3rd HARMONIC SYSTEM OF THE SLS STORAGE RING

FIRST RESULTS

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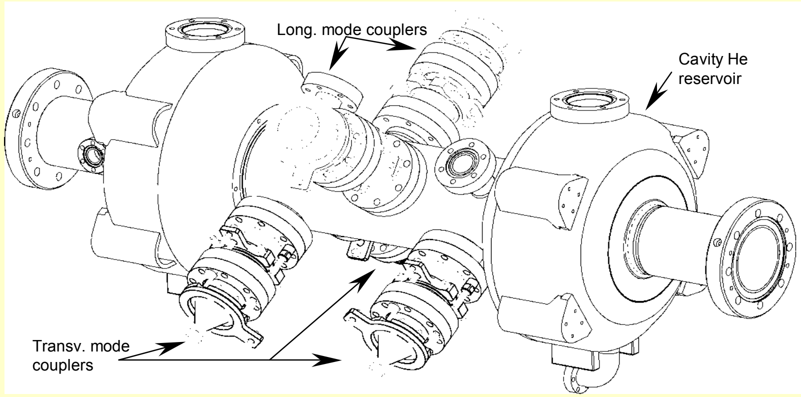
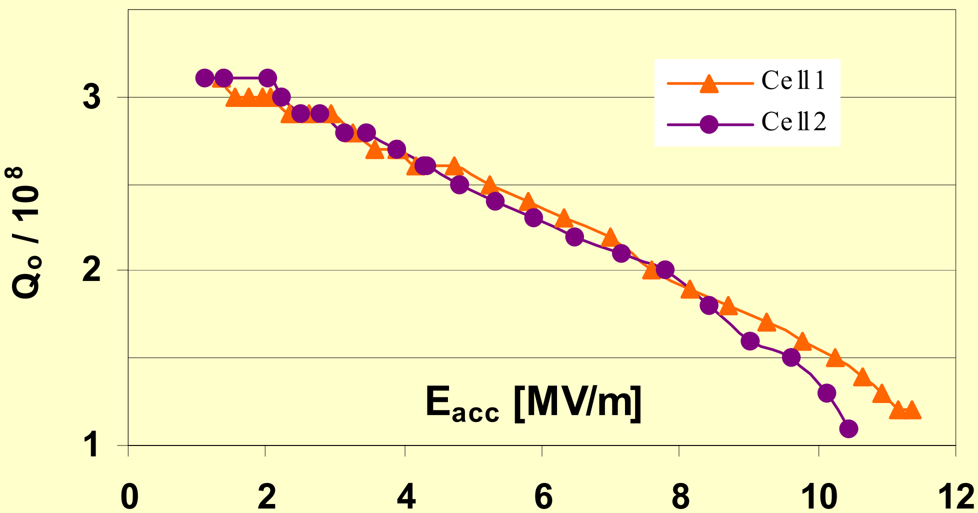
INTRODUCTION

- In SLS, the beam lifetime is dominated by Touschek scattering
- The 3rd harmonic (1.5 GHz) RF system allows:
  - ↳ bunch lengthening → decrease of charge density
  - ↳ increase of beam lifetime (~ factor 3)
- Use of an idle (only beam-powered) superconducting (sc) cavity
- "Scaling" of the 350 MHz sc cavity developed at Saclay for SOLEIL
  - ➢ 2 Nb/Cu cells (4.5 K)
  - ➢ 6 coaxial HOM couplers (2 long. and 4 transv.)
- SUPER 3HC Project: CEA-Saclay, PSI, Sincrotrone Trieste and CERN
  - ↳ production of 2 cryomodules (1 for SLS, 1 for ELETTRA)

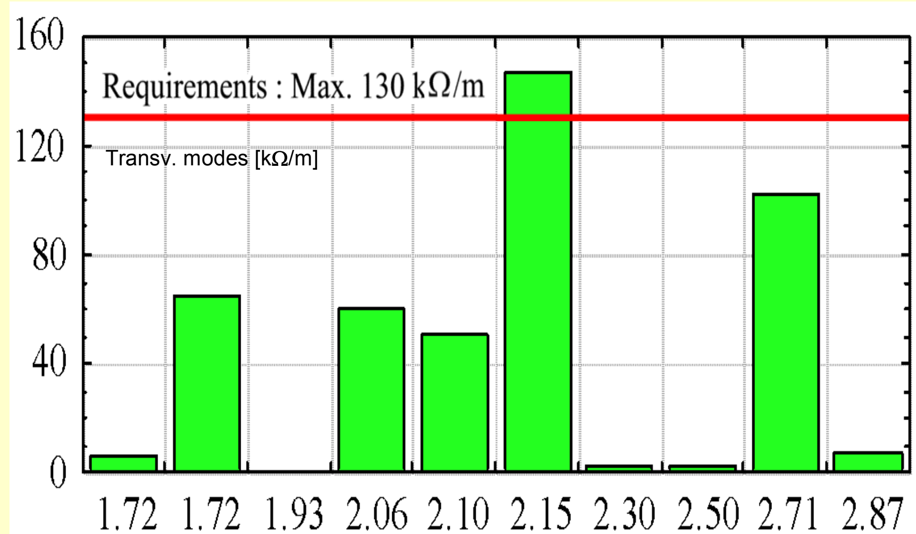


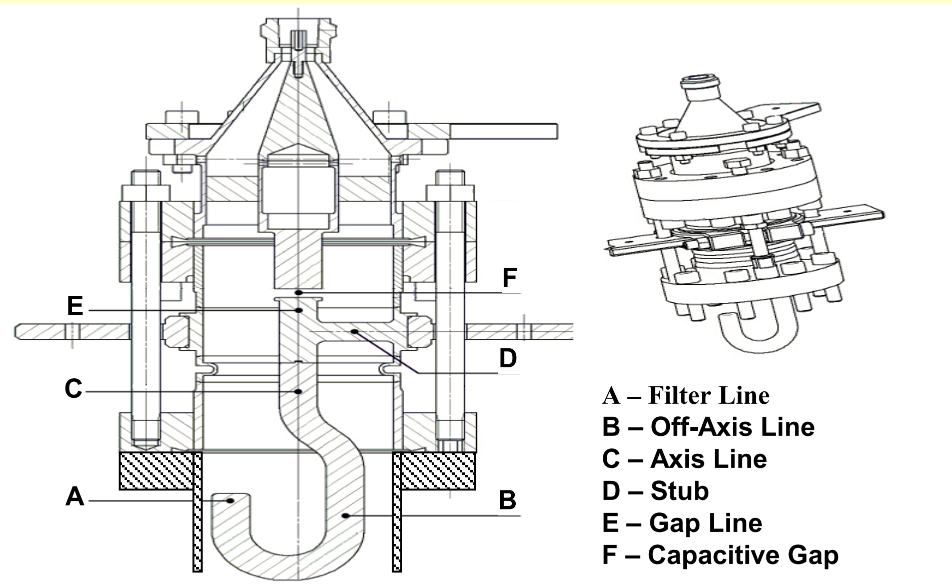
View of the 2 Cell cavity module


Complete cryo-module before installation at the SLS

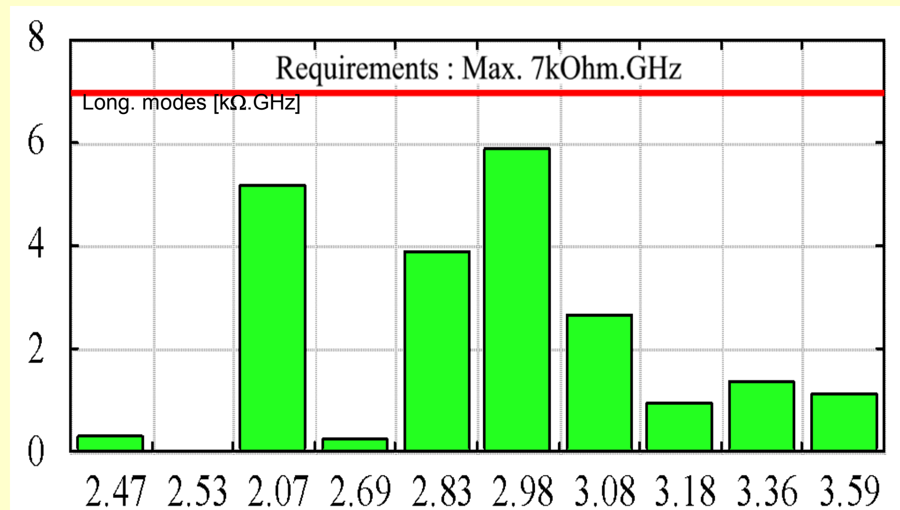


Measured Q_o (at 4.5 K) vs. field for the 2 cells.





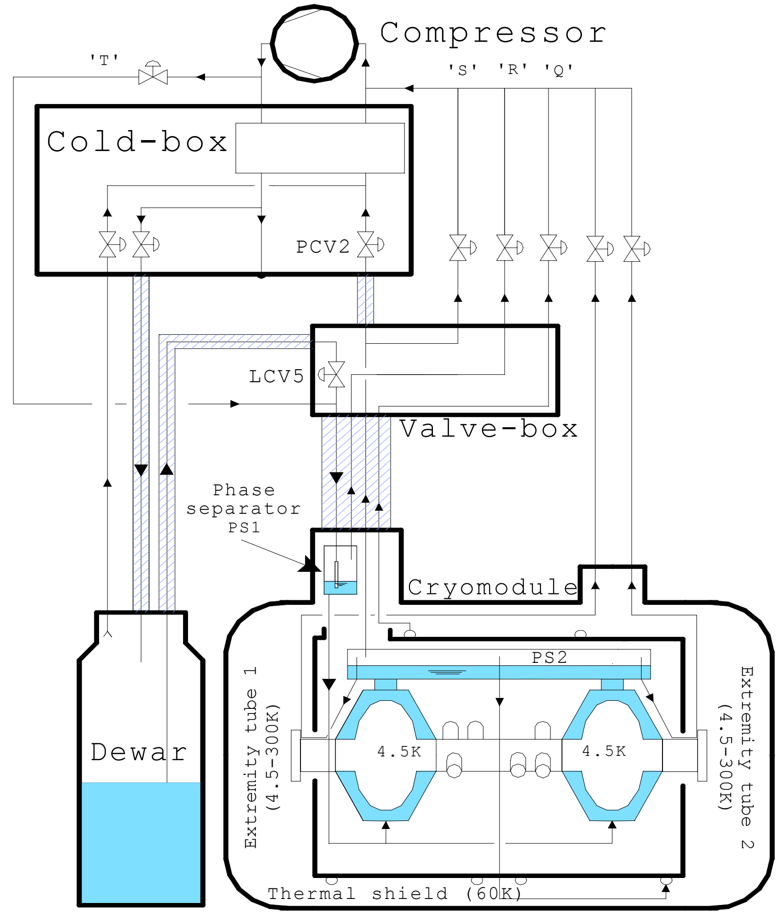
HOM coupler



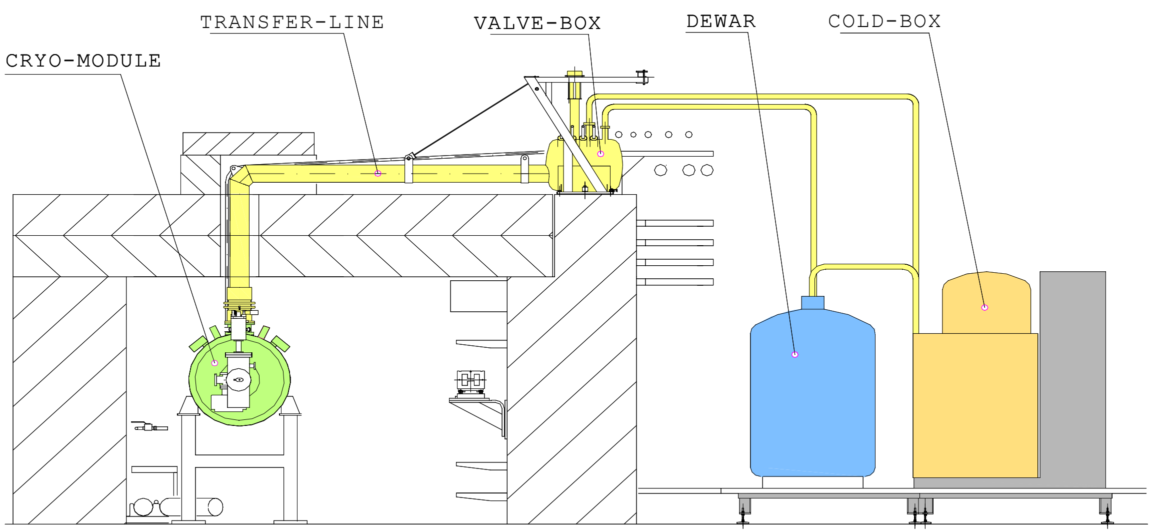
Measured HOM Impedance vs. frequency

CRYOGENIC SYSTEM DESCRIPTION

- LHe from Dewar enters the cryomodule through phase separator PS1
- The 2 cavity tanks are filled with LHe at 4.5 K from the bottom
- On top, common vessel (PS2) recuperates the cold GHe
  - → part returned to cold-box
  - → part used to cool the copper thermal shield (60K)
  - → part used to cool the 2 extremity tubes (4.5-300K)
- Inner tube and HOM couplers cooled by conduction
- Layers of super-insulation on the shield
- Line “T” (inlet) and “S” (outlet) for “warm” GHe circulation in case of “warm operation” of the cryomodule (cryo-source failure, for instance)
- Line “T” also used to mix GHe with LHe (temperature control of the incoming fluid during cooldown)



Scheme of the complete cryogenic system



Layout in the SLS building

- Compressor and oil removal system located in a dedicated hutch outside.
- 6 m^3 GHe buffer outdoor
- Gas recovery → existing PSI system

Cryogenic requirements

Component	Load	Comments
2 RF cells	22 W	Directly in LHe bath
2 L – couplers	3 W	Cooled by conduction
4 T – couplers	8.5 W	Cooled by conduction
2 Extremity tubes	0.2 W	With 2 x 0.05 g/s cold GHe
Cryomodule static losses	5.1 W	With 0.071 g/s cold GHe in thermal shield (60 K)
Transfer-lines	6.5 W	Assuming 0.5 W/m load
Total refrigeration power at 4.5 K: 45.3 W		
Total GHe flow: 0.171 g/s → 5.2 l/h of liquefaction duty		

Estimated cryogenic load @ 4 MV/m, 400 mA and Q=2 10^8

Cryogenic source

Helial 1000 refrigerator/liquefier from ***Air Liquide***, designed for 7.5 l/h liquefaction and 65 W of refrigeration at 4.5 K (mixed mode) that is about 50 % more than the anticipated requirement.

Measured max power 160W

***Air Liquide* supply:**

- Screw compressor with oil removal system
- Turbine-based-cold-box
- Control command system
- 500 Liter dewar
- Cryogenic transfer lines (including valve-box)

PROJECT MAILSTONES

- Fabrication and cold tests of the "bare" cavity completed in October 2001 at CERN (at 4MV/m, Q_o was about 2.6 10^8 for both cells)
- Tests of the complete cryomodule at Saclay (April 2002) confirmed the previous results
- Cryogenic source installation in the SLS starting May 2002.
- Cryomodule installed in the SLS ring, June 2002.
- "Warm operation" with beam at 200 mA starting June 17, 2002
- Cryogenic source commissioning on dewar July, 2002
- Cavity cooldown September 23-27, 2002.
- "Cold operation" with beam starting September 30, 2002
- Monday September 2002, 400 mA stable operation with cold cavity (voltage harmonic system 750 KV)

SLS OPERATION WITH 3rd HARMONIC - FIRST RESULTS SUMMARY

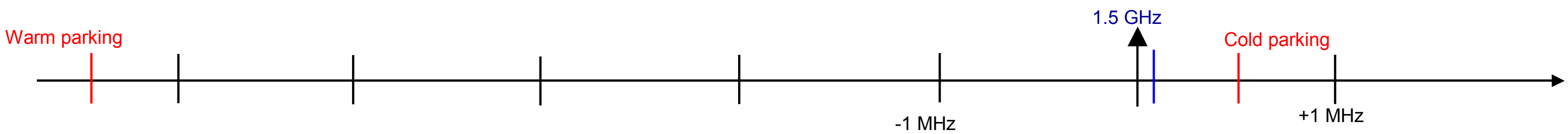
WARM OPERATION (cavity cooling with air or Ghe).

With parked cavity, stable operation up to 200 mA.

At higher I overheating of the cavity and excitation of the long. Coupled Bunch Modes (CBM):

#430 - generated probably by an High Order Mode of the normal conducting cavity system.

#474 - generated by the fundamental mode of the warm 3rd harmonic cavity.



COLD OPERATION (4.5K)

- With parked cavity, stable operation up to 200 mA
- At higher current excitation of the longitudinal CBM:

#430 - generated probably by HOM's of the normal conducting cavity system.

- With tuned cavity, stable operation at to 400 mA.

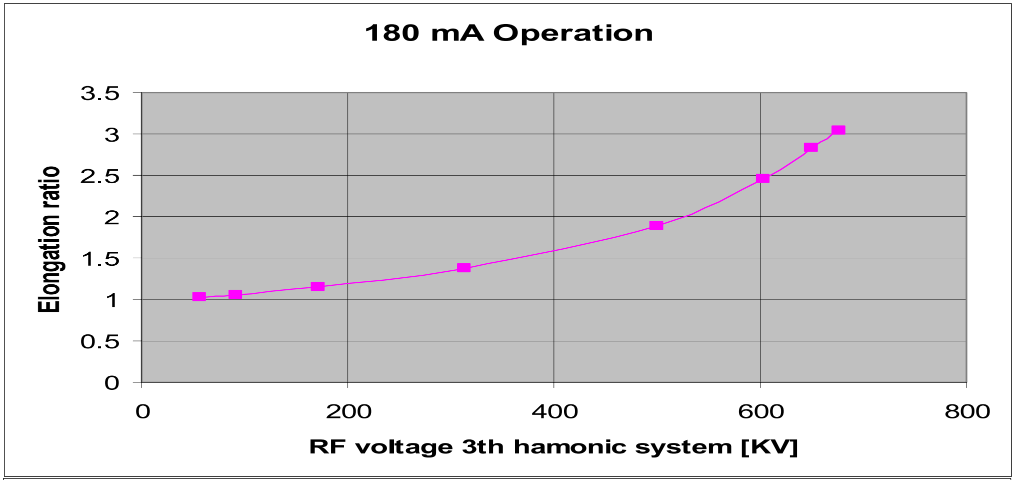
3rd harmonic system global voltage ~750 KV - normal conducting system global voltage 2.1 MV

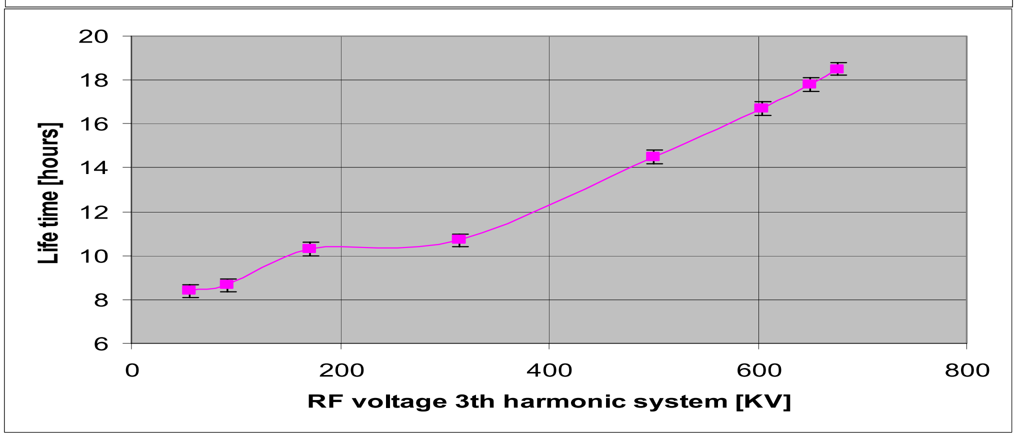
-The additional Landau dumping from the harmonic system suppress the longitudinal CBM.

- Since October 1st, user operation at 300 mA with tuned cavity.

Amplitude loop disabled, tune adjusted for max lengthening at 400 mA. 3rd harmonic system global voltage at 300 mA ~550 KV - normal conducting system global voltage 2.1MV

First life time and bunch lengthening measurements





For I=180 mA:

Bunch lengthening of a factor of 3.

life time improved by a factor 2.2.

Vacuum scattering could still partially decrease the life time, and additional measurements are needed.

For I=300 mA:
beam longitudinally unstable for 3rd harmonic system voltage below 480 kV (main system 2.1 MV)

For I=50 mA:
beam max voltage in 3rd harmonic system ~290 KV with a detuning of ~20kHz. For lower detuning beam lost due to over voltage in the 3rd harmonic system (resonance with harmonic of the synchrotron frequency)

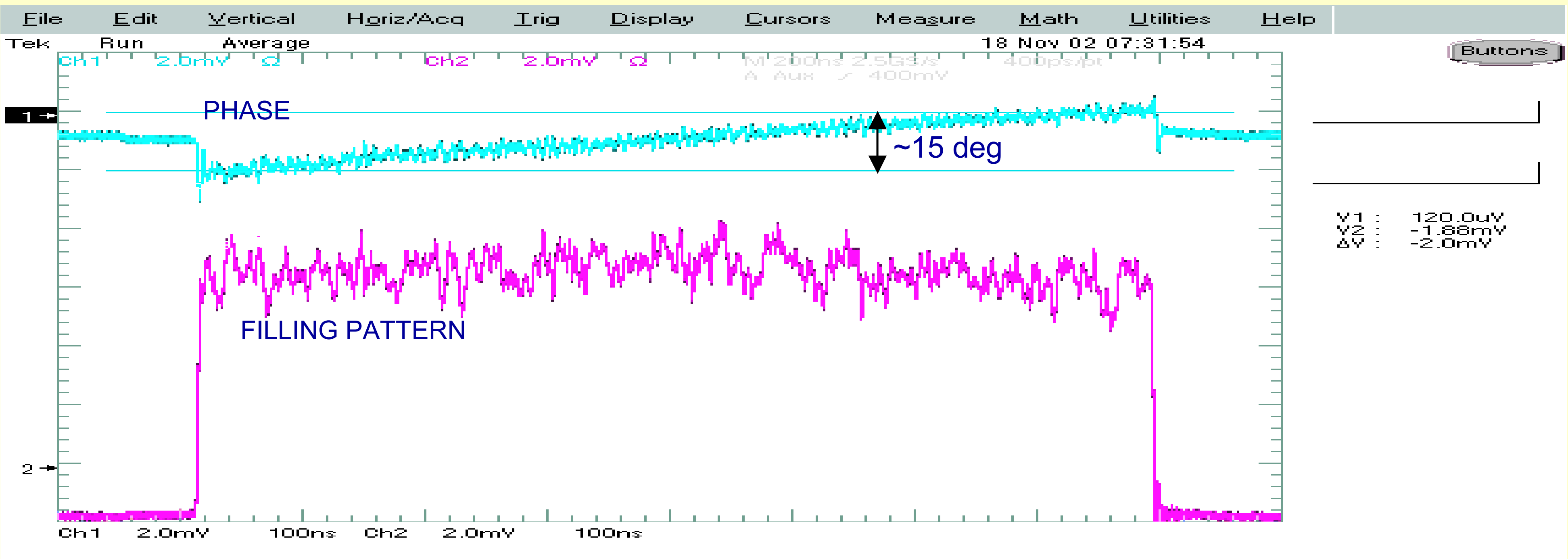
300 mA - 20% GAP FILLING PATTERN AND BUNCH PHASE ALONG THE TRAIN

3rd harmonic F_3 = 1498.957365 MHz

Cavity Tune: Δf = 72 kHz

3rd harmonic Voltage: $V_{sc} = R/Q * I * F_3/\Delta f$ = 552 KV

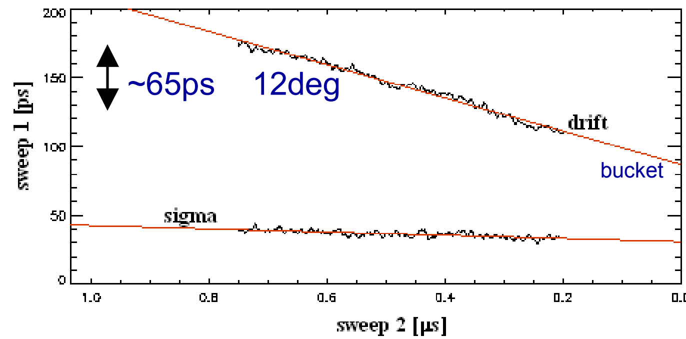
Main accelerating voltage: V_{nc} = 2.08 MV

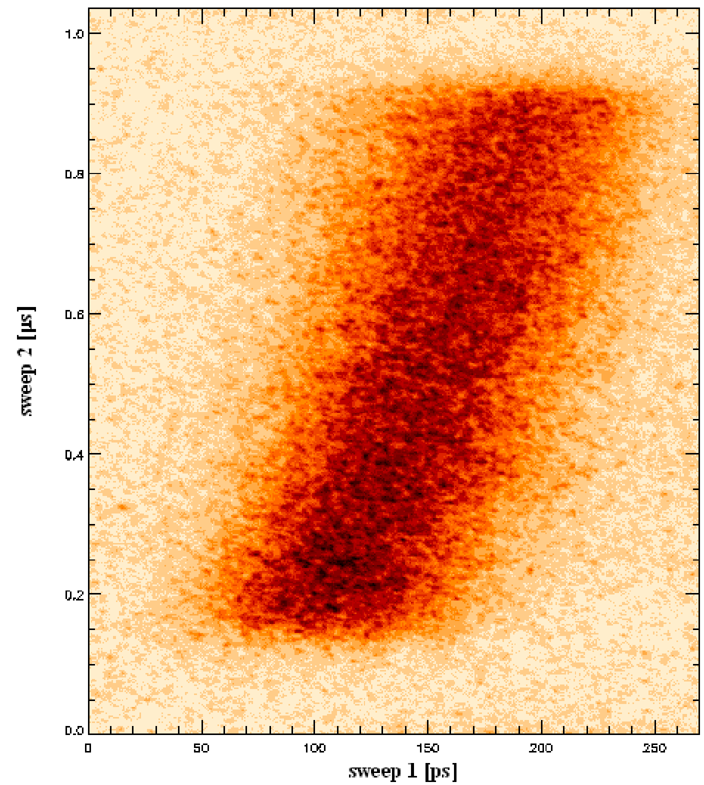


At 300 mA, beam longitudinally unstable for 3rd harmonic system voltage below 480 kV (main system 2.08 MV)

FIRST STREAK CAMERA MEASUREMENT OF THE BUNCH LENGTH AT 300 mA

Sigma = 36.3 ps (Expected theory without Harmonic system ~13 ps)
Drift = 240 fs/bucket





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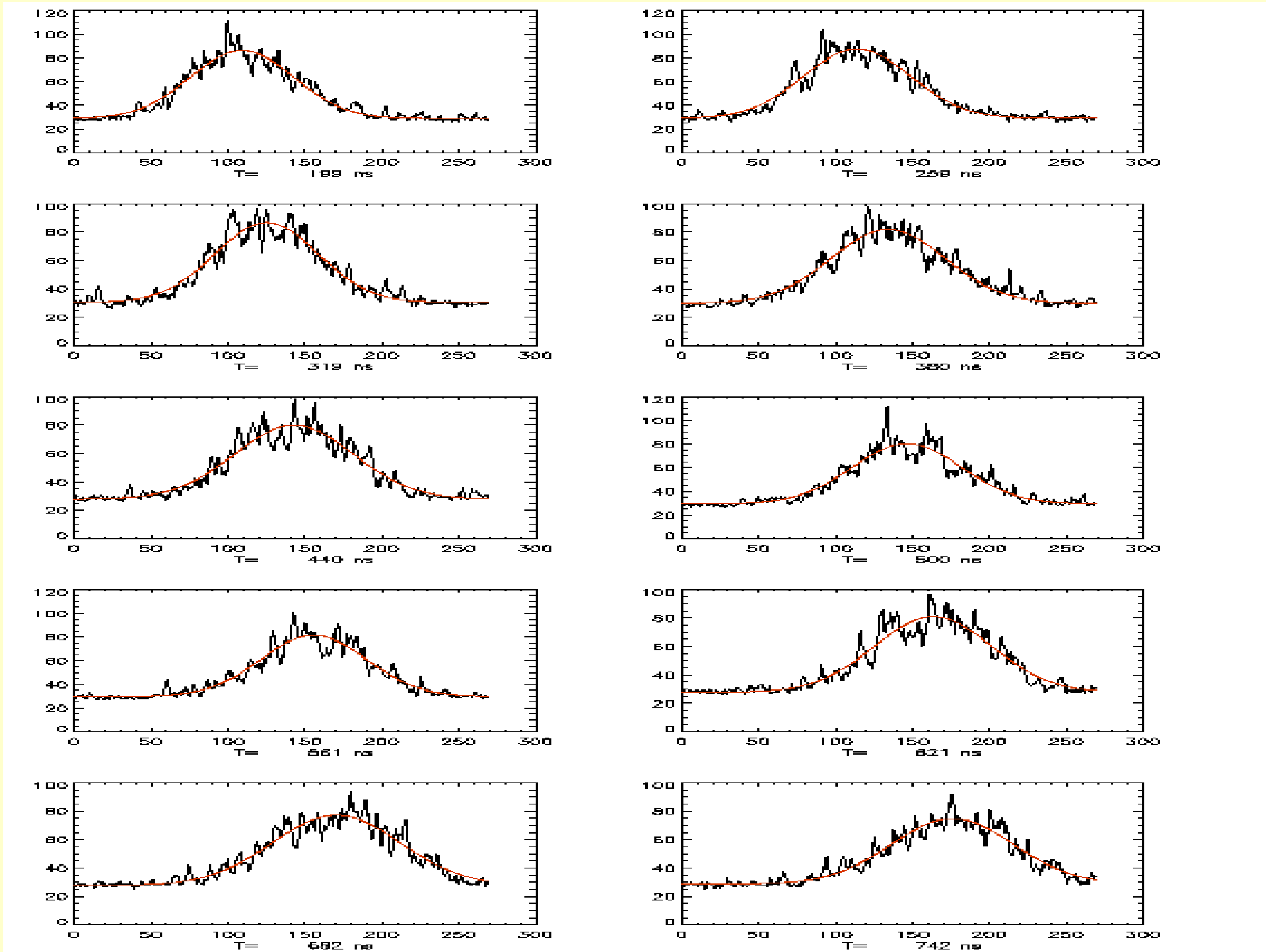
Main accelerating voltage: V_{nc} = 2.08 MV

Synchrotron frequency: 2.79 KHz **(detuned 6.25 KHz)**

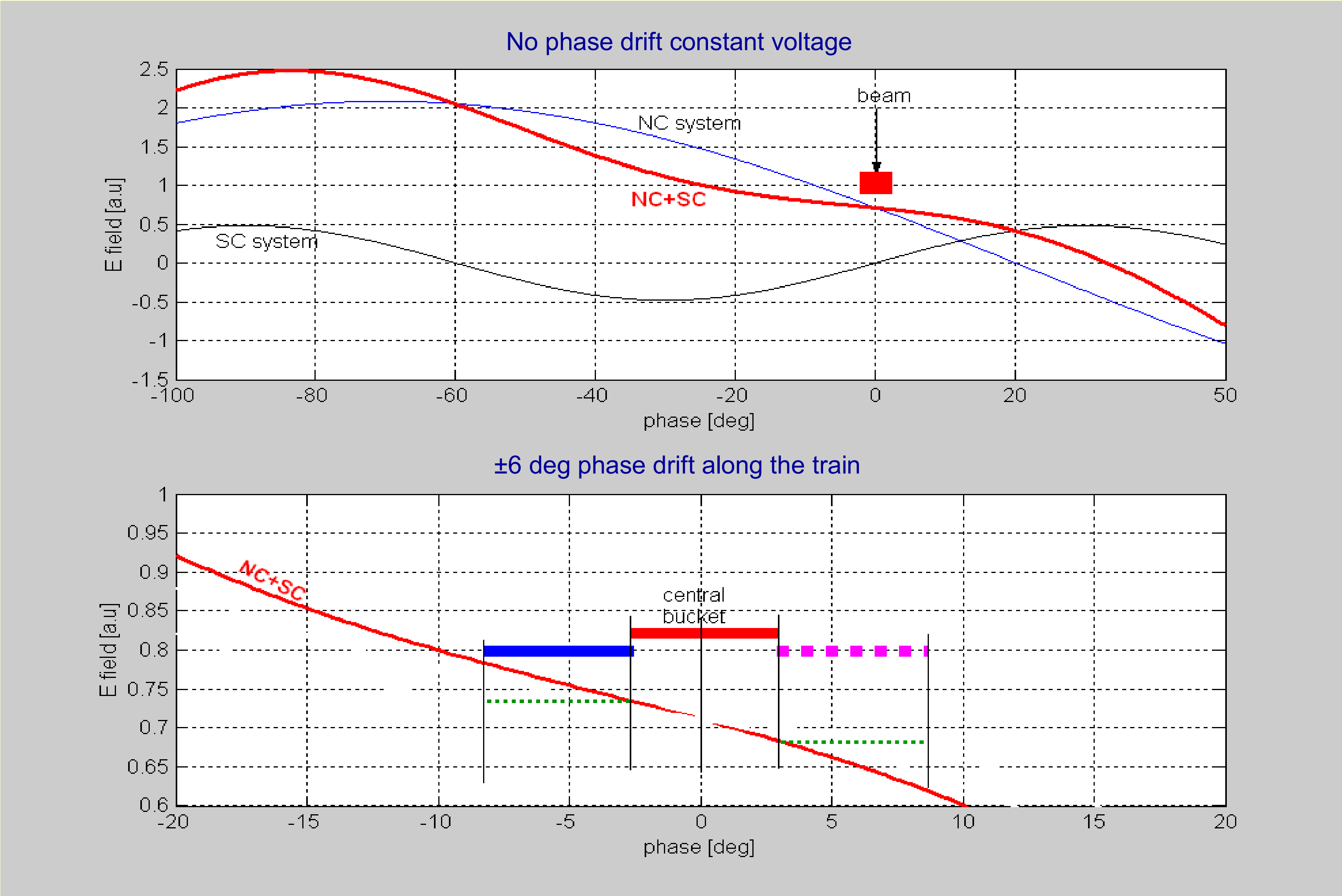
➨ elongation: 2.24

300 mA - Bunch shape along the bunch train



No significant deformation observed

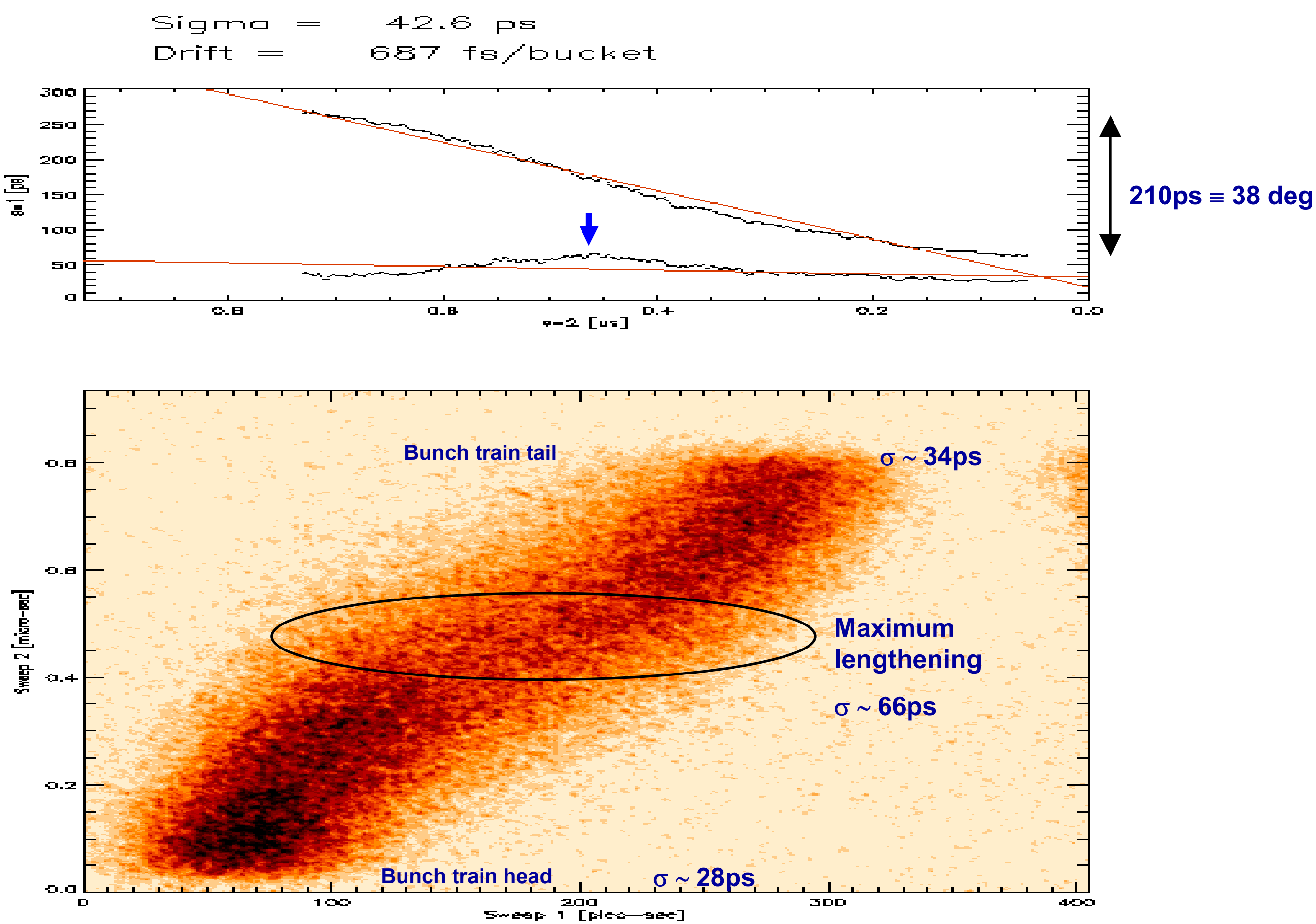
300 mA operation - Global voltage seen by the beam



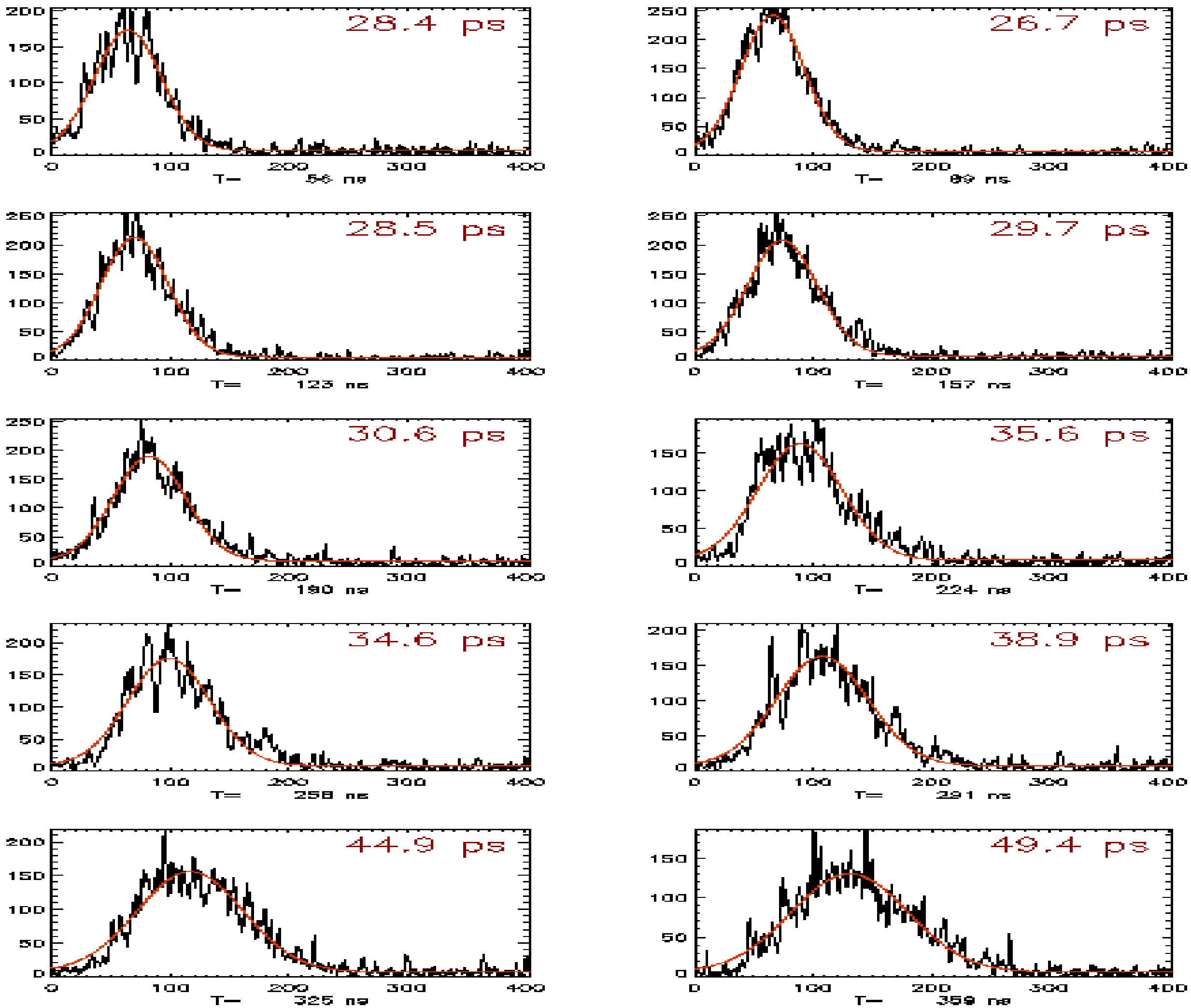
BUCKET PHASE DRIFT ⇨ At equilibrium no INCREASED ENERGY SPREAD measured.

320 mA operation

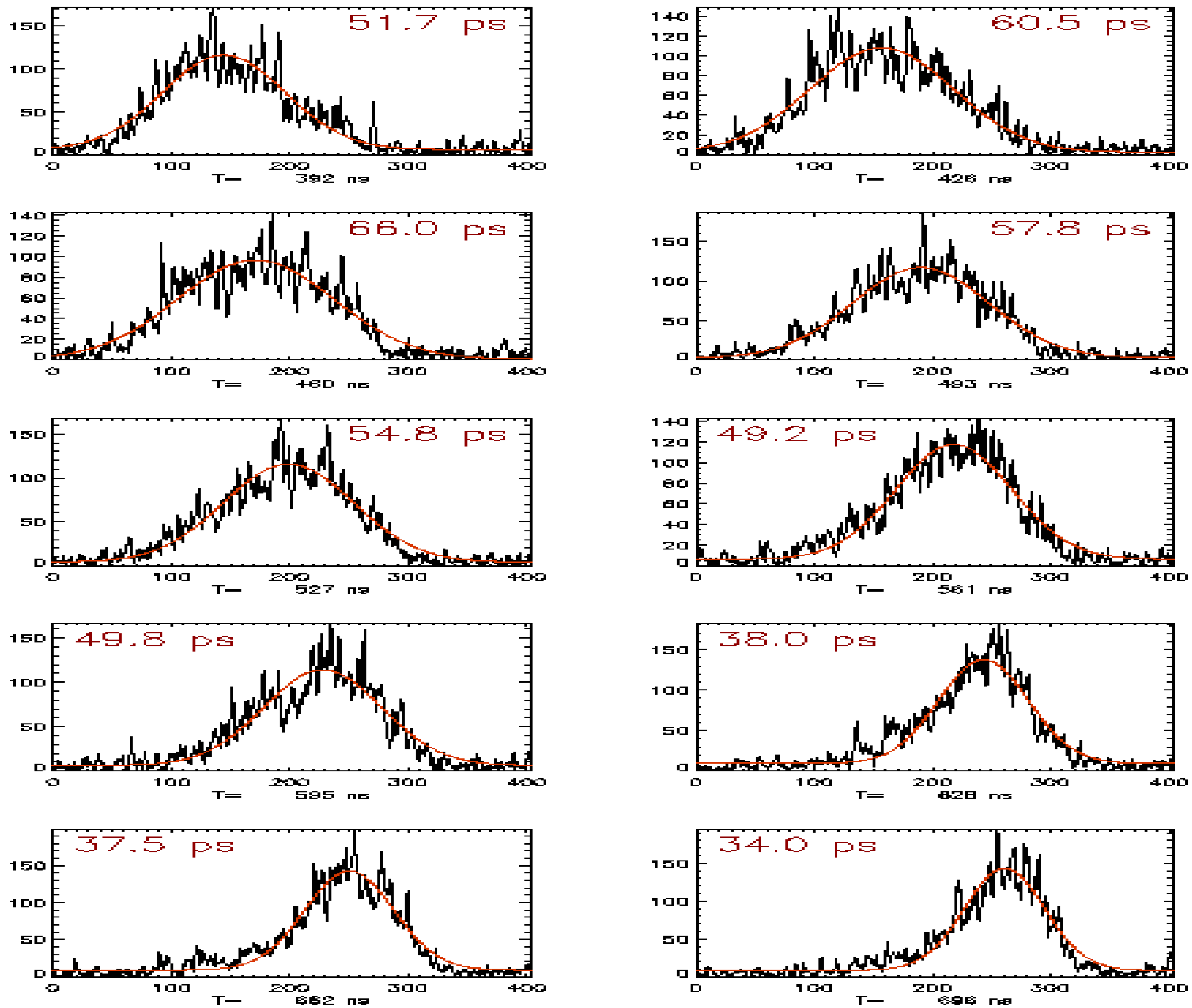
Train and bunch distortion at maximum lengthening



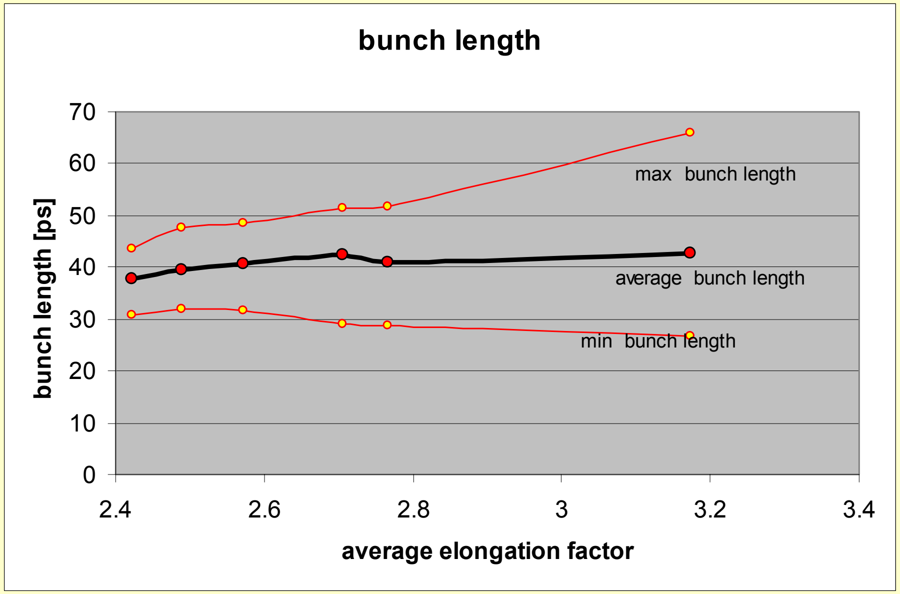
Bunch shape along the bunch train - 320 mA operation

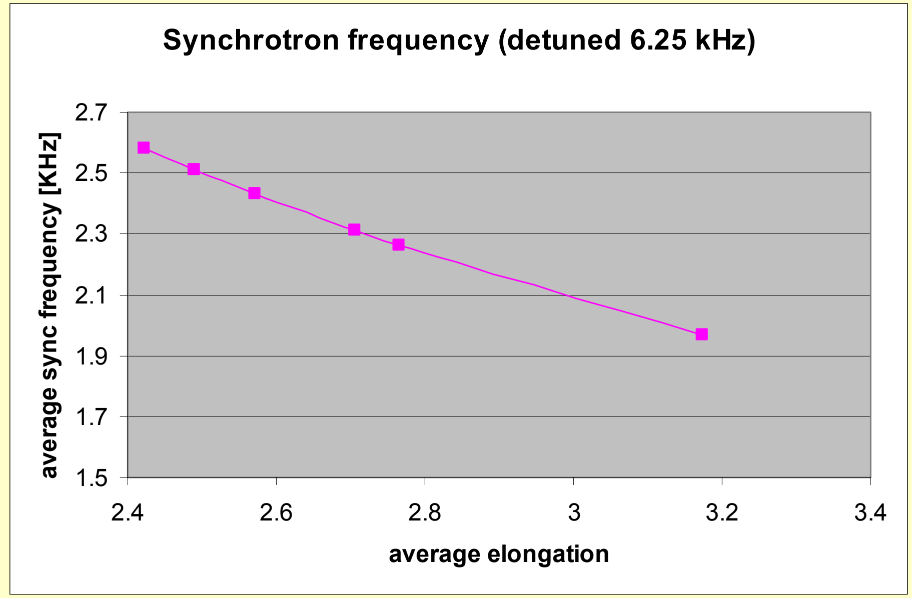


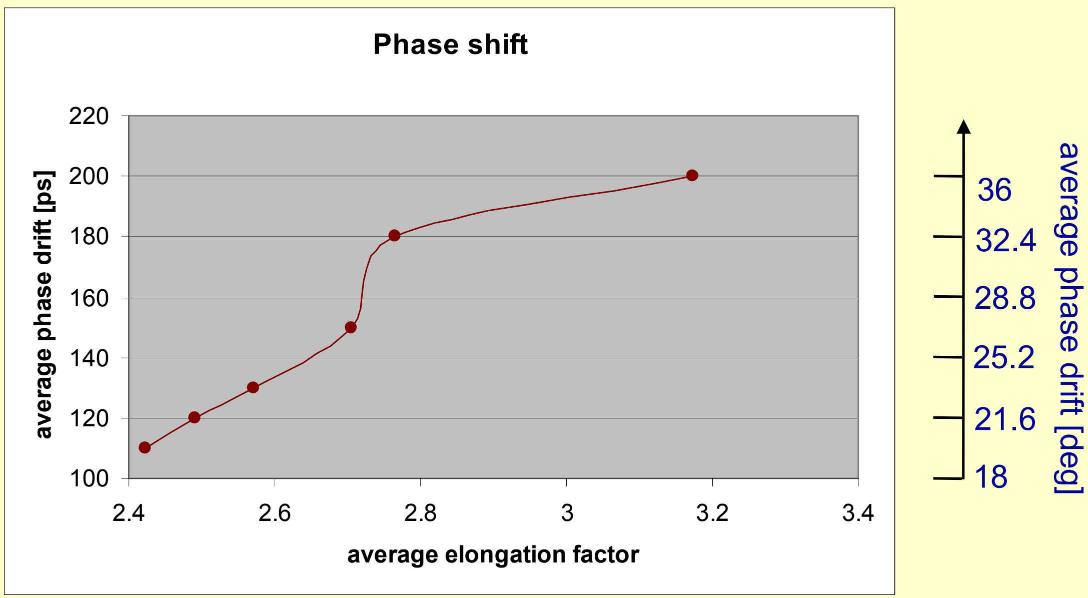
Bunch shape along the bunch train - 320 mA operation



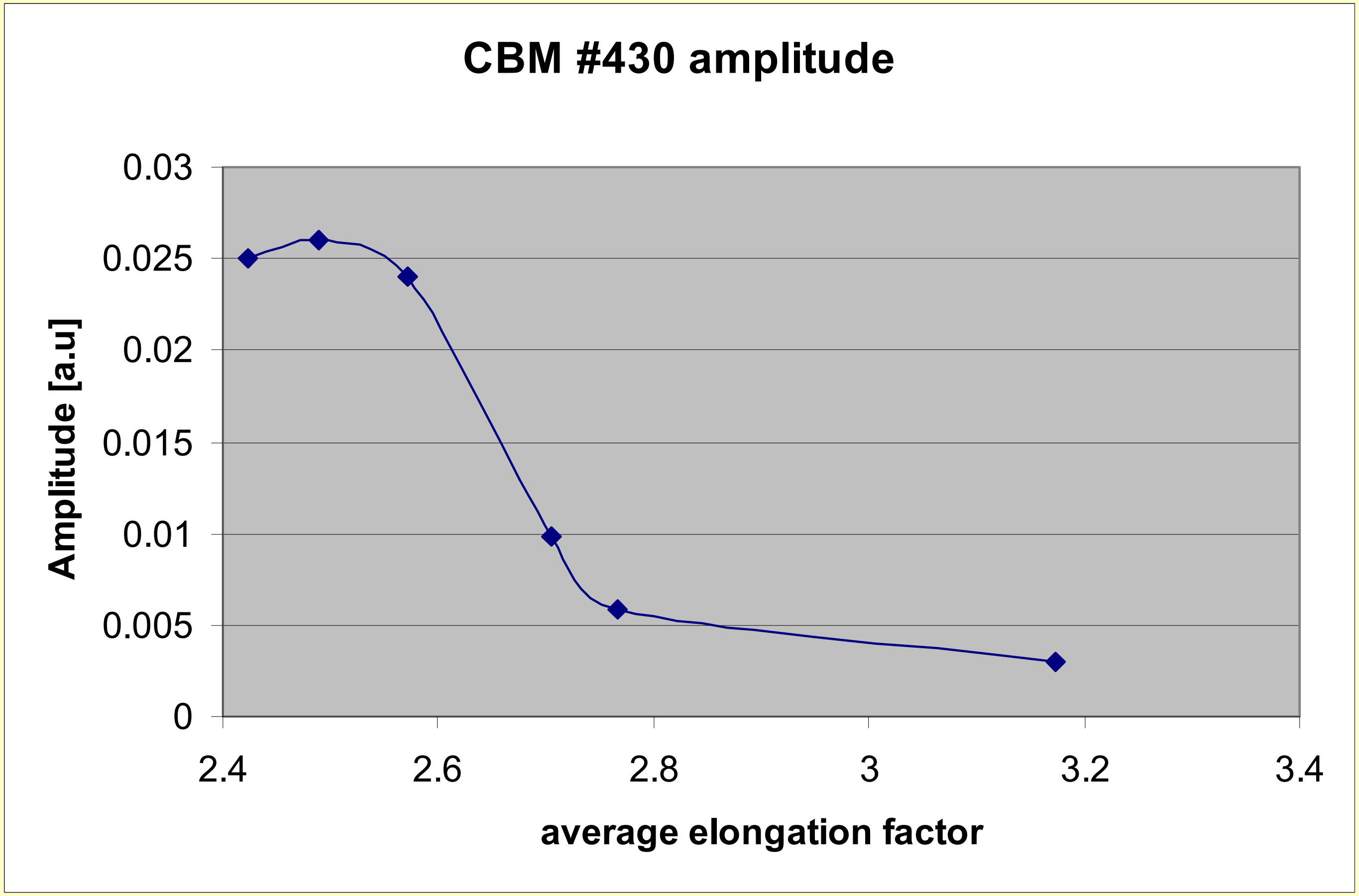
320 mA operation







Suppression of CBM #430 by increased Landau damping 320 mA operation



CONCLUSIONS

First demonstration of SR operation with super conducting Landau cavity

Warm operation

- Current limited at 200 mA in warm operation, due to cavity overheating (with cryostat isolation vacuum).

Cold operation

- Stable operation at 400 mA and maximum elongation demonstrated.
- Bucket elongation up to a factor of 3 with life time amelioration of a factor 2. 2.
- Increased Landau damping and suppression of CBM #430 demonstrated.
- 20% gap induces a dispersion in synchrotron frequency, bucket phase drift and voltage fluctuations.
-Stable user operation at 300 mA at reduced S3HC voltage.

Next steps

- Additional studies with uniform filling pattern (no gap).
- Check energy spread at high elongation.
- Additional test at currents below 100 mA.
- Reproduce stable 400mA operation.
- Check transverse instability threshold versus S3HC voltage.
- Check operation with tuning loop enabled.