Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

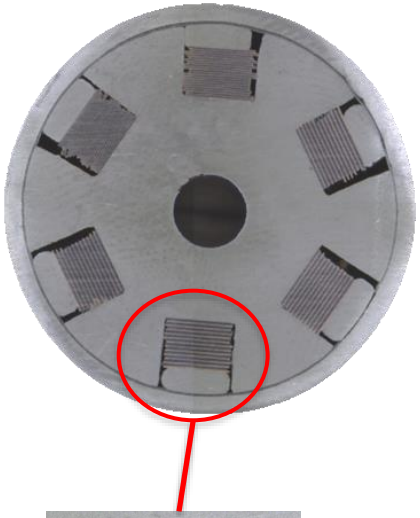
MAG EU-CN collaboration 2019-2020

ENEA HTS Cable-in-Conduit Conductor Sample

Final meeting – ENEA, February 11th 2020

Andrea Augieri
ENEA, Frascati Research Centre - Superconductivity Laboratory

ENEA HTS cable – layout



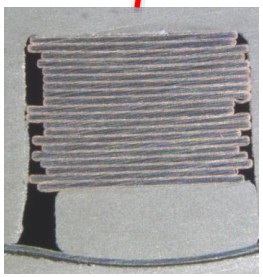
Twisted 6 slot Al-core (t.p. = 500 mm)

3 HTS stacks + 3 empty slots (no tapes)

HTS tape from **SuperOx** (4 mm x 0.15 mm)

Expected average I_c(4.2 K, 12 T) = 200-250 A

Pos.	Description	
1	**04-30Ag-20Cu-100H**	
	2G HTS Wire	
	Superconductor	GdBCO
	Substrate	Hastelloy C276, 102 ± 2 µm
	Width	4 ± 0.13 mm
	Silver layer HTS side	3 ± 0.5 µm
	Silver layer substrate side	1 ± 0.5 µm
	Copper layer	20 µm ± 20% per side
	Target (not guaranteed) average I_c at 77 K, s.f.	160 A
	I_c standard deviation (TapeStar XL data) at 77 K	≤ 3%
	Expected average I_c at 4.2 K, 12 T (average lift-factor 1.4)	200-250 A
	Single piece length	Multiple of 7 m

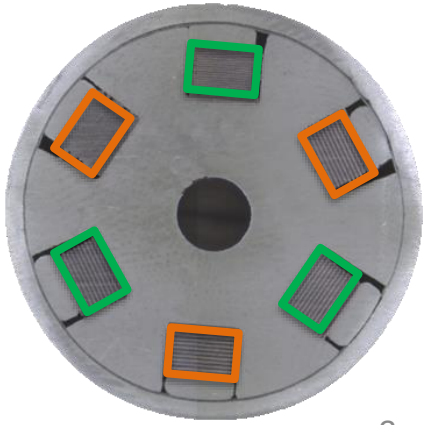


Stack configuration 20 tapes per stack

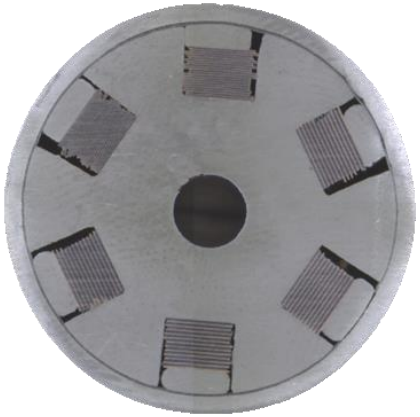
Expected cable I_c @ 12 T, 4.2 K: 250 × # tapes = 12 – 15 kA

Stack distribution: alternate **HTS**

Empty slots : for tape voltage and temperature sensors wiring



ENEA HTS cable – layout: jacket



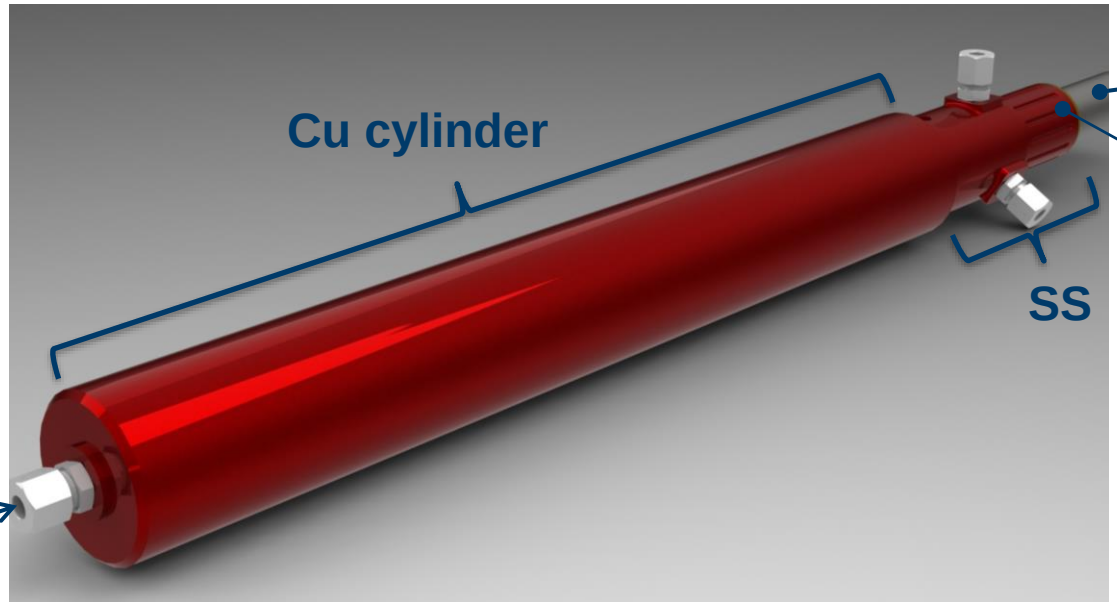
Round jacket Al-foil 1.5 mm welded and compacted by drawing

+

SS-tube (1 mm thick) crimped on Al-jacket

SS tube is functional for the cooling purpose:
guarantee suitable He-tight for the cooling system

ENEA HTS cable – layout: termination



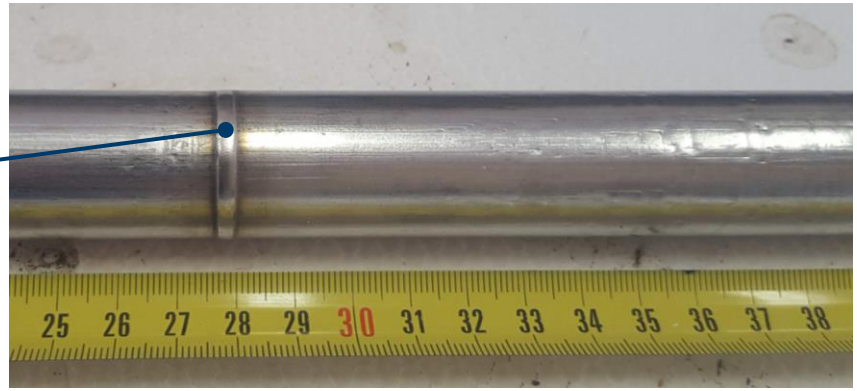
SS tube external jacket

Tig-welded joint

He inlet

Terminator:
Cu cylinder
+
SS extremity

Bottom box based on the same concept

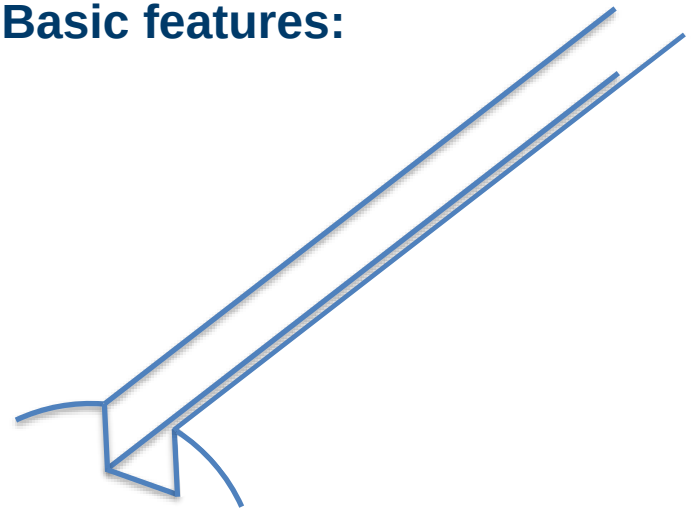


Tig-welded joint

No damage occurred on HTS tape after welding.
Successfully tested!

ENEA HTS cable – layout: termination

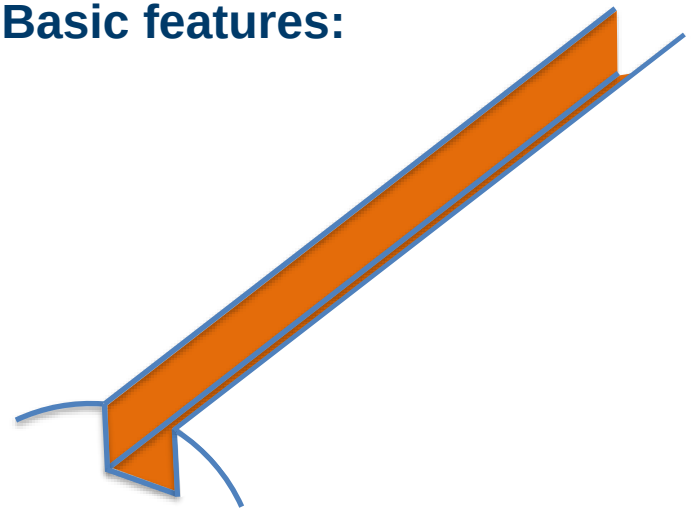
Basic features:



ENEA HTS cable – layout: termination

electrodeposited Cu coating of slots;

Basic features:



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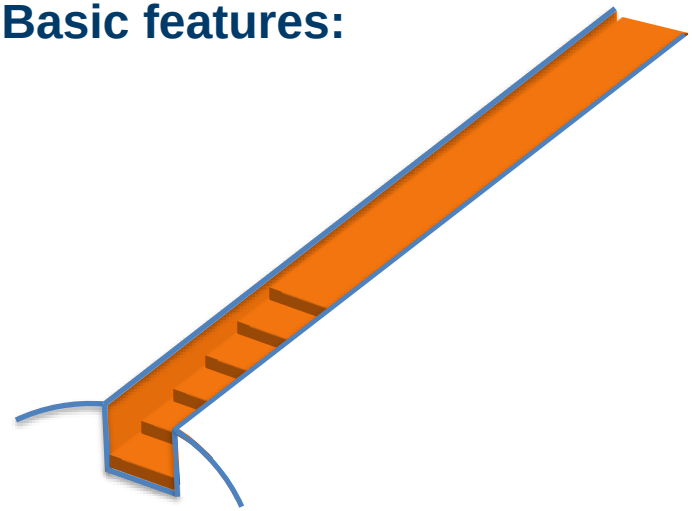

electrodeposited Cu coating of slots;

staggered stack end inserted into the slot of the Al-core;

ENEA HTS cable – layout: termination

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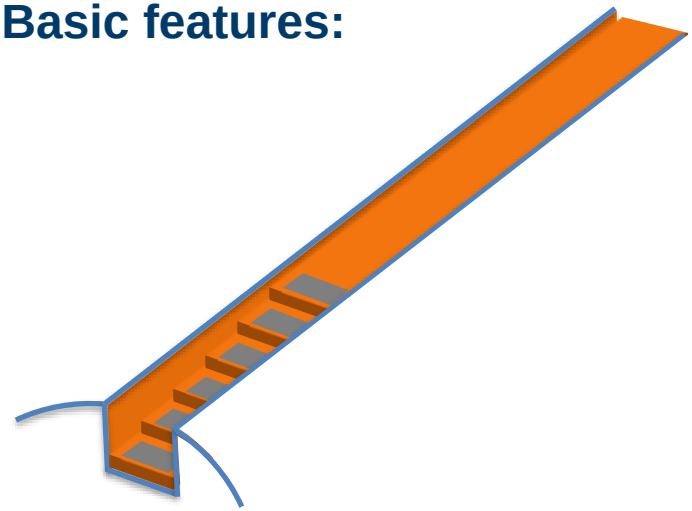

electrodeposited Cu coating of slots;

staggered stack end inserted into the slot of the Al-core;

filled with Pb-Sn paste

ENEA HTS cable – layout: termination

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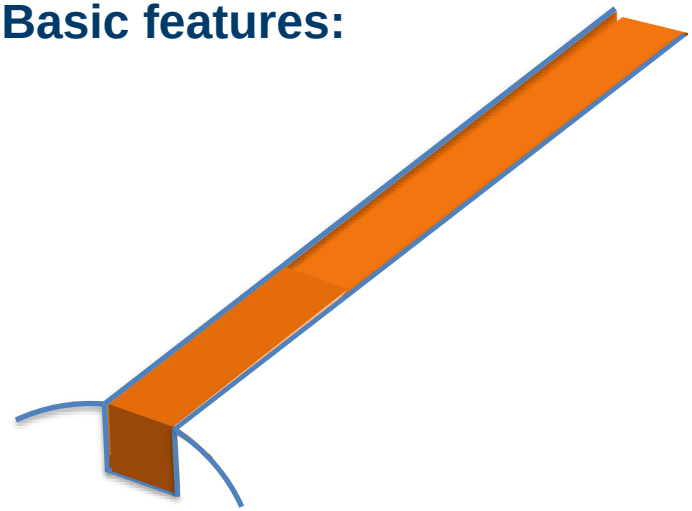

electrodeposited Cu coating of slots;

staggered stack end inserted into the slot of the Al-core;

triangle-shaped Cu filler soldered with Pb-Sn paste

ENEA HTS cable – layout: termination

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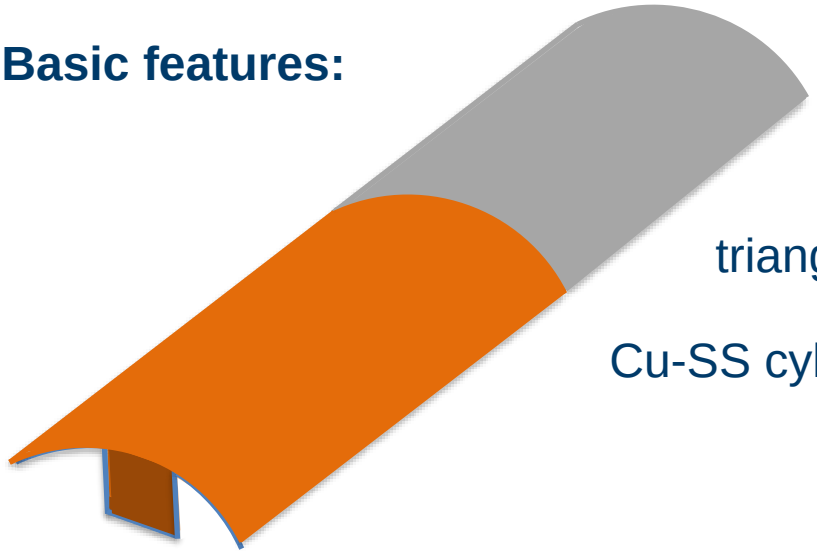

electrodeposited Cu coating of slots;

staggered stack end inserted into the slot of the Al-core;

triangle-shaped Cu filler soldered with Pb-Sn paste

Cu-SS cylinder crimped on

ENEA HTS cable – layout: termination

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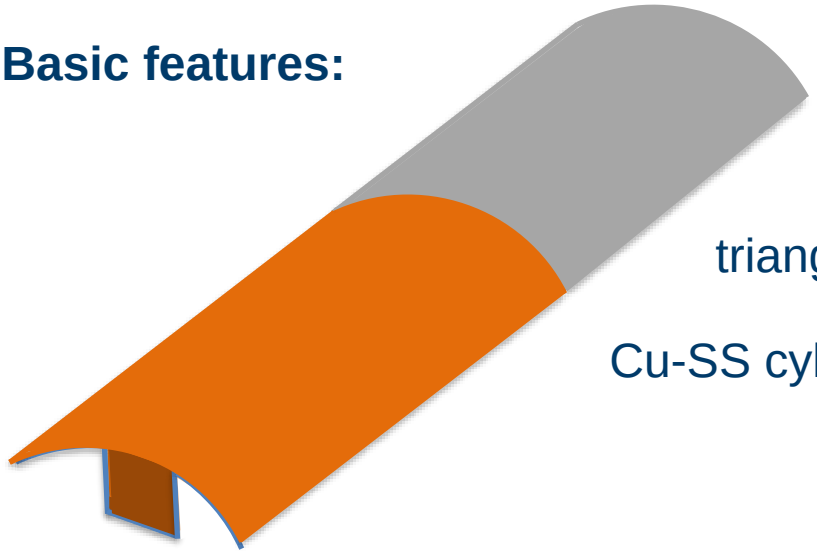

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staggered stack end inserted into the slot of the Al-core;

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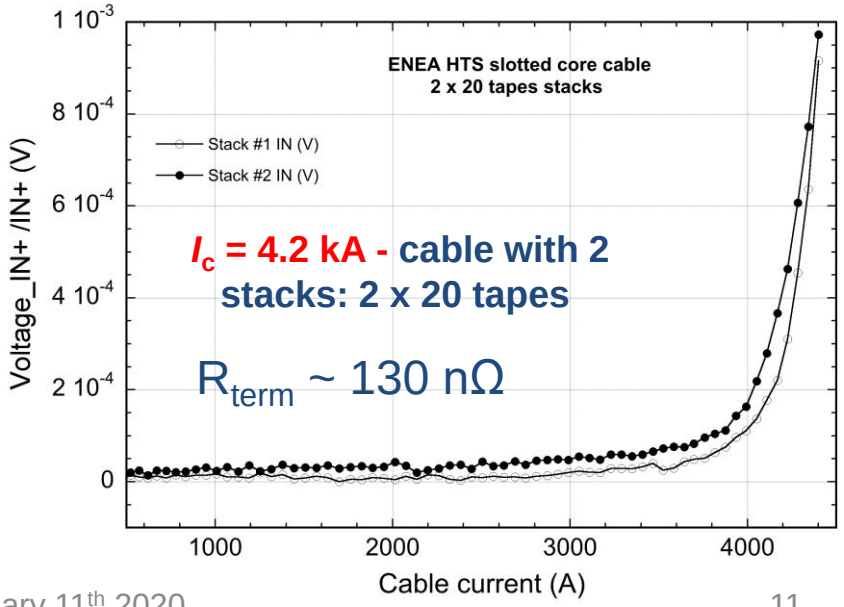
Cu-SS cylinder crimped on

LN2 bath Test @ ENEA 20 kA facility



ENEA HTS cable – mock-up sample

Prototype cable fro SULTAN quench experiment has been manufactured

2 m long – 3 HTS slots (20x3 tapes)

He leak test done: **PASSED!** Electrical test: on going (in few weeks)

Manufacturing Photo Story

Several problems encountered

Several solutions found

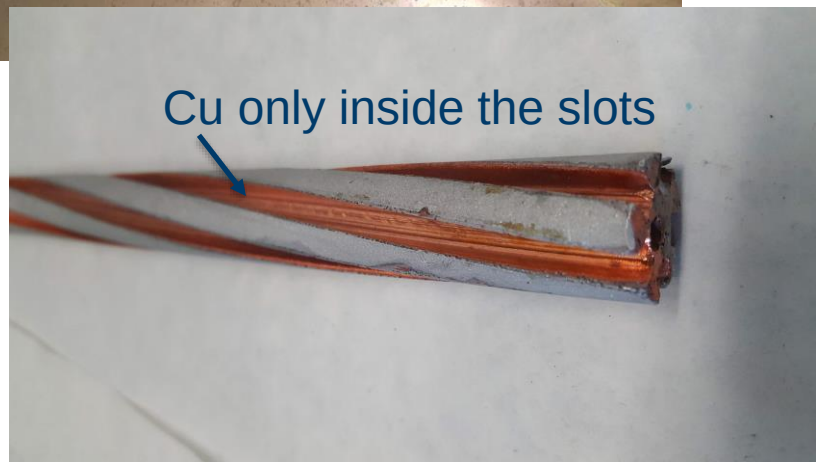
Thanks to **Marcello Marchetti**

STEPS

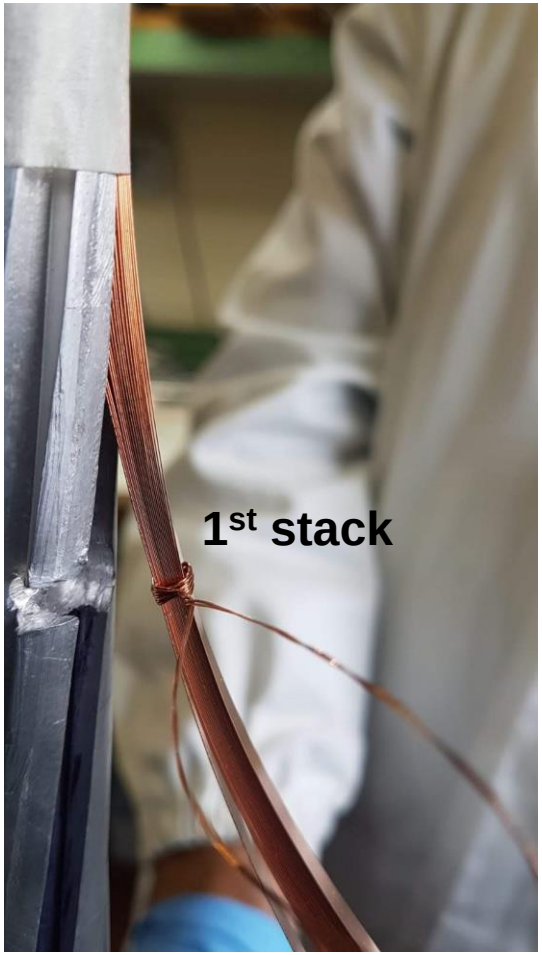
- Slots Cu electro-deposition
- Stack insertion
- Wrapping + jacketing
- Stack staggering
- Cu filler insertion and soldering
- Termination soldering and crimping

ENEA HTS cable – mock-up sample

- **Slots Cu electro-deposition**

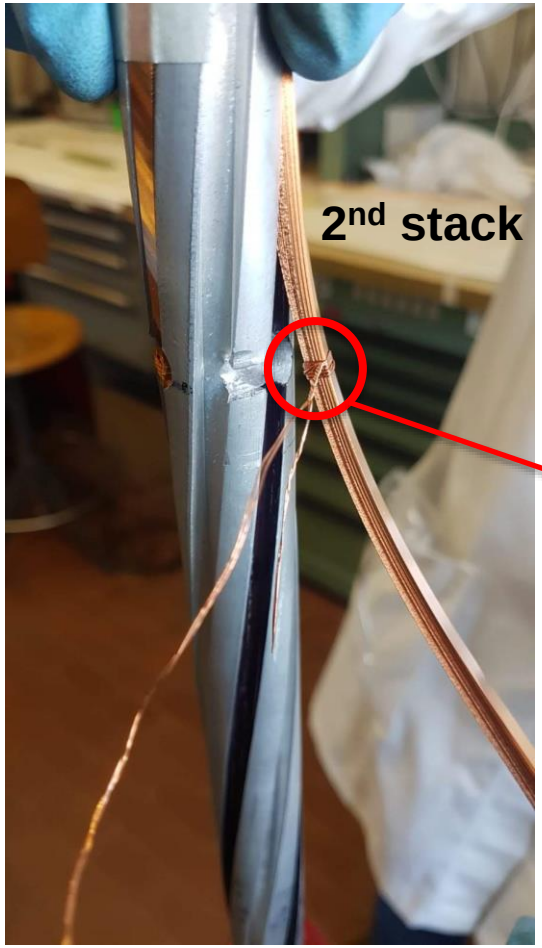


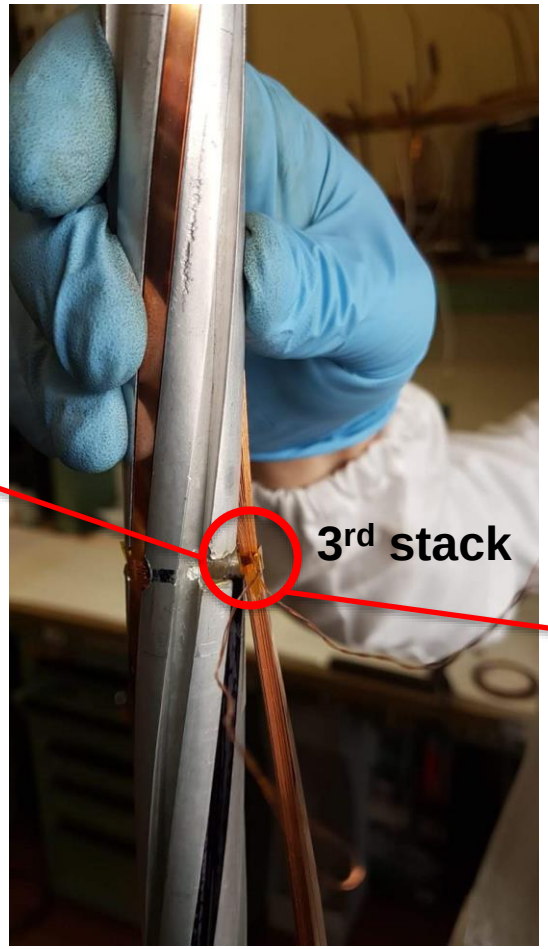
- **Stack insertion**



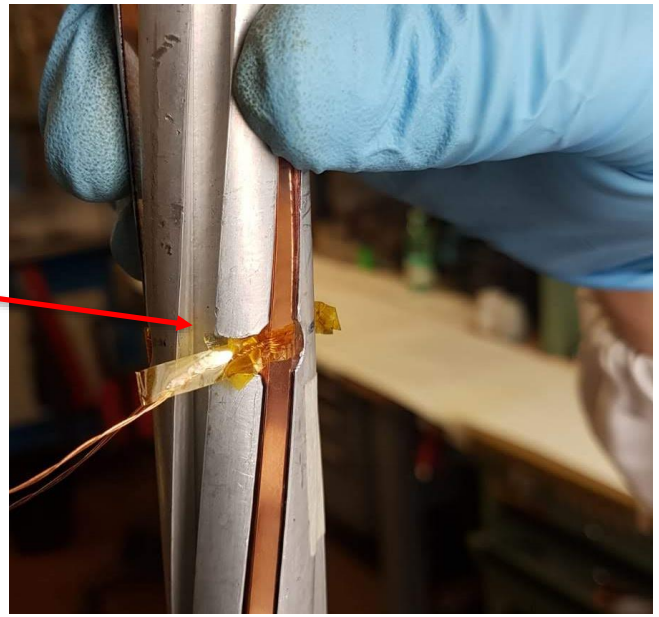
ENEA HTS cable – mock-up sample

- **Stack insertion**

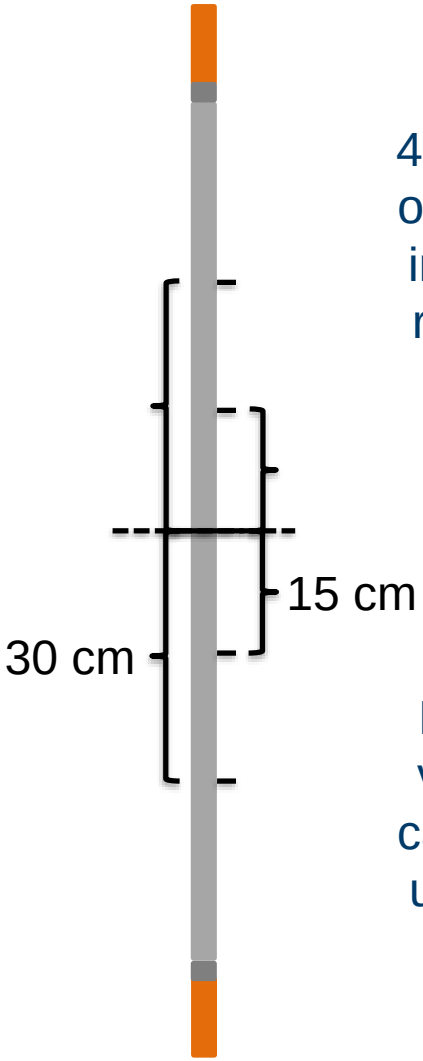




Voltage taps on each stack insulated with Kapton
Wires running out from the closest empty slot



ENEA HTS cable – mock-up sample



4 voltage taps on each stack in the central region of the cable

More than 4 voltage taps can be placed using thinner wires

ENEA HTS cable – mock-up sample

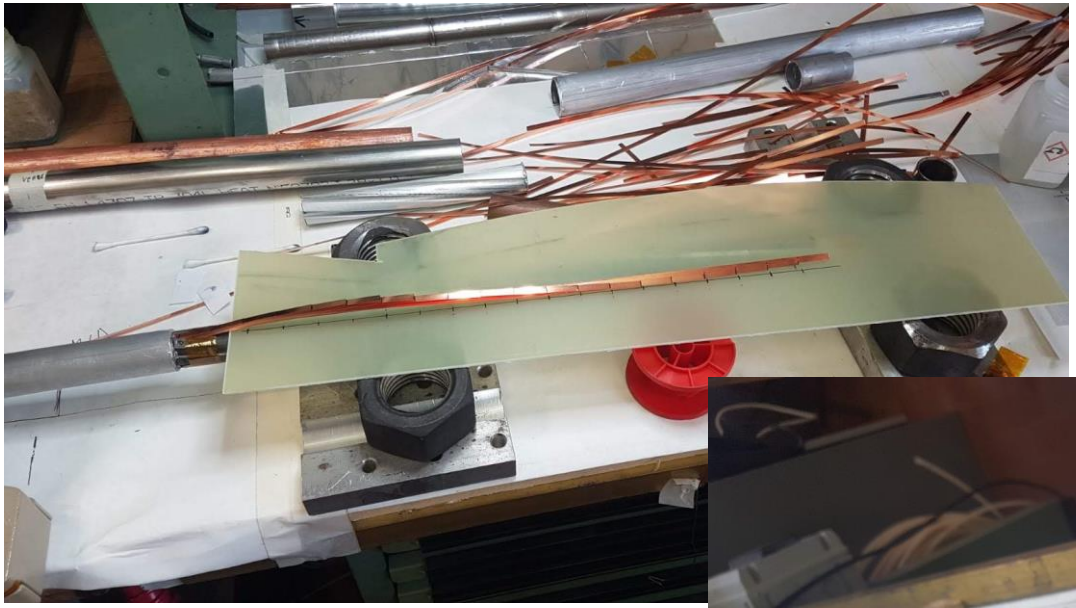
- **Wrapping + jacketing**

1.5 mm Al jacket (drawing)

1.0 mm SS jacket (no crimping)

ENEA HTS cable – mock-up sample

- **Stack staggering**



Al and SS jacket removed from the termination region

Stack staggered in 1 cm steps

Cu filler pre-shaped in the core slots

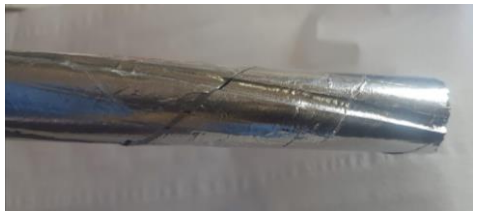
ENEA HTS cable – mock-up sample

- **Cu filler insertion and soldering**

Termination region after soldering e polishing

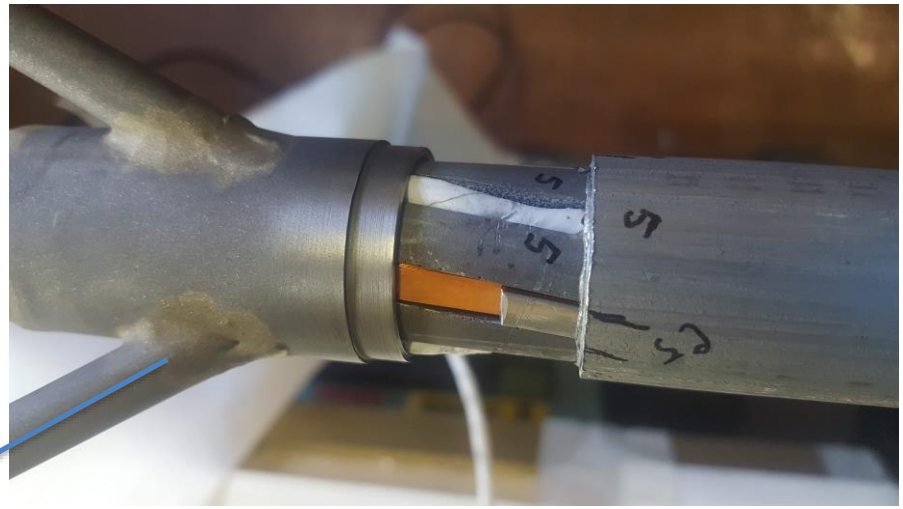
ENEA HTS cable – mock-up sample

- **Termination soldering and crimping**



Term A: In-foil

Term B: coated



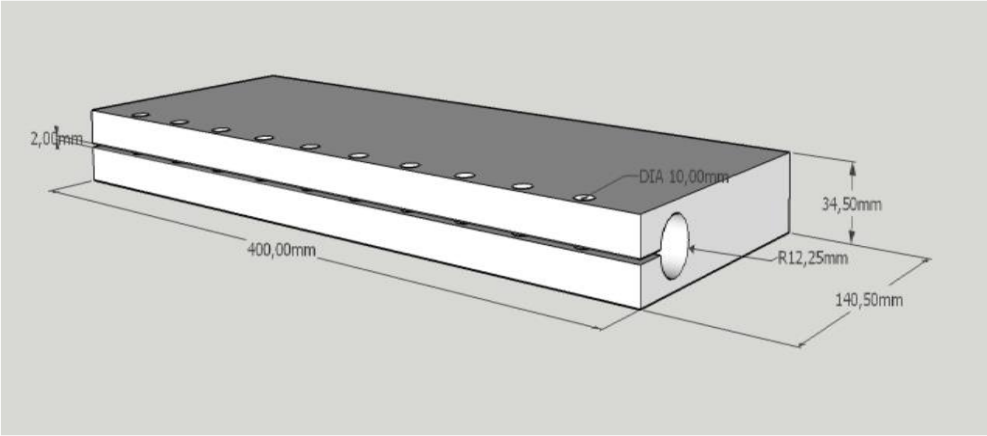
wires

ENEA HTS cable – mock-up sample

- **Termination soldering and crimping**

ENEA HTS cable – mock-up sample

We are currently manufacturing the termination plates (Cu)

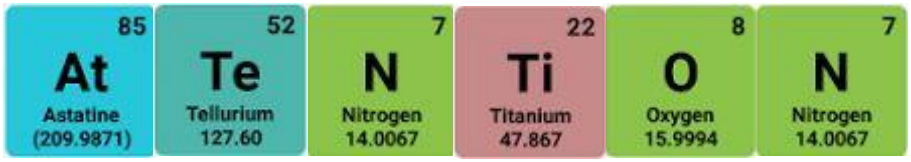


The same design, with two holes, will be used in the SULTAN sample as bottom connection

ELECTRICAL TEST AT LN2 SCHEDULED FOR THE END OF FEBRUARY

ENEA HTS cable – SULTAN Quench Experiment

Thank you for your



Thanks to all the ENEA HTS Cable Team and especially to **M. Marchetti**