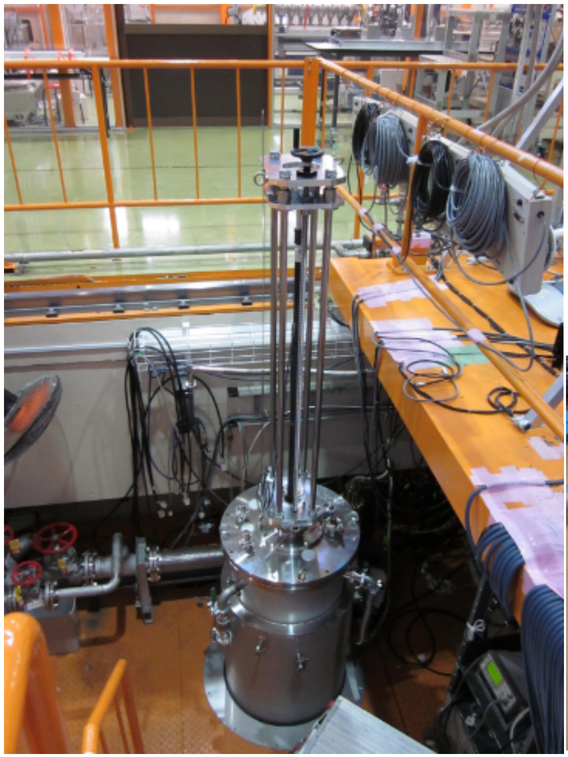
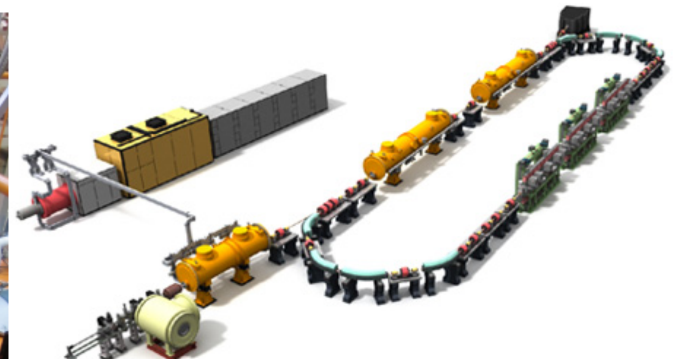
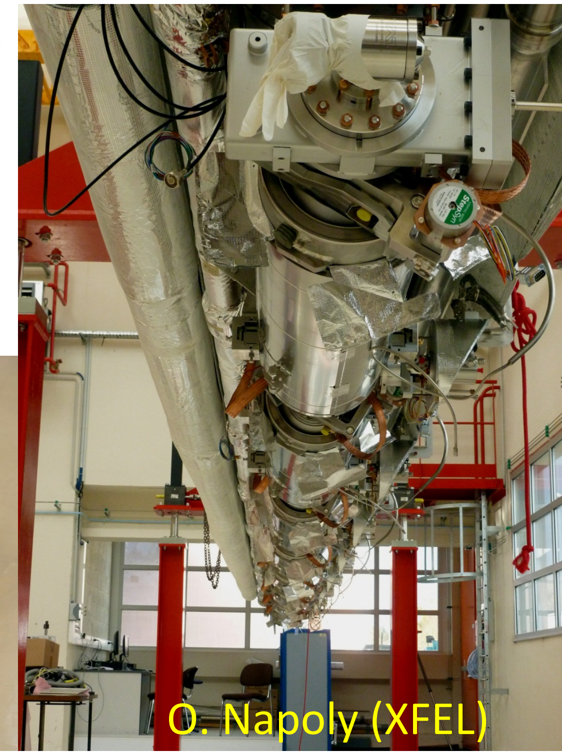
A_RD_7:
Study of the effects of an external magnetic field on Superconducting RF cavity performance



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2014 Joint Workshop of the France-Japan
(TYL/FJPPL) and France-Korea (FKPPL)
Particle Physics Laboratories

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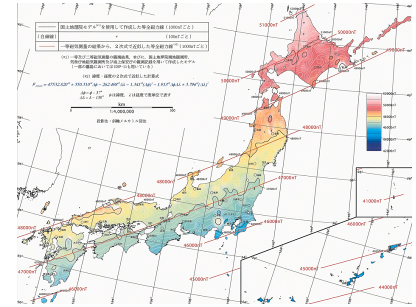
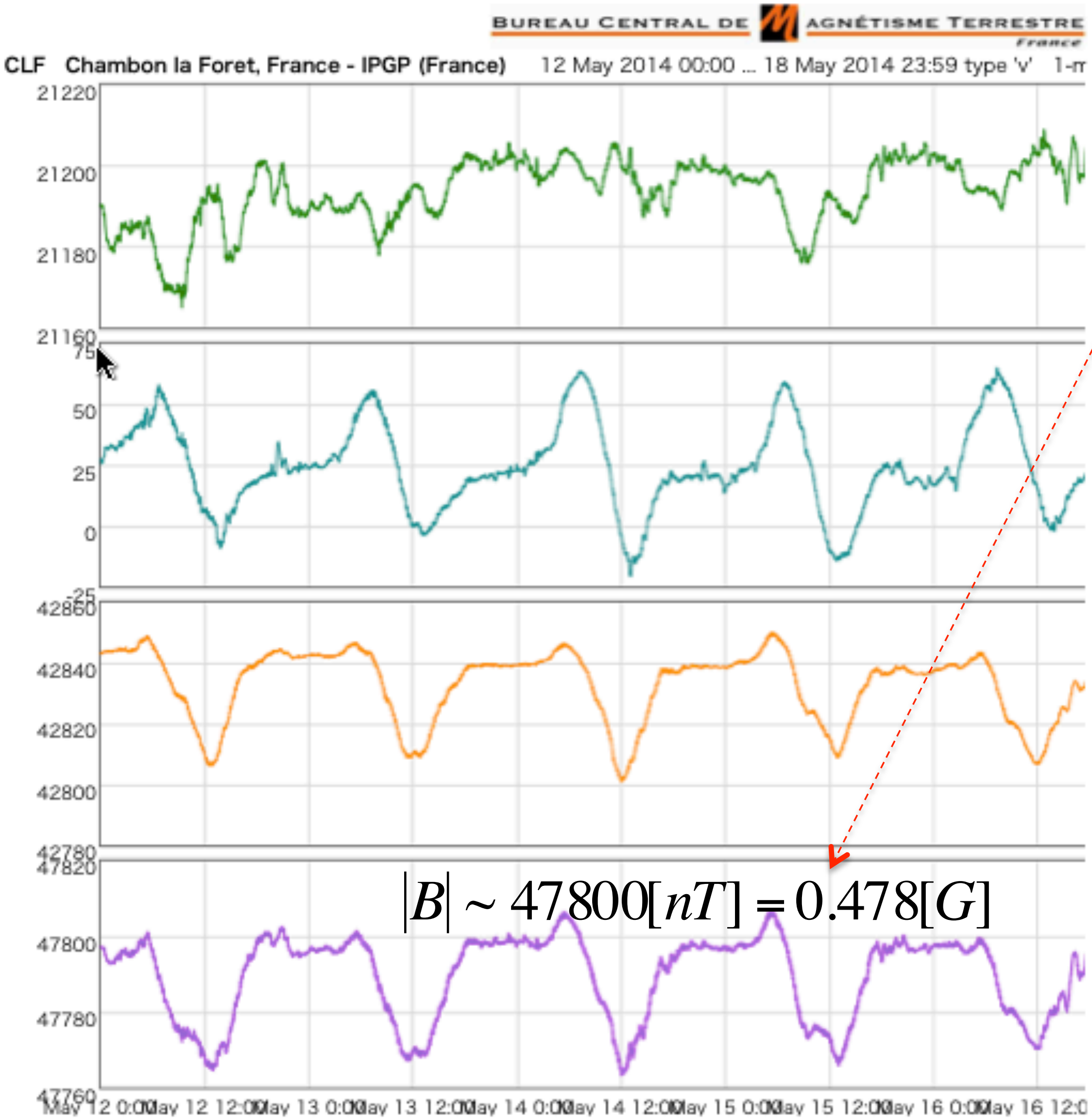
Introduction

- Magnetic shielding is a key technology for superconducting RF cavities.
- It is necessary to optimize the shielding method, including the choice of materials and the shape of the magnetic shield, and to establish a method for quality control suitable for large-scale production.
- A few ~10 % of the cost of an SC cavity system comes from magnetic shielding.
- Finding a good enough material and establishing a good and solid technology are important.

Ambient field: Earth's magnetic field

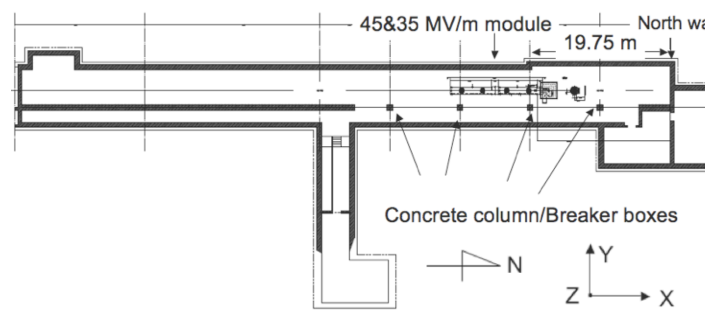




$$|B| \sim 47800[nT] = 0.478[G]$$

Earth's magnetic field: ~0.47 G in the open air around KEK.
Similar in Chambon la Foret, France.

- Ambient field is NOT uniform though in buildings, experimental halls and accelerator tunnels.
- Earth's field is not the only source of ambient field in the tunnel.

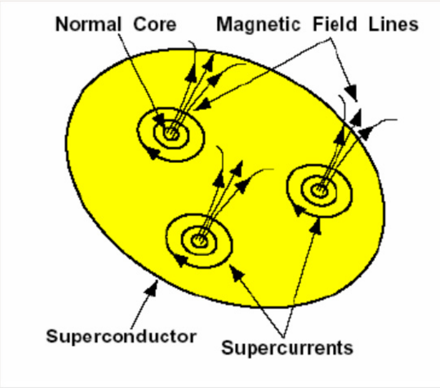


Non-uniformity & stronger fields come from ferro-concrete columns, power cables, breaker boxes, and so on.

Let us just remind that

During the cool down of the niobium cavity, flux lines of static magnetic field are trapped in the material.

Their presence in the superconducting state of Niobium is responsible of an enhancement of the residual resistance of the cavity



⇨ Achievement of challenging Q_0 in cavities, (ie low surface resistance goes through an effort to **minimize magnetic field close to the cavities**

Need for magnetic shield

- The acceptable level of ambient magnetic field depends on factors such as
  - operating RF frequency
  - acceleration gradient
  - operating mode, either pulsed (linear collider) or CW (ERL)

    → The wall losses on the cavity surfaces are determined by the surface resistance R_{surf}, which has contributions from three terms:

R_{BCS} comes from BCS theory
Depends on T and frequency

R_{res} Comes represents the residual resistance, depends on cavity fabrication method & treatment.

R_{mag} Comes from trapping and pinning of the ambient magnetic field.

$$R_{surf} = R_{BCS} + R_{res} + R_{mag}$$

→ The acceptable level of ambient magnetic field can be as low as a few mG (a few hundreds of nT).

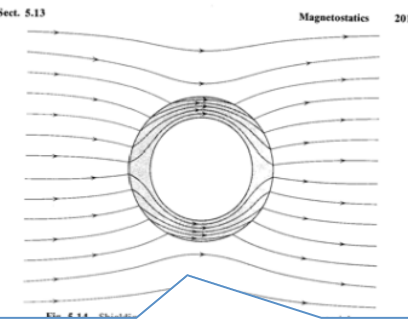
→ A factor of 100 reduction from ~500 mG to ~5 mG is needed.

- Superconducting cavities
  - They are operated at LHe temperatures (4K, 2K)

    → Shielding effectiveness at cryogenic temperatures is important.

We need magnetic shielding, a factor of 100 reduction or more, for cryogenic use.

CEA/KEK collaboration in the framework of FJPPL



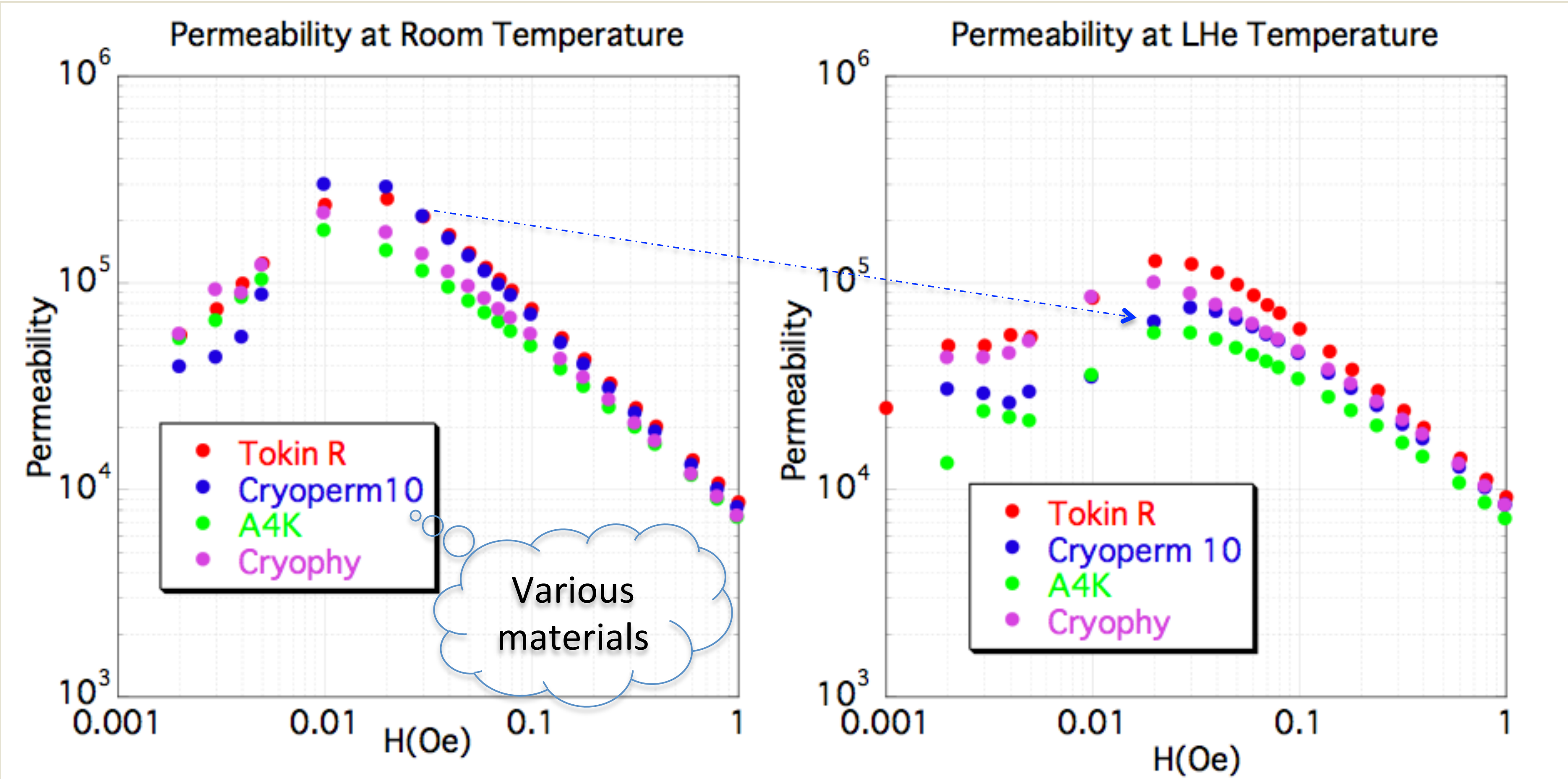
CEA-Saclay and KEK have been measuring the permeabilities μ of various shielding materials.

$$\vec{B} = \mu \vec{H}$$

Shielding using high μ material to bypass the magnetic flux

- We measured μ of the same sample at both CEA and KEK
    - At room temperature and cryogenic temperature
- Make comparisons
    - Evaluate possible systematic errors between the two groups.
- We exchange information about vendors, materials and so on.
- Compare shielding effectiveness in the cryomodules.

Evaluation of various shielding materials (for cryogenic use)

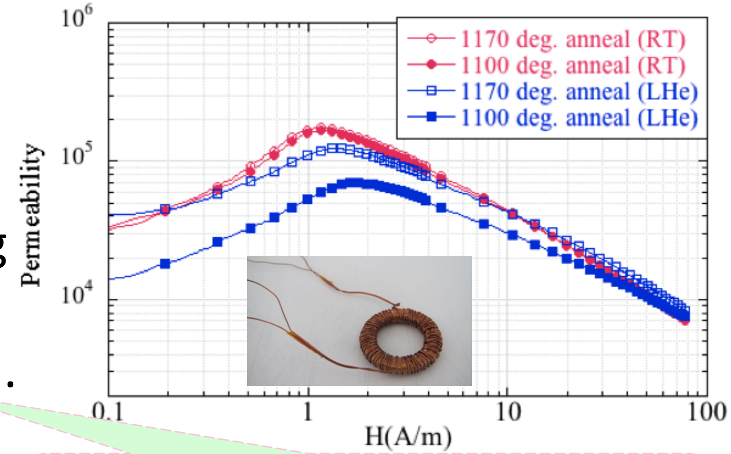


Evaluation of various shielding materials
Our choice

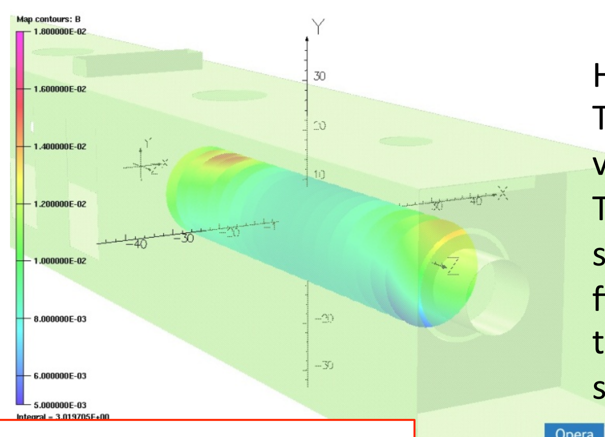
The characteristics studied by KEK & Saclay include:

- Permeability dependence on the ambient temperature, annealing temperature and annealing patterns.
- Permeability degradation due to mechanical strain.
- Permeability variations among samples.

→From the results of our study, we selected a suitable material (Cryophy) for both XFEL (CEA) and cERL (KEK), and good cavity performance was obtained.

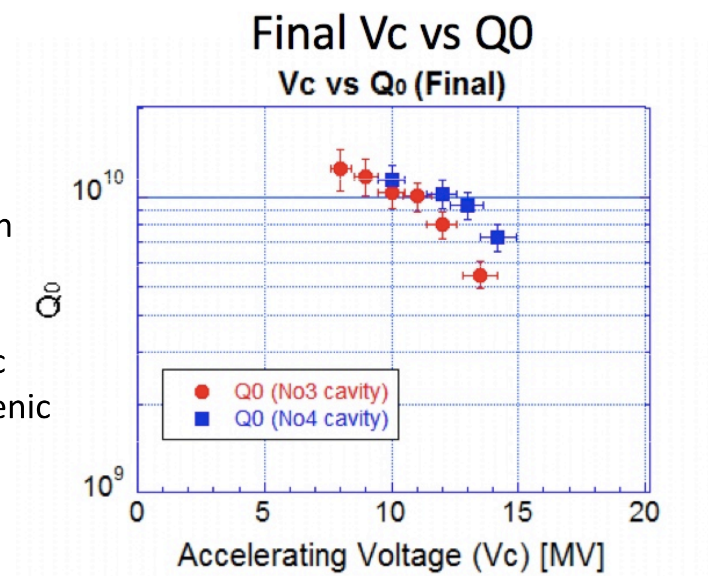


When dropped (~ 1m height) :
Permeability is reduced by a factor of 2!
"Drop test" by Amuneal, communication with J.Plouin (CEA)



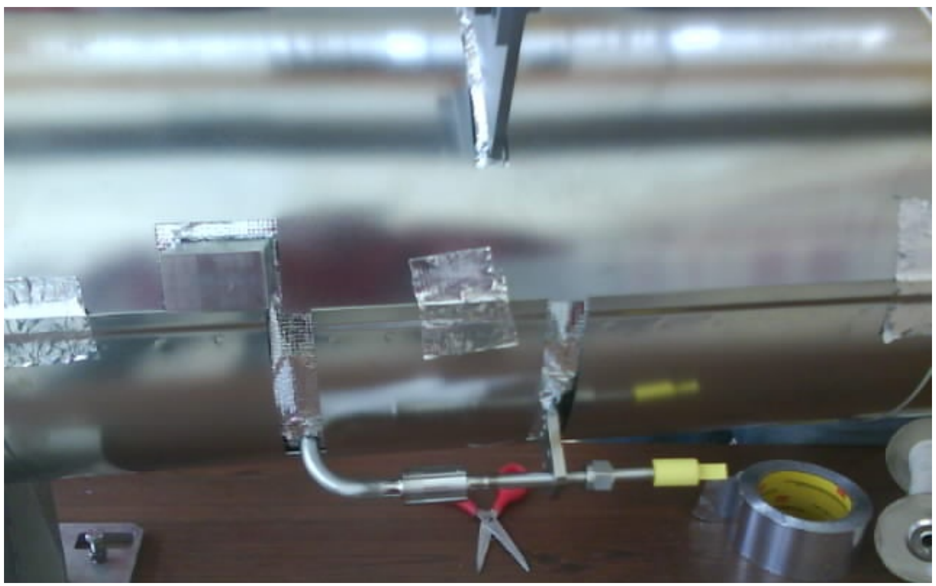
cERL Main Linac Cavity system

High Power Test
The Q_0-value exceeded the design value of 10^{10} .
This indicates that the magnetic shield kept the ambient magnetic field to a level of 10 mG at cryogenic temperature, agreeing with the simulation.



Magnetic Shieldings

Series by MecaMagnetic for XM-3 and XM-2 cryomodules



Magnetic shields are qualified by the excellent dynamic cryogenic performance of XM-3

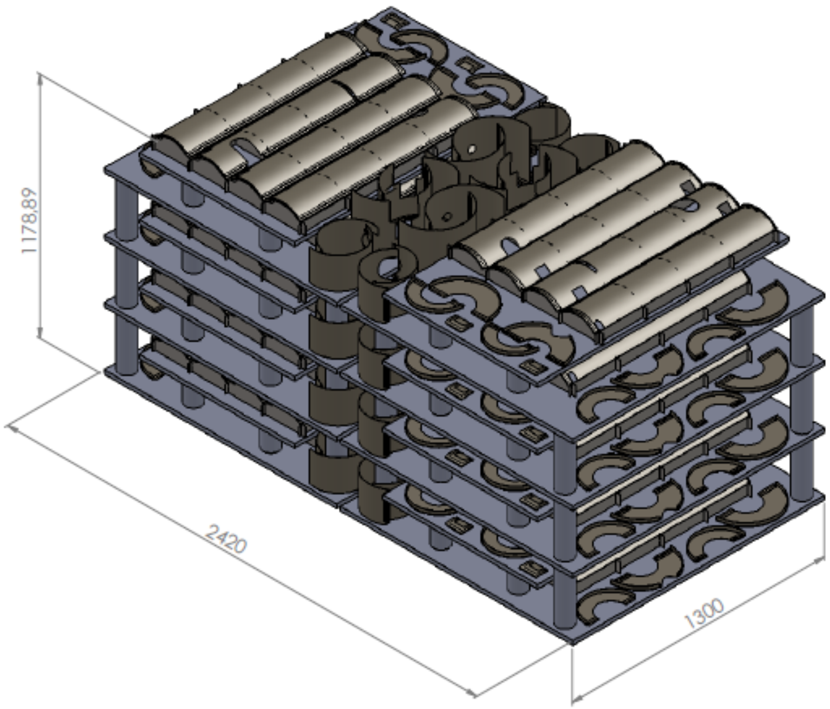
Proposal for A_RD_7
"Study of the effects of an external magnetic field on Superconducting RF cavity performance"

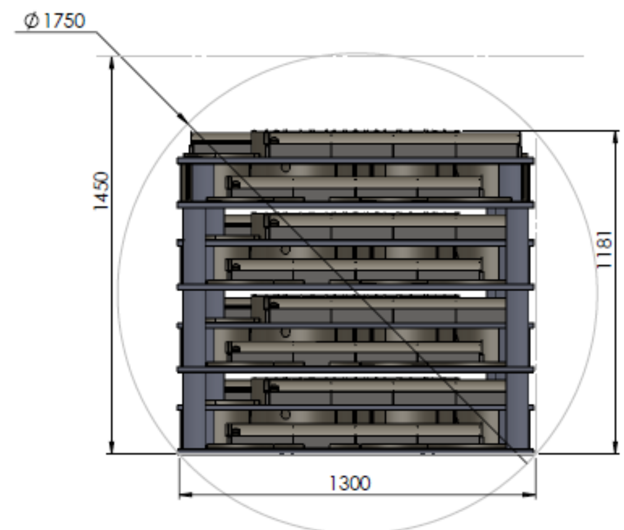
We plan to:

- Continue to evaluate the permeability of various shielding materials for superconducting RF cavities.
- Investigate possible causes for the performance degradation of shielding material at cryogenic temperature.
    - CEA has shown examples of good thermal treatment and shipping packing at TTC (TESLA Technology Collaboration) in March.

Thermal treatment at Bodycote ABMT

Two cryomodules per thermal treatment (~24h)
Oven temperature homogenity is OK over this volume
(same oven as for the IPHI RFQ)v





Ind.	Rev.	Date	Etabli par	Commentaires
0	A	01/12/2011	B. LEGENDRE	

Matière :	Epaisseur :	Traitement :
/	/ mm	4h à 1150°C
Poids net : 796038.25 g	Echelle : 1:15	
Tolérance générale ou normes : ISO 2768 mK		A3

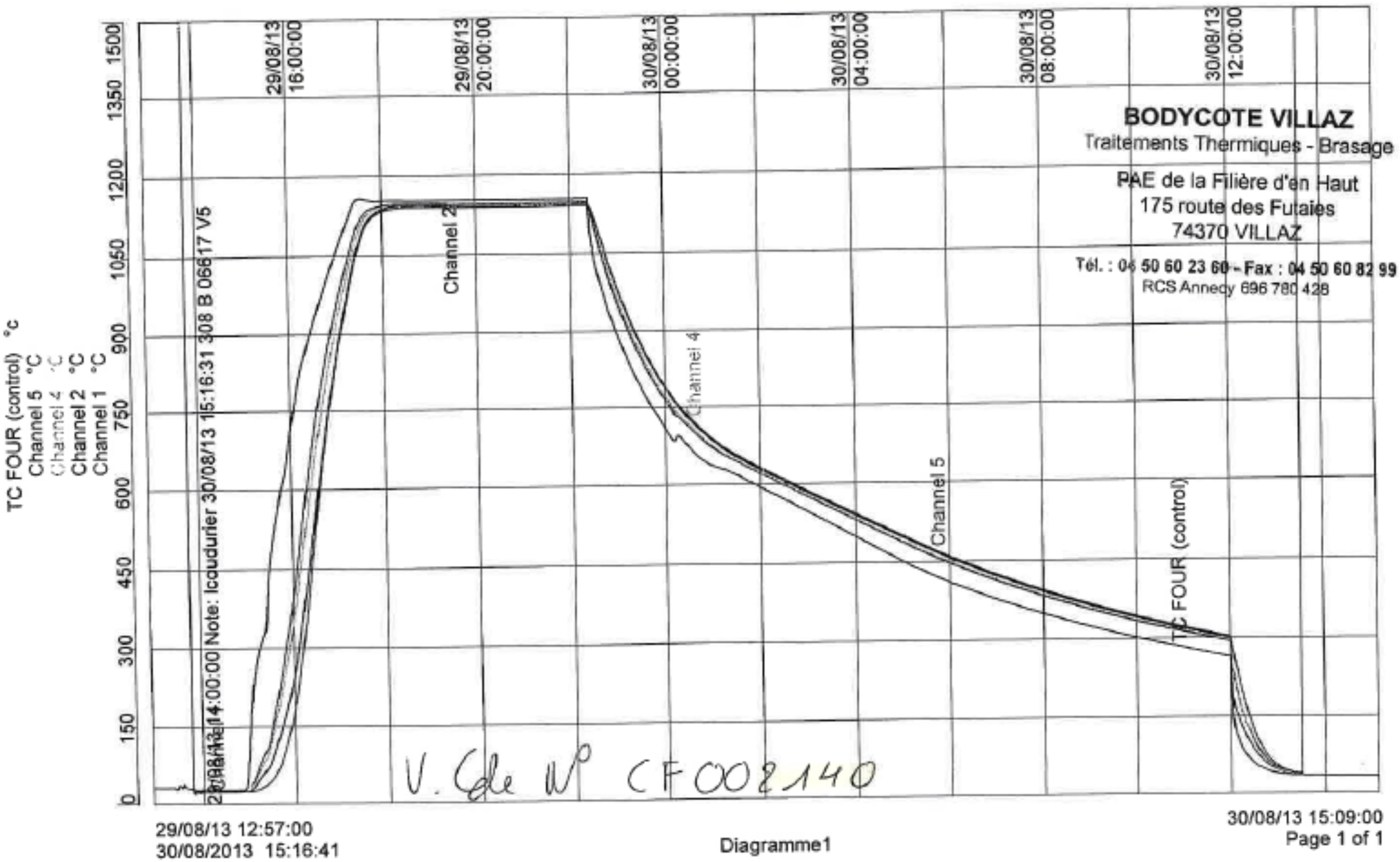
MECA MAGNETIC
490 rue de la Fontaine
45200 AMILLY
Tel : 02.38.07.13.13
Fax : 02.38.07.13.07
contact@mecamagnetic.com

Libellé :
FOURNEE TTH XFEL
IMBRICATION POUR 2 CRYOMODULES

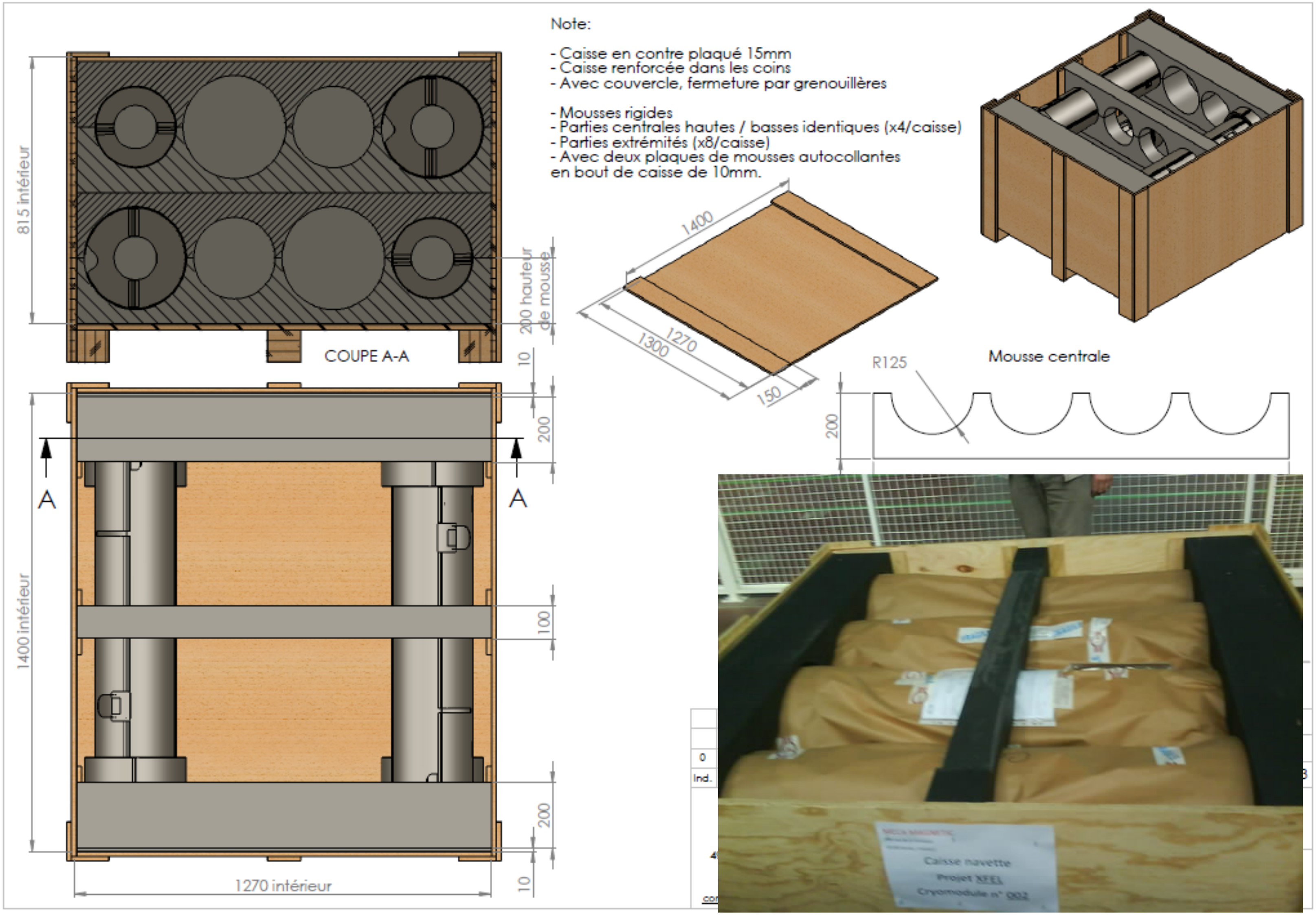
Code article indicé :
four tth

Cost of thermal treatment is ~30%

Thermal treatment at Bodycote



Shipment packaging to CEA and to/from Bodycote

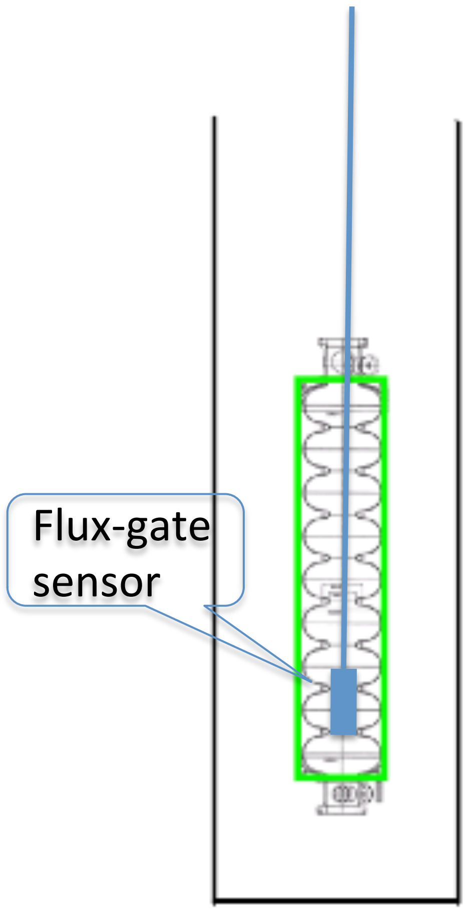


Proposal for A_RD_7
"Study of the effects of an external magnetic field on Superconducting RF cavity performance"

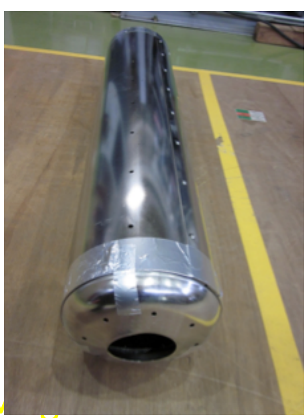
We plan to

- Study the dependence of cavity performance on the ambient magnetic field.
    - Measure the quality factor (Q_0-value) of the cavity using different magnetic shields.

Procedures

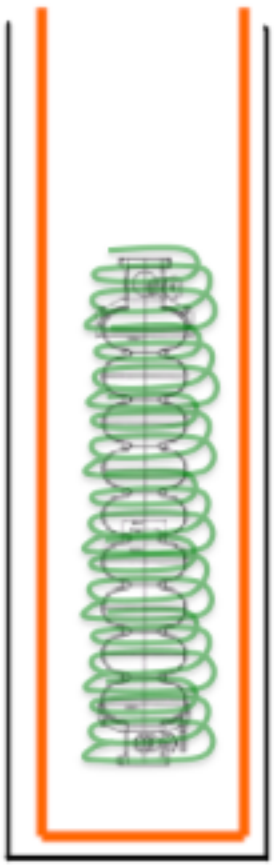


- Measure the external ambient magnetic field inside the shield without the cavities at room temperature (RT), 4K and 2K.
    - A flux-gate sensor, which is designed to measure low magnetic fields, is used.
- Install the 9-cell cavity system and measure Q_0-value at 4K and 2K.
- Repeat this for <u>two different shields made of different materials</u>.



Proposal for A_RD_7 "Study of the effects of an external magnetic field on Superconducting RF cavity performance"

Procedures
We are currently investigating the feasibility of this test



- Wind a solenoid coil around the cavity system to generate a magnetic field

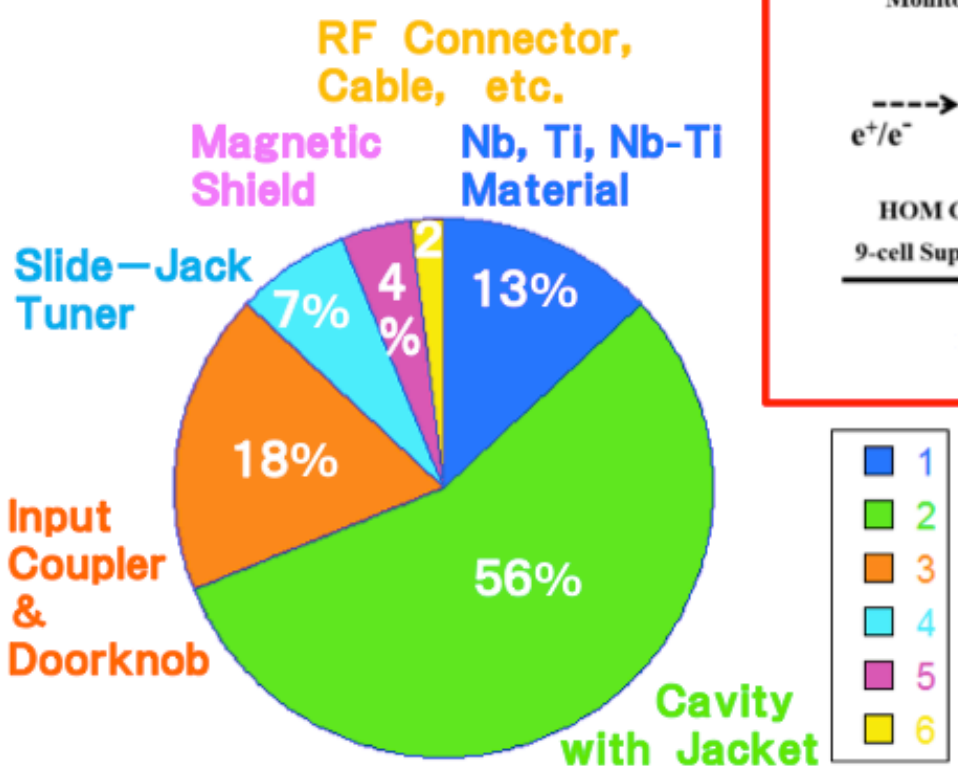
- Cool it down to 4K and 2K
- Measure the Q_0-value at different magnetic fields.

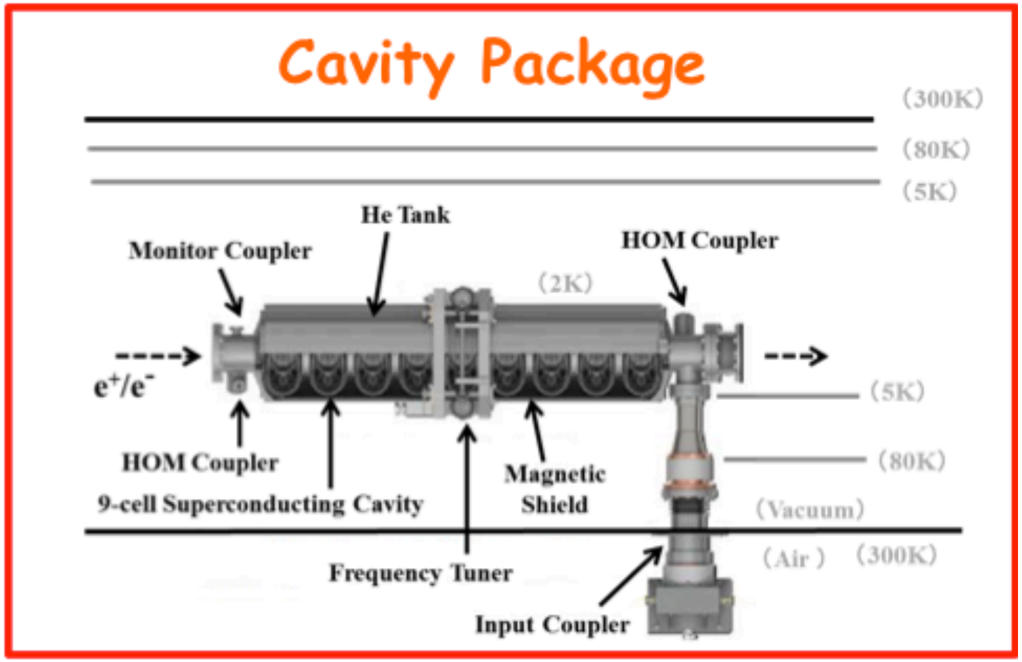
→We will be able to see the effects of the strength of the magnetic field on the cavity performance.

Summary

- Continue to evaluate the permeability of various shielding materials for superconducting RF cavities.
- Continue to investigate possible causes of performance degradation of shielding materials at cryogenic temperatures, and develop solutions.
- Develop a quality control method, suitable for use in mass production.
- Relate ambient magnetic field to the cavity performance (Q_0-value).
    - Q_0-value measurements at KEK with different magnetic shields.
    - More Q_0-value data from XFEL via CEA with the magnetic shield made of Cryophy.
- We believe that we have brought more attention to magnetic shielding in the superconducting RF community through the work in the frame of FJPPL and we would like to continue our activity.
    - ⇨We would like to find a recipe to optimize cost vs shielding effectiveness.
    - ⇨Contribute to a shielding material database that the community can share.
- Study of feasibility of reducing the ambient magnetic field to the level of 1 mG or less.

STF2—CM2b





In the case of STF2 (Superconducting RF Test Facility 2).