SMACC 13 T

HFM Forum

D. Araujo on behalf of CHART/MagDev2 team
PSI, 18 July 2024

Work packages overview – KE5943

RD Line	Work Package	Tasks, deliverables	TASK/DELIVERABLE DESCRIPTION
RD2	**RD2**	**RD2**	**HTS Conductors and HTS Magnet Technologies**
RD2	**WP2.19**	**WP2.19**	**R&D relating to HTS technology - PSI/CHART collaboration KE5943**
RD2	WP2.19	D2.1	HTS Roadmap Conceptual Report
RD2	WP2.19	D2.2	ReBCO Cable Test Report
RD2	WP2.19	D2.3	Technology Racetrack Test Report
RD3	**RD3**	**RD3**	**Nb3Sn Magnets**
RD3	**WP3.14**	**WP3.14**	**R&D relating to LTS technology - PSI/CHART collaboration KE5943**
RD3	WP3.14	D1.1	BOX Powered-Sample Test Report
RD3	WP3.14	D1.2	SMCC Sub-scale Test Report
RD3	WP3.14	D1.3	SMCC Ultimate-Field Demonstrator Conceptual Design Report
RD3	WP3.14	D1.4	SMCC Ultimate-Field Demonstrator Technical Design Folder
RD3	WP3.14	D1.5	Reel-to-reel Inspection and 10-Stack Characterization of Cables as Received

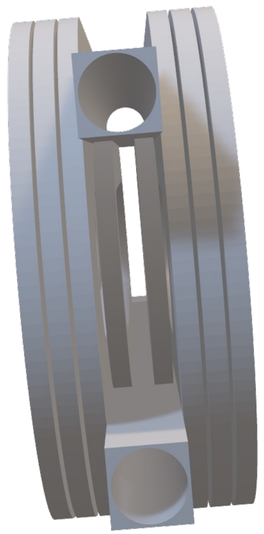
This Presentation

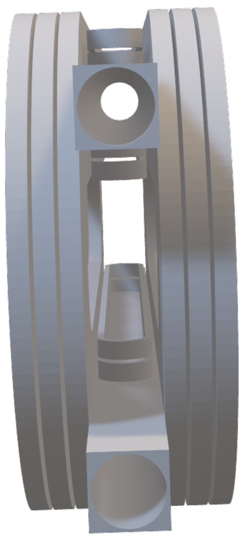
SMACC Concept + 2D and 3D magnetic analysis

Stress-Managed Asymmetric Common-Coils Conceptual Design | Motivation

In respect to standard common-coils magnet, we would like to:

- Introduce stress-management for common-coils
- Simplify the manufacturing processes (no curing, no mold for reaction and impregnation)
- Have a design suitable to try react & winding technique for Nb_3Sn





Agenda

- Goals and Assumptions
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- 2D Mechanical Analysis
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Goals and Assumptions

Assumptions

- 4 layers (per side) magnet design
- High-field coils (layers 1 and 2) made out the existent R2D2 cable design
- Low-field coils (layers 3 and 4) made out the existent 400 m of produced 34 x 0.7 mm cable produced with the Nb_3Sn RRP® 78/91

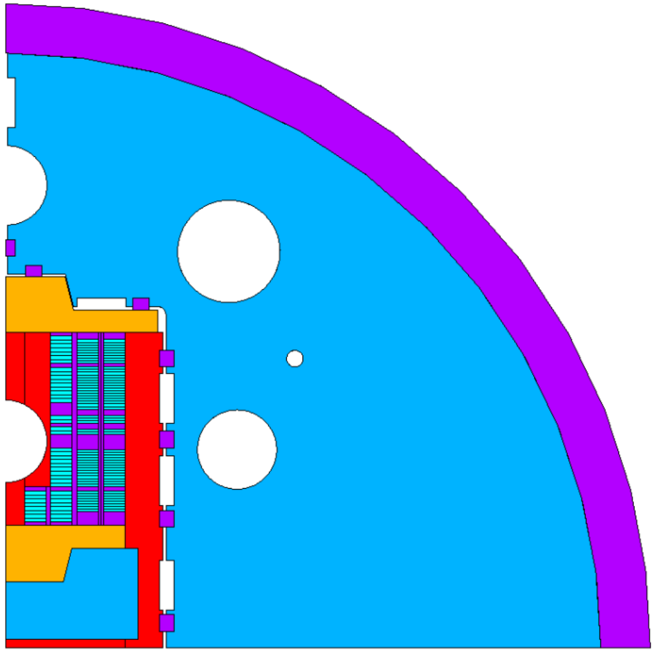
- Straight-section of 0.5 m
- External shell diameter < 800 mm
- Intra-beam distance of 250 mm
- Clear bore of 50 mm

Goals

- Build and test the first stress-managed asymmetric common-coils
- Validate the concept, modelling assumptions and manufacturing steps before the building the 14 T demonstrator

- 13 T at 4.22 K with 10% of eng. margin
- Protection with Energy Extraction limiting the voltage to 1 kV
- 2 identical low-field layers
- Field quality to the level of ± ~10 units

Cross-section



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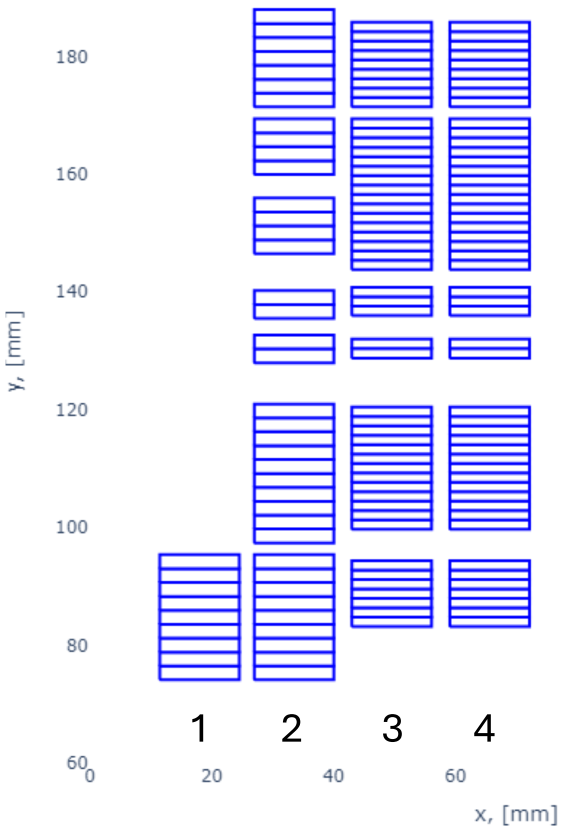
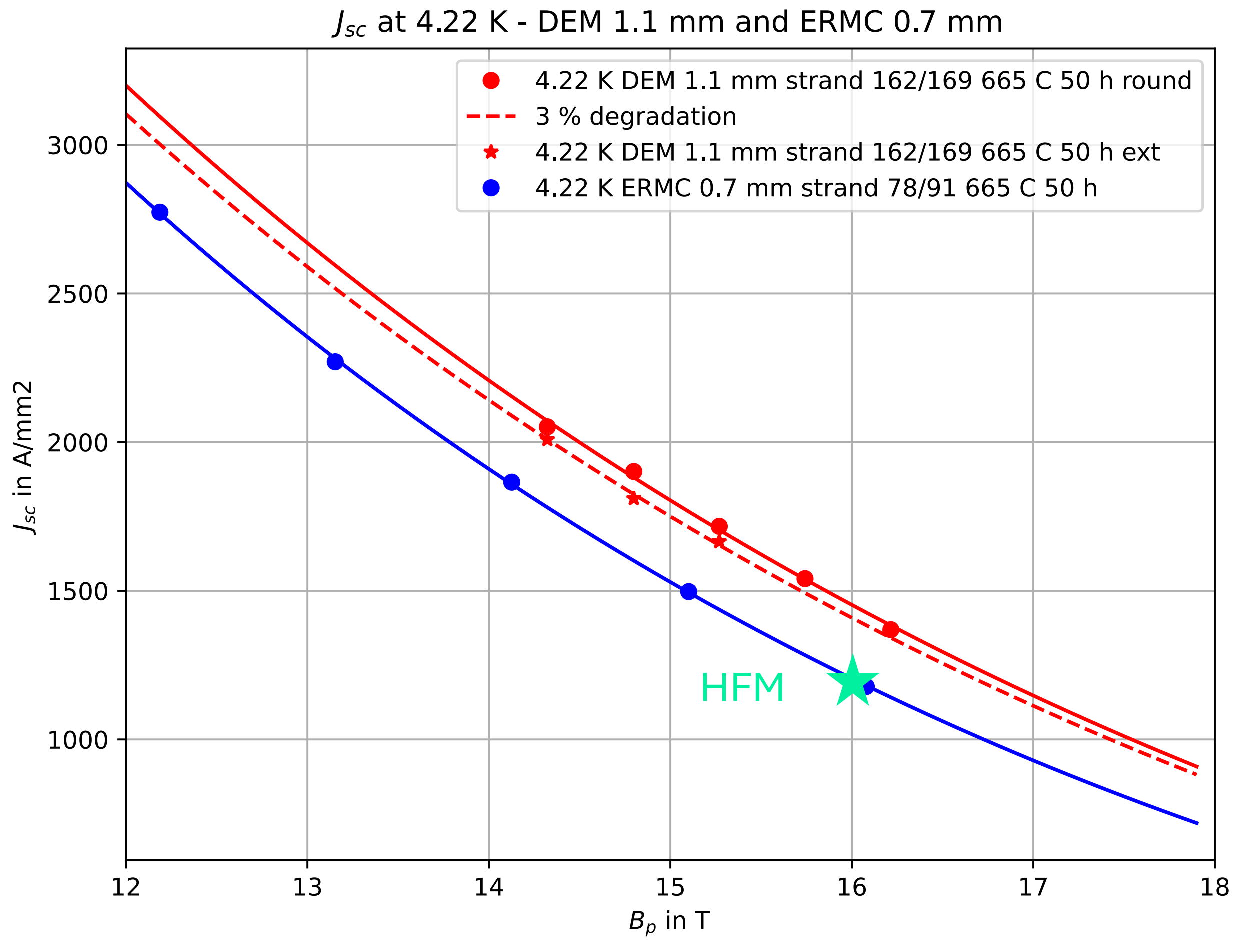


Layers	1	2	3/4
Wire type	Nb_3Sn RRP® 162/169	Nb_3Sn RRP® 162/169	Nb_3Sn RRP® 78/91
N wire x dia in mm	21 x 1.1	21 x 1.1	34 x 0.7
Cu/nCu	0.9	0.9	1.2
Bare Cable dimensions in mm	12.74 x 2.06	12.74 x 2.06	12.77 x 1.3
Insulation thickness in mm	0.155	0.155	0.155
Number of turns	9	38	50/50

Conductor performance assumptions



Wire type	Nb_3Sn RRP® 162/169	Nb_3Sn RRP® 78/91
dia in mm	1.1	0.7
Cu/nCu	~0.9	~1.2
dia sub-element in μm	64	54
CERN denomination	DEM-1.1	ERMC-0.7

665 C/ 50 hr

3% of degradation due to cabling

Corrected with self-field contribution

S. Hopkins, Status of Conductor Procurement, 10 Dec 2019

S. Hopkins, T. Boutboul, DEM-1.1 stability.xls

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Magnetic Design | 2D

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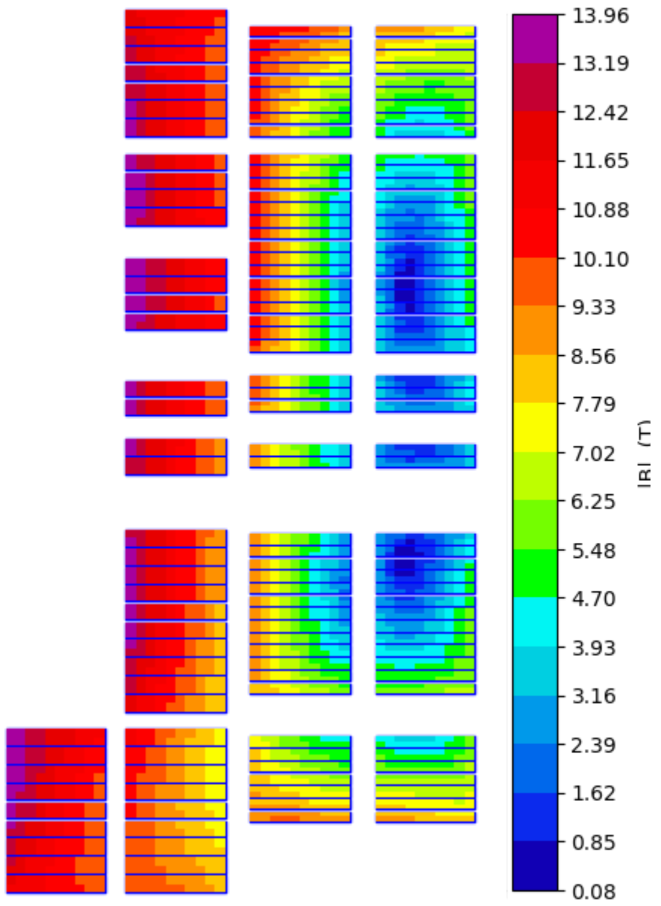
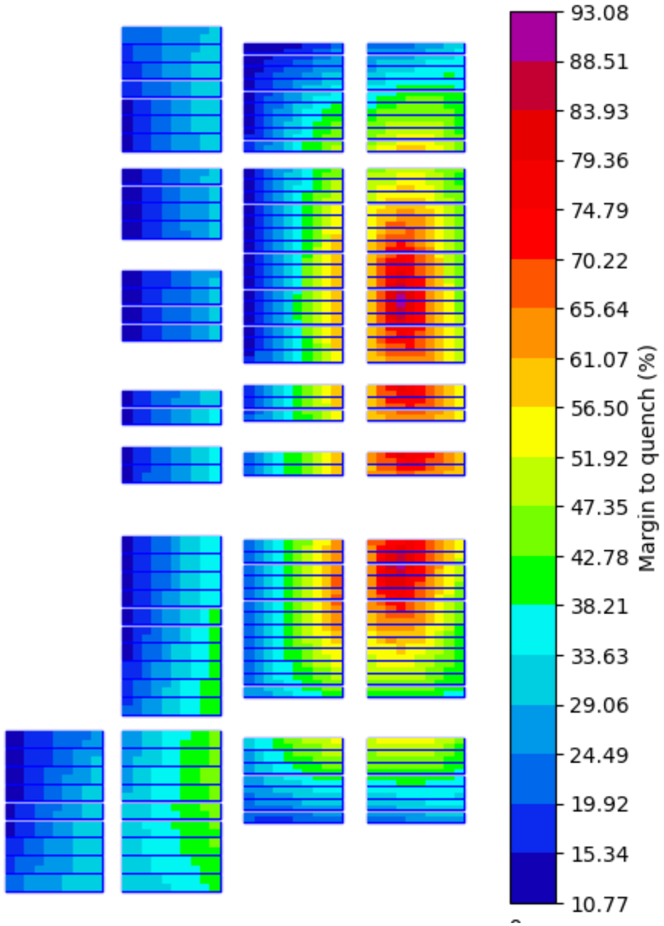




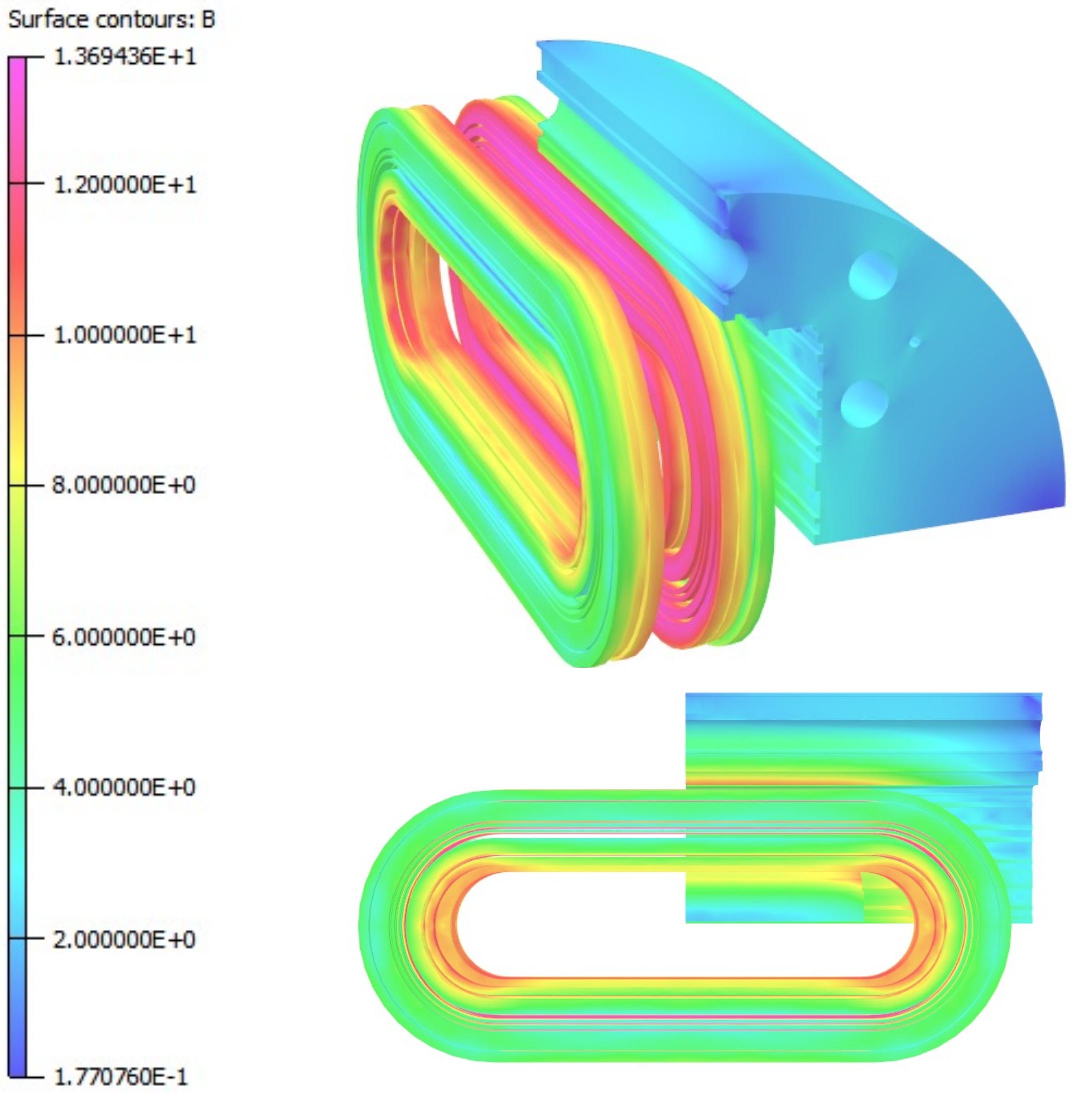
B_0 in T	B_{peak} in T	T_{op} in K	% Margin	I_{op} in kA
13.0	< 14.0	4.22	10.8	14.16

Layer	B_{peak} in T	% Margin	J_{sc} in A/mm²	J_{cu} in A/mm²	J_{ov} * in A/mm²
1	13.9	11.0	1348	1498	460
2	14.0	**10.8**			
3	10.9	**10.8**	2381	1984	677
4	9.0	22.0			

Self-field included

Magnetic Design | 3D

HFM High Field Magnets Programme | CHART Swiss Accelerator Research and Technology | PSI



B_0 of 13 T	B_{peak} in T Self-field	B_{peak} in T No self-field	% Margin	I_{op} in kA
2D	13.96	13.67	10.8	14.16
3D	-	13.69		

3D	B_0 of 13.0 T	E = 1.7 MJ	L = 16 mH	~100 MJ/m^3

2D	B_0 of 13.0 T	Fx = 10 MN/m	Fy = 0.6 MN/m

2D vs 3D Magnetic Analysis Field Quality

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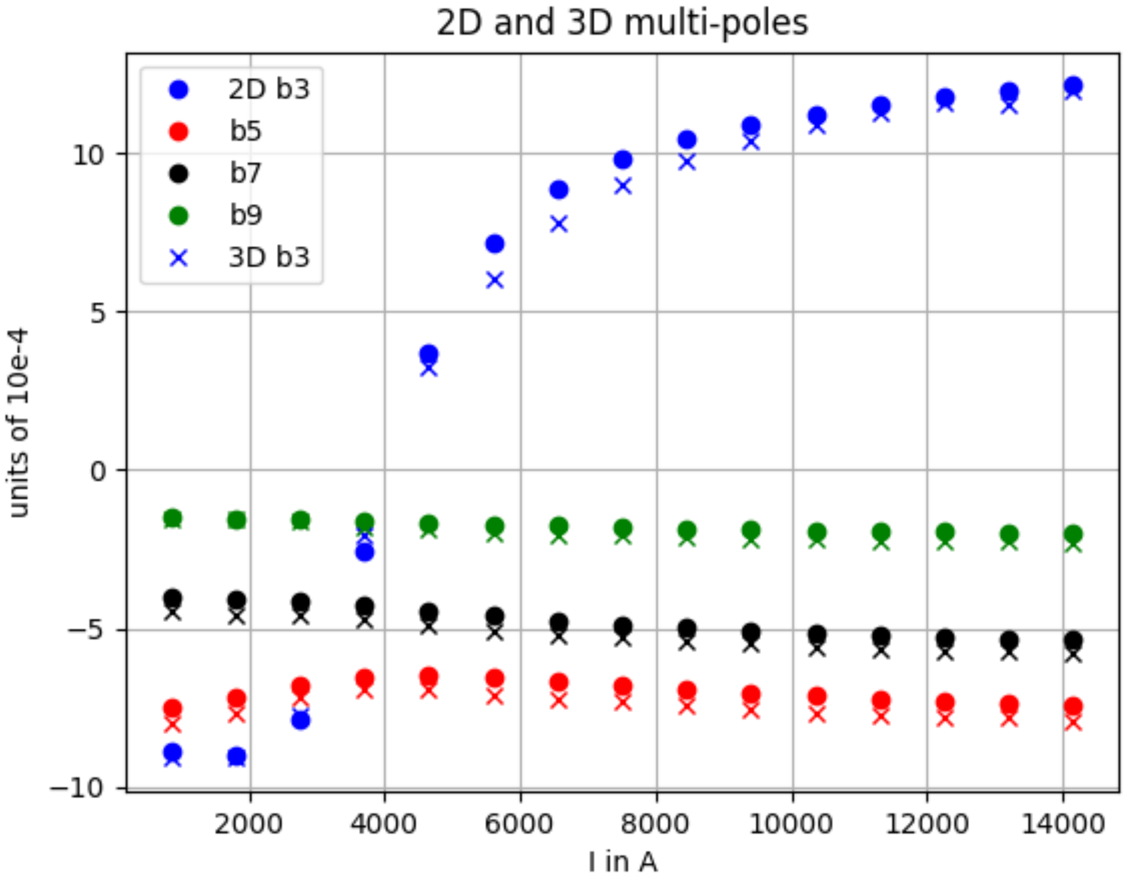

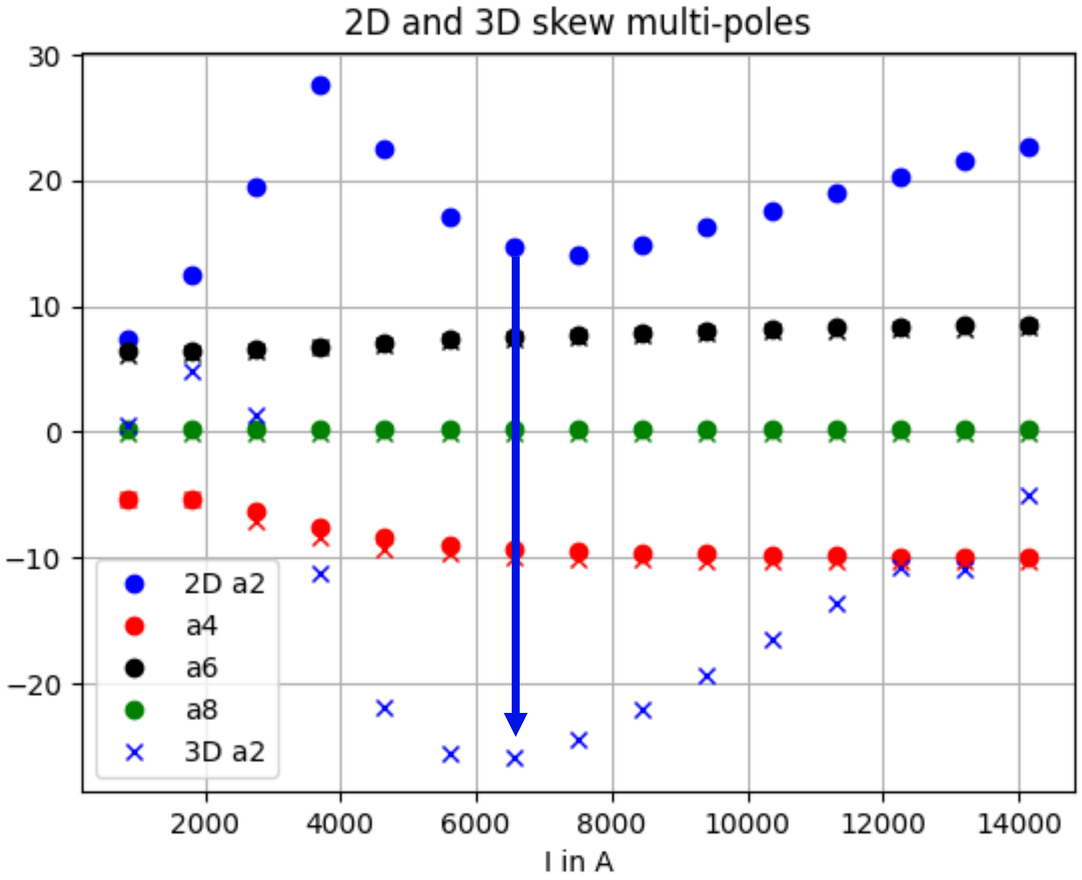

- 40 units from 2D to 3D

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Cross-section

All components, expect for the **iron pole and yoke** made from stainless steel

Dext shell = 720 mm

Shell thickness = 35 mm

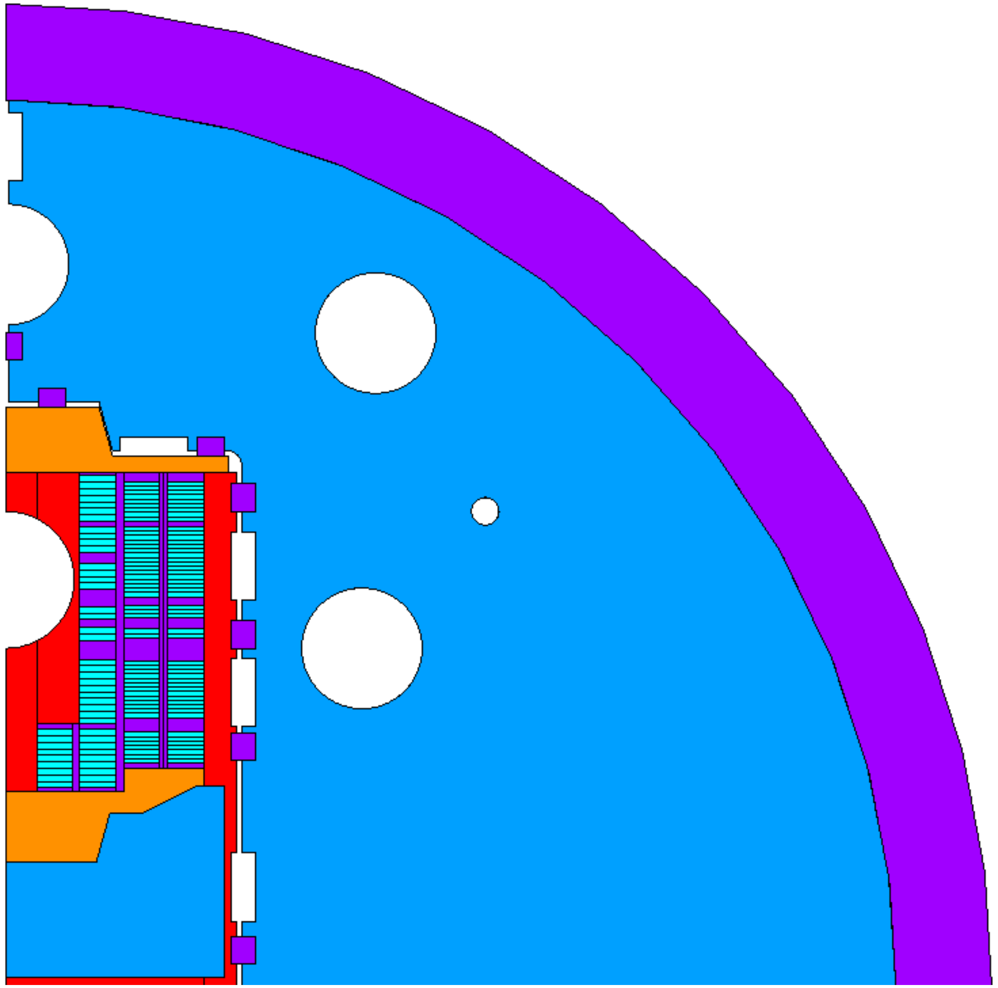
Cooling channels and rod d = 42 mm

Shell and keys

Outer and inner vertical pad

Horizontal pad and non-magnetic pole

Coil formers



Mechanical Analysis | 2D | 13 T

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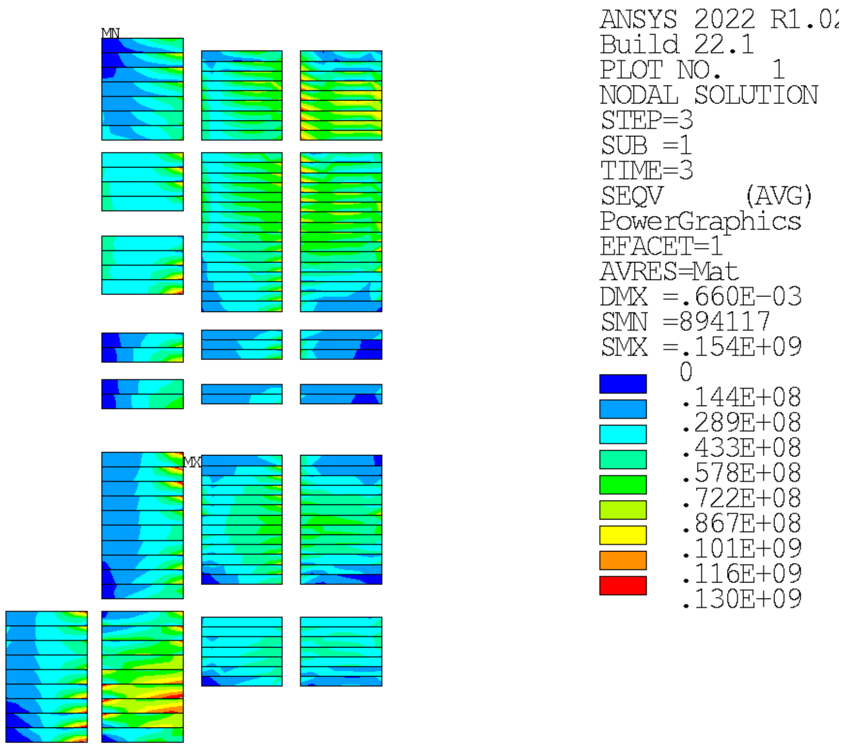
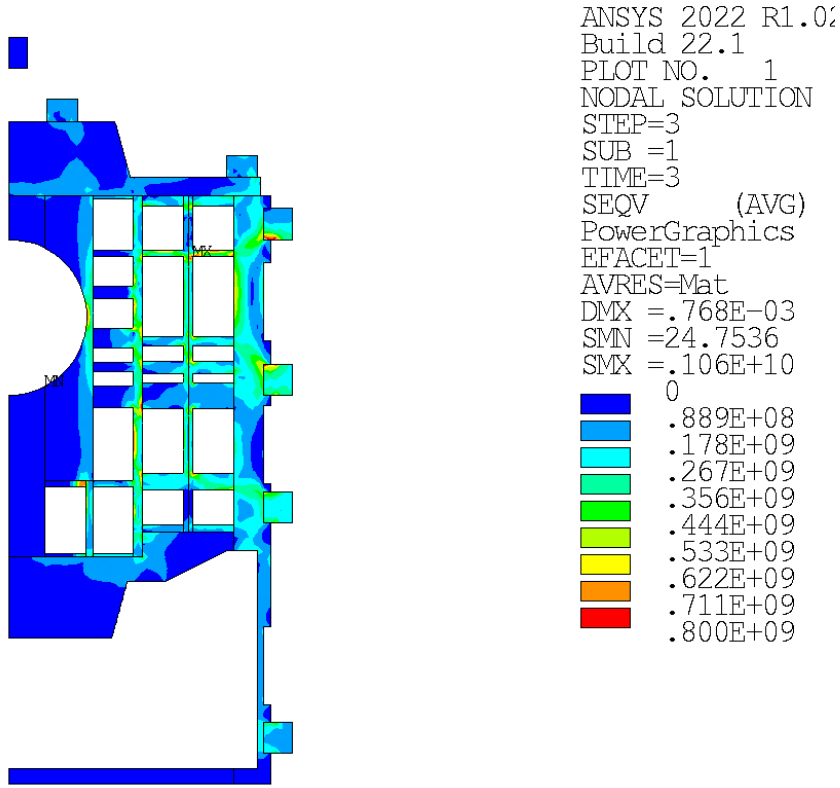
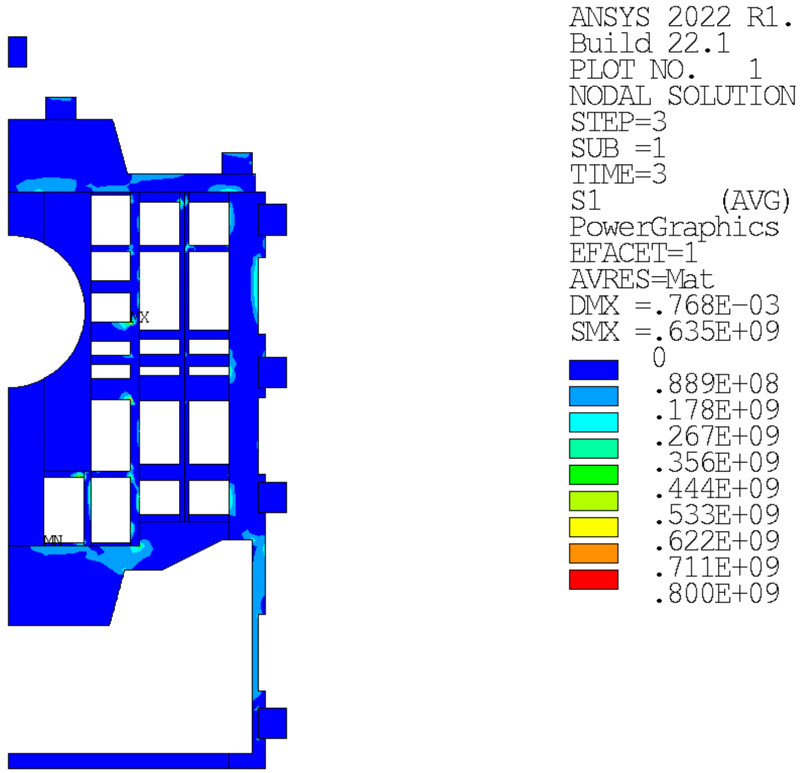




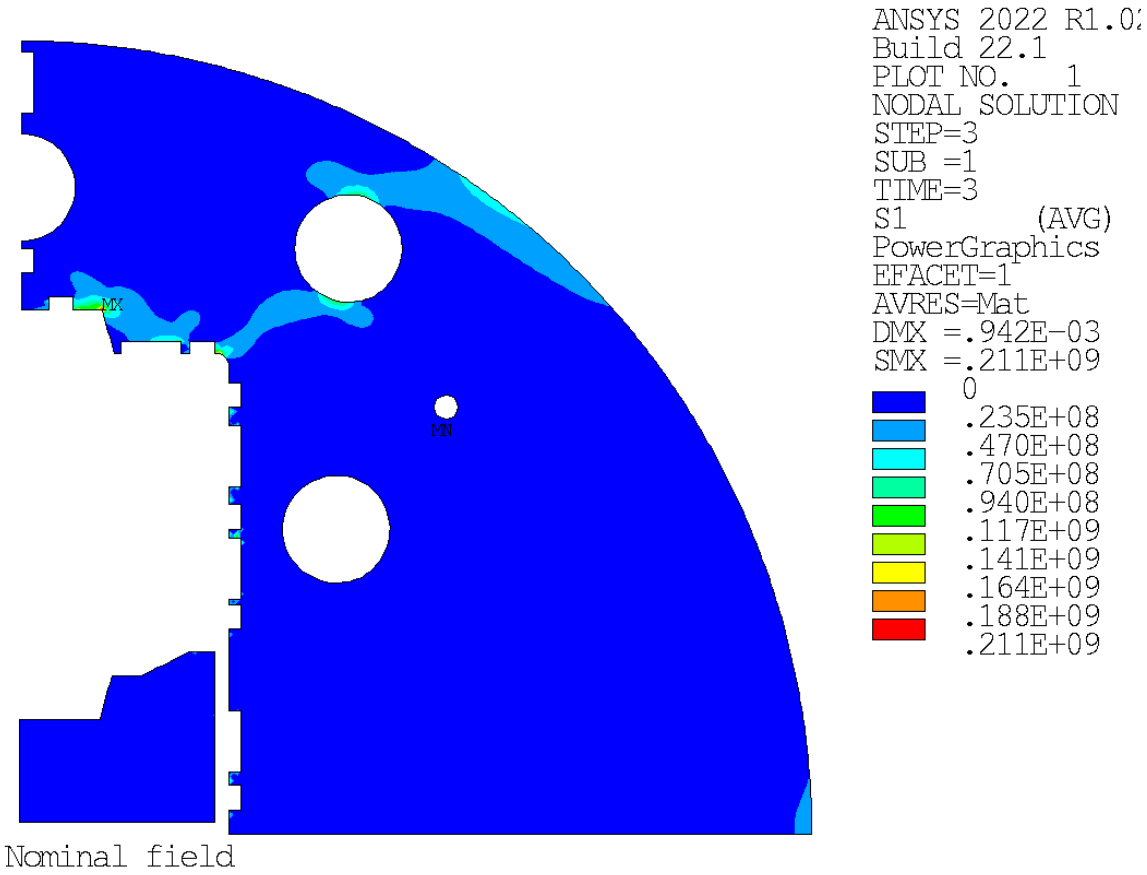


130 MPa with higher peaks on the insulation thickness

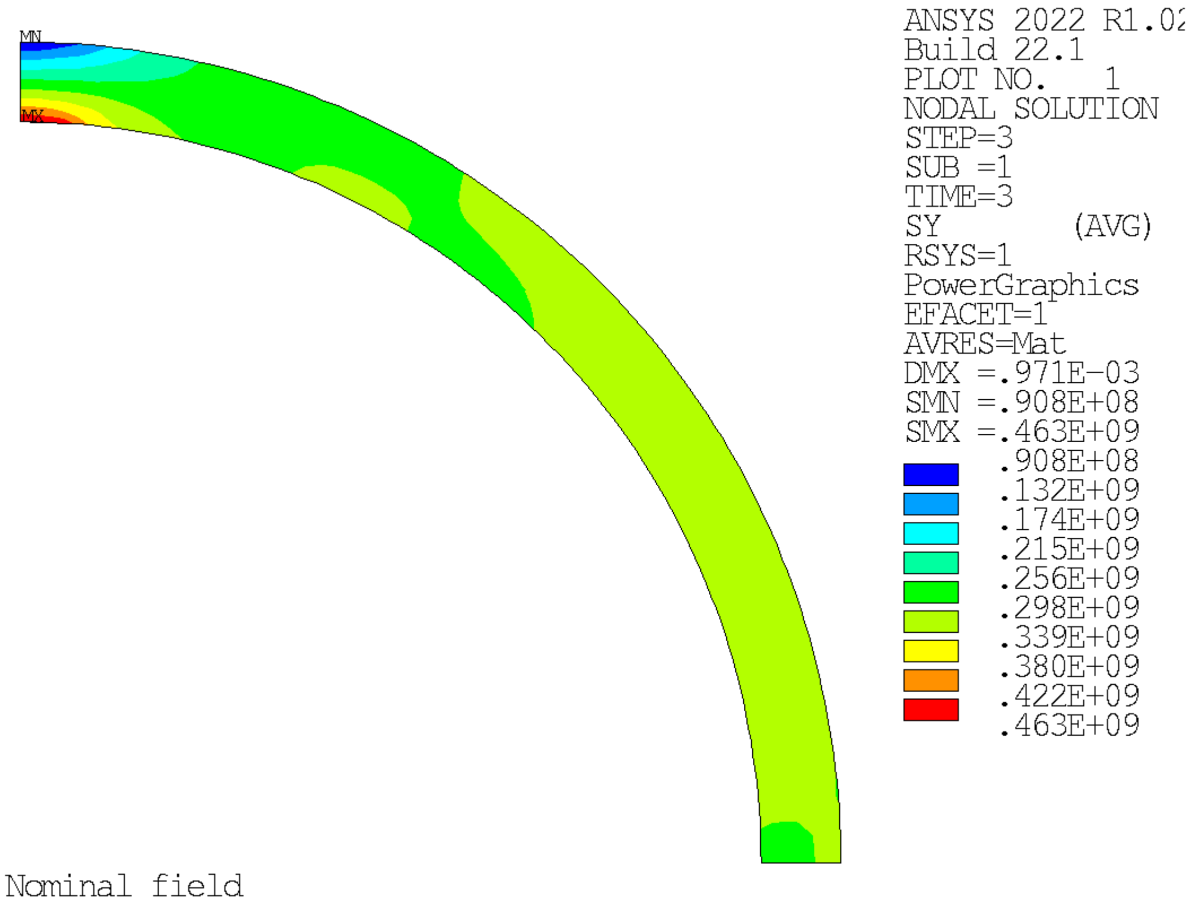
600 MPa (SEQV) with higher peaks on the former corner

635 MPa (S1)

Mechanical Analysis | 2D | 13 T

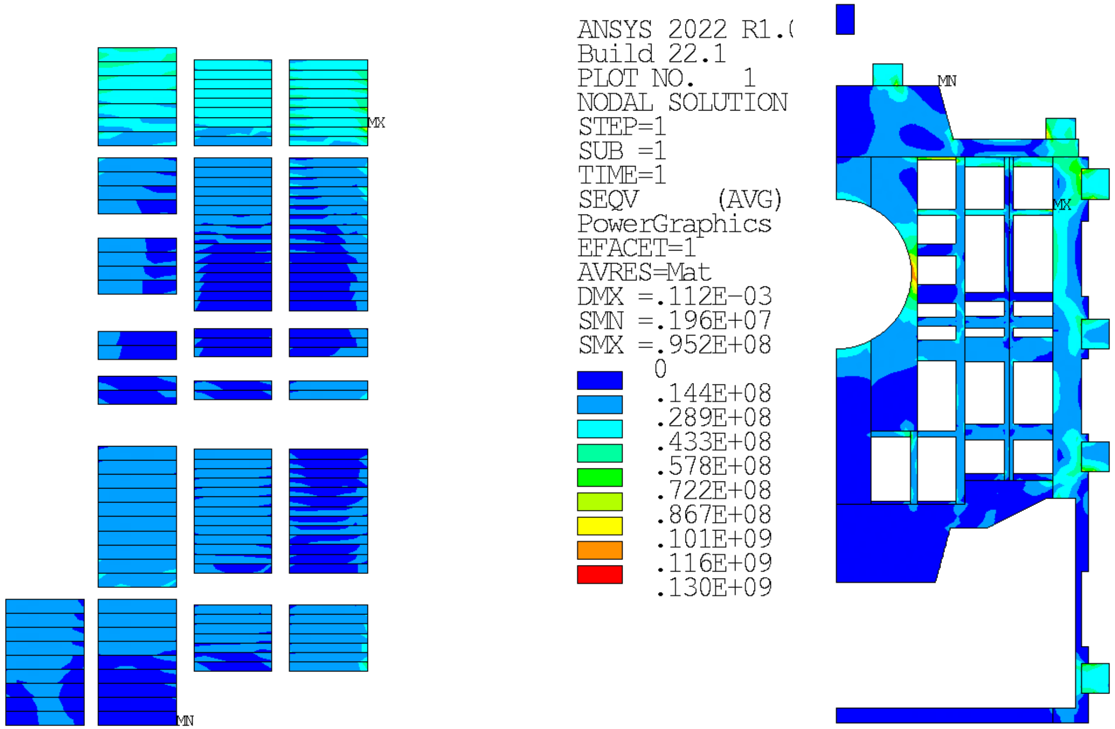


210 MPa (S1)



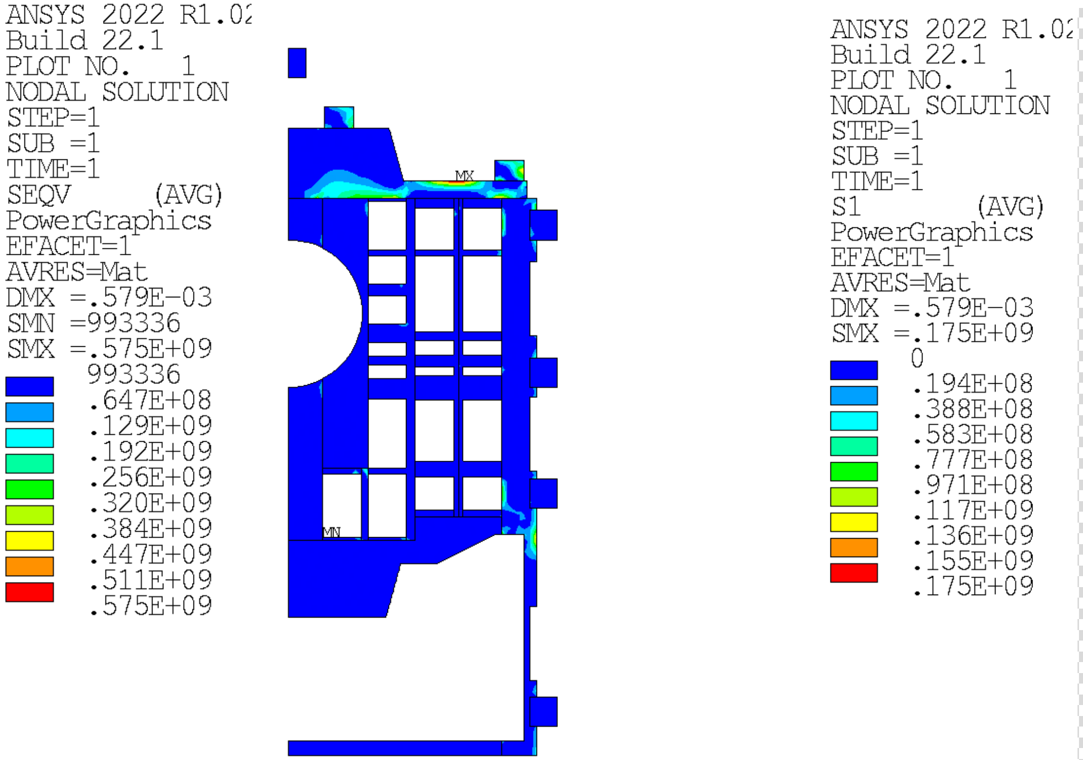
460 MPa (Stheta)

Mechanical Analysis | 2D | Pre-load



0.6 mm interference

575 MPa (SEQV)



175 MPa (S1)

2D vs 3D Magnetic Analysis Field Quality

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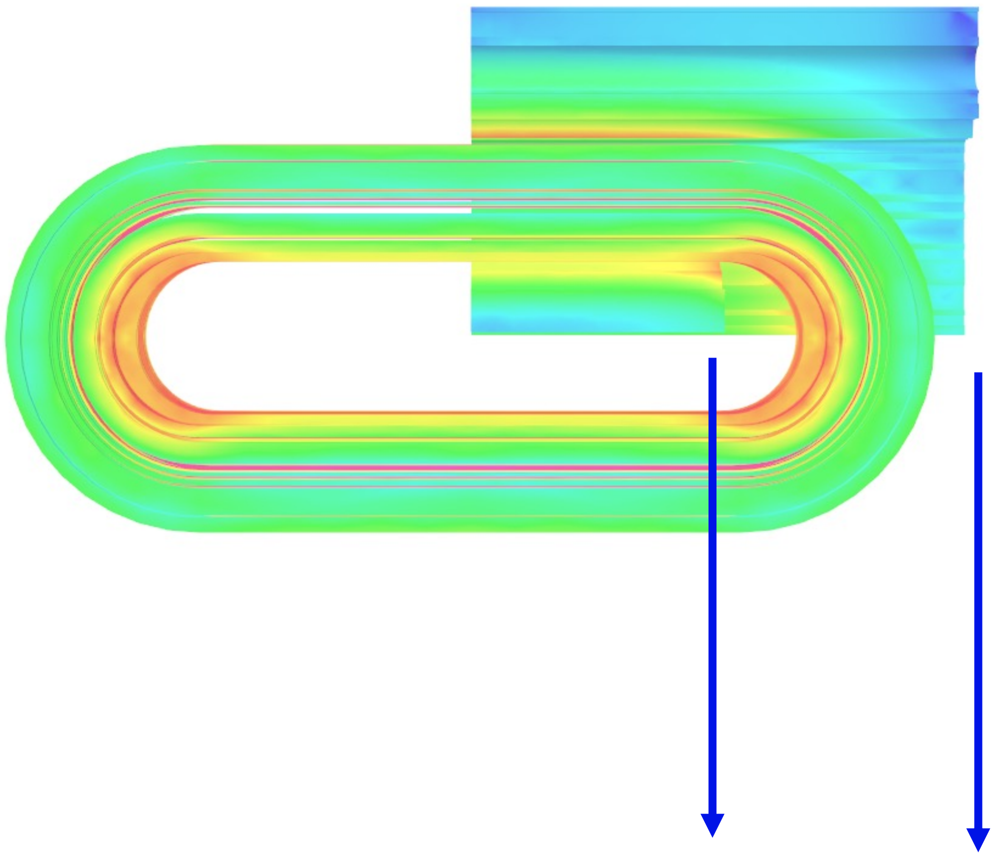
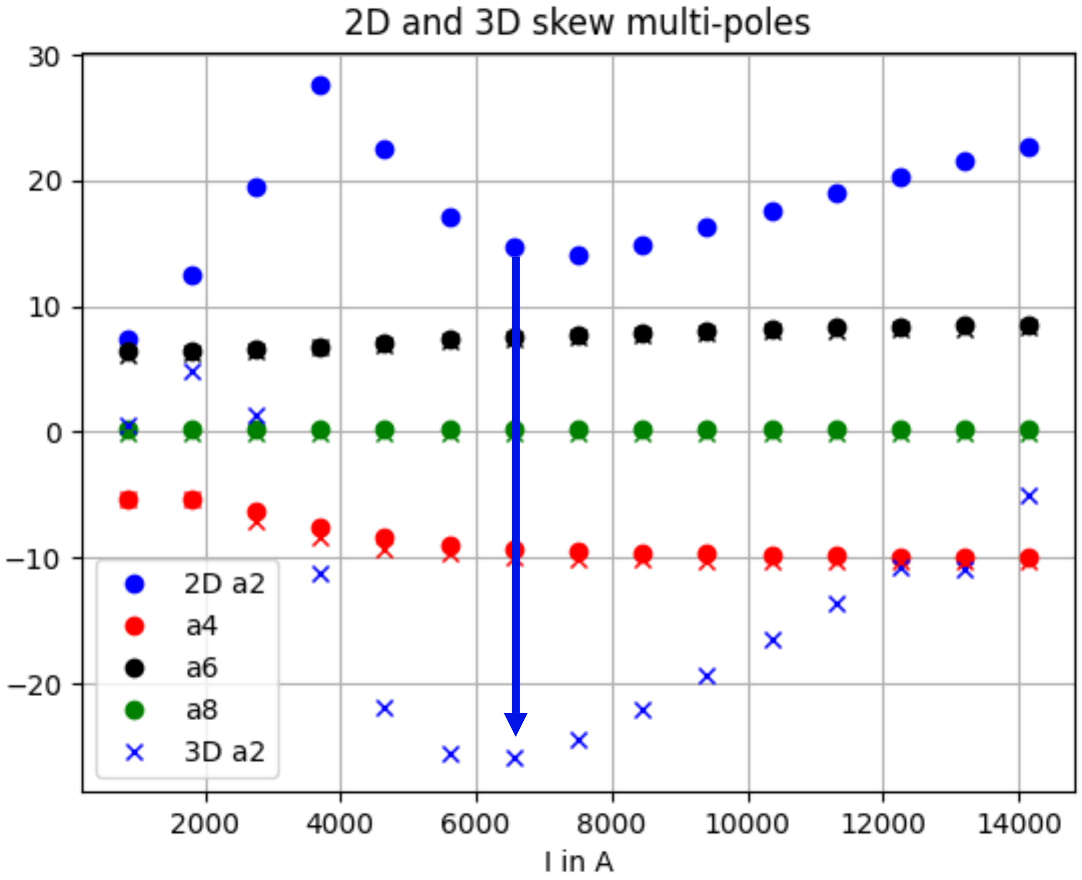
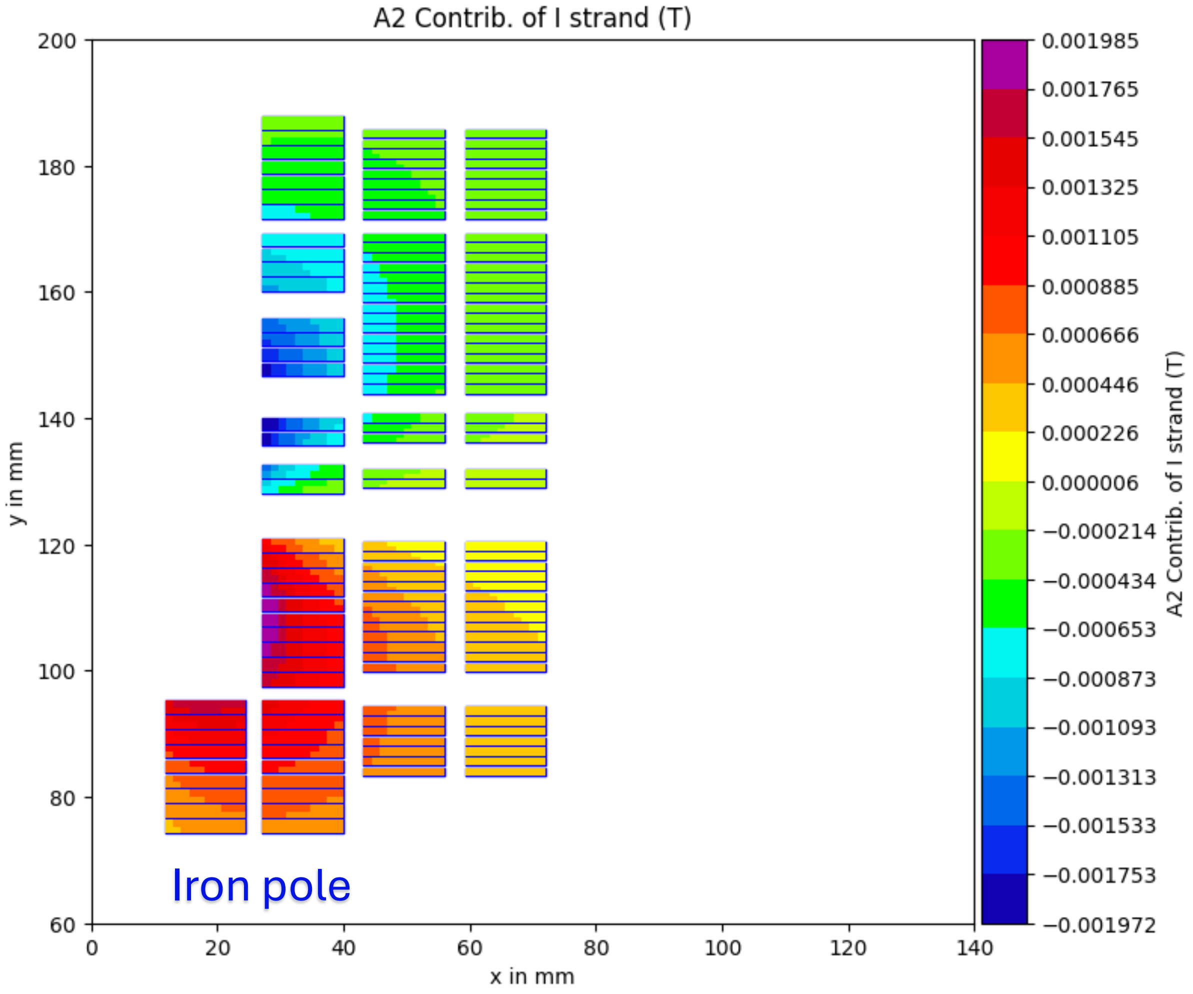


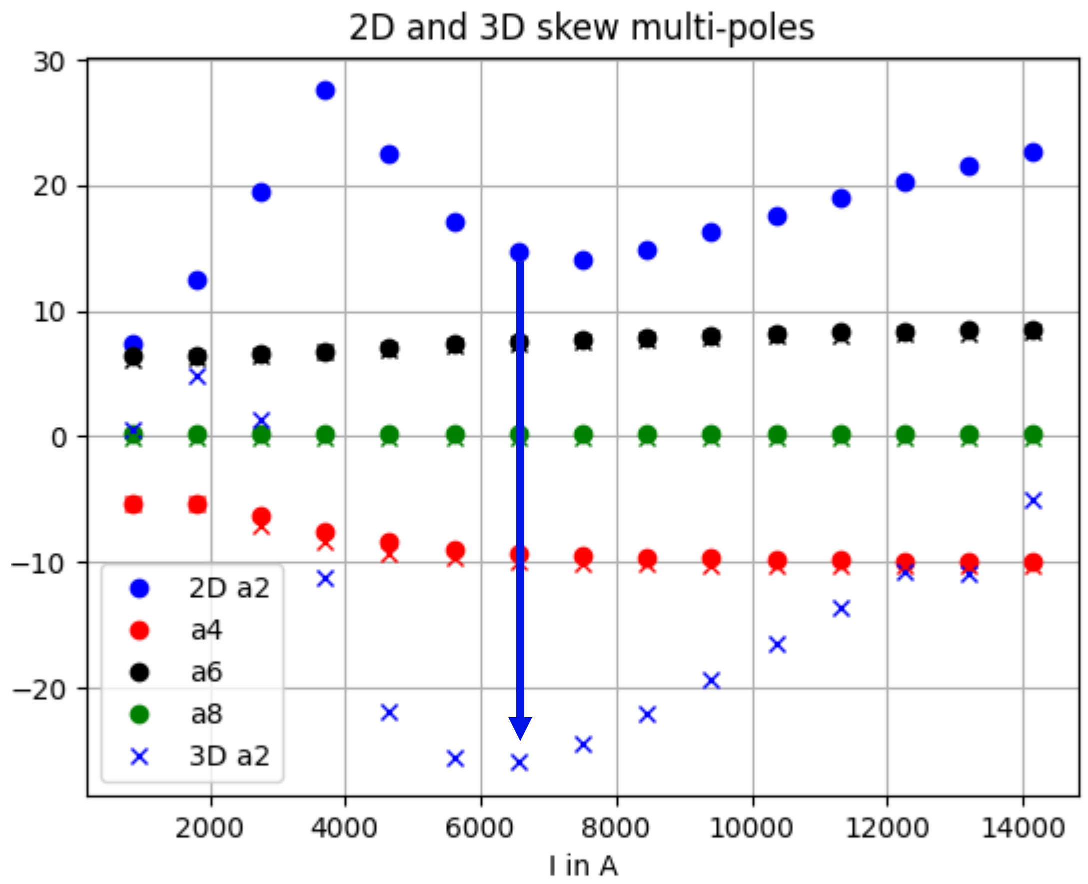
Iron Pole   Yoke



- 40 units from 2D to 3D

2D vs 3D Magnetic Analysis Field Quality





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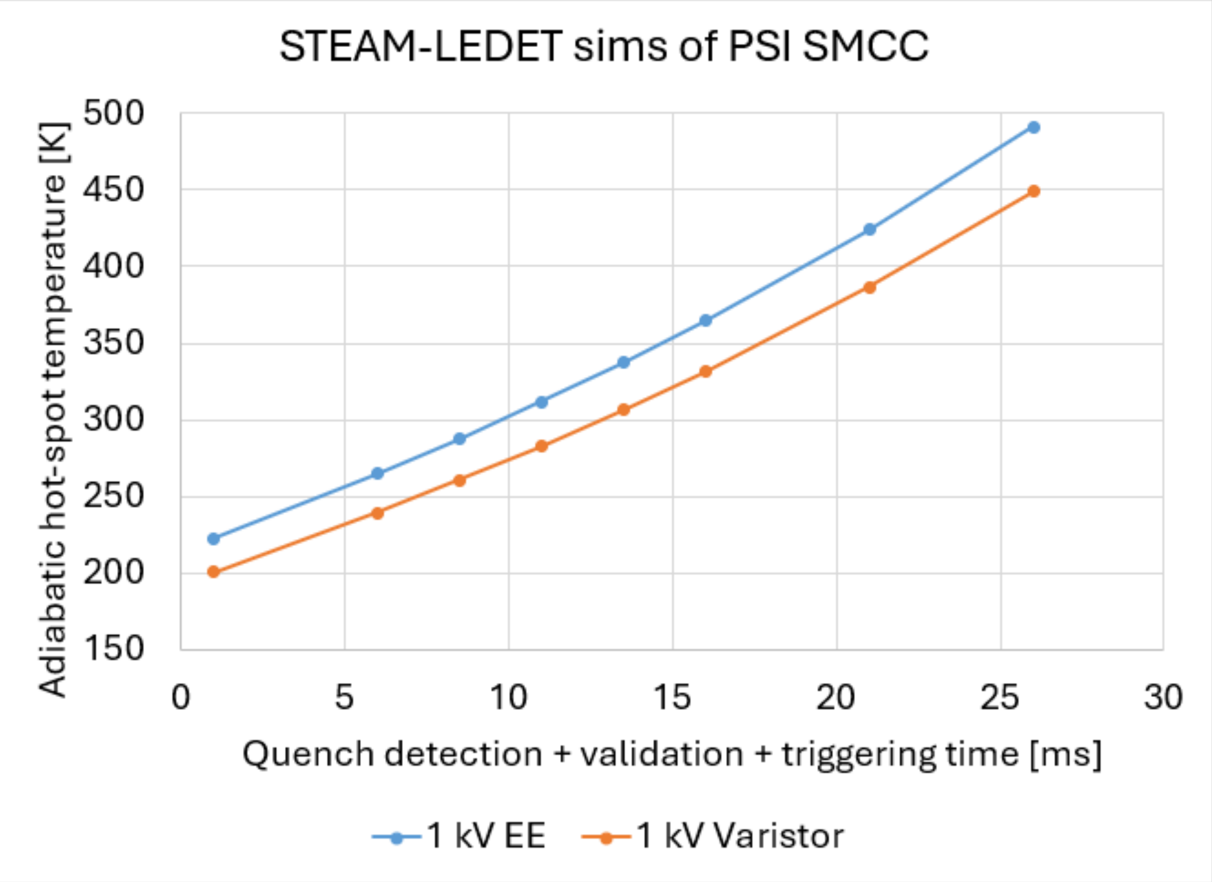
Powering, Cryostats and Protection

SM-18, 20 kA thyristor-based PS on the HFM Cryostat

- Protection with dump resistor would require Vmax > 1 kV (or 1 kV, ground, 1 kV)
  - The 20 kA PS is not grounded on the central point and Vmax is limited to 1 kV
- Protection with varistor
  - The 20 kA thyristor based PS seems to be incompatible with varistor
  - The Cluster D power supply
- Protection with CLIQ and dump resistor
  - Compatible with the 20 kA PS and Vmax < 1 kV

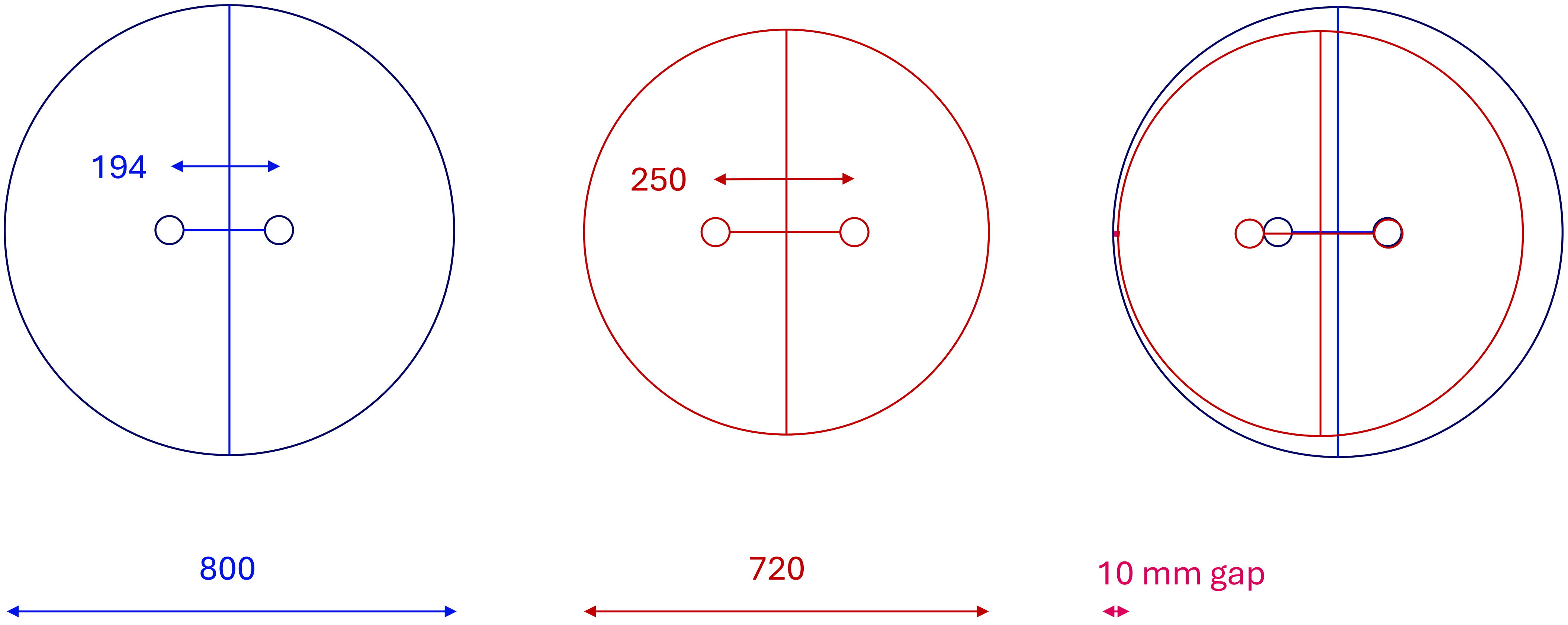
SM-18, 15 kA IGBT based PS on the Cluster D

- Protection with varistor with Vmax of 1 kV



STEAM-LEDET, E. Ravaioli

Cluster D: 800 mm and intrabeam of 194 mm
SMACC1: 720 mm and intrabeam of 250 mm



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SMACC 13 T Cable need overview

Total cable need for a 0.5 m straight section SMACC 13 T

No spare coils considered in the table bellow

<table>
<tr><th>Layer</th><th>N turns</th><th>N Strands per turn</th><th>Average turn length in m</th><th>cable length per layer</th><th>Total cable length per type</th></tr>
<tr><td>1</td><td>9</td><td>21 (DEM-1.1)</td><td>1.6</td><td>15</td><td rowspan="2">170</td></tr>
<tr><td>2</td><td>38</td><td>21 DEM-1.1)</td><td>1.8</td><td>70</td></tr>
<tr><td>3</td><td>50</td><td>34 (ERMC-0.7)</td><td>1.8</td><td>90</td><td rowspan="2">360</td></tr>
<tr><td>4</td><td>50</td><td>34 (ERMC-0.7)</td><td>1.8</td><td>90</td></tr>
</table>

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R&D Activities

Ongoing

HTS-based splicing between layers for SMACC

PSI / University of Twente Compression BOX using the SMACC 13 T / high-field cable

Preparation of samples for B-H curve measurement in cryogenics temperature with CERN

Cable trials using the SMACC 13 T / high-field cable

Filled Wax impregnation trials (PSI 4-stack) using the SMACC 13 T / high-field cable

Axial Pre-load System using commercial Bolt Tensioners

To start soon

Development of a setup to pressurize the bladders

Cable trials using the SMACC 13 T low-field cable (shipment pending)

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Version: June, 2024		… Aug 2024	Sep Oct 2024	Nov Dec 2024	Jan Feb 2025	Mar Apr 2025	May Jun 2025	Jul Aug 2025	Sep Oct 2025	Nov Dec 2025
Concept	Finished conceptual design and review									
Design	Preliminar eng. design									
	Formers and winding, reaction and impregnation toolings design			Procurement						
	Magnet and integration design				Procurement					
Coil fabrication and instrumentation	2 x Coil 1									
	2 x Coil 2									
	4 x Coil 3 / 4									
	Intra-layers splicing and coil packs assembly									
Assembly validation	Structure instrumentation									
	Bladders & Key, axial pre-load				Procurement					
	Cooling-down with dummy coils					Procurement				
Final assembly	Magnet assembly, pre-load, checks and shipment to CERN									
Testing	Cryostat integration and testing									