DE LA RECHERCHE À L'INDUSTRIE

www.cea.fr

PROGRESS AND STATUS ON ESS MEDIUM BETA PROTOTYPE CAVITIES AT CEA

E. Cenni *on behalf of cavities work unit*

7th SLHiPP meeting Orsay 2017

OUTLINE

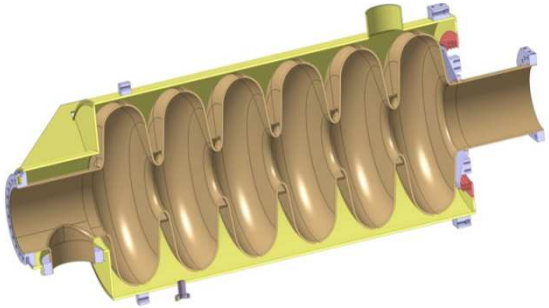
- **Manufacturing and preparation**
  - Shape control
  - RF measure
  - Heat treatment
  - Final BCP
- **Latest results**
  - Surface resistance
  - Q-E curves
  - X-ray measures
  - 100K parking
  - LFD
  - Tuning sensitivity
  - Magnetic shielding
- **Cavities status**
- **Lessons learned**
- **Summary and outlook**

MEDIUM BETA PROTOTYPES AT CEA

DESIGN

MANUFACTURING

PREPARATION AND TEST

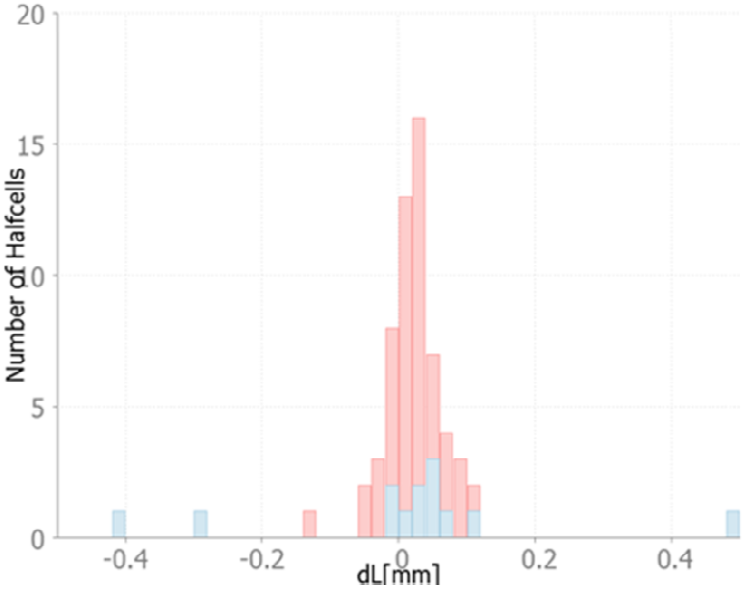


M-ECCTD will be equipped with 3 cavities from CEA and 1 cavity from INFN-LASA

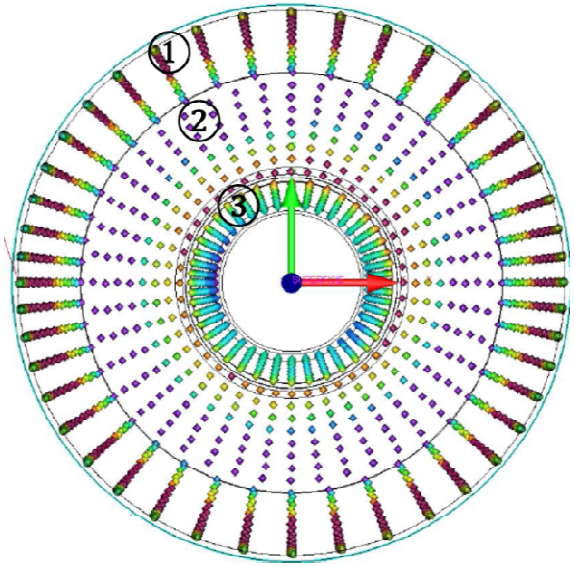
This talk will be about the work done in CEA concerning medium beta prototypes

Manufacturing

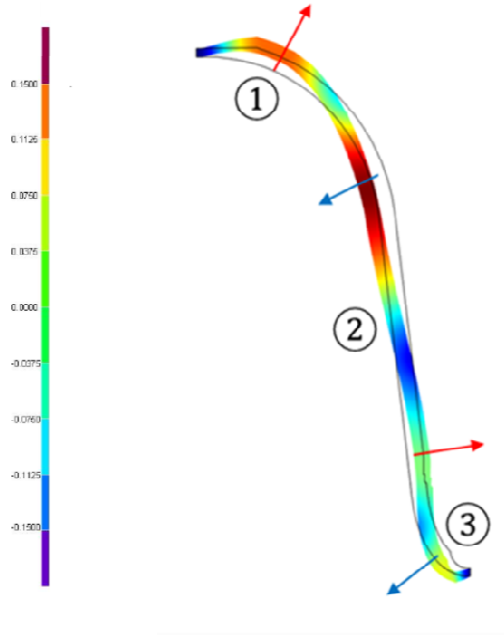
MANUFACTURING (SHAPE CONTROL)



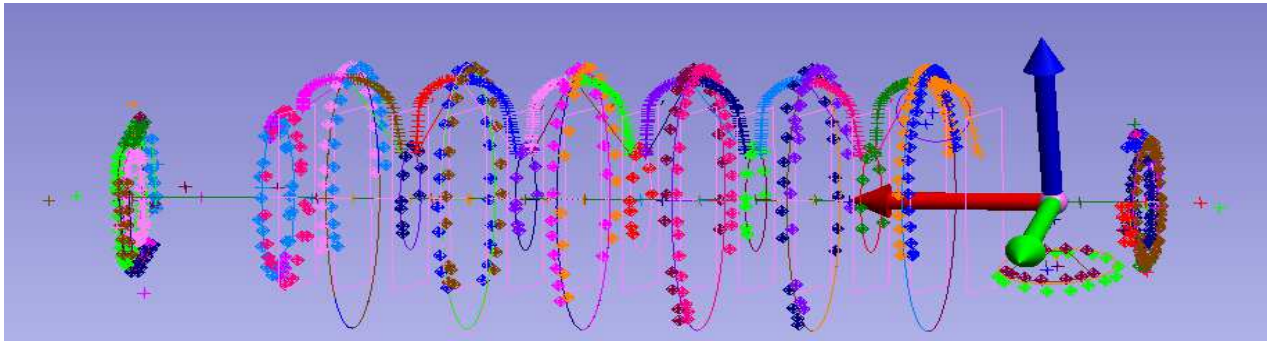
Length difference between ideal and measured values on central group (red) and end group (blue) halfcells, each bin has 0.02mm width.



3D CMM result on a central half cell, red +0.15mm, purple -0.15mm (shape tolerance 0.3).

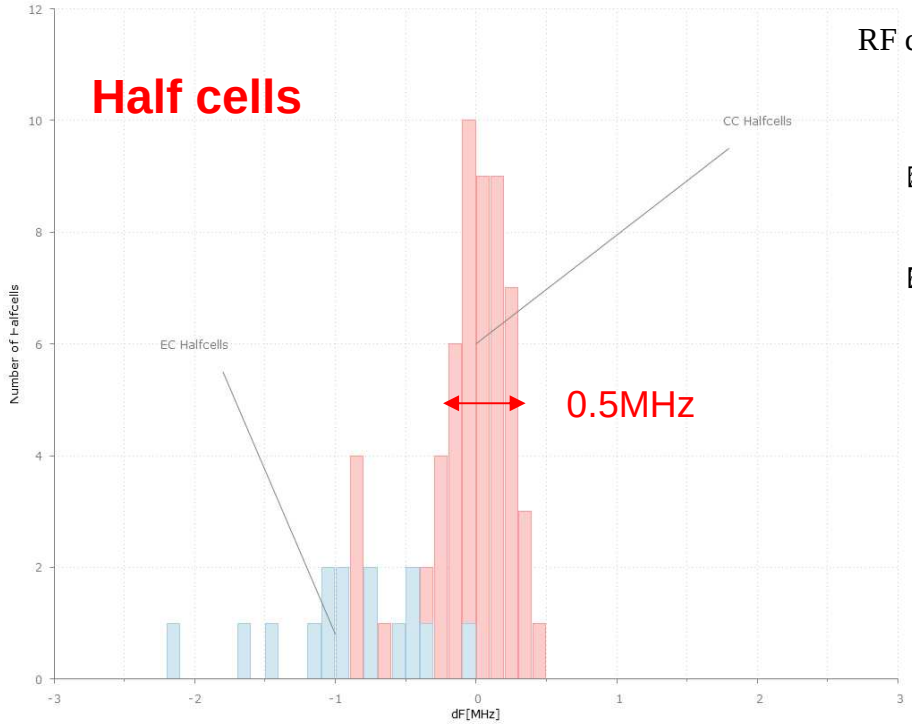


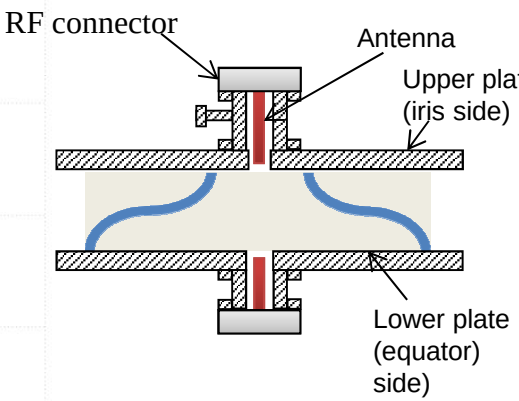
Sketch of average deformation observed on central half cell <u>not in scale.</u>

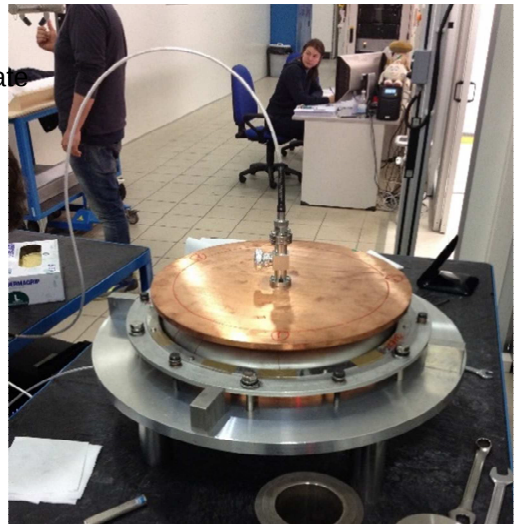


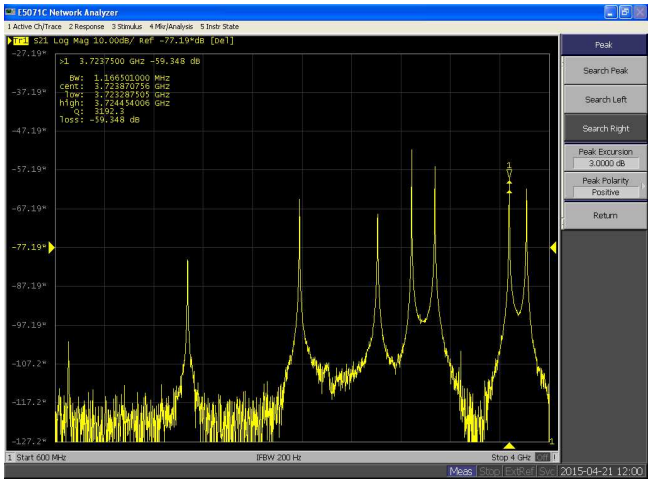
Laser tracking 3D measure performed at CEA

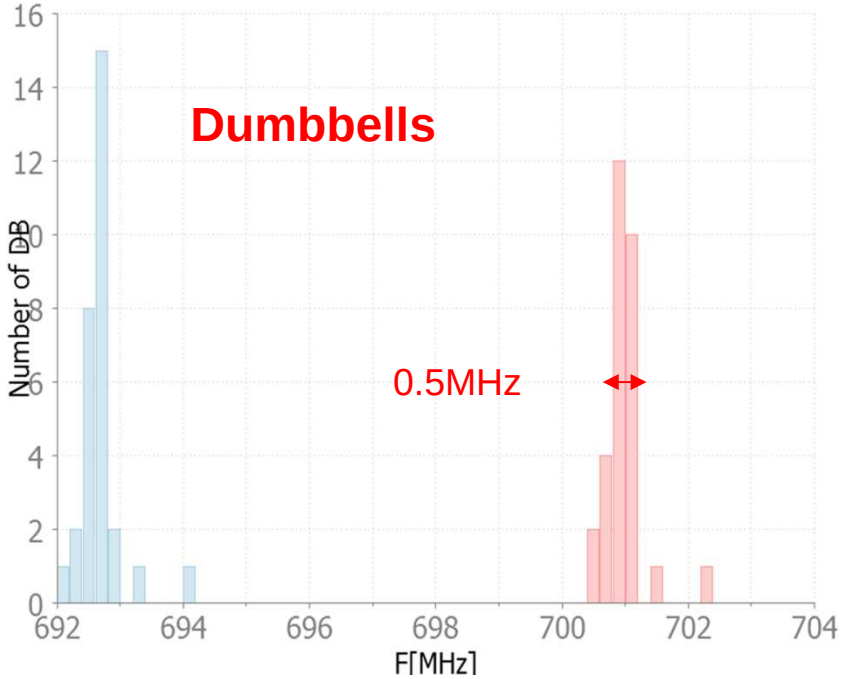
MANUFACTURING (RF MEASURES)











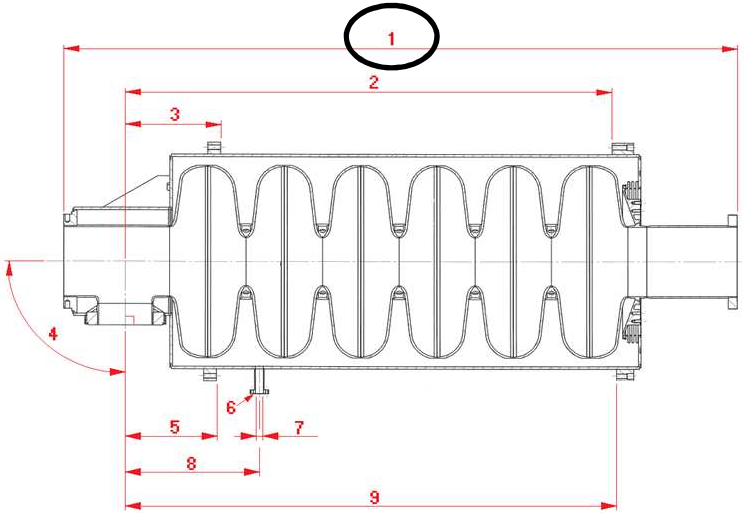
MANUFACTURING (INTEGRATED CAVITY)

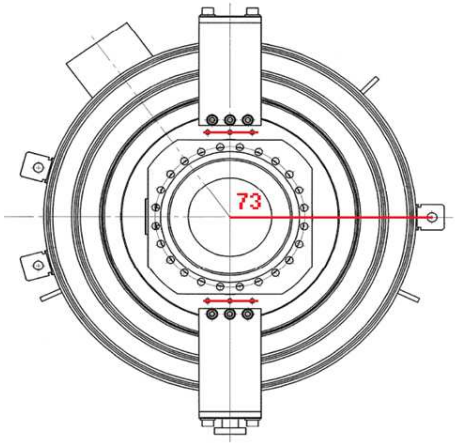
We have created a dimension control plan on each subparts

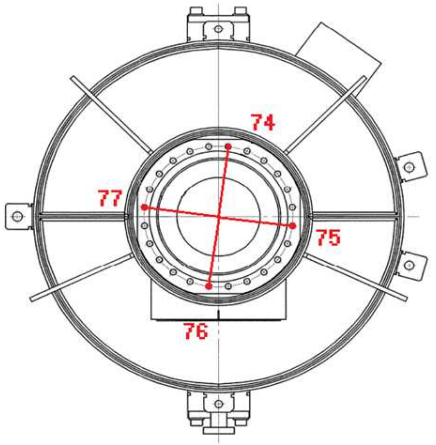
- 300 points on each halfcells and dumbbells by means of CMM
- On the integrated cavity we put about 80 dimensional controls (this will be optimized after string assembly feedback)

Some number related to the first 4 integrated cavities:

- Maximum displacement between beam flanges 1mm (average is 0.6mm)
- Maximum angular displacement 0.5° (average is 0.2°)



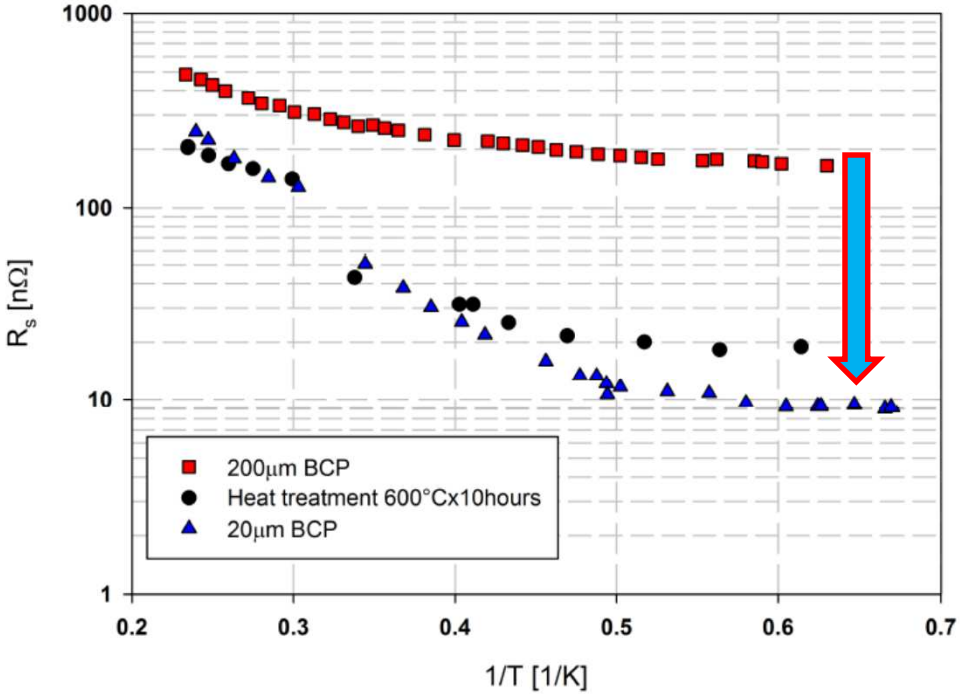


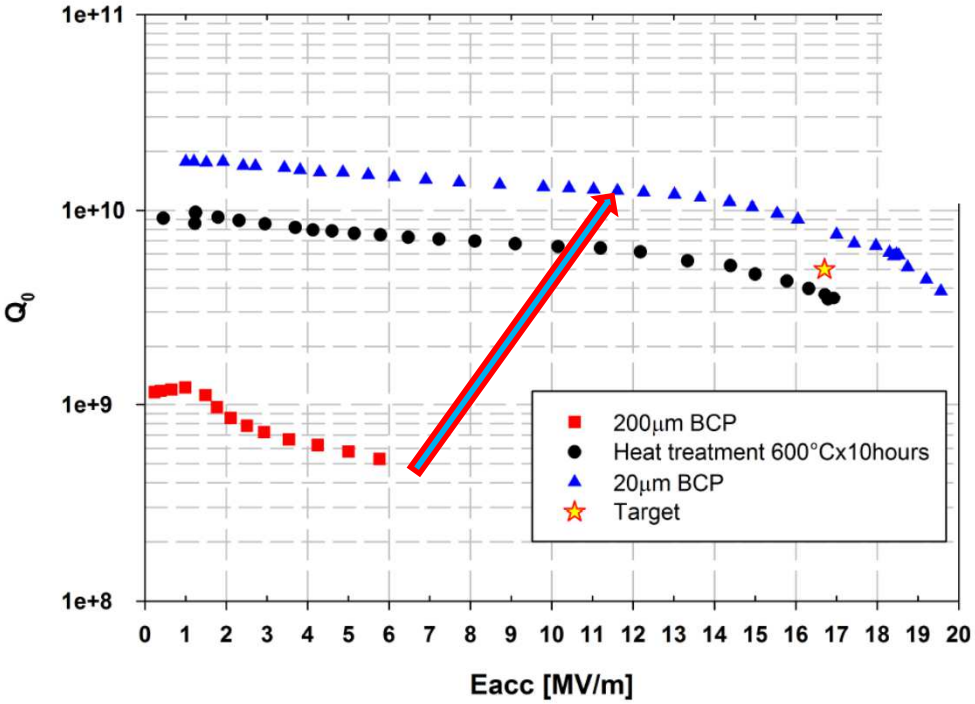


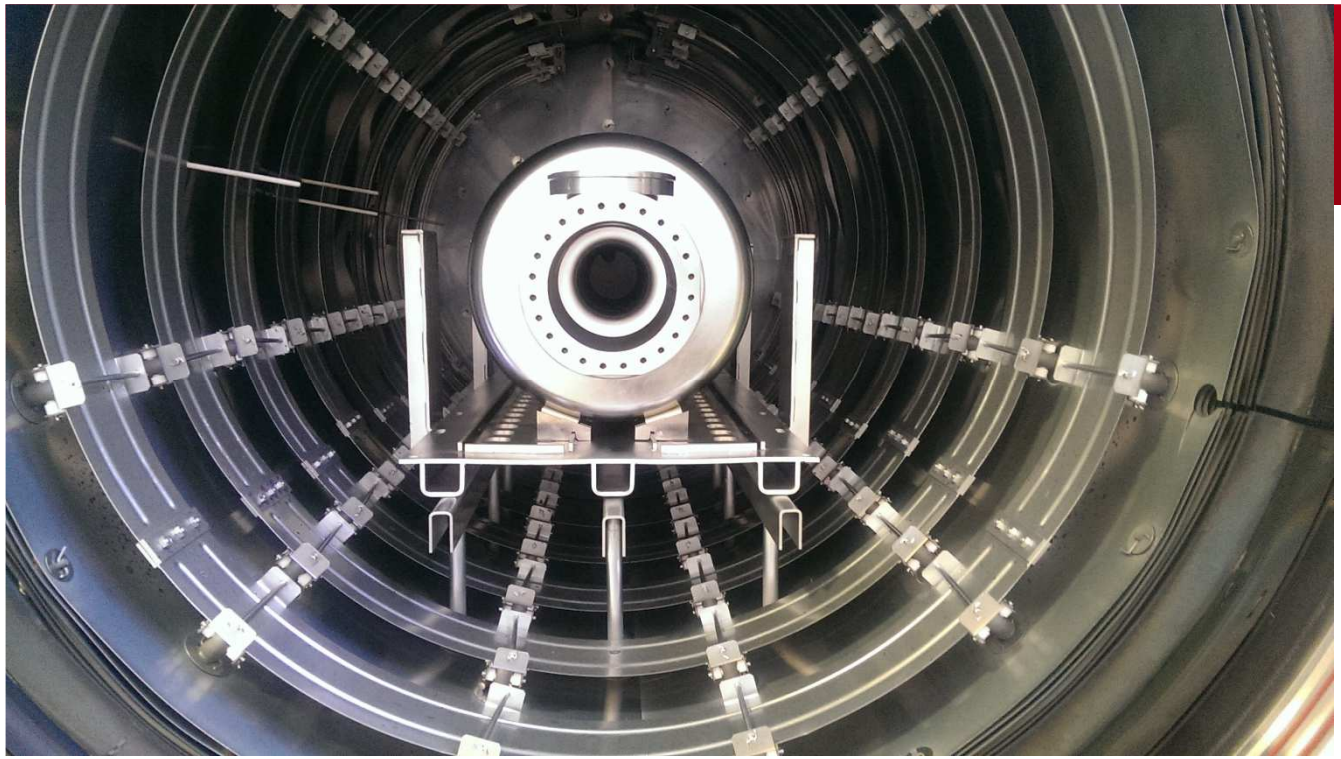
Measures and results

FIRST RESULTS

Process	Rs @2K [nΩ]
BCP (~200µm)	~200
Heat treatment+HPR	~20
BCP(~20µm)+HPR	~10

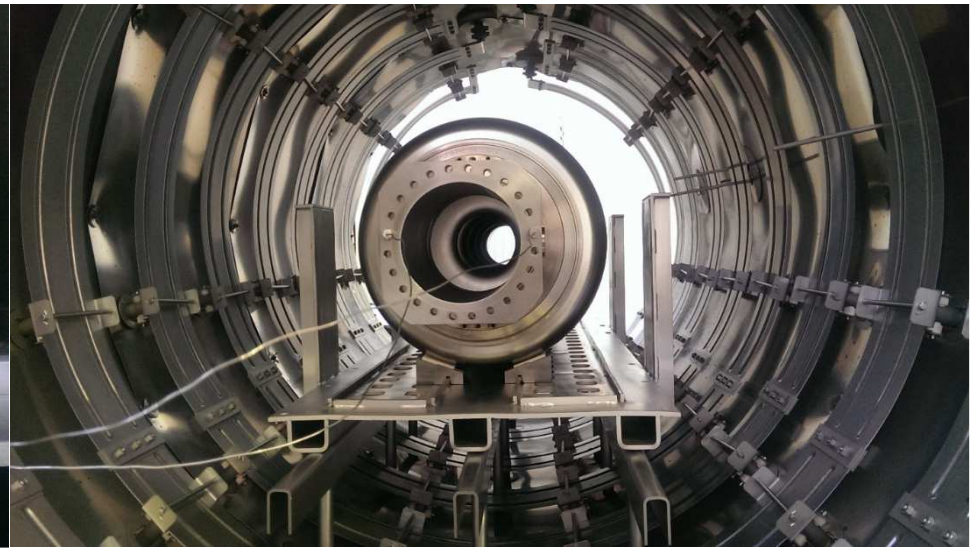


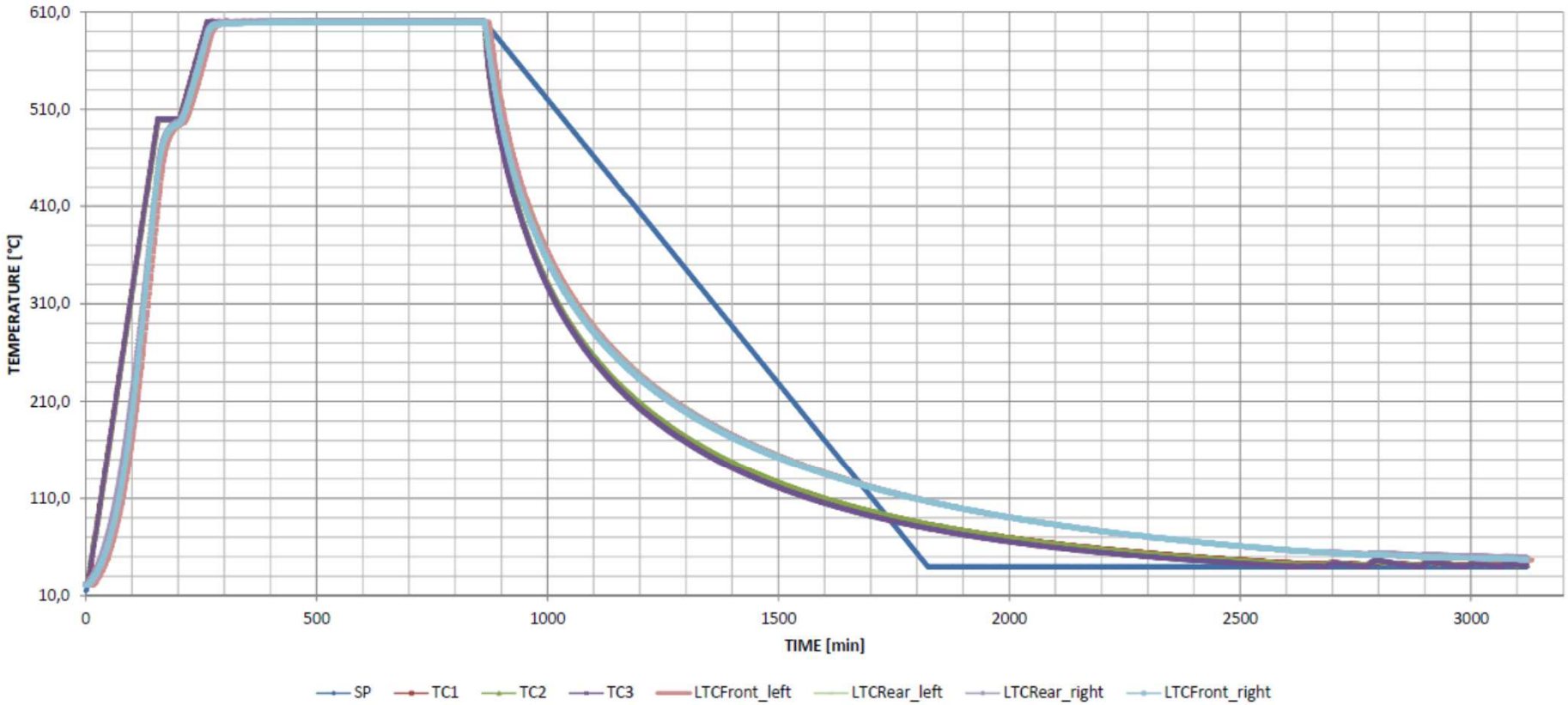




Zanon

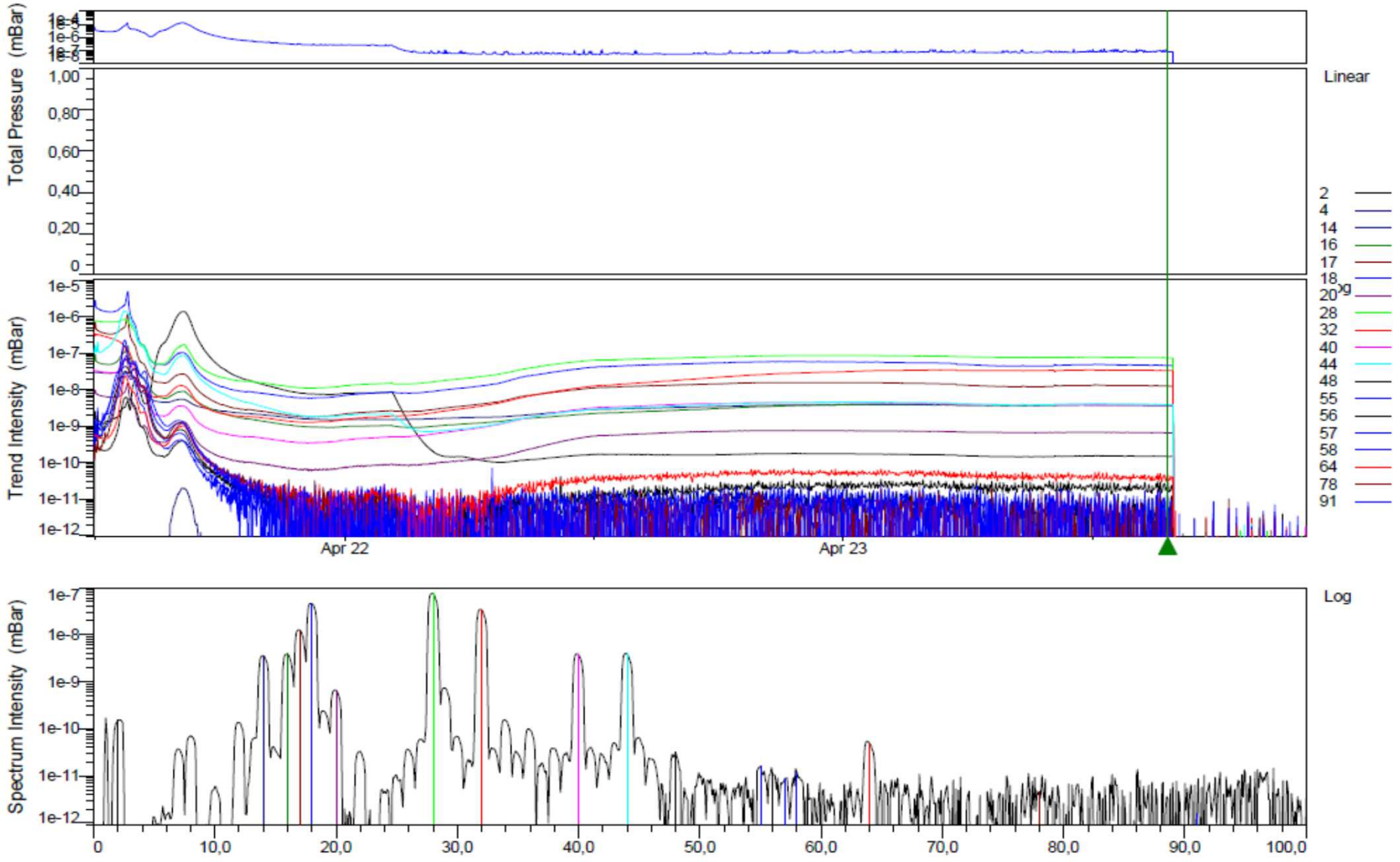
First shield and heating system made with Molybdenum. Same oven used for XFEL and LCLS2




2016_04_26 CAV01_EZ_ESS_MR_temperature
TEMPERATURE [°C]
610,0
510,0
410,0
310,0
210,0
110,0
10,0
0
500
1000
1500
2000
2500
3000
TIME [min]
SP
TC1
TC2
TC3
LTCFront_left
LTCRear_left
LTCRear_right
LTCFront_right

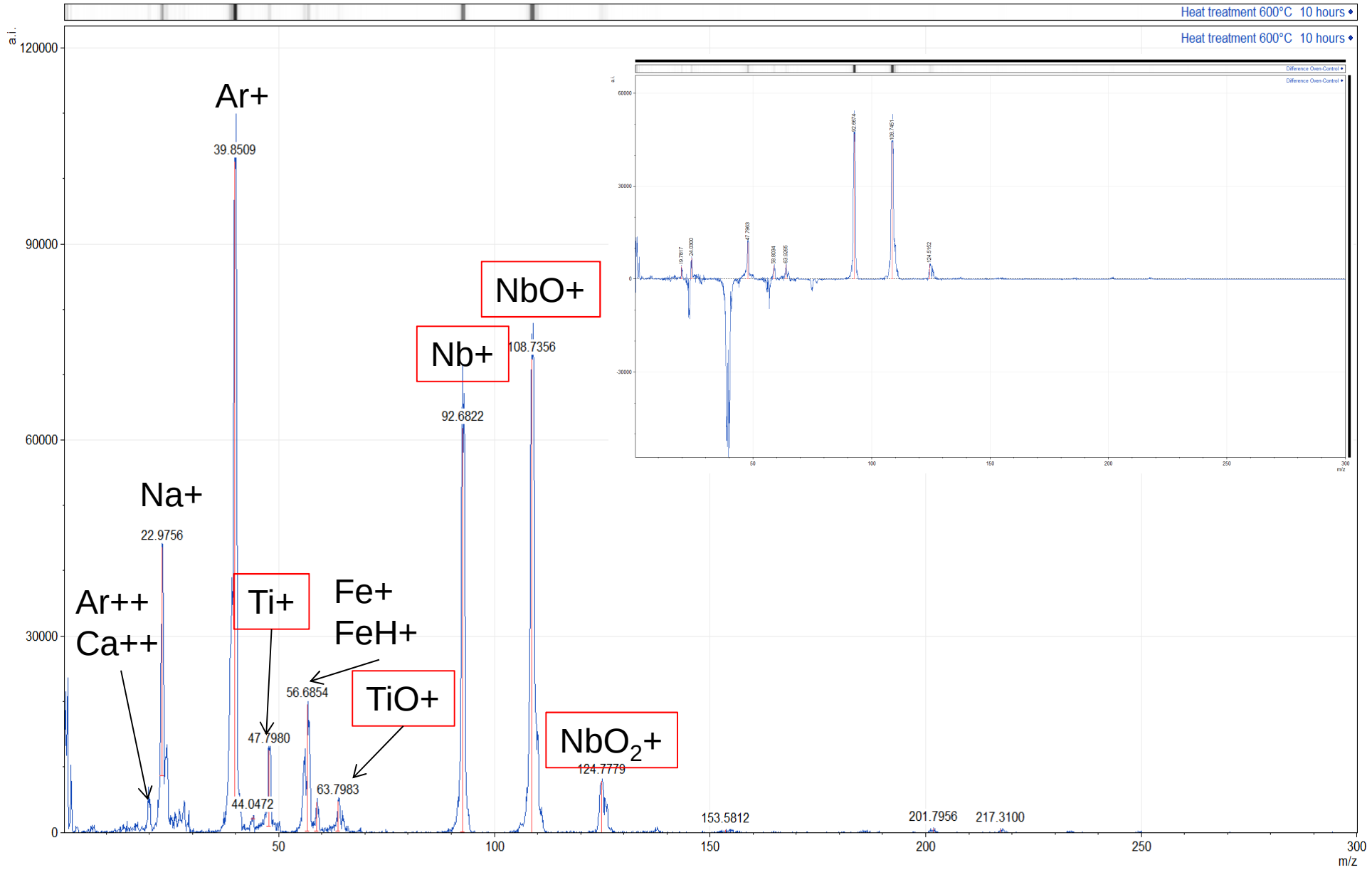
RGA

Zanon


Total Pressure (mBar)
1,00
0,80
0,60
0,40
0,20
0
Linear
Trend Intensity (mBar)
1e-5
1e-6
1e-7
1e-8
1e-9
1e-10
1e-11
1e-12
Apr 22
Apr 23
2
4
14
16
17
18
20
28
32
40
44
48
55
56
57
58
64
78
91
Spectrum Intensity (mBar)
1e-7
1e-8
1e-9
1e-10
1e-11
1e-12
Log
0
10,0
20,0
30,0
40,0
50,0
60,0
70,0
80,0
90,0
100,0

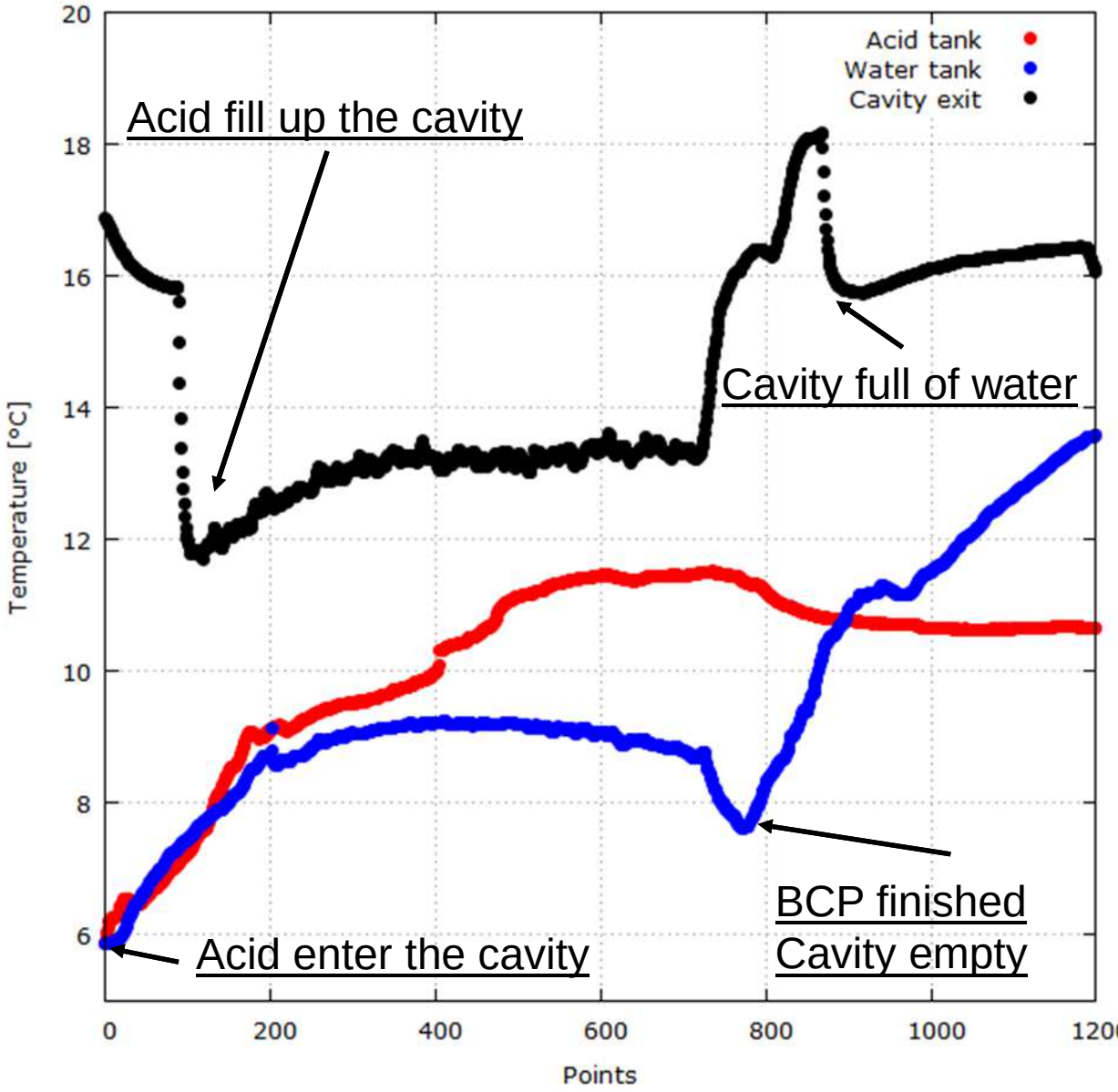
SIMS ANALYSIS (ARGON BEAM)

D. LONGUEVERGNE
IPNO



BCP WITH HELIUM TANK AND WATER COOLING

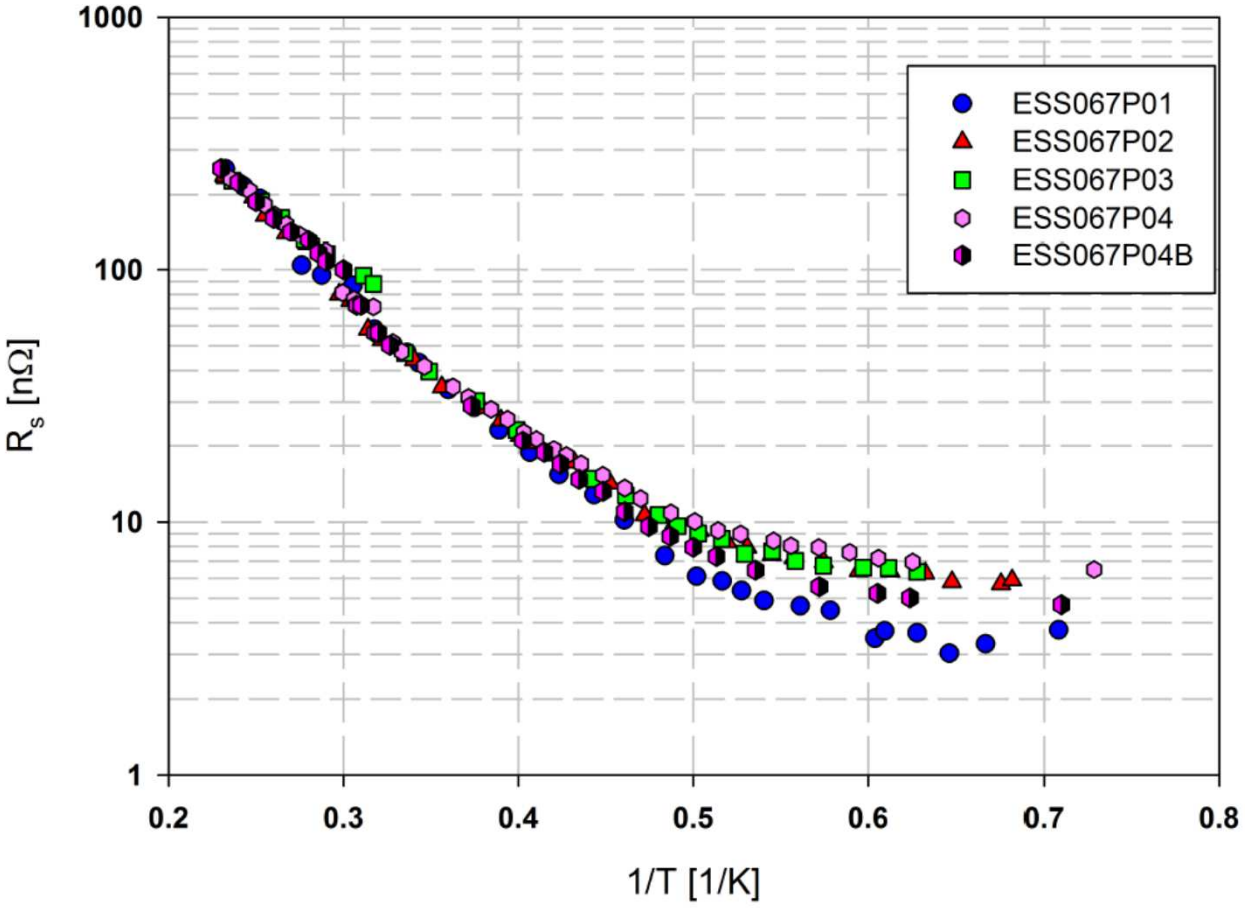
X. Hanus
C. Servouin
F. Eozenou
Y. Boudigou,
G. Monnereau
CEA - Saclay



We are able to limit the temperature increase during BCP.

LATEST RESULTS (RS)

D. Roudier
L. Maurice



We were able to obtain good surface resistance on all cavities.
BCP process has been strongly improved

Data fitted with

$$R_S = \frac{A}{T} \times e^{-\frac{\Delta}{T}} + R_0$$

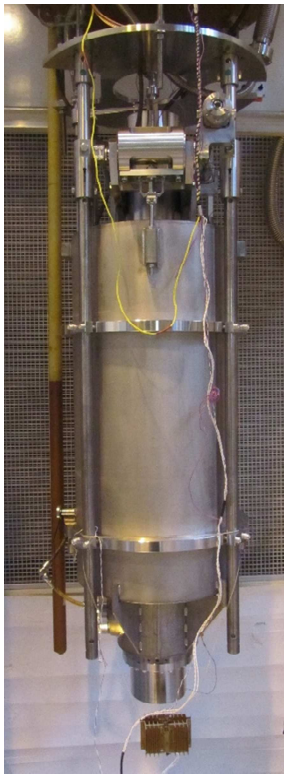
Cavity serial number	Residual resistance (R_0) [nΩ]	Q0 at 1MV/m @2K
MP01	3.14	3.2×10^{10}
MP02	6.09	2.2×10^{10}
MP03	6.06	2.1×10^{10}
MP04	7.09	1.9×10^{10}
MP04 (b)	4.85	2.5×10^{10}

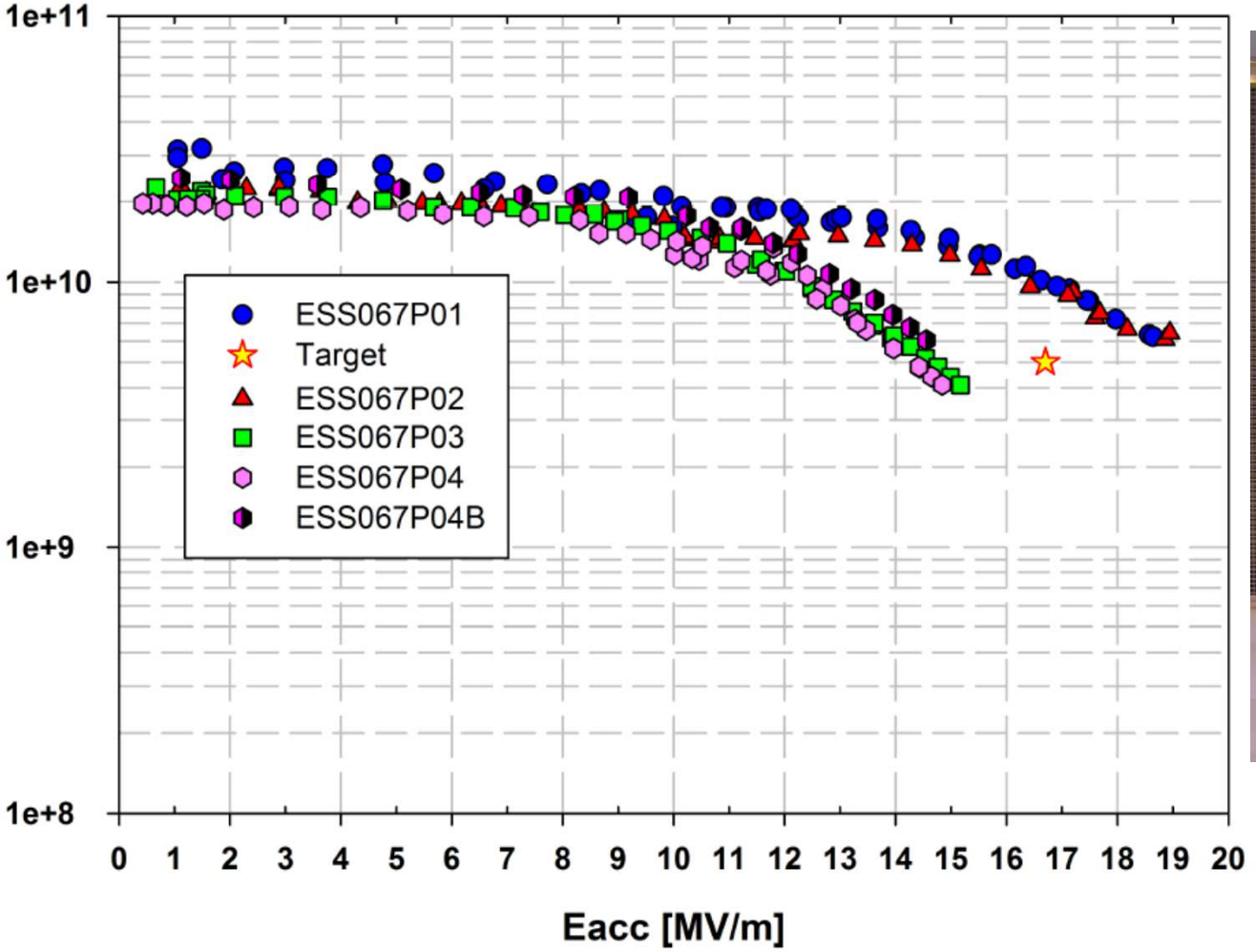
Q_0(2K) at low field is ≥ 1.9×10^{10} for all cavities

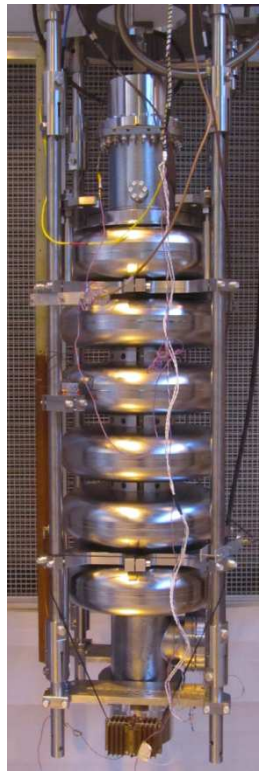
LATEST RESULTS (Q-E)

D. Roudier
L. Maurice

Vertical test ESS medium beta prototypes with tank
(CW mode @2K)

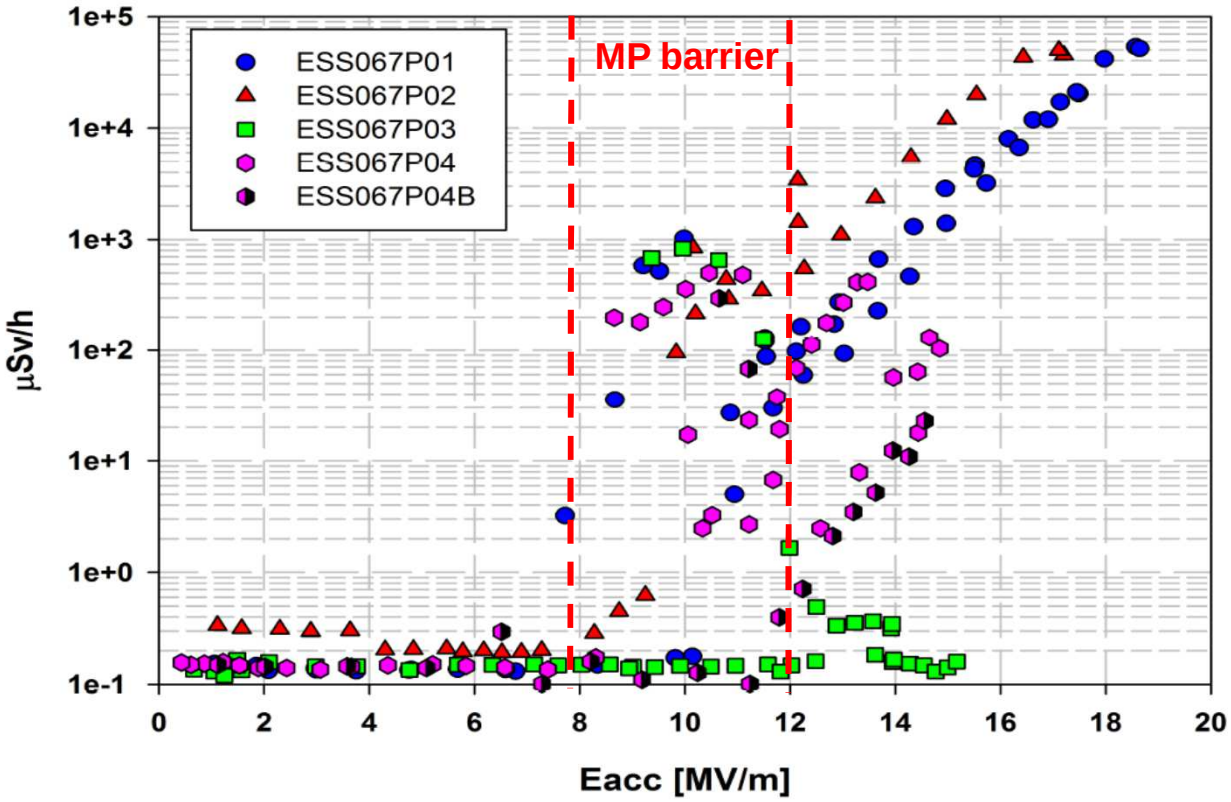


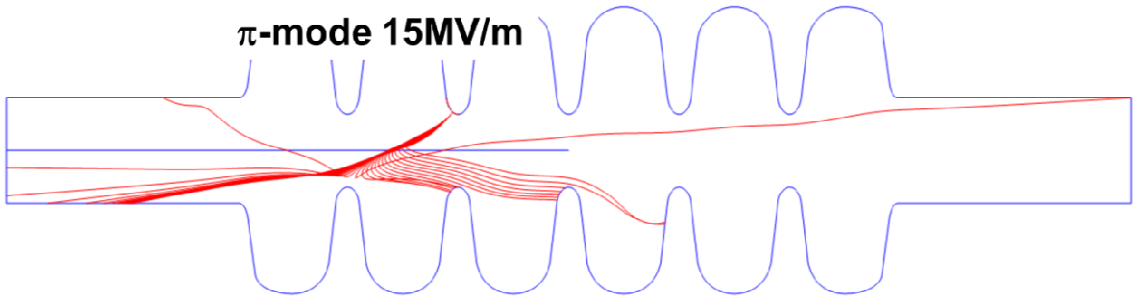




X-RAYS (FIELD EMISSION)

D. Roudier
L. Maurice





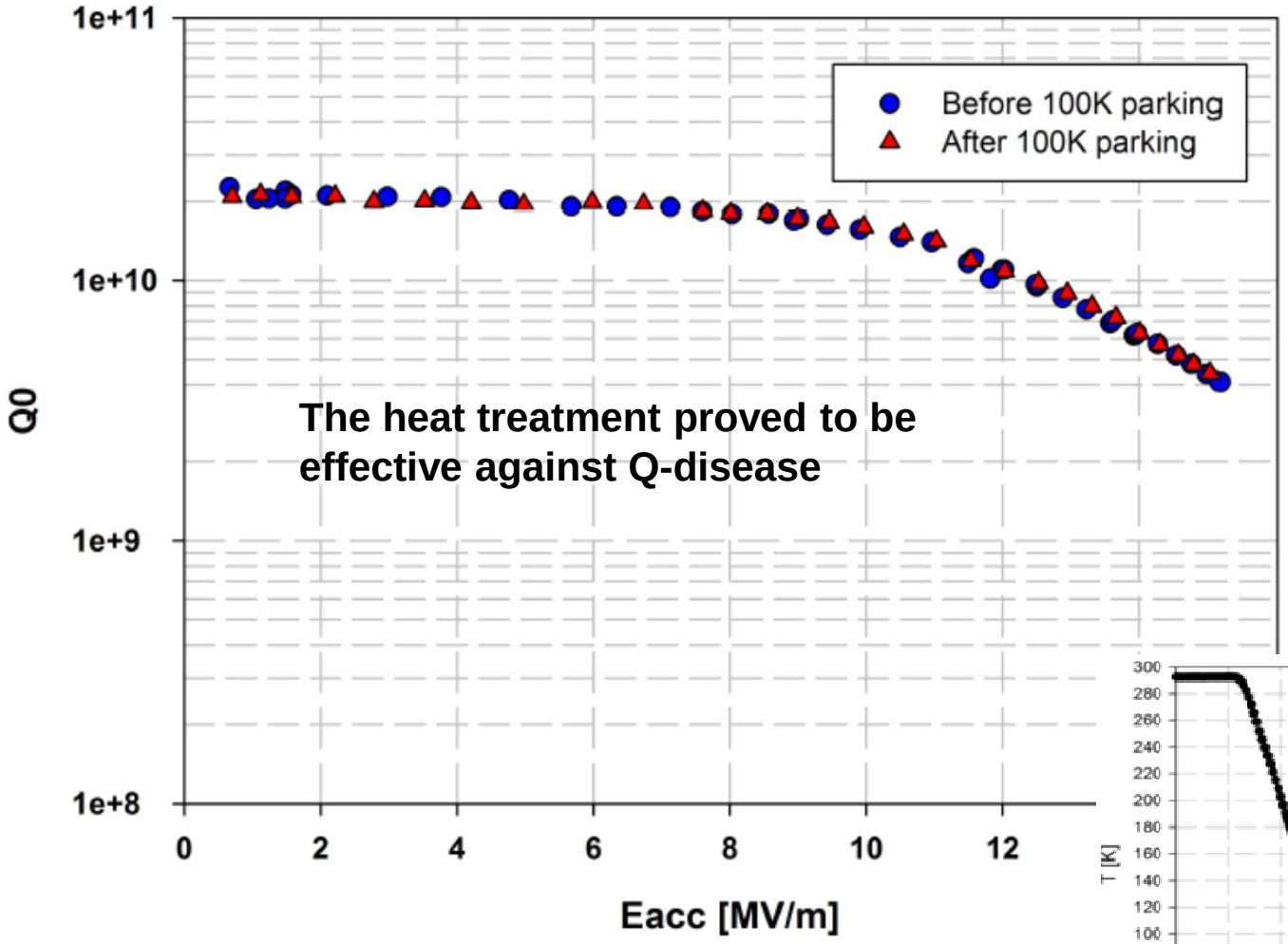
NaI(Tl) scintillator

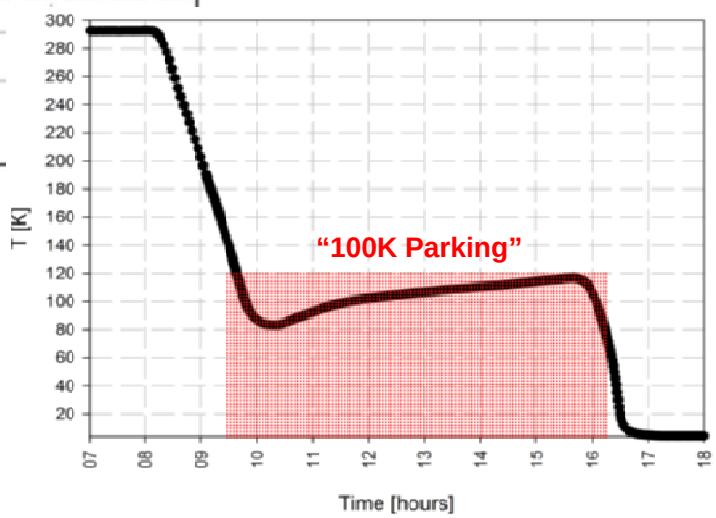
We plan to implement systematic x-ray spectra recording on vertical cryostat and cryomodule.

Cavity serial number	X-ray dose rate at ~15MV/m (π-mode) [mSv/h]
MP01	2.8
MP02	18.6
MP03	0.0002 (background)
MP04	0.1
MP04 (b)	0.022

100K EFFECT

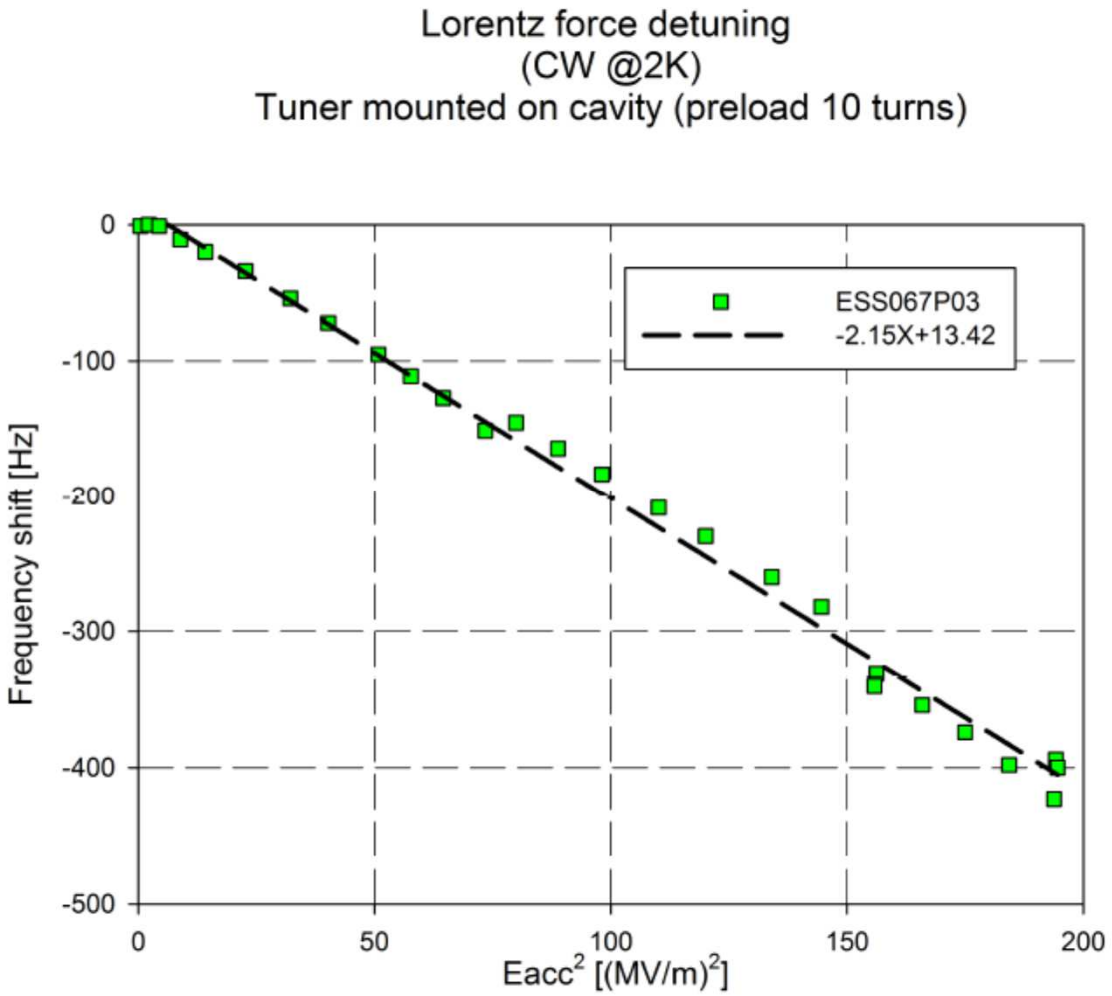
D. Roudier
L. Maurice
P. Sahuquet



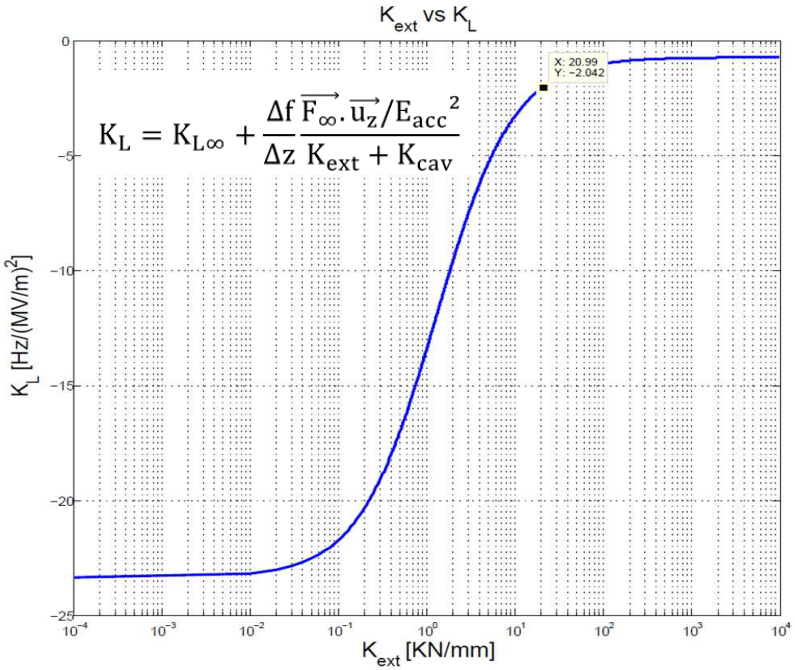


LORENTZ FORCE DETUNING

D. Roudier
L. Maurice
G. Devanz



The measure is consistent with calculation



TUNING SENSITIVITY

D. Roudier
E. Jacques

Passband mode frequencies in vacuum while moving the tuner

Blue 10 turns pull (~1mm)

Orange 0 turn (blocked before pumping)

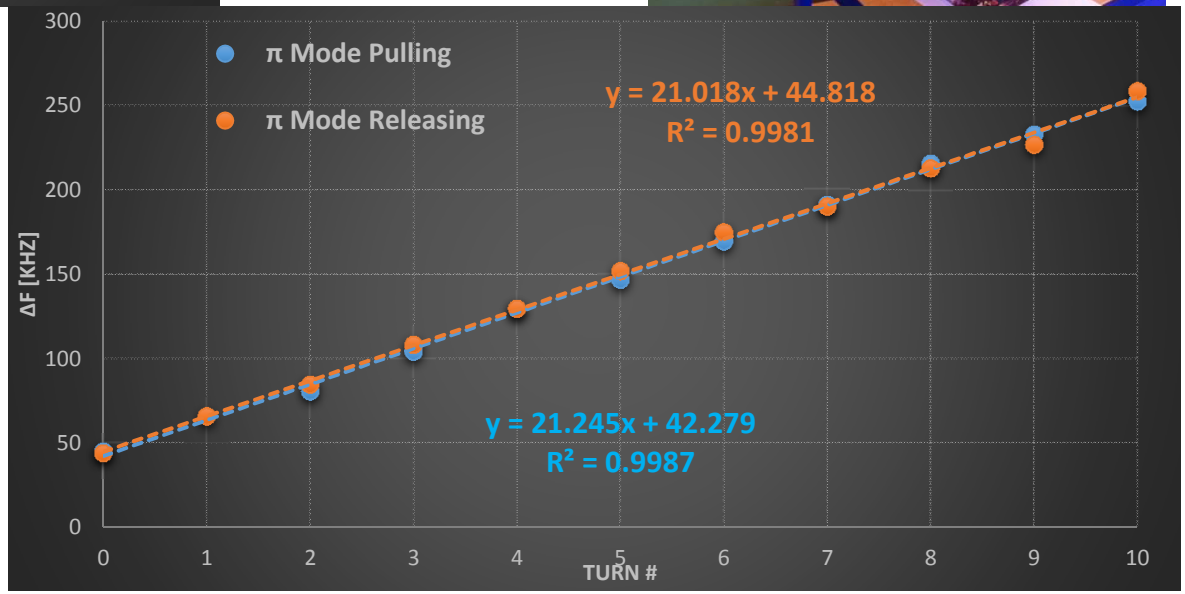
Tuning sensitivity:

Pulling

Releasing

No backlash

Computation predict 211kHz/mm measured value is between 210-212 kHz/mm

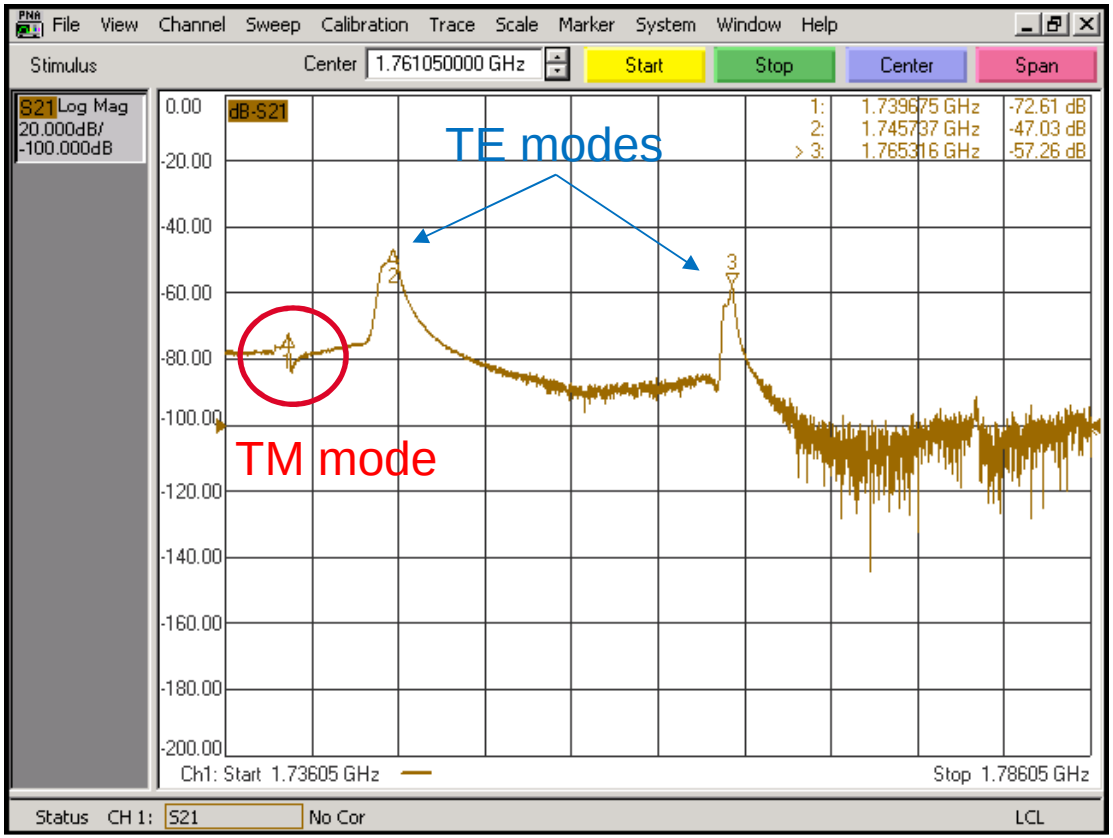


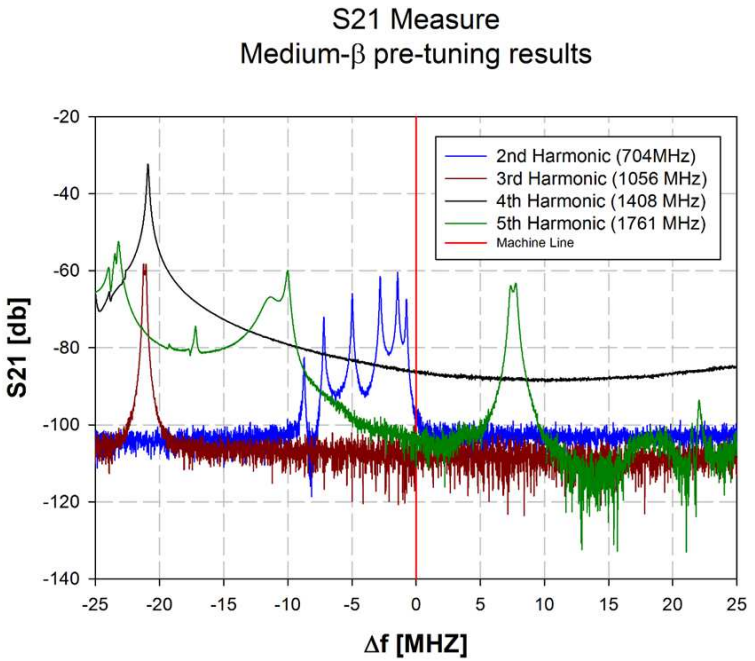
FF AND HOMS

D. Roudier

Cavity Field flatness are consistently brought to 95%, heat treatment and tank integration can change the field flatness about 1-2% depending on the accumulated stress on the cavity.

HOMs are monitored during manufacturing and they are away from machine lines as designed (typically more than 20MHz)

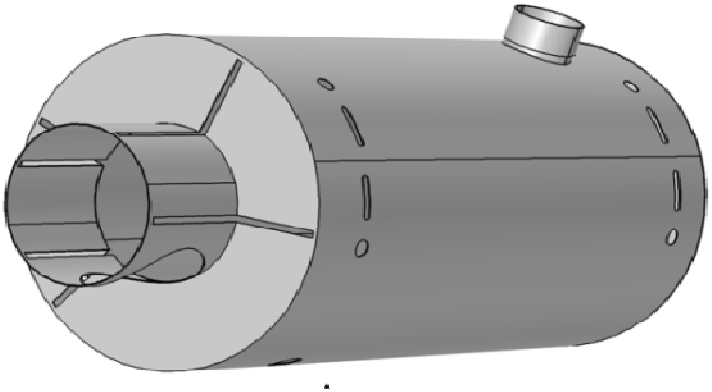




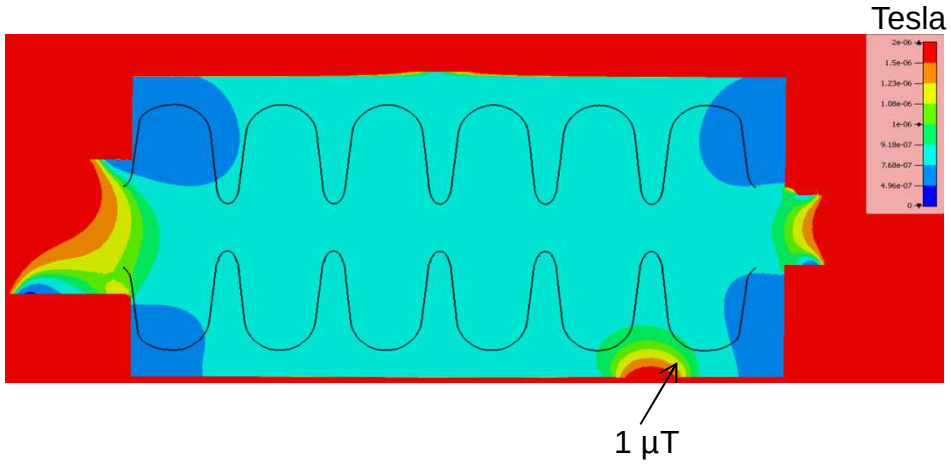
Note: each BCP moves the dangerous TM mode more away from machine line

MAGNETIC SHIELDING DESIGN

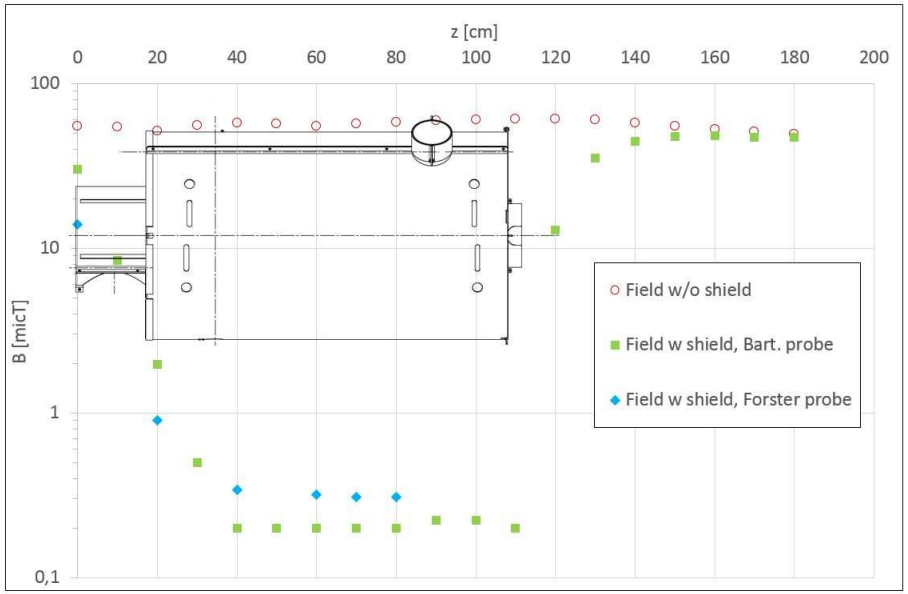
J. Plouin



Requirements: maximal field around cavity < 2 µT



Field is lower than 1 µT inside the shield, and mainly around 0,5 µT
We are confident for a value <2 µT at cold temperature



CAVITIES STATUS

Cavities	Status	Details
MP01	Assembled on the string	
MP02	Assembled on the string	
MP03	Assembled on the string	
MP04	Equipped with tank	R&D
MP05	Naked	R&D
MP06	Naked 200µm BCP performed at Zanon	R&D

LESSONS LEARNED AND OUTLOOK

- ✓ Manufacturing process looks to be reproducible and reliable (learning curve shall be took into account), still there is space for improvement
- ✓ BCP temperature shall be monitored, water cooling proof to be effective with integrated cavity (recently we were able to obtain very low Rs)
- ✓ Frequency change rate with BCP is about 2.9kHz/µm and the average etching rate is about 1µm/min with 1:1:2.4 mix (FNP), in good agreement with simulation
- ✓ Heat treatment at 600°C for 10 hours works fine (no Q-disease has been observed)

SUMMARY AND OUTLOOK

•We have successfully manufactured 6 medium cavities, 4 of them are now equipped with helium tank.

•Three cavities have been successfully assembled with power couplers, they are assembled on the string.

•For P01 and P02 Q-E curves are above specifications even with field emission.

•P03 has not reached ESS specification but is field emission.

•P04 also shows field emission, we are currently working on HPR and clean room operation.

We keep working on the remaining prototypes in order to have the best recipe for cavity series and *High beta cryomodule demonstrator*

THANK YOU FOR YOUR ATTENTION

Thanks to: D. Roudier, L. Maurice, X. Hanus, F. Peauger, P. Bosland, C. Madec, F. Eozenou, C. Servouin, Y. Boudigou, G. Monnereau, E. Jacques, J-P. Charrier, P. Sahuquet, P.Carbonnier, J. Pluoin, G. Devanz.