ITALIAN NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND SUSTAINABLE ECONOMIC DEVELOPMENT

EUROfusion

Feasibility study of the system for transport measurements during cryogenic gamma irradiation

PRD-3.HTS.01-T023 - D002

WPMAG Final Meeting 2025 16/01/2026

Valentina Pinto / FUSEN-COND

Acknowledgments

TASK PRD-3.HTS.01-T023: Understanding neutron and secondary radiation effects on the superconducting state and on the microstructure of HTS 2G tapes
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Gamma Irradiation Effect on HTS Film

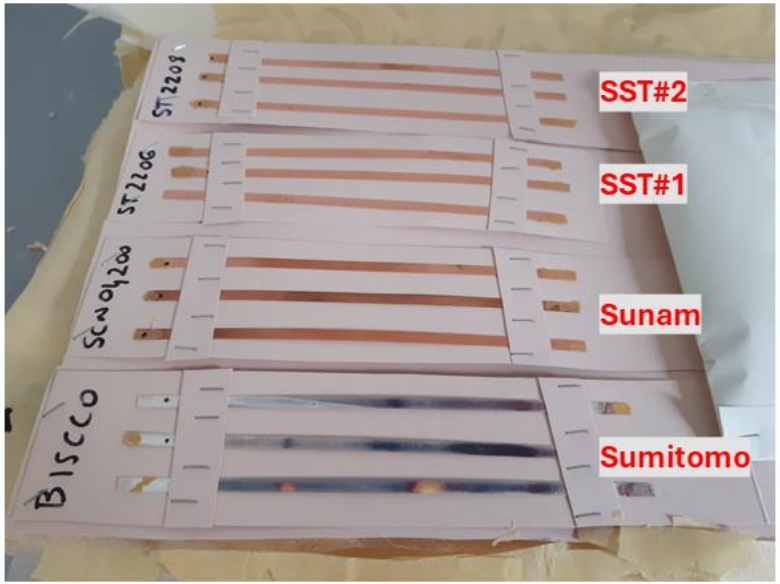
Origin of some contradictions in the literature data:

- Scarce statistical significance (often no or few replicates are studied)
- Irradiated samples are compared to a reference control sample
- Few details on the experimental conditions

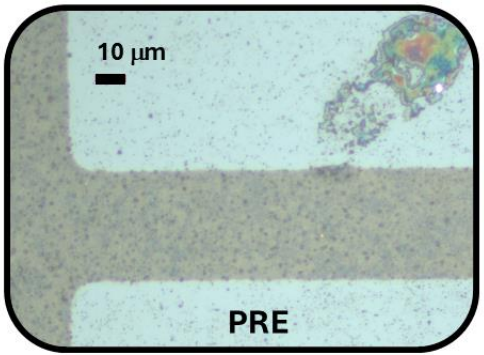
Starting Point: 2024 Activity

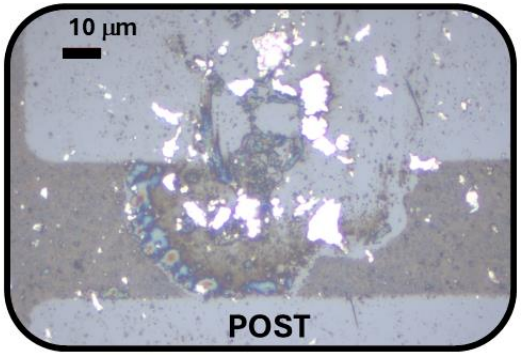
Gamma irradiation of REBCO CCs, BiSCCO wires and lab-scale YBCO films at fusion relevant conditions (dose equal to 7.1 MGy)

What Emerged by 2024 Activity



Samples degradation due to secondary reactions of photons with the test environment





Absolute necessity of experiments carried out in the real operative conditions

In situ measurements during cryogenic irradiation

2025 Activity

Feasibility study of the proper system for transport measurements during cryogenic irradiation

Towards *in-situ* measurements during gamma irradiation

Gamma irradiation of liquid nitrogen. A real problem?

In-situ measurements of Superpower tapes in LN_2 irradiated up to 3.5 kGy.

Risks of LN_2 explosions after a dose of 10 kGy were reported [Chislett, UKAEA report 2023].

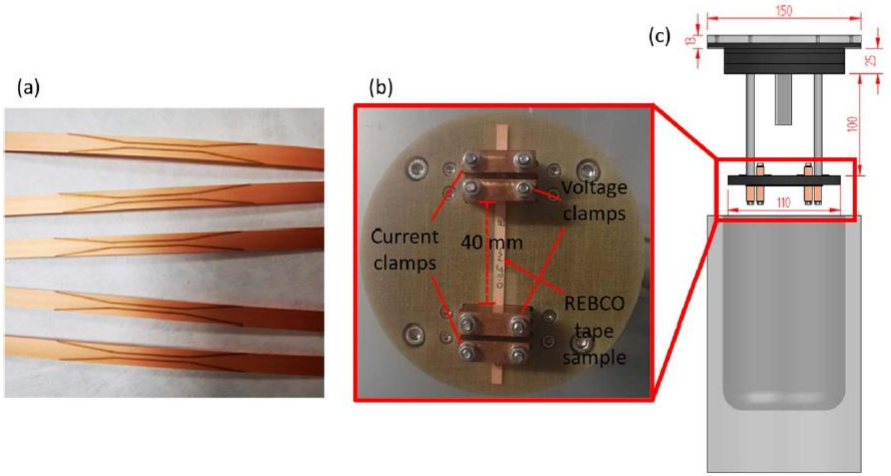


Figure 3. (a) SuperPower SCS4050-AP (4 mm wide) samples with laser-cut bridges of 1 mm width, 33.8 μm depth. (b) Test fixture viewed from below. The sample is connected to the measurement circuit via copper clamps. (c) CAD model and dimensions of the Gamma ICE test fixture and 2 l dewar into which it is lowered.

Chislett et al [*SUST*, 2023]

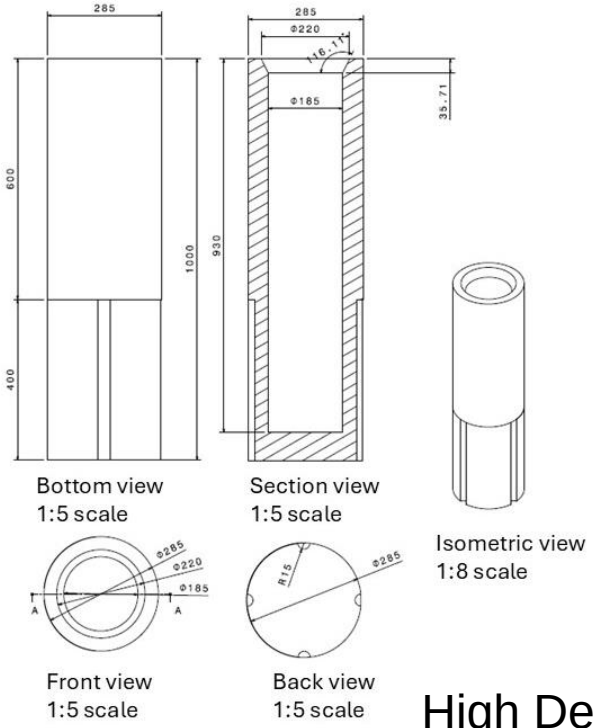
Towards *in-situ* measurements during gamma irradiation

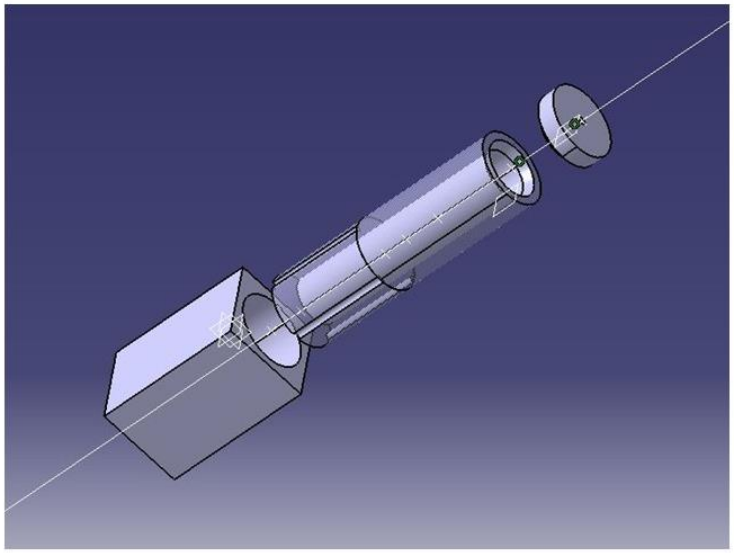
Gamma irradiation of liquid nitrogen. A real problem?

Duke et al [*IEEE*, 2024] reported irradiation study of fiber optics in LN_2 up to **1.2 MGy** and **60 kGy/h**. **No explosion occurred.**

Tests of LN_2 irradiation to verify the safety of the apparatus for *in-situ* transport measurements

2025 Activity: Design of the Cryostat



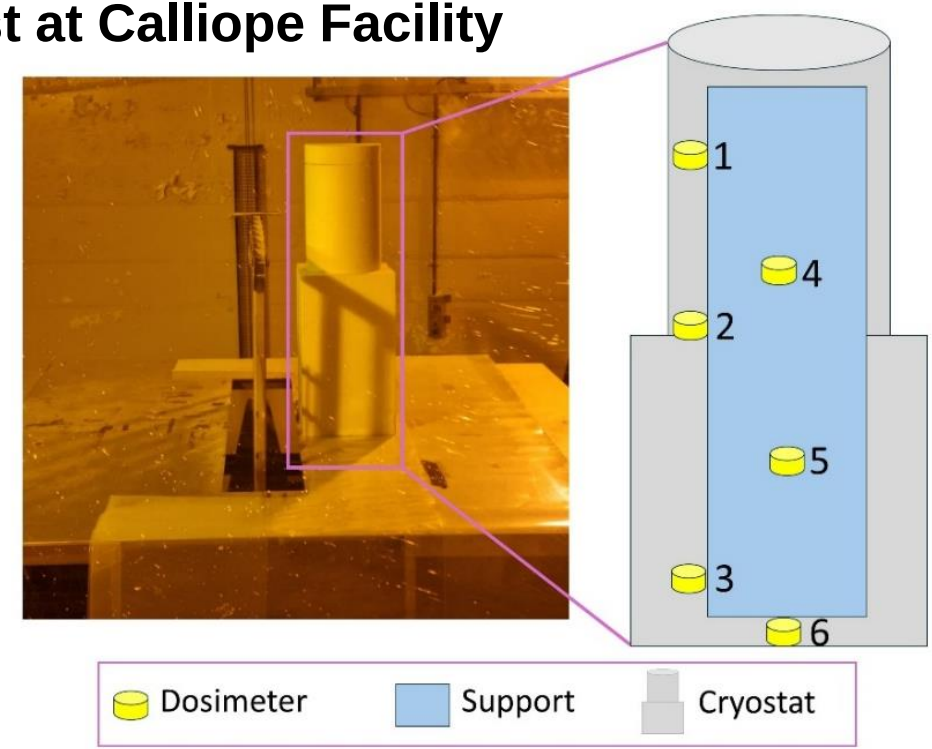


High Density Sintered Expanded Polystyrene (HD-EPS)

2025 Activity: Design of the Cryostat

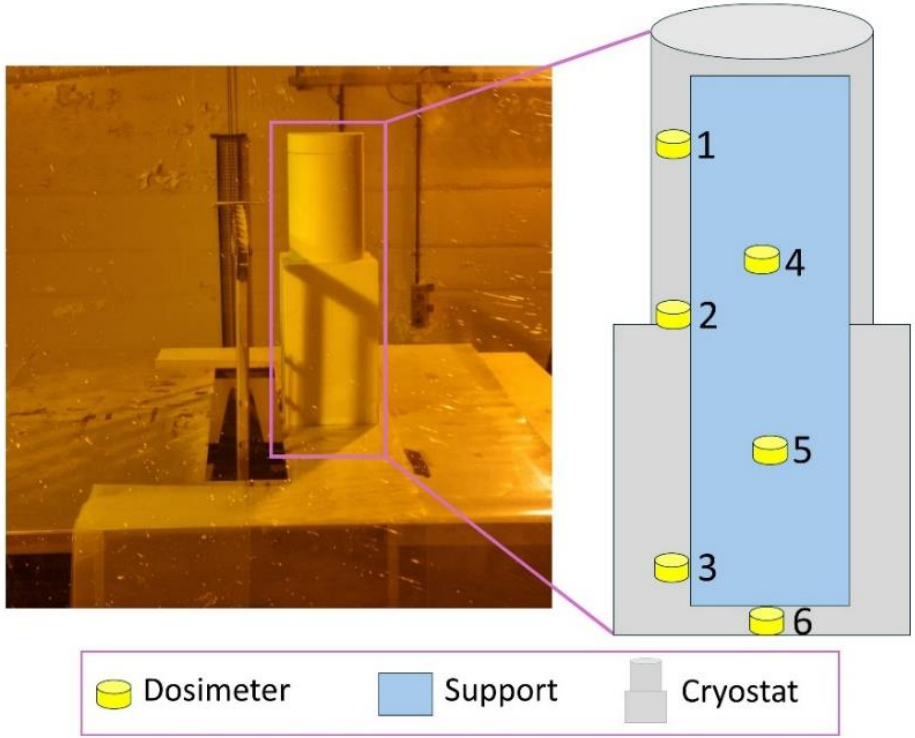
2025 Activity: Liquid Nitrogen Irradiation

Test at Calliope Facility



Dosimeter	Dose rate (water) (Gy/h)	Dose rate (air) (Gy/h)
1	2953	2541
2	3078	2642
3	2863	2463
4	2384	2049
5	2305	1991
6	1916	1647

2025 Activity: Liquid Nitrogen Irradiation



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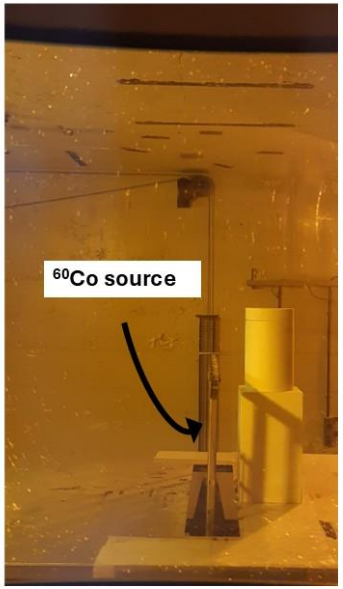
2025 Activity: Liquid Nitrogen Irradiation

LN_2 5.0 grade with a purity ≥ 99,999% and a level of O_2 contamination < 10 ppmv

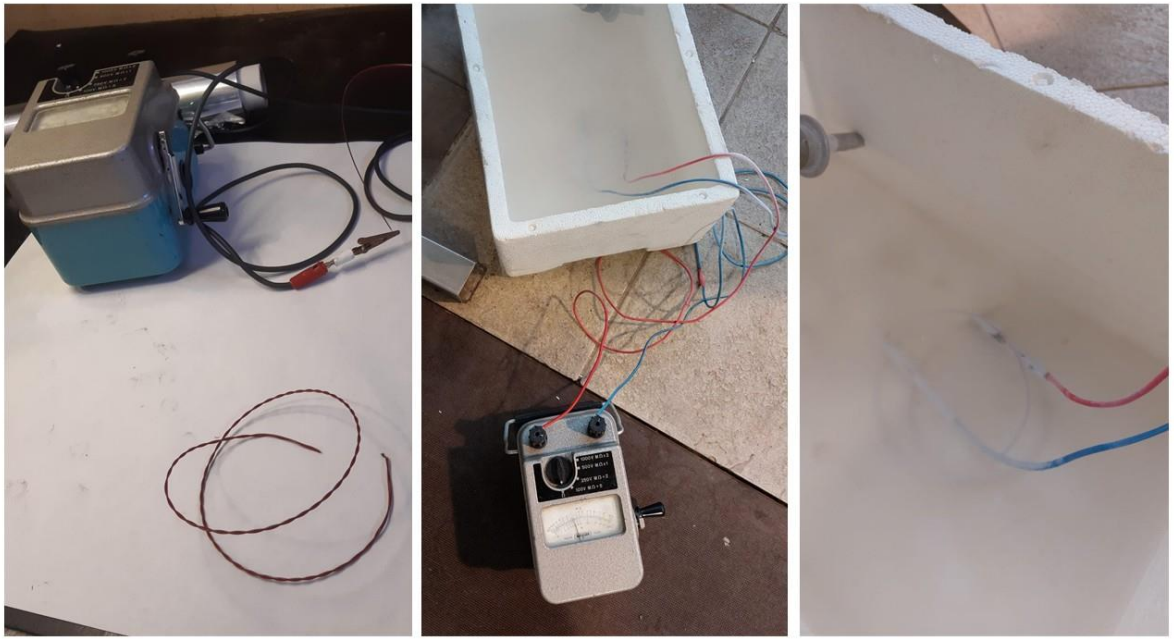


Dose [kGy]	Dose/rate (air) [kGy/h]	LN_2 volume [L]
1	0.8	2
1.5	0.8	2
5.1	2.6	19
11.1	2.6	19

No explosion occurred up to 11.1 kGy

2025 Activity: Tests of Cable Radiation Hardness

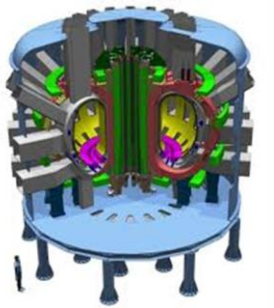
Test of radiation hardness of cable for voltage measurement

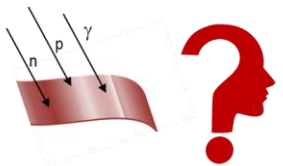


No changes up to 1.6 MGy and 2.8 kGy/h

Conclusions

- A cryostat was designed, realized and used for the test of LN_2 irradiation
- LN_2 can be used as cryogenic liquid up to 11 kGy with no risk of explosions
- Tests on radiation hardness of cable for voltage measurement are currently ongoing
- The procurement of other necessary equipment, such as source meter, nanovoltmeter and thermometers, has started.





THANK YOU

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Backup

Irradiation Test

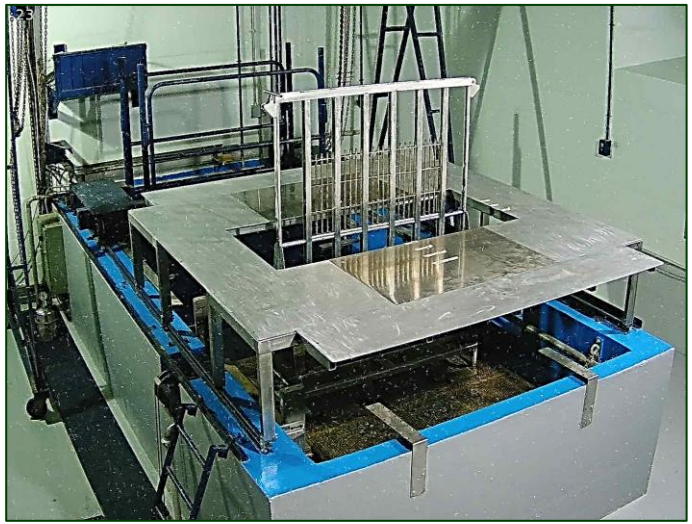
Commercial HTS:

- EuBCO+$BaHfO_3$ by **Shanghai** Superconducting Tech. (**#2 different APCs content**). Cu stabilizer thickness of 10 μm
- GdBCO, SCN04220, by **Sunam**. Cu stabilizer thickness of 15 μm each side.
- BiSCCO 2223, by **Sumitomo**. Ag/Ag-alloy matrix.

Chemically deposited film used as reference:

- YBCO on STO and LAO
- YBCO-Gd10% on LAO

Calliope Facility at ENEA



- **Large dimensions**
- **Fusion relevant dose/rate**

Pool-type irradiation plant in a large volume (7x6x3.9 m^3) shielded cell.

Plane rack, active area: 40 cm × 75 cm .

^{60}Co gamma source with a maximum dose rate value of about 5.5 $kGy \cdot h^{-1}$ (June 2024).

Calliope Plant Main Features

Features	
Source	^{60}Co, stainless steel double encapsulated rod
Geometry	Plane rack
Emitted radiation	2 photons emitted in coincidence
Mean photon energy	1.25 MeV
Max licensed activity	$3.70 \cdot 10^{15}$ Bq (100 kCi)

Irradiation test with fusion relevant conditions

Dose: 7.1 MGy (corresponding to 5.9 MGy_{YBCO})

Dose rate: 3.9 kGy/h

- ITER Qualifications: doses up to 8 MGy
- ‘’*the 5 MGy dose was chosen to enable evaluation of prolonged gamma irradiation effects*’’ (Campbell et al [J. of Superconductivity and Novel Magnetism, 2024])