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WP8 - Innovative Superconducting Magnets report on Tasks 8.1 – 8.5

Ernesto De Matteis, INFN of Milan (Italy) – LASA laboratory

and all WP8 collaborators

I.FAST – 10th Steering Committee Meeting

14.December.2023 – online

WP8 – magnets members

(WP8 comprise also Task 8.6 on special SC cable for fast ramping led by GSI)

	Coordination	Tasks	Task leader	Deputy-task leader
WP8 Innovative superconducting magnets	E. De Matteis (INFN) T. Lecrevisse (CEA) C. Roux (GSI)	8.1 - Coordination and HTS Strategy Group	E. De Matteis (INFN)	A. Ballarino (CERN)
		8.2 – Preliminary Engineering design of combined CCT magnet	E. De Matteis (INFN)	D. Barna (Wigner Inst.)
		8.3 – Preliminary Engineering design of HTS CCT	S. Sorti (INFN)	A. Ballarino (CERN)
		8.4 - Construction of combined CCT magnet demonstrator	J. Munilla (CIEMAT)	D. Barna (Wigner Inst.)
		8.5 – Construction of HTS CCT magnet demonstrator	A. Echeandia (Elytt)	S. Sorti (INFN)
		8.6 – Development of ReBCO HTS nuclotron cable	T. Winkler (GSI)	C. Roux (GSI)

WP8 – Scope

- *Form a permanent **European Strategy Group**, open to worldwide partners, to discuss the European strategy for HTS magnets for accelerators, and to improve Industry involvement in this technology;*
- *Exploring **Canted Cosine Theta with HTS superconductor (main goal),** preceded by a **combined function CCT based on LTS** → involving the industries that want to learn about the CCT magnets;*
- ***Construction of the two demonstrators**: winding and magnet assembly, magnet test and validation;*

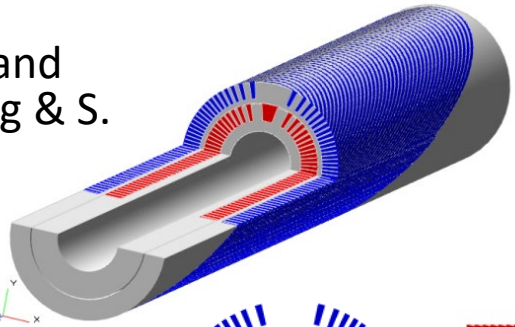
BERKELEY LAB

Program based on CORC and CCT layout led by X. Wang & S. Prestemon

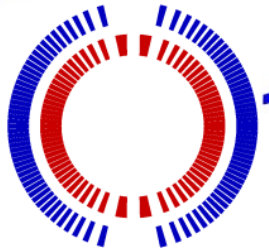
CORC® By Advanced Conductor Technologies

Outer layer

Courtesy of Xiaorong Wang



CCT dipole
4 T target
Ø =80 mm;
L <= 1000 mm



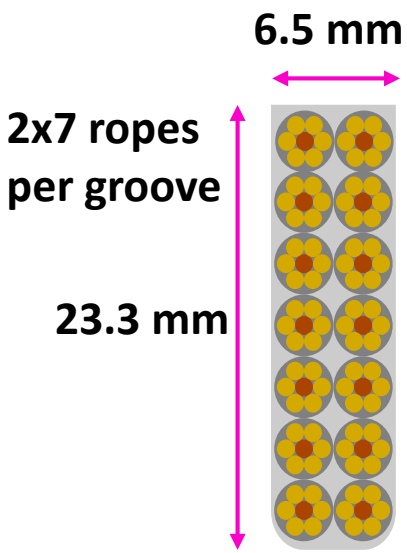
12 mm HTS REBCO tape

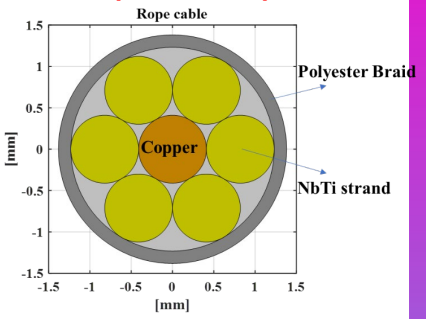
Courtesy of Tengming Shen

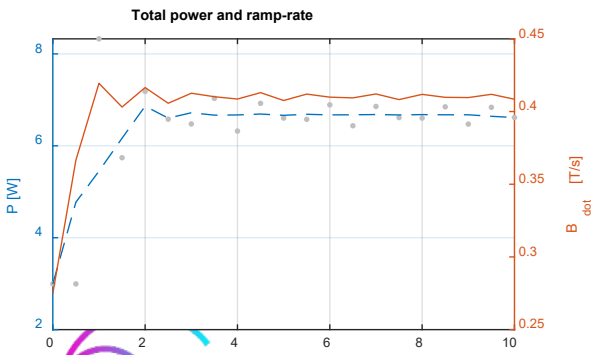
Task 8.4 - Construction of combined CCT magnet demonstrator

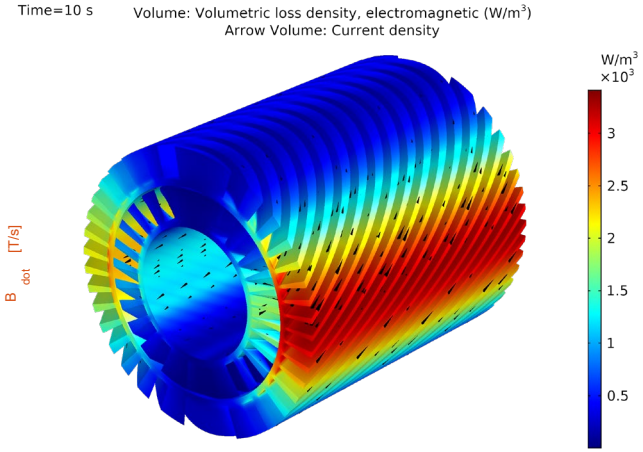
Task 8.4 – J. Munilla (CIEMAT)

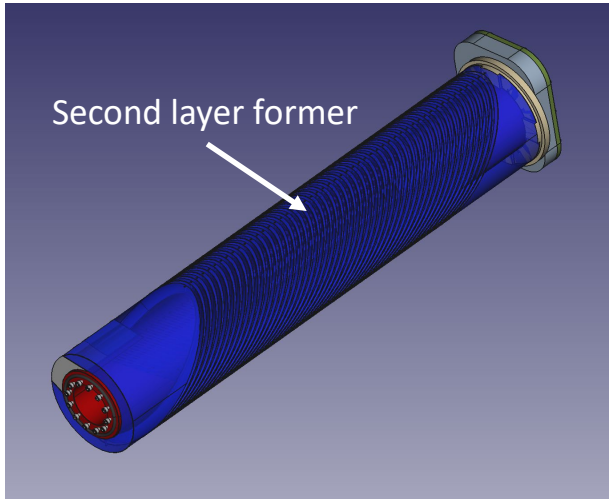
- **Combined CCT based on LTS** (rope 6 NbTi + 1 copper strand as HITRIplus):
- **4 T dipole + 5 T/m quadrupole (important feature to test it for CCT);**
- **Ramped at 0.2- 0.4 T/s** → challenge is the heat extraction generated by superconductor, and former;
- Straight geometry, Top of 4.2 K, nominal current of 1.5 kA;
- **Demonstrator for testing the combined feature of CCT and thermal study of AC losses;**
- Former made in Al-Br, wax impregnation;
- No iron yoke on the final demonstrator;

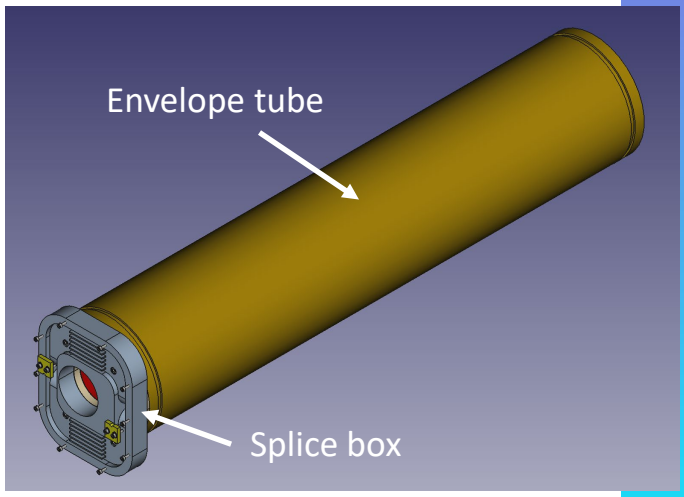












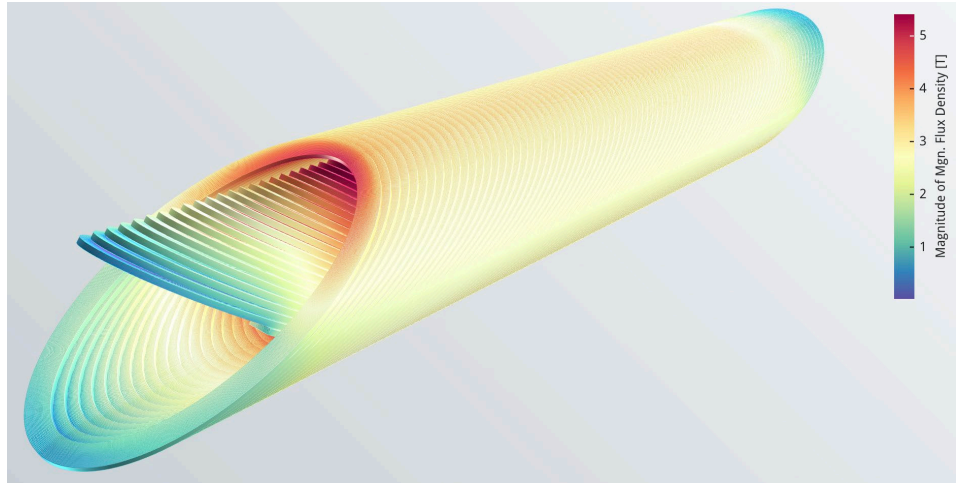
Task 8.5 - Construction of HTS CCT magnet demonstrator

Task 8.5 – A. Echeandia (ELYTT)

CCT based on HTS (REBCO tape 4 mm wide):

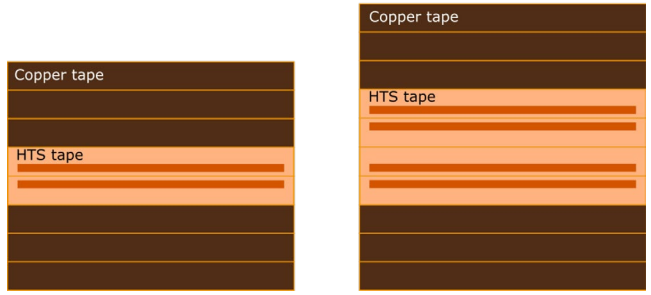
- **4 T dipole** with a new Top of **20 K** (> 10 K of margin);
- Frenet-Serret frame used for the conductor (avoid hard way bending);
- **Straight geometry** just to start the study (HTS is already difficult enough);
- **Two design options:** 2-tapes (980 A) and 4-tapes cable (1990 A);
- Quench protection is demanded (Cu stabilizer added for this);

Company Elytt Energy (Spain) in charge of the construction of demo;

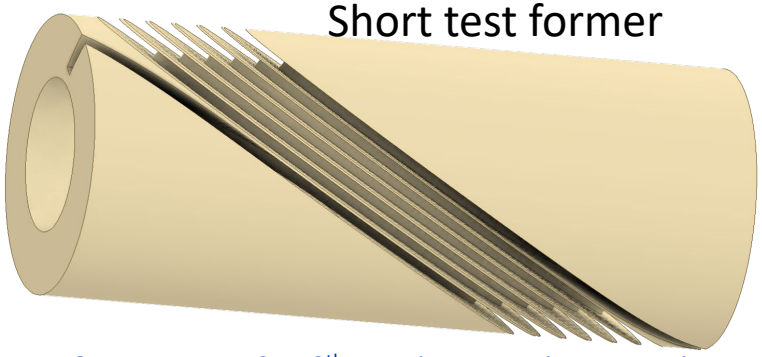


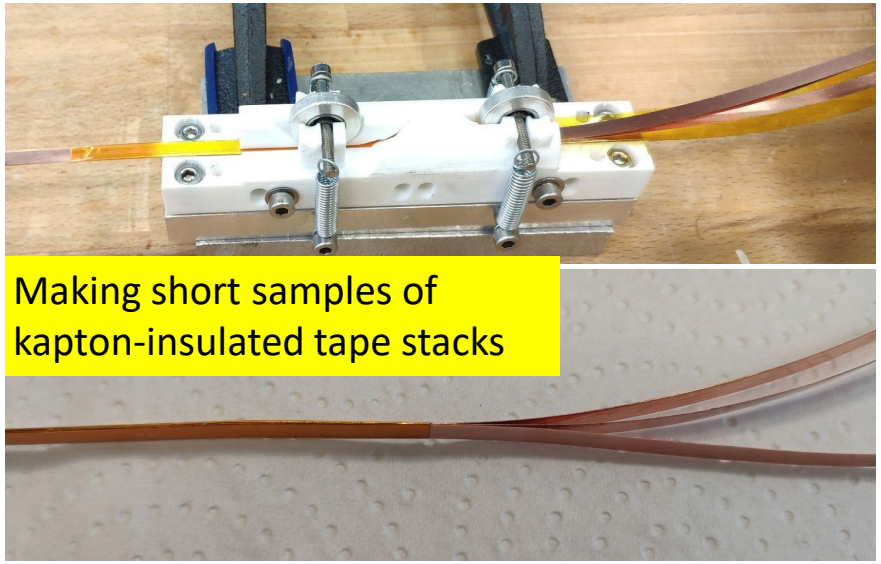
The **AC-losses (ramping at 0.4 T/s)** during operating for both designs are on average **50 W.** This is compatible with a conduction cooling system at 20 K.

1) No need of helium gas;
2) Power efficiency of cryocooler higher at 20 K wrt 4.5 K;



Short test former



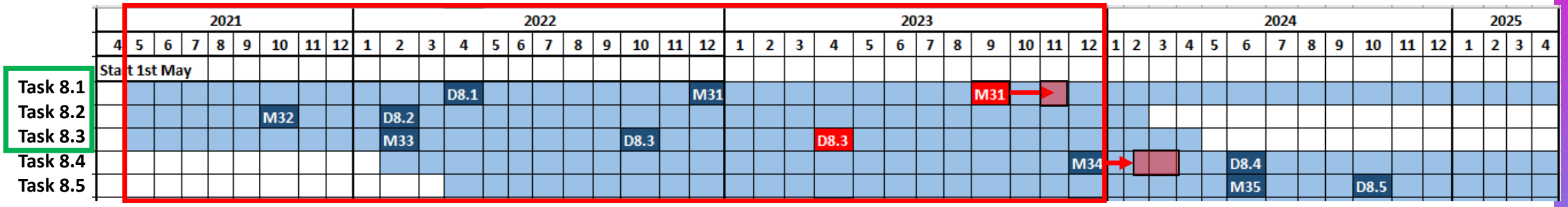


Making short samples of kapton-insulated tape stacks

WP8 – Timeline, Milestones and Deliverables

32 months activities

IFAST WP8: Innovative Superconducting Magnets
Task 8.1 - Coordination and High-Temperature Superconductor (HTS) Strategy Group
Task 8.2 - Preliminary Engineering design of combined Canted Cosine Theta (CCT) magnet
Task 8.3 - Preliminary Engineering design of HTS CCT
Task 8.4 - Construction of combined CCT magnet demonstrator
Task 8.5 - Construction of the HTS CCT magnet demonstrator



Deliverables:

- D8.1 (04/2022): HTS European Strategy Group (**ACHIEVED**) (CERN and INFN)
- D8.2 (02/2022): Conceptual Design of combined CCT in LTS (**ACHIEVED**) (INFN);
- D8.3 (10/2022 →04/2023): First Engineering design of HTS demonstrator (**ACHIEVED**) (CEA→INFN)
  - Difficulty of CEA in finding people to hire and change of responsibility from CEA (T. Lecrevisse) to INFN (S. Sorti) of Task 8.3.

Milestones: Difficulty of CEA in finding people to hire and

- M32 (10/2021): Characterization of the first length of superconductor for low losses (**ACHIEVED**) (INFN, Univ. Geneva, and CERN)
- M33 (02/2022→06/2022): Conceptual design of HTS magnet (**ACHIEVED**) (CEA)
- M31 (12/2022 → 11/2023): Construction readiness of combined CCT demonstrator (**SUBMITTED FOR APPROVAL**) (INFN/CIEMAT)
  - Delay due to the withdrawal of the companies from Task 8.4;

Milestone MS31 : Construction readiness of combined CCT demonstrator[1] (1/2)

Task 8.1 – E. De Matteis (INFN)


CONSTRUCTION READINESS OF COMBINED CCT DEMONSTRATOR

Milestone: MS31
Date: 31/10/2023

IFAST

Innovation Fostering in Accelerator Science and Technology

Horizon 2020 Research Infrastructures GA n° 101004730

MILESTONE REPORT

Construction readiness of combined CCT demonstrator

MILESTONE: MS31

Document identifier:	MS31
Due date of milestone:	End of Month 20 (December 2022)
Justification for delay:	Change of the beneficiary responsible
Report release date:	31/10/2023
Work package:	WP8: Innovative superconducting magnets
Lead beneficiary:	INFN
Document status:	Draft 1.0

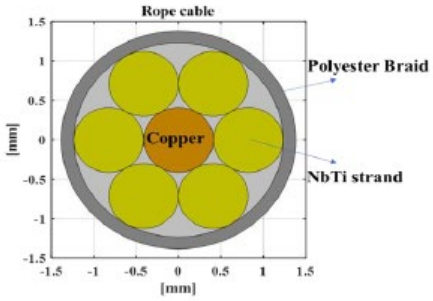
ABSTRACT

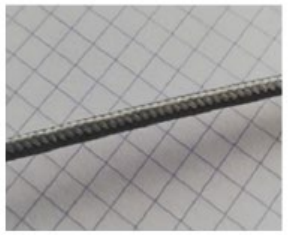
The report presents the construction readiness of the combined function CCT demonstrator. The document summarizes the components and the procedures that should be done to productively start and sustain magnet construction operations.

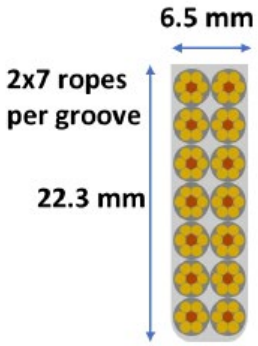
Grant Agreement 101004730 PUBLIC 1 / 23

The document summarizes the assembly process of the demonstrator magnet with detailed 3D illustrations, and listing the main components (conductor, formers, envelope tube, end plates, and splice box) and the main procedures (winding, impregnation and mechanical assembly).

- The conductor is a rope (6 NbTi strands+1 copper core) with a double braid of polyester, fully characterized in terms of critical current, high voltage and splice measurements, produced and delivered to CIEMAT (Madrid, Spain).
- The former material is aluminium-bronze, chosen due to its low electrical conductivity and favourable manufacturing properties;



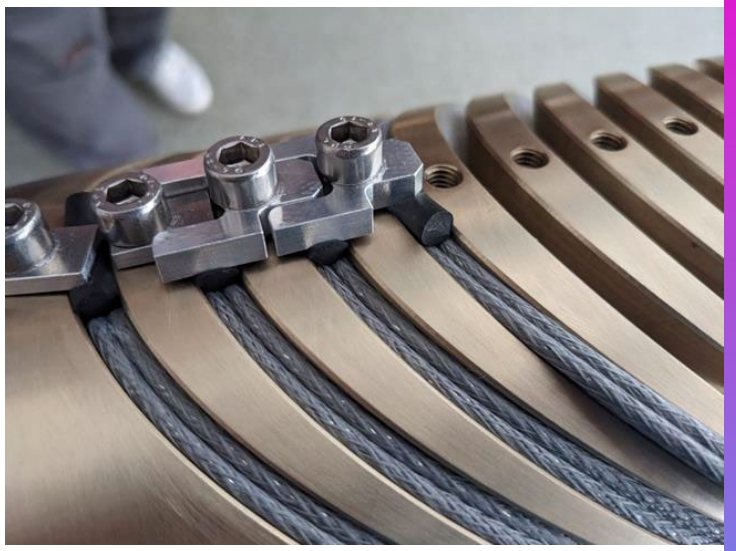


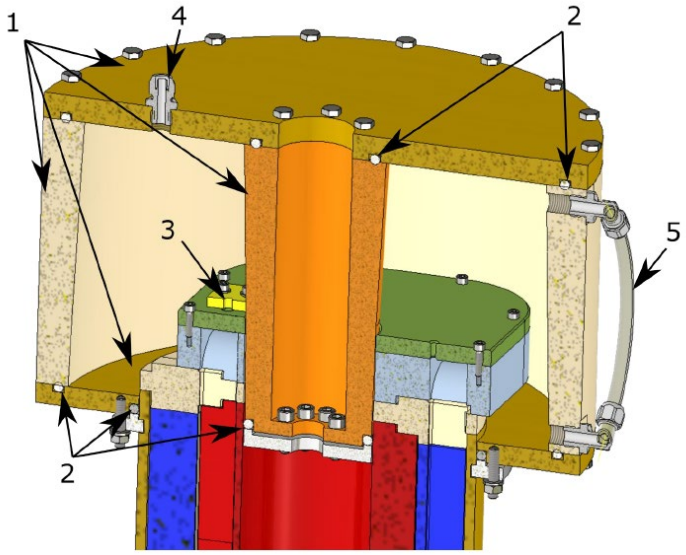


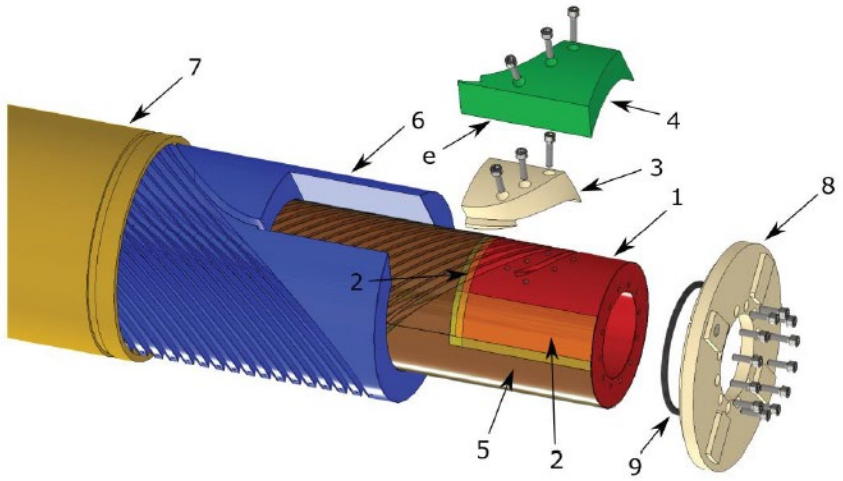
[1]E. De Matteis, D. Barna, F. Toral and R.U. Valente, '' **Construction readiness of combined CCT demonstrator** '', IFAST WP8.1 Milestone 31, submitted for approval

Milestone MS31 : Construction readiness of combined CCT demonstrator[1] (2/2)

- Winding procedure is described highlighting the improvements done during the tests;
- Wax impregnation is considered highlighting its effectiveness in preventing quenches and describing the impregnation process;
- The assembly procedure involves winding two layers of 2x7 ropes on inner and outer formers, testing insulation, adding support for layer transition, installing the envelope tube, end plates, and splice box, making rope joints and voltage taps, and concluding with wax impregnation and cleanup;
- The readiness table provides an overview of the construction status, indicating the construction level (ready and medium).







Components	Readiness status	Comments
Conductor	ready	Final production launched
Formers	ready	Company for the final production to be found
Envelope tube	medium	Missing mechanical simulation for establishing the final thickness
End plates	ready	
Splice box	medium	To verify the production by CNC-machining and material (G10)
Procedures		
Winding	ready	Winding techniques ready, 3D model ready, fabrication drawings ongoing
Impregnation	ready	Design ready, components to be manufactured with the other parts.
Assembly	medium	To be defined the interlayer and the external surfaces of the formers.

[1]E. De Matteis, D. Barna, F. Toral and R.U. Valente, '' **Construction readiness of combined CCT demonstrator** '', IFAST WP8.1 Milestone 31, submitted for approval

WP8 – Timeline, Milestones and Deliverables

Next steps

IFAST WP8: Innovative Superconducting Magnets

- Task 8.1 - Coordination and High-Temperature Superconductor (HTS) Strategy Group
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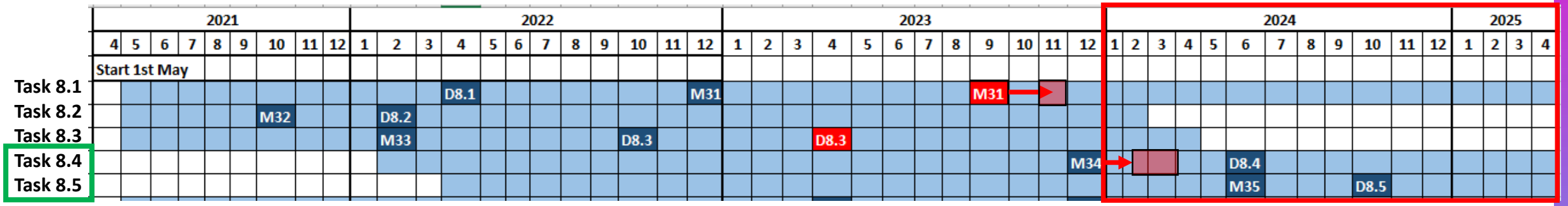

Deliverables:

- D8.4 (06/2024): Construction of combined CCT demonstrator (CIEMAT);
  - Deliverable is the " Magnet demonstrator complete with electrical termination and transport constraints";
  - The demonstrator will be tested and qualified in conditions near to the operative ones by cold test (Uppsala University, Freia laboratory);
- D8.5 (10/2024): Construction of HTS CCT demonstrator (ELYTT) → trying to recover the 6 months of delay from the task 8.3
  - Deliverable is the "Magnet demonstrator complete with electrical termination and transport constraints";
  - The demonstrator will be tested and qualified in conditions near to the operative ones by cold test (INFN, LASA laboratory);

Milestones:

- M34 (12/2023→02-03/2024): Construction of the formers for combined CCT winding (**delay**) (CIEMAT) - Report with conformity Certificate
  - CIEMAT launched the order with a company → still paying for the delay due to the withdrawal of the companies from Task 8.4;
- M35 (60/2024): Test of mock up coils with dummy cable (ELYTT);
  - Report on test and assessment of CI