Italian National Agency for New Technologies,
Energy and Sustainable Economic Development

VNS TF coils

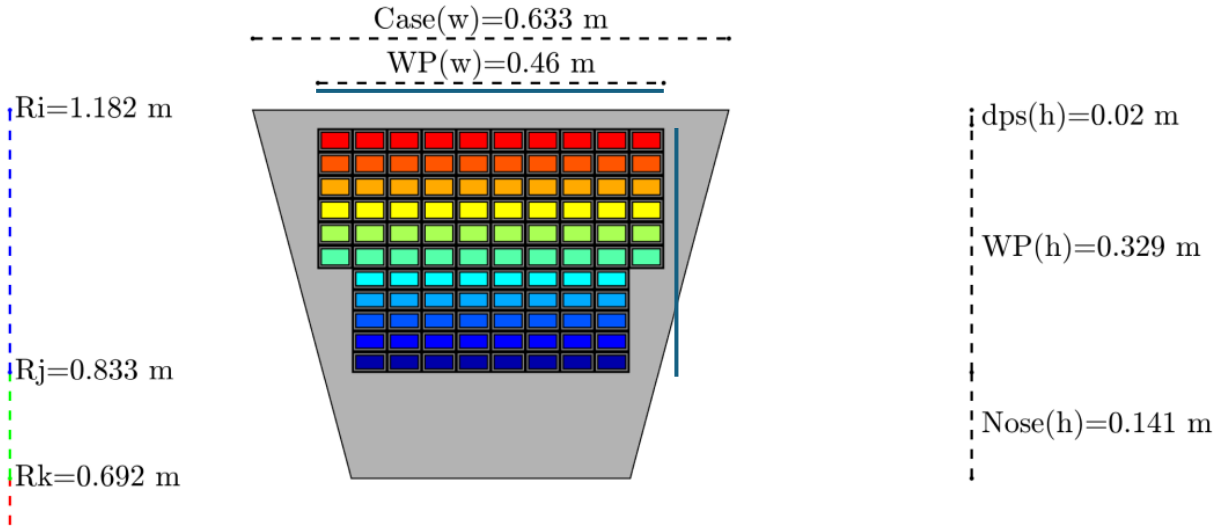
MAG-S.01.01-T032-D001: Feasibility studies for an alternative LTS solution

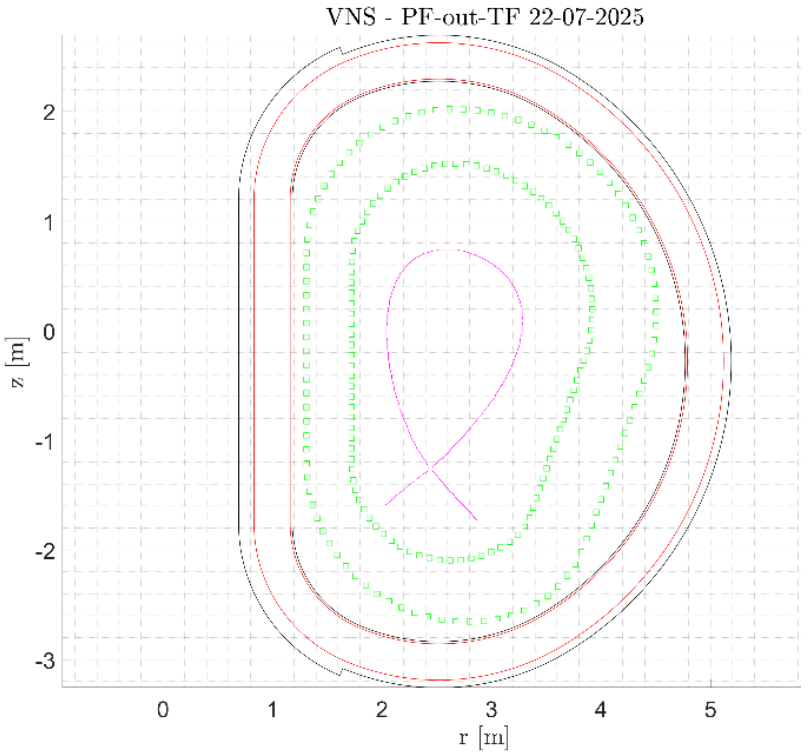
WPMAG EUROFusion Final meeting (2025)

January 14th, 2026 – EPFL-SPC Paul Scherrer Institut

Aldo Di Zenobio & Francesco Giorgetti

n grades=2, N=100 , Iop=62 kA, Sa(VT)=513 MPa, Sa(JT)=513 MPa, tau=4 s

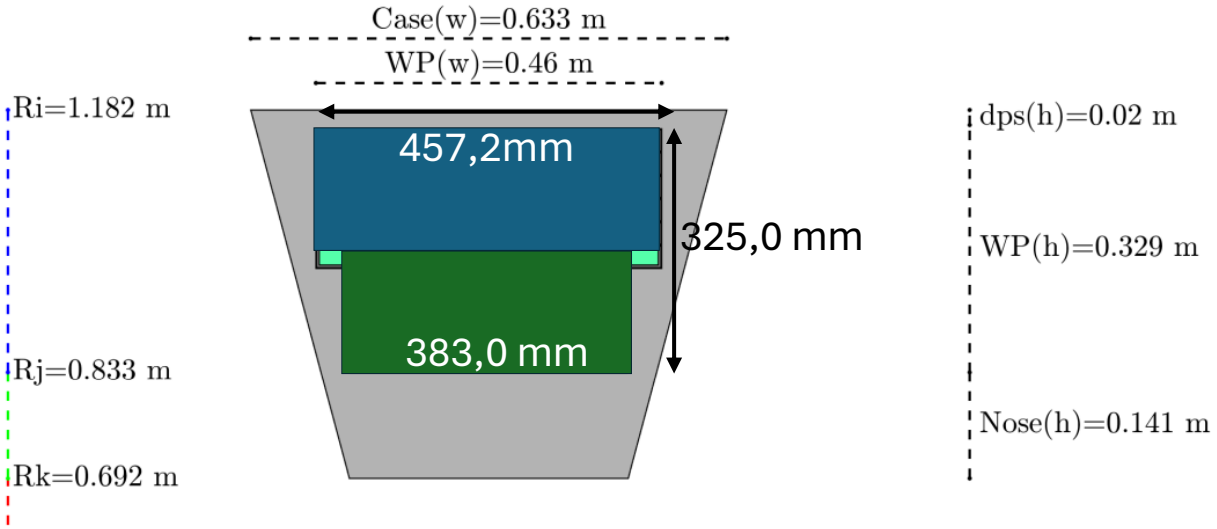




Inputs by L. Giannini

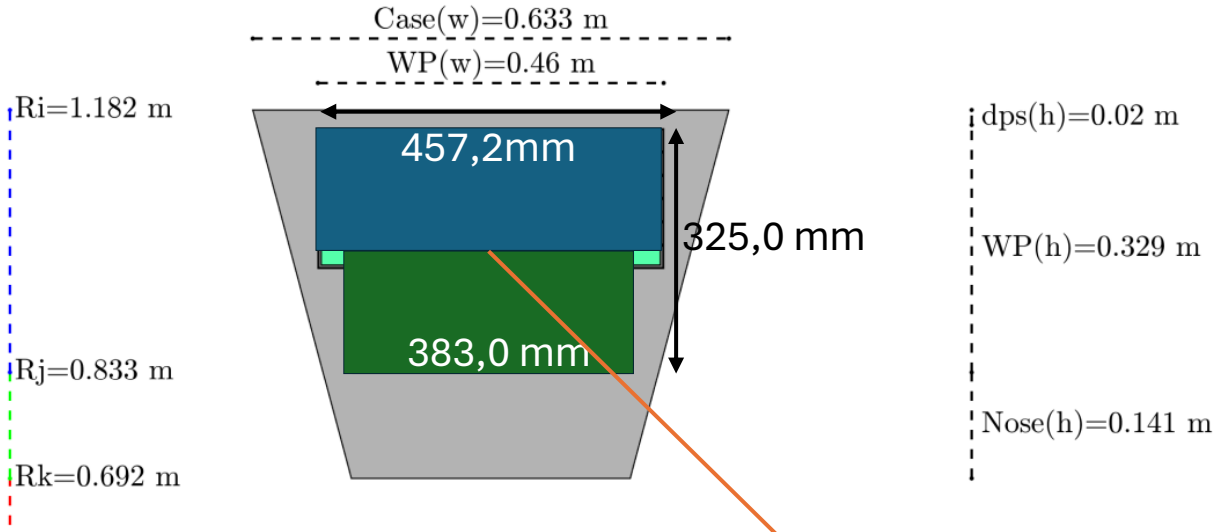
	PF-out-TF
Pulse	Steady-state
R0	2.67 m
a	64 cm
A	4.25
B0	5.6 / 13.2 T
Pfus	37.9 MW
PNB, PEC	42 / 8 MW
NWL peak	0.50 MW/m^2
k95	1.38
bN [Tm/MA]	2.76 %
q95/Pl. Current	3.02/2.5 MA
T consumption	2.1 kg / fpy
Electricity cons.	
• NB	118.5 MW
• EC	20 MW
• Total	161.5 MW

n grades=2, N=100 , Iop=62 kA, Sa(VT)=513 MPa, Sa(JT)=513 MPa, tau=4 s



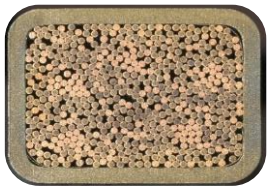
React & Wind study

n grades=2, N=100 , Iop=62 kA, Sa(VT)=513 MPa, Sa(JT)=513 MPa, tau=4 s



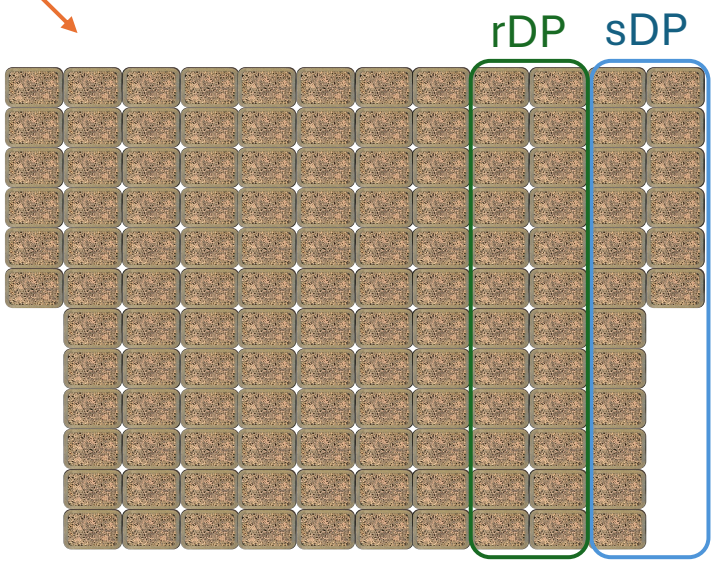
React & Wind study

Based on a strand similar to DTT TF
(0,82mm OD, Cu-nonCu: 0.95)



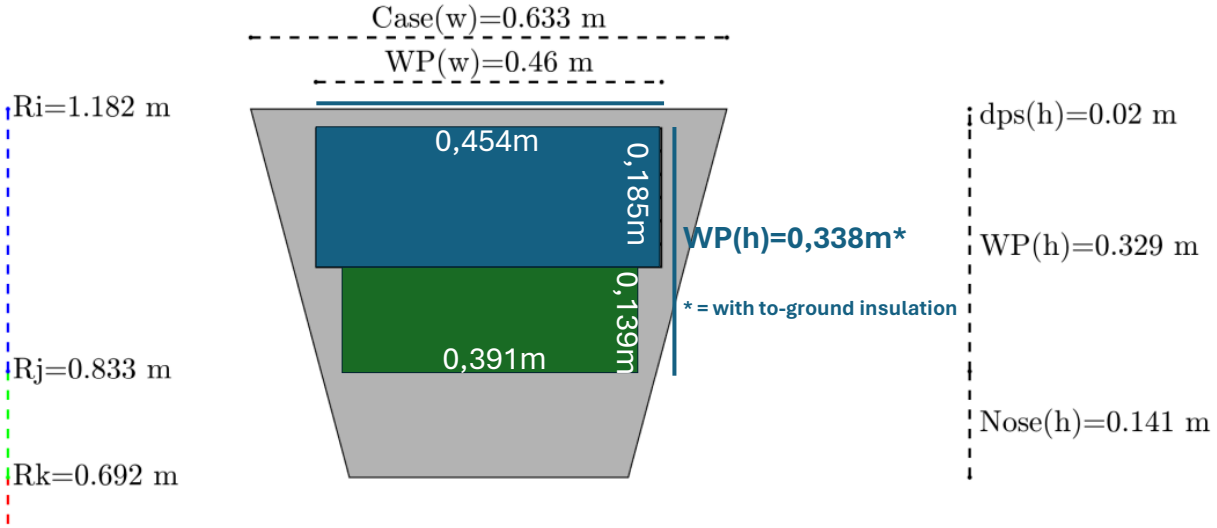
Conductor		
SC strand #	432	(0,82mm OD)
Cu strand #	240	(1,00mm OD)
Total strand #	672	
SS Wrap thickness	0,1	mm
SS Wrap overlap	30,0	%
I_{op}	47,20	kA
B_{peak}	13,2	T
T_{inlet}	4,5	K
Max ΔT_{margin}	1,4	K
Applied strain (R&W)	-0,4%	
Width (outer)	34,6	mm
Height (outer)	24,0	mm
Jacket thickness	2,0	mm
Inner corner radius	4,0	mm
VF	26,8	%

6 Double Pancakes



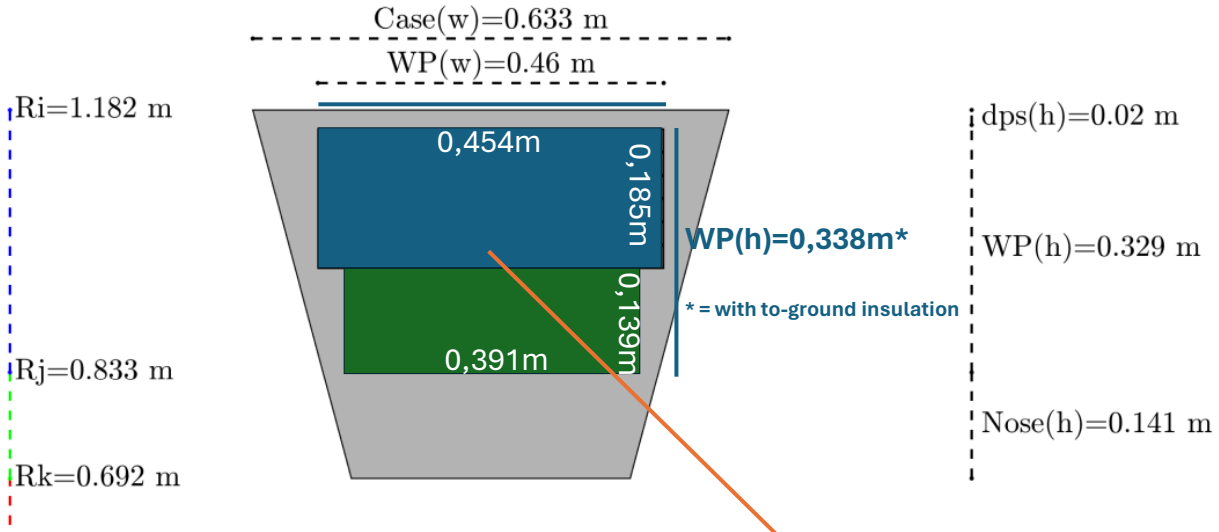
Winding Pack		
Total turns (1 coil)	132	
MAturns (1 coil)	6,230	
Total DP #	6	
Turn insulation	1,0	mm
DP insulation	0,5	mm
WP insulation	6,0	mm
Radial turns	12	
HF zone toroidal turns	12	
LF zone toroidal turns	10	
HF radial dimension	156,5	mm
LF radial dimension	156,5	mm
WP radial dimension	325,0	mm
HF zone toroidal dimension	457,2	mm
LF zone toroidal dimension	383,0	mm

n grades=2, N=100 , Iop=62 kA, Sa(VT)=513 MPa, Sa(JT)=513 MPa, tau=4 s



Wind & React study

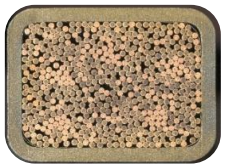
n grades=2, N=100 , Iop=62 kA, Sa(VT)=513 MPa, Sa(JT)=513 MPa, tau=4 s



Wind & React study

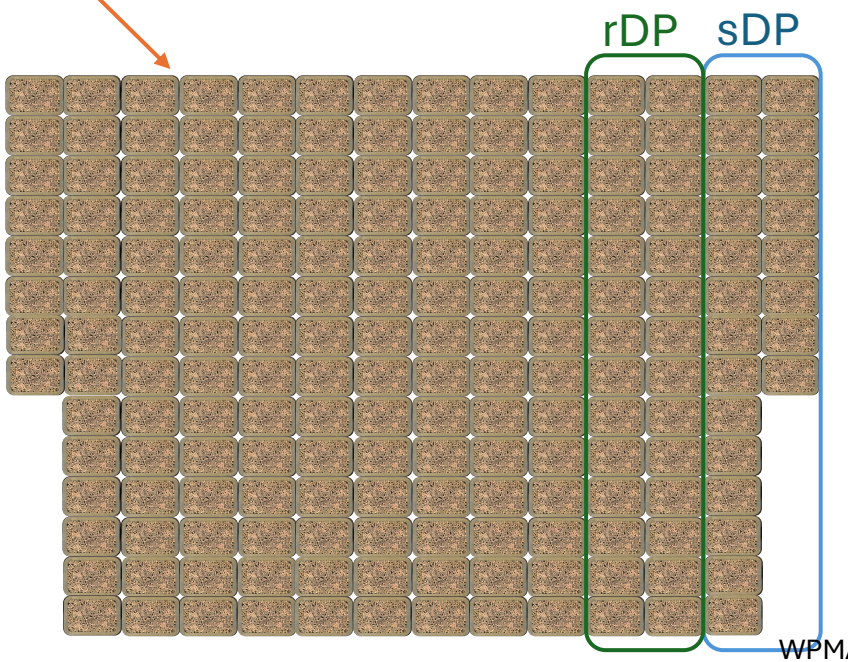
Based on a strand similar to DTT TF

(0,82mm OD, Cu-nonCu: 0.95)



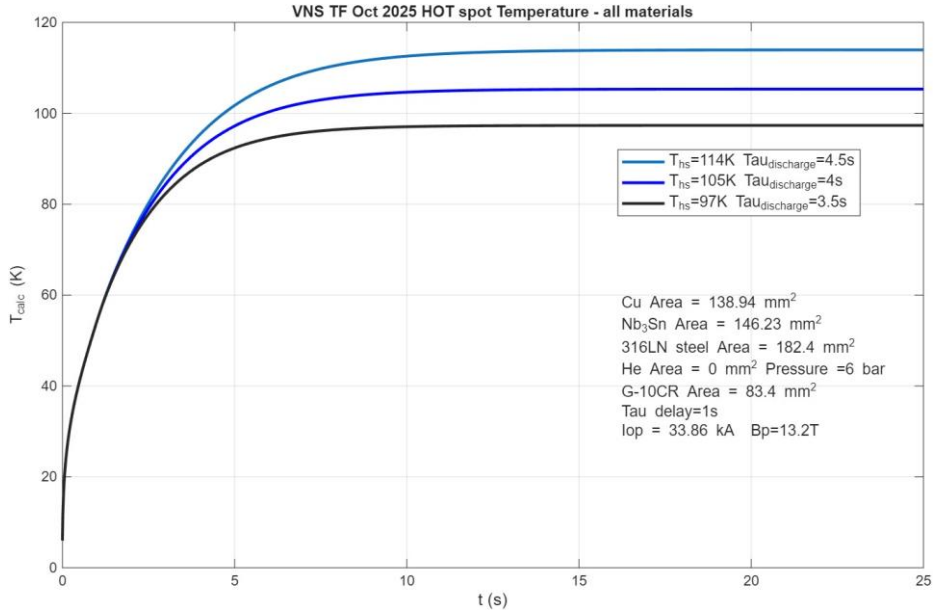
Similar to DTT TF conductor

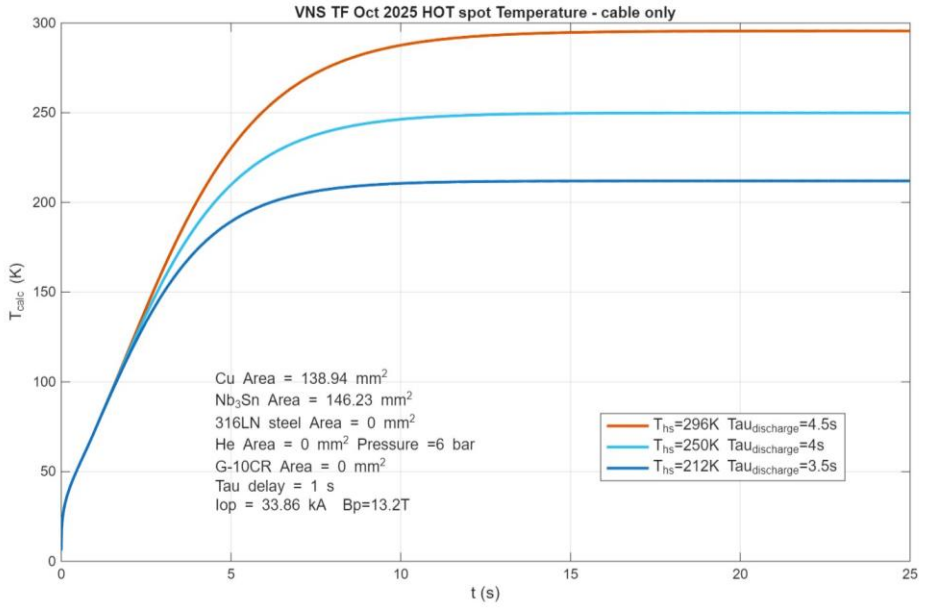
Conductor		
SC strand #	540	
Cu strand #	0	
Total strand #	540	
SS Wrap thickness	0,05	mm
SS Wrap overlap	30,0	%
Iop	33,9	kA
Bpeak	13,2	T
Tinlet	4,5	K
Max ΔTmargin	1,4	K
Applied strain (R&W)	-0,6%	
Width (outer)	28,6	mm
Height (outer)	21,0	mm
Jacket thickness	2,0	mm
Inner corner radius	4,0	mm
VF	26,8	%



7 Double Pancakes

Winding Pack		
Total turns (1 coil)	184	
MAturns (1 coil)	6,230	
Total DP #	7	
Turn insulation	1,0	mm
DP insulation	1,0	mm
WP insulation	6,0	mm
Radial turns	14	
HF zone toroidal turns	14	
LF zone toroidal turns	12	
HF radial dimension	185,0	mm
LF radial dimension	139,0	mm
WP radial dimension	338,0	mm
HF zone toroidal dimension	454,4	mm
LF zone toroidal dimension	391,2	mm

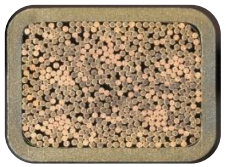




$\tau_{discharge}$ = 4.0 s
t_{delay} = 1.0s

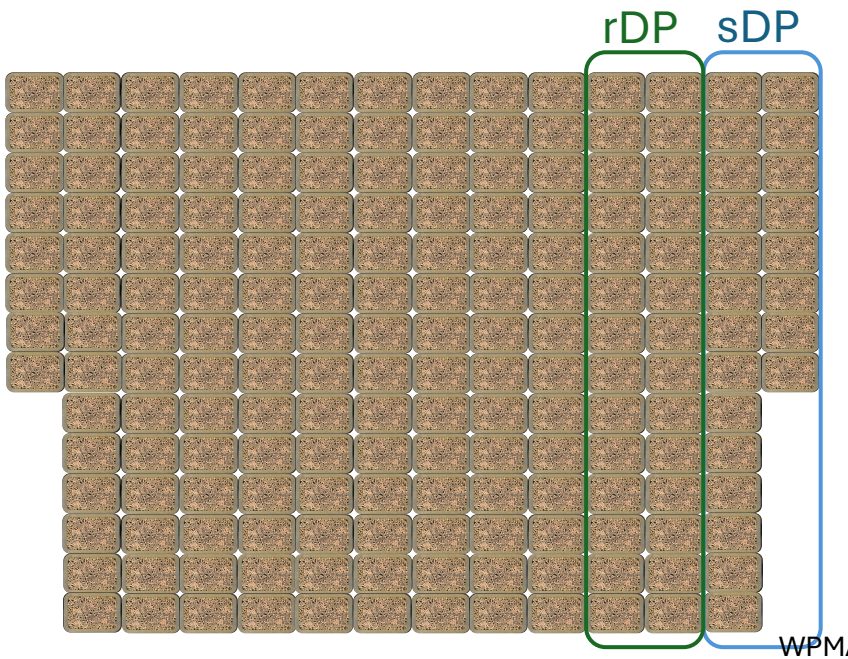
Calculated by ***Chiarasole Fiamozzi Zignani***

Based on a strand similar to DTT TF
(0,82mm OD, Cu-nonCu: 0.95)



Similar to DTT TF conductor

Conductor		
SC strand #	540	
Cu strand #	0	
Total strand #	540	
SS Wrap thickness	0,05	mm
SS Wrap overlap	30,0	%
Iop	33,9	kA
Bpeak	13,2	T
Tinlet	4,5	K
Max ΔTmargin	1,4	K
Applied strain (R&W)	-0,6%	
Width (outer)	28,6	mm
Height (outer)	21,0	mm
Jacket thickness	2,0	mm
Inner corner radius	4,0	mm
VF	26,8	%



7 Double Pancakes

Winding Pack		
Total turns (1 coil)	184	
MAturns (1 coil)	6,230	
Total DP #	7	
Turn insulation	1,0	mm
DP insulation	1,0	mm
WP insulation	6,0	mm
Radial turns	14	
HF zone toroidal turns	14	
LF zone toroidal turns	12	
HF radial dimension	185,0	mm
LF radial dimension	139,0	mm
WP radial dimension	338,0	mm
HF zone toroidal dimension	454,4	mm
LF zone toroidal dimension	391,2	mm

VNS TF COIL EM AND STRUCTURAL SIMULATIONS

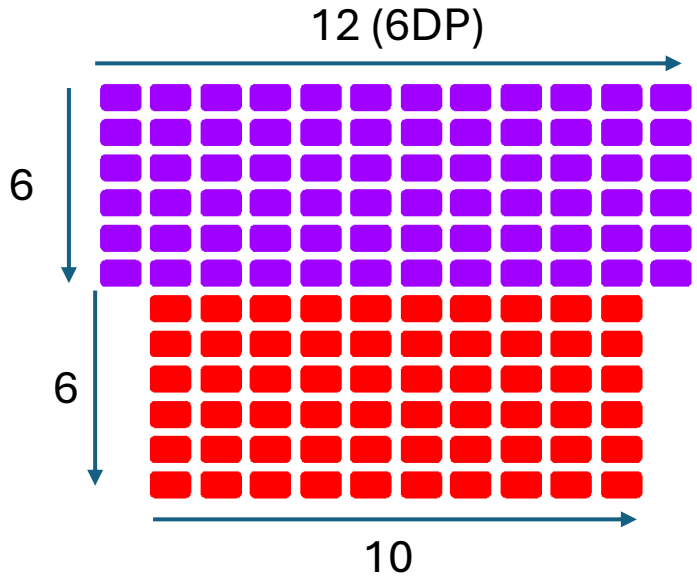
Reference: VNS - PF-in-TF (LTS) 07-03-2025

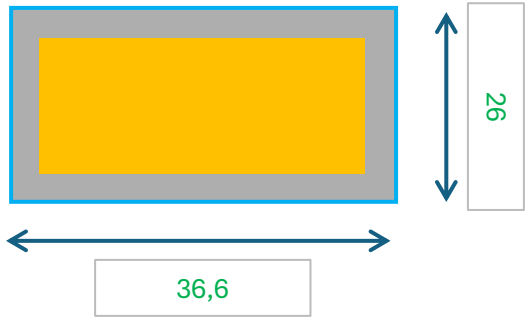
Version:

1. W&R with 6 Double Pancakes

Conductor		
SC strand #	432	
seg Cu #	240	
tot strand #	672	
Wrap thickness	0,05	mm
Wrap overlap	30,0	%
Iop	47,20	kA
Bpeak	13,20	T
ΔT_{margin} (T_{op} :4.5K) =	1,4	K
VF	27,9%	
Width (outer)	34,6	mm
Height (outer)	24,0	mm
Jacket thickness	2,0	mm
Inner corner radius	4,0	mm
Inter-turn insulation	1,0	mm
DP insulation thickness	0,5	mm

Coil	
Total turns #	132
MAturns (1 coil)	6,230
WP perimeter insulation (mm)	6,0
HF radial turns	6,0
HF toroidal turns	12,0
LF radial turns	6,0
LF toroidal turns	10,0
HF radial dimension	156,5
LF radial dimension	156,5
WP total height	325,0
DP insulation thickn.	0,5
HF toroidal size	457,2
LF toroidal size	383,0

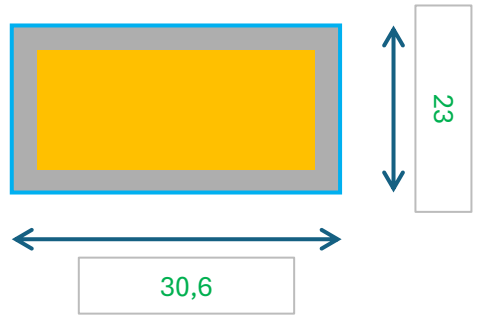


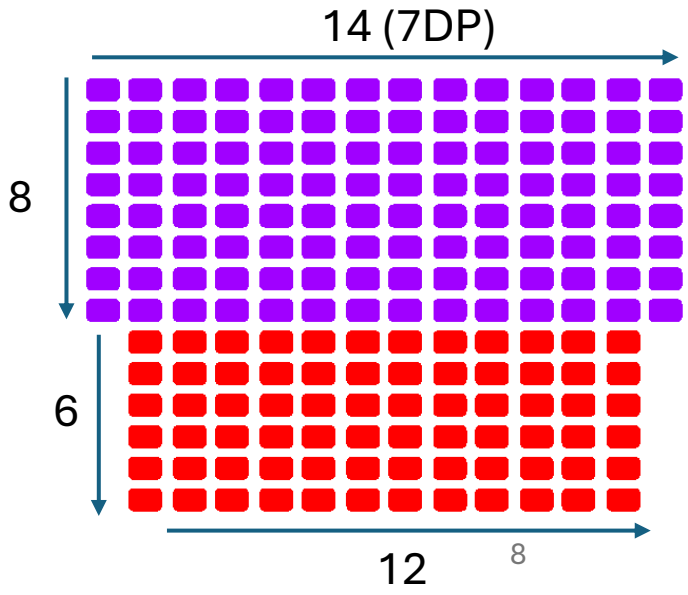


2. “Standard” R&W with 7 Double Pancakes

Conductor		
SC strand #	540	
seg Cu #	0	
tot strand #	540	
Wrap thickness	0,05	mm
Wrap overlap	30,0	%
Iop	33,86	kA
Bpeak	13,20	T
ΔT_{margin} (T_{op} :4.5K) =	1,4	K
VF	26,8%	
Width (outer)	28,6	mm
Height (outer)	21,0	mm
Jacket thickness	2,0	mm
Inner corner radius	4,0	mm
Inter-turn insulation	1,0	mm
DP insulation thickness	1,0	mm

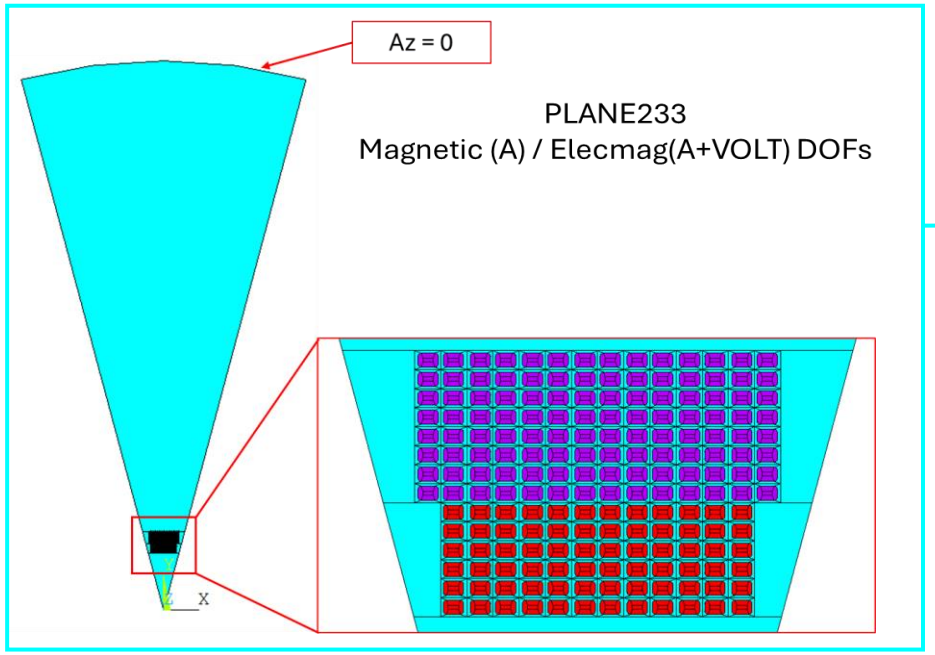
Coil	
Total turns #	184
MAturns (1 coil)	6,230
WP perimeter insulation (mm)	6,0
HF radial turns	8
HF toroidal turns	14
LF radial turns	6
LF toroidal turns	12
HF radial dimension	185,0
LF radial dimension	139,0
WP total height	338,0
DP insulation thickn.	1,0
HF toroidal size	454,4
LF toroidal size	391,2





FEA models

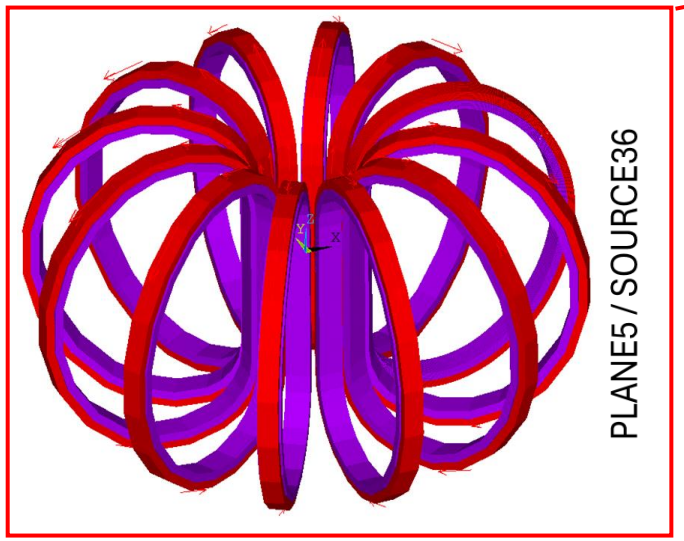
2D EM MODEL



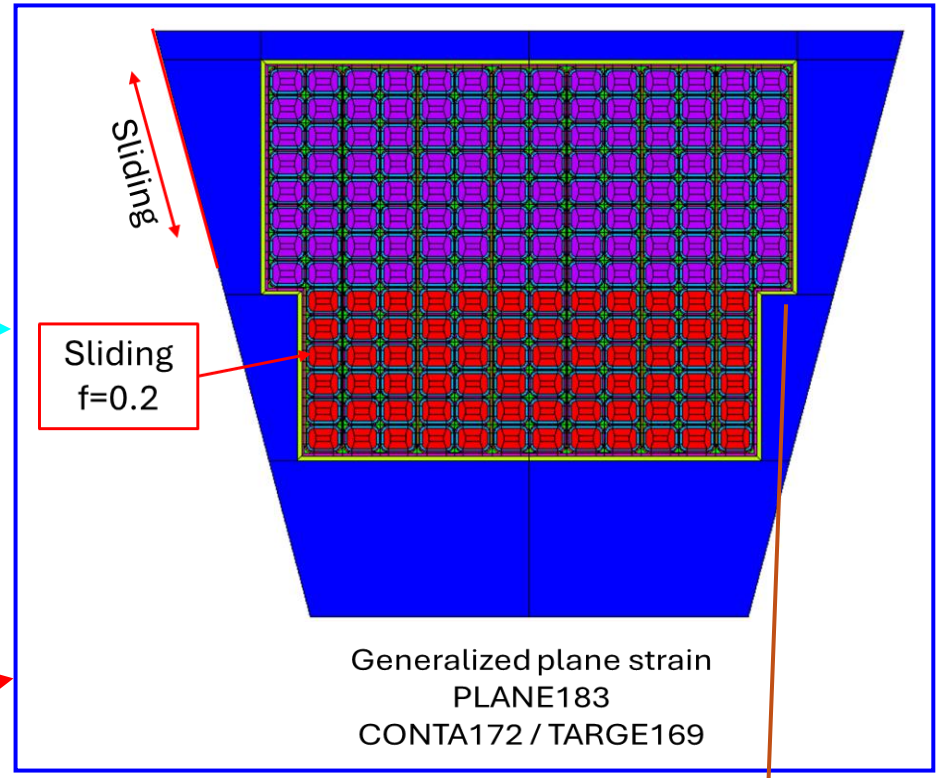
Cable EM forces

Vertical EM Force

3D EM MODEL

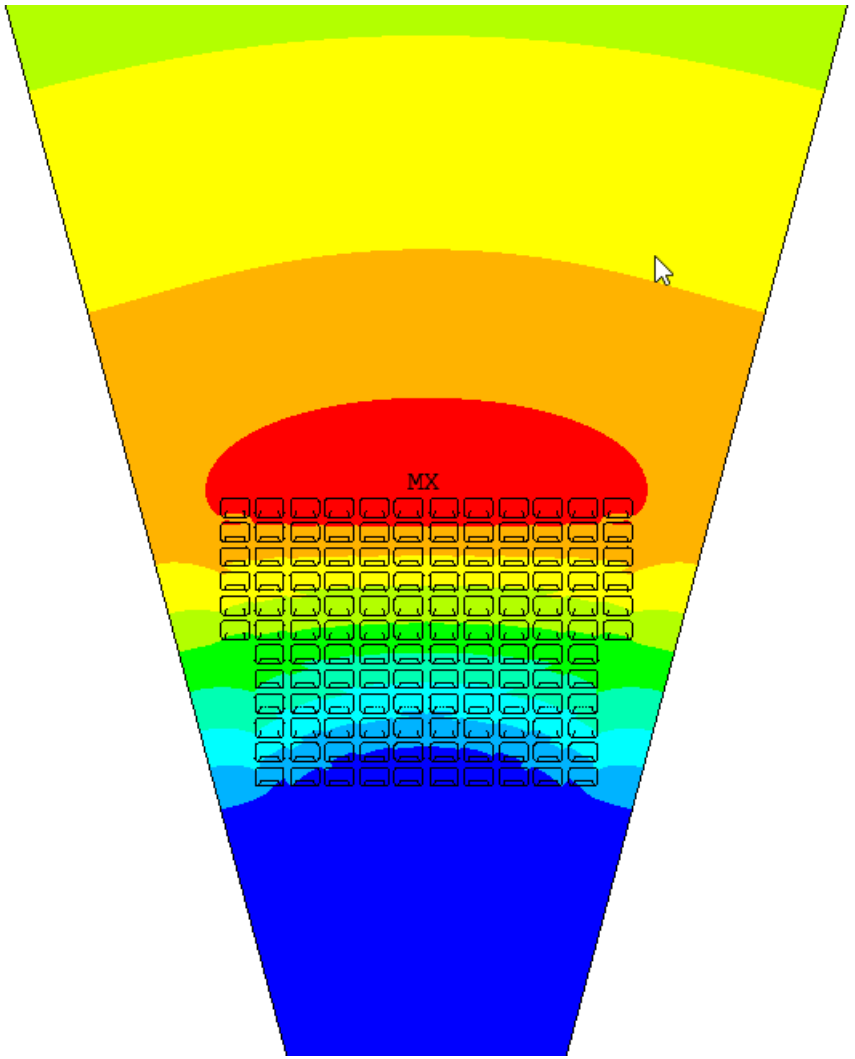


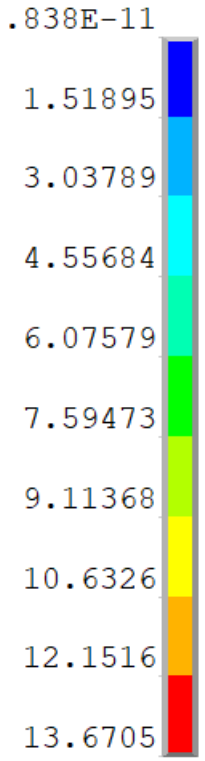
2D STRUCTURAL MODEL

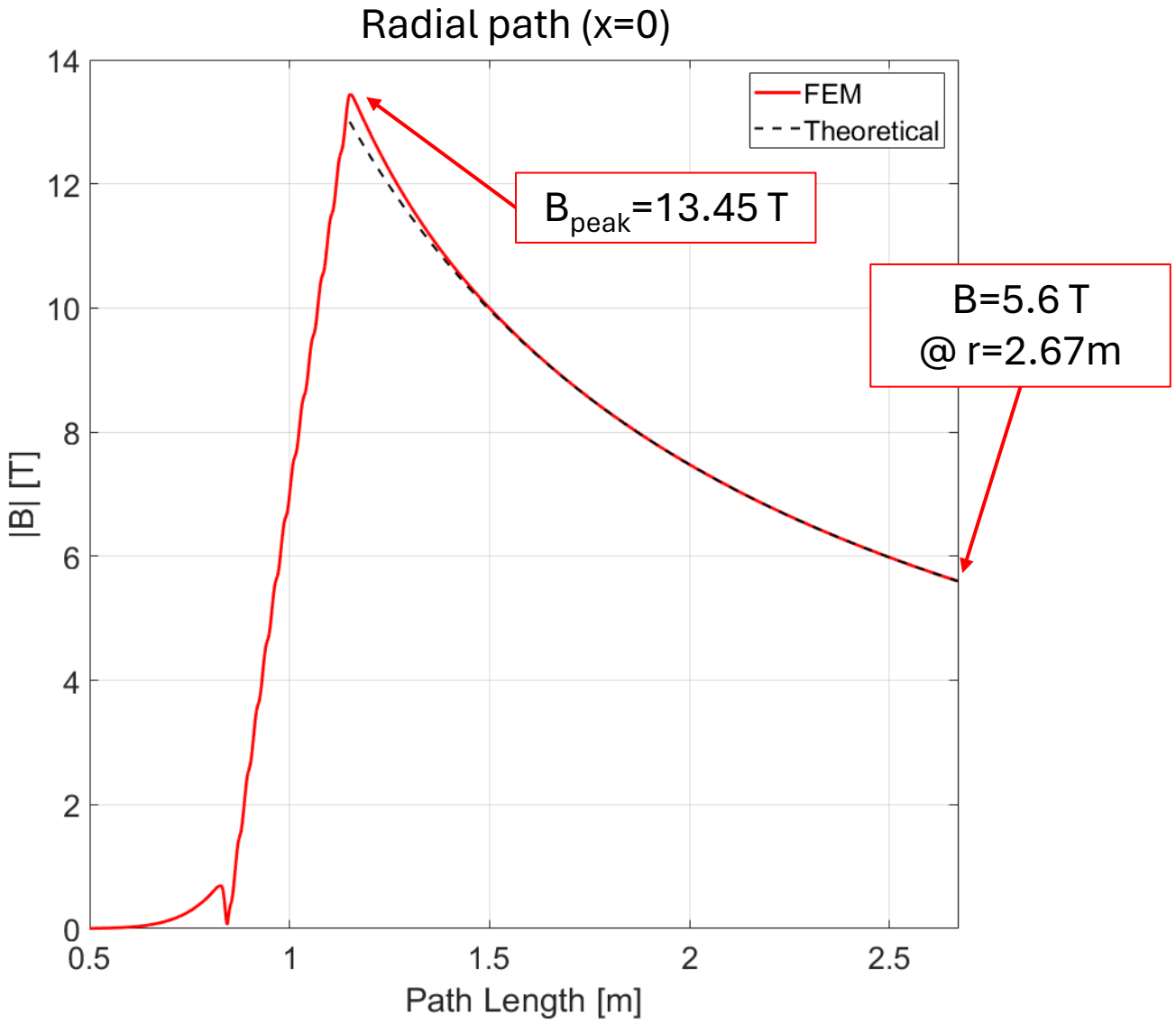


*The step is not definitive; indeed, we intend to remove it.

2D EM MODEL: Version 1 (6DP)

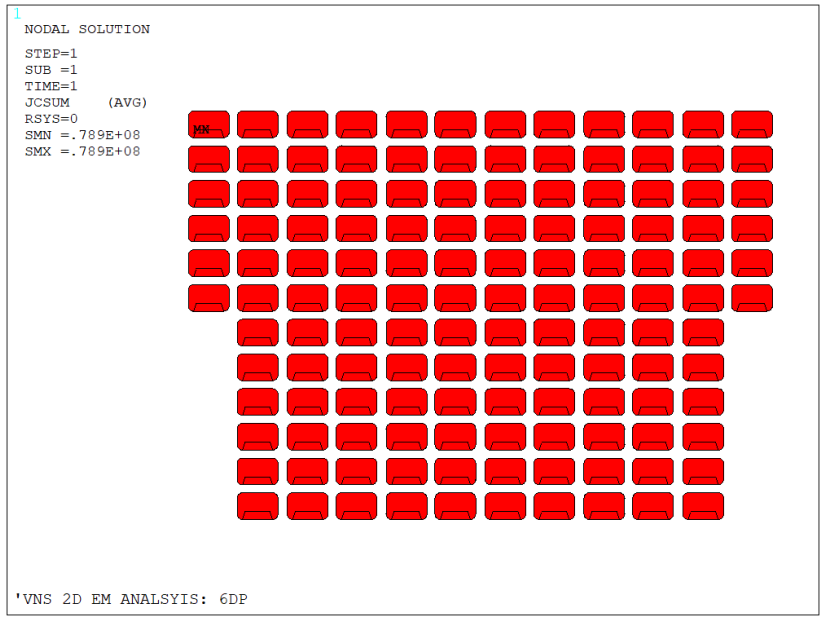






2D EM MODEL: Version 1 (6DP)

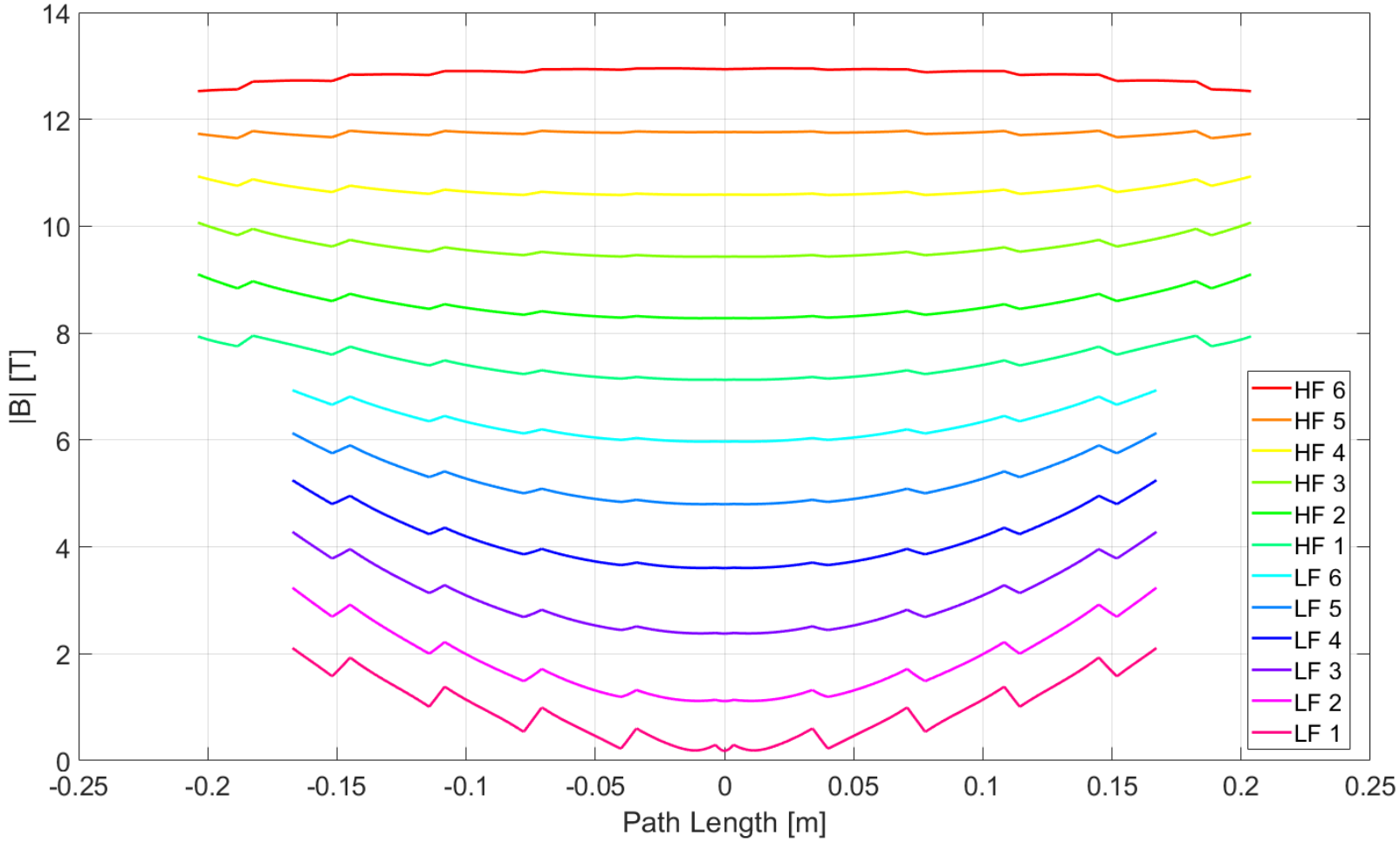
Current density



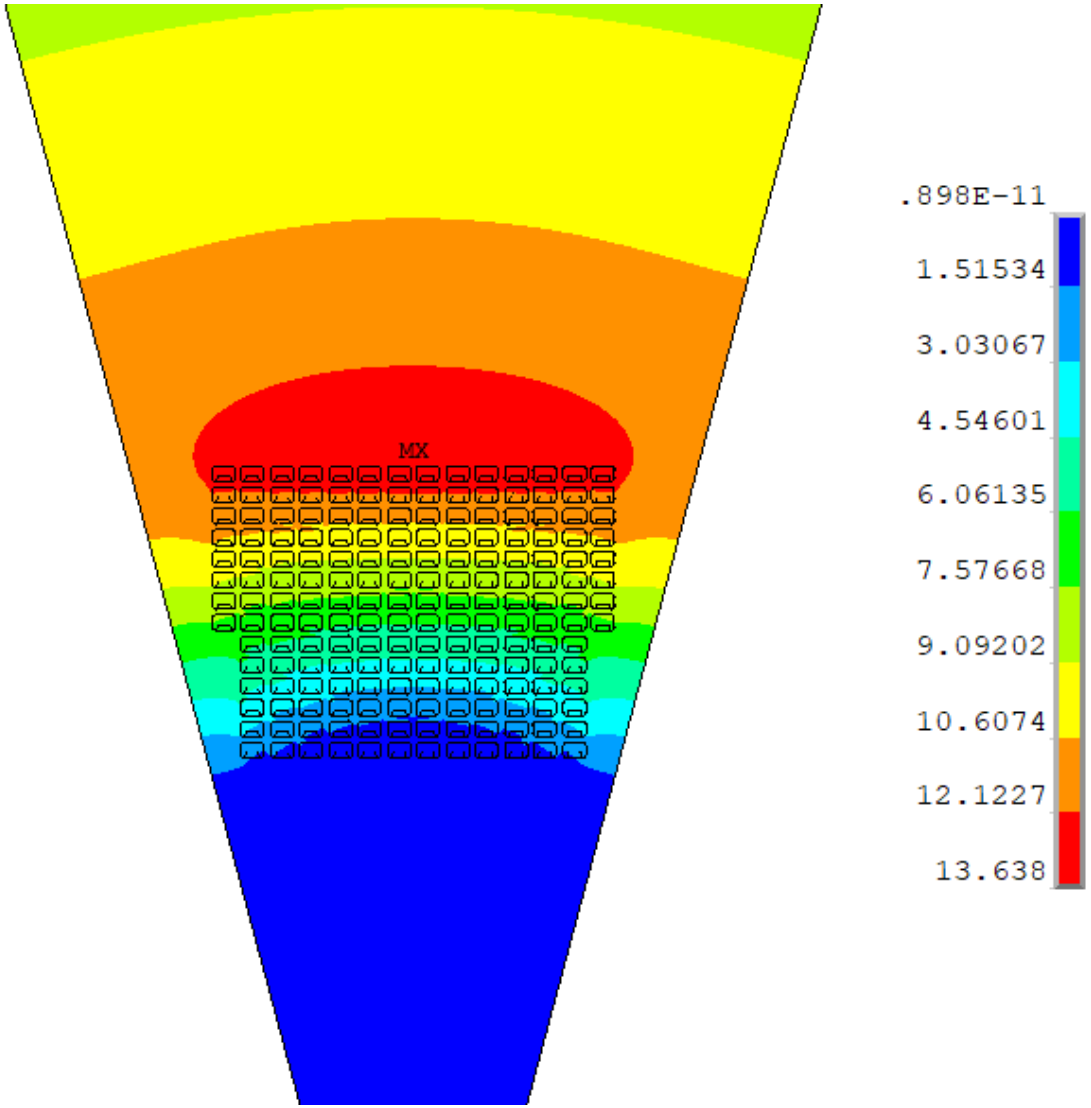
J_{eng} LF = 47.2 A/mm^2

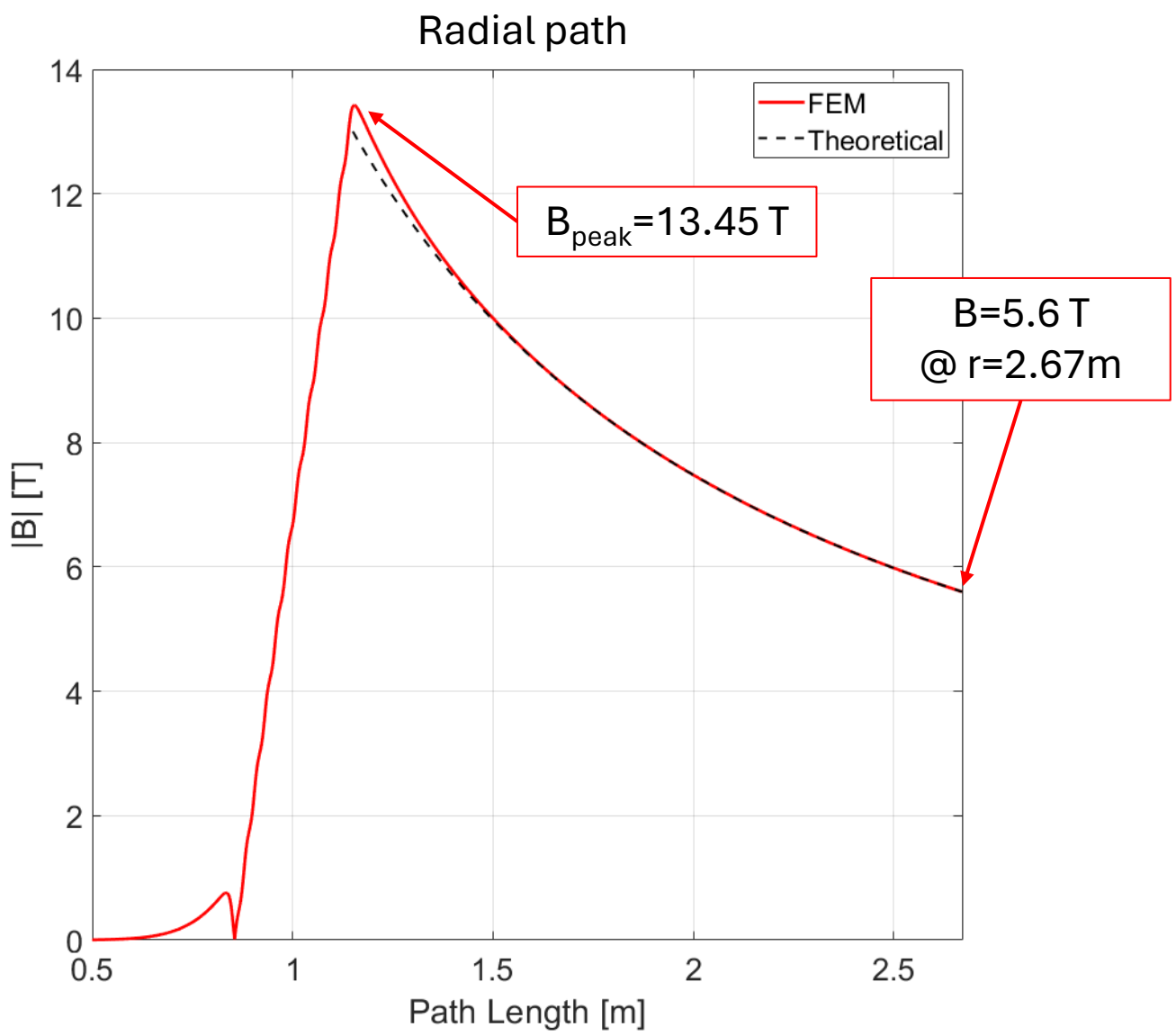
J_{eng} HF = 47.5 A/mm^2

Toroidal paths (Center of cables)



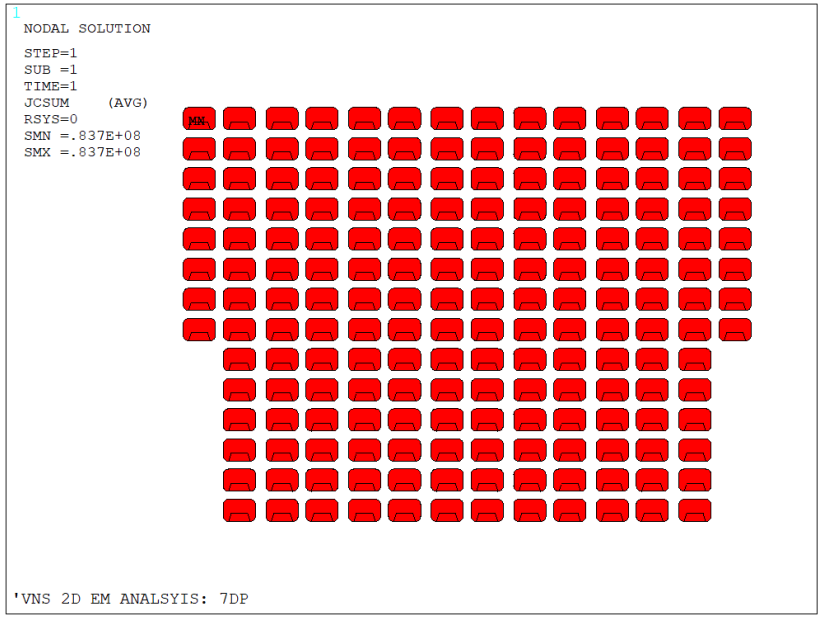
2D EM MODEL: Version 2 (7DP)





2D EM MODEL: Version 2 (7DP)

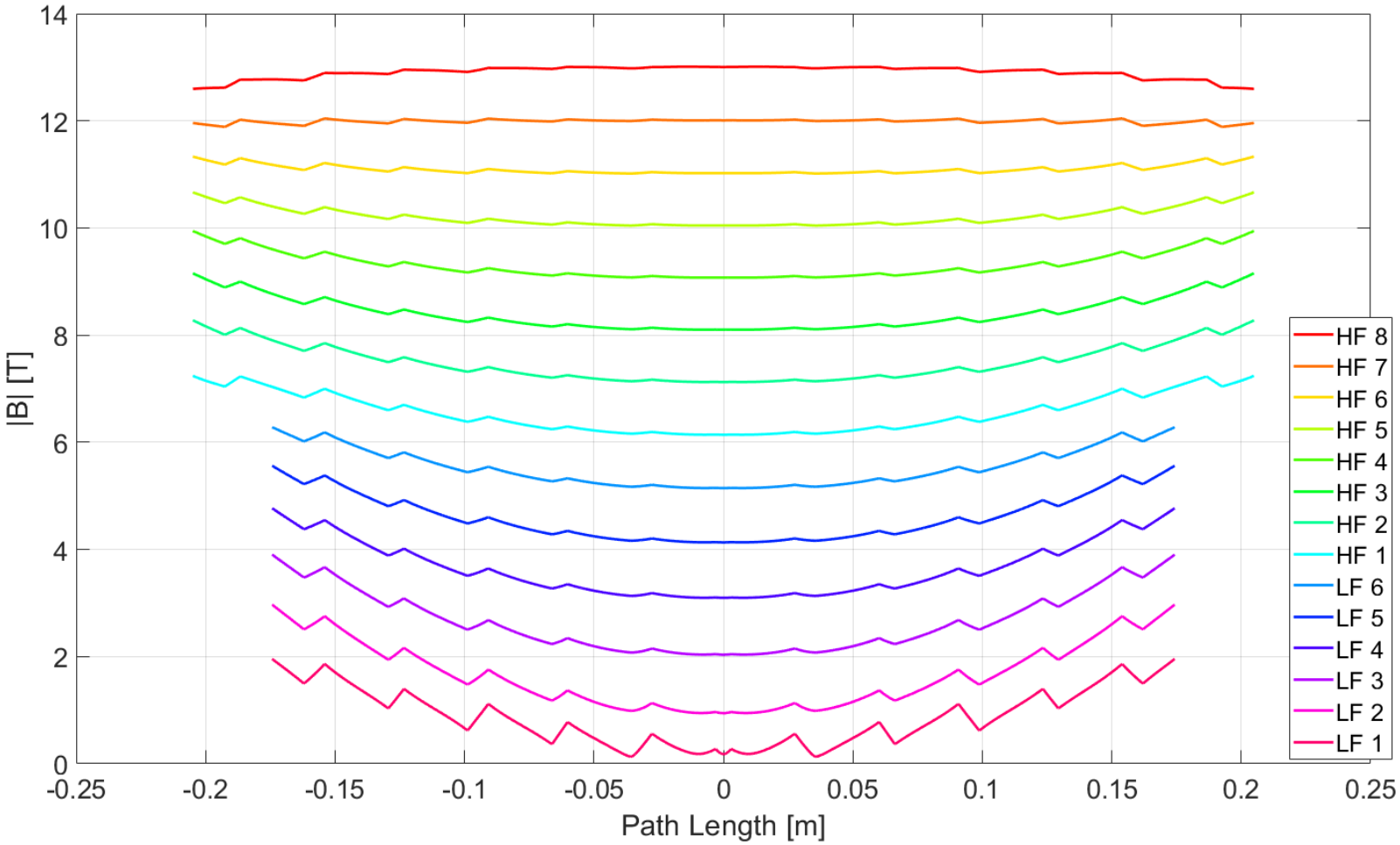
Current density



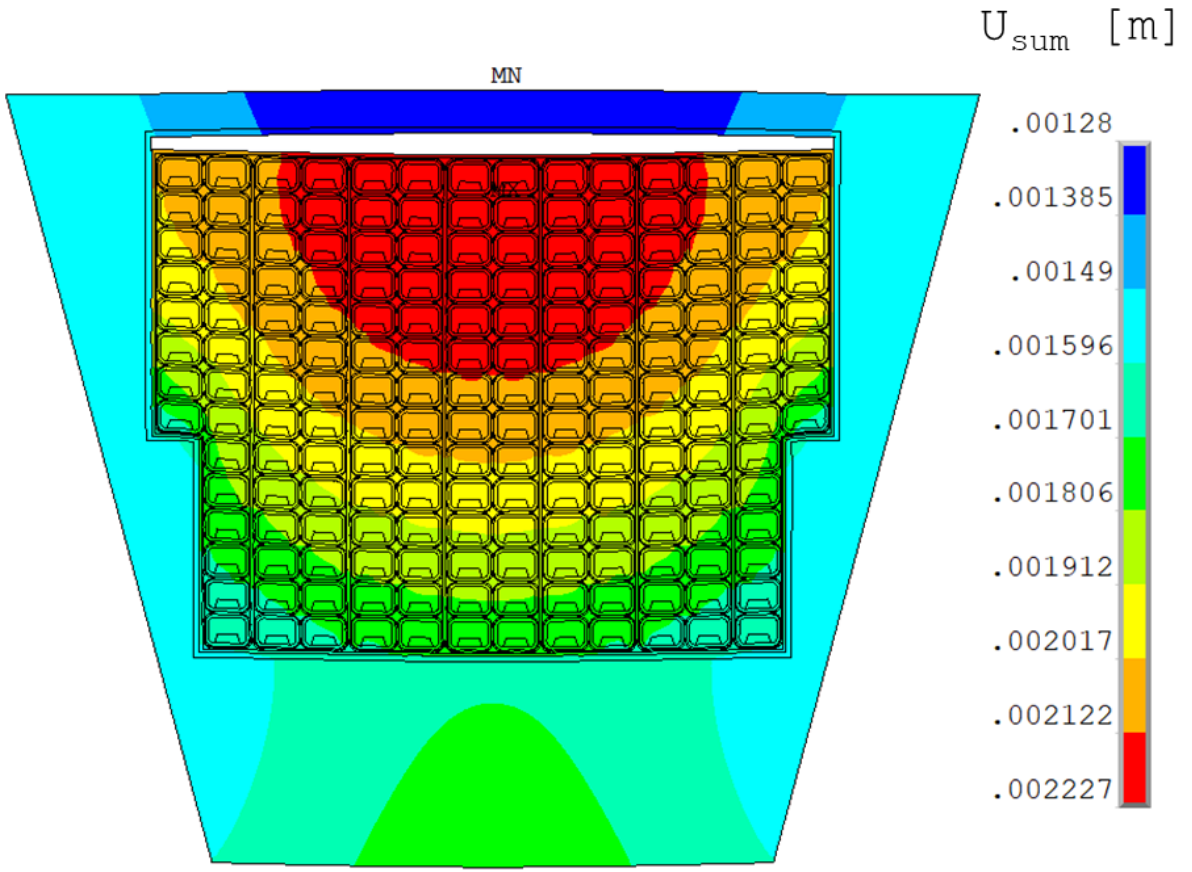
J_{eng} LF = 44.8 A/mm^2

J_{eng} HF = 45.1 A/mm^2

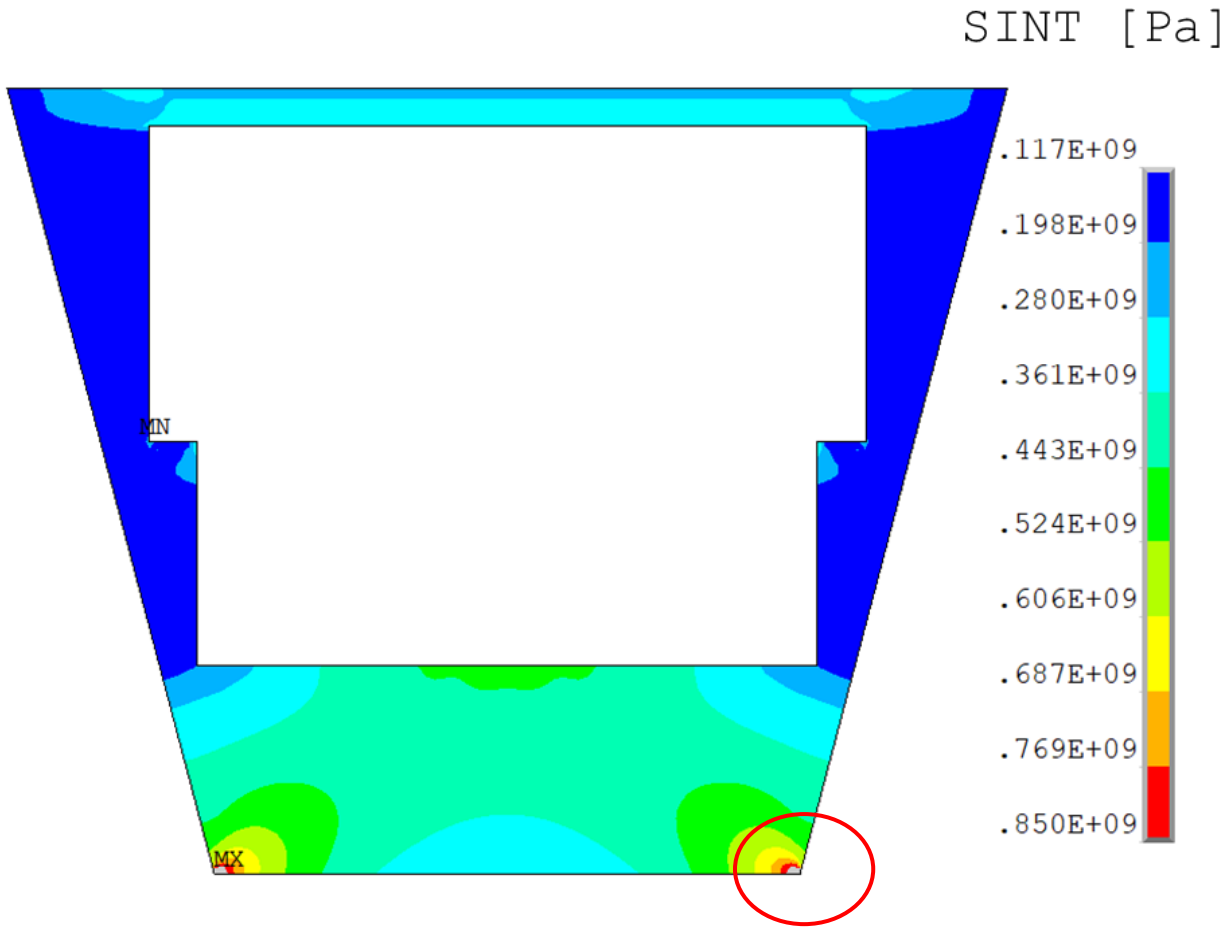
Toroidal paths (Center of cables)



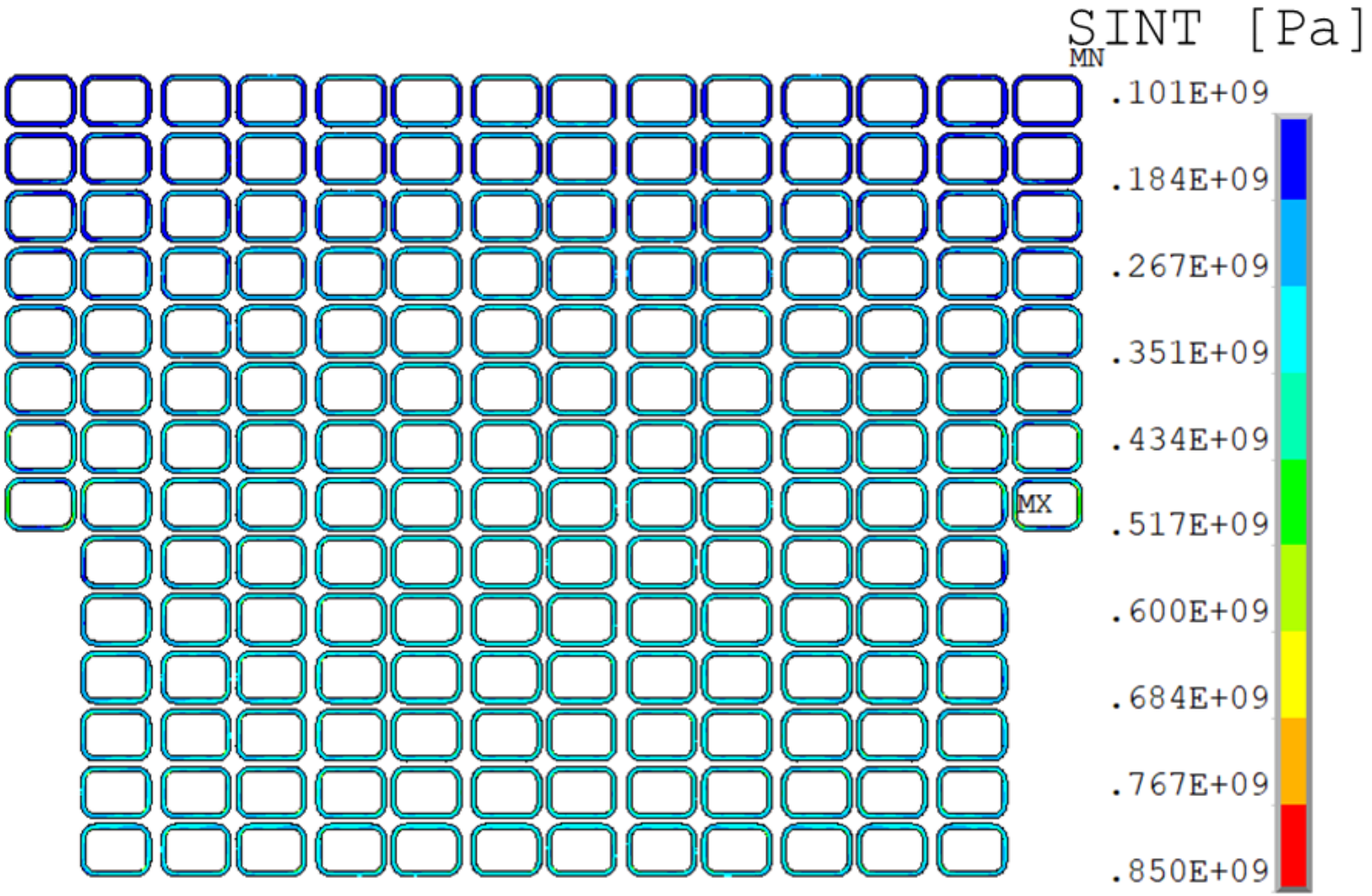
2D STRUCTURAL MODEL: Version 2 (7DP)

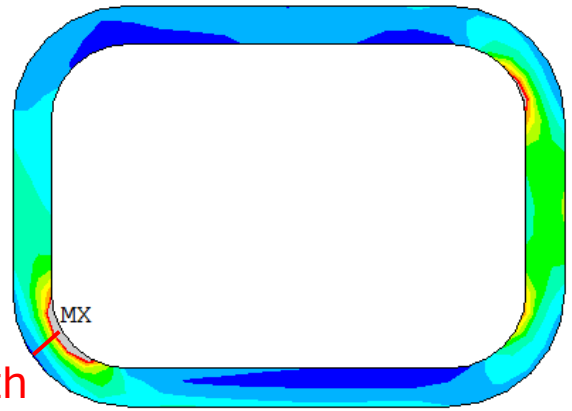


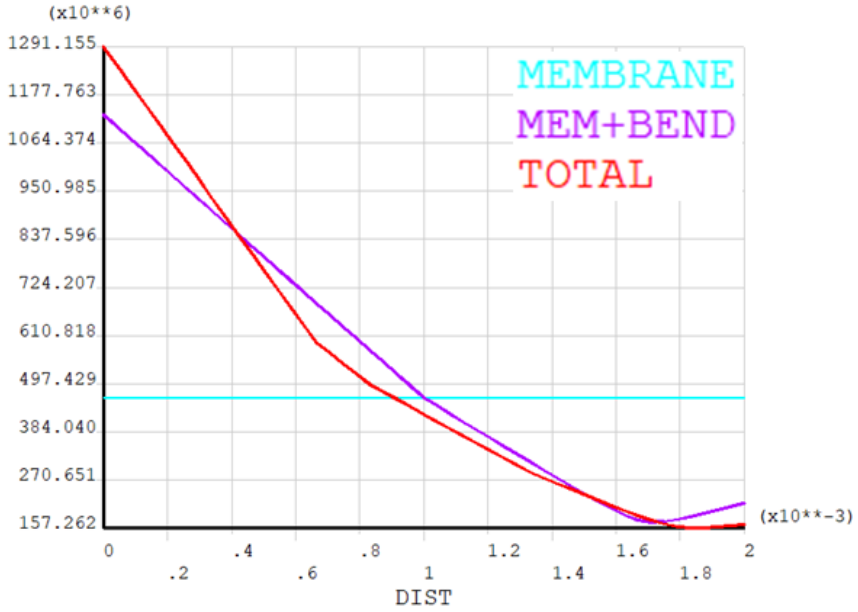
20x Displacement scaling



2D STRUCTURAL MODEL: Version 2 (7DP)



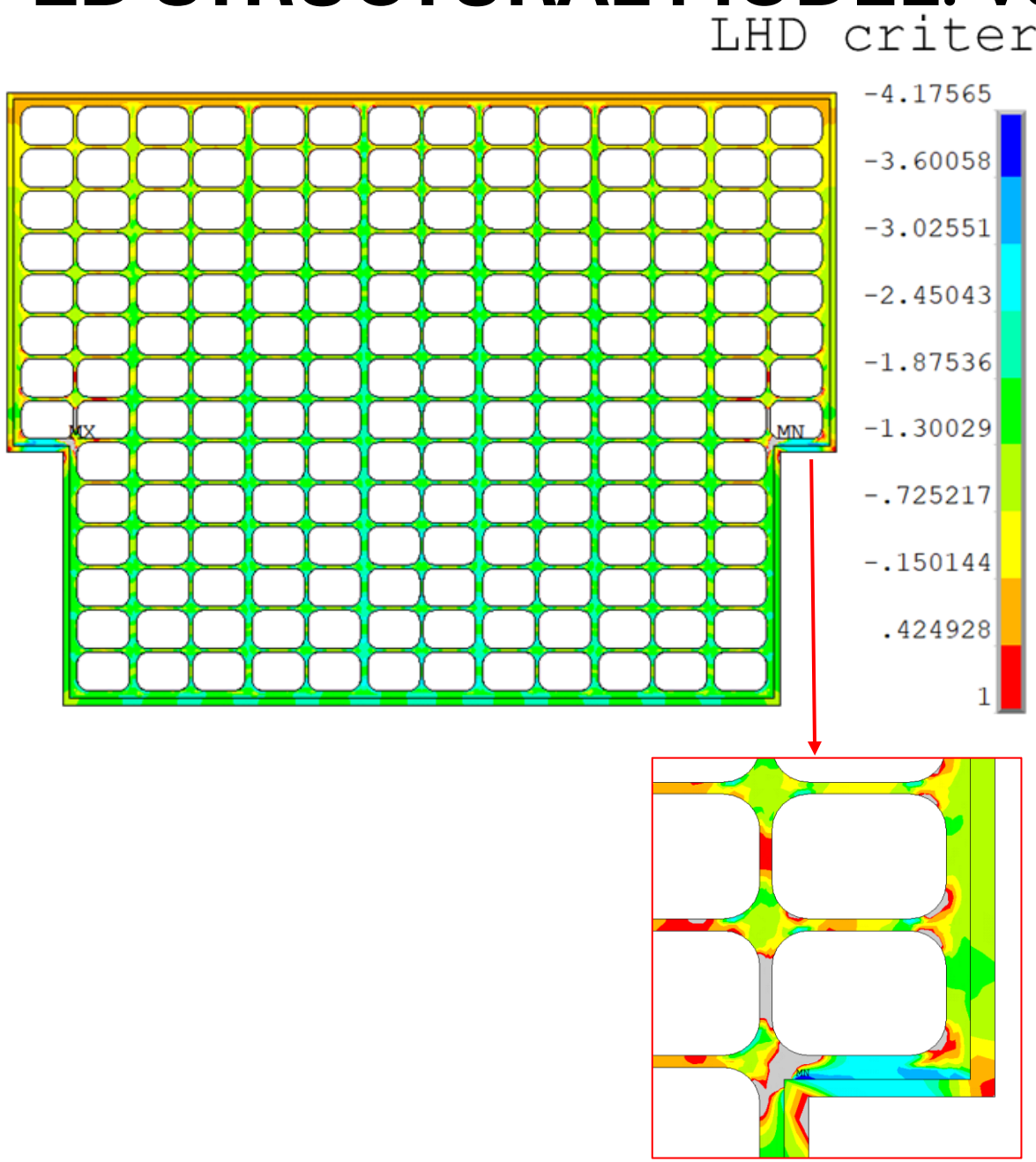


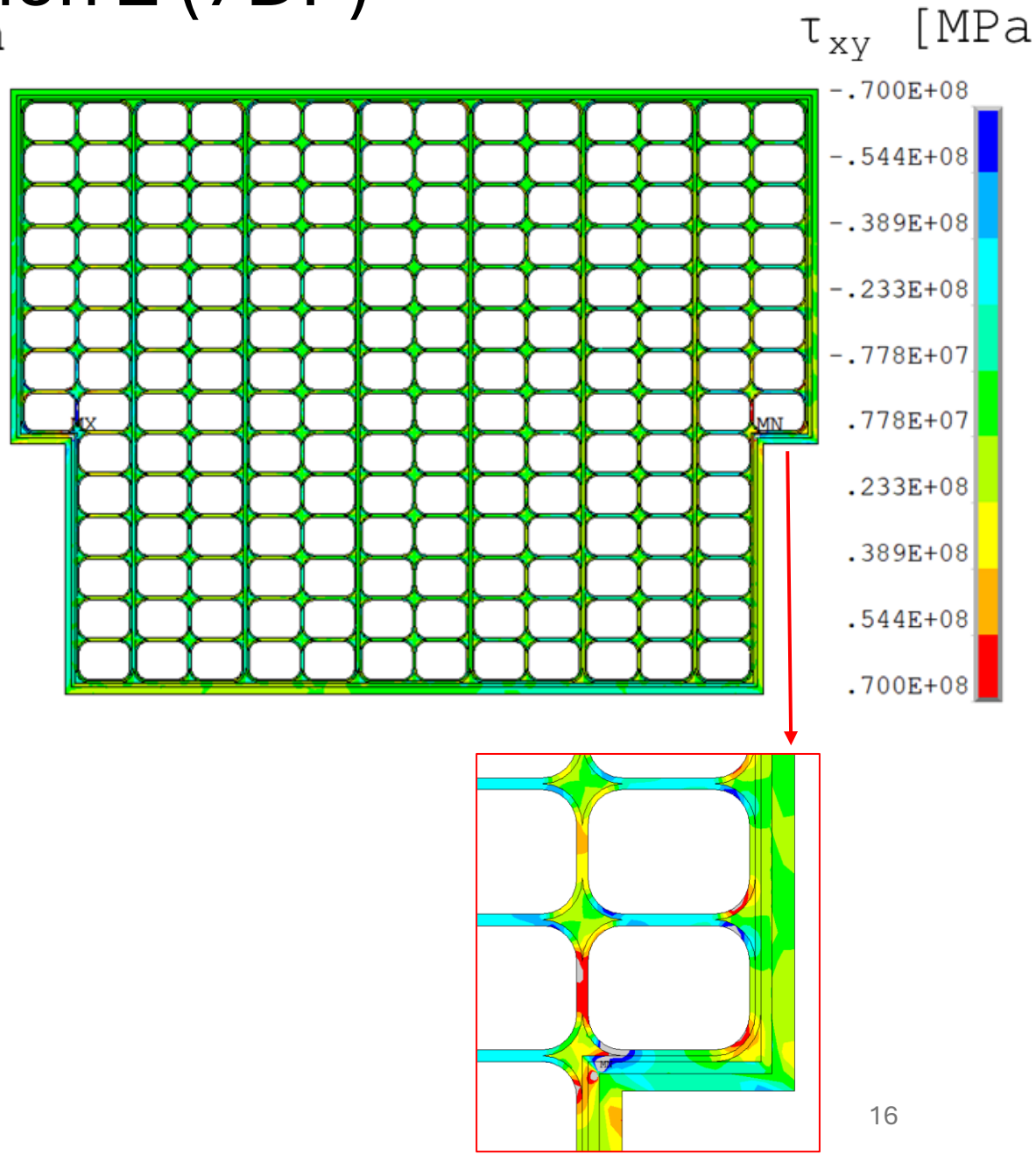


σ_m = 463.7MPa

σ_{m+b} = 1131MPa

2D STRUCTURAL MODEL: Version 2 (7DP)





Thank you