Stability limits with the new operational scenario

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Updated stability limits

	CFC	Old baseline	Retracted β*=1.4m
Oct. thes. [A]	820	550	460
Equi. teleindex	2.3	1.0	1.0

(a) Positive polarity

	CFC	Old baseline	Retracted β=1.4m
Oct. thes. [A]	-2100	-1540	-1350
Equi. teleindex	3.6	2.9	2.7

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Table 1: Stabilising octupole current together with the teleindex required to reach the equivalent detuning coefficient when operating the octupoles at the maximum of their capacity.

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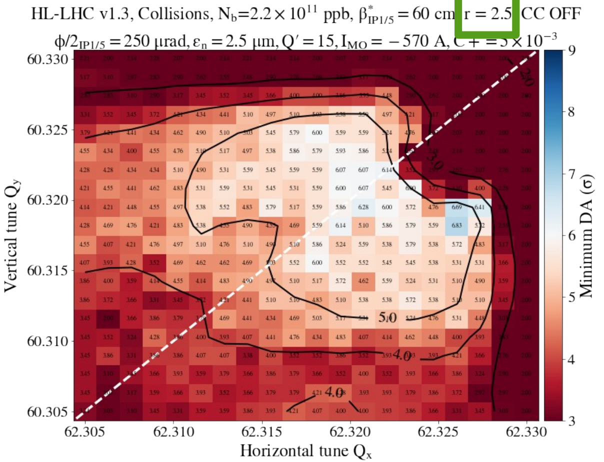

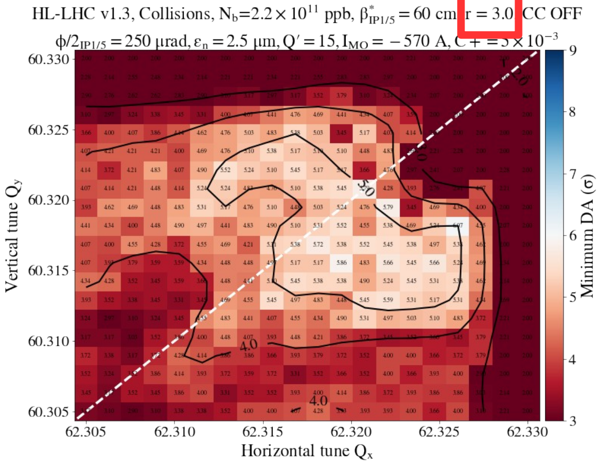

- It seems difficult to conciliate DA and stability requirement with the negative polarity, even with the new collimator settings

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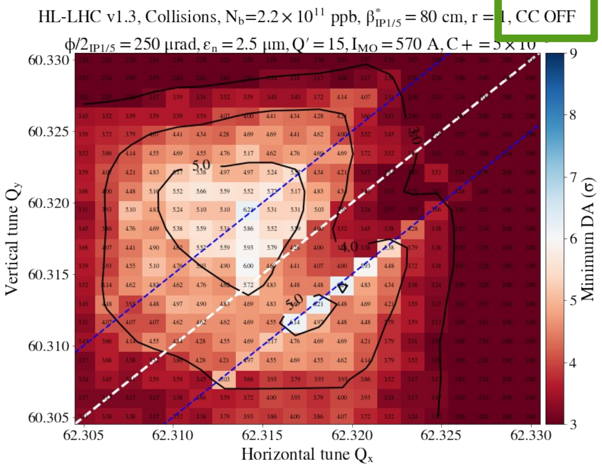

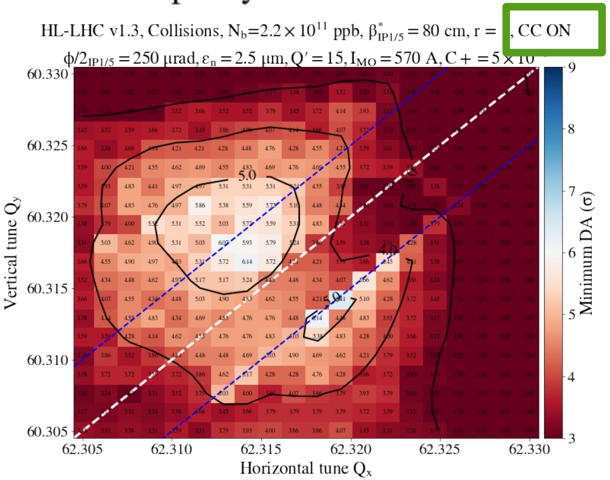

- The *old baseline* was at the edge in terms of DA. The new collimator settings

Why is HL-LHC much more critical than LHC with the negative polarity

- The old baseline settings of HL-LHC are *comparable* to LHC 2016 settings*, a simple scaling for the octupole threshold (single beam) yields :

$$200[A] \times \left(\frac{2.3 \cdot 10^{11}}{1 \cdot 10^{11}}\right)\left(\frac{2.0[\mu m]}{1.7[\mu m]}\right)\left(\frac{7[TeV]}{6.5[TeV]}\right) \approx 582[A]$$

*Coll settings (3.5 μm) in 2016 : 5.5 / 7.5
HL-LHC nominal : 5.67 / 7.68

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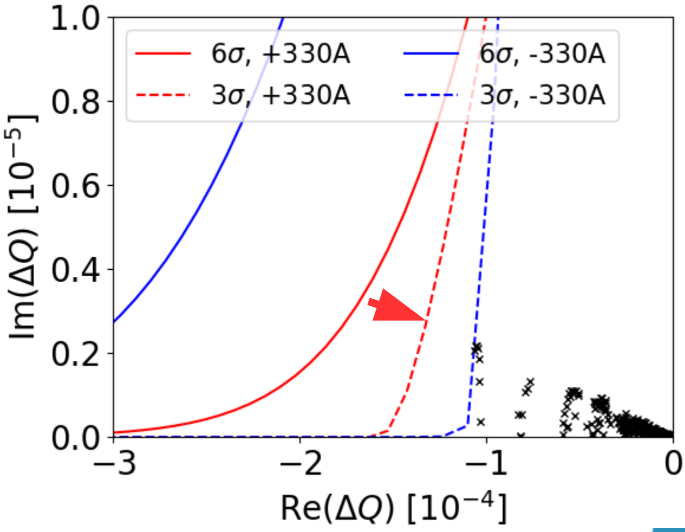
- With the positive polarity, cutting the tails at 3σ results in an increase of the threshold by +25 % → 727 A (10 % from real estimate)



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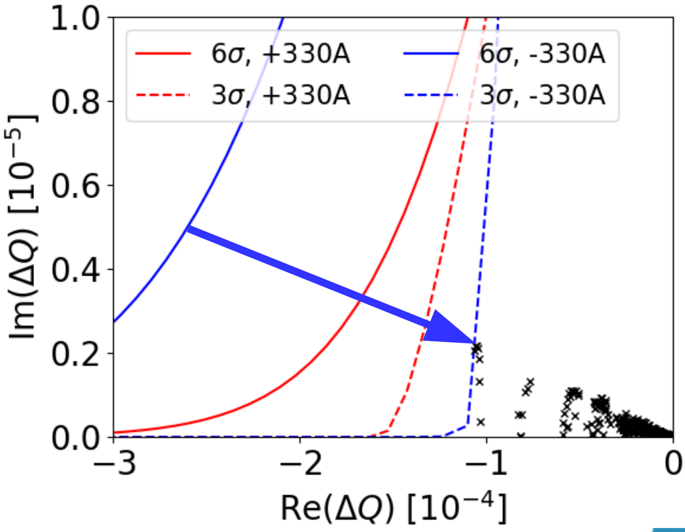
- With the positive polarity, cutting the tails at 3σ results in an increase of the threshold by +25 % → 727 A (10 % from real estimate)

- With the negative polarity the increase due of the threshold to the cut tails reaches a factor 2, such that it is worse than the positive polarity by +30 % → 945 A **(less than half the estimate for two beams)**



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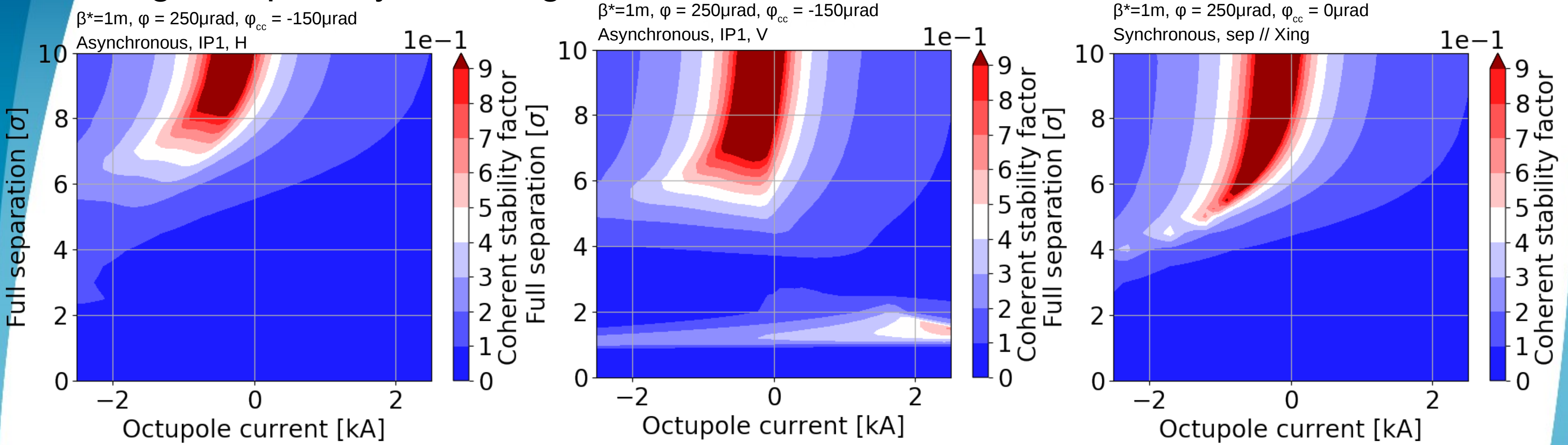
Negative polarity : Limiting factor



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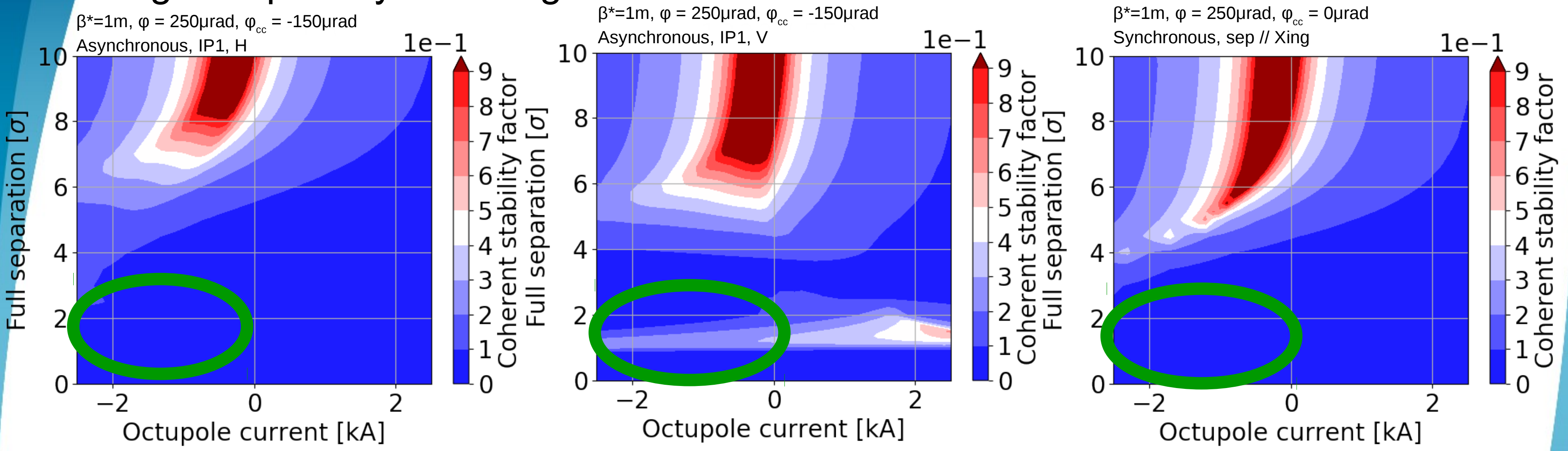

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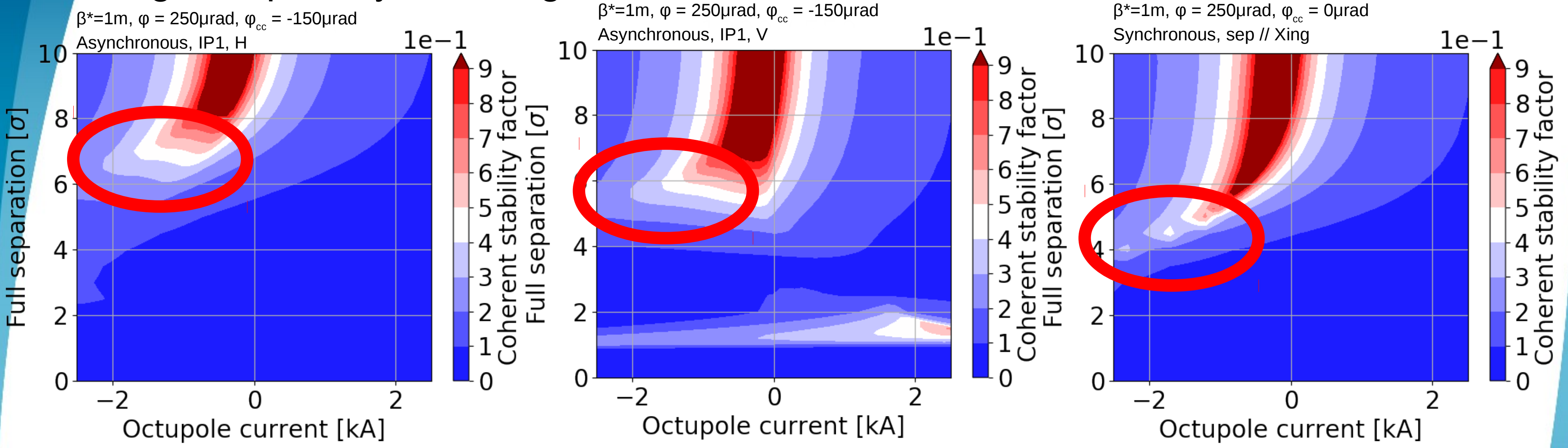

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- There exists solutions to mitigate the minimum of stability at 1.5σ

  → The most stringent limit is for separations ~5-7σ due to the **long-range contribution of the interaction at the IP**

Negative polarity : Speeding through the transient

- If we discard this transient unstable phase from the analysis (since it is shorter than the instability rise time), the requirement is reduced by approx. a factor 2 making it acceptable for DA

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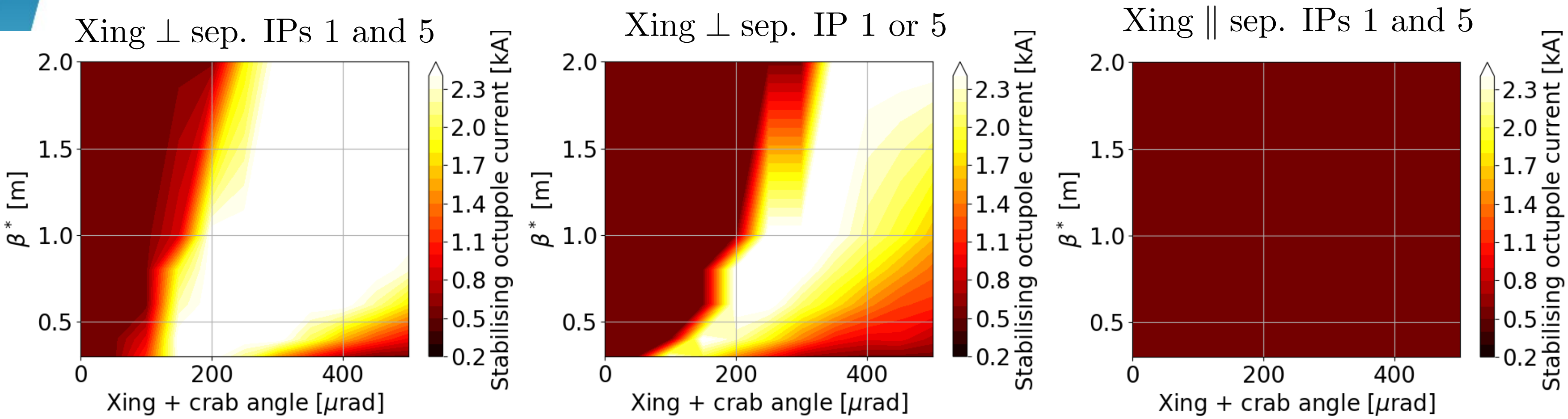
Oct. thes. [A]	-1040	-830	-670
Equi. teleindex	2.3	1.9	1.5

(b) Negative polarity

Table 2: Stabilising octupole current together with the teleindex required to reach the equivalent detuning coefficient when operating the octupoles at the maximum of their capacity.

- Speeding through the minimum of stability at 1.5σ was demonstrated in MDs in Run 2, a similar demonstration could be envisaged for the minimum at 6-8σ in Run 3

Parameter space with the positive polarity



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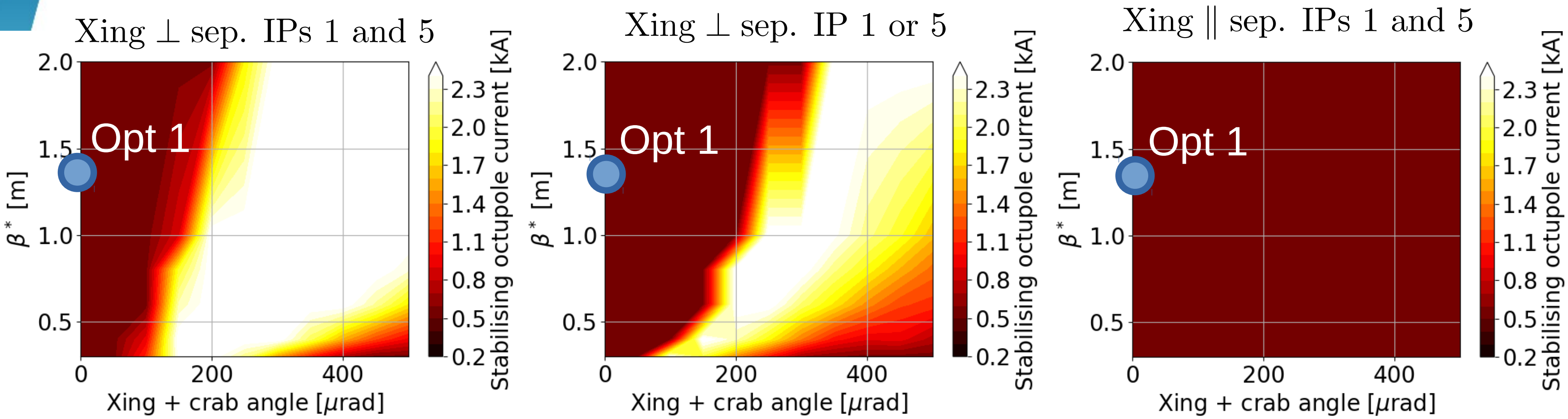

- Option 1 is feasible with various types of processes for the collapse of the separation bump

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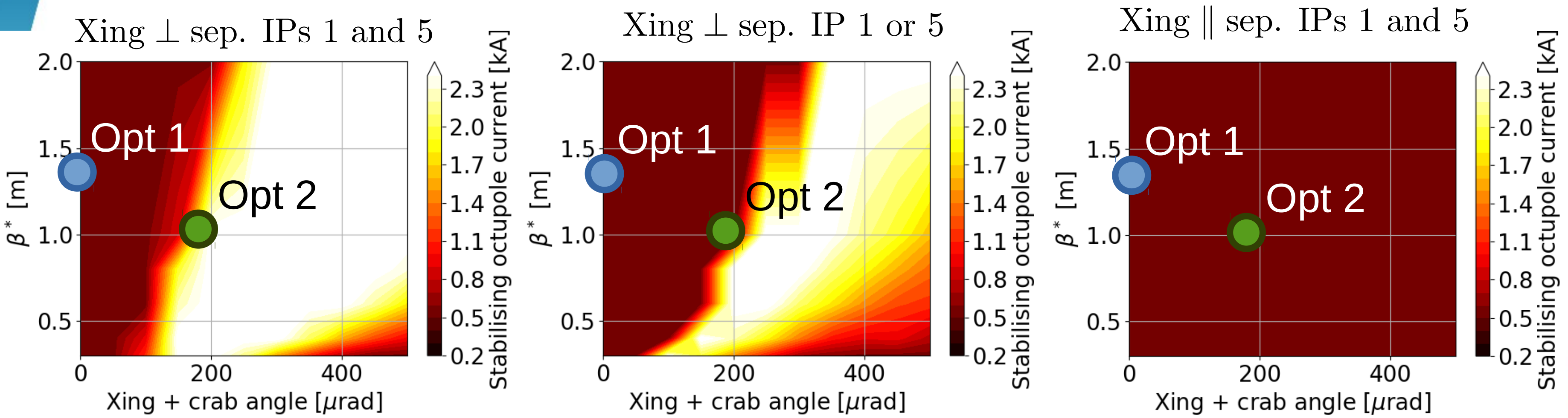
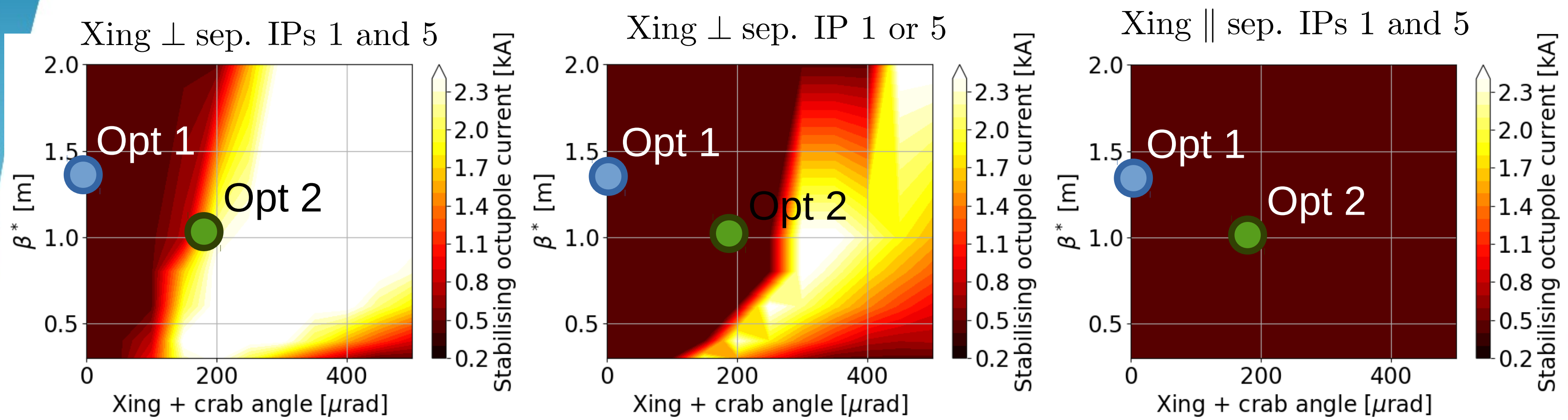


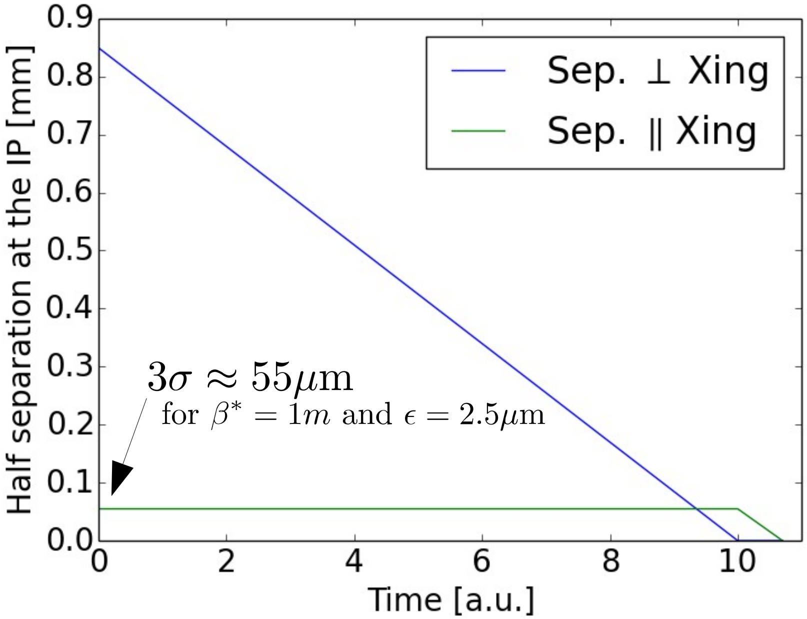
- Option 1 is feasible with various types of processes for the collapse of the separation bump
- Option 2 (CC disabled during the collapse) is limited by the impact of the Piwiniski angle at separations ~1.5σ. It is fully mitigated if a separation bump is introduced in the crossing plane.

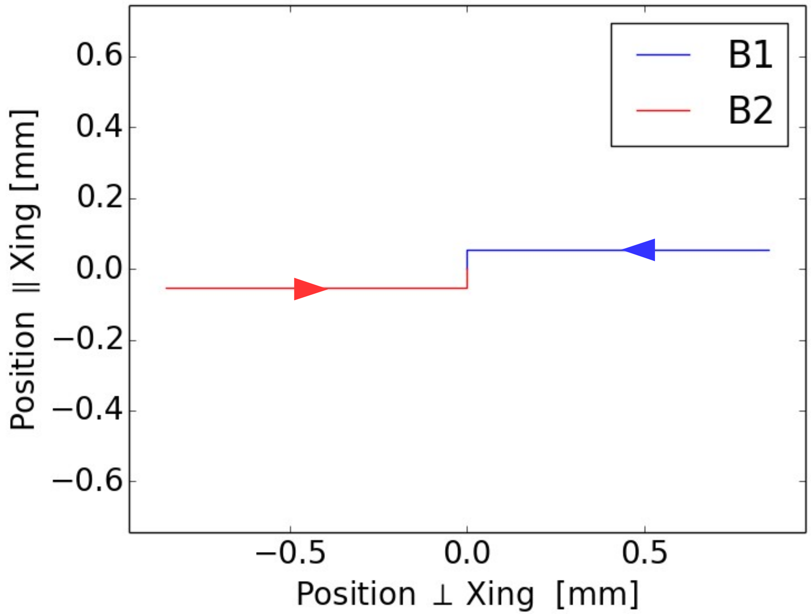
Parameter space with the positive polarity and relaxed collimator settings



- Option 2 becomes doable with a asynchronous collapse of the separation bumps in IPs 1 and 5

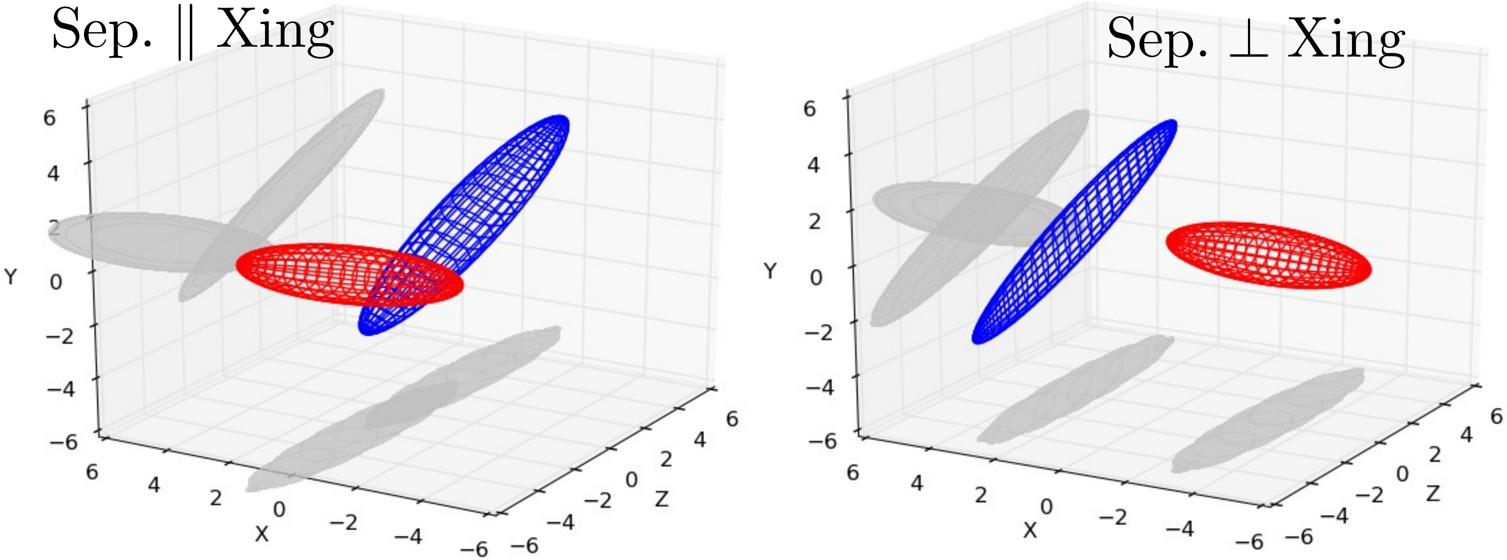
Mitigation with a separation bump in the crossing plane : possible implementation





- For a proper mitigation it is sufficient to implement the separation in the parallel plane for the last bit of the process (~6σ total separation)
  - The existing 'lumiscan knobs' could do the job

Mode coupling instability of colliding beams with sep. // Xing



- The beam-beam forces differ significantly in the two configurations
- Note : The variations of the beam-beam force along the bunch are neglected in the computation of the stability diagrams

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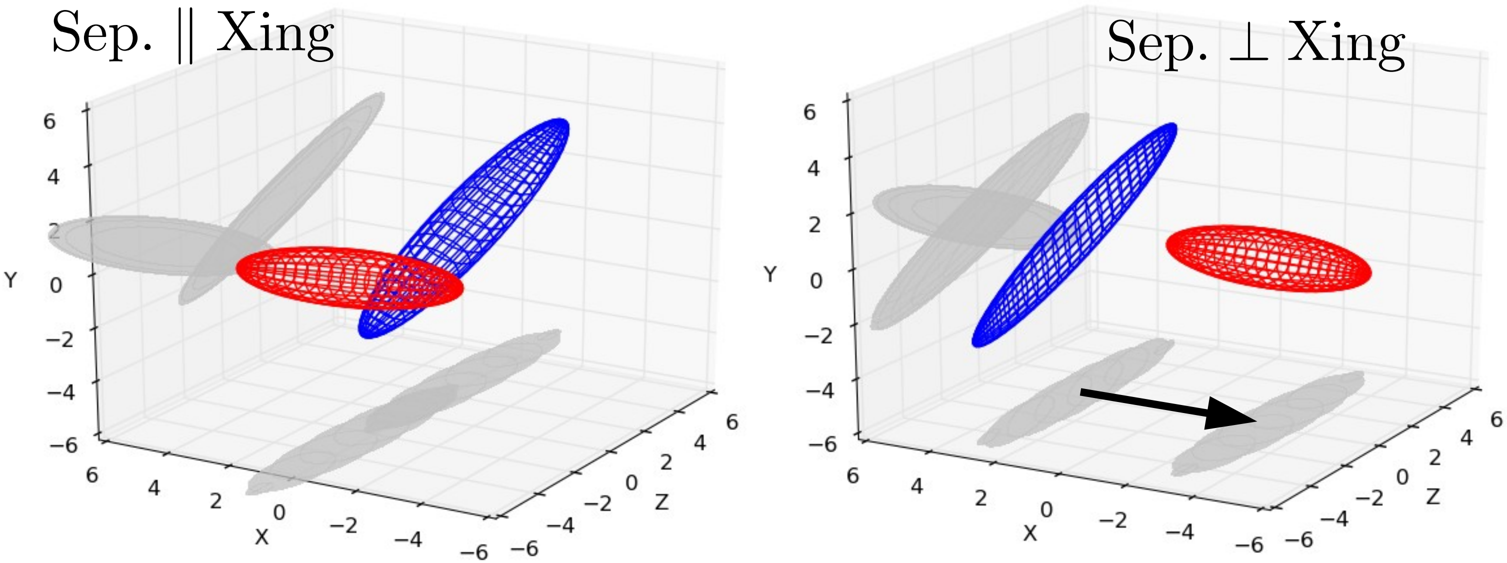

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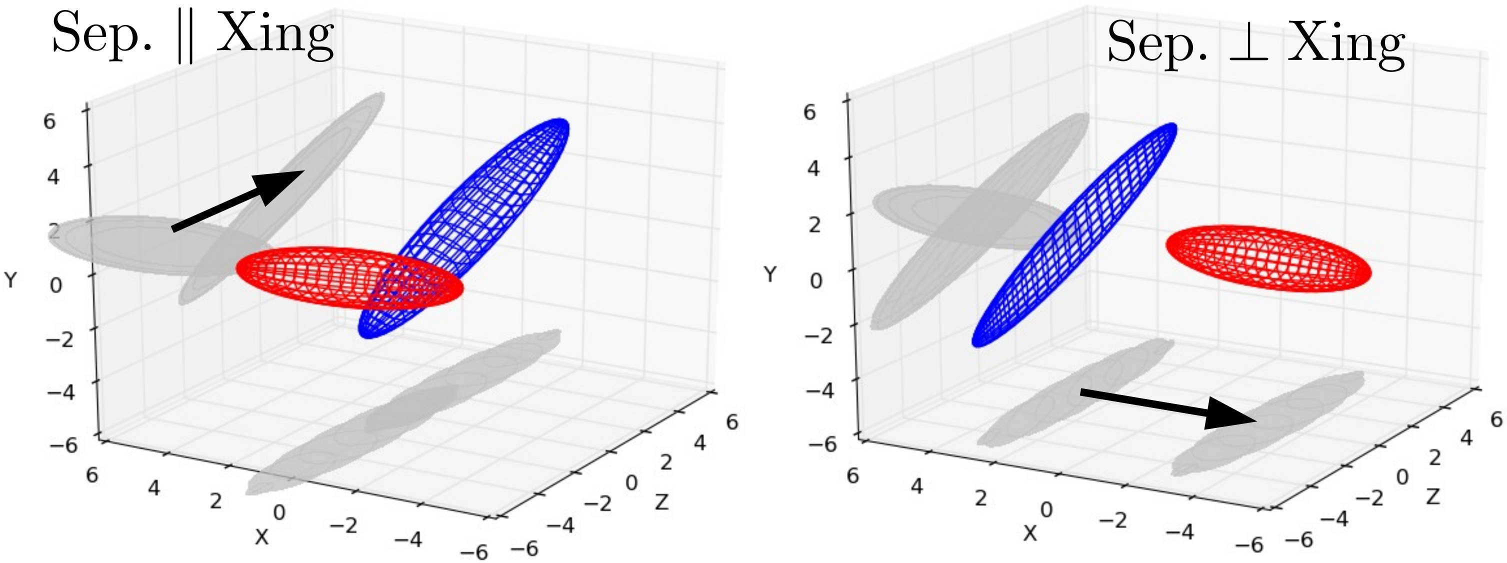

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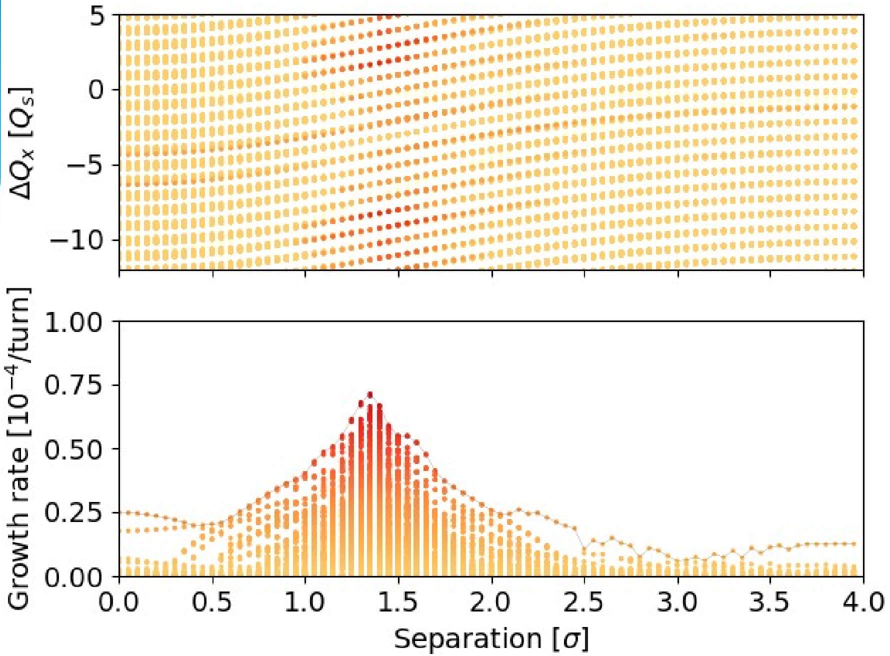

- The mode coupling instability of colliding beams is usually well damped by the damper
- The separation in the crossing plane seem to induce a mode coupling instability between radial modes of the same synchrotron sideband. The damper is totally ineffective for sidebands > 4

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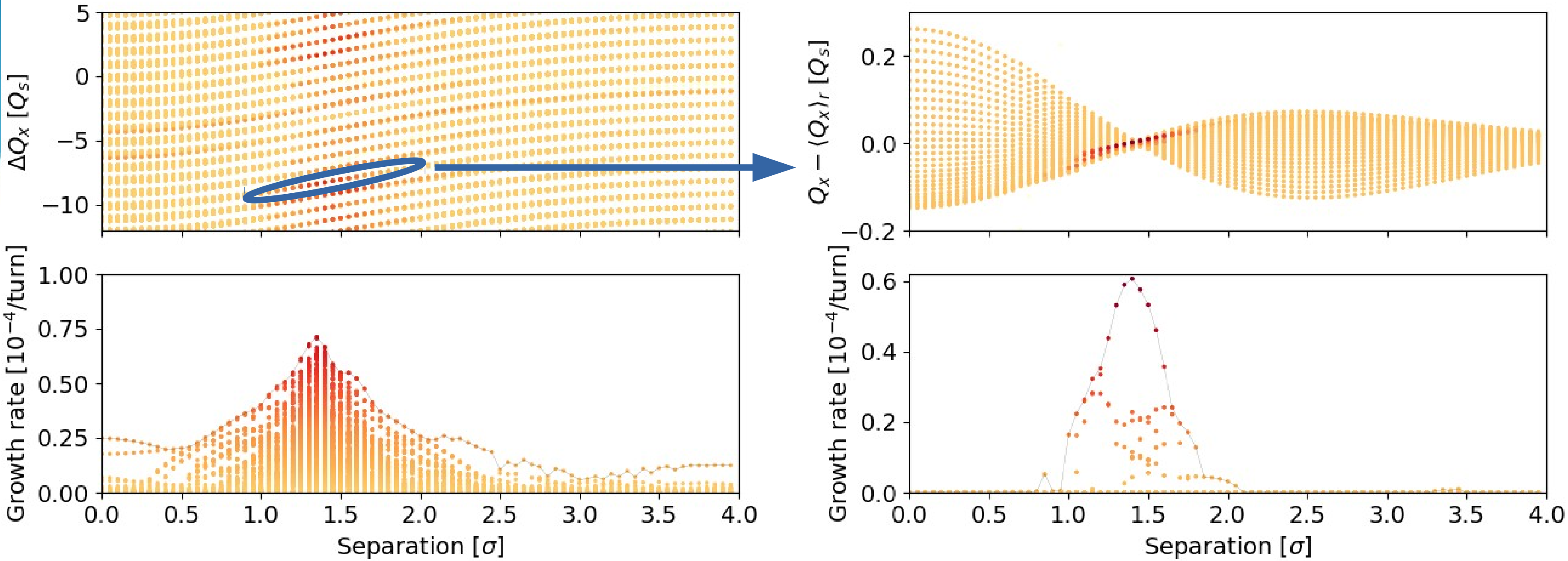

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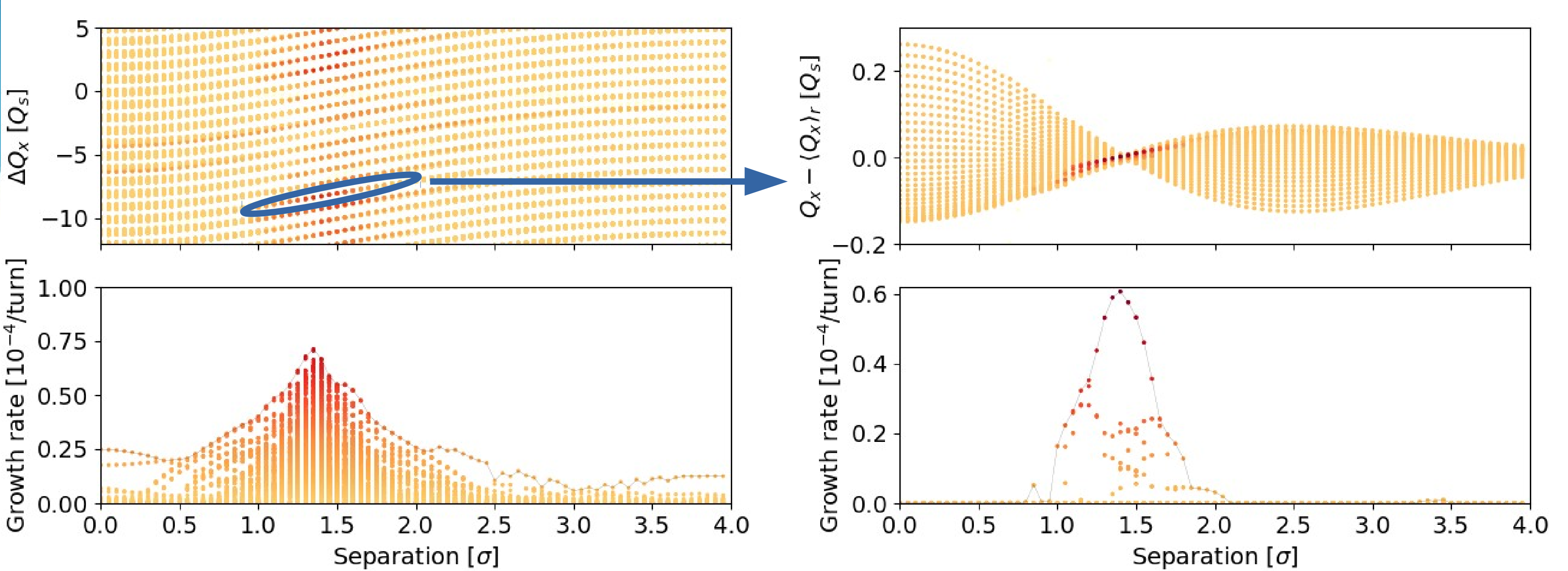

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  - Given the low growth rate, these modes will likely be Landau damped. To be confirmed with tracking simulations (on going)

Offset levelling at the low luminosity IPs

- With both polarities of the spectrometer the Piwinski angle is low in IP2 (Φ = 0.16 / 0.38). Operating with the positive polarity of the octupoles, there is no restriction on the separation (i.e. no need for a separation in the crossing plane)

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- In IP8, the Piwinski angle is large for the spectrometer polarity that enhances the crossing angle at the IP (Φ = 0.27 / 1.38)

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  → Operating with the positive polarity, it will lead to instabilities of the IP8 private bunches

  - Get rid of IP8 private bunches when operating LHCb with the bad polarity (if they are problematic for operation)
  - Level the luminosity a separation in the crossing plane

Summary

- The negative polarity is unfavoured by the long-range interaction at the IP during the collapse of the separation bump
  - The current required for Landau damping are not compatible with DA at the start of collision
  - The only possibility would be to rely on the speed of the collapse of the separation bump
- Option 1 (collision at β*=1.4 with CC enabled) with the positive polarity features no reduction of Landau damping due to beam-beam through the cycle
  - The impact of crab cavity amplitude noise on non-colliding beams should be assessed (see. Sondre's talk)
- Option 2 (collision at β*=1.05 with CC disabled) with the positive polarity features loss of Landau damping due to the offset interaction at the IP
  - The usage of the lumiscan knobs to introduce a separation in the crossing plane sounds offers a interesting alternative
  - Landau damping of a new type of mode coupling instability is under study
  - The speed of the collapse is also an possible alternative
- Without mitigation, IP8 private bunches may become unstable with the spectrometer polarity that enhances the crossing angle at the IP