

PSI Center for Accelerator Science
and Engineering



subSMACC Magnet Design Overview

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Acknowledgements to Q. Gorit (VDL) and D. Biek (SPC)

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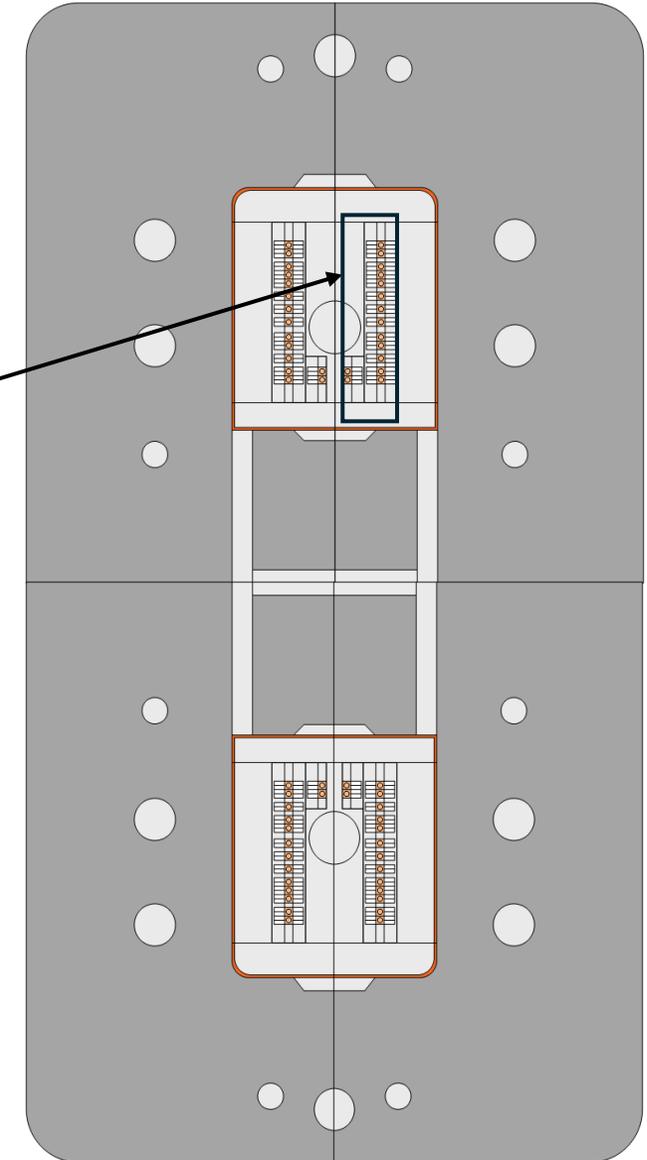
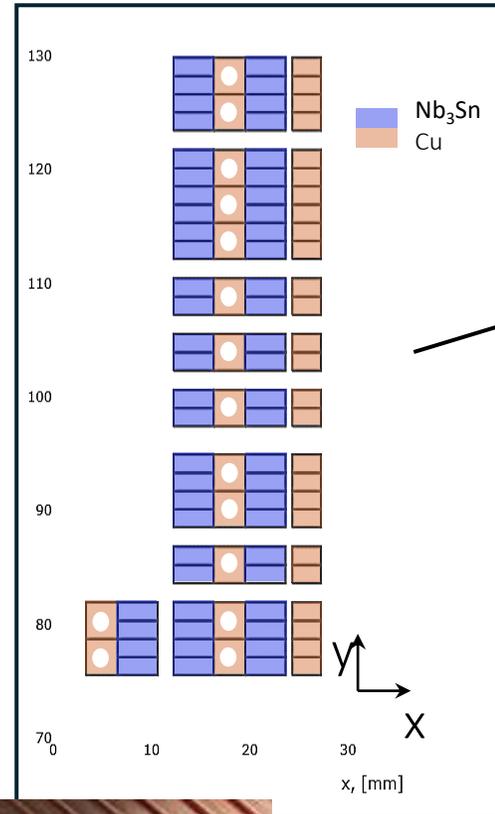
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This work was partially funded by the HFM program

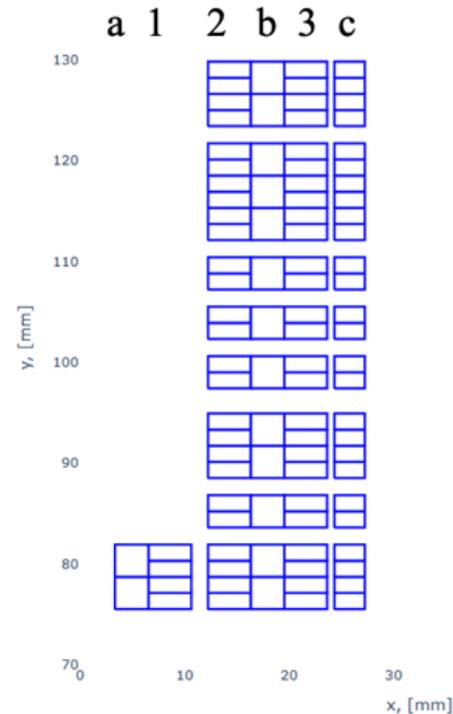
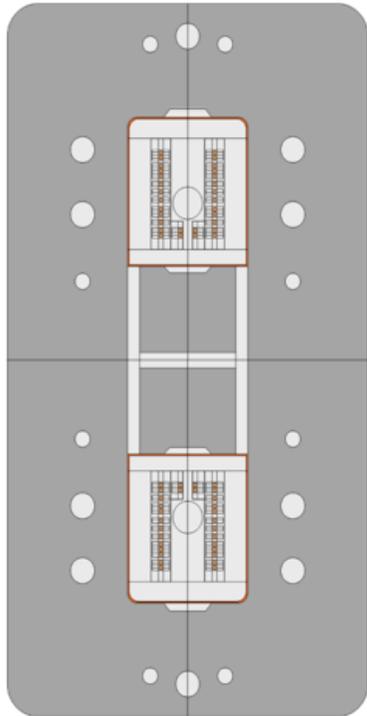
Magnet conceptual design



1. The magnet has 194 mm intra beam distance
2. Number of turns needs to be even number to fit conduction cooling cables
3. Coils of Lines 2 and 3 must be equal to reduce fabrication cost
4. Conduction cooling system will be reutilized for quench protection
5. Magnet yoke is kept at 77K to reduce cooling requirements



Magnet Specifications



Preliminary subSMACC cross-section and $\frac{1}{4}$ of the coil cross-section 1, 2 and 3 are Nb₃Sn layers, and a, b and c cooling / ESC coils .

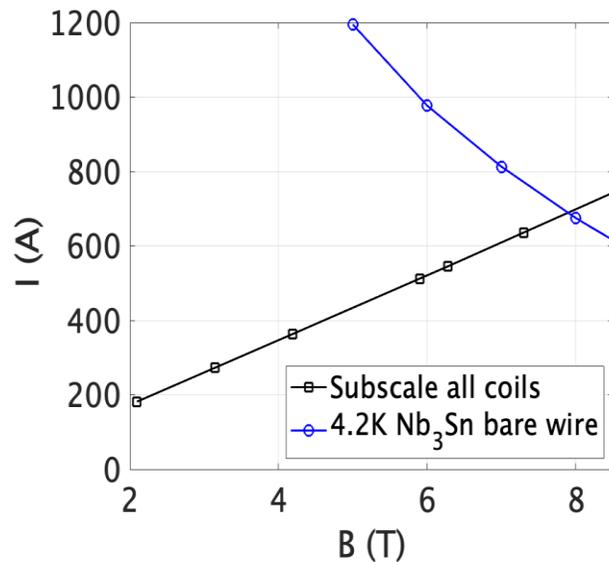
Table. II subSMACC short sample parameters.

Aperture (mm)	22
Bore field (T)	5.8
Paek field (T)	6.9
Temperature (K)	1.9
Equivalent coil width (mm)	10.7
Magnetic length (m)	0.43
Outer dimensions (mm)	240 × 440
Current (A)	6600
j overall (A/mm ²)	982
j sc (A/mm ²)	4605
j Cu (A/mm ²)	3936
Loadline fraction (%)	85
Loadline margin (%)	15
Current margin (%)	29
Temperature margin (K)	3.8
Energy (kJ/m)	60.9
Inductance (mH/m)	2.7
N turns	52+4
N strands	11
strand diameter (mm)	0.6
Coil equivalent width (mm)	11.2
Coil efficiency / $2\mu_0$	0.84
Cu/non-Cu	1.2
Bare cable width (mm)	3.9
Bare cable thickness (mm)	1.3
Insulation thickness (mm)	0.15

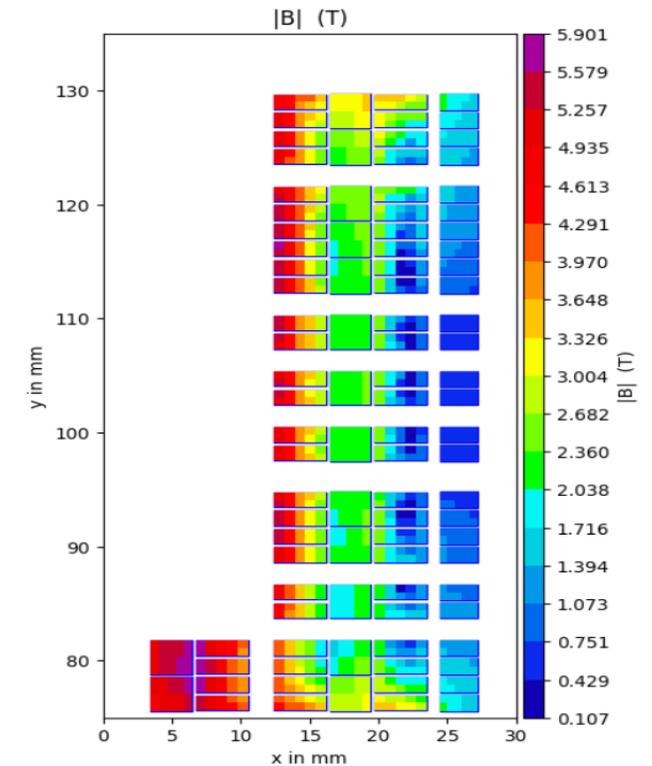
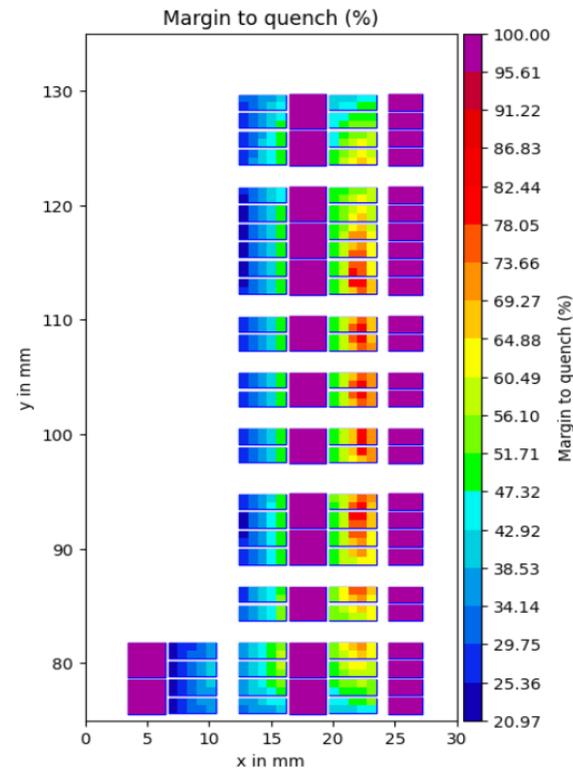
Electromagnetic Optimization



1. Multipole value < 10 units
2. Conductors and spacers are placed to have similar margin in layers 1 and 2 to **use the conductor efficiently**



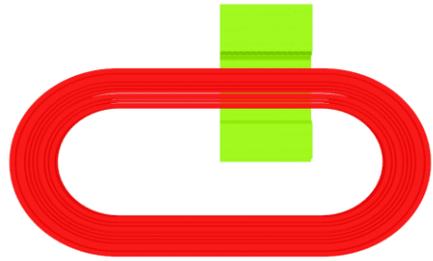
$I=5760$ A @ 20% Margin (4.2 K)



D. M. Araujo, I. S. P. Peixoto, et al. Combined System for Cryogenics and Protection of High-Field Superconducting Magnets, submitted to IEEE TAS, Oct. 2025.

I. S. P. Peixoto, D. M. Araujo, et al. Subscale Stress-Managed Asymmetric Common Coil Design, submitted to IEEE TAS, Oct. 2025.

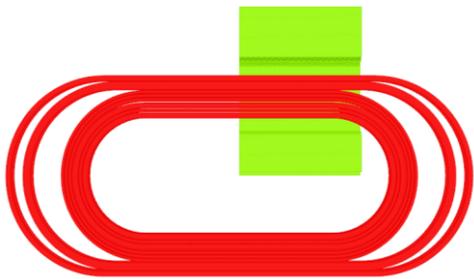
Electromagnetic Optimization



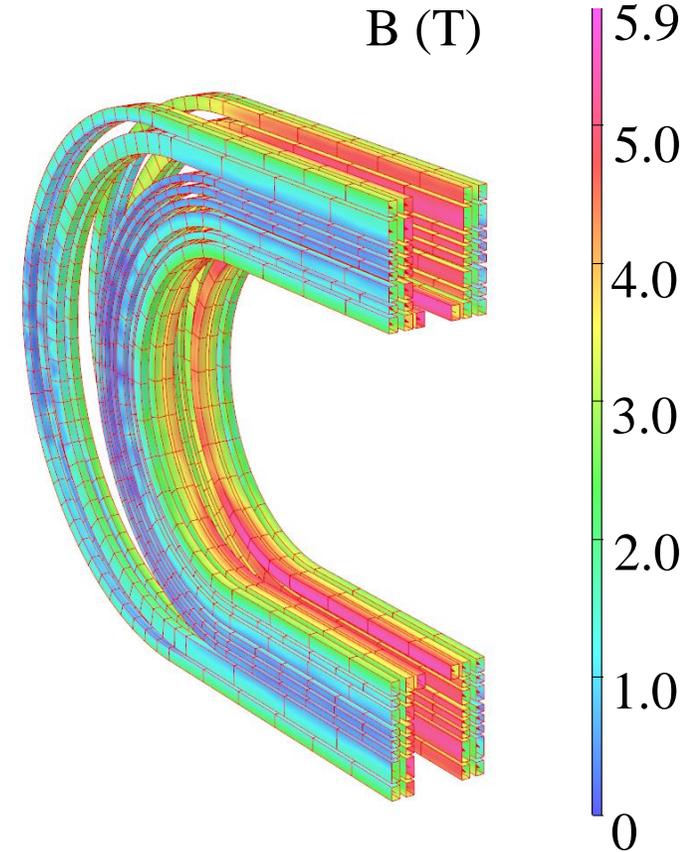
Initial 3D model

3D model Considers yoke influence

Numeric algorithm finds most efficient distance for each coil block to keep multipole value <10 units



Optimized coil and core



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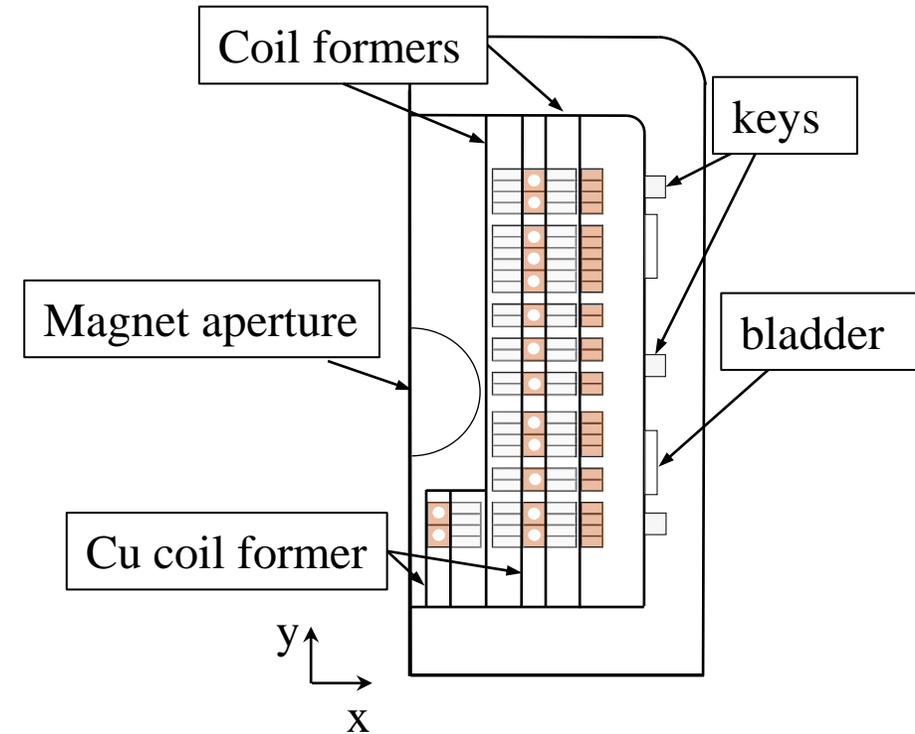
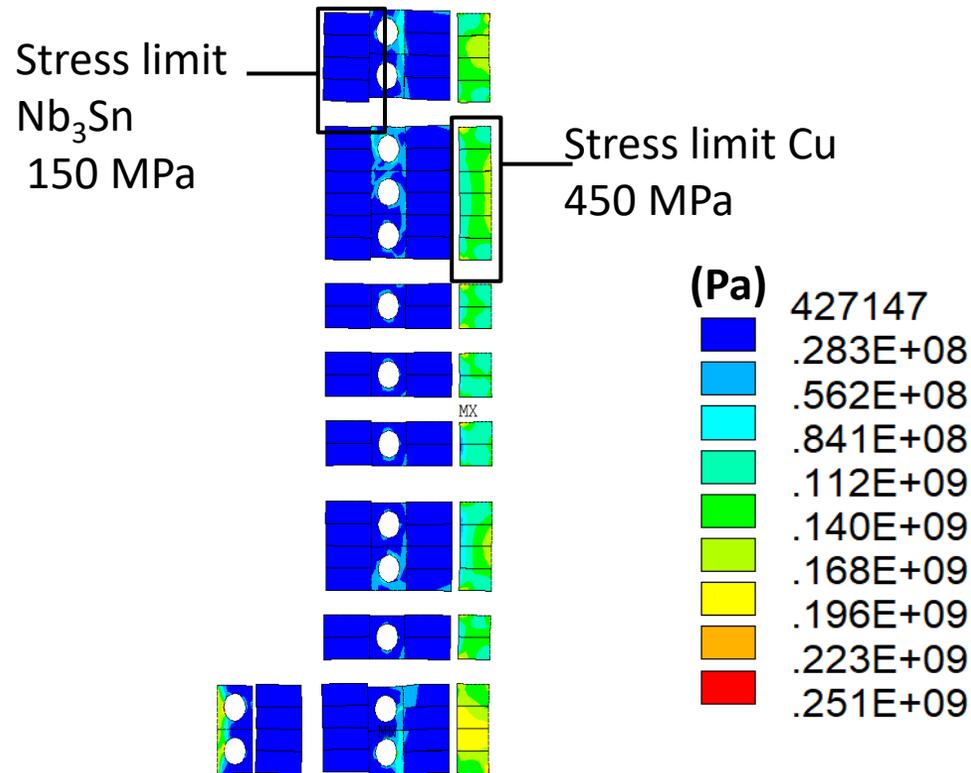
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Mechanical Model (ANSYS)



Stress solution at nominal field (4.2 K, 5640 A)

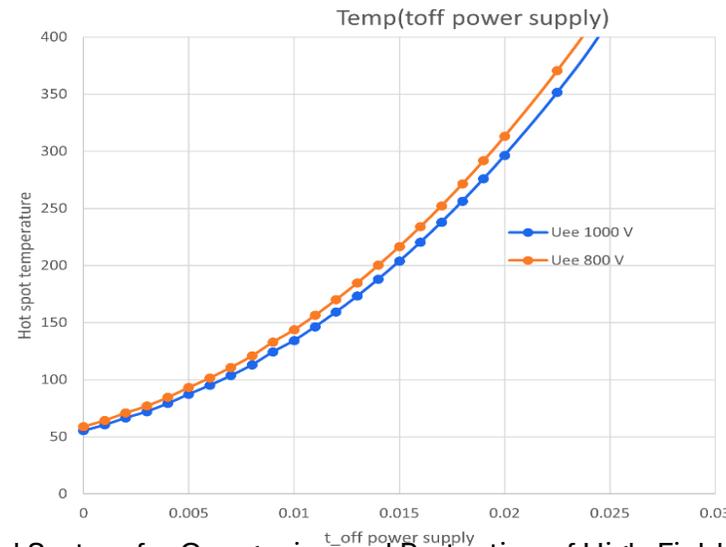
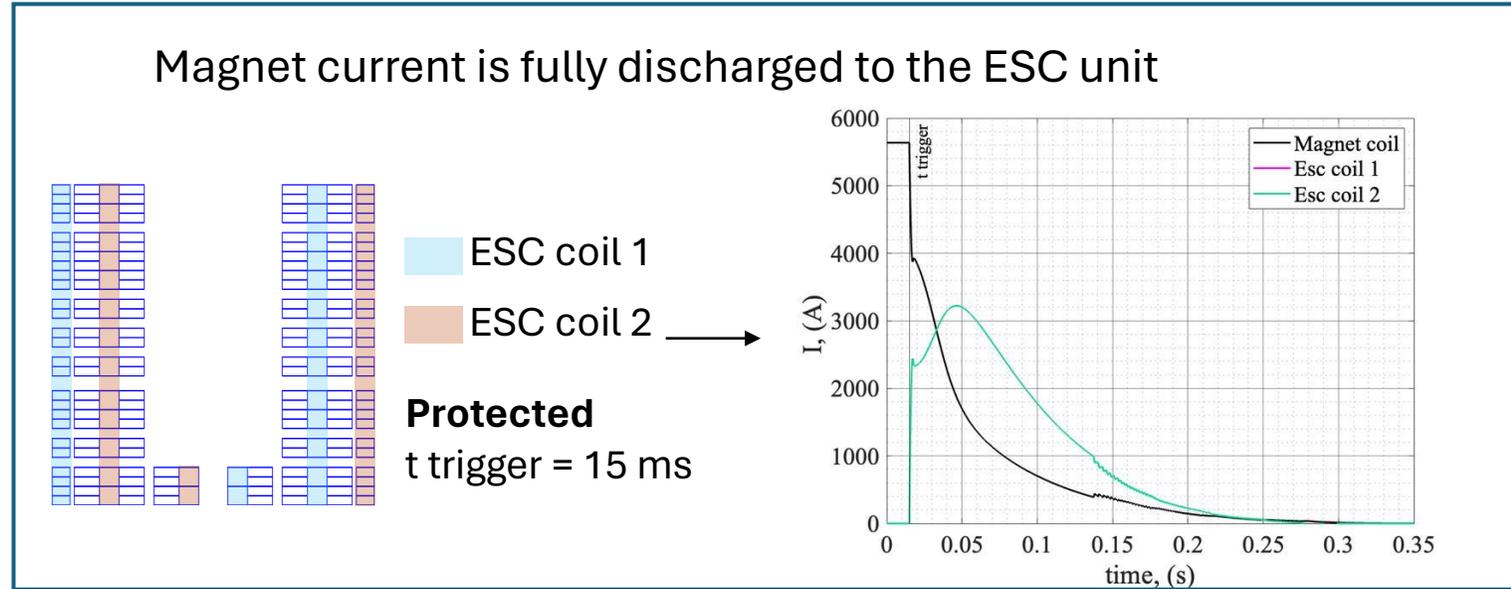
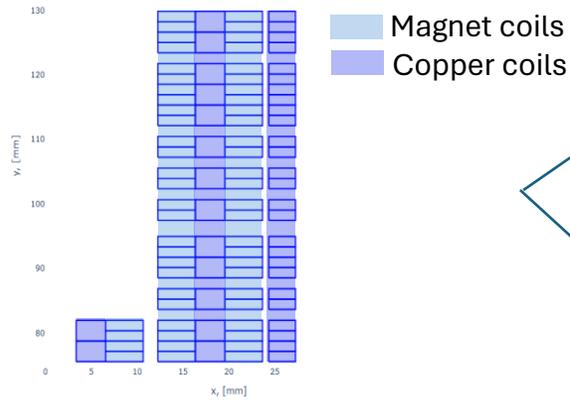
1. Magnet integrity (no excessive movement in the pieces)
2. Different material stress limits are respected



Transient Analysis: Quench Protection



- Analyses with LEDET-STEAM framework on the possible **ESC and EE** configurations can lead to protected or unprotected solutions.



Magnet can be protected by energy extraction or energy shift with coupling

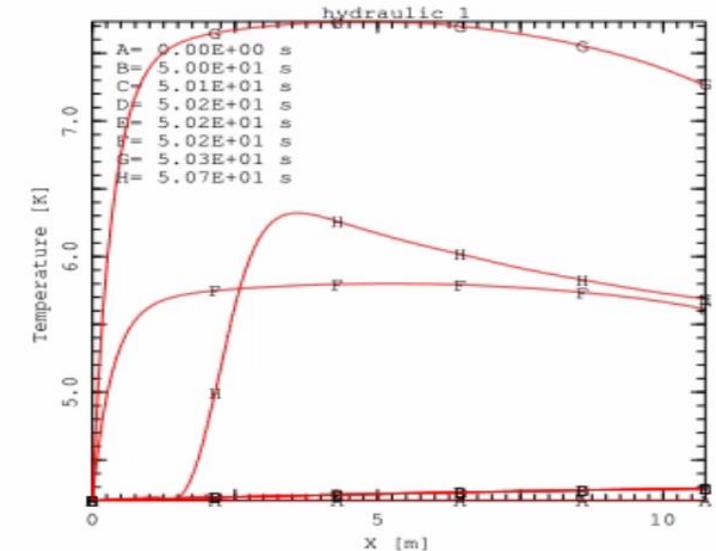
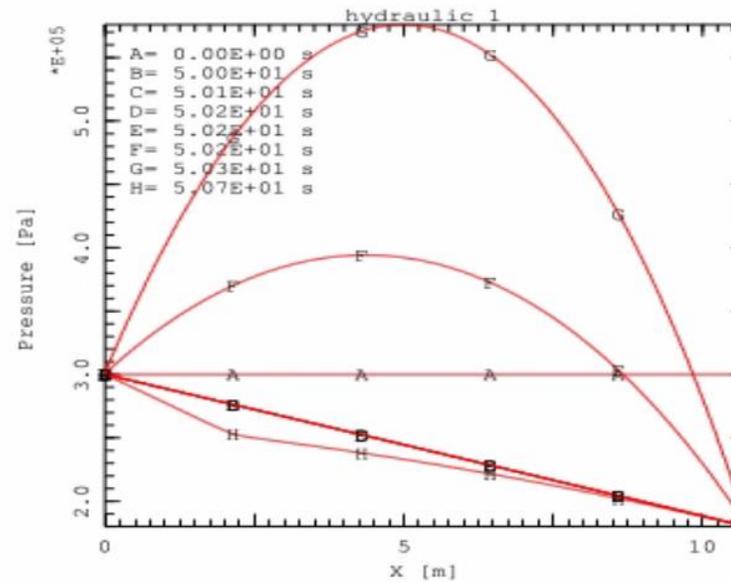
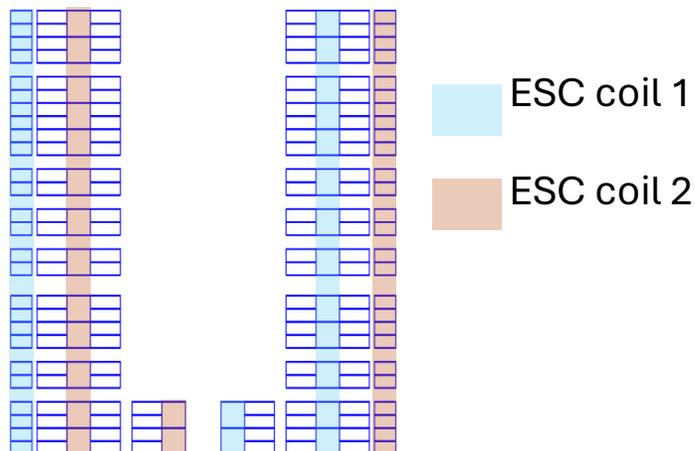


Thermal Model (THEA)



- For a specific ESC solution, a thermal simulation is performed on the cooling cables' maximum pressure and temperature when the discharge occurs:
- Cooling cables maximum pressure reached 5.5 bar and max temperature 7.5 K

The result show that **magnet heating is controlled** and **limit pressure** in the **cooling cables** is within **safety** limits.



Pressure tests

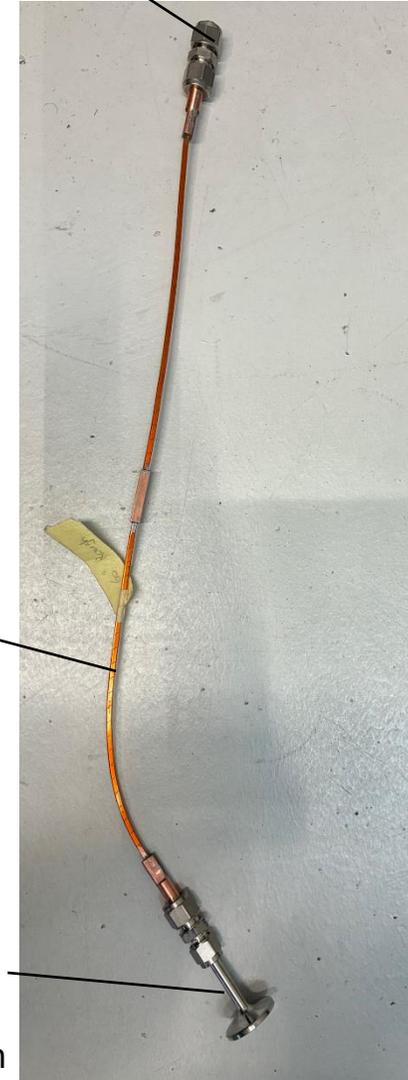
- The samples are prepared with one cooling circuit connection and one closed end.
- The splice is done by adding two copper shells around the connected cables and soldering the shells to make a sleeve.



- Two samples were tested with gaseous He:
- The samples were exposed repeatedly to LN₂ and ambient temperatures (thermal cycle)
- Gaseous He was inserted in the channel at varying pressures (up to 22 bar) to verify the samples are leak tight
- For each pressure value the valves were closed, and no pressure drop was observed

Samples prepared by N. Kehl
The test was conducted at PSI, video provided by Q. Gorit

Closed end



Cooling circuit connection



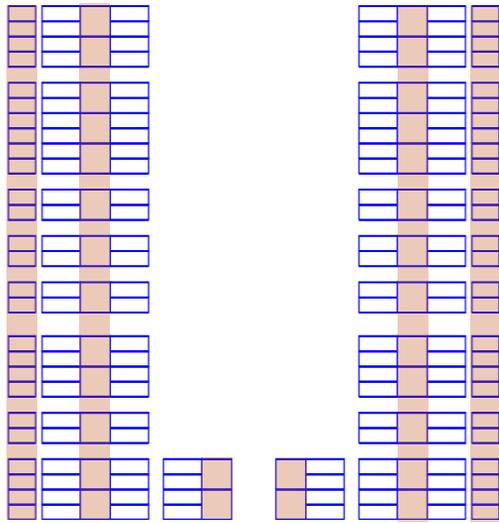
HFM
High Field Magnets
Programme



Engineering Design

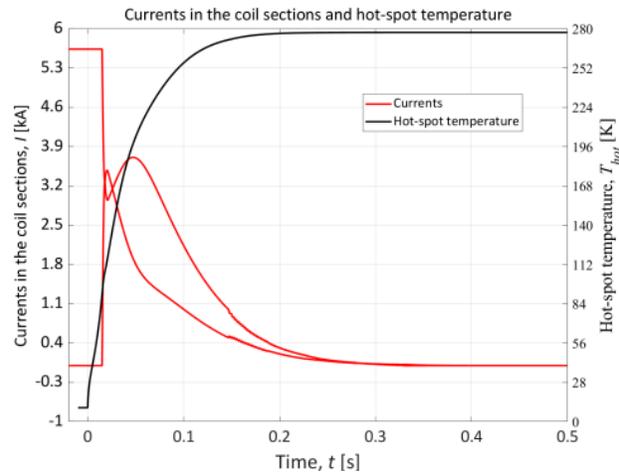


- ESC solution is chosen based on engineering design



ESC coil

Protected
t trigger = 15 ms



Engineering Design

- ongoing CAD model
- geometry update → magnet electromagnetic optimization

