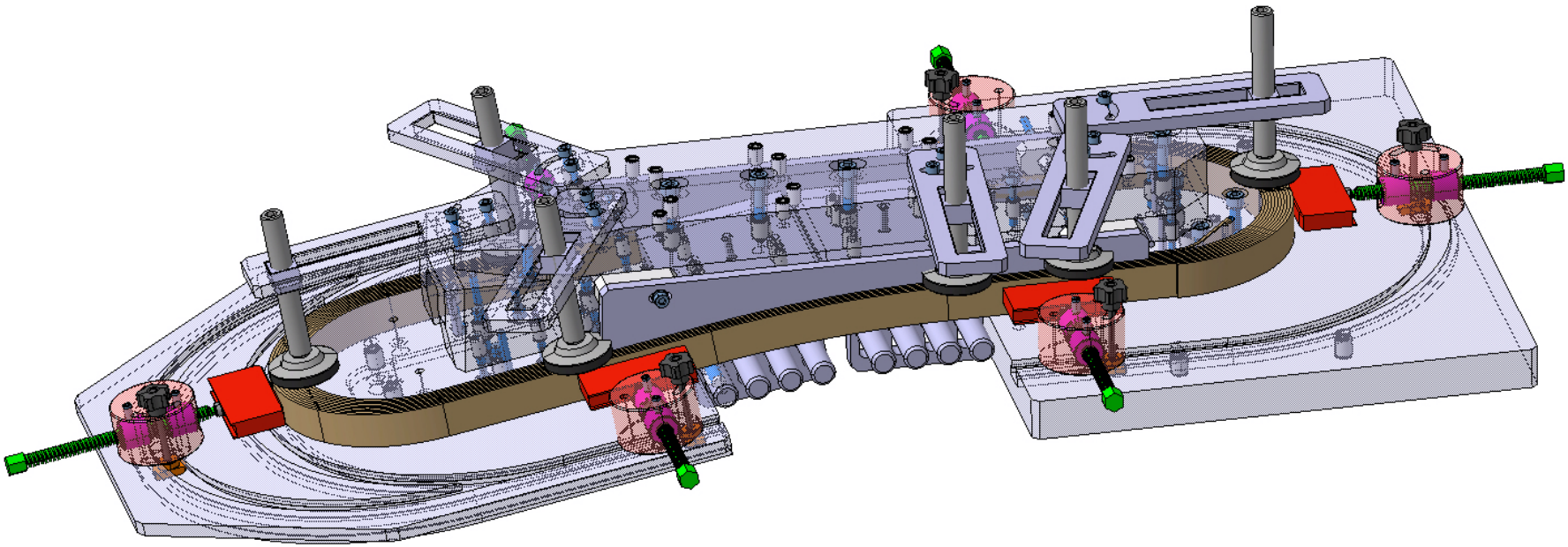
HEPDipo

Status of the cable trials
Historic of the conceptual design
New studies

MSC-MDT

Status of cable trials

- 3D view of the tooling used for cable testing of several geometries

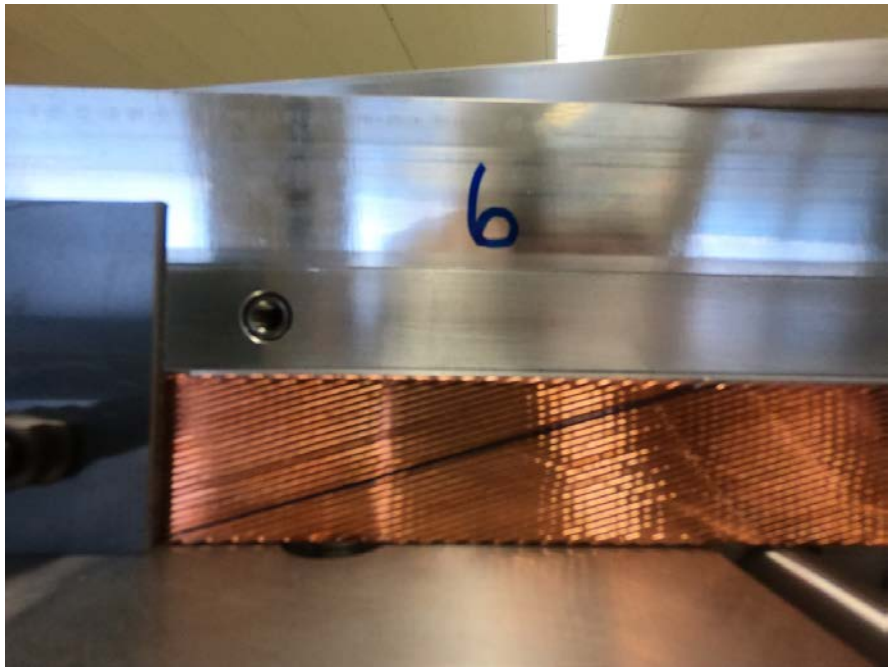


- Conceptual design and drawings – November 2019 to January 2020
- Manufacturing – February 2020
- Cable trials – February and March 2020
- Data analysis – March 2020 ongoing

Thanks to P. Martin

Baseline geometry with 25 kg of load – hard way bend – z deviation

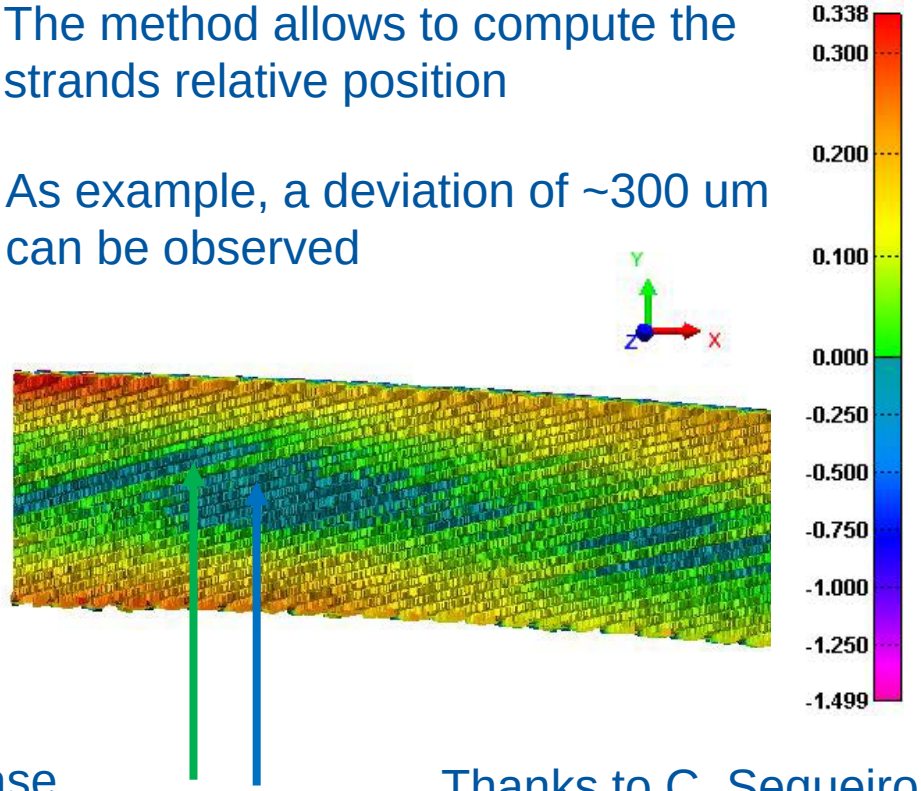
- tooling



- Analysis being performed

The method allows to compute the strands relative position

As example, a deviation of ~300 um can be observed



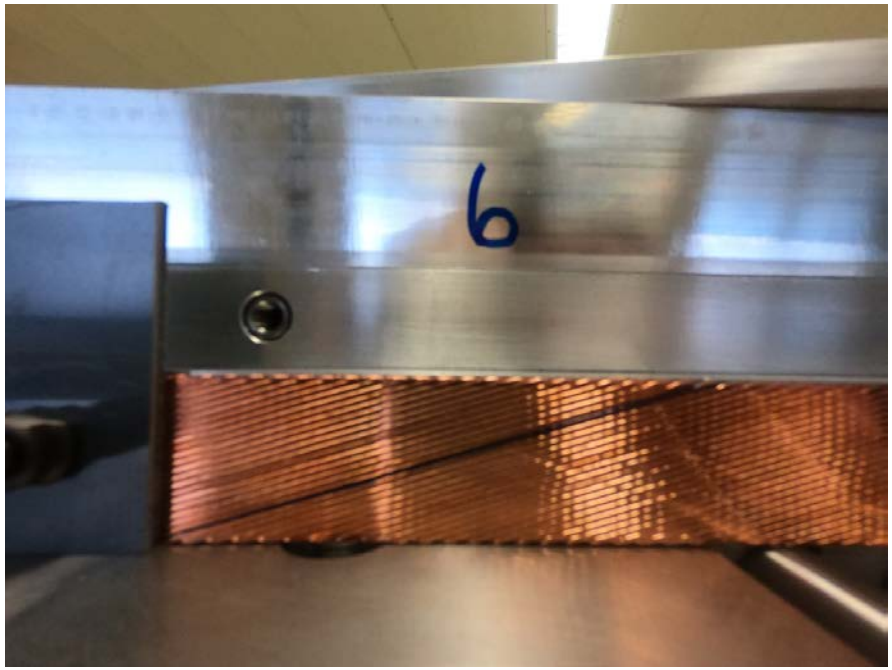
No pop out strand was identified in this case

Thanks to C. Sequeiro

This measurement will help us to better choose the winding machine parameters

Baseline geometry with 25 kg of load – hard way bend – radial deviation

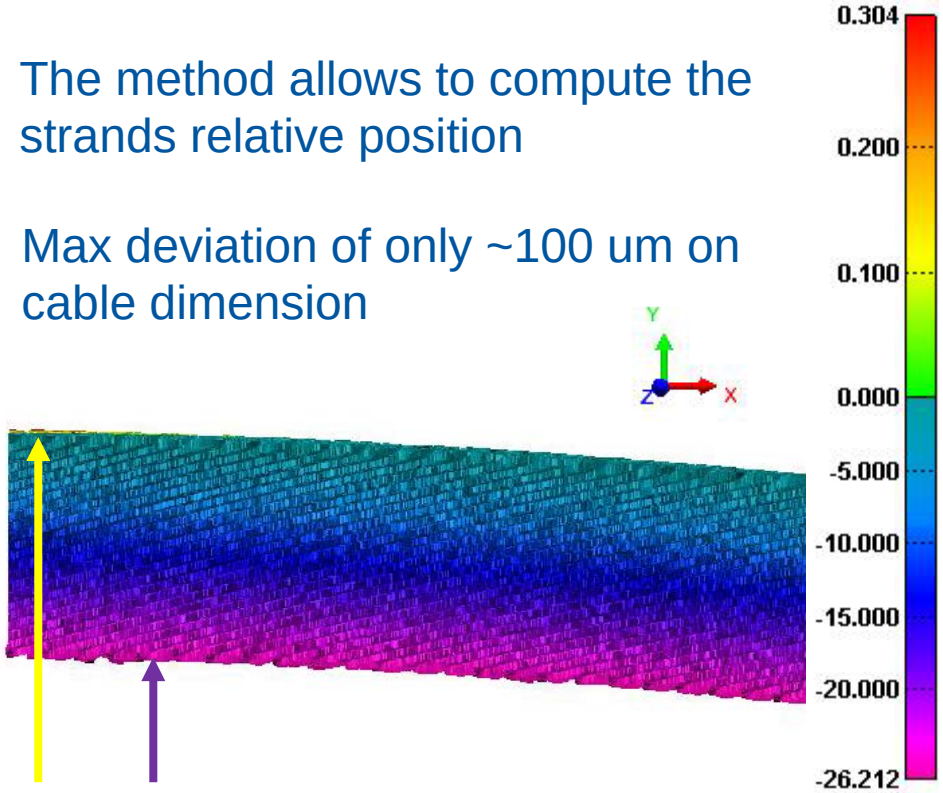
- tooling



- Analysis being performed

The method allows to compute the strands relative position

Max deviation of only ~100 um on cable dimension



No pop out strand was identified in this case

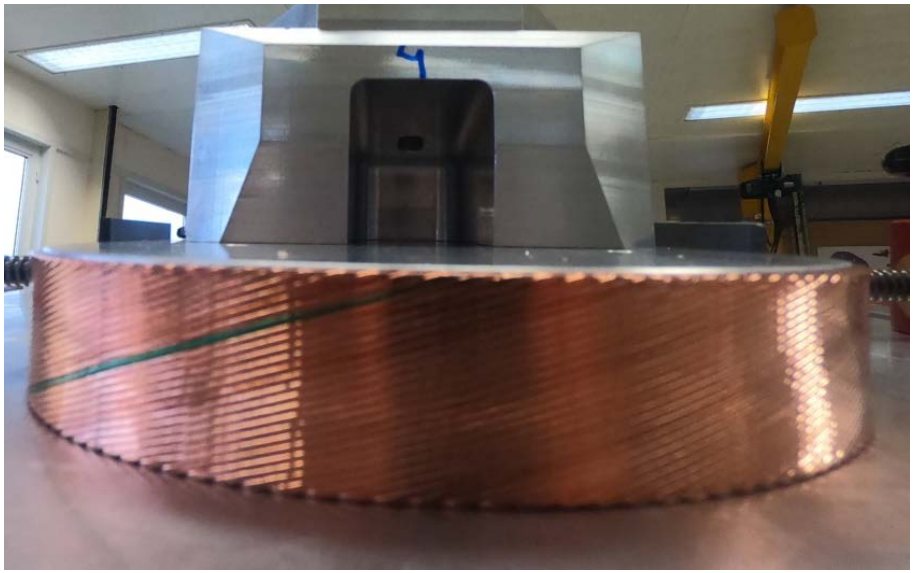
This measurement will help us to better understand differences between the ideal coil geometry and reality

Baseline geometry with 25 kg of load – easy way bend – radial deviation

- tooling

No pop out strand was identified in this Case

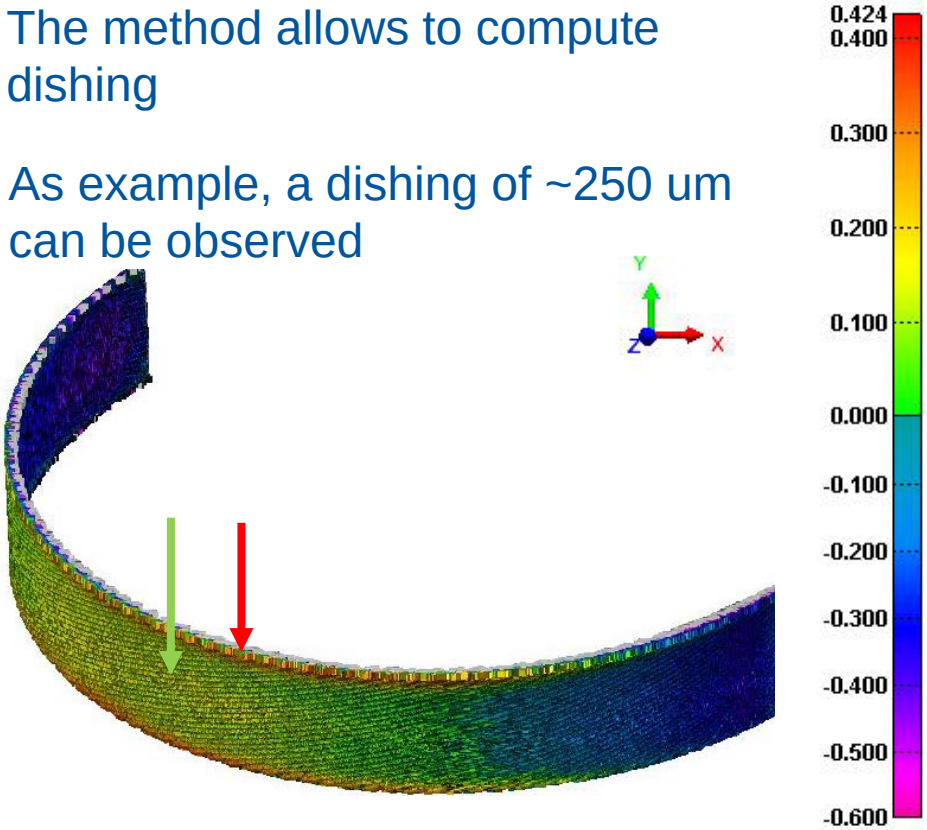
Dishing is difficult to be measured with a caliper



- Analysis being performed

The method allows to compute dishing

As example, a dishing of ~250 um can be observed



This measurement will help us to better predict coil geometry

Status of cable trials

Magnet / option	Ramp angle (°)	Winding machine load 25 and 50 kg	Geometric measurements	Laser track
HEPDipo baseline	10	✓	✓	✓
HEPDipo baseline	17 (FRESCA2)	✓	✓	✓
HEPDipo 4 coils Outer coil	10	✓	✓	✓
HEPDipo 4 coils Outer coil	17 (FRESCA2)	✓	✓	✓
DEMO 16 T for FCC Inner layer	-	✓	✓	✓
DEMO 16 T for FCC Outer layer	-	✓	✓	✓
Status	finished	finished	finished	Data under analysis

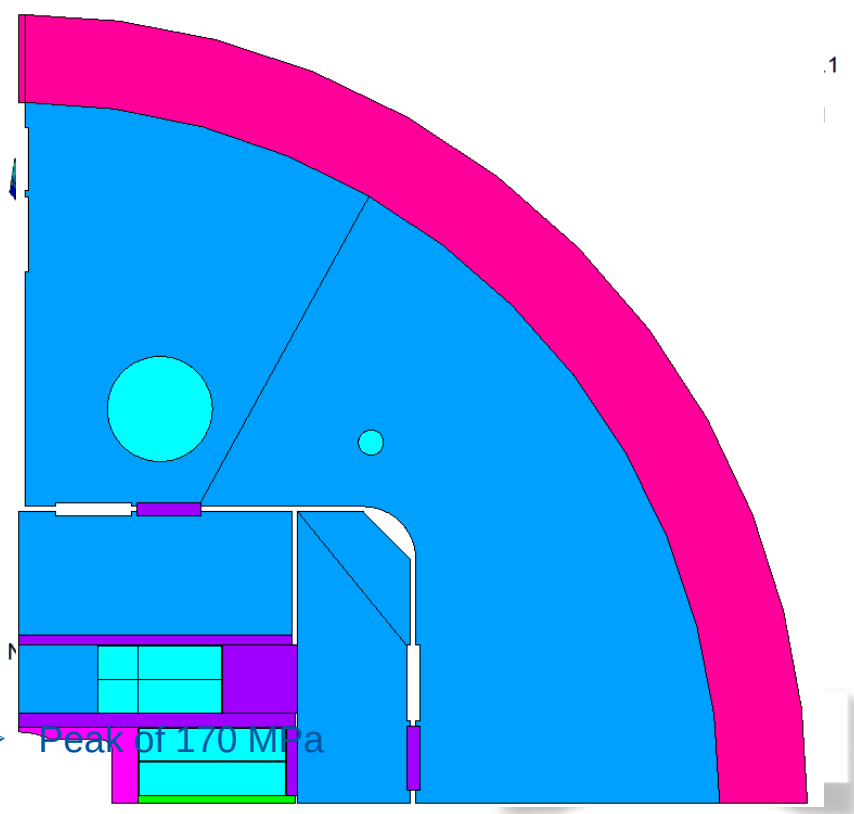
Brief historic of modelling and options

ASC 2018
End of 2018 - review

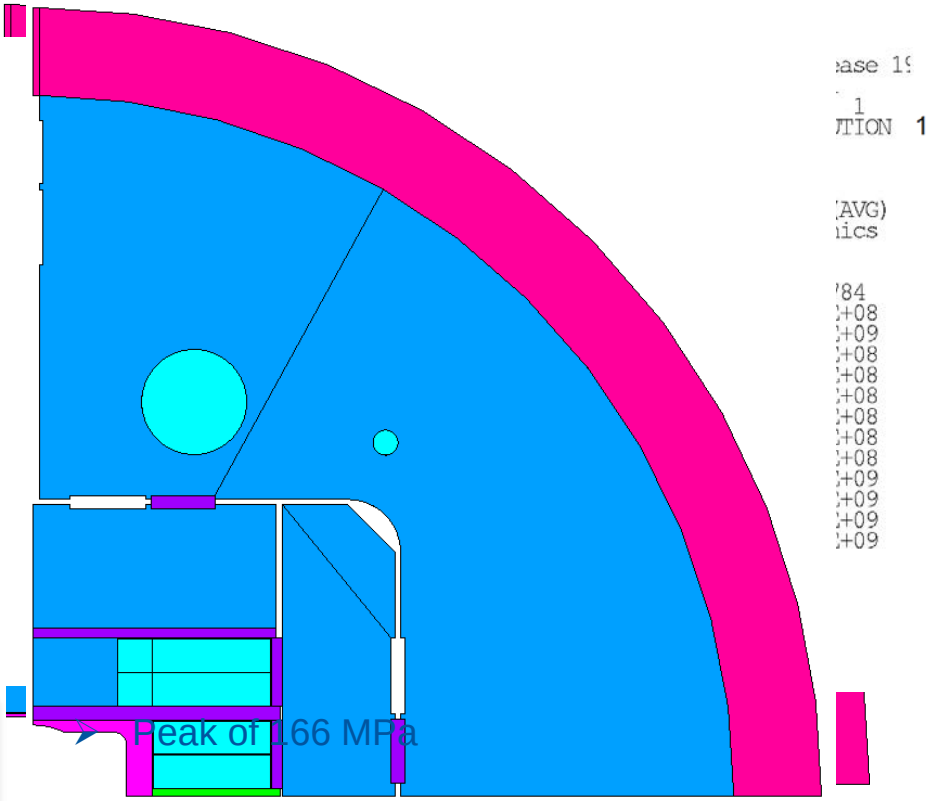
2019

End of 2019 - review

2020



- Peak of 170 MPa

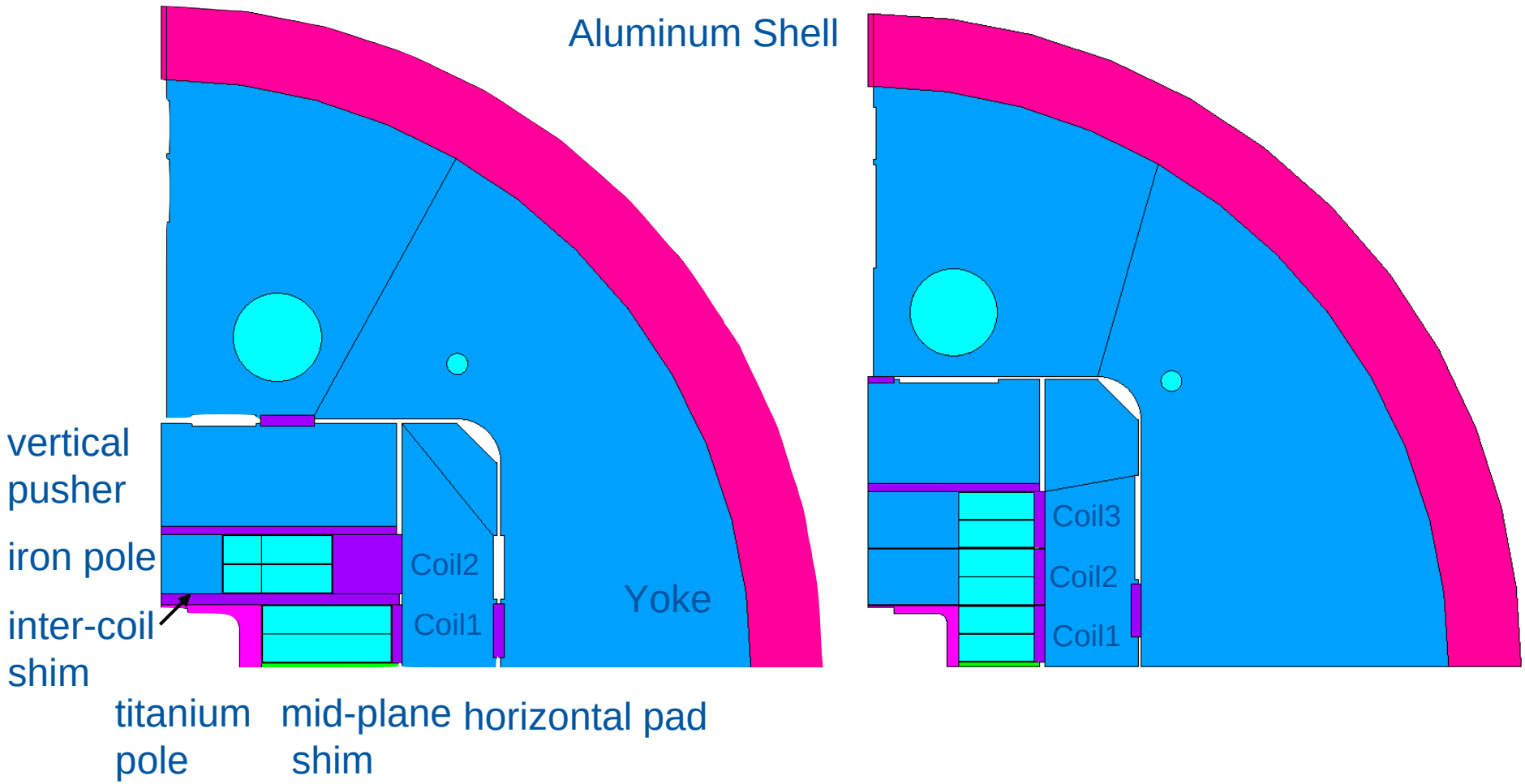


- Peak of 166 MPa

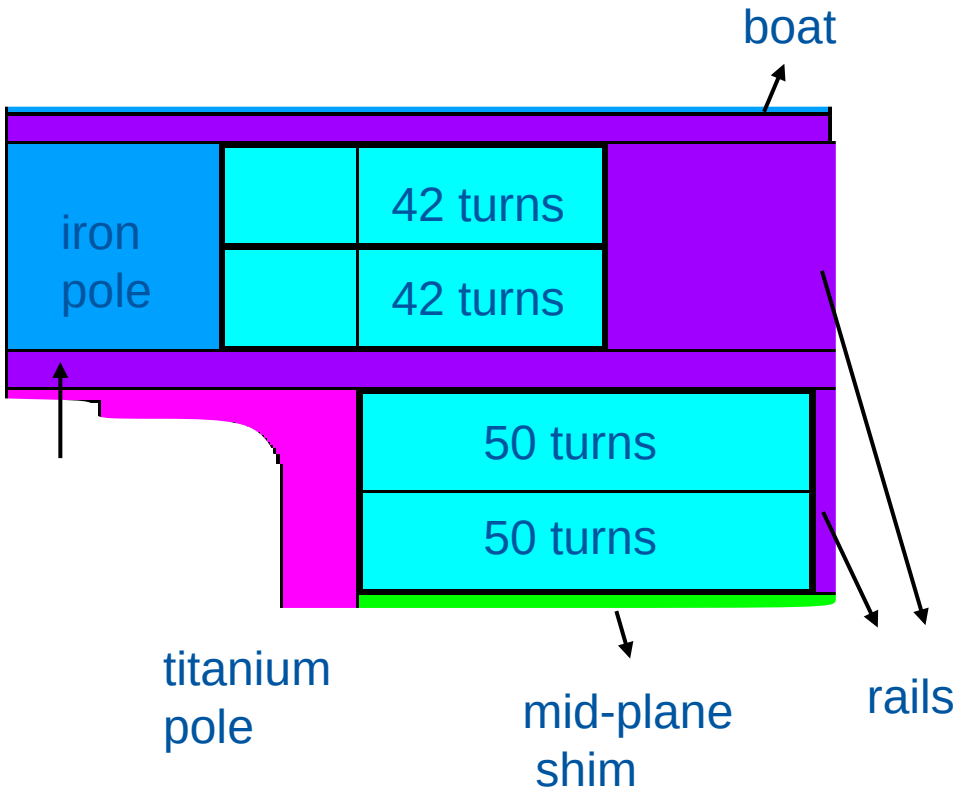
Status of models and design

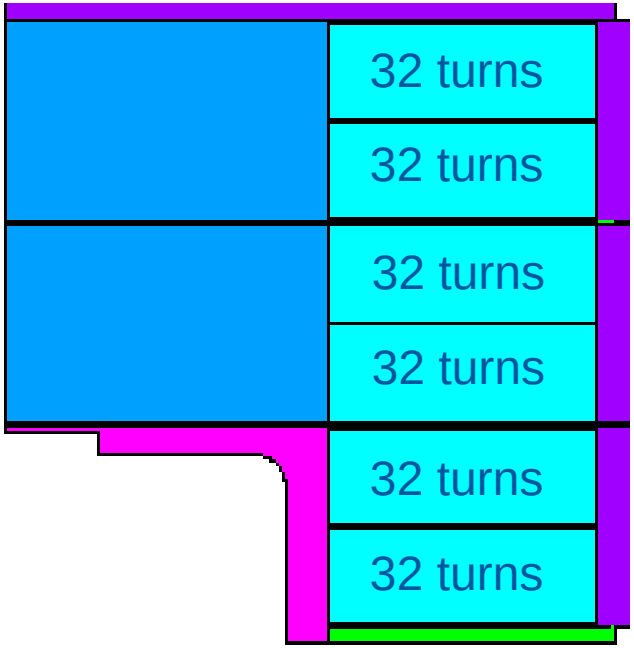
Model	Baseline	4 coils option
2D Ansys magnetic	✓	✓
2D Opera magnetic	✓	✓
2D Roxie magnetic	✓	✓
2D Ansys mechanical	✓	✓
3D Ansys magnetic	✓	✓
3D Opera magnetic	✓	✓
3D Ansys mechanical	✓	Updating for the new 4 coils solution
Magnet protection	✓	Updating for the new 4 coils solution
Status of design	Addressing issues: - pre-load criterium - Ti pole deformation - Stress on the wedge - Rod (Al / SS)	Addressing issues: - pre-load criterium - Stress on the end plate - etc..

New studies: 4 coils option vs 6 coils (baseline)



4 coils option vs 6 coils (baseline)



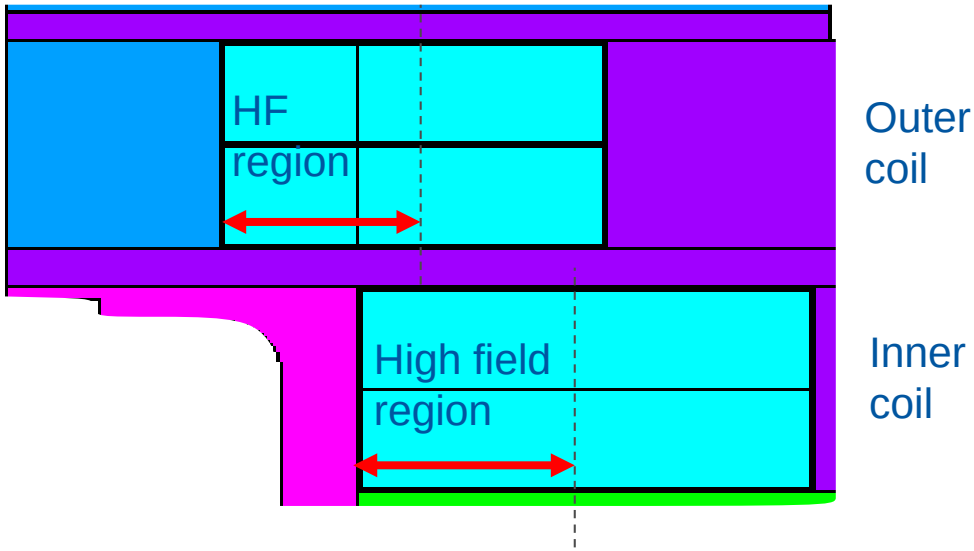


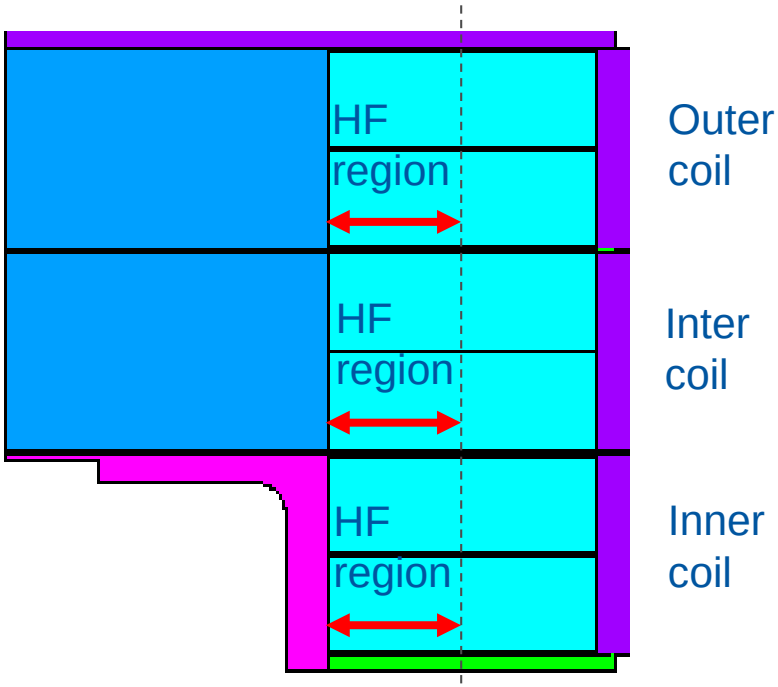
	Turns (1/4)
4 coils	92
6 coils	96

Magnetic results comparison (85 % of LL – 4.2 K)

Parameter	4 Coils value	6 Coils value
Bap - aperture field (T)	14.84	14.82
Bpk - Coil peak field (T)	15.17	15.31
Field quality b3, b5, b7, b9 (units)	- 5.86, - 4.01, 2.05, - 0.10	42.08, - 10.49, - 0.80, - 0.14
Energy per length (MJ/m)	7.3	6.86
Horizontal Lorentz force (1/4) (MN/m)	14.37	14.41
Vertical Lorentz force (1/4) (MN/m)	- 8.56	- 7.11
Operational current (kA)	14.67	14.28
(Bap/Bpk)/(SC_area) ($1/mm^2$)	8.09E-5 (+5.5%)	7.68E-5

Stress on coils comparison



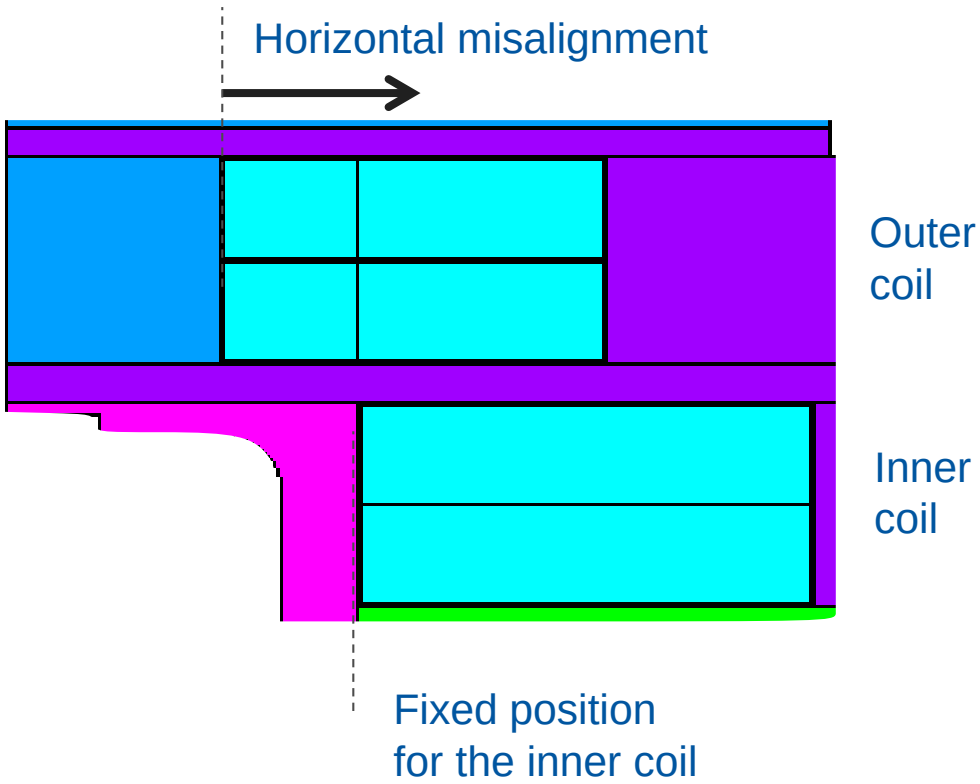


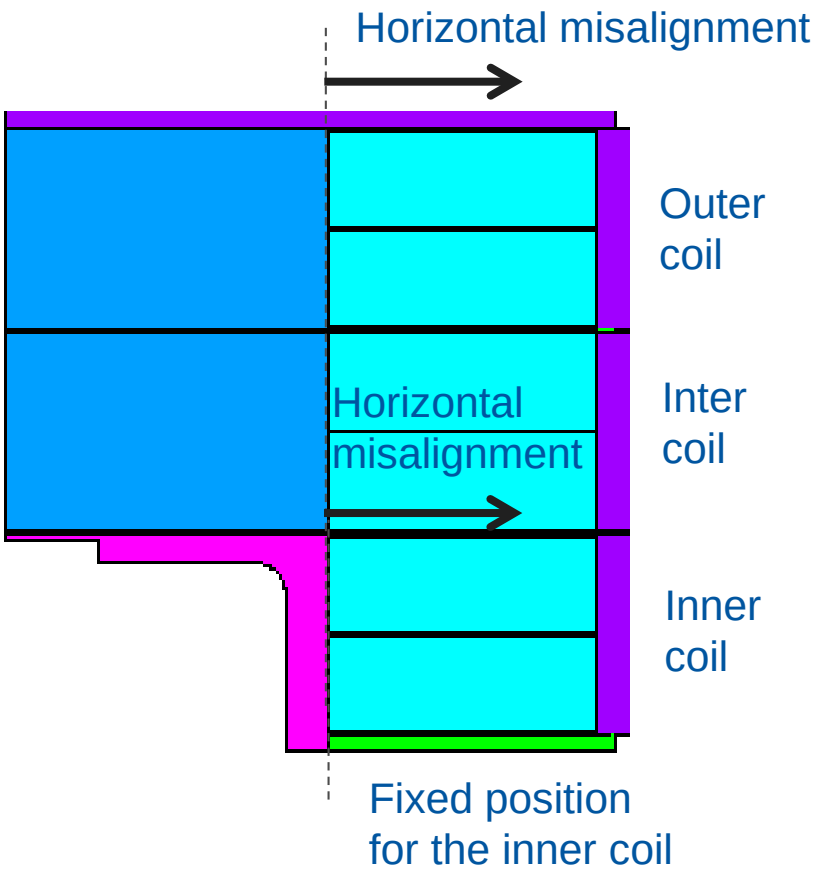
15 T operation	4 Coils von Mises stress	6 Coils von Mises stress
Inner / inter / outer coils	145 / / 120 MPa	158 / 115 / 110

Mechanical results comparison

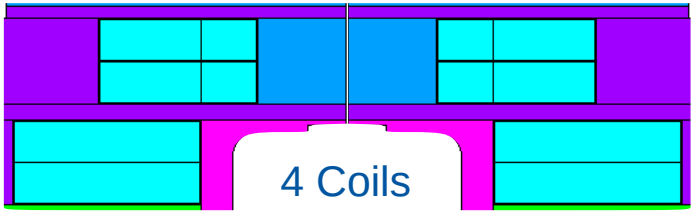
Parameter	4 Coils value (MPa)	6 Coils value
	Room temperature / cooling down / 15 T	Room temperature / cooling down / 15 T
Inner coil	9 / 52 / 145	48 / 110 / 158
Inter coil	-	74 / 154 / 145
Outer coil	55 / 103 / 135	53 / 113 / 117
Iron pole (S1)	1 / 13 / 280	1 / 15 / 246
Horizontal pad (S1)	92 / 157 / 109	100 / 200 / 130
Vertical pad (S1)	44 / 54 / 128	57 / 77 / 78
Yoke (S1)	92 / 155 / 194	105 / 108 / 140
titanium pole (Von Mises)	81 / 590 / 800	370 / 766 / 1225
Shell (Azimuthal)	70 / 163 / 154	123 / 215 / 234

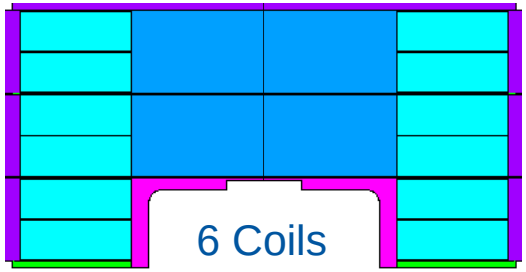
Parametric analysis: horizontal tolerance

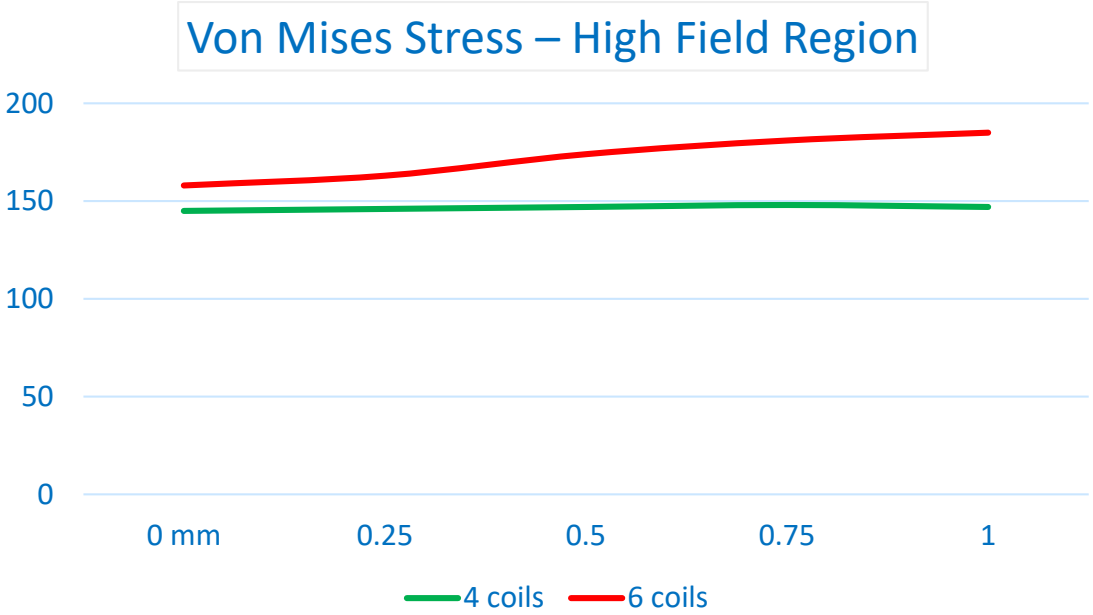




Parametric analysis: horizontal tolerance



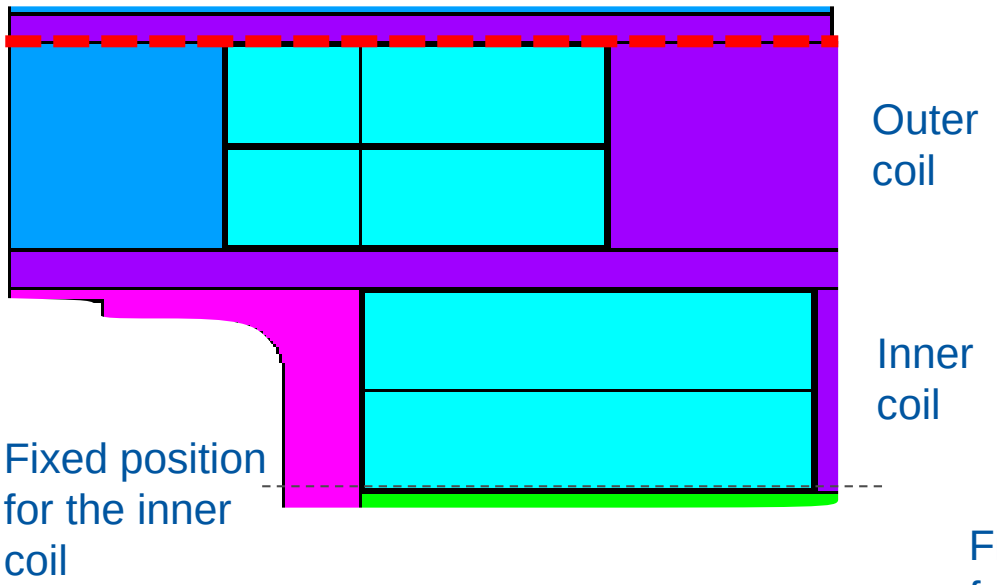


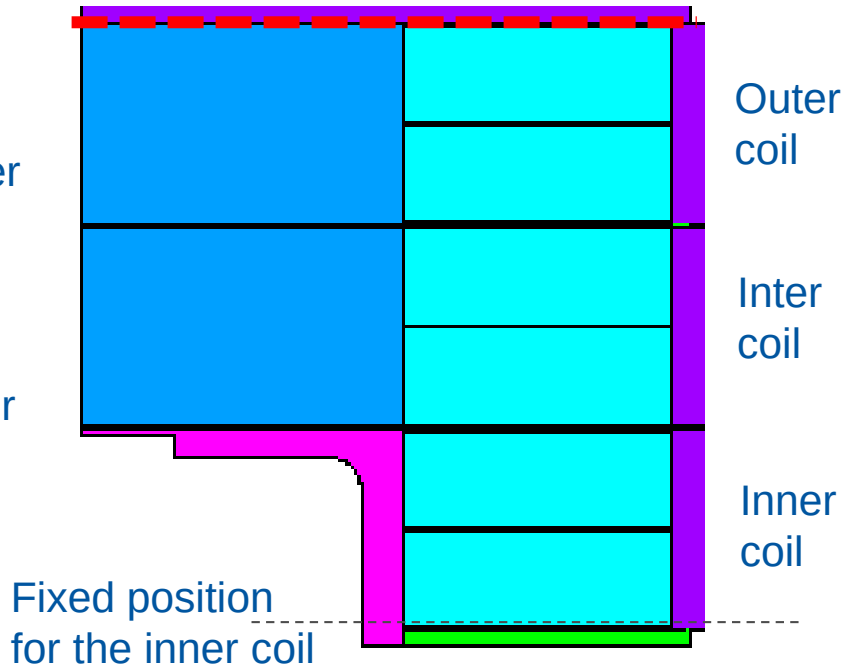


For a mm of displacement the peak of stress of the 4 coils option remains the same.

The peak is stress of the 6 coils option goes from 157 to 186 MPa

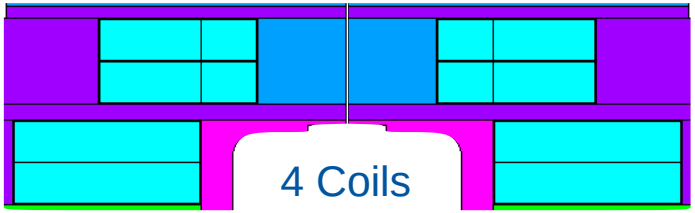
Parametric analysis: vertical tolerance

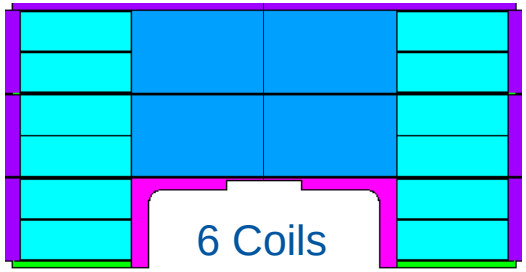


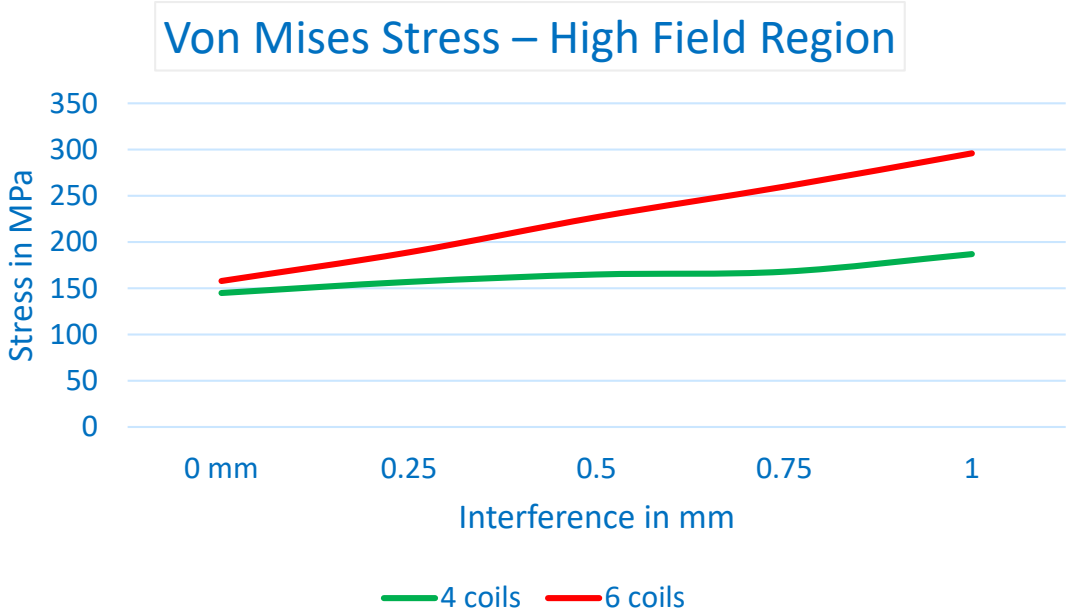


The inner coil position is fixed. An interference, representing the dimension tolerance is introduced between coils (▬ ▪)

Parametric analysis: vertical tolerance - coils



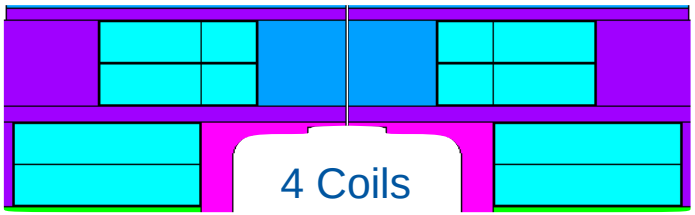


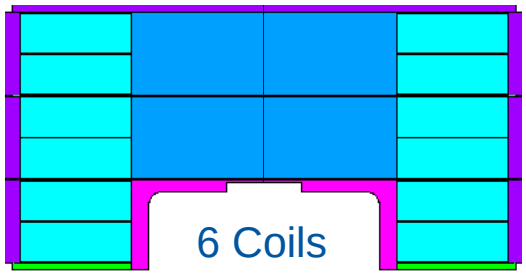


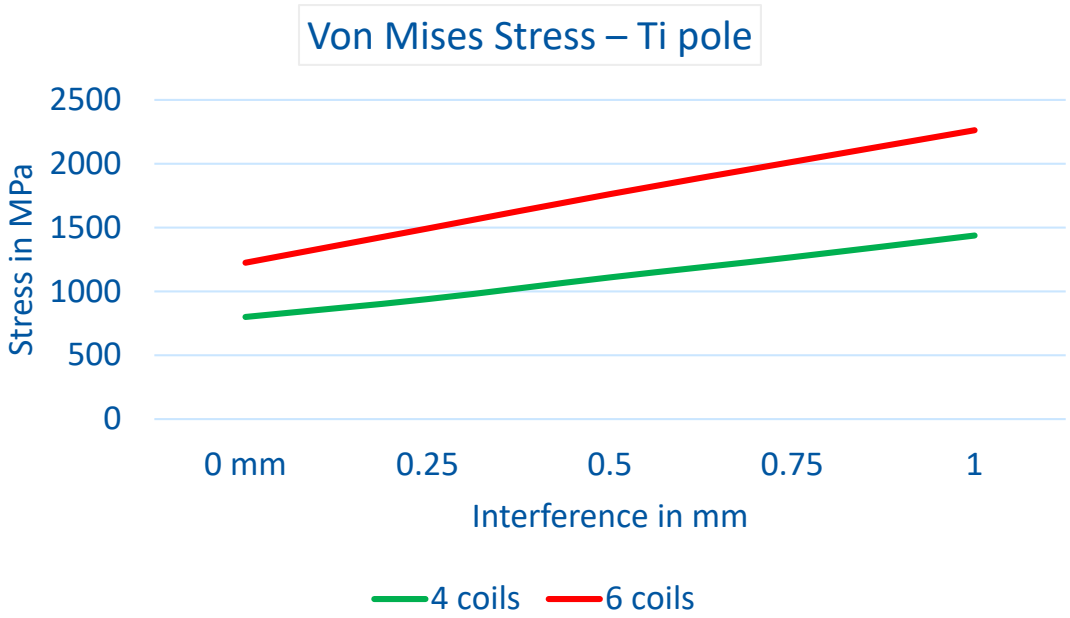
For a mm of interference between Coils, the peak of stress of the 4 coils option goes from 145 to 187 MPa

The peak of stress of the 6 coils option goes from 157 to 290 MPa

Parametric analysis: vertical tolerance – Ti pole







For a mm of interference between coils the peak of stress on the Ti Pole of the 4 coils option goes from 800 to 1438 MPa

The peak is stress on the Ti pole of the 6 coils option goes from 1225 to 2262 MPa

Conclusions about the 4 coils option

- Magnetic analysis
  - The 4 coils option is more efficient
  - It presents a better field quality
  - It requires less sc conductor
- Mechanical analysis
  - The 4 coils option seems to be more robust in respect to tolerances
  - It is easier to reach compression criterium (end)
  - It presents less stress on the Ti pole
- Coil manufacturing
  - It requires 6 coils (4 + 2 spares) instead of 9
  - Since it requires less coils, it could be delivered faster