DE LA RECHERCHE À L'INDUSTRIE

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DEVELOPMENTS AND PROGRESS WITH ESS ELLIPTICAL CRYOMODULES AT CEA-SACLAY AND IPN-ORSAY

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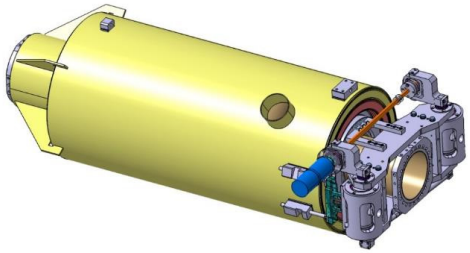
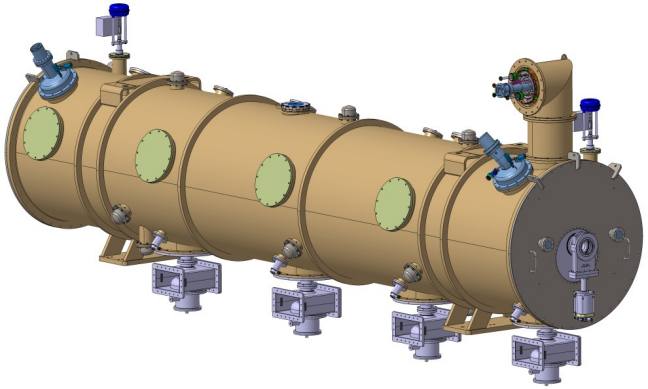
SRF2017 Lanzhou, China
18th International Conference on RF Superconductivity

July 17-21, 2017
IMP and IHEP, CAS (CHINA)

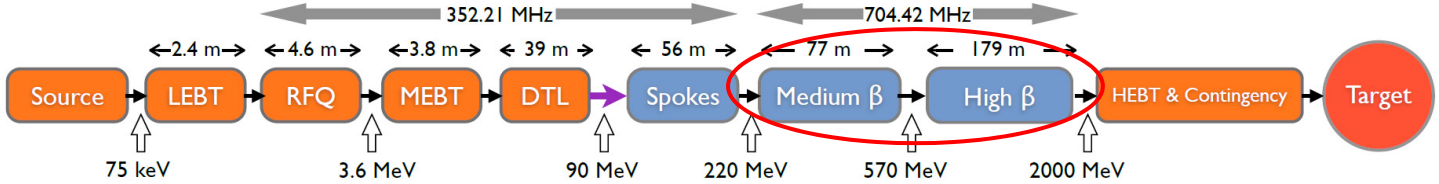
OUTLINE

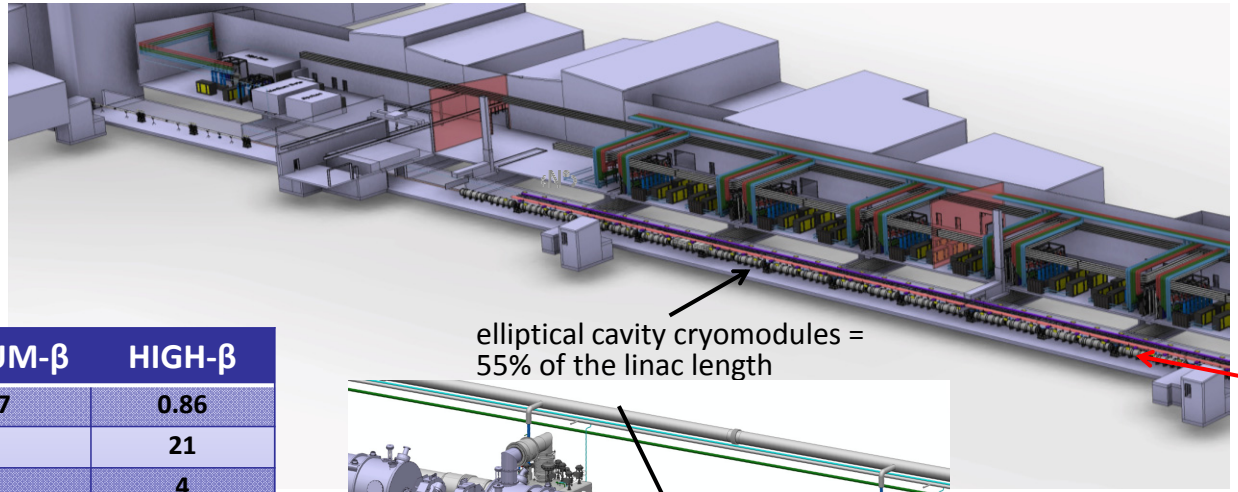
- Introduction and context
- ESS elliptical cryomodule description
- Medium beta cryomodule demonstrator M-ECCTD
  - Cavities and couplers individual performances
  - Cryomodule assembly
- High beta cryomodule demonstrator H-ECCTD
- Series cryomodule production preparation
  - Procurement plan
  - Series power couplers RF conditioning
  - Series cryomodules integration plan
- Conclusion

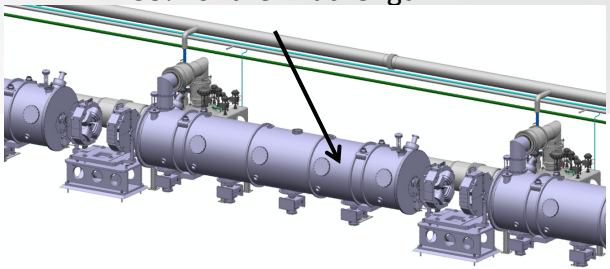




ELLIPTICAL CRYOMODULES IN THE ESS LINAC







	MEDIUM-β	HIGH-β
β	0.67	0.86
# CM	9	21
Cav. /CM	4	4
# Cav.	36	84
CM L [m]	6.584	6.584
Sector L [m]	77	179

COLLABORATIONS

- Cryomodule requirements and interfaces
- Cryomodule transport
- Cryomodule test stand
- Tunnel installation and operation

- Cryomodule and cavity design
- M-ECCTD and H-ECCTD construction and test
- Series cryomodule components procurement and assembly
- Series couplers
- Cryomodule test stand

- Cryomodule engineering design
- M-ECCTD cryostat components procurements

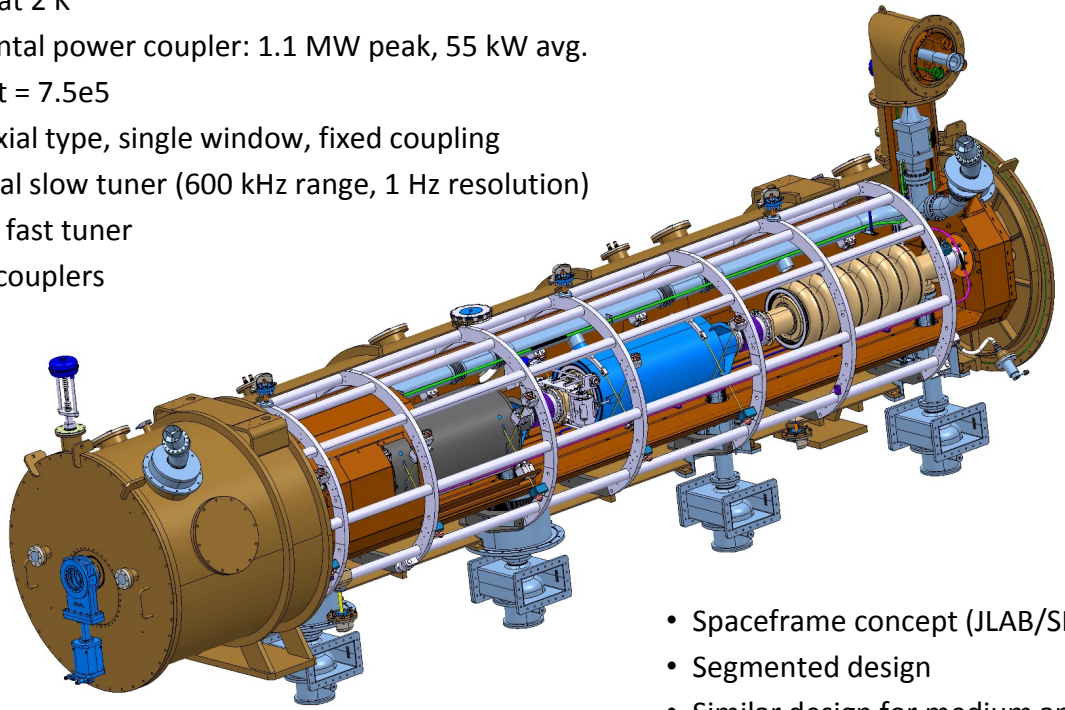
- Medium Beta Cavity design
- Medium Beta Cavity procurements
- Medium Beta Cavity vertical tests

- High Beta Cavity procurements
- High Beta Cavity vertical tests

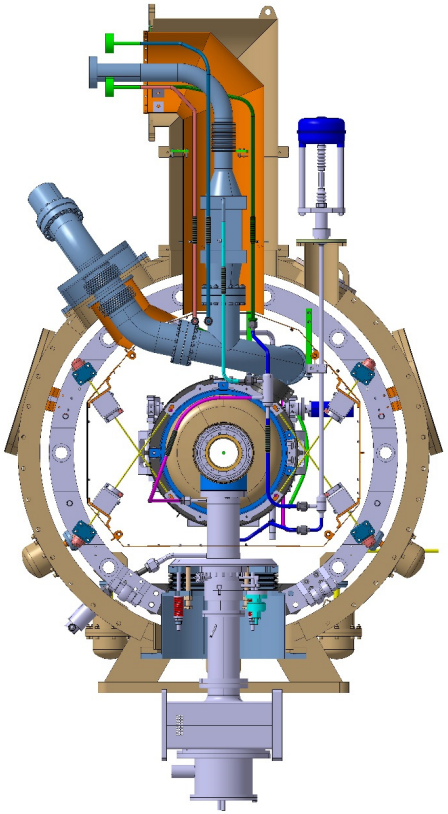
- Cavity horizontal test

ELLIPTICAL CRYOMODULE MAIN FEATURES

- 704 MHz, 3.6 ms RF pulse at 14 Hz
- Eacc = 16.7 MV/m (MB) and 19.9 MV/m (HB) (Epeak = 40/44 MV/m)
- Q0 > 5e9 at 2 K
- Fundamental power coupler: 1.1 MW peak, 55 kW avg.
  - Qext = 7.5e5
  - Coaxial type, single window, fixed coupling
- Mechanical slow tuner (600 kHz range, 1 Hz resolution)
- 1+1 Piezo fast tuner
- No HOM couplers



6.6 m long

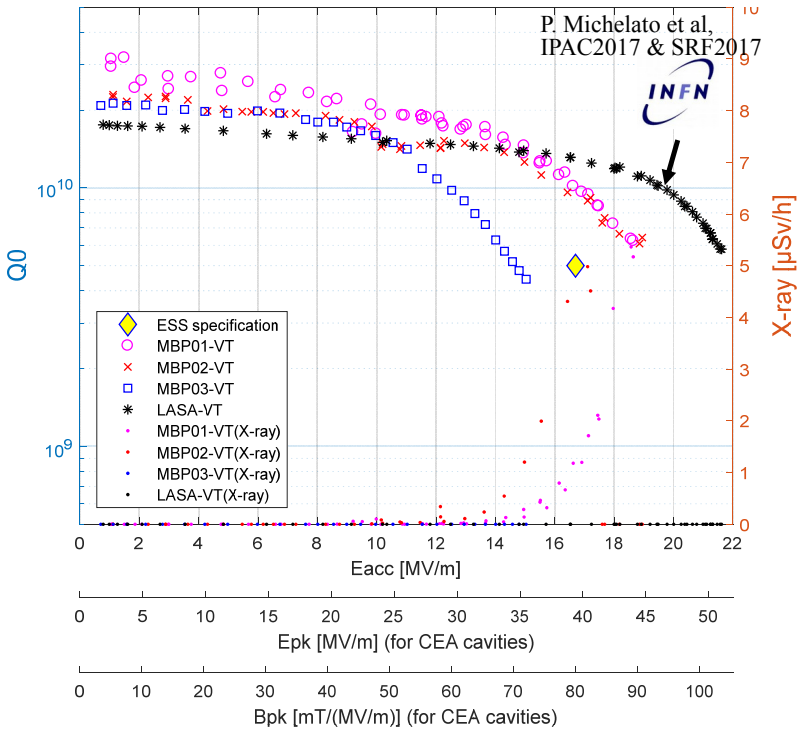


- Spaceframe concept (JLAB/SNS)
- Segmented design
- Similar design for medium and high beta cavities

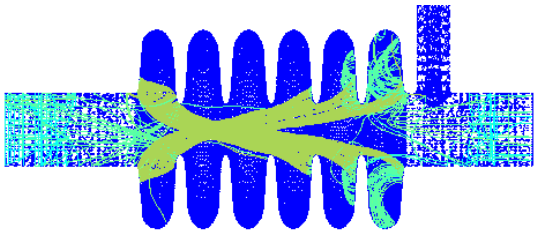
P. Bosland
G. Olivier
G. Devanz

M-ECCTD CAVITIES PERFORMANCES IN VERTICAL CRYOSTAT

E. Cenni

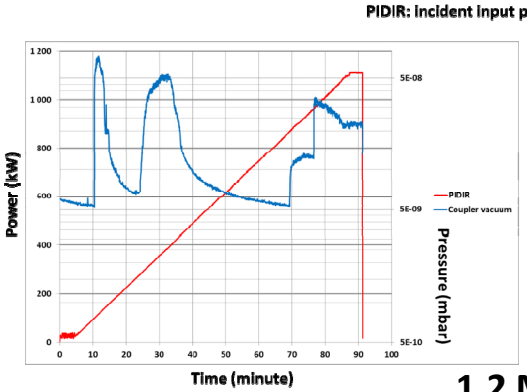


- All cavities chemically treated with BCP
- Three cavities reach the ESS specification
- Very good Q0 at low field for CEA cavities, very good accelerating gradient for LASA cavity
- Origin of this Q drop is not fully understood, but probably due to field emission and secondary emission effect inside inner cells (triggered by surface quality obtained after chemical treatment)

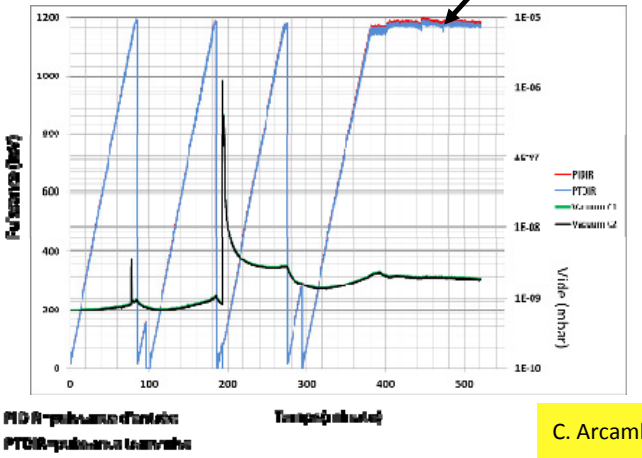


T. Hamelin

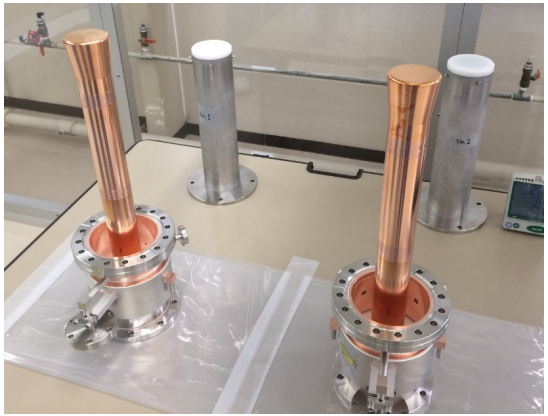
M-ECCTD POWER COUPLER RF CONDITIONNING

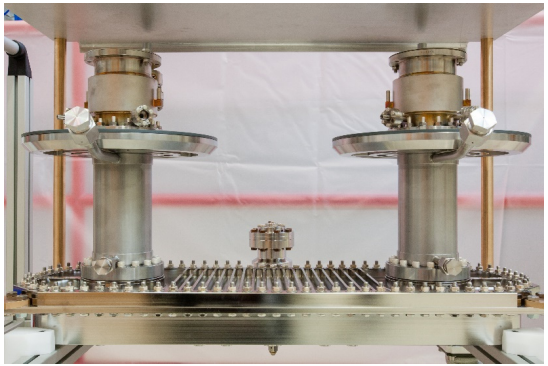


1.2 MW peak



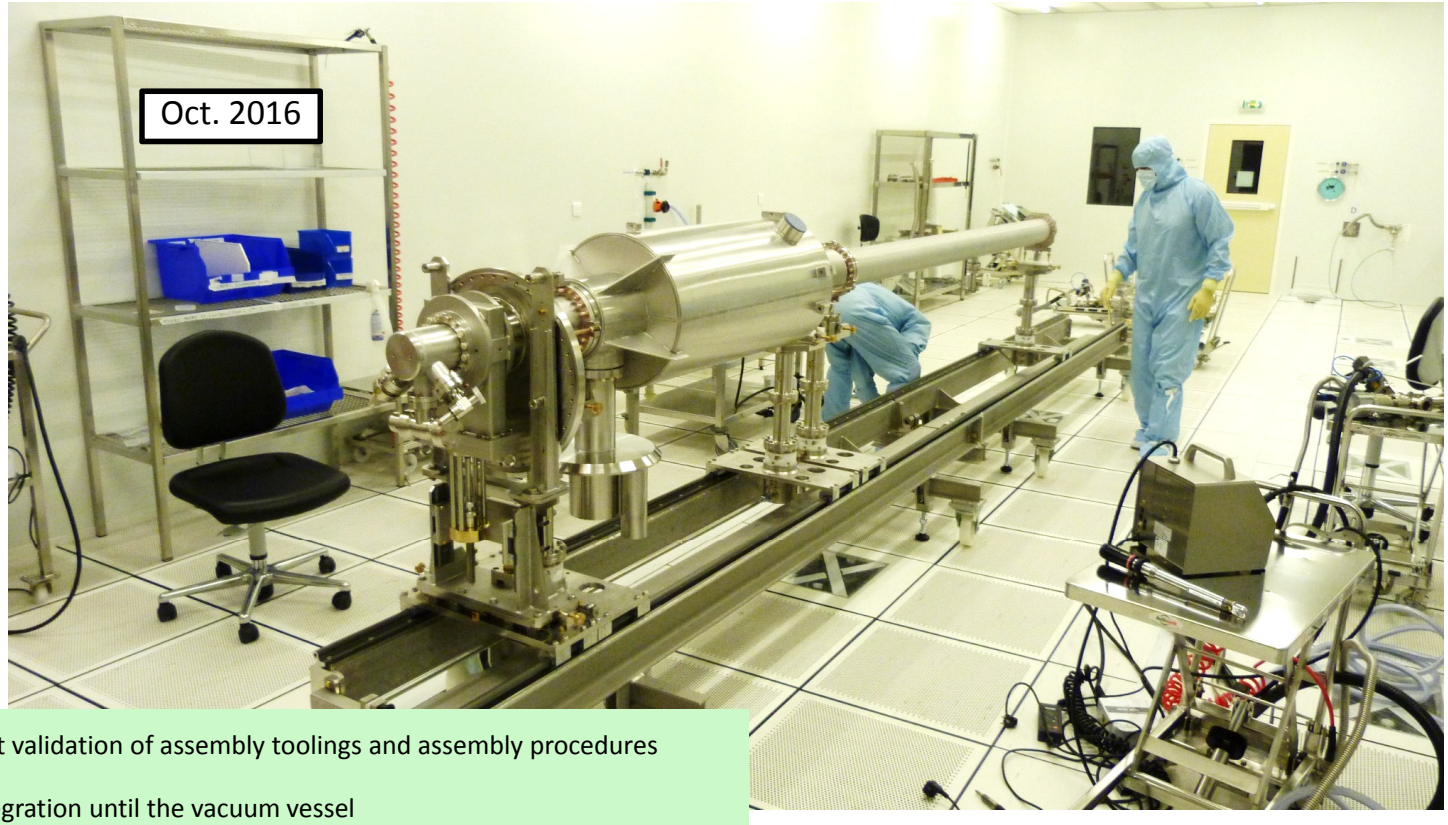
C. Arcambal





- Coupler pairs mounted on stainless steel air cooled coupling boxes in clean room
- Baking at 170 °C
- Multipactor regions found at 100, 300 and 900 kW during power ramping but easily conditioned without the use of the DC bias system
- **Three pairs have been successfully tested for now**

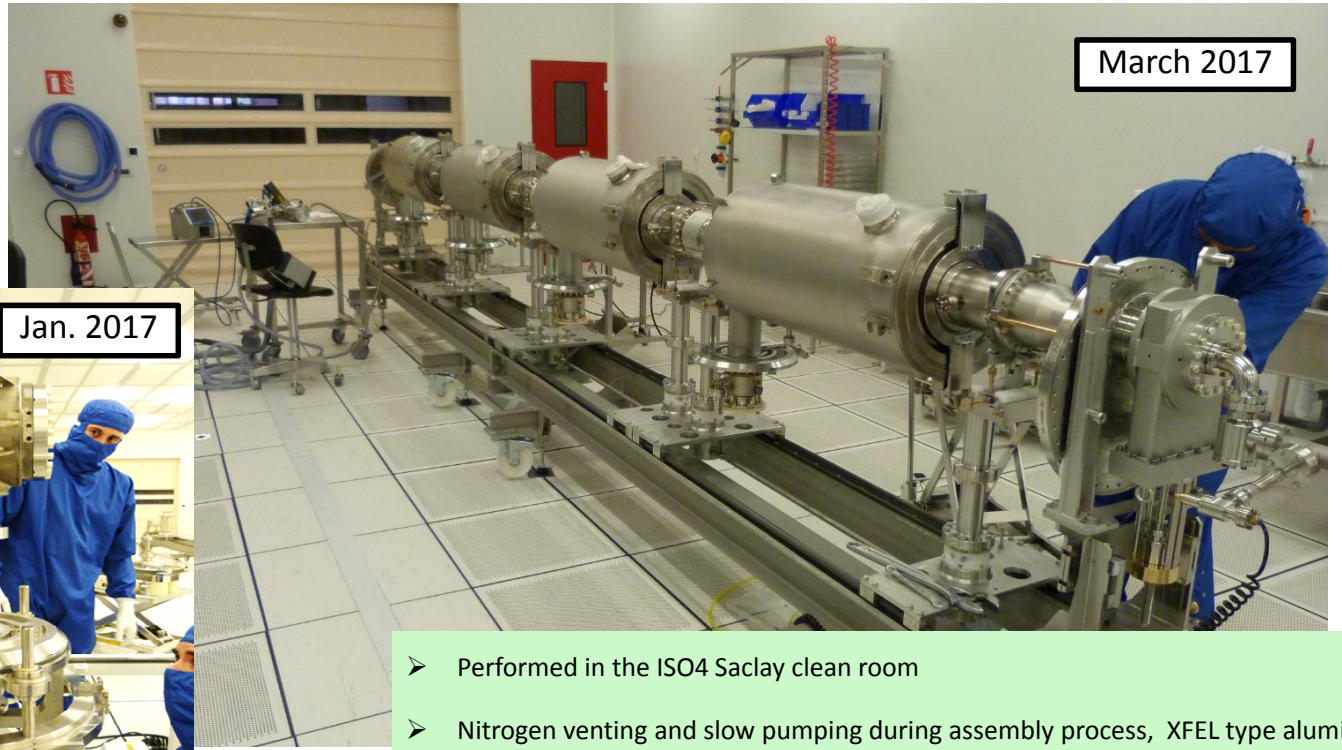
CRYOMODULE ASSEMBLY TRAINING USING A MOCK-UP CAVITY



- First validation of assembly toolings and assembly procedures
- Integration until the vacuum vessel

M-ECCTD CRYOMODULE CLEAN ROOM ASSEMBLY

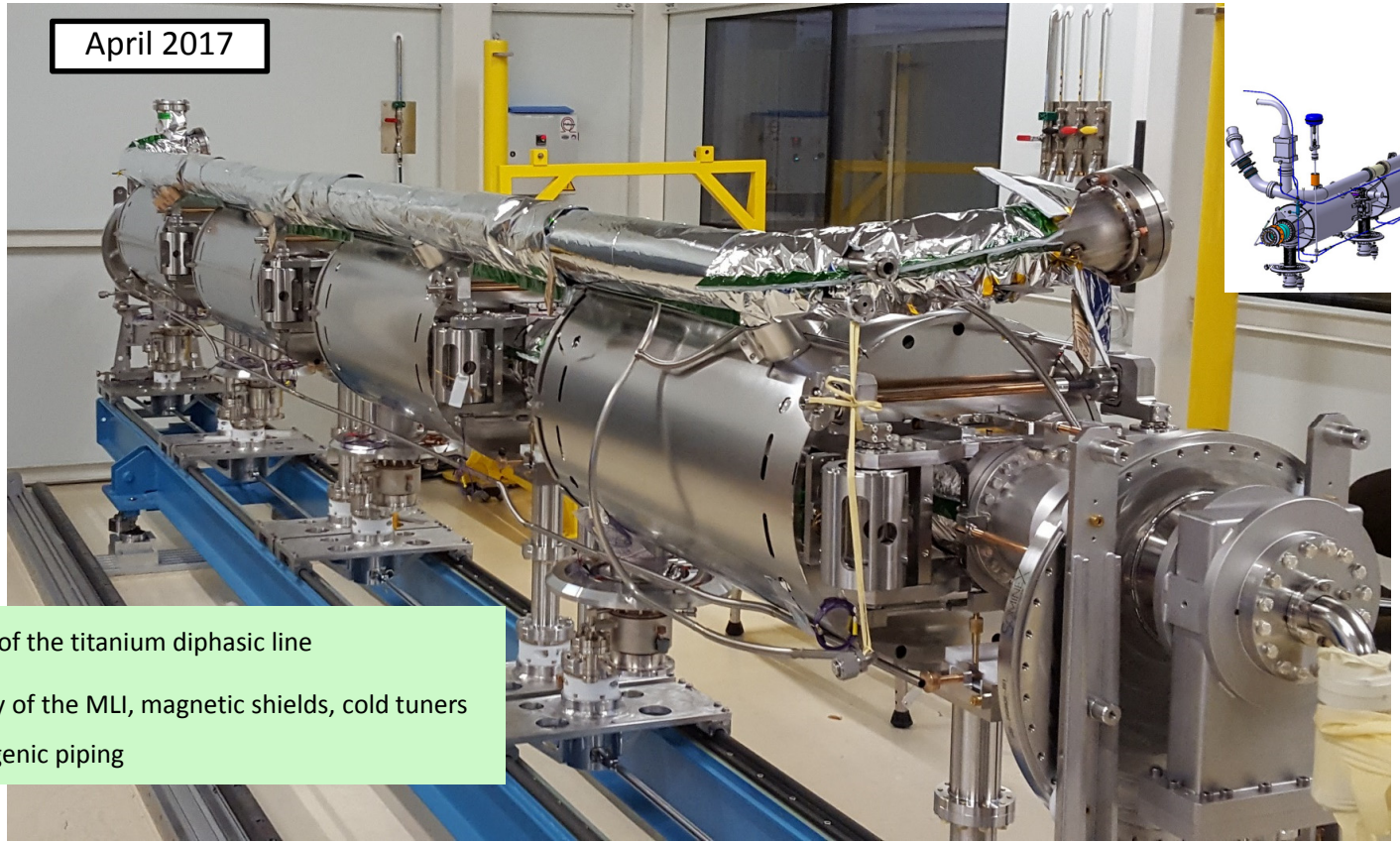
S. Berry
J.P. Poupeau
A. Bouygues

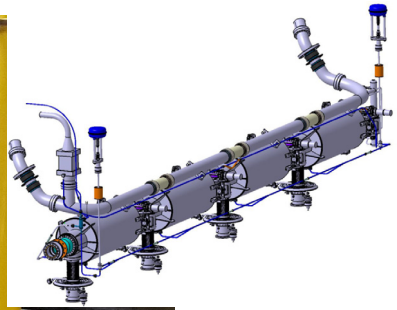


- Performed in the ISO4 Saclay clean room
- Nitrogen venting and slow pumping during assembly process, XFEL type aluminium gaskets
- Cavities pre-aligned, under vacuum before rolling out of the clean room

CAVITY STRING DRESSING

April 2017

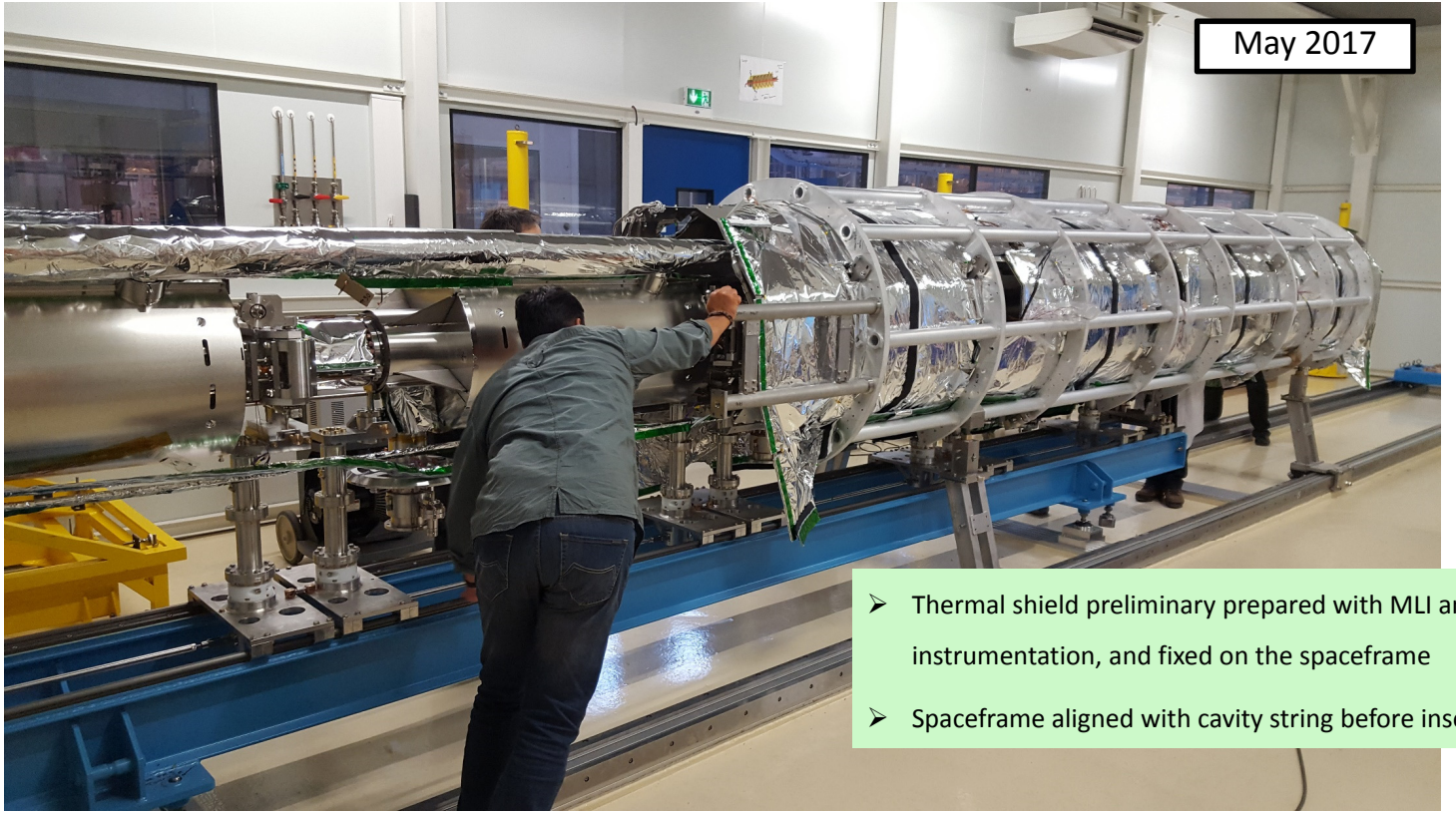




J.P. Charrier
J. Plouin
G. Devanz

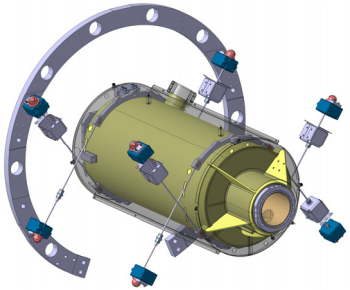
- Welding of the titanium diphasic line
- Assembly of the MLI, magnetic shields, cold tuners and cryogenic piping

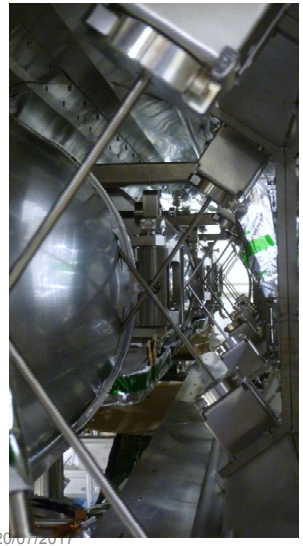
CAVITY STRING INSERTION INSIDE THE SPACEFRAME

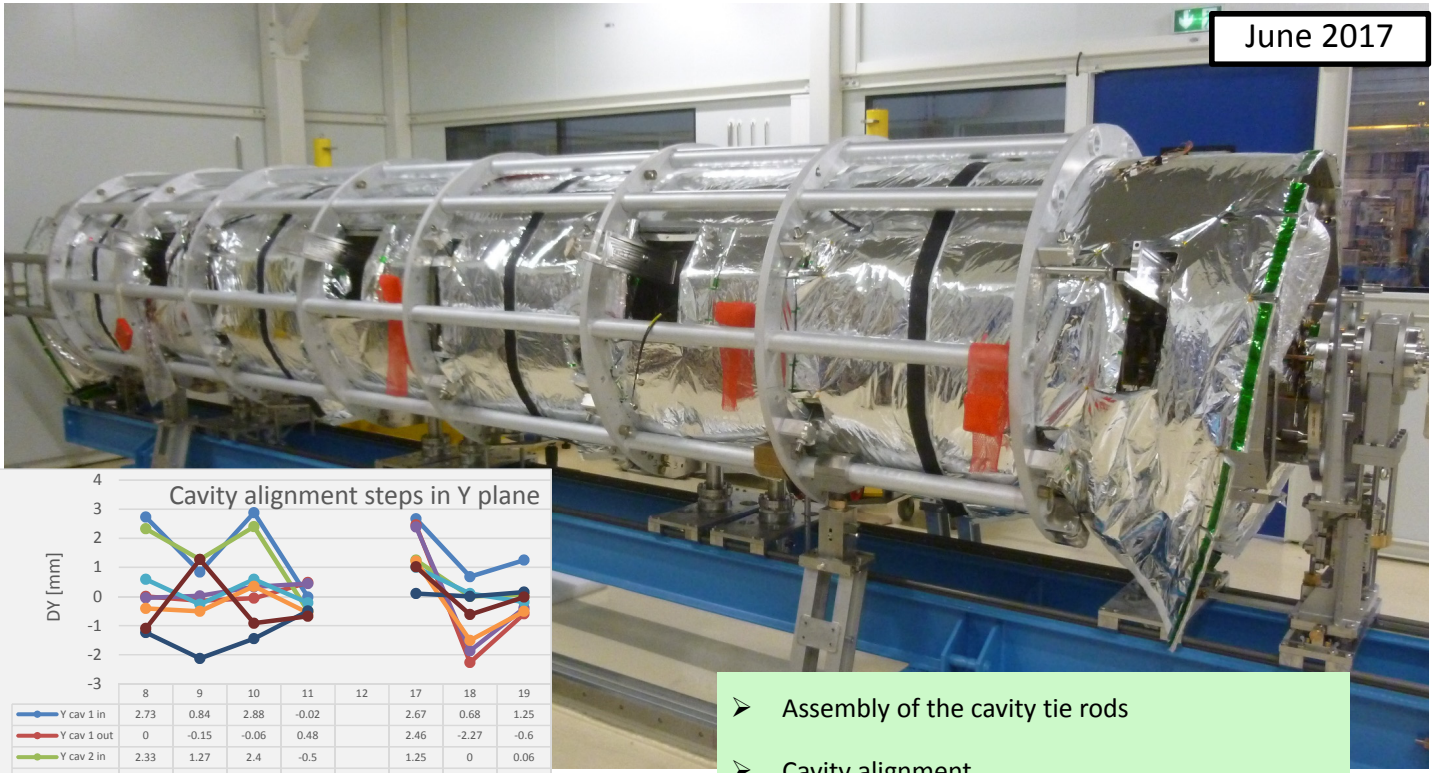


- Thermal shield preliminary prepared with MLI and instrumentation, and fixed on the spaceframe
- Spaceframe aligned with cavity string before insertion

CAVITY STRING MASS TRANSFER ON THE SPACEFRAME







	8	9	10	11	12	17	18	19
Y cav 1 in	2.73	0.84	2.88	-0.02		2.67	0.68	1.25
Y cav 1 out	0	-0.15	-0.06	0.48		2.46	-2.27	-0.6
Y cav 2 in	2.33	1.27	2.4	-0.5		1.25	0	0.06
Y cav 2 out	-0.05	0.02	0.33	0.44		2.39	-1.87	-0.4
Y cav 3 in	0.59	-0.27	0.59	-0.22		1	0.1	-0.19
Y cav 3 out	-0.41	-0.51	0.35	-0.56		1.21	-1.51	-0.51
Y cav 4 in	-1.24	-2.13	-1.45	-0.5		0.1	0	0.15
Y cav 4 out	-1.1	1.27	-0.92	-0.68		1.02	-0.62	-0.02

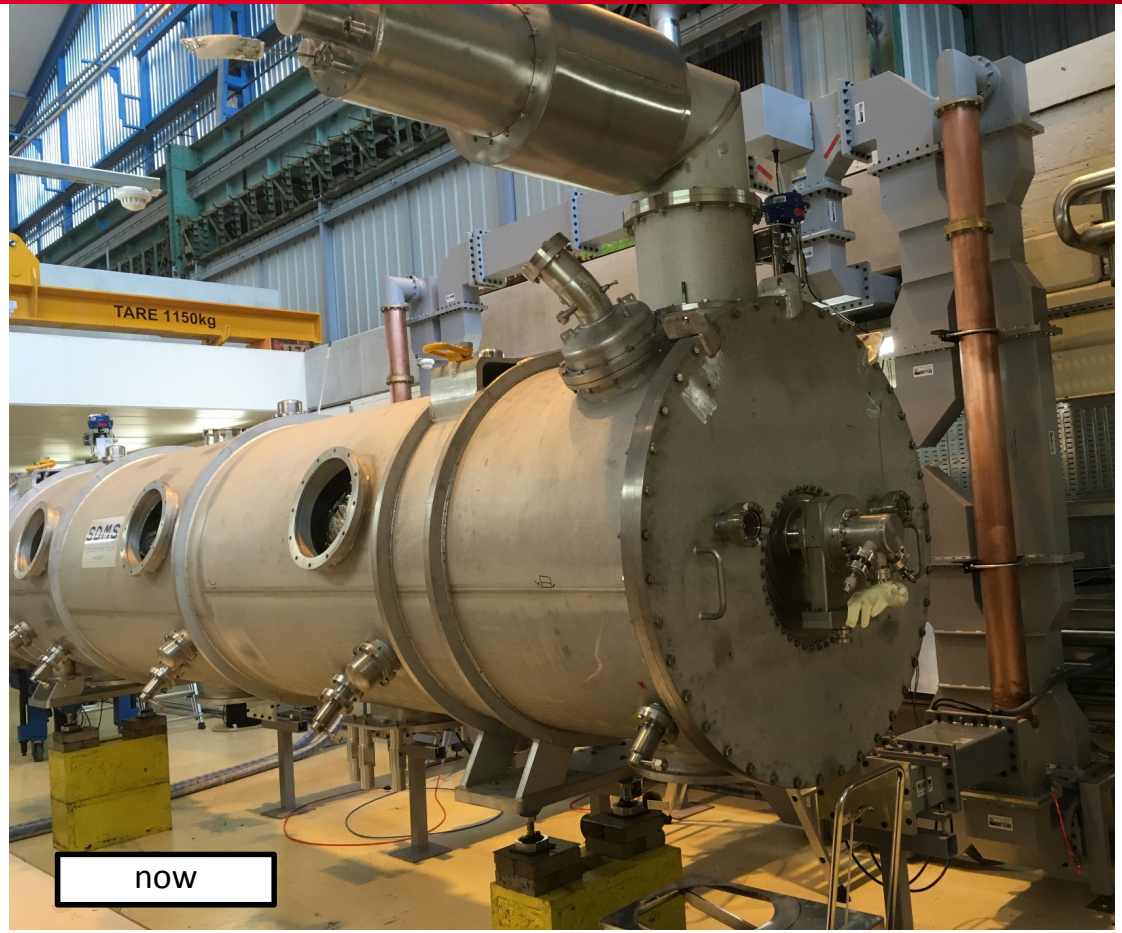
- Assembly of the cavity tie rods
- Cavity alignment
- The clean room cavity posts can be removed

M. Fontaine

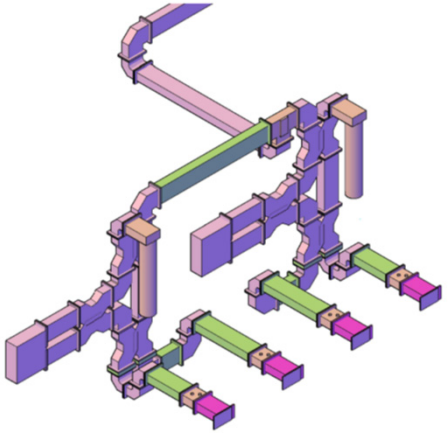
SPACEFRAME INSERTION INSIDE THE VACUUM VESSEL

- Jumper connection assembly
- cryogenic connections at the cryomodule extremities
- Leak check of all the cryogenic circuits

CRYOMODULE INSTALLED INSIDE THE TEST STATION AT SACLAY

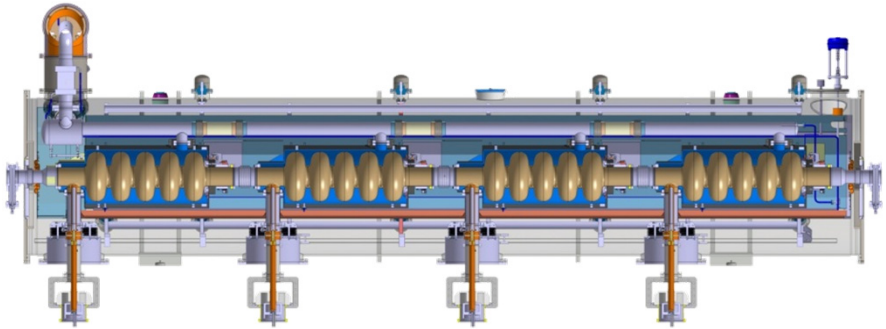


- Last assembly operations: atmospheric compensation system on coupler flanges, doorknob transitions
- Beam line and insulating vacuum pumping
- Instrumentation cabling, cryogenic and waveguide connections
- **First cooldown to 2K and warm conditioning of couplers are planned in July / August 2017**



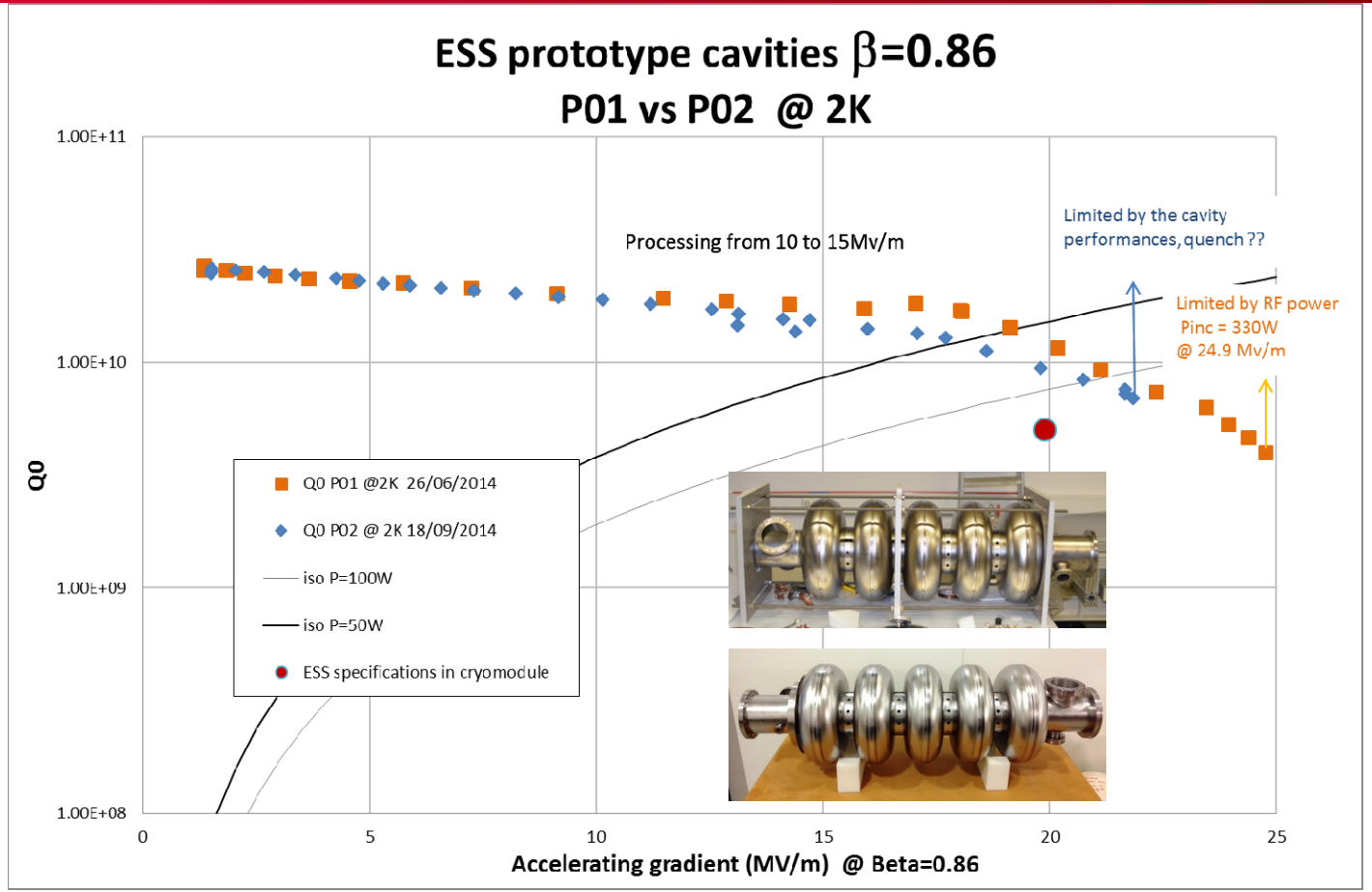
H-ECCTD CRYOMODULE PROCUREMENT STATUS

- **Five new high beta cavities ordered at Research Instrument GmbH** (deep drawing of half cells and RF controls in progress)
- Four RF windows and antenna already available. New external conductors (copper plated) recently manufactured
- Magnetic shields, cold tuners, motors, piezo-actuators, internal RF cables and titanium bellows available
- Titanium diphasic tubes procurement anticipated
- Inter-cavities bellows and cold warm transitions, 2K heat exchanger, cryogenic piping and the internal instrumentation procurements to be launched
- All the other cryomodule components are procured as pre-series of the series cryomodule contracts. The vacuum vessel, spaceframe and thermal shield have been ordered, with deliveries expected for the first quarter of 2018.



➢ Cryomodule design improvements, limited to minor changes after lessons learnt from M-ECCTD assembly

HIGH BETA PROTOTYPES TESTED IN 2014



STRATEGIC DECISIONS ON THE SERIES PHASE

- Cryomodule components procurement:
  - Divided in several procurement contracts adapted to the skills of the companies
- Cryomodule assembly :
  - Assembly rate of one cryomodule per month
  - Will be performed in the former “XFEL Village” which becomes officially now the “ESS Village”
    - Fully dedicated to the ESS cryomodule (no interference with other projects at Irfu)
  - Will be done by an industrial partner on CEA Saclay site, under the supervision of CEA team
    - The contract include an industrialization phase and training on the first cryomodules
    - Include clean room cavity string assembly, rool –out activities, alignment and cryostating (XFEL like)
- Cryomodule tests at CEA:
  - Will be done on the three first series MB and HB cryomodules only
  - These tests are mandatory to have a fast feedback on the quality of the cryomodule assembly

PROCUREMENT PLAN

- **Procurement plan deals with 40 contracts of ~1 M€ average** for the cryomodule workpackage
- **32 contracts dedicated to components procurement**

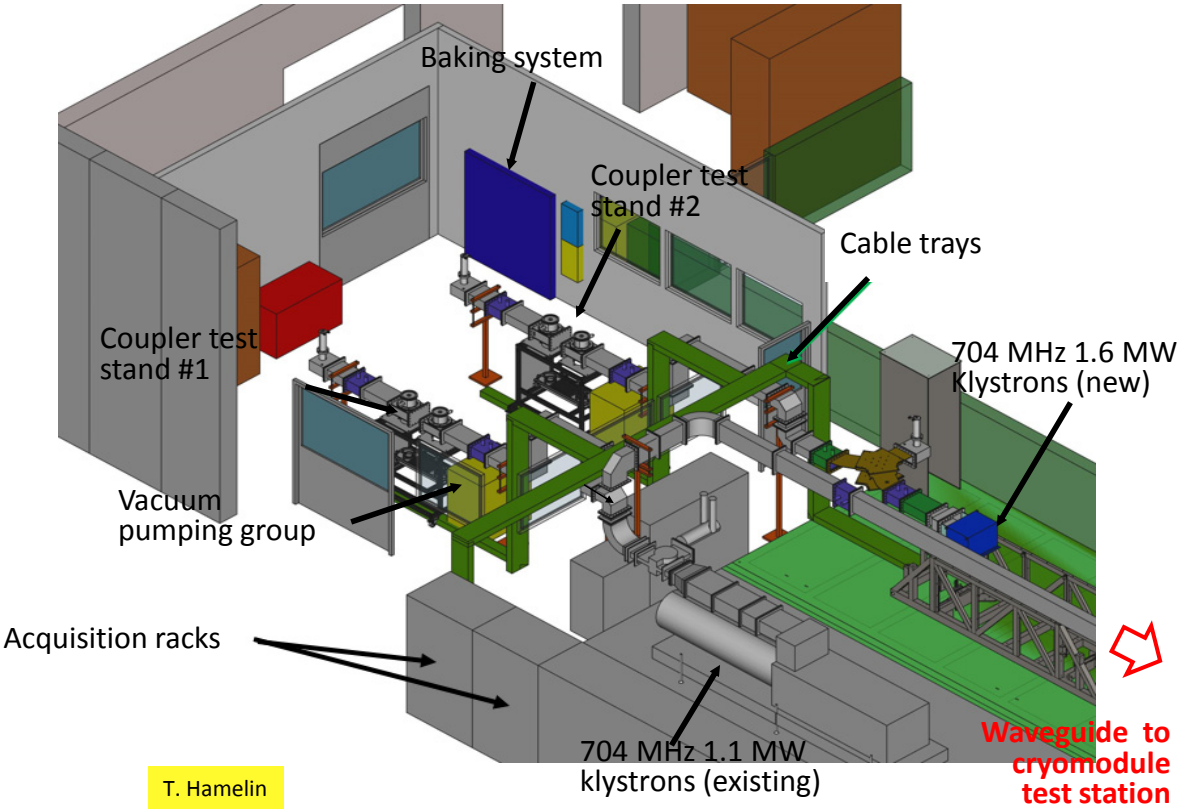
  -> with 19 contracts for specific machining/ manufacturing systems
- 60 % of the tenders have been published and 20 % awarded
- Some critical tenders are in stand by and wait for the first cryomodule testing

Order placed
Tendering launched
Tendering in stand by
Shared procurement with ESS
Tendering process in preparation

	Contract title	Qty	Company
1	Vacuum vessel	30 + 2	ACPP
2	RF Couplers	120	PMB
3	Tuners (mechanical parts)	120	
4	Stepper motors for tuners	120+2	PHYTRON
5	2K Heat exchangers	31	
6	Coupling boxes for coupler conditioning	12 + 3	SDMS
7	Diphasic pipes, cryogenic circuits	31	
8	Intercavity belows / cold warm transitions	31	
9	Titanium belows for diphasic lines	31	
10	Cryomodule assembly at CEA Saclay	30	
11	Spaceframe	30 + 2	SDMS
12	Magnetic shieldings	120.	
13	Thermal shieldings	30 + 2	SDMS
14	Multi Layer Insulation	31	
15	Screws set (for clean room assembly)	.	
16	Piezo for tuners	240	
17	Cavity supports	31	
18	RF cable	120	
19	RF feedthrough	62	
20	Aluminium gaskets		
21	Copper gaskets	300	GAVARD
22	Internal instrumentation	31	
23	Vacuum gauge for couplers	120	
24	Cryogenic valves	62	
25	Thermal sensors (Cernox)	325 + 480	
26	Safety valve	31	
27	Pressure sensor	64	
28	Controled safety valve	31	
29	Rupture disks	62	
30	Vacuum components	31	
31	Helium level sensor	62	
32	Thermal braids	31	

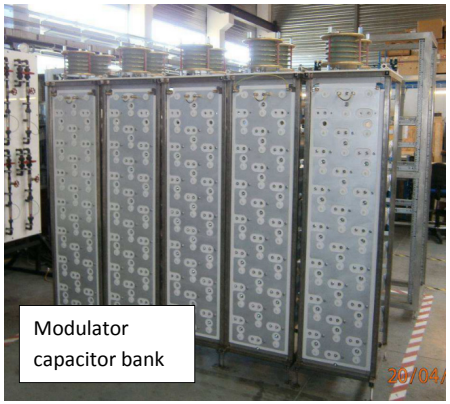
POWER COUPLER RF CONDITIONING STANDS

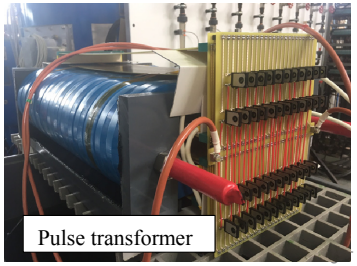
- 120 couplers shall be RF conditioned at CEA in the next 3 years
- Two coupler pairs will be powered in parallel in a clean testing area (except when a cryomodule is under test)

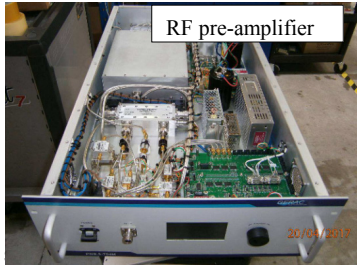


NEW 704 MHZ RF SOURCE FOR POWER COUPLERS RF CONDITIONING

- Contract launched in July 2016 with THALES
- Installation of components will start in July 2017
- Fully operationnal in October 2017

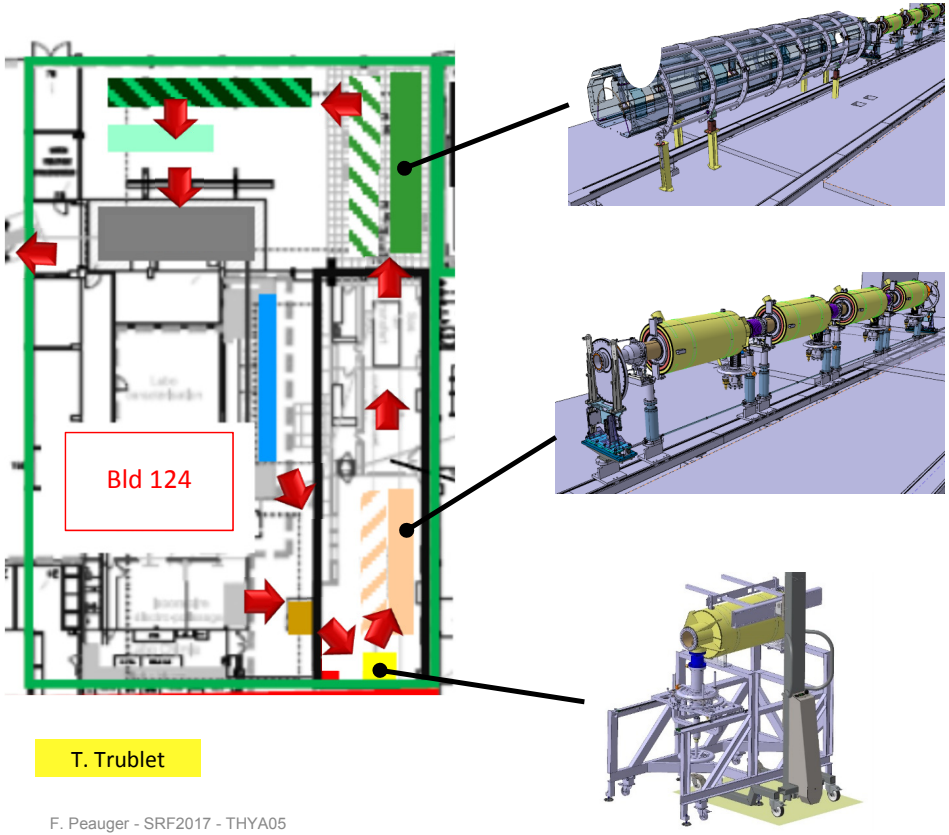






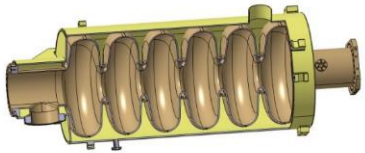
CRYOMODULE ASSEMBLY WORKSTATIONS AT SACLAY

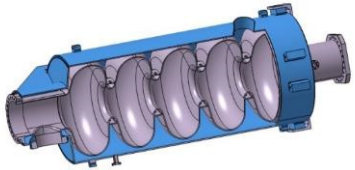
- Workstations definition is finalized
- Assembly tooling design upgrade is in progress

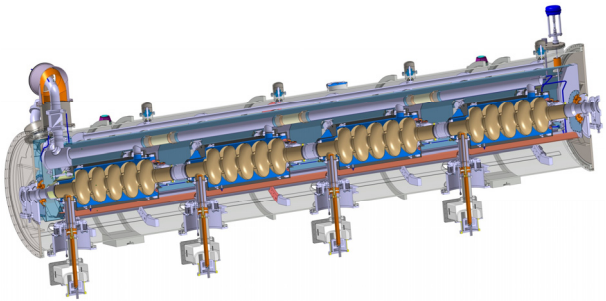


CONCLUSION

- CEA Saclay and IPN Orsay are developing together high gradient / high power / long pulse cryomodules for the ESS elliptical cavities
- Important effort to conduct four activities in parallel :
  - first prototyping phase : final assembly and RF tests of the medium beta demonstrator will occur this summer 2017
  - fabrication of a second high beta cryomodule demonstrator in progress
  - Anticipation of the series component procurement with more than 60% of contracts launched
  - Preparation of the industrialization phase of the series cryomodules assembly with an industrial partner

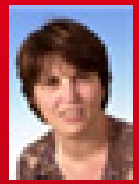




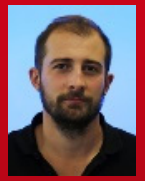













Thank you

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