SUPER-3HC at ELETTRA Update

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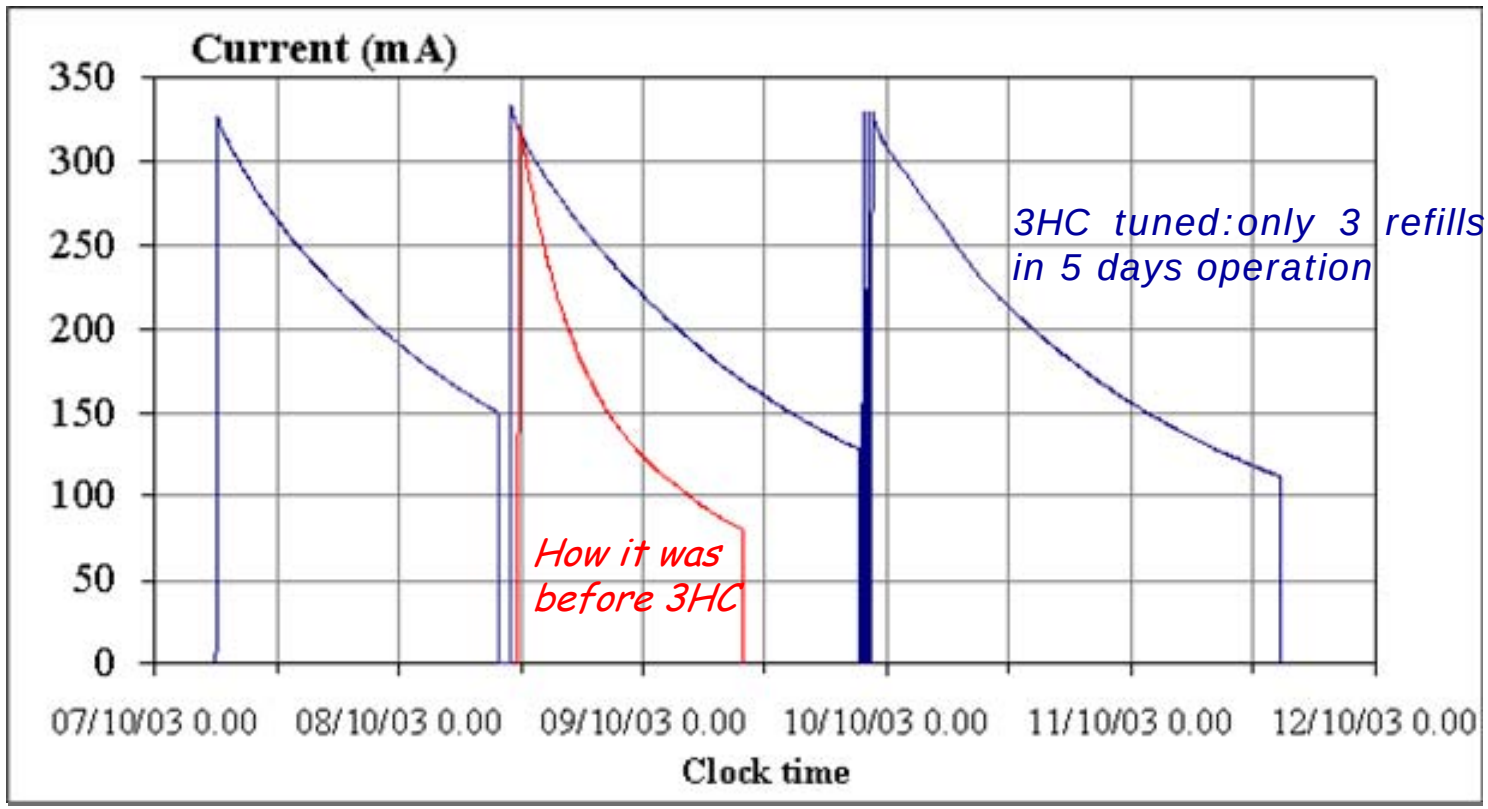
- Operation
- Uptime
- Maintenance
- Performance vs filling
- Conclusions

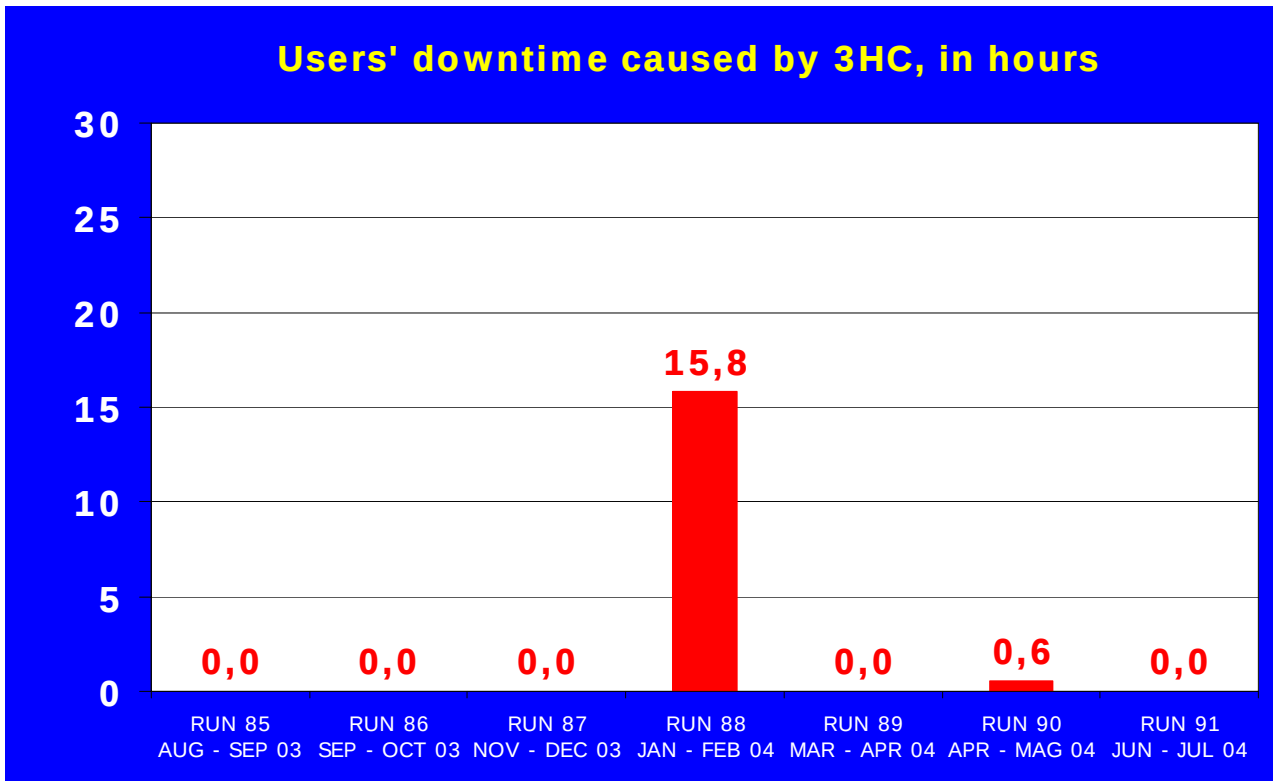
Operation / Uptime / Maintenance / Performance vs Filling

- **3HC** is routinely in operation during user's shifts.
- **Lifetime** depends on ultimate vacuum conditioning and filling pattern, highest value we can obtain is **27 hrs** (320 mA; 2.0 GeV)
- Filling pattern set to **96%**
- During refill and energy ramping 3HC set at **+94 kHz** (from 3rd harmonic) - Transverse Feedbacks **ON**
- Once beam is at 2.0 Gev 3HC is activated by tuning it at **+64 kHz**
- Longitudinal Coupled Bunch Instabilities are **cured** by 3HC, Transverse Instabilities are cured by Feedbacks.

- The increase in Beam Lifetime obtained when 3HC is active, allows us to **refill** ELETTRA **every 36 hrs** instead of 24 hrs, as it used to be in the past.

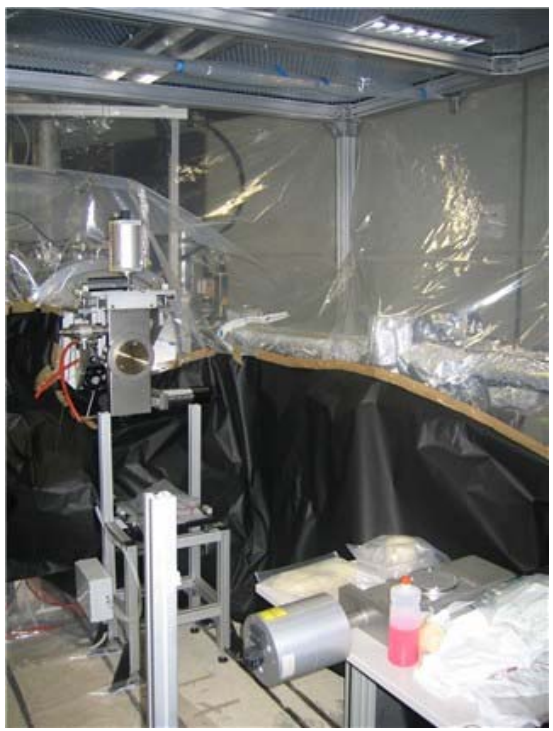


- General uptime of the system is good. Since September 2003 only **one event** caused significant User's downtime, on Saturday, 31/01/2004.

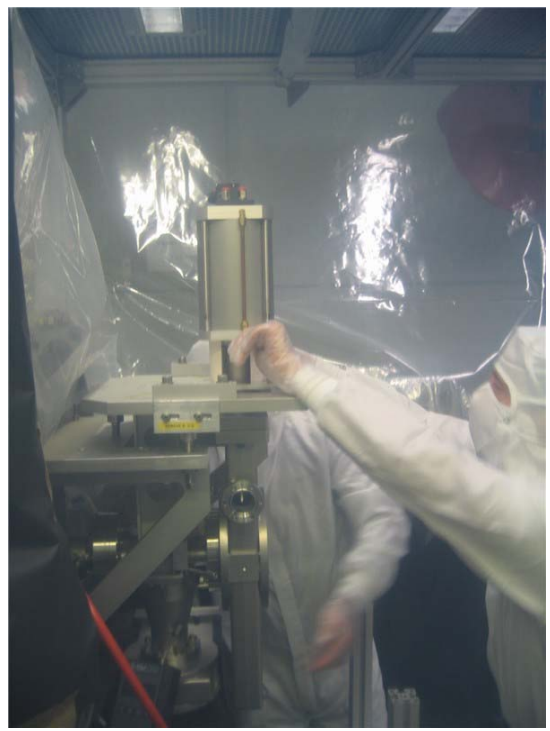


- The event on 31/01/04 was related to a failure of a **rough pumping unit** of the valve-box insulation vacuum. This was a temporary installation, replaced during the next shutdown with a fail-safe one.
- The uptime statistics does not include systems stops due to electrical power interruptions, mostly caused by **thunderstorms** in the surroundings. In this case most machine systems are stopped and the restart time of the cryogenic plant is hidden in the general restart of the systems. For this reason the idea of connecting 3HC to a new **UPS** has not yet been implemented (also financial reasons).
- We still do not have a **He recovery system**, the experience made so far shows that we can survive without it, not affecting the uptime of the system.

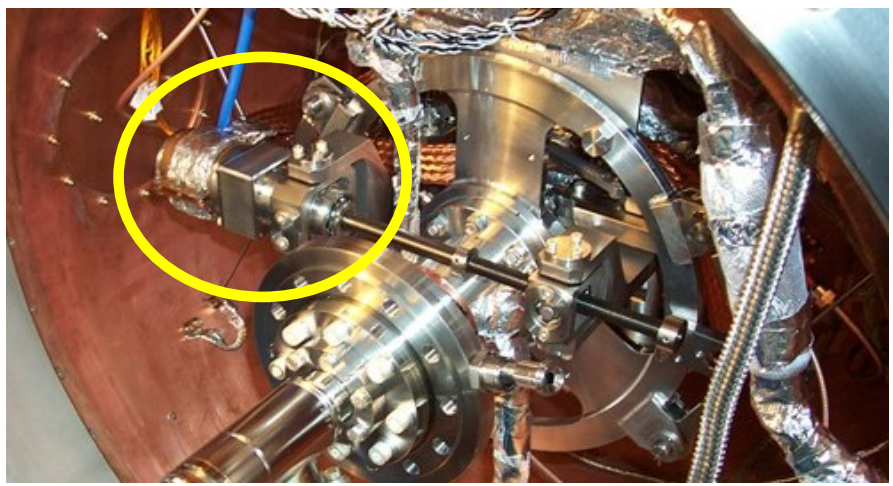
- Several important maintenance interventions have been successfully performed in the last 12 months.
- In November 2003 the **leaky gate valve** between 3HC and the superconducting wiggler was substituted.



This required to break the cavity vacuum. A clean area was therefore created inside the storage ring tunnel. The replacement followed clean room procedures and was done by CEA and Elettra staff.
The field performance of the cavity has not been affected by this intervention.



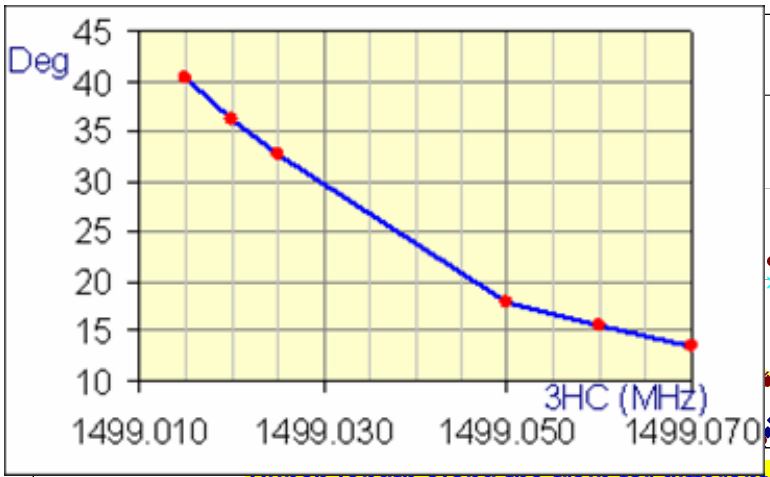
- In December 2003 the **tuning system of cell 1 failed** for the 2nd time (1st time in March). In January 2004 the tuning system was replaced with an upgraded version.
- The tuning system is under vacuum, at cold. The gear box was found to be blocked.
- Tests at Saclay showed that the reason could be a heating problem (from the motor).
  - Even if the number of cycles after which this shows up is huge, we are limiting the movements of the system.
  - ***No problem since January 04***
  - CEA is studying a solution to move the motor outside the cryomodule.

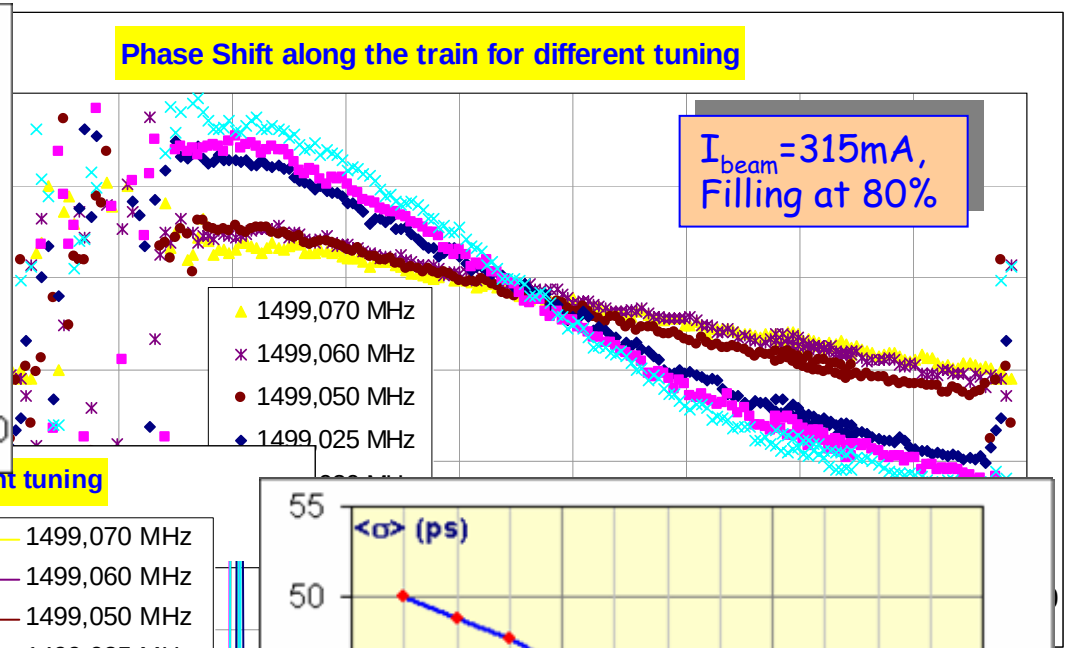


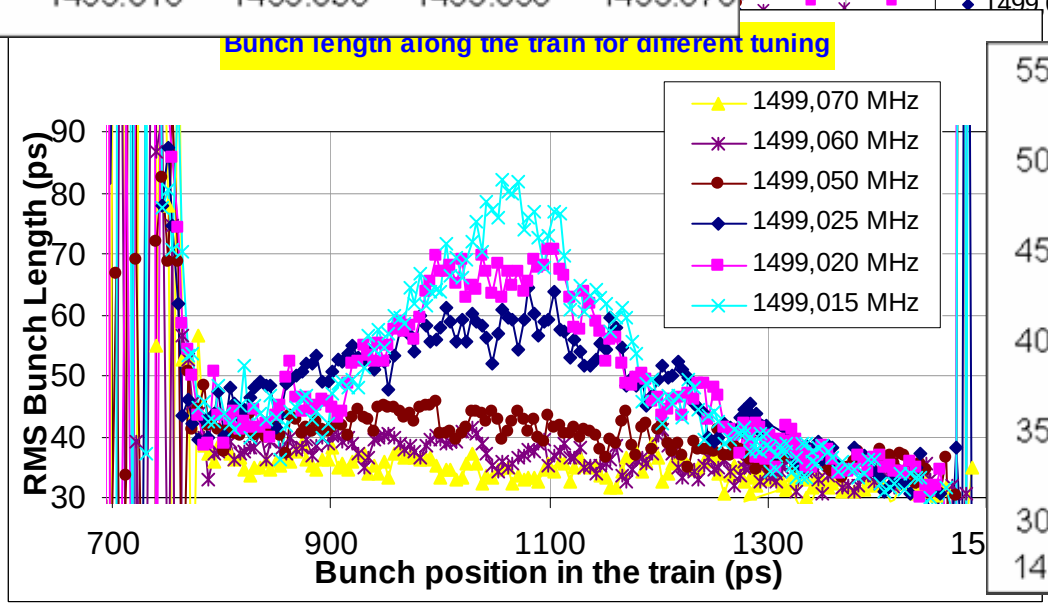
- During the January shutdown the cryogenic plant annual maintenance was performed.
- After this maintenance the nominal performance is back to the original, i.e. about 30-35 litres/hour at 13 bar of HP.
- In August 2004 the cryomodule has been warmed-up again in order to replace a coaxial cable which takes out the voltage signal of cell 2.
- In this occasion also the fundamental mode rejection of the dipolar HOM couplers has been improved. In fact on one of them some over-heating effects were observed when tuning the cell.

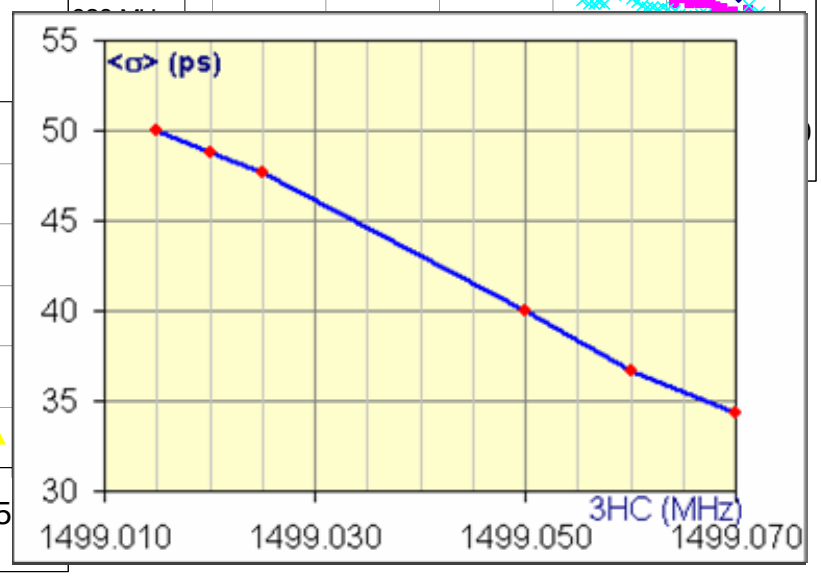
- ELETTRA used to operate with a partial filling of the bunch train: typically a 10% empty gap was present.
- As well known, with such a gap the passive third harmonic cavity induces a phase modulation over the bunch train.
- Several **STREAK CAMERA experiments** were performed for **various fillings**, measuring the effect on:
  - **Phase Shift**
  - **Bunch lengthening**
  - **Landau Damping**
  - **Beam Lifetime**
- As a result, a new optimum filling was set for operations.

80% Filling: Phase Shift / Bunch Length / Landau / Lifetime

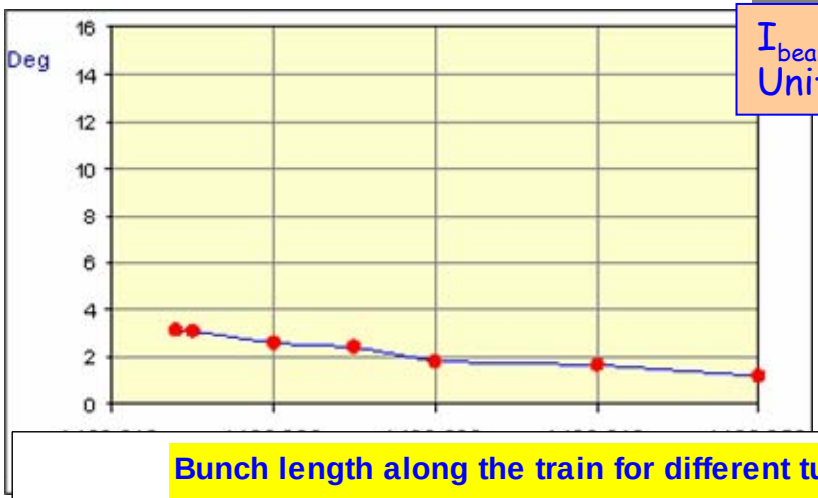




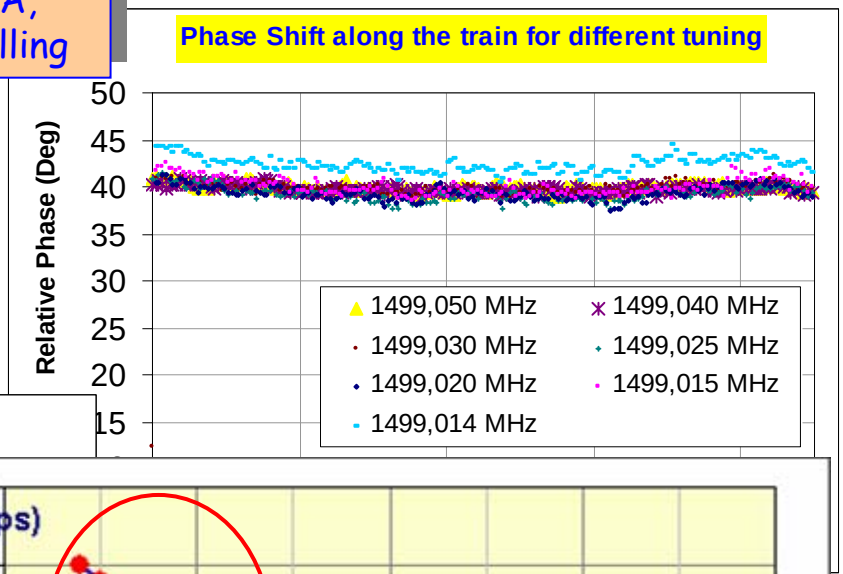


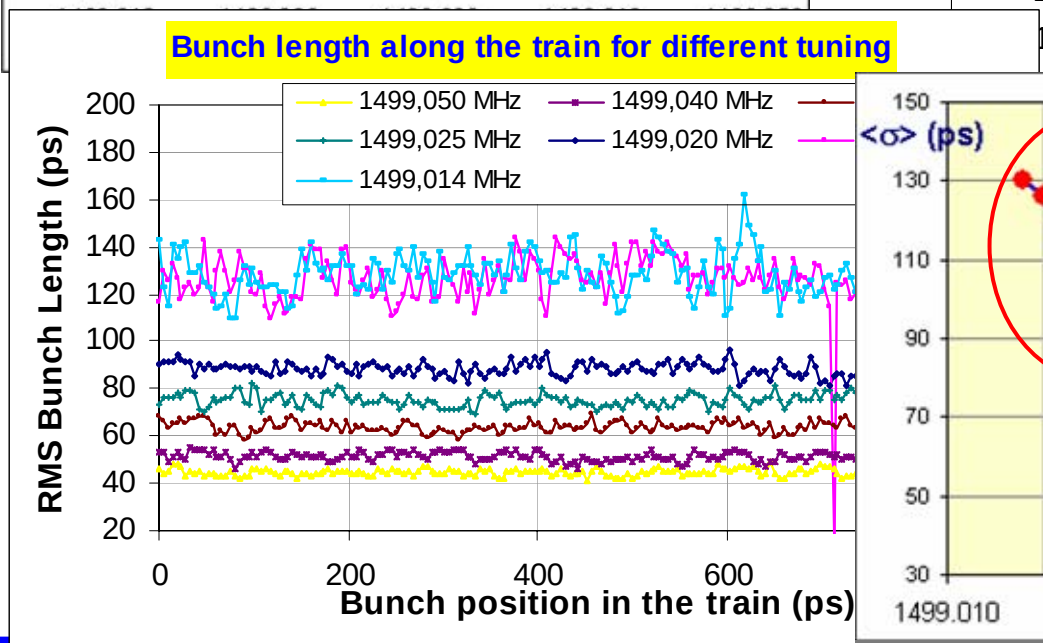


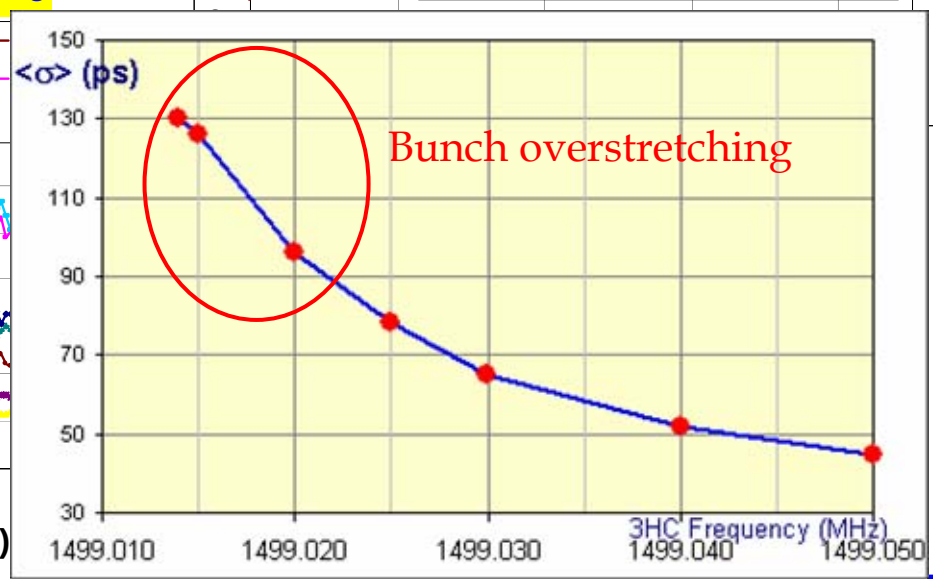
100% Filling: Phase Shift / Bunch Length / Landau / Lifetime



I_{beam}=315mA, Uniform Filling



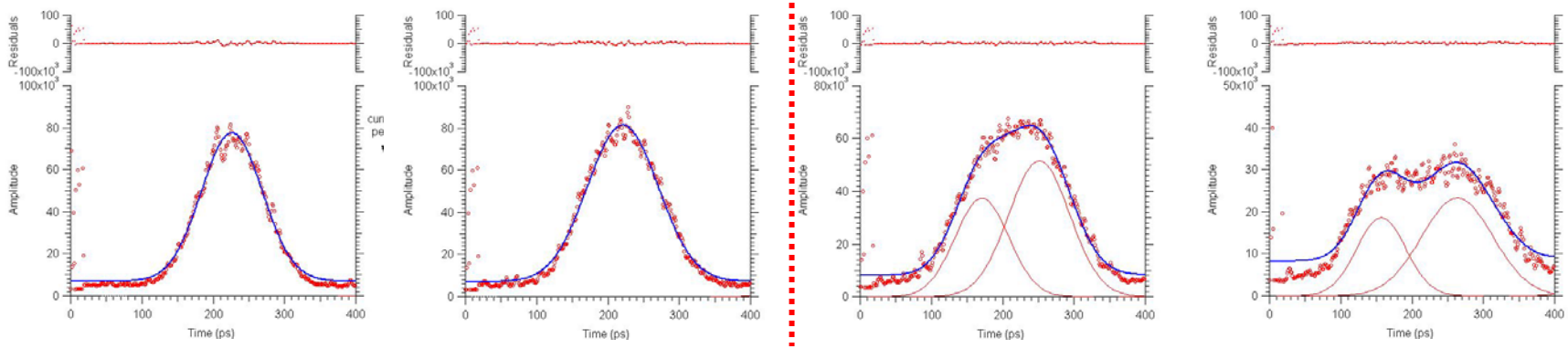




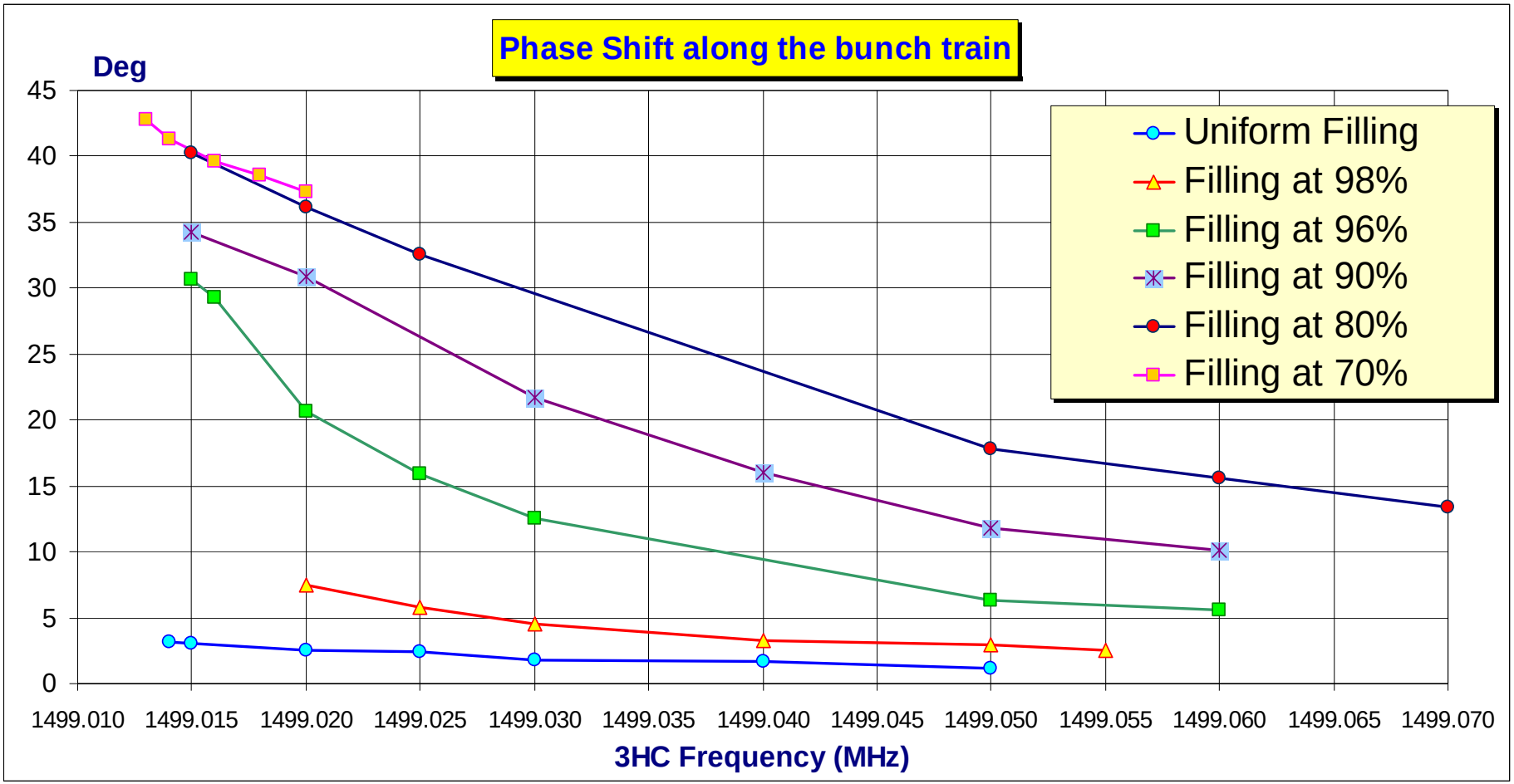
100% Filling: Phase Shift / Bunch Length / Landau / Lifetime

The ***Bunch Profile Averaged*** on the bunch train in the case of **Uniform Filling** is shown below for different tuning positions of 3HC. The "nominal tuning" of 3HC would be around +75 kHz. Beyond this postion the Bunch begins to show an ***overstreched*** profile. Beam Lifetime increases until the position of **+62 kHz**, which is the operating position. A few kHz beyond that, lifetime starts to decay to a few hours; further the beam is lost.

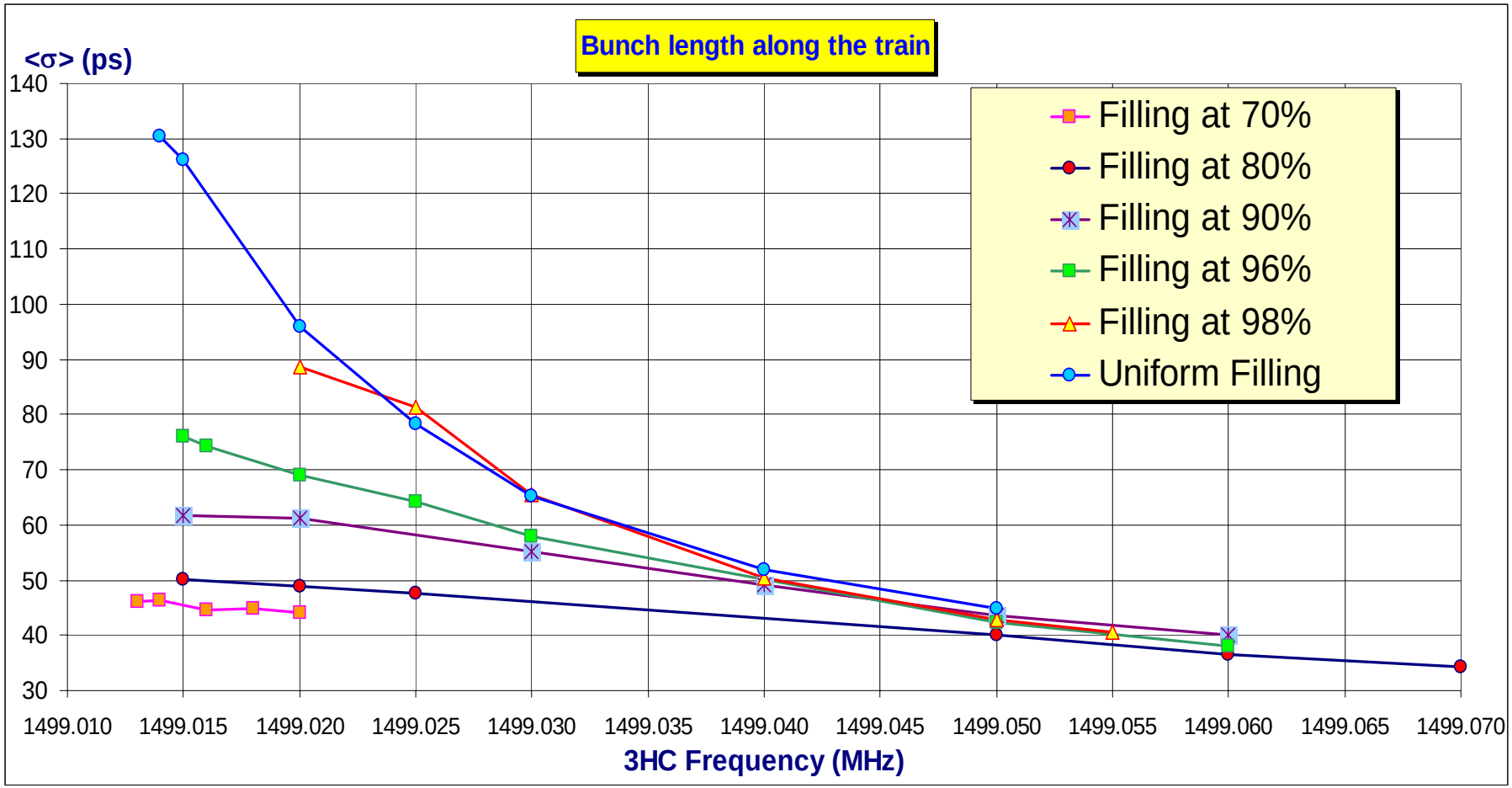
$\Delta f = +92$ kHz → $\Delta f = +82$ kHz → $\Delta f = +72$ kHz → $\Delta f = +62$ kHz



Various Fillings: Phase Shift / Bunch Length / Landau / Lifetime



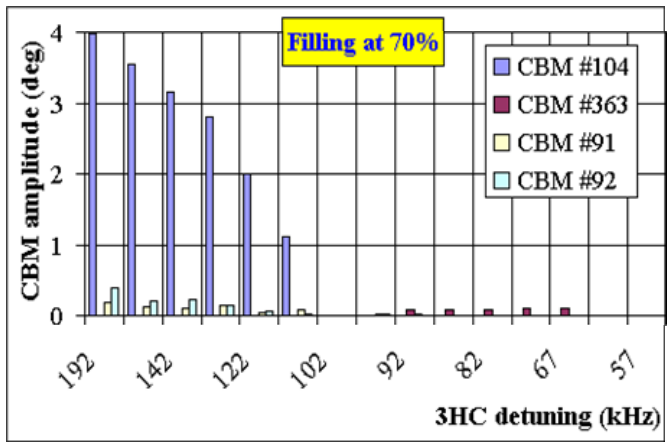
Various Fillings: Phase Shift / Bunch Length / Landau / Lifetime

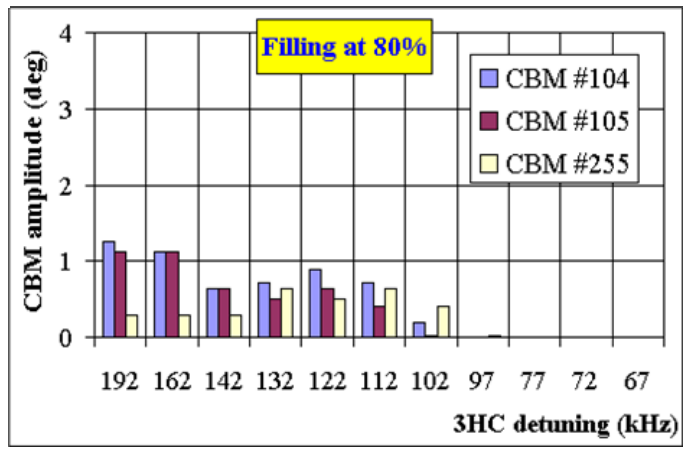


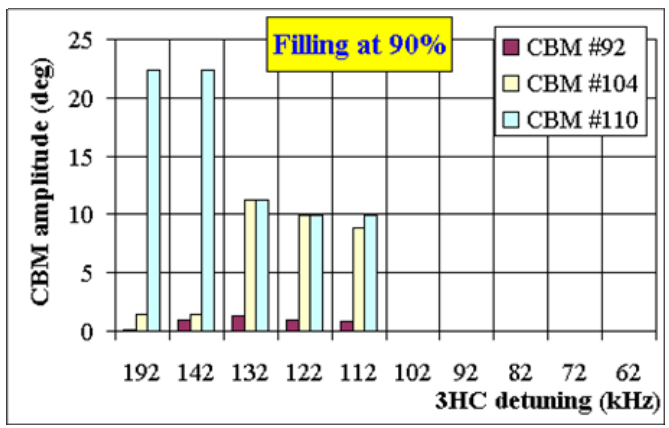
Various Fillings: Phase Shift / Bunch Length / Landau / Lifetime

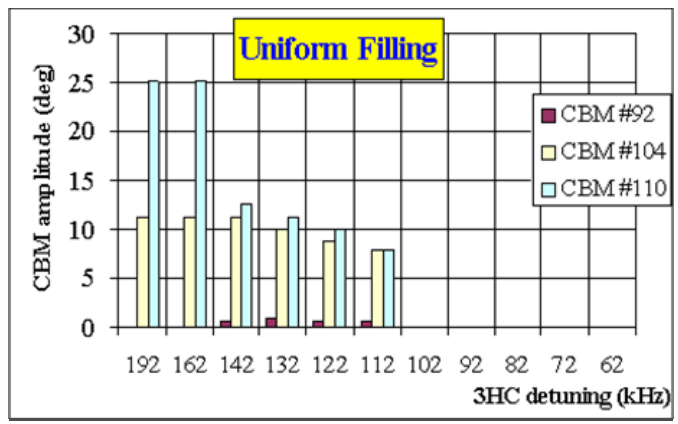
The Landau damping seems to be influenced by the different contribution of the increasing gap width and of the average bunch length, which is reduced as the gap increases.

Scale is different!









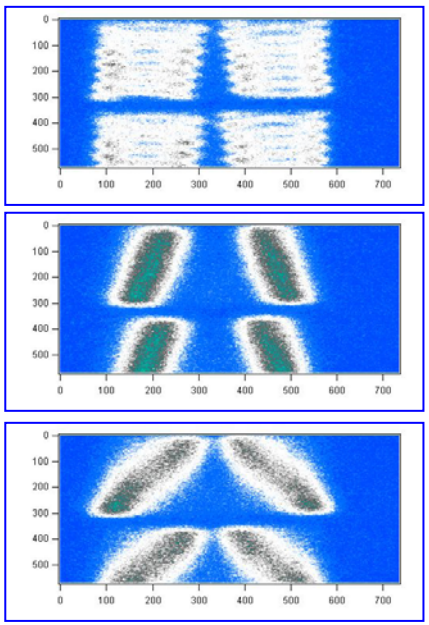
Various Fillings: Phase Shift / Bunch Length / Landau / Lifetime

These strak camera images show the different effect of 3HC on the beam between 90% filling (on the left) and uniform filling (on the right). The Landau damping effect is similar in both cases, the 90% filling shows the expected effect of the phase modulation along th ebunch train.

Phase Modulation present.

Stronger Phase Modulation

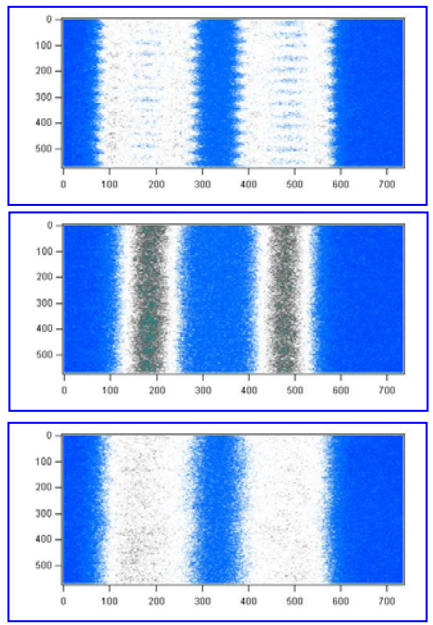
Bunches are longer in the train centre.



Δf= +112 kHz

Δf= +92 kHz

Δf= +62 kHz



Longitudinal **UNSTABLE** Beam

Longitudinal **STABLE** Beam

Bunch Length is Uniform

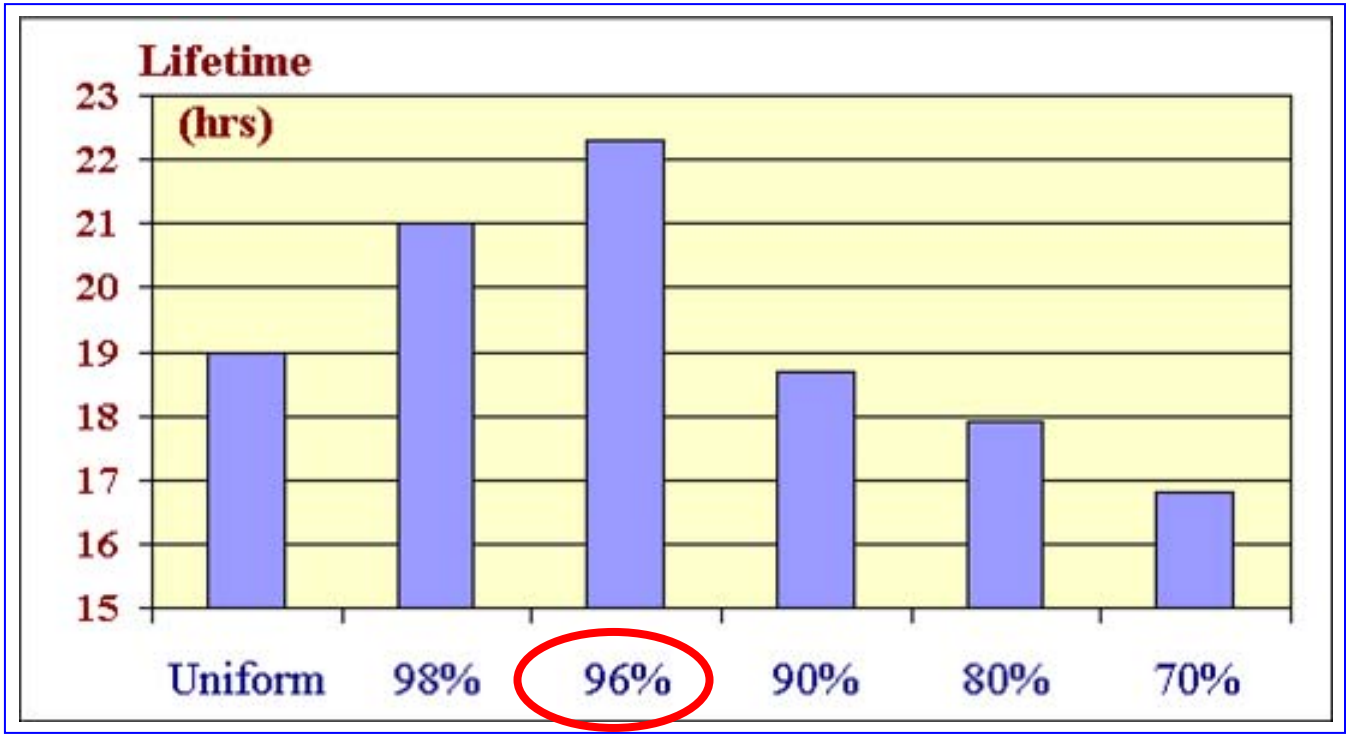
90% Filling

Uniform Filling

Various Fillings: Phase Shift / Bunch Length / Landau / Lifetime

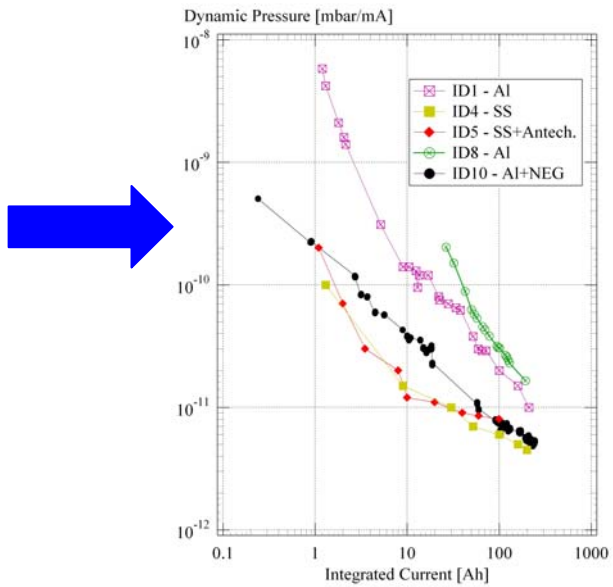
The best performance in terms of lifetime is obtained with a fractional filling of 96%. By further increasing the filling, the maximum obtained lifetime is lower, suggesting that the optimum setting for ELETTRA requires a small amount of “empty gap”.

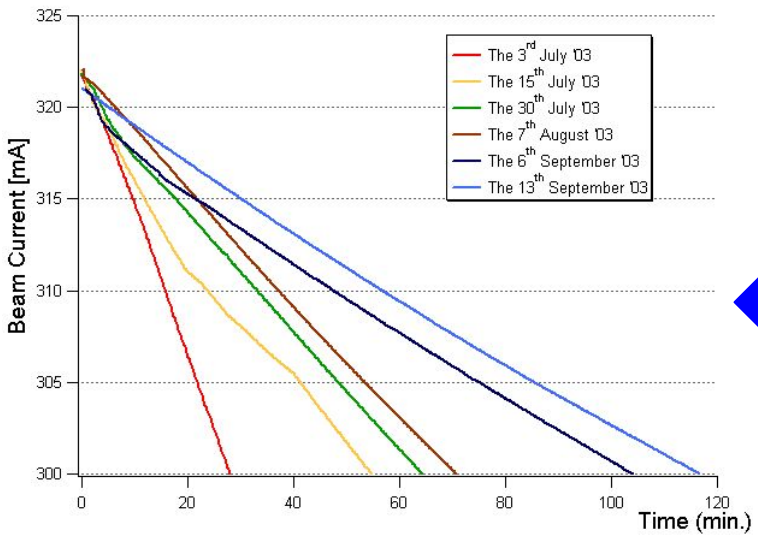
The **96% filling** is now taken as the **new standard filling pattern** for User’s Operation Mode (320mA, 2.0GeV). In this condition 3HC is usually tuned from 1499.050 MHz (Δf=92kHz) to 1499.020MHz (Δf=62kHz).



Machine Upgrades and Ultimate Lifetime Value

During 2003 and 2004 several new vacuum chamber installations were performed. In June 2003 a new **Aluminum-NEG coated** chamber was installed in section **ID10**. In pre-3HC conditions the nominal lifetime was recovered at a dynamic pressure of about 10^{-11} mbar/mA. In the example of the **ID10 chamber** this took about 70 Ah, i.e. about **2,5 weeks operation**.





In fact the ultimate lifetime with 3HC active, i.e. about **27 hours at 2.0 GeV 320 mA**, was reached mid of September 2003, that is about **6 weeks of operation** after the **ID10 installation** (there were 2 weeks shutdown in August).

Conclusions

- 3HC routinely in operation at Elettra
- Stable Beam, refill every 36 hours
- Operability and Reliability good
- Careful maintenance to prevent faults, recovery time can be long!
- Experiments at different fillings confirm expected effects (phase modulation, bunch lengthening)
- New standard filling set to 96%