LHC-3
Superconducting Magnets for the LHC Luminosity Upgrade

KEK : N. Kimura, A. Yamamoto, K. Tsuchiya, T. Ogitsu,
T. Nakamoto, K. Sasaki, Q. Xu, S. Pietrowicz*, Y. Iwamoto**

** Wroclaw University of Technology*
***JAEA, Tokai, Japan*

Irfu/CEA : B. Baudouy, J. Rifflet, M. Durante, F. Rondeaux, M. Segreti,
S. Pietrowicz*

KEK-CEA Superconducting Magnet Co-operation Program

The 3rd FJPPL workshop held at Tsukuba, May, 20-21, 2009

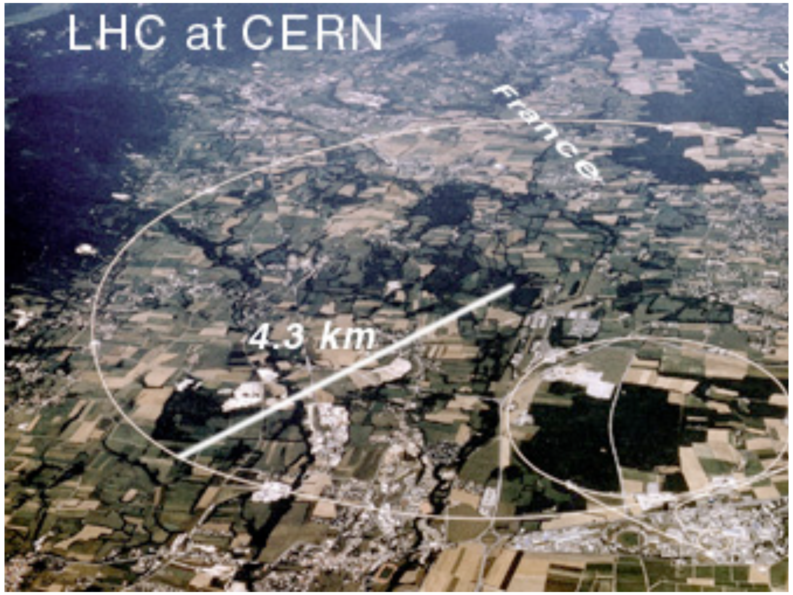
Objectives

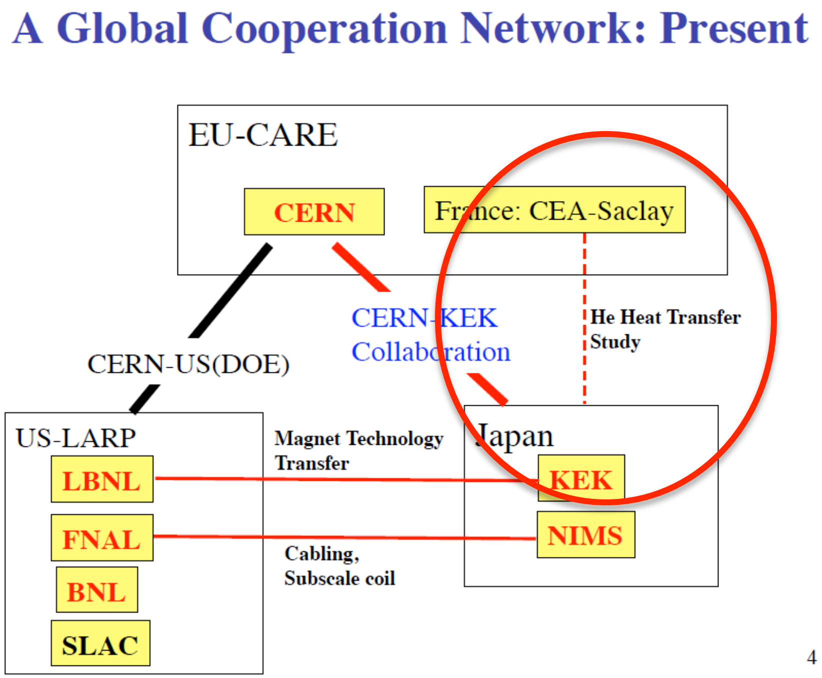
For LHC luminosity upgrade, Cryogenic Science Center of KEK and Irfu/CEA have started a collaboration on :

- Model coil to evaluate cable performance at 13 T,
  - A common coil magnet design using Nb3Sn and Nb3Al in progress at KEK
- Heat transfer through electrical insulation in LHe
  - Cooperative work for heat transfer through insulation in superfluid helium and supercritical helium

Background

LHC luminosity upgrade: Replacing the final focus system of the interaction regions with new higher performance magnets, to get a higher luminosity.
For the magnetic field: 9 T by NbTi >> beyond 12 T by Nb3Sn or Nb3Al.





Final Goal is;
To construct of high field magnet for LHC upgrade wound with Nb_3Al or Nb3Sn cable. It withstands higher beam loss compare than original magnet wound with NbTi.

The 3rd KEK-Saclay co-operation program workshop on superconducting magnets and cryogenics for accelerator frontier

KEK-CEA/Saclay workshop held on 24, March ,2009 at KEK

A workshop for the Saclay-KEK cooperation program
on superconducting magnets and cryogenics for accelerator frontier,
to be held at KEK, Mar. 24, 2007

9:15~9:30 A. Yamamoto, Opening remark

SC magnet Development (chair Yamamoto)
9:30~10:00 F. Rondeaux, Ceramic insulation for Nb3Sn accelerator magnet
10:00~10:30 M. Durante, The SAFIRS project overview (European funded accelerator magnet development for the upgrade of LHC at Saclay
10:30~11:00 K. Tsuchiya, NbAl developement
11:00~11:15 Yamamoto, discussion

J-PARC (chair Kimura)
11:15~11:45 Y. Makida, Nu-Cryogenics system
11:45~12:15 K. Sasaki, Nu-Magnet system

12:15~14:00 lunch (go out side KEK, arrange Kimura, booked traditional Japanese food restraint in Tsukuba city)

Future project in Japan (chair Makida)
14:00~14:30 Adachi, Study of superconducting solenoids for high intensity muon beam lines
14:30~15:00 H. M. Shimizu, Cryogenics for Neutron Fundamental Physics

15:00~15:15 Coffee Break

Cryogenics (chair Kimura)
15:15~15:45 B. Baudouy, Cryogenics R&D for future accelerator magnet
15:45~16:15 S. Takada, The hydrodynamic and heat transfer characteristics of film boiling modes in He II
16:15~16:30 Kimura, discussion

16:30 Yamamoto Closing

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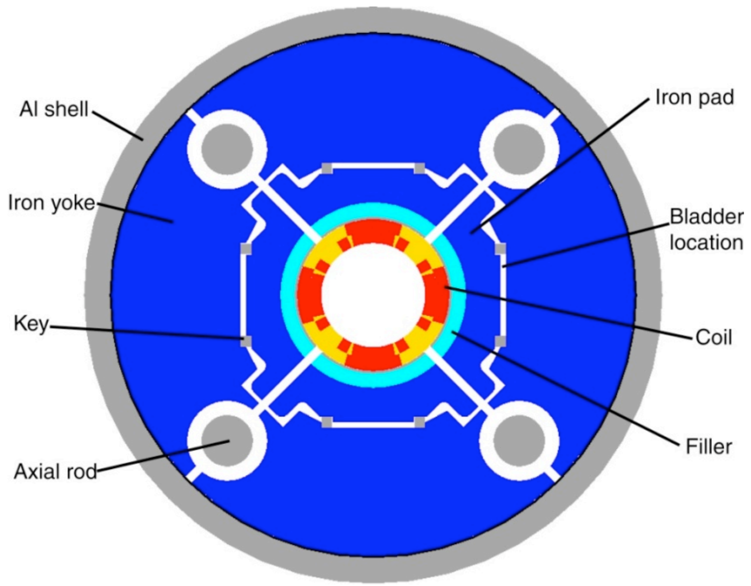
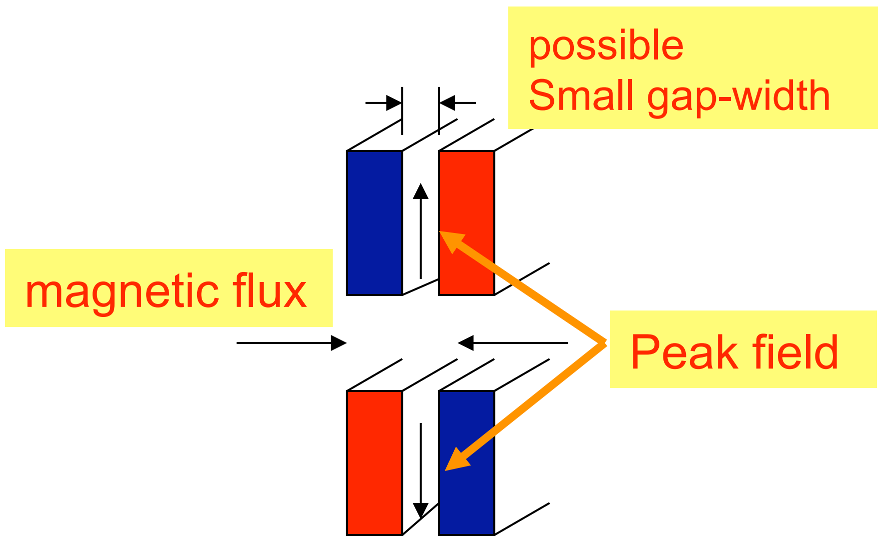
Background – Basic design concept

Shell Structure - Easy to assembly



- Pre-stress + thermal stress of Al shell to overcome Lorenz force
- Pre-stress is applied with bladder

Common coil configuration

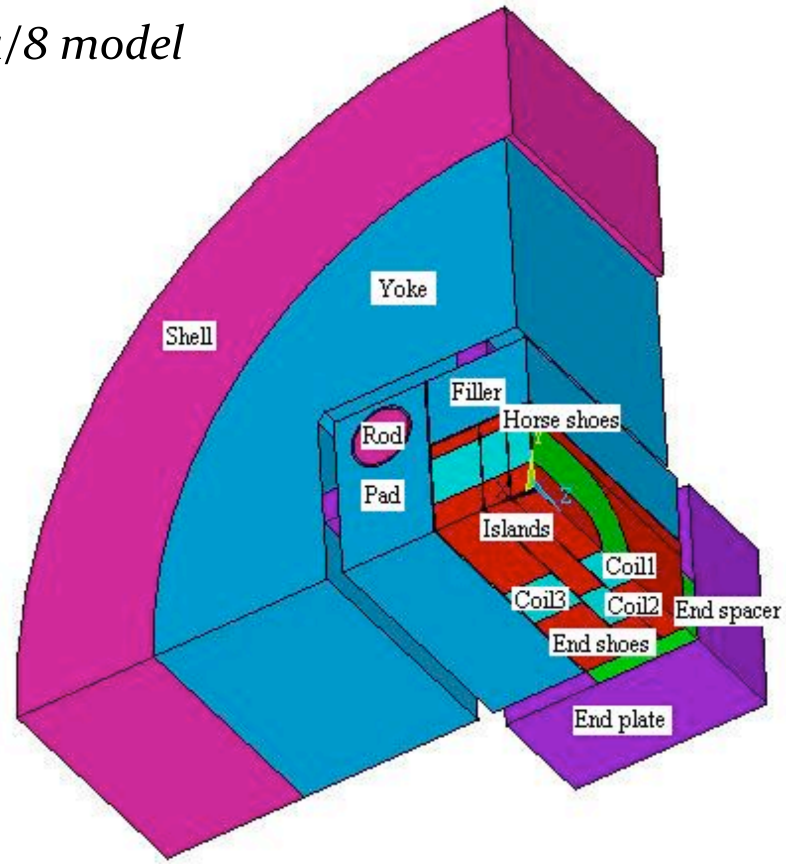


- Easy to realize high magnetic field
- With race-track coil structure, easy to fabricate

Structure and key parameters

Operation current	12.2kA
Peak field	13.2T
Stored energy	71.8kJ
Inductance	0.97mH
Magnet Length	740 mm
Iron Yoke Dia.	500 mm
Al Shell Dia.	680 mm
Maximum stress of the coils during excitation	90MPa
Maximum strain of Nb3Al coils during excitation	0.0024
Maximum strain of Nb3Sn coils during excitation	0.0025

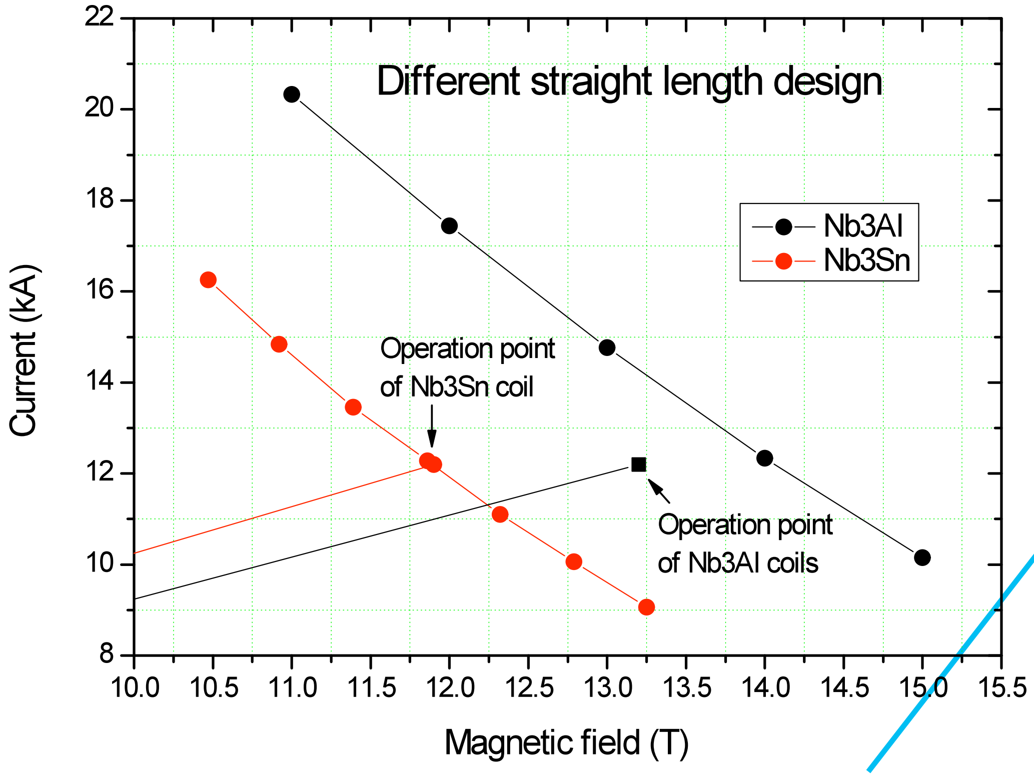
1/8 model

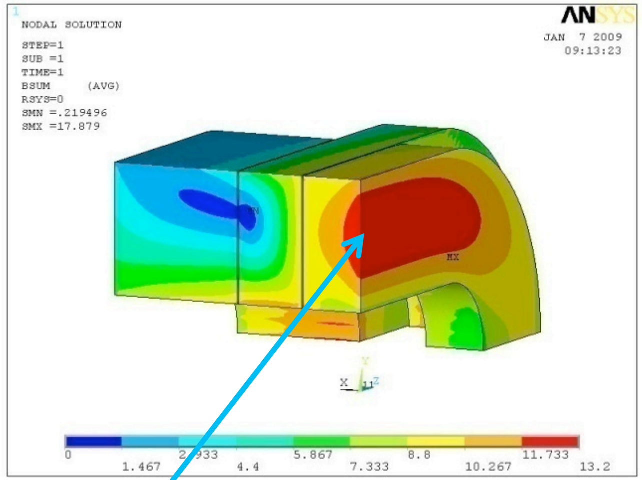


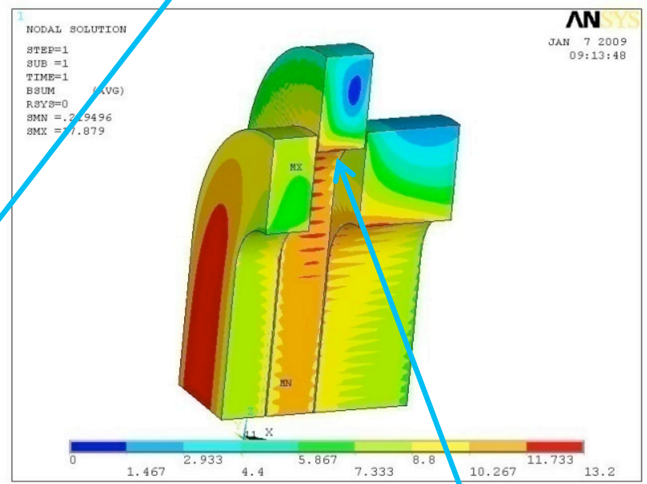
Courtesy of Q. Xu (KEK)

Magnetic field design

Reduce the straight length of the Nb3Al coils







The peak field of Nb3Al coils- 13.2T; The peak field of Nb3Sn coil- 11.9T

Courtesy of Q. Xu (KEK)

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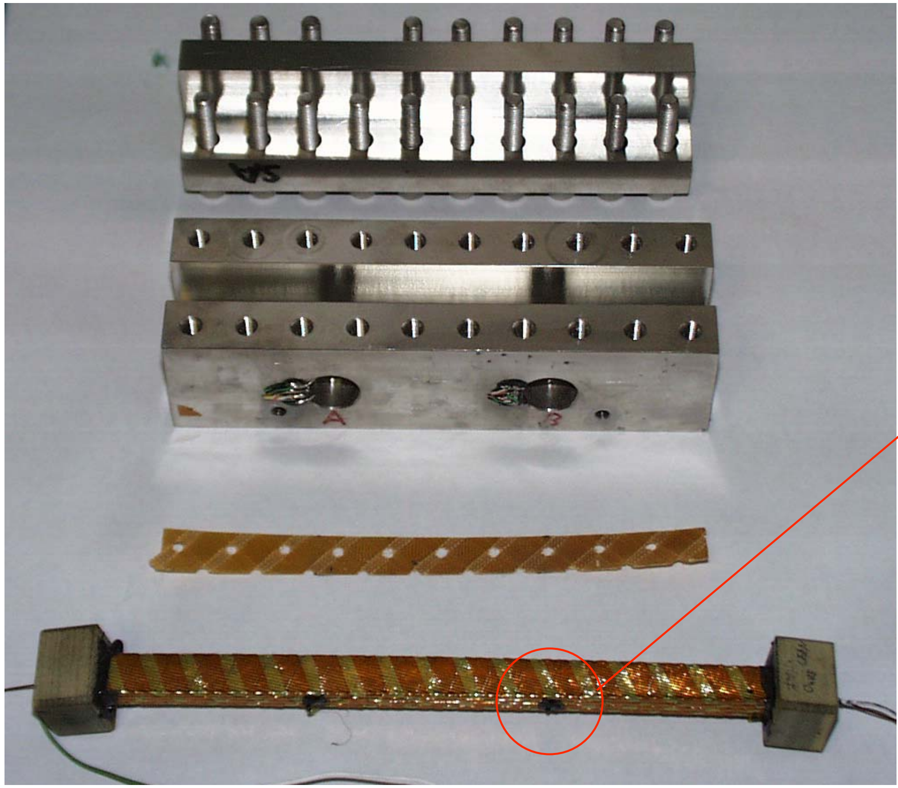
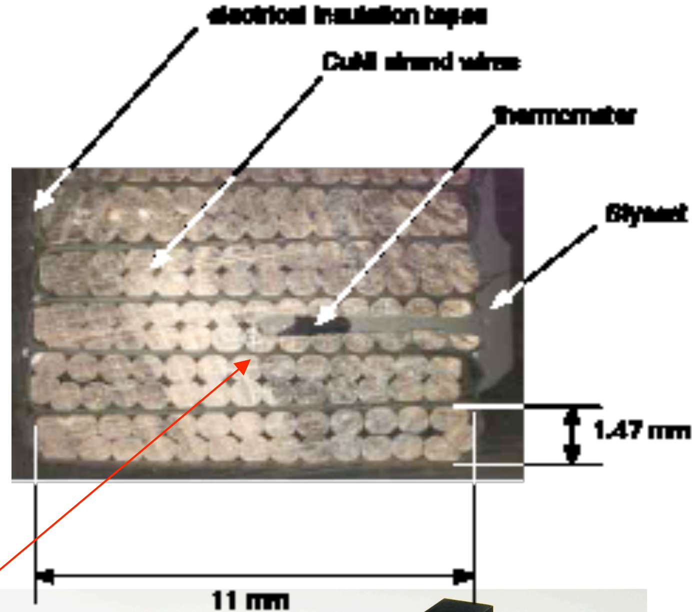
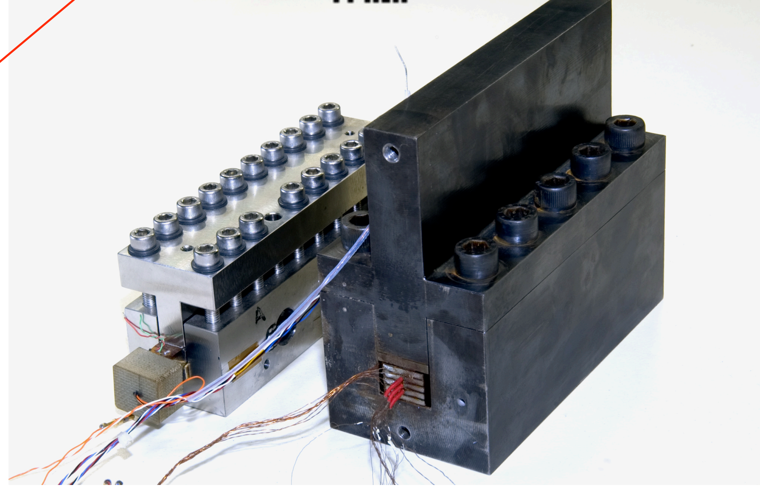
The Stack Experiment : A Common tool

- 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)

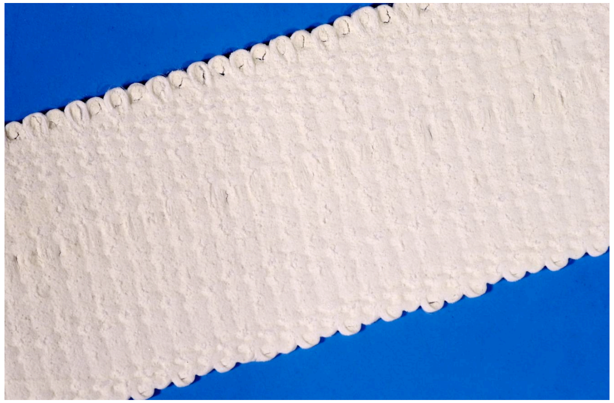


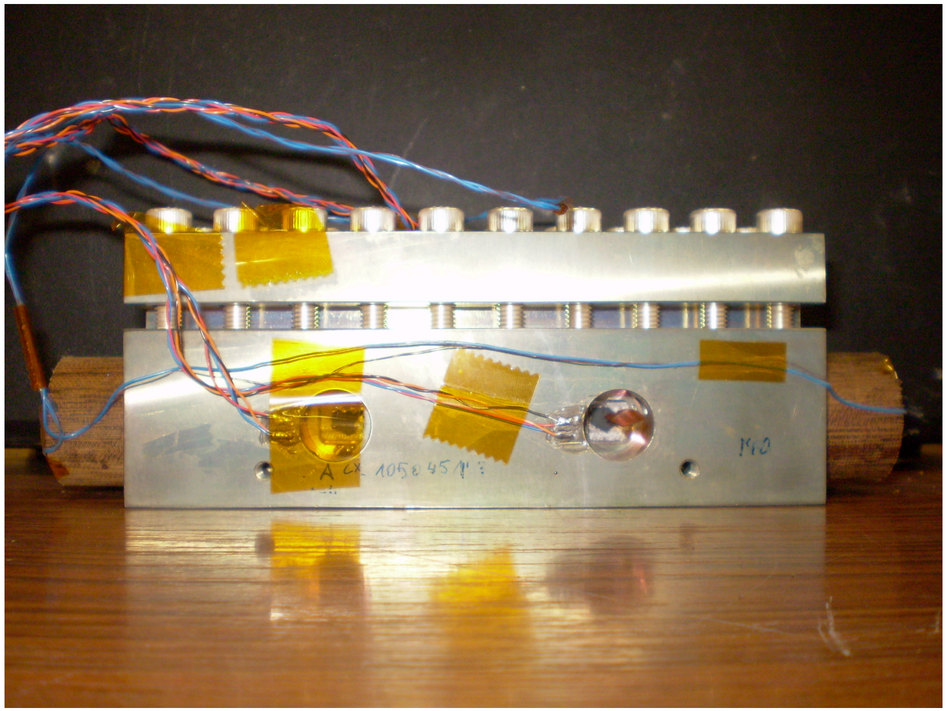


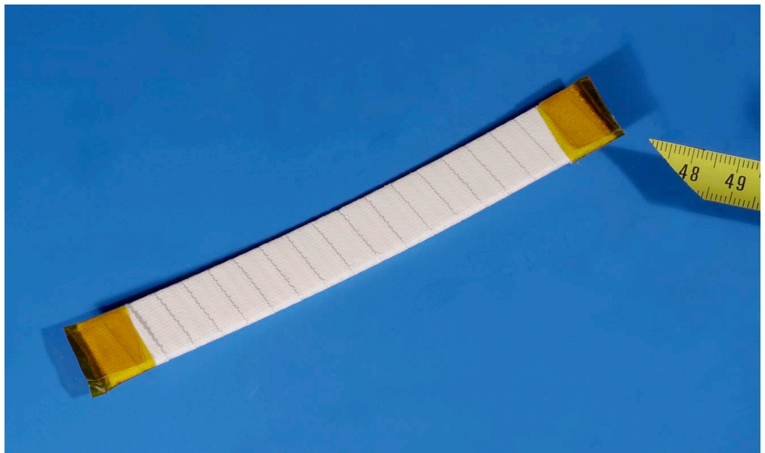


Tests on the innovative insulation at Saclay

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



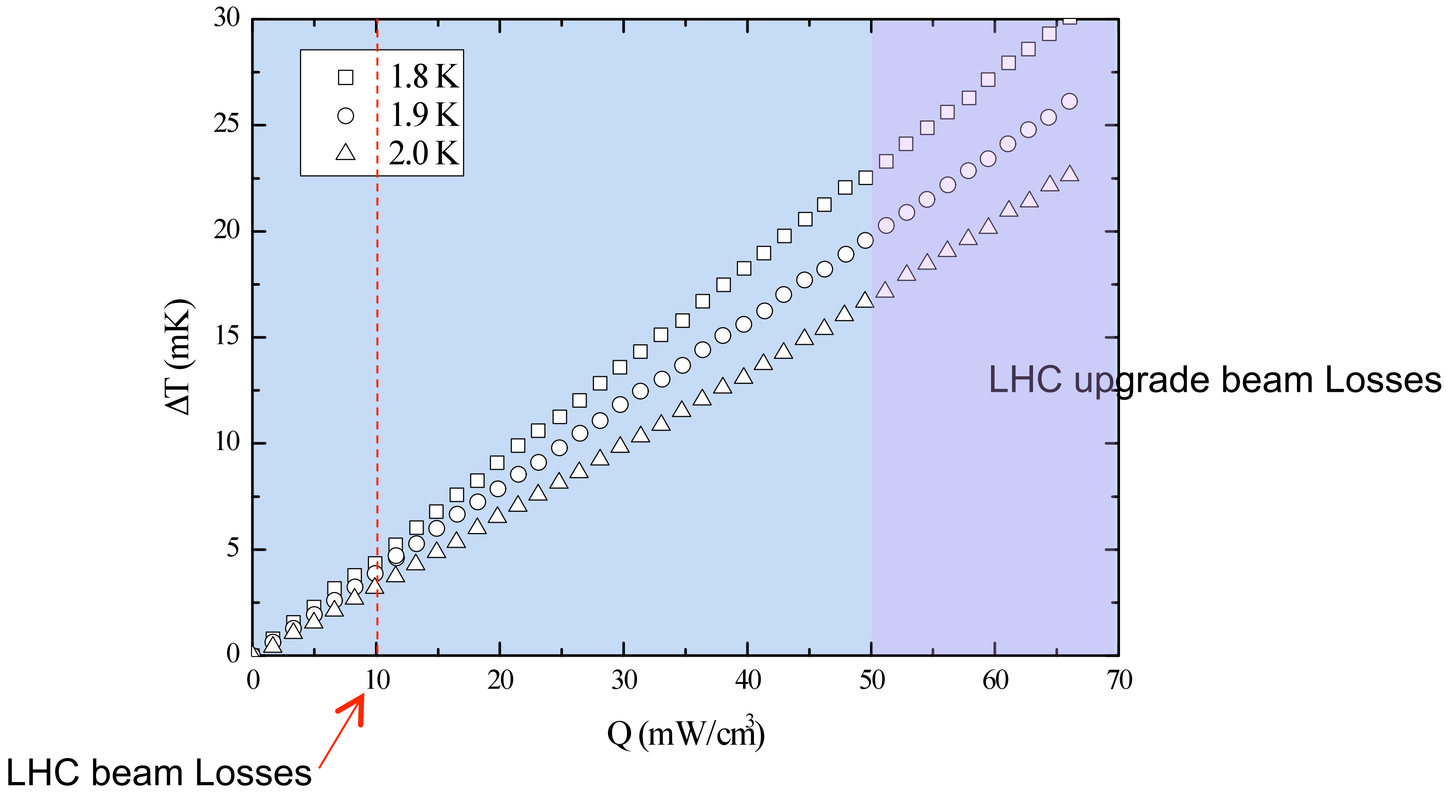




Courtesy of F. Rondeaux (CEA)

Tests on the innovative insulation at Saclay

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



Stack Experiment using Saclay stack model under SHe (An experiment result on Helium thermodynamics effect)

The heat load on superconducting magnet induced
by beam loss is a major subject to be solved
for stable operation such as J-PARC neutrino beam line.

Acceptable beam loss in view of shielding and maintenance
has to be investigated

↓

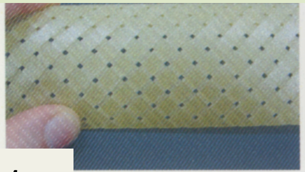
Calculate heat load for a 10 W/point beam loss
in the cable by MARS CODE

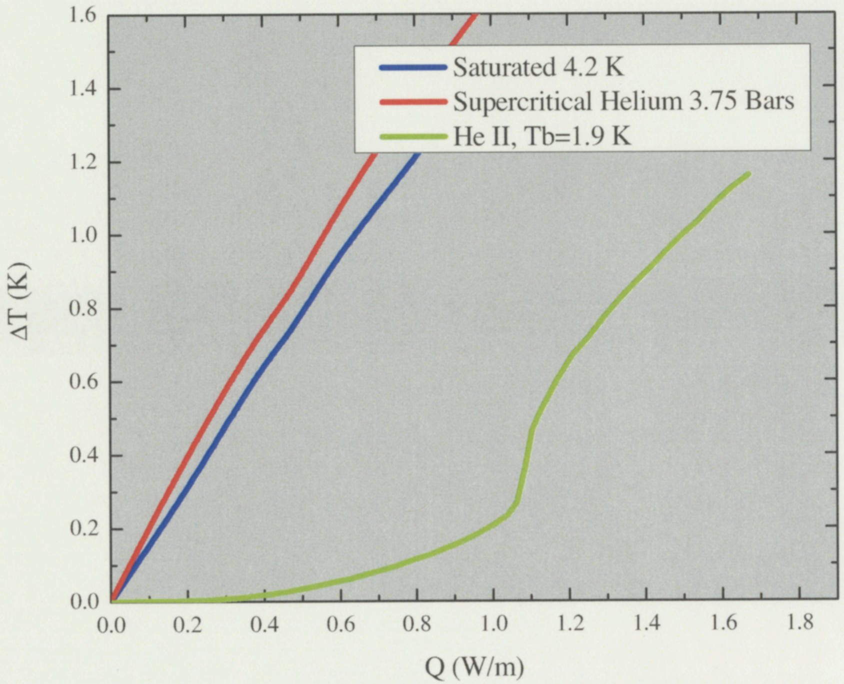
↓

Measurements of temperature rise of
the cable with a mock up model under various pressures of SHe and
saturated Helium.

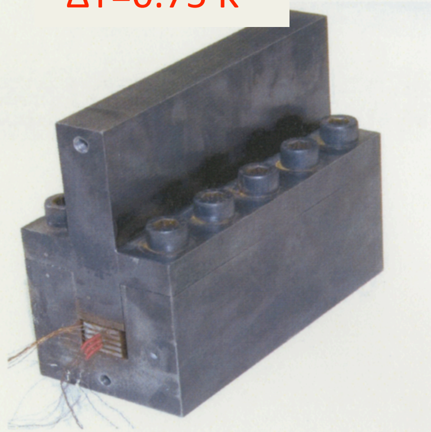
Helium thermodynamics effect

- Measurements in Saturated He I, Supercritical He I and He II
- Measurements done with the inner spacer located on one "small face"





- Q=0.4 W/m
  - ΔT=0.02 K
  - ΔT=0.65 K
  - ΔT=0.75 K

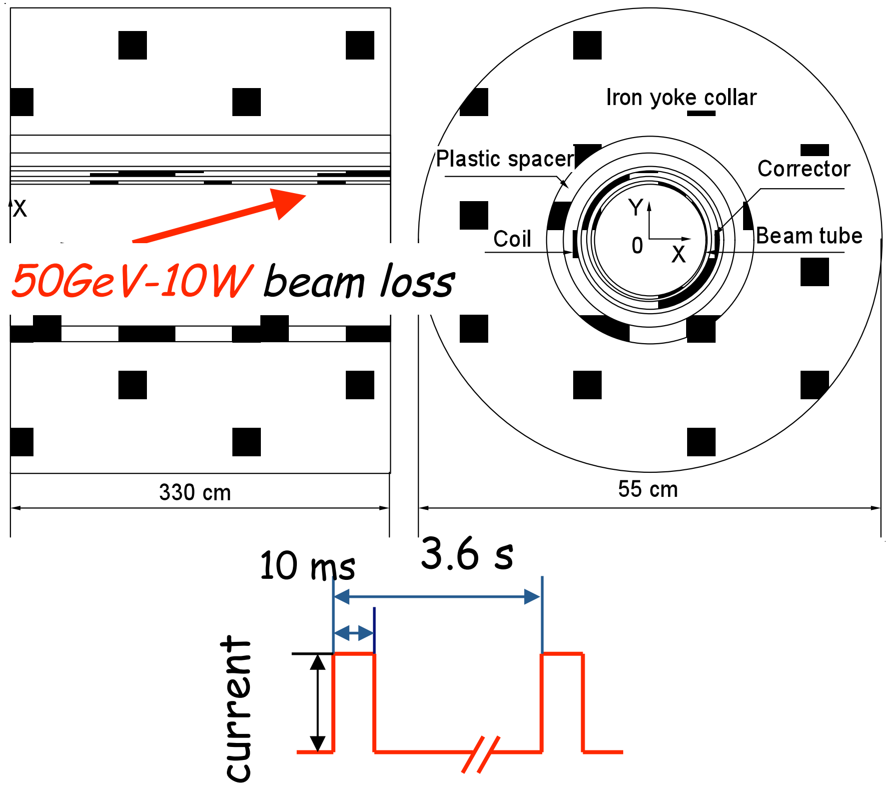


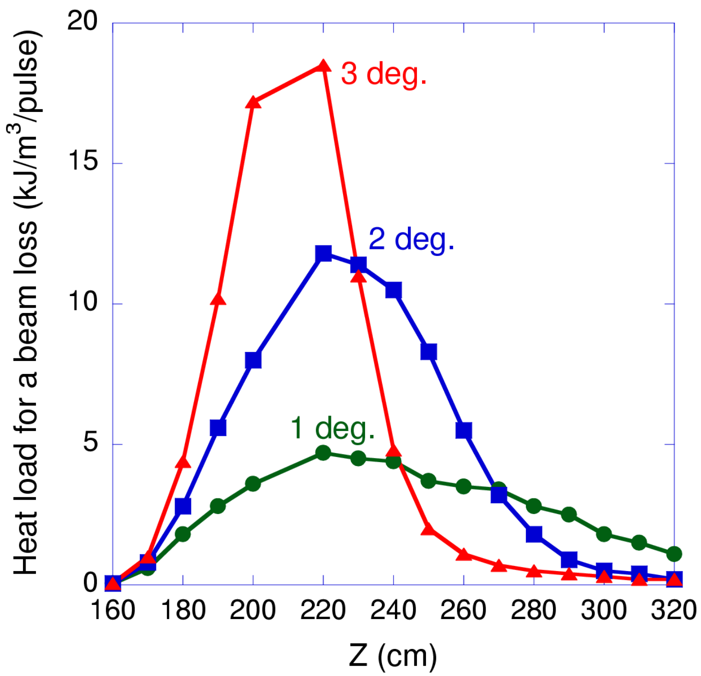
- Equivalent measurements should be performed on the porous insulation
  - Saturated He and SHe at KEK and He II at Saclay

S Pietrowicz N Kimura B Baudouy J Polinski A Yamamoto "Thermal behaviors of Rutherford type stack of cables with polyimide isolation in normal and supercritical helium" ICEC Seoul

Heat Load Simulation using MARS CODE

MARS calculates the nuclear reactions and the particle transport.

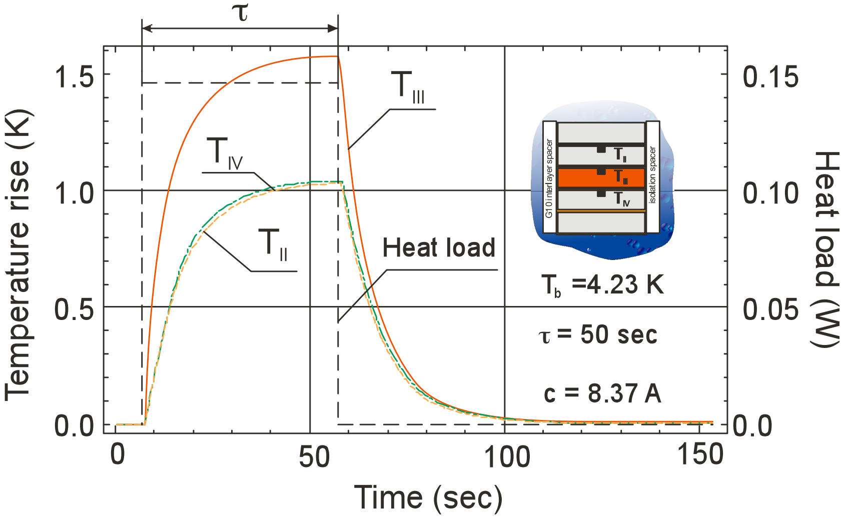




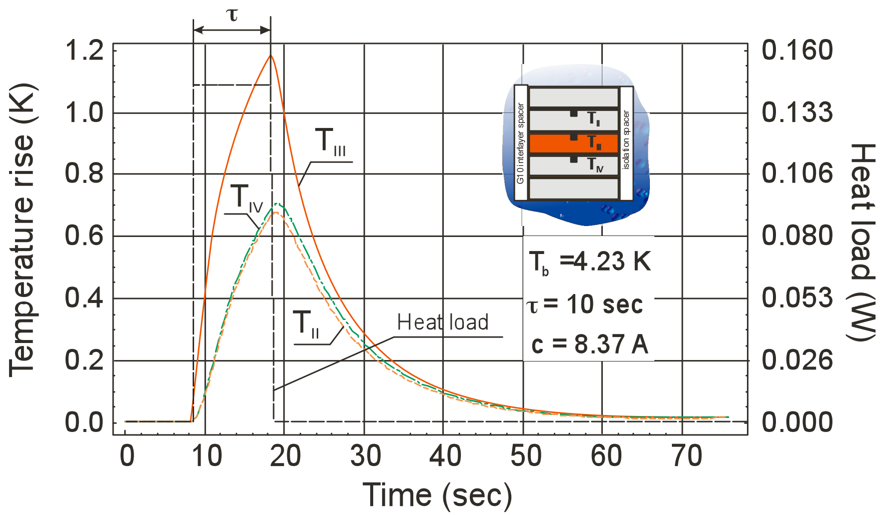
Heat load will be up to 20kJ/m³/pulse with 10 mS pulse width.
Heating of 0-~1.1MJ/m³/pulse with several pulse width
were used in experiment.

Courtesy of Y. Iwamoto (KEK)

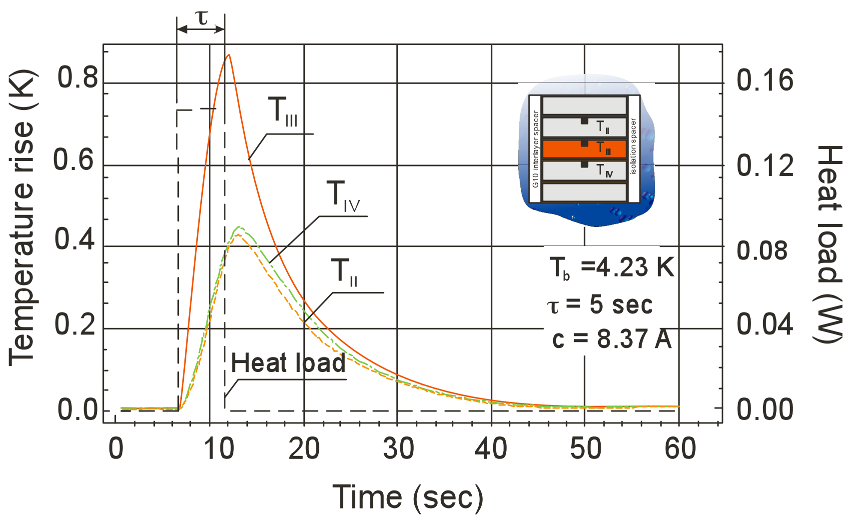
Measured heat load and temperature of conductors for different heat loads at 3,75 bar and 4.23 K



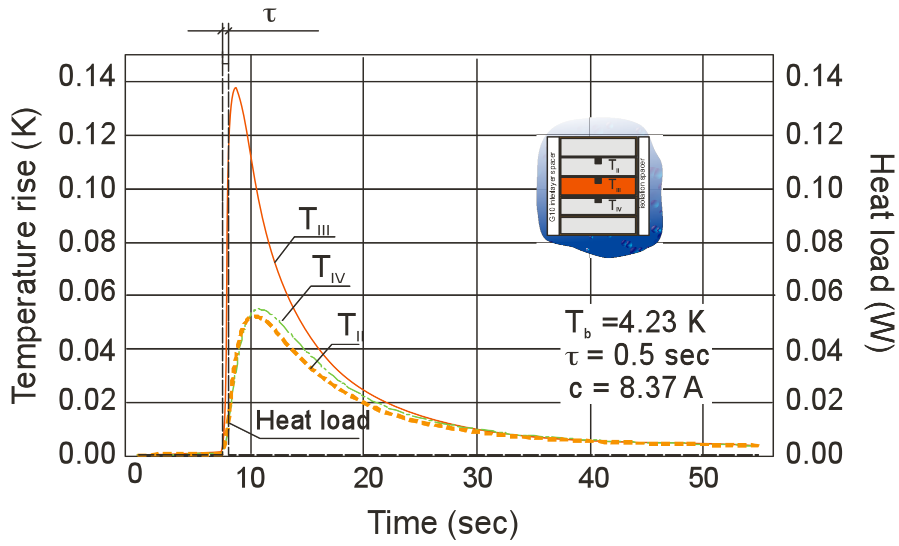
Pulse heat load – 1,122 MJ/m³/pulse



Heat load – 224,21 kJ/m³/pulse

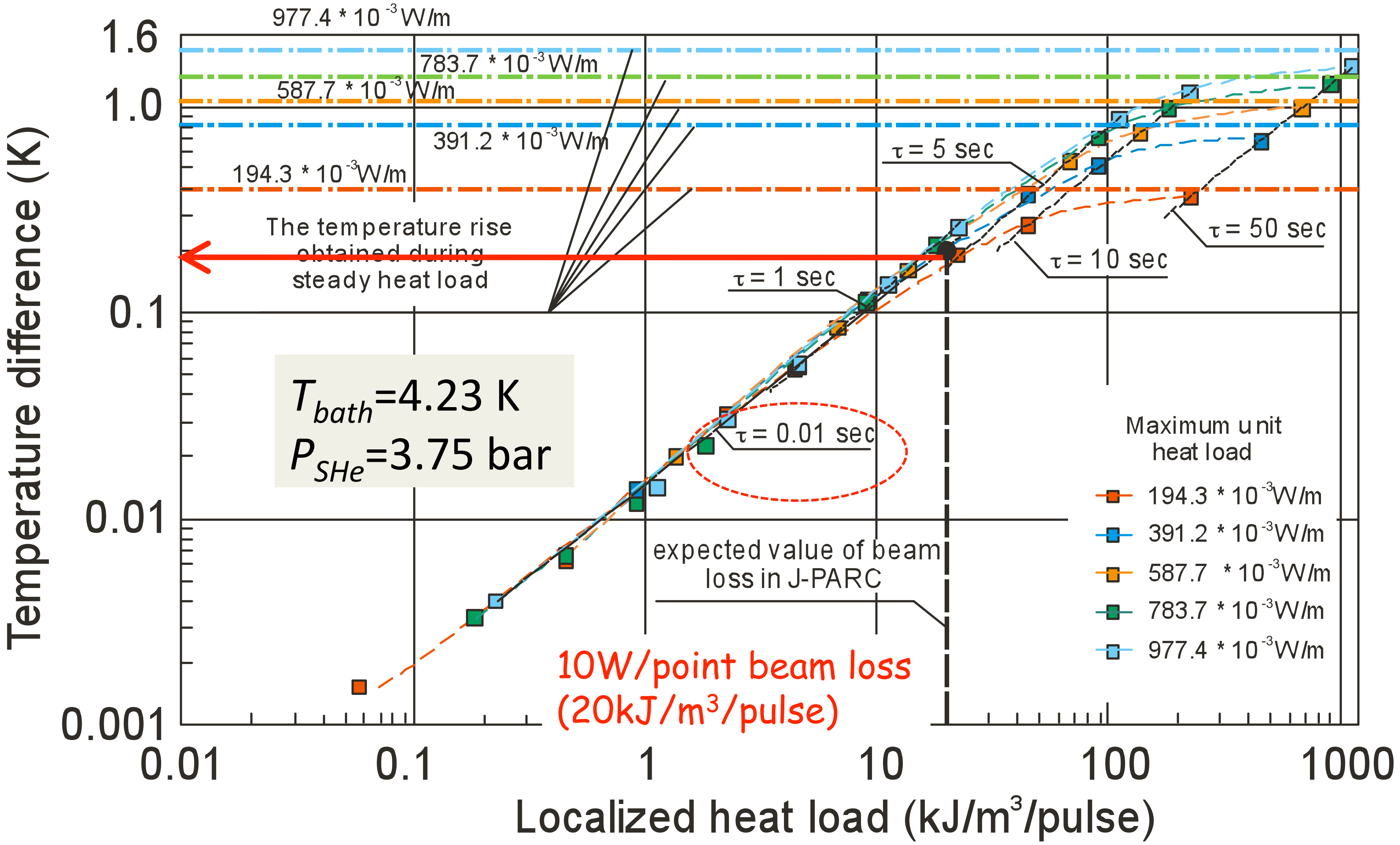


Heat load – 112,16 kJ/m³/pulse



Heat load – 11,21 kJ/m³/pulse

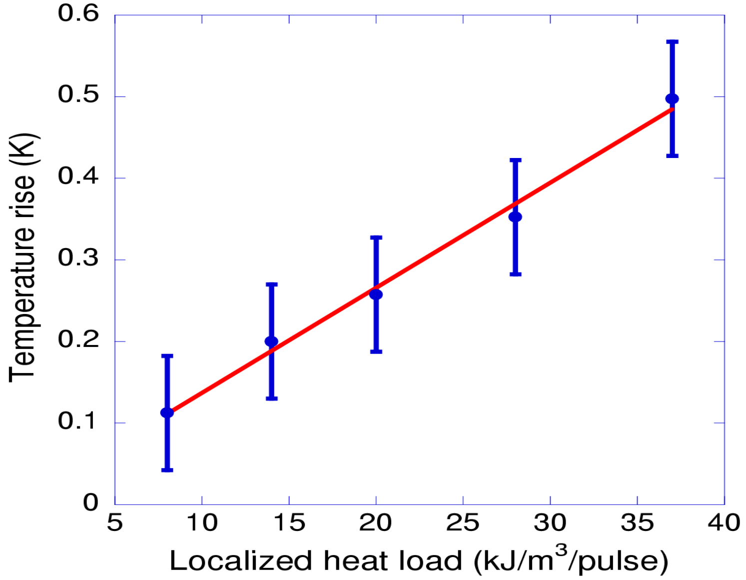
The changes of temperature in conductor III for different heat load and frequencies (SHe) (3.75 bar)



It is confirm that temp. diff. by the pulse heat loads asymptotic to steady heat load.

When heat load in coil was induced to 20 kJ/m^3/pulse,
Instantaneous temp. rise in the cable = 0.22 K

These results were consistent with previous experiment*



20 kJ/m^3/pulse for a 50GeV-10W loss
Instantaneous temp. rise = 0.25 K

*Ref.:Y. Iwamoto, N. Kimura, et al:; "Quench Stability against Beam-loss in Superconducting Magnets at the 50 Gev Proton Beam Line for the J-PARC Neutrino Experiment", *IEEE Trans. on Appl. Supercond.* **14** (2004) pp.592-595

Temp. rise is proportional to heat load.

Cooperation program summary

- High Field magnet R&D development is being carried out for interaction region magnets toward the LHC luminosity upgrade
- A common coil magnet design in progress at KEK realizing

  ~ 15 T or higher field magnets
  - The cable for the first Nb3Al coil has been fabricated and the winding process will start soon (in collaboration with NIMS).
- Classical electrical insulation have been tested at KEK under SHe and Saturated Helium
  - It is established how to measure of temperature in the stack model on unsteady state condition, and proved to performance pulse heat beam loss such as J-PARC neutrino beam line.
- Two new stack models have been constructed with Glass-fibre epoxy insulation at Saclay, and to be tested at KEK and Saclay

  in this year.
  - To be started to measure of pure heat conductivity of ceramic (AlO_2 etc.) insulation tape at KEK in this year.