WP5 Elliptical cavities

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4th SPL collaboration meeting jointly with ESS

Lund – 2010/07/01

Irfu cea saclay

Objectives

- The main objective of this WP 5 is to provide the engineering design of the fully equipped cryomodules for both medium and high beta elliptical 704 MHz cavity sections of the ESS linac operating at 2 K with an accelerating field of about 15 MV/m.

- One goal of the Design Update phase is to prepare for construction :
  - The Technical Design report which will also include
    - a cost evaluation with a 20% accuracy
    - Preparation of PBS and WBS for construction
    - Preparation of upgrade scenario

- Prototypes will be fabricated to demonstrate the feasibility and performance of critical components.

Work Breakdown structure

Work units

- 5.1 Management
- 5.2 Medium beta elliptical cavity
- 5.3 High beta elliptical cavity
- 5.4 Power coupler
- 5.5 Elliptical cavity cryomodule
- 5.6 Superconducting quadrupoles
- 5.7 Prototypes and tests

Medium beta cavity design

704 MHz beta = 0.65 5-cell cavity.
Eacc = 15 MV/m (baseline)

- RF and mechanical study of the medium beta elliptical cavity with its helium vessel.

- RF and mechanical design of the HOM couplers according to the damping specifications provided by WP2 and WP8-RF modeling WU.

- Design of the magnetic shield of the medium beta cavity.

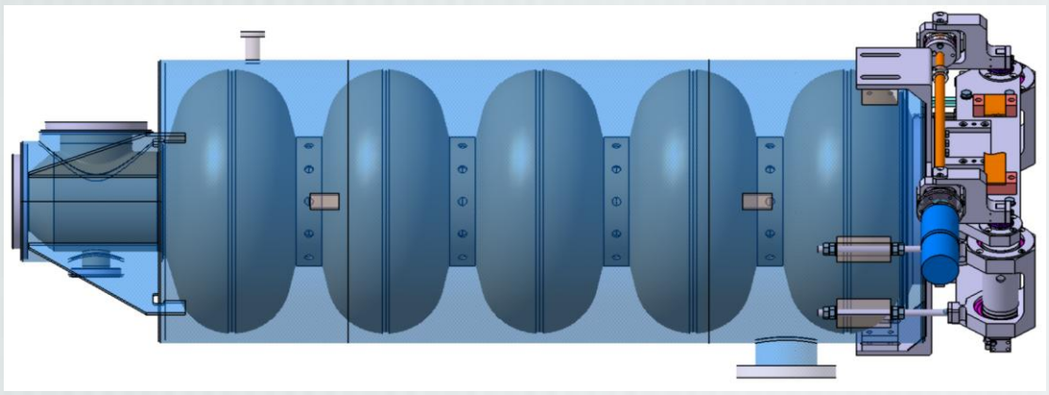
- Write-up of TDR section on the medium beta elliptical cavities, including costing.

Similar development going on for SPL Eucard at IPNO

High beta cavity design

704 MHz beta = 0.92 5-cell cavity.
Eacc = 15 MV/m (baseline)

- Study of the preparation procedure
- RF and mechanical study of the high beta elliptical cavity with its helium vessel.
- RF and mechanical design of the HOM couplers according to the damping specifications provided by WP2 and WP8-RF modeling.
- Design of the magnetic shield of the high beta cavity.
- Design of the cold tuning system combining slow and fast tuning
- Write-up of TDR section on the medium beta elliptical cavities, including costing.



Similar development going on for SPL Eucard at CEA-Saclay (beta=1)

Power coupler design

704 MHz 1 MW peak power, max 10% duty cycle
The design should be compatible with any upgrade scenario

- RF and mechanical study
- Thermal – cooling study
- Write-up of TDR section on the power coupler, including costing.

Similar development going on at CERN and CEA for the SPL

Elliptical cavity cryomodules

Contain 8 cavities operating at 2K

The work is focusing on the high beta cryomodule. The medium beta cryomodule will share the same mechanical and cryogenic design, assembly and alignment methods but the additionnal modeling/CAD work is included

Conceptual designs with SC quads and with external RT quads have to be compared (tradeoff between energy efficiency and complexity, capital cost)

- Mechanical design of the high beta cryomodule. This phase takes into account the assembly phase of the cavity string inside the modules, vacuum and cryogenic sectorisation, mechanical and thermal loading of the system, alignment, and integration of the instrumentation and superconducting quadrupoles.
- Cryogenic and vacuum design of the modules. This includes the detailed design of the valve box, cryo and vacuum interfaces.
- Mechanical design of the clean room cavity string assembly tools.
- Mechanical design of cryomodule assembly tools.
- Write-up of cryomodule interface document
- Write-up of the TDR section on elliptical cavities cryomodules including costing.

Similar development going on at CERN and IPNO for the SPL short scale cryomodule

Superconducting quads

Caracteristics not defined as of now

- Magnetic design of SC quads and steerers
- Mechanical design
- Current feeds design
- Write-up of the TDR section on SC quads including costing.

Prototyping and testing

- Fabrication of cavity, tuner, coupler prototypes
- Design and procurement of coupler test bench and tooling
- Design and procurement of cavity tuning bench
- Design and procurement of cavity preparation and handling tools
- Prototype cavities preparation and tests

State of the art

Main SRF accelerating components similar to ESS needs have been fabricated and tested. Example of what is installed on running linacs or tested in horizontal cryostats, in the 0.7-1GHz frequency range

Beta <1 elliptical multi-cell cavities freq < 1 GHz for high power pulsed beams

	F (MHZ)	beta	cells	Eacc operating range (MV/m)	Number of cavities
SNS	805	0.61	6	9-16	33
		0.81	6	8-16	48
J-PARC	972	0.725	9	12	2
CEA-Saclay	704	0.47	5	16	1

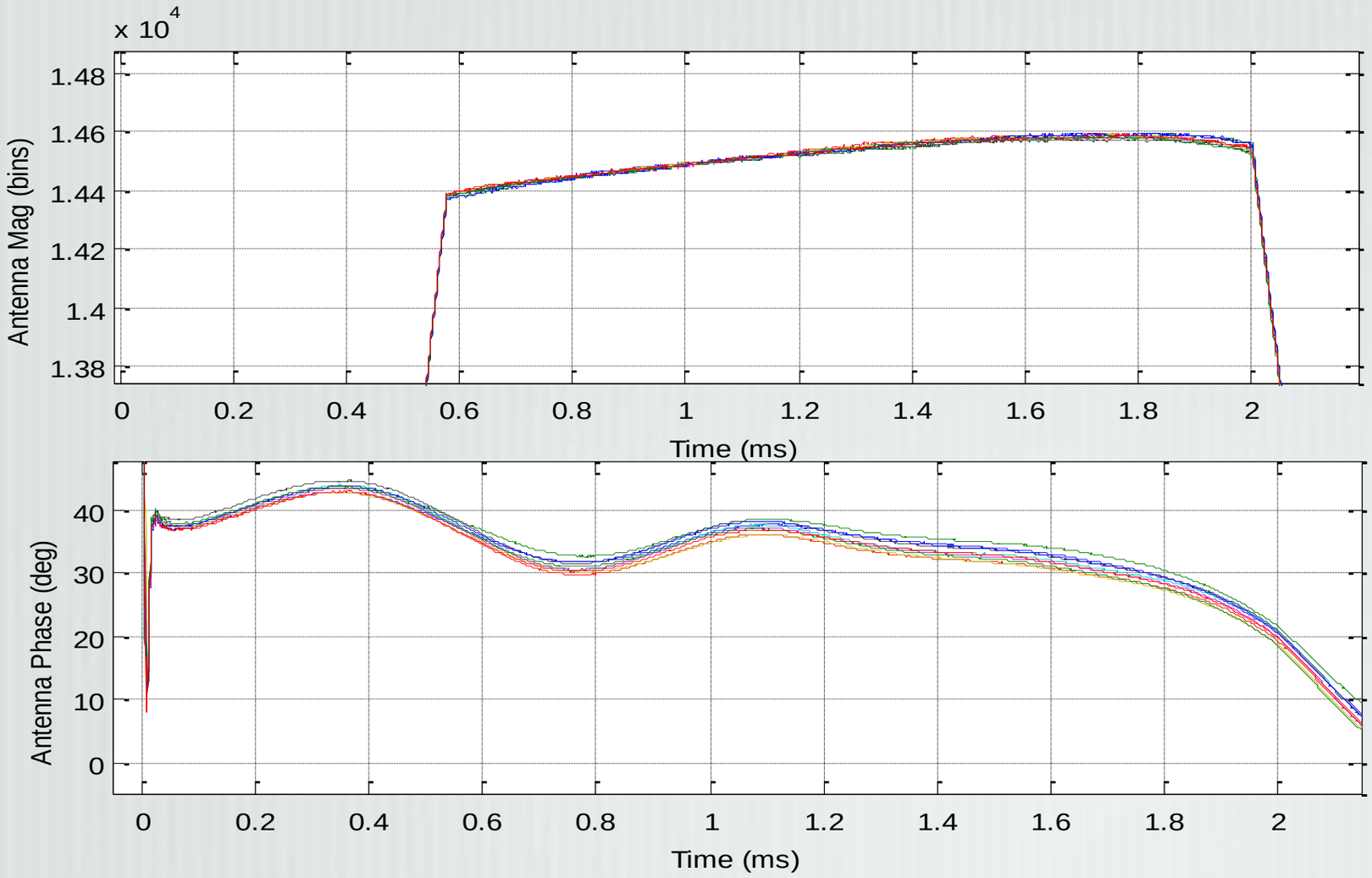
New related developments

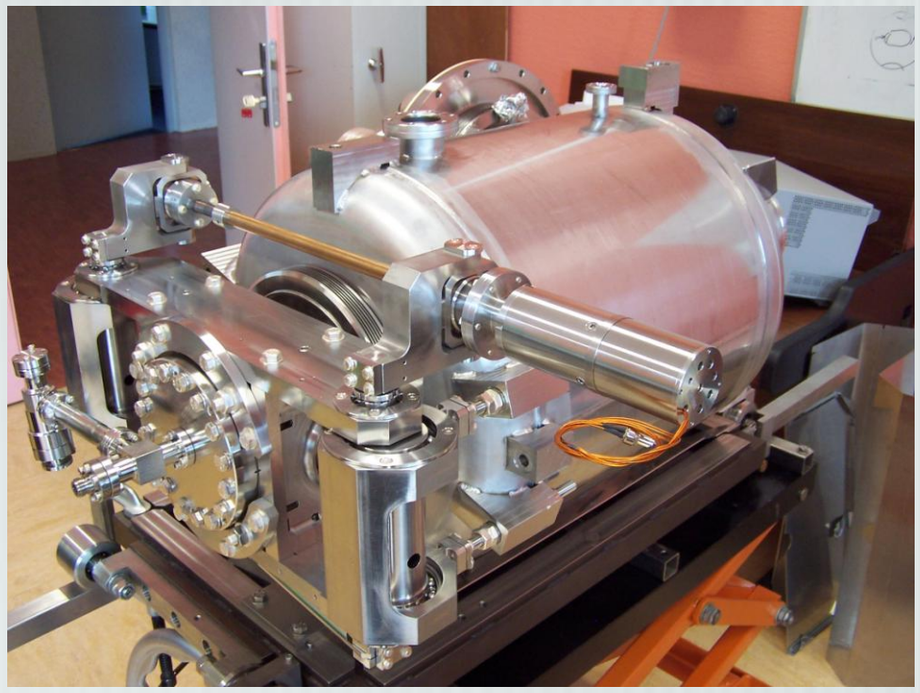
- FNAL 650 MHz R&D program
- SPL and Eucard R&D program (CERN,CEA,IPNO)
- SLHC-PP lorentz detuning compensation tests at Saclay

State of the art

LDF compensation on the Saclay beta=0.47 704 MHz 5-cell cavity with the piezo tuner (Saclay-V)
Eacc = 13 MV/m. **RF pulses 2 ms 50 Hz**. Static KL=-3.8 Hz/(MV/m)²

	Piezo off	Piezo on
Phase excursion on flat top	+/- 25 deg.	+/- 8 deg.
Amplitude variation on flat top	45%	1.4%





Good repeatability although mechanical modes have no time to decay between successive RF pulses (10 pulses recorded with CERN LLRF crate)

State of the art

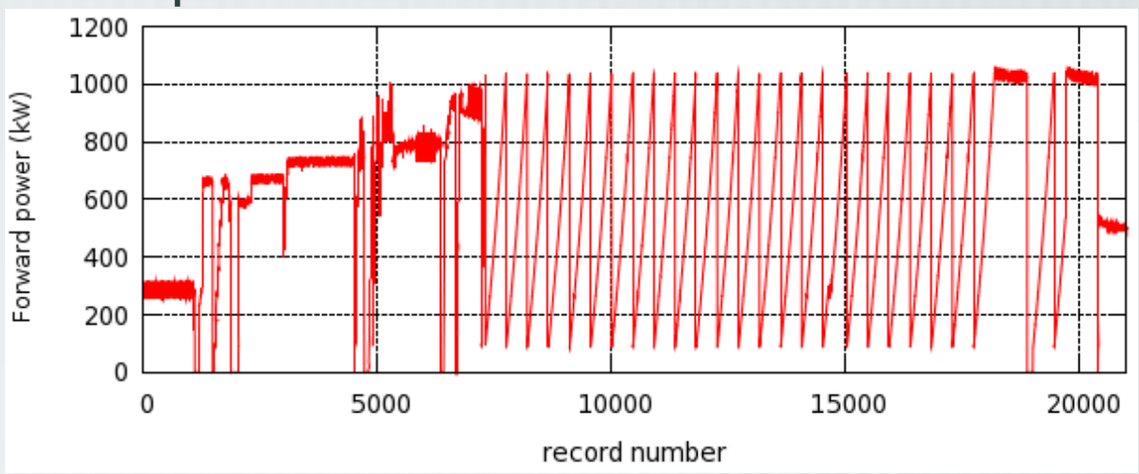
Existing power couplers, high peak power, high average power tested in cryogenic environment freq < 1 GHz, pulsed mode

	F (MHZ)	Max Peak power TW (kW)	Rep. Rate (Hz)	Pulse length	Max. avg power (kW)	Number
SNS	805	1000	60	1.3	80	81+
J-PARC	972	1000	25	0.6	30	2
CEA-Saclay	704	1200	50	2	120	2

All of the above derive from KEK-B design. Power values on room temperature test stand

Recent developments:

- CERN R&D for SPL
- Recent results from CEA coaxial coupler 1MW 2ms 50Hz in full reflection on a SC 704 MHz cavity at 2K



Critical design requirements

- Reliability – availability above 95%
- Power couplers
  - The nominal power forward is set no higher than 900 kW. This ultimately limits the gradient of the cavities to 12 MV/m in the 75 mA upgrade scenario
  - A test of couplers up to 1.5-2 MW would be very desirable in order to check the operational margins. No test place with the required RF power exist as of now. An option is to upgrade the CEA 1MW 50Hz existing test stand running a pair of 1MW klystrons driven by a single HV modulator
- Consistent performance of cavities
  - From the large scale SNS experience, limitation due to field emission heating the end groups (not cooled) and HOM couplers
  - Cavity preparation procedures must meet the higher standards and follow latest developments, yet not trade for large dispersion in cavity test results

Prototypes

Early prototypes (end 2012)

- A pair of high beta cavities without HOM couplers. Tested in vertical cryostat and horizontal cryostat.
- piezo tuner

Late prototypes (launched mid/end 2012)

- A pair of medium beta cavities
- A pair of fundamental power couplers

Later prototypes (after 2012)

- 8 fully equipped cavities (tank, FPC, HOM couplers, tuner, magnetic shield)
- Full length cryomodule (test place with RF power + cryogenics?)

SPL short scale prototype cryomodule

A SPL short scale cryomodule will be designed by CERN and IPNO, built and ready to be tested at CERN in 2013. It will contain 4 fully equipped elliptical cavities.

It is agreed between SPL and ESS that common specifications for this module will allow the projects to gather sufficient data from the test to consolidate the design produced for the full scale “machine cryomodule” in the design update.

The work of defining the set of features of the machine cryomodule needed to be included in the half scale prototype is starting today.

- What can be tested within the upgraded test places capabilities
- Start to List of assembly driven, aligment driven, cryo driven, tunnel space driven features

Scientific Collaboration

Identified partner laboratories

- CERN
- IPN-Orsay
- INFN-Milano
- CEA
- Royal Holloway University of London
- ESS-Lund
- Joining very recently and potential partners J-Lab, U-Rostock