DIAGNOSTICS FOR THE CTF3 PROBE BEAM LINAC CALIFES

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Abstract

CALIFES is the probe beam linac developed by the CEA/DAPNIA and CNRS/LAL in the frame of the CFT3 collaboration at CERN. Its objective is to "mimic" the main beam of CLIC in order to measure the performances of the 12 GHz CLIC accelerating structures.

The requirements on the bunched electron beam in terms of emittance, energy spread and bunch-length are quite stringent and lead to use the most advanced techniques: laser triggered photo-injector, velocity bunching, RF pulse compression...

In order to tune the machine and assess its performances before delivering the beam to the CLIC structure test stand a complete suit of diagnostics is foreseen including charge monitor, beam position and video profile monitors, deflecting cavity, RF pick-up and analysis dipole. All these diagnostics will be interfaced to the CERN control system network. A special effort has been done on the Video Profile Monitors that make use of both scintillation and OTR (Optical Transition Radiation) screens and are fitted with 2 optical magnifications to fulfill field of view and resolution performances (<20µm). Their performances can be checked via an integrated resolution pattern.

SCOPE OF CTF3

CTF3 (CLIC Test Facility 3rd phase) is a collaboration driven by the CERN aimed to demonstrate before 2010 the feasibility of the future multi-TeV linear collider CLIC (Compact Linear Collider). Its scope is to check the two main innovative concepts of this accelerator: the two beams acceleration scheme using 12 GHz RF power and copper structures offering a very high gradient of acceleration (100 MV/m) [1].

The RF power at 12 GHz is generated by decelerating an electron beam (150 MeV – 30 A peak current, 5 Hz repetition frequency) in PETS cavities (Power Extraction and Transfer Structure). This beam, called "drive beam", is produced in a Linac followed by a delay loop and a combiner ring in order to "densify" the trains of bunches from 1.5 GHz to 12 GHz, and so to increase their intensity (fig. 1)

This RF power feeds accelerating structures that provide a high accelerating gradient to the main beam reaching in the CLIC project the energy of 1.5 TeV after 15 km.

For CTF3, an accelerator called CALIFES (Concept d'Accélérateur Linéaire pour Faisceau d'Electron Sonde) injects this beam, acting here as a probe beam, into the 12 GHz accelerating structures. Its installation in a new building is to be completed by the end of 2007.

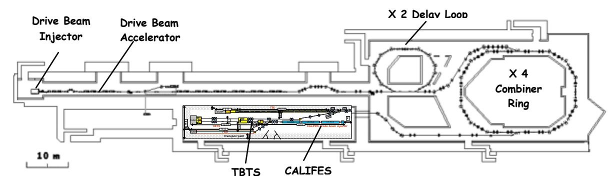

Figure 1: CTF3 Complex at CERN

The TBTS (Two Beam Test Stand) will allow studying the beam quality after high gradient acceleration (emittance, energy spread…) and to test the accelerating structures in operation (breakdown rate, wake-fields…).

PROBE BEAM SPECIFICATIONS

The accelerator CALIFES is built, for cost saving purposes, with 3 former LEP injector linac (LIL) sections at 3 GHz. A laser driven photo-injector delivers trains of short bunches (6 ps) that are velocity compressed in the first section down to 0.75 ps and accelerated up to 200 MeV in the 2 following ones [2].

The stringent beam characteristics detailed in table 1 with their reasons, are checked by a set of diagnostics that allow the tuning of the accelerator (power and phase of the RF, laser pulse power…).

Table 1: CALIFES beam parameters

Parameters		Motivation
Energy	~ 200 MeV	Avoid beam disruption in high RF fields
norm. rms emittance	< 20 π mm.mrad	Fit in 30 GHz structure acceptance
Energy spread	< ± 2%	Measurement resolution
Bunch charge	0.6 nC	~ CLIC parameters
Bunch spacing	0.667 ns	
Number of bunches	1 - 32 - 226	Measure 30 GHz structure transients
rms bunchlength	< 0.75 ps	Acceleration with 30 GHz

The diagnostic suit includes: 6 BPM (beam position monitors) to check the axis of the beam all along the accelerator and tune the steerers, a ICT (Integrated Current Transformer) to measure the bunches train charge just behind the photo-injector, 3 VPM (Video Profile Monitors) to measure the transverse profile of the beam and a RF pick-up for pulse length measurement and tuning of the velocity compression.

Transverse emittance measurement is performed with scanning the gradients of the triplet of quadrupoles associated with transverse profile measurement. Energy spread measurement is performed with a spectrometer made of an analysis dipole and a VPM, and longitudinal charge distribution measurement is performed with a deflecting cavity tuned at zero crossing (crab cavity) also followed by a VPM.

Most of these diagnostics are grouped in the diagnostic section (fig 2) just before the beam delivery to the TBTS.

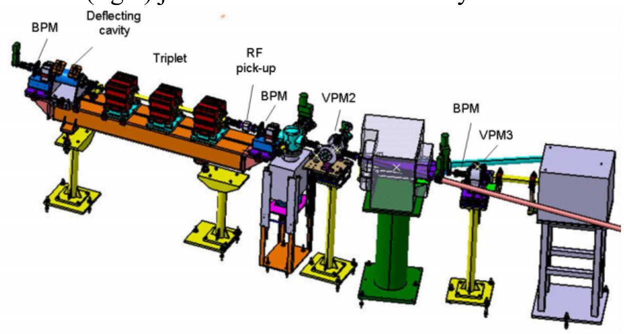

Figure 2: Diagnostics section

BPM

BPM are based on a coaxial re-entrant cavity, with 4 small antennas to pick-up the RF signal. Their low quality factor (Q=52) allow a high bandwidth (115 MHz) and consequently BPM are the only diagnostic providing time resolution along the bunch train. Taking advantage of this capability, a BPM is located just after the analysis dipole to provide data about the mean energy shift due to beam loading. More details on the CALIFES BPM are given at ref. [3]

ICT

Bunches charge delivered by the photocathode depends on its quantum efficiency, likely to evolutes with time and on the laser pulses power. It has to be accurately monitored during the tests and a reference diagnostic (ICT + Integrate-Hold-Reset electronic from BERGOZ) is foreseen just after the photo-injector. For installation ease, a “in flange” ICT model compatible with UHV has been retained. Electronic processing delivers an analog output that is sampled by a digitizer PCB (SIS-3300) to interface with the CERN control network and is driven via TTL signals.

VPM

Most of the beam characteristics measurements (emittance, energy spectrum, charge distribution) rely on the acquisition of beam transverse profile. This is done with a video camera that images a screen, either ceramic based for phosphorescent screen or aluminum for OTR (Optical Transition Radiation) that can be inserted in the electron beam.

Three VPM will be installed in the CALIFES accelerator.

First VPM

The first VPM (fig.3), installed upstream to the compression section, has the function to check the beam delivered by the photo-injector while its energy is about 6 MeV and its transverse size around 1 mm. A ceramic screen (AF995R from Saint-Gobain), is used for its high efficiency (around 600 photons/electron), the relatively large beam size insuring not to damage it. The screen dimensions are 40x40 mm^2, it is inserted at 45° respectively to the beam axis by an air jack. It is viewed through a fused silica viewport perpendicular to the beam axis, reflected by a 50 mm diameter mirror downward to the optical line. The optical line includes a doublet achromatic lens, a motorized diaphragm and a monochrome CCD camera (TELI CS8630HC) with analog output in order to easily interface with the CERN control network. With a CCD chip of 3.6x4.8 mm^2 the desired field of view of 22.3x30 mm^2 is obtained with a magnification of 0.16. Due to the relatively low number of pixels delivered by the frame grabber (312 x 416), the resolution is limited to 217 µm on 3 pixels. The purpose of this VPM being mainly to assess the beam presence, this is considered as acceptable.

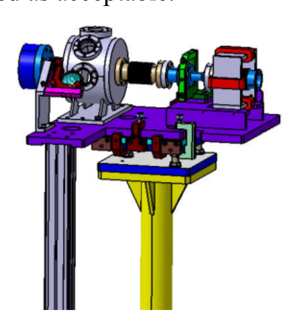

Figure 3: ICT, first VPM and BPM

Second VPM

The second VPM (fig 4), used to measure the transverse and longitudinal beam emittances, is located downstream to the triplet of quadrupoles and the deflecting cavity, after bunch compression and acceleration to 200 MeV.

Due to the low expected transverse emittance (around 10π mm.mrad), the beam size when focused on the screen is only about 50 µm. The density of charge per screen surface unit then exceeds what a phosphorescent screen can withstand. Alternatively, an OTR screen, made of alumina deposited on a silicium slice, offers in this case robustness and a better spatial resolution, while its low efficiency (around 1 photon for 100 electrons at 200 MeV) is no longer a problem. However, for non focused beam the light contrast is insufficient with the OTR screen, and a selectable ceramic screen is also foreseen.

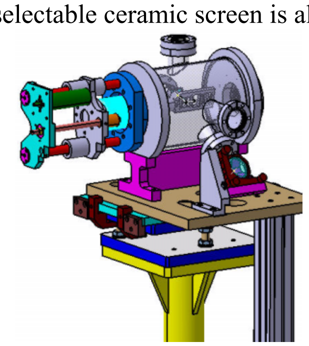

Figure 4: Second VPM

To obtain a sufficient resolution (20 µm desired) a magnification of 1.73 is required, limiting the field of view to 2.1x2.8mm^2. To comply with the field of view requirement of 10x10 mm^2, a second magnification (0.36) is selectable with a resolution limited to 96 µm. These two magnifications are obtained by inserting either a f=200mm or a f=250mm lens by motorized flipper mount (New Focus 8892) in the optical line. Optical performances like aberrations have been computed with Apilux code.

Light attenuation when necessary (long train of bunches) is obtained with a motorized filters wheel, a diaphragm being not able to provide accurate tuning with the narrow lobes of OTR light at 200 MeV.

An optical pattern (line grid) can be inserted at the same place of the screens in order to check the characteristics of the optical line and possibly to correct the distortion by software. Both ceramic and OTR screens and the optical pattern are mounted on a translatable carrier driven by a DC motor through a below. The optical pattern is back lighted via a dedicated viewport and a small mirror.

Due to the relatively high magnification (1.73), the depth of field is limited. Consequently, the angle between the screens and the electron beam has been lowered to 15°, the optical path exiting the tank at 30° to collect the back-OTR lobe through a CF40 fused silica viewport.

Third VPM

The third VPM is used to measure the energy spectrum after the analysis dipole bending the beam at 17.5°. The electron beam being spread a high efficiency phosphorescent screen is required. The screen, whose dimensions are 40x20mm^2, intercepts the beam at 45° and is viewed with a magnification of 0.22. An air jack is used to insert a line grid at the place of the screen for calibration purposes of the optic line. Light intensity is controlled via a motorized diaphragm.

TRANSVERSE EMITTANCE MEASUREMENT

Transverse emittance is computed by scanning quadrupole strength and measuring the corresponding beam size on the second VPM. Should the waist size be too small to be resolved by the optical line and to allow accurate measurement, it is possible to apply an alternative method using various sets of quadrupoles strengths leading to beam sizes (either vertical or horizontal) large enough to minimize measurement errors.

CHARGE LONGITUDINAL DISTRIBUTION MEASUREMENT

A traveling wave deflecting cavity is used at zero crossing for tilting electron bunches [4]. When fed with 3 GHz pulse power of 7 MW, the transversal electric field reaches 1.54 MV/m. The head of a bunch of 0.225 mm (0.75 ps) receives a kick that pitches it of 0.055 mrad and the opposite for the tail. The transverse beam size focused on the second VPM screen is then 200 µm versus 40 µm when the deflecting cavity is off.

RF PICK-UP

For basic operational tuning a non-intercepting measure of bunch length is foreseen that will be calibrated with the deflecting cavity method. It is based on EM field by propagating with the electron bunch [5]. The shorter the bunch length, the wider the generated RF spectrum that is collected by a waveguide and analysed between 30 to 176 GHz. This equipment has been developed by CERN for the drive beam and has to be adapted to the probe been characteristics.

ACKNOWLEDGMENT

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