

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

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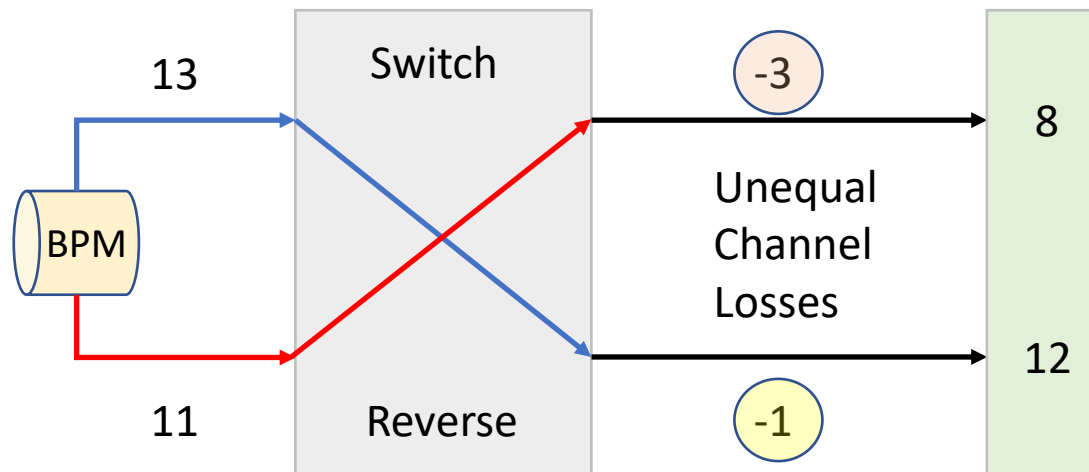
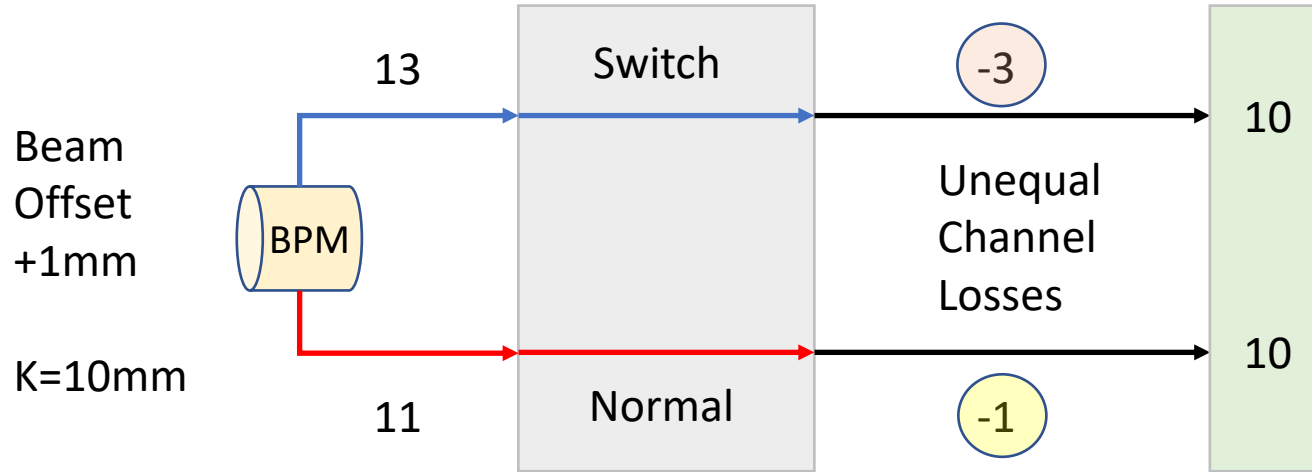
6 DA 7 U] V f U h] c b 7 \ U `` Y b [Y g

- 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

8mbU a]W' 7U`]VfUh]cb`Vm`Gk]hW\]b [

- 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

G k]hW \]b ['9 IU a d`Y



Normal

$$\text{Position} = (10-10) / (10+10) * 10 * (1) = 0\text{mm}$$

Average Position = +1mm

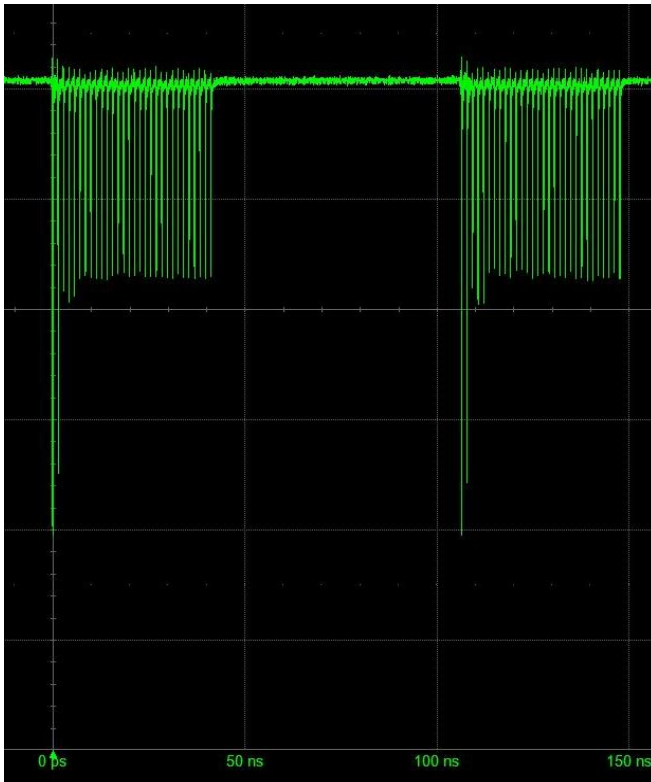
Reverse

$$\text{Position} = (8-12) / (8+12) * 10 * (-1) = +2\text{mm}$$

Sign Reversal

6 YbW \ 'HYgh]b [' JUf]c i g' 6 DA 'G] [bU`g

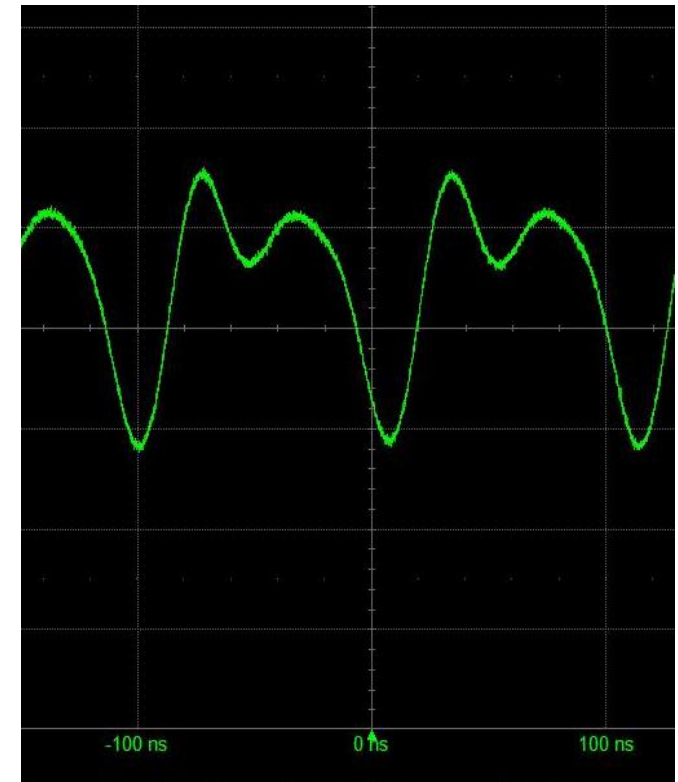
LEReC electron macrobunch
704MHz x 9MHz



LEReC electron macrobunch
10MHz low-pass (diplexer)

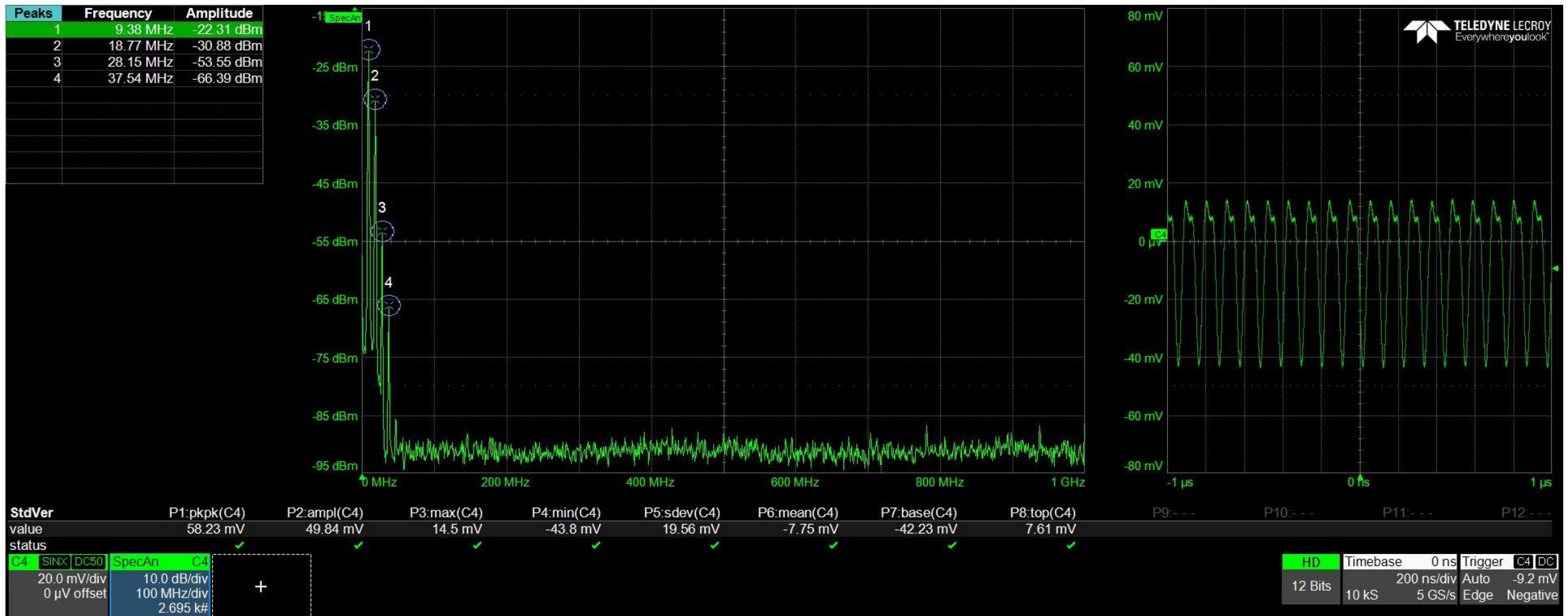


RHIC ion bunch
10MHz low-pass (diplexer)



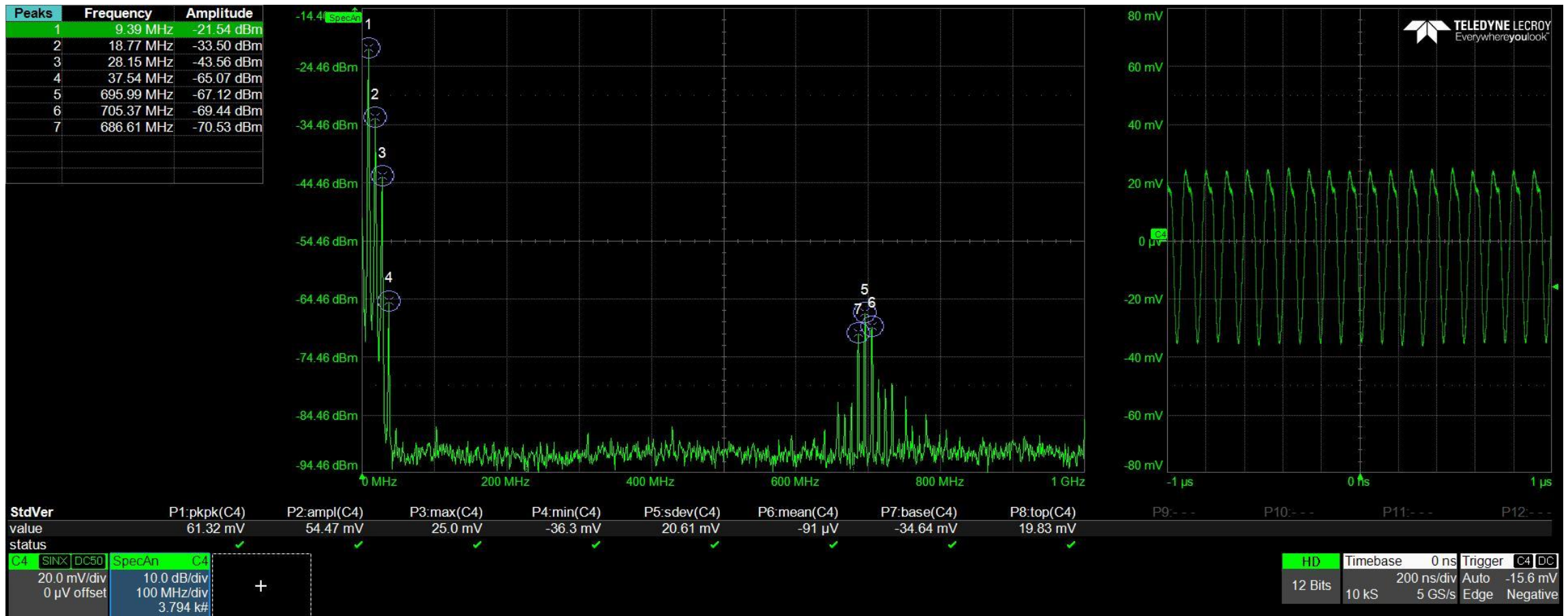
G][bU` : fYe i YbWm`GdYW hf i a

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



G][bU` : fYe i YbWm'GdYW hf i a

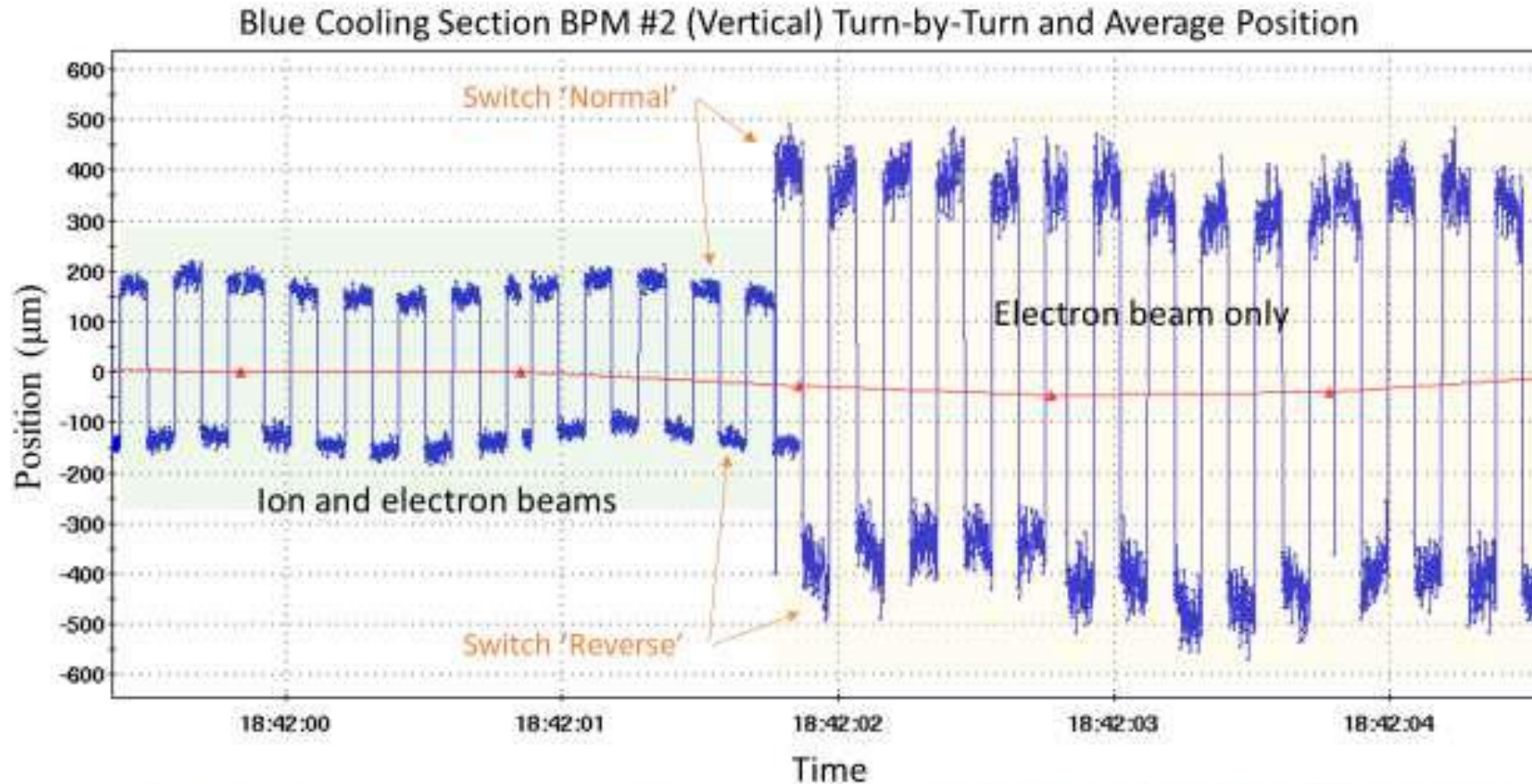
- Train of 704MHz electron macro-bunches through low-pass filter : 1GHz span



@9FY7 9 | dYf]YbWY' k]h \ ' 6DA'G k]hW \]b [

- 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)

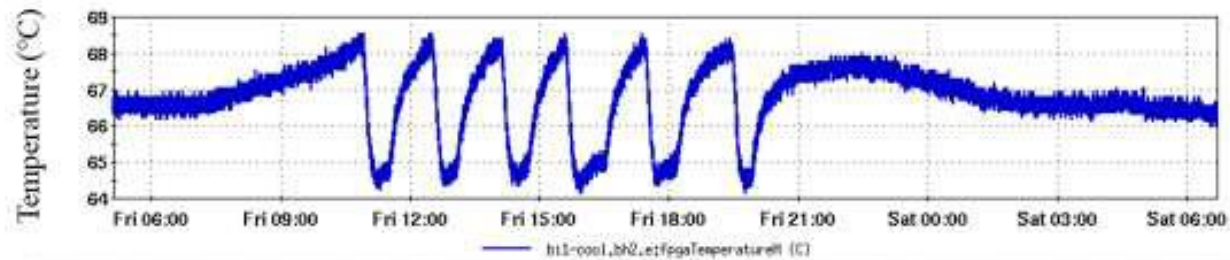
@9FY7 =cb' jg" 9`YWhfcb' 8jZZYfYbWYg



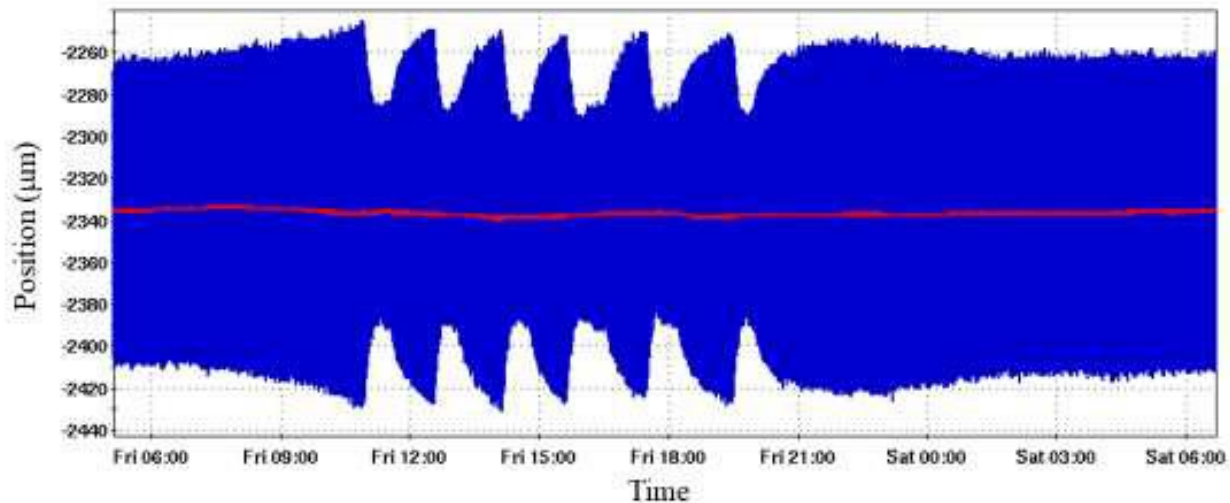
Blue Trace = Instantaneous Turn-by-Turn Position

Red Trace = 1Hz Running Average Position

@9FY7 H\Yf aU`8f]Zh'7c a dYbgUh]cb



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

Blue Trace = Turn-by-Turn Position

Red Trace = Average Position

7 cbW i g]cbg

- 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

5W_bck`YX[Y a Ybhg

- 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

FYZYfYbWYg

S. Seletskiy *et al.*, “Some Considerations about Switching BPM Channels”, BNL Report No. BNL-213694-2020-TECH, Feb. 2020.

Z. Sorrell, P. Cerniglia, R. L. Hulsart, K. Mernick, and R. J. Michnoff, “Beam Position Monitors for LEReC”, in Proc. 5th Int. Beam Instrumentation Conf. (IBIC'16), Barcelona, Spain, Sep. 2016, pp. 47-50.
doi:10.18429/JACoW-IBIC2016-MOPG08

R. L. Hulsart, R. J. Michnoff, S. Seletskiy, P. Thieberger, “Beam Position Monitor Calibration by Rapid Channel Switching”, in Proc. 10th Int. Beam Instrumentation Conf. (IBIC'21), Korea, Sep. 2021. MOPP20.