Irradiation Effect on Superconductivity of REBCO Coated Conductors

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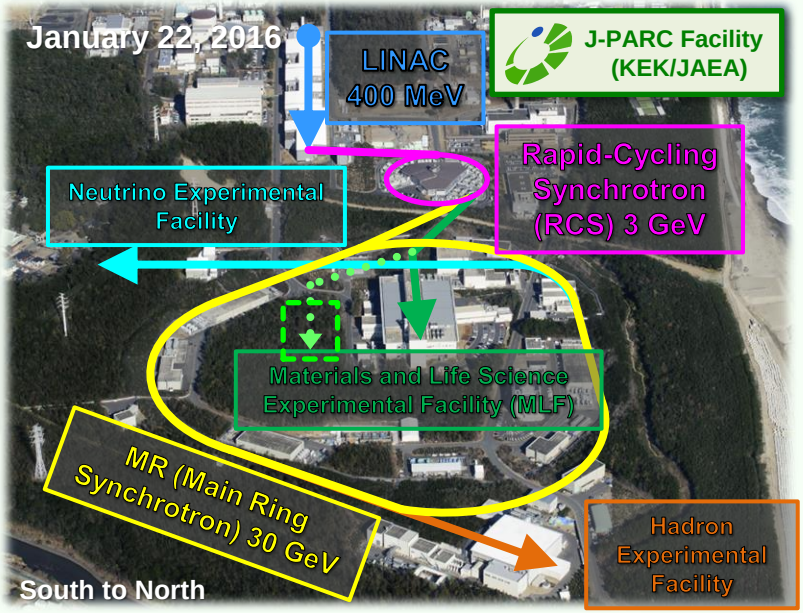
Contents

J-PARC (KEK / JAEA)

Purpose:

Research for the creation and structure of our universe by investigating matters at all levels, from quarks to atoms.

☐ MW-class High Power Proton Driver

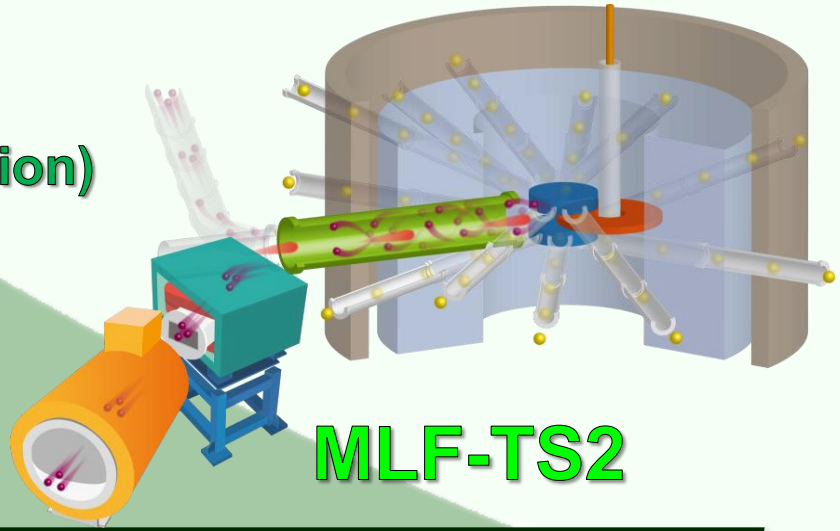


➢ **Construction of MLF 2nd Target Station (MLF-TS2) is proposed**

TS2-Pion Capture Solenoid

(10 years operation)

- **Heat Deposit: ~ 1 KW**
- **Neutron flux: 7.7 x 10^{21} n/m^2**
- **Absorbed Dose: > 100 MGy**



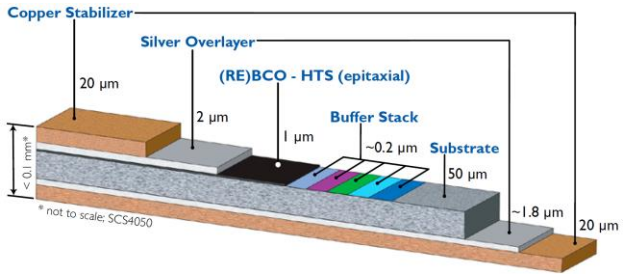
MLF-TS2

Requirements for High radiation-resistant SC-magnets

R&D of Mineral Insulated HTS Coils

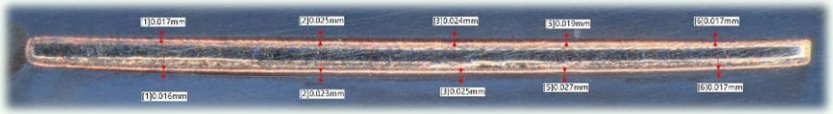
Rare-Earth Barium Copper Oxide (Re: Y, Gd, Eu, Sm)

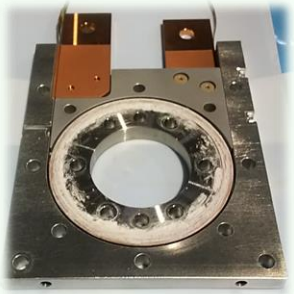
- **High temperature margin**
  - Conduction cooling operation in the temperature range of 20 K.
- **High magnetic field tolerance of Ic**
  - Potential for 20T class high field magnet



Ceramic coating and bonding technology

- Ceramic coating on REBCO and magnet materials
- Demonstration of coil assembly with ceramic adhesive
- Cooling and excitation test





Studies on radiation resistance

- Neutron irradiation
  - Commercial REBCO tapes, Ceramic coating samples, BT-GFRP
- Gamma-ray irradiation
  - Commercial REBCO tapes, Ceramic coating samples

Neutron Irradiation

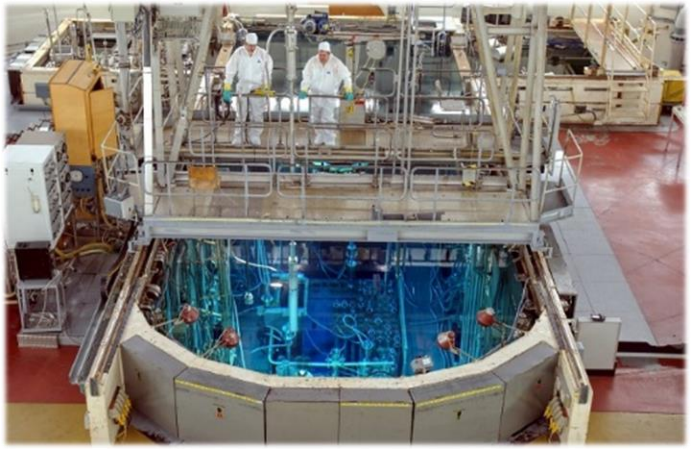
Irradiation Flow

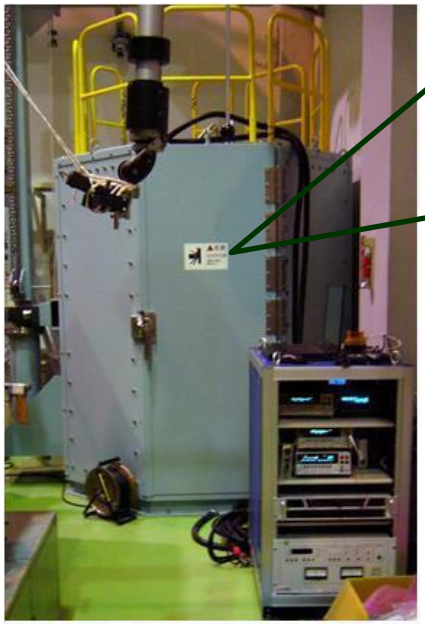
Inter-university cooperative research program

International Research Center for Nuclear Materials Science, Institute for Materials Research, (IMR-Oarai) Tohoku University

Sample (REBCO, T=0.1 mm, W=4 mm, L=32mm)

BR2 @Belgian nuclear research center

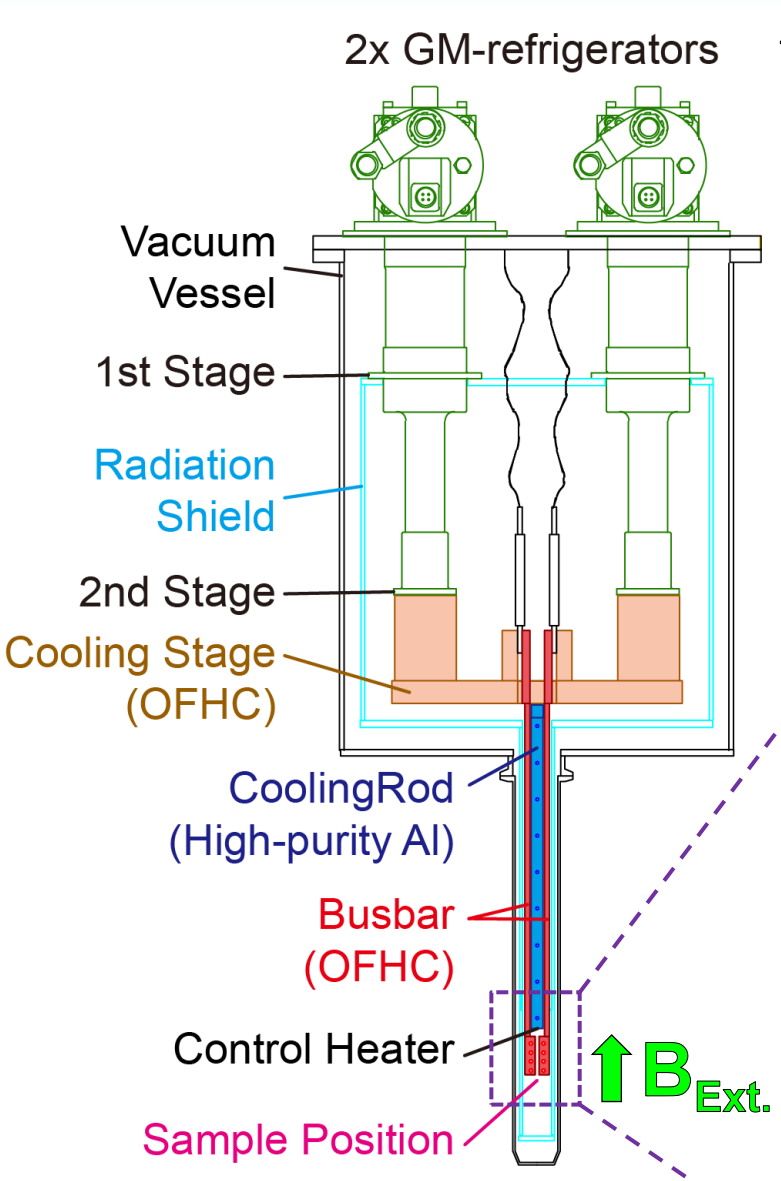




Superconducting Properties Evaluation System @IMR-Oarai

Temperature Range	4 ~ 80 K
Max. Current	500 A
Max. External Field	15.5 T

Variable Temperature Insert (VTI)



Conduction Cooling

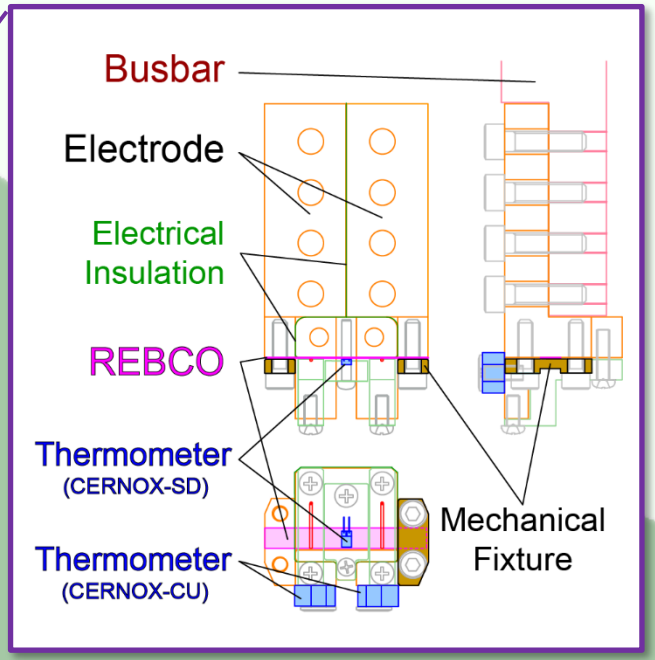
GM Refrigerators → Cooling Rod (Al) → Busbars (Cu) → Electrodes (Cu) → REBCO Sample

Easy and Quick handling to minimalize radiation expose

- Mechanical contact **w/o soldering**

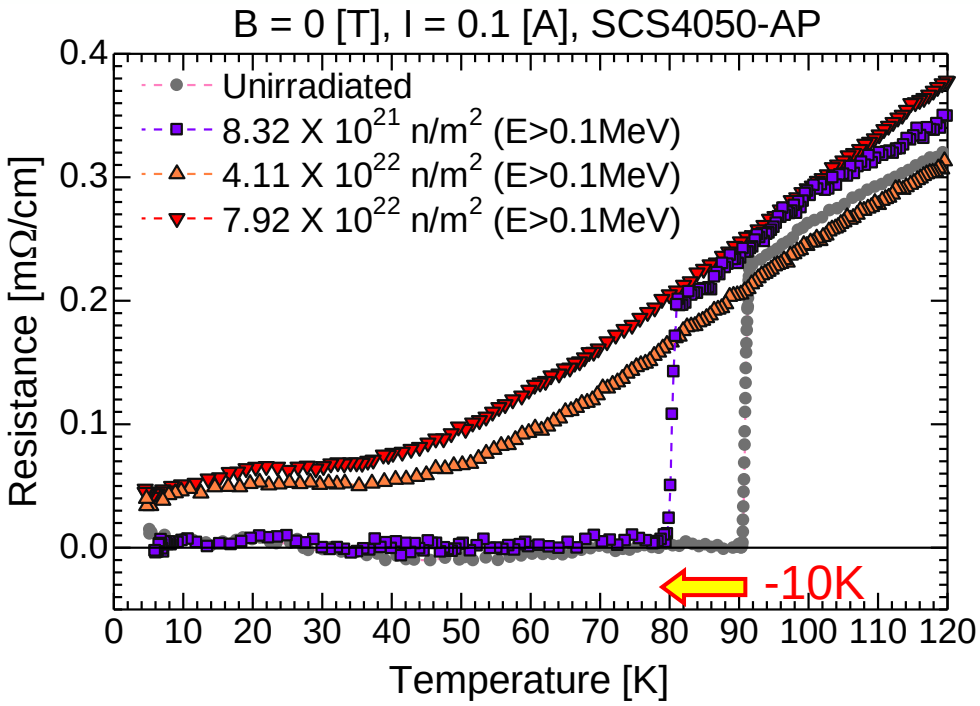
Temperature rise due to ohmic heat is non-negligible

For higher I_C around 400A, temperature rise becomes larger (~15 K or more)



Latest Results of PIE

PIE (Superconducting Transition Temperature)



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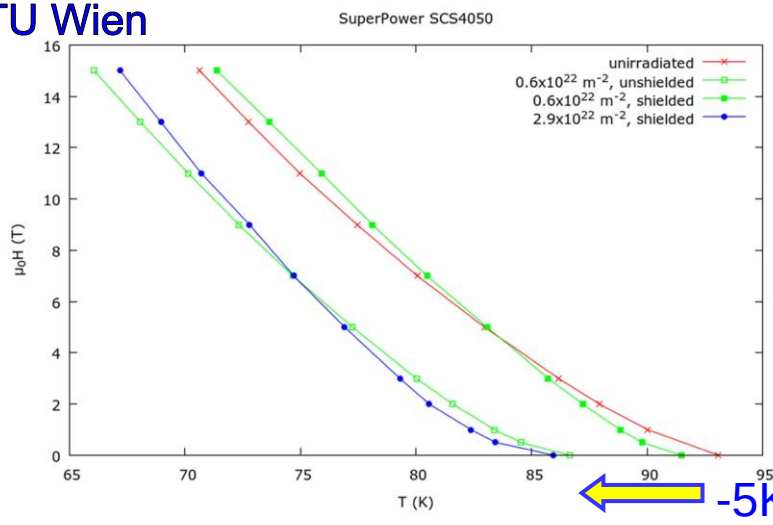
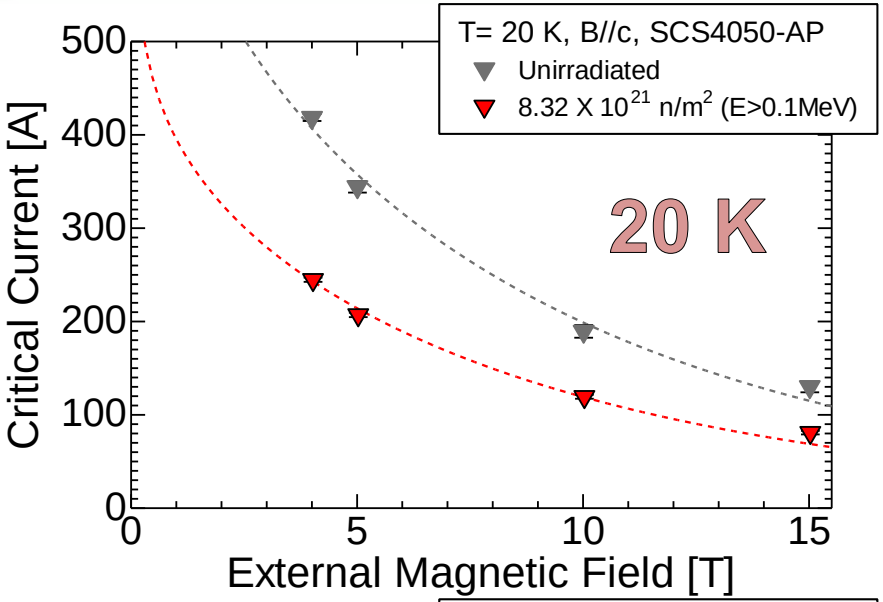


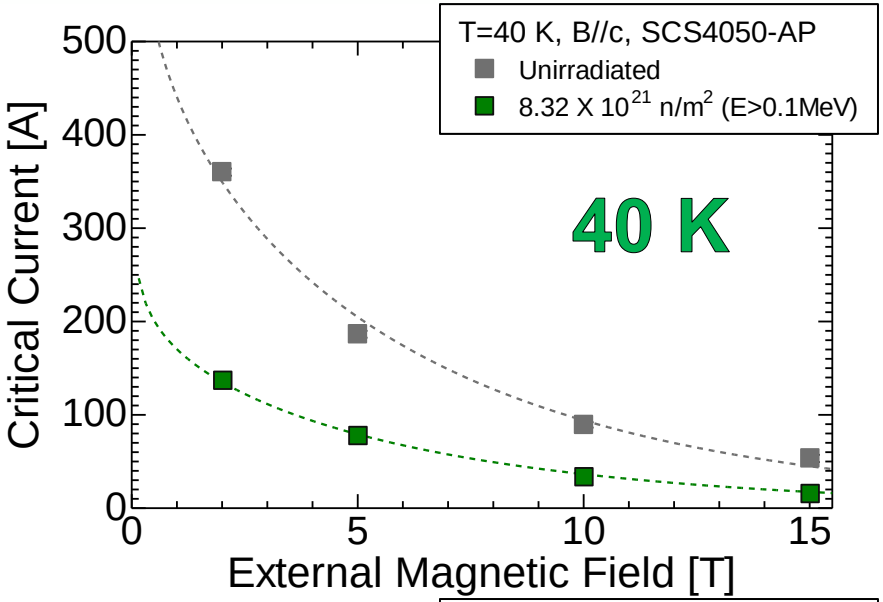
- **No significant degradation in shielded HTS tape at 6 x 10^{21} n/m² (E>0.1MeV).**
- **Reduction of Tc by 5 K in unshielded sample.**
- **Reduction of Tc by 5 K in shielded sample at 2.9 x 10^{22} n/m² (E>0.1MeV)..**

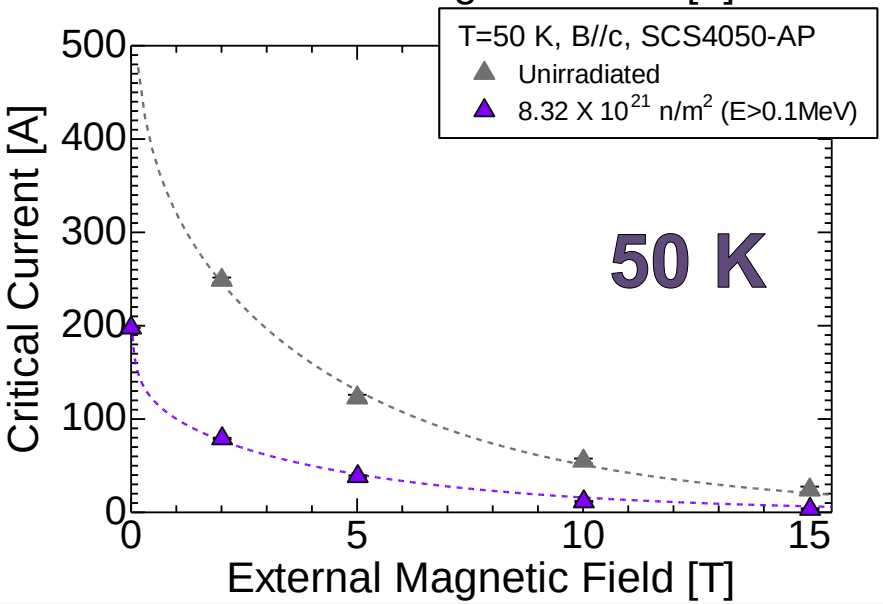
- Vanishment of superconductivity in GdBCO tapes even at 4.11 x 10^{22} n/m².
- **Tc reduction of 10 K at 8.32 x 10^{22} n/m².**
- Our results are similar to the reference data.

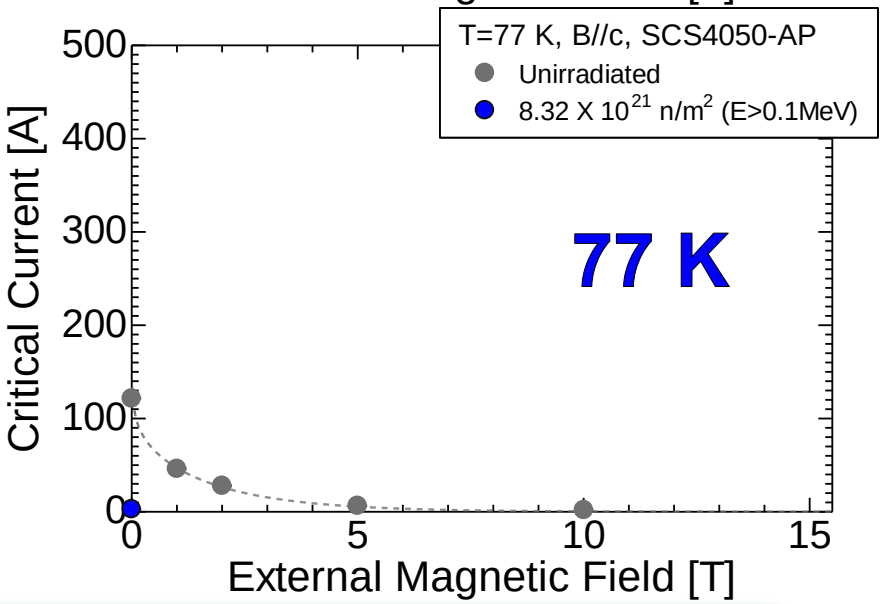
PIE (I_C-B curve)

I_c criteria: 1 μV/cm, V-tap distance: 1.4 cm



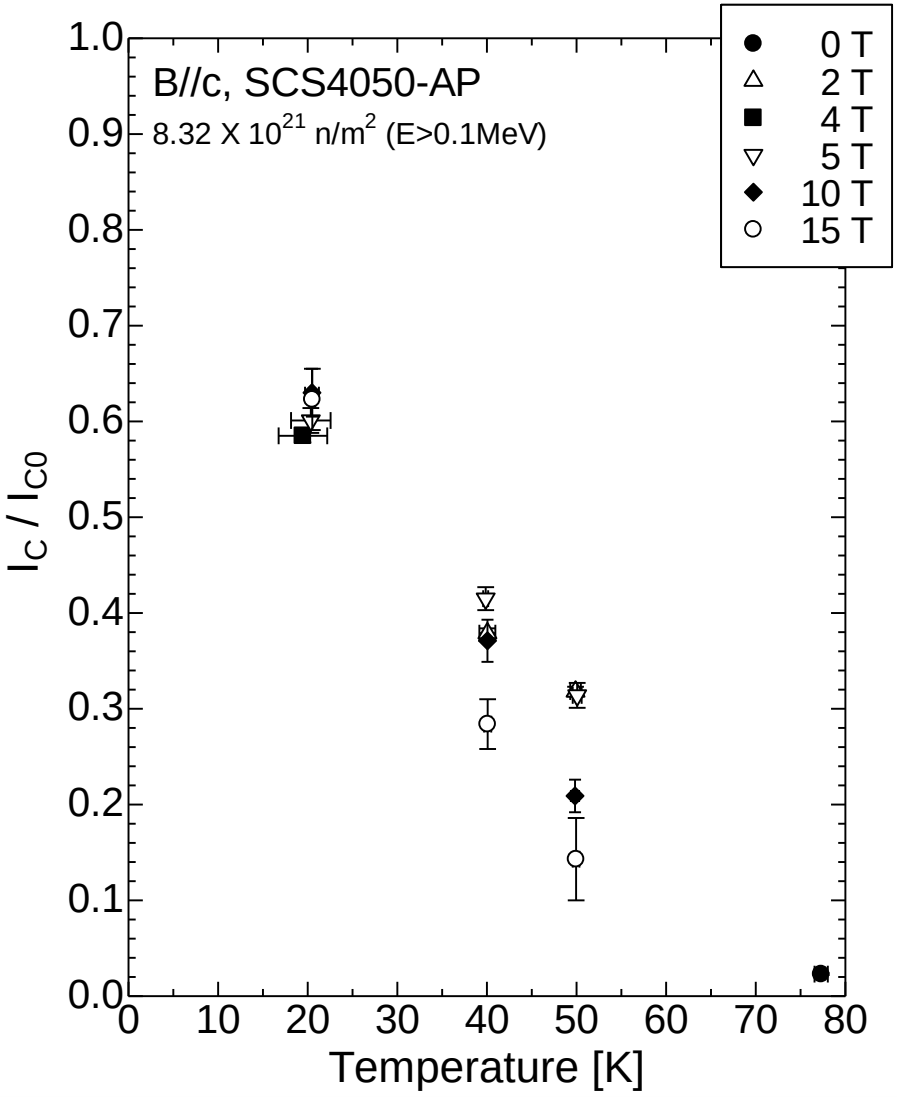






Fitting Function: L. Bottura, LHC Project Report 358

Degradation Rate (Ic/Ic0)



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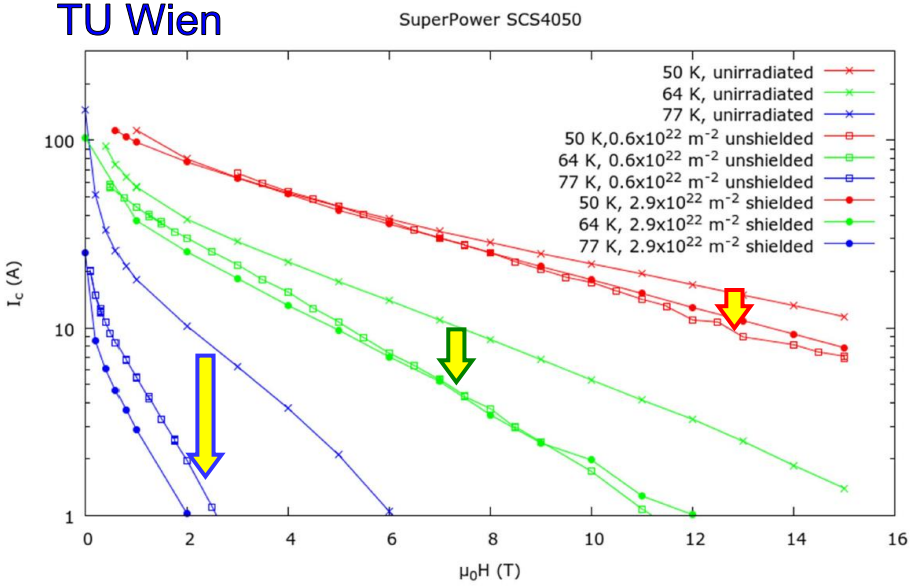


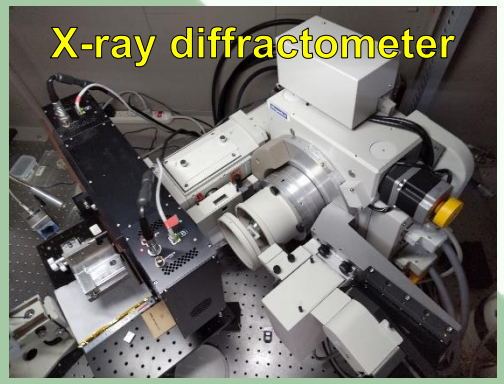
- Degradation rate is not constant
- Relatively small effect in the low temperature range
  (0.6@20K ⇔ 0.02@77K)
- Our results are similar to the reference data.

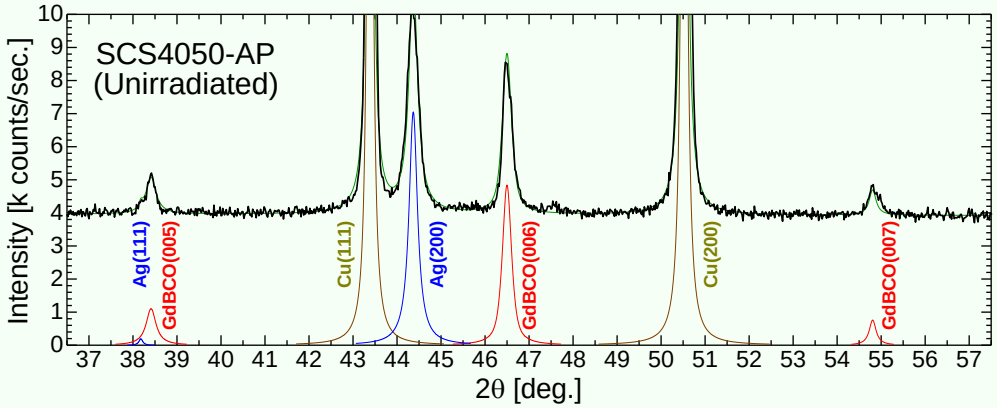
The neutron irradiation effect on I_c of REBCO is not a simple mechanism.

Future Studies & Irradiation plan

To understand the mechanism and provide feedback

- **Microscopic analysis such as X-ray Diffraction.**





Irradiation plan:

- Target Fluence: ~10^{21} n/m^2 (En>0.1 MeV, T < 100℃)
- Thermal neutron-suppressed irradiation: With Cd shield
- Another REBCO : EuBCO, (YBCO) Is Gd sensitive?

Summary

- R&D of radiation-resistant REBCO magnet is underway to realize the pion capture solenoid for the further J-PARC MLF 2nd target station.
- Neutron irradiation effects on REBCO tapes have been investigated at IMR-Oarai center, Tohoku Univ.
- Superconductivity of GdBCO tape disappeared even at 4.11 x 10^{22} n/m^2 (E>0.1MeV).
- Tc decrease and Ic degradation are confirmed at 8.32 x 10^{21} n/m^2 (E>0.1MeV).
- The degradation rate of Ic seems to change depending on the measurement temperature. And it's similar to other reference data.
- Microscopic analysis such as X-ray diffraction of REBCO samples will be performed to investigate structure change by irradiation.

Thank you