Pushing intensity with LHC-type beams

H. Bartosik, I. Karpov, I. Mases, L. Mether, G. Papotti, K. Paraschou, G. Rumolo, C. Zannini,
F. Asvesta, X. Buffat, H. Damerau, A. Lasheen, K. Li, M. Barnes, R. Calaga,
E. de la Fuente, G.P. Di Giovanni, A. Huschauer, G. Iadarola, V. Kain, B. Mikulec, B. Salvant,
M. Schenk, F.M. Velotti, PSB-PS-SPS OP teams

Intensity reach in the last three years

Intensity reach at flat top with nominal bunch length [$10^{11} ppb$]		
Year	**8b4e (4 x 56 bunches)**	**LHC25ns (4 x 72 bunches)**
2022	1.5	1.52
2023	2.15	2.2
2024	x	2.3

During 2024 scrubbing we demonstrated the LIU intensity

LIU beam (288 bunches with ~2.3e11 ppb and ~1.6ns bunch length) accelerated to 450 GeV

LIU beam at 2.3e11 ppb never fully restored

Beam availability during MDs, struggling with RF cavity limits, beam readiness from injectors after long gaps, magnet exchanges, ….

Consolidation of LIU beam and exploration of intensity limits with 8b4e beam

Key to be well prepared for the 2026 reliability run

Trasverse stability at injection energy

- Horizontal instability studied in detail in 2018 for 1.8e11 p/b
  - Mitigation strategy developed in simulations: high chromaticity + octupoles
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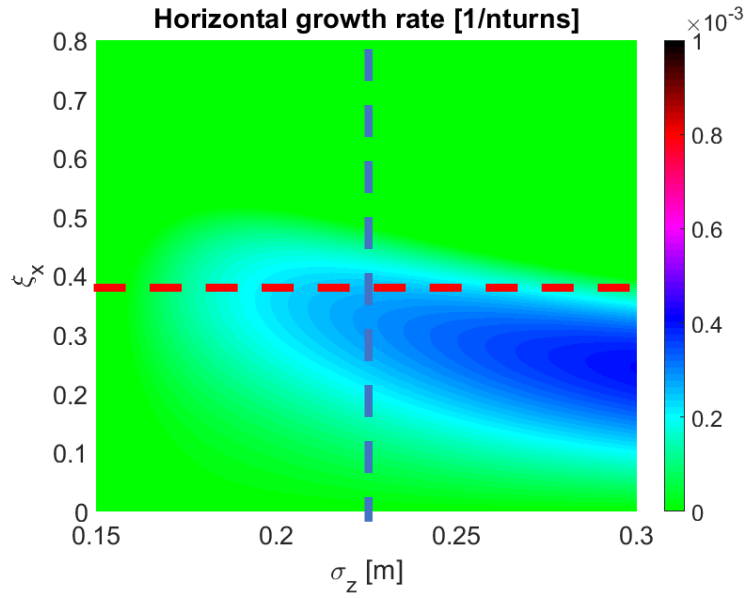
Criticality of short bunches at injection (<4 ns) to ensure stability, also confirmed in simulations



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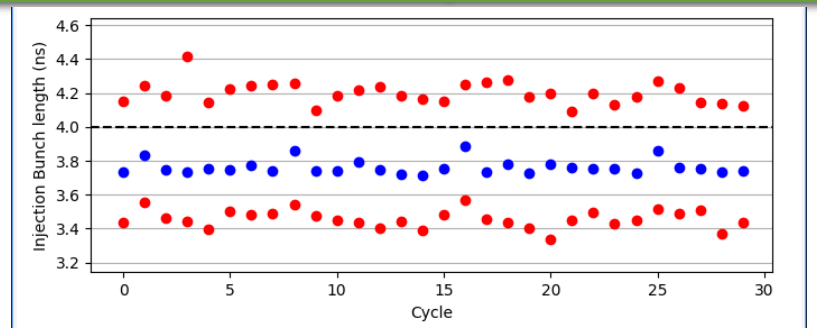
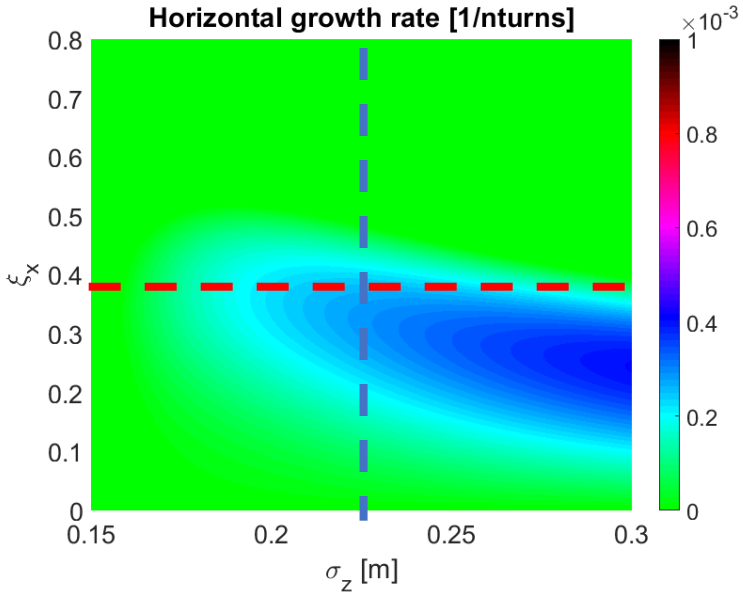
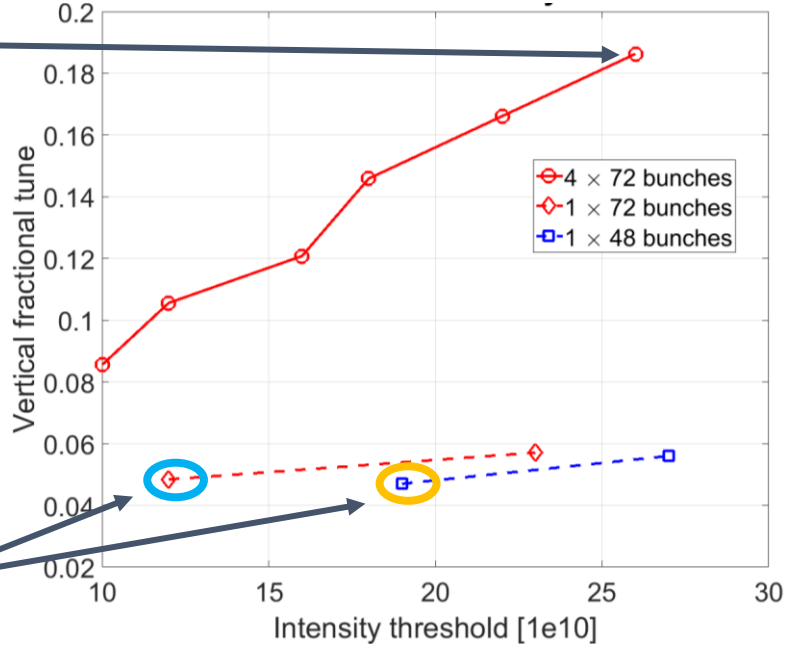




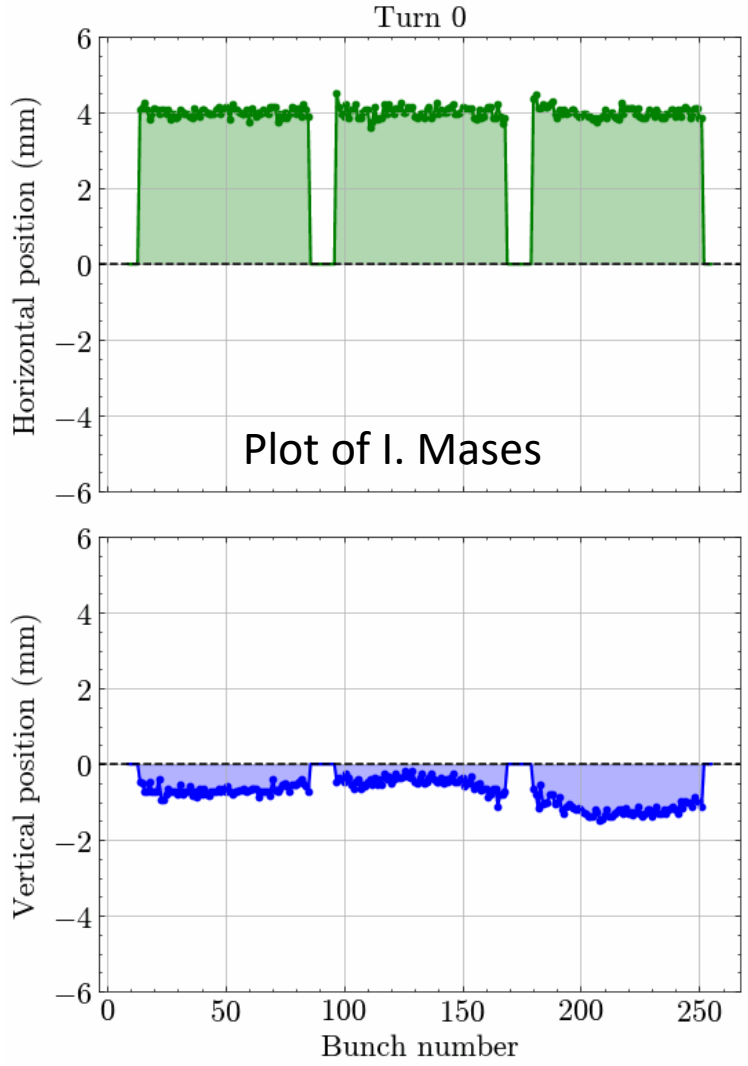
Transverse stability successfully tested in 2024 (~30h with ~2.7e11 ppb injected and **4 x 72 bunches**)

Observation of vertical instability

Studies with 4 batches in 2024



Experimentally confirmed with 1 batch and low intensity in 2021 and 2022



At tune **Qv = 20.18**, and **QPV = 0.6** (knob),
we reduced gradually the **gain of the damper**

SCAN OF THE VERTICAL CHROMATICITY AT NOMINAL DAMPER GAIN

Vertical chromaticity (knob) needs to be QPV >= 0.6

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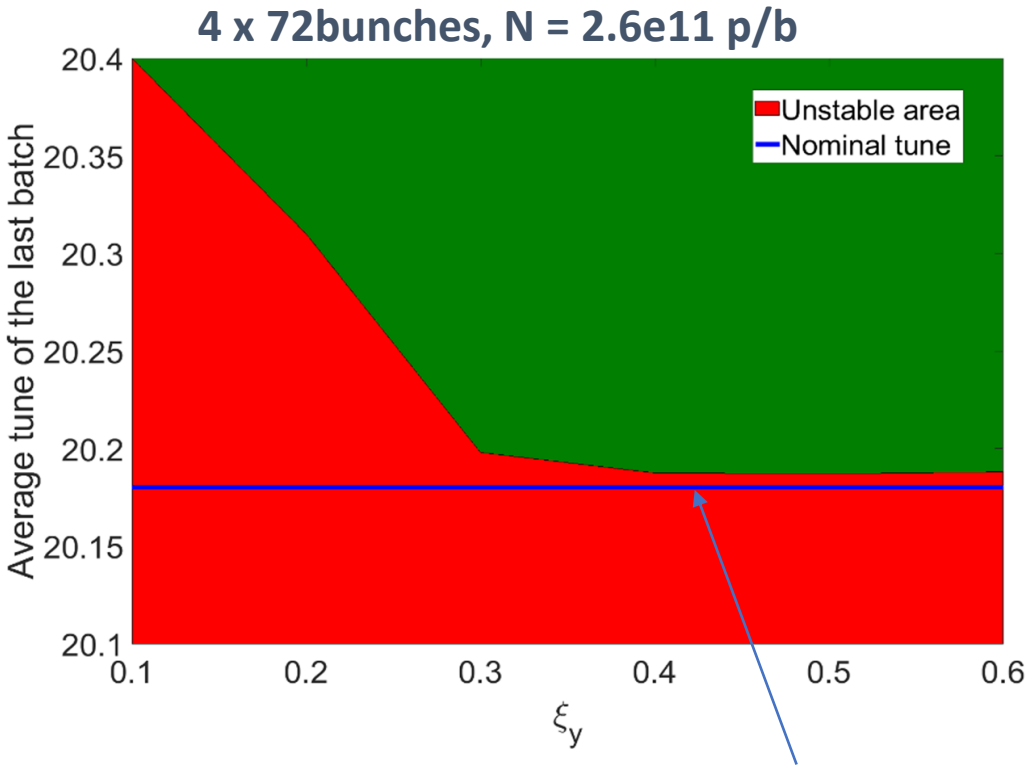

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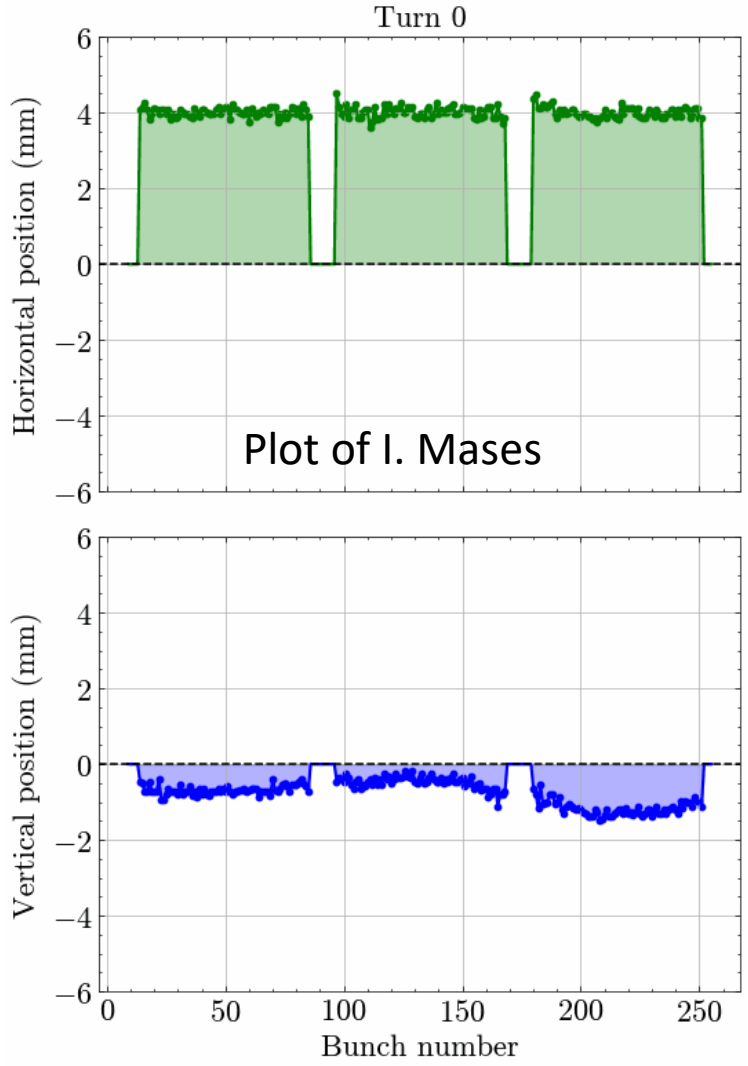
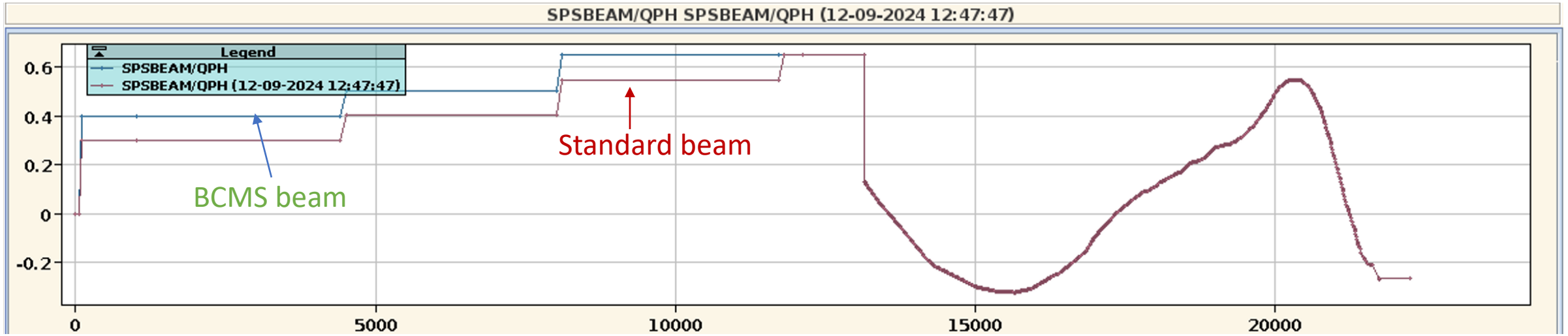
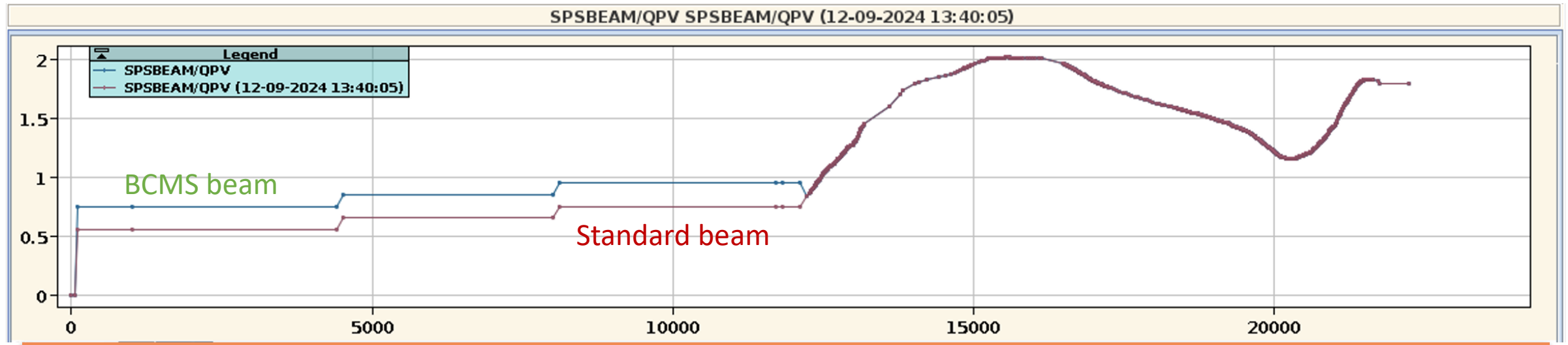


Horizontal and vertical chromaticity





Higher chroma needed for transverse stability with BCMS beam in both planes due to the smaller emittances

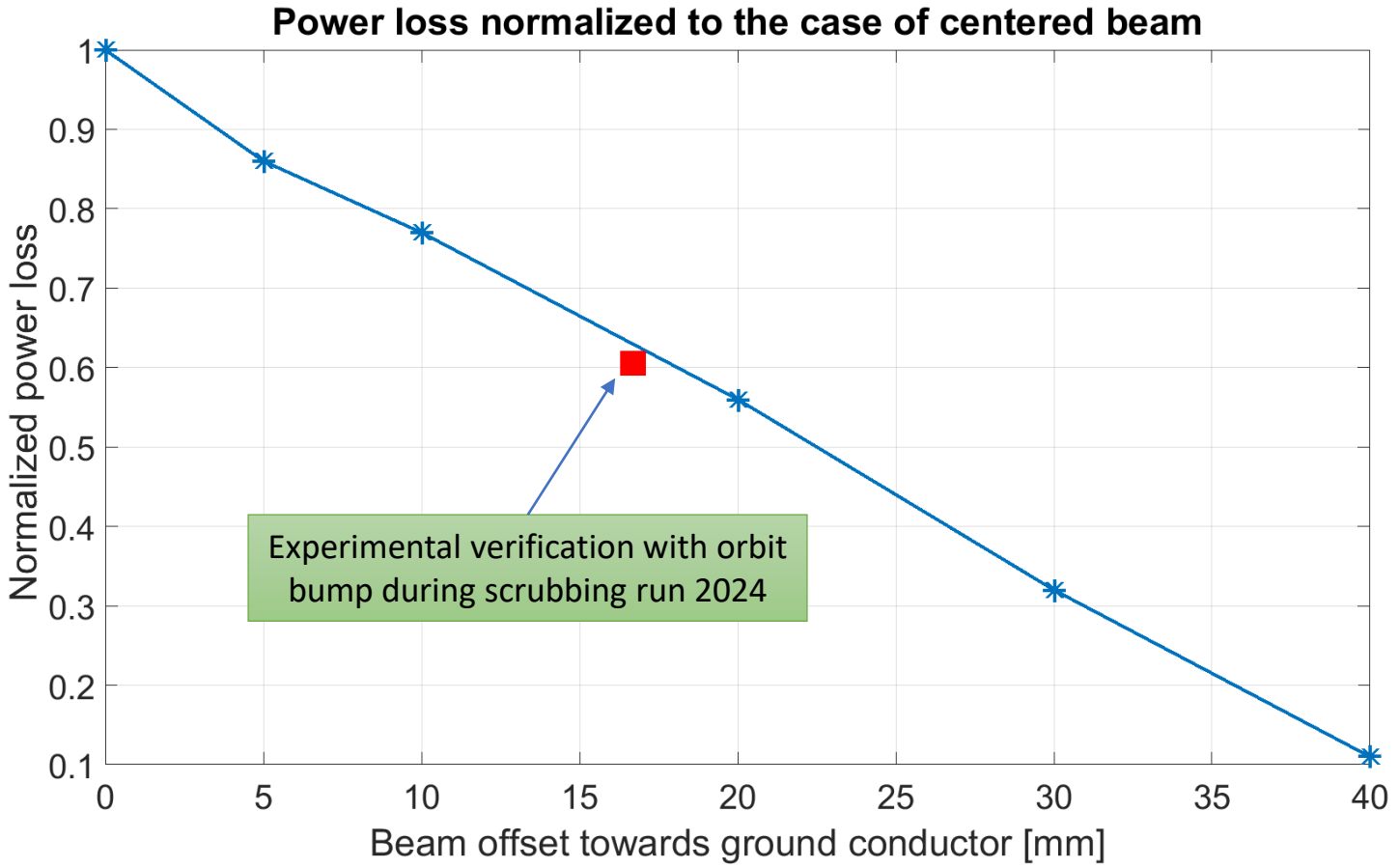
Could **Q22 optics** help to reduce the needed chromaticity for transverse stability?

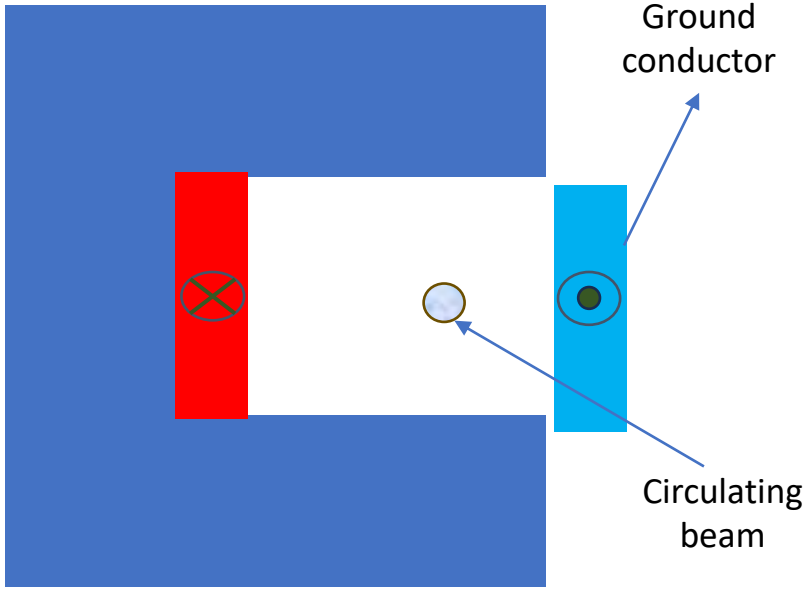
Investigation with Q22 optics revealed that indeed horizontal stability can be improved as predicted by Xavier (**stability reached for a 0.1-0.15 lower H chromaticity**). Stability become more critical in the vertical plane (**0.1-0.15 higher V chromaticity**)

SPS injection kicker beam induced heating mitigation

After the optimization of the MKP-L, MKP-S became the major bottleneck in term of beam induced heating
Scrubbing run 2023 and 2024 had to be modulated to accommodate cool down of the MKP-S magnet

Offsetting the **circulating beam** towards the **ground conductor** is expected to be beneficial in terms of beam induced heating





Desiderata for 2025

- Consolidation of LIU beam (scrubbing + at least 4-5 MD slots)
  - Starndard (during scrubbing) and BCMS (dedicated MD cycle)
- Exploration of intensity margins for LIU beam – at least 2-3 MD slots
- Pushing intensity with 8b4e beam (goal is to give 2.3e11 ppb to LHC for 2026 high intensity studies) - at least 2 MD slots
- Beam quality optimization (emittance, tails, batch-by-batch tune correction)
- Minimization of PS-SPS mismatch (tuning of transfer line optics)

meas. time	Standard				BCMS			
	epsn $[\mu m]$	**Intensity** $[10^{11} ppb]$	**Brightness** $[10^{11} ppb/\mu m]$	**Target brightness** $[10^{11} ppb/\mu m]$	**epsn** $[\mu m]$	**Intensity** $[10^{11} ppb]$	**Brightness** $[10^{11} ppb/\mu m]$	**Target brightness** $[10^{11} ppb/\mu m]$
PS extr.	2.05	2.64	1.29	-	1.59	2.64	1.66	-
SPS inj.	2.25	2.59	1.15	1.36	1.73	2.59	1.50	1.71

Thank you for your attention

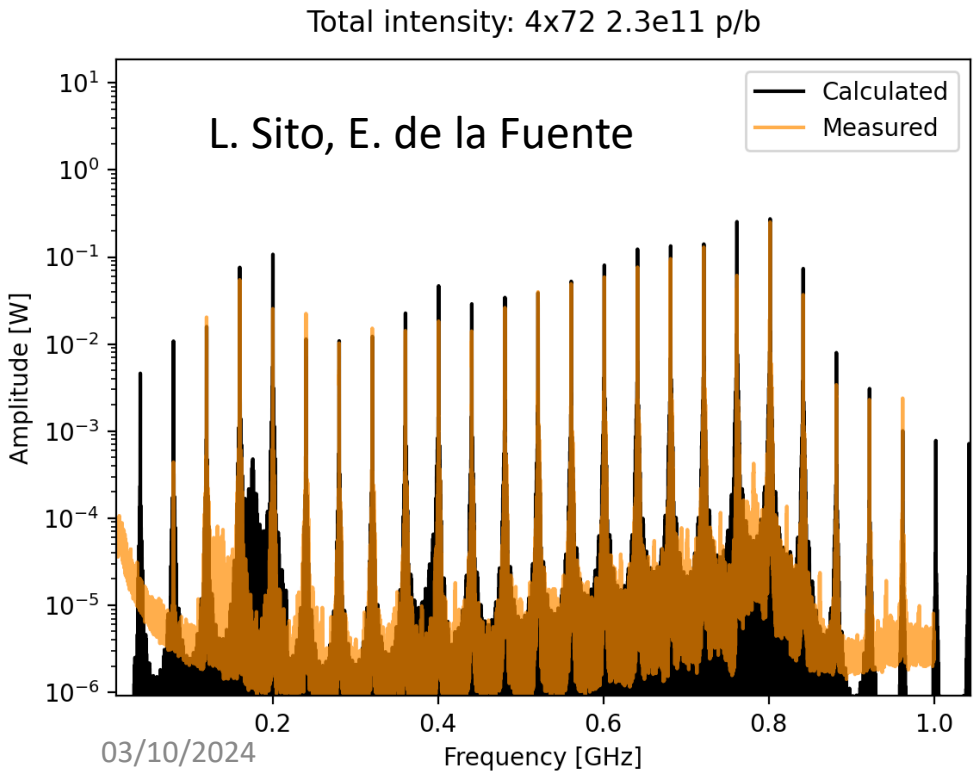
Additional studies

SPS Wire scanner failure

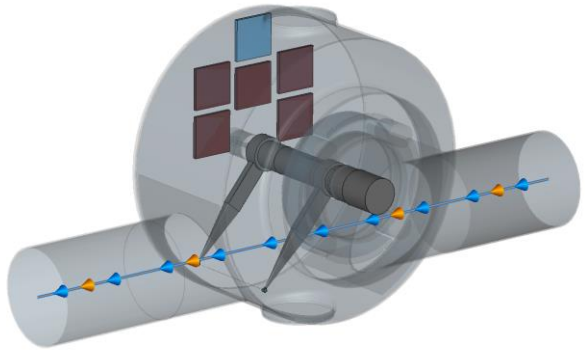
YETS 23/24: installation of ferrites and coupler in all 4 wire scanners tanks

As predicted from power loss calculations, no issues observed in parking position up to LIU intensities

Development of an **advanced model** that can reproduce the beam induced power loss over the relevant frequency range



An SPS wire scanner get stuck close to beam halo during 2024 operation



Breakage expected for >6.5 W

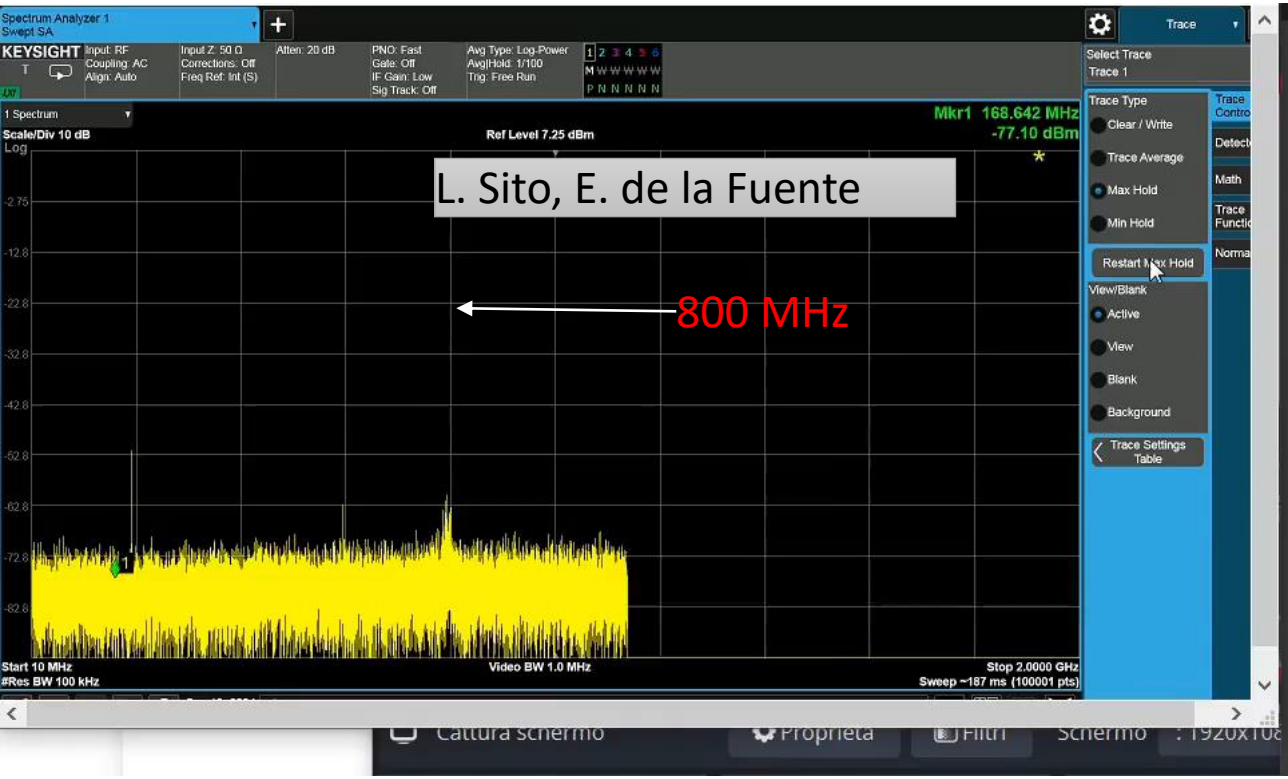
Beam type	Parking position [W]	Stuck position [W]
Operational	<0.9	<4.5
MD beam (breakage)	<2.4	>6.8
LIU	<5	>14

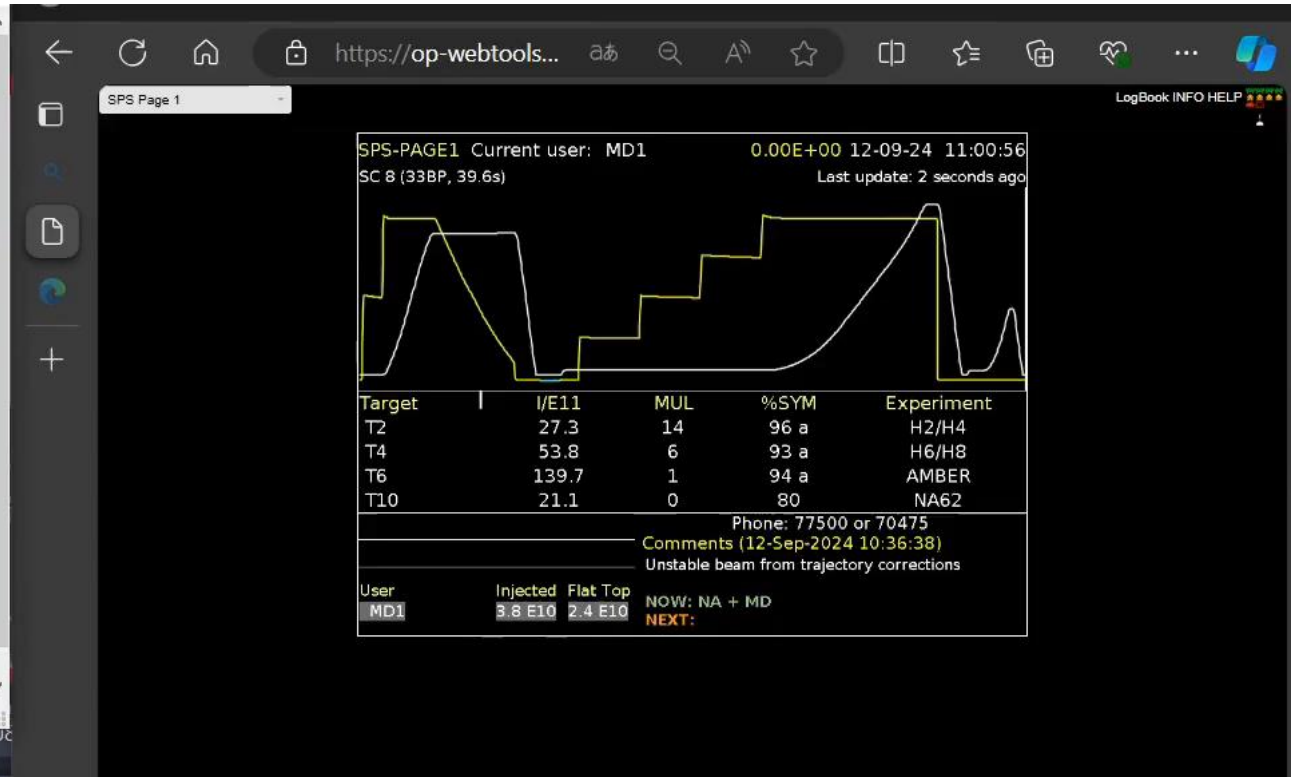
The stuck wire broke with significantly lower intensity than LIU, consistently with the **advanced model** predictions

SPS Wire scanners: expectations for coming years

YETS 23/24: installation of ferrites and coupler in all 4 wire scanners tanks

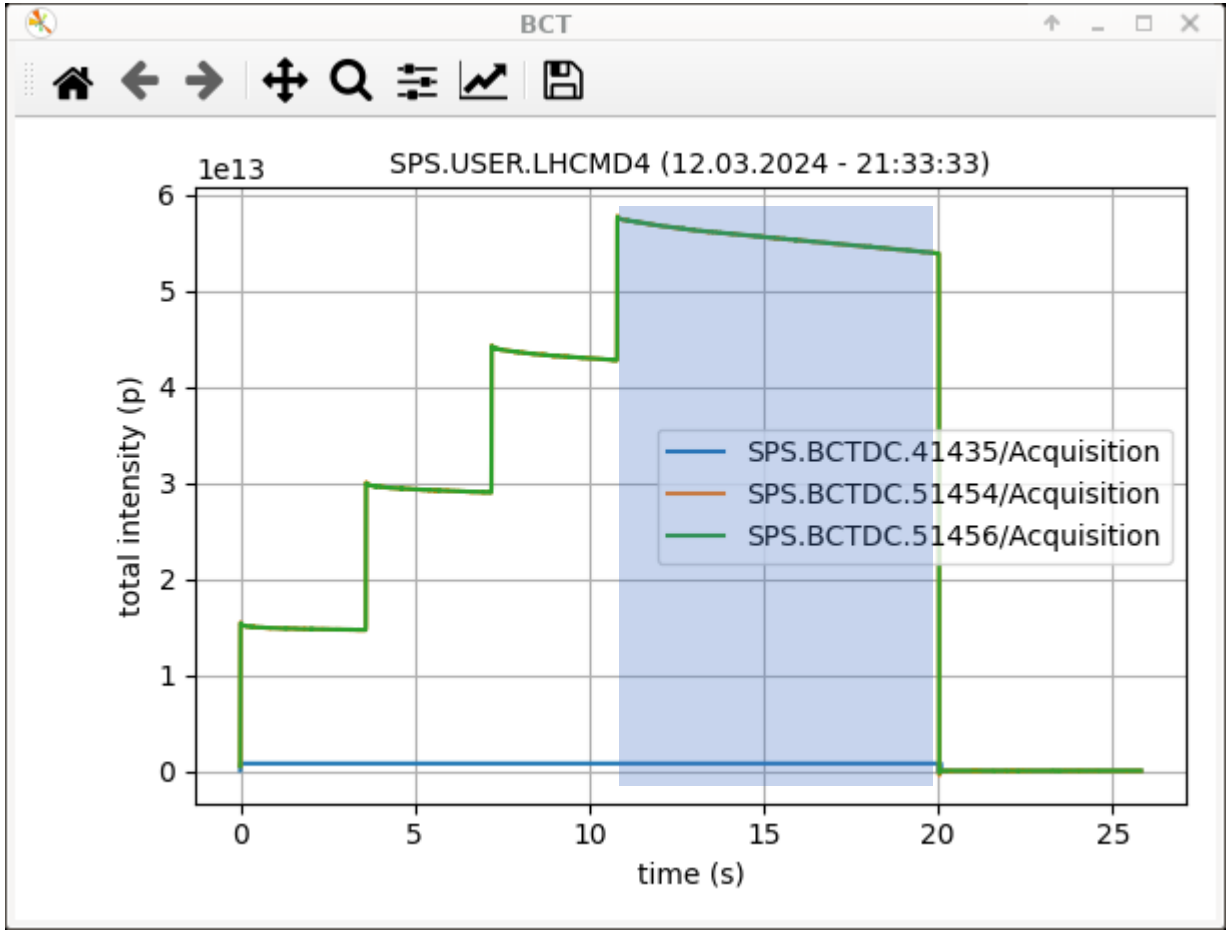
From power loss calculations, no issues are expected if considering **peak power on the wire along the cycle.**

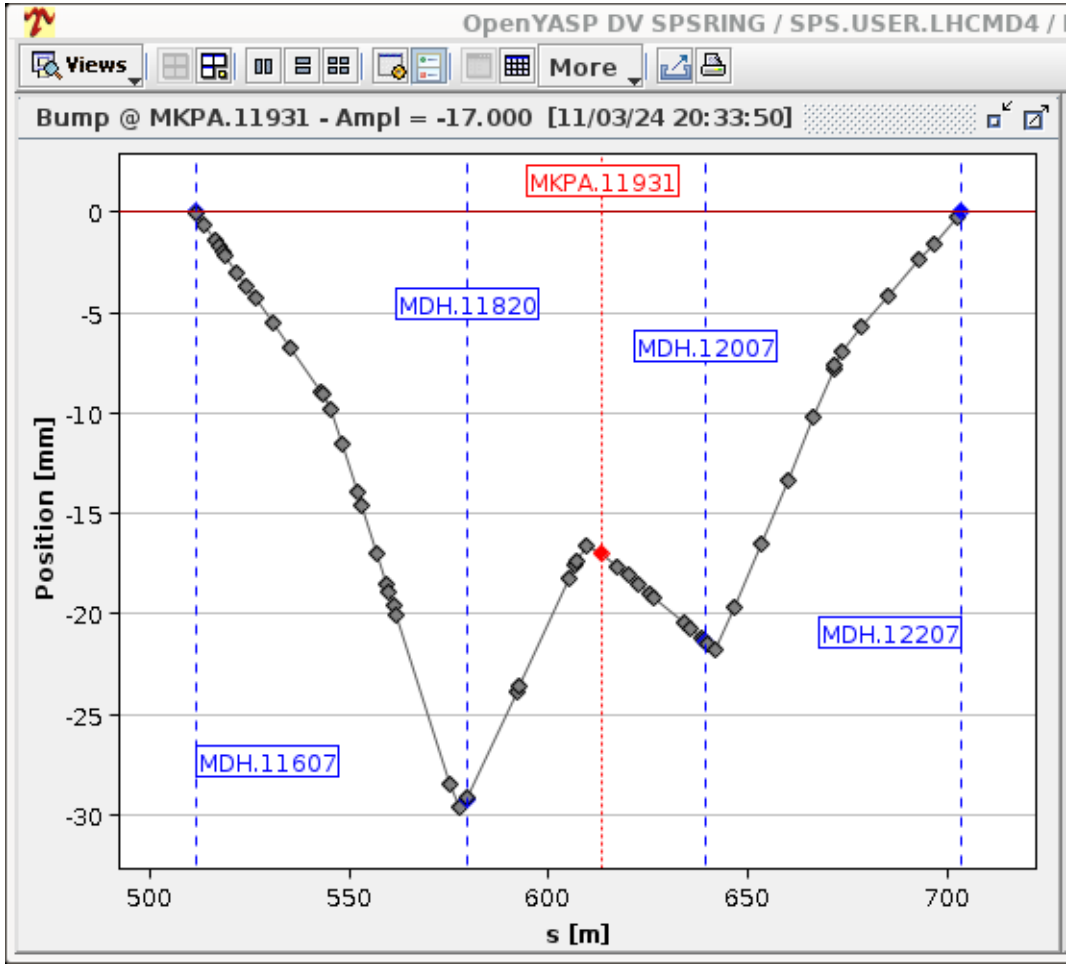




Appendix

MKP-S beam induced heating mitigation





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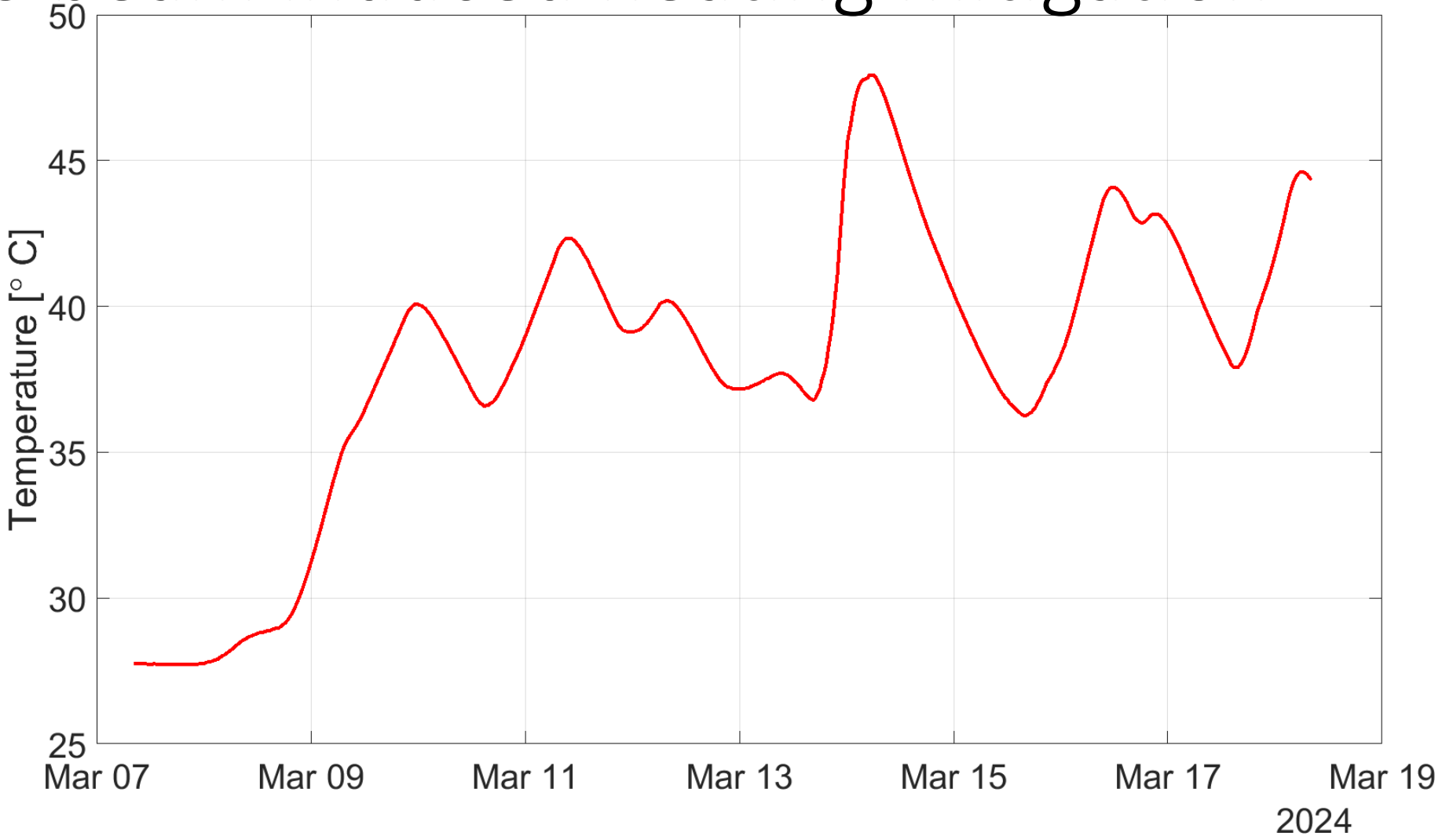

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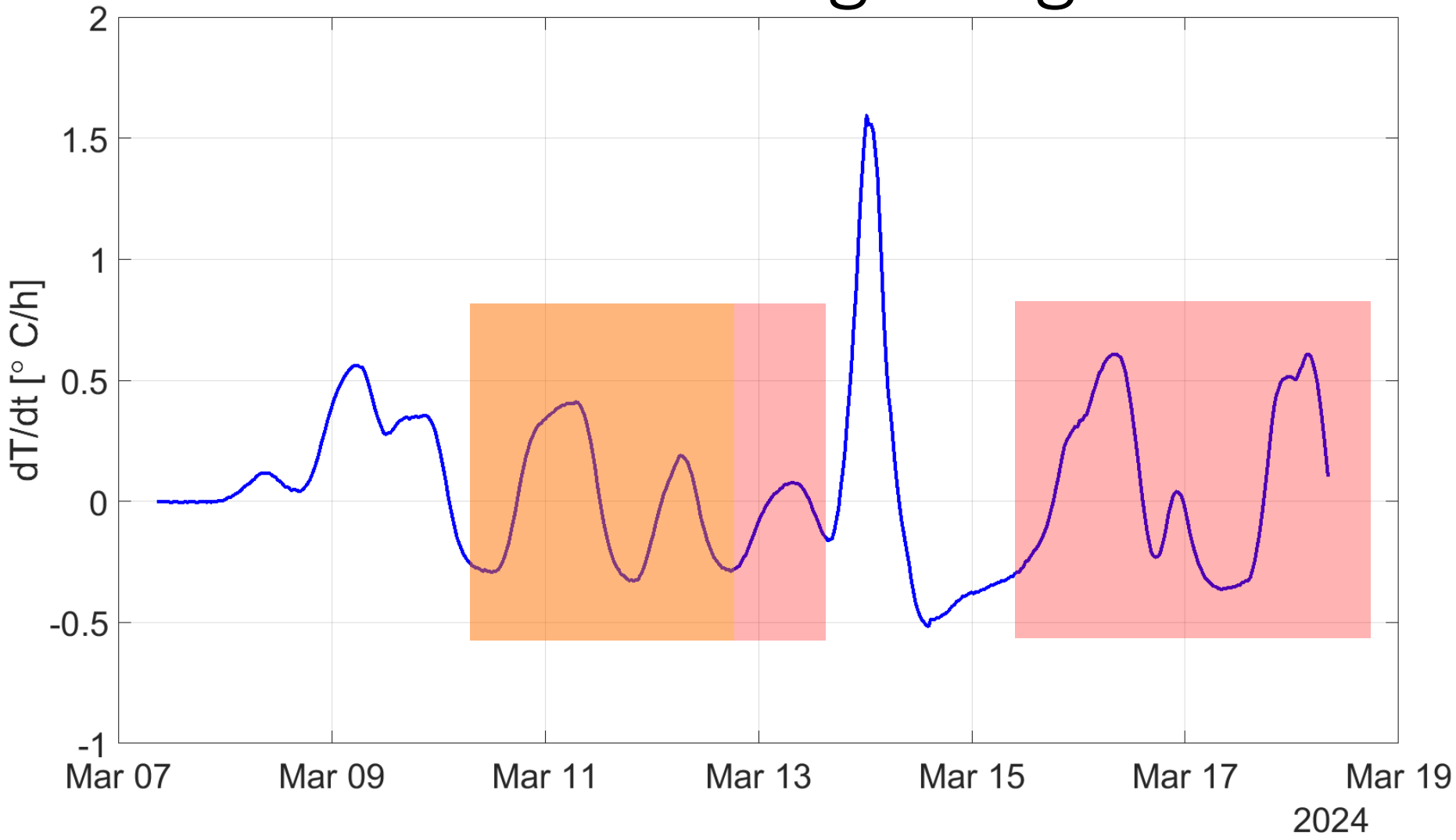

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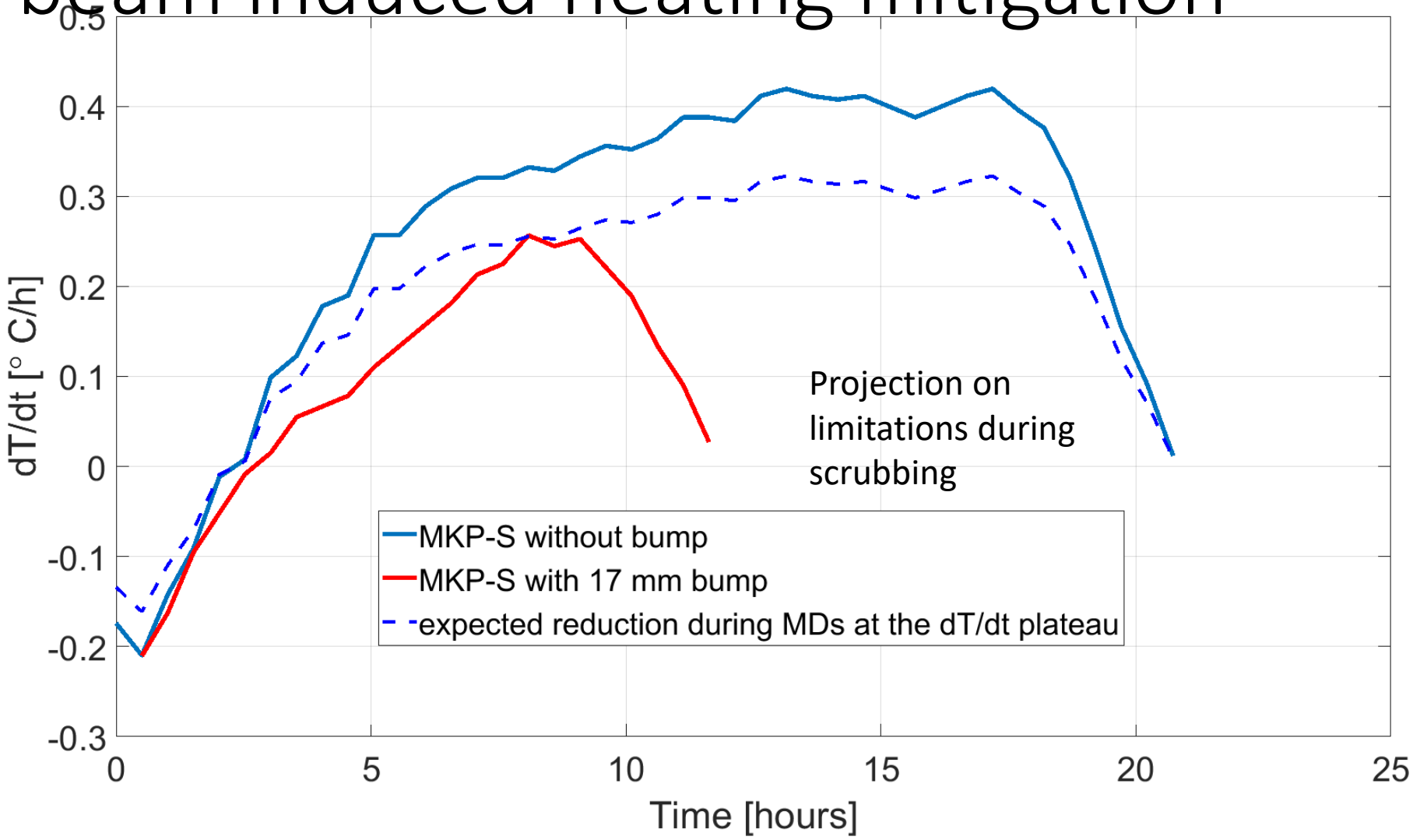

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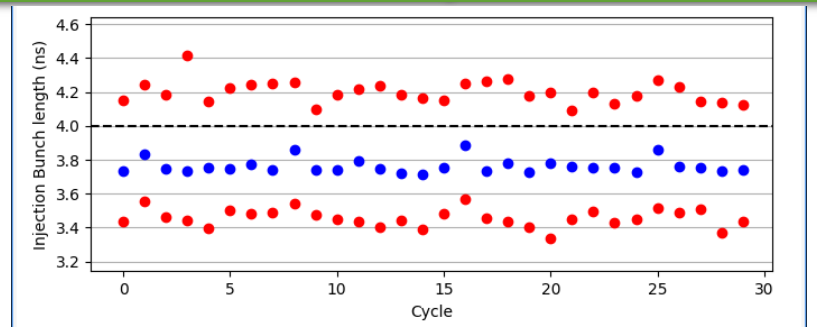

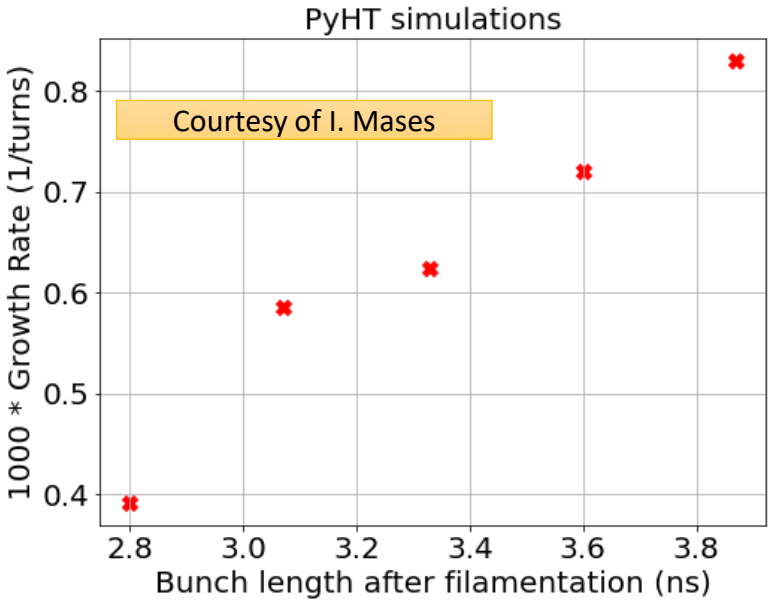

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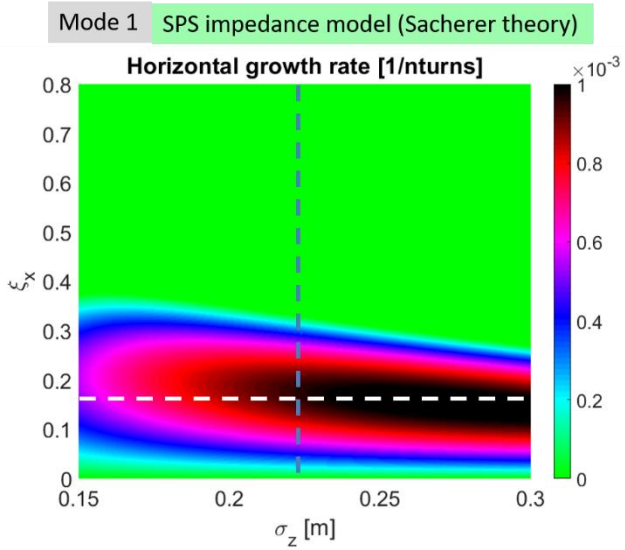

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