STATUS OF CTF3 STRETCHER-COMPRESSOR AND TRANSFER LINE

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Abstract

The first part of the CTF3 transfer line is already installed. It includes a chicane in which, because of its very flexible lattice and large aperture vacuum chamber, the bunch length can change in a wide range.The chicane can be used as a stretcher to lengthen the pulses coming from the linac in order to reduce the coherent synchrotron radiation (CSR) in the recombination rings. A possible use as a bunch compressor is also foreseen in order to make CSR experiments and to characterize beam instrumentation. This paper describes the final design of the vacuum chambers, including beam diagnostics components, and their laboratory tests. The installation status of the magnetic and vacuum chamber components together with the ancillary systems is reported.

INTRODUCTION

The Compact Linear Collider (CLIC) project is a multi-TeV electron-positron collider for particle physics based on the two-beam acceleration concept; a high-intensity drive beam powers the main beam of a high-frequency (30 GHz) linear accelerator with a gradient of 150 MV/m, by means of transfer structure sections [1].

The aim of the CLIC Test Facility (CTF3) is to make exhaustive tests of the main CLIC parameters. An international collaboration participates to the construction of the machine and the LNF contributes to the realization of a large part of the recombination system, consisting in two rings which will multiplicate the bunch frequency and peak current by a factor of ten [2,3].

CTF3 is under construction in the LEP preinjector complex existing building at CERN. It uses where possible the existing magnets, power supplies, equipments and ancillary system.

TRANSFER LINES

The first part of the INFN Frascati contribution to CTF3 project is the transfer line that join the Linac to the diagnostic station and to the spectrometer line. It is already installed in the experimental area. The layout is shown in Fig. 1.

Transfer lines design

The main part of the transfer line is a magnetic chicane that can be used as stretcher, isochronous line or compressor.

In the nominal configuration it will stretch the bunch length to lower the peak current before entering in the recombination rings in order to reduce the effects of the coherent synchrotron radiation emission and impedance that increase the energy spread of the beam. It can be used for experimental purpose as a bunch compressor, to study the effect of the coherent synchrotron radiation on very short bunches and high charge. It can also be used in the isochronous mode without changing the longitudinal beam distribution.

There is also a by-pass in which the beam can be transported, in the case that the chicane will not be used (see Fig.1).

The chicane has a symmetric design with four dipoles and seven quadrupoles. The tunability in the R_{56} transport matrix term is between +50, -30 cm, that allows to vary the bunch length in a very wide range, according to the energy spread of the beam and the longitudinal phase space correlation at the Linac exit.

The chicane is joined to the Linac exit by a line where a quadrupole triplet matches the optical function to the chicane input. A symmetric line follows the chicane, and the corresponding triplet can be independently powered, to add flexibility in the operation.

Because of the choice of reusing existing magnets the constraints in gradient, gap and external size must be taken into account.

Vacuum chamber and magnets

The vacuum chamber shape has been dictated by the beam stay clear considerations together with the overall optimisation of the available element position.

The vacuum chambers of the straight sections including the by-pass have round section with 40 mm stay clear aperture diameter. The beam position monitors (BPMs) design developed at CERN [4] and the small aperture quadrupole magnets, used in the Linac, are used in this section.

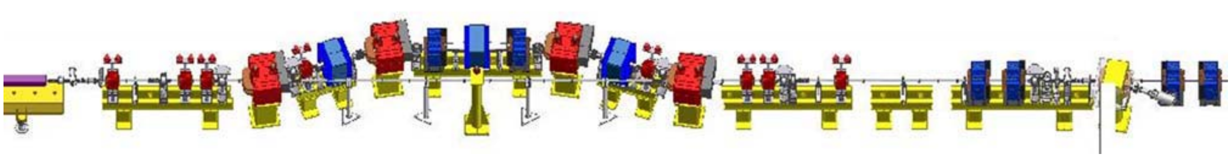

Figure 1: Transfer Line Layout.

The chicane vacuum chamber design follows the requirements of the beam taking into account the following constraints:

- the dipoles are the old EPA transfer line ones, and the vertical size of the corresponding vacuum chamber is the maximum possible compatibly with the magnets gap.
- the horizontal size of the chicane vacuum chamber is tapered with a maximum of the value at the chicane center, which corresponds to the highest dispersion function in the configuration of negative R_{56}.

For all the vacuum chamber components, like shielded bellows, pumping port sections, beam position monitors, we use the same design already developed for the Delay Loop and the Combiner Ring [5,6].

The vacuum chamber inner transverse dimensions must not present strong discontinuities in order to reduce the energy spread degradation due to the beam coupling impedance. The chicane vacuum chamber starts with round profile 40 mm diameter. In the first dipole it is splitted in two branches; the first curves to the chicane line, the second goes straight to the by-pass line.

After the first dipole one BPM, Linac type, is used, followed by a small quadrupole, then a tapered chamber change the beam stay clear aperture from 40 mm round to 90x37 mm^2 dimension, which is the size of the combining ring vacuum chamber. A square shape pumping port and a bellow are placed before the second dipole and a BPM is installed after the dipole before the straight.

Using a large aperture quadrupole magnet this straight vacuum chamber doubles its inner transverse dimensions on the horizontal and vertical plane at the central point, by means of two long tapers, and allow a wide variation of the beam size.

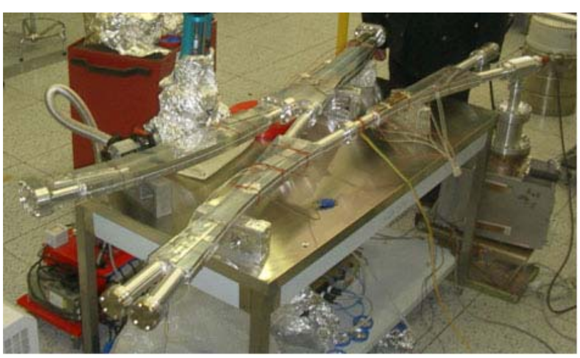

Figure 2: Dipole vacuum chambers under test.

The same components are symmetrically installed with respect to the chicane central point. The vacuum chamber of the third and fourth dipole have synchrotron radiation view ports which will be used for optical beam measurements.

All vacuum chambers are in aluminium, with the exception of the bellows and BPMs, and have been tested in the INFN laboratories before the shipment to CERN. They all achieved a static pressure better than $5x10^{-10}$ Torr after the heating cycle at 150 ^{0}C.

Measurement station

The installed transfer line is terminated with a measurement station that includes the spectrometer line.

The diagnostic equipments, that we describe in the following paragraph, are:

- RF deflector for the bunch length measurements.
- Beam position monitors.
- Beam profile monitor using OTR screen.
- High frequency current monitor.
- Spectrometer for energy and energy spread measurements.

These diagnostic tools are realised by CERN except for the RF deflector; this is the 3 GHz structure realised by INFN for the Combiner Ring and successfully used in the CTF3 Preliminary Phase [7].

BEAM MEASUREMENTS

The diagnostic tools of this transfer line are redundant and each beam measurement will be performed with at least two different methods.

Emittance measurements

Two emittance measurements systems are foreseen in this transfer line: in the OTR beam profile monitor the beam passing in the screen produce the image that is collected by an optical system on a CCD camera and captured and analysed by a frame grabber [8]. The emittance measurement is performed with the quadrupole scan method, acquiring the transverse beam distribution for different current sets of the quadrupoles.

The second emittance measurement is done with a synchrotron radiation monitor: the synchrotron radiation produced by the beam in the bending magnets escapes the vacuum chamber from optical windows with the maximum transmittivity in the visible range, in two positions: one in a point in which the value of the dispersion function is close to zero to perform the emittance measurement; the other one in a high dispersion point. The synchrotron radiation is collected by an optical system to a CCD camera; the video signal is digitised by a frame grabber and analysed.

Bunch length

Two alternative methods are also foreseen for the bunch length measurement. The synchrotron radiation produced in the dipole is sent to a streak camera with 2 ps resolution via an optical transfer line. The bunch length is directly determined measuring the light pulse distribution.

An alternative measurement will be also performed using an RF deflector in which the bunches of the train pass in the zero crossing point of the deflecting field.

The head and the tail of each bunch receive opposite kicks in the vertical direction; the bunch length measurement can be determined by the vertical distribution of the image create on an OTR screen.

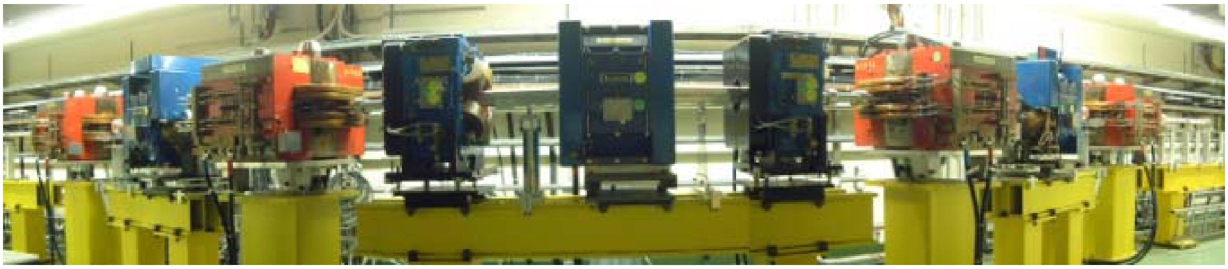

Figure 3: Installed chicane fish-eye picture

Looking at a second OTR screen placed after the spectrometer dipole, the longitudinal phase space can be reconstructed. The expected resolution will be better than 0.5 ps. This system is described in a dedicated paper in these proceedings [9].

The RF deflector is the 3 GHz structure realised by INFN for the injection test of the CTF3 preliminary phase and that will be used in the second ring of the recombination system (Combiner Ring).

Energy measurements

The energy and energy spread can be measured with three systems.

The first is a classical spectrometer line placed at the end of the described transfer. The energy of the beam is determined measuring the position of the centre of mass of the beam on an OTR screen, knowing the magnet current; the beam energy spread is given by the horizontal transverse distribution. The bending angle, the OTR screen distance and the vacuum chamber aperture have been chosen in order to have the possibility to measure energy spreads up to $\Delta E/E=5\%$

An independent measurement of the energy spread will be performed making the imaging of the horizontal beam distribution with synchrotron radiation emitted from the beam in a high dispersion function point. The synchrotron light is extracted from a channel tangent to the third dipole vacuum chamber of the chicane and collected, acquired and analysed with a system similar to the emittance measurement system described before.

Finally also the RF deflector used for the longitudinal phase space characterization can be used as a spectrometer, shifting the phase of the deflector to make the beam pass on the crest of the field.

Current measurement

Current measurements will be done with the two wide band current monitors described in [10] placed at the exit of the Linac and before the spectrometer line. These measurements interlock the safety system because when part of the beam is lost an interlock system is activated.

Eight BPMs have been installed along the line to allow beam trajectory reconstruction. As an option, the beam current along the line can be derived from the sum of the signals coming from strip-lines of the BPMs.

CONCLUSIONS

The first part of the transfer line is almost ready for the commissioning. The Linac will be characterized measuring the beam parameters. The manipulation of the Linac bunches with the chicane will be tested. Direct and indirect measurements on CSR and its effect versus the bunch length and current are also foreseen.

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