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# **15T Demonstrator: mechanical design, analysis and optimization**

Igor Novitski

Video Meeting

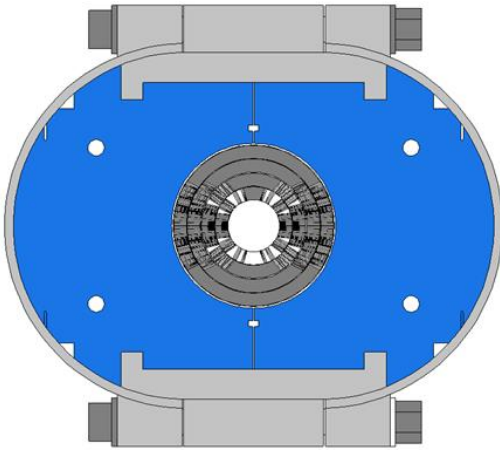
18 October 2016

# Outline

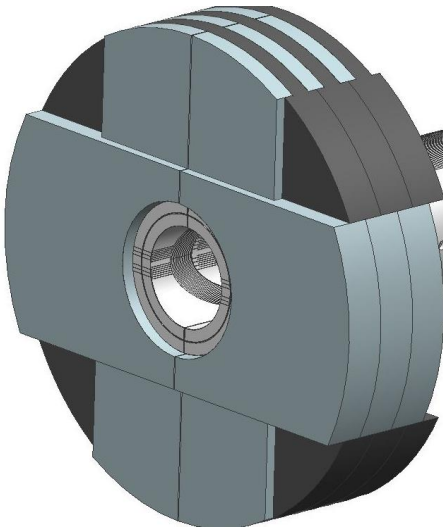
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- Magnet concept evolution
- Models and Materials
- Design 1: C-Clamp
- Design 2: IC-Clamp
- “HD-2” structure optimization
- Design 3: AL Cylinder
- Summary

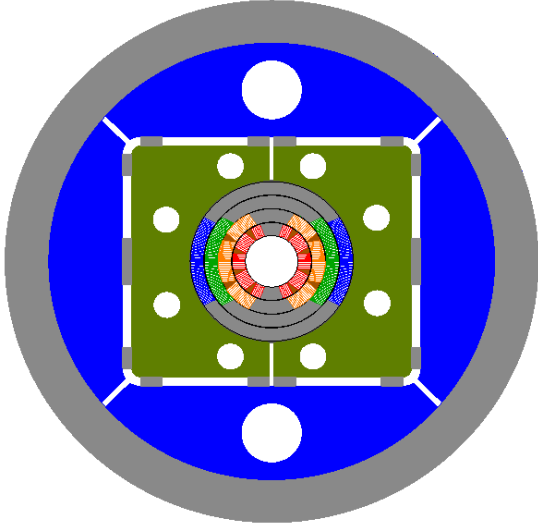
# Magnet Concept Evolution



C-Clamp Magnet

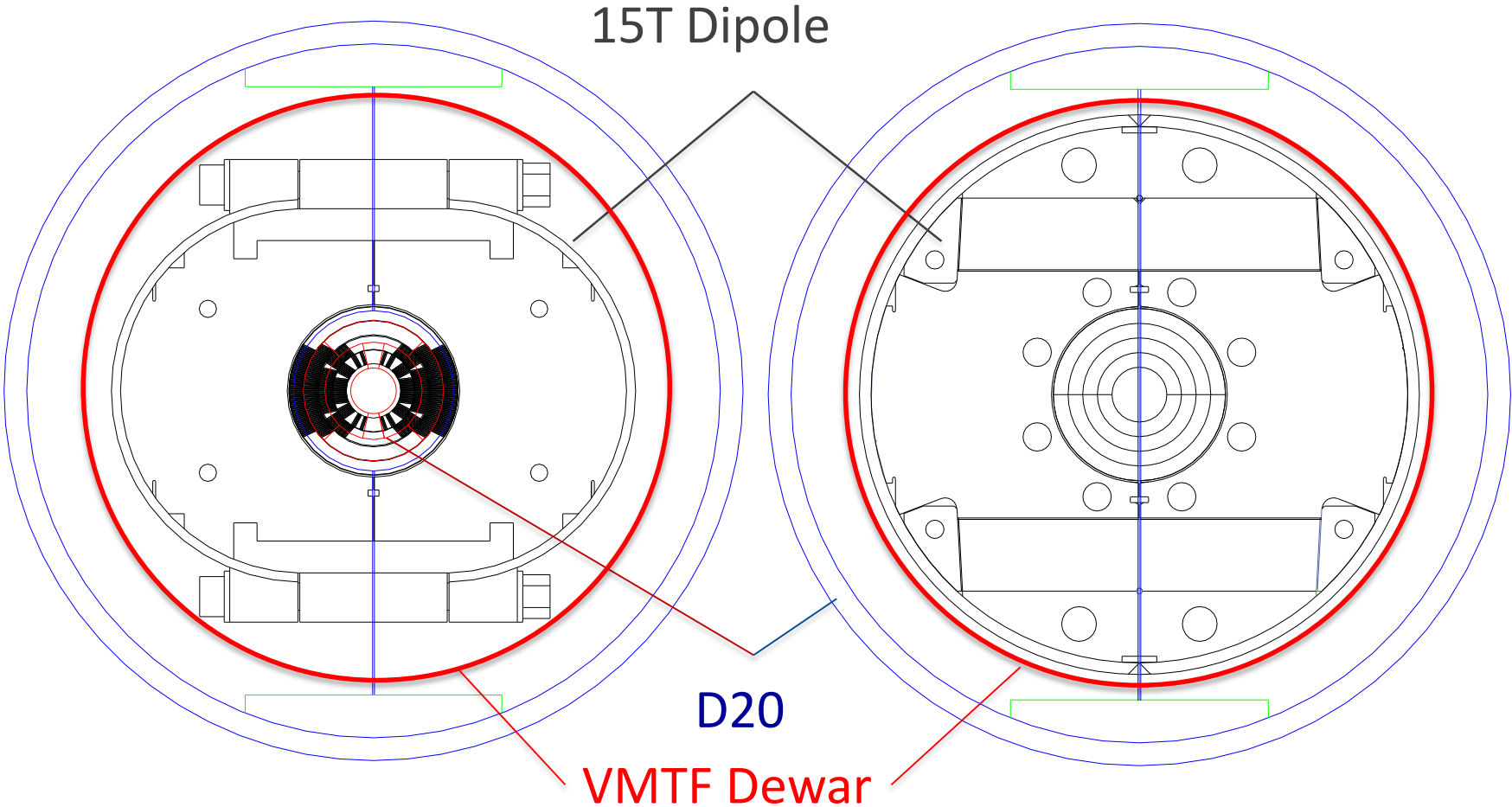


I-Clamp Magnet

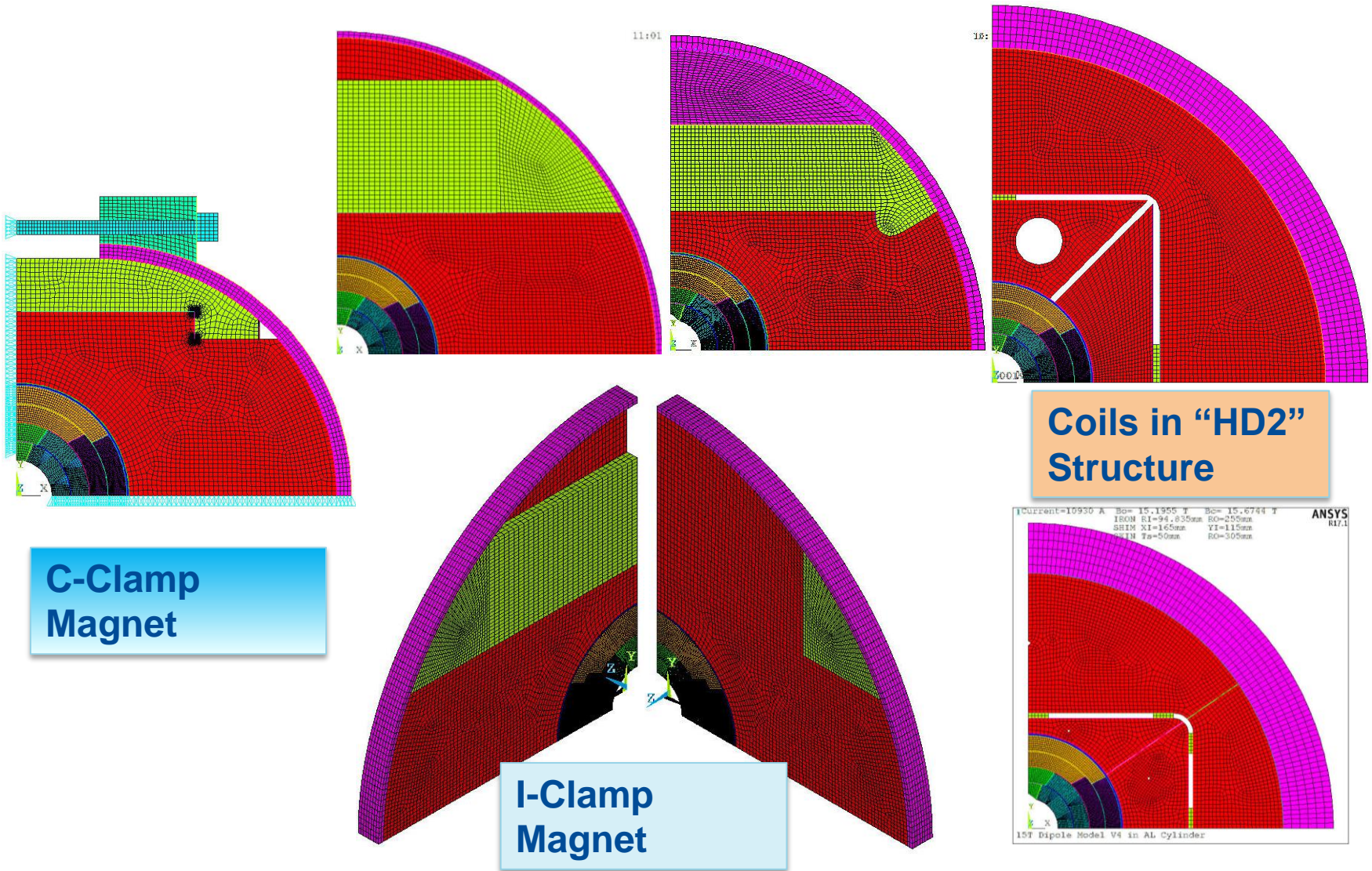


Al Shell Magnet

# Geometry Comparison



# FEA Models



C-Clamp Magnet

I-Clamp Magnet

Coils in "HD2" Structure

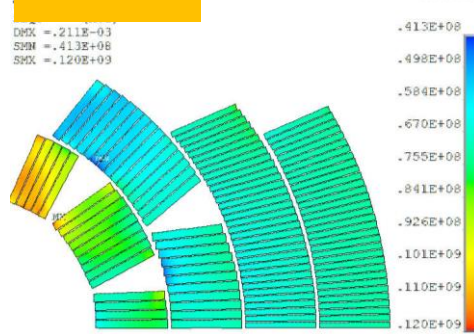
# Material Properties

Structural element	Material	Thermal contract. (300-2 K),	Elasticity modulus, GPa		Yield stress, MPa	
		mm/m	warm	cold	warm	cold
Coil (rad/azim)	Nb <sub>3</sub> Sn composite	2.9/3.3	35/20	40/40	n/a	n/a
In.coil pole blocks	Ti-6Al-4V	1.7	115	125	650	>900
Out.coil pole blocks	St St	2.9	195	215	230	500
Wedges	Bronze	3.2	110	120	280	350
Coil-yoke spacer	St St	2.9	190	210	230	500
Clamp	Aluminum	4.1	70	81	500	700
Yoke	Iron	2.0	205	225	220	500
Skin	St St 316	2.9	190	210	290	580



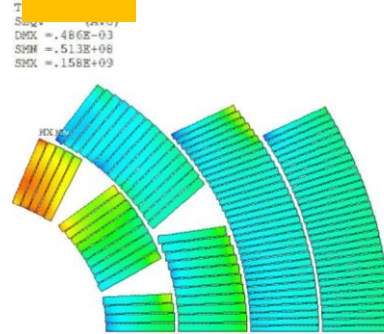
# Design 1: C-Clamp+20mm Skin, FEA Results

300K



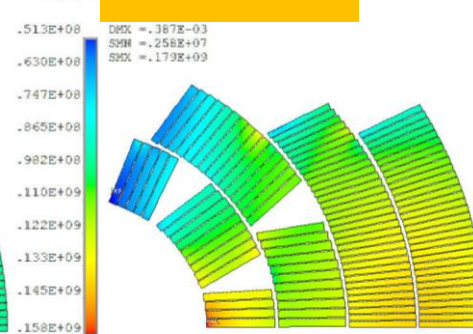
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4K

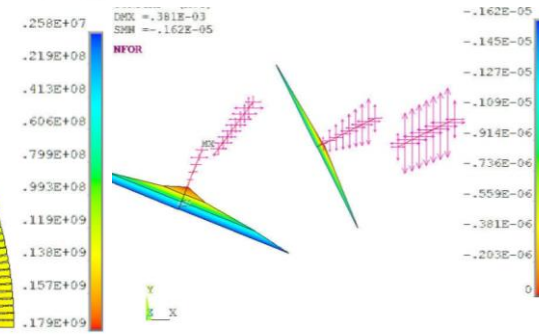


Seqv=158MPa

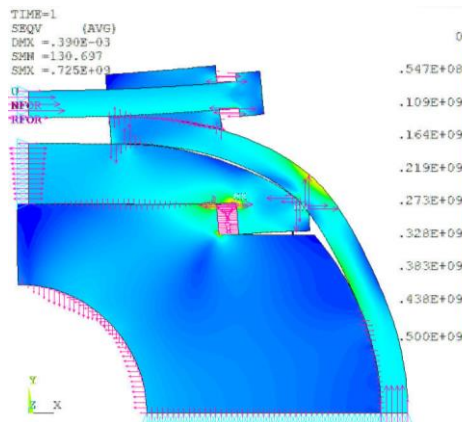
4K+15T



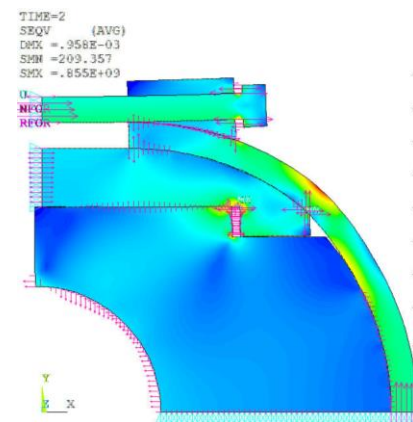
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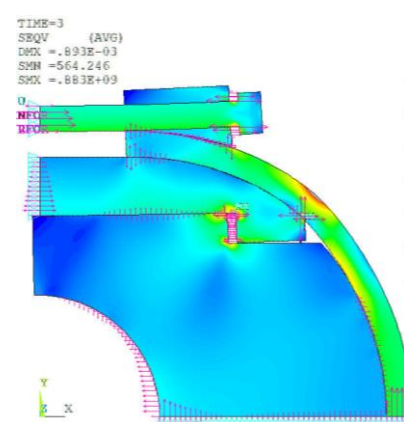
Inner Pole Gap=0.002mm



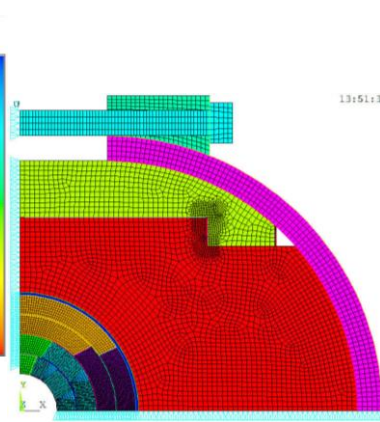
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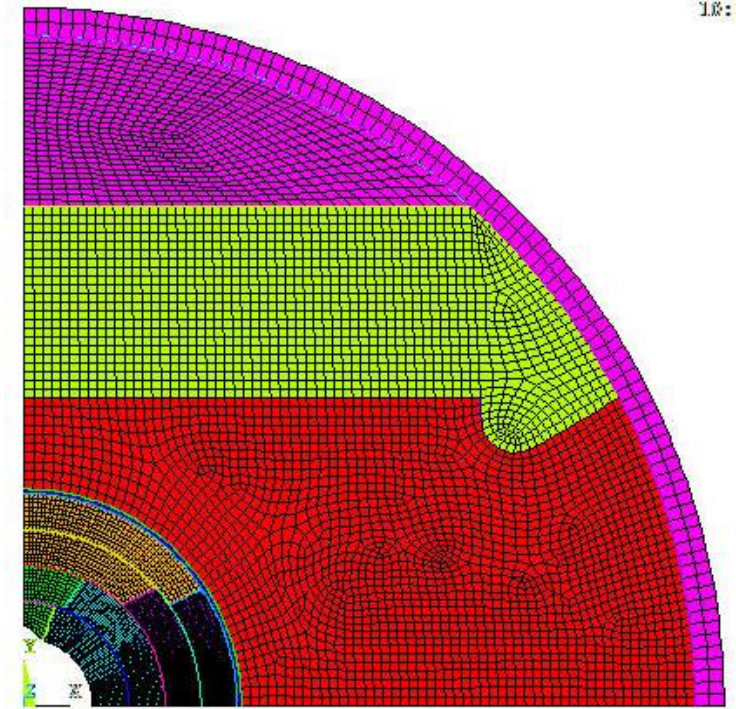
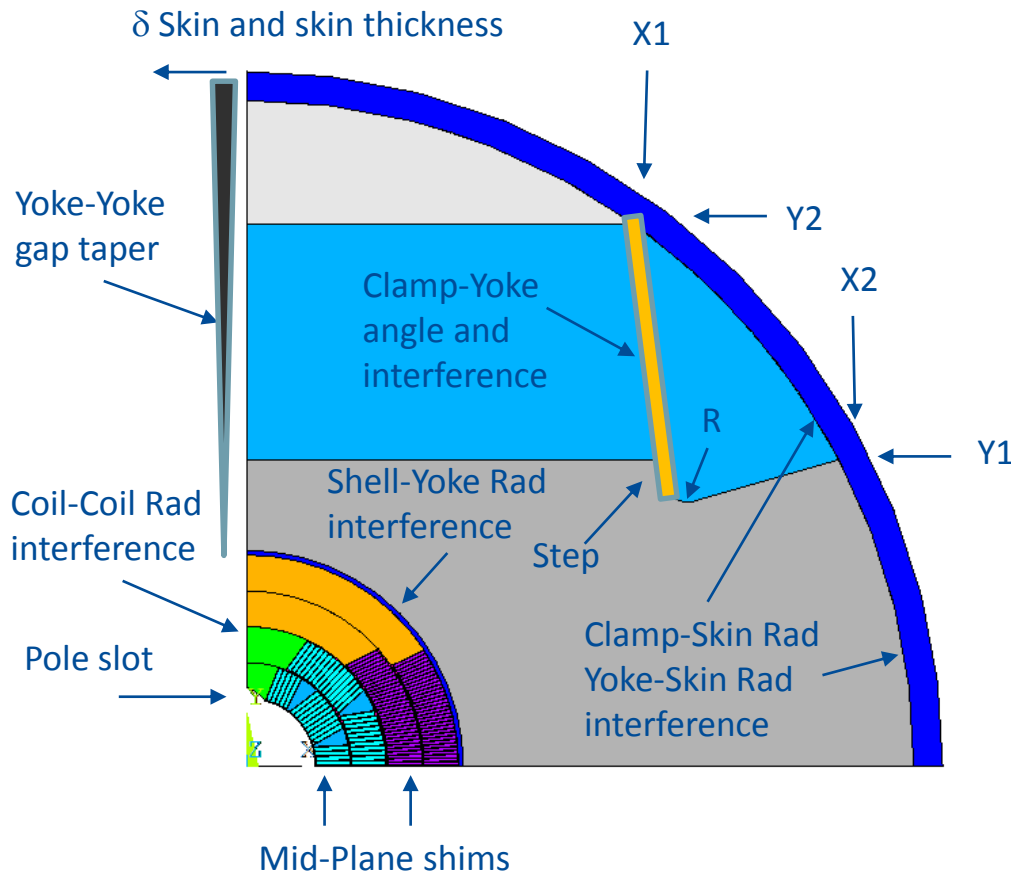
Seqv=850MPa



Seqv=880MPa

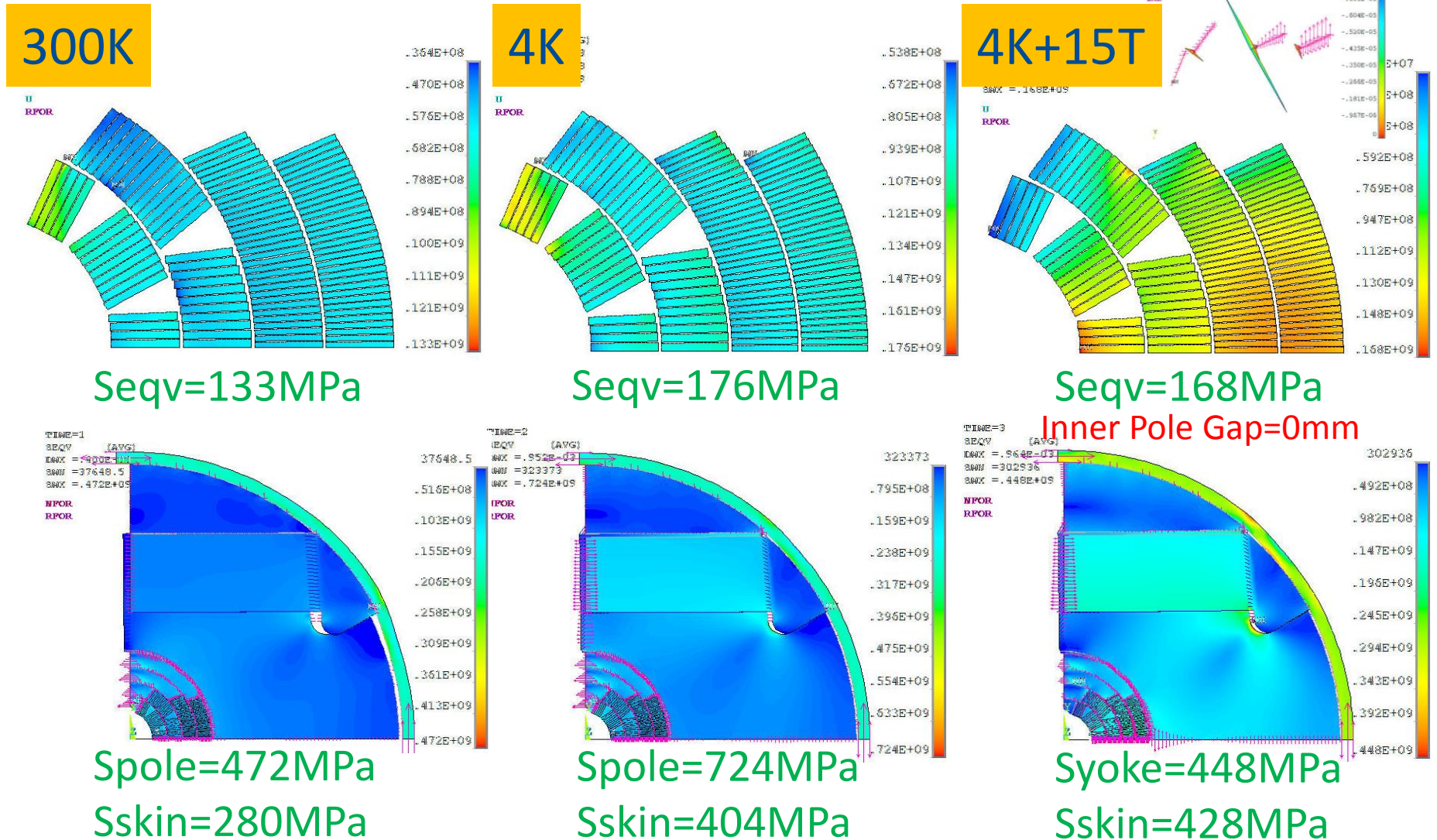


# Design 2: IC-Clamp+12mm Skin, FEA Model

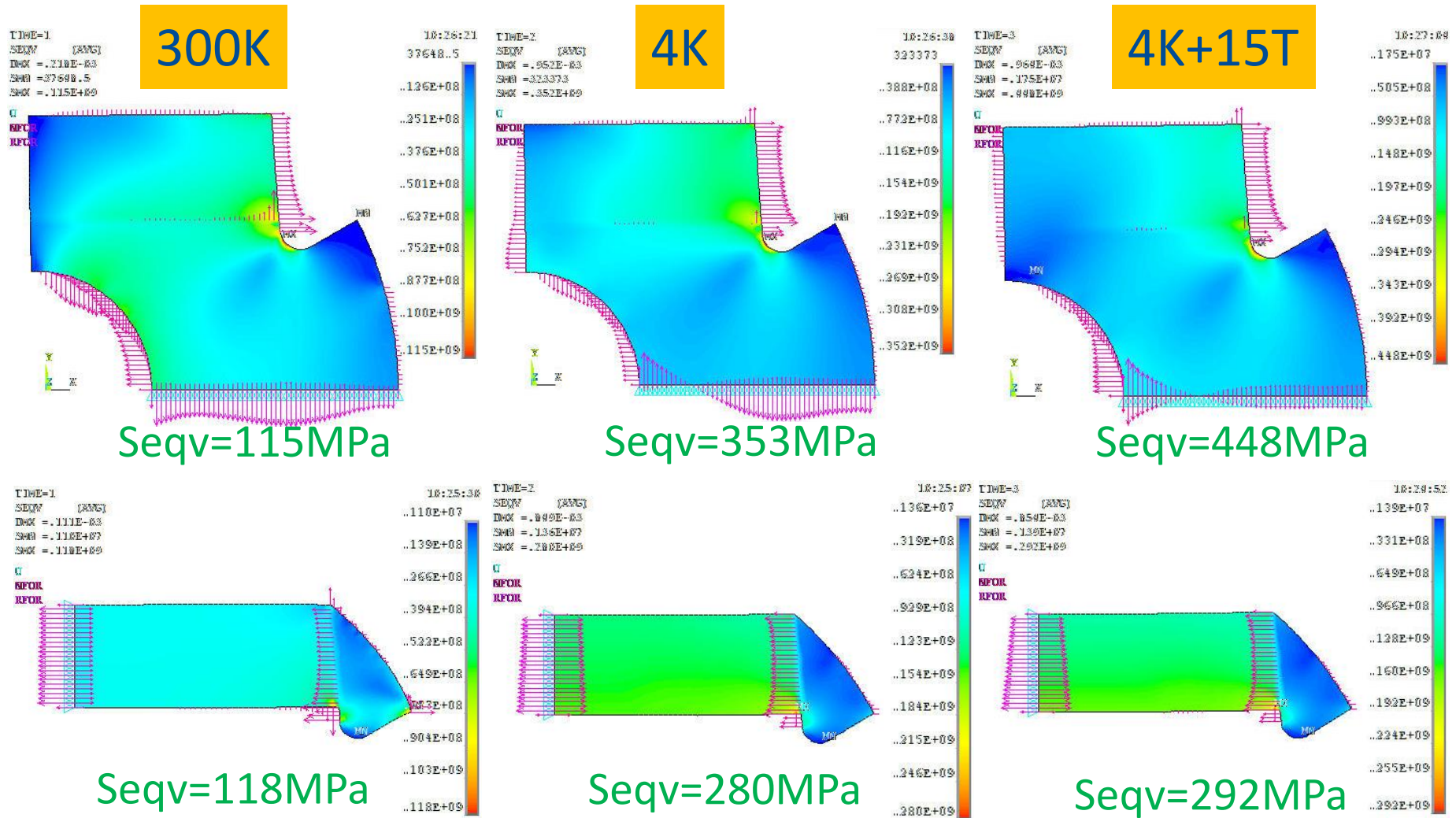




# Design 2: IC-Clamp+12mm Skin, FEA Results

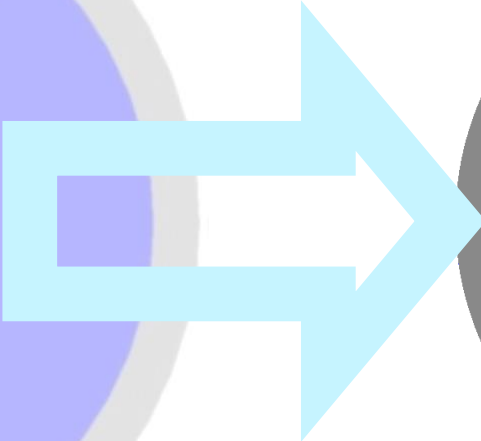
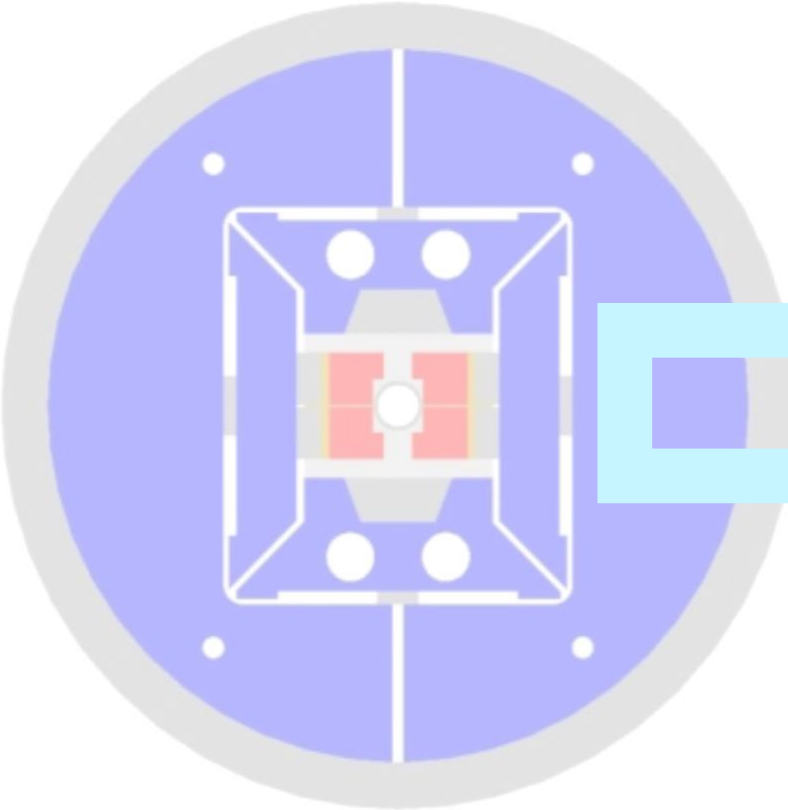


# Design 2: IC-Clamp+12mm Skin, FEA Results

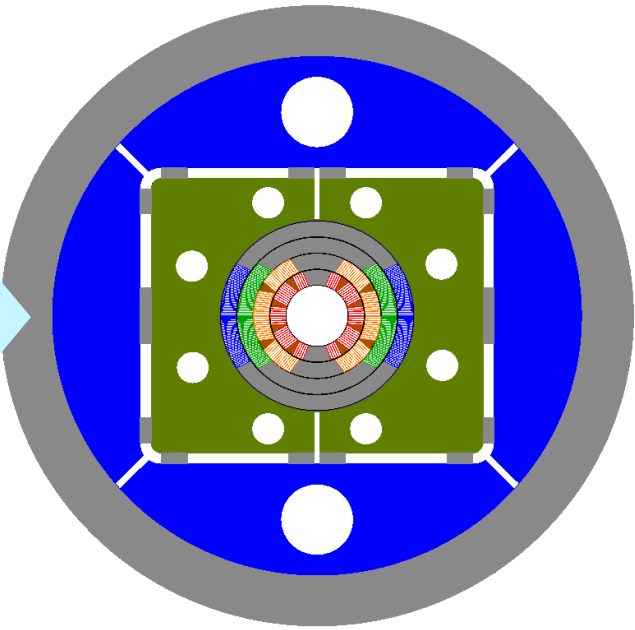


# AL Shell Design

HD2

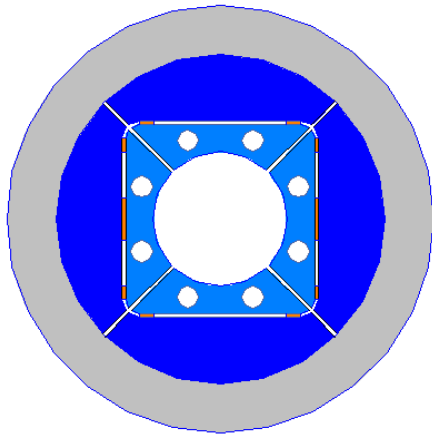


15 T Alternative

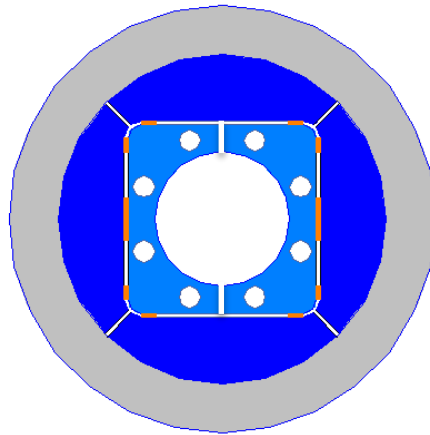


# Parametric Model of the Structure

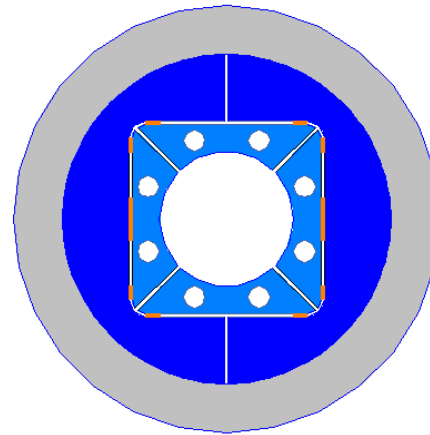
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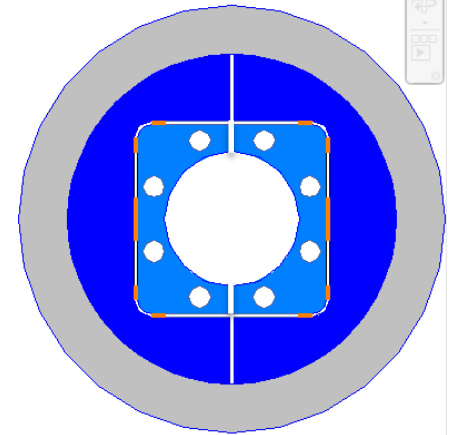
2



3



4

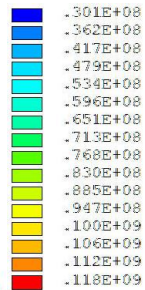


Al Shell: 50 and 70 mm thick  
Iron Pad: 2 or 4-piece  
Iron Yoke: 2 or 4-piece

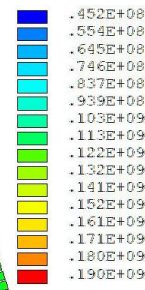


# Design 3: 50mm AL Cylinder, FEA Results

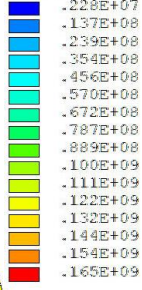
300K



4K



4K+15T

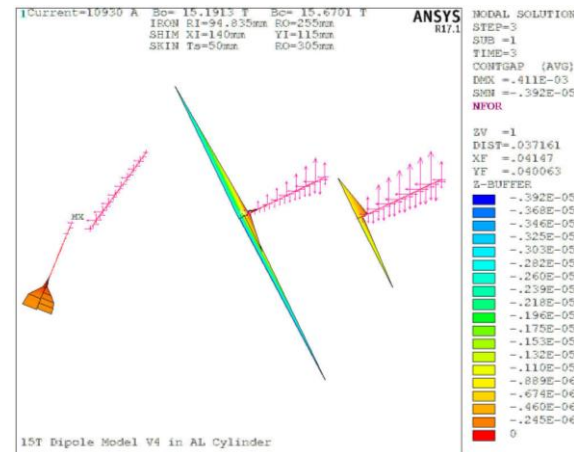
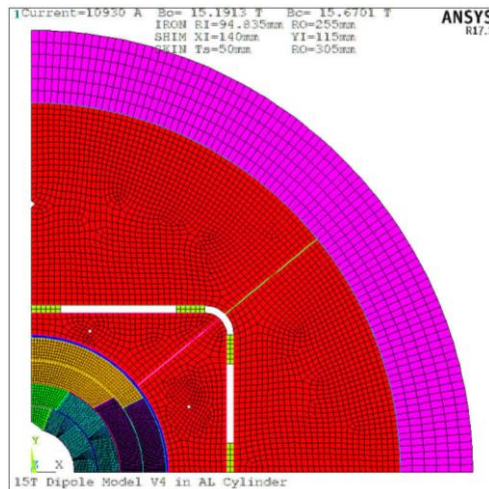


Seqv=118MPa

Seqv=190MPa

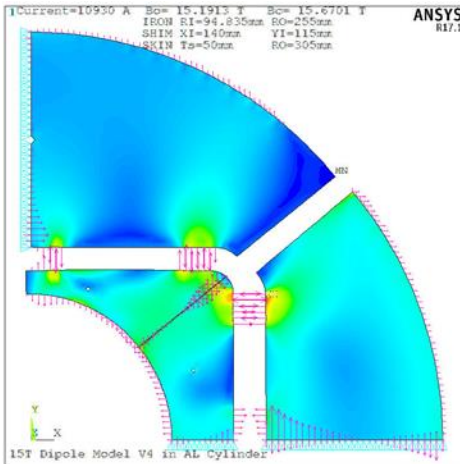
Seqv=165MPa

Inner Pole Gap=0.3um

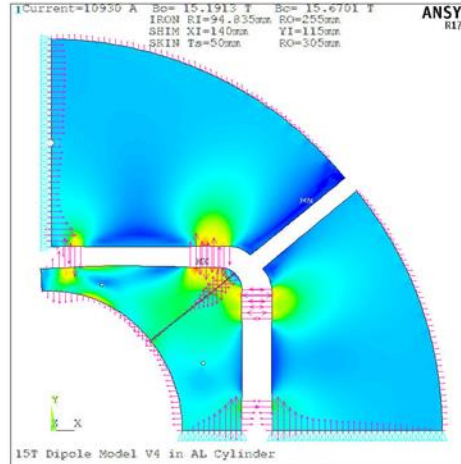




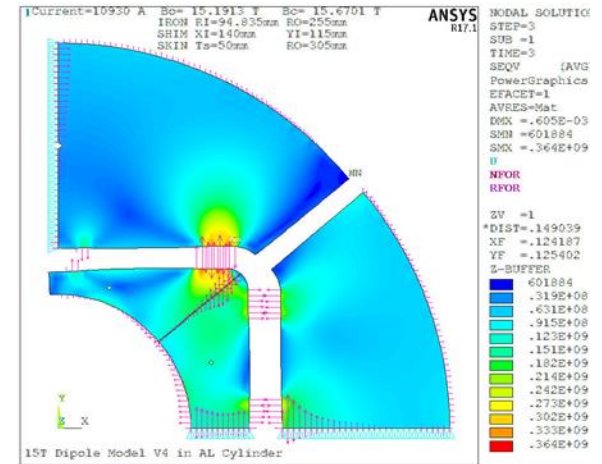
# Design 3: 50mm AL Cylinder, FEA Results



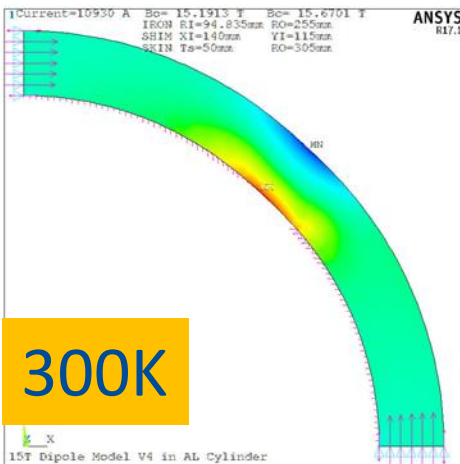
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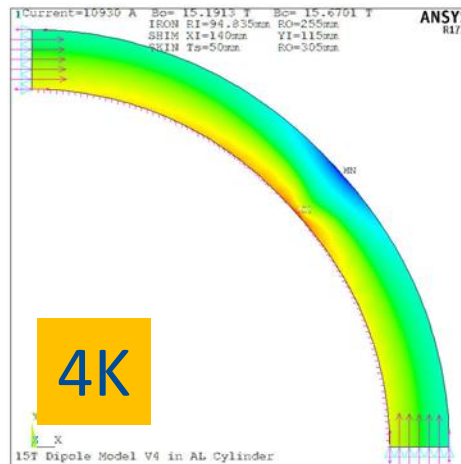
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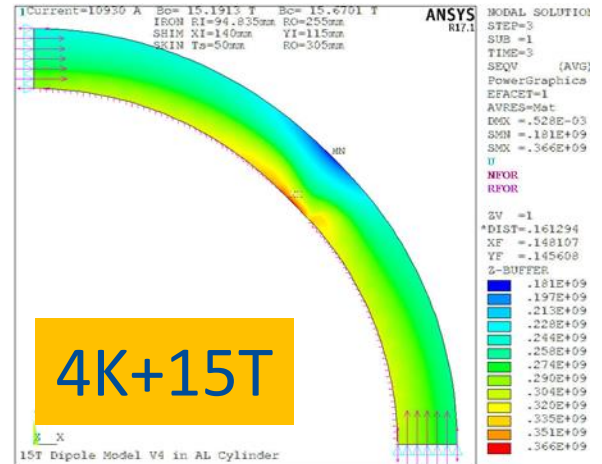
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Seqv=206MPa



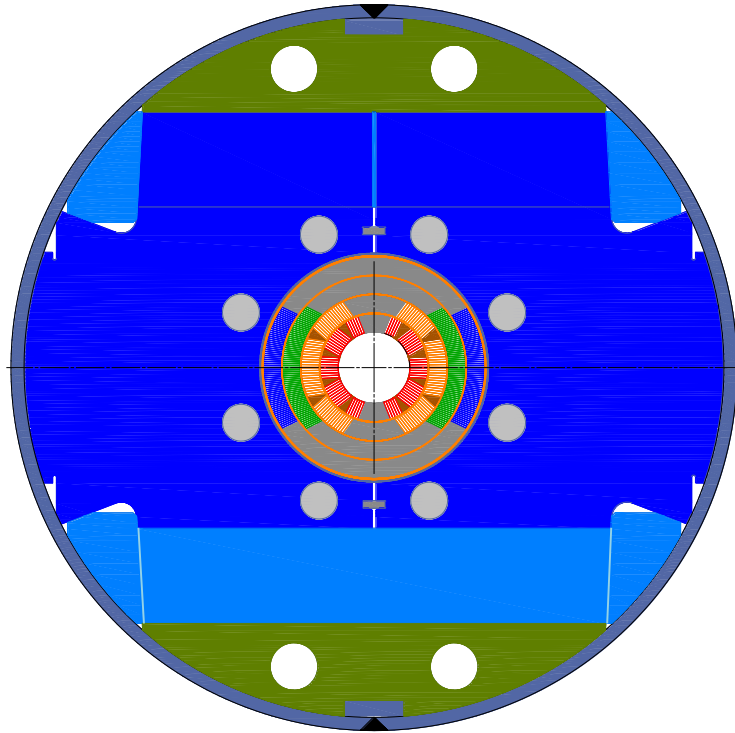
Seqv=339MPa



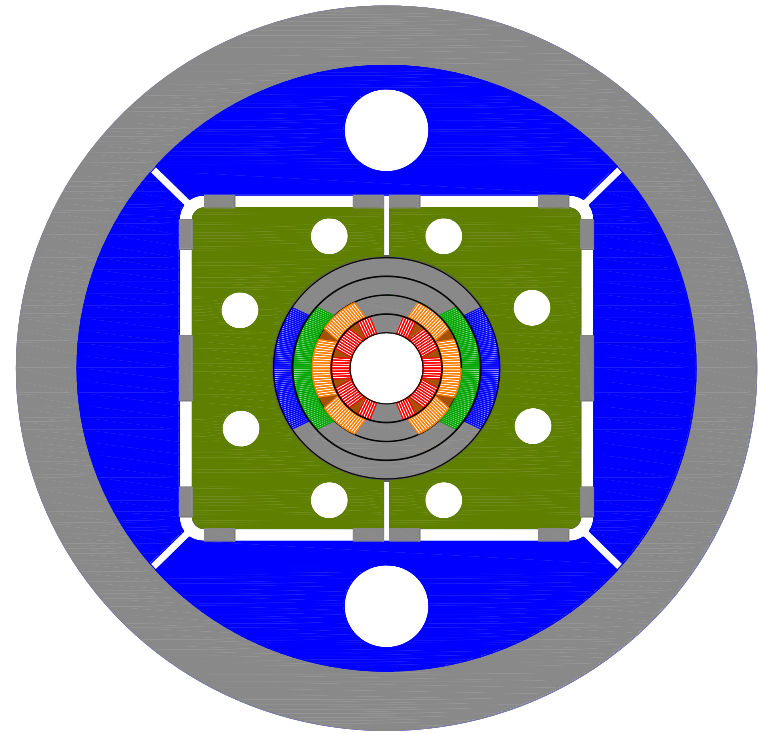
Seqv=366MPa

# 15 T Demonstrator Support Structures

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Baseline



Alternative

# Comparison of Baseline and Alternative Designs

Position in coil	Baseline, Azimuthal Coil Stress, MPa			Al Shell, Azimuthal Coil Stress, MPa		
	Assembly	Cool down	B=15 T	Assembly	Cool down	B=15 T
Pole 1	88	138	9	89	168	3
Pole 2	46	75	21	45	87	21
Pole 3	64	97	36	65	123	37
Pole 4	62	95	62	61	113	63
Mid-plane 1	64	95	153	59	99	149
Mid-plane 2	65	107	127	66	134	127
Mid-plane 3	62	92	153	61	107	153
Mid-plane 4	66	103	153	67	131	157

## MAXIMUM EQUIVALENT STRESS IN KEY STRUCTURAL ELEMENTS (MPa).

Structural element	Baseline design			Design with Al shell		
	Assembly	Cool down	B=15 T	Assembly	Cool down	B=15 T
Coil	133	176	168	118	190	165
Yoke	115	353	448	174	308	364
Clamp	118	280	292	-	-	-
Skin	280	404	428	206	339	366

## Contact gaps at poles

Al Shell at 15T:

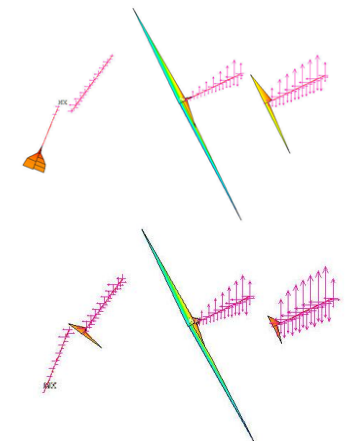
Inner Pole Gap=0.3um (30%)

Layer 3 pole Gap=4um (15%)

Baseline at 15T:

Inner Pole Gap =0um

Layer 3 pole Gap=7um (20%)



# Summary

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- Several concepts of mechanical structure have been analysed and compared.
- Mechanical designs with IC-Clamps (Baseline) provides the required coil prestress and restricts turn radial, azimuthal and longitudinal motion for the operating current range up to 15T.
- Alternative magnet support structure based on a 50 mm thick aluminum shell, 4-piece iron yoke and 2-piece iron pad behave likewise.
- Both structures allow keeping the stresses in the coil and support structure within acceptable limits during magnet assembly and operation.