Update on the difference between old and new HL-LHC impedance model

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Acknowledgements: R. Bruce, A. Mereghetti, J. Mitchell.

A few more updates to the model

- The factors due to the shape and weld of the octagonal triplet beam screens were computed accurately (using CST) by **C. Zannini**
  → replace the previous (pessimistic) rough estimates that were used, giving lower factors than these:

Factor	BS88 new (*old*)	BS101 new (*old*)	BS121 new (*old*)
Long. factor	1.5942 (*1.74*)	1.36 (*1.68*)	1.0738 (*1.68*)
Dip. factor x	0.72855 (*1.0*)	0.89452 (*1.0*)	0.8587 (*1.0*)
Dip. factor y	1.6422 (*2.31*)	1.6231 (*2.15*)	1.3022 (*2.15*)

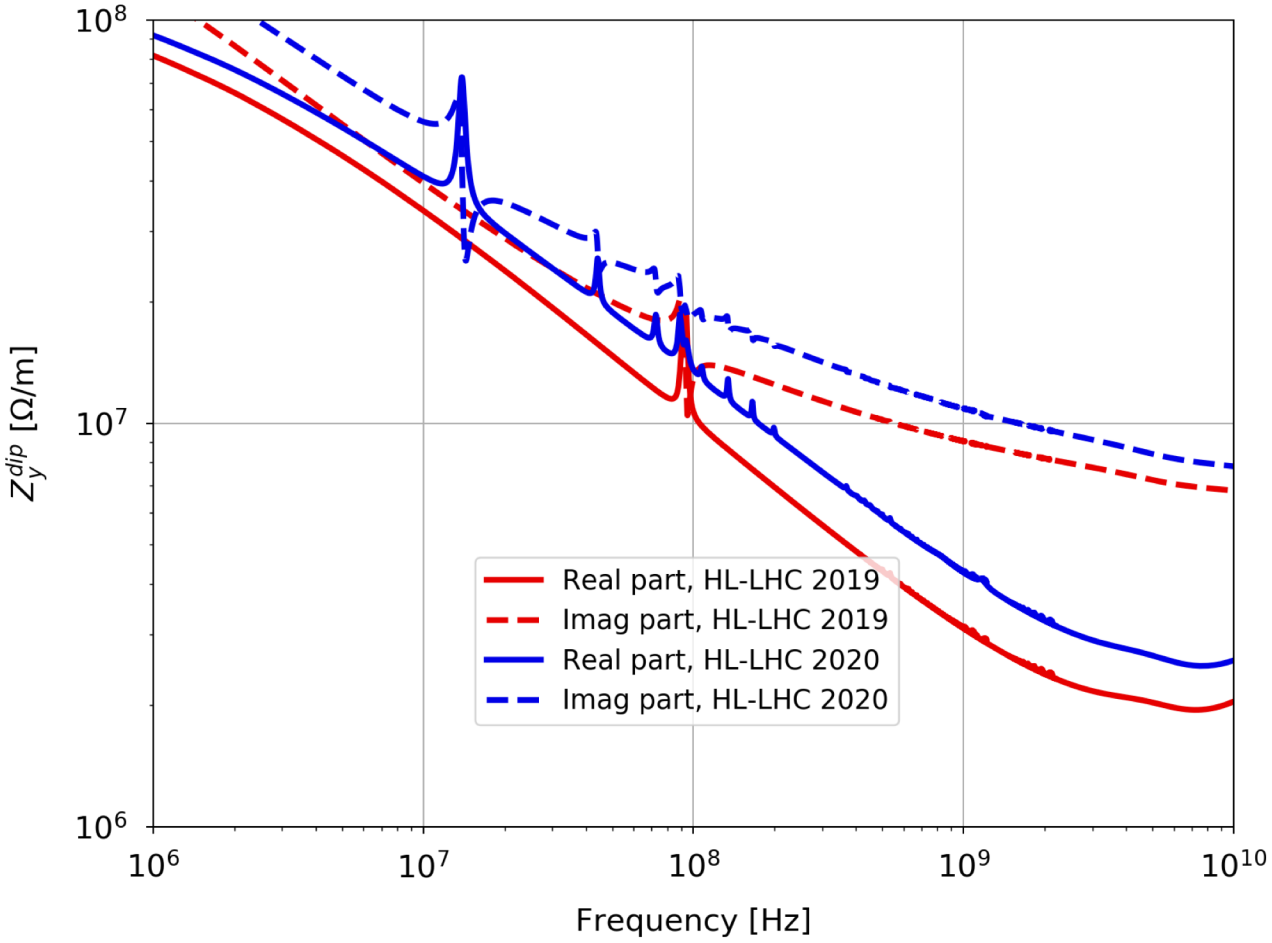
Courtesy C. Zannini

  → this has an impact only at low frequencies, so the effect of the change is negligible for any operational configuration with transverse damper.

- Model updated for β^*=40cm
  → settings in #σ depend on β^* in the TCTs and TCLs of IR1/5 and this has some impact (see next slides).
- List of devices included in model summarized in appendix.

The question

- **Why is the impedance significantly higher with the new HL-LHC impedance model**, compared to the previous one computed by S. Antipov in 2019?



No crab cavities here (would add high order peaks).

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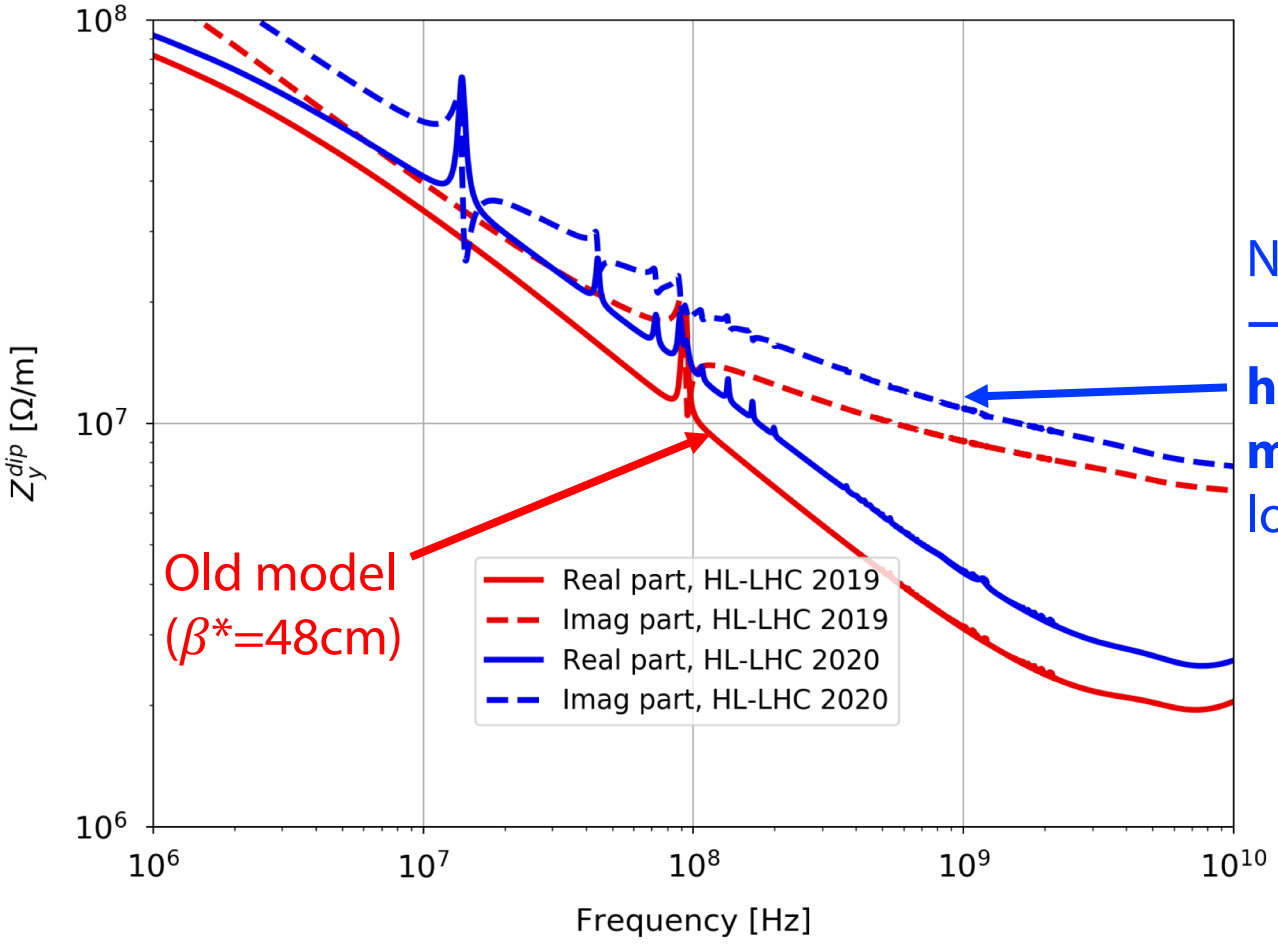

New model (β*=40cm) ⟶ **20% to 40% higher than old model in y** (increase is lower in x).

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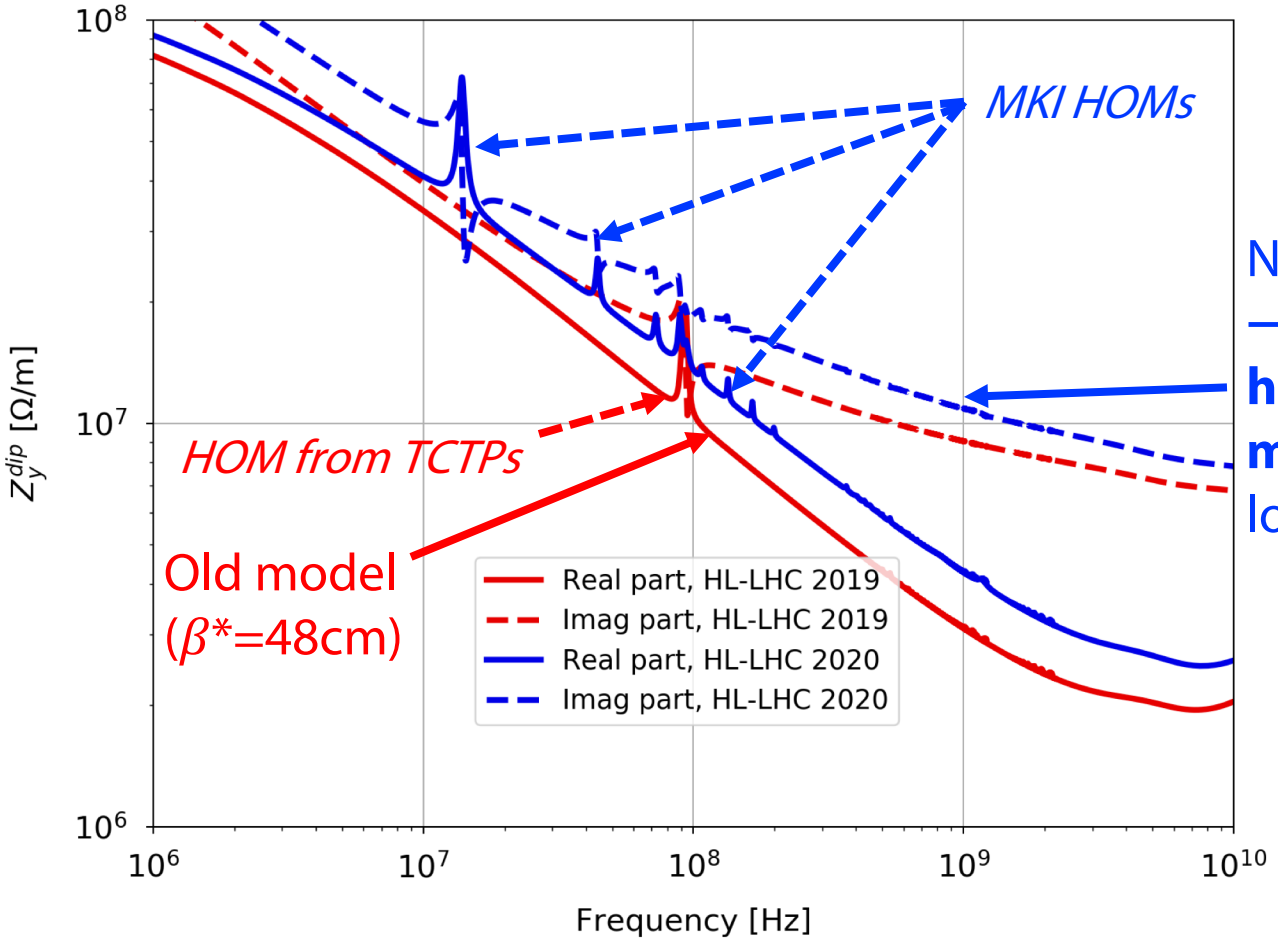

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The importance of TCTs & TCLs

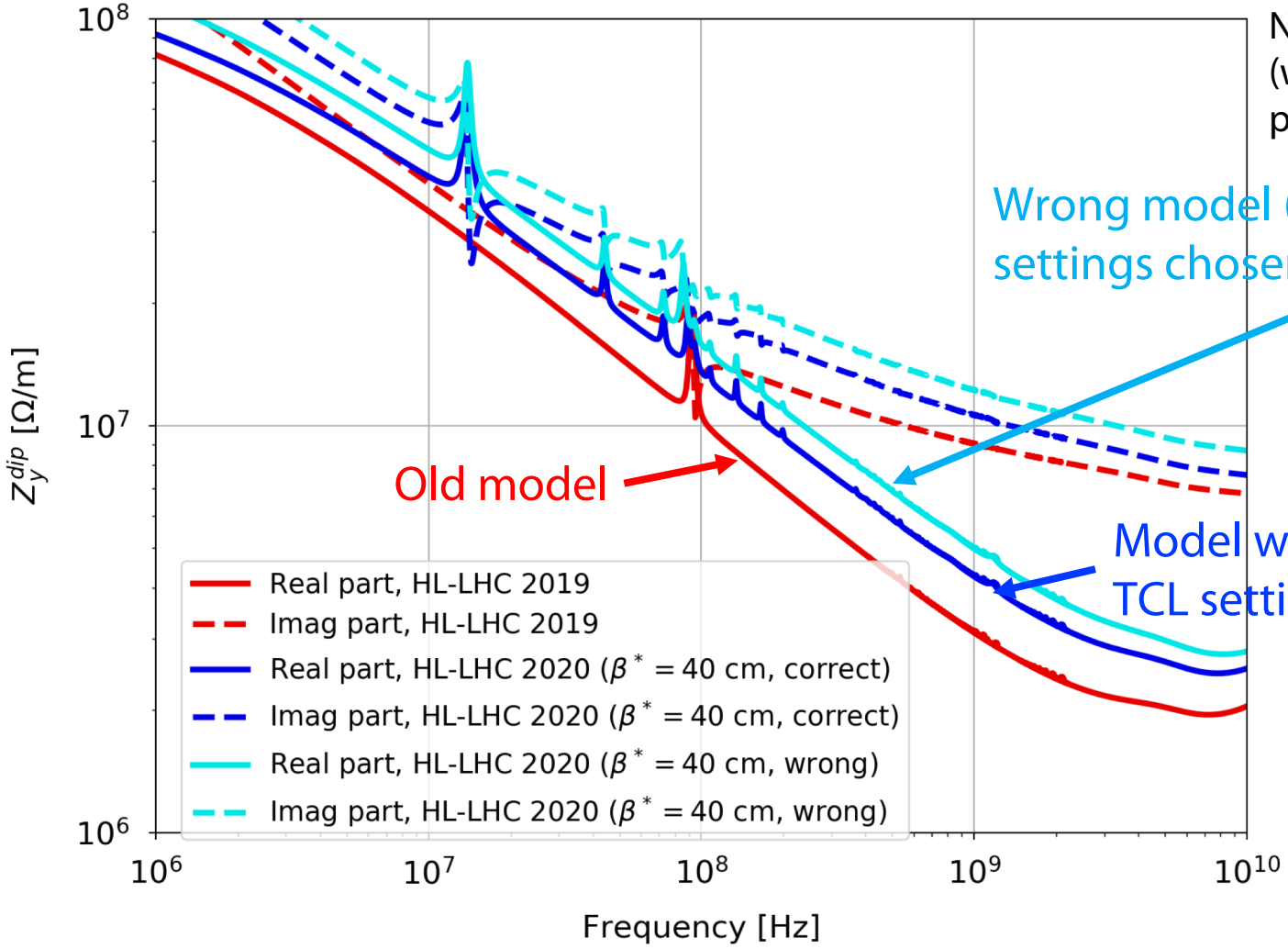
- Collimator settings (σ computed with $\varepsilon = 2.5$ μm.rad) at top energy – for two different β^*

Collimators	Half-gap [#σ] β^*=15cm	Half-gap [#σ] β^*=40cm
TCP/TCS/TCLA(D) IR7	6.7 / 9.1 / 12.7 (16.6)	6.7 / 9.1 / 12.7 (16.6)
TCP/TCS/TCLA IR3	17.7 / 21.3 / 23.7	17.7 / 21.3 / 23.7
TCDQ/TCS IR6	10.1	10.1
TCT IR1/5	10.4	16.4
TCL (IR1/5) Q4/Q5/Q6	14.2	22.4
TCT IR2/8	43.8 / 17.7	35.5 / 17.7

Note: injection protection collimators are always in parking position at top energy.

The importance of TCTs & TCLs

- **Impact of TCT & TCL settings on impedance:**



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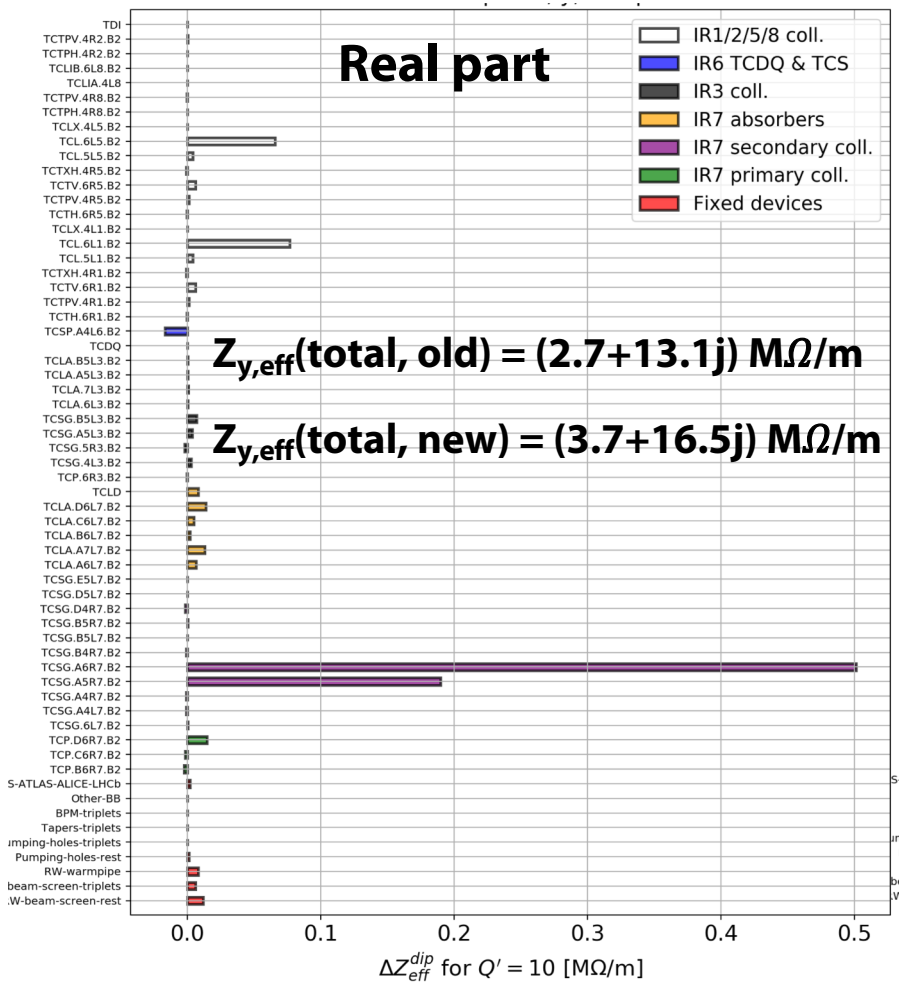
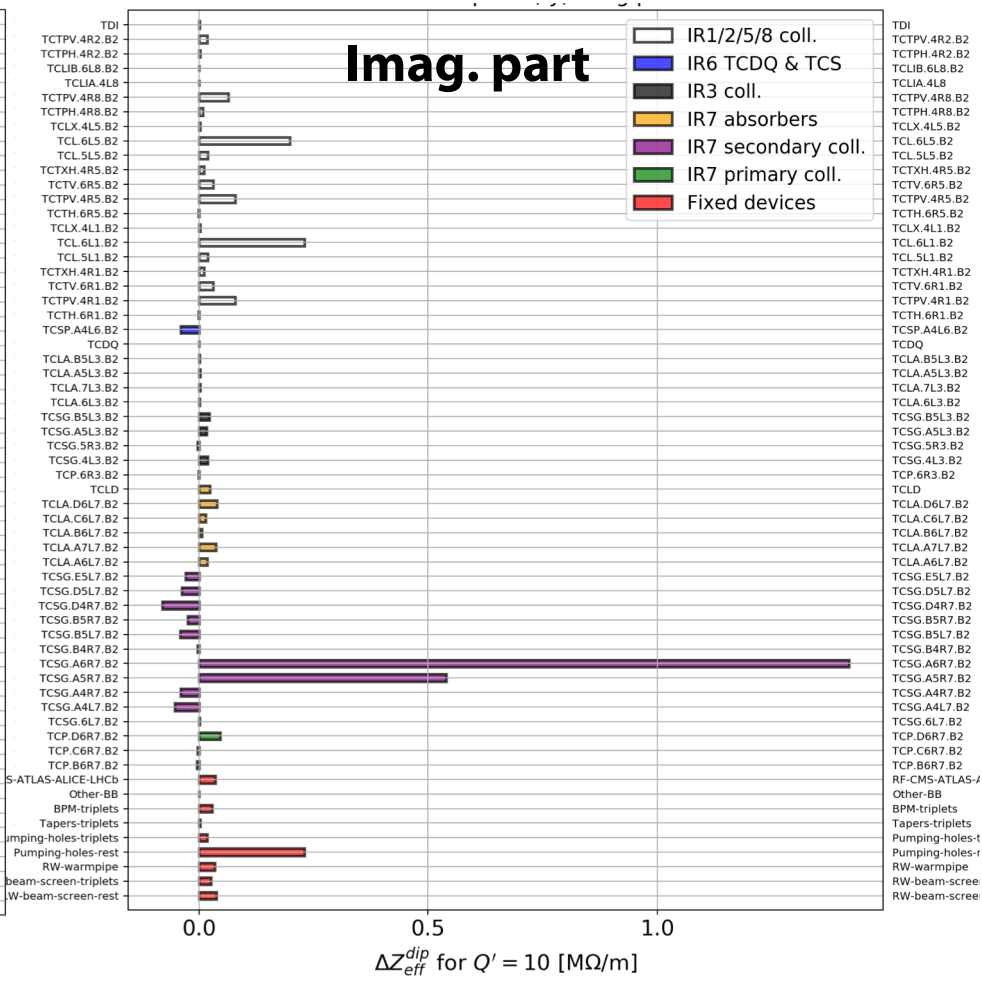
Impedance contributions between old and new models

- Difference in effective impedance (**vertical**, Q'=10) in single bunch, between old (β*=48cm) and new (β*=40cm, no crab) model:





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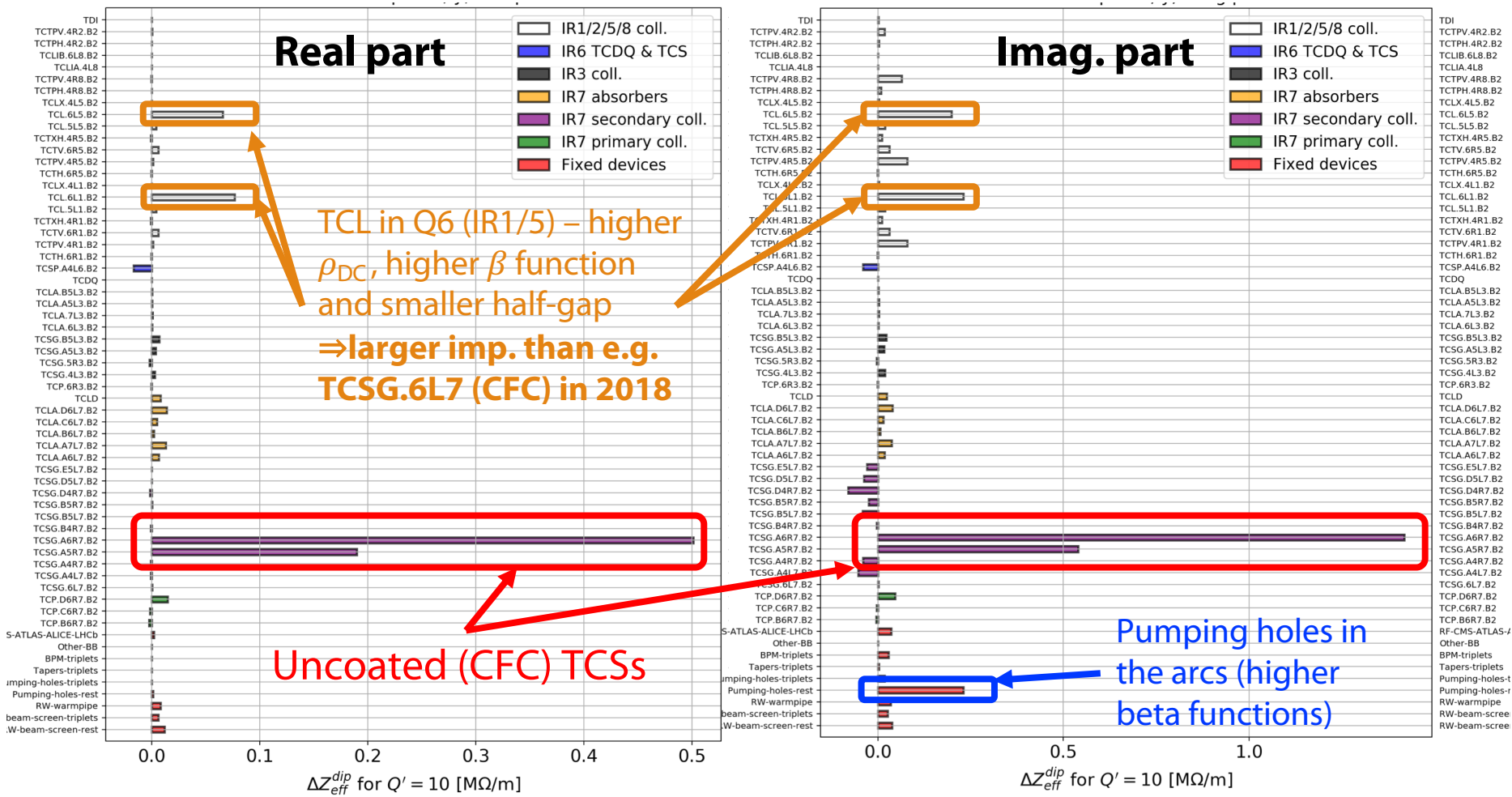
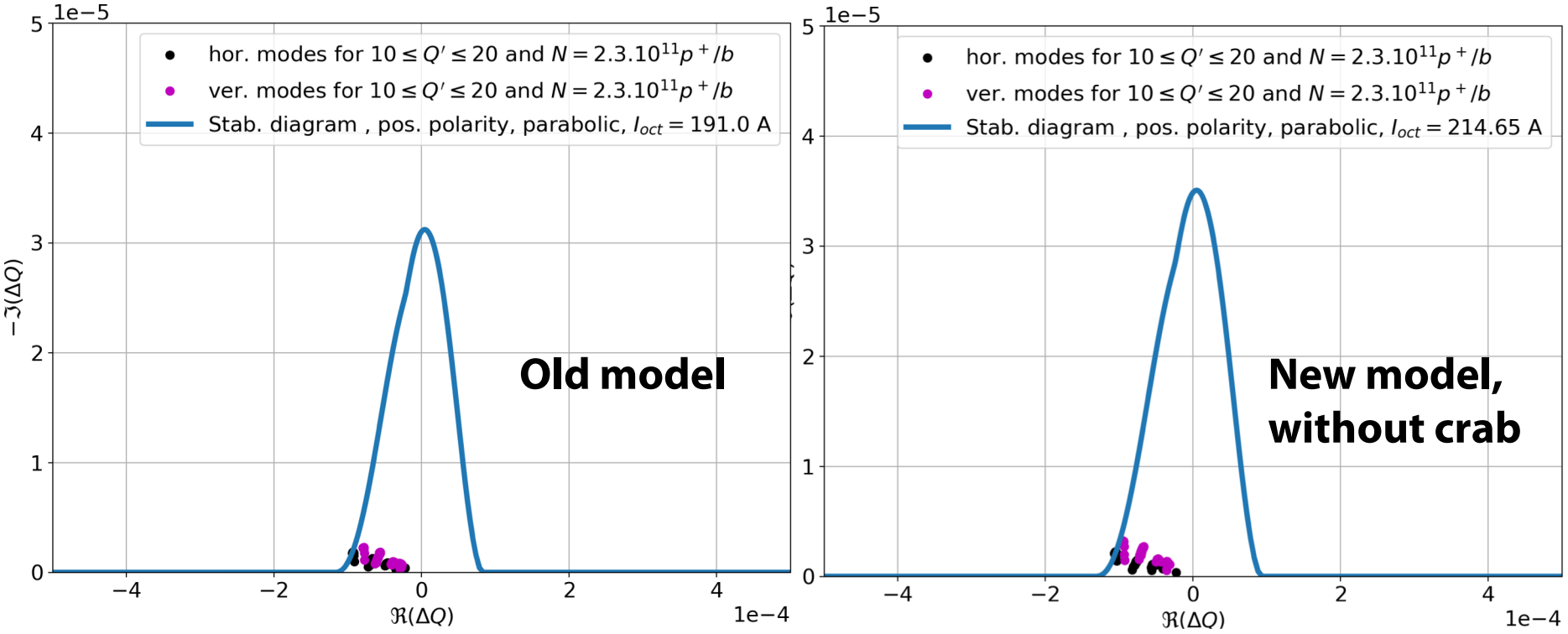


Overall impact of new model on stability

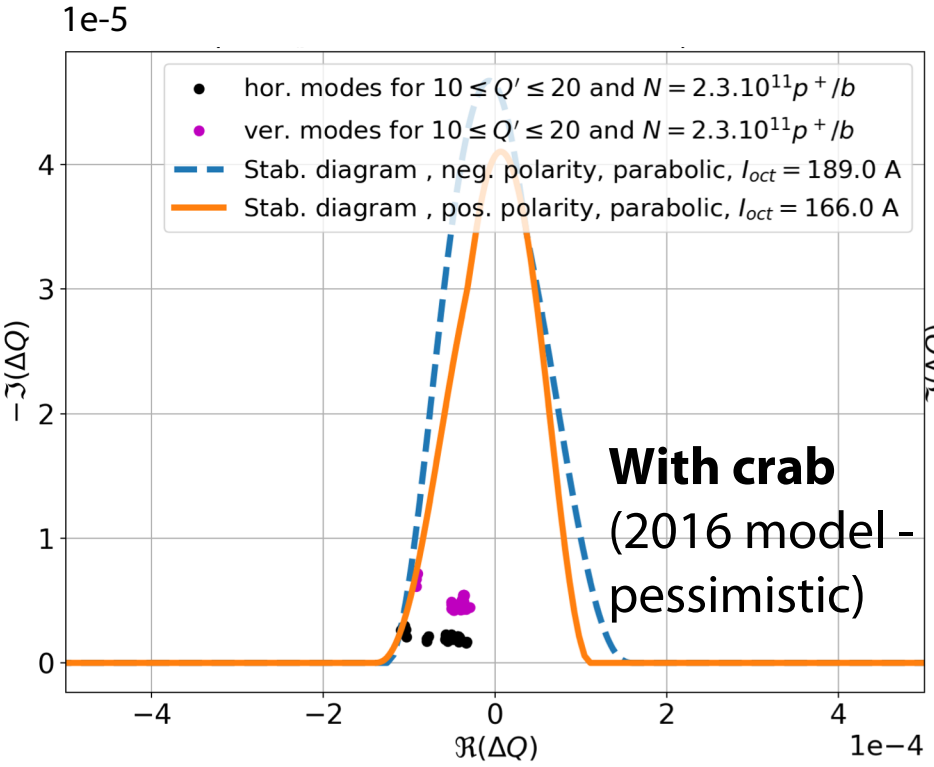
- Modes inside the stability diagram (N_b=2.3e11 p+/b, 25ns beam, ε=2.1μm, 4σ_{RMS}=1.2ns, 100 turns damper, taking all modes for 10<Q'<20, **no factor 2**), using the same optics (β*=48cm, no ATS) to get the octupolar tune spread:

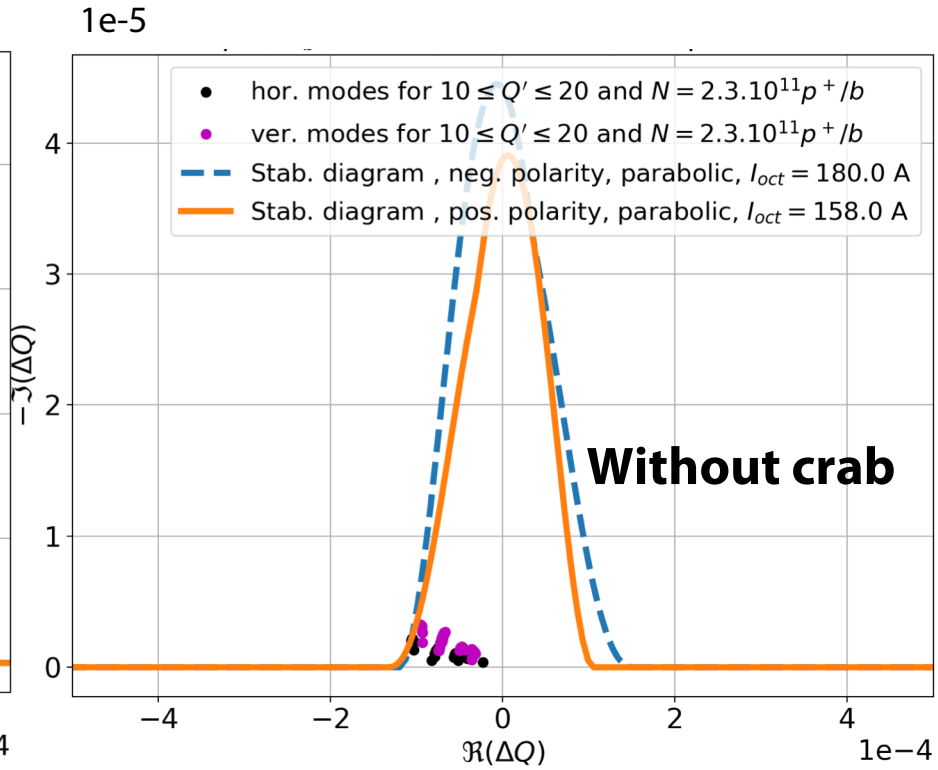


⇒ The impact on stability is ~13% -- the increase of tune shifts for the most critical plane (horizontal) is lower than for the other one.

Impact of the crab cavities

- Modes inside the stability diagram (N_b=2.3e11 p+/b, 25ns beam, ε=2.1μm, 4σ_{RMS}=1.2ns, 100 turns damper, taking all modes for 10<Q'<20, **no factor 2**):





⇒ Despite a quite significant effect on imaginary tune shifts, the impact of crab cavities on stability is small (<10A, i.e. 5%) – note that here, **teleindex~2** as the v1.4 optics with β*=40cm are used.

Conclusions

- Most significant changes of the impedance model w.r.t. the 2019 one:
  - the 2 uncoated secondary collimators,
  - to a lesser extent, the TCLs in Q6 IR1/5 (more resistive, closer, higher beta functions, than in old model),
  - to a lesser extent, the pumping holes in the arcs (higher beta functions in the arcs with 40cm optics).

  ⇒ impact on impedance from +20% to +40%,

  ⇒ overall impact on stability threshold +13% (adding +5% more with crab cavities).

- Crab cavities have a significant effect on imaginary tune shifts but overall a small impact on stability thresholds (conform to specifications).

Appendix

HL-LHC impedance model

- Changes w.r.t. the LHC that are **included** in the HL model:
  - ✓ Collimator at almost 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; tungsten TCLD absorber in IR7,
  - ✓ Updated collimator tapers,
  - ✓ Beta functions in the arcs and triplets (optics v1.4),
  - ✓ TDIS (with graphite, Ti_6Al_4V and CuCr1Zr),
  - ✓ New MKI-cool – 4 of them,
  - ✓ New octogonal beam screens in triplets, with up-to-date dimensions, aC-coating, 75K copper, pumping holes and welds (accurate weld & shape factors from **C. Zannini**),
  - ✓ Updated experimental chambers (ATLAS & CMS),
  - ✓ Tapers and BPMs in the triplets region,
  - ✓ Crab cavities,
  - ✓ Deformable RF-fingers, VAX and Y-chambers in triplet region.

HL-LHC impedance model

- Modifications that are not (yet) in the model:
  - ✗ VELO,
  - ✗ experimental chambers ALICE and LHCb, possibly also CMS,
  - ✗ new instrumentation,
  - ✗ possible aC-coating in some sectors,
  - ✗ possible additional collimators in IR1 & 5, TCLD in IR2 (in parking for protons) and updated design of all tertiaries and TCLs, old CFC collimators in parking?
  - ✗ crab cavities HOMs as measured in real cavities,
  - ✗ electron lens and crystal collimators (recently added to baseline),
  - ✗ new roman pots,
  - ✗ "SMOG3" in LHCb.