Bunch-by-bunch Feedback at the MLS

Updates and Beam Studies

F. Falkenstern[1], J. Feikes[1], M. Ries[1], A. Shaelicke[1], D. Teytelman[2], et. al.

[1]HZB, Berlin, Germany
[2]Dimtel, Inc., San Jose, CA, USA

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Outline

Work Summary

- Updated all 4 iGp12 units to a new gateware/software release:
  - Feedback filter lengthened from 16 to 24 taps;
  - BRAM acquisition memory increased from 192k to 324k;
  - Single-bunch acquisition engine added, BTF functionality;
  - Trigger capture, polarity;
  - Front-end phase tracking;
  - Time-domain modulation of drive signal.
- Performed timing offset calibrations, should simplify future updates;
- Found front/back-end DAC unresponsive (controls phase shifters, fan speed). Need to replace GPIO cable, will provide a standard short cable.

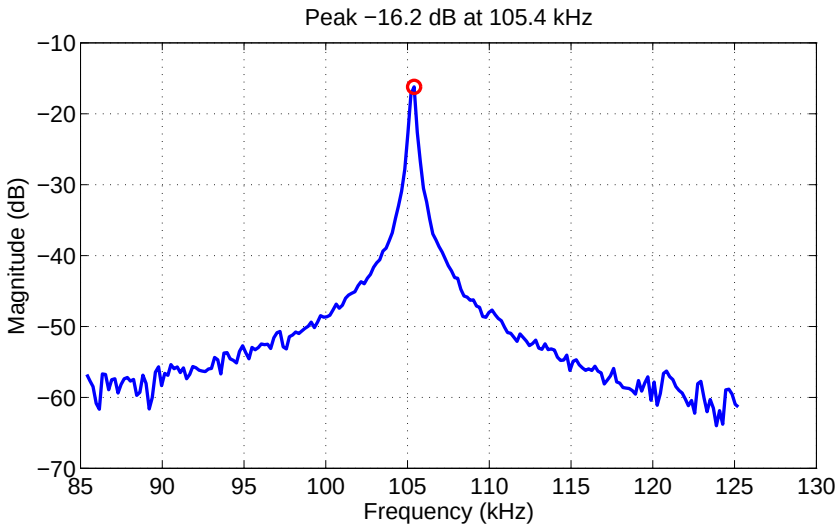
What Was Done When

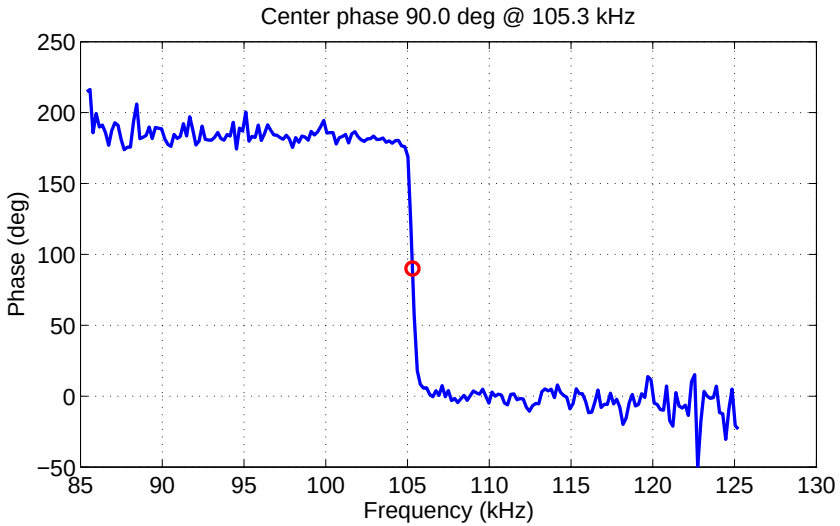
Day by Day

January 8	Calibration of Y and SPARE units, a bit of tuning in the longitudinal plane, some testing with beam, BESSY II work.
January 9	Updated and calibrated Z unit, timed and phased longitudinal and horizontal, optimized bunch-to-bunch isolation, demonstrated bunch cleaning, single bunch transfer function.
January 10	Timed and phased vertical plane, set up post-mortem diagnostics, Z feedback on the ramp, growth rate studies, 10 ps optics.

Outline

Longitudinal Beam Transfer Function





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- Shift gain of 0;
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- BTF peak vs. feedback gain.

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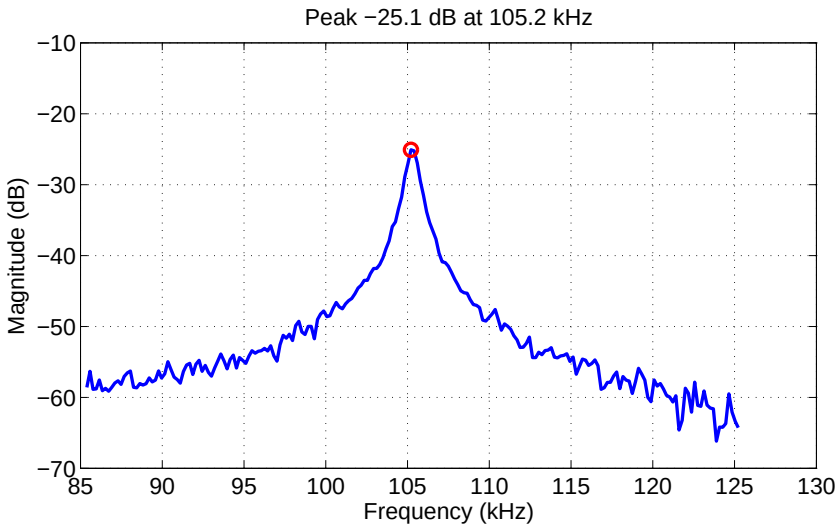

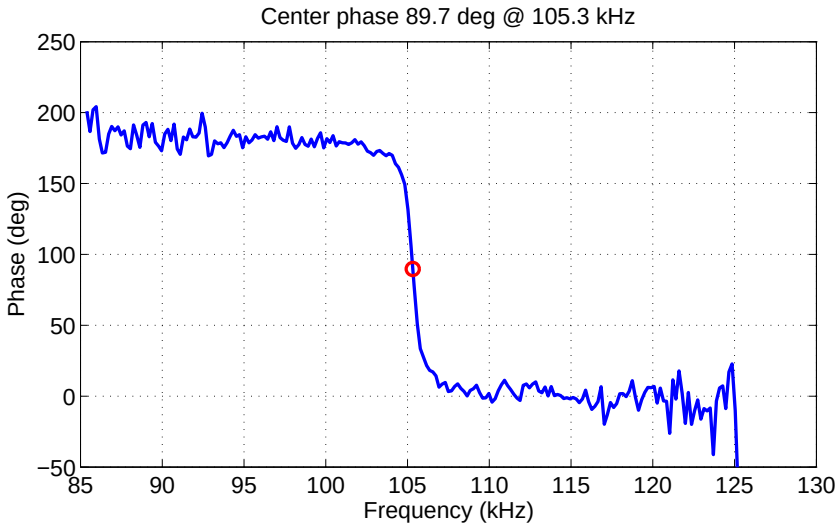

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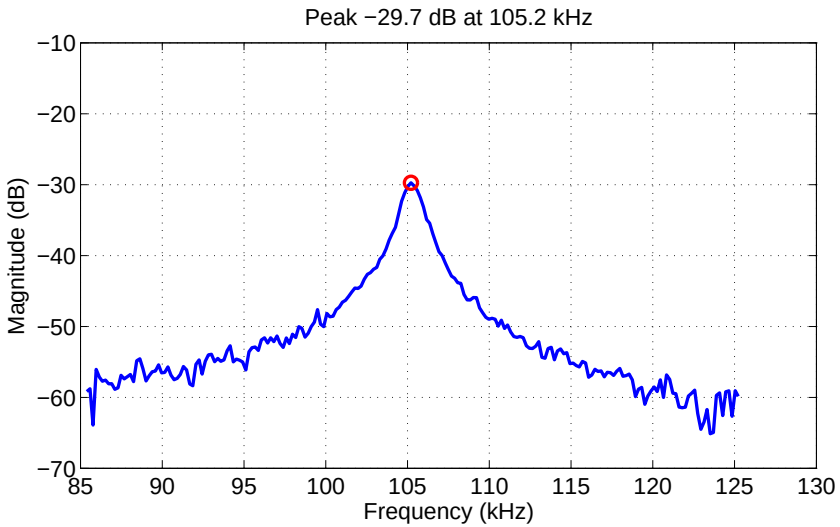

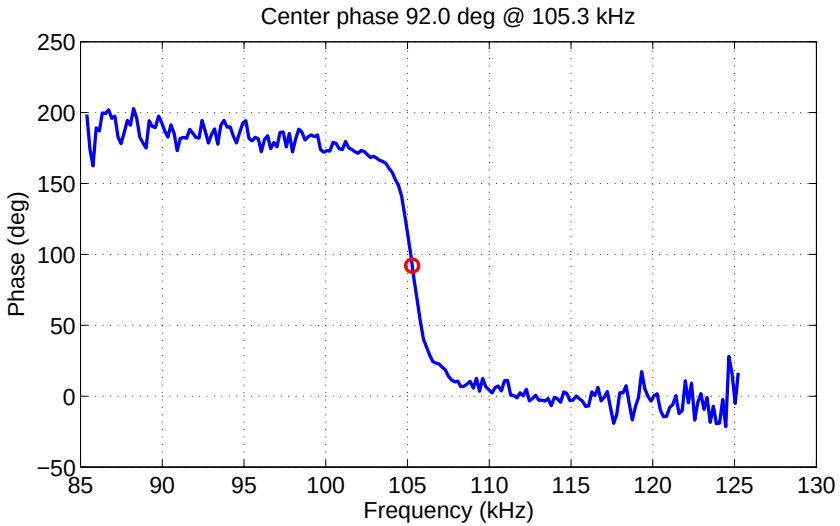

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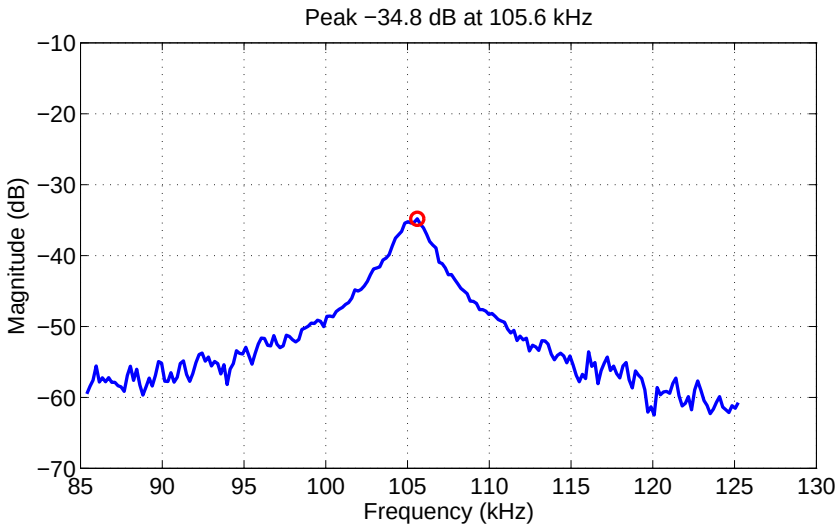

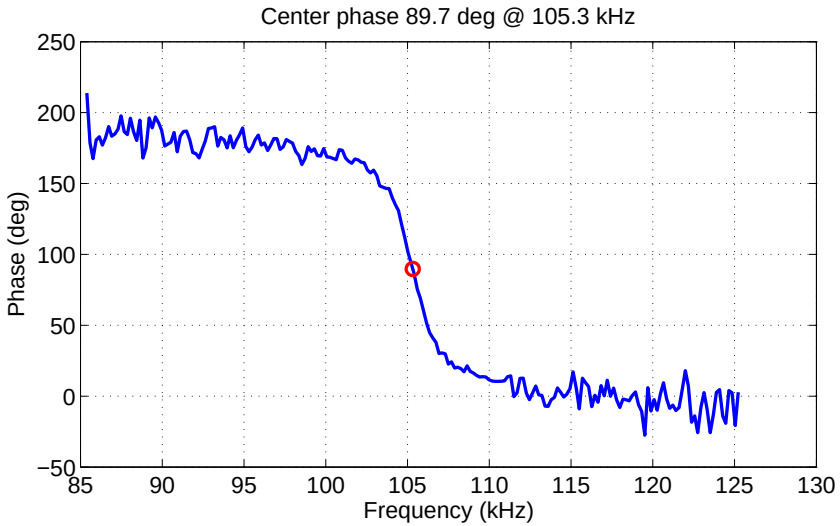

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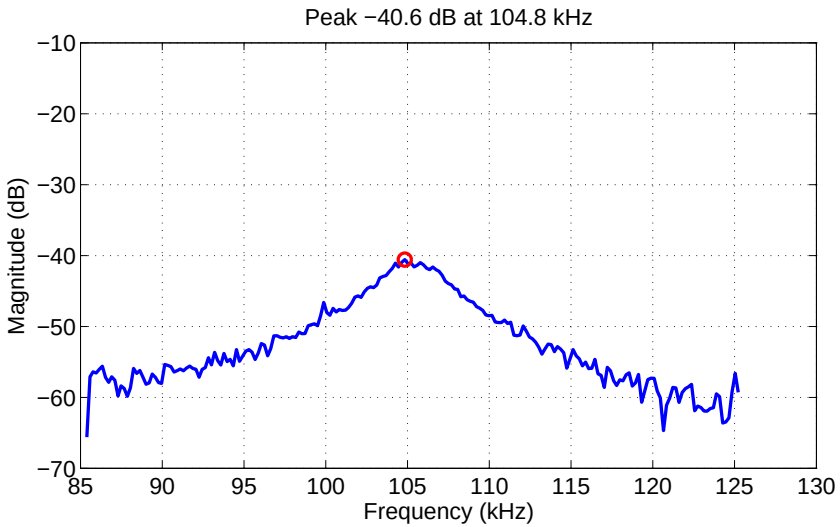

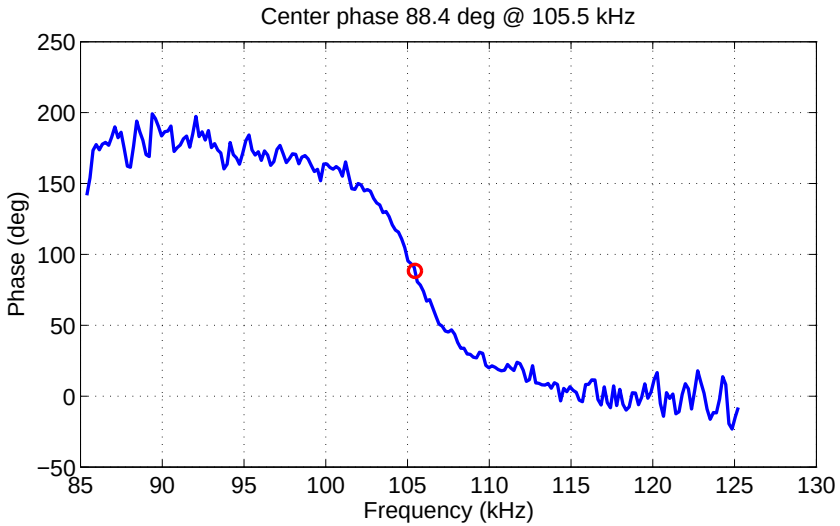

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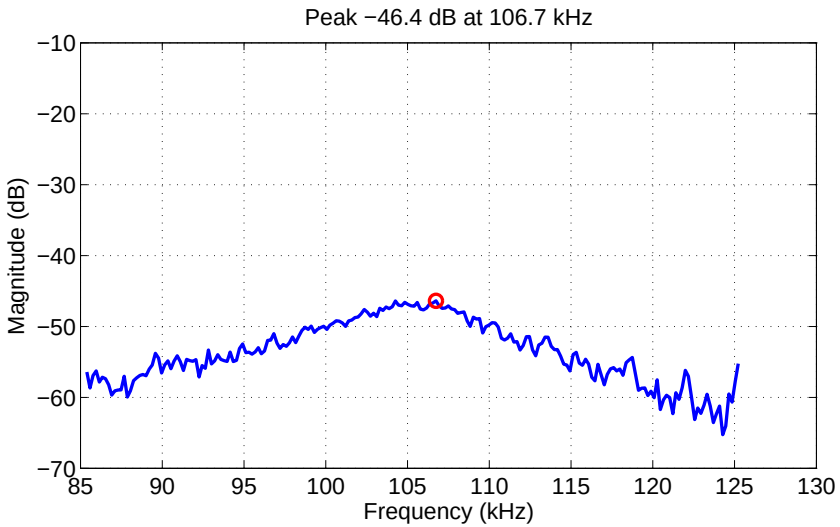

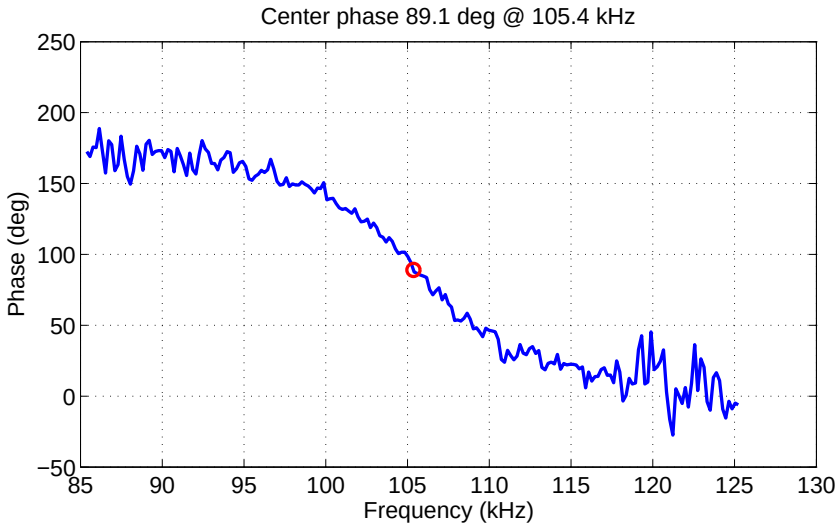

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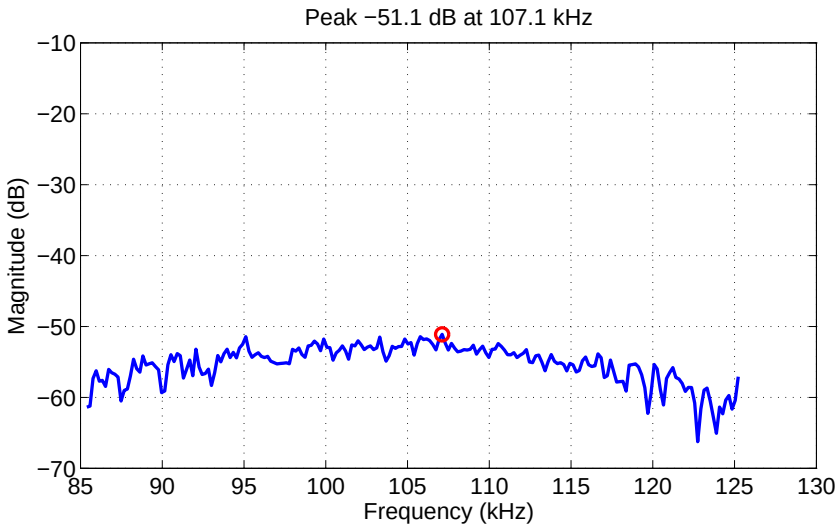

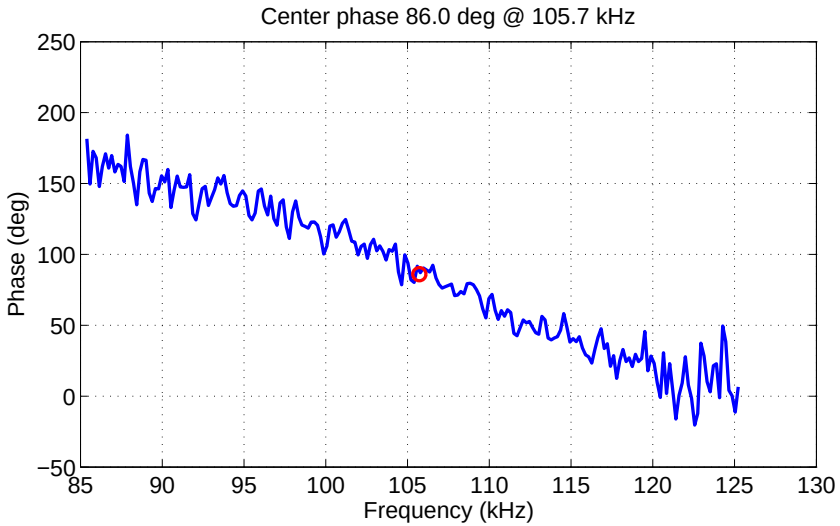

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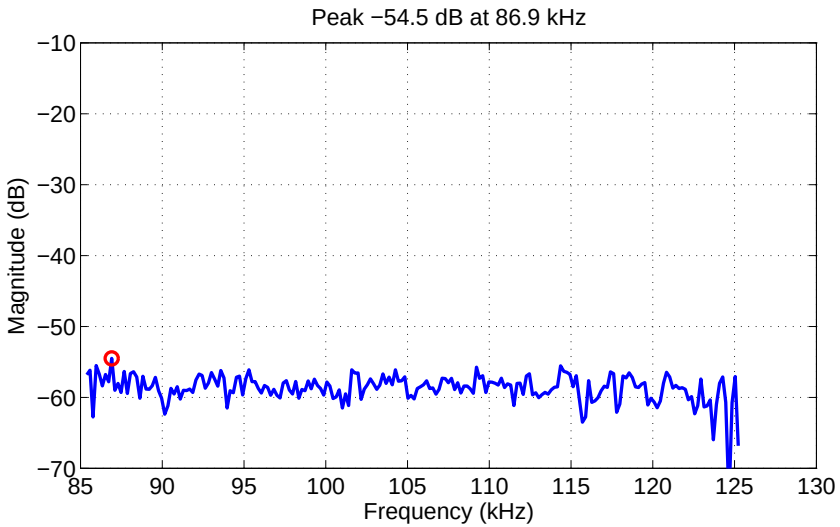

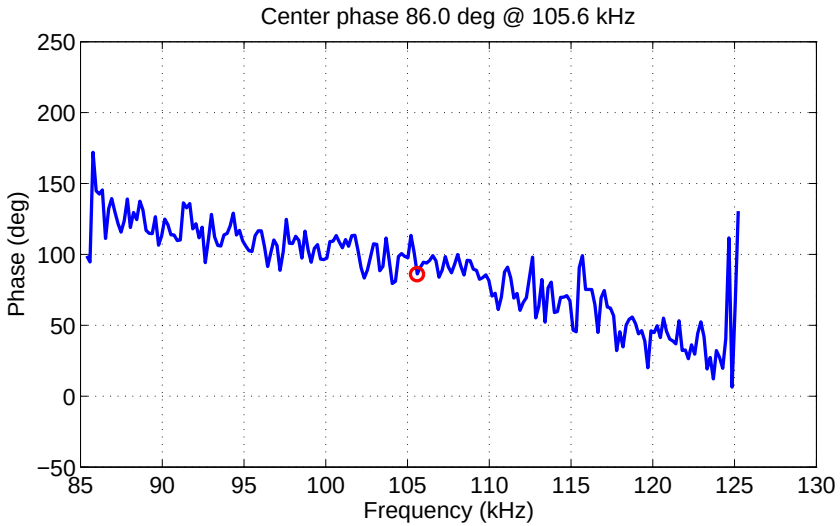

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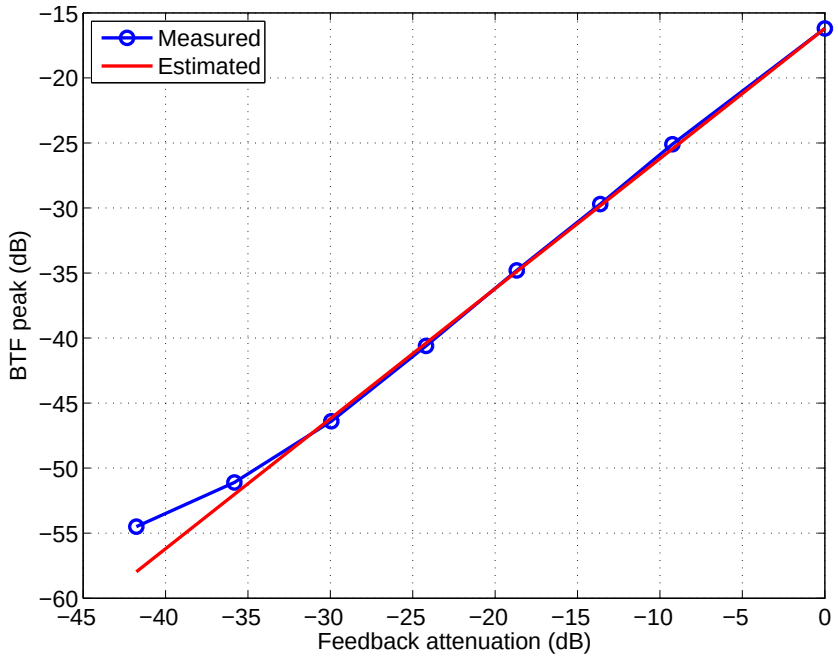

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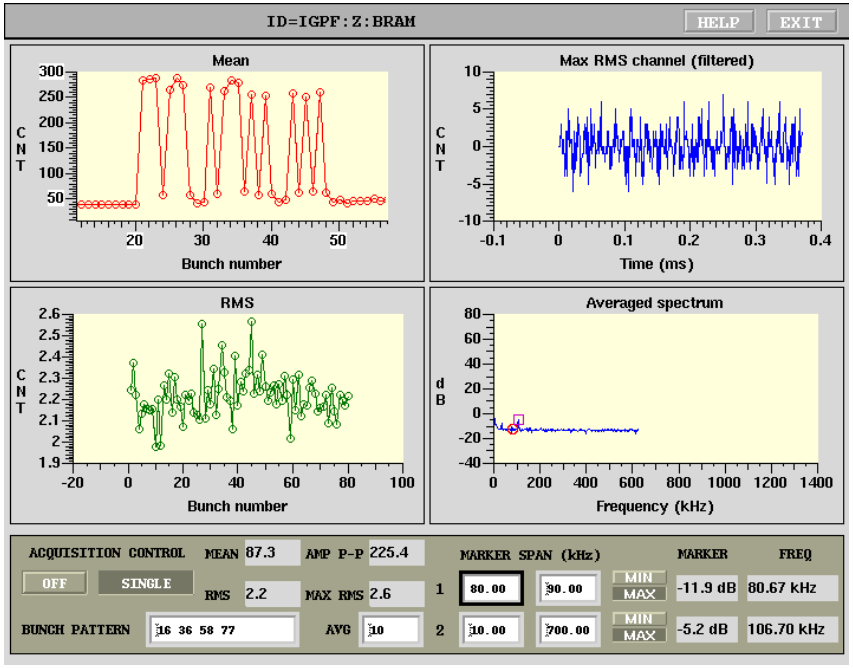

- After re-tuning checked bunch cleaning at injection and at the top of the ramp;
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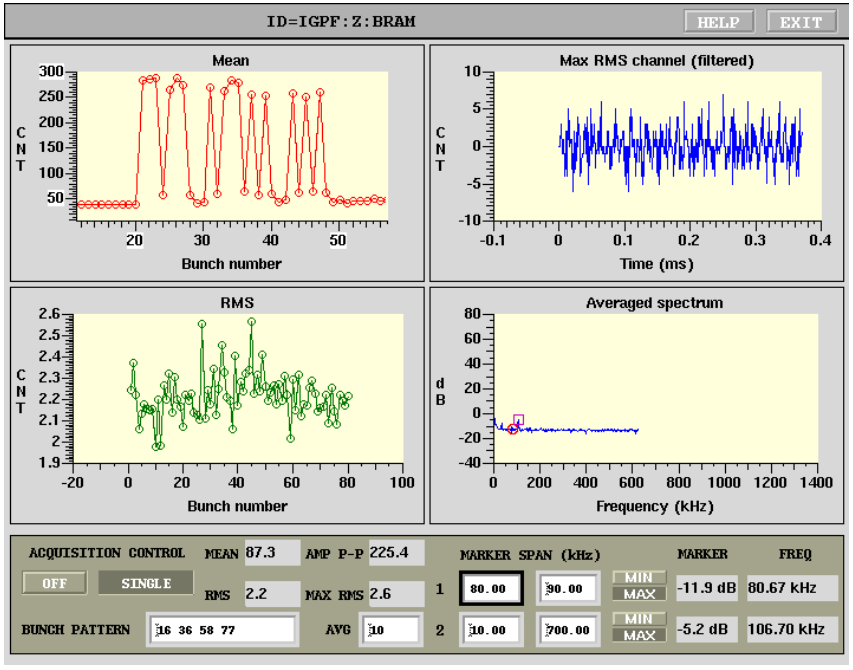

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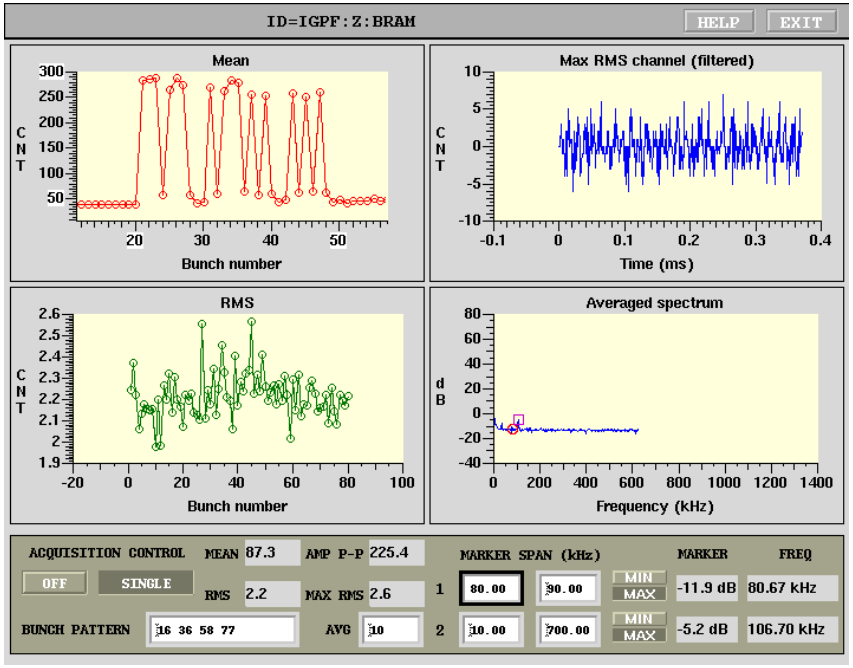

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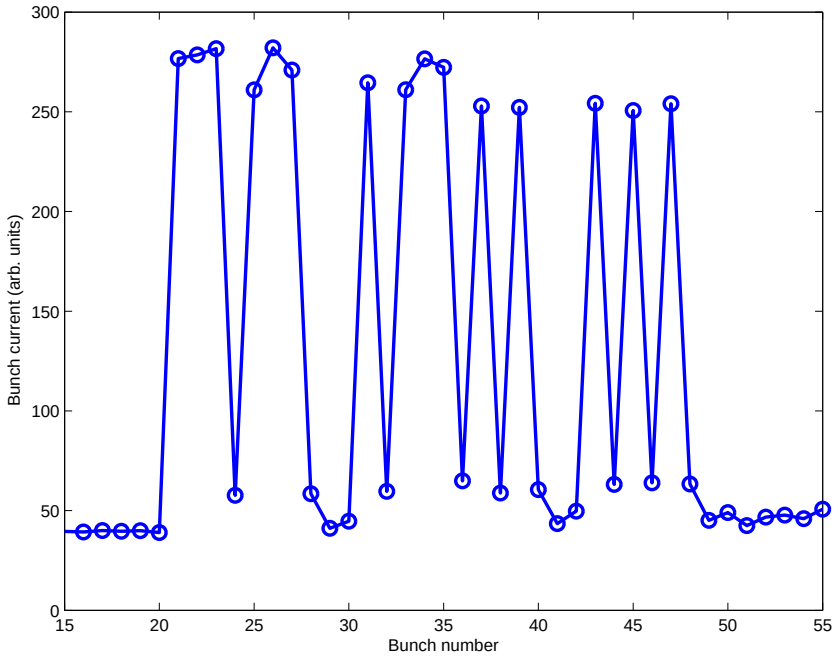

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Limiting Factors in the Longitudinal Plane

- Found two limiting effects:
  - Downward frequency shift of mode 0 due to beam loading;
  - Synchrotron frequency change from 85 to 105 kHz.

- An example from the the ALS;
- Mode 0 shifts from 12 to 4.8 kHz.

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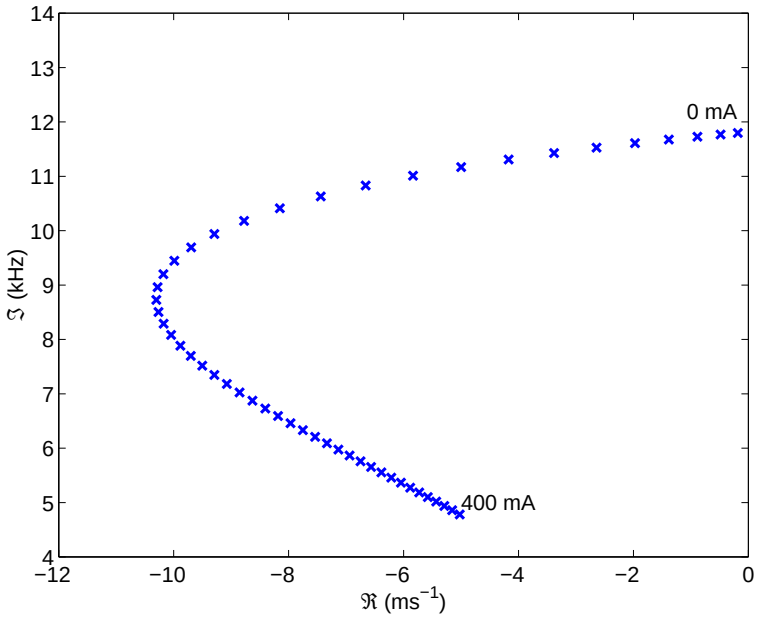

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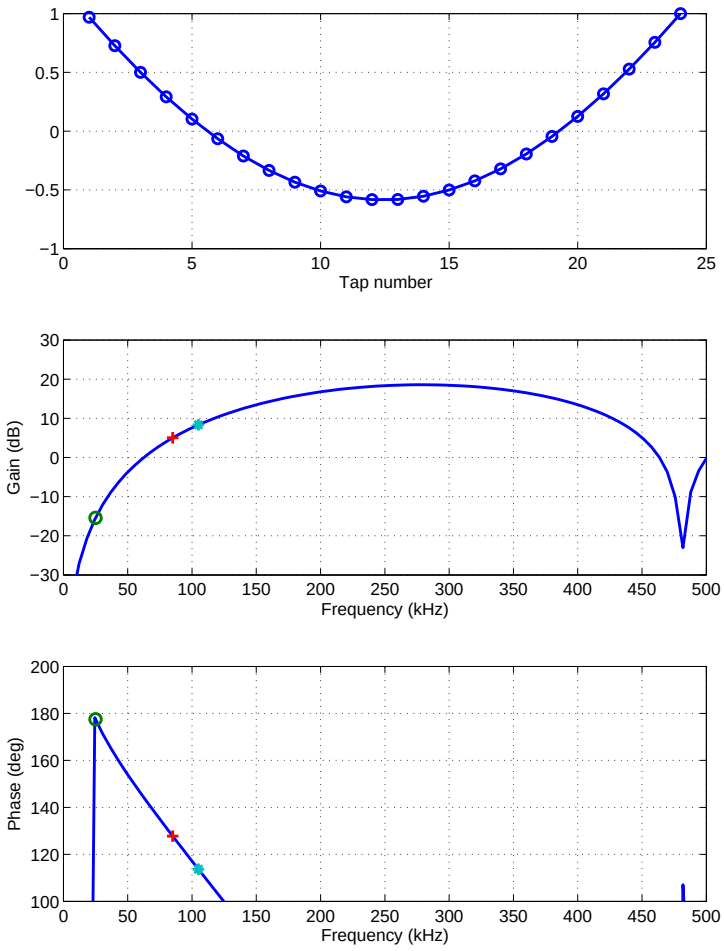

- Used a 24 tap filter with no downsampling;
- Roughly half synchrotron period long;
- Filter gain peaks around 270 kHz, but the beam has no response there;
- Only 14° phase shift between 85 and 105 kHz;
- Gain at 25 kHz is 20 dB down and 50° away from resistive phase.

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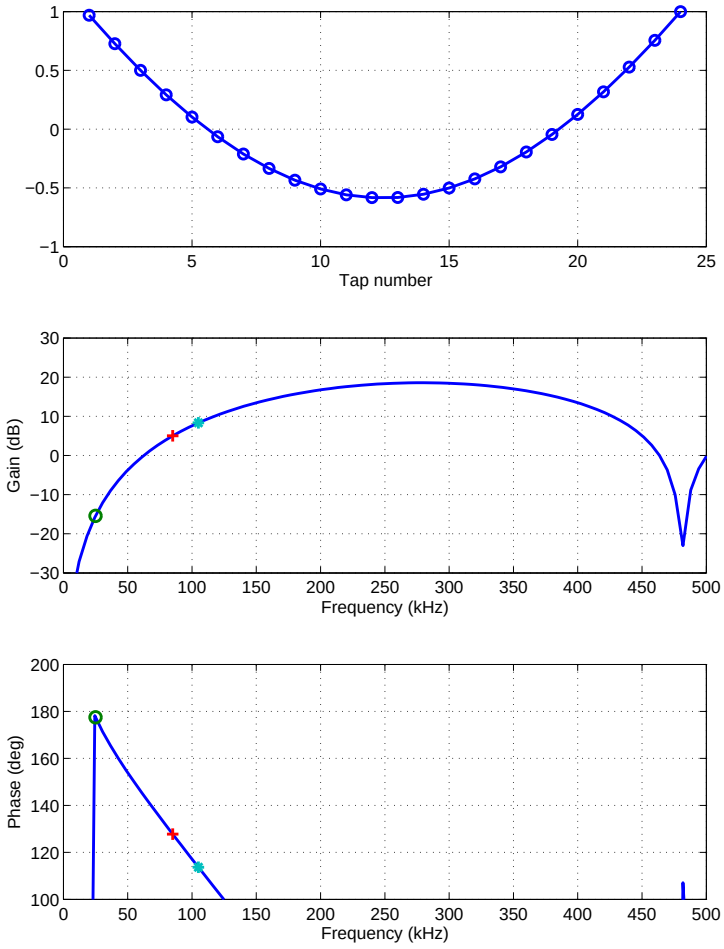

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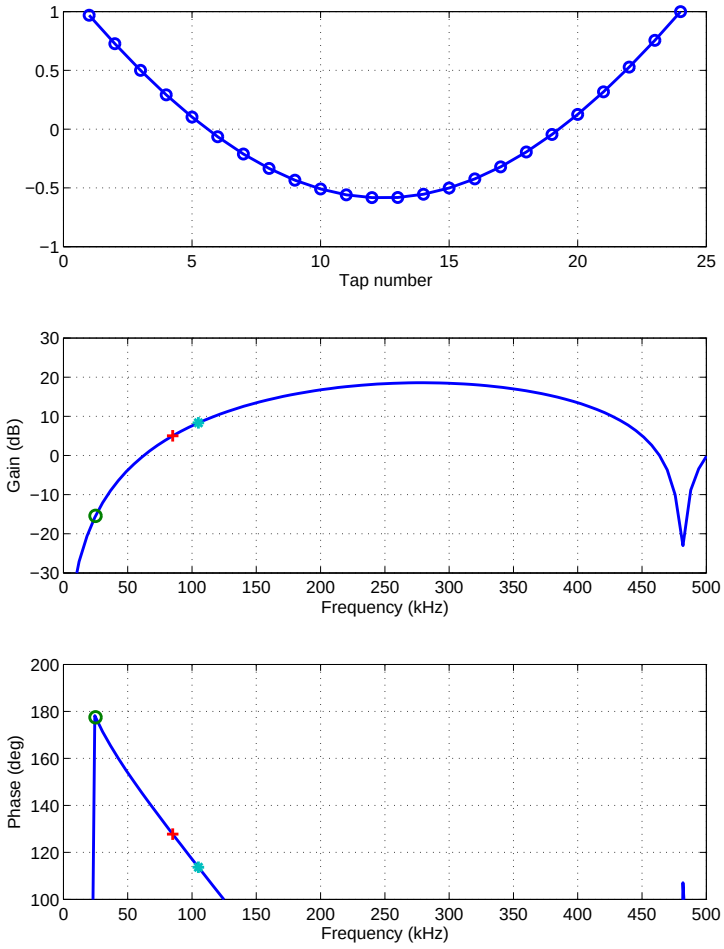

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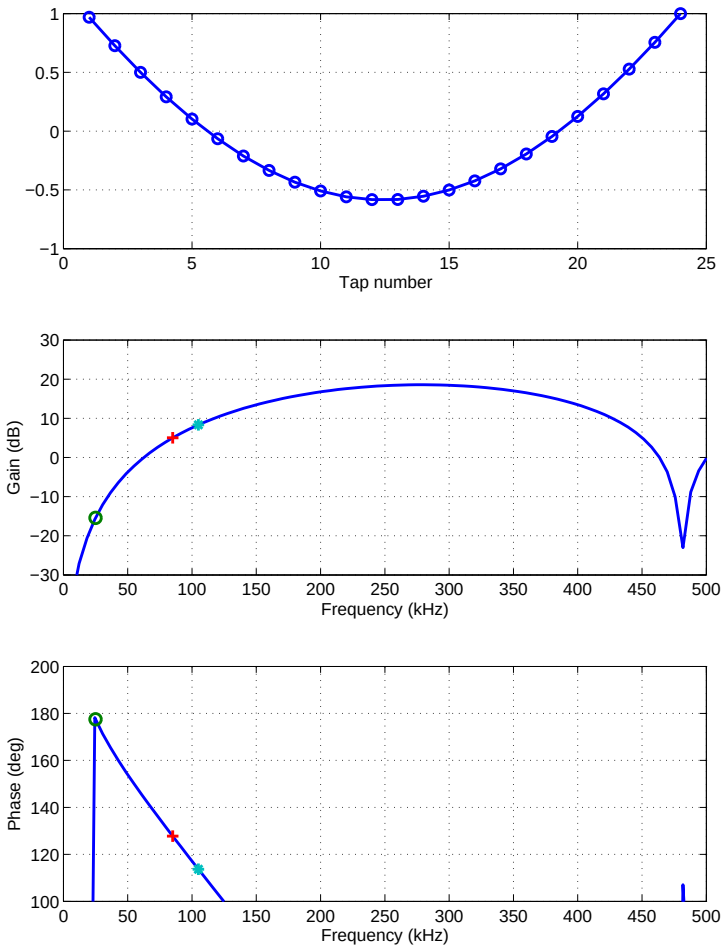

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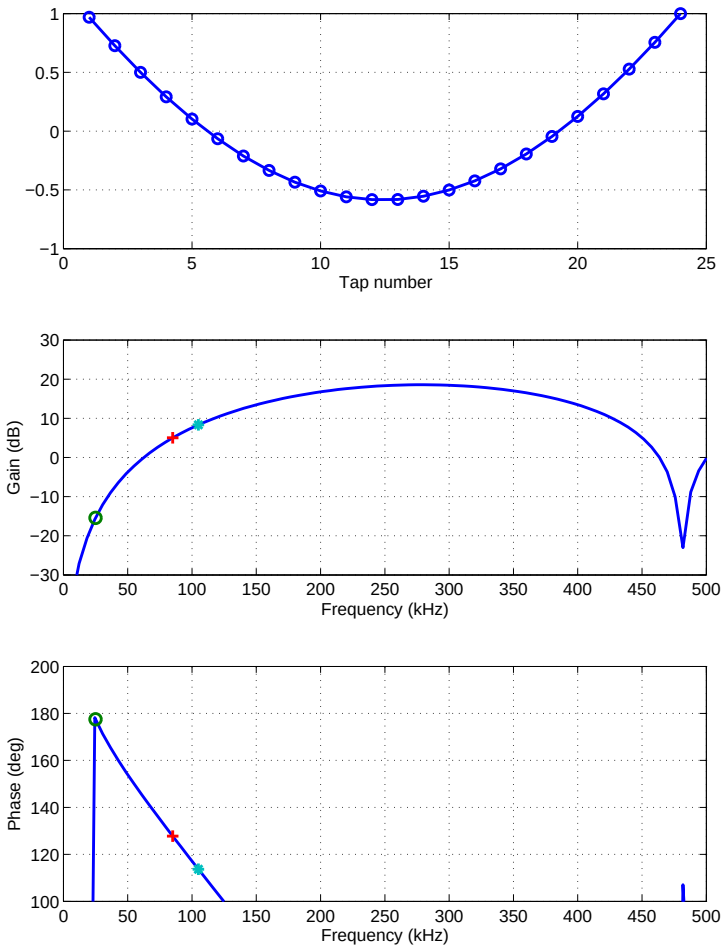

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Longitudinal Feedback and Ramping

- Minimum turn-on energy is 150 MeV ...
- ... but the lifetime suffers;
- Converged on feedback turn-on at 200 MeV;
- Use phase servo to maintain front-end phase detection;
- Seemed fairly stable in the short testing we have performed;
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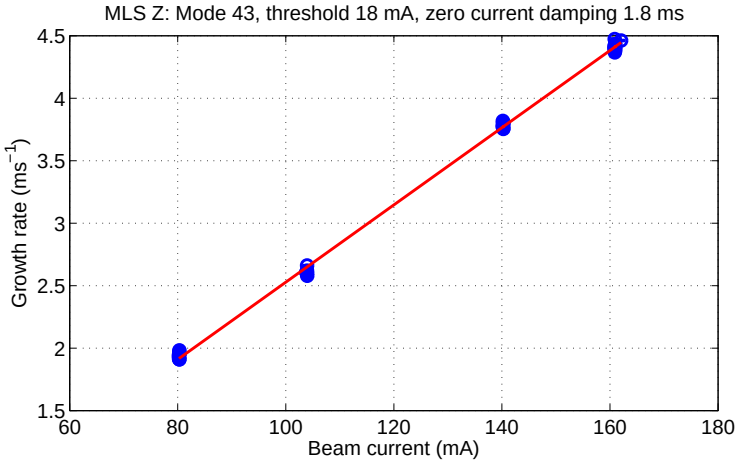
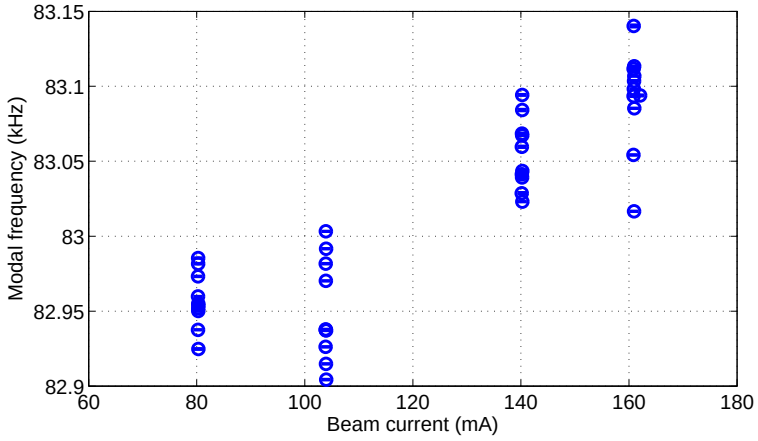
Longitudinal Growth Rates vs. Beam Current (1/3)





- Mode 43 open-loop eigenvalues vs. beam current;
- Threshold of 18 mA, zero current damping of 1.8 ms;

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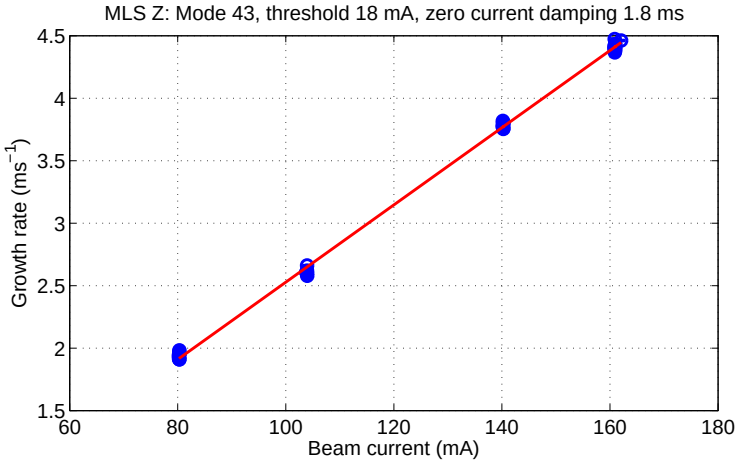

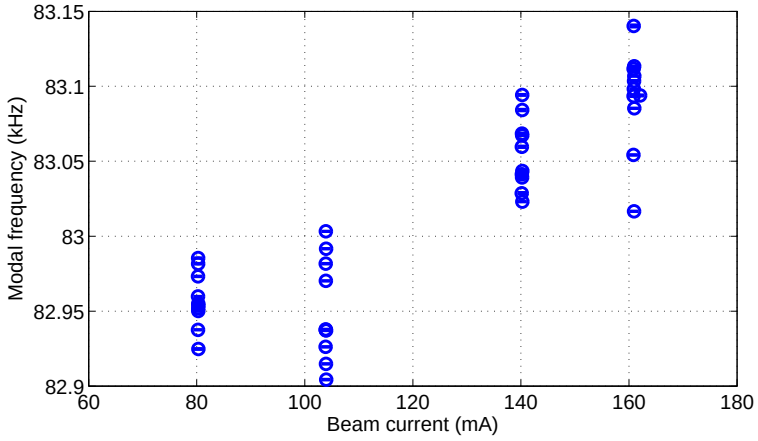

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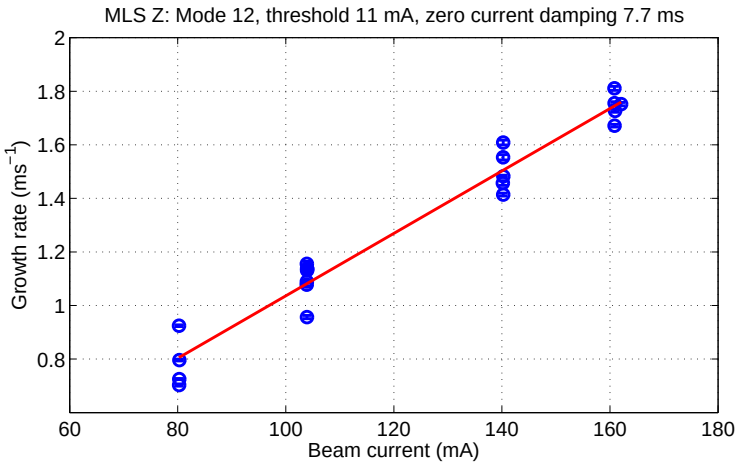
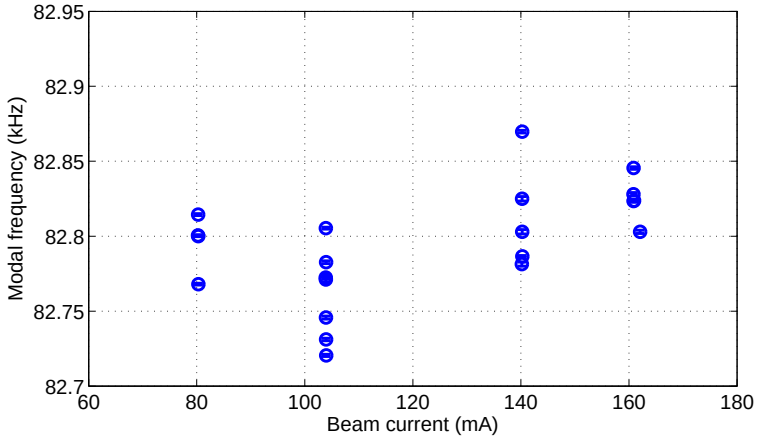
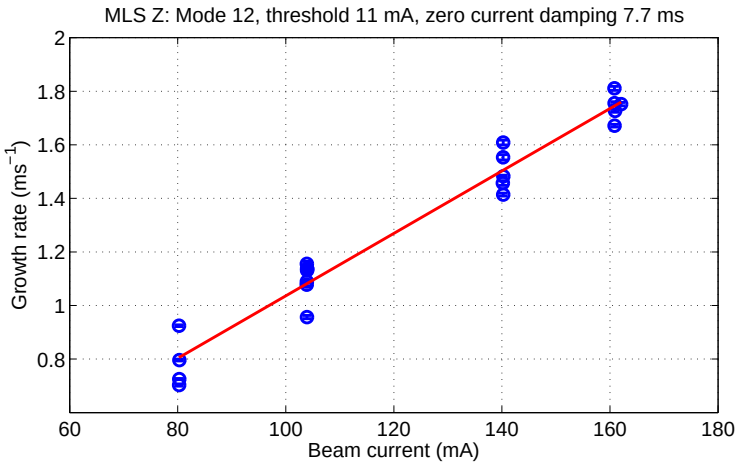
Longitudinal Growth Rates vs. Beam Current (2/3)

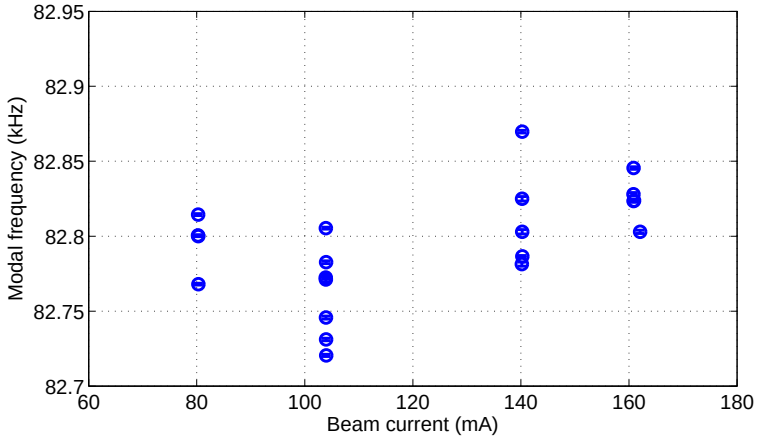




- Mode 12 open-loop eigenvalues vs. beam current;
- Threshold of 11 mA, zero current damping of 7.7 ms;

Longitudinal Growth Rates vs. Beam Current (2/3)





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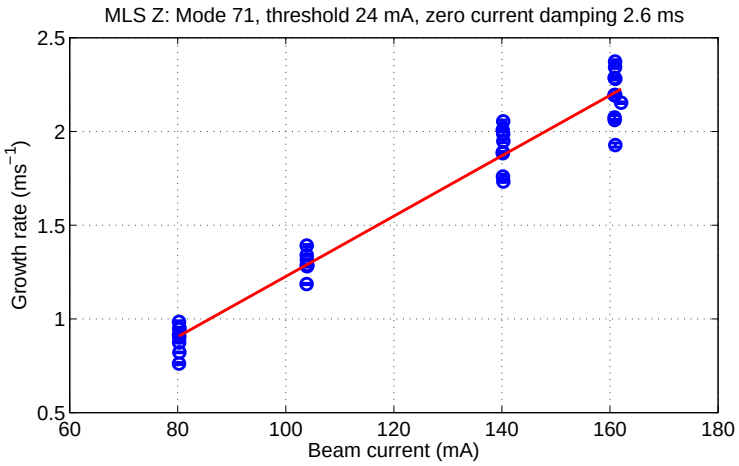

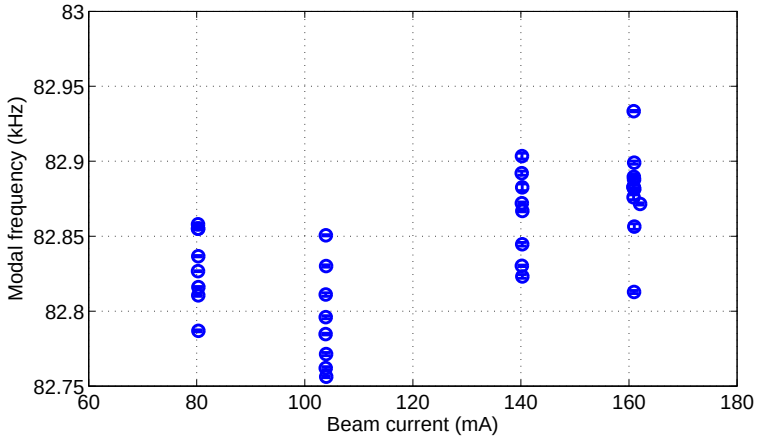

- Mode 71 open-loop eigenvalues vs. beam current;
- Threshold of 24 mA, zero current damping of 2.6 ms;

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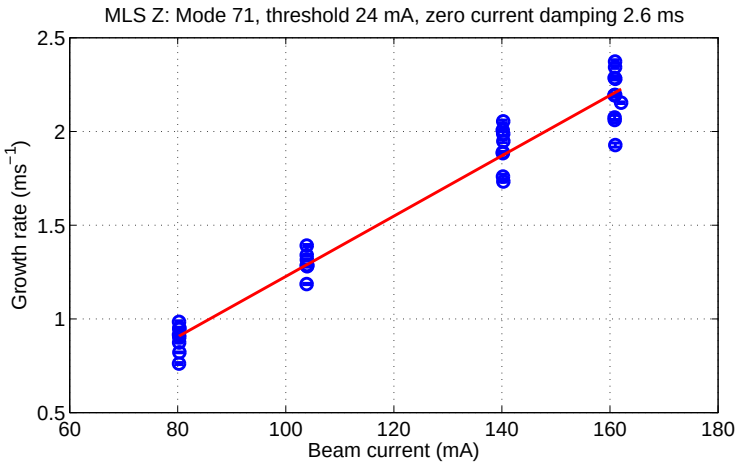

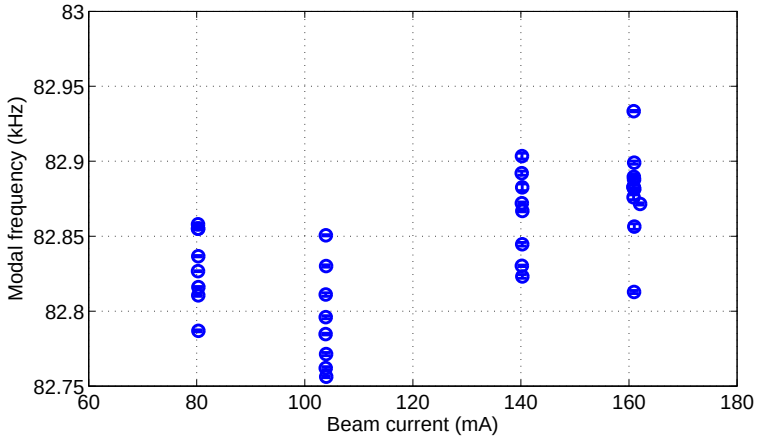

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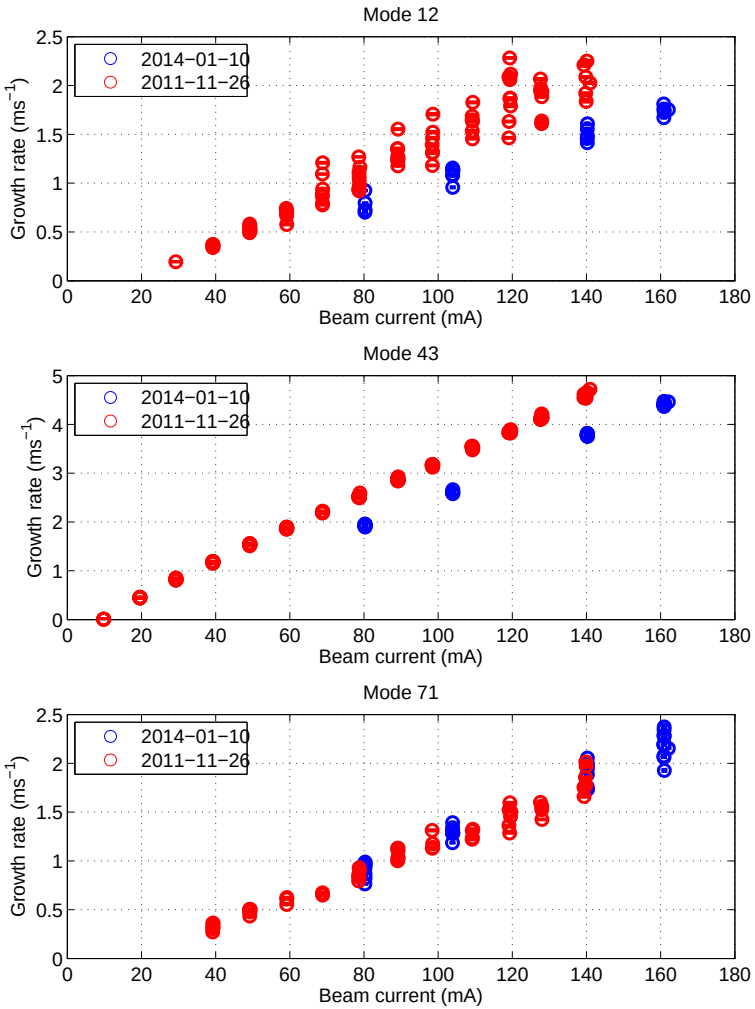
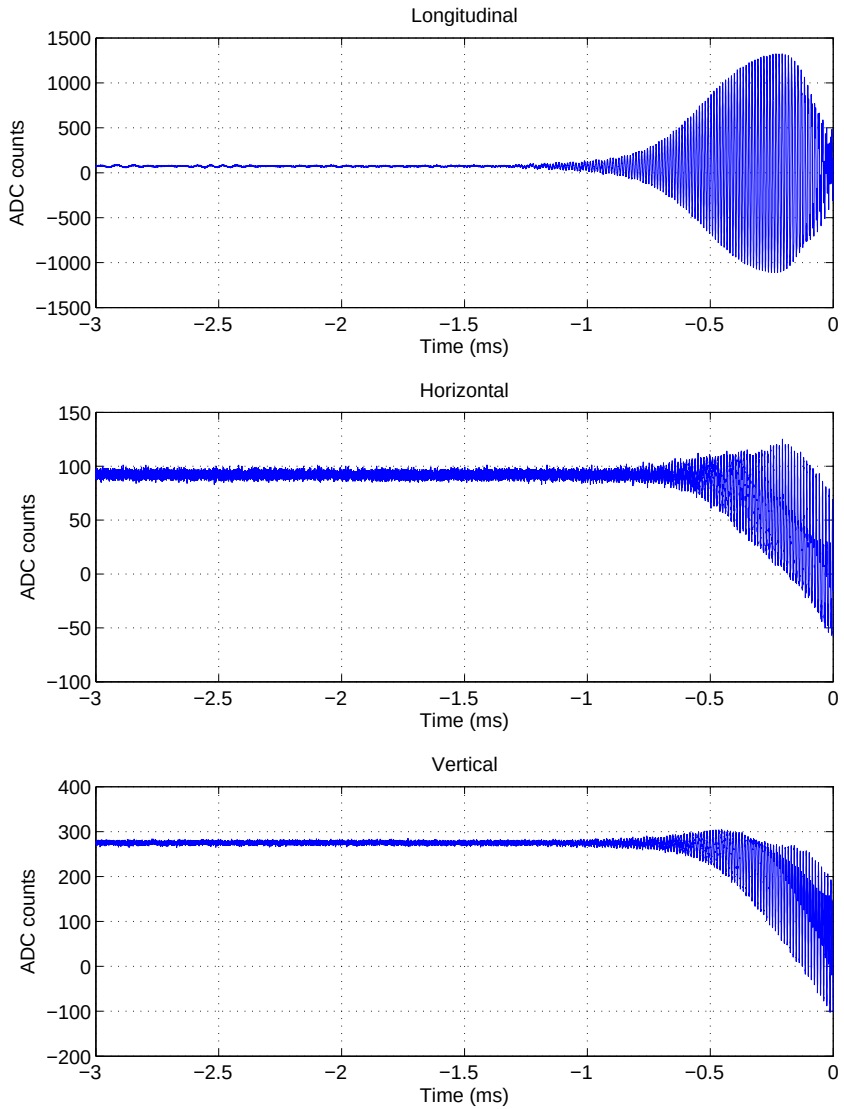
Longitudinal Growth Rates: Historical Comparison



- A clear reduction for modes 12 and 43, mode 71 unchanged.

Outline

Beam Loss: Longitudinal Instability



- Beam loss due to longitudinal instability;
- Relatively slow loss over 0.5 ms;
- Spectrum is dominated by synchrotron frequency and harmonics;
- A faint knockout line is visible;
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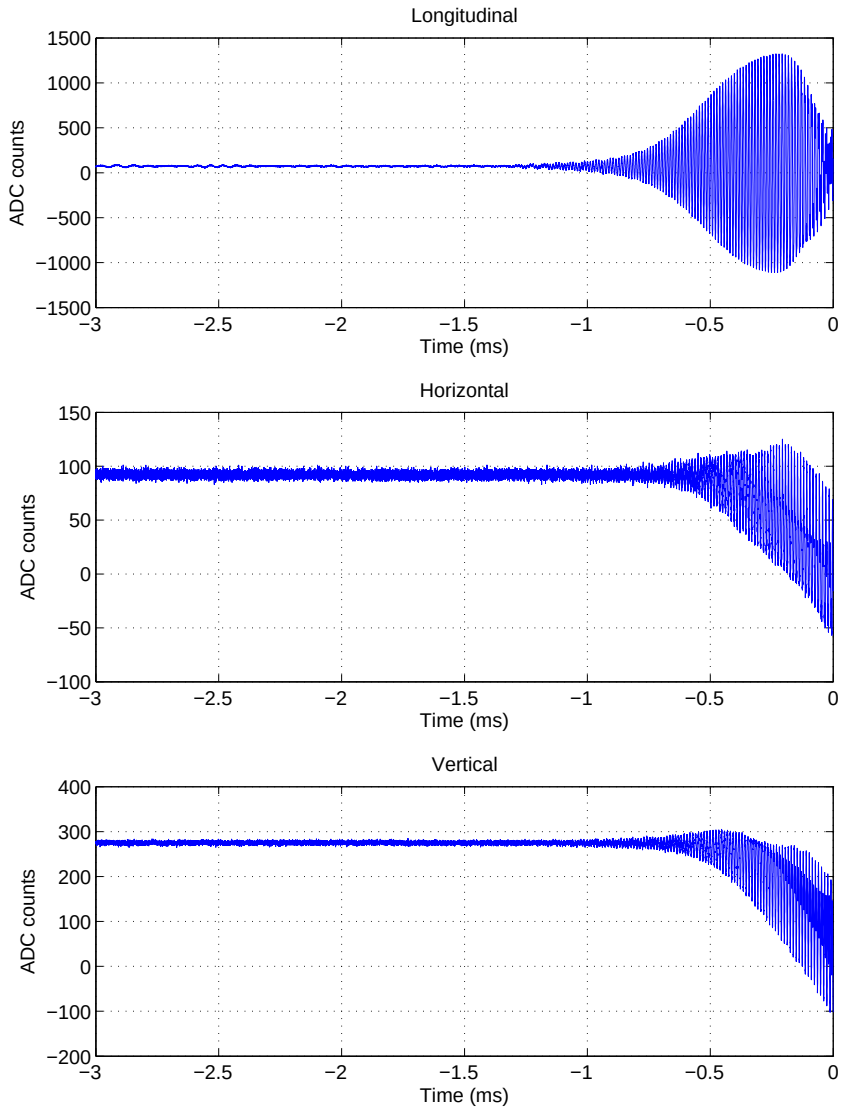
Beam Loss: Longitudinal Instability



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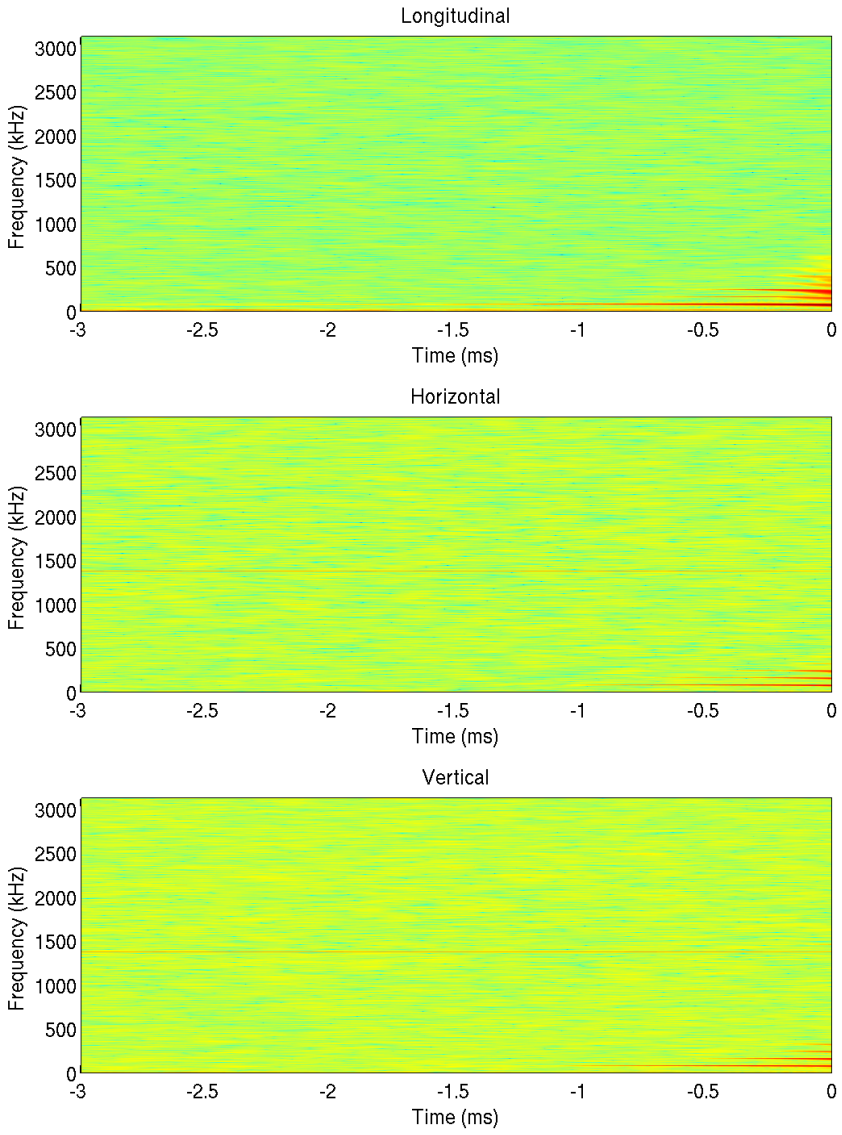

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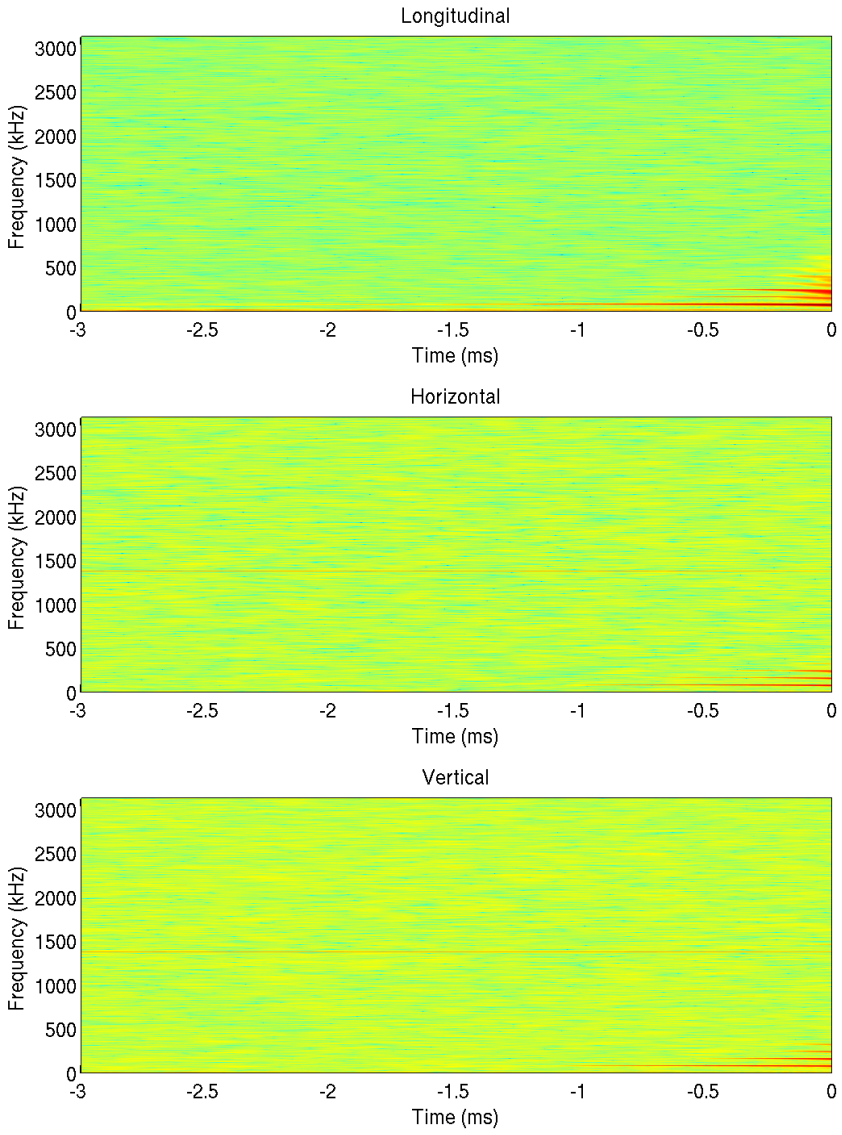

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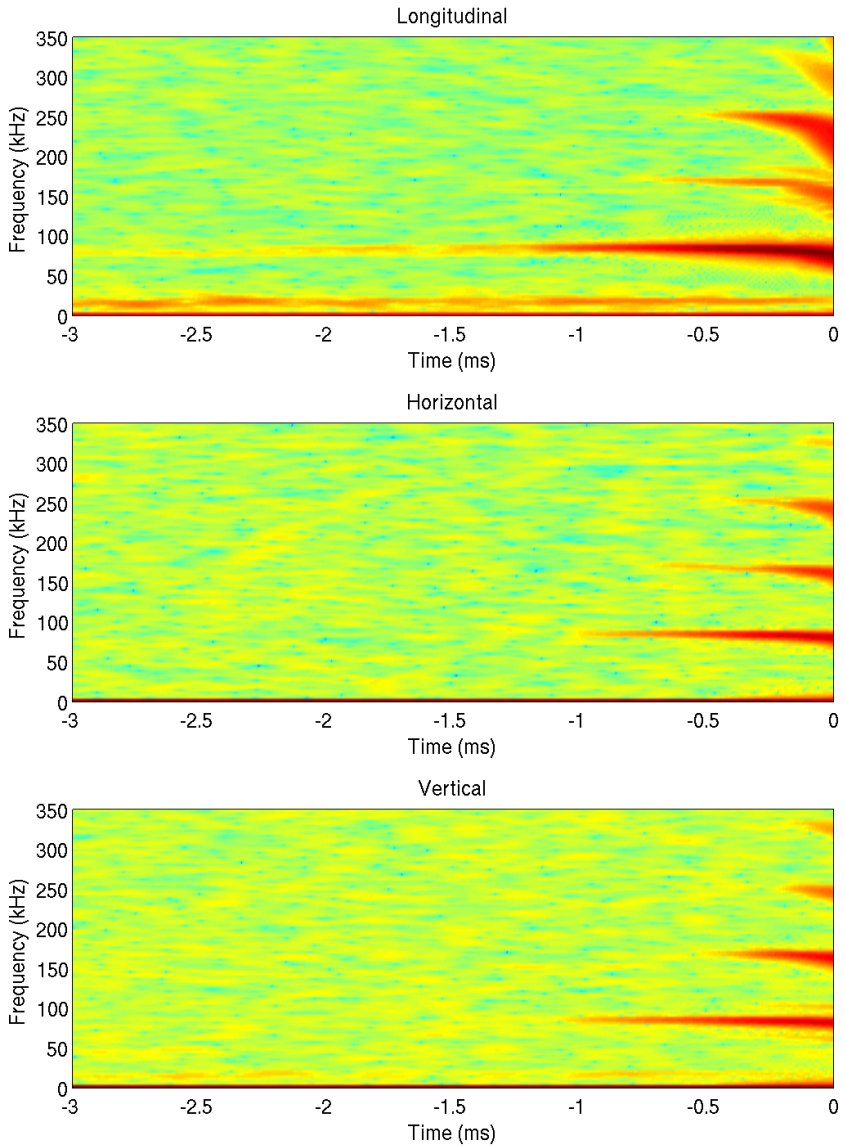

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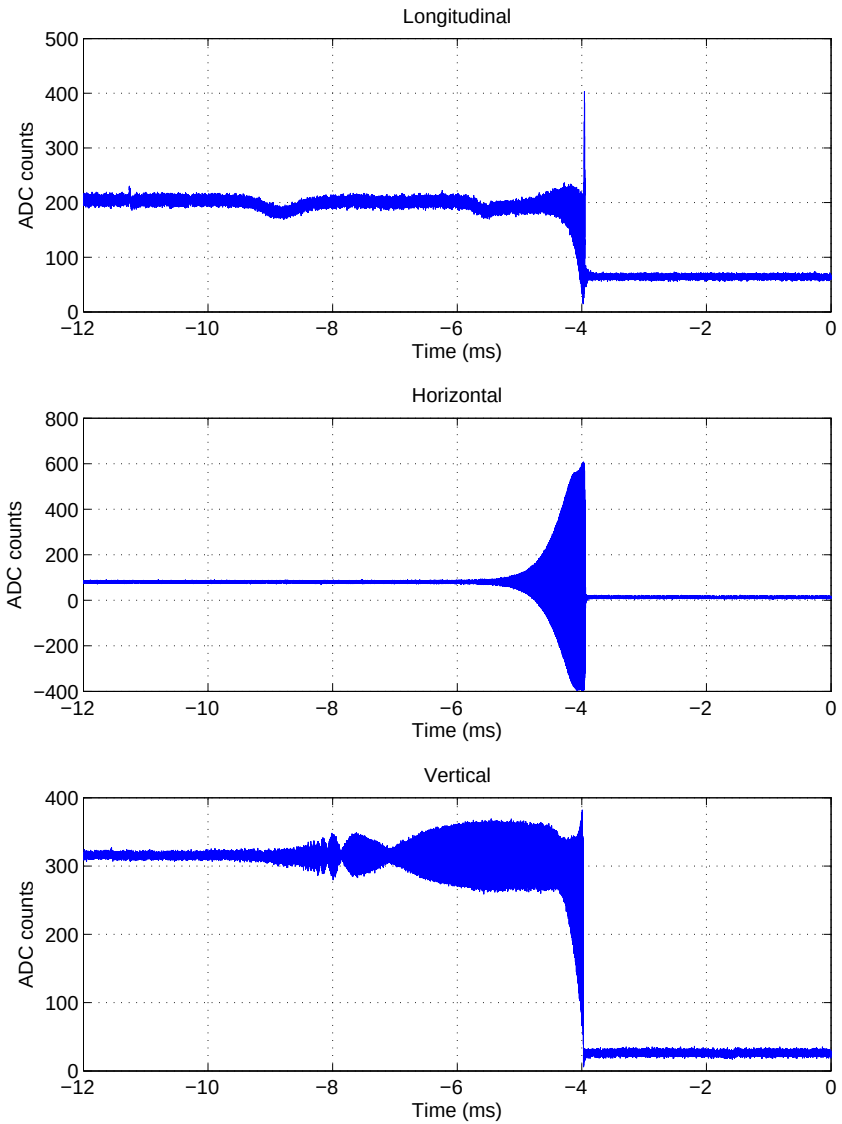

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- Fast loss — roughly 100 turns;
- The vertical tune shifts to 1380 kHz;
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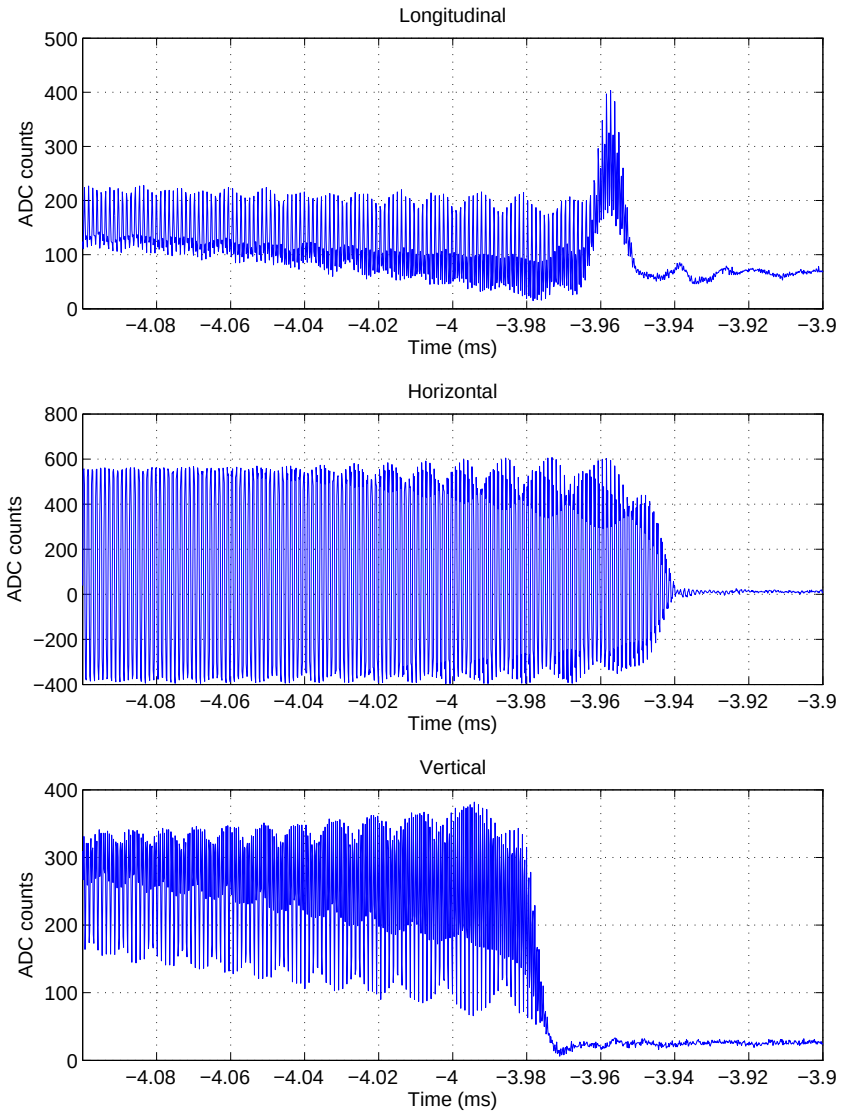

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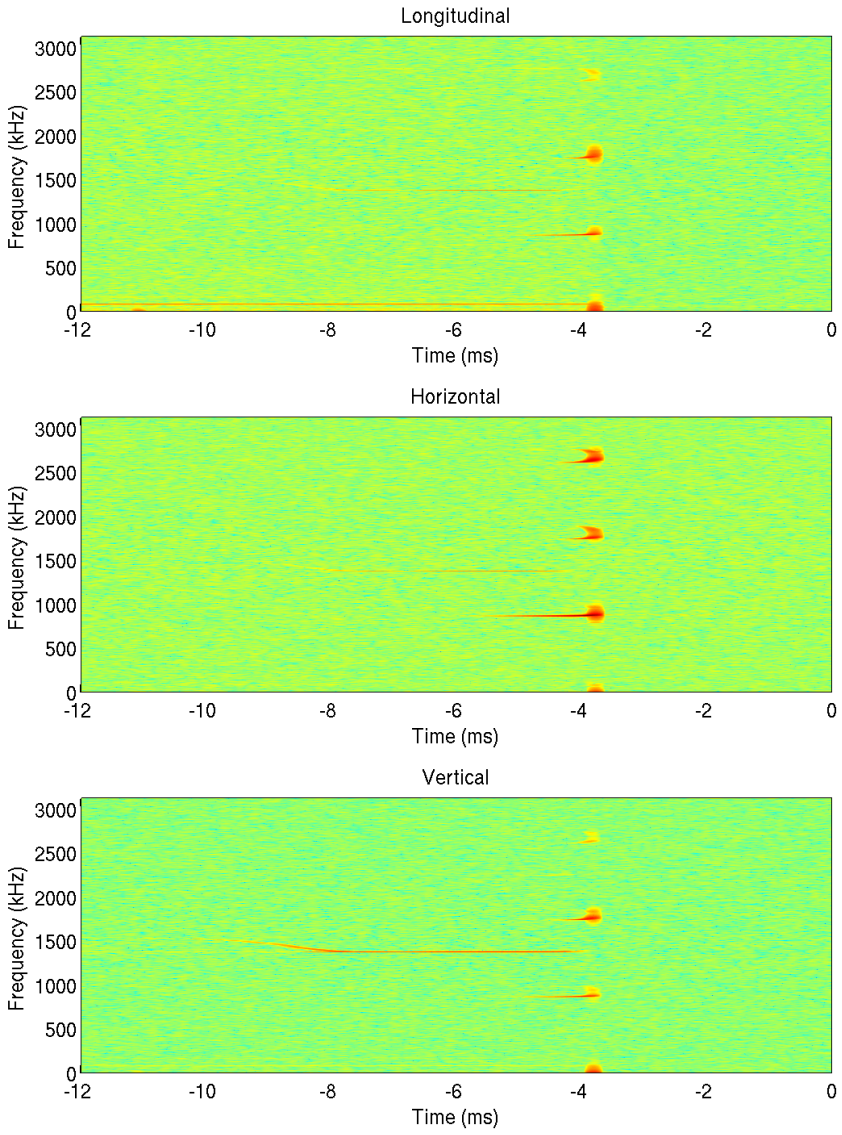

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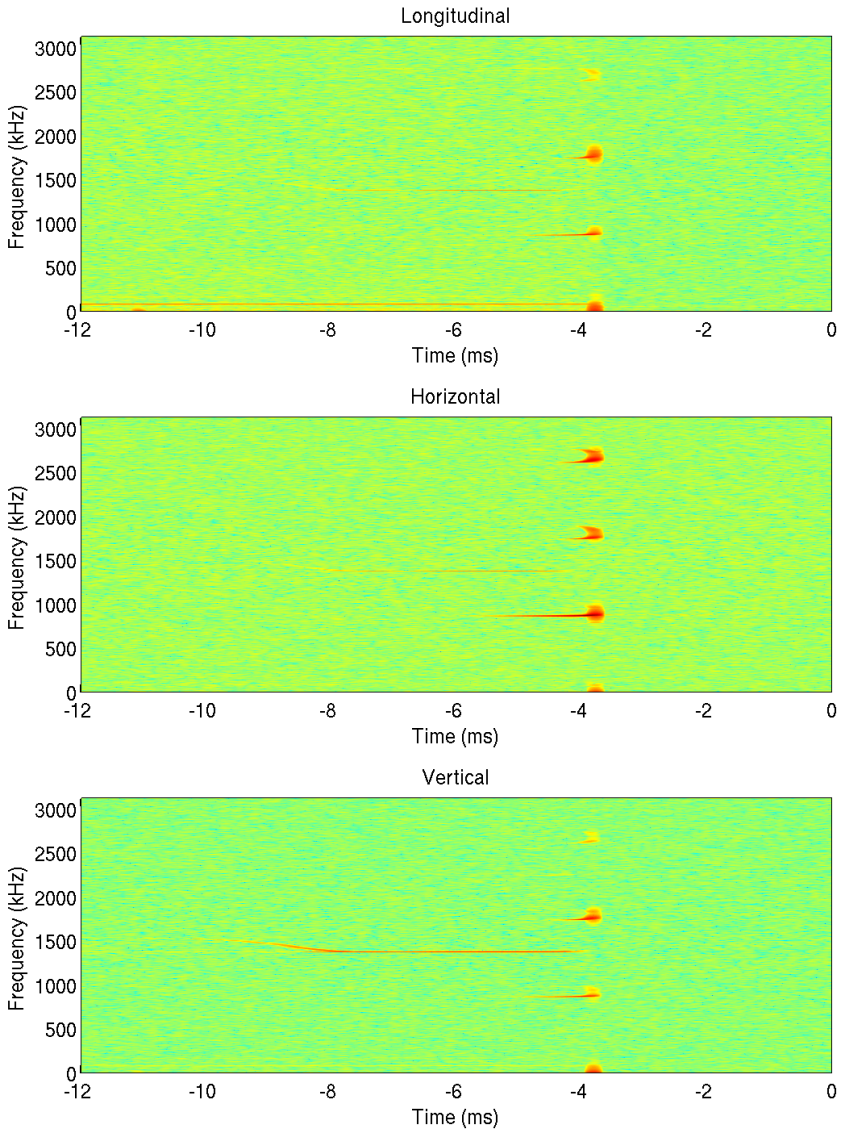

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Summary

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- Demonstrated longitudinal feedback operation through the energy ramp and optics transition;
- Configured and tested post-mortem data acquisition, beam transfer function measurements, bunch cleaning;
- Longitudinal growth rates have shifted slightly since 2011.

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