CARE/JRA3: First Quarterly Report 2007
30/04/2007

<u>Title</u>: High Intensity Pulsed Proton Injectors (HIPPI)

<u>Coordinator</u>: M. Vretenar (CERN), Deputy: A. Lombardi

<u>Participating Laboratories and Institutes</u>:

Institute (participant number)	Acronym	Country	Coordinator	Scientific Contact	Associated to
CCLRC Rutherford Appleton Laboratory (20)	CCLRC	UK	P. Norton	C. Prior	
Commissariat à l'Energie Atomique (1)	CEA	F	R. Aleksan	A. Mosnier	
CERN (17)	CERN	CH	G. Guignard	M. Vretenar	
Forschungszentrum Jülich (7)	FZJ	D	R. Tölle	R. Tölle	
Gesellschaft für Schwerionenforschung, Darmstadt (4)	GSI	D	N. Angert	L. Groening	
Institut für Angewandte Physik - Frankfurt University (5)	IAP-FU	D	U. Ratzinger	U. Ratzinger	
INFN-Milano (10)	INFN-Mi	I	S. Guiducci	C. Pagani	INFN
CNRS Institut de Physique Nucléaire d'Orsay (3)	CNRS-IN2P3-Orsay	F	T. Garvey	G. Olry	CNRS
CNRS Laboratoire de Physique Subatomique et de Cosmologie (3)	CNRS-LPSC	F	T. Garvey	J.M. De Conto	CNRS
INFN-Naples	INFN-Na	I	S. Guiducci	V.G. Vaccaro	INFN

<u>Main Objectives</u>: Research and Development of the technology for high intensity pulsed proton linear accelerators up to an energy of 200 MeV.

<u>Cost</u>:

Total Expected Budget	EU Funding
12 M€ (FC) + 2.7 M€ (AC) **Total 14.7 M€**	**3.6 M€**

1 MANAGEMENT ACTIVITY

1.1 Meetings

1.1.1 List of meetings

All meetings to be organized by HIPPI in the year 2007 have been planned (Work Package meetings, general meeting). The HIPPI Work Package 3 meeting took already place at Orsay on April 28th, while all other WP meetings will take place between May and June. The participation from HIPPI to the other events in 2006 (International Conferences and workshops, workshops of other collaborations or activities) has been defined, and a first Conference with contributions from HIPPI took already place in January 2007 (Asian Particle Accelerator Conference, Indore, India). The events concerning HIPPI during the year 2007 are shown in Table 1.1.1a. A review of the accelerating structures for Linac4 (one of the projects supported by HIPPI) has been integrated into the WP2 Meeting (May 24-25th at CERN, Geneva).

1.1.2 General meeting

The HIPPI general meeting for 2007 will be hosted by IPNO at the Orsay Laboratory (Paris region), from September 26th to 28th.

The quite successful structure of last year meeting, with general presentations in parallel to the Work Package sessions, will be repeated.

1.2 External Scientific Advisory Committee

Contacts (exchange of e-mails) with the members of the ESAC have continued after the HIPPI Meeting in Jülich (September 2006) and some measures have been taken following the ESAC recommendations, in particular:

- A test of the interference (electromagnetic compatibility) between the chopper pulser and the bunch shape and halo monitor, considered as the most sensitive beam detector in the chopper line, has been performed at CERN (and shows no appreciable effect).
- A crash programme for the construction of a short DTL prototype has been started at CERN.
- The CCDTL pre-prototype is undergoing repair and testing will restart soon.

Table 1.1.1a: Overview of meeting, workshop and event (co)organized by the Activity or with Activity contributions

	Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CARE & HIPPI												
CSC Meeting				17-18 Paris					? (CERN)			
WP2 Meeting					24-25 CERN							
WP3 Meeting				28 Orsay								
WP4 Meeting						11 CERN						
WP5 Meeting					21 Saclay							
HIPPI Annual Meeting									26-28 Orsay			
CARE Meeting										29-31 CERN		
Collaboration meetings												
IPHI-SPL meetings						7-8 CERN						
ISTC meetings		19-20 Moscow	.	18-20 Moscow		(25-29) CERN						
Conferences, workshops												
APAC 2007	29– 2.2 Indore											
PAC 2007						25-29 Albuquerque						

Table 1.1.1b: List of meeting, workshop and event (co)organized by the Activity

Date	Title/subject	Location	Main organizer	Number of participants	Comments and Web site
28 April 2007	WP3 (Superconducting) meeting	Orsay (F)	IPNO	10	http://hippiwp3.in2p3.fr/

2 DISSEMINATION ACTIVITY

2.1 List of talks

Some talks relevant to HIPPI were presented during the first quarter of 2007. The list is given in Table 2.1.

Table 2.1: List of talks presented by the JRA

M. Vretenar	Proton intensity upgrades at CERN (LINAC4, SPL)	APAC2007	http://apac07.cat.ernet.in
I. Hofmann (GSI)	Space charge studies in the CARE-HIPPI project	Joint DESY and University of Hamburg Accelerator Physics Seminar	http://www-mpy.desy.de/AccPhySemDESY/index.html

2.2 List of papers

Three CARE notes have been issued during the first quarter of 2007; they are listed in Table 2.2. The first two represent a milestone for WP2 and WP4 respectively. One CARE report has been issued in support of HIPPI deliverable number 21 for 2006. Two HIPPI related papers have been presented at APAC conference (Jan07, Indore). They have all been filed as HIPPI publications and the numbers can be found in Table 2.2.

Table 2.2: List of document issued by the NA or JRA

#	CARE document type and number	Title	Authors and Labs	Date
1	CARE-Note-2007-001-HIPPI	Development, construction and testing of a room temperature CH-DTL .	G.Clemente, H.Podlech, R.Tiede, U.Ratzinger IAP Frankfurt; L.Groening GSI Darmstadt; S.Minaev ITEP Moscow	01/2007
2	CARE-Note-2007-002-HIPPI	HIPPI Work Package 4 (WP4): The RAL Fast Beam Chopper Development Programme Progress Report for the period: July 2005 – December 2006	M. A. Clarke-Gayther, CCLRC RAL.	03/2007
3	CARE-Note-2007-003-HIPPI	Pi-mode 352 MHz scaled LEP cavities as an alternative accelerating structure for the energy range of 90 to 160 MeV in CERN	E. Sargsyan, A. Lombardi	04/2007

		Linac4/SPL		
4	CARE-Report-2007-016-HIPPI..	Beam Induced Fluorescence Profile Monitor at GSI	P. Fork, C.Andre, A. Bank and F. Becker , GSI.	03/2007
5	CARE Conf-07-001-HIPPI .	Linear Accelerator Designs For The Upgrade Of The Cern Proton Injector Complex (Linac4, Spl)	M. Vretenar, G. Bellodi, R. Garoby, F. Gerigk, K. Hanke, A. M. Lombardi, S. Maury, M. Pasini, C. Rossi, E.Z. Sargsyan, CERN, Geneva	01/2007
6	CARE Conf-07-002-HIPPI	High Power Rf Testing Of A Cell Coupled Drift Tube Linac Prototype For Linac4	M. Vretenar, Y. Cuvet, F. Gerigk, J. Marques Balula, M. Pasini, CERN, Geneva	01/2007

2.3 Web site

The HIPPI web site (**http://mgt-hippi.web.cern.ch/mgt-hippi/**) contains the most recent information on the JRA activity.

3 ADDITIONAL STAFF HIRING

GSI has been successful to replace Dr. W. Bayer by another post-doc, P. Clemente, effective from July 2007.

Table 3: Temporary staff hiring

#	Lab	Job Type	Duration	Work subject	Status
1	GSI	Post-doc	18 months	Beam dynamics (replacement)	Hired , effective july07

4 STATUS OF THE WORK

4.1 Work Package 1 : Management and Communication

The main Management activities in the 1st Quarter 2007 have been:

- the follow-up of implementing the recommendations from the ESAC reviewers,
- the preparation of the Work Package meetings and of the HIPPI Annual meeting,
- the follow-up of the HIPPI milestones and deliverables: contacting the responsible persons for the different deliverables, keep track of the delays, and when the deliverable is achieved be sure that the proper supporting document is prepared and submitted required a constant care from the Coordinators.

Another important management activity went to the follow-up of some problems for the HIPPI planning coming from delays in the supply of essential components from Institutes outside HIPPI. The first problem concerns a DTL prototype tank that was intended to be built by a Russian collaboration (ITEP and VNIIEF) and delivered to CERN. The power coupler for this prototype has been designed and built inside HIPPI (mentioned as “critical DTL component” in the planning) and was intended to be tested at high power with the Russian prototype, which was scheduled to be finished in February 2007. In a meeting at Moscow in February, it was announced that the prototype is late by more than a year, and that because of lack of funding it will not be equipped for high-power testing. The consequence is that the coupler will be at the moment tested only at low power, while we are looking for an alternative installation where this coupler could be tested.

The second potential problem concerns the delay in the construction of the CEA IPHI RFQ, intended to be delivered to CERN and to be used for testing of the chopper line built inside HIPPI. An emergency solution was found last year, planning the test of the CERN chopper line at Saclay instead of CERN, in order to speed up the tests without waiting for the reinstallation of the RFQ at CERN. Now, more delays have been announced, and it is doubtful that even the tests in Saclay could take place before end 2008.

4.2 Work Package 2: Normal Conducting Accelerating Structures

4.2.1 Drift Tube Linac

4.2.1.1 Activities at Rutherford Laboratory (RAL) (WBS 2.1.4)

Buncher cavities for the FETS (Front End Test Stand) project: All the problems with a 2D cylindrical symmetry have been studied by using SuperFish and the RF properties of the buncher cavities have been calculated. Estimated the frequency shifts due to mechanical errors have been estimated, numerically but also analytically. A 3D model using MicroWave Studio has been created to study the problems that lack cylindrical symmetry: tuning range, dissipated power distribution, the effects of ancillary equipment, etc. The design at the stage where mechanical drawings can be made and the possibility of building a cold model can be taken into account.

Hybrid quadrupoles for the FETS project: A private contractor is manufacturing various designs for the printed circuit EM quadrupoles. A series of magnetic measurements will be performed at Daresbury Laboratory in the second half of May in collaboration with the ASTeC Magnetics and Radiation Sources Group.

Beam dynamics studies and simulations: An important part of the work done at RAL was concentrated on the beam dynamics for the RAL Front End Test Stand. A code comparison between GPT and TraceWin/Partran is in progress to evaluate the accuracy and the limits of the results obtained so far with GPT for the FETS Medium Energy Transport Line (MEBT). TraceWin/Partran was used to calculate the beam dynamics in the compact RAL Scheme C that uses hybrid quadrupoles placed inside the nose cones of the re-bunching cavities. We have also performed a simulation study of high intensity beam dynamics and beam transport together with CERN when the RAL and CERN MEBT designs are each fed into the same CERN structure for LINAC4. Particular advantages and disadvantages of both structures have been observed.

4.2.1.2 DTL and coupling port design at CEA Saclay and LPSC (part of WBS 2.1.3)

The 1 MW coupling port has been built and delivered to LPSC. It has now to be sent to CERN for copper platting. The final report is under way.

Figure 4.2.1: Side view of the coupling port and of the its cooling system. The lateral flange (on the right) is the coupling window to the DTL tank.

Figure 4.2.2: View of the water-cooled coupling window

Figure 4.2.3: View of the two short-circuit wave guide terminations. They will be used to know the optimal position of the short circuit.

DTL design work at CERN

The drift tube linac (DTL) has been completely redesigned in the first months of 2007 based on the following issues:

- Reconsidering the maximum operating power of the different types of LEP klystrons, it was found that the assumption that a maximum output power in pulsed mode of 850 kW at the cavity port is overly conservative and that rather up to 1 MW can be expected for most klystrons.
- The effective shunt impedance of a DTL is higher than of alternative RF structures as the CCDTL for particle energies up to about 50 MeV. Consequently it is preferable to reach this energy with a DTL structure but with a limited number of klystrons.
- Many DTL designs have problems with RF breakdown in the first few cells. The origin and processes are not completely understood, however a report (A.Bross – MuCool RF program) at the recent MICE collaboration meeting 17 showed quantitative data on the known but so far unstudied dependence of surface electric

field limits versus magnetic field in vacuum: A design magnetic field of 0.5 T on the drift tube surface perpendicular to the metallic surface reduces the maximum electric field by about 30 %.

The DTL design effort therefore focused on two points:

- The design shall be adapted to the higher klystron power and it should reach 50 MeV after the third tank using a reasonably small number of klystrons.
- The peak surface electric field shall be reduced for the first drift tube cells.

The new base design of the DTL tanks was found using the DTL_GEN software provided by CEA DSM DAPNIA SACM, Saclay, France and Superfish provided by Los Alamos National Lab, USA. Applying the new klystron power values and limiting the number of klystrons to 5, it was found that a beam output power of 47.7 MeV can be reached with an accelerating gradient of 3.5 MV/m. Reduction of the accelerating gradient to 3.2 MV/m allowed to better use the RF power reaching a beam output power 50.6 MeV. The raw tank length increases moderately from 15.6 m to 18.2 and features 108 cells instead of 94. The decrease in accelerating gradient immediately helps to achieve the second goal of lower peak surface electric fields.

Older DTL designs in fact approached the reduction in peak surface field only by reducing the accelerating gradient in the first cells leading to a ramped gradient design (e.g. CERN Linac2 is ramped in gradient by 21% over the full first tank). In the study it was found that the peak surface electric field of the first cell can be reduced by 29.4% by increasing the drift space but without considerable decreasing the particle acceleration (E_0T). E_0 kept constant, the time transit factor T is reduced by only 4.1 %. As a consequence in the new design, the peak surface magnetic field was reduced to 1.2 times the Kilpatrick limit for the first few shorter drift tubes and then increased linearly for cells with longer drift tubes where the surface electric fields do not coincide with high magnetic fields inside the drift tubes. The maximum peak field of the rest of the tanks was kept below 1.6 times the Kilpatrick limit, a value which appears to be achievable in absence of magnetic fields and under appropriate vacuum conditions. The overall design reaches a beam output power of 50.1 MeV.

4.2.2 H-mode DTL (IAP Frankfurt)

4.2.2.1 RF cold model design & construction (WBS 2.2.2)

As already mentioned in the last quarterly report of 2006, the “cold” model has been completed. An intensive RF investigation was performed showing an excellent agreement within the simulation and the experiments: in particular, after solving some minor problem with the ceiling the measured Q_0 was 13000, around 95 % of the predicted value of Microwave Studio. Since this model was equipped with a complete cooling system it was decided to test the cavity with a 2 kW cw amplifier available at IAP, going in this way much further the original aim of this model which was originally conceived only to test the fabrication steps and the feasibility of the copper plating process.

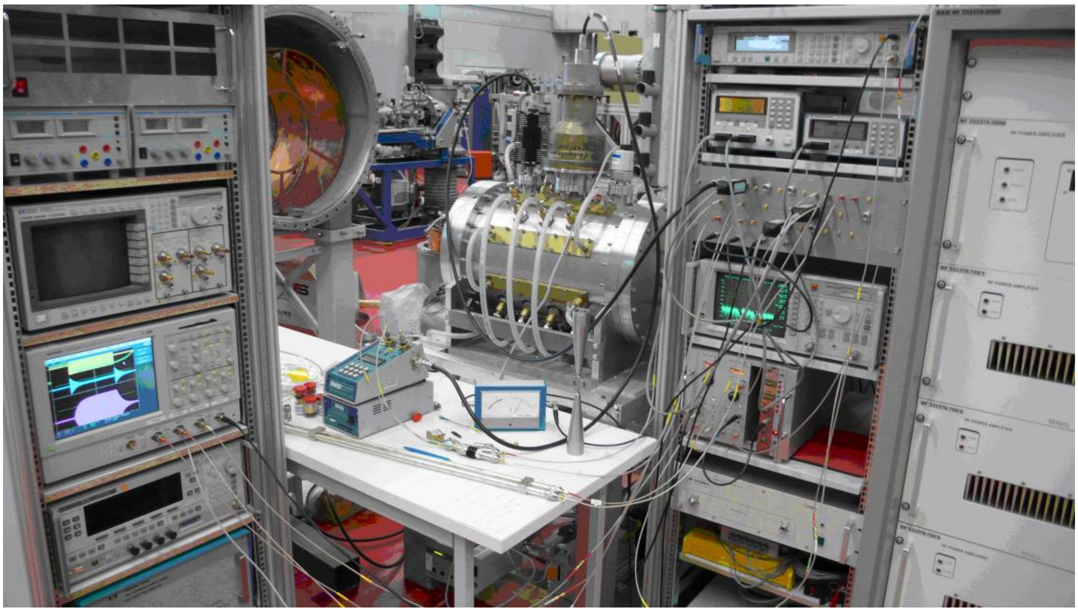


Figure 4.2.4: The experimental setup for the high power test on the CH test model

The results were really promising: the full power level was reached in less than 20 minutes without any significant multipacting effect and: moreover, the temperature on the outer cylinder remained stable during the test proving the capabilities of the cooling system. A detailed Hippi NOTE was released at the beginning of the year explaining all the fabrication steps together with a complete description of the experimental results.
Concerning the real prototype, as announced in the last annual meeting, it has been decided to base the new GSI Proton Injector on coupled CH cavities. In order to test the innovative coupling scheme a scaled model (1:2) of the second resonator of the GSI Proton Injector is in advanced production. We foresee to test this model within summer 07. Parallel to this model we already contacted an external industry in order to produce the full scale prototype which we foreseen to deliver within 2008.

Figure 4.2.5: The stem of the scaled model for the coupled CH

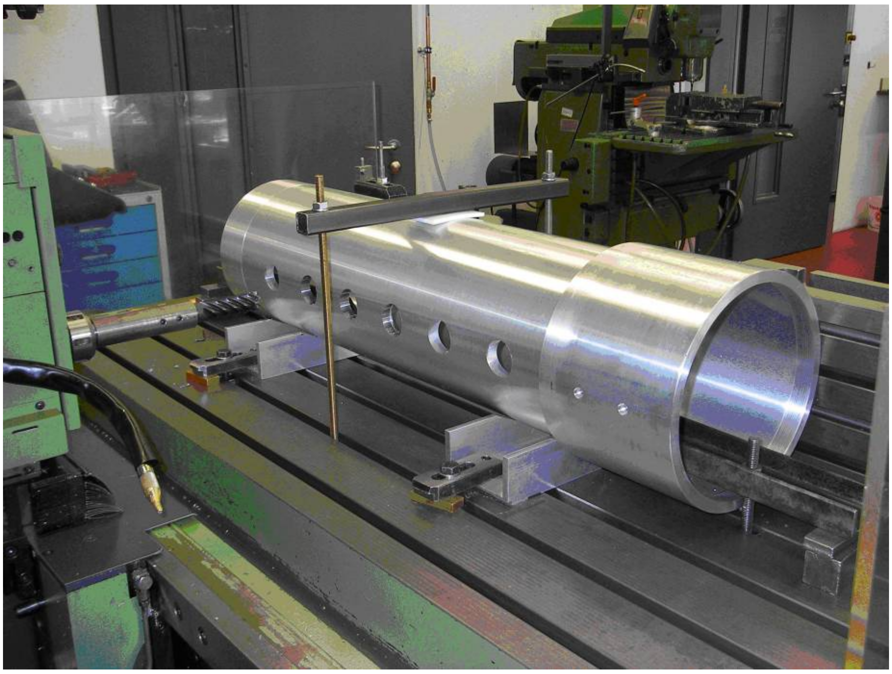


Figure 4.2.6: The first tank and the coupling cell during fabrication.

4.2.3 Side Coupled Linac (LPSC and CERN) (WBS 2.3.1 and 2.3.2)

The cavity prototype has been manufactured at LPSC and is now under test. It consists of 20 plates made of a half accelerating cell and a half coupling cell. The prototype is at the 0.7 scale, so the expected resonant frequency is 1005.7 MHz (instead of 704 MHz). The individual frequency of each cell has been measured by two methods:

- The first method is done by direct frequency measurement, after assembling one of the cells, the half end-cells being short circuited (total one full cell + 2 half cells). This method shows that the accelerating cells frequencies are in the 1004-1009 MHz range, while the coupling cells are in the 996-1000 MHz. This shows that the accelerating cell design is acceptable but not the coupling cell design.
- The second method consists also of assembling two successive full cells, also with short-circuiting the half end-cells (total two full cell + 2 half cells). In that case, the cavity has two eigenmodes. The two eigenfrequencies F_1 and F_2 are measured and varied by introducing a tuner in one of the cavities. It can be shown easily that we have the relation $F_1^2 + F_2^2 = \frac{F_0^2}{1-k^2} + \frac{F_1^2 F_2^2}{F_0^2}$, where k is the coupling factor and F_0 the frequency of the cavity without the tuner. A linear fit between the quantities $Y = F_1^2 + F_2^2$ and $F_1^2 F_2^2$ gives the value of k and F_0 .

The first comparisons between the 2 methods give a good agreement. The k value is around 3%, which is the expected value.

The next step, under way, is the machining of the tuning rings (accelerating cells) and of the gap (coupling cells). The frequency expected is 1004.5 GHz. Machining is a delicate operation. In particular, the calculation of the sensitivity of the tuning ring machining varies by 50% between codes like Superfish and HFSS, so the first machining will be done very progressively. It has been started at the LPSC shop and will be finalized in May.

Figure 4.2.7: View of the SCL prototype (4/5 of the cells are assembled)

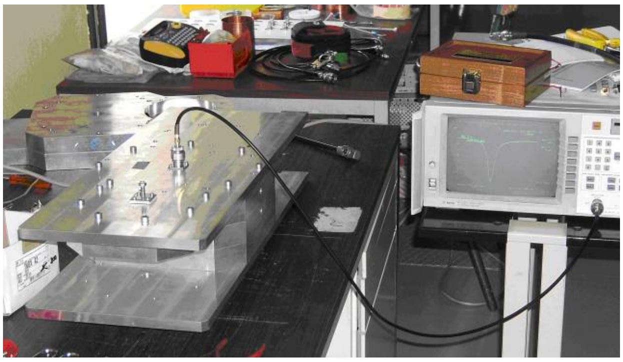


Figure 4.2.8: Single cell measurement

Figure 4.2.9: Preparation of the bead-pull measurement setup

4.2.4 Cell Coupled DTL (CERN) (WBS 2.4.1 to 2.4.3)

This paragraph describes the Cell Coupled DTL pre-prototype and prototype status

During the high power test of the CERN pre-prototype in November 2006 it was found that a cooling circuit inside a drift tube was obstructed, limiting the duty cycle achievable during the tests. At the end of the tests, the end plates and the faulty drift tube were dismounted. Following the ESAC recommendations, it was decided to perform a new complete copper plating of the covers in order to improve the Q-value and to investigate the effect on the Q-value of the grooves that were not plated in the first configuration. In parallel, the drift tube was sent to the CERN workshop for repair. Looking into the open prototype, some signs left by electrical discharges were evident, especially in the nose region (see Fig.1). The new plating of the covers was performed at the end of January, while the reparation of the drift tube is still ongoing. Plans are to install the drift tube as soon as possible, to mount the end cover and to start again the high power test, possibly by the end of April.

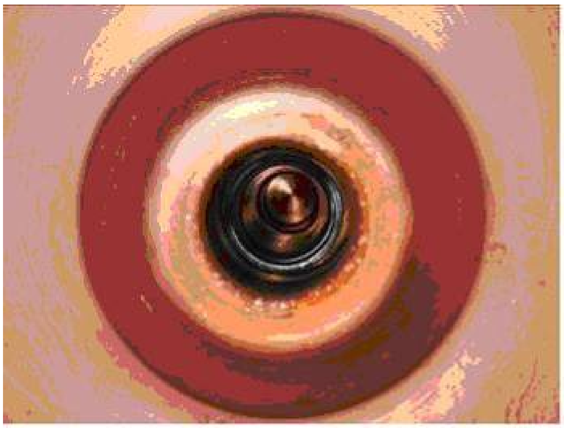


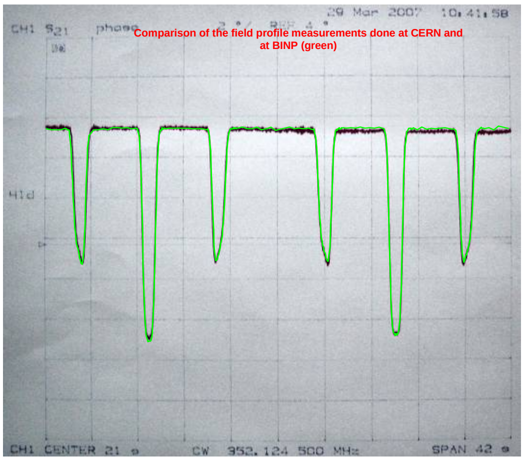
Figure 4.2.10: Nose region after high power test. The white dots in the centre are marks left by electrical discharges during conditioning

On February 6th was delivered to CERN the CCDTL prototype, which was built in Russia with the collaboration of the RFNC-VNIITF institute in Snezinsk and the BINP institute in Novosibirsk. The prototype consists in two full accelerating structures of DTL type, each equipped with two drift tubes. An off-axis coupling cell connects the two accelerating structures, so to allow the insertion of a magnetic quadrupole. Fig. 2 shows the CCDTL prototype in the assembly area, on its support frame and connected to the waveguide.
The module was delivered with the drift tubes fixed to protecting arms in order to assure a safe transportation. As a first operation, the accelerating cells were opened, the protecting arms were dismounted and the alignment of the drift tube was checked. It was found that the shift in position of the drift tubes was less then 0.1 mm in the radial direction and negligible in the longitudinal direction. After mounting all the proper vacuum joints, the single cells frequencies were measured and found to be in agreement with the previous measurements in Novosibirsk. Only the coupling cell showed a frequency higher by 275 kHz due to the different joint thickness. After installing the waveguide T-section, and pulling out the coupling cell tuner by 7.35 mm in order to compensate for the frequency shift, the electric field on-axis was checked with a bead-pull measurement and the coupling between waveguide and cavity was measured for different positions of the waveguide short-circuit. The results are shown in Table 1 and Fig. 2.

Figure 4.2.11 : The CCDTL prototype

	Frequency (MHz)	Q-value (unloaded)
Tank 1-2	352.105	36276
Coupling cell	352.352	9413
Tank 2-3	352.113	36960

Table 4.2.1. Frequency and Q-value measurements of the CCDTL prototype



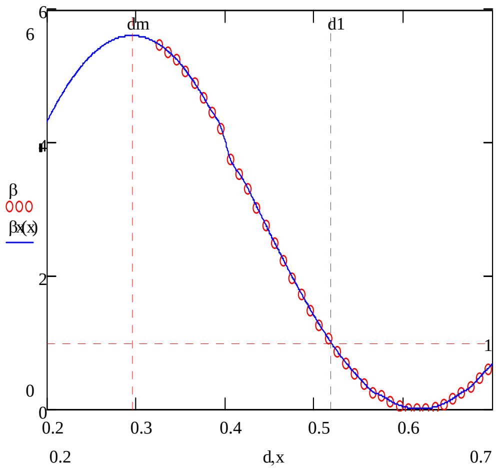


Figure 4.2.12: On the left: bead pull measurements comparison between CERN (black trace) and BINP (green trace). On the right: Coupling between waveguide and cavity as a function of the sliding short-circuit plate position.

After the low level measurements the whole module was sealed and vacuum tested. No leaks were found to a level of 10^{-7} mbar. After two weeks of pumping, the vacuum level is $2.4 \cdot 10^{-7}$ mbar. High power tests should be possible within the next months after the fabrication of a waveguide end-cup and the connection of the cooling manifold.

Table 4.2a : Status of the Sub tasks in WP2 which are supposed to have started according to the MS project breakdown in Annex 1

WBS #	Title	Original begin date (Annex 3)	Original end date (Annex 3)	Estimated Status	Revised end date
2.1	**Drift Tube linac**				
2.1.1	DTL Design	July 2004	June 2007	On time	
2.1.5	DTL Coupler prototype construction	July 2005	June 2007	95%(*)	
2.1.4	DTL beam dynamics design	January 2004	June 2008	On time	
2.2	**H mode DTL**				
2.2.2	RF cold model design & construction	January 2004	January 2005	100%	April 2006
2.2.3	RF model construction	December 2004	June 2005	50%	December 2008
2.3	**Side Coupled Linac**				
2.3.2	RF model mechanical design	July 2004	December 2004	100%	June 2006
2.3.3	RF model construction	January 2005	December 2005	100%	November 2006
2.3.4	RF model testing	January 2006	June 2006	20%	End 2006
2.3.5	SCL module design	January 2006	June 2007	On time	
2.4	**Cell Coupled DTL**				
2.4.2	Pre-prototype high power RF tests	July 2004	March 2005	10%	July 2006
2.4.3	Prototype mechanical design	January 2005	December 2005	100%	
2.4.4	Revision of design	October 2005	October 2006	30%	December 2006
2.4.5	Prototype high-power RF tests	August 2006	June 2007	Delayed	December 2006

(*): Copper plating to be done + final report.

Table 4.2b: Status with respect to the interim reports and deliverables due in 2007 according to the MS project breakdown

WBS #	Title	Due date in Annex 1	Status	Revised delivery date
	DTL design intermediate report	June 2007	On time	
	DTL components intermediate report	January 2007	Delayed	March 2007
	DTL components prototype ready	January 2007	Finished	
	Side Coupled Linac prototype report	December 2007	On time	
Milestones and deliverables from 2006				
2.4.3	CCDTL Prototype ready	June 2006	Completed	
2.2.7	**CH-DTL Prototype ready**	December 2006	Delayed	Spring 2008
2.4.4	**CCDTL Design report**	December 2006	Delayed	June 2007
Milestones from 2005				
2.4.1	CCDTL Pre-prototype intermediate report	June 2005	Completed	
2.2.5	CH model cavity construction test Intermediate report	Dec 2005	Completed	

4.2 Work Package 3: Superconducting Accelerating Structures

INFN-Milano

Tuner construction (subtask 3.1.4)
In progress.

CEA-Saclay

Construction of cavity B (subtask 3.1.6)
The cavity has been delivered by ACCEL in March 2007.
First measurements of dimensions, RF frequency and field flatness with the cavity as received have been performed. The results will be part of the CARE report, corresponding to the deliverable ‘cavity B ready’, which is in preparation.

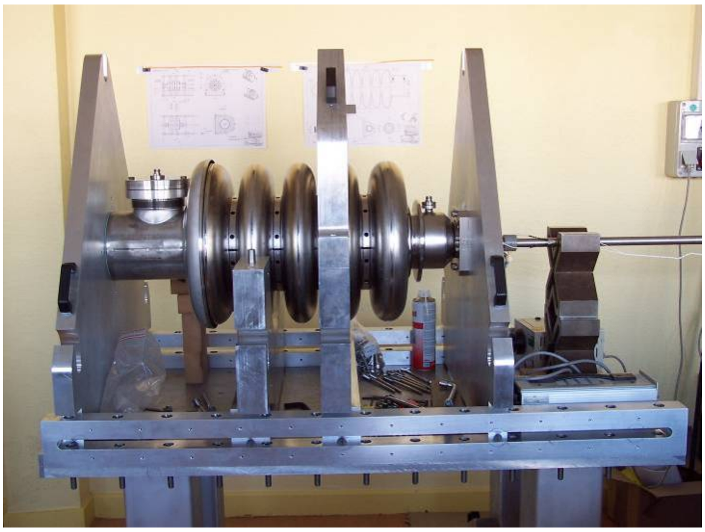


Figure 4.3.1: Cavity B

Power coupler design and engineering (subtask 3.1.7)
The drawings of the power coupler are validated. Order has been placed for the 704 MHz RF windows with a delivery time of seven months. We are now preparing orders for the cold connection to cavity and doorknob. We aim to get all the pieces for assembling a complete coupler in December 2007.

RF source order and preparation (subtask 3.1.8)
The klystron tested at full power at CPI factory in September 2006 is now installed at Saclay. The extra Xray shielding is being installed. All the auxiliary power supplies are delivered and tested (cathode heater, solenoide1 and solenoide2, vacuum ion pumps). The air blower for klystron window cooling is delivered and the air flow meter will be delivered by the end of May. Klystron connections would be completed in June. The hardware and software of the control/command are ready. Some connections to power supplies have still to be done and should be completed in June. The circulator and RF loads are delivered, and installation will begin after delivery of the missing waveguide parts.

Figure 4.3.2: The klystron installed at the Saclay test stand

Modulator preparation for the 700 MHz test stand (subtask 3.1.10)
The new High Voltage power supply, partially tested at factory, is delivered and connected. The pulse operation, only achievable with the modulator, is not yet performed. The modulator modifications are completed. The modulator is in place and ready to start.

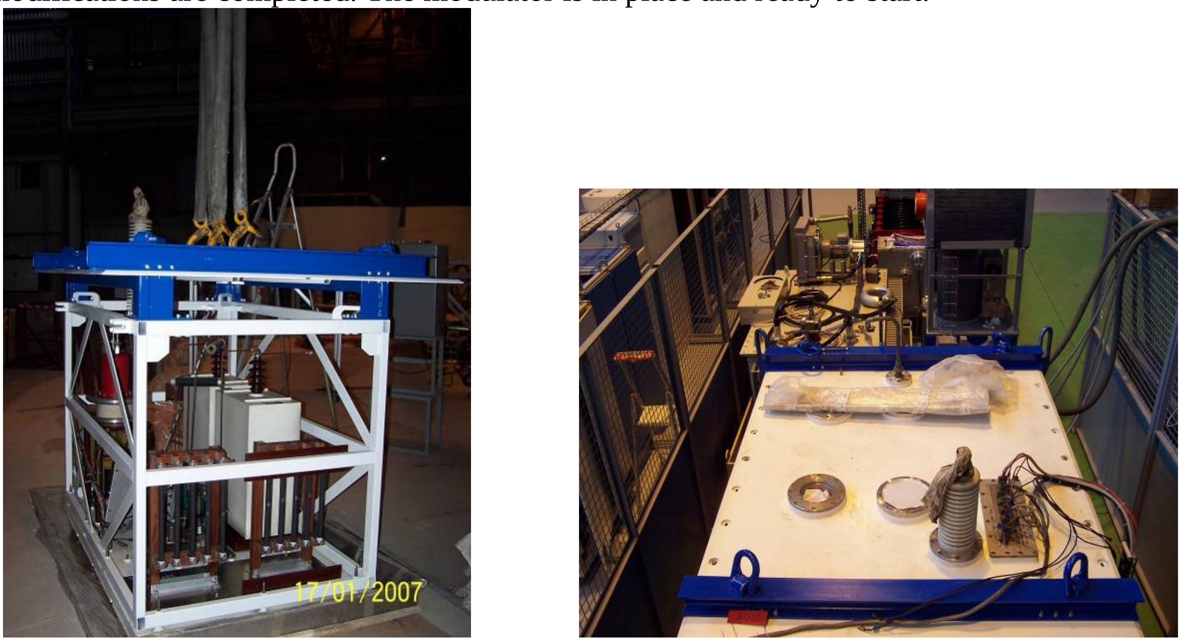


Figure 4.3.3: The klystron modulator

FZ-Juelich

RF design of 352 MHz multi-gaps resonator (subtask 3.2.6)
Although the 352 MHz multigap resonator is being built without a He cover for use in a bath cryostat provisions are made to allow a later use in a ‘dry’ cryostat. Beam ports and coupler ports are equipped with special rings to which a He cover can be welded at a later time. For cavity stiffening the method of copper spraying of the end caps is under evaluation. A backup stiffening scheme (much more time consuming to implement) is available.

Final mechanical design of resonator (subtask 3.2.7)
Drawings of the mechanical design of all resonator parts are finished. Little activity remains to account for auxiliary parts for EB welding fixation parts and integration into the FZJ bath cryostat.
Integration of coupler. Tuning options (subtask 3.2.8)
The cavity is prepared to take the coupler as developed by the Orsay colleagues.
Preparations for electron beam welding (subtask 3.2.9)
a) EB welding quality assurance
Welding parameters are fully developed for all required welding tasks. Handling a wall thickness of 4 mm for nearly all cavity welds and assuring the proper quality concerning to the superconducting HF requirements was the main challenge. As the result the upper and the lower welding bead is smooth and without significant seam sags or grooves at the border for all different working heights in the EB chamber.

b) RRR measurements and consequences for the processing of the cavity
Various RRR measurements were performed to check the RRR value of the EB seam and the heat affected zone and to compare them with the RRR values of the delivered sheets. All RRR values are in the same range as the reference material (RRR = 320 – 380, see next figure), even if alumina fixation components are placed nearby the hot weld region. RRR do not decrease below the initial values by the required welding tasks.

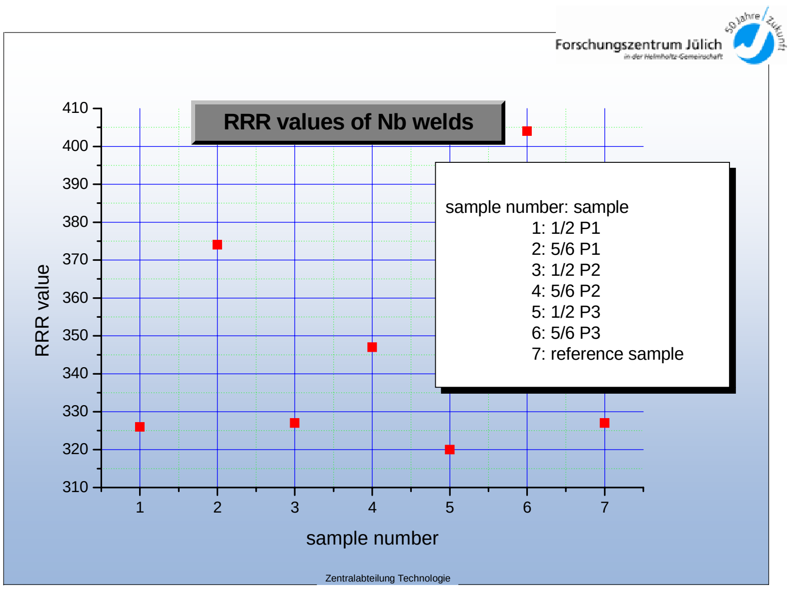


Figure 4.3.4: RRR values of welded samples

Manufacturing of 352 MHz Multi-gap Resonator (subtask 3.2.10)
All parts of the cavity are fabricated now.
The cavity body half shells are rolled and prepared for welding to the coupler ports.

Figure 4.3.5: Rolled half shell of the cavity body (left) and coupler port with hot brazed SS flange (right)

End caps are formed by deep drawing and prepared for welding to the beam ports. The spoke half shells were welded together after deep drawing. Welding the beam pipes and the adapter rings to the spokes will follow next.

Figure 4.3.6: Formed niobium end cap (left) and welded niobium spoke (right)

IPN-Orsay

Evaluation of 352 MHz 2-gap prototypes (subtask 3.2.3)

In parallel of the multigaps Spoke cavity stiffening studies, the developed programs have been used to evaluate the Lorentz forces factor for the 2-gaps Spoke cavity. The interest resides on the possible comparison between calculations and experiments since the prototypes (without stiffening system for Lorentz forces) were tested in 2006 with a horizontal cryostat.

The simulations results give the limits of two extremities: the Lorentz forces factor for a completely contained cavity and the same factor for a total free cavity. In the first case, this factor is -20 $Hz/(MV/m)^2$ while in the second case it is -72 $Hz/(MV/m)^2$. The experimental results differ a little from one experience to another, the Lorentz forces factor is situated between -55 $Hz/(MV/m)^2$ to -47 $Hz/(MV/m)^2$, inside the range predicted by the calculations.

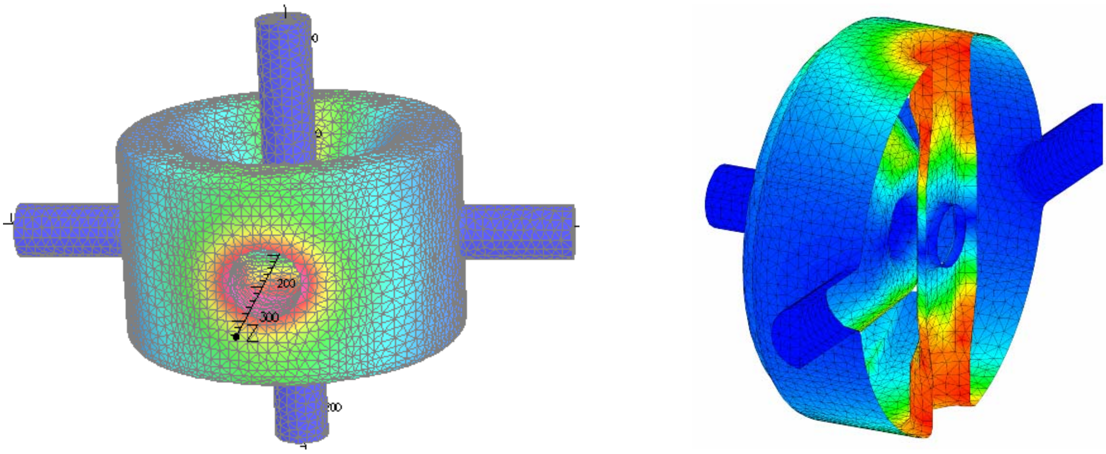


Figure 4.3.7: H field in vacuum space (Soprano) and H distribution on the surface of the cavity (Cast3m)

Construction of Coupler Prototype (subtask 3.2.5)

Alumina windows for the coupler are fabricated and will be tested at Orsay.

RF design of 352 MHz multi-gap resonator (subtask 3.2.6)

In order to reduce the frequency shift due to Lorentz forces, the stiffening systems have been proposed for the 352 MHz multi-gap spoke resonator by the Jülich group. The cavity is planed to be built without He cover for use in a bath cryostat.

At IPN Orsay, in addition to the created platform which assumes the linkage from CAD code Catia to mechanical code Cast3m and the electromagnetic code Soprano, some new programs have been developed to take into account the stiffening system at the outside surface of the cavity wall.

Without stiffening system, to avoid the errors dues to interpolation of the electromagnetic field simulated from Soprano on the mechanical model in Cast3m, the mechanical simulations were performed on the shell elements, exactly taken out of the envelop of the vacuum volume used by Soprano. With the stiffening system, we should use the volumes' elements to construct model of the cavity wall: the cavity wall has an inner surface different to the outer surface in which the stiffening system has been added.

The new programs allow to import the volume elements model of the cavity wall from Catia to Cast3m and to extract the inner surface elements from the cavity wall's model. As the inner surface of the cavity wall must coincide with envelop of the vacuum space for electromagnetic simulation, this vacuum space model is performed by Cast3m from inner surface of the cavity wall. Then the FE vacuum space model is exported to Soprano which simulated the resonance frequency and the electromagnetic fields. The fields distribution at the inner surface of the cavity wall is transferred back to Cast3m to determinate the radiation pressure and to perform the mechanical deformations on the volume elements model of the cavity wall. Then the interfaces programs modify the vacuum space model in Soprano according the displacements calculated by Cast3m at the nodes of the inner surface, and the new resonance frequency is simulated by Soprano and finally the frequency shift is obtained.

The evaluated stiffening system is shown in the left figure below, the cavity is supposed to be 4 mm thick. The right figure below shows the axial displacement distribution on the volume elements model of the cavity wall. The Lorentz forces factor, which means the frequency shift over the square of the accelerating field, has been reduced to about $1\,Hz/(MV/m)^2$, this value is 4 times less then the Lorentz forces factor calculated without stiffening system.

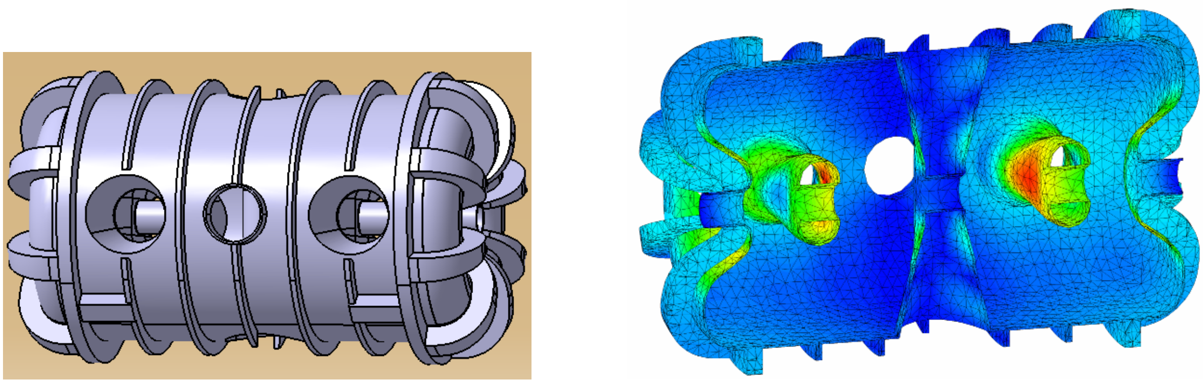


Figure 4.3.8: Cavity stiffening ribs designed under Catia and displacement due to Lorentz forces (Cast3m)

IAP-Frankfurt University

Conceptual studies of a tuning system (subtask 3.3.1)

The rf-tuning concept for the super conducting CH-structure in Frankfurt provides two tuning stages: a slow but effective mechanical axial tuner drive with a maximum applied tuning force of F_{max} = 5 kN corresponding to a compression of Δs_{max} = 1 mm, which results in a measured frequency shift of Δf = 400 kHz and the piezo tuner for a fast tuning in the 0.01 mm range corresponding to Δf_p = 4 kHz. The frequency shift as a result of applying a squeezing force at the end flanges of the tank from outside has now experimentally been determined. In the course of that the changes regarding field distribution along the structure has also been investigated in detail by means of a bead pull measuring system. These experiments have both been carried out at room temperature. The experimental result comes up with only half of the frequency shift we had expected from simulations, but is still sufficient. The piezo actors and sensors will be tested in the near future on a specially designed test stand with special respect on their performance at cold temperatures.

Construction of tuning system (subtask 3.3.2)

First parts of the piezo tuning system are currently under construction at our workshop. They have been designed with special respect to the requirements of the piezo actors as they should be prestressed at operation to extent their durability. This is automatically realized by transmitting the force of the slow mechanical axial tuner drive (F_{max} = 5 kN) over the piezos. In addition to that we have to avoid shearing and twisting forces, which could cause a damaging of the piezos. Therefore we introduced a mechanical guidance, tolerated strong enough to guide the movement on the one hand but giving enough space to avoid canting of the parts.

WBS	Title	Participants	Original begin date	Original end date	Estimated Status	Revised end date
3.1	**Elliptical cavities**					
3.1.2	Tuner design	INFN	07 / 2004	12 / 2005	100%	
3.1.3	Integration of piezo design	INFN	07 / 2004	12 / 2005	100%	
3.1.4	Tuner construction	INFN	01 / 2006	06/2006	80%	02/2007
3.1.6	Construction cavity B	CEA	11 / 2005	06/2006	100%	03/2007
3.1.7	Power coupler design & engineering	CEA	01 / 2005	04/2006	100%	
3.1.9	RF coupler construction	CEA	05 / 2006	05/2007	15%	11/2007
3.1.8	RF source order and preparation	CEA	07 / 2004	12/2006	100%	
3.1.10	Modulator preparation for test stand	CEA	01 / 2005	12/2006	100%	01/2007
3.1.11	RF source testing	CEA	01 / 2007	04 / 2007	20%	06/2007
3.1.12	High power pulsed tests	CEA	05/2007	06/2007	0%	09/2007
3.1.13	Cavity A assembly with tuner	INFN	06/2006	03/2007	0%	
3.1.14	Vert. test & final welding of cavity B	CEA	07/2006	03/2007	0%	11/2007
3.2	**Spoke cavities**					
3.2.2	Evaluation of 700 MHz prototype	FZJ	09 / 2004	09 / 2005	100 %	
3.2.4	Design of coupler prototype	IPNO	01 / 2004	12 / 2005	100%	
3.2.5	Construction of coupler prototype	IPNO	01 / 2006	06 / 2006	90%	12/2006
3.2.8	Final design of 352 MHz multigap res.	FZJ-IPNO	07 / 2005	06 / 2006	100 %	
3.2.9	Test of coupler prototype	FZJ-IPNO	07/2006	07/2007	0%	12/2007
3.2.10	Manufacturing of 352 MHz multigap res	FZJ-IPNO	04/2006	09/2007	50%	12/2007
3.3	**CH resonators**					
3.3.1	Design of tuning system	IAP-FU	01 / 2004	06 / 2006	70 %	
3.3.2	Construction of tuning system	IAP-FU	01/2006	12/2006		
3.3.1	Measurements of tuning system	IAP-FU	01/2007	06/2007		

Table 4.3a : Status of the Sub tasks in WP3 which are supposed to have started according to the MS project breakdown inAnnex 1

Table 4.3b: Status with respect to the interim reports and deliverables due in 2007 according to the MS project breakdown

WBS #	Title	Due date in Annex 1	Status	Revised delivery date
3.1.6	Cavity B ready (deliverable)	June 2006	Cavity at Saclay – CARE report in progress	March 2007
3.3.1	Report on CH tuners (milestone)	June 2005		March 2007
	Cavity A ready in CRYOLAB	March 2007		November 07
	Measurements of CH tuner prototype			Dec-08: Final report
	High power Test stand ready	March 2007	Components at Saclay – water cooling system in construction	June-07
	High power tests of cavity A and B	Dec 2008		Dec-08: Final report
	Multigap spoke prototype ready for testing	October 2007		Jan08
	Testing of Multigap spoke prototype	Dec 2008		Dec-08: Final report
	Comparative assessment of SC structures	Dec 2008		Dec-08: Final report

4.4 Work Package 4: Beam Chopping

Web-site: http://lombarda.home.cern.ch/lombarda/WP4/WP4main.htm

The CERN chopper structure is completed and ready to be installed on the 3 MeV line. A new set of plates from the company Kyocera are still to be delivered, but the present plates (CERN made) are perfectly acceptable for a first test. The chopper has undergone electric testing, vacuum testing and heat-transport teasting. There are no modifications needed to the structure. The next step will be the high power test when the amplifier delivering the full power is ready. In the next months the decision should be taken whether to use the commercial solution from FID technology or to build three more modules of the CERN made amplifier based on MOSFETst. The delay on delivery from FID technology is now somehow worrisome.

A test of electromagnetic interference is planned for the next months. The recommendation from the ESAC at HIPPI06 was to test the functioning of the Beam Shape and Halo Monitor in presence of fast-switching signal from the chopper. It has been decided to make a test to check the susceptibility of the BSHM signal in presence of the chopper amplifier.

The main issue for the future months is the preparation of the 3MeV test stand, where the chopper system should be measured and its suitability proven. There are delays in the delivery of the RFQ components and the present possible date for the start of the tests in Saclay is June 2008. This means about 1 year delay on the original tests schedule, the delays of 2 WP4 deliverables and the impossibility of making any chopper modifications should the results from the test stand be not completely satisfactory.

CERN:

In general the woks advanced steadily and first low power measurement have been started on the chopper plates. Measurement of the prototype with high power will be possible after the completion of all the vacuum tests which have been the bottleneck for the chopper prototype testing in the last two quarter.

1. Chopper structure (subtask 4.1.4): the chopper structure is completed and is waiting for the high power tests.

2. Chopper driver (subtask 4.1.3): The order of four pulse amplifiers placed at the beginning of 2006, scheduled the delivery of the 1st unit for mid 2006 and the remaining units for the end of same year. Prototype measurements provided in May 2006 showed encouraging results but difficulties of various orders imposed to reschedule the delivery later in the year. Additional measurements provided in October showed considerable progress and email exchanges suggested that the evolutions would have led to the achievement of the specified parameters. A visit took then place end of 2006 for a general verification of the amplifier status in view of the delivery of the first unit at the beginning of 2007. Unfortunately the prototype that could be measured did not achieve the specified performance. The fast switching power devices, manufactured by the company, provided fast enough fronts with the expected amplitude but no prove of their ability to handle the required average power could be given. Moreover, the use of an excessively complex driver stage based on paralleled and cascaded commercial devices, brought along considerable timing problems. The solution proposed by FID Technology was an alternative, home made driver stage based on their own technology that they had already designed and built. At that time it could only work at half the repetition rate (20 MHz

instead of 40 MHz) but considering the cumulated delays and the need of performing beam tests in 2008 in Saclay, this limitation was not considered as crucial and a new pulser prototype was then assembled in two weeks. A detailed set of measurements proved the achievement of most of the specifications and, based on these results, a first pulse amplifier unit has then been manufactured. This unit is now traveling to CERN where it should get beginning of May. It is not expected to fully achieve the specifications but still to be compatible with the foreseen operation although at a maximum repetition frequency of 30 MHz. Full characterization of the device is foreseen before end of June..

3. Dump (subtask 4.2.1): task finished

4. The chopper pulse amplifier/generator will be installed in the AD hall where the BSHM detector is located for a short (1-2 days) test. The output signal goes via some flexible coax cable into a 6 dB attenuator followed by a single turn wire loop .With the magnetic field from this wire loop we try to influence the BSHM detector until we see some reaction in the 5 s readout period. Then we can quantify the EMI immunity threshold.

5. Simulations have been done to explore the possibility of increasing the field coverage factor on axis, at the expenses of a lower field coverage factor off axis. This new geometry could be implemented in a future chopper plate, should the amplifier voltage be a limiting factor on the chopper effectiveness. Studies are ongoing to evaluate the effect of a beam misalignment on this new geometry.

RAL:

Important aspects of the RAL HIPPI activity for this quarter are as follows:

1. RAL Chopping Schemes : Ciprian Plostinar continues development of the RAL FETS chopping schemes A, B, C1 and C2, using the TraceWin code. An 'SNS' type PM quadrupole, has been purchased from Aster Enterprises Inc. (USA), and will be used to conduct proof of principle testing on the proposed hybrid quadrupole designs. Papers and posters entitled: 'A Hybrid Quadrupole Design for the RAL Front-End Test Stand', Dan Ciprian Plostinar (CCLRC/RAL/ASTeC), and Michael A. Clarke-Gayther (CCLRC/RAL/ISIS), and 'RF Design Options for a 180 MeV H- Linac for Megawatt Beam Facilities', Dan Ciprian Plostinar (CCLRC/RAL/ASTeC), have been provisionally accepted for inclusion in the proceedings of the PAC 2007 conference.

2. Fast chopper electrodes - slow-wave structures :High frequency analysis, and the mechanical design of prototype modules for the RAL planar A, and helical B2, slow-wave electrode structures are progressing. However, effort for this task was temporarily re-directed to a higher priority FETS design task, resulting in a slower than expected rate of progress during the quarter.

3. RAL fast pulse generator (FPG): The RAL FPG has been relocated to the new laboratory area (G17, R2), and will be set up to test new slow-wave electrode structures. The range of available pulse amplitudes, and durations are +/- 200 to +/- 1400 V, and 8 to 15 ns, respectively.

4. RAL slow pulse generator (SPG): The RAL SPG test set-up (bread-board) has been relocated to the new laboratory area (G17, R2), and will be set up to continue testing of 4kV rated MOSFET switches.

5. Laboratory and office relocation at RAL: The relocation of laboratory and office space was completed during the quarter, and has, inevitably, slowed progress in some areas.

6. . PAC 2007 :The submitted paper and poster entitled: 'Slow-wave chopper structures for next generation high power proton drivers', Michael A.Clarke-Gayther (CCLRC/RAL/ISIS), has been provisionally accepted for inclusion in the proceedings of the PAC 2007 conference.

7. CARE-Note-2007-002-HIPPI: A CARE Note entitled: 'HIPPI Work Package 4 (WP4): The RAL Fast Beam Chopper Development Programme / Progress Report for the period: July2005 - December 2006', Care-Note-2007-002-HIPPI, was delivered during the quarter. This represents a milestone for WP4.

Table 4.4a: Status of the Sub tasks in WP4 which are supposed to have started according to the MS project breakdown in Annex 1

WBS #	Title	Original begin date (Annex 1)	Original end date (annex1)	Estimated Status	Revised end date
4.1	Chopper structure A (CERN)				
4.1.3	Driver construction, testing.	January 2004	June 2005	80%	June2007
4.1.6	Prototype testing w/o beam	January 2006	December 2007	90%	
4.2	Chopper Line				
4.2.3	Beam line assembling	June 2005	December 2007	20%	
4.3	Chopper structure B (RAL)				
4.3.3	Prototype construction	January 2006	June2007	50%	Octobre 2007
4.3.4	Prototype testing	November 2007	June2008		

Table 4.4b: Status with respect to the interim reports and deliverables due in 2007 according to the MS project breakdown

WBS #	Title	Due date in Annex 1	Status	Revised delivery date
4.1.4	Chopper A prototype testing w/o beam	August 2007	50%	
4.2.3	Chopper A beam line assembling and meas	Decembre 2007	20%	December 2008
4.3.3	Prototype ready	June 2007	50%	October 2007

4.5 Work Package 5: Beam Dynamics

The joint code benchmarking project has made important progress in two directions:

1. Measurements: Experimental data on input/output distributions and rms quantities obtained at the UNILAC experiment in November/December 2006 have been evaluated. Some difficulties with interpreting the longitudinal measurements have been analyzed.

2. Code comparison: The measured data have been extensively compared with simulation using the PARMILA code, with the help of Dr. D. Jeon from SNS/Oakridge who visited GSI in March/April. Comparsion with earlier results from the in-house DYNAMION code has shown good agreement, in most cases within a few percent of deviation only as far as rms quantities are concerned. Discrepancies with measurements are larger and currently analyzed to form a basis for further measurements.

Other activities in the working package include:

1. At CERN a measurement of the EM compatibility of the Beam Shape and Halo Monitor has been done, as recommended by the ESAC in the September review.
The pulse amplifier was placed ~2m away from the detector and the pulser load on the detector itself. We synchronized the burst and the detector with the same trigger pulse and produced a 450us burst of 20MHz, 50% duty-cyle pulses with 500V amplitude. The detector did now show any sign of perturbation in its output data.

2. Beam dynamics simulations of the electron transport in the BSHM are carried on in order to optimize the detector setting for time and space resolution

3. Studies on the optimal condition for a frequency jump (352 MhZ to 700 Mhz) are continuing, in a collaboration between CERN and CEA.

4. A module has been coded to automatically steer a beam on its reference trajectories in a linear accelerator or a transfer line. The module is interfaced with the CERN code PATH. It will be used for steering LINAC4 in presence of mahine and beam errors.

5. For CEA, new simulations of a neutralized LEBT with H- beams have been started. These simulations have been performed with the recent parallelized code and they show a good agreement with the previous simulations.

The annual meeting of working package 5 will be held in Saclay on May 21. Registration is open at http://www-dapnia.cea.fr/Sacm/seminaire/index.php.

Table 4.5a : Status of the Sub tasks in WP5 which are supposed to have started according to the MS project breakdown in Annex 1

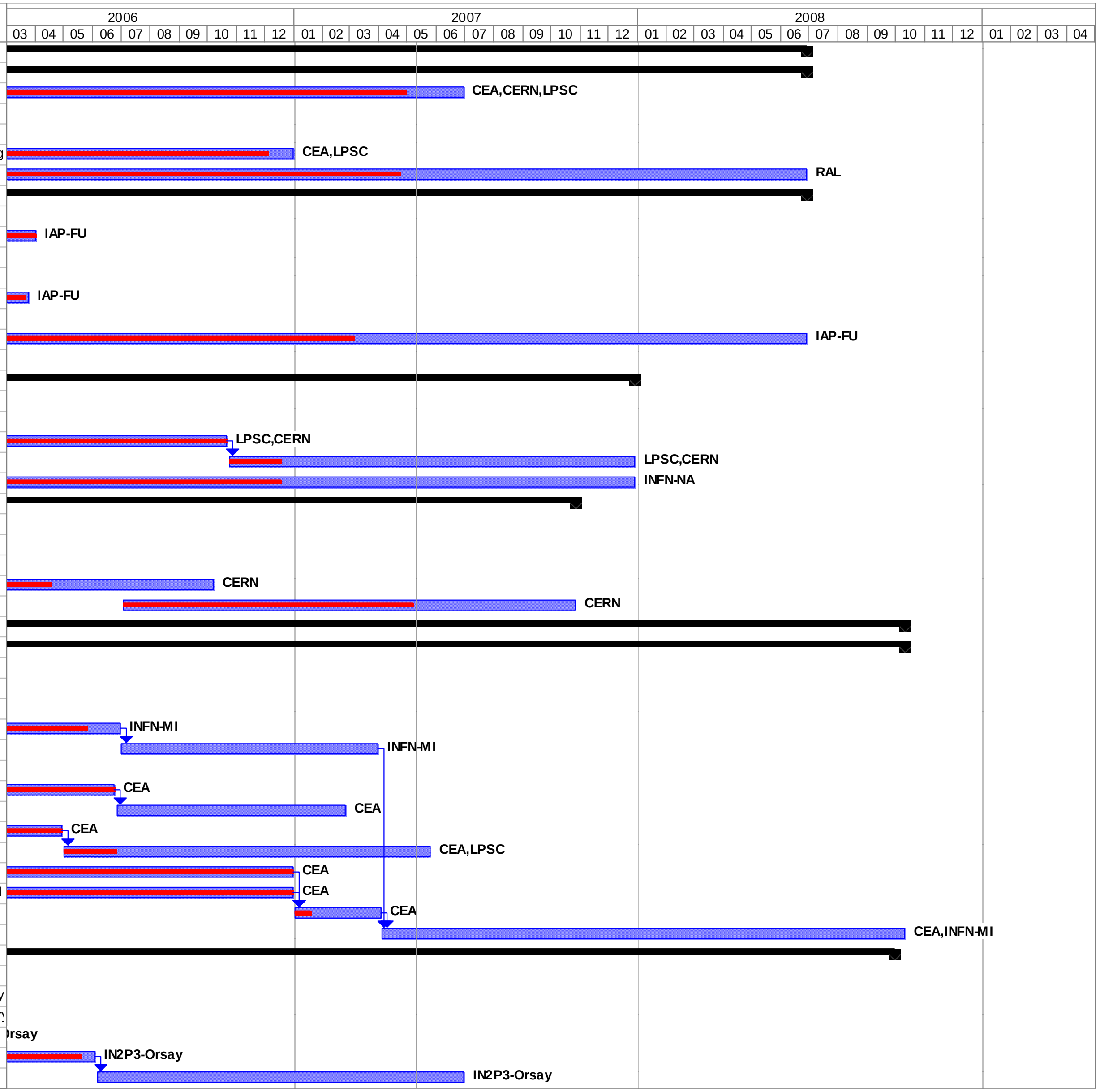
WBS #	Title	Original begin date (Annex 3)	Original end date (Annex 3)	Estimated Status	Revised end date
5.1	Code development				
5.1.1	Preparation, Dev. of 3D space charge routines, Testing	January 2004	June 2006	0%	Decembre 2007
5.1.3	Neutralization and ECR source model.	January 2004	December 2005	delayed	June 2008
5.1.6	Codes preparation for SC linacs	January 2004	December 2006	90%	June 2007
5.1.7	Code comparison and benchmarking	January 2005	September 2008	90%	
5.2.2,3	Measurement campaigns	June and Oct. 2006		1st camp. done	July 2007
5.3	Diagnostics and collimation				
5.3.4	Non-interceptive bunch measurement construction (GSI)	January 2005	December 2006	90%	April 2007
5.3.9	Halo monitor tests and improvement (CERN)	January 2004	June 2005	100 %	March 2007
5.3.7	Beam profile monitor design (FZJ)	January 2005	June 07	80%	
5.3.6	On-line transmission control (GSI)	October 2005	September 2007	50%	

Table 4.5b: Status with respect to the interim reports and deliverables due in 2007 according to the MS project breakdown

WBS #	Title	Due date in Annex 1	Status	Revised delivery date
5.1.1	RAL 3D code development	December 2007	0	
5.5.1	Profile measurement by fluorescence final report	July 2006	delivered	February 2007
5.2	Simulations and experiment at UNILAC final report	December 2006	delayed	July 2007
5.3.4	Non-interceptive bunch measurement final report	December 2006	Unknown (90%)	April 2007
5.3.6	Online Transmission Control	October 2007	Unknown (50%)	
5.3.7	Beam profile monitor for high Intensity (FZJ)	June 2007	80%	

Appendix 1: Gantt chart at end of April 2007

ID	Task Name
1	**WP2: NORMAL CONDUCTING STRUCTURES**
2	**2.1 Drift Tube Linac**
3	2.1.1 DTL design
4	2.1.2 Decision on prototyping
5	2.1.3 DTL coupler prototype design
6	2.1.5 DTL coupler prototype construction and testing
7	2.1.4 DTL beam dynamics design
8	**2.2 H-mode Drift Tube Linac**
9	2.2.1 RF model CH tank1 RF design
10	2.2.2 RF cold model design & construction
11	2.2.3 RF model construction
12	2.2.4 Beam dynamics design CH tank1
13	2.2.5 CH model cavity tests
14	2.2.6 CH-prototype design
15	2.2.7 CH-prototype construction, tests
16	2.2.8 CH-DTL beam dynamics study
17	**2.3 Side Coupled Linac**
18	2.3.1 RF model RF design
19	2.3.2 RF model mechanical design
20	2.3.3 RF model construction
21	2.3.4 RF model testing
22	2.3.5 SCL module design
23	**2.4 Cell Coupled Drift Tube Linac**
24	2.4.1 Pre-prototype construction
25	2.4.2 Pre-prototype high-power RF tests
26	2.4.3 Contribution to ISTC prototype construction
27	2.4.4 Revision of design after prototype testing
28	2.4.5 Testing of ISTC prototype
29	**WP3: SUPERCONDUCTING STRUCTURES**
30	**3.1 ELLIPTICAL CAVITIES**
31	3.1.1 Cavity A vertical tests
32	3.1.2 Tuner design
33	3.1.3 Integration of piezo design
34	3.1.4 Tuner construction
35	3.1.13 Cavity A assembly with tuner
36	3.1.5 Design cavity B
37	3.1.6 Construction cavity B
38	3.1.13 Preparation, vert. test & welding cavity B
39	3.1.7 Power coupler design & engineering
40	3.1.9 RF couplers construction & preparation
41	3.1.8 RF source order & construction
42	3.1.10 Modulator preparation for 700 MHz test stand
43	3.1.11 RF source testing
44	3.1.12 High power pulsed tests
45	**3.2 SPOKE CAVITIES**
46	3.2.1 Test stand preparation at FZJ
47	3.2.2 Evaluation of 760 MHz resonator in vertical cry
48	3.2.3 Evaluation of 352 MHz 2-gap res. in vertical cr
49	3.2.4 Design of coupler prototype
50	3.2.5 Construction of coupler prototype
51	3.2.9 Test of coupler prototype



ID	Task Name	
52	3.2.6 RF design of 352 MHz multi-gap resonator	
53	3.2.7 Engineering of resonator, coupler and tuner	
54	3.2.8 Final design of 352 MHz multi-gap prototype	FZJ,IN2P3-Orsay
55	3.2.10 Manufacturing of 352MHz multi-gap prototyp	FZJ
56	3.2.11 Evaluation of 352MHz multi-gap prototype	FZJ,IN2P3-Orsay
57	**3.3 CH RESONATOR**	
58	3.3.1 Design of tuning system	IAP-FU
59	3.3.2 Construction of CH tuning system	IAP-FU
60	3.3.3 Measurement of tuning system	
61	**WP4: CHOPPING**	
62	**4.1 CHOPPER STRUCTURE A**	
63	4.1.1 Pre-prototype construction	
64	4.1.2 Pre-Prototype testing	
65	4.1.3 Driver construction, testing	
66	4.1.4 Full scale prototype design	
67	4.1.5 Full scale prototype construction	
68	4.1.6 Prototype testing w/o beam	CERN
69	**4.2 CHOPPER LINE**	
70	4.2.1 Dump design	
71	4.2.2 Dump construction	
72	4.2.3 Beam line assembling	CERN,CEA,LPSC
73	**4.3 CHOPPER STRUCTURE B**	
74	4.3.1 Pre-prototype design and test	RAL
75	4.3.2 Prototype design	RAL
76	4.3.3 Prototype construction	RAL
77	**WP5: BEAM DYNAMICS**	
78	**5.1 Code development**	
79	5.1.1 3D space charge routines development, testing	RAL
80	5.1.2 LORASR development	
81	5.1.3 Neutralization and ECR source modelization st	CEA
82	5.1.4 Improvement, modelling high current	GSI
83	5.1.5 Code preparation for 3 MeV test stand	CERN
84	5.1.6 Code preparation and analysis for SC linacs	FZJ
85	5.1.7 Code comparison and benchmarking	GSI,RAL,IAP-FU,CEA,CERN,LPSC
86	5.1.8 Code benchmarking with experiment	GSI,RAL,IAP-FU,CEA,CERN,LPSC
87	**5.2 Experiment at UNILAC**	
88	5.2.1 Preparation, simulations	GSI
89	5.2.2 First experiment campaign	GSI
90	5.2.3 Second experiment campaign	GSI
91	**5.3 Diagnostics and collimation**	
92	5.3.1 Profile measurement prototype des., constructi	
93	5.3.2 Profile measurement testing	GSI
94	5.3.3 Non-interceptive bunch measurement design	
95	5.3.4 Non-interceptive bunch measurement const., te	GSI
96	5.3.5 Halo monitor design, construction	
97	5.3.9 Test and improvement of halo monitor	
98	5.3.6 On-line transmission control	GSI
99	5.3.7 Beam profile monitor design	FZJ
100	5.3.8 Collimators study	
101	**5.4 Experiment at CERN**	
102	**5.5 Comparative assessment of dynamics and meas.**	