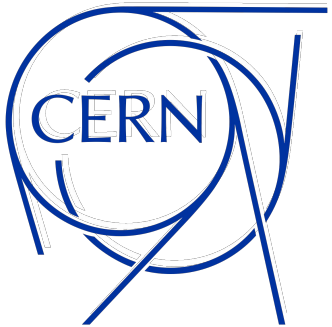


Update on DA studies

Yannis Angelis,
HL-LHC WP2 Meeting, 29 August 2023

Contents

- Optics for Collapse and Start of Levelling
- DA tune scans for flat and round optics (v1.6 Optics)
- DA octupole scans for flat optics (v1.6 Optics)
- Next steps and conclusions

Collapse process

Collapse process is defined by the target lumi in the range of 1-2.5e34

L-Nb [10^34]	Energy	beta sep	beta cross	MO	Emit [um]	ppb	Crab	sep	crossing	Q'	LHCb - 1.5m / Alice 10m [10^34]	ATS Factor	f_{MO}/g_{MO}	Optics
2.5 - 2200	7	0.7	0.7	450	2.3	2.3	0	0	250	15	0.2/0.014	1	1/1	700_thick, 700_thin
2.5 - 2200	7	0.6	1.2	450	2.3	2.3	0	0	250	15	0.2/0.014	0.83/0.42	1.50/1.21	600_1200_thick, 600_1200_thin
2.5 - 2200	7	0.45	1.8	450	2.3	2.3	0	0	250	15	0.2/0.014	1.1 / 0.28	2.36/1.47	450_1800_thick, 450_1800_thin
2.3 - 2200 or 2.0 - 1960	7	0.5	2	450	2.3	2.3	0	0	250	15	0.2/0.014	1/0.25	2.76/1.56	500_2000_thin
2.5 - 2748 or 1.8 - 1960	7	1.1	1.1	450	2.3	2.3	0	0	250	15	0.2/0.014	1	1/1	1100_thick
2.5 - 2748 or 1.8 - 1960	7	0.9	1.8	450	2.3	2.3	0	0	250	15	0.2/0.014	0.55/0.28	2.56/1.64	900_1800_thick, 900_1800_thin
2.5 - 2748 or 1.8 - 1960	7	0.7	2.8	450	2.3	2.3	0	0	250	15	0.2/0.014	0.71/0.18	4.67/2.02	700_2800_thick, 700_2800_thin
	7	1.0	1.0	450	2.3	2.3	0	0	250	15	0.2/0.014	1	1/1	1000_thick,1000_thin

$$\begin{cases} \frac{\partial Q_x}{\partial J_x} = \frac{\partial Q_y}{\partial J_y} \propto \frac{I_{\mathrm{MO}}}{\gamma} \times \beta_{\max}^2 \times f_{\mathrm{MO}}(r_X^{\mathrm{Tele}}, r_{\|}^{\mathrm{Tele}}) + \mathbf{O}\left(\beta_{\min}^2\right) \\ \frac{\partial Q_x}{\partial J_y} = \frac{\partial Q_y}{\partial J_x} \propto \frac{I_{\mathrm{MO}}}{\gamma} \times \beta_{\min} \times \beta_{\max} \times g_{\mathrm{MO}}(r_X^{\mathrm{Tele}}, r_{\|}^{\mathrm{Tele}}) \end{cases}$$

$$\text{with} \begin{cases} f_{\mathrm{MO}}(r_x, r_y) \stackrel{\mathrm{def}}{=} \frac{1}{8}\left[4 + \left(r_x^2 + \frac{1}{r_x^2}\right) + \left(r_y^2 + \frac{1}{r_y^2}\right)\right] = \frac{1}{8}\left[\left(r_x + \frac{1}{r_x}\right)^2 + \left(r_y + \frac{1}{r_y}\right)^2\right] \\ g_{\mathrm{MO}}(r_x, r_y) \stackrel{\mathrm{def}}{=} \frac{1}{2}\left[1 + \frac{1}{4}\left(r_x + \frac{1}{r_x}\right)\left(r_y + \frac{1}{r_y}\right)\right] \end{cases}$$

https://cds.cern.ch/record/2622595/files/CERN-ACC-2018-0018.pdf

Tune scan on the bunch with max of long range

Start of levelling

Start of leveling is defined by pile-up e.g. 140

Bunch scheme	Pile up	Energy	beta cross	beta sep	MO	emit	ppb	Crab	sep	crossing	ATS Factor	f_{MO}/g_{MO}	Q'	LHCb - 1.5m / Alice 10m [10^34]	Optics
hybrid	140	7	0.58	0.58	60	2.5	2.2	190	0	250	1	1/1	15	0.2/0.014	580_1500_thick, 580_1500_thin
hybrid	140	7	0.42	0.84	60	2.5	2.2	190	0	250	0.59/1.19	1.51/1.25	15	0.2/0.014	420_840_thick, 420_840_thin
hybrid	140	7	0.3	1.2	60	2.5	2.2	190	0	250	0.417/1.67	1.74/1.34	15	0.2/0.014	300_1200_thick, 300_1200_thin
8b4e	140	7	0.58	0.58	60	2.5	2.2	190	0	250	1	1/1	5	0.2/0.014	580_thick, 580_thin
8b4e	140	7	0.42	0.84	60	2.5	2.2	190	0	250	0.59/1.19	1.51/1.25	5	0.2/0.014	420_840_thick, 420_840_thin
8b4e	140	7	0.3	1.2	60	2.5	2.2	190	0	250	0.417/1.67	1.74/1.34	5	0.2/0.014	300_1200_thick, 300_1200_thin

Tune scan on the bunch with max of long range

First test scan with 0.5/2.0m flat optics

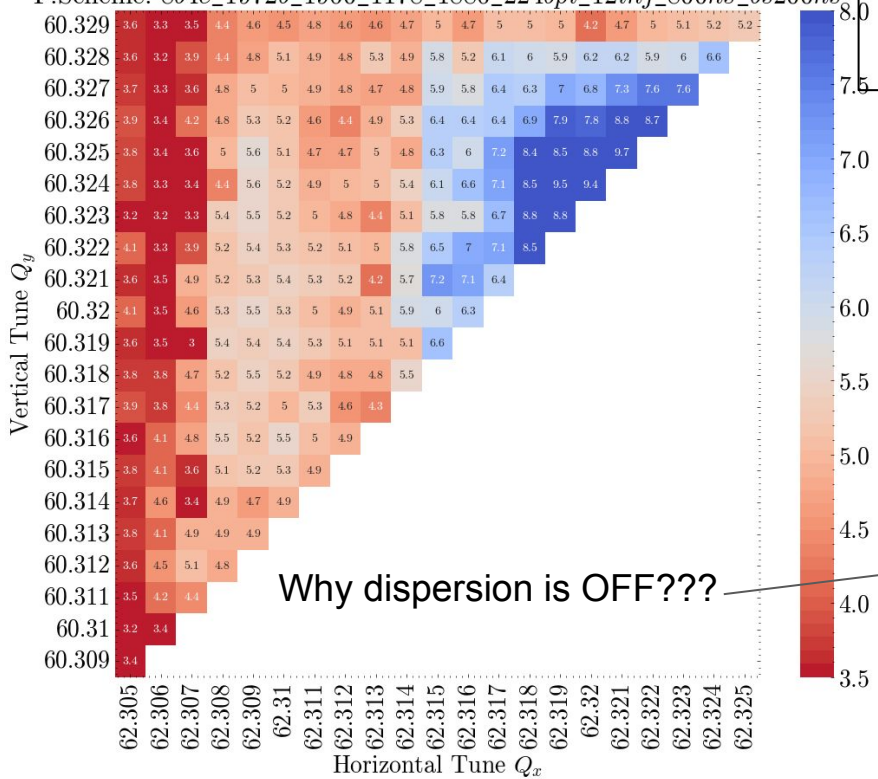
HL-LHC v1.6. Flat Optics. . Bunch 89

$N_b = 2.3 \cdot 10^{11}$ppb. $\beta^*_{y,\,IP1} = 0.5m$, $\beta^*_{x,\,IP1} = 2.0m$, $\Phi/2_{1,5} = 250\mu rad$

$\Phi/2_8 = 170\mu rad$, $\epsilon = 2.5\mu m$, $Q' = 5.0$, $I_{MO} = 60A$

Dispersion = OFF

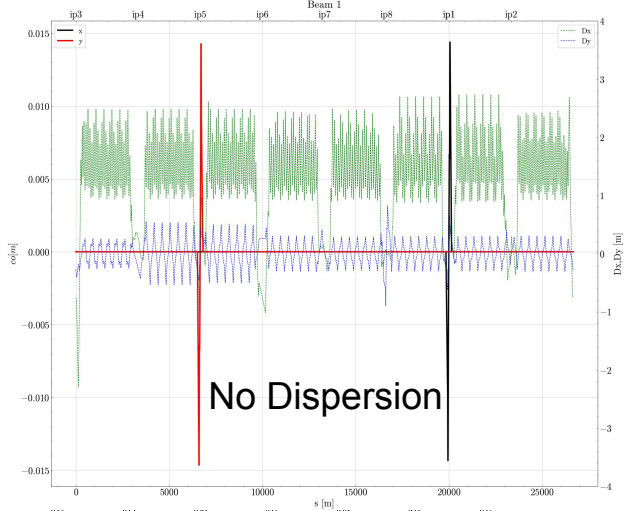
F.Scheme: $8b4e\_1972b\_1960\_1178\_1886\_224bpi\_12inj\_800ns\_bs200ns$

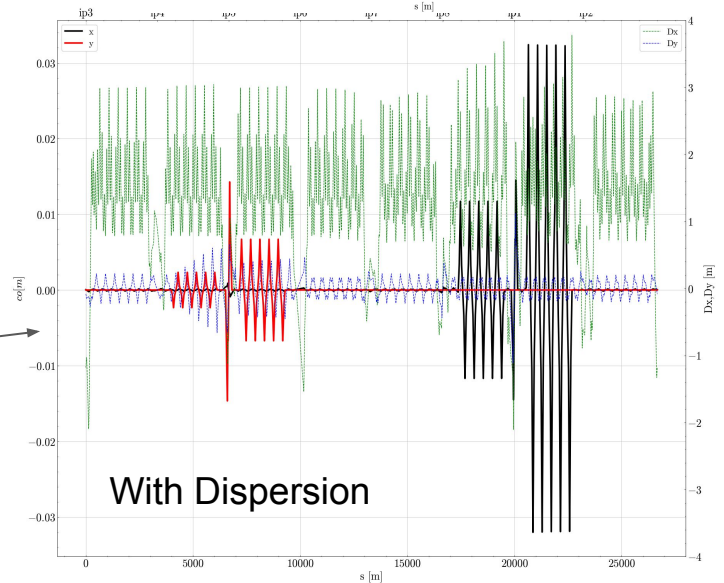


Why dispersion is OFF???

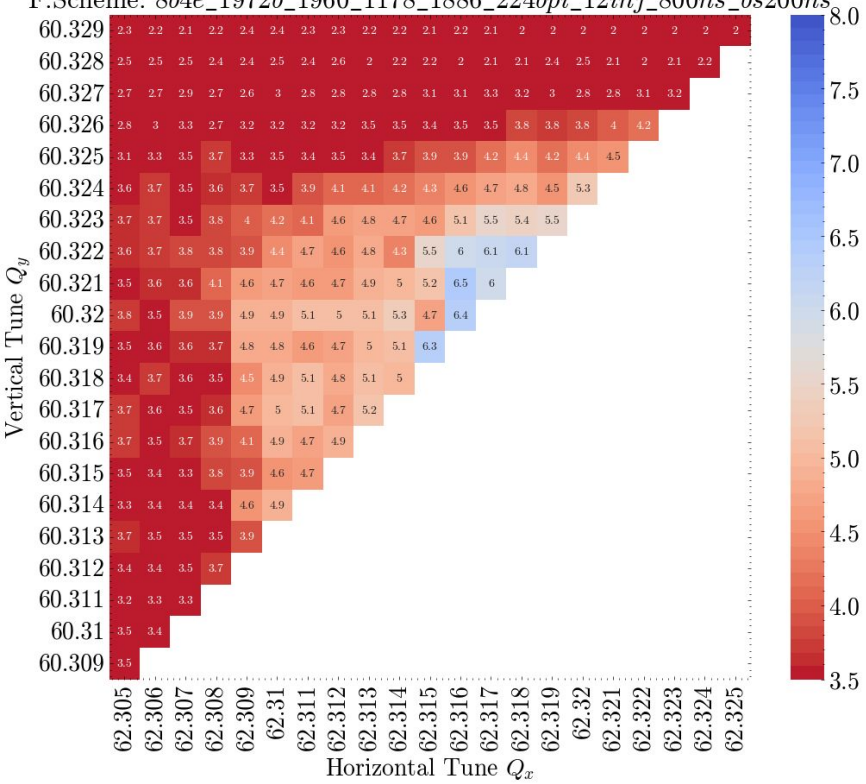
Dispersion knobs are not optimal for this optics, causes, due to

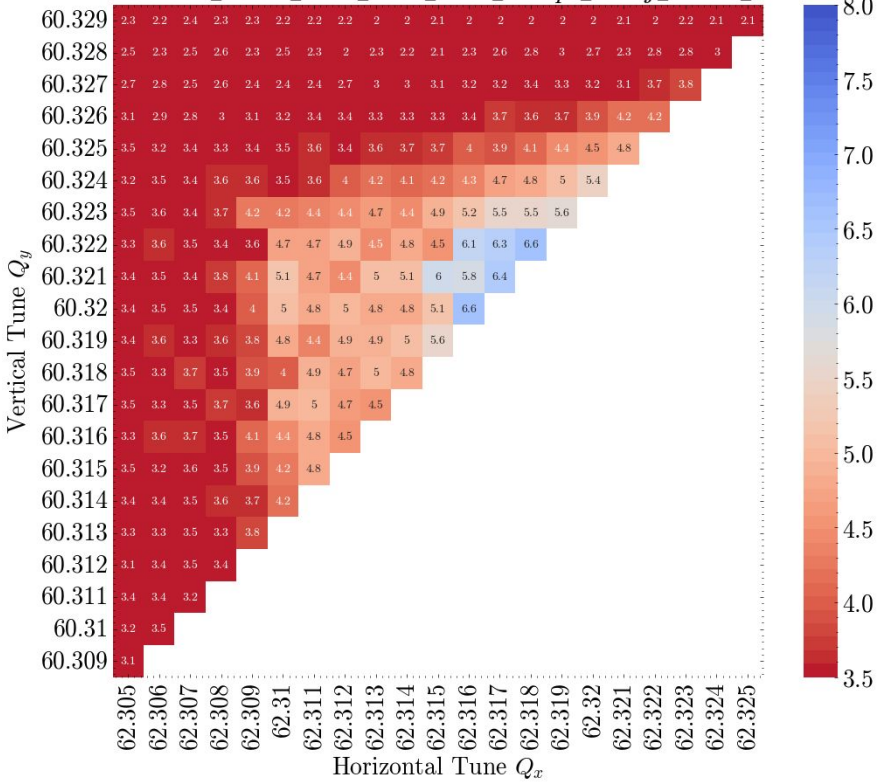
- sextupoles strength opimized also for off-momentum
- beta-beating in point 8
- beta function too low to make it effective



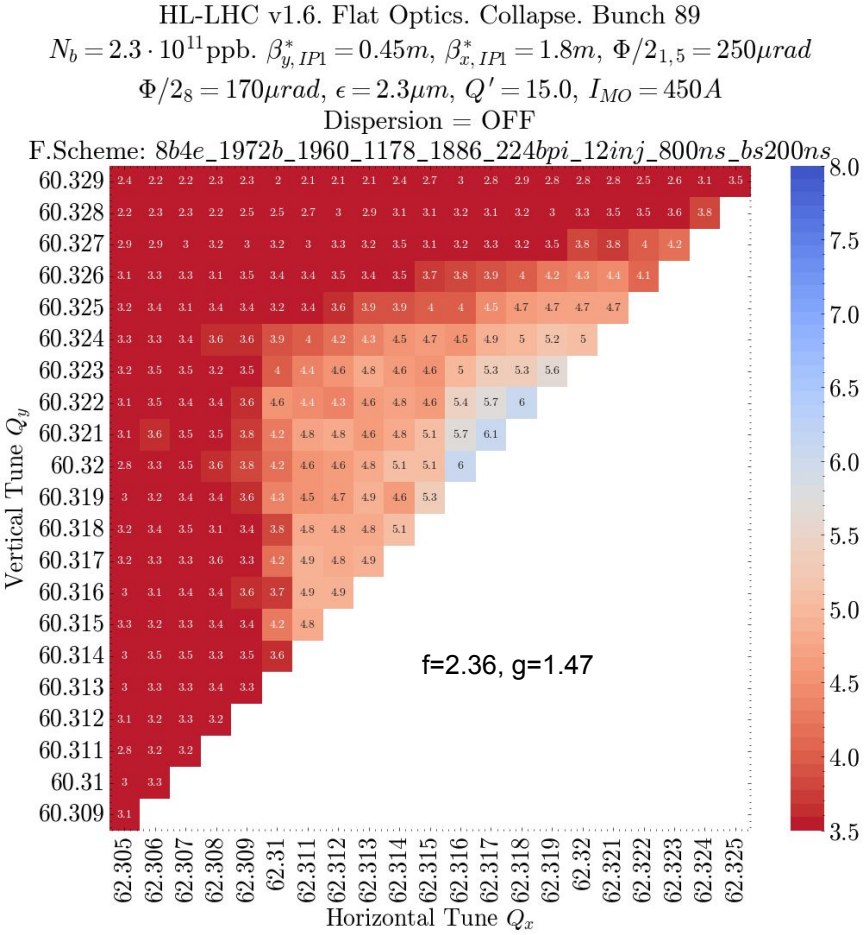


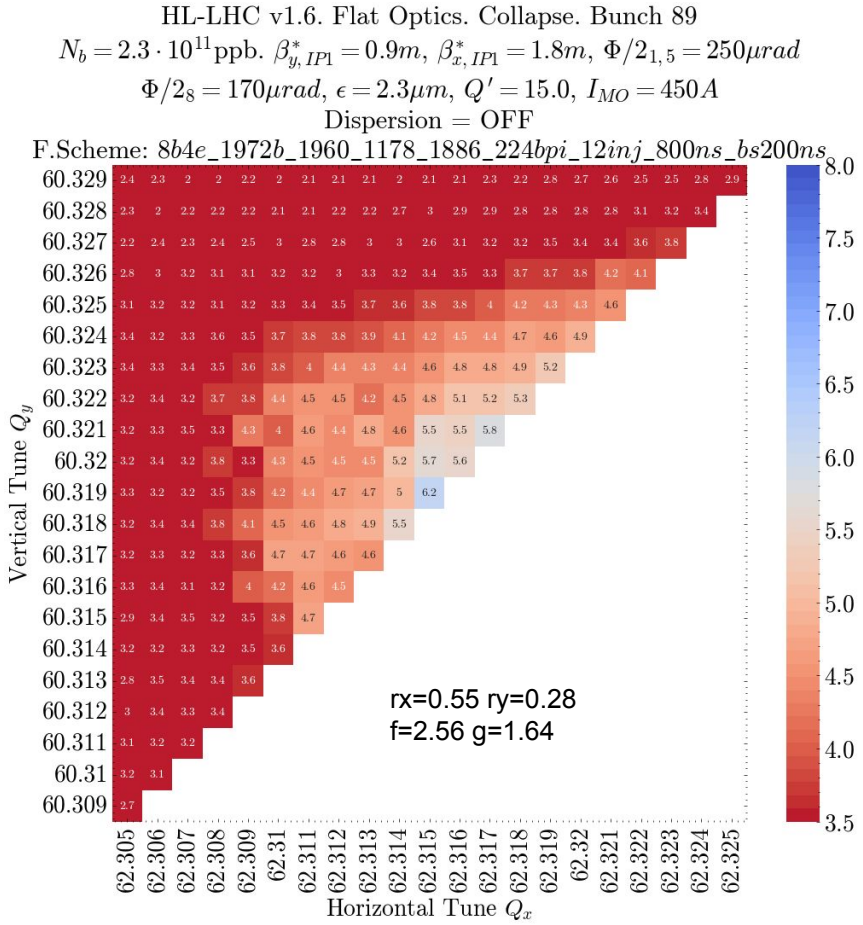
Collapse DA tune scans



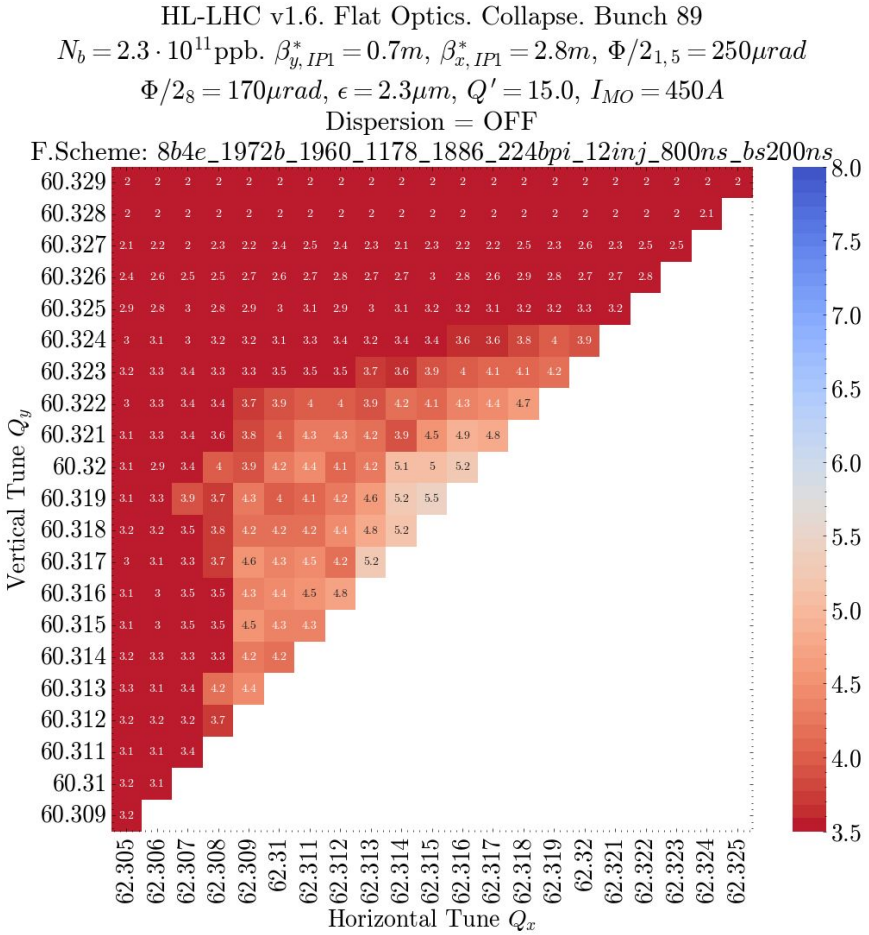


Collapse DA tune scans

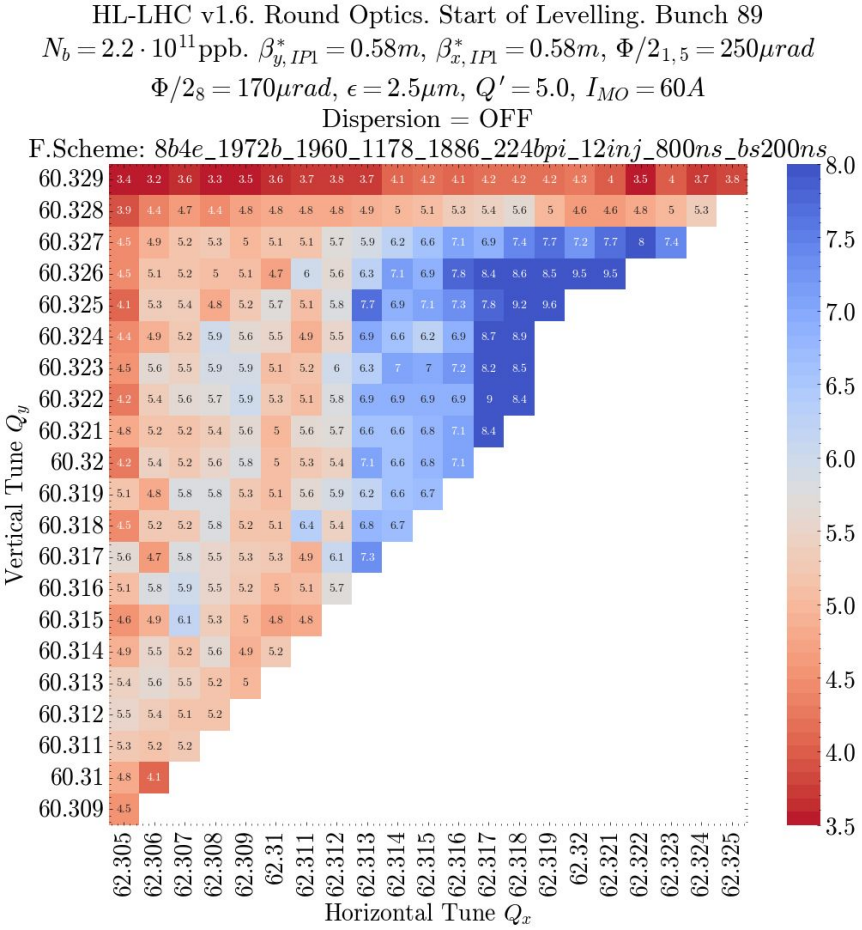


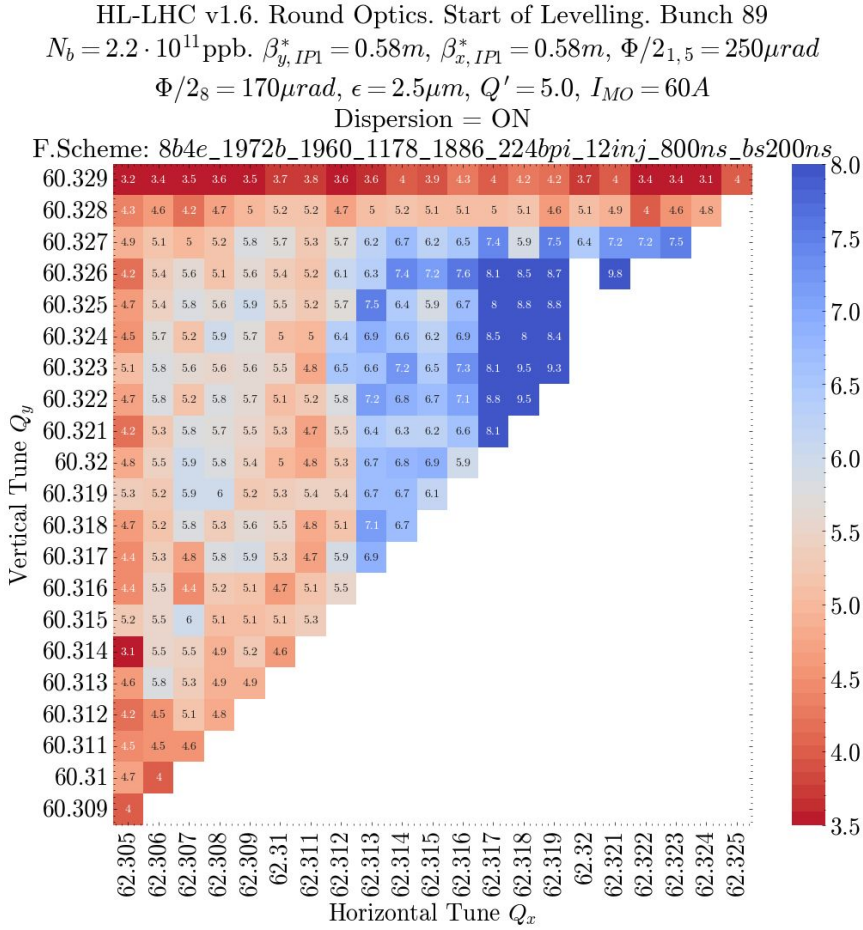


Collapse DA tune scans

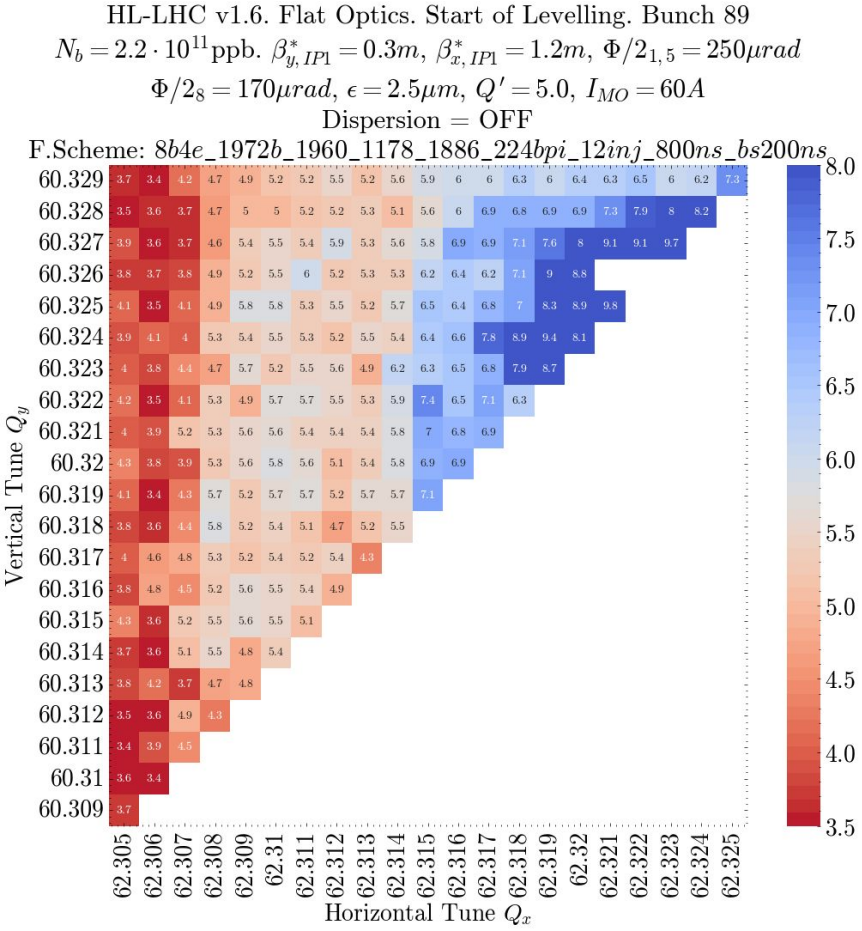


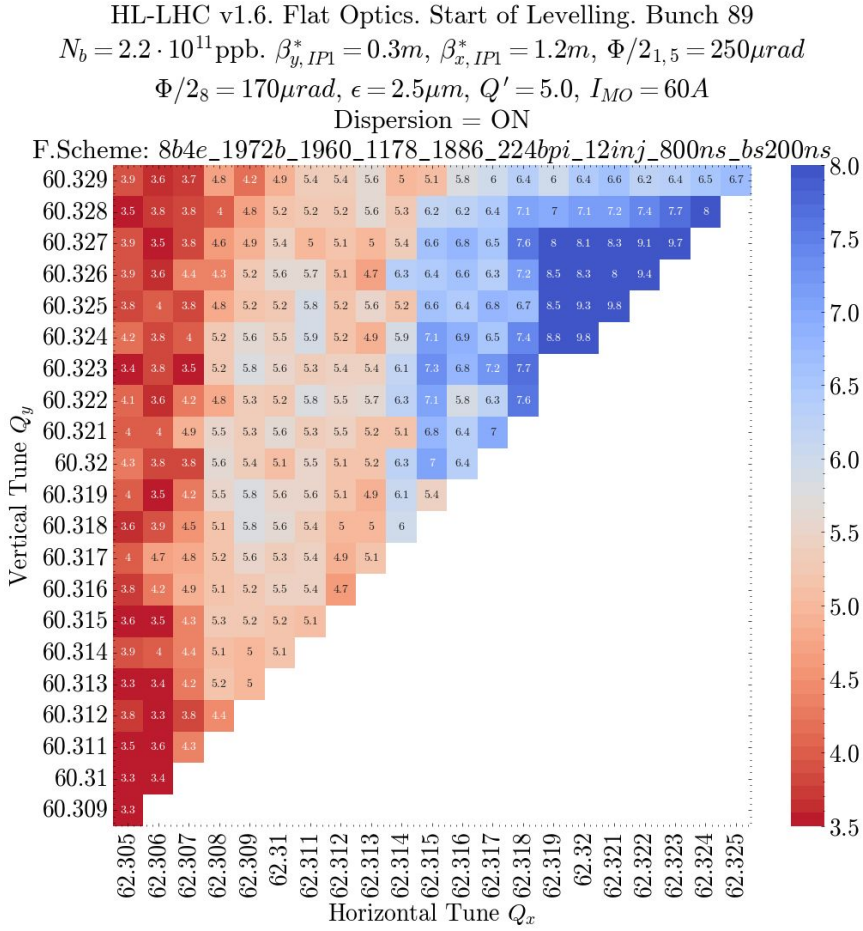
Start of Levelling





Start of Levelling

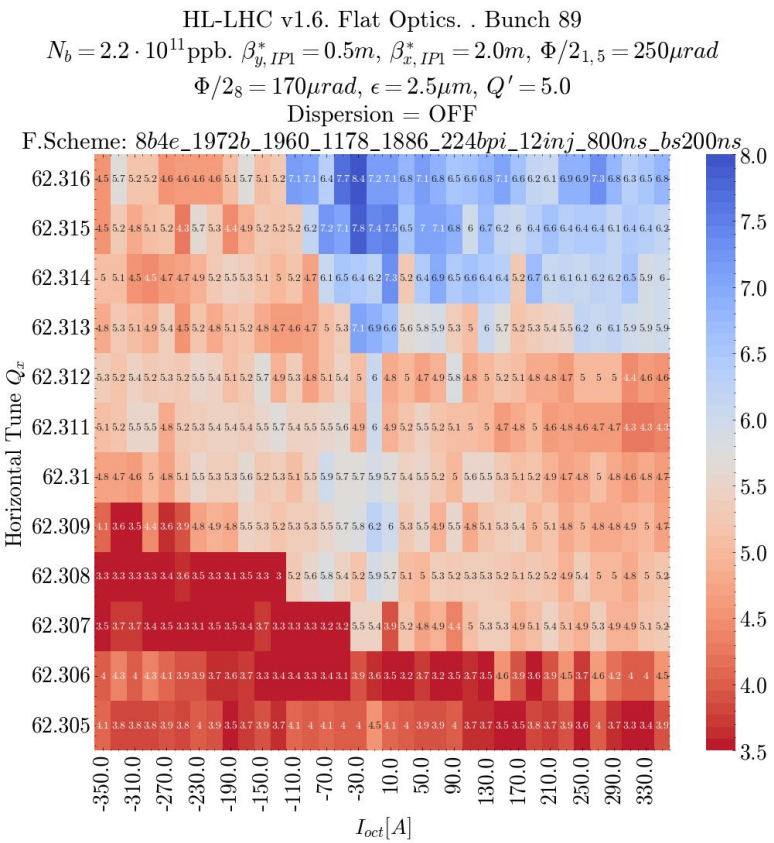


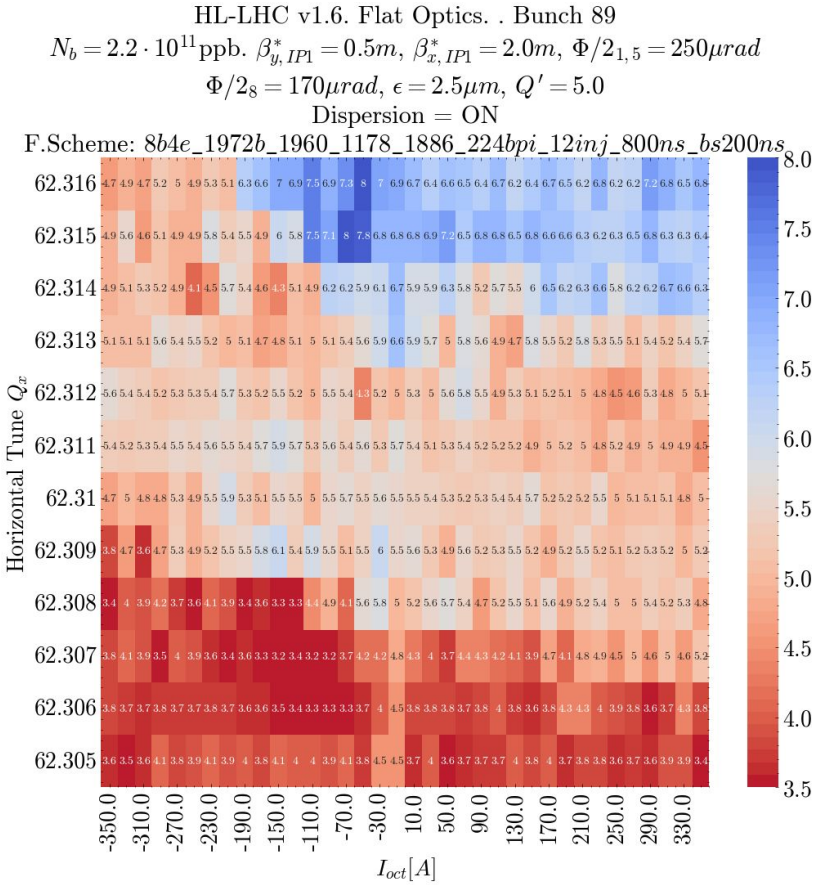


MO scans

Keeping Q_y=60.32

Instead of scanning the diagonal





Conclusions and next steps:

- Optics for collapse and start of levelling
- Scans for collapse and SoL can be done without dispersion
- Dispersion knobs not working correctly for all the optics shown

Amplitude detuning from an octupole

$$\mathrm{H_n} = \frac{1}{B\rho}\,\mathrm{Re}\left[\frac{1}{n}\left[B_n(s) + iA_n(s)\right](x+iy)^n\right]$$

Normal octupole $\rightarrow \mathrm{H_4} = \frac{1}{4!}K_4L\,(x^4 - 6x^2y^2 + y^4)$

In action-angle coordinates $(x, y = \sqrt{2J_{x,y}\beta_{x,y}}\cos\phi_{x,y})$

$$\mathrm{H_4} = \frac{1}{4!}K_4L\,(4J_x^2\beta_x^2\cos^4\phi_x - 24J_xJ_y\cos^2\phi_x\cos^2\phi_y + 4J_y^2\beta_y^2\cos^4\phi_y)$$

$$Q_x = \frac{1}{2\pi}\frac{\partial\langle \mathrm{H}\rangle}{\partial J_x} = \frac{1}{16\pi}K_4L\left(J_x\beta_x^2 - 2J_y\beta_x\beta_y\right)$$

$$\frac{\partial Q_x}{\partial \epsilon_x} = \frac{1}{32\pi}\beta_x^2K_4L \qquad \frac{\partial Q_x}{\partial \epsilon_y} = -\frac{1}{16\pi}\beta_x\beta_yK_4L \qquad \frac{\partial Q_y}{\partial \epsilon_y} = \frac{1}{32\pi}\beta_y^2K_4L$$