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Follow up on the impact of crab cavity noise on luminosity

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Introduction

- **Crab cavities** (CCs) induce **emittance blow-up**[1].
- Simulations of the optimum fills for the **Baseline**, **Flat**, **No CCs**, and **Pushed**[2], at **nominal** ($\mathcal{L}_{\text{lev}} = 5.0 \times 10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$) and **ultimate** ($\mathcal{L}_{\text{lev}} = 7.5 \times 10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$) operation, to asses the impact on **integrated performance**.
- Growth rates from phase and amplitude noise: **0.94 %/h** and **3.7 %/h**, respectively (at $\beta^* = 15\,\text{cm}$ and with 2 CCs).
    - In addition to intrabeam scattering and synchrotron radiation (and 40h growth in the vertical plane).

Parameter	**Unit**	**Baseline**	**Flat**	**No CCs**	**Pushed**
Minimum $\beta^*_\times$, $\beta^*_\parallel$	cm	20, 20	40, 15	40, 15	15, 15
Full crossing angle	µrad	510	360	360	480
Minimum beam separation	σ	12.5	12.5	12.5	10.0
Crabbing angle	µrad	380	360	0	380

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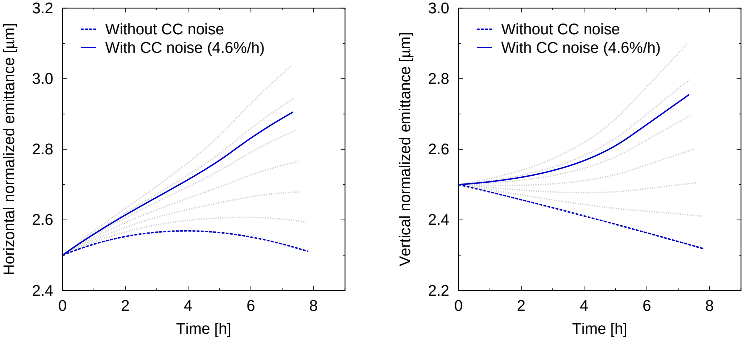
[1] P. Baudrenghien, 96th HiLumi WP2 Meeting

[2] Y. Papaphilippou, LHC Performance Workshop Chamonix 2017.

Emittance evolution: baseline nominal



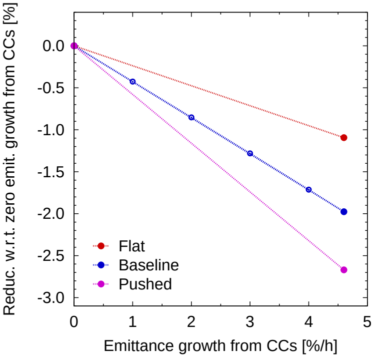
- Contributions to both transversal planes:

$$\left(\frac{d\epsilon}{dt}\right)_{\mathrm{CC}} \approx 4.6\,\%/\mathrm{h} \cdot \frac{V_{\mathrm{CC}}^2}{(6.8\,\mathrm{MV})^2}\,\frac{15\,\mathrm{cm}}{\beta^*} \approx 4.6\,\%/\mathrm{h} \cdot \frac{\theta_{\mathrm{CC}}^2}{(380\,\mu\mathrm{rad})^2}\,\frac{15\,\mathrm{cm}}{\beta^*}$$

- Emittance growth rates of 1.1 %/h and 3.5 %/h at the beginning and at the end of the β^*-levelling, respectively.

Integrated luminosity: nominal

- Reduction of $\mathcal{L}_{\text{int}}$ is **linear** for small emittance growth rate from CCs.
- **Baseline nominal** performance is reduced by **2 %**.
- CC noise results in only 1 % lumi loss in the Flat scenario.
- The largest impact is on Pushed (2.7 %).
- Relative performance loss from the absence of CCs w.r.t. baseline shrinks from 9 % to 7 %.

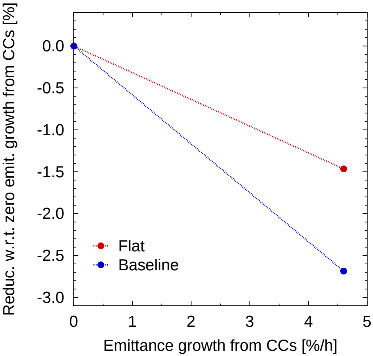


Nominal ($\mathcal{L}_{\text{lev}} = 5.0 \times 10^{34}$ cm^{-2} s^{-1})

Parameter	Unit	Baseline	Flat	No CCs	Pushed
$\epsilon_{x,\text{n}}$ at the end of fill	μm	2.51 → 2.90	2.56 → 2.74	2.59	2.48 → 2.95
$\epsilon_{y,\text{n}}$ at the end of fill	μm	2.32 → 2.76	2.32 → 2.52	2.35	2.30 → 2.80
Yearly integ. lumi.	fb^{-1}/160 days	234 → 229	234 → 231	214	244 → 238

Integrated luminosity: ultimate

- **Baseline**: $\mathcal{L}_{\text{int}}$ increase from nominal to **ultimate**, reduced from **37.5 %** to **34 %**.
- Integrated performance of Flat scenario is lowered by 1.5 %.
- No CCs: 14.7 % → 12.4 % relative loss w.r.t. baseline.
- An optimized Pushed at ultimate operation is needed for evaluation.



Ultimate ($\mathcal{L}_{\text{lev}} = 7.5 \times 10^{34}\,\text{cm}^{-2}\,\text{s}^{-1}$)

Parameter	**Unit**	**Baseline**	**Flat**	**No CCs**
$\epsilon_{x,\text{n}}$ at the end of fill	μm	2.52 → 2.86	2.55 → 2.71	2.57
$\epsilon_{y,\text{n}}$ at the end of fill	μm	2.38 → 2.76	2.38 → 2.56	2.38
Yearly integ. lumi.	fb^{-1}/160 days	321 → 313	322 → 318	274

Conclusions

- **Baseline performance** is reduced by 2 % (nominal) and 2.7 % (ultimate) due to CC noise.
- Flat scenario less sensitive to this due to reduced crossing (and crabbing) angle and larger β^*: 1 % (nominal) and 1.5 % (ultimate).
- Implementation of **mitigation techniques** to reduce the impact of **CC noise** on the integrated performance are **required**, specially in view of the Pushed scenario.
- Lumi loss from the **absence of CCs** goes from 9 % to 7 % (nominal) and 14.7 % to 12.4 % (ultimate) w.r.t. baseline.