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Deliverable Number: 7.1	**Due date: 11.30.2021**
Deliverable Title: Proceedings Workshops &Conference Sessions **WP number: 7** **Leader Beneficiary: RU** **Deliverable type: Report, Presentations** **Dissemination level: Confidential**	**Reporting period: RP1** **Issue date: 04.29.2022** **Authors: Peter Christianen** **Reviewers: ISABEL Coordination Board** **Status**:

ISABEL

Improving the sustainability of the European Magnetic Field Laboratory

Proceedings Workshops and Conference Sessions

Start date of the project: 1st November 2020

Duration: 48 months

Project Coordinator: Geert Rikken – CNRS LNCMI (P1 - CNRS)

Contact:

Version	Modifications	Date	Authors
1.0	First draft	28.04.2022	Peter Christianen
1.1	Final version	29.04.2022	Peter Christianen, Geert Rikken

DOCUMENT ABSTRACT

The aim of task 7.1 is to create a global network of parties interested in the development of the next generation of high-field magnets and to stimulate stronger interaction between facilities and other large-scale research infrastructures on the one hand, and industrial companies on the other. This should lead to the definition of a Global Roadmap for future high-field developments.

Starting point of the network is the existing global high-field forum (HIFF), formed by the directors of the individual high magnetic field facilities in the USA, Europe and East Asia, combined with the partners of the ISABEL project. The aim is to identify other partners that are active in high field technology and connect to them. One vehicle to advertise the activities of EMFL to external partners is the participation to conferences and workshops on high field technology.

This document summarizes the list of high field conferences and workshops attended and an overview of presentations given, specifically to advertise the activities of EMFL to external partners. An updated version will be submitted later in the ISABEL project.

Table of contents

1. Identification of partners in high magnetic field research

In the task 7.1 creation of a global network in high-field technology, first the most prominent actors in high field technology have been identified.

- The partners of the global high-field forum (HIFF)
- The partners within the ISABEL project
- The partners in the SuperEMFL project
- The other large scale infrastructures in Europe, organized in ARIE, the Analytical Research Infrastructures in Europe
- The partners of FuSuMaTech (Future Superconducting Magnet Technology)
- The new High-field Magnet Network of CERN
- The European High Field MRI community, organized in The European Society for Magnetic Resonance in Medicine and Biology (ESMRMB)
- The partners of the Muon Magnet project

Due to the effects of the COVID-19 pandemic most in-person meetings have been postponed and/or canceled. Several meetings continued on-line, which was very useful, but which to some extent also prohibited to connect to new networks.

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2. High Field Meetings and Presentations

The table below shows an overview of the conferences and workshops related to research in high magnetic fields took place in the reporting period.

Conference	Date	Place	Link
CERN Magnet Technology workshop	April 14-16, 2021	On-line	see presentation 1
FuSuMaTech workshop	April 21, 2021	On-line	see presentation 1
CERN Magnet Technology workshops	June 1, 2021 June 3, 2021	On-line	
EMFL user meeting	June 15, 2021	Dresden On-line	https://emfl.eu/events/
6th Superconductivity Summer School	July 6-8, July 13-15, 2021	UK On-line	http://super2021.iopconfs.org/1027558
Superconducting Hybrids @ Extreme	June 28 – July 02, 2021	UAM Madrid online	nanocohybri.eu
International Conference on Magnet Technology MT 2021	November 15-18, 2021	Fukuoka, Japan hybrid	https://csj.or.jp/conference/MT27/

Many employees and partners of EMFL participated to these events. The outcome of the first CERN Magnet technology and FuSuMatech workshops is summarized in the following presentation

1) *Status HFM+Fusumatech*, P. Vedrine, May 10, 2021:

The final report and roadmap will be published at a later stage.

In three cases a special presentation was given to advertise the activities of EMFL and the ISABEL project.

2) *Introduction EMFL*, P.C.M. Christianen, EMFL User meeting, June 15, 2021.
3) *H2020 project Isabel*, G. Rikken, EMFL User meeting, June 15, 2021.
4) *European Magnetic Field Laboratory,* A. Patanè, 6th Superconductivity Summer School, UK, July 6, 2021

ISABEL WP7

Summary

- Outcome HFM State-of-the-Art Workshop April 14-16
- Outcome Fusumatech meeting April 21Revised schedule¶

Pierre Vedrine CEA

Outcome HFM State-of-the-Art Workshop April 14-16

STATE OF THE ART WORKSHOP – 14-16 APRIL 2021 - 1ST AND 3RD DAY

250 invitations sent - 188 registrations – 150 participants in each session on average – 19 time zones

Written executive summary for each presentation - will be included in the technical appendices of the report as a state of the art.

Session	Speaker	Room	Time
Welcome	Pierre Vedrine	ZOOM	14:30 - 14:40
Introduction to the R&D roadmap process	Prof. Dave Newbold	ZOOM	14:40 - 15:00
LTS : The FCC Nb3Sn Conductor Development Program - Status and challenges	Amalia Ballarino	ZOOM	15:00 - 15:25
LTS : New alleys for Nb3Sn	Xingchen Xu	ZOOM	15:25 - 15:50
LTS : Nb3Sn characterization	Marc Dhallé et al.	ZOOM	15:50 - 16:15
LTS : LTS cables	Dr Ian PONG	ZOOM	16:15 - 16:40
Virtual Coffee Break		ZOOM	16:40 - 16:55
HTS : REBCO status and perspectives	Bernhard Holzapfel	ZOOM	16:55 - 17:20
HTS : REBCO cables	Davide Uglietti	ZOOM	17:20 - 17:45
HTS : BSCCO status and perspectives	Eric Hellstrom	ZOOM	17:45 - 18:10
HTS : Alternative HTS: status and perspectives in IBS and other materials	Valeria Braccini	ZOOM	18:10 - 18:35

Session	Speaker	Room	Time
Feedback from the 32 T experience	Hubertus Weijers	ZOOM	14:30 - 14:55
US-LARP, US-AUP, status and process challenges	Giorgio Ambrosio	ZOOM	14:55 - 15:35
CERN MQXF and 11T, status and process challenges	Dr Ezio Todesco	ZOOM	15:35 - 16:15
Overview of FCC Nb3Sn magnet development and technical challenges	Daniel Schoerling	ZOOM	16:15 - 16:40
Virtual Coffee Break		ZOOM	16:40 - 16:55
Racetrack and block magnets	Gijs De Rijk	ZOOM	16:55 - 17:20
US-MDP	Soren Prestemon	ZOOM	17:20 - 17:45
Design and Modeling Challenges	Paolo Ferracin	ZOOM	17:45 - 18:10
Closing	Luis Garcia-Tabares	ZOOM	18:10 - 18:25

▶ https://indico.cern.ch/event/1012691/timetable/?layout=room#20210414.detailed

State of the Art Workshop – 2nd day

Session	Speaker	Time
Joint technology for HFM	*Pierluigi Bruzzone*	08:30 - 08:55
Magnet protection for HFM	*Mariusz Wozniak*	08:55 - 09:20
Advances in imaging and diagnostics	*Stefano Sgobba*	09:20 - 09:45
The lure of NI and PI coils	*S. Hahn*	09:45 - 10:10
Virtual Coffee Break		10:10 - 10:25
Overview of HTS magnet developments and technical challenges	*Gijs De Rijk*	10:25 - 10:50
Results from the EU HTS Program	*Lucio Rossi*	10:50 - 11:15
The Japanese HTS program for accelerators	*Toru Ogitsu*	11:15 - 11:40
Iron based superconductor: the Chinese route to HFM	*Qingjin XU*	11:40 - 12:05
Results from the US - Bi2212 HTS Program	*Tengming Shen*	15:00 - 15:25
Results from the US - REBCO HTS Program	*Xiaorong Wang*	15:25 - 15:50
Virtual Coffee Break		16:25 - 16:40
Coil insulation for HFM	*Steve Krave*	16:40 - 17:05
Coil Composite and Interface Engineering	*Giorgio Vallone*	17:05 - 17:30
Advanced testing for HFM	*Maxim Marchevsky*	17:30 - 17:55
Advanced analytical tools for HFM R&D	*Lucas Brouwer*	17:55 - 18:20

All sessions: *ZOOM*

ROADMAP PREPARATION WORKSHOP -ROAP

Workshop on "**High Field Accelerator Magnets - Roadmap Preparation**" to take place virtually on **June 1&3, 2021**.

Focus the contributions and discussion along two main lines:

(i) topical and comprehensive reviews of selected technical subjects, providing a prioritized development outlook with objectives over a five to ten years horizon,

(ii) presentation of institutional views, with a description of the development vision and the strategic position towards a high-field magnet program proposal.

The contributions are intended to cover all aspects of superconducting accelerator magnet science, from conductors to magnets, LTS and HTS, and associated technologies.

Participation will be extended to all main actors in the field, worldwide, to ensure a comprehensive view.

The presentations will be documented in the form of short written contributions, produced by the presenters and contributors, and edited in the form of proceedings

https://indico.cern.ch/event/1012691/ invitations sent very soon

ROADMAP PREPARATION WORKSHOP – TOPICAL PERSPECTIVES SUB-SESSION

	Session	Proposed Title	Proposed Syllabus	Proposed Speaker
		Needs of HFM for future colliders		
Topical perspectives	Conductors for HFM	**Superconductors for a future collider**	LTS and HTS wires and tapes specifications for the magnets in the 16 to 20 T range. Define critical parameters for the magnet performance, including all aspects relevant to the magnet and the accelerator. A table with a collection of critical parameters, minimum and targets to achieve 16 T (LTS) and 20 T (HTS). Examine cable options and alternative to common wisdom on transposition, current sharing, operating margin, etc. Set cost targets acceptable from the magnet construction point of view. The talk includes an overview on development needs.	A. Ballarino (CERN)
	Conductors for HFM	**Future Nb3sn capability in industry**	Manufacturing of Nb3Sn wires from the industrial perspective. Technical and business case considerations. Review cost drivers and expectations for a future production.	J. Parrell (B-OST)
	Conductors for HFM	**Future REBCO capability in industry**	Highlights from industry. Technical and business case considerations. Review cost drivers and expectations for a future production.	W. Prusseit (THEVA)
	Nb3Sn Magnets Perspective	**Design Concepts for High Field Magnets**	Review of coil layout and pre-stress / stress-management strategy for Nb3Sn, critical analysis of potential for HFM.	E. Todesco (CERN)
	Nb3Sn Magnets Perspective	**Subscale magnets and powered samples - a necessary step ?**	How can subscale magnets and powered samples (wire, cable,transverse-pressure sample, BOX, SMC, etc) boost our innovative potential and what issues we cannot address. How does subscale work fit into the overall development timeline? What are the steps needed to define an ideal development: from cable to racetracks to models to prototypes, and associated timeline	H. Felice (CERN)
	Nb3Sn Magnets Perspective	**Specific needs for high-field quadrupole magnets (lattice/insertion) for a future collider**	Needs and options for Nb3Sn/HTS main lattice and insertion quadrupoles	C. Lorin (CEA)
	Nb3Sn Magnets Perspective	**Construction of HFM for a future hadron collider**	Construction of Nb3Sn magnets, challenges and perspective towards industrialization on a large scale. Set cost targets acceptable from the magnet construction point of view.	F.Savary (CERN)
	Nb3Sn Magnets Perspective	**HFM magnet manufacturing industry perspective**	Construction of Nb3Sn magnets from the industrial perspective. Technical and business case considerations. Review cost drivers and expectations for a future production.	W. Walter (BNG)
	HTS Magnets Perspective	**Frontier designs towards a high-field accelerator dipole**	Review possible design for a 20 T hybrid or a 15-20 T H all HTS at 10-20 K for a future hadron collider.	T. Lecrevisse (CEA)
	HTS Magnets Perspective	**Technology development for enabling HTS high-field accelerator magnets**	Review critical technological bottlenecks for use HTS in accelerator quality magnet	G. Kirby (CERN)
	Technology advances and innovation	**Advanced design techniques for HFM**	Ideas and proposals for design, analysis and calculation framework and the establishment of a design code (brittle superconductors).	B. Auchmann (PSI)
	Technology advances and innovation	**Cooling design tools for HFM magnets**	Review of experimental and numerical tools for the cooling design of HFM magnets. Focus on the internal cooling of HFM magnets including working conditions and transient events (quench).	R. Van Weelderen (CERN)
	Technology advances and innovation	**Thermal management of magnets for a future collider**	Look at the benefits and drawbacks of cooling in the range of 1.9 K to 20 K (LTS and HTS).. Cooling, shields and continuous cryostat. Challenges and opportunities for development and improvement of thermodynamic efficiency	L. Tavian (CERN)

Roadmap Preparation Workshop – Institutional views sub-session

	Session	Proposed Title	Proposed Syllabus	Proposed Speaker
Institutional views and proposals	Institutional views and proposals	**France - CEA, CNRS**		A.-I. Etienvre (CEA-IRFU)
	Institutional views and proposals	**CERN**		M. Jimenez, M. Lamont (CERN)
	Institutional views and proposals	**Spain - CIEMAT, ICMAB**		J.M. Perez (CIEMAT)
	Institutional views and proposals	**CHART - PSI, University of Geneva, ETHZ, EPFL**		L. Rivkin (PSI)
	Institutional views and proposals	**Italy - INFN (CNR, ENEA, Universities)**		P.L. Campana (INFN)
	Institutional views and proposals	**Germany - KIT**		M. Noe (KIT)
	Institutional views and proposals	**The Netherlands - Twente University**		M. Dhalle (University of Twente)
	Institutional views and proposals	**Sweden - Uppsala University**		R. Ruber (Uppsala University)
	Institutional views and proposals	**Finnland - Tampere University**		T. Salmi (Tampere University)
	Institutional views and proposals	**Poland**		D. Bocjan (IFJ-PAN)
	Institutional views and proposals	**Austria - University of Vienna, ATI**		M. Eisterer (ATI)
	Institutional views and proposals	**UK**		ask B. Shepherd
	Institutional views and proposals	**Roadmaps from companion programs (fusion, high-field science, medical, energy,…)**	a view of the roadmaps from other fields of application of superconductivity. Set as introductory talk for RoaP	M. Noe (KIT)

DRAFT

Revised Schedule

- 1 & 3 June : 2nd Workshop RoaP: Roadmap Preparation - open workshop
- 7 June : target for version 0 of the report
- **14-15 June SPC : presentation of the scope and initial findings of the roadmap panels**
- 17-18 June Council: present background to process (no recommendations)
- **June: proposed public workshop for HEP community (NEW)**
- **30 July EPS-HEP: public presentation of progress for feedback**
- **July/August : report drafting**
- **July LDG Council : intermediate report presentation to LDG**
- **6- 9 September (TBC) : 3rd "Workshop" RoaI restricted to the EP : Roadmap Implementation**
- **September : Interim report to SPC/Council :** present of interim findings (facts, not priorities)
- **End of September: draft final report to SPC**
- **Late October : feedback on draft final report for review by SPC**
- **Novembre : writing of the final report**
- **December : final report presentation to Council : roadmaps, options and priorities.**

Outcome Fusumatech meeting April 21¶

Commissariat à l’énergie atomique et aux énergies alternatives - www.cea.fr

65 registrations – 60 participants in each session on average

Contribution	Speaker	Location	Time
Opening of the virtual conference room		zoom, video conference	12:30 - 13:00
Welcome address from the host	Stephane Sanfilippo	zoom, video conference	13:00 - 13:05
FuSuMaTech Coordinator	Pierre Vedrine	zoom, video conference	13:05 - 13:10
FuSuMaTech Chairman	Ziad Melhem	zoom, video conference	13:10 - 13:15
Global overview of the ten existing proposals	Ziad Melhem	zoom, video conference	13:15 - 13:25
Status of superconducting magnet at PSI and CHART	Bernhard Auchmann	zoom, video conference	13:25 - 13:35
Update WP T4.2	Simon Canfer	zoom, video conference	13:35 - 13:45
Update on the cryogenic WP T4.3	Bertrand Baudouy	zoom, video conference	13:45 - 13:55
Update WP T4.5	Klaus Peter Weiss	zoom, video conference	13:55 - 14:05
Social / mammo maget	Denis Le Bihan	zoom, video conference	14:05 - 14:15
PSI development on a superconducting gantry for proton therapy	Jacobus Maarten Schippers	zoom, video conference	14:15 - 14:25
Follow up of SuperEMFL project	Xavier Chaud	zoom, video conference	14:25 - 14:35
Pascal Tixador / CNRS, Neel laboratories		zoom, video conference	14:50 - 14:55
Chris Riley / Dassault System Opera Software, 3ds		zoom, video conference	14:55 - 15:00
Pasquale Fabbricatore / INFN		zoom, video conference	15:00 - 15:05
Tiina Salmi / Tampere University		zoom, video conference	15:05 - 15:10
Matteo Alessandrini, Daniel Eckert, Davide Nardelli / Bruker Biospin		zoom, video conference	15:10 - 15:15
Klaus Schlenga / Bruker EAS GmbH		zoom, video conference	15:15 - 15:20
Werner Prusseit / Theva		zoom, video conference	15:20 - 15:25
Kevin Pepitone / Uppsala, Dept Physics and Astronomy/FREIA and High Energy Physics Division		zoom, video conference	15:25 - 15:30
Serdar Atamert / Epoch Wires		zoom, video conference	15:30 - 15:35
Marco Breschi / University of Bologna, LIMSA		zoom, video conference	15:35 - 15:40
Bernardo Barbiellini / PhD LUT University, Dept. of Physics		zoom, video conference	15:40 - 15:45
Carmine Senatore / University of Geneva		zoom, video conference	15:45 - 15:50
Chris Grovenor, Oxford University Materials Department		zoom, video conference	15:50 - 15:55
Gaelle Decroix / CEA		zoom, video conference	16:00 - 16:20
Break		zoom, video conference	16:20 - 16:25
Multi-physics / multi-scale modelling and simulation of HTS coils using SIMULIA Opera, SIMULIA Insight and other soft.	Chris Riley		
Modelling	Tiina Salmi	zoom, video conference	16:35 - 16:45
Materials database	Simon Canfer	zoom, video conference	16:45 - 16:55
Chairman conclusion	Ziad Melhem	zoom, video conference	16:55 - 17:00
Final address	Stephane Sanfilippo	zoom, video conference	17:00 - 17:05
Break		zoom, video conference	17:05 - 17:30
General Assembly / Closed Session / New zoom link		zoom, video conference	17:30 - 18:30

- https://indico.psi.ch/event/11030/timetable/#20210421.detailed

26 Fusumatech Members

Present Members:

Anne-Isabelle ETIENVRE CEA
Gijs DE RIJK CERN
Klaus-Peter WEISS KIT
Charles SIMON CNRS
Simon CANFER STFC
Matt MARTIN Oxford Instruments
Ben LEIGH TESLA
Frederick FOREST SIGMAPHI
Angel GARCIA ELYTT
Michael GEHRING BILFINGER
Stephane SANFILIPPO PSI

New Members :

- Oxford Quantum Solution (Ziad Melhem)
- CNRS Institut Neel / G2Elab represented by Pascal TIXADOR
- DASSAULT SYSTEMES / Opera Software Division represented by Chris Riley
- BRUKER BioSpin represented by Daniel ECKERT
- BRUKER EAS GmbH represented by Klaus SCHLENGA
- INFN represented by Pasquale FABBRICATORE
- TAMPERE University represented by Tiina SALMI
- GENEVA University / Department of Quantum Physics / Group of Applied Superconductivity represented by Carmine SENATORE
- UPPSALA University / Department of Physics and Astronomy / FREIA Laboratory and High Energy Physics Division represented by Tord EKELÖF, Roger RUBER and Richard BRENNER.
- IFJPAN represented by Darius BOCIAN
- THEVA Dünnschichttechnik GmbH represented by Werner PRUSSEIT
- BOLOGNA University / ALMA MATER STUDIORUM represented by Marco BRESCHI
- EPOCH WIRES represented by Serdar ATAMERT
- LUT University / School of Engineering Science / Physics Department represented by Bernardo BARBIELLINI.
- OXFORD University / Materials Department represented by Chris GROVENOR

Conclusions

- Bring together the FuSuMaTech collaboration again (current and new members) within 3 to 4 months in order to define the various possibilities of rapprochement with other organisations involved in promoting superconductivity research or industrial applications (as ESAS and CONECTUS)
- Work in parallel on a strategic roadmap for FuSuMaTech and Applied Superconductivity to support future calls for funding and/or lobbying in direction of EU.
- Stephane SANFILIPPO (PSI) has mentioned the informal approval of his hierarchy concerning the face-to-face meeting in December 2021 if the health situation allows it; a visit to the CHART laboratory could be considered.
- Anne-Isabelle ETIENVRE (Head of IRFU) has kindly accepted that CEA/IRFU PARIS/SACLAY will host the 2022 FuSuMaTech annual meeting.

On behalf of
the EMFL user committee &
the EMFL Board of Directors

Welcome to the EMFL user meeting

June 15th, 2021

Current status & developments

- Operation of the facilities
- Infrastructure developments
- H2020 projects ISABEL and SuperEMFL

Programme of today

Operation of the facilities

- Facilities are open, but still operation in “lock-down” situation
- Limited access for external users due to travel restrictions
- Mail-in & staff-support procedures whenever possible
- Backlog of projects
- Regular calls continued: new proposals require urgency statement
- We hope/expect that the situation will improve soon

	2018	2019	2020	2021
Proposals received	350	361	270	319
Proposals executed total	247	248	186	

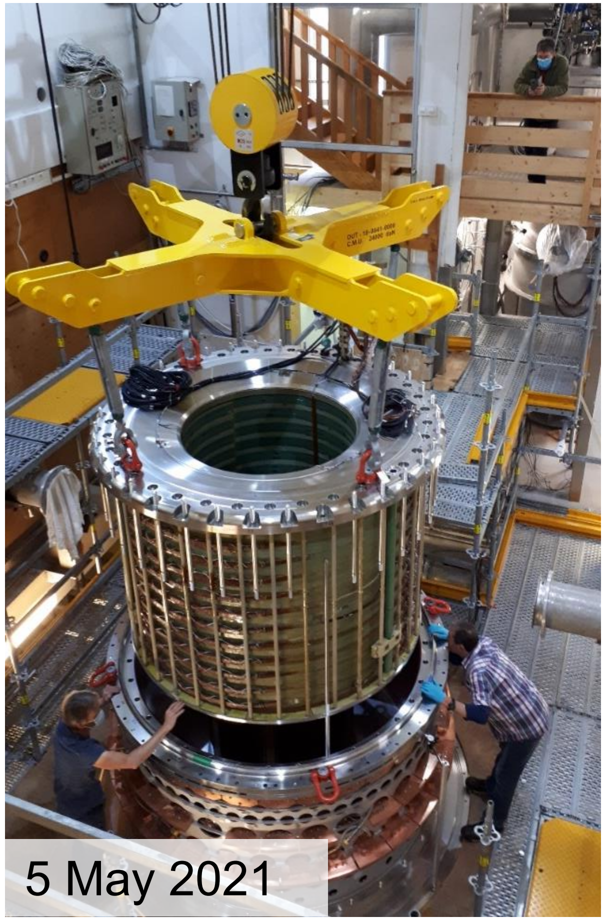
- Link to provide user feedback: https://forms.gle/k5uJBvdWZsk3dVr86

European Magnetic Field Laboratory

Infrastructure developments

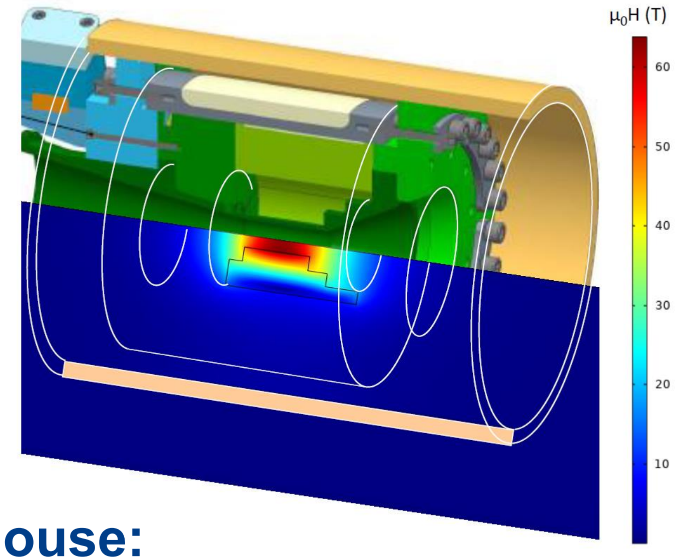
Grenoble & Nijmegen

2 Hybrids under construction



Dresden

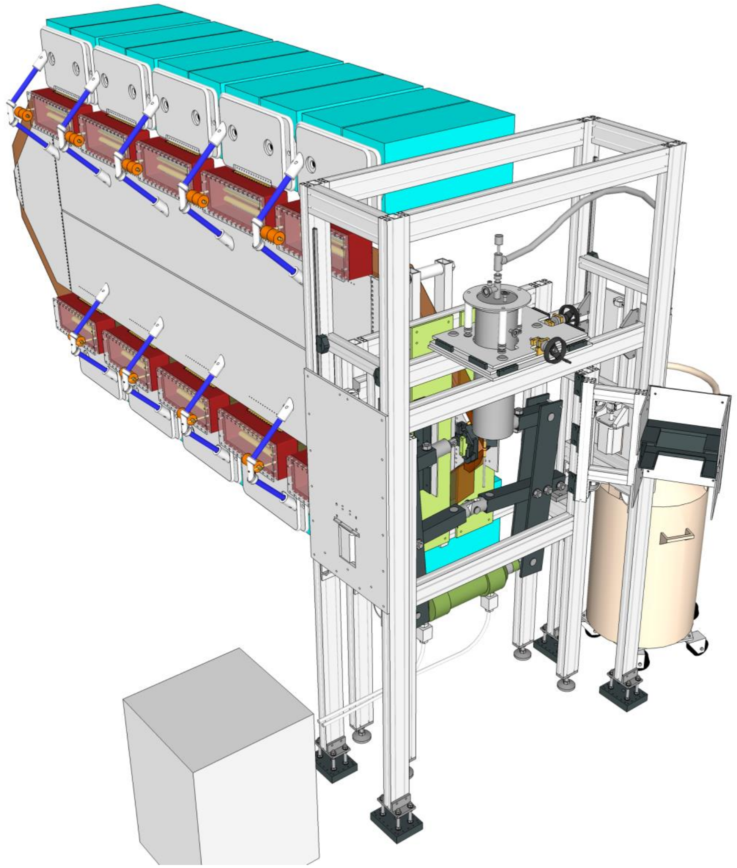
Pulsed magnetic fields at XFEL



Toulouse:

New 14 MJ & 1 MJ capacitor banks

Toulouse: Renewal and upgrade of Megagauss installation



EMFL European Magnetic Field Laboratory

H2020 Projects – User involvement

ISABEL – Coordinator: Geert Rikken

Improving the Sustainability of the European Magnet Field Laboratory

2020-2023, 18 partners, of which 5 industrial, budget 4,9 M€, started 1 November 2020

- New access modes – user survey launched after this meeting
- Secondment programme – first call out end of June– deadline September 30th 2021
- Roadmap next generation user magnets – user survey in preparation

SuperEMFL – Coordinator: Xavier Chaud

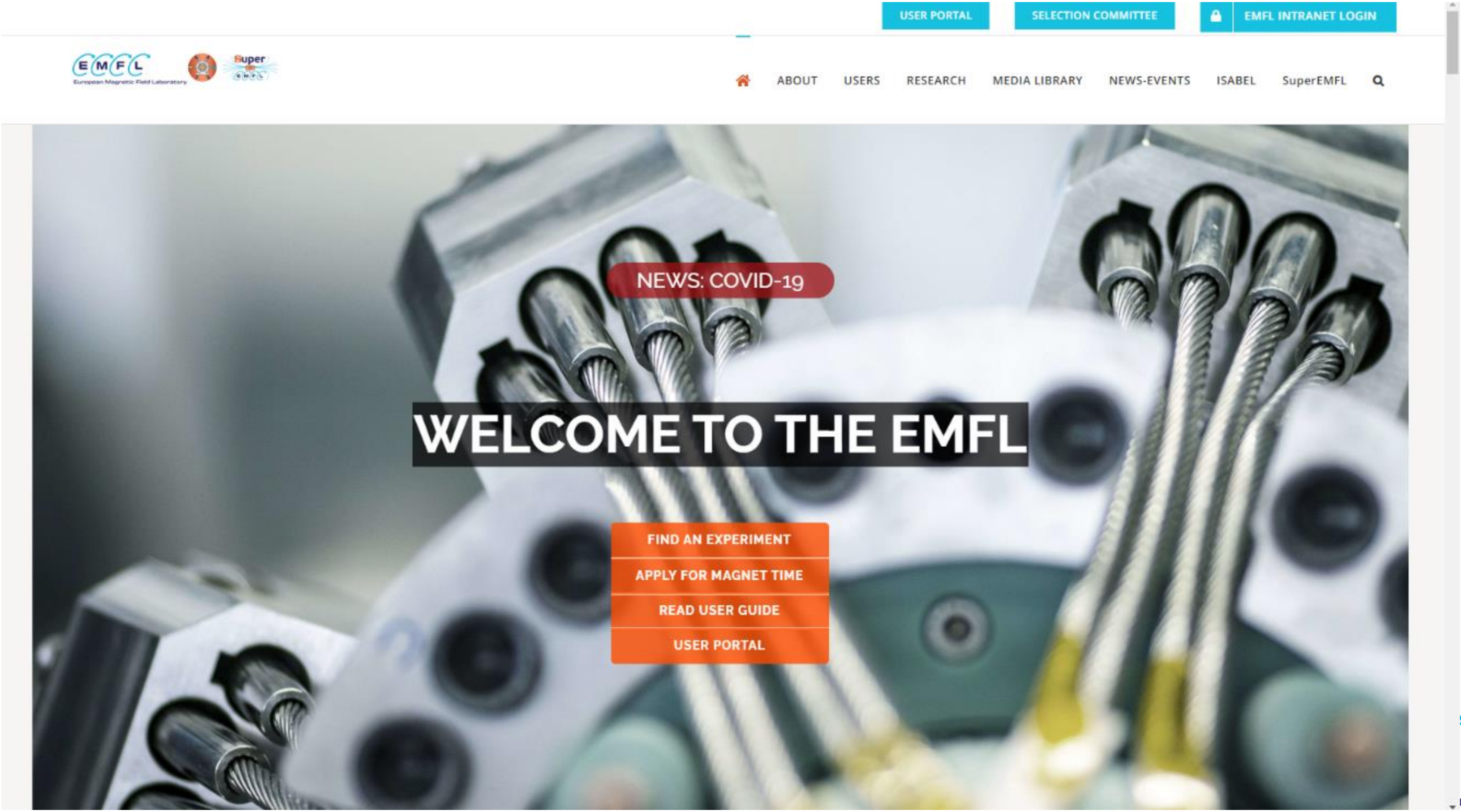
All superconducting magnets for the European Magnet Field Laboratory

2021-2024, 11 partners, of which 3 industrial, budget 2,9 M€, started January 2021

- Design study all superconducting user magnets – user survey in preparation

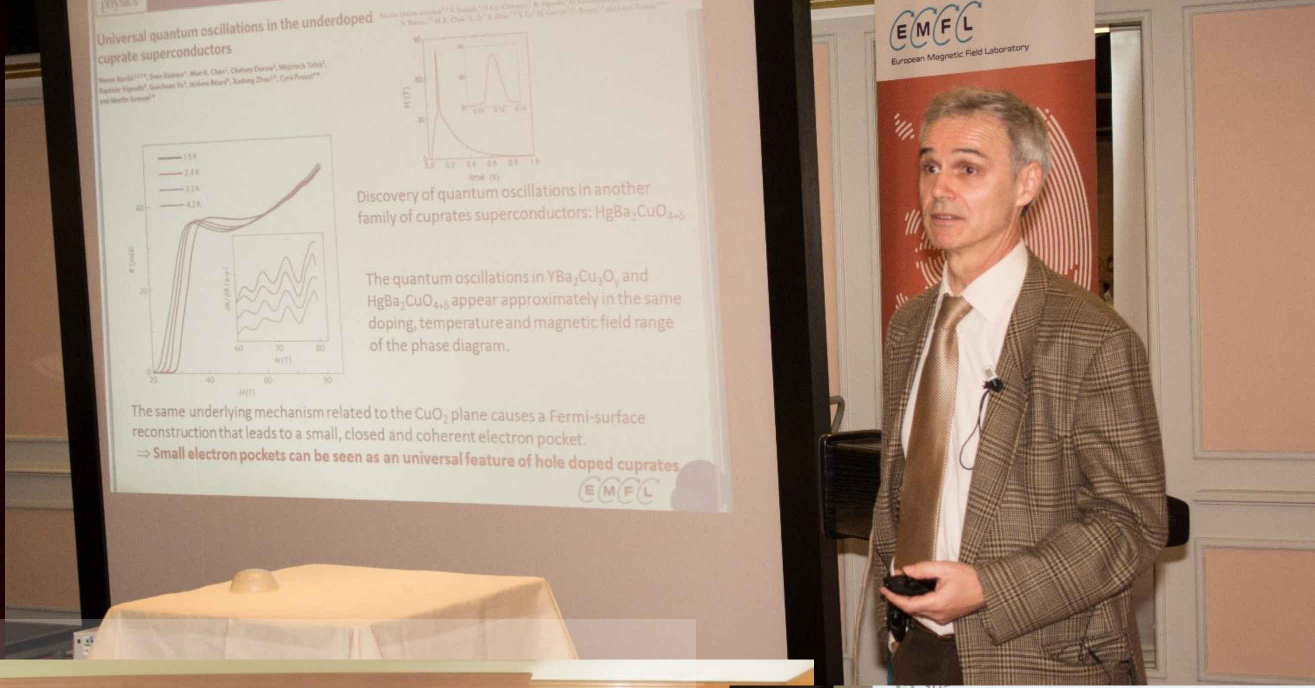
European Magnetic Field Laboratory

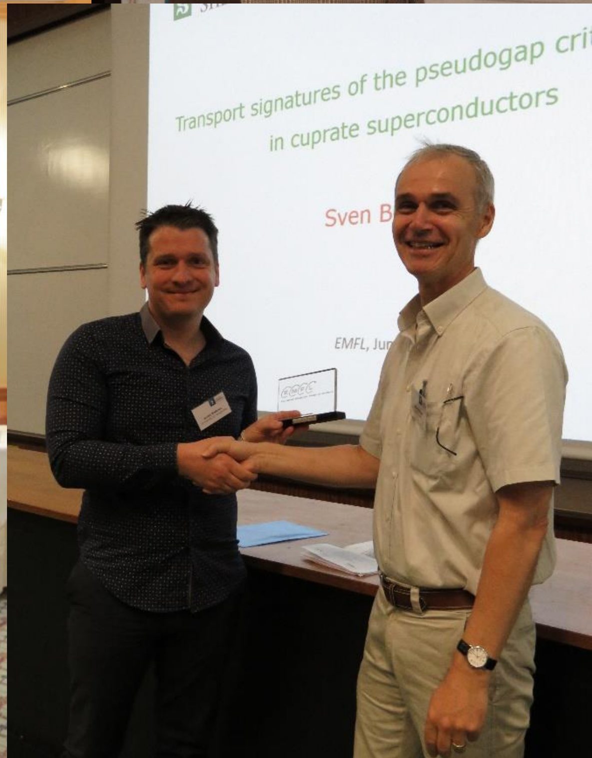
All information on EMFL Website



d Laboratory

Thank you Geert





Programme of Today

Time	What	Presenter(s)	Chair
09:00	Welcome	Peter Christianen	
09:10	Announcement & talk EMFL Price Winner	Price Winner	Jochen Wosnitza
09:40	Presentations by EMFL users (part 1)	Benoît Fauqué, Suchitra Sebastian	Jochen Wosnitza
10:20	Coffee Break		
10:50	Presentations by EMFL users (part 2)	Sven Spachmann, Alexandre Pourret, Malte Grosche	Alix McCollam
11:50	Lunch Break		
12:50	Presentations by EMFL users (part 3)	Satya Prakash Bommanaboyena, Krzysztof Gałkowski, Alban Potherat	David Vignolles
13:50	H2020 project ISABEL	Geert Rikken	Charles Simon
14:10	H2020 project SuperEMFL	Xavier Chaud	Charles Simon
14:30	Coffee Break		
14:45	User Committee Meeting		Raivo Stern
15:45	Report User Committee Meeting		Raivo Stern

Link to provide user feedback: https://forms.gle/k5uJBvdWZsk3dVr86

European Magnetic Field Laboratory

Everything you never wanted to know or ever bothered to ask about

H2020-INFRADEV-ISABEL

Improving the sustainability of the European Magnetic Field Laboratory

G. Rikken

EMFL User Meeting 15/06/2021

- Context: H2020-INFRADEV
- The EMFL and H2020
- The ISABEL project

H2020, the EC R&D program for 2014-2020, budget 80 G€

EUROPEAN COMMISSION

HORIZON 2020

Excellent Science (24.4 B €)

- European Research Council (13.1 B €)
- Future and Emerging Technologies (2.7 B €)
- Marie Skłodowska-Curie Actions (6.1 B €)
- Research Infrastructures (2.5 B €)

Industrial Leadership (17 B €)

- LEIT = Leadership in enabling and industrial technologies
  - ICT
  - Nano, new materials
  - Biotechnology
  - Space

  (13.5 B €)
- Access to Risk Finance (2.9 B €)
- Innovation in SMEs (0.6 B €)

Societal Challenges (29.7 B €)

- Health (7.5 B €)
- Food (3.9 B €)
- Energy (6 B €)
- Transport (6.3 B €)
- Climate (3 B €)
- Inclusive Societies (1.3 B €)
- Security (1.7 B €)

Spreading Excellence (0.8 B €)

Science for Society (0.5 B €)

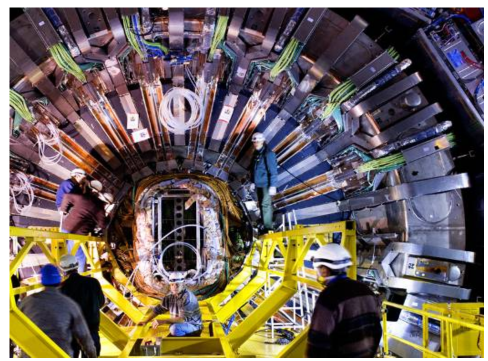
EIT (2.7 B €) | **JRC (1.9 B €)** | **Euratom (1.6 B €)**

Research Infrastructures

- Research infrastructures are facilities, resources and services that are used by the research communities to conduct research and foster innovation.

Major scientific equipments

Knowledge-based resources



e-infrastructures

Why an EU approach for Research Infrastructures?

- To address collectively the complexity and cost of the design and development of new world class research infrastructures
- To open access to the research infrastructures existing in the individual Member State to all European researchers
- To avoid duplication of efforts and to coordinate and rationalise the use of these research infrastructures
- To trigger the exchange of best practice, develop interoperability of facilities and resources, develop the training of the next generation of researchers
- To connect national research communities and increase the overall quality of the research and innovation
- To help pooling resources so that the Union can also develop and operate research infrastructures globally

- **Note:** The EU does not operate RIs and will only give limited support to the day-to-day operation of RIs

Call H2020-INFRADEV-Individual support to ESFRI & OWC RIs 2019

Call specifics:

Support will be provided to activities aimed at ensuring long-term sustainability, including enlargement of the membership, European coverage, international cooperation, limited pilots of access provision for testing and improving user services to increase reliability and create trust, definition of service level agreements and business/funding plan, outreach, and technology transfer activities.

Specific attention should be given to the interaction with industry and SMEs and the fostering of the innovation potential of the infrastructures. Activities may also facilitate the development of Regional Partner Facilities and their integration in the European research infrastructure landscape.

The EMFL and H2020

The EMFL has been on the ESRFI Roadmap for European Ris since 2009, and was considered sucessfully implemented by ESRFI in 2017 and therefore transfered to the ESRFI Landmark list.

The ESRFI Landmark is just a label and does not come with concrete support. However it does open eligibility to the *H2020-INFRADEV-Individual support to ESFRI & OWC RI* call

In response to call INFRADEV-03-2018-2019, the ISABEL proposal was submitted in March 2019, and was accepted in March 2020. Coordinator G. Rikken, 18 partners, duration 4 years, start date 1/11/2020, budget 4,94 M€.

Part. No.	Participant organisation name	Country
1 (Coord.)	Centre National de la Recherche Scientifique	France
2	Helmholtz-Zentrum Dresden-Rossendorf	Germany
3	Radboud University	Netherlands
4	University of Nottingham	United Kingdom
5	University of Oxford	United Kingdom
6	University of Warsaw	Poland
7	University of Geneva	Switzerland
8	Universidad Autonoma de Madrid	Spain
9	Charles University	Czech Republic
10	National Institute of Chemical Physics and Biophysics	Estonia
11	Commissariat à l'Energie Atomique /Energies Alternatives	France
12	Oxford Instruments Nanotechnology Tools Limited	United Kingdom
13	I-Cube Research	France
14	University of Salento	Italy
15	European Magnetic Field Laboratory AISBL	Belgium
16	Bilfinger Noell GmbH	Germany
17	Metel B.V.	Netherlands
18	Ampulz B.V.	Netherlands

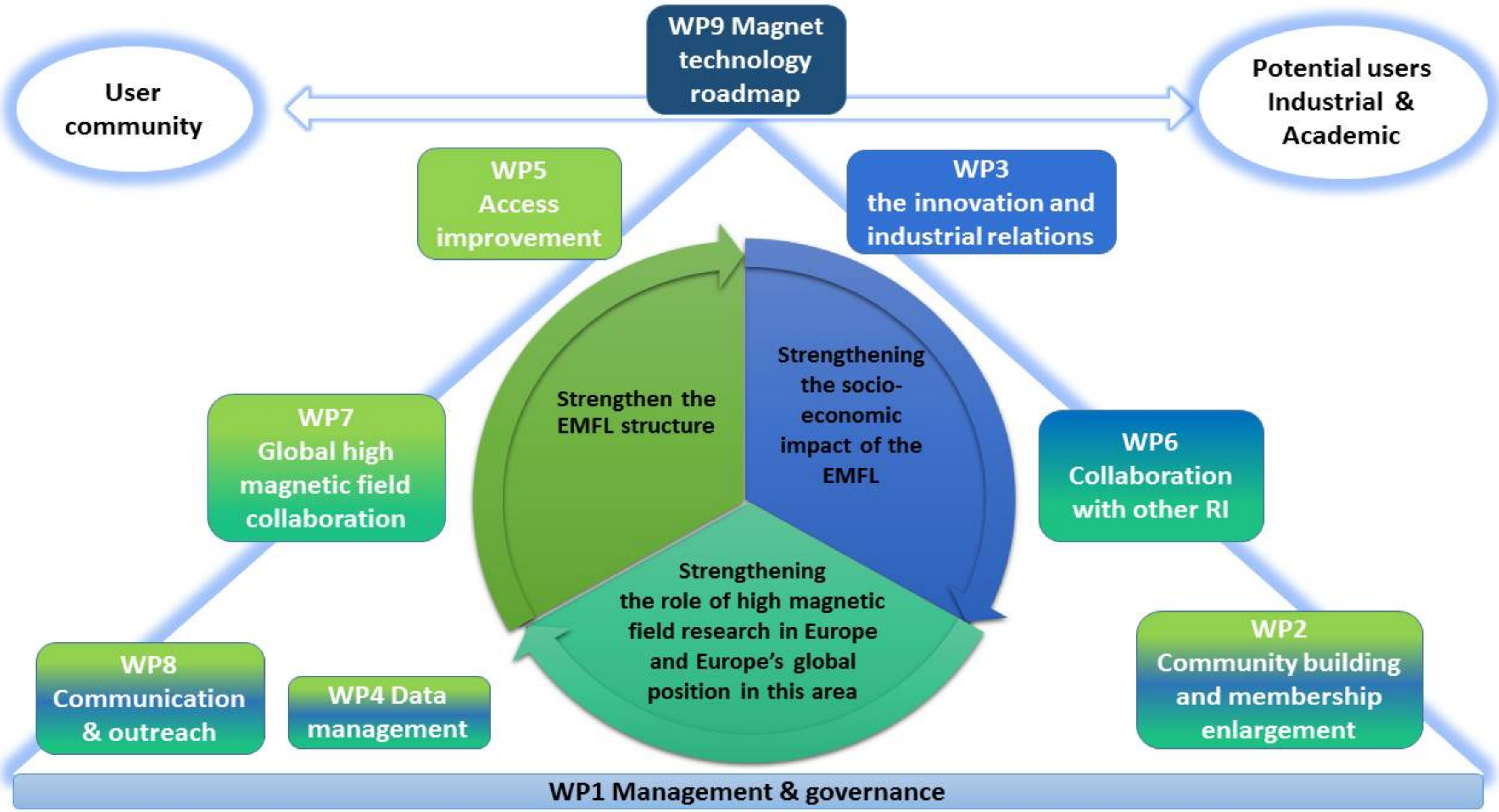
EMFL members

Potential EMFL members

Industrial partners

Structure of ISABEL

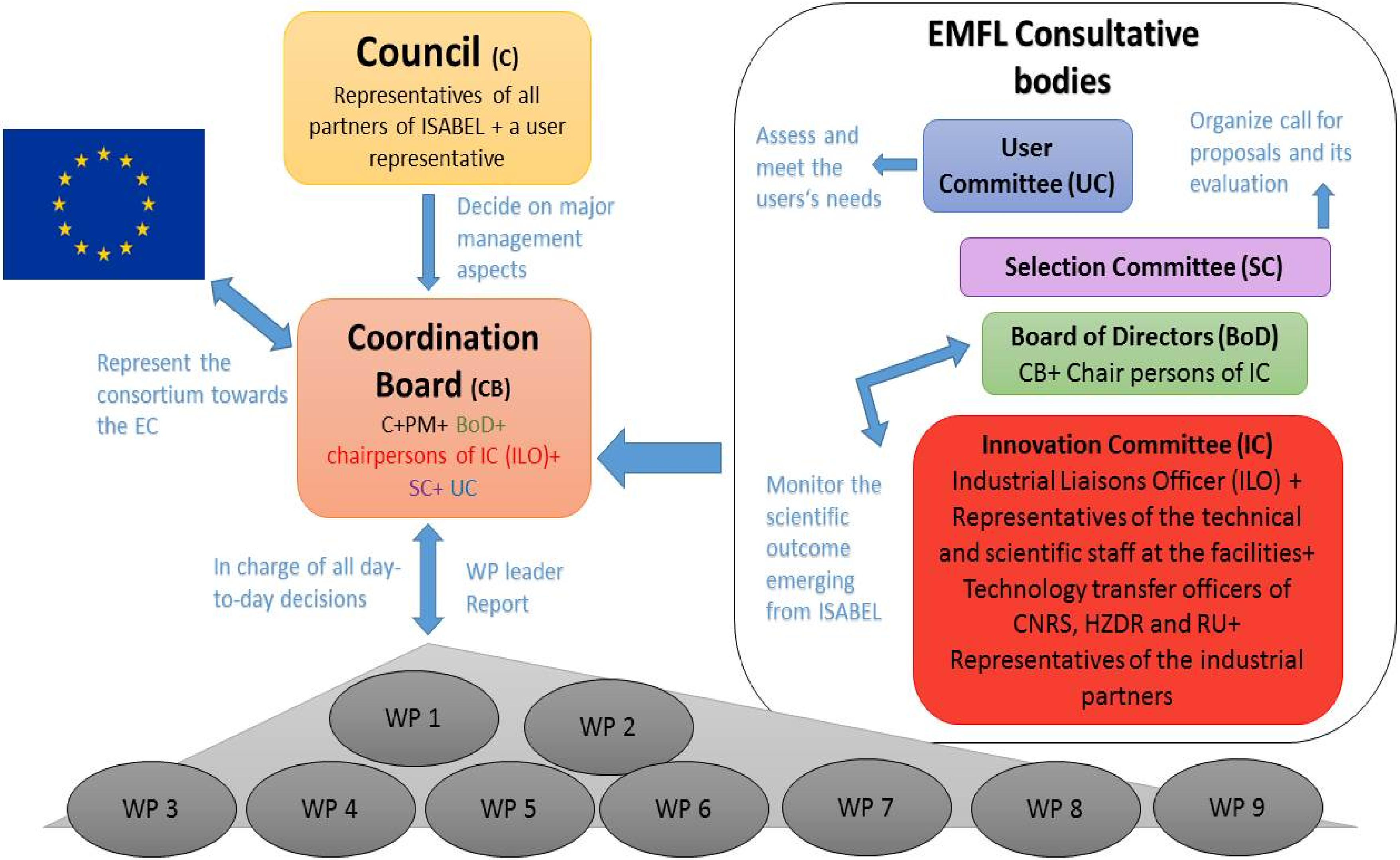
WP	Work Package Title	WP Leader	Partner	Person Months
1	Management & governance	Rikken	CNRS	45
2	Community building & membership enlargement	Patané	UNOT	23
3	Bridging the EMFL-industry gap	Lecouturier	CNRS	71
4	Data management	Wosnitza	HZDR	30
5	New access procedures	Hermannsdorfer	HZDR	37
6	Collaboration with other European RI	Simon	CNRS	22
7	Global high magnetic field collaboration	Christianen	RU	19
8	Communication & Dissemination	Van Breukelen	RU	49
9	Magnet technology evolution	Portugall	CNRS	93
	Total			389


WP9 Magnet technology roadmap
User community
Potential users Industrial & Academic
WP5 Access improvement
WP3 the innovation and industrial relations
Strengthen the EMFL structure
Strengthening the socio-economic impact of the EMFL
WP7 Global high magnetic field collaboration
WP6 Collaboration with other RI
Strengthening the role of high magnetic field research in Europe and Europe's global position in this area
WP2 Community building and membership enlargement
WP8 Communication & outreach
WP4 Data management
WP1 Management & governance

Budget ISABEL

Partner	Direct personnel cost	Other direct cost	Indirect cost	Special unit cost	EU contribution
CNRS	1090900	389200	370025	148800	1998925
RU	490740	139000	157435	100000	887175
UWAR	26500	22000	12125	9860	70485
UAM	6100	21800	6975	15025	49900
NICPB	5800	22000	6950	9860	44610
OI	28500	4000	8125	0	40625
UNOT	44900	32000	19225	9740	105865
CEA	102000	15000	29250	0	146250
EMFL	62000	250000	78000	0	390000
USAL	5900	22000	6975	10680	45555
UOX	8152	5000	3288	23223	39663
HZDR	454900	94000	137225	48800	734925
UGE	63500	20000	20875	0	104375
UCHA	6100	22500	7150	8637	44387
ICUBE	43000	4000	11750	0	58750
BN	41252	5000	11563	0	57815
Metel	38400	12500	12725	0	63625
Ampulz	40752	5000	11438	0	57190
Total	2559396	1085000	911099	384625	**4940120**

ISABEL management structure



ISABEL staff effort

	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9	Total part.
CNRS	**36**	4	**40**	6	12	**15**	4	15	**36**	**168**
HZDR	3	3	9	**18**	**12**	3	3	12	12	**75**
RU	3	2	12	6	9	3	**10**	**18**	12	**75**
UNOT		**2**			2					**4**
UOXF		1								**1**
UWAR		4			1					**5**
UGE		1							6	**7**
UAM		1								**1**
UCHA		1								**1**
NICPB		1								**1**
CEA			2				1		18	**21**
OI			2						2	**4**
ICUBE			3							**3**
USAL		1								**1**
EMFL	3	2			1	1	1	4		**12**
BN			1						2	**3**
MET			1						3	**4**
AMP			1						2	**3**
Total WP	**45**	**23**	**71**	**30**	**37**	**22**	**19**	**49**	**93**	**389**

Work package description	Milestones (month)	Deliverables (month)
WP1 Management		
T1.1 Financial and administrative management		48
T1.2 Organisation of management meetings	1	2, 3, 6, 9, 12, 13, 15, 18, 21, 24, 25, 27, 30, 33, 36, 37, 39, 42, 45, 48
T1.3 Evaluation current/future EMFL structure		36
WP2 Community Building		
T2.1 Development of regional partner networks		
T2.2 User community meetings	6, 18, 30, 42	10, 12, 22, 24, 34, 46
T2.3 Training early career researchers		22, 46
WP3 Bridging the EMFL-industry gap		
T3.1 Raising staff awareness		12, 18
T3.2 Raising awareness in industry of EMFL	24	14
T3.3 Stimulating collaborations	12, 36	46
T3.4 Attracting industrial users		36
WP4 Development of data management plan		
T4.1 Research data inventory		12
T4.2 Data analysis tool inventory		24
T4.3 Research data management		6, 24, 48
T4.4 EMFL data policy development		12
WP5 Access improvement		
T5.1 User survey novel access modes	6	10, 24, 45
T5.2 Development fast track access	13	24
T5.3 Development long term access	13	
T5.4 Development industrial access	13	
T5.5 Developement regional partner facility access	1	
T5.6 Development novel community access	13	36
WP6 Collaboration with European RI		
T6.1 Elaboration scientific case	24, 26, 28, 30	36
T6.2 Definition joint access procedures		36
T6.3 Elaboration roadmap high-field installation at advanced sources		46
WP7 Development global high-field collaboration		
T7.1 Creation of global network high-field technology		12, 24
T7.2 Development of global roadmap		48
T7.3 Elaboration international governance structures		48
WP8 Communication & dissemination		
T8.1 General public		6
T8.2 Internal		12, 24
T8.3 Users		12
T8.4 Industry		9
WP9 Magnet technology roadmap		
T9.1 Inventory of needs and potential	8	12
T9.2 Inventory & characterization of materials		19
T9.3 Energy procurement for DC facilities		36
T9.4 Creation design center for high-field magnets		36
T9.5 Roadmap definition		45

Timeline: Months 1–48 (1st year, 2nd year, 3rd year, 4th year; quarters 1–4 each).

▲ Milestones ○ Deliverables

WP1 Management

Task 1.1 **Financial and administrative management**

This task concerns the management of the progress towards the financial, administrative and legal obligations of the project (incl. reporting).

Task 1.2 **Meetings**

- A kick-off meeting will be held at the start of the project to confirm all tasks, responsibilities and timings. This will ensure that the project gets off to a good start.
- Video meetings of the Coordination Board (CB) will be organised every two weeks
- WP leader video meetings every three months to discuss progress of each WP and their interactions.
- Council meetings will be organised every year

Task 1.3 **Evaluation of the current and future EMFL structure**

The current and potential partners will be consulted whether the current EMFL AISBL structure is still adequate to realize the ambitions of EMFL.

Deliverables (brief description and month of delivery):

D1.1 Kick-off meeting report (M2)

D1.2 Council meetings reports (M13, M25, M37, M48)

D1.3 Governance analysis and outlook report M36

D1.4 WP leader meeting reports every 3 months (M3-45)

D1.5 Final report for the Commission (M48)

Milestones

M1.1 Kick-off meeting (M1)

WP2 Community building and membership enlargement

Task 2.1 *Targeted development of regional partner networks through meetings in UK, Poland, Switzerland, Estonia, Czech Republic, Italy, Spain**

Task 2.2 *User community meetings EMFL + regional facilities*

Task 2.3 *Training early-career researchers (schools), sharing knowledge and skills through exchange of facility staff, secondments***

* Other countries welcome!

** Call in autumn

WP3 Bridging the EMFL-industry gap

T3.1. Raising staff awareness and training staff on IPR and economic and societal issues: seminars, training courses, dedicated innovation funding call*

T3.2. Making industry aware of the frontier science and the unique technical developments at EMFL: skills map, exhibition participation, press, EMFL Industrial Club,….

T3.3. Stimulating collaboration with industry; analysis of best-practice, early detection of innovation (Innovation Committee), defining and supporting a clear transfer strategy (supported by CNRS Innovation)

T3.4. Attracting industrial users to the EMFL facilities; fast track confidential access (joint with WP5), hot line, consultancy, metrology service,…..

The position of Industrial Liason Officer (ILO) is currently open! Candidates welcome!

** First call end of June 2021*

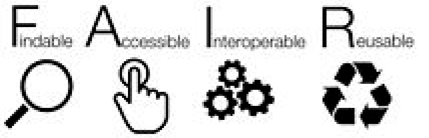
WP4 Development of data management plan

T4.1 Define a common data policy for all EMFL facilities

T4.2 Perform an in-depth inventory of the types, metadata and volume of data produced

T4.3 Identify user-friendly data-analysis software solutions that should be provided to the users

T4.4 Set up an EMFL data-management plan according to the FAIR principle



WP5 New access procedures*

Novel EMFL access procedures

Fast track access
Long-term access
First-time access
Industrial access

Provision of dual-access to EMFL facilities and the regional partner facilities:

Superconducting magnet laboratory, University of Nottingham
Oxford Centre for Applied Superconductivity, University of Oxford
Nicholas Kurti High Magnetic Field Laboratory, University of Oxford
Laboratory of Low Temperatures and High Magnetic Fields, UAM
Research Laboratories of the Faculty of Physics, University of Warsaw
Materials Growth and Measurement Laboratory, Charles University, Prague.
Research Facilities of the NICPB, Tallinn
Spintronics and Nanomagnetism Laboratory, University of Salento

***** user query will be sent soon

Summary of new TNA provision: EMFL + Regional facilities

Access provider	Infra-structure	Installation	Country	Unit of access	Unit cost (UC) (€)	Min. quantity of access provided	Access costs On the basis of UC (k€)	Access costs As actual costs (€)	# novel access users	# novel access projects
CNRS	LNCMI	LNCMI-T	FR	Magnet pulse	488	100	48,8		25	20
CNRS	LNCMI	LNCMI-G	FR	Magnet hour	1000	100	100		20	15
HZDR	HLD	HLD	DE	Magnet pulse	488	100	48,8		20	15
RU	HFML	HMFL	NL	Magnet hour	1000	100	100		25	20
UNOT	SML	SML	UK	Week	2365	4		9462	10	5
UOXF	SL	SL	UK	Week	5591	4		22365	10	5
UWAR	RLFP	RLFP	PL	Week	1594	4		6375	10	5
NICPB	EC	EC	EE	Week	2465	4		9860	10	5
UAM	LLTHMF	LLTHMF	ES	Week	3756	4		15025	10	5
USAL	SNL	SNL	IT	Week	2669	4		10676	10	5
UCHA	MGML	MGML	CZ	Week	1534	4		6137	10	5

WP6 Collaboration with other European RI

T6.1 Elaboration of the scientific case for high-field experiments at advanced sources

T6.2 Definition of access procedures for joint high-field experiments at advanced sources

T6.3 Elaboration of a roadmap for the development of high-field installations at the different advanced sources

RI name	Country	type	Previous EMFL experiments
ALBA	Spain	Synchrotron	no
ELBE	Germany	THz FEL	yes
ESS	Sweden	Neutron spallation	no
ESRF	France	Synchrotron	yes
FELIX	Netherlands	THz FEL	yes
ILL	France	Neutron reactor	yes
LULI	France	High power laser	yes
PSI	Switzerland	XFEL	yes
European XFEL	Germany	XFEL	no

WP7 Development of a global high magnetic field collaboration

T7.1 Creation of a global network in high-field technology

T7.2 Global Roadmap for future high-field developments

T7.3 Blueprint for an international governance structure

WP8 Communication and Dissemination

Task 8.1 Communication with the general public

Task 8.2 Internal EMFL communication

Task 8.3 Communication with EMFL users

Task: 8.4 Communication with industry (joint with WP3)

(EMFL News, website, flyers, videos,…)

WP9 Magnet technology evolution

T9.1 Inventory of needs and potential for user magnets*

T9.2 Materials for high-field magnets; inventory, characterization and industrialization

T9.3 Energy for DC high-field facilities; procurement, efficiency and recycling

T9.4 Design center for high-field magnets

T9.5 Roadmap definition

* User query this autumn

- ISABEL will help to make the EMFL stronger and provide better service to its users.

- For news and updates on ISABEL: https://emfl.eu/isabel/

- If you have any questions/suggestions: isabel@lncmi.cnrs.fr

EUROPEAN MAGNETIC FIELD LABORATORY

Science and Technologies

Professor Amalia Patanè
School of Physics and Astronomy
University of Nottingham, UK

Outline

- ❖ Magnet technologies at the EMFL
- ❖ Access to the EMFL

EMFL: Labs for High Magnetic Field Research

World class high magnetic field facilities for research across different disciplines and by users from all over the world

https://emfl.eu/

High magnetic field installations are expensive (several hundred millions) and therefore rare.

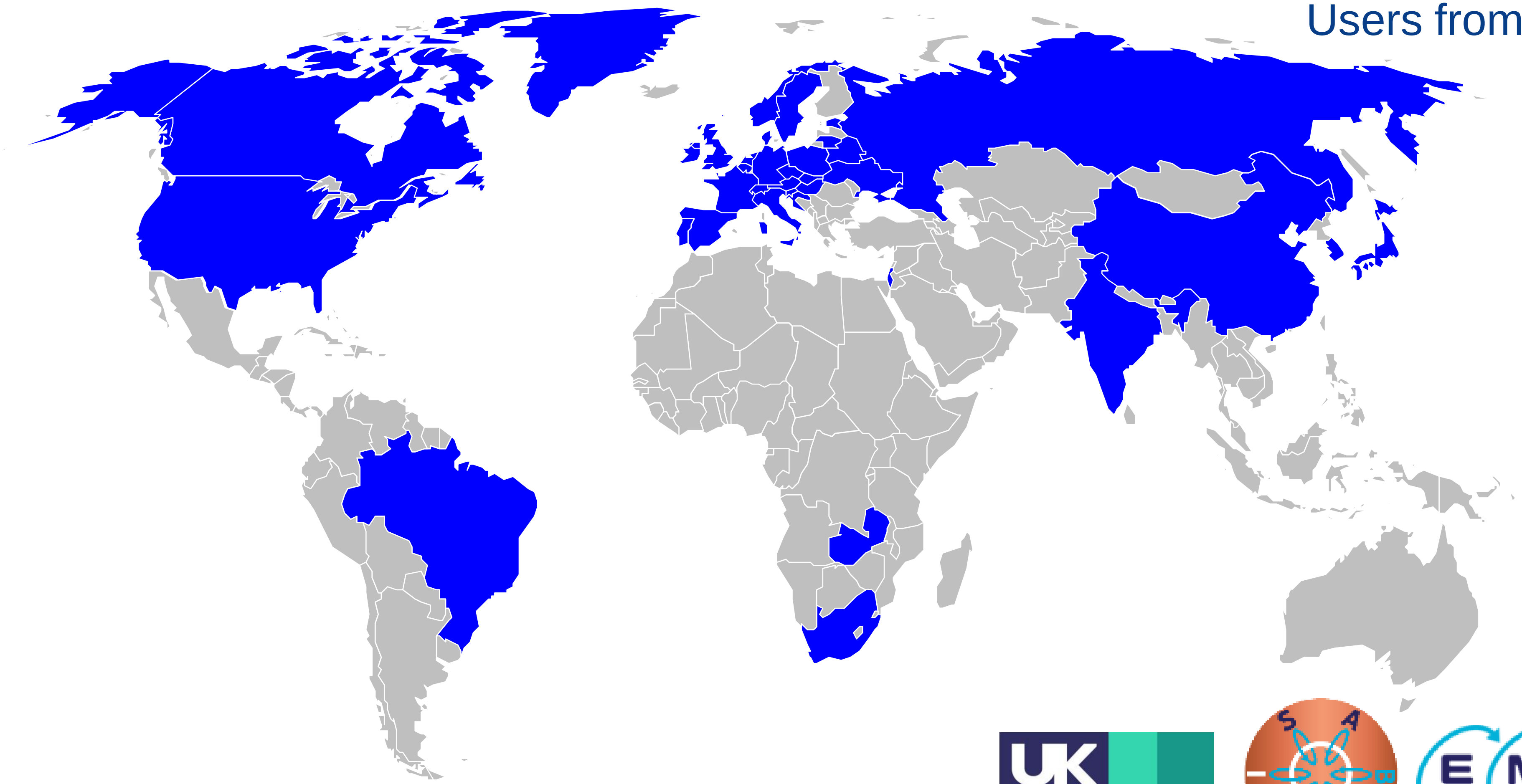
European Magnetic Field Laboratory

EMFL: Labs for High Magnetic Field Research

World class high magnetic field facilities for research across different disciplines and by users from all over the world

https://emfl.eu/

Users from ~37 countries



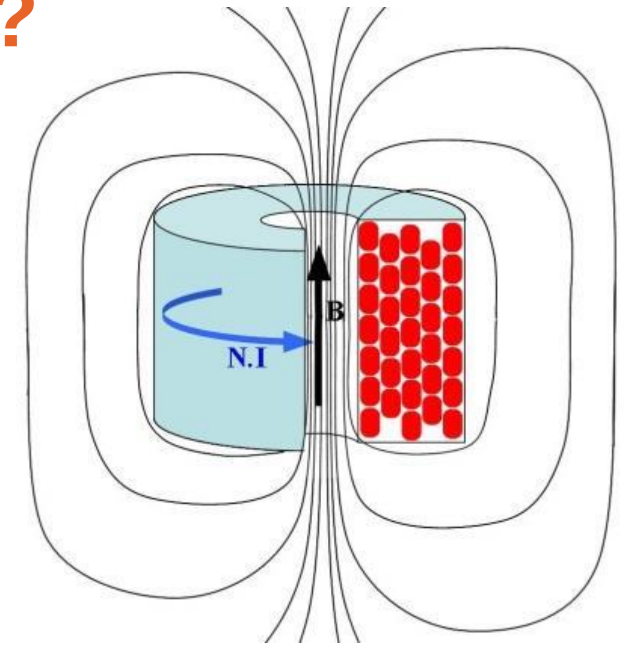
European Magnetic Field Laboratory

How to generate high magnetic fields?

Solution: a current flowing in a coil, **B ∝ I**

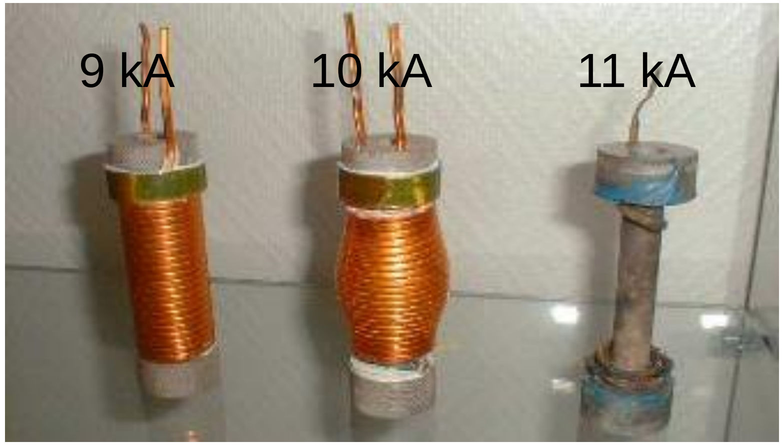
Limitation n°1: Heating (Joule effect) **P ∝ RxI²** ∝ B^2

Solutions:
- superconductors R = 0 (B < B_{crit})
- cooling: static fields
- pulsed current (< 1 s)



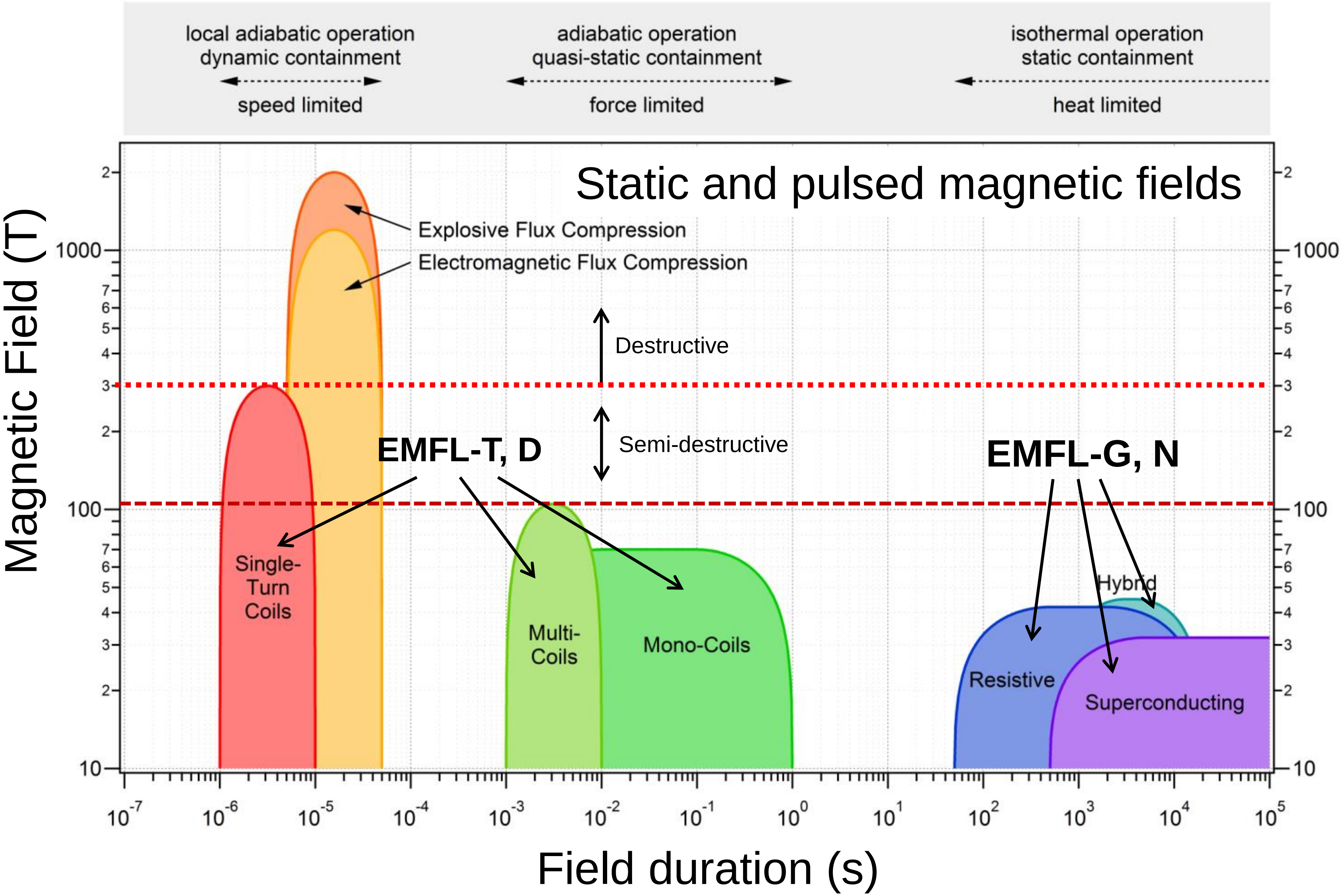
Limitation n°2: Lorentz force on the coil ∝ **BxI** ∝ B^2

Solutions:
- strong conductor
- mechanical reinforcement
- sacrifice the coil



European Magnetic Field Laboratory

EMFL State-Of-The-Art Magnet Technology



EMFL-T, Toulouse

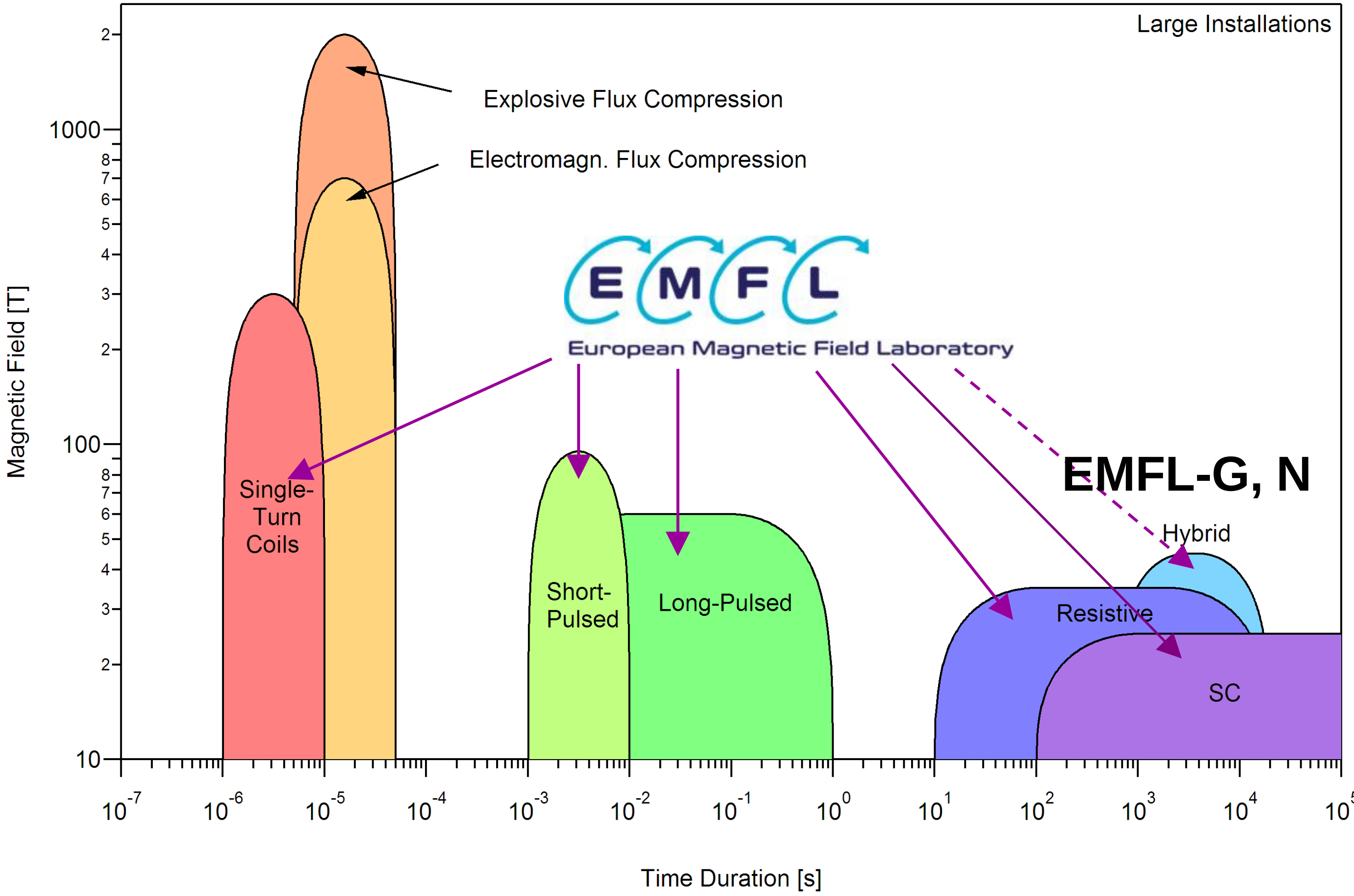
EMFL-D, Dresden

EMFL-G, Grenoble

EMFL-N, Nijmegen

EMFL State-Of-The-Art Magnet Technology

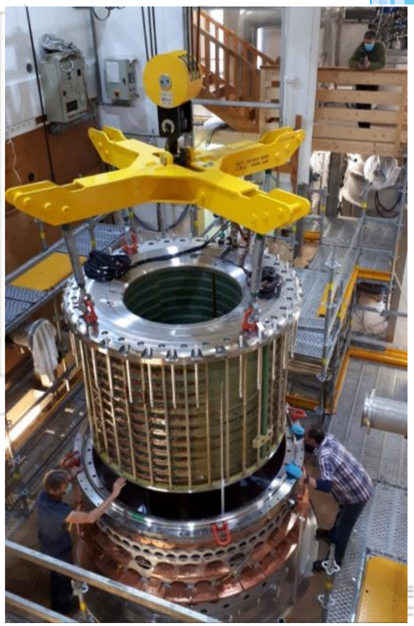
Static and pulsed magnetic fields



Static magnetic fields

- ❖ Resistive coils up to about 38 T
  DC current, >20 MW, 300 L/s of cold water
- ❖ Hybrid magnet system:
  45 T under construction

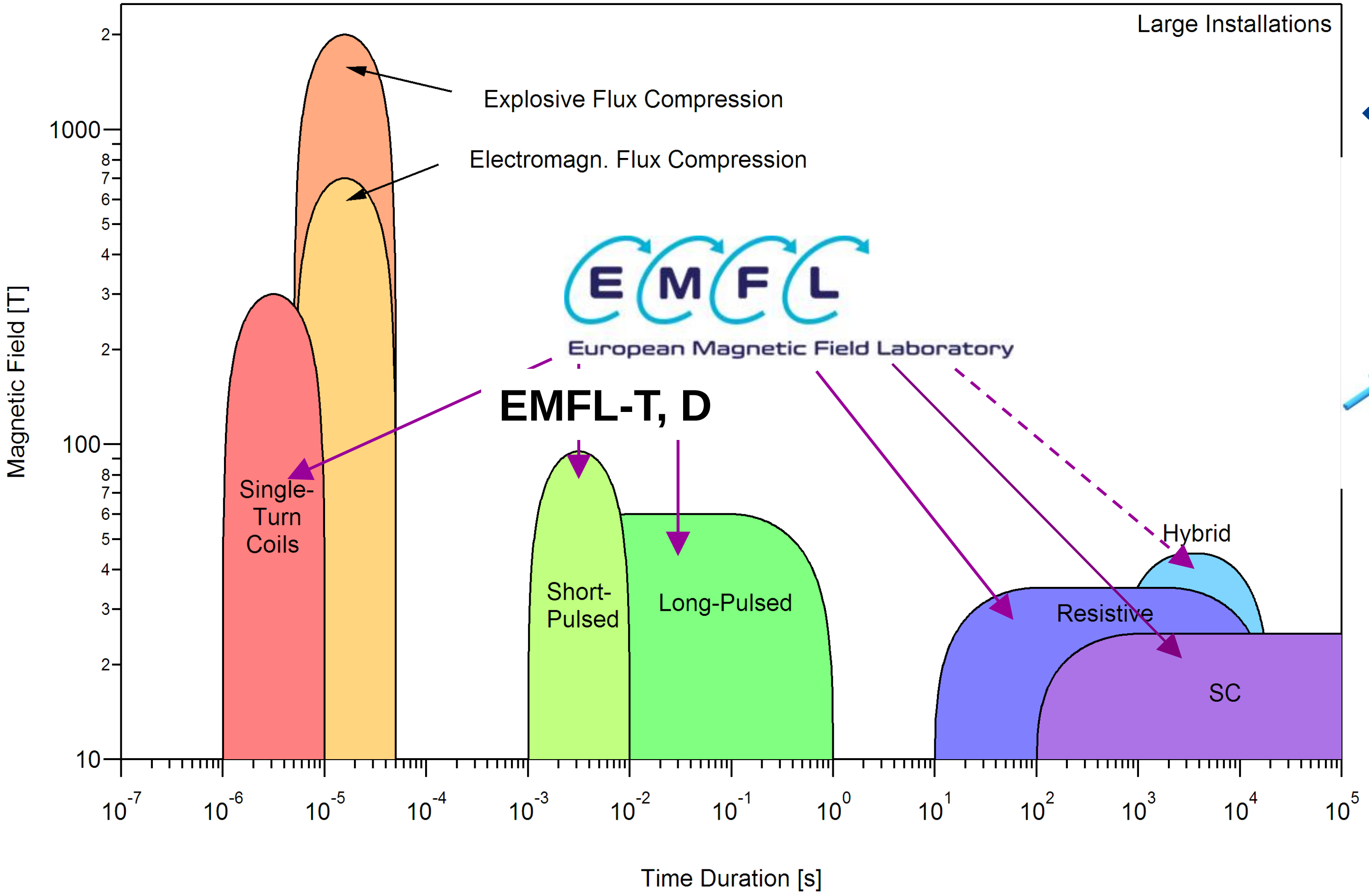
The hybrid magnet combines a **resistive insert** with a large-bore **superconducting outsert** (Nb_3Sn) to create an overall continuous magnetic field of 45T in a bore size of 32 mm.



Final assembly & integration ongoing, test in early 2022

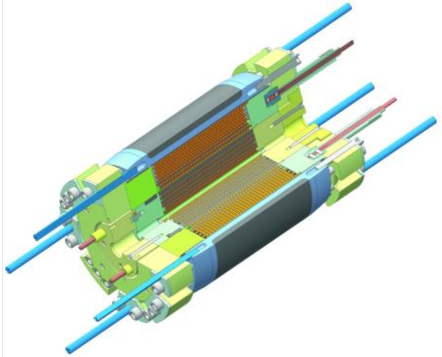
EMFL State-Of-The-Art Magnet Technology

Static and pulsed magnetic fields



Pulsed magnetic fields

- Non-destructive pulsed fields: 100 T



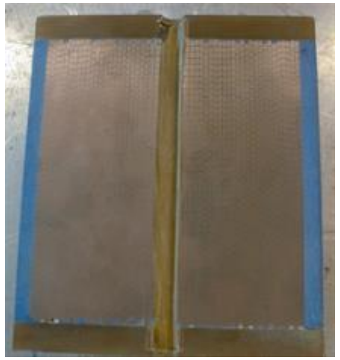
The construction of coils for B up to 100 T is technologically challenging due to the enormous electrical, magnetic, thermal, and mechanical stresses that occur on the coils.

Mechanical stress resulting from the pressure generated by the Lorentz force are large. Since B is proportional to the current and the Lorentz force is proportional to B times the current, the forces in the coil wires grow with B^2. In the simplest approximation, the pressure on the wire inside a coil is given by $p = B^2 / 2\mu$. For 100T, this corresponds to a pressure 4 GP (40000 atmospheres).

How to generate pulsed non-destructive magnetic fields

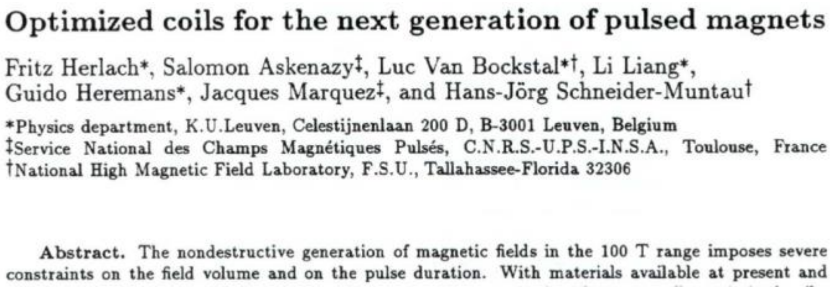
Progress over one century:

From 1924 to 1990 the field increased from 50 T to 70 T by improving the same technique:
The conductor is reinforced by the outside with a high strength metallic cylinder



Copper ~ 35T
Copper/Stainless Steel composite ~ 60T

1990-today field increase from 70 T to 80 T with single coil by using an optimized reinforcement technique



Optimized coils for the next generation of pulsed magnets

Fritz Herlach*, Salomon Askenazy‡, Luc Van Bockstal*†, Li Liang*,
Guido Heremans*, Jacques Marquez‡, and Hans-Jörg Schneider-Muntau†

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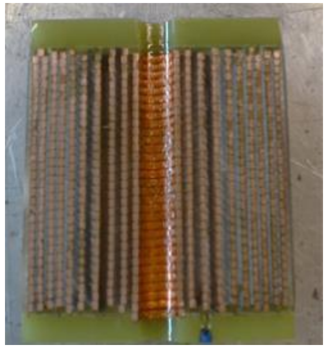
‡Service National des Champs Magnétiques Pulsés, C.N.R.S.-U.P.S.-I.N.S.A., Toulouse, France
†National High Magnetic Field Laboratory, F.S.U., Tallahassee-Florida 32306

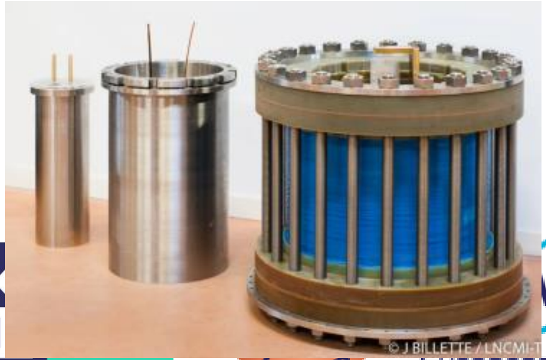
Abstract. The nondestructive generation of magnetic fields in the 100 T range imposes severe constraints on the field volume and on the pulse duration. With materials available at present and



Copper/Zylon ~ 60T
Copper/Stainless Steel/Zylon ~ 80T

2000-today field increase from 80 T to 100 T with dual coil systems powered by 2 different generators

Next step is the use of 3 or 4 concentric coils to take advantages of existing materials properties

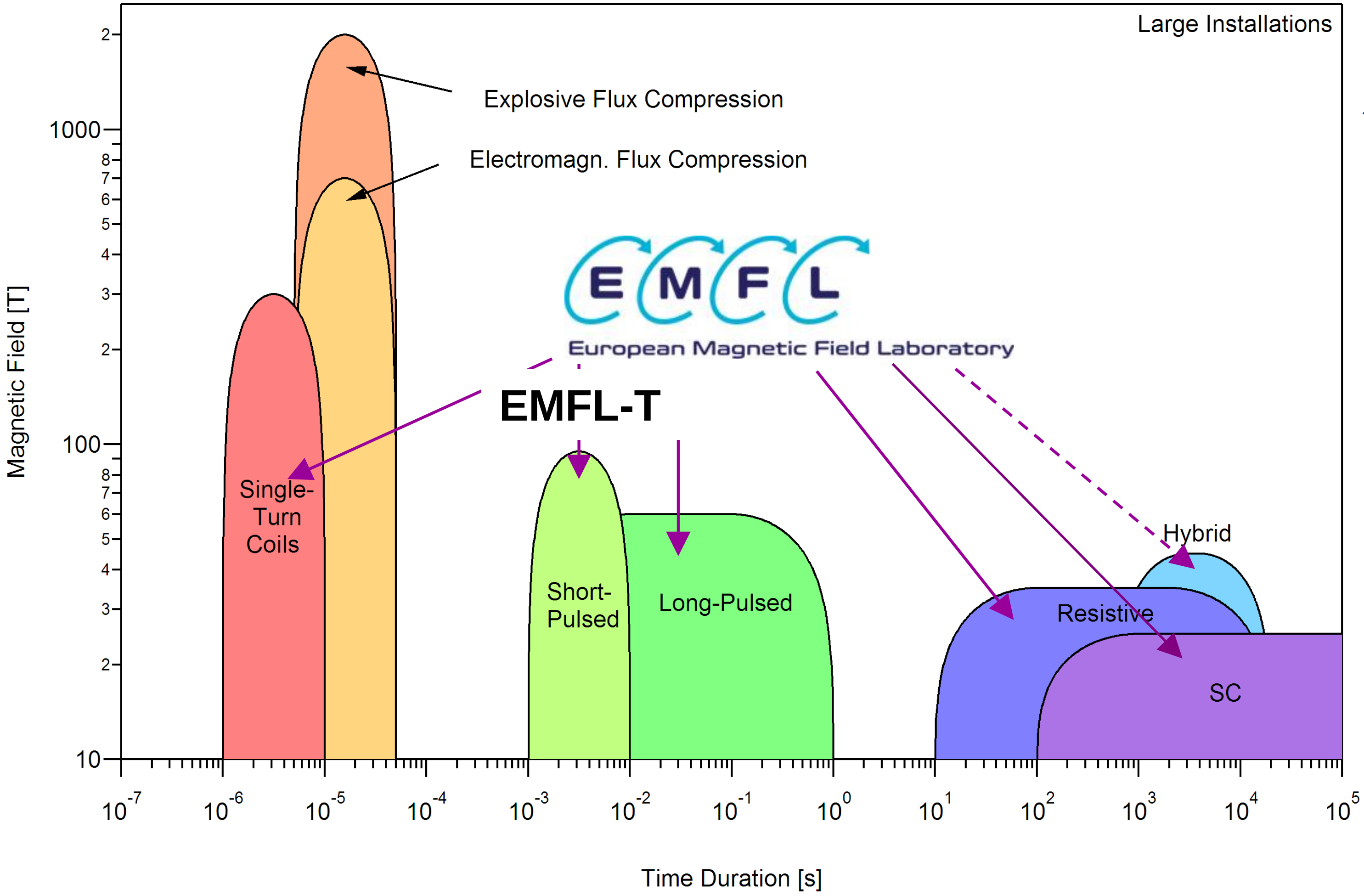


100 T triple coil

European Magnetic Field Laboratory

EMFL State-Of-The-Art Magnet Technology

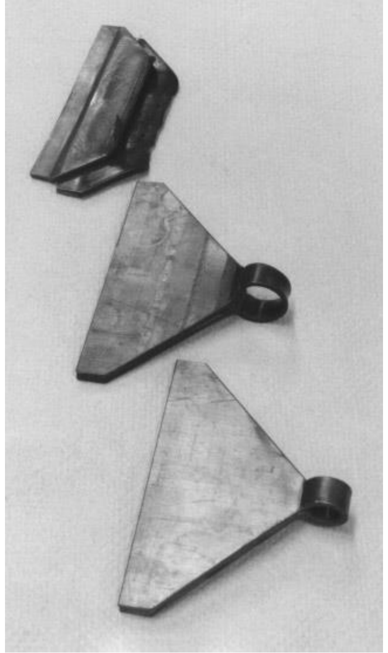
Static and pulsed magnetic fields



Pulsed magnetic fields

❖ Semi-destructive pulsed fields: 200 T

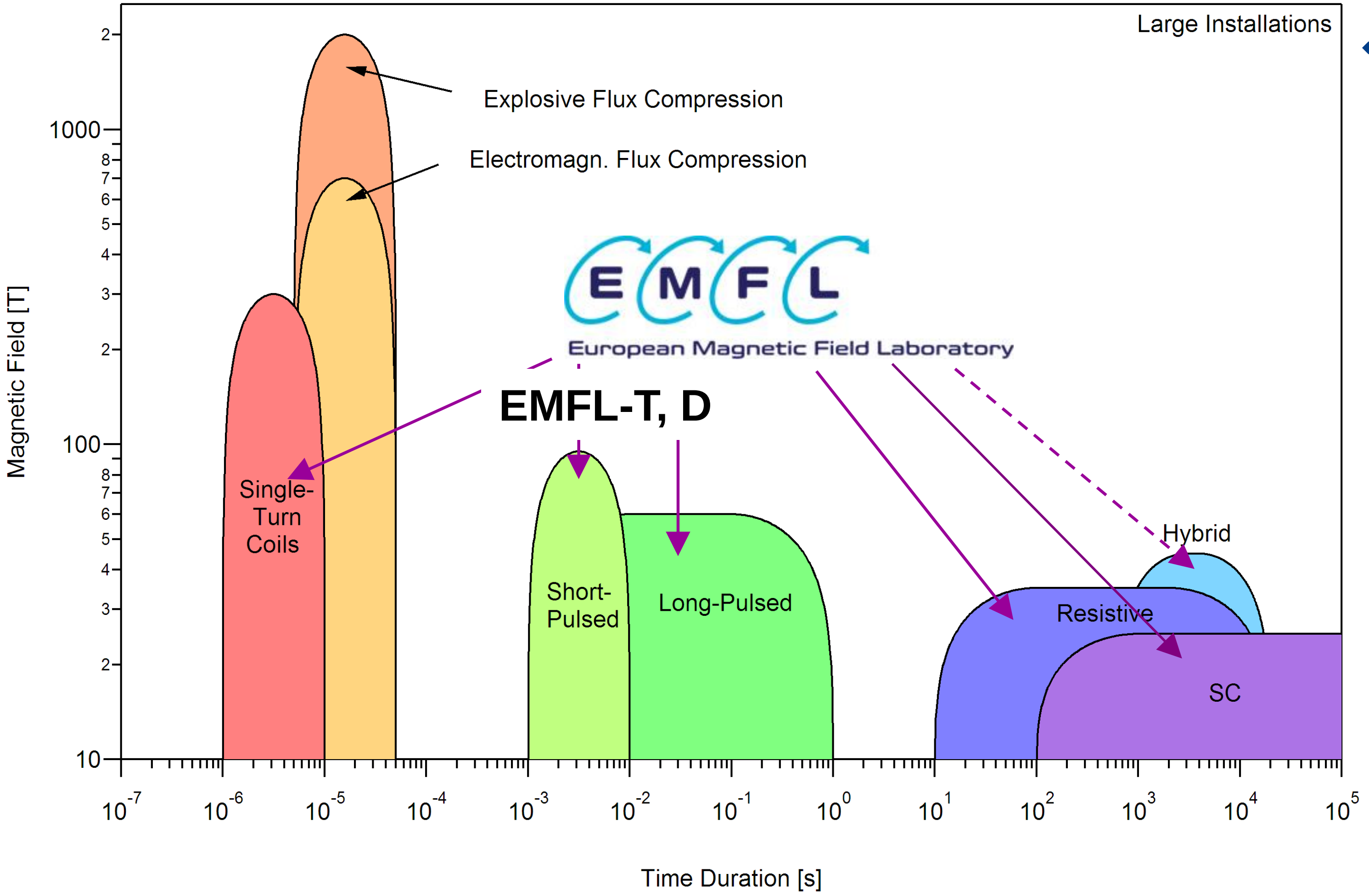
12 mm × 12 mm × 3 mm single-turn coils before the experiment (bottom), after a 10 kV, 6 kJ discharge with 37 T peak field (middle) and after a 55 kV, 189 kJ discharge with 188 T peak field (top).



The middle coil shows the effect of elastic deformation without actually breaking the loop. In the case of the 55 kV discharge the coil is completely destroyed and part of the triangular feed flanges are ripped off. The inner surface of the remaining pieces exhibits traces of melting caused by the extreme current density.

EMFL State-Of-The-Art Magnet Technology

Static and pulsed magnetic fields



Pulsed magnetic fields

- Non-destructive pulsed fields: 100 T

High-energy capacitor banks to provide the current (> 100kA) for the coils within a short time.

Example in Dresden: 500 capacitors with a capacity of 350 μF each can store a total energy of 50 MJ. Prior to a B pulse, the required capacitors are charged from the mains. The required energy is then supplied to the coil systems via electronic switches (thyristors).

H2020 SuperEMFL

Design study on all-SC magnet for the EMFL

2021-2024, 11 partners, of which 3 industrial, budget 2,9 M€, started January 2021

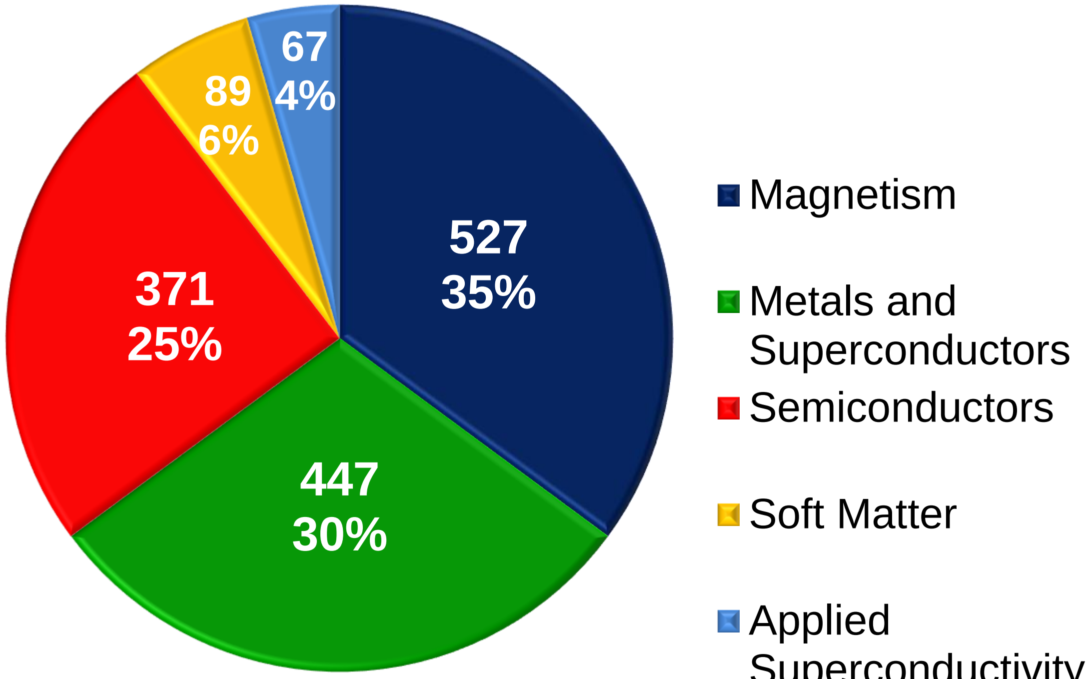
HTc Superconductors for high magnetic fields

Development of all-superconducting user magnets at unprecedented field strengths of 40 T and beyond, granting the European high-field user community:

- ❖ more magnet time
- ❖ novel low-noise high-sensitivity capabilities
- ❖ reducing operating costs and environmental impact

Research in high magnetic fields

Research across different disciplines
(physics, chemistry, biology, engineering)



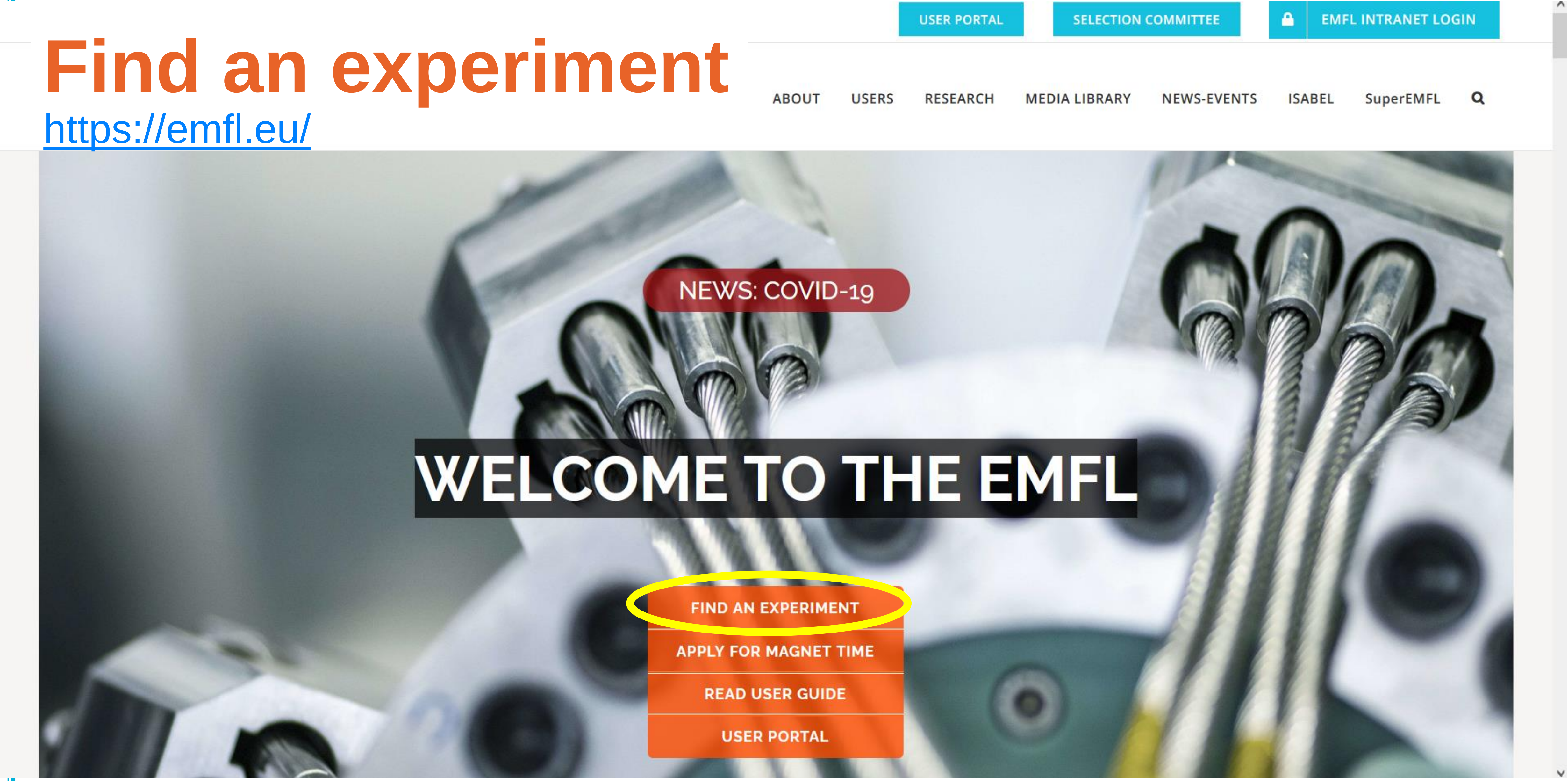
Wide range of experimental techniques

High-field experiments can be executed with **high spatial** and **energy resolution** over a **wide range of temperatures** down to the millikelvin range, in complex environments, such as **high-pressure**, and in **combination with other large instruments**, such as neutron sources, synchrotrons, and free electron lasers.

UKRI SABL EMFL European Magnetic Field Laboratory

Find an experiment

https://emfl.eu/



EMFL European Magnetic Field Laboratory

Find an experiment

MAGNETO-OPTICS

- OPTICAL MICROSCOPE IMAGING
- BIREFRINGENCE, DICHROISM AND FARADAY ROTATION
- PHOTOLUMINESCENCE AND RAMAN SPECTROSCOPY
- INFRARED SPECTROSCOPY
- ULTRAFAST DYNAMICS
- SCANNING TUNNELLING MICROSCOPY

THERMODYNAMIC PROPERTIES

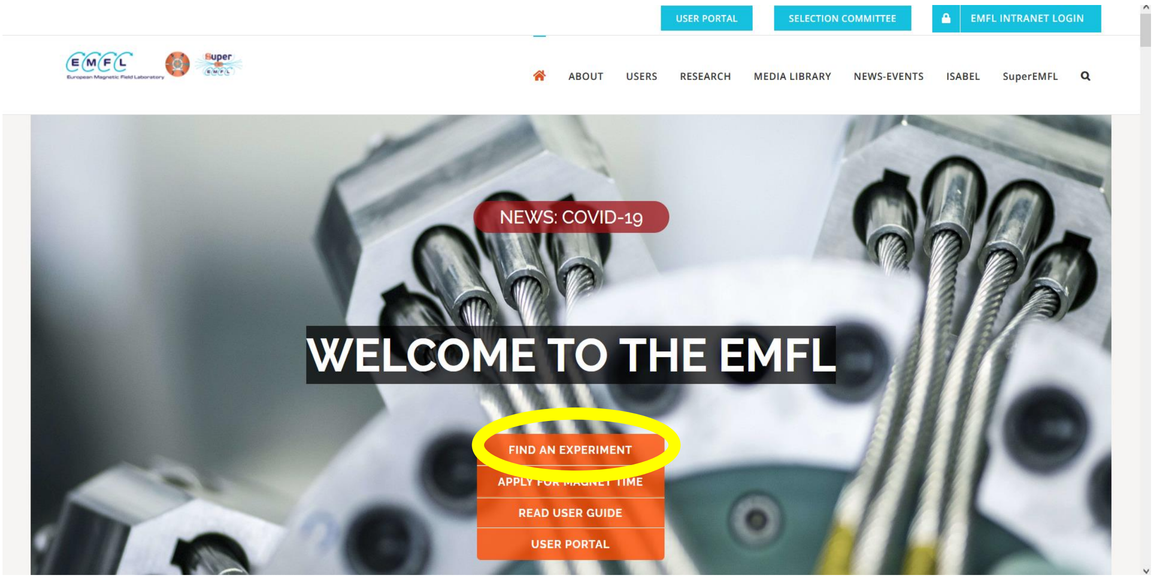
- SPECIFIC HEAT
- THERMOPOWER AND NERNST-ETTINGHAUSEN
- MAGNETOSTRICTION
- SOUND VELOCITY AND ATTENUATION
- MAGNETOCALORIC EFFECT
- ...

MAGNETOMETRY

- COMPENSATED-COIL MAGNETOMETRY
- FARADAY BALANCE
- VSM VIBRATING-SAMPLE MAGNETOMETER
- TORQUE MAGNETOMETRY

MAGNETOTRANSPORT

- RF CONTACTLESS TRANSPORT
- CRITICAL CURRENT SUPERCONDUCTORS
- MAGNETOTRANSPORT (IN-SITU SAMPLE ROTATION)
- LOW NOISE&LOW RESISTANCE



MAGNETIC RESONANCE

- ELECTRON SPIN RESONANCE
- NUCLEAR MAGNETIC RESONANCE

ELECTRIC POLARIZATION

- ELECTRIC POLARIZATION

ADVANCED SOURCES

- X-RAY
- NEUTRONS

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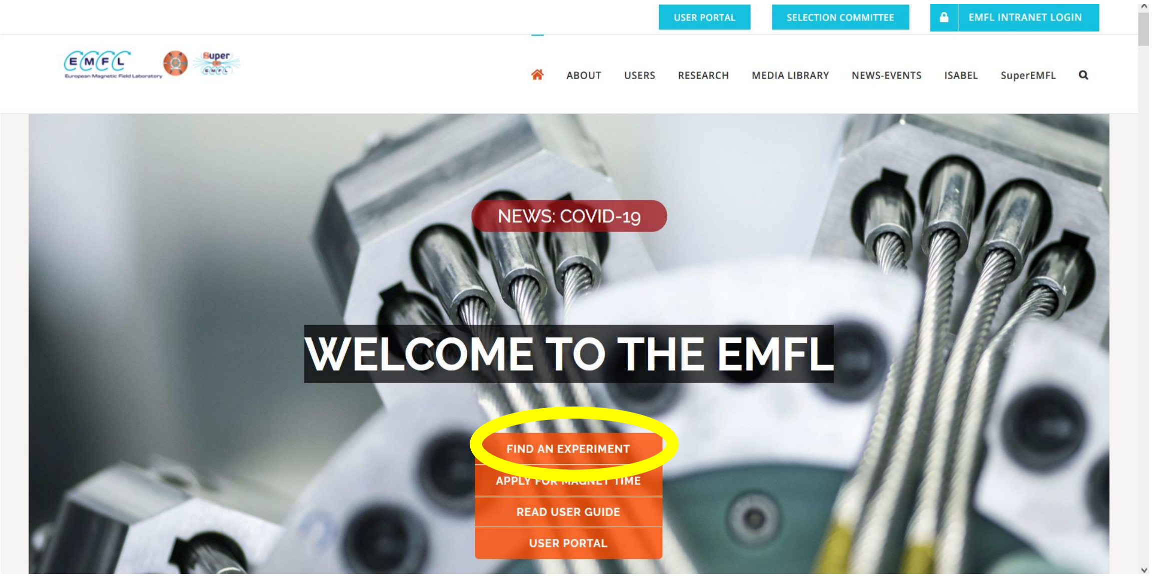
Find an experiment

- ❄ ^{4}He Cryostats and/or VTI 300 K to 1.2 K
- ❄ ^{3}He Cryostats down to 300 mK
- Dilution ^{3}He – ^{4}He refrigerator down to 20 mK
- Thermostats – up to 300°C
- High pressure
- Field-independent thermometry



Importance
of the local contact

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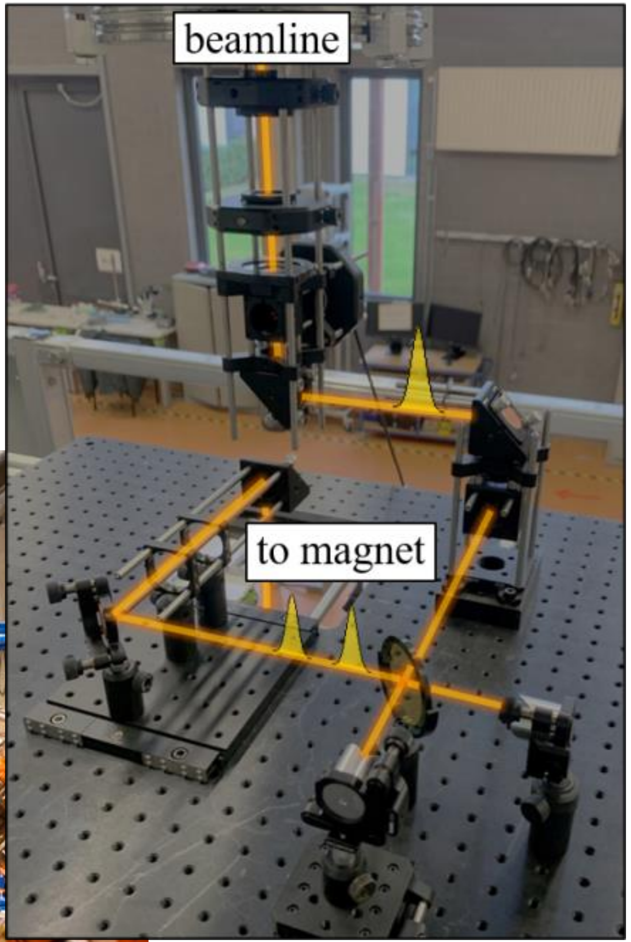
Advanced Sources and High Magnetic Fields

EMFL- Nijmegen

FELIX: **F**ree-**E**lectron **L**asers for **I**nfrared e**X**periments

The FELIX Laboratory develops and exploits intense, short-pulsed infrared and Terahertz free-electron lasers.



The FELIX generates and uses very intense radiation in the (far)infrared region of the radiation spectrum.

The four lasers **FELIX-1**, **FELIX-2**, **FELICE** and **FLARE** each produce their own range of wavelengths and together, they provide a tuning range between **3 µm** and **1500 µm**.

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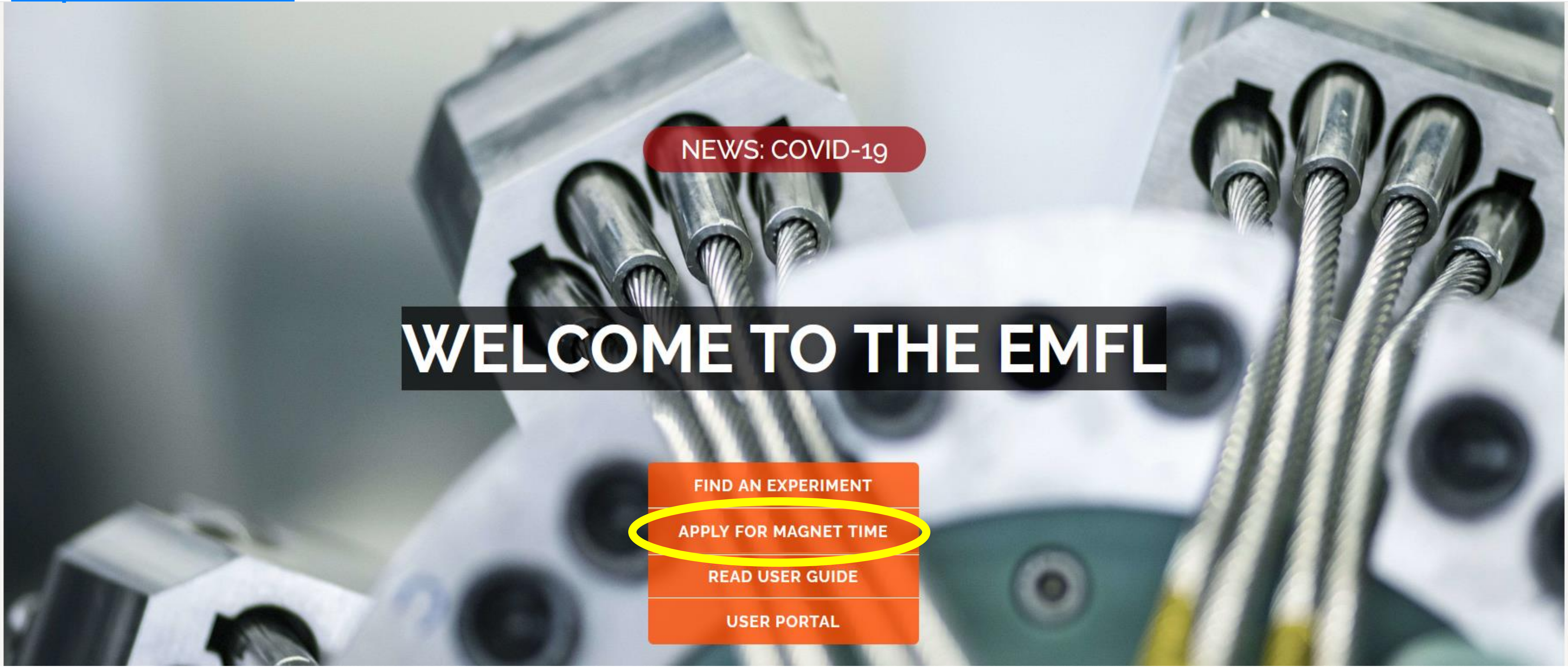
Apply for magnet time

https://emfl.eu/



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EMFL a

- Two cal
- Online
- Submis
- **New:** du
  and EMF

ISABEL – C

Improving th
Field Laborato

2020-2023, 18
4,9 M€, started 1

EMFL access procedures

- Two calls per year open 15 April and 15 October
- Online proposal form at: www.emfl.eu
- Submission deadlines: 15 May and 15 November
- **New:** dual access to regional partners

  and EMFL facilities sponsored by ISABEL
- EMFL and ISABEL partners are developing new access procedures for :
  - Fast track access
  - Long-term access
  - Industrial access
  - First-time access

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Selection procedure

Evaluation within one month (15 June and 15 December) by

Selection Committee

- 18 members in 5 categories

  Magnetism, Superconductors & Metals, Semiconductors, Soft Matter, Applied Superconductivity

Ranking

A: Proposal should be carried out

B: Facilities have freedom to decide on amount of magnet time depending on availability, feasibility and ranking (+,0,-)

C: Proposal rejected

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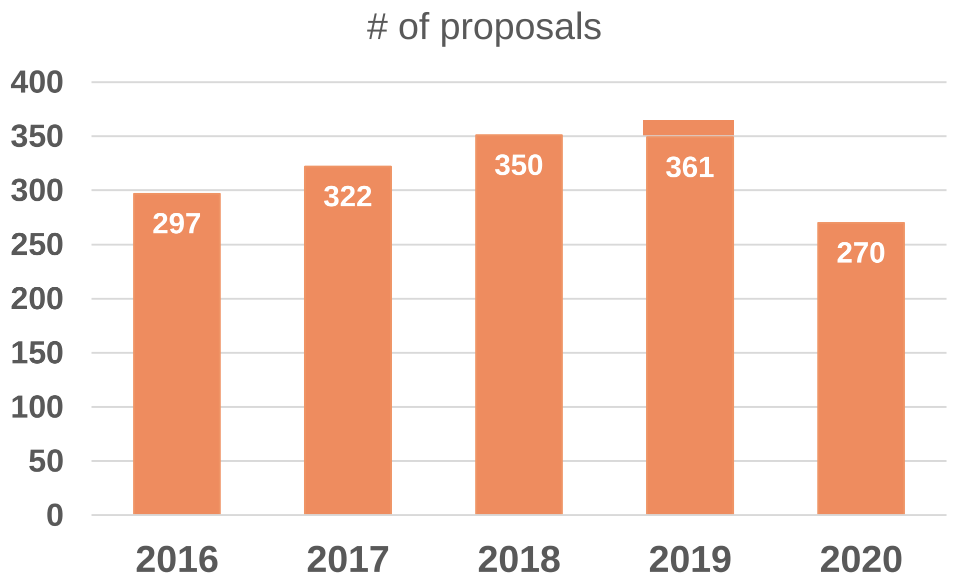
Granted access involves

- use of installation including auxiliary equipment
- supply of cryogenic liquids
- support by local staff



EMFL scientific staff (2021):
43 permanent researchers
83 engineers/technicians
30 postdocs
45 PhD students
13 administration

Scientific output (2015-2020):
~1135 publications
~56 thesis

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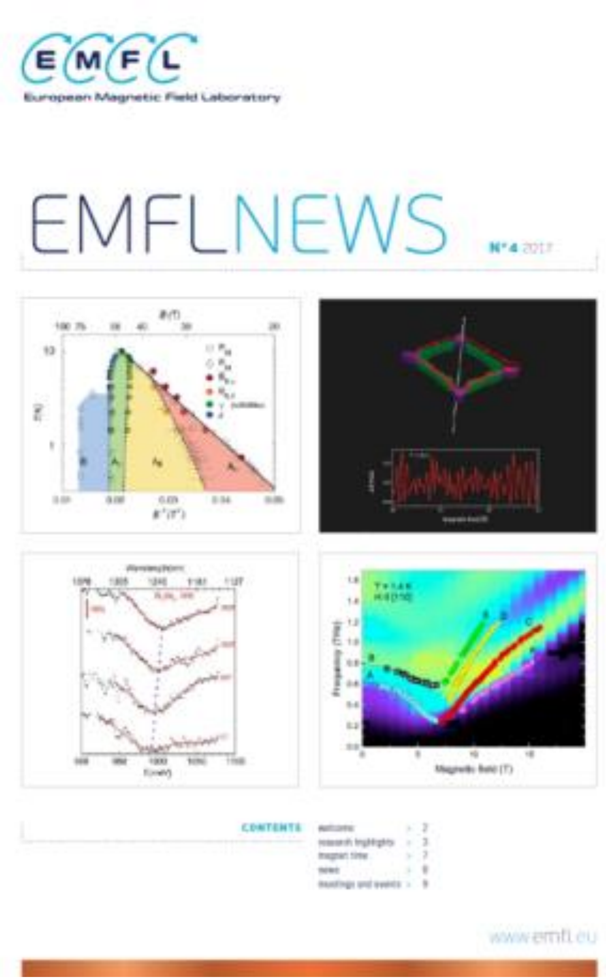
EMFL: dissemination and training

Dissemination
- *Website*
- *Press releases*
- *EMFLNews*
- *Organizing workshops and conferences*

Training of students/post-doctoral researchers

Developing skills, sharing best practices, summer schools ...



https://emfl.eu/emfl-news/

UKRI

EMFL
European Magnetic Field Laboratory

UKRI

EMFL

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Research in High Magnetic Fields

“Strongly Correlated Electron Systems” High magnetic fields provide a tool to influence magnetic and electronic interactions in correlated electron systems whose understanding represents one of the outstanding challenges in modern condensed matter physics. Electron-electron interactions can cause unconventional superconductivity, quantum criticality, and new forms of magnetic and charge ordering.

“Probing and manipulating quantum states at the nanoscale” The small magnetic length scales associated with high magnetic fields means that quantum systems (quantum dots, molecular clusters, *etc*) and materials (organic and inorganic perovskites, van der Waals crystals, *etc*) can be investigated at the nanoscale in a reversible and reproducible way.

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Research in High Magnetic Fields

“Quantum Magnetism and Functional Materials” Magnetic interactions constrained to low dimensions (*e.g*. in molecular magnets or magnetic nanoparticles) can lead to exotic physical properties. High magnetic fields will enable the phase diagrams of these nanoscale systems to be mapped out and understood.

Also, the magnetic alignment of organic materials, polymers, molecular aggregates and nanostructures provides a route for investigating the relationship between material structure and functionalities.

Research in High Magnetic Fields

“Magnetic Levitation” High field magnets can be used to effectively tune the gravitational forces on Earth to study a wide range of phenomena spanning from the exploration of fluids and granular systems to the behaviour of biological organisms in weightless conditions.

“Magneto-science” Magnetic fields can be used to investigate the solidification of microstructures and unravel the thermo-physical properties of highly reactive materials, for example, titanium alloys for use in aero-engines, zirconium for nuclear applications, and lithium for nuclear fusion. Large magnets provide new possibilities to investigate liquid metal levitation for metal matrix nano-composites production. Magnets suitable for combined action of steady and alternating fields offer a new perspective to traditional induction melting techniques (melting large volumes, controlling turbulence, achieving high superheat).

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