Reliability and Availability Aspects of the IPHI Project

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for the IPHI Team

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I P H I

Injecteur de Protons Haute Intensité

High Intensity Proton Injector

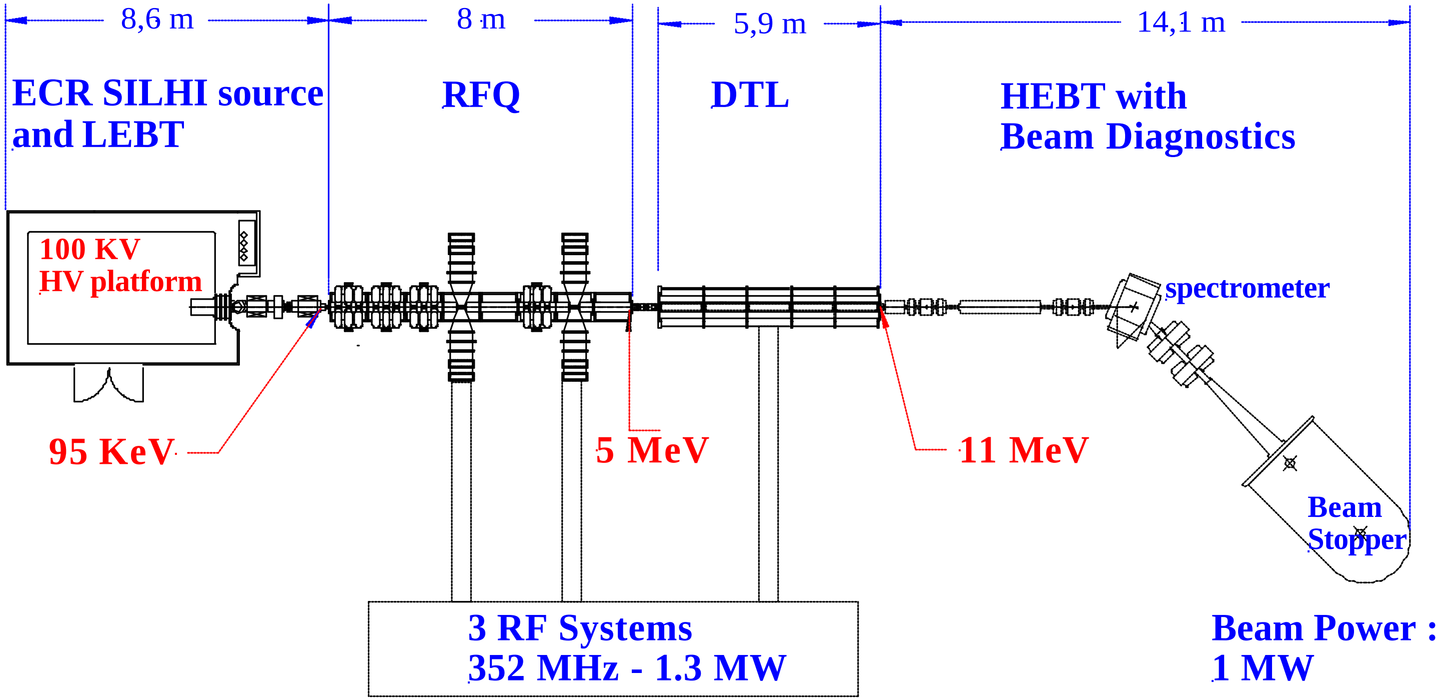
Prototype of the low energy part of HPPAs

Collaboration CEA/DSM – CNRS/IN2P3

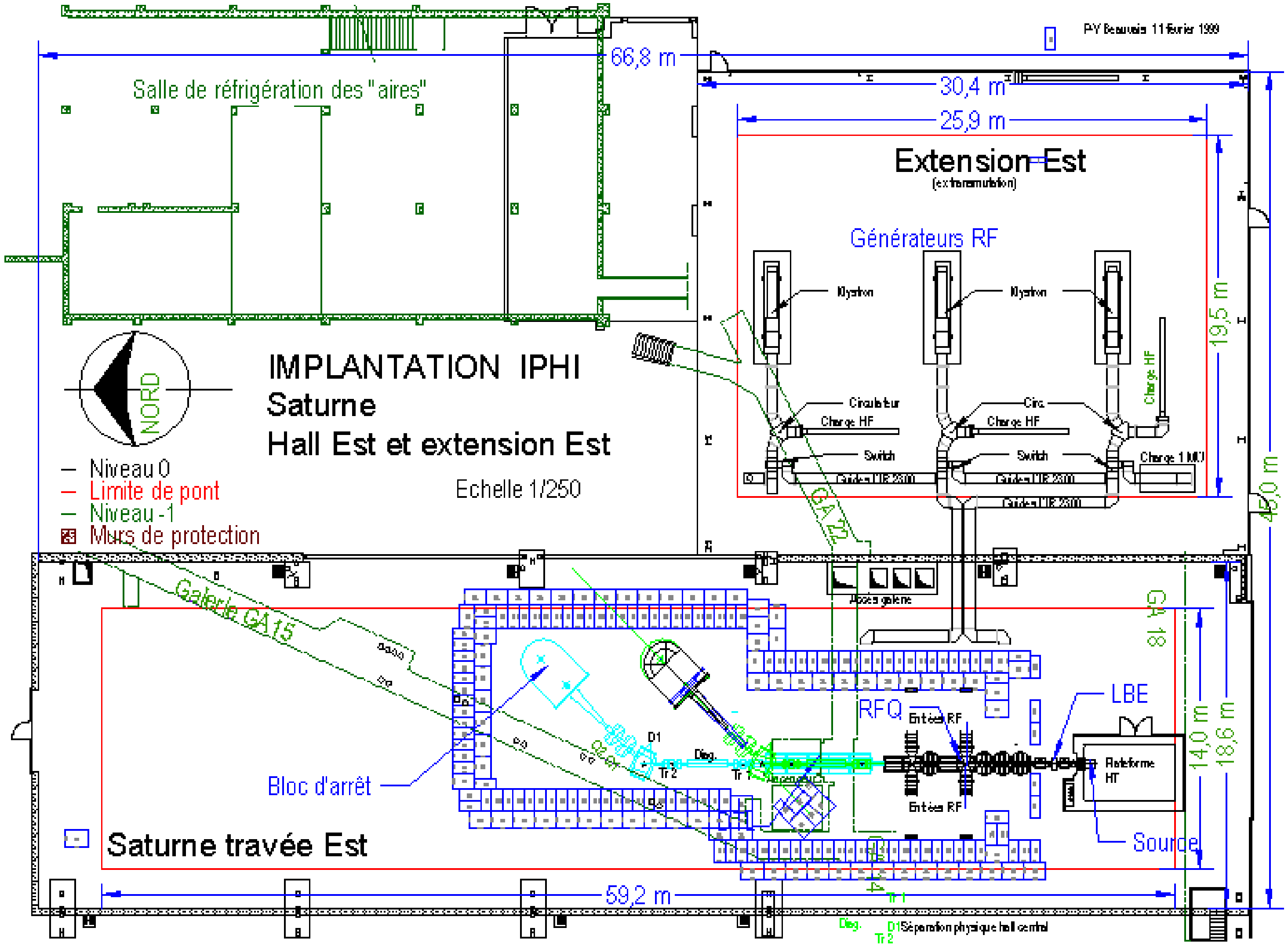
HPPA Applications

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 – 40 MW	~ 1 GeV	~ 10 – 40 mA
Condensed Matter Studies (SNS, ESS)	5 MW	1.3 GeV	3.75 mA
Radioactive Beams	> 200 kW	> 200 MeV	~ 1 mA
Muons, Neutrinos	4 MW	2 GeV	2 mA

IPHI Schematic layout of the Injector

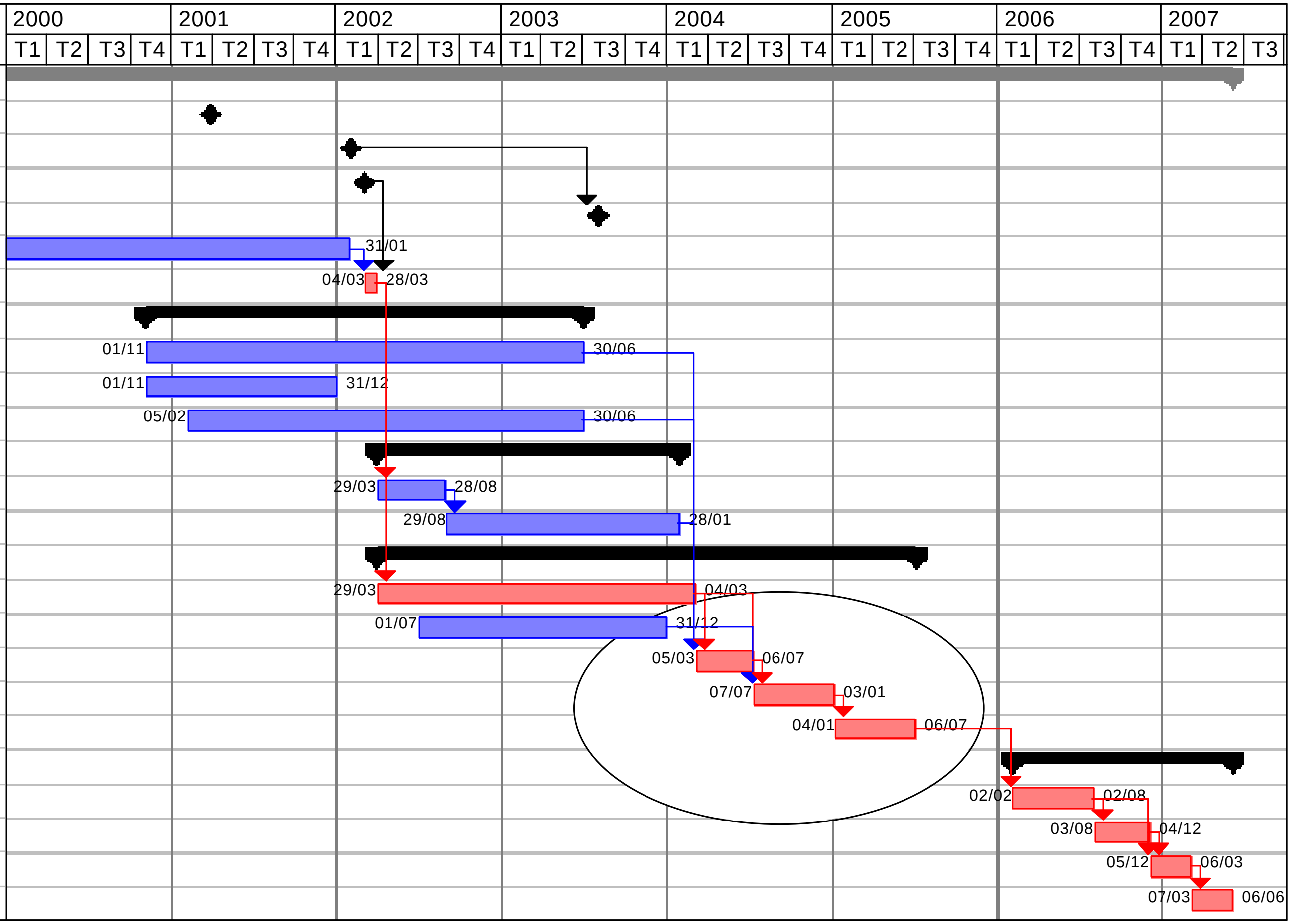


Beam Power :
1 MW


IMPLANTATION IPHI
Saturne
Hall Est et extension Est
Echelle 1/250
Niveau 0
Limite de pont
Niveau -1
Murs de protection
NORD
Salle de réfrigération des "aires"
66,8 m
30,4 m
25,9 m
Extension Est
Générateurs RF
Klystron
Circulateur
Charge HF
Switch
Charge 1 MW
19,5 m
45,0 m
GA 22
Galerie GA15
GA 18
Accès galerie
RFQ
LBE
Plateforme HT
Source
Bloc d'arrêt
Saturne travée Est
59,2 m
14,0 m
18,6 m
Séparation physique hall central
P-Y Beauvais 11 février 1999

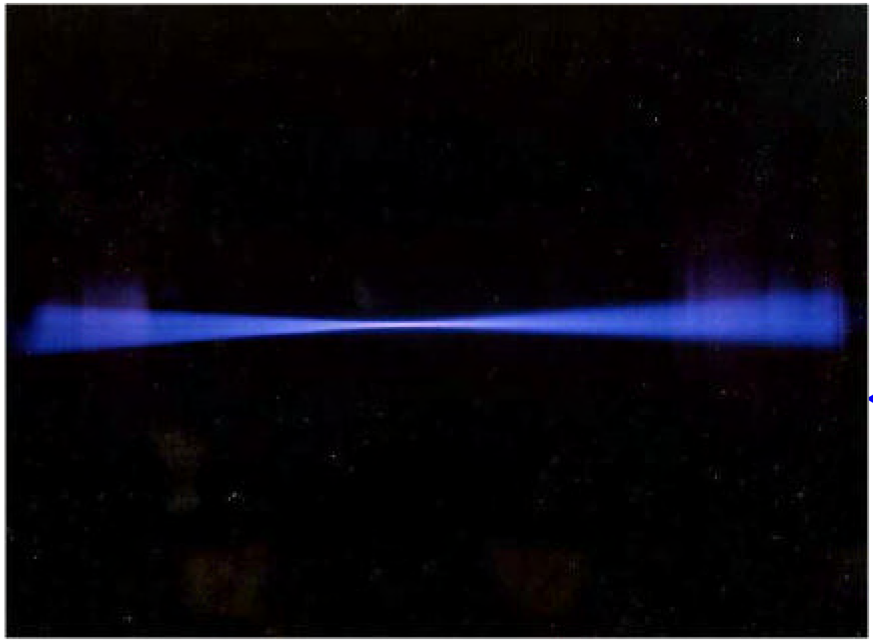
IPHI installation and operation schedule

Nº	Nom de la tâche
1	**IPHI intallation and operation**
2	CLS IPHI
3	Safety report sent to DSIN
4	IPHI installation authorization
5	IPHI operation authorization
6	IPHI site "cleaning up"
7	IPHI / INB 48 division
8	**Conventional facility developments**
9	Power supply distribution overhaul and adaptation
10	Building developments
11	General cooling system overhaul and adaptation
12	**IPHI 100 keV**
13	SILHI / LBET settling
14	SILHI 100 keV tests
15	**IPHI 5 MeV**
16	Accelerator assembly (RFQ, RF, HEBT, BS)
17	Radiation shielding installation
18	RF conditioning of RFQ
19	5 MeV tests (pulsed mode)
20	5 MeV tests (CW)
21	**IPHI 10 MeV**
22	Accelerator assembly (DTL, RF, HEBT, BS)
23	RF conditioning of DTL
24	10 MeV tests (pulsed mode)
25	10 MeV tests (CW)



SILHI source and LEBT

- **(100 keV, 100 mA CW)**
- **tests and optimization in progress at Saclay**



Proton beam at cross-over
6 kW on few mm^2

SILHI / IPHI technological choices

- Large safety margins on all LVPS and HVPS
- Optimization of PS air or water cooling
- Separate cable path and shielding for signals and power
- Galvanic insulation of analog and digital signals
- Use of EMI hardware especially for all sensitive electronic devices
- Minimization of electric fields between extraction electrodes (electrode shape optimization)
- Development of EPICS controlled automatic start/restart procedures
- Development of beam current feedback
- Development of specific beam diagnostics

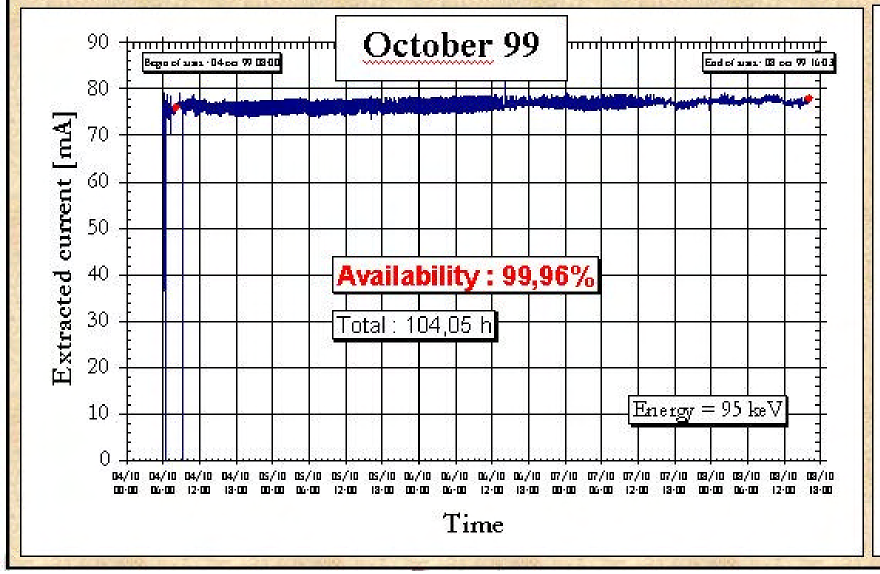
Reliability tests

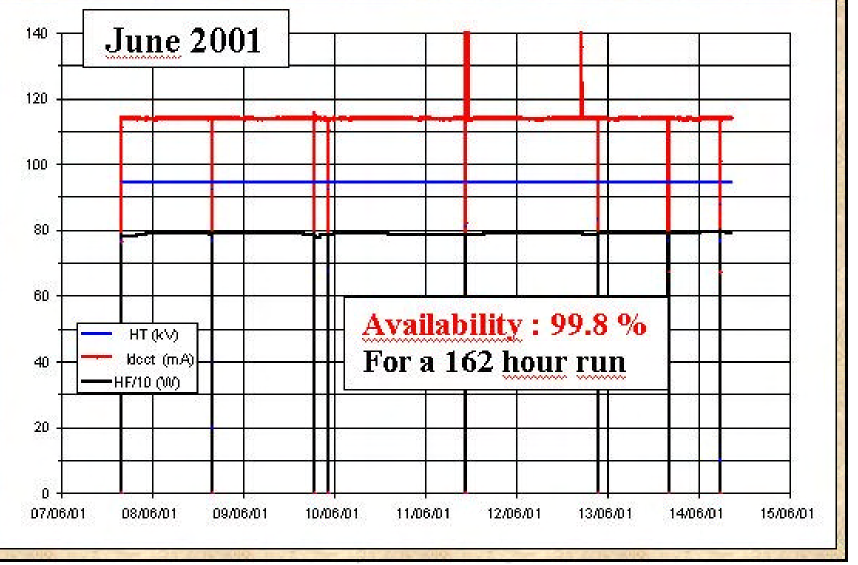
Parameters	Déc. 97	Mai 99	Oct. 99	March 01	June 01
Energy (keV)	80	95	95	95	95
Intensity (mA)	100	75	75	118	114
Duration (h)	103	106	104	336	162
Beam off number	53	24	1	53	7
MTBF (h)	1.75	4	n. appl.	≈ 6	23.1
MTTR (mn)	6	5.3	2.5	≈ 18	2.5
Uninterrupted beam (h)	17	27.5	103	25	36
Availability (%)	94.5	97.9	99.96	95.2	99.8

5 reliability tests have been performed :

3 with a limited extracted beam (old extraction system)
and the 2 last ones with the new system which limits beam losses on the electrodes.

A new run will be performed at~60 mA at the beginning of 2002.





SILHI reliability tests review

- **More than 1000 hours of continuous operation already performed during 6 separate tests.**
  - Almost all the beam interruptions are due directly or indirectly to HV breakdowns inside the extraction electrode system.
  - Intermediate electrode fed by a “low current” (10 mA) HVPS constitutes a weak point which has to be fixed
  - No HV breakdowns without beam (after completion of the HV electrodes conditioning)
  - The breakdown rate seems to decrease rapidly when the beam current is decreased (to be confirmed by specific tests)
  - No PS failure due to HV breakdown
  - No PLC reboot due to EM disturbances
  - EPICS controlled automatic restart needs at least several seconds to recover the beam
    - A fast analog feedback could solve this problem (must be demonstrated)

RFQ cavity and RF system

- Experience from several laboratories shows that a large fraction of beam interruptions comes from an RF feed interruption due to :
  - Sparks inside the cavity induced by beam losses and/or low vacuum,
  - Vacuum bursts or spikes induced by sparks,
  - Multipactoring in the tapered wave guides at low power (< 200 kW),
  - Arcs in the RF windows,
  - Low level RF interrupted by a reflected power detection
  - Instrumentation fault (sensors, switches…)
  - Defect or failures on utility and ancillary systems
- Beam interruption probability can be minimized by choices concerning
  - the RFQ design,
  - The vacuum system design
  - The RF power distribution
  - The characteristics of the beam entering the cavity (emittance, aberrations,matching, alignment…)

IPHI RFQ choices (1)

- RFQ design
  - Very slow adiabatic beam bunching (gentle buncher)
  - Vane shape optimization (minimization of electric field)
  - Limitation of Kilpatrick (1.7)
  - Optimization of theoretical transmission (99.2%)
  - Safety margins (emittance, current)
- RFQ vacuum system
  - High pumping capacity (12000 / 5700 l/s)
  - Dry pumps and cryogenic pumps
  - Optimization of pumping ports design
  - No elastomer O rings
  - Minimization of desorption rate
    - UHV cleaning and conditioning rules
    - Possibility of heating up to 120°C (cavity under vacuum)

IPHI RFQ choices (2)

- RFQ RF system
  - Safety margins on RF windows (450 kW per window tested up to 900kW)
  - RF power coupling through only 4 tapered guides to work above multipactoring levels, (experince of LEDA)
  - Safety margins on klystron power (600 kW / 850 kW per klystron)
- Beam caracteristics
  - Improvement of emittance by optimization of extraction system,
  - Control of beam caracteristics at the RFQ matching point
  - reduction of optical aberrations by improvement of the space charge compensation (gas addition in the LEBT)
  - Use of total r – r' emittance instead of RMS emittance,
  - Development of non interceptive beam diagnostics and of beam intensity control devices

- **As prototype of the low energy part of HPPAs and especially of accelerators for ADS, Reliability, Availability and stability are of the major concern for IPHI.**
  - **These qualities have to be taken in account from the conception and development process**
- **As IPHI is a test facility, commissioning and operation periods will be essential to learn about and improve the weak points.**
  - **Specific operation tests related to ADS requirements will be performed.**
  - **weak points encountered will have to be checked and fixed when possible**
  - **At least, way to cure these points on a high energy industrial machine will have to be proposed. (PS redundancy or spare for example...)**