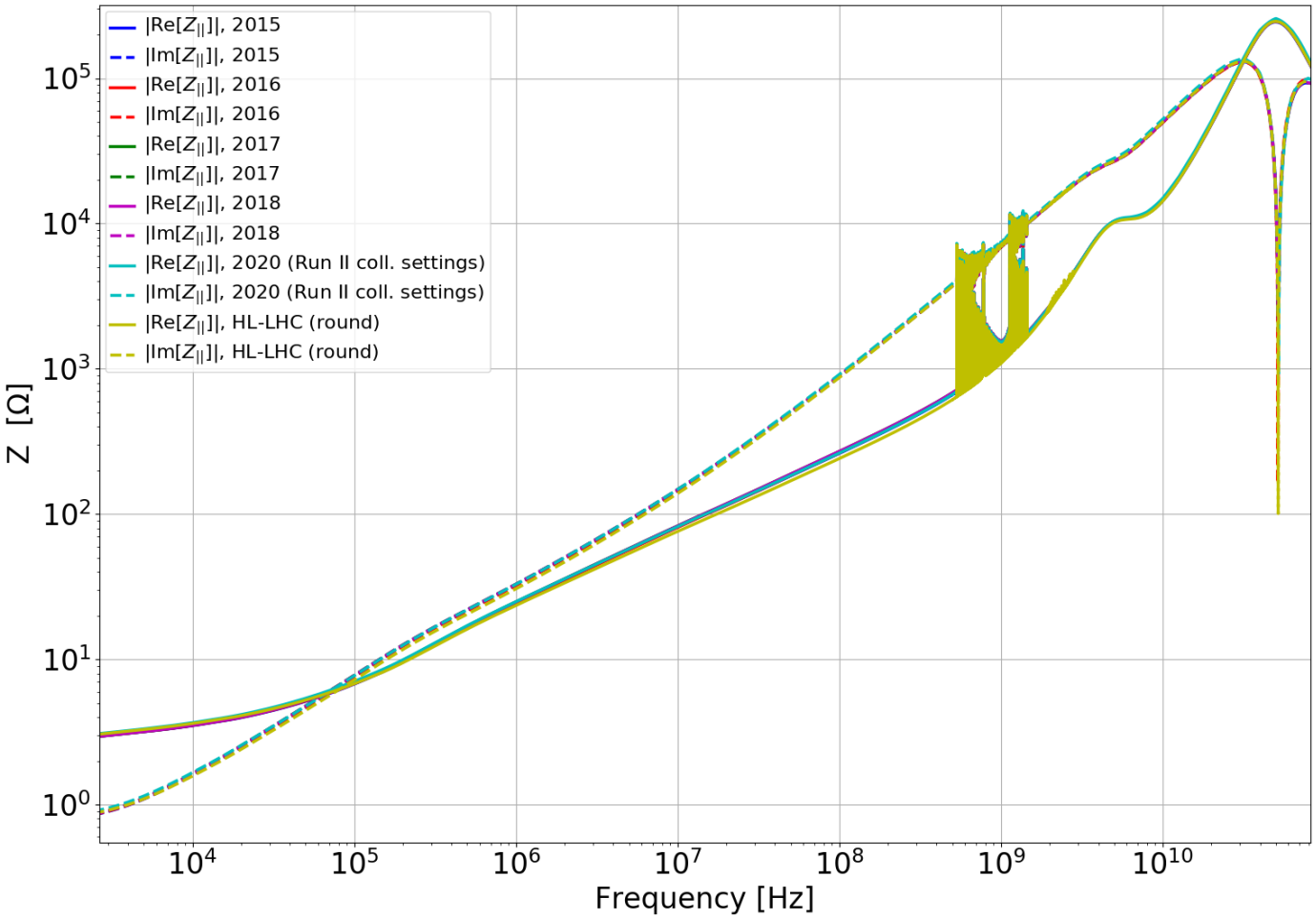

Longitudinal