Division Accélérateurs
Groupe Electronique Accélérateurs
(june 2014)

Beam Diagnostics

Les accélérateurs ont besoin de diagnostics de faisceau afin de pouvoir caractériser le faisceau et déterminer sa position. Dans le cadre des projets IPHI (Injecteur de Protons à Haute Intensité) et SPIRAL2, nous avons développés des compétences sur différents diagnostics de faisceaux tels que les moniteurs de position, les transformateurs d'intensité et les électrodes de temps de vol.

1 Beam Position Monitor for SPIRAL2

In the framework of IPHI and SPIRAL2 projects, we have developed two types of BPM. For SPIRAL2 project, the ion beams characteristics are : 1 mA for Q/A= 1/3 ions at 14.5 MeV/amu and 20 MeV /amu for deuterons.. A doublet of magnetic quadrupoles is installed between the cryomodules for the transverse horizontal and vertical focusing of the beam.

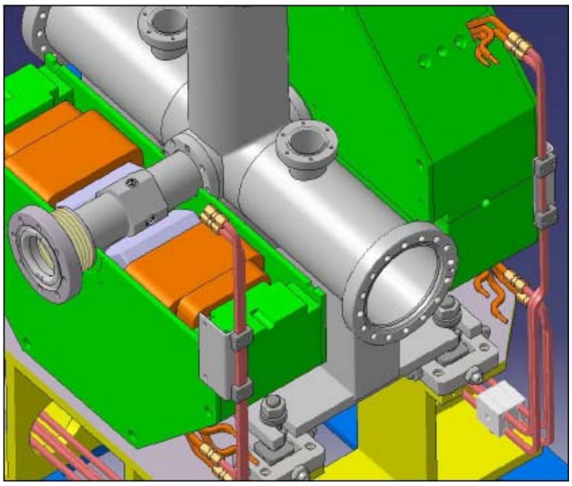

Figure 1 Details of diagnostics implementation inside a quadrupole with on the left the BPM.

In order to save room, the Beam Position Monitors (BPM) are inserted in the vacuum pipe inside the quadrupoles which will be buried at their turn in the quadrupole magnet. The LINAC will be equipped with 20 of these BPM sensors.

A BPM sensor has four electrodes that couple to the beam through the image charge produced by the beam. Due to the beam characteristics, the design criteria of the BPM sensor were the followings:

- The extremely compact section at room temperature of the LINAC leads to install the BPM in one arm of the « diagnostic box ».
- The BPM sensor must exhibit a high resistance to baking at 125 °C and withstand the high activation level of the LINAC environment. Therefore few materials may be considered: stainless steel and ceramic.

After considering several possible BPM designs, the best solution is the capacitive electrode (figure2). The four 48 mm diameter electrodes (two diametrically opposite horizontal locations for the horizontal plane and two other ones at 90° for the vertical plane), are located in a small cavity flush with the inner wall of the chamber. In this way no disruptive resonance is expected.

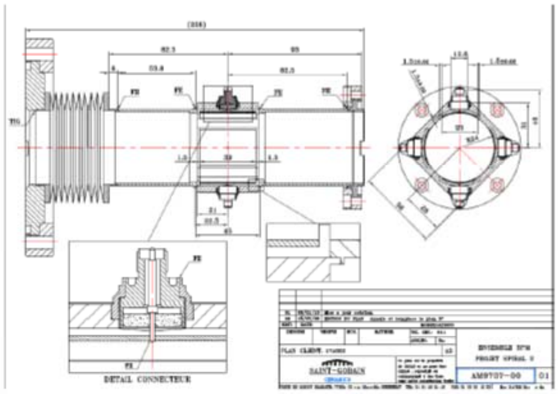

Figure 2 Capacitive electrode assembly

Each electrode is 39 mm long and covers a subtended angle of 60°. They are brazed at their center on the end of the central rod of a 50 Ω feed-through. The other end of this feed-through is terminated with a re-verse male polarity 50 Ω SMA connector so as to fit in the available tiny space left by the poles of the quadrupole.

Figure 3 Test benc for BPM block

All the BPM for SPIRAL2 were delivered and will be integrated in the quadrupole in 2014.

2 Diagnostics for IPHI

In the case of IPHI project, the High Energy Beam Transport line is installed and the commissioning is planned for end of 2014. This line is composed by several diagnostics due to the high intensity of the beam (100mA max).

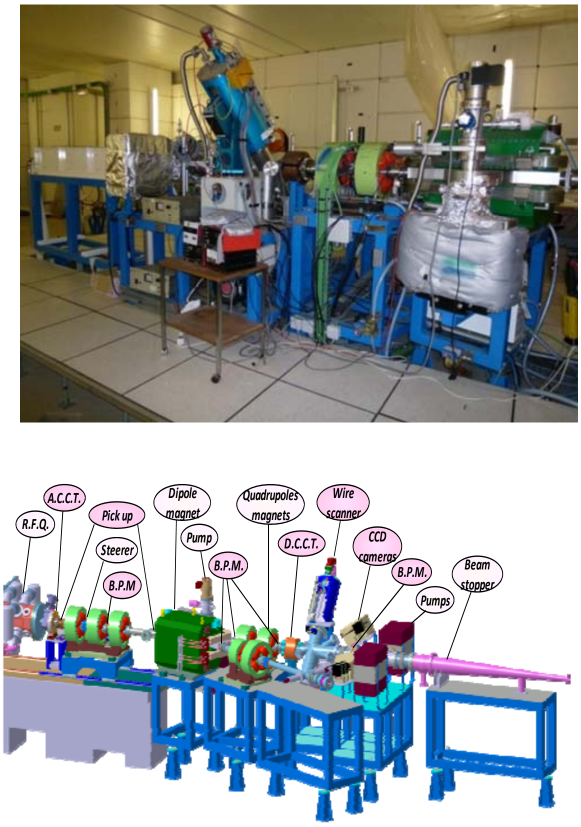

Figure 4 HEBT line

For example, we will develop the Time Of Flight (TOF) diagnostic which allows to measure the beam energy:

The main request is to measure the protons energy after the RFQ via a non-interceptive way. The precision required is 10^{-3} i.e. ± 0.1% of the nominal energy (3 MeV). The beam is composed of particles bunches at the RFQ frequency (352.2 MHz). Although the beam intensity is 100 mA, the measurement can be done in the 10 mA – 100 mA range. The system has to operate in pulsed mode with a pulse width of 100 µs and with a variable repetition period.
The principle of this method is to determine the phase difference ϕ at the frequency f between the two electrodes separated by a distance L. Thanks to this phase measurement we deduce a time t, t is the time that a bunch takes to do L. Knowing t and L, we can calculate the particles bunch velocity v and the particles kinetic energy Ec is deduced from the velocity β.We observe the bunch thanks to the electromagnetic field due to the charged particles. This charged particles bunch moves in a vacuum line and creates a charge on the wall tube with an opposite sign. We determine the intensity with an electrostatic electrode put around the beam into the vacuum tube but isolated from it.The voltages received on the electrodes depend on the Gaussian standard deviation of the protons bunch. This standard deviation varies with the electrode location. Indeed, the space force charge and the energy scattering in a bunch make the bunch longer along the beam line.After an established time rather short, we can observe that the voltage measured is a sine line. We measure the phase difference between these sine lines.Taking into account the powers levels for a 10 mA – 100 mA intensity range, the cables attenuation, the electrodes responses, the system should be able to measure the phase differences for a -2.4 dBm / -47 dBm power range.

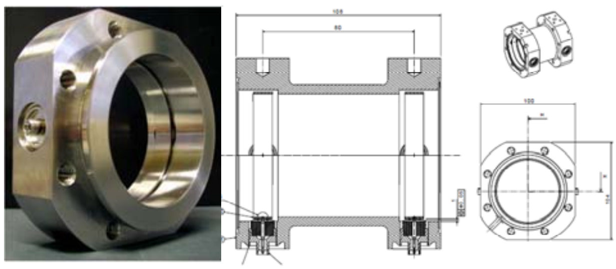

Figure 5 Simple Electrode picture and Double electrode sketch

Others developments are describe into several articles, accessible via the web links on the diagnostics web page.