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PSI

CHART

Swiss Accelerator Research and Technology

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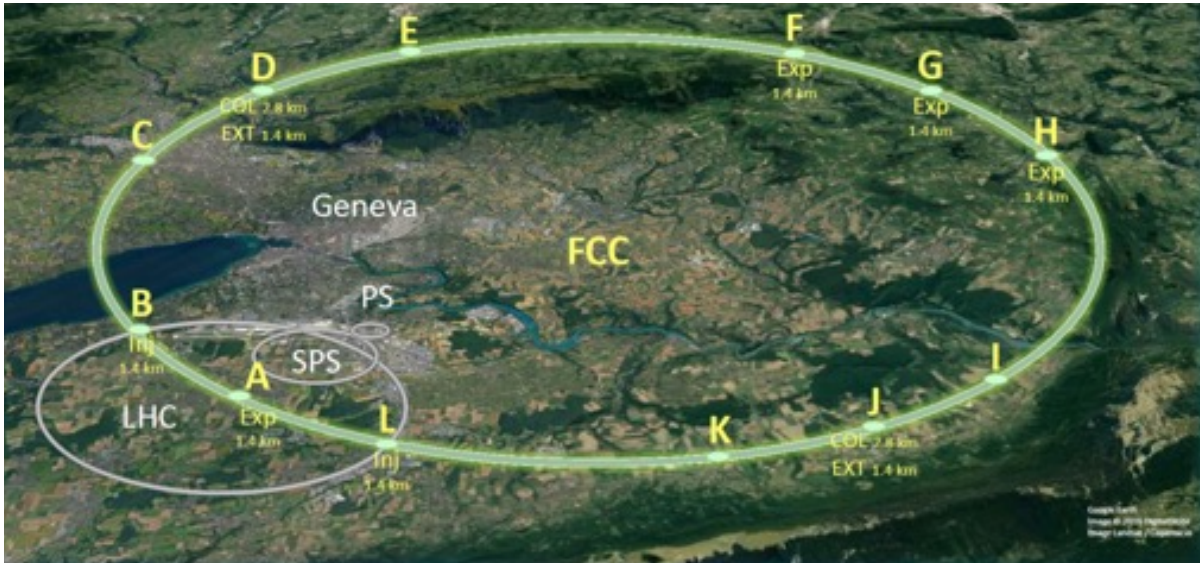
Joint Annual Meeting of the Austrian Physical Society and the Swiss Physical Society, University of Innsbruck, September 1st, 2021.

High-Field Magnet Development in CHART MagDev

Work supported by the Swiss State Secretariat for Education, Research and Innovation SERI.
http://chart.ch

CHART – What, Who How?

- From the application for support of the Swiss Accelerator Research and Technology Initiative (2018):
  - ***CHART**, the Swiss Center for Accelerator Research and Technology, **was founded to support** the future oriented accelerator project **Future Circular Collider (FCC)** at CERN and **the development of advanced accelerator concepts in Switzerland beyond the existing technology**.*



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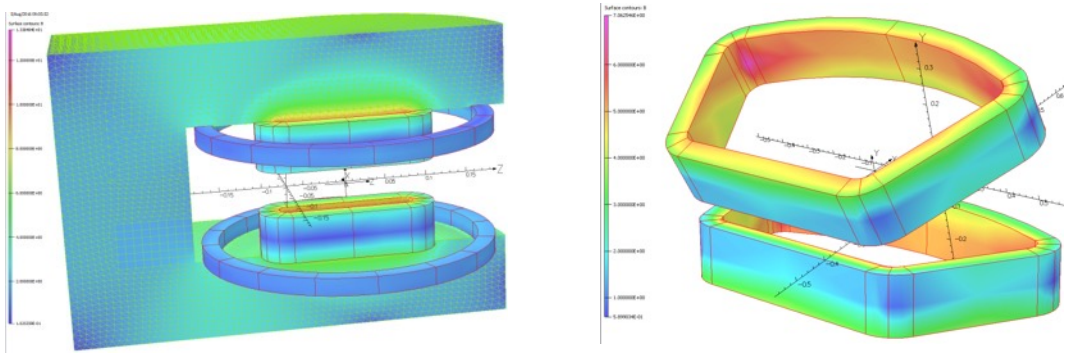
  - *CHART, the Swiss Center for Accelerator Research and Technology, was founded to support the future oriented accelerator project Future Circular Collider (FCC) at CERN and the development of advanced accelerator concepts in Switzerland beyond the existing technology. […]* ***The high field magnet R&D has strong synergies with PSI projects*** *[…]*
- For example:
  - SuperBend magnets and undulators for PSI light sources.
  - Gantry magnets.

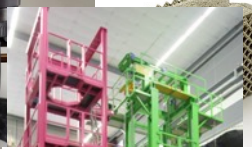


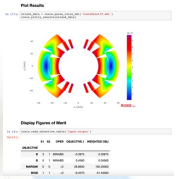
SLS 2.0 Superbend SC Gantry PSI

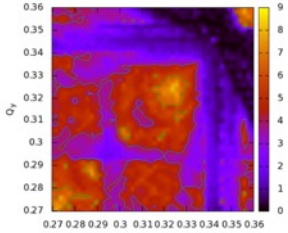
Courtesy Ciro Calzolaio

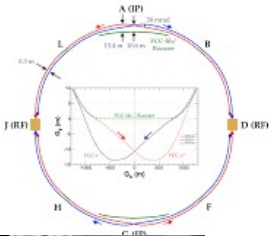
- In return, CHART activities enjoy steadfast support from PSI magnet section.

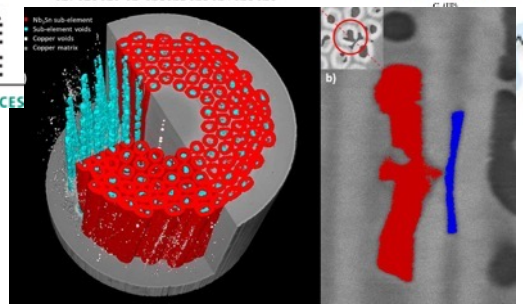
CHART HFM Activities











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ETH zürich

EPFL SWISS PLASMA CENTER

CERN

UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES

CHART
Swiss Accelerator Research and Technology

CHART – What, Who How?

- Topics of ongoing **ASC projects** in CHART:
  - WireChar – SC wire and tape characterization
  - WireDev – Nb_3Sn wire development
  - MagDev1 – SC magnet development
  - MagRes – resin development
  - MagAM – additive manufacturing for coil components
  - MagNum – numerics for design and analysis
  - HTS Bulk Undulator – Bulk REBCO undulator technology
  - FCCee Injector – injector test at SwissFEL, incl. NI solenoid
- Other ongoing CHART projects:
  - FCC / LHC Lumi
  - FCCee Beam Dynamics Simulation
  - FCChh Stability
  - FCC Geodesy
  - FCC Geology 3D Model

CHART HFM – Technology Pillars

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WireChar
WireDev

MagDev1
MagDev2
FCCee Injector

Strand / Tape

LTS and HTS strand/tape
R&D, Procurement, QA

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Cable

Rutherford / Roebel production

CERN

BERKELEY LAB

Fermilab

Magnet Design

FCC-hh / HE-LHC conceptual and technical

Coil Manufacturing

Nb3Sn and HTS coils

PAUL SCHERRER INSTITUT PSI

Mechanical Assembly

Mechanical loading

Testing

LTS and HTS magnet tests

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CERN

BERKELEY LAB

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CHART HFM – Enabling Technology R&D

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X-ray tomography
Billet manufacturing

Strand / Tape

LTS and HTS strand/tape R&D, Procurement, QA

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Cable

Rutherford / Roebel production

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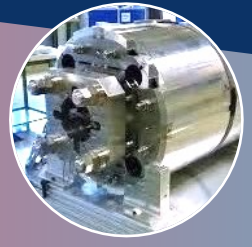
PAUL SCHERRER INSTITUT PSI

Mechanical Assembly

Mechanical loading



Testing

LTS and HTS magnet tests

EPFL SWISS PLASMA CENTER

BERKELEY LAB

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Fermilab

CHART HFM – Enabling Technology R&D

Swiss Accelerator Research and Technology

MagNum

Sustainable design and analysis workflows
Multi-scale modeling

Strand / Tape

LTS and HTS strand/tape R&D, Procurement, QA

Cable

Rutherford / Roebel production

Magnet Design

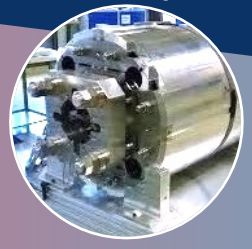
FCC-hh / HE-LHC conceptual and technical

Coil Manufacturing

Nb3Sn and HTS coils

Mechanical Assembly

Mechanical loading



Testing

LTS and HTS magnet tests

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CHART HFM – Enabling Technology R&D

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MagRes

Polymer R&D
Insulation and composite R&D
Splices and Joints
REBCO NI Coil Technology

Strand / Tape

LTS and HTS strand/tape R&D, Procurement, QA

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Cable

Rutherford / Roebel production

CERN

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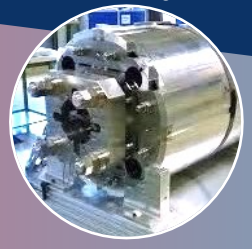
Mechanical Assembly

Mechanical loading



Testing

LTS and HTS magnet tests

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CHART HFM – Enabling Technology R&D

Swiss Accelerator Research and Technology

MagAM

Additive manufacturing
Coil interfaces
Process digitization QA/QC

Strand / Tape

LTS and HTS strand/tape R&D, Procurement, QA

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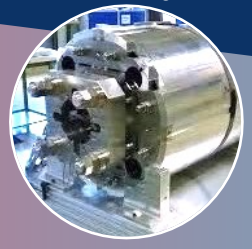

Testing

LTS and HTS magnet tests

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CHART HFM – Enabling Technology R&D

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UNIVERSITY OF TWENTE. · BROOKHAVEN NATIONAL LABORATORY · EPFL · Haute école d'ingénierie et d'architecture Fribourg / Hochschule für Technik und Architektur Freiburg

Subscale sample tests in background field
Quench Protection
Instrumentation and Signal Analysis

STRAND / TAPE

LTS and HTS strand/tape R&D, Procurement, QA

UNIVERSITÉ DE GENÈVE – FACULTÉ DES SCIENCES

CABLE

Rutherford / Roebel production

CERN · BERKELEY LAB · Fermilab

MAGNET DESIGN

FCC-hh / HE-LHC conceptual and technical

COIL MANUFACTURING

Nb3Sn and HTS coils

PAUL SCHERRER INSTITUT PSI

MECHANICAL ASSEMBLY

Mechanical loading

TESTING

LTS and HTS magnet tests

EPFL SWISS PLASMA CENTER · CERN · BERKELEY LAB · PAUL SCHERRER INSTITUT PSI · UNIVERSITÉ DE GENÈVE – FACULTÉ DES SCIENCES

LTS Driving Questions

- How to increase the overall robustness and perf… performance of Nb3Sn technology in terms of
  - increased field,
  - increased yield of conforming coils,
  - reduced magnet training to ultimate field, and
  - resilience to operational and thermal cycles?
- To which level can the magnetic field be pushed in an economical way?
- How to reduce the manufacturing complexity and material cost?

How to demonstrate technical and financial feasibility of FCC Magnet System? (ESPPU 2020)

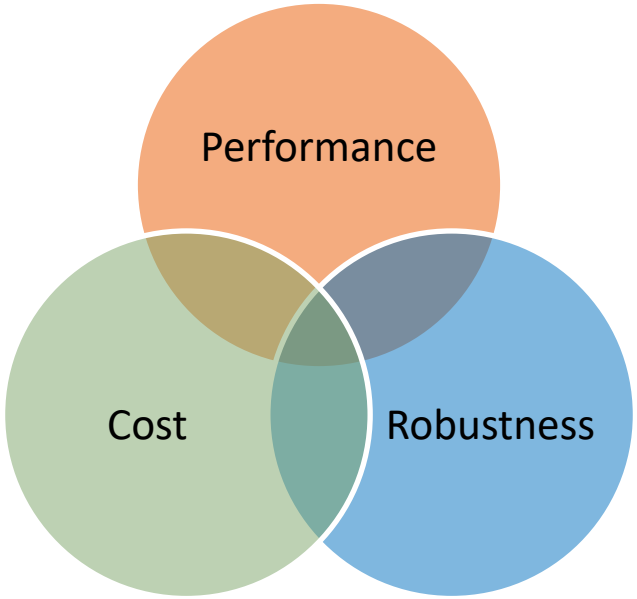
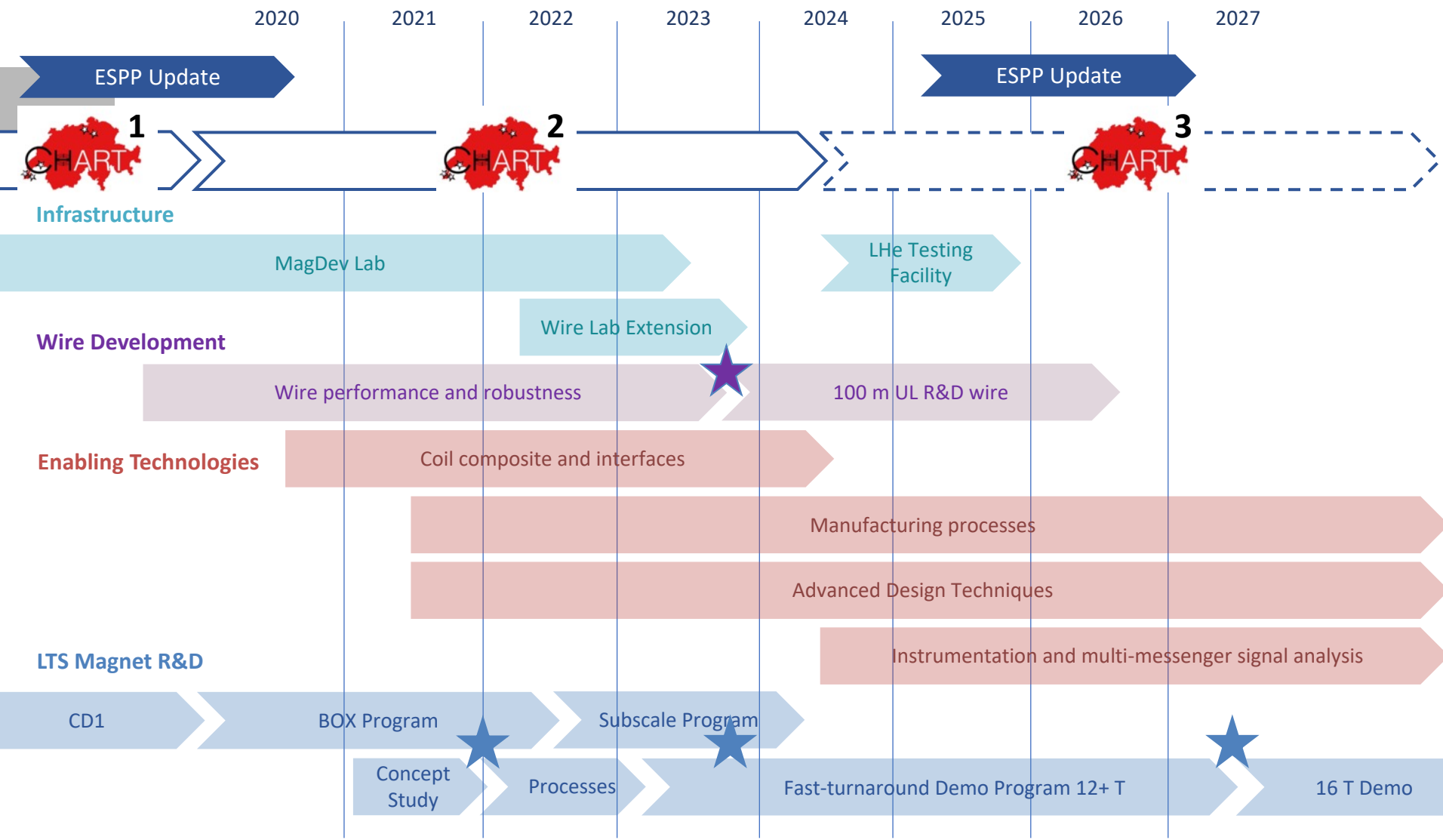


CHART LTS HFM Roadmap



Caveat: CHART3 is not today an approved program. The funding envelop will determine the possible level of engagement, and a selection of activities may have to be made according to priorities.

CHART1/3 Achievements

Completion of CD1 (Canted Dipole 1) technology demonstrator, designed and built at PSI.
Test at LBNL interrupted due to a cryoplant issue after first quench at 11.1 kA or 62.5% of short sample, 6 T in the bore.

CHART2/3 Achievements

Bernhard Auchmann
Project Leader

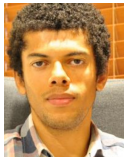
Christoph Hug
Technician

Michael Daly
LTS, BOX

André Brem
Materials

Jaap Kosse
REBCO

Douglas Martins
LTS

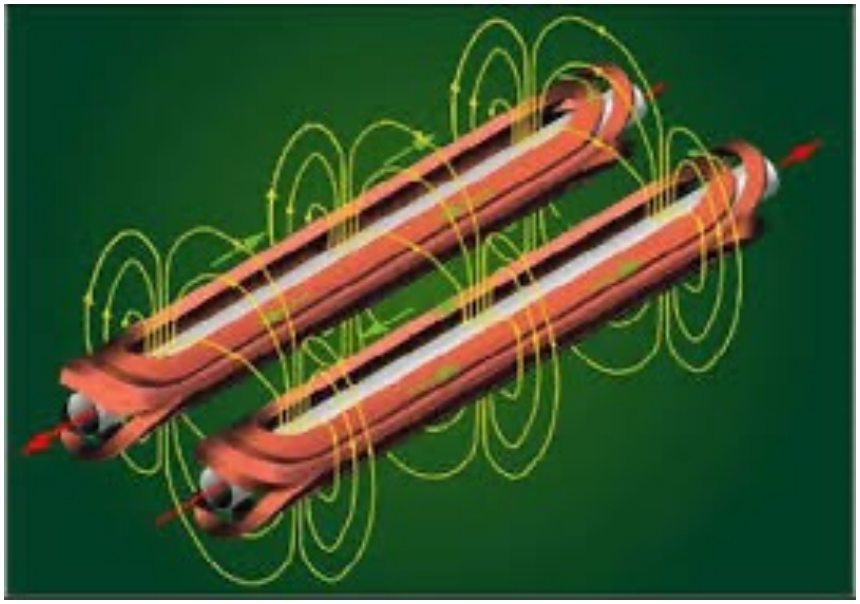


Henrique Rodrigues
Technician

Ramping up of activities in ***new MagDev Lab*** at PSI (400 m2).
Missing items: winding table (order placed), impregnation system (procurement started).

Interfaces and stress management

- How to deal with high forces?
- Numerous reports of bonding failures between cable / coil-blocks and structural coil components

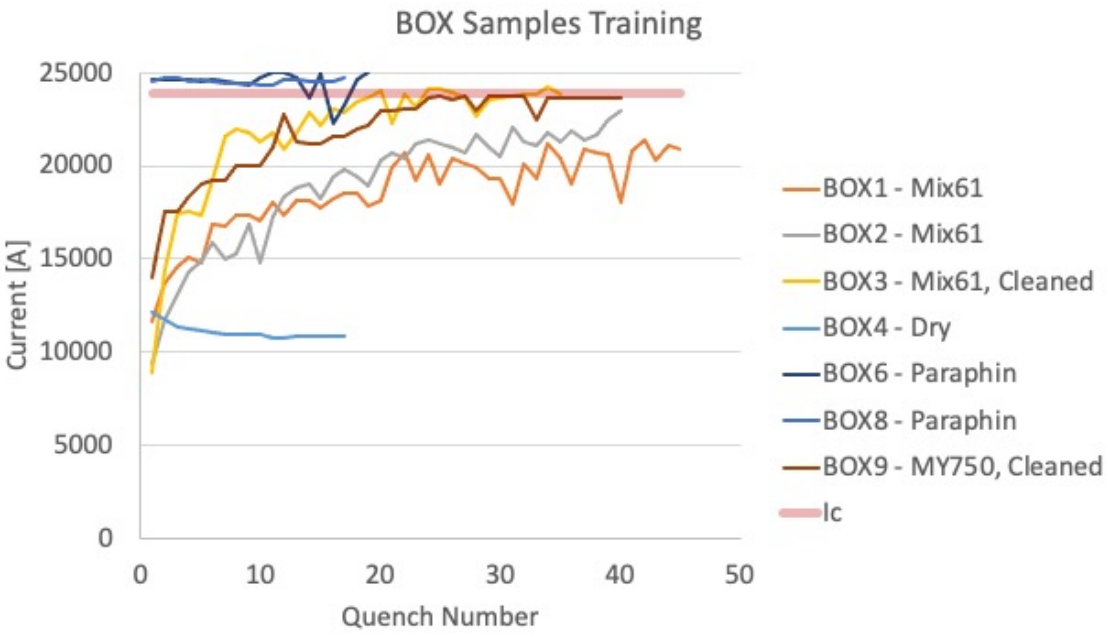


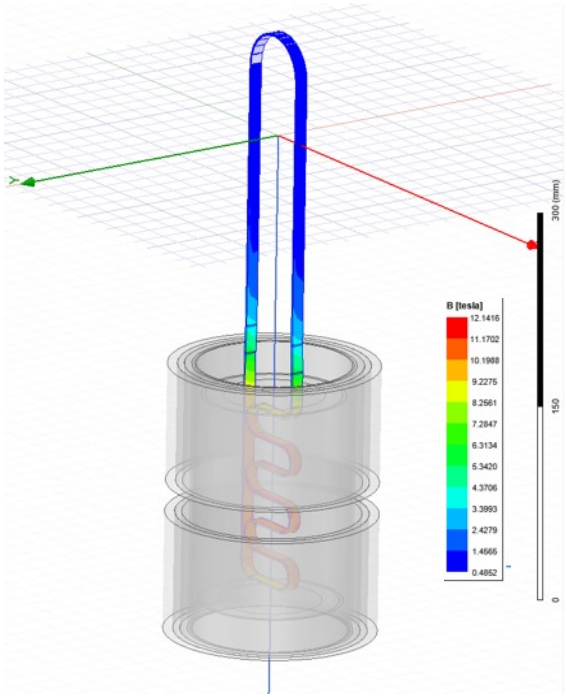
- Typical interface issue

- Stress management structure

Pictures by A. Zlobin

CHART3/3 Achievements





Pictures by M. Daly, S. Sidorov

BOX (BOnding eXperiment) program with uTwente has shown a wide variety of results, from complete conductor ***degradation (no impregnation)*** to substantial ***training (epoxy)*** to ***no-training (wax),*** with ***10 BOX samples*** manufactured and 7 tested to date***. Narrow-edge pressure amounts to 100 MPa at Ic.***

HTS Driving Questions

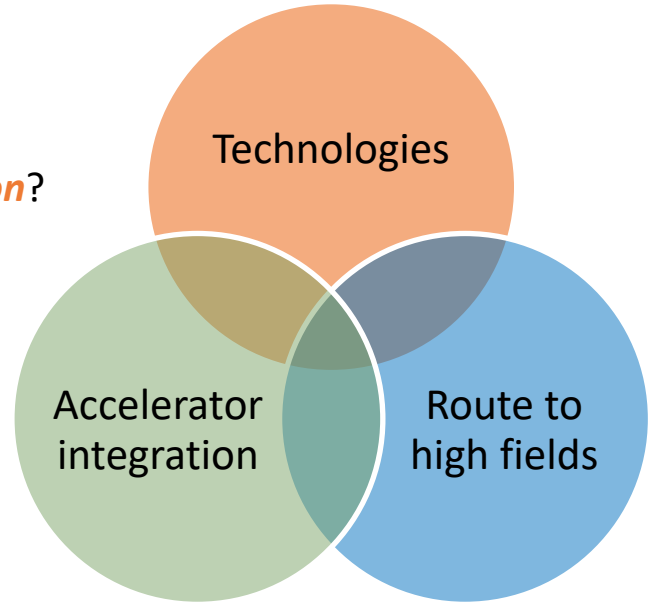
We are limiting ourselves to ***REBCO tapes*** due to their availability from multiple suppliers, relative robustness, low infrastructure requirements, and the proven track record.

Cost is an issue, but not one that we expect to directly address in the coming years.

What would an HTS accelerator magnet even look like?

Driving questions:

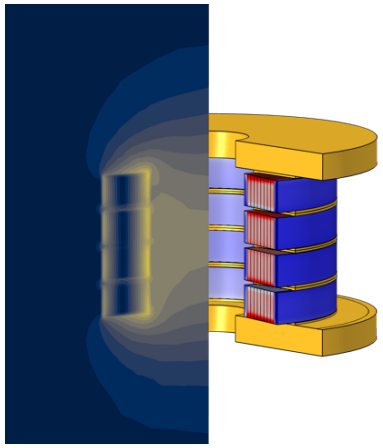
- Basic technology questions:
  - Which aspects of ***tape technology*** need improving?
  - ***cable-, coil-configuration, insulation, quench protection***?
- Route to high fields:
  - ***hybrid HTS/LTS strategy***, aiming for 20+T,
  - or an ***HTS-only path*** towards 16+T?
- Accelerator integration:
  - How reach ***"accelerator quality"*** in terms of field quality for a 20+T accelerator?
  - ***Operating temperature*** of an HTS-only accelerator?



How much progress can we achieve by the next strategy update?

HTS No-Insulation Coil Development

Pictures by M Duda



Pictures by J. Kosse

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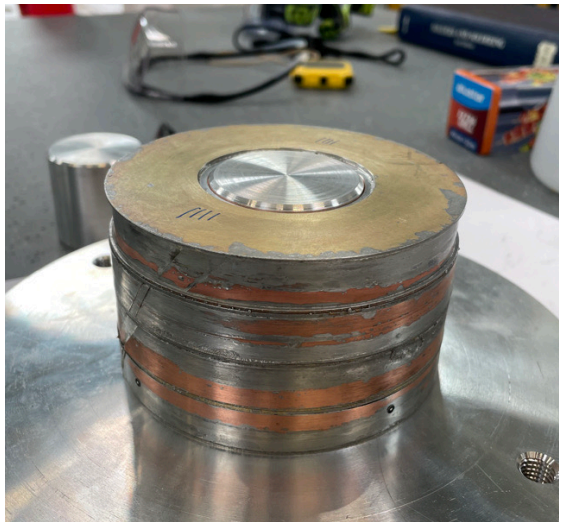

Pictures by J. Kosse and H. Garcia

Conclusion

- CHART is a Swiss research network, active in the field of superconducting accelerator magnets, contributing to the international HFM project.
- Identifying LTS and HTS driving questions
- Fast-track key technology R&D with academia and industry.
- Use fast-turnaround subscale samples and coils as innovation funnel.
- Benefit from existing infrastructure
- Increase the cross-linking among CHART members