HTS REBaCuO coated conductors for the FCC-hh beam screen: Performance under photon irradiation at the ALBA Light Source

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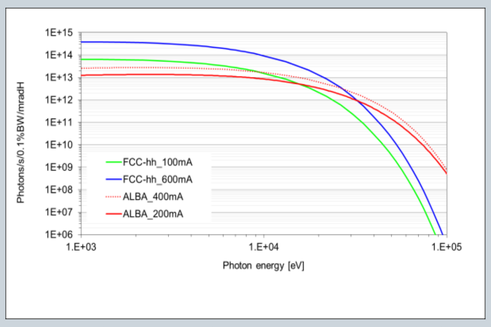
Abstract

High-Temperature Superconductor (HTS) coated conductors (REBCO-CC) are being considered as possible coating materials for the beam screen of the FCC-hh vacuum chamber to replace Cu.

Sufficiently understanding the behaviour of the tapes under the influence of RF fields, magnetic fields and synchrotron radiation is fundamental to achieve a sound decision.

Samples from different manufacturers have been irradiated at the ALBA Synchrotron Light Source which produces a photon flux spectrum comparable to that expected at the FCC-hh and later their sc properties have been re-measured.



Photon flux per mrad(H) and 0.1% BW vertically integrated for FCC-hh and ALBA with different currents in the machines

$$\frac{d^2F}{d\Theta \cdot d\omega/\omega}\left(\frac{photons}{s \cdot mrad_H \cdot 0.1\%BW}\right) = 2.458 \cdot 10^{13} \cdot E[GeV] \cdot I[A] \cdot G1\left(\frac{\omega}{\omega_c}\right)$$

Expression for the photon flux vertically integrated per mrad(H) and 0.1% BW for an electron machine. For a proton machine the ration of electron to proton mass to the appropriate power has to be used.

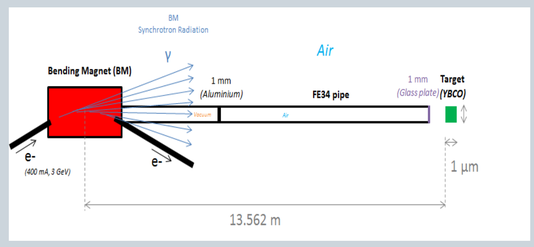
Dose estimation

FLUKA is a Monte Carlo simulation package for the interaction and transport of particles in matter.

FLUKA is used to estimate the energy deposited onto the sample while irradiating with synchrotron radiation under different conditions. The input for the simulations has been the photon flux generated by the ALBA bending magnet and the current in the storage ring, as well as the different attenuators in front of the sample.

The FLUKA results have been obtained for a target volume (1 mm x 1 µm x 5 mm) and with a cutoff energy of 1 keV.

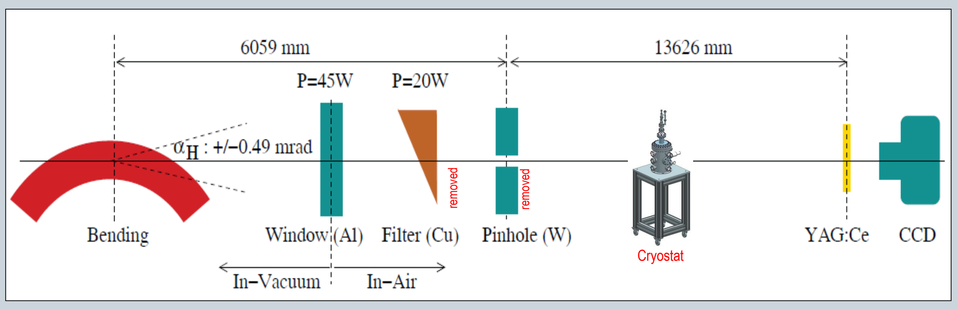
SR current	100 mA		200 mA
Attenuator	Crotch absorber (35mmCu)		Al wind (1mm)+air+Kodial wind (3mm)
Irradiation time	144h	552h	2h (typical)
Photons @ sample	4.96e14	1.90e15	4.10e18
Energy deposited	*calculation ongoing*		4.50 J
Absorbed dose	*calculation ongoing*		1.43e8 Gy

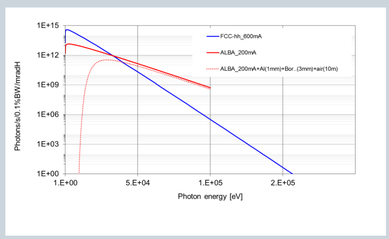


In-situ irradiation & testing

The ALBA Light Source is equipped with an x-ray pinhole that during normal operation monitors continuously the transverse beam size. During the HTS tests, the pinhole and the filter have been removed from the beam path and an HTS sample mounted perpendicular to the beam line has been installed about 13.5 m from the source.

In the presence of an Al-window (1mm) separating vacuum from air and a Kodial window (3mm) separating RT from cryogenic temperatures at the cryostat, the photon flux that reaches the sample has energies starting at 10 keV.

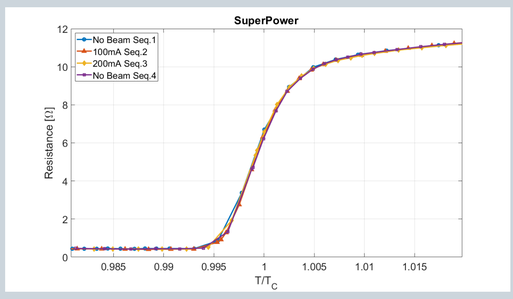


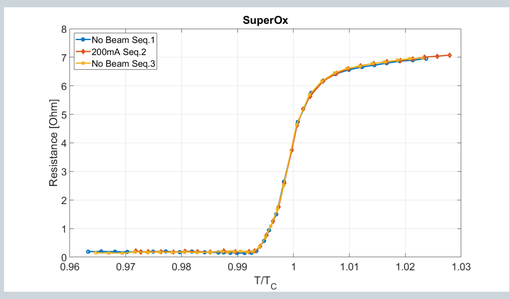


Photon flux (ph/s/mradH/0.1%BW) that reaches the HTS sample in this configuration as a function of energy. For comparison the photon fluxes for FCC-hh and ALBA in the absence of attenuators are also plotted. Note that the low energy part of the spectrum is absorbed mainly by the Al window.

In-situ irradiation & testing

The critical temperature has been measured during irradiation and compared to data taken w/o irradiation. The results indicate neither a change in the critical temperature, nor in the value of the resistance below/above transition.



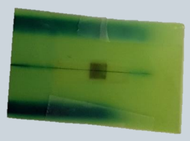


Resistance as a function of temperature for two different HTS-CC samples of different providers. The measurement sequence is as follows: first a measurement is performed w/o beam current in the storage ring, then 100mA (or 200mA) are injected into the storage ring, the sample is irradiated and the resistance measured as a function of temperature while the sample receives the photon flux. A last measurement without irradiation is performed to confirm no damage on the sample.

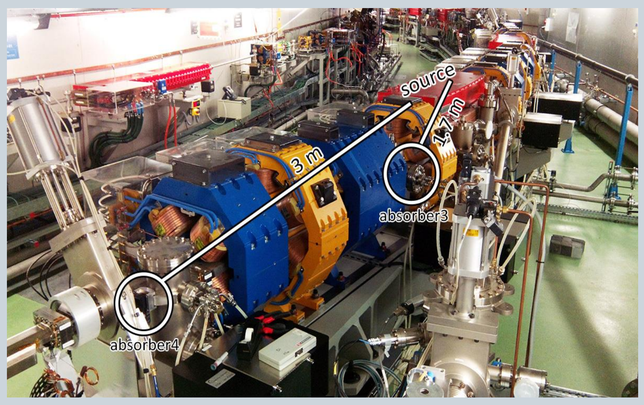
In-situ irradiation & Ex-situ testing

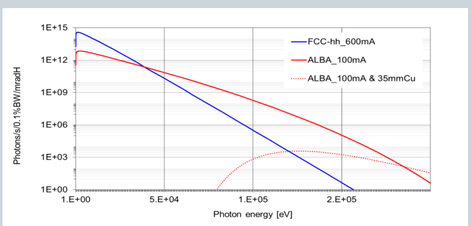
For this experiment, the HTS-CC samples were mounted behind the ALBA crotch absorbers and irradiated by the high energy residual x-rays that traverse the 35 mm copper absorber and 2 mm steel anti-chamber wall.

Samples have been irradiated for different lengths of time making use of the normal operation of the Light Source for users.



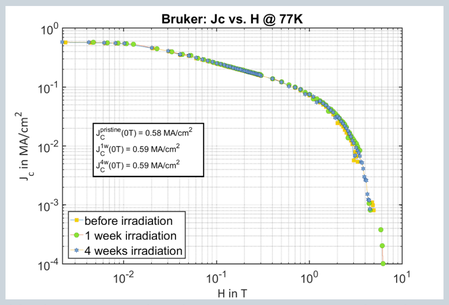
Irradiated 5x5 mm² HTS-CC sample



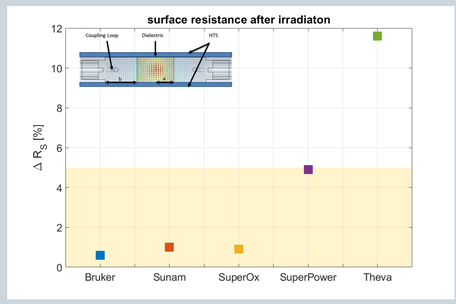


Photon flux (ph/s/mradH/0.1%BW) that reaches the HTS-CC samples in this configuration as a function of energy. For comparison the photon fluxes for FCC-hh and ALBA in the absence of attenuators are also plotted. The photon flux reaching the HTS-CC samples behind the crotch absorber is of very high energy and low in intensity

In-situ irradiation & Ex situ testing



Critical current density at 77K as a function of magnetic field for a sample after undergoing long time irradiation at ALBA. The results for a sample not irradiated are also shown. J_c does not change within the uncertainty of the measurements.



Change in surface resistance at 77K, after irradiation. Except for one manufacturer, no changes within the uncertainty of the measurements have been detected. For details on the Dielectric Resonator method see tomorrow's talk, by P.Krkotic (ID_450).

Outlook

We have demonstrated, that the transport properties of HTS-CC samples from several manufacturers are not affected by the irradiation with photons of energies higher than 10 keV and under absorbed doses of the order of 140 MGy. This is a necessary step towards the use of HTS-CC material as coating for the beam screen vacuum chamber.

Next step, already in preparation, will be to study the effect of photon irradiation on the surface impedance.

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Acknowledgments: The authors thank A.Devienne from the Safety group of ALBA for performing the FLUKA simulations

Work under the agreement FCC-GOV-CC-0072 (KE3358)