

A Selection of PSB Longitudinal Studies

MD14643, MD14483, MD14443, MD13483,
MD12303, MD11764, (possibly others)

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With thanks to Linac₄ and PSB operations teams

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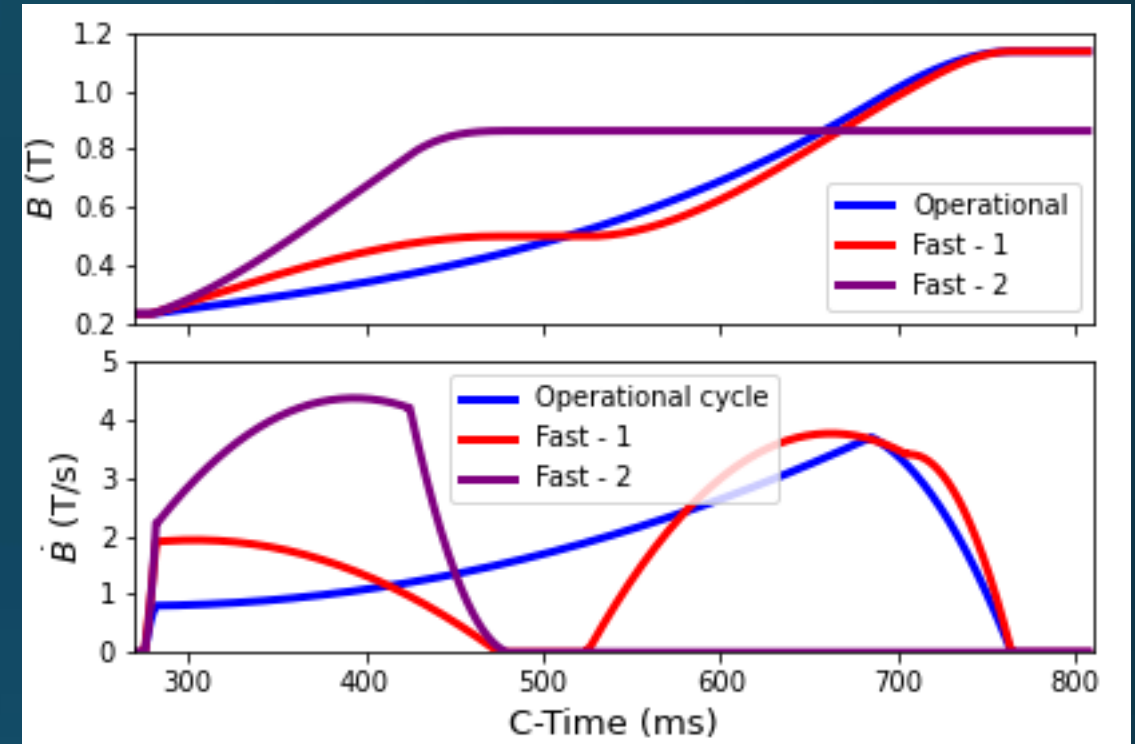
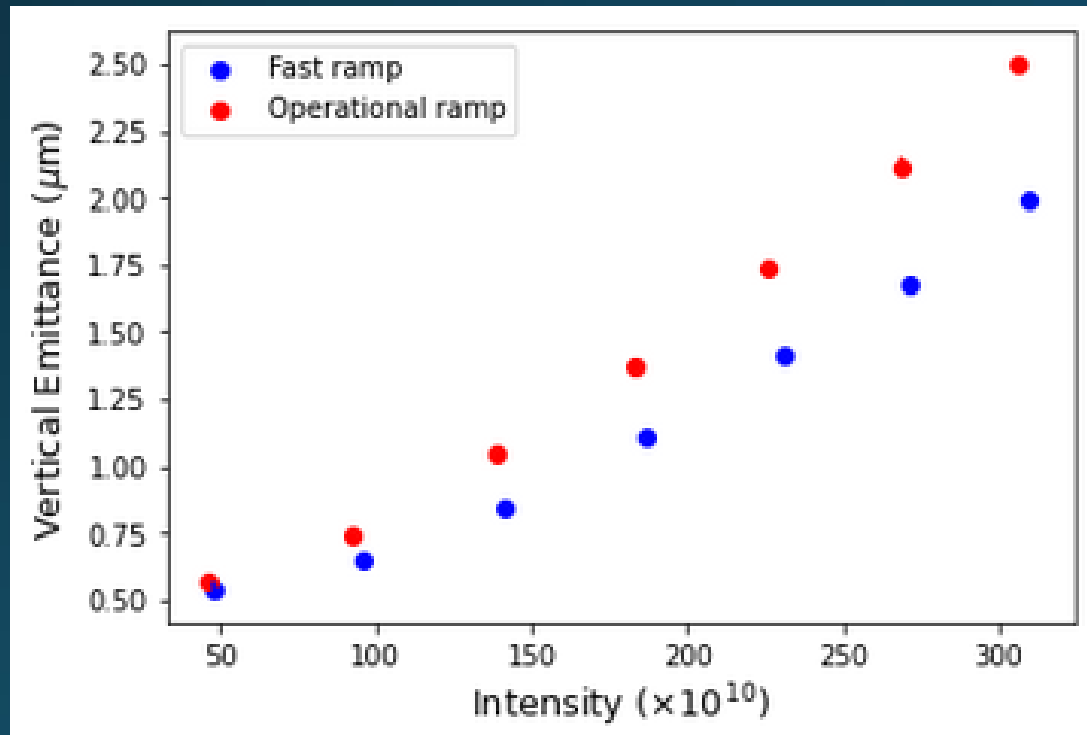
- **Magnetic Cycle Studies**
 - Early extraction
 - Ramp rate/shape
- **Acceleration Harmonic**
 - Single bunch in $h=2/h=3$
 - Direct double bunch production
- **Longitudinal Painting**
 - Quantifying the benefits
 - Linac₄ RF power demand

Magnetic Cycle Studies

- **Ramp rate:**
 - Fast ramp with small longitudinal emittance vs slow ramp with large longitudinal emittance
- **Early extraction:**
 - Extract earlier to allow a faster ramp
 - Can we reach required beam parameters with double flat-top?

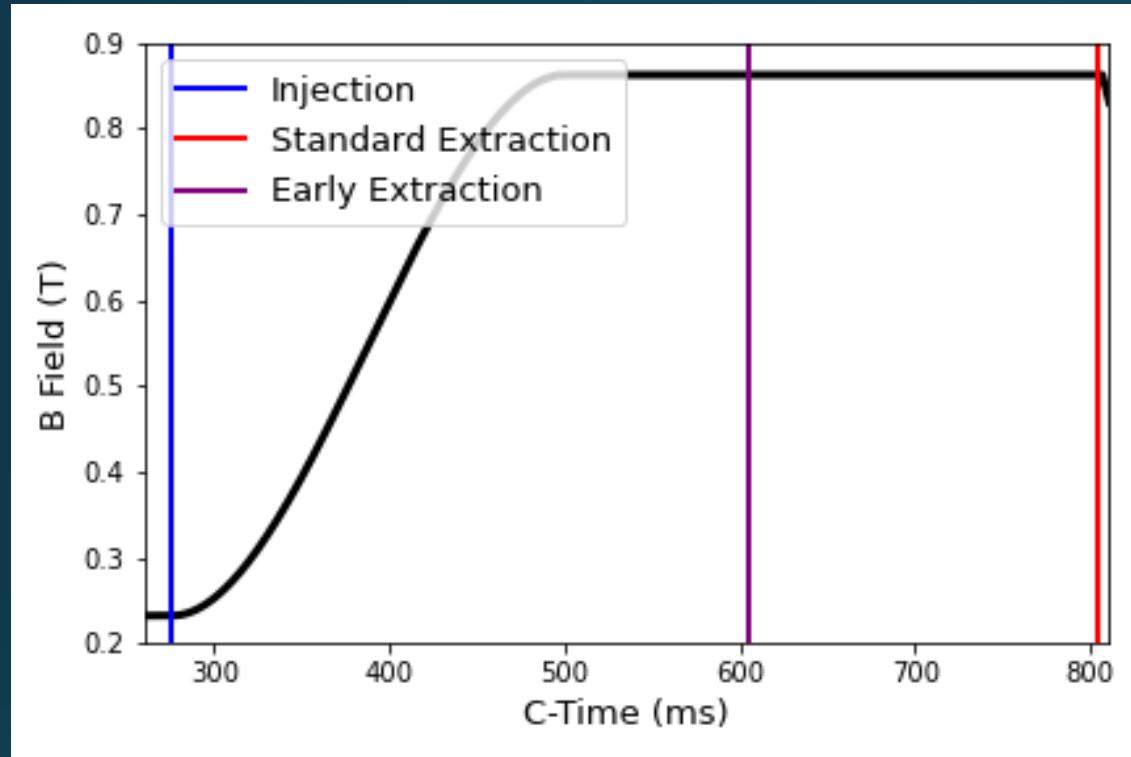
Ramp Rate

- Fast ramping of interest for space charge reasons
- Intermediate flat top required due to RMS current limit

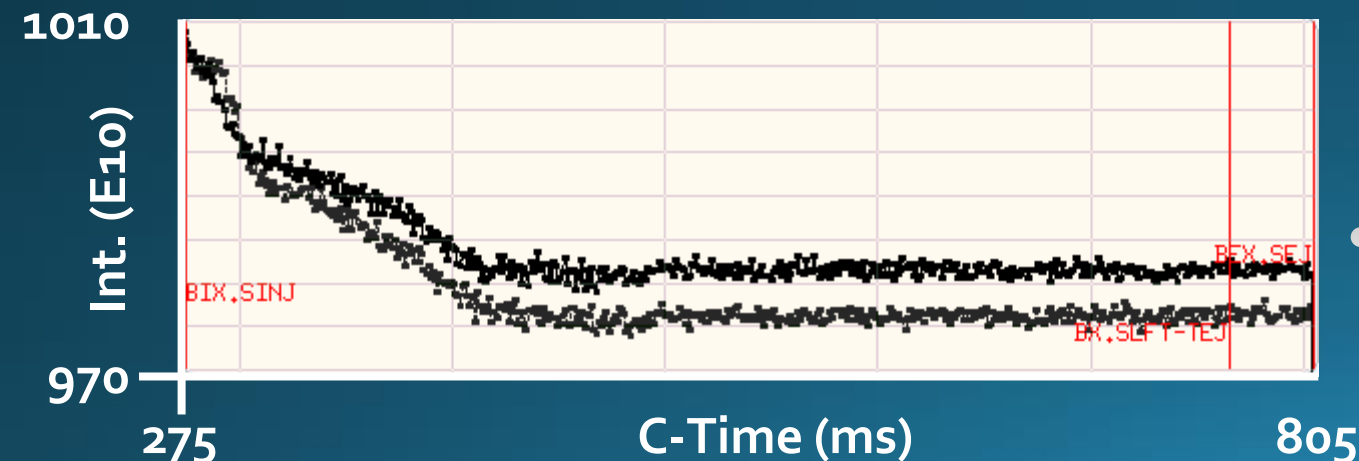


- Promising preliminary result motivates test with faster ramp
- Very fast ramp to 1.4 GeV is possible, but no decent measurements yet

Early Extraction



- Ramp to 1.4 GeV by $\sim C_{500}$
- Extraction can be anticipated to C_{605} (usually C_{805})
- Must respect minimum time between extractions on sequential cycles



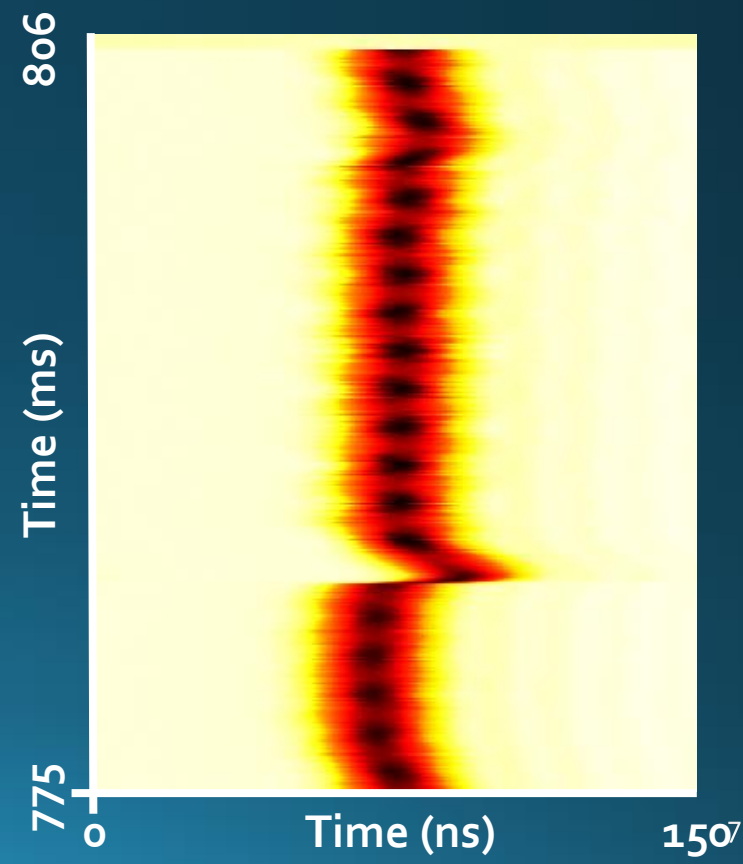
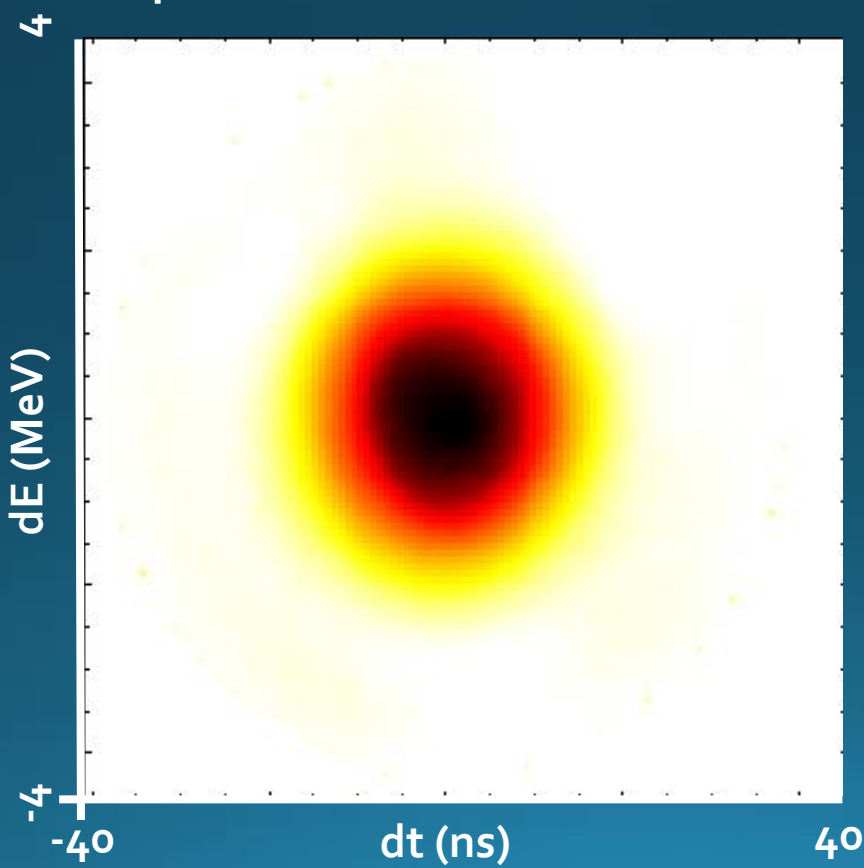
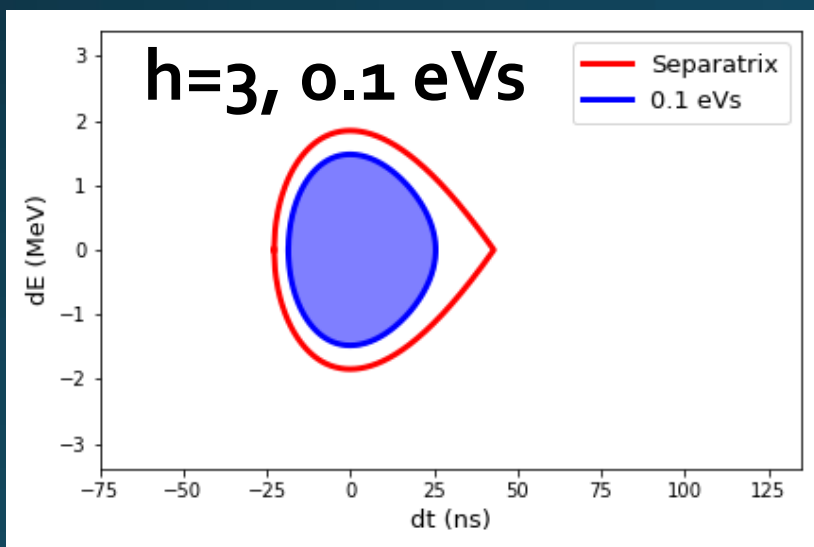
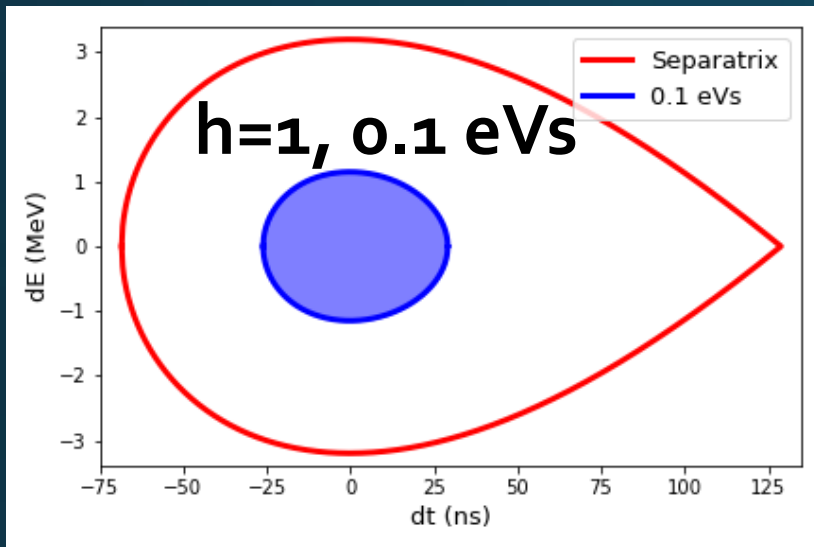
- Valuable input to double extraction (parasitic ISOLDE) studies
- Increases flexibility for studies relating ramp rate to beam parameters

Acceleration Harmonic Studies

- **Single bunch in $h=2$ or $h=3$:**
 - Not an intended operation mode for the PSB LLRF, needs validation
 - Can we accelerate and synchronise with an empty bucket?
- **$h=2$ injection:**
 - Further studies of direct injection at $h=2$

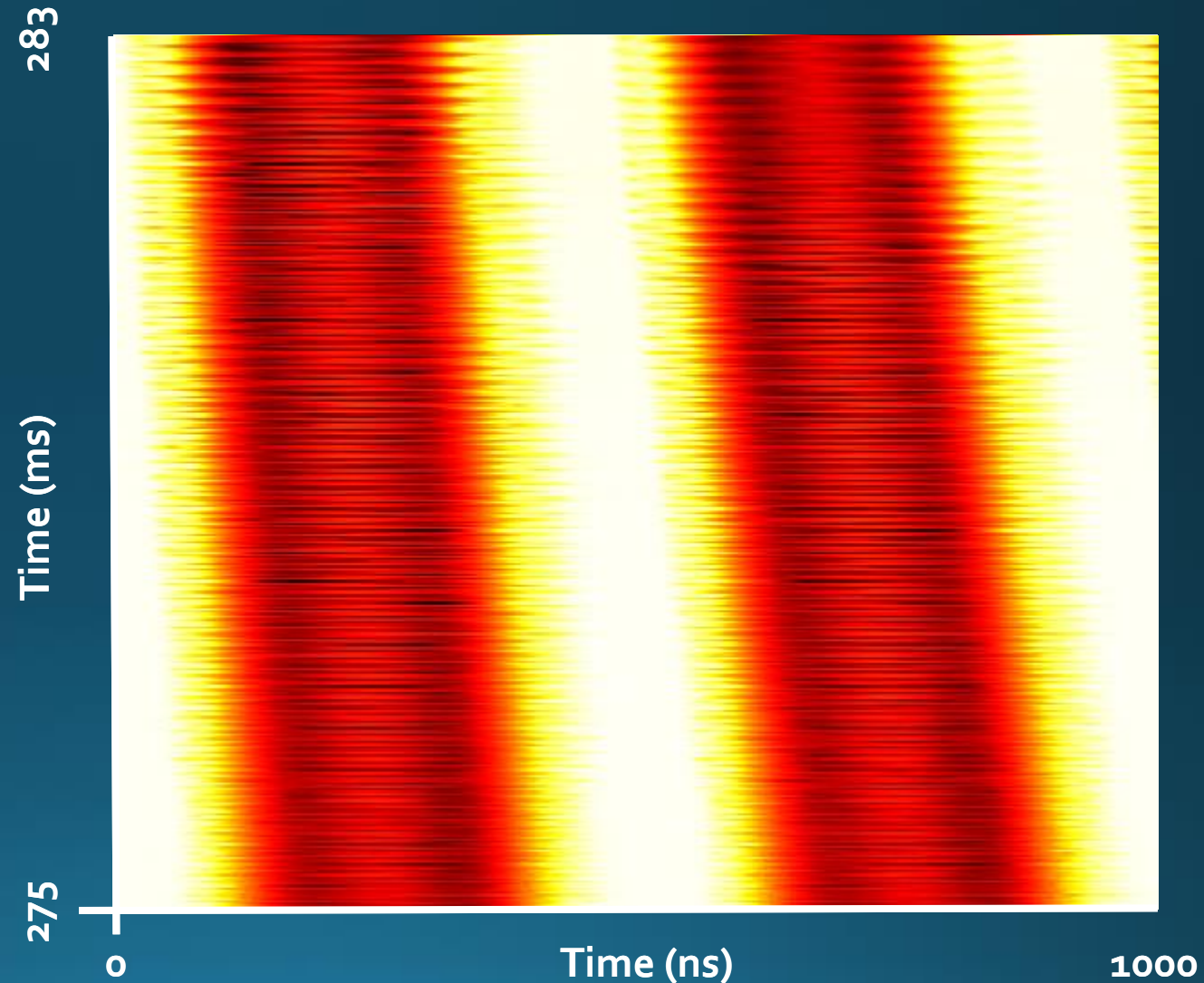
Single bunch in $h=2/h=3$

- Higher harmonic \rightarrow larger filling factor \rightarrow Landau damping
- LLRF designed for $n_{\text{bunches}} = h_{\text{rf}}$ and $h_{\text{rf}} = 1$ or 2
- ~ 100 V at $h=1$ gives enough signal for beam loops



Direct production $h=2$

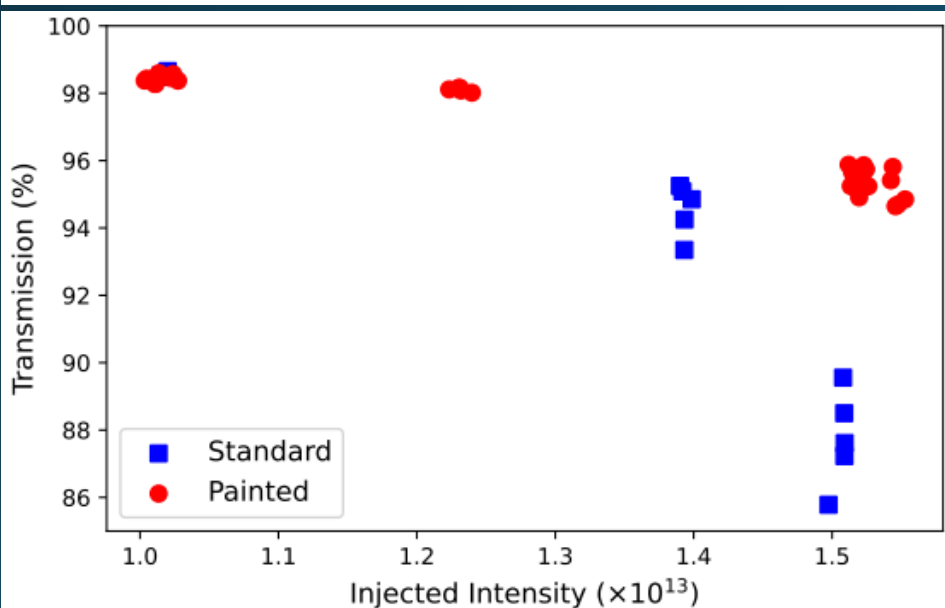
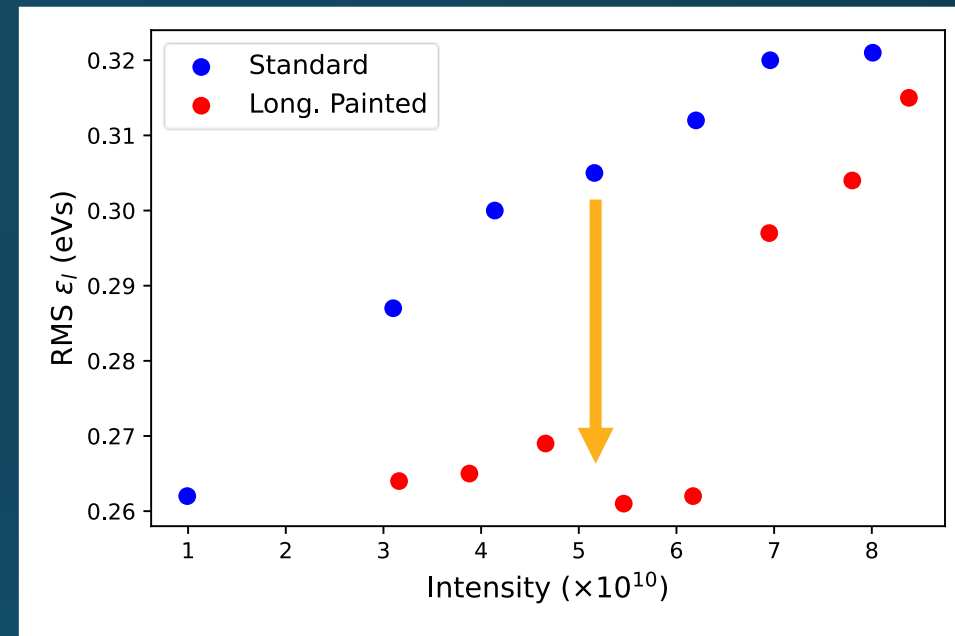
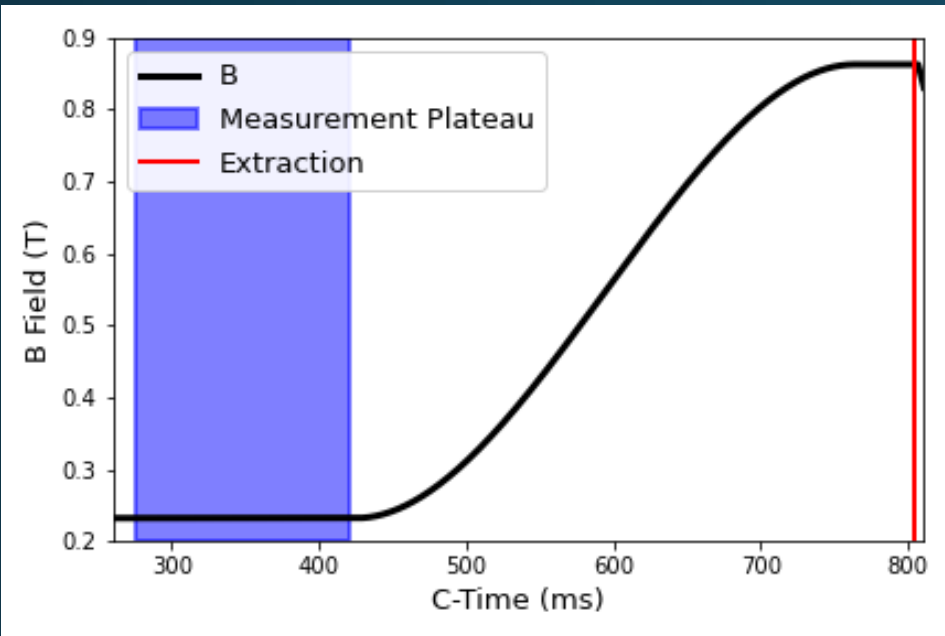
- Follows on from studies in previous years
- Previously, injected into alternating buckets for each turn
- Demonstrated injecting to both buckets in the same turn
- Reached 500×10^{10} with 100 injected turns
- Controlled and uncontrolled emittance blow-up to be studied



Longitudinal Painting Studies

- **Quantifying the benefits:**
 - Transmission
 - Transverse emittance
- **Linac₄ RF power:**
 - Can they be reduced with modified painting functions?

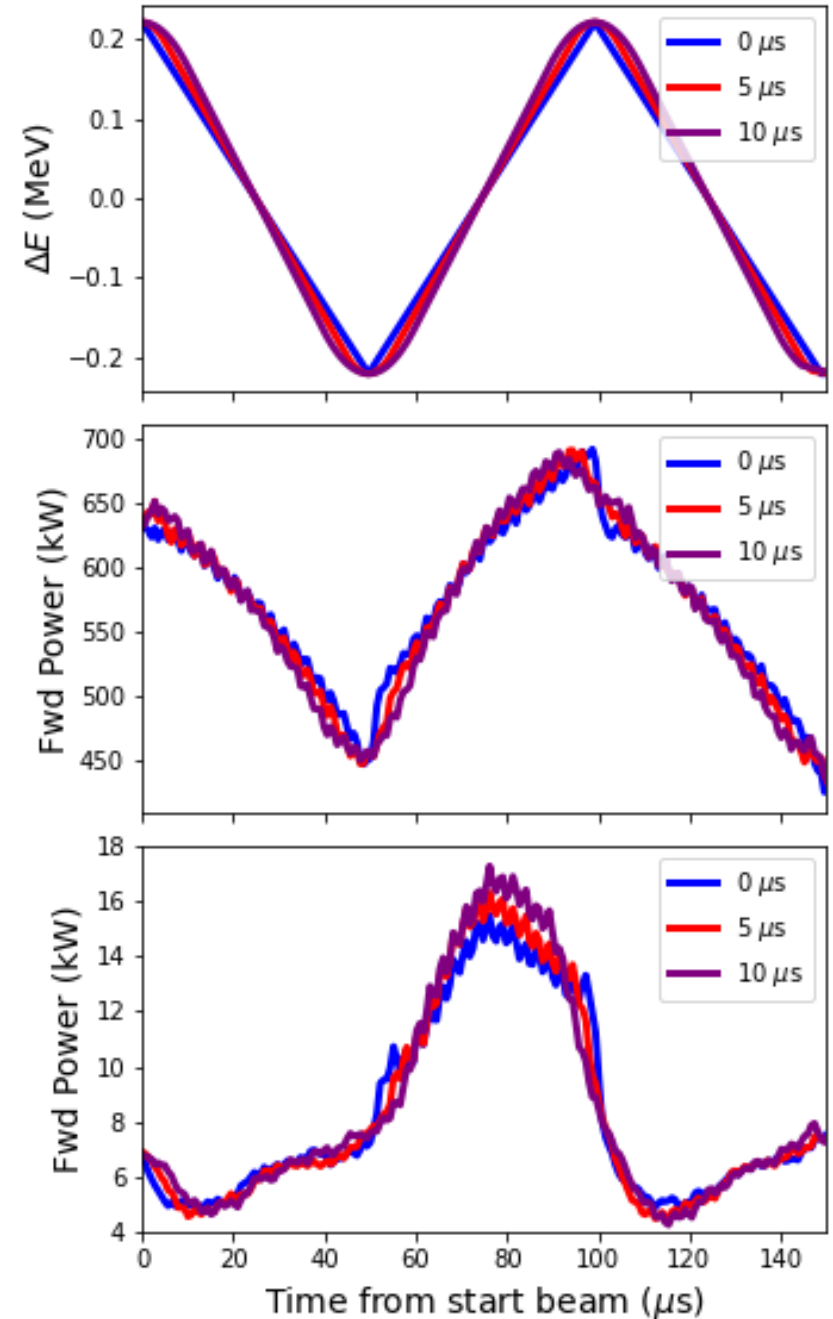
Quantifying Longitudinal Painting Impact



- Measurement of longitudinal RMS emittance growth on a long flat-bottom
- Blow-up reduced for a large intensity range using longitudinal painting
- At high ($>1 \times 10^{13}$) intensity, improved transmission seen for TOF-style cycle

Linac₄ RF Power

- Available power for the PIMS₁₁₁₂ (in principle) and DEBUNCHER (in practice) limits the painting
- Suspected that the sudden change of gradient of the amplitude/phase swings increases power demand
- Tested rounding of the transition to reduce second derivative
- Slightly worse effect due to required increase of first derivative



Conclusion

- Preliminary sign of benefits when using a faster ramp
- Early extraction works:
 - Important part of double extraction studies
 - Facilitates further exploration of ramp-rate optimisation
- Acceleration and extraction of a single bunch in “high” harmonic (>1), applications for AWAKE and h2+4 BCMS (see A. Lasheen’s talk)
- Direct production of two bunches progressing, stability, transmission and beam parameters to be investigated
- Reduced longitudinal emittance growth and improved transmission at high intensity with longitudinal painting
 - Inconclusive measurements for transverse emittance growth
- Unsuccessful attempt to reduce required Linac4 RF power with longitudinal painting

Open questions for 2025

- Magnetic cycle studies:
 - How robust is the observed benefit?
 - How fast is too fast?
 - Can we deliver required TOF/ISOLDE beam parameters with a double flat-top?
- Acceleration harmonic studies:
 - Can we simplify beam production for INDIV/AWAKE style beams?
 - Can direct $h=2$ production be used for MTE?
- Longitudinal painting studies:
 - Is it needed/beneficial for foreseen operational conditions?
- No special requirements, just lots of MD time and Foteini on speed dial