A more systematic DA study on flat optics for HL-LHC

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Introduction

Conduct more systematic studies to simulate and converge to a realistic scenario with flat optics:

- All simulations are done with Xsuite.
- Using a realistic 8b4e filling scheme, study the DA sensitivity on bunch intensity, chromaticity, octupole current, crossing angle, filling scheme & optics for the start and end of luminosity leveling.
- Very large number of simulations. At the moment, focused on the end of luminosity leveling with 7.5/18 cm:

  I. Used exact 8b4e filling scheme for the BB encounters.

  II. Impact from chromaticity: required chromaticity is driven by e-cloud, considered chroma of 5 and 15 (could potentially operate with chroma 5 and 8b4e but to be checked- input from Xavier).

  III. Impact from bunch intensity: can we operate with 1.4e11 ppb based on DA at the EOL?

  IV. Impact from octupole current: 60 A needed (input from Xavier based on x-y tele-indexes) but also studied effect of switching octupole polarity.

  V. Impact of IP1/5 crossing angle: ranging from 500 to 590 μrad (not limited by aperture, but by orbit corrector strength- input from Riccardo).

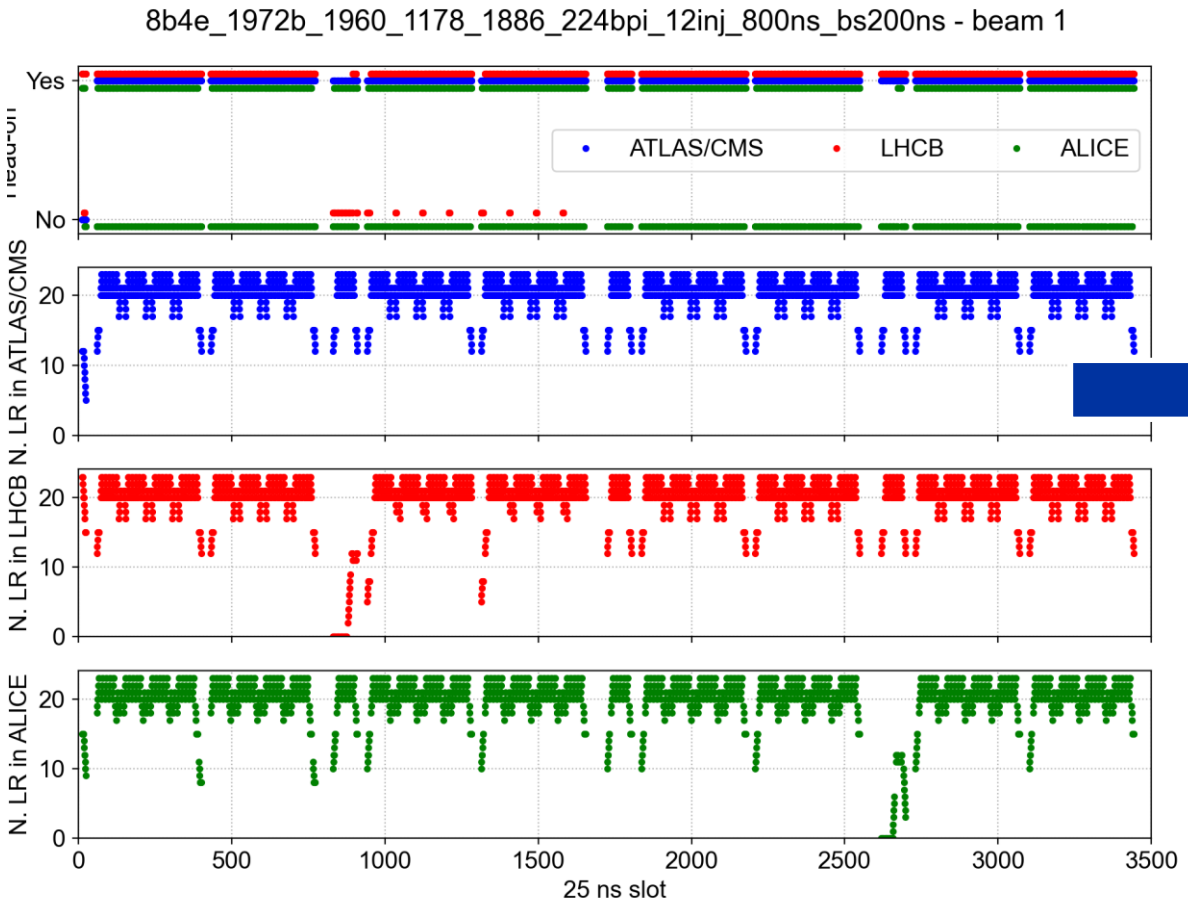
  VI. Bunch-by-bunch DA variations.

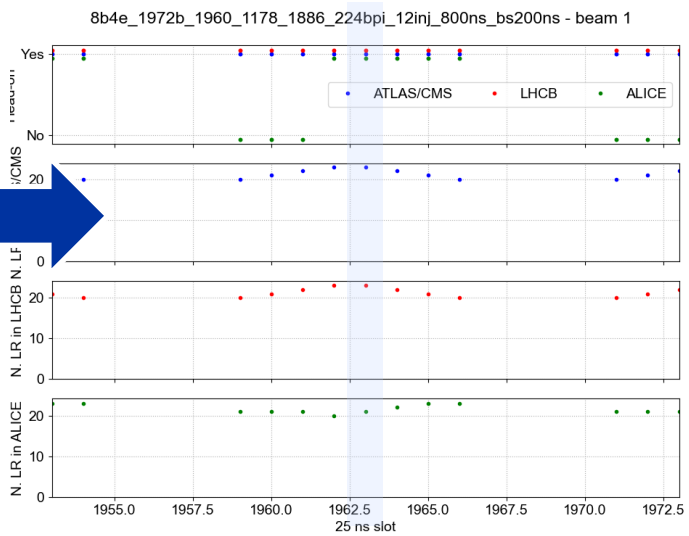
Including an 8b4e filling scheme

- Possibility to simulate exact BB encounters for a specific bunch in pymask!
- Simulate worst bunch in terms of DA: - HO in IP1/2/5/8, maximum number of LR in ATLAS/CMS, LHCb and large LR number in ALICE → Selected bunch number 1963

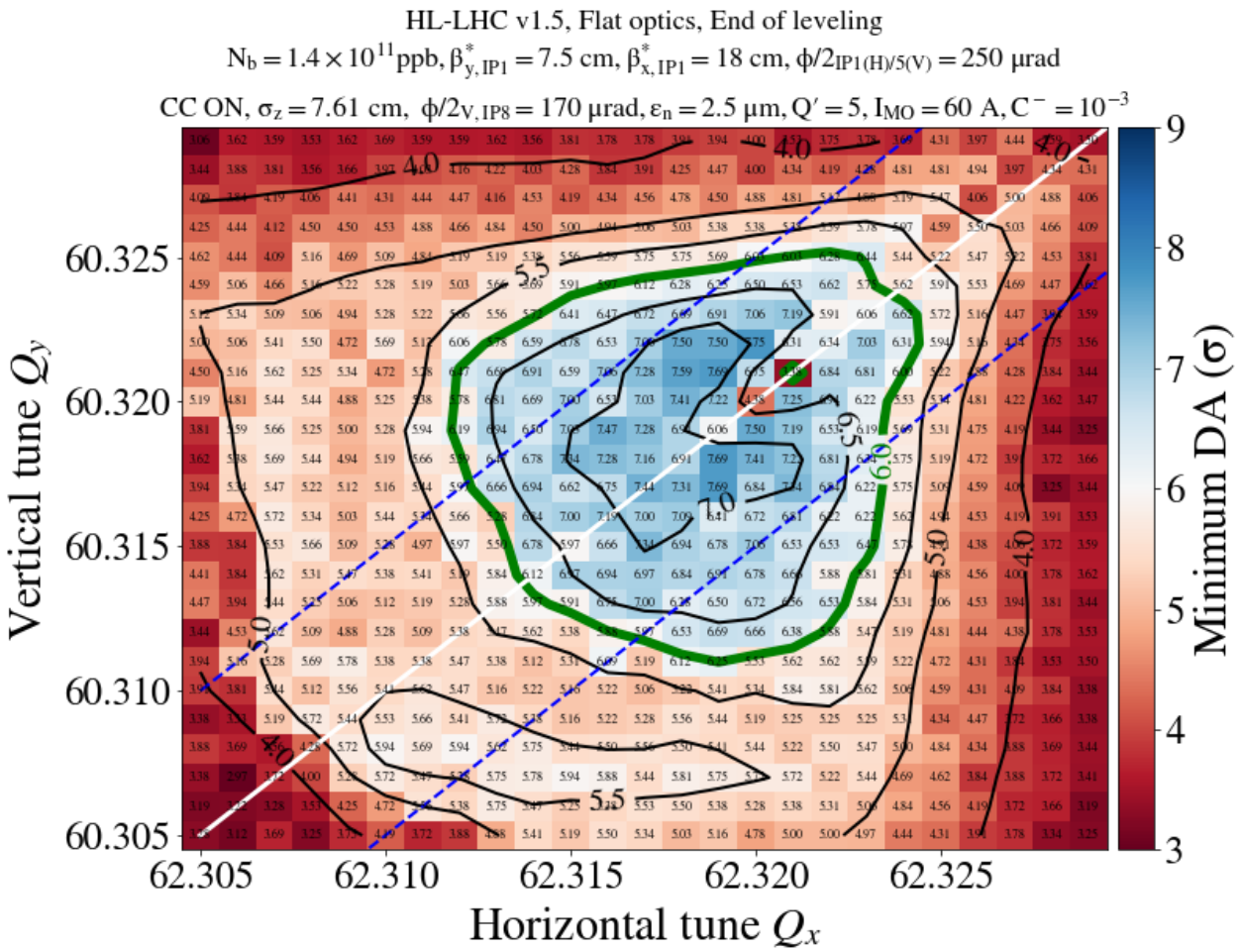
Filling scheme:
8b4e_1972b_1960_1178_1886_224bpi_12inj_800ns_bs200ns.csv

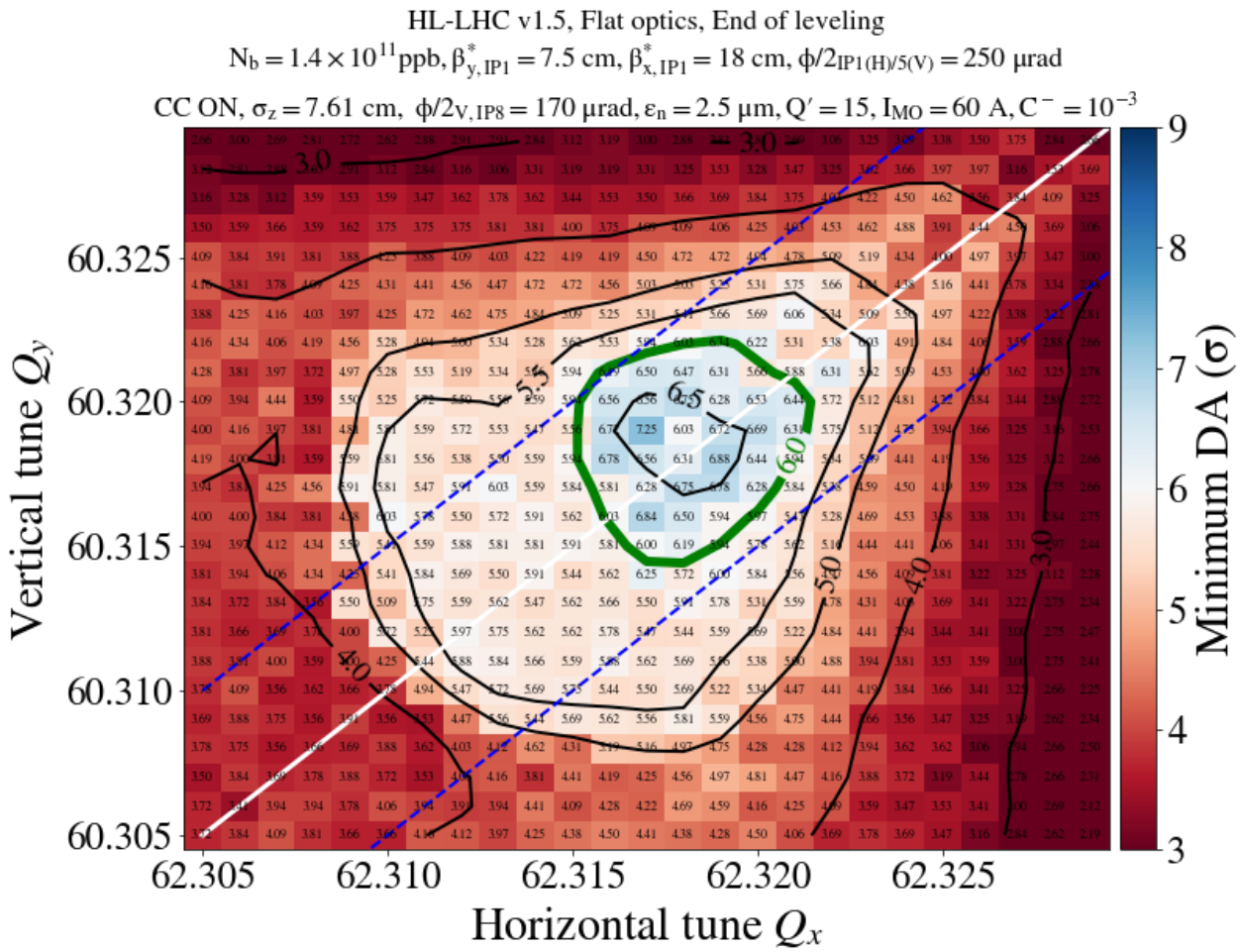
Filling pattern computed using https://github.com/PyCOMPLETE/FillingPatterns





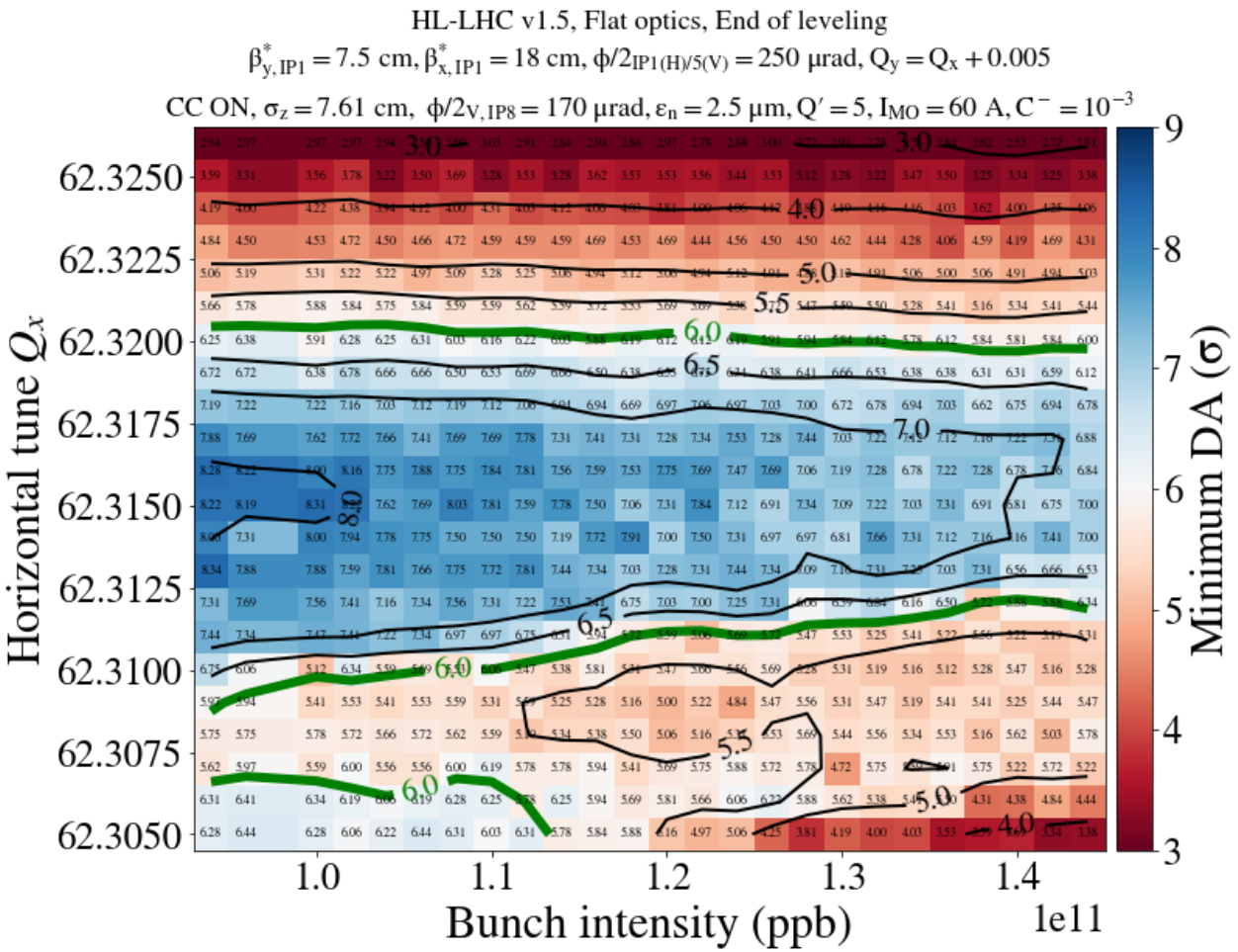
Tunescan chroma 5 vs 15

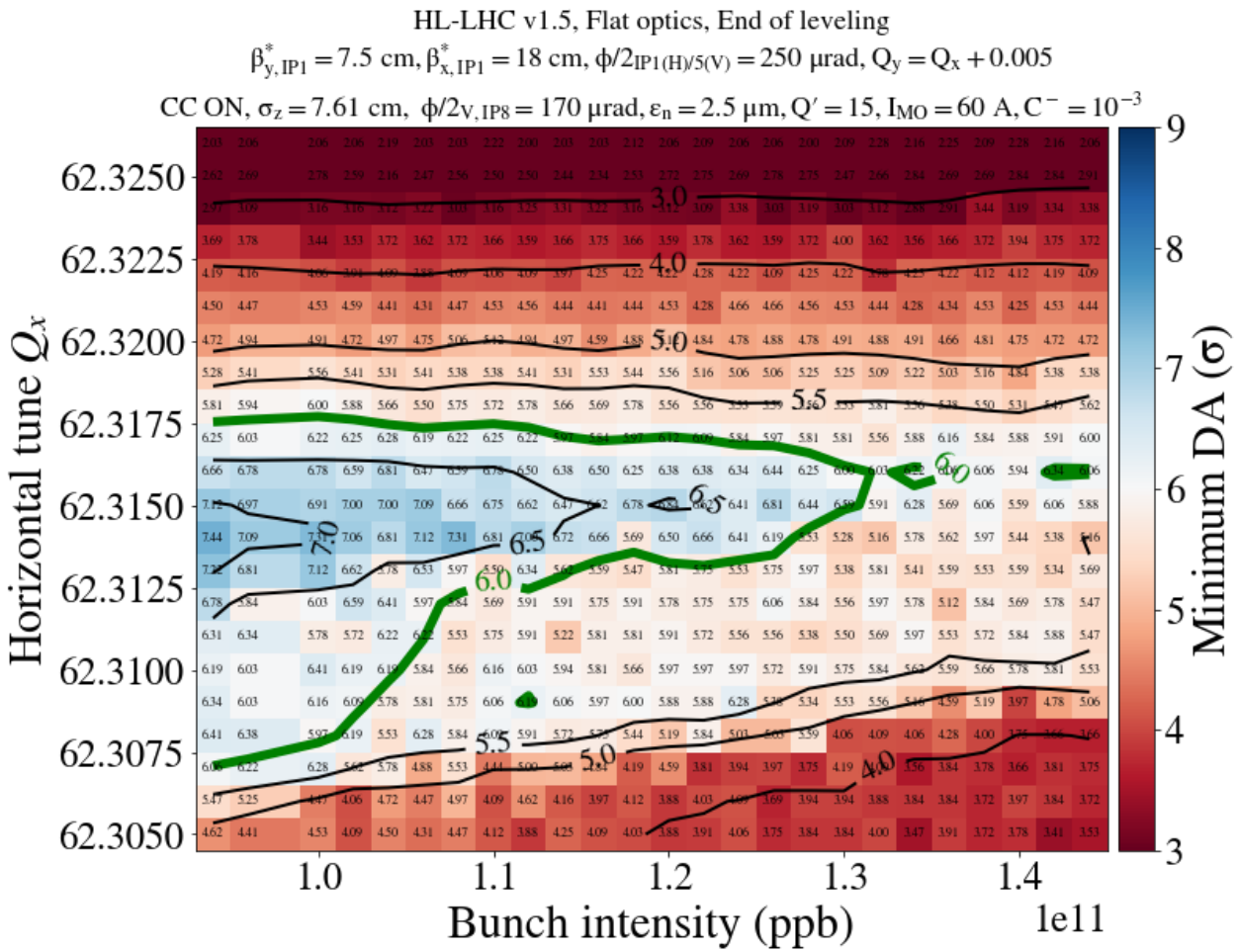




- DA target easily reached with chroma 15 and 1.4e11 ppb, marginally reached with chroma 15.
- Loosing 1 σ DA when going from 5 to 15 chroma.

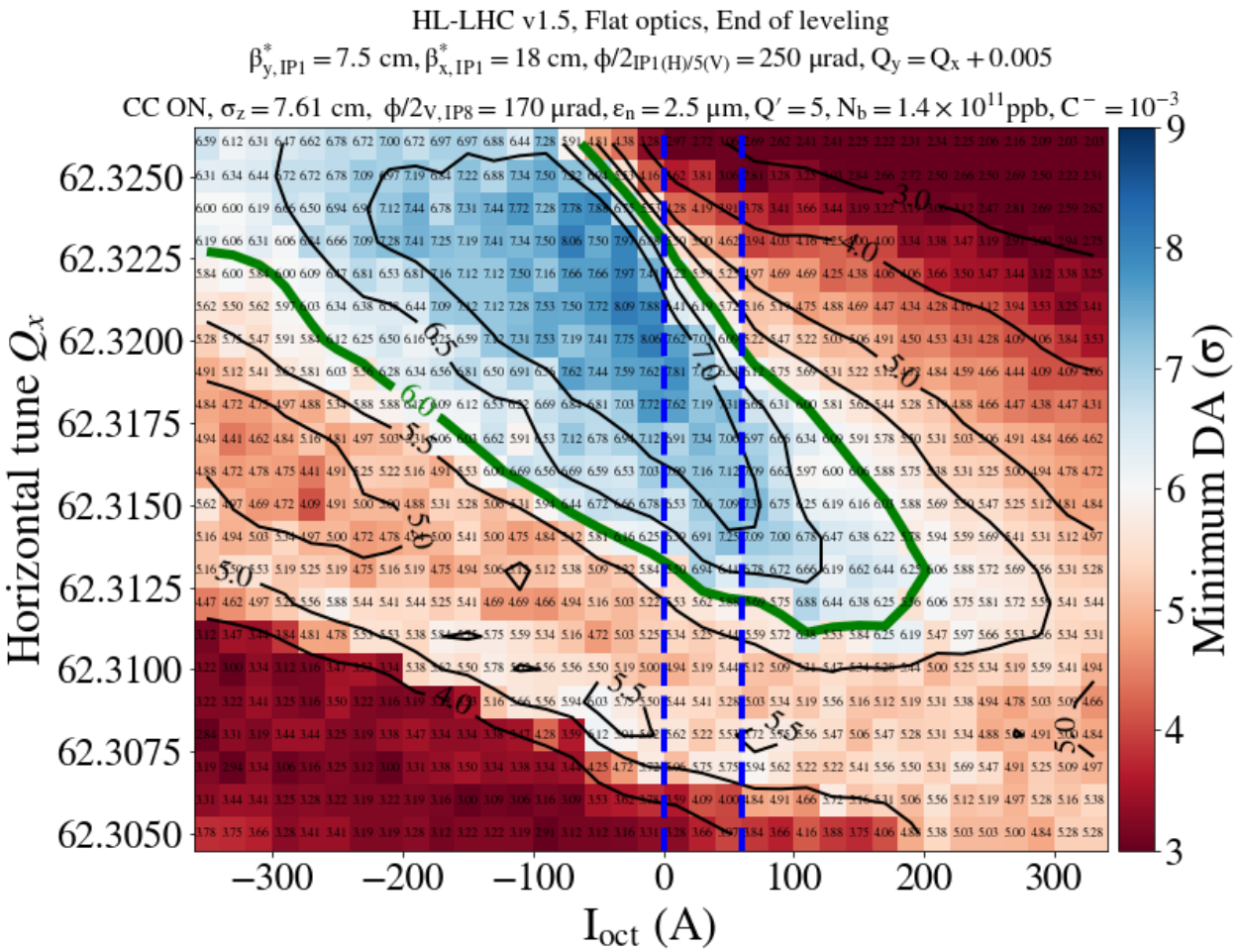
Bunch intensity vs WP for chroma 5 vs 15

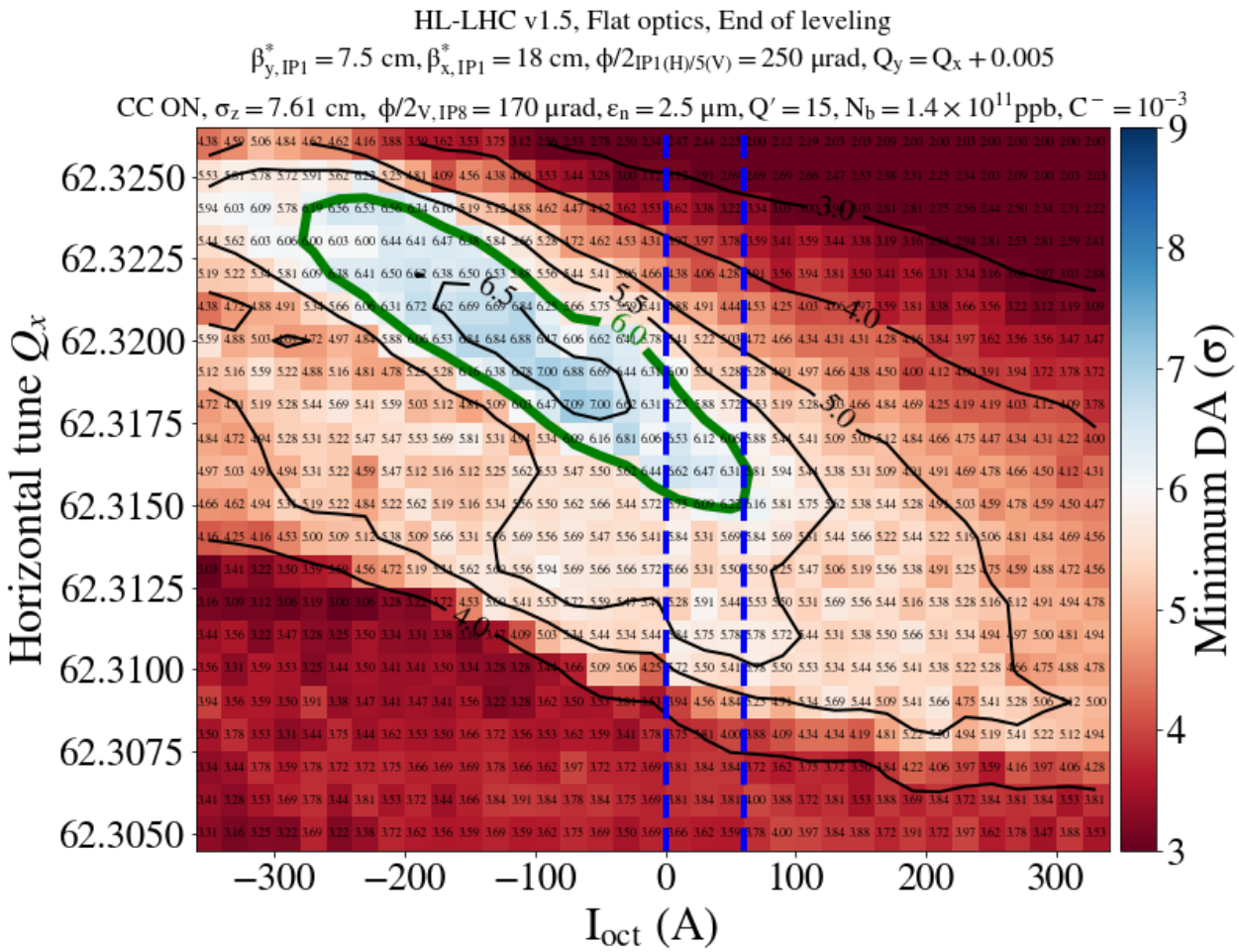




- Bunch intensity even > 1.4e11 ppb with chroma of 5.
- 1.4e11 ppb is the limit for chroma 15.

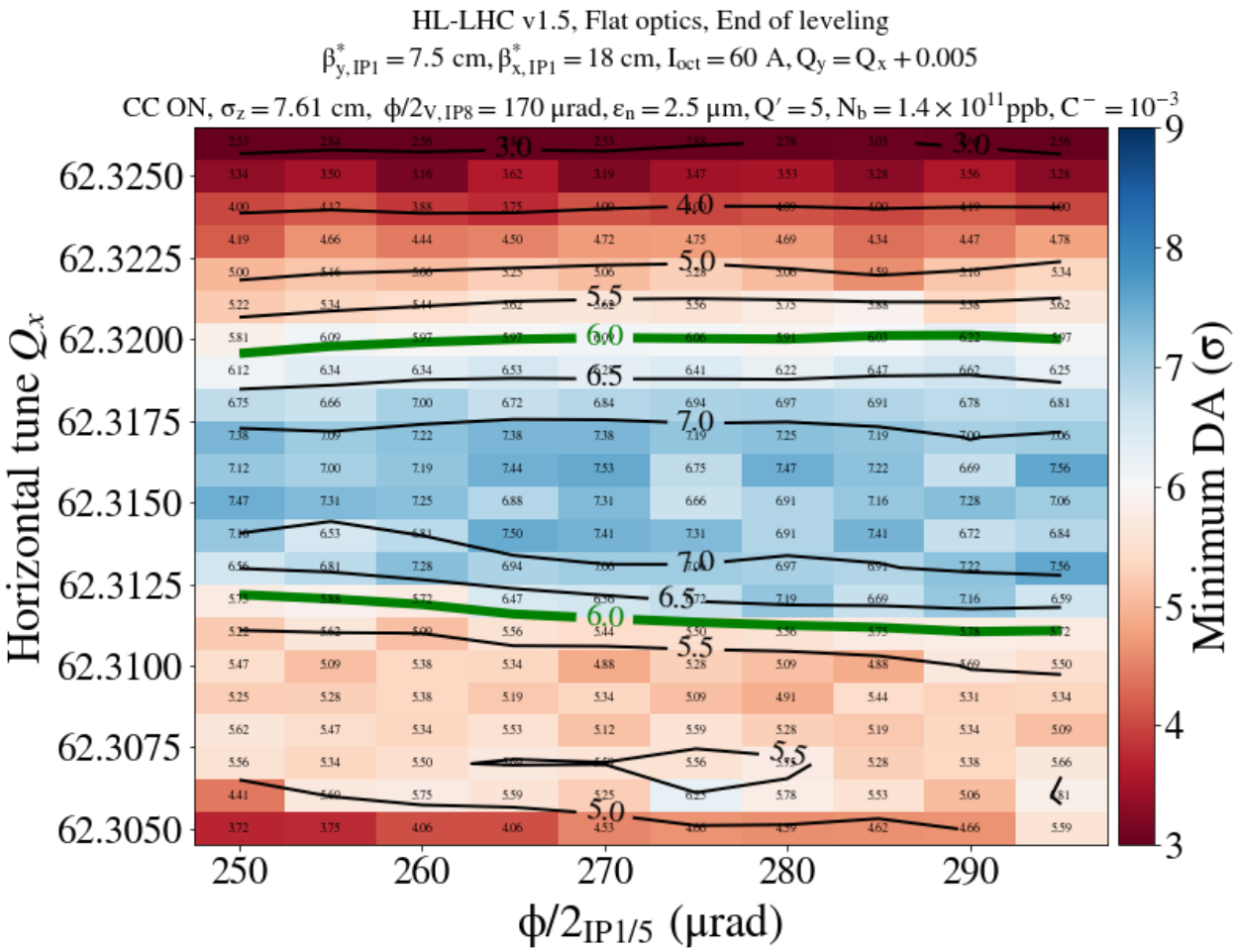
Octupoles vs WP for chroma 5 vs 15

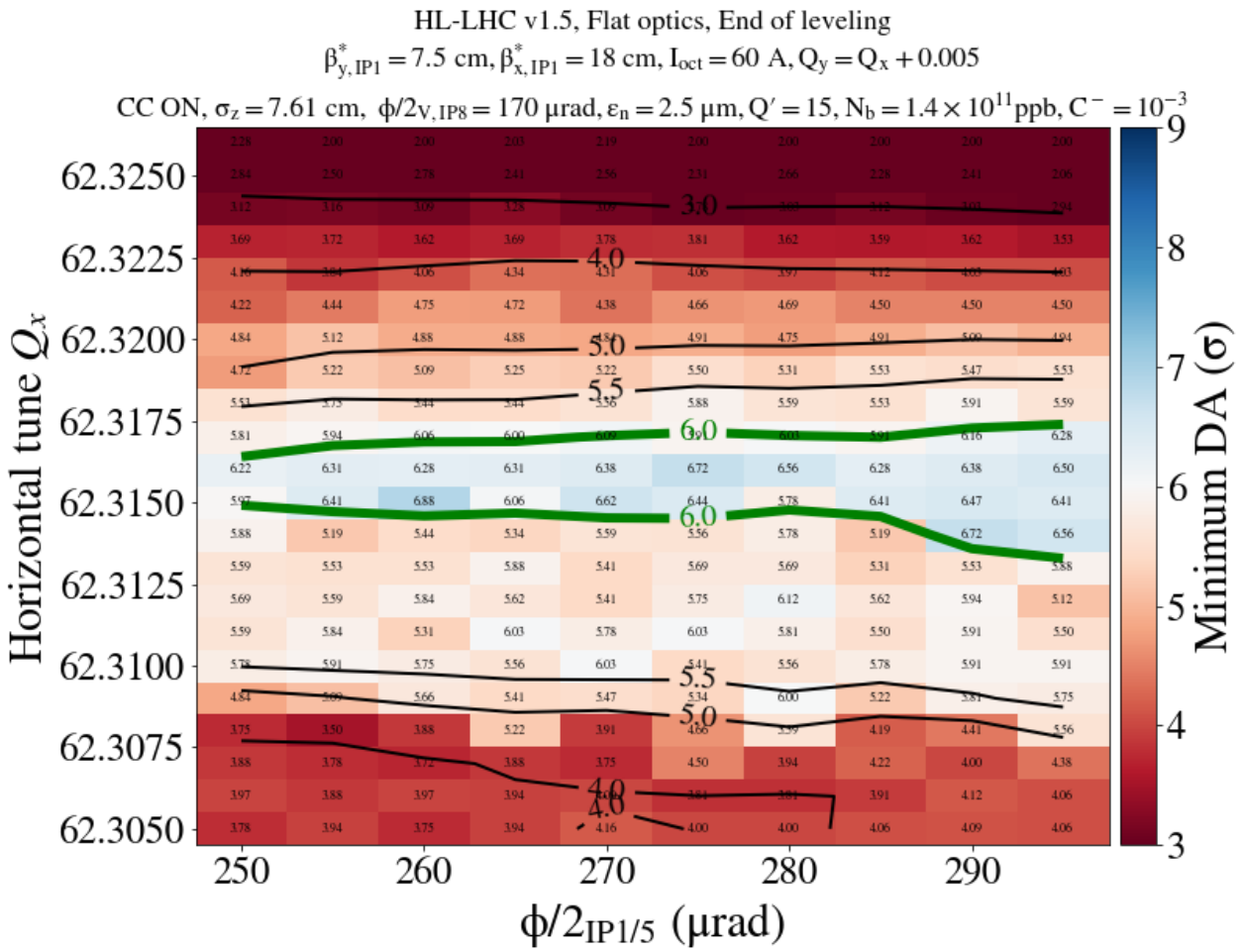




- Clearly shows beneficial impact of octupole polarity reversal (up to -350 for chroma 5, -330 for chroma 15).

Crossing angle vs WP for chroma 5 vs 15

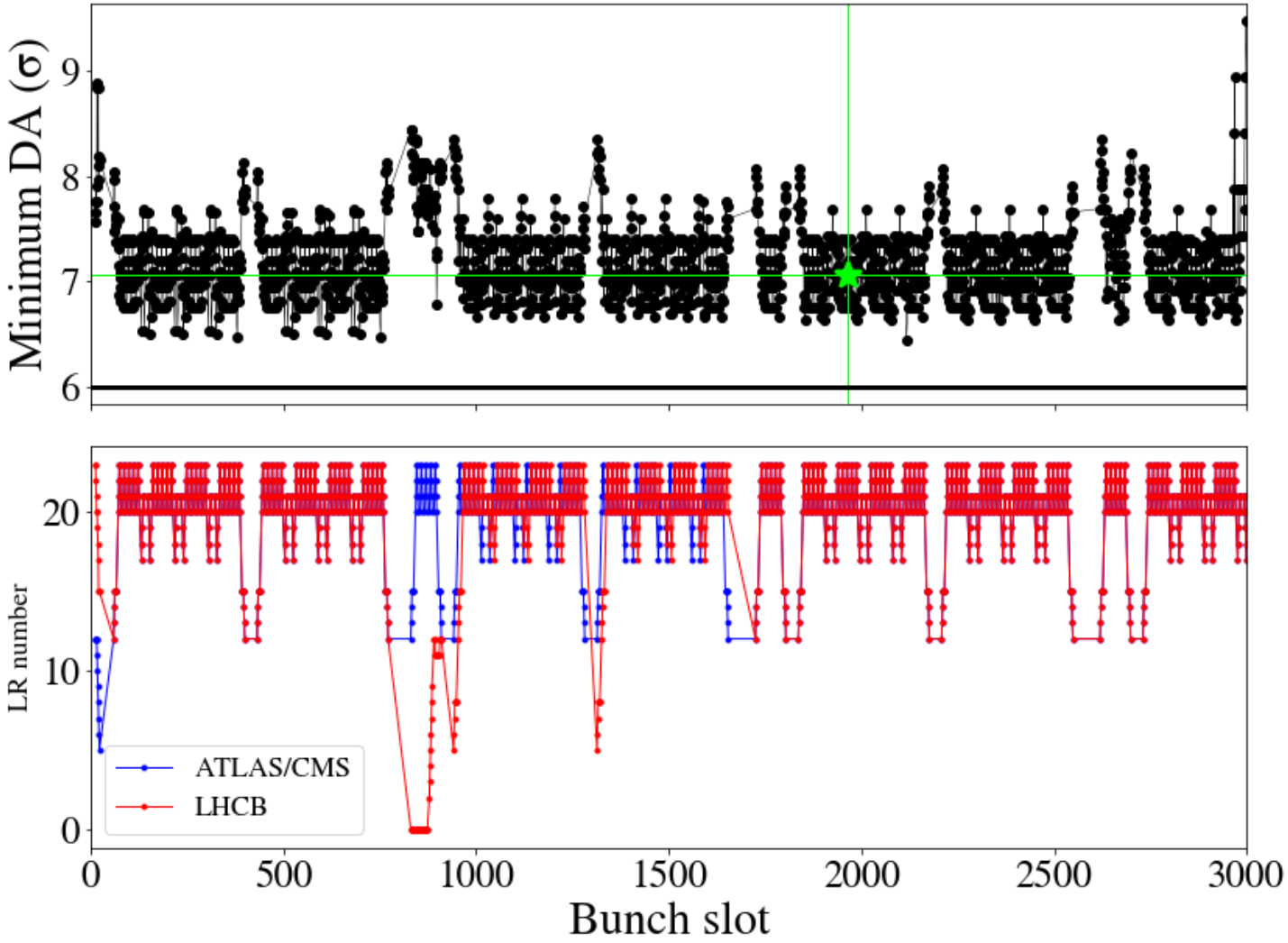




- No significant improvement

Bunch-by-bunch DA variations

- Goal is to simulate each bunch with its exact number of BB encounters to see the DA bbb flunctuations.
- Best approach would be to scan the diagonal as a function of the bunch slot.
- However, scanning only 1 WP is already ~30 K jobs!
- Shows that we are not actually simulating the worst bunch in terms of DA.
- Nevertheless, worst bunch DA is above 6.5 σ & within 0.5 σ from DA of bunch that we are simulating.
- Since DA bbb variations appear to be periodic, we could focus on specific trains and scan the diagonal to see if this 0.5 σ deviation holds for several WP.



Conclusions

End of leveling with 7.5/18 cm:

- 1.4e11 ppb, 60 A, 250 μrad, 60 A, chroma 5: DA target is easily achieved.
- 1.4e11 ppb, 60 A, 250 μrad, 60 A, chroma 15: DA target is marginally reached.
- Important impact of chromaticity from 5 to 15 (loss of 1 σ DA).
- Octupole reversal polarity looks very promising: up to -350 A for chroma 5 and -330 A for chroma 15.
- No significant improvement when increasing crossing angle from 500 to 590 μrad.

➢ Overall, reducing chroma with 8b4e and switching to negative octupole polarity are both powerful approaches to improve the DA, not the case with crossing angle increase (within the acceptable range).

- Bunch-by-bunch DA variations: not actually simulating the worst bunch in terms of DA. Nevertheless, all bbb DA above 6.5 σ and within 0.5 σ from bunch that we are simulating.

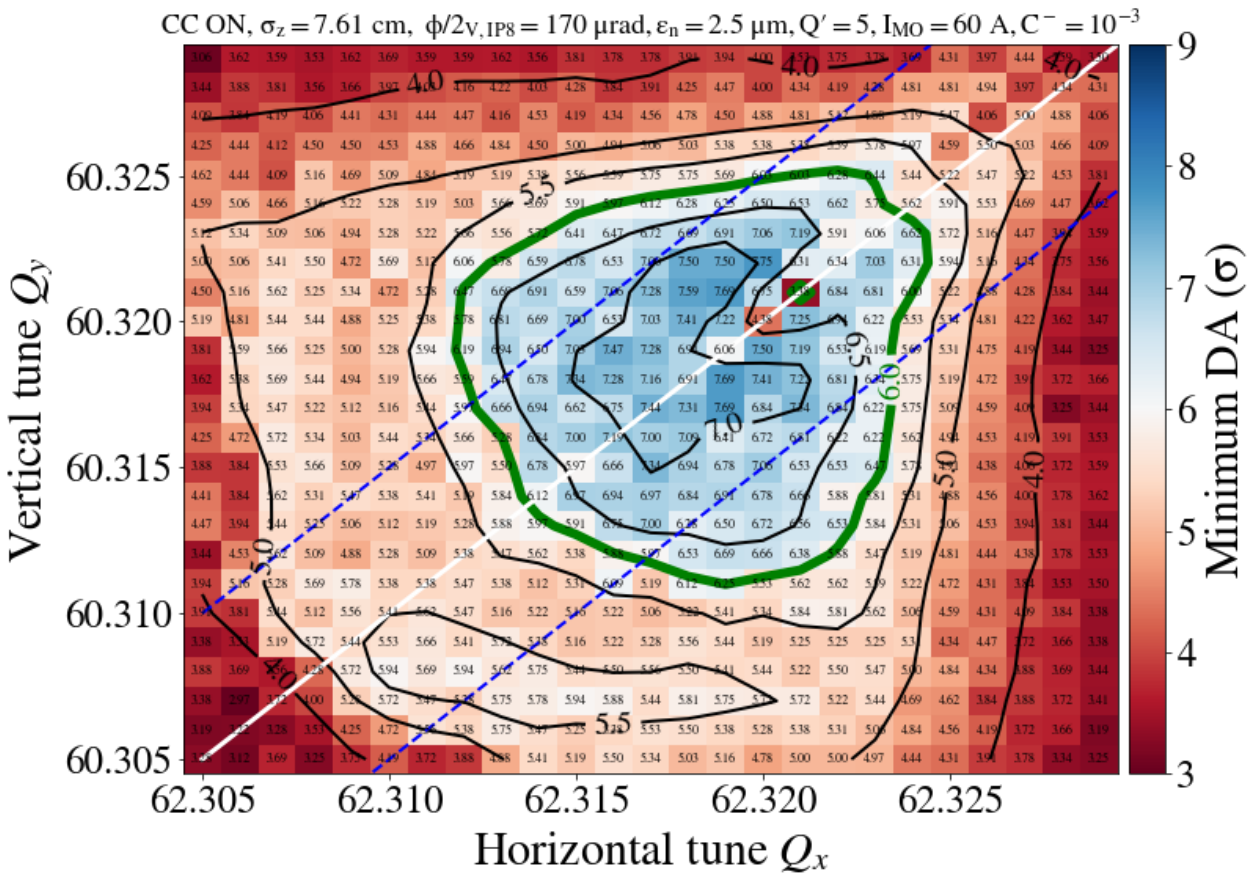
Next steps

- End of leveling:
  - Including the wire.
  - Optics with β^*=9/18 cm.
- Start of leveling with existing optics 0.5/1m:
  - Include realistic 8b4e filling scheme.
  - Sensitivity to chromaticity, crossing angle, octupoles with 2.3e11 ppb .
  - Can we operate with 2.5e11 ppb & 8b4e?
  - Test other optics such as 0.5/2 m and 1/2 m (2m needed for CC- input from Riccardo).
- Further insights on bbb DA variation: More detailed studies are needed to further understand bbb DA variations. Would also be very interesting to compare bbb DA variations with experimental bbb losses.

Backup

Tunescan chroma 5 vs 15

Bunch 1963



Bunch 2116