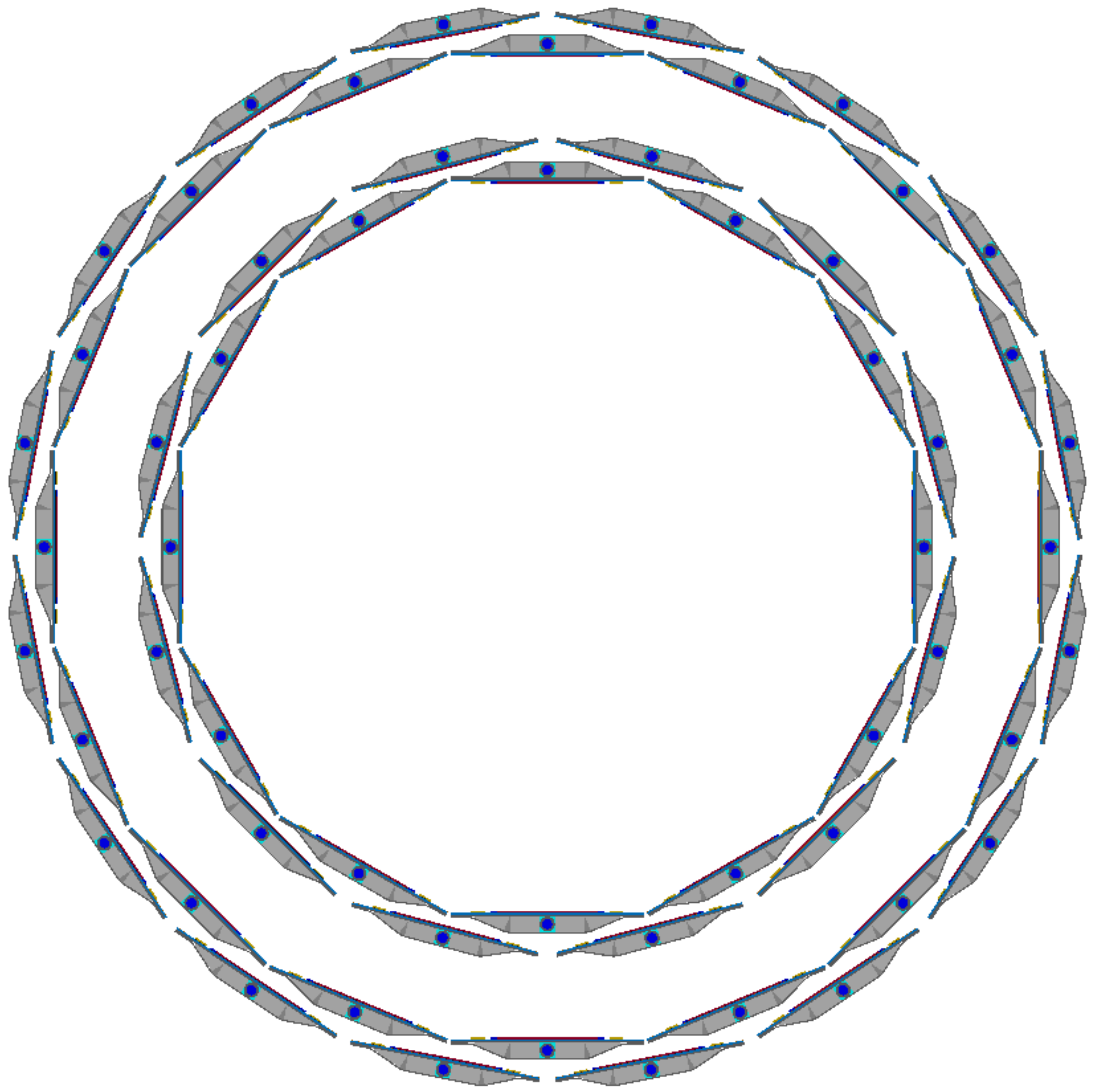
Summary of updates on the INTT geometry for Geant4

Genki Nukazuka (RBRC), INTT Bi-weekly meeting, 01/July/2020

Updates

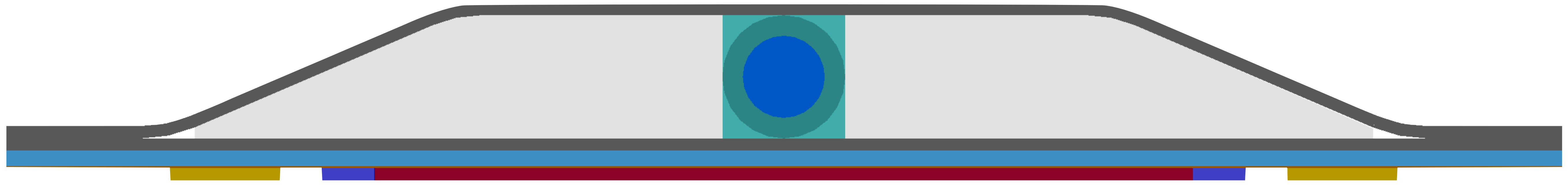


Ladder configuration

- A number of ladders in layers
- Distance of layers from the beam-axis

Ladder geometry

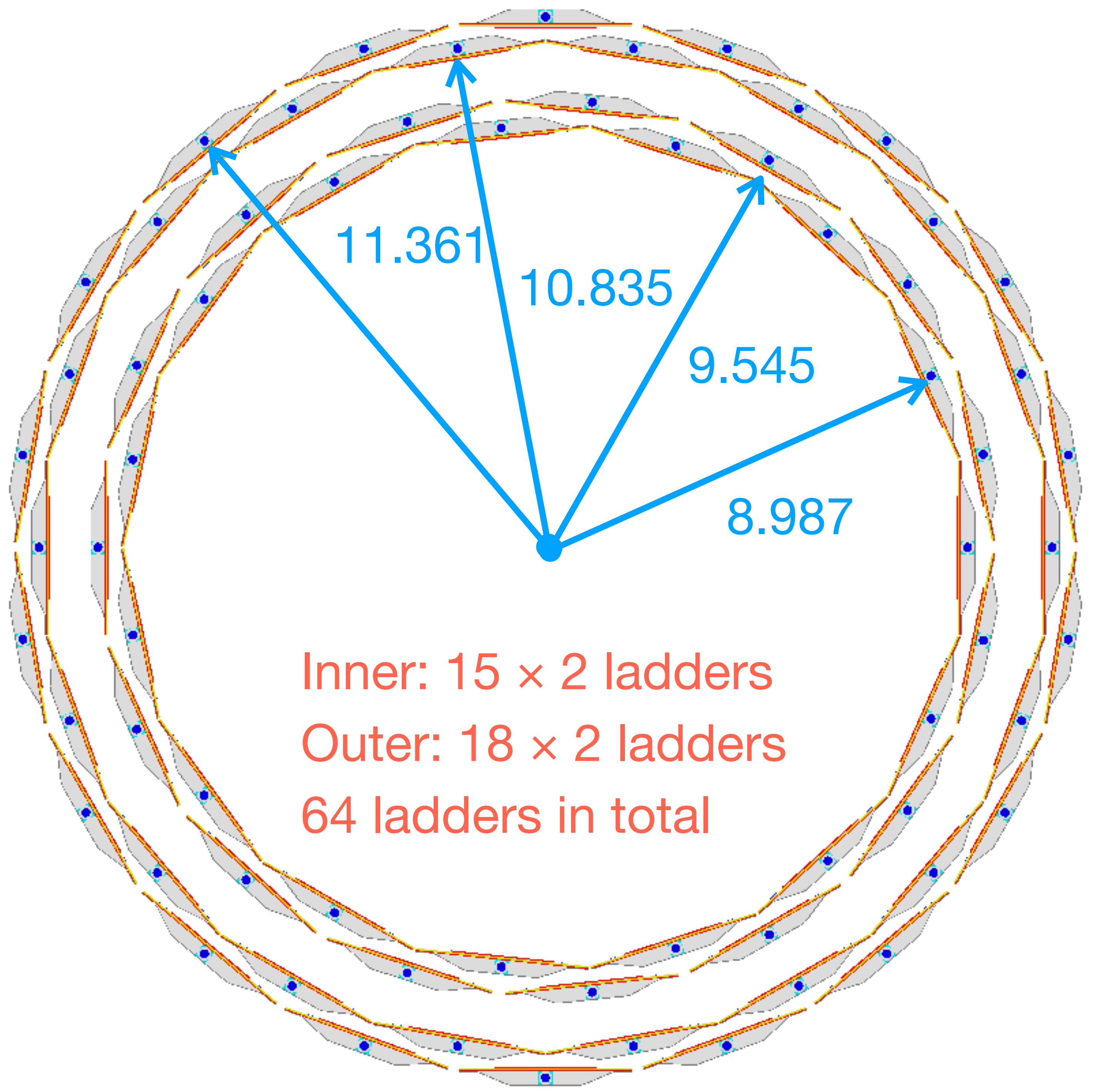
- Replacement of PGS to the flat CFRP plate
- Change of thickness of the formed and flat CFRP plates
- Change of thickness of the copper layer in HDI
- Addition of the silver epoxy glue for the silicon sensor and FPHX chips



Ladder configuration

Model in the current repository

Layer	#ladder	Distance from the beam-axis (cm)
1a (Innermost)	15	8.987
1b (2nd innnermost)	15	9.545
2a (2nd outermost)	18	10.835
2b (Outermost)	18	11.361



(cm)

Ladder configuration

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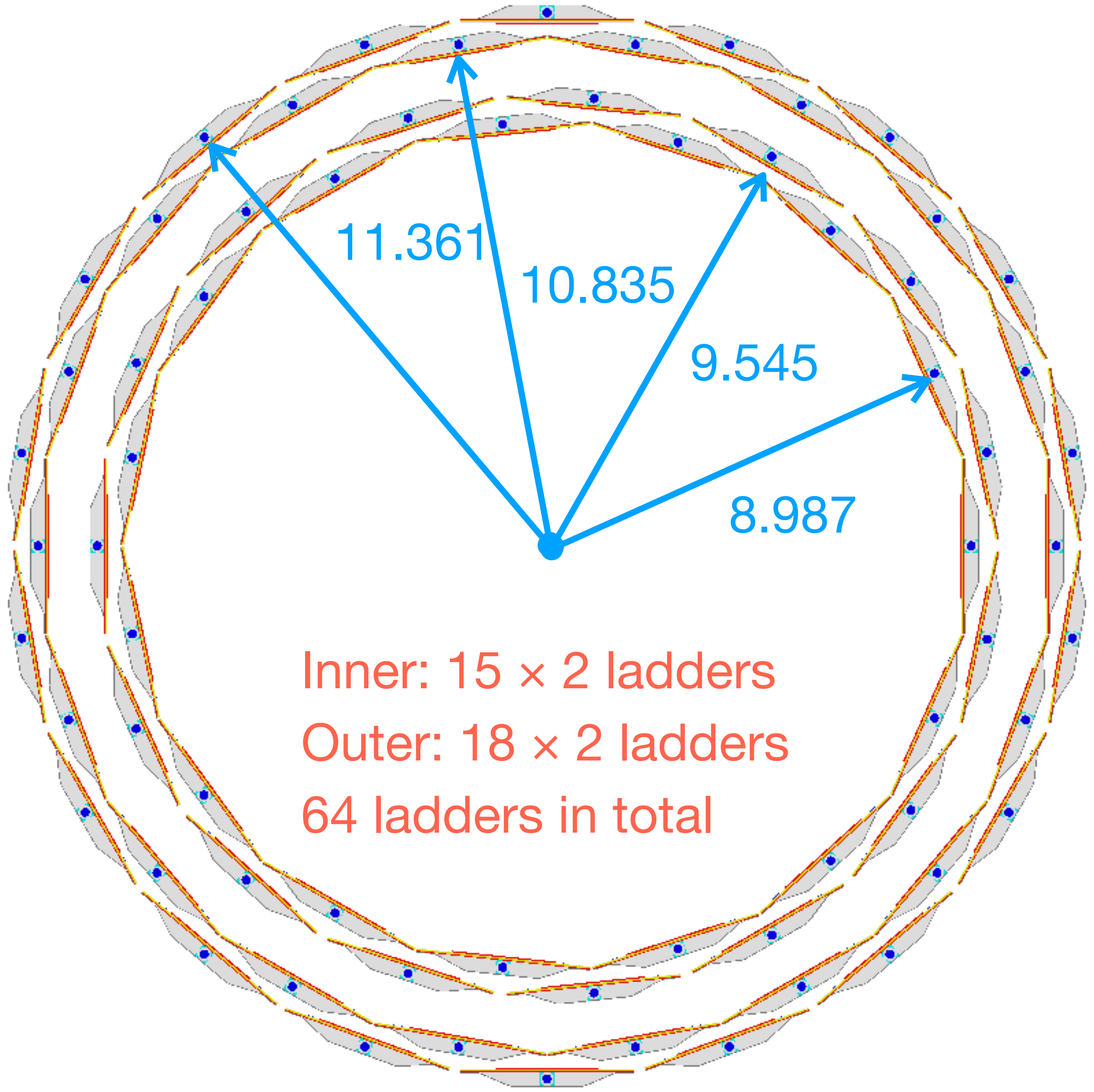
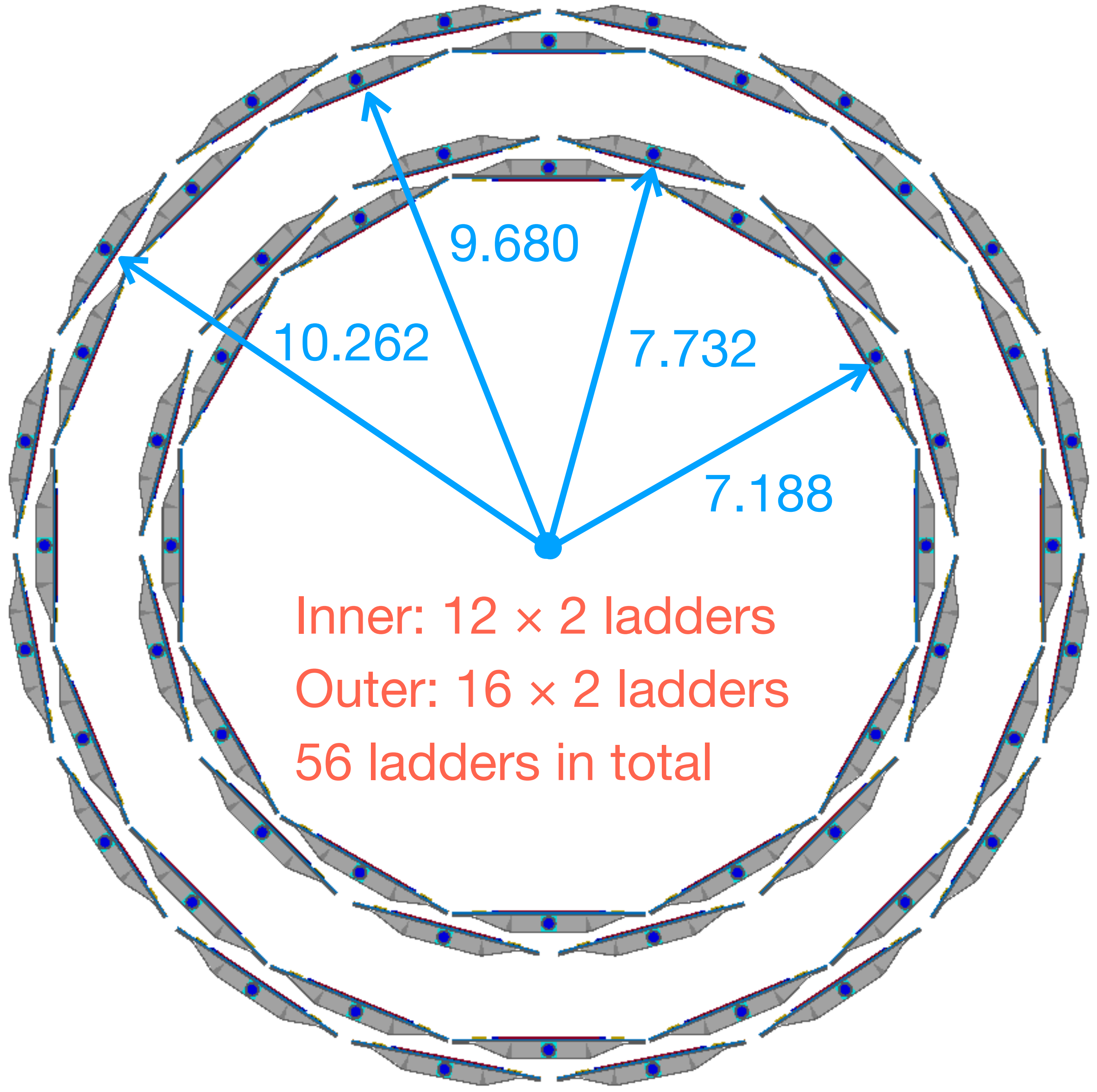


Updated model

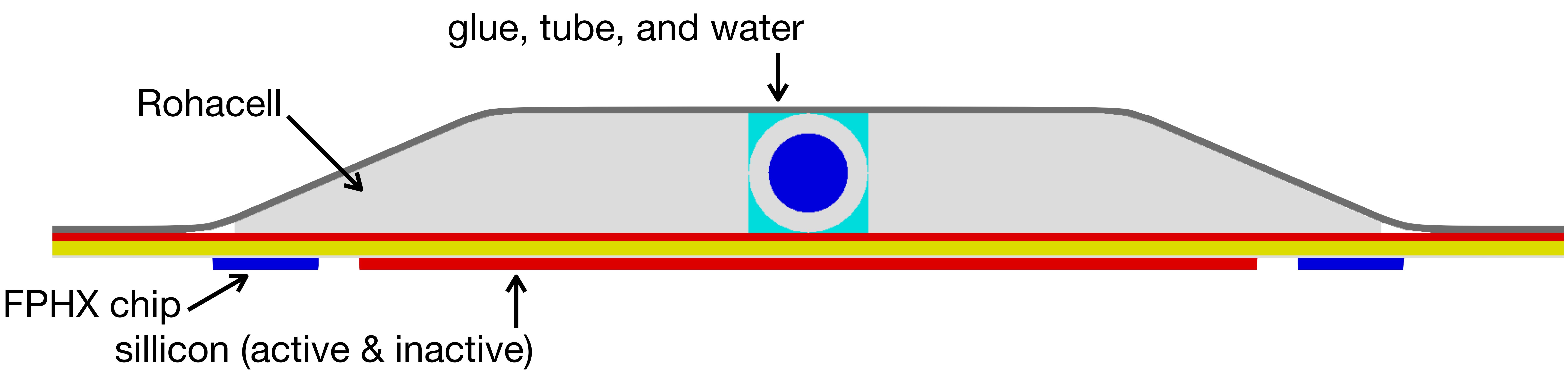
Layer	#ladder	Distance from the beam-axis (cm)
1a (Innermost)	12	7.188
1b (2nd innnermost)	12	7.732
2a (2nd outermost)	16	9.680
2b (Outermost)	16	10.262



(cm)

Geometry of the ladder

Model in the current repository



Geometry of the ladder

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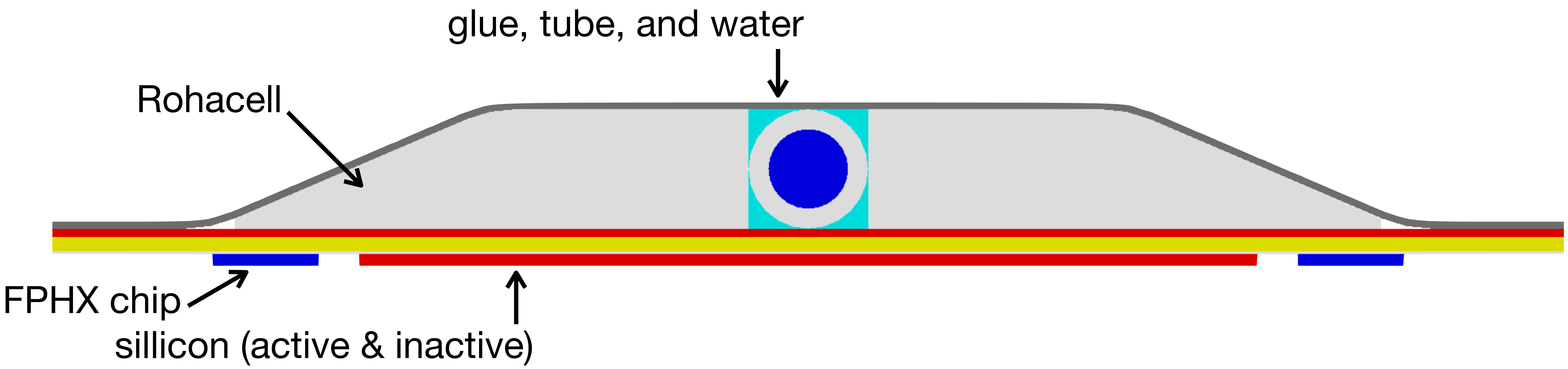
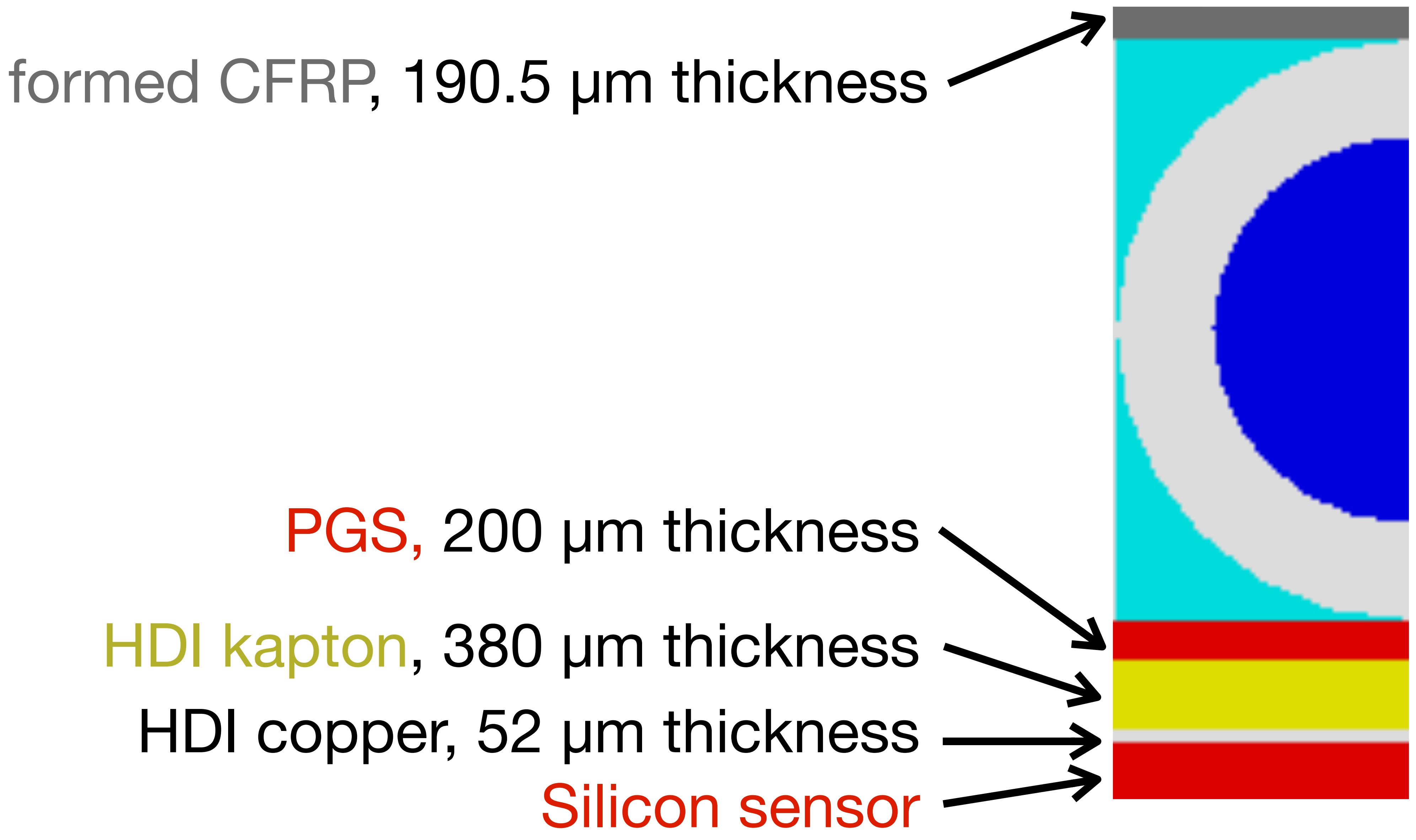
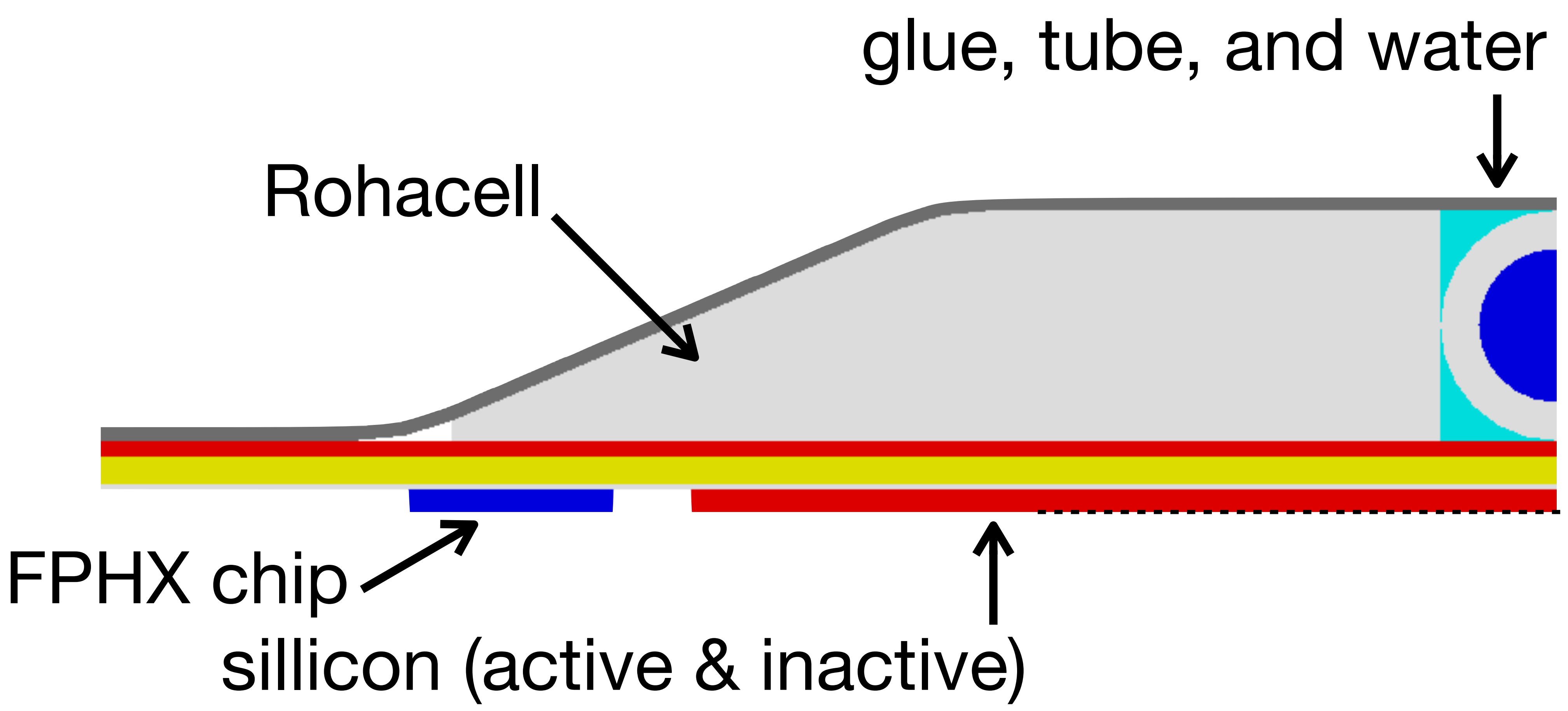


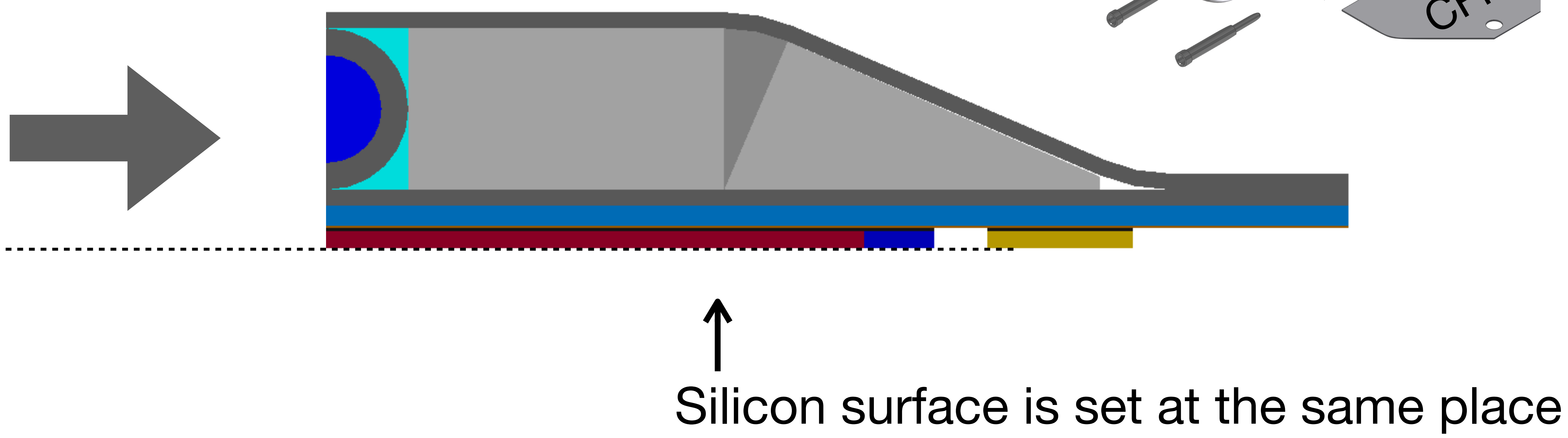


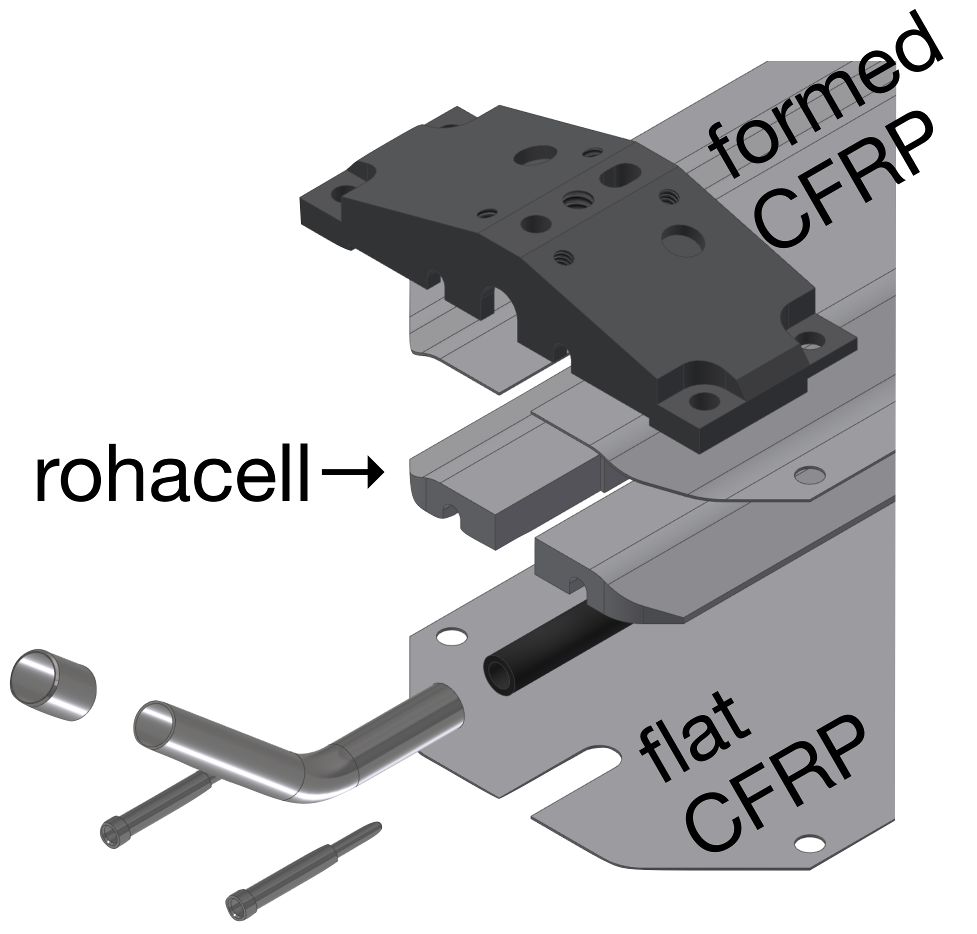
Geometry of the ladder

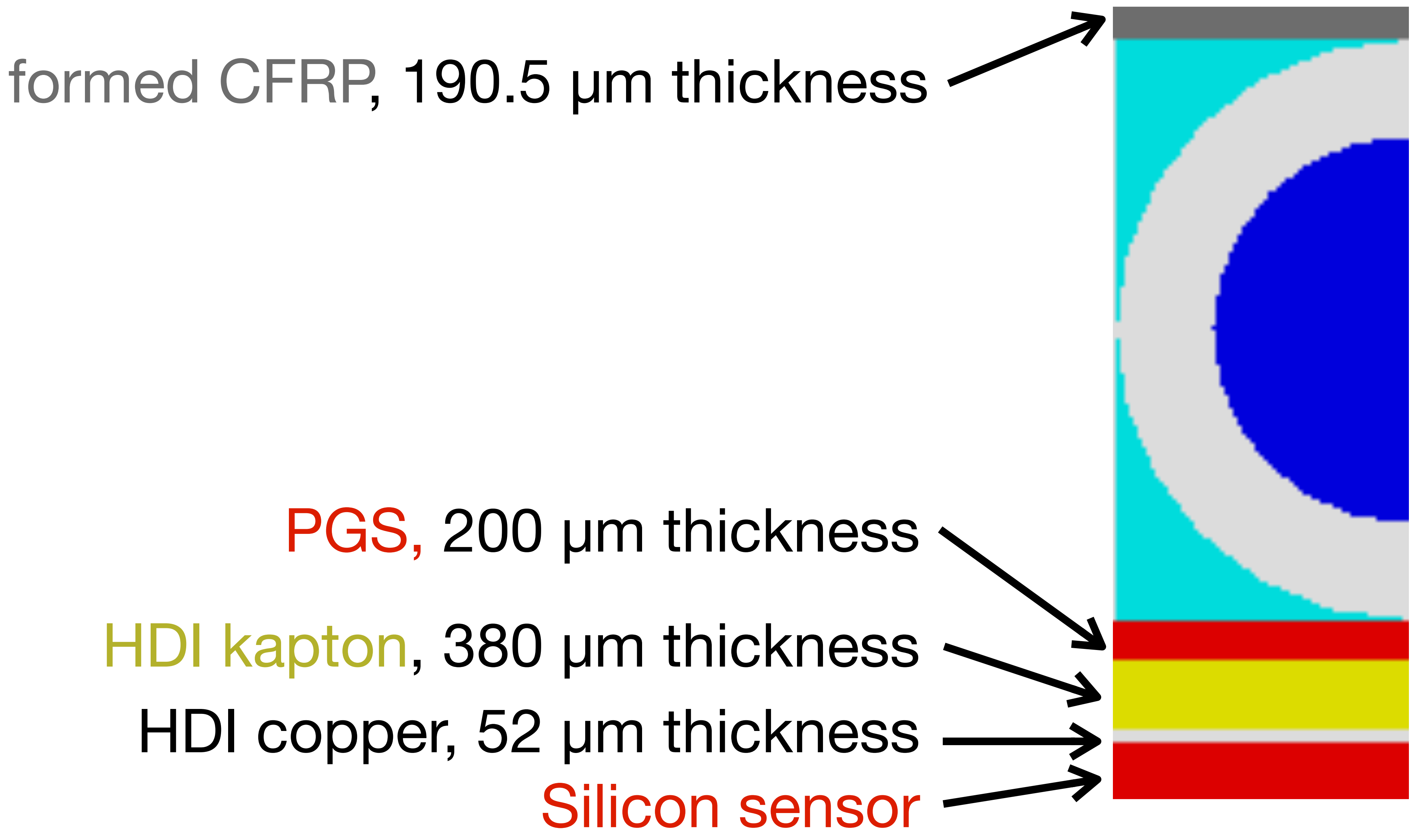
Model in the current repository



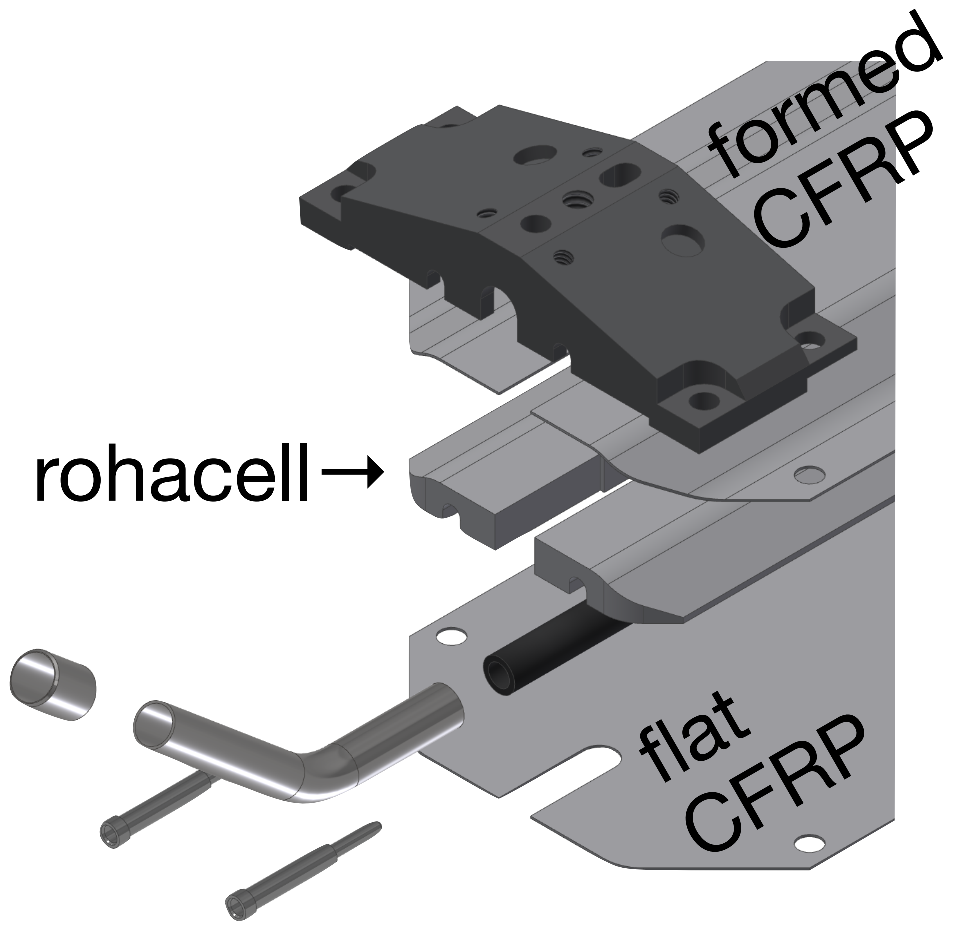
Updated model





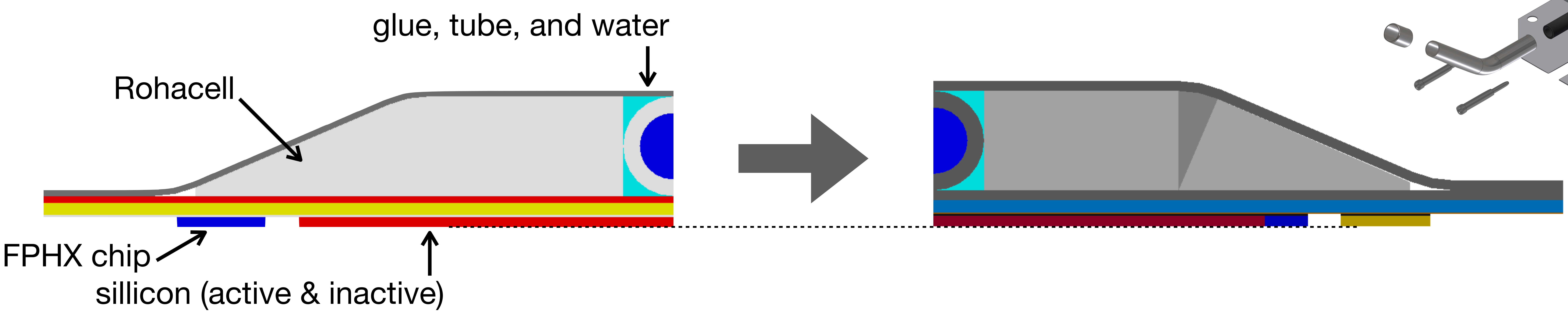


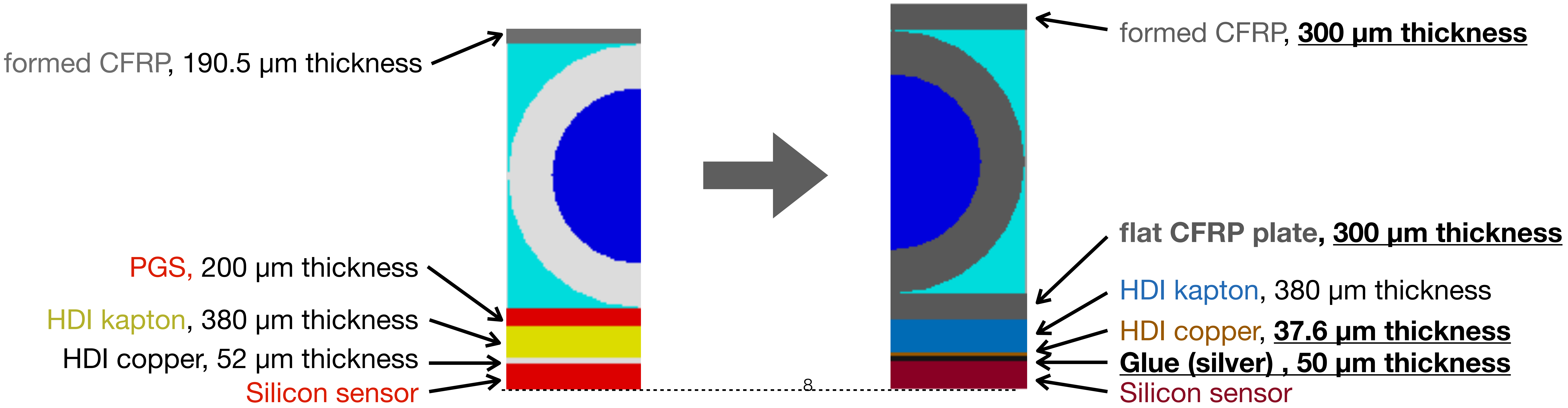
Geometry of the ladder



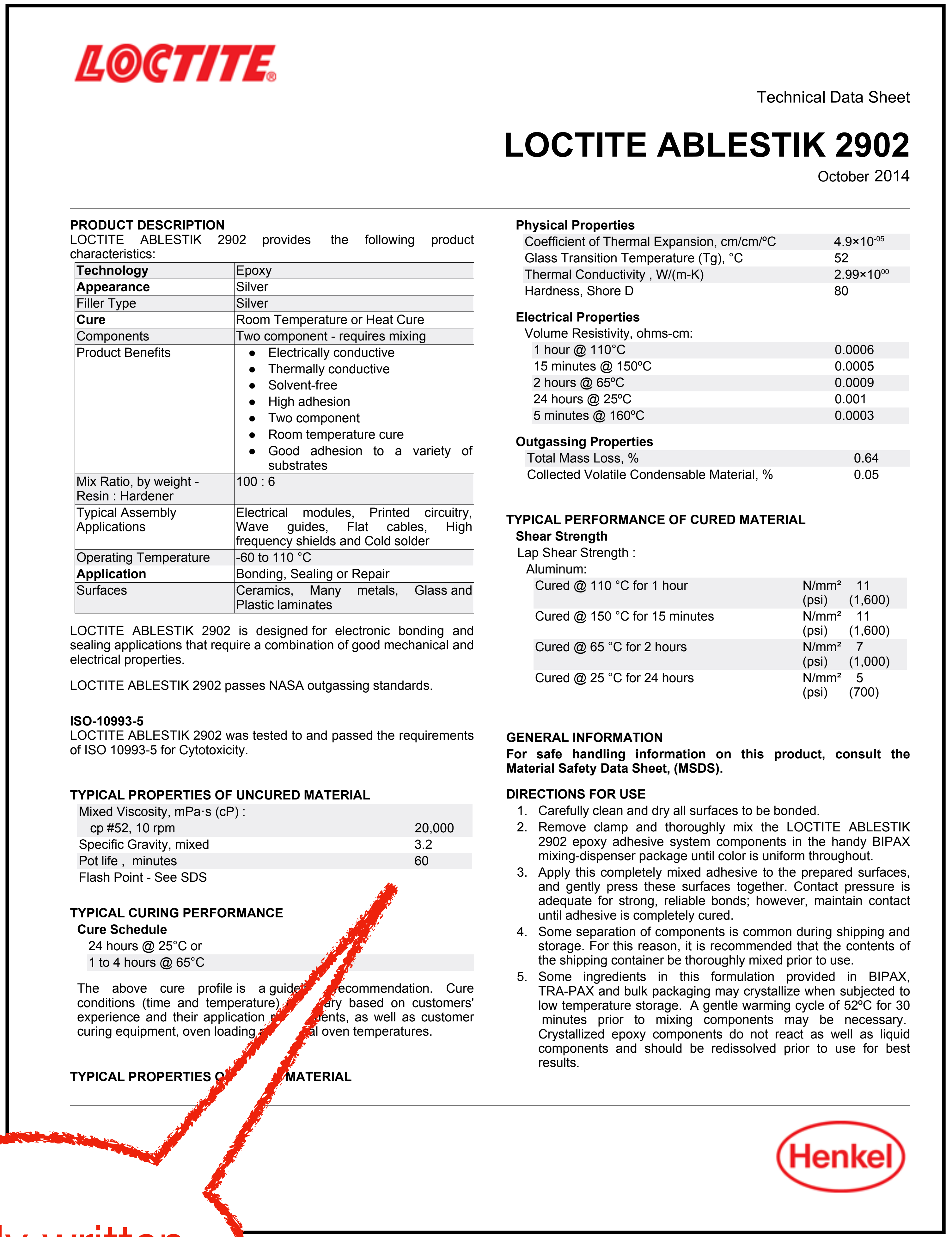
Model in the current repository

Updated model





The silver epoxy glue for FPHX chips



LOCTITE

Technical Data Sheet

LOCTITE ABLESTIK 2902

October 2014

PRODUCT DESCRIPTION
LOCTITE ABLESTIK 2902 provides the following product characteristics:

Technology	Epoxy
Appearance	Silver
Filler Type	Silver
Cure	Room Temperature or Heat Cure
Components	Two component - requires mixing
Product Benefits	• Electrically conductive • Thermally conductive • Solvent-free • High adhesion • Two component • Room temperature cure • Good adhesion to a variety of substrates
Mix Ratio, by weight - Resin : Hardener	100 : 6
Typical Assembly Applications	Electrical modules, Printed circuitry, Wave guides, Flat cables, High frequency shields and Cold solder
Operating Temperature	-60 to 110 °C
Application	Bonding, Sealing or Repair
Surfaces	Ceramics, Many metals, Glass and Plastic laminates

LOCTITE ABLESTIK 2902 is designed for electronic bonding and sealing applications that require a combination of good mechanical and electrical properties.

LOCTITE ABLESTIK 2902 passes NASA outgassing standards.

ISO-10993-5
LOCTITE ABLESTIK 2902 was tested to and passed the requirements of ISO 10993-5 for Cytotoxicity.

TYPICAL PROPERTIES OF UNCURED MATERIAL

Mixed Viscosity, mPa·s (cP) :	
cp #52, 10 rpm	20,000
Specific Gravity, mixed	3.2
Pot life , minutes	60
Flash Point - See SDS	

TYPICAL CURING PERFORMANCE
Cure Schedule
24 hours @ 25°C or
1 to 4 hours @ 65°C

The above cure profile is a guide[illegible] recommendation. Cure conditions (time and temperature) [illegible]ary based on customers' experience and their application [illegible]ents, as well as customer curing equipment, oven loading a[illegible]al oven temperatures.

TYPICAL PROPERTIES O[illegible] MATERIAL

Physical Properties

Coefficient of Thermal Expansion, cm/cm/°C	4.9×10^{-05}
Glass Transition Temperature (Tg), °C	52
Thermal Conductivity , W/(m-K)	2.99×10^{00}
Hardness, Shore D	80

Electrical Properties
Volume Resistivity, ohms-cm:

1 hour @ 110°C	0.0006
15 minutes @ 150°C	0.0005
2 hours @ 65°C	0.0009
24 hours @ 25°C	0.001
5 minutes @ 160°C	0.0003

Outgassing Properties

Total Mass Loss, %	0.64
Collected Volatile Condensable Material, %	0.05

TYPICAL PERFORMANCE OF CURED MATERIAL
Shear Strength
Lap Shear Strength :
Aluminum:

Cured @ 110 °C for 1 hour	N/mm² (psi)	11 (1,600)
Cured @ 150 °C for 15 minutes	N/mm² (psi)	11 (1,600)
Cured @ 65 °C for 2 hours	N/mm² (psi)	7 (1,000)
Cured @ 25 °C for 24 hours	N/mm² (psi)	5 (700)

GENERAL INFORMATION
For safe handling information on this product, consult the Material Safety Data Sheet, (MSDS).

DIRECTIONS FOR USE
1. Carefully clean and dry all surfaces to be bonded.
2. Remove clamp and thoroughly mix the LOCTITE ABLESTIK 2902 epoxy adhesive system components in the handy BIPAX mixing-dispenser package until color is uniform throughout.
3. Apply this completely mixed adhesive to the prepared surfaces, and gently press these surfaces together. Contact pressure is adequate for strong, reliable bonds; however, maintain contact until adhesive is completely cured.
4. Some separation of components is common during shipping and storage. For this reason, it is recommended that the contents of the shipping container be thoroughly mixed prior to use.
5. Some ingredients in this formulation provided in BIPAX, TRA-PAX and bulk packaging may crystallize when subjected to low temperature storage. A gentle warming cycle of 52°C for 30 minutes prior to mixing components may be necessary. Crystallized epoxy components do not react as well as liquid components and should be redissolved prior to use for best results.

Henkel

already written, actually…

Provided information by Henkel: Specific gravity is 3.2

	Specific gravity	Ratio	Ratio (average)
Glue	3.2		
Ag	10.5	0.198 - 0.223	0.21
Epoxy	1.1 - 1.4	0.777 - 0.802	0.79

The silver epoxy glue for FPHX chips

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Glue	3.2		
Ag	10.5	0.198 - 0.223	0.21
Epoxy	1.1 - 1.4	0.777 - 0.802	0.79

Definition of the material in Geant4 to be added:

```
g4main/PHG4Reco.cc
L876
---------------------------------------------------------------------------------------------
  //from http://www.physi.uni-heidelberg.de/~adler/TRD/TRDunterlagen/RadiatonLength/tgc2.htm
  //Epoxy (for FR4 )
  //density = 1.2*g/cm3;
  G4Material *Epoxy = new G4Material("Epoxy", 1.2 * g / cm3, ncomponents = 2);
  Epoxy->AddElement(G4Element::GetElement("H"), natoms = 2);
  Epoxy->AddElement(G4Element::GetElement("C"), natoms = 2);


  // Silver epoxy glue LOCTITE ABLESTIK 2902 for the silicon sensors and FPHX chips of INTT
  G4Material *SilverEpoxyGlue_INTT = new G4Material("SilverEpoxyGlue_INTT", density = 3.2 * g / cm3, ncomponents = 2);
  SilverEpoxyGlue_INTT->AddMaterial(Epoxy, fractionmass = 0.79);
  SilverEpoxyGlue_INTT->AddMaterial(G4Material::GetMaterial("G4_Ag"), fractionmass = 0.21);
```

Epoxy for something else

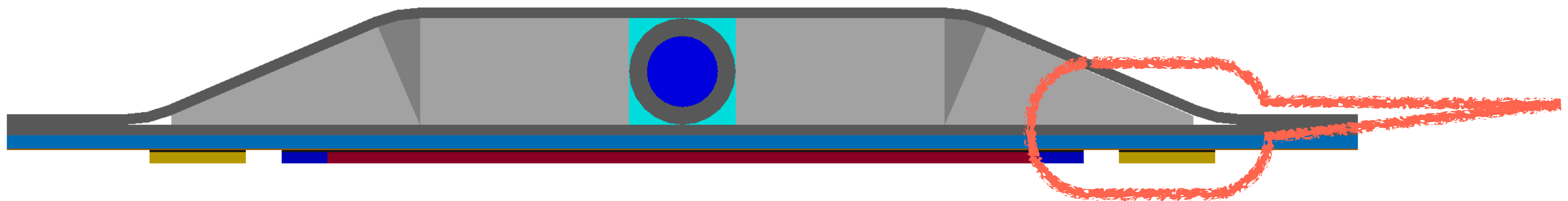
The silver epoxy glue for FPHX chips

Provided information by Henkel: Specific gravity is 3.2

	Specific gravity	Ratio	Ratio (average)
Glue	3.2		
Ag	10.5	0.198 - 0.223	0.21
Epoxy	1.1 - 1.4	0.777 - 0.802	0.79

Amount of material in the glue with respect to the copper in HDI:

	Material	Density (g/cc)	Effective thickness (μm)	Amount ratio wrt Cu of HDI
Cu of HDI	Cu	8.94	37.6	1.00
Glue, Ag	Ag	10.49	10.5	0.33
Glue, epoxy	H, C, O	1.1 - 1.4	39.5	0.15



HDI copper, 37.6 μm thickness

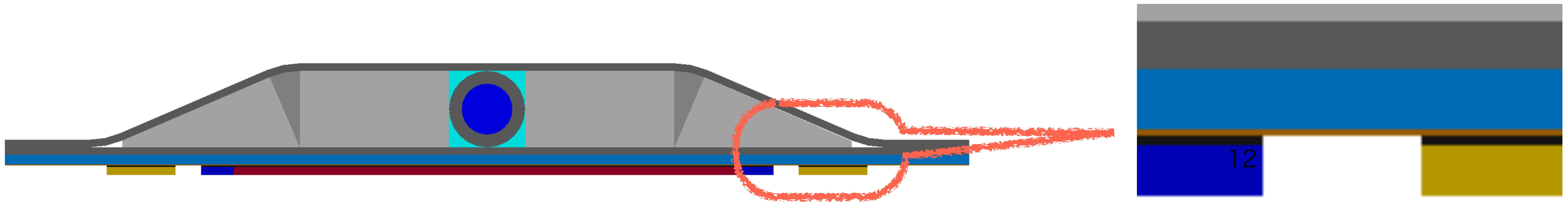
Silver epoxy glue, 50 μm thickness

The silver epoxy glue for FPHX chips

The effective thickess 37.6 µm of the copper in HDI is input to Geant4 while the actual thickness is 52 µm. Should the glue thickness is given in the same way?

Amount of material in the glue with respect to the copper in HDI:

	Material	Density (g/cc)	Effective thickness (µm)	Amount ratio wrt Cu of HDI
Cu of HDI	Cu	8.94	37.6	1.00
Glue, Ag	Ag	10.49	10.5	0.33
Glue, epoxy	H, C, O	1.1 - 1.4	39.5	0.15



HDI copper, 37.6 µm thickness

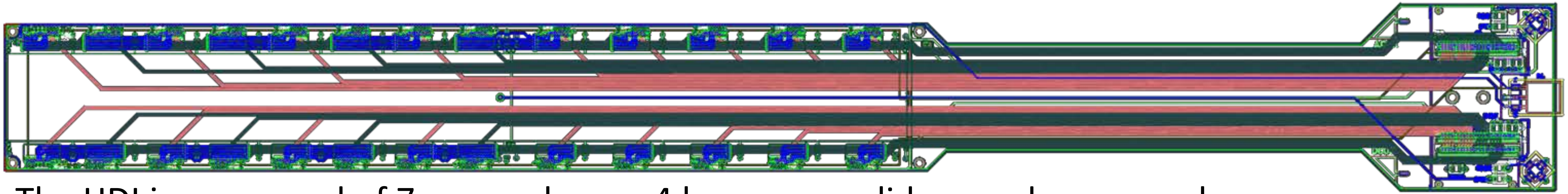
Silver epoxy glue, 50 µm thickness

Radiation Length of INTT Ladder

Material	Thickness [µm]	X/X_0
Silicon	320	0.30%
HDI	473	0.40%
Stave	3620	0.40%
Total	4413	1.10%

HDI Material	Thickness [µm]	X/X_0
Copper*	38	0.26%
Polyimide	380	0.14%
Total**	432	0.40%

*Copper thickness is not physical thickness, but average thickness.
**Total thickness is not 473µm, because of copper average thickness.



The HDI is composed of 7 copper layers. 4 layers are solid ground or power layers.
The remaining 3 layers are signal line layers containing a few percent of solid copper per layer.
All components are averaged over the area of the stave in the active region.

Dan Cacace, "INTT Ladder and Barrel Final Design and Safety Review", 05/05/2020

Stave Average Radiation Length

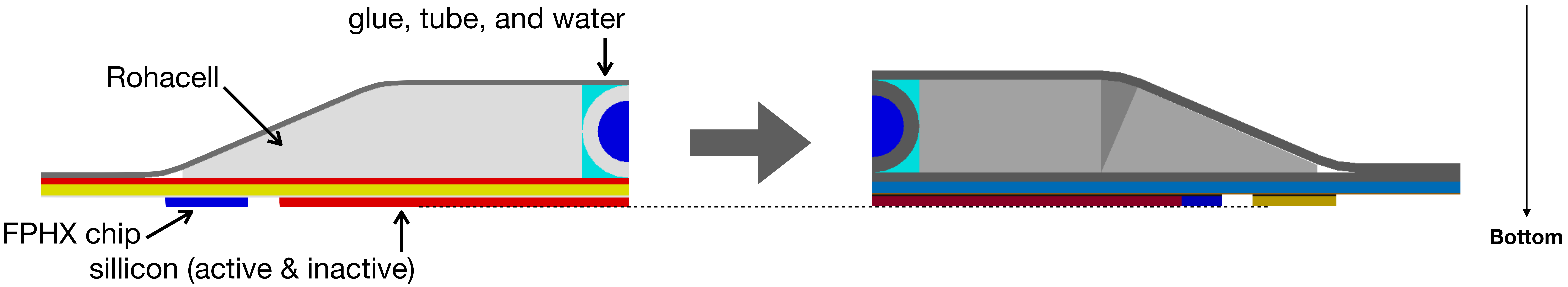
Stave	Equivalent Thickness (mm)	Radiation Length (mm)	X/X0 *100
CFC Flat	0.3300	256.4122	0.1287
CFC Formed	0.3411	256.4122	0.1330
CFC Tube	0.1033	282.2909	0.0366
Foam	1.4740	3771.3741	0.0391
Epoxy	0.1016	298.7463	0.0340
Water	0.0826	356.7854	0.0231
		Total	0.3946

	Radiation Length (mm)	Fraction
CFC	194.0909	0.6
Epoxy	349.8941	0.4
Total	256.4122	
Water	360.8000	0.7
Glycol	349.2849	0.3
Total	356.7854	

Dan Cacace, “INTT Ladder and Barrel Final Design and Safety Review”, 05/05/2020

Summary of Geometry of the ladder

Model in the current repository | **Updated model**



Top → Bottom	Name	Materi	Thickne	X/X_0	
	formed CFRP	CFRP	190.5	0.07%	?
	Rohacel, CFRP tube, water			0.13%	
	PGS	CFRP	200	0.08%	?
	Kapton of HDI	Kapton	380	0.14%	
	Copper of HDI	Copper	52	0.36%	?
	Sillicon/FPHX chips			0.30%	
				1.08%	

Top → Bottom	Name	Materi	Thickne	X/X_0	
	formed CFRP	CFRP	300	0.12%	
	Rohacel, CFRP tube, water			0.13%	
	flat CFRP	CFRP	300	0.12%	
	Kapton of HDI	Kapton	380	0.14%	
	Copper of HDI	Copper	37.6	0.26%	
	Silver epoxy glue	Ag, epoxy	50	0.26%	?
	Sillicon/FPHX chips			0.30%	
				1.32%	

Implementation

~Usability or Safety?~

There are 2 choices to change the geometry:

- Changing parameters at **source level**
  Only experts touch
- Changing parameters at **macro level**
  Any end-users can touch

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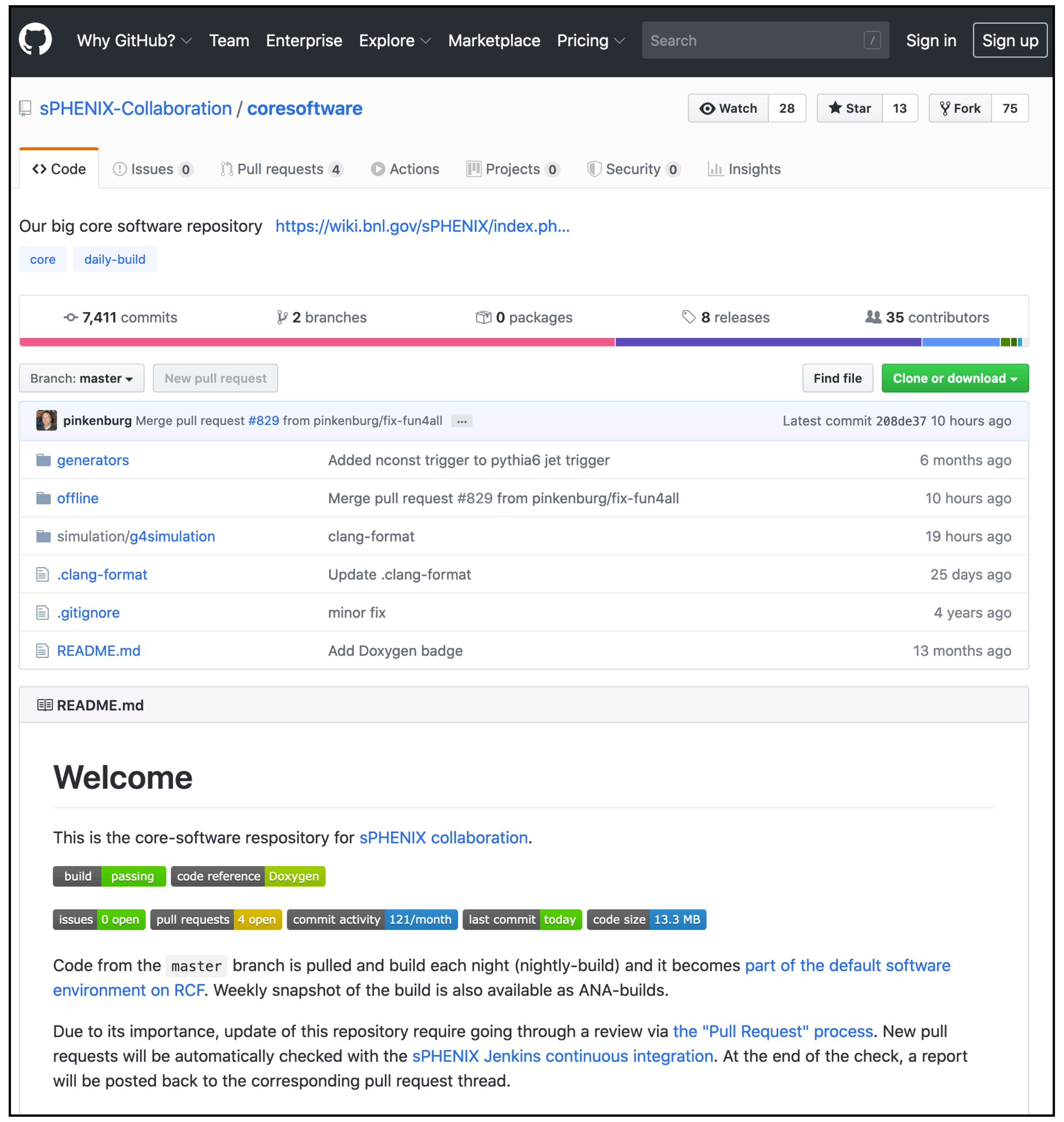
Steps to run the simulation

1. in coresoftware repository,
   making a shared library (libg4intt.so) etc.




```
coresoftware repository
├─── generators
├─── offline
└─── simulation
     └─── g4simulation
          ├─── g4detectors
          ├─── g4dst
          ├─── g4eval
          ├─── g4gdml
          ├─── g4histos
          ├─── g4intt
          ├─── g4jets
          ├─── g4main
          ├─── . . .
```

building shared lib. etc.

libg4intt.so etc.

Implementation
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Steps to run the simulation

1. in coresoftware repository,
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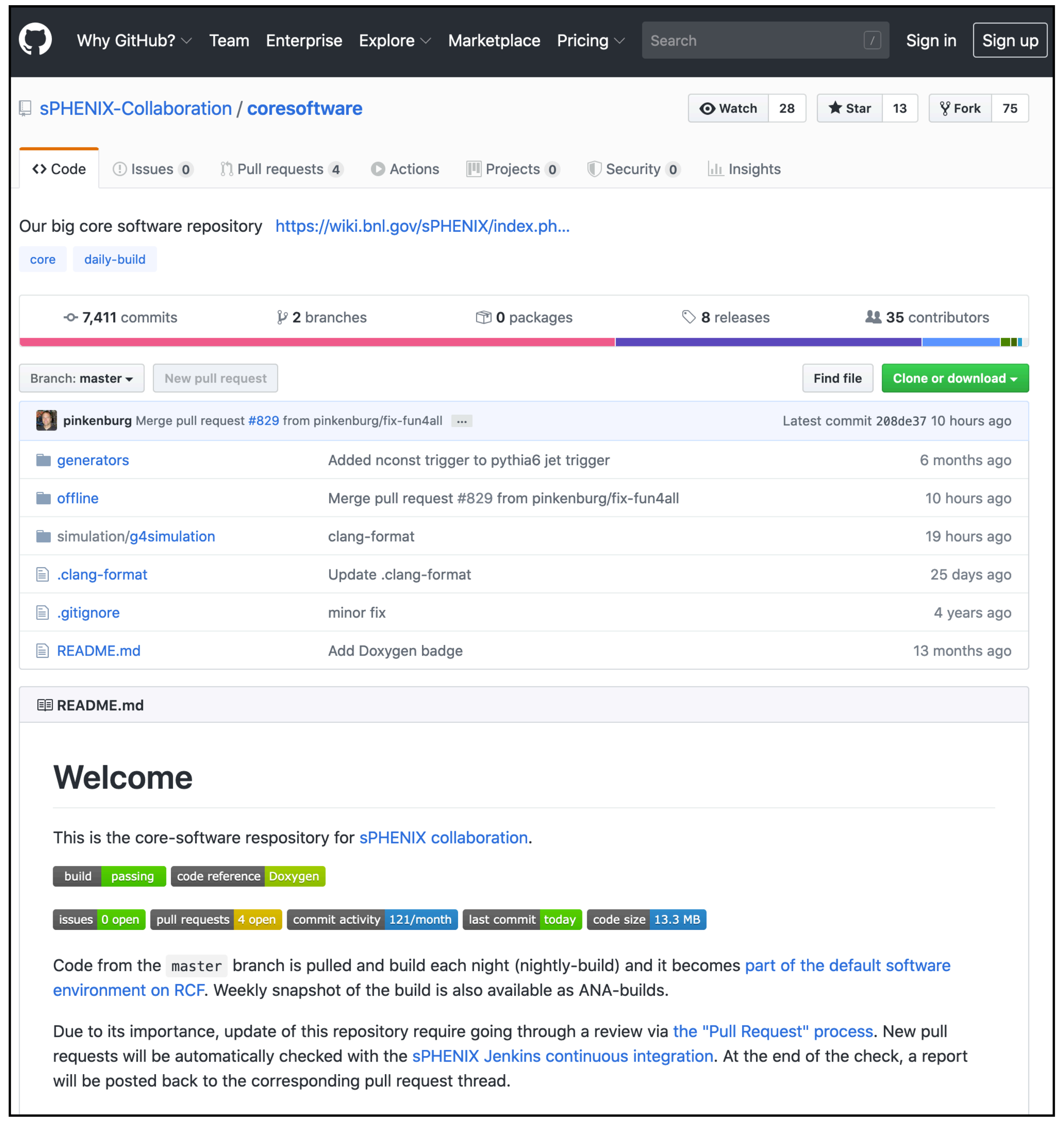
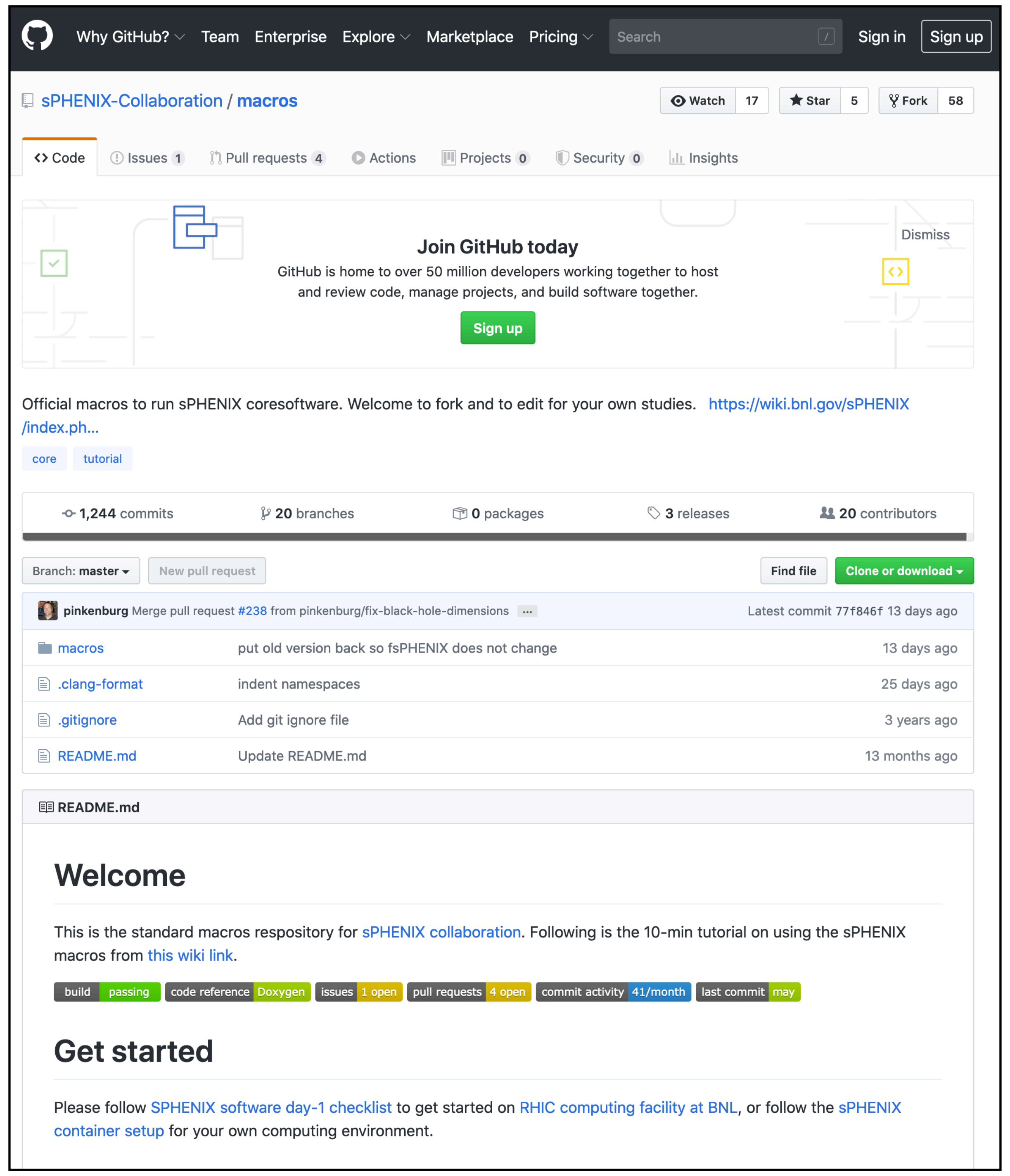
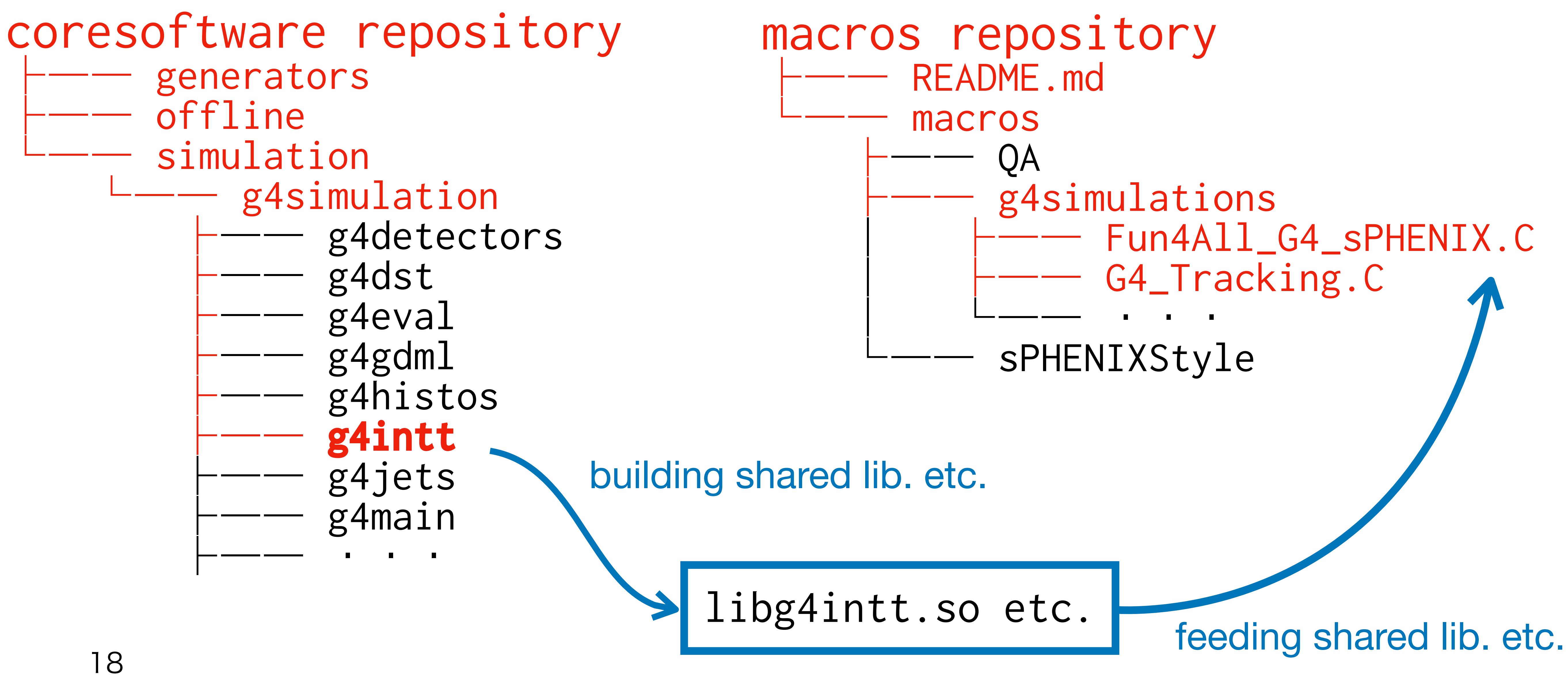
2. in macro repository,
   running Fun4All_sPHENIX.C
   - Fun4All_sPHENIX.C uses G4_Tracking.C to construct INTT.
   - Parameters can be changed in G4_Tracking.C.







Implementation

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There are 2 choices to change the geometry:

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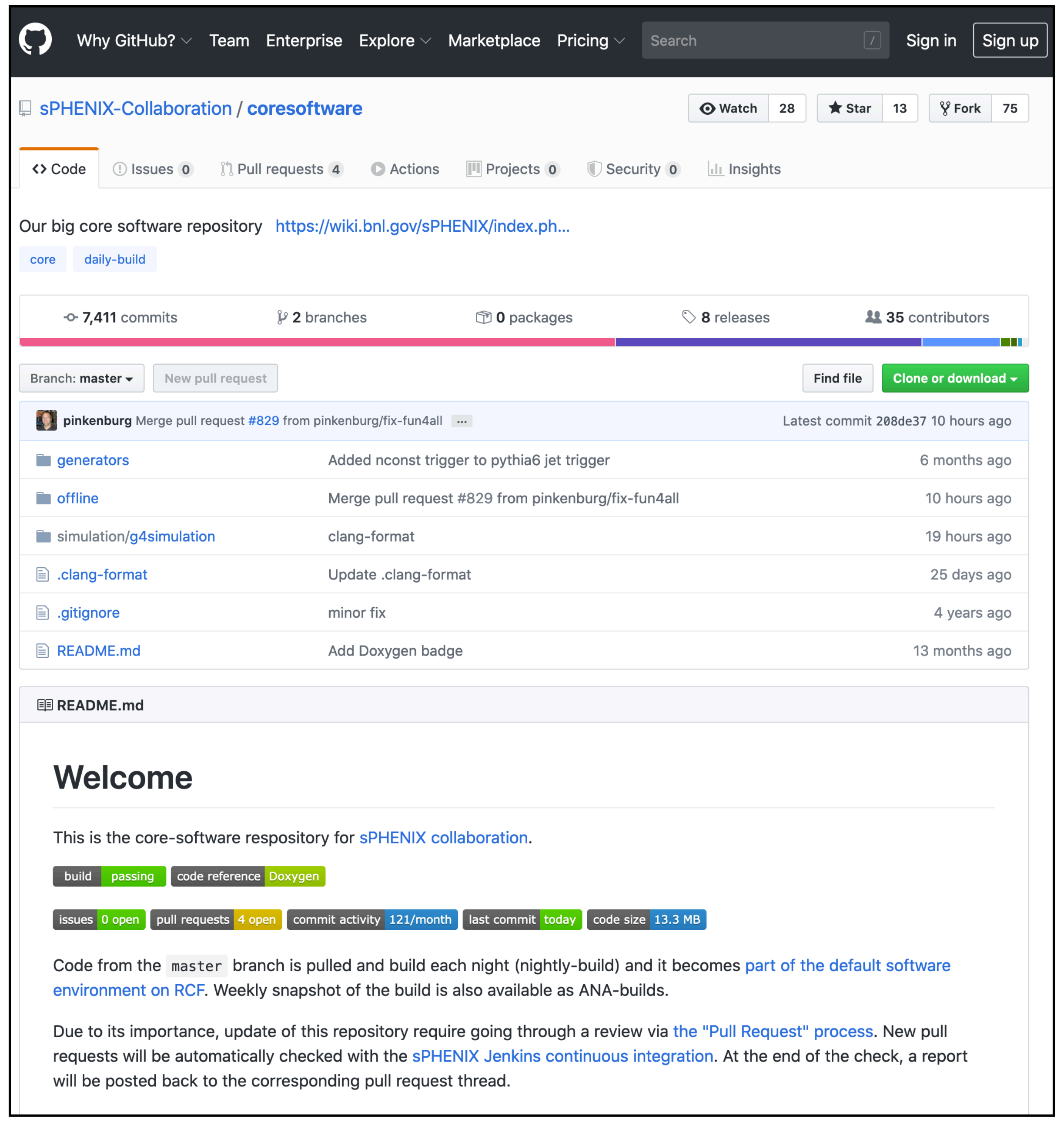
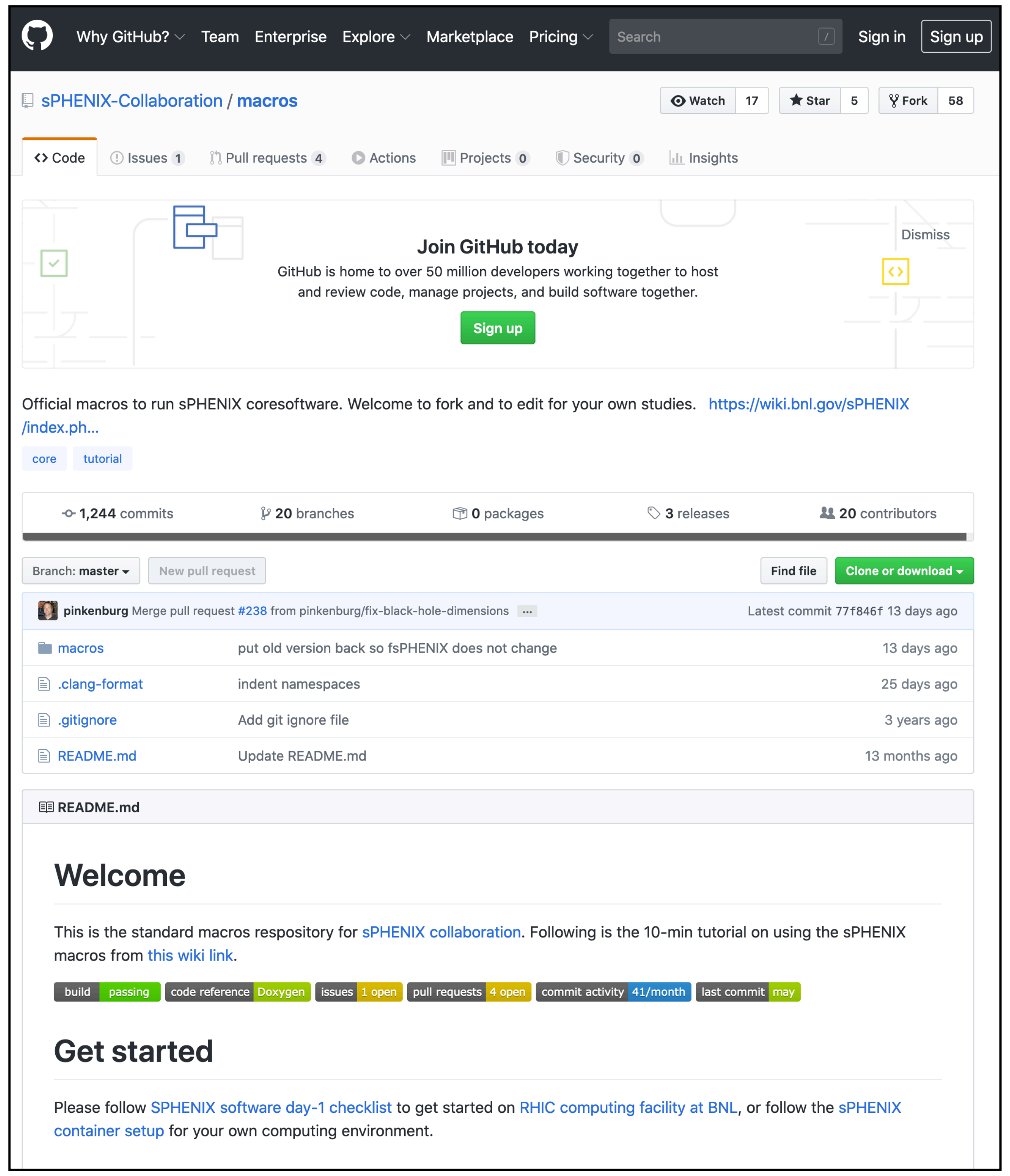
   - Fun4All_sPHENIX.C uses G4_Tracking.C to construct INTT.
   - Parameters can be changed in G4_Tracking.C.

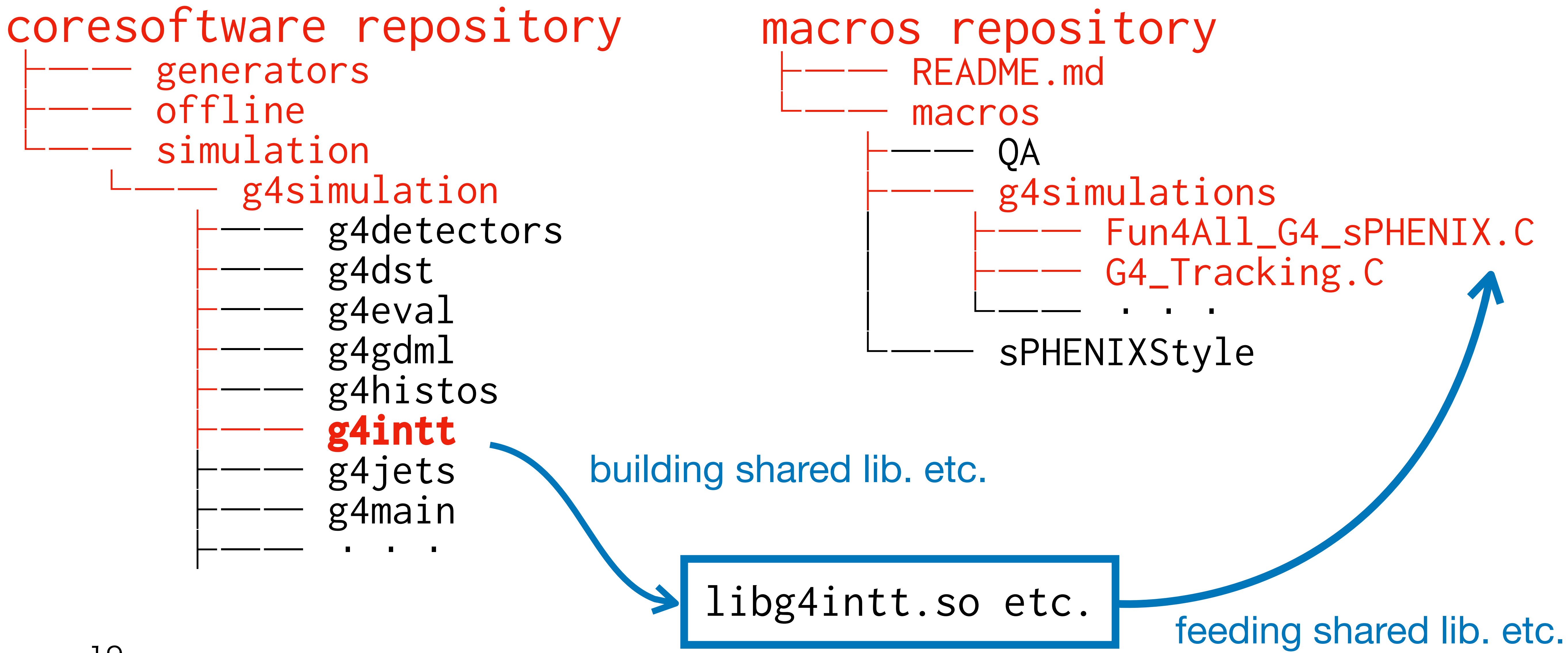
Parameters in the source are hard corded.

Users can change parameters in the macro,
so it's useful but danger.

When parameters can be fixed, it may be good to disable to change them at the macro level.







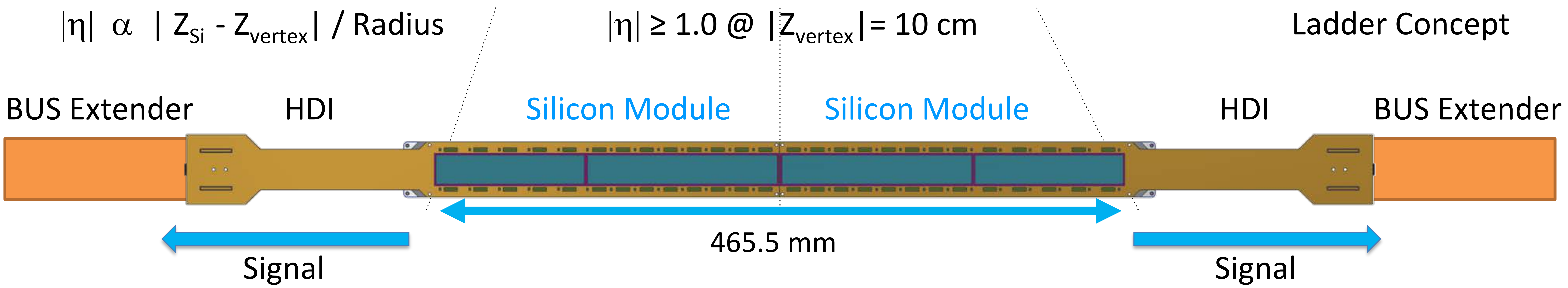
backup

Two Barrel Configuration

$|\eta| \propto |Z_{Si} - Z_{vertex}| / \text{Radius}$

$|\eta| \geq 1.0 \ @ \ |Z_{vertex}| = 10 \text{ cm}$

Ladder Concept

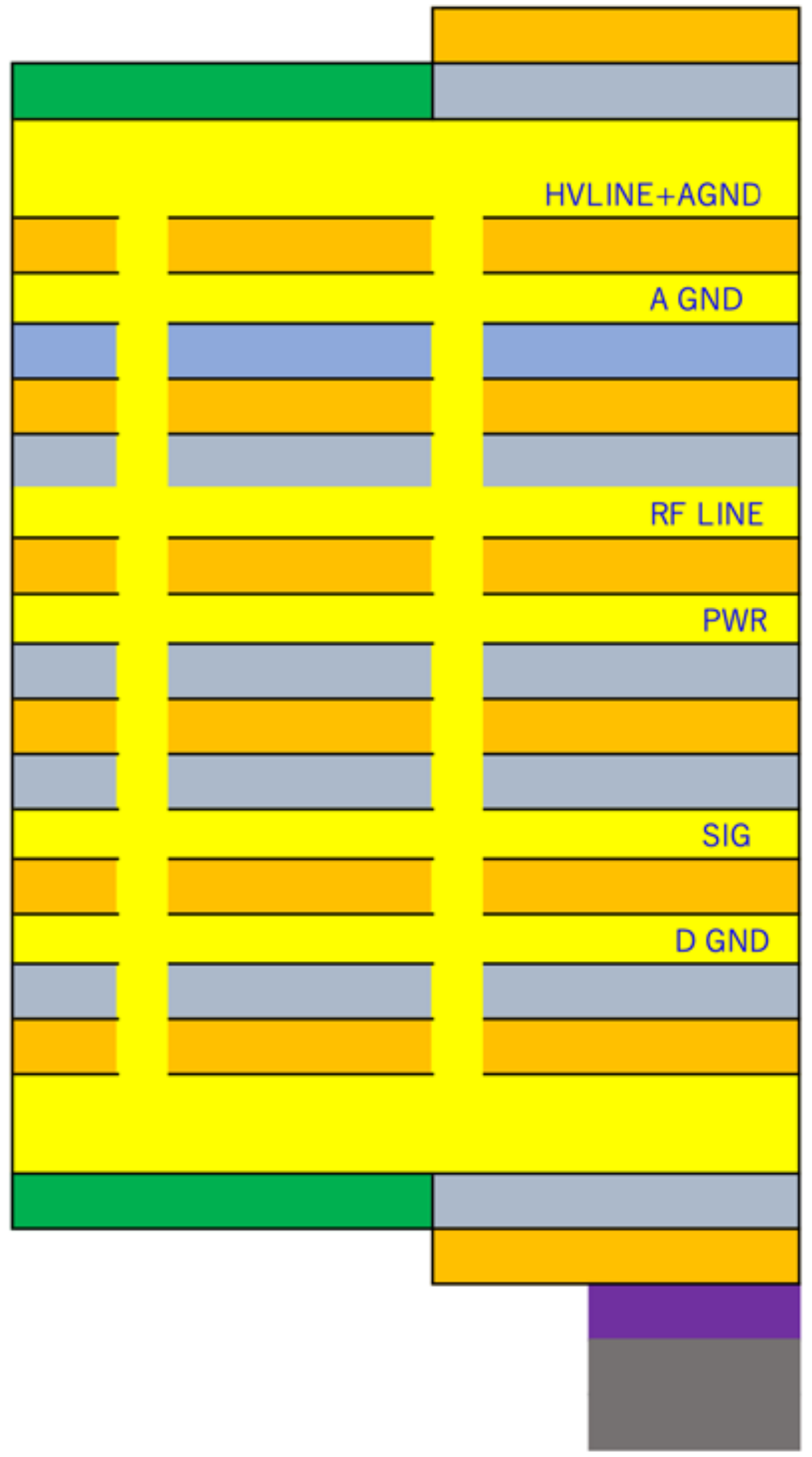


Barrel	Center of Sensor Tangent Radius (mm)	Pseudo rapidity	QTY of Ladders	Angle (deg)	Coverage (PHI) (%)	Overlap (%)	Clearance (mm)	Chip Power Dissipation (W)	Stave Rad Length (%)	Barrel Rad Length (%)
1	-	-	24	-	100	1.8	2.0	62.30	0.80	2.20
1a (Inner)	71.88	1.37	12	0	52.7	0	0.6	31.15	0.40	1.10
1b (Outer)	77.32	1.31	12	0	49.4	0	3.6	31.15	0.40	1.10
2	-	-	32	-	100	1.8	2.0	83.07	0.80	2.20
2a (Inner)	96.80	1.12	16	0	52.4	0	0.6	41.53	0.40	1.10
2b (Outer)	102.62	1.07	16	0	49.4	0	3.0	41.53	0.40	1.10
Total	-	-	56	-	-	100	11.22	145.37	1.60	4.40

Dan Cacace

Layer Structure of HDI

	Regist	20 µm
	Copper plated	15 µm
L1	Electrolytic copper foil	9 µm
	Base Polyimide	50 µm
L2	Electrolytic copper foil	9 µm
	Glue	25 µm
	Base Polyimide	12.5 µm
	Glue	15 µm
L :	Electrolytic copper foil	9 µm
	Base Polyimide	50 µm
L4	Electrolytic copper foil	9 µm
	Glue	25 µm
	Base Polyimide	12.5 µm
	Glue	15 µm
L5	Electrolytic copper foil	9 µm
	Base Polyimide	50 µm
L6	Electrolytic copper foil	9 µm
	Glue	25 µm
	Base Polyimide	25 µm
L7	Electrolytic copper foil	9 µm
	Copper plated	15 µm
	Regist	20 µm
		µm
		438 µm
	TOTAL厚	438 µm

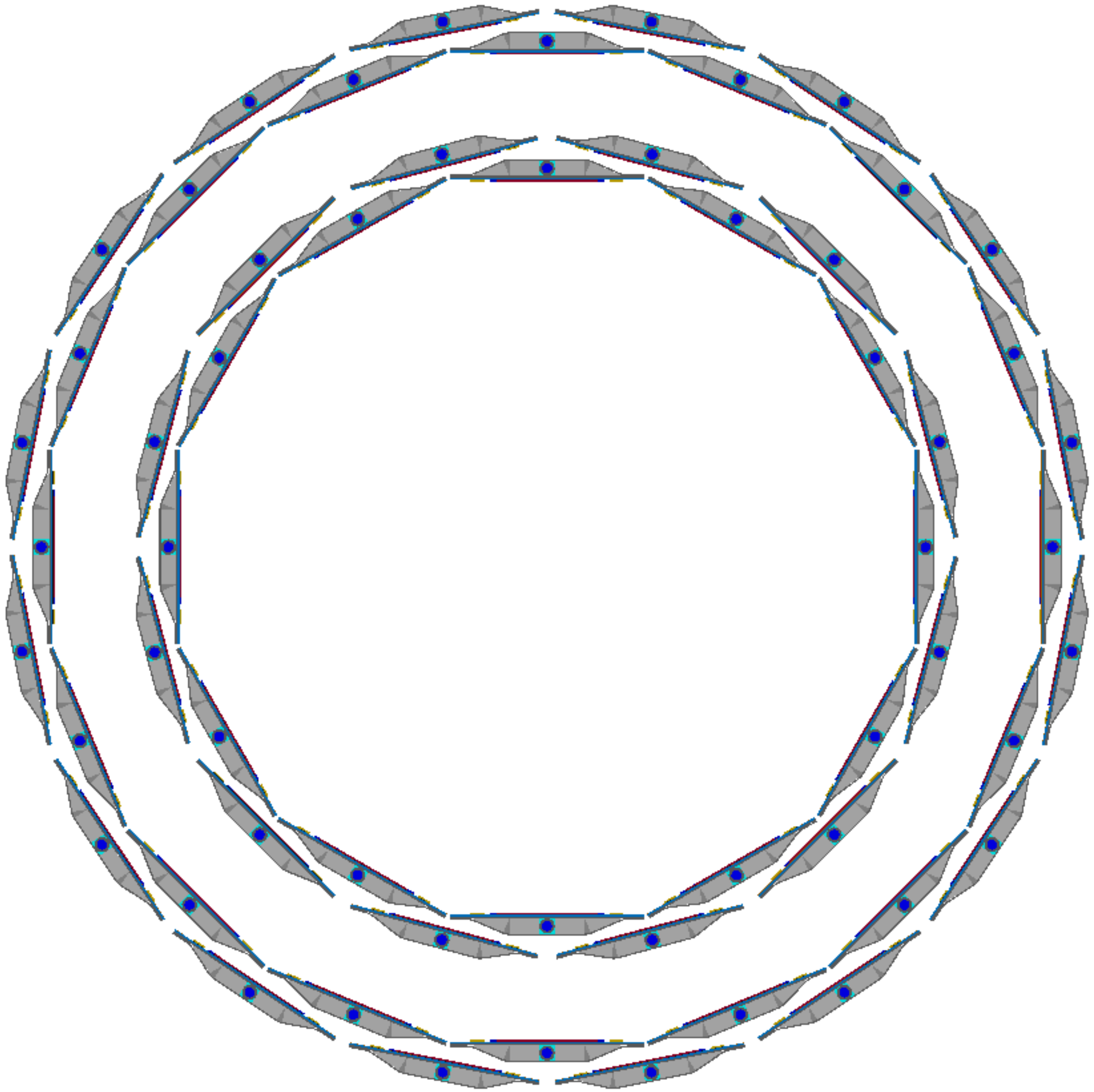


			Sub Component Thickness			
			Copper Layers			Else
Layer	Thickness		Occupancy	Effective[µm]	Real [µm]	[µm]
Coverlay Polyide	12.5	µm				12.5
Coverlay Glue	25	µm				25
Copper plated	15	µm	71.3%	10.69	15	
L1 Electrolytic copper fo	9	µm		0.00	9	
Base Polyimide	50	µm				50
L2 Electrolytic copper fo	9	µm	93.5%	8.42	9	
Glue	25	µm				25
Base Polyimide	12.5	µm				12.5
Glue	15	µm				15
L : Electrolytic copper fo	9	µm	6.50%	0.59	9	
Base Polyimide	50	µm				50
L4 Electrolytic copper fo	9	µm	94.0%	8.46	9	
Glue	25	µm				25
Base Polyimide	12.5	µm				12.5
Glue	15	µm				15
L5 Electrolytic copper fo	9	µm	7.20%	0.65	9	
Base Polyimide	50	µm				50
L6 Electrolytic copper fo	9	µm	93.2%	8.38	9	
Glue	25	µm				25
Base Polyimide	25	µm				25
L7 Electrolytic copper fo	9	µm	4.68%	0.42	9	
Copper plated	15	µm		0.00	15	
Coverlay Glue	25	µm				25
Coverlay Polyimide	12.5	µm				12.5
Glue for support plate	40	µm				
Support Plate FR-4 1	1000	µm				
TOTAL厚	473	µm	Total	37.605	93	380
			Radiation Length [	1.435		28.6
			X/Xrad [%]	0.262		0.1329

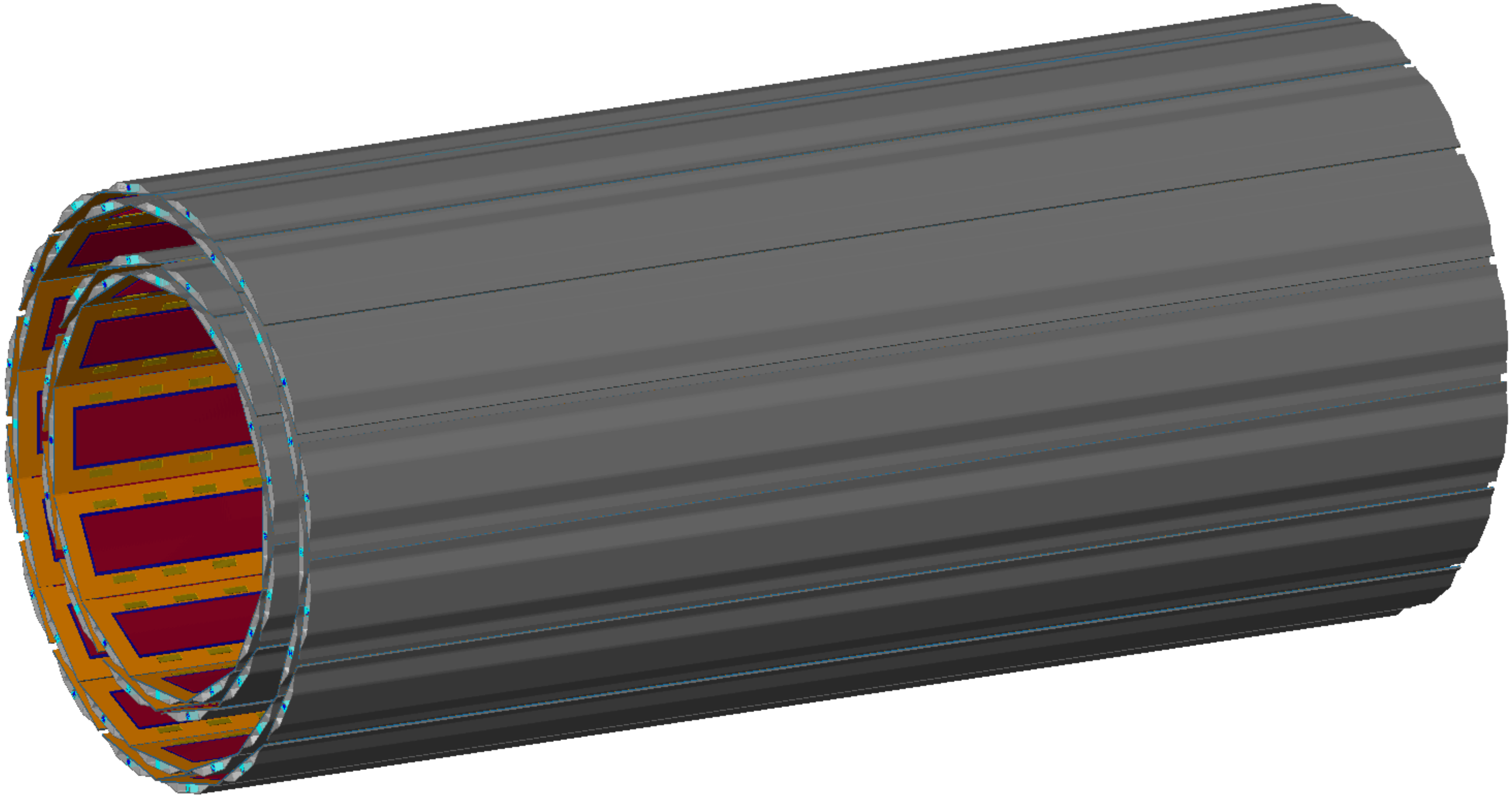
Total 0.3949

Dan Cacace

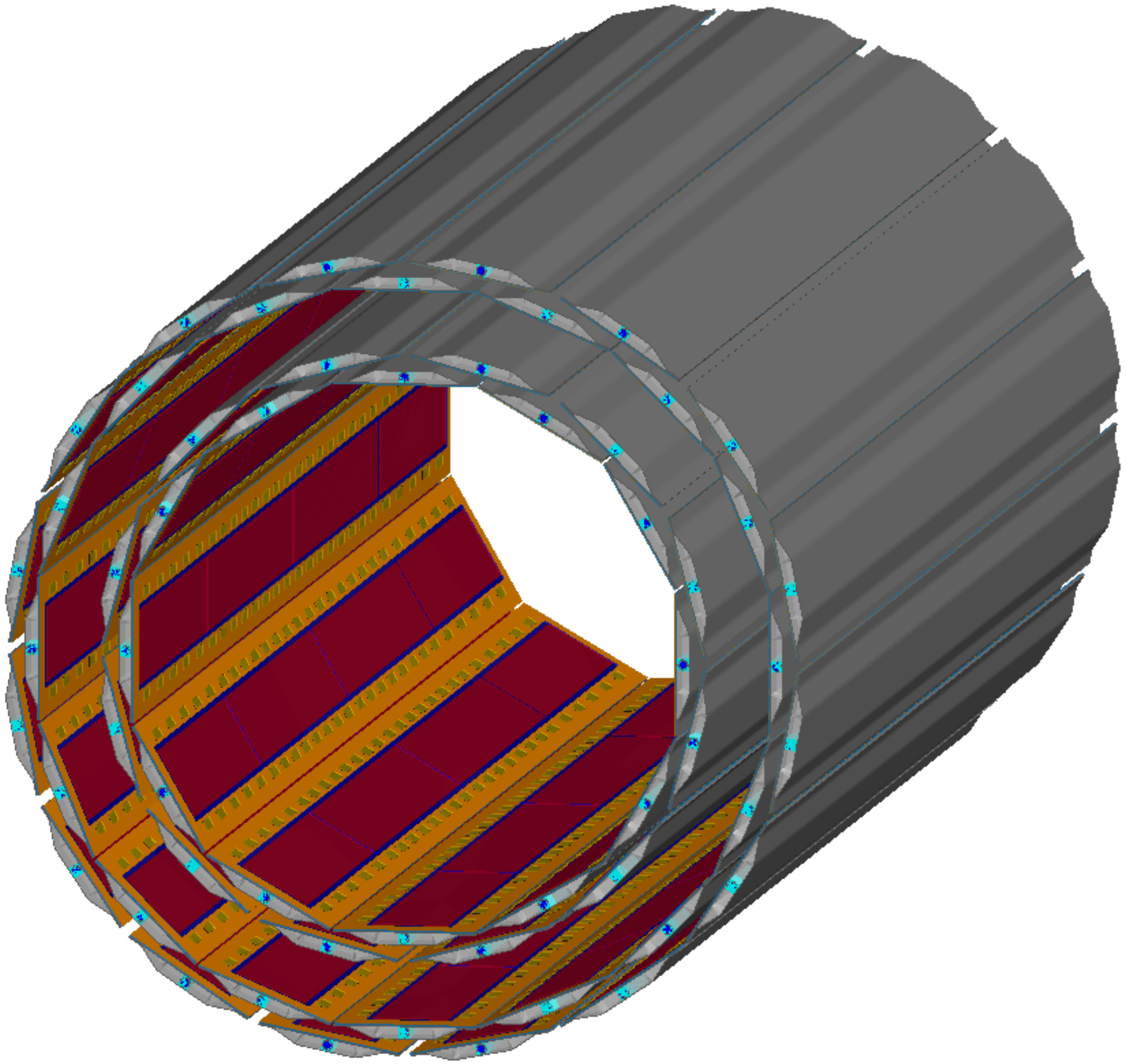
Gallery of the updated model

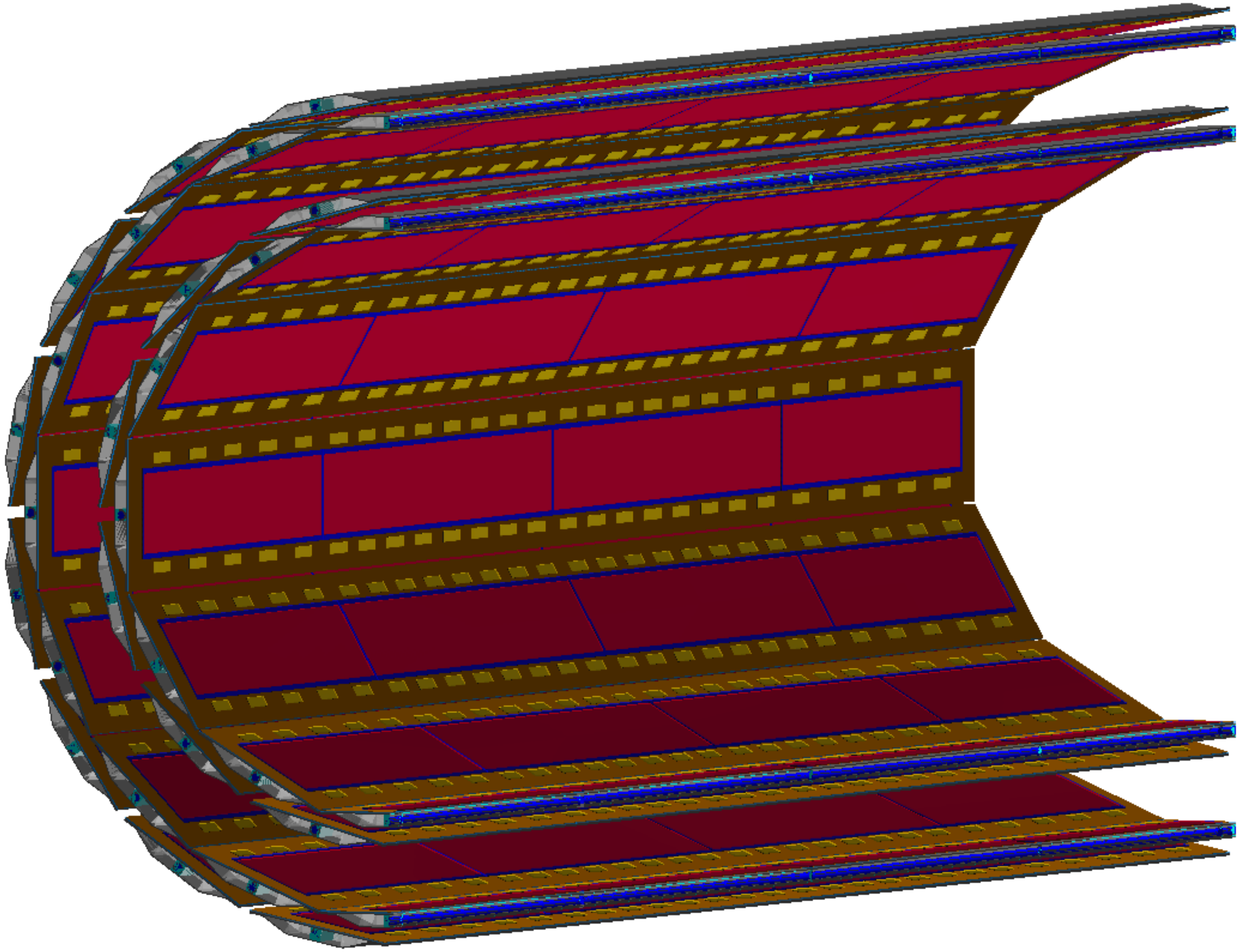


Gallery of the updated model

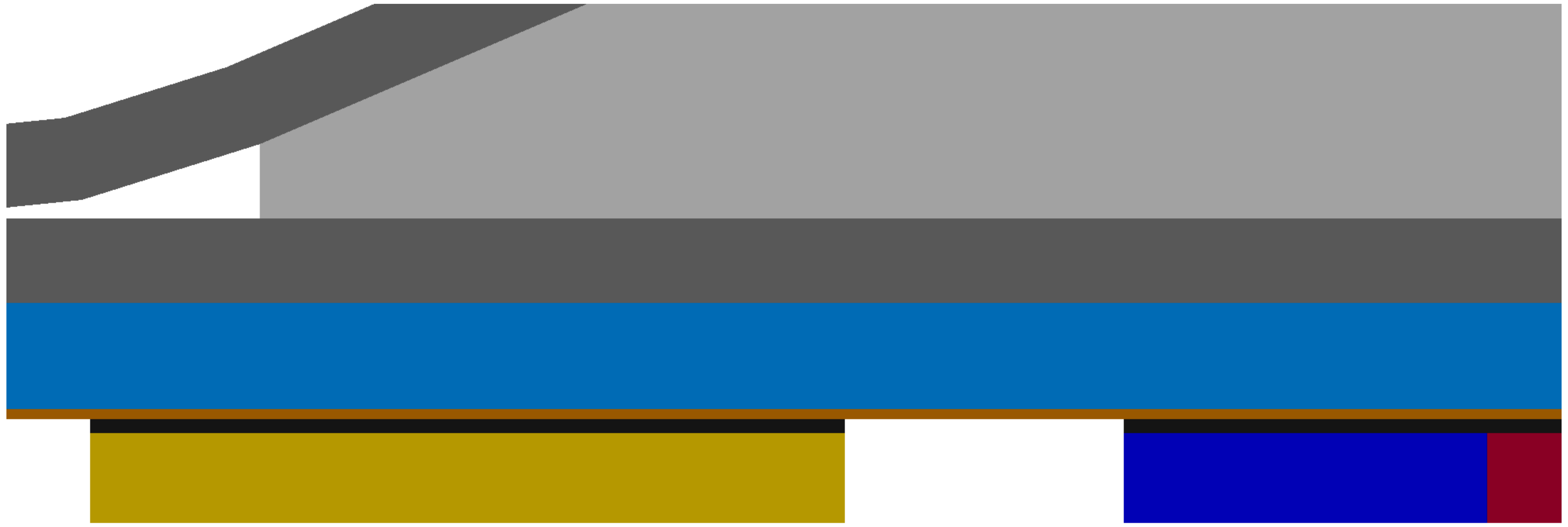


Gallery of the updated model

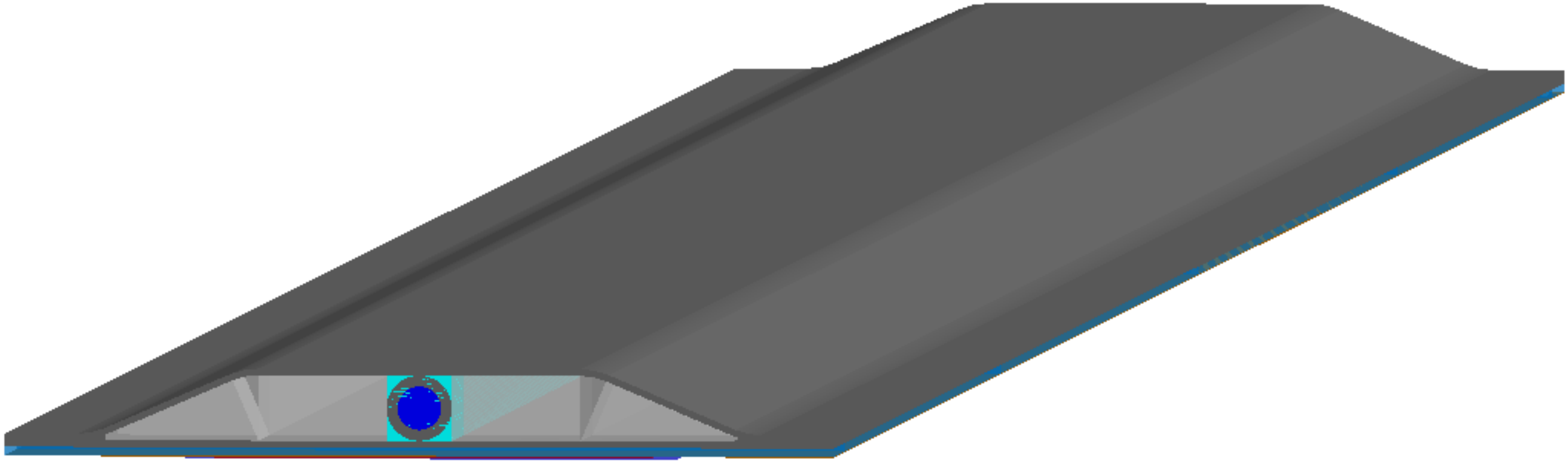




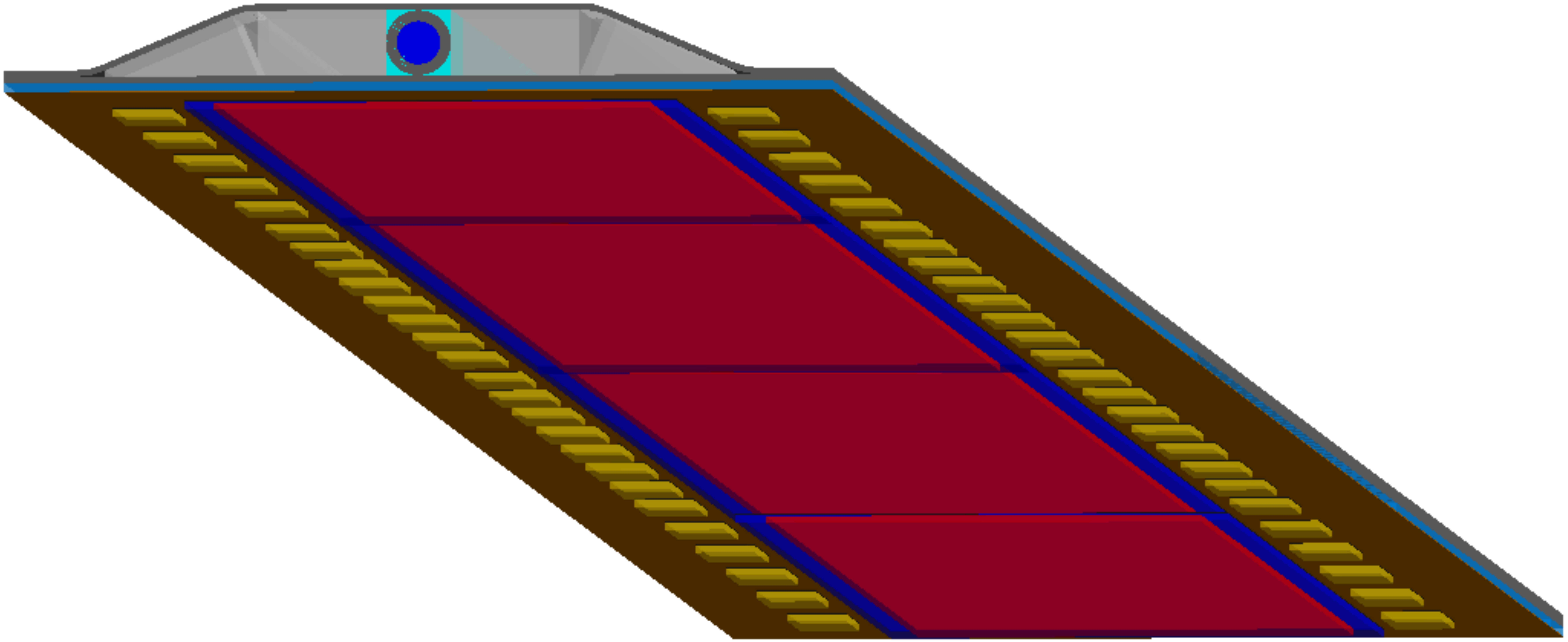
Gallery of the updated model



Gallery of the updated model



Gallery of the updated model



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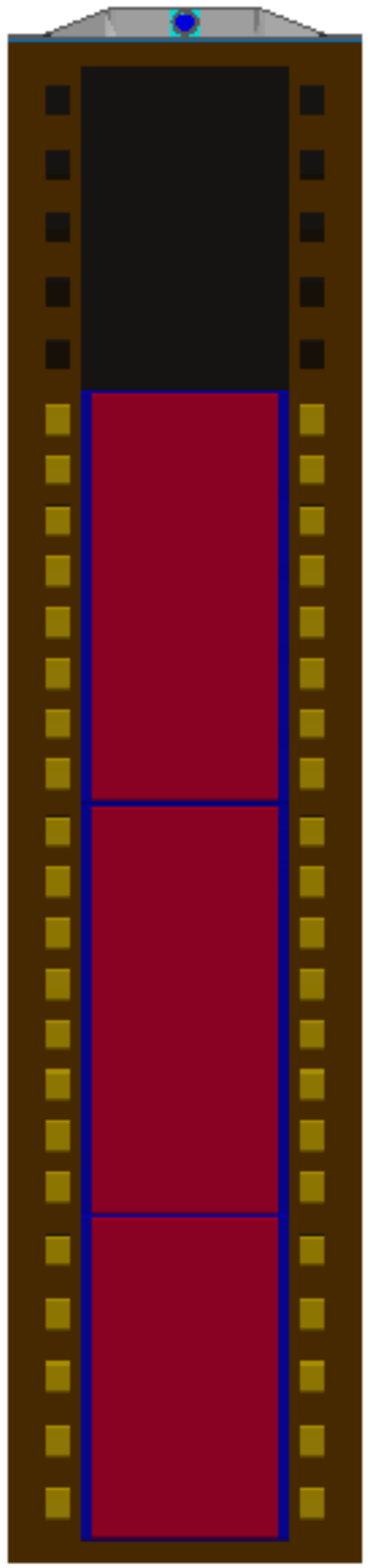
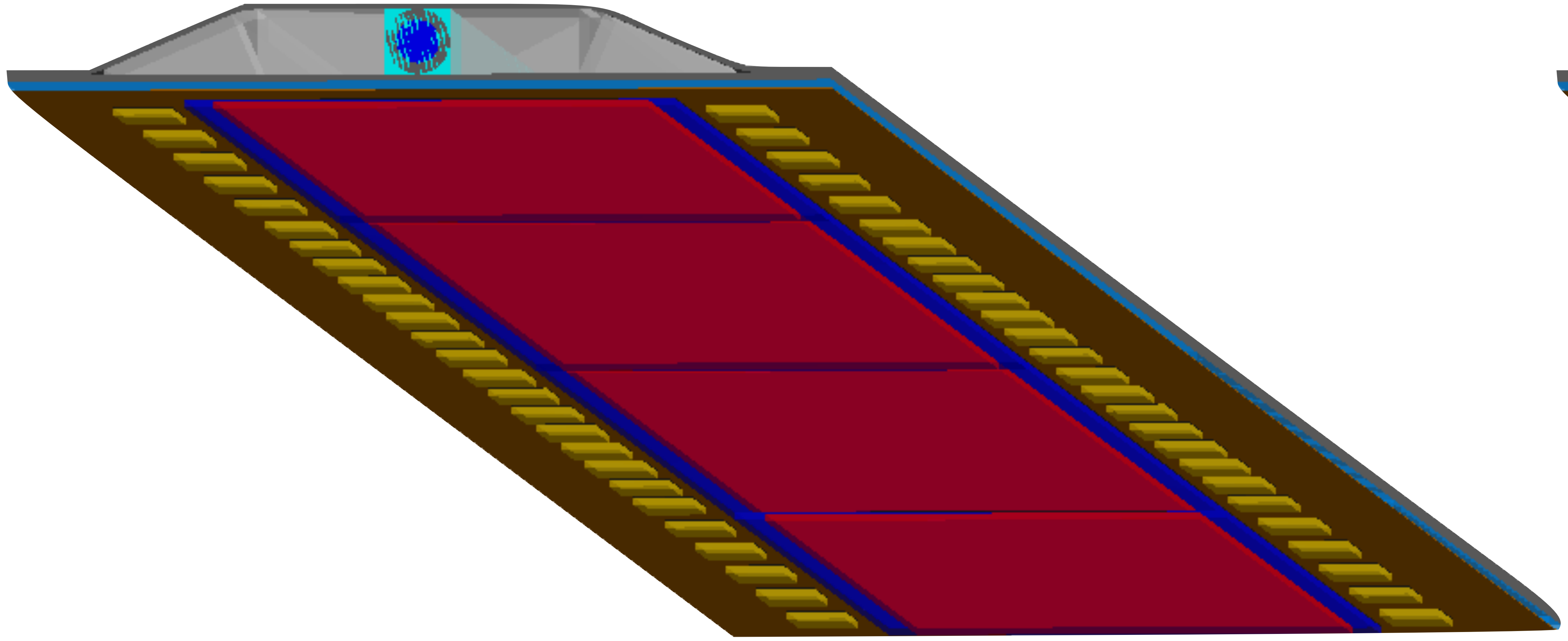
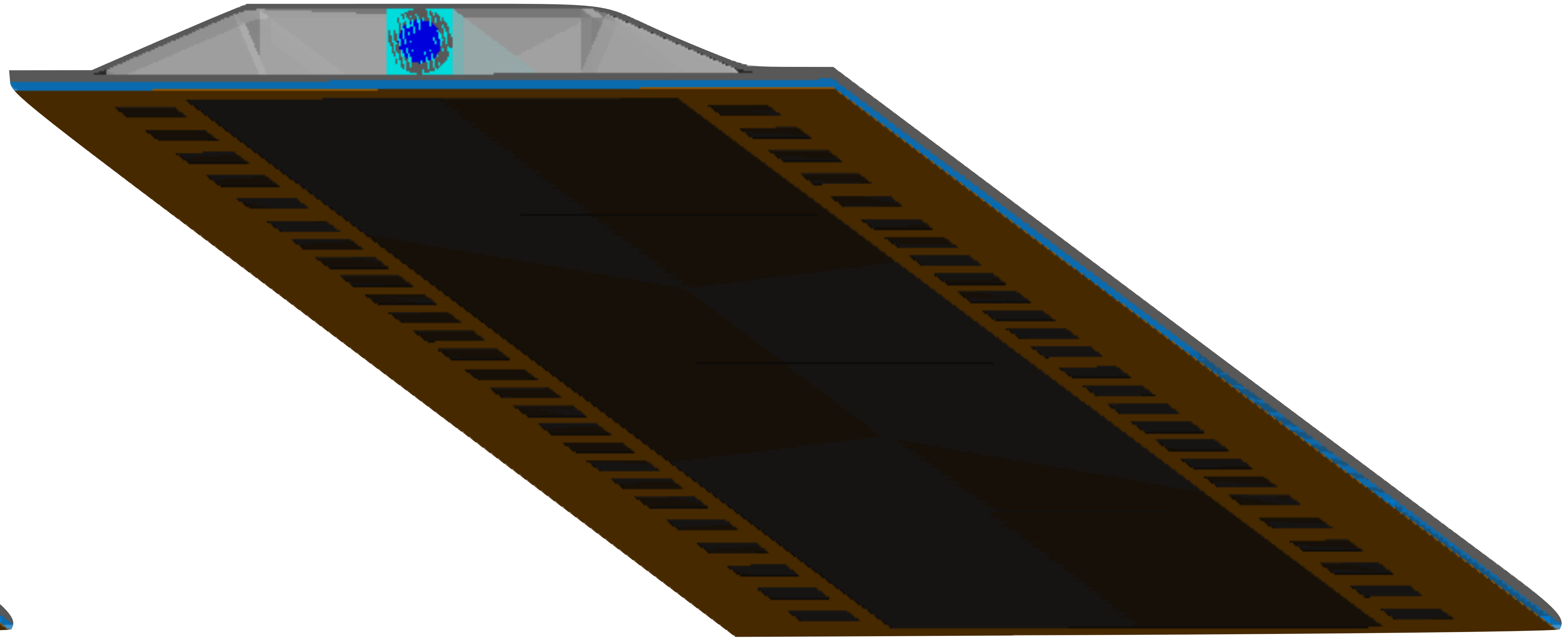


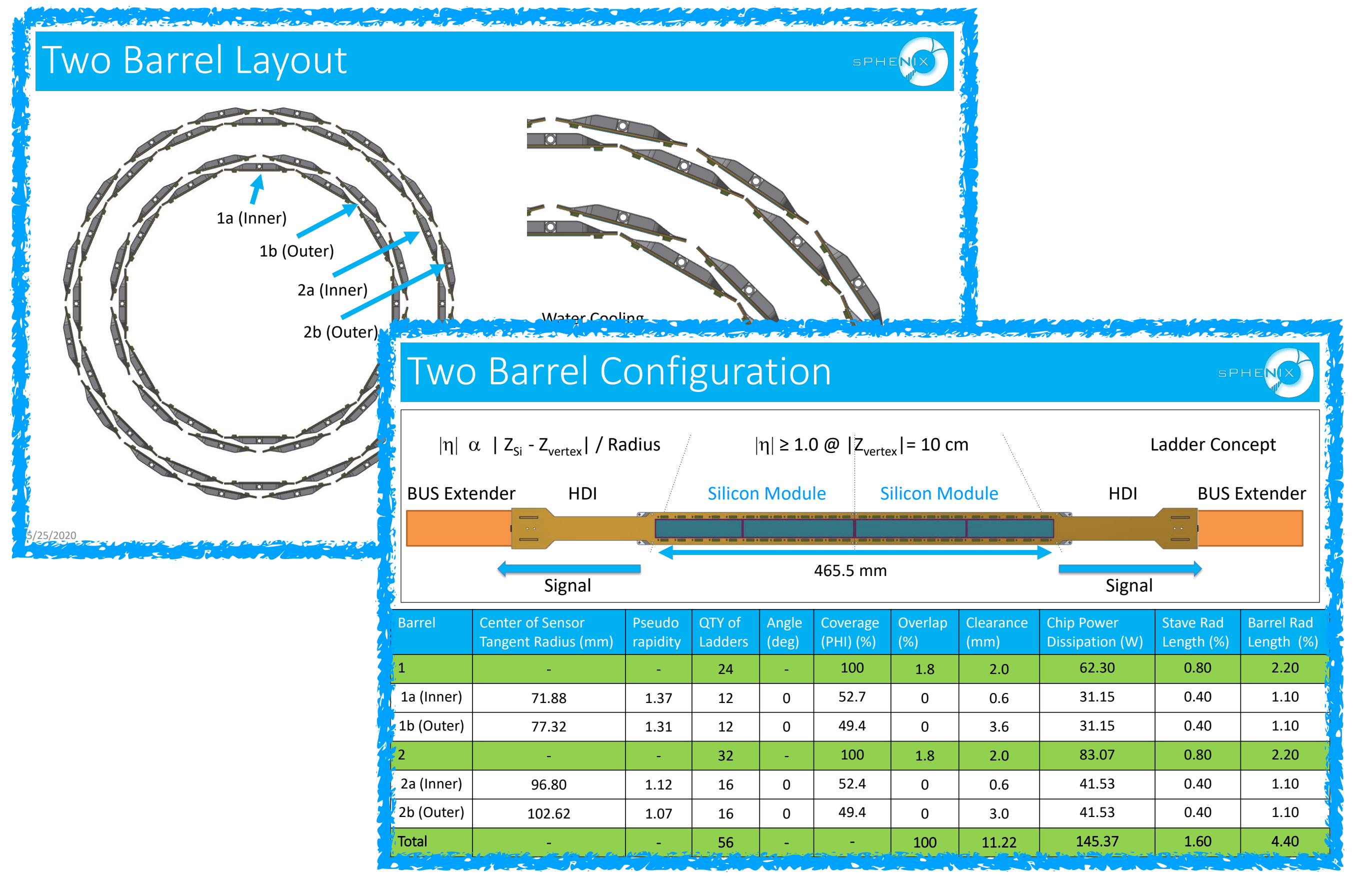
Gallery of the updated model



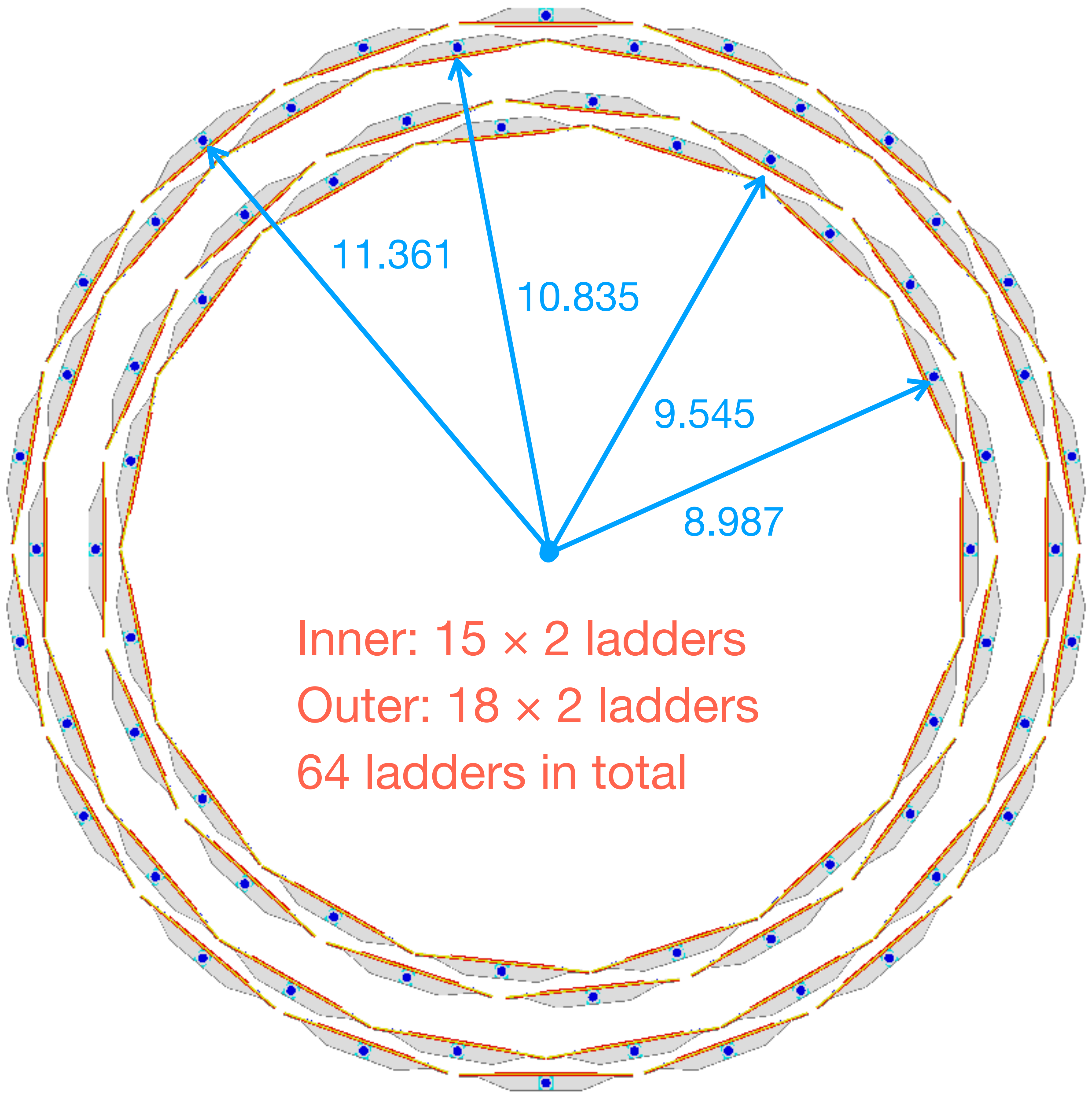


Layout updated

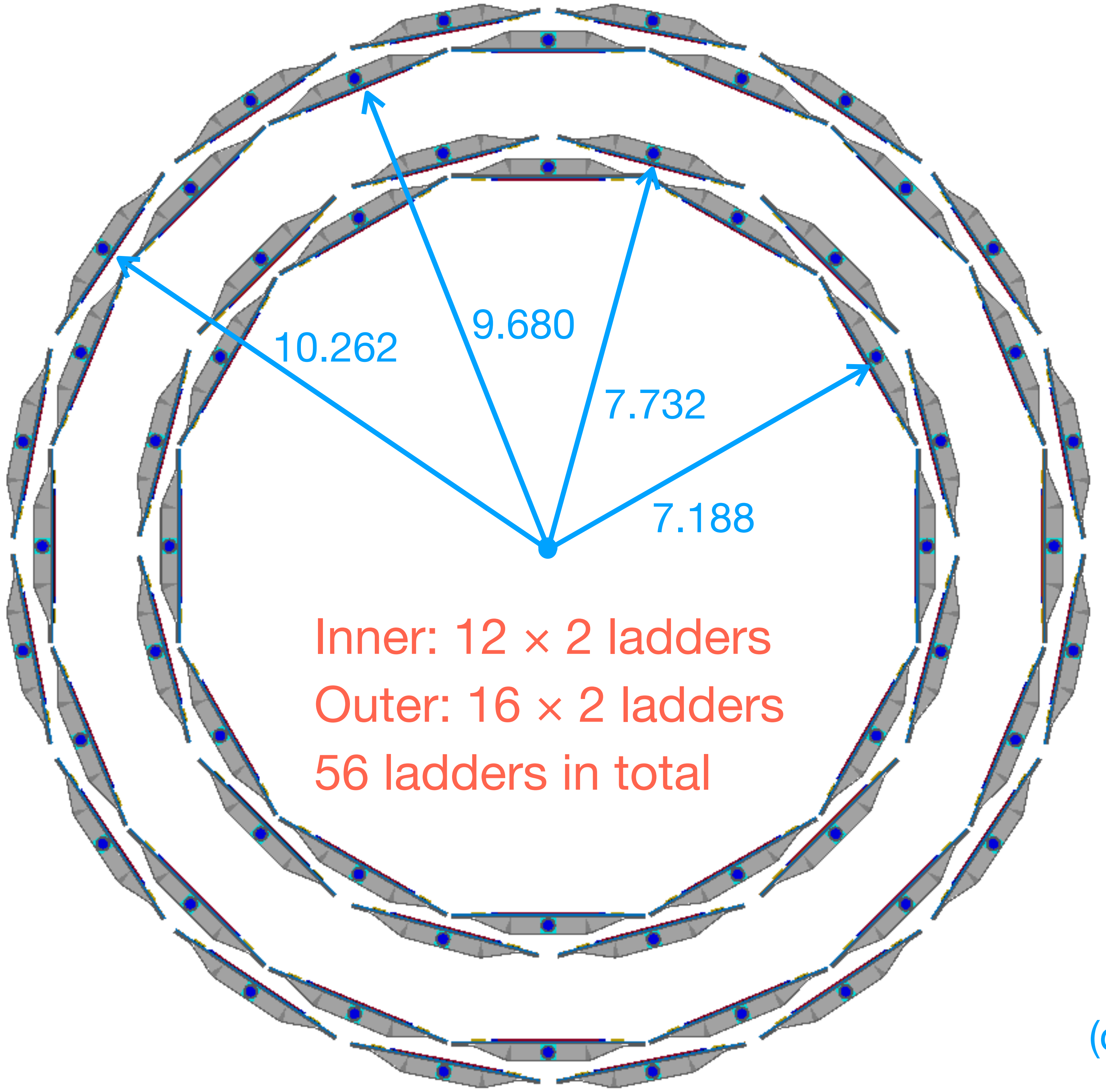
Dan provided the information!→



Barrel	Center of Sensor Tangent Radius (mm)	Pseudo rapidity	QTY of Ladders	Angle (deg)	Coverage (PHI) (%)	Overlap (%)	Clearance (mm)	Chip Power Dissipation (W)	Stave Rad Length (%)	Barrel Rad Length (%)
1	-	-	24	-	100	1.8	2.0	62.30	0.80	2.20
1a (Inner)	71.88	1.37	12	0	52.7	0	0.6	31.15	0.40	1.10
1b (Outer)	77.32	1.31	12	0	49.4	0	3.6	31.15	0.40	1.10
2	-	-	32	-	100	1.8	2.0	83.07	0.80	2.20
2a (Inner)	96.80	1.12	16	0	52.4	0	0.6	41.53	0.40	1.10
2b (Outer)	102.62	1.07	16	0	49.4	0	3.0	41.53	0.40	1.10
Total	-	-	56	-	-	100	11.22	145.37	1.60	4.40



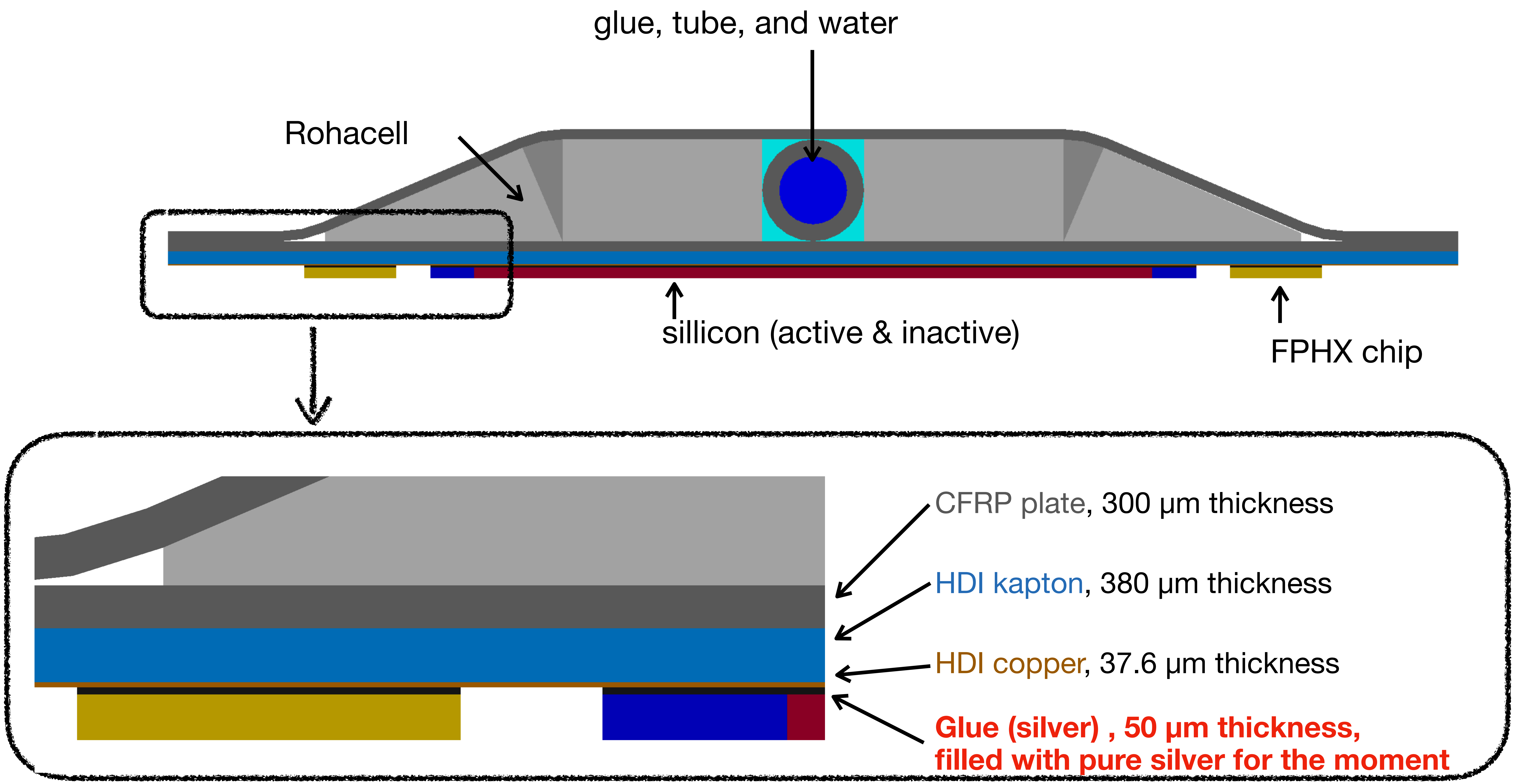
Model in the current repository



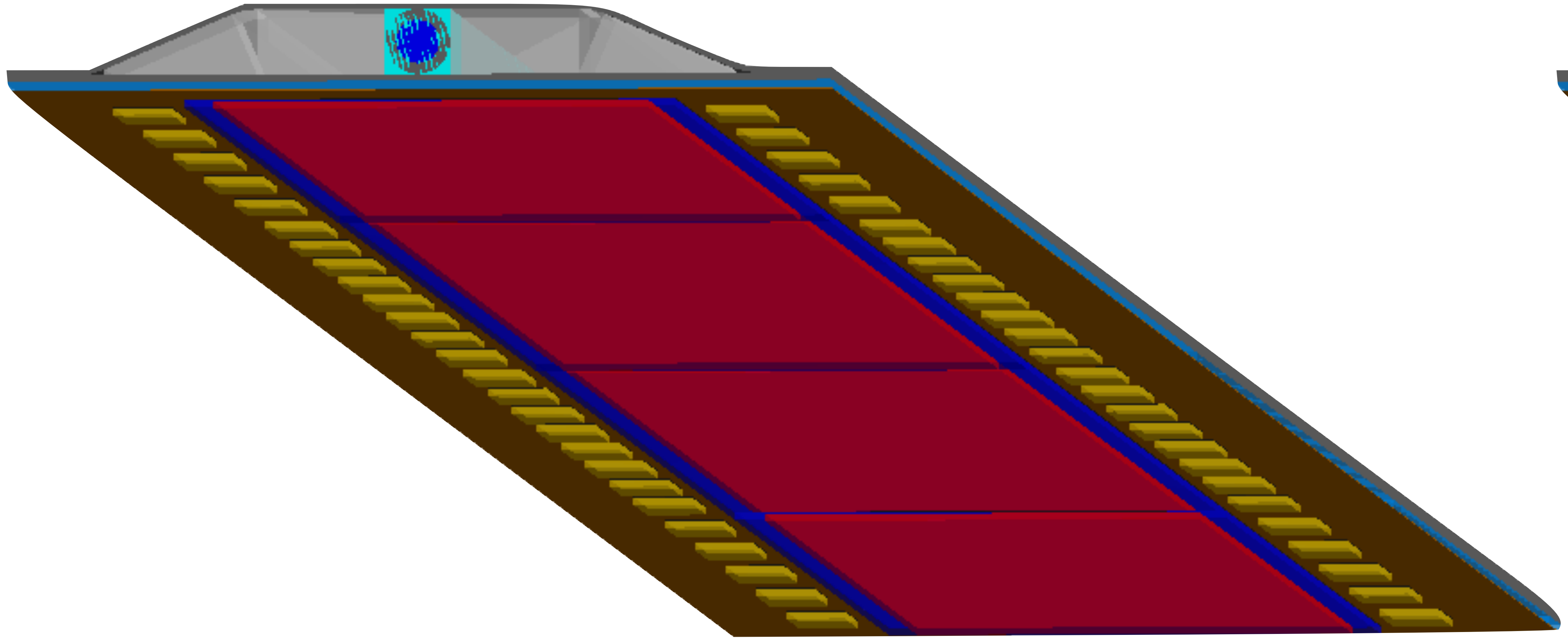
(cm)

Updated model

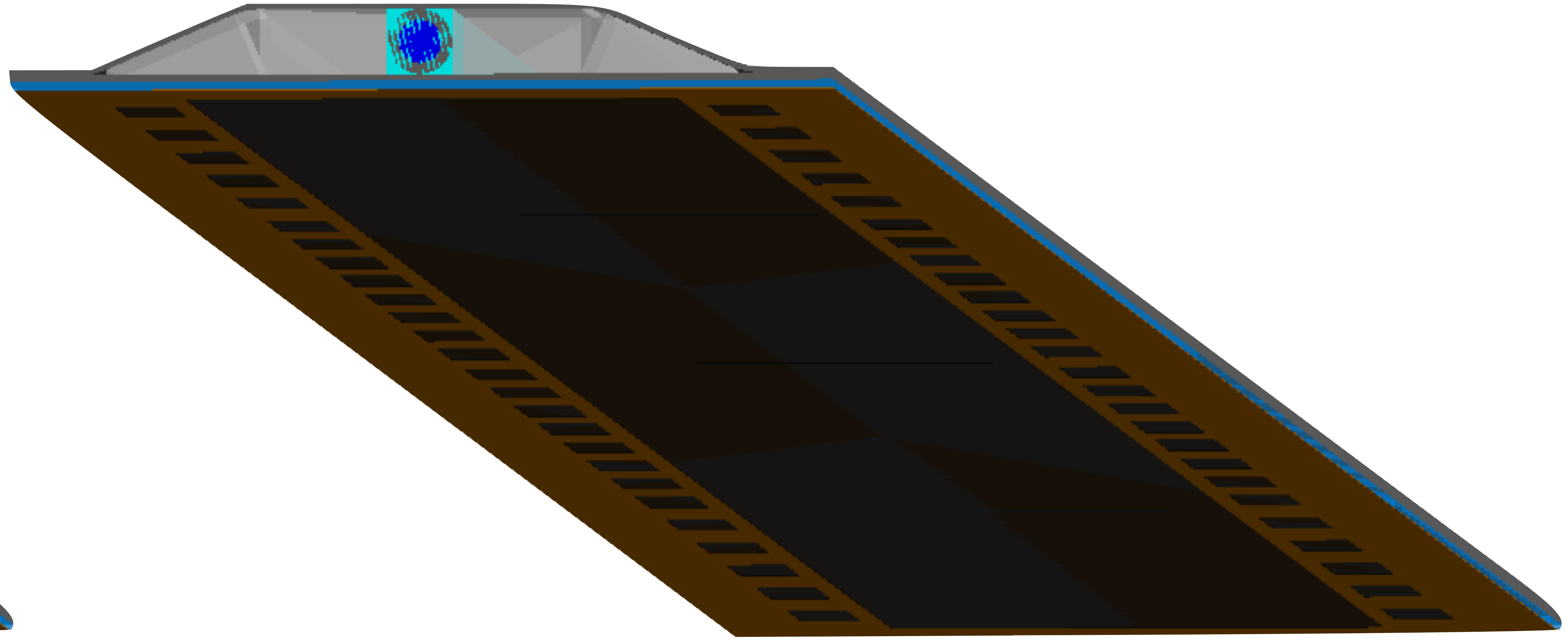
Geometry of a ladder



Geometry of a ladder



View from bottom

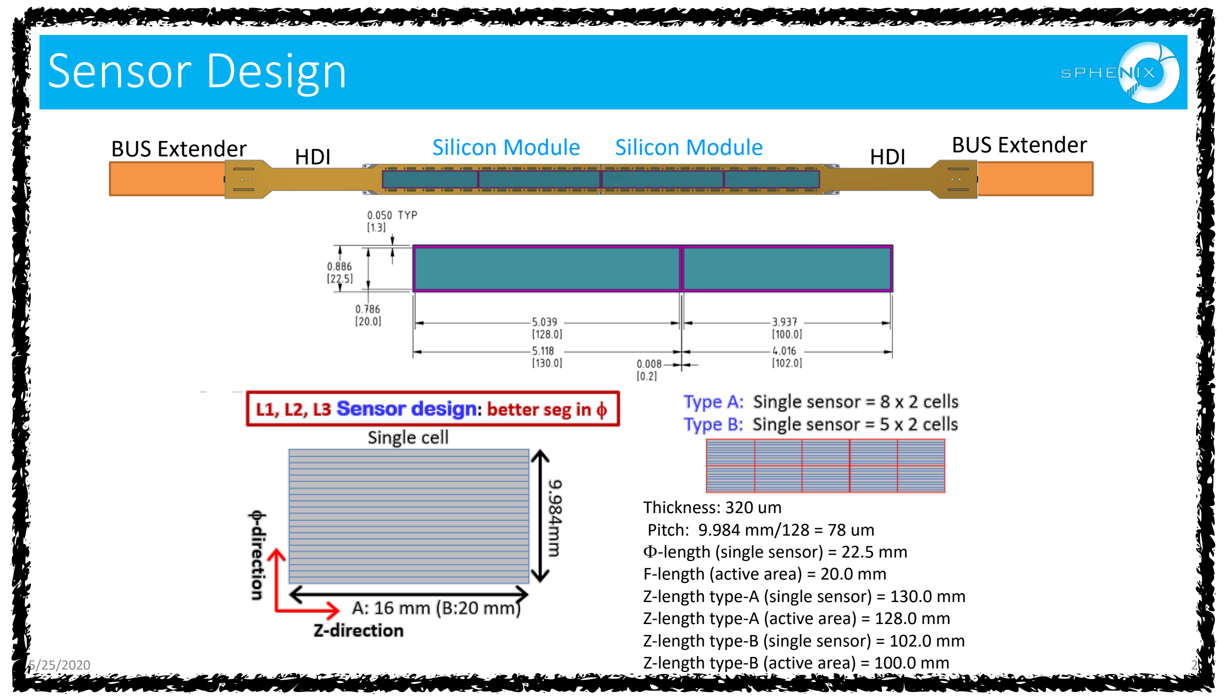


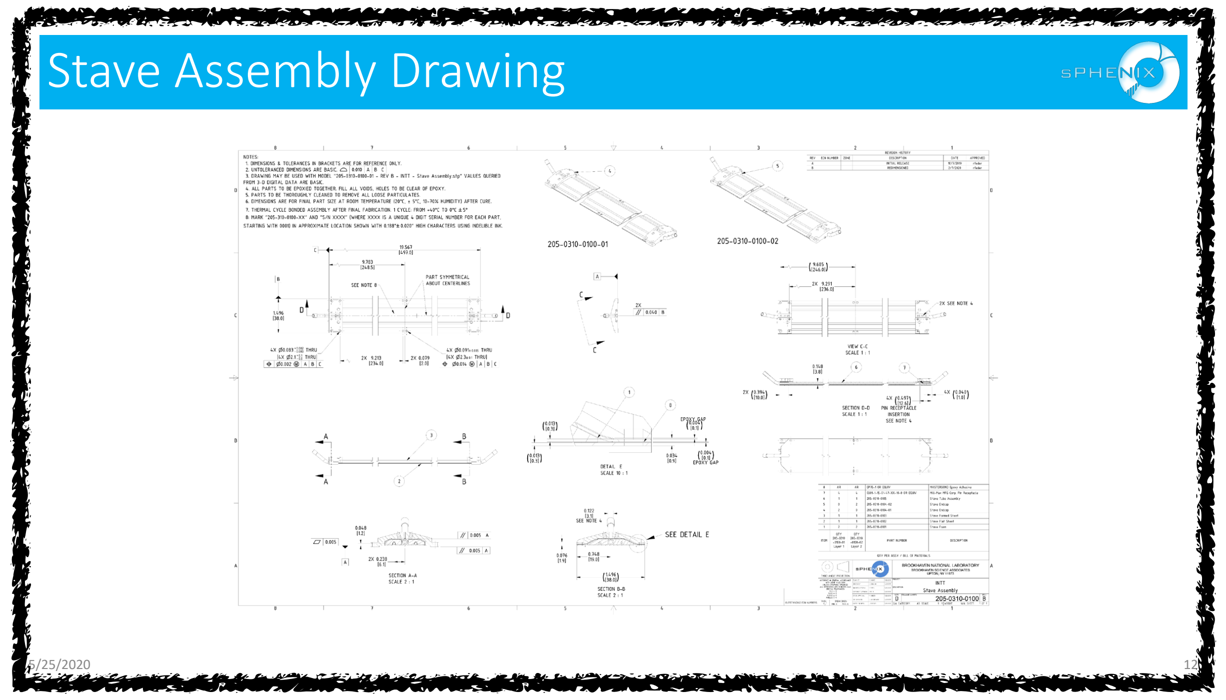
Sillicon sensors and
FPHX chips removed

Size of glue is exactly the same as sillicon's and chips'.

Geometry of a ladder, dimension

No major discrepancy was found in the Geant4 codes for the moment although I need to take more time to understand Dan’s drawing.





Dan provided the information!

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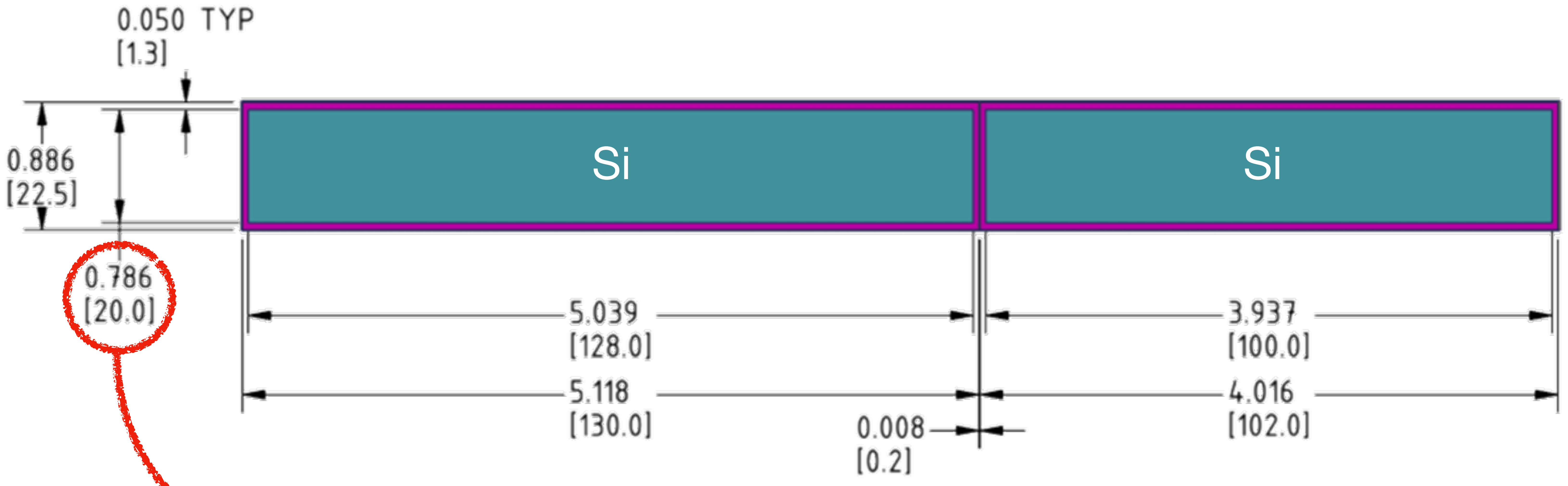
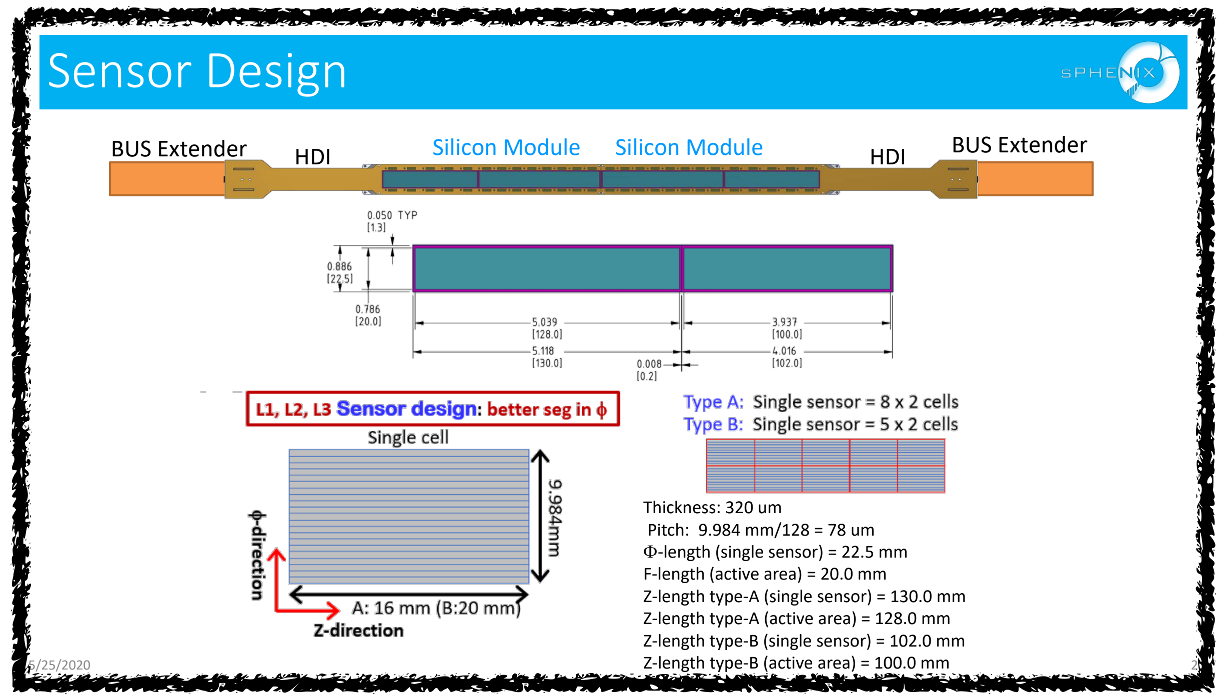
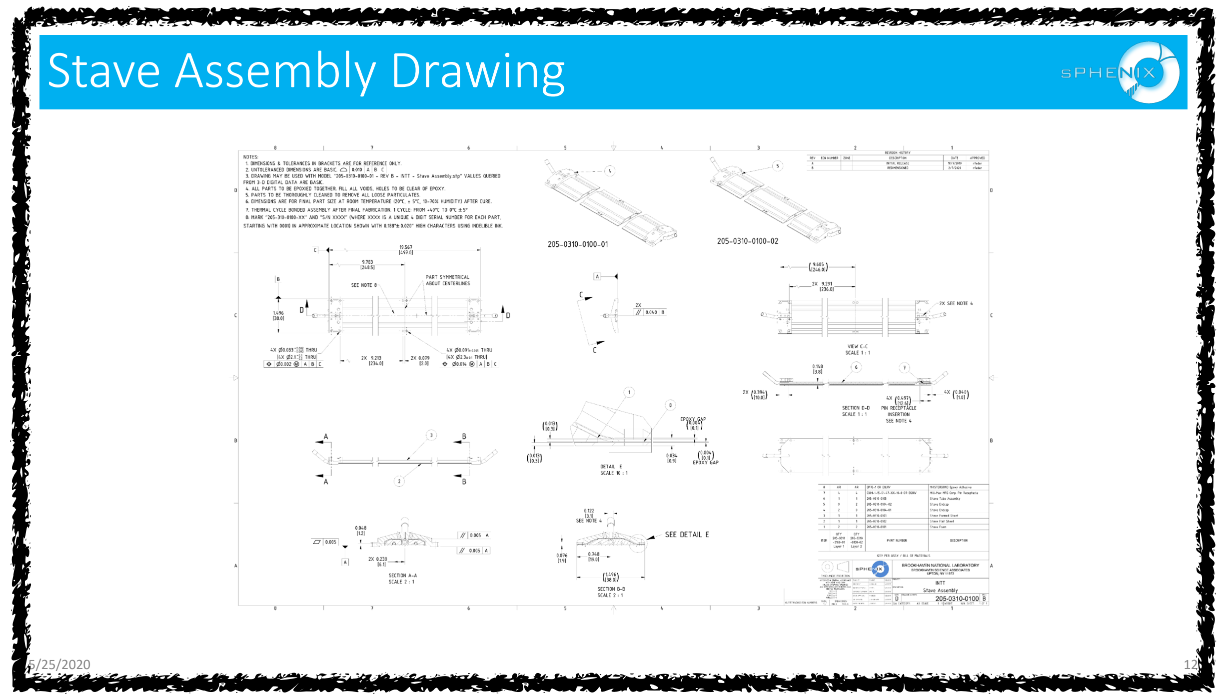
Minor difference I found:



(mm)

Width of the silicone sensor in Geant: 0.0078 × 256 = 1.9968 cm





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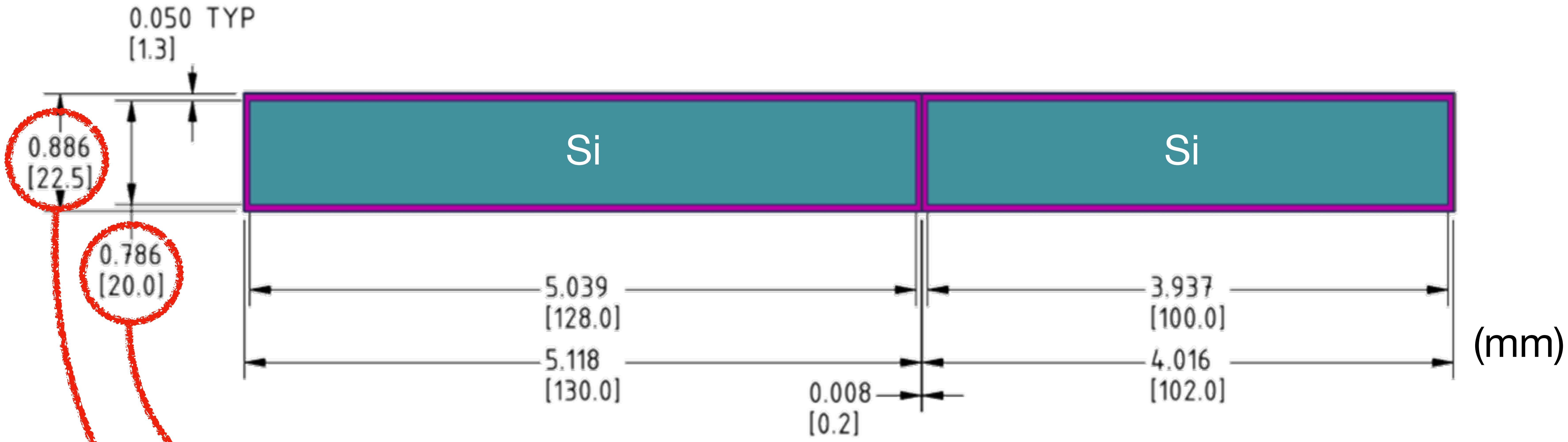
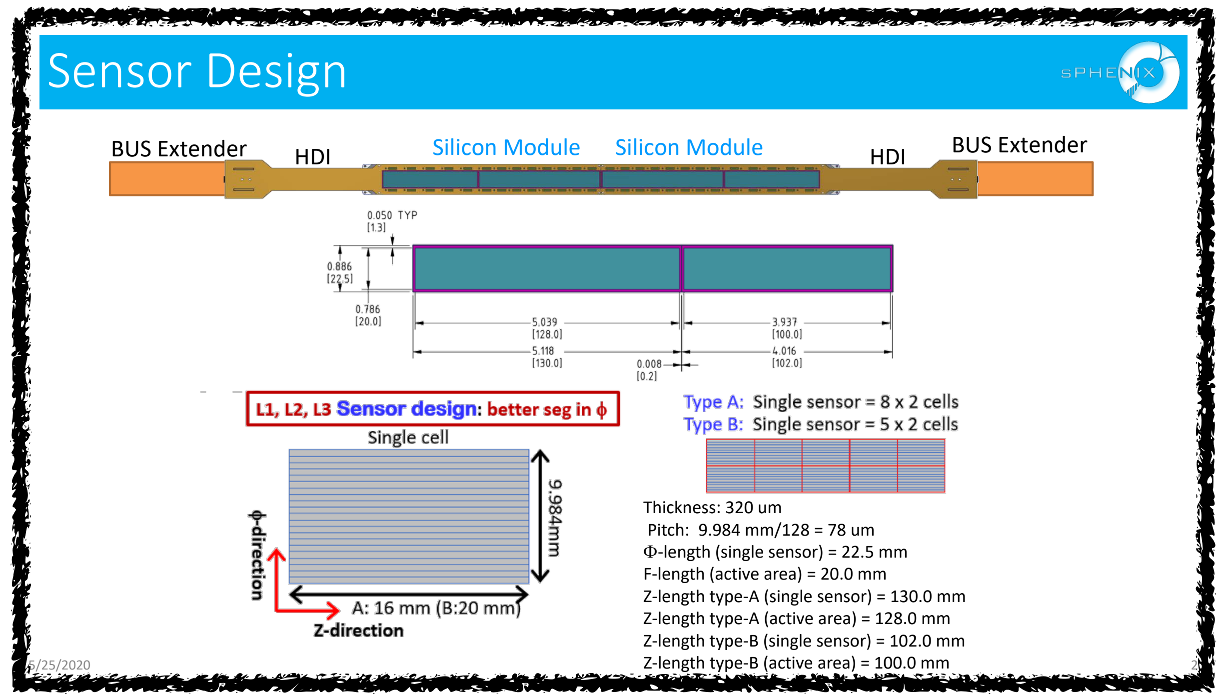
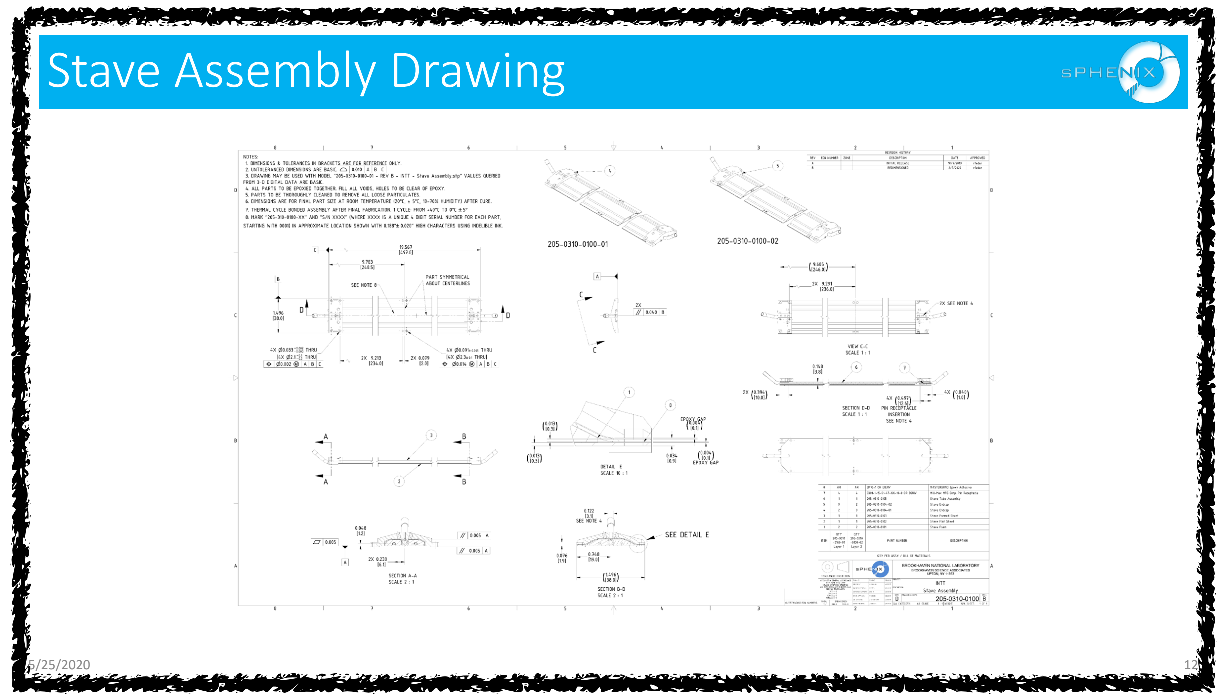


Width of the silicone sensor in Geant: 0.0078 × 256 = 1.9968 cm

Width of the silicone in Geant: 1.9968 + 2 × 0.13 = 2.2568 cm





Dan provided the information!

Ag, X_0 = 8.543 mm, 10.5 um, X/X_0 = 0.123%

Epoxy, X_0 = 299 mm, 39.5 um, X/X_0 = 0.013%

Radiation length in a composite material : $$\frac{W}{X_0} = \sum \frac{W_i}{X_{0,i}}$$ where $w_{(i)}$ is the total mass of the sample in g and $X_{0(,i)}$ is radiation length in g/cm^2

$$\frac{W_{Ag}}{X_{0,Ag}} = \frac{10.5(g/cc) \times 10.5(\mu m)}{8.97(g/cm^2)} = 0.00123$$

$$\frac{W_{Epoxy}}{X_{0,Epoxy}} = \frac{0.125(g/cc) \times 39.5(\mu m)}{298.7(mm) \times 0.125(g/cc)} = 0.00132$$

$$X_0 = W/\left(\frac{W_{Epoxy}}{X_{0,Epoxy}} + \frac{W_{Ag}}{X_{0,Ag}}\right) = \frac{3.2(g/cc) \times 50\mu m}{0.00123 + 0.00132} = 1.96cm$$

Is it correct? (this calcuration was done just before 10min from the talk, so there may be some mistakes………)