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BUNCH COMPRESSION WITH THE FIRST CHICANE FOR LINAC RF POWER SOURCE

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Abstract

The use of the first stage of the CTF3 DBA as a 30 GHz power source requires a compression of the bunches produced by the CTF3 injector. The nominal bunch length of the injector of about 5 ps (rms) has to be shortened to almost 2 ps in order to achieve efficient power production.The main topic of this work is to investigate the possibility of using the cleaning chicane of the CTF3 DBA as a bunch compressor by varying the chicane angle and the longitudinal phase space correlation by changing the phase of the accelerating structures before the chicane. It has to be clarified if the cleaning chicane can fulfill the demands for 30~GHz power production or if a dedicated chicane has to be built. The necessary simulations were performed using the code PARMELA.

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1 Introduction

The present facility CTF II will see its final shut–down at the end of 2002. CTF3 will be operational at its Nominal Phase earliest in 2005. Due to this fact the ongoing studies of high–gradient damage and limitations in CLIC 30 GHz prototype structures experience a significant delay. Therefore it is desirable to have a 30 GHz power–source available before the Nominal Phase of CTF3 — preferable at an early stage of CTF3 after the CTF II shut–down.

One interesting possibility is to use the first part of the CTF3 drive beam linac after the commissioning of the CTF3 injector in 2003. The layout of this linac part is shown in Fig. 1. It consists of the gun with the injector, the chicane and 4 accelerating structures (2 accelerator modules).

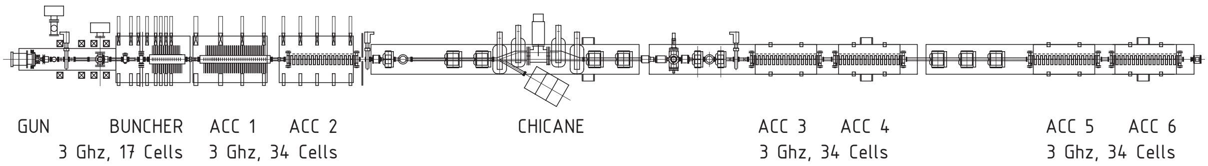

Figure 1: Layout of the Injector with the first part of the linac how it will be available in the second half of 2003.

2 Performing the simulation

The simulations were performed using the electron linac code PARMELA [1]. This code was written at the Los Alamos National Laboratory and allows the simulation of an electron linac including space–charge. The existing PARMELA input–files as created by A. Yeremian/SLAC for calculating the beam dynamics through the injector were taken and extended by the chicane and the accelerator sections. The quadrupole strengths were calculated by F. Tecker using MAD. They had to be scaled for the different energies which are achieved by different chicane angles.

A longitudinal compression of the bunches was achieved by introducing a correlation between the longitudinal momentum p_z and the phase of the beam–particles before the chicane. Because of the non–zero value of R_{56} in the transfer matrix of the chicane a longitudinal compression of the bunch can be achieved. The necessary correlation is achieved by a shift in the phase of the rf in the acceleration section before the chicane. The simulation shows that the highest compression can be achieved by using a chicane with an angle of 14.6° and a phase shift for the accelerating structures of −32.5° off–crest.

The simulations were performed for an output current of 3.5 A as well as for a high-current mode with an output current of 5 A.

3 Results

The main results of the simulations are compiled in Tab. 1.

The first column is the nominal case with an angle of the chicane of 8.6° and with on–crest acceleration of the electron bunch in the accelerating structures before the chicane. The second column shows the result for a chicane angle of 14.6°. In the third column the effect of the bunch

chicane angle	8.6°	14.6°	14.6° compression	14.6° compression high-current
$\phi_{acc1/2} - \phi_{crest}$	0°	0°	−32.5°	−32.5°
I_{Gun} [A]	4.7	4.7	3.8	5.4
I_{final} [A]	4.23	4.18	3.50	4.99
30 GHz Field Form Factor	0.631	0.626	0.906	0.871
$I_{final} \times$ FormFact. [A]	2.67	2.62	3.17	4.35
$E_{chicane}$ [MeV]	17.9	17.9	15.9	20.4
E_{final} [MeV]	50.5	50.4	48.3	66.9
$(\Delta E)_{final}$ [MeV]	1.4	1.6	3.0	4.0

Table 1: Main results

compression by introducting a phase correlation before the chicane is shown. A shift of −32.5° off–crest results in the highest possible compression. The fourth column of Tab. 1 shows the corresponding values for the high–current operation with an electron beam current of 5 A at the end of the drive beam linac.

The left part of Fig. 2 shows the resulting bunch for the nominal operation, *i.e.* 9.6° chicane but without scraper. The right part shows the bunch for a 14.6° chicane with compression. The asymmetric shape of the bunches explains why in Tab. 1 only the 30 GHz Fourier form factors instead of the r.m.s. bunch lengths are given.

The second and the third row show the beam–current at the gun exit and at the end of the linac, respectively. In the nominal operation of CTF3 the gun delivers 4.7 A which lead to a electron beam of 3.5 A at the end of the DBL. As one can see in Tab. 1 column one and two the current available for 30 GHz production is significantly higher than in the normal operation. The reason for this is the different mode of operation of the chicane and the DBL. In the nominal

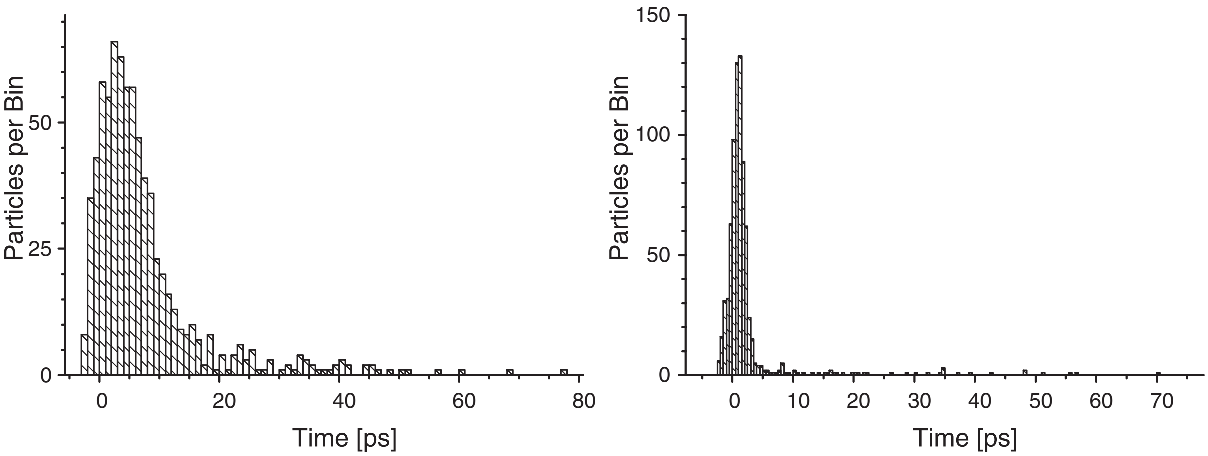

Figure 2: Bunch length at the end of the linac for the nominal case (left) and after compression (right).

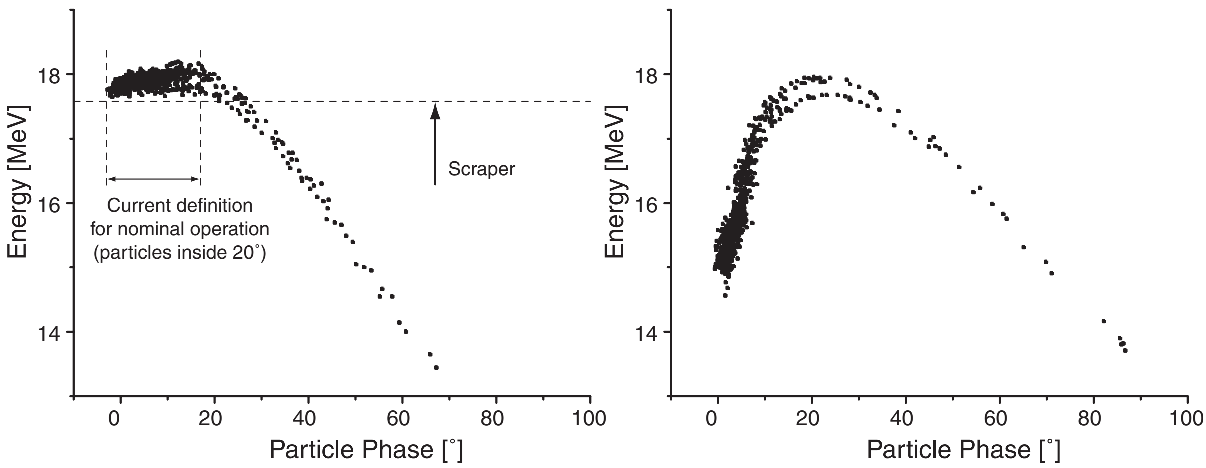

Figure 3: Particle Energy vs. Phase at the center of the chicane ($\hat{=}$ position of the scraper).

case the chicane is used as a cleaning chicane. It has a scraper in the middle which cuts the low energy tail of the electron bunch. Furthermore the definition of "usable current" in the nominal operation takes only the charge of single bunches within 20° of longitudinal phase space into account [2]. In the left part of Fig. 3 both effects are marked to show the particles available for the current definition. For 30 GHz power production all particles within 360° are available, which is taken into account for the calculation of the 30 GHz form factor. Furthermore the energy of the core bunch particles is lowered to almost the same energy as the tail, due to the off–crest operation of the accelerating structures in front of the chicane. Because the core and the tail have now the same energy, the tail particles are not lost after the chicane (right part of Fig. 3). Due to these effects a lower gun current than the nominal 4.7 A is necessary to achieve the 3.5 A beam current available for power production. The same arguments are applicable to the "high–current" mode, where a gun current of only 5.4 A is required to provide 5 A beam current.

4 Conclusion

The simulations have shown, that the cleaning chicane of the CTF3 can indeed be used as a bunch compressor during the initial phase of CTF3. This simplifies the use of the DBA as a 30 GHz power source because no special chicane has to be designed and built. Because of different demands on the time structure of the bunches a more efficient use of the produced electron beam leads to a lower required output current of the electron gun to achieve a beam current of 3.5 A and 5 A respectively.

A detailed discussion of the required 30 GHz power and the demands on the PETS and the electron beam can be found in [3].

References

[1] Lloyd M. Young, *Parmela, an electron linac design code*, Los Alamos National Laboratory.

[2] G. Geschonke, A. Ghigo, *CTF3 Design Report*, CERN/PS 2002-008, 2002

[3] I. Syratchev, *30 GHz RF power production*, Seventh CLIC/CTF3 Collaboration Meeting, http://collab.home.cern.ch/collab/Meeting7/Mainpage.htm, June 2002