

# Bunch rotation studies in the PS and SPS

MD Days 04/02/2025

Jake Flowerdew, Alexandre Lasheen, Ivan Karpov,  
Heiko Damerau

Acknowledgements:

PSB, CPS and SPS operators, MD coordinators

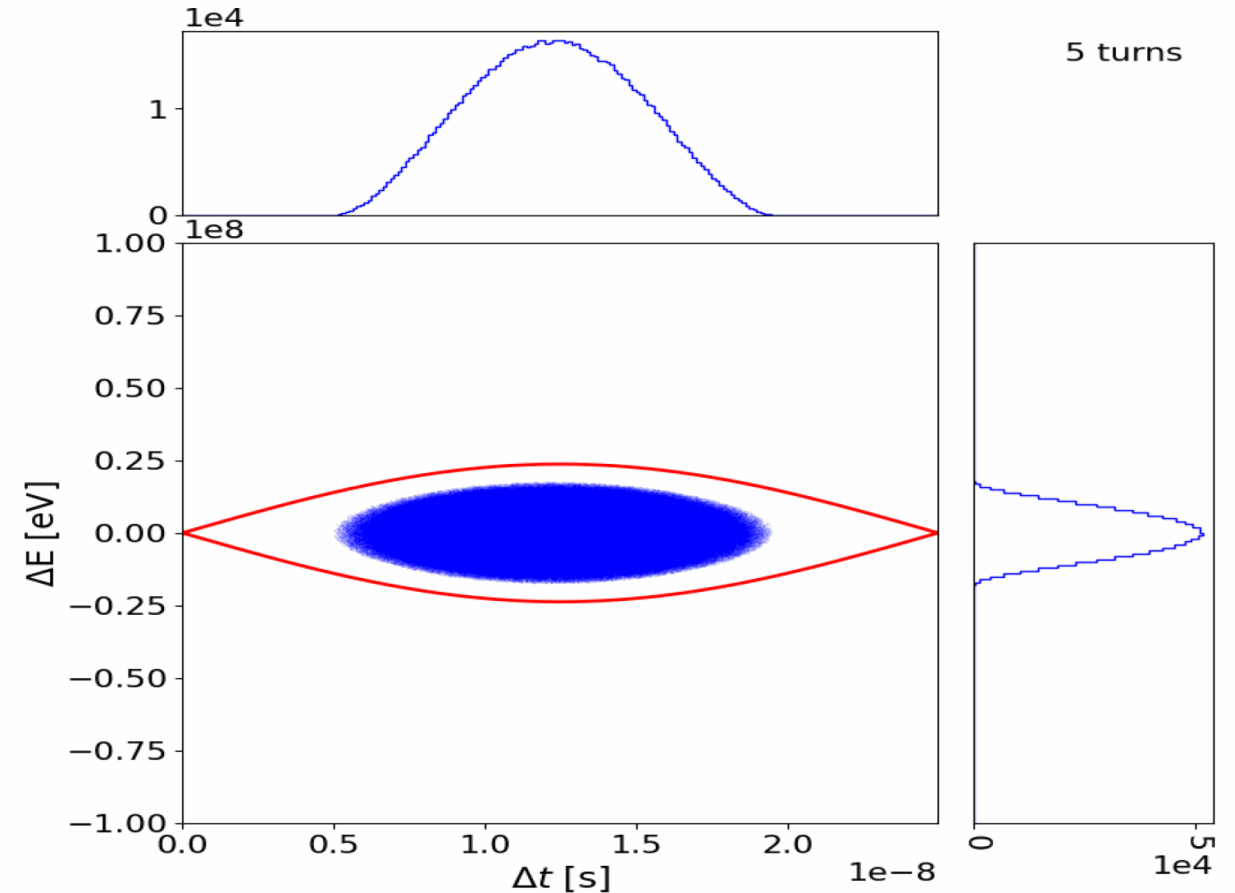
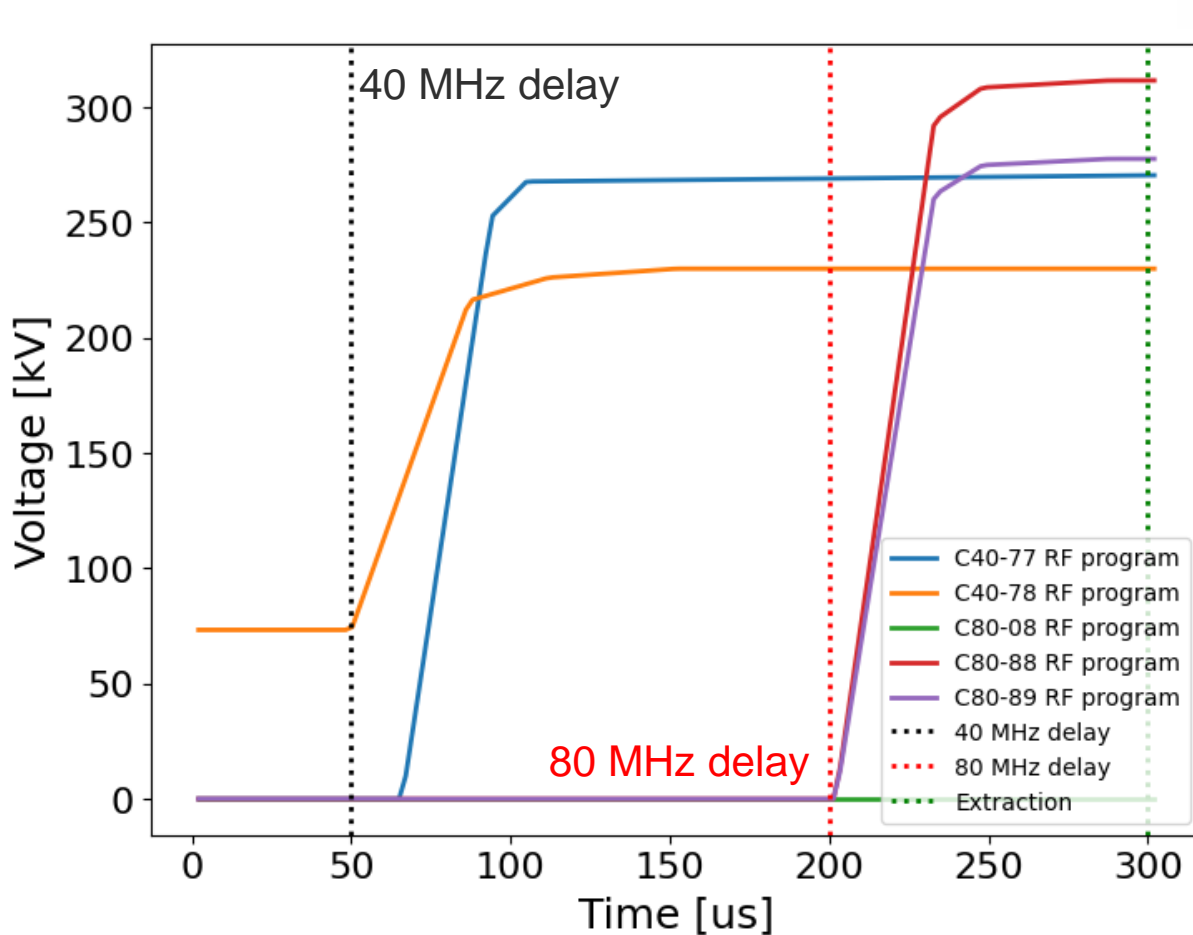
# Outline

- **Bunch rotation in the PS: PS-to-SPS transfer studies**
  - RF parameter scans for LHC-type beam at LIU intensities.
  - Tomography as a prediction tool.
  
- **Bunch rotation in the SPS for short AWAKE bunches**
  - First implementation of 'Quadrupole pumping' bunch rotation scheme at CERN.

# Bunch rotation in PS: PS-to-SPS transfer studies

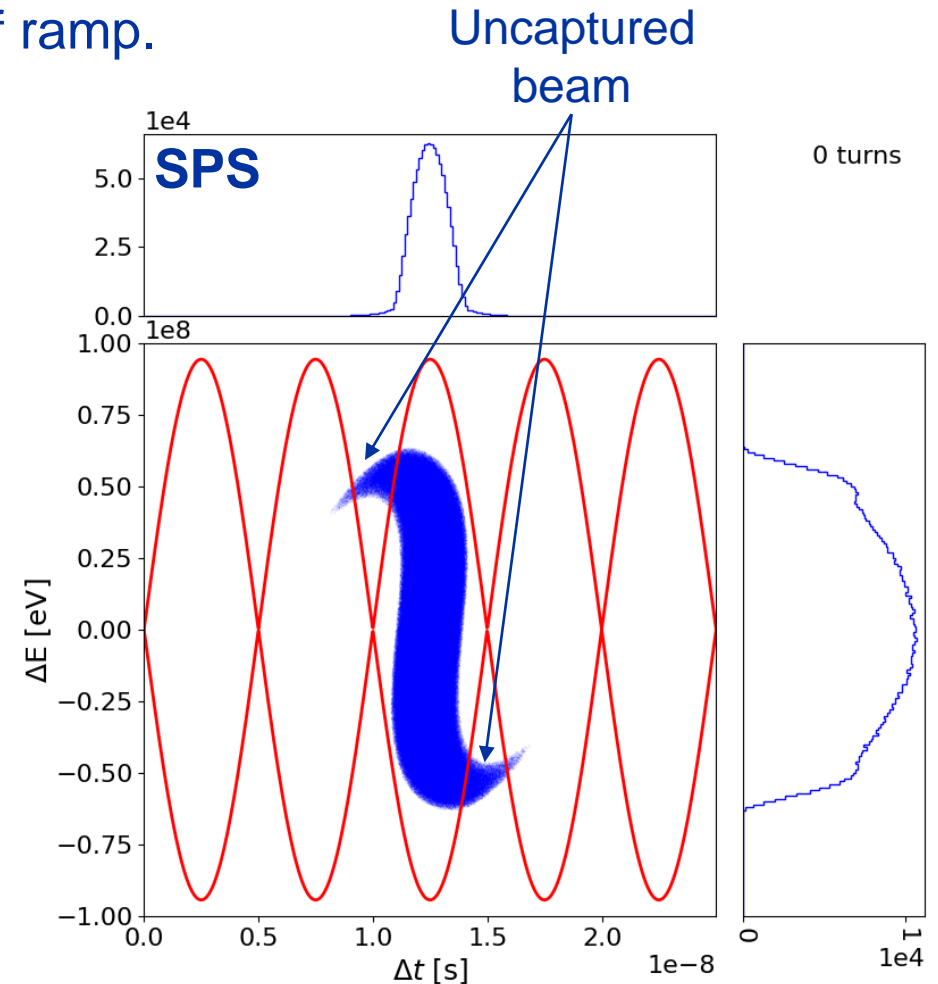
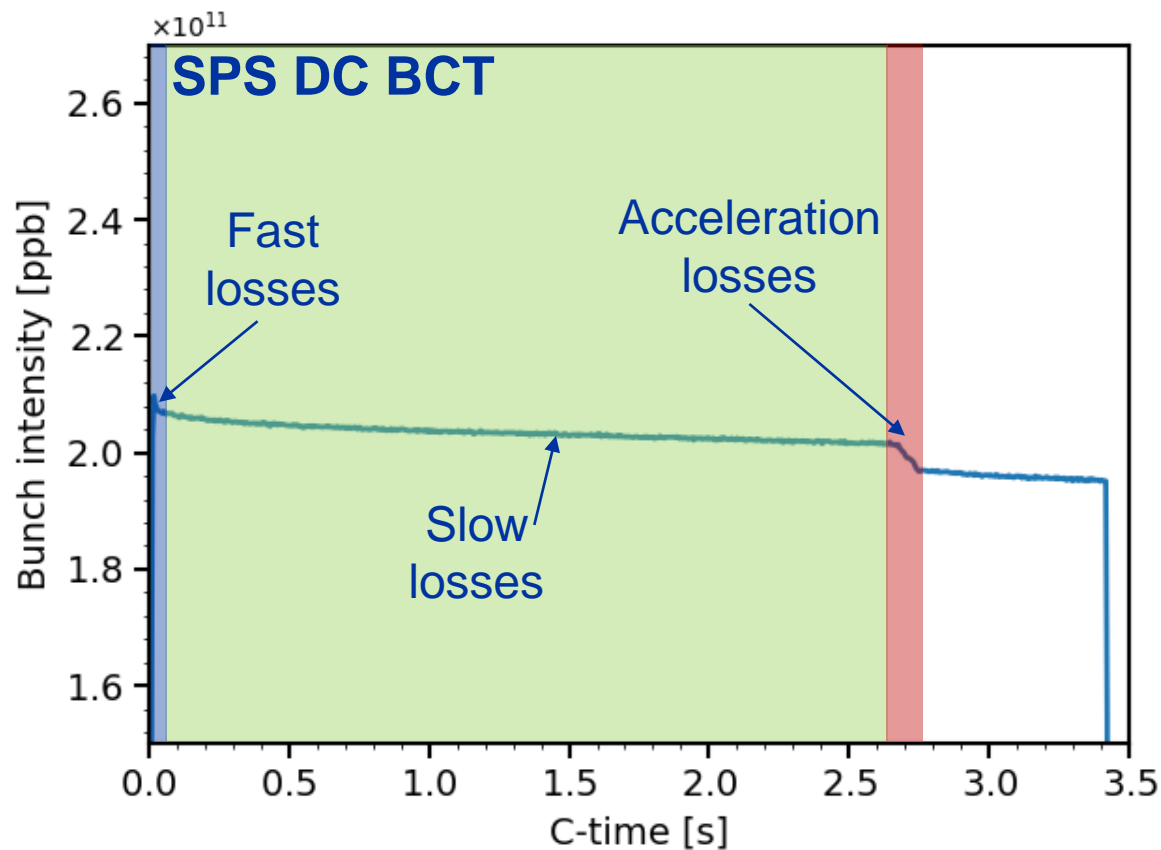
# Bunch rotation in the PS

- **PS-to-SPS transfer** involves handing over from **40 MHz RF (PS)** to **200 MHz RF (SPS)**.
  - Need to fit a **14 ns bunch** in a **5 ns bucket**.



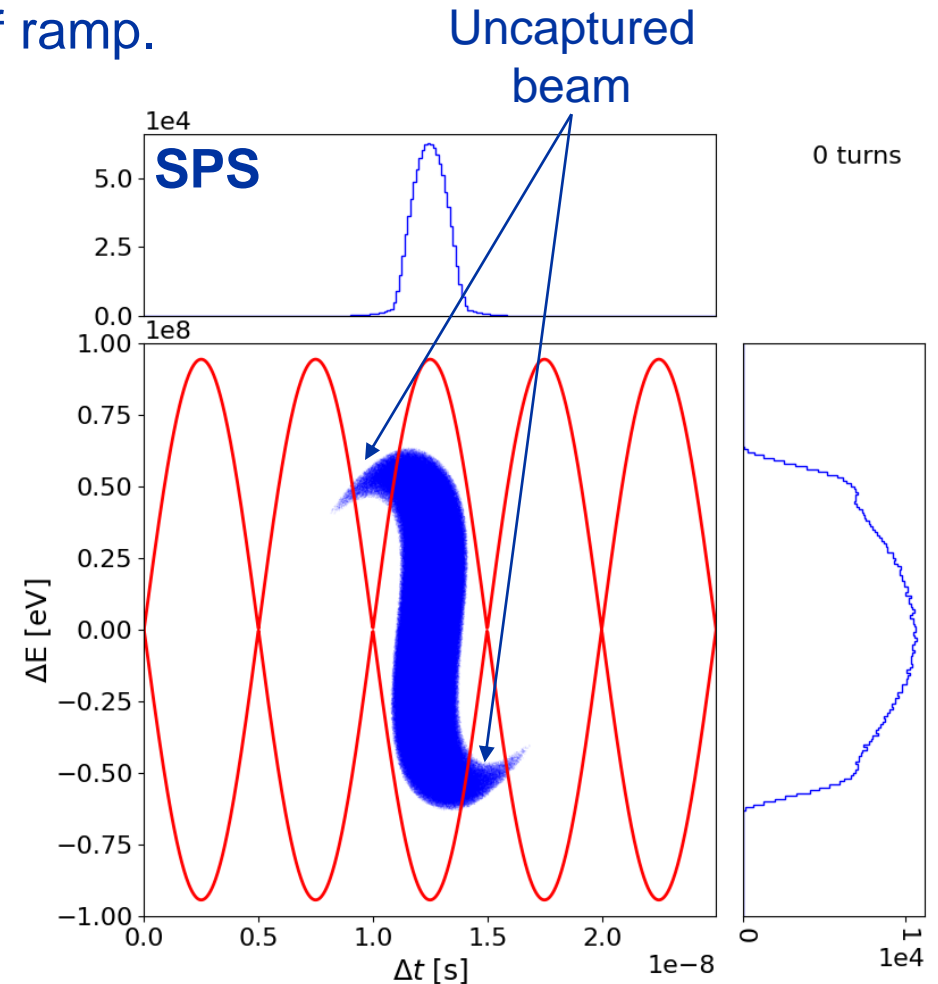
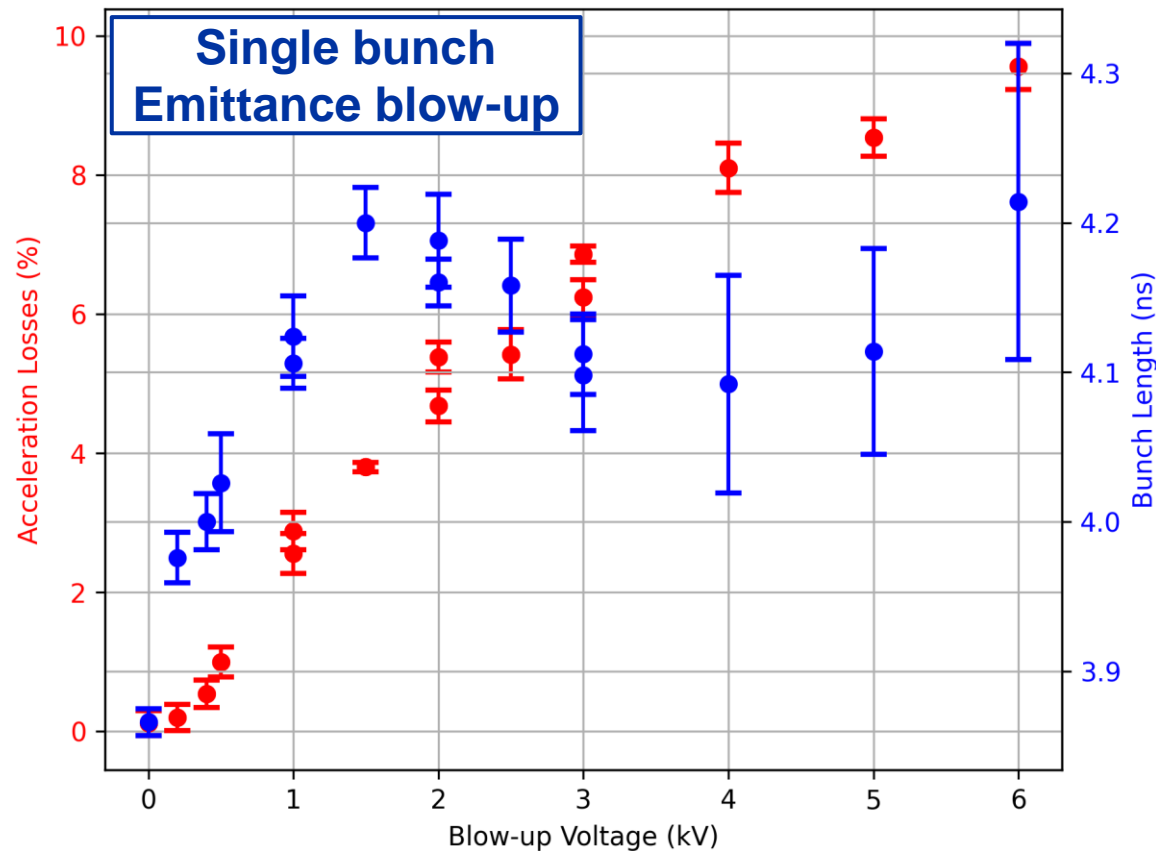
# Definition of losses in the SPS

- Fast losses: Losses observed at injection (first 50 ms)
- Slow losses: Flat bottom losses
- **Acceleration losses:** Uncaptured beam, lost at start of ramp.



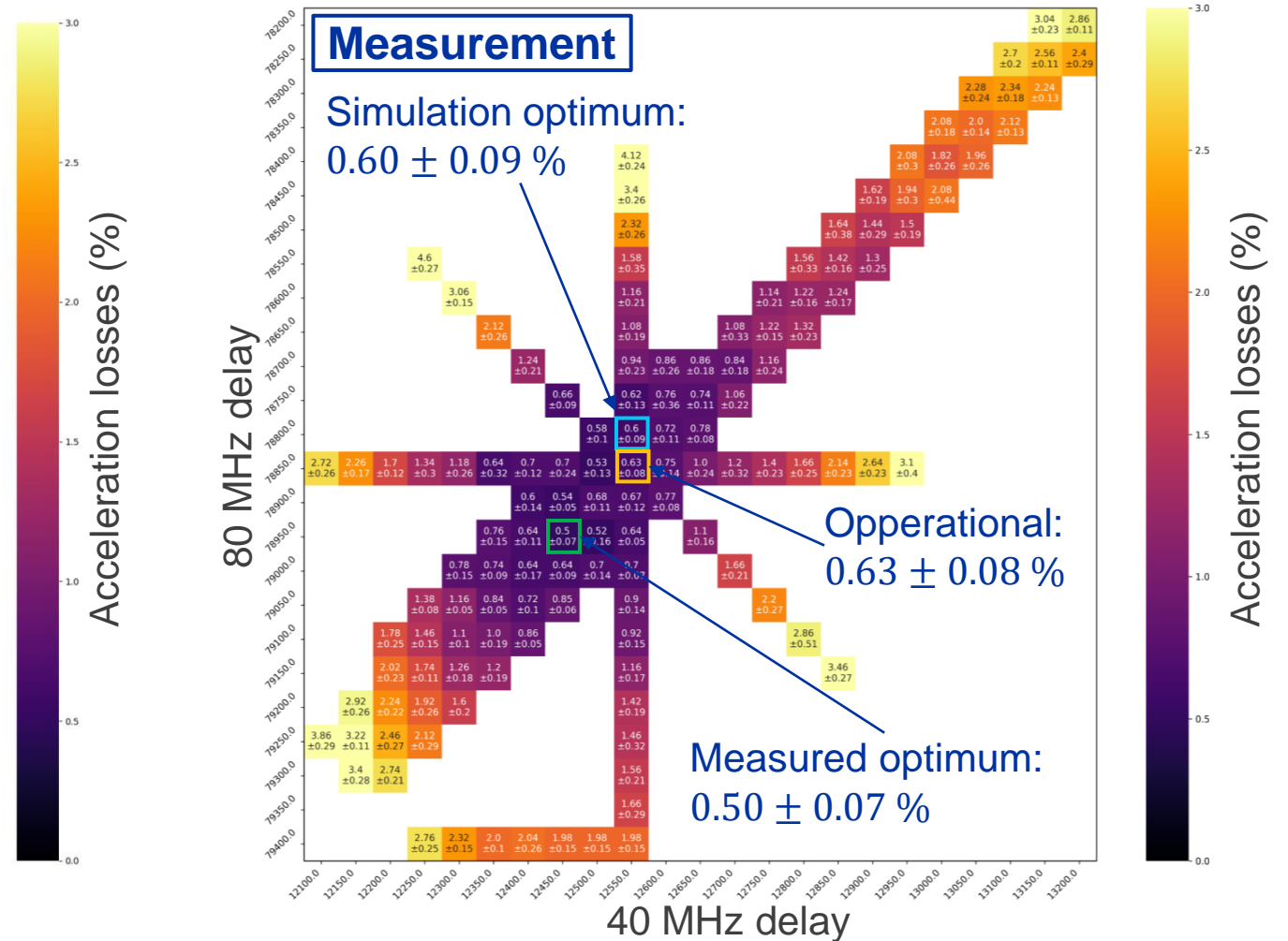
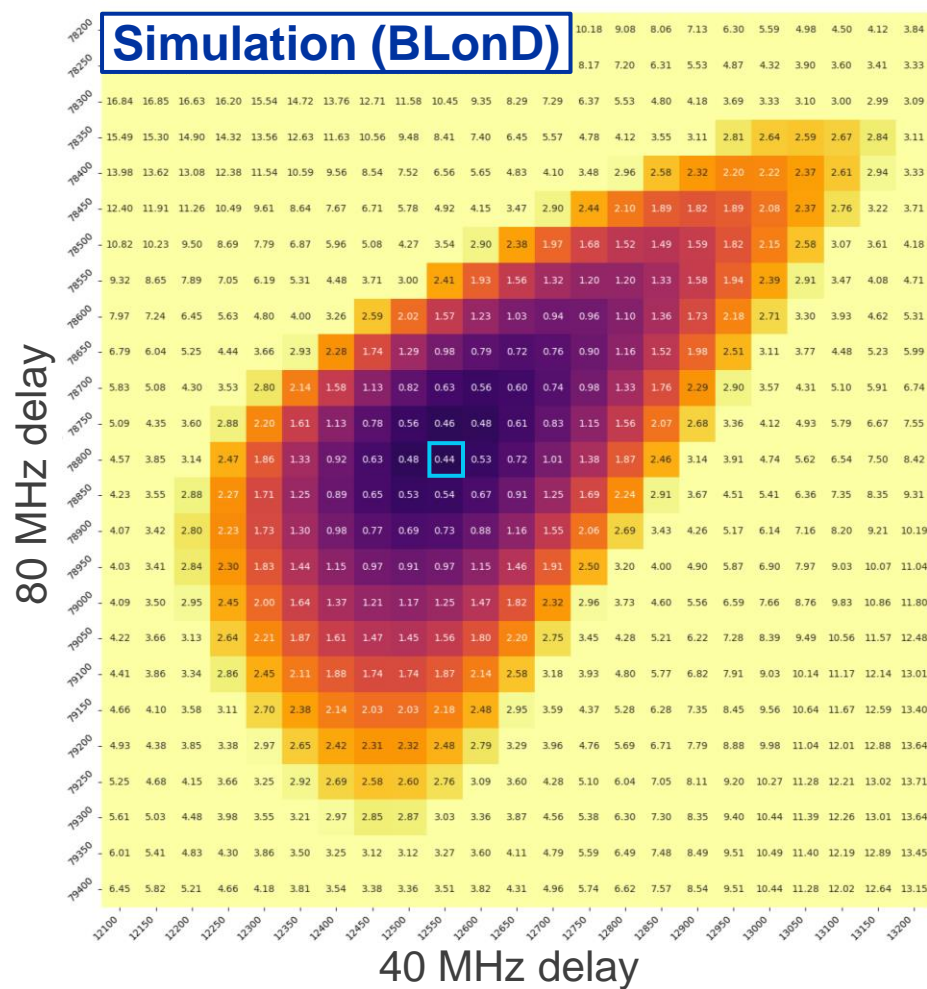
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# Bunch rotation parameter scans at LIU intensity

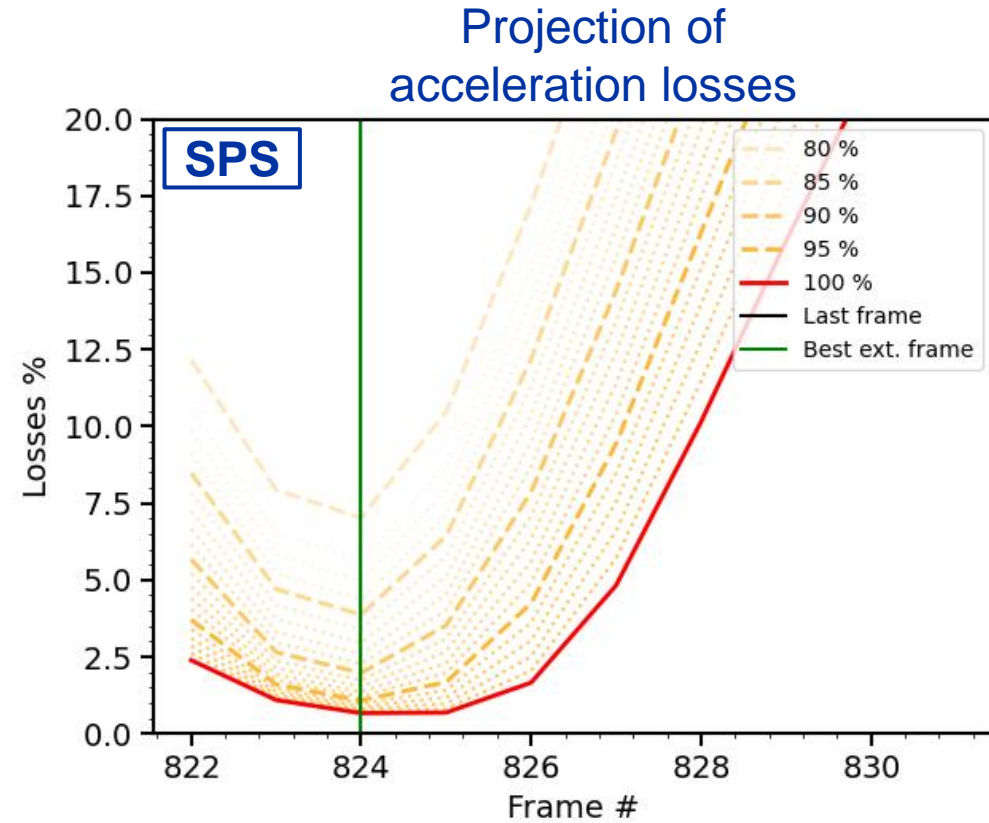
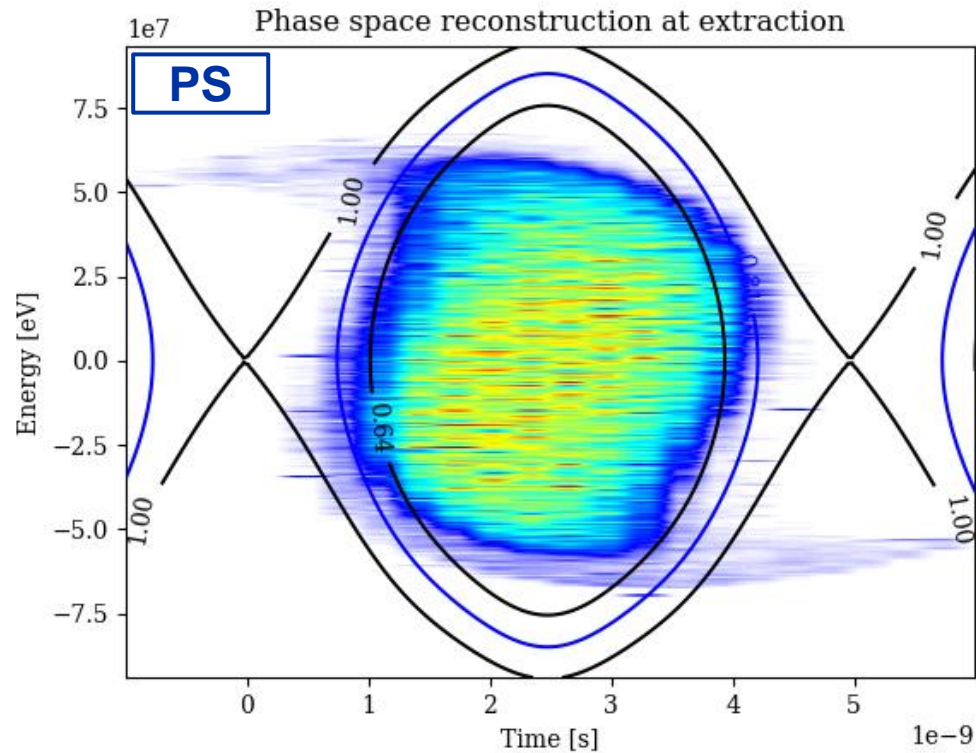
- MD with LHC-type beam at  $2.6 \times 10^{11}$  ppb, 72 bunches – scan 40 & 80 MHz delays
- **< 1 % acceleration losses** at LIU intensities.





# Tomography during bunch shortening in PS

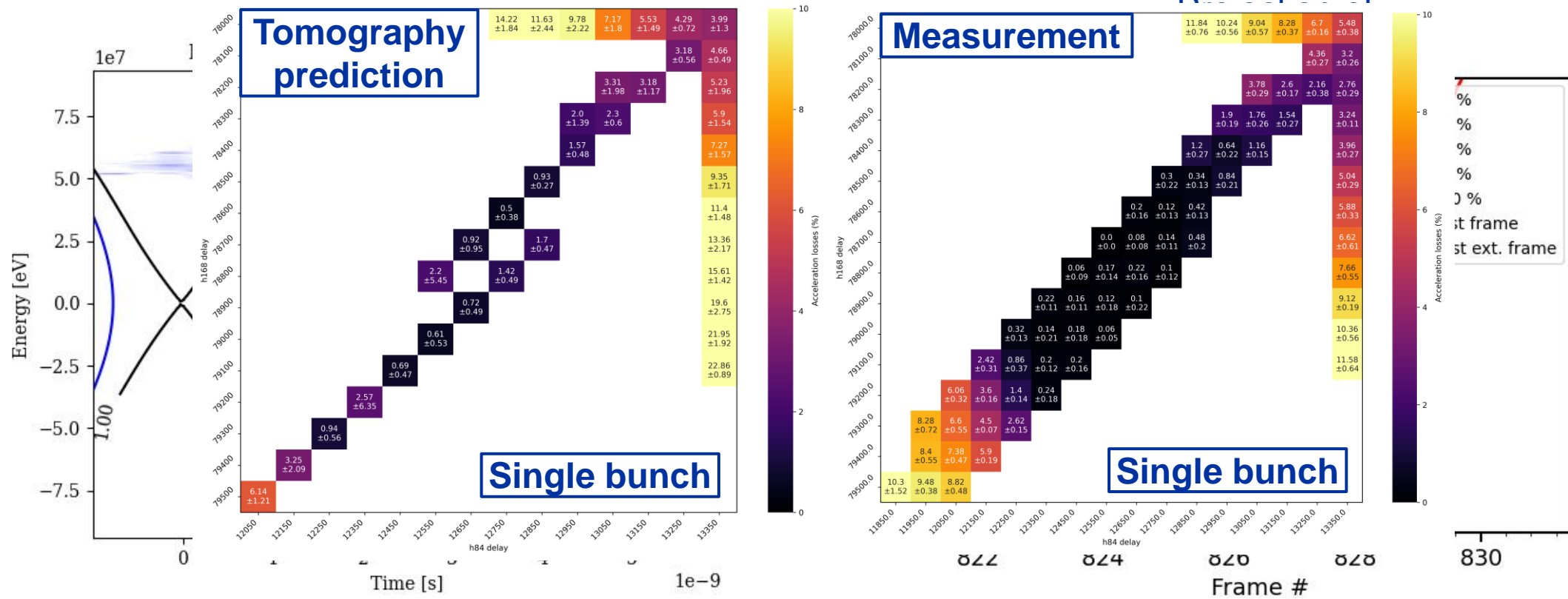
- Analysis ongoing to use **tomography** in the PS to **predict acceleration losses** in the SPS.





# Tomography during bunch shortening in PS

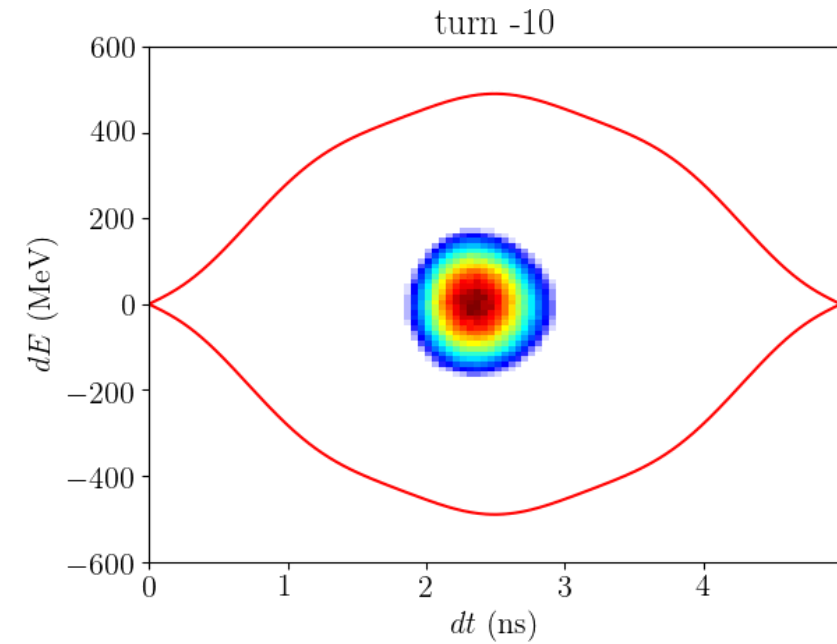
- Analysis ongoing to use **tomography** in the PS to **predict acceleration losses** in the SPS.
- Good agreement between tomography prediction and measurement for single bunch.
  - Extending analysis to multi-bunch (ongoing – more details at IPP).



# Bunch rotation in SPS: Short bunches for AWAKE

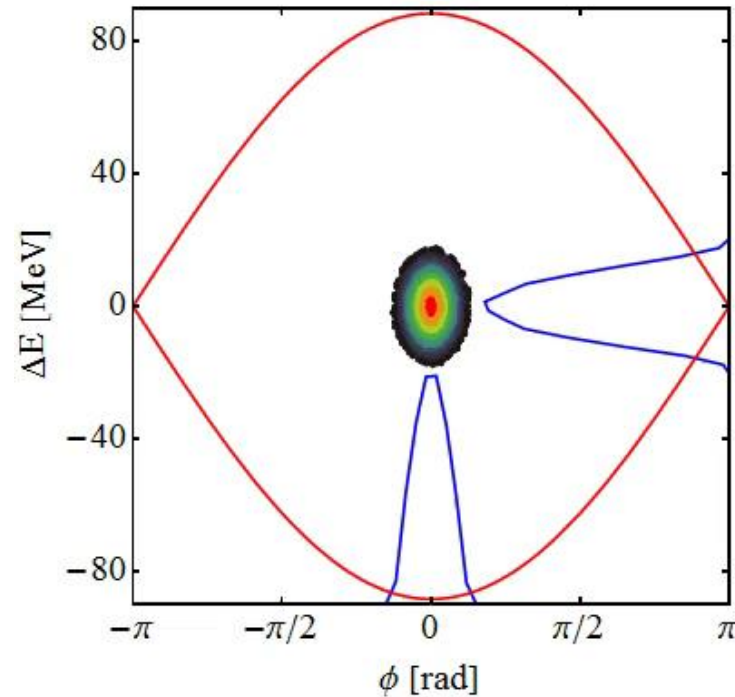
# Bunch rotation schemes

Double voltage jump  
(Operational for AWAKE)



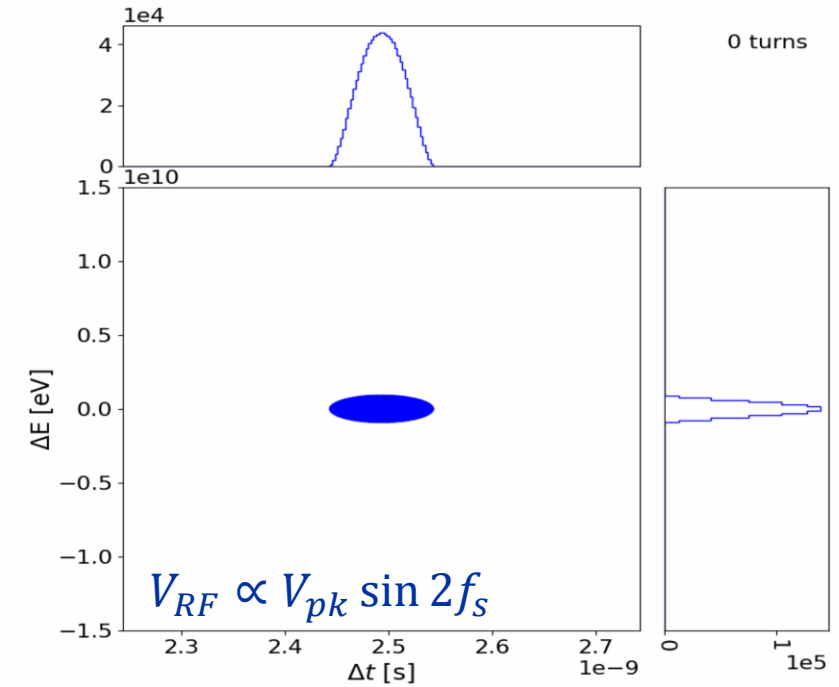
I. Karpov, [IPP 2024](#)

Phase jump  
to unstable fixed point



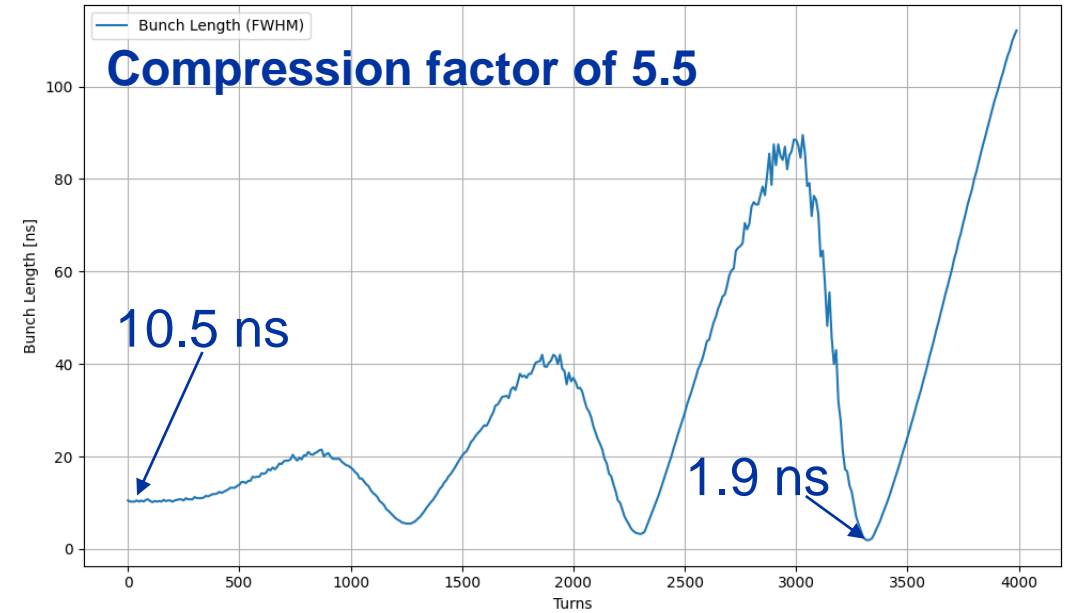
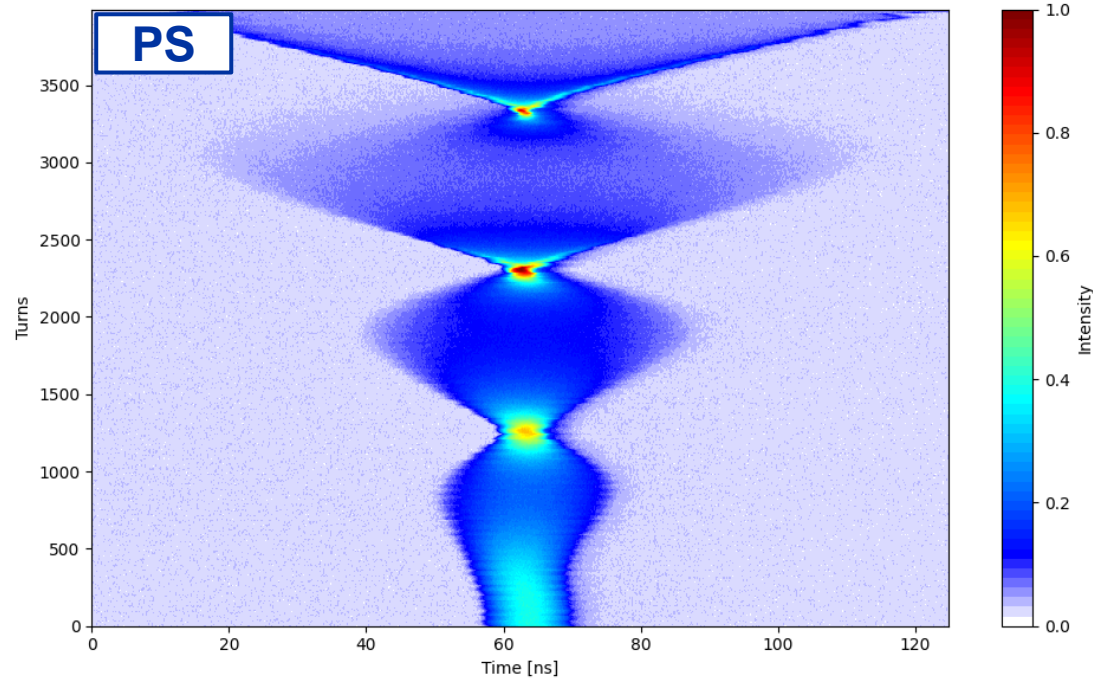
H. Damerau, [CAS 2023](#)

Quadrupole pumping\*  
\*F. Willeke



J. Flowerdew, [PEEP 2024](#)

# Quadrupole pumping in the PS



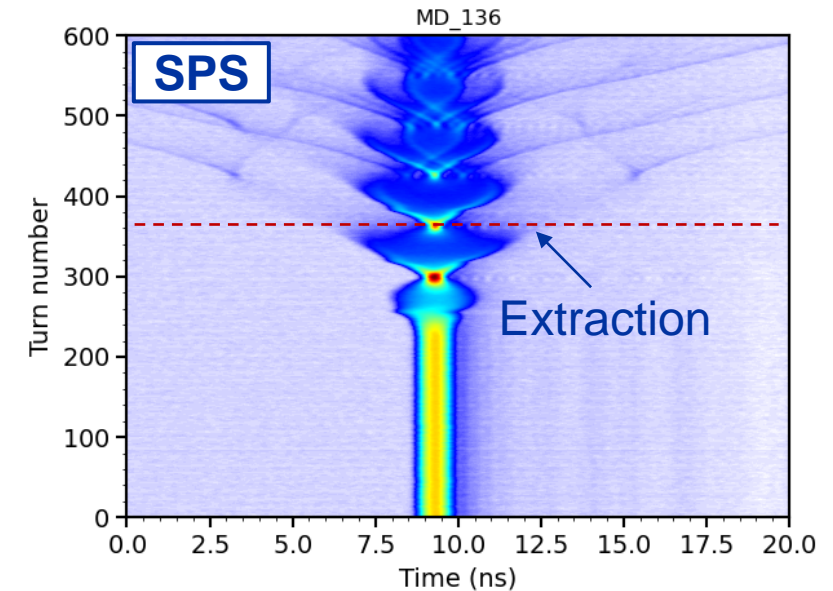
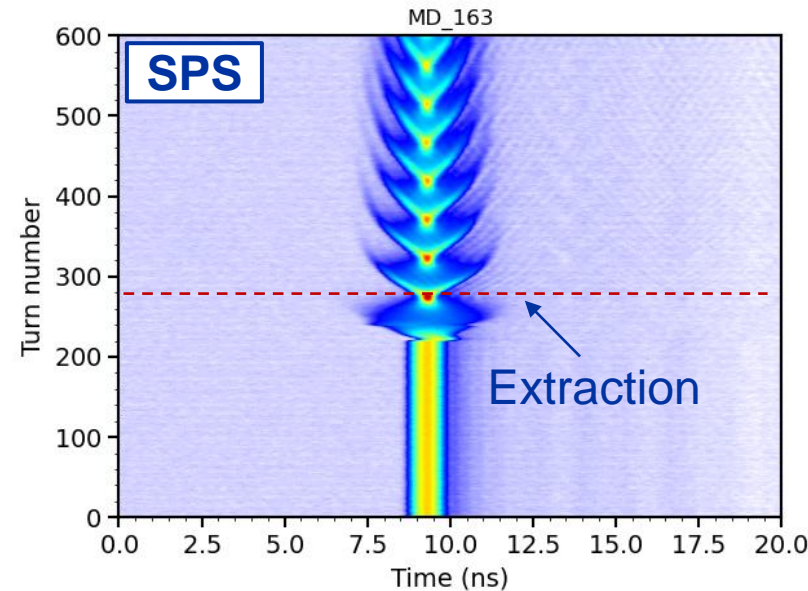
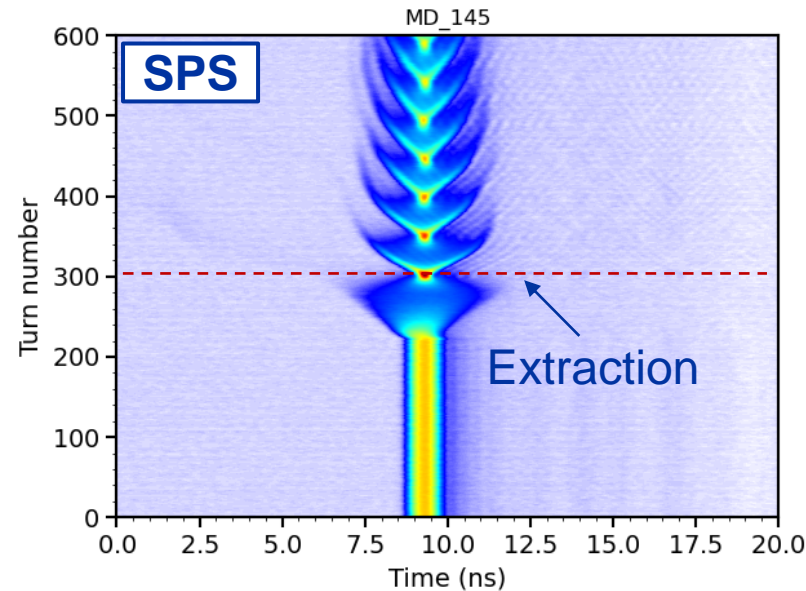
- Proof-of-principle demonstration of quadrupole pumping in the PS (Sep. 2024).
- Single bunch, moderate intensity (no RF linearization).
- First time at CERN!

# Comparison of bunch rotation schemes in the SPS

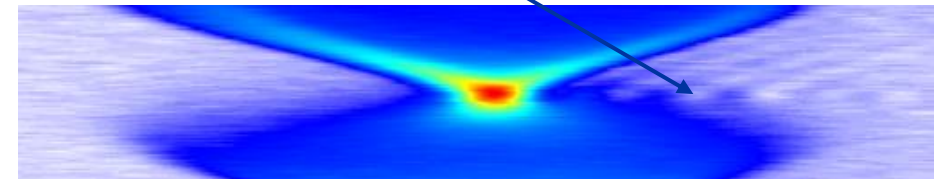
Double voltage jump

Phase jump  
to unstable fixed point

Quadrupole pumping

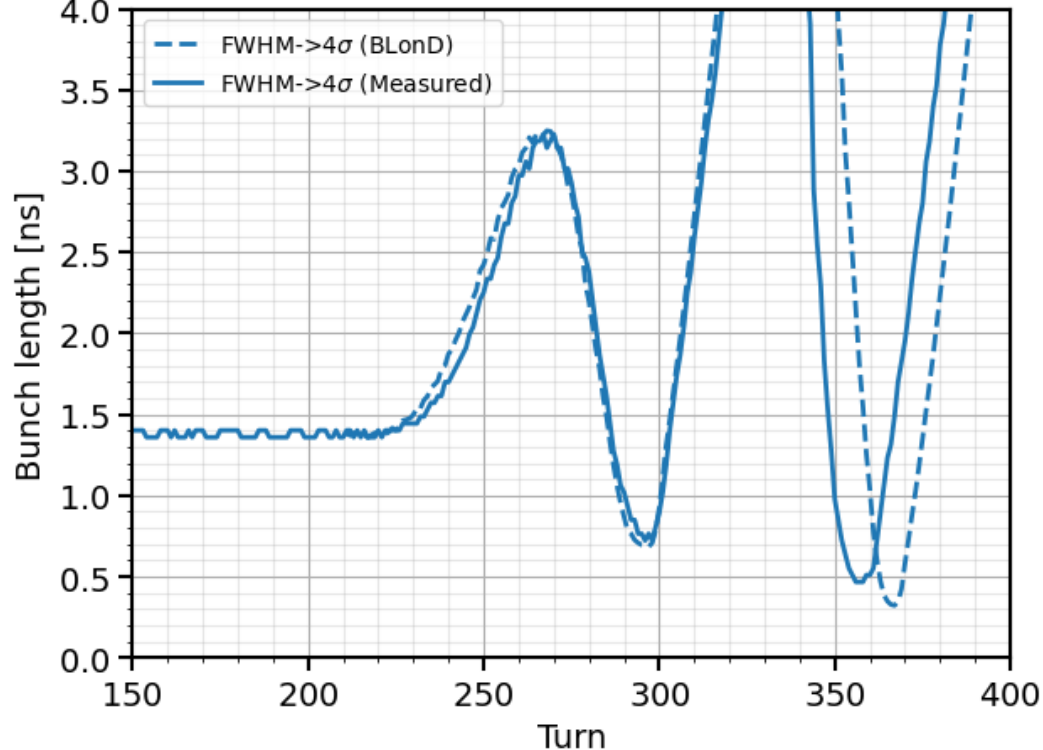


- Tested AWAKE bunch,  $1 \times 10^{11}$  ppb @ 200 GeV.
- Some problems measuring shorter bunches (<0.5 ns) due to limitations of acquisition system.

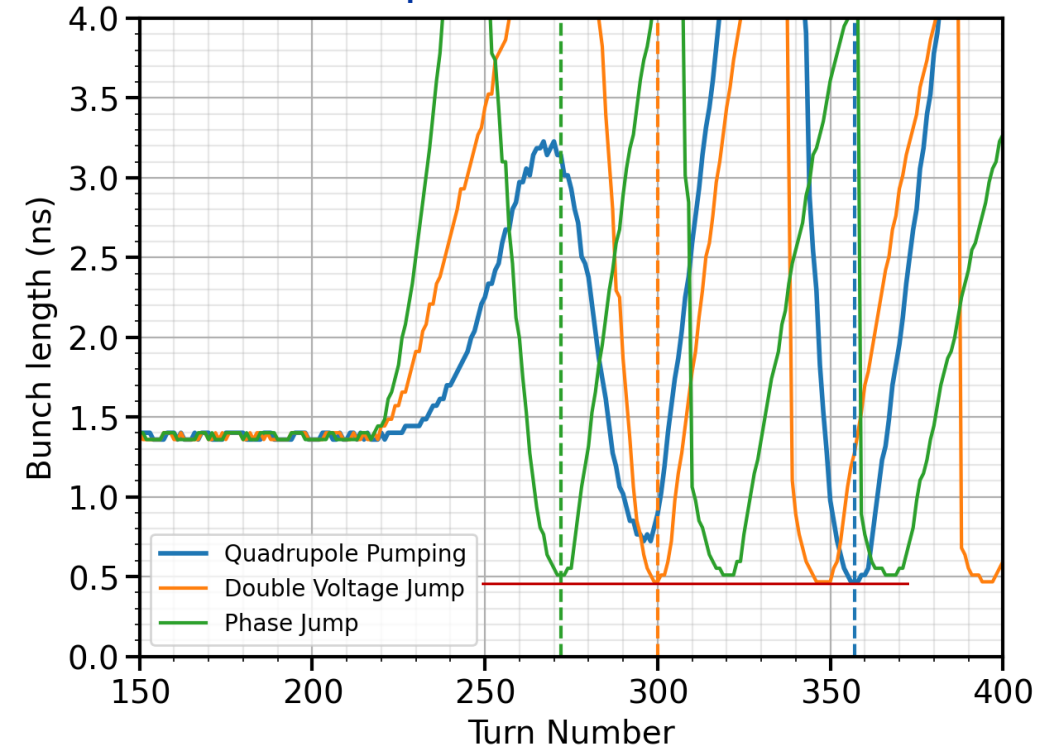


# Quadrupole pumping for AWAKE?

Measurement vs simulation



Comparison of schemes



- Analysis still ongoing...
- No significant improvement over the double voltage jump or phase jump.
- However, quadrupole pumping needs shorter initial bunches to stay within linear region.
- Measurements with streak camera.



# Conclusions

## PS-to-SPS studies & Bunch Rotation (MD12244)

- Issues: No blocking issues.
- Status: Ongoing, reduced MDs in 2025 (multiple batches).
- Problem is understood, resources should be focused on observation/ monitoring.

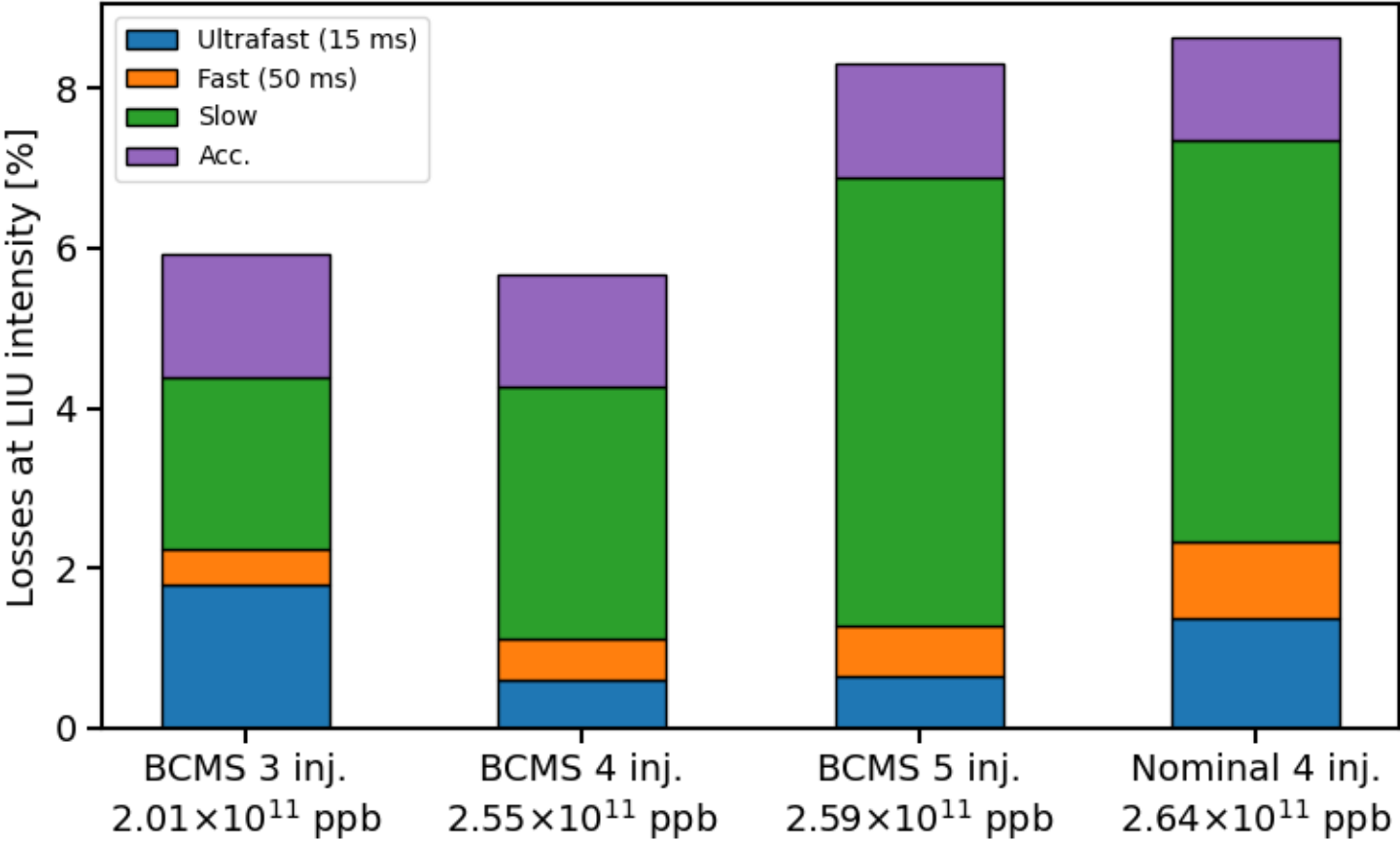
## Quadrupole Pumping for Bunch Shortening in SPS (MD14123)

- Issues: MD scope acquisition limitations for bunches  $< 0.5$  ns.
- Status: Measurements complete, analysis ongoing. Streak camera measurements would be needed to take scheme further.
- Quadrupole pumping technique demonstrated, further work needed to see benefits.

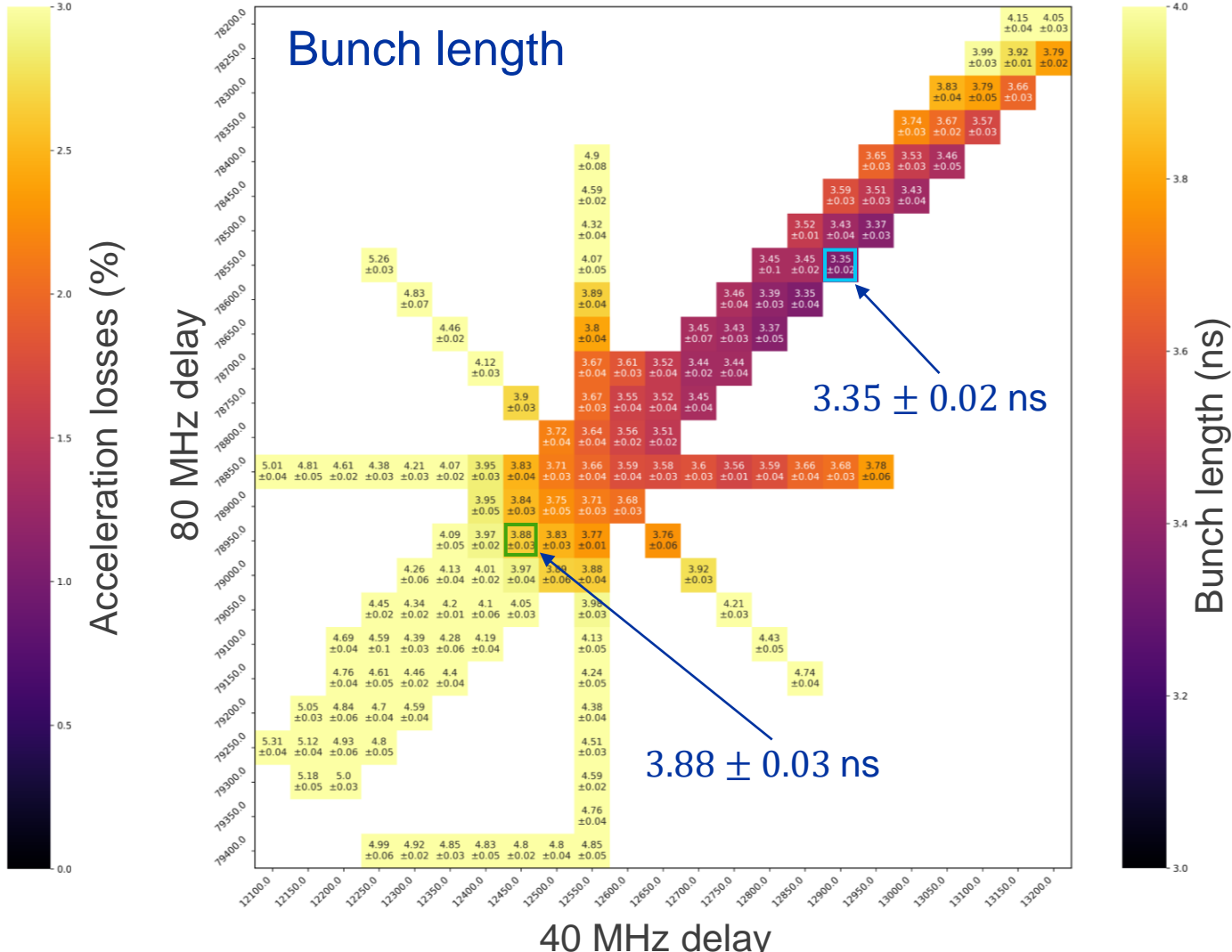
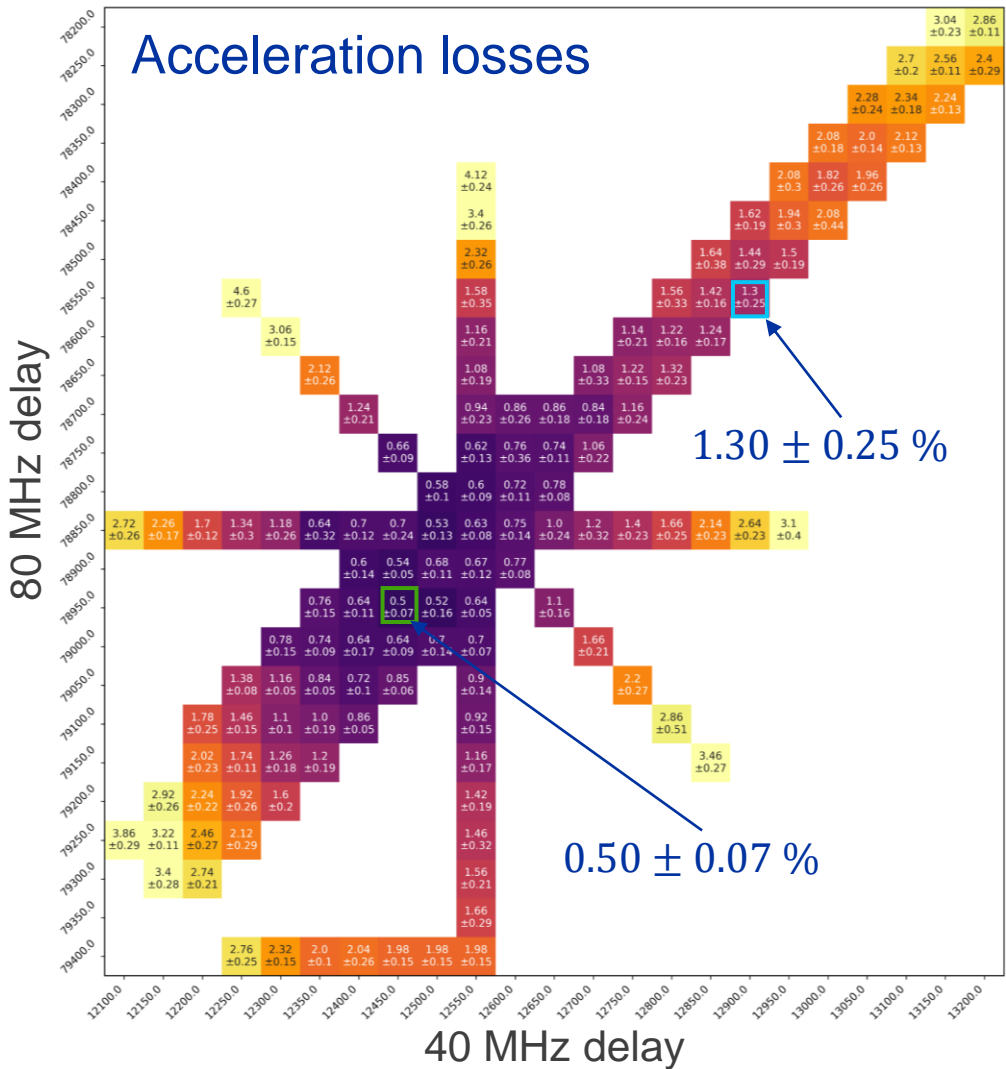


# Back up slides

# PS-to-SPS losses 2024

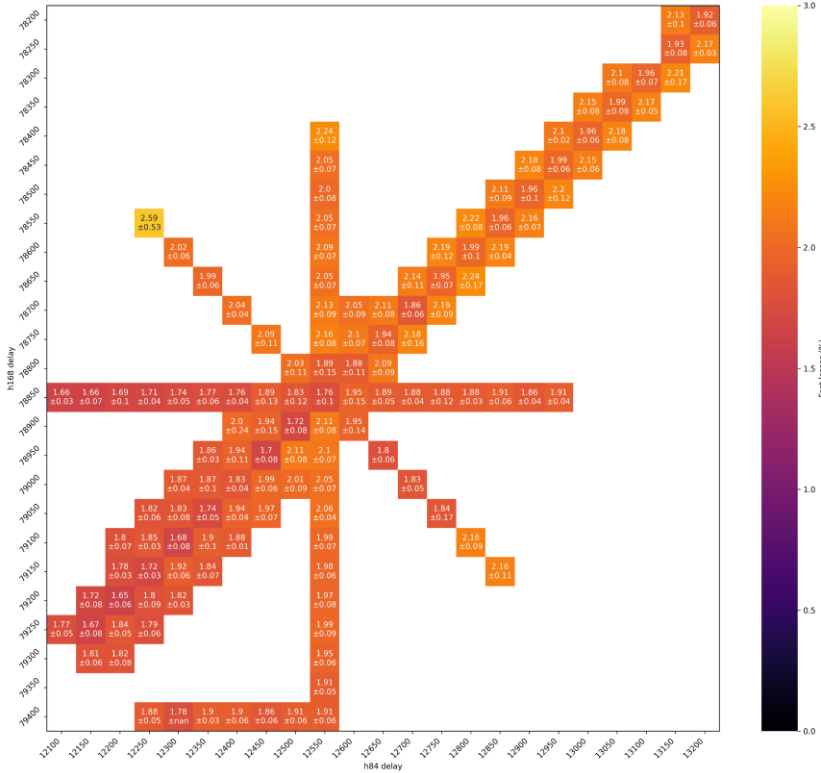


# Acceleration losses and bunch length

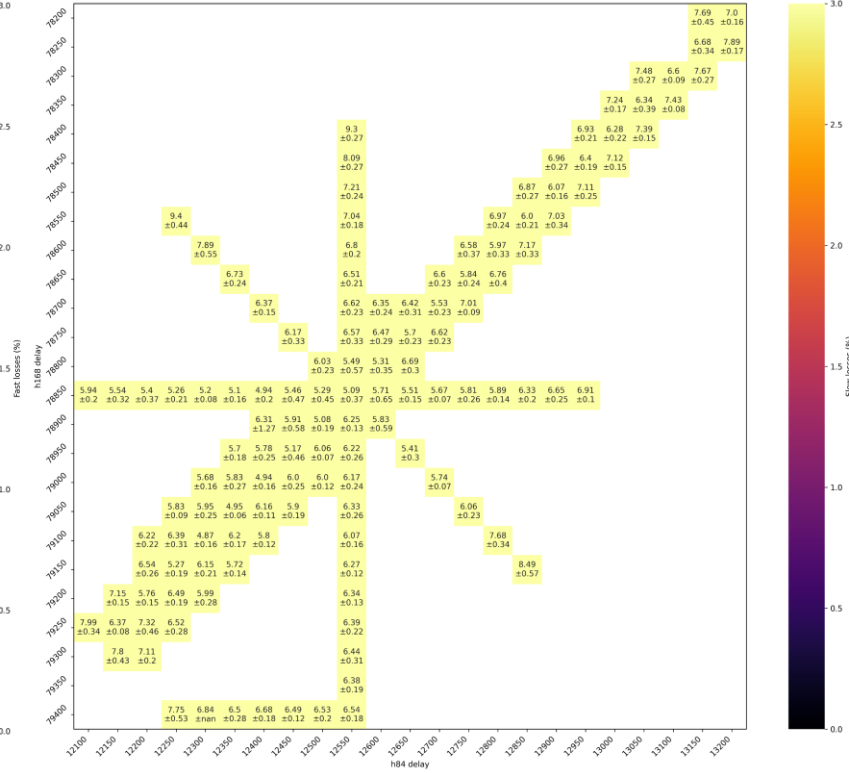


# Comparison of Fast, Slow and Acceleration losses

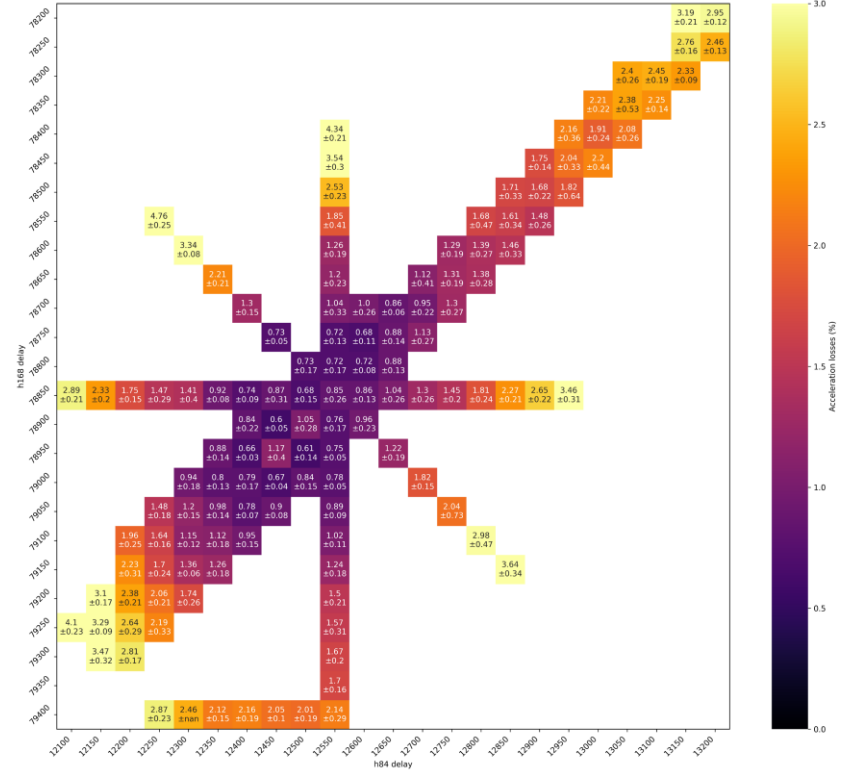
## Fast losses



## Slow losses



## Acceleration losses



# Fast and Slow losses

