Recent measurements of the coupled-bunch instabilities in DAΦNE

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Outline

Longitudinal instabilities

- Positron ring
- Positive momentum compaction
- Negative momentum compaction
- Electron ring
- Preliminary negative α measurements
- Mode 0 in normal ring configuration

Transverse instabilities

- Horizontal instabilities in positron ring
- Feedback performance and limits
- Possible development ideas

Summary

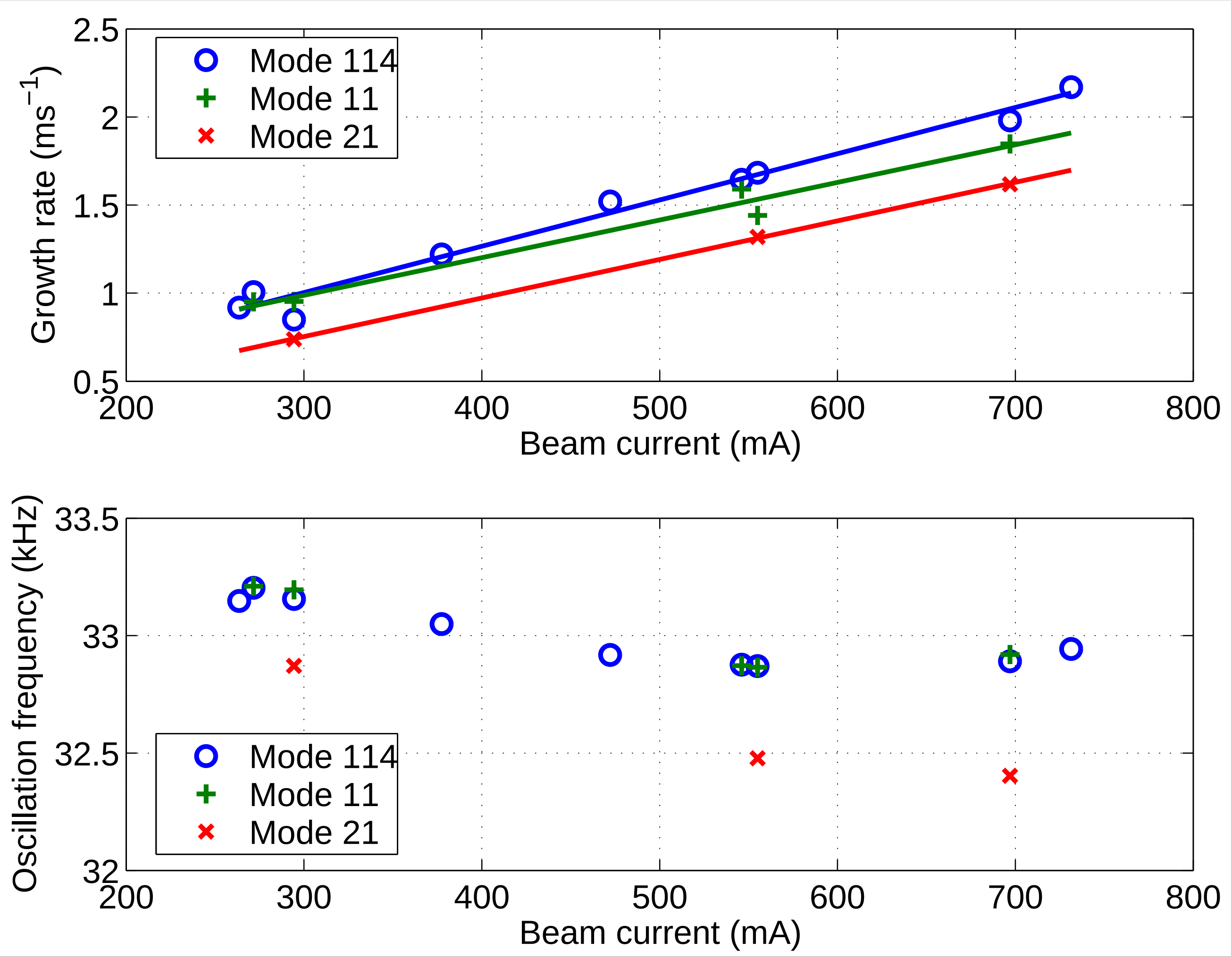
Measurements in the positron ring: positive alpha

Three clear modes: 11, 21, 114.

In the past we have seen modes 11 and 21, 114 is new.

Modes 11 and 114 have very similar growth rates and tune shifts - somewhat puzzling

Tunes do not show linear change with current. All modes show similar behavior - synchrotron frequency might be varying



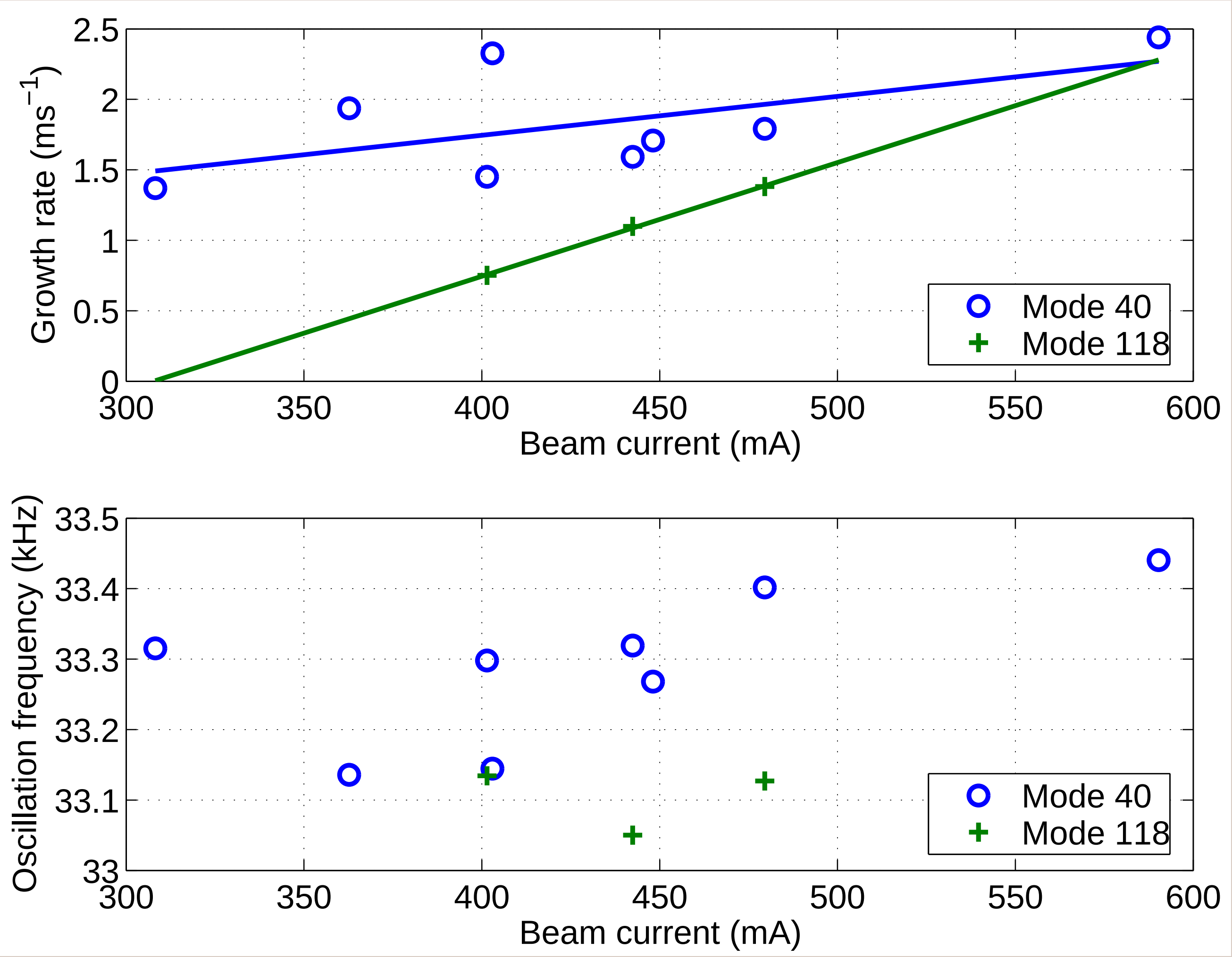
Growth rates are in-line with those measured in the past

Measurements in the positron ring: negative alpha

Many modes: 29, 40, 103, 118

Based on the modes measured with positive α we would expect 109, 99, and 6.

Growth rates are reasonable, however mode 40 shows little scaling with beam current - not a fixed impedance?

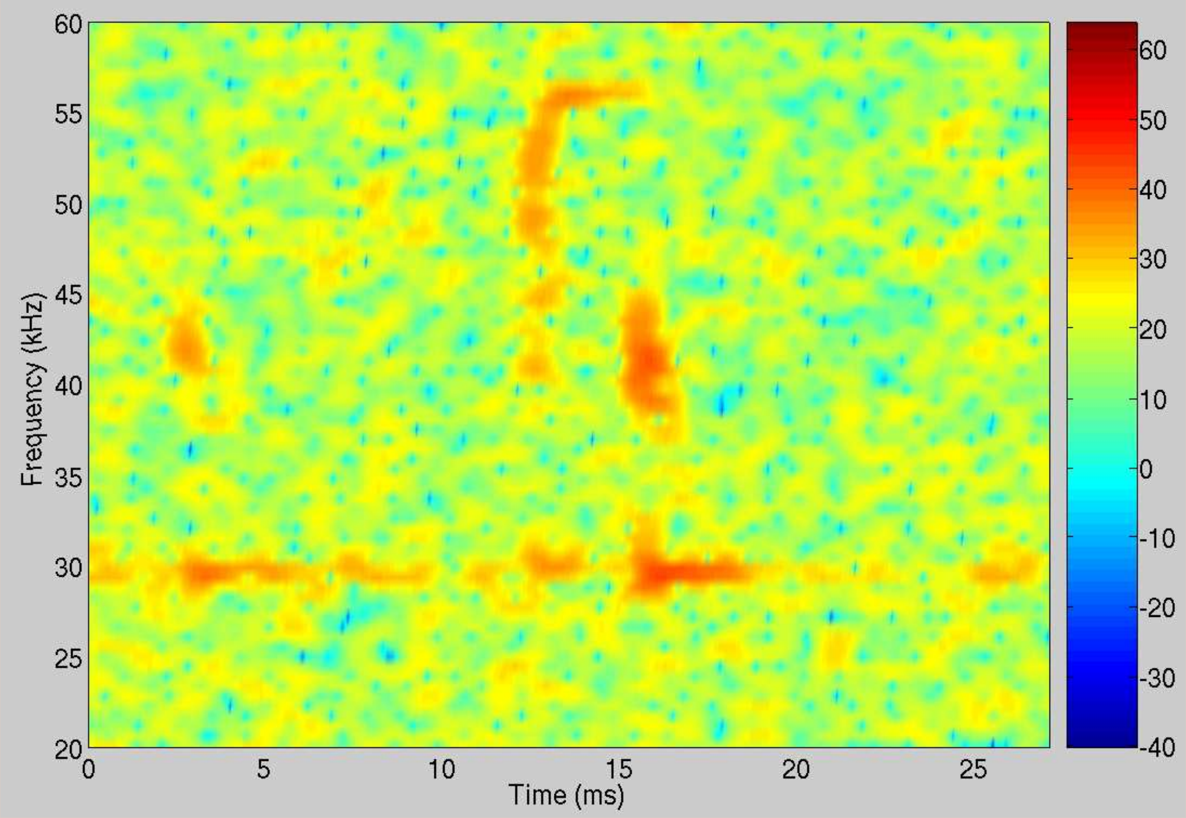


Negative momentum compaction in the electron ring

In the electron ring we ran into single-bunch instability at bunch currents above 4-5 mA.

The instability manifested itself as bursts of oscillation (detectable in the LFB front-end) at 40-45 kHz.

The frequency is roughly midway between synchrotron and quadrupole frequencies,



Single bunch spectrum vs. time on the right shows bursts the instability as well as bursts of dipole and quadrupole motion.

In presence of this instability multibunch currents were limited to ~300 mA most likely due to the oscillation bursts saturating the LFB control channel.

Mode 0 control

In the past we always assumed that LFB excites mode 0 via positive feedback

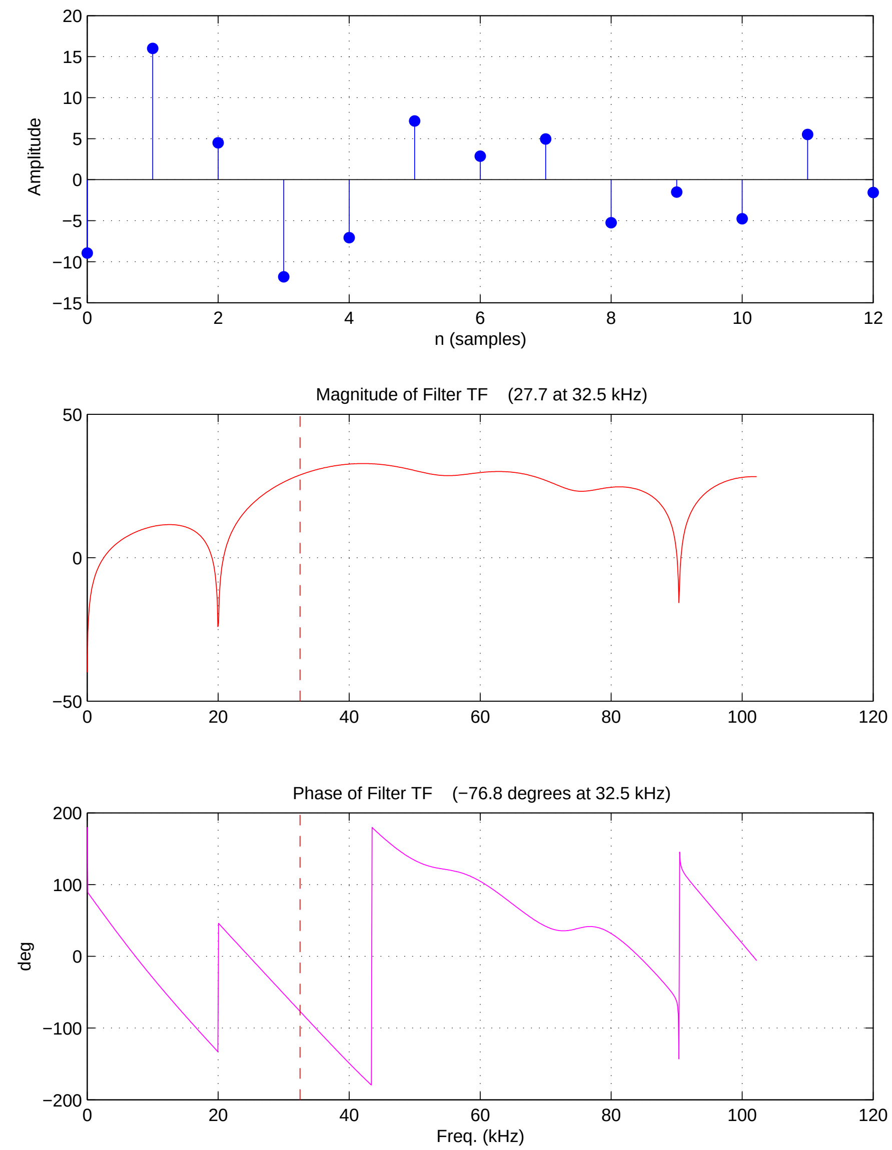
A separate mode 0 FB was developed at DAFNE to stabilize the motion.

During the MD in the electron ring we turned off the mode 0 feedback and experimented with different IIR filters.

We observed, that mode 0 motion at 16 kHz could not be suppressed by placing a notch in the filter response at that frequency.

It seems that due to beam loading mode 0 damping is significantly reduced and it is driven by the noise in the RF system

Placing a filter zero at 20 kHz we generated negative feedback for mode 0.

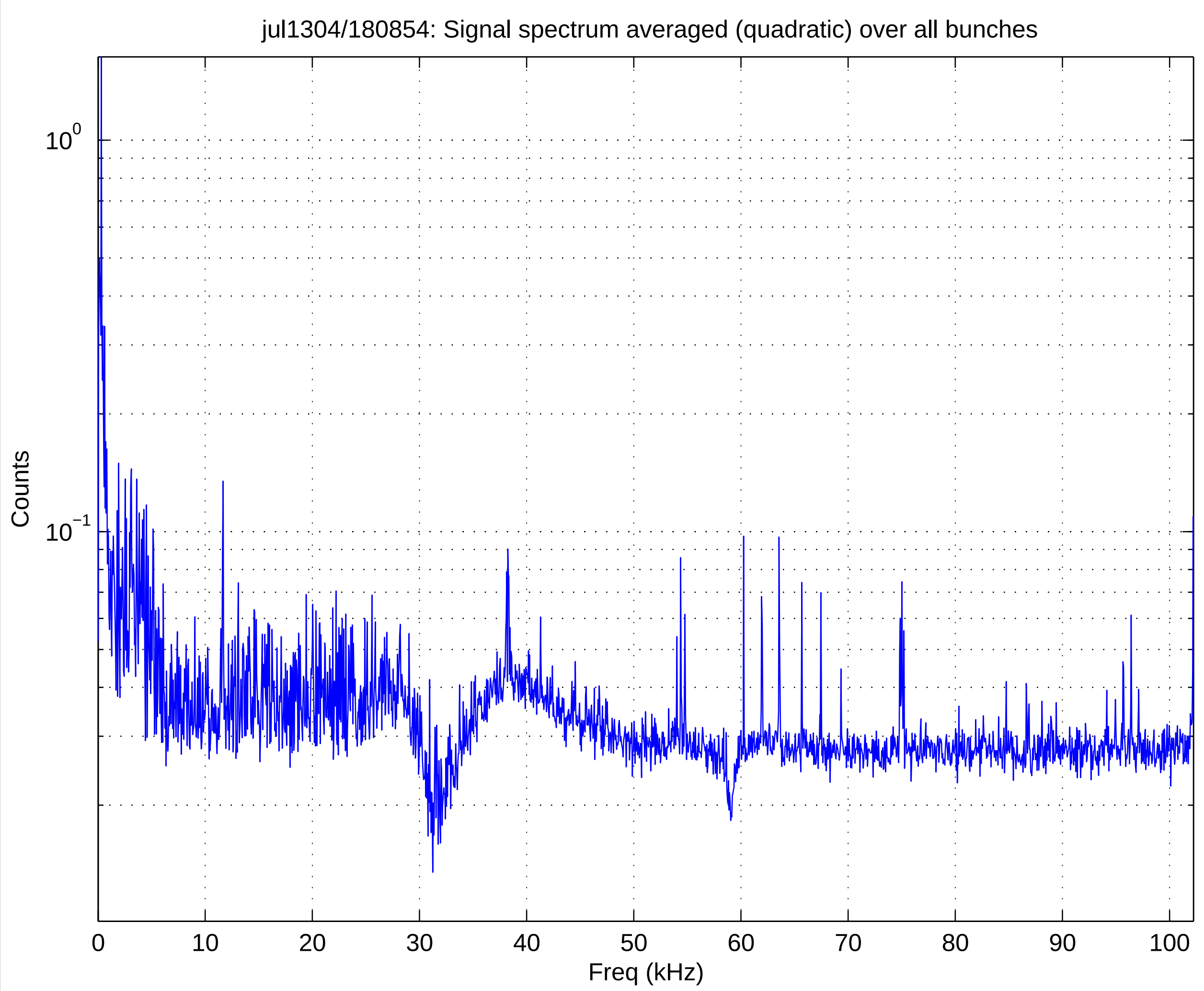


Closed-loop record

Simultaneous control of:

- Dipole instabilities
- Quadrupole instabilities
- Mode 0

Eliminates the need for AC coupling, dedicated feedback etc.



Measurements of horizontal instabilities in the positron ring

Grow/damp measurements acquired by the LeCroy scope

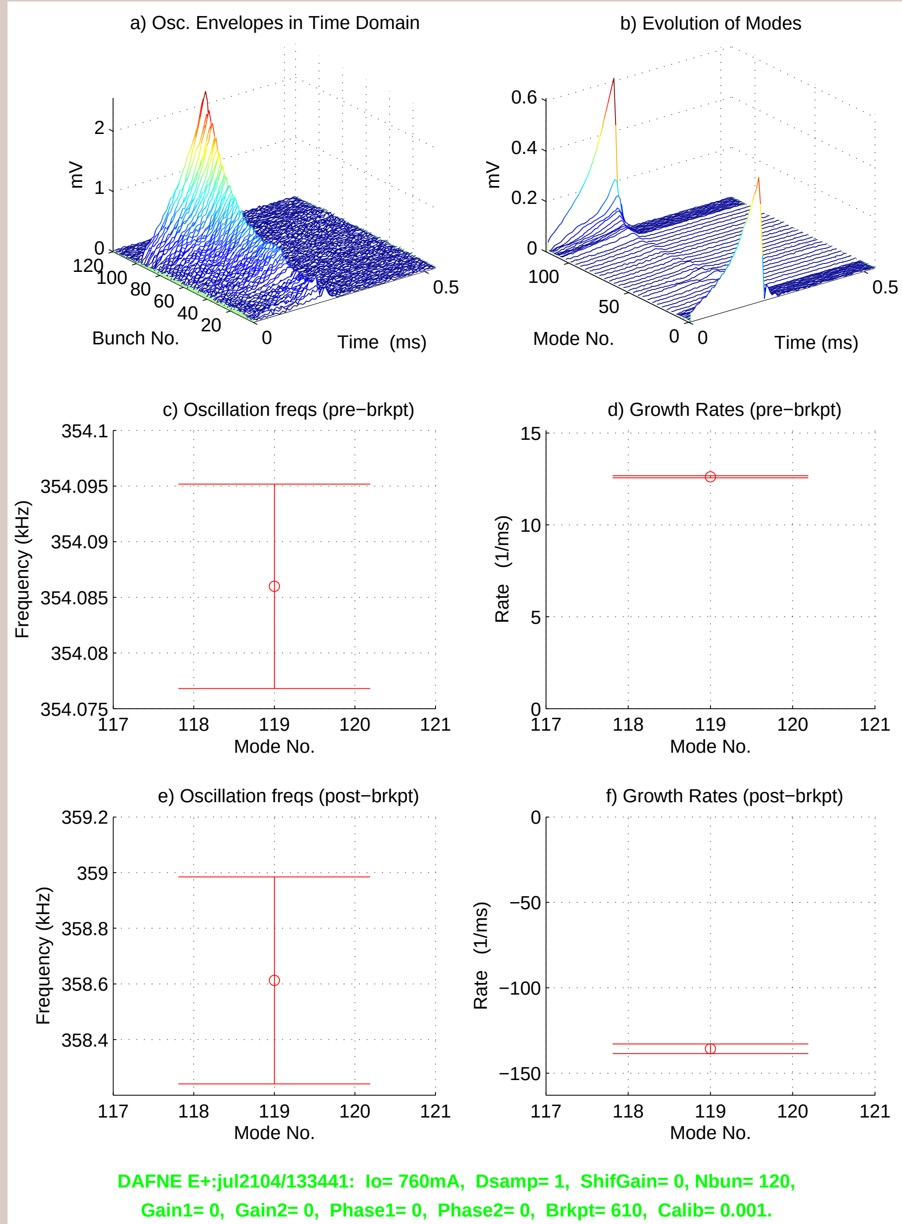
Converted to standard format accepted by the LFB analysis tools

A typical grow/damp shows very fast damping - high transverse feedback gain.

We consistently see only one eigenmode in all horizontal grow/damps: -1

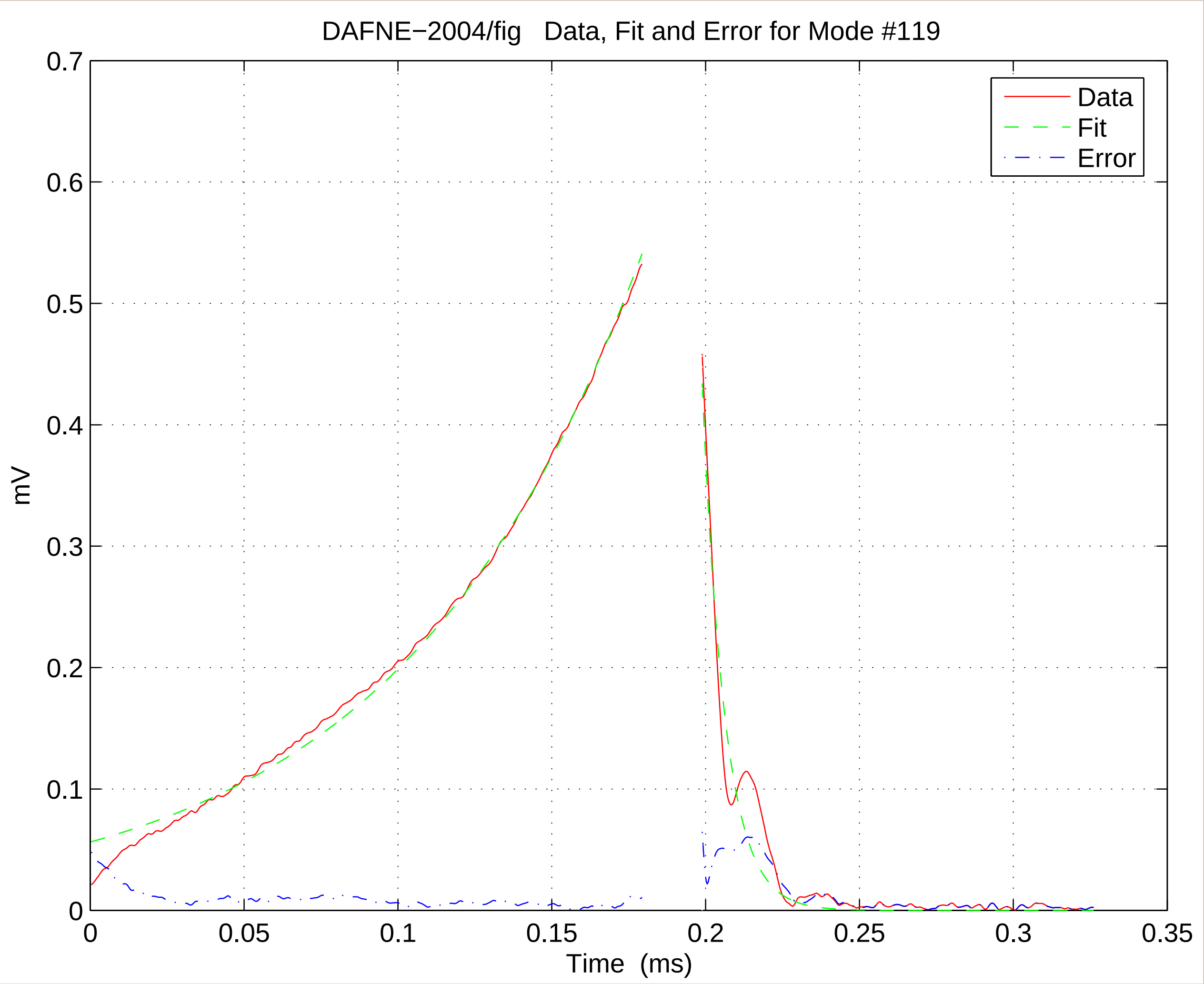
There is some tune shift between open and closed loop. Eigenvalue shift :

$$148 \cdot 10^3 s^{-1} + 28 \cdot 10^3 \text{rad/s}$$



Complex exponential fits to growth and damping transients

Excellent open-loop fit indicates that growth rate and oscillation frequency have little dependence on oscillation amplitude



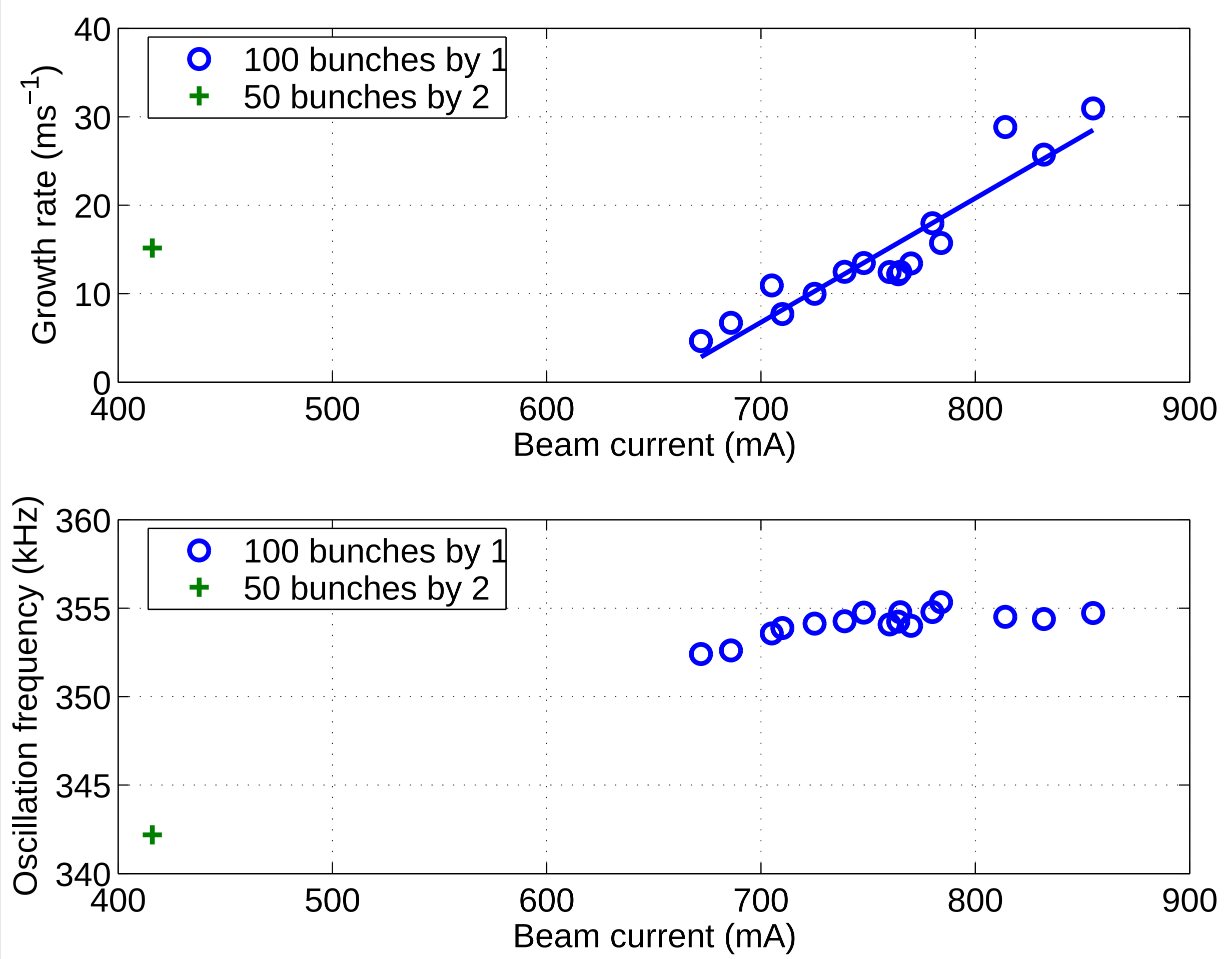
Growth rates of mode -1 vs. beam current and fill pattern

Roughly linear change in growth rate with current

Changing bunch spacing from one to two RF buckets scales the growth rate by 2

Growth rates induced by a constant impedance should scale with total current.

Is this instability driven by electron cloud?



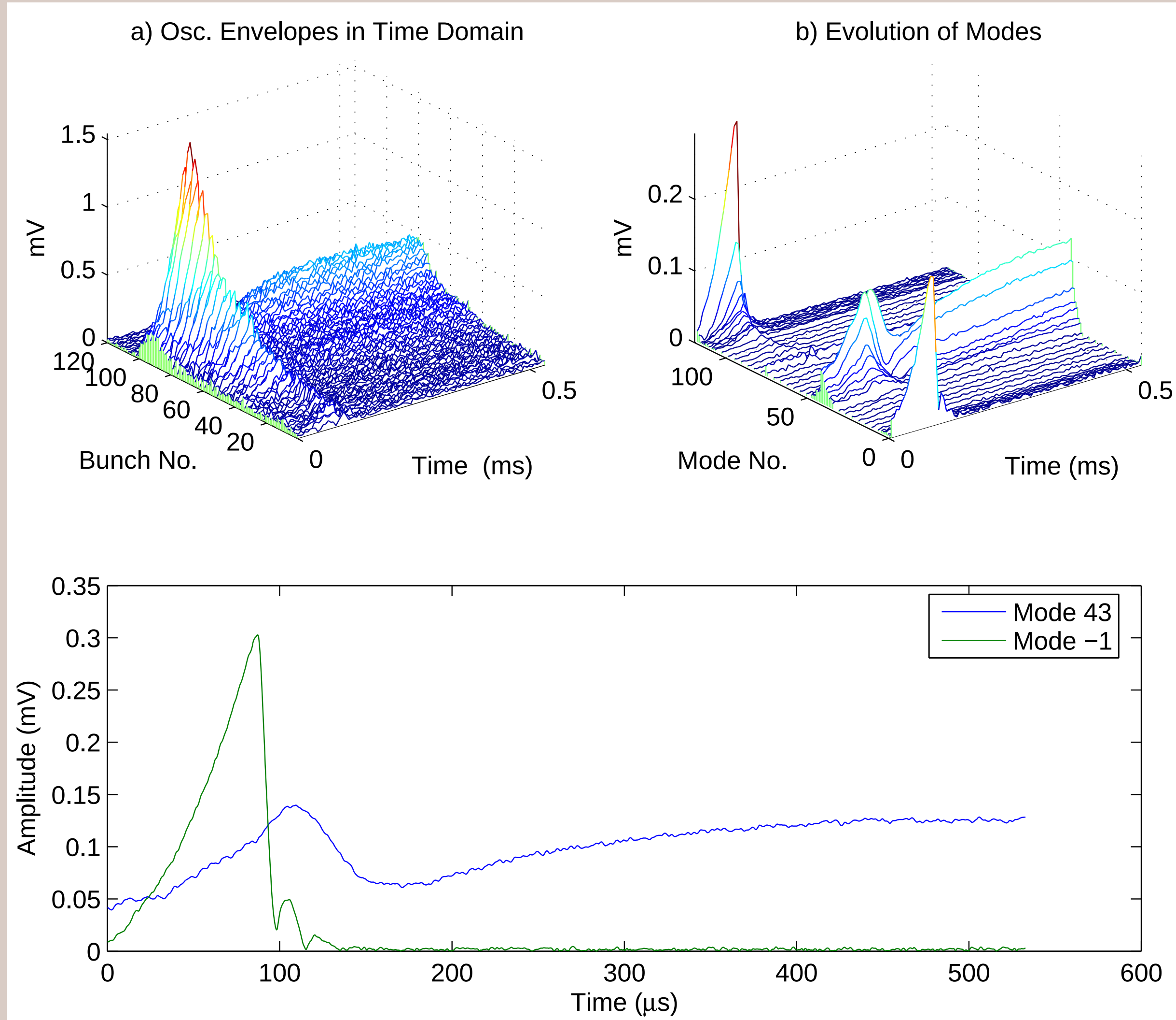
TFB performance at high currents

Normal growth and damping of mode -1.

Band of modes around 43 grows in open-loop (much slower than -1). However in the closed-loop it is evident that these modes are lightly damped and are excited by noise to an appreciable level.

Two possibilities: the TFB is incorrectly phased for these modes or has excessive gain.

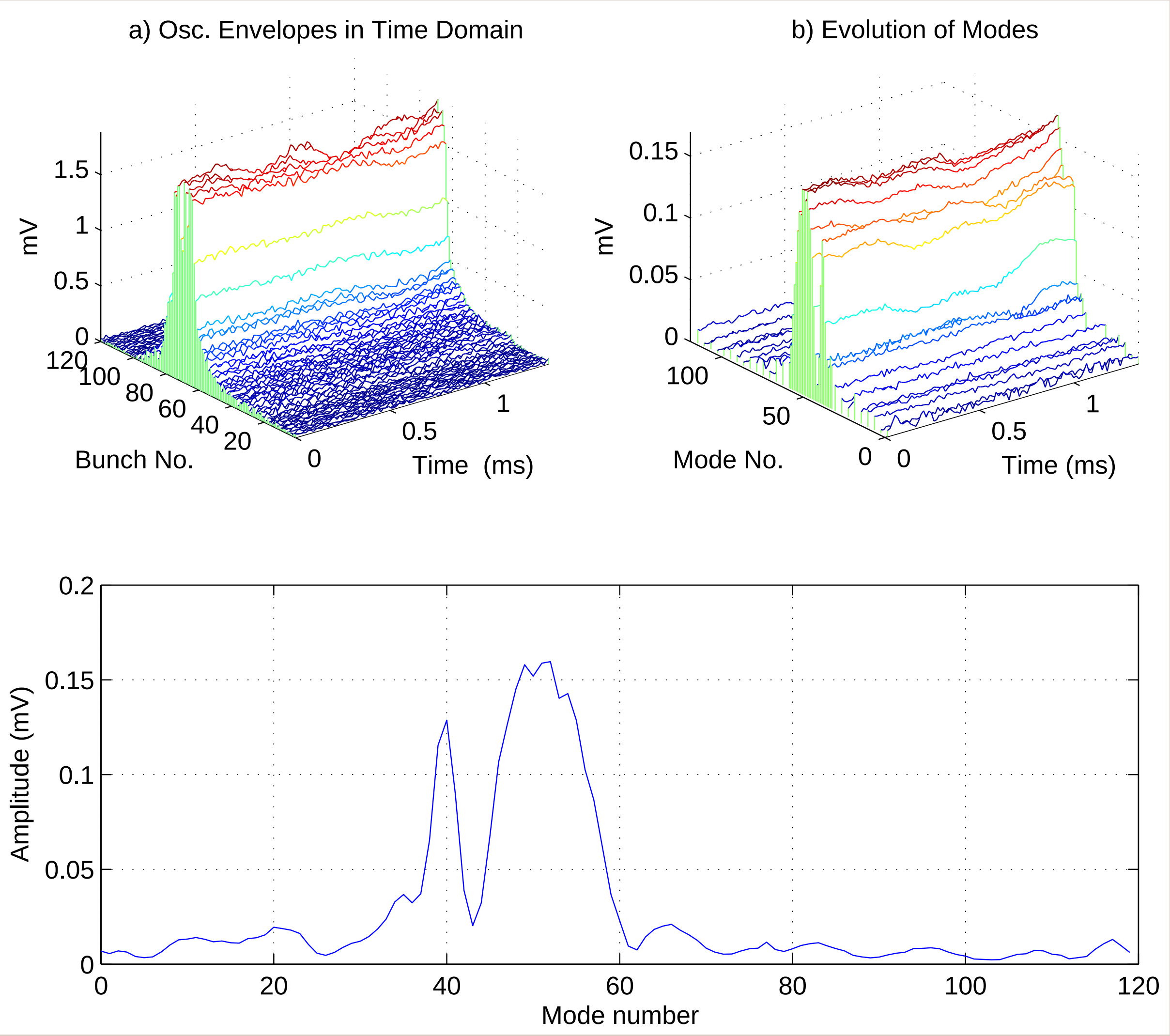
We tried lowering the gain by 12 dB.



TFB performance at high currents, continued

Between 800 and 900 mA (850 mA in this plot) bunches in the middle of the train break out in oscillation.

Modal analysis shows only high-frequency modes participating in this motion



TFB performance at high currents, continued

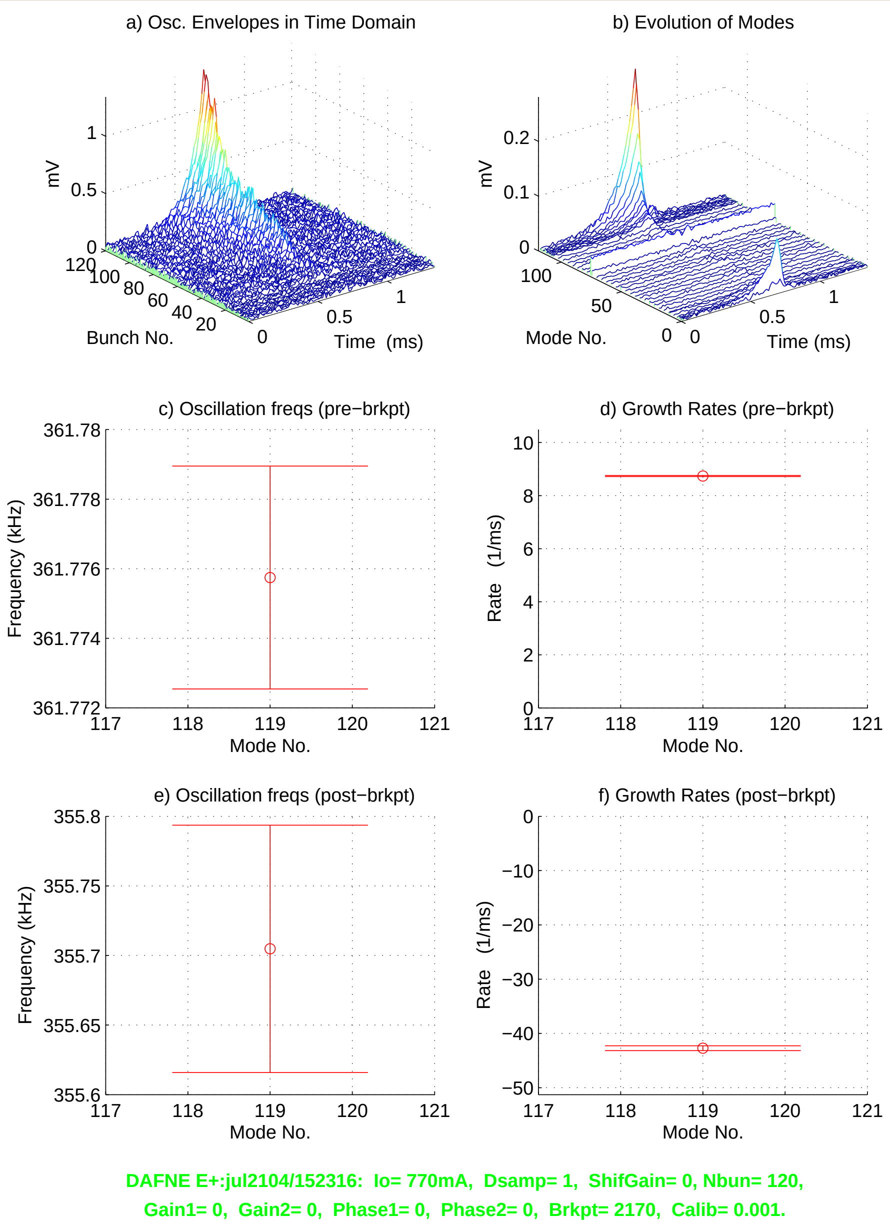
After a short while some current is lost and the motion damps.

A grow/damp at that current shows excellent control of mode -1 with very little other motion. Due to the reduced gain the damping rates is slower than in the earlier plot.

Incorrect feedback timing can cause such symptoms with negative feedback for low-frequency modes and positive feedback at high frequencies.

In the limited MD time remaining we attempted to adjust timing (-2, -1, +1, +2 ns) without any improvement.

Open-loop beam transfer function measurements should help diagnose the problem.



Summary

DAΦNE is a machine with very rich dynamics and generates numerous puzzles and surprises.

Tests of longitudinal control with the negative momentum compaction have been very successful with the positron ring reaching beam currents above 600 mA.

Single-bunch instability in the electron ring should be further studied after optics optimization.

Longitudinal feedback systems in DAΦNE are capable of simultaneously controlling dipole and quadrupole instabilities as well as of damping the motion of noise-sensitive mode 0.

Horizontal grow/damp measurements in e+ ring show growth and fast damping of mode -1. Growth rates as a function of fill pattern show that this motion is not due to a fixed impedance (resistive wall).

At high currents TFB seems to run out of stability margin at high frequencies. While there is significant damping of mode -1, much more stable modes 40-60 get undamped. Measurements of BTF at different frequencies should help pinpoint the problem and, possibly, solve it.