Update on the operational scenario taking into account of the constraints on coupling and non-linear optics corrections

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WP2 meeting – 17.09.2019

Content

- Coherent stability requirements
- Dynamic aperture requirements
- Intensity limit and possible mitigation

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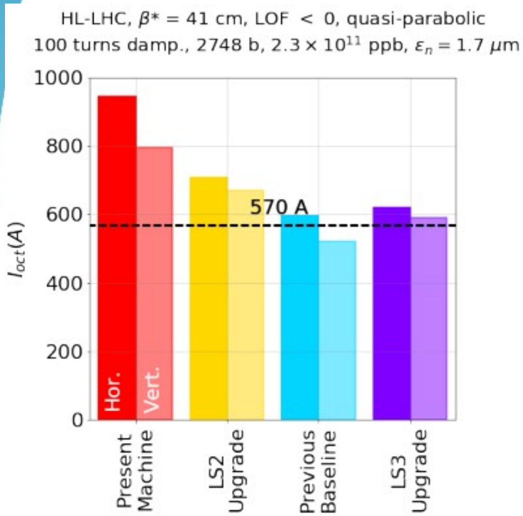
Assumptions to estimate Landau damping

- The stability diagram is dominated by the effect of sextupoles, octupoles and beam-beam interactions obtained with MAD-X *thintrack* without errors
- The *static stability* is ensured if the diagram includes at least 2 times the estimated complex tune shifts driven by the impedance
- The 6D distribution is Gaussian
  - tails are cut at 3 beam σ in the transverse plane
- The *static stability* should be ensured at every step of the cycle (even dynamic ones)
- **Sufficient margin in the arc octupoles strength should be left to compensate for potential uncorrected coupling and lattice errors**

One-beam vs two-beam stability threshold (E. Métral @ Coll. Review, 11 Feb. 2019)



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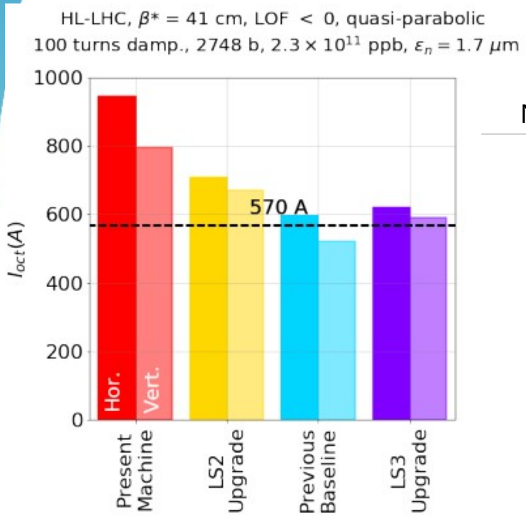
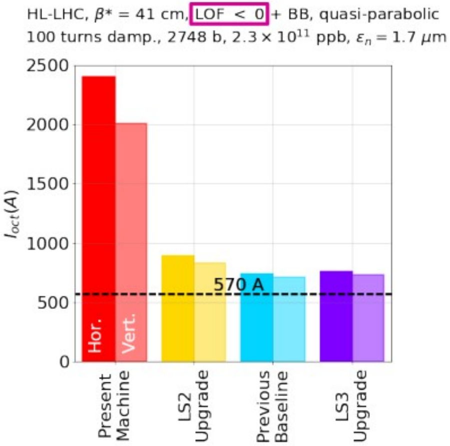


2 beams
Negative polarity

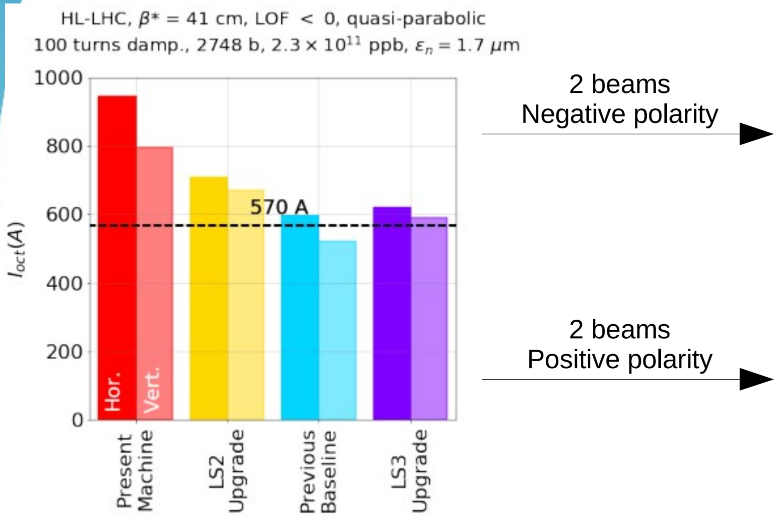


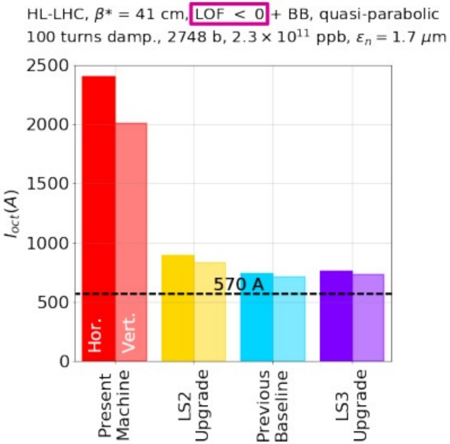
- Beam-beam effects during the collapse of the separation bumps significantly increase the need for octupole strength

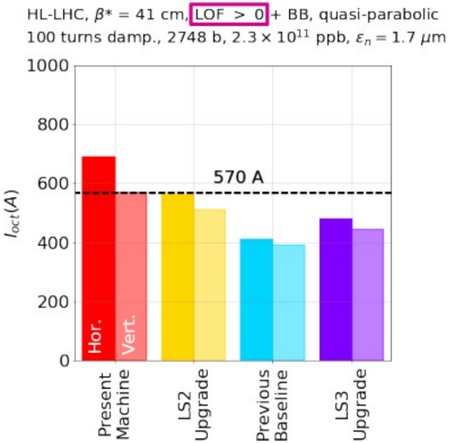
  → A telescopic optics is needed already at the end of the ramp

  → Collapsing the separation in a single IP at first is beneficial

One-beam vs two-beam stability threshold (E. Métral @ Coll. Review, 11 Feb. 2019)







- Beam-beam effects during the collapse of the separation bumps significantly increase the need for octupole strength

  → A telescopic optics is needed already at the end of the ramp

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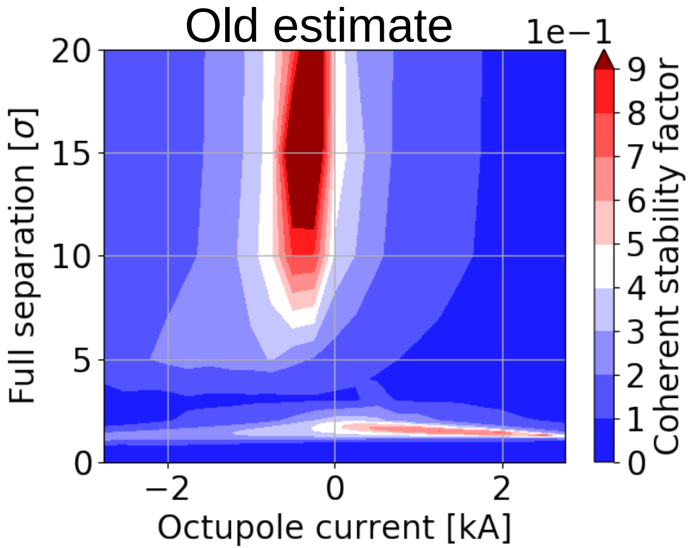
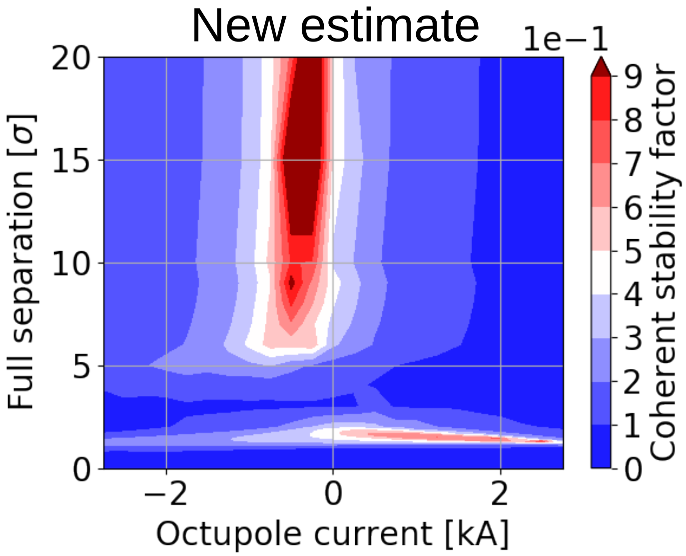
- Beam-beam effects are overall favourable for beam stability

Static vs transient stability during ADJUST





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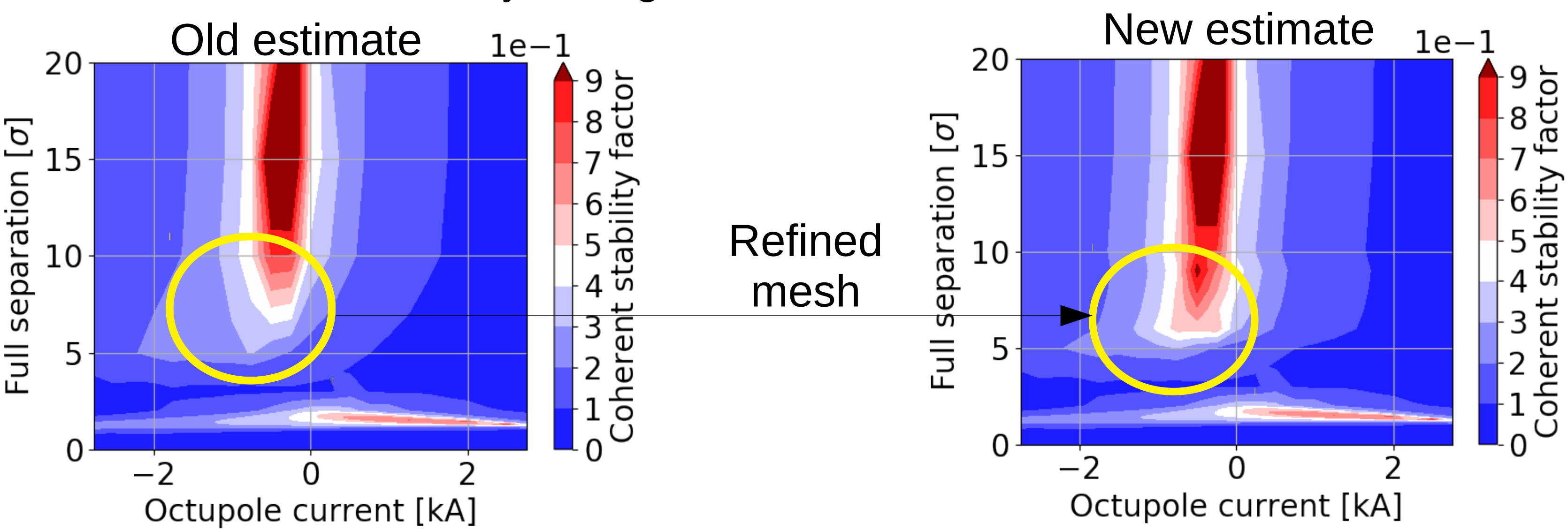

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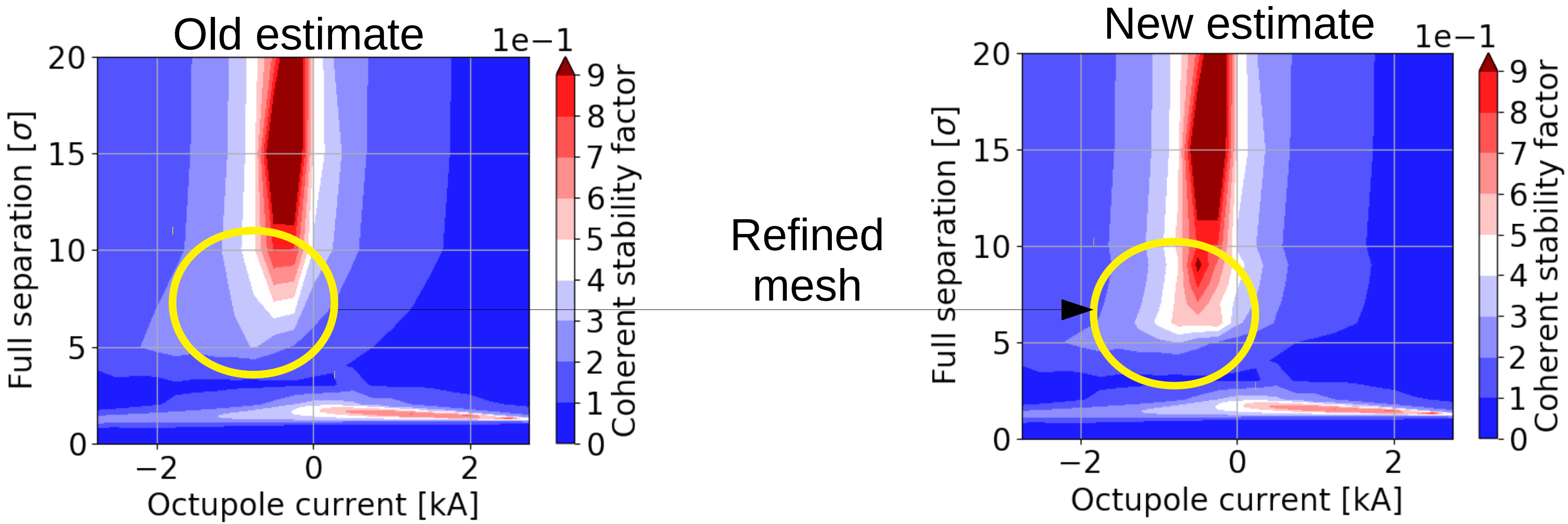
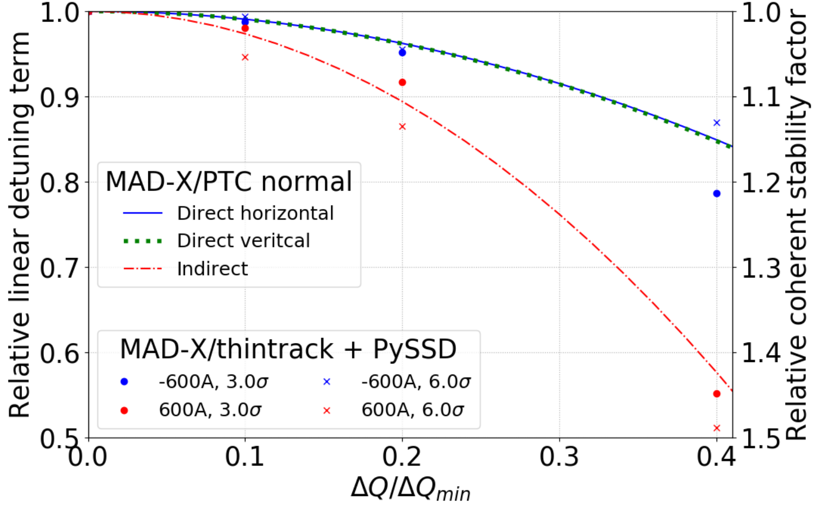


- The octupole requirement is dominated by short transient phases during the collapse of the separation bumps
  - Challenging numerically → New estimates with finer mesh
  - The collimator upgrade reduces significantly the instability rise growth rate to (3 to 12s), such that transient instabilities may not be critical

    → Decided to maintain this criterion for operational robustness (e.g. orbit drift)

The impact of linear coupling



- A residual $\Delta Q_{min} \sim 10^{-3}$ should be expected after optics correction
- The effect of linear coupling is worse for the positive polarity of the octupoles as it affects mostly the indirect detuning term
  - The impact of ADECTA on Landau damping is negligible in this regime

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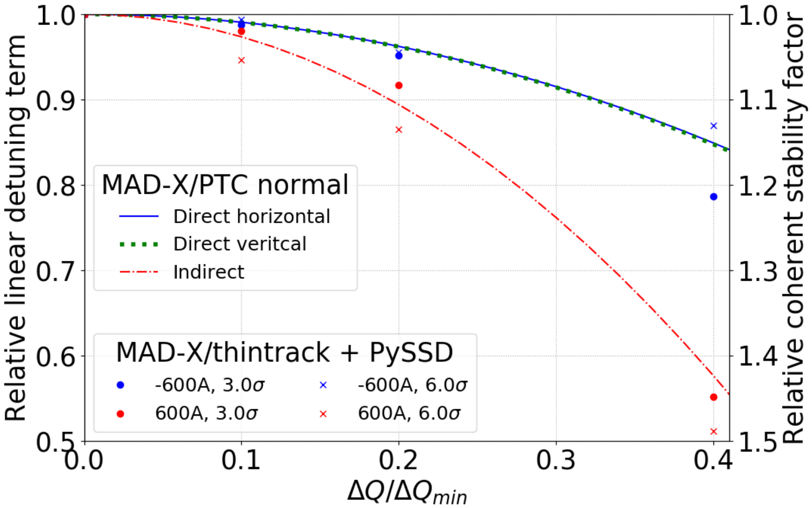
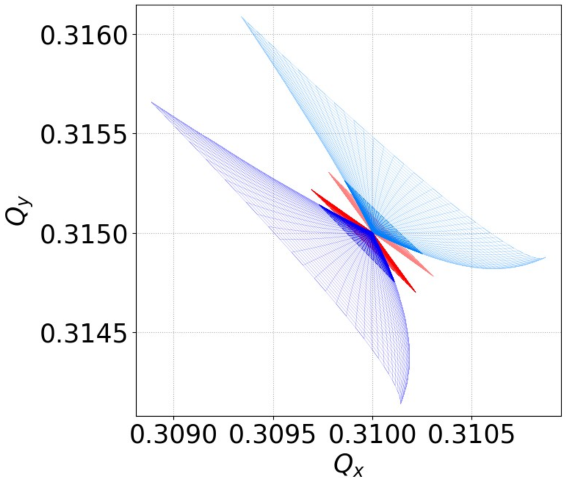
The impact of linear coupling





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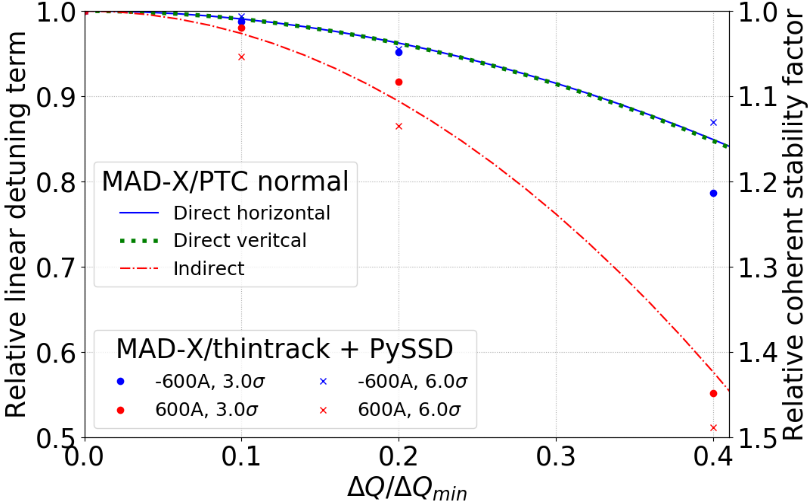

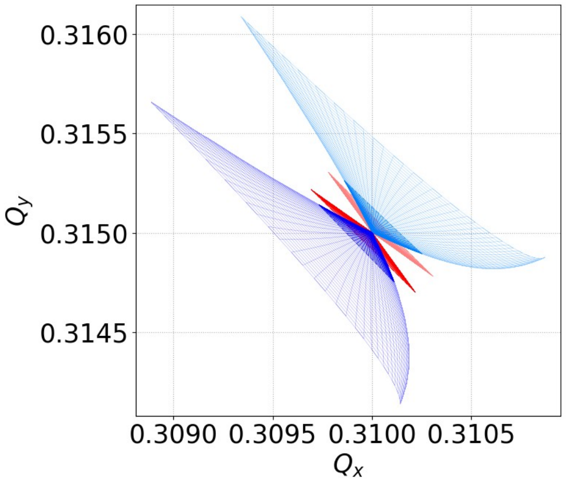

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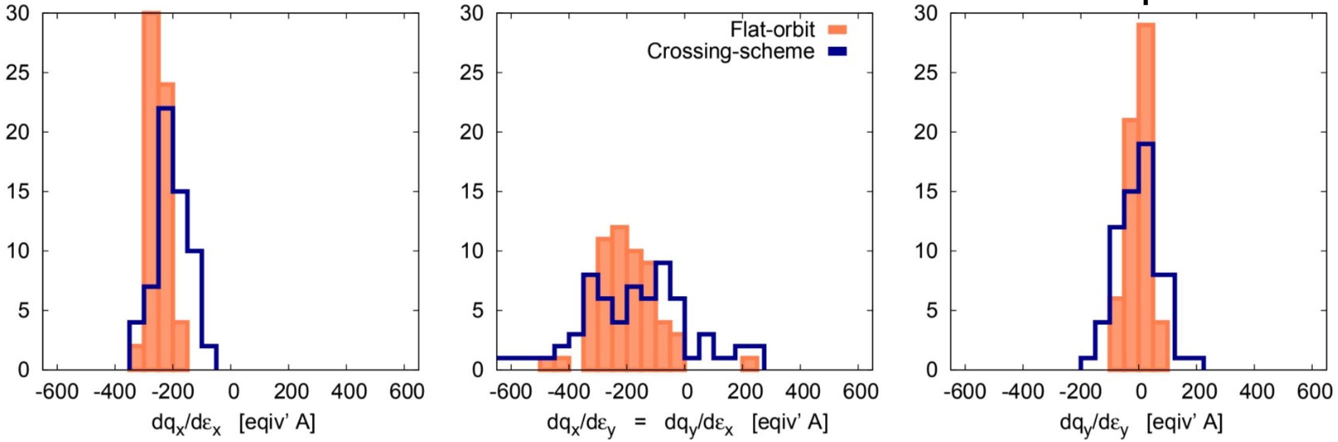
- The effect of linear coupling is worse for the positive polarity of the octupoles as it affects mostly the indirect detuning term
  - The impact of ADECTA on Landau damping is negligible in this regime
- **We need an understanding of the maximum tune separation to quantify the effect on the beam stability**
  - Let's assume that we are at constrained 10^{-2} before collision and $5 \cdot 10^{-3}$ in collision

The impact of lattice non-linearities (E. Maclean)

β*=15cm



- Using the full WISE model and including beam-based local correction of b4 as well as feed-down from a5, b5, a6 and b6 we can obtain the maximum reduction of the detuning coefficients and the required arc octupole current to restore Landau damping :

	Negative polarity	Positive Polarity
64cm	14 A	-24 A
41cm	34 A	-51 A

Setup proposal

	$I_{oct} > 0$		$I_{oct} < 0$	
	I_{oct} [A]	r_{ATS}	I_{oct} [A]	r_{ATS}
LS2	518	1.5	-535	2.4
Full	410	1.0	-538	2.0

- The setup proposal feature a larger telescopic index and a reduced octupole current lower than the maximum (±570A), to allow for compensation of the potential detrimental effect of linear coupling and lattice NL
- Pessimistically, we require a sufficient dynamic aperture with the full current in the octupoles and the required telescopic index

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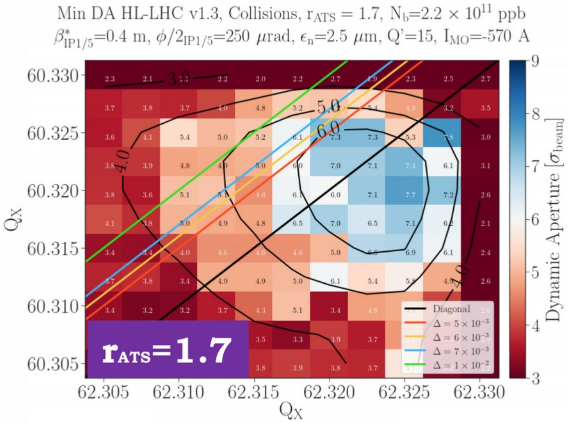
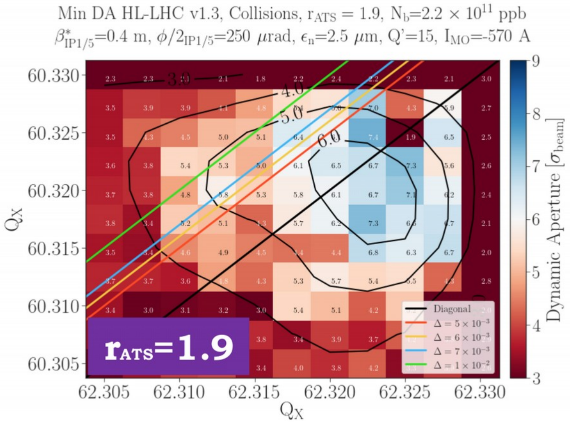
*Not compatible with full brightness non-colliding bunches

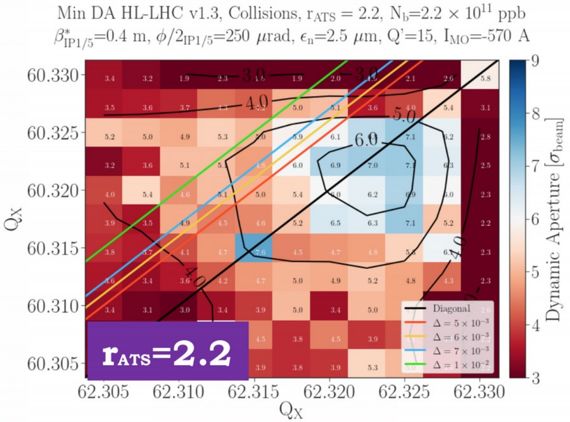
Assumptions for DA simulations

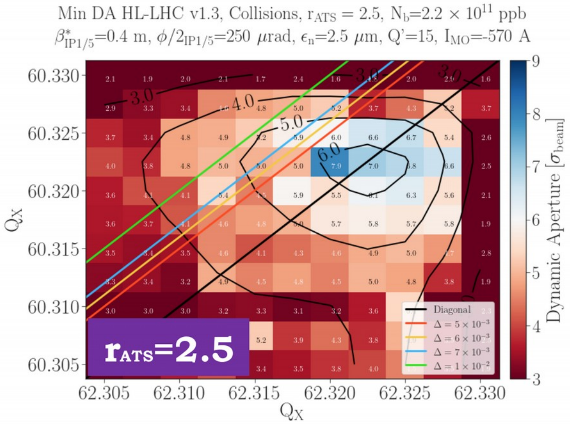
- The design criterion is a DA above 6 beam σ (2.5 μm) for particles with $\Delta P/P_0=10^{-4}$ in collision, excluding lattice errors
  - Note : for stability considerations we consider the smallest emittance, i.e. 1.7 μm
- All beam-beam interactions are considered, including crabbing in IPs 1 and 5 and offset levelling in IPs 2 and 8
- Chromaticity is maintained at 15 units in collision

β* = 0.4 m , I_MO = -570 A



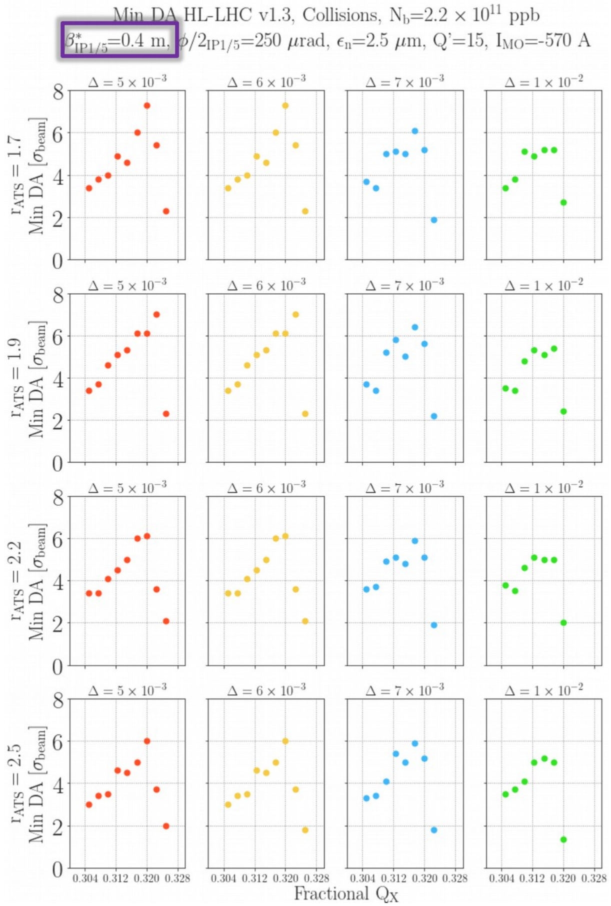






Dynamic aperture for a fixed tune separation – negative polarity

- All configurations require a tune control better than 10^{-3}



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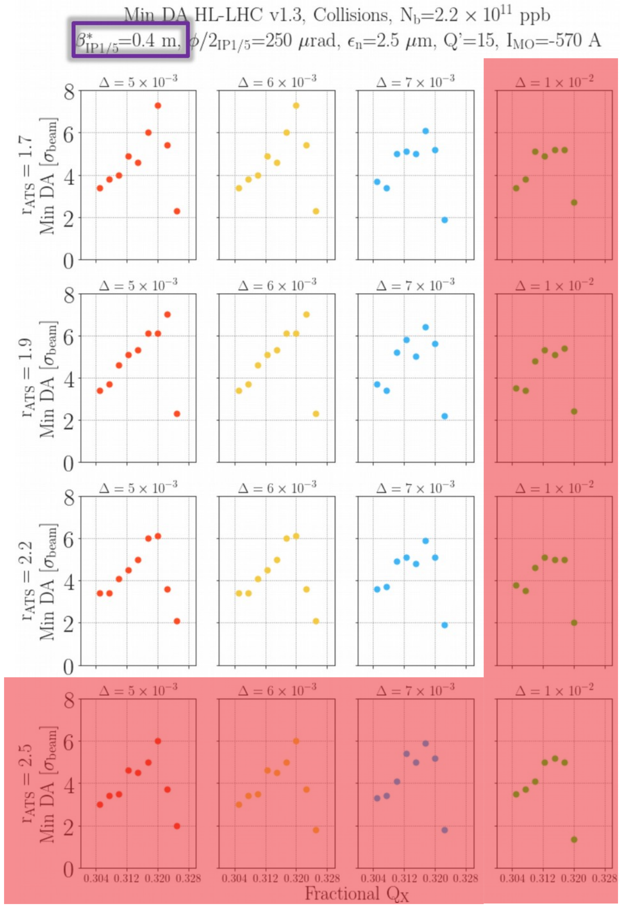

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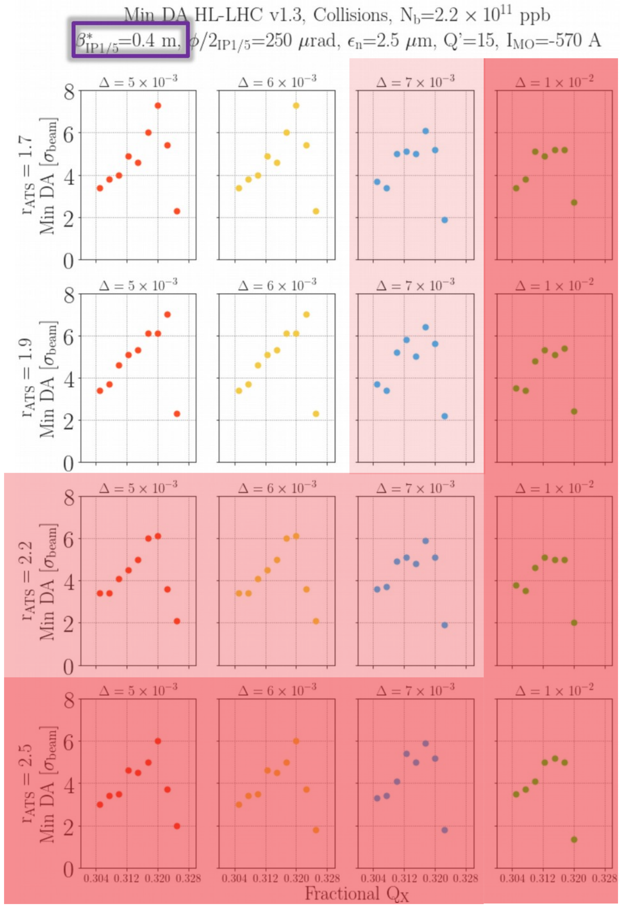

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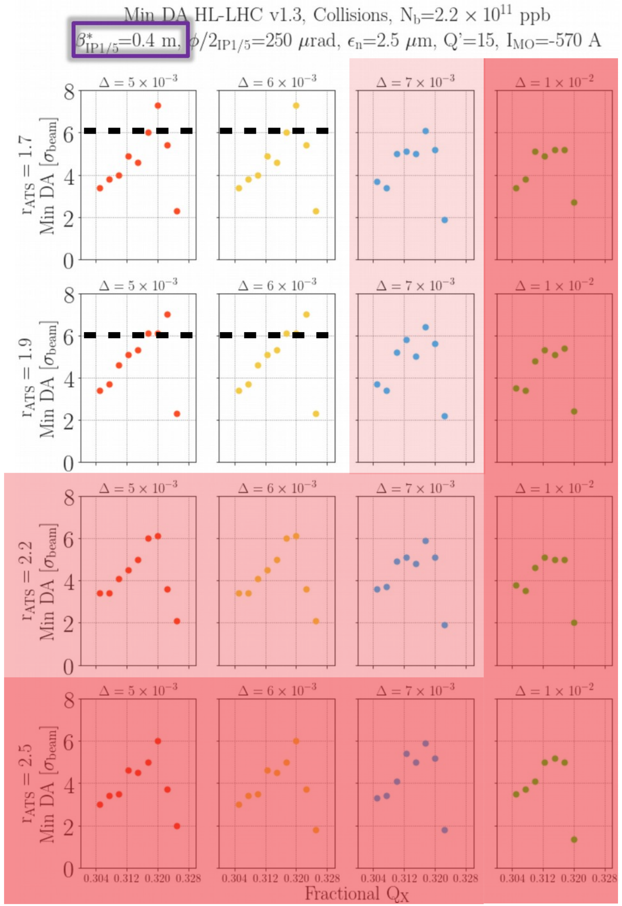

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$I_{oct} < 0$

	I_{oct} [A]	r_{ATS}
LS2	-535	2.4
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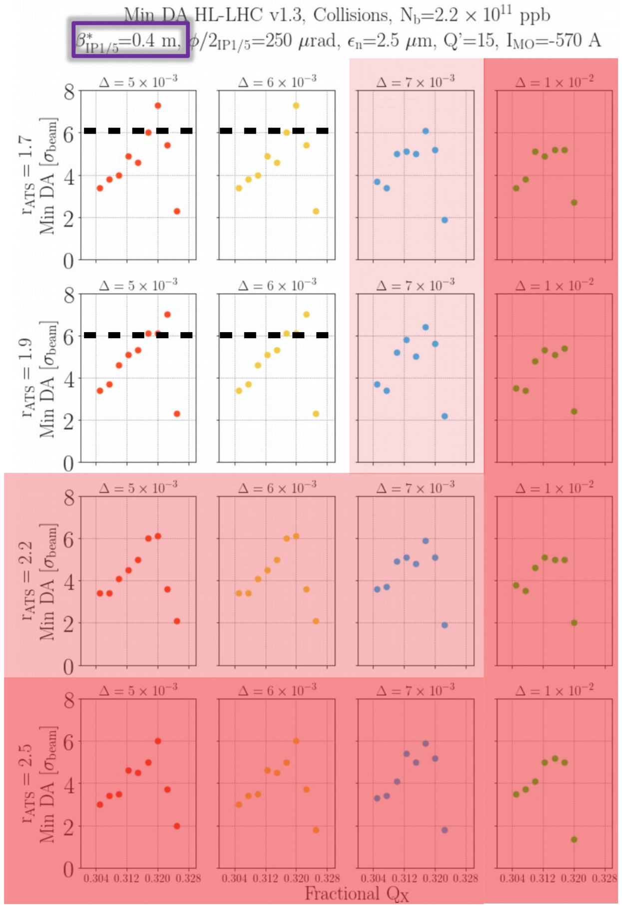
- The stability requirement with the LS2 upgrade only are out of reach



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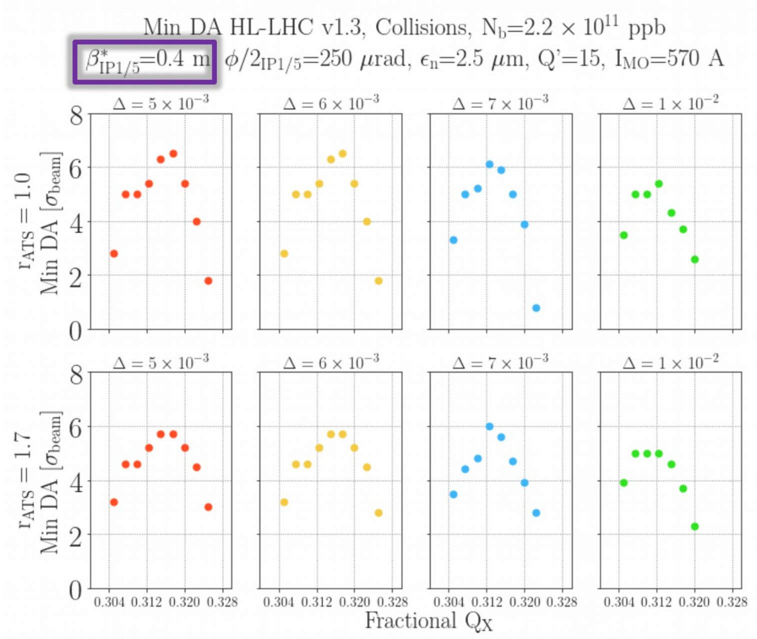

Dynamic aperture for a fixed tune separation – positive polarity

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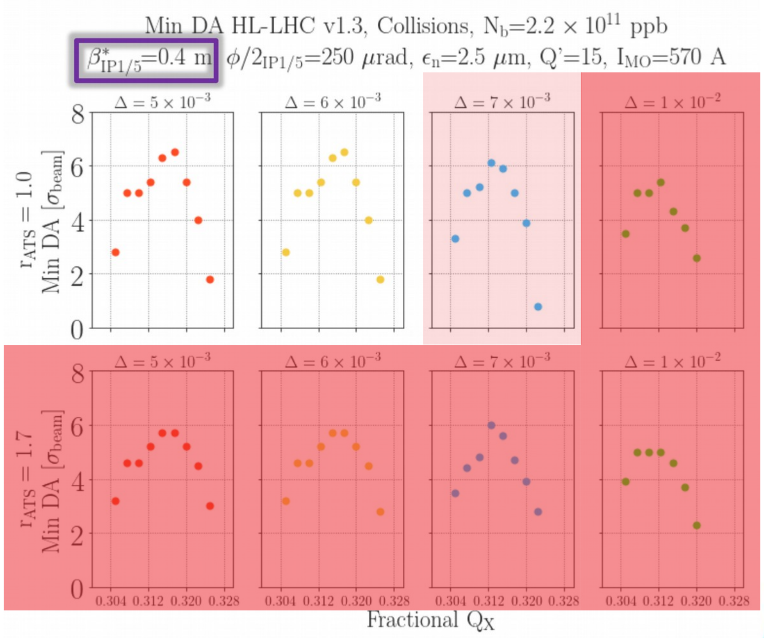

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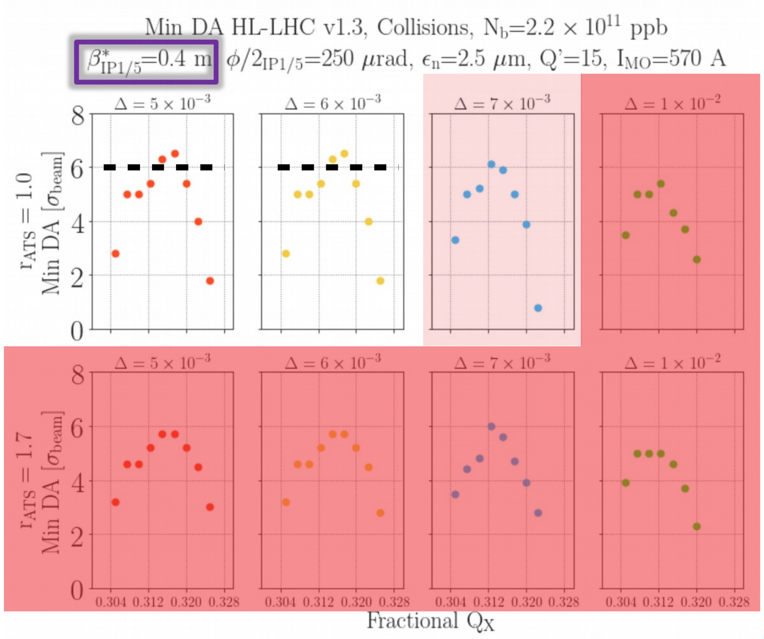


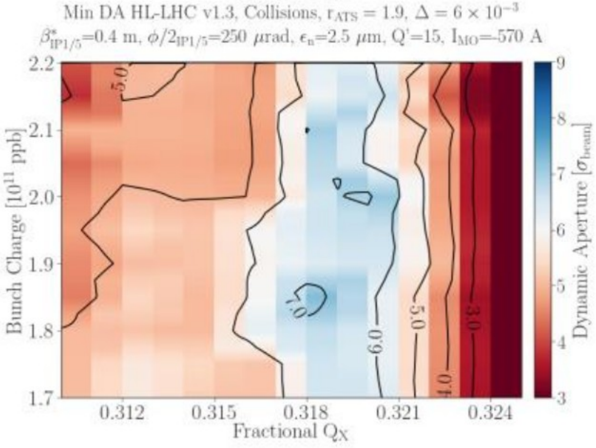
Summary

- With either polarity of the octupoles, we seem cornered by the coherent stability and dynamic aperture requirements during the collapse of the separation bump, **even with the full collimator upgrade**
- Several imperfections may result in unacceptable reduction of DA or Landau damping, thus leading to a bunch intensity limit below the design $2.3 \cdot 10^{11}$, such as:
  - Coupling imperfections that are not yet included in DA simulations
  - Offsets at the IP due PACMAN orbit effect with bunch-by-bunch intensity variations (To be studied)
  - Breaking of the passive compensation of PACMAN tune shift due to orbit misalignments in the IR (To be studied)
  - PACMAN linear coupling
- We may consider the following mitigations :
  - → Review the PHYSICS beam process
  - → Reduce further the impedance (e.g. relaxing collimator settings)
  - → Accept transient unstable configurations and the underlying reduction of tolerance to fill-to-fill orbit drifts

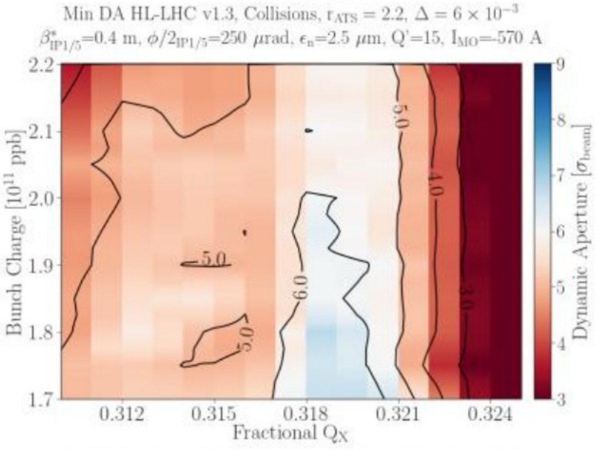
Tentative estimate of the intensity limit linked to the collimator upgrade

Δ=6e-3

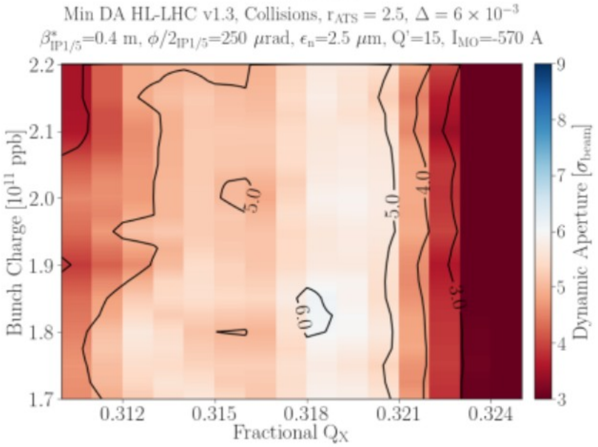
r_{ATS} = 1.9



r_{ATS} = 2.2



r_{ATS} = 2.5



- The scaling of DA with intensity is rather weak, if we neglect it, **assuming that 2.0 is acceptable** (Full coll. upgrade) and use a rough linear scaling of the stability requirement with intensity, we find a bunch intensity limit at ~$1.8\cdot10^{11}$
- **This statement should be revised based on the improved beam process**

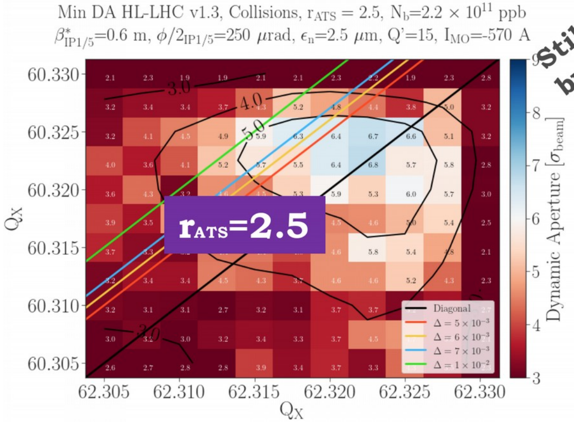
Example of reviewed beam process

- Collapse separation bump in IP 1 or 5 with the setup proposed (e.g. I_{oct} = -538 A and r_{ATS} = 2.0)
  - Determine optimal crab angle for DA during the collapse (absence of crabbing during the collapse is preferred for Landau damping)
- Reduce the octupole current and chromaticity to the non-colliding bunch stability limit (e.g. I_{oct} = -382 A and r_{ATS} = 2.0 and consider reducing their brightness if needed)
- Collapse separation bumps in the other IPs and enable crab cavities only once the conditions favourable for DA are established

→ Beneficial impact to be confirmed with DA simulations

Asynchronous Collapse & CC

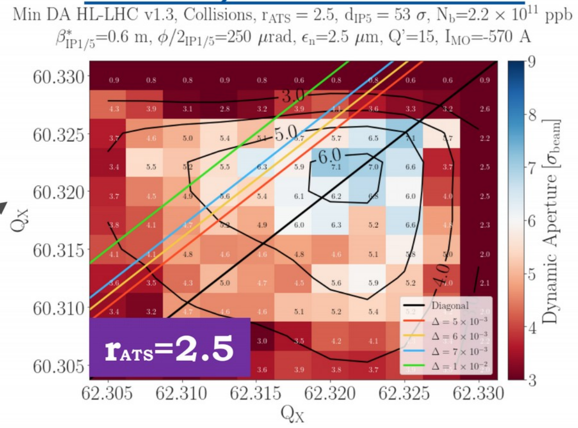
Both IPs HO & CC on



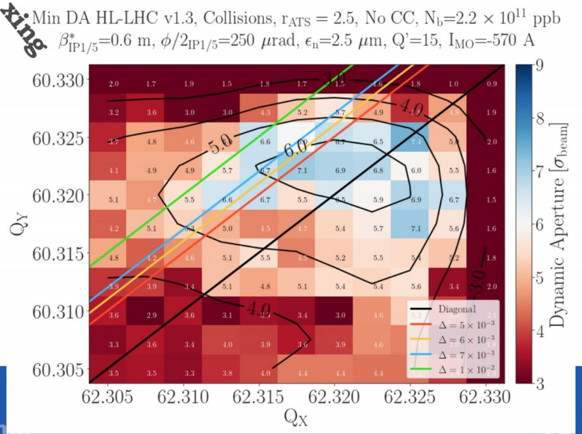
Still a bit tight, but almost +1σ in the worst case.

The increased xing opens up the available DA space.

IP1 HO, IP5 halo = 53 σ



Both IPs HO & CC off



- First results of DA simulations including an intermediate step with a single IP colliding or crab cavities off show promising results

Impedance reduction by retraction of collimators (S. Antipov @ todays' HSC meeting)

- A significant reduction of the stability requirement is obtained by retracting the entire collimator hirearchy by 1.5 σ
  - Feasability and stability requirement in adjust to be studied