International Study Group on Linear Colliders

ATF nanoBPM Studies

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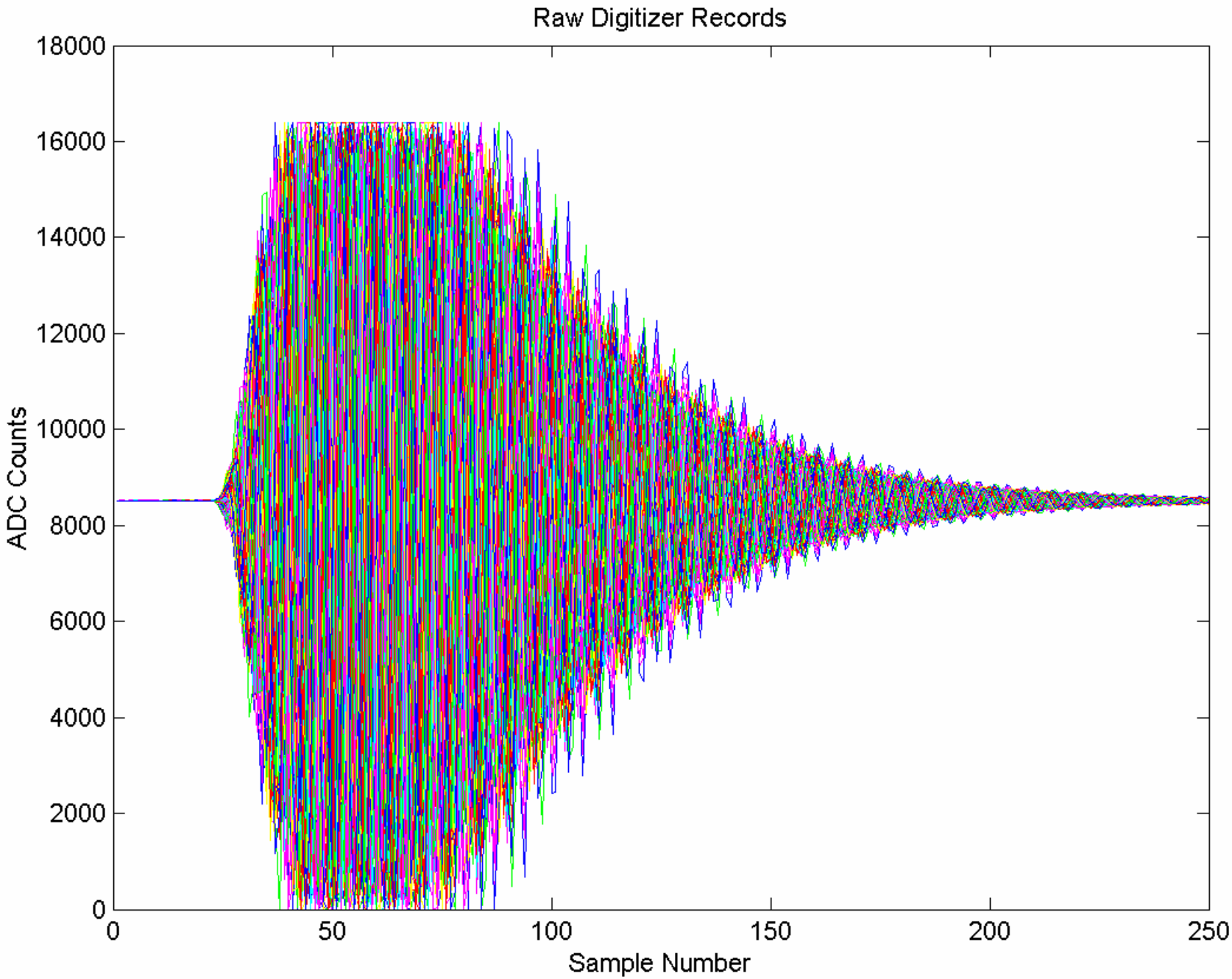
Cavity Beam Position Monitors

- 3 Cavity BPMs
  - C-band (6426 MHz nominal)
  - Dipole-mode couplers
    - Good rejection of symmetric (common) mode
  - Vogel, *et al*
- 1 Reference cavity
  - Fundamental mode at 6426 MHz
  - Phase and beam charge normalization
- Front-end electronics local to cavities
  - Low noise
  - Downconvert to 15 MHz
  - Digitized to 14-bits at 100 M samples/sec in VME
  - Final downconversion digital (in Matlab)
- All BPMs mounted on X, Y, X', Y' movers

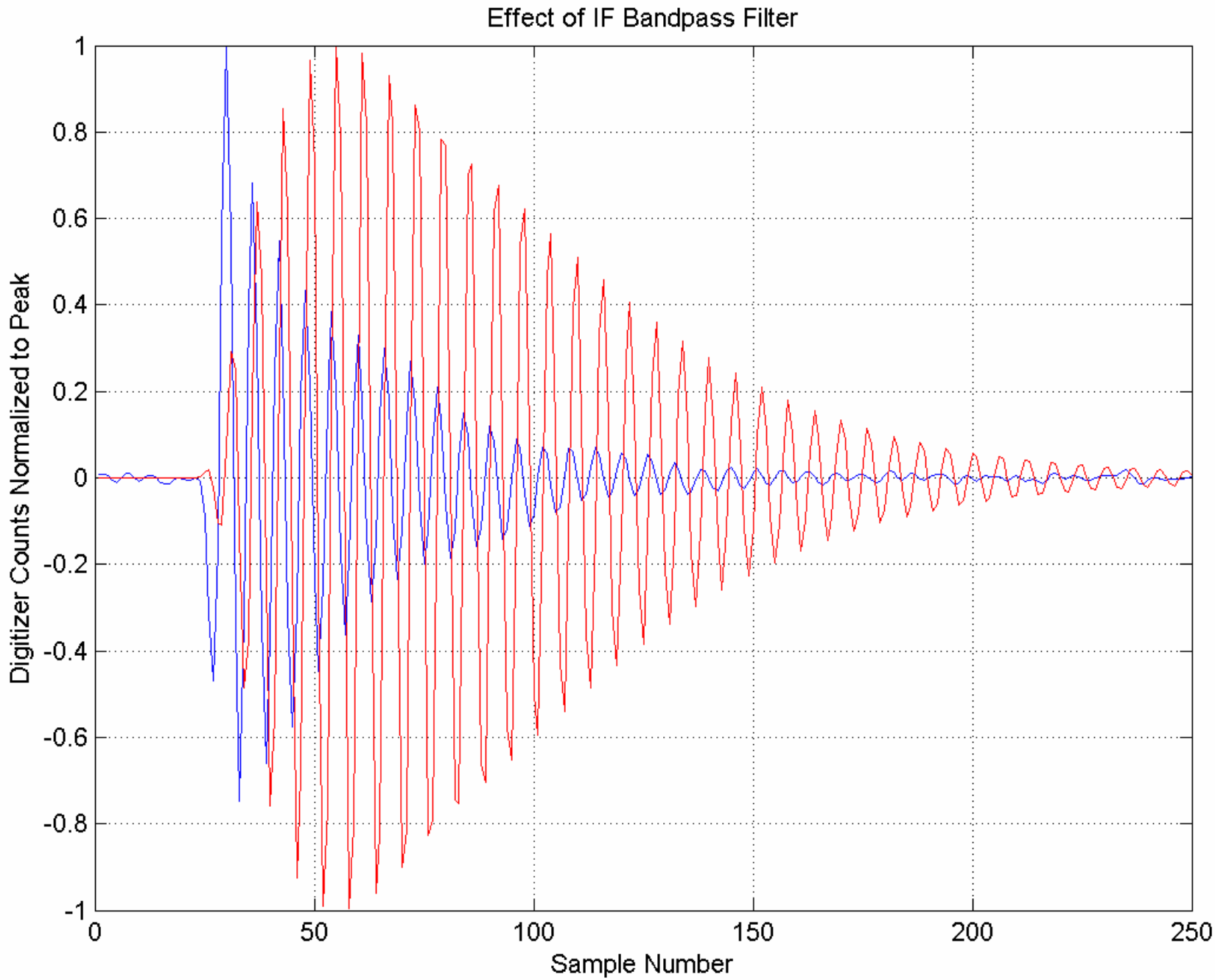

Raw Digitizer Records
ADC Counts
Sample Number
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
0
50
100
150
200
250

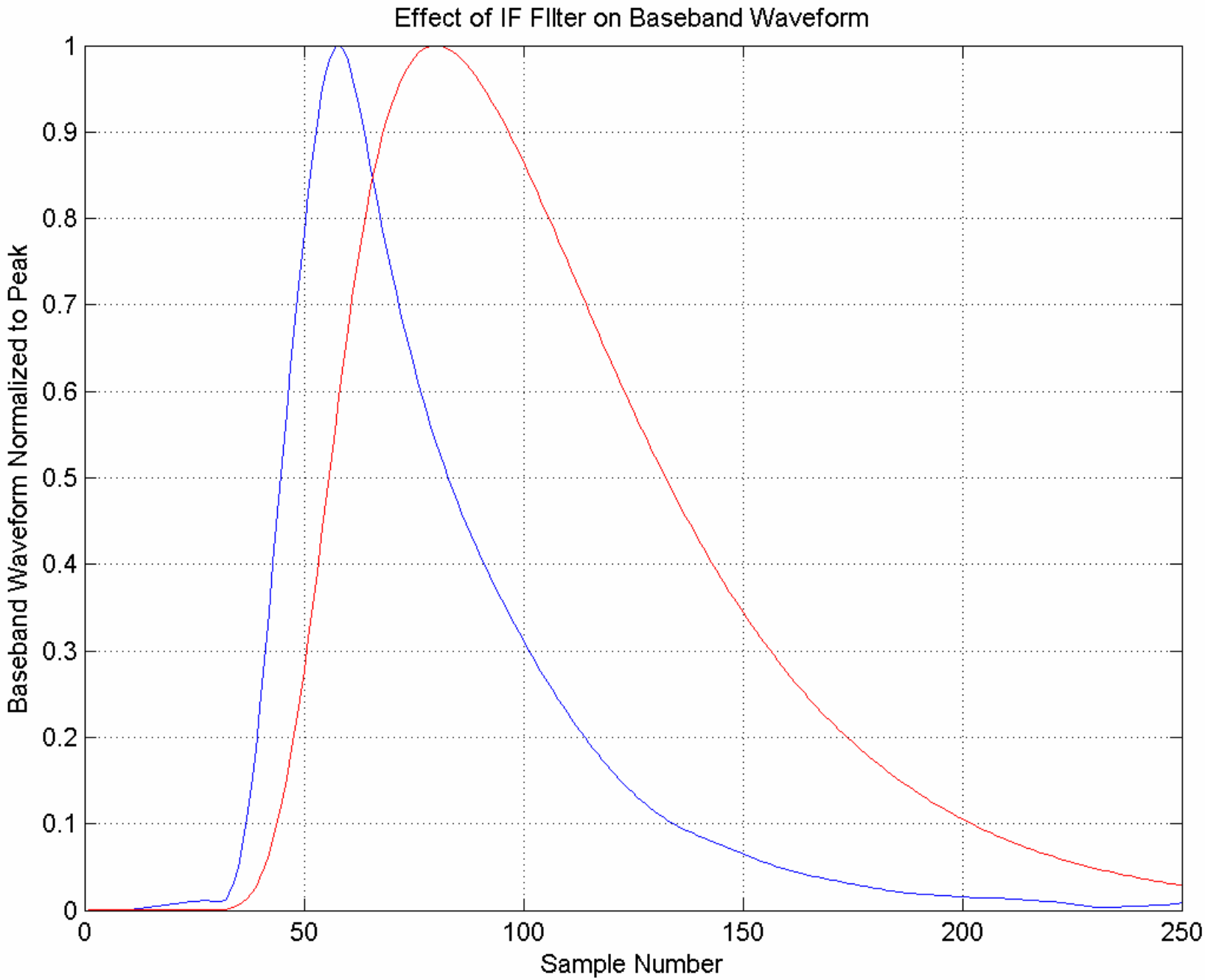
Calibration

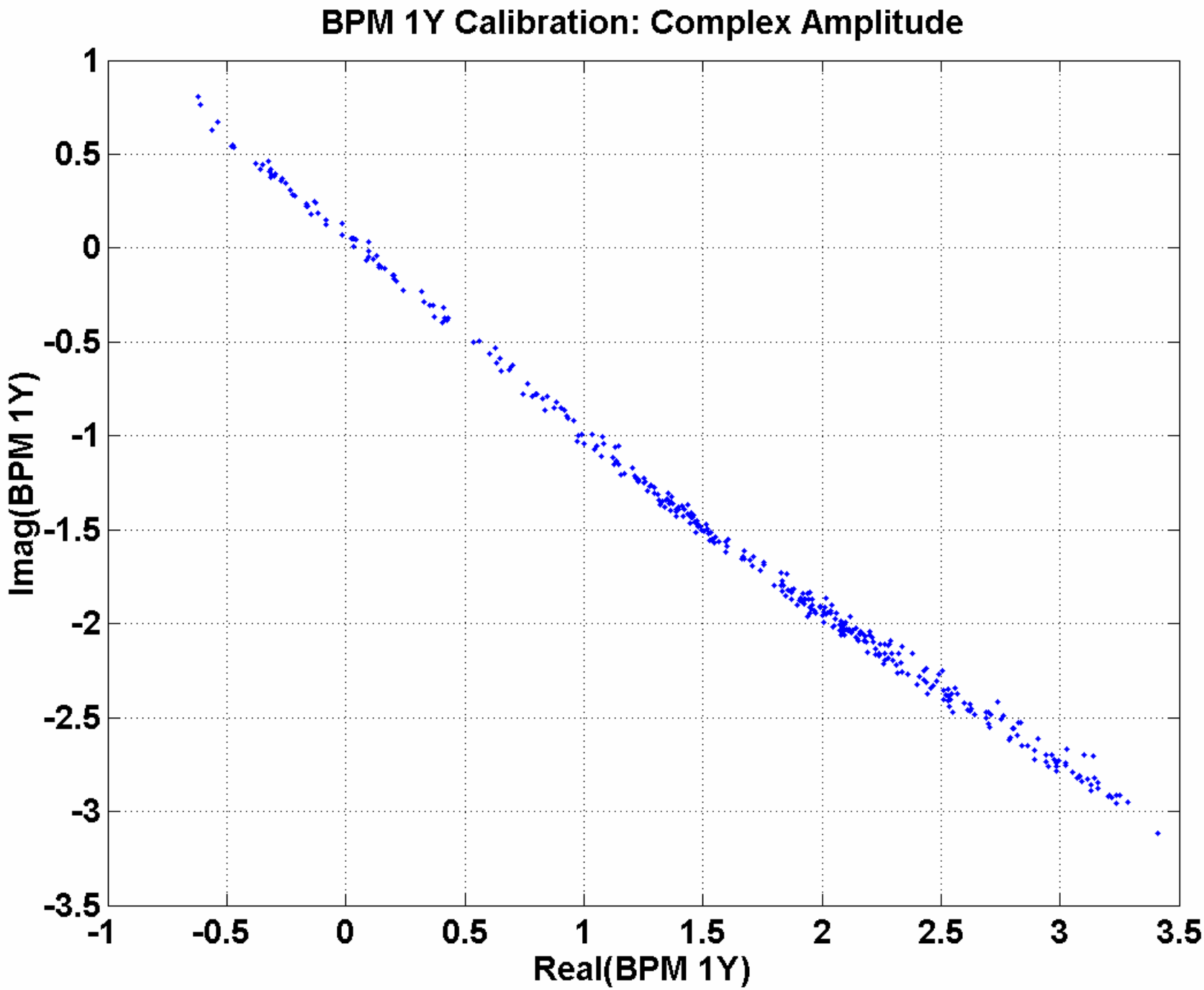
- Calibrate:
  - Exercise movers
  - Normalize BPM response to Reference cavity response
  - Fit BPM (complex) amplitude vs. mover setting
  - Yields:
    - Offset (complex)
    - Gain (complex, *i.e.* phase and gain)
- Evaluate:
  - Normalize measured BPM (complex) amplitude to reference cavity.
  - Compare each BPM to linear least-squares best fit prediction from all other BPMs

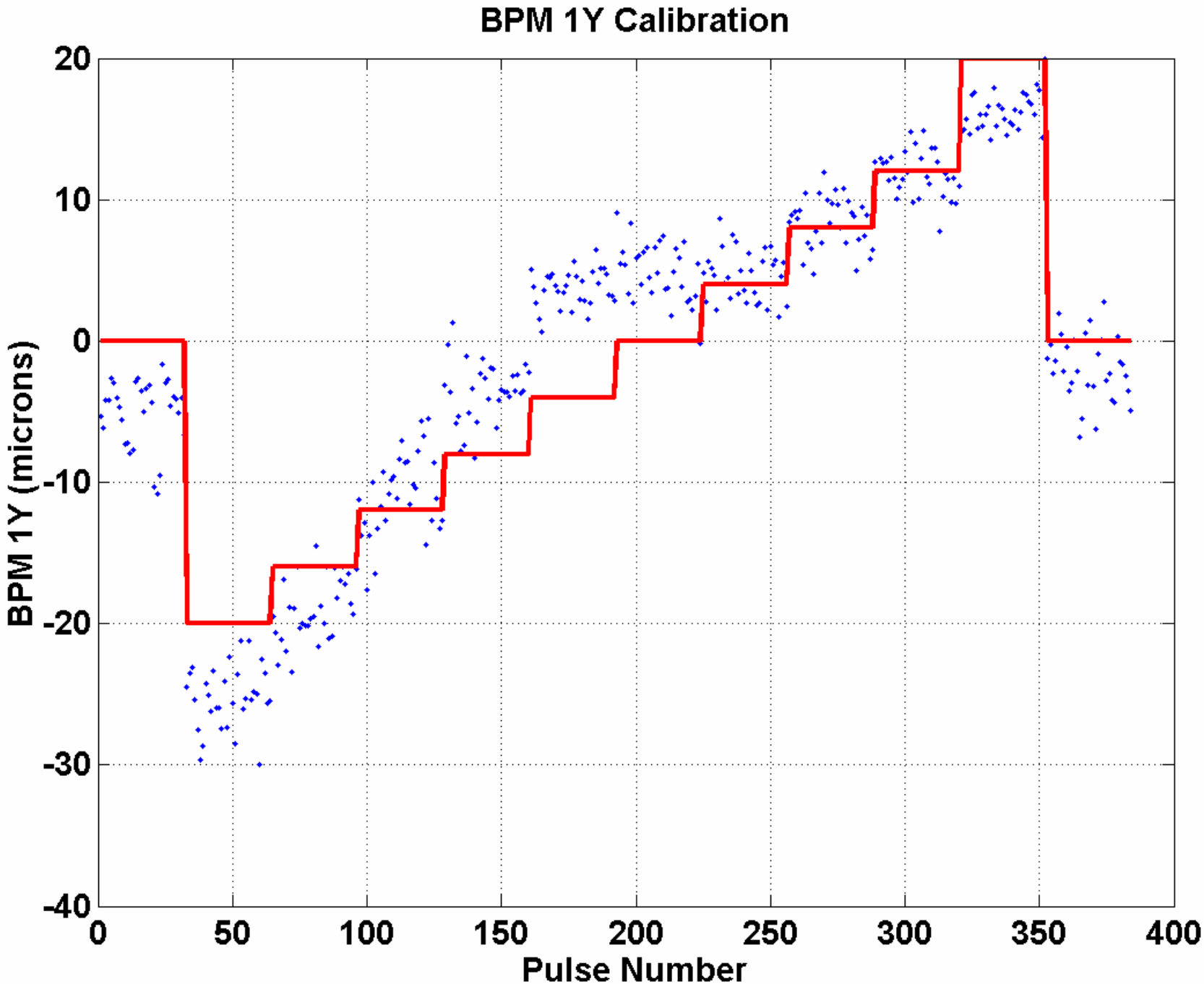
Issues

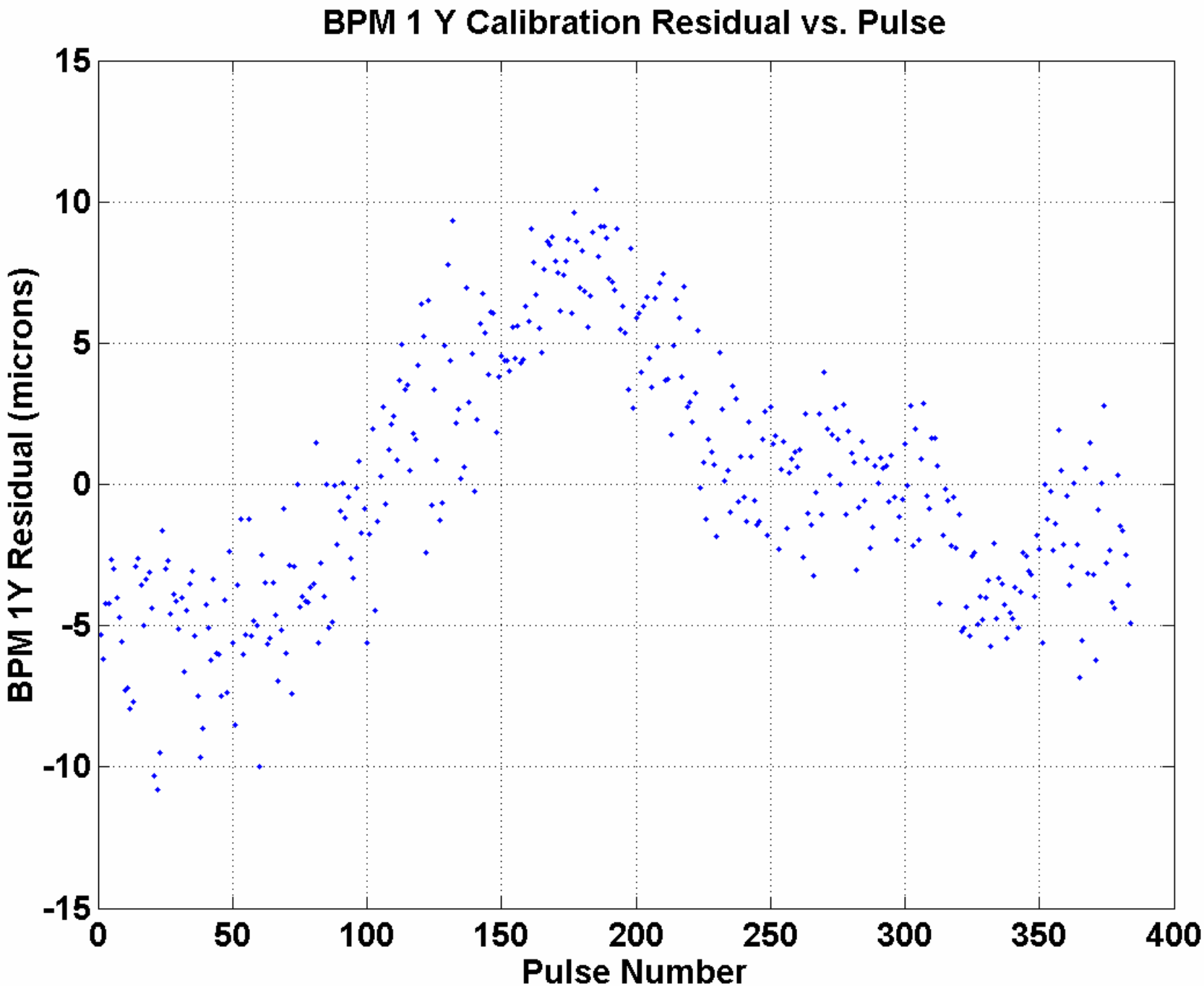
- Attempt to measure nm-scale phenomena in presence of much larger beam jitter:
  - 10 μm in X
  - Several μm in Y
- Dynamic range
- Stability
- Vibration
- Coupling (i.e. X ⇔ Y)
- Long bunch ⇔Tilt sensitivity
  - Sensitivity to tilt scales by $\omega\sigma$ with respect to position sensitivity
- Very preliminary analysis (!)
  - This data taken owl shift last Thursday

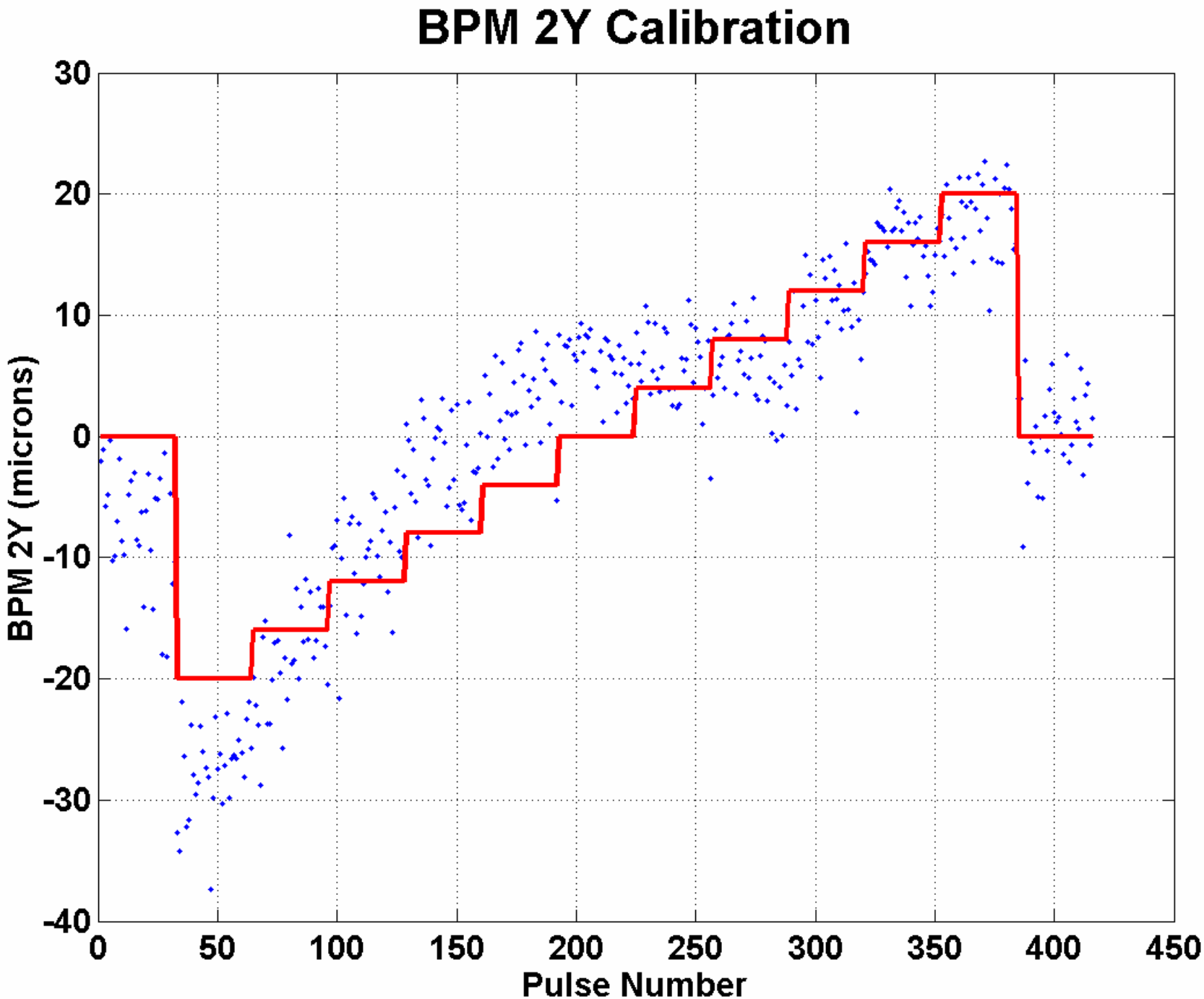

Effect of IF Bandpass Filter
Digitizer Counts Normalized to Peak
Sample Number
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
50
100
150
200
250

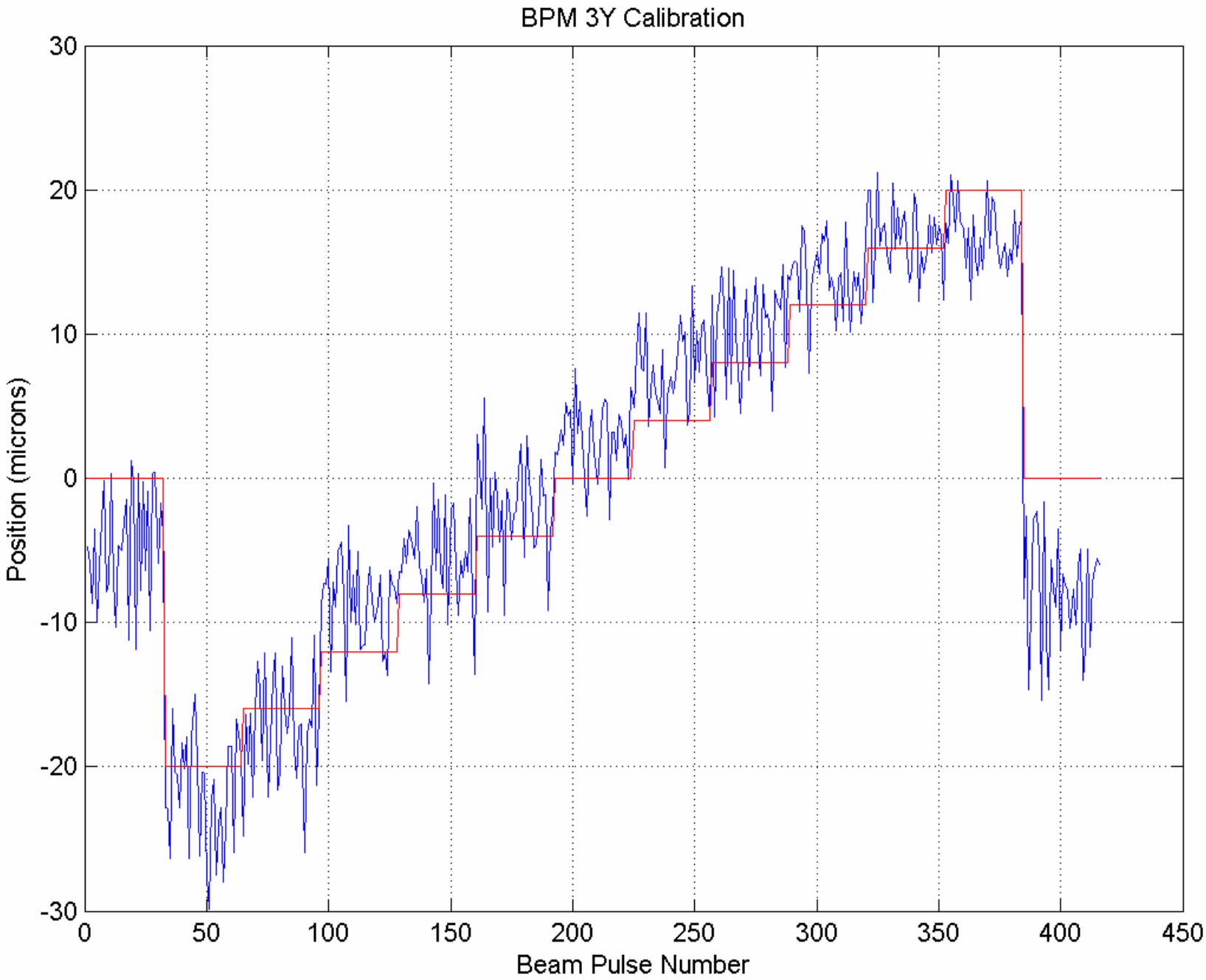

Effect of IF FIlter on Baseband Waveform
Baseband Waveform Normalized to Peak
Sample Number
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
50
100
150
200
250

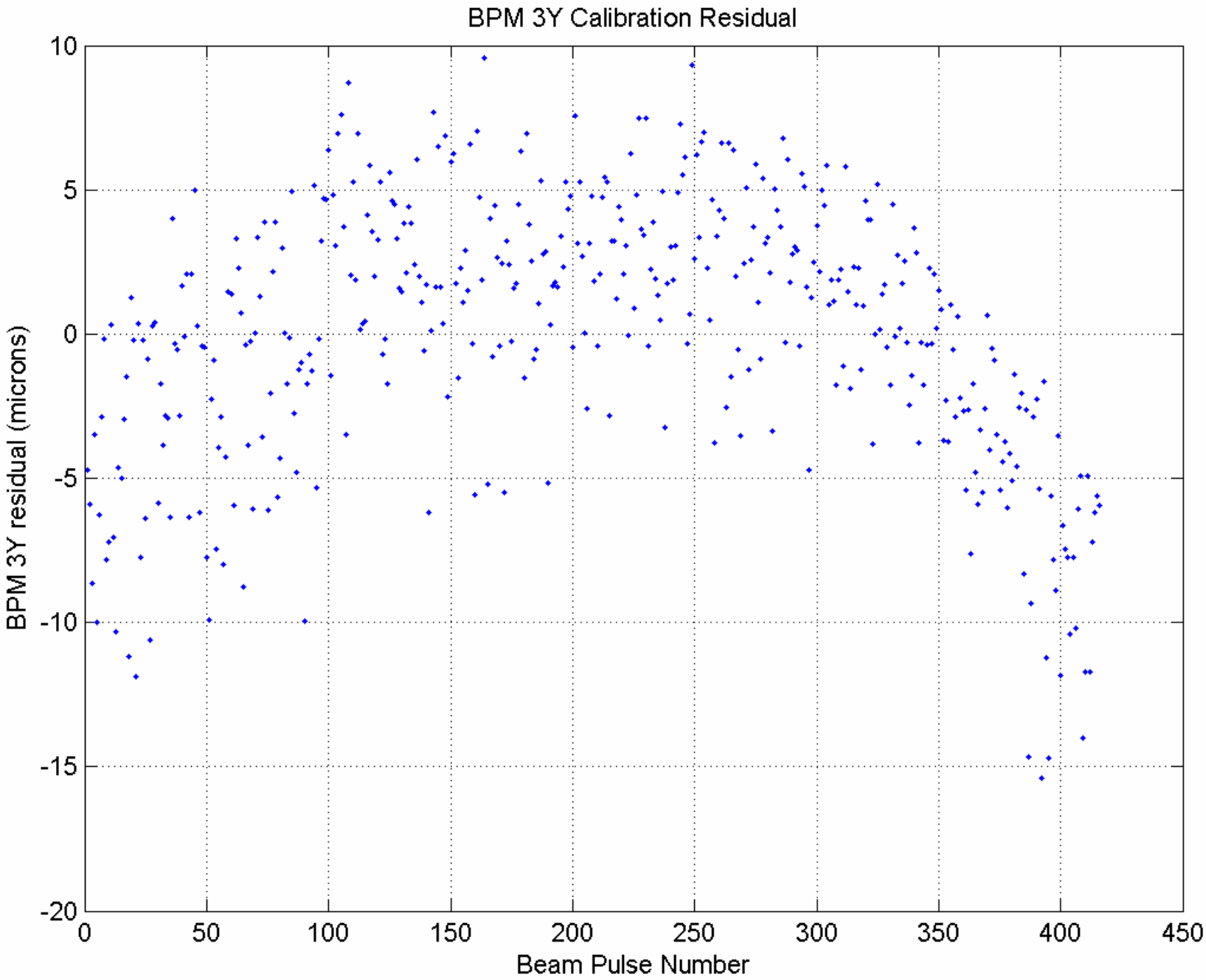

BPM 1Y Calibration: Complex Amplitude
Imag(BPM 1Y)
Real(BPM 1Y)
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-1
-0.5
0
0.5
1
1.5
2
2.5
3
3.5

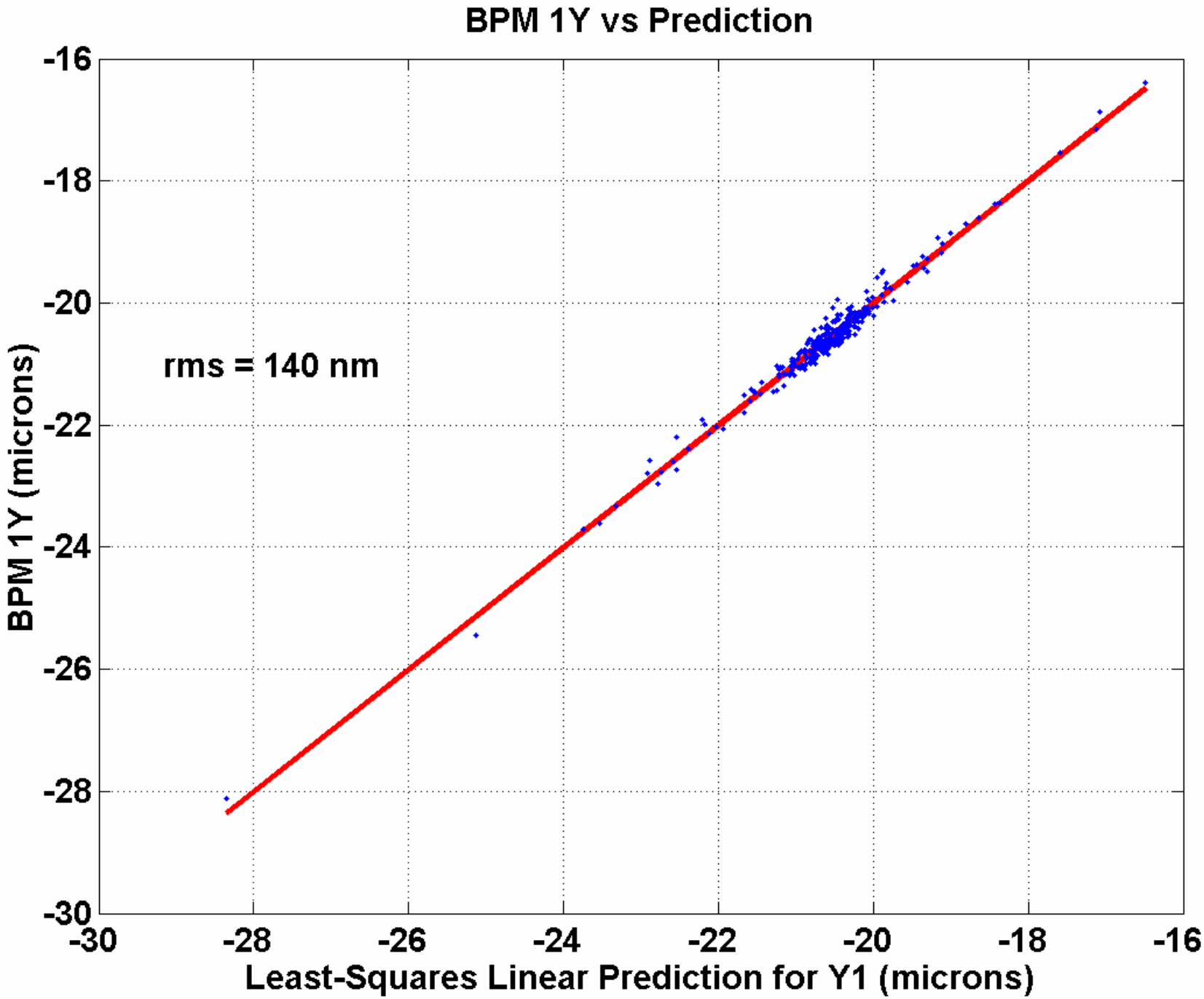

BPM 1Y Calibration
BPM 1Y (microns)
Pulse Number
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400

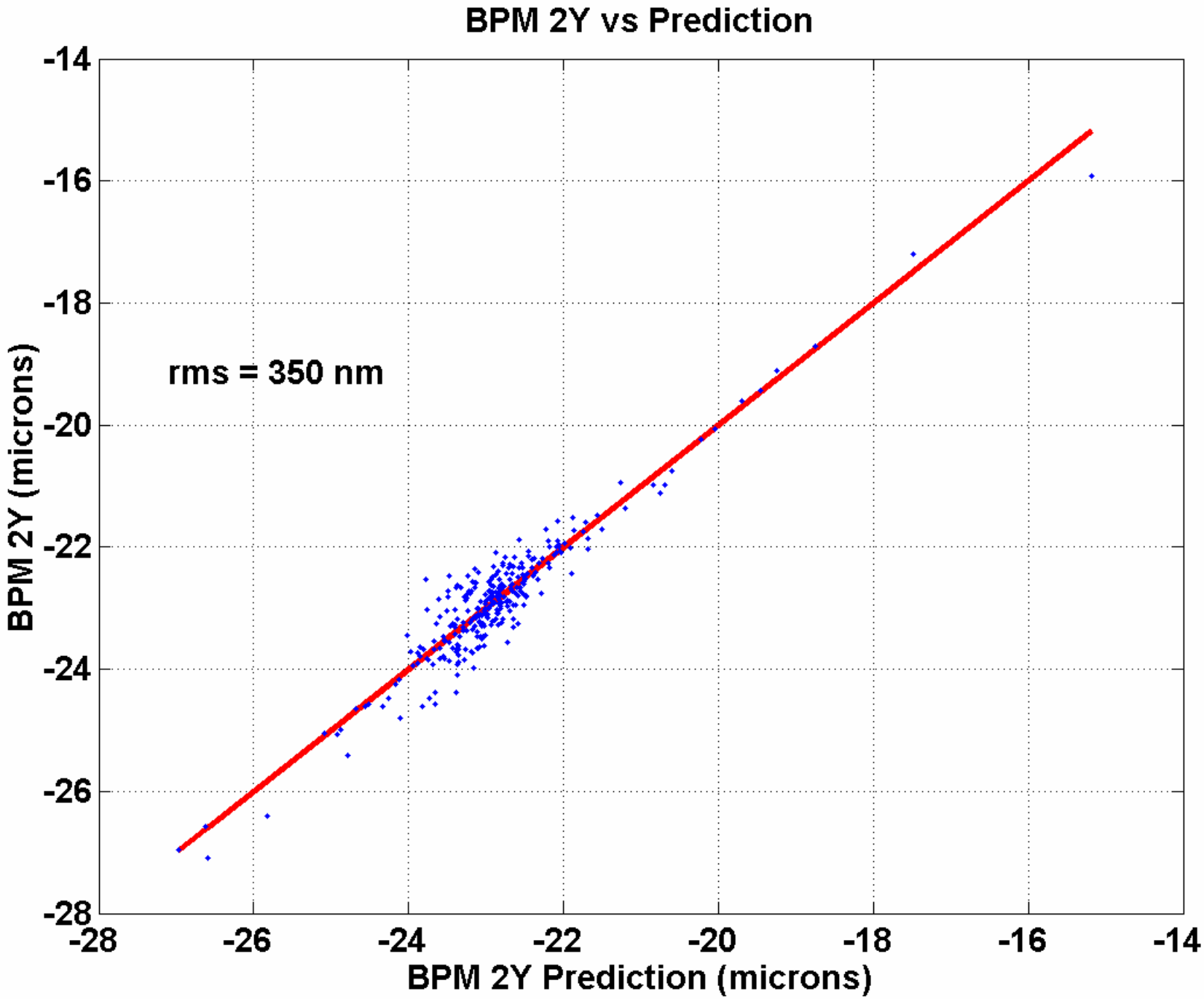

BPM 1 Y Calibration Residual vs. Pulse
BPM 1Y Residual (microns)
Pulse Number
15
10
5
0
-5
-10
-15
0
50
100
150
200
250
300
350
400

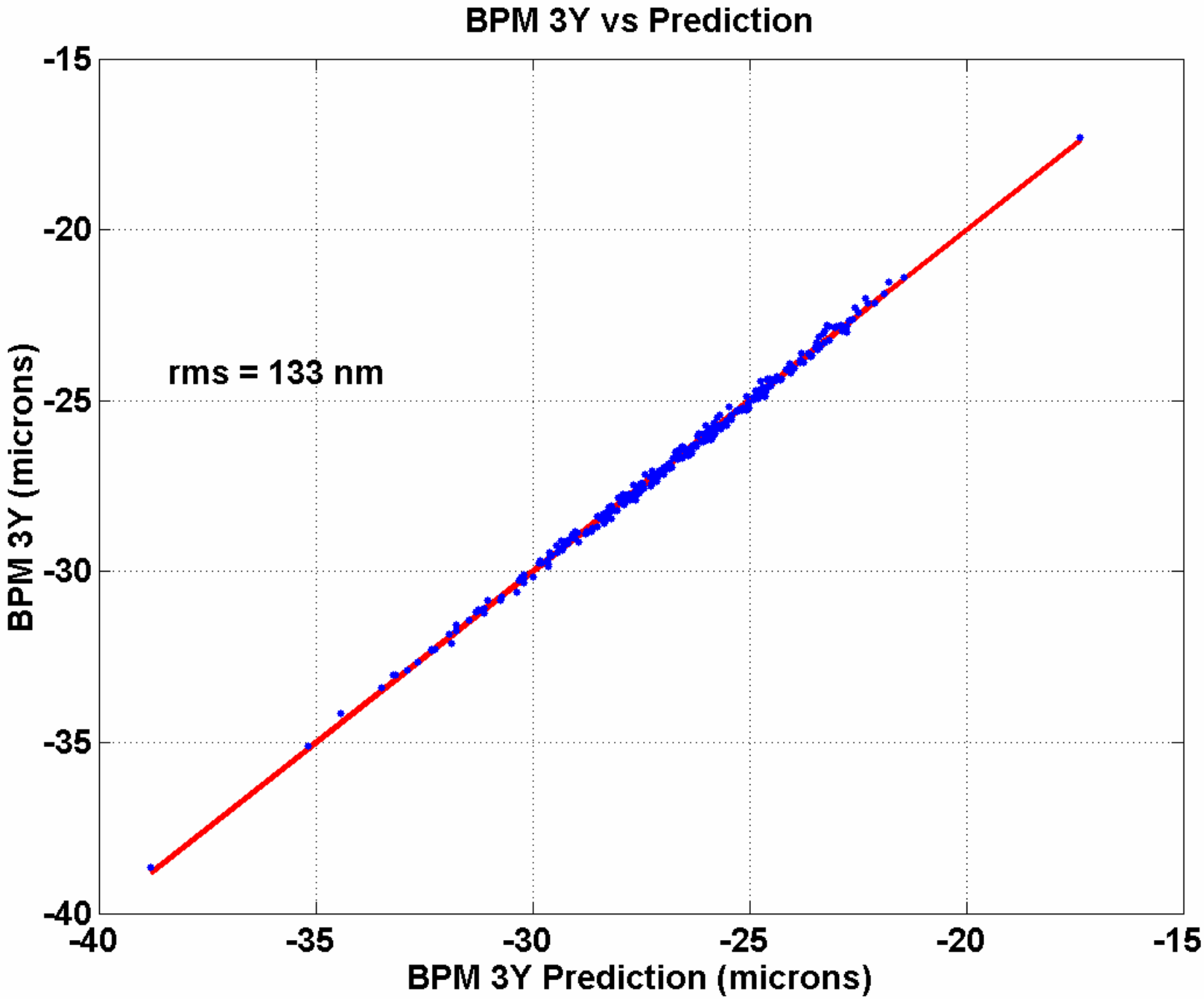

BPM 2Y Calibration
BPM 2Y (microns)
Pulse Number
30
20
10
0
-10
-20
-30
-40
0
50
100
150
200
250
300
350
400
450

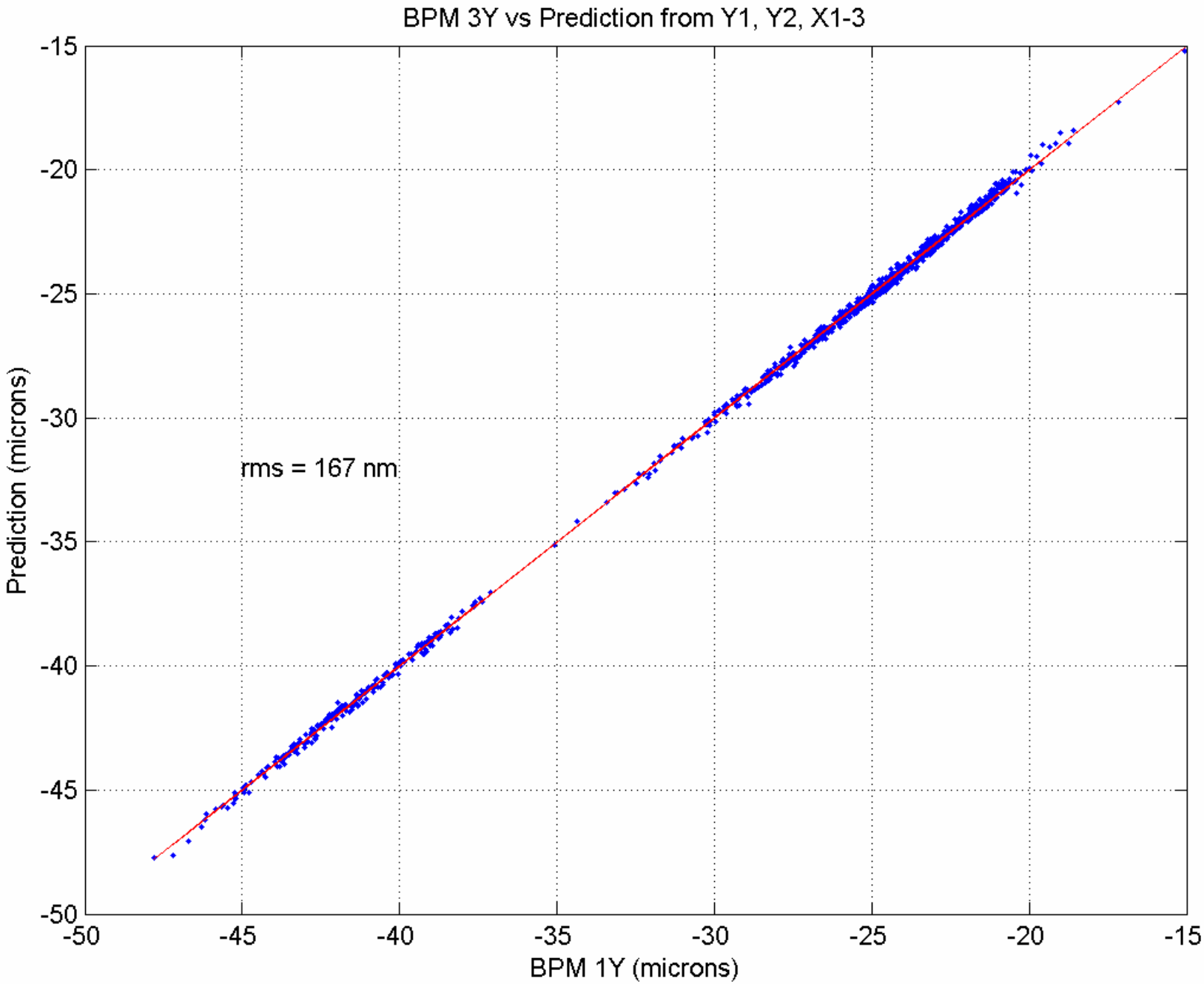

BPM 3Y Calibration
Position (microns)
Beam Pulse Number
30
20
10
0
-10
-20
-30
0
50
100
150
200
250
300
350
400
450

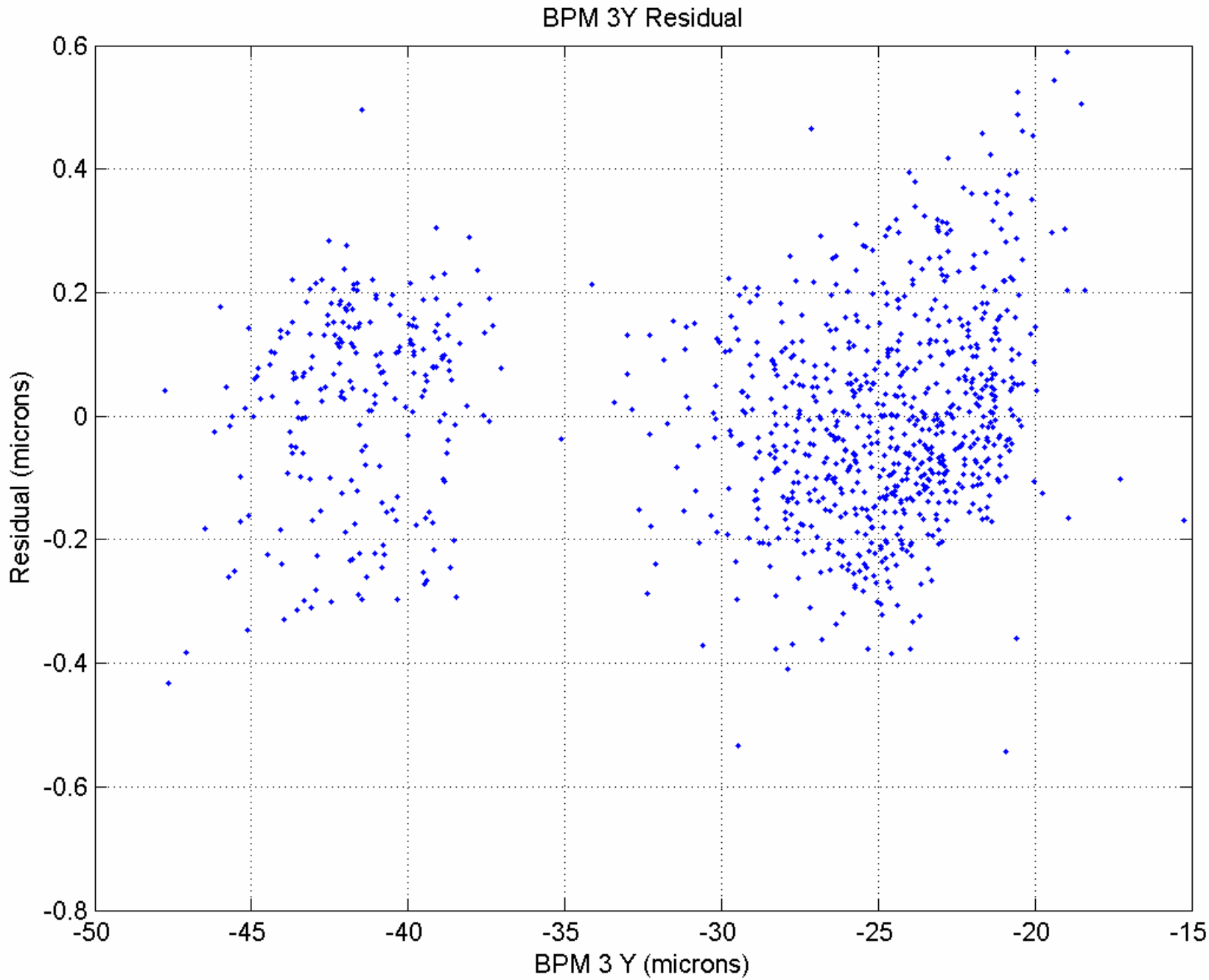

BPM 3Y Calibration Residual
BPM 3Y residual (microns)
Beam Pulse Number
10
5
0
-5
-10
-15
-20
0
50
100
150
200
250
300
350
400
450


BPM 1Y vs Prediction
rms = 140 nm
BPM 1Y (microns)
Least-Squares Linear Prediction for Y1 (microns)
-16
-18
-20
-22
-24
-26
-28
-30
-30
-28
-26
-24
-22
-20
-18
-16


BPM 2Y vs Prediction
rms = 350 nm
BPM 2Y (microns)
BPM 2Y Prediction (microns)
-14
-16
-18
-20
-22
-24
-26
-28
-28
-26
-24
-22
-20
-18
-16
-14


BPM 3Y vs Prediction
rms = 133 nm
BPM 3Y (microns)
BPM 3Y Prediction (microns)
-15
-20
-25
-30
-35
-40
-40
-35
-30
-25
-20
-15


BPM 3Y vs Prediction from Y1, Y2, X1-3
rms = 167 nm
Prediction (microns)
BPM 1Y (microns)
-15
-20
-25
-30
-35
-40
-45
-50
-50
-45
-40
-35
-30
-25
-20
-15


BPM 3Y Residual
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
Residual (microns)
-50
-45
-40
-35
-30
-25
-20
-15
BPM 3 Y (microns)

Measurement Limits

- Beam drifts limit accuracy of calibration
- Proposal:
  - Rough-calibrate each BPM against its mover
    - Gives ~200 nm errors
  - Then use rough calibration to predict coordinate of each calibration pulse on each BPM.
  - Yields ‘refined’ calibration
- Need careful pulse-by-pulse data qualification
  - Cut on beam charge, position, channel saturation, etc.
- Need careful study of systematics
  - Performance (linearity, stability, phase jitter, coupling)
  - Processing parameters (bandwidth, filter characteristics, saturation)

Plans for Improvement

- Beam drifts limit accuracy of calibration
- Beam drifts & jitter consume entire dynamic range
- Reduce electronics noise, maybe as much as 6 dB with:
  - Replace first amplifier
    - Lower noise figure
    - Higher gain (reduce noise contribution from mixer, IF amps)
  - Single-sideband IF downconversion reduces front-end noise 3dB.
- Improve isolation, intermodulation systematics
- Increase dynamic range
  - Replace first amplifier
    - Increase P_{1dB}
  - Dual gain backend
- Alignment/Vibration Control (?)

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