Beam Position Monitor Calibration by Rapid Channel Switching*

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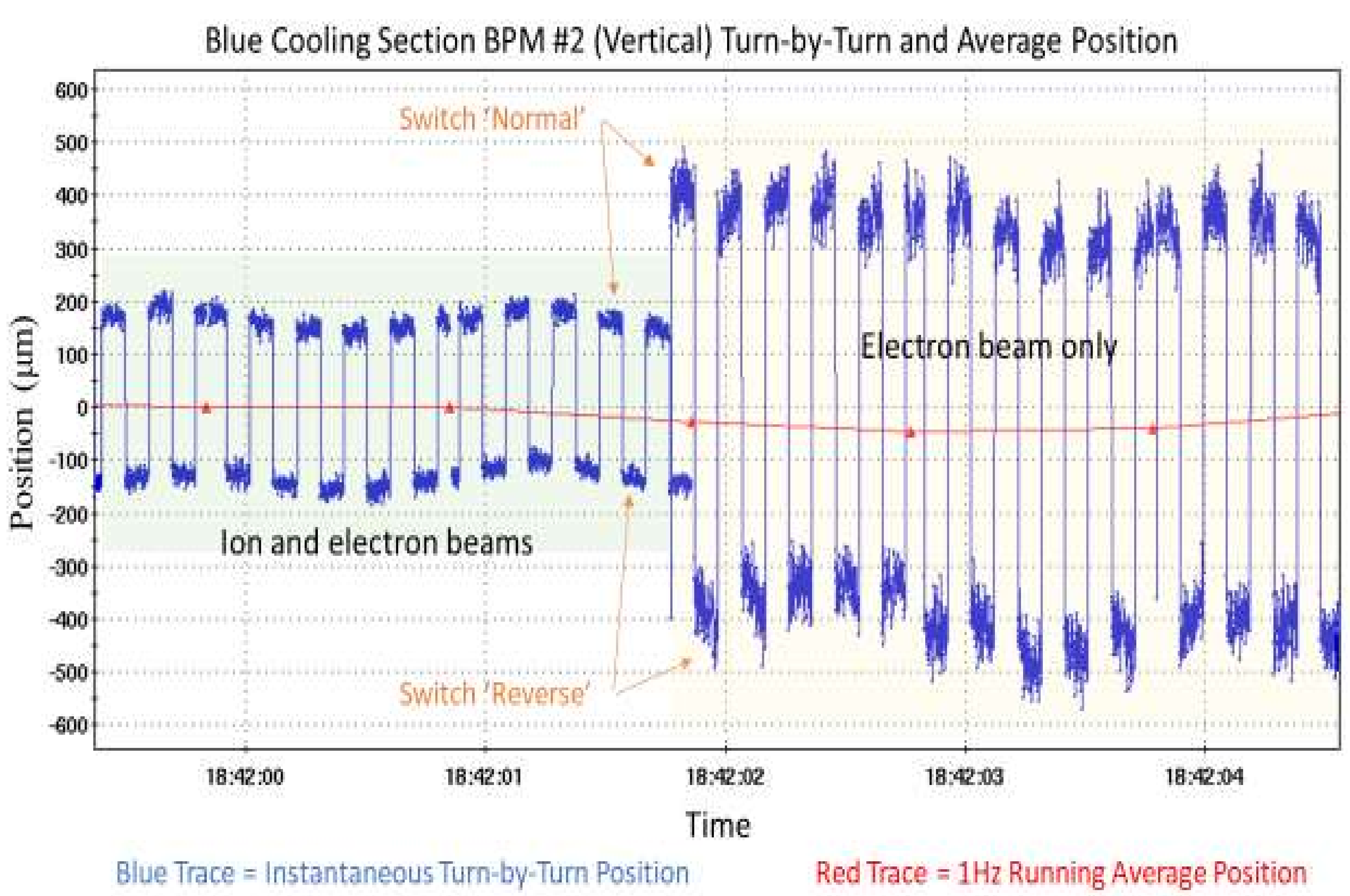
Abstract

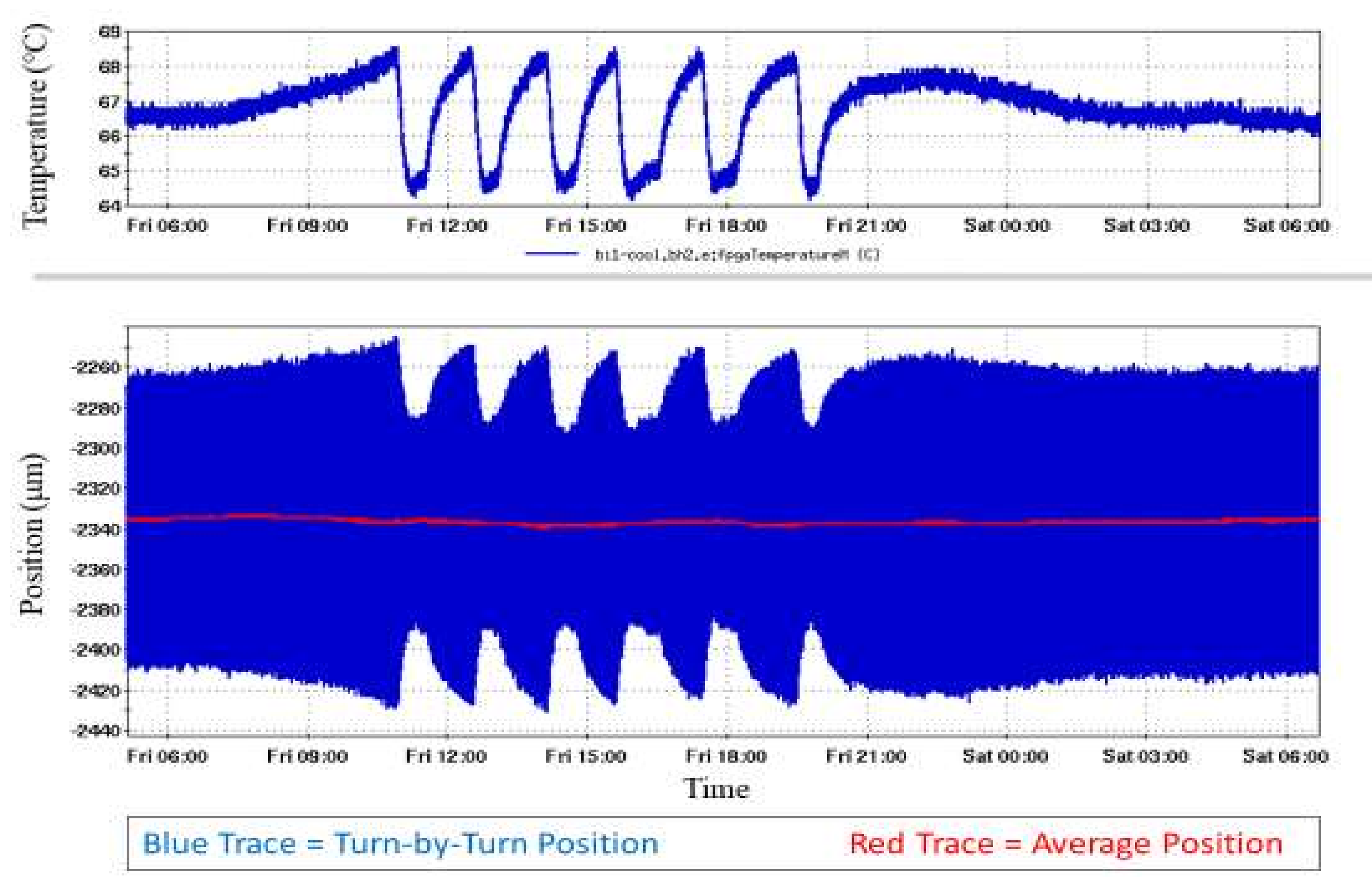
One of the requirements for low-energy RHIC electron cooling (LEReC) is a small relative angle between the ion and electron beams as they co-propagate. In order to maximize beam overlap, BPM measurements of both beams must be very accurate. Achieving this requires good electronic calibration of the associated cables and RF components, due to their inherent imperfections. Unfortunately, these are typically frequency dependent, especially in the RF filter and amplifier stages. The spectral content of the ion vs. electron bunch signals varies significantly, presenting a calibration challenge, even when using the same sampling channels and electronics to measure both beams. A scheme of rapidly swapping the BPM signals from the pickup electrodes between the two signal cables (and sampling channels), using switches installed near the BPM was implemented to combat these calibration issues. Bias in each signal path appears as an offset which has an equal and opposite component when the cables are reversed. Taking the average of the two measurements with the channels in normal and reverse positions reduces this offset error. Successful transverse cooling of the RHIC ion beam has been verified after using this switching technique to provide continuous calibration of the BPM electronics. Details of the processing hardware and switch control methodology to achieve this result will be discussed.

BPM Switching for LEReC with Ion and Electron Beams



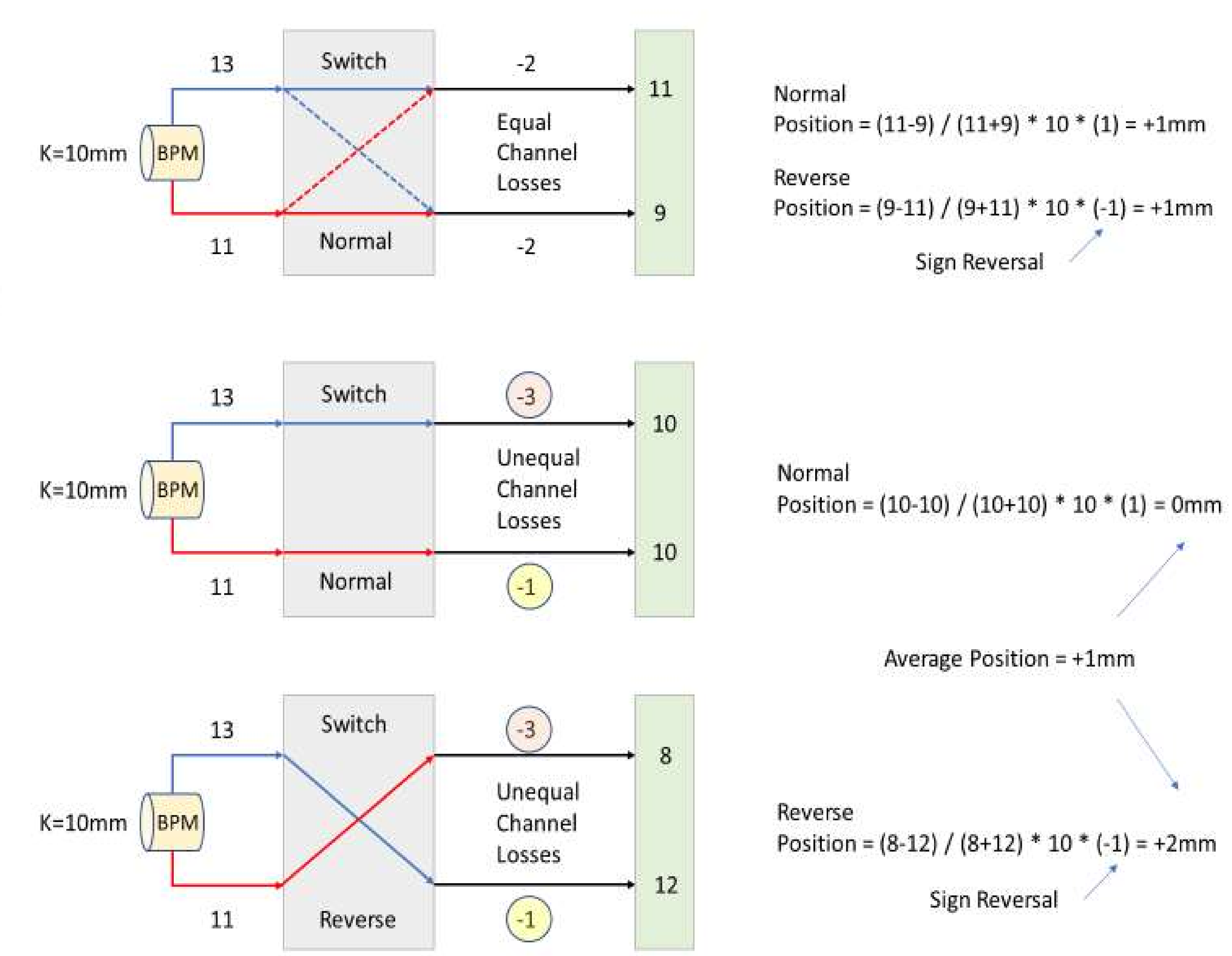
The figure above illustrates the differences in calibration very clearly during the moment that the ion beam in RHIC was removed. In this particular case the ion beam intensity was several times higher than the electron beam, so that it dominated the BPM response when both beams were present (therefore the response shown on the left is nearly identical with ion beam alone). When the ions were removed it is evident that the position appears to have shifted by ~200µm when looking at the turn-by-turn data in either switch position. The average of these two positions remains the same however, which illustrates that this offset comes from a source downstream of the switches, and not the beams themselves. This was further verified by the fact that transverse cooling was evident (using other instrumentation) when the beams were centered based on these BPM measurements. Note that the time axis in this figure is not continuous – only 1024 turns are reported each second, despite the revolution frequency of ~76KHz. The jumps in the position correspond to changing the switches every 100 turns.

Temperature and Drift Compensation



By running the switching in this continuous mode, long-term drifts due to thermal effects are also compensated for. Any changes in attenuation in the long cables running out of the tunnel due to temperature will be averaged out by this same method. In addition, thermal effects within the electronics, both in the filtering stages and amplifiers, also benefit from the same averaging. Figure 4 shows the result when a test signal was applied to a LEReC BPM where the envelope of the turn-by-turn data can be seen to change by ~40µm as temperature is changing (top plot) by ~4°C due to air conditioner cycling in the equipment building. The average position (red trace) however remains almost unaffected.

Switching Example Illustration



Any difference between A and B gets inverted when the switch position is changed, however, any difference that appears after the switch between 1 and 2 will remain unaffected. Since the arrangement of PUE's A and B are related to the sign convention of the accelerator, the calculated position needs to be inverted in sign when the switch is in the reverse position, because the PUEs are now reversed with respect to the beam direction through the BPM. By inverting the calculation when the switch is in the 'Reverse' position, the true position produced by the beam will remain correct in sign. The offset that exists due to differences between paths 1 and 2 will also change sign, and so appear as an equal but inverted offset when combined with the true position from the BPM. This has the effect of producing two positions, one equal to 'true position + electronic offset' and the other 'true position – electronic offset'. By observing this envelope one can separate the beam position from the electronic offset. In addition, by rapidly switching back and forth, the mean of these two measurements will remove the offset, and only include the true position.

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