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FREIA test facility

24 April 2023

Tommaso Bagni

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Outlines

FREIA laboratory

HNOSS

GERSEMI

Conclusions

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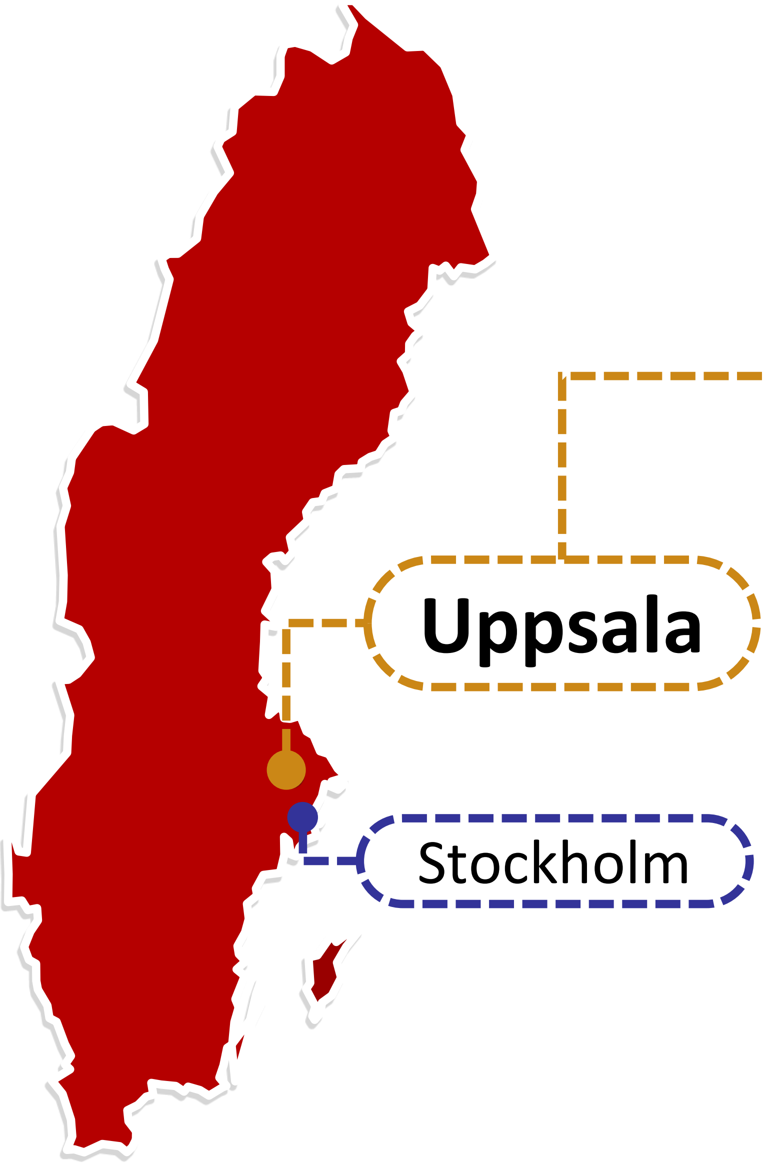
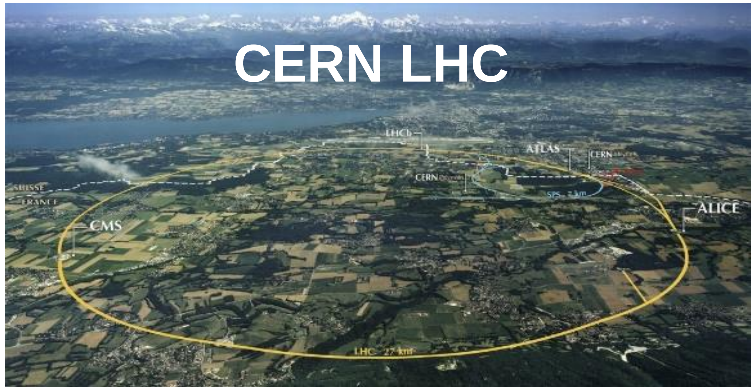
The FREIA laboratory

The FREIA laboratory



Facility for Research Instrumentation and Accelerator Development

- The FREIA Laboratory was inaugurated in 2013 within the department of Physics and Astronomy at Uppsala University, to develop and test new particle accelerator and detector instrumentation.
- 1000 m^2 large, 10 m high
- Has a 7.2-ton movable crane and other mechanical equipment
- Small workshops for mechanics and electronics and 50 m^2 control room
- Office space for ~20 people

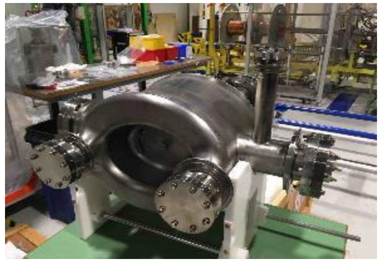


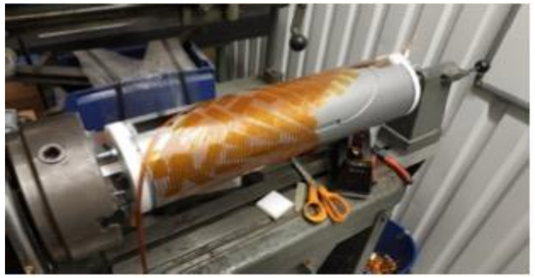
Scientific infrastructure

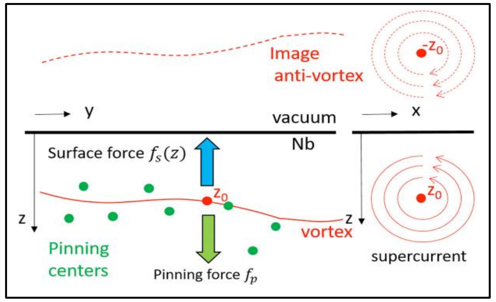
Particle physics
Nuclear physics

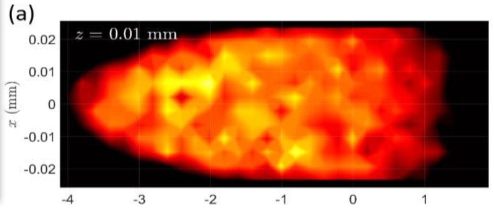
Condensed matter physics
Material science

Basic R&D

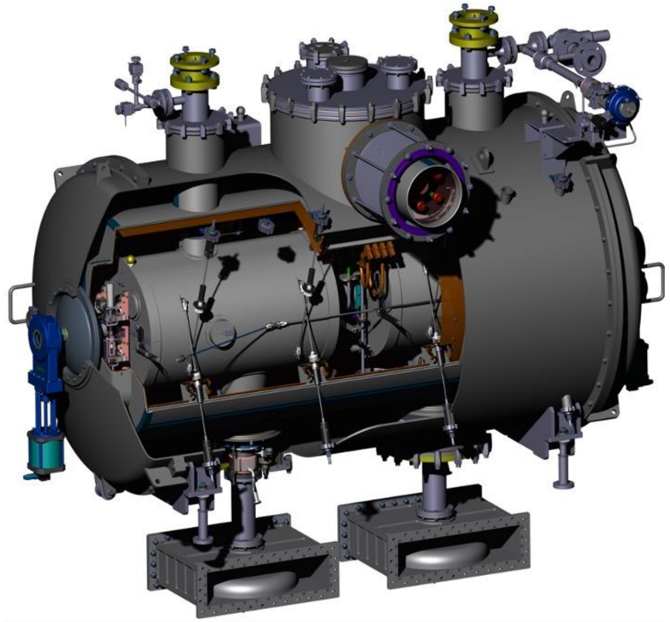








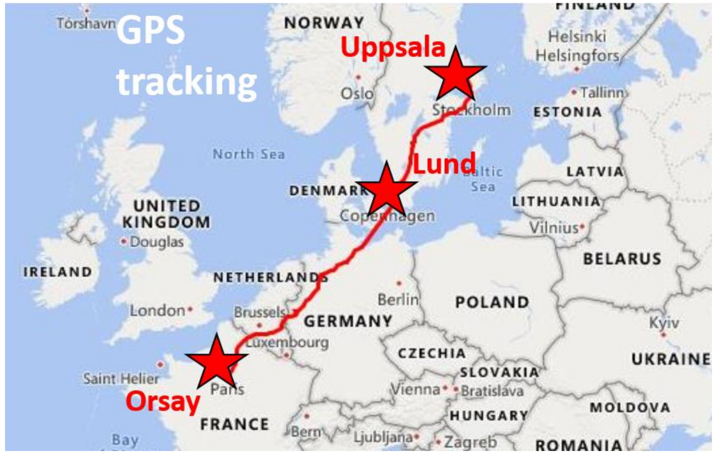
ESS cryomodules



Test & assessment at **FREIA laboratory in Uppsala**




Assembly in **IJCLab**



12/14 modules approved → Installation in **ESS**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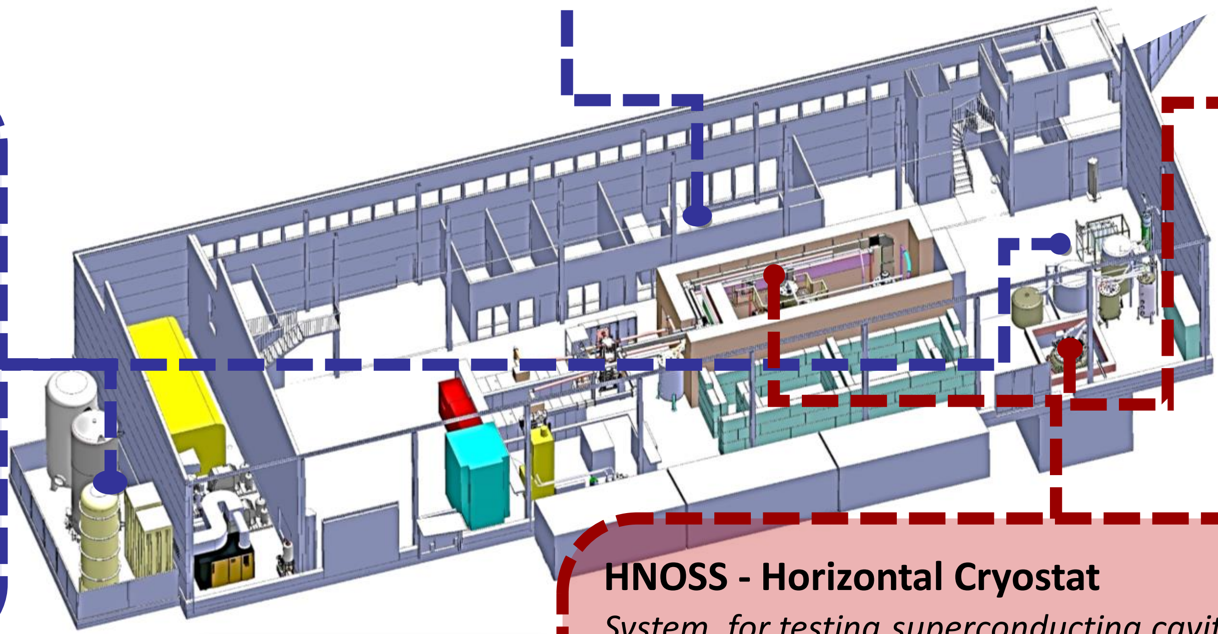
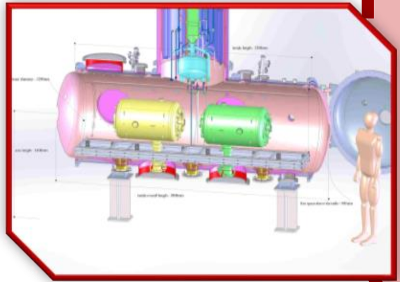
The FREIA Laboratory

Control Room
- The overall control system is based on EPICS
- Self-excited loop, 352 MHz, 1 kW CW
- Standard Measurement Equipment

Cryo system:
- 2000 L dewar (+ 1000 L extra dewar)
- 140 L/h liquefier
- 19.2 m^3 high pressure storage at 200 bar
- 132 kW recovery compressors
- 100 m^3/h circulating compressor (Kaeser)
- 100 m^3 gas bag



Gersemi - Vertical Cryostat
System for testing superconducting devices such as accelerating cavities and magnets
- Dimensions: 1.1 m diameter, 2.8 m height
- Range of operation: 1.8 to 4.5 K, 16 to 1250 mbar
- Pressure stability at 16 mbar: +/- 0.1 mbar
- Cooling power at 1.8 K: 90 W
- Maximum allowed weight up to 5 ton
- 2 x 2 kA power converters
- 1 kW RF power in a self-excited loop

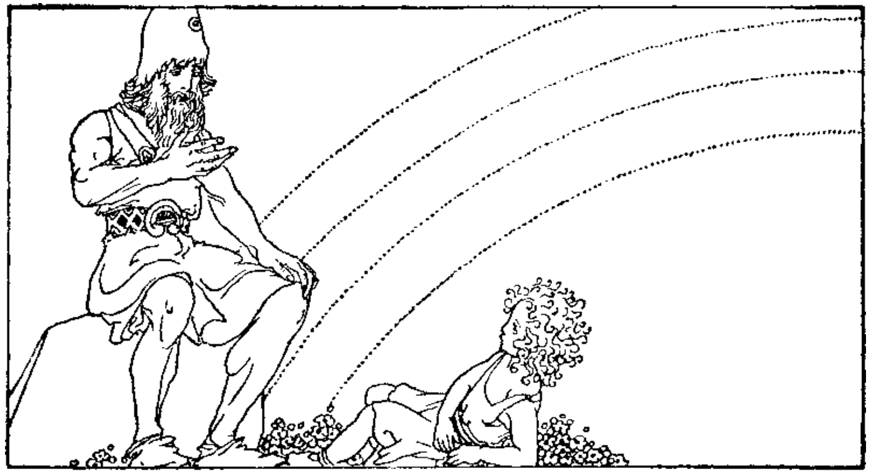


HNOSS - Horizontal Cryostat
System for testing superconducting cavities.
- Inner measures 3.2 m length and 1.19 m diameter
- Range of operation: 1.8 to 4.5 K, 16 to 1250 mbar
- Supercritical Helium external closed circuit
- Internal warm magnetic shielding: mu-metal, 1 mm
- Pressure stability at 16 mbar: +/- 0.1 mbar
- Cooling power at 1.8 K: 90 W

What are Hnoss and Gersemi standing for?

Hnoss and Gersemi (both mean "treasure“ or “precious” in Old Norse*) **are the two daughters of the goddess Freyja.**

Hnoss and Gersemi



In Norse mythology, **Freyja** (*Old Norse: "(the) Lady") **is a goddess associated with love, beauty, fertility, sex, war, gold, and seiðr** (magic for seeing and influencing the future).

Freja (1905) by John Bauer (1882–1918)

**Old Norse is a stage of development of North Germanic dialects before their final divergence into separate Nordic language*

https://en.wikipedia.org/wiki/Hnoss

HNOSS

Horizontal cryostat HNOSS for **jacketed cavities**

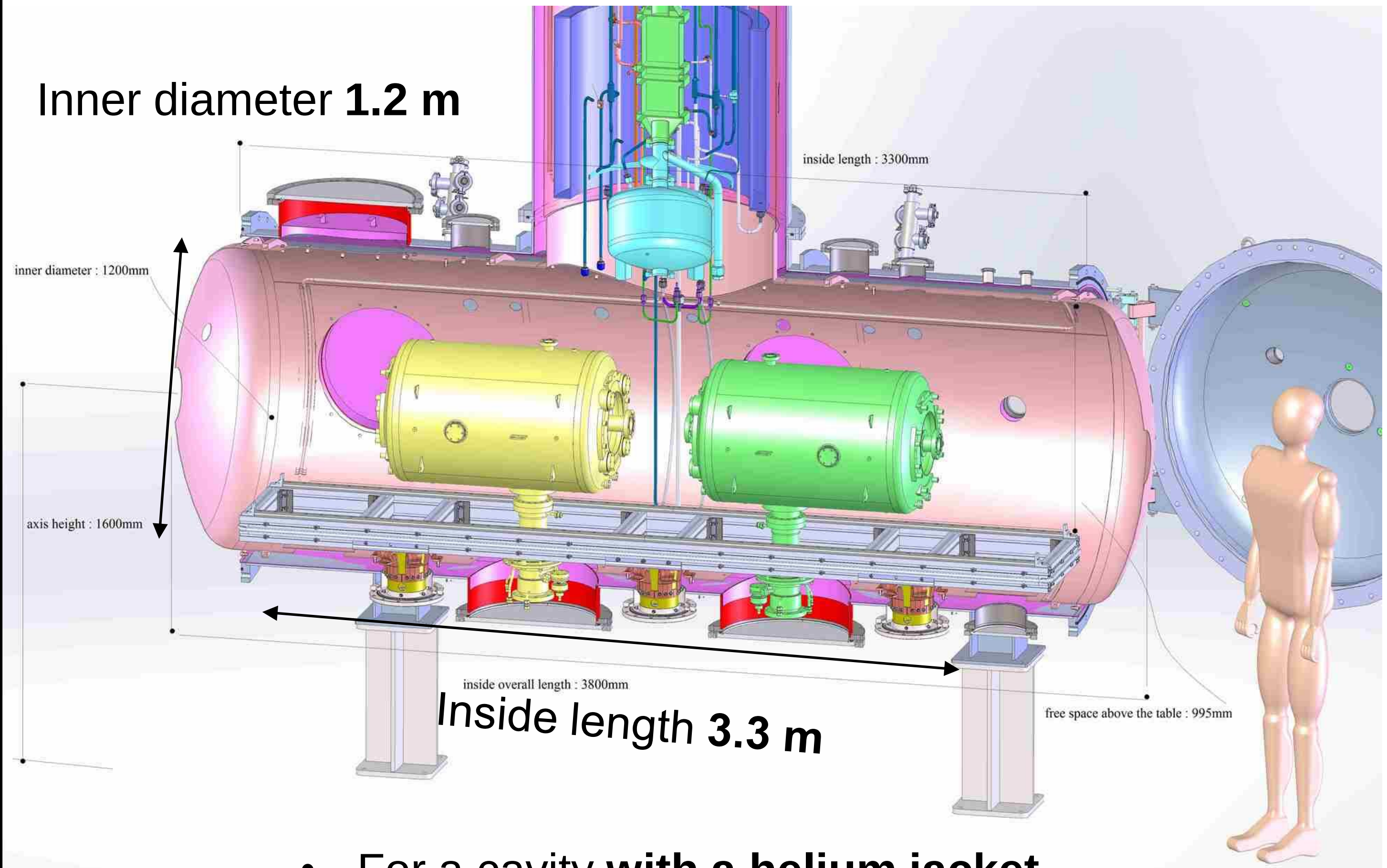
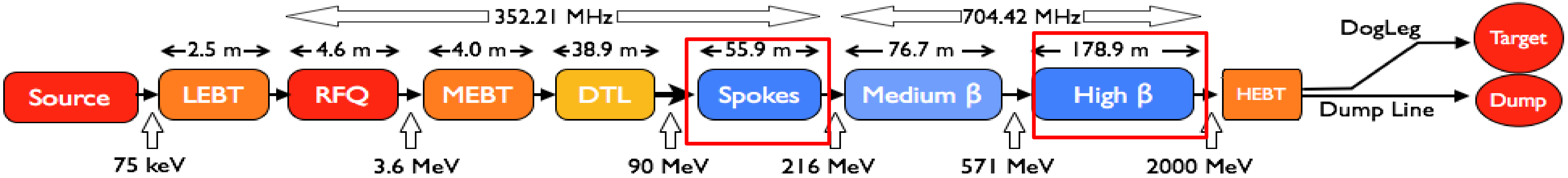
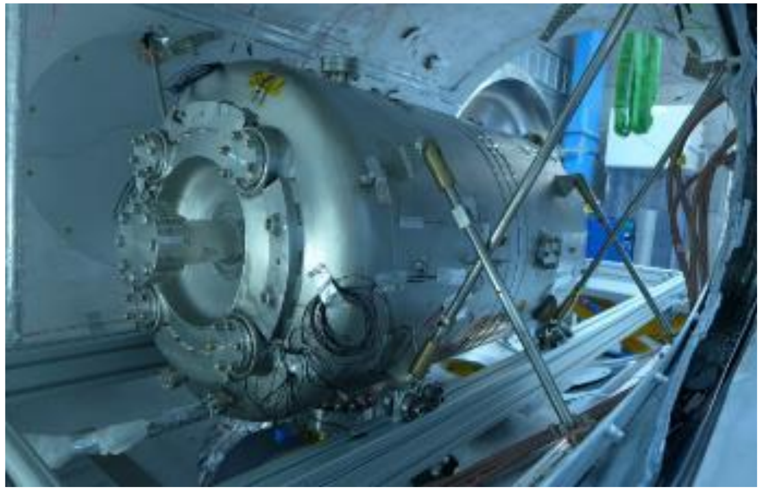


Figure 2: left #1 (Romea); middle #2 (Giulietta); right #3 (Germaine)

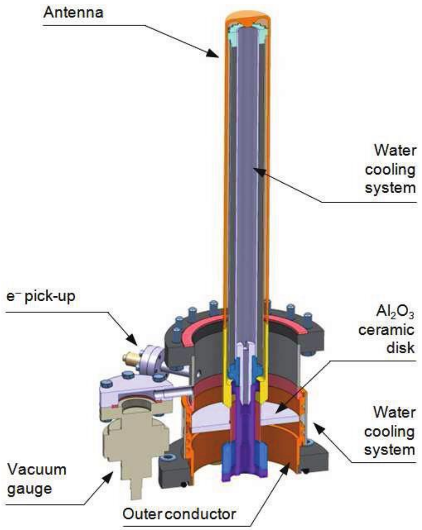
- For a cavity **with a helium jacket**
- Ideal for **coupler testing**: FPC, HOM
- **Multiple cavities** may be tested at the same time
- Supercritical helium closed circuit
- Cavity with power couplers placed sideway can be tested

Cavity testing with power couplers & tuners





Double spoke and elliptical cavities tested for ESS with/without the power couple connected.



- Our Low Level Radio Frequency (LLRF) card is equipped with Self-Excited-Loop (SEL) to lock critically coupled cavities
- **Quality vs. Electric field acceleration, and other standard measurements can be performed in HNOSS if the cavities are equipped with He jackets**

Cleanroom is available for SC activities

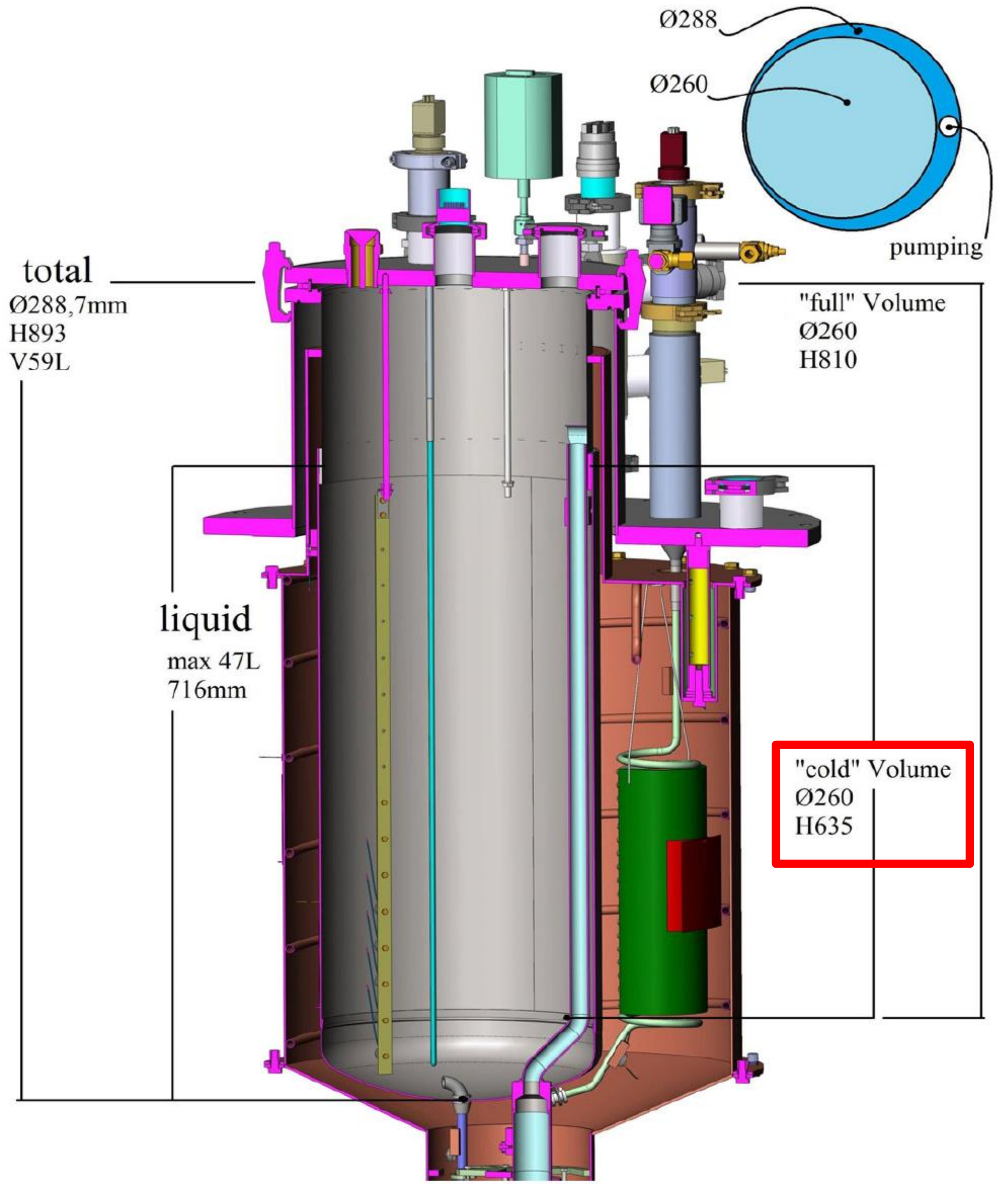
- ✓ A pick-up antenna falling off during transport was fixed in the cleanroom

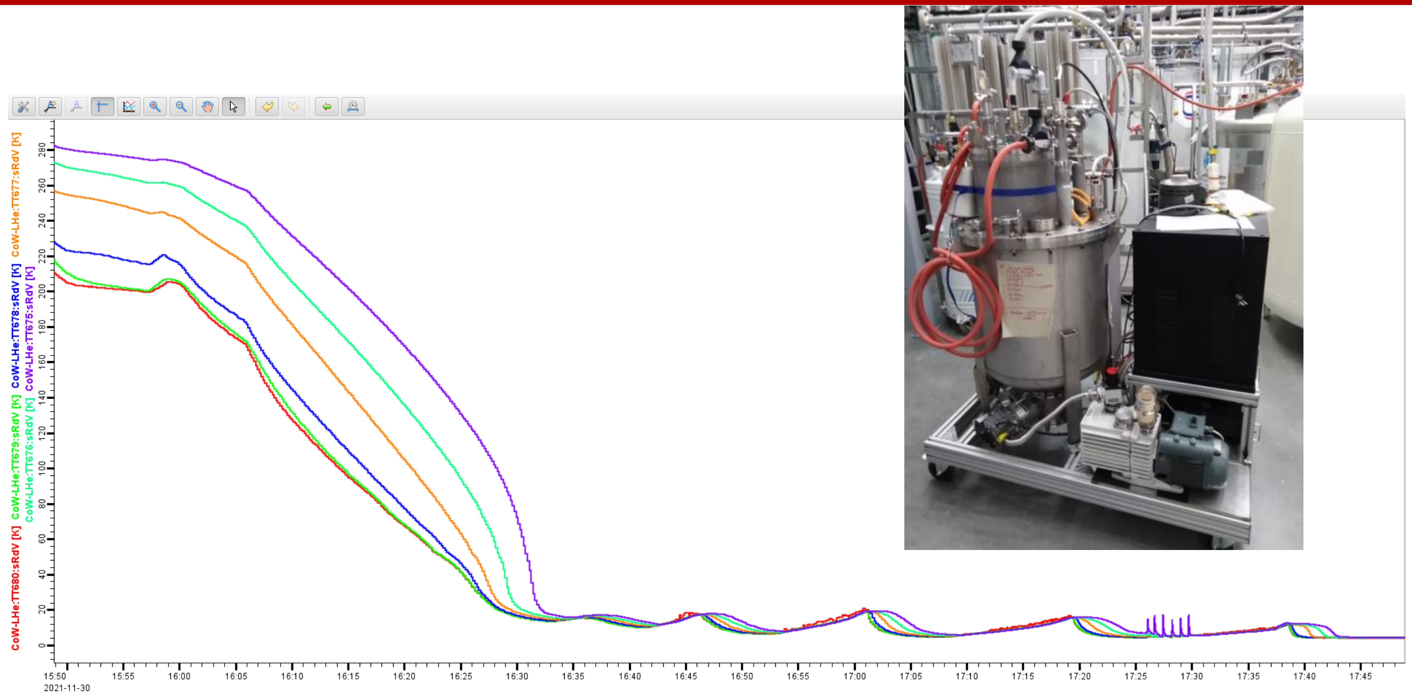
HNOSS summary

HNOSS (Horizontal)				
No	Property name	Value	Unit	Comment
1	LHe volume	He jacket only	L	
2	Operating temperature	1.8 - 4.2	K	
3	Diameter / size	1.2 / 3.3	m	
4	Number of inserts			
5	RF Frequency	352	MHz	To be upgraded
6	Maximum Incident power	100	W	
7	Additional instrumentation			
8	Typical testing rate (Vts / year)	0.5-1	Per month	
9	Possibility to test naked cavities	NO	YES / NO	
10	Infrastructure for small intervention	YES	YES / NO	Clean room ISO10

CoW

CoW cryostat





- Mobile cryostat (Cryostat on Wheel) for 4 K
- Possible to install a λ-plate for 2 K
- Excellent for testing equipment and materials
- For R&D of small magnets

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CoW summary

CoW				
No	Property name	Value	Unit	Comment
1	LHe volume	47	L	
2	Operating temperature	4.2	K	
3	Diameter / size	0.26 / 0.635	m	
4	Number of inserts	1		
5	Maximum current			To be defined
6	Typical testing rate (Vts / year)	3-4	Per month	
7	Possibility to test small coils	YES	YES / NO	To be upgraded
8	Infrastructure for small intervention	YES	YES / NO	Clean room ISO10

GERSEMI

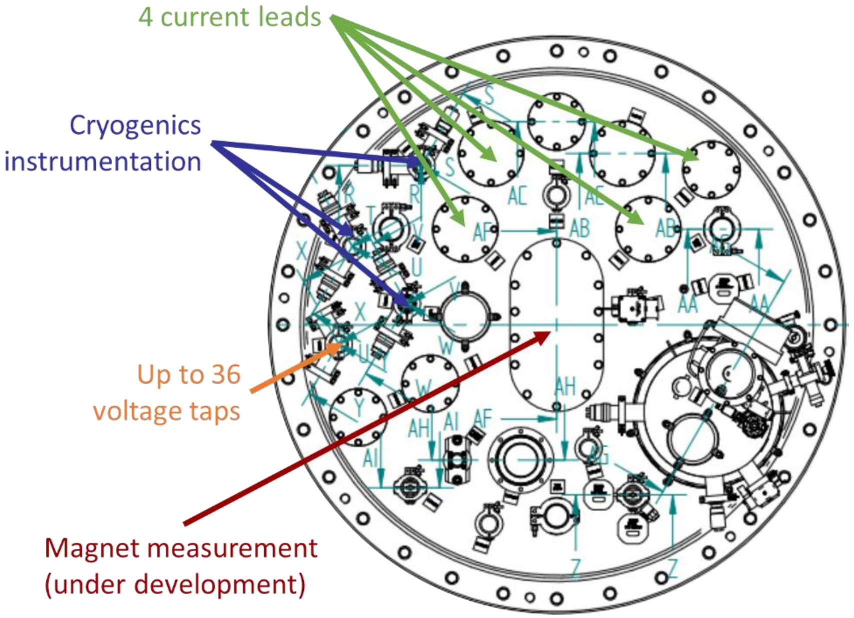
Gersemi – 2 operation modes: liquid, pressurized bath

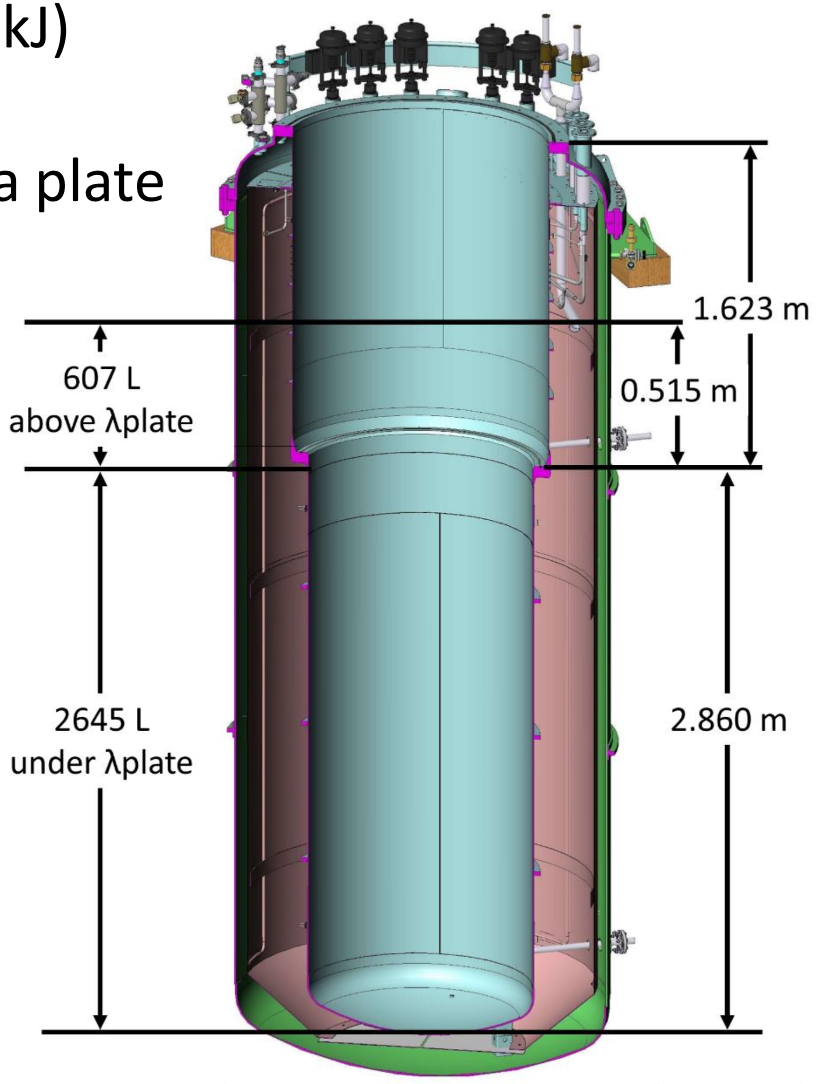
Test of SC cavities & magnets (<350kJ)

- 3.2 m x ø1.1 m total volume
- 2.8 m x ø1.1 m below lambda plate

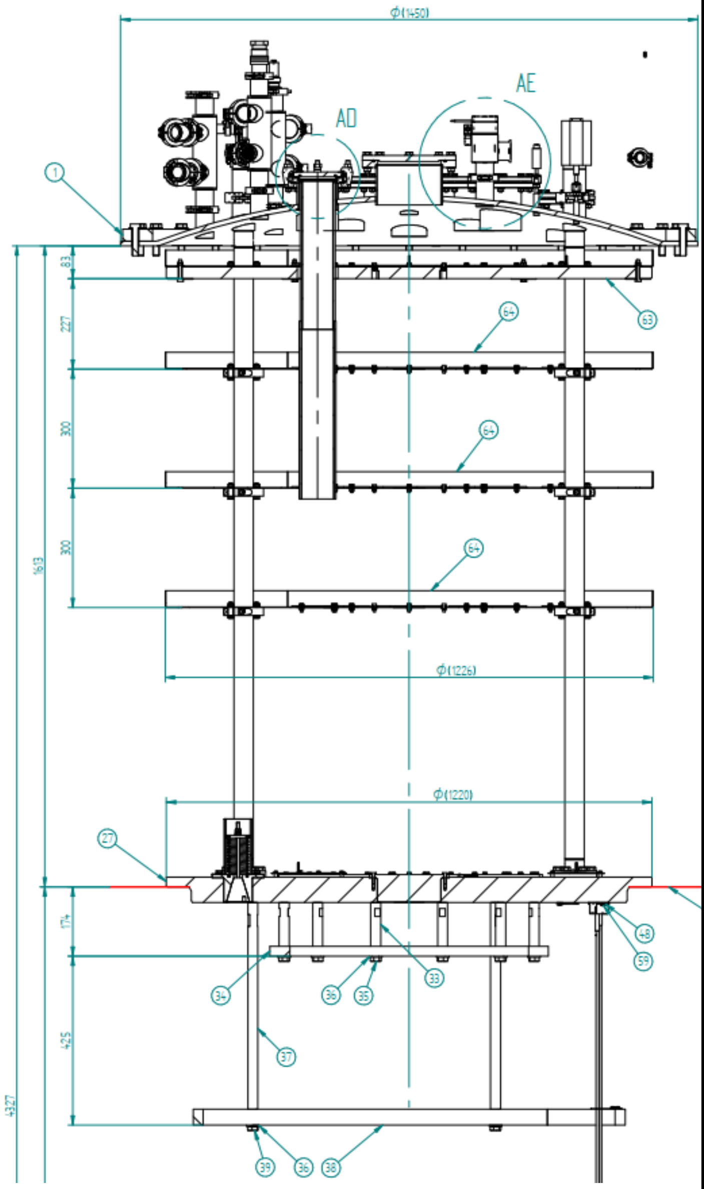
The design, incl. the joint, is based on experience from the cluster D

Top view



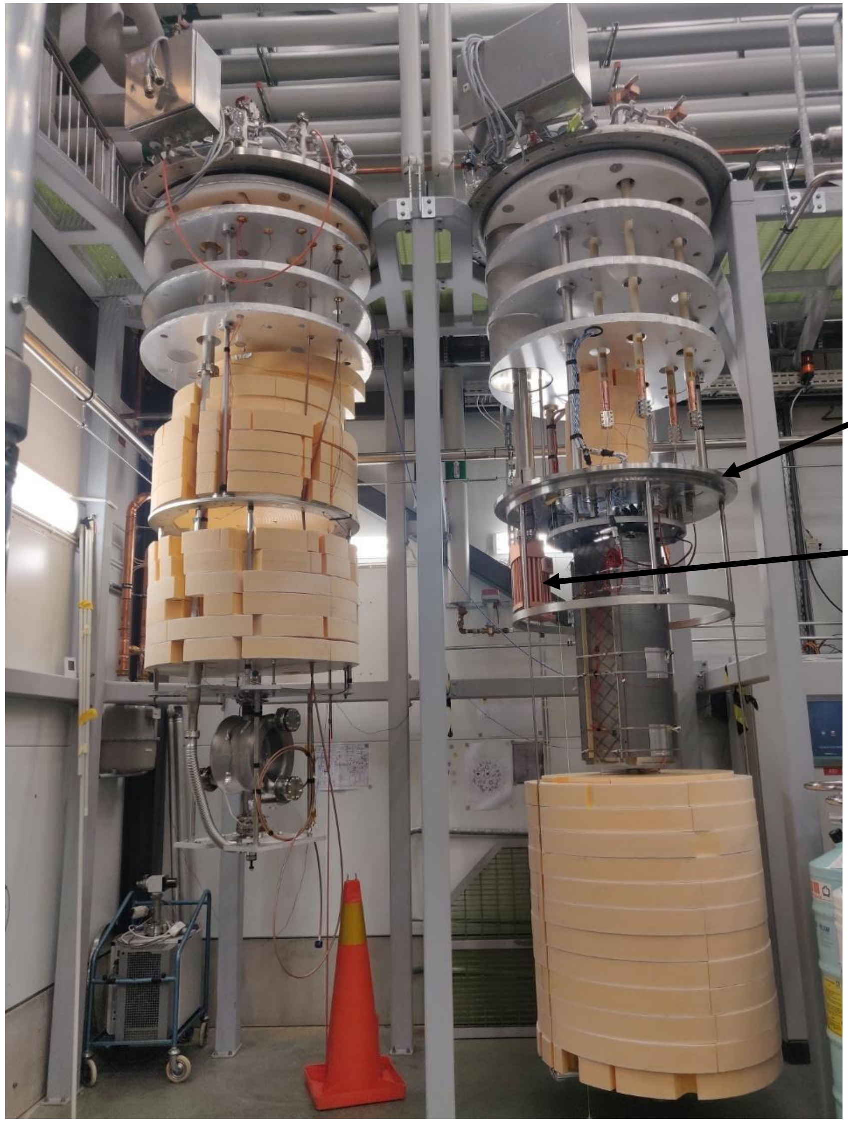


Diameter above/below λ plate: 1.256 m / 1.106 m



Insert(s)

Cavity (liquid) insert



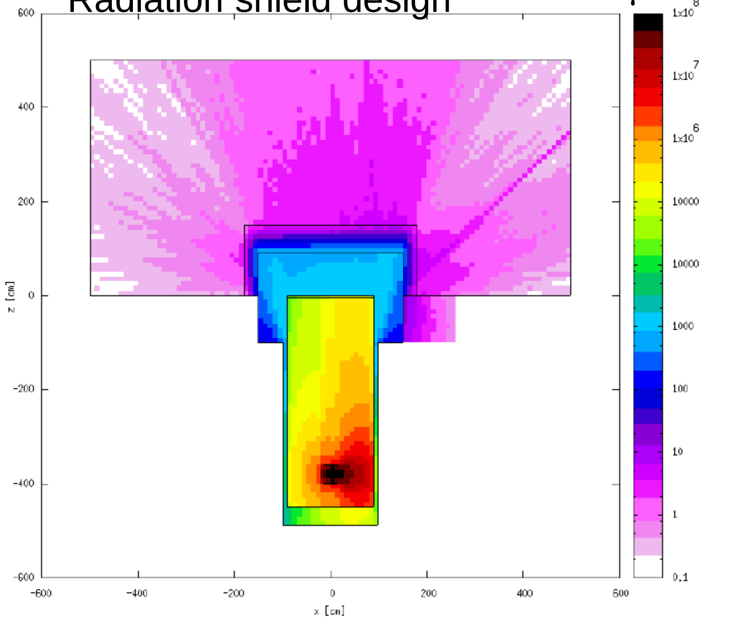
Magnet insert

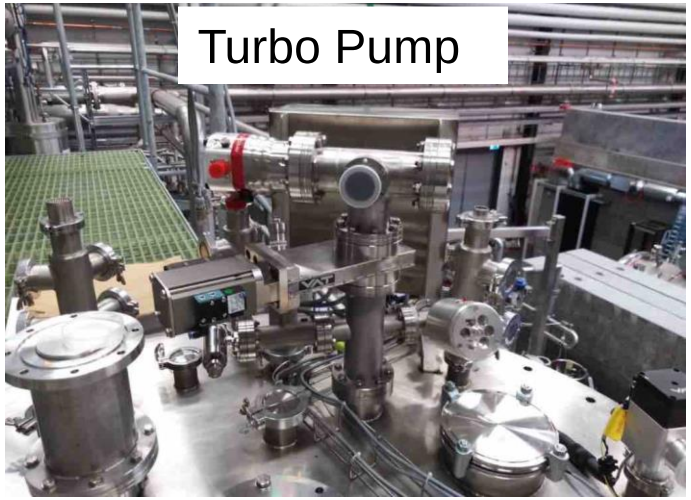
Operation:

- **Lambda plate** to separate 2K pressurized helium from 4K helium
- **Heat exchanger** with sub-atmospheric 2K helium in contact with the pressurized 2K helium

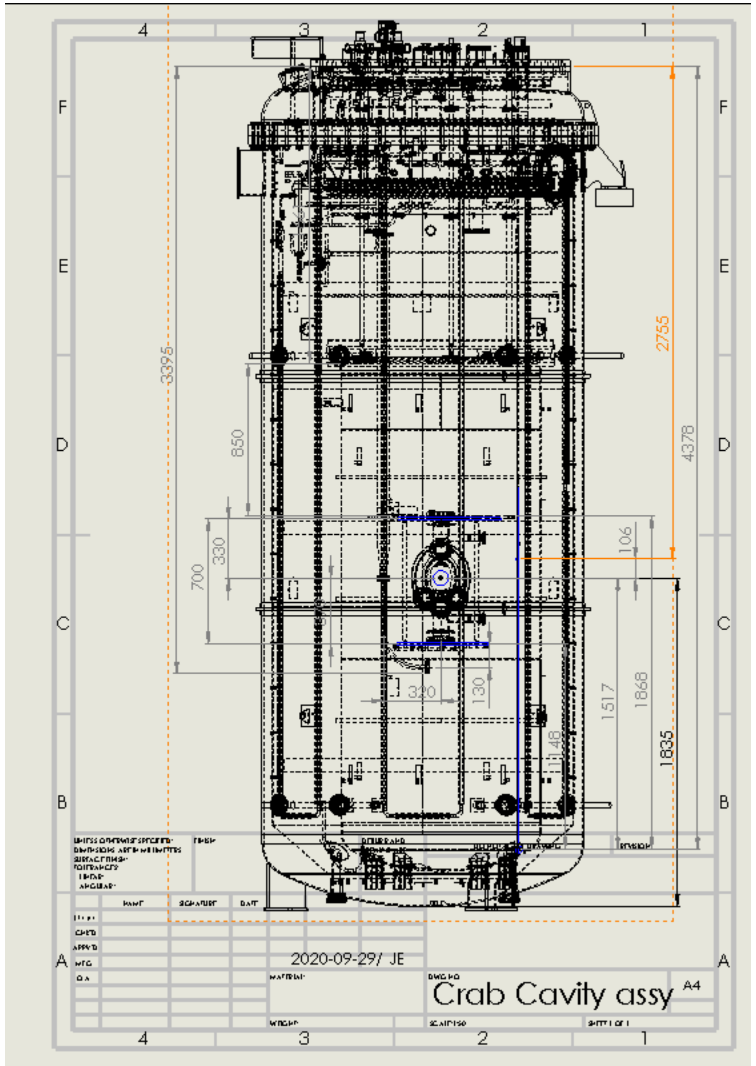
Radiation shield and cavity insert for cavities

Radiation shield design

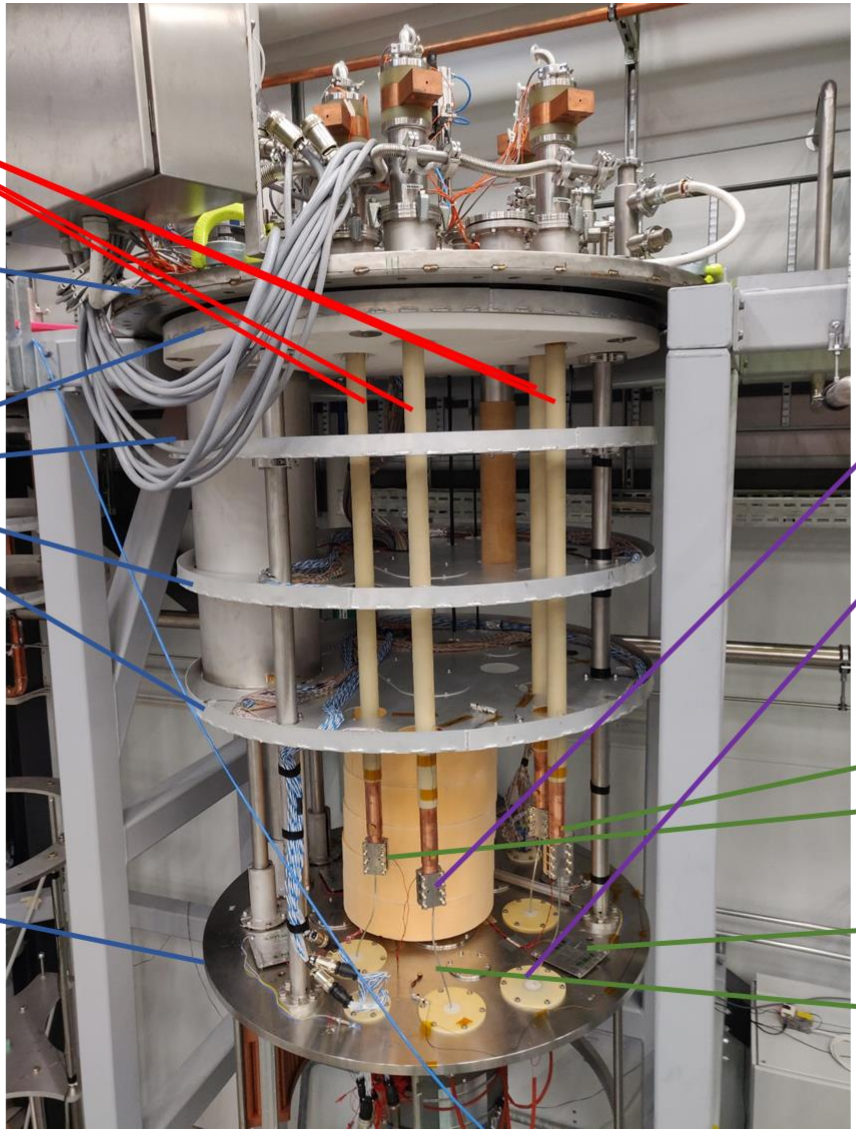




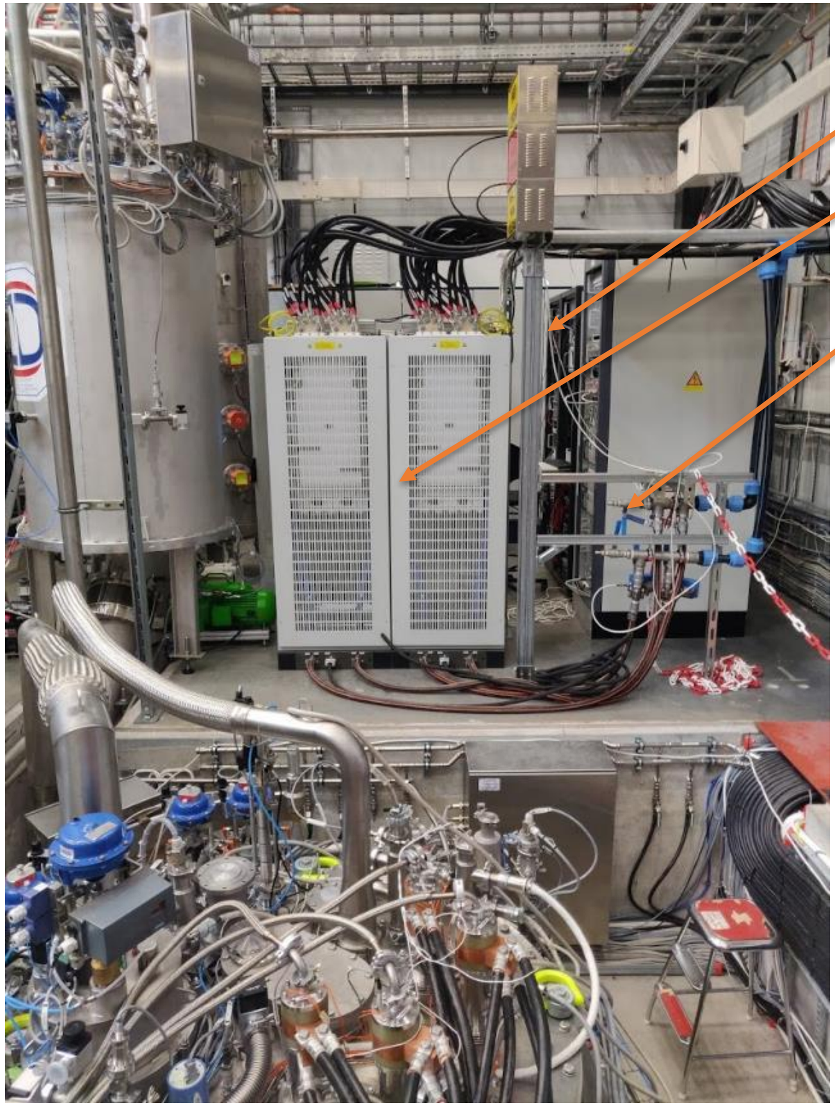
Mechanical design of the supporting structure



Magnetic insert – Above the lambda plate



General view

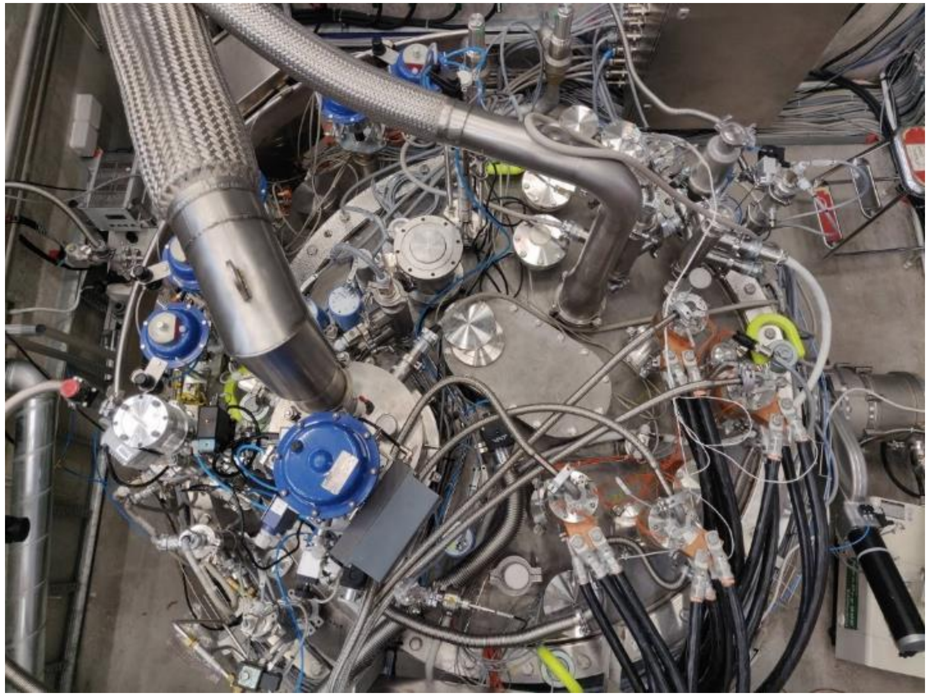


Data acquisition and PLC

Energy extraction units

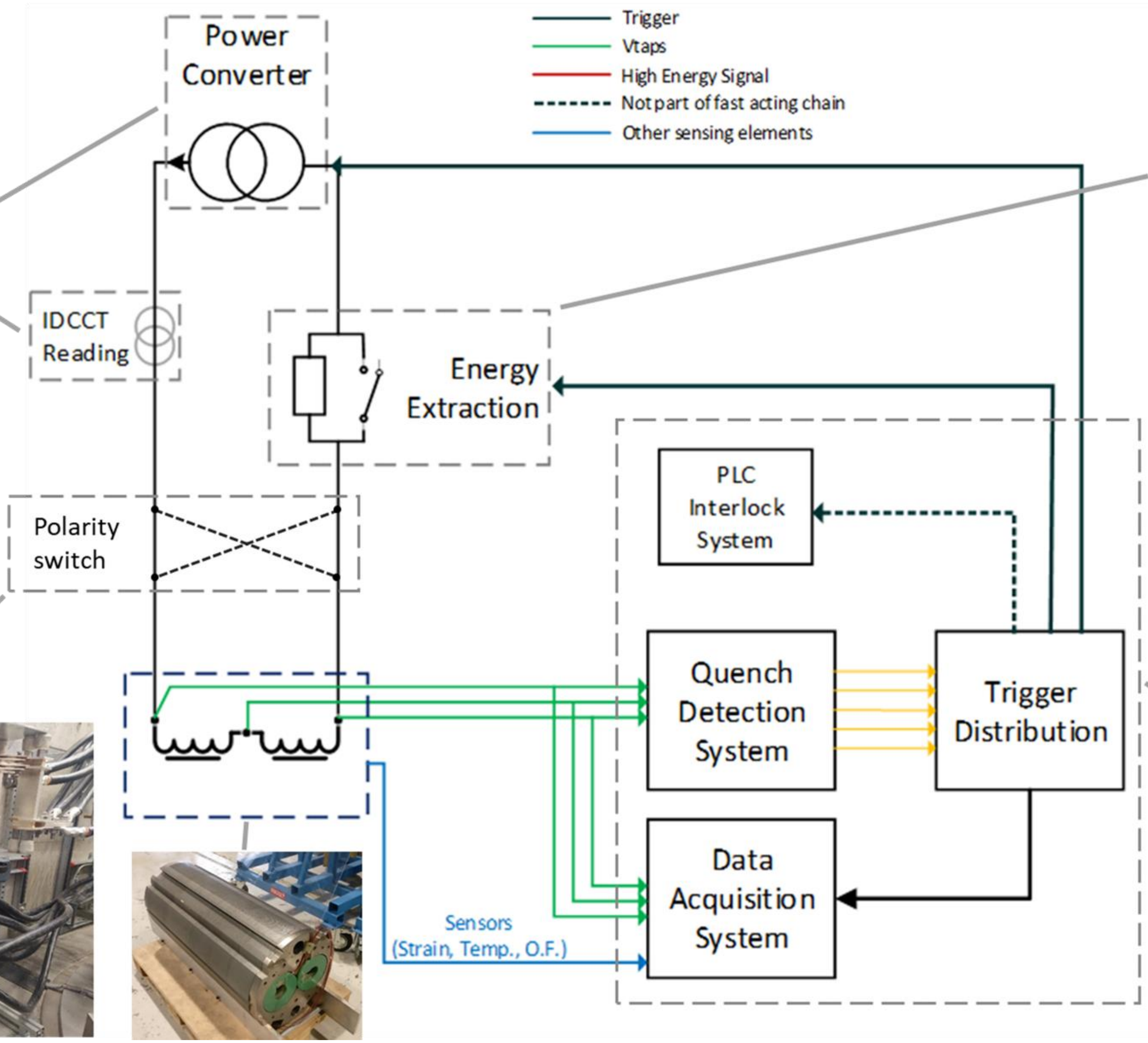
Power converters 2x2 kA

Magnetic insert fully equipped

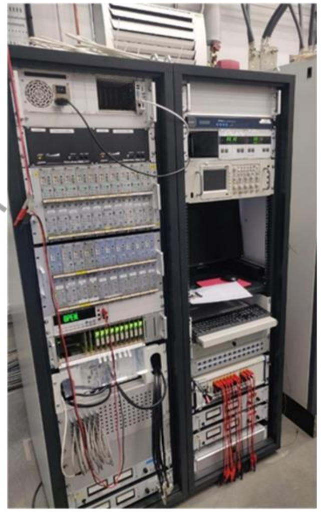


Satellite Equipment

Power converters can provide a maximum of 2 x 2 kADC for a maximum voltage of 10 VDC in one quadrant



IGBT based energy extraction units
Dump resistors between 77 mΩ and 3200 mΩ



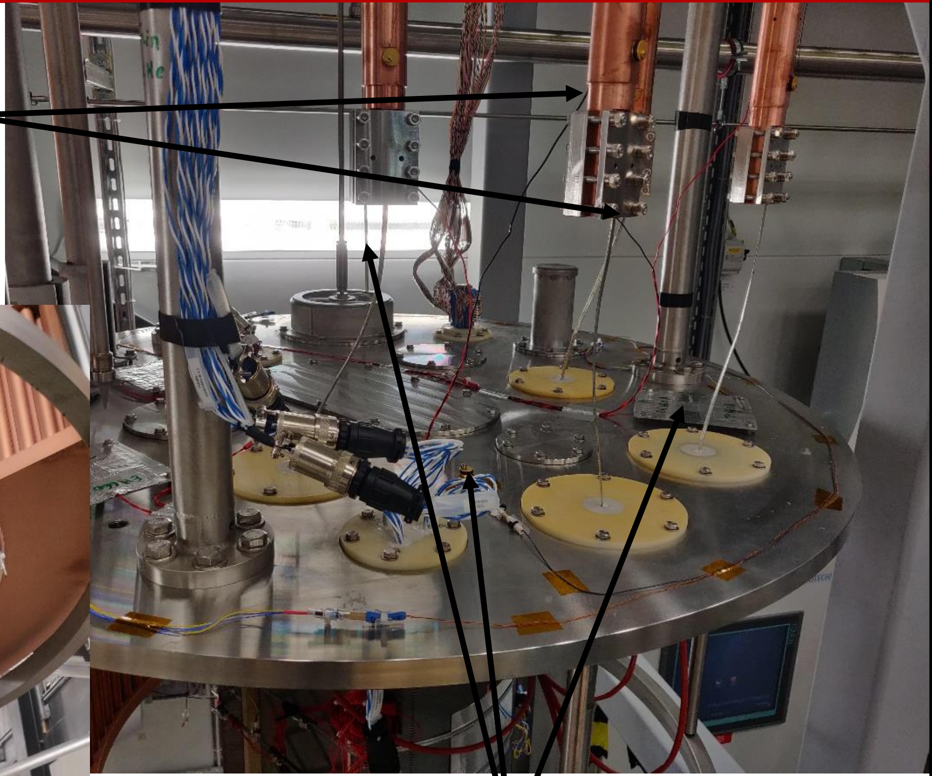
Polarity reversing switches have been installed to operate in four quadrants

DAQ
72 LF channels
64 HF channels
DMM
10 channels crate
Safety
20 PotAim cards
1 uQDS
PLC

Sensors

Cable thermalized
Heaters, temperature
sensors

Many Vtaps for the
beginning



Heaters, temperature
sensors on the magnet

Heaters, level probe and temperature
sensors on the lambda plate

Foam and level prob

Level probes with and without protection

$2m^3$ of foam to save a lot of helium and be more efficient/faster

Gersemi summary

GERSEMI				
No	Property name	Value	Unit	Comment
1	LHe volume	3300	L	To be reduced
2	Operating temperature	2.0 - 4.2	K	Pressurized bath
3	Diameter / size	1.1 / 2.8	m	
4	Number of inserts	1 (+1)		+ Cavity insert
5	Maximum current	2000 (x2)	A	2 Power converters
6	Additional instrumentation	Polarity switch		1 for each Pc
7	Quench protection system	YES	YES / NO	PotAim cards+uQDS
8	Energy Extraction Unit	YES	YES / NO	IGBT based
9	EE resistors	77 - 3200	mΩ	+ Metrosil
10	Typical testing rate (Vts / year)	0.5-1	Per month	

Vertical anti-cryostat and magnetic measurement systems

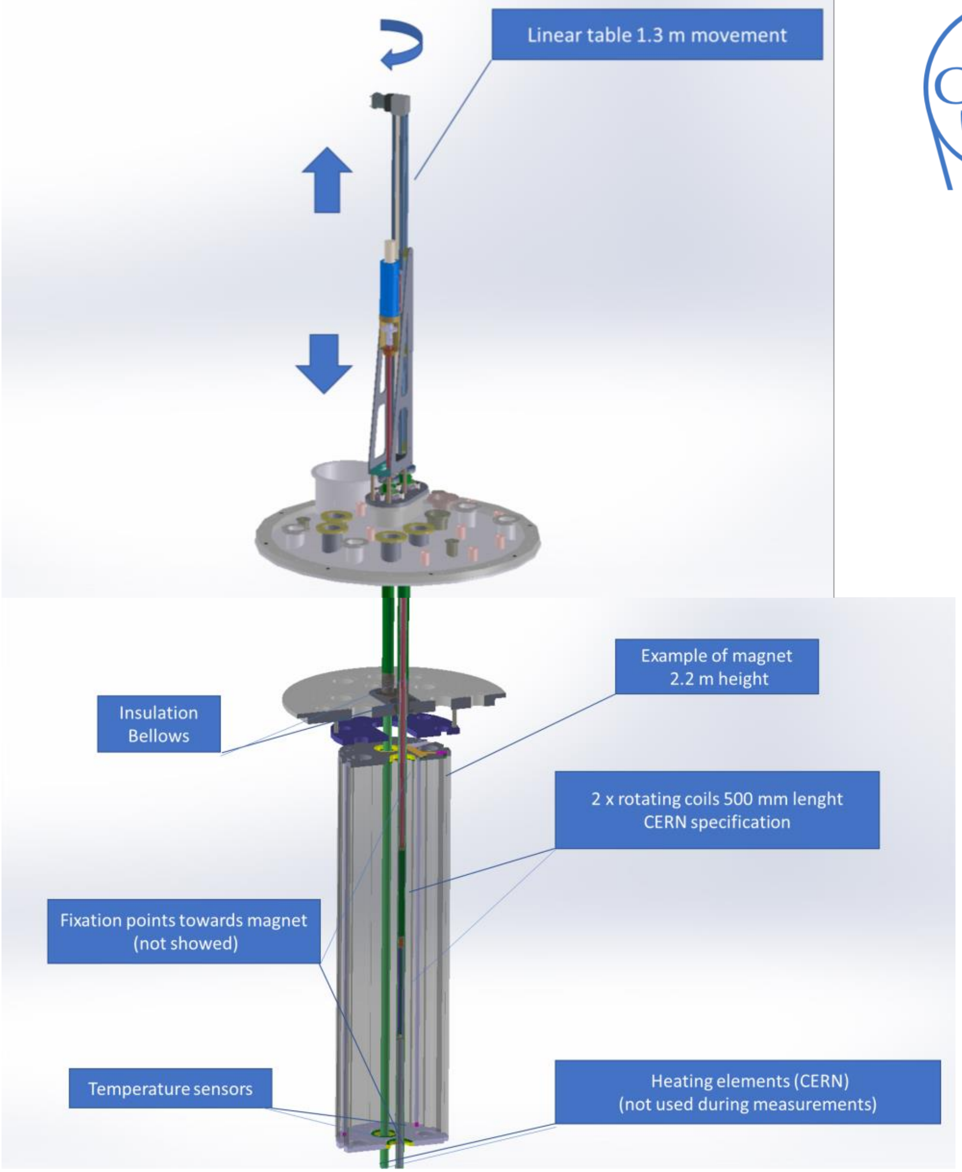
Magnetic **measurement:** room temperature **rotating coils**

ADVANTAGES:

- Reduced **complication** for the measurement shaft
- No **moving** mechanical parts at cryogenic temperature
- Easy **adjustable** measurement head
  - both measurement and quench revealing
- Easy access for **debugging**
- No dimensions shrinkage -> consistent **calibration** factors

Anti-cryostat

To be completed in 2024



1st successful magnet test: SuShi

Tommaso Bagni, Maja Olvegård, Kevin Pepitone,
Rocio Santiago Kern, Carl Svanberg
(University of Uppsala)
D. Barna, K. Brunner (Wigner RCP)
Miro Atanasov, Jan Borburgh, Glyn Kirby,
Friedrich Lackner (CERN)

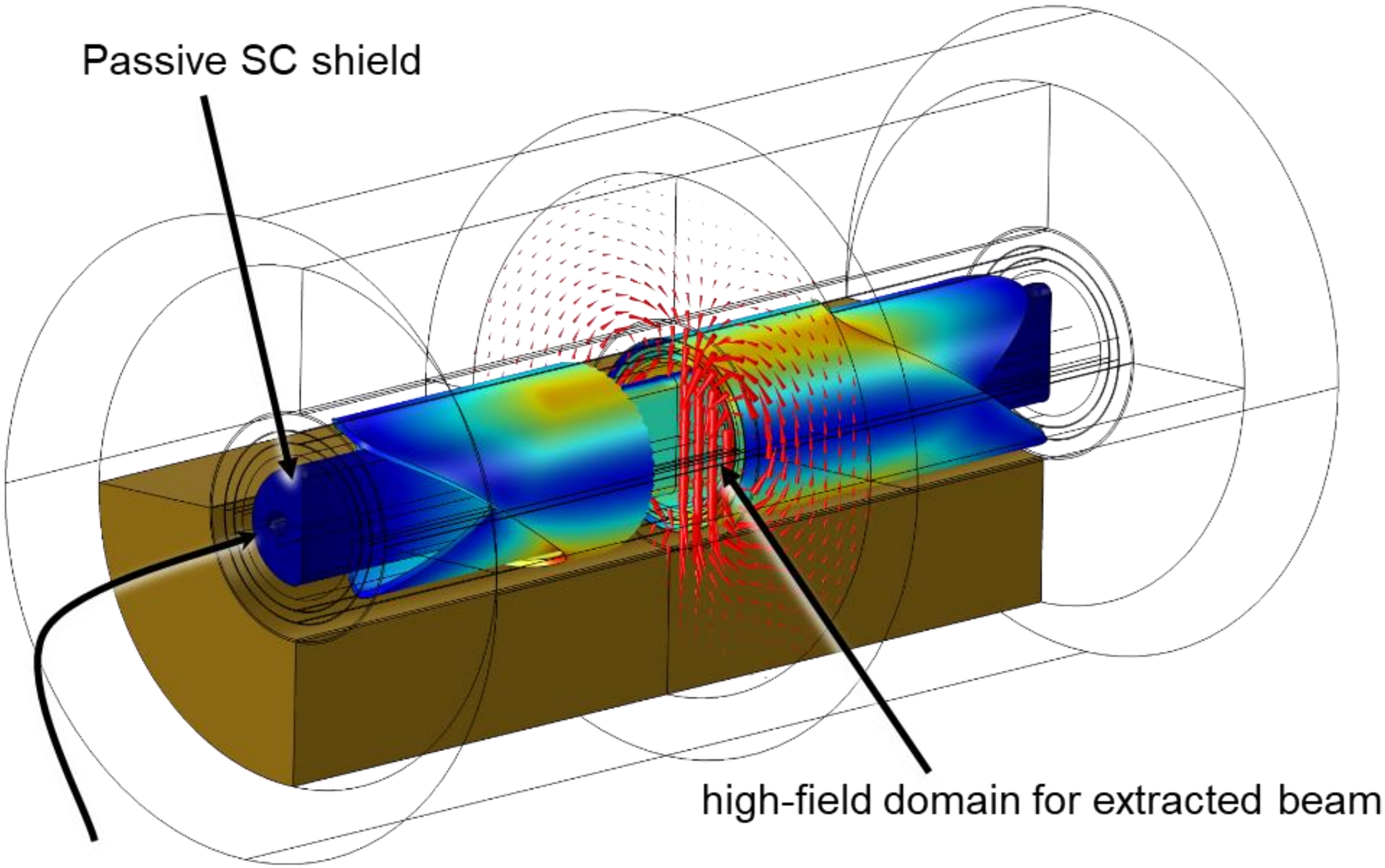
WP3 – Transnational access to Research Infrastructures for Accelerators

EURO-LABS Supports Transnational Access (TA) to a broad spectrum of installations, to test concepts for future accelerators, based on improving the present facilities, and for R&D studies for future colliders like CERN/FCC or the Muon Collider.

Type of access	Type of beams / Theory support	Access provider	Infrastructure	Country	Facility Coordinator Contact
TA	Magnet & RF Cavity testing	FREIA	GERSEMI – HNOSS	Sweden	rocio.santiago_kern@physics.uu.se

- **PROJECT ACRONYM: EURO-LABS –** EUROpean Laboratories for Accelerator Based Science
  PROGRAMME: Horizon EU
- **DURATION:** September 2022- August 2026 (4 years)
- **AIMS OF EURO-LABS:** Fostering the sharing of knowledge and technologies across scientific fields; To create synergies and collaborations between the RIs of the Nuclear and High Energy communities;

SUperconducting SHield septum magnet



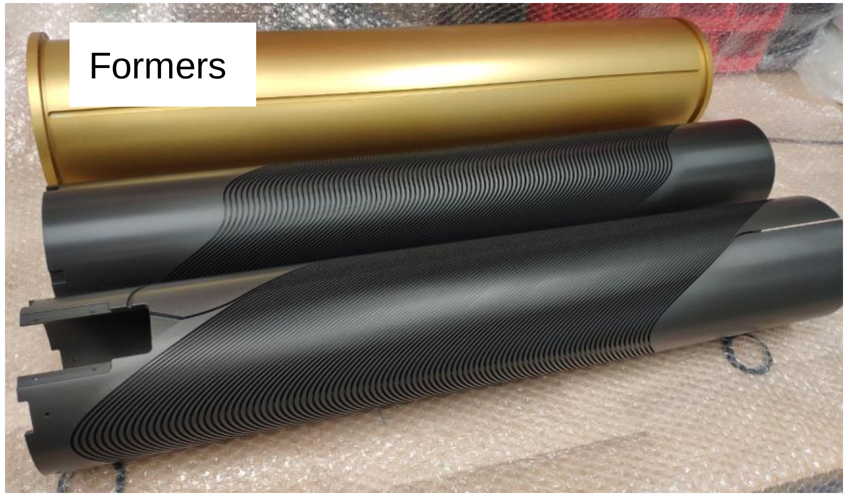
Courtesy of Barna D.

The magnet is one of the first Canted-Cos-Theta (CCT) magnet impregnated with wax.

The SuShi septum is a Nb-Ti magnet using a passive superconducting shield to generate a field-free region within the aperture of a CCT magnet, to create the required field configuration for beam extraction from the Future Circular Collider.

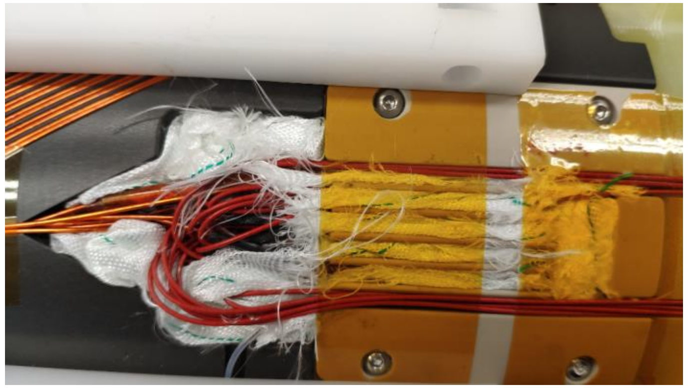
The testing of the empty magnet is crucial to understand the behaviour of the magnet winding before shield test

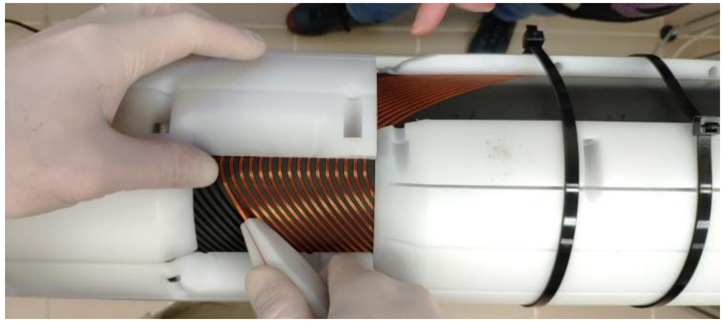
Magnet manufacturing and assembly

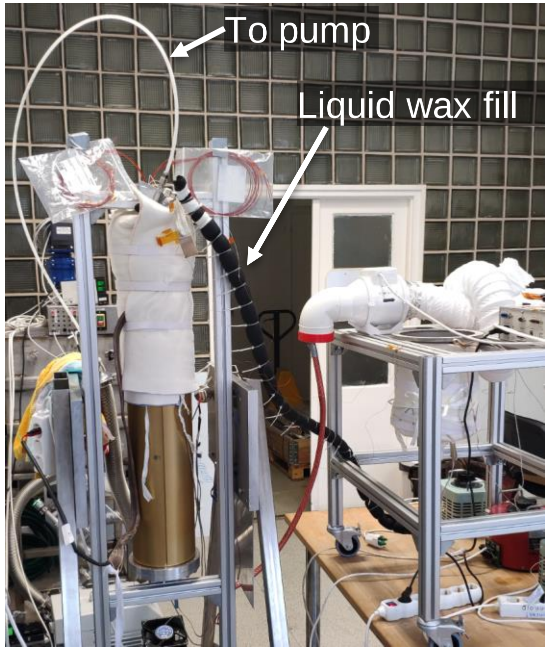


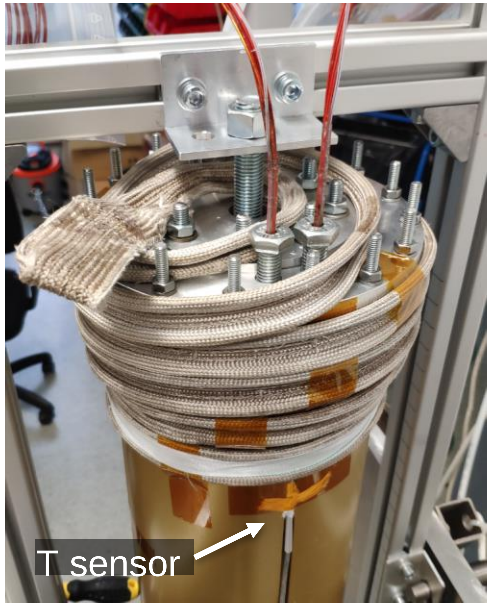
Protocol of the hi-lumi CCT magnets.

3 crimp sleeves + soft-solder over 44 mm length, sealed by a kapton tube







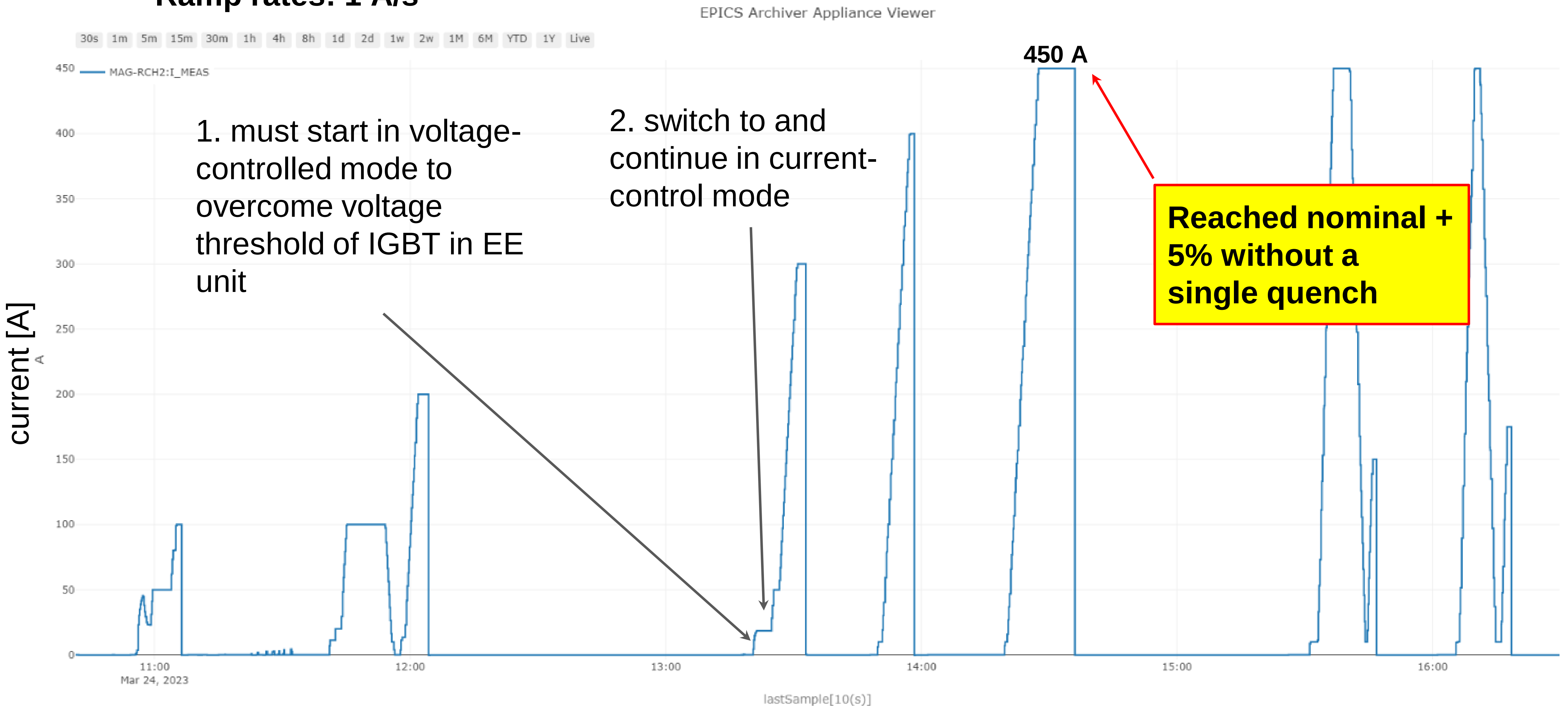


Courtesy of Barna D.

SuShi @ FREIA

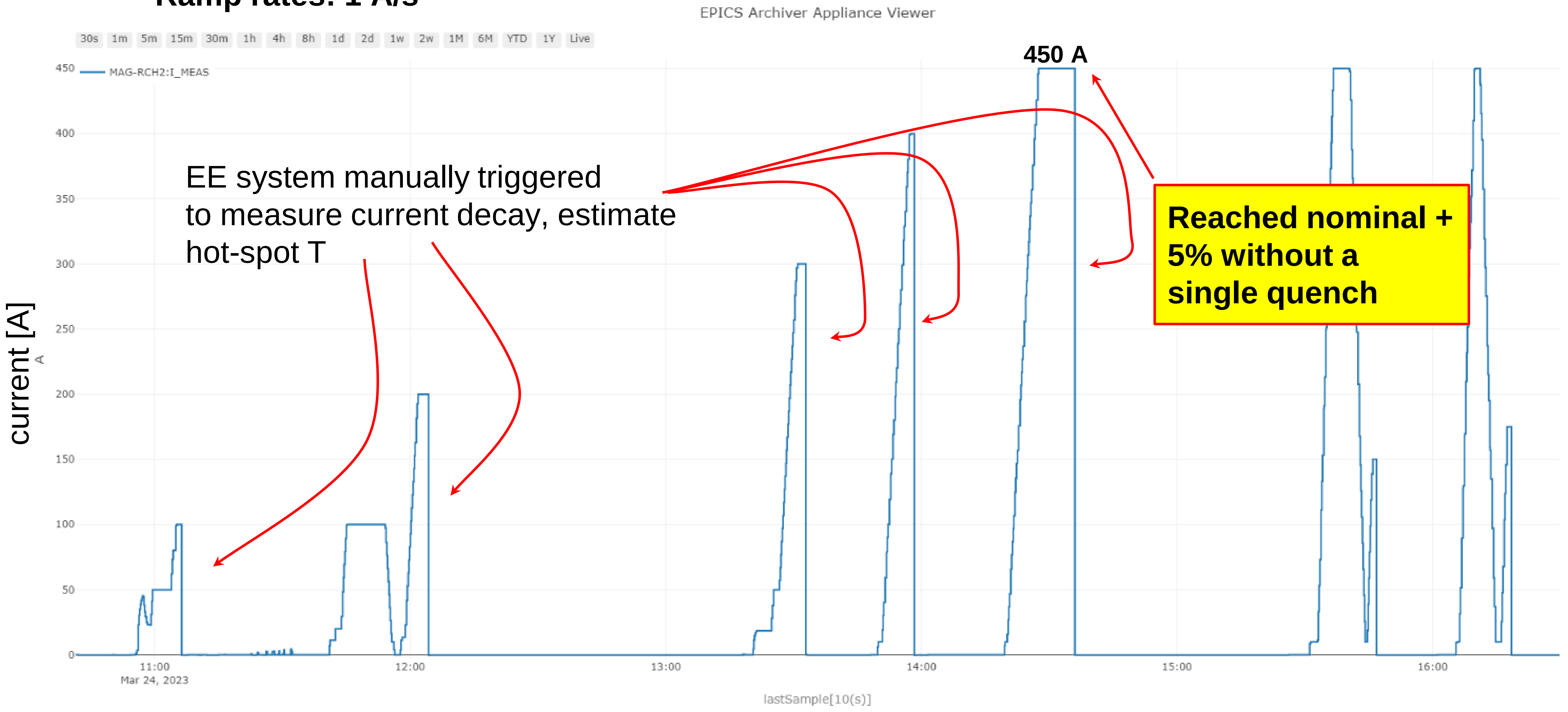
Powering cycles (1st day full history)

Ramp rates: 1 A/s

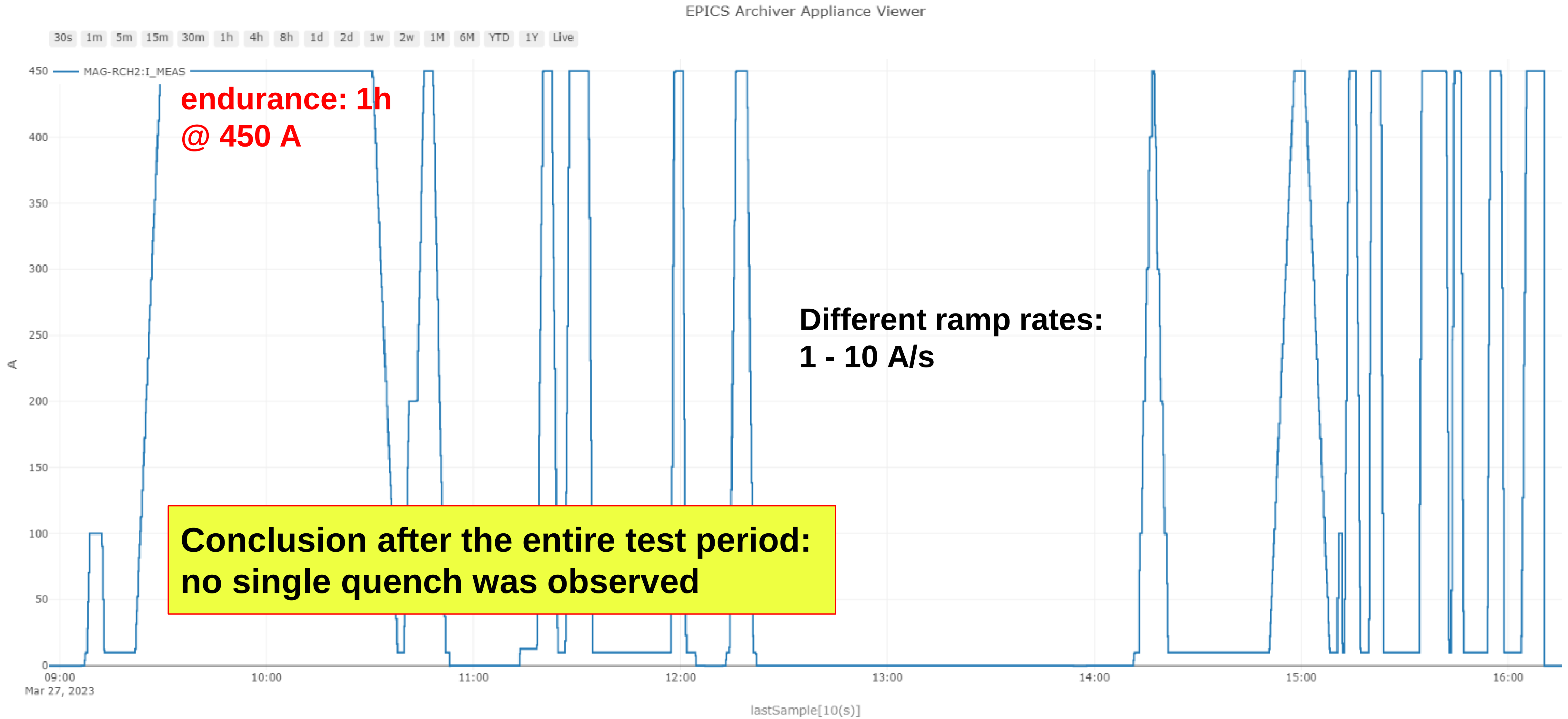


Powering cycles (1st day full history)

Ramp rates: 1 A/s



Powering cycles (2nd day) - endurance & ramp-rate



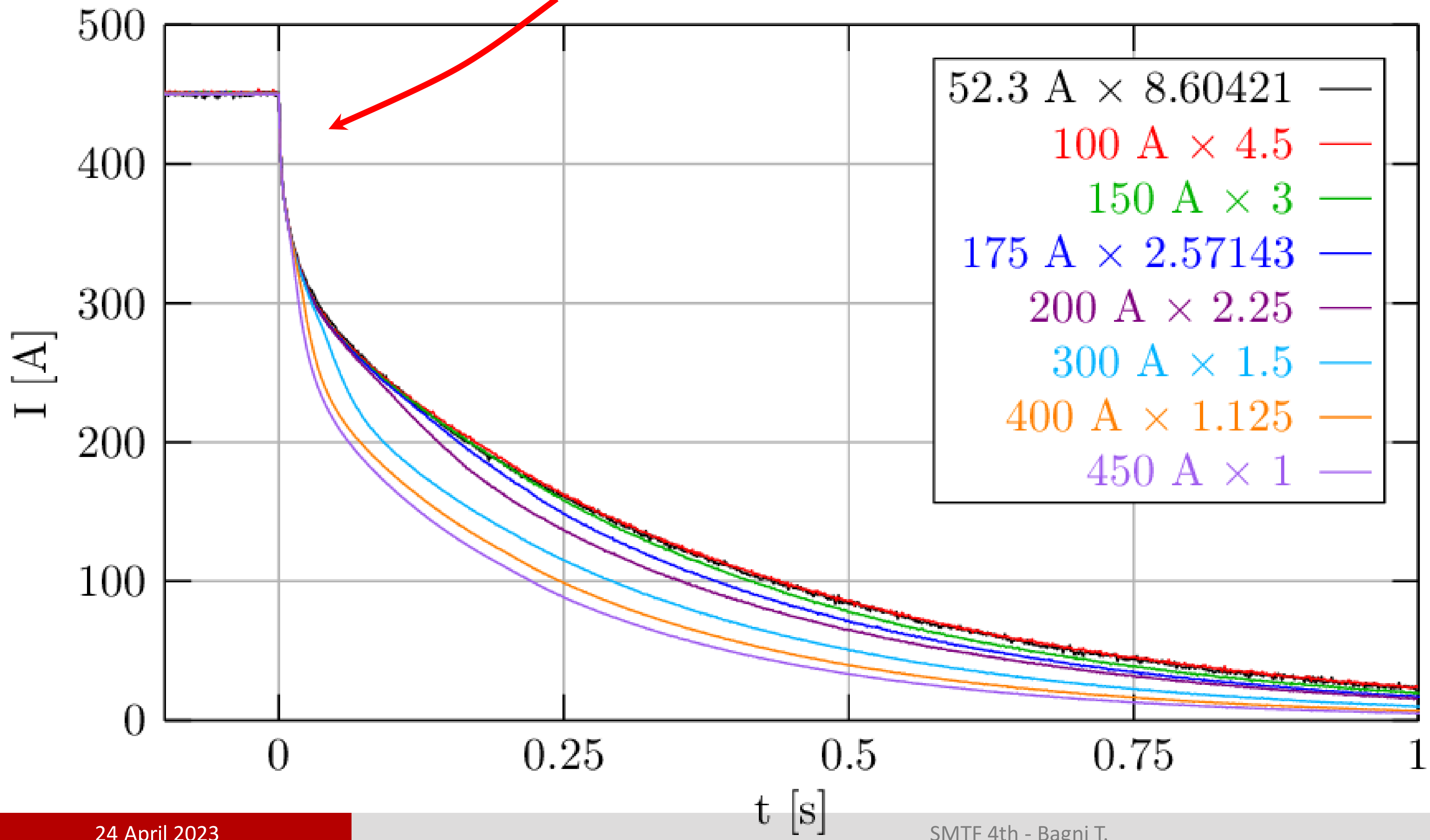
endurance: 1h @ 450 A

Different ramp rates: 1 - 10 A/s

Conclusion after the entire test period: no single quench was observed

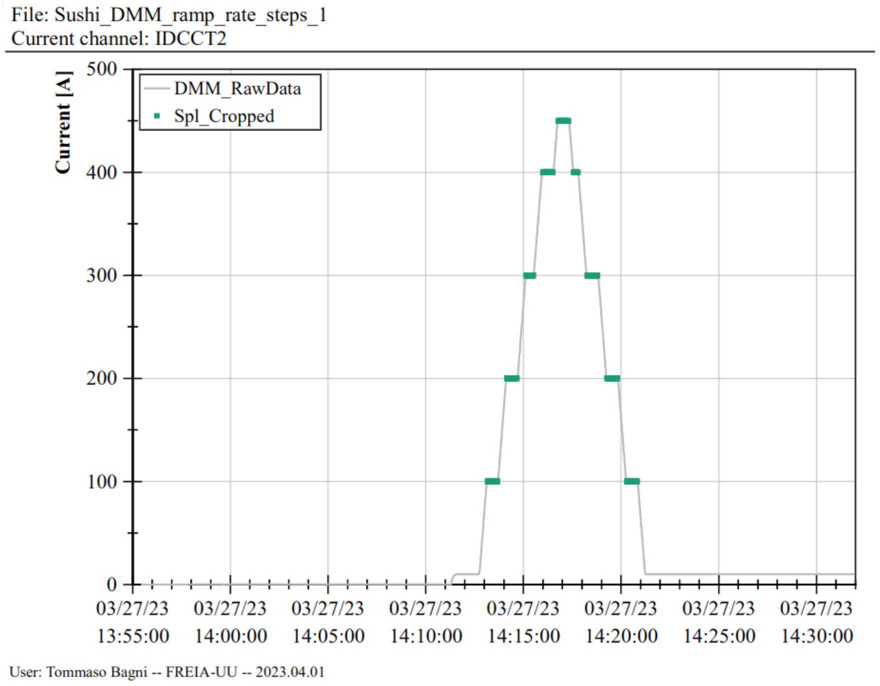
Energy extractions, current decay curves

Perfect overlap (scaling) before quench-back.

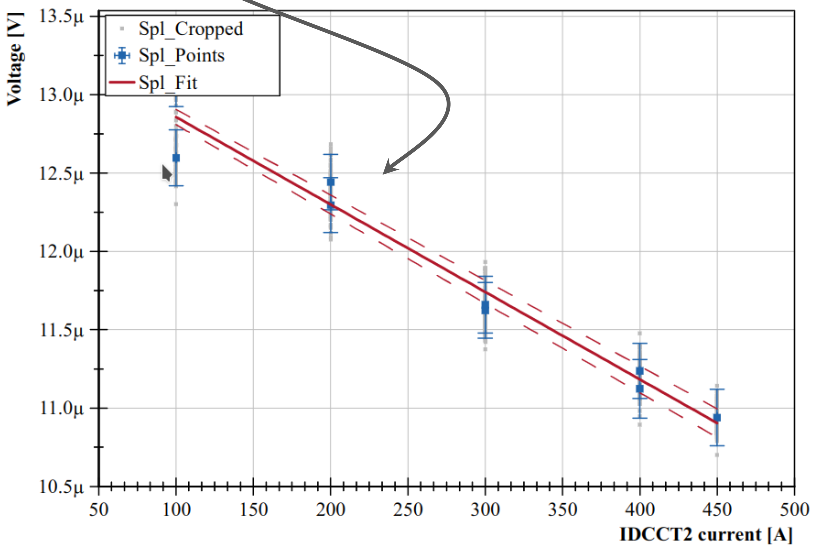


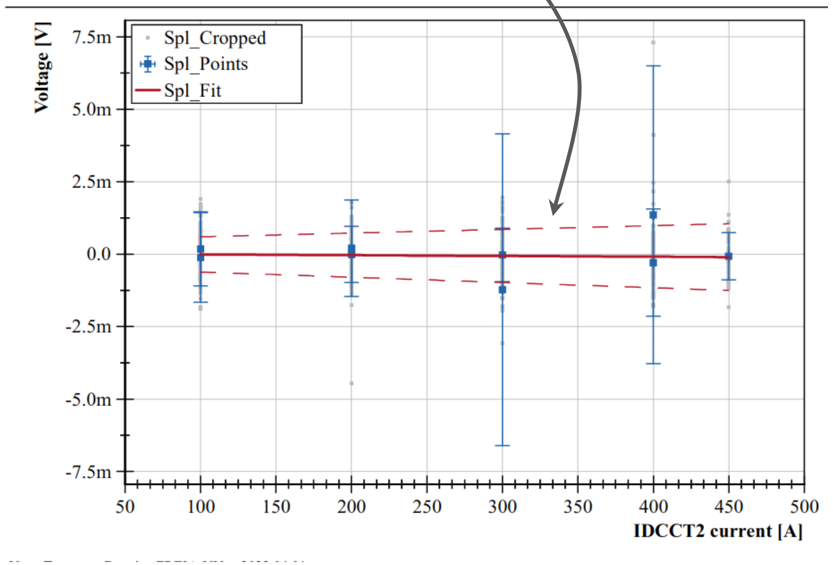
Onset of quench-back! Entire coil becoming resistive due to heating by eddy currents

Splices (resistances)



- Introduce plateaus of the current (I=const, no dI/dt)
- Time-average voltage across splice on the plateaus
- Plot (fit) U-I curve to get R
- Splice resistances: **4.5-7.3 nOhm**
  - Exception #8: 263 +/- 795 nOhm (inductive noisepicked up by 2 winding loops)



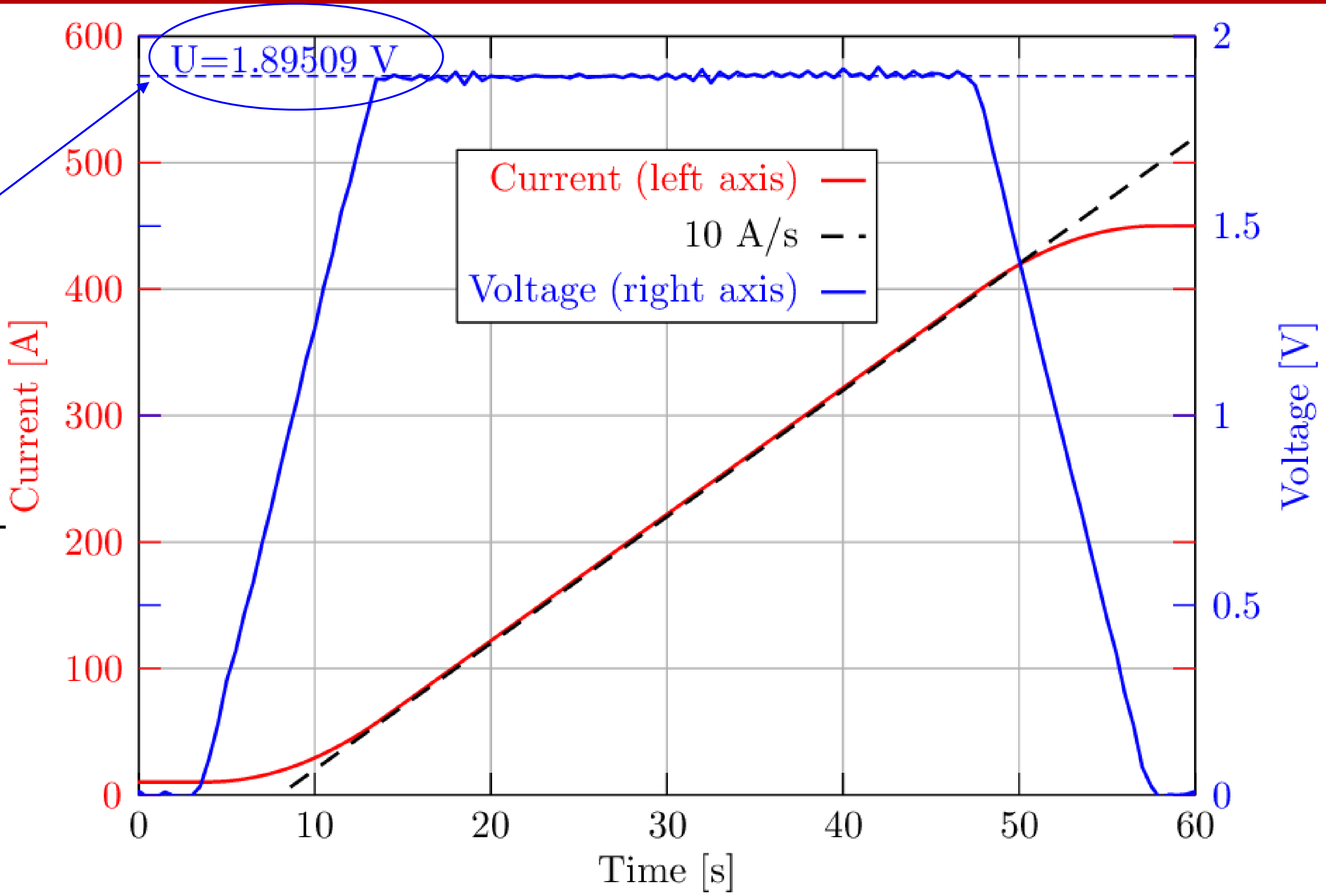


Inductance measurement

Voltage measured during 10 A/s ramp

⇒ L = 189 mH

(perfect agreement with homogenized coil 3D COMSOL simulation result)



”Cold Magnets”

An R&D project in collaboration between
Swedish universities and industry

EUROPEISKA UNIONEN
Europeiska regionala utvecklingsfonden

REGION KRONOBERG

RYDVERKEN

wst.se
VATTENSKÄRNING

SCANDITRONIX

Linnéuniversitetet
Kalmar Växjö

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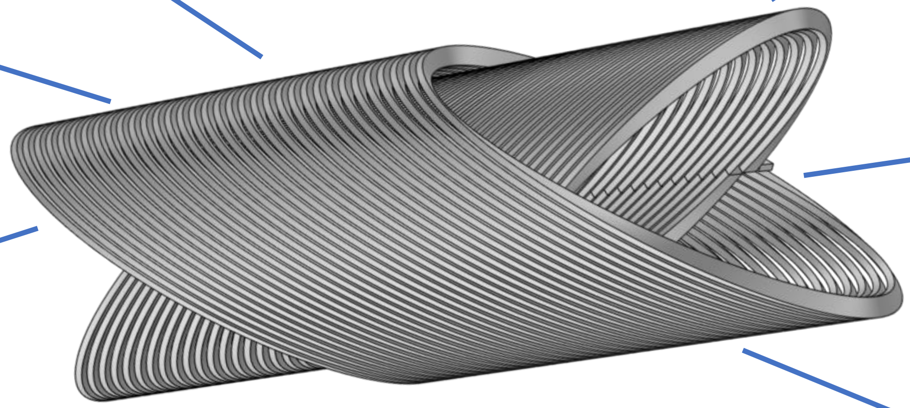
Members and roles

Uppsala University: project management, magnet design, simulations, purchase of Sc-cable, qualification test of magnet assembly in cryostat



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SCANDITRONIX

Linnéuniversitetet Kalmar Växjö

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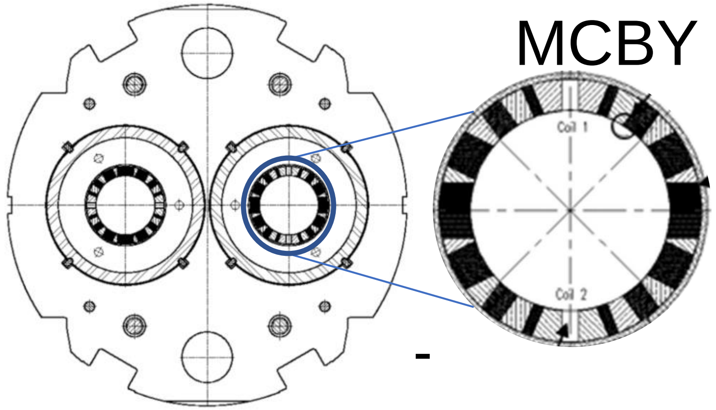
Motivations

This magnet was intended **to replace the current LHC orbit corrector magnets** which are reaching the end of their expected life due to the radiation load.

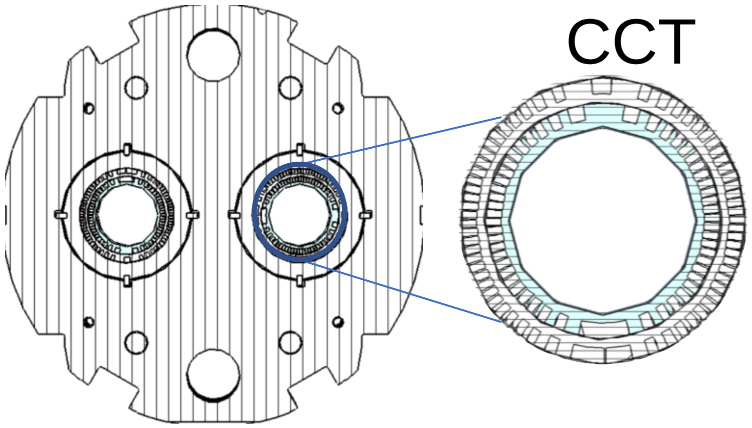
One to one replacement:

- **120 A power supply**
- **No energy extraction**
- **1.1 m long**
- **2.81 Tm**

MCBY



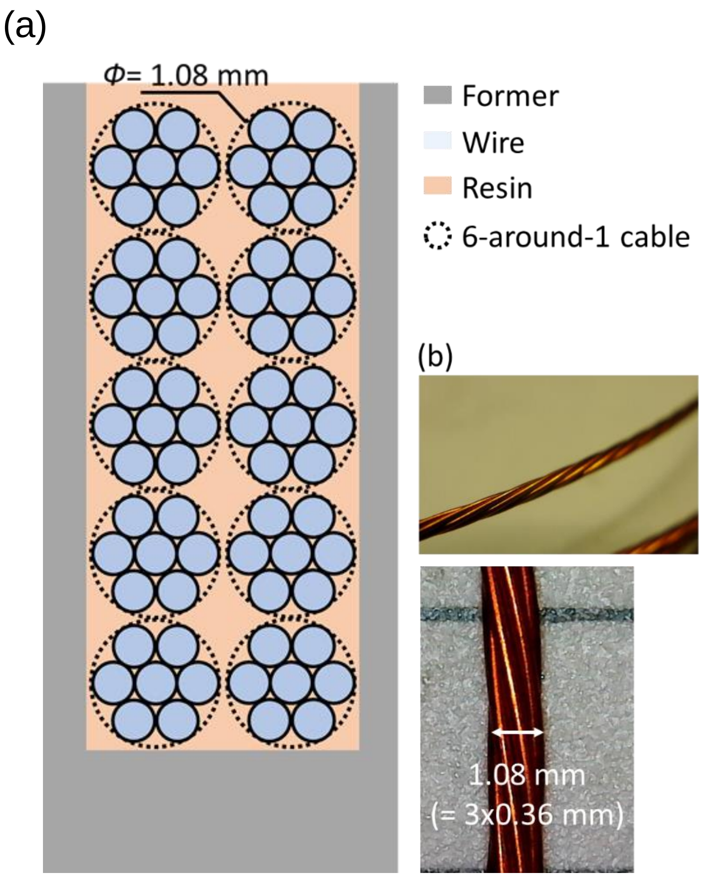
CCT

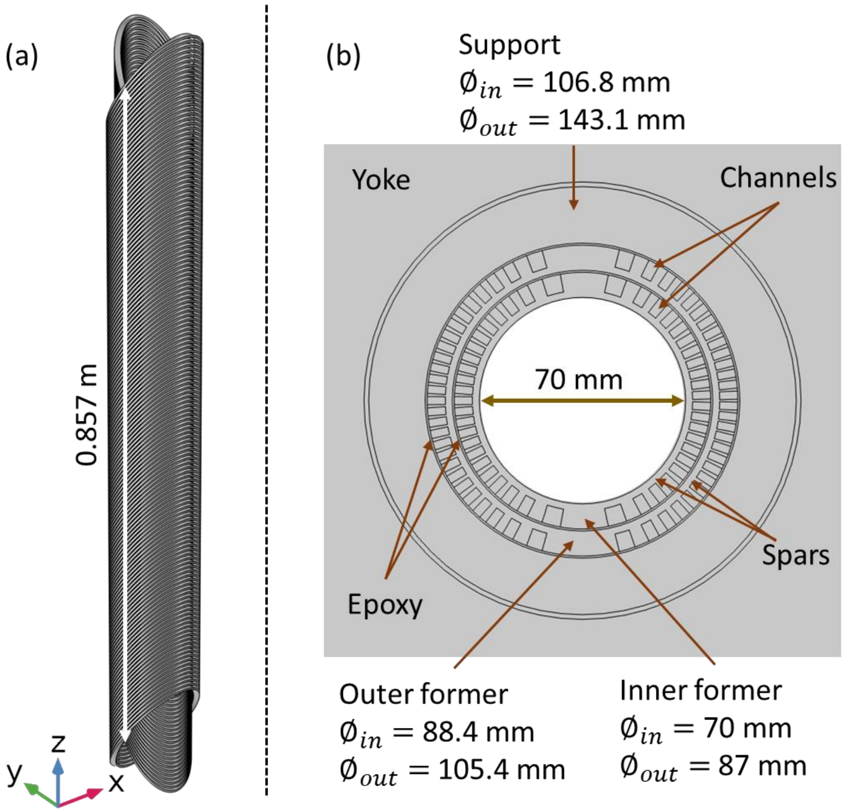


Note: In the LHC, they are in the dispersion suppressor regions and long straight sections and are used as closed orbit corrector dipoles placed in the vicinity of the interaction points

Design with a 6-around-1 cable

One to one replacement:
- **120 A power supply**
- **No energy extraction**
- **1.1 m long**
- **2.81 Tm**





Conclusions

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At FREIA laboratory we have proven competence and capability in:

- Superconducting magnet testing → Gersemi — Complete
    - 1st magnet test — Complete
        - ✓ Magnet installation
        - ✓ Cooldown
        - ✓ Energy extraction, understanding and control
        - ✓ Powering the magnet
- Magnet design and simulations → Cold Magnet project — In-Progress
- CoW magnet testing — In-Progress

- Cryomodules testing (for ESS) — In-Progress
- Jacket cavity testing → HNOSS — Complete
- Naked cavity testing → Gersemi

Thank you for your attention