Laboratori Nazionali di Frascati

TUPG001

Mitigation and Control of Instabilities in DAFNE Positron Ring

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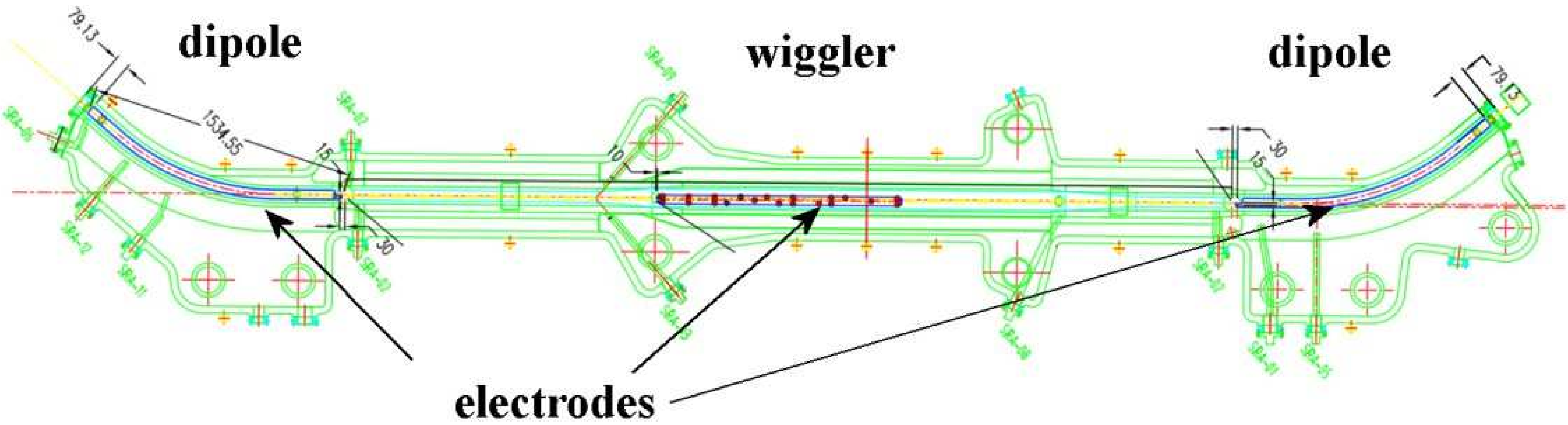
Abstract

- The positron beam in the DAFNE e+e- collider has always been suffering from strong e-cloud instabilities.
- In order to cope with them, several approaches have been adopted along the years: flexible and powerful bunch-by-bunch feedback systems, solenoids around the straight sections of the vacuum chamber and, in the last runs, e-cloud clearing electrodes inside the bending and wiggler magnets.
- Classic diagnostics tools have been of course used to evaluate of the effectiveness of the adopted measures and the correct setup of the devices, in order to acquire the total beam current and the bunch-by-bunch currents, to plot in real time synchrotron and betatron instabilities, to verify the vertical beam size enlargement in collision and out of collision.
- Besides, to evaluate the efficacy of the solenoids and of the clearing electrodes versus the instability speed, the more powerful tools have been the special diagnostics routines making use of the bunch-by-bunch feedback systems to quickly compute the growth rate instabilities in different beam conditions as well as bunch-by-bunch betatron tune spread.

Metallic clearing electrodes have been designed to absorb the photo-electrons in the DAFNE positron ring. They have been inserted in the wiggler and bending magnet vacuum chambers and have been connected to external voltage generators.



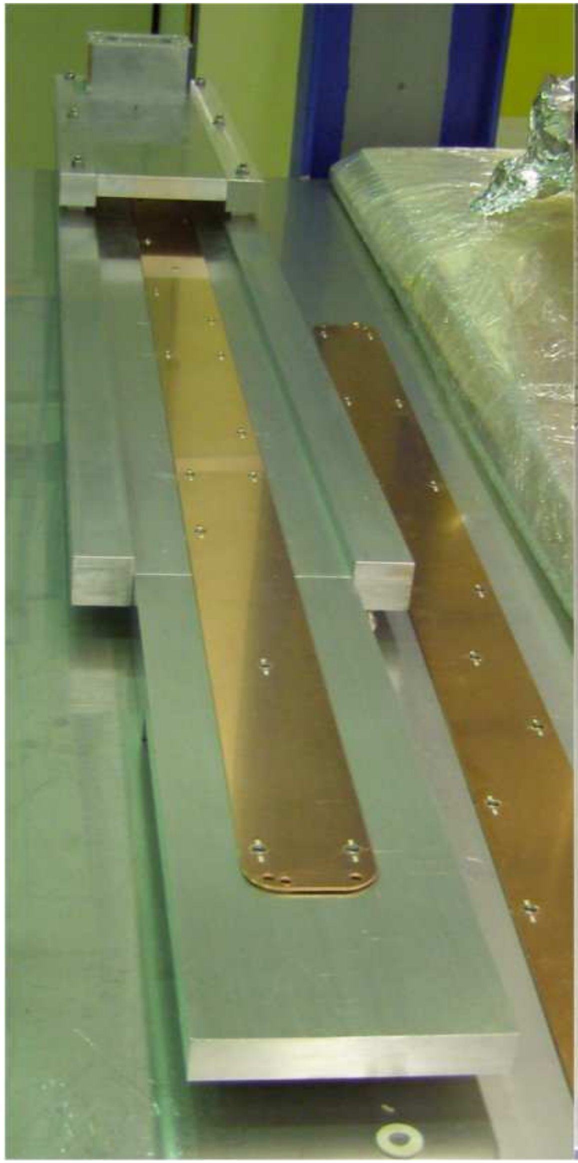
A short description

- ✓ The electrodes have been made in copper and have a distance of 0.5 mm from the vacuum pipe. This small distance has been chosen to reduce the beam coupling impedance of the devices. Special ceramic supports sustain the strips.
- ✓ Analytical calculations and electromagnetic simulations have been done to estimate the power released from the beam to the electrodes. We expect a maximum temperature increase of the order of 100^{o}C with a 2A beam for the wiggler electrodes. This temperature increase has been considered acceptable since the electrodes have been heated up to this level without damage and also because it is in the range of operation of all the components (SHAPAL and feed-throughs).
- ✓ The electrodes are connected to external generators and have been tested (with the beam) applying dc voltages of up to 250 V.
- ✓ RF measurements have been done to precisely measure the resonant frequencies of the electrodes modes.

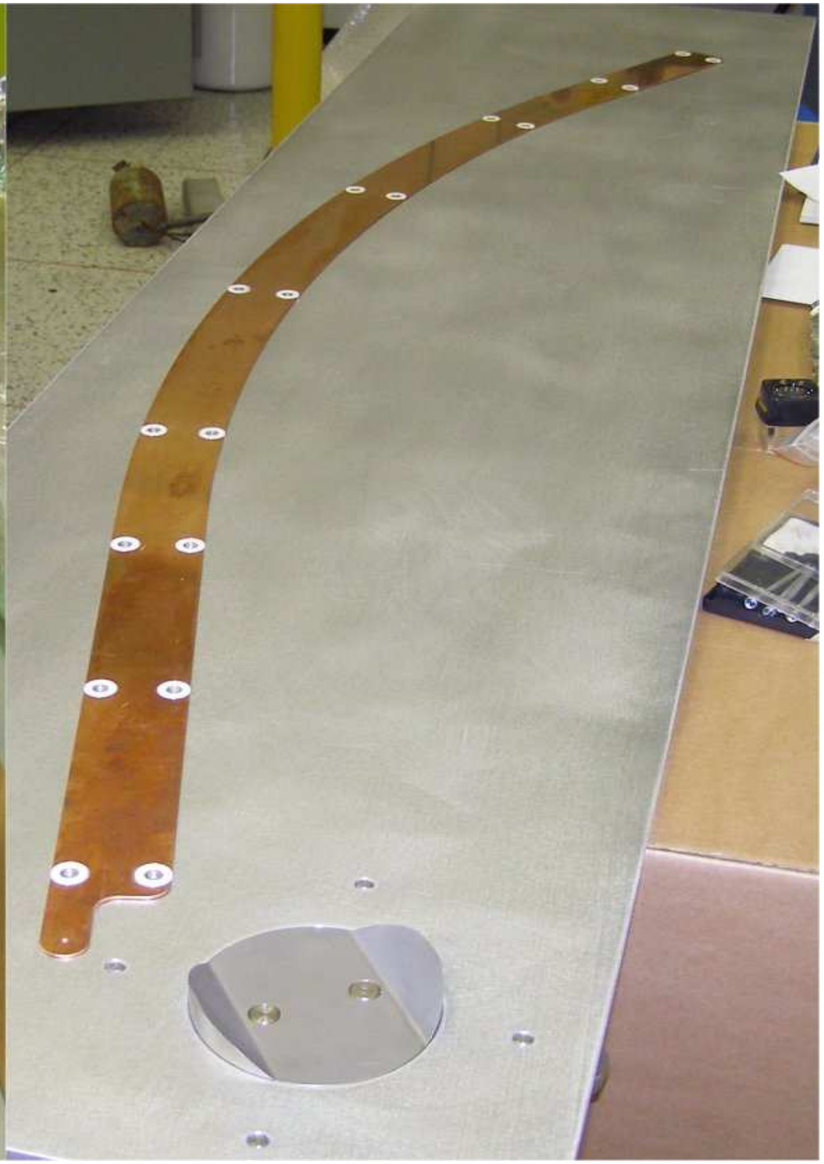
The electrodes before installation

The distance of the electrodes from the beam axis is 8 mm in the wigglers and 25 mm in the bending magnets.

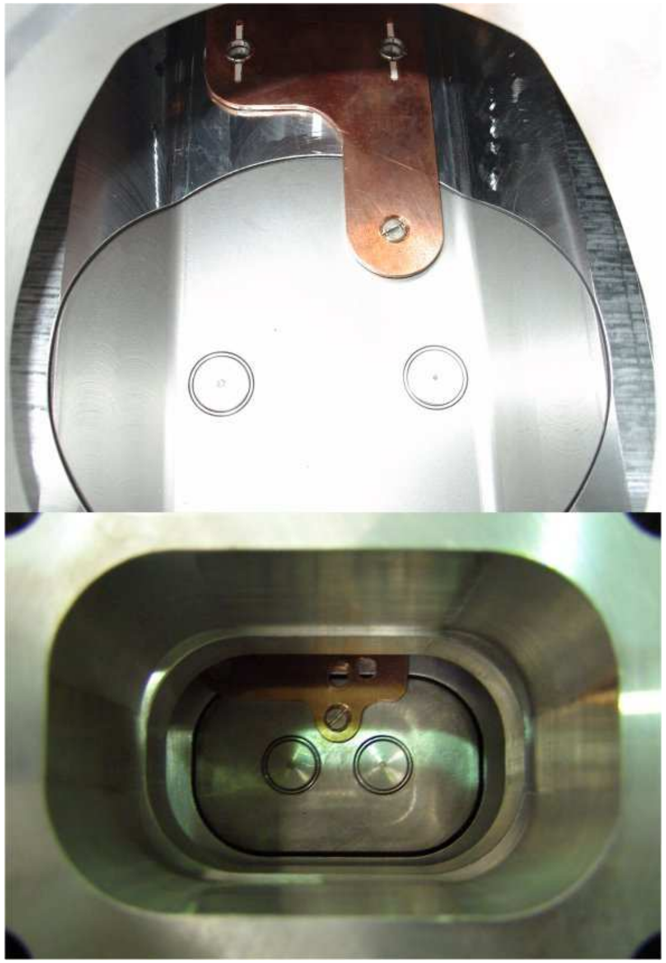
In the wigglers



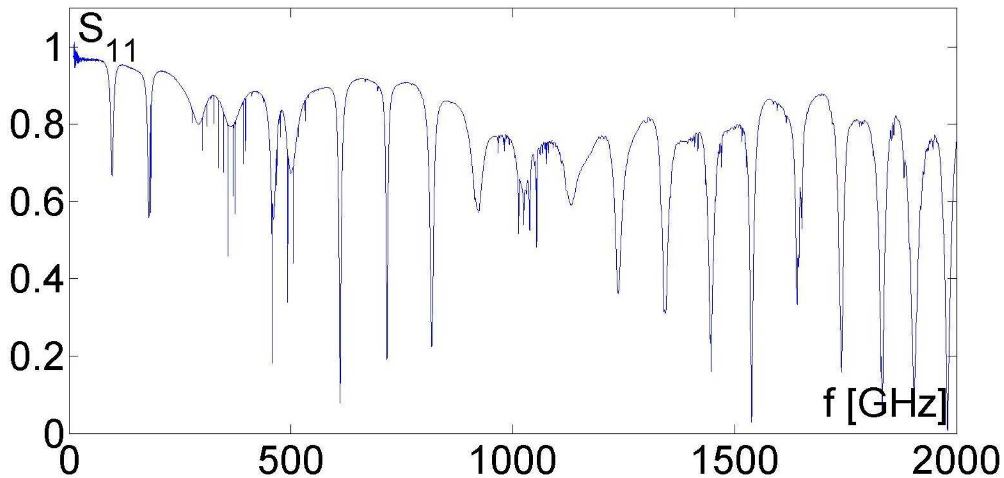
In the bending magnet

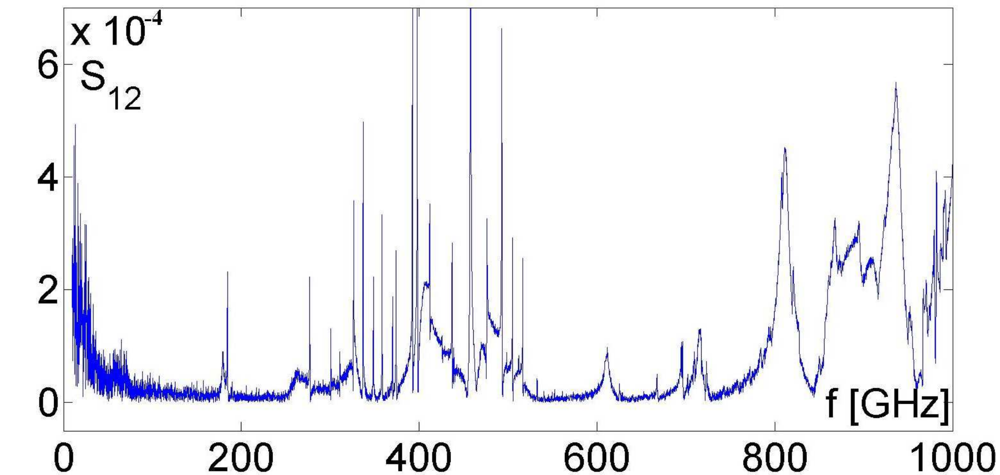


RF measurements with a network analyzer have been performed before and after the electrode installation. We have done two types of measurements: reflection coefficient at the feedthrough port and transmission coefficient between one BPM near to the strip and the feedthrough. ***In both cases it was possible to measure the resonant frequencies of the strip modes.***

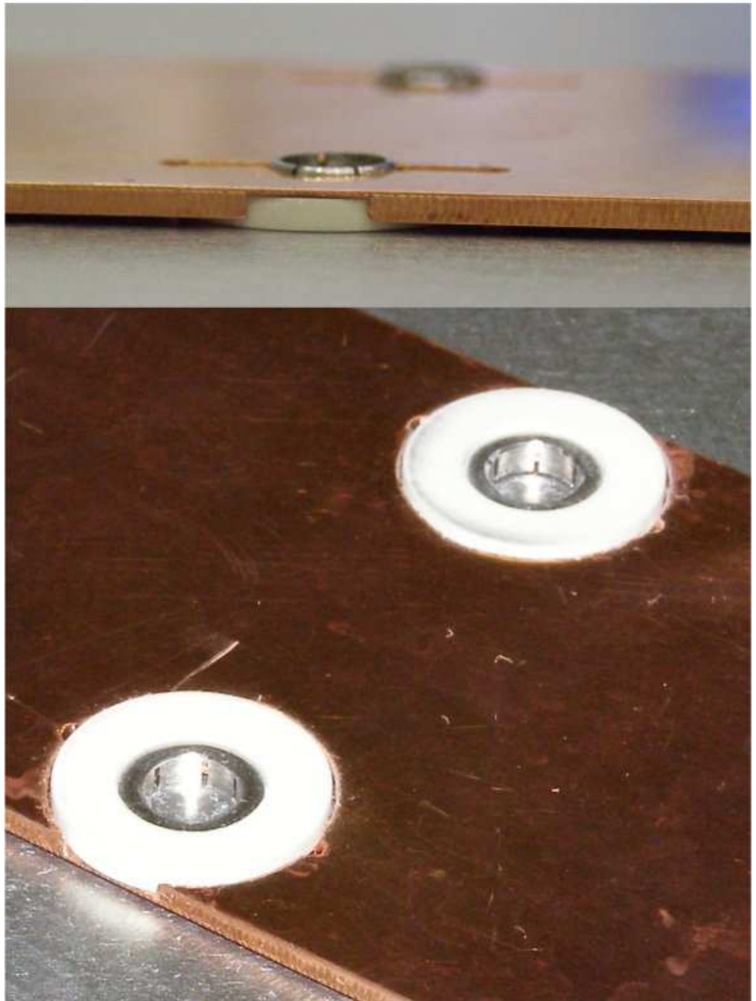


Detail of the electrode output connection





The ***dipole electrodes*** have a length of 1.4 or 1.6 m depending on the considered arc, while the ***wiggler ones are 1.4 m long***. They have a width of 50 mm, thickness of 1.5 mm and their distance from the chamber is about 0.5 mm. This distance is guaranteed by special ceramic supports made in SHAPAL and distributed along the electrodes.



Installed electrodes

The electrode impedance consists of two contributions: a resistive wall impedance due to a finite conductivity of the electrode and a strip-line impedance since the stripline is created between the electrode and the vacuum chamber wall.

Resistive wall

$$\frac{dP}{dz} = \frac{(eN)^2 n_b c}{2\pi R}\frac{dk_l}{dz} = 5.58\frac{W}{m}$$

Considering 120 circulating bunches with 20 mA we each electrode should dissipate ***7.8 W***, or 112 W/m^2 for the 50 mm wide electrode. Such power density would result in electrode heating under vacuum up to 50^0-55^0 C.

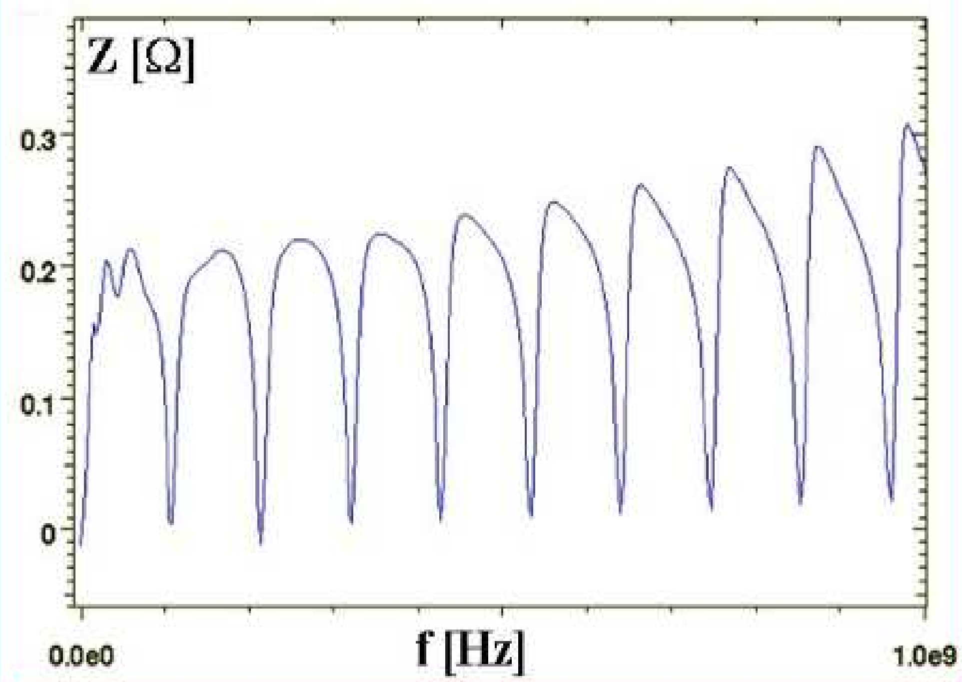
Strip-line Impedance

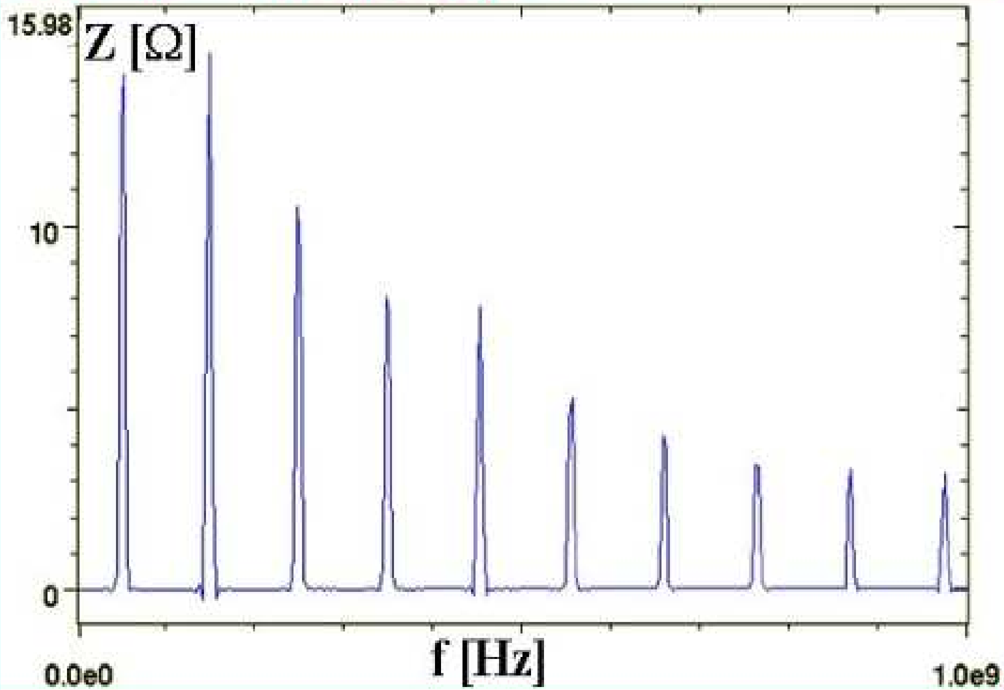
We have simulated ***two extreme cases***: the perfectly matched electrode and the short-circuited one.

Loss factors: 1.87x109 V/C (shorted) and -1.56x109 V/C (matched).

In both cases the lost power is not negligible and can result in excessive heating of the electrode. In order to prevent this possible damage, electrode supports are made of thermo-conducting dielectric material the SHAPAL.

The estimated low frequency broad-band impedance of the electrode *Z/n* is about 0.005 Ω that should be a small contribution to the total ring impedance.



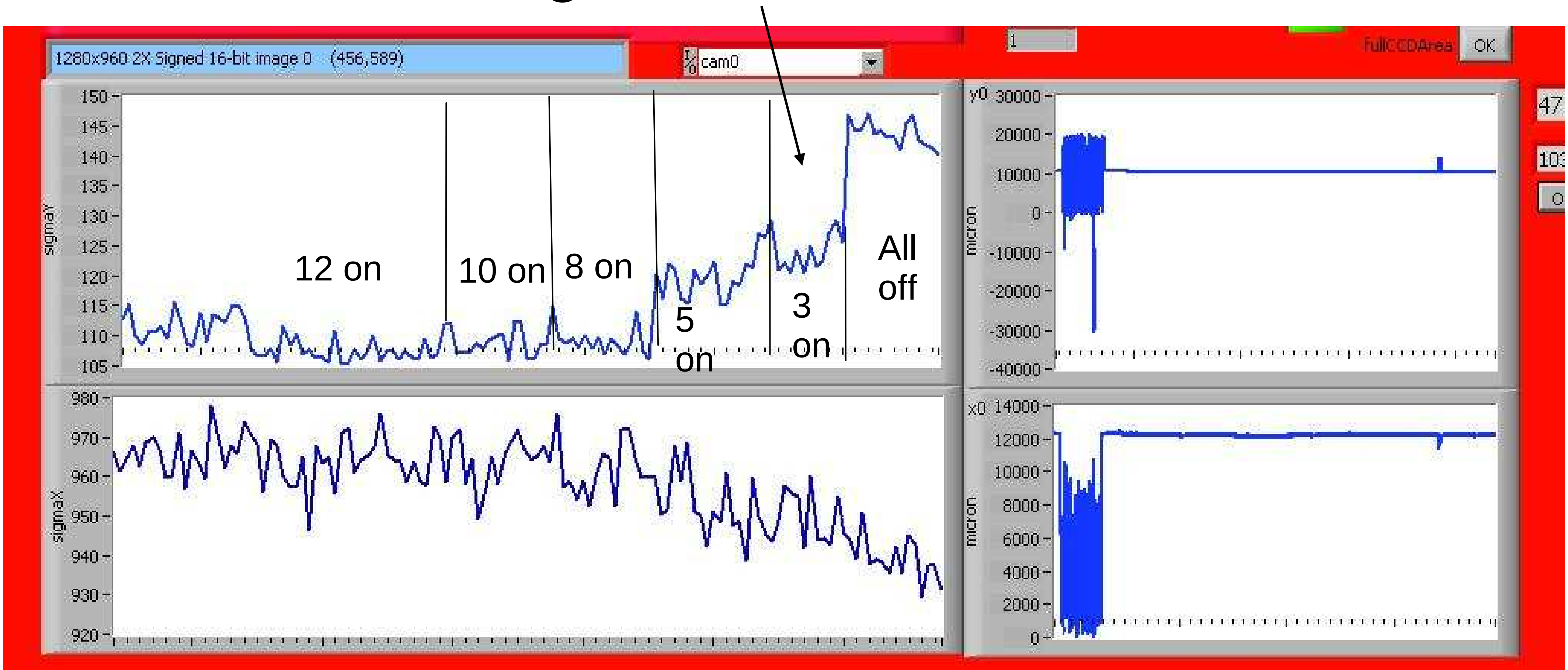


Performance analysis methods

1) Synchrotron light monitor (not bunch-by-bunch)
2) Spectrum analyzer (by using FFT)
3) Instability grow rates made by using bunch-bunch feedback (H/V) with its capability to stop damping actions
4) H/V tune spreads measured by using bunch-by-bunch feedback system only as recording tool (i.e. parasitically)

Looking at the effect on the real positron beam, tests have been carried on by using the synchrotron light monitor, the FFT spectrum analyzer, and the bunch-by-bunch horizontal and vertical feedback systems.

Turning off the electrodes, a vertical enlargement is evident on the SLM

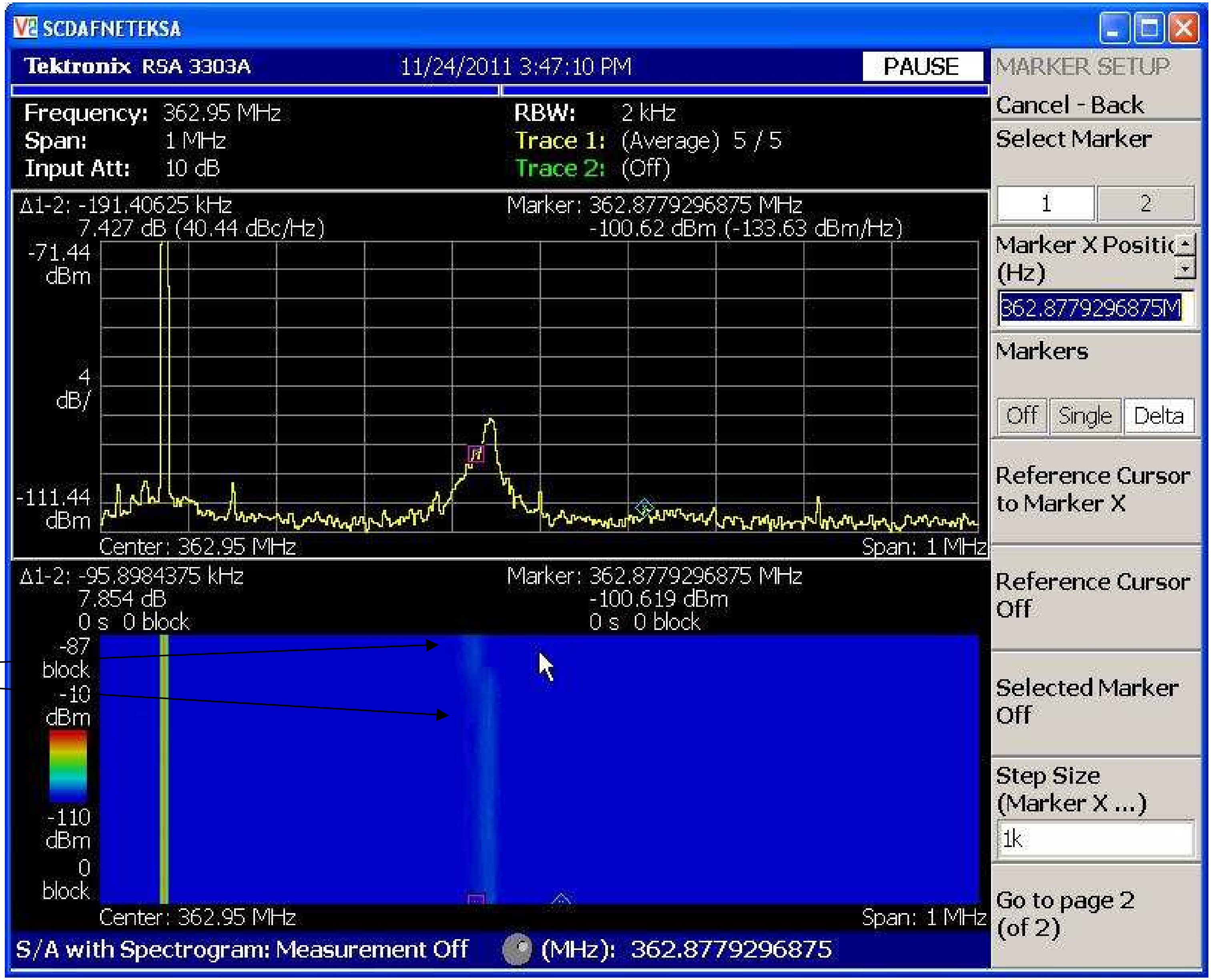


E+ horizontal tune shift goes up when (all) electrodes are turned off

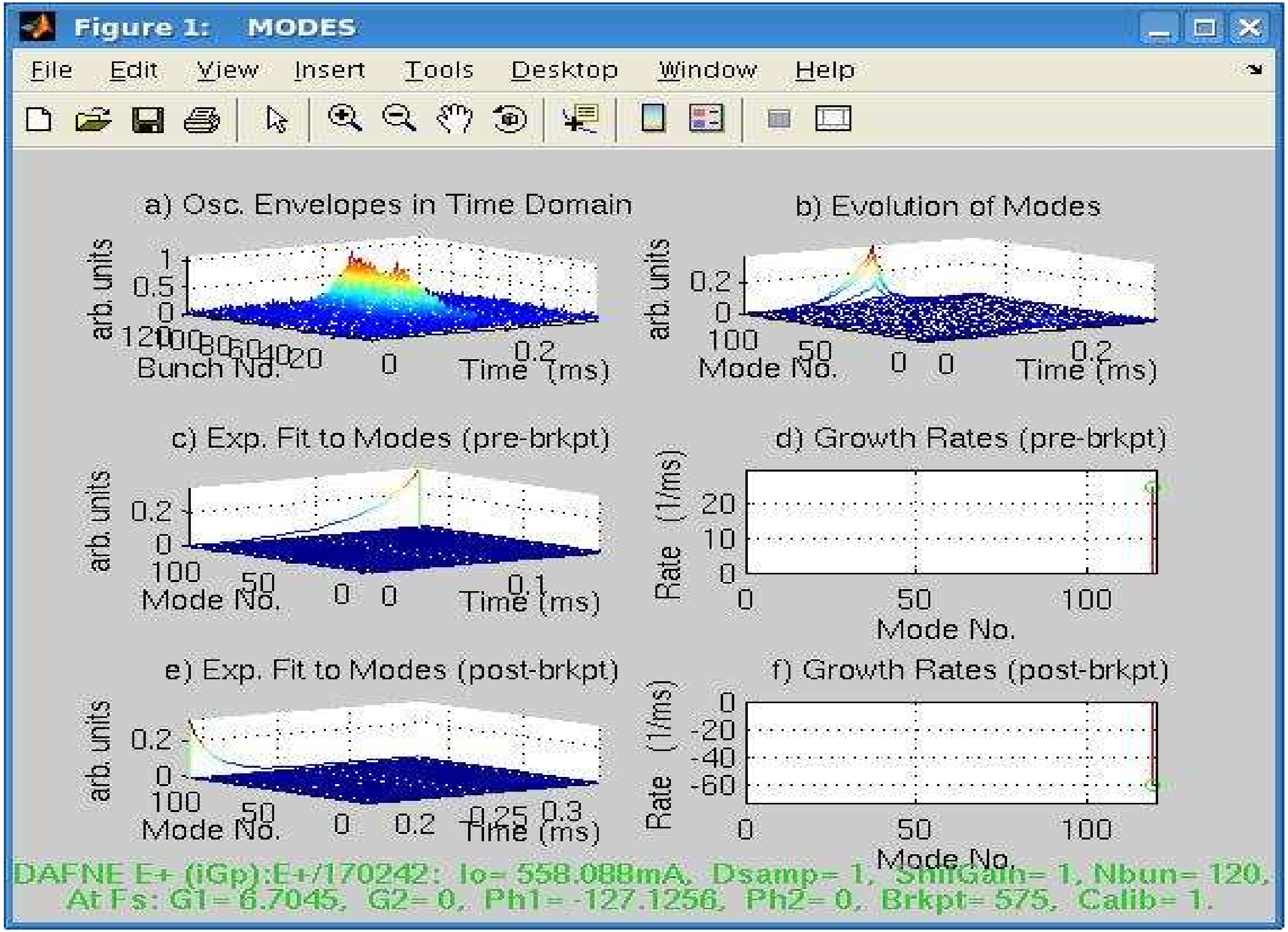
550mA
e+ beam
current

Freq.diff=~20kHz

Tune difference=0,0065

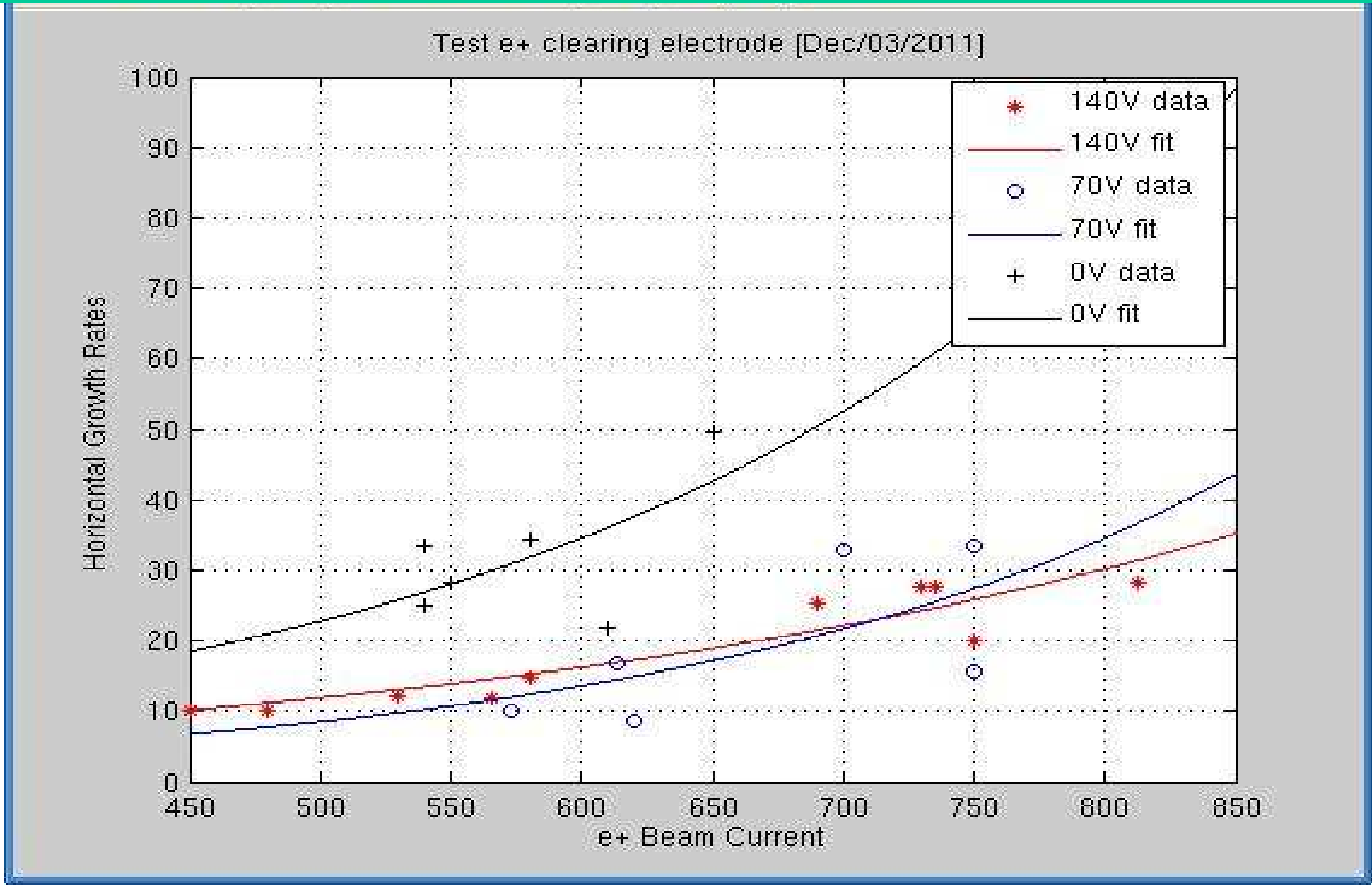


Growth rate measurements can be quickly done by using bunch-by-bunch feedback

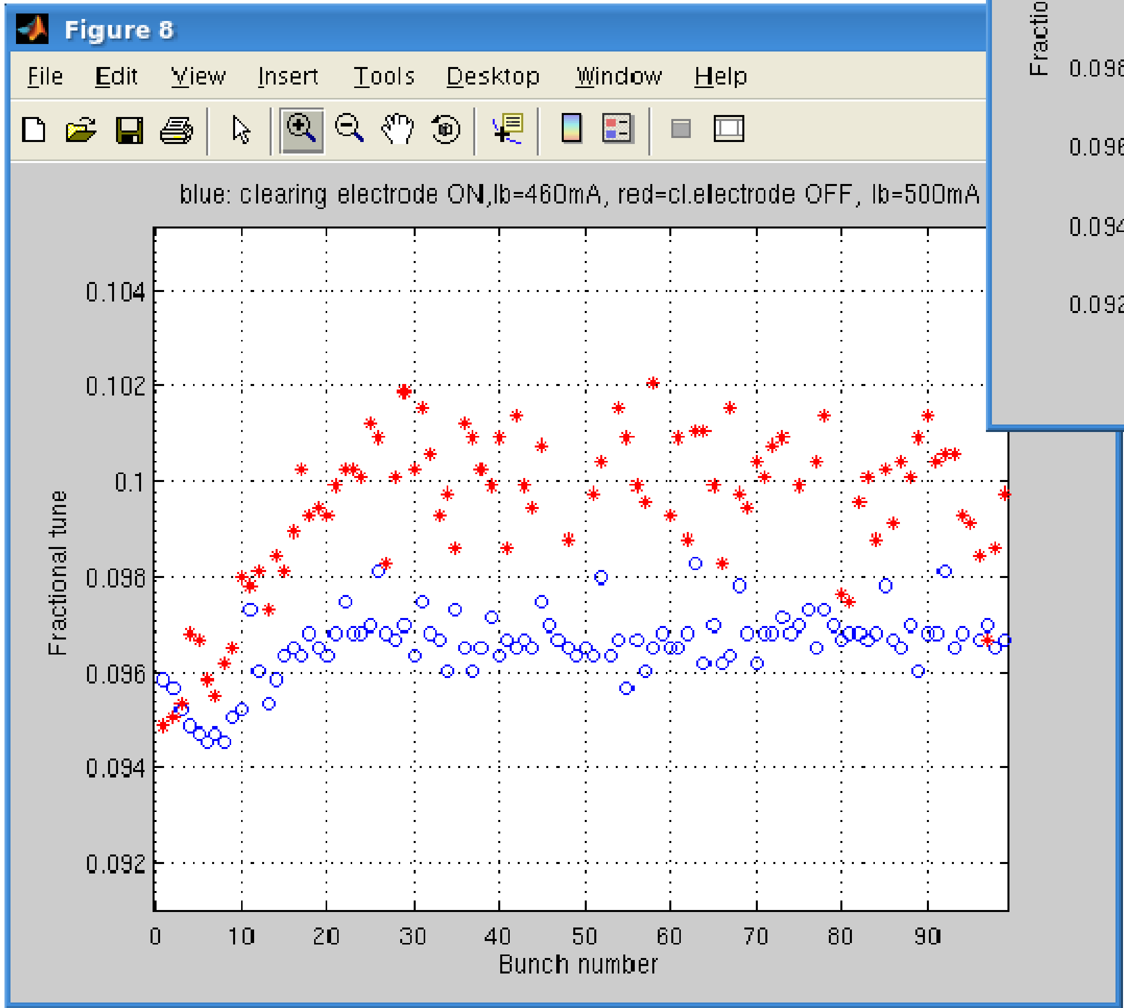


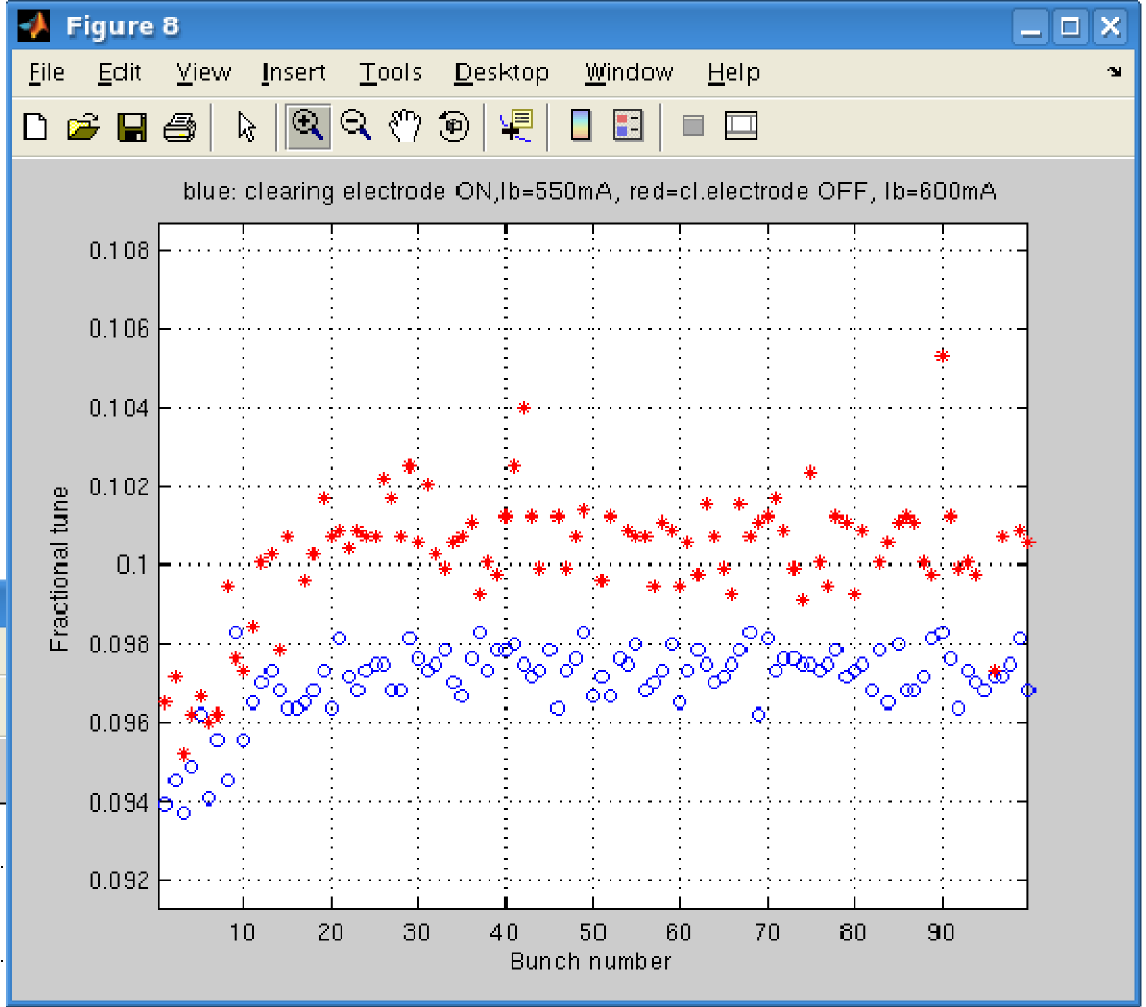
In this picture the horizontal growth rate measure is plotted showing a strong resistive wall instability (i.e. mode -1)

The e-cloud clearing electrodes are able to decrease the horizontal instability growth rates.
Voltages applied in this measure are 140V, 70V and 0V



Horizontal bunch-by-bunch fractional tune measured by the feedback system

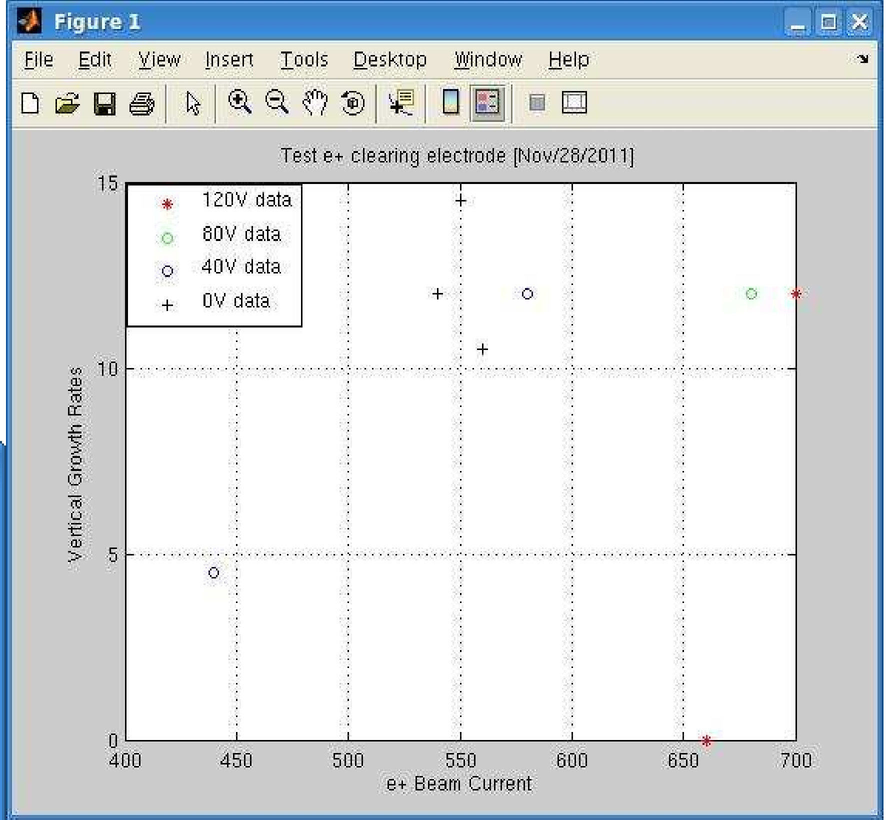


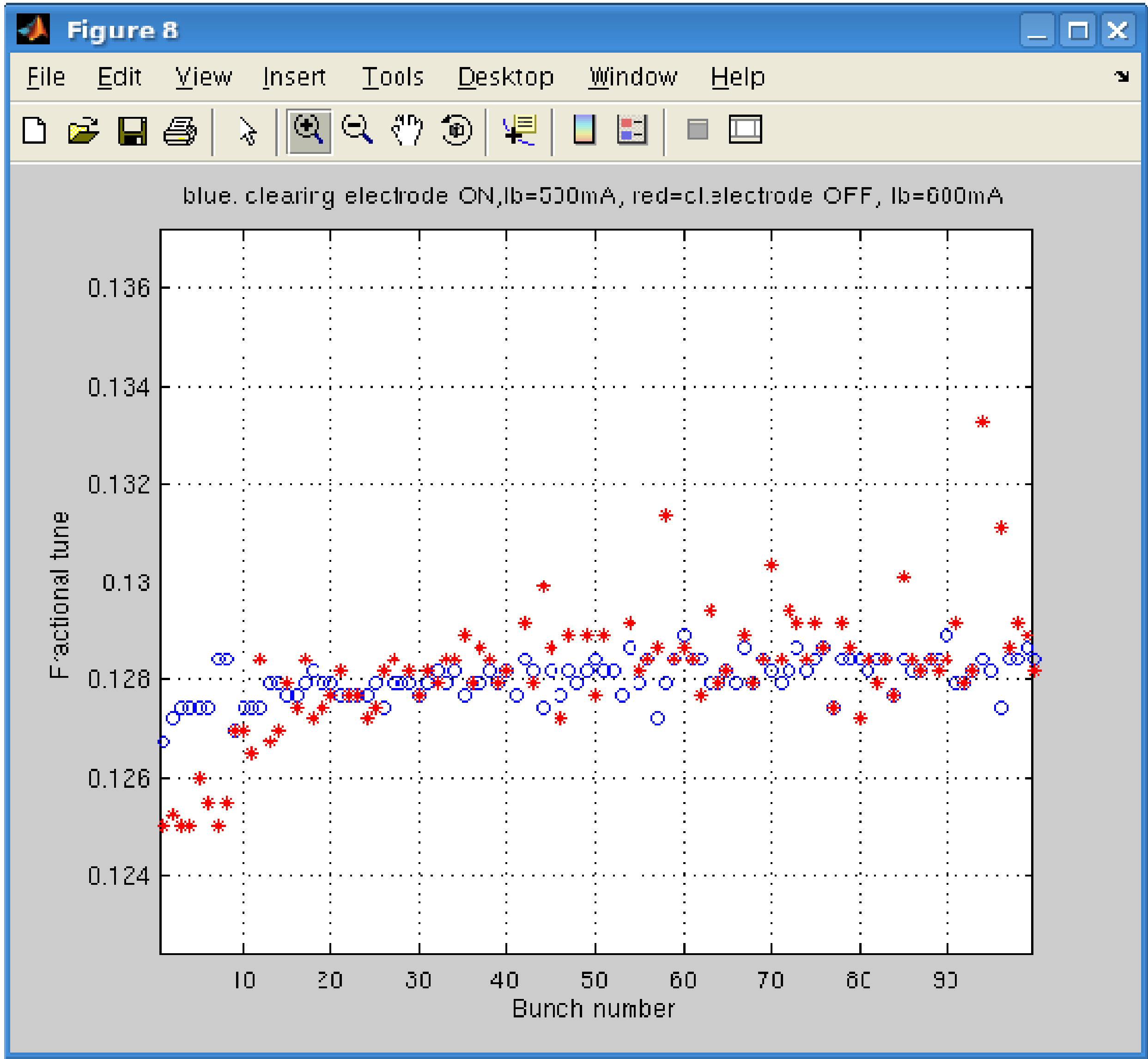


DAFNE e+ beam,
100 bunches, spaced by 2.7ns
with 20 buckets gap

Turning off the electrodes
in 4 wigglers and 2 dipoles,
the horizontal tune goes up

Vertical fractional tune spread (down) and vertical growth rates (right) measured by bunch-by-bunch feedback system





In the vertical plane the spread has a different shape w.r.t. the horizontal behavior but, again, the electrodes are very effective !

Conclusion

- Metallic clearing electrodes have been inserted in the wiggler and bending magnet vacuum chambers of the DAFNE positron ring to fight the instability due to the e-cloud.
- Electrode placement is complementary to solenoids that are allocated in the straight sections of the e+ ring.
- Experience with clearing electrodes in the DAFNE positron beam is largely positive: smaller vertical dimensions, less transverse tune spread and slower growth rates clearly indicates a good behavior of these devices.
- Transverse bunch-by-bunch feedback systems with many diagnostics analysis tools are unique instruments to evaluate solenoid and e-cloud clearing electrode performances.

Acknowledgements

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