RECENT EVOLUTIONS IN THE DESIGN OF THE FRENCH HIGH INTENSITY PROTON INJECTOR (IPHI)

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Abstract

In 1997, the two French national research agencies (CEA and CNRS) decided to collaborate in order to study and construct a prototype of the low energy part of a High Power Proton Accelerator (HPPA). The main objective of this project (the IPHI project), is to allow the French team to master the complex technologies used and the concepts of controlling the HPPAs. Recently, a collaboration agreement was signed with the CERN and led to some evolutions in the design and in the schedule. The IPHI design current was maintained at 100 mA in Continuous Wave mode. This choice should allow to produce a high reliability beam at reduced intensity (typically 30 mA) tending to fulfill the Accelerator Driven System requirements. The output energy of the Radio Frequency Quadrupole (RFQ), originally set to 5 MeV, was reduced to 3 MeV, allowing then the adjunction and the test in pulsed mode of a chopper line developed by the CERN for the Superconducting Proton Linac (SPL). In a final step, the IPHI RFQ and the chopper line should become parts of the SPL injector. In this paper, the IPHI project evolutions are reported together with the construction and operation schedule.

INTRODUCTION

The funding difficulties encountered in years 2002 and 2003 led us to redefine the characteristics and the performances of the accelerator. We also sought to develop this important R&D effort by a possible later use of this machine as injector of a high energy Linac. CERN developing such a linac (Linac 4 and SPL projects), we decided to reduce the final energy of the RFQ cavity to fit the one of the CERN projects.

Objectives

The fundamental objectives of the IPHI project as defined from 1997 [1] have been maintained, especially those of a feasibility demonstrator of the HPPAs and those linked to the Accelerator Driven Systems (ADS) problematics. The beam characterization in pulsed mode as well as in CW mode keeps still the main place. A long duration run with a reduced intensity beam (typically two or three months uninterrupted) will end the test period at Saclay. The installation of the main parts of IPHI at CERN in 2007 is a new challenging objective which demands to start the RF conditioning at the latest during the first semester of 2006.

New performances

The main change concerns the output energy of the RFQ cavity which decreases from 5 MeV to 3 MeV. The nominal intensity is maintained at 100 mA in CW mode. The construction of a second accelerating stage – a drift tube linac - which had been chosen in the first IPHI design to increase the energy from 5 to 11 MeV is abandoned. Nevertheless, a short hot model was developed, built and successfully tested at nominal electric field to validate the technological choices [2].

EVOLUTION OF THE PROJECT

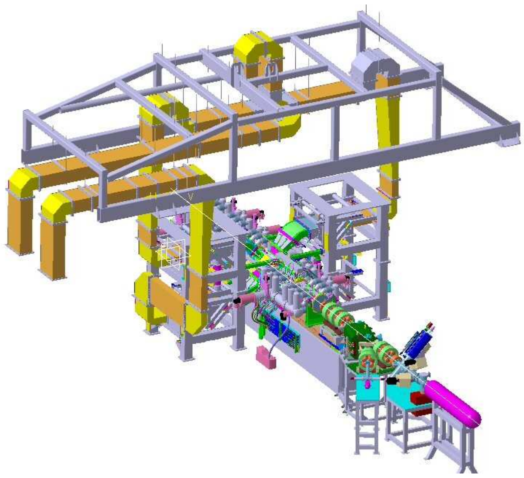

Figure 1 : 3D view of IPHI showing the RFQ and its pumping system, the diagnostics line and the RF distribution layout.

RFQ

The initial design of the RFQ comprised 8 sections of 1 meter long each assembled in 4 segments separated by coupling plates [3]. As the energy at the exit of the third segment was calculated to be 3 MeV (table 1), the energy modification has consisted mainly in suppressing the last segment. Obviously, to provide a good matching with the diagnostics line, the end of the sixth section was modified to integrate a fringe field and a Crandall cell.

Table 1: IPHI RFQ parameters

Structure	4 vanes
Frequency	352.2 MHz
Total length	6 m, (6 one meter sections)
Resonant coupling plate	2
Vane voltage	87 to 123 kV (Kp ≤ 1.7)
Output energy	3 MeV
Theoretical transmission	99.1 %(accelerated)
Beam power	300 kW
Max total power	1200 kW (two 1.3 MW klystrons)

RF ports

In the original configuration, the RF power provided by the 2 klystrons was injected in the cavity by 4 RF ports disposed on 2 different sections. For the new design (figure 2), we chose to keep a maximum power level per port almost identical to the original one (400 kW). So, the number of ports was reduced from 4 to 3, all arranged on the fourth section.

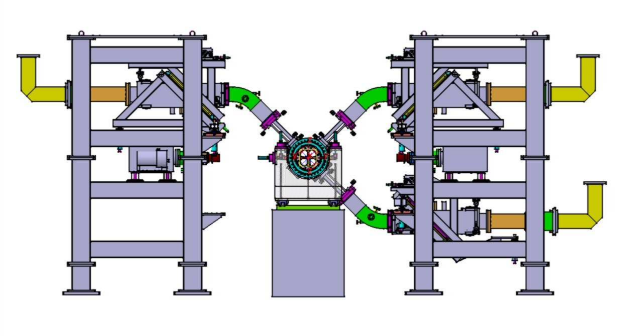

Figure 2 : Arrangement of the three RF ports on the fourth section

The original design of the RF ports comprised a ridged taper. The experimentations carried out on the RFQ cold model (figure 3) showed that this configuration does not allow a good matching. It is planned to replace the taper by a quarter wave length transformer. The first measurements done seem to confirm the validity of this choice.

Figure 3 : View of the RFQ cold model

New design of the diagnostics line

A major simplification of the beam diagnostics line was decided to gain in compactness and cost. The high power beam dump is now located in straight line about six meters downstream of the RFQ. New beam dynamics calculations allowed then to use a set of existing compact magnets (figures 1 and 6).

Energy spread

The energy spread measurement planned initially at full CW beam will be performed only at low duty cycle (10^{-3}). The system chosen is a classical spectrometer and comprises a 28.5° dipole, two slits and a Faraday cup. By choosing properly the couple of slits, the resolution should be better than 10^{-3}.

Beam dump

Due to the reduction of the beam energy, the beam dump has now to withstand a maximum beam power of 300 kW plus some safety margin. Beam dynamics calculations show that a conical shape is acceptable and allows limiting the power density to 120W/cm^2 (figure 7). Thus, a monophasic cooling system combined with a static pressure of 2 or 3 bars can be used instead of a biphasic one as envisaged previously.

The material intended as active part of the beam dump is not yet decided. An experiment is in progress on the Van de Graff tandem accelerator of IN2P3-Orsay to determine the best choice at the energy of 3 MeV from the radioactivity point of view.

CONSTRUCTION STATUS

Source

The proton source SILHI and its LEBT developed at Saclay produces now routinely a high intensity beam (100 mA @ 95 keV) fulfilling the IPHI requirements. Several long duration tests at different beam currents showed good performances in term of reliability and availability [4]. SILHI is presently used to optimize diagnostics for the high energy line.

RFQ

The fabrication of the RFQ sections is in progress. The first section has been already machined and brazed (figure 4). It is a great success in terms of achieving the mechanical tolerances however a problem encountered during the brazing process required to carry out several brazing repairs. Precise vacuum tests will be made soon to validate this section. The second section delivery is expected at the end of 2004 and the last one at the end of 2005.

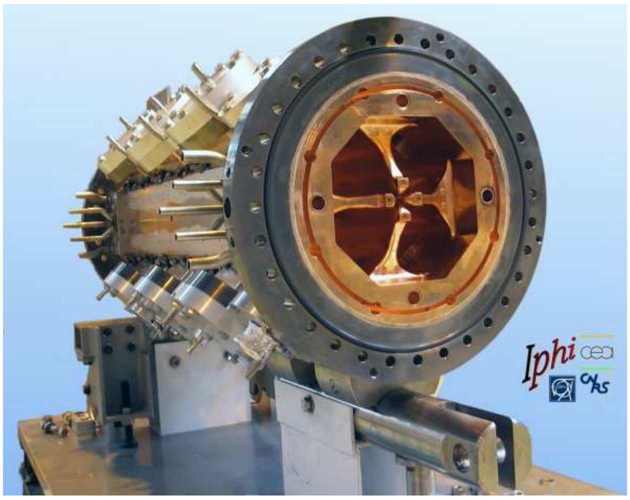

Figure 4 : the first RFQ section viewed from the beam entrance side

RF systems

The power RF system uses two 1.3 MW/352 MHz Thales™ klystrons coming from the CERN LEP. The installation of this system is presently in progress (figure 5) and first tests using a salt water 1.4 MW load are planned during the last trimester of 2004.

Figure 5 : View of the RF power system assembly

Diagnostics line (figure 6)

The mechanical drawings of the main parts of the diagnostics line are completed. All magnets are available and power supplies will be ordered this year. The fabrication of most of the beam diagnostics units is in progress [5], [6]. Some of them as wire scanner or Beam Position Monitors have been already delivered and are under test.

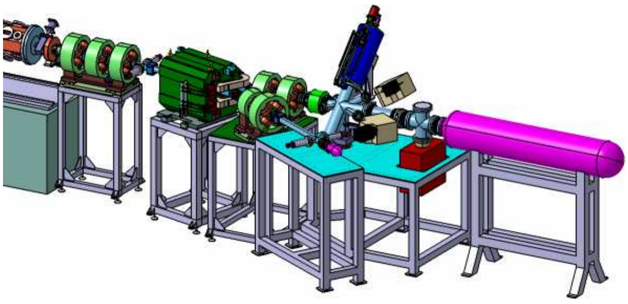

Figure 6 : 3D representation of the new diagnostics line

Beam Dump

The beam dump is presently in a development process. Beam dynamics and thermo mechanical calculations have been performed which validate the design (figure 7). Massive nickel or nickel plated copper seem to be good candidates as inner tube. This has to be confirmed from activation and vacuum points of view. The technical specifications should be completed for the end of 2004.

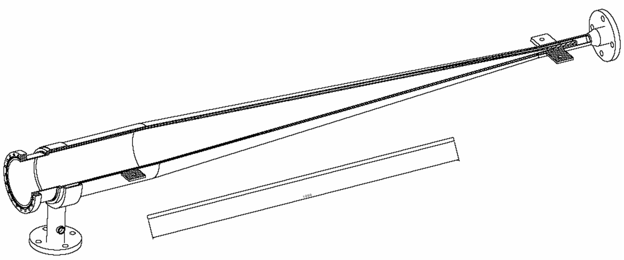

Figure 7 : 3D view of the conical beam dump showing the water inlet and outlet.

Building and utilities

The IPHI building is now available. The construction of the radiation shielding will be spread over the twelve next months. The general cooling system will be operational from October 2004 to allow the klystron power tests to be undertaken.

CONSTRUCTION SCHEDULE

The IPHI construction schedule such as presented (table 2) is fairly tight. First beam is expected by June 2006. The fabrication of the RFQ sections is clearly on the critical path. From the delivery completion up to beam operation, four months at least are necessary to assemble, to tune and to condition the RFQ cavity. Moreover, the CERN team is strongly interested to have a test stand operational before the end of 2007.

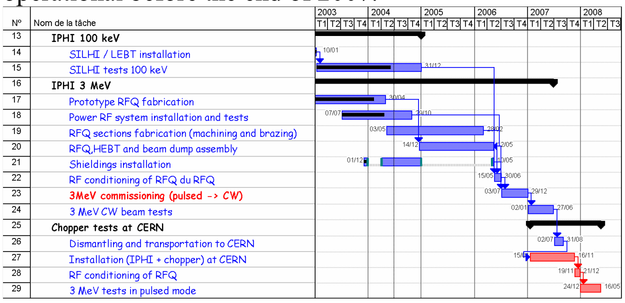

Table 2 : IPHI schedule (2003 – 2008)

CONCLUSION

Since 1997, the IPHI reference design and the performances have several times changed. 2003 was an important year for the project. The decision to insure a future to IPHI after the tests completion at Saclay - by using the main components as part of a high energy linac - created a new dynamic. It also permits to obtain complements of financing. In exchange, the schedule - and especially the period allocated to the commissioning and to the beam characterization in CW mode as well in pulsed mode - is limited at the best to one year.

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