CEA-Saclay

Planned contributions to the SPL

Introduction

CEA-Saclay is involved in programs aiming at designing and prototyping a complete cryomodule housing 700 MHz sc cavities for the CERN-SPL

- European program FP7 (EuCARD, CNI-PP-SLHC)
- Contribution Exceptionnelle de la France au CERN

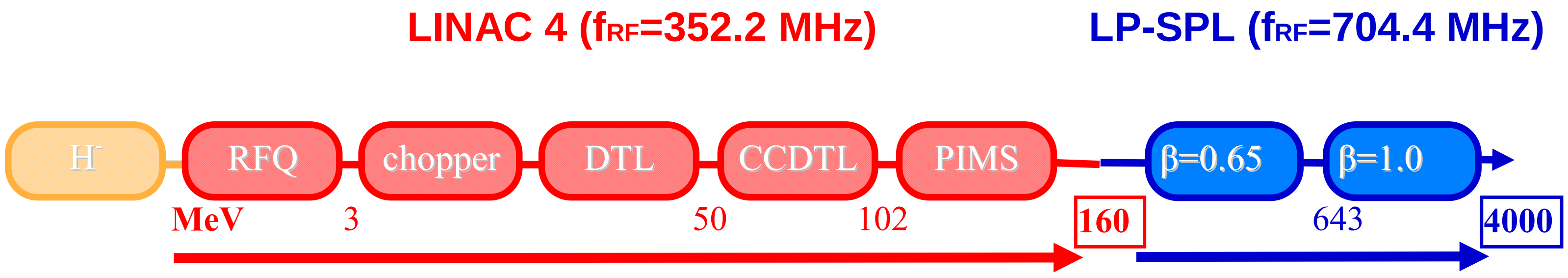
We participate in various tasks consisting in:

- the design and prototyping of accelerator components (cavity, power coupler, tuning system)
- the study and upgrade/construction of equipments needed for preparation and test of components (vertical EP set-up, field flatness tuning bench, HPR station, assembly tools)
- the RF tests at cold of components (cavities alone and cavities fully equipped)
- the processing of power couplers up to 1MW

704 MHz Elliptical Cavities

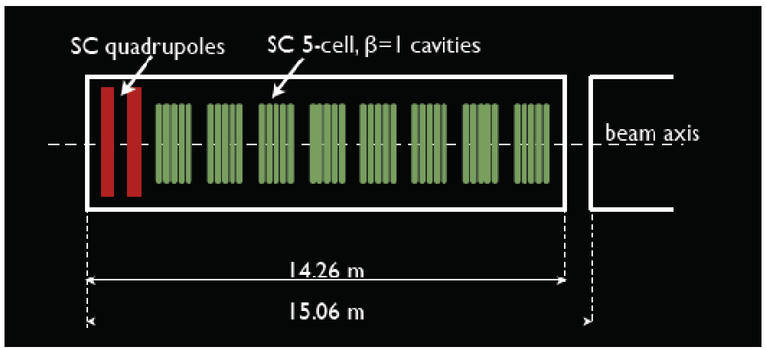
SPL Design:

The acceleration in the High Energy section (from 643 MeV to 4 GeV) is provided by β=1 elliptical cavities operating at 704 MHz



Main parameters of HE cavities

- freq = 704.4 MHz
- 5 cells
- *β=1.0*
- *Eacc = 25MV/m*
- *RF power/ cavity: 1MW*
- *200 cavities (in 25 cryomodules)*



from F.Gerigk

704 MHz Elliptical Cavities

Identified tasks:

- design of β=1 cavities
- fabrication of 2 prototypes
- low power RF test of prototypes
- implementation of new equipments

  EP vertical set-up

  modification of the bench for field flatness tuning

  HPR station (?)

  vertical insert of cryostat (?)

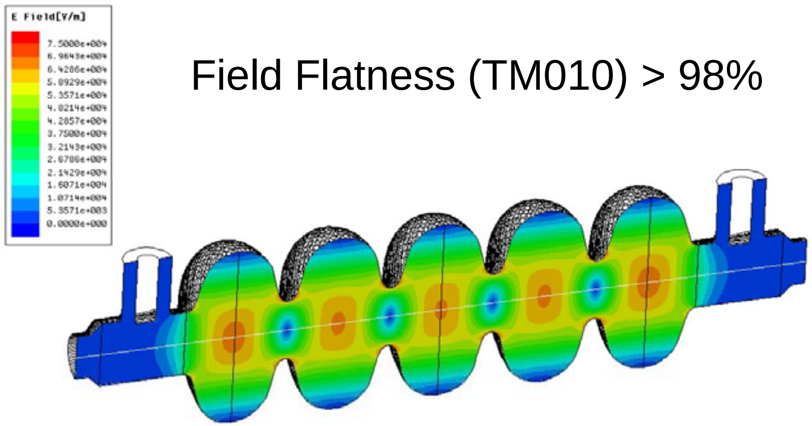
704 MHz Elliptical Cavity: design (1)

First Optimisation of HE cavity (704.4 MHz ; β=1)

RF parameters

diamétre tube (mm)	Frés (MHz)	G (Ohms)	r/Q (Ohms)	Ep/Eacc	Bp/Eacc (mT/MV/m)	cell to cell coupling	plat de champ
140	704,4	271	562	1,98	4,18	1,92%	99%

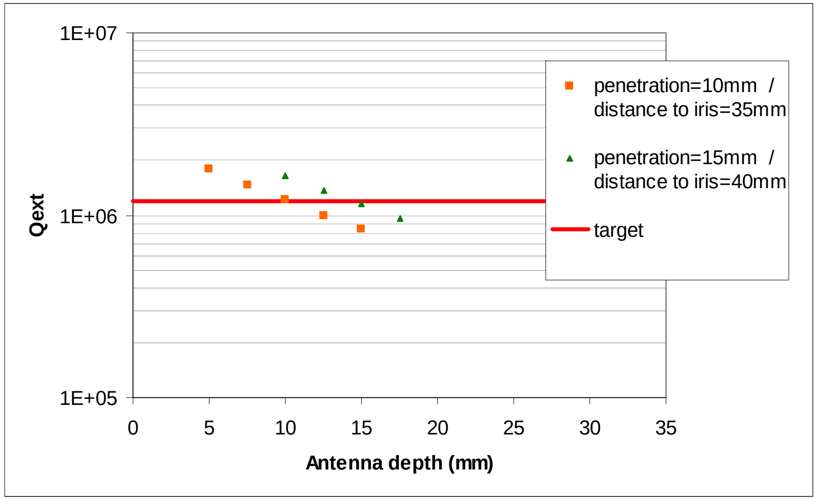
Field Flatness (TM010) > 98%



geometry	k_L Hz/(MV/m)^2
w/o cones; w/o rings	-0.62
w/o cones; with rings	-0.42
with cones; with rings	-0.66

if: Eacc = 25 MV/m, Io = 40 mA, ϕs = 15deg

➡ **Qext,opt = 1.2 E6**



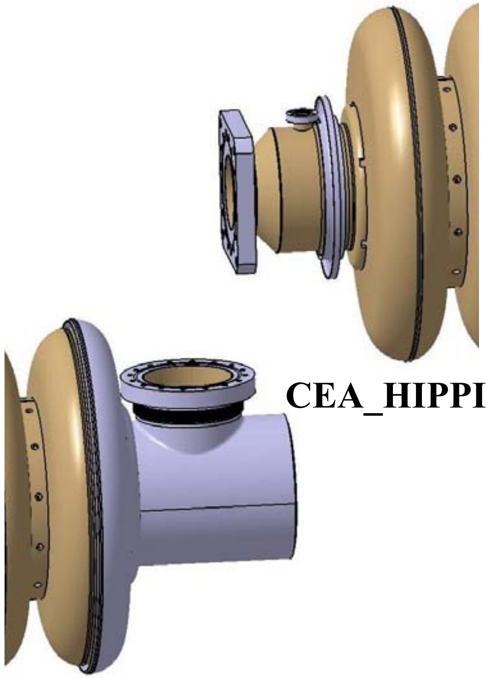
for a 50Ω – Ø100mm coupler

704 MHz Elliptical Cavity: design (2)

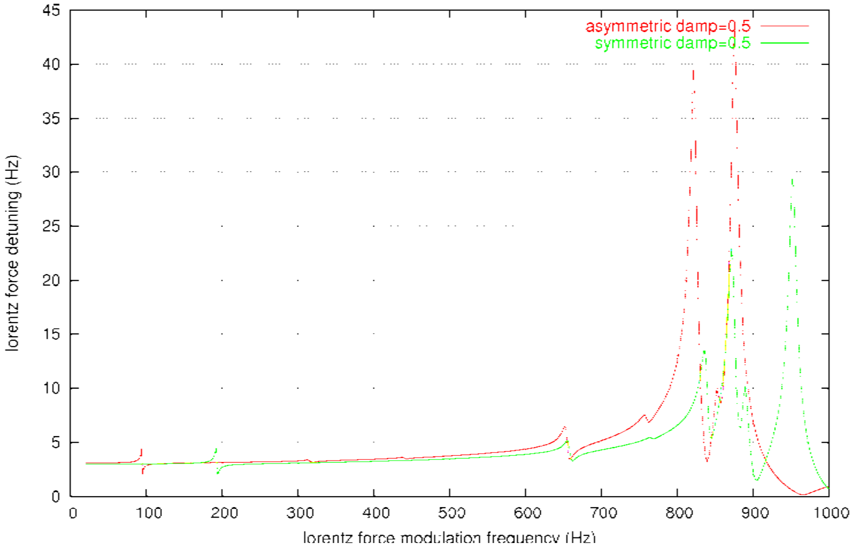
Options/Interfaces:

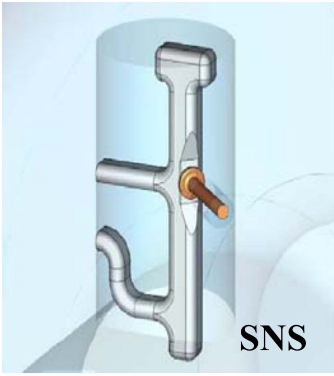
-which gaskets? same for both IE and HE cavities?
-max. diameter of the flanges?
-is the conical part of the tube necessary?
-do we keep a LHe cooled end-tube on the coupler side?
-symmetrical end-tubes?
-how many HOM couplers? which type?
-material (SS, Ti) for the LHe tank?

… to be addressed in the WG2



CEA_HIPPI cavity





SNS

704 MHz Elliptical Cavity: preparation & test (1)

For HE cavities, accelerating field in operation = 25 MV/m

⇨ **Eacc in vertical test ≥ 27 MV/m**

Requires a preparation recipe identical to XFEL

Need EP !

+

= vertical EP set-up for multicell cavities to be developed at Saclay within the EuCARD program

<u>Cavity Preparation:</u>

1) EP 150 microns

1 bis) surface endoscopy

2) UHV annealing at 800°C

3) field flatness checking

4) flash BCP 10 microns

or 4) final EP 30 microns

5) alcohol rinsing

6) drying in class 10

7) UHV baking at 120°C

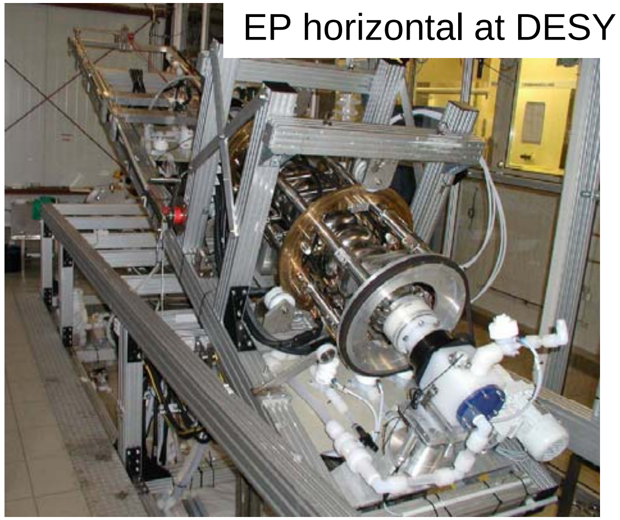
8) HPR at 100 bars (6 times)

9) drying in class 10

how to share the preparation between participants?

➡WG2

704 MHz Elliptical Cavity: preparation & test (2)



EP horizontal at DESY

Endoscopy at KEK

cavity on vertical frame for test in cryostat at Saclay

field flatness set-up at Saclay

HPR upper plate in Saclay (small) CR

Other developments

Apart from cavities, we are involved in the study of:

- power couplers
- LFD compensation and LLRF
- cryomodule assembly

704 MHz power coupler (1)

Coupler developments:

In the previous FP6/HIPPI program, we started the development of a high power coupler operating in pulsed mode

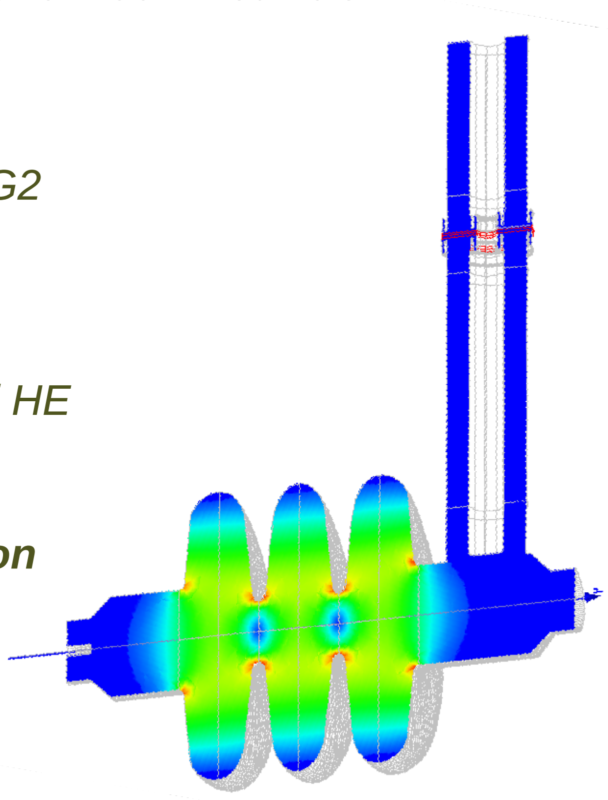
G. Devanz designed most of the critical parts (doorknob, window, LHe and water cooling circuits, …) for an average power of 100kW sufficient for the operation of the HE cavities at 25MV/m

- *Characteristics to be detailed by G. Devanz in WG2*

- *If RF power processing and tests at cold are satisfying, this coupler design is a very good starting point for SPL couplers for both IE and HE cavities*

- ***CERN experience in LHC coupler fabrication and RF processing is very welcome***

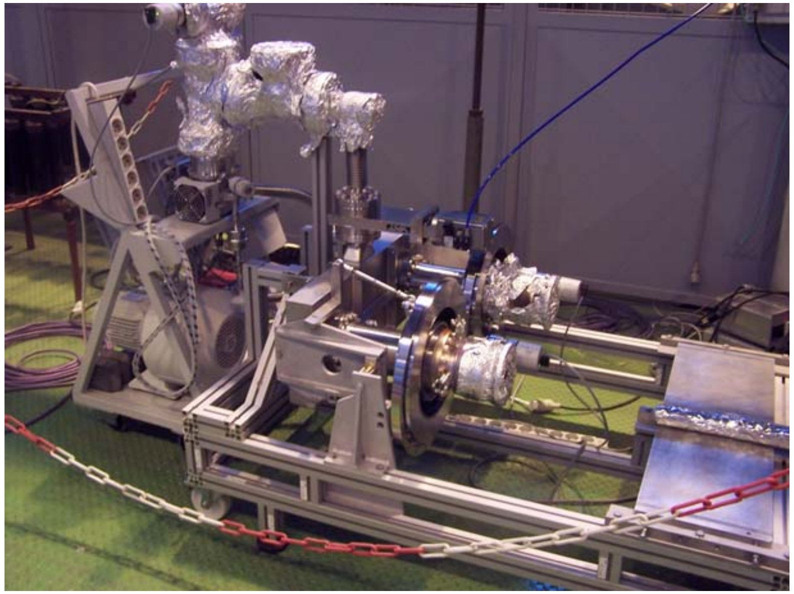
- *sharing of the tasks to be discussed in WG2*



704 MHz power coupler (2)

High power tests in progress:

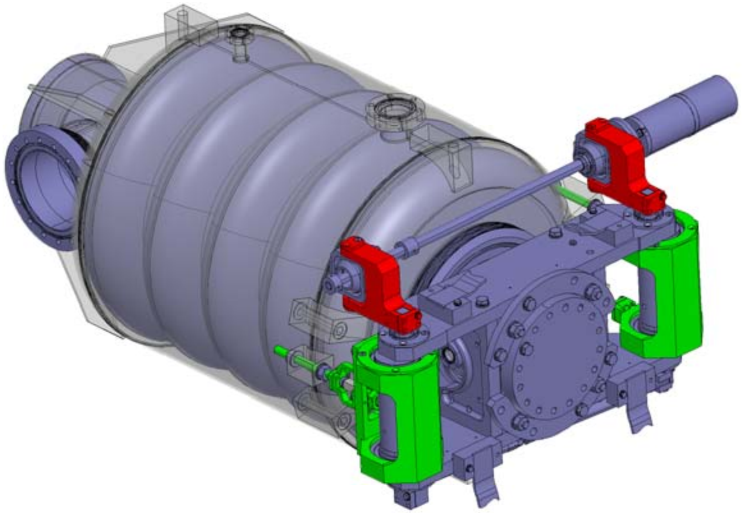
☑ assembly of couplers on the power test bench
☑ UHV baking (4 days – from 100 to 180° C)
☑ mounting of the doorknobs
☐ connection to cooling system and RF waveguide
☐ test of interlocks
☐ RF power processing

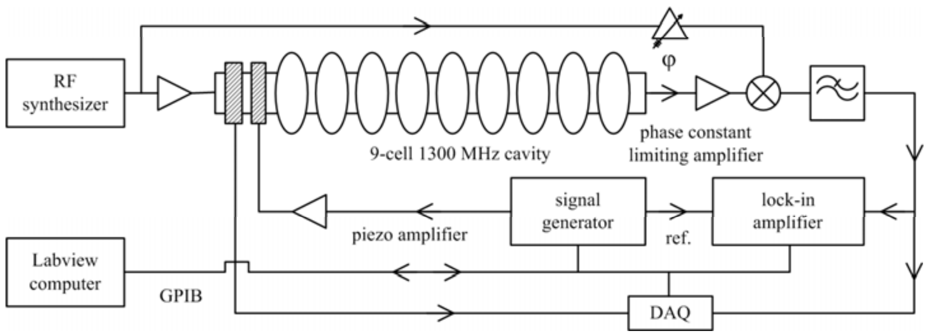


LFD compensation & LLRF

In collaboration with CERN, we already launched studies about field stabilization in pulsed mode

- cold RF test (with HIPPI cavity+power coupler+tuning system&piezo) dedicated to the optimization of feed-forward parameters
- study of a LLRF system
- eventually, test of both systems (compensation and LLRF) in pulsed mode





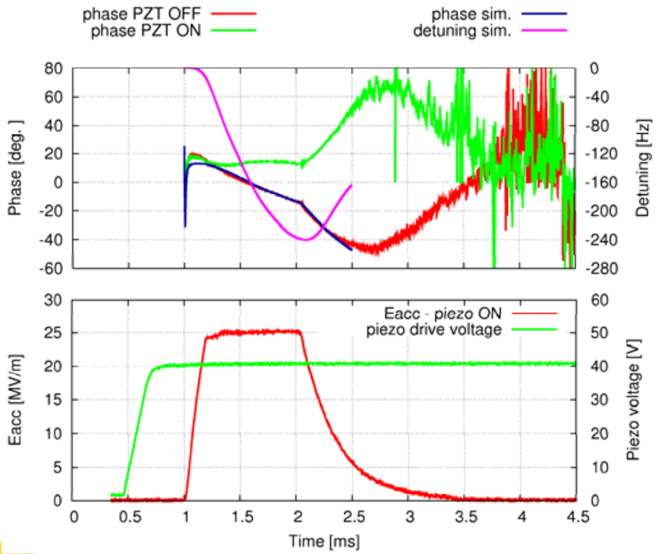
LFD compensation scheme

LFD compensation

Objective: To limit the variation of the phase during the beam pulse in order to achieved more easily the required field stability

- -analysis of β=0.5 cavity behavior under pulse excitation
- -study and development of a correction algorithm for LFD
- -implementation and measurement on a real cavity

beta	Eacc [MV/m]	K_L [Hz/(MV/m)^2]	static detuning [Hz]	% BW
0.47 (HIPPI)	15	-3.8 (measurement)	855	147
0.65 (SPL)	19	-2 (simulation)	720	113
1 (SPL)	25	-0.6 (simulation)	376	64
1 (FLASH)	23.6	-0.7, -0.9 (measurement)	390, 501	90, 116



Measurements performed on a 1300MHz cavity operating at 25MV/m:

- -rather simple shape of the piezo drive voltage
- -reduction of the φ variation from 615° to 63°

If the KL for HE SPL cavities can be lowered down to -0.6, LFD compensation should not be an issue

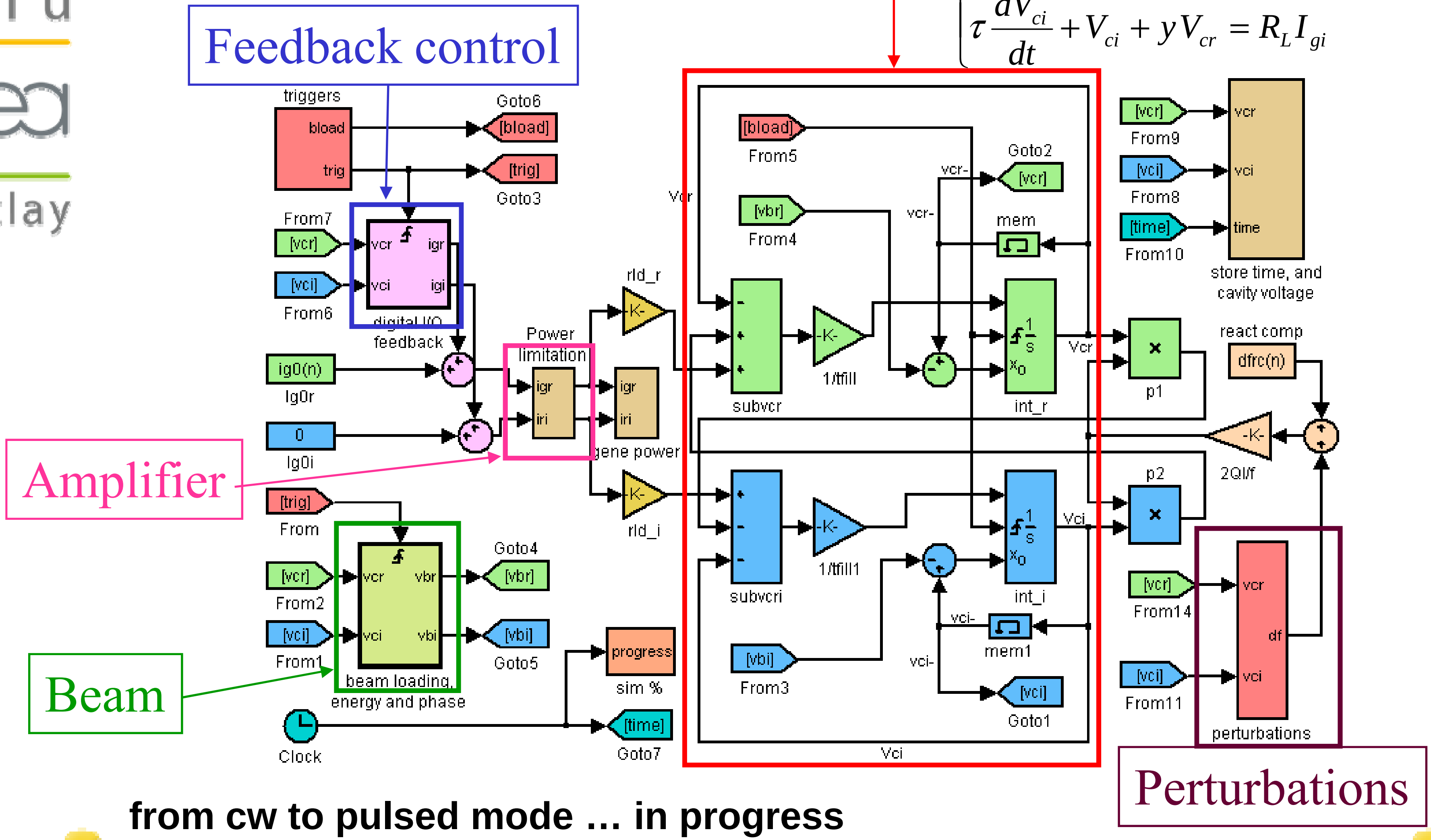
To be checked for IE cavities

Field simulation tools

Implementation architecture for cavity simulation

MATLAB/Simulink

$$\begin{cases} \tau \dfrac{dV_{cr}}{dt} + V_{cr} - yV_{ci} = R_L I_{gr} \\ \tau \dfrac{dV_{ci}}{dt} + V_{ci} + yV_{cr} = R_L I_{gi} \end{cases}$$

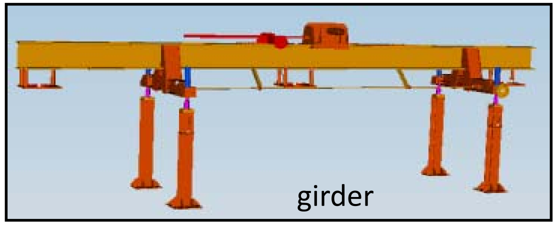


from cw to pulsed mode … in progress

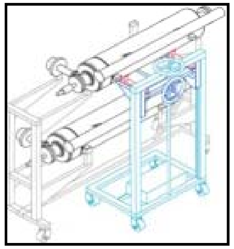
Cryomodule assembly (1)

Assembly of long cryomodules requires many different tools …

- Tools to be adapted to infrastructure or to be developed
- Other specific tools
- Tools available on catalogue

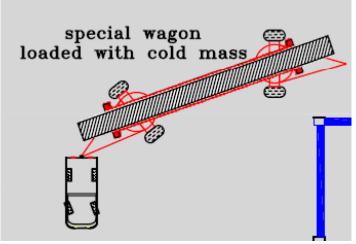


girder

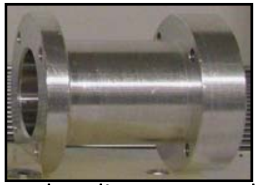


cavity handling tool

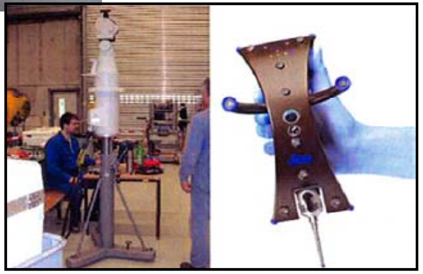
cantilever



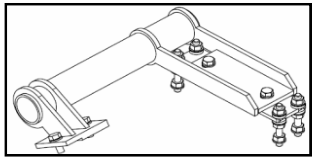
outside transportation wagon



coupler alignment tool



laser tracker



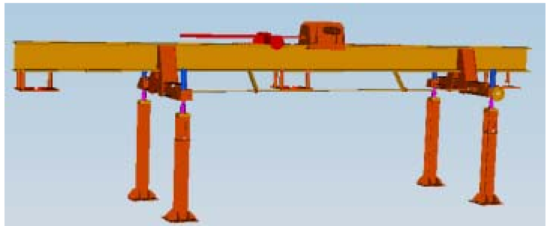
gate valve 1 support tool

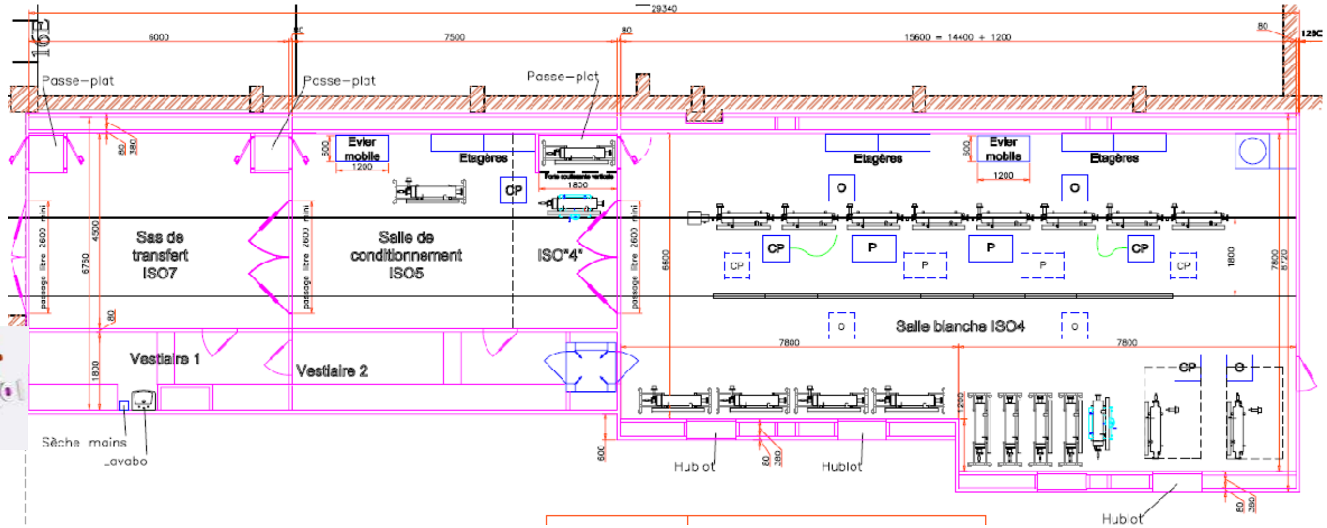
soldering tool

Cryomodule assembly (2)

… and we proposed to study some of them!

Examples of tools we could bring to the collaboration:
-girder used to handle the cold masses
(XFEL design to be adapted to new infrastructure)
- specific tools for coupler assembly in clean room are required





Remarks:
- Design of these tools is not (yet) on the critical path
- Drawings of components and/or cryomodule are needed to start
- It seems reasonable to define the infrastructure characteristics first

Conclusion

❑ CEA-Saclay has participated to FP6/HIPPI program

❑ In the SPL collaboration, we are involved in a “patchwork” of tasks

❑ Some of these tasks have already started (LFD measurements and compensation scheme, design of HE cavity)

❑ For other tasks, we need to freeze some parameters/options (WGs discussions)

❑ Collaborations with identified partners are very welcome, for example on couplers and cavity preparation

The end