Loss of Landau damping threshold studies

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Acknowledgments:

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Introduction

- **Landau damping** is a natural stabilization mechanism to mitigate coherent beam instabilities
- The **loss of Landau damping (LLD)** can lead to beam quality degradation and particle loss
- LLD threshold prediction in the single-harmonic RF system overestimates the measurements by ~25% (see SPS MPC #50)
- The discrepancy may indicates missing elements in the broad-band part of the SPS impedance model, RF noise excitation, or systematic overestimation in the bunch length measurements
- Follow-up: single bunch measurements in single and double-harmonic RF systems

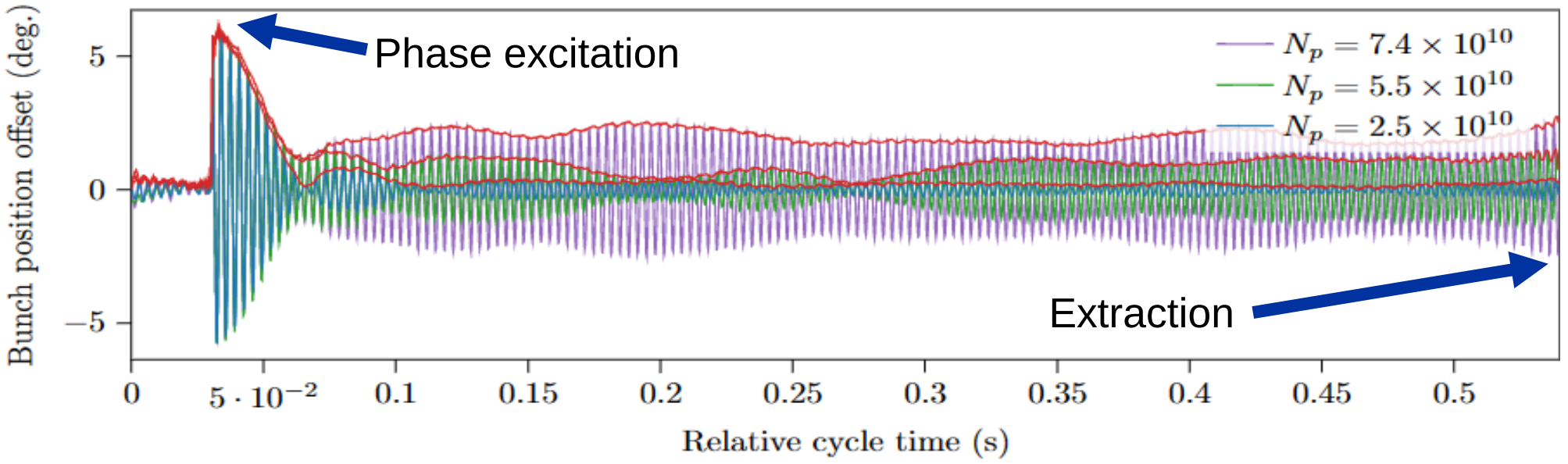
Measurement setup

❑ Long flattop at 200 GeV → Space charge negligible

Measurement methodology

- Active feedbacks on the beam phase off
- Phase excitation
- Observation of the bunch oscillation

Bunch phase offset evolution in the SPS



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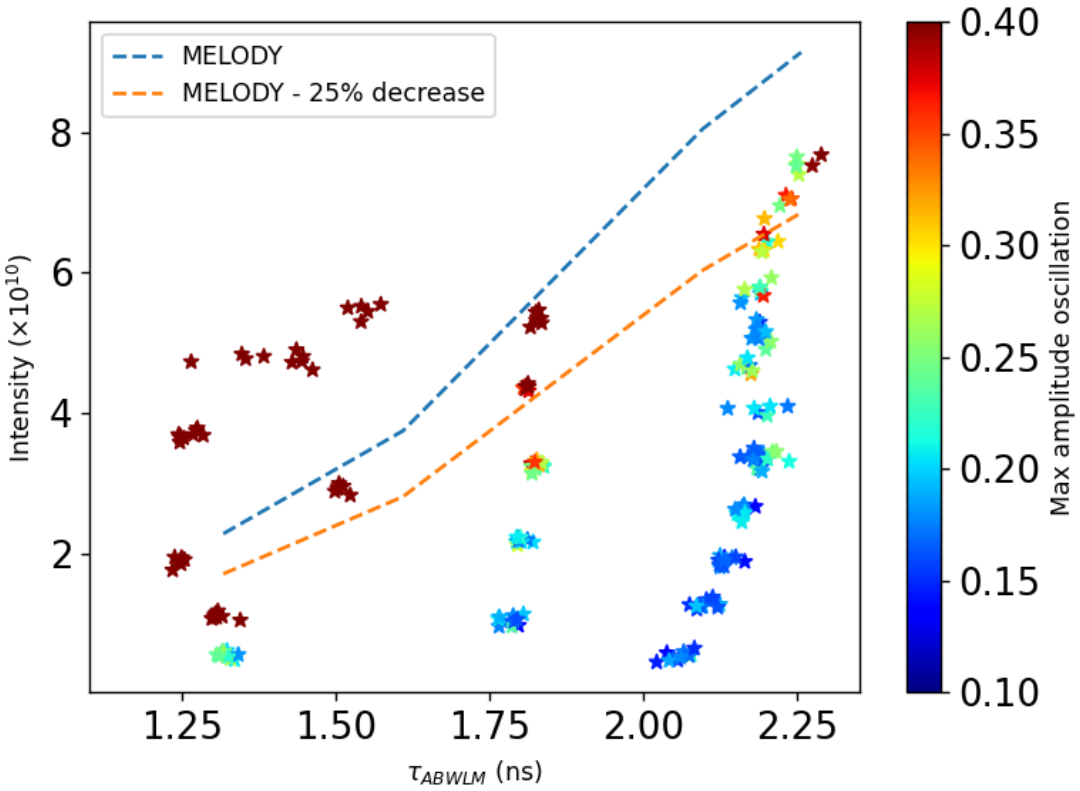
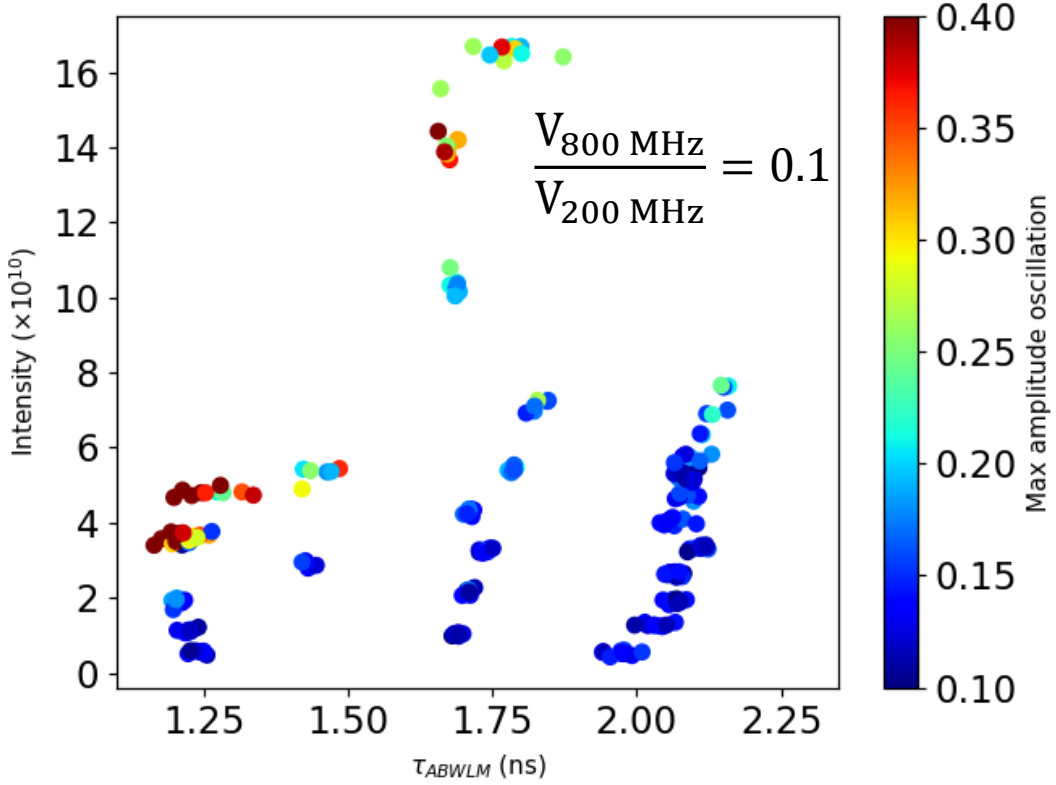
- Single bunch and emittance ranging between 0.1-0.3 eVs

- Intensity scan performed in the range of 5×10^9-2×10^{11} p/b

800 MHz cavity system disabled



800 MHz cavity system enabled

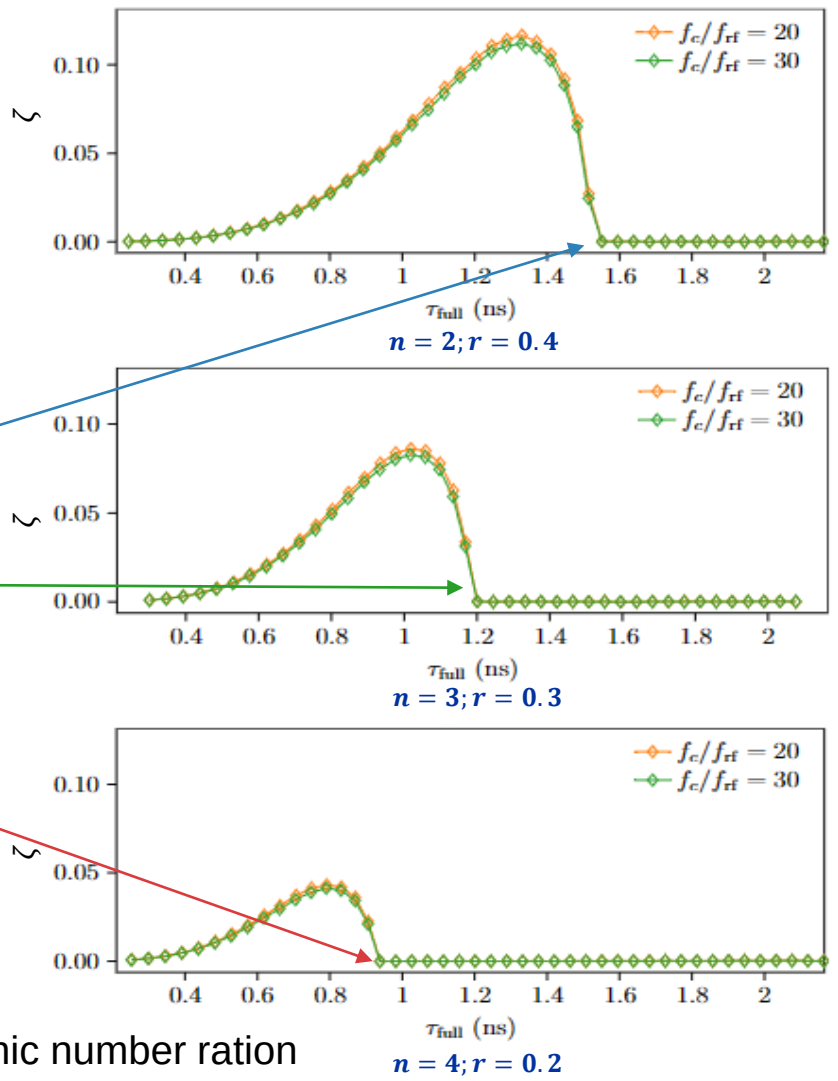


→ Further analysis and MELODY/BLonD cross-checks are needed

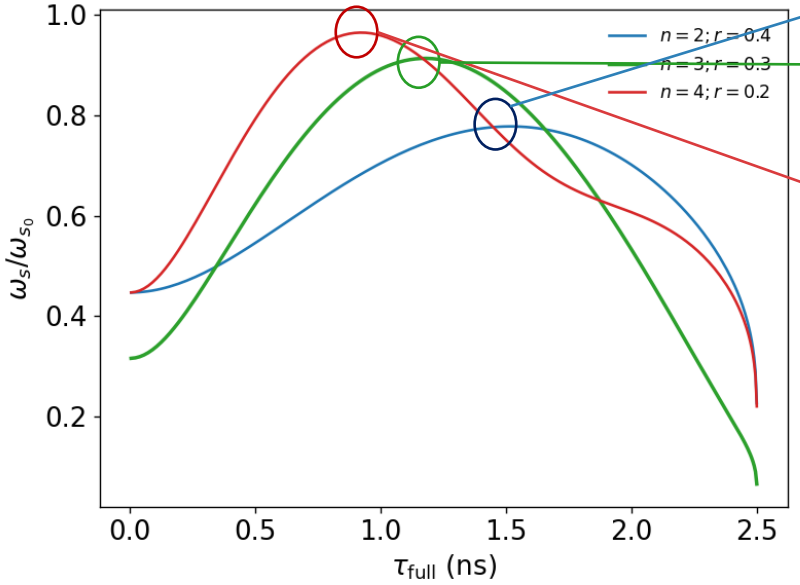
Bunch lengthening mode: expectations

- Bunch lengthening mode (BLM) → RF systems in counter-phase at the bunch position
- The LLD threshold is **non-monotonic** → $\zeta_{\mathrm{th}} = 0$ when the $\max[\omega_s(\phi)] \neq \omega_s(\phi_{\max})$
- N.B. $\zeta \propto \mathrm{N}_p$ dimensionless intensity parameter

LLD threshold in MELODY



Synchrotron frequency distribution



n = harmonic number ration
r = voltage ratio

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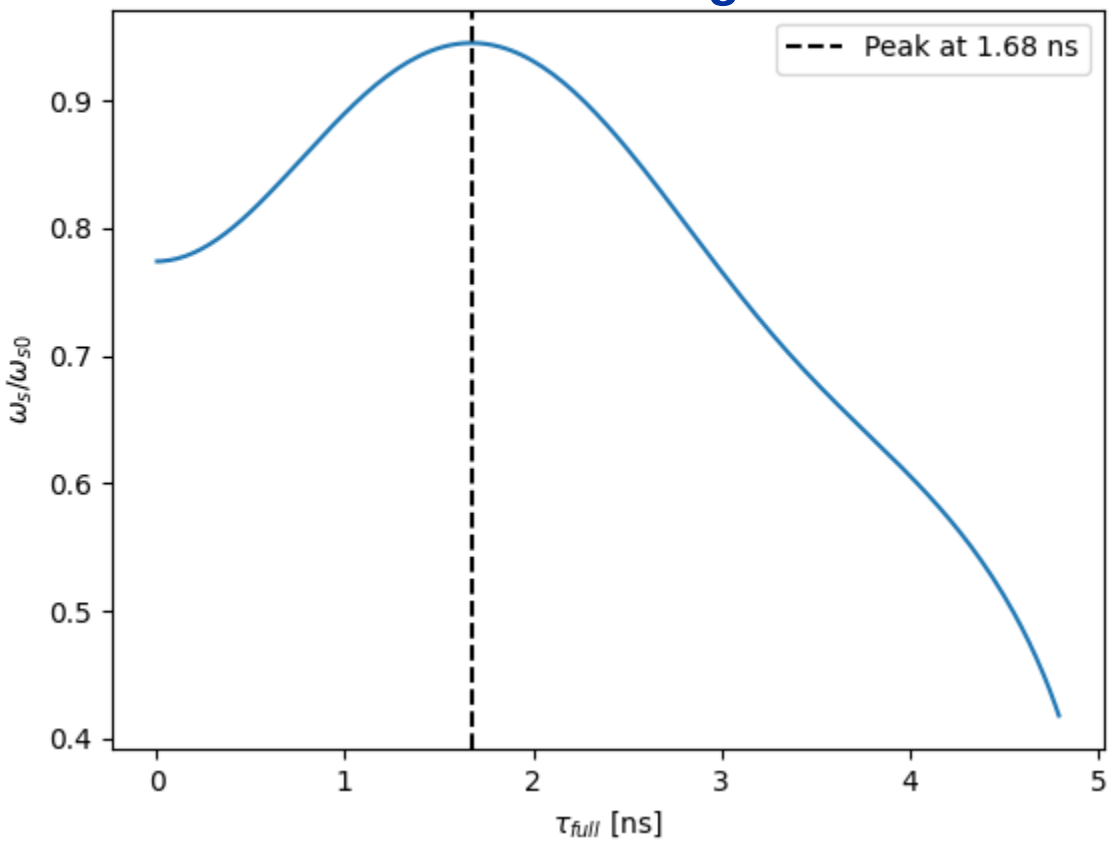
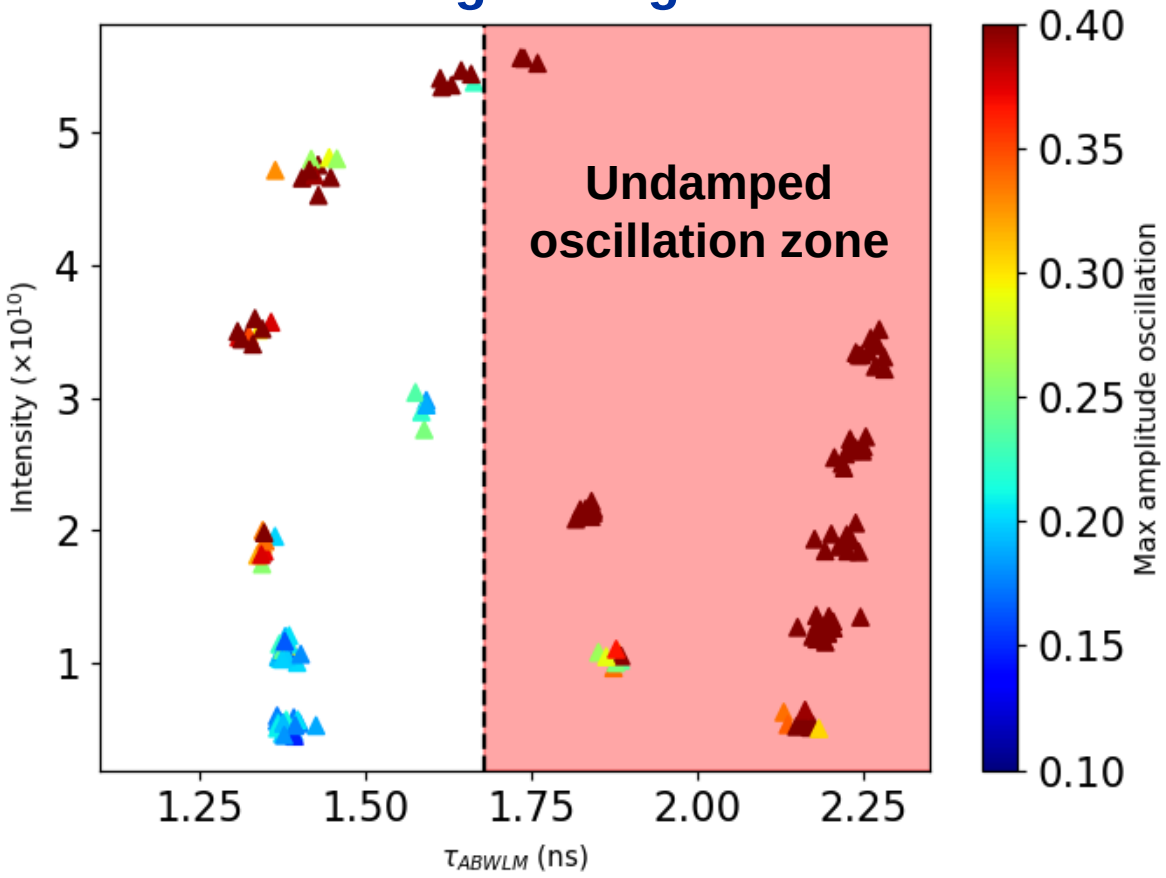
- $V_{200\mathrm{MHz}} = 6.5$ MV; $V_{800\ \mathrm{MHz}}/V_{200\ \mathrm{MHz}} = 0.1$

Synchrotron frequency in BLM with SPS settings



Bunch lengthening mode



Issues and Downtime

- ~~31-05-2024 08:00 - 31-05-2024 14:00 (6 h)~~
- ~~10-06-2024 08:00 - 10-06-2024 14:00 (6 h)~~
- ~~11-06-2024 14:00 - 11-06-2024 20:00 (6 h)~~

SPS broken dipole

- ~~17-06-2024 08:00 - 17-06-2024 14:00 (6 h)~~
- ~~17-06-2024 14:00 - 17-06-2024 20:00 (6 h)~~
- ~~18-06-2024 14:00 - 18-06-2024 20:00 (6 h)~~

SPS magnet exchange

- ~~24-06-2024 08:00 - 24-06-2024 14:00 (6 h)~~ → PSB intervention + LHC fill
- 24-06-2024 14:00 - 24-06-2024 20:00 (6 h)
- 25-06-2024 08:00 - 25-06-2024 14:00 (6 h) → RF amplifier issue
- 22-07-2024 08:00 - 22-07-2024 14:00 (6 h) → 2 LHC fill + SBDS problem
- 23-07-2024 08:00 - 23-07-2024 14:00 (6 h)

❑ Only two full slots (2×6 h) used out of 11 requested, with significant downtime due to faults and interventions

Summary

- Only two full slots (2×6 h) used out of the 12 requested → Significant downtime due to faults and interventions

- Preliminary analysis **confirms** the discrepancy between **measurements** and **predictions**

- Further analysis is required, including **cross-check** with simulation in **BLonD** and **semi-analytical calculation**

→ **No additional MD requests is foreseen**

Thank you for your attention

Backup

Reference case in single-harmonic RF

- Measured oscillation amplitude is slightly higher than predicted
- LLD threshold depends on the effective cutoff frequency (SPS MPC #50)
  → Further refinement in the broad-band part of the impedance model (?)
- MELODY prediction (dashed) overestimates the threshold by ~25%