

THE DIAGNOSTIC LINE OF ELETTRA BOOSTER 100MEV PRE-INJECTOR

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Abstract

In order to fully characterize the beam of the new 100MeV linac pre-injector for the Elettra Booster, a standard diagnostic set-up has been designed which includes strip line BPMs, scintillating screens and current transformers. During the initial commissioning of the pre-injector, made of a thermo-ionic gun followed by a 500MHz pre bunching cavity, an S-band bunching structure and two LIL (Linac Injector of LEP) accelerating sections, some extra diagnostics have been used to get a deeper understanding of the pre-injector operating point. In particular some prototypes of the FERMI@elettra diagnostics, installed on the same booster pre-injector, have been used to better characterize the beam transverse and longitudinal beam axis. An improved resolution screen system, equipped with a YAG screen, has been used as well as a wideband longitudinal pick-up. The measurement results as well as the tuning procedure are here presented.

PRE-INJECTOR LAYOUT

The Elettra Booster preinjector is a 100MeV Linac made of a thermo ionic gun, a 500 MHz pre bunching cavity, an S-band bunching structure and two LIL accelerating sections. The standard beam diagnostics provided for this section of the machine are:

1. A fast current monitor (FCT) positioned just after the thermo-ionic gun to measure the charge emitted and the shape of the pulse.
2. A second FCT is positioned after the bunching structure to monitor the efficiency of the bunching system.
3. The first pair BPM and Scintillation screen is positioned just before the first LIL accelerating section.
4. Between the first and second accelerating section there is an integrating current monitor (ICT), a BPM and a Scintillation screen.

At the end of the second accelerating section, the low energy transfer line steers the beam to the booster. The diagnostic elements in the straight section of the transfer line are an ICT and a BPM positioned just after the accelerating section; after two quadrupoles there is a short diagnostics beamline equipped with a BPM and a scintillation screen used for testing purposes.

Furthermore some diagnostics prototype developed for FERMI, have been installed which have been used as redundant pre-injector diagnostics.

CURRENT MONITORS

The current monitors used in the Elettra pre-injector are Bergoz FCT and ICT.

The first two FCT in the pre-injector provide some insights into the time structure of the beam. The fast response of these two current monitor allowed us see the shape of the beam emitted by the gun, and the effect of the bunching system on the beam.

At the end of each LIL accelerating section there is a ICT to measure the current in order to evaluate the transport efficiency of each accelerating section.

To acquire the signal from the first three current monitor a 1GHz BW LeCROY 104Xs scope is used. During the commissioning the acquired signal was remotized up to the control room using a dedicated fiber optic (f.o.) link; at present the integration of the scope acquisition in the Tango based main control system of the machine is under way.

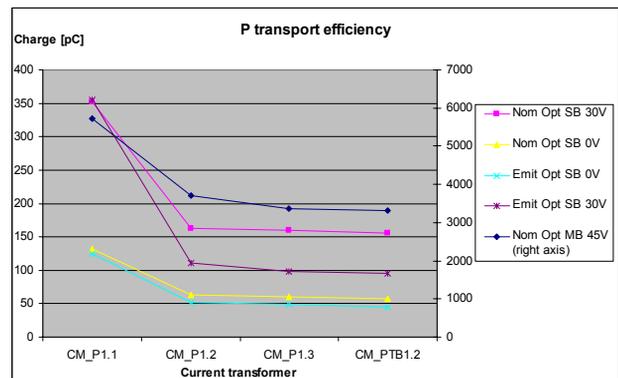


Figure 1: Charge measurements along the pre injector in single (SB) and multi (MB) bunch with different optics (nominal and emittance measurement setup).

The last ICT of the pre-injector, is acquired by the Bergoz Beam Charge Monitor (BCM), Integrate-Hold-Reset version, positioned in the pre injector service area thus connected through 20 m coaxial cable. The BCM output voltage, is proportional to the beam charge present in a configurable time interval started by a trigger, is kept up to 400 μ s and then reset. This signal is measured by a 16 bit ADC module located in a VME crate, and driven by a CPU running dedicated RT software. The acquisition SW starts sampling after a specific trigger and computes the charge value from the average of the acquired samples.

A similar acquisition system is used for the ICT placed at the end of the transfer line in order to evaluate the

transport efficiency. A huge spurious signal from the linac modulators called for a dedicated filter implemented by means of RF choke in the cables layout.

Fig. 1 shows the plot of the charge measured along the pre-injector at different FCT and ICT locations in multibunch (MB) and single bunch (SB) and with different optics used to evaluate the transport efficiency of the machine. The LINAC optics leading the best overall performance (5mA MB at the end of booster ramp) has a transport efficiency of 58% in the pre-injector.

SCINTILLATION SCREENS

A new scintillation screens system was developed for the Elettra injector.

The mechanical design is based on a standard vacuum cross CF63 flanged. From the upper flange the $\text{Al}_2\text{O}_3:\text{CrO}_2$ Chromox 0.5% doping target is inserted to intercept the beam. The positioning of the in vacuum target is obtained with a pneumatic actuator to give an absolute measurement of the beam position with respect to the chamber.

The lower part of the cross chamber is windowed where a standard CCD camera with a zoom objective is faced. Around the objective a LED based illuminating system is positioned to illuminate the target during the calibration of the acquisition system obtained measuring the known distance between four points painted on the target. A cylindrical Pb shield protects the camera from radiation. The repeatability of the positioning assured by the construction mechanic precision was measured by the acquisition system after the whole assembly and is less than 300 μm .

Every scintillation screen mechanic is controlled by a local controller equipment that receives commands from the unique control centre via a CAN bus. The controller receives the images acquired by a standard EIA camera (SONY XC-ES30) and sends the signal to the control centre via a dedicated f.o. link.

The control centre manage all the scintillation screen of the new injector sending commands to the actuator (screen on-off, illumination system, focus, zoom, diaphragm) via the CAN bus. The image acquired by a Leutron IPB Picport PMC board is analyzed by dedicated software that calculates position and sigma of the beam with different selectable algorithms; the image with superimposed some graphics tools (pointers, cursors, grid, rulers, infos) are displayed on a dedicated graphic card which image is sent to the control room with a dedicated f.o. link in order to assure the required image refresh rate. The analysis results are available real time on the workstations placed in the control room and to the high level software [1].

The CPU of the control centre is seen by the control system as a Tango server implementing also some complex commands like saving stream of acquired images, or save "the beam path" in which all the screen are sequentially inserted and the acquired image is saved.

Log file of requested operation and errors reported are saved for system diagnostic purposes.

For hardware debugging purposes and maintenance in shutdown period, LabVIEW application software that runs on a palm computer interfaced to the CAN-bus with a bluetooth-can interface has been developed to manage the mechanic locally.

BEAM POSITION MONITORS

The beam position monitor pickups adopted in the pre-injector are 150mm long, rotated strip line grounded at downstream end.

The signals from this pickup are amplified by wide band (1GHz) amplifiers and processed by Bergoz Log-Ratio front ends giving two voltages proportional to horizontal and vertical position and a third signal whose area gives information about the charge.

These three signals are acquired by two A/D converters: the INCAA VD10 (ADC) is used to acquire the position signals while the charge signal is acquired by CAEN V965A integrating A/D (QDC).

The gate signal required by the QDC is obtained from a CAEN V462 dual gate generator board that, triggered by the timing system, produces two gate signals: the first one enables the Bergoz front-end and the second one drives the integrating A/D.

Four in house developed interface boards, housed in the Bergoz crate, collect the signals from up to 12 Bergoz LR-BPM frontend connecting the signals to the A/D board with a reduced number of cables. The same boards also distribute the gate signal to each frontend.[2]

FERMI@ELETTRA DIAGNOSTICS PROTOTYPES

FERMI@Elettra is a seeded FEL in construction at Sincrotrone Trieste. The required electron beam quality is posing demanding specifications on beam diagnostics. For this reason a test setup for profile measurements and bunch arrival measurements has been installed at the end of the booster pre-injector (100MeV).

The system includes multi screen motorized in vacuum station for transverse profile measurements allowing for direct comparison of different screen performances. Together with a standard Chromox scintillator a YAG:Ce scintillator, an OTR screen and a grid calibration pattern were mounted on the same support at 45 degrees with the beam direction. The vertical position of the support with respect to the beam can be selected with 10 microns accuracy by means of a stepper motor actuator.

The detection system consists in a firewire CCD (Basler A312f) on which a telecentric lens objective (Goyo 50-NL) has been mounted. At the present magnification the image calibration is of 35 μm /pixel. The acquisition and control of the camera is implemented via a LabVIEW program running on a PXI/Windows controller which is also interfaced with the control system.

The performance in terms of spatial resolution of YAG:Ce and Chromox has been measured by means of a

quadrupole scan and a dedicated optics setup. Figure 2 shows the rms beam size versus the quadrupole k value measured using both type of screens.

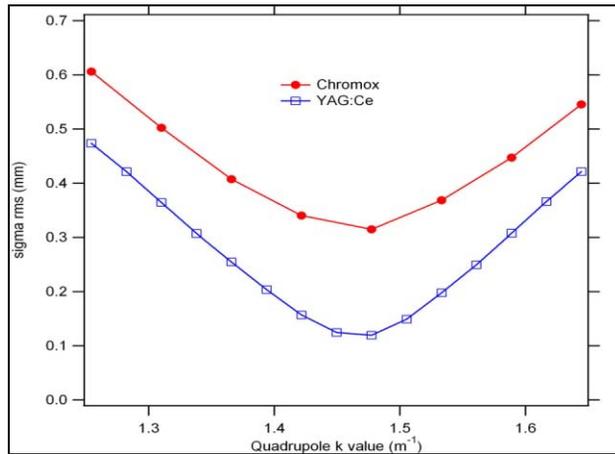


Figure 2: rms beam size vs the quadrupole k value measured for YAG:Ce (blue) and Chromox (red) screens

As could be expected the resolution of chromox is much worse with respect to the YAG:Ce. The beam size rms saturates at strong focusing to a value of 320 μm , while for YAG:Ce the minimum rms beams size is of 120 μm . For this reason YAG:Ce has been adopted to measure the beam emittance[3].

The other new diagnostics item installed is the prototype of a bunch arrival monitor (BAM) pickup: a large bandwidth 4 feedthrough pickup designed at DESY [4]. Two opposite outputs are summed and the system is connected to an 8GHz Tektronics DPO70804 oscilloscope through an AIRCOM PLUS cable. The system response has been calculated via a gaussian fit of the measured single bunch signal and the signal corresponds to a Gaussian pulse with a sigma of 42psec thus giving an effective bandwidth of 4.5 GHz.

This setup has shown to be a valuable tool for accurate studies of the bunching systems performances. In Figure 3 the signal from the single bunch operation of the pre-injector is shown as a function of the thermo ionic gun grid value. To produce the single bunch the cathode of the gun is driven by a fast voltage pulse while the grid value let us control the charge emitted. By increasing the grid voltage to enhance the charge also the duration of the bunch increases and, when it exceeds twice the bunching system, period satellites will become clearly visible on both sides of the main signal as small peaks 330ps apart.

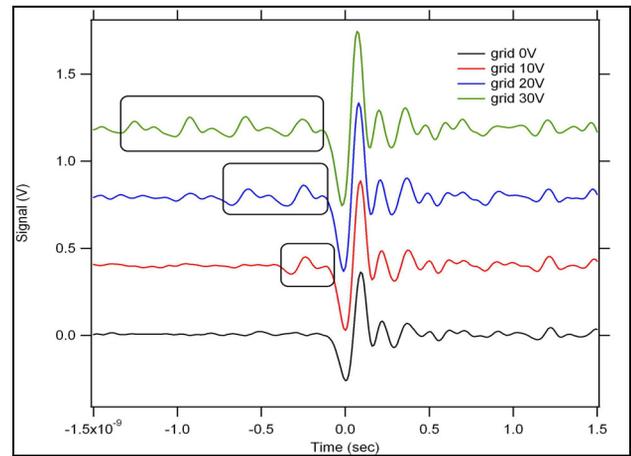


Figure 3: BAM acquired signals for single bunch operation at different grid voltage: increasing the grid voltage the charge increase but also some satellite appears.

CONCLUSIONS

The beam current monitor, initially available as a raw signal on the scope monitor, was commissioned resolving some spurious signal interference with the aid of some RF filters on the cables. Testing the BCM acquisition system with different values in the beam charge a possible, easy to implement, improvement is to realize the auto scale feature to improve the resolution of the system at different charge values. Further improvements of this system may be the installation of the BCM in the tunnel.

The BPM system was calibrated using a pair BPM - scintillating screen using the second one to calibrate the first.

In the initial part of the commissioning of the new - injector the scintillations screen was the most useful diagnostic system due to the fact that they give self-explaining information about position, charge, short and long term stability in charge and position without further calibration than the laboratory one.

After the necessary final calibration of BPM and current monitor more precise measurement and machine tuning was possible.

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