SL-MD Note

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Analysis of turn by turn data for the SPS beam-beam wire experiment

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Summary

This is a draft report summarising briefly the preliminary analysis undertaken on the turn by turn data recorded during the SPS during the beam beam long range wire experiment.

1 Introduction

2 Data preprocessing and BPM statistics

Eight sets of turn-by-turn data were recorded with the 1000-turn system during the MD on September 3rd. The first four were taken without wire excitation and the rest with a current of 67 A in the wire. For each group of data (with and without excitation), the beam was kicked vertically with increasing amplitude, giving a displacement of 2, 4, 6 and 8 mm at the location of the kick (**is that true?????**). During the whole data acquisition, a 7 mm bump was applied to the beam at the location of the wire.

All data were first pre-processed in order to remove the closed orbit. Then, it was “cleaned” by removing the BPMs with bad readings. Finally, it was frequency analysed using a MatLab version of Laskar’s NAFF algorithm [1].

In figure 4, we plot the the horizontal and vertical rms positions (taken over all the BPM) before and after throwing away the “bad” BPM. Note the strange shifting of the kick timing for three acquisitions (4, 6 and 8mm kick without wire excitation)

The spikes in the raw data, are due to the fact that some BPM give from time to time unnaturally high values in the measured transverse position. These values can be as large as a factor of five with respect to the extremities of the oscillation envelope. This is not a continuous behaviour, i.e. one can observe spikes appearing when plotting the position over time. These ”spikes” sometimes appear even when the beam is not excited, i.e. in the first few tens of turns before the kick.

More details can be seen in figures 3 where all the ”bad” sets of BPM data are plotted (horizontal and vertical) in the case of a 2mm kick, without wire excitation. They can be roughly divided in three categories:

- data characterised with spontaneous high values (spikes) The horizontal BPMs with this behaviour are: 11833, 30409,30609, 30809, 31009, 31209, 31609, 31809, 32009, 32809, 33009, 33609, 40409, 40609, 42409, 42809, 43009, 43609, 51009, 61009. All apart the first one are of the BPH type (the first one is a double one - BPDH); and the vertical ones (all of BPV type): 11109, 30509, 32109, 32909, 41109, 42109, 42309, 42909, 43509, 50909.

- data with abnormal decoherence behaviour or high noise: The horizontal BPMs with this behaviour are: BPHA21805 and BPH30209; and the vertical ones: BPV10709, BPVD11906, BPV12709, BPDV11833, BPVA21931, BPV22107, BPV22509, BPCN22709, BPVA21607, BPVA21805, BPV31909, BPV32509, BPV33309, BPCEV41801, BPV50109, BPV52309, BPVA61931, BPV63309, BPDV61607, BPVA61805.

- data with very low signal: BPCEH41931, BPH62609, BPH62809 and BPV50509.

In figure 4, we present an histogram with the percentage of BPM versus the number of failures (from 1 to 8) for all the data sets analysed. Around 60% of BPMs provide always good readings and around 20% of them give “noisy” data in all analysed cases. The second plot presents the distribution of failures around the ring. There is an unexplained concentration of failures around the 3rd sextant, as it can be also seen by table 1, where we present the failure percentages for all BPMs around the ring (neglecting the ones that gave no failure). This table may help the BPM experts to trace down the potential problems. According to preliminary discussion, the noise may occur when the timing of the gate is marginal, i.e. when the gate is not well centred on the beam. Concerning the enlarged pick-ups (BPHA, BPVA, BPDH, BPDV, BPCEH, BPCEV), the noise is due to the larger aperture and apparently there is not much to do.

3 Beam decoherence

In figures 5 we plot the vertical rms position from all the “clean” BPM around the ring, versus time, in logarithmic scale, for all measured data sets. The decoherence time decreases for all cases without wire excitation indicating that there should be some stronger detuning with amplitude in the case of the wire excitation. The decoherence difference between the two cases can be observed more easily in figure 6, where the decoherence time is plotted versus the kick amplitude for all measured data. The error bars in the estimation of the decoherence time after a exponential fit to the rms vertical position are scarcely visible (they are the size of the points). It is clear that the decoherence is faster for the cases with wire excitation. Notice also that the dependence of the decoherence on the kick amplitude is linear without the excitation which is somehow expected if there is practically no detuning with amplitude. On the other hand this is not the case when the wire is excited. In fact, the simple linear fit should not work in that case. By using a non-linear fit one may expect to estimate the detuning with amplitude.

4 Tune-shift

The average fractional tunes from all the “clean” BPM is plotted in figure 7 versus the vertical kick amplitude. The statistical error is small (the size of the points). Note that measurement of the horizontal tune-shift is possible due to coupling. The horizontal tune-shift with vertical amplitude (the cross term) has a symmetrical but opposite direction between the two cases (with and without wire). On the other hand, the situation is less clear in the case of the vertical tune-shift without the wire. The abnormal variation of the tune-shift with amplitude may be due to fluctuations of the base tune between the different cycle. In any case, the tune-shift in the case where the wire is excited is quite well defined and opposite direction with respect to the horizontal one.

Finally, in the figure 8, the vertical tune as computed in all BPMs is plotted versus the BPM index (starting from the first (vertical) BPM of the first sextant i.e. BPV10109). Note the strange periodic jumps appearing in the case of 2mm kick without wire and 8mm kick with wire. These jumps appear periodically in the the tunes extracted for the first 5 vertical BPM of each sextant (BPV*01* to BPV*09*). The linear optics functions for these BPMs do not provide any clue about this strange behaviour.

5 Work to be done

- Decoherence analysis
    - Amplitude and phase analysis
    - Tune analysis by using a sliding time frame
    - Spectrums for all cases (resonance driving terms
    - Tunes from all symmetrical BPMs
    - Theoretical evaluation of tune-shift and driving terms and comparison

References

[1]

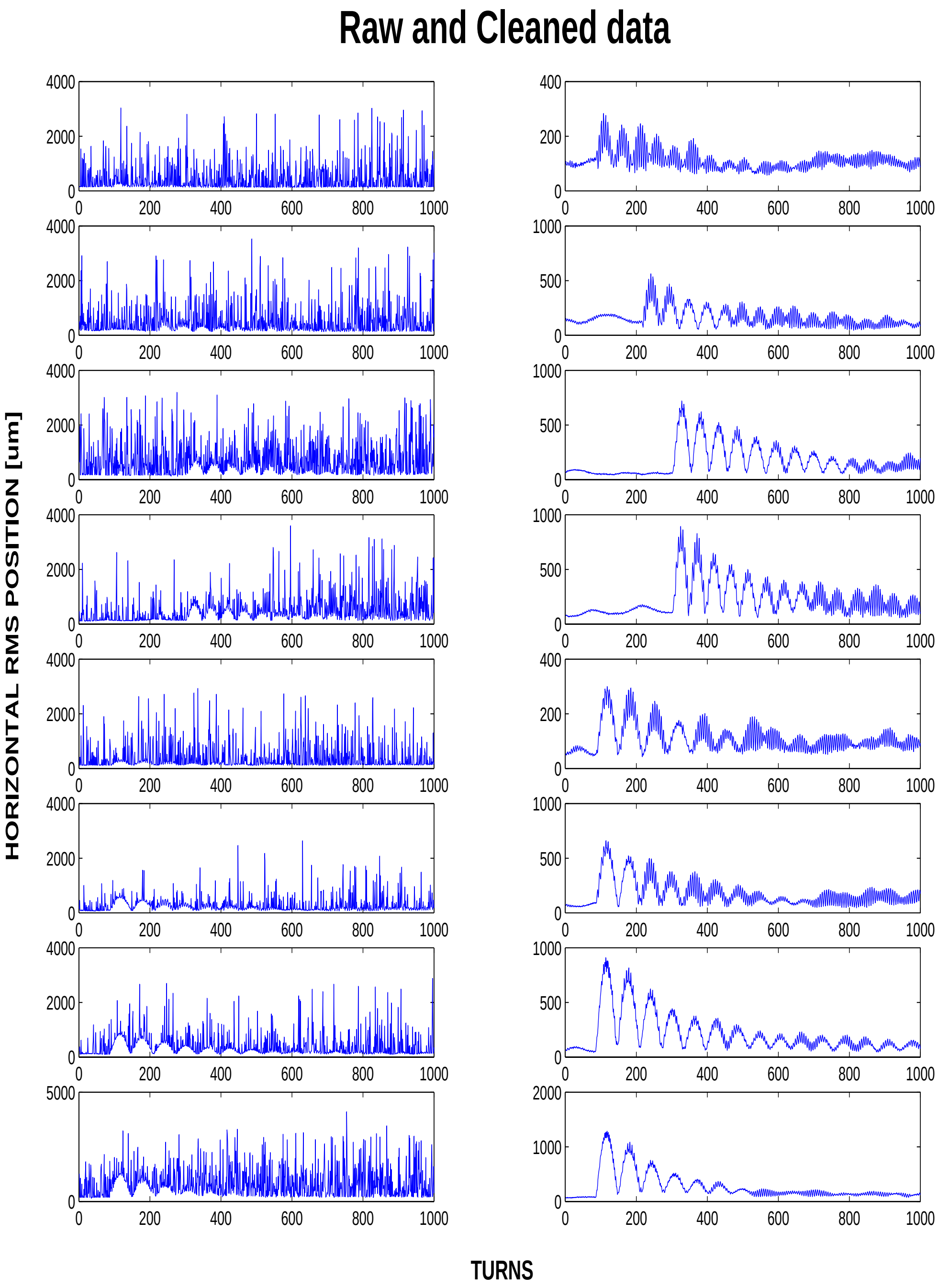

Figure 1: Raw (left) and cleaned (right) horizontal RMS positions.

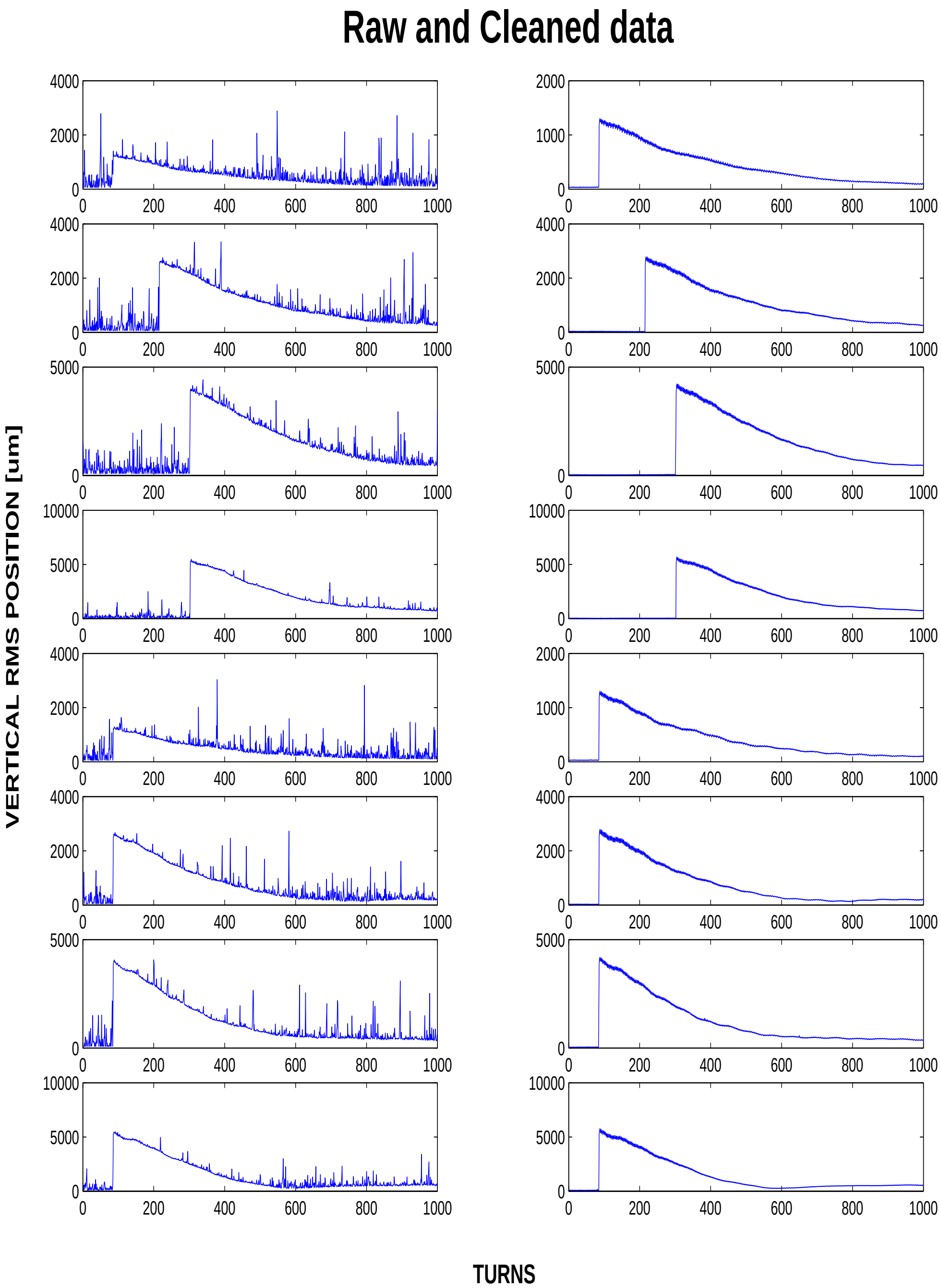

Figure 2: Raw (left) and cleaned (right) vertical RMS positions.

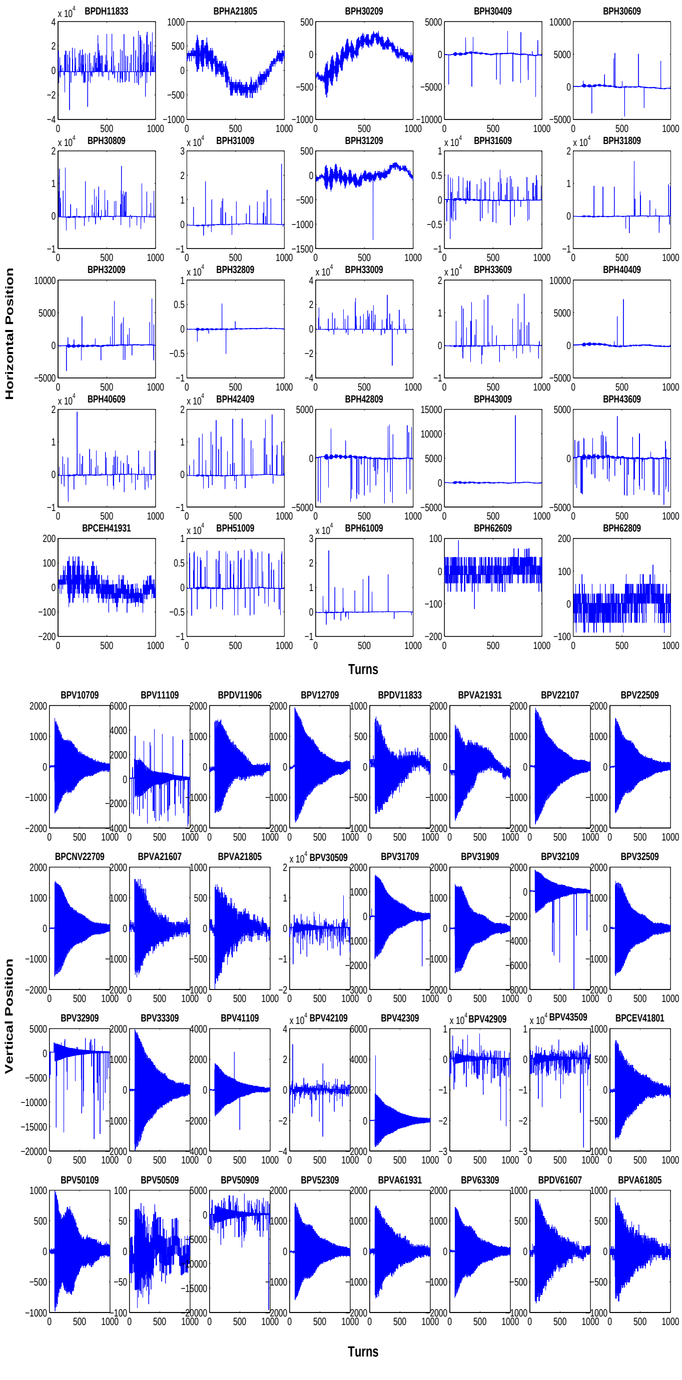

Figure 3: Horizontal (top) and vertical (bottom) “bad” BPM readings for a 2mm kick without wire excitation.

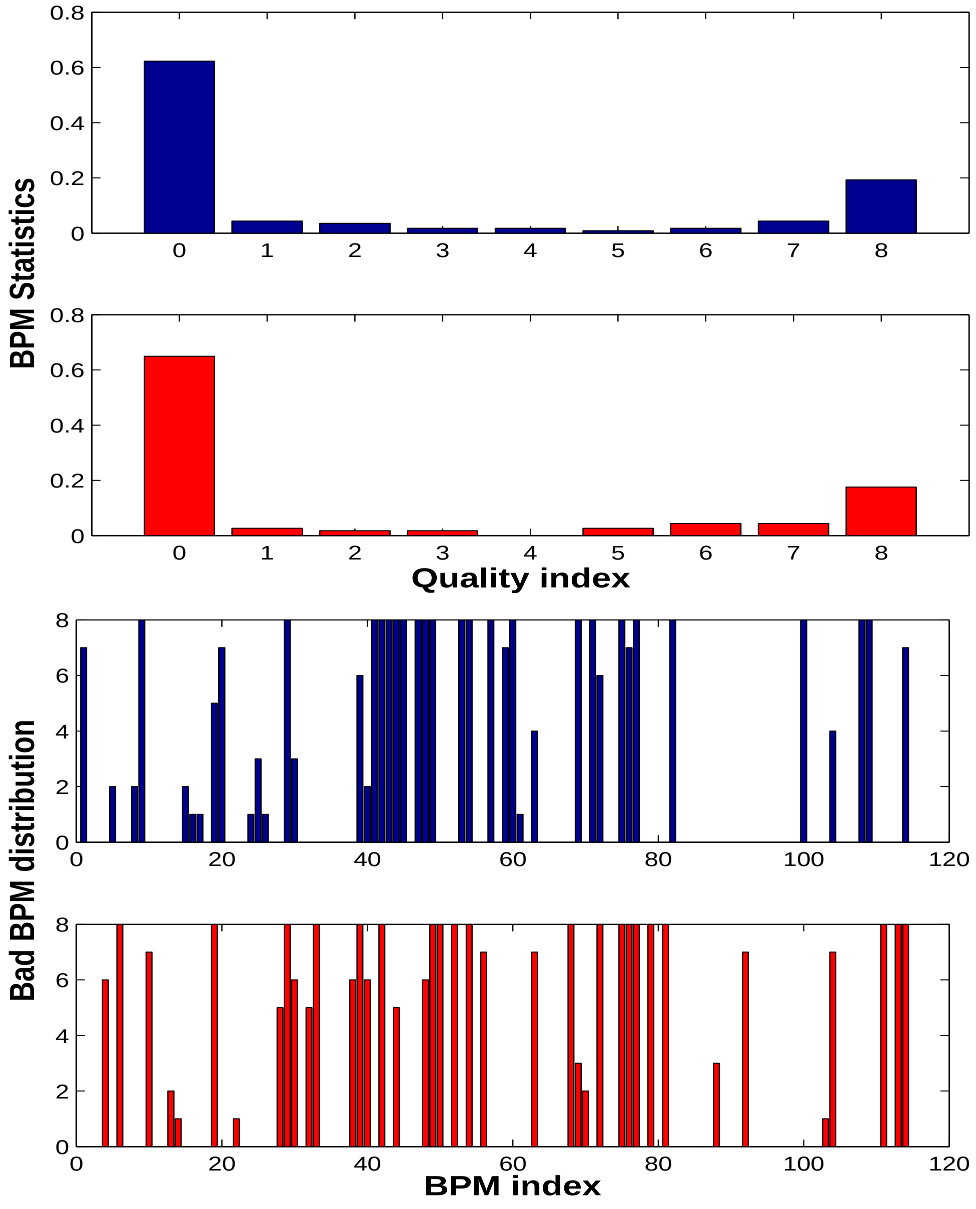

Figure 4: Histogram of failures (top) and statistics of all horizontal (blue) and vertical (red) BPMs around the SPS ring.

Table 1: List of all horizontal and vertical BPMs and the corresponding failure percentage.

BPM name	Failures [%]	BPM name	Failures [%]
BPH10209	83	BPV10309	8
BPH11009	25	BPV10709	75
BPH11606	25	BPV11109	100
BPDH11833	100	BPDV11906	83
BPH13009	41	BPCNV12509	33
BPH13209	25	BPV12709	8
BPH13409	16	BPDV11833	100
BPDH11906	66	BPV20509	8
BPCNH12509	91	BPV20709	8
BPH20809	8	BPVA21706	66
BPH21009	25	BPVA21931	91
BPH21209	8	BPV22107	83
BPHA21805	100	BPV22509	66
BPH22009	50	BPCNV22709	100
BPH23609	8	BPVA21607	83
BPHA21706	75	BPVA21805	100
BPH30209	33	BPV30109	75
BPH30409	91	BPV30509	100
BPH30609	91	BPV30909	66
BPH30809	91	BPV31109	8
BPH31009	100	BPV31709	66
BPH31209	100	BPV31909	91
BPH31409	8	BPV32109	91
BPH31609	100	BPV32509	91
BPH31809	100	BPV32909	100
BPH32009	100	BPV33309	83
BPH32209	8	BPV41109	91
BPH32609	8	BPV42109	100
BPH32809	100	BPV42309	41
BPH33009	100	BPV42509	25
BPH33609	91	BPV42909	100
BPH40409	75	BPV43509	100
BPH40609	100	BPCEV41801	100
BPH40809	8	BPV50109	100
BPH41209	50	BPV50509	100
BPH42409	100	BPV50909	100
BPH42809	100	BPV52309	50
BPH43009	83	BPV53109	83
BPH43609	100	BPDV61731	25
BPCEH41706	91	BPVA61931	91
BPCEH41931	91	BPV63309	91
BPH51009	100	BPDV61607	100
BPH51409	8	BPVA61805	100
BPH61009	100		
BPDH61607	16		
BPHA61805	41		
BPH62609	100		
BPH62809	100		
BPDH61731	83		

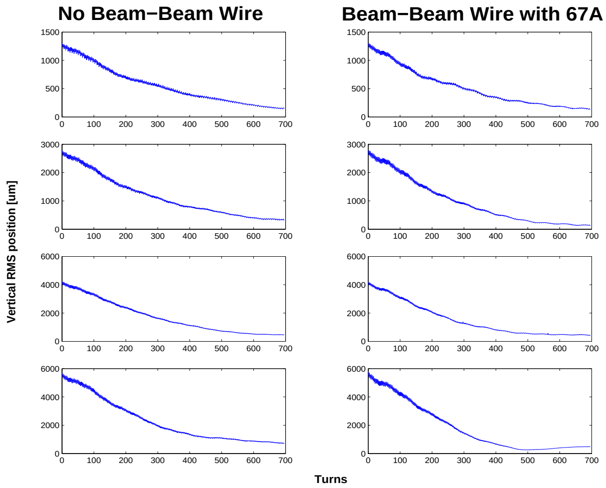

Figure 5: Vertical RMS position for all sets of data without (left) and with (right) wire excitation.

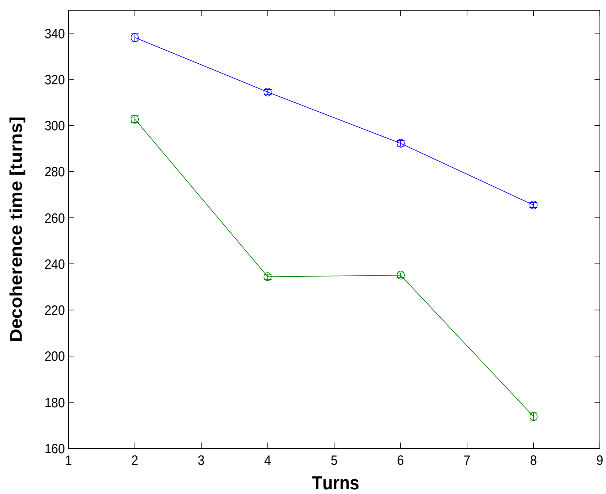

Figure 6: Vertical decoherence time versus kick amplitude without (blue) and with (green) wire excitation.

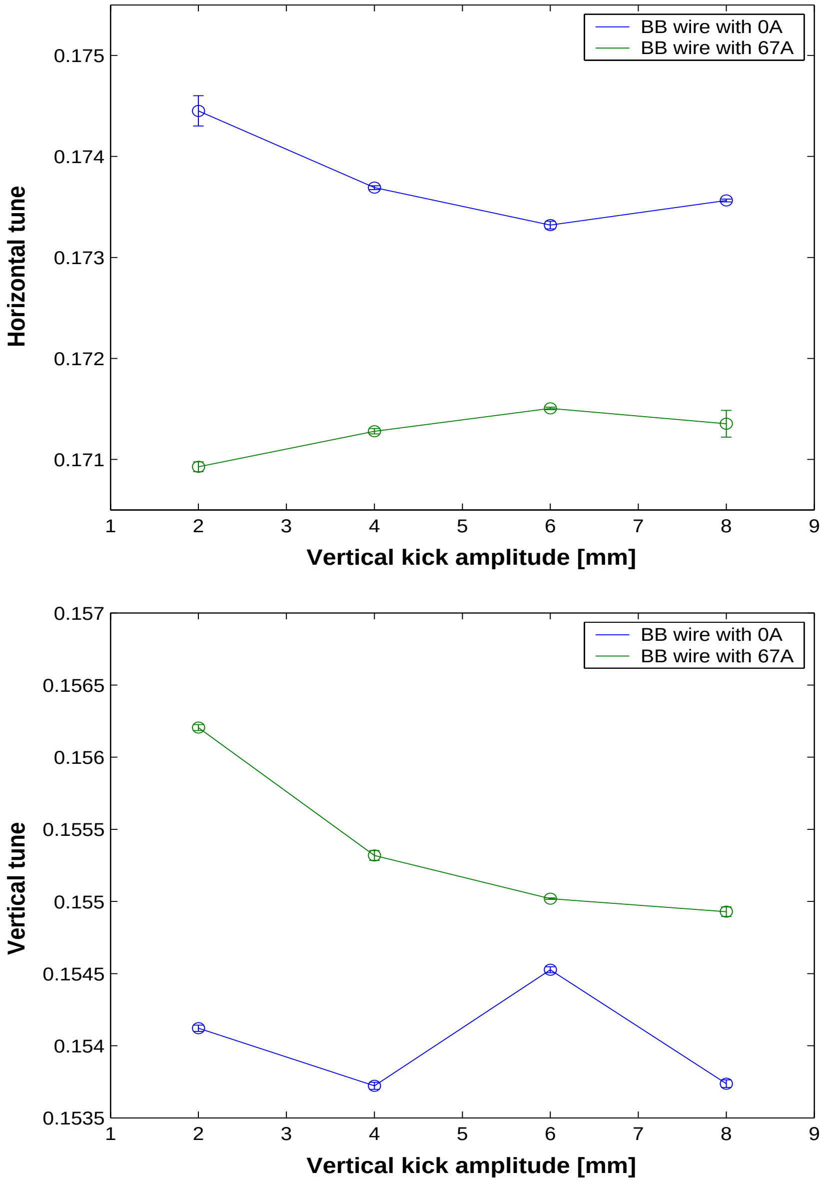

Figure 7: Average horizontal and vertical tune-shift.

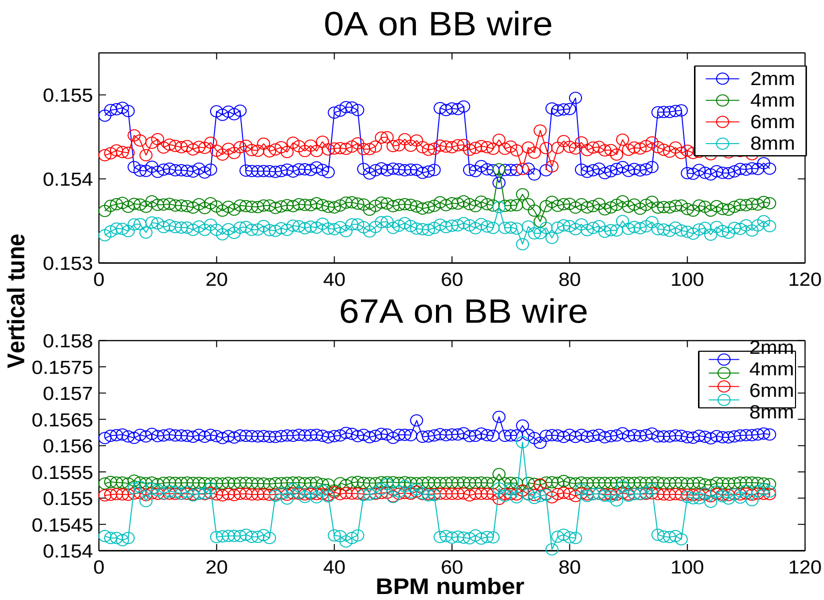

Figure 8: Vertical tune-shift from all measurements.