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Impact of beam-beam β-beating on collimation

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Introduction

- **Head-on (HO) and long-range (LR) beam-beam interactions add an aperture dependent β-beating.**

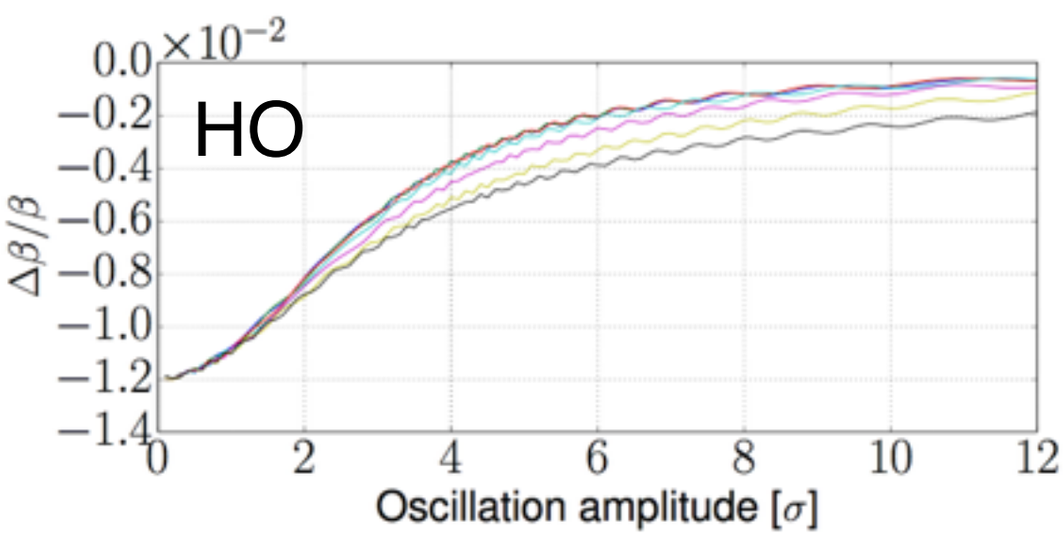
  See recent Refs.: HB2016 and IPAC2017 papers by Tatiana, Rogelio et al.

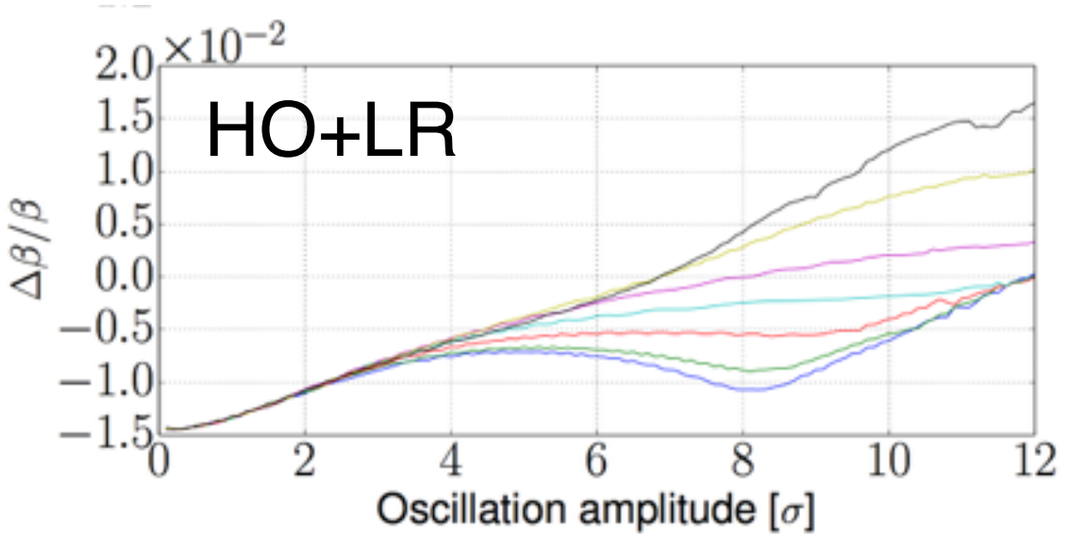
  LHC: HO contribution > several % at small amplitudes.
  LR: smaller but amplitudes close to collimator cuts.

- **β-beating might affect collimation performance in several ways**

  Tolerance on hierarchy violations (by-pass primary collimators, TCPs);
  Degradation of cleaning in multi-turn process;
  Passive protection in case of fast failures (starting conditions in IP6 for asynch dumps);
  Loss spikes in case of change of optics at amplitudes close to TCPs — smooth during levelling, "sudden" at collision onset?

LHC case





http://accelconf.web.cern.ch/AccelConf/hb2016/papers/mopr027.pdf

General considerations

- **From collimation, we keep the design goal of 1 σ retraction**

  Use this as assumption for optics correction criteria.

- **Present baseline hierarchy for HL: "2σ retraction", more tolerant to optics errors** (see presentation by Roderik)**.**

  A much larger optics error would be needed to violate the collimation hierarchy.

  Example: TCP/TCS at 5/6 σ, 1.20 error in β gives ~10% setting error

  ↦ can get in the worst case 5.5/5.4σ settings: Hierarchy violation!

  Still somehow pessimistic:

  — one needs to look at real phase of beating;

  — most secondary collimators are skew, so get another factor ~√2!

- **Present LHC operational scenario, with <10% beating**

  Nominal optics used to setup the collimator gaps: BIG advantage

  No problem observed, even with tighter settings that HL baseline

  Deployed TCP/TCS settings of 5.0/6.5σ in 2017: OK!

- **We are testing further improvements (MDs):**

  Collimation hierarchy studies

  Angular alignment of collimators (faster algorithms being developed)

Overall strategy

- We believe that we can operate the HL-LHC as the present LHC if the beating is kept < 10% at top energy.
- Present target for aperture calculations is still 20%
- The LHC operation so far profited of a good machine reproducibility and excellent correction.
- We should take as a baseline that the dynamic beating from BB should be corrected to the target same level within ~%.

  Preliminary studies indicate that this is possible for HO, trickier for LR
  Can estimate tolerance for dynamic beating on to of static one used for collimator alignment.

- **Even with hollow e-lenses, it would probably be tricky to change the IR7 hierarchy in collision during the levelling!**

  Built-in optics corrections, if possible, are the preferred solution.

- **Determination of the beam-based beam sizes at collimators is very tricky and time-consuming at top energy!**

  Probably would have to rely on simulations rather than measurements.

Possible simulation work

- **On-going work:**
  - Assess amplitude-dependent beating for HL-LHC, as done for present LHC and FCC-hh (Javier, P. Jorge: master thesis);
  - Assess hierarchy violation through “n1” aperture simulations with different aperture dependent beat (Javier + Roderik)
- **Tracking simulations of collimation (single particle):**
  - Single-pass losses IR7 ↦ small effect expected.
  - assess multi-turn losses round the ring (effect from new phases);
    ↦ small effect expected, check TCT distributions.
  - Fast failures ↦ effect of perturbed initial distributions in IR6.
- **Requirements:**

  Lattice with simulated beating or beam-beam element(s)

  ↦ *available (work by Javier et al.)*

Proposed MDs studies

General setup for studies

- work at 450 GeV to minimised problems from impedance and amplify effects, as in http://accelconf.web.cern.ch/AccelConf/ipac2017/papers/tupva030.pdf
- push bunch intensity with reduced (or zero-ed) crossing angle.

Assess beam-based hierarchy in IR7 + TCTs

- Repeat beam-based alignment with HO for different primary collimator cuts (5, 4, 3, 2 sigma) ↦ direct demonstration, to be compared to optics simulations.
- Repeat for different bunch intensities.
- [Challenging]: try BLM alignment with one train to see LR effects.
- Loss maps with colliding beams (pilot against nominal).

Tests at top energy (6.5TeV, 30cm):

- Collisions HO of several INDIV at different I_b, monitor losses (dBLM).

Ongoing:

Development with BI (MD4 request by A. Sounas) to use non-linearities of BLM signal to measure collimator beam size

↦ *see report at upcoming CWG, Oct. 9th*