STATUS REPORT ON THE CONSTRUCTION OF THE FRENCH HIGH INTENSITY PROTON INJECTOR (IPHI).

P-Y Beauvais for the CEA and CNRS IPHI team, CEA Saclay, DSM/DAPNIA 91191 Gif sur Yvette Cedex

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)[1]. The main objective of this project (the IPHI project), is to allow the French team to master the complex technologies used and the control concepts of the HPPAs. The applications of such accelerators are numerous : Accelerator Driven Systems, irradiation tool, condensed matter studies, radioactive beam, muon or neutrino production… This demonstration linear accelerator, the assembly of which is presently in progress on the Saclay site, could reach in a final state a power of more than 1 MW for an energy of about 10 MeV (not presently funded). In a first step, the energy beam will be limited to 5 MeV. This paper reports on the state of the construction and assembly of IPHI. The planning of assembly and starting is also presented.

1 INTRODUCTION

The majority of the applications of HPPAs require intensities ranging from about 1 to 100 mA (see table 1) and some of them in CW mode. In order to insure a good maintainability and reparability of these machines all along their operation life, it is imperative to limit drastically to an acceptable level the activation of the accelerating structures. Moreover, for applications like Accelerator Driven Systems (ADS), reliability and availability are of the highest importance. These requirements show how the construction of a low energy, high intensity demonstrator is essential to measure and optimize the beam characteristics. The only good way (but not sufficient) to satisfy those demands is to design all the subsystems of the accelerator with large safety margins compared to the operation conditions and to perform long duration qualification runs. This approach has been chosen to design IPHI.

2 IPHI OBJECTIVES

IPHI is a high intensity proton injector dedicated to be a prototype of the low energy part of HPPAs. The objectives were clearly defined from the very start of the project. These objectives should lead to a great mastery of technologies and control concepts of rising generation of accelerators by:

- Validation of beam dynamics and structure computer codes,
- Validation of the technological choices to have references for the future technical choices,
- Accurate characterization of the 5 MeV beam (then 10 MeV) to optimise all the rest of the accelerator,
- Development of methods to rise the nominal beam power and to restart the beam after failure,
- Development and test of specific beam diagnostics used for the tuning and the control of the accelerators,
- Training of a team holding a solid experience for the development and the adjustment of a high power accelerator

Table 1: Applications of the HPPAs

Application	Max beam power	Energy	Average current
Accelerator Driven Systems ↳ 100 MWth demonstrator ↳ Industrial Facility	 ~ 5 MW ~ 50 MW	 ~ 600 MeV ~ 1 GeV	 ~ 10 mA ~ 50 mA
Irradiation tool (IFMIF)	10 MW	40 MeV	2 x 125 mA
Condensed Matter Studies (SNS, ESS)	2 - 10 MW	1GeV	~ 5 mA
Radioactive Beams	> 200 kW	> 200 MeV	~ 1 mA
Muons, Neutrinos	4 MW	2 GeV	2 mA

3 GENERAL DESCRIPTION

IPHI is a High Intensity Proton Injector designed to accelerate a 100 mA, CW beam up to 5 MeV (see Figure 1) or 11.6 MeV by adding a DTL stage between the RFQ and the diagnostics line.

An ECR type source - the SILHI source [2] - was chosen for its well known qualities. SILHI produces a 130 mA, 95 keV proton beam with an emittance better than 0.15 π.mm.mrad (r-r', RMS normalized) with a very high reliability. The second accelerating stage is a four-vane type RFQ [3]. It consists of 8 long sections of one meter each resonantly coupled every two meters.

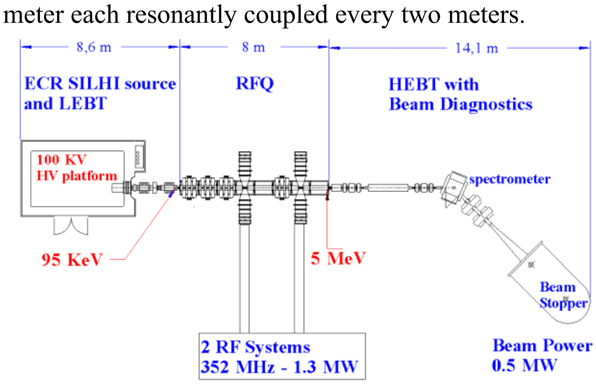

Figure 1 schematic representation of IPHI 5 MeV

This cavity is powered through four RF windows by two 1.3 MW klystrons lent by CERN. The total power dissipated in the copper is about 1.2 MW.

4 CONSTRUCTION STATUS

4.1 Source and Low Energy Beam Transport (LEBT)

The SILHI source constantly improved since its starting in 1996 produced till March 2002 a high intensity proton beam fulfilling all the IPHI requirements. The operation was stopped in April and will start again in late September 2002 after moving on the final IPHI test place.

4.2 RFQ Cavity

The beam dynamics studies are completed as well as most of the mechanical, thermal and stress studies. The drawings of the first sections are finalized. The delivery of the first section is expected for June 2002 (Figure 2) and that of the last one for mid 2004 [4] [5].

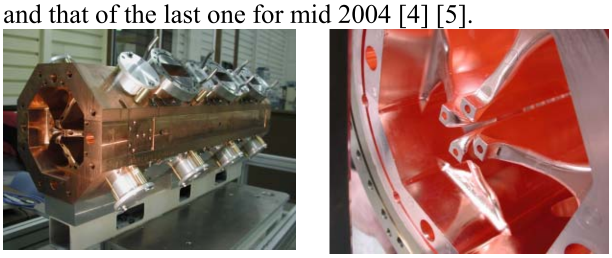

Figure 2 : First RFQ section before and after brazing

4.3 RF System

Most of the RF system components are coming from the CERN - LEP and are already available excepted the high voltage power supply (100 kV, 44A) which will be installed on its final place during the first trimester of 2003. The studies of the low level RF feedback and control system are in progress and a prototype will be tested during the second semester of 2002.

4.4 RFQ Cold Model

Since the voltage law all along the RFQ has to be tuned with a high accuracy, it has been decided to use automatic tuning procedures [6] based on the bead pulling principle associated with a powerful mathematical formalism [7], [8]. A six-meter long cold model was build to develop and validate these procedures [9], which were already successfully tested on two sections equipped with a coupling plate [10]. A procedure was also developed in order to check possible vane displacements during the brazing process [11].

4.5 RFQ Cooling System

The cooling system of the RFQ must fulfil two essential functions: to evacuate the 1.2 MW of power dissipated in the copper and to maintain, by adjustment of the temperature, the resonance frequency of the cavity.

Most of the parameters are known and the major components are already determined. The specifications document will be finished at the end of this year; manufacture will begin in 2003.

4.6 RFQ Vacuum

8 cryogenics pumps through 72 ports will provide a vacuum lower than 2.10^{-5} Pa in the RFQ [12]. The port and manifold conductances have been optimised to obtain a pumping speed of 5700 l/s at the cavity level for 12000 l/s at the pump level. The design and the mechanical drawings are completed. Most of the components are already available and fabrications will start soon this year.

4.7 RFQ Environment

Studies of general implantation of the machine and the biological shielding are in progress and will be completed at the end of this year (see Figure 3 below).

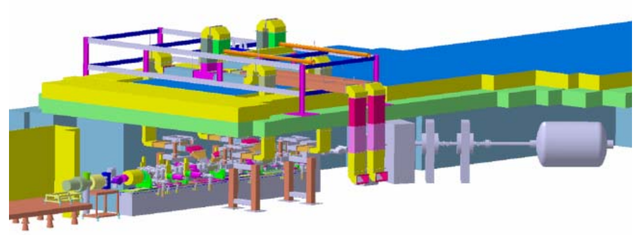

Figure 3 : General layout of IPHI.

4.8 HEBT and Beamstop.

The HEBT is dedicated to precise beam characterization at 5 MeV and 11.6 MeV. Beam dynamics studies are completed and mechanical drawings are in progress. Renovation and adaptation of dipole, quadrupoles and power supplies coming from the Saturne synchrotron is in progress.

A beamstop probably identical to that of American program LEDA will be manufactured in 2003.

4.9 Diagnostics

It is essential to have a broad panel of diagnostics to measure the beam characteristics (longitudinal, transverse, intensity…) under all the operating conditions of IPHI. Most of them are non-interceptive devices (CCD cameras, ACCT, DCCT, pick-up or strip-line electrodes) and are the subject of specific developments [13] [14]. Several prototypes were constructed; some have been tested on the LEBT.

4.10 Control System

The EPICS control system was chosen for IPHI. The SILHI source is used as test bench for all developments. A lot of very useful tools are already validated. On SILHI, control as well as automatic start and restart procedures allows a fully remote control of the operation.

4.11 Safety

The IPHI safety report is completed; it was transmitted to the French nuclear safety authorities. The authorization of exploitation is awaited for the end of 2003.

The radiation control system will use 10 detectors (7 γ and 3 neutron) laid out inside as well as outside the accelerator tunnel. The fabrication is in progress. The delivery is expected for the end of 2003.

4.12 Shielding Construction

The IPHI shielding is based on the use of standard concrete blocks and beams already available. The thickness of the vertical walls is 2.1 meters, that of the roof is 1.2 meters (see Figure 4).

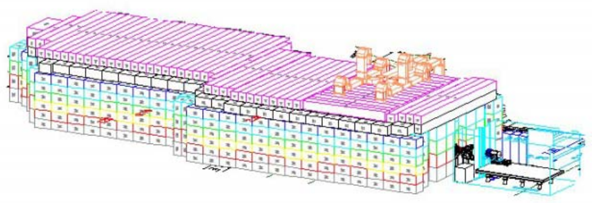

Figure 4 : 3D view of the radiation shielding.

4.13 Conventional Facilities

The mains loop (15 kV, 9 MW) will be powered in June 2002. The power supply distribution is in progress.

The secondary loop of the general cooling system is completed and will be tested during the next trimester.

The accelerator and RF buildings are available as well as the control room.

4.14 DTL short tank hot model

A short tank hot model of DTL (3 drift tubes) was build and will be tested at CERN in June at nominal electric field [15].

4.15 IPHI planning

The IPHI schedule (see table 2) is strongly depending on the RFQ sections delivery and could shift of several months in case of difficulties during machining or brazing processes.

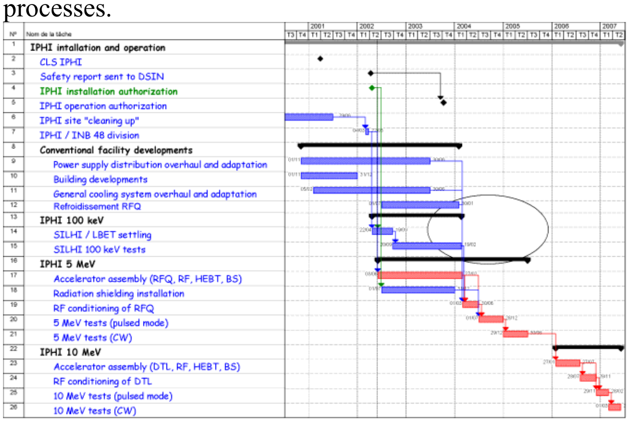

Table 2 : IPHI installation and operation schedule

5 SUMMARY

The IPHI project initiated in 1997 and mainly funded by the two French National Research Agencies, the CEA and the CNRS, is entering now in an active phase of construction. This project is technologically very challenging for the French team. First beam in pulsed mode is expected for the second semester of 2004. Numerous diagnostics devices should allow to perform very precise measurements of the fundamental beam characteristics, which are essential to design properly the future High Proton Power Accelerators.

REFERENCES

[1] LINAC Architecture for High Power Proton Sources, Jean-Michel Lagniel, CEA-Saclay, DSM-DAPNIA-SEA, France, LINAC 2000 conference.

[2] Saclay High Intensity Light Ion Source Status, R. Gobin et al., CEA, Gif-sur-Yvette; this conference THPRI003

[3] Status Report on the 5 MeV IPHI RFQ, R. Ferdinand et al., CEA, Gif-sur-Yvette; LINAC 2000 conference.

[4] Main steps for fabrication of the IPHI RFQ, M. Painchault, J. Gaiffier, C. Chauvin, J. Martin, CEA, Gif-sur-Yvette; LINAC 2000 conference.

[5] A MAFIA to I-DEAS Link for Thermal Studies in the IPHI RFQ, P. Balleyguier, CEA, Bruyères-le-Châtel; F. Launay, CNRS, Orsay; this conference.

[6] "A Fully Automated Test Bench for the Measurement of the Field Distribution in RFQ and Other Resonant Cavity", F. Simoens, F. Ballester, A. France, J. Gaiffier, A. Sinanna, CEA, Gif-sur-Yvette; this conference.

[7] "Theoretical Analysis of a Real-life RFQ Using a 4-Wire Line Model and the Spectral Theory of Differential Operators." F. Simoens, A. France, CEA, Gif-sur-Yvette

[8] "Electromagnetic Characterization of the First IPHI RFQ Section" F. Simoens, A. France, J. Gaiffier, CEA, Gif-sur-Yvette; this conference.

[9] "Simulations vs. Measurements on the IPHI RFQ Cold Model", P. Balleyguier, CEA, Bruyères-le-Châtel; F. Simoens, CEA, Gif-sur-Yvette; this conference.

[10] "A New RFQ Model applied to the Longitudinal Tuning of a Segmented, Inhomogeneous RFQ with Highly Irregularly Spaced Tuners", F. Simoens, A.France, J. Gaiffier, CEA, Gif-sur-Yvette; this conference.

[11] "A New RFQ Model Applied to the Estimation of Mechanical Defaults Distribution", F. Simoens, A. France, J. Gaiffier, CEA, Gif-sur-Yvette; this conference.

[12] Status of the Vacuum System for the IPHI Project, N. Rouvière, D. Francis, IPN, Orsay, this conference; WEPDO017.

[13] Optical Transverse Beam Profile Measurements for High Power Proton Beam, P. Ausset et al., IN2P3, IPN Orsay, this conference; THPRI066

[14] Transverse Beam Profile Measurements for High Power Proton Beam, P. Ausset et al., IN2P3, IPN Orsay, this conference; THBGB003.

[15] Thermo-mechanic of a DTL Vessel for the IPHI Project, M. Painchault, P-E. Bernaudin, CEA, Gif-sur-Yvette; this conference, THPLE031.