Status of Irfu-ESS discussions on french contribution under the responsibility of CEA

Lund, 10th october 2012

Florence Ardellier (Head of Irfu-SIS)

&

Antoine Daël (Head of Irfu-SACM)

Thanks to Pierre Bosland , Guillaume Devanz & Bruno Pottin

Summary

- Introduction
- Early contacts
- Existing collaboration in P2B & ADU : technical results
- The CEA-Irfu ESS Working Group for IKC
- Workpackages under discussion
- List of actions : to define
- Conclusion

Early Contacts (May 2009)

1. Since the very beginning of the ESS project CEA-Irfu has been very active to contribute to the LINAC Construction , in parallel with the contributions of the french neutron scientific community.

2. Early guide lines for the P2B , ADU & IKC have been already defined in fall 2009 and are still valid

3. An industrial meeting has been organised in Paris in march 2010

4. The cooperation agreement has been signed.

5. Amendment n° 1 to the Cooperation Agreement in the field of neutron and accelerator sciences to the ESS design phase is ready to be signed

Existing collaboration in P2B & ADU : technical results

1. Project 1 : Injector realibility test
2. Project 2 : 352 MHz power coupler bunker
3. Project 3 : 8 equipped and tested superconducting cavities
4. Project 4 : contribution to the TDR
5. Project 5 : engineering design effort
6. Project 6 : (IPNO) Cryomodule spoke
7. Project 7 :(IPNO) New infrastructure for SRF cavities
8. Project 8 : ECCTD (CEA-Irfu & CNRS-IPNO)

The progress of these projects is monitored by
ad hoc franco-suédois follow up committee

CEA-Irfu &ESS Working Group for IKC

1. **ESS :**
   - **Stephen Molloy , Lead Cavity Engineer**
   - **Christine Darve, Lead Cryomodule Engineer**
   - **David Mcgannis, RF group leader**

2. **CEA-Irfu:**
   - **Florence Ardellier (Head of Irfu-SIS)**
   - **Antoine Daël (Head of Irfu-SACM)**
   - **Pierre Bosland , CALHI Project Leader at Irfu**

3. **Steering group has been proposed on the 2nd october @ Saclay**

Road Map of the ESS & CEA-Irfu IKC Working Group

- Establish a schedule for the preparation of the IKC
- Establish a short list of Workpackages of common interest
- Establish a mapping of these Workpackages in the PBS/WBS of the ESS Linac Project and select relevant milestones
- Define priorities and options , commonly approved
- Review and approve the ESS rules for costing in order to share a common view on the IKC values both for manpower and material costs
- Follow the guidelines and support ESS efforts in view of cost reduction & « design to cost »
- Propose an IKC list to the ad hoc « ESS & CEA-Irfu IKC Steering Committee », an IKC list together with procurement rules
- Maintain a close collaboration with CNRS partners and the relevant coordination in the definition of the CNRS & CEA french IKC.
- Follow common quality rules for the technical annexes

Meetings of the Working Group

- September 20th call conference
- September 28th call conference
- October the 2nd meeting at Saclay
- October the 10th (today) meeting at Lund

LIST OF Proposed WORKPACKAGES for IKC

1. **ESS LINAC front End :**
   - Full responsibility of RFQ with RF power test
   - Option : functional test of ESS front end at Saclay (with partly existing infrastructures)

2. **High Beta cavity cryomodules:**
   - Full responsibility of design , components and test of the components
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3. **Option** : contribution to **Medium Beta cavity cryomodules** in the frame of an international collaboration leaded by ESS

4. **Option**: other contributions in CC , mechanical design and beam dynamics.

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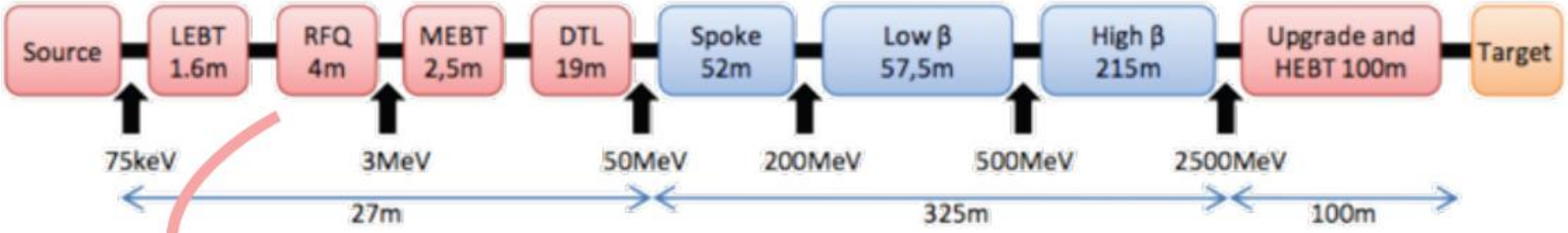
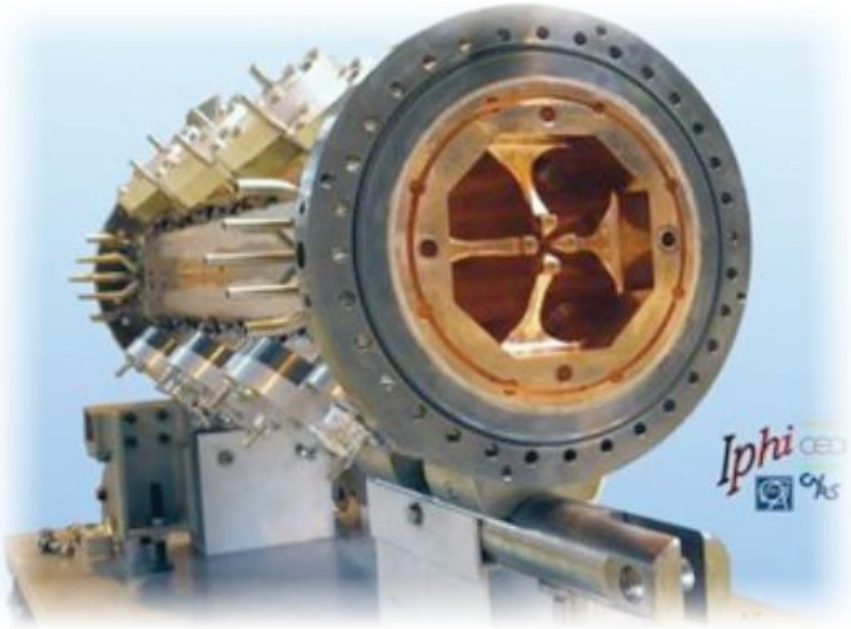
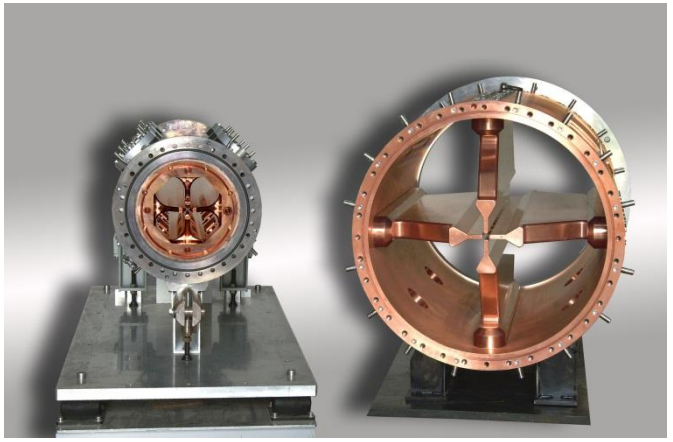
1. RFQ cavity @ 352 MHz





Technologie 4 lames

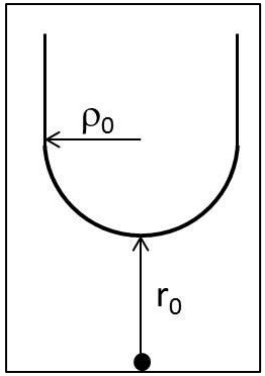
RFQ



- **We use the technological heritage with three RFQs : IPHI, SPIRAL2 for GANIL and LINAC4 for CERN**

- **<u>Main parameters of the ESS RFQ</u>**

ESS RFQ Parameters	Value	Units
Frequency	352.21	MHz
Beam energy	3	MeV
Peak beam current	75	mA
RF duty cycle	7.5	%
Length	4.95	m
Vane voltage	from 80 to 120	kV
r0	from 3.445 to 4.737	mm
ρ0	3	mm
Max field on pole tip	34	MV/m
Kilpatrick value	1.8	

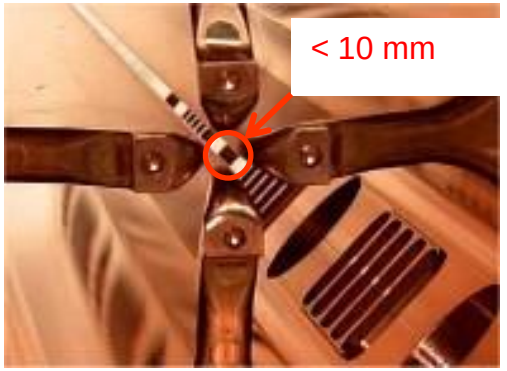


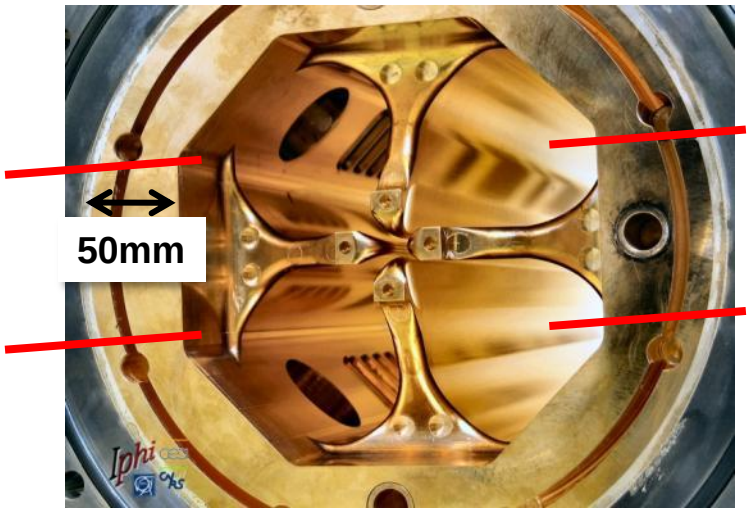
RFQ modules construction
(based on experience)

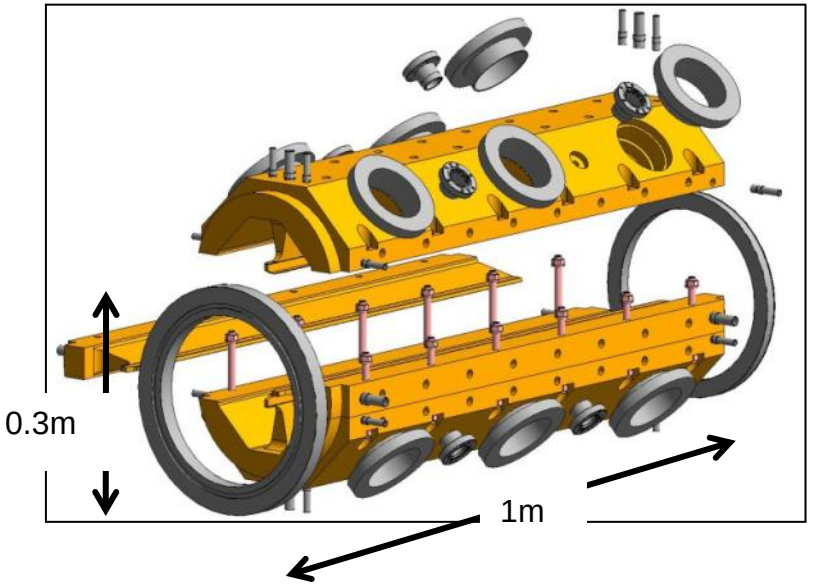
Each module is built in 4 parts corresponding to 4 electrodes with very tight tolerances : few microns/1m.

→ machining and alignment are very important.

ASSEMBLY by BRAZING : precision about 10µm

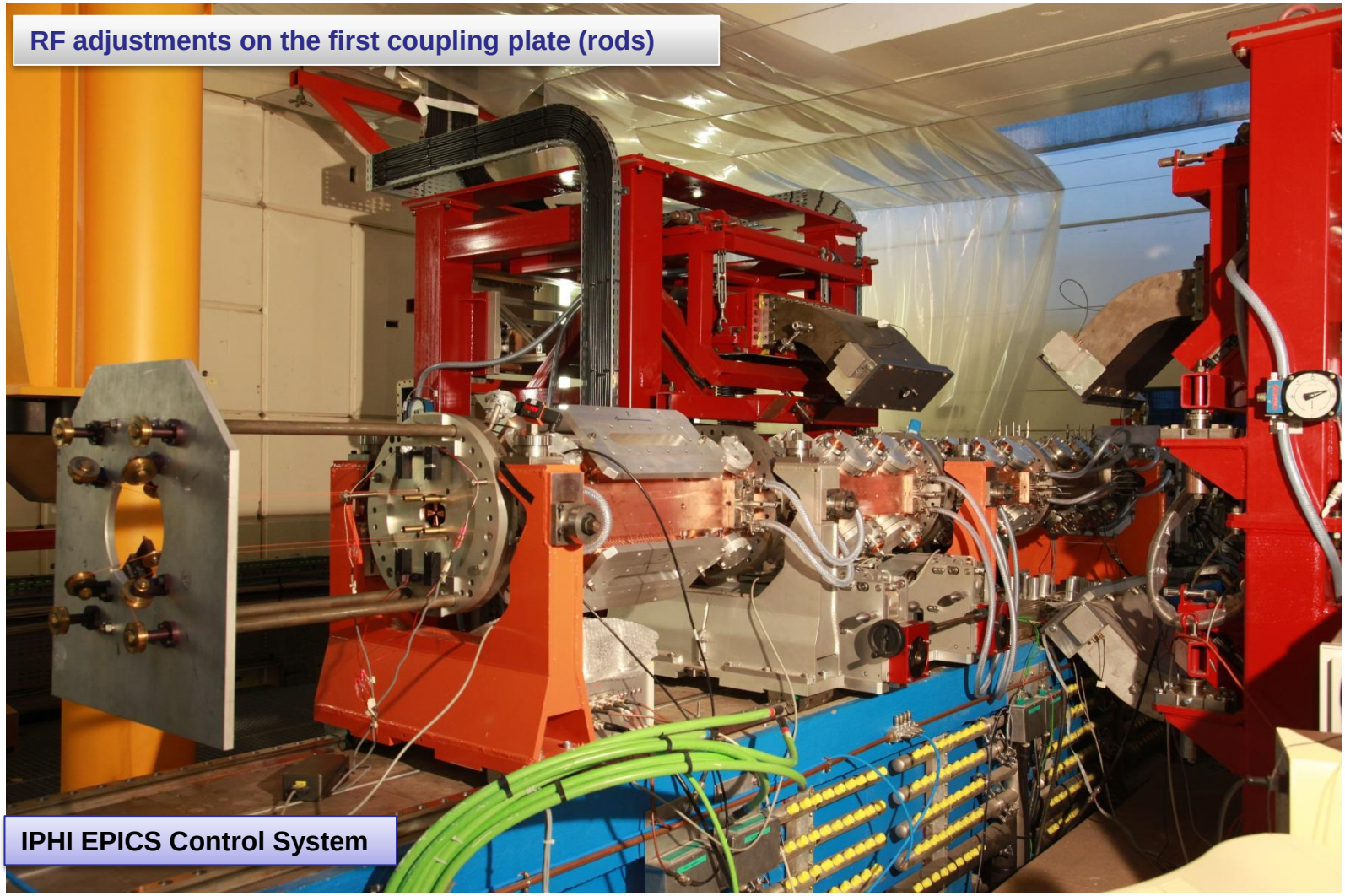




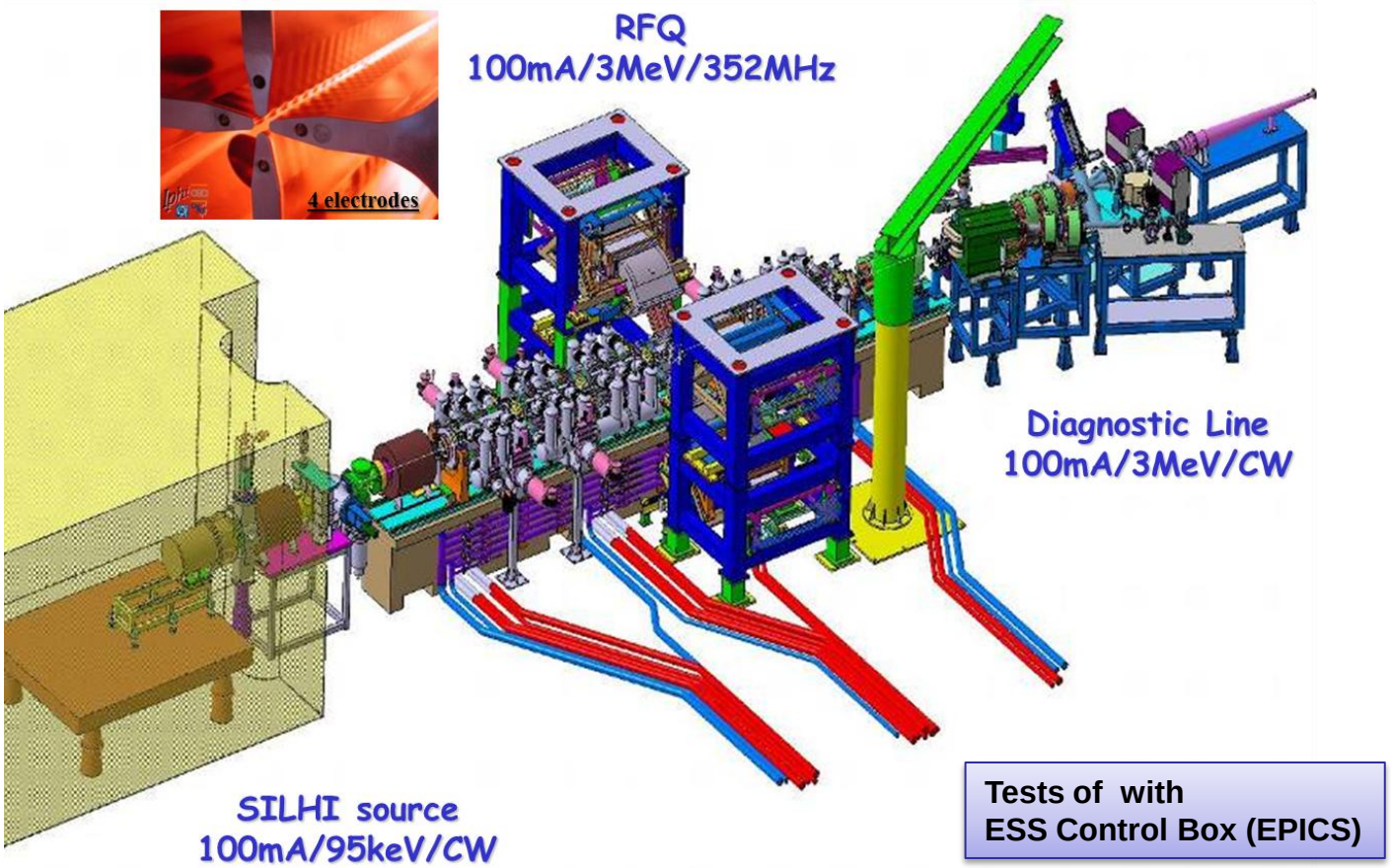


RF measurements for 4 modules

RFQ construction requires a lot of RF measurements at different stages



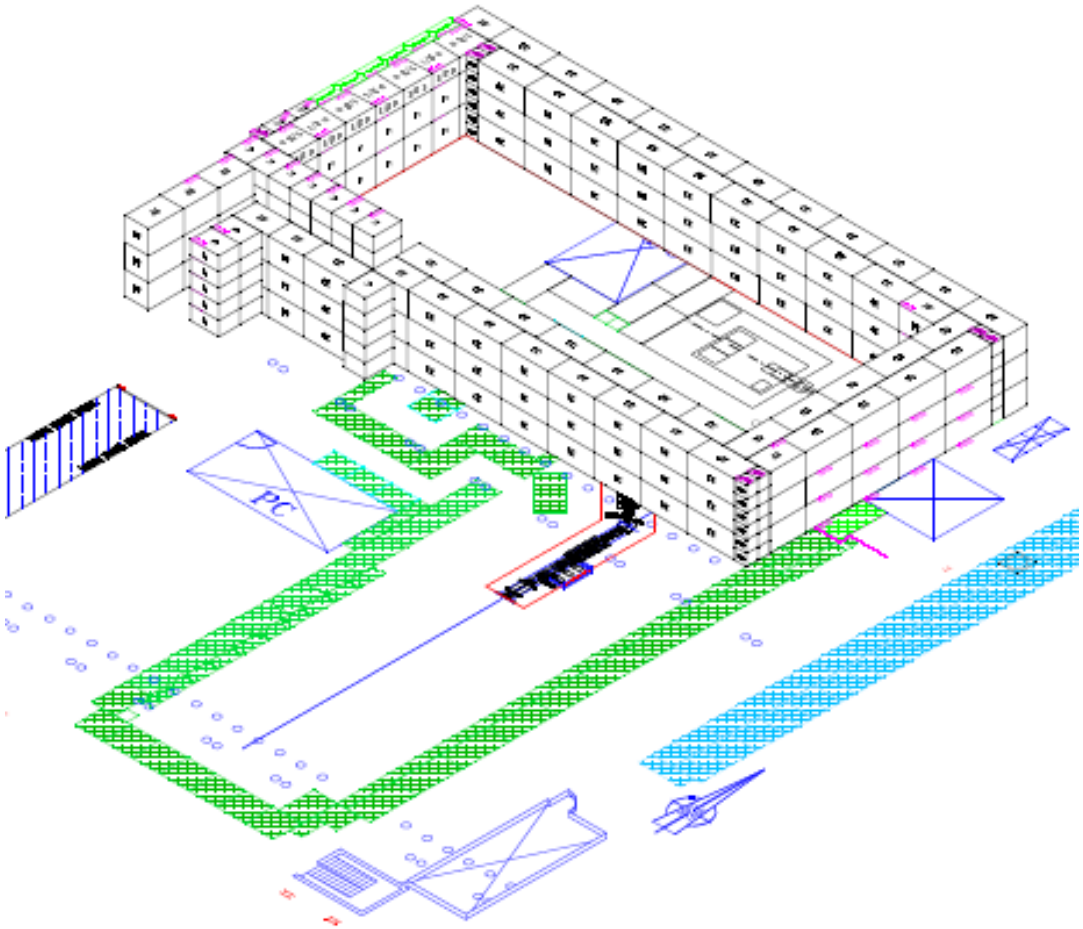
IPHI: facility for the ESS tests



The CEA will operate the IPHI-RFQ with relevant parameters for the ESS (duty cycle, peak current, pulse length) to provide a feedback for the reliability of the future ESS RFQ

A new bunker for ESS RFQ & injector(?)

1. **After completion of Spiral2 & IFMIF tests existing bunkers can be refurbished**
2. **Watercooling is available for RFQ test at full power**
3. **Electrical power is available for full power RF test**
4. **Installation of ECR source for commissionning of the entire injector is very welcome**
5. **CC : EPICS with ESS Control Box**



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Objectives and benefits of ECCTD

- Preparation of ESS construction phase

  Teams training

  Infrastructure preparation

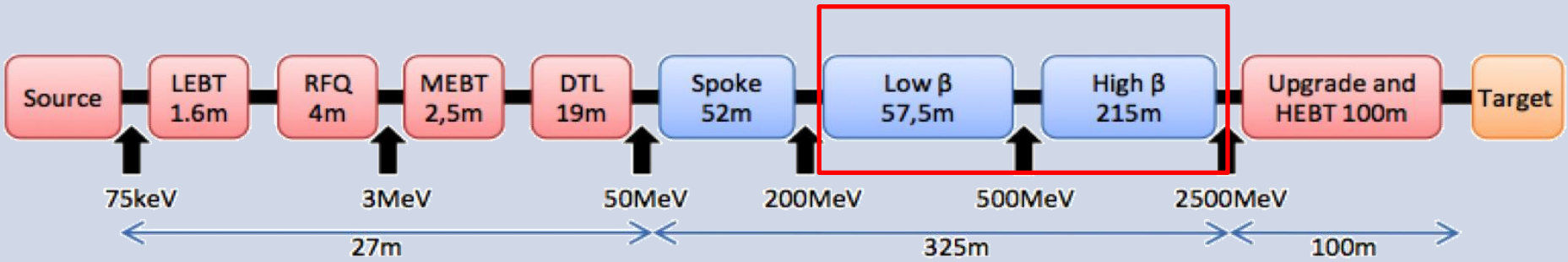
  Development of processes

- Design, fabrication and fine-tuning of ESS clean room and assembly tooling in the clean room

- Design, fabrication and fine-tuning of ESS assembly tooling outside of the clean room

- IPNO/Irfu synergy in P2B phase and in preparation of the construction phase

Elliptical superconducting cavities



- 5-cell cavities, bulk niobium
- two beta families
- frequency = 704.42 MHz
- performance specifications (T = 2 K):

beta	Eacc VT (MV/m)	Eacc Linac (MV/m)	Qo @ nominal Eacc
0.70	17	15	5e9
0.90	20	18	6e9

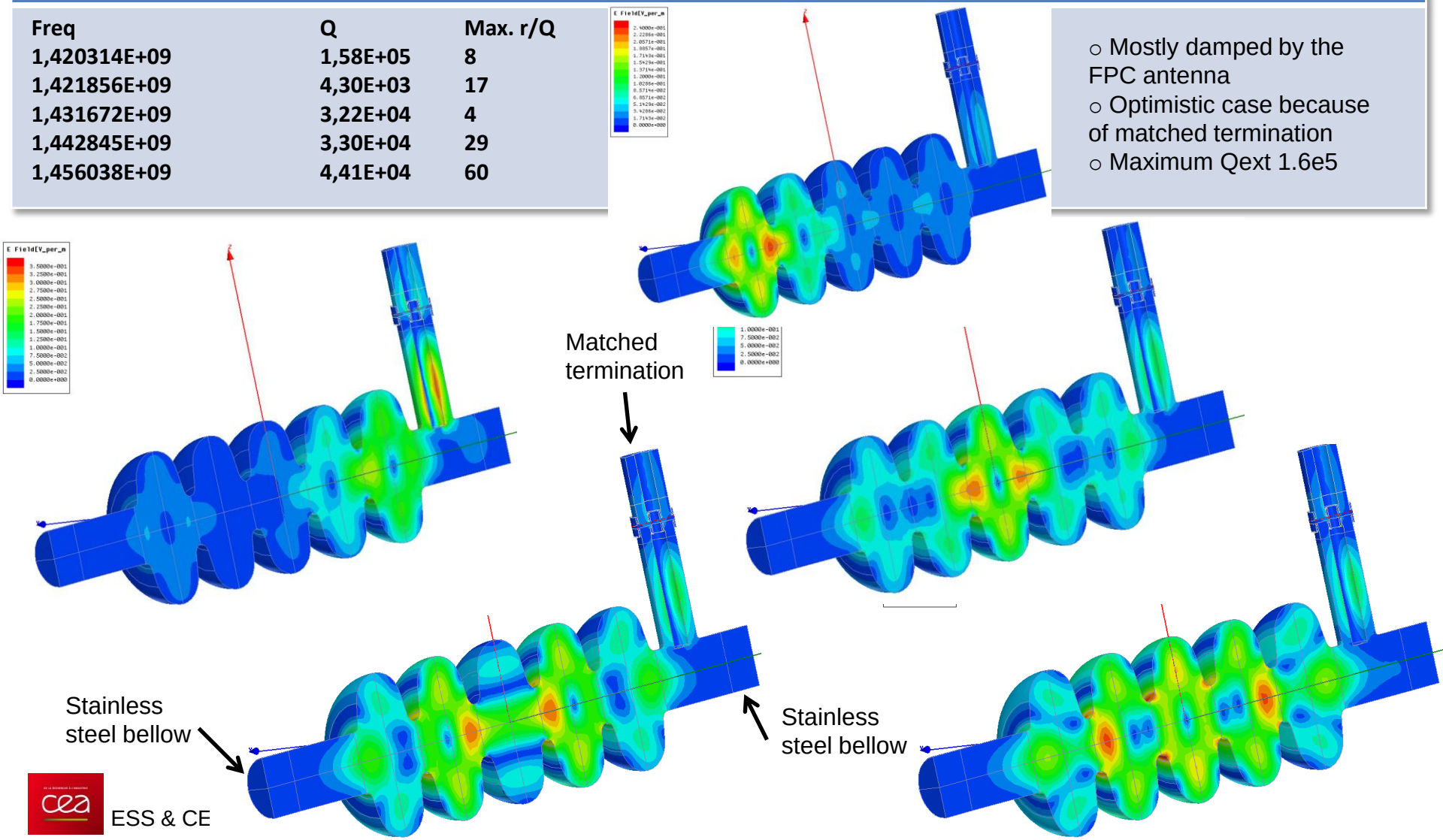
- Peak field specifications : Epk < 40 MV/m

ESS Linac : example of present studies

First monopolar HOM band – Matched termination on FPC

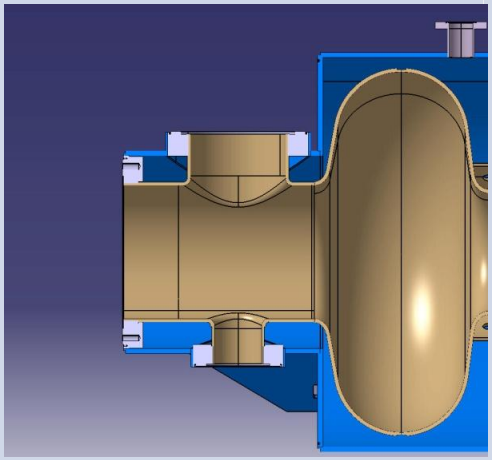
Freq	Q	Max. r/Q
1,420314E+09	1,58E+05	8
1,421856E+09	4,30E+03	17
1,431672E+09	3,22E+04	4
1,442845E+09	3,30E+04	29
1,456038E+09	4,41E+04	60

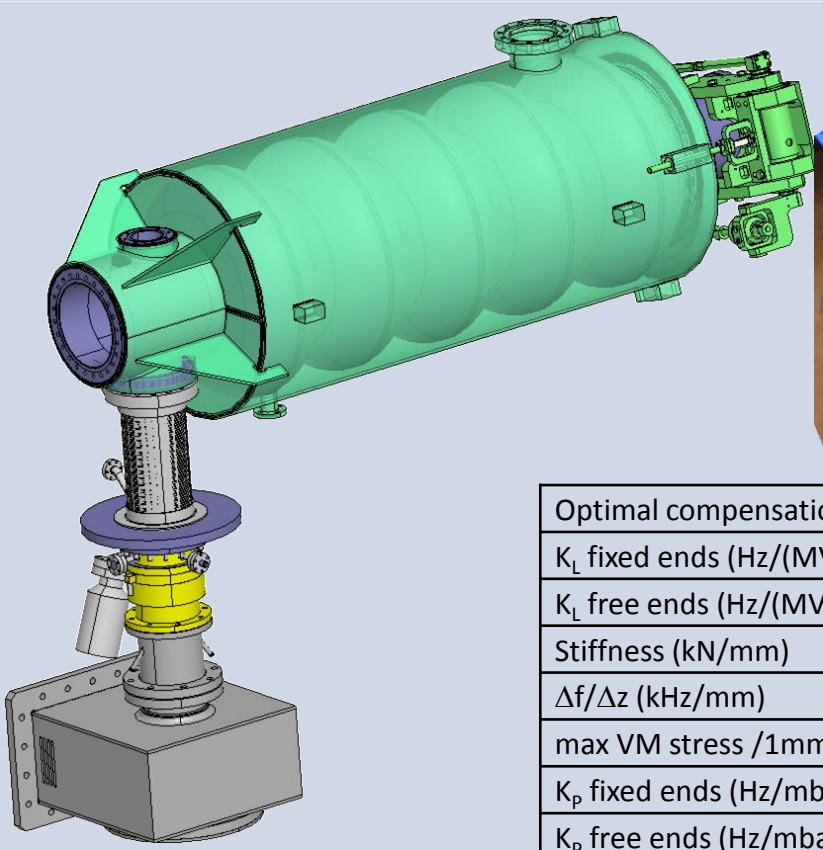
- Mostly damped by the FPC antenna
- Optimistic case because of matched termination
- Maximum Qext 1.6e5



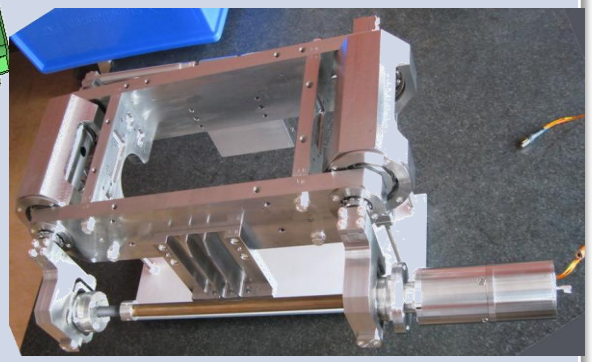
Mechanical design

- Niobium RRR>250
- Titanium He vessel (no brazing, marginal differential shrinkage with Nb, compact FPC port)
- Single titanium hydroformed bellow
- NbTi flanges
- Al Mg Si Hex seals





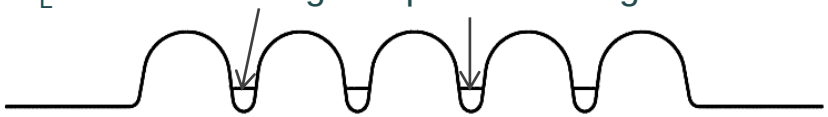
Saclay V type piezo tuner



Optimal compensation ring radius (mm)	84
K_L fixed ends (Hz/(MV/m)²)	-0,36
K_L free ends (Hz/(MV/m)²)	-8.9
Stiffness (kN/mm)	2.59
$\Delta f/\Delta z$ (kHz/mm)	197
max VM stress /1mm (MPa)	25
K_p fixed ends (Hz/mbar)	4,85
K_p free ends (Hz/mbar)	-150
max VM stress /1bar fixed (MPa)	12
max VM stress /1bar free (MPa)	15

RF/mechanical design

K_L reduction using compensation rings

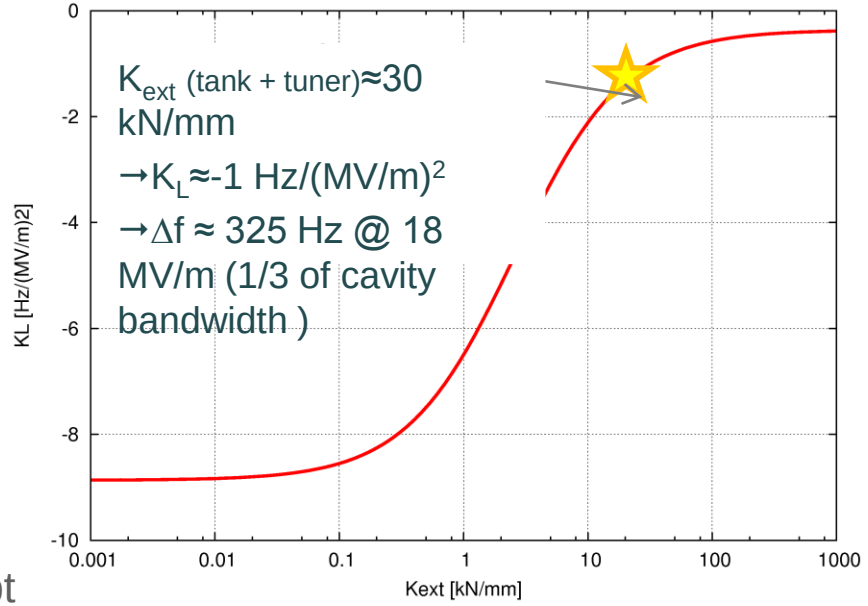


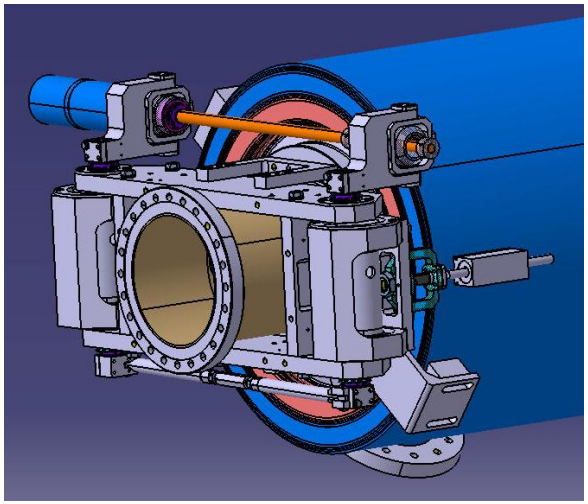
Lorentz detuning

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

$$K_L = K_{L\infty} + \frac{\Delta f}{\Delta z} \frac{\vec{F_\infty} . \vec{u_z} / E_{acc}^2}{K_{ext} + K_{cav}}$$

Cavity stiffness Kcav [kN/mm]	2.59
Tuning sensitivity Df/Dz [kHz/mm]	197
K_L with fixed ends [Hz/(MV/m)²]	-0.36
K_L with free ends [Hz/(MV/m)²]	-8.9
Pressure sensitivity K_P [Hz/mbar] (fixed ends)	4.85

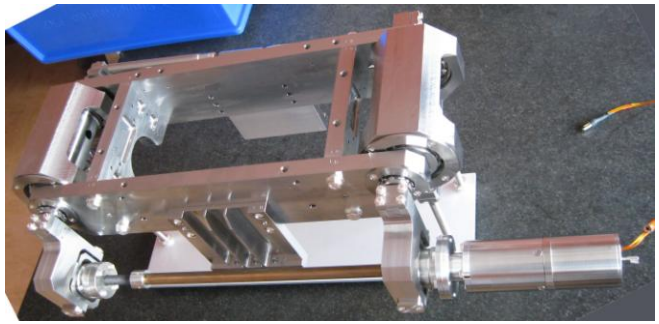




Saclay-V tuner concept adapted to the ESS cavity

Fast/slow tuner (with piezo)

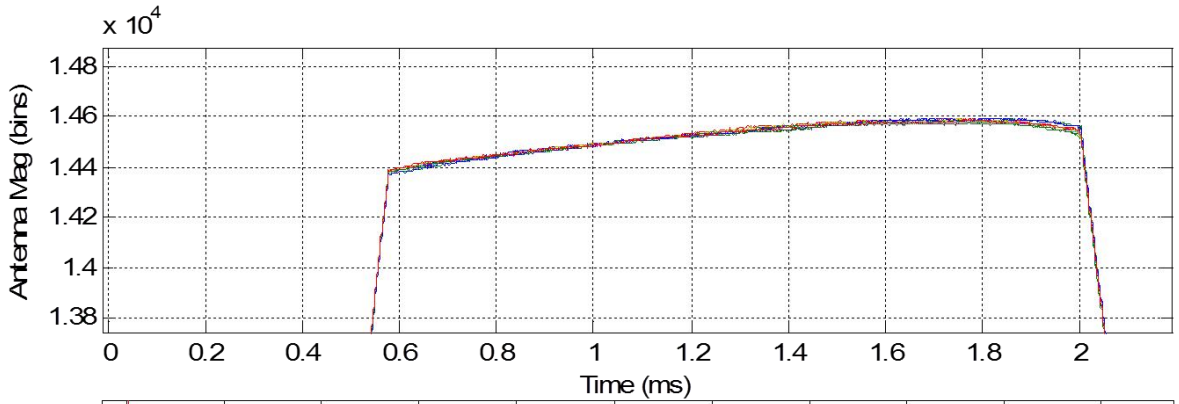
SPL tuner

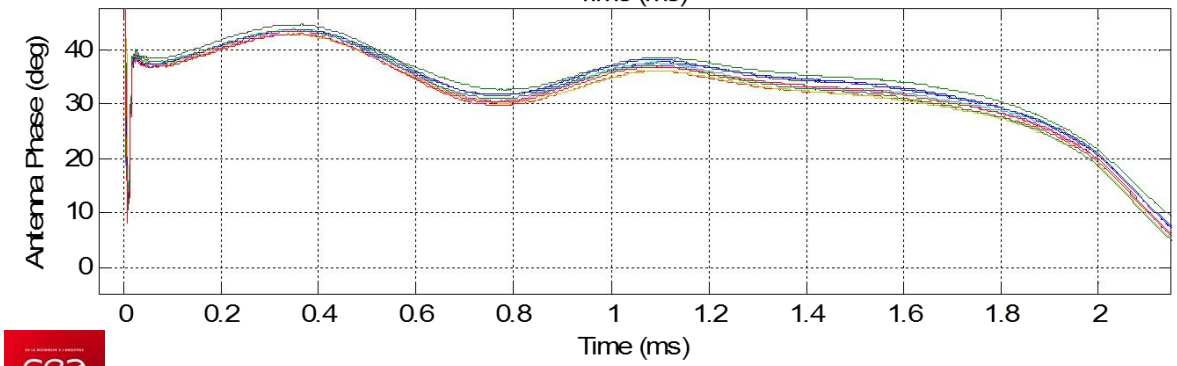


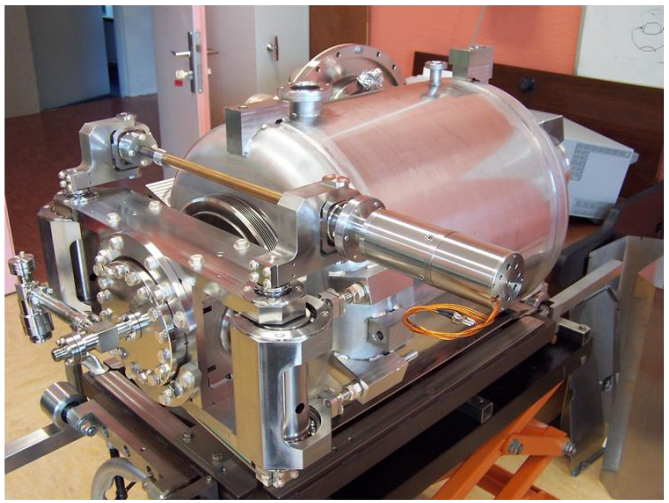
Piezo tuner – type Saclay V

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%



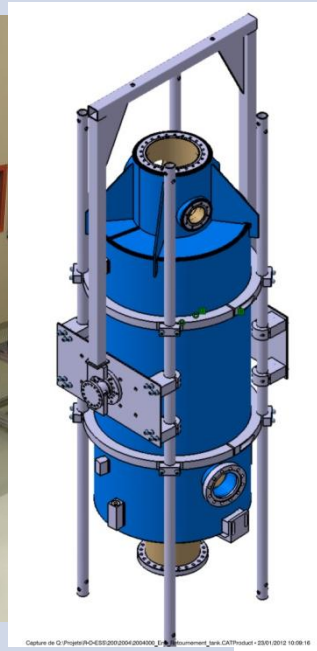


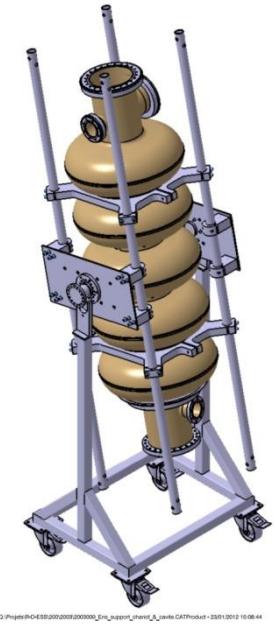


Good repeatability although mechanical modes have no time to decay between successive RF pulses (10 pulses recorded with CERN LLRF crate)

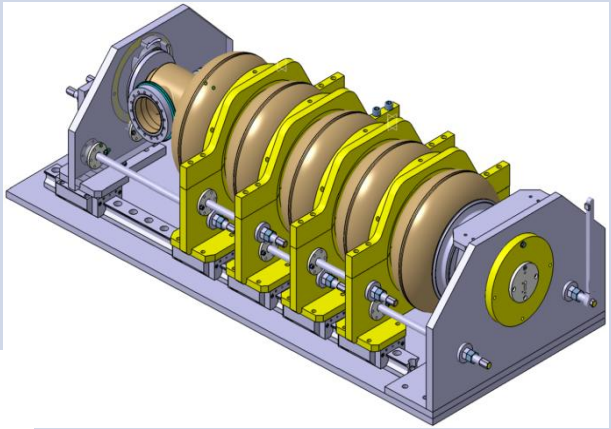
Cavity tooling & operating scenario

New Saclay vertical EP station: commissionned with 1.3 GHz single cell



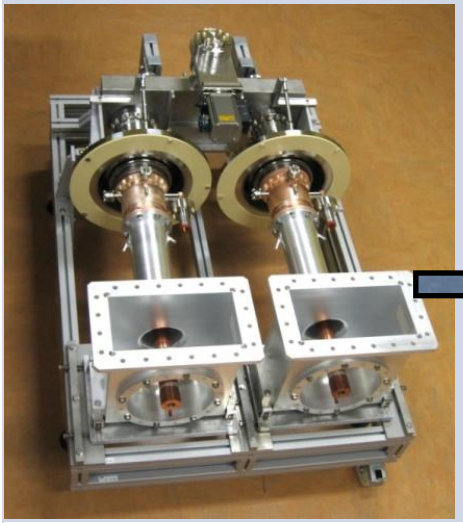


Design of cavity handling tools

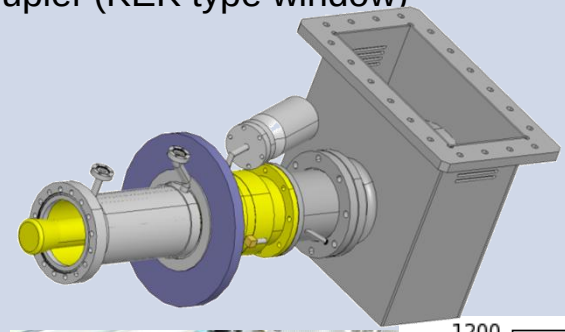


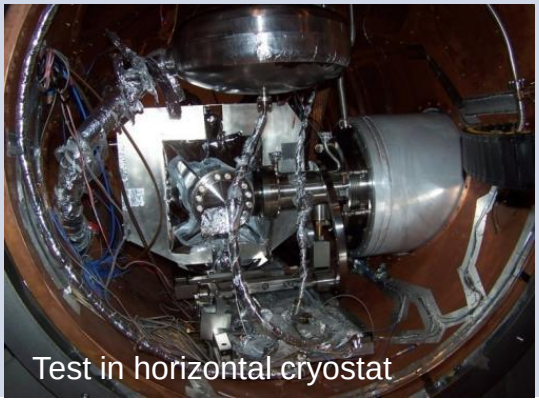
Field flatness tool under fabrication

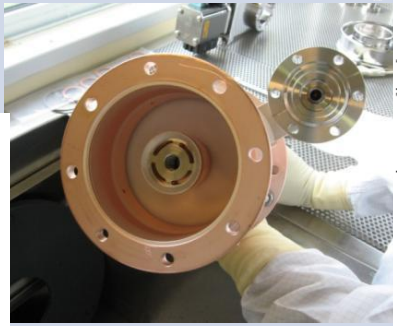
Power coupler design

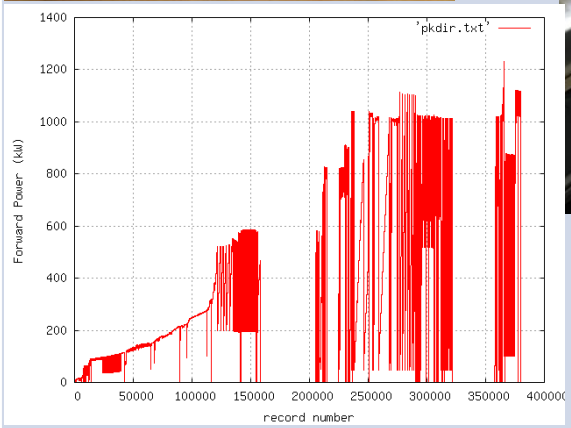


Starting from Saclay HIPPI 1MW 10%DC coupler (KEK type window)

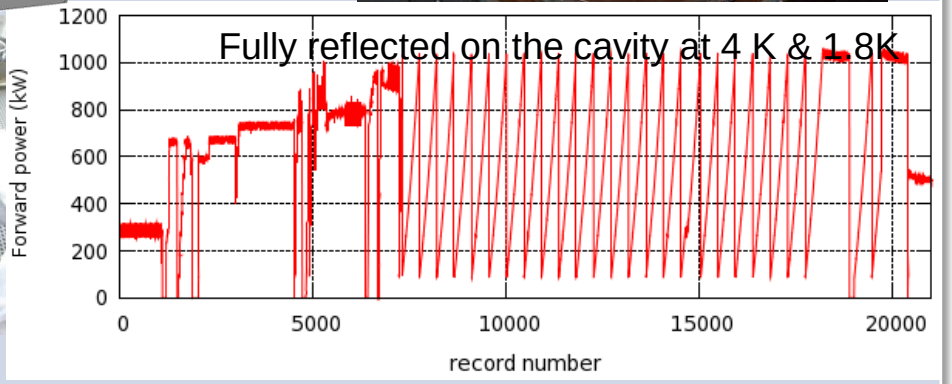








TW conditioning up to 1.2 MW 10%DC



Current activities:

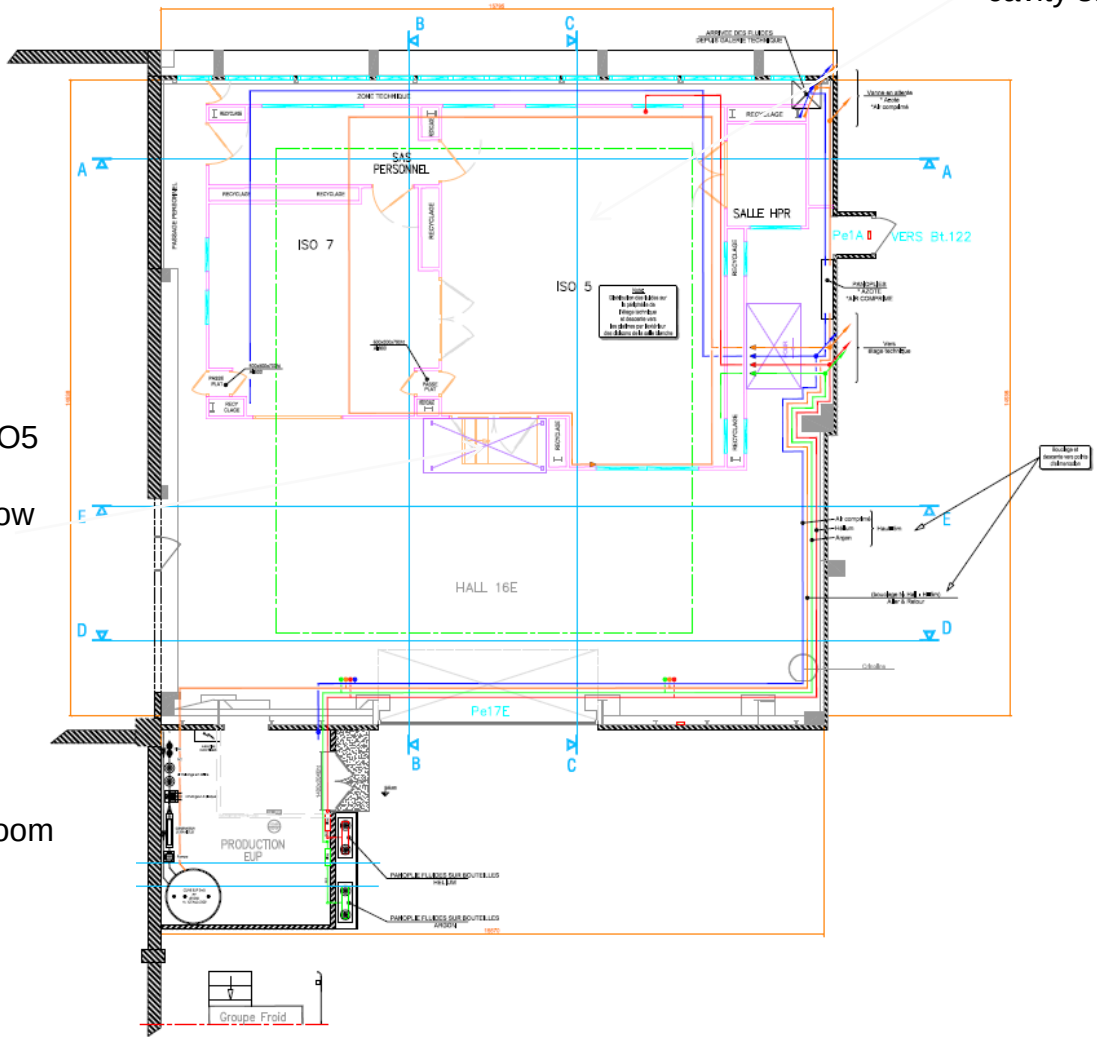
- Evaluation of maximum admissible peak power of Saclay HIPPI power coupler in SW and TW regime
- Study of antenna HV biasing started
- Starting thermo-mechanical calculations for air cooling assessment (tested up to 25kW average full reflection in horizontal cryostat)

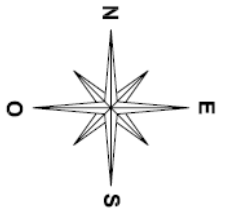
New clean room at CEA/Saclay

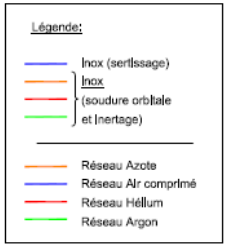
ISO5 fits a 4-ESS cavity string

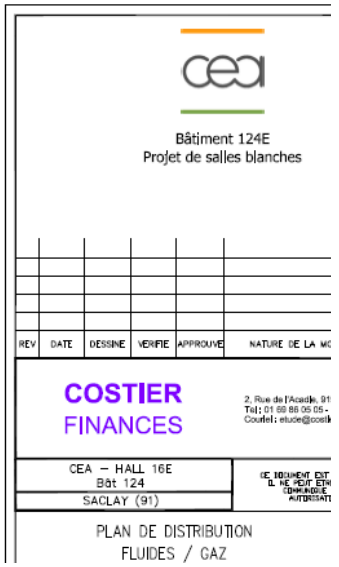
Direct exit from ISO5 protected with external laminar flow

XFEL cleanroom

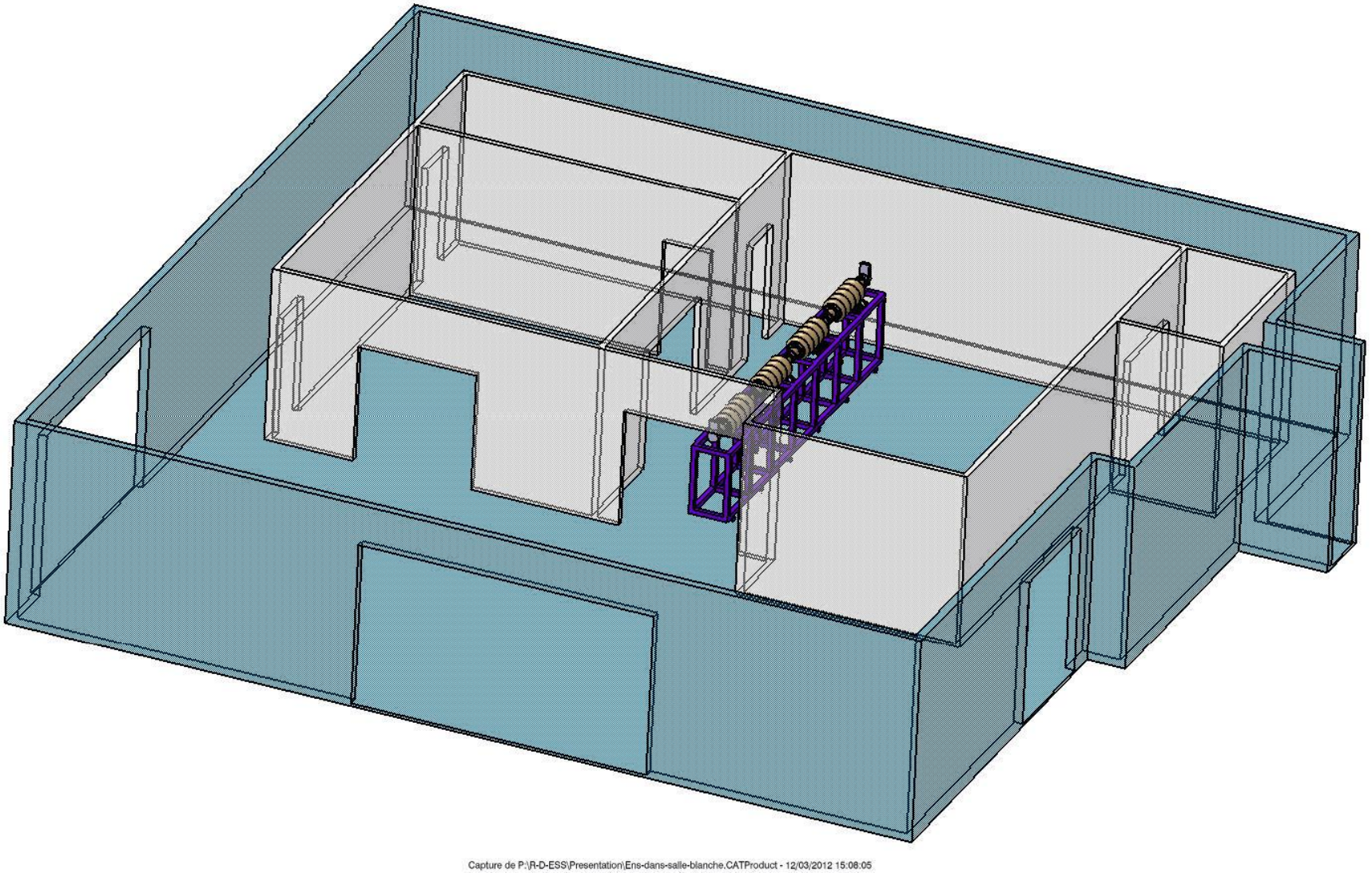








Irfu Artist view of the new clean room with ESS cavity string



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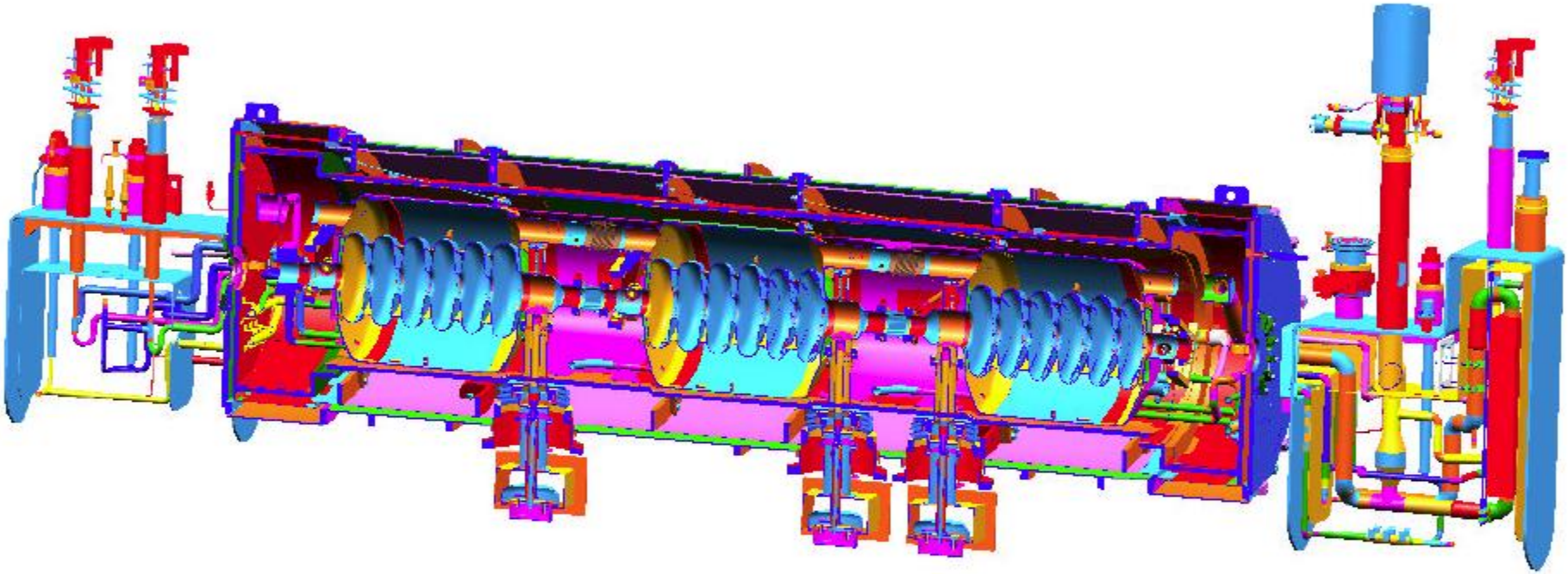
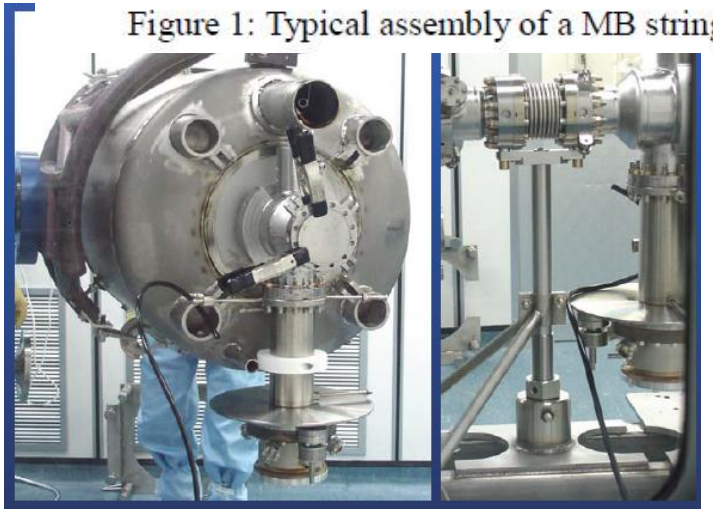
SNS Medium Beta Cryomodule (β=0.61)



Assembly process SNS/Cebaf

SNS cavity string assembly in JLab clean room



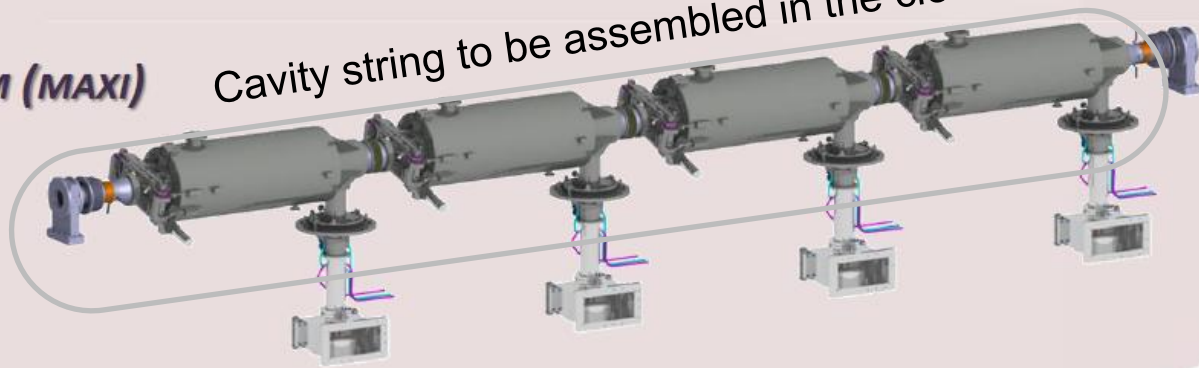
ASSEMBLY LENGTH

4 CAVITIES WITH WARM VALVES

- DN100 VALVE = 85MM
- C/W TRANSITION = 300MM (MAXI)
- BELLOWS= 150MM
- CAVITY = 1317MM (MAXI)

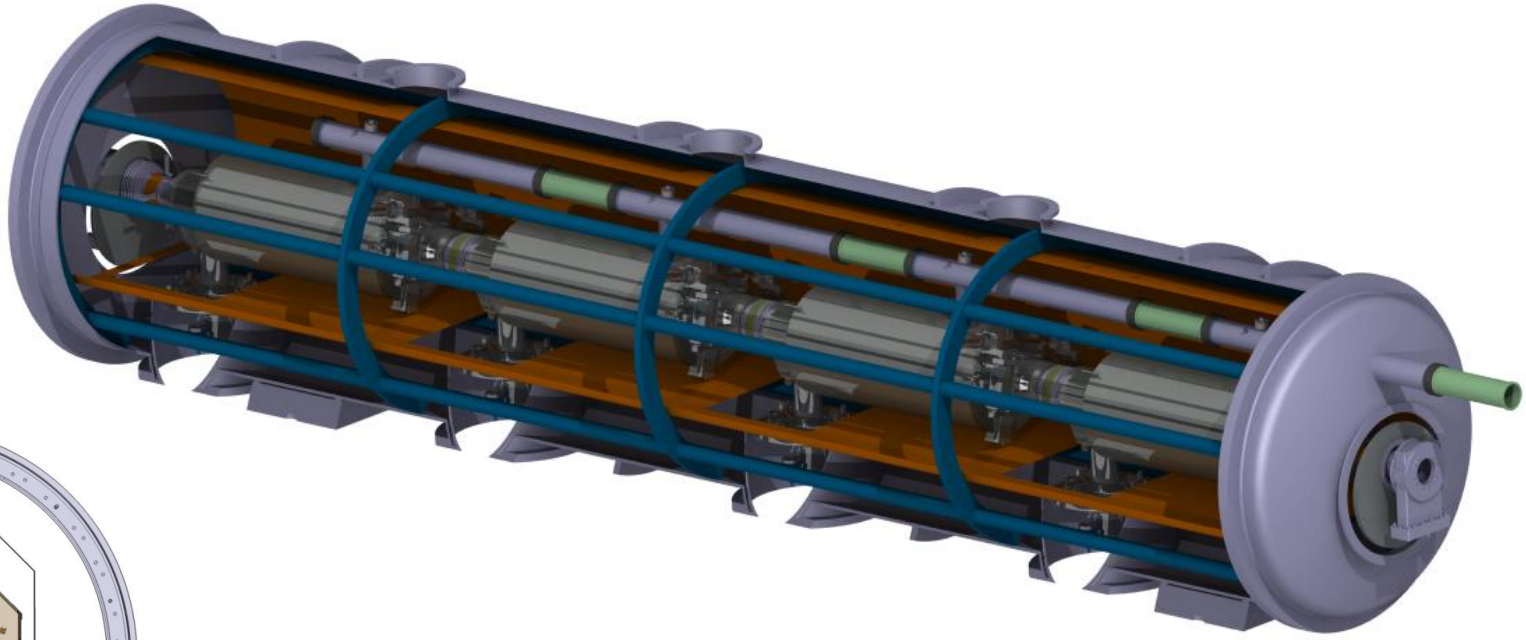
(G. Olivier)

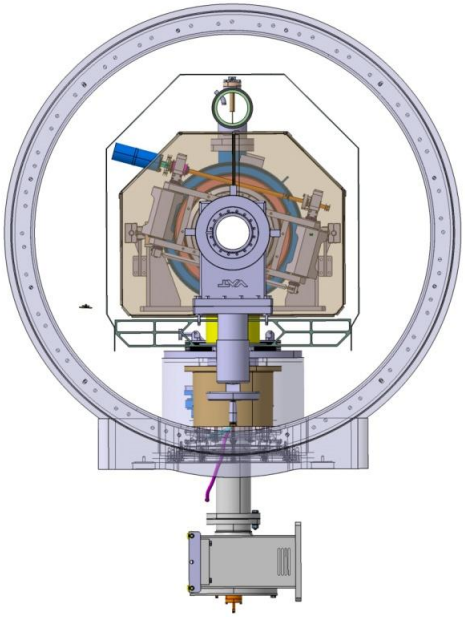
Cavity string to be assembled in the clean room



High beta elliptical cryomodule

ESS high beta cryomodule could be based on an SNS cryomodule topology





(S. Bousson)

LIST OF Proposed WORKPACKAGES for IKC

1. **ESS LINAC front End :**
   - Full responsibility of RFQ with RF power test
   - Option : functional test of ESS front end at Saclay (with partly existing infrastructures)

2. **High Beta cavity cryomodules:**
   - Full responsibility of design , components and test of the components
   - Full responsibility of integration at Saclay site

3. **Option** : contribution to **Medium Beta cavity cryomodules** in the frame of an international collaboration leaded by ESS

4. **Option**: other contributions in CC, LLRF electronics, mechanical design and beam dynamics **=> TO BE DISCUSSED**

CONCLUSIONS

- The IKC working group and steering group have been created/
- The IKC working group has a clear roadmap
- Open Issues have to be discussed :Strategy for front end test & collaboration on Medium Beta Cryomodules.
- RISK ANALYSIS has to be prepared based on XFEL example and according to ESS standards
- Next step ?