INSTALLATION OF THE FRENCH HIGH-INTENSITY PROTON INJECTOR AT SACLAY

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Abstract

The installation of the French high intensity injector "IPHI" is in progress on the Saclay site. The source, RF power system, cooling plant, diagnostics line as well as shielding are now in place. The first section of the RFQ cavity is installed on its support. Commissioning is planned during the first half of 2007. At the beginning of 2008, a beam chopper, developed at Cern, will be inserted between the RFQ and the diagnostics line and tested with a proton beam. At the end of 2008, a part of IPHI will be moved from Saclay to Cern. New tests, intended for the LINAC4 project, will be carried out using a negative hydrogen beam. This paper describes the fabrication and assembly operations. The future of IPHI at Cern is evoked.

INTRODUCTION

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). This part is considered as one of the more difficult to develop in so far as it conditions the optical quality of the beam and thus the reliability, availability, maintainability (RAM) of the entire accelerator.

Evolution of Performances [1]

The performances foreseen at the beginning (100 mA at 11 MeV) have been reviewed several times. The construction of the DTL has been abandoned and the final energy of the Radio Frequency Quadrupole cavity (RFQ) was reduced from 5 to 3 MeV. The fundamental objectives of the IPHI project as defined from 1997 [1] have nevertheless been maintained, especially those of a feasibility demonstrator for 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 months uninterrupted) will end the CW mode test period at Saclay.

Cern Chopper Line Tests at Saclay

Due to technical difficulties in the fabrication of the RFQ, the schedule has been drastically delayed. A part of the tests planned to be carried out at Cern after the dismantling of IPHI, will therefore be done at Saclay. The diagnostics line will be pushed few meters downstream and the fast beam chopper developed at Cern will be installed just at the RFQ output and tested with a low duty cycle proton beam.

FINAL IPHI DESIGN

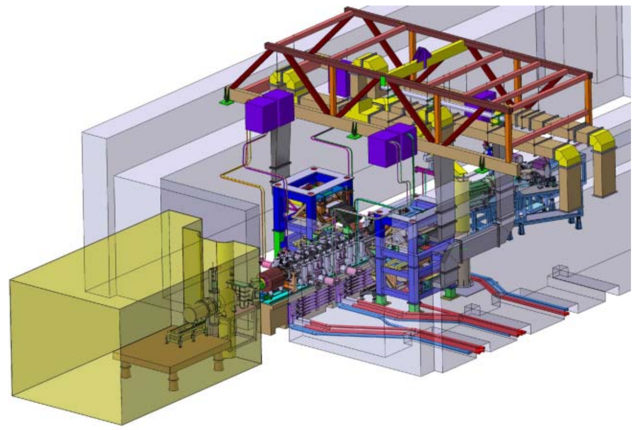


Figure 1: 3D view representing the final arrangement of the IPHI injector.

The 3D view of the injector (Figure 1) shows the final arrangement of IPHI. The ECR source located on a high voltage platform is linked to the RFQ cavity through a magnetic focusing, low energy beam transport line (LEBT). A crossbar system supported by the biological shielding holds the RF distribution as well as the RFQ cryopump compressors. The supports (in blue) located on both side of the RFQ, are especially designed to fully compensate the weight of the RF feeders. The constraints on the RFQ RF ports are thus eliminated.

STATUS OF THE INSTALLATION

Source and LEBT

Figure 2: View of the source and the LEBT at Saclay. A part of the LEBT is located on the RFQ concrete support.

The ECR source, developed for IPHI, is for some years producing routinely beam currents of 130 mA. It has already demonstrated on several occasions a very high reliability and a very high availability. The LEBT assembly (Figure 2) is now completed up to the final H_2^+/H_3^+ collimator facing the RFQ. Recently, an automatic beam transmission optimization procedure has been successfully tested and a current of 93 mA has been injected through the collimator representing a transmission ratio of about 85%. The beam is also used to optimize diagnostics for the high energy line and to carry out measurements linked to fundamental studies on space charge compensation [2].

RFQ

The IPHI RFQ is made up of 6, one-meter sections assembled in three coupled segments by two coupling plates. The coupling plates as well as the end plates are equipped with four bars insuring the tuning and the damping of the parasitic resonance modes. Each section is machined in four parts (the vanes) which are brazed together in a horizontal furnace after RF checking. In a second step, the pumping ports, the tuner ports, and all the flanges are brazed in a vertical furnace (Figure 3).

The first section of the RFQ is available and already placed on the concrete support. The fabrication of the second one is also complete but final vacuum tests have revealed some leaks for which a repair will be necessary.

Figure 3: The second section of the IPHI RFQ entering the brazing furnace.

The third and fourth sections are machined and are ready for brazing at Cern. The vanes of the last two sections are ready for the final machining. The machining process should be completed by the end of October 2006.

RF Systems

The total RF power necessary to energize the cavity and to accelerate 100 mA of protons at 3 MeV is about 1.2 MW. The RF power system of the RFQ is based on the use of two 1.3MW klystrons working at 352 MHz in CW mode.

The RF system itself, the high voltage power supply, and the cooling plant are already installed (Figure 4). The crossbar RF distribution system and the RF feeder supports are also assembled. First tests of the klystrons on the “salted water” load are now planned for the last trimester of 2006.

Figure 4: View of the RF power system showing the two klystron lines, the circulators and the 1.4 MW, salt water load.

RF Tuning System

Since years, the tuning process of the RFQ is studied and a six-meter long cold model has been developed (Figure 5). Recently, the tuning of the cold model has been successfully realized. In six iterations only between measurement by “beadpull” method, RF computing and tuner adjustment, the cavity has been tuned with an accuracy better than +/- 1% compared to the theoretical curve.

Figure 5: Six-meter long cold model of the RFQ used to develop the tuning process of the IPHI cavity.

Diagnostics Line and Beam Dump

Since the primary objectives of IPHI are of characterizing and optimizing the high intensity proton beam, a set of diagnostics were developed [3].

The energy will be measured by the time of flight method on the beam bunches. The energy spread will be measured with a spectrometer, but at low duty cycle only. DCCT, ACCT, and calorimetric measurements on the beam dump will give the intensity along the line. Beam position will be measured by a set of button position monitors (BPM). A wire scanner (WS) located close to the beam dump will allow the acquisition of the profile at low duty cycle. Developments are still in progress to use a CCD camera for the profiles of CW beam.

Most of those diagnostics units are already available. The WS unit has been tested at 95 keV on the LEBT. Likewise, very interesting profile measurements have been performed using an optical Doppler method on the low energy beam; this method allows separating the three main hydrogen ions present in the LEBT beam. Most supports and magnets of the diagnostics line are installed (Figure 6). The beam dump with its cooling system is expected in September 2006.

Figure 6: Installation in progress of the diagnostics line with the wire-scanner on the left.

Conventional Facilities and Nuclear Safety

Conventional facilities for such a machine represent a very important part of the project. The building conversion as well as the shielding construction or the utilities installation… are now practically completed. The specific RFQ temperature control system will be operational before the end of 2006.

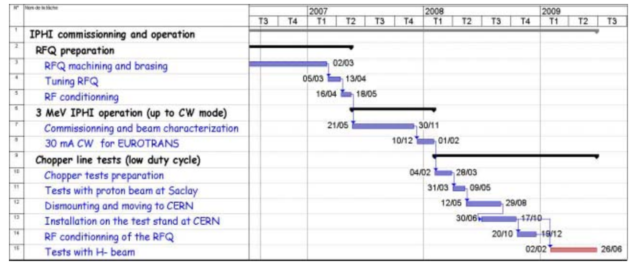
Figure 7: View of the chilled water plant connected to the RFQ temperature control system.

The safety assessment document was validated by the nuclear safety authorities by the end of 2005 and the period of official advertisement took place during past May. The administrative licence should be delivered before the end of 2006.

INSTALLATION AND OPERATION SCHEDULE

The completion of the installation of IPHI is planned for the second trimester of 2007(Table 1). The start of the RF conditioning process will depend on the delivery of the RFQ modules and particularly on the brazing schedule.

Table 1: IPHI Schedule 2006 – 2009



IPHI AT CERN

The final energy of the IPHI RFQ has been adapted to the Cern requirements in order to permit beam tests of the fast chopper (rise time lower than 2 ns), developed in the framework of the Linac4 studies. At the end of these tests, performed at Saclay first then at Cern, the IPHI RFQ will become the first accelerating cavity of the Linac4 injector if its construction is decided.

CONCLUSION

The IPHI project was started in 1997. The very ambitious performances envisaged at that time (100 mA CW at 12 MeV), have been reduced several times and finally, the output energy was set to 3 MeV. The acceleration of a high intensity beam in CW mode enforces strong constraints on the main component of the injector: the RFQ cavity. Machining the elementary pieces, drilling the cooling channels, or brazing turned out to be very difficult in order to insure the final mechanical precision of the modules and thus the efficiency of the cavity. A set of powerful tools have been developed to design the cavity itself [4] as well as to tune it with the high precision needed [5]. Generally speaking, a very important know-how of the technologies used for these cavities has been acquired.

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