DRAFT

Beam-Beam DA Simulations for HL-LHC

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on behalf of the HiLumi LHC WP2

Outline:

- Brief recap of baseline scenario at flat top and focus on alternatives
- Impact of high telescopic index at end of squeeze
- Delivering high luminosity to LHCb
- Quick look on the DA feasibility of flat optics in the HL-LHC

8th HL-LHC Collaboration Meeting - 18.10.2018, CERN, Geneva, Switzerland

Baseline Simulation Setup

For WP2

- **Optics and Collisions**
- HL-LHC v1.3 optics, baseline (MS10 included)
- $I_{MO} = -300A$, $Q' = 15$ ➔ WP optimization required
- Collisions: IP1/5/8 head-on, IP2 halo at 5σ
- 2 CC per IP per side, max crab angle (full) 380μrad (6.8MV)
- Assuming constant round beams 2.5μm emittance (*see Stefania's talk*)

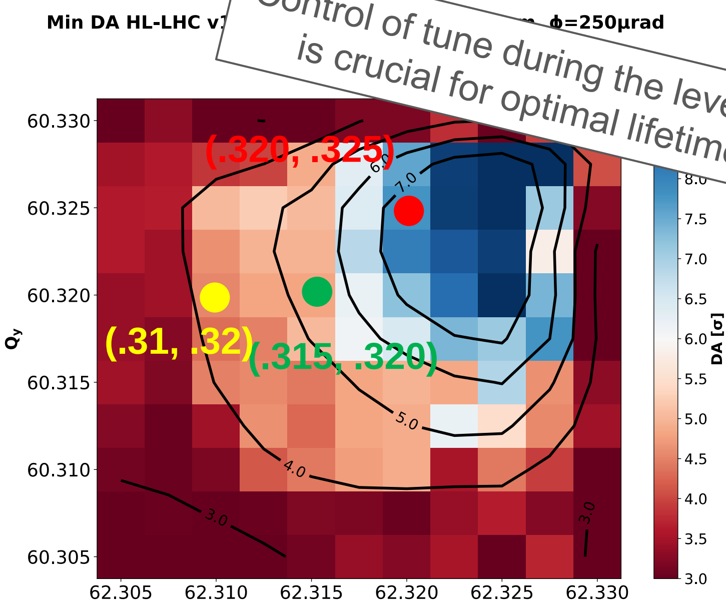
- **LHCb**
- Negative dipole polarity ➔ subtract from the external crossing angle
- Luminosity is levelled at $2 \cdot 10^{33} Hz/cm^2$ → *Not applicable for the specific study*

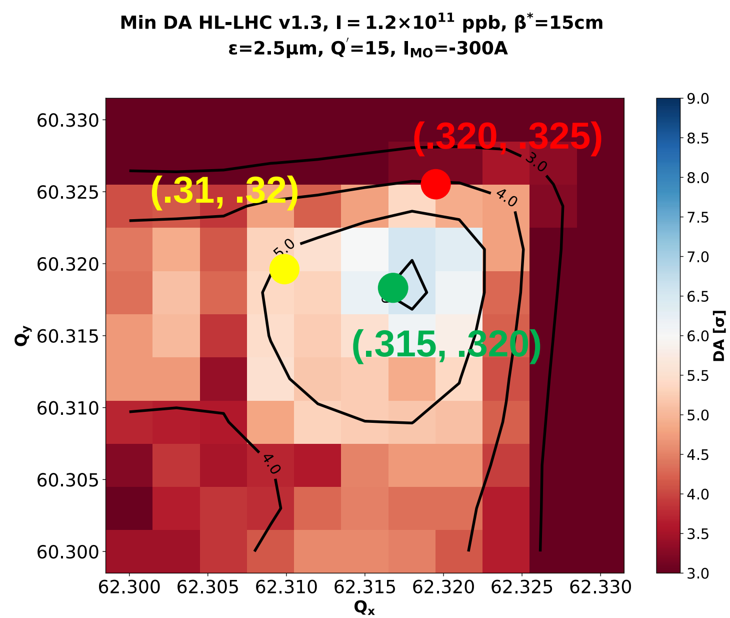
- **Tracking with SixTrack**
- 1M turns
- 5 angles in the (x,y) space
- Amplitudes in the range 0σ-10σ [up to 20σ for Squeeze]
- Estimator: minimum Dynamic Aperture over the angles and amplitudes

- **Targets**
- 6σ ➔ "Relaxed"
- 5σ ➔ "Aggressive"

Recap of Operational Scenario

Control of tune during the leveling is crucial for optimal lifetime

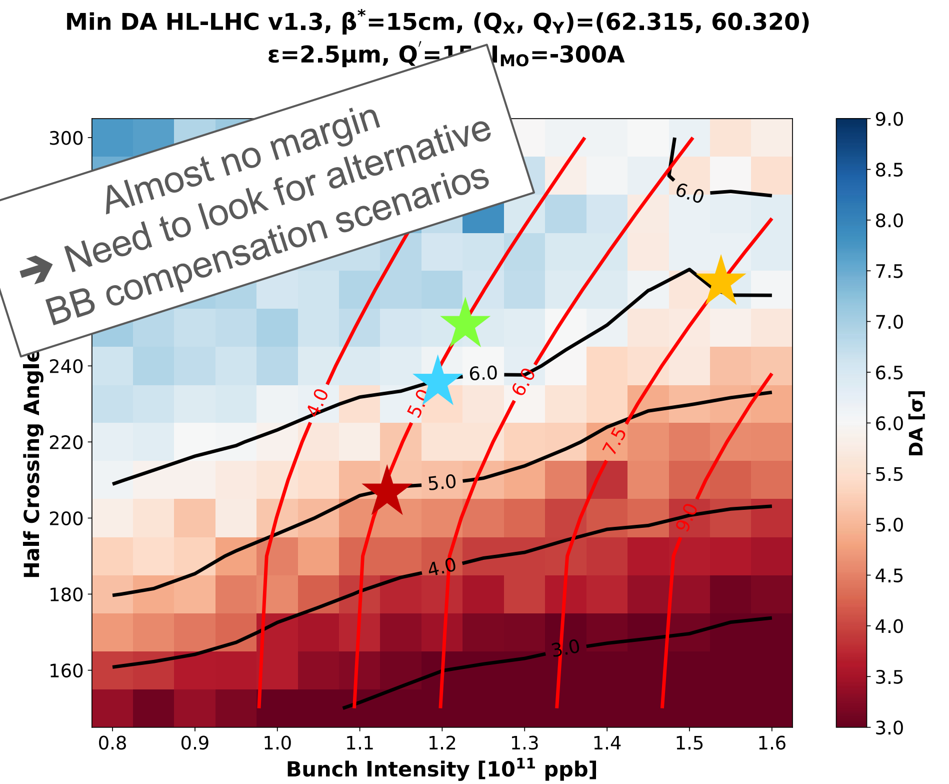




- DA [σ]
- Luminosity $[10^{34} Hz/cm^2]$
- Baseline
- Relaxed (6σ)
- Aggressive (5σ)
- Ultimate Relaxed (6σ)

Scenario	Half-crossing angle [μrad]	I [ppb]
Baseline	250 (10.5σ)	1.22
Relaxed	235 (9.9σ)	1.19
Aggressive	207 (8.8σ)	1.13
Ultimate Relaxed	260 (11σ)	1.53

Almost no margin
➔ Need to look for alternative BB compensation scenarios

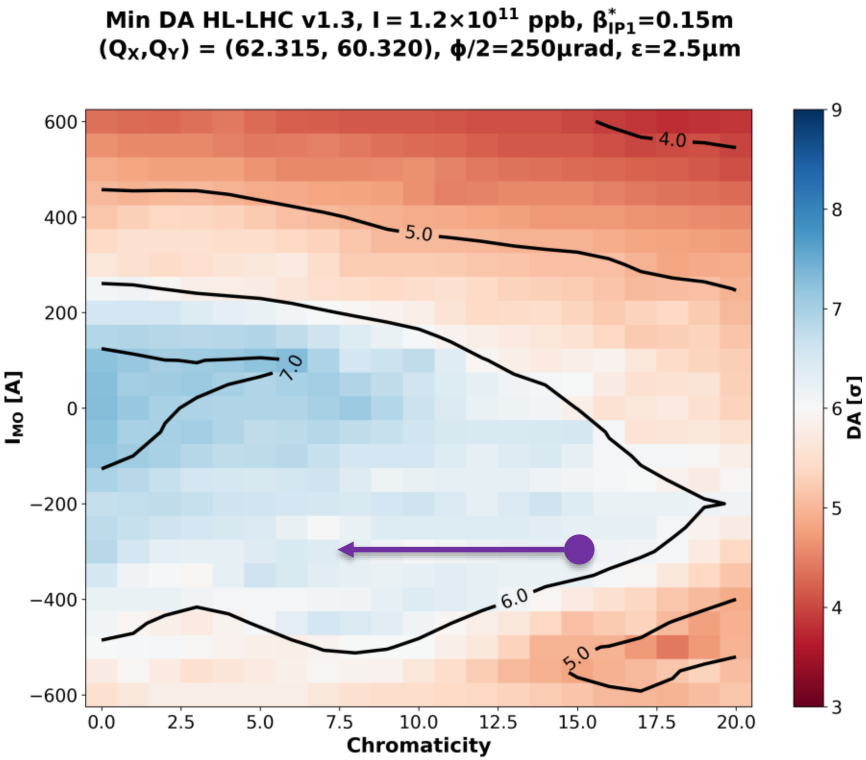


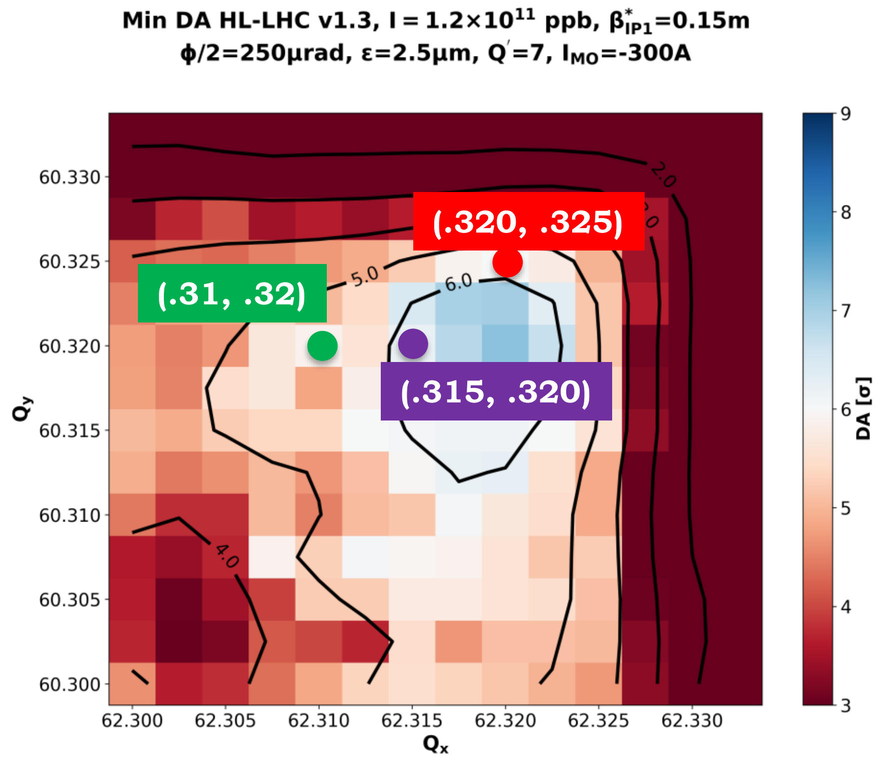
E. Metral *et al.*, *"Update of the HL-LHC operational scenarios for proton operation"*, CERN-ACC-NOTE-2018-0002

N. Karastathis *et al. "Refining the HL-LHC Operational Settings with inputs from Dynamic Aperture simulations: A Progress Report"*, IPAC2018-MOPMF041

Chromaticity & Octupoles @ End of Levelling

For WP2





1. What happens before the collapse?

Beam Stability at Flat Top

- For impedance-driven instabilities, the **beam-beam interaction** can substantially **reduce the stability margin** during the squeeze and **as the beams are brought into collision**
- Detailed studies for the **stability considerations** have been performed under various scenarios (i.e. collimator upgrades).

Courtesy of X. Buffat

Separation [σ]	Equivalent octupole current [A] (Telescopic index)					
	Nominal			Ultimate		
	CFC	LS2 upg.	Full upg.	CFC	LS2 upg.	Full upg.
6-10	-1250 (2.6)	-1000 (2.2)	-750 (1.7)	-1020 (2.2)	-900 (2.0)	-780 (1.7)
1.5-2	-2500 (3.9)	-1000 (2.2)	-750 (1.7)	-2750 (4.2)	-900 (2.0)	-780 (1.7)

(a) $\varepsilon = 2.5\mu$m

- The **ATS** scheme already had proven to have a **beneficial impact on the beam stability** (*X. Buffat, 7th HL-LHC Collaboration Meeting, Madrid 2017*)

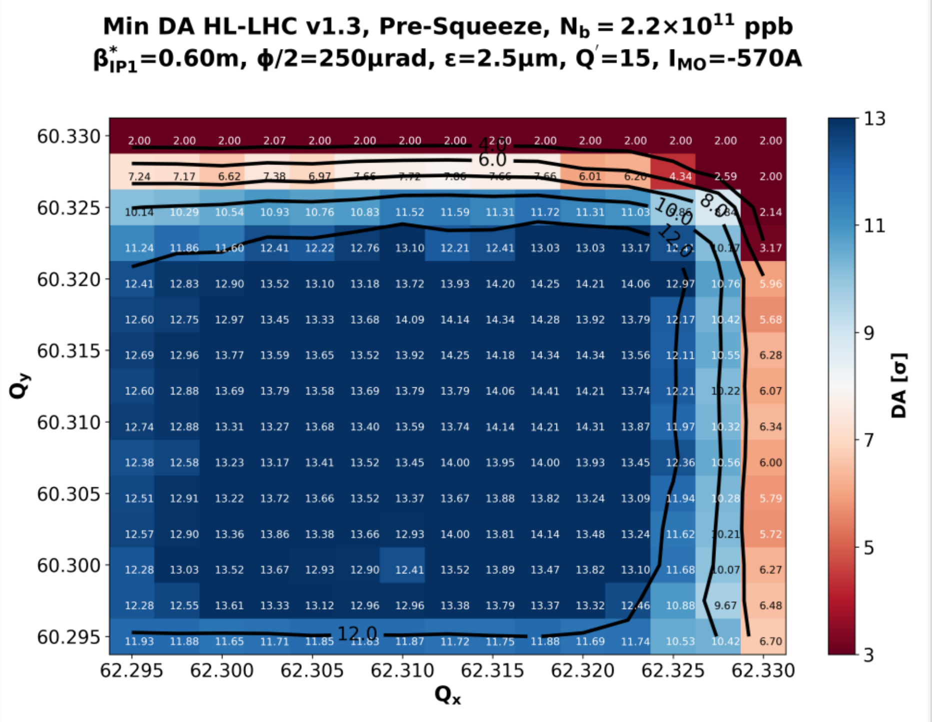
- The **telescopic squeeze** is already needed at flat top **to recover the stability margins** of a factor 2 (*even when including the low-impedance collimator upgrade*)
- In the case of **no collimator upgrade** → **Very large telescopic index** would be required (~4.2).

- Dynamic Aperture studies including the **beam-beam** effects have been performed to evaluate the impact of the **increased telescopic index** at the moment of the **collapse** and at the start of **collisions** on the **beam lifetime** ➔ Cases tested: $\mathbf{r_{ATS} = 1.0}$ (nominal), **1.7**, **2.2**, **3.0**, **3.33**

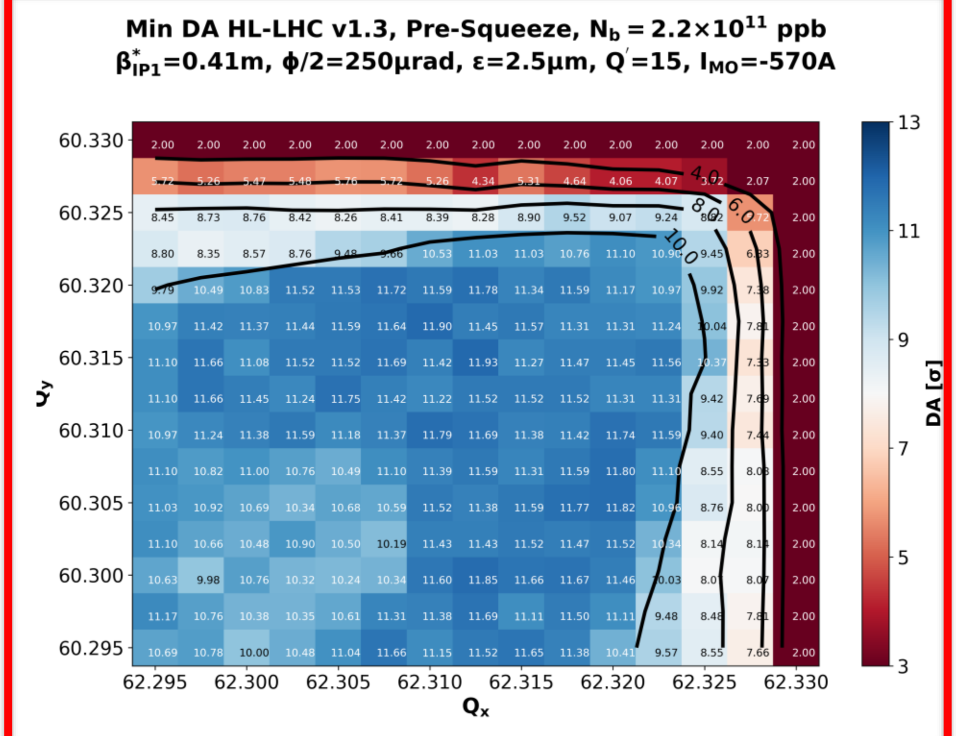
X. Buffat et al, *"Status of the studies on collective effects involving beam-beam interactions at the HL-LHC"*, CERN-ACC-NOTE-2018-0036

r_{ATS} = 1.0 - Nominal Scenario

$L_{lev} = 5 \times 10^{34} \mathrm{Hz/cm^2}$



$L_{lev} = 7.5 \times 10^{34} \mathrm{Hz/cm^2}$

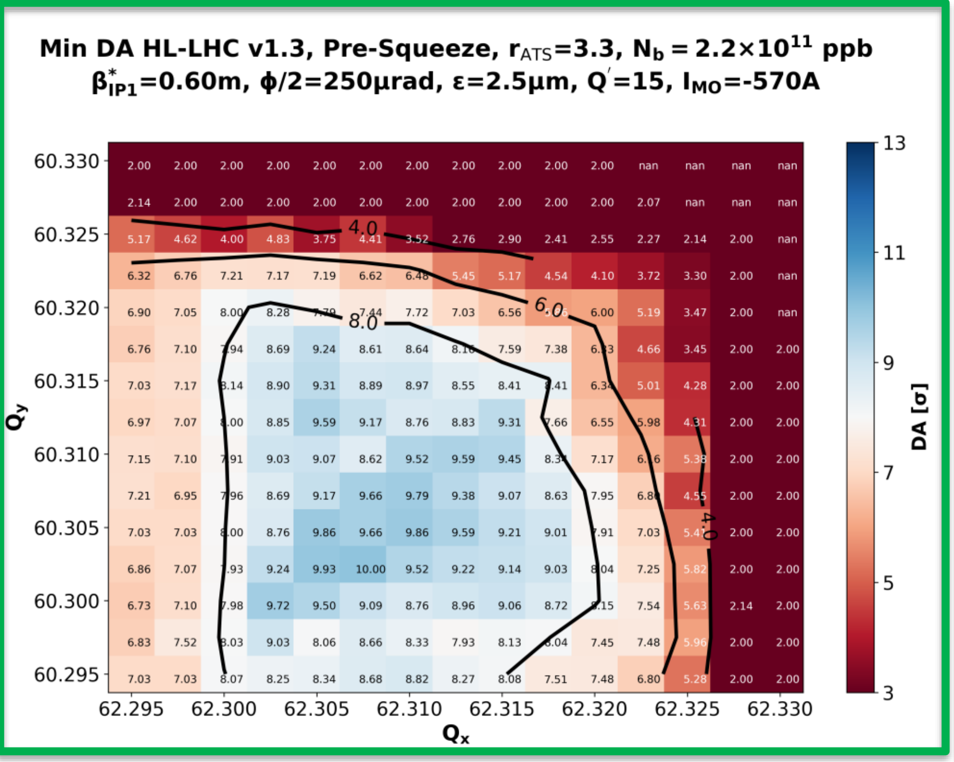


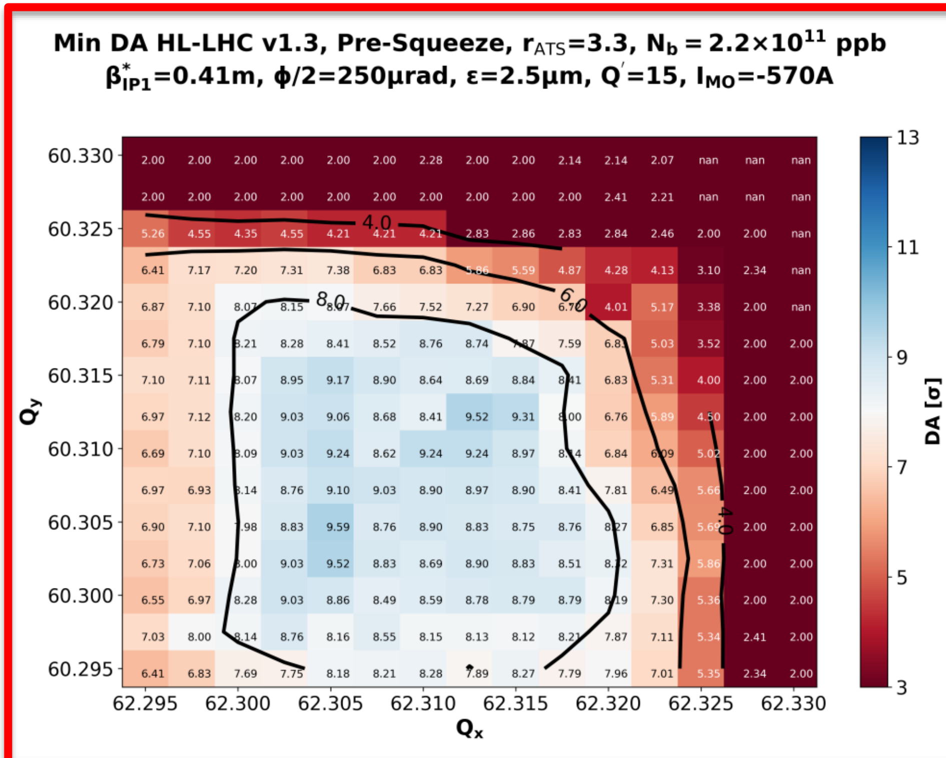
Due to the **reduced β***, the effect of the **beam-beam is stronger** → **reduced DA**

r_{ATS} = 3.3 - Pushed Scenario

$L_{lev} = 5 \times 10^{34} Hz/cm^2$

$L_{lev} = 7.5 \times 10^{34} Hz/cm^2$



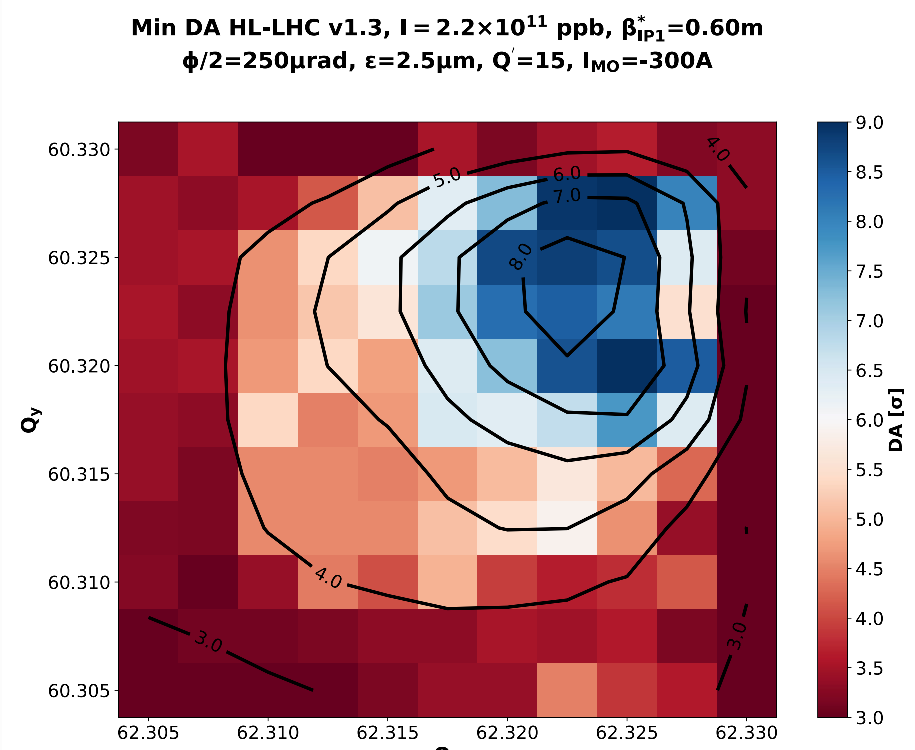


The effect of the **octupoles** is enhanced by the increased **telescopic index**

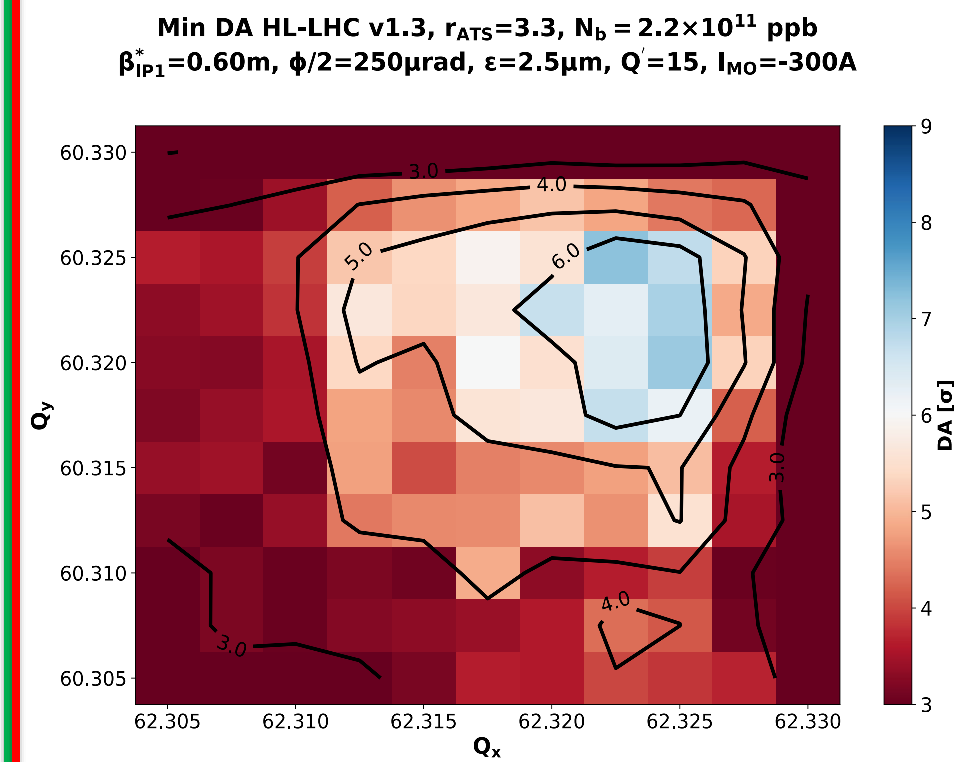
DA still ok-ish → *what would happen if I start colliding?*

Start of Collisions

r_{ATS} = 1.0



r_{ATS} = 3.33

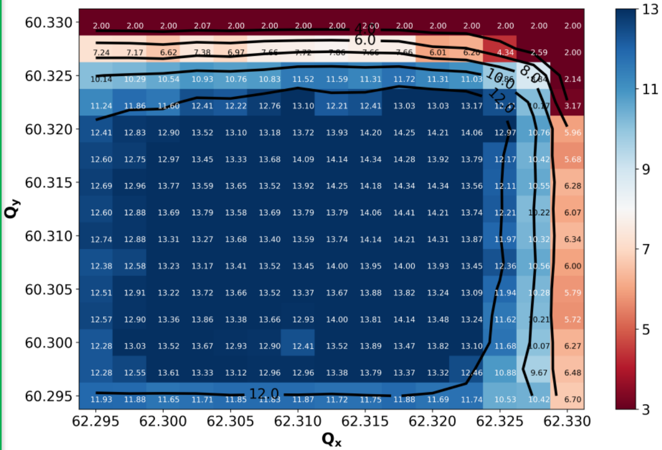


- The **octupoles** are too strong
  ➔ Distortion (**folding**) of the footprint (**BBLR over-compensation**)

Squeeze with different r_{ATS}

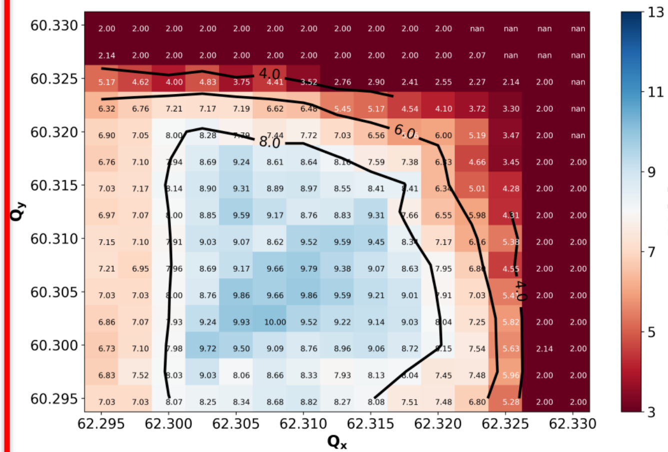
$r_{ATS} = 1.0$

Min DA HL-LHC v1.3, Pre-Squeeze, $N_b = 2.2\times10^{11}$ ppb
β^*_{IP1}=0.60m, $\phi/2$=250μrad, ε=2.5μm, Q′=15, I_{MO}=-570A



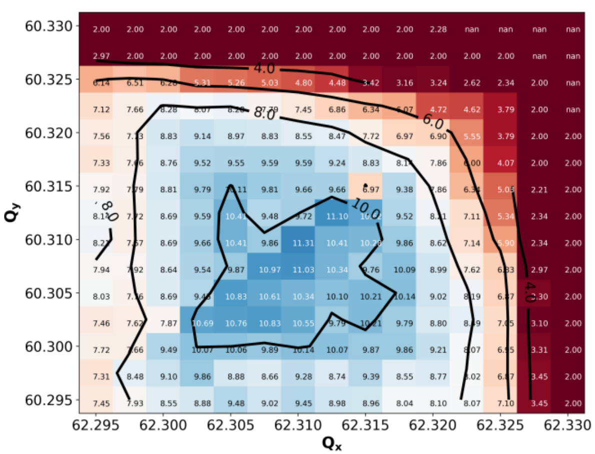
$r_{ATS} = 3.3$

Min DA HL-LHC v1.3, Pre-Squeeze, r_{ATS}=3.3, $N_b = 2.2\times10^{11}$ ppb
β^*_{IP1}=0.60m, $\phi/2$=250μrad, ε=2.5μm, Q′=15, I_{MO}=-570A



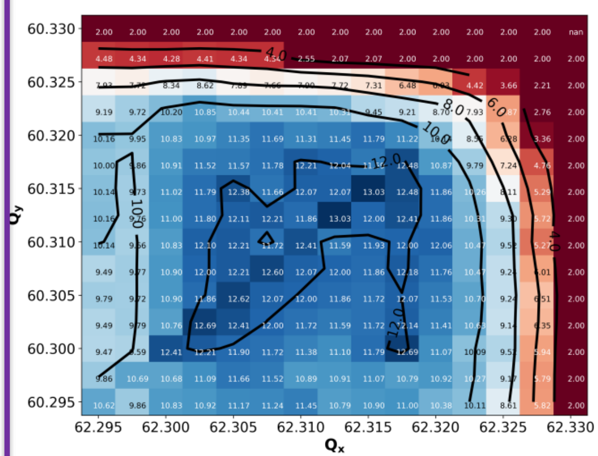
$r_{ATS} = 3.0$

[illegible] DA HL-LHC v1.3, Pre-Squeeze, r_{ATS}=3.0, $N_b = 2.2\times10^{11}$
β^*_{IP1}=0.60m, $\phi/2$=250μrad, ε=2.5μm, Q′=15, I_{MO}=-570A



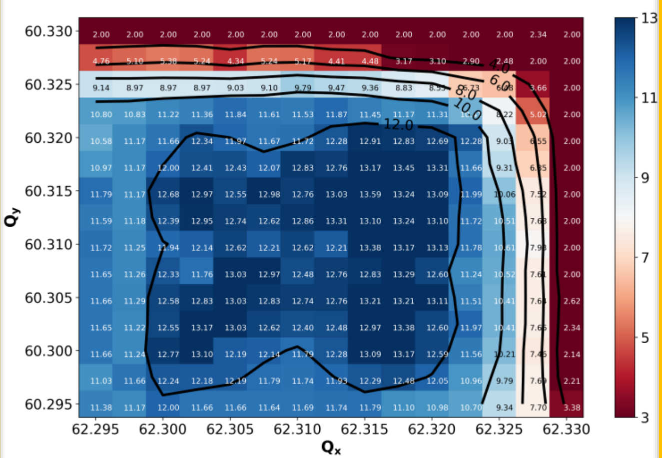
$r_{ATS} = 2.2$

Min DA HL-LHC v1.3, Pre-Squeeze, r_{ATS}=2.2, $N_b = 2.2\times10^{11}$
β^*_{IP1}=0.60m, $\phi/2$=250μrad, ε=2.5μm, Q′=15, I_{MO}=-570A



$r_{ATS} = 1.7$

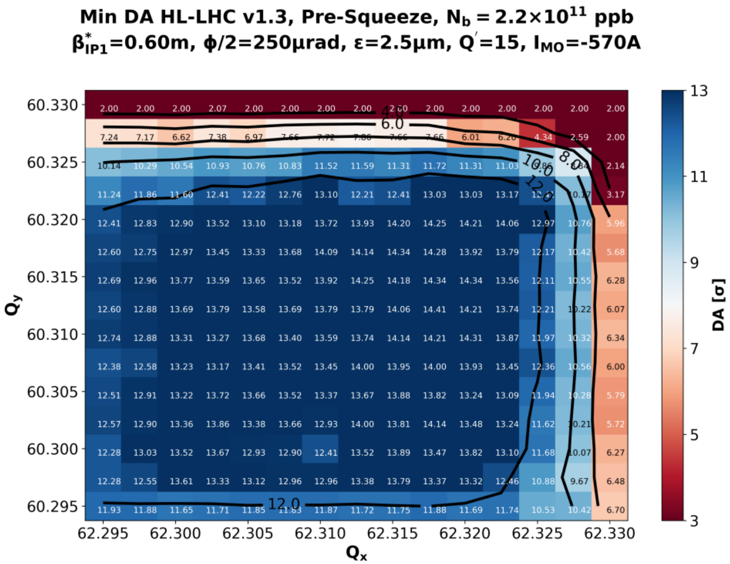
Min DA HL-LHC v1.3, Pre-Squeeze, r_{ATS}=1.7, $N_b = 2.2\times10^{11}$ ppb
β^*_{IP1}=0.60m, $\phi/2$=250μrad, ε=2.5μm, Q′=15, I_{MO}=-570A

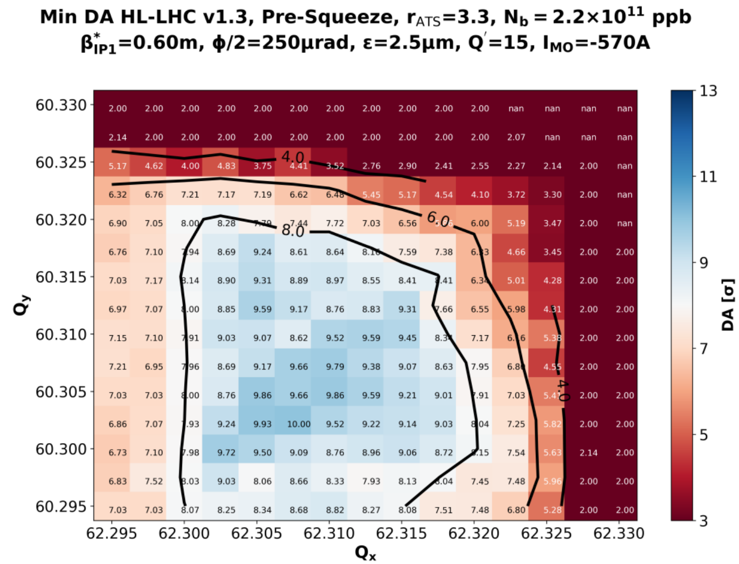


r=3.3

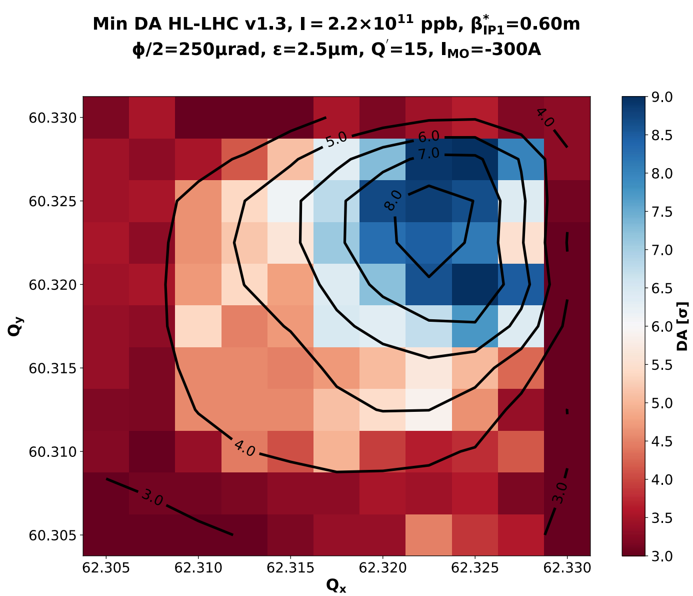
r_{ATS} = 1.0 | **r_{ATS} = 3.3**

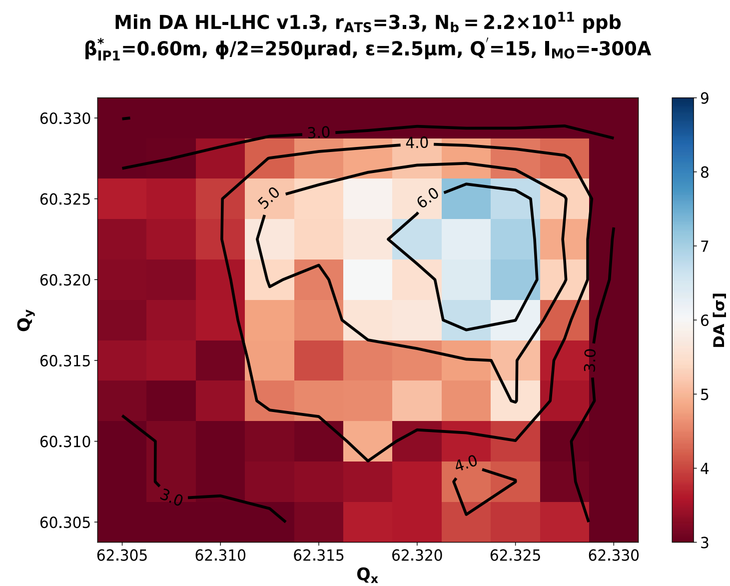
Pre-Squeeze





Start of Collisions



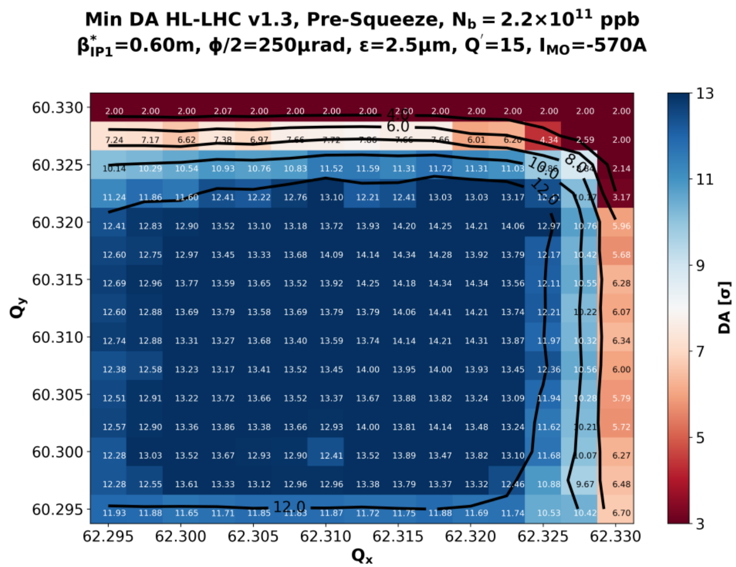


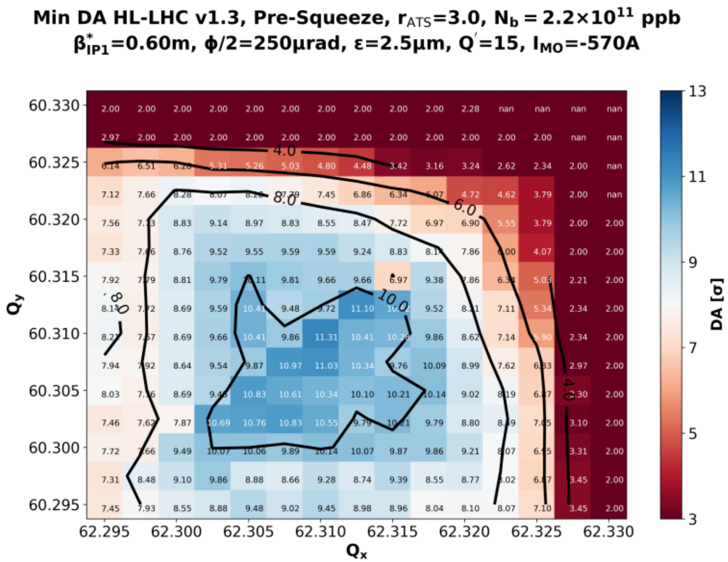
r=3.0

r_{ATS} = 1.0

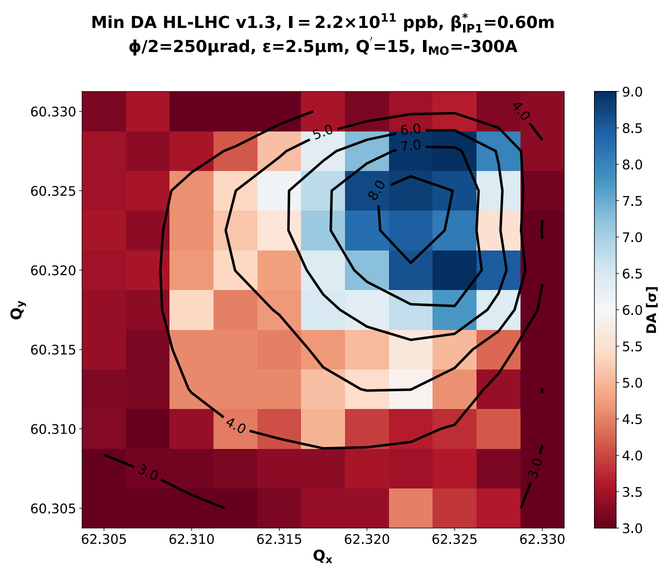
r_{ATS} = 3.0

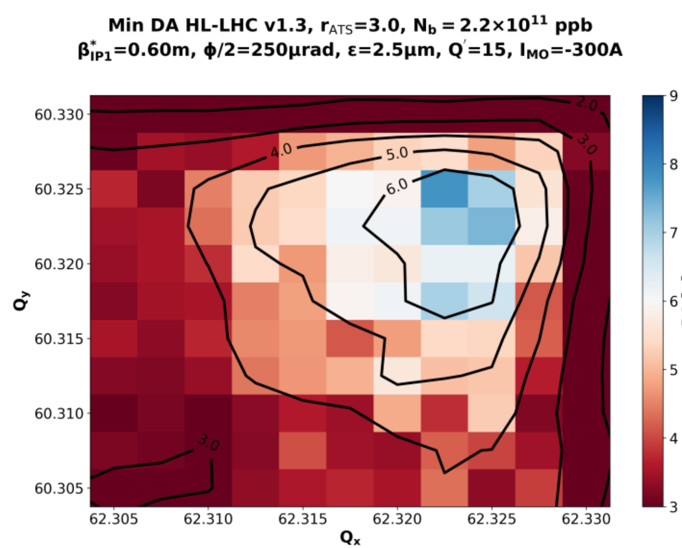
Pre-Squeeze





Start of Collisions

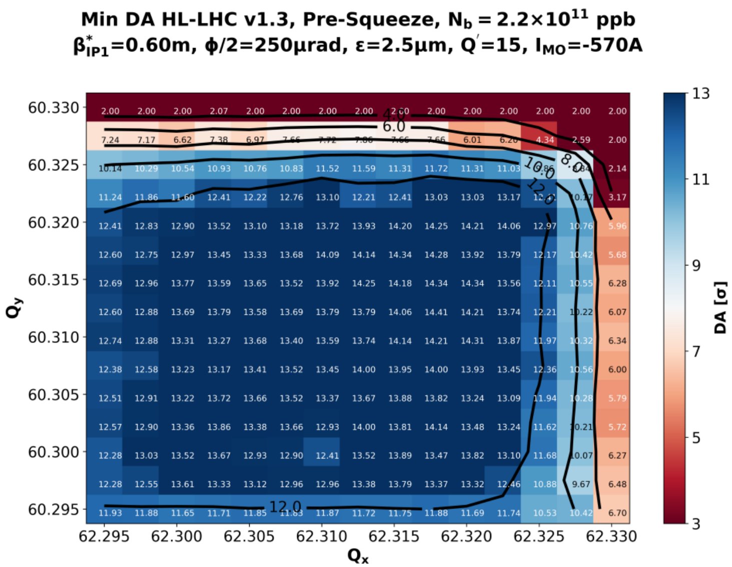


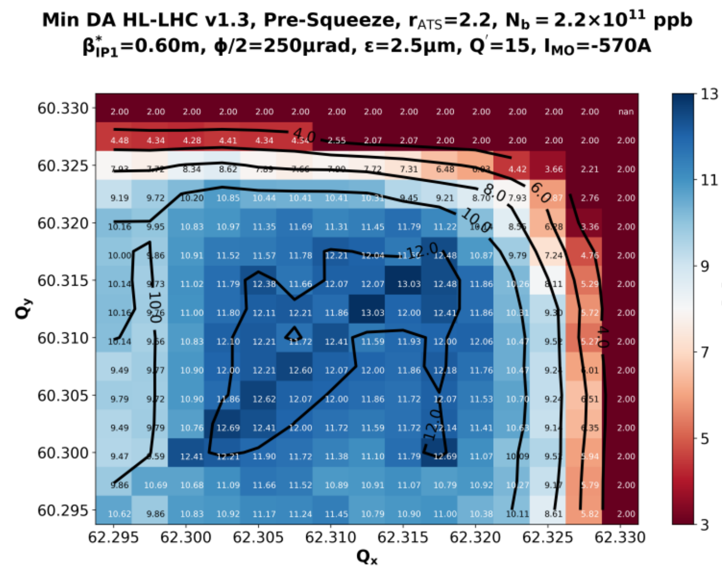


r=2.2

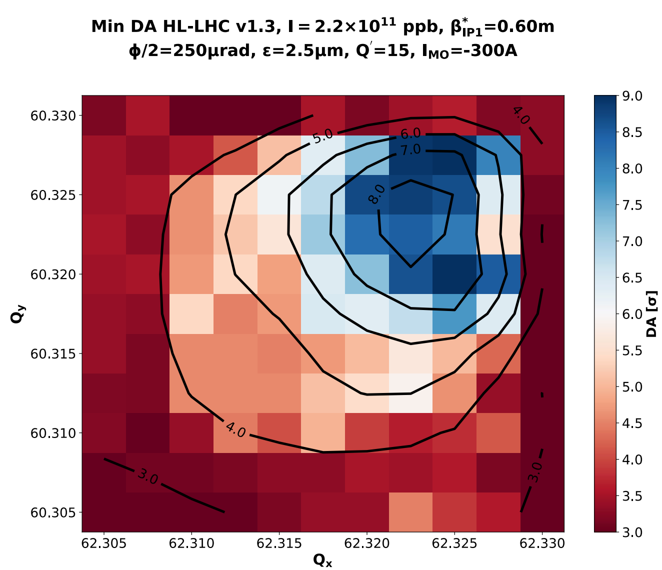
r_{ATS} = 1.0 | **r_{ATS} = 2.2**

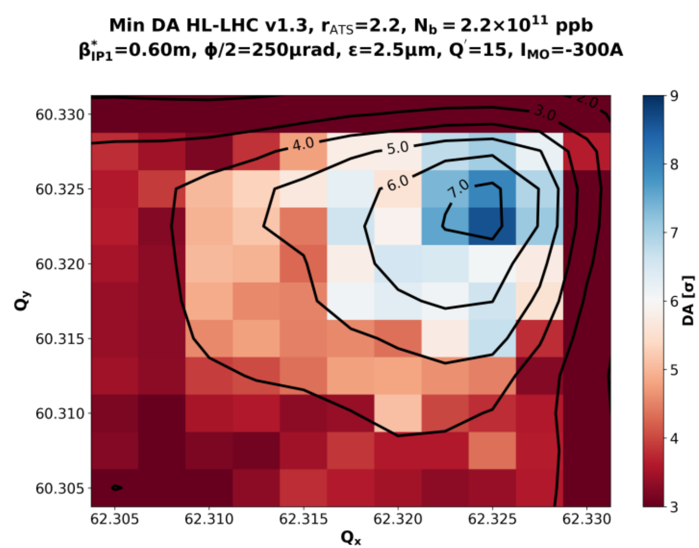
Pre-Squeeze





Start of Collisions



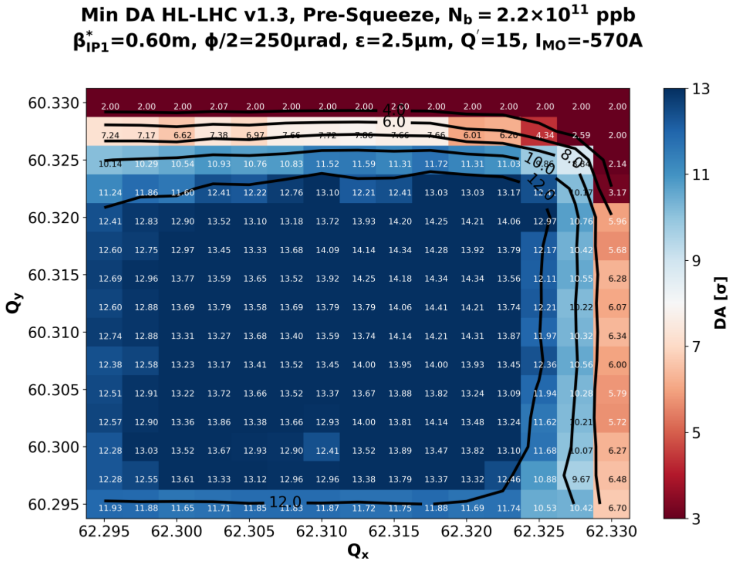


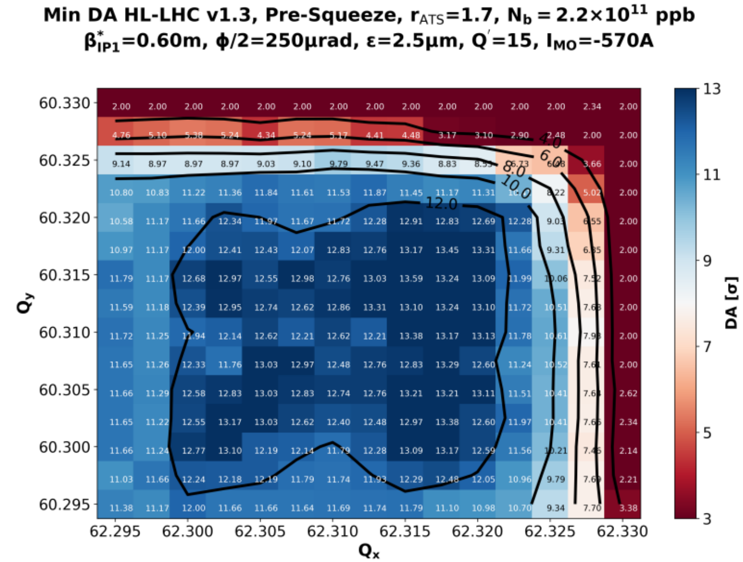
r=1.7

r_{ATS} = 1.0

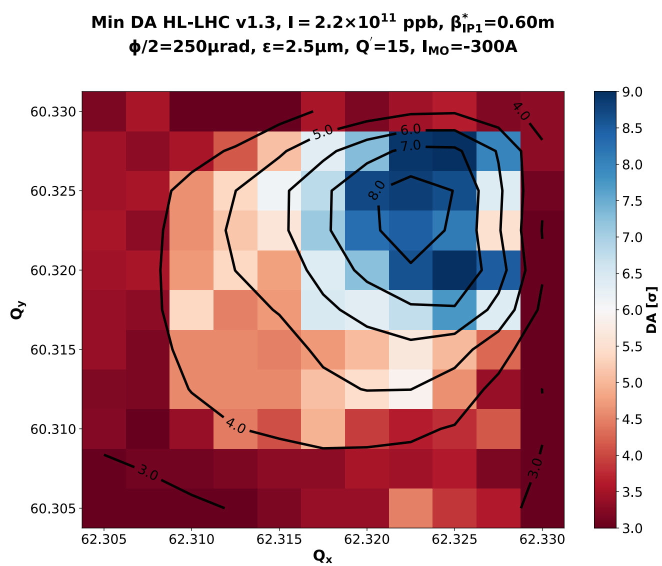
r_{ATS} = 1.7

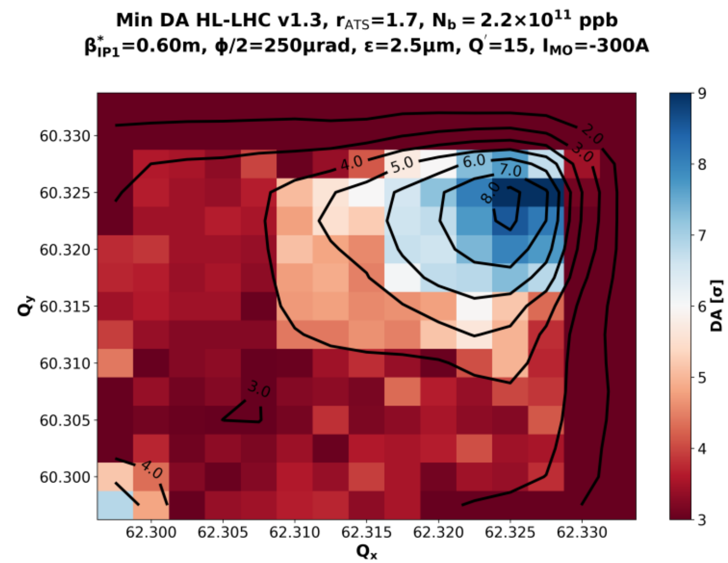
Pre-Squeeze





Start of Collisions





HiLumi HL-LHC PROJECT

Karastat

Reduction of Octupoles at Collisions

- To approach the DA at the r_{ATS}=1.0, try a **simple scaling** of the -300A of the operational scenario by the weighted average (h_{MO}) of the direct (f_{MO}) and cross (g_{MO}) **anharmonicities**

$$f_{MO}(r_x, r_y) \equiv \frac{1}{8}\left[\left(r_x + \frac{1}{r_x}\right)^2 + \left(r_y + \frac{1}{r_y}\right)^2\right]$$

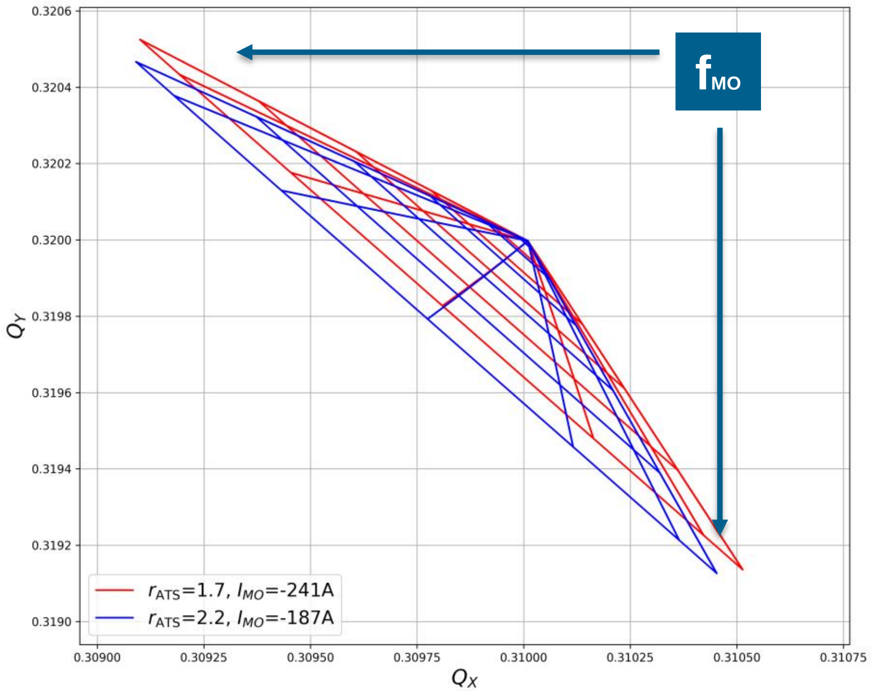
$$g_{MO}(r_x, r_y) \equiv \frac{1}{2}\left[1 + \frac{1}{4}\left(r_x + \frac{1}{r_x}\right)\cdot\left(r_y + \frac{1}{r_y}\right)\right]$$

$$c_{MO} = 2 \times \frac{\sum_{i\in MO}\beta_{xi}\beta_{yi}}{\sum_{i\in MO}\beta^2{yi}} \approx 0.71$$

$$h_{MO} \equiv \frac{f_{MO}+c_{MO}\cdot g_{MO}}{1+c_{MO}}$$

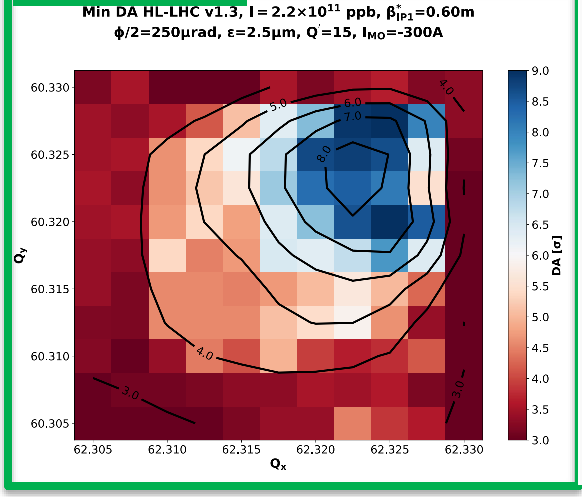
S. Fartoukh et al, "About flat telescopic optics for the future operation of the LHC", CERN-ACC-2018-0018

- Scaling by the h_{MO} we get:
  - For r_{ATS} = 1.0 ➔ I_{MO} = -300 A
  - For r_{ATS} = 1.7 ➔ I_{MO} = -241 A
  - For r_{ATS} = 2.2 ➔ I_{MO} = -187 A
  - For r_{ATS} = 3.0 ➔ I_{MO} = -124 A
  - For r_{ATS} = 3.3 ➔ I_{MO} = -106 A

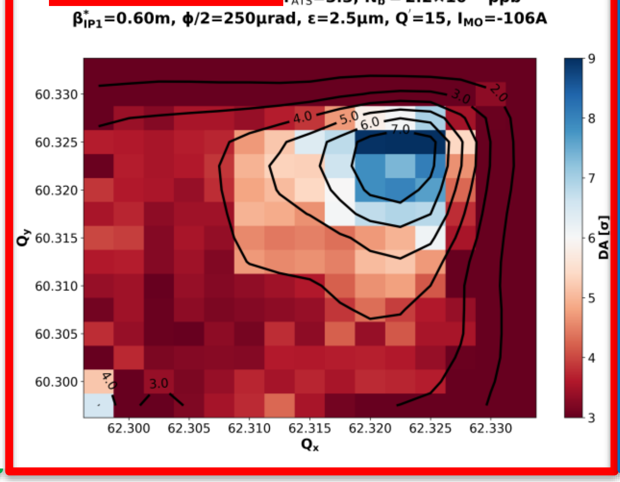


Reduction of Octupoles at Collisions

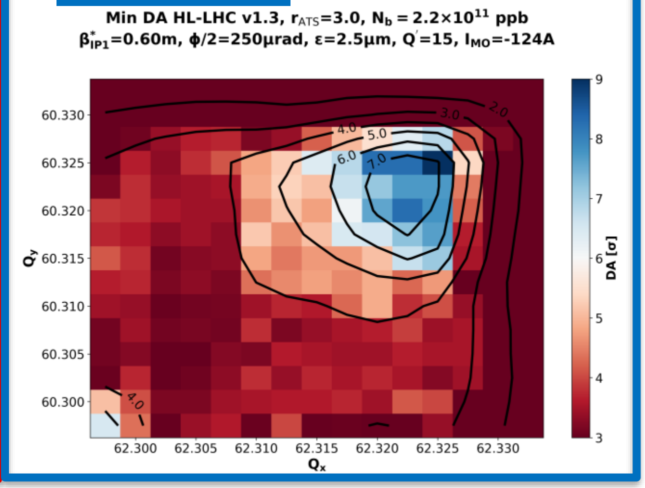
r_{ATS} = 1.0



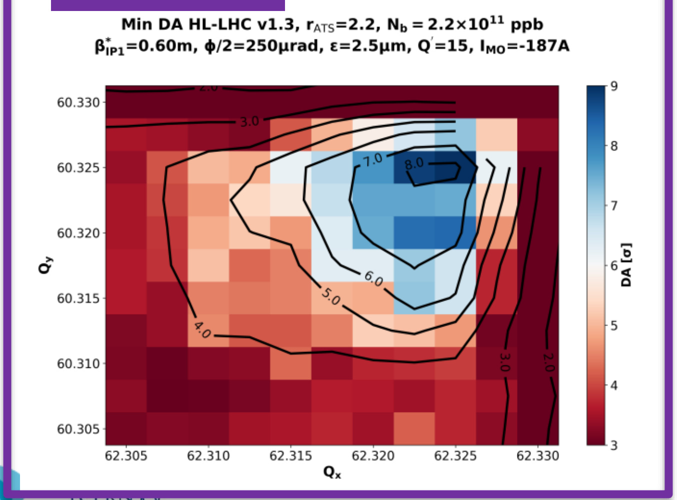
r_{ATS} = 3.3



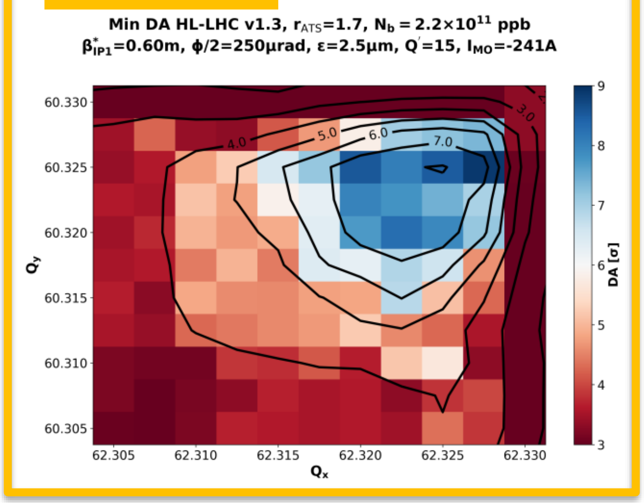
r_{ATS} = 3.0



r_{ATS} = 2.2



r_{ATS} = 1.7



Squeeze Stability - Summary

- The **increased telescopic index** before the **collapse** has a detrimental effect in terms of **DA**, enhancing the tune spread induced by lattice octupoles.

- The nominal configuration of **r_{ATS} = 1.0** gives **14σ DA for the nominal** and **12σ for the ultimate** scenario → visible the effect of the **reduced β***.

- For **very large telescopic** index (r_{ATS} = 3.33) the **octupoles are dominating the DA** result (twisting of the footprint)
→ no significant difference between the nominal (60cm) and ultimate (41cm)

- With the reduction of the telescopic index we observe the increase of the DA.
→ **r_{ATS} = 1.7 very close to the nominal**

- Right after the collapse, at the **start of collisions**, due to the **increased effective octupoles** a **reduction of the DA** is observed
→ In this respect, **favorable the 1.7 and 2.2** tele-index cases, with still **reduced DA**.

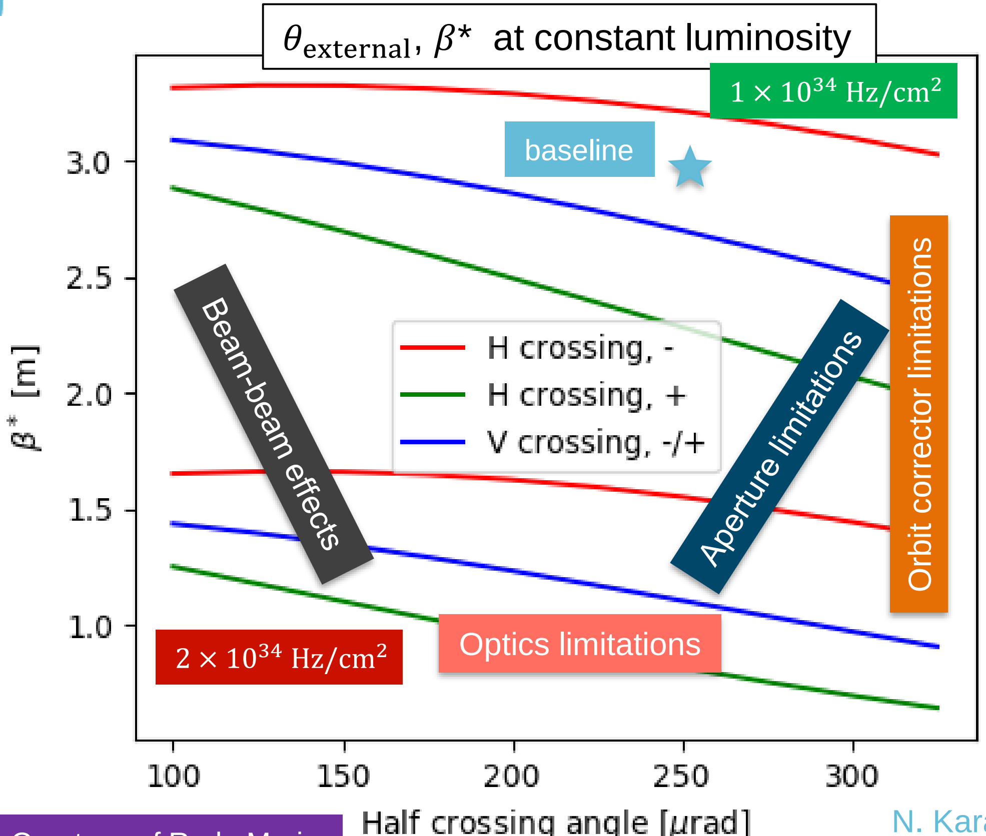
- **Reducing the octupole current** at any tele-index **some DA margin is recovered**.
→ *This acceptable for coherent stability (reduced #LR for the non-colliding bunches)*
→ *Need of optimization of octupole reduction function from the collapse to collisions*

2. What is the impact of HiLumi LHCb?

LHCb Phase II Upgrade

- The LHCb collaboration proposed an Upgrade II during HL-LHC operation, where IP8 will collide at high-luminosity $(\approx \mathbf{1-2 \times 10^{34}\ Hz/cm^2})$ to collect more than $\mathbf{300fb^{-1}}$ by the end of HL-LHC operation.
  - This luminosity target is comparable with the present LHC ATLAS/CMS luminosity.
- *Would this be feasible, while preserving acceptable IP1/5 performance?*

$$L = \frac{N_b^2 f_{rev} k_b}{4\pi\epsilon\sqrt{\beta_\times^*\beta_\parallel^*}} \cdot \frac{1}{\sqrt{1+\Phi_p^2}} \qquad \Phi_p = \frac{\sigma_s}{\sigma_\times}\cdot\frac{\theta_\times}{2} = \frac{\sigma_s}{\beta_\times^*}\cdot\frac{\text{bb}_{\text{sep}}}{2} \qquad \theta_\times = \boldsymbol{\theta}_{\textbf{external}} \pm \boldsymbol{\theta}_{\textbf{spectrometer}} \cos \boldsymbol{\alpha}_{\textbf{plane}}$$



Courtesy of R. de Maria

Protons per bunch	N_b	2.2 10^{11}
Number of Bunches	k_b	2572(2374)
R.M.S. bunch length	σ_s	7.61(9.0) cm
+/- Polarity		B_y<0 / B_y>0

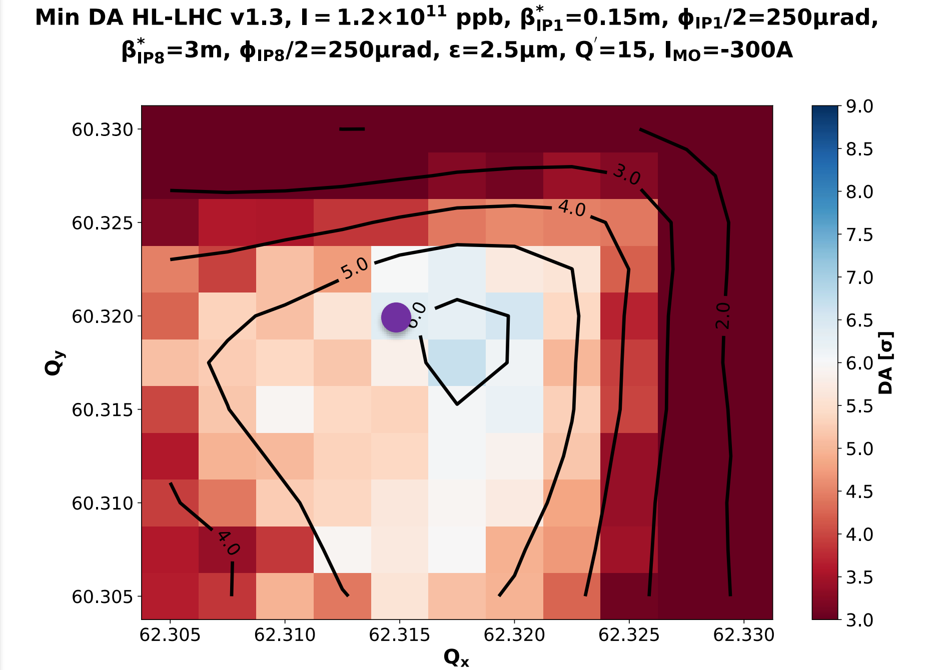
- Minimum β* is constrained by **optics** flexibility.
- Maximum crossing angle limited by **orbit corrector strength**
- For a given β*:
  - **Aperture** constrains maximum crossing angle.
  - **Beam-beam** effects constrains minimum crossing angle.

I. Efthymiopoulos *et al*, *"LHCb Upgrades and operation at $10^{34}\ cm^{-2}s^{-1}$ luminosity –A first study"*, CERN-ACC-NOTE-2018-0038

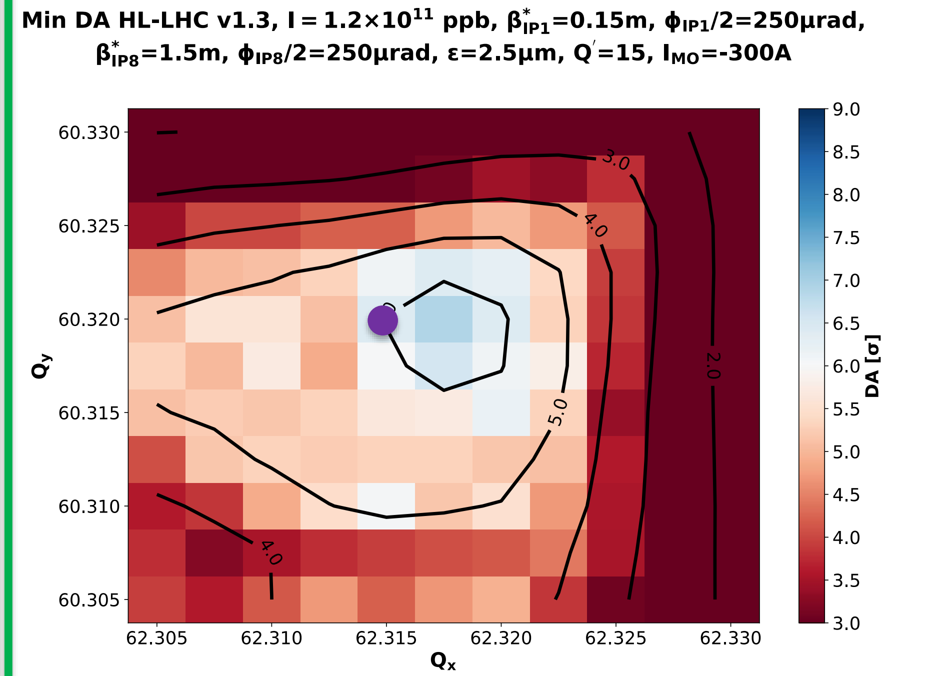
Effect of β* and Levelling

- Available Dynamic Aperture at the end of IP1/5 Leveling.

β*=3m, $L_{lev} = 0.2 \times 10^{34} \mathrm{Hz/cm^2}$



β*=1.5m, $L_{lev} = 1 \times 10^{34} \mathrm{Hz/cm^2}$

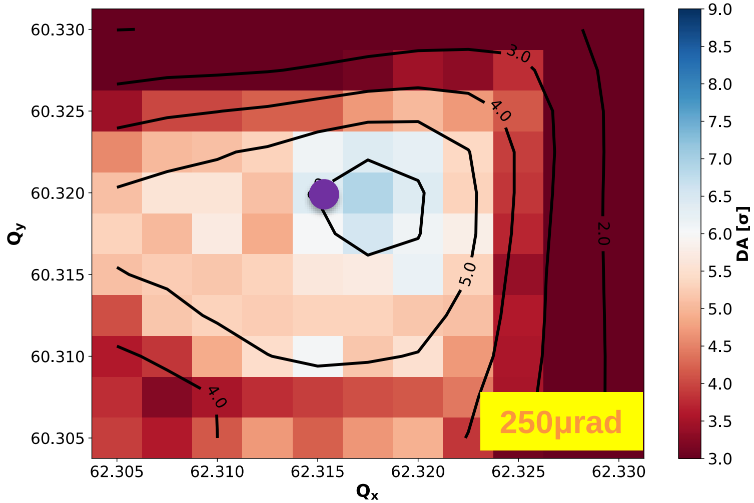


- No significant impact found.

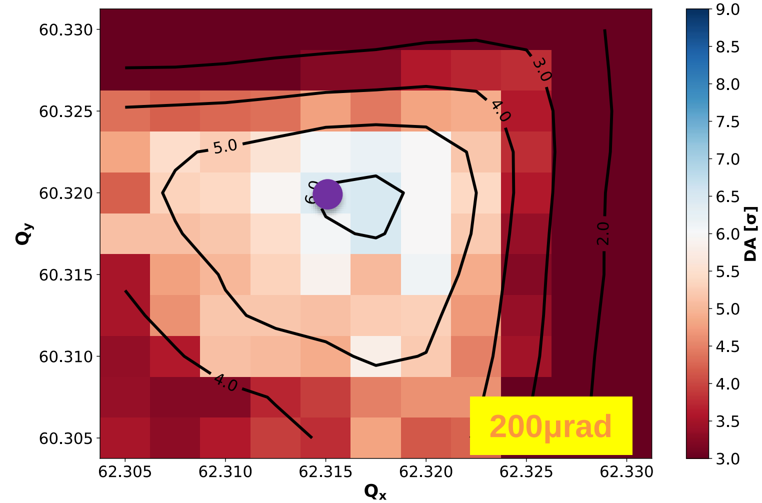
Effect of the External Angle

- Available Dynamic aperture at the end of the IP1/5 leveling

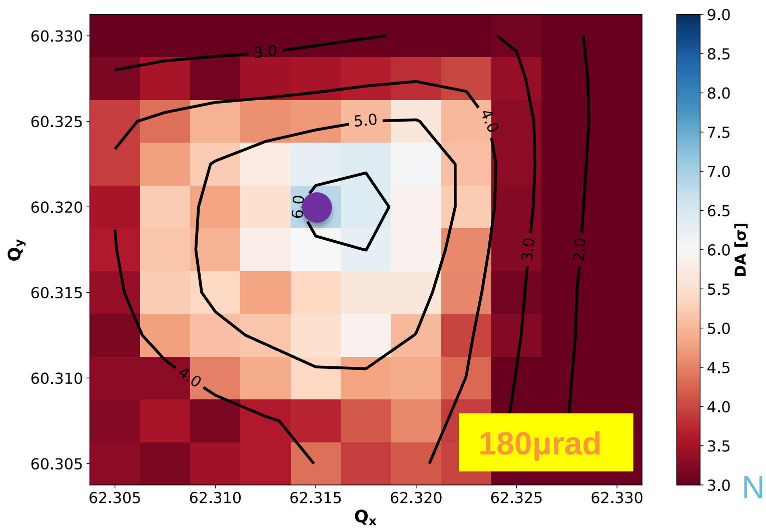
Min DA HL-LHC v1.3, $I=1.2\times10^{11}$ ppb, β^*_{IP1}=0.15m, $\phi_{IP1}/2$=250μrad, β^*_{IP8}=1.5m, $\phi_{IP8}/2$=250μrad, ε=2.5μm, Q'=15, I_{MO}=-300A



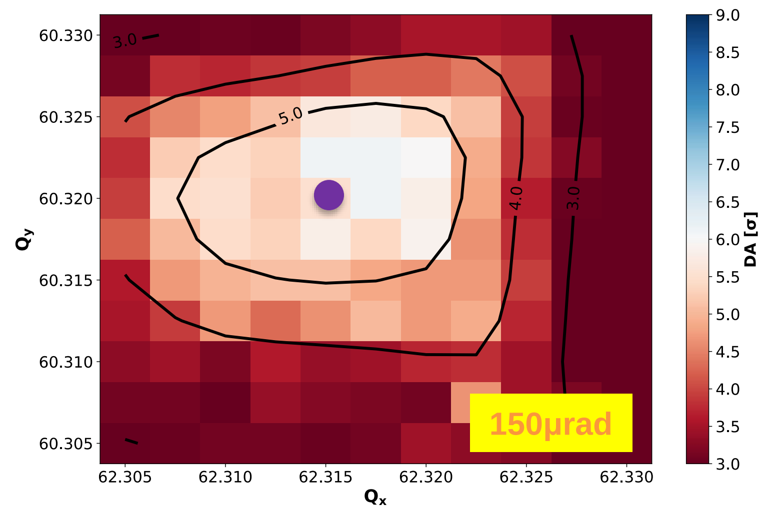
Min DA HL-LHC v1.3, $I=1.2\times10^{11}$ ppb, β^*_{IP1}=0.15m, $\phi_{IP1}/2$=250μrad, β^*_{IP8}=1.5m, $\phi_{IP8}/2$=200μrad, ε=2.5μm, Q'=15, I_{MO}=-300A



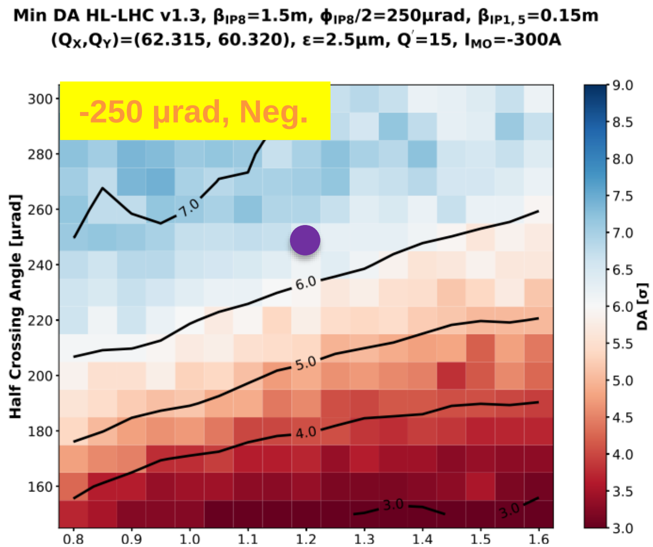
Min DA HL-LHC v1.3, $I=1.2\times10^{11}$ ppb, β^*_{IP1}=0.15m $\phi_{IP1}/2$=250μrad, β^*_{IP8}=1.5m, $\phi_{IP8}/2$=180μrad ε=2.5μm, Q'=15, I_{MO}=-300A

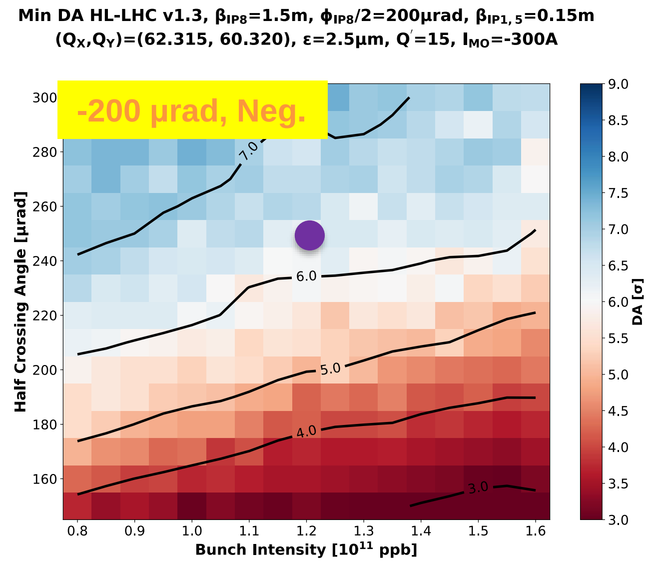


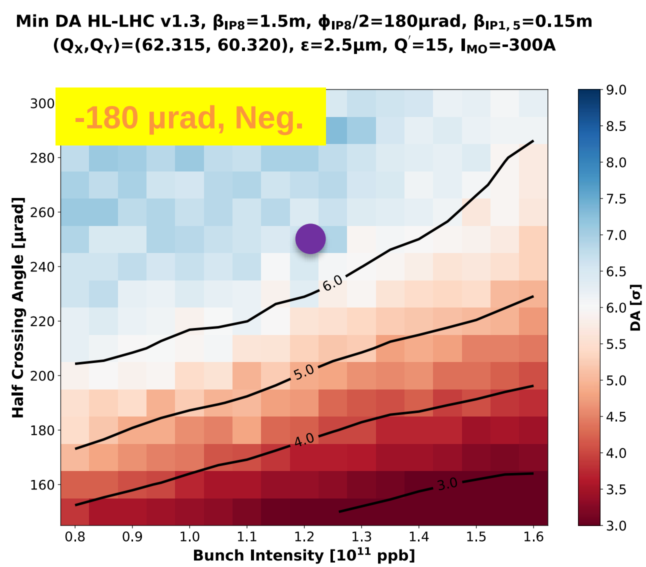
Min DA HL-LHC v1.3, $I=1.2\times10^{11}$ ppb, β^*_{IP1}=0.15m, $\phi_{IP1}/2$=250μrad, β^*_{IP8}=1.5m, $\phi_{IP8}/2$=150μrad, ε=2.5μm, Q'=15, I_{MO}=-300A

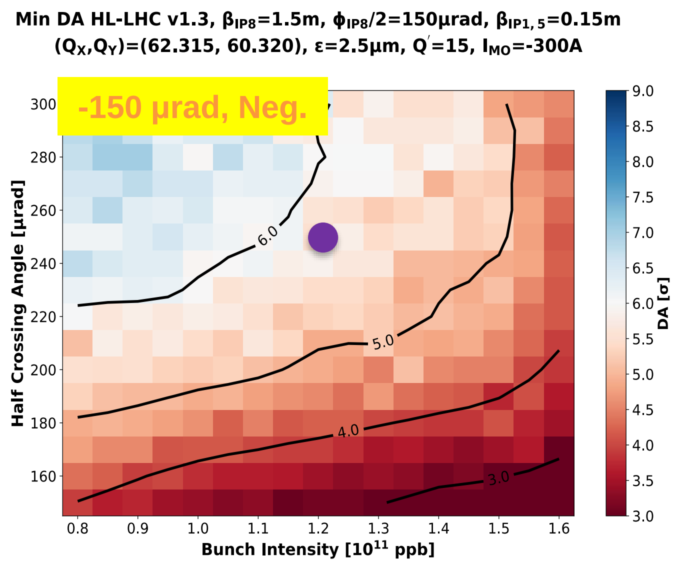


Beam-beam limitations at collision



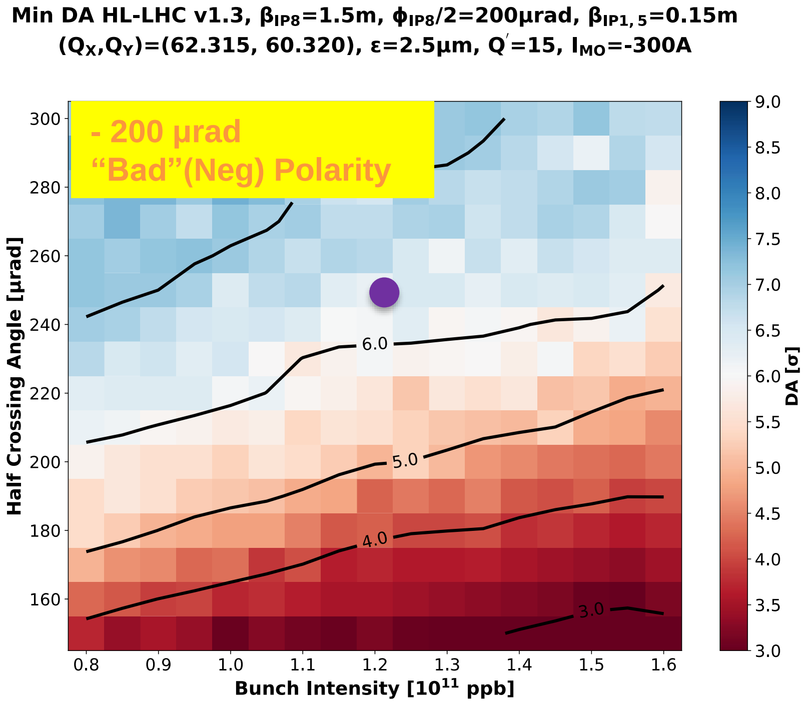


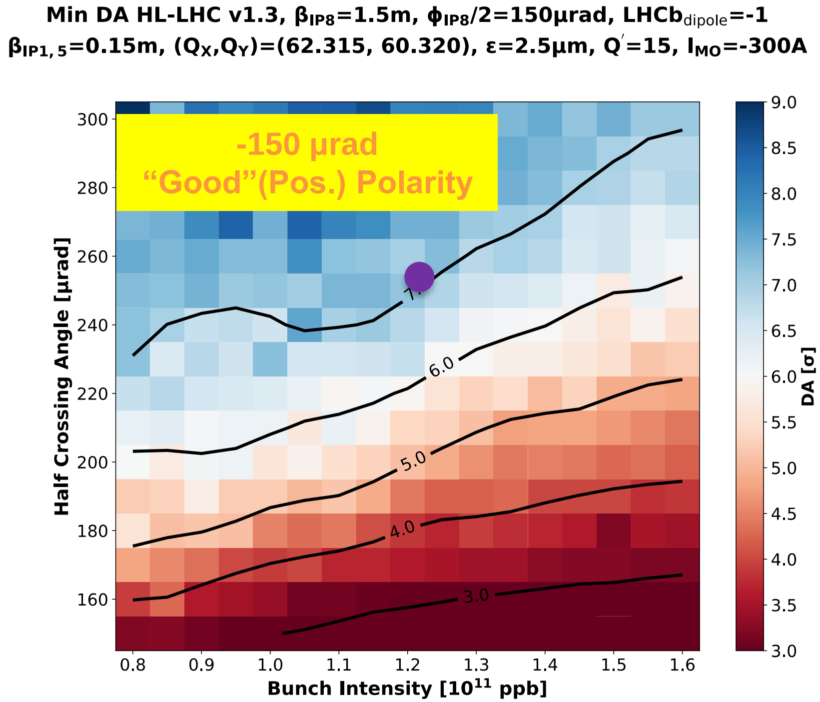




Effect of Spectrometer Polarity

- **Spectrometer polarity** has an impact of minimum external crossing angle.
- Tentative IR8 external half crossing angle with horizontal crossing:
  - -200 µrad with Neg. polarity (-65 µrad half crossing angle)
  - -150 µrad with Pos. polarity (-285 µrad half crossing angle)

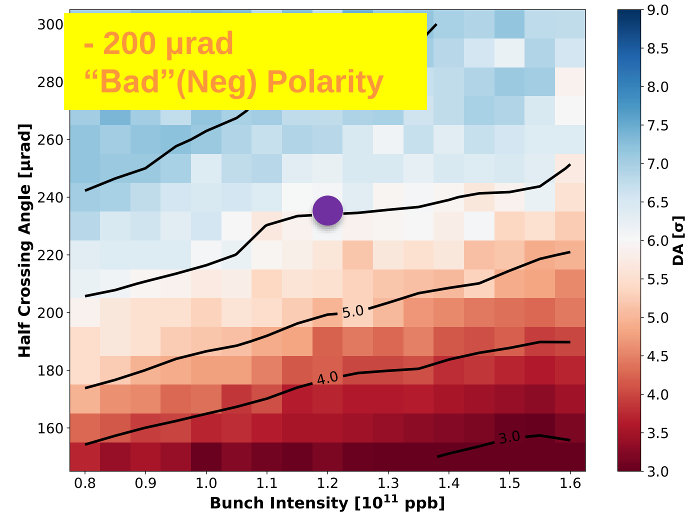




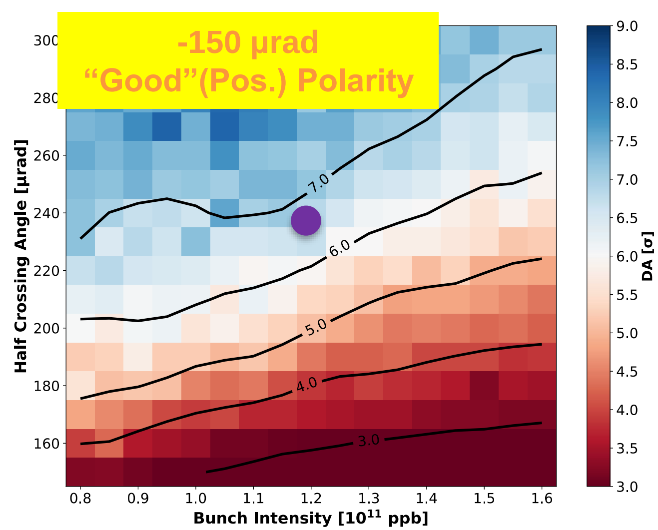
Crossing Angle Plane

- A **vertical external** half crossing angle of 160 μrad is expected to behave in between the two **horizontal options** (210 μrad half crossing angle)
  - ➢ no need of beam screen rotation.

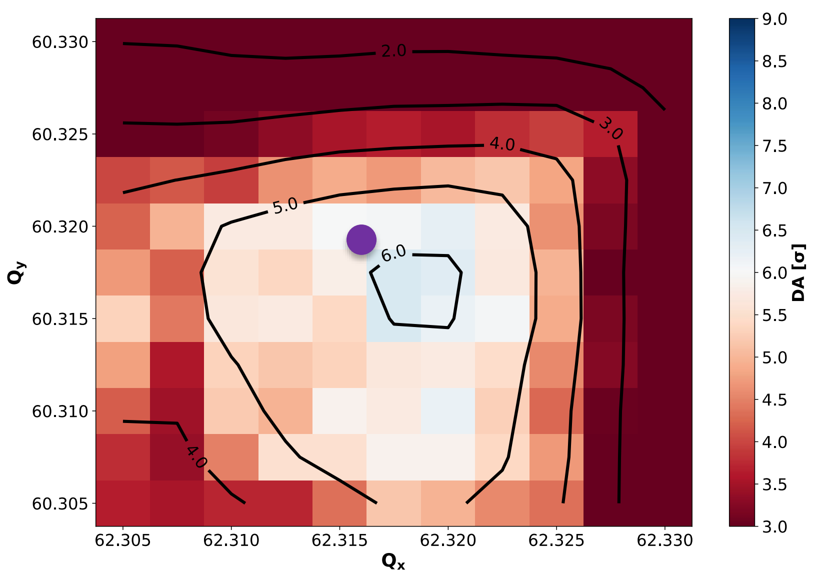
Min DA HL-LHC v1.3, β_{IP8}=1.5m, $\phi_{IP8}/2$=200μrad, $\beta_{IP1,5}$=0.15m
(Q_X,Q_Y)=(62.315, 60.320), ε=2.5μm, Q'=15, I_{MO}=-300A



Min DA HL-LHC v1.3, β_{IP8}=1.5m, $\phi_{IP8}/2$=150μrad, $LHCb_{dipole}$=-1
$\beta_{IP1,5}$=0.15m, (Q_X,Q_Y)=(62.315, 60.320), ε=2.5μm, Q'=15, I_{MO}=-300A

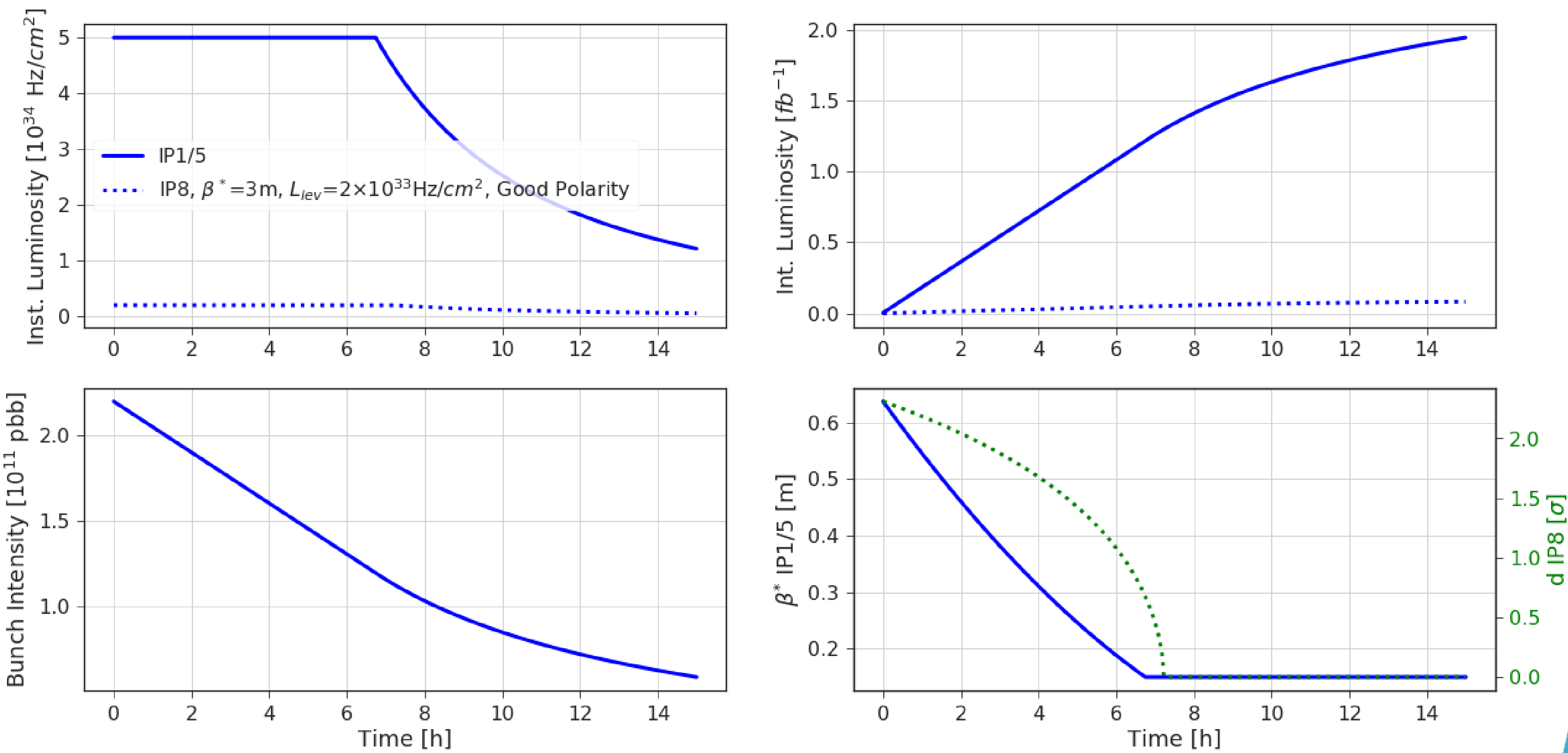


Min DA HL-LHC v1.3, I = 1.2×10^{11} ppb, β^*_{IP1}=0.15m
$\phi_{IP1}/2$=250μrad, β^*_{IP8}=1.5m, $\phi_{IP8}/2$=150μrad (Vertical)
ε=2.5μm, Q'=15, I_{MO}=-300A



Simple Model: Constant ε evolution & xing-angle

Some Performance Estimates



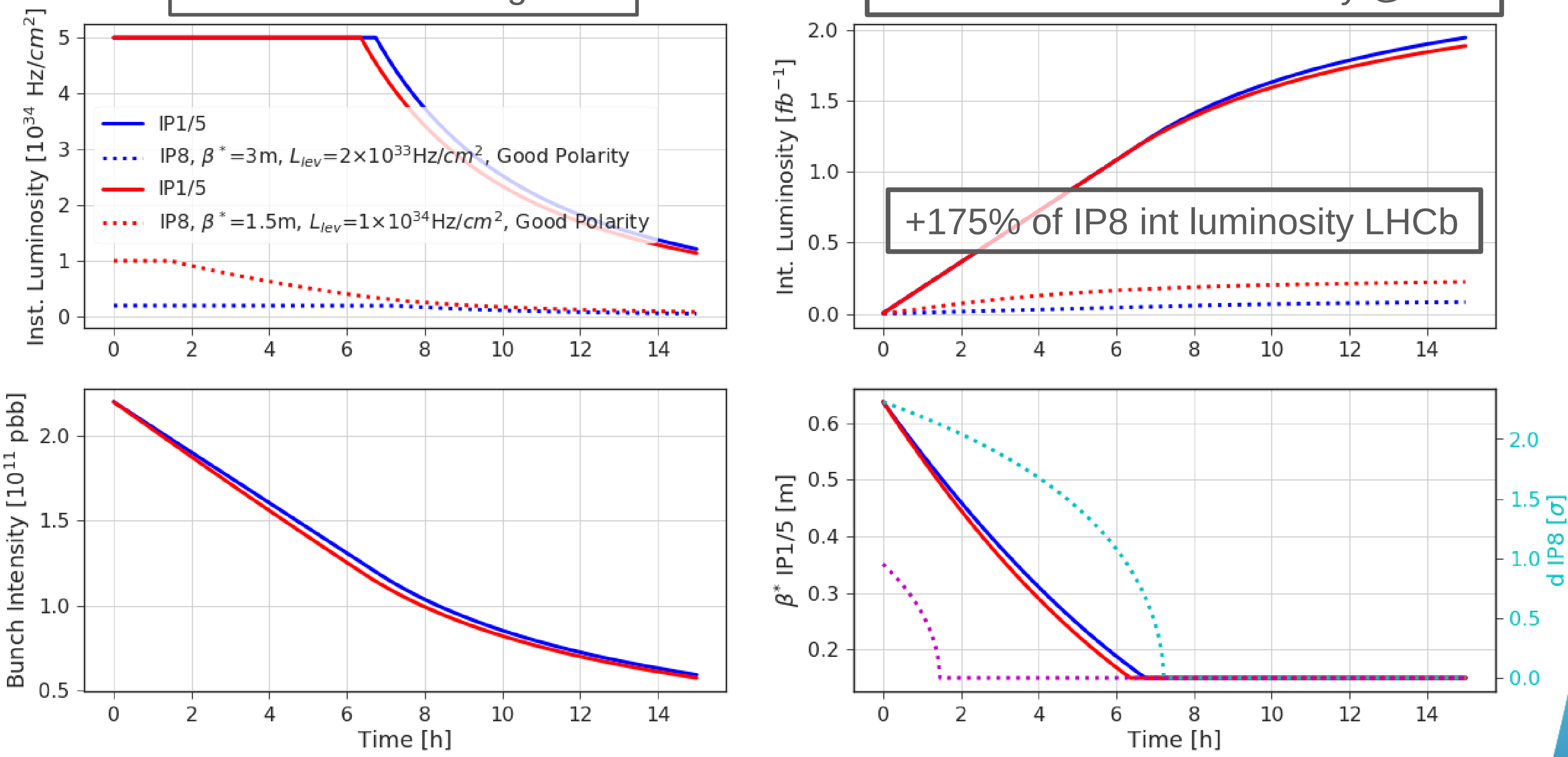
Simple Model: Constant emittance & xing-angle, 110mb burn-off

Some Performance Estimates

-6% of IP1/5 leveling time

-3% of IP1/IP5 int. luminosity @ 15h

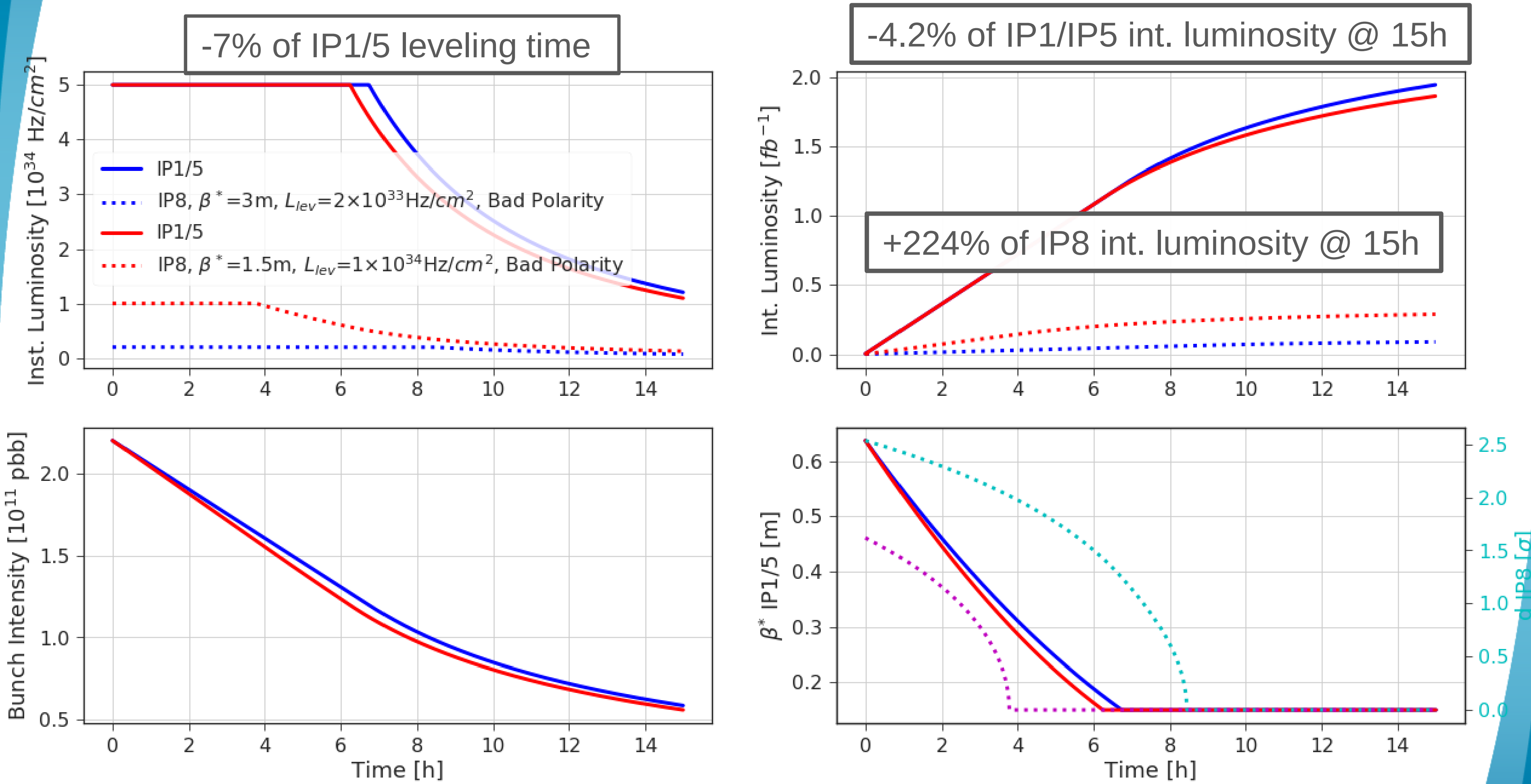
+175% of IP8 int luminosity LHCb



Simple Model: Constant emittance & xing-angle, 110mb burn-off

LHCb Upgrades

LHCb at 250μrad → Spectrometer adds in xing



LHCb Phase II Upgrade - Summary

- For the **Phase-II upgrade of the LHCb** detector, increased luminosity should be provided (**$\sim 1.0 \times 10^{34} \mathrm{Hz/cm^2}$**) without large degradation of the luminosity provided to the main IPs.

- Different constraints arise from optics, aperture and beam-beam effects.
  - **Reduction of β* from 3m to 1.5m**, increasing the delivered luminosity 5 times → No significant impact on the end of IP1/IP5 levelling DA.
  - Reduction of the **external crossing angle impacts** the IP1/5 end of levelling DA.
  - The **spectrometer polarity impacts** the DA and the integrated performance.

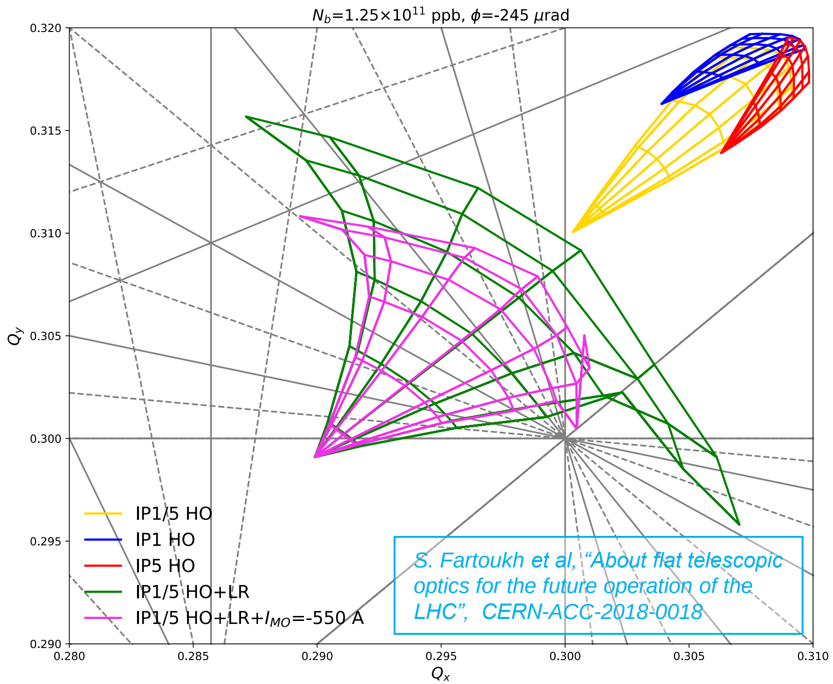
- Tentative scenarios identified with levelled luminosity of $1.0 \times 10^{34} \mathrm{Hz/cm^2}$ and similar performance:
  1. **Horizontal crossing** with **-200/+150 μrad** external→ Polarity significantly impacts performance.
  2. **Vertical crossing** is also possible with rotation of the crossing plane at flat top

- Also, **flat optics** could be a solution for LHCb operation since:
  - Can improve **luminosity at constant aperture** and beam-beam separation in the triplet
  - Triplet irradiation without BS rotation

3. First look at HiLumi with flat optics

"Layman's" Intro to Flat Optics

- **Flat Optics** have been proposed as ***"plan B"*** of HL-LHC operation **without CC**, due to their increased performance in terms of virtual luminosity.
- Contrary to the LHC case, the HL-LHC triplet beam screens allow for flattening the beams in the two main IPs **without restrictions of the crossing plane**.
- Alternating crossing planes, the flat optics option **reduces the head-on beam-beam tune shift** (and spread) at constant peak luminosity.
- The **long range beam-beam** induced tune shift is not full compensated
  → significant impact on the tune shift, **almost similar to HO**.
- The **BBLR compensation** (octupoles, wires, etc) plays a **crucial** role on the available operational margins (*see Guido's, Kyriacos' talks*).



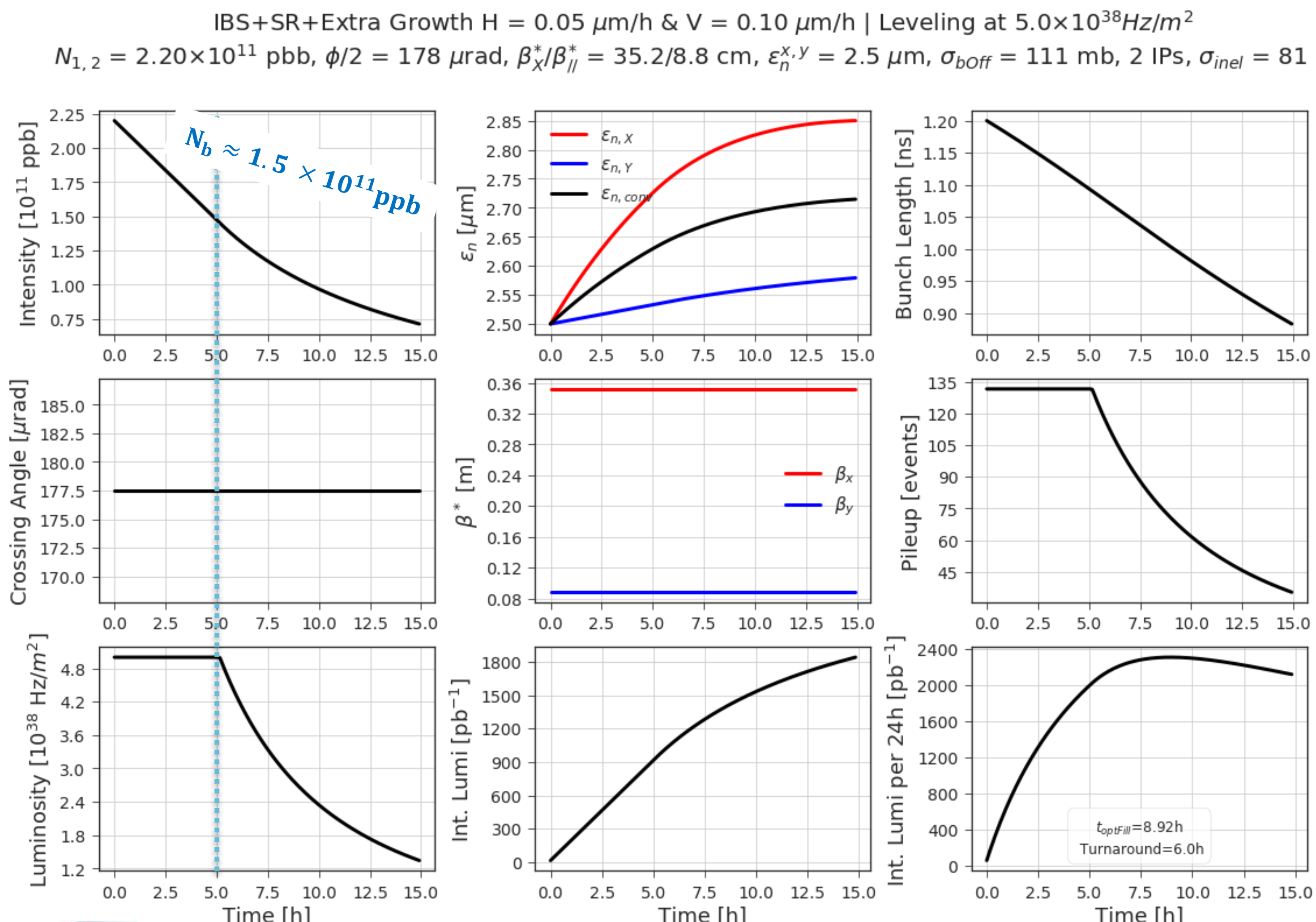
S. Fartoukh et al, "About flat telescopic optics for the future operation of the LHC", CERN-ACC-2018-0018

- A scheme containing flat optics would require to **start collide at round optics** then flatten the β*, squeezing more in the parallel plane while intensity decays.

  ➔ Such operational scenario is still **on-going work**.
- Here we have a **first look** at the **end of levelling conditions**.

What is my end of levelling?

- Optics from the "catalogue": **r*=4** i.e. **$\beta_x/\beta_{//}$ = 35.2/8.8 cm**
- Assuming **11.5σ** crossing angle, **leveling by separation** and some additional **emittance growth** on top of IBS+SR



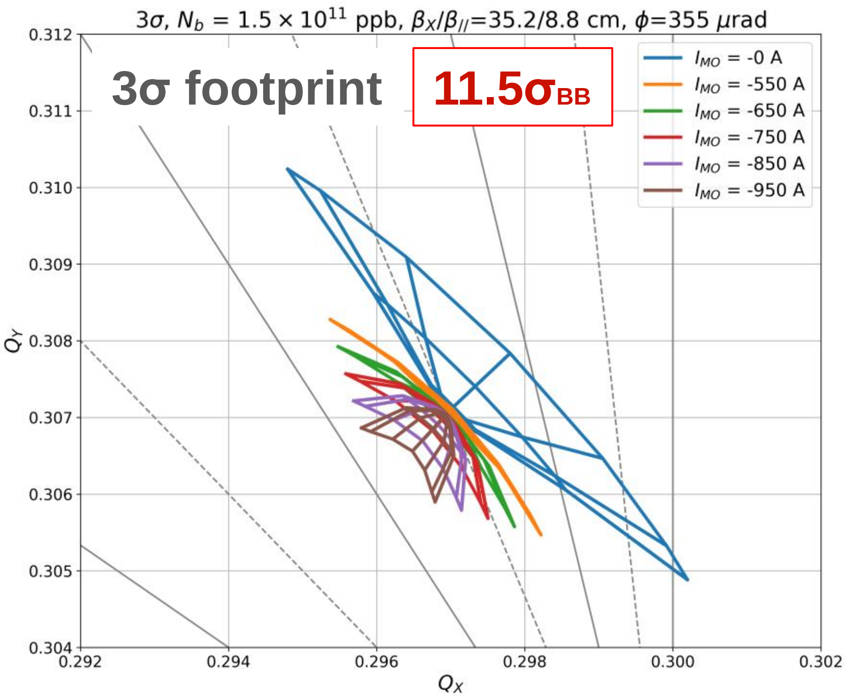
Pessimistic turnaround

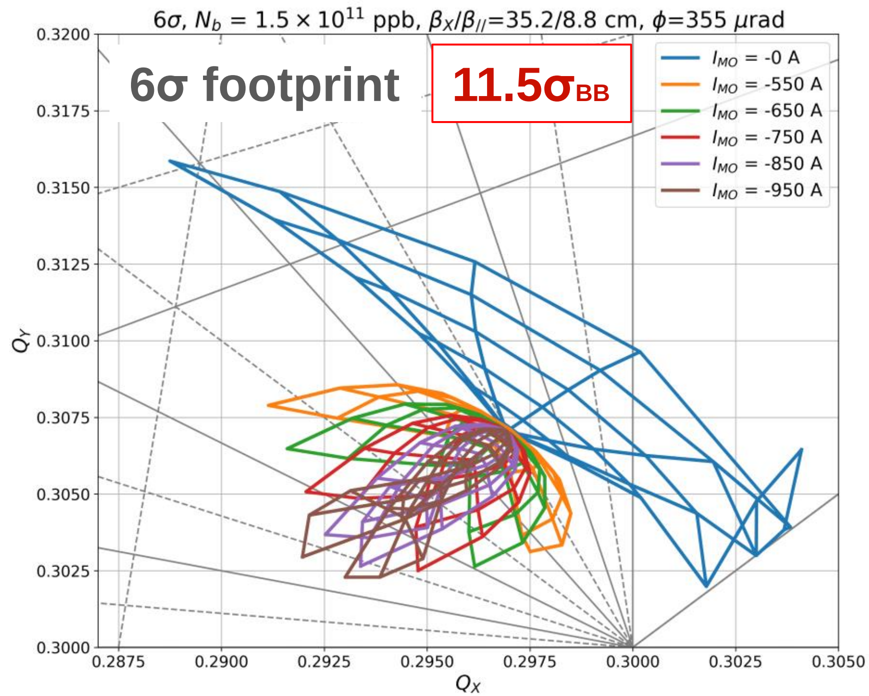
Footprints

- The scaling of octupole current for the BB compensation follows:

$$I_{MO}^{bb} = 315[A] \times \frac{N_b[10^{11}]}{1.25} \times \left(\frac{80}{\beta_X[cm]}\right)^2 \times \left(\frac{300}{\Theta_X}\right)^4 \times \frac{h_{bb}(r^*)}{h_{MO}(r_X, r_{//})}$$

- For our end of leveling conditions: $I_{MO}^{bb} \approx 1557$ A

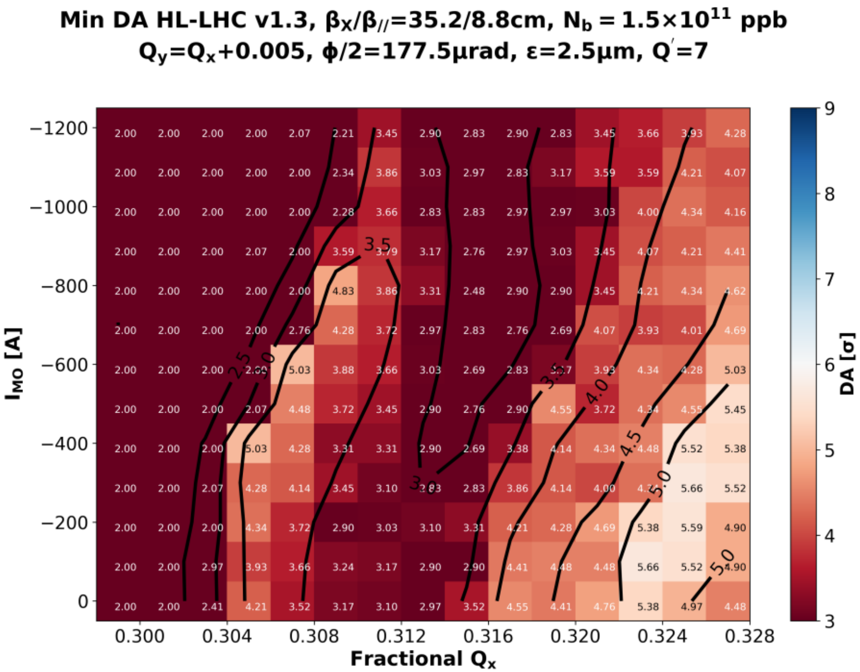




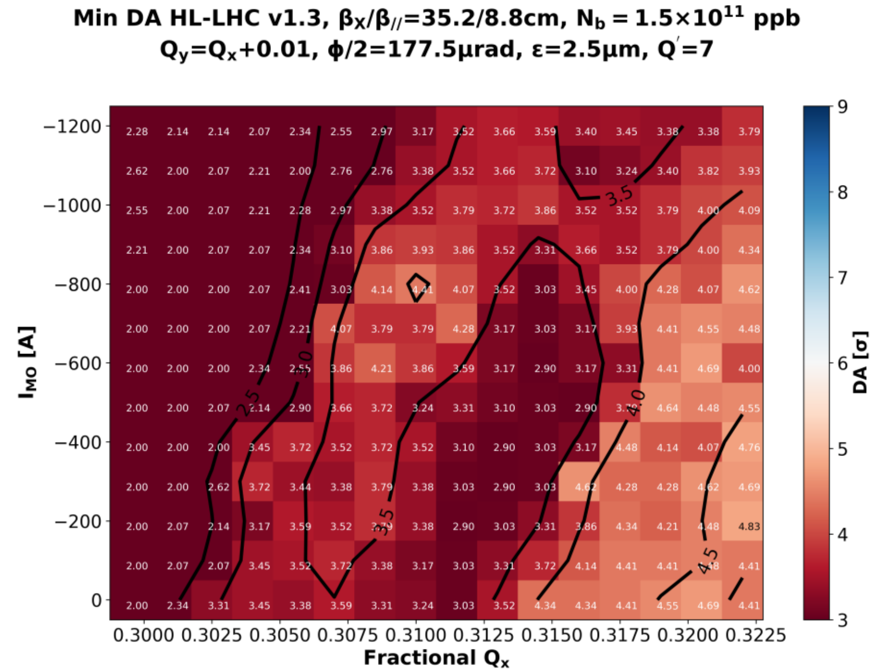
- Some **b6** effect still visible even on **3σ** footprint → a simple **BBLR mitigation with octupoles** could be **marginal**

Tune & Octupoles: 11.5σ & Q' = 7

Tune split d = 5×10^{-3}



Tune split d = 10^{-2}



- Optimal configuration seems around $\mathbf{I_{MO} = -100\ A}$ with **5.7σ** of DA with **(.324, .329)**
- BBLR compensation with **octupoles** are **not enough** to preserve good DA even with **11.5σ**
- Increasing the normalized crossing would **significantly affect the integrated performance**.

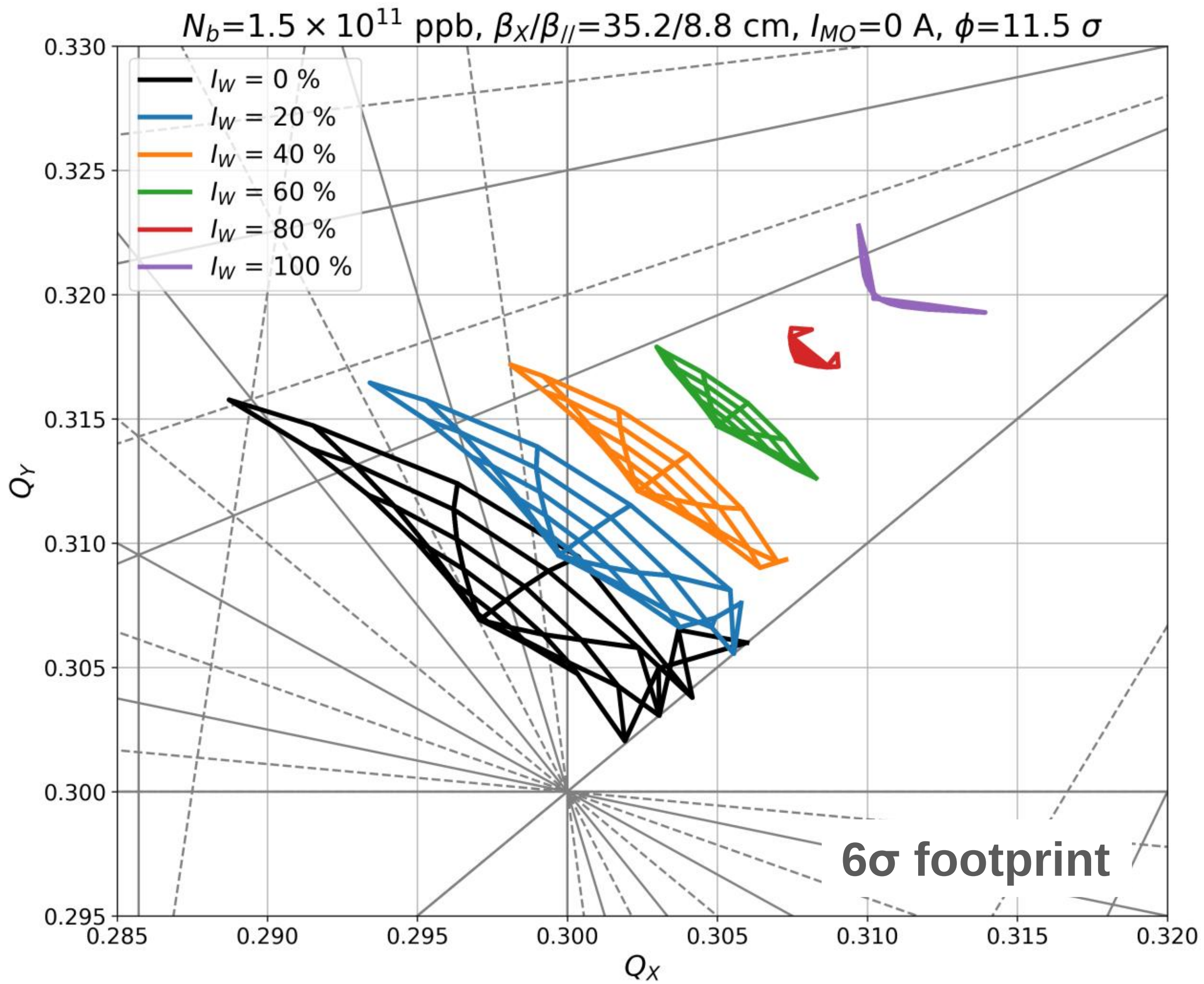
See Kyriacos' talk for an intro on the wire optimization for round optics

Wire Compensation

- Using the tools developed for S. Fartoukh, *et al.*, *"Compensation of the long-range beam-beam interactions as a path towards new configurations for the high luminosity LHC"*, PRAB 18 121001 (2015)

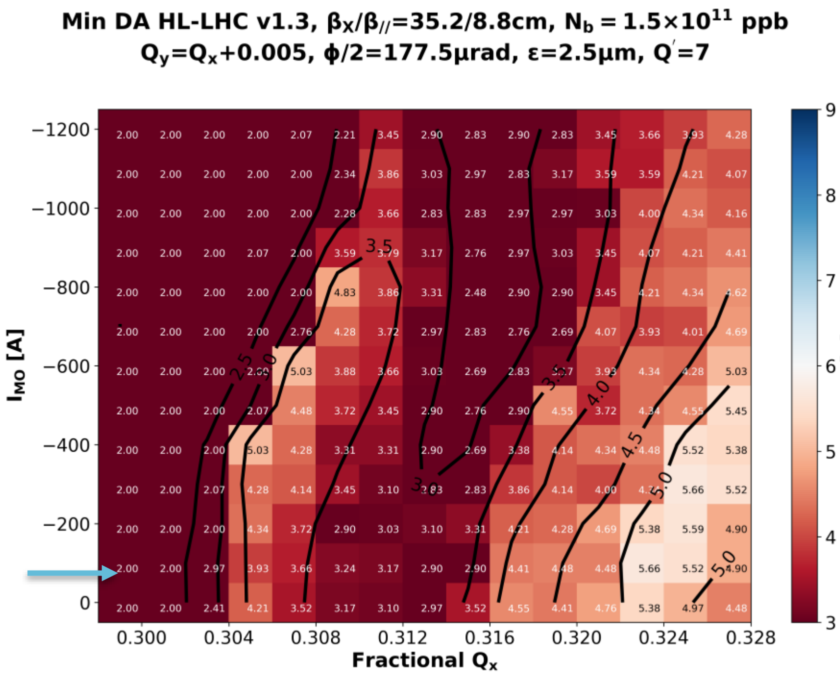
S_{WIRE}: 198.04m from the IP

I_W [%]	I_W [A m]
20	26.84
40	53.68
60	80.53
80	107.37
100	134.21



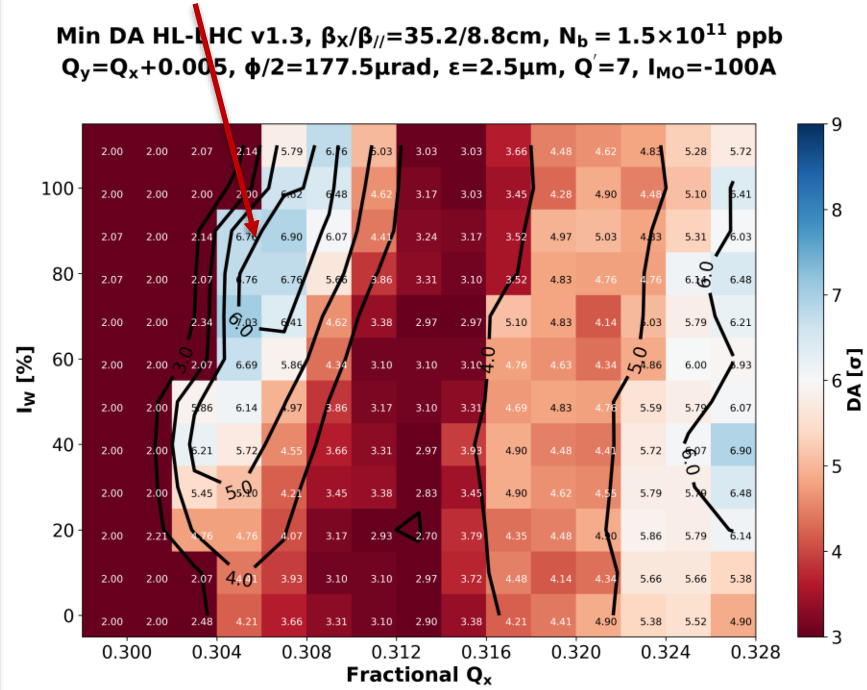
BBLR Compensation @ 11.5σ

Octupoles



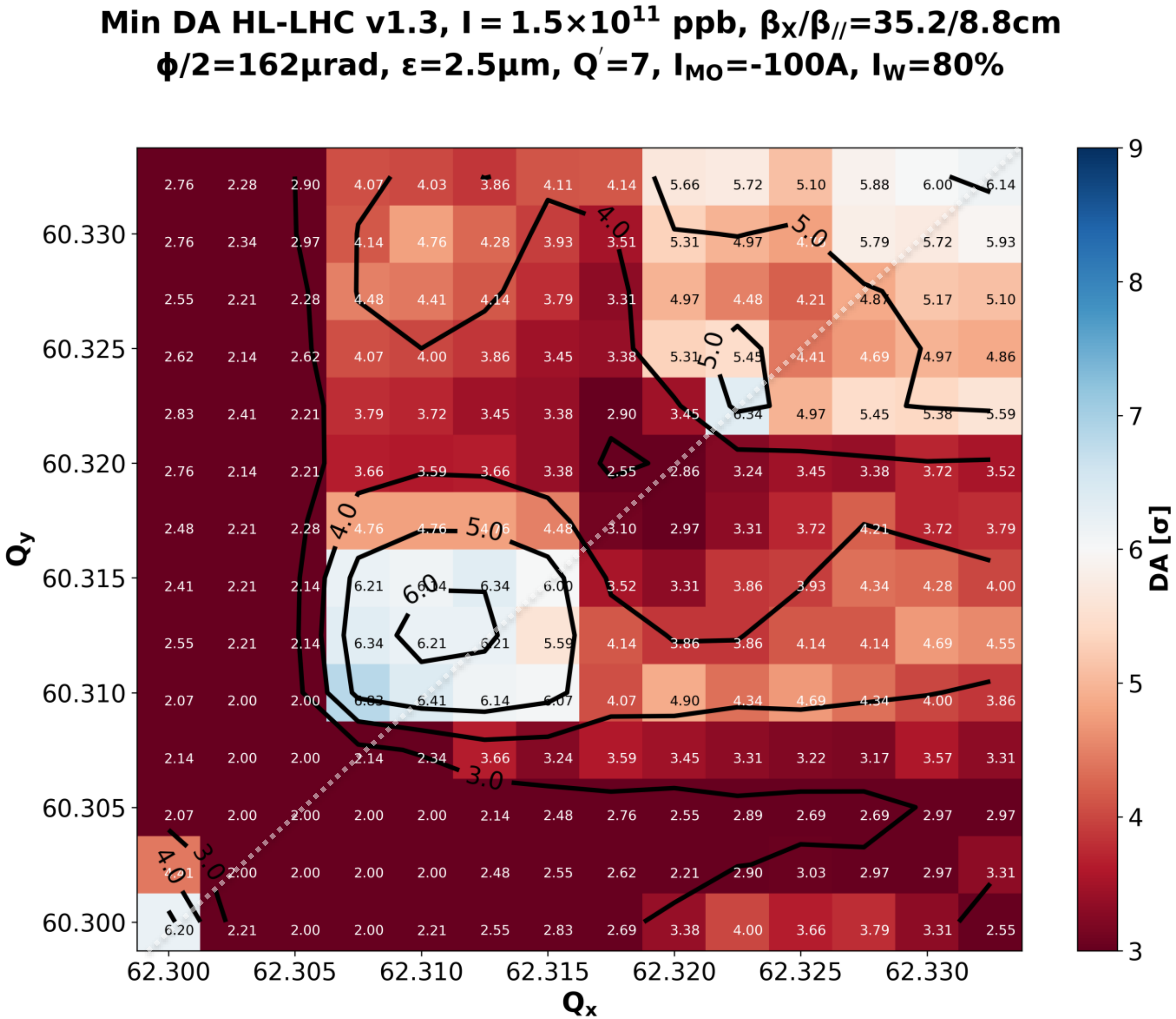
~7σ island

Wire [IMO=-100A]



- The addition of the wire adds ~**1.5σ at constant normalized crossing angle**.
- Additional studies showed that **the minimum DA** is only marginally affected by the **collisions in IR2/IR8 (~0.3σ)**, and that the additional **LR in the D1 have no impact**.
  → *But they do affect the shape of the tune space.*

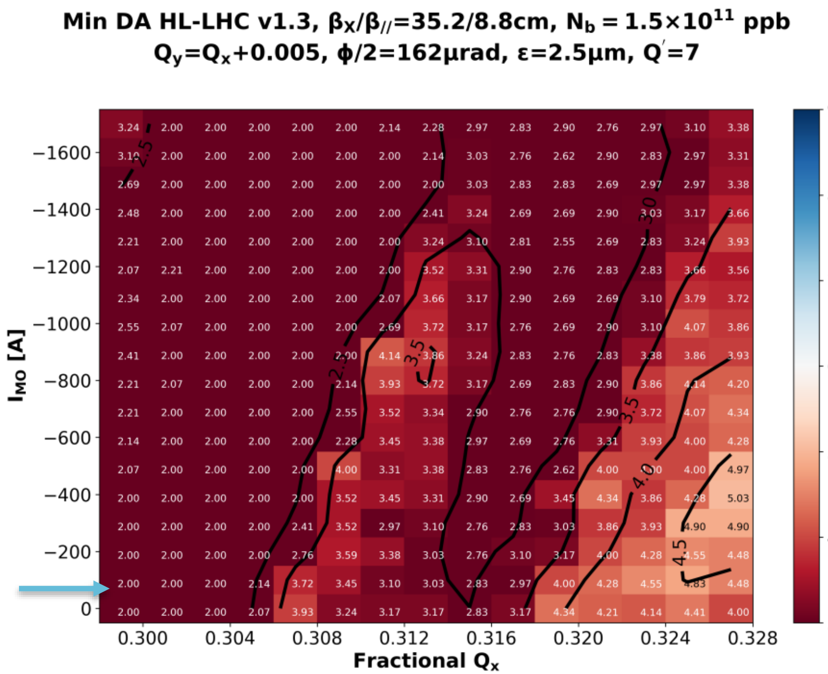
Tune Scan with wire at ~107.4 A m for 10.5σ



BBLR Compensation @ 10.5σ

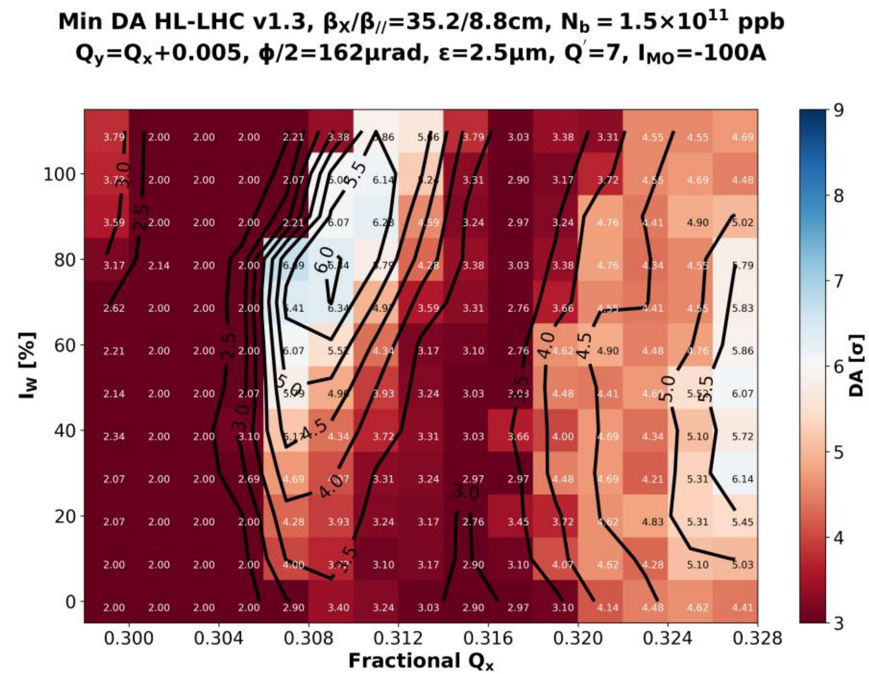
Octupoles

10.5σ



Wire [IMO=-100A]

10.5σ



- *Could even try to reduce further the crossing? (or increase chroma?)*

Flat Optics Simulations - Summary

- Due to the reduced β* in one of the two planes, the **flat optics option** can be a **great performance booster**, **with or without Crab Cavities** (*see Stéphane's talk*)

- However, the lack of LR passive compensation would require **to start collisions at the round mode** and switch to flat with the reduction of intensity.

- At small crossing angles (~10.5σ) the b6 effect is impacting the footprint, **making the compensation with octupoles quite difficult** (<5σ DA).

- On the other hand, an optimal interplay between octupole compensation and **DC wire** compensation can be found.
  - The wire would be a **relatively cheap BBLR compensator** allowing to push the crossing angle and thus boost performance.
  - However a **good control of the tune** would be again crucial for the optimal operation.

- First DA studies show that HL-LHC at the end of levelling intensity $\approx \mathbf{1.5 \times 10^{11} ppb}$ up to **6.7σ of DA** can be achieved at a crossing angle as low as **10.5σ with DC wire**.

- Additional **optimizations** can be improve even further the situation resulting in more pushed crossing angle.

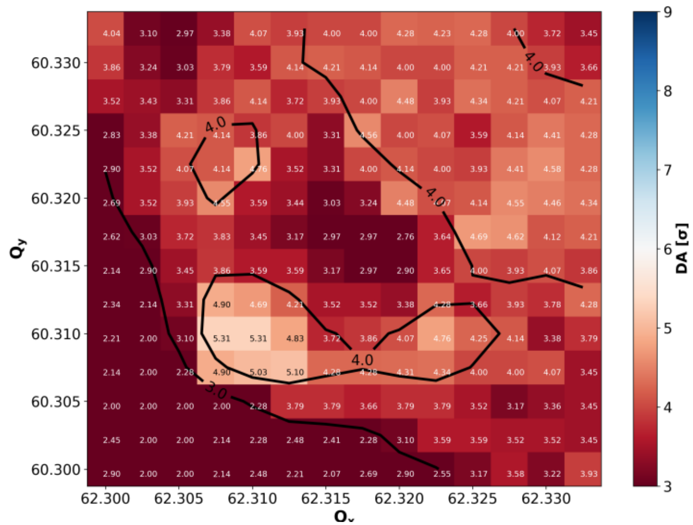
Thank you for your attention

and many thanks to all the LHC@home SixTrack *volunteers!*

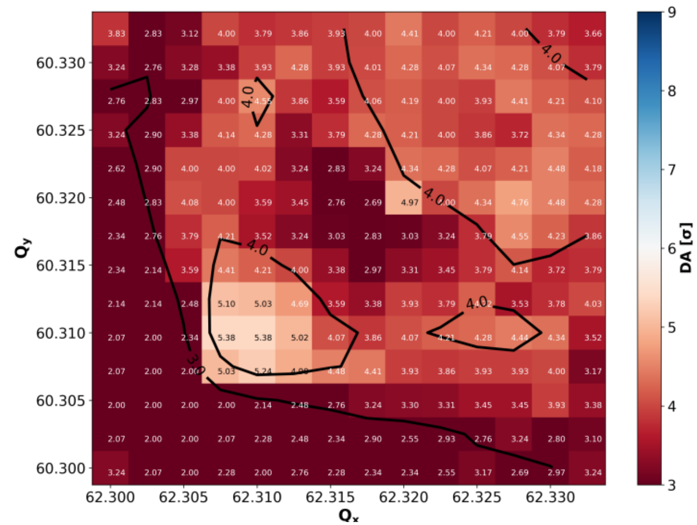
Preliminary study for 10.5σ (~5.5σ DA)

For WP2

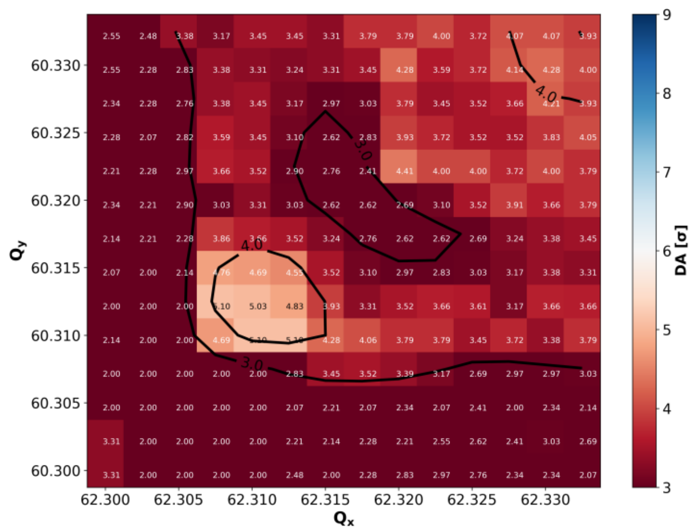
Min DA HL-LHC v1.3, $N_{LR,D1}$=0, No IR2/8, I = 1.5×10^{11} ppb
$\beta_X/\beta_{//}$=35.2/8.8cm, $\phi/2$=162μrad, ε=2.5μm, Q′=2, I_{MO}=0A, I_W=80%



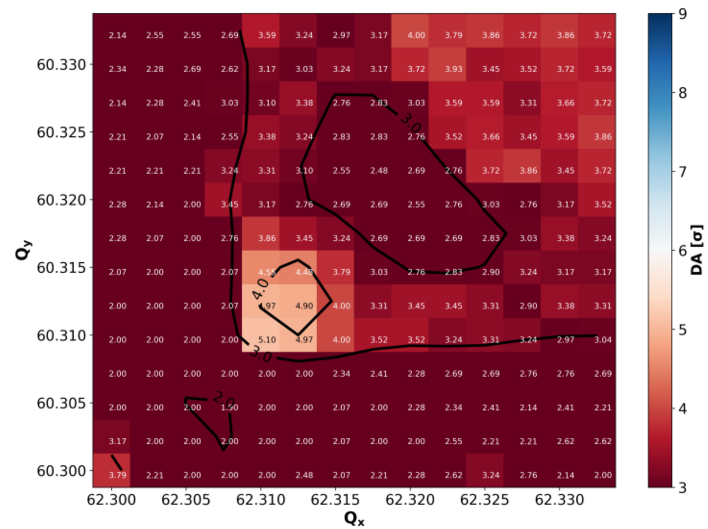
Min DA HL-LHC v1.3, $N_{LR,D1}$=5, No IR2/8, I = 1.5×10^{11} ppb
$\beta_X/\beta_{//}$=35.2/8.8cm, $\phi/2$=162μrad, ε=2.5μm, Q′=2, I_{MO}=0A, I_W=80%



Min DA HL-LHC v1.3, $N_{LR,D1}$=5, With IR2/8, I = 1.5×10^{11} ppb
$\beta_X/\beta_{//}$=35.2/8.8cm, $\phi/2$=162μrad, ε=2.5μm, Q′=2, I_{MO}=0A, I_W=80%



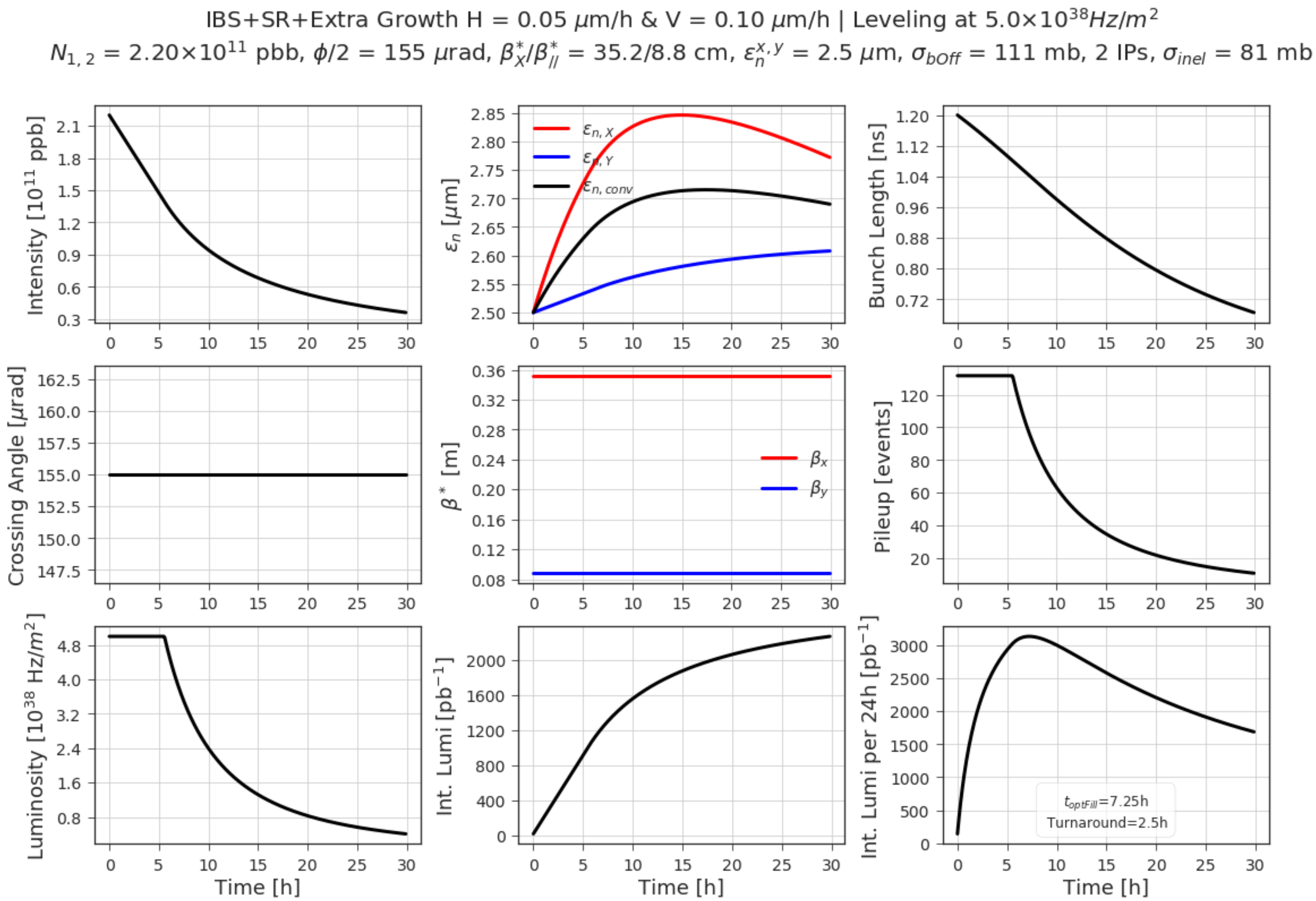
Min DA HL-LHC v1.3, I = 1.5×10^{11} ppb, $\beta_X/\beta_{//}$=35.2/8.8cm
$\phi/2$=162μrad, ε=2.5μm, Q′=7, I_{MO}=-100A, I_W=80%



HiLumi HL-LHC PROJECT

Levelling at 5e34 @ 10σ (155)

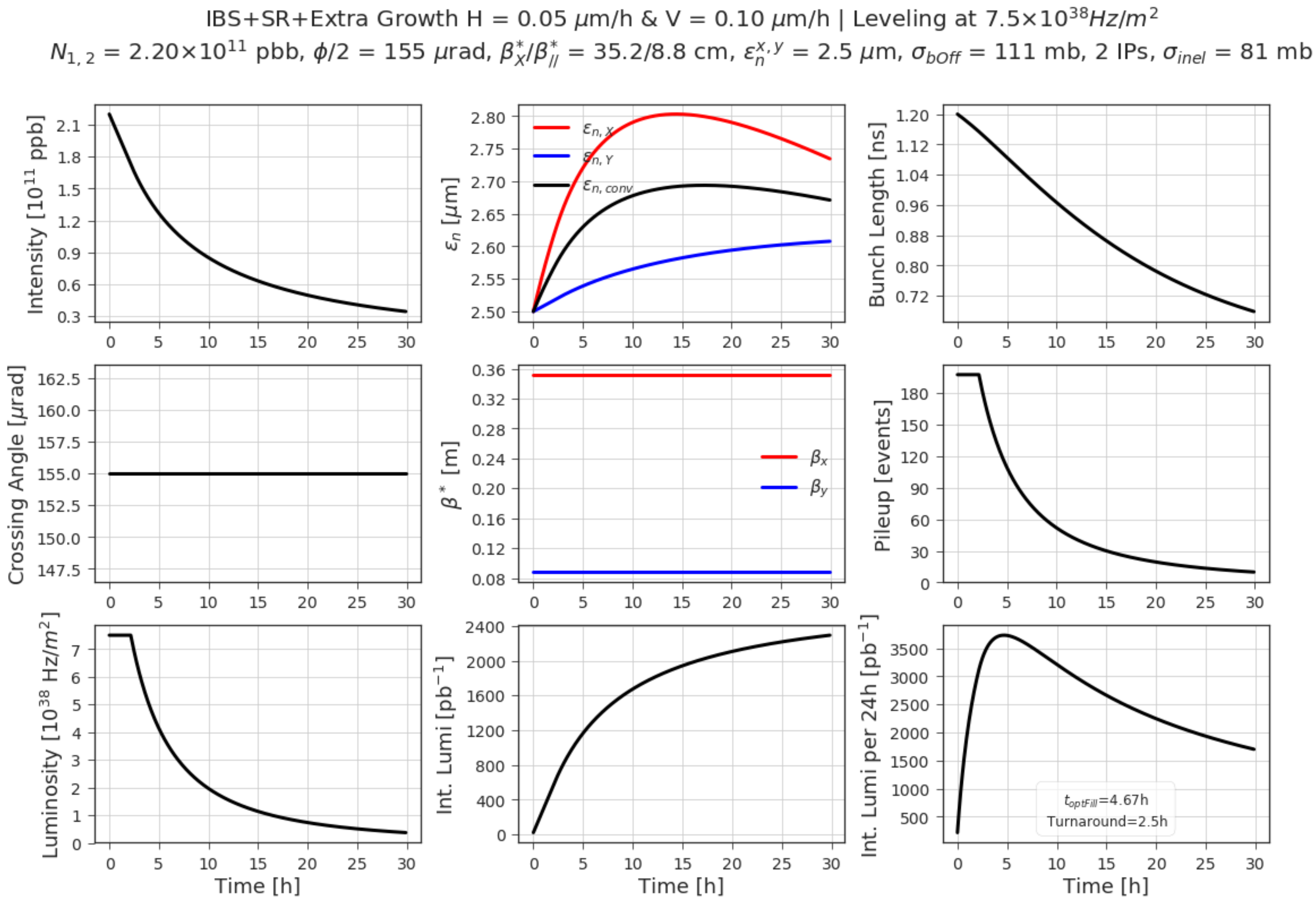
End of levelling bunch intensity ~ 1.4e11



3.13/fb

Levelling at 7.5e34 @ 10σ (155)

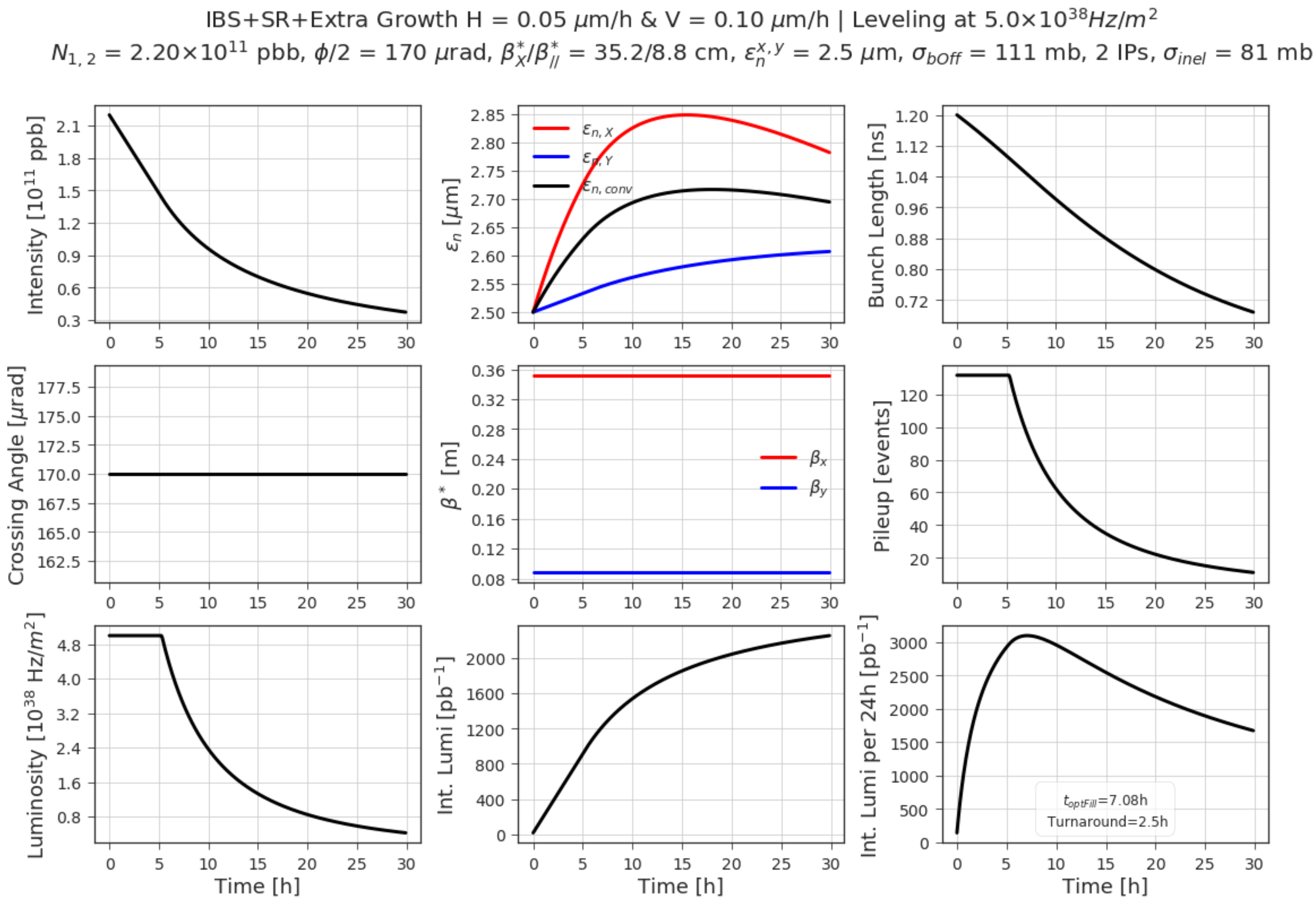
End of levelling bunch intensity ~ 1.7e11



3.73/fb

Levelling at 5e34 @ 11σ (170)

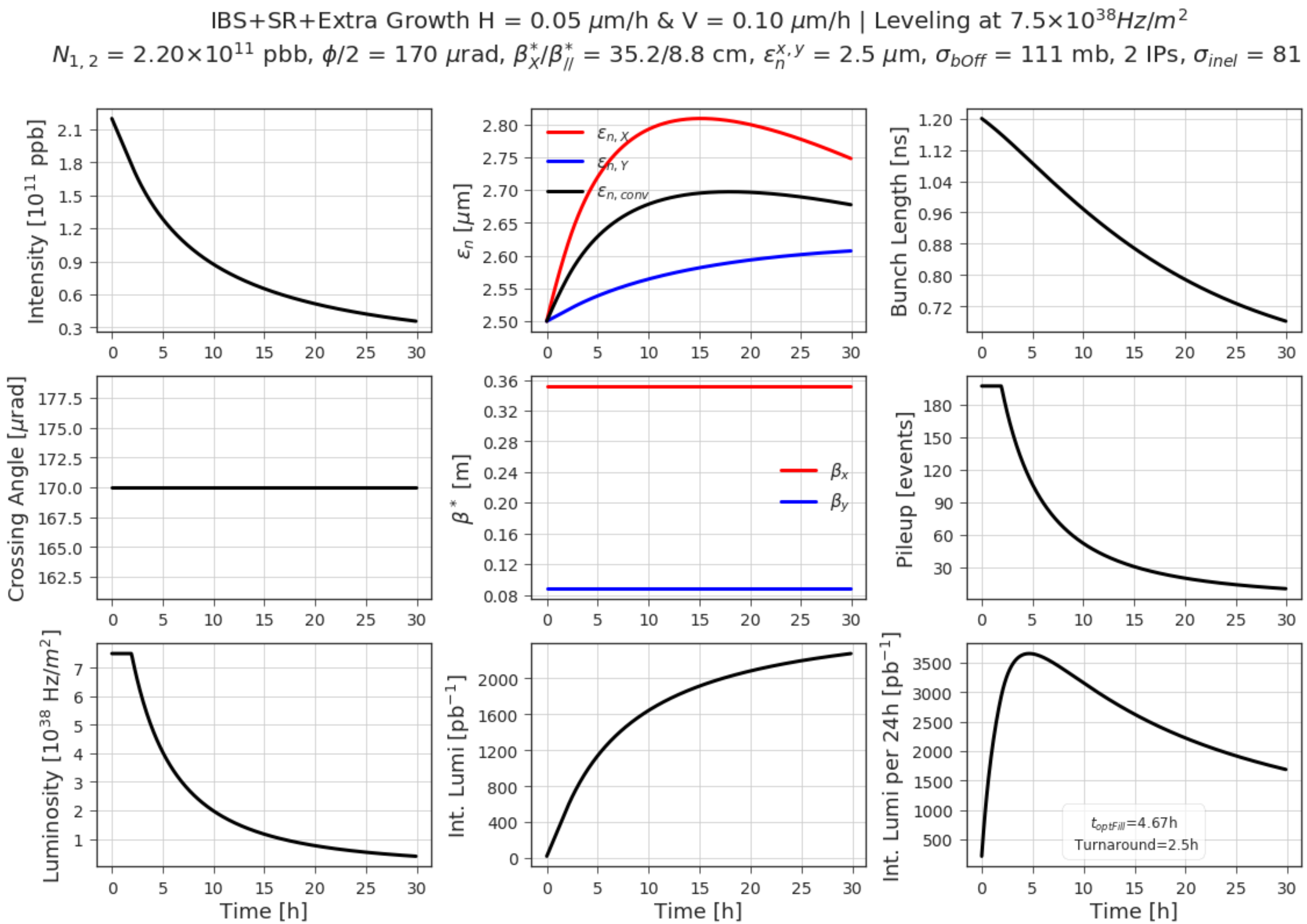
End of levelling bunch intensity ~ 1.4e11



3.1/fb

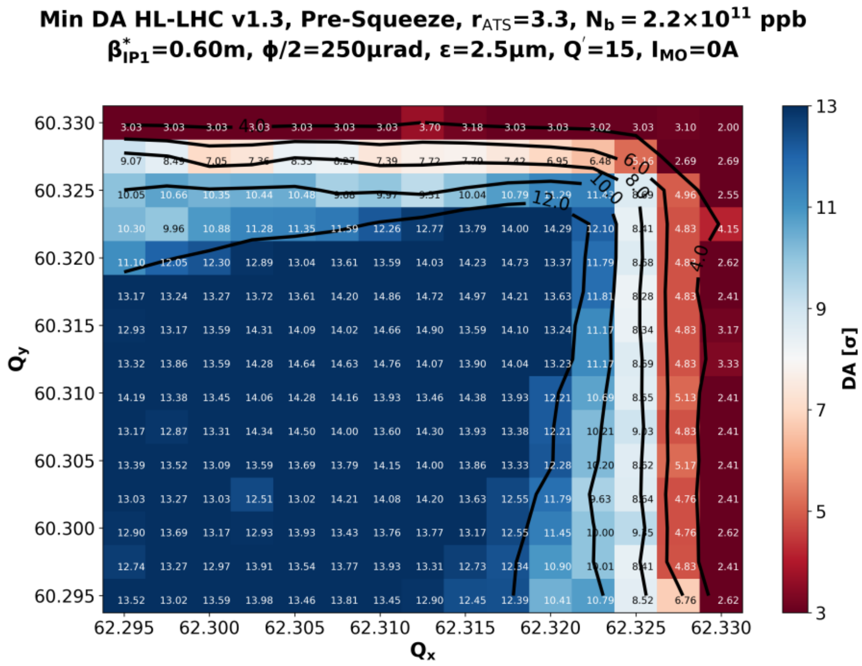
Levelling at 7.5e34 @ 11σ (170)

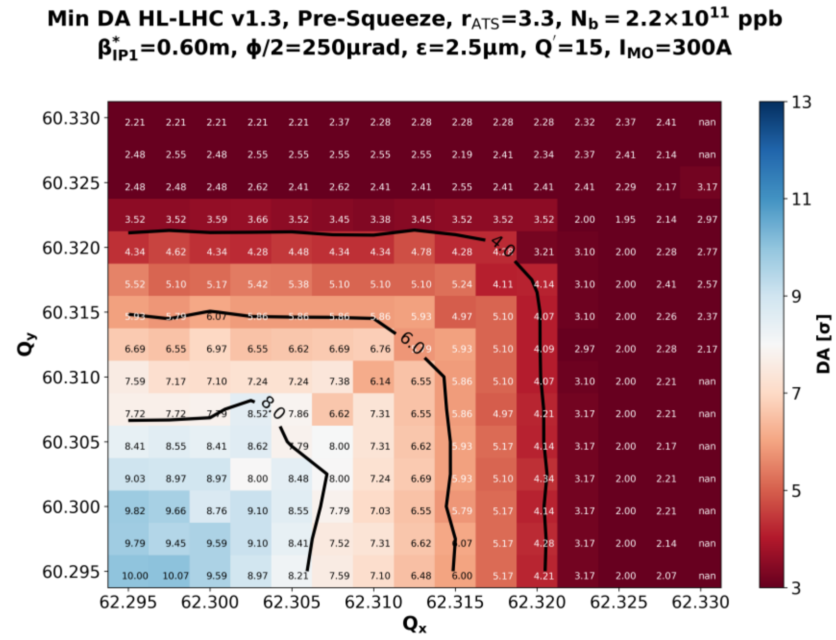
End of levelling bunch intensity ~ 1.8e11

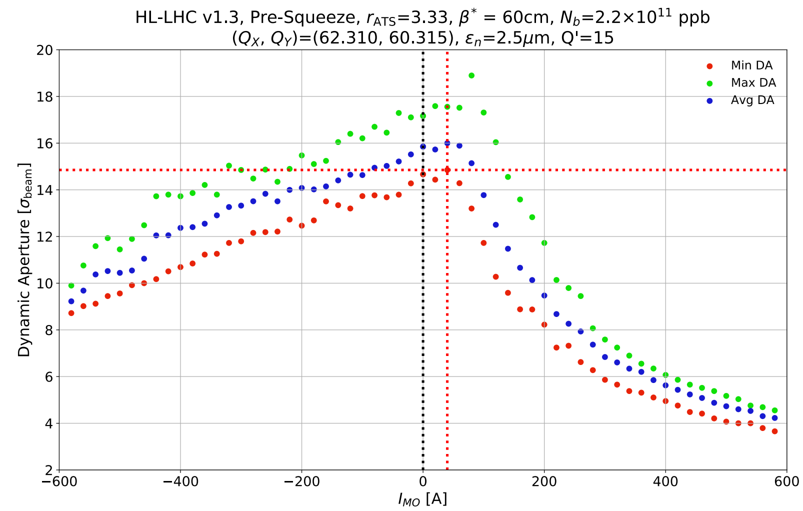


3.66/fb

More Squeeze stuff

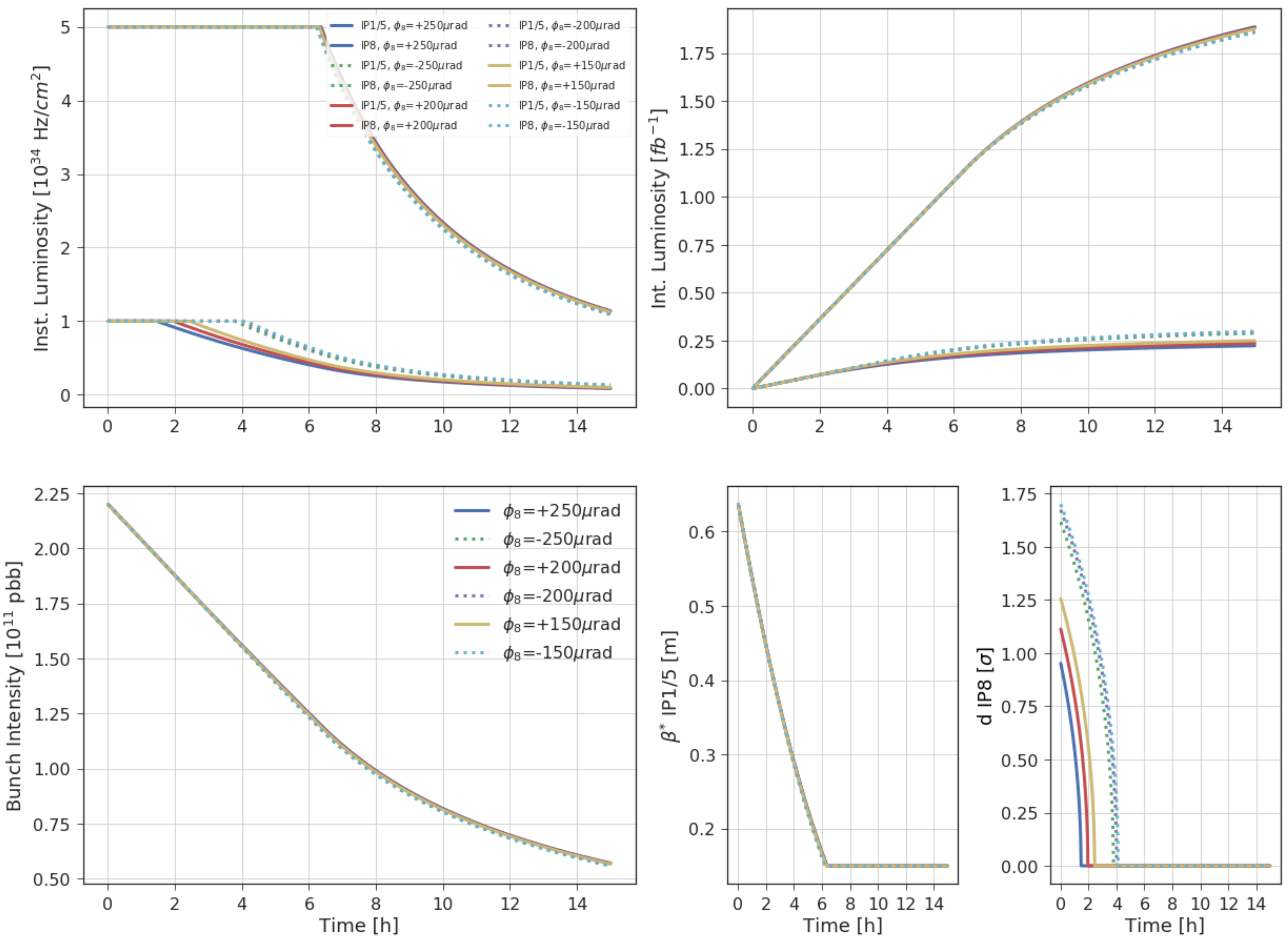






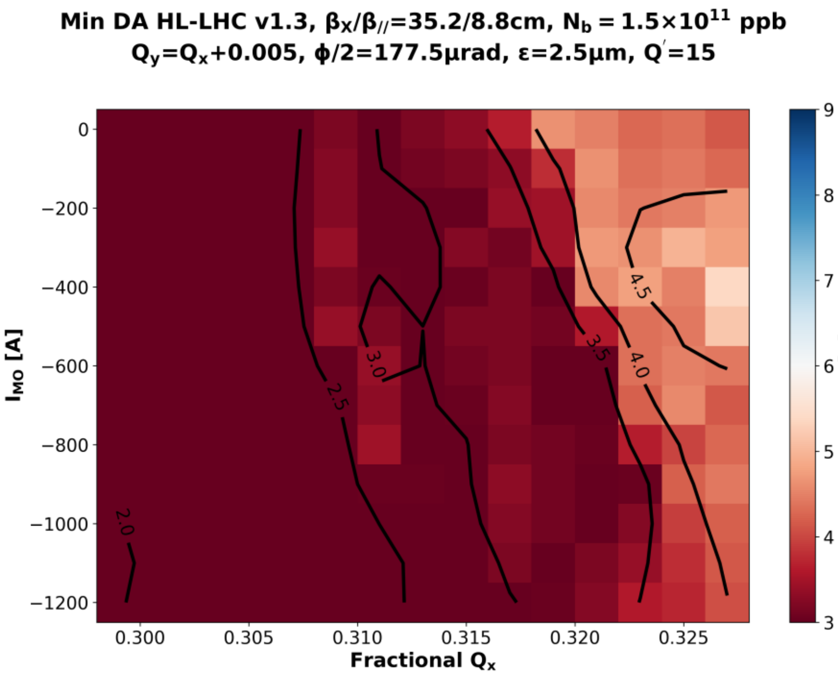
Simple Model: Constant emittance & xing-angle, 110mb burn-off

Impact of External Crossing Angle

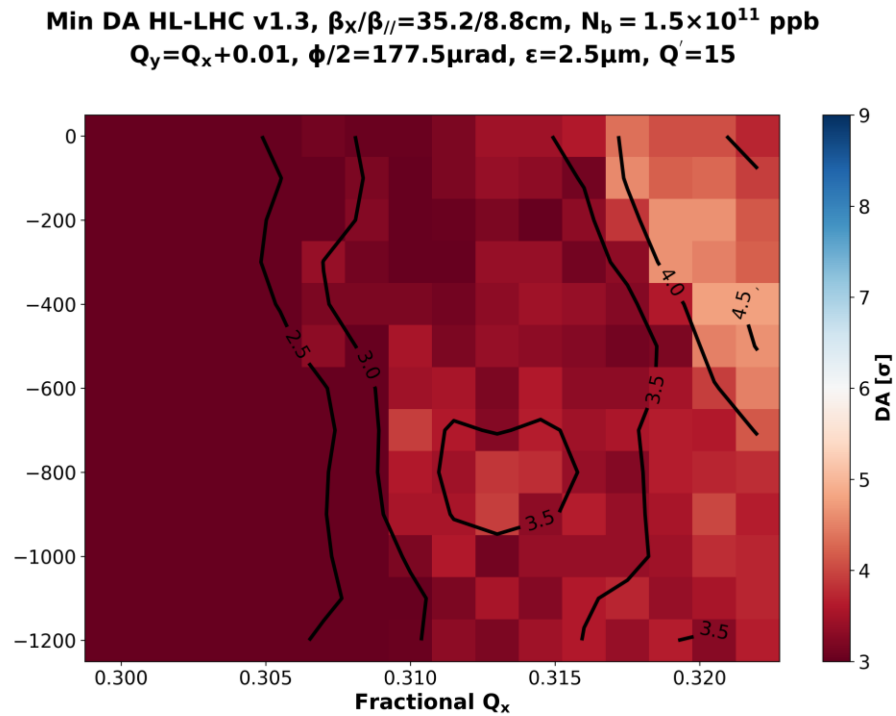


Tune & Octupoles: 11.5σ & Q’ = 15

Tune split d = 5×10^{-3}



Tune split d = 10^{-2}



- Reducie the **chromaticity** to gain some margin (targeting 6σ)