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LHC-3

Superconducting Magnets for the LHC Luminosity Upgrade

KEK : Nobuhiro Kimura, Akira Yamamoto, Kiyosumi Tsuchiya, Toru Ogitsu, Tatsushi Nakamoto, Ken-ichi Sasaki

Irfu : Bertrand Baudouy, Jean-Michel Rifflet, Maria Durante, Françoise Rondeaux, Michel Segreti

2nd FJPPL Workshop

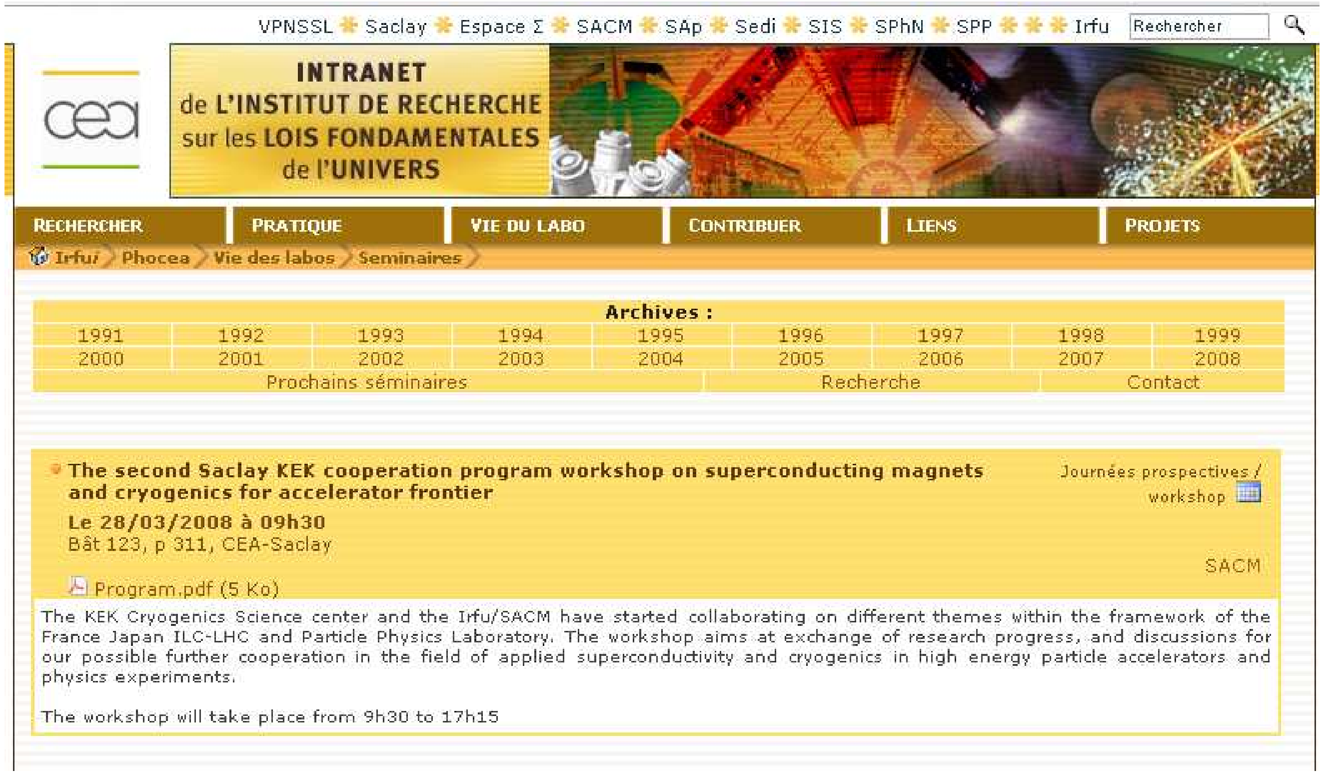
May 15-16 2008 Paris

Objectives

For LHC luminosity upgrade, Irfu/SACM and the Cryogenic Science Center of KEK have started a collaboration on :

- High-field superconductor and cable beyond 15 T,
  - Nb3Al conductor with Ta matrix in progress
- Model coil to evaluate cable performance at 15 T,
  - A sub-scale race-track coil and magnet design in progress
- Heat transfer through electrical insulation in LHe
  - Cooperative work for heat transfer through insulation in superfluid helium and supercritical helium

The 2nd Saclay-KEK cooperation program workshop on superconducting magnets and cryogenics for accelerator frontier



March 28 2008

CEA/Saclay

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The 2nd Saclay-KEK cooperation program workshop on superconducting magnets and cryogenics for accelerator frontier

March 28, 2008 CEA Saclay France
Bld 123, Room 311

9h00 9h30	WELCOME and OPENING Breakfast Bertrand Baudouy

CRYOGENICS R&D Chair: B. Baudouy	
9h30 10h00	Heat transfer in superfluid helium through porous media Hervé Allain, CEA Saclay
10h00 10h30	Visualization study of film boiling in narrow channel under He II Suguru Takada, KEK
10h30 10h45	Coffee Break
10h45 11h15	Heat tranbfer through Nb3Sn electrical insulation Jaroslaw Polinski, CEA Saclay
11h15 11h45	Heat transfer characteristics of classical insulation system under SHe Slavomir Pietrowicz, WUT

12h00 13h45	Lunch

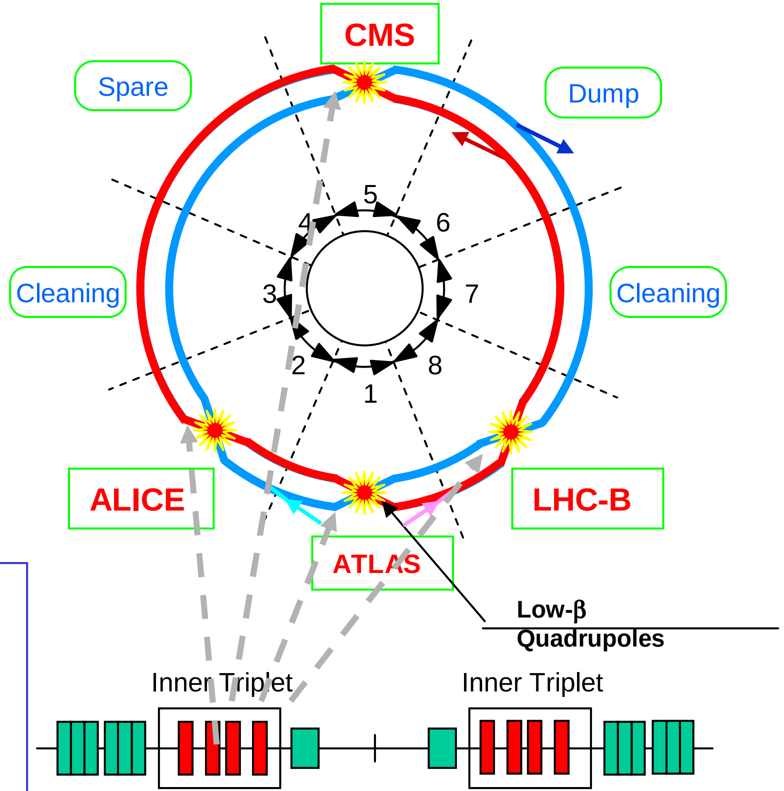
MAGNET DEVELOPMENT Chair : Jean-Michel Rifflet	
14h00 14h30	Neurospin/Iseult Cryogenics Philippe Brédy, CEA Saclay
14h30 15h00	Update on J-Park project Nobuhiro Kimura, KEK
15h00 15h30	Update on Nb3Sn Quadripole project Maria Durante, CEA Saclay
15h30 15h45	Coffe Break
15h45 16h15	Developpement of the ceramic Insulation for accelerator magnets Françoise Rondeaux, CEA Saclay
16h15 16h45	Design study of 15 T superconducting magnet with Nb3Al cable in KEK Ken-ichi Sasaki, KEK
16h45 17h15	R3B-Glad Cryogenics Jean-Pierre Lottin, CEA Saclay

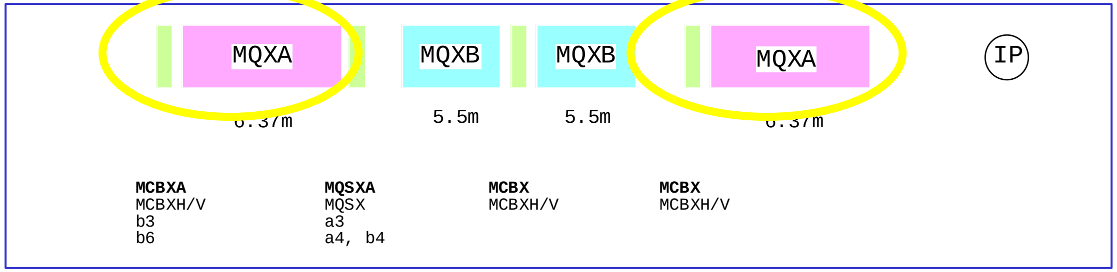
CERN-LHC IR Quad. Inner Triplet Being Commissioned

G = 215 T/m,
Aperture = 70 mm (Radius = 35 mm)
Higher Order Multipoles < 1 unit (10^{-4})

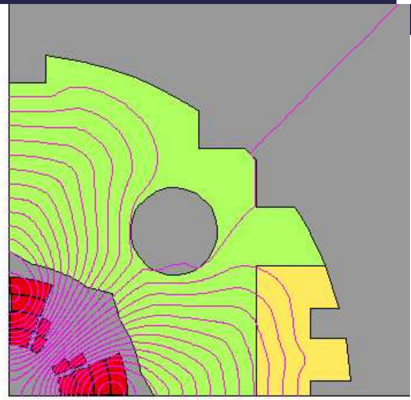
Beam Heating: 5 ~ 10 W/m

A Part of Japanese Contribution

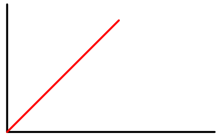


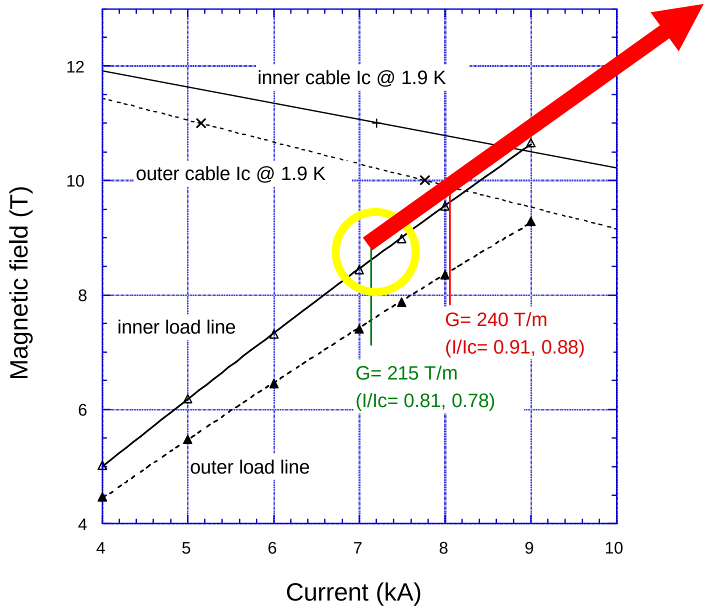


IRQ Upgrade required for luminosity Upgrade

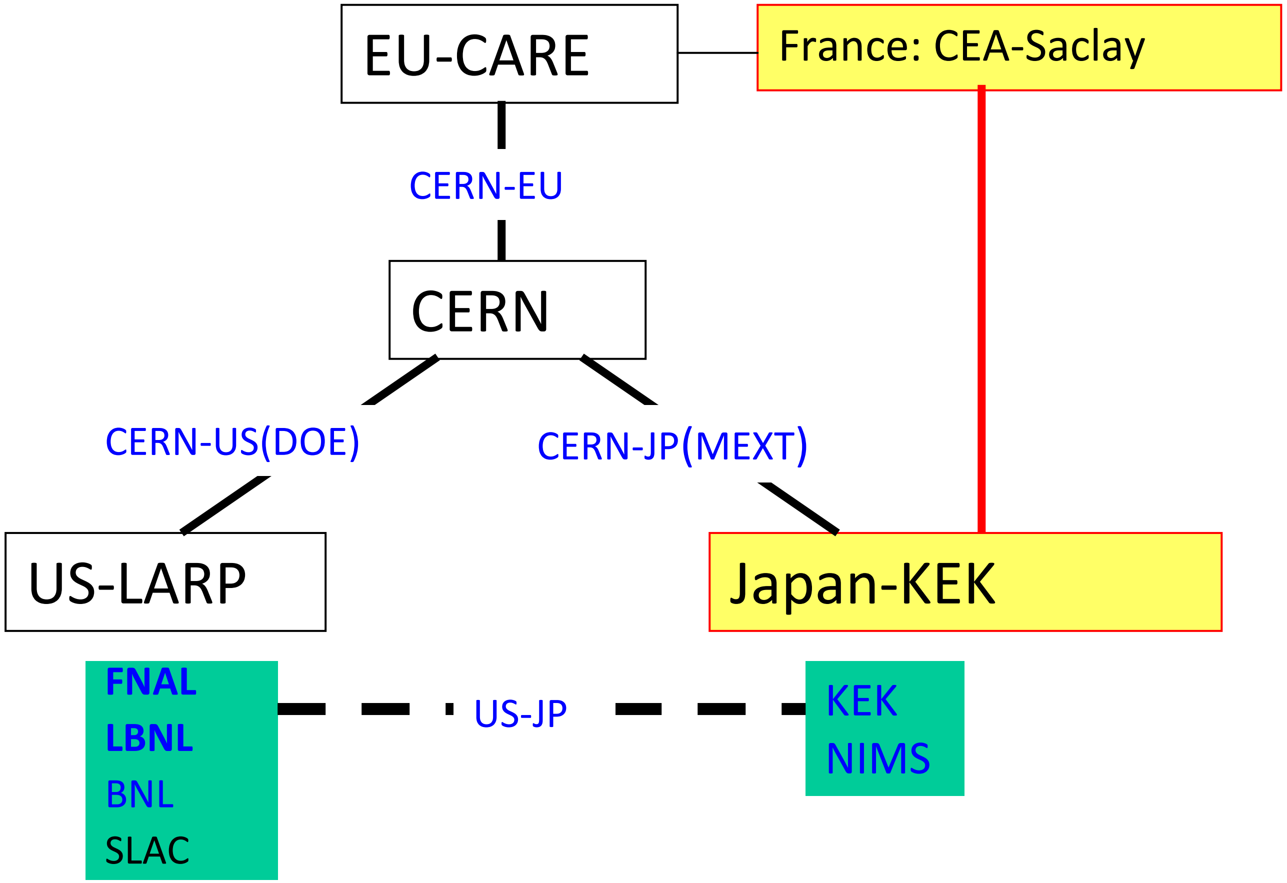


Parameters	LHC start--> Upgrade
Field gradient	215 T/m --> 250 T/m
Coil inner radius	35 mm --> 50 mm
Yoke outer radius	235 mm
Magnetic length	6.37 m
Peak field in coil	8.63 T --> ~ 15 T
Current	7149 A
Superc. load-line ratio	80 %
Inductance	87.9 mH
Stored energy	2.24 MJ
Mag. force/pole (octant)	
Fx	1.19 MN/m
Fy	-1.37 MN/m





A Global Cooperation Network



Objectives

- High-field superconductor and cable beyond 15 T,
  - Nb3Al conductor with Ta matrix in progress
- Model coil to evaluate cable performance at 15 T ,
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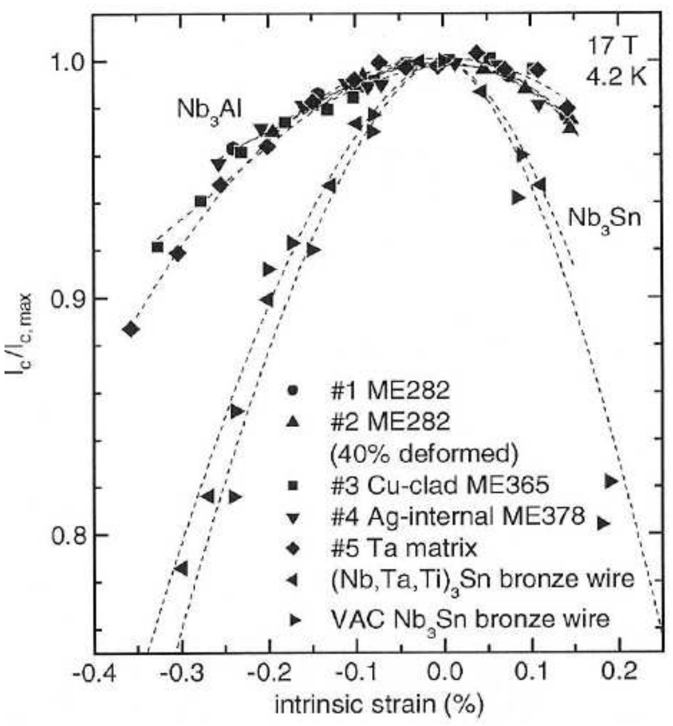
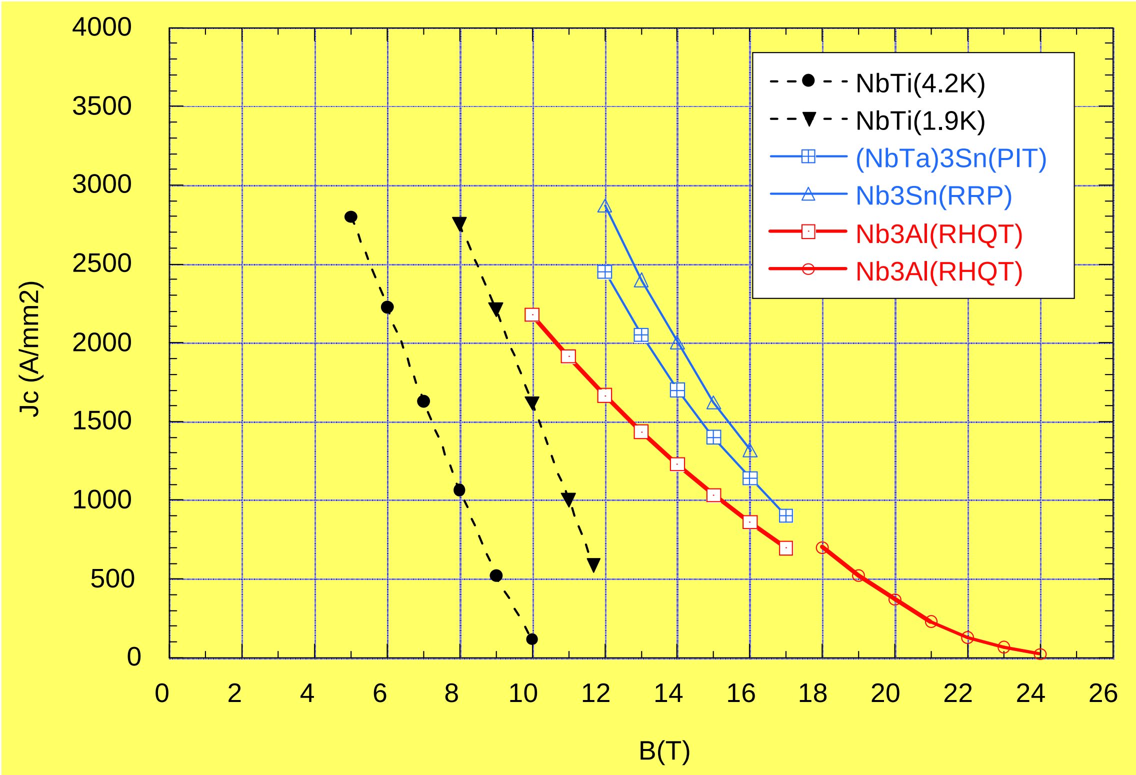
Status of Nb_3Al Development compared with Nb_3Sn



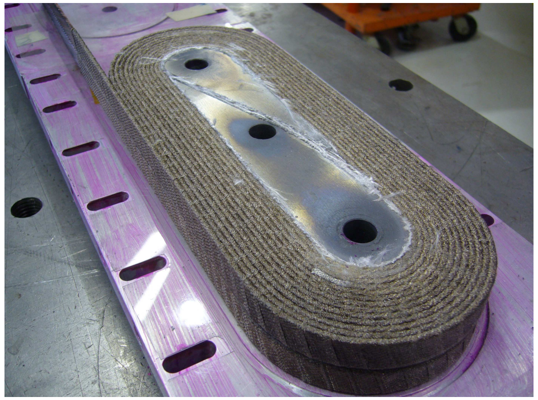
Supercond. Sci. Technol. 18 (2005) p. 284.
by N. Banno et al.



- **Stable against mechanical strain,** and potential for **"React and Wind"**
- High Jc in high magnetic field at **> 15 T**

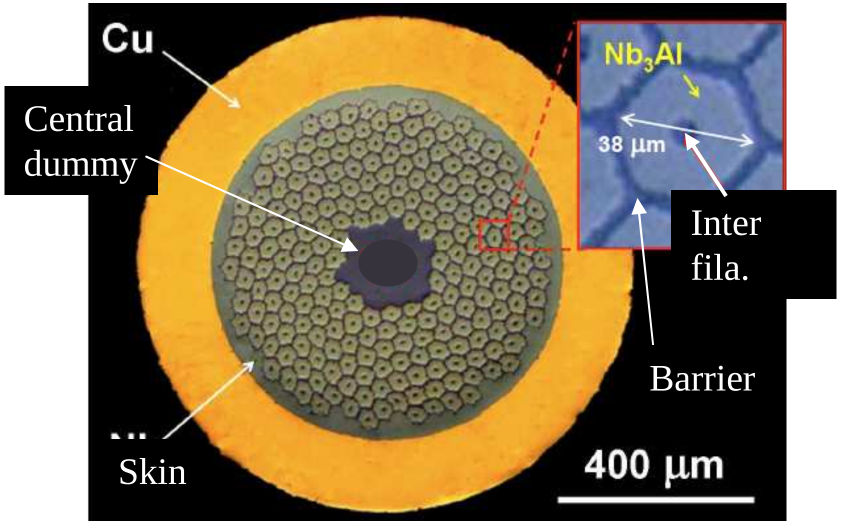
Strand/Cable R&D

- **Strand**
  - Highest Jc : 1021 A/mm^2 @ 15 T
  - Develop the continuous Cu electro-plating apparatus
- **Cable**
  - Succeed the trial fabrication
    - Rutherford cable
    - Small racetrack magnet (@Fermi Lab)
      - Peak Field : 9.3 T @ 21.8 kA, 3.95 K



New strands & cable -> In progress

KEK: All Tantalum matrix/barrier
NIMS: Tantalum barrier
Niobium matrix



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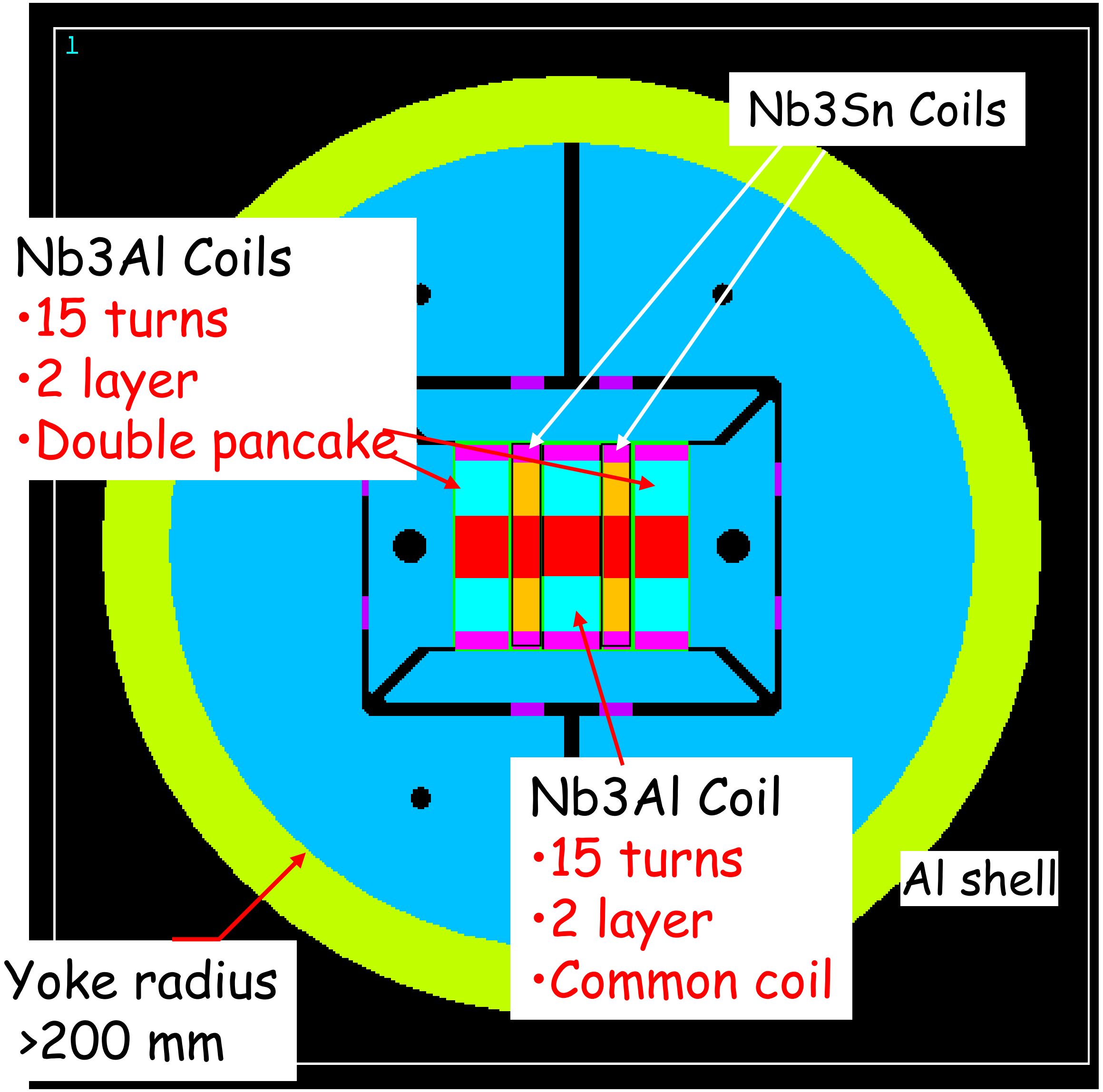
2D Magnetic Design



- Cable parameters
  - Strand Dia. : 1mm
  - Cu ratio : 0.75
  - non-Cu Jc = 873.8 A/mm2 @ 15 T
  - Cable insulation 0.25mm
  - No. of Strands : 27

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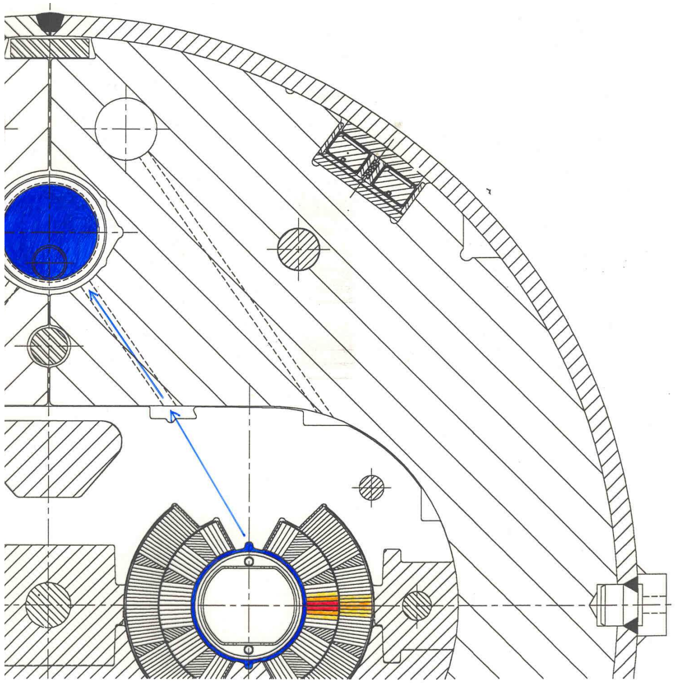
Heat transfer in accelerator magnets (1/2)

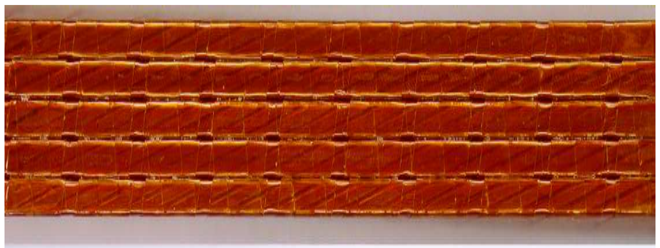
- "Wet" magnets with "heat exchanger"
  - Large internal losses and smaller stored energy
  - Single phase coolant in contact with conductor
  - Cooling Source: Internal tube flow heat exchanger

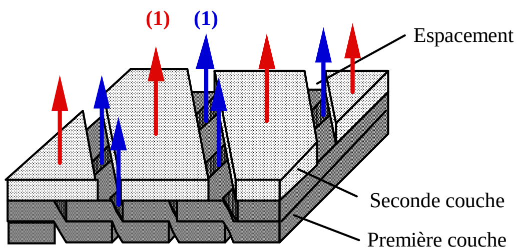


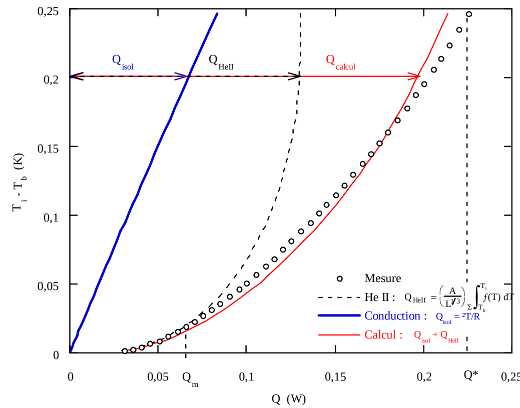
- Heat transfer between the conductor and the cooling source determines the temperature margin

- Electrical insulation constitutes the largest thermal barrier

- LHC Electrical Insulation : All-polyimid
  - 10 mW/cm^3 or 0.4 W/m (cable)
  - **ΔT<0.3 K with permeable insulation or** ΔT~4 K with monolithic insulation
  - **He II + Conduction**







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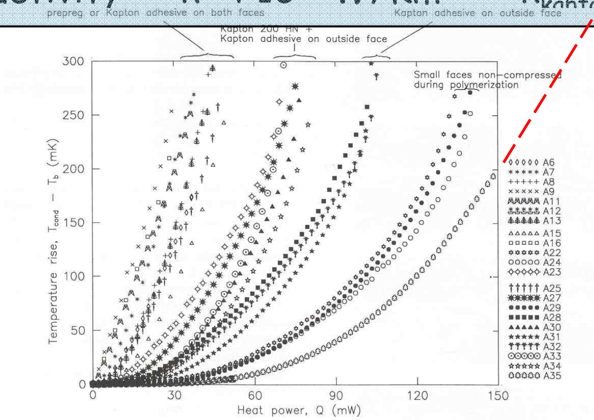
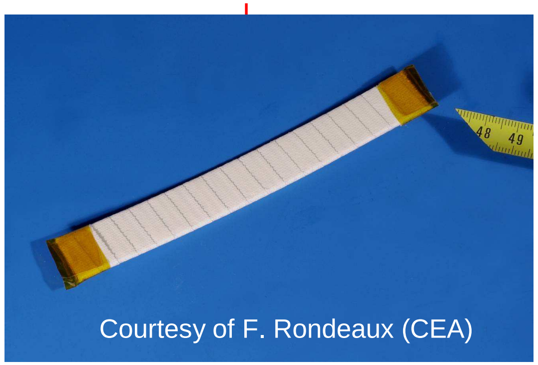
Heat transfer in accelerator magnets (2/2)

- "Beam losses" of LHC upgrade with Nb_3Sn Magnets
  - 50 to 80 mW/cm^3 or 2 to 3 W/m (cable) → ΔT~ K with polyimide insulation
  - **Dry insulation for Nb_3Sn Magnets !**
- **Development of "innovative" ceramic insulation**
  - Thermal treatment (insulation+Nb_3Sn, easier and less costly construction)
  - Fiberglass + ceramic precursor (CEA patent)
  - Higher heat transfer rate, larger He volume in the insulation (Cp) and heat exchange surface increase (matrix participation)

	Ceramic	Classic (Polyimid)	Full impregnation
Pore size	d~100 μm (peak)	10 to 100 μm	-
Porosity ε	4.5 to 29 %	~1 %	-
Conductivity	$k \approx 4\ 10^{-2}$ W/Km	$k_{kapton} \approx 10^{-2}$ W/Km @ 2 K	- $k_{epoxy} \approx 10^{-2}$ W/Km

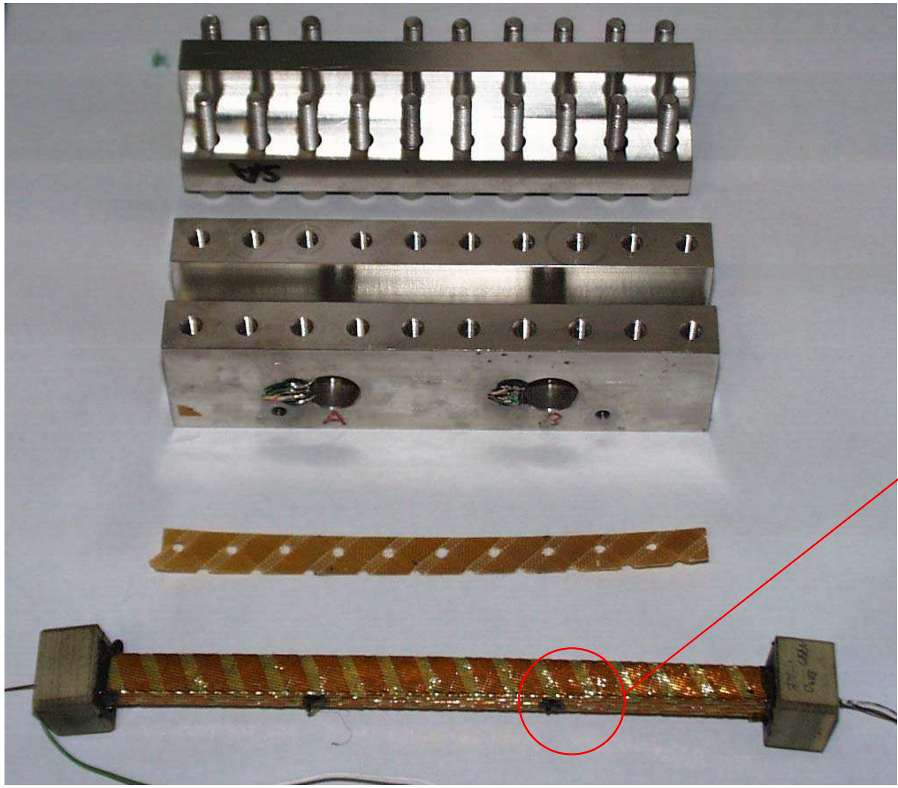


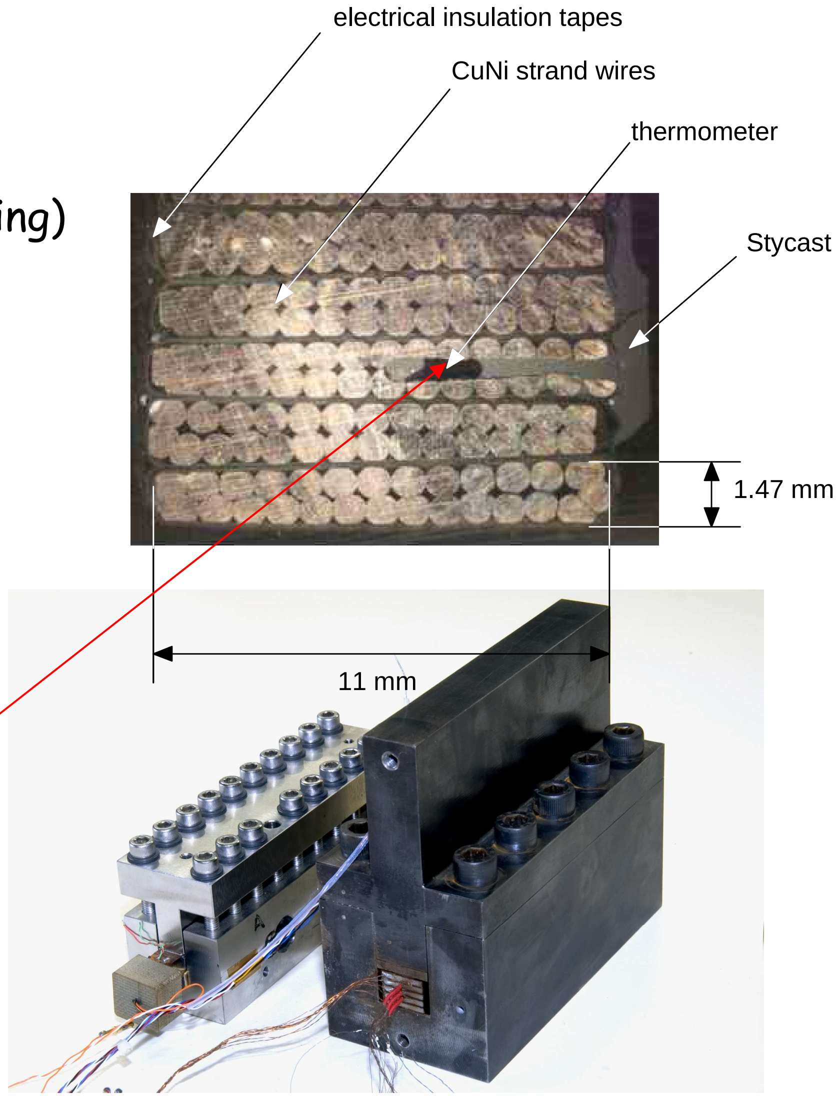


Courtesy of F. Rondeaux (CEA)

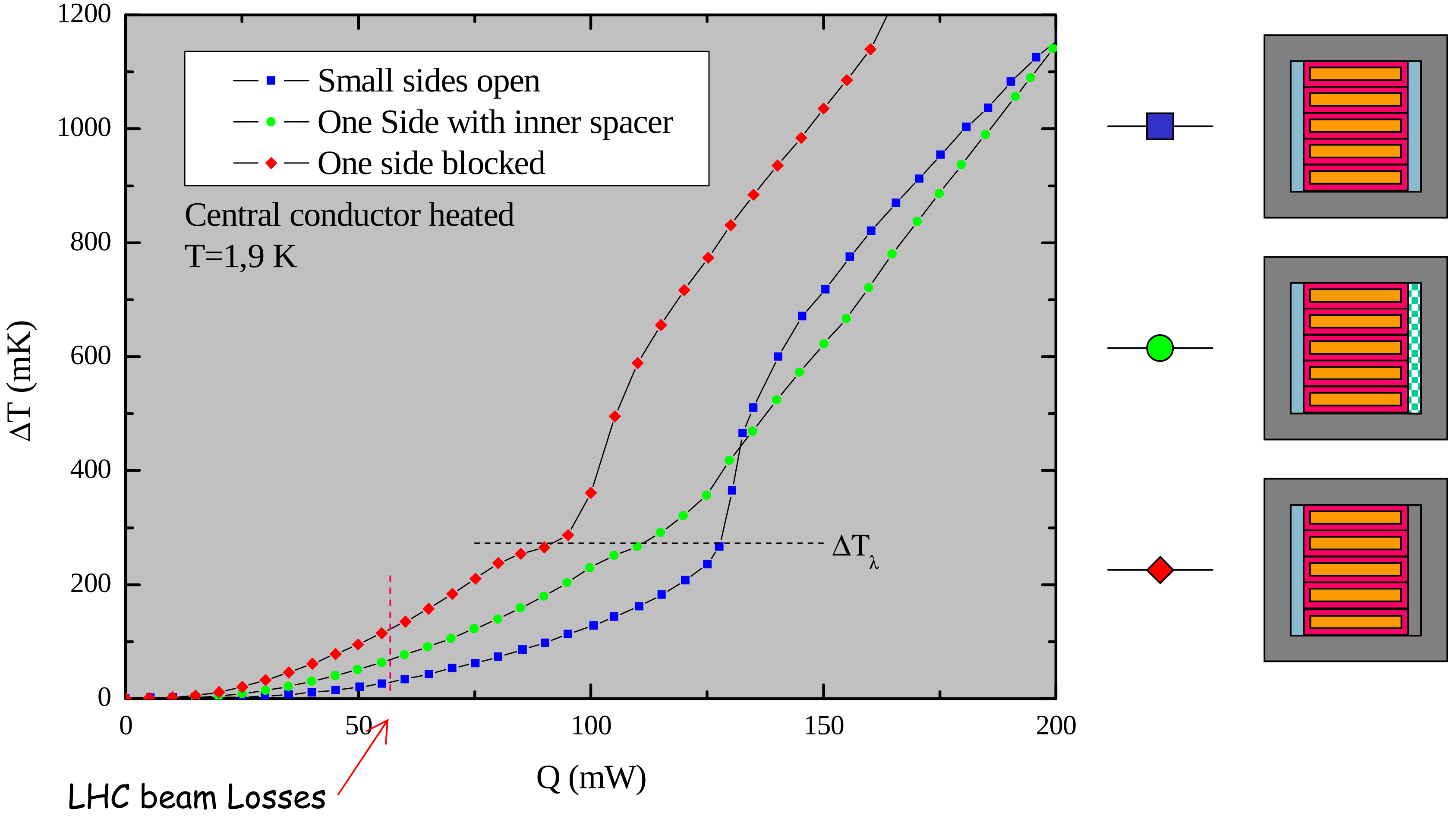
The Stack Experiment : A Common tool

- Characterization of the thermal performance of the magnet insulation
  - "real cable" geometry (CuNi cable)
  - Real electrical insulation
  - Mechanical constraints (compression)
  - Heat transfer configuration (Joule heating)



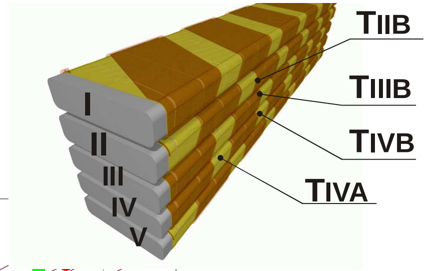


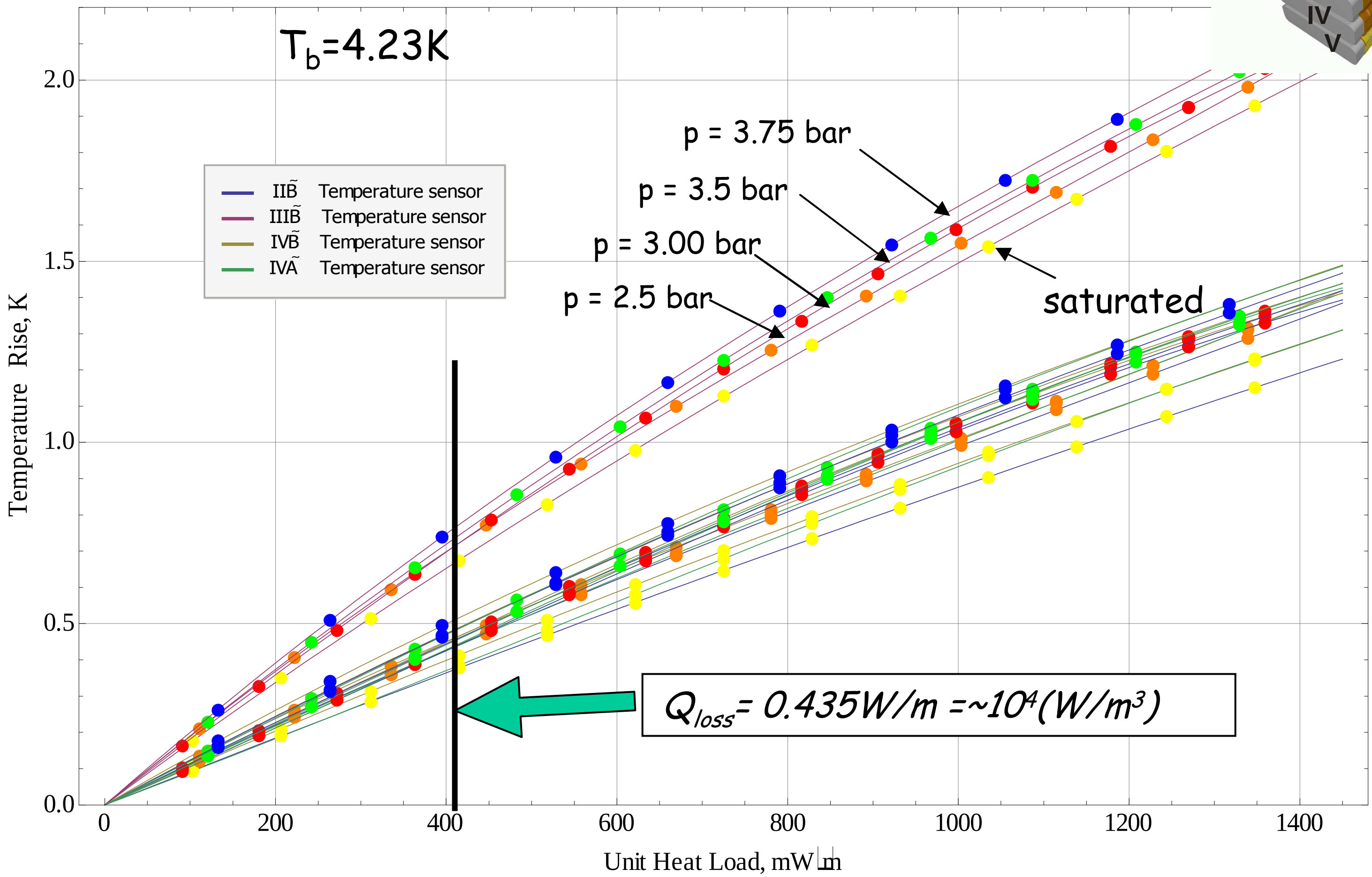
Tests of Polyimide insulation at Saclay in He II



Tests of polyimide insulation at KEK in He I and HeS

- Tests done by S. PIETROWICZ from WUT and N. KIMURA (KEK)

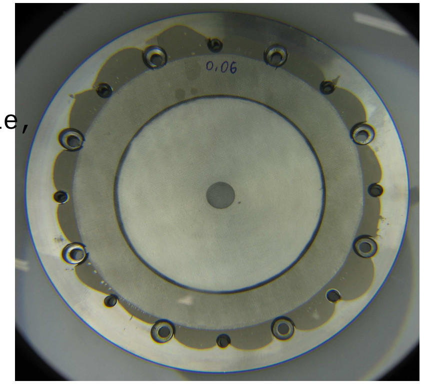


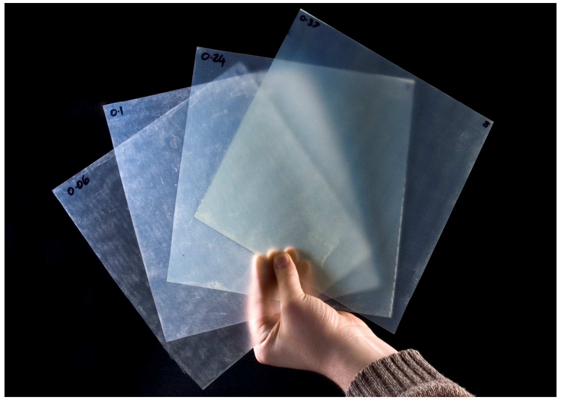


Tests on the Glass-fibre epoxy insulation

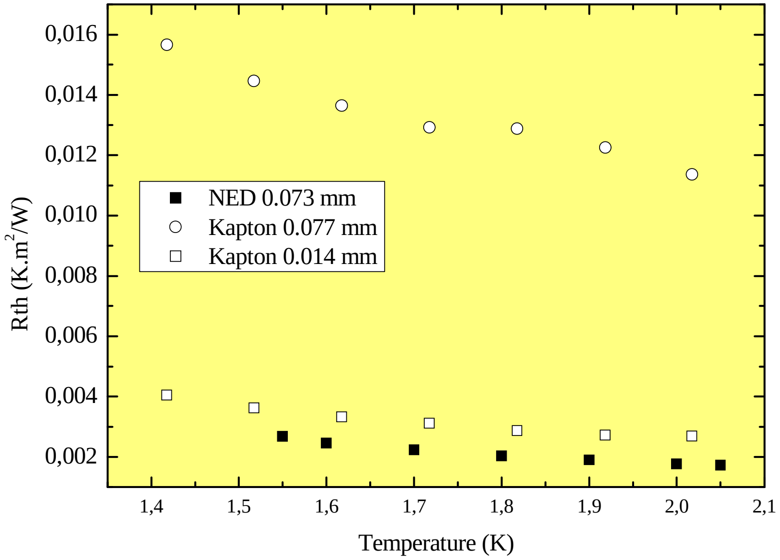
- Glass-fibre epoxy insulation
  - Developed by RAL

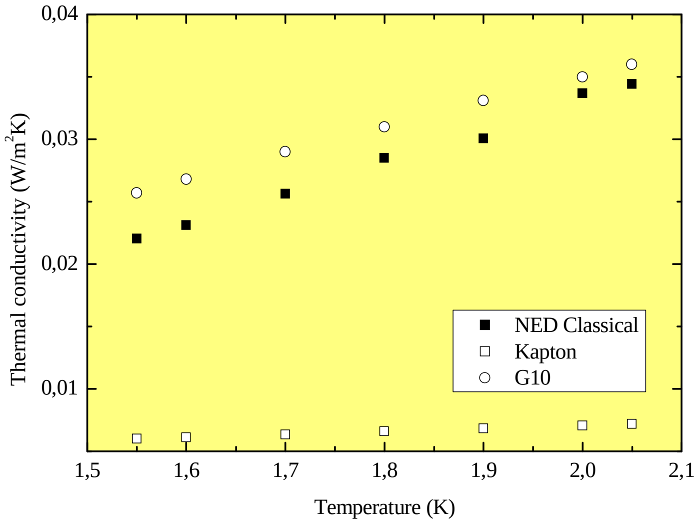
Insulation Development for the Next European Dipole, S. Canfer *et al.*, MT20, Philadelphia, USA, 2007





- Determination of Λ and R_{Kapiza}
  - To be published

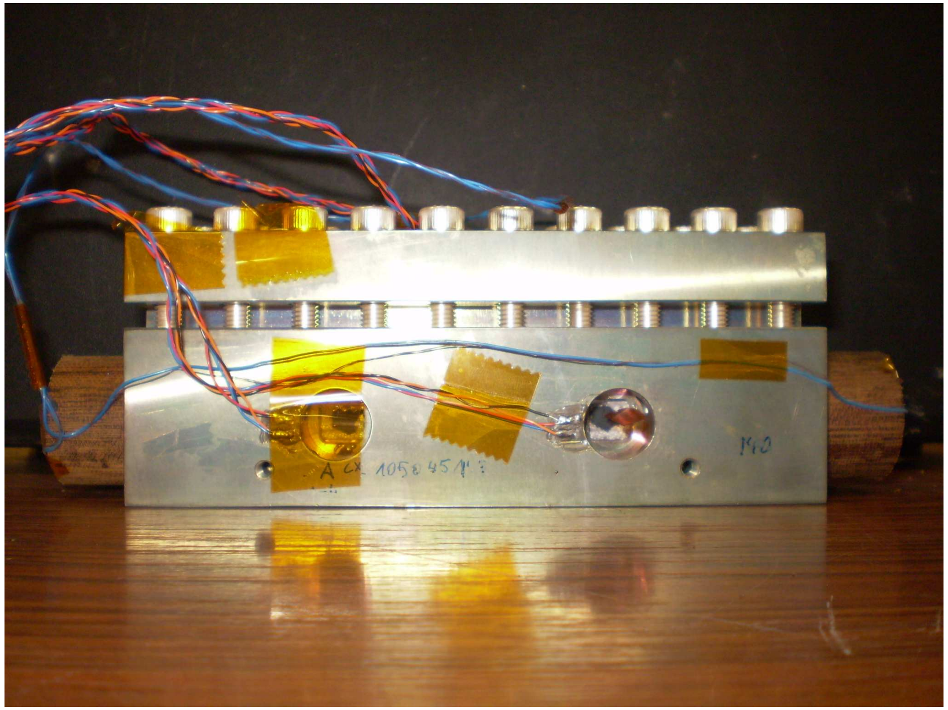


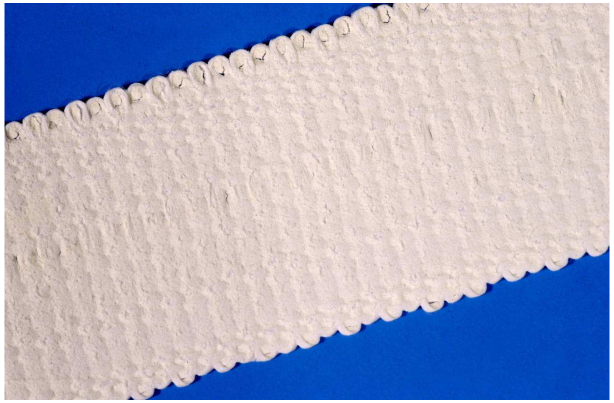


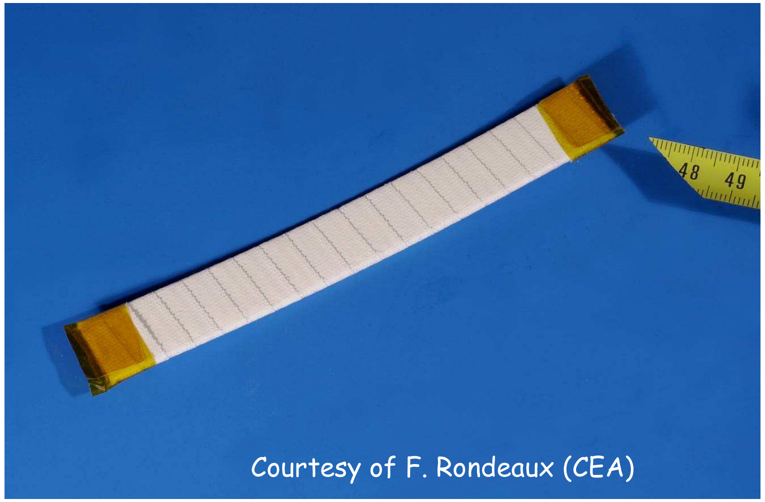
Low temperature heat transfer properties of conventional electrical insulation for the Next European Dipole, J. Polinski *et al.*, CEC 2007, Chattanooga, USA, 2007

Tests on the innovative insulation at Saclay

- One wrapping with 50% overlap
- Heat treatment of 100 h at 660 °C
- **10 MPa compression only !**
- 5 conductors heated
- With N. Kimura @ Saclay



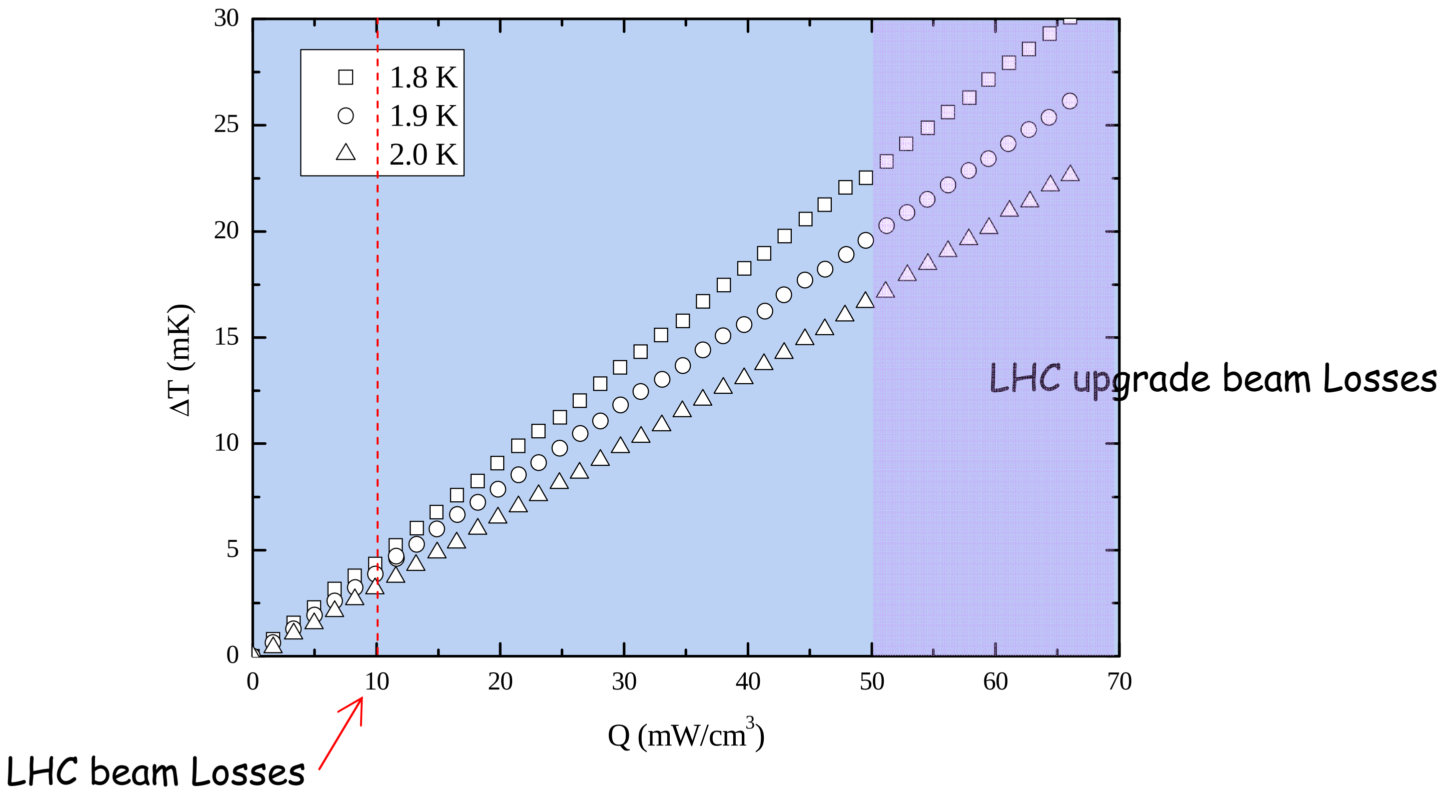




Courtesy of F. Rondeaux (CEA)

Tests on the innovative insulation at Saclay

- Very small ΔT, at least **one order of magnitude smaller** than for the LHC insulation tests



Cooperation program summary

- High Field magnet development is being carried out for interaction region magnets toward the LHC luminosity upgrade,
- Nb_3Sn quadrupole R&D in progress at Saclay , and Nb_3Al conductor development in progress at KEK, with aiming at realizing ~ 15 T or higher field magnets
- Innovative electrical insulation to be tested at KEK in supercritical helium
- A new stack model to be constructed with Glass-fibre epoxy insulation and tested at KEK and Saclay
- 3rd Workshop to be organized at KEK in 2009