Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Fast Switching and Signal Processing Techniques for Co-Propagating Unequal Bunch Length Beams

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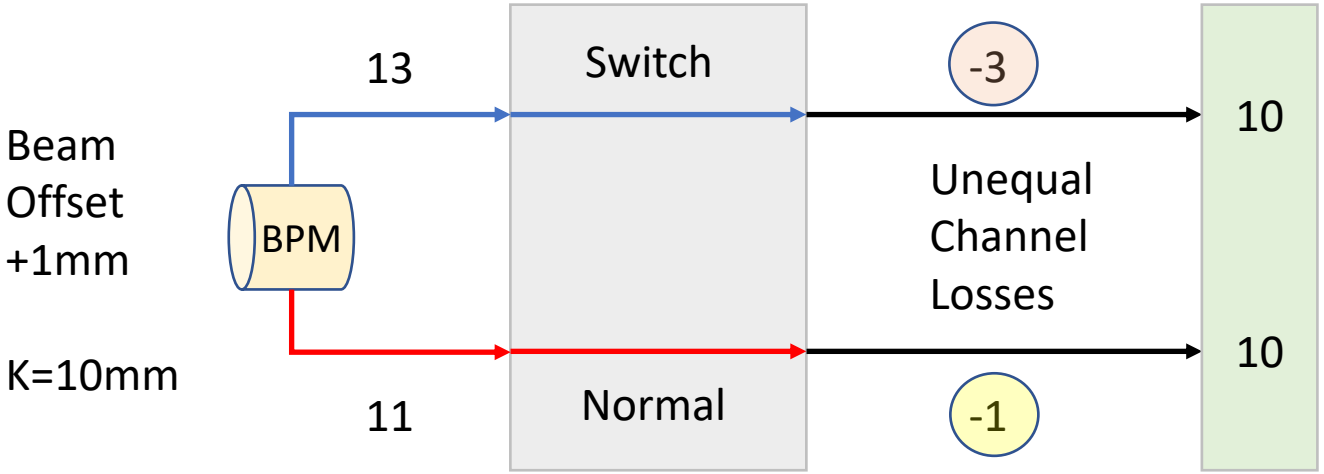
BPM Calibration Challenges

- Many BPM circuit elements have frequency dependent responses
  - Especially some types of bandpass filters and amplifiers
- Wideband processing methods are susceptible to mis-matching of analog filters
  - Narrowband systems may alleviate some of these issues
- Calibration test signals are difficult to match to beam signals with high precision
  - Extremely short test pulses are difficult to obtain
- Beam based alignment methods determine offsets for a particular configuration
  - How often can BBA be performed? Long term temperature drifts?
- Presence of multiple beams of varying frequency spectrum
  - Overall signal intensity can also be different

Dynamic Calibration by Switching

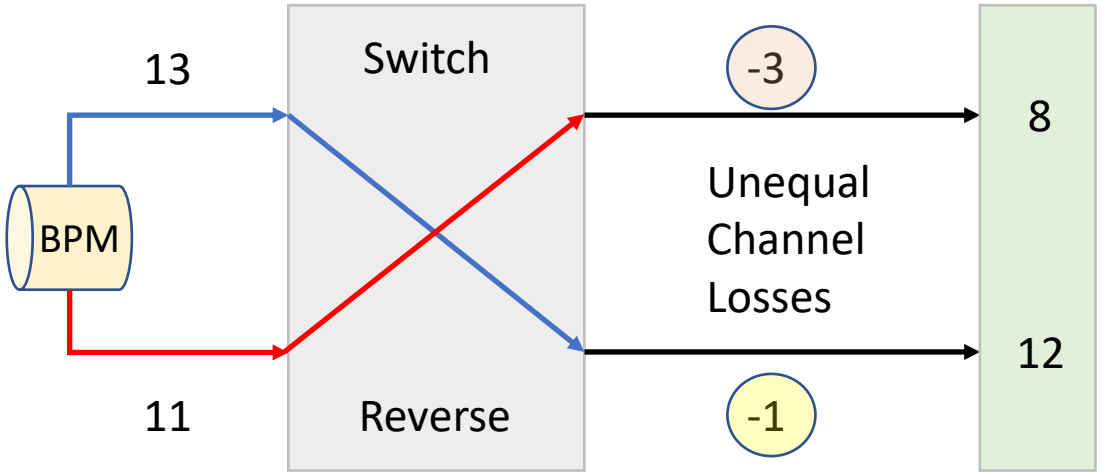
- Use a reversing switch to swap channels from PUE to electronics
- Locating the switch close to the BPM allows long cables to also be compensated
  - Especially useful to eliminate thermal drift, external RFI noise effects in cables
- Bias from elements downstream of switch are nulled when difference is taken
- BPM positions are reversed in sign convention when cables are reversed
  - If BPM processor is controlling the switch, this is automatically compensated
- By rapidly switching and averaging, downstream offsets are removed

Switching Example



Normal
Position = (10-10) / (10+10) * 10 * (1) = 0mm

Average Position = +1mm

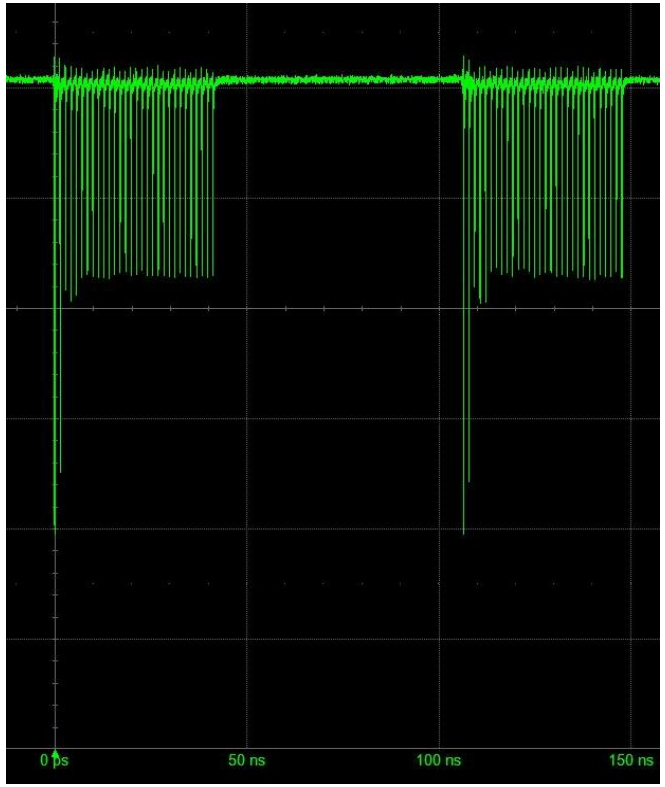


Reverse
Position = (8-12) / (8+12) * 10 * (-1) = +2mm

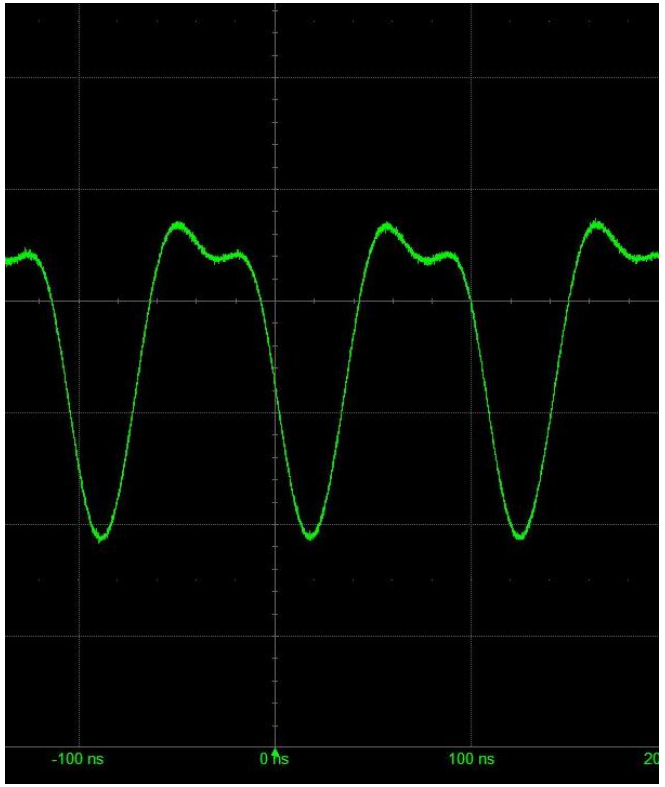
Sign Reversal

Bench Testing Various BPM Signals

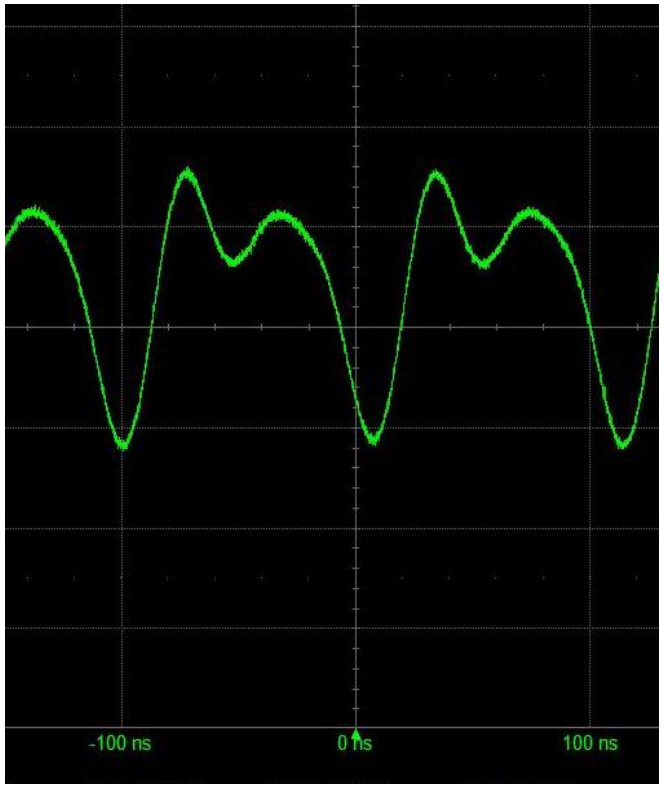
LEReC electron macrobunch
704MHz x 9MHz



LEReC electron macrobunch
10MHz low-pass (diplexer)

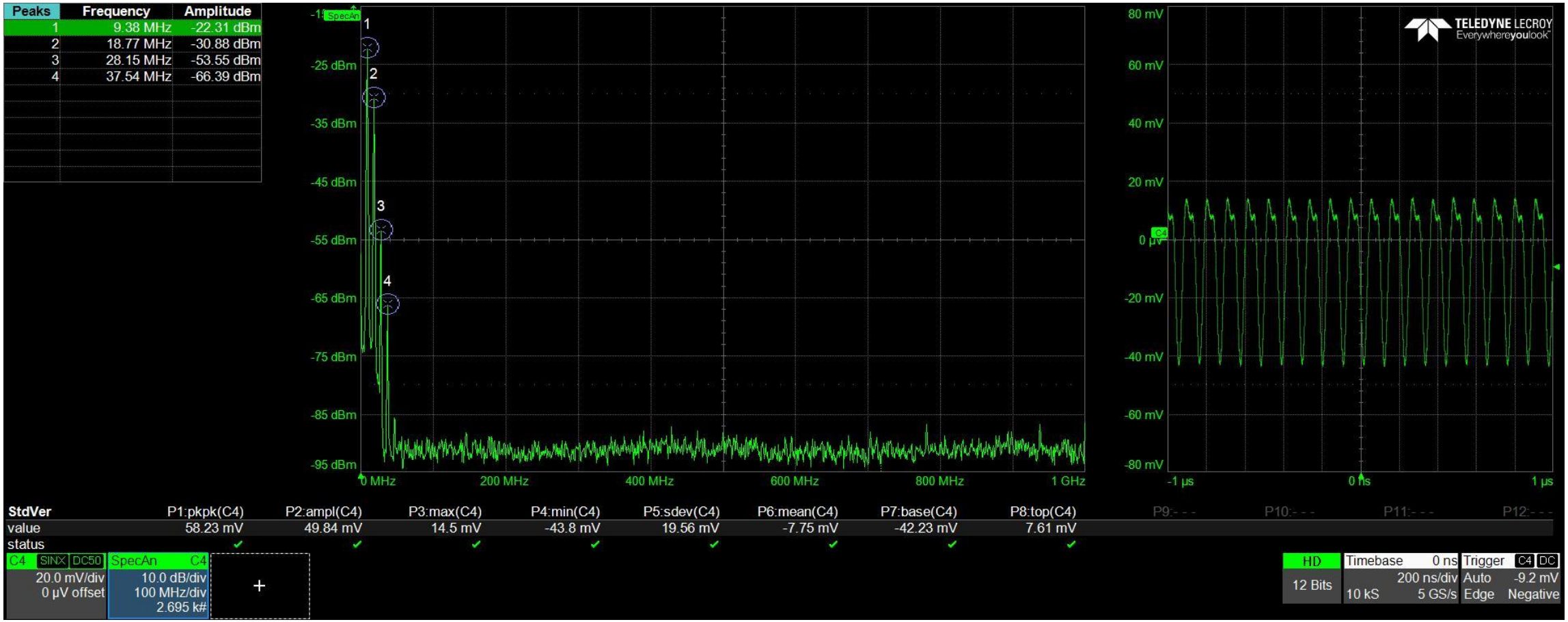


RHIC ion bunch
10MHz low-pass (diplexer)



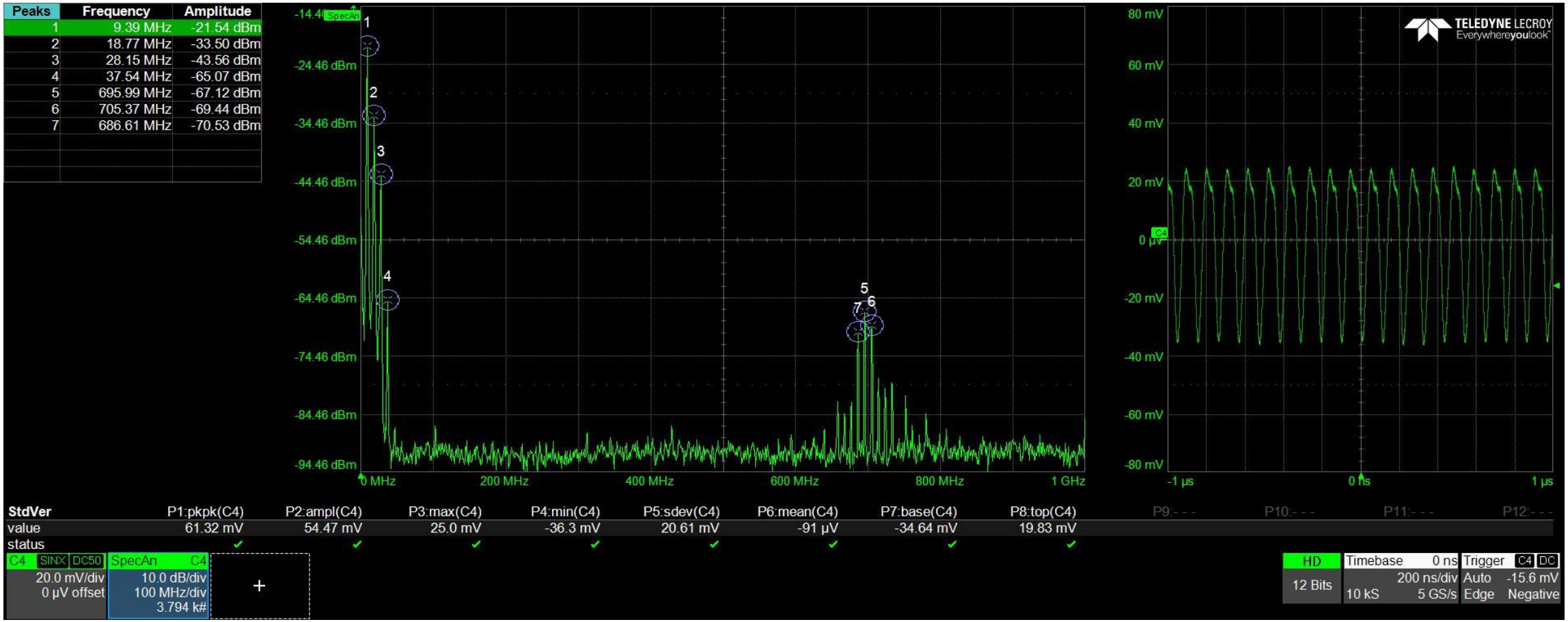
Signal Frequency Spectrum

- Train of 9MHz ion bunches through 10MHz low-pass filter : 1GHz span



Signal Frequency Spectrum

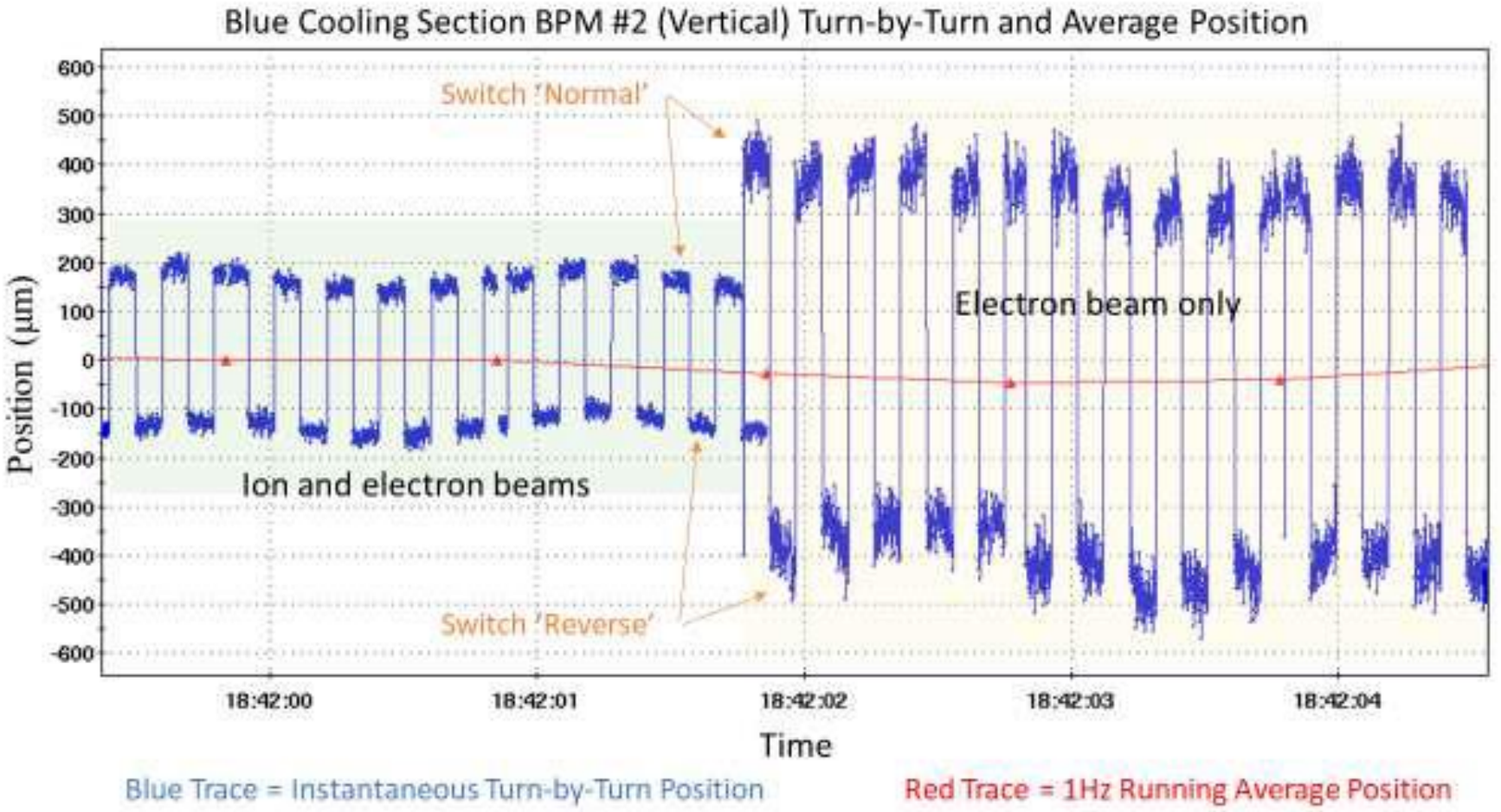
- Train of 704MHz electron macro-bunches through low-pass filter : 1GHz span



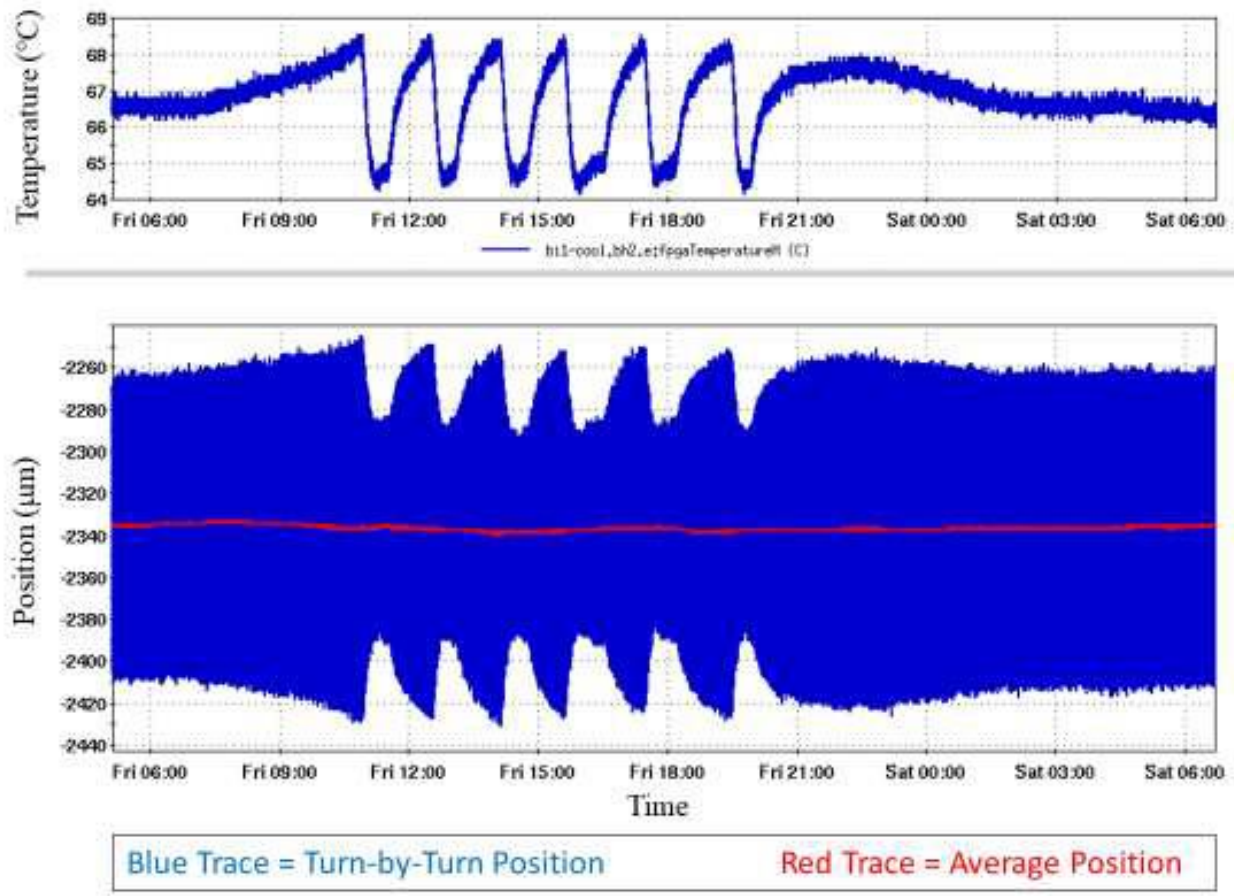
LEReC Experience with BPM Switching

- Electron beam signal contains high-frequency components
  - Even with low-pass filtering some signal remains above noise floor
- Wide dynamic range difference between ion and electron signal levels
- Same BPM electronics used to measure both beams during alignment
  - Signal split to additional 704MHz BPM electronics to monitor electron beam only
- Hadron beam only was used for BBA (drift region) to determine BPM offsets
  - Dynamic switching was enabled during BBA
- Electron beam only was aligned to same trajectory (with dynamic switching active)

LEReC Ion vs. Electron Differences



LEReC Thermal Drift Compensation



BPM electronics temperature
Room A/C cycling ~4 deg C

Turn-by-turn and average positions

Test signal split equally to both channels

Switching produces envelope
which is changing with temperature

Average of envelope remains constant

Conclusions

- Switching was used to help successfully align beams for LEReC experiment
  - Mitigated frequency and intensity dependent effects
- Switching also helps to reduce drifts allowing long-term operations
  - BBA was only needed a few times over several months of 24/7 operations
- Switching hardware was relatively inexpensive to install
- Added benefit of helping to diagnose BPM signal cable issues

Acknowledgements

- Peter Thieberger
  - For suggesting this calibration method early in the design of the LEReC project

- The LEReC team of physicists, engineers and technicians
  - Lots of patience and hard work was required to achieve success

- Michiko Minty, Peter Forck and the HB2021 conference organizers
  - Thanks for the opportunity to share this experience

References

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