HFM

High Field Magnets

HFM infrastructure needs at CERN

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HFM instrumentation needs at CERN

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Infrastructure Needs and Progress Status for Conductors

Infrastructure needs for conductors (1)

For HFM program, there is a stringent need to upgrade the B163/103 facilities to cope with characterization and cabling requirements, in particular two new critical current stations and a new cabling machine:

1. **Critical current station with solenoid magnet of 20 T (vertical field):**

- To develop high-field accelerator magnets with fields in the 14-20 T range, need to have adequate test station to characterize potential superconductors for use in such magnets.
- Capacity of CERN critical current test stations presently limited to fields of 15 T (suitable for ITER and HL-LHC, which operate at fields around 12 T).
- New test station will position CERN at the leading edge of high-field characterization of both LTS and HTS.

Infrastructure needs for conductors (2)

2. Critical current station with split-coil magnet of 10 T (horizontal field):

- Test stations with vertical solenoidal field only enable characterization of MgB_2 and HTS wires and tapes in most favourable configuration (*i.e.*, with field parallel to sample axis) because of minimum bending requirements on these brittle materials (*e.g.*, 100 mm minimum radius of curvature for MgB_2 wires).
- Given that HTS materials such as YBCO and REBCO are anisotropic, the critical current is strongly dependent on field orientation, and it is critical to fully characterize such dependence in order to assess in-coil performances of conductors.
- New test station will enable CERN to carry out characterization of transport current properties of HTS materials as a function of temperature, field amplitude and field orientation, a capability that is presently not available at CERN.

Infrastructure needs for conductors (3)

3. New cabling machine (60 strands):

- The current cabling machine in Building 103 can manufacture Rutherford cables with up to 40 wires.
- Several cable designs (MQXF, FRESCA 2, Falcon D, ERMC…) already make use of this maximum capacity.
- For HFM, on-going block-coil designs require larger cable widths in order to cope with increased aperture radius.
- For such designs, 44-56 strands appear to be necessary.
- Therefore, a new cabling machine able to manufacture up to 60 strands would have a genuine added value for sake of future high-field accelerator magnets.

20 T solenoid magnet system: main technical specs

Solenoid:

- Operating magnetic field at 4.2 K of up to 20 T, vertical field,
- Clear vertical bore diameter: 100 mm,
- Field homogeneity better than 1% in a cylinder volume of 200 mm height and 85 mm diameter, centred around the magnetic centre of the solenoid,
- Stray field: 200 mT radial limit from magnet centre: 0.5 m; 0.5 mT radial limit: 5 m (target).

Cryostat:

- Cryostat for liquid helium cooled solenoid,
- Maximum height of the cryostat: 2500 mm, Maximum diameter of the cryostat: 1200 mm. Maximum weight of cryostat, solenoid and liquid helium (in operation): 2000 kg (target).

10 T split-pair system: main technical specs

Split-pair magnet:

- Operating magnetic field at 4.2 K of up to 10 T, horizontal field,
- Clear vertical bore diameter: 100 mm,
- Field homogeneity better than 3% in a cylinder volume of 20 mm vertical height and 60 mm diameter, centred around the field centre of the split-pair,
- Stray field: 200 mT radial limit from magnet centre: 0.5 m (target); 0.5 mT radial limit: 6 m (target).

Cryostat:

- Cryostat for liquid helium cooled solenoid,
- Maximum height of the cryostat: 2000 mm, Maximum diameter of the cryostat: 1000 mm. Maximum weight of cryostat, split-pair and liquid helium (in operation): 2000 kg (target).

60-strand cabling machine: main technical specs

Preliminary technical requirements:

- Machine able to manufacture Rutherford cables of up to 60 strands and up to 35mm width and 2.5mm thickness (with stainless steel tape inside of up to 25mm width).
- Option for fabricating round cable up to 30mm diameter (with core inside if needed of up to 25mm diameter).
- Machine able to rotate in both directions.
- Planetary machine with back twist of up to 110%.
- Maximum cabling speed of, at least, 3 m/minute.
- Strand spool size and mass similar to current machine (up to 34 kg).
- Strand diameter ≤ 1.3mm and length on spool ≤ 1.5 km.

Progress on: Upgraded/New I_c Stations

- Procurement and installation of upgraded/new I_c stations (up to **20 T vertical** and up to **10 T horizontal field**).
- **Full magnet systems** including **magnet**, **cryostat**, **magnet PS**/current leads, **protection systems** and ancillaries to be procured from industry.
- **CERN** will cope to station upgrade/construction for **civil engineering**, **cryogenic/electrical** connections and racks…
- **Combined Market Survey** for both magnet systems launched in **June 2023.**
- **Individual invitation to tender** issued for **20 T** system on September 28th, 2023. Deadline for offers: 16th of November 2023.
- Contract for 20 T system expected to be **signed** in **March 2024**.
- **20 T station** expected to be **commissioned Mid-2026**.
- Finalization of **tender documentation** for **10 T** split-pair system **ongoing**.
- **Invitation to tender** for **10 T** system expected to be launched by **end of 2023**.
- Contract for 10 T split-pair system expected to be **signed** in **June 2024**.
- **10 T split-pair station** expected to be **commissioned Q4 2026**.

Progress on: New Cabling Machine

- Procurement and installation by the industry of a **new cabling machine** for the manufacturing of Rutherford cables of up to **60 wires**.
- Machine normally to be **installed** in **B927**.
- **Market Survey** launched on **15th of September**; some feedback already received.
- **Invitation to Tender** expected to be issued **Q1 2024**.
- **Contract** expected to **be signed Q3 or Q4 2024**.
- Cabling **machine** expected to be **commissioned** by **end 2026**.

Infrastructure Needs and Progress Status for short Nb_3Sn models

Building 927 – Preparation of infrastructures for HFM (and others)

Winding house
- New lighting
- New hallway and closed clean area
- New floor Q4 2023
- 2 new winding machines - Q1 and Q2 2024

Laser cutting area
- New room layout (more space)
- New cutting machine

Coil measurement area
Refurbishment of:
- E-press - Q2 2024
- Ten stack presses - Q1 2024
- Mock-ups press - Q1 2024

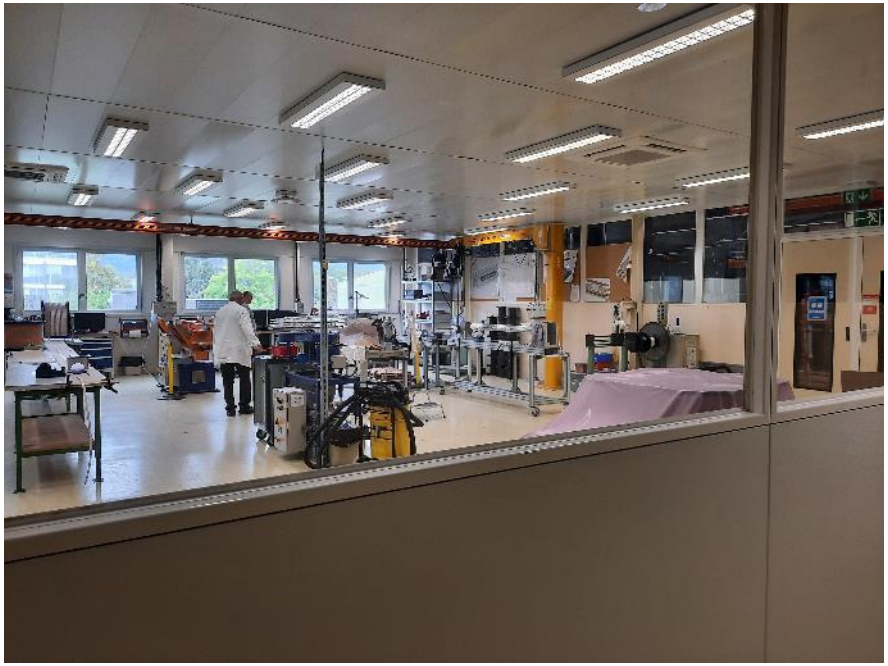
New HV testing room

Refurbishment of the three coil heat treatment ovens – Q2 2024

- Refurbishing of office space and general clear up of storage areas.
- Small tools – keep what we use, store or discard the rest.

Winding house

- Hallway and separate clean area ready
- New lights installed
- New floor Q4 2023



Two winding machines under fabrication

- One optimized for solenoids and CCTs (straight and curved). Q1 2024.
  Not financed by HFM but ready when and if needed.
- One optimized for flat coils, flared ends. Q2 2024
- Refurbishing of the brake of the existing cosθ winding machine (not urgent - 2024)

Laser cutting area

CERN wide service

- Closed area ready (clean)
- New machine

Coil measurement area – key asset

Goal:
Improve the knowledge of coil mechanical properties.

- Ten stack measurements
- E – measurement machine

Tests on arch (coil shape) elements (RT and 77K). – 300 t press.

Presses (one E coil measurements, two ten stacks and a 300 t mock-ups) to be refurbished and re-installed – **New layout under definition** – Full area operational Q4 2024

New HV measurement room

See Roland’s talk

Coil HT ovens – Large, medium, small size.

Design of the systems to **limit Argon consumption** of two ovens on going.

Repair / change of a third small oven under evaluation.

First improvements (Argon) Q3 2024

New control system in 2025

Infrastructure Needs and Progress Status for Nb_3Sn long models

New tools - building 180

• Reaction furnace	2026
• Vacuum pressure impregnation station	2026
• Marble and metrology needs	2025-26
• Reconfiguration of winding machine and forming / curing press	2025-26

HFM instrumentation needs at CERN

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Instrumentation and measurement equipment needs for the HFM R&D program

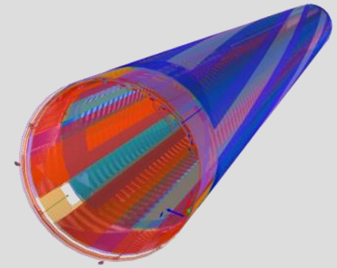
Main aspects

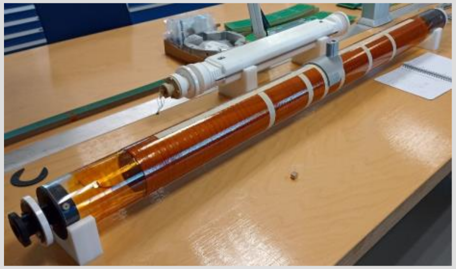
- Non-invasive quench localization
- New sensors and techniques
- High-performance data acquisition
- Magnetic measurements
- Measurement infrastructure

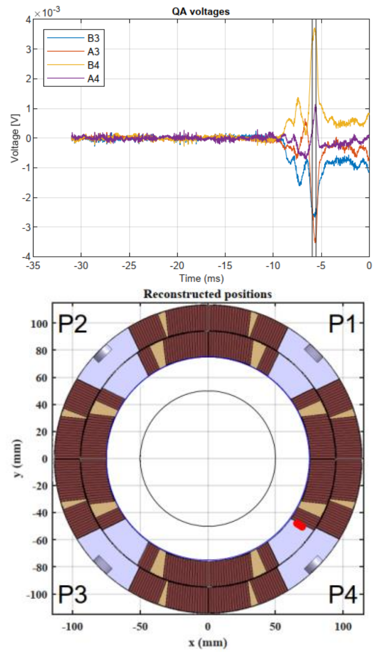
Non-invasive quench localization

- Precise localization of quench origin by means of non-invasive methods
- Recent developments:
  - Flexible printed circuits
  - Improved reconstruction based on multipoles
  - Combined transverse and longitudinal localization
  - Reduced number of channels
- The sensor can be use for the study of other fast phenomena (mechanical vibration, flux-jumps)

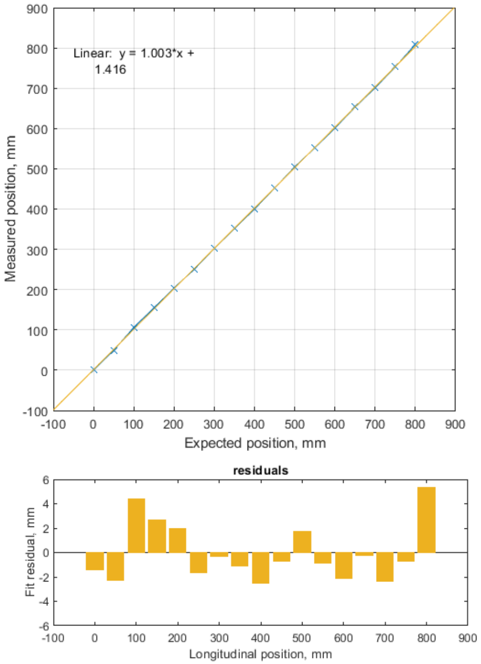
Prototype sensor for transversal and longitudinal quench localization (CERN)







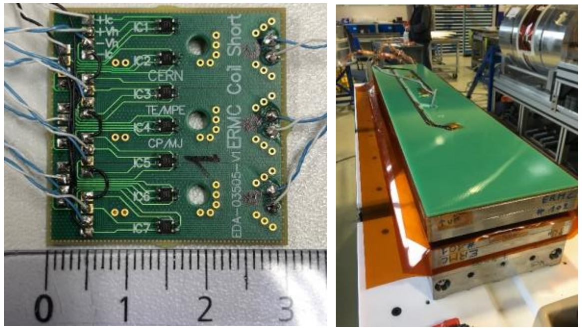
Transversal localization (real quench)



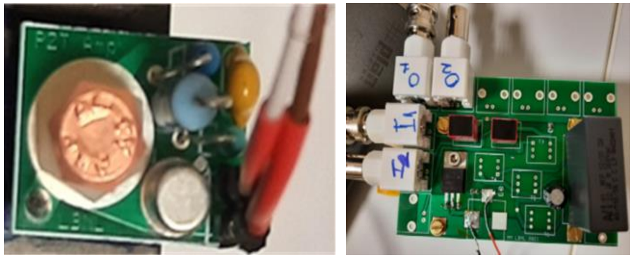
Longitudinal localization (test source)

Sensors

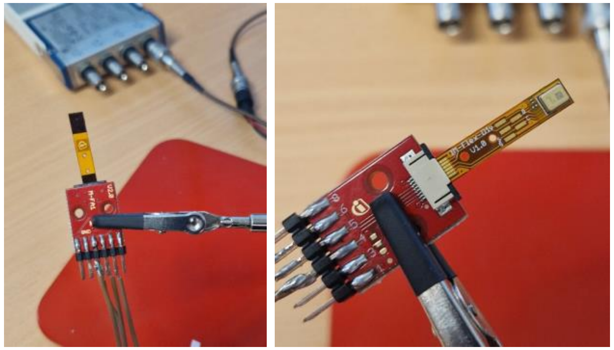
- Explore new possibilities
- Variety of sensors
  - Pick-up coils
  - Hall probes
  - Acoustic-emission sensors
  - Accelerometers
  - Thermometry
- Combination of techniques
- Small sensors can be embedded in the magnet



Hall-probe array for racetrack-coil magnets (CERN)



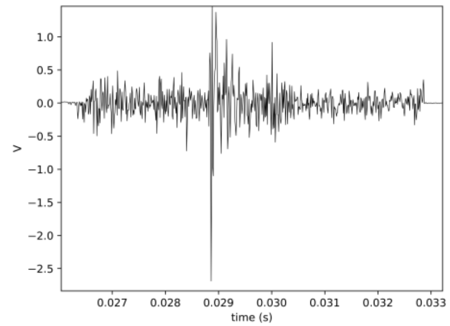
Acoustic-emission sensor (M. Marchevsky, LBNL)



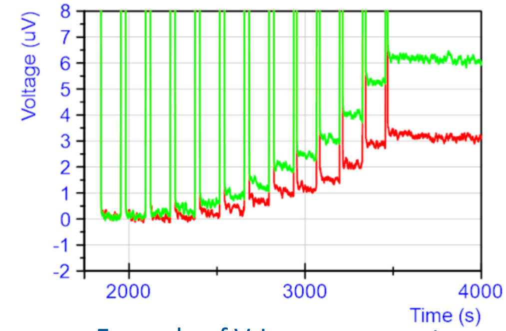
Small-size MEMS microphones

Data acquisition

- High-performance data acquisition systems
  - High sample-rate
  - High precision
  - Multiple channels
  - On-line processing
- Signal conditioning
  - Low-noise amplifiers



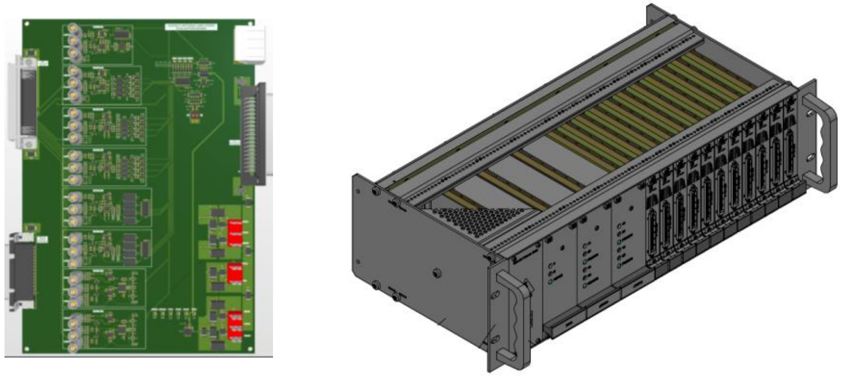
Example of mechanical vibration



Example of V-I measurement


UQDS acquisition unit (CERN)

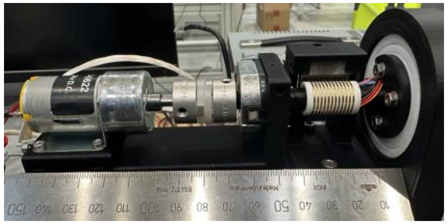

Commercially-available systems


Multi-channel low-noise amplifier (CERN)

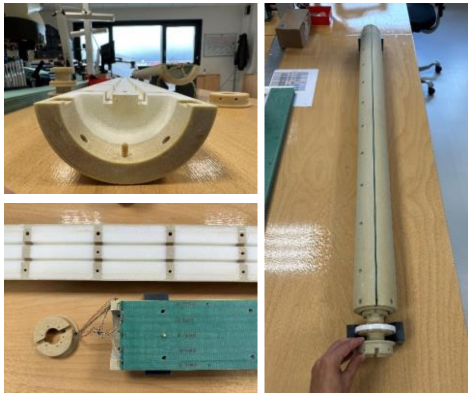
Magnetic measurements

- Full exploitation of well-known techniques
- Recent developments:
  - Improved accuracy (printed circuits, new calibration methods)
  - Improved time and spatial resolution (multi-segment fast rotating coils)
  - Scanning systems (mechatronic for positioning, optical targets for precise alignment)
- Specific instruments adapted to the new magnet dimensions

Rotating-coil scanner for HL-LHC



Prototype of a miniaturized motor-encoder unit for 50-mm magnets



Rotating-coil segment for HL-LHC

Measurement infrastructure

- Easy access to the magnet aperture at ambient temperature
- Flexibility of changing sensor type or position during test run
- On-going work for developing
  - 50-mm anti-cryostats
  - Positioning system

Anti-cryostats for 50-mm aperture magnets

Thank you for your attention

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