Update on
Muon Collider Target Magnets Layout

13 May 2025

A. Portone, J. Lorenzo, P. Testoni

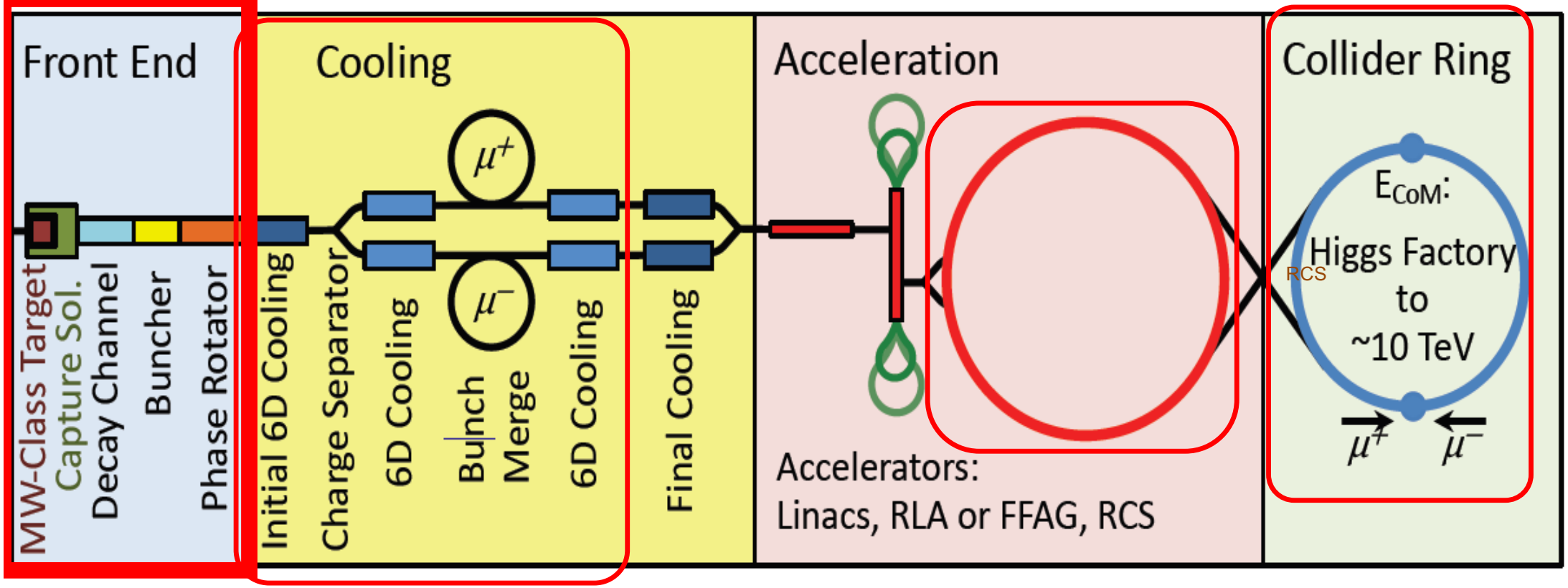
Outline

- Recall Dec23 baseline design layout
- May 2025 magnets design layout
  - Target coils
  - Chicane coils
- Conclusions

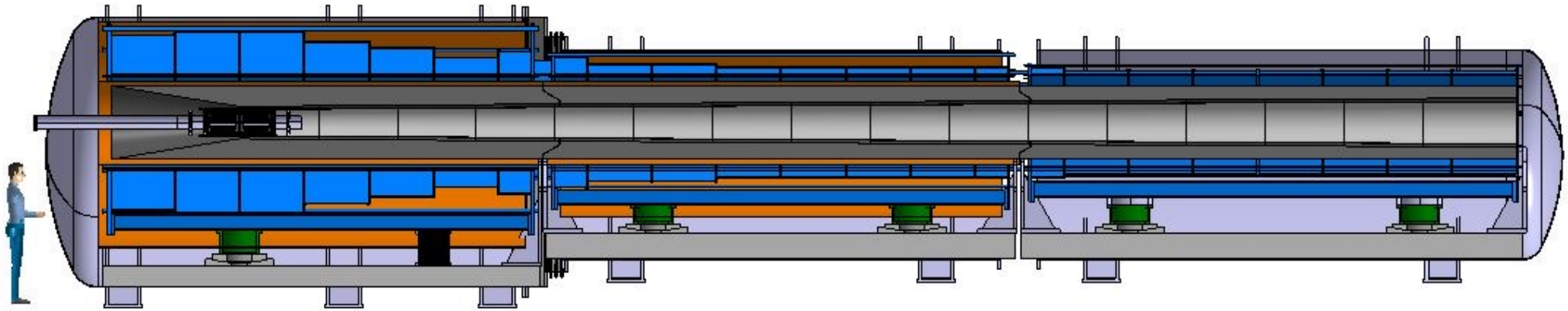
Muon Collider target magnets "specs"

Target solenoids: 2 T<B<20 T, ∅≥ 1.2 m, L ≅ 18 m

(B-profile as per H. K. Sayed and J. S. Berg, 2014)



Muon Collider target magnets assembly



IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 34, NO. 5, AUGUST 2024 4101705

Conceptual Design of a Target and Capture Channel for a Muon Collider

C. Accettura, L. Bottura, M. Calviani, D. Calzolari, R. Franqueira Ximenes, A. Kolehmainen, A. Lechner, J. Lorenzo Gomez, A. Portone, F. J. Saura Esteban, and P. Testoni

Design point: December 2023

FUSION FOR ENERGY

REPORT

REPORT

ON

PRELIMINARY STUDY OF THE MUON COLLIDER

TARGET AND CAPTURE MAGNETS

Abstract

This document summarizes the preliminary magnetic design and structural analyses carried out at Fusion for Energy for the Muon Collider project.

idm@F4E Reference:	F4E_D_35MBYQ v2.2	**Contract/GA**	2011-NN
ITER PA/ITA Reference			
Subject:	*Solenoid Design for Muon Collider*		

Prepared by	Reviewed by	Approved by	---
Name & Affiliation José Lorenzo Alfredo Portone Pietro Testoni Date: 17/12/2023	Name & Affiliation Francesca Cau Boris Bellesia	Name & Affiliation P.Y. Chaffard	

(F4E review and approval is performed and recorded in idm@F4E)

F4E_D_35MBYQ - Conceptual magnetic design for the IMCC Target Magnets

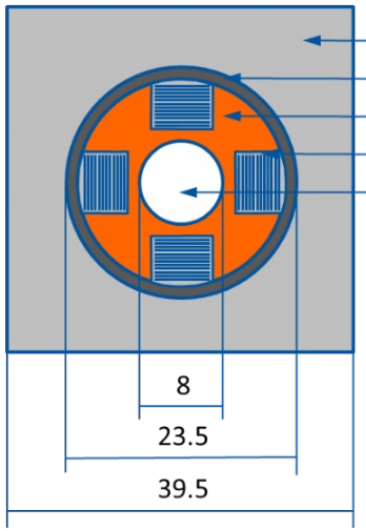
F4E_D_35MBYQ v2.2 - REPORT Page 1/50

Common building block for all solenoid coils: VIPER-like HTS conductor

MIT "VIPER" conductor

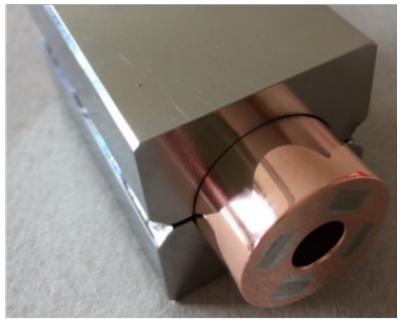
M. Takayasu et al., IEEE TAS, 21 (2011) 2340
Z. S. Hartwig et al., SUST, 33 (2020) 11LT01

HTS conductor design

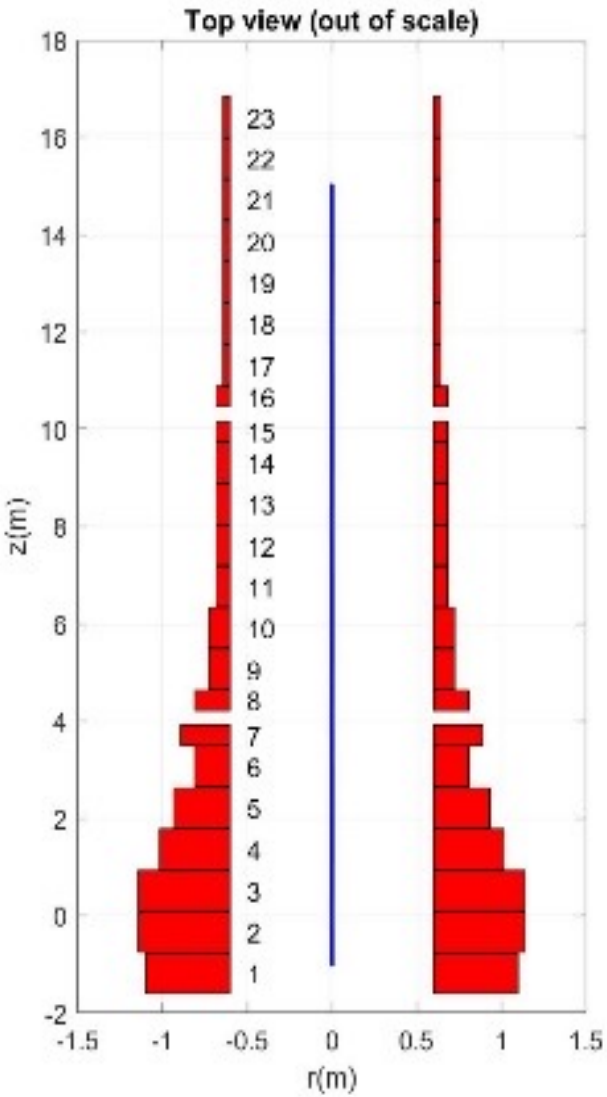


Operating current: 58 kA
Operating field: 20 T
Operating temperature: 20 K

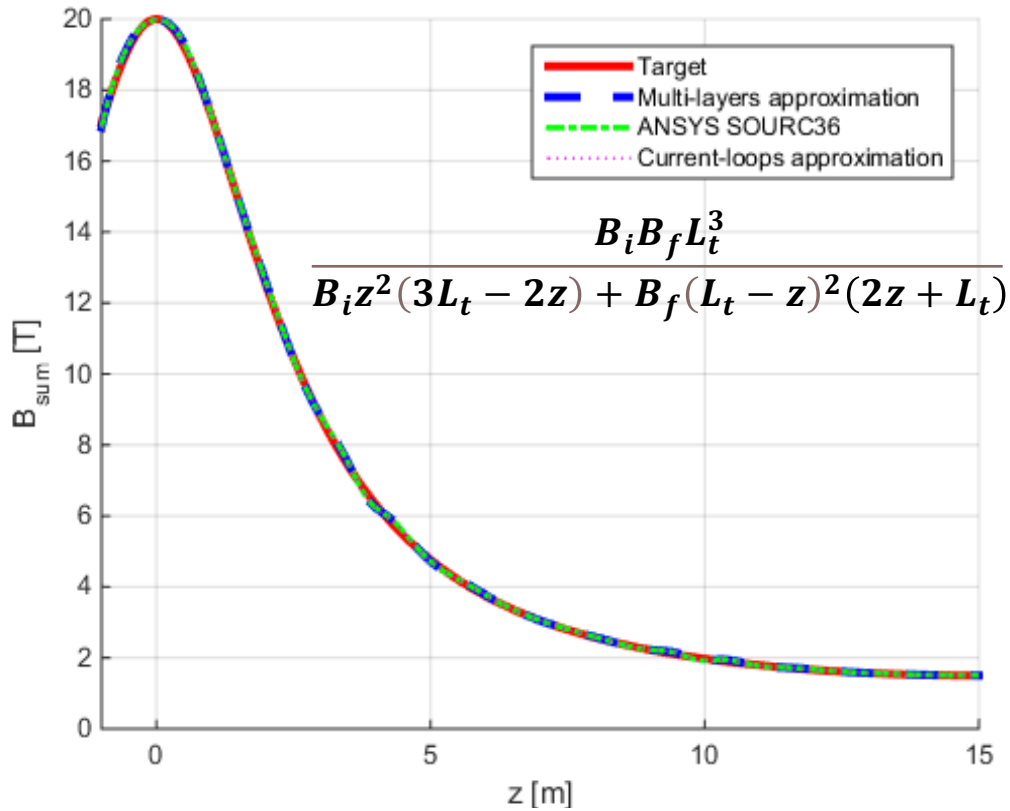
- STAINLESS STEEL JACKET
- STAINLESS STEEL WRAP
- COPPER FORMER
- SOLDERED HTS STACK
- COOLING CHANNEL



Design point: December 2023

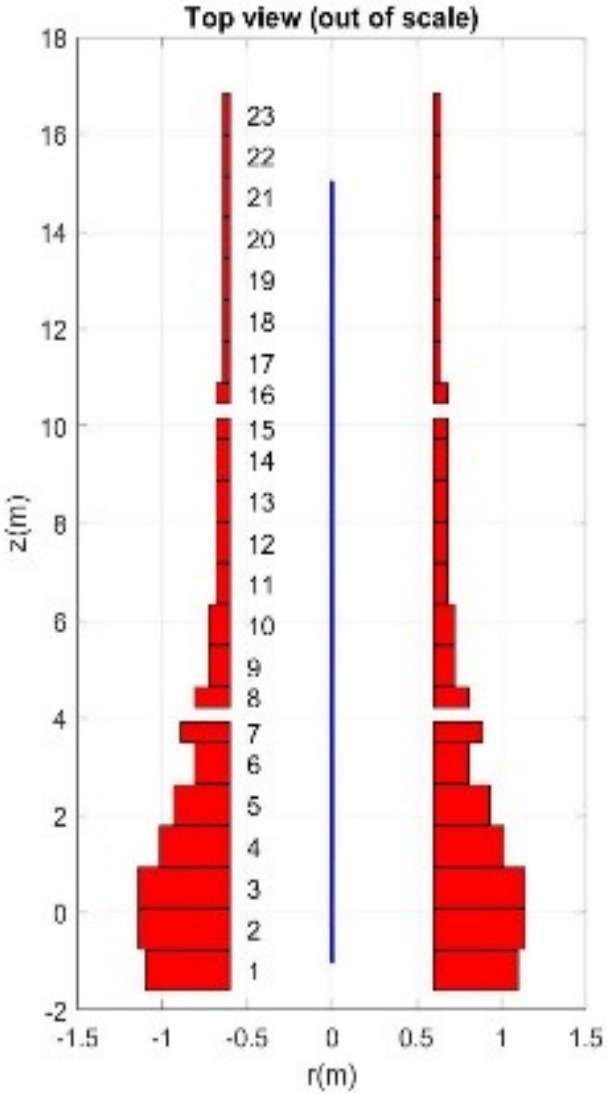


- Magnets channel bore = 1.2 m diameter
- 23 solenoidal coils, 3 sections, ≅ 5.5 m long each, 0.3 m gaps between sections
- Magnetic energy ≅ 1.1 GJ, VIPER cable ≅ 8.75 km, ≅ 30.2 t, steel jacket ≅ 79 t
- Good fitting of Sayed-Berg profile |δB/B|≅3.8%, |δB|≅0.18 T on 16 m channel
- No cumulative repulsive axial forces among solenoids



$$\frac{B_i B_f L_t^3}{B_i z^2 (3L_t - 2z) + B_f (L_t - z)^2 (2z + L_t)}$$

Design point: December 2023



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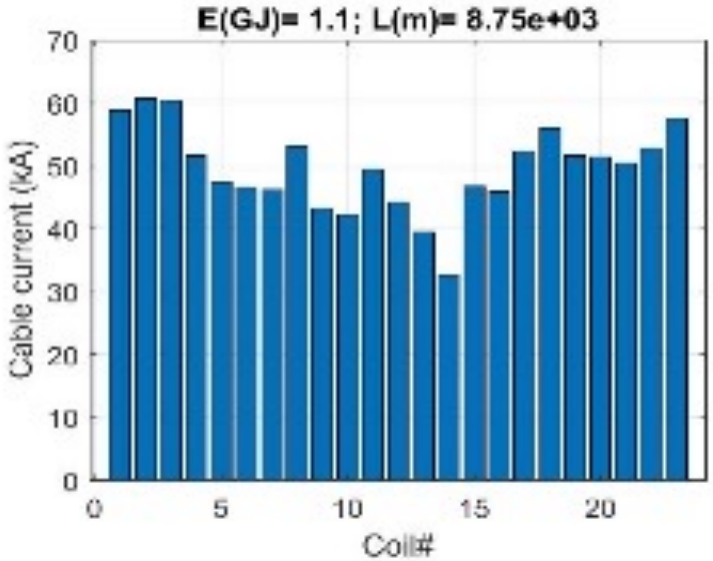
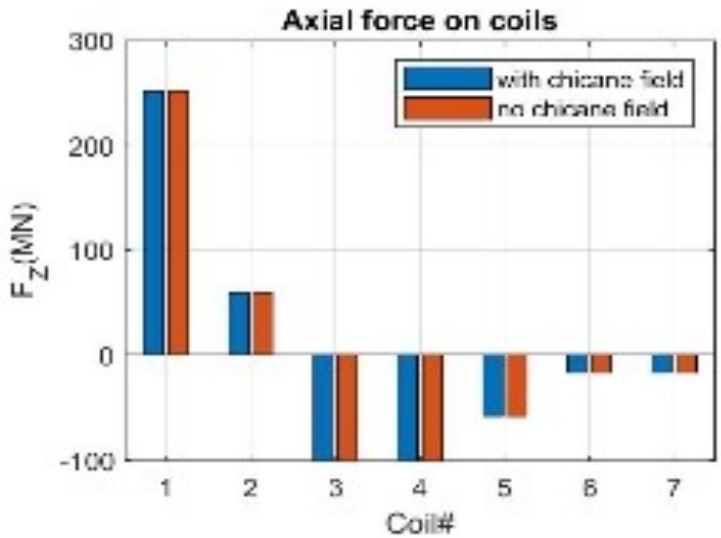
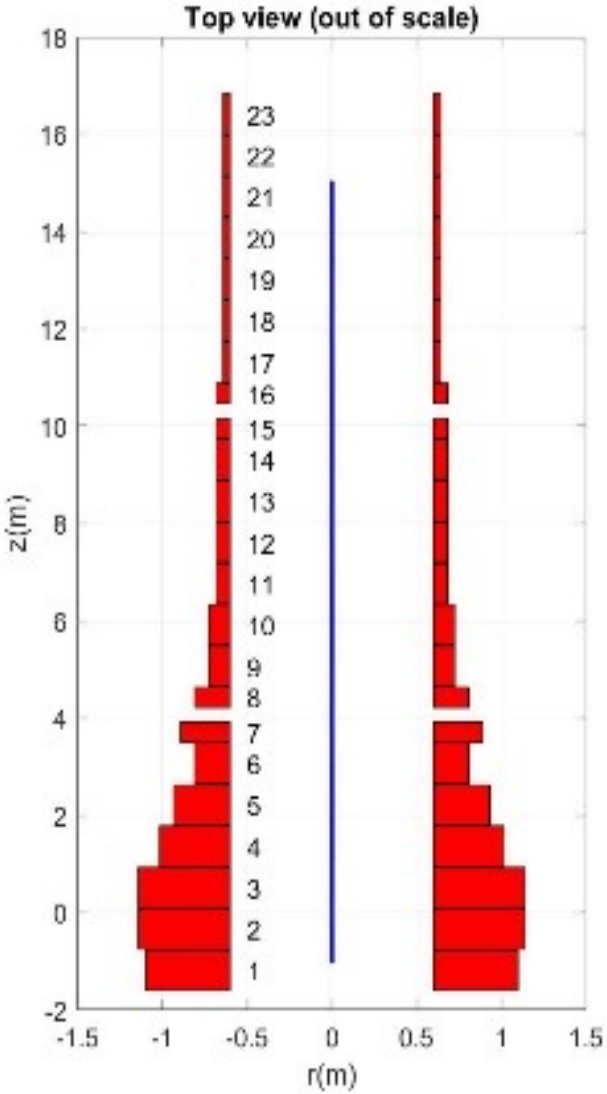




Design point: December 2023



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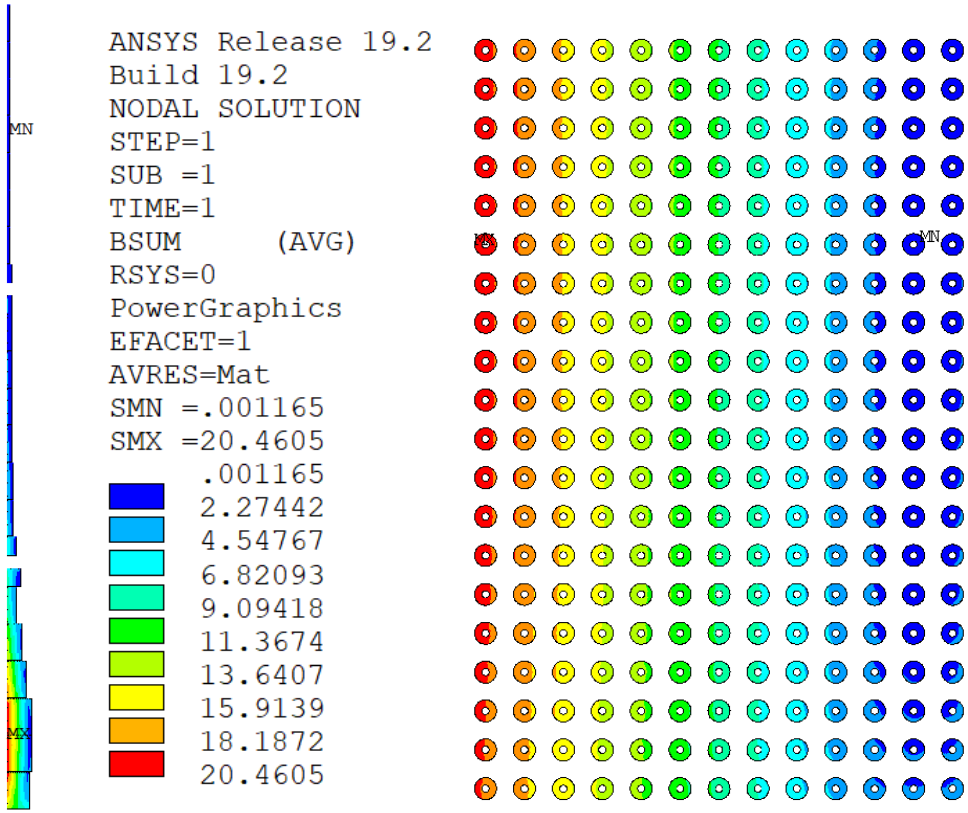

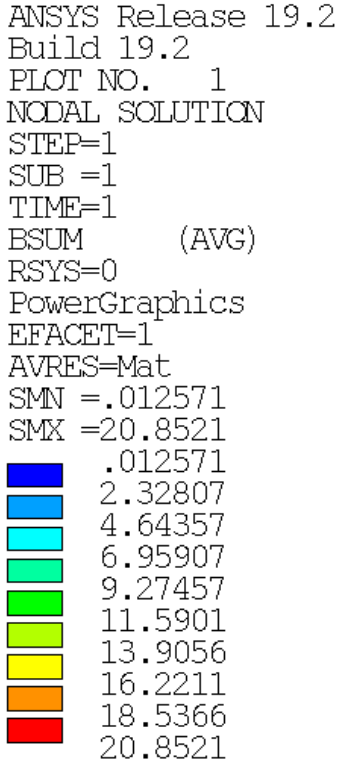

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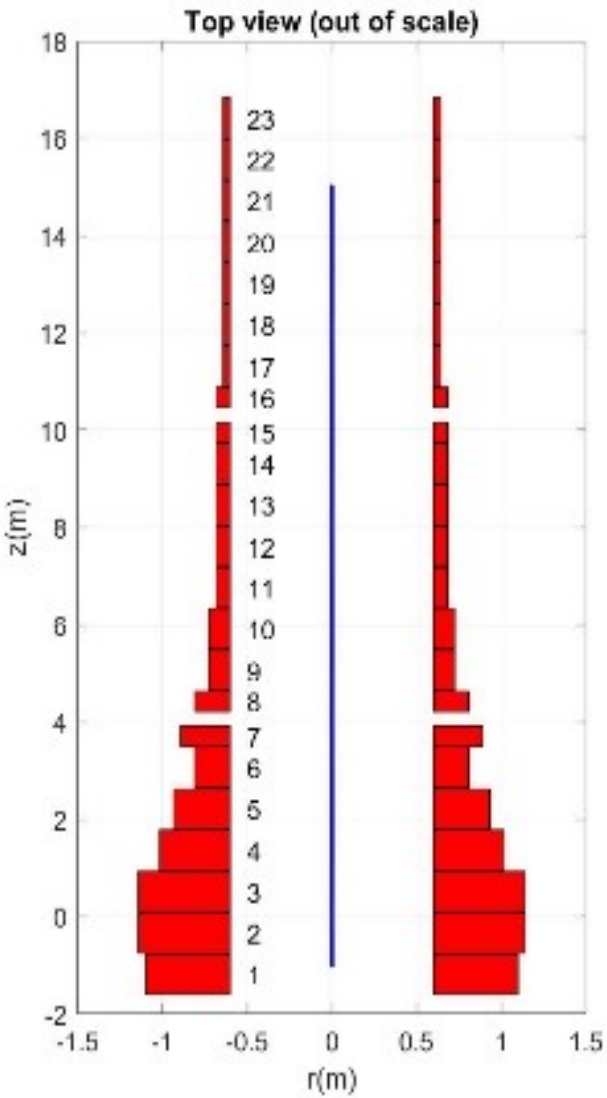

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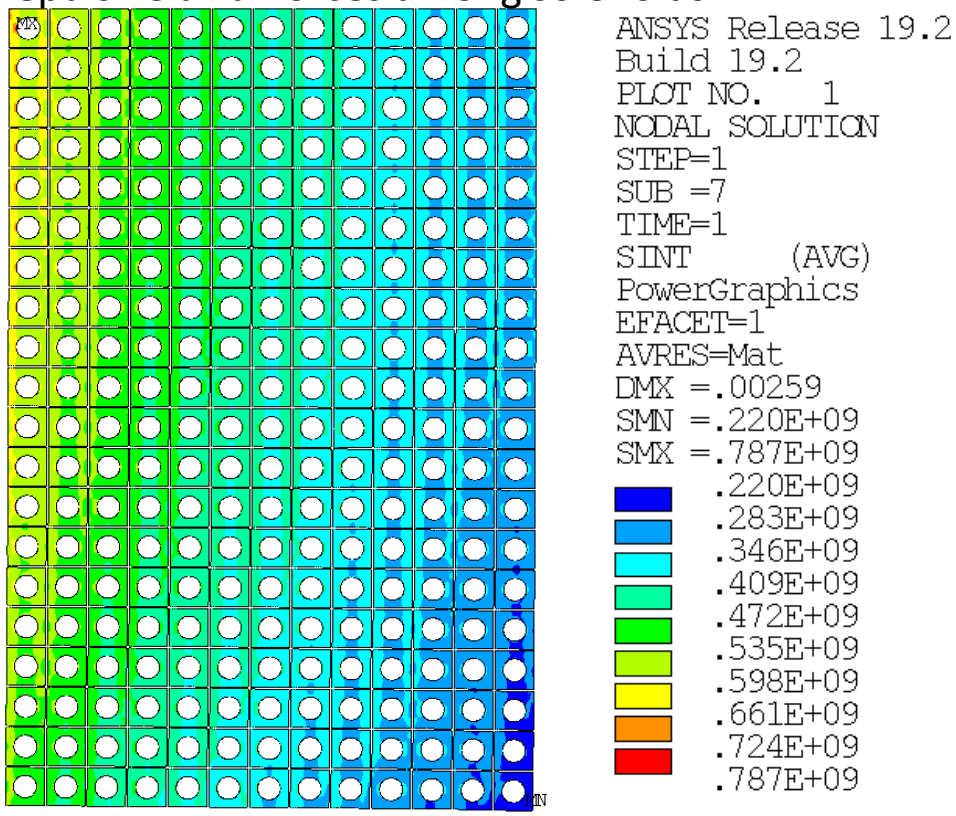
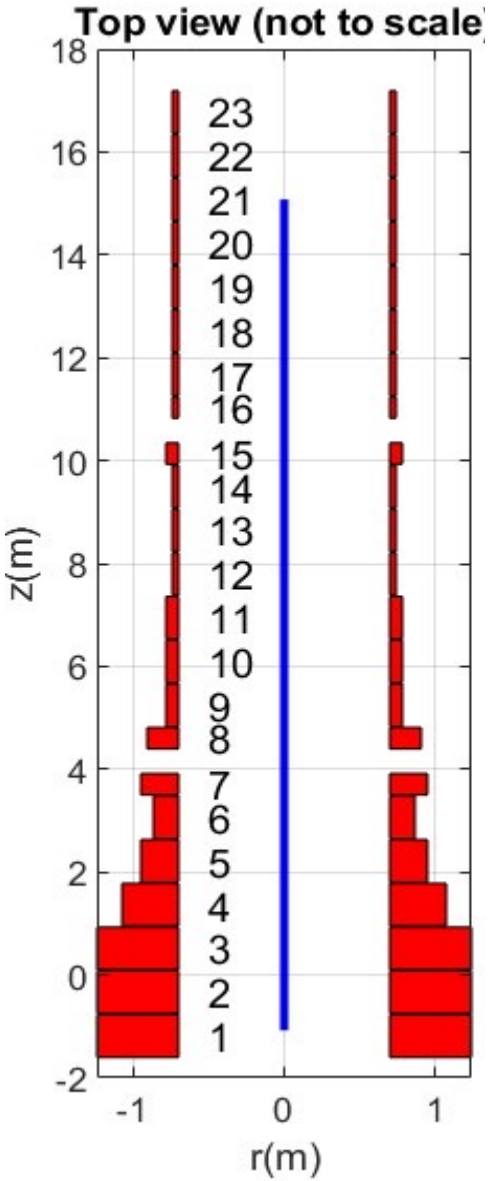


Design issues

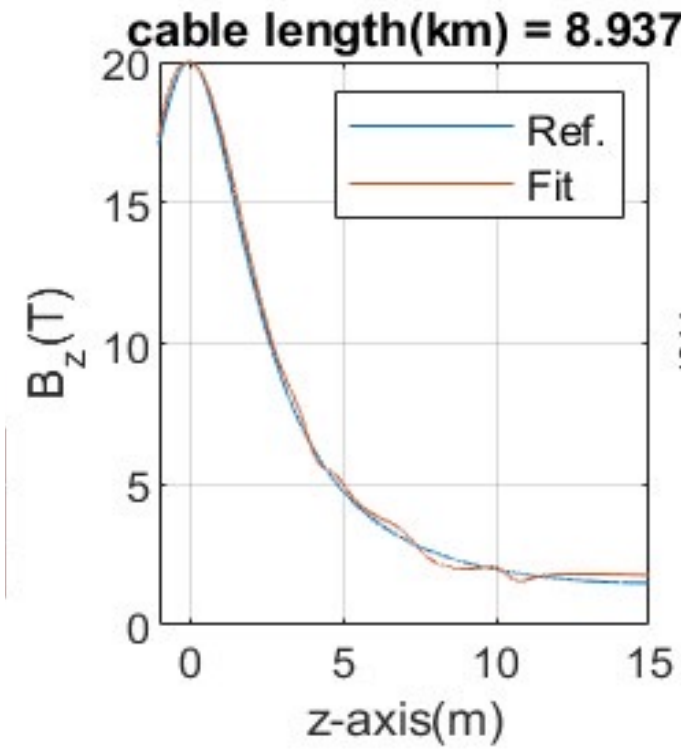
Main Issues:

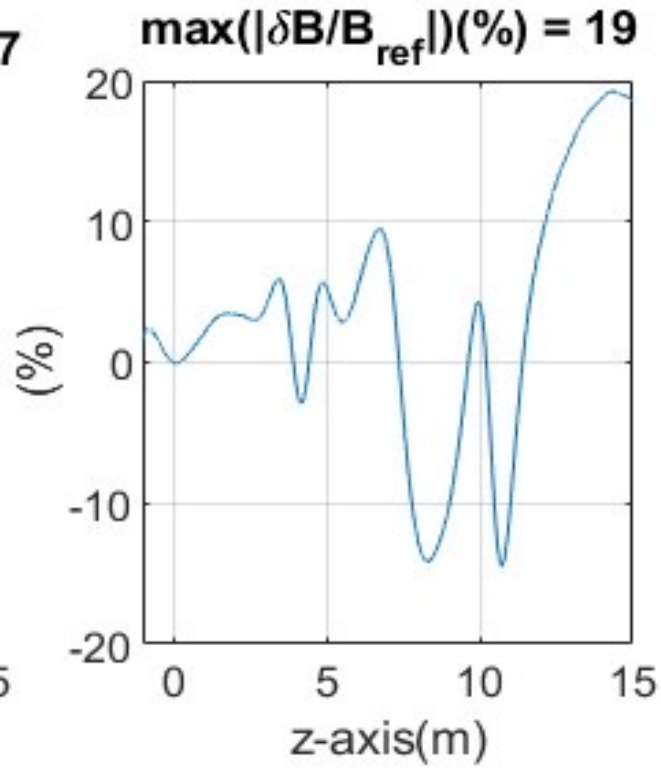
- Increase space between sections for mechanical structure (→ gaps = 480 mm)
- Increase coils shielding in (high field) collision region (→ bore diameter > 1.3 m)
- Reduce coils power supply cost/complexity (→ all coils currents I ≅ 60 kA)
- Assess impact on B_Z due to chicane coils current
- Define beam extraction path from target region channel (pending)

Design evolution: May 2025



- **ALL COILS CURRENT = 61.15 kA**
- All coils inner bore **1.4 m** and **0.48 m** gaps between sections
- 23 solenoidal coils, 3 sections, ≅ 5.5 m long each
- Magnetic energy **≅ 1.48 GJ**, VIPER cable ≅ **9 km**
- Fair fitting of Sayed-Berg profile |δB/B|≅**20%**, |δB|≅**0.5 T**





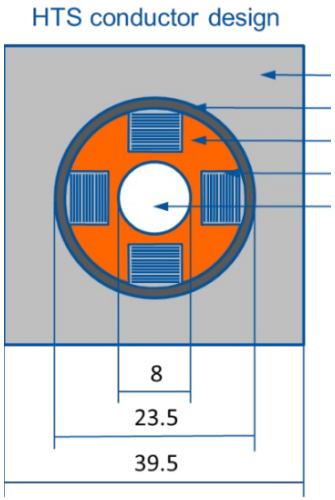
Design evolution: May 2025

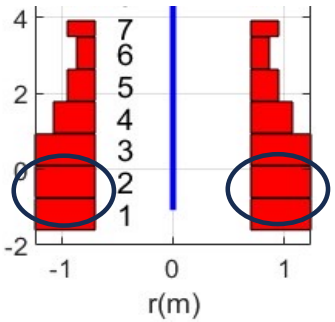
- Cable diameter = 23.5 mm, cooling channel diameter = 8 mm
- Square conductor jacket = 39.5 mm
- Insulated conductor jacket = 41.5 mm
- Smeared cable inside the jacket with E=100 GPa

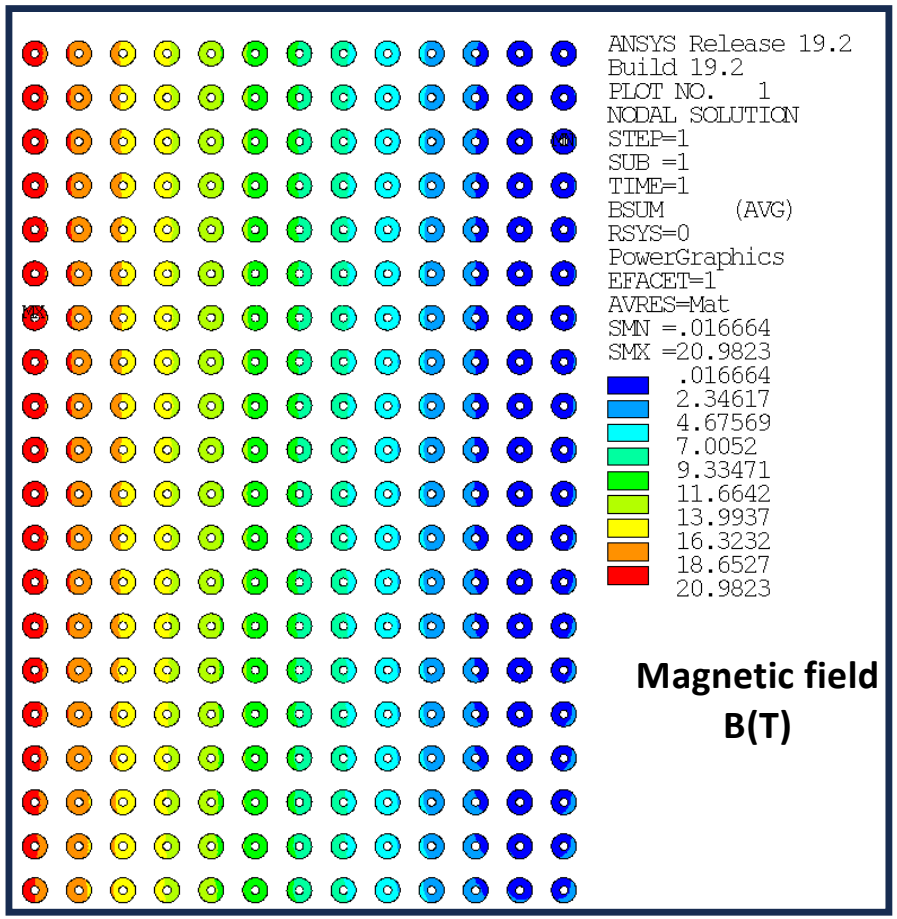
Coil # 2 most critical

Pm = 730 MPa > 660 MPa

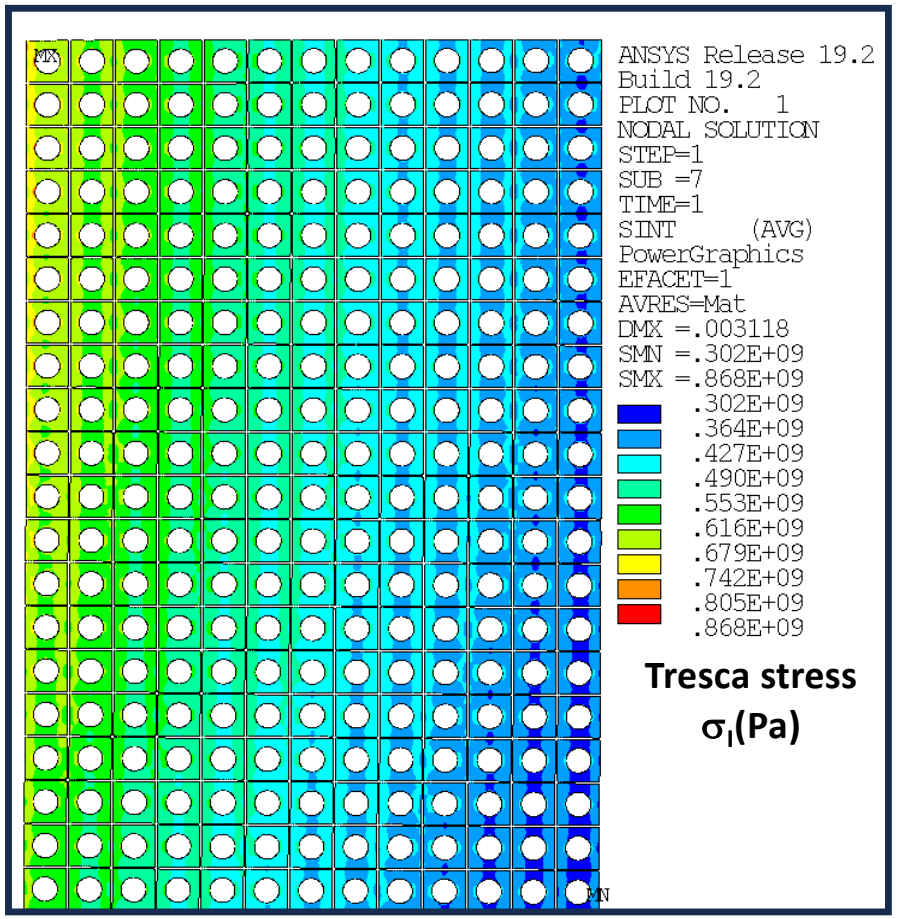
Pm + Pb = 820 MPa < 867 MPa





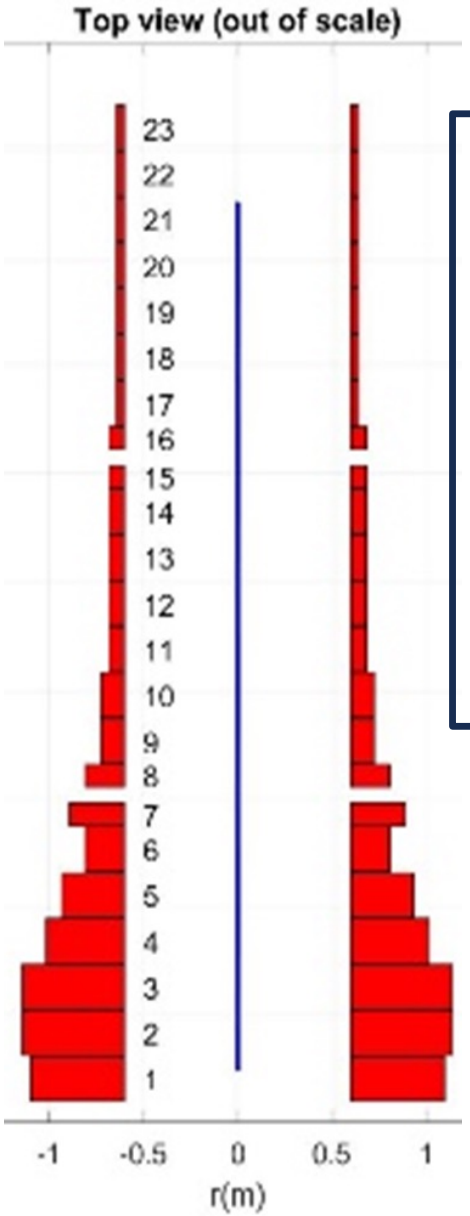


Magnetic field B(T)

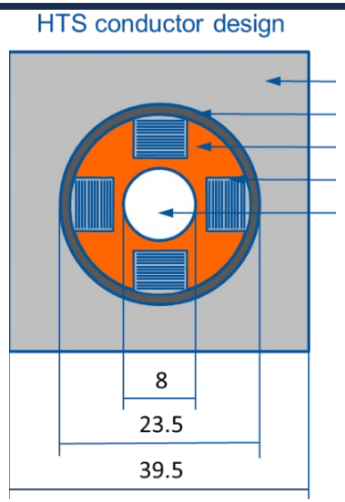


Tresca stress σ_I(Pa)

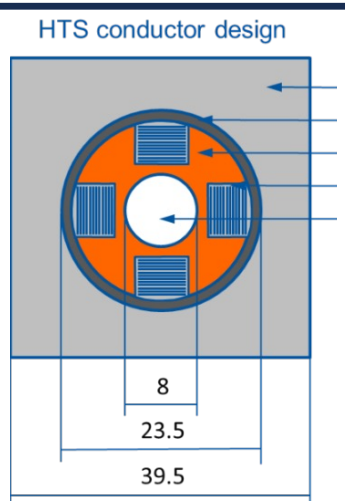
Design evolution: May 2025

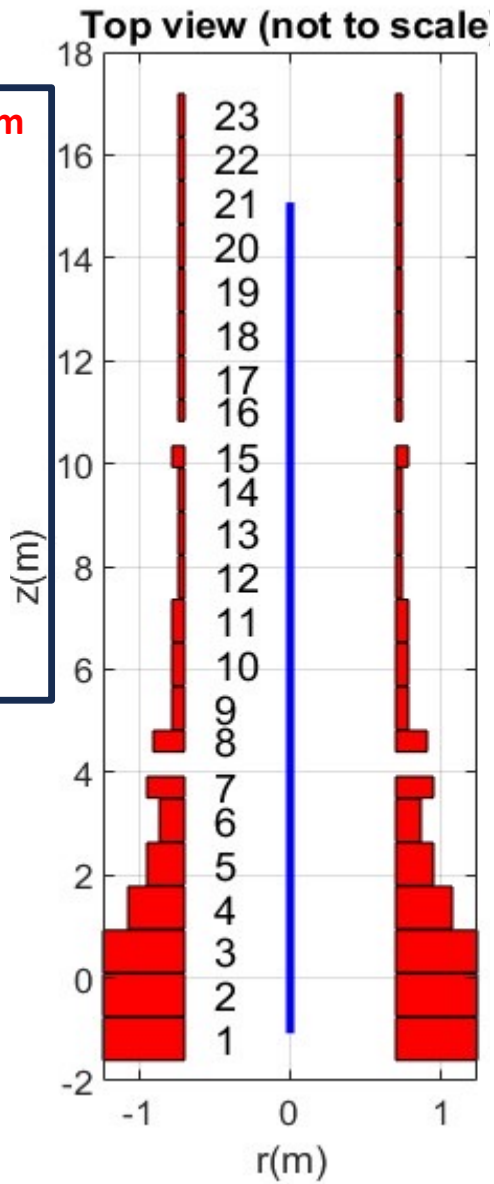


- Magnets bore diameter= 1.2 m
- 23 solenoidal coils
- 3 sections, ≅ 5.5 m long each
- 16 m channel z-profile
- 0.30 m gaps between sections
- Magnetic energy ≅ 1.1 GJ
- VIPER cable ≅ 8.8 km, ≅ 30.2 t, steel jacket ≅ 79 t
- Good fitting Sayed-Berg profile $|\delta B/B| \cong 3.8\%$, $|\delta B| \cong 0.18$ T
- No axial repulsive forces
- 32 kA $< I_k <$ 61 kA, k=1,2,…,23



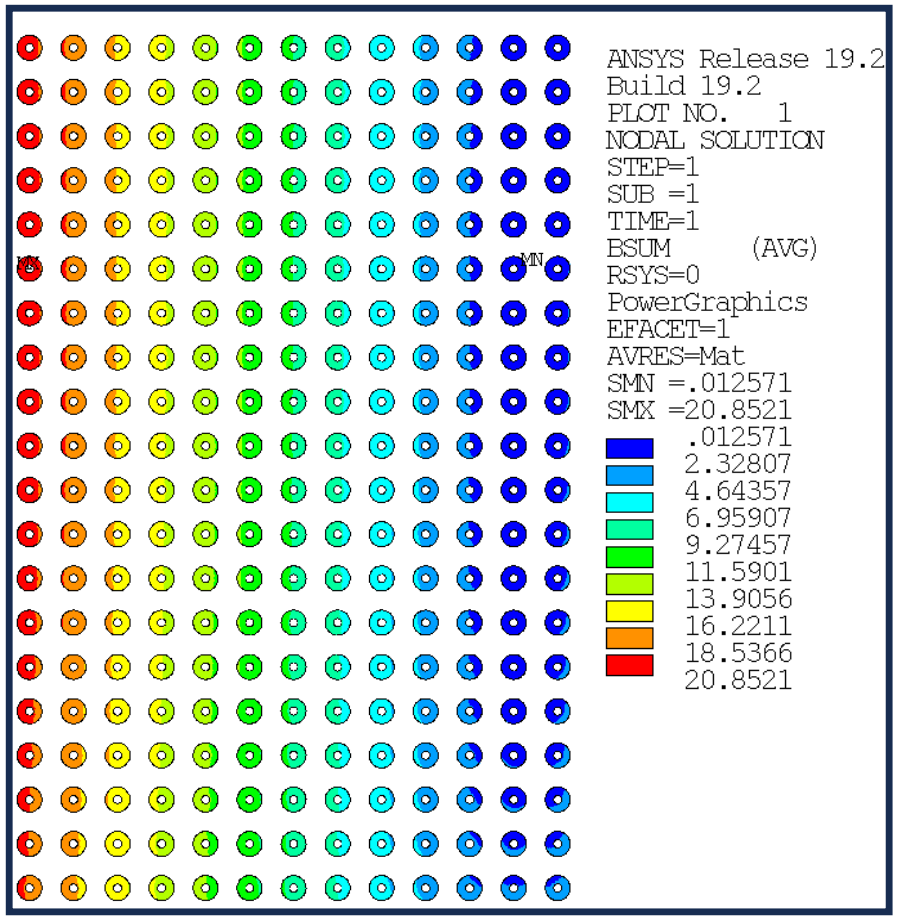
- **Magnets bore diameter = 1.4 m**
- 23 solenoidal coils
- 3 sections, ≅ 5.5 m long each
- 16 m channel z-profile
- **0.48 m gaps between sections**
- **Magnetic energy ≅ 1.48 GJ**
- **VIPER cable ≅ 9 km, ≅ 30.9 t**
- **Steel jacket ≅ 81 t**
- **Fair fitting Sayed-Berg profile $|\delta B/B| \cong 19\%$, $|\delta B| \cong 0.5$ T**
- No axial repulsive forces
- **I_k = 61.15 kA, k=1,2,…,23**





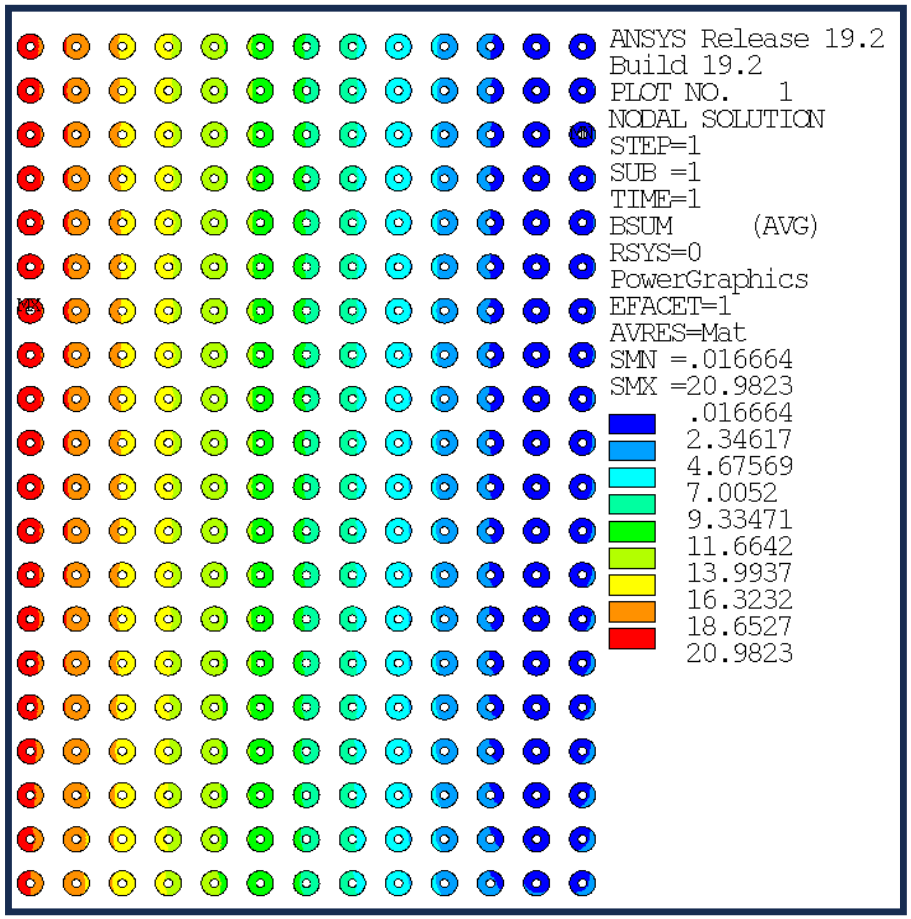
Design evolution: May 2025

DEC. 2023



Magnetic field B(T)

MAY 2025



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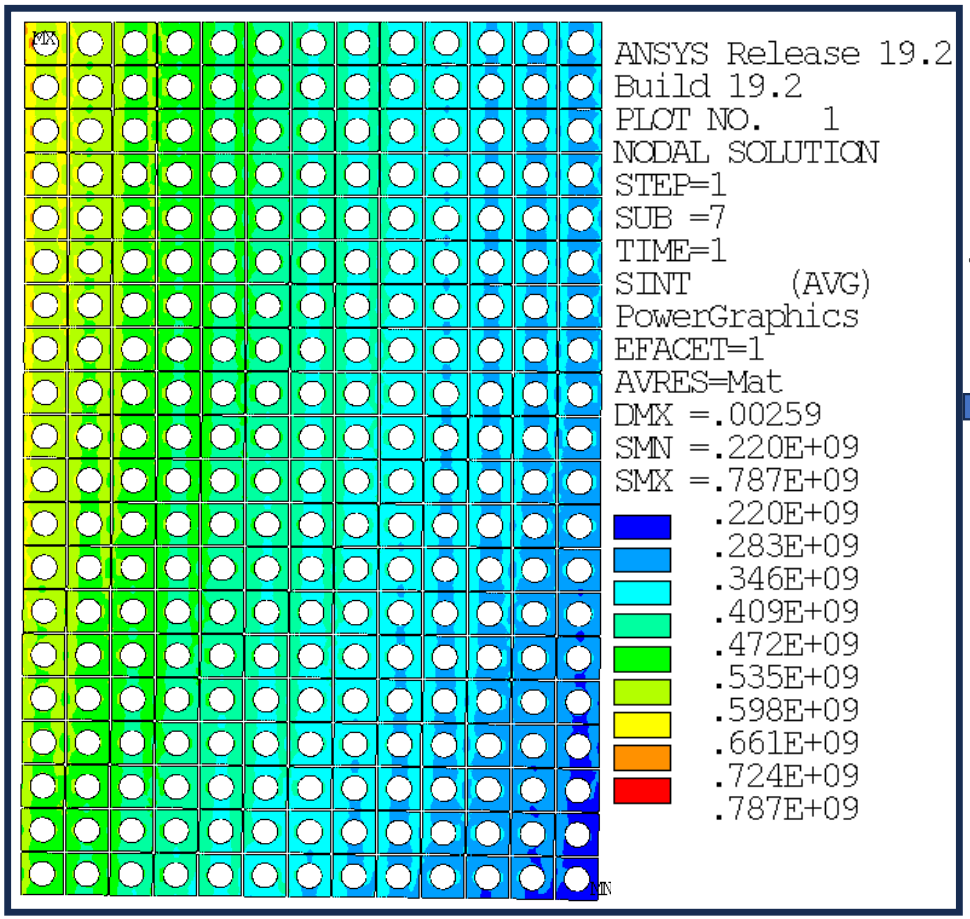
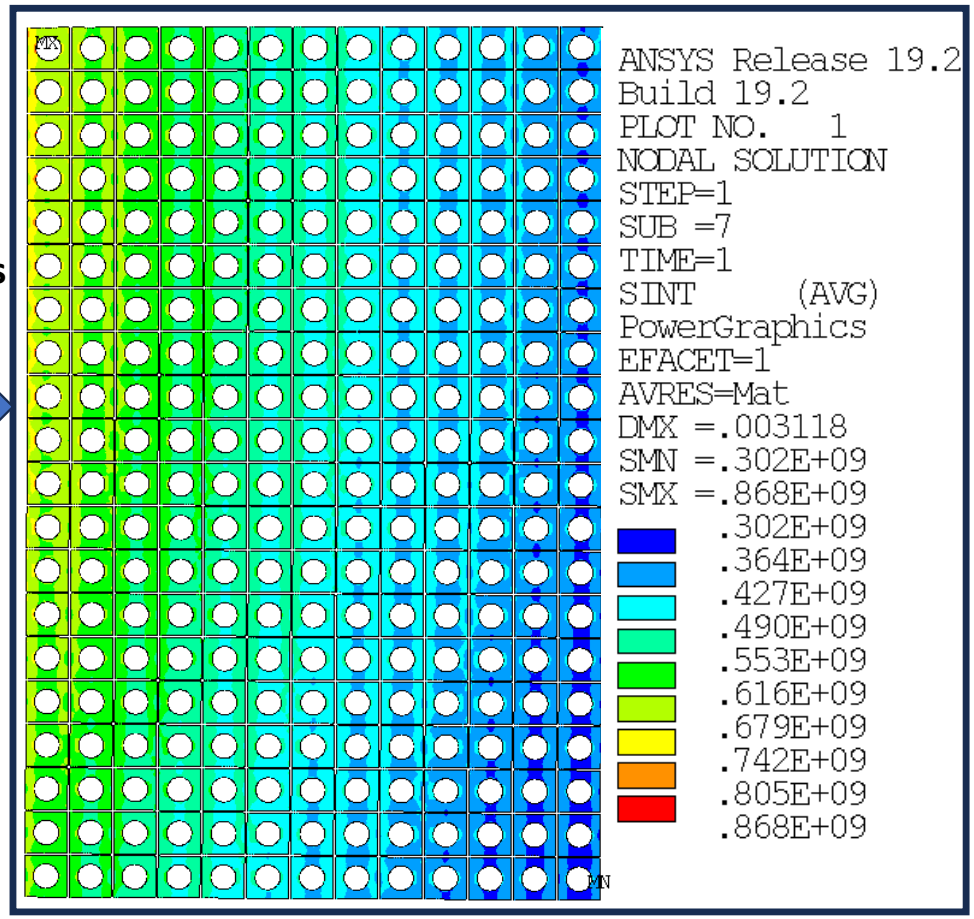


Tresca stress
σ_I(Pa)

MAY 2025



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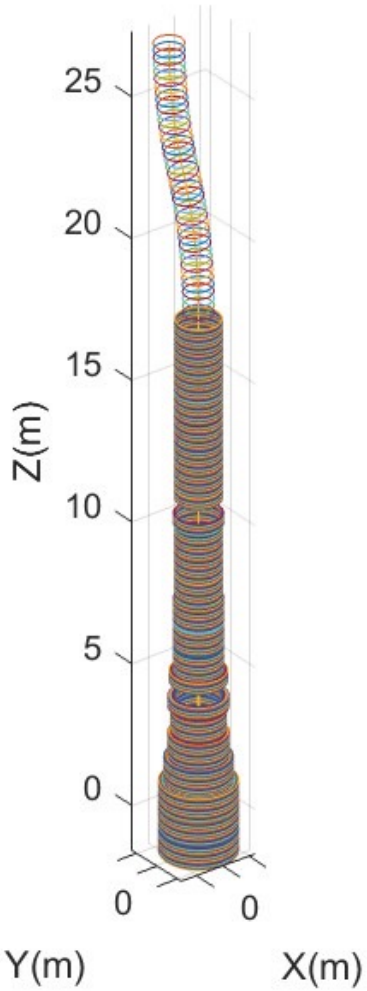

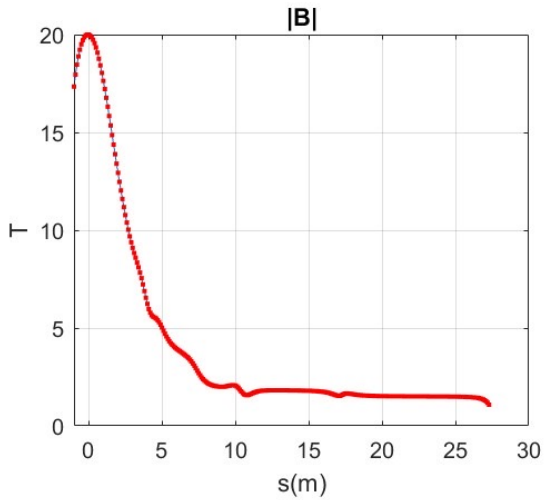

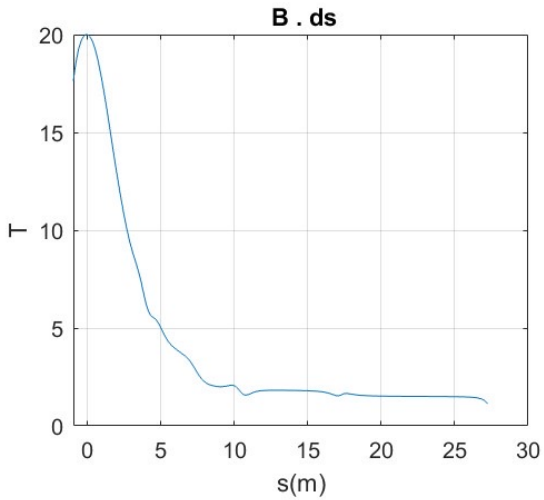

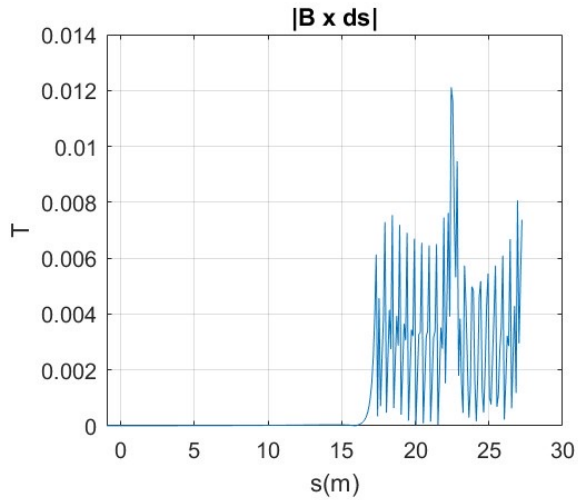

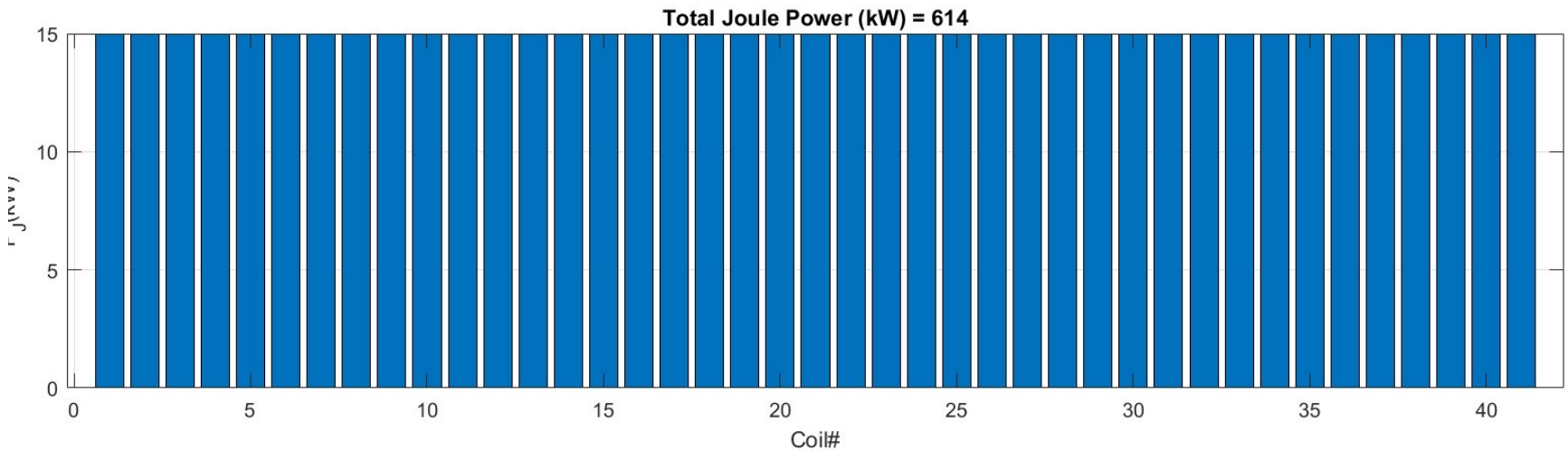

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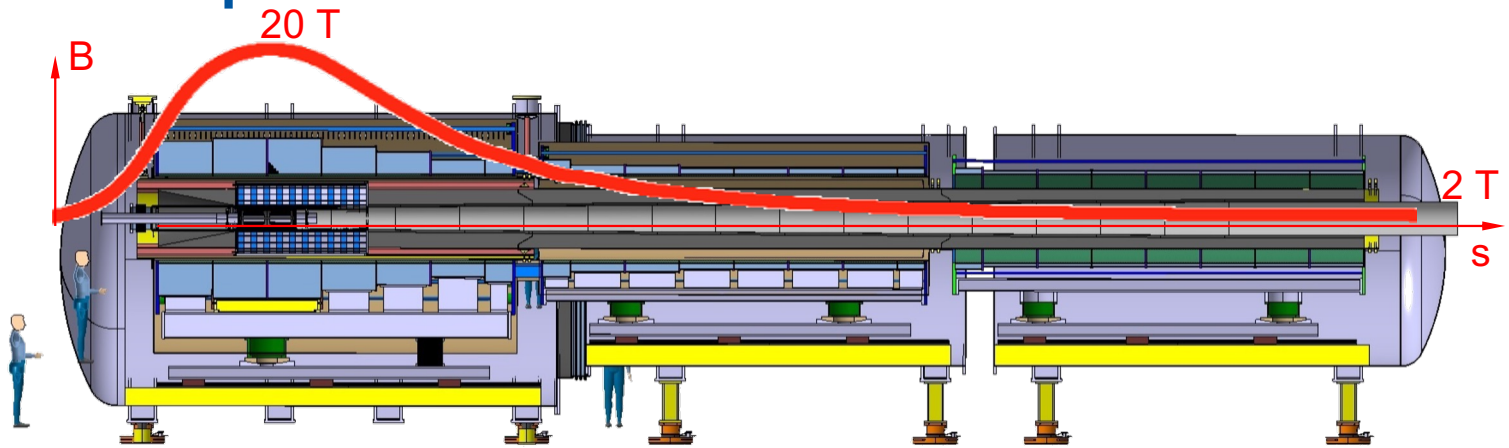
- ✓ Reduce coils power supply cost/complexity (→ all coils current **I ≅ 61 kA**)
- ✓ Assess impact on B_Z due to chicane coils current (→ old chicane design: $\delta B/B \cong$ **0.5 %**)
- × Define beam extraction path from target region channel (pending)

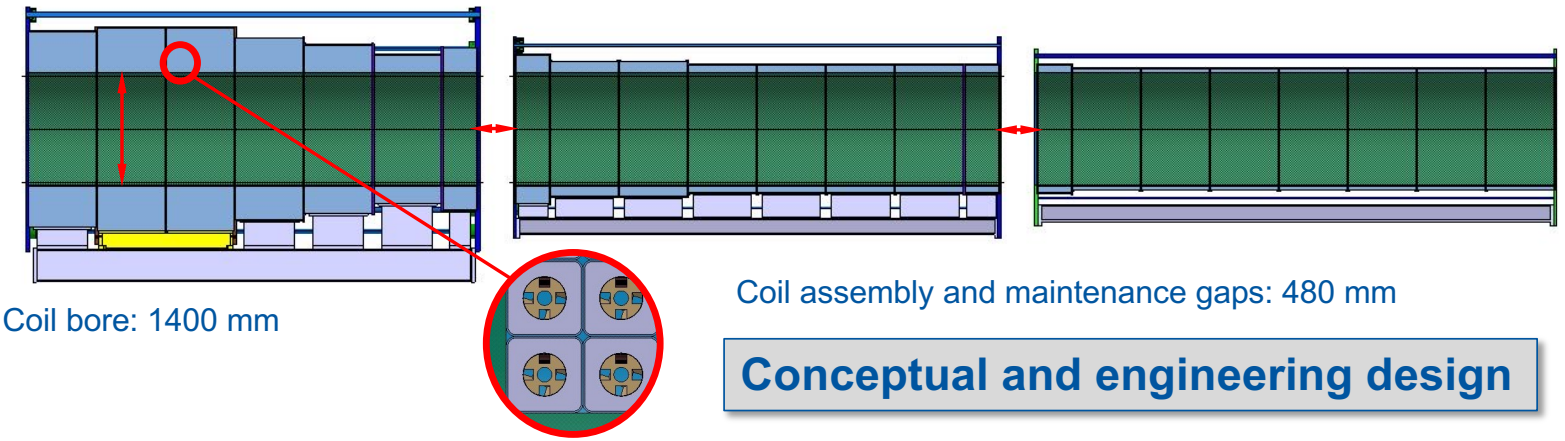
Target and capture



Coils: 100 t
Steel work: 12 t

Coils: 26 t
Steel work: 6 t

Coils: 14 t
Steel work: 4 t

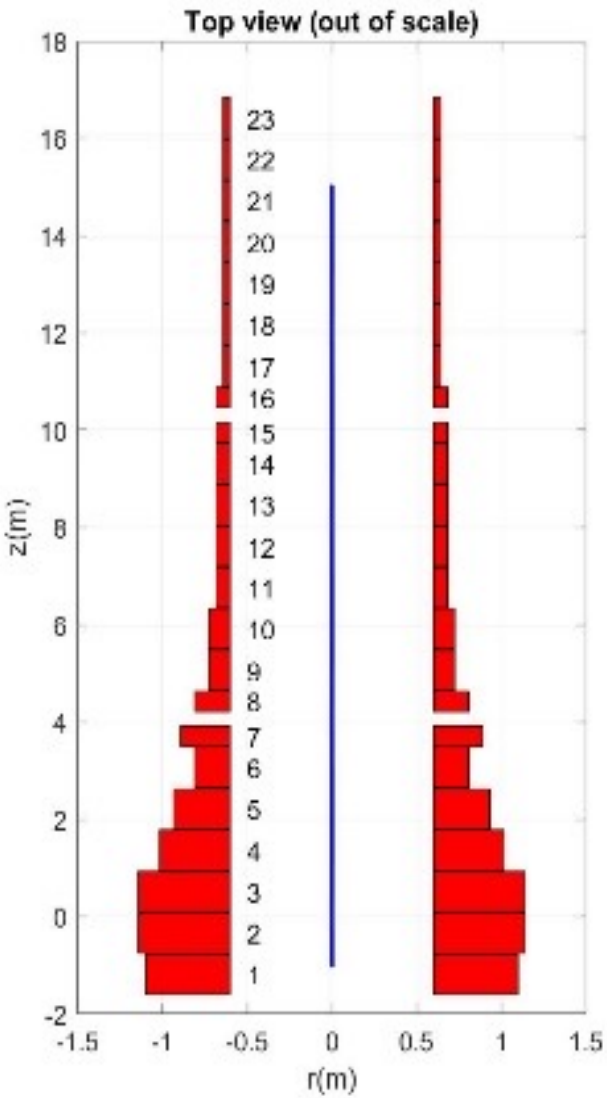


Coil bore: 1400 mm

Coil assembly and maintenance gaps: 480 mm

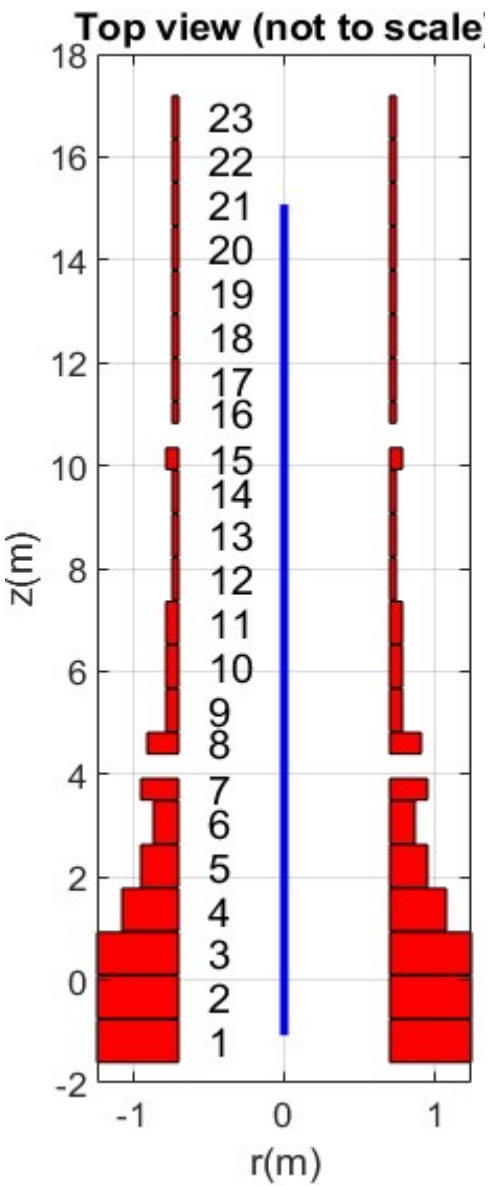
Conceptual and engineering design

Design point: December 2023



Coil	Rc [m]	Zc [m]	DR [m]	DZ [m]	N_R	N_Z	I [A]	It [MAt]
1	0.849	-1.185	0.498	0.830	12	20	58905	14.137
2	0.870	-0.335	0.540	0.830	13	20	60710	15.785
3	0.870	0.515	0.540	0.830	13	20	60392	15.702
4	0.808	1.365	0.415	0.830	10	20	51654	10.331
5	0.766	2.215	0.332	0.830	8	20	47469	7.595
6	0.704	3.065	0.208	0.830	5	20	46504	4.650
7	0.745	3.708	0.291	0.415	7	10	46293	3.240
8	0.704	4.423	0.208	0.415	5	10	53168	2.658
9	0.662	5.065	0.125	0.830	3	20	43280	2.597
10	0.662	5.915	0.125	0.830	3	20	42146	2.529
11	0.642	6.765	0.083	0.830	2	20	49452	1.978
12	0.642	7.615	0.083	0.830	2	20	44183	1.767
13	0.642	8.465	0.083	0.830	2	20	39567	1.583
14	0.642	9.315	0.083	0.830	2	20	32713	1.309
15	0.642	9.958	0.083	0.415	2	10	46717	0.934
16	0.642	10.673	0.083	0.415	2	10	45905	0.918
17	0.621	11.315	0.042	0.830	1	20	52310	1.046
18	0.621	12.165	0.042	0.830	1	20	56056	1.121
19	0.621	13.015	0.042	0.830	1	20	51602	1.032
20	0.621	13.865	0.042	0.830	1	20	51376	1.028
21	0.621	14.715	0.042	0.830	1	20	50471	1.009
22	0.621	15.565	0.042	0.830	1	20	52861	1.057
23	0.621	16.415	0.042	0.830	1	20	57438	1.149

Design evolution: May 2025



Coil	Rc [m]	Zc [m]	DR [m]	DZ [m]	N_R	N_Z	I [A]	It [MAt]
1	0.970	-1.185	0.540	0.830	13	20	61.15	15.899
2	0.970	-0.335	0.540	0.830	13	20	61.15	15.899
3	0.970	0.515	0.540	0.830	13	20	61.15	15.899
4	0.887	1.365	0.374	0.830	9	20	61.15	11.007
5	0.825	2.215	0.249	0.830	6	20	61.15	7.338
6	0.783	3.065	0.166	0.830	4	20	61.15	4.892
7	0.825	3.708	0.249	0.415	6	10	61.15	3.669
8	0.804	4.603	0.208	0.415	5	10	61.15	3.058
9	0.742	5.245	0.083	0.830	2	20	61.15	2.446
10	0.742	6.095	0.083	0.830	2	20	61.15	2.446
11	0.742	6.945	0.083	0.830	2	20	61.15	2.446
12	0.721	7.795	0.042	0.830	1	20	61.15	1.223
13	0.721	8.645	0.042	0.830	1	20	61.15	1.223
14	0.721	9.495	0.042	0.830	1	20	61.15	1.223
15	0.742	10.138	0.083	0.415	2	10	61.15	1.223
16	0.721	11.033	0.042	0.415	1	10	61.15	0.612
17	0.721	11.675	0.042	0.830	1	20	61.15	1.223
18	0.721	12.525	0.042	0.830	1	20	61.15	1.223
19	0.721	13.375	0.042	0.830	1	20	61.15	1.223
20	0.721	14.225	0.042	0.830	1	20	61.15	1.223
21	0.721	15.075	0.042	0.830	1	20	61.15	1.223
22	0.721	15.925	0.042	0.830	1	20	61.15	1.223
23	0.721	16.775	0.042	0.830	1	20	61.15	1.223