Mu2e CD-2 Director Review: Calorimeter 475.07.03 Mechanics

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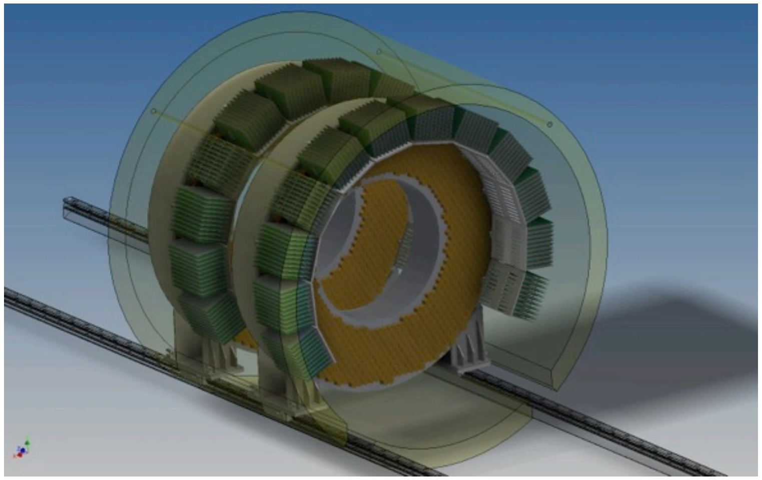
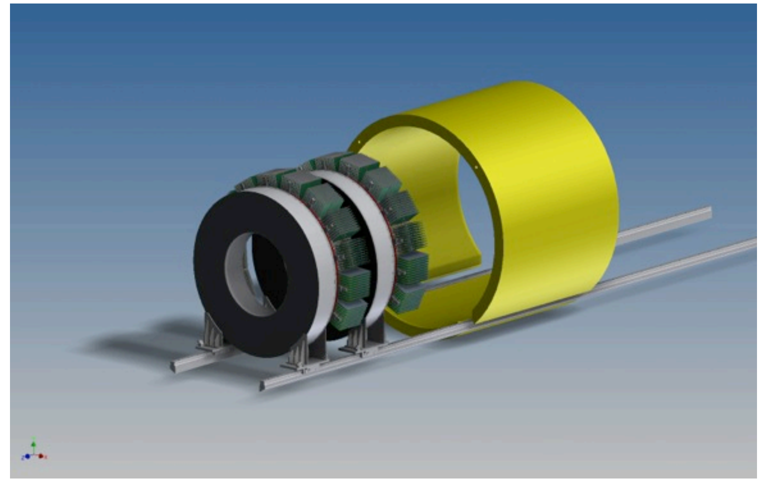
INFN Lecce
7/8/2014

Calorimeter design

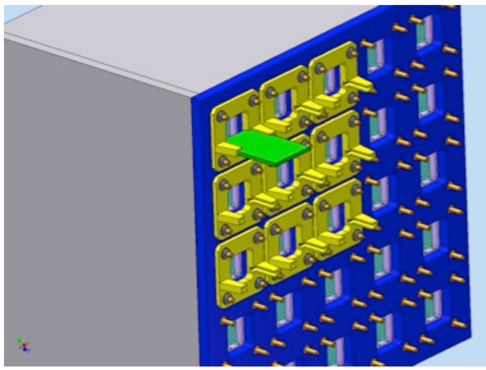
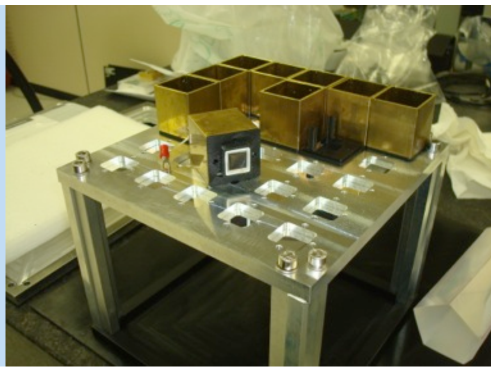
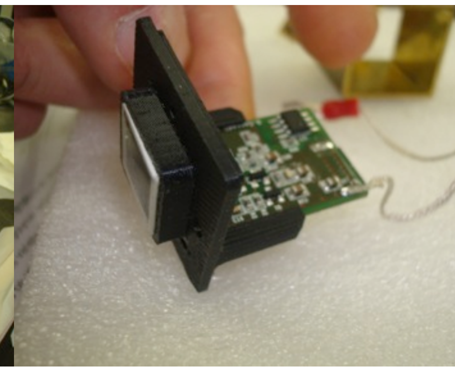
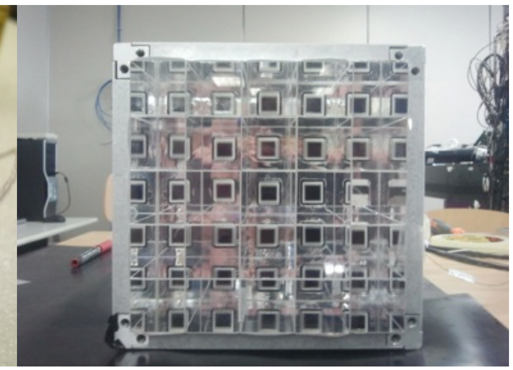


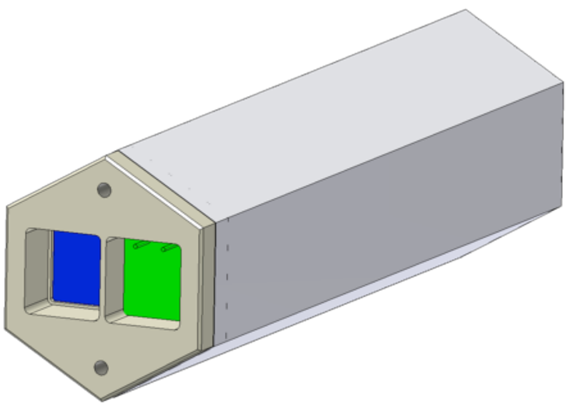


- The calorimeter consists of two identical disks filled with stacked up BaF2 crystals. The two disks are connected and roll in-out solidly
- Each disk is made of:
  - An Inner cylinder made of light material (Carbon Fiber) to reduce interaction with electrons
  - An Outer supportive cylinder made of Aluminum or stainless steel
  - A front plate made of light material (Carbon Fiber) housing also the calibration source piping
  - 12 Read out electronics crates (10 boards, 16 ch each)
  - Lumber of 930 hexagonal BaF2 crystals (16.5 mm apothem, 200 mm long)

Inner layout

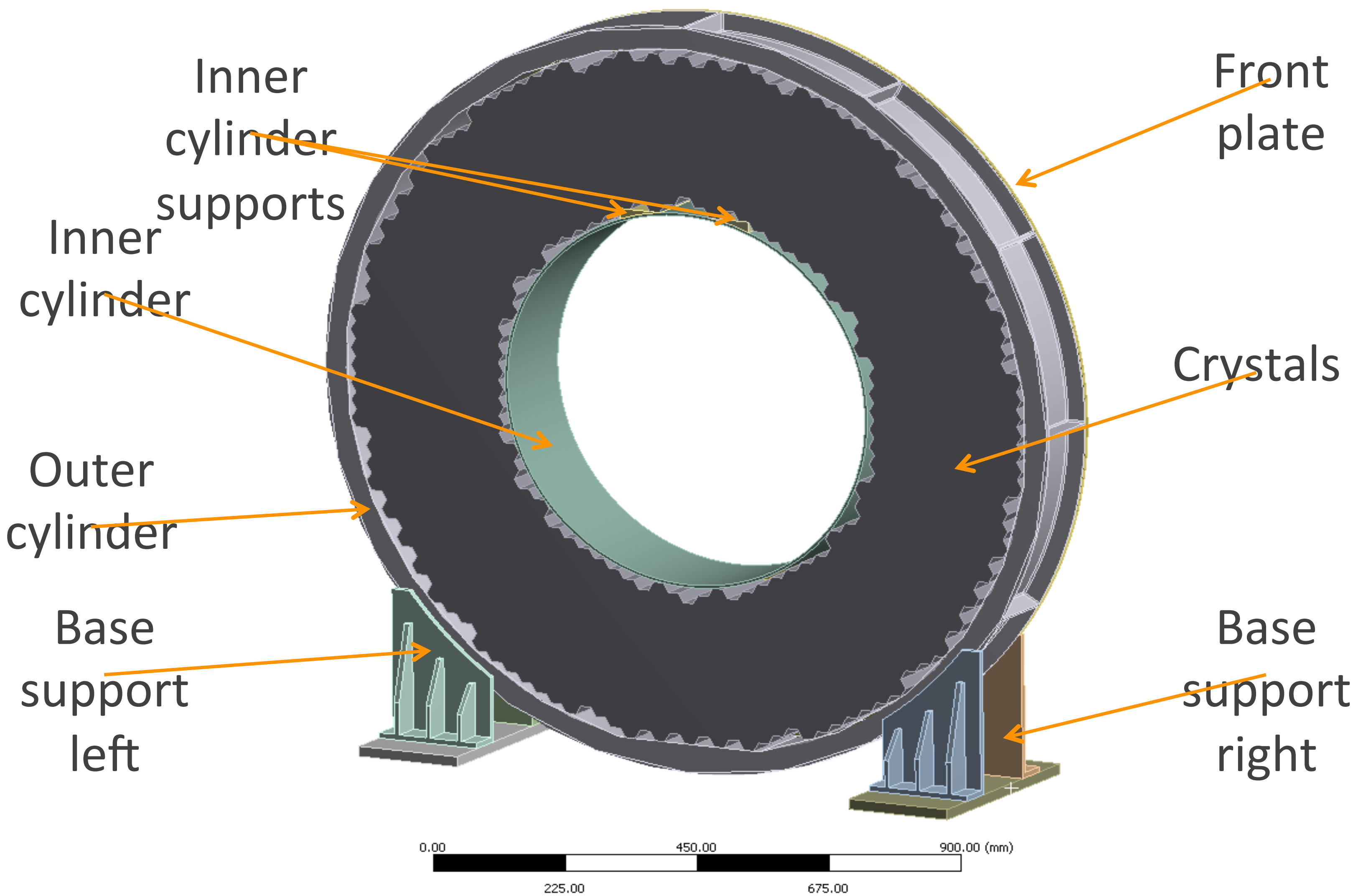
If we put a stainless steel plate facing the crystals, the layout of the calorimeter will be as the small 5x5 matrix prototype we just built and that will be tested at MAMI next fall: wrapped crystals are arranged/piled and then coupled with optical grease to photosensors



The second option of the basic unit is to pile up crystals with glued photosensors and a frame to hold the Preamps.
This unit can be individually tested.
This is the baseline options we are designing.

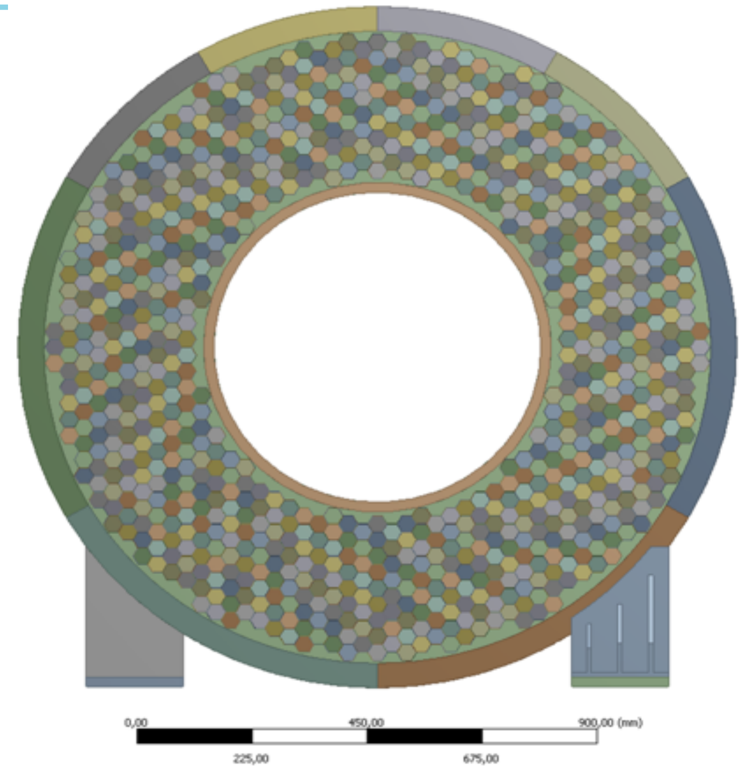
Disk components

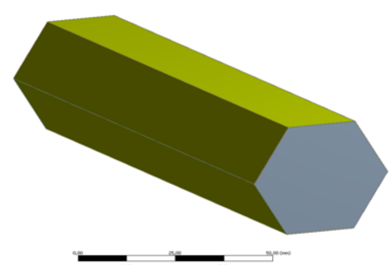


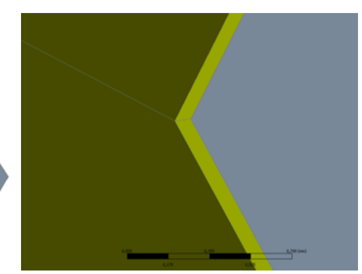
Crystals arrangement

- **Self standing layout** to lumber the crystals that will distribute the load uniformly towards the outer ring.
  → Critical issues are the Crystal mechanical properties (Young modulus or tensile modulus, Poisson ratio or torsional modulus of elasticity, yield strength and ultimate strength.)

- **Finite Element Model to**
  → arrange the crystals
  → perform a structural analysis verifying the actual displacement field and the tensional/deformation status of all the components
  → Critical issues will be identified and mechanics layout will be adapted to optimize the local and global mechanical response.







Material properties

Aluminum Alloy

Properties of Outline Row 3: Aluminum Alloy

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	2.77E-06	kg mm^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
4	Coefficient of Thermal Expansion	2.3E-05	C^-1		
5	Reference Temperature	22	C		
6	Isotropic Elasticity				
7	Derive from	Young's Modulus and...			
8	Young's Modulus	71000	MPa		
9	Poisson's Ratio	0.33			
10	Bulk Modulus	69608	MPa		
11	Shear Modulus	26692	MPa		
12	Alternating Stress R-Ratio	Tabular			
16	Tensile Yield Strength	280	MPa		
17	Compressive Yield Strength	280	MPa		
18	Tensile Ultimate Strength	310	MPa		
19	Compressive Ultimate Strength	0	MPa		
20	Isotropic Thermal Conductivity	Tabular			
23	Specific Heat	8.75E+05	mJ kg^-1 C^-1		
24	Isotropic Relative Permeability	1			
25	Isotropic Resistivity	Tabular			

Barium Fluoride

Properties of Outline Row 3: Barium Fluoride

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	4.89E-06	kg mm^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
4	Coefficient of Thermal Expansion	1.8E-05	C^-1		
5	Reference Temperature	22	C		
6	Isotropic Elasticity				
7	Derive from	Young's Modulus and...			
8	Young's Modulus	53070	MPa		
9	Poisson's Ratio	0.343			
10	Bulk Modulus	56338	MPa		
11	Shear Modulus	19758	MPa		
12	Tensile Yield Strength	26.9	MPa		
13	Compressive Yield Strength	26.9	MPa		

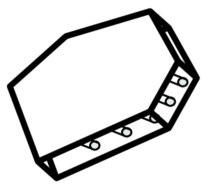
Steel alloy

Properties of Outline Row 4: Structural Steel

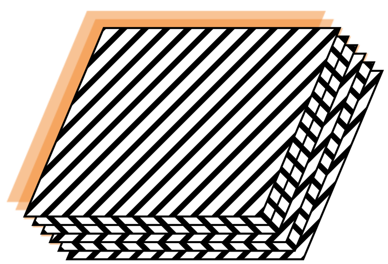
	A	B	C	D	E
1	Property	Value	Unit		
2	Density	7.85E-06	kg mm^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
4	Coefficient of Thermal Expansion	1.2E-05	C^-1		
5	Reference Temperature	22	C		
6	Isotropic Elasticity				
7	Derive from	Young's Modulus and...			
8	Young's Modulus	2E+05	MPa		
9	Poisson's Ratio	0.3			
10	Bulk Modulus	1.6667E+05	MPa		
11	Shear Modulus	76923	MPa		
12	Alternating Stress Mean Stress	Tabular			
16	Strain-Life Parameters				
24	Tensile Yield Strength	250	MPa		
25	Compressive Yield Strength	250	MPa		
26	Tensile Ultimate Strength	460	MPa		
27	Compressive Ultimate Strength	0	MPa		

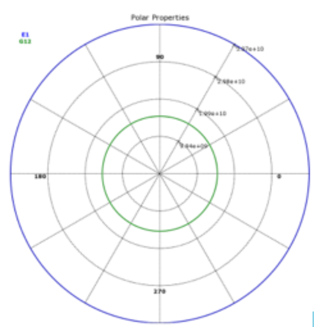
Material properties

Carbon Epoxy T300 Woven – t = 0.41666mm



Front plate layup – 12 layer: [0°/30°/60°]$_{x2\text{-}SE}$



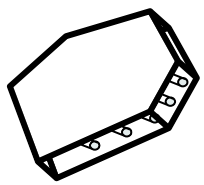


Properties of Outline Row 4: HexPly F593 Woven T300 (F3T584) nominal

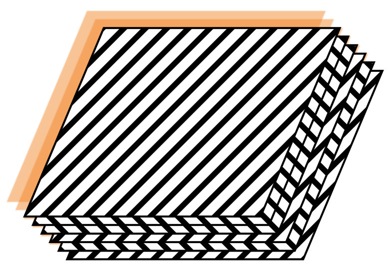
	A	B	C	D	E
1	Property	Value	Unit		
2	Density	1.486E-06	kg mm^-3		
3	Orthotropic Elasticity				
4	Young's Modulus X direction	53800	MPa		
5	Young's Modulus Y direction	53800	MPa		
6	Young's Modulus Z direction	10000	MPa		
7	Poisson's Ratio XY	0.05			
8	Poisson's Ratio YZ	0.35			
9	Poisson's Ratio XZ	0.35			
10	Shear Modulus XY	5000	MPa		
11	Shear Modulus YZ	4500	MPa		
12	Shear Modulus XZ	4500	MPa		
13	Orthotropic Stress Limits				
14	Tensile X direction	563	MPa		
15	Tensile Y direction	563	MPa		
16	Tensile Z direction	80	MPa		
17	Compressive X direction	-516	MPa		
18	Compressive Y direction	-516	MPa		
19	Compressive Z direction	-200	MPa		
20	Shear XY	100	MPa		
21	Shear YZ	67.5	MPa		
22	Shear XZ	67.5	MPa		
23	Orthotropic Strain Limits				
24	Tensile X direction	0.010465			
25	Tensile Y direction	0.010465			
26	Tensile Z direction	0.008			
27	Compressive X direction	-0.0095911			
28	Compressive Y direction	-0.0095911			
29	Compressive Z direction	-0.02			
30	Shear XY	0.02			
31	Shear YZ	0.015			
32	Shear XZ	0.015			
33	Ply Type				
34	Type	Woven			

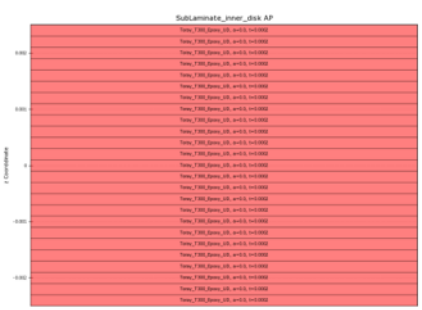
Material properties

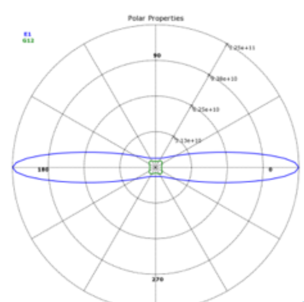
Carbon Epoxy T300 UD – t = 0.2mm



Inner disk layup – 25 layer: [0°]x25



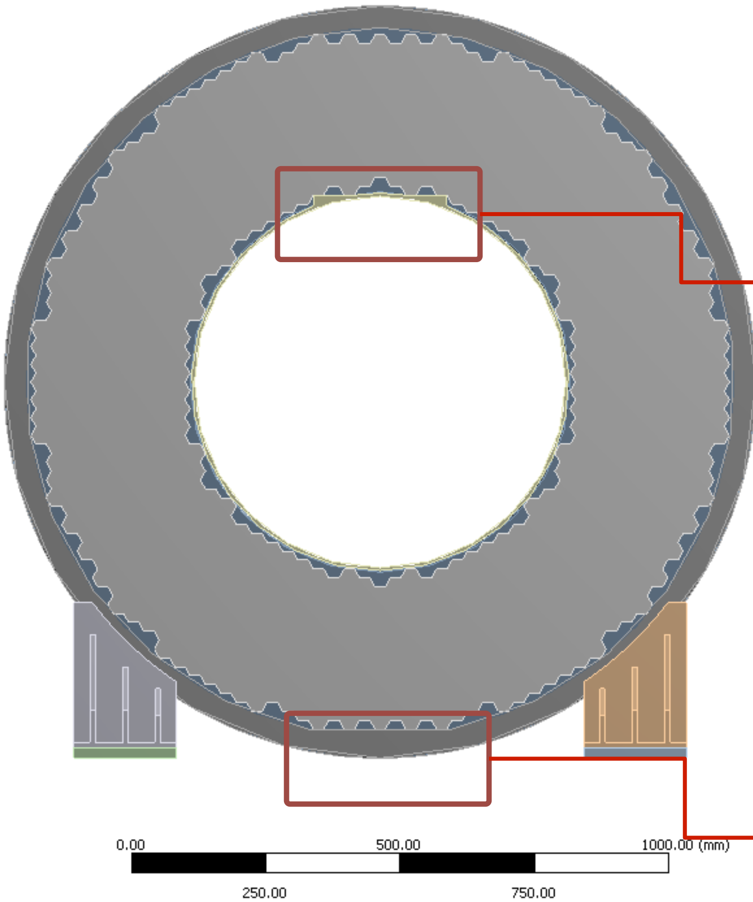


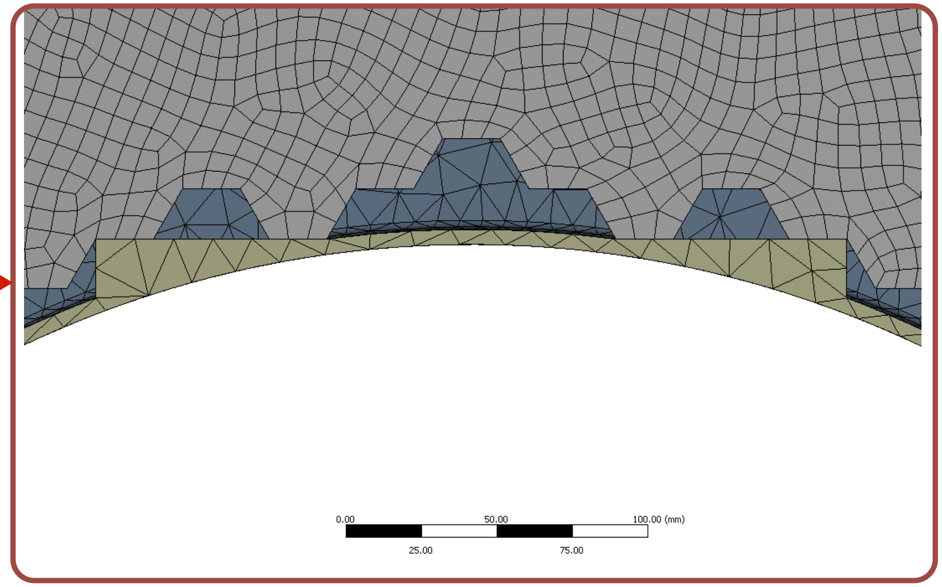


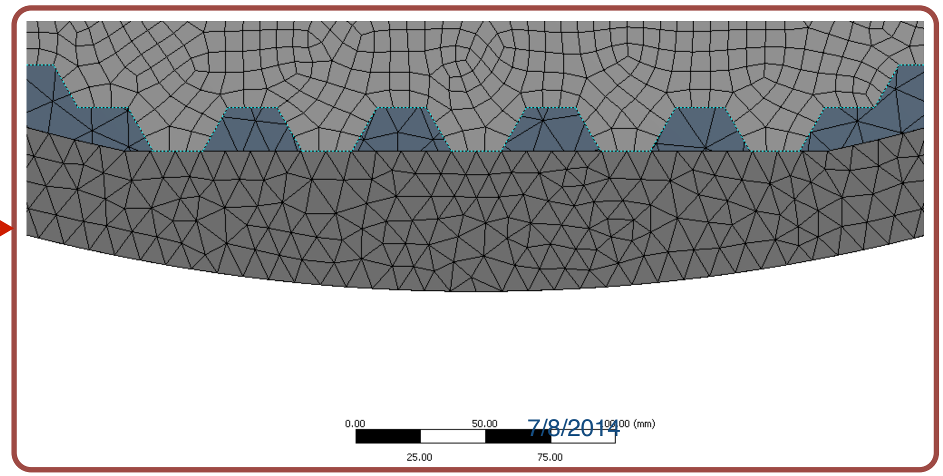
Properties of Outline Row 7: T300;Epoxy;UD-.200/210/60

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	1.55E-06	kg mm^-3		
3	Orthotropic Secant Coefficient of Thermal Expansion				
4	Coefficient of Thermal Expansion				
5	Coefficient of Thermal Expansion X direction	-4.5E-07	C^-1		
6	Coefficient of Thermal Expansion Y direction	3E-05	C^-1		
7	Coefficient of Thermal Expansion Z direction	3E-05	C^-1		
8	Reference Temperature	20	C		
9	Orthotropic Elasticity				
10	Young's Modulus X direction	1.25E+05	MPa		
11	Young's Modulus Y direction	8000	MPa		
12	Young's Modulus Z direction	8000	MPa		
13	Poisson's Ratio XY	0.3			
14	Poisson's Ratio YZ	0.3			
15	Poisson's Ratio XZ	0.3			
16	Shear Modulus XY	5000	MPa		
17	Shear Modulus YZ	3076.9	MPa		
18	Shear Modulus XZ	5000	MPa		
19	Orthotropic Stress Limits				
20	Tensile X direction	1600	MPa		
21	Tensile Y direction	40	MPa		
22	Tensile Z direction	40	MPa		
23	Compressive X direction	-1000	MPa		
24	Compressive Y direction	-220	MPa		
25	Compressive Z direction	-220	MPa		
26	Shear XY	80	MPa		
27	Shear YZ	36.923	MPa		
28	Shear XZ	80	MPa		
29	Orthotropic Strain Limits				
30	Tensile X direction	0.0128			
31	Tensile Y direction	0.005			
32	Tensile Z direction	0.005			
33	Compressive X direction	-0.008			
34	Compressive Y direction	-0.0275			
35	Compressive Z direction	-0.0275			
36	Shear XY	0.016			
37	Shear YZ	0.012			
38	Shear XZ	0.016			
39	Ply Type				
40	Type	Regular			

Crystals' supports on the outer-inner disks



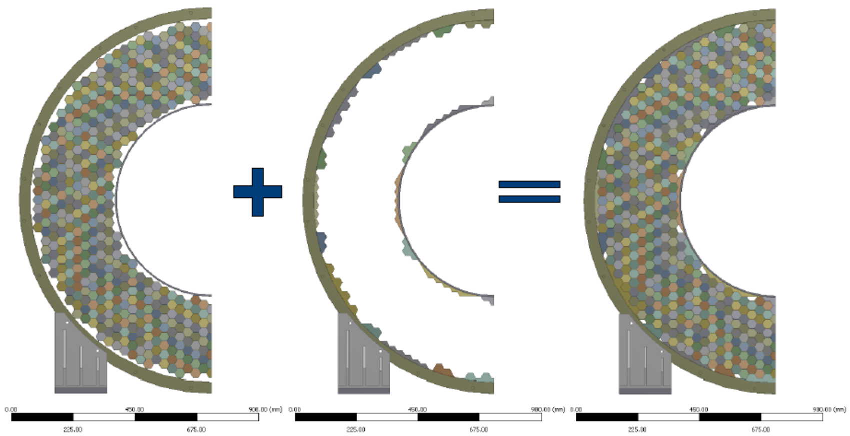




Outer disk radius = 660 mm
Inner disk radius = 351 mm
N. of crystals = 930
Crystal size = 33 mm

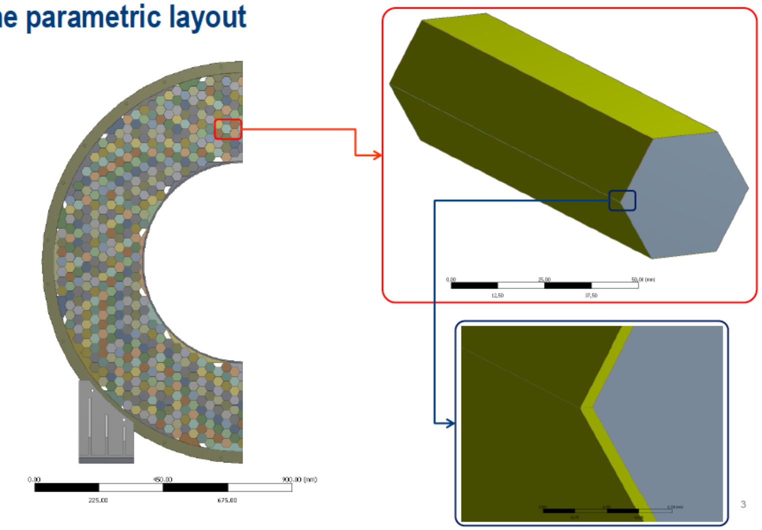
Details on crystal supports

Layout of crystals and cores

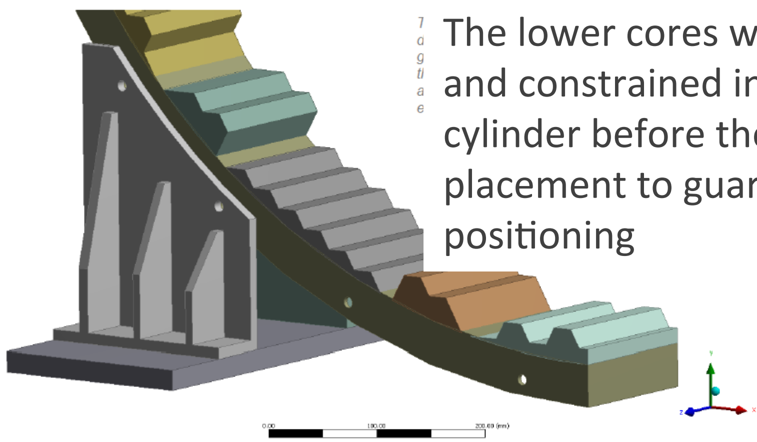


Crystals External Cores Full assembly

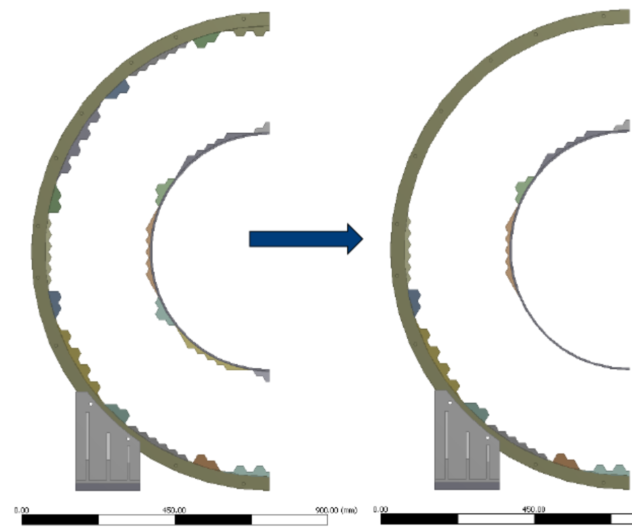
The parametric layout



Layout of crystals and supports – Assembly operations

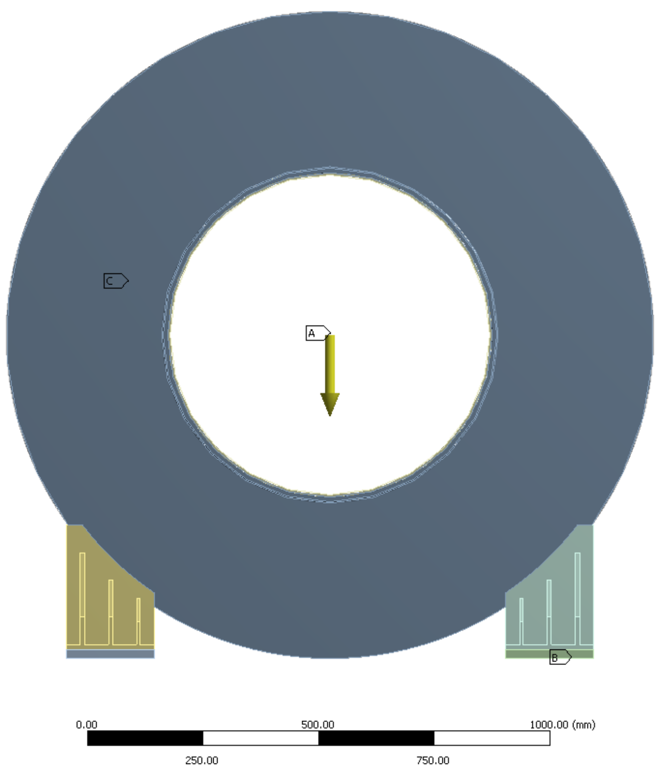


The lower cores will be placed and constrained in the outer cylinder before the crystal placement to guarantee their positioning

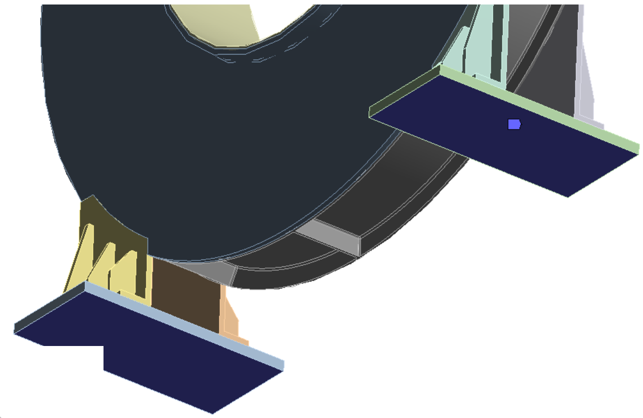


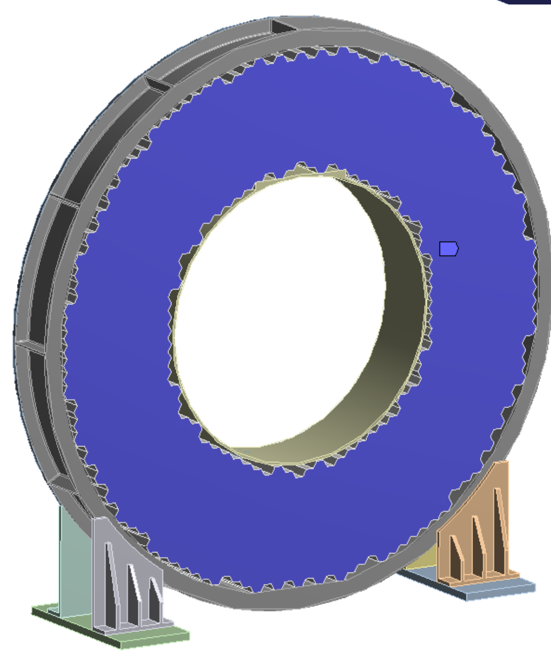
Loads & Boundary conditions

Standard Earth Gravity



Fixed supports



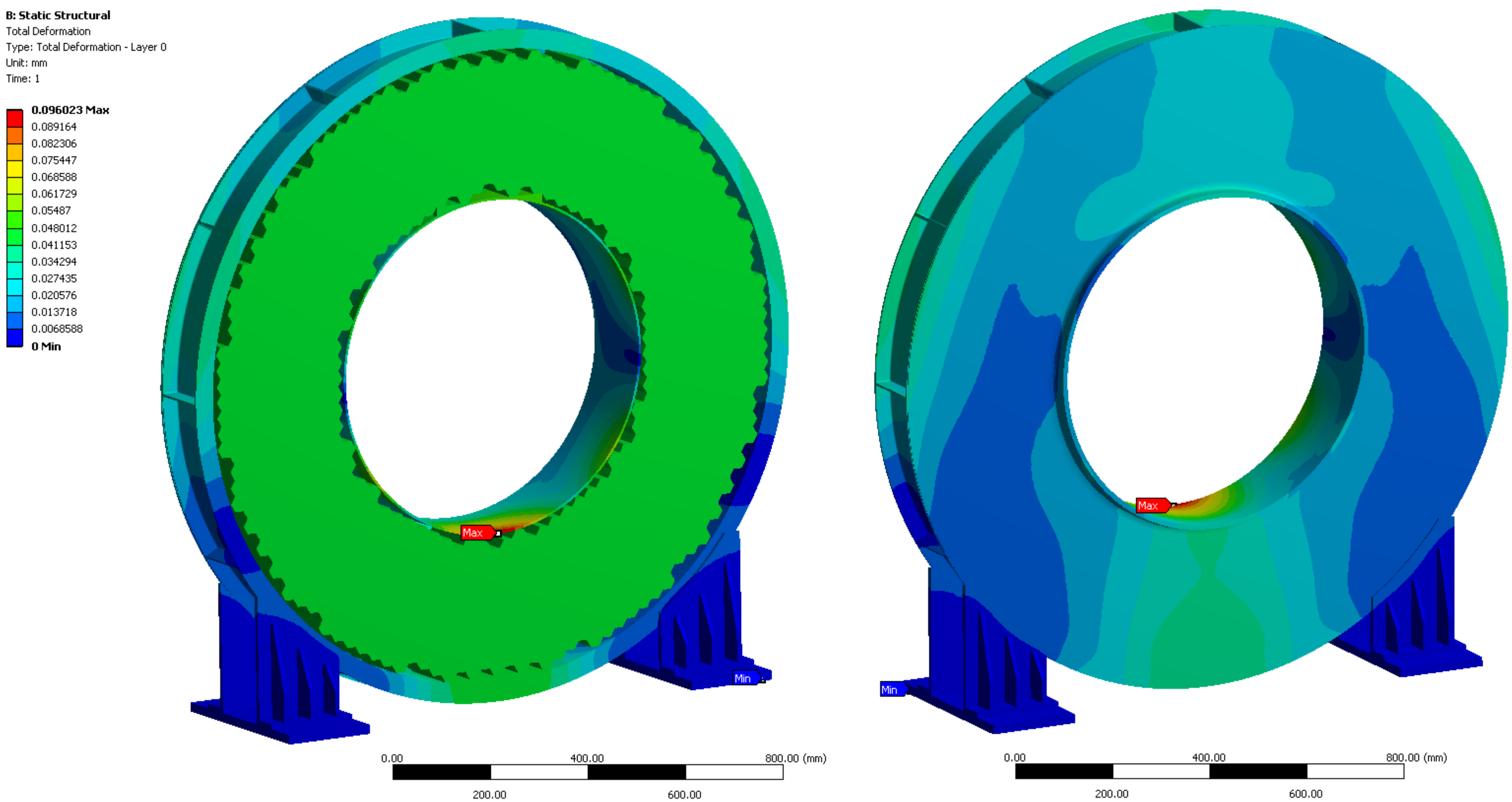


Frictionless support

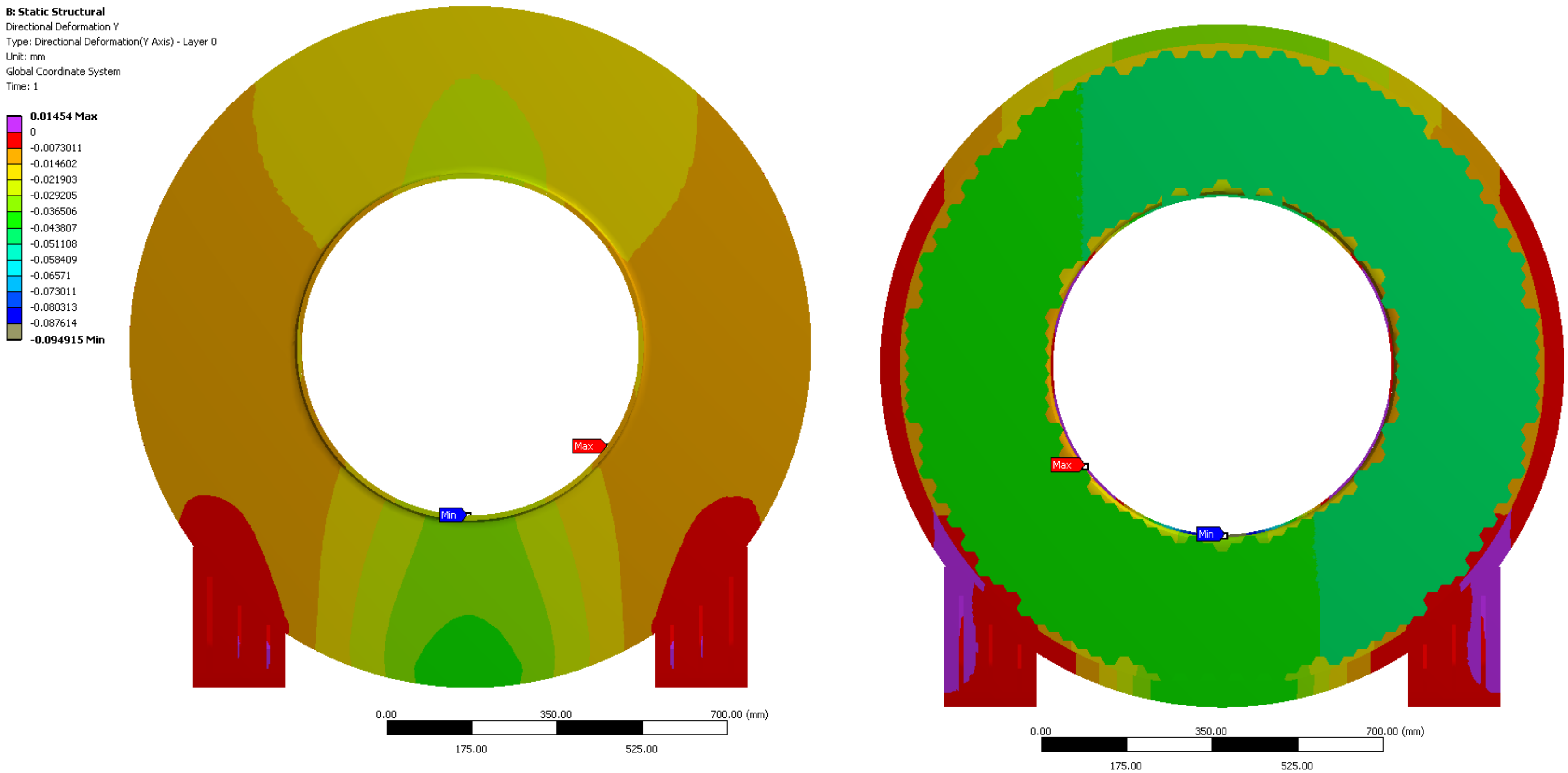
Preliminary FEM analysis – 4 configurations

PRELIMINARY FEM ANALYSIS - SUMMARY								
Parts	**Configuration 1**		**Configuration 2**		**Configuration 3**		**Configuration 4**	
	Material	**Weight [kg]**	**Material**	**Weight [kg]**	**Material**	**Weight [kg]**	**Material**	**Weight [kg]**
Crystals	Barium Fluoride	605.19	Barium Fluoride	605.19	Barium Fluoride	605.19	Barium Fluoride	605.19
Base_support_right	Structural steel	21.38	Aluminum alloy	7.54	Structural steel	21.38	Aluminum alloy	7.54
Base_support_left	Structural steel	21.38	Aluminum alloy	7.54	Structural steel	21.38	Aluminum alloy	7.54
Inner_ring	Structural steel	16.87	Aluminum alloy	5.95	Composite material	3.03	Composite material	3.03
Outer_ring	Structural steel	39.71	Aluminum alloy	14.01	Structural steel	39.71	Aluminum alloy	14.01
Front_plate	Structural steel	94.80	Aluminum alloy	33.45	Composite material	9.02	Composite material	9.02
Inner_ring_supports	\		\		Structural steel	1.40	Aluminum alloy	0.50
Total weight [kg]	704.53		640.23		699.71		646.33	
Maximum displacement Y-axis [mm]	0.008217		0.017841		0.072286		0.094915	
Maximum Equivalent Von Mises on metals [MPa]	5.80		7.93		22.21		14.47	
Inverse Reserve Factor on composites [adim.]	\		\		0.068		0.088	

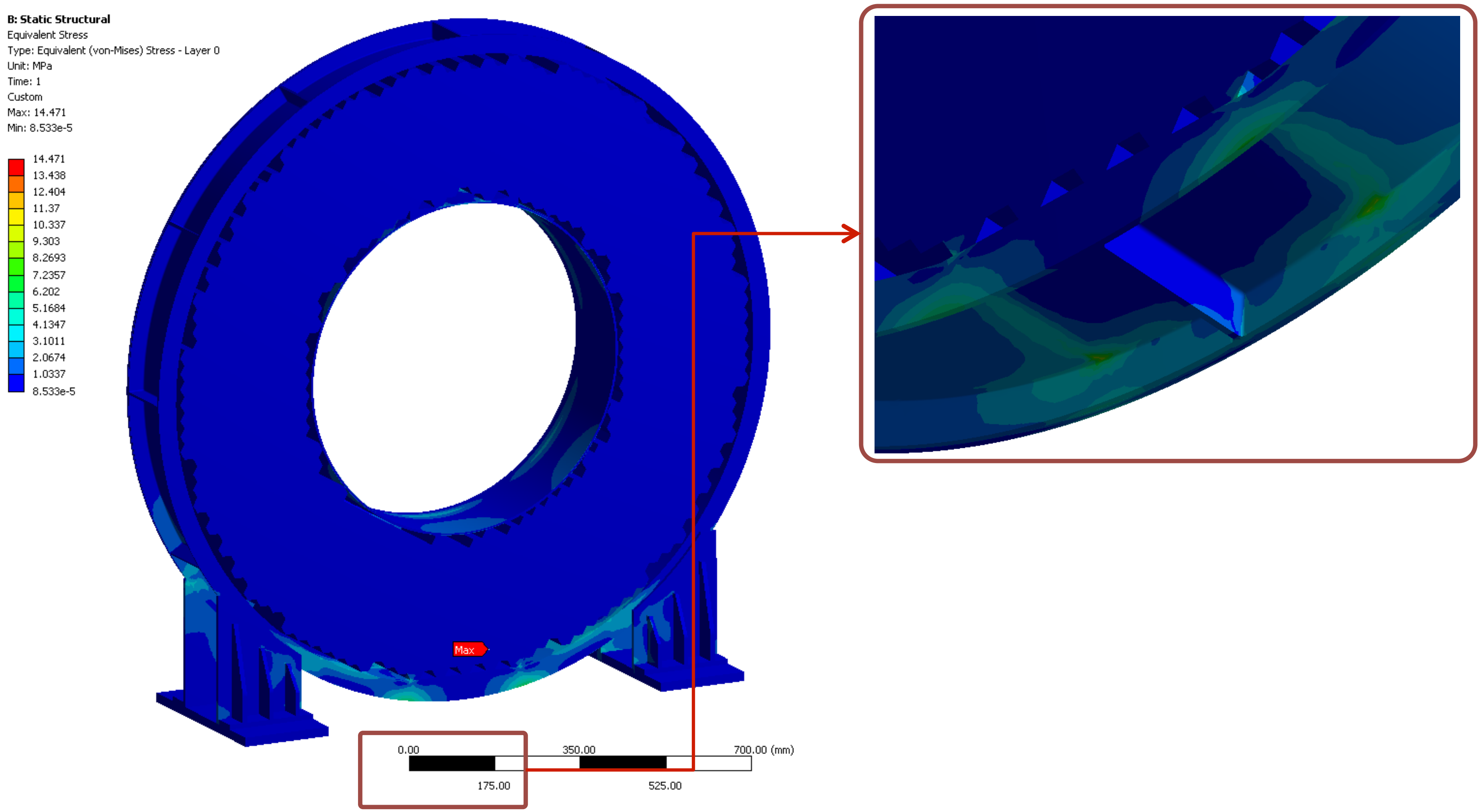
Conf. 4 – Tot deformation – Max value = 0.096mm



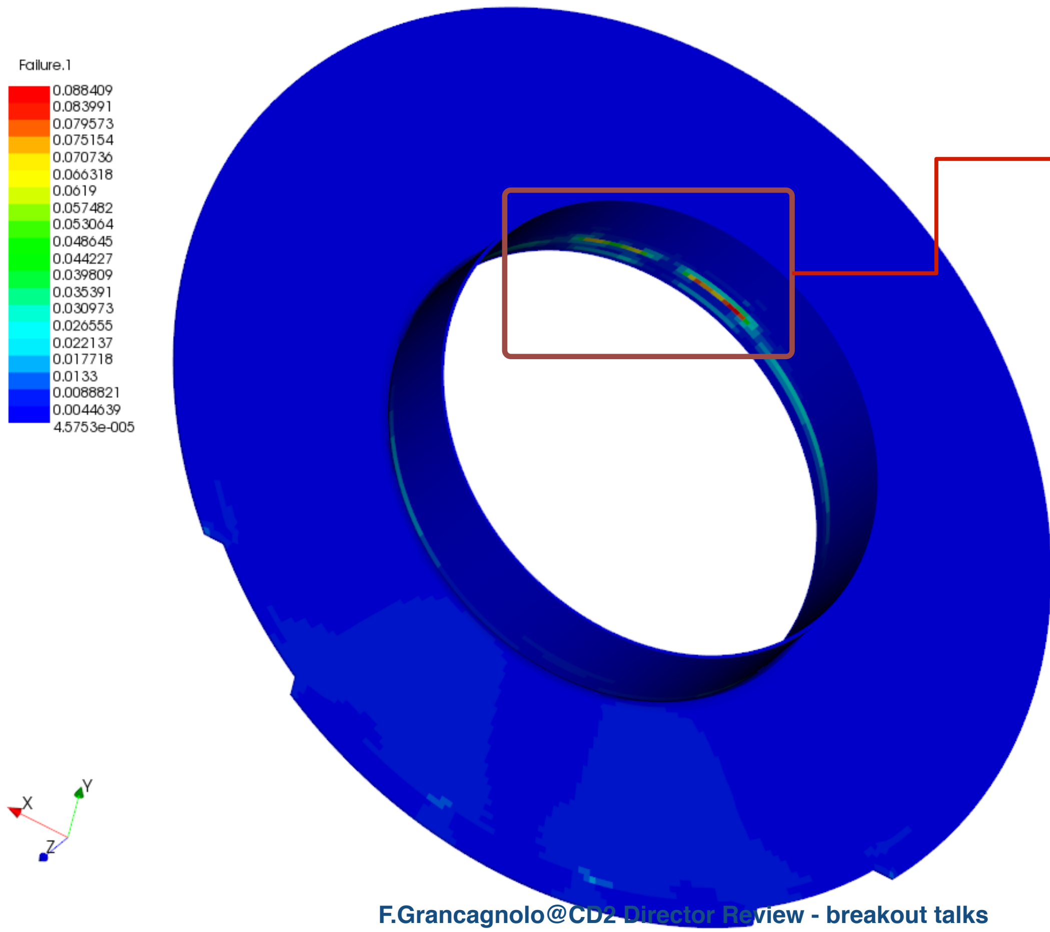
Conf. 4 – Directional deformation – Min value = 0.095mm

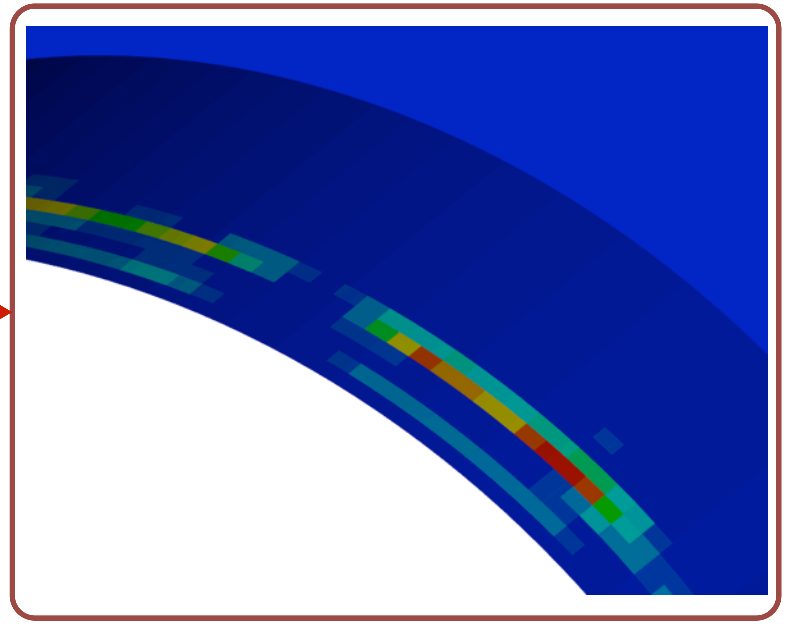


Conf. 4 – Von Mises eq. stress – Max value = 14.47MPa



Conf. 4 – Inverse Reserve Factor – Max value = 0.088





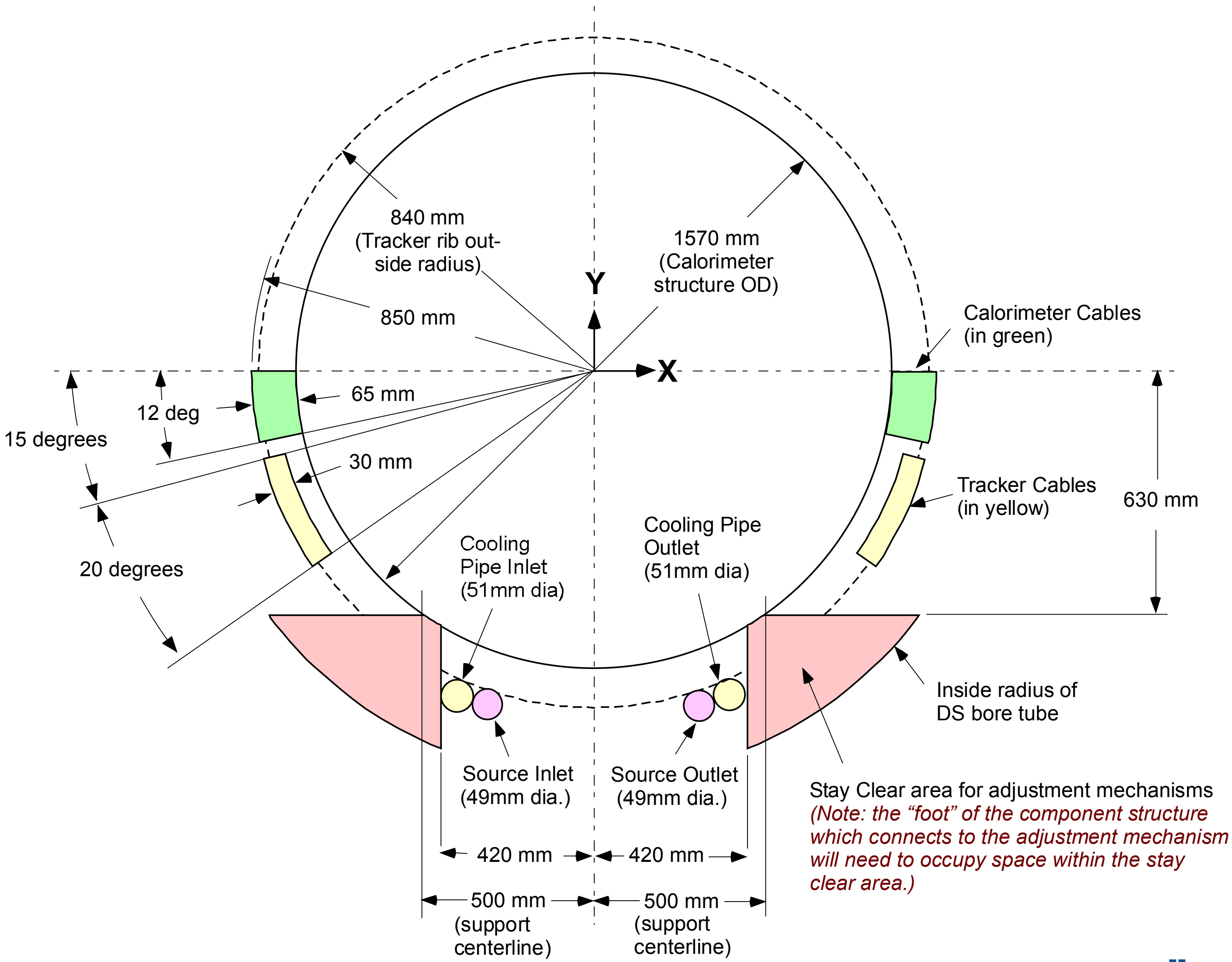
FEE mechanics

- The Front End electronics will be mounted on board of the calorimeter
- For each disk there are 12 crates with 10 pairs of boards (16ch modularity).
  - Each pair consist of a HV/LV controller for the Preamp and a Digitizer

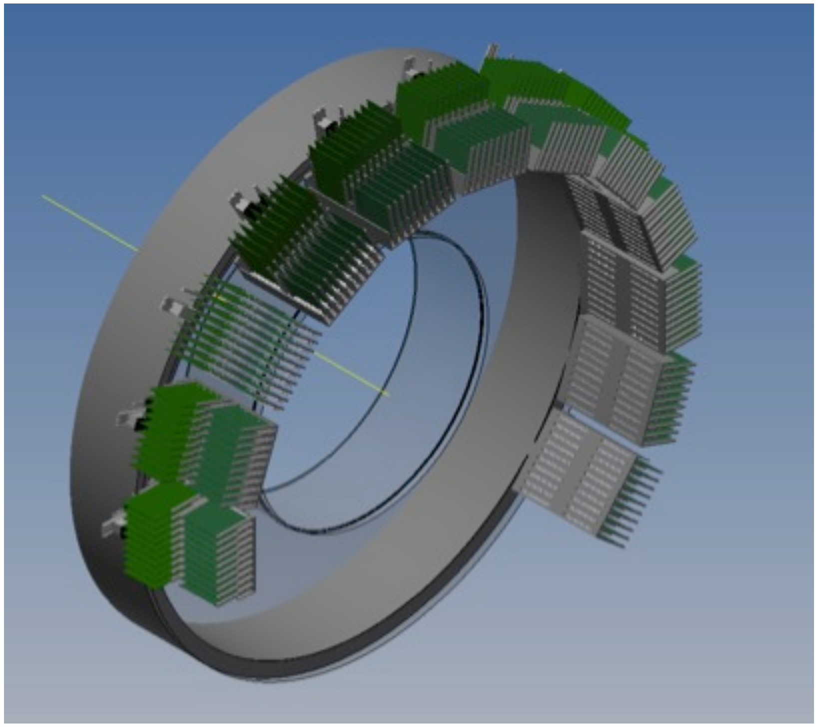
- The placement of the crates over the calorimeter has to:
  - Allow the access to the Preamp + photosensor of each disk
  - The lower edge of the crates in the first has to lie above the trajectory of electrons
  - Leave room for the routing of cables of the Tracker and Calorimeter itself

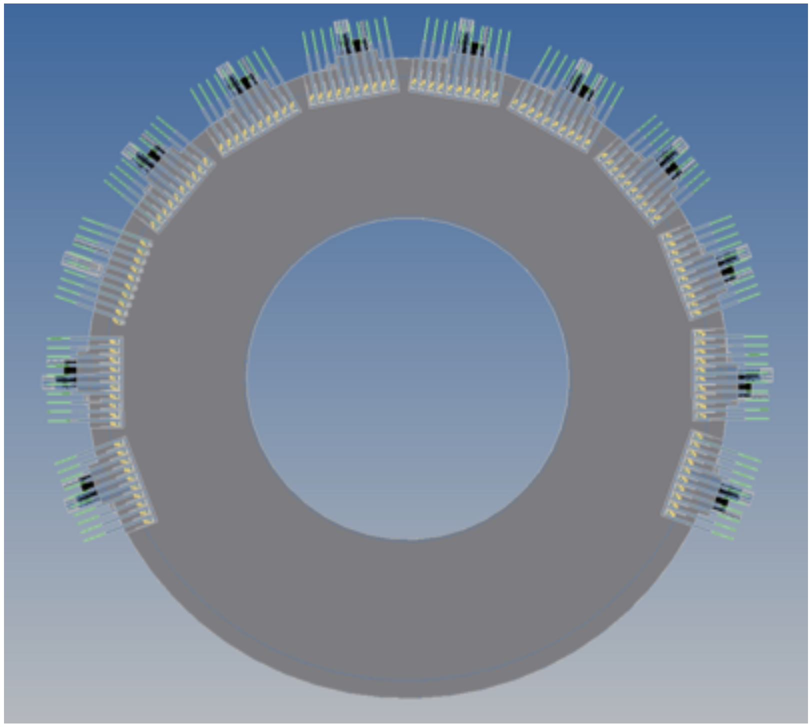
- To address these requirements and interference with the tracker we have two solutions under scrutiny depending on the maximum volume that we can occupy in the DS bore **that is still under negoziation at the moment.**

Transverse Section of Calorimeter Region Highlighting Services Layout and Rail System Stay Clears



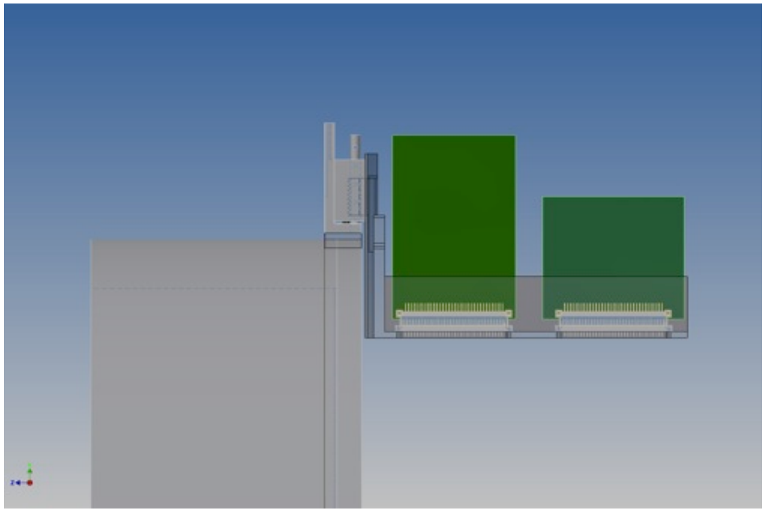
FEE granularity layout

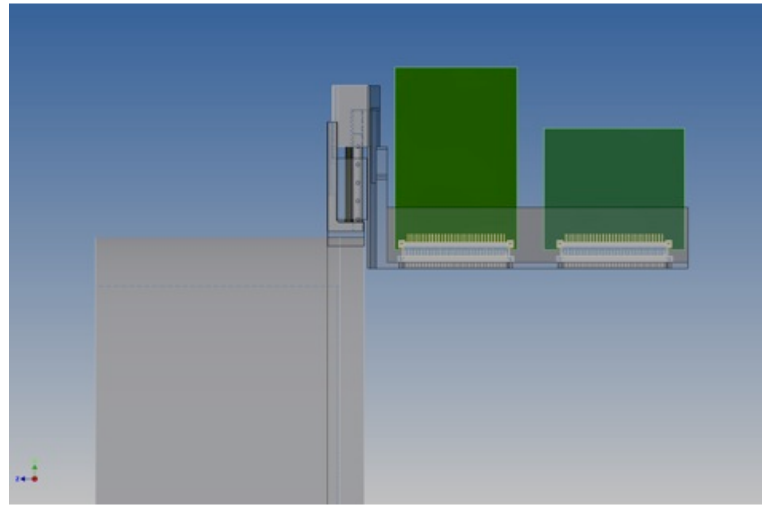


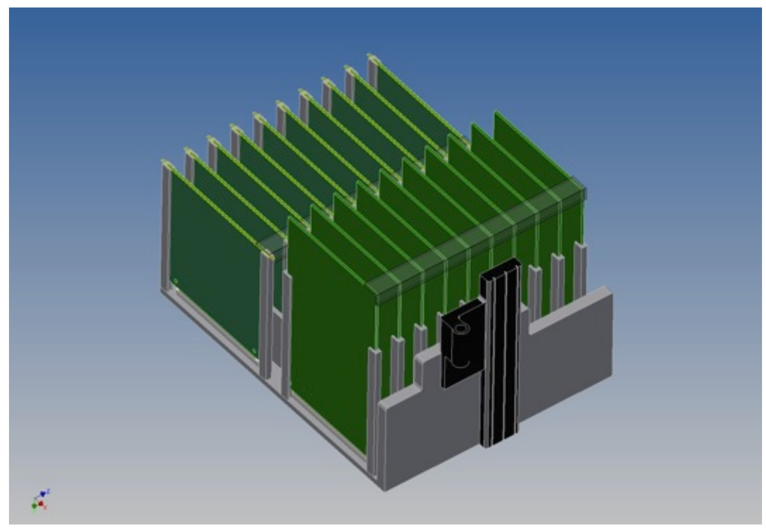


we have 1920 channels: 12 – racks, 10 boards 16 channels each
we have 930 crystals, 2 photosenors each, 60 channels kept fo spares

FEE slide in-out mechanism







Cost

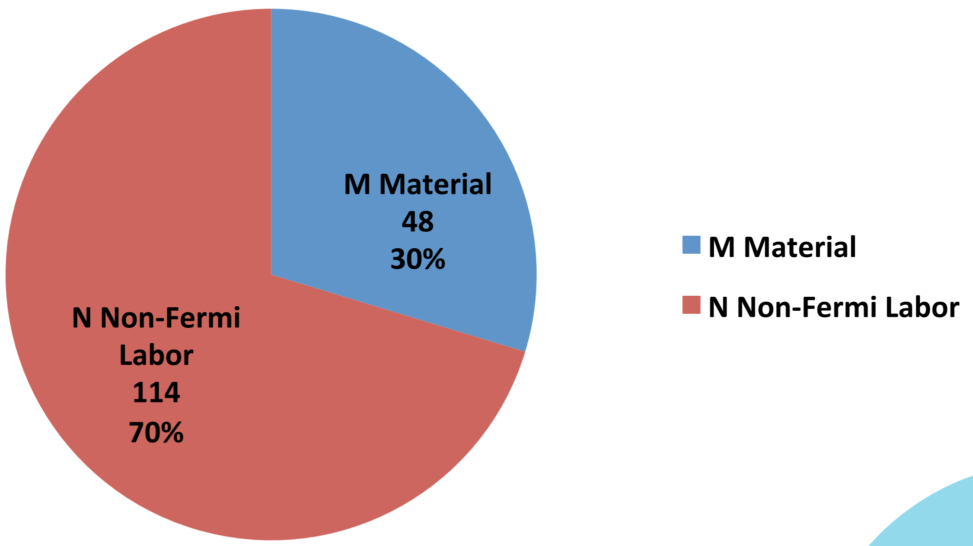
- From the point of view of Cost and Schedule, the responsibility of the mechanical structure is ~ 100% of INFN.
- We have estimated a total cost of M&S of 350 k$ (with 20% contingency included).

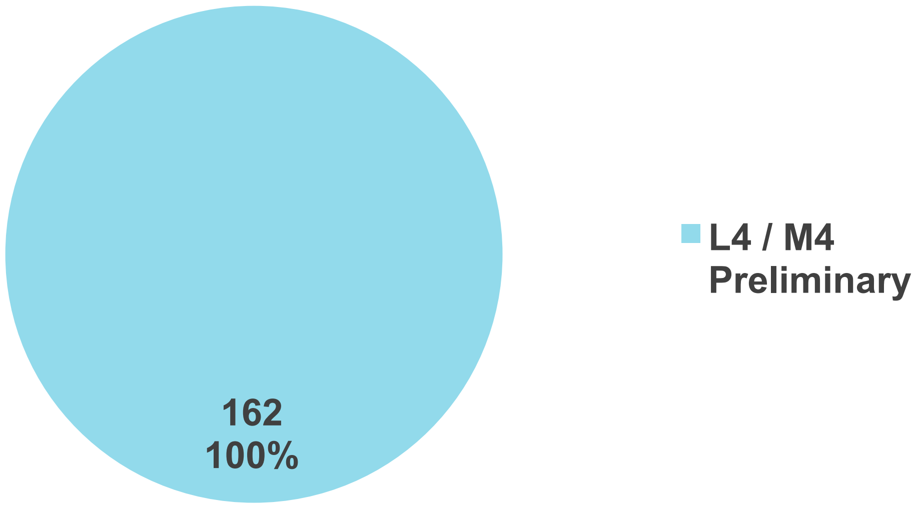
- For the DOE point of view, the only contribution will be

→ the installation of 24 radfets (12 per disk, on the front face) for monitoring the dose;

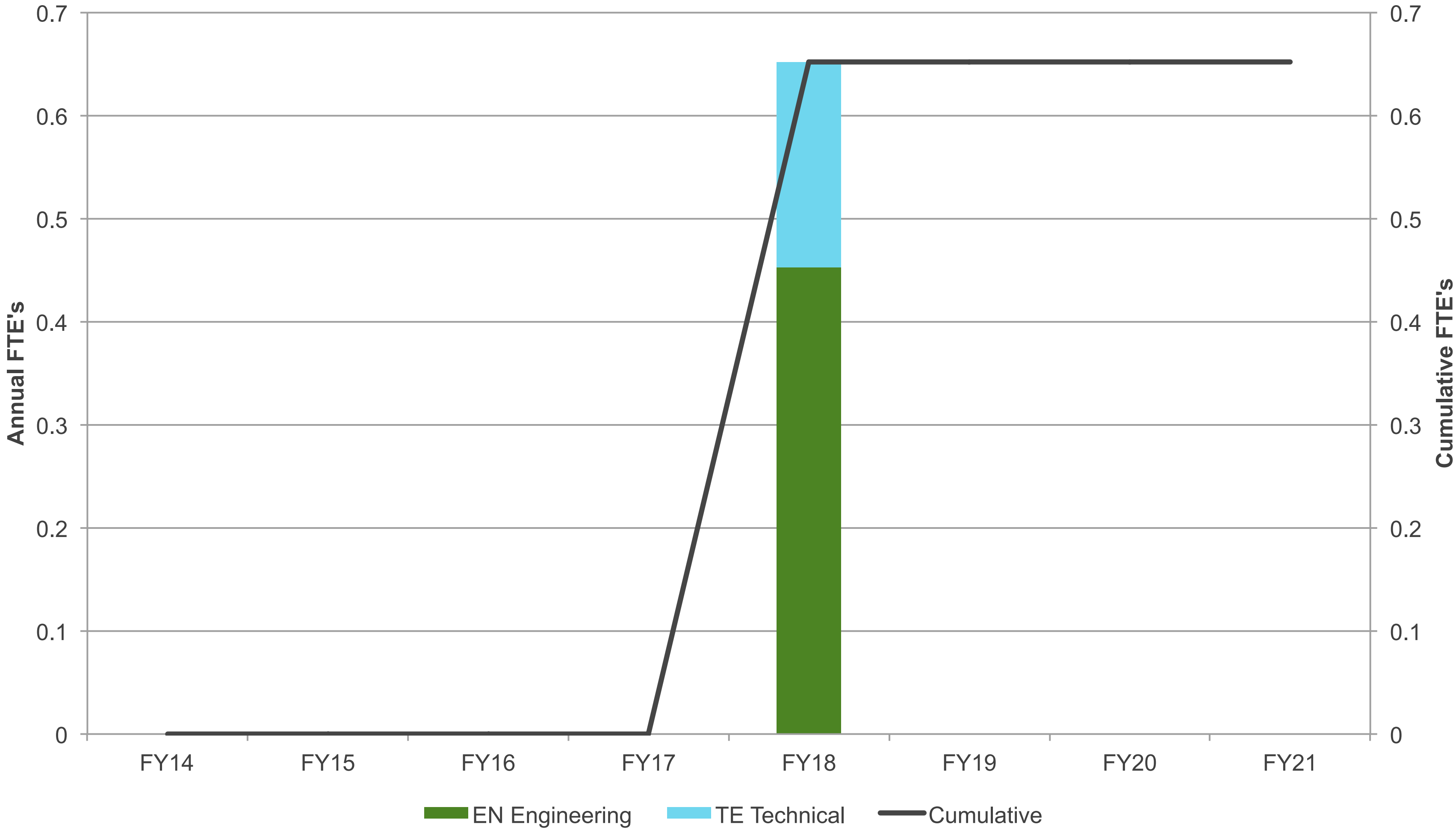
→ 24 temperature sensors (12 per disk) with the related readout electronics, cabling and crates.

Resource type and quality of estimate



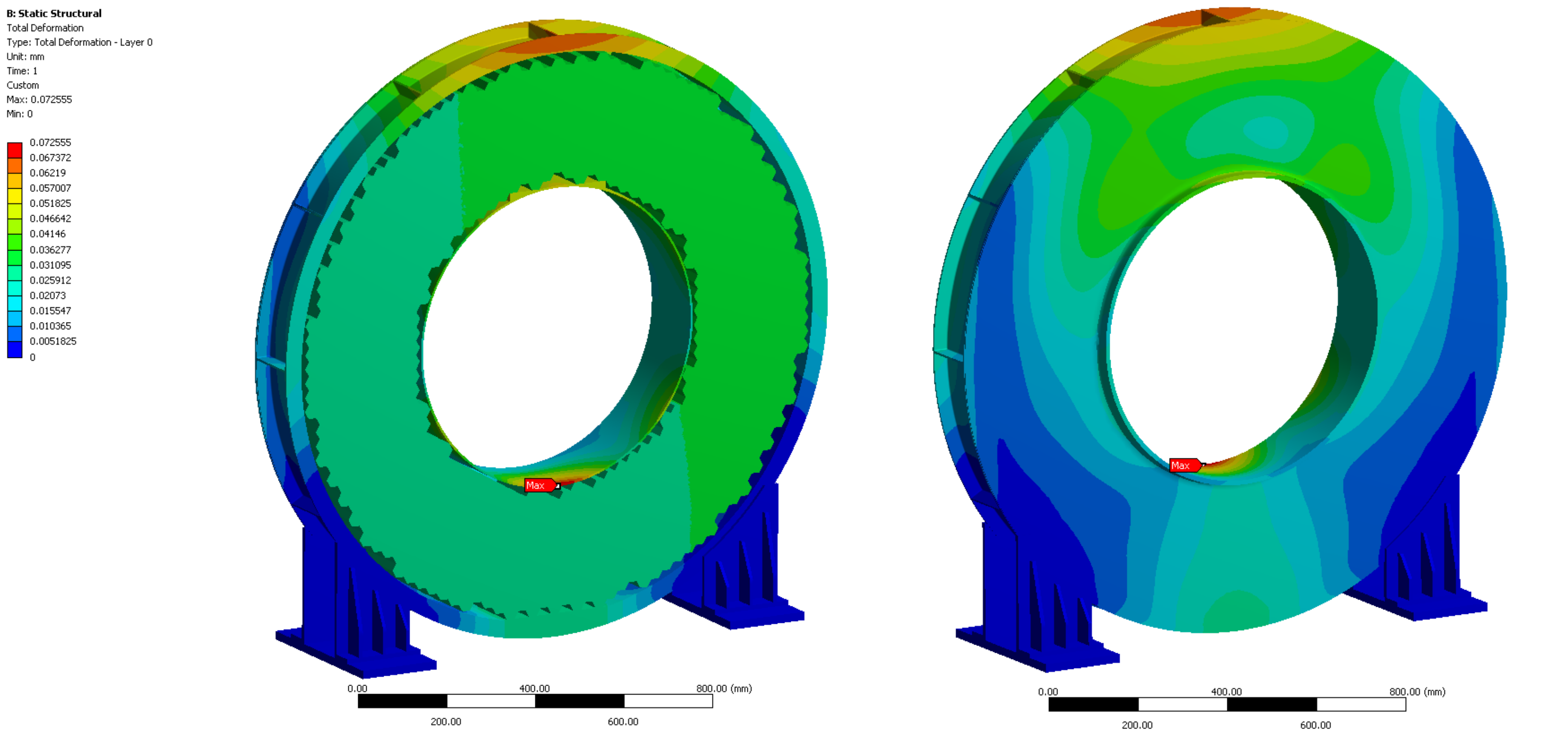


Labor resources

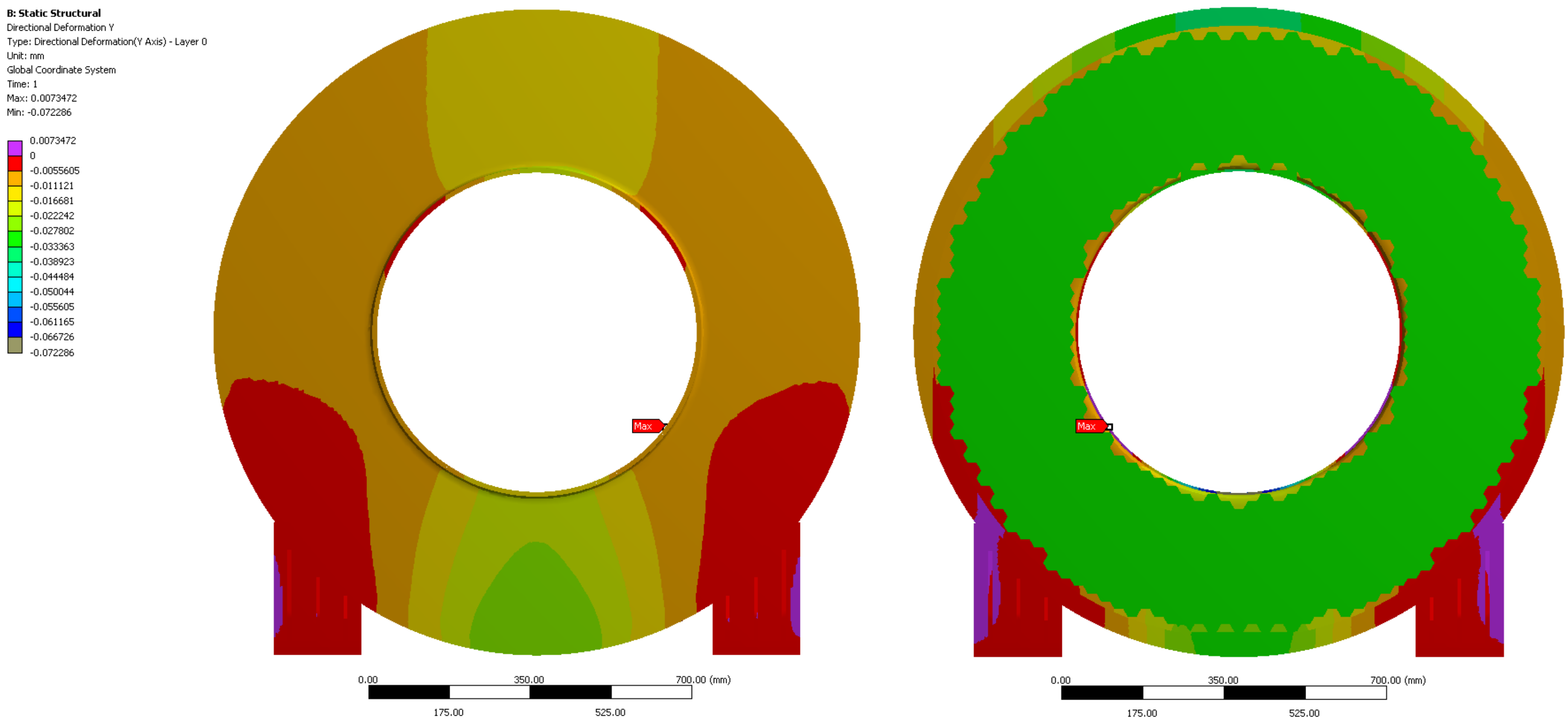


Additional material

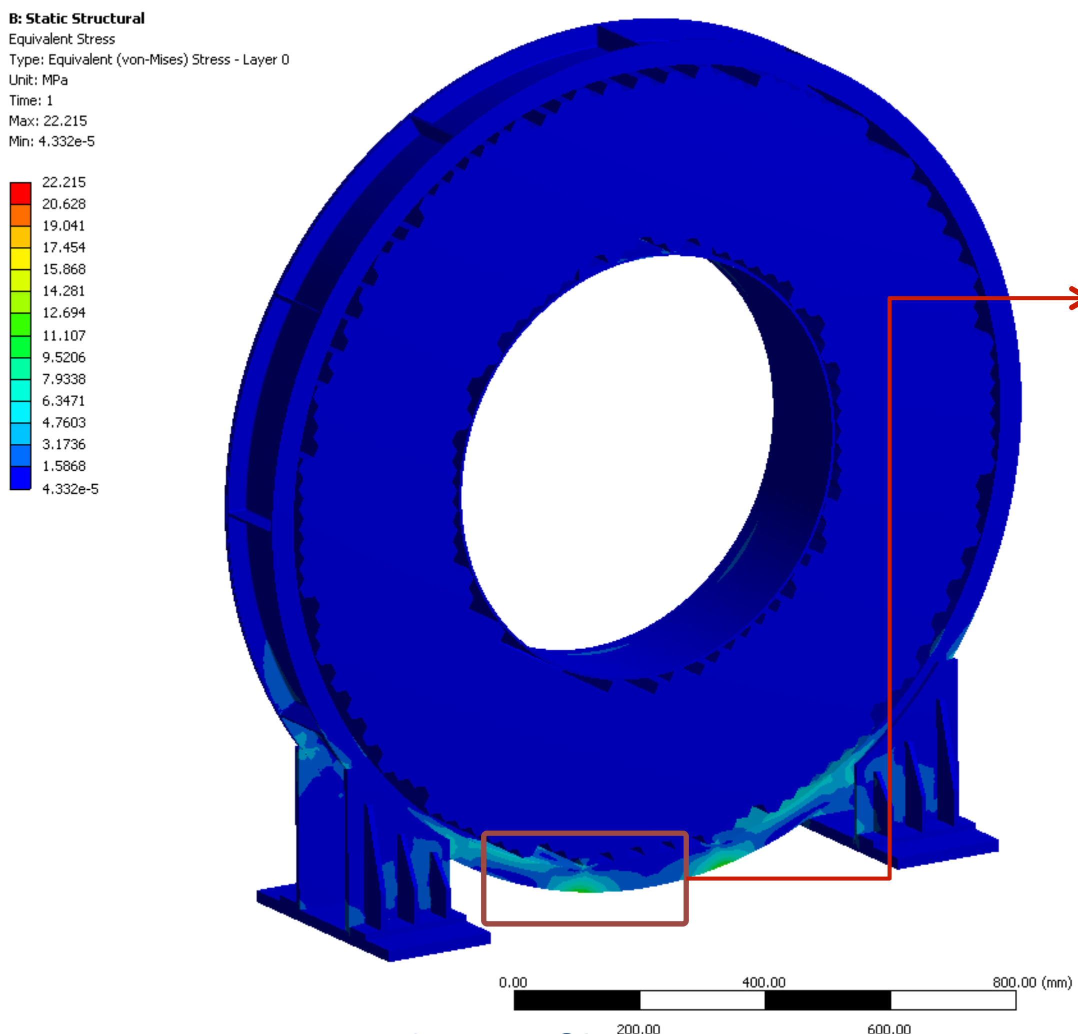
Conf. 3 – Total deformation – Max value = 0.0725mm

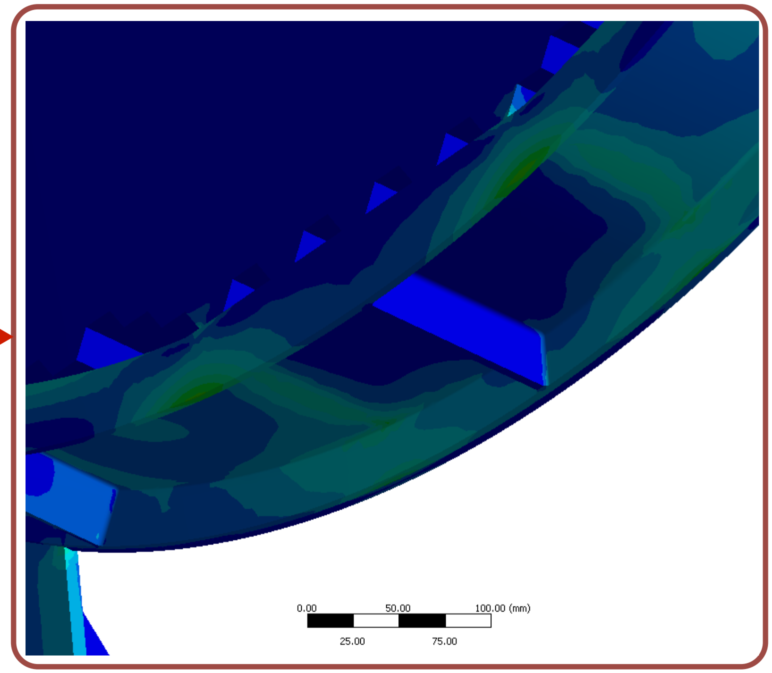


Conf. 3 – Directional deformation – Min value = 0.0723mm

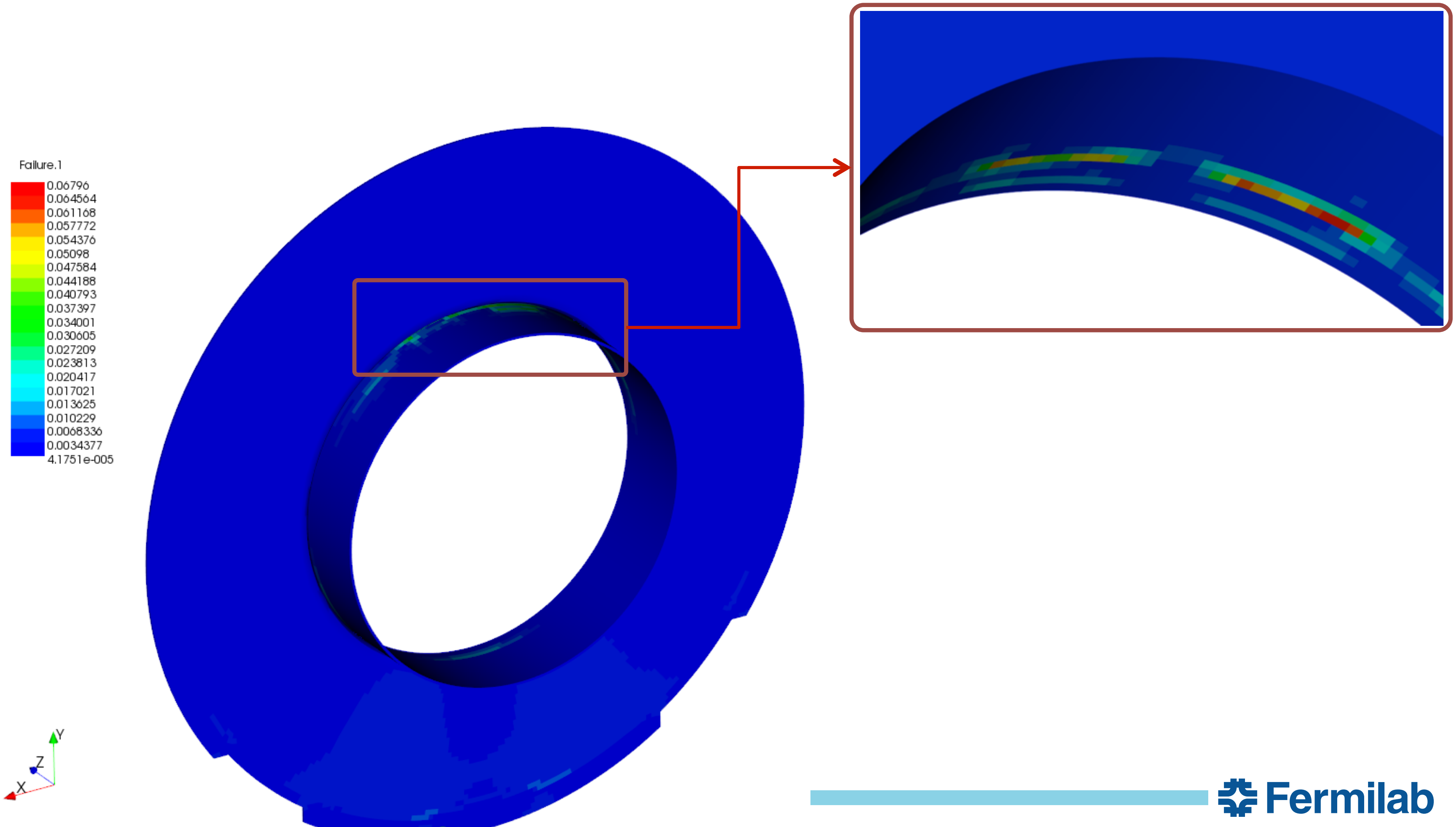


Conf. 3 – Von Mises equivalent stress – Max value = 22.2MPa

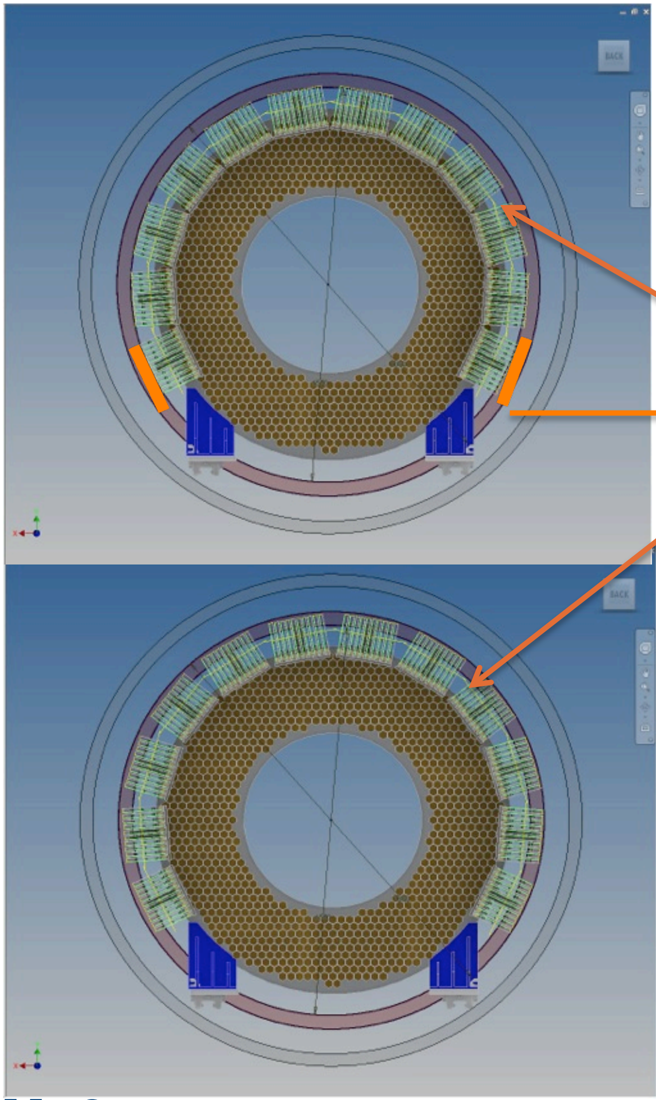




Conf. 3 – Inverse Reserve Factor – Max value = 0.068



Cables routing and crate positioning



In the first solution the crates can slide in (in operation) and slide out (during the maintenance of the detector, outside the DS) leaving room for access all the crystals

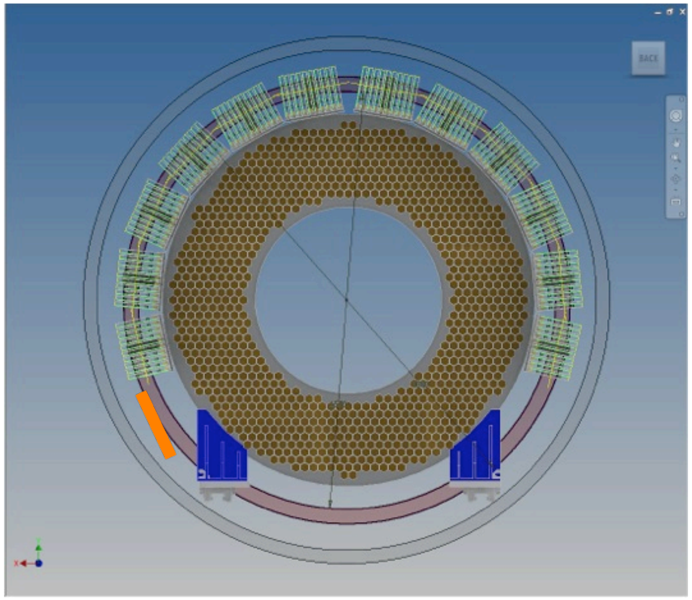
Crates parked

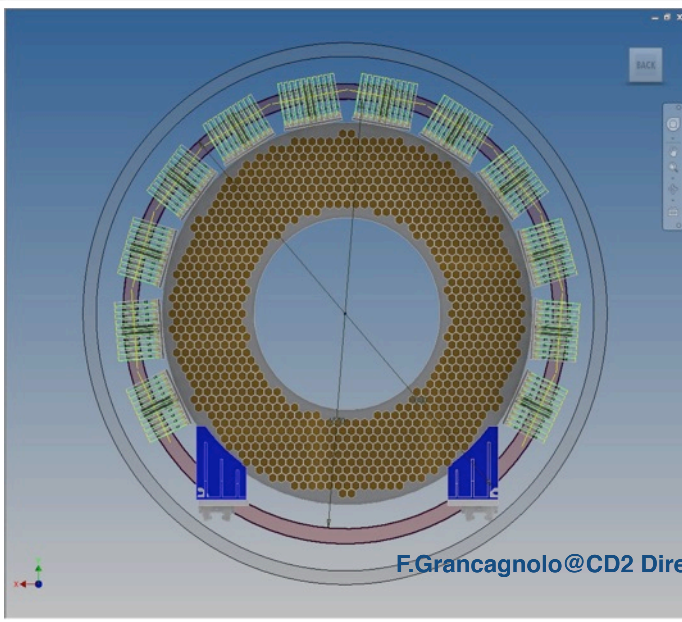
Crates opened

Tracker cables

The routing of the cables in this case appears difficult, it would prevent the opening out of the lower crates.

Cables routing and crate positioning





In the second solution the crates are fixed and lay at an inner radius of 700 mm with on outer radius of 875 mm
The crystals are all accessible in this case.

- Having the crates laying at a bigger radius increase the radial space between them.
- We can decide to pile them up to leave room for the tracker cables in the bottom
- Or we can leave them widely separated and route the   cables of both, tracker and calorimeter, between the   crates
- In this case there is some interference in the tracker alignment

Calorimeter Volume

		length (mm)		Cumulative length (mm)		length available for access to preamps (mm)	Cumulative (mm)
disk 1	cal source	50		50			
disk 1	crystals (11 cm for LYSO and 20 cm for BaF)	200		250			
disk 1	preamps	40		290			
disk 1	cable routing	50		340		50	50
disk 1	HV/LV	100		440		100	150
disk 1	digitizer	150		590		150	300
disk 1	open space	110		700		110	410
				700			
disk 2	cal source	50		750			
disk 2	crystals	200		950			
disk 2	preamps	40		990			
disk 2	cable routing	50		1040		50	50
disk 2	HV/LV	100		1140		100	150
disk 2	digitizer	150		1290		150	300
disk 2	open space	88		1378		88	388
	Available service space assuming disk 2 is shifted						498