WP10: SRF

Task 10.2: SC Cavities for proton Linacs

Status of beta=1 cavity development

Juliette Plouin

EuCARD-SRF Annual Review 2011

Task 10.2 subdivision at CEA - Saclay

- design of β=1 cavities
- fabrication of 1 or 2 β=1 cavity prototype(s)
  - *purchase of Nb material*
- low power RF test of cavity prototype(s)
  - *set-up for tuning of field flatness*
  - *vertical insert of cryostat*

Team :
G. Devanz, J. Plouin & S. Chel (SACM)/
S. Cazaux, Ph. Hardy, A. Mohamed, G. Abada (SIS)

⇨ **This presentation**

- new vertical EP station
- new HPR station
- surface preparation of cavity prototype(s)

Team :
F. Eozénou, Y. Gasser & S. Chel /
J.-P. Poupeau, T. Vappereau

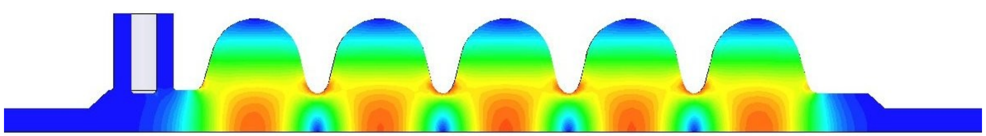
⇨ **Fabien's presentation**

RF design of the cavity

REFERENCE PARAMETERS (CDR, 2006)	
RF frequency	704.4 MHz
Cavity β	1
Accelerating gradient (E_{acc})	25 MV/m
Average pulse current (I_{beam})	40 mA
Synchronous phase (j_s)	-15 °
Peak RF power	1 MW

Already presented at EUCARD meeting in april 2010

- → *Optimization of r/Q, Epk, Bpk*
- → *Achievement of the external coupling*
- → *Resistance to Lorentz detuning (stiffeners)*



704.4 fundamental mode (pi-mode)

RF PARAMETERS OF THE CAVITY	
Number of gaps (Ngap)	5
Frequency [MHz]	704.4
Beta	1
Bpk/Eacc [mT/(MV/m)]	4.20
Epk/Eacc	1.99
G [Ohm]	270
Cell to cell coupling	1.92 %
r/Q [Ohms]	566
Beam diameter aperture [mm]	129.2
L_{acc} = Ngap.β.λ/2 [m]	1.0647
Maximum energy gain @ Bpk = 100 mT	25 MeV
Operating Temperature (O.T.)	2 K
R_{BCS} @ O.T. (theoretical)	3.2 nΩ
Q_0 @ O.T. for R_{BCS}	$8.4*10^{10}$

Lorentz Force Detuning (LFD)

LFD : measures the resonance frequency shift produced by the mechanical deformation induced by the electromagnetic field in continuous wave (cw).

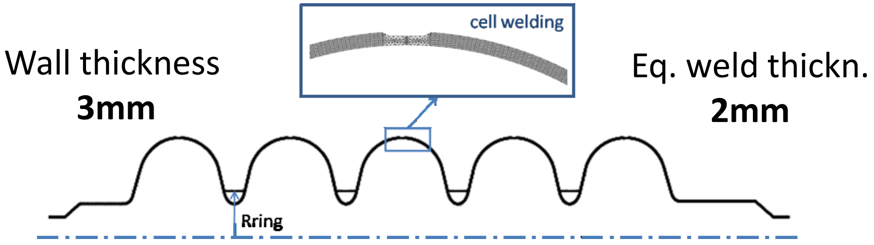
$$K_L = \Delta f / E_{acc}^2$$

LFD is critical in pulsed mode

RF/MECHANICAL PARAMETERS OF THE CAVITY		
Nominal wall thickness	3	[mm]
Cavity stiffness K_{cav}	3.84	[kN/mm]
Tuning sensitivity $\Delta f/\Delta z$	164	[kHz/mm]
K_L with fixed ends	-0.55	[Hz/(MV/m)²]
K_L with free ends	-5	[Hz/(MV/m)²]
K_L with realistic boundary conditions	-1	[Hz/(MV/m)²]
Pressure sensitivity K_P (fixed ends)	1.2	[Hz/mbar]

→ **Reduction of K_L with stiffening rings down to $|K_L|$= 1 Hz/(MV/m)²**

→ **Fast tuning system in pulsed mode (tests & operation)**



Optimal position of stiffeners: **Rring= 91 mm**

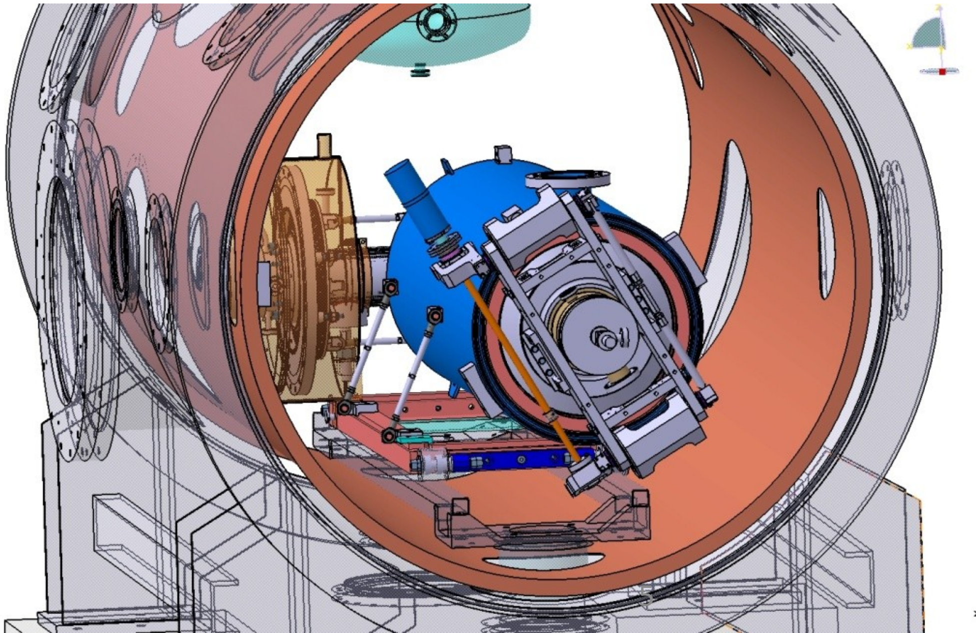
Mechanical design : future integration in CRYHOLAB

In the Description of Work of EuCARD program, the tasks assigned to CEA are :

- **Fabrication of 1 or 2 prototype cavities**
- **Vertical test in cryostat ($\beta_{coupling}$=1)**

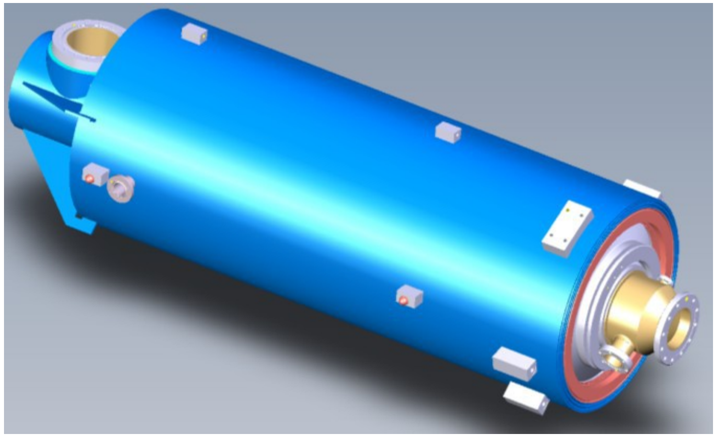
As qualification of the prototype will require more complete and representative tests, we designed a fully equipped cavity (with He tank, tuning system, coupler interfaces…) which fits on our horizontal cryostat CryHolab

➡ **cavity & tank & other interfaces fit on the horizontal cryostat CRYHOLAB.**

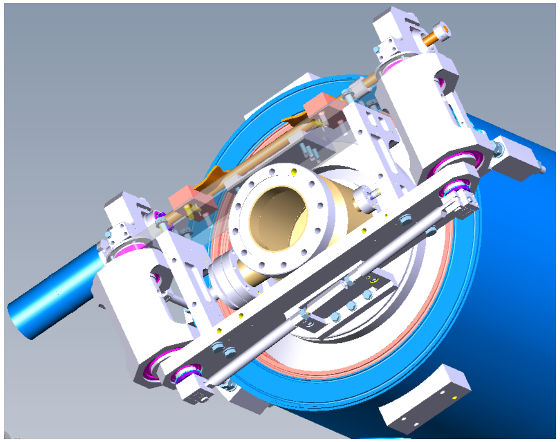


Cavity/tank design : CEA/CERN

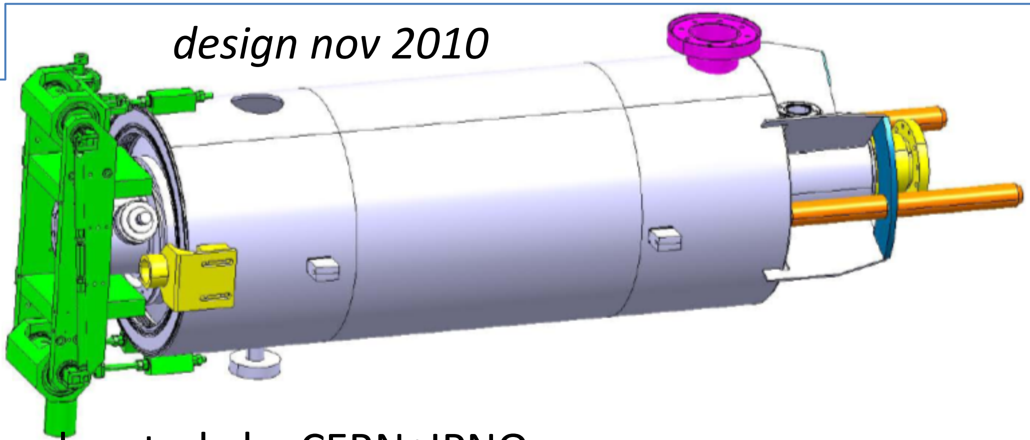
Two designs are studied in parallel :



At CEA design for tests in CRYHOLAB



design nov 2010



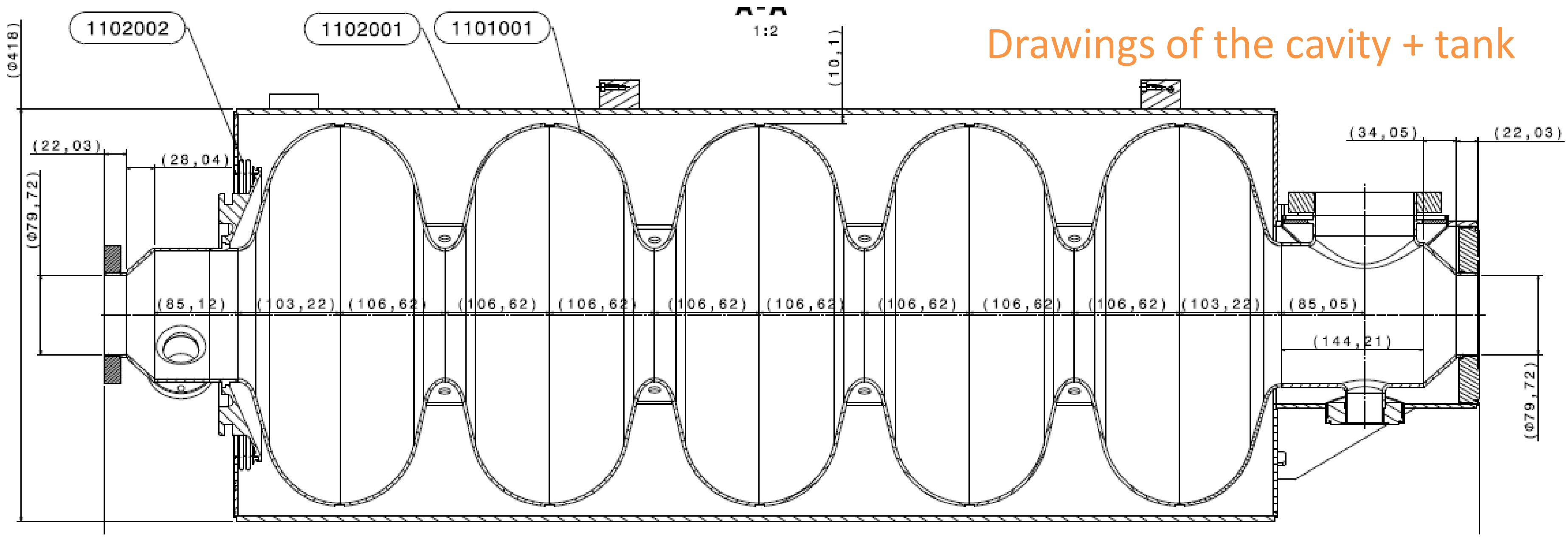
At CERN: integration of 4 cavities string in SPL short cryomodule

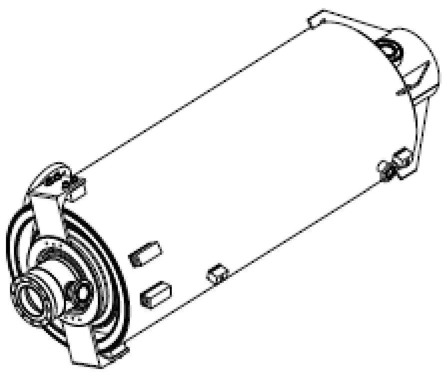
-the so-called 'short SPL cryomodule' is under-study by CERN+IPNO

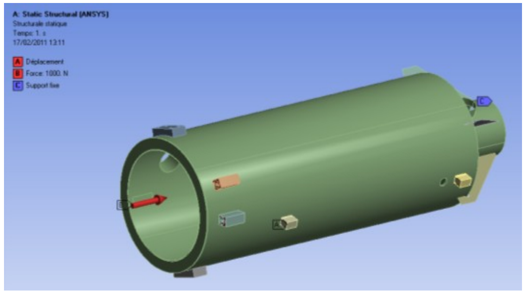
- compatibility of b=1 prototype to be checked once the cryomodule design is available

Mechanical design

Drawings of the cavity + tank







Helium tank in Titanium
Thicknesse : 5 mm
stiffness : 65 kN/mm

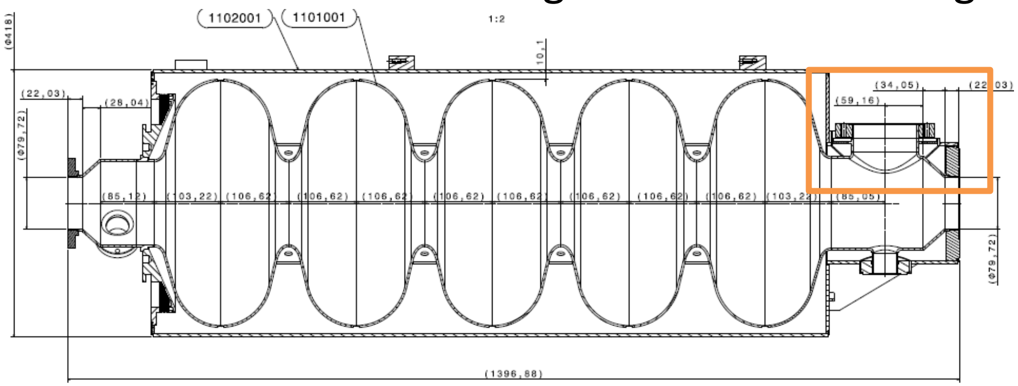
All the flanges and pick-ups are made of Nb/Ti or Ti, to be EB welded to the cavity (except the FPC flange)

Cavity / fundamental coupler flange

NbTi flange + Copper gasket for this dimension could lead to problems with differential thermal shrinking

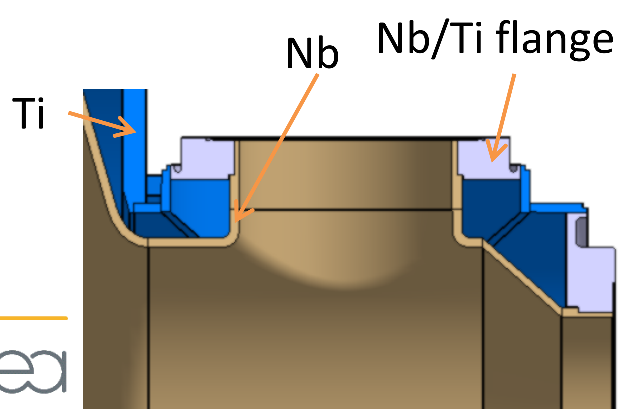
Copper gasket option kept for security reasons (tested at 1MW)

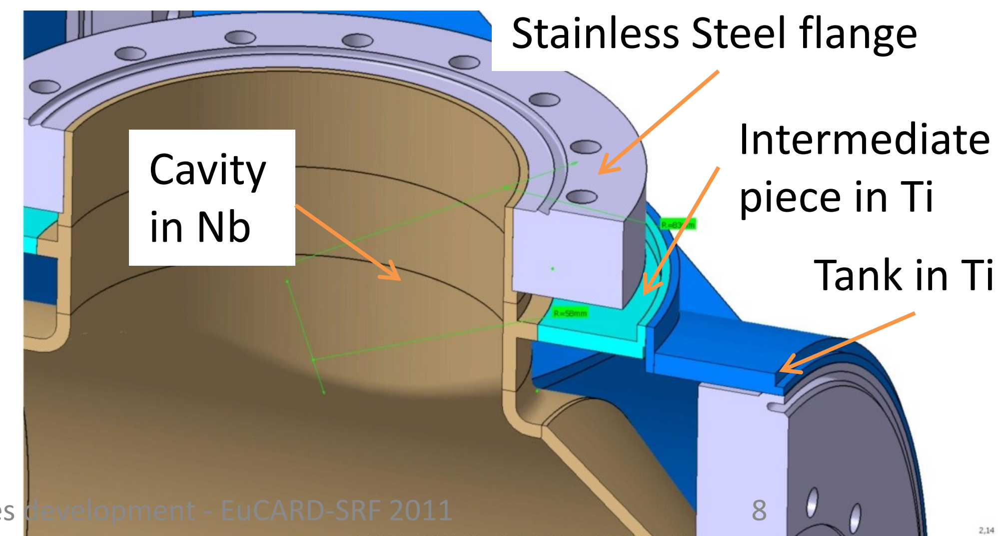
⇨ The flange material was changed from NbTi to stainless steel



Current version

Previous version

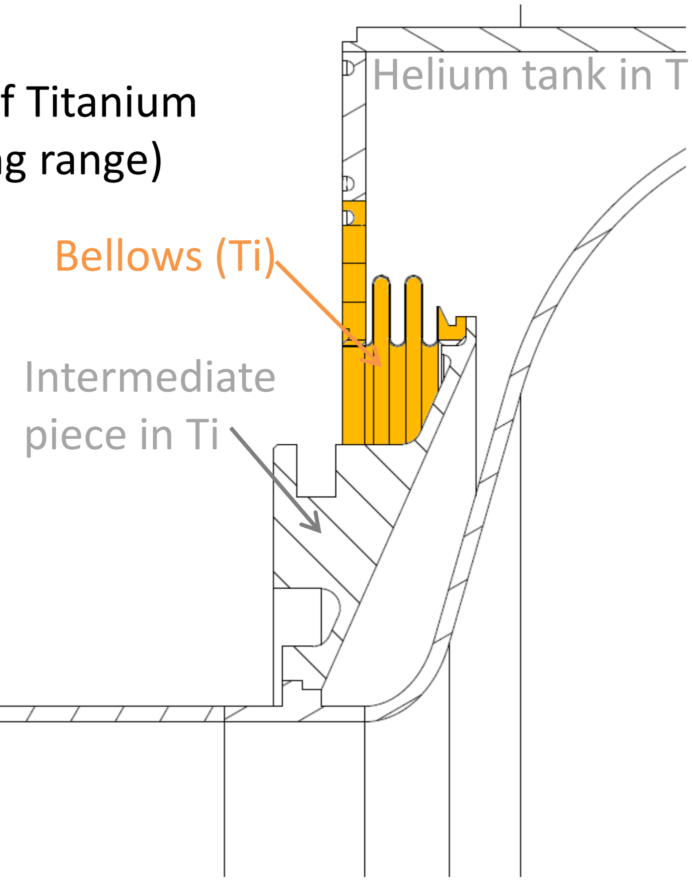




Cavity/helium tank bellows

Modification of Ti bellows

- Ti bellow to be welded on the Helium tank made out of Titanium
- axial stroke of +/- 3 mm w/o plastic deformation (tuning range)
- small stiffness with respect to the cavity

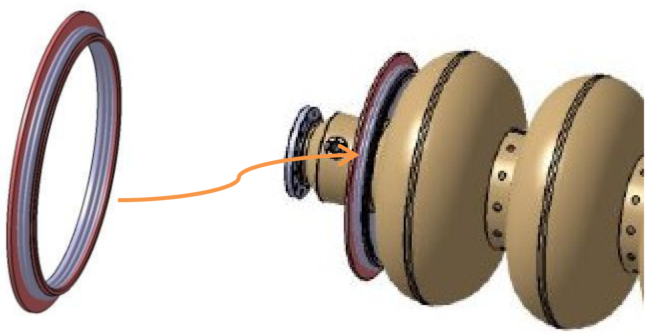


Hydroformed Ti waves

- Easy to clean
- Stiffness with wall thickness

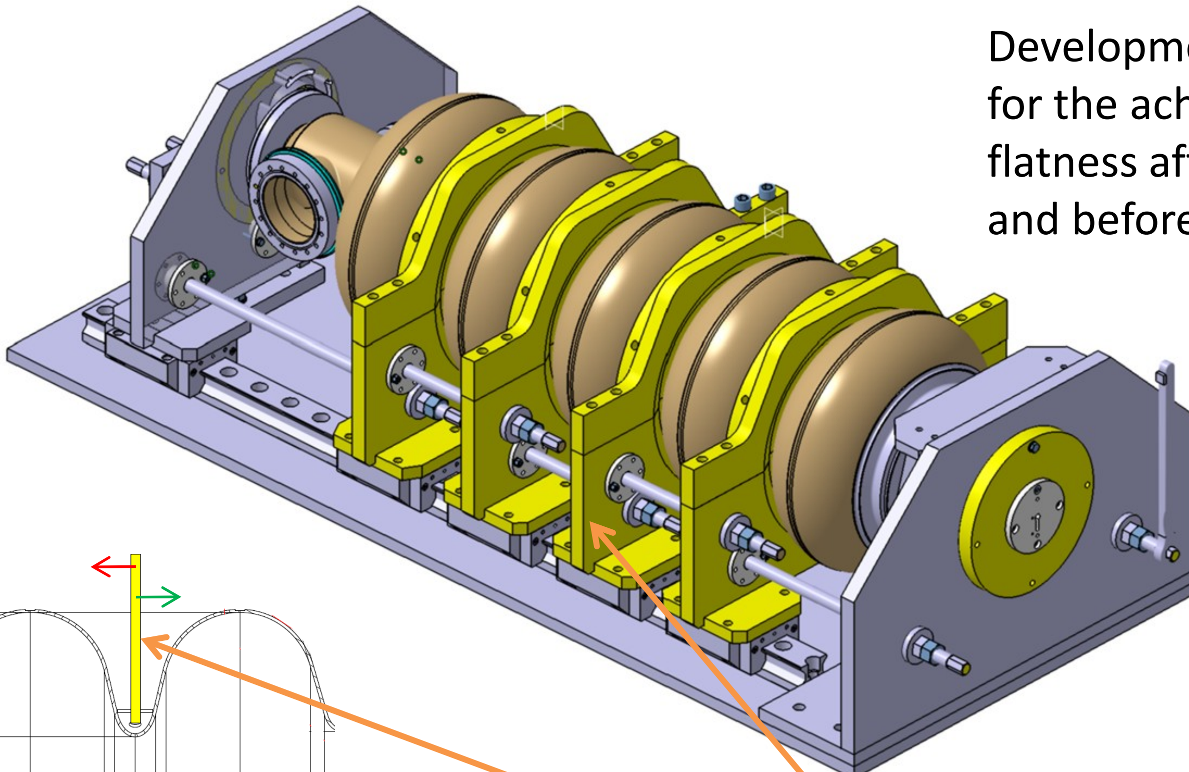
0.25mm: 700 N /mm

- Cheapest option



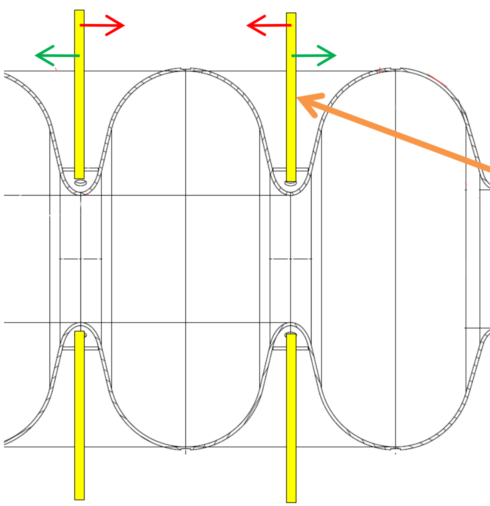
Offer received from Skodock GmbH for a 2 waves bellow :
Ti bellow qualified at 3 bars in a temperature range +50/-271 °C

Tuning set-up

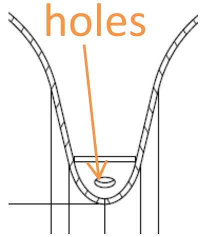


Development of a new tuning set-up for the achievement of the field flatness after reception of the cavity and before test in vertical cryostat

Under study



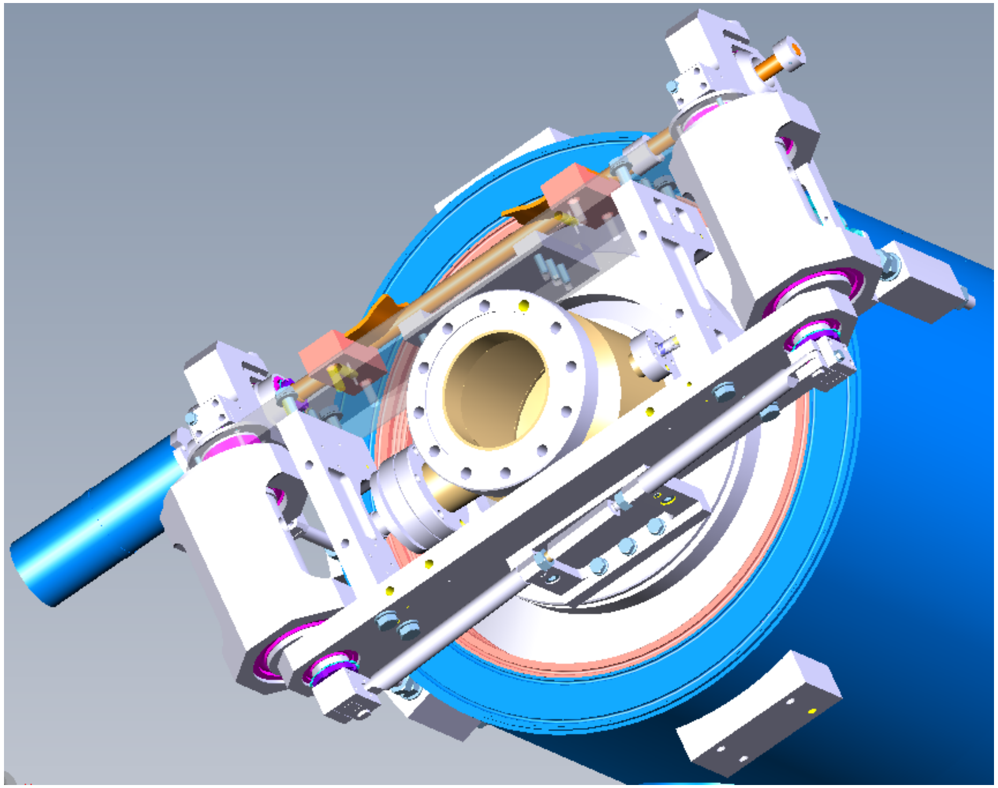
Special holes



Cell by cell tuning with **plates** fixed on the stiffening rings of the cavity

Fast tuning system

- Saclay V type
- 1 piezo
- Planetary gearbox (1/100e)
- Piezo support has a stiffness 10 times higher than the cavity ⇨ piezo preload at 2K is independant of the cavity springback force

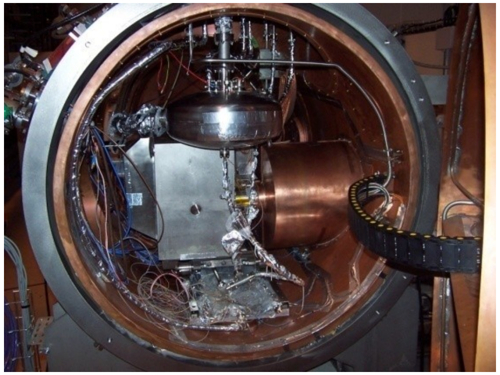


9 tuners will be ready in June 2011

LFD compensation in Cryholab at CEA-Saclay

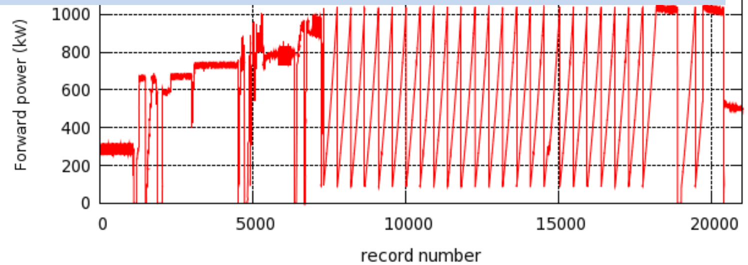
- Cold tuning system tests at 1.8 K on the CARE-HIPPI 700 MHz cavity
- High power tests of 1MW power coupler (full reflection)
- Lorentz force compensation at Eacc 13 MV/m in mode pulsed mode (2 ms 50 Hz)

Fully equipped cavity
(magnetic shield is open)

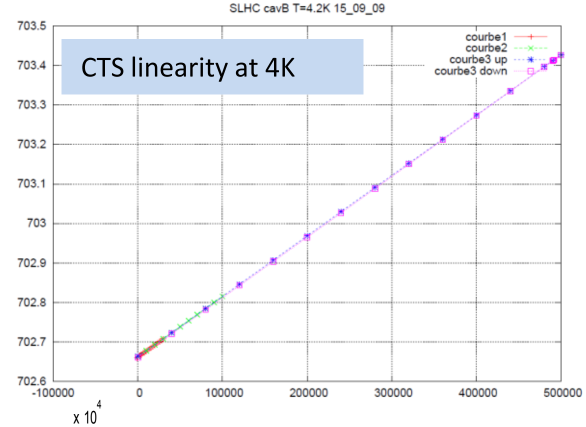


Full system installed in Cryholab

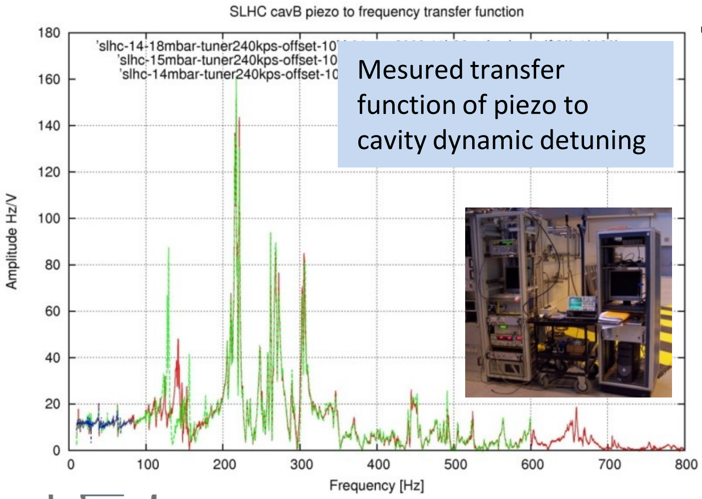
Test of the 1MW power coupler on the cavity cavity at 1.8 K



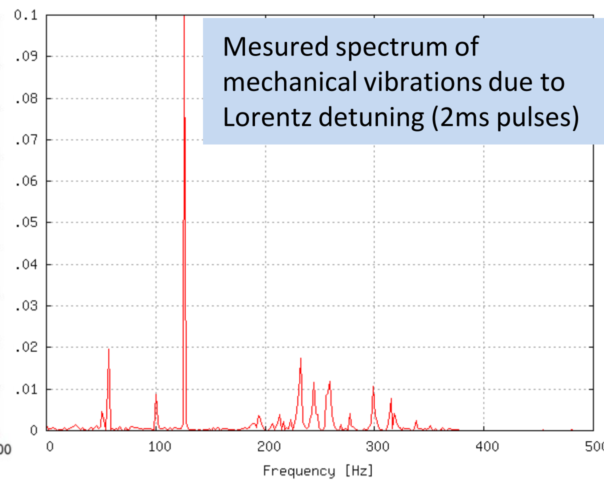
CTS linearity at 4K



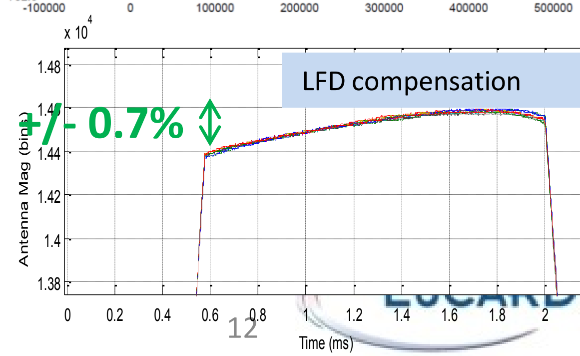
Mesured transfer function of piezo to cavity dynamic detuning



Mesured spectrum of mechanical vibrations due to Lorentz detuning (2ms pulses)



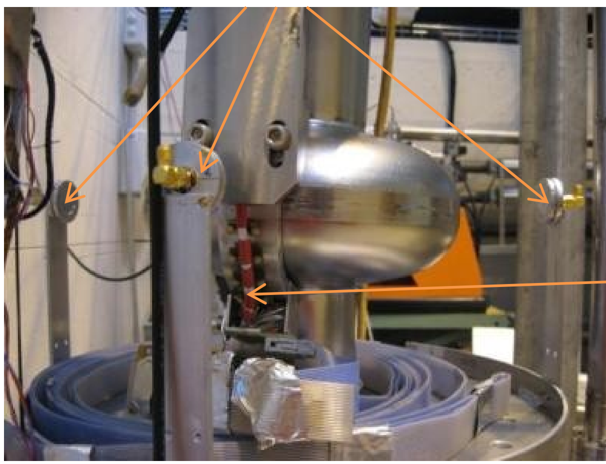
LFD compensation



Quench localization by 2nd sound detection

A program of quench detection by 2^{nd} sound detection with Oscillating Superleak Transductors is in development at CEA.
The system could be used during vertical tests of the SPL cavity

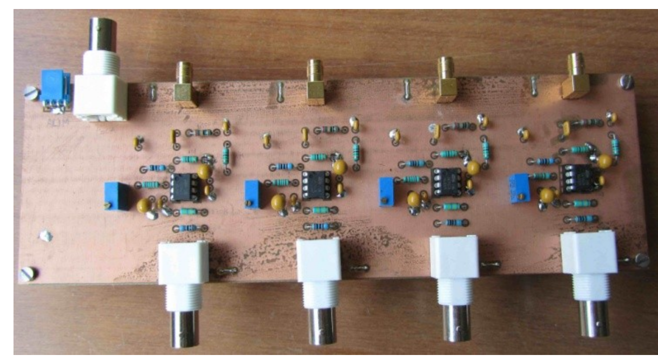
OST's



T-map sensor

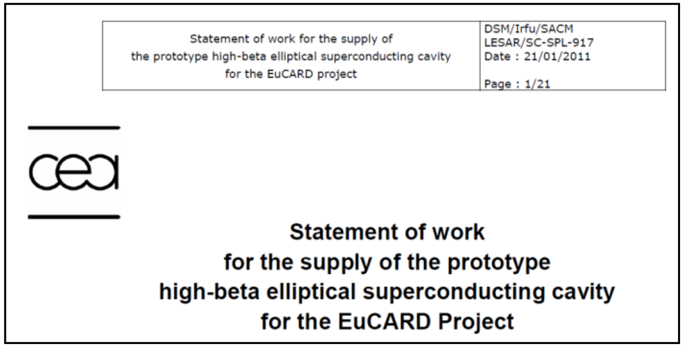
8 Oscillating Superleak Transducers (OST) received from Cornell

1 prototype electronics circuit developed at Saclay



First tests on a 1.3 GHz monocell cavity : signal measured on OST's
Unfortunately, the tests with OST's + Tmapping have not been achieved yet because of cavity leaks problems

Cavity fabrication



Statement of work for the supply of the prototype high-beta elliptical superconducting cavity for the EuCARD project	DSM/Irfu/SACM LESAR/SC-SPL-917 Date : 21/01/2011 Page : 1/21

cea

Statement of work
for the supply of the prototype
high-beta elliptical superconducting cavity
for the EuCARD Project

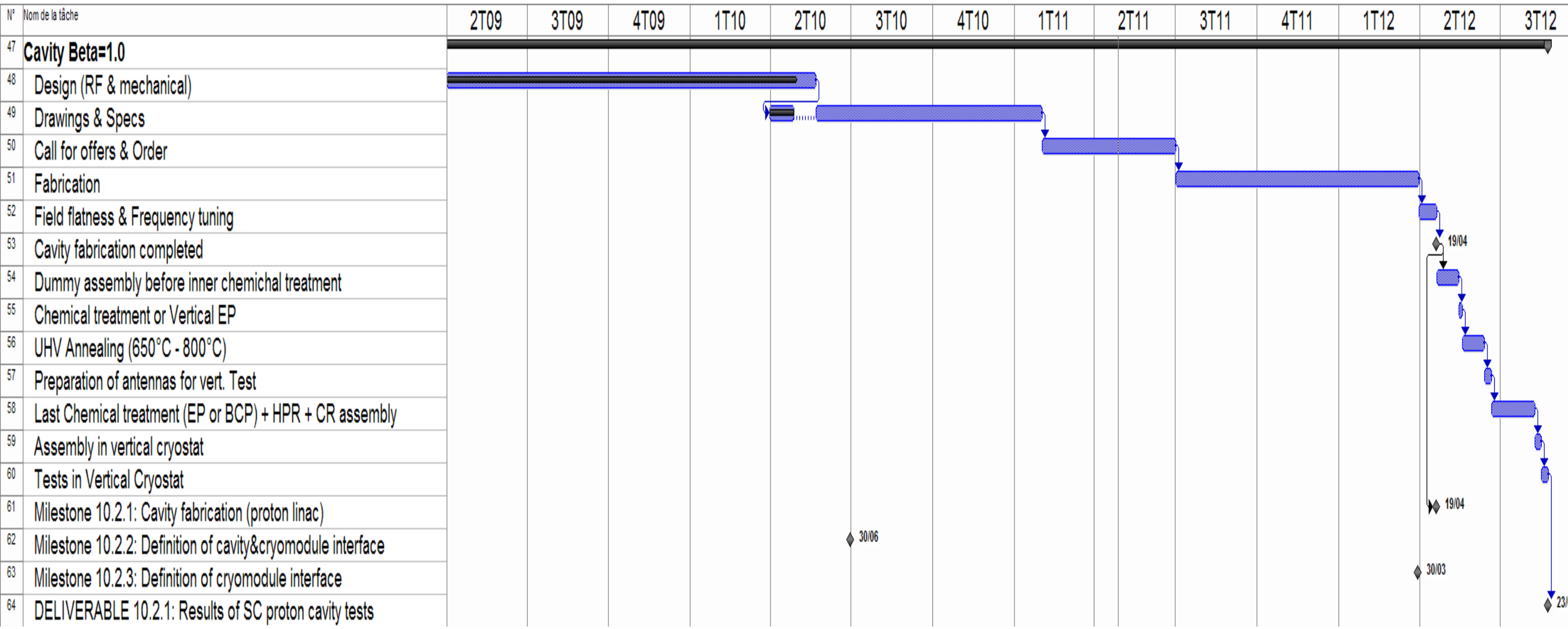
4th June 2010 : European announcement (APPC) for β=1 cavity fabrication

02 May 2011 – 10 June : call for offer for β=1 cavity fabrication

17 Nov 2010 – 16 Dec 2010 : Call for offer for procurement of Niobium Material

23 Feb 2011 : order of Niobium material (delivery time = 6 months !)

Schedule



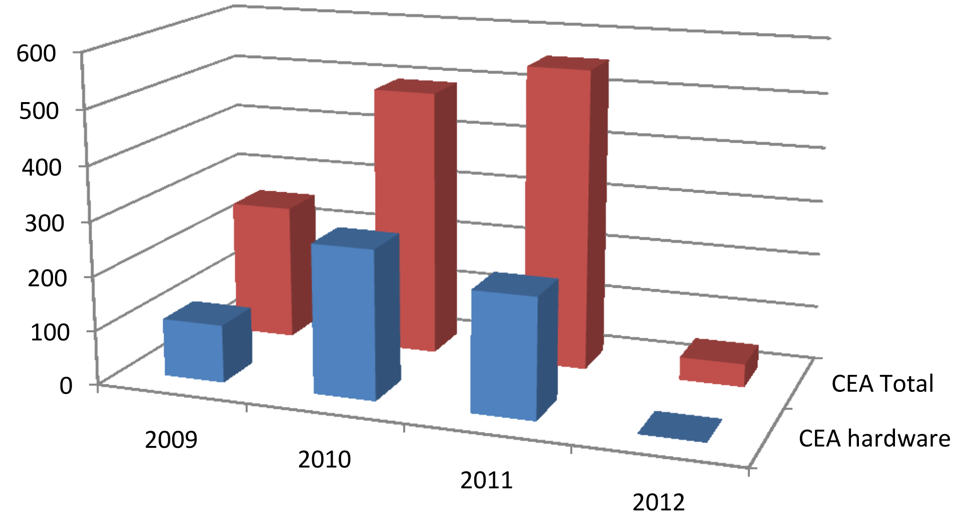
1) Definition of cavity interface: delay of 3.5 months (new concept of cryomodule)
2) Procurement of Niobium material: delivery time is increased by 3 months

⇨ Due to total delay of 6.5 months, preparation and tests of the cavity will de done in the 4th year of program

Task 10.2: CEA expenses

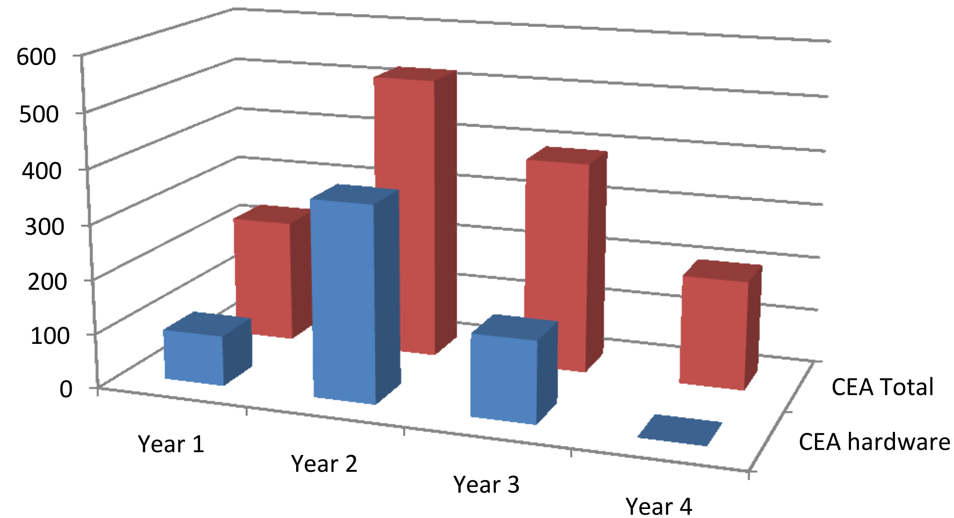
Reference spending profile

(as presented the 23th March 2009 at the kick-off meeting)



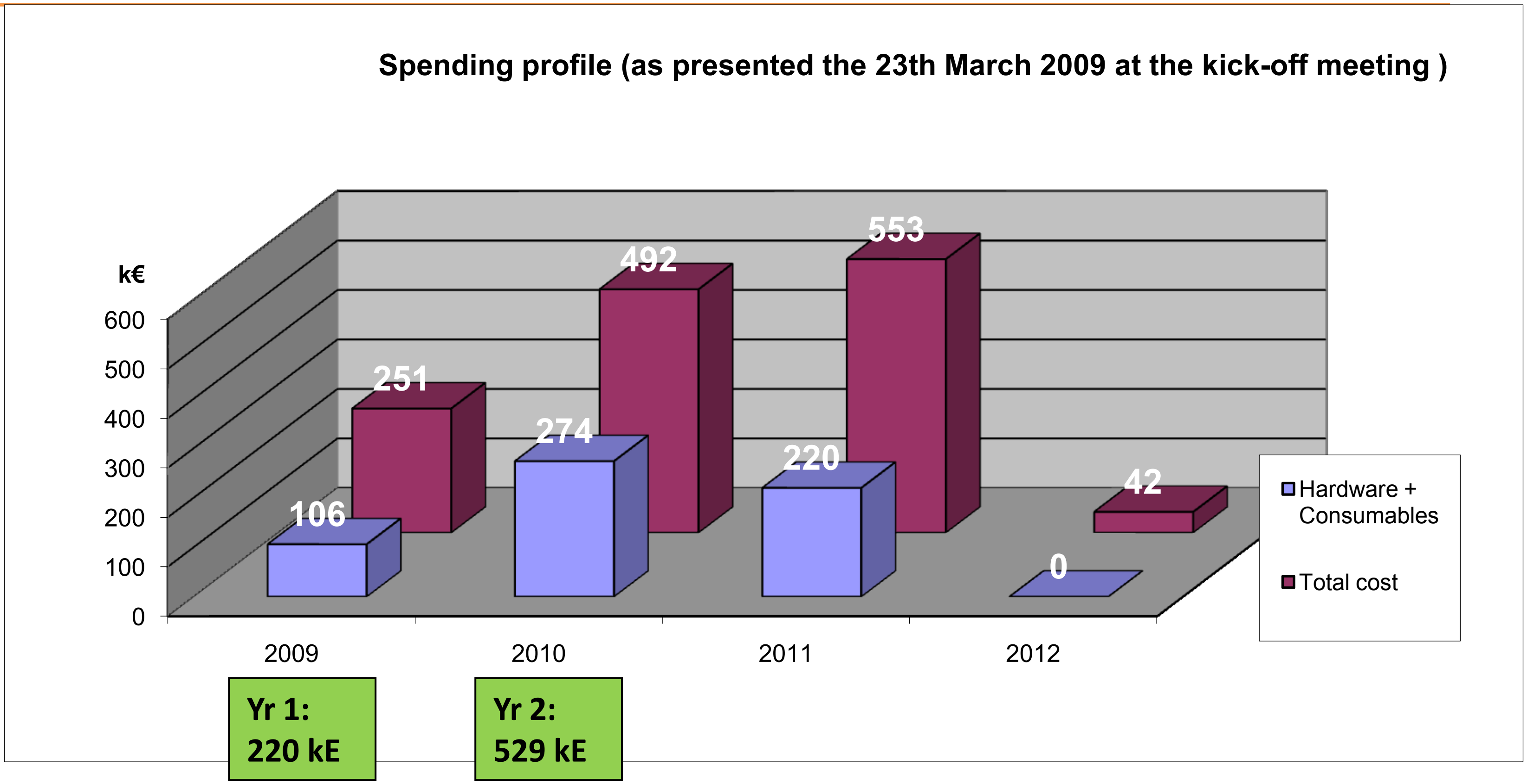
After 2 years of program: the total expenses are at the expected level

But it becomes clear that investment in Year 3 won't reach the foreseen amount ; the 4th and last year of program will be necessary for cavity preparation and test



Thank you for your attention !

Task 10.2: CEA expenses



Beneficiary short name (all costs in €)	Person-Months	Personnel direct costs	Personnel indirect costs	Sub-contracting cost	Consumable and prototype direct costs	Travel direct costs	Total costs (direct +indirect)	EC requested funding[1]
CEA	71	440 200	277 326	0	600 000	20 900	1 338 426	401 550
CERN	8	49 600	29 760	0	0	3 500	84 960	25 219
CNRS/IPNO	17	79 594	47 756	0	90 000	7 000	282 550	97 150
Totals:	**96**	**569 394**	**354 842**	**0**	**690 000**	31 400	**1 705 936**	**523 919**