Measurements of the electron cloud driven instabilities in DAΦNE

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Dimtel, Inc., San Jose, CA, USA

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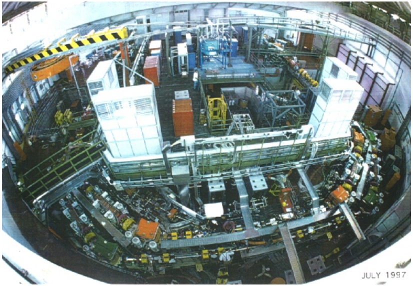
Outline

DAΦNE



- Two ring e^+/e^- collider;
- Nominally identical rings;
- Transverse coupled-bunch instabilities were expected in all four planes.
- Resistive wall was expected to be the largest driving impedance.
  - Copper cavities with HOM damping.

DAΦNE

Parameters (e^+/e^-)

Energy	510 MeV
Circumference	97 m
RF frequency	368 MHz
Harmonic number	120
Horizontal tunes	5.12/5.16
Vertical tunes	5.16/5.22

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The Big Difference

- Fairly early on it became obvious that something is "different" about the horizontal beam stability in the positron ring;
- Over the years we used different tools to study transverse instabilities in DAΦNE:
  - LeCroy scope to record bunch motion;
  - Gproto - digital transverse feedback prototype;
  - iGp - bunch-by-bunch transverse feedback systems currently installed in DAΦNE.
- Clear agreement: instability growth rates are much faster in the positron ring.

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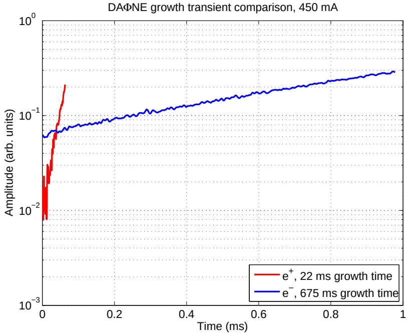
Growth Rates Comparison



- Comparison of horizontal growth transients in positron and electron rings;
- Beam currents around 450 mA;
- In the electron ring we had to lower chromaticity to make the beam unstable;
- The same mode is unstable in both cases - mode -1.

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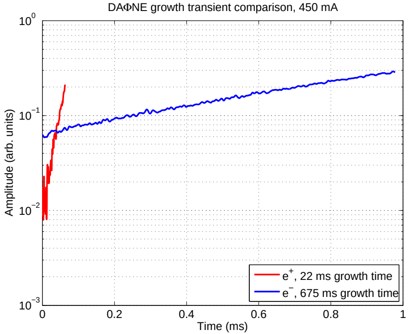

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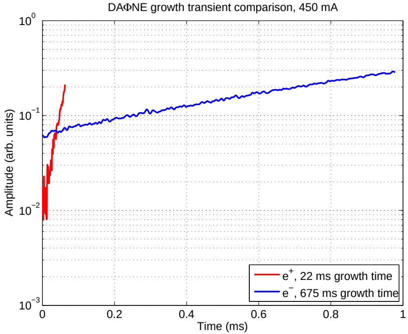

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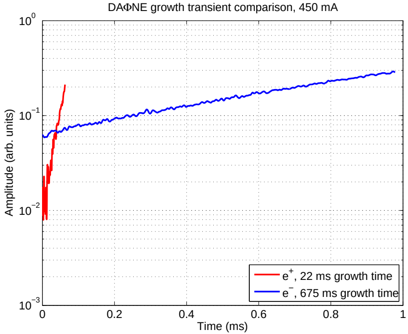

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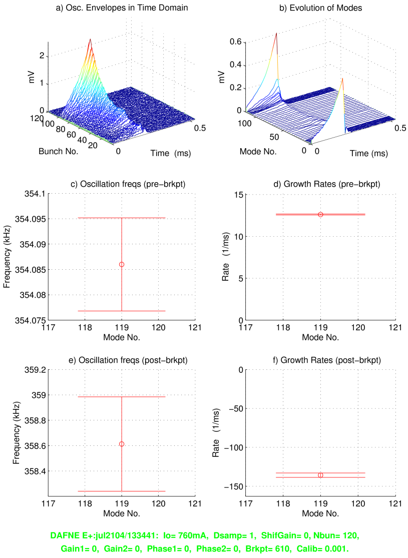
1. Introduction
2. Earlier Measurements
   - Historical Background
   - Grow/Damp Measurements
   - Fill Pattern Sensitivity
   - Tune Shifts
3. New Measurement Methods
   - Technical Description
   - Measurement Results

A Grow/Damp Measurement



- Let the oscillation grow for roughly 200 μs, then turn on the feedback.
- Growing eigenmode is -1
  - Most strongly driven by the resistive wall.
- Growth transient is nicely exponential;
- No tune shift with amplitude.

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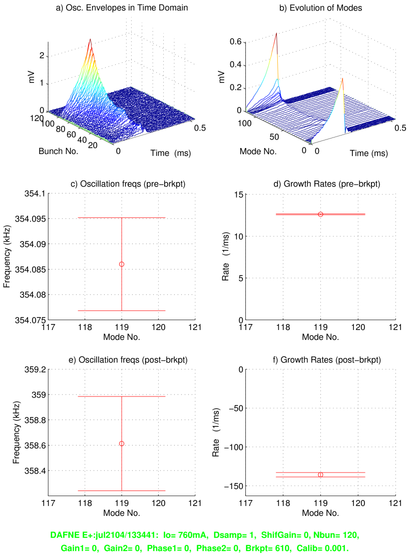

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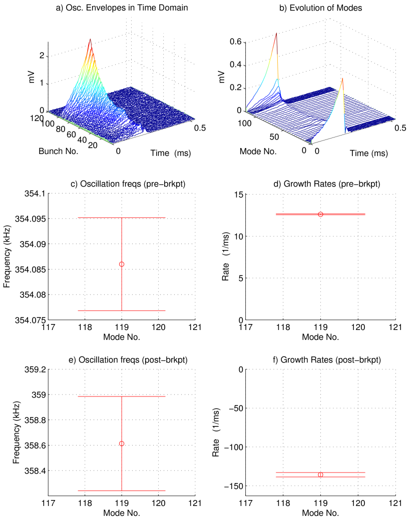

DAFNE E+:jul2104/133441: Io= 760mA, Dsamp= 1, ShifGain= 0, Nbun= 120, Gain1= 0, Gain2= 0, Phase1= 0, Phase2= 0, Brkpt= 610, Calib= 0.001.

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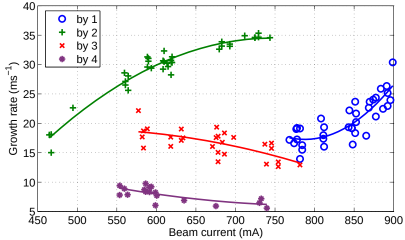
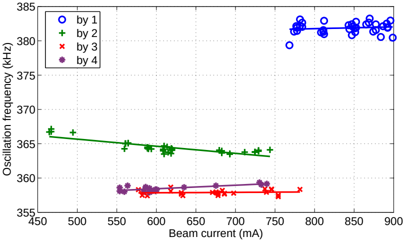
Horizontal Instability and Fill Patterns





- Changed bunch spacing:
  - Constant gap size;
  - 100×1
  - 50×2
  - 33×3
  - 25×4
- Always the same eigenmode growing;
- Going from 2.7 to 5.4 ns spacing doubles the growth rates;
- Large tune shifts.

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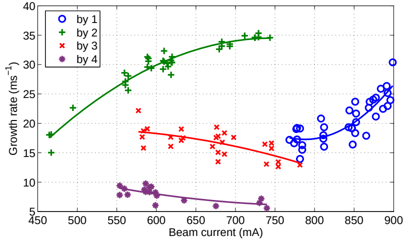

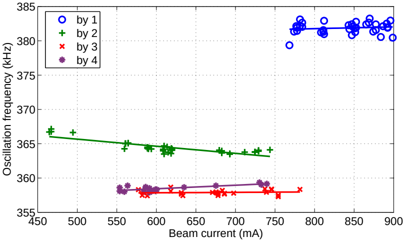

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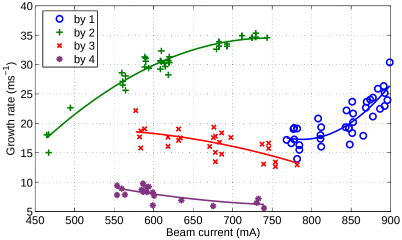

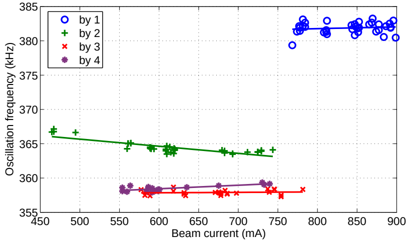

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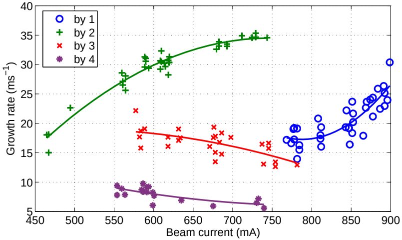

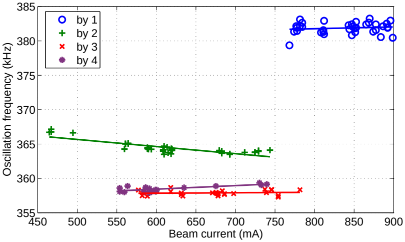

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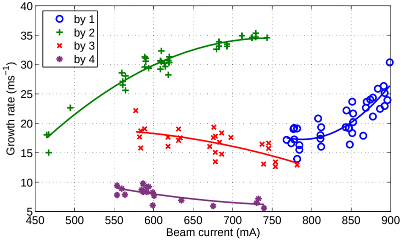

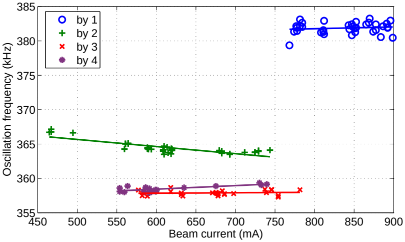

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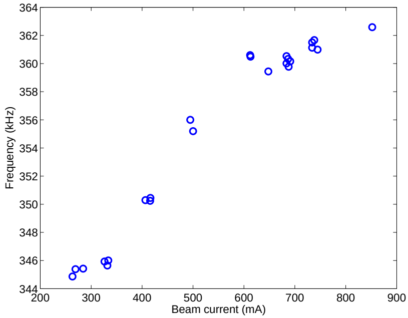
Tune Shift vs. Beam Current



- Measure tunes at different currents;
- Instability threshold is 600 mA;
- Large tune shift below the threshold.

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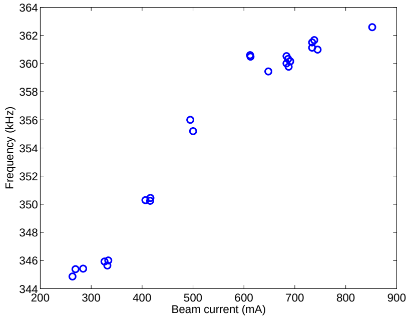

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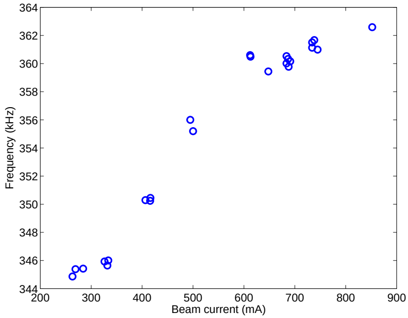

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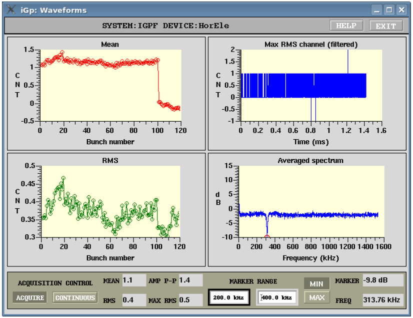
Upgrades and New Diagnostics



- In 2005–2008 DAΦNE upgraded to modern bunch-by-bunch feedback systems with integrated diagnostics;
- This upgrade created new measurement possibilities;
- Key to these measurements is a curious notch in the beam spectrum.

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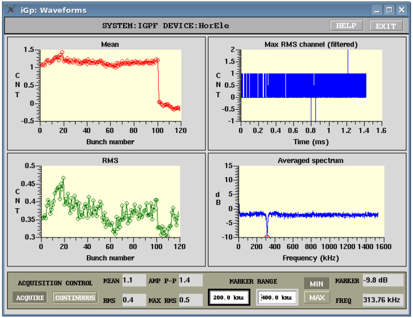

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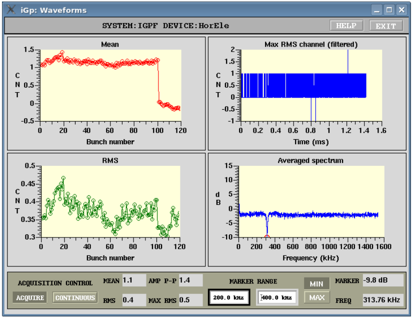

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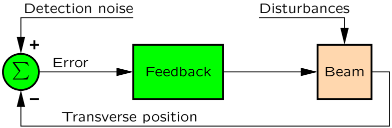

- Beam response is resonant at the tune frequency;
- Attenuation of detection noise by the feedback is proportional to the loop gain;
- Transfer gain from noise to the feedback input is $\frac{1}{1+L(\omega)}$
- Maximum attenuation at the resonance, thus a notch.

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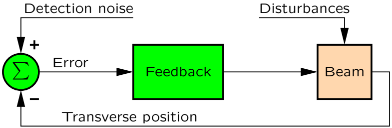

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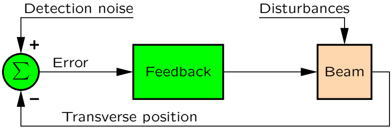

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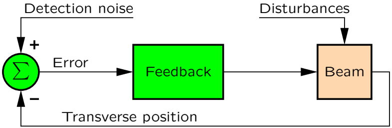

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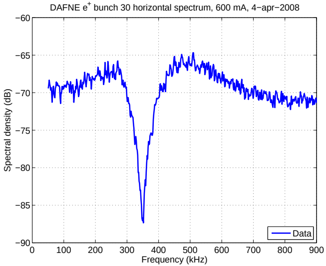
Bunch-by-bunch Tunes



- Start from computing bunch spectrum;
- Fit model beam/feedback response to the spectrum;
- Repeat for all filled bunches;
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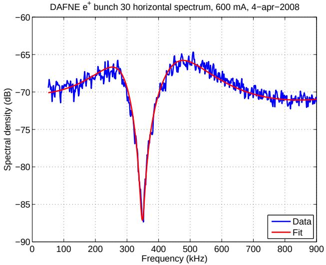

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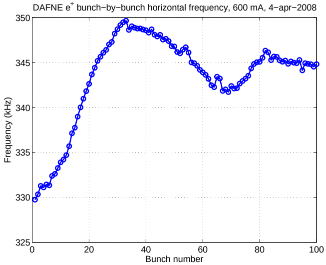

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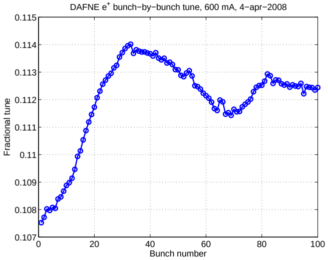

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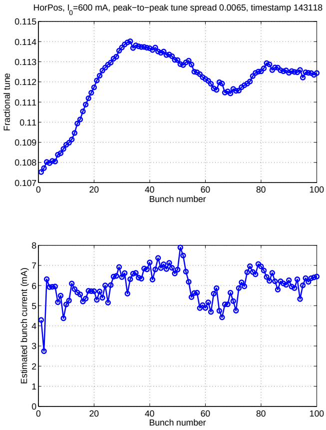
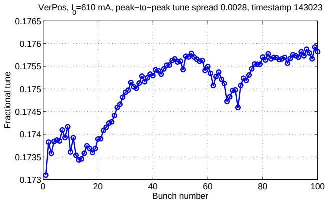
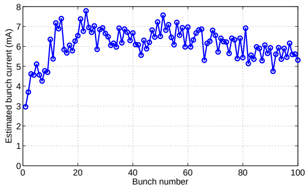
Horizontal vs. Vertical



- Two measurements at 420 mA;
- Horizontal tune spread is 6.5×10^{-3};
- Vertical tune spread is 2.8×10^{-3}.

Horizontal vs. Vertical





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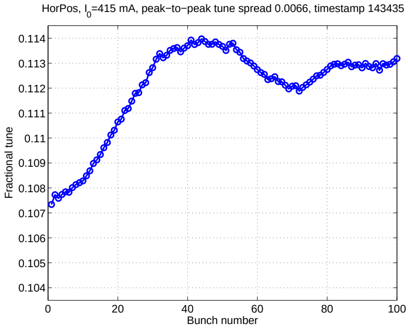
Tunes vs. Beam Current



- Complex behavior;
- Shape changes;
- Average tune moves around;
- Some of the local features are due to current variation along the train.

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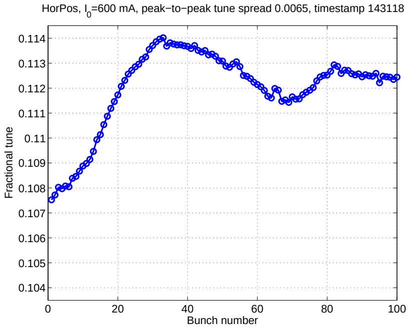

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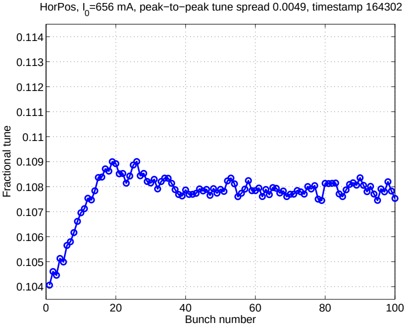

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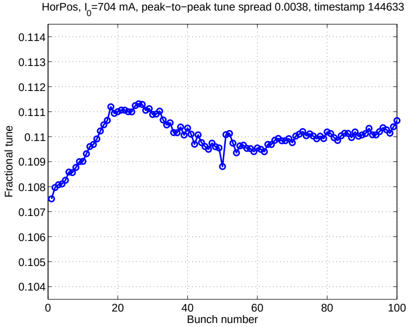

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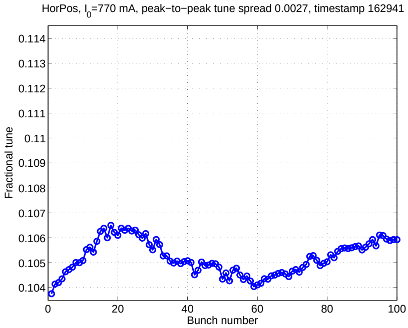

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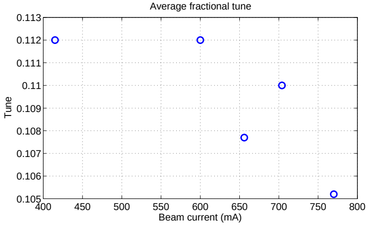

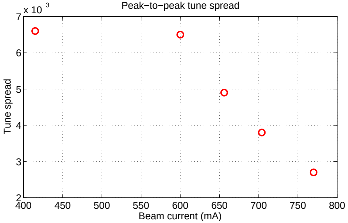

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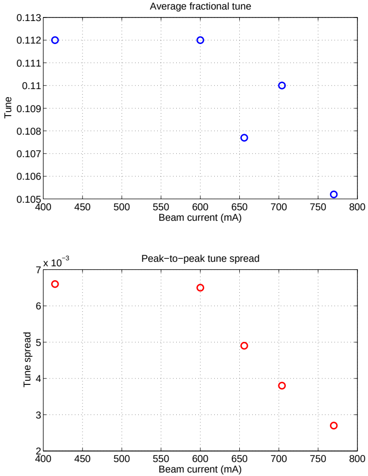
  - Peak-to-peak tune variation.

Tunes vs. Beam Current



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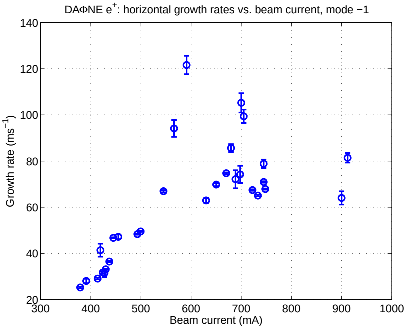

- Growth rates rise sharply between 400 and 600 mA;
- Peak measured value is 120 ms^{-1} (25 turns);
- Above 600 mA the growth rates seem to drop.

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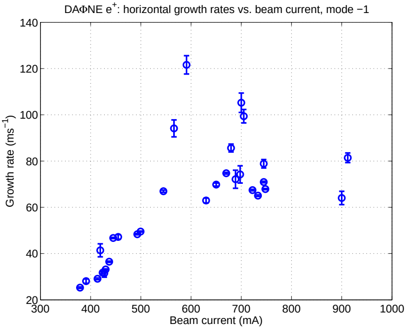

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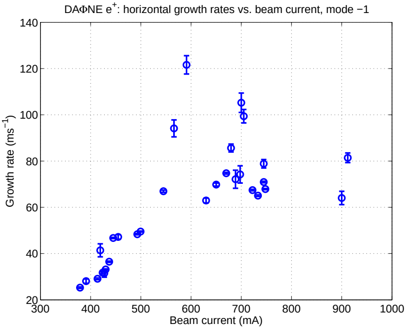

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Summary

- Horizontal dipole instabilities in DAΦNE positron ring are inconsistent with a constant-impedance driving source (resistive wall, HOM, etc).
- New measurement technique has been developed that allows characterization of bunch-by-bunch tunes at high currents;
  - Completely parasitic;
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