# Test on the high field facility (LNCMI-Grenoble) in the frame of the Eucard project

**EUCARD I in Grenoble :**

- Development of a test facility up to 20 T in 170 mm

➔ adaptation of a resistive site and development of the instrumentation

- Caracterisation of Htc
- Development of coils (YBaCuO) for mechanical tests & quench modelling

- Test of a small prototype dipole in large bore solenoidal configuration

( 10 T/376 mm) ➔ Planned for June 2013

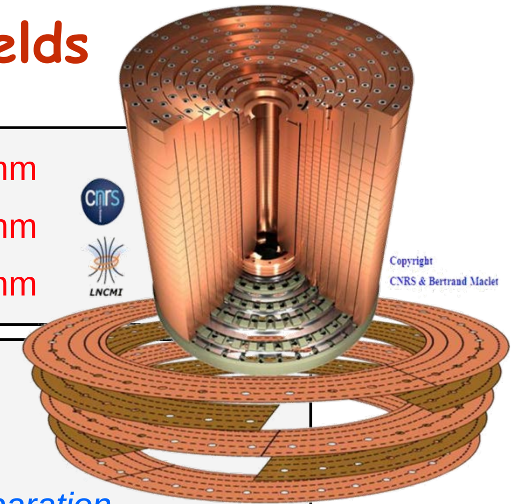
*A collaborative effort between different teams :*

**CNRS/IN/Grenoble INP** : Pascal TIXADOR (coordinator) , André Julien VIALLE, Benjamin VINCENT, Jean Paul LEGGERI, Anne GERADIN, Guillaume DONNIER-VALENTIN, Olivier TISSOT, Gérard BARTHELEMY

**CNRS-LNCMI** : Xavier CHAUD, François DEBRAY, Yasuyuki MIYOSHI, Eyub YILDIZ, Julien AUBRIL, Christophe TROPHIME, Nadine VIDAL, Jurgen SPITZNAGEL, Claude MOLLARD, Jean Marc TUDELA,

**CEA-SACM IRFU** : Jean Michel REY, Mélanie DEVAUX, Philippe FAZILLEAU Thibault LECREVISSE


# State of the Art for steady high magnetic fields




| | | |
|---|---|---|
| **Resistive: Copper alloys** | ➔ Grenoble, France | 35 T in 34 mm |
| | ➔ Tallahassee, United States | 35 T in 32 mm |
| | ➔ Nijmegen, the Netherlands | 33 T in 32 mm |

**Hybrid: NbTi, $Nb_3Sn$ + Copper Alloys**

**Existing**

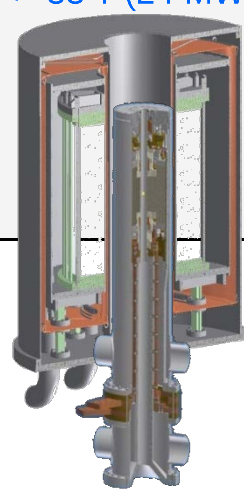
➔ Tallahassee, US 45 T = 11 T (Nb3Sn) + 34 T (30 MW)

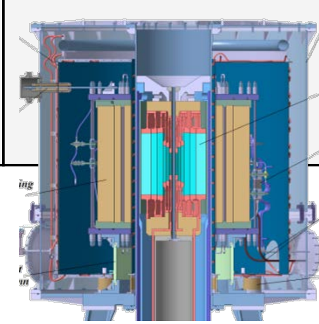
➔ Tsukuba, Japan 38 T* = 14 T (Nb3Sn) + 24 T (14 MW)

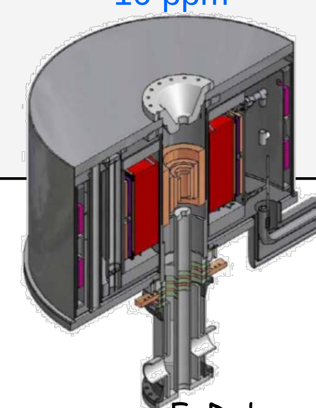
** unavailable since 2011, Sendai / Tsukuba project under preparation.*

**For 2015 -2018**

| Grenoble, 43 T | Nijmegen, 45 T | Hefei, 40 T | Tallahassee, 36 T |
|---|---|---|---|
| 8.5 T (NbTi) | 12 T ($Nb_3Sn$) | 11 T ($Nb_3Sn$) | 14 T ($Nb_3Sn$) |
| + 34.5 T (24 MW) | + 33 T (24 MW) | + 29 T (20 MW) | + 22 T (12 MW) |
| | | & 28 MW upgrade | 10 ppm |



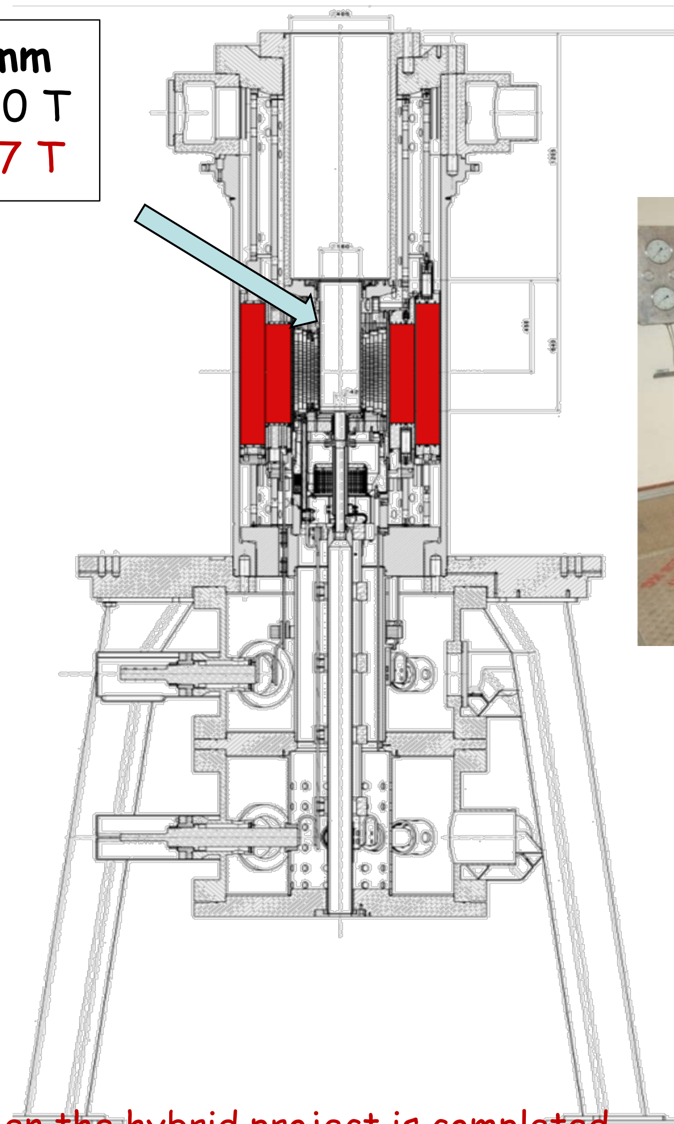




F. Debray 28/02/2013

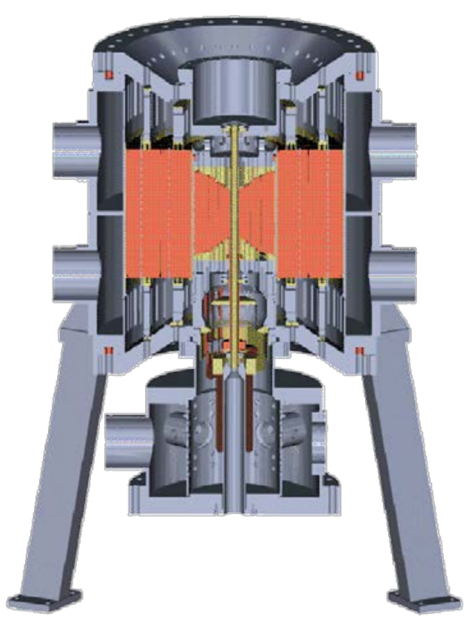
# High field configurations available at the LNCMI-Grenoble for HTS development

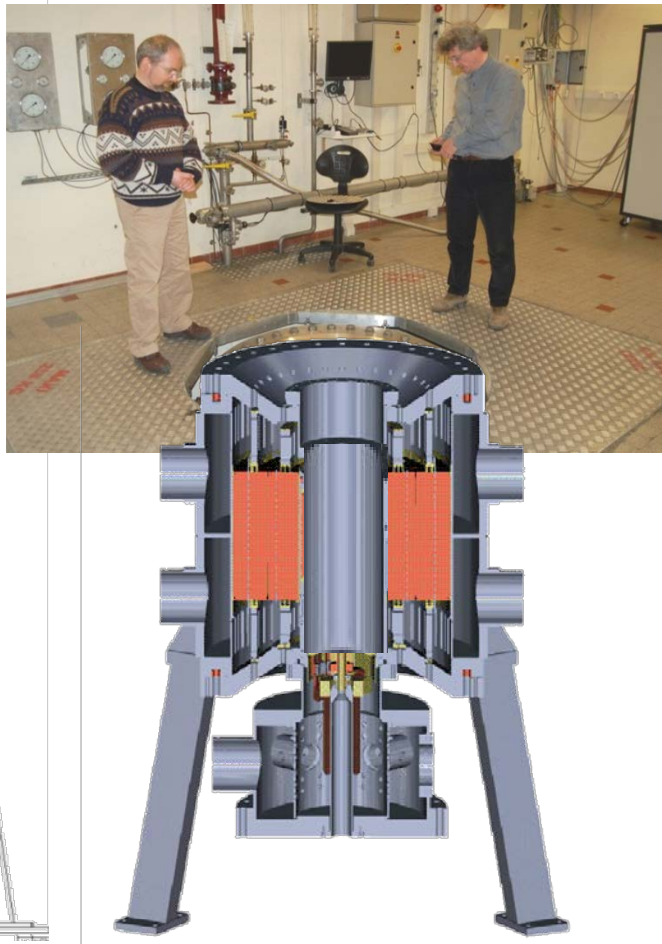
**In Φ = 170 mm**
Today : 20 T
In 2015 * : 27 T



**In Φ = 376 mm**
Today : 10 T
In 2015 * : 18 T

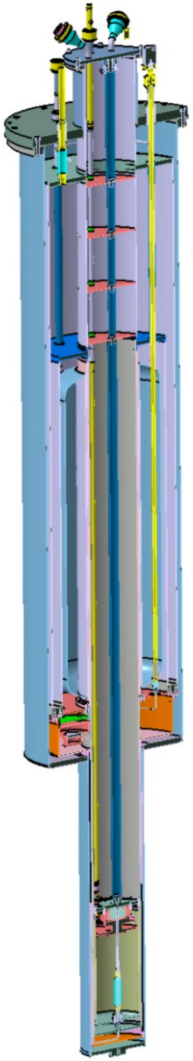
**In Φ = 50 mm**
Today : 30 T
In 2015 * : 40 T



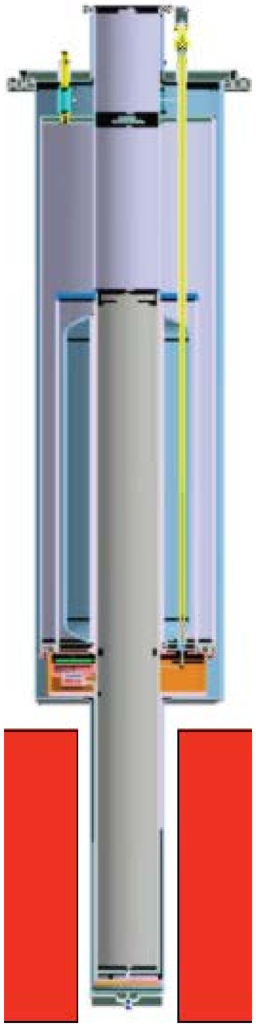


* when the hybrid project is completed

# Test bench for HTS coils:
# a Specific development in the frame of Eucard



InstitutNéel-MCBT-Cryostat SuperSmes



**Variable temperature cryostat for 170 mm warm bore**

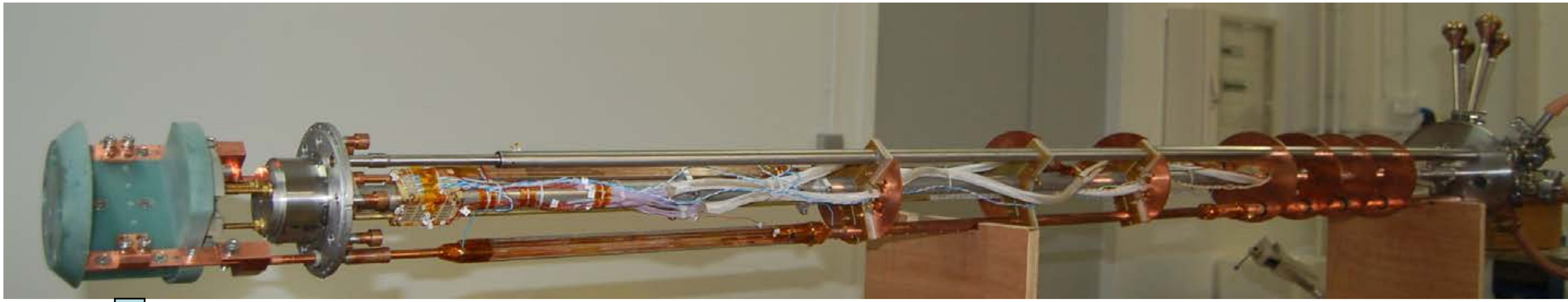
From 4 to 200 K
(1.8 K possible upgrade)

Coil size
Ø int : 26 mm min
Ø ext : 115 mm max
Height : 140 mm max

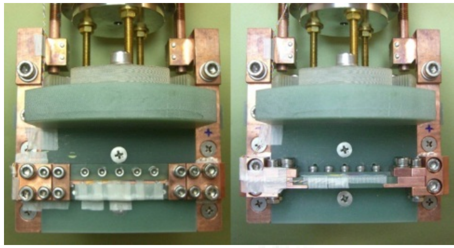
And straight samples
up to 100 mm long

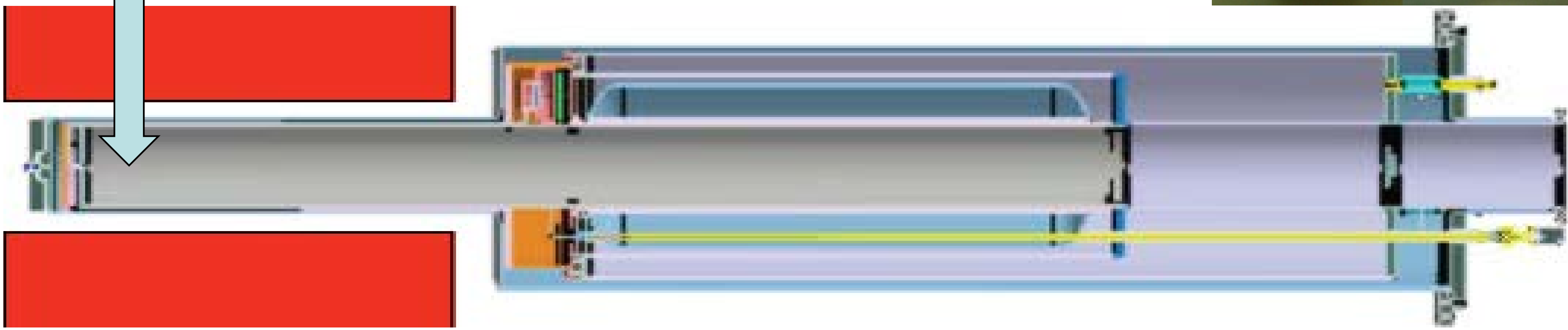
Mounted on a 20 MW 20 T site
(27 T en 2015 with the new hybrid)

# Coil holder to characterize & develop HTS inserts



- **Test 4.2 K of model coils**
- **Test 4.2K of straigth « long » straight samples** (100mm) (with more than 1000A)
- **Instrumented current leads*** tested up to 1000 A / 5 mn





# Ic measurements

**For LTS** (e.g. Nb3Sn) an international standard in Ic measurement.

- ❑ Ramp-and-hold or constant sweep method
- ❑ minimum sweep rate (10 s to Ic) and minimum ramp-and-hold step (3s to Ic)
- ❑ Monotonically increasing current
- ❑ Reproducibility within 1 %
- ❑ Temperature within ±0.02 K
- ❑ B field within ±0.02 T
- ❑ Measurement mandrel material and dimension

etc…

**No such agreement** has been made **for HTS** yet.
Standardization in progress.
Usually a fast current ramp to 1 μV/cm is used.

NORME INTERNATIONALE
INTERNATIONAL STANDARD

CEI
IEC
61788-2

Deuxième édition
Second edition
2006-11

**Supraconductivité –**

**Partie 2:**
**Mesure du courant critique – Courant critique continu des supraconducteurs composites $Nb_3Sn$**

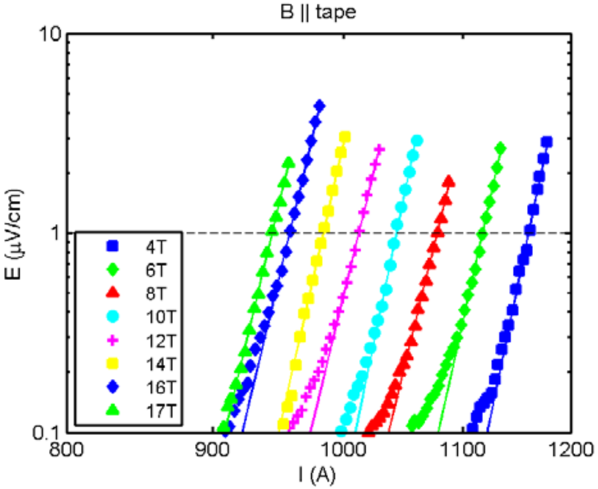
**Superconductivity –**

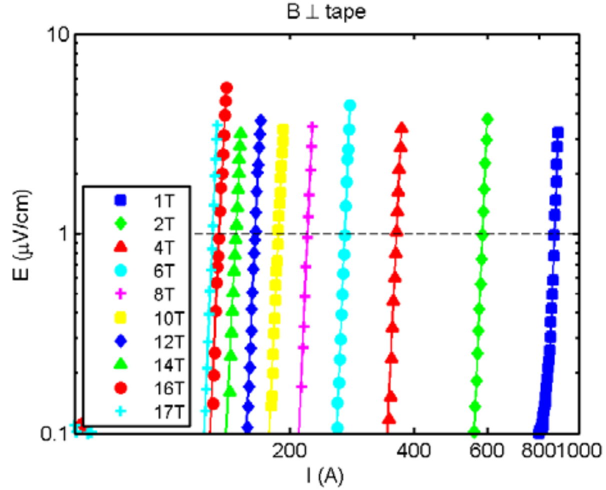
**Part 2:**
**Critical current measurement – DC critical current of $Nb_3Sn$ composite superconductors**

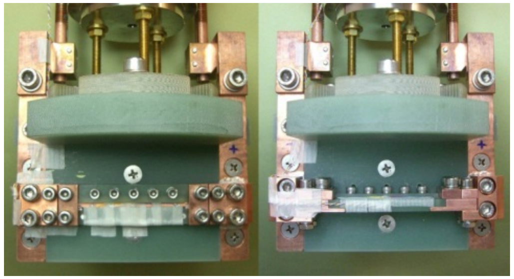
IEC

Numéro de référence
Reference number
CEI/IEC 61788-2:2006

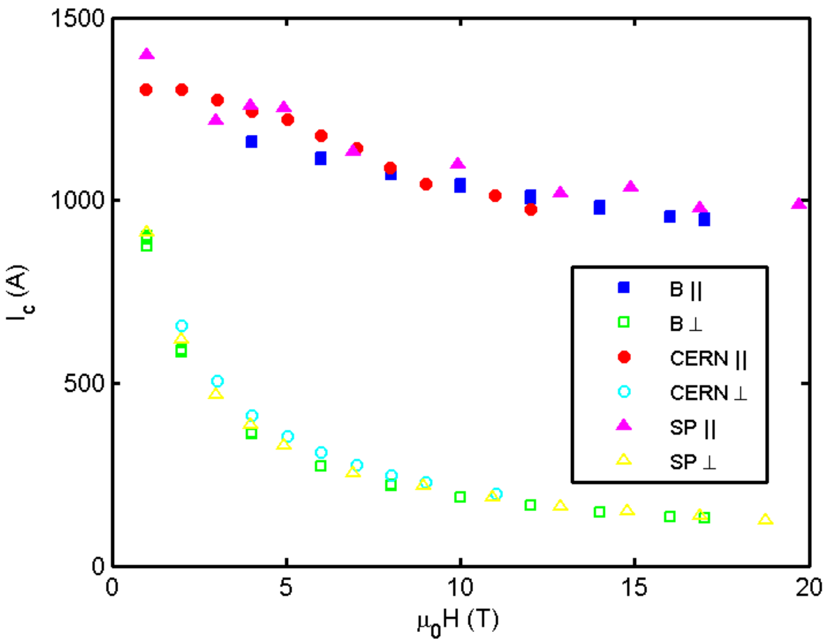
# Ic measurement example



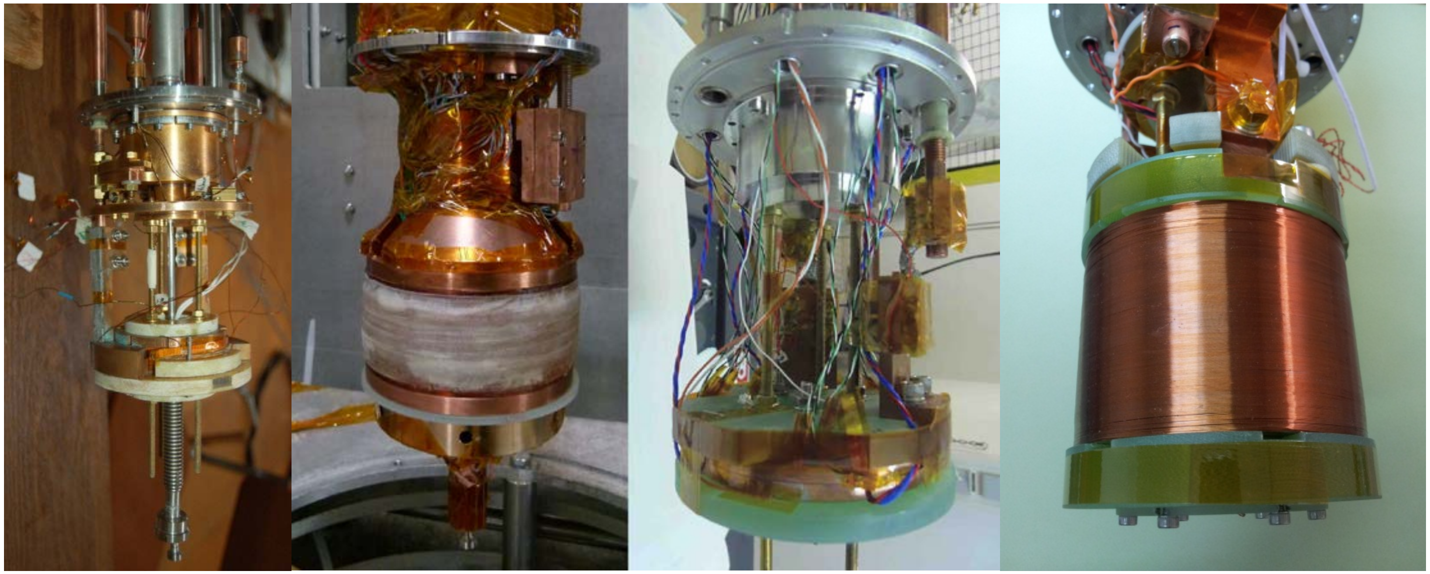
- Sample: SuperPower tape SCS4050-AP.
- Ic measured at 4.2 K in both B directions at 1 µV/cm .




**Good agreement** with data from CERN and from SuperPower for the same tape.

**Limitation** : this is a coil test probe and not optimized for many short sample tests.

# Coil tests

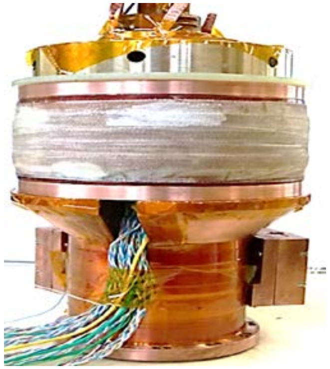


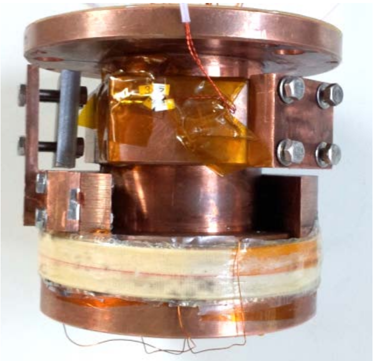
These last 3 years different coils have been tested at the LNCMI

With NIMS: Ic in a Bi-2223 coil
With Tohoku : Ic and stress in a double pancake (GdBaCuO) coil.

**For Eucard** , coils were developed for mechanical tests **and validation of numeric code.**

# Coils for Numerical code validation

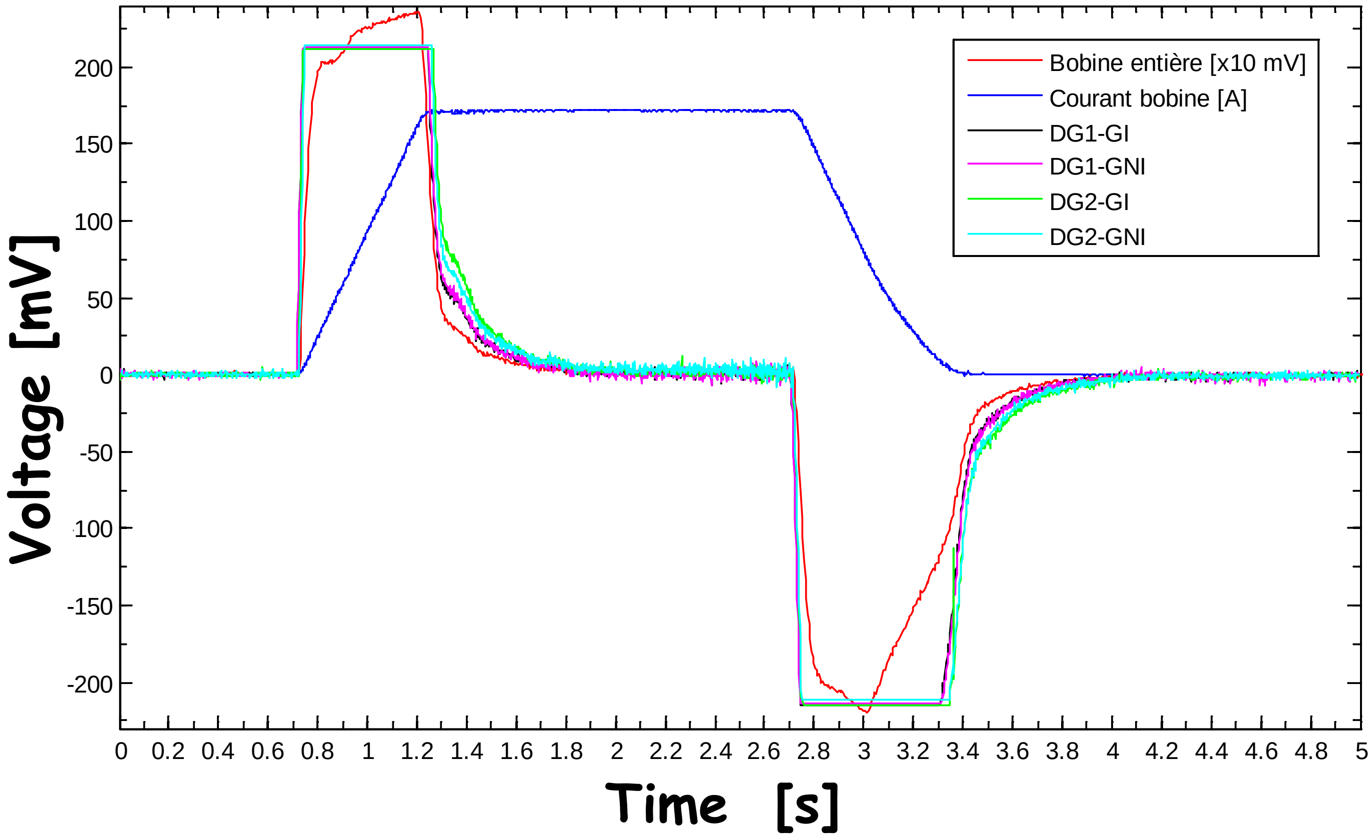




| | HTS1 | HTS2 | MARS |
|---|---|---|---|
| Number of pankakes | 2x1 + 2x2 | 2x1 + 1x2 | 2x1 |
| Total turns | 228 | 151 | 100 |
| Added Stabilizer | 100 µm Copper | 150 µm Copper | None |
| Inductance | 5,6 mH | 2.1 mH | 0.6 mH |
| Ic (77 K, SF) | 110 A | 86-106 A | 35 A |

# Validation of numeric code

**HTS1, 4,2 K, 18 T, 196 A**




Typical ramp cycle

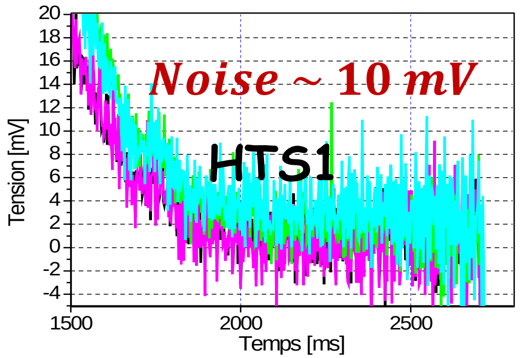
Protection by a resistance

Saturation of the signals when ramping

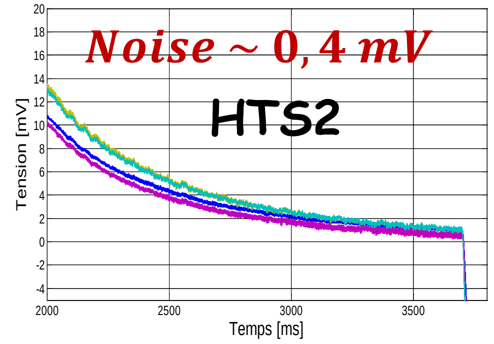
**HTS 1 : 0.6 T under 18 T background B (HTS1)**

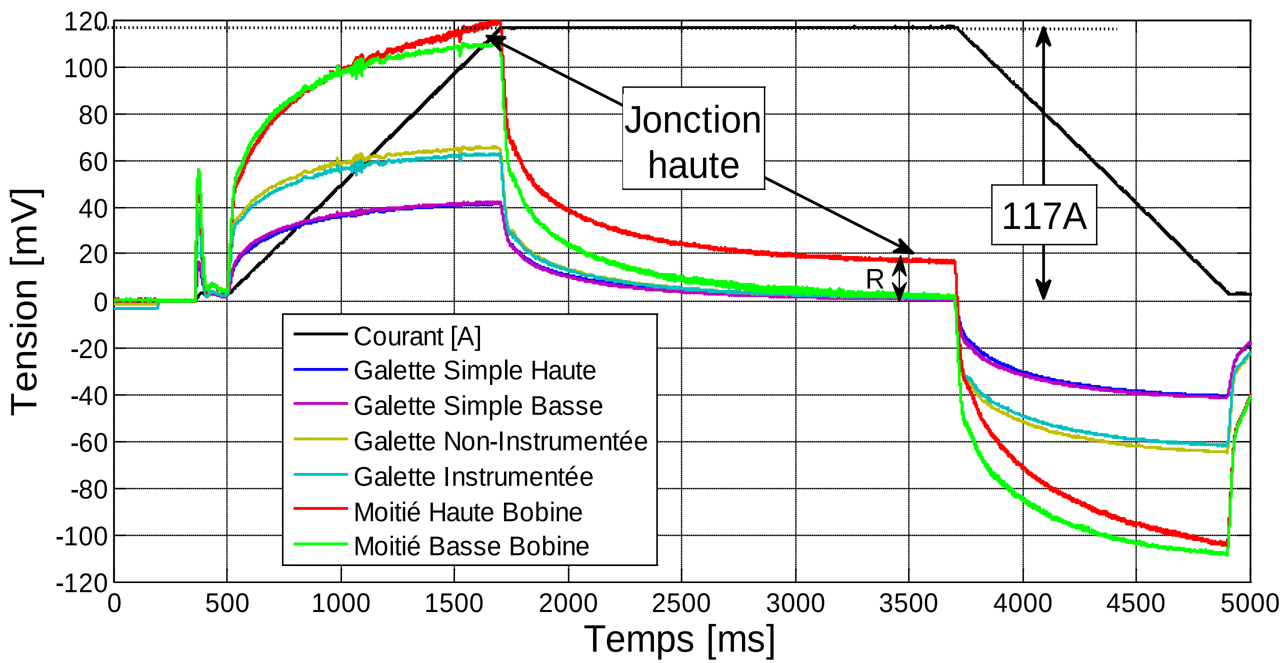
**No quench propagation measurement, mechanical problem**

# HTS2, 4,2 K, self field , 117 A




**Measurement improvment**
**→ Noise /~20**




Upper jonction
**140 µΩ** (4,2 K)
& **2 mΩ** (77 K)

Lower jonction
**370 nΩ** (4,2 K)
& **1 µΩ** (77 K)

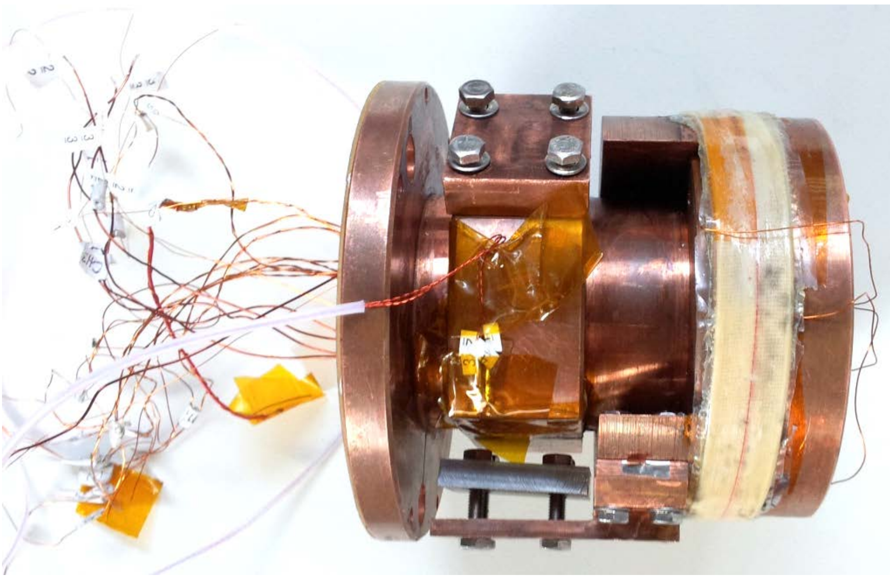
**Problem on the upper junction : 400 to 1000 time more resistive**

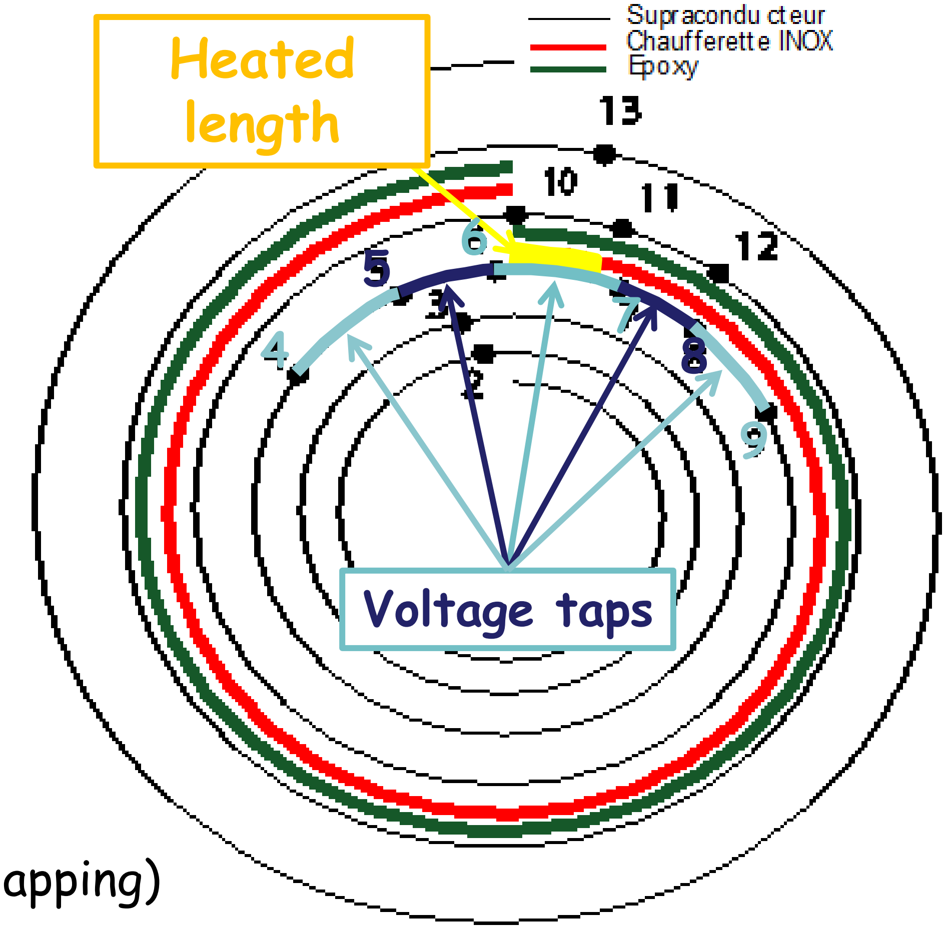
***No quench experiments*** **➔**, junction have been checked and prepared again

A new series of measurement on the High field facility next week ( 5th of March)

# Validation of numeric code

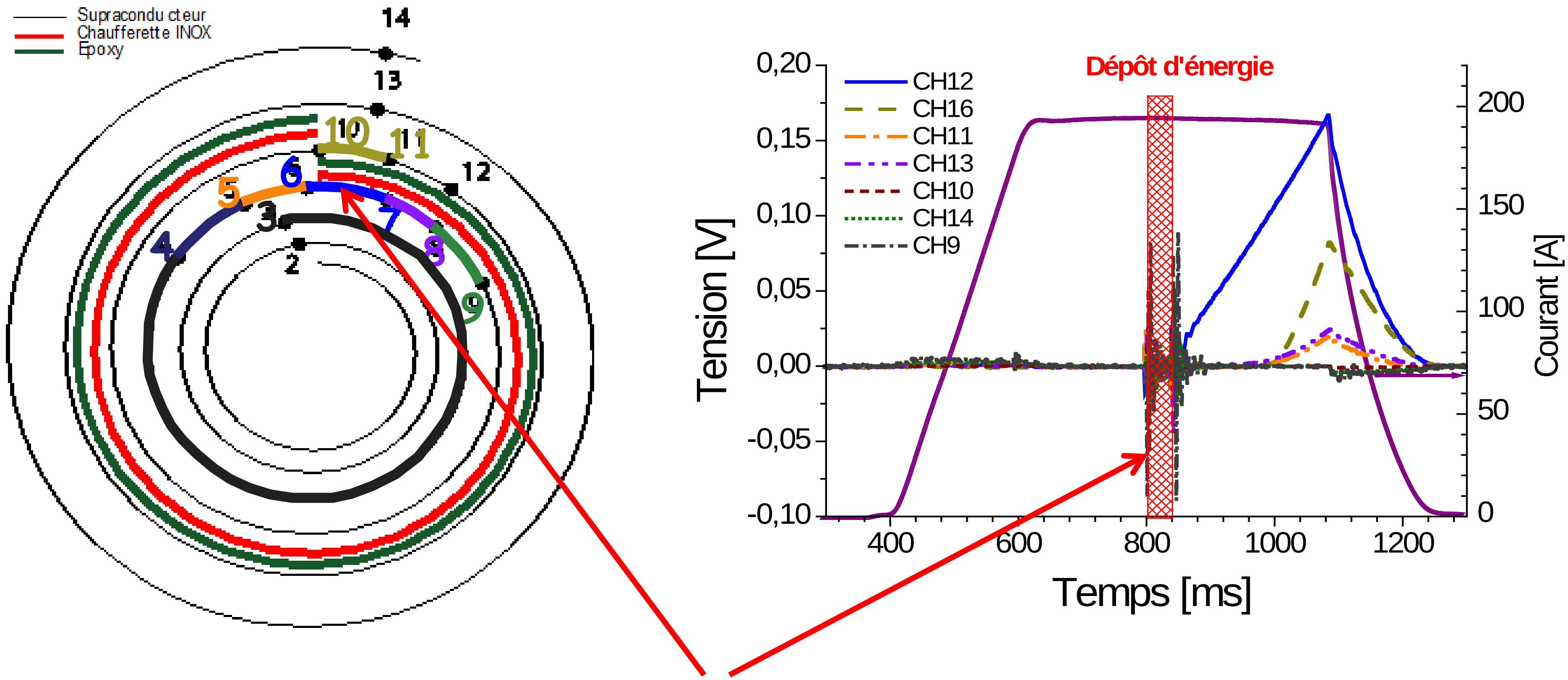
**MARS : specifically designed and instrumented for measurement of longitudinal velocity of propagation**






- Ribbon SCS4050-AP
- Insulating layer with kapton 50% overlapping)

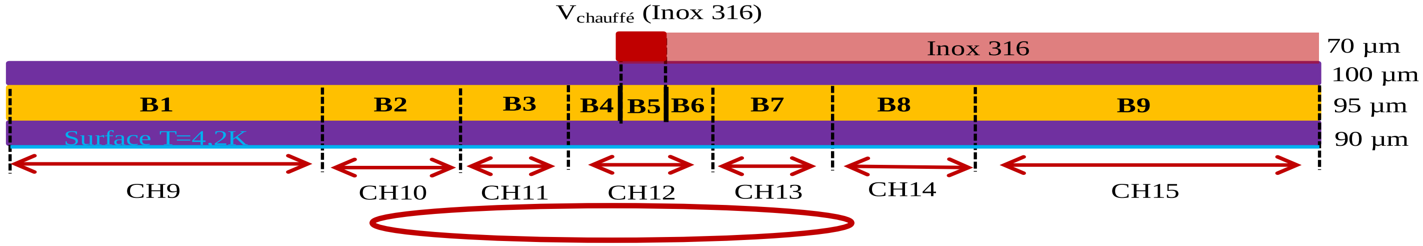
# Mars : Test @ 17 T, 4.2 K & 196 A



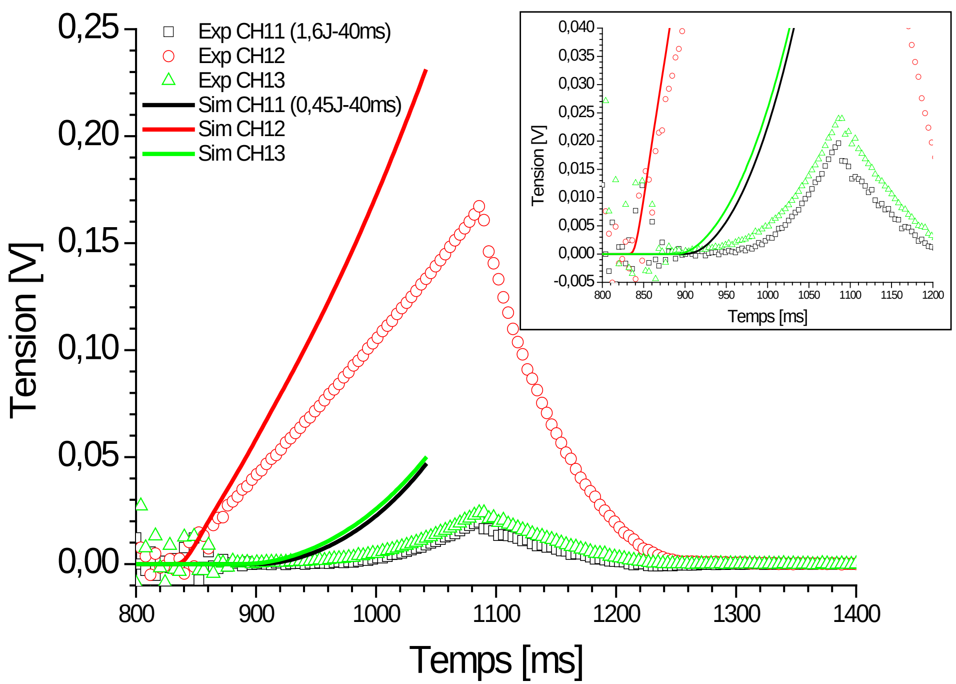

→ Long. Propagation on less than **20 mm : $U_l$ < 80 mm/s**

→ No transverse propagation.

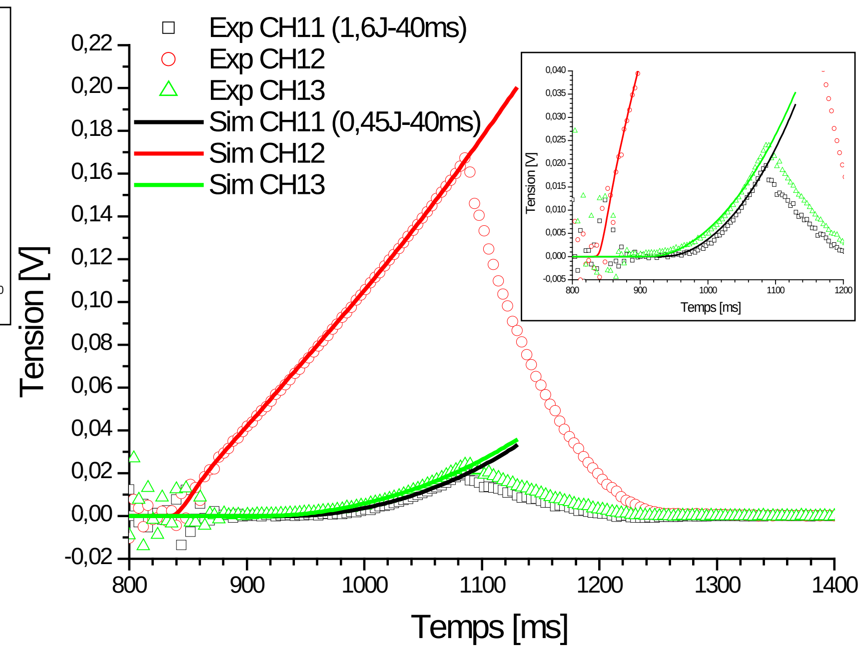
# Numeric code validation




## Adiabatic case




## Cooled case




→ Numeric model confortted by the experiments

→ Ajustable parameters : deposit energy, type of cooling

→ More experiments required ➔ HTS2 in March

# (Partial) conclusions on the use of Htc for magnets

**Protection** : « ancient » schems not applicables

**Time available for protection < 200 ms** (in an adiabatic assumption)

→ Very fast and includes the discharge

→ Detection of low level signal in noisy environment

→Need to discharge the energy out of the windings

→ Use of «**heaters**» **for large magnetic structure seems unrealistic**

**Example :** ➔ LHC NBTi dipole $\sim 50 - 60\ ms$ for 1mJ

➔ For HTS Superconductors ➔ MQE x $\sim 200$

- **Protection**: Optimization of the windings themselves

**Needs of a Numeric code for quench study**

→ Next steps : Integration of thermomecanics

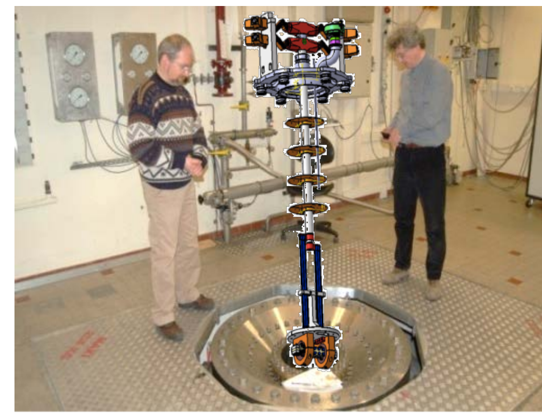
Integration of conductor anisotropy

→ Use of the code for magnet conception

# Eucard I activities at the high field facility

- Ic measurements on "short" samples
- Ic measurements on coils
- Hoop stress measurements on coils
- Quenching a coil:  construction of a numerical model and validation by comparison.

# Continuation



**March 2013 :** Quenching a coil: HTS2  new measurements

**June 2013 :** Test of the 260 mm long dipole prototype in 10 T

**LNCMI-CNRS and IRFU-CEA** have applied together  to ANR funds  for the construction of a 10 T insert in  20 T.

➔ **Answer in June 2013**

**Thanks to all participants !**