Vertical Instability Studies at the MLS

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Outline

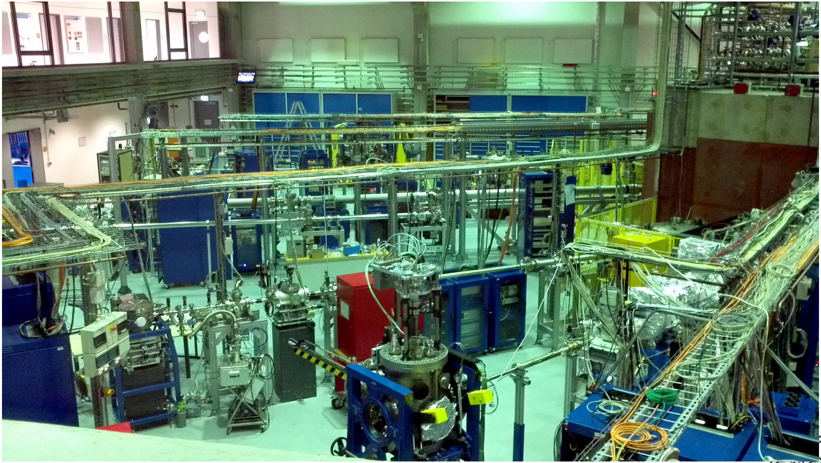
Machine Parameters

- Small 500 MHz electron storage ring;
- Used by German national metrology institute;
- Very low energy injection, ramping;
- Too small for an ion clearing gap;
- Rich beam dynamics.

Parameters

Injection energy	105 MeV
Operating energy	629 MeV
Circumference	48 m
Harmonic number	80
Beam current	200 mA
RF frequency	500 MHz
Tunes, X/Y	3.18/2.23
Natural emittance	110 nm rad
Damping time, $\parallel/\perp$	11/22 ms

MLS Beamlines



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   - Coupled-bunch Instabilities
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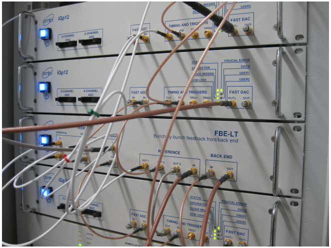
   - Longitudinal Grow/Damp Measurements
   - Vertical Grow/Damp Measurements

Instabilities and Control



- Both transverse and longitudinal coupled-bunch instabilities are present in the MLS;
- Strong energy sensitivity;
- In the transverse plane the beam is very sensitive to the coupling;
- A full complement of bunch-by-bunch feedback systems is installed and commissioned.

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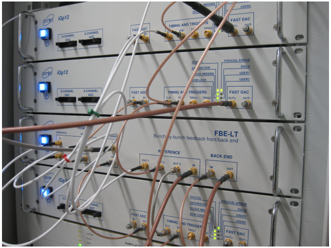

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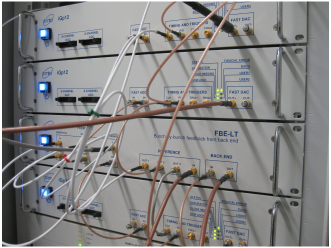

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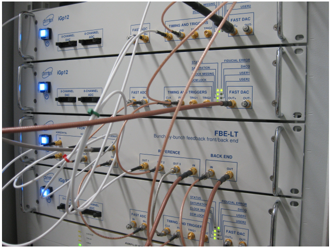

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Operating Approach

- Inject and ramp without feedback;
- Coupling knob dialed to 100% to reduce losses;
- At full energy, turn on the feedback systems (Z→X→Y);
- Reduce the coupling knob to 10%–25%;
- Beam spot shrinks, lifetime drops;
- Sometimes coupling reduction still leaves the beam blown up;
- Transient excitations can often facilitate the transition.

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Qualitative Observations

- With all feedback systems operating the beam is stable long-term;
- Destabilizing transients (feedback tuning, grow/damps) can lead to the loss of control;
- Unstable motion in both X and Y;
- Impossible to recapture, see both centroid motion and blow-up;
- Need to raise the coupling, turn off the feedback systems to re-stabilize;
- Sensitivity to gain balancing between horizontal and vertical planes.
- Very strong sensitivity to fill patterns.

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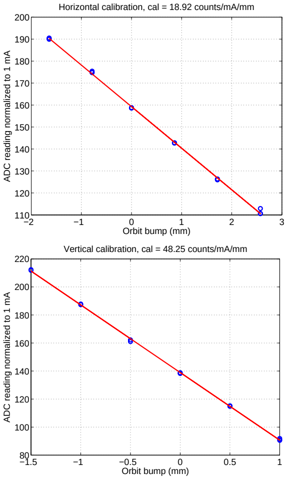
Front-end Calibration: Transverse Plane



- Set up controlled orbit bumps in X and Y;
- Measure bunch signal displacement in ADC counts;
- At 2 mA per bunch ADC LSB corresponds to 26 and 10 μm in X and Y respectively;

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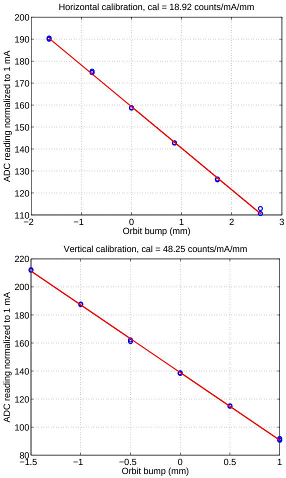

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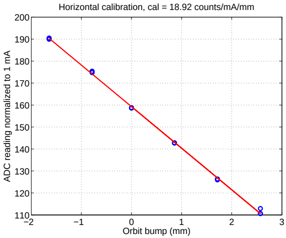

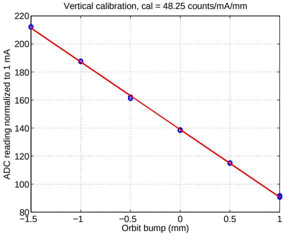

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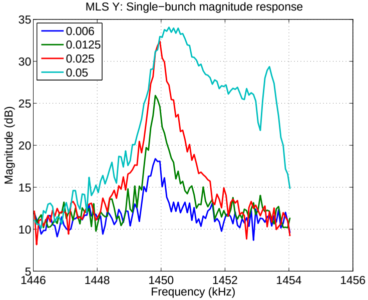
Vertical Tune Measurement



- Single bunch at 0.23 mA excited with a swept-sine signal;
- Sweep span of 7 kHz around 1450 kHz;
- At the excitation amplitude of 0.05 FS tune is "pushed" by the swept excitation;
- Fit second-order beam response to the spectrum;
- Little tune shift at low amplitudes.

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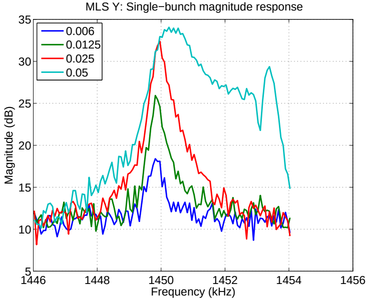

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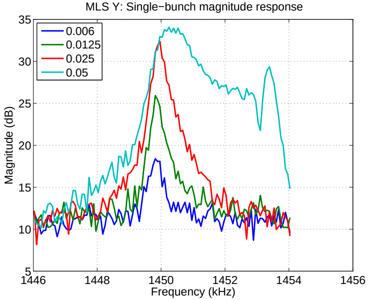

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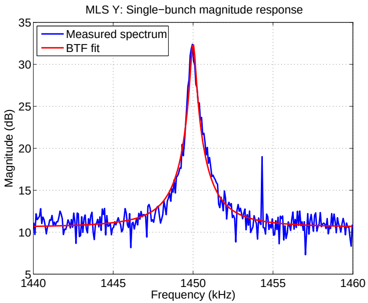

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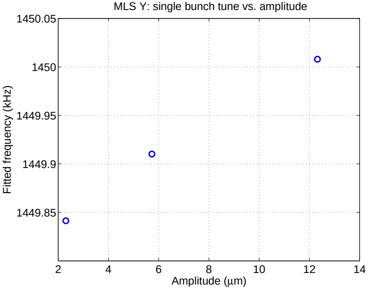

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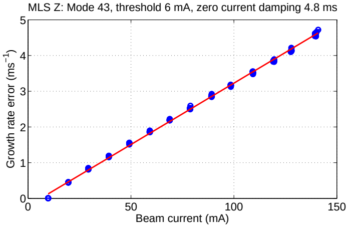
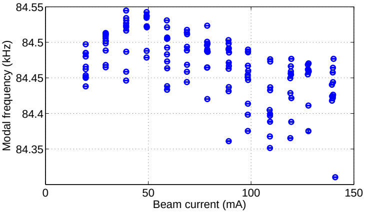
Longitudinal Growth Rates vs. Beam Current





- Fairly typical HOM-driven instabilities;
- Mode 43 open-loop eigenvalues vs. beam current;
- Threshold of 6 mA, zero current damping of 4.8 ms;
- Effective impedance of 39.2 kΩ at $nf_{\mathrm{rf}} + 268.6$ MHz.

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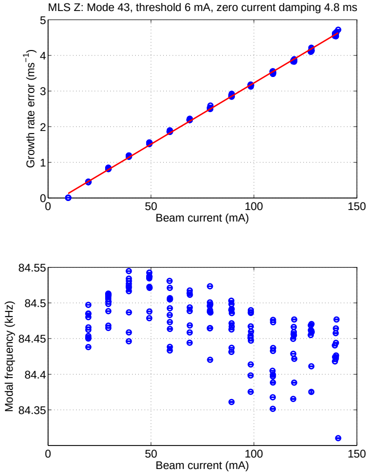

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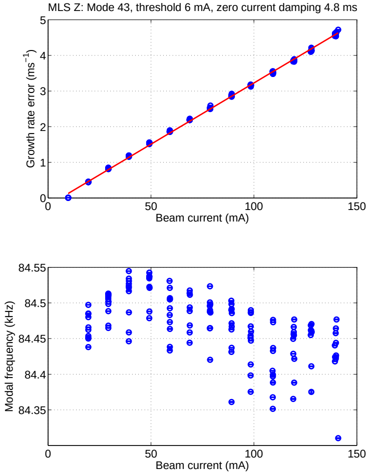

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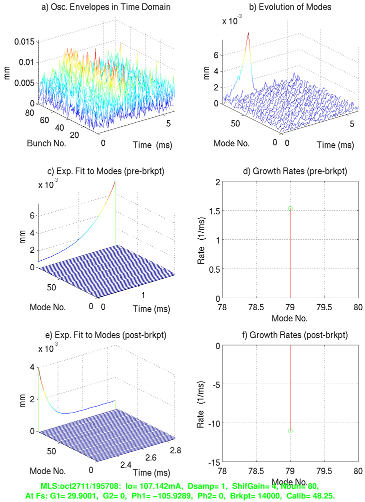
A Grow/Damp Measurement (Small)



- Mode -1 growing and damping at low amplitude (9 μm peak);
- Fast feedback damping;
- Exponential fits look good;
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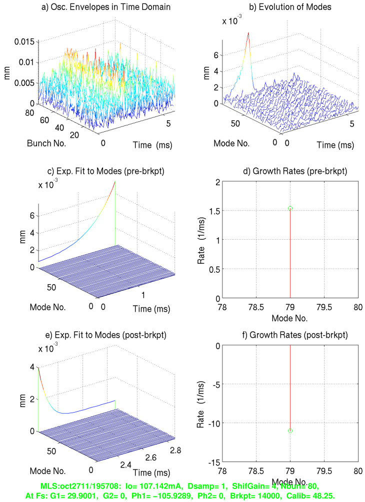

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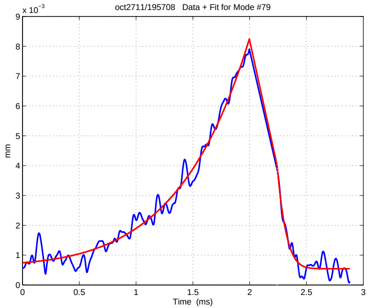

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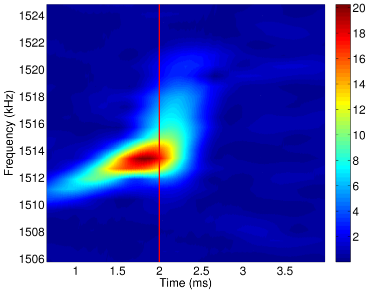

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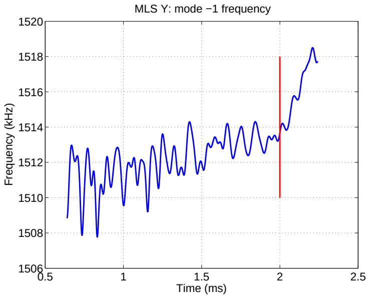

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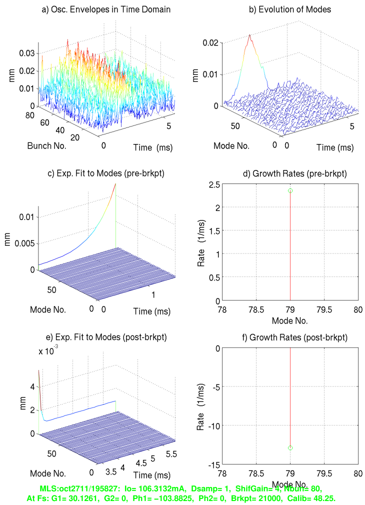

- Mode -1 growing to 21 μm peak;
- Same initial frequency as before, large downward shift;
- Large tune shift starts at around 12 μm amplitude.

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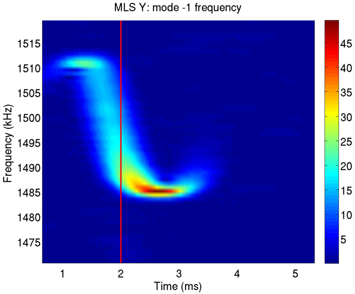

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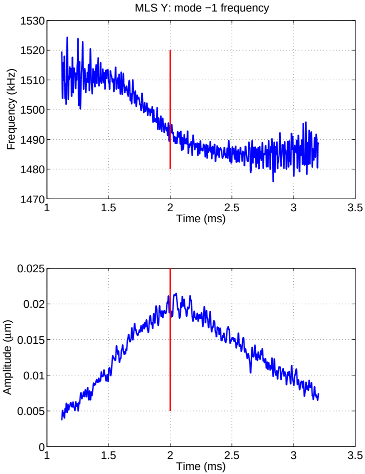

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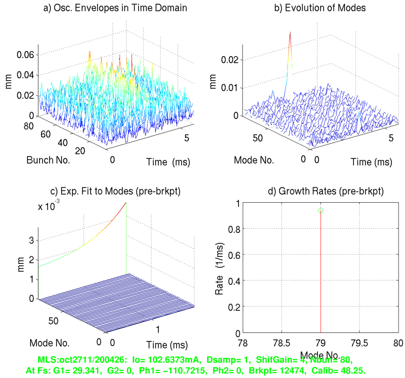

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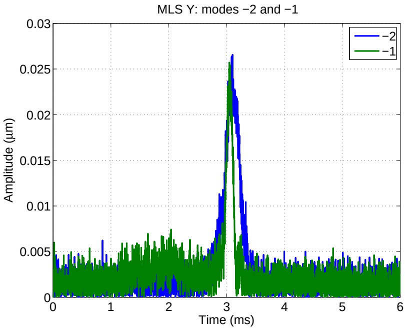

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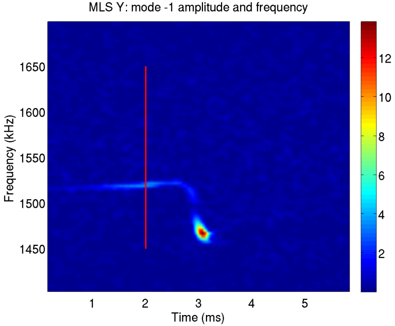

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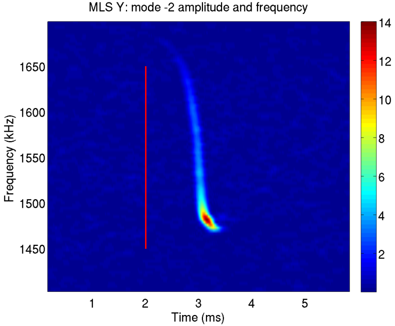

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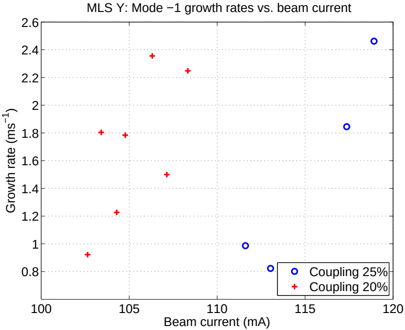

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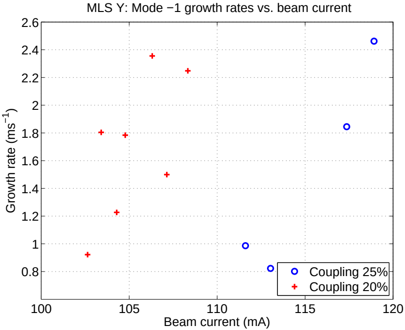

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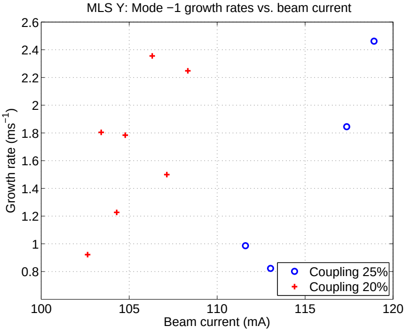

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Two States: A Hypothesis

- It almost seems that feedback is mis-tuned when transverse motion cannot be suppressed;
- Reasonable ($\pm$60 degrees) feedback phase adjustments do not help;
- Are we picking up signals from both the beam and the ions?
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- In transients, ion motion makes the difference between clean damping and loss of control/spikes in closed-loop.

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- Use a second acquisition system to measure the signal between the bunches;
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Summary

- We have observed very rich transverse dynamics;
- Dramatically different behavior from machines at higher energy (or operating with ion clearing gap);
- Can we mine the data for more information? What else should we measure?
- What is the best way to test the "mixed signals" model?

Summary

- We have observed very rich transverse dynamics;
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