STATUS OF LONGITUDINAL BEAM DYNAMICS STUDIES IN CTF3

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Abstract

The aim of the CLIC Test Facility CTF3, built at CERN by an international collaboration, is to address the main feasibility issues of the CLIC electron-positron linear collider technology by 2010. One key-issue studied in CTF3 is the generation of the very high current drive beam, used in CLIC as the RF power source. It is particularly important to simulate and control the drive beam longitudinal dynamics in the drive beam generation complex, since it directly affects the efficiency and stability of the RF power production process. In this paper we describe the ongoing effort in modelling the longitudinal evolution of the CTF3 drive beam and compare the simulations with experimental results. Our study is based on single bunch simulation.

INTRODUCTION

The result of PARMELA [1] for the injector (see Fig. 1) was used as the input for PLACET [2] simulation code and for a 1-D analytical model using MathCAD. By these simulation codes, the CL (CTF3 Linac) from girder 3 in the injector (see Fig. 1), CT and CTS lines (See Fig. 1) were simulated. Measurements of the bunch length in CT and CTS lines by using RF deflector of delay loop in the CT line and OTR screen in the CTS line were done and were compared to the result of the simulation.

Table 1: Simulation Codes Comparison

PARMELA	MathCAD	PLACET
Injector, Chicane	Girder 3, Chicane, DBA†, CT & CTS lines	DBA, INFN-Frascati chicane
Space charge	No space charge	No space charge
No wake field	Wake field	Wake field
Longitudinal & Transverse	Longitudinal	Longitudinal & Transverse
No CSR‡	No CSR	CSR

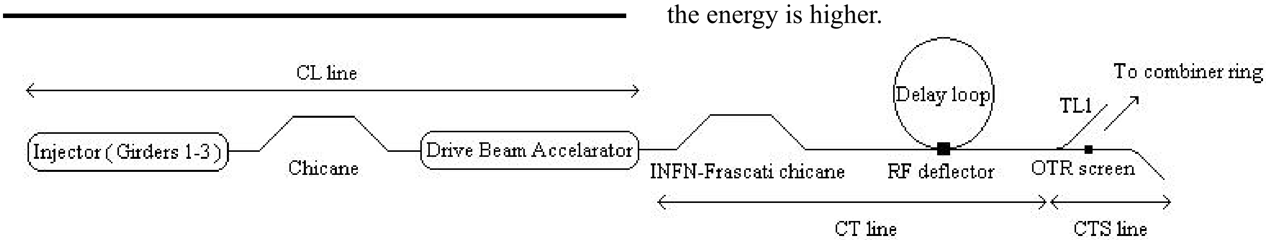


Figure 1: Layout of CTF3 from the injector to the combiner ring.

SIMULATION

Injector

In the Injector, the electron beam is produced by a DC electron gun, is bunched at 1.5 or 3 GHz by the bunching system and is accelerated to about 18 MeV.

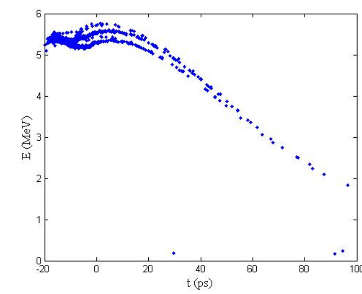


Figure 2: The result from PARMELA after girder 2 and the input for MathCAD.

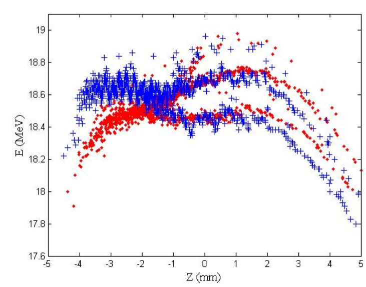


Figure 3: The result from MathCAD (no wake field) and PARMELA (+) after the injector, between z=-5 and z=5 mm. The rest will be cut in the chicane of girder 4.

Fig. 3 shows a good agreement between MathCAD and PARMELA result. In Fig. 13 you will see a little difference in the final bunch length, after the INFN-Frascati chicane.

The main reason for this difference is the space charge effect that is included in PARMELA and it is not included in MathCAD. The space charge effect is even less and hence insignificant in other parts of the machine where the energy is higher.

*Presently at Fermilab, #Presently at Siemens, †Drive Beam Accelerator, ‡Coherent Synchrotron Radiation.

Chicane

Chicane (in the girder 4) is used for two reasons:

1- To cut the low energy tail of the bunch: Each particle in the bunch travels in a different orbit related to its energy then by using an adjustable slit in chicane it is possible to stop the particles of a chosen energy.

2- To change the bunch length: R_{56}=15.2 mm. The simulation shows that the minimum bunch length after the chicane is obtained by the phase of the input RF power source feeding the accelerating structure on girder 3 equal to -3 degree from crest.

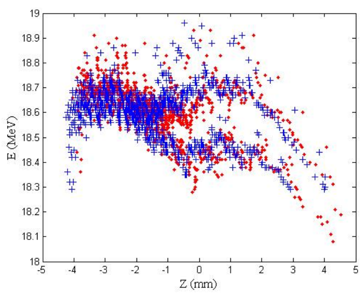


Figure 4: The result from MathCAD (no wake field) and PARMELA (+) after chicane starting from the end of the injector. Input is from PARMELA.

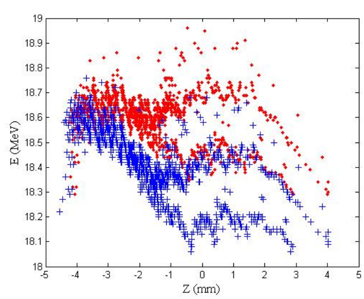


Figure 5: The result from the MathCAD after the chicane with wake field (+) (input for the MathCAD) and without wake field.

Drive Beam Accelerator (DBA)

In the Drive Beam Accelerator (girders 5-15), the electron beam is accelerated to about 120 MeV by structures located in girders 5,6,7,11,12,13,15. Each of these girders has two accelerating cavities and each of these cavities contains 34 cells [3]. (See Fig. 5, 6, 7).

INFN-Frascati Chicane

The INFN-Frascati Chicane is used to change the bunch length (R_{56}=0.46 m (calculated by MadX and PLACET), T_{566}=-1.14 m (calculated by PLACET)). The optimum bunch length should be around 2 mm r.m.s. that means not too short because of the coherent synchrotron radiation in the delay loop and the combiner ring and not too long because of acceptable injection into the delay loop and the combiner ring. (See Fig. 8, 9).

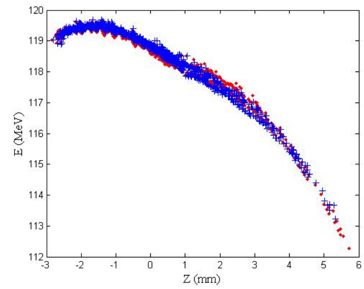
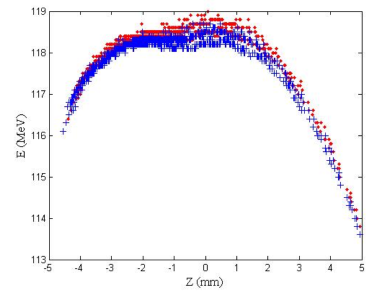


Figure 6: The result from MathCAD and PLACET after the DBA. Input is from PARMELA.



(+)

Figure 7: The result from MathCAD after the DBA with wake field (+) and without wake field. Input is from MathCAD.

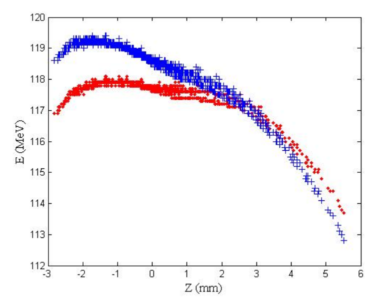


Figure 8: The result from MathCAD before the INFN-Frascati chicane with changing the phase by -20 degree in girder 15 from crest and without changing the phase (+). For both: σ=1.62 mm. Input is from MathCAD.

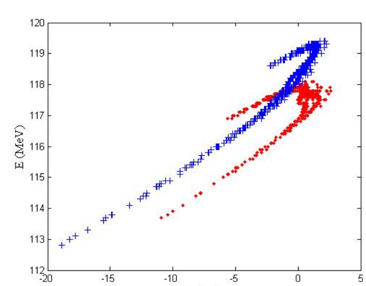


Figure 9: The result from MathCAD after the INFN-Frascati chicane with changing the phase by -20 degree in girder 15 from crest (σ=1.47mm) and without changing the phase (+) (σ=2.43mm). Input is from MathCAD.

BUNCH LENGTH MEASUREMENT

The RF deflector is a cavity in TE mode that gives a transverse kick to the electron bunch. The RF deflector is used to inject the electron beam into the delay loop but if it is used near zero crossing is useful for the bunch length measurement, making a correlation between transverse and longitudinal positions in the bunch. (See Fig. 10). Therefore the transverse shape on the OTR screen, give the information of longitudinal shape too. [5, 6, 7].

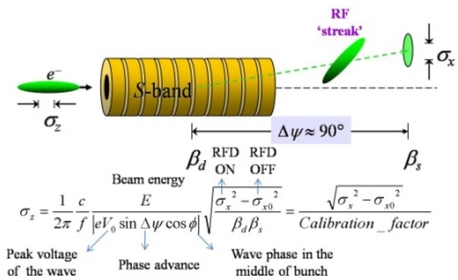


Figure 10: Using RF deflector for bunch length measurement [4]. f=1.5 GHz.

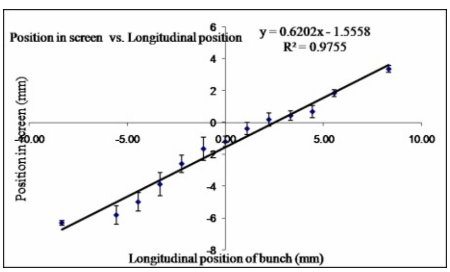


Figure 11: The method for finding the calibration factor that shows the relation between the screen position unit and the longitudinal position unit.

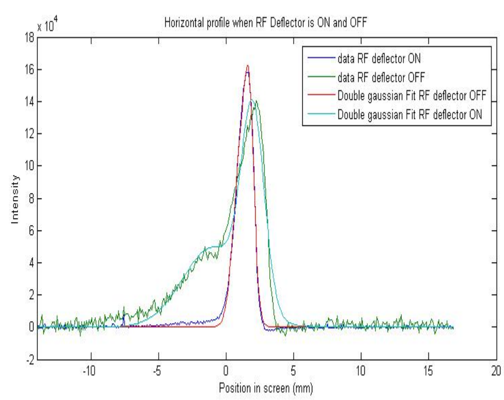


Figure 12: This shows the horizontal profile on screen when the RF deflector is ON and when it is OFF. ($\sigma > \sigma_0$).

In this method the horizontal size of beam on the screen is measured when RF deflector is on (σ) and off (σ_0). Instead of finding the magnitude of each parameter in the equation in the Fig. 10, the calibration factor is calculated by a measurement of the beam position on the screen versus RF deflector phase. Fig. 11 shows the result of one measurement. It shows a good linear fit. The slope is the calibration factor. Fig. 13 shows the result of one measurement for different wave phase in the girder 15 (last girder of DBA).

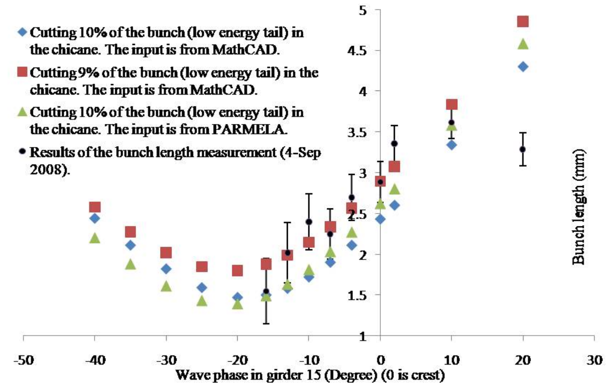


Figure 13: The result of bunch length measurement by RF deflector and the result of different simulations.

CONCLUSION

Fig. 13 shows a good agreement between simulations by MathCAD and bunch length measurement by RF deflector. The errors in measurement, mainly, are from the jittering of beam on the screen. RF deflector and electron gun are the main source of this jittering. Non-linearity of OTR screen is another reason of errors. The measurement was done by RF pickup too but it didn't show a good agreement but more or less the same shape. The work will continue to find the root of this difference.

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