Update on the HL-LHC impedance model in the new operational scenario, and considerations on crab cavity HOMs

N. Mounet, D. Amorim, S. Antipov, N. Biancacci, X. Buffat, B. Salvant, C. Zannini.
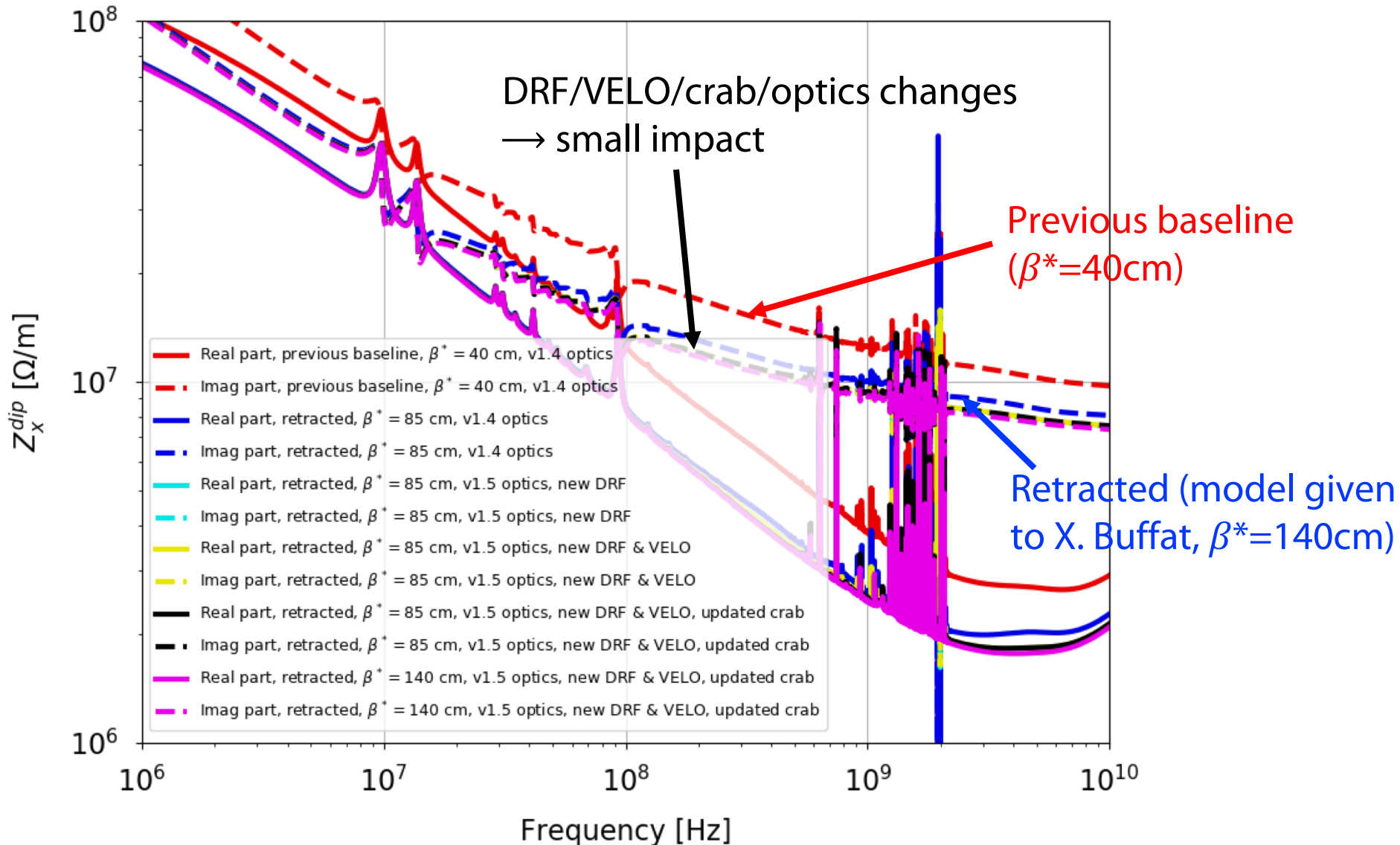
HL-LHC impedance model update

➢ Primaries and secondaries were retracted to decrease the impedance (σ computed with ε = 2.5 μm.rad - top energy) – from **E. Belli & R. Bruce** :

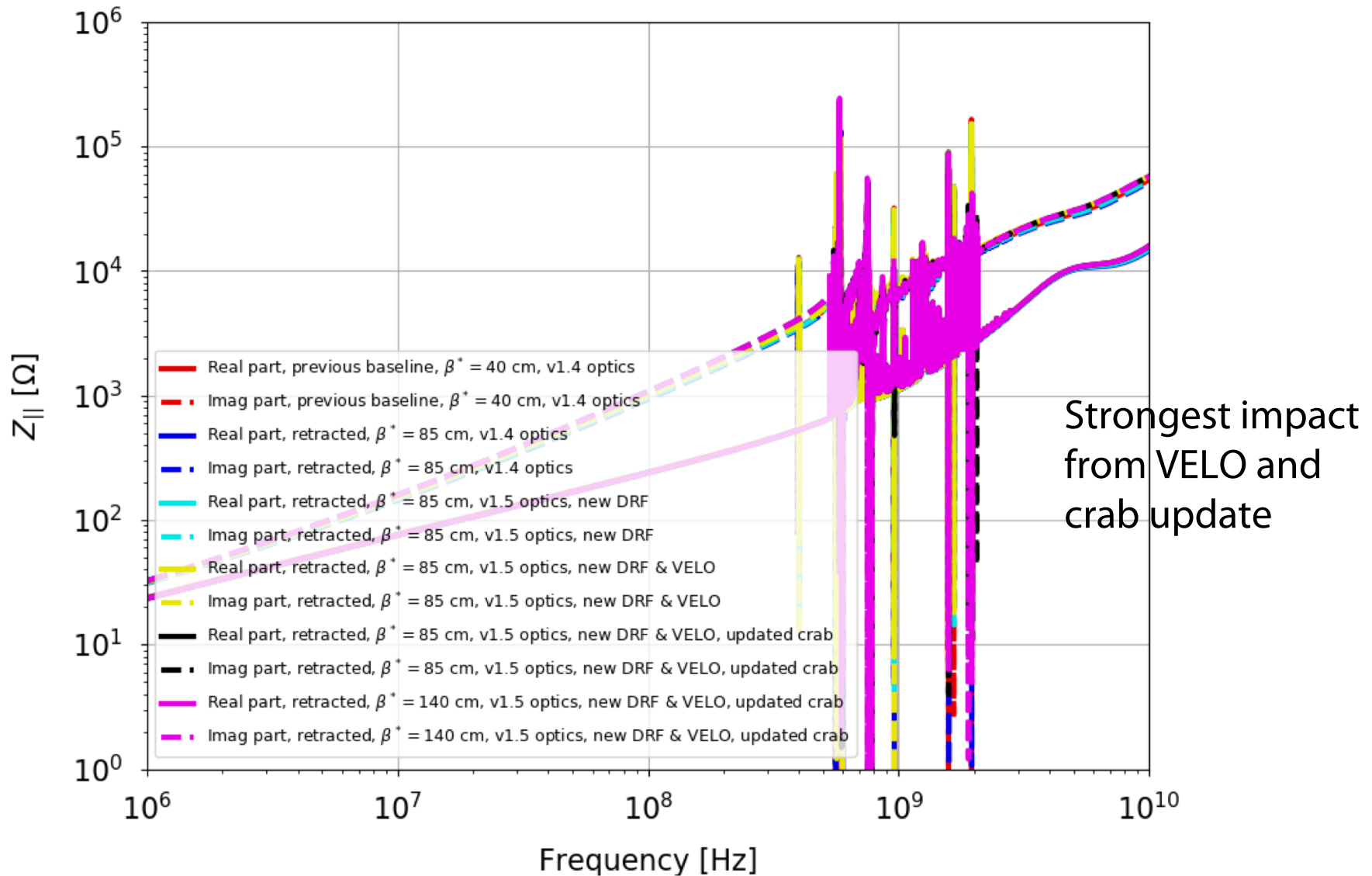| Collimators	Previous baseline	Retracted
TCPs (IR7)	6.7 σ	**8.5 σ**
TCSs (IR7)	9.1 σ	**10.1 σ**

Full settings in appendix

➢ Model updated using HL-LHC v1.5 optics (was 1.4 previously) and for β*=85cm/105cm/140cm (instead of 40cm), with or without anti-telescope, in agreement with the new operational scenario (**G. Arduini**, **R. Bruce**, **R. De Maria**, **R. Tomás** et al),

➢ Crab cavities updated (**J. Mitchell** et al),

➢ VELO added (**N. Biancacci** et al),

➢ DRF in crab cavities updated (**B. Salvant** et al),

➢ NOTE: to save time, a first model was provided to Xavier where ONLY the collimator settings were changed (the rest kept as in previous model).

Impact of the model updates - transverse

DRF/VELO/crab/optics changes → small impact

Previous baseline (β*=40cm)

Retracted (model given to X. Buffat, β*=140cm)

Legend:
- Real part, previous baseline, $\beta^* = 40$ cm, v1.4 optics
- Imag part, previous baseline, $\beta^* = 40$ cm, v1.4 optics
- Real part, retracted, $\beta^* = 85$ cm, v1.4 optics
- Imag part, retracted, $\beta^* = 85$ cm, v1.4 optics
- Real part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF
- Imag part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF
- Real part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF & VELO
- Imag part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF & VELO
- Real part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF & VELO, updated crab
- Imag part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF & VELO, updated crab
- Real part, retracted, $\beta^* = 140$ cm, v1.5 optics, new DRF & VELO, updated crab
- Imag part, retracted, $\beta^* = 140$ cm, v1.5 optics, new DRF & VELO, updated crab

Z_x^{dip} [Ω/m]

Frequency [Hz]

Impact of the model updates - longitudinal

Strongest impact from VELO and crab update

Legend:
- Real part, previous baseline, $\beta^* = 40$ cm, v1.4 optics
- Imag part, previous baseline, $\beta^* = 40$ cm, v1.4 optics
- Real part, retracted, $\beta^* = 85$ cm, v1.4 optics
- Imag part, retracted, $\beta^* = 85$ cm, v1.4 optics
- Real part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF
- Imag part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF
- Real part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF & VELO
- Imag part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF & VELO
- Real part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF & VELO, updated crab
- Imag part, retracted, $\beta^* = 85$ cm, v1.5 optics, new DRF & VELO, updated crab
- Real part, retracted, $\beta^* = 140$ cm, v1.5 optics, new DRF & VELO, updated crab
- Imag part, retracted, $\beta^* = 140$ cm, v1.5 optics, new DRF & VELO, updated crab

Overall impact of new model on stability

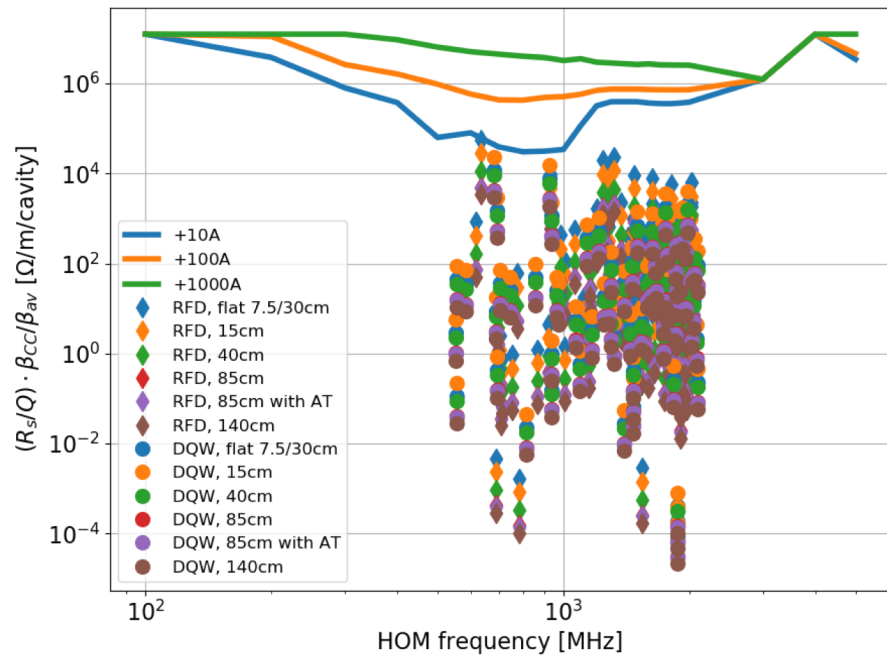B1, positive oct. polarity, $\tau_b = 1.2$ ns, Nb=2.3e+11 , M=3564 , damp=0.01
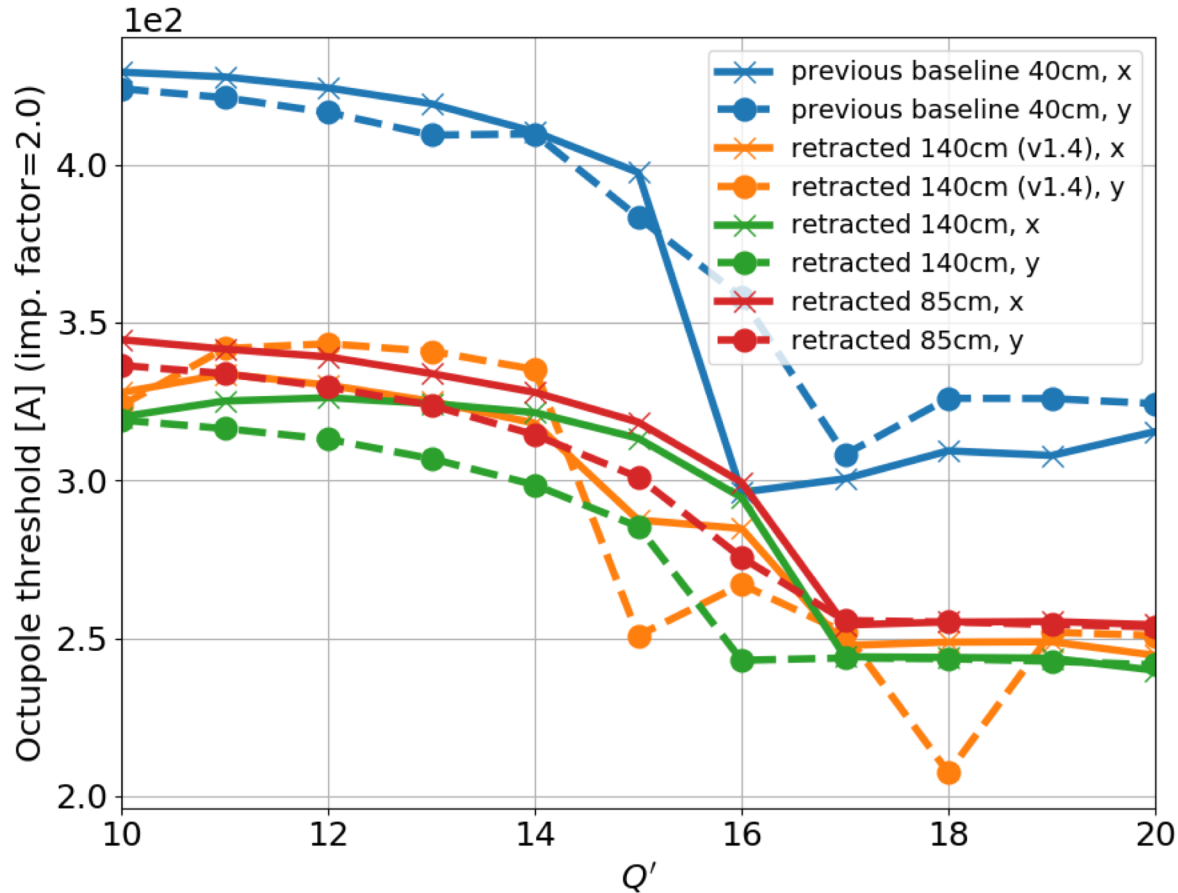
TeleIndex=1

⇒ Strong impedance reduction with retraction of collimators (as expected).
⇒ Optics & beta* (from 85cm to 140cm) has smaller impact

Impact of HOMs in crab cavities – single bunch

B1, x, pos oct., $\varepsilon = 2.1\mu m$, $\tau_b = 1.2$ ns, Nb=2.3e+11 , M=1 , damp=0.01

B1, y, pos oct., $\varepsilon = 2.1\mu m$, $\tau_b = 1.2$ ns, Nb=2.3e+11 , M=1 , damp=0.01
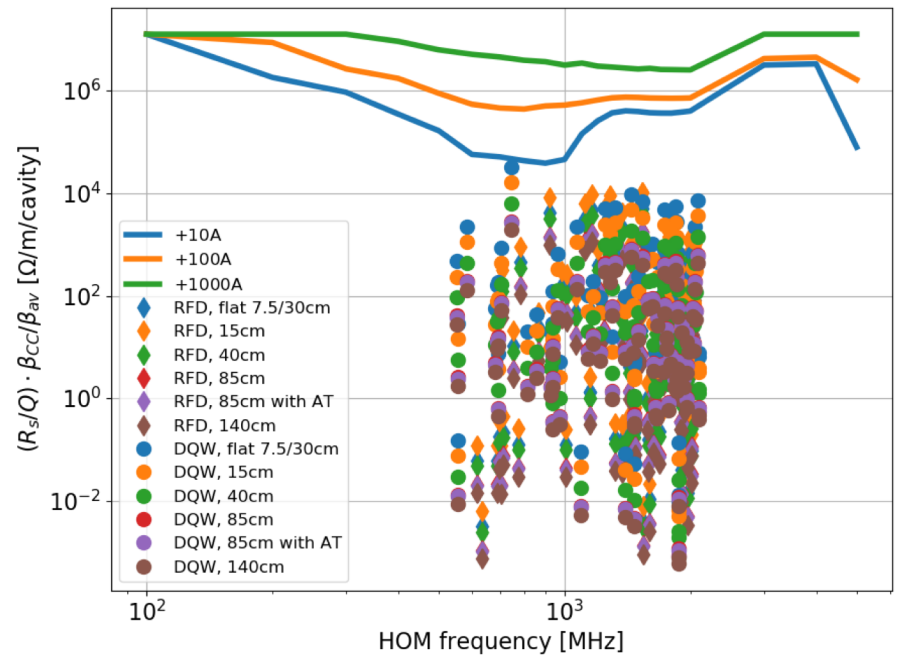
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⇒ Far from the limit most of the time (close to the limit with flat optics)
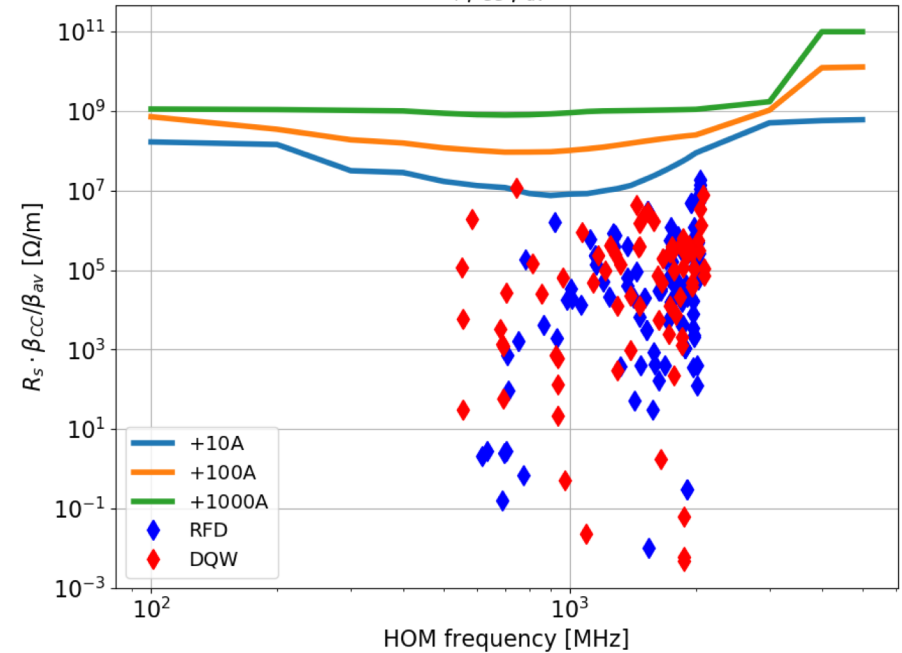
Impact of HOMs in crab cavities – multibunch

B1, x, pos oct., $\varepsilon = 2.1\mu m$, $\tau_b = 1.2$ ns, Nb=2.3e+11 , M=3564 , damp=0.01

40cm, $\beta_{CC}/\beta_{av} = 21.7$
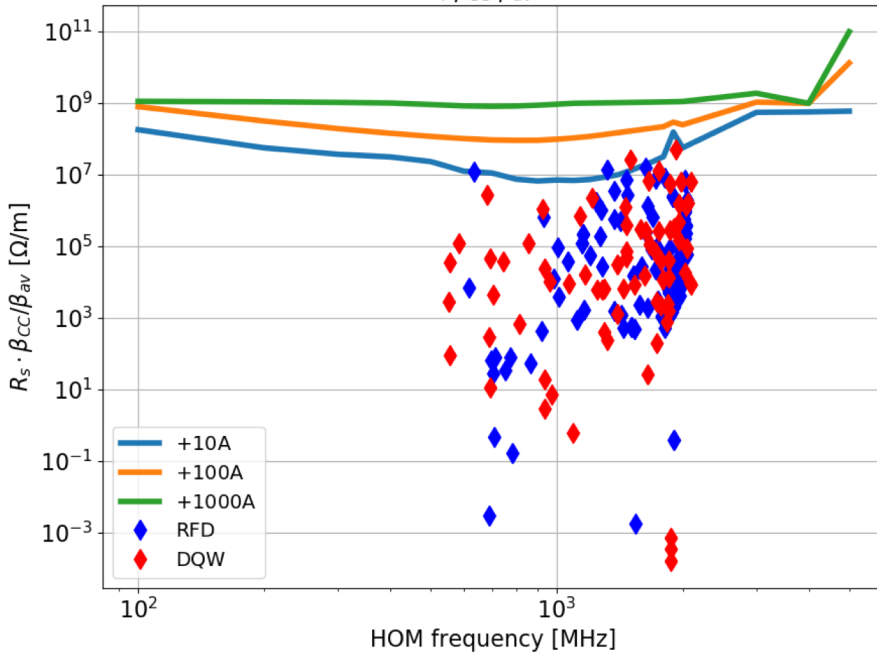
B1, y, pos oct., $\varepsilon = 2.1\mu m$, $\tau_b = 1.2$ ns, Nb=2.3e+11 , M=3564 , damp=0.01

40cm, $\beta_{CC}/\beta_{av} = 21.8$

TeleIndex=1

⇒ Close to the limit even with beta*=40cm

Appendix

HL-LHC impedance model

➢ **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 (**S. Antipov**, **E. Carideo**),
- ✓ 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,
- ✓ Updated crab cavities (2019 HOMs),
- ✓ Deformable RF-fingers, VAX and Y-chambers in triplet region (including new design for DRF in crab cavities – **B. Salvant**),
- ✓ VELO (**N. Biancacci** et al – *Elba, 30th May 2017*).

HL-LHC impedance model

➢ Modifications that are not (yet) in the model:

- ✗ 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.