



DA and Beam-Beam

C. Droin, S. Kostoglou, G. Sterbini on behalf of WP2 team

We thank Y. Angelis, H. Bartosik, R. De Maria, I. Efthymiopoulos, M. Giovannozzi, G. Iadarola, L. Methner, E. Métral, N. Mounet, Y. Papaphilippou, R. Tomás.

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Introduction

Beam-beam Studies Results

End of Injection

End of Collapse

Start of \mathcal{L} -Levelling

End of \mathcal{L} -Levelling

Conclusions

DA as main observable

- HL-LHC performance strongly depends on the **orchestration of several beam and machine parameters during the cycle.**

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- The Run 3 observations on present e-cloud limitations called for exploring new filling schemes and non baseline HL optics (see R. Tomás' presentation). We will present and discuss the Beam-Beam (BB) implications.

DA as main observable

- HL-LHC performance strongly depends on the **orchestration of several beam and machine parameters during the cycle**.
- The Run 3 observations on present e-cloud limitations called for exploring new filling schemes and non baseline HL optics (see R. Tomás' presentation). We will present and discuss the Beam-Beam (BB) implications.
- For the beam-beam and incoherent effects, the selection/validation of the configuration for operation is based on numerical simulation supported by the experience of the past runs: previous studies established a **correlation between beam lifetime from experimental data and DA from simulations** [1].

HL-LHC DA requirements

Based on this experience, an operational scenario is characterized as feasible when there are working points that satisfy the following criteria in the simulations:

- A minimum **DA of at least 6σ** .

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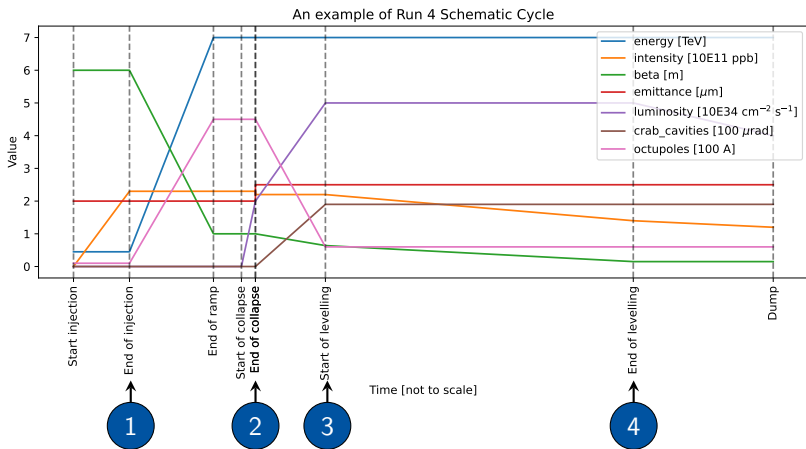
- A minimum **DA of at least 6σ** .
- Working point condition $q_x + 5 \cdot 10^{-3} < q_y$: no experience operating below the diagonal and tune split of $+5 \cdot 10^{-3}$ to prevent possible instabilities.

HL-LHC DA requirements

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- A minimum **DA of at least 6σ** .
- Working point condition $q_x + 5 \cdot 10^{-3} < q_y$: no experience operating below the diagonal and tune split of $+5 \cdot 10^{-3}$ to prevent possible instabilities.
- HL-LHC layout V1.5 or V1.6 are assumed (**MS10 included**).

Schematic of the Run 4 Cycle



4 special transitions in the cycle (courtesy of R. De Maria).

Filling schemes

Depending on the strategy adopted to cure the e-cloud, three different filling schemes are considered:

- **baseline** (2760 bunches):
25ns_2760b_2748_2492_2574_288bpi_13inj_800ns_bs200ns
- **hybrid** (2228 bunches):
25ns_2228b_2216_1686_2112_hybrid_8b4e_2x56b_25ns_3x48b_12inj
- **8b4e** (1972 bunches):
8b4e_1972b_1960_1178_1886_224bpi_12inj_800ns_bs200ns

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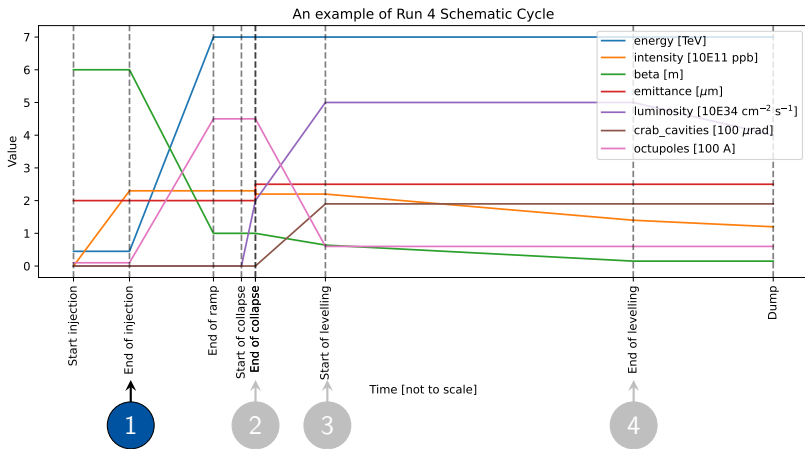
End of Collapse

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End of Injection

Parameters (unit)	HL-LHC (values)
Beam energy (GeV)	450
Bunch population (protons)	2.3×10^{11}
Normalized emittance ($\mu\text{m rad}$)	2.3
Filling scheme	baseline
IP1/5 $\beta_{x,y}^*$ (m)	6
IP8/2 $\beta_{x,y}^*$ (m)	10
Nominal working point (Q_x, Q_y)	(62.27, 60.295)
Chromaticity $Q'_{x,y}$	15
IP1/5 half crossing angle (μrad)	500 (H) / 500 (V)
IP2/8 half crossing angle (μrad)	170 (V) / 170 (H)

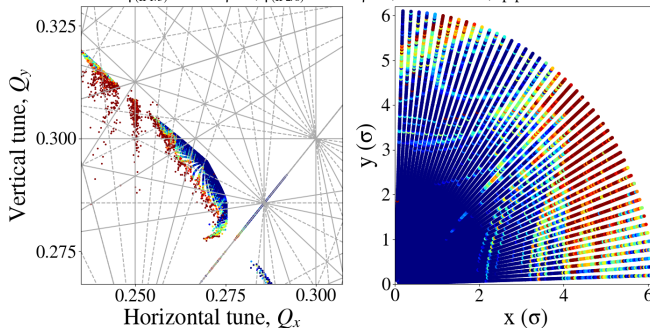
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DA dominated by the arc octupoles.

About I_{MO} polarity

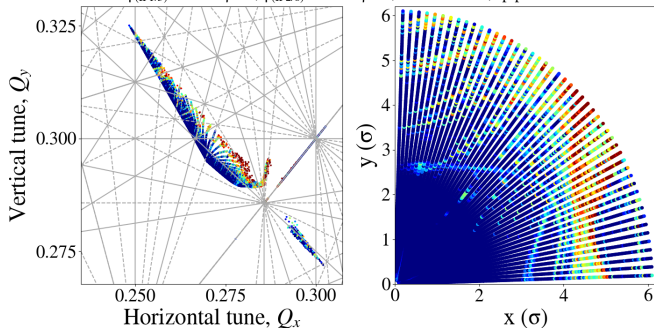
450 GeV, 2.3×10^{11} ppb, $\epsilon_n = 2.3 \mu\text{m}$, $Q' = 15$, $\beta_{IP1/5}^* = 6 \text{ m}$, $I_{oct} = -45 \text{ A}$
 $\phi_{(IP1/5)}/2 = 500 \mu\text{rad}$, $\phi_{(IP2/8)}/2 = 170 \mu\text{rad}$, $C^- = 3 \times 10^{-3}$, $\delta p/p = 0$



$$I_{MO} = -45 \text{ A}$$

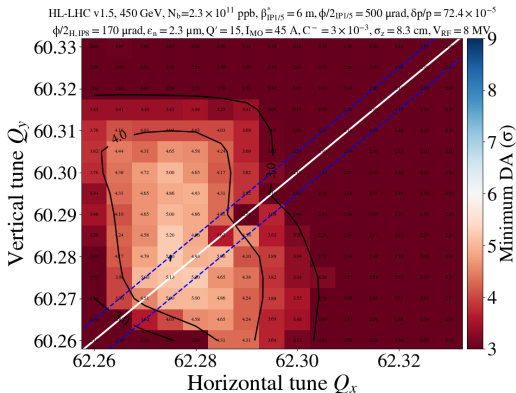
About I_{MO} polarity

450 GeV, 2.3×10^{11} ppb, $\epsilon_n = 2.3 \mu\text{m}$, $Q' = 15$, $\beta_{IP1/5}^* = 6 \text{ m}$, $I_{oct} = 45 \text{ A}$
 $\phi_{(IP1/5)}/2 = 500 \mu\text{rad}$, $\phi_{(IP2/8)}/2 = 170 \mu\text{rad}$, $C^- = 3 \times 10^{-3}$, $\delta p/p = 0$



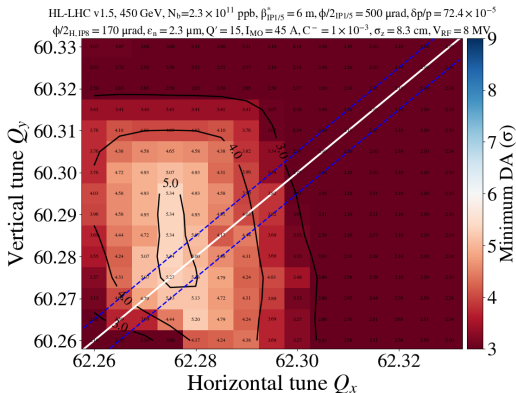
$$I_{MO} = +45 \text{ A}$$

Correcting coupling helps



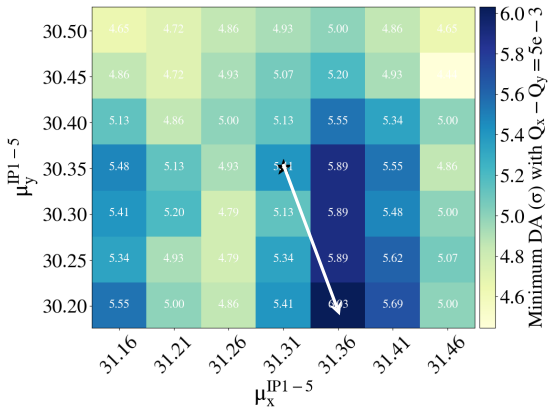
$$I_{MO} = +45 \text{ A}, \quad C^- = 3 \times 10^{-3}$$

Correcting coupling helps



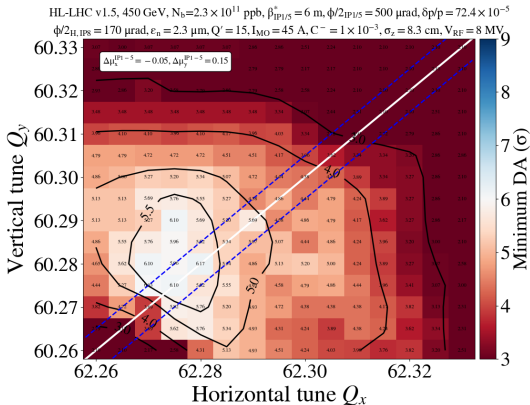
$$I_{MO} = +45 \text{ A}, \quad C^- = 10^{-3}$$

$\Delta\mu^{IP1 \rightarrow IP5}$ optimization



Assuming $I_{MO} = +45$ A, $C^- = 10^{-3}$

$\Delta\mu^{IP1 \rightarrow IP5}$ optimization



$I_{MO} = +45$ A, $C^- = 10^{-3}$, **optimized $\Delta\mu$**

End of Injection Studies Summary

- Incoherent effects at injection dominated by amplitude detuning from octupoles (driven by e-cloud/stability considerations).
- A DA conservative scenario is assumed ($I_{MO} = 45$ A).
- DA target achieved by **positive octupole** current, together with an excellent **coupling control** and **IP1/5 phase optimization**.

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Beam-beam Studies Results

End of Injection

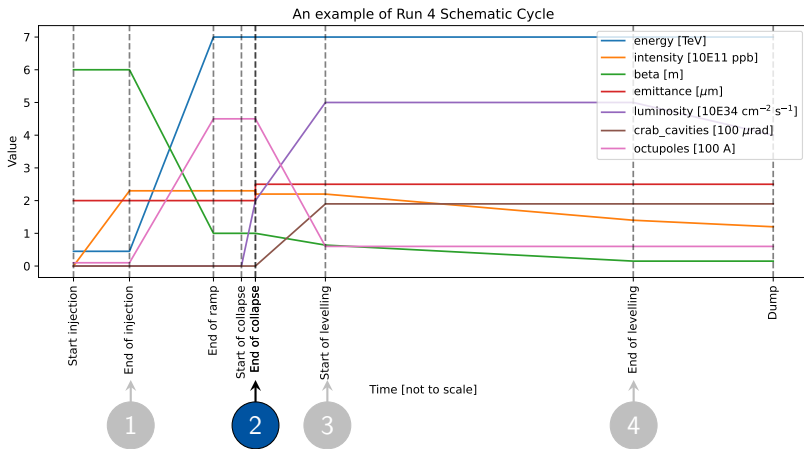
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End of Collapse

Parameters (unit)	HL-LHC (values)
Beam energy (TeV)	7
Luminosity (10^{34} Hz/cm ²)	≈ 2.5
Bunch population (protons)	2.3×10^{11}
Filling scheme	baseline/8b4e
Normalised emittance ($\mu\text{m rad}$)	2 or 2.3
Nominal working point (Q_x, Q_y)	(62.31, 60.32)
Chromaticity $Q'_{x,y}$	15
IP1/5 half crossing angle (μrad)	250(H) / 250(V)
IP2/8 half crossing angle (μrad)	-170(V) / 170(V)
IP1/5 β^* (m)	1 (round) or 0.7/2.8 (flat ¹)
IP2/8 β^* (m)	10/1.5
Half crab-cavity angle (μrad)	0

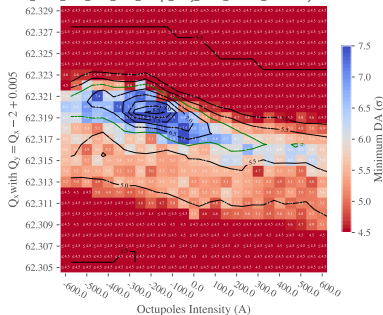
¹This is intended to probe an extreme tele-index=4.

DA vs I_{MO} (round optics)

baseline filling scheme

HL-LHC v1.6. E = 7.0 TeV. $N_b \approx 2.3 \times 10^{11}$ ppb,
 $L_{105} = 3.14 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$, $L_2 = 4.78 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$, $L_{18} = 1.71 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$
 $\beta_{x,1}^* = 1 \text{ m}$, $\beta_{y,1}^* = 1 \text{ m}$, polarity $IP_{208} = 1/1$
 $\Phi/2_{(10)} = 250 \mu\text{rad}$, $\Phi/2_{(5V)} = 250 \mu\text{rad}$, $\Phi/2_{(2V)} = -170 \mu\text{rad}$, $\Phi/2_{(8V)} = 170 \mu\text{rad}$
 $\sigma_x = 7.61 \text{ cm}$, $e_0 = 2.3 \mu\text{m}$, $Q = 15$, $C^- = 0.001$

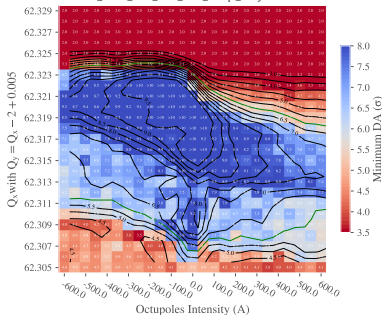
25ns_2760b_2748_2492_2574_288bpi_13inj_800ns_bs200ns_converted.json. Bunch 150.



8b4e filling scheme

HL-LHC v1.6. E = 7.0 TeV. $N_b \approx 2.3 \times 10^{11}$ ppb,
 $L_{105} = 2.04 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$, $L_2 = 3.46 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$, $L_{18} = 2 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$
 $\beta_{x,1}^* = 1 \text{ m}$, $\beta_{y,1}^* = 1 \text{ m}$, polarity $IP_{208} = 1/1$
 $\Phi/2_{(10)} = 250 \mu\text{rad}$, $\Phi/2_{(5V)} = 250 \mu\text{rad}$, $\Phi/2_{(2V)} = -170 \mu\text{rad}$, $\Phi/2_{(8V)} = 170 \mu\text{rad}$
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8b4e_1972b_1960_1178_1886_224bpi_12inj. Bunch 89.

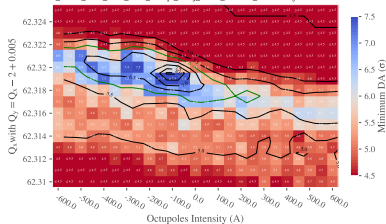


Baseline configuration marginally OK with $I_{OCT} > 0$.
Negative octupoles option interesting to explore.

DA vs I_{MO} (round optics)

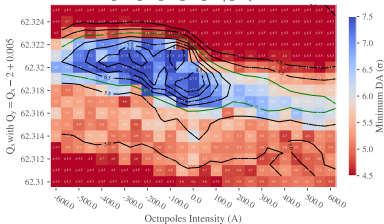
baseline filling scheme

HL-LHC v1.6. E = 7.0 TeV, $N_b \approx 2.3 \times 10^{11}$ ppb,
 $L_{1,5} = 3.53 \times 10^{31} \text{cm}^{-2}\text{s}^{-1}$, $L_2 = 4.86 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$, $L_6 = 1.62 \times 10^{31} \text{cm}^{-2}\text{s}^{-1}$
 $\beta_{x,1}^* = 1 \text{ m}$, $\beta_{y,1}^* = 1 \text{ m}$, polarity $IP_{238} = 1/1$
 $\Phi/2_{110} = 250 \mu\text{rad}$, $\Phi/2_{23V} = 250 \mu\text{rad}$, $\Phi/2_{2, V} = -170 \mu\text{rad}$, $\Phi/2_{8, V} = 170 \mu\text{rad}$
 $\sigma_x = 7.61 \text{ cm}$, $e_x = 2.0 \mu\text{m}$, $Q = 15$, $C^* = 0.001$
25ms_2760b_2748_2492_2574_288bpi_13inj_800ms_bs200ns_converted.json, Bunch 150.



8b4e filling scheme

HL-LHC v1.6. E = 7.0 TeV, $N_b \approx 2.3 \times 10^{11}$ ppb,
 $L_{1,5} = 2.63 \times 10^{31} \text{cm}^{-2}\text{s}^{-1}$, $L_2 = 1.56 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$, $L_6 = 1.51 \times 10^{31} \text{cm}^{-2}\text{s}^{-1}$
 $\beta_{x,1}^* = 1 \text{ m}$, $\beta_{y,1}^* = 1 \text{ m}$, polarity $IP_{238} = 1/1$
 $\Phi/2_{110} = 250 \mu\text{rad}$, $\Phi/2_{23V} = 250 \mu\text{rad}$, $\Phi/2_{2, V} = -170 \mu\text{rad}$, $\Phi/2_{8, V} = 170 \mu\text{rad}$
 $\sigma_x = 7.61 \text{ cm}$, $e_x = 2.0 \mu\text{m}$, $Q = 15$, $C^* = 0.001$
8b4e_1972b_1960_1178_1886_224bpi_12inj, Bunch 89.



DA gets tighter for smaller emittances ($2.3 \rightarrow 2 \mu\text{rad}$).

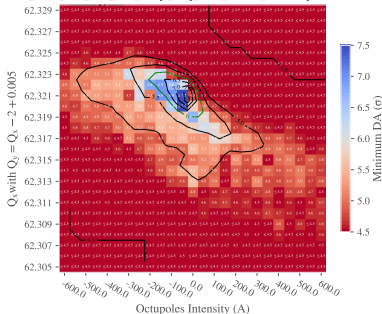
DA vs I_{MO} (flat optics)

baseline filling scheme

HL-LHC v1.6. $E = 7.0$ TeV. $N_b \approx 2.3 \times 10^{11}$ ppb,
 $L_{1,5} = 2.82 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$, $L_2 = 4.5 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$, $L_8 = 1.73 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$
 $\beta_{s,1}^* = 2.8$ m, $\beta_{s,1}^* = 0.7$ m, polarity $IP_{238} = 1/1$

$\Phi/2_{(1H)} = 250$ μrad , $\Phi/2_{(5V)} = 250$ μrad , $\Phi/2_{2,V} = -170$ μrad , $\Phi/2_{8,V} = 170$ μrad
 $\sigma_x = 7.61$ cm, $\sigma_y = 2.3$ μm , $Q = 15$, $C^* = 0.001$

25ns_2760b_2748_2492_2574_288bpi_13inj_800ns_bs200ns_converted.json. Bunch 150.

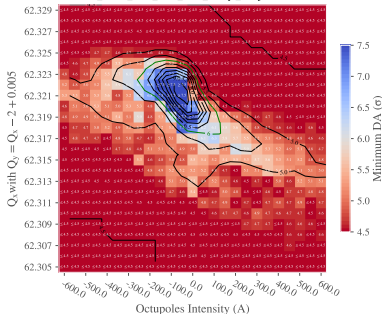


8b4e filling scheme

HL-LHC v1.6. $E = 7.0$ TeV. $N_b \approx 2.3 \times 10^{11}$ ppb,
 $L_{1,5} = 2.09 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$, $L_2 = 1.61 \times 10^{30} \text{cm}^{-2}\text{s}^{-1}$, $L_8 = 1.66 \times 10^{33} \text{cm}^{-2}\text{s}^{-1}$
 $\beta_{s,1}^* = 0.7$ m, $\beta_{s,1}^* = 2.8$ m, polarity $IP_{238} = 1/1$

$\Phi/2_{(1H)} = 250$ μrad , $\Phi/2_{(5V)} = 250$ μrad , $\Phi/2_{2,V} = -170$ μrad , $\Phi/2_{8,V} = 170$ μrad
 $\sigma_x = 7.61$ cm, $\sigma_y = 2.3$ μm , $Q = 15$, $C^* = 0.001$

8b4e_1972b_1960_1178_1886_224bpi_12inj. Bunch 89.

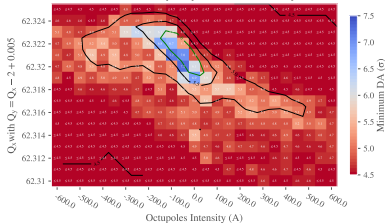


The (**tele-index=4**) flat optics shows a smaller good DA region (but could alleviate the impedance of the CC).

DA vs I_{MO} (flat optics)

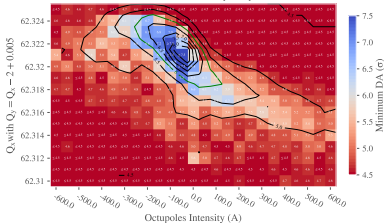
baseline filling scheme

HL-LHC v1.6. E = 7.0 TeV. $N_b = 2.3 \times 10^{11}$ ppb,
 $L_{15} = 3.24 \times 10^{14} \text{cm}^{-2}\text{s}^{-1}$, $L_2 = 4.62 \times 10^{10} \text{cm}^{-2}\text{s}^{-1}$, $L_8 = 1.65 \times 10^{11} \text{cm}^{-2}\text{s}^{-1}$
 $\beta_{x,1}^* = 2.8 \text{ m}$, $\beta_{x,1}^* = 0.7 \text{ m}$, polarity IP28 = 1/1
 $\Phi(2_{10}) = 250 \mu\text{rad}$, $\Phi(2_{5V}) = 250 \mu\text{rad}$, $\Phi(2_{2V}) = -170 \mu\text{rad}$, $\Phi(2_{8V}) = 170 \mu\text{rad}$
 $\sigma_x = 7.61 \text{ cm}$, $\sigma_y = 2.0 \mu\text{m}$, $Q = 15$, $C^* = 0.001$
25ns_2760b_2748_2492_2574_288bpi_13inj_800ms_bs200ns_converted.json. Bunch 150.



8b4e filling scheme

HL-LHC v1.6. E = 7.0 TeV. $N_b = 2.3 \times 10^{11}$ ppb,
 $L_{15} = 2.43 \times 10^{14} \text{cm}^{-2}\text{s}^{-1}$, $L_2 = 1.55 \times 10^{10} \text{cm}^{-2}\text{s}^{-1}$, $L_8 = 1.55 \times 10^{11} \text{cm}^{-2}\text{s}^{-1}$
 $\beta_{x,1}^* = 0.7 \text{ m}$, $\beta_{x,1}^* = 2.8 \text{ m}$, polarity IP28 = 1/1
 $\Phi(2_{10}) = 250 \mu\text{rad}$, $\Phi(2_{5V}) = 250 \mu\text{rad}$, $\Phi(2_{2V}) = -170 \mu\text{rad}$, $\Phi(2_{8V}) = 170 \mu\text{rad}$
 $\sigma_x = 7.61 \text{ cm}$, $\sigma_y = 2.0 \mu\text{m}$, $Q = 15$, $C^* = 0.001$
8b4e_1972b_1960_1178_1886_224bpi_12inj. Bunch 89.



The (**tele-index=4**) flat optics shows a smaller good DA region (but could alleviate the impedance of the CC).

End of Collapse Summary

- Strong effect of the octupoles on DA.
- Baseline optics and filling scheme reaching (marginally) target DA.
- Margin further reduces with lower emittance.
- With 8b4e DA improves (at the clear cost of performance).

Introduction

Beam-beam Studies Results

End of Injection

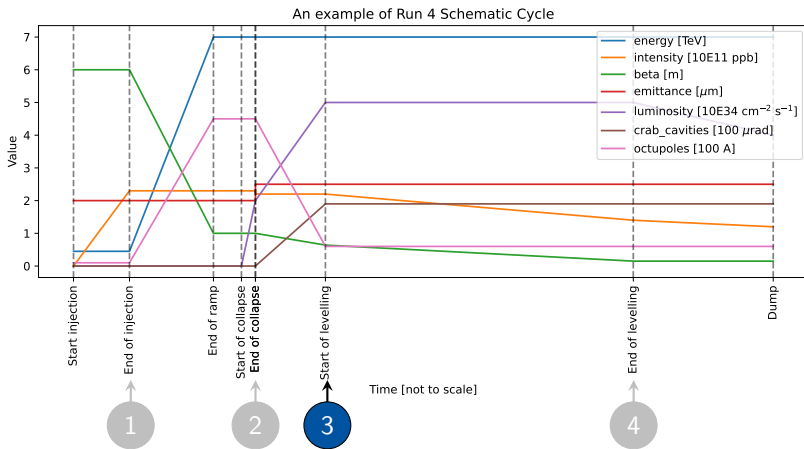
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Start of \mathcal{L} -Levelling



Start of the \mathcal{L} -levelling

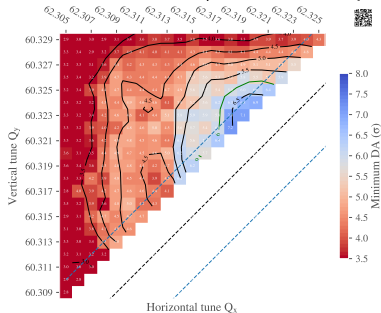
Parameters (unit)	HL-LHC (values)
Beam energy (TeV)	7
Luminosity (10^{34} Hz/cm ²)	5
Bunch population (protons)	$2.2\text{-}2.3 \times 10^{11}$
Filling scheme	hybrid/8b4e
Normalized emittance ($\mu\text{m rad}$)	2.5
Nominal working point (Q_x, Q_y)	(62.31, 60.32)
Chromaticity $Q'_{x,y}$	5 or 15
IP1/5 half crossing angle (μrad)	250(H) / 250(V)
IP2/8 half crossing angle (μrad)	-170(V) / 170(V)
IP1/5 β^* (m)	1/0.5 (flat)
IP2/8 β^* (m)	10/1.5
Landau octupoles' current (A)	410²
Half crab-cavity angle (μrad)	190

²It is expected to be at 60 A → **conservative approach.**

Flat optics with $Q' = 5$

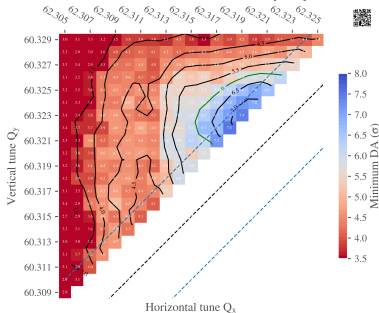
hybrid filling scheme

HL-LHC v1.5. Flat optics. Start of levelling. CC ON. Bunch 1147.
 $N_b \approx 2.2 \times 10^{11}$ ppb, $\beta_{y,IP1}^* = 0.5$ m, $\beta_{x,IP1}^* = 1$ m, $\Phi/2(p10)(S/V) = 250 \mu\text{rad}$
 $\sigma_x = 7.61$ cm, $\Phi/2(p8, v) = 170 \mu\text{rad}$, $\epsilon_x = 2.5 \mu\text{m}$, $Q = 5.0$, $I_{MO} = 410.0$ A, $C^- = 0.001$
 F. Scheme : 25ns_2228b_2216_1686_2112_hybrid_8b4e_2x56b_25ns_3x48b_12inj



8b4e filling scheme

HL-LHC v1.5. Flat optics. Start of levelling. CC ON. Bunch 1963.
 $N_b \approx 2.3 \times 10^{11}$ ppb, $\beta_{y,IP1}^* = 0.5$ m, $\beta_{x,IP1}^* = 1$ m, $\Phi/2(p10)(S/V) = 250 \mu\text{rad}$
 $\sigma_x = 7.61$ cm, $\Phi/2(p8, v) = 170 \mu\text{rad}$, $\epsilon_x = 2.5 \mu\text{m}$, $Q = 5.0$, $I_{MO} = 410.0$ A, $C^- = 0.001$
 F. Scheme : 8b4e_1972b_1960_1178_1886_224bpi_12inj



Reasonable DA margin.

Flat optics with $Q' = 15$

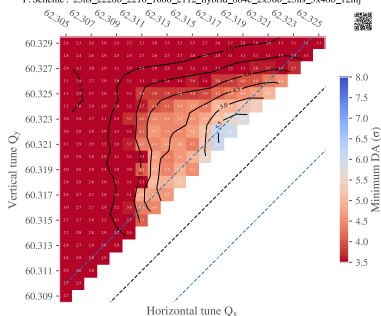
hybrid filling scheme

HL-LHC v1.5. Flat optics. Start of levelling. CC ON. Bunch 1147.

$N_b \approx 2.2 \times 10^{11}$ ppb, $\beta_{y,ip1}^* = 0.5$ m, $\beta_{x,ip1}^* = 1$ m, $\Phi/2(p_{H/S/V}) = 250 \mu\text{rad}$

$\sigma_x = 7.61$ cm, $\Phi/2(p_{H/S/V}) = 170 \mu\text{rad}$, $\epsilon_0 = 2.5 \mu\text{m}$, $Q' = 15$, $I_{MO} = 410.0$ A, $C^- = 0.001$

F. Scheme: 25ns_2228b_2216_1686_2112_hybrid_8b4e_2x56b_25ns_3x48b_12inj



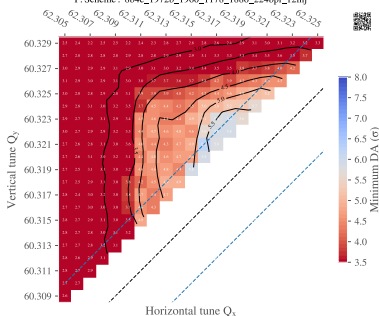
8b4e filling scheme

HL-LHC v1.5. Flat optics. Start of levelling. CC ON. Bunch 1963.

$N_b \approx 2.3 \times 10^{11}$ ppb, $\beta_{y,ip1}^* = 0.5$ m, $\beta_{x,ip1}^* = 1$ m, $\Phi/2(p_{H/S/V}) = 250 \mu\text{rad}$

$\sigma_x = 7.61$ cm, $\Phi/2(p_{H/S/V}) = 170 \mu\text{rad}$, $\epsilon_0 = 2.5 \mu\text{m}$, $Q' = 15$, $I_{MO} = 410.0$ A, $C^- = 0.001$

F. Scheme: 8b4e_1972b_1960_1178_1886_224bpi_12inj



Detrimental effect on DA by **increasing chromaticity**.

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End of Injection

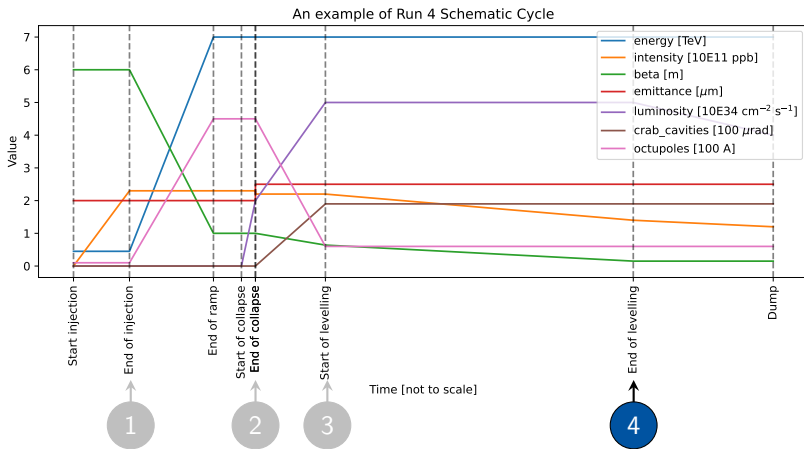
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Conclusions

End of \mathcal{L} -Levelling



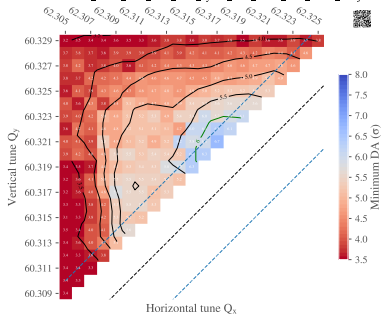
End of the \mathcal{L} -levelling

Parameters (unit)	HL-LHC (values)
Beam energy (TeV)	7
Luminosity (10^{34} Hz/cm ²)	5
Bunch population (protons)	$1.3\text{-}1.4 \times 10^{11}$
Filling scheme	hybrid/8b4e
Normalized emittance ($\mu\text{m rad}$)	2.5
Nominal working point (Q_x, Q_y)	(62.31, 60.32)
Chromaticity $Q'_{x,y}$	15
IP1/5 half crossing angle (μrad)	250(H) / 250(V)
IP2/8 half crossing angle (μrad)	170(V) / 170(V)
IP1/5 β^* (m)	7.5/18 (flat)
IP2/8 β^* (m)	10/1.5
Landau octupoles' current (A)	60 or 100
Half crab-cavity angle (μrad)	190

Flat optics with $Q'=5$

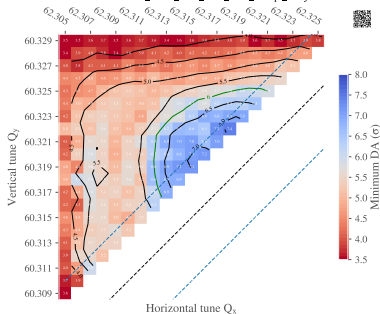
hybrid filling scheme

HL-LHC v1.5, Flat optics, End of levelling, CC ON, Bunch 1147.
 $N_b \approx 1.3 \times 10^{11}$ ppb, $\beta_{y,IP1}^* = 7.5$ cm, $\beta_{x,IP1}^* = 18$ cm, $\Phi/2(p_{10}(v)) = 250 \mu\text{rad}$
 $\sigma_x = 7.61$ cm, $\Phi/2(p_{98}, v) = 170 \mu\text{rad}$, $e_s = 2.5 \mu\text{m}$, $Q = 5.0$, $I_{MO} = 60.0$ A, $C^- = 0.001$
 F. Scheme : 25ns_2228b_2216_1686_2112_hybrid_8b4e_2x56b_25ns_3x48b_12inj



8b4e filling scheme

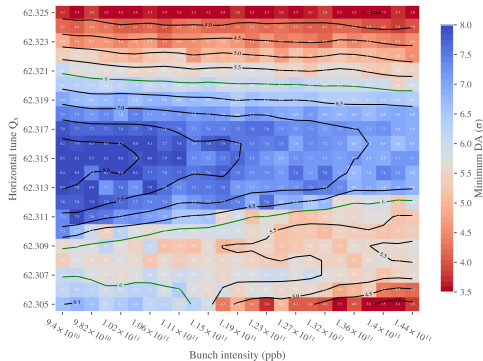
HL-LHC v1.5, Flat optics, End of levelling, CC ON, Bunch 1963.
 $N_b \approx 1.4 \times 10^{11}$ ppb, $\beta_{y,IP1}^* = 7.5$ cm, $\beta_{x,IP1}^* = 18$ cm, $\Phi/2(p_{10}(v)) = 250 \mu\text{rad}$
 $\sigma_x = 7.61$ cm, $\Phi/2(p_{98}, v) = 170 \mu\text{rad}$, $e_s = 2.5 \mu\text{m}$, $Q = 5.0$, $I_{MO} = 60.0$ A, $C^- = 0.001$
 F. Scheme : 8b4e_1972b_1960_1178_1886_224bpi_12inj



The DA target is met with $Q'=5$.

Flat optics with $Q' = 5$

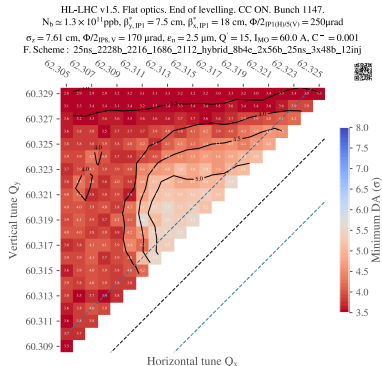
HL-LHC v1.5. Flat optics. End of leveling. CC ON
 $N_b = 1.4 \times 10^{11}$ ppb, $\beta_{x,IP1}^* = 7.5$ cm, $\beta_{x,IP4}^* = 18$ cm, $\Phi/2_{IP(1)(5)(V)} = 250$ μ rad
 $\sigma_x = 7.61$ cm, $\Phi/2_{IP8,V} = 170$ μ rad, $\epsilon_{11} = 2.5$ μ m, $Q' = 5$, $I_{500} = 60$ A, $C^- = 10^{-3}$



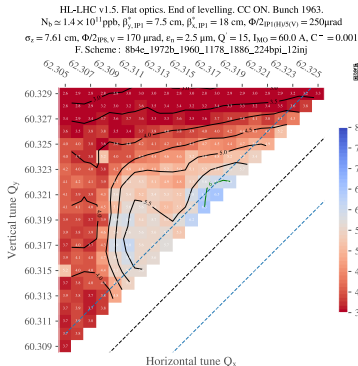
As expected, the DA improves after the end of leveling (plot for 8b4e).

Flat optics with $Q' = 15$

hybrid filling scheme

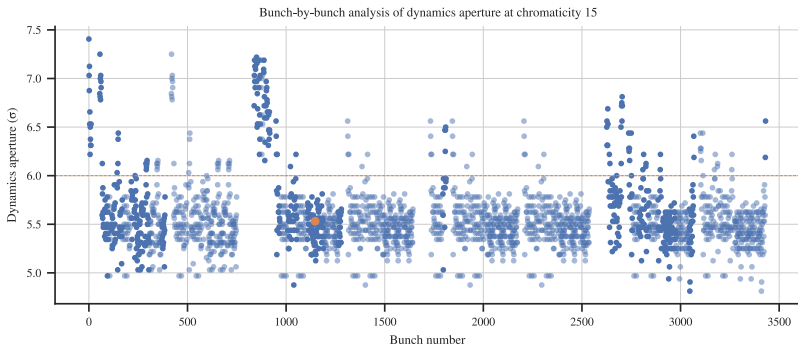


8b4e filling scheme



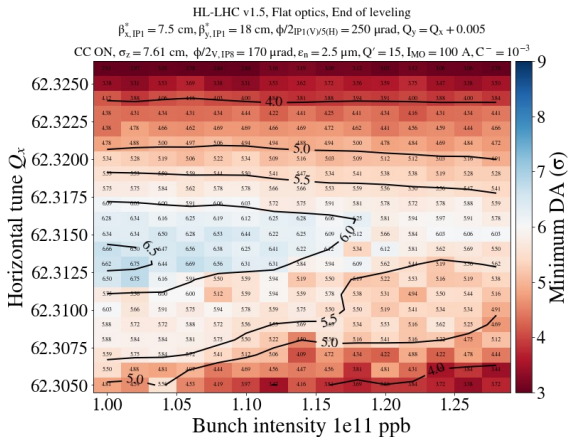
$Q' = 15$ critical for the hybrid filling scheme. Investigations ongoing to improve by IP1/5 phasing optimization and/or negative octupole.

Flat optics with $Q'=15$



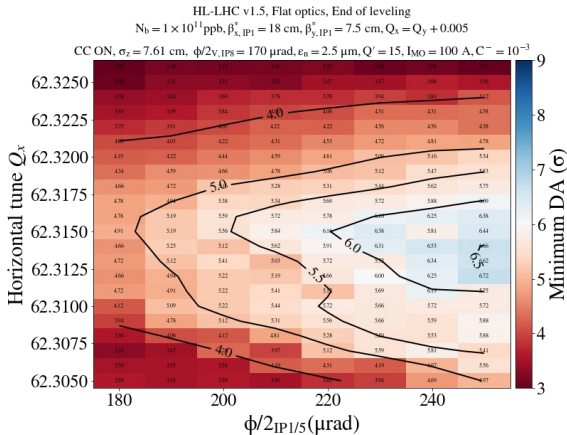
BBB DA: situation can become critical for some bunches.

Flat optics with $Q' = 15$



DA sensitivity vs bunch intensity with (flat optics).

Flat optics with $Q' = 15$



DA sensitivity vs crossing angle (flat optics).

Introduction

Beam-beam Studies Results

End of Injection

End of Collapse

Start of \mathcal{L} -Levelling

End of \mathcal{L} -Levelling

Conclusions

Conclusions

- At 450 GeV, incoherent effects at injection dominated by amplitude detuning from octupoles: DA target achieved with **positive octupole** current, together with a very good **coupling control** and **IP1/5 phase optimization**.
- **DA analysis of flat optics alternative scenarios** is progressing.
- At the end of collapse, **the round optics and baseline filling scheme reaches (marginally) the target DA**. Lower emittances reduce the margins, while negative octupoles improve them. High tele-index flat optics seems only compatible with negative octupoles.
- At the **start of the levelling** the situation, also with flat optics, is more relaxed (in particular with $Q' = 5$).
- At the **end of the levelling** the situation with **flat, hybrid, $Q'=15$ and $I_{OCT}=60$ A** still below target DA. IP1/5 phase scans, negative octupoles (and wire compensation studies) are planned.

Thank you for your attention.



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References (I)



D. Pellegrini, G. Arduini, S. Fartoukh, G. Iadarola, N. Karastathis, Y. Papaphilippou, and G. Sterbini.

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