

Feedback Commissioning and Diagnostics in BEPC II e^+ Ring

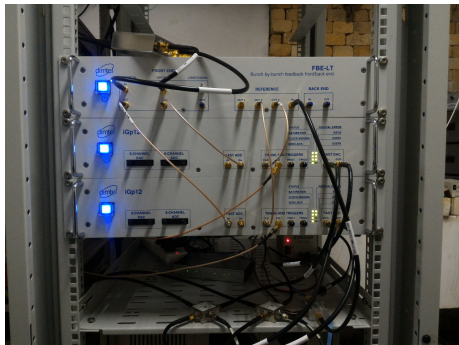
D. Teytelman¹, et. al.

Dimtel, Inc., San Jose, CA, USA

December 21, 2017



Hardware Setup



- Completed installation, might benefit from cabling cleanup;
 - Three channel front/back-end;
 - Two iGp12-396F;
 - BPM hybrid network (Dimtel BPMH-20-2G);
 - Used differential outputs of X and Y units with two 180° hybrids to drive four striplines.



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Day by Day Summary

- Monday (2017-12-18):
 - iGp12 IOC and network configuration;
 - Connected master oscillator reference and fiducial signals;
 - Software updates.
- Tuesday (2017-12-19):
 - BPM hybrid input delays trimmed for best common mode rejection;
 - Configured amplifier drive network;
 - Amplifier gains set up for 1 dB saturation (X and Y at max drive);
 - Established front-end timing and phasing;
 - Trimmed amplifier cables to properly time align all four striplines;
 - Some multibunch running, limited due to injection issues;
 - Set up and demonstrated bunch cleaning.
- Wednesday (2017-12-20):
 - Multi-bunch studies, grow/damp measurements up to 560 mA;
 - Single bunch tune tracking tested;
 - Longitudinal plane measurements;
 - Training.



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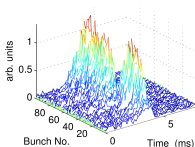
Outline

- 1 Setup
- 2 Transverse Measurements**
 - Horizontal Plane
 - Vertical Plane
- 3 Longitudinal Measurements
- 4 Tune Measurement
 - Tune Notch
 - Phase Tracking

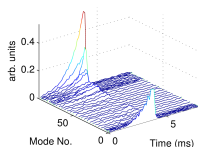


Grow/Damp Measurements

a) Osc. Envelopes in Time Domain

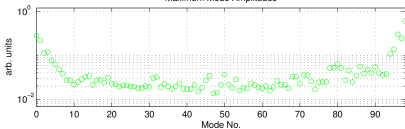


b) Evolution of Modes



BEPC-II E+.dec2017/103659: Io= 515.7033mA, Dsamp= 1, ShfGain= 0, Nbun= 99,
At v: G1= 3.4504, G2= 5.921e-05, Ph1= -67.5528, Ph2= -88.5652, Brkpt= 4959, Calib= 1.

Maximum Mode Amplitudes

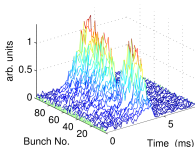


- At 516 mA, 90 bunch fill pattern;
- Typical resistive wall instability, with mode -1 dominating;
- Fit growth and damping rates, very fast damping;
- Transients are fairly clean;
- 41 measurements at different currents.

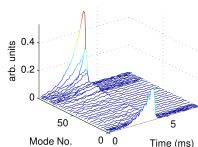


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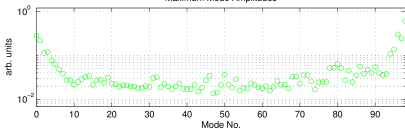


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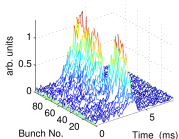


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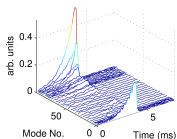


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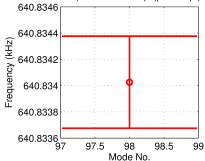
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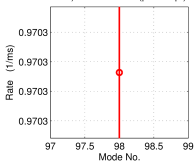
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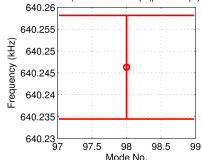
c) Oscillation freqs (pre-brkpt)



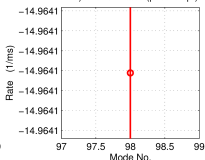
d) Growth Rates (pre-brkpt)



e) Oscillation freqs (post-brkpt)



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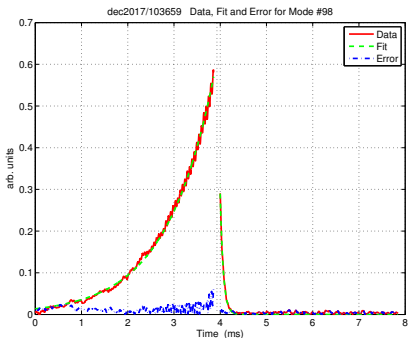


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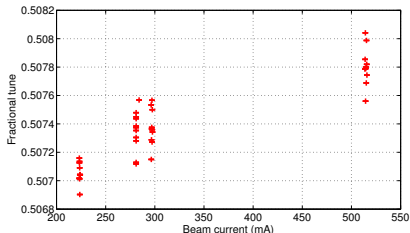
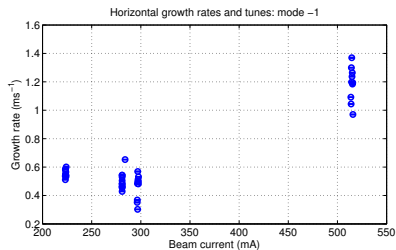
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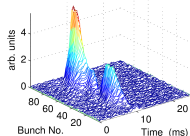
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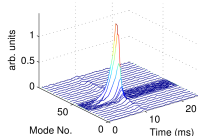


Grow/Damp Measurement: 300 mA

a) Osc. Envelopes in Time Domain

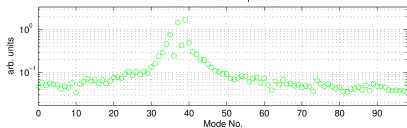


b) Evolution of Modes



BEPC-II E+:dec2017/095543: Io=300mA, Dsamp=1, ShifGain=2, Nbun=99,
At v: G1= 8.6441, G2= 0.00026514, Ph1= -16.383, Ph2= -77.1558, Brkpt= 12533, Calib= 1.

Maximum Mode Amplitudes

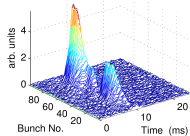


- At 300 mA, 90 bunch fill pattern;
- Suggestive of a wide HOM centered around mode 37;
- Fits “paint” the resonance;
- Damping rates are much faster than growth rates;
- Fairly clean fits to all the modes.

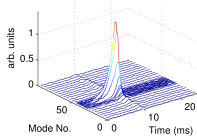


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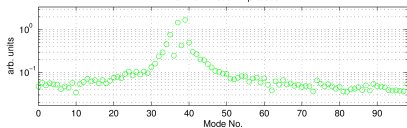


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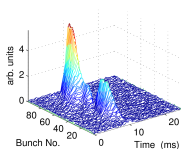


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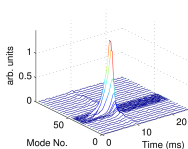


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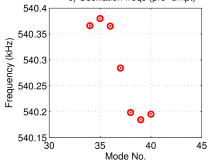
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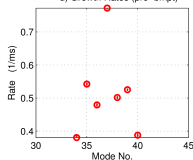
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c) Oscillation freqs (pre-brkpt)



d) Growth Rates (pre-brkpt)



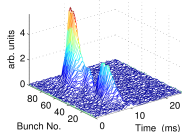
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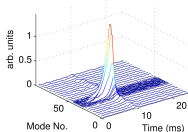


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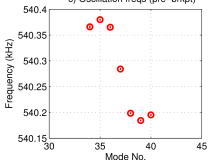
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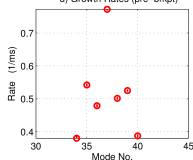
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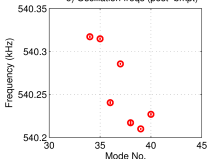
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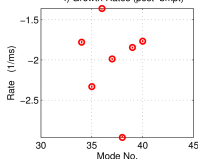
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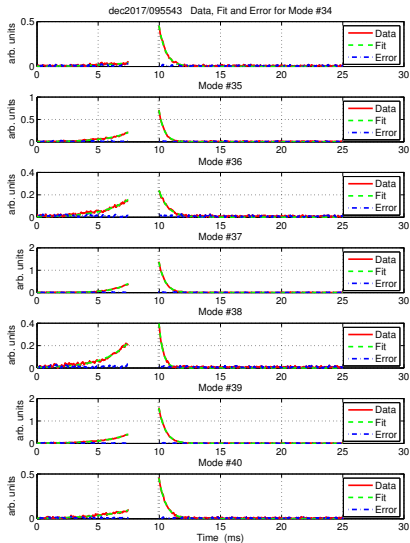


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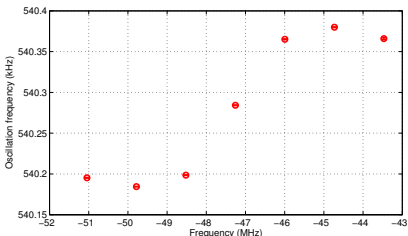
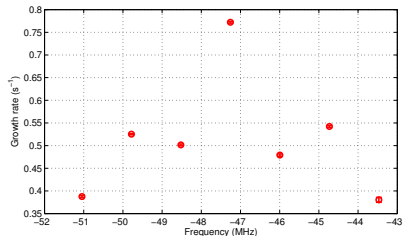
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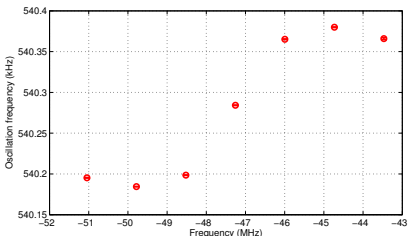
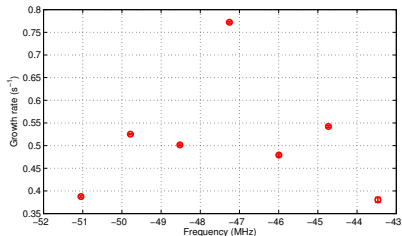
Fitting the Resonance



- Plot eigenvalues versus modal frequency;
- Transversely, negative frequencies drive the instabilities, thus the frequency scale;
- Fit resonant HOM response;
- Reasonably consistent, but needs further study.



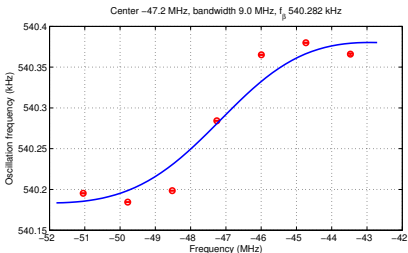
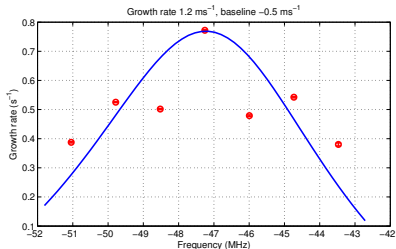
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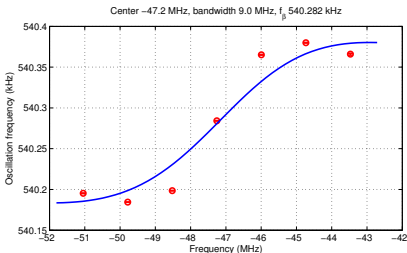
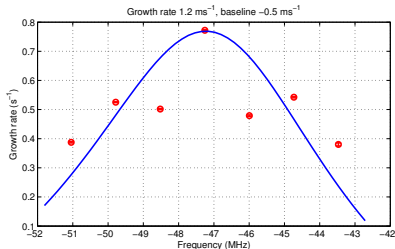
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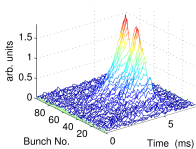


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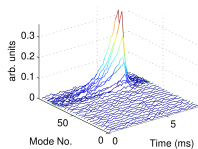


Grow/Damp Measurement: 550 mA

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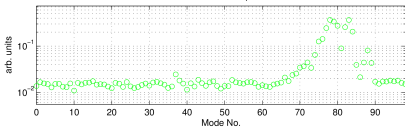


b) Evolution of Modes



BEPC-II E+ dec2017/103115: Io= 548.9476mA, Dsamp= 1, ShifGain= 2, Nbnun= 99,
At v: G1= 8.6328, G2= 0.00026535, Ph1= -15.887, Ph2= -77.0703, Brkpt= 7484, Calib= 1.

Maximum Mode Amplitudes

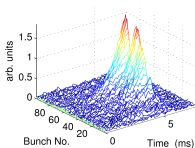


- Completely different modal picture at 550 mA;
- Two HOMs centered at 78 and 82;
- Fits point to a wider mode around 78, narrower around 82;
- Consistently fast damping;
- Same resonance tuning with beam current?

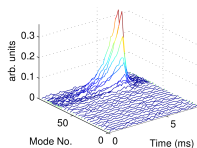


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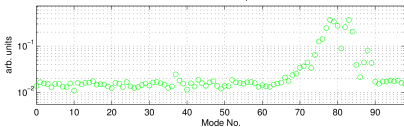


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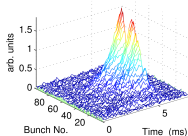


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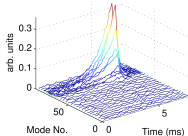


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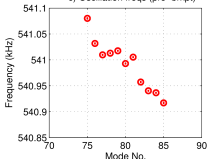
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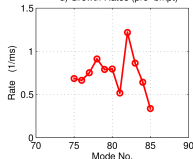
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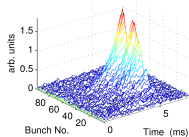
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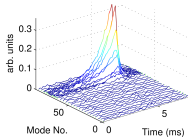


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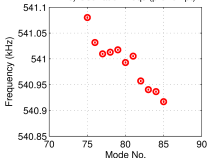
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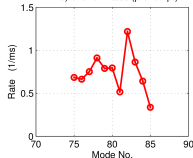
b) Evolution of Modes



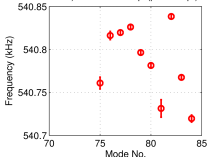
c) Oscillation freqs (pre-brkpt)



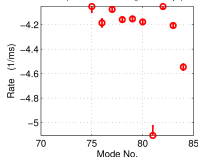
d) Growth Rates (pre-brkpt)



e) Oscillation freqs (post-brkpt)



f) Growth Rates (post-brkpt)



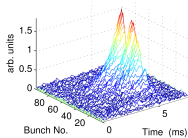
- Completely different modal picture at 550 mA;
- Two HOMs centered at 78 and 82;
- Fits point to a wider mode around 78, narrower around 82;
- Consistently fast damping;
- Same resonance tuning with beam current?

BEPC-II E+-dec2017/103115: I_o= 548.9476mA, D_{samp}= 1, ShfGain= 2, Nbun= 99,
At v: G1= 8.6328, G2= 0.00026535, Ph1= -15.887, Ph2= -77.0703, Brkpt= 7484, Calib= 1.

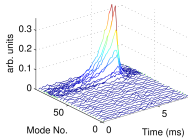


Grow/Damp Measurement: 550 mA

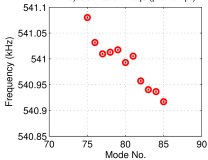
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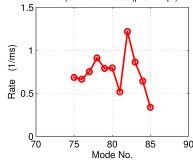
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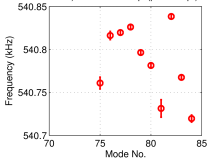
c) Oscillation freqs (pre-brkpt)



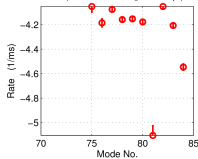
d) Growth Rates (pre-brkpt)



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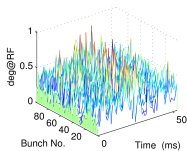
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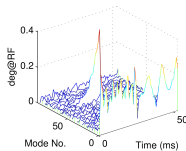


Longitudinal Grow/Damp Measurement

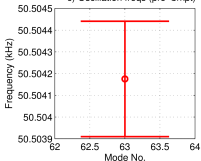
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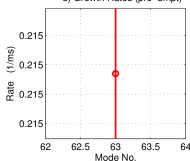
b) Evolution of Modes



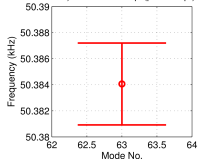
c) Oscillation freqs (pre-brkpt)



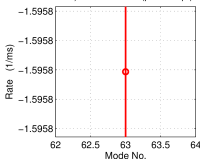
d) Growth Rates (pre-brkpt)



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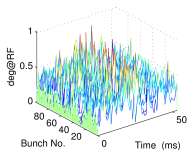
BEPC-II E+:dec2017/115403: lo=255.0603mA, Dsamp=9, ShifGain=5, Nbun=99,
 At v: G1=0, G2=13.9494, Ph1=0, Ph2=8.3217, Brkpt=3776, Calib=0.7172.

- Longitudinal grow/damp measurements to check new kicker;
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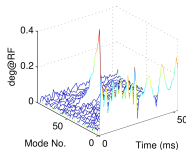


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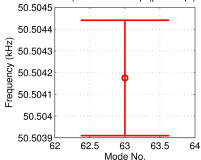
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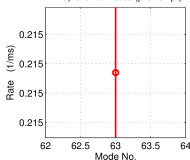
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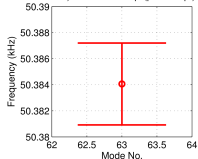
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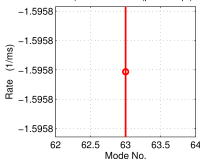
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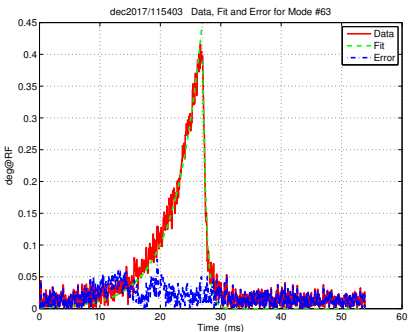


BEPC-II E+dec2017/115403: Io=255.0603mA, Dsamp=9, ShifGain=5, Nburn=99,
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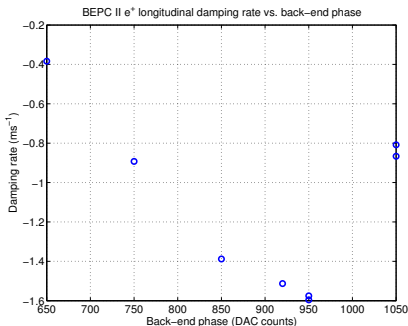
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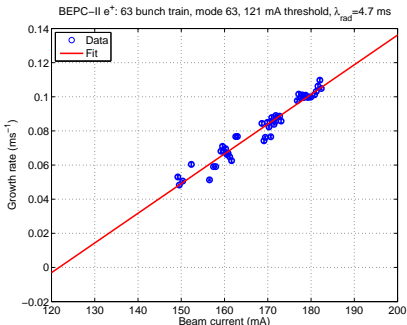
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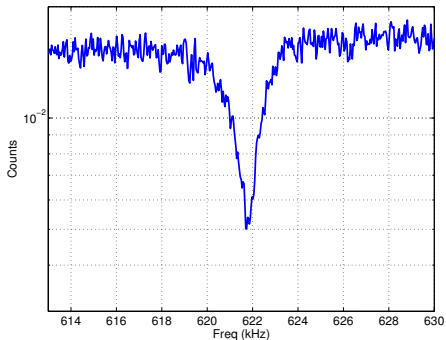
Outline

- 1 Setup
- 2 Transverse Measurements
 - Horizontal Plane
 - Vertical Plane
- 3 Longitudinal Measurements
- 4 Tune Measurement**
 - Tune Notch**
 - Phase Tracking



Spectral Notch Tune Monitoring

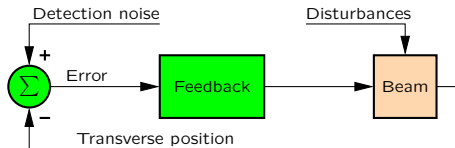
dec2017/095346: Signal power spectrum averaged (quadratic) over all bunches



- In closed loop operation, feedback signals show a notch at the betatron frequency;
- Beam response is resonant at the tune frequency;
- Attenuation of detection noise by the feedback is proportional to the loop gain;
- Transfer gain from noise to the feedback input is $\frac{1}{1+L(\omega)}$
- Maximum attenuation at the resonance, thus a notch



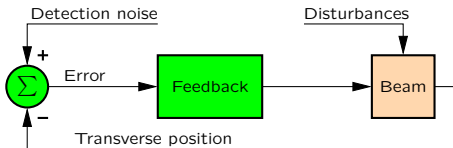
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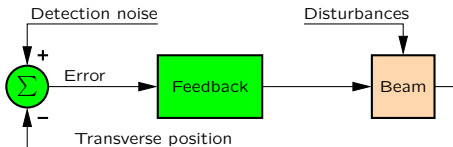
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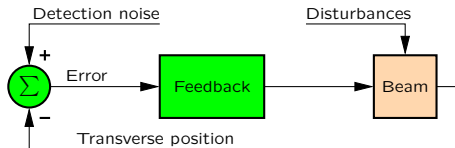
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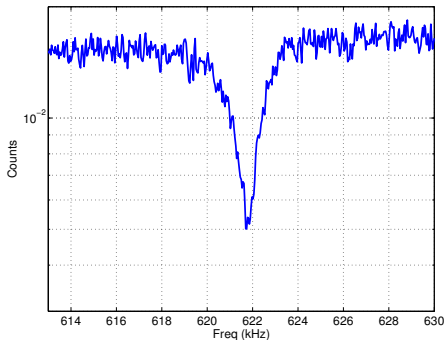


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Tune Notch: Horizontal Plane

dec2017/095346: Signal power spectrum averaged (quadratic) over all bunches

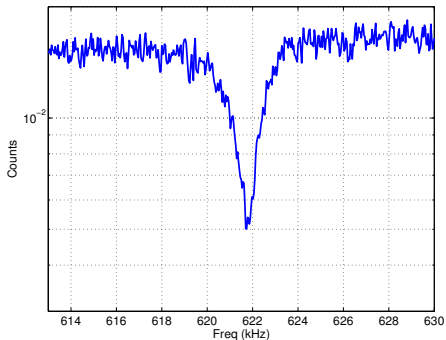


- 25.2 ms acquisition, 90 bunches, 220 mA;
- Bunch spectra averaged;
- Marker search for the minimum measures the tune;
- Available in EPICS at 2 Hz rate;
- Notch disappears if there is transverse excitation (injection, instability).



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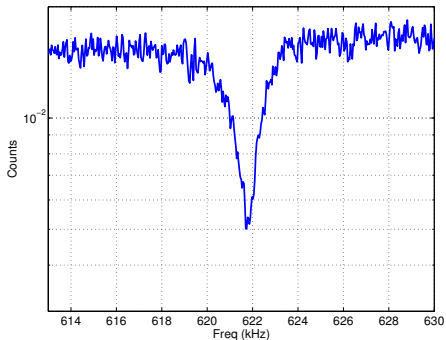


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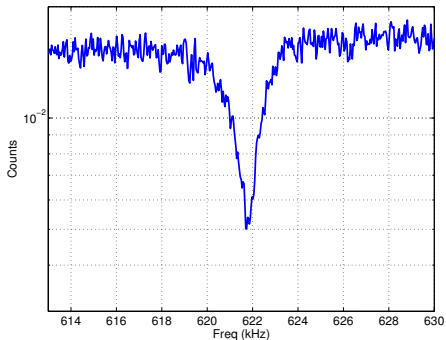


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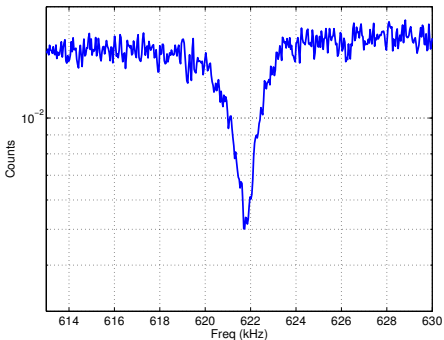


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Tune Jitter: Horizontal Plane

- Ten snapshots around 220 mA;
- Jitter on the order of 1 kHz (8×10^{-4}).

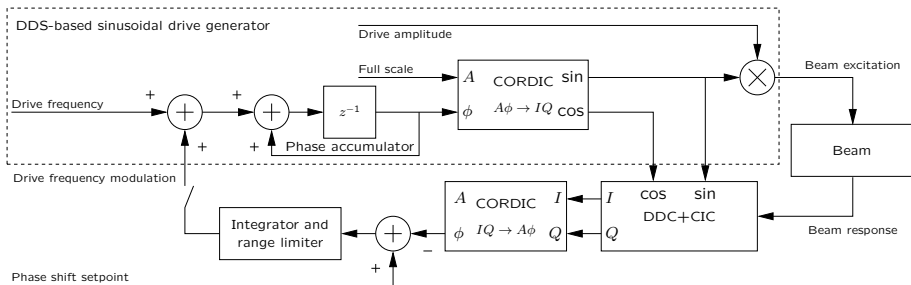


Outline

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 - Vertical Plane
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 - Tune Notch
 - Phase Tracking



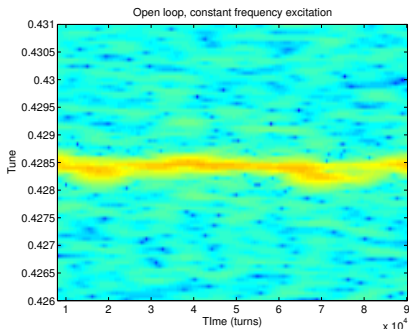
Single Bunch Phase Tracking



- A single bunch is excited with a sinusoidal excitation at low amplitude;
- Response is detected relative to the excitation to determine the phase shift;
- In closed loop, phase tracker adjusts the excitation frequency to maintain the correct phase shift value;
- Adjustable integration time, tracking range, loop gain.



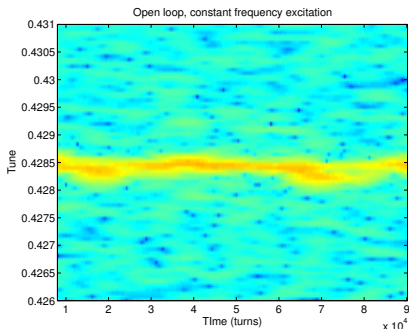
Fast Phase Tracking



- Open-loop excitation, constant drive frequency;
- Amplitude varies as the beam walks on and off the excitation;
- Closed-loop tracking — excitation follows the tune;
- Lower excitation of 0.004;
- One more set;
- More precise analysis is possible, not enough time...



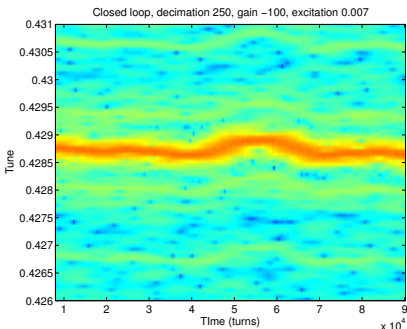
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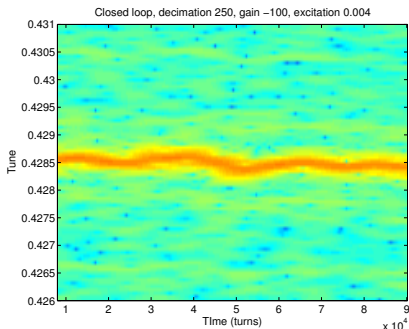
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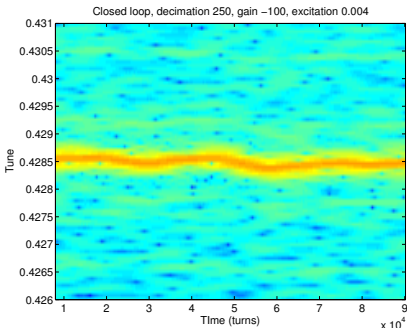
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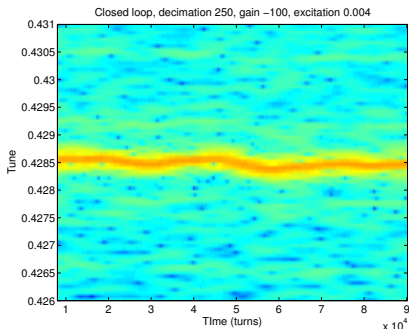
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Summary

- Successful commissioning overall, would be nice to have more time to run with the beam;
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- Observing the signals with beams in collision several times saw transverse instabilities in the electron ring coupling to the positron ring via beam-beam interaction.



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