PROGRESS ON THE BEAM ENERGY MONITOR FOR THE SPIRAL2 ACCELERATOR

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Abstract

The first part of the SPIRAL2 project entered last year in the end of the construction phase at GANIL in France. The facility will be composed of an ion source, a deuteron/proton source, a RFQ and a superconducting linear accelerator. The driver is planned to accelerate high intensities, 40 MeV deuterons up to 5 mA and heavy ions up to 1 mA.

A monitoring system was built to measure the beam energy on the BTI line (Bench of Intermediate Test) at the exit of the RFQ. As part of the MEBT commissioning, the beam energy will be measured on the BTI with an Epics monitoring application.

At the exit of the LINAC in the HEBT, another system should measure and control the beam energy. The control consists in ensuring that the beam energy stays under a limit by taking account of the measurement uncertainty. The energy is measured by a method of time of flight; the signal is captured by non-intercepting capacitive pick-ups.

This paper describes the BTI monitor interface and presents the system evolution following the design review of the HEBT monitor.

INTRODUCTION

The beam energy will be measured on BTI which is directly placed at the RFQ exit to qualify the beam properties in front of the LINAC. The beam energy at the LINAC exit in the HEBT will be also measured for the beam tuning and the energy control. The energy is monitored in order to ensure the respect of the accelerator operating range and the thermal protection of the machine. The energy is measured by a method of time of flight (TOF) [1].

Beam time structure may vary by using a slow chopper or a single bunch selector. The duty cycle of the slow chopper is included between 1/10000 and 1/1 with a frequency of 1 Hz and 5 Hz. The intensity beam will range from a few 10 µA to 5 mA.

As the energy control is part of the safety functions, Failure Modes and Effects Analysis (FMEA) and the measurement uncertainty are required on this control device.

BEAM ENERGY MEASUREMENTS

The energy monitor is composed by three electrodes installed along the beam line, the energy is calculated by a time of flight method (TOF).

In 2014, before the final installation, the BTI was assembled at the IPHC laboratory (Fig. 1) for mechanical verifications.

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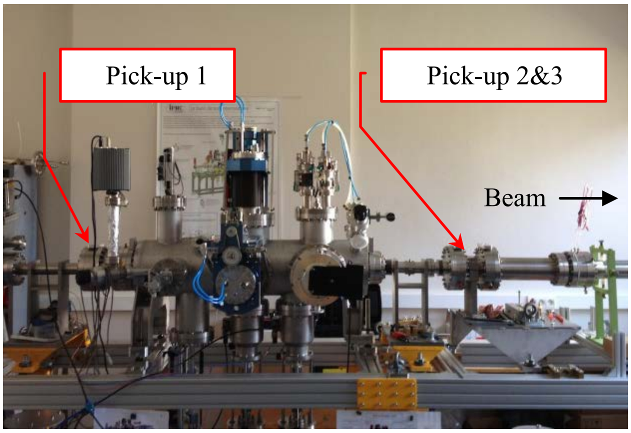

Figure 1: Electrodes along the BTI.

The first unit includes the Pick-up1 and the second unit is composed by the Pick-up2 and 3 (Fig. 2). The pick-up3 is designed to determine the number of bunches between the two first pick-ups. The length between the second and the third pick-up is calculated to be smaller than the distance between two bunches.

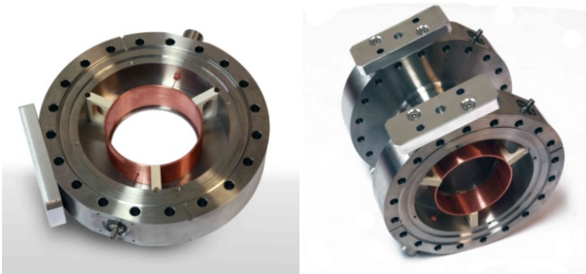
Figure 2: Pick-up1, Pick-up2&3.

The HEBT required performances are the following:
- Intensity range: from 10 µA to 5 mA
- Energy range: from 2 MeV/A to 33 MeV/A
- Response time: 1 s
- Required accuracy:
  - +/-1 per mille for the beam tuning
  - +/-1 per cent for the beam control

ELECTRONIC DESCRIPTION

The phase measurement of the TOF is based on an electronic system which realizes the lock-in amplifier function [2]. The signals come from three pick-up electrodes. The phase of the first harmonic is measured by the TOF device.

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The TOF electronic system (Fig. 3) is composed by :

- ADCs card with a clock part
- FPGA board
- Microcontroller board
- High Frequency Amplifier
- Alarm board

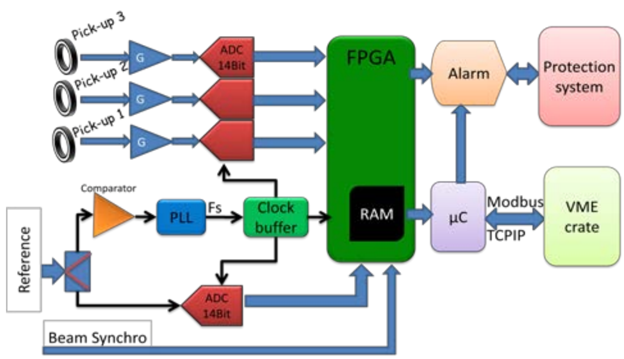

Figure 3: Electronic synoptic.

BTI MONITOR INTERFACE

The graphical interface of the BTI device is composed of a dedicated CSS/BOY project associated to EPICS TOFApp module and iocTOF IOCs.

The module application contains the EPICS interface with the measurement system of the energy by time of flight. This module is created on the SPIRAL2 EPICS skeleton. The module can run with the systems VxWorks and Linux IOCs. Concerning the final control system for the SPIRAL2 facility, the application is accommodated on an IOC VME VxWorks. For tests in laboratory, the application is running under IOC Linux.

The Modbus-TCP protocol is used for the communication between the EPICS IOC and the TOF measurement system connected together via Ethernet. The Modbus operations of reading and writing are done with EPICS Modbus driver developed by the University of Chicago [3].

An electronic test device allows injecting a test signal directly on each probe. The test commands are sent and read by a VME ADAS ICV196 board.

This GUI (Fig. 4) allows us to adjust the sample size in the average calculations. From the x and y coordinates of the measured vector, the phase and the amplitude of the signal on each probe are deduced. The application gives two information which allow us to calculate the ion velocity: the phase and the number of bunches between probes 1 and 2. Then knowing the mass of the accelerated ion, the beam energy and its standard deviation can be calculated.

The delay compensation between the three chains is done by injecting this test signal. The interface is used for calibration operation like offset deduction.

The graphical interface is composed of few tabs. A histogram tab allows seeing the dispersion and the distribution (Fig. 5) of measurements, and its evolutions.

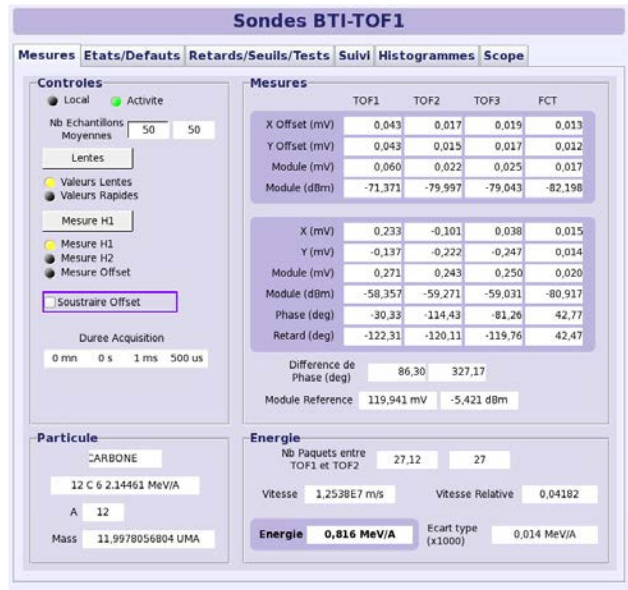

Figure 4: Energy measurement.

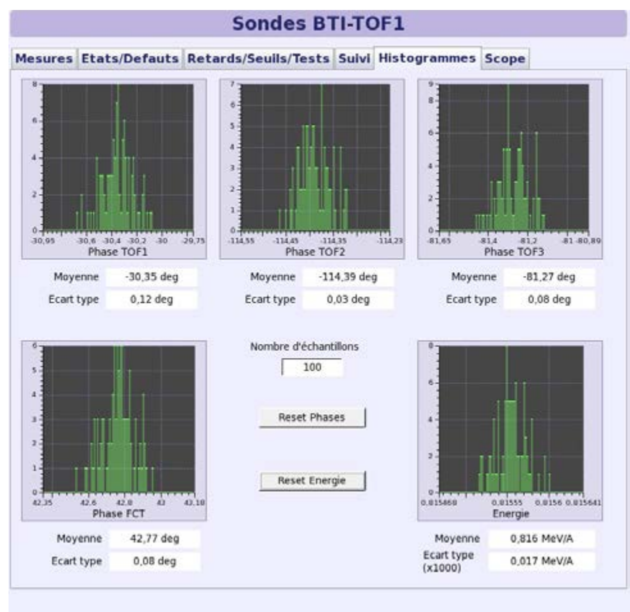

Figure 5: Statistic measurements.

SINGLE PULSE TEST BENCH

A single bunch selector, installed in the MEBT, will reduce the bunch repetition rates by a factor of 100 to 10000 [4]. This working mode was tested in laboratory.

The beam is simulated by injecting a signal in a coaxial line at 88 MHz (Fig. 6).

The three signals which come from the probes are measured by the TOF device.

The energy measurements are realized after the offset and delay compensation.

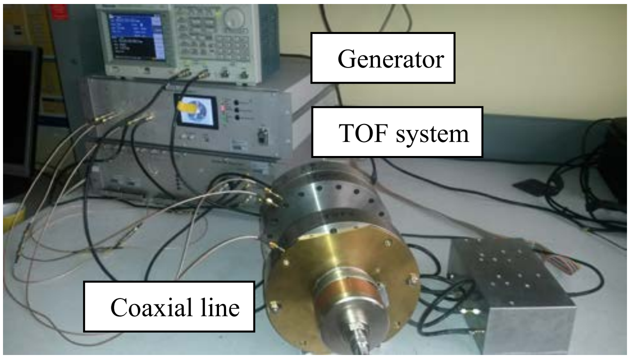

Figure 6: Single pulse test bench.

To simulate the single bunch selector, a generator with two outputs at the same frequency is used. The first output corresponds to the RF frequency (Fig. 7: green curve) and the second (Fig. 7: yellow curve) to the pulse. The generator allows us to select a single bunch mode.

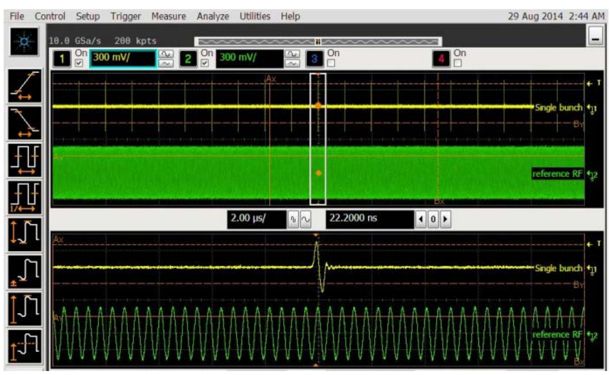

Figure 7: Single bunch mode.

The TOF device measures the energy of the high intensity beam.

As the energy is calculated from the average values of the signal phases, the repetition rates decrease the average module and increase the phase uncertainty.

The beam intensity average has to be higher than 10 µA that means an intensity peak higher than 1 mA for a bunch repetition rate of 100.

ALARM CONTROL SYSTEM

The energy measurement is non interceptive, in order to control continuously beam parameters and beam losses.

Alarm System

The TOF alarm management system is based on a microcontroller, which calculates the beam velocity. This velocity is compared to a threshold of the Enlarged Protection System (EPS) and to thresholds of the Thermal Protection System (TPS) [5].

The EPS threshold is defined following the operation schedule. An alarm is sent by the TOF device to the EPS when the velocity exceeds this threshold.

TPS thresholds are calculated from the beam velocity measured and memorized during the beam tuning at the LINAC exit. A fork of few percents in plus and in minus gives a maximum and minimum thresholds. When the velocity exceeds the maximum threshold or is less than the minimum, a cut-off request is sent to the TPS.

Threshold Guarantee

For each new beam, the thresholds have to be sent to the HEBT TOF device. Following the FMEA [6], a robust transfer protocol was developed to guarantee that the threshold values used by the energy control device are correct.

The thresholds for beam loss detection have to be recalculated for each beam, due to the specificity of SPIRAL2, which accelerates a large range of beams, with various intensities and energies. The general control system calculates these thresholds.

CONCLUSIONS

Currently, two TOF systems are realized to be used during the MEBT commissioning in the BTI (Bench of Intermediate Test). The monitor interface is operational and will allow us to qualify the beam at the RFQ exit.

The TOF electronic digitalization, which works with under sampling, can measure beam phases in the single bunch mode.

Following the FMEA and the design review in 2014, the HEBT electronic device is under development. The new design is an upgrade of the BTI device.

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