CERN

Status of studies of:
The impact of noise on beam stability

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WP2 Meeting, November 2019

Latent Instability in the LHC

L2D2 – Loss of Landau damping Driven by Diffusion

Impact of L2D2 on HL-LHC

Summary & Outlook

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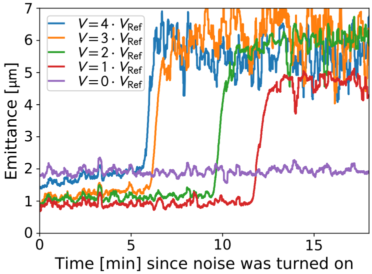

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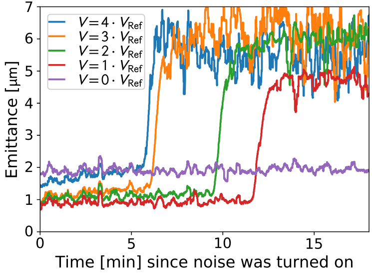

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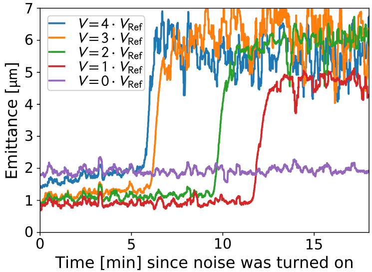
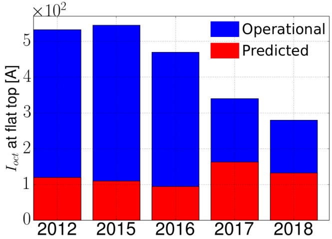
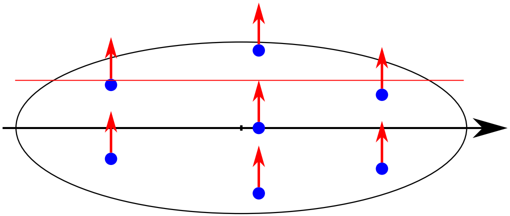
- Reproduced in dedicated experiments. [S.V. Furuseth *et al.*, WEPTS044, IPAC 2019.]
- The instabilities are driven by noise, not caused by machine variations.
- This mechanism is linked to the discrepancy between the predicted and required octupole current in the LHC. [X. Buffat *et al.*, Evian Workshop 2019].





Noise definitions

Rigid-bunch/dipolar noise:
Equal stochastic kicks to all particles in a bunch, as the low-frequent noise in the LHC.



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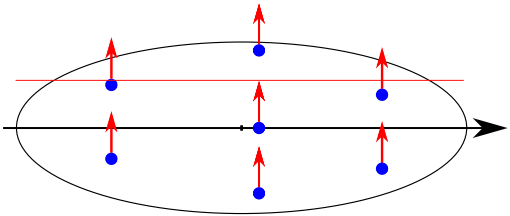
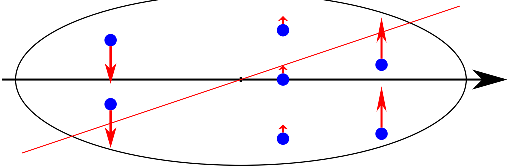


Crab amplitude noise: Kick dependent on longitudinal phase

$$\Delta p \propto \sin(\phi_s)\Delta V.$$

[Crab Noise, P. Baudrenghien, 2015]



L2D2 –
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Noise Excited Wakefields – Numerical Model

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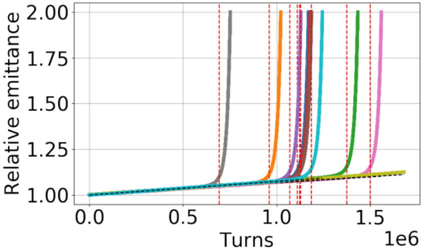

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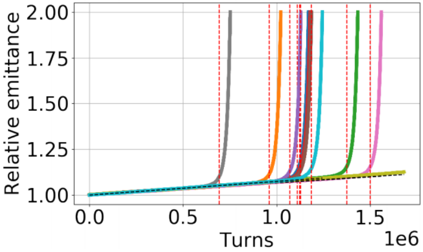
- Beyond a numerical threshold, the latency (τ) for one case scales as



$$\tau \propto \frac{I_{\mathrm{oct}}^3 G}{\sigma_\xi}$$

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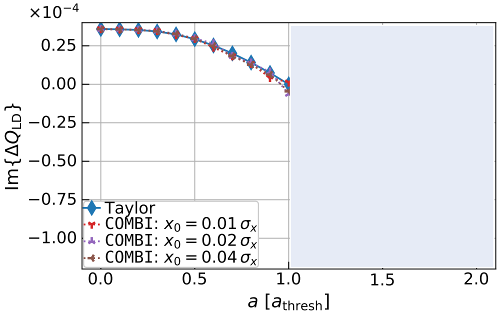

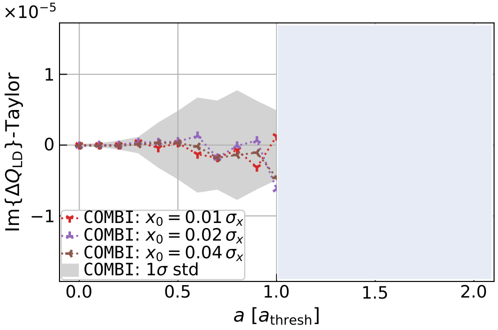

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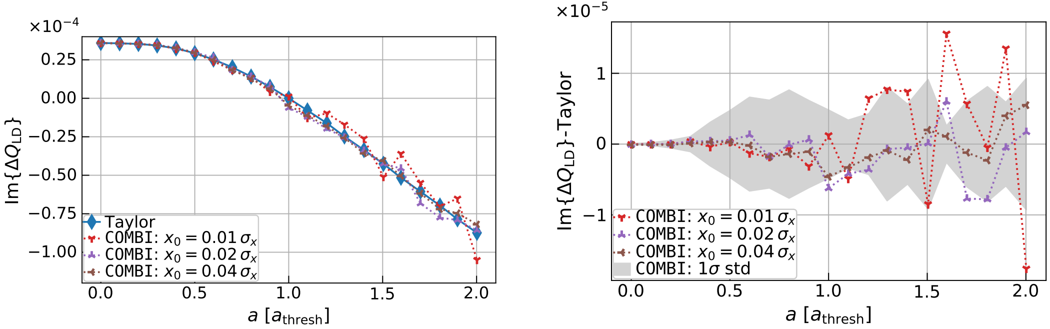

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$$D(\omega) = J \cdot \frac{\omega_\mathrm{rev}}{2} \cdot \frac{\eta_m^2 \sigma_\xi^2 |\Delta\omega_m|^2}{\mathrm{Im}\{\Omega_m\}^2} \cdot B(\omega; \Omega_m) \cdot C(\omega_m, \Omega_m).$$

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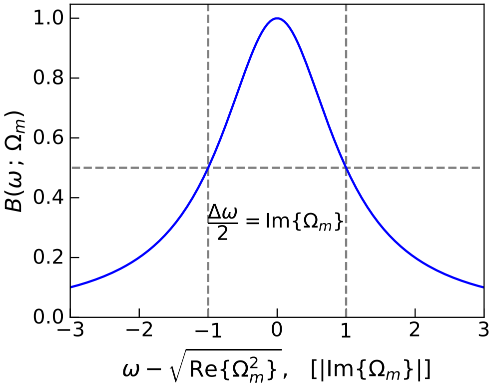
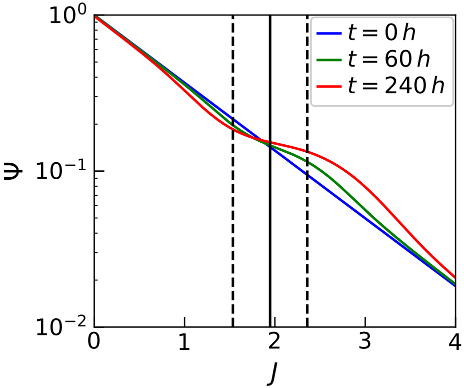
- See more details of the derivation in [ABP Forum 2019-11-07].

Wakefield driven Diffusion in 1D

The diffusion is centred at the mode frequency, $\omega(J) = \Omega_m$.





Wakefield driven Diffusion in 2D, $\eta_m = 0.01$

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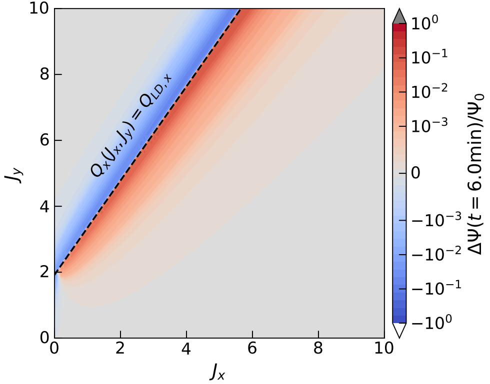
Mode 1 and rigid-bunch noise.



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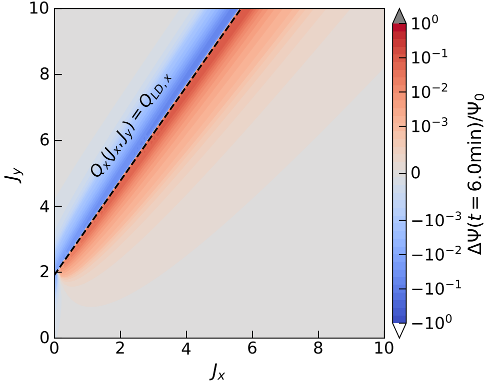

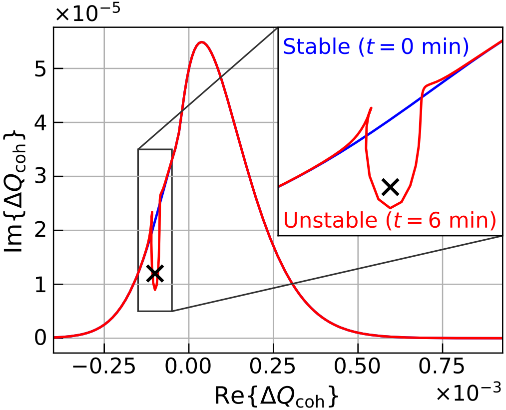

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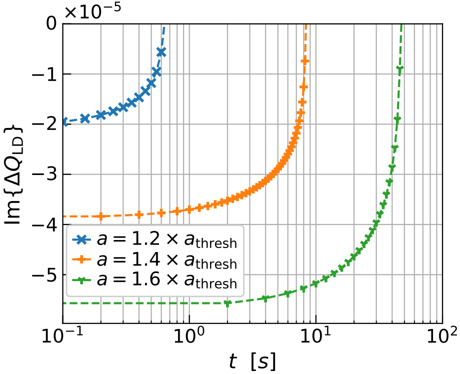

Initial results of simplified model.

Wakefield driven Diffusion in 2D, $\eta_m = 1$

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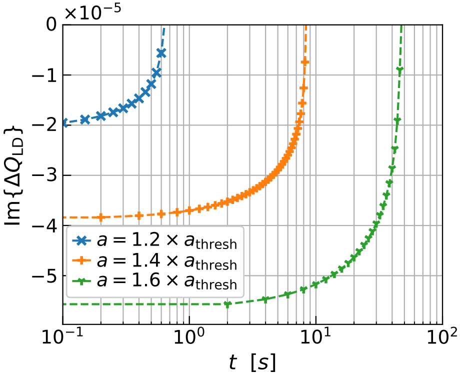
- Mode 0 and rigid-bunch noise.
- **Mode 1 and crab amplitude noise.**



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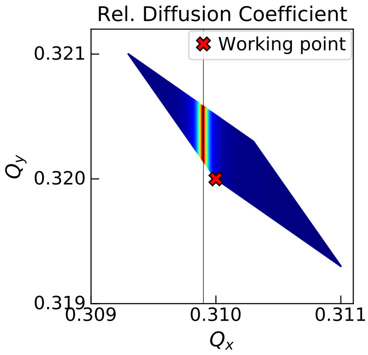

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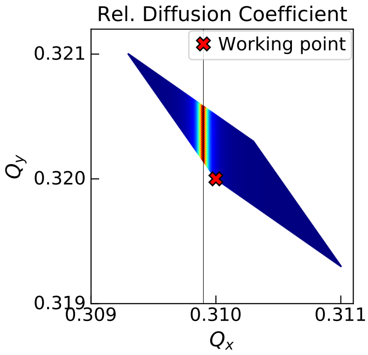

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- Change the detuning qualitatively.
  - Avoid detuning dependence on d.o.f. in the same plane (RFQ, Q'', $a=0$). TBI.

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  [S.V. Furuseth *et al.*, MD3288]
- Vary parameters to compare to theory (Q', G, I_{oct}, N).
- Difficult to get many data points in the LHC.
  - Can we test in SPS or IOTA (V. Lebedev)? TBI.

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- Will the HO beam-beam detuning be sufficient to mitigate L2D2 from crab amplitude noise during STABLE BEAM ($\eta^2 \sim 1$)?

Thank you for your attention!

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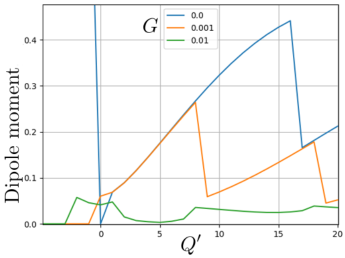
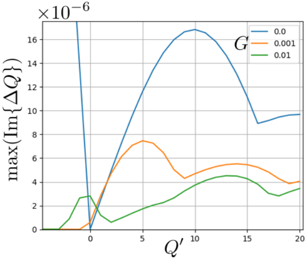
Backup: Mode description

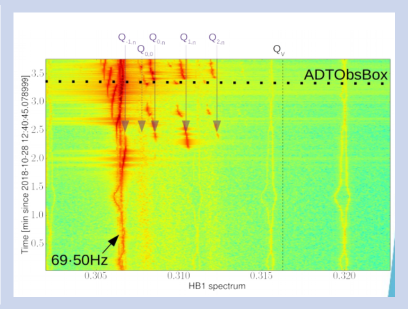
- The chromaticity and gain affects both the moments (η_m) and complex tune shifts ($\Delta\omega_m$) of the modes.
- Figures show the dipole moment and growth rate of the dominant mode.
  - $Q' < 0$: Mode 0 is dominant.
  - $Q' > 0$: Mode 0 is stable. Dipole moment of mode 1,2,... increases.
- To be done: Calculate the dependence of the latency on Q' and G.





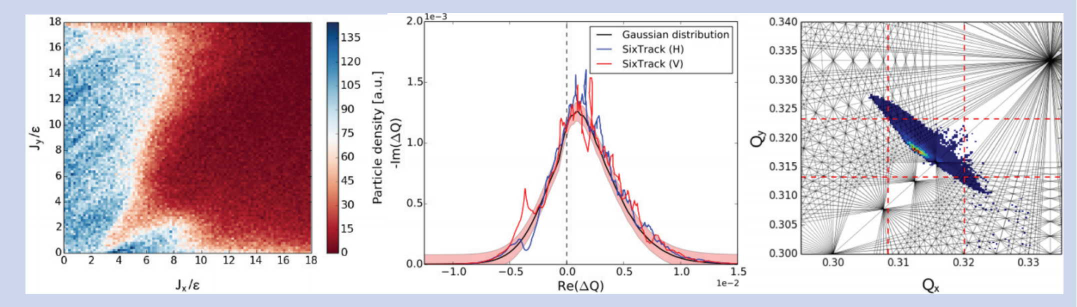
Backup: Diffusion driven by colored noise

- 50 Hz lines may drive a narrow diffusion that cannot be mitigated.
- Non-reproducible instabilities seen in the LHC with $\sim$ 10 times more Landau damping than needed according to the model.
- Not destabilizing unless a 50 Hz line is at the correct frequency.
  - If so, the wakefields will enhance the diffusion.



[X. Buffat, 153rd WP2 Meet.]

Backup: Diffusion driven by non-linearities



[C. Tambasco, PhD Thesis]

- Non-linearities can cause a frequency dependent diffusion.
- Most resonance lines are given by $mQ_x + nQ_y = p$, where $m, n \neq 0$. They do not lead to diffusion for all particles of a specific tune.

Backup: Mitigation Technique

- The diffusion and drilling is narrow in frequency.
- Can try to vary the frequency of the single particles to drill everywhere.
- This might counteract the importance of keeping Ω_j small.
- These calculations were done with constant diffusion coefficient based on the initial distribution.