

Bunch Rotation for AWAKE

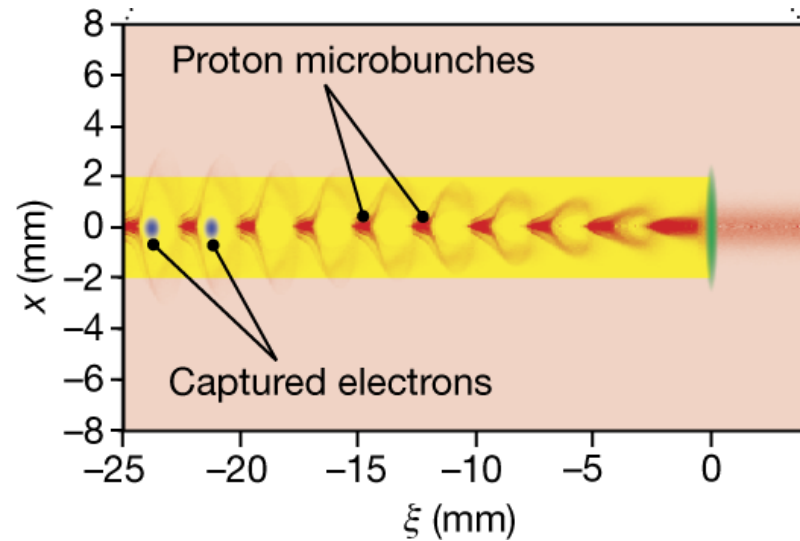
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Acknowledgements:

PSB, CPS and SPS operators, MD coordinators

Introduction

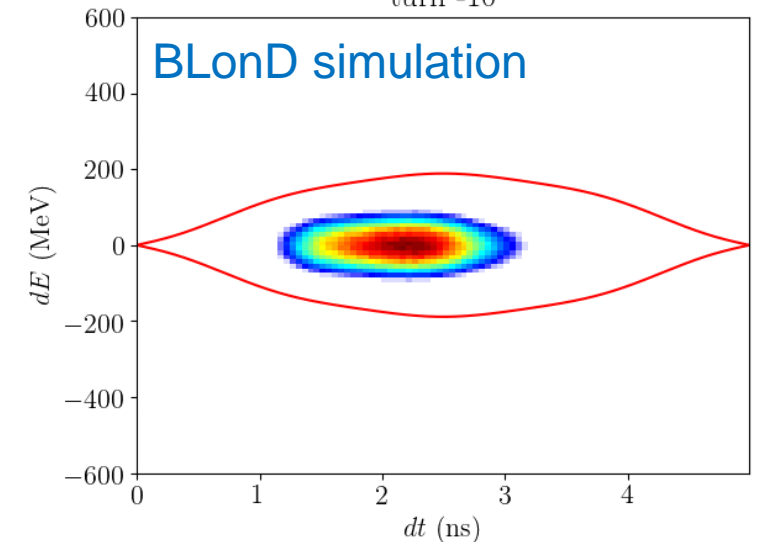
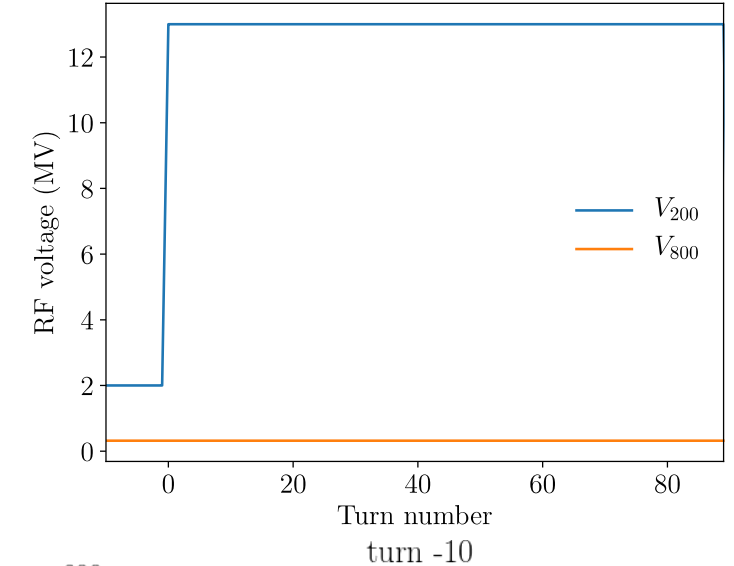
Advanced WAKEfield Experiment (AWAKE) facility uses short intense proton bunches for plasma wakefield acceleration



[AWAKE Collaboration, Nature, 2018](#)

→ Stability of bunch length and shape for intensity range $0.5 - 3 \times 10^{11}$ is a key requirement for Run 2

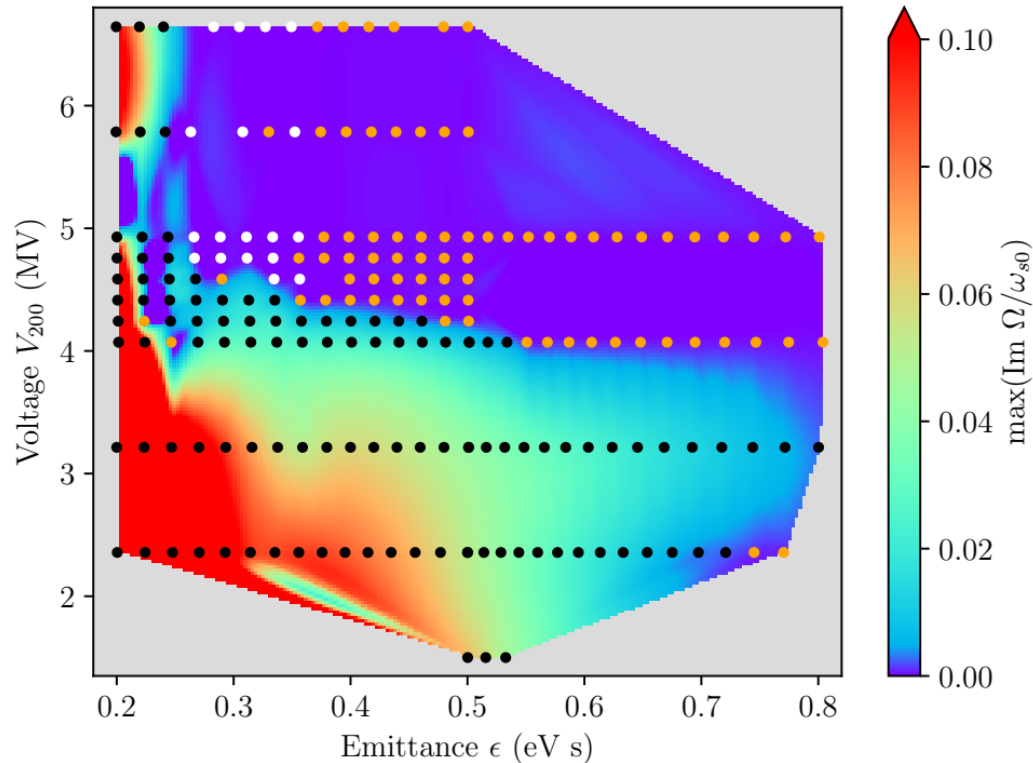
Single voltage jump bunch rotation



Mode-coupling instability for low RF voltage

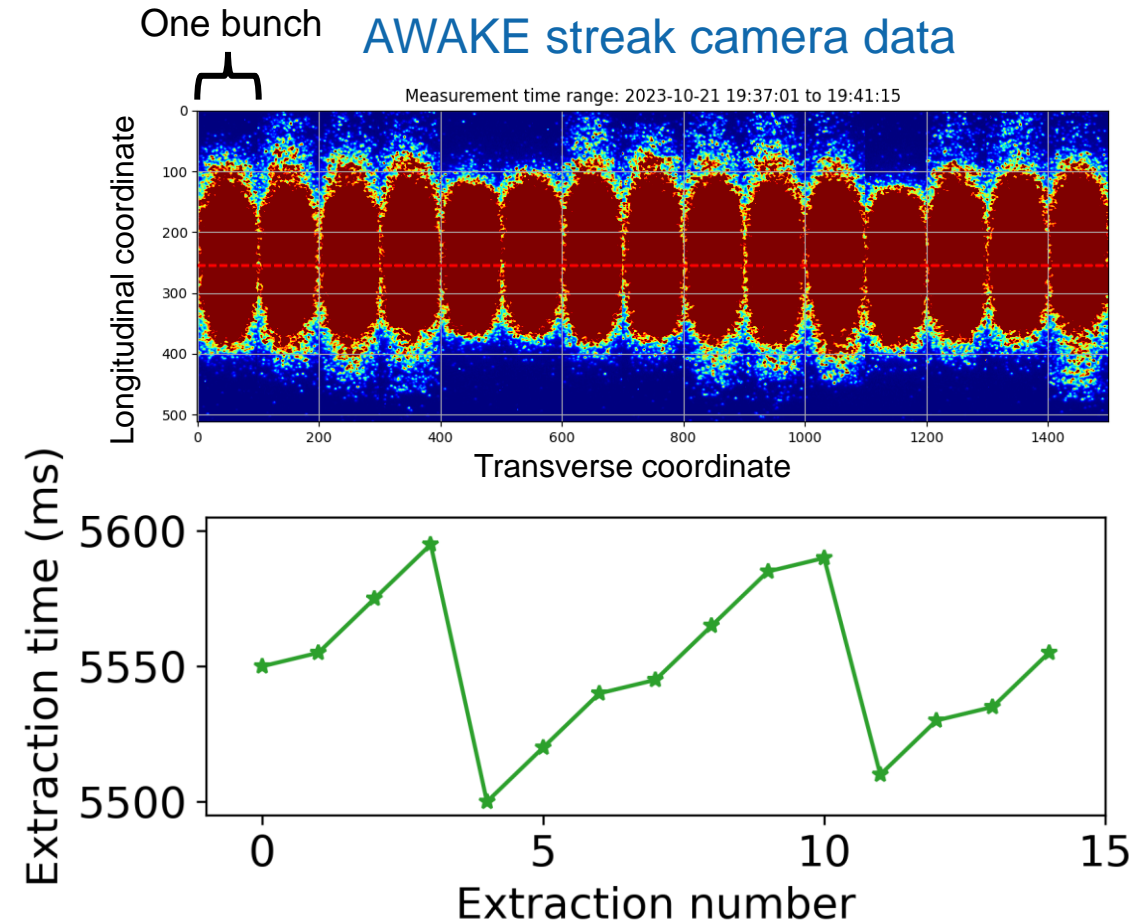
Stability map before bunch rotation for 4×10^{11}

$$V_{800}/V_{200} = 30\%$$



[M. Gadioux, SS report, 2020](#)

Low voltage configuration is prone to instability
→ Higher V_{200} cures instability at a price of longer extracted bunch length

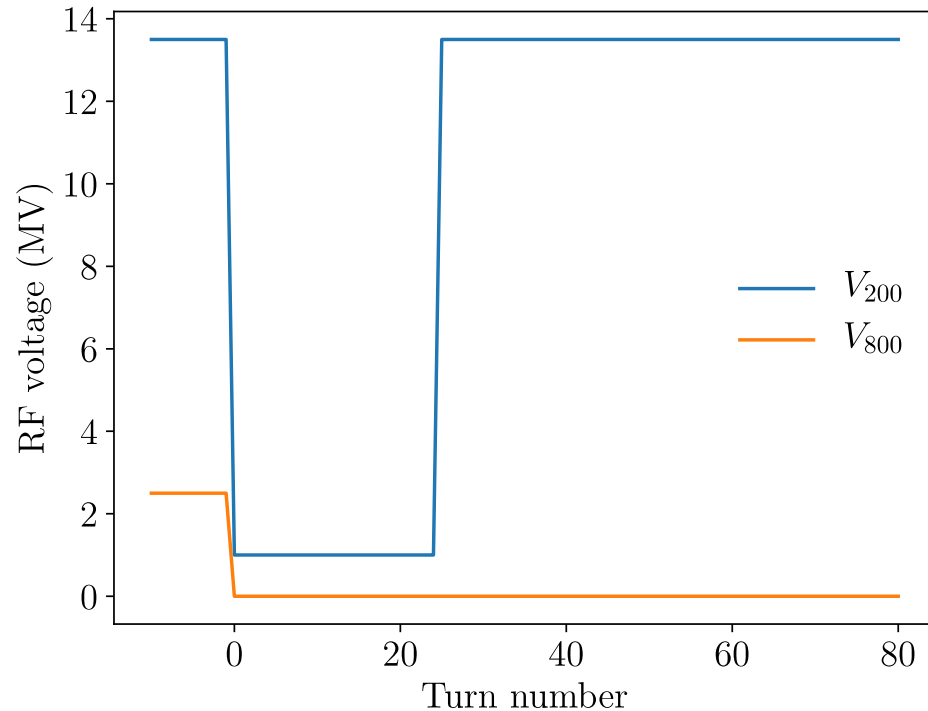


Example of shot-to-shot bunch shape change (last two days of the 2023 run)
→ Strong correlation with extraction time

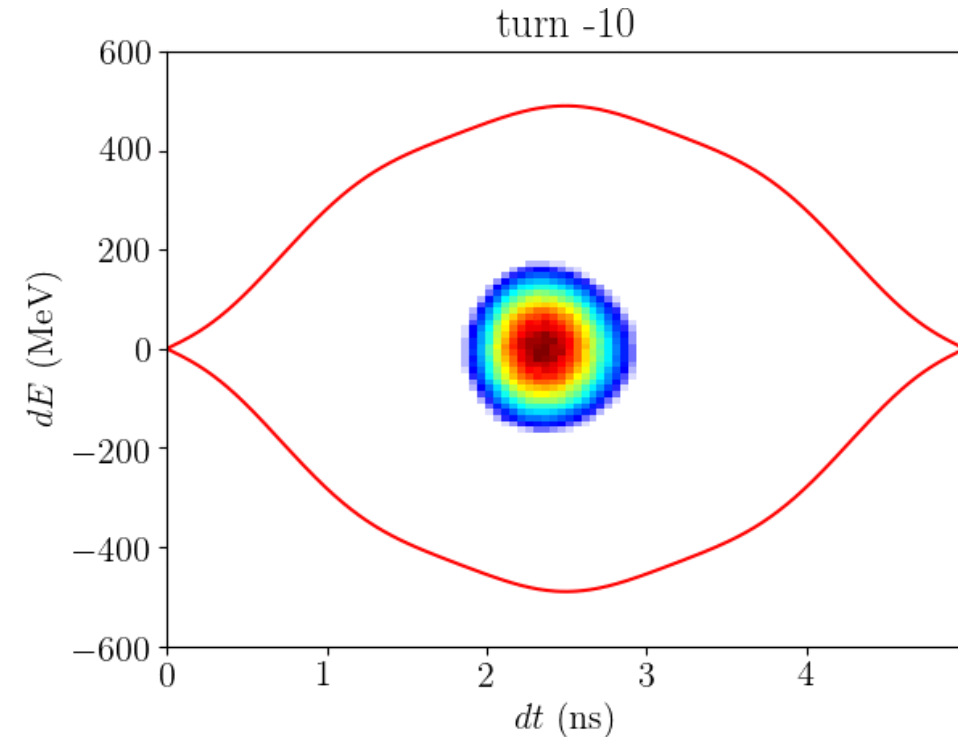
Bunch rotation using double jump scheme

Proposed and tested in PS to mitigate electron cloud instabilities [H. Damerou, EPAC08, 2008](#)

Voltage programs



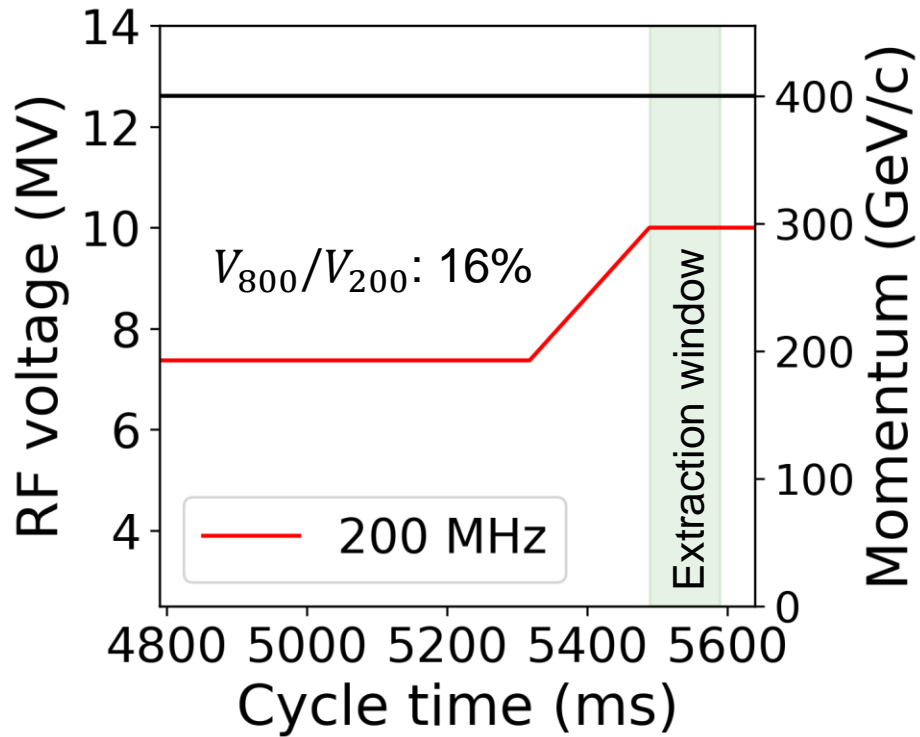
BLoND simulations of bunch rotation



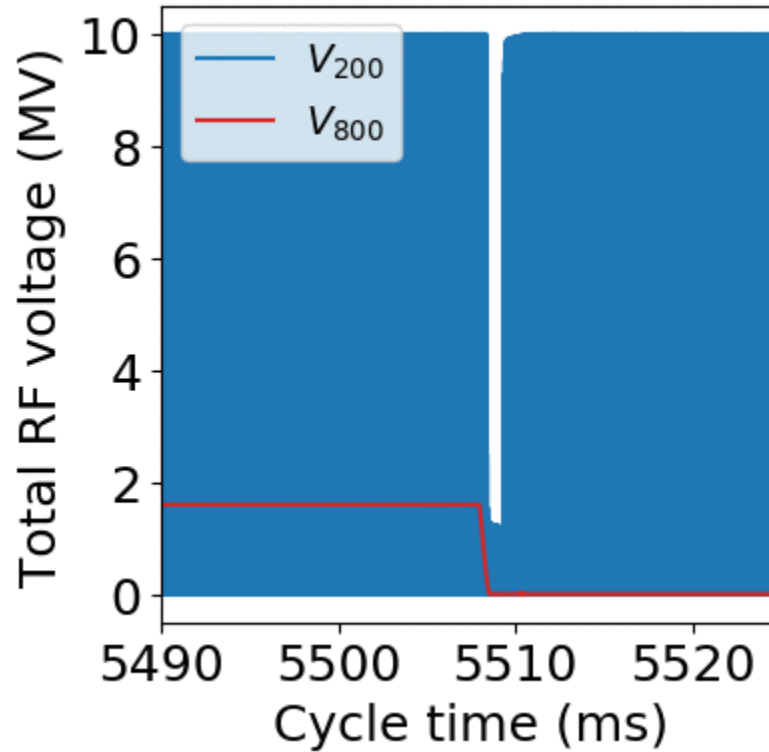
- High V_{200} and V_{800} before jumps and short reproducible time with low RF voltages guarantee beam stability
- First MDs were performed at the end of 2023
- This option requires modification 800 MHz LLRF system (synchronized RF OFF with extraction timing)

Present RF settings: flat top

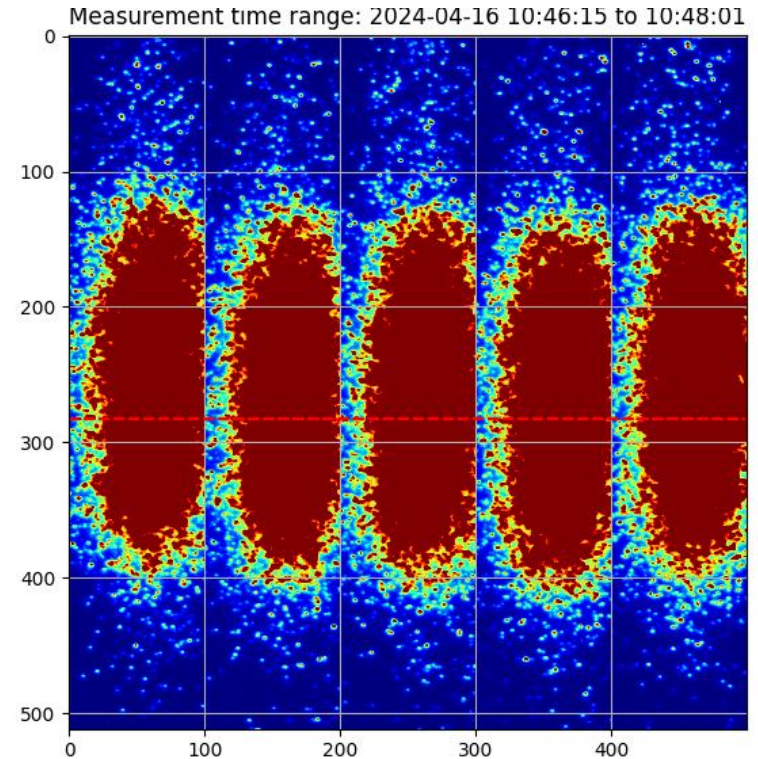
AWAKE cycle as from 16.04.2024



Measured RF voltages



AWAKE streak camera data



→ Double voltage jump scheme was implemented in 2024 to avoid mode-coupling instability with low RF voltage

→ Beam stability and reproducibility was demonstrated up 3×10^{11} with $\sigma \sim 175$ ps

Beam parameters for AWAKE Run 2c/d

New request for beams after LS3 ([E. Gschwendtner, IPP, 19.07.2024](#)):

Bunch intensity: $0.5 - 4 \times 10^{11}$

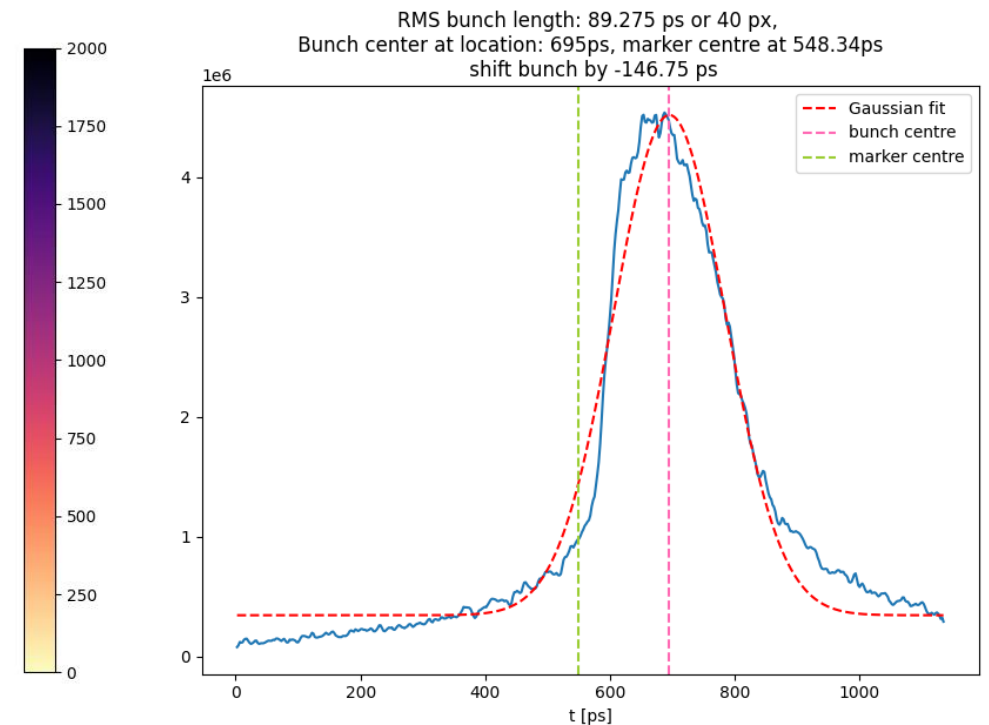
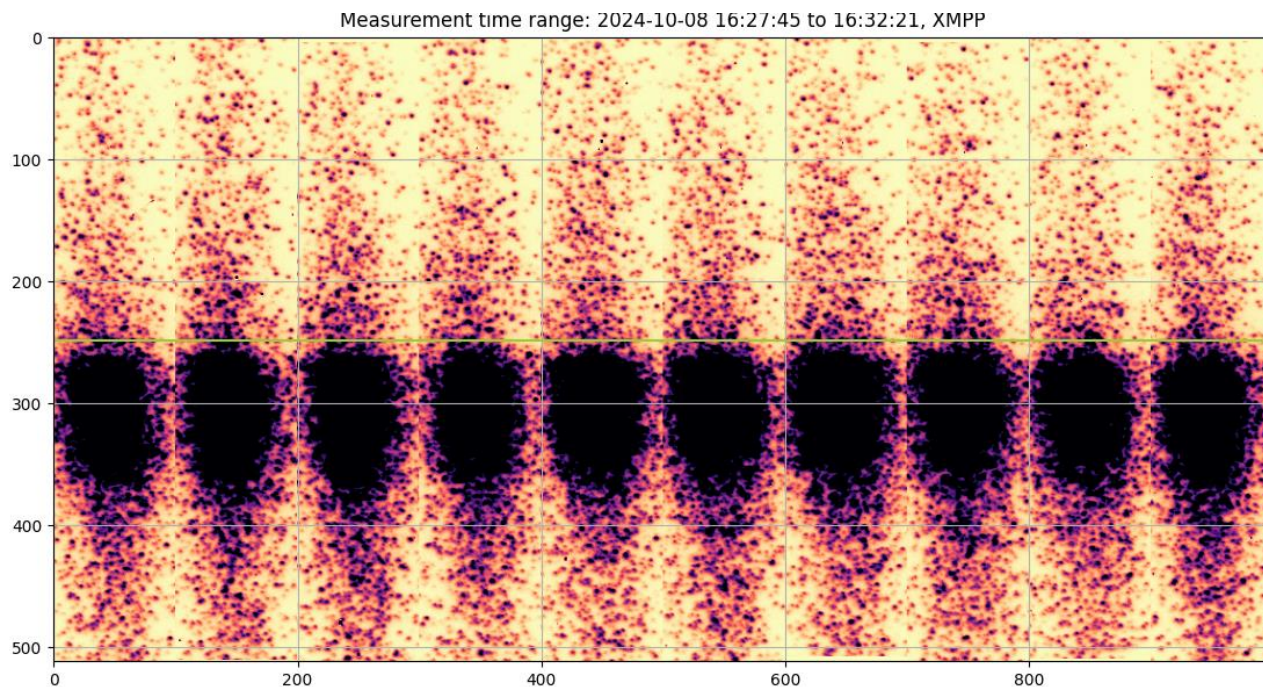
Bunch length: 1 sigma \sim 100 ps (streak camera measurement)

→ Difficult to measure with existing SPS bunch length measurement system (25 ps time resolution, limited dynamic range, and limited bandwidth)

→ Impact of increased peak current on different SPS equipment needs to be evaluated

Ultimate performance in 2024

A new production scheme was developed to reduce longitudinal emittance and tune settings were optimized to suppress transverse emittance blowup during the cycle in PSB:
→ 50 ps gain on in rms bunch length already before rotation (at the limit of stability in PS&PSB)
→ Bunches with 3×10^{11} with ~ 90 ps rms bunch length were measured with a streak camera during AWAKE run



Summary and outlook

Double-voltage jump scheme improved stability of extracted beam parameters and opens possibility of further bunch length reduction

Combining with a smaller initial emittance in PSB, 90 ps rms bunch length was reached for 3×10^{11} and it was requested for 2025 AWAKE run

In 2025, to reach 100 ps rms bunch length for 4×10^{11} in MDs, beam stability during the whole chain needs to be probed

Final verification requires joint measurements with AWAKE streak camera

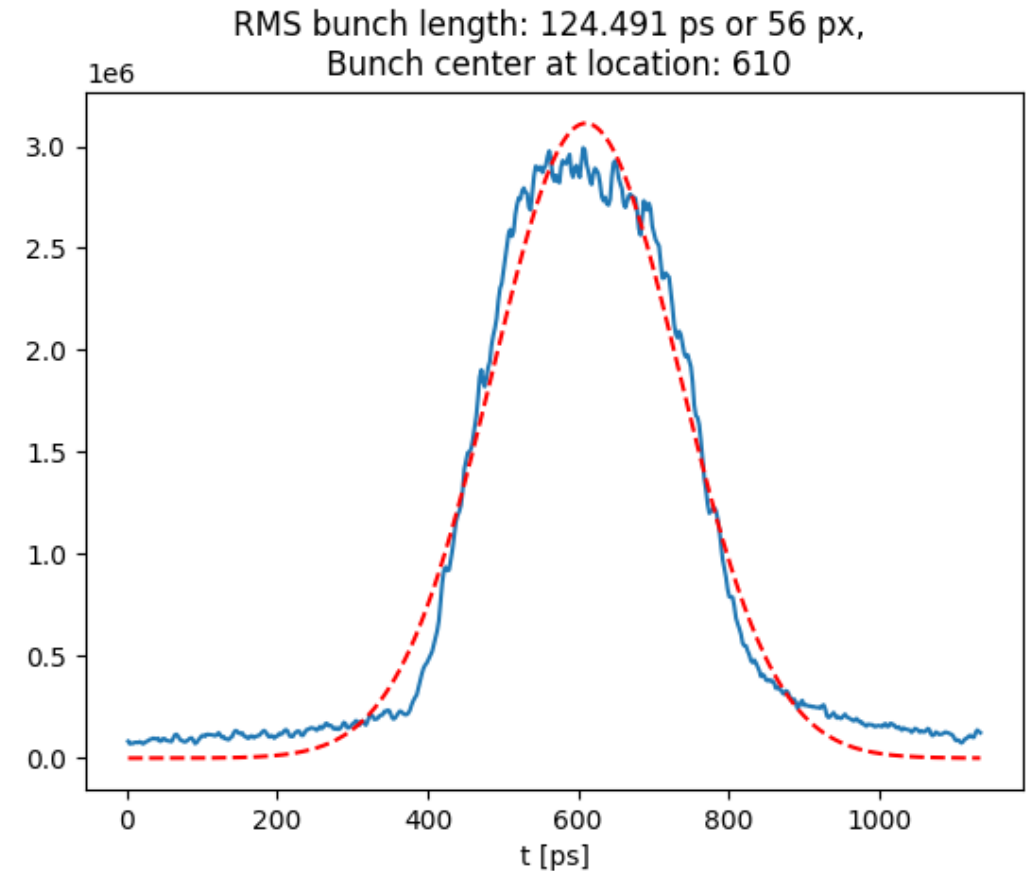
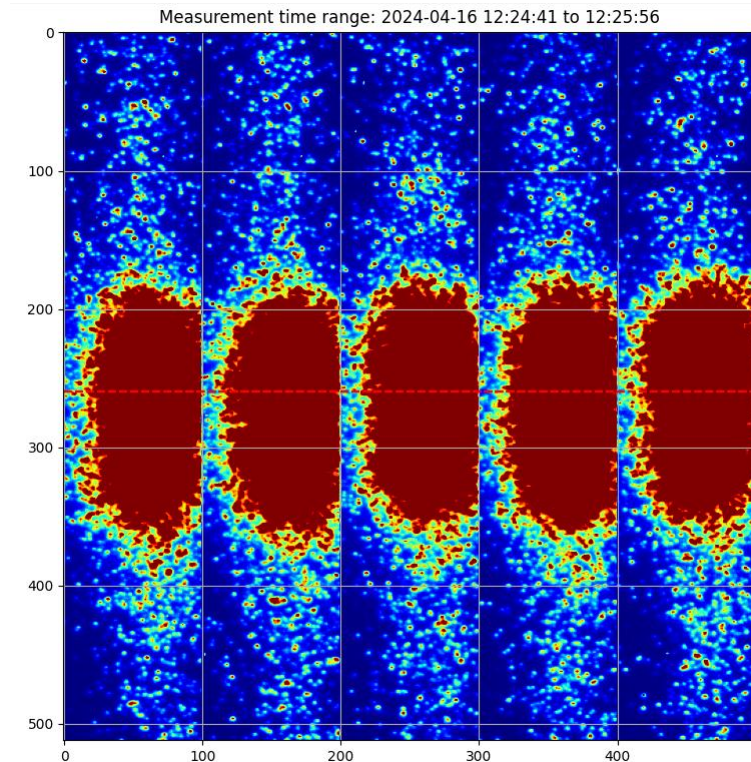
What is the policy for 400-GeV cycles in the SPS (MD1 is required...)?

Thank you for your attention!

Backup slides

First test with shorter bunches

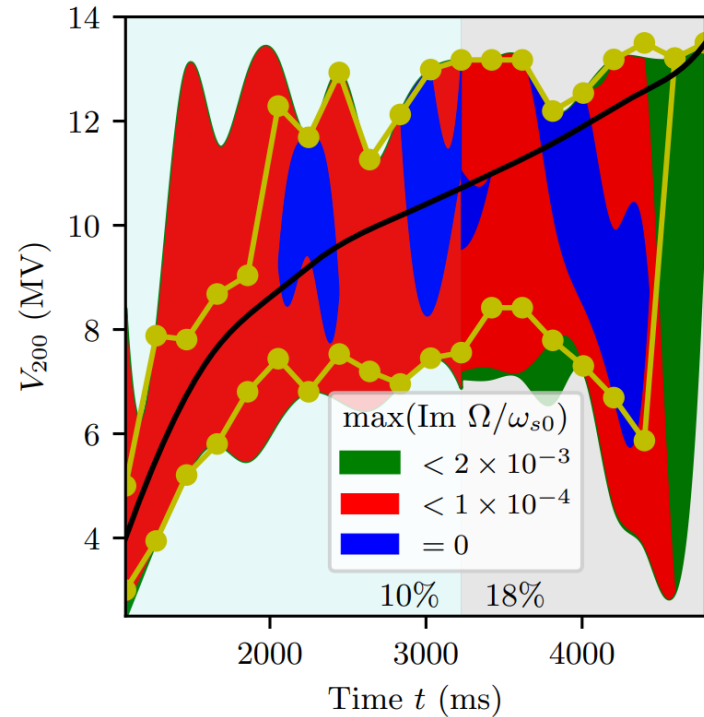
AWAKE streak camera data



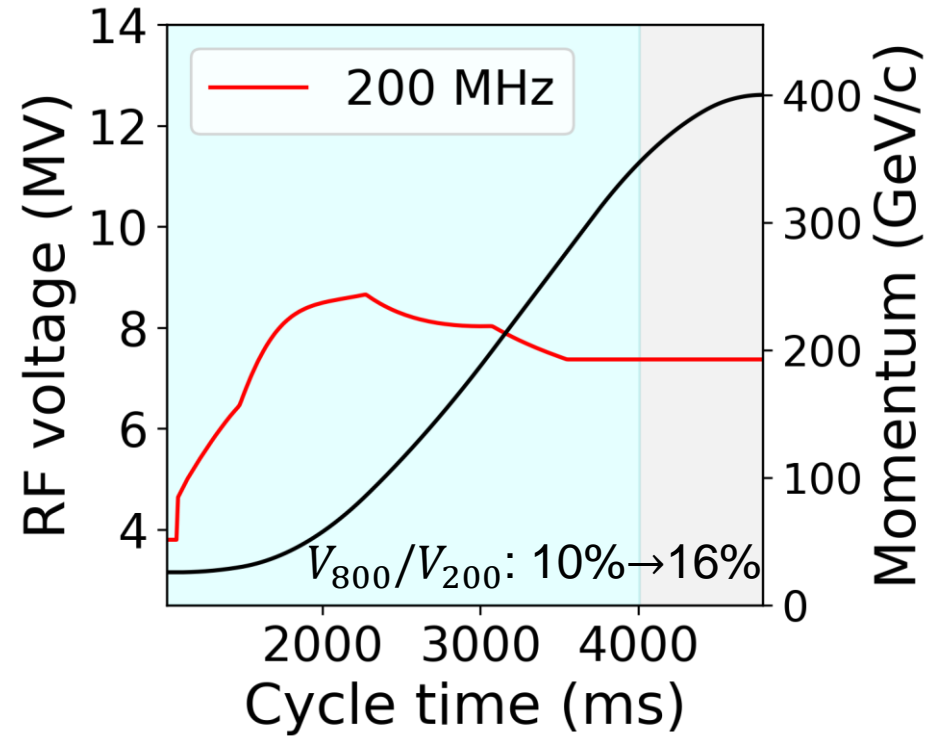
The shortest rms bunch length is **125** ps for 3×10^{11} bunch adjusting rotation timings and increasing $V_{200} = 11$ MV (13 MV is maximum achieved during ion run in 2023)
→ Further tests require full SPS RF power (4×1 MW + 2×1.6 MW) in addition with potentially reduced initial longitudinal emittance

Present RF settings: acceleration

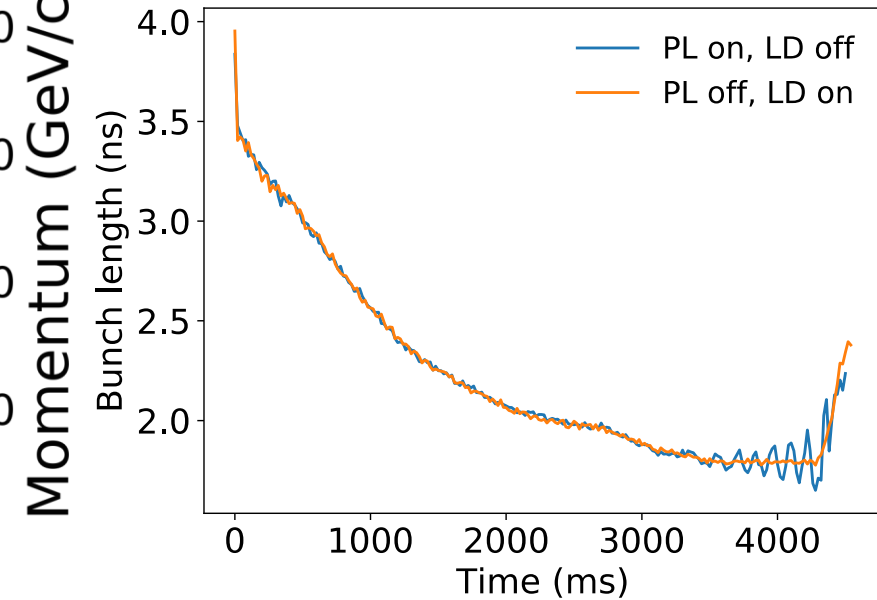
RF voltage range for stable acceleration for 4×10^{11}



AWAKE cycle as from 16.04.2024



Bunch length excitation in presence of phase loop

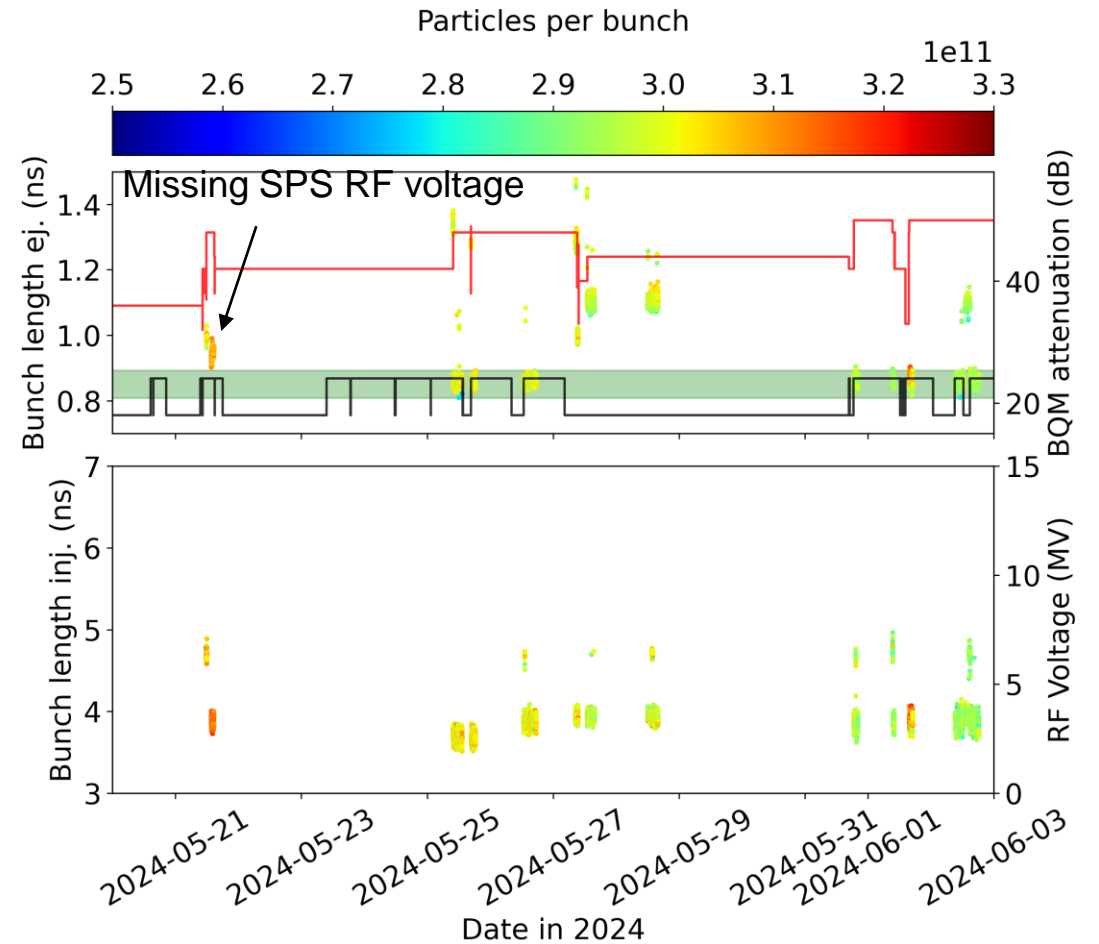
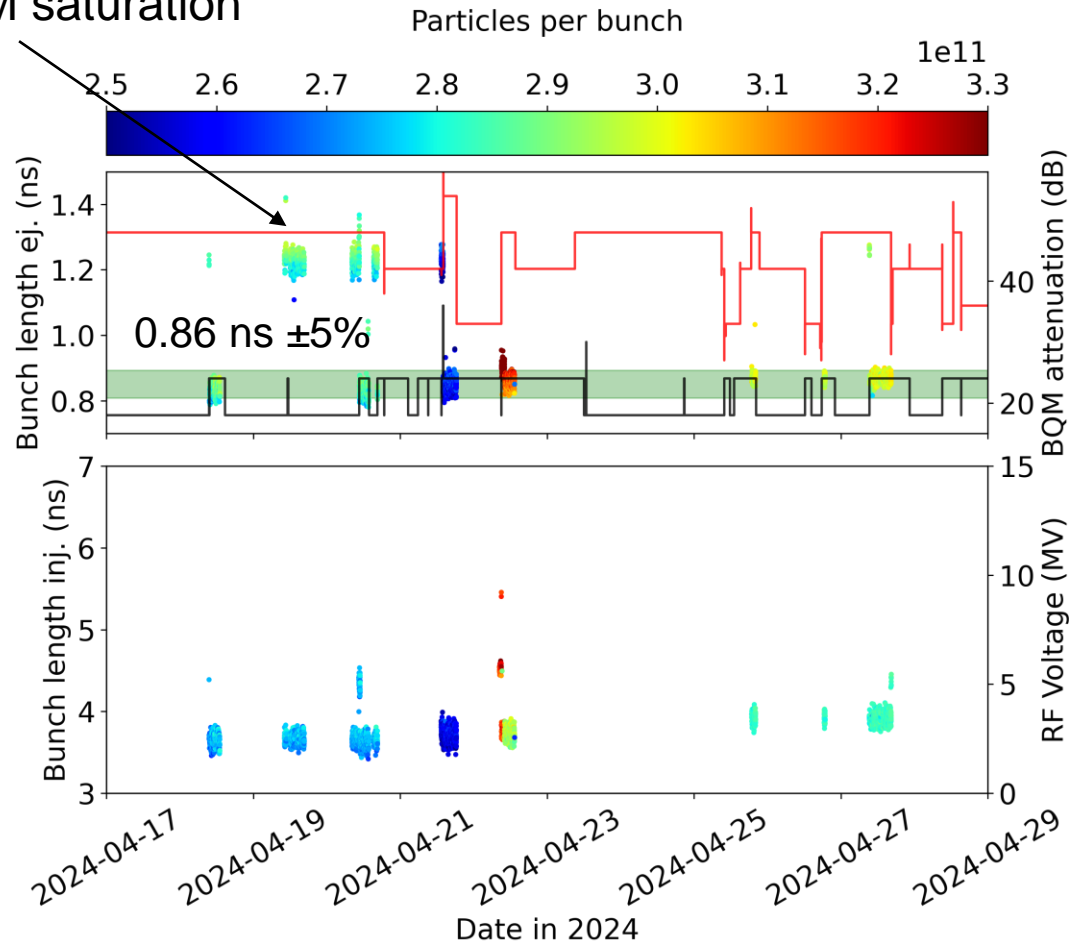


[M. Gadioux, SS report, 2020](#)

- Operational voltage programs are consistent with prediction
- Unexpected "instability" correlated with presence of beam phase loop (PL) is under investigation (temporary solution: PL OFF + longitudinal damper ON)

Parameter stability

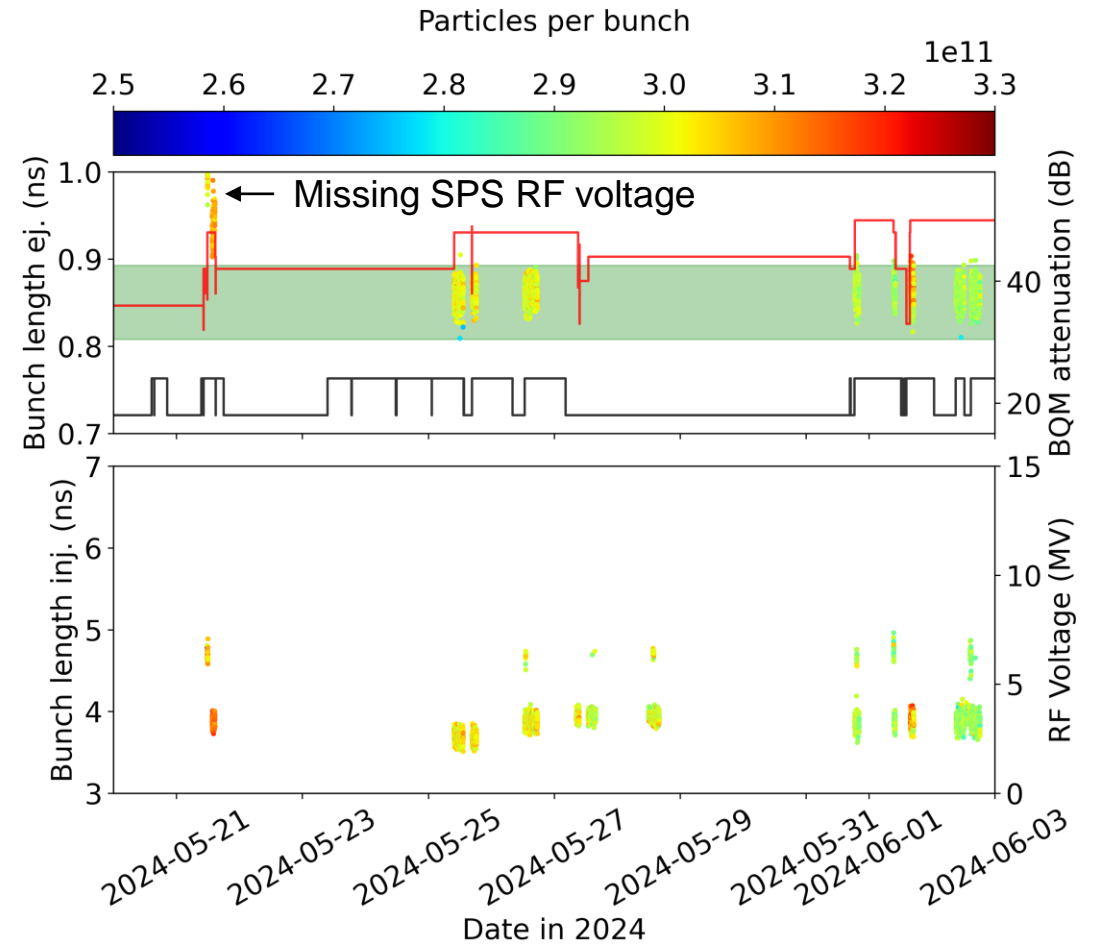
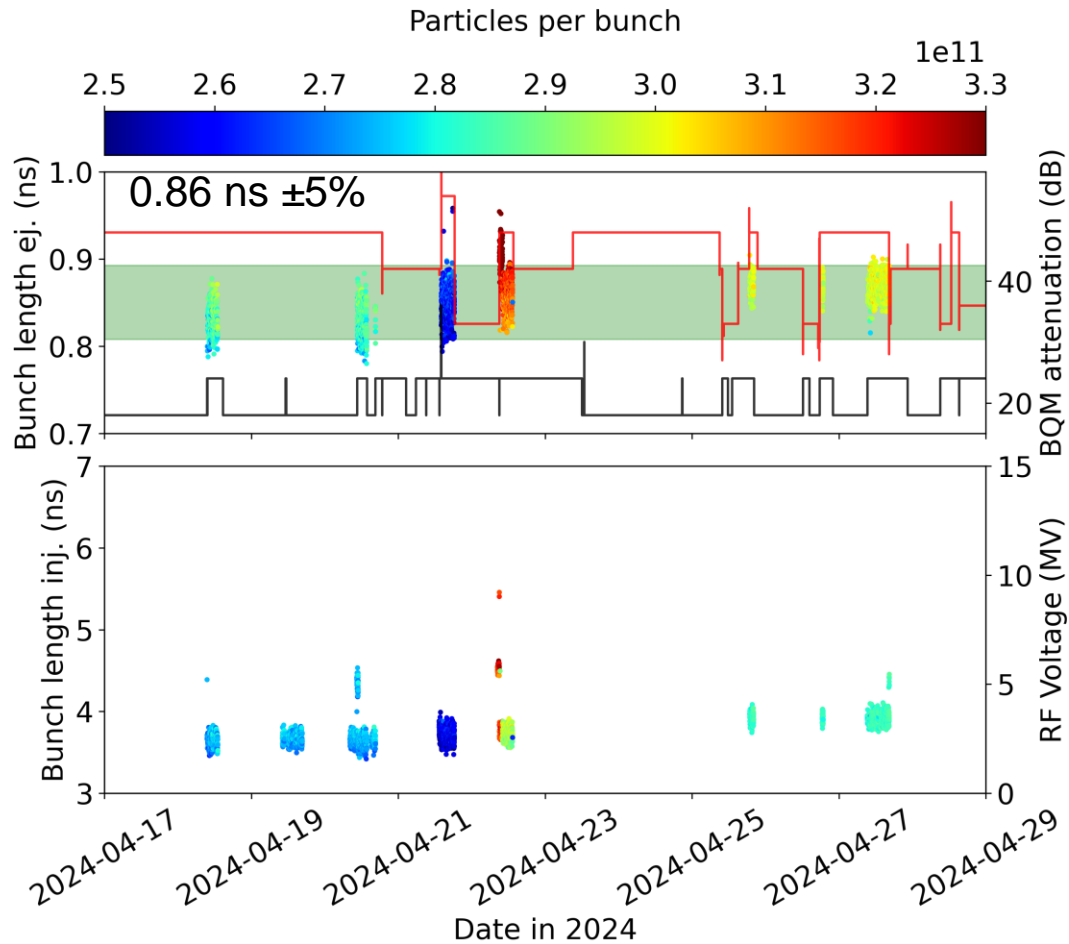
BQM saturation



BQM reading of 0.86 ns corresponds to 4σ bunch length of 0.7 ns according to AWAKE streak camera data ([detailed comparison of measured profiles is ongoing](#))

→ Reproducible bunch length with a spread of $\pm 5\%$ is achieved over long period

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