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CTF3 Preliminary Phase Commissioning
Report on Fourth Week, 12-16 November 2001

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Abstract

In this note, we describe the beam studies done during the fourth week of commissioning of the Preliminary Phase of CTF3, from November 12th to November 16th 2001. Detailed studies were carried out in order to understand the beam energy fluctuations. Measurements with the streak camera were performed at the end of the linac and we observed a shorter bunch length than during the previous weeks. The beam was then sent in the transfer line HIE for dispersion measurements and transport optimisation. Eventually, the beam was injected in the straight section of the EPA ring where preliminary diagnostic checks were done.

Geneva, Switzerland
February 12, 2002

1 Goals

The primary goal of this week was to transport and study the beam in the injection line HIE. However, since the energy fluctuations were preventing us from performing precise measurements in the transfer line, some time was dedicated to study these variations. Unfortunately, no explanation was found by the end of the week. Additional beam studies in the linac allowed to transport the beam at 4 MeV up to WL.UMA29, and to refine the measurements done with WL.TCM37 at 330 MeV. During the last days, the beam was injected into the ring. Since all EPA magnets were switched off, the beam was lost after HR.UMA91, at the end of the straight line.

2 Start-Up

Some timing problems appeared during the start-up. First, the modulator MDK25 was not pulsing and we had to bypass the switch between 3 GHz and 19 MHz in order to make it pulse. Then, following a problem of timing jumps by one RF period, the electronics was changed: a counter of one RF period and a delay cable were suppressed. Since the timing was then moved by two RF periods with respect to the previous weeks, the gates for the instrumentation had to be adjusted again.

After the “deconsignation” of the power supplies, we checked the polarity of the magnets in the EPA ring although it was not foreseen to use the ring this week since the safety of the magnets still had to be checked by the hardware specialists. The results are detailed in the paper log-book.

Some instrumentation checks were again performed and we noticed the following points which were all addressed during the week:

- Horizontal and vertical planes were inverted in WL.WBS28.
- The signal range was still 5 mm instead of 10 mm in HIE.WBS21.
- The software of the SEM-Grid HIE.MSH23 had to be modified in order to give the right energy values according to the theoretical dispersion at this point.
- A bug was fixed in WL.MSH36: the software was displaying the first profile with inverted wires, resulting in a two-profile image in the case of very few acquisitions over one basic period. In the case of a larger number of acquisitions, this error was relatively small and the wrong profile was not visible anymore on the display.

The measurement scale on MDK25 was changed from high power range to low power range since we are working below 5 MW. The low power value read before on the high power range was significantly wrong. The value shown in the MDK-CTF3 parameter program has now to be scaled down by a factor 10 to reach the correct value of the output power in MDK25.

The modulator MDK27 was tripping very frequently during the first day of operation. On Tuesday, instabilities in the D’Quing system were found and the thyratron was changed. This lead to a more stable operation.

On Tuesday, some radiation measurements were performed by TIS people all along the linac at different energies. We intentionally lost the beam at various locations using the vertical dipoles while some measurements were taking place in the klystron gallery. Some data were also recorded when sending the beam into the beam dump HIP.

3 Dispersion Measurement in HIE

The dispersion measurement took place right after some radiation measurements for which it was necessary to put the modulator MDK31 on stand-by. As a result, in order to avoid setting-up the beam at a higher energy, we decided to start the dispersion measurement with MDK31 on stand-by and with a beam energy of 177 MeV (computed from the current in HIE.BSH00). We thus scaled all currents of the magnetic elements in the injection line and measured the position of the beam in the pick-up HIE.UMA23 as a function of the current (corresponding to a given energy). Figure 1 shows the recording of the horizontal, vertical and integrated signals from HIE.UMA23, as a function of time for various current settings. For each current setting, the fluctuations of the pick-up signal correspond to the energy variations. In the following, these variations are treated as tolerances on the measurement of the position. A more precise measurement must be possible in the absence of energy fluctuations.

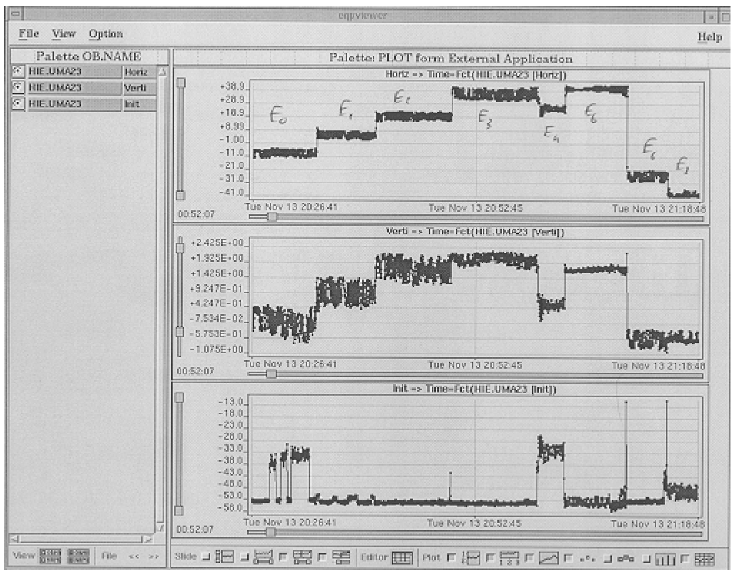

Figure 1: Signals in the pick-up HIE.UMA23 during the dispersion measurement in the injection line. Top: horizontal signal, middle: vertical signal, bottom: sum signal.

3.1 Horizontal dispersion

The values of the energies and the corresponding values of the beam position are summarised in Table 1. Figure 2 shows the corresponding points with the dispersion curve as given by MAD using the on-line model of the injection line and reading the AQN currents as inputs for the simulation. The shape of the dispersion curve fits the experimental data except for a large negative energy deviation. This discrepancy can be due to a saturation effect in the pick-up since a position of 40 mm with respect to the centre of the chamber is already quite large, as suggested also by the smaller spread observed on the pick-up signal (see right-hand side of Figure 2, top graph).

3.2 Vertical dispersion

Table 1 and Figure 3 summarise the results for the vertical plane. For positive energy deviations, the behaviour of the simulation seems to be close to the measurements, whereas for large negative energy error, there is again a difference between the measurements and the simulation. Even though the values of the beam displacement are small in this plane, the saturation in the horizontal plane could result in wrong vertical values.

Energy [MeV]	Horizontal Beam Position Min/Max [mm]	Vertical Beam Position Min/Max [mm]
162.5	38.9 / 42.9	1.71 / 1.81
166.0	33.5 / 40.0	1.87 / 2.20
169.5	17.3 / 22.3	1.50 / 2.10
173.1	2.5 / 7.6	0.53 / 1.32
176.6	-11 / -6	-0.38 / 0.32
180.1	-28.5 / -22	-0.80 / -0.30
183.7	-40.5 / -37	-0.68 / -0.38

Table 1: Horizontal and vertical beam positions recorded in HIE.UMA23 for various energies in the injection line.

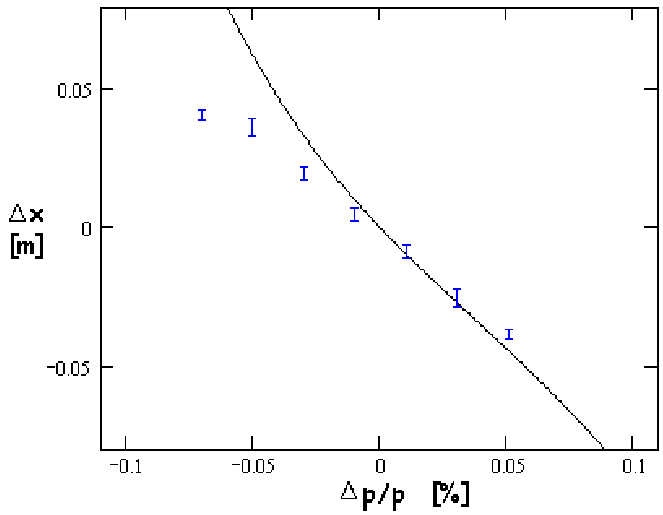

Figure 2: Measured and simulated dispersion at HIE.UMA23 (horizontal plane).

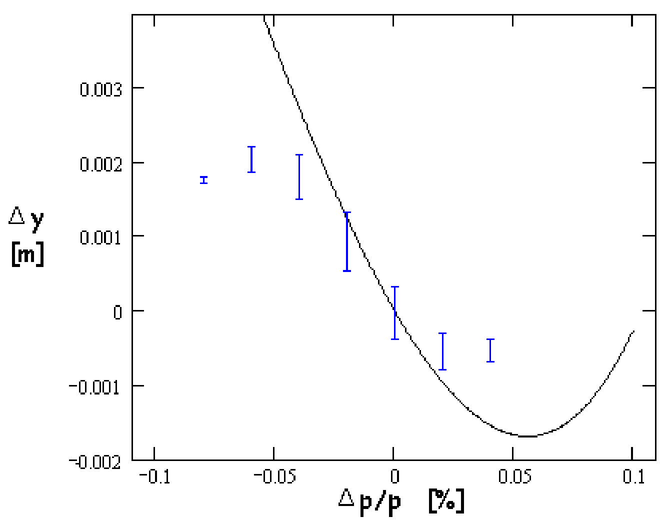

Figure 3: Measured and simulated dispersion at HIE.UMA23 (vertical plane).

4 Energy measurement at the buncher exit

The energy measurement at the buncher output of the third week of commissioning [1] was repeated for a reduced klystron power of 3.8 MW. Apart from this, the conditions were identical to the previous measurement, i.e. the quadrupoles of the first triplet WL.QSA271, WL.QLA27 and WL.QSA272 were not powered. The beam position was observed in the pick-up WL.UMA27 while changing the current in the downstream correction coils WL.DQSA272H and WL.DQLA27V.

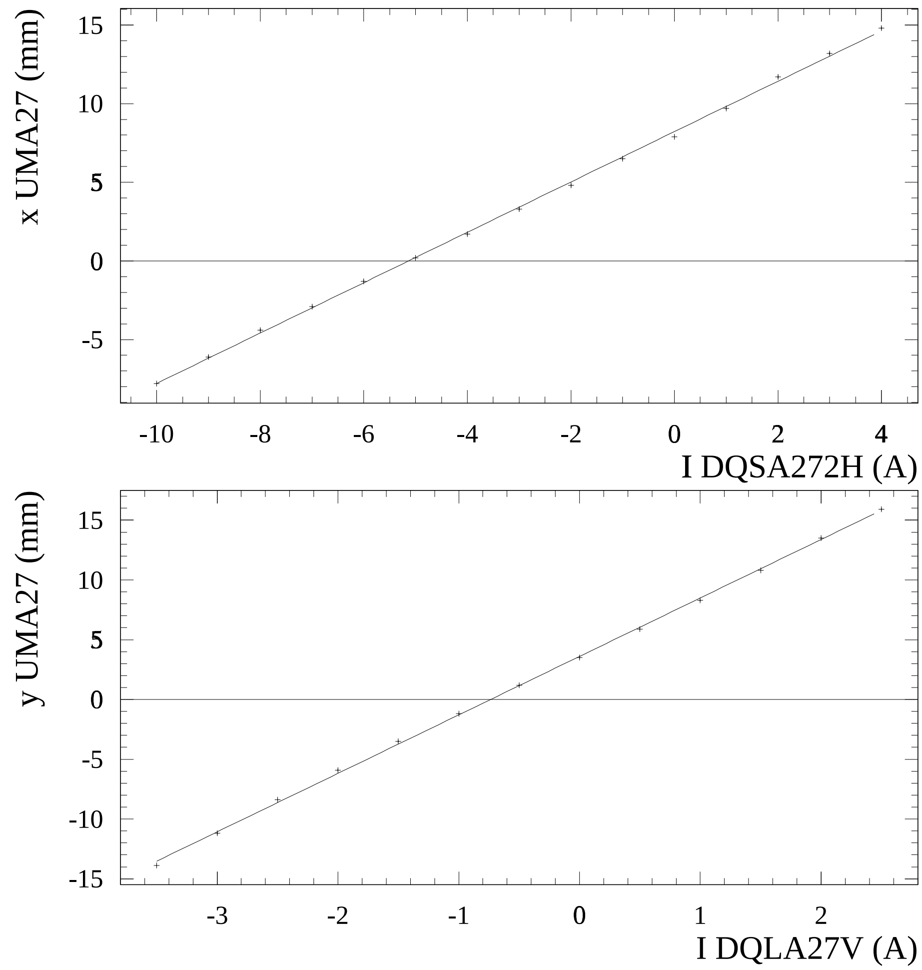

Figure 4: Beam position in WL.UMA27 as a function of the current in WL.DQSA272H (top) and WL.DQLA27V (bottom).

Figure 4 shows that the UMA response is linear in both cases. Taking into account an error of 0.1 mm (from the resolution of the UMAs and the hysteresis effects), a linear fit results in $(1.60{\pm}0.01)$ mm/A in the case of WL.DQSA272H and $(4.89{\pm}0.02)$ mm/A for WL.DQLA27V. This leads to a momentum of respectively 5.7 and 5.0 MeV/c at the buncher exit. For an unknown reason, these values are not consistent with each other, and the measurement is thus questionable. Consequently, this also brings some doubts on the previous measurement [1].

A few attempts were made to transport the beam at 4 MeV up to the spectrometer line in section 36 in order to measure the energy at the output of the buncher with a good accuracy. However, the beam was always lost between WL.UMA27 and WL.UMA29 where the quadrupole families do not allow to modify enough the transverse optics.

5 Investigations on the energy fluctuations

For two weeks, we have been observing some energy instabilities of the order of a few percents at 350 MeV. Although not disturbing in the linac, they become harmful in the injection line where the dispersion amplifies the phenomenon. These fluctuations are clearly visible in HIE.UMA23 (see Figure 1). Figure 5 shows the horizontal signal in HIE.UMA23 oscillating because of these energy fluctuations. In this case, the currents in the magnetic elements of the injection line had been scaled so that the mean value of the oscillation was zero. Injection in the ring was then possible, as shown by the sum signals of the first two pick-ups of the ring.

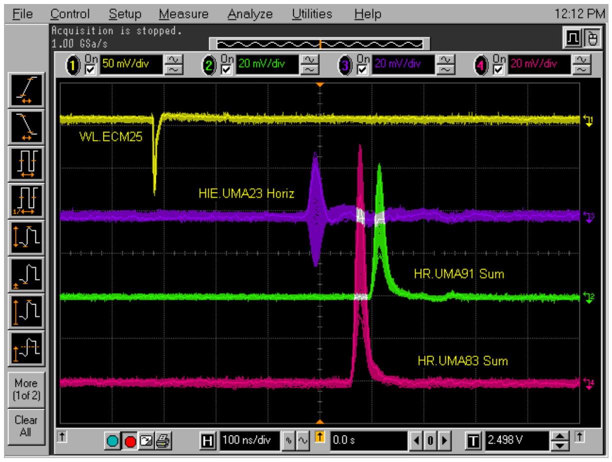

Figure 5: Energy fluctuations seen on HIE.UMA23.

During this week, some time was dedicated to understand the source of these energy fluctuations. Various tracks were investigated, but none of them lead to any conclusion:

- We first observed that the variations were visible on each of the five pulses of the gun, and that they had the same amplitude. As a consequence, these fluctuations were not coming from the gun. We then tried to see the fluctuations in the middle of the linac by using a correction dipole to create dispersion and by observing the beam position in a pick-up. This technique was not conclusive and we could not trace an origin point along the linac for the fluctuations.
- Thinking that the power supply of one of the correction dipoles in the linac could be responsible for the observation of these variations, we switched off one by one the rectifiers that power the correction magnets. But the fluctuations were still visible.
- The temperature of the cooling water of the accelerating cavities was also monitored for some time. However, the temperature fluctuations are much slower than the observed energy variations and cannot be responsible for the energy variations.
- We then studied in detail the klystron-modulator signals. We looked at the PKI power signal at the output of the klsytrons. Some small amplitude variations of the order of $\Delta V/V \simeq 1\%$ were observed on a signal of 4 V, and with a time scale of the order of a few seconds. This was not related to the energy fluctuations. We then measured the phase errors on the three modulators. The measurement was done first between the input and output signals of the "A box" and then between the input and output signals of the MDK itself. The results are summarised in Table 2. The phase errors are small in amplitude and the variations in time are fast. As a consequence, they cannot explain the energy instabilities.

	$\Delta\phi$ A box	$\Delta\phi$ MDK
MDK25	$< 1^\circ$	$< 4^\circ$
MDK27	$< 1^\circ$	$< 3^\circ$
MDK31	$< 1^\circ$	$< 3^\circ$

Table 2: Phase errors between the input and output signals of the "A box" and of the klystron-modulator.

6 Streak camera measurement using TCM37

During one session, we used the Cherenkov and Transition Monitors WL.TCM37 located in the matching section at the end of the linac with a beam energy of 330 MeV, and with the nominal current.

The first goal was to make a chromatic analysis of the light transport line by using various colour filters in front of the streak camera. We first optimised the position of the streak camera in order to have a good image of the beam on the CCD camera in focus mode. Going to the sweep mode at the highest sweep speed (50 ps/mm), we observed the bunch images with colour filters ranging from 400 nm to 600 nm. For the 600 nm filter, the bunches are hardly visible and this wavelength is therefore the limit. The best result corresponds to the shortest bunches and was obtained with a 550 nm filter. Figure 6 shows the streak camera image obtained from the Cherenkov screen when using a 550 nm filter. In that case the bunch length is shorter than without the filter, and is of the order of 7.5 ps rms, which is the lowest value measured so far using the streak camera.

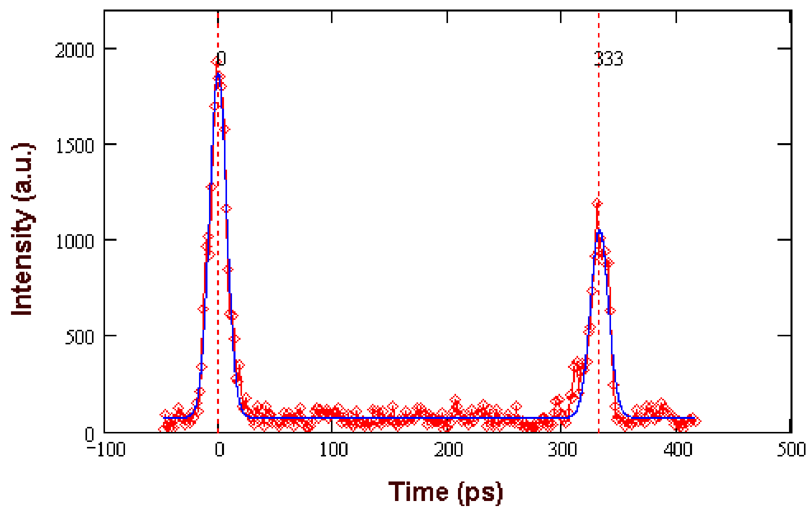

Figure 6: Bunch profiles from the image of the Cherenkov monitor WL.TCM37. The image was taken at the highest sweep speed and with a 550 nm colour filter. The measured bunch length is 7.5 ps rms (18 ps FWHM).

We also tested the Transition screen and we noticed that the intensity was lower than with the Cherenkov radiator. Because of the 45 degree tilt of the Transition screen, the image of the beam is stretched in one direction. However, more set-up time will be needed to extract good results from the transition screen.

During operation, the CCD camera suddenly broke down, preventing us from further use during the week.

7 First beam in EPA

At the end of the week, the beam was injected into the EPA ring. The efficiency of the injection was obviously badly affected by the energy fluctuations, and losses were important. However, the beam signal is clearly visible in the pick-ups HR.UMA83 and HR.UMA91, as seen on Figure 5. Since the magnets were off in the ring, the beam could not be transported further than the injection straight line.

Using the injected beam, we tested the wire scanner HR.WBS82 by changing the current in the septum HIE.SMH33 and observing that the beam was moving in the horizontal plane with the right sign convention.

8 Timing modifications

From the beginning of the commissioning, we have experienced some instabilities on the RF signals (see previous commissioning note [1]) due to random trigger jumps from positive to negative slope at the zero crossing of the 50 Hz signal from the mains. This problem was solved by modifying the central timing electronics. New connections are now available to switch from a central timing at 100 Hz (LPI normal mode) to a central timing at 50 Hz, thus avoiding the jumps from one slope to the other. The TPG signal is now synchronised with the positive slope of the mains signal, as seen on Figure 7. These timing modifications were implemented on the evening of the last day of operation, and were therefore tested on the machine the following week.

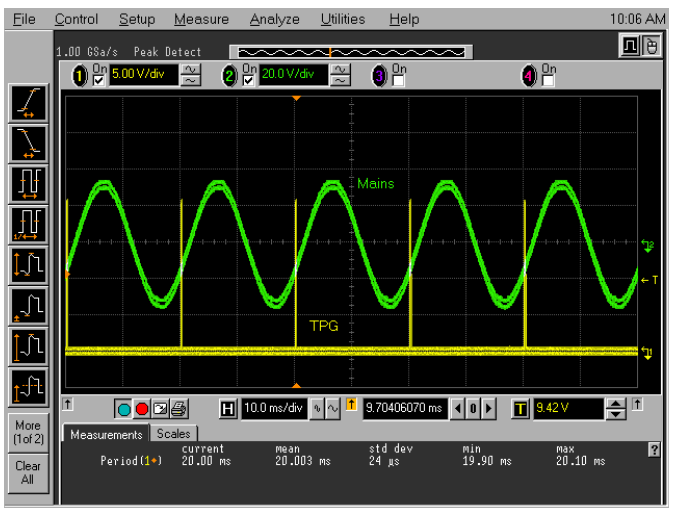

Figure 7: Central timing at 50 Hz.

Acknowledgement

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References

[1] R. Corsini, L. Rinolfi, T. Risselada, P. Royer (Ed.), F. Tecker, CERN, A. Ferrari, Uppsala University, M. Belli, C. Milardi, A. Stecchi, INFN-LNF Frascati “CTF3 Preliminary Phase Commissioning - Report on Third Week, 29 October - 2 November 2001”, CTF3 Note 040, PS/AE Note 2001-020.