

SCRF Cost Reduction R&D at CEA and IN2P3

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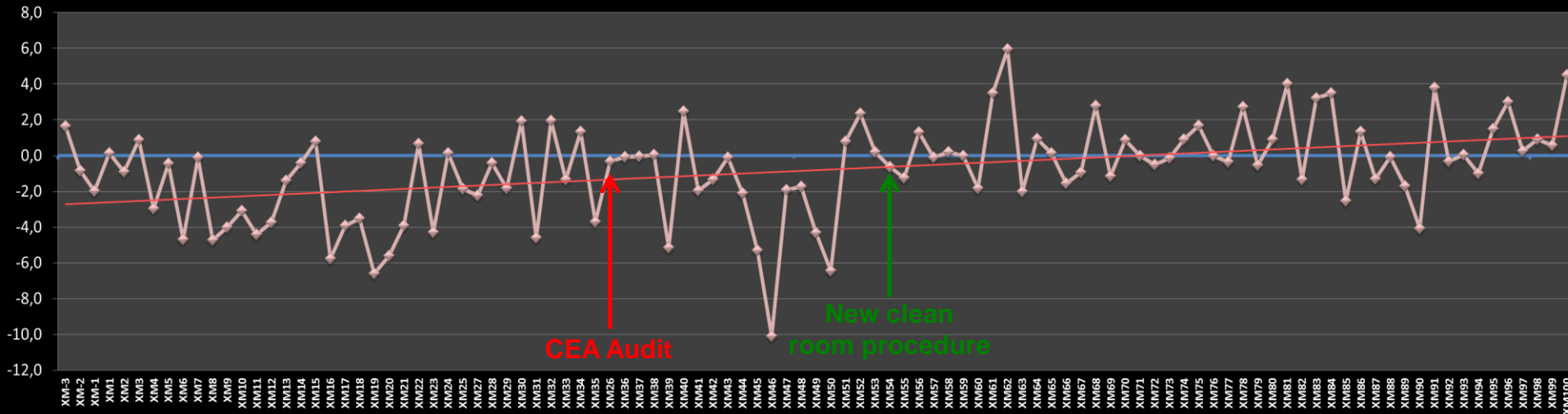
After the completion of the 103 E-XFEL modules assembly in July 2016, CEA is mostly involved in the construction of SRF linacs:

- IFMIF/LiPAC : one 8-HWR-cavity cryomodule (176 MHz)
- ESS : 30 medium and high beta cryomodules (704 MHz)
- SARAF : four 7-HWR-cavity cryomodules (176 MHz)

CEA is therefore naturally inclined to improve module assembly process w.r.t. quality, productivity and cost.

R&D programs need a new boost !

Average gradient gain (MT-VT, MV/m) for individual cavity RF distribution



1st sample of 34 series CM
 $\Delta E_{op} = -2.1$ MV/m

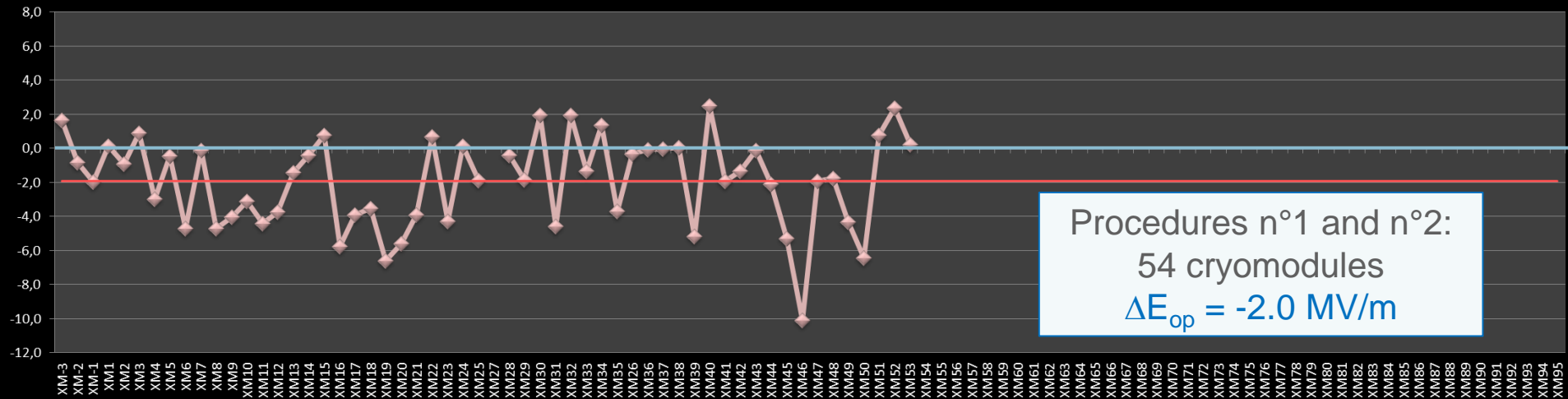
2nd sample of 19 series CM
 $\Delta E_{op} = -1.7$ (-0.9) MV/m

last 47 series CM
 $\Delta E_{op} = +0.5$ MV/m

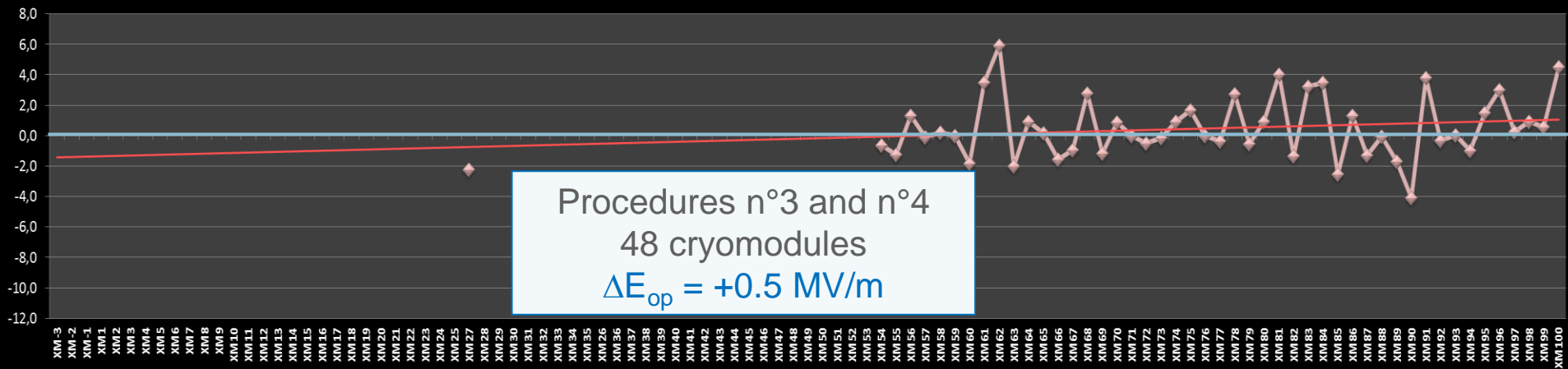
- Significant gradient degradation from XM6 to XM23, while CEA and Alsytom put all their effort in achieving production goal of 1 CM/week: **an audit of string and module assembly was conducted by CEA on XM26**
- A simplification of the clean room procedures was introduced at XM54: **no degradation after**

Cryomodule Performance: n°1-2 vs. n°3-4

Average gradient gain (HT-VT, MV/m) for individual cavity RF distribution



Average gradient gain (MT-VT, MV/m) for individual cavity RF distribution



Number of vacuum operations for a complete cryomodule assembly

| Procedure | n°1 | n°2 | n°3 | n°4 |
|-----------------------------------|-----|-----|-----|-----|
| # Angle valve to pipe connections | 20 | 22 | 14 | 14 |
| # Angle valve open/close cycles | 29 | 21 | 13 | 13 |
| # N2 blowing after an opening | 17 | 17 | 9 | 9 |
| # Leak checks | 48 | 40 | 32 | 23 |

Two assembly ‘parameters’ could be correlated to module results :

- 1) The clean room operator invasiveness
- 2) The vacuum operation invasiveness (mostly but not only in the clean room)

From E-XFEL experience, the cost of module assembly for ILC 500 GeV is in the ballpark of 200 M€, almost entirely in labour cost.

→ Automation and Robotization

- Once the vacuum groups are connected to the cavities, vacuum operations (pumping, venting, flushing, leak checking) should be **fully automated**, to include slow pumping and venting, and valve opening.
- **Robotization** could be implemented e.g.
 - Ionized N₂ cleaning
 - Cold coupler assembly
 - String assembly
 - Warm coupler assembly

Robotization will be beneficial with respect to :

- Reducing labour cost
- Reducing the assembly mistakes and non-conformities
- Uniformization of assembly procedures across the 3 or 4 regional assembly plants
- Introducing some 'plug-compatibilty' in the module design

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NOT FUNDED

CEA will continue investigation on **surface preparation**:

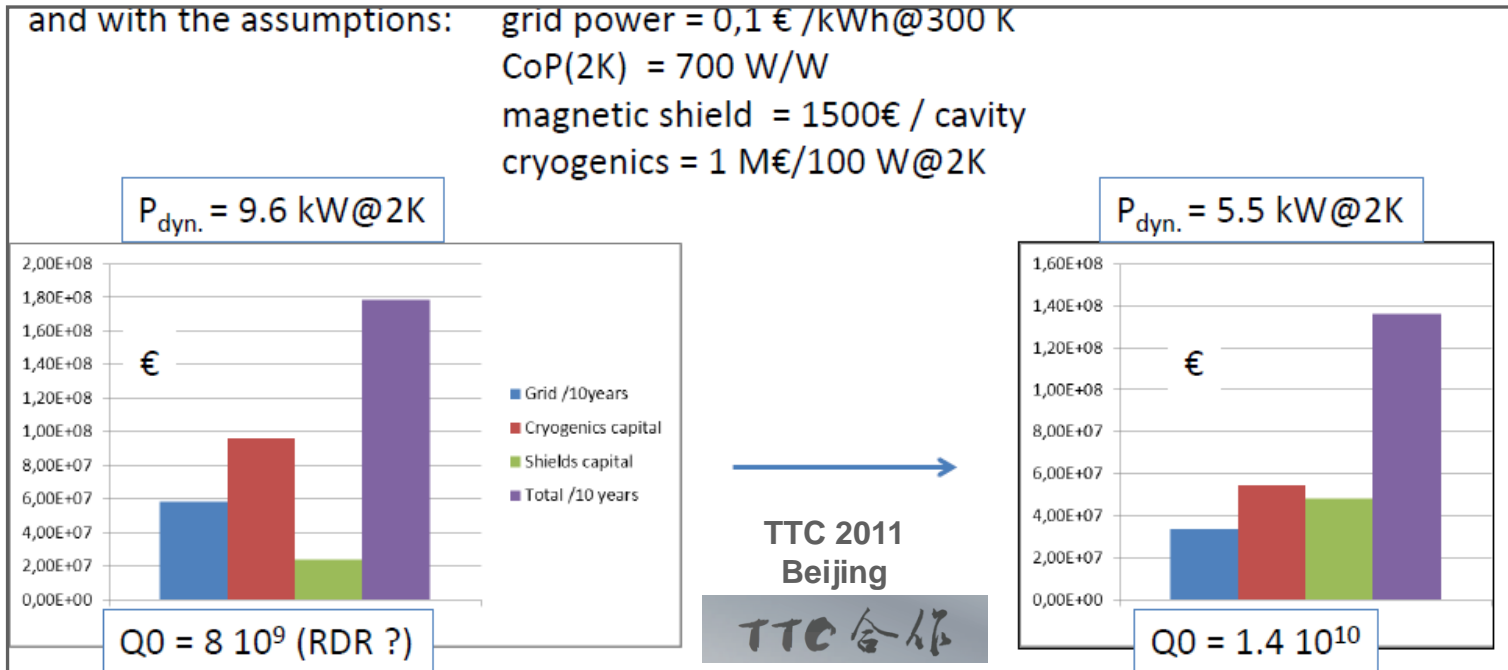
- Electropolishing, and in particular Vertical EP
- 120°C baking, and in particular N₂-infusion recipe



CEA can join in an international collaboration on these topics.

CEA will continue investigate **magnetic shielding material**:

- Optimize CRYOPHY material for highest permeability at 9K
- Double-layer magnetic shields



- In-depth investigation on the lightening observed during the RF conditioning in some XFEL couplers: Origin, impact on coupler and how to suppress it.
 - Test on a “new” multipactor suppressor thin layer on ceramic: Cr_2O_3 .
 - Impact of different finishing processes (Brushing, glass bead blasting, burnishing...) on copper plated surface roughness, RRR and SEY.
 - Coupler cleaning-rinsing-drying procedure automatization: to avoid operator dependence, guarantee the process repeatability and save time and money.
 - Mechanical design, thermal and RF studies of coupler operating in CW mode.
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