

Study with one global crab cavity at IR4 for LHC Upgrade

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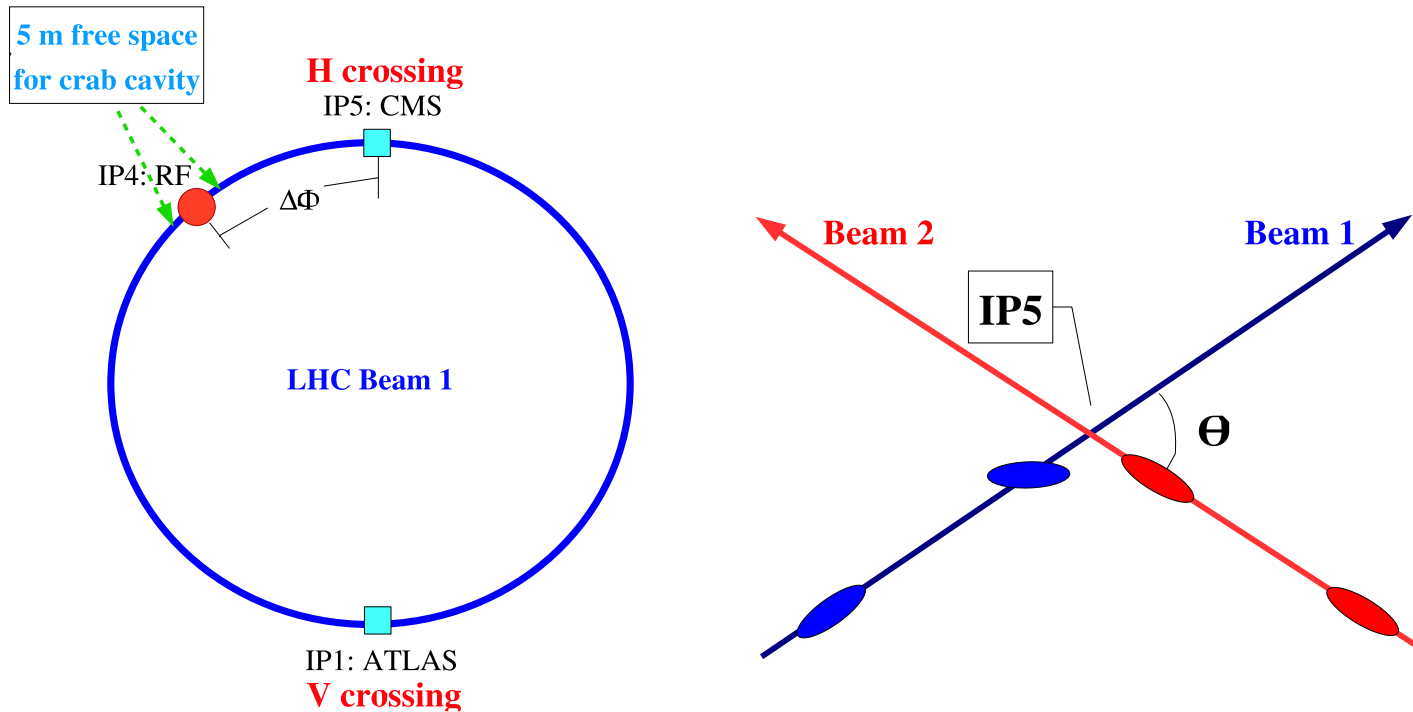
Thanks to D. Schulte, C. Bracco (MATLAB code), S. White, K. Jean-Pierre, M. Giovannozzi, F. Schmidt, and U. Dorda

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- Introduction & Optics
- Luminosity & Dynamic aperture
- Beta-beating & Collimation tracking

Minimal test scenario: 1 CC



A single global crab cavity at IR4 to benefit IP5

Optics

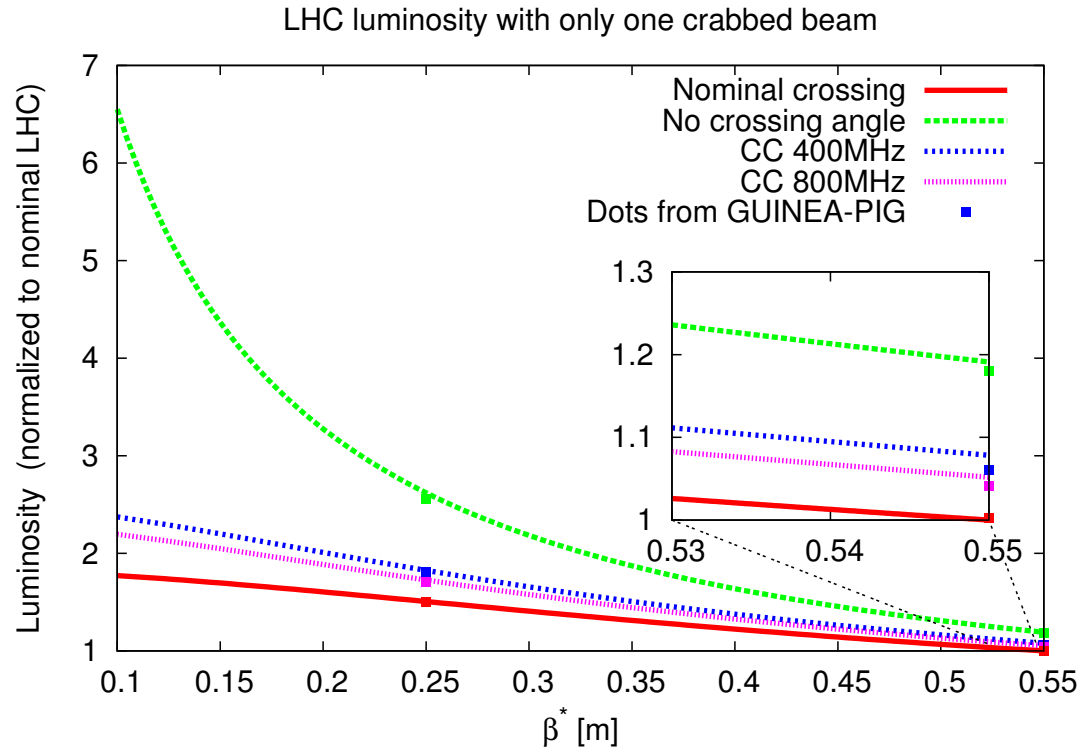
- Nominal optics, 800-MHz crab cavity: **9.3** MV

| | s [m] | β_x [m] | β_y [m] | Phase x | Phase y |
|-----|---------|---------------|---------------|-----------|-----------|
| IP1 | 0 | 0.55 | 0.55 | 0 | 0 |
| CC | 9968 | 208 | 174 | 24.382 | 21.838 |
| IP5 | 13329 | 0.55 | 0.55 | 32.047 | 29.609 |

- Lowbetamax optics, 800-MHz crab cavity: **25.7** MV \rightarrow Increase β

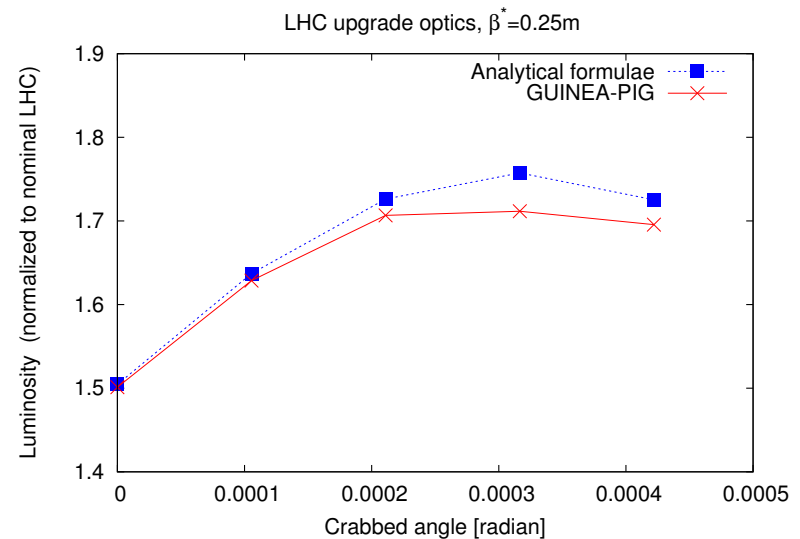
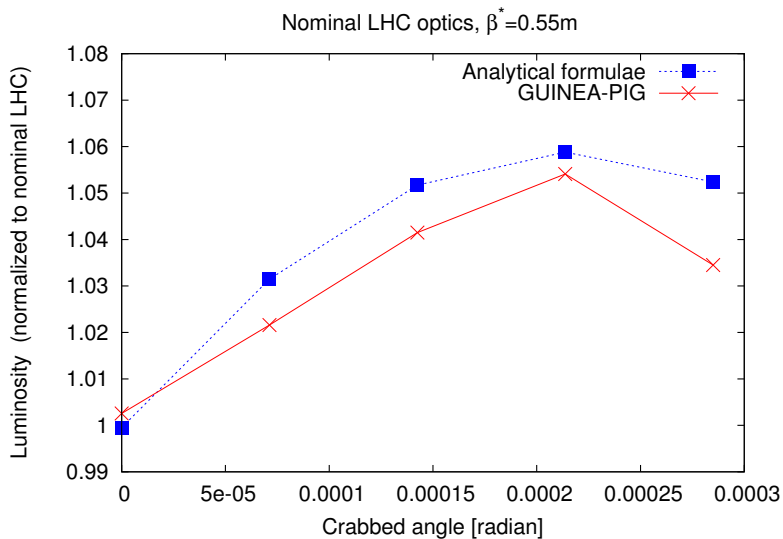
| | s [m] | β_x [m] | β_y [m] | Phase x | Phase y |
|-----|---------|---------------|---------------|-----------|-----------|
| IP1 | 0 | 0.25 | 0.25 | 0 | 0 |
| CC | 10028 | 113 | 250 | 24.557 | 22.379 |
| IP5 | 13329 | 0.25 | 0.25 | 32.253 | 29.736 |

Luminosity



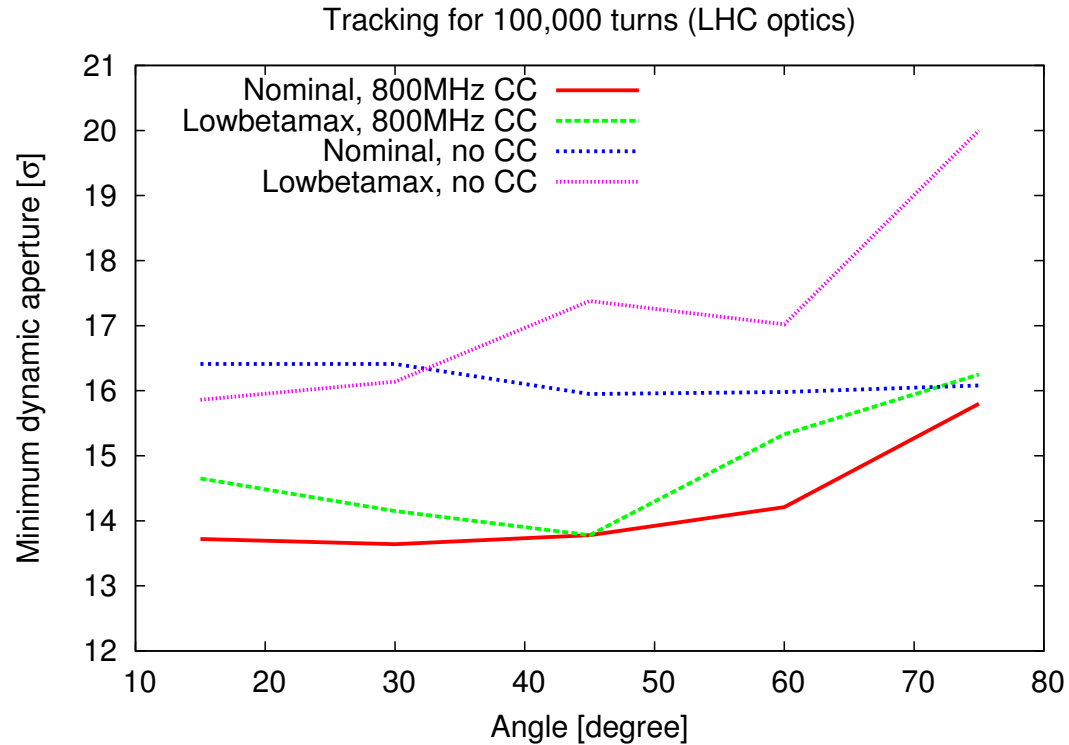
- Curves: analytical formulae; Dots: GUINEA-PIG
- Good agreement
- 5 percent gain at IP5, 5 percent loss at IP1, with $\beta^* = 0.55m$

Luminosity scan



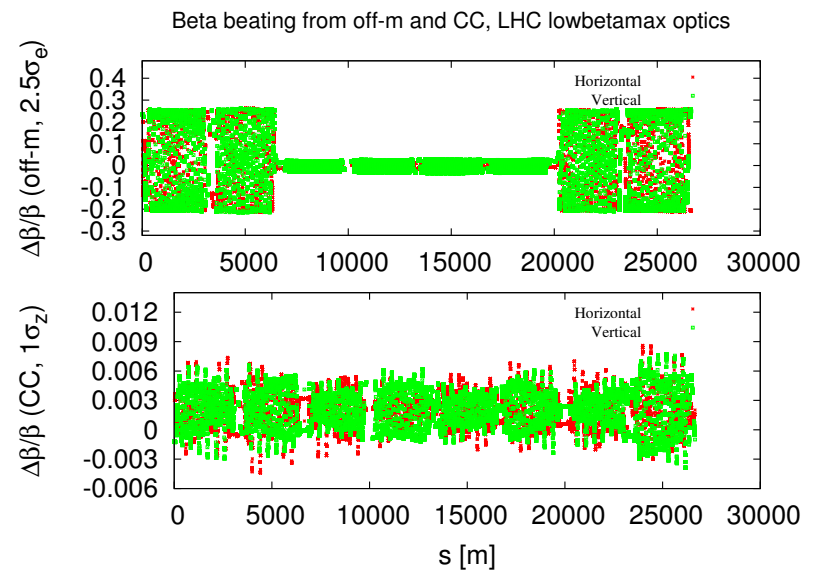
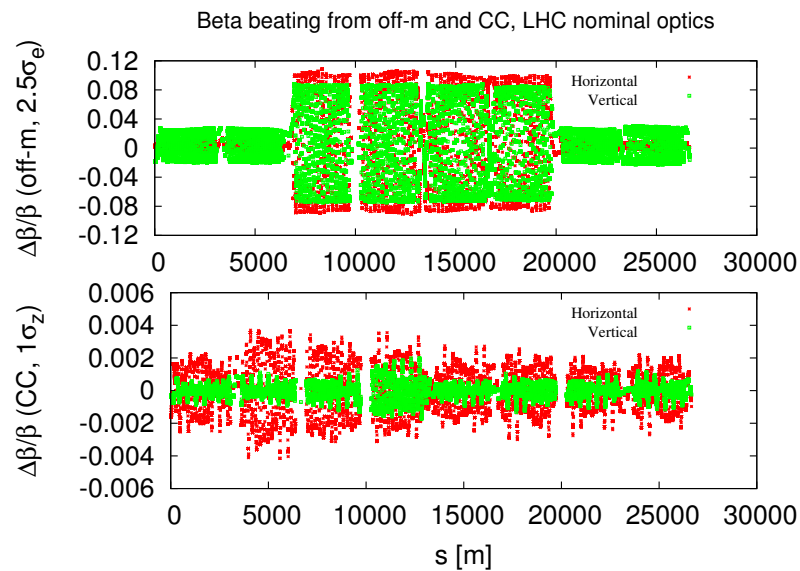
- Only beam 1 is crabbed
 - Peak luminosity at $\frac{3\theta_c}{4}$
 - Measurement resolution 0.01 (Courtesy Simon White)
- <https://edms.cern.ch/file/347396/1.1/LHC-B-ES-0007-10-00.pdf>

Dynamic aperture



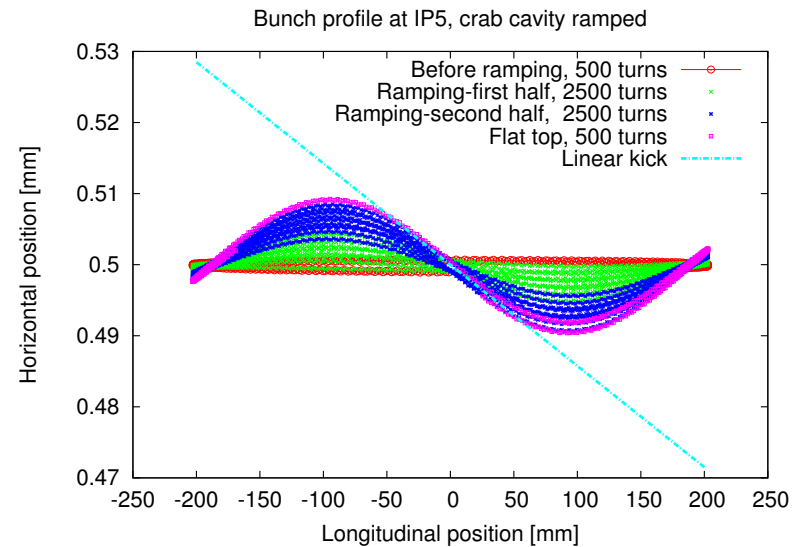
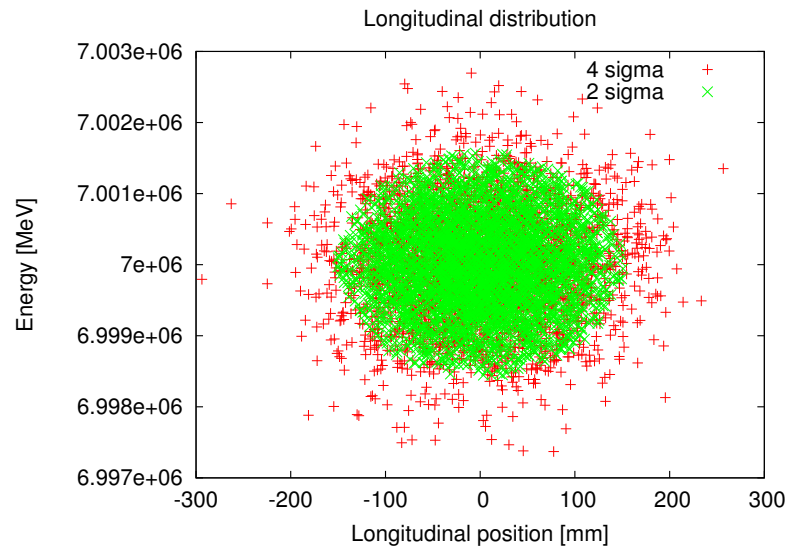
- Two error seeds
- Momentum offset 0.00027, 100,000 turns
- 2 to 2.5 σ degradation due to CC

Beta beating



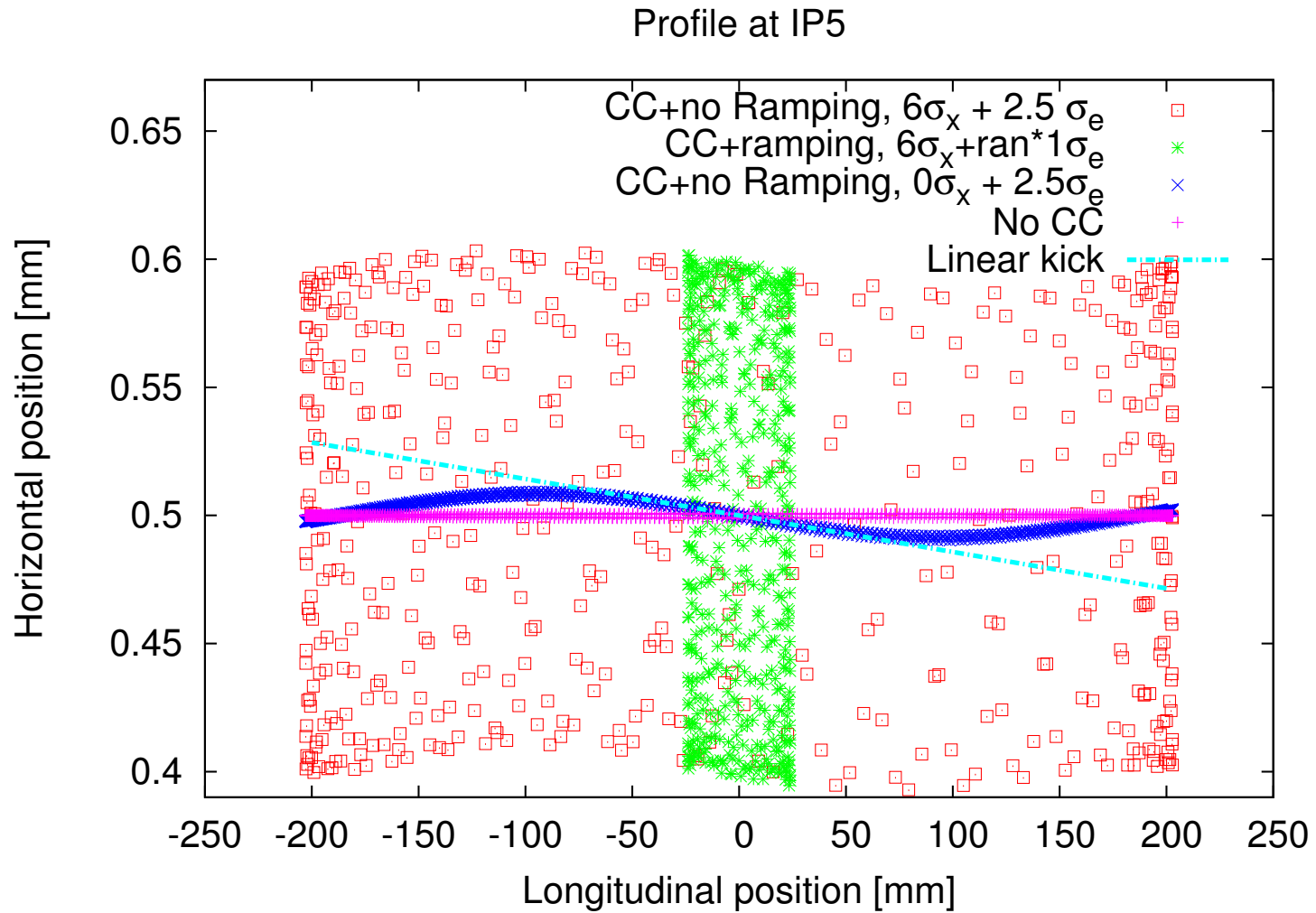
Left: LHC nominal optics; Right: LHC lowbetamax optics

SixTrack code & CC ramping



Left: SixTrack code longitudinal cut 2→4; Right: CC ramping check at IP5

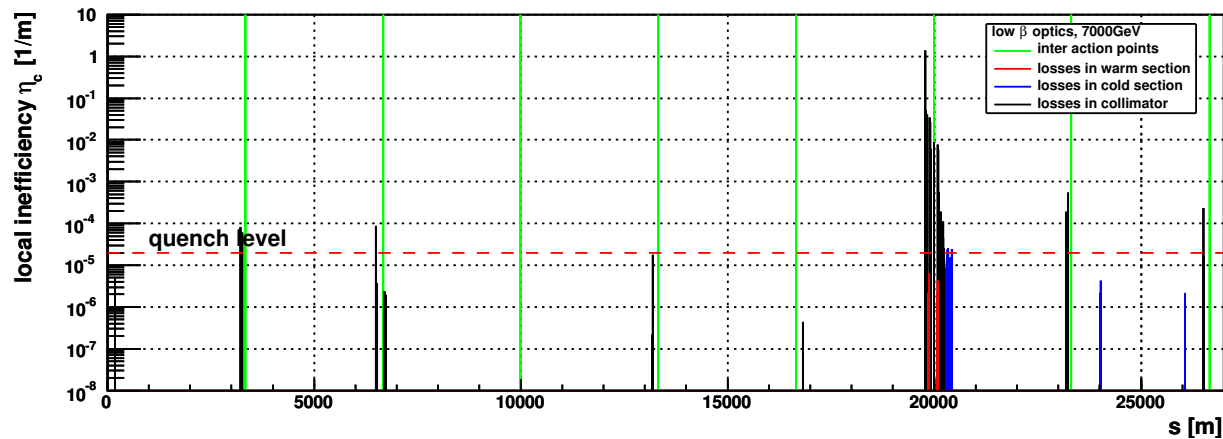
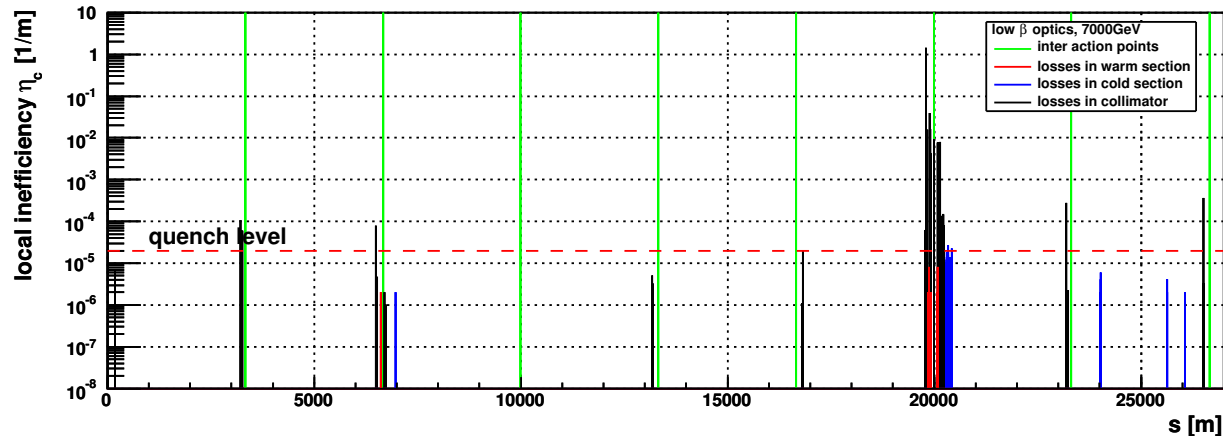
Comparison



Collimation, tracking conditions

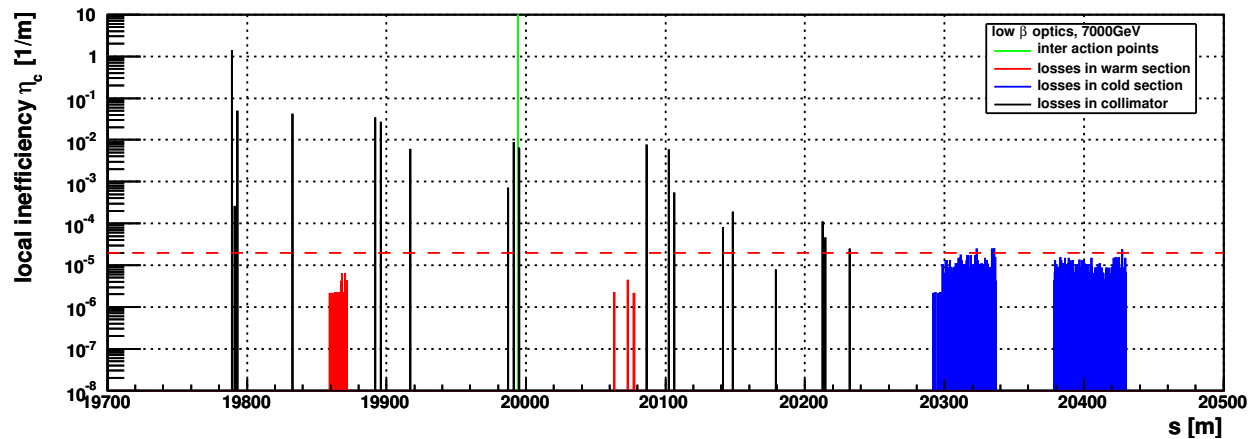
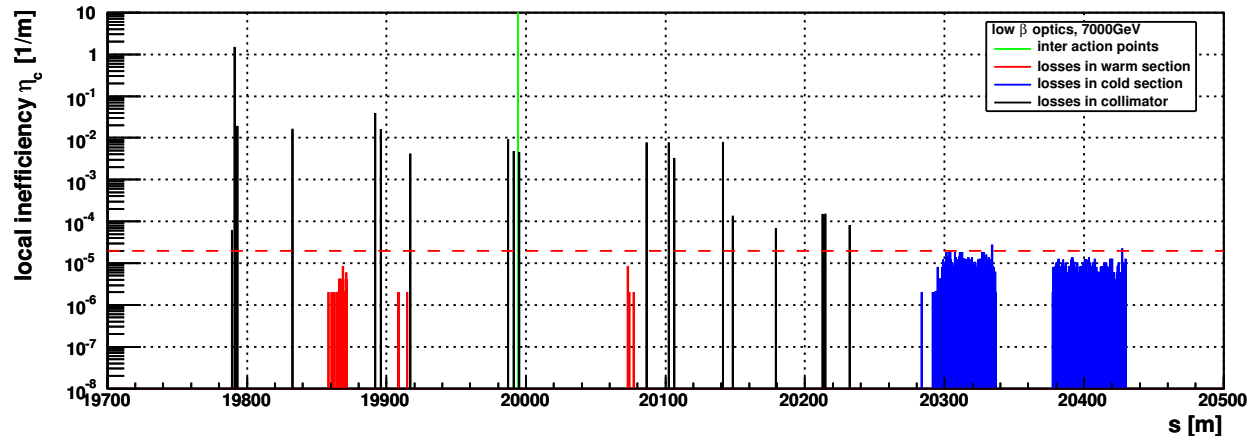
- Nominal LHC optics, beam 1
- Code: SixTrack_coll_cc & SixTrack_coll_cc_2sigma
- 5,000,000 particles, 200 turns
- For CC, ramp 1000 turns without collimators first, then track for another normal 200 turns
- $5.958 \sigma + .0015 \sigma$ smear
- $\sigma_e = 1.129\text{E-}4$, $\sigma_z = 75.5$ mm

Loss map, Thomas Weiler



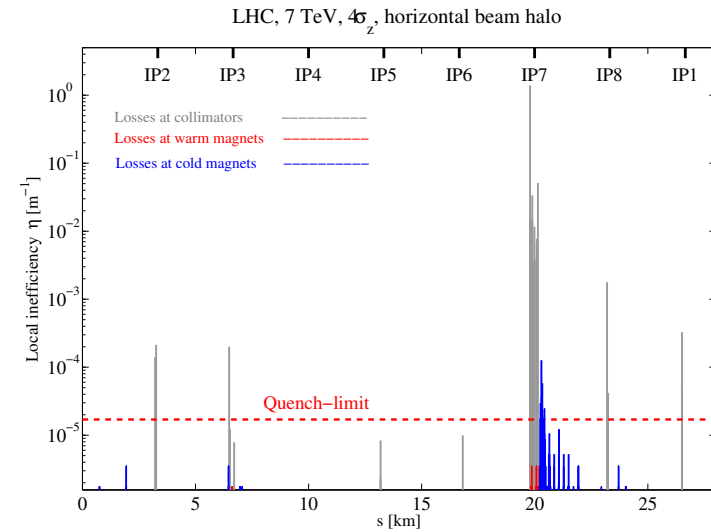
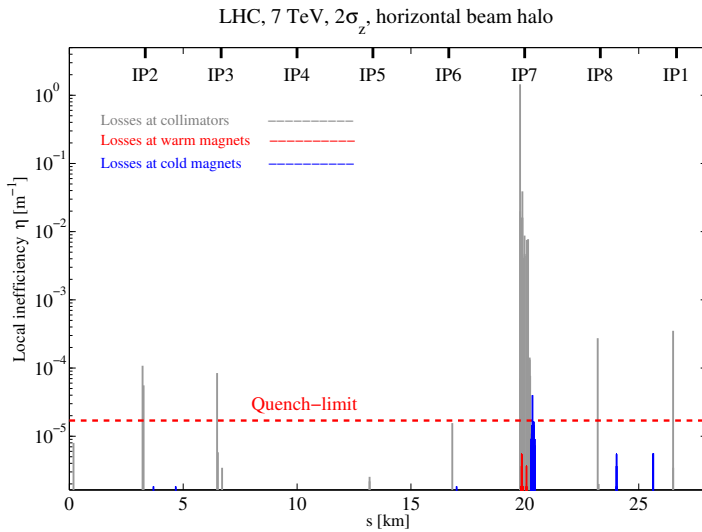
$2\sigma_z$ cut. Up: hor halo ; Down: ver halo

Loss map, Thomas Weiler (Zoom-in)



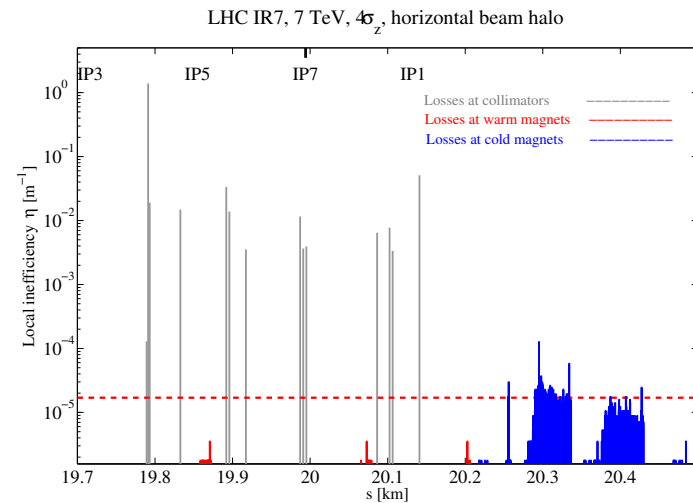
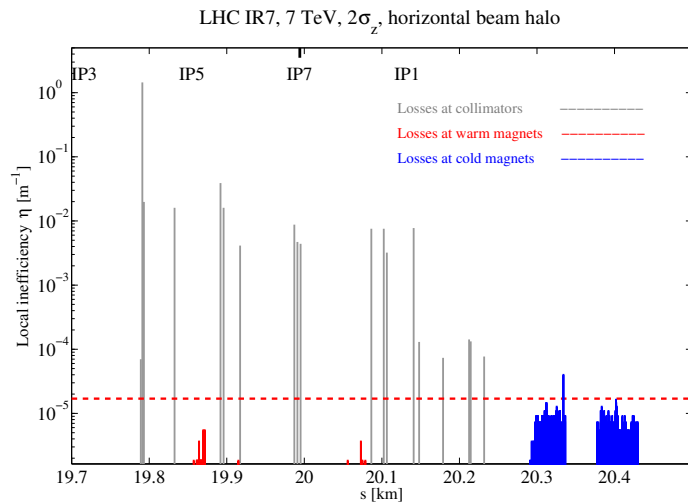
LHC IR7, $2 \sigma_z$ cut. Up: hor halo ; Down: ver halo

Loss map, hor halo, no CC



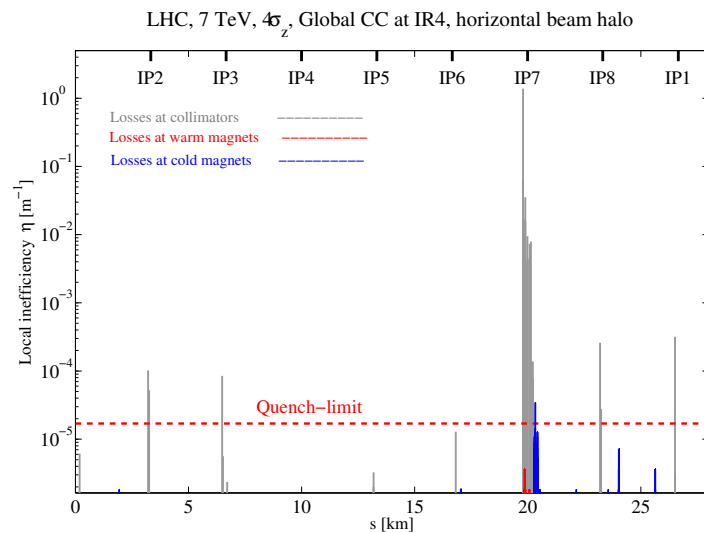
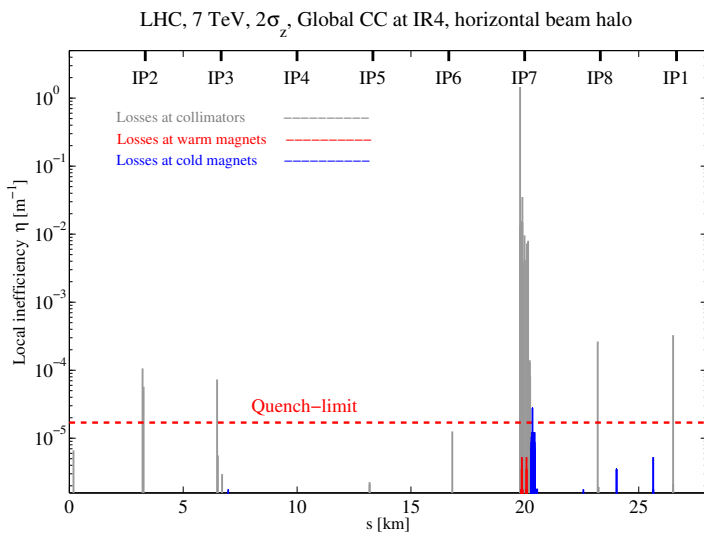
Left: $2\sigma_z$ cut; Right: $4\sigma_z$ cut

Loss map, hor halo, no CC (Zoom-in)



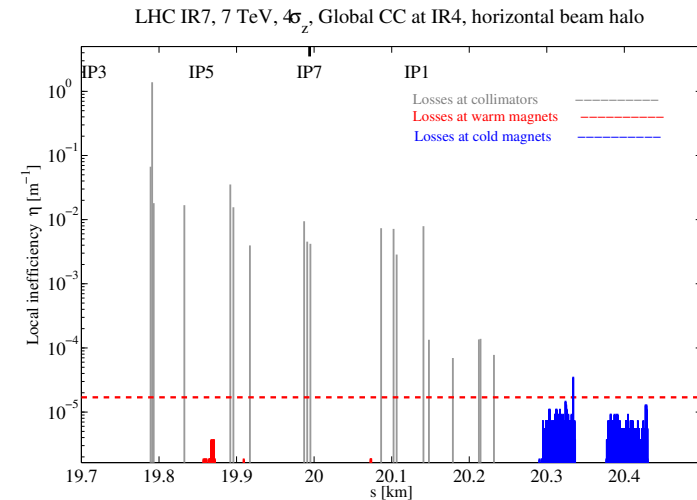
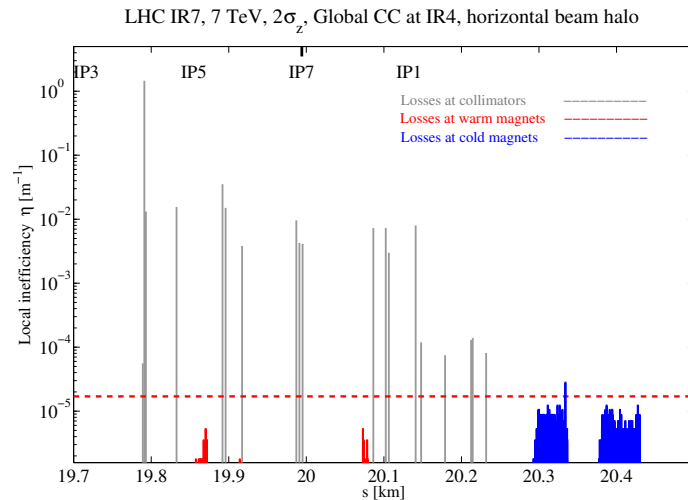
LHC IR7, Left: $2\sigma_z$ cut; Right: $4\sigma_z$ cut

Loss map, hor halo, Global CC



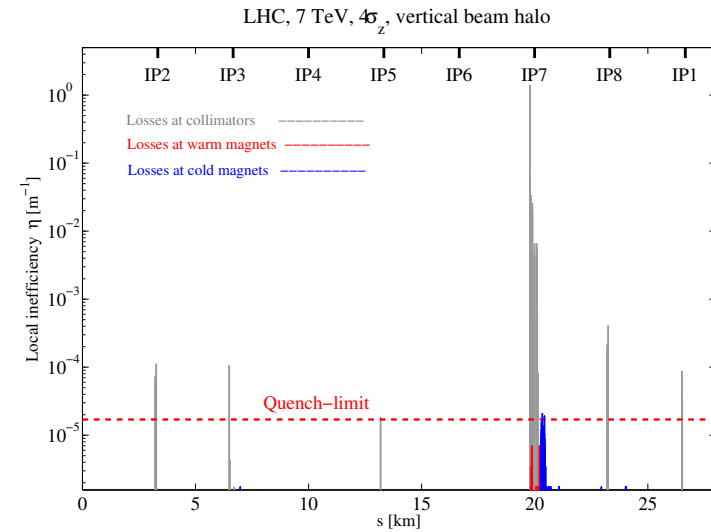
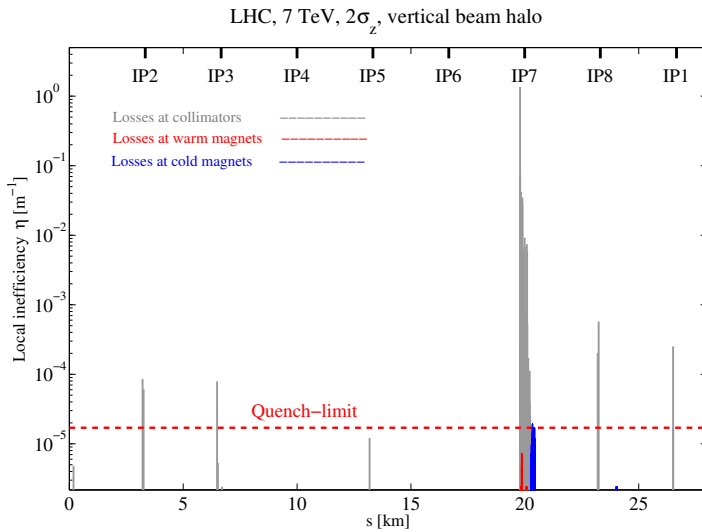
Left: $2\sigma_z$ cut; Right: $4\sigma_z$ cut

Loss map, hor halo, Global CC (Zoom-in)



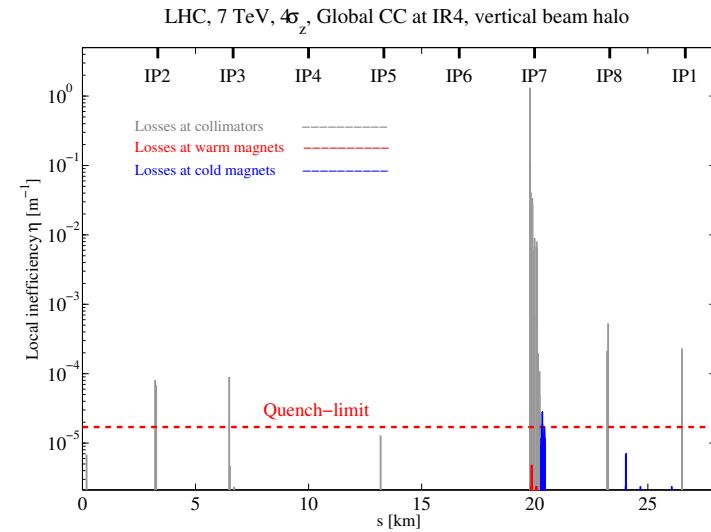
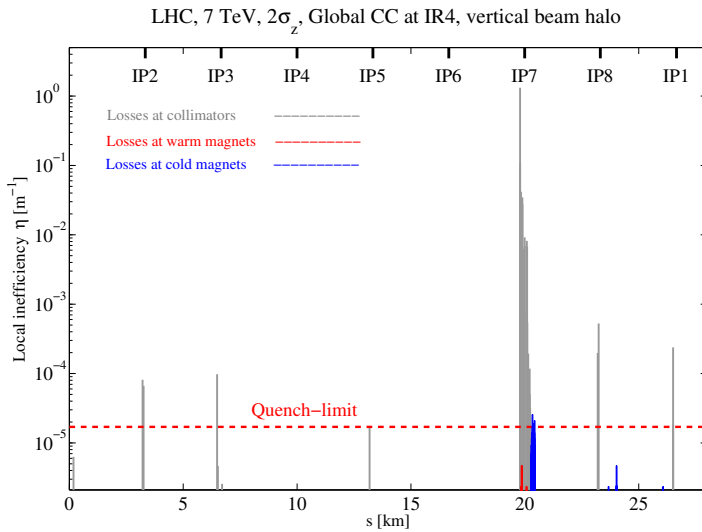
LHC IR7, Left: $2\sigma_z$ cut; Right: $4\sigma_z$ cut

Loss map, ver halo, no CC



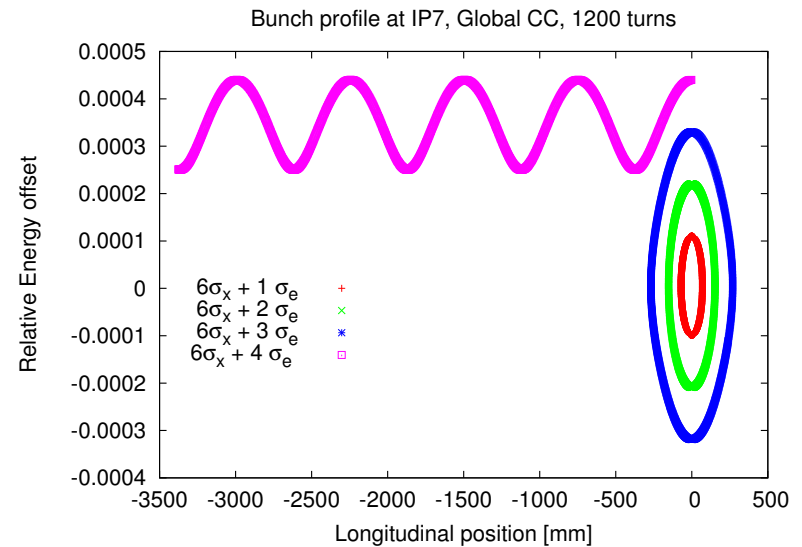
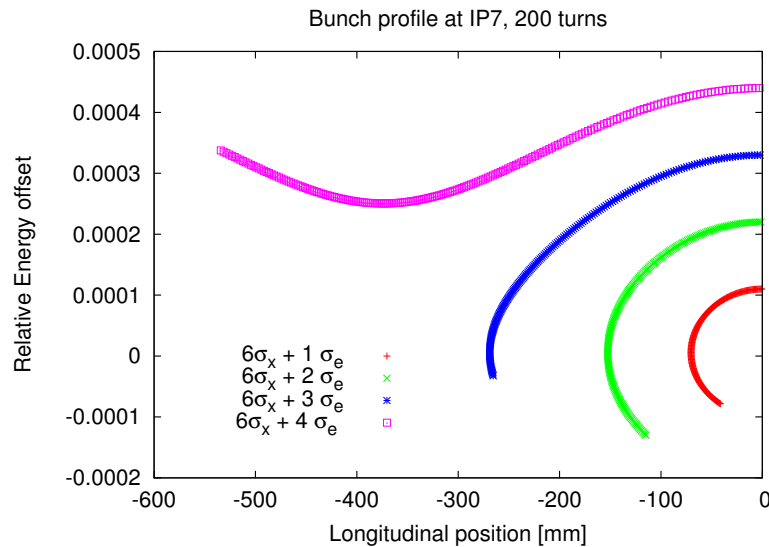
Left: $2\sigma_z$ cut; Right: $4\sigma_z$ cut

Loss map, ver halo, Global CC



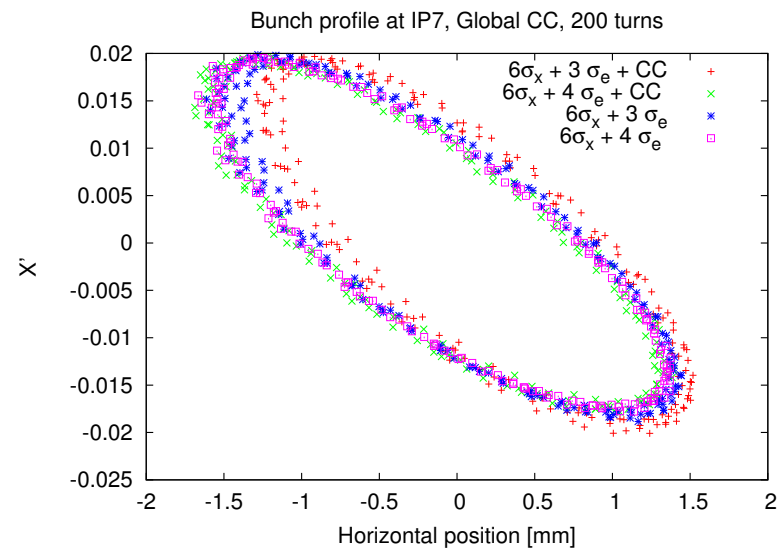
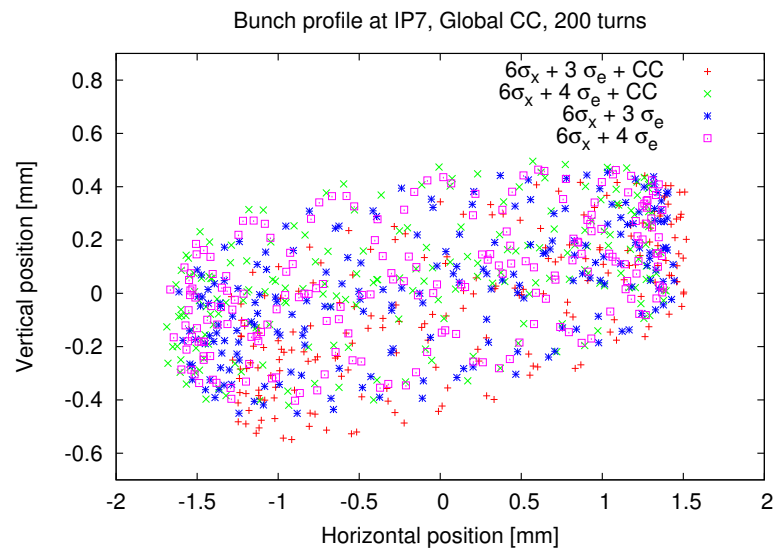
Left: $2\sigma_z$ cut; Right: $4\sigma_z$ cut

Long phase space, at IP7



Left: no CC (200 turns); Right: Global CC (1000 turns ramping + 200 turns)

Transverse phase space, at IP7



Left: Phase space X-Y; Right: Phase space X-X'