Commissioning and Operation of SUPER-3HC at ELETTRA

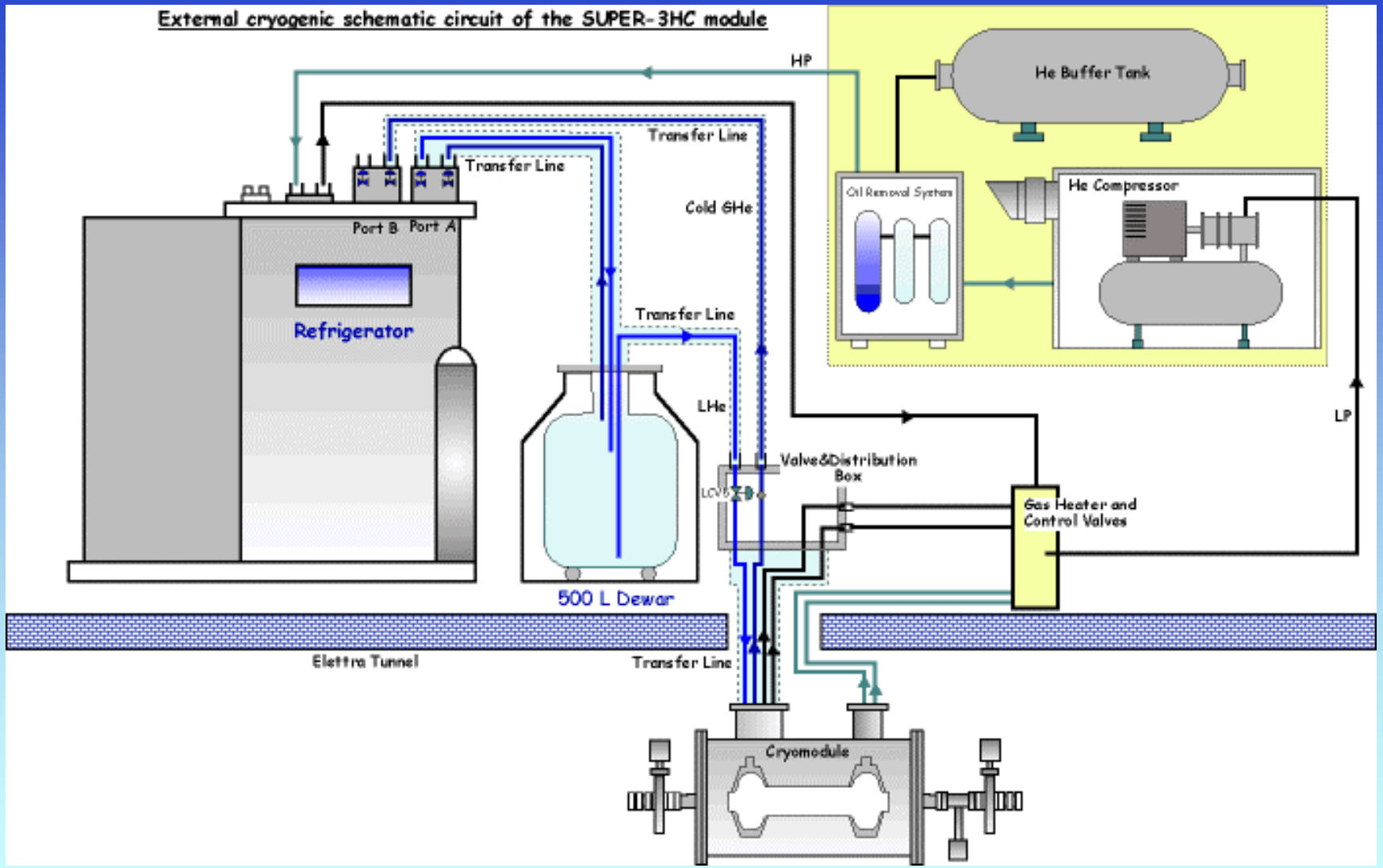
M.Svandrlik

- Last year history and system overview
- Commissioning and Operational Experience
- Lifetime increase and Landau damping
- Effect of a gap in the bunch train
- Outlook and Conclusions

What happened in the last year

- August - September 2002: INSTALLATION
- October - December 2002: Cryogenic System Commissioning and Warm Cavity SR operation
- January 2003: Cavity cool-down and first operation with beam.
- February - June 2003: cavity commissioning with beam while operating the storage ring for user's.
- *Since July 2003: standard cavity operation for user's shifts established.*

Overview of the System

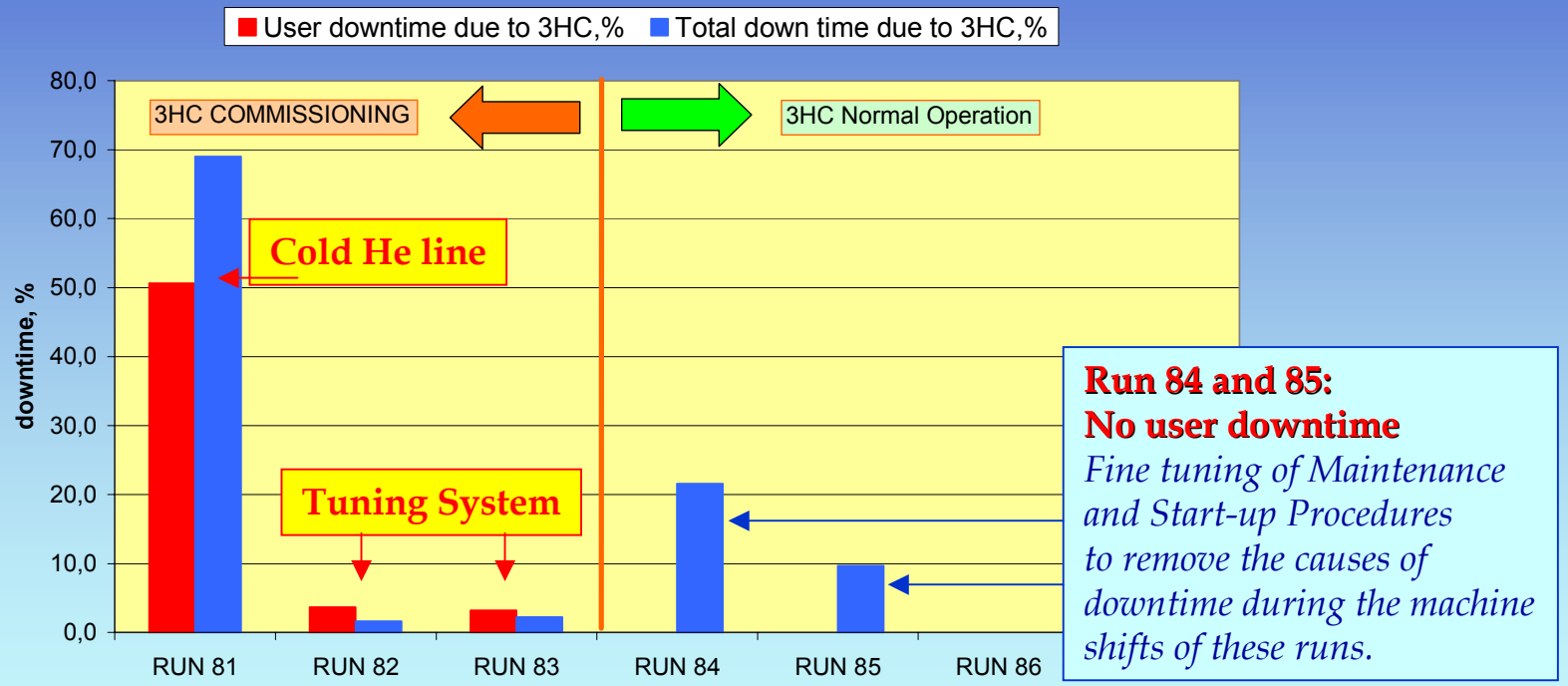


Commissioning Experience

- Quite tricky faults on the system have been solved:

  a) Leak on the insulation vacuum of the cold He gas return line (02/2003)

  b) Replacement of the under vacuum, cold tuning system (06/2003)



- System stops due to external reasons are not included in the above statistics:
  - *3 stops due to electrical power interruptions caused by thunderstorms*
  - *2 stops caused by electrical power blackouts (on 28/09 Italian blackout)*

Operational Experience

- Operation

  1) The cavity is parked during injection and energy ramping

  2) The voltage is build-up in the cavity by tuning it at the end of the ramping.

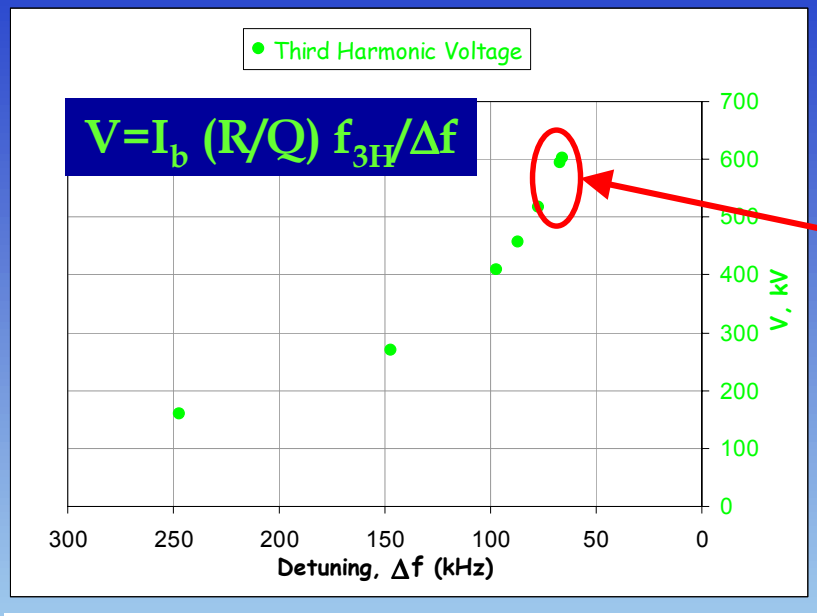
  3) A slow voltage feedback keeps the voltage constant for the first part of the current decay, from 320 mA down to 230 mA. Then it stops.

- **Standard Settings**

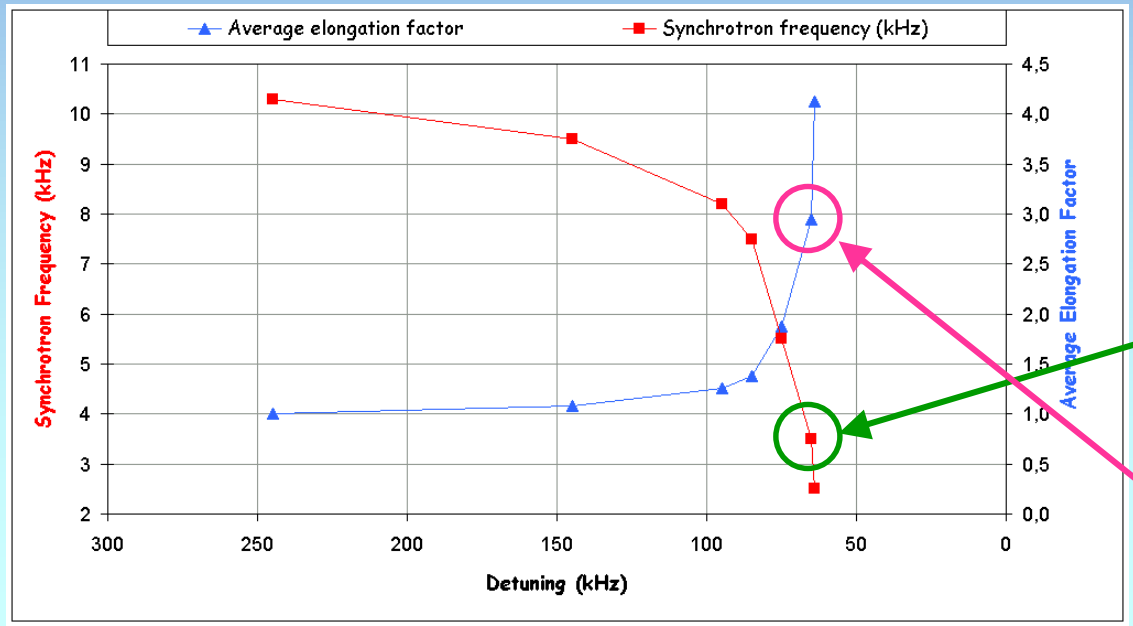
3rd harmonic frequency	1498.955 MHz
Cavity frequency at 320 mA	1499.015 MHz
Parking Position	1499.200 MHz
Δf at 320 mA	+60kHz
Nominal Voltage per cell	300 kV

No instability driven by 3HC during injection, ramping and operation

Bunch lengthening experiment



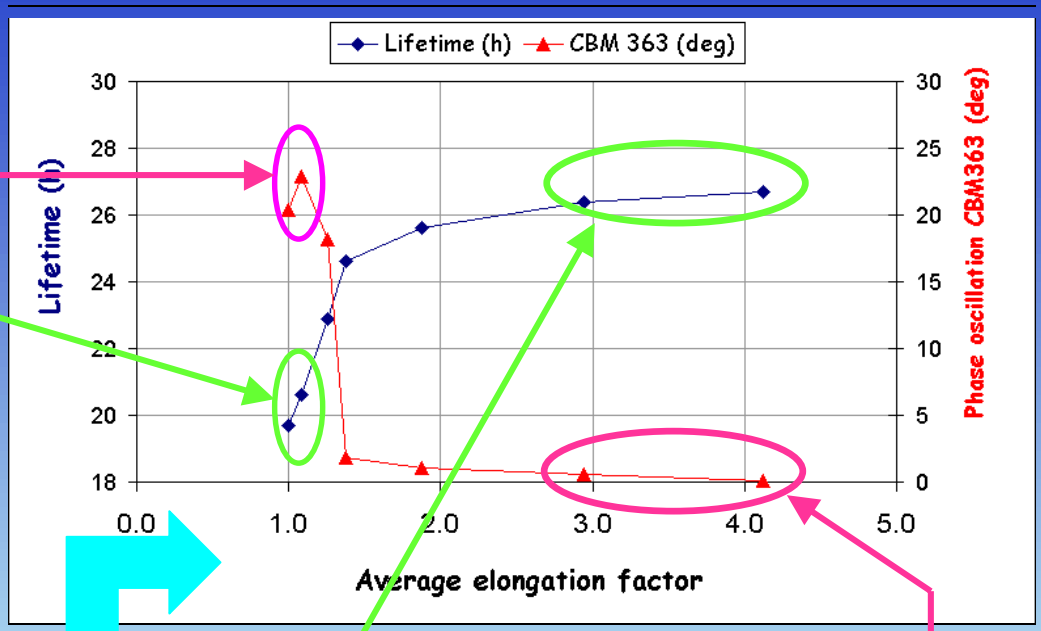
The theoretical voltage build-up in the cavity, for I_b = 300 mA, shows that in the detuning region between 70 and 65 kHz the voltage should approach about 1/3 of the main RF voltage (1,7 MV).

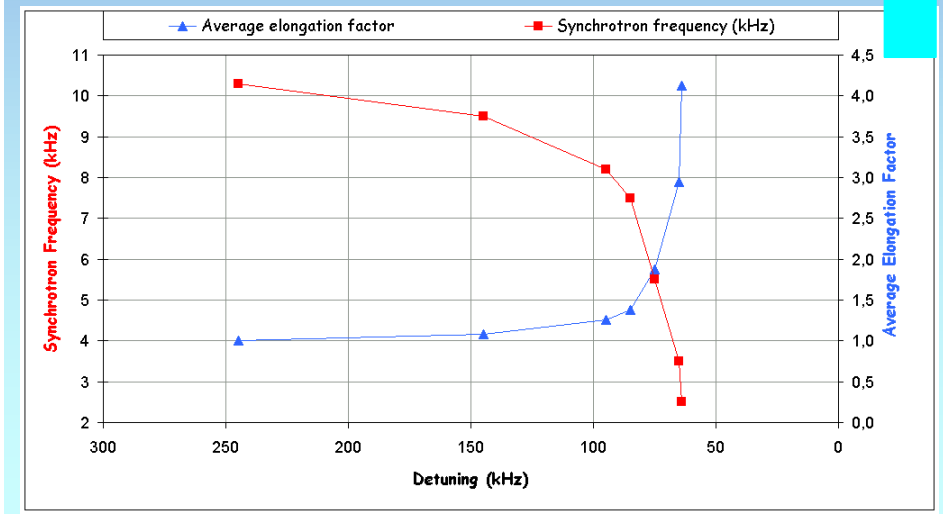


This measurement is performed at 2,0 GeV, 300 mA. The measured f_s decreases with the detuning; at Δf = 67 kHz, f_s is 3,5 kHz, which corresponds to an average elongation factor 2,9.

Lifetime and Landau damping in the same experiment

In the same experiment, before activating the cavity, **the beam performs strong longitudinal oscillations (20-23 deg).**
Lifetime is about 20 hours
Due to the strong bunch dilution it is much higher than the theoretical value for this optics, **7,7 hours.**





Activating the cavity, when the average elongation factor reaches 3, **the longitudinal oscillation is Landau damped.**

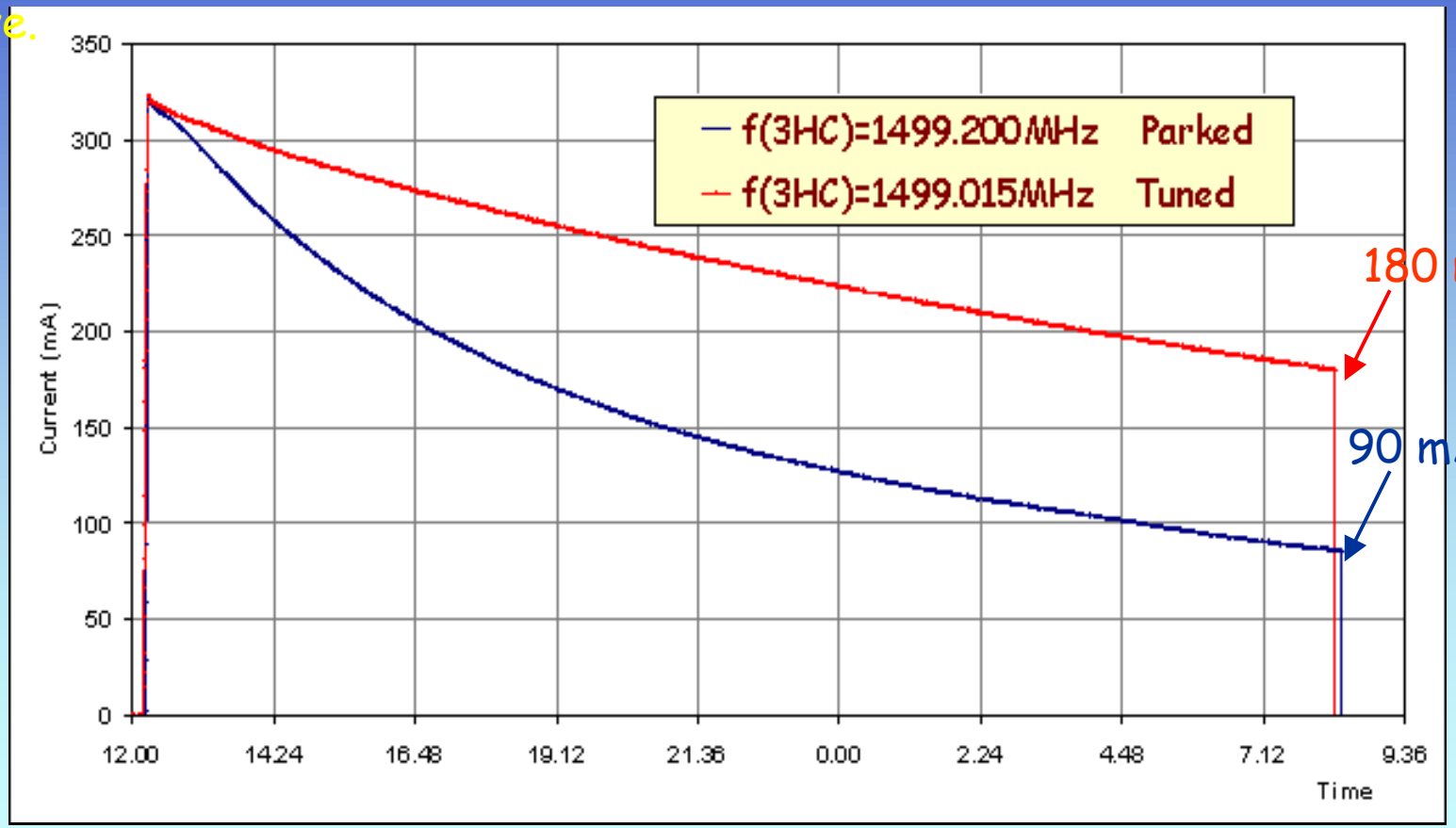
THE BEAM IS STABLE
(transverse feedbacks are ON)

Lifetime is increased to 27 hours

Hence the gain factor to the theoretical value is **3,5**

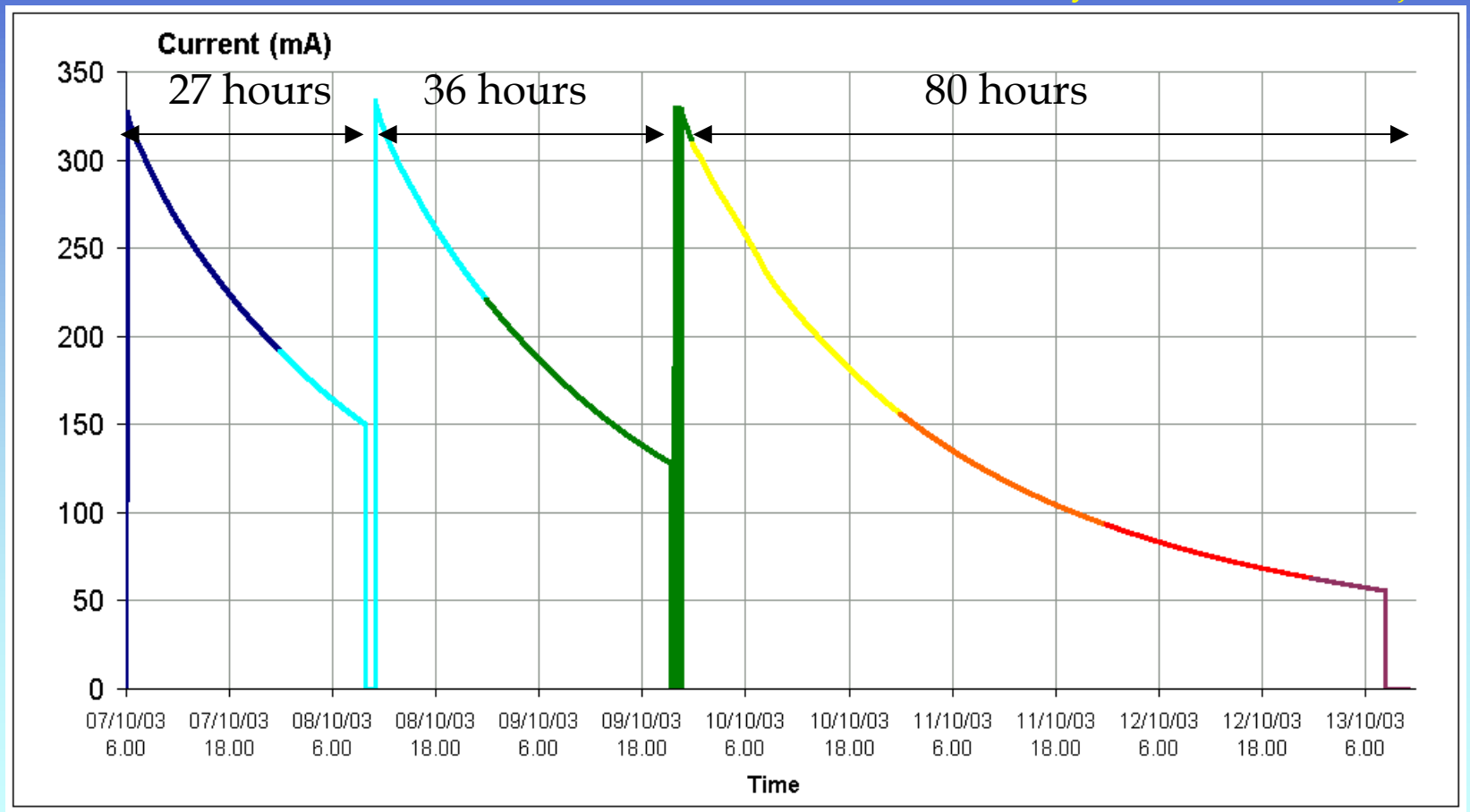
A typical day at 2.0 GeV, User's Mode

By comparing a typical day with the 3rd harmonic tuned (beam longitudinally stable) to a day when it is parked (controlled longitudinal excitation) one can see that the final current, before dumping the beam, is **doubled** when the cavity is active.



Benefits of large lifetime: last week at 2 GeV

- On the 1st day, 27 hours between two injections (as usual for the 1st day, then every 24 hrs)
- On the 2nd day, the users decided for injections every 36 hours, due to the large lifetime.
- In the following 3 days, in fact no injections due to a linac fault, now solved. The users could however work with a reasonable beam current intensity; 80 hrs without injecting.

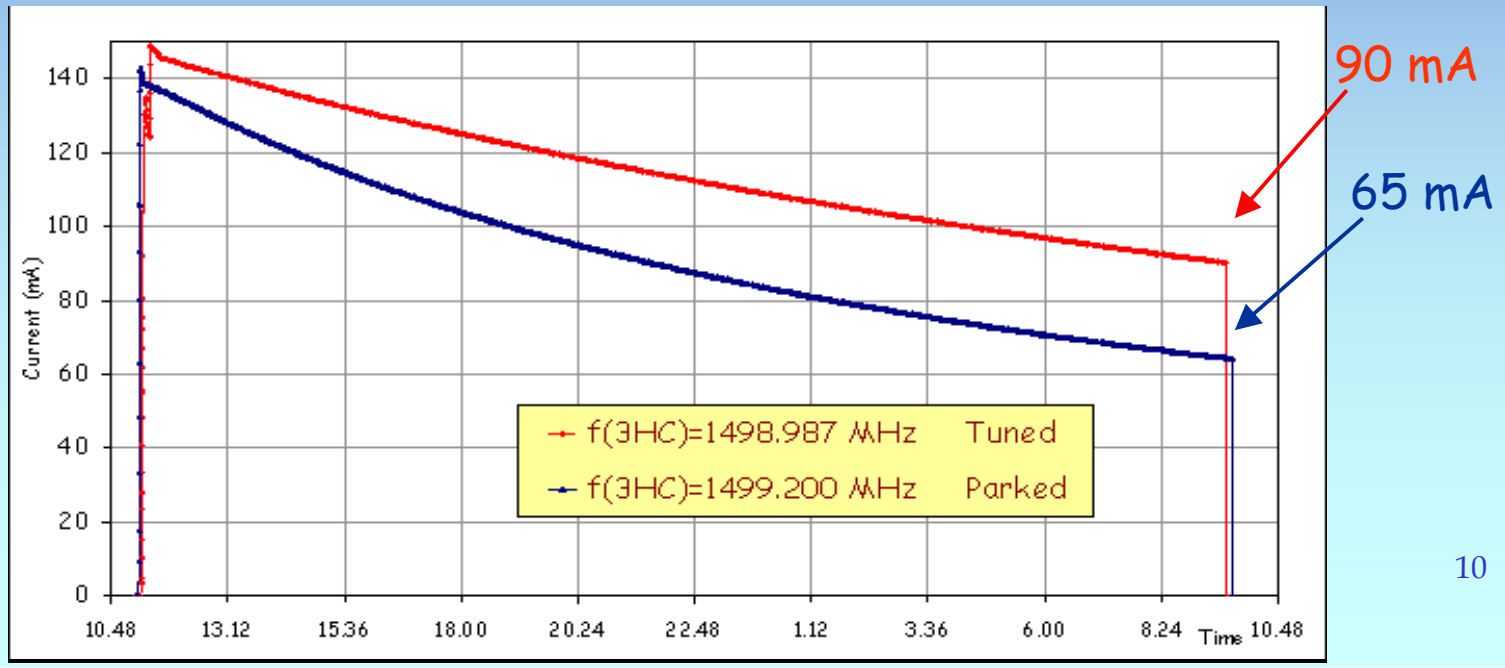


A typical day at 2.4 GeV, User's Mode

During the 2.4 GeV period scheduled for the first part of the present run 86 the cavity has been activated also at this energy, where the current is limited to 140 mA, due to vacuum chamber thermal load limitation.

At this current, for safe operating conditions we must stop at +43 kHz detuning. The 3rd harmonic voltage is then about 350 kV, i.e. 60% of the nominal voltage.

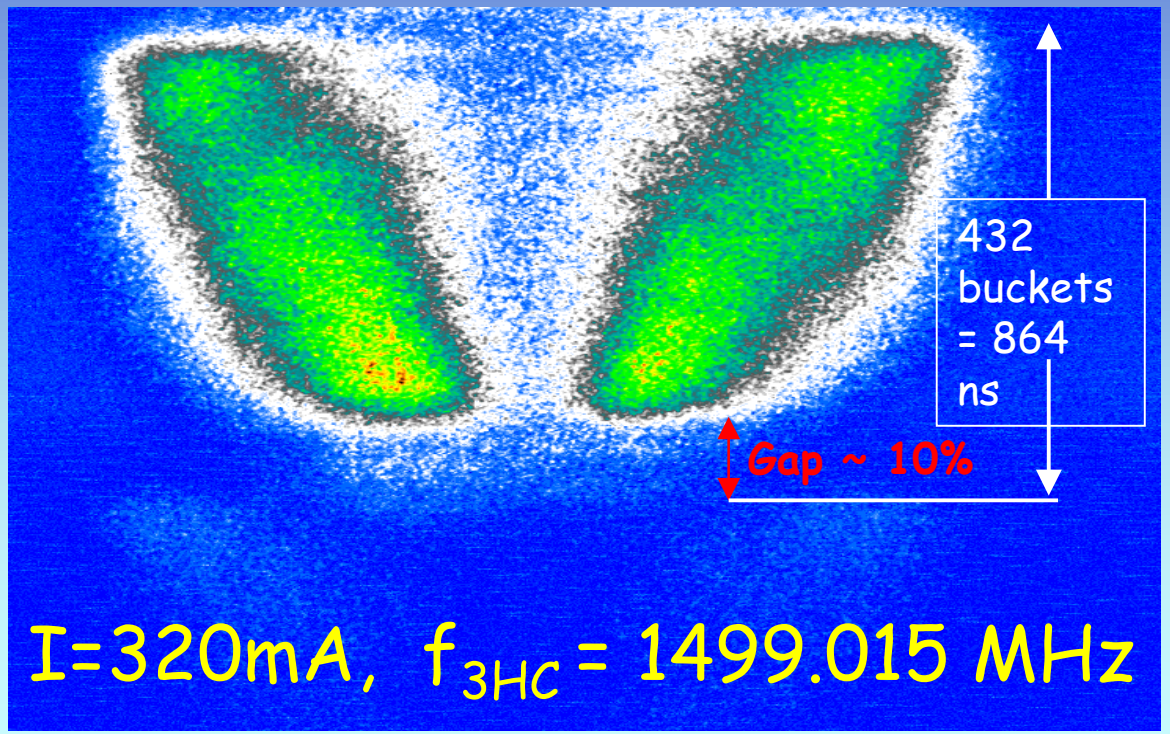
Nevertheless the typical beam lifetime attains 45-50 hours, that means a **50%** improvement to the lifetime with parked cavity (where at 2.4 GeV, 140mA the beam is already stable).



Effect of a gap in the bunch train

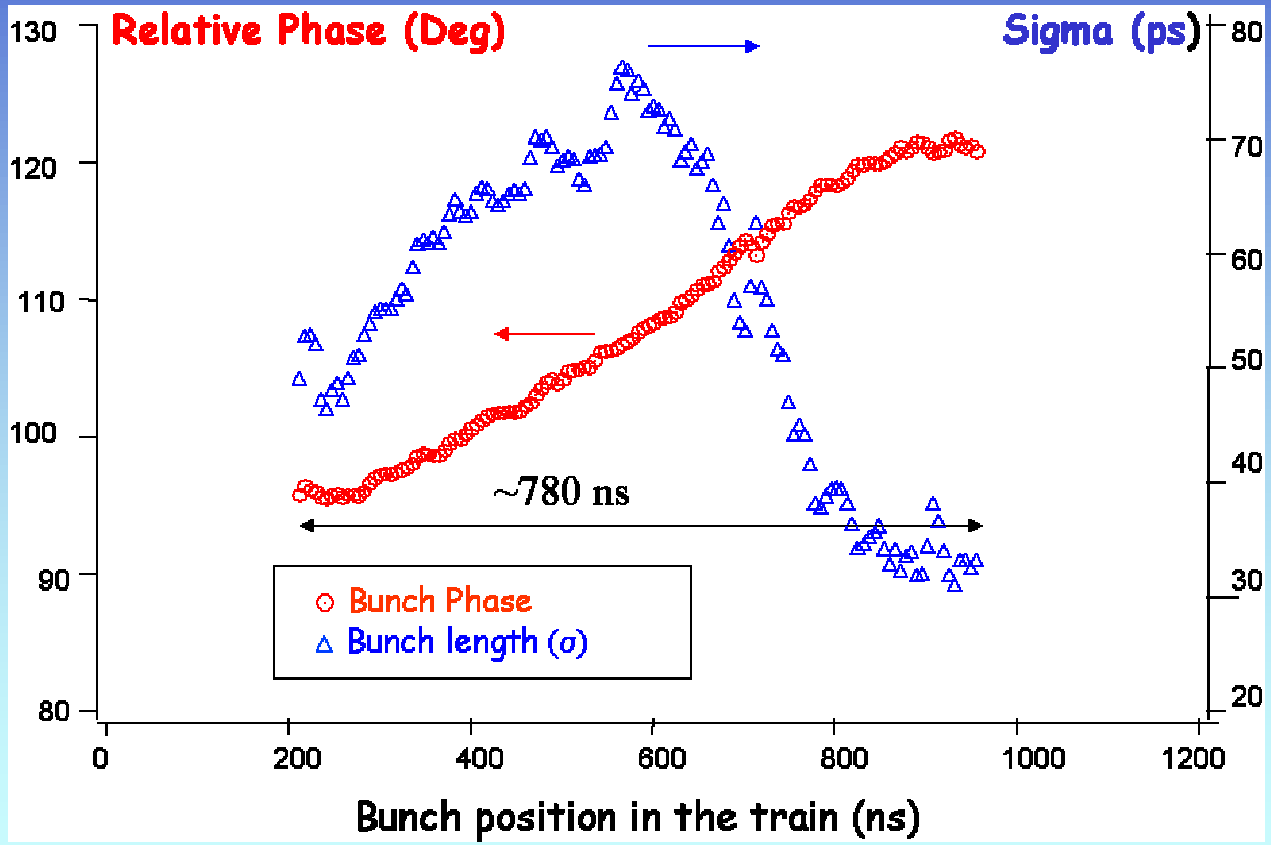
The streak camera measurements allow to characterise the phase modulation along the bunch train when a gap is present. At ELETTRA a gap of about 43 empty buckets in the 432 bucket of the ring allows to clear trapped ions (*10%,i.e. 86 ns gap*).

This gap induces a phase modulation along the bunch train.



Bunch phase and length along the train

The Streak Camera data elaboration shows that the phase shift "head-tail" is about 30deg and the bunch length changes from almost 76ps to about 32ps, with an average lengthening factor ~ 3.



Outlook

- In the November shutdown we will replace one of the two gate valves on the beam tubes.
- In January 2004 we will perform the first general maintenance of the system.
- To decrease the number of system interruptions we are planning to connect the compressor station to a UPS.
- We are considering the possibility of installing a Helium recovery system, which would be then used by all cryogenic systems at ELETTRA.
- Further studies on the effects of gaps in the bunch train and on Landau damping are considered, possibly also in collaboration with the ESRF.

Conclusions

- The cryogenic plant and the cavity have been successfully commissioned.
- Since July 03 the cavity is routinely running during the standard user's operation mode.
- At 2.0 GeV, 320 mA with active cavity the lifetime attains 27 hours, that is the lifetime is increased by a factor 3.5.
- For the first time it has been possible at Elettra to deliver a completely stable beam at 2.0 GeV, 320 mA.
- Characterisation studies of the effect of an empty gap in the train have been started.