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Multi-physics simulations of CORC® cables with different layouts / Development of a surrogate model for the prediction of the CORC® V-I

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Research pathline

- Numerical characterization of CORC® cable
  - Critical current and VI curve
  - Current distribution
- Prediction of different cable and layouts
- Optimization
- How to scale to coil level?

D002: Multi-physics simulations of CORC® cables with different layouts Sofia Viarengo

**D003:** Development of a surrogate model for the prediction of the CORC® V-I

Giordano Tomassetti

- COMSOL → Full **3D multi-physics model** aims at the evaluation of the **critical current Ic**, with a self-consistent current redistribution.

- Assumptions:
  - ✓ Tape assumed as a **homogeneous** and single material,
  - ✓ Jc depending on **temperature, magnetic field, and strain**
  - ✓ **Current redistribution** among tapes and layers
  - ✓ Coupling with the **thermal module** for cable cooling
  - ✓ Analytical definition of **strain map**

- Model validation:
  - ✓ Validated for V-I of CORC® cables (straight and bended) up to 6 tapes (Ic ok but **overestimation of the N-value)**
  - ✓ **Validated for** V-I of CORC® cables with 12 tapes (Ic ok but **overestimation of the N-value)**

$$\langle E \rangle = \frac{1}{w} \cdot \frac{1}{L_{tape}} \iint \frac{\iint E_{norm} \, dS}{}$$
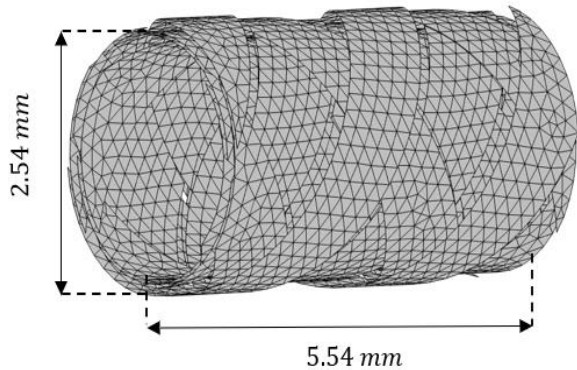
Termination effect!

- Ic well capture
- N-value overestimated

$I_{c,meas} = 526\ A$

$I_{c,COMSOL} = 527\ A$
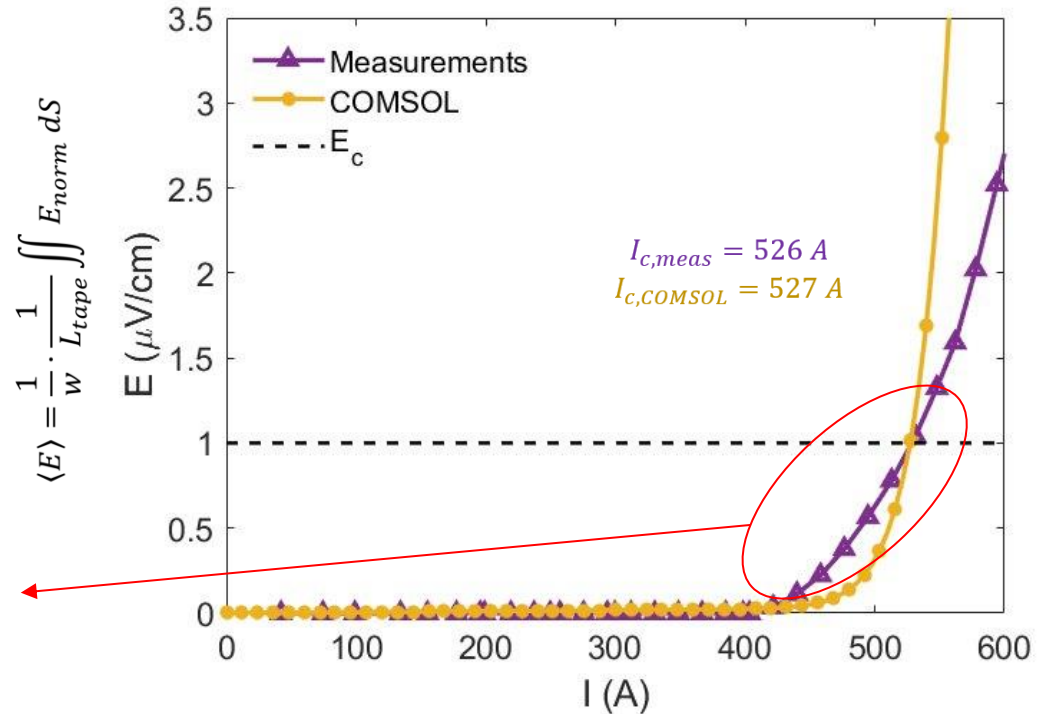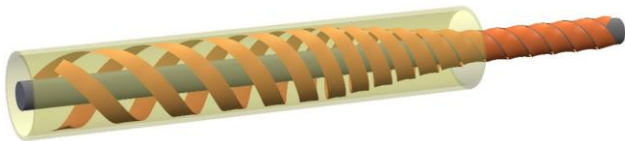
Cable specification
- Tape: 4 mm wide, 95 μm thick → *SuperPower Tapes*
- Tape I_c = 180 A @ 77 K
- 2 samples, with cable length = 1 m (already including 10-cm long terminations)
- CORC® composed of 4 tapes, 2 layers
- Cable I_c = 720 A @ 77 K
  - Expected I_c = 500-600 A, 20% reduction due to self-field

In collaboration with:
- **Prof. Freschi** and **Prof. Vaschetto** + **Prof. Laviano** @ PoliTo
- **Prof. Arend Nijhuis** @ University of Twente
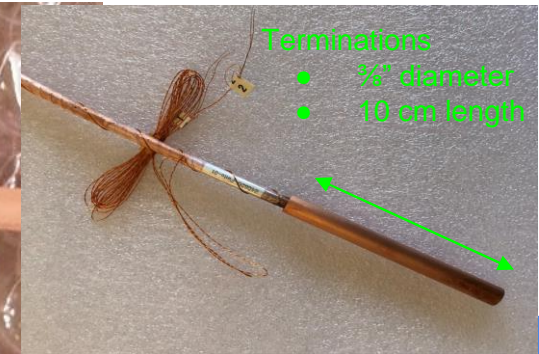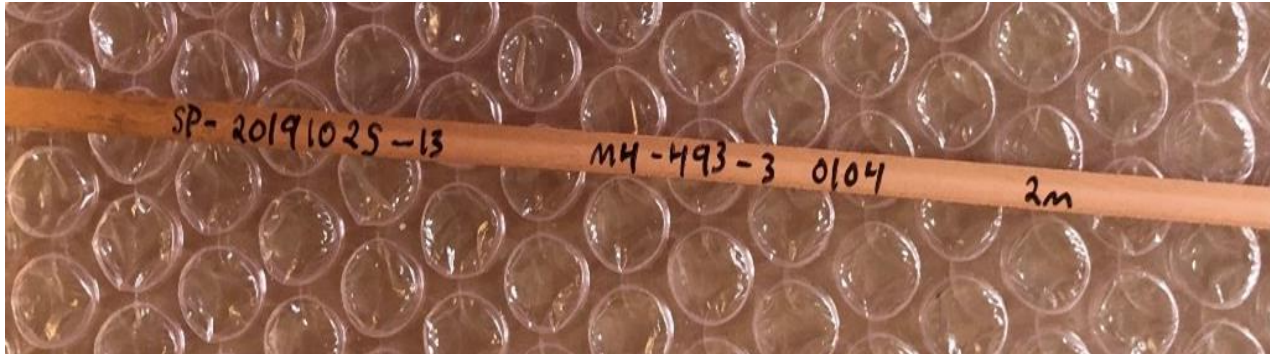
- FEM model computational expensive (already at the level of O(10) tapes on a single module → Not scalable to an entire coil
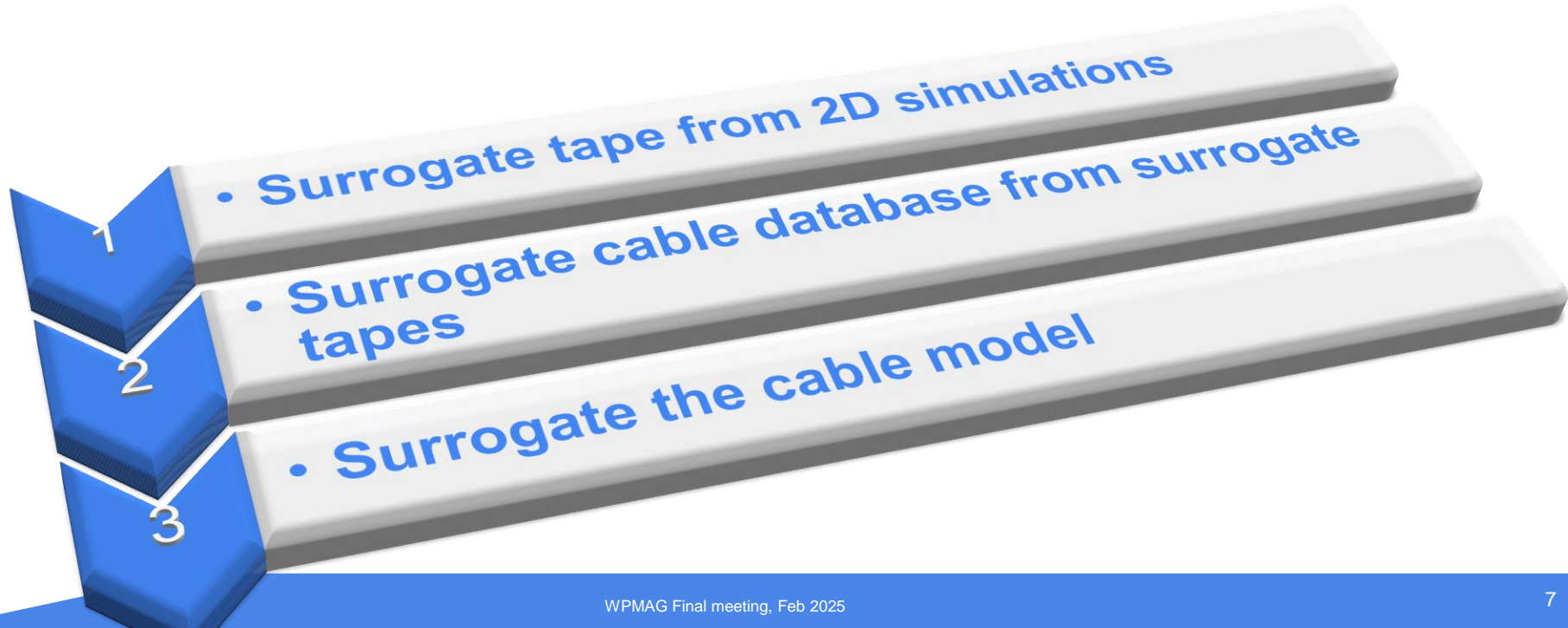- Experimental data are scares and heterogeneous
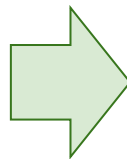
Surrogate models for an approximated **estimation of the critical current Ic** and the entire voltage-current **(V-I) curve** for different possible CORC® cable layout and operating magnetic field

Large sample size could be required to train the surrogate model to achieve the desired accuracy
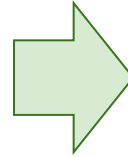
Introduce the surrogate model already at the level of the cable simulations

1. • **Surrogate tape from 2D simulations**
2. • **Surrogate cable database from surrogate tapes**
3. • **Surrogate the cable model**

→ 2D simulations (T-A formulation) for the homogenized tapes performed, considering:
- Different tape width: 2 mm to 12 mm
- Self- field due to operation at different current
- Temperature from 4.5 K to 20 K
- Different background field up to 20 T (@20K) and 7 T (@ 77K)
- *Still to be considered: different strain*

→ V-I curve extracted from COMSOL simulations

→ Based on that, an ANN is under development to surrogate the behavior of tape ….*COMING AT MT29*

Thank you for your attention!

Jc scaling law

Kim-like model

$$J_c(B, T, \varepsilon) = \psi(\varepsilon) \frac{I_{c0}}{A_{sc}} \cdot \left(\frac{\theta_{c0} - \theta_{sc}}{\theta_{c0} - \theta_0} \right) \cdot \frac{1}{\left[1 + \frac{\sqrt{(k \cdot B_\parallel)^2 + B_\perp^2}}{B_c} \right]^b} \left(\frac{A}{m^2} \right)$$

Err$_{max}$~1.2%