Bunch-by-bunch Feedback Potpourri

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Dimtel, Inc., San Jose, CA, USA

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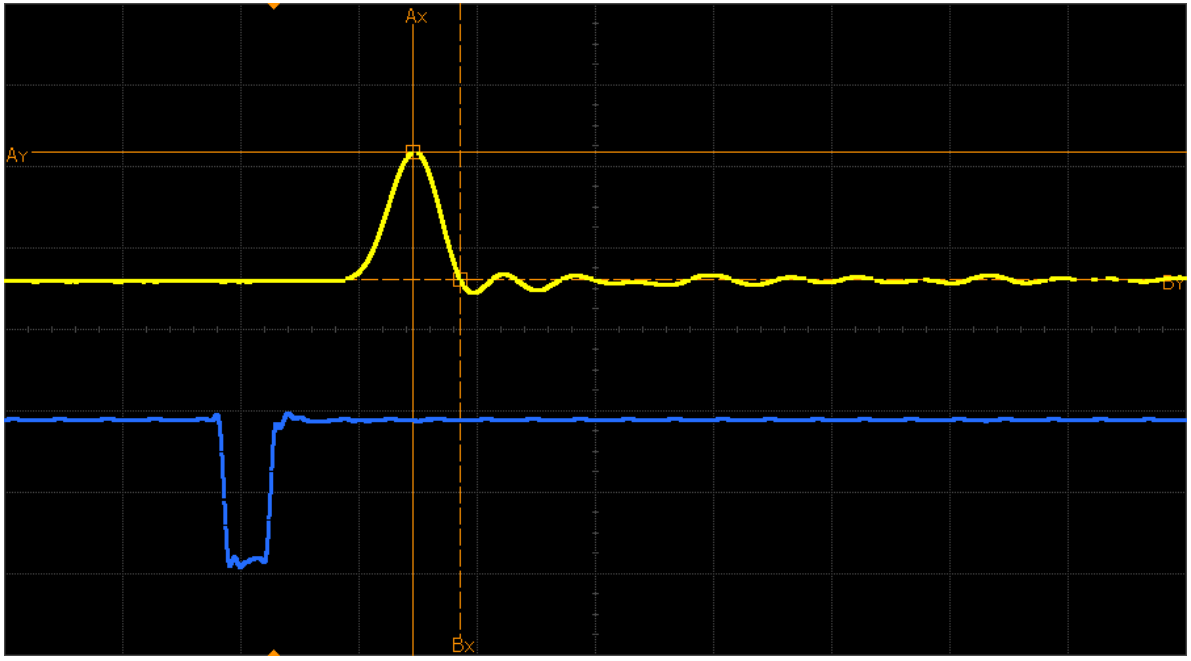
Outline

Problem Definition



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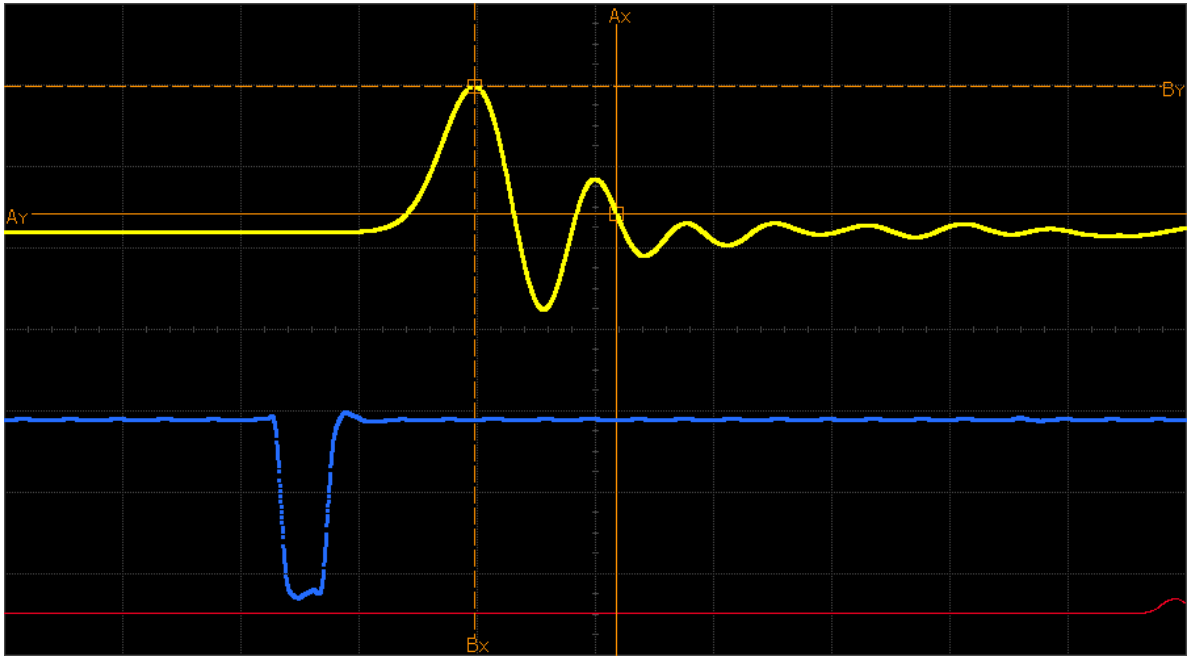

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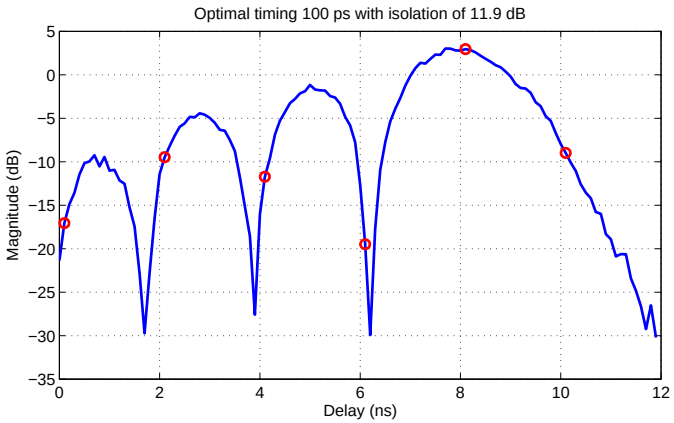
BESSY II Vertical Amplifier Response



- Drive the single bunch at the betatron frequency;
- Adjust back-end delay;
- Record betatron oscillation magnitude;
- Optimal timing has 11.9 dB isolation;
- Can extract impulse response of the DAC/amplifier/kicker chain.

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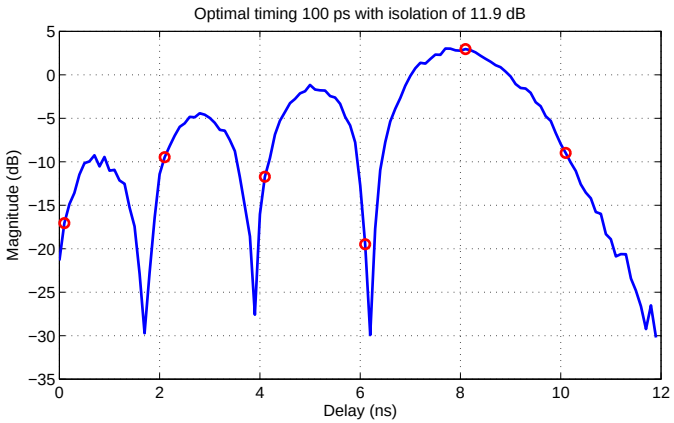

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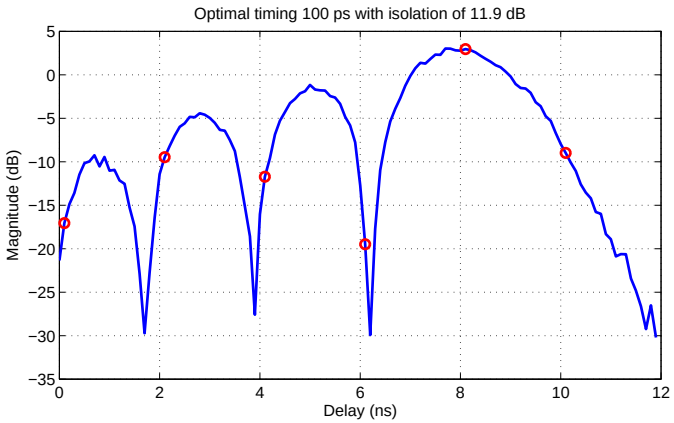

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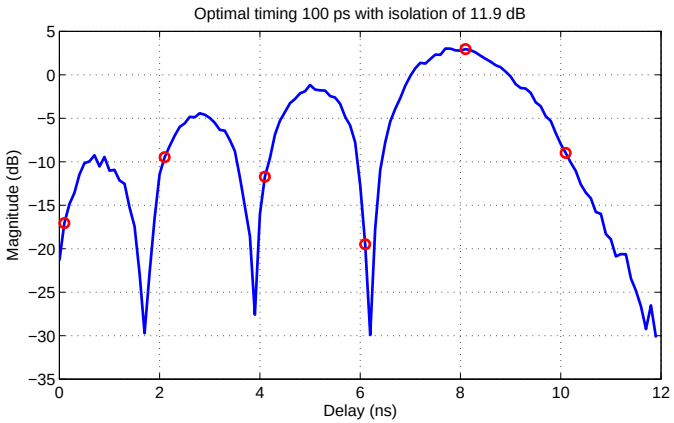

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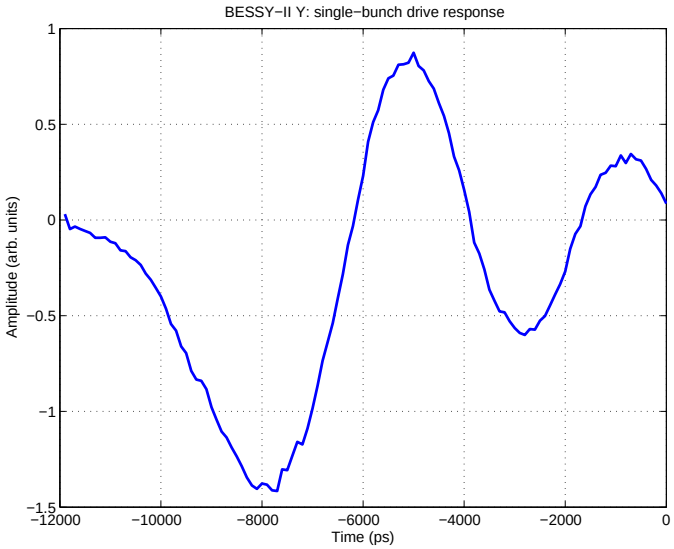

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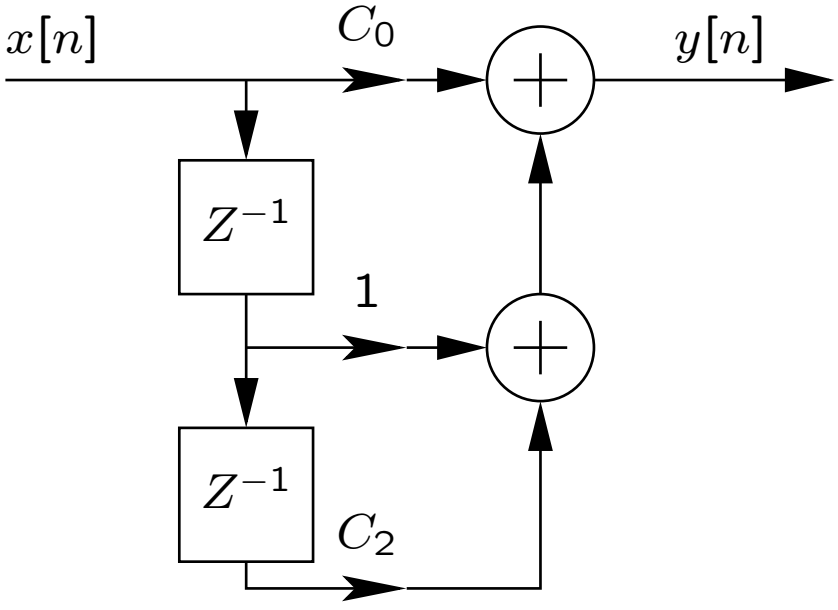

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- Kick for a given bunch can be coupled to the neighboring buckets;
- We are pre-distorting amplifier drive signal to compensate for its response.

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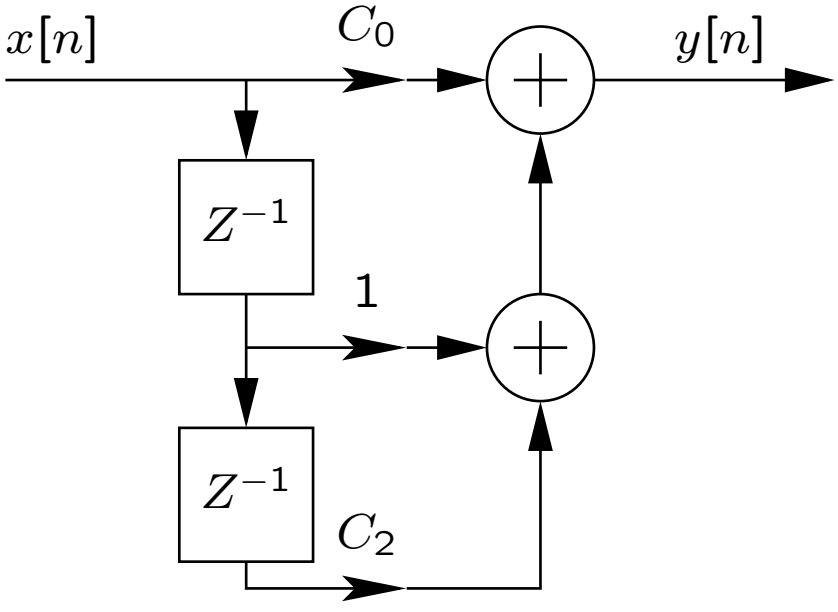

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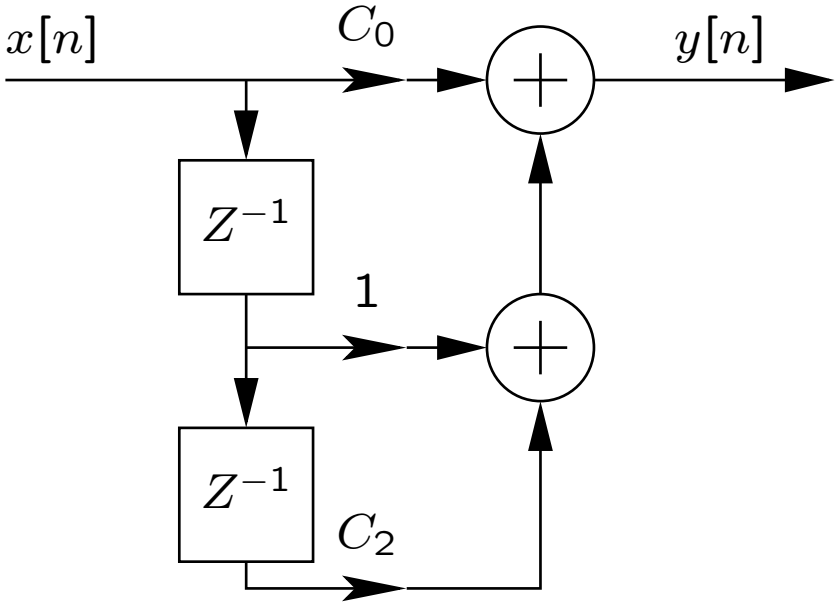

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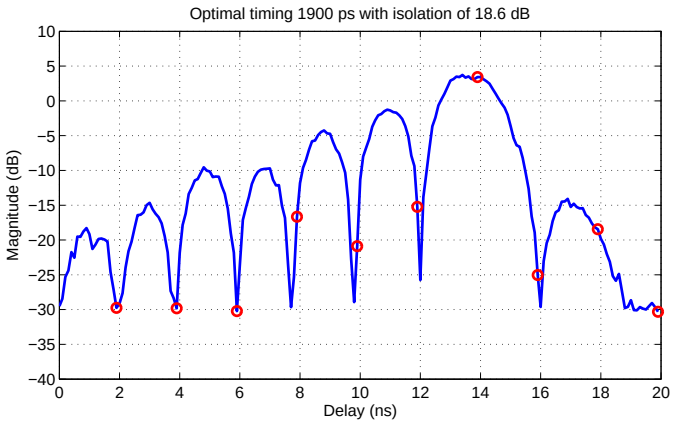

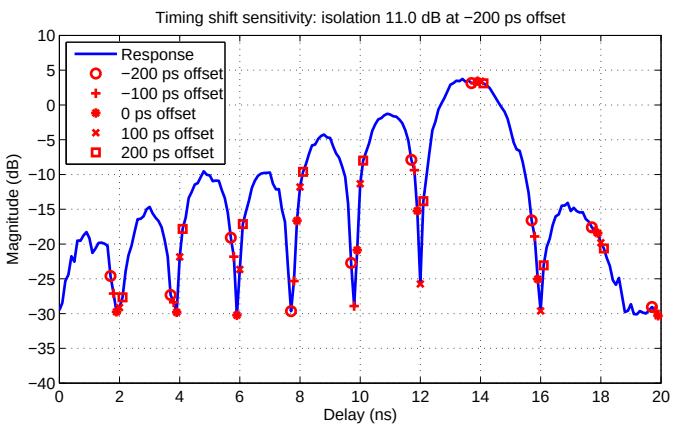

- Response with shaper FIR $[-0.3 \;\; 1 \;\; 0.15]$;
- Isolation improved to 18.6 dB;
- Compare with the impulse response derived signal.

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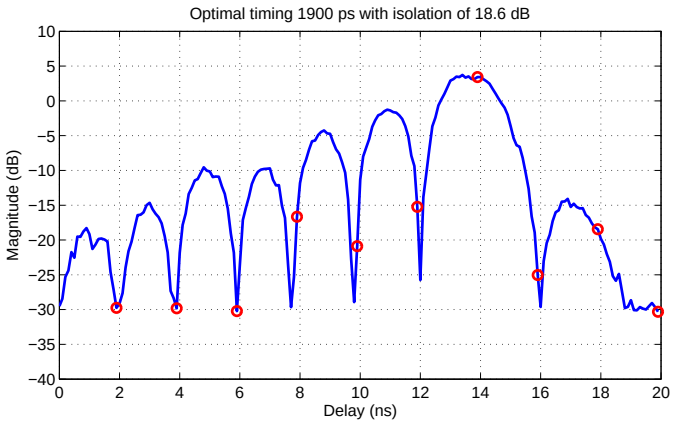

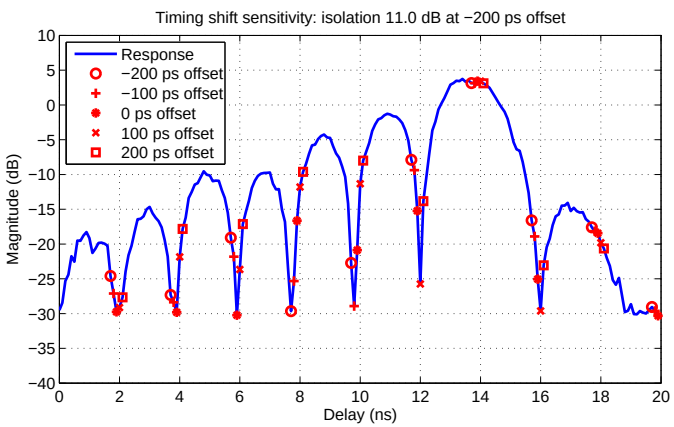

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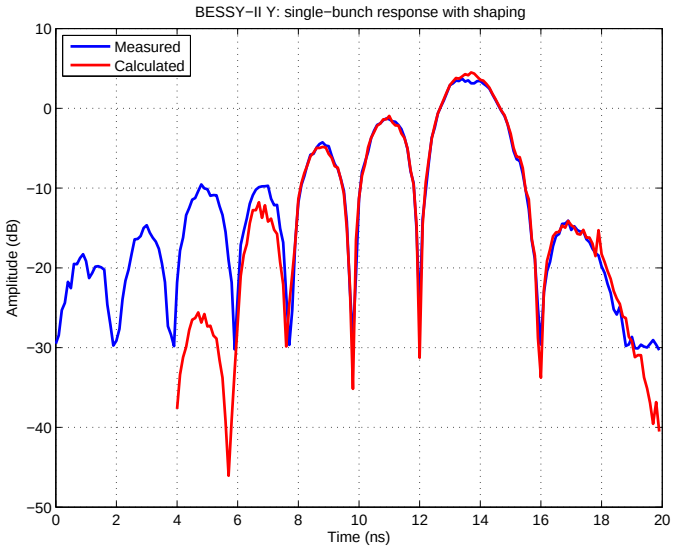

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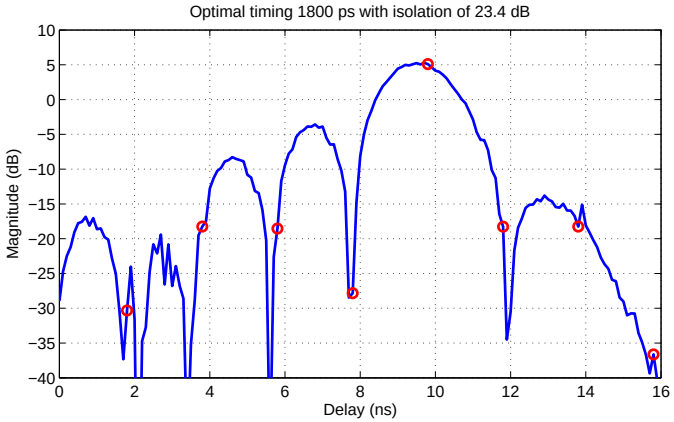
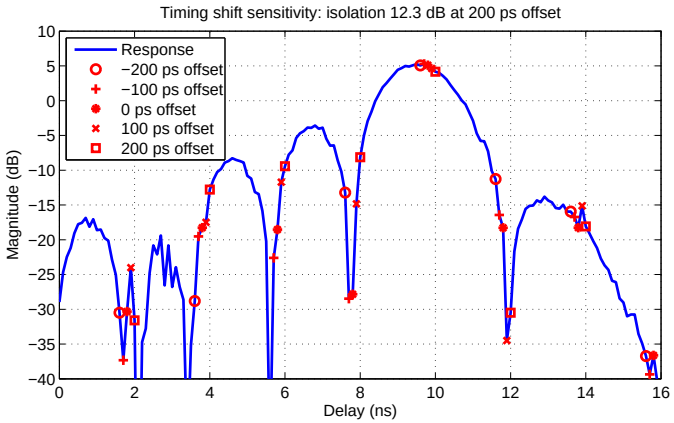
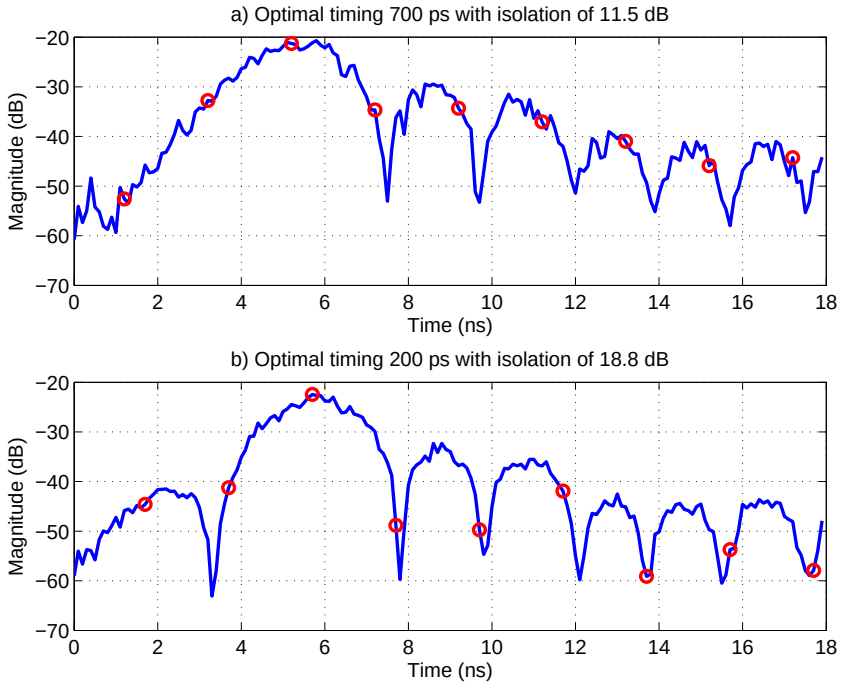




- Using the measured impulse response, optimize shaping coefficients and timing;

Isolation vs. Config	
No shaping	11.9 dB
Empirically optimized	18.6 dB
Numeric optimization	23.4 dB

TLS Horizontal Amplifier: Optimized FIR Shaper



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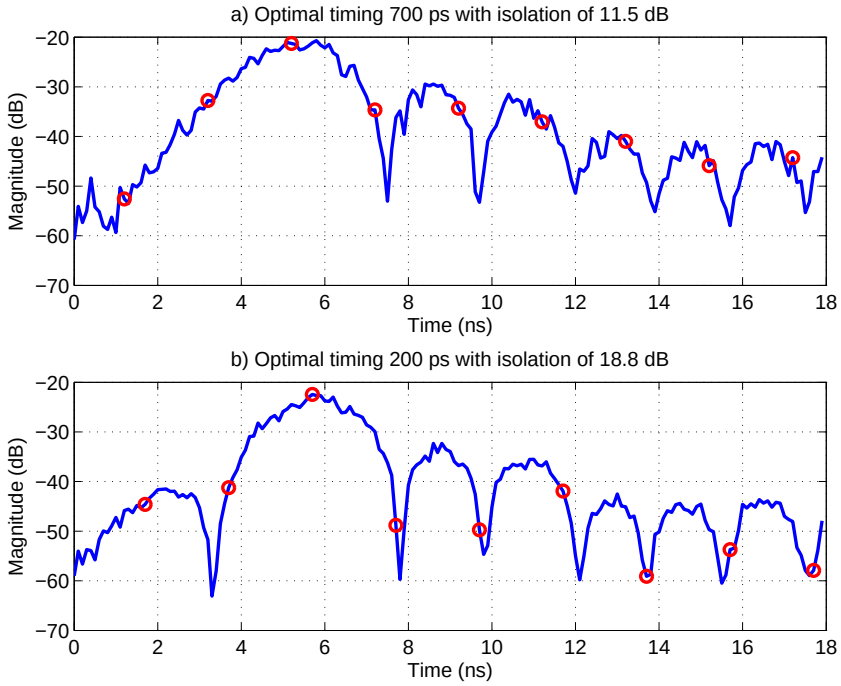

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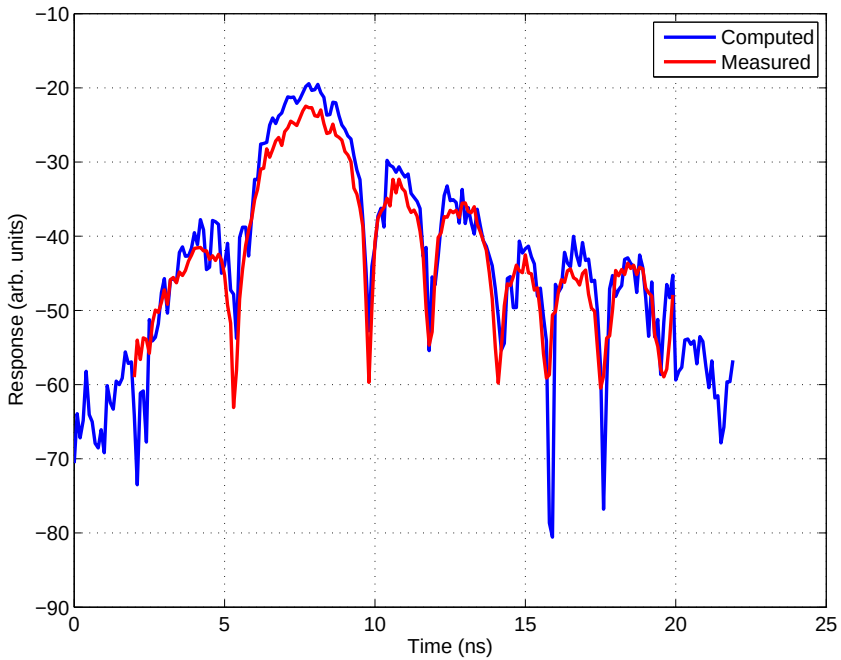

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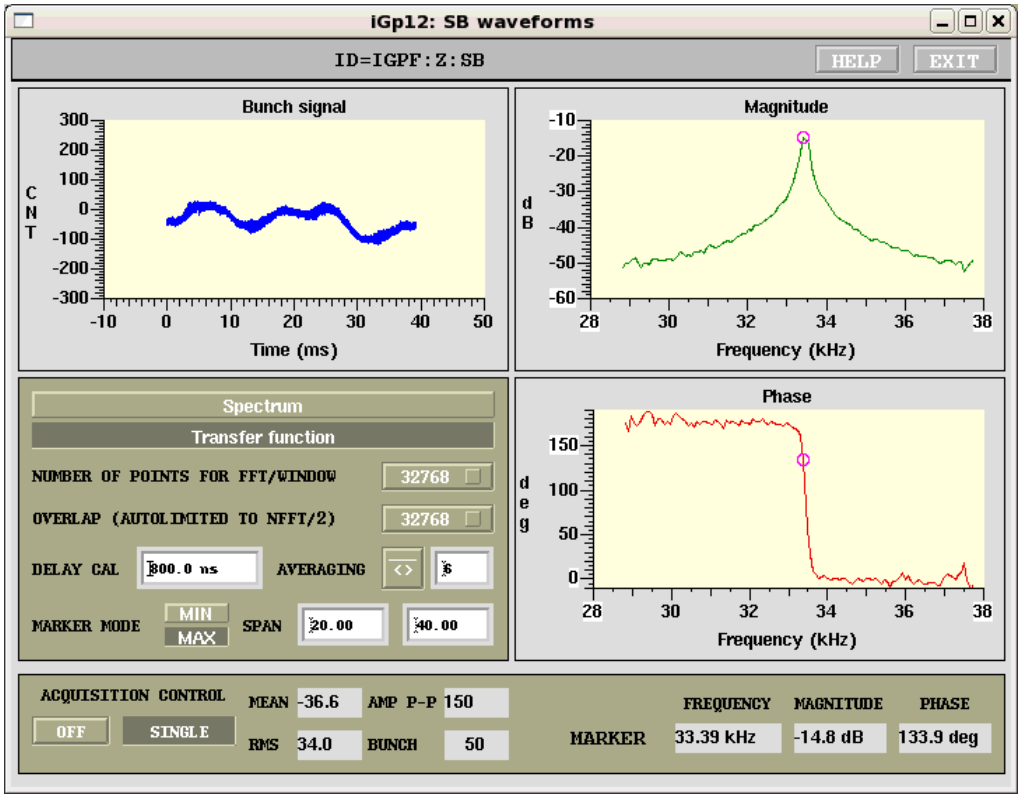

- New single-bunch acquisition engine captures 96k samples for one bunch together with excitation signal;
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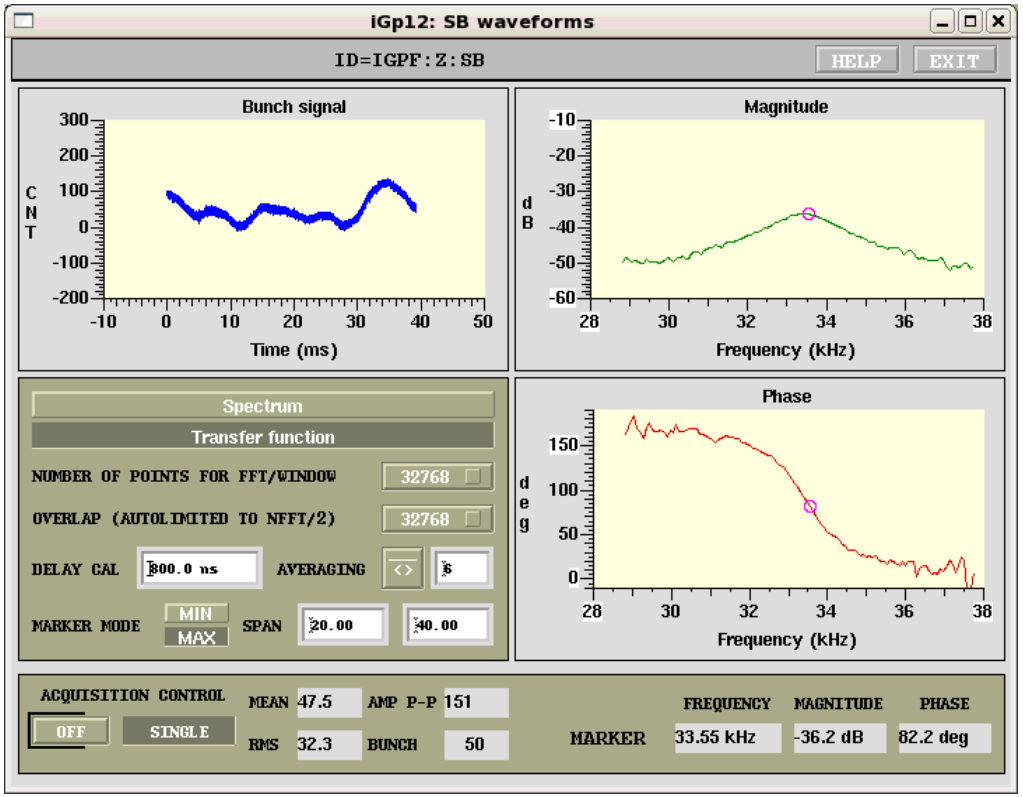

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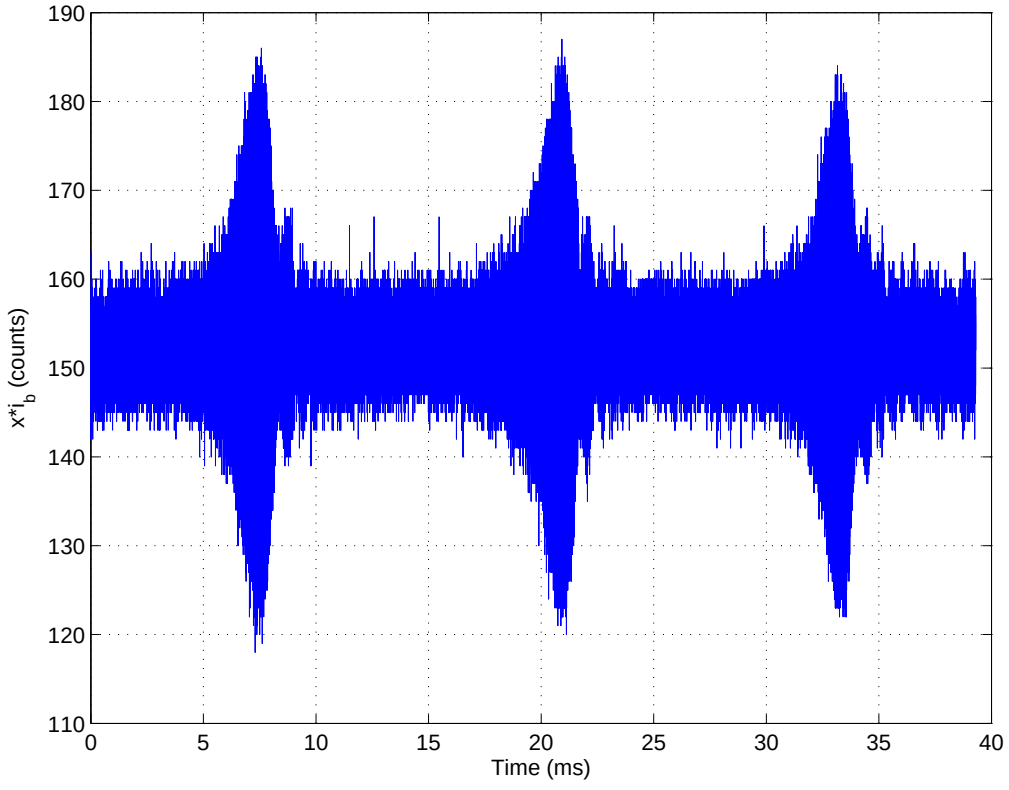

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- Frequency domain transfer function
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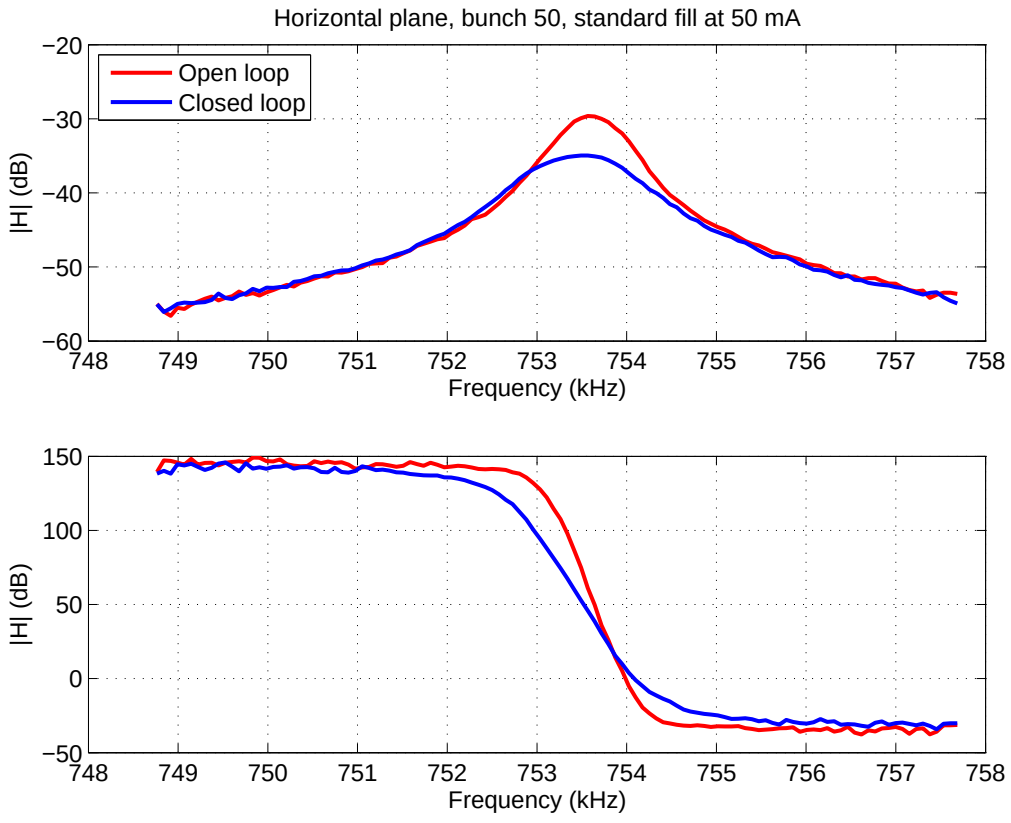

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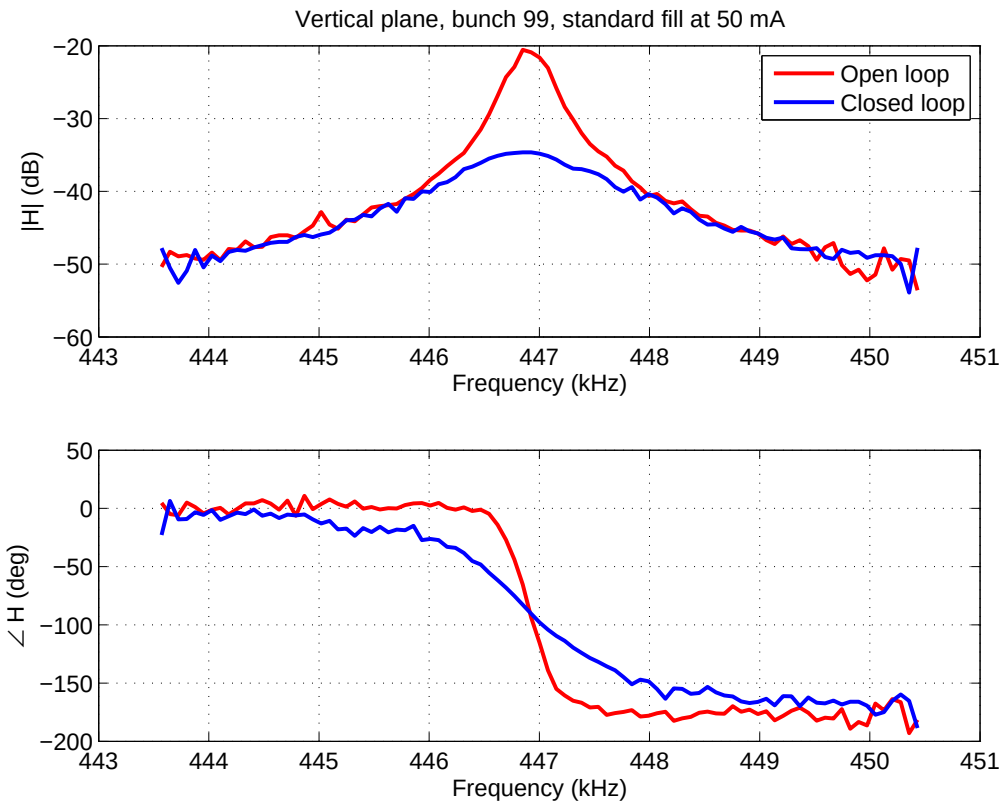

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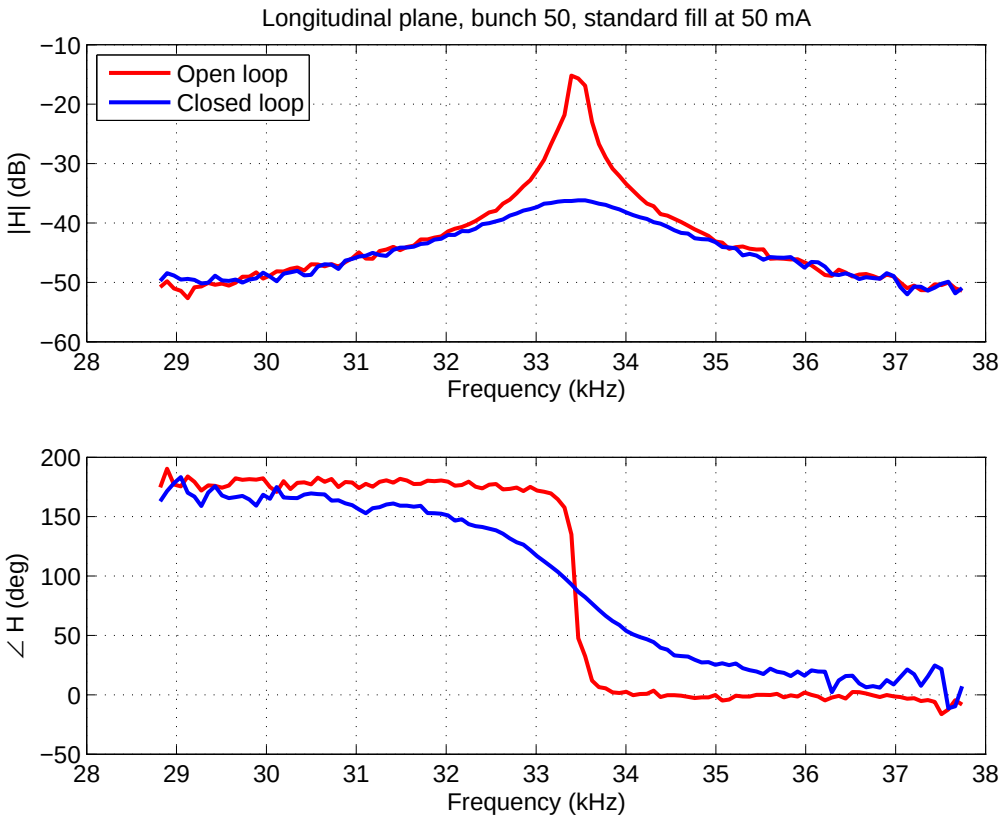

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BTF: Interesting Questions So Far

- Measurement is often difficult due to tune modulation;
- In low energy machines, long damping times can interfere with the measurements;
- Amplitude-dependent tune shift creates BTF asymmetry
  - Use the asymmetry to measure the tune shift?
- Finding combinations of excitation frequency spans, sweep periods, and amplitudes for reliable BTF measurement is not well understood.
- Sweep direction is important — needs further study.

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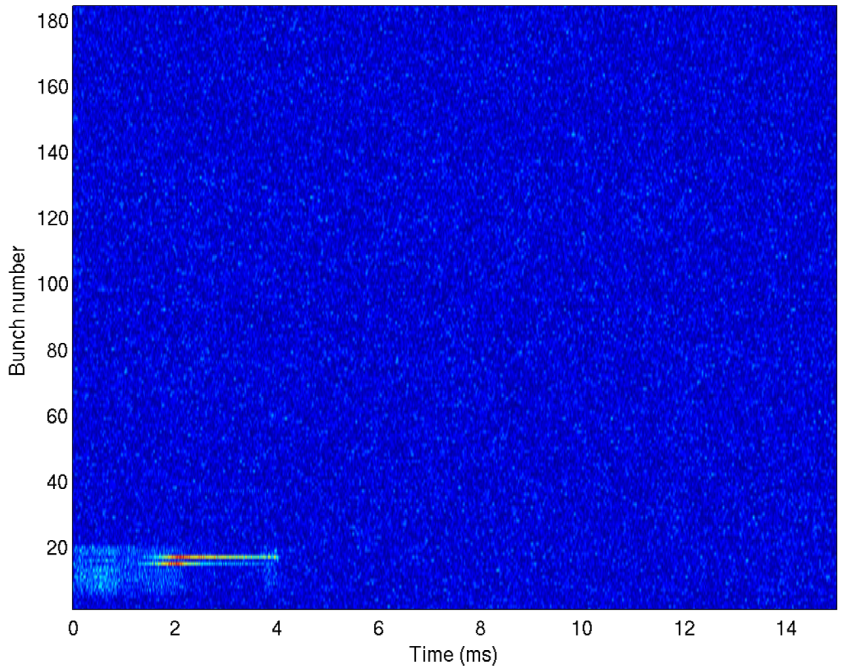

- Modulate excitation signal on/off together with transient measurements;
- Example from ANKA: 20 bunches driven for 4 ms with feedback turned off;
- Bunch 15 spectrogram;
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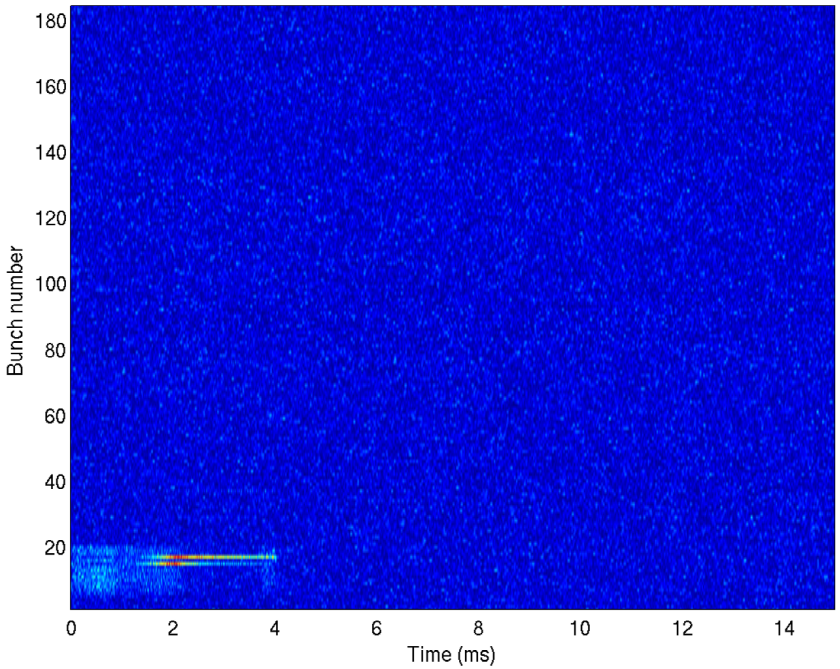

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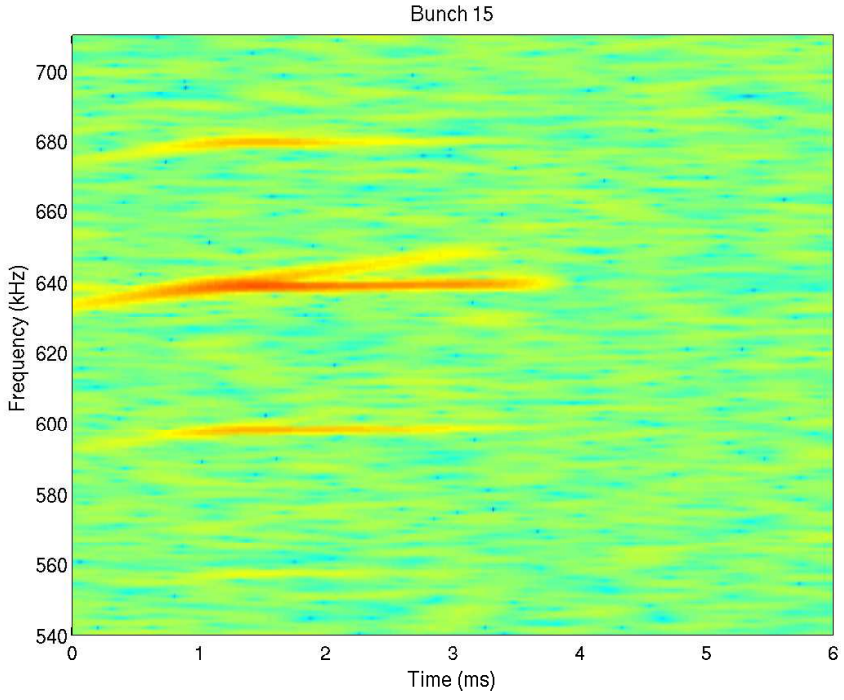

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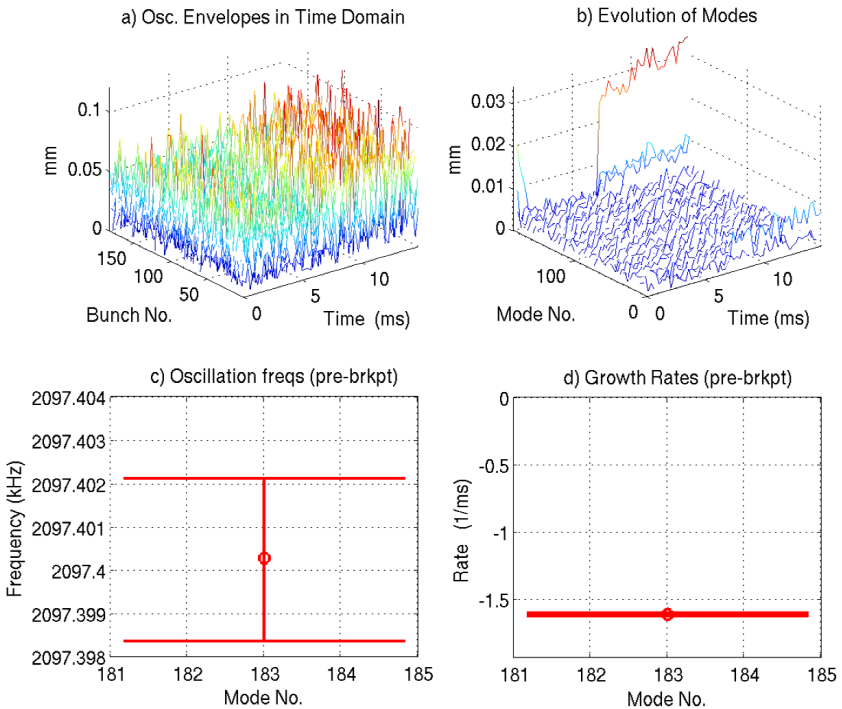

- Set up constant frequency excitation to drive mode -1;
- Excitation is on during normal running, off during growth period;
- Feedback is also off — measuring open loop trajectory of one mode;
- Can measure slow or stable eigenmodes.

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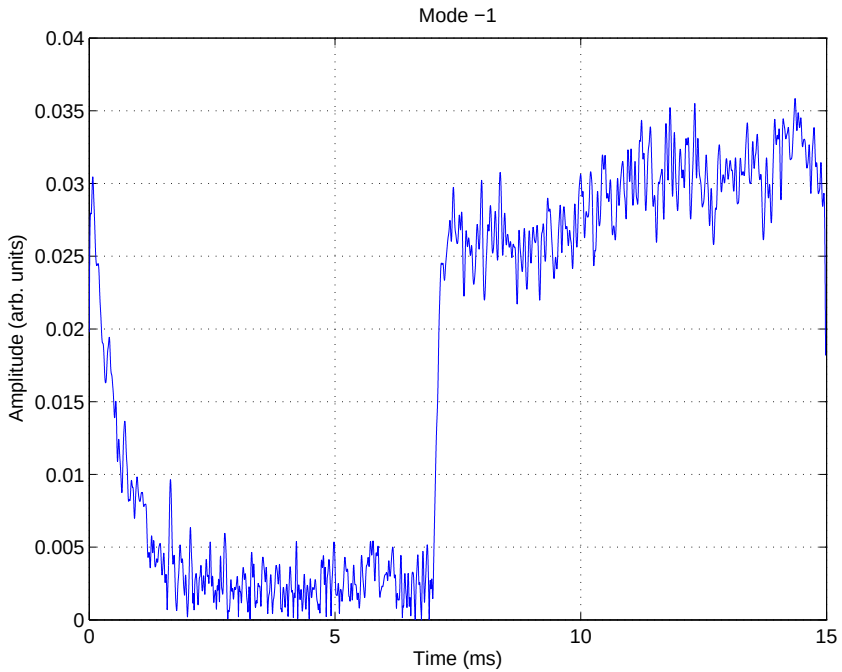

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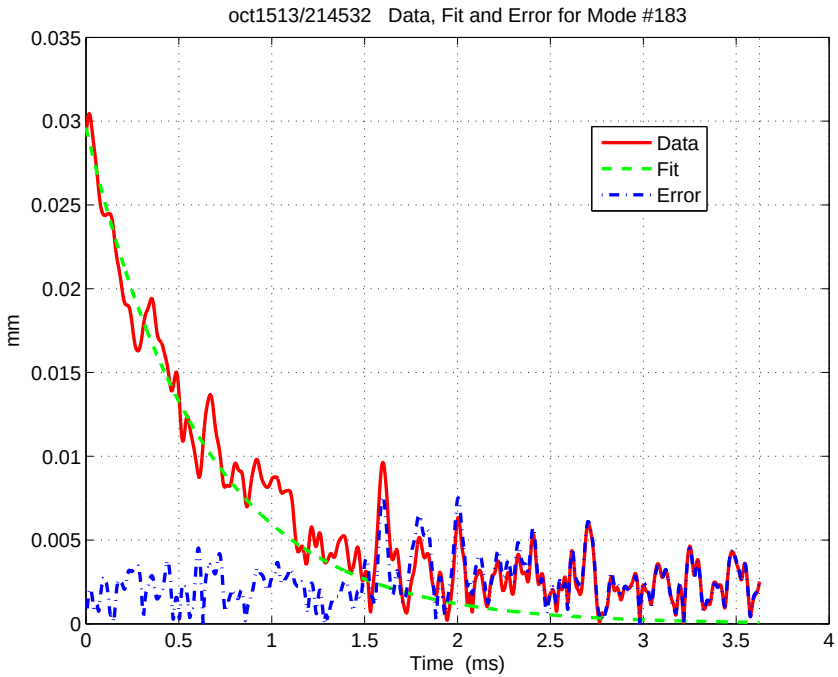

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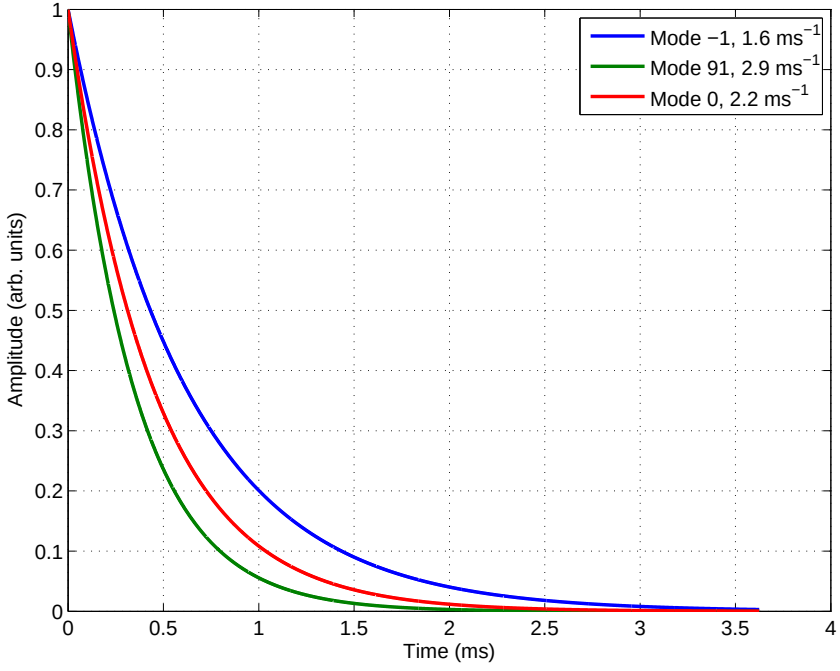

- Three transients, modes 0, 91, and -1;
- Fits scaled to the same starting point;
- Expect slower damping for mode -1, driven by the resistive wall impedance;
- Actual data is less convincing.

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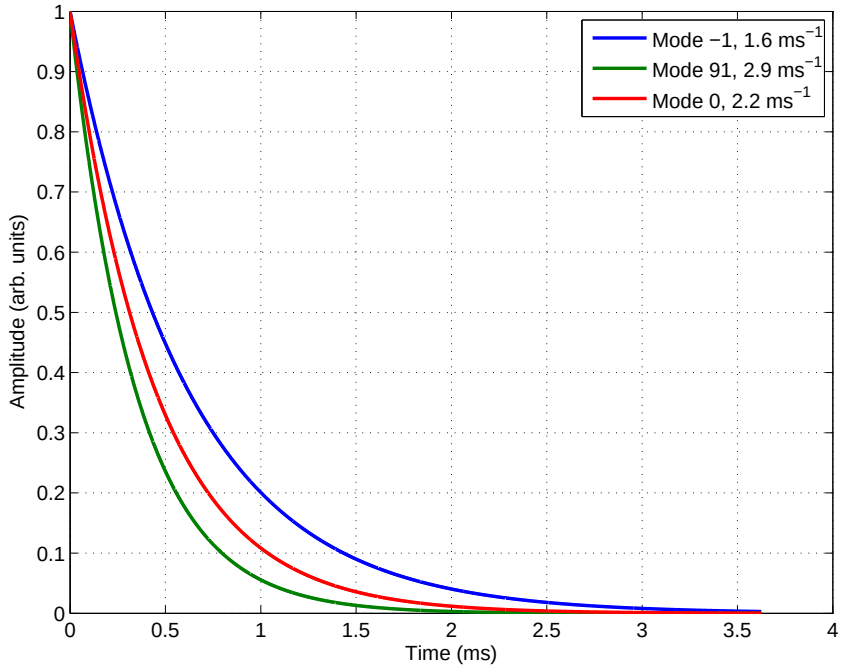

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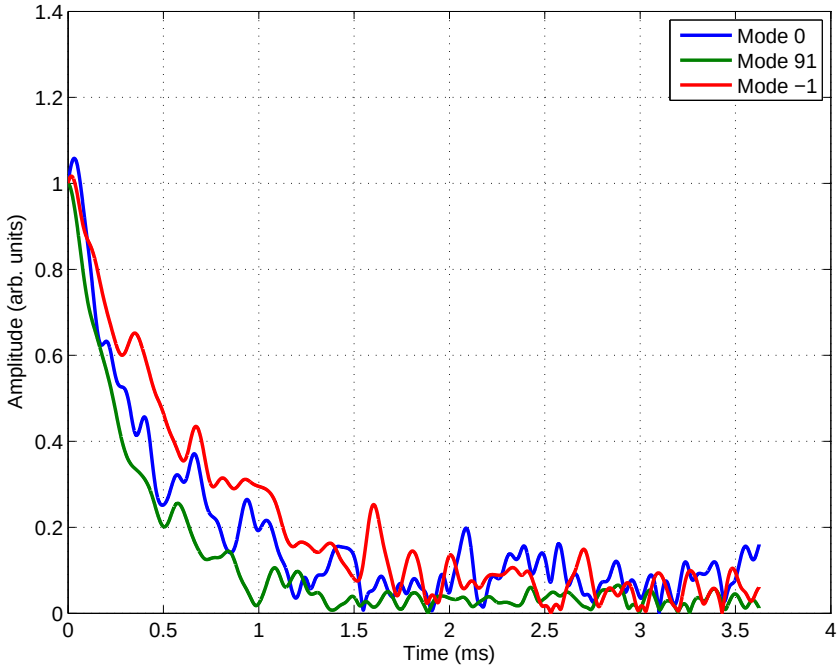

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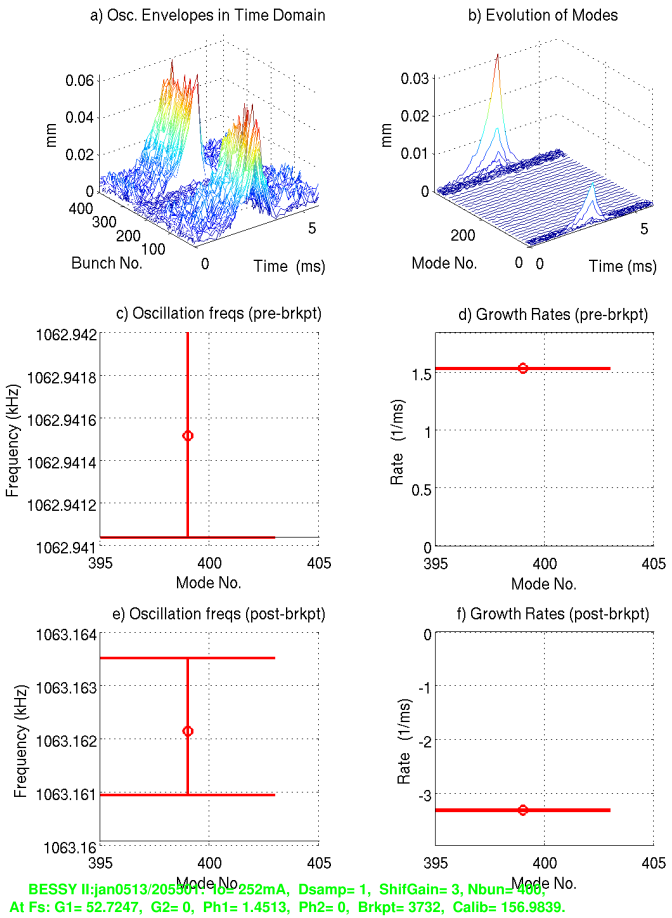

- Horizontal grow/damp at -3.0 units, 245 mA, no camshaft;
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- Very fast damping;
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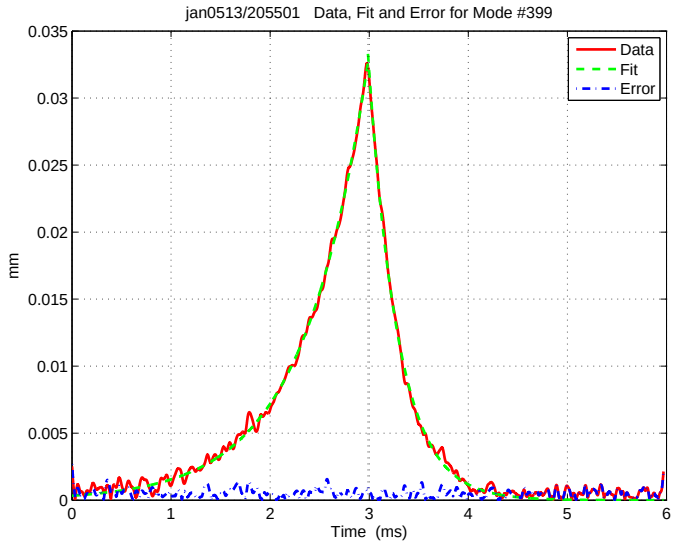

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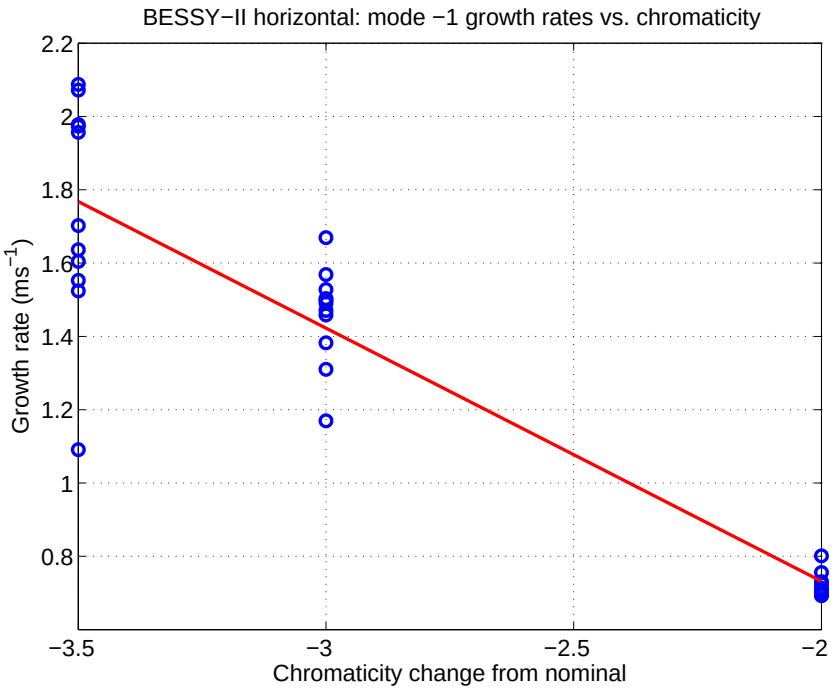

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- Need to collect many measurements to really quantify dependencies;
- Automated analysis of 61 measurements, no cleanup.

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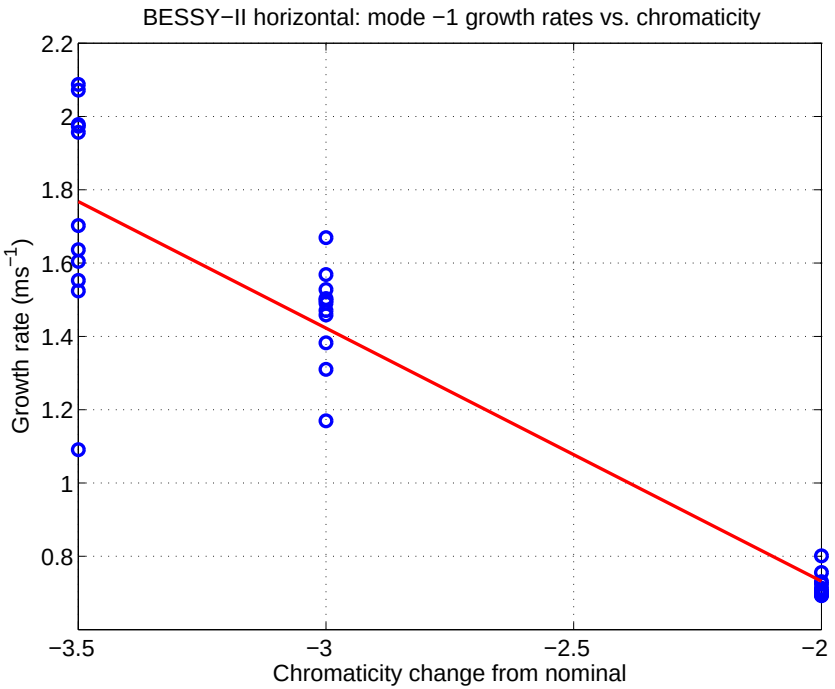

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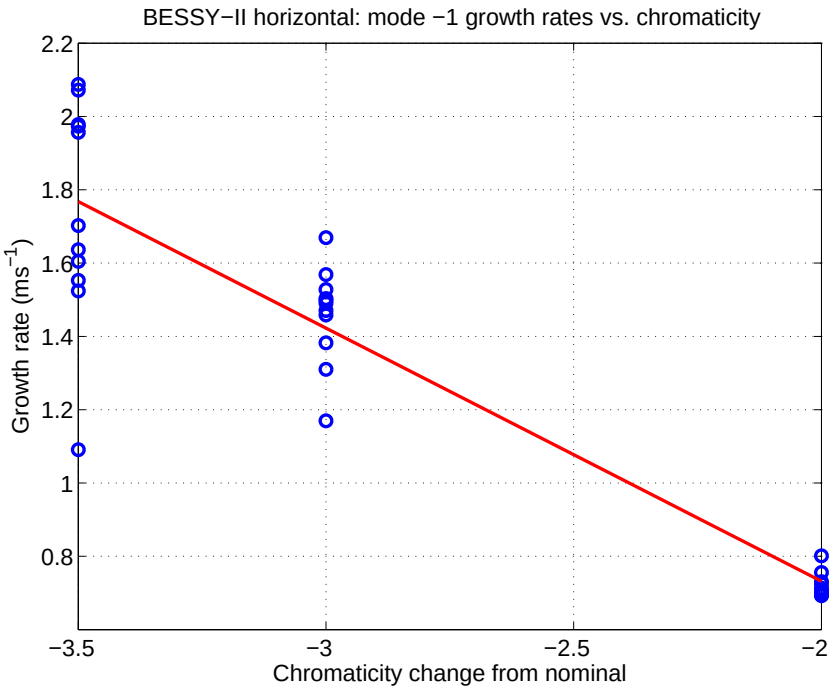

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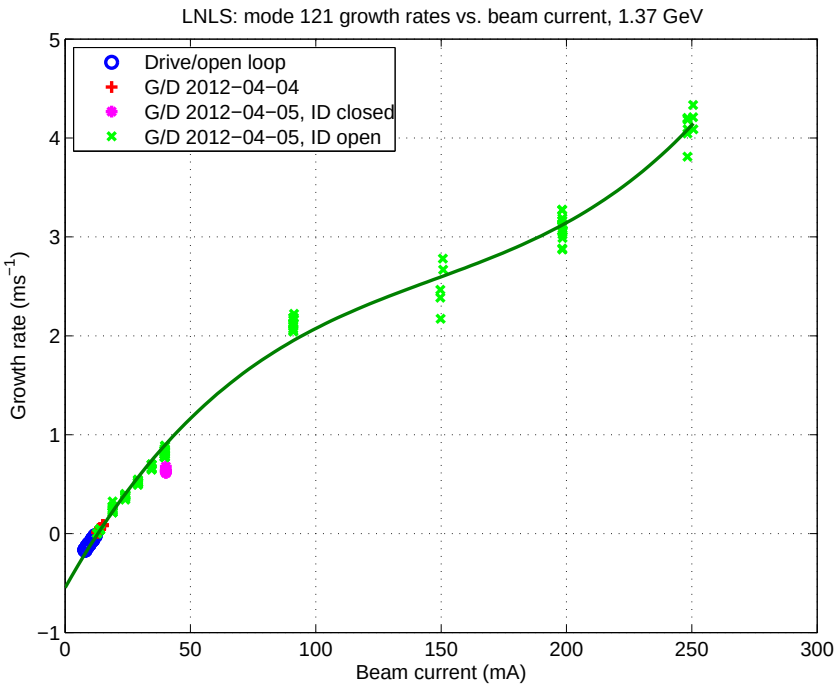

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- High confidence in the growth rates;
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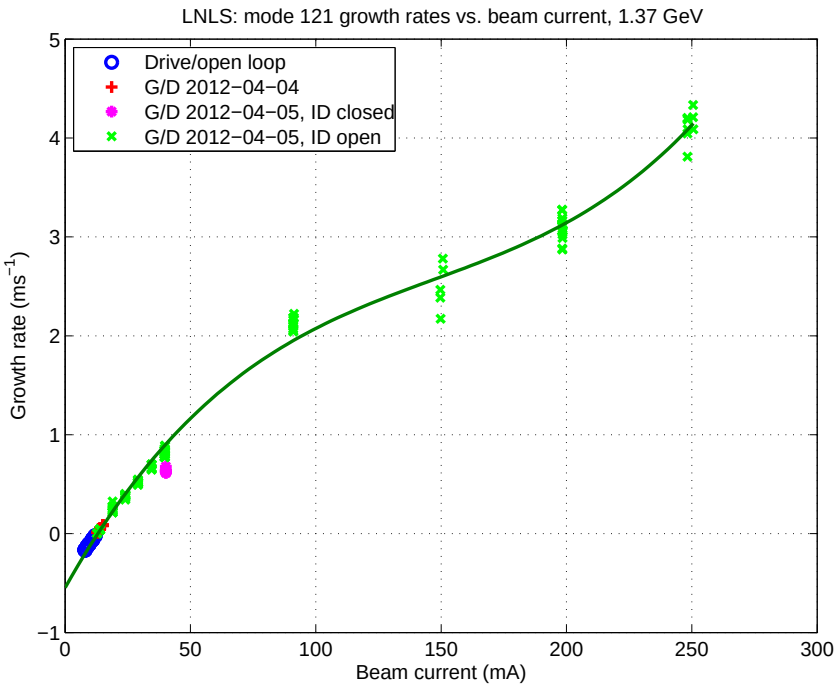

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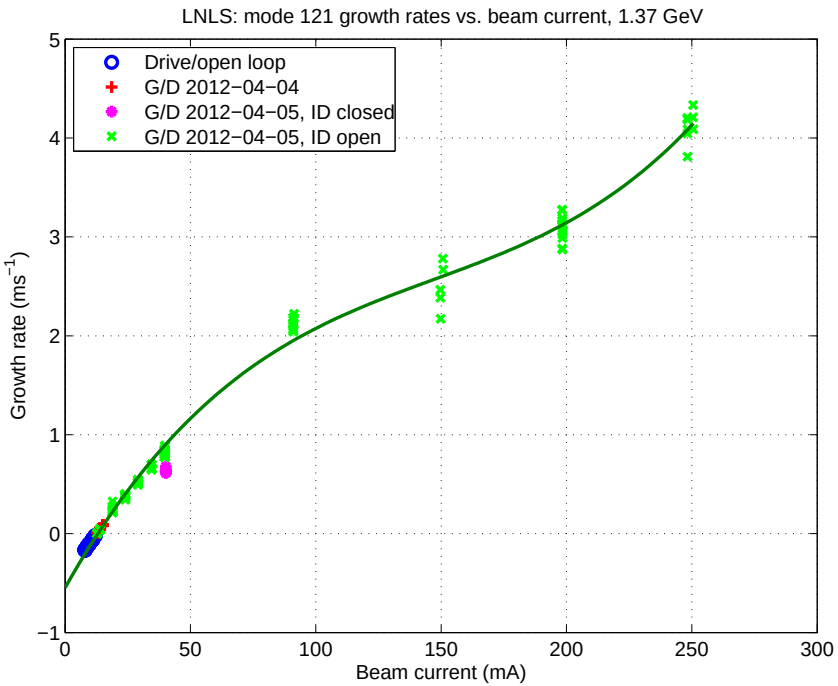
LNLS Longitudinal Growth Rates



- A total of 208 data sets;
- High confidence in the growth rates;
- 2 GB of data collected over two days.

Summary

- Kick signal pre-distortion can significantly improve feedback system performance;
- Beam transfer function measurements might offer interesting beam dynamics information beyond the simple harmonic oscillator model;
- Modulated excitation feature can be used to systematically map modal eigenvalues;
- Fast data acquisition and automated post-processing are critical for quantifying instabilities and determining acceptable operating conditions.

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