

SUPERCONDUCTING RF ACTIVITIES AT THE IPN ORSAY LABORATORY

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Abstract

IPN Orsay is presently involved in several R&D programs for the future accelerators in Europe. High intensity linear proton accelerators are proposed for Nuclear Physics (EURISOL) and for Nuclear Waste Transmutation (XADS). Both projects propose to use Superconducting RF cavities for the whole energy range (5 MeV - 1 GeV). Two types of cavities are developed: spoke type for the low/intermediate energy and elliptical multi-cell type for the high-energy range. Power couplers, cold tuning systems and ancillary equipments are also under development. A horizontal cryostat (CRYHOLAB), constructed in collaboration with the CEA Saclay, is now entered into a routine operation phase. An associated helium liquefier and RF power sources allow to test cavities with couplers and auxiliary equipments under conditions which are very close to those encountered in a real accelerator. More recently IPN Orsay has started a new SRF development for the Spiral-2 Radioactive Beams Facility project. A 176 MHz half-wave resonator was designed and is under construction. Other important activities concern the new developments around the TESLA cavities, in particular the low temperature characterization of materials proposed for some components like the power couplers or the piezo tuning system.

R & D PROGRAMS FOR FUTURE ACCELERATORS IN EUROPE

One of the major R & D axes of the CNRS-IN2P3 [1] is the accelerator technology for different fields, in the fundamental physics research or for applications. The activities are developed in several laboratories: IPN Orsay, LAL Orsay, LPSC Grenoble, GANIL Caen, etc. All the developments are conducted and managed in close collaboration with the CEA/DAPNIA.

In the last years, most of these developments have taken place in the frame of large international collaborations, mainly within the European Union. In the fundamental physics area, the IPNO takes part at the international effort for the construction of the next LHC. Other projects presently at the level of the design studies: the next european facility for radioactive beams (EURISOL), the next electron-positron collider and the next neutrino beam facility (ESGARD-CARE).

Following the major involvement of the CNRS-IN2P3 in the nuclear energy field (nuclear wastes and new

concepts for reactors), the IPNO laboratory is involved into the design studies and preliminary R&D programs for the Accelerator Driven System development in Europe.

Most of these programs started within the 5th FWP of the EU, and for the next 4 years, the participation into the 6th FWP programs will give a clear orientation to the accelerator technology activities in the french laboratories. Programs coordination takes place progressively in different european institutions and networks (EURATOM, NUPECC, ESGARD, etc.)

HIGH INTENSITY PROTON LINEAR ACCELERATORS

The study and development of High Intensity Proton Linear Accelerators is one of the major issues in the field of accelerator technology. Presently, several european projects propose the use of this type of accelerator as drivers for different facilities. The IPNO laboratory participates to three collaborations: XADS, EURISOL and CARE(HIPPI)

XADS [2]

Initiated by several european Research Ministers in 1998, a Technical Working Group under the chairmanship of Prof. Carlo Rubbia, presented a "Roadmap for Developing Accelerator Driven Systems for Nuclear Waste Incineration" in 2001. The next step was the set up of the PDS (Preliminary Design Study) of an Experimental ADS (XADS) supported by the European Commission (Euratom) in the period 200-2004

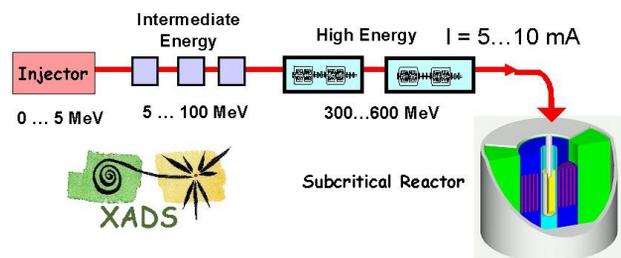


Figure 1 : Experimental ADS concept (XADS project)

(5th FWP). At the present time, a reference design is studied (Fig. 1): a proton linear accelerator (mainly composed of SRF cavities) must deliver a beam of 600 MeV (a second version, MYHRRRA, at 375 MeV is also being considered) with a current of 5-10 mA, to a spallation target (liquid metal Pb/Bi or Pb) which is surrounded by a sub-critical thermal assembly ($k < 0.98$, thermal core power 100 MW) containing the nuclear waste to be incinerated.

A R&D program for the accelerator components is under preparation and will be supported by the Euratom 6th FWP. The main issues will be related to the specific reliability aspects of this project, the required low number of beam trips imposed by the thermal stability of the reactor, imposes the development of fault tolerant concepts for the operation of a SRF linac composed of independent phased and powered cavities.

EURISOL [3]

The EURISOL RTD (Research and Technical Development) program was launched in 2000 and supported by the EU under the 5th FWP, is now close to present his final report. The european nuclear physics community, NuPECC, has identified EURISOL as a high priority in its long-range plan. A Design Study (DS) proposal for funding within the EU 6th FWP is now under preparation.

Two accelerators have been considered for this facility (Fig. 2): a linear proton driver, composed of SRF cavities of different beta and type, and a post accelerator for the radioactive beams produced at the target/ion source level. Two options are considered for this post accelerator: cyclotron or superconducting linac.

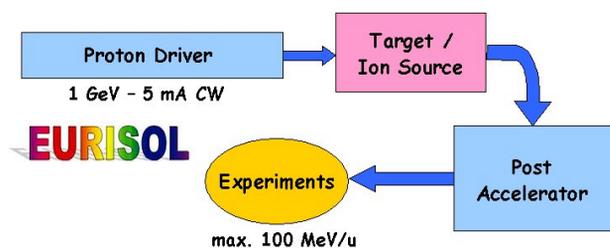


Figure 2 : EURISOL radioactive beams facility

For the driver accelerator the R&D program is strongly connected to the XADS project, both linacs have the same operating mode (CW) with the same beam power. All the main components (cavities, couplers, RF systems and cryogenic equipments) are identical and must benefit from this natural synergy between these two projects.

HIPPI Joint Research Activity [4]

More recently, and related to future high energy physics facilities, the ESGARD group has initiated a common integrated activity (CARE) to propose a large number of accelerator technology developments for the next generation of accelerators (e-p colliders, neutrino factory, etc.) One important aspect is the development of pulsed high intensity proton accelerators as drivers for secondary beams generation (HIPPI Joint Research Activity proposal for the 6th FWP). Most of the components needed in this type of accelerator are very similar to those studied into the XADS and EURISOL projects. The IPNO laboratory will participate to the studies and tests to demonstrate the performances of spoke cavities in pulse mode operation.

SRF CAVITIES FOR PROTON LINEAR ACCELERATORS

Elliptical Cavities

Multicell 700 MHz Superconducting RF cavities are considered for the high-energy sections ($\beta \geq 0.5$) of XADS and EURISOL projects. After the fabrication and tests of several single cell cavities [5], a complete 5-cell cavity ($\beta = 0.65$) was designed, constructed by the french company CERCA, and tested by the CEA/CNRS collaboration (Fig. 3). The cavity was equipped with a stainless steel helium tank and a power coupler port.



Figure 3 : 700 MHz ($\beta = 0.65$) Niobium SRF cavity

Vertical tests have shown very good quality factor and high accelerating gradient, limited only by the available RF power (Fig 4). The same results were confirmed in a complete test at 2K performed in CRYHOLAB (horizontal cryostat).

A new cold tuning system has been constructed and is ready to be tested in the horizontal cryostat.

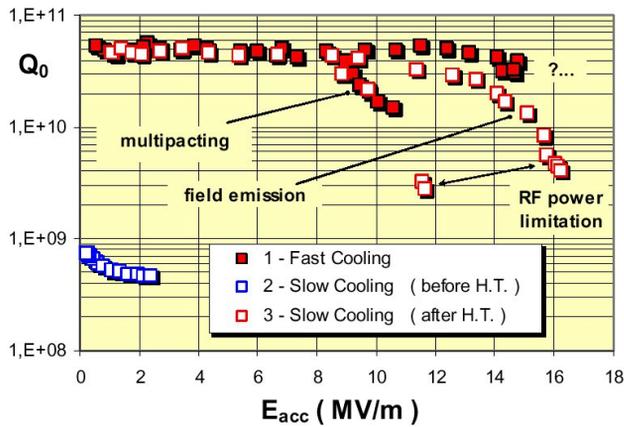


Figure 4 : Tests results (2K) of the 700 MHz, $\beta = 0.65$ cavity in a vertical cryostat

A power coupler is now being designed, it is based on the KEK-SNS concept. The designed power level is 150 KW. Construction of the firsts prototypes are scheduled for the next two years, and test at a maximum power of 80 KW is planned at the CRYHOLAB facility.

A detailed description of the last results is presented in this conference [5]

Spoke Cavities

Two years ago we started a program to develop superconducting RF structures able to offer good stability and efficiency in the low-intermediate energy range of a high intensity linear accelerator [6] [7]

A first 352 MHz $\beta = 0.35$ two gap niobium prototype was constructed by the french company CERCA (Fig. 5)



Figure 5 : 352 MHz two gap $\beta = 0.35$ spoke cavity

After preparation (chemistry, HPR) at the CEA-Saclay laboratory, the tests at 4.2 K were performed in a new vertical test facility at IPNO. Results presented in Fig. 6 confirm the fabrication quality and good surface quality. Measurements of resonant frequency have confirmed also

a good mechanical stability and very low Lorentz force coefficient.

The last results of this program are presented in this conference [8]

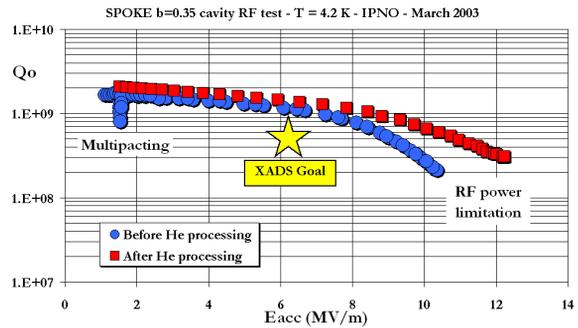


Figure 6 : Tests of the 352 MHz spoke cavity at 4.2 K

This program will be continued in the short term by the development of a power coupler (5 – 10 KW), and the fabrication of a second two gap prototype ($\beta = 0.15$) equipped with helium tank and tuner. In the frame of the HIPPI collaboration, with the FZ Jülich laboratory, the study of a new multigap prototype is proposed in order to explore the performances of spoke cavities in high power pulsed proton accelerators.

CRYHOLAB

This facility, constructed and managed by the CEA/CNRS collaboration, has entered, last year, in a fully operational phase. At the present time the horizontal cryostat is connected to the helium liquefier and to the helium pumping system, offering the possibility to handle very long term tests of cavities and associated components (power couplers, tuners, cryogenic equipments, etc) with high flexibility. Fig. 7 shows an overall view of the cryostat, and Fig. 8 a view of a recent test of a 700 MHz multicell cavity.



Figure 7 : CRYHOLAB

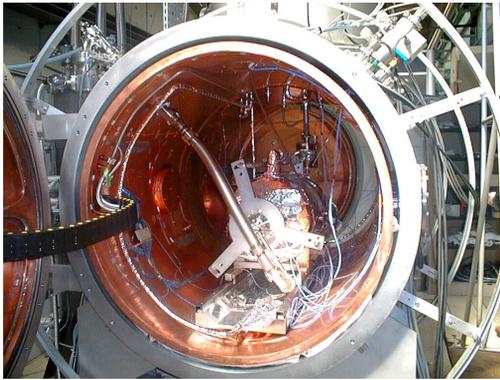


Figure 8 : CRYHOLAB test of a 700 MHz multicell cavity

A 1.3 GHz modulator-klystron power amplifier is installed in this facility allowing tests at full power of TESLA cavities and couplers. A 700 MHz 80 KW CW power amplifier has been recently installed and a larger modulator-amplifier for pulsed power tests of 700 MHz cavities is now under design.

More details of the cryogenic tests in CRYHOLAB of 700 MHz cavities are given in this conference [5]

SPIRAL-2 PROJECT

A new radioactive beam facility, SPIRAL-2, is presently proposed for the GANIL laboratory in France. A CEA/CNRS study group has started a detailed design study [9]. The driver (Fig. 9) with an accelerating voltage of 40 MV will deliver beams of deuterons (5mA), light ions ($A/q=3$, 1mA) and heavier ions ($A/q=6$) in a later stage.

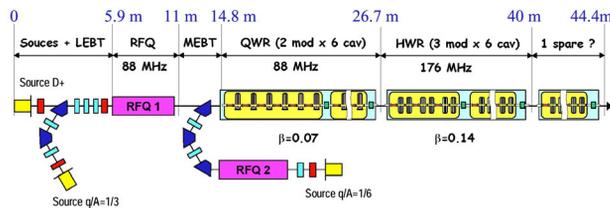


Figure 9 : Driver accelerator of the SPIRAL-2 project

After the injector sections, the driver is composed of two accelerating sections composed of superconducting resonators: QWR 88 MHz and HWR 176 MHz, with a total of 36 resonators distributed in 6 cryomodules.

The IPNO laboratory participates to many aspects of this project : beam dynamic studies, cryogenic refrigerator, cavities and cryomodules, targets, ion sources and mass separators and post acceleration.

For the driver high energy sections we have proposed a Half Wave Resonator at 176 MHz (Fig. 10). A prototype is now completely designed and the fabrication will start in October.

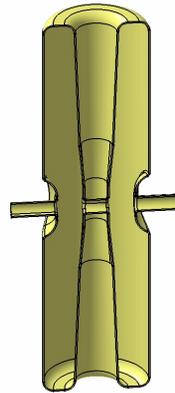


Figure 10 : 176 MHz HWR resonator for SPIRAL-2

Main Parameters $\beta = 0.14$	
r/Q	215
G	40
E_{peak}/E_{acc}	4.5
B_{peak}/E_{acc}	9.5
$E_{acc} @ B_{peak}=80mT$	9 MV/m

Details on this design are given in the paper from J.L. Biarrotte in this conference [10].

ACTIVE TUNERS FOR HIGH GRADIENT PULSED SRF CAVITIES

Compensate the Lorentz force detuning of high gradient SRF cavities in pulsed mode is an important issue for the next generation of accelerators, either for the e-p colliders, or the medium beta elliptical cavities proposed for proton linear accelerators.

At the IPNO a R&D activity has been started to study the performances of dynamic tuners based on piezoelectric actuators. A dedicated experimental device was designed and successfully used to characterize these actuators in the low temperature range (Fig. 11)

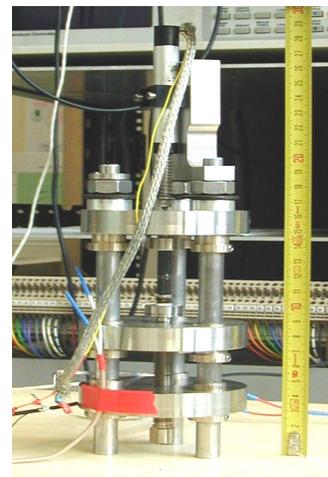


Figure 11 : Test apparatus for characterization of piezoelectric actuators

The device and the detailed results obtained with commercial samples is presented in this conference [11]

A typical result obtained in these experiment is shown in Fig. 12, where the full range displacement obtained at

maximum voltage was measured in the 1.8 K <T< 52K temperature range.

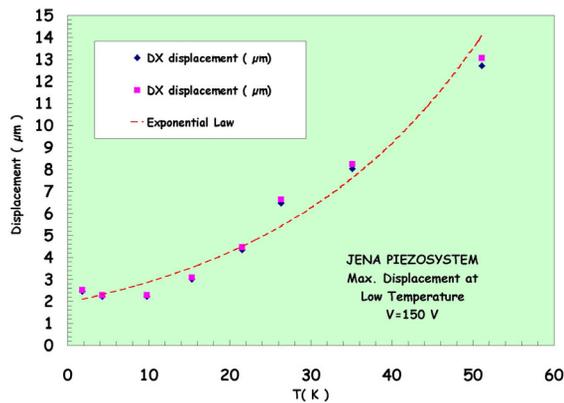


Figure 12 : Piezoelectric actuator displacement in the 1.8 K<T<56 K temperature range

A cold tuner system including a piezoelectric actuator has been constructed adapted to the 700 MHz proton cavities and will be tested in the CRYHOLAB facility.

New developments are foreseen within the CARE – SRFTECH Joint Research Activity in the 6th FWP : further characterisation of actuators, radiation hardness tests, integration and test with TESLA type cavities.

ACKNOWLEDGEMENTS

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