Investigation of Geometry Modeling Method for ATLAS Simulation

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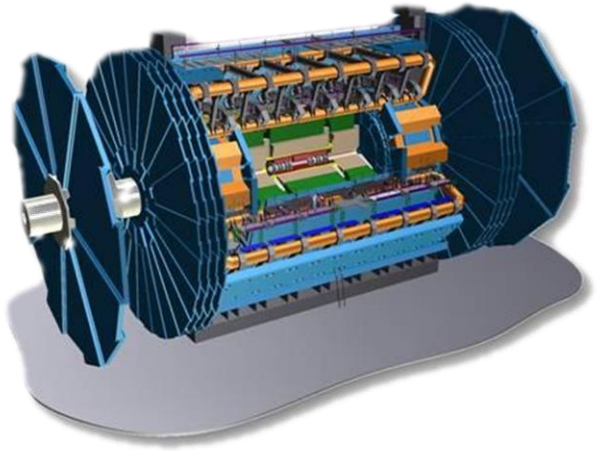
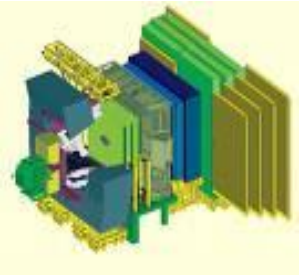
LHC Machine at CERN



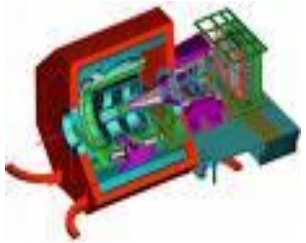
ATLAS Detector

length ~40 m,
height ~22 m,
weight ~7’000 tones

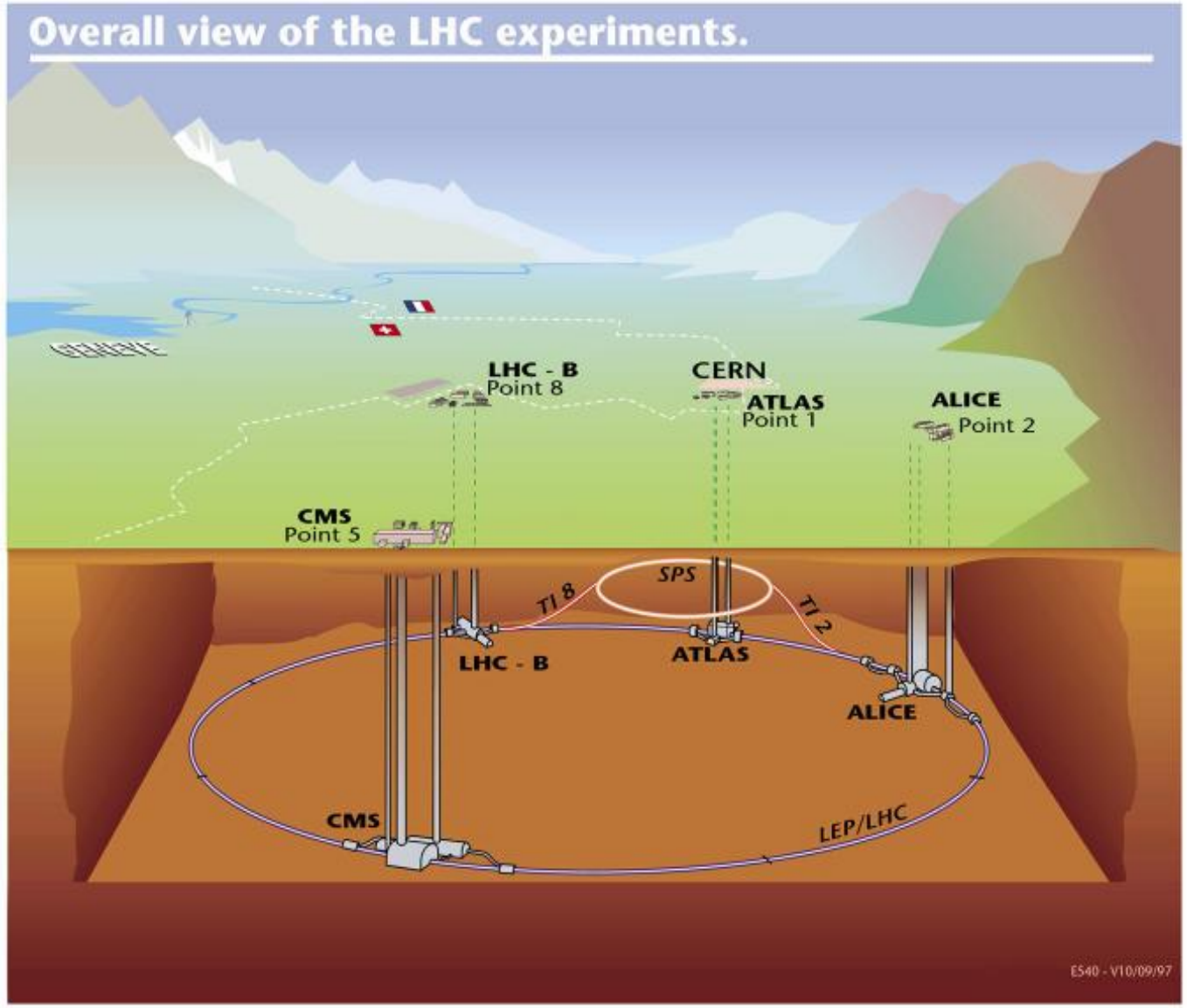
CMS Detector



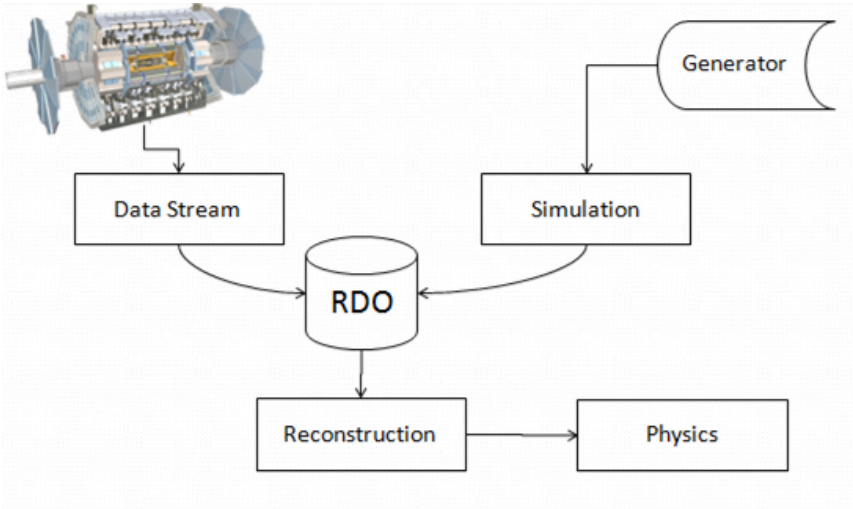
ALICE Detector



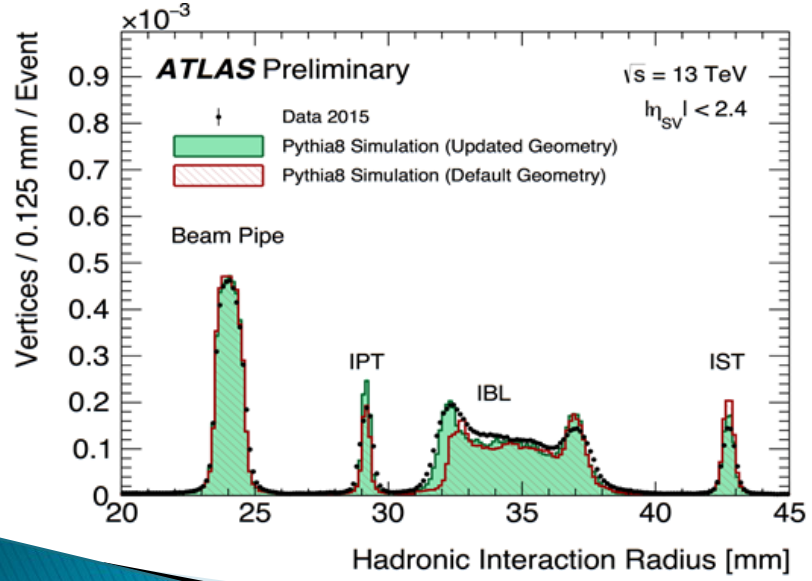
LHCB Detector



Research Hypothesis



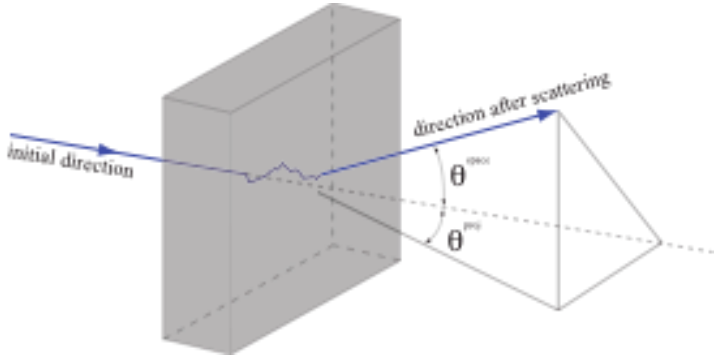
- Several reasons can cause discrepancies between Data and Monte-Carlo. Several investigations show that they are coming by the reason of geometry descriptions in simulation
- It is possible to predict 2 hypothesis why faults are exist in geometry descriptions:

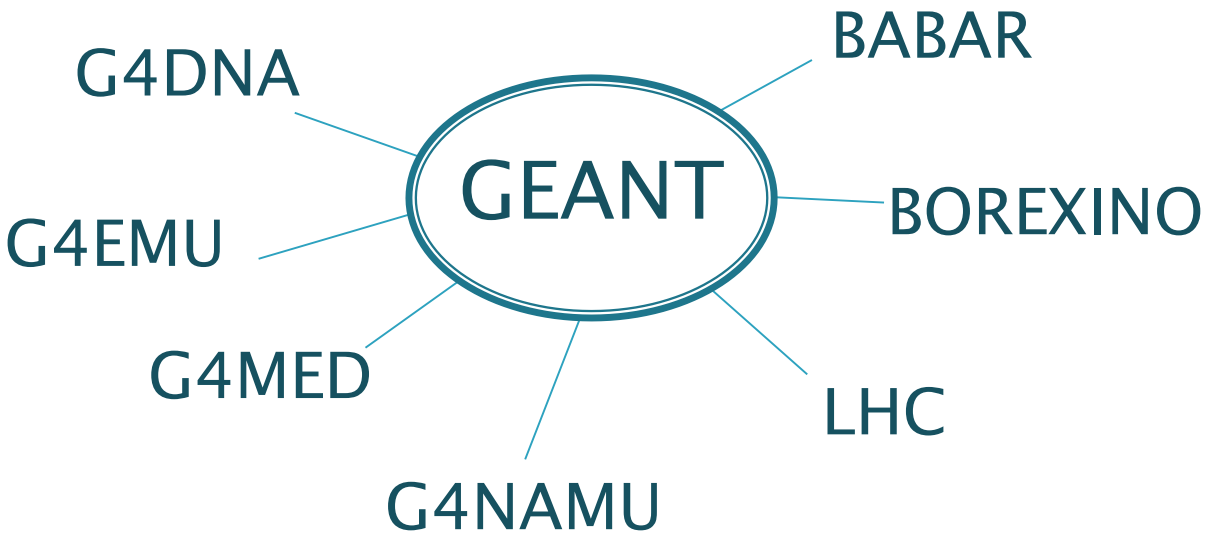


1. Hypothesis #01: Inaccuracies added by geometry transactions within the simulation software infrastructure
2. Hypothesis #02: Discrepancies between the design and the geometry implementation inside the simulation

Geant4 Toolkit

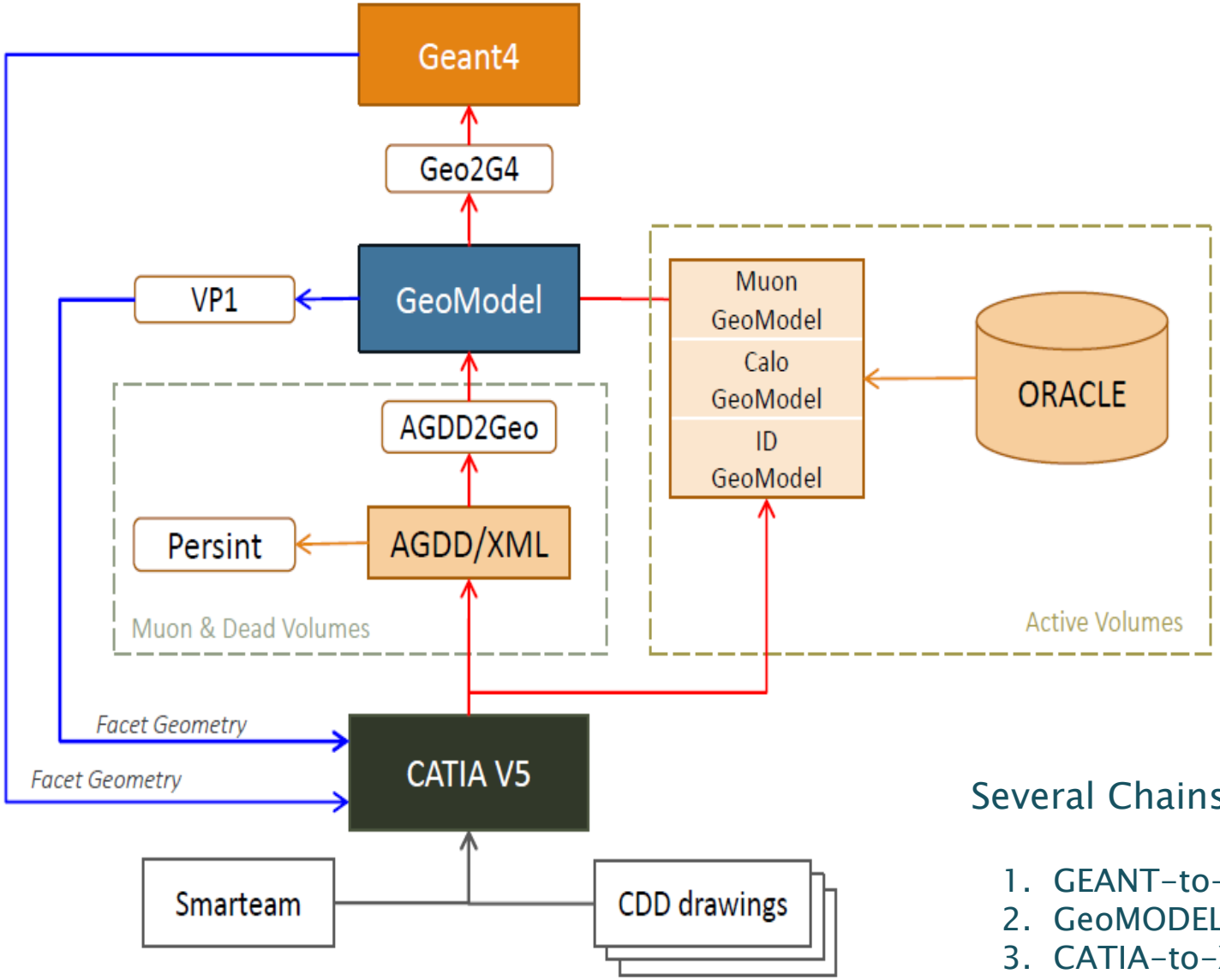
- GEANT4 is a platform for simulation of facilities and physical events by modelling of the passage of particles through the matter
- GEANT4 implementing in High Energy, nuclear and Accelerator physics as well for studies in medical and in space science





4

Geometry Simulation Loop



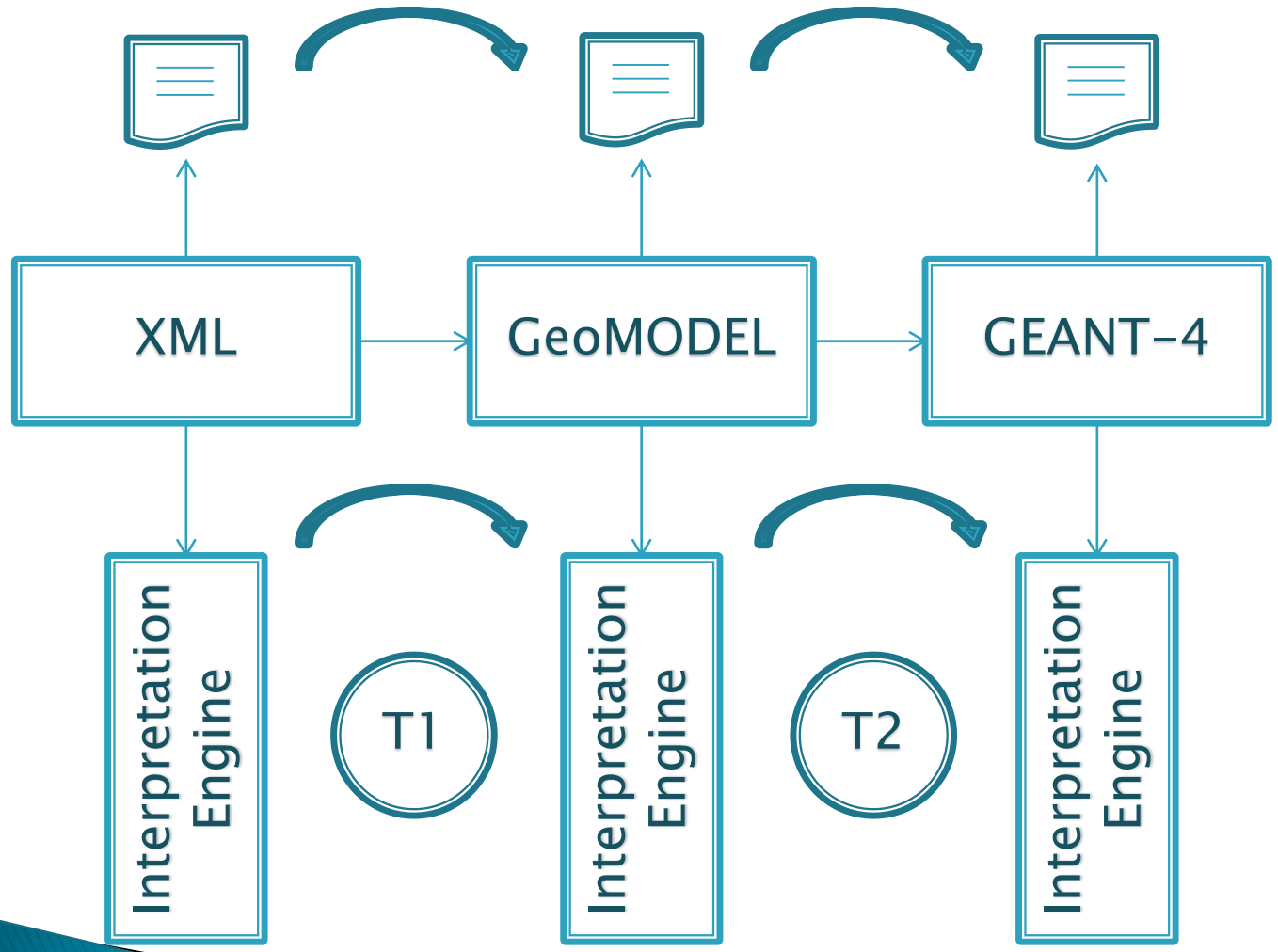
Several Chains have been developed:

1. GEANT-to-CATIA
2. GeoMODEL-to-CATIA
3. CATIA-to-XML
4. CATIA-to-GeoMODEL

Checking Hypothesis 01:

Investigation of Simulation Infrastructure

Objectives of Analyses



1. Categorization of geometry of Detector components
2. Selection Methods for description
3. Test runs of test examples
4. Case study of transactions
5. Systematization and learning of results

I. Categorization of Geometry

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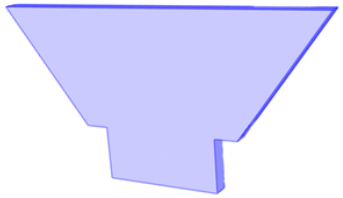
Geometric Primitives

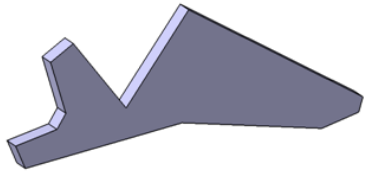
- ✓ Shapes without cuts
- ✓ Both regular/irregular shapes
- ✓ Both convex/concave shapes

22 typical primitives have been separated

Octagonal Prism



Dodecagonal Prism

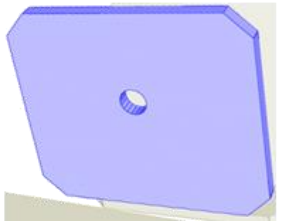


Combined Objects

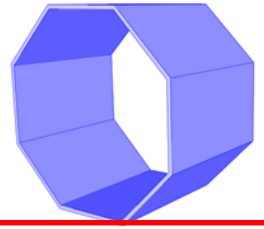
- ✓ Grouping components with cuts

33 combined objects have been separated

Octagonal Prism with cut



Octagonal prism with cut

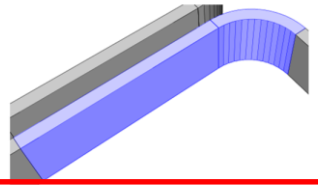


Typical Joining

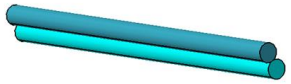
- ✓ Grouping components with typical joining's

29 combined objects with typical joining's have been separated

Cube and Tube Joining



Tubes Joining



I. Categorization of Geometry

1st class	Geometric Primitives		22	Total: 84
2nd class	Combined Object		33	
3rd class	Typical Joining		29	

Conclusion: ATLAS detector geometry can be described by 84 typical representors of class of objects

II. Selection of Methods for Description

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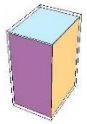
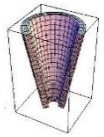
Geant4

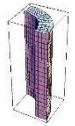
Box



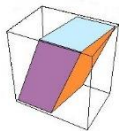
Cone
Conical Section



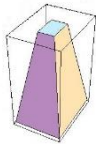
Cylindrical
Section or Tube



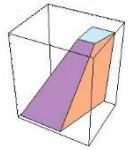
Parallelepiped



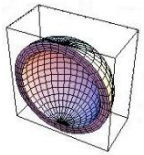
Trapezoid



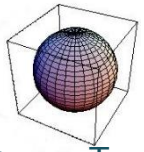
Generic
Trapezoid



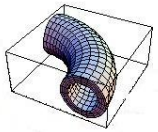
Sphere, or a Spherical
Shell Section



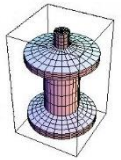
Solid Sphere



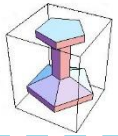
Torus



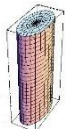
Polycons



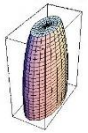
Polyhedra



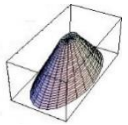
Tube With an
Elliptical Cross Section



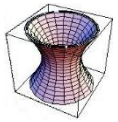
Ellipsoid



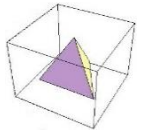
Cone With an
Elliptical Cross Section



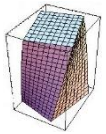
Tube With a
Hyperbolic Profile



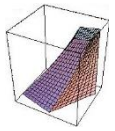
Tetrahedra



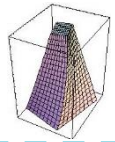
Box
Twisted



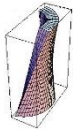
Trapezoid
Twisted



Twisted
Trapezoid

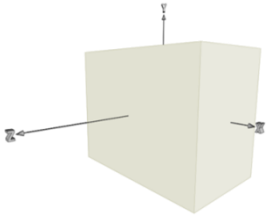


Tube Section
Twisted

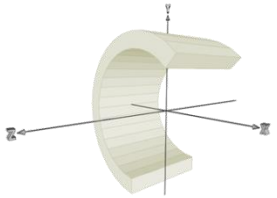


AGDD/XML

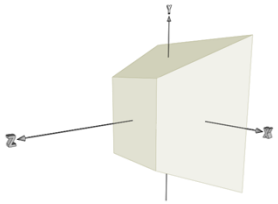
Cube



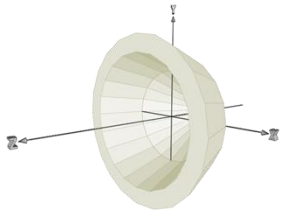
Tube



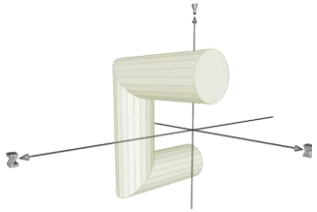
Pyramid



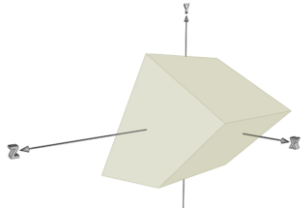
Cylinder



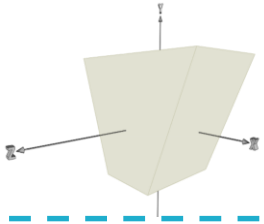
chain



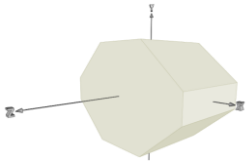
Arbitrary



Symmetric

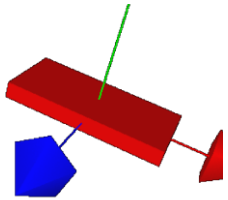


Double
Symmetric

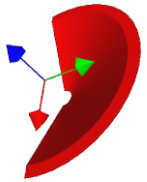


GeoModel

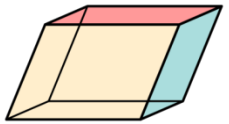
Box



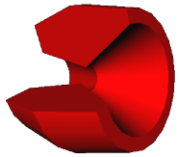
Cone



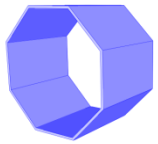
Parallelepiped



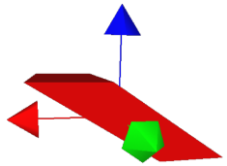
Polycone



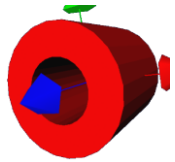
Polygon



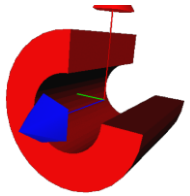
Trapezoid
(Complex)



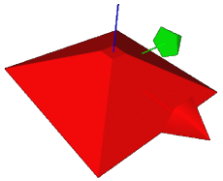
Tube



Tube Section

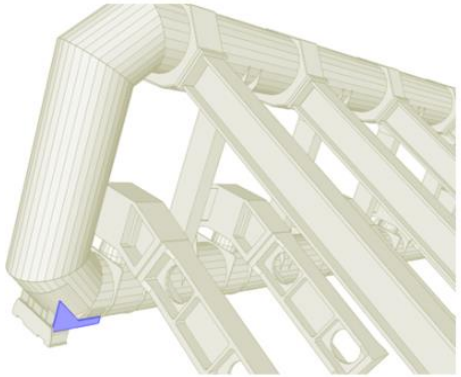


Trapezoid
(Simple)



II. Selection of Methods for Description

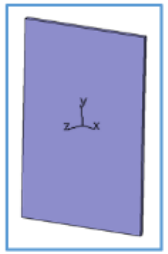
Pentagonal Prism



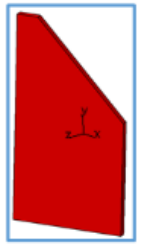
Method 01

	Cube
	Arbitrary
T1	Subtraction
T2	Move
T3	Rotation

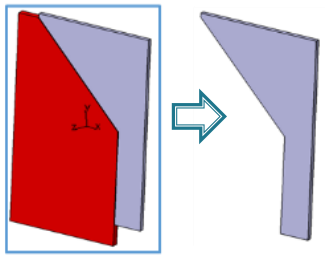
I. | Cube



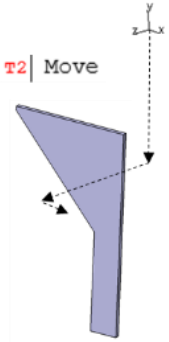
II. | Arbitrary



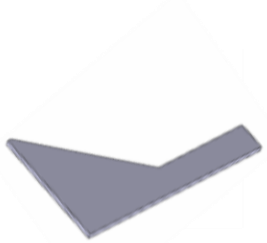
III. T1| Subtraction



IV. T2| Move



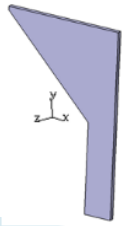
V. T3| Rotation



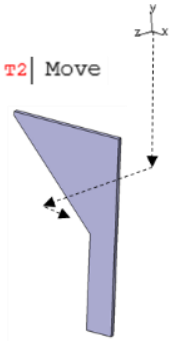
Method 02

	Arbitrary
T1	Move
T2	Rotation

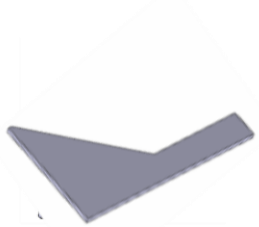
I. |Arbitrary



II. T2| Move



III. T3| Rotation



II. Selection of Methods for Description

Finally, for all above selected typical representatives of object classes of ATLAS detector, full set of possible methods of description were selected:

1st class of 22 objects:	4’460 methods
2nd class of 33 objects:	6’579 methods
3rd class of 29 objects:	4’636 methods

Total: **15’675** methods

II. Selection of Methods for Description

Criteria #01: *Arbitrary_polygon* method should be separated as a standalone method, while

1. Geometry description requires minimal number of Boolean operations and Move/Rotation transactions
2. Geometry can be described directly in position by only Z axis displacement and Z axis rotation.

Example: Descriptions of Octadecagonal Prism

I.

```
Arbitrary
Move (Z)
Rotation
```

II.

```
Cube
Arbitrary
Subtraction
Move
rotation
```

III.

```
Cube
Pyramid
Move
Subtraction
Cube
Move
Subtraction
Cube
Move
Cube
Move
Cube
Move
Cube
Pyramid
Move
Subtraction
Union
Move
Rotation
```

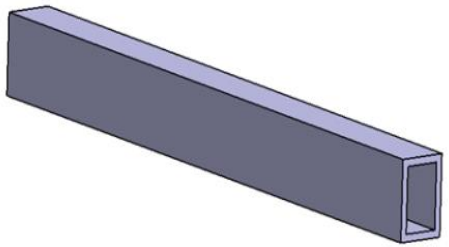
Conclusion: Exclude Methods II and III

II. Selection of Methods for Description

Criteria #02: Minimization of number of used methods in description

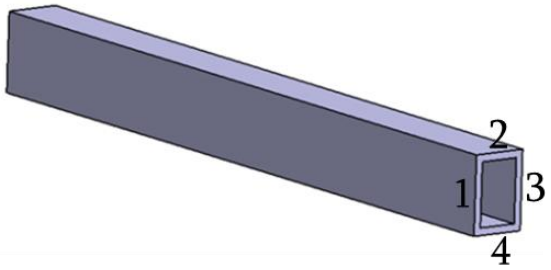
1. Ensure compactness of code
2. Reduce number received clashes, contacts and inaccuracies of positioning
3. Ensure better performance by reducing number of regions for consideration during the tracking

Example: Descriptions of Cube with Cut



I.

```
Cube
Cube
Subtraction
Move
Rotation
```



II.

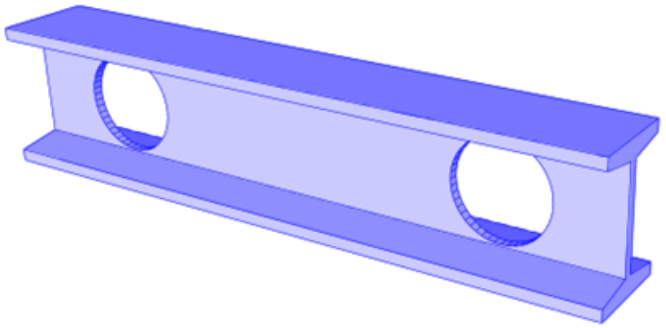
```
Cube
Move
Cube
Move
Cube
Move
Cube
Move
Union
Move
Rotation
```

Conclusion: Exclude Method II

II. Selection of Methods for Description

Criteria #03: Exclude descriptions which are using same transactions and methods

Example: Descriptions of Dodecagonal Prism with Cuts



I.

Arbitrary
Tube
Rotation
Move
Subtraction
Rotation
Move
Subtraction
Move (Z)
Rotation

II.

Symmetric
Tube
Rotation
Move
Subtraction
Rotation
Move
Subtraction
Move (Z)
Rotation

Conclusion: Either I or II should be excluded

II. Selection of Methods for Description

Criteria #04: Exclude descriptions with same consequence of methods

Example: Descriptions of Icositetrahedronal prism with cuts

Icositetrahedronal Prism with Cuts

I.	II.
Cube	Pyramid
Symmetric	Symmetric
Move	Move
Subtraction	Subtraction
Move	Move
Subtraction	Subtraction
Arbitrary	Arbitrary
Subtraction	Subtraction
Tube	Tube
Move	Move
Subtraction	Subtraction
Cube	Cube
Move	Move
Subtraction	Subtraction
Tube	Tube
Move	Move
Subtraction	Subtraction

Conclusion: Either I or II should be excluded

II. Selection of Methods for Description

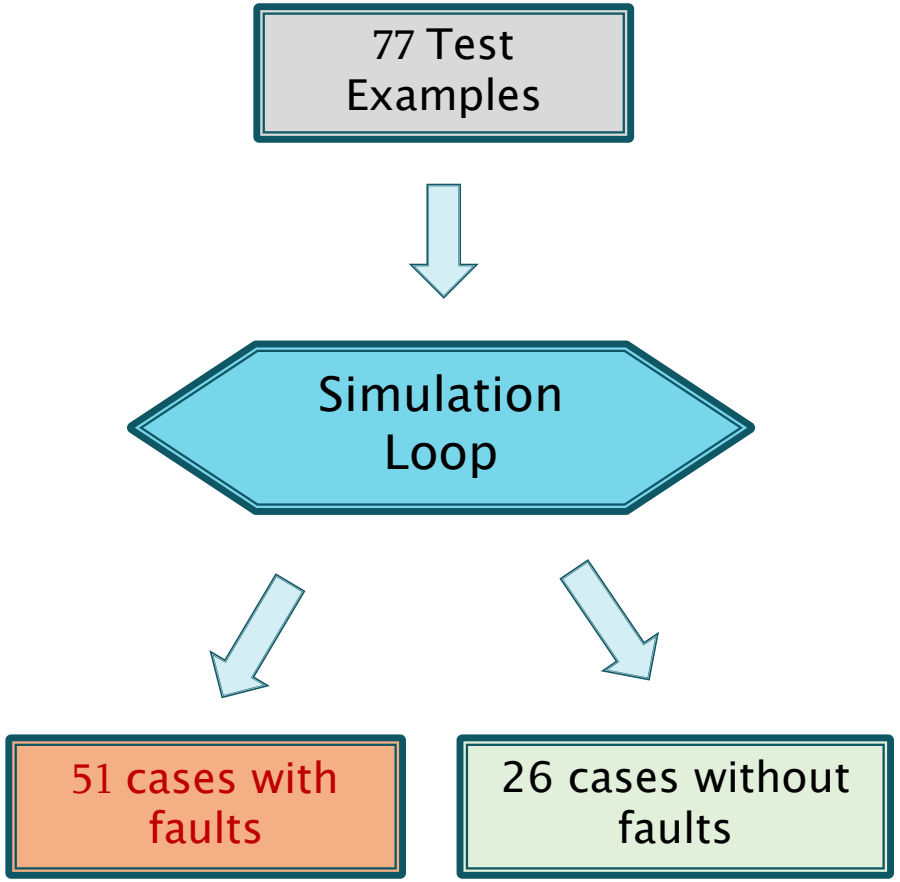
- Total number of methods has been analysed and just unique cases of descriptions were selected:

Before Separation		After Separation	
1st class of 22 objects:	4'460 methods	*1st class* of 4'460 methods:	11 methods
2nd class of 33 objects:	6'579 methods	*2nd class* of 6'579 methods:	38 methods
3rd class of 29 objects:	4'636 methods	*3rd class* of 4'636 methods:	28 methods
Total:	**15'675** methods	Total:	**77** methods

Conclusion: 77 unique examples have been formed for the investigation of quality of geometry transformations doing by simulation software.

III. Test Runs

III. Test Runs



Test Example N	Max. inaccuracies
1	0.25
2	0.03
3	0.00
4	0.03
5	0.00
6	0.23
7	0.09
8	0.01
9	0.01
10	0.04
11	0.09
12	0.09
13	0.03
14	0.03
15	0.01
16	0.04
17	0.04
16	0.19
19	0.06
20	0.14
21	0.00
22	0.03
23	0.23
24	0.02
25	0.21
26	0.2
27	0.26

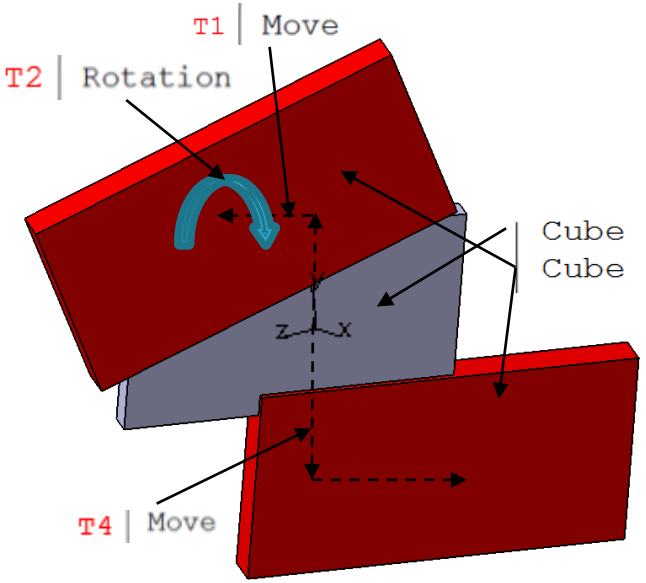
Test Example N	Max. inaccuracies
28	0.26
29	0.03
30	0.03
31	0.03
32	0.08
33	0.08
34	0.01
35	0.01
36	0.17
37	0.21
38	0.03
39	0.24
40	0.12
41	0.12
42	0.00
43	0.00
44	0.00
45	0.00
46	0.00
47	0.00
48	0.00
49	0.00
50	0.00
51	0.00
52	0.00
53	0.00
54	0.00

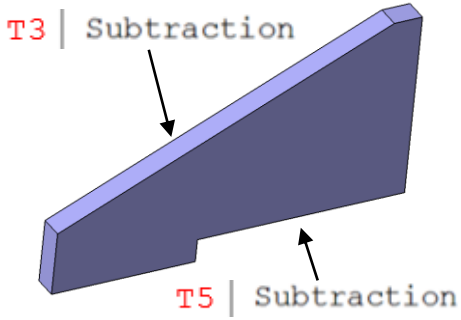
Test Example N	Max. inaccuracies
55	0.08
56	0.03
57	0.07
58	0.21
59	0.26
60	0.09
61	0.09
62	0.00
63	0.09
64	0.00
65	0.00
66	0.00
67	0.00
68	0.06
69	0.00
70	0.00
71	0.08
72	0.00
73	0.08
74	1.44
75	1.75
76	0.00
77	0.00

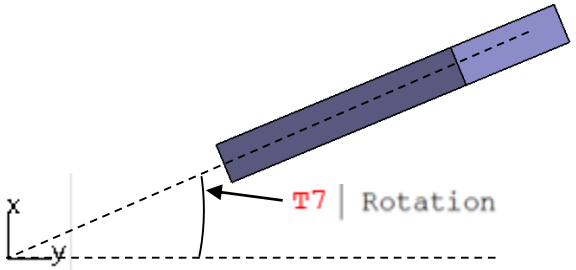
Example of Test Run

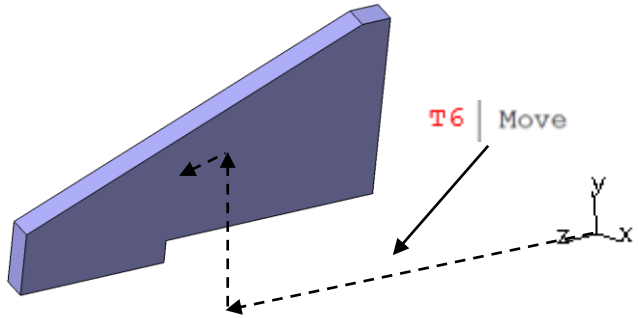
```
<box  name="Box"  material="Aluminium"  X_Y_Z="20.; 180.; 305. " />
<box  name="Box1"  material="Aluminium"  X_Y_Z="21.; 180.; 350 " />

<subtraction name="ExampleN02" >
   <posXYZ  volume="Box"   X_Y_Z=" 0.; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Box1"  X_Y_Z=" 0. ; 107. ; 55. "  rot=" 24. ; 0. ; 0. "/>
   <posXYZ  volume="Box1"  X_Y_Z=" 0. ; -160. ; -147.5 "  rot=" 0. ; 0. ; 0. "/>
</subtraction>

<composition  name="ECT_Toroids" >
  <posXYZ  volume="ExampleN02" X_Y_Z=" 2121. ; 4154. ; 12462.5" rot=" 0.; 0.; -22.5 " />
</composition>
```

	Cube
	Cube
T1	Move
T2	Rotation
T3	Subtraction
T4	Move
T5	Subtraction
T6	Move
T7	Rotation

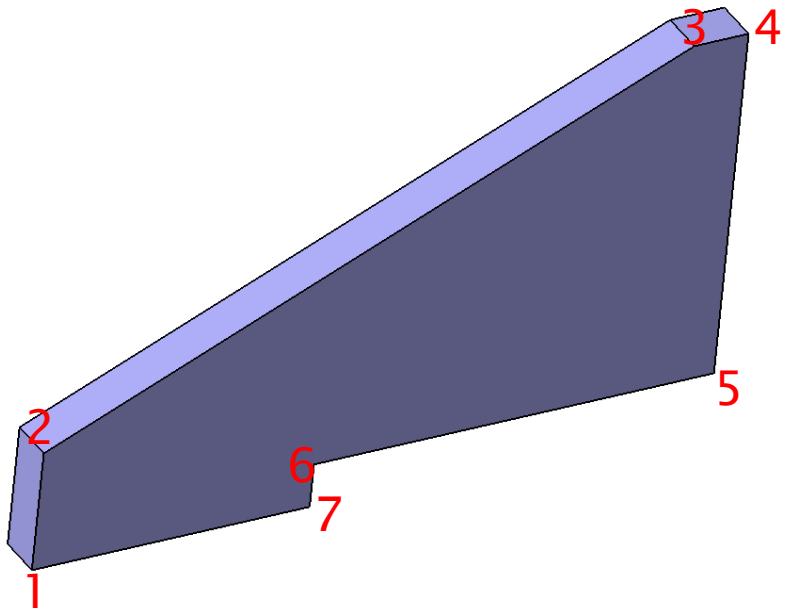








Example of Test Run



		GeoM Δ_1	G-4 Δ_2
1	x	0	0
	y	0	0
	z	0	0
2	x	-0.01	-0.02
	y	0	0
	z	0	0
3	x	0	0
	y	0	0
	z	-0.02	0.01
4	x	0	0
	y	0	0
	z	0	0
5	x	0	0
	y	0	0
	z	0	0
6	x	0	0
	y	0	0
	z	0	0
7	x	0	0
	y	0	0
	z	0	0
Volume			
		0	0

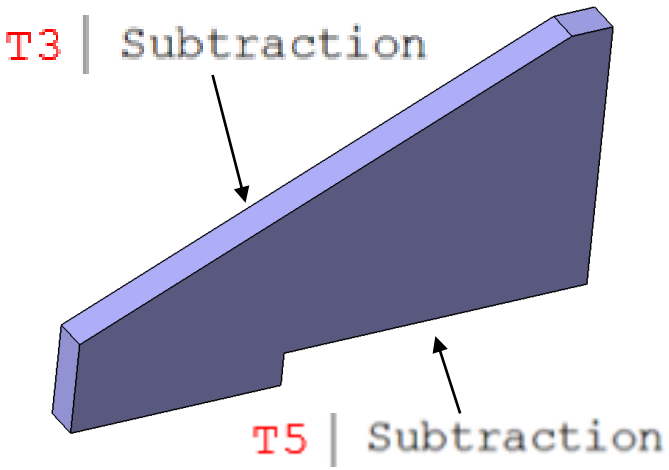
IV. Case Study of Transactions

IV. Case Study of Transactions

Sub-Case №01: T1/T2/T4 transactions together with Boolean Subtraction

```
<box  name="Box"  material="Aluminium"  X_Y_Z="20.; 180.; 305. " />
<box  name="Box1"  material="Aluminium"  X_Y_Z="21.; 180.; 350 " />

<subtraction name="ExampleN02" >
   <posXYZ  volume="Box"   X_Y_Z=" 0.; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Box1"  X_Y_Z=" 0. ; 107. ; 55. "  rot=" 24. ; 0. ; 0. "/>
   <posXYZ  volume="Box1"  X_Y_Z=" 0. ; -160. ; -147.5 "  rot=" 0. ; 0. ; 0. "/>
</subtraction>

<composition  name="ECT_Toroids" >
  <posXYZ  volume="ExampleN02" X_Y_Z=" 0. ; 0. ; 0." rot=" 0.; 0.; 0. " />
</composition>
```

	Cube
	Cube
T1	Move
T2	Rotation
T3	Subtraction
T4	Move
T5	Subtraction
T6	Move
T7	Rotation



Results:

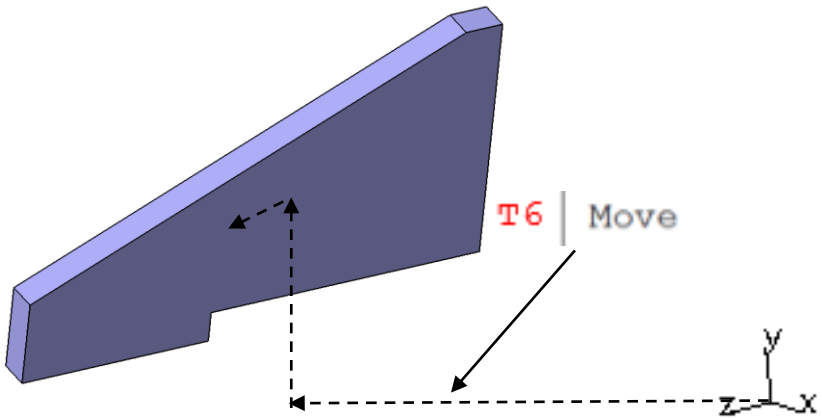
		GeoM Δ_1	G-4 Δ_2
1	x	0	0
	y	0	0
	z	0	0
2	x	0	0
	y	-0.01	-0.01
	z	0	0
3	x	0	0
	y	0	0
	z	-0.02	-0.02
4	x	0	0
	y	0	0
	z	0	0
5	x	0	0
	y	0.01	0.01
	z	0	0
6	x	0	0
	y	0.01	0.01
	z	0	0
7	x	0	0
	y	0	0
	z	0	0
Volume			
		0	0

IV. Case Study of Transactions

Sub-Case #02: T6 movement together with T1/T2/T4 transactions and T3/T5 Boolean Subtraction

```
<box  name="Box"  material="Aluminium"  X_Y_Z="20.; 180.; 305. " />
<box  name="Box1"  material="Aluminium"  X_Y_Z="21.; 180.; 350 " />

<subtraction name="ExampleN02" >
   <posXYZ  volume="Box"   X_Y_Z=" 0.; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Box1"  X_Y_Z=" 0. ; 107. ; 55. "  rot=" 24. ; 0. ; 0. "/>
   <posXYZ  volume="Box1"  X_Y_Z=" 0. ; -160. ; -147.5 "  rot=" 0. ; 0. ; 0. "/>
</subtraction>

<composition  name="ECT_Toroids" >
  <posXYZ  volume="ExampleN02" X_Y_Z=" 2121. ; 4154. ; 12462.5" rot=" 0.; 0.; 0. " />
</composition>
```

	Cube
	Cube
T1	Move
T2	Rotation
T3	Subtraction
T4	Move
T5	Subtraction
T6	Move
T7	Rotation



Results:

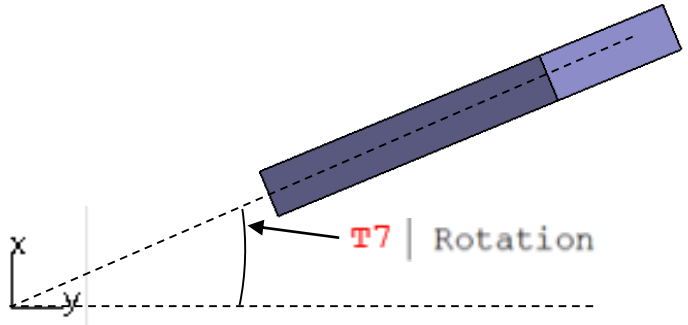
		GeoM Δ_1	G-4 Δ_2
1	x	0	0
	y	0	0
	z	0	0
2	x	0	0
	y	-0.01	-0.01
	z	0	0
3	x	0	0
	y	0	0
	z	-0.02	0.01
4	x	0	0
	y	0	0
	z	0	0
5	x	0	0
	y	0.01	0.01
	z	0	0
6	x	0	0
	y	0.01	0.01
	z	0	0
7	x	0	0
	y	0	0
	z	0	0
Volume			
		0	0

IV. Case Study of Transactions

Sub-Case #03: T7 rotation transaction and T1/T2/T4 transactions together with T3/T5 Boolean Subtraction

```
<box  name="Box"  material="Aluminium"  X_Y_Z="20.; 180.; 305. " />
<box  name="Box1"  material="Aluminium"  X_Y_Z="21.; 180.; 350 " />

<subtraction name="ExampleN02" >
   <posXYZ  volume="Box"   X_Y_Z=" 0.; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Box1"  X_Y_Z=" 0. ; 107. ; 55. "  rot=" 24. ; 0. ; 0. "/>
   <posXYZ  volume="Box1"  X_Y_Z=" 0. ; -160. ; -147.5 "  rot=" 0. ; 0. ; 0. "/>
</subtraction>

<composition  name="ECT_Toroids" >
  <posXYZ  volume="ExampleN02" X_Y_Z=" 0. ; 0. ; 0." rot=" 0.; 0.; -22.5 " />
</composition>
```

	Cube
	Cube
T1	Move
T2	Rotation
T3	Subtraction
T4	Move
T5	Subtraction
T6	Move
T7	Rotation



Results:

		GeoM Δ_1	G-4 Δ_2
1	x	0	0
	y	0	0
	z	0	0
2	x	-0.01	-0.02
	y	0	0
	z	0	0
3	x	0	0
	y	0	0
	z	-0.02	-0.02
4	x	0	0
	y	0	0
	z	0	0
5	x	0	0
	y	0	0
	z	0	0
6	x	0	0
	y	0	0
	z	0	0
7	x	0	0
	y	0	0
	z	0	0
Volume			
		0	0

V. Systematization and Learning of Results

V. Systematization and Learning of Results

		Used Methods										Transactions					Inaccuracies: GeoModel						Inaccuracies: Geant4					
	№	Cub	Tube	Pyr	Trap	Cone	PolyC	PolyG	Arbitr	Sym	Dsym	M1	R1	Subt	M2	R2	M1	R1	Subtr.	M2	R2	Conf	M1	R1	Subt	M2	R2	Conf
1	1			3X								5X	4X	5X	X	X	0	0	ΔX=0.25 ΔY=-0.15 Δ_V=0.0014	ΔX=-0.02 ΔY=0.01	ΔX=0.07 ΔY=-0.18		0	0	ΔX=0.25 ΔY=-0.15 Δ_V=0.0014	ΔX=-0.02 ΔY=0.01	ΔX=0.06 ΔY=-0.17	
2	2	2X										2X	X	2X	X	X	0	0	ΔY=0.01 ΔZ=-0.02	0	ΔX=0.01		0	0	ΔY=0.01 ΔZ=-0.02	ΔZ=0.03	ΔX=-0.01 ΔY=-0.02	
3	4	X							X					X	X	X			ΔX=-0.03 ΔY=-0.02	0	ΔX=0.02 ΔY=-0.02 ΔZ=-0.02				ΔX=-0.03 ΔY=-0.02	0	ΔX=0.02 ΔY=-0.02	
4	6	2X										X		X	X	X	0		ΔX=-0.23 ΔZ=-0.13 ΔV=0.0002	0	ΔX=0.03 ΔY=0.1 ΔZ=0.01		0		ΔX=-0.23 ΔZ=-0.13 ΔV=0.0002	ΔZ=0.03	ΔX=0.03 ΔY=0.1 ΔZ=0.01	
5	7	X							X					2X	X	X			ΔX=-0.07 ΔY=-0.05	ΔX=0.01 ΔY=0.05	ΔX=-0.02 ΔY=0.09				ΔX=-0.07 ΔY=-0.05	ΔX=0.01 ΔY=0.05	ΔX=0.04 ΔY=0.09	
6	8	2X										X	X	X	X	X	0	0	ΔZ=-0.01	0	0		0	0	ΔZ=-0.01	0	0	
7	9								2X			2X		2X	X	X	0		0	0	ΔX=-0.01		0		0	0	0	
8	10	3X										4X		4X	X	X	0		ΔX=0.03 ΔY=0.03	ΔX=0.03 ΔY=0.03	ΔX=-0.04 ΔY=-0.02		0		ΔX=0.03 ΔY=0.03	ΔX=0.03 ΔY=0.03	ΔX=-0.04 ΔY=-0.02	
9	11	2X												X	X	X			ΔY=-0.09 ΔZ=-0.06	0	ΔX=0.03 ΔY=0.01				ΔY=-0.09 ΔZ=-0.06	ΔY=-0.01 ΔZ=-0.01	ΔX=0.03 ΔY=0.02	
10	12								2X					X	X	X			ΔX=-0.09 ΔY=-0.06	ΔY=-0.02	ΔX=0.03 ΔY=0.01				ΔX=-0.09 ΔY=-0.06	ΔY=-0.03	ΔX=0.03 ΔY=0.02	
11	13	X	X							X		X		2X	X	X	0		ΔX=0.01 Δ_V=0.0002	ΔX=-0.03 ΔY=-0.02	ΔX=-0.01 ΔY=0.02		0		ΔX=0.01 Δ_V=0.0002	ΔX=0.03 ΔY=-0.03	ΔX=-0.01 ΔY=0.03	
12	14	X	X						X			2X		2X	X	X	0		ΔX=-0.03 ΔY=-0.02 Δ_V=0.0002	0	ΔX=-0.01 ΔY=0.02		0		ΔX=-0.03 ΔY=-0.02 Δ_V=0.0002	0	ΔX=-0.01 ΔY=0.03	
13	15	X		X								X		X	X	X	0		0	0	ΔX=0.01		0		0	0	ΔX=0.01 ΔY=-0.01	
14	16		X						X			X		X	X	X	0		ΔX=-0.03 ΔY=-0.02	0	ΔX=-0.01 ΔY=0.02		0		ΔX=-0.04 ΔY=-0.03	0	ΔX=-0.01 R=0.01	
15	17		2X									2X	2X	2X	X	X	0	0	ΔX=0.04 ΔY=0.02 ΔV=0.002	ΔX=0.01	ΔX=0.02 ΔY=0.03 R=0.01		0	0	ΔX=0.04 R=0.02 ΔV=0.002	ΔX=0.01 ΔY=0.01 ΔZ=0.01	ΔX=0.02 ΔY=0.03 R=0.05	
16	18		2X						X	X		2X		3X	X		0		ΔX=-0.11 ΔY=0.19 Δ_V=0.0003	0			0		ΔX=-0.11 ΔY=0.19 R=0.01 Δ_V=0.0003	ΔX=-0.07 ΔY=-0.04 R=0.08		

V. Systematization and Learning of Results

		Used Methods										Transactions					Inaccuracies: GeoModel						Inaccuracies: Geant4					
	№	Cub	Tube	Pyr	Trap	Cone	PolyC	PolyG	Arbitr	Sym	Dsym	M1	R1	Subt	M2	R2	M1	R1	Subtr.	M2	R2	Conf	M1	R1	Subt	M2	R2	Conf
17	19		2X						X			2X		2X	X	X	0		ΔX=0.06 ΔY=0.04 ΔV=0.0003	0	ΔY=-0.03		0		ΔX=0.06 ΔY=0.01 R=0.03 ΔV=0.0003	ΔX=-0.03 ΔY=-0.04 R=0.05	ΔX=0.04 ΔY=0.06 R=0.09	
18	20		2X	X						X		3X	X	3X	X	X	0	0	ΔX=-0.14 ΔY=-0.08 Δ_V=0.0003	ΔX=0.01 ΔY=0.01	ΔX=-0.03 ΔY=0.06		0	0	ΔX=-0.14 ΔY=-0.08 R=0.03 Δ_V=0.0003	ΔX=0.01 ΔY=-0.04 R=0.03	ΔX=-0.03 ΔY=0.06 R=0.01	
19	22		X						X			X		X	X	X	0		ΔX=-0.03 ΔY=-0.02 Δ_V=0.0001	0	ΔY=0.02		0		ΔX=-0.03 ΔY=-0.02 Δ_V=0.0001	0	ΔY=0.02	
20	23		X	X					2X			X	2X	4X	X	X	0	0	ΔX=0.23 ΔY=-0.09 Δ_V=0.0001	0	ΔX=-0.03 ΔY=-0.09		0	0	ΔX=0.23 ΔY=-0.09 Δ_V=0.0001	0	ΔX=-0.03 ΔY=-0.09	
21	24	X	X									X		X	X	X	0		ΔX=-0.02 ΔY=0.01 ΔZ=-0.01	ΔX=-0.01 ΔY=-0.01 ΔZ=-0.01	ΔX=0.02 ΔY=0.01		0		ΔX=-0.02 ΔY=0.01 ΔZ=-0.01	ΔX=-0.02	ΔX=0.01 ΔY=0.02	
22	25		X						2X			2X		3X	X	X	0		ΔX=0.03 ΔY=0.02 Δ_V=0.0005 R=0.01	0	ΔY=-0.02		0		ΔX=0.03 ΔY=0.21 Δ_V=0.0001 R=0.17	0	ΔY=0.23 R=0.05	
23	26	2X	X									2X		3X	X	X	0		ΔX=0.03 ΔY=0.02	ΔY=-0.02 R=0.01	ΔX=0.02		0		ΔX=0.03 ΔY=0.2 R=0.02	ΔY=-0.01 R=0.02	ΔX=0.07 ΔY=-0.03 R=0.05	
24	27								4X			3X	2X	4X	X	X	0	0	ΔX=0.15 ΔY=-0.22 ΔZ=-0.06	ΔX=0.01 ΔZ=-0.02	ΔX=-0.09 ΔY=0.07		0	0	ΔX=0.15 ΔY=-0.16 ΔZ=0.08	ΔX=0.26 ΔY=0.03 ΔZ=-0.02	ΔX=-0.07 ΔY=-0.04	
25	28	2X									2X	3X	2X	4X	X	X	0	0	ΔX=0.15 ΔY=-0.22 ΔZ=-0.06	ΔX=0.01 ΔZ=-0.02	ΔX=-0.09 ΔY=0.07		0	0	ΔX=0.15 ΔY=-0.16 ΔZ=0.08	ΔX=0.26 ΔY=0.03 ΔZ=-0.02	ΔX=-0.07 ΔY=-0.04	
26	29		X						2X			X	2X	3X	X	X	0	0	ΔX=0.01 ΔY=-0.03 ΔZ=0.01 Δ_V=0.0002	ΔY=-0.01 ΔZ=0.01	ΔX=-0.01 ΔY=0.01 ΔZ=0.01		0	0	ΔX=0.01 ΔY=-0.03 ΔZ=0.01 Δ_V=0.0002	ΔY=0.01 ΔZ=0.03	ΔX=0.01 ΔY=0.03 ΔZ=-0.01	
27	30		X						2X			8X	7X	8X	X	X	0	0	ΔX=0.03 ΔY=-0.03 ΔZ=-0.02 Δ_V=0.0003	ΔY=-0.03 ΔZ=0.03	ΔY=0.01 ΔZ=0.04		0	0	ΔX=0.03 ΔY=-0.03 ΔZ=0.03 Δ_V=0.0003	ΔY=0.03 ΔZ=-0.03 R=0.01	ΔX=0.01 ΔY=-0.03 ΔZ=0.02 R=0.01	

V. Systematization and Learning of Results

		Used Methods										Transactions					Inaccuracies: GeoModel						Inaccuracies: Geant4					
	№	Cub	Tube	Pyr	Trap	Cone	PolyC	PolyG	Arbitr	Sym	Dsym	M1	R1	Subt	M2	R2	M1	R1	Subtr.	M2	R2	Conf	M1	R1	Subt	M2	R2	Conf
28	31		X							X	X	8X	8X	8X	X	X	0	0	ΔX=0.03 ΔY=-0.03 ΔZ=-0.03 Δ_V=0.00031	ΔY=-0.03 ΔZ=0.03	ΔY=0.01 ΔZ=0.04		0	0	ΔX=0.03 ΔY=-0.03 ΔZ=-0.03 Δ_V=0.00031	ΔX=0.02 ΔY=0.03 R=0.01	ΔX=-0.02 ΔY=-0.03 ΔZ=0.03 R=0.01	
29	32					X			3X			7X	5X	7X	X	X	0	0	ΔX=0.03 ΔY=0.03 ΔZ=0.03 Δ_V=0.0016	ΔX=-0.03 ΔZ=-0.02 Δ_V=0.0033	ΔX=0.01 ΔZ=0.02		0	0	ΔX=-0.05 ΔY=0.03 ΔZ=-0.03 Δ_V=0.0016 R=0.01	ΔX=0.04 ΔY=0.06 ΔZ=-0.05 Δ_V=0.0033 R=0.02	ΔX=0.05 ΔY=-0.08 ΔZ=-0.02 R=0.04	
30	33					X			2X	X		7X	5X	7X	X	X	0	0	ΔX=0.03 ΔY=0.03 ΔZ=0.03 Δ_V=0.0016	ΔX=-0.03 ΔZ=-0.02 Δ_V=0.0033	ΔX=0.01 ΔZ=0.02		0	0	ΔX=-0.05 ΔY=0.03 ΔZ=-0.03 Δ_V=0.0016 R=0.01	ΔX=0.04 ΔY=0.06 ΔZ=-0.05 Δ_V=0.0033 R=0.02	ΔX=0.05 ΔY=-0.08 ΔZ=-0.02 R=0.04	
31	34		X						X			2X	2X	2X	X	X	0	0	Δ_V=0.0001	0	0		0	0	ΔY=0.01 Δ_V=0.0001	0	0	
32	35		X							X		2X	2X	2X	X	X	0	0	Δ_V=0.0001	0	0		0	0	ΔY=0.01 Δ_V=0.0001	0	0	
33	36		X						X			2X		2X	X	X	0		ΔX=0.02 Δ_V=0.00001	0	ΔX=-0.01 ΔZ=-0.01		0		ΔX=0.02 ΔZ=0.01 Δ_V=0.00007	ΔX=0.02 ΔZ=-0.02 R=0.03	ΔX=-0.17 ΔZ=0.17 R=0.25	
34	37	2X	2X									3X		3X	X	X	0		ΔX=0.01 ΔZ=0.01 Δ_V=0.00007	0	ΔZ=0.02		0		ΔX=0.02 ΔZ=0.01	ΔX=-0.03 ΔZ=0.05 R=0.05	ΔX=-0.16 ΔZ=-0.21 R=0.19	
35	38		2X						X			X		2X	X		0		ΔX=-0.03 ΔY=-0.03 ΔV=0.0009	0			0		ΔX=-0.03 ΔY=-0.03 ΔV=0.0009	0		
36	39	X	2X						X	X		2X		4X	X		0		ΔX=-0.24 ΔY=-0.18 ΔV=0.0009	0			0		ΔX=-0.24 ΔY=-0.18 ΔV=0.0009	0		
37	40								5X				2X	4X	X	X		0	ΔX=0.11 ΔY=0.09 ΔZ=-0.12 Δ_V=0.0004	ΔX=0.01 ΔY=-0.01 ΔZ=0.01	ΔX=0.09 ΔY=0.1			0	ΔX=0.11 ΔY=0.09 ΔZ=-0.12 Δ_V=0.0004	ΔX=0.01 ΔY=0.01 ΔZ=0.01	ΔX=0.09 ΔY=0.1	

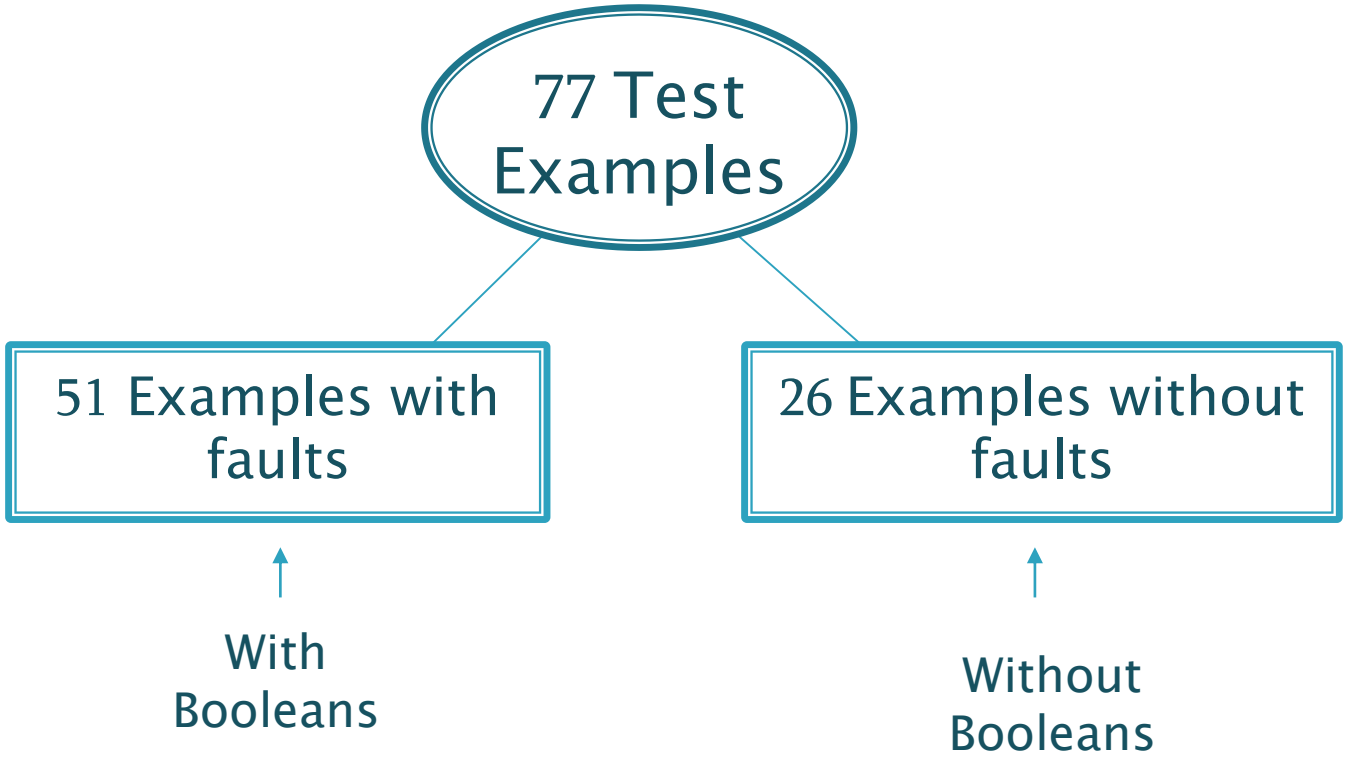
V. Systematization and Learning of Results

		Used Methods										Transactions					Inaccuracies: GeoModel						Inaccuracies: Geant4					
	№	Cub	Tube	Pyr	Trap	Cone	PolyC	PolyG	Arbitr	Sym	Dsym	M1	R1	Subt	M2	R2	M1	R1	Subtr.	M2	R2	Conf	M1	R1	Subt	M2	R2	Conf
38	41	X							4X				3X	4X	X	X		0	ΔX=0.11 ΔY=0.09 ΔZ=-0.12 Δ_V=0.0004	ΔY=0.01	ΔX=0.09 ΔY=0.1			0	ΔX=0.11 ΔY=0.09 ΔZ=-0.12 Δ_V=0.0004	ΔY=0.01	ΔX=0.09 ΔY=0.1	
39	55	X			X							2X	2X	2X	X	X	0	0	ΔX=0.08 ΔY=0.01	ΔY=0.02	ΔX=-0.01 ΔY=0.02	-	0	0	ΔX=0.08 ΔY=0.01	ΔY=0.02	ΔX=-0.01 ΔY=0.01	-
40	56	2X										3X		3X	X	X	0		ΔX=0.03 ΔY=0.02	0	ΔX=0.01	-	0		ΔX=0.03 ΔY=0.02	0	0	-
41	57		2X									2X	2X	X	X	X	0	0	ΔX=0.04 ΔY=0.02 ΔV=0.002	ΔX=0.01	ΔX=0.02 ΔY=0.03 R=0.01		0	0	ΔX=0.04 R=0.02 ΔV=0.002	ΔX=0.01 ΔY=0.01 ΔZ=0.01	ΔX=0.02 ΔY=0.03 R=0.05	-
42	58	2X	X									X		2X	2X	X	0		ΔX=0.03 ΔY=0.02	ΔY=-0.02 R=0.01	ΔX=0.02		0		ΔX=0.03 ΔY=0.2 R=0.02	ΔY=-0.01 R=0.02	ΔX=0.07 ΔY=-0.03 R=0.05	-
43	59	2X	X									X		2X	2X	X	0		ΔX=0.03 ΔY=0.02 Δ_V=0.0005 R=0.01	0	ΔY=-0.02		0		ΔX=0.03 ΔY=0.21 Δ_V=0.0001 R=0.17	0	ΔY=0.23 R=0.05	-
44	60	X									2X	X	X	2X	2X	2X	0	0	ΔX=0.15 ΔY=-0.22 ΔZ=-0.06	ΔX=0.01 ΔZ=-0.02	ΔX=-0.09 ΔY=0.07		0	0	ΔX=0.15 ΔY=-0.16 ΔZ=0.08	ΔX=0.26 ΔY=0.03 ΔZ=-0.02	ΔX=-0.07 ΔY=-0.04	-
45	61								3X			X	X	2X	2X	2X	0	0	ΔX=0.15 ΔY=-0.22 ΔZ=-0.06	ΔX=0.01 ΔZ=-0.02	ΔX=-0.09 ΔY=0.07		0	0	ΔX=0.15 ΔY=-0.16 ΔZ=0.08	ΔX=0.26 ΔY=0.03 ΔZ=-0.02	ΔX=-0.07 ΔY=-0.04	-
46	63	2X												X	X	X	0		ΔY=-0.09 ΔZ=0.06	ΔZ=0.01	ΔX=0.03 ΔY=0.01	-	0		ΔY=-0.09 ΔZ=0.06	ΔY=-0.01 ΔZ=0.01	ΔX=0.03 ΔY=0.02	-
47	69	X	X									X		X	X		0		ΔX=-0.06 ΔY=-0.05	0		-	0		ΔX=-0.06 ΔY=-0.05	0		-
48	72	X			X							3X	3X	2X	X	X	0	0	ΔX=0.08 ΔY=0.01	ΔY=0.02	ΔX=-0.01 ΔY=0.02	0	0	0	ΔX=0.08 ΔY=0.01	ΔY=0.02	ΔX=-0.01 ΔY=0.01	0
49	74	4X			2X							6X	6X	5X	2X	2X	0	0	ΔX=0.08 ΔY=0.01	ΔY=0.02	ΔX=-0.01 ΔY=0.02	-	0	0	ΔX=0.08 ΔY=0.01	ΔY=0.02	ΔX=-0.01 ΔY=0.01	-
50	75	2X	X									2X		X		X	0		ΔX=-1.34 ΔZ=0.94 Δ_V=0.175		ΔX=-0.47 ΔZ=0.33	Clash=1.28	0		ΔX=-1.44 ΔZ=-0.9 Δ_V=0.044		ΔZ=-0.09	Clash=0.91
51	77	X	2X									X	X	X	X	X	0		ΔX=-1.71 ΔZ=-1.25 Δ_V=34.45	0	0	-	0	0	ΔX=-1.75 ΔZ=-1.25 R=0.05 ΔV=34.45	0		-

V. Systematization and Learning of Results

Conclusion №01

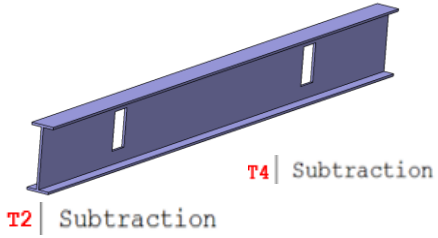
- For all type of detector geometries dimensional, form and positioning faults are caused by *Boolean operations*



Conclusion №02

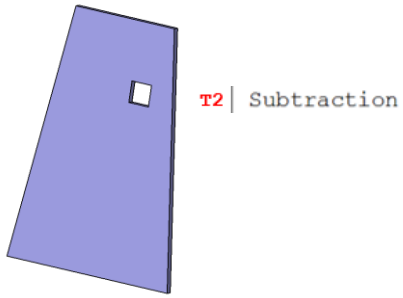
- All internal surfaces received by *Boolean* subtraction of parametrical primitives from Box brings 0 faults

- Test Example #09



	Arbitrary
	Arbitrary
T1	Move
T2	Subtraction
T3	Move
T4	Subtraction
T5	Move (Z)
T6	Rotation

- Test Example #15



	Pyramid
	Cube
T1	Move
T2	Subtraction
T3	Move
T4	Rotation

V. Systematization and Learning of Results

Conclusion №03

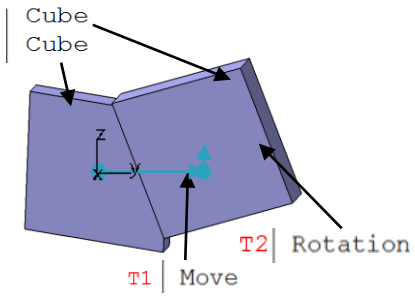
- *Boolean* operations are correlate with *Move* and *Rotate* transactions executing after the *Boolean*. All *Move*/*Rotate* transactions before *Boolean* are fine

		Geometric Primitives										Transactions					CATIA vs GeoModel (VP1)						CATIA vs Geant4					
							GeoModel																					
	Ex. №	Cube	Tube	Pyr	Trap.	Cone	PolyC.	PolyG.	Arbitr.	Sym.	Dsym	M	R	Subt.	M	R	M	R	Subtr.	M	R	Conf	M	R	Subt	M	R	Conf
1	1			3X								5X	4X	5X	X	X	0	0	ΔX=0.25 ΔY=-0.15 Δ_V=0.0014	ΔX=-0.02 ΔY=0.01	ΔX=0.07 ΔY=-0.18		0	0	ΔX=0.25 ΔY=-0.15 Δ_V=0.0014	ΔX=-0.02 ΔY=0.01	ΔX=0.06 ΔY=-0.17	
2	2	2X										2X	X	2X	X	X	0	0	ΔY=0.01 ΔZ=-0.02	0	ΔX=0.01		0	0	ΔY=0.01 ΔZ=-0.02	ΔZ=0.03	ΔX=-0.01 ΔY=-0.02	
3	4	X							X					X	X	X			ΔX=-0.03 ΔY=-0.02	0	ΔX=0.02 ΔY=-0.02 ΔZ=-0.02				ΔX=-0.03 ΔY=-0.02	0	ΔX=0.02 ΔY=-0.02	
4	6	2X										X		X	X	X	0		ΔX=-0.23 ΔZ=-0.13 ΔV=0.0002	0	ΔX=0.03 ΔY=0.1 ΔZ=0.01		0		ΔX=-0.23 ΔZ=-0.13 ΔV=0.0002	ΔZ=0.03	ΔX=0.03 ΔY=0.1 ΔZ=0.01	
5	7	X							X					2X	X	X			ΔX=-0.07 ΔY=-0.05	ΔX=0.01 ΔY=0.05	ΔX=-0.02 ΔY=0.09				ΔX=-0.07 ΔY=-0.05	ΔX=0.01 ΔY=0.05	ΔX=0.04 ΔY=0.09	
6	8	2X										X	X	X	X	X	0	0	ΔZ=-0.01	0	0		0	0	ΔZ=-0.01	0	0	
7	9								2X			2X		2X	X	X	0		0	0	ΔX=-0.01		0		0	0	0	
8	10	3X										4X		4X	X	X	0		ΔX=0.03 ΔY=0.03	ΔX=0.03 ΔY=0.03	ΔX=-0.04 ΔY=-0.02		0		ΔX=0.03 ΔY=0.03	ΔX=0.03 ΔY=0.03	ΔX=-0.04 ΔY=-0.02	
9	11	2X												X	X	X			ΔY=-0.09 ΔZ=-0.06	0	ΔX=0.03 ΔY=0.01				ΔY=-0.09 ΔZ=-0.06	ΔY=-0.01 ΔZ=-0.01	ΔX=0.03 ΔY=0.02	
10	12								2X					X	X	X			ΔX=-0.09 ΔY=-0.06	ΔY=-0.02	ΔX=0.03 ΔY=0.01				ΔX=-0.09 ΔY=-0.06	ΔY=-0.03	ΔX=0.03 ΔY=0.02	
11	13	X	X							X		X		2X	X	X	0		ΔX=0.01 Δ_V=0.0002	ΔX=-0.03 ΔY=-0.02	ΔX=-0.01 ΔY=0.02		0		ΔX=0.01 Δ_V=0.0002	ΔX=0.03 ΔY=-0.03	ΔX=-0.01 ΔY=0.03	
12	14	X	X						X			2X		2X	X	X	0		ΔX=-0.03 ΔY=-0.02 Δ_V=0.0002	0	ΔX=-0.01 ΔY=0.02		0		ΔX=-0.03 ΔY=-0.02 Δ_V=0.0002	0	ΔX=-0.01 ΔY=0.03	

Conclusion №04

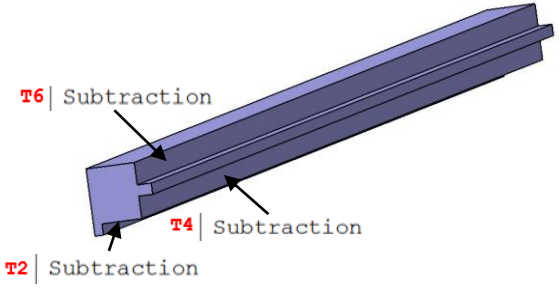
- For all external surfaces created by subtraction of parametrical primitives from Box, *Boolean* operation don't correlated with *Move*/*Rotation* transactions

- Test Example #08



	Cube
	Cube
T1	Move
T2	Rotation
T3	Subtraction
T4	Move
T5	Rotation

- Test Example #56

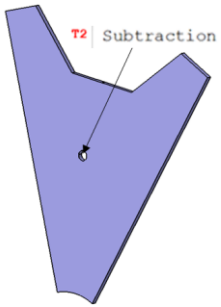


	Box
	Box
T1	Move
T2	Subtraction
T3	Move
T4	Subtraction
T5	Move
T6	Subtraction
T7	Move
T8	Rotation

Conclusion №05

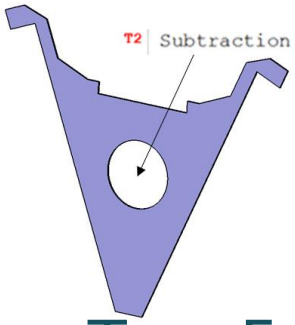
- For some internal surfaces created by subtraction of parametrical primitives from Polygon methods, *Boolean* operation don't correlated with *Move* transactions

- Test Example #19, #20



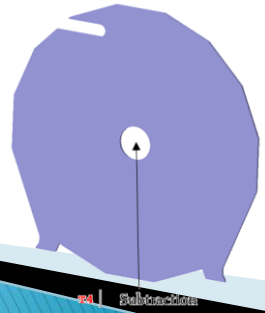
	Arbitrary
	Tube
T1	Move
T2	Subtraction
	Tube
T3	Move
T4	Subtraction
T5	Rotation
T6	Move

- Test Example #22



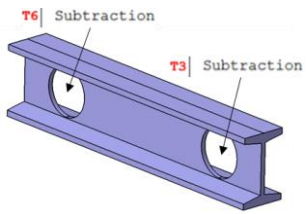
	Arbitrary
	Tube
T1	Move
T2	Subtraction
T3	Move (Z)
T4	Rotation

- Test Example #38, #39



	Symmetric
	Arbitrary
T1	Subtraction
	Cube
T2	Move
T3	Subtraction
	Tube
T4	Subtraction
	Tube
T5	Move
T6	Subtraction
T7	Move

- Test Example #34, #35



	Arbitrary
	Tube
T1	Rotation
T2	Move
T3	Subtraction
T4	Rotation
T5	Move
T6	Subtraction
T7	Move (Z)
T8	Rotation

Conclusions of Hypothesis #1

1. Hypothesis #01 has been confirmed: The simulation software infrastructure introduces geometrical inaccuracies

2. For all type of detector geometries the faults in dimension, form and positioning are caused by Boolean operations

3. All internal surfaces received by Boolean subtraction of parametrical primitives from a Box result in zero faults

4. Boolean operation inaccuracies are correlated with Moving/Rotation transactions in GEANT4

5. For all external surfaces created by the subtraction of parametrical primitives from a Box, Boolean operation Inaccuracies do not correlate with Moving/Rotation transactions

6. For some internal surfaces created by the subtraction of a Polygon methods via Tube method, Boolean operation do not correlate with Moving transactions

Checking Hypothesis 02:

Investigation of discrepancies between the design and the geometry implementation inside the simulation

Objectives of Analyses

1. Reproduction of Geometrical Model of COIL in CATIA
2. Decomposition and Mass analysis of COIL
3. Compare analysis between CATIA and Geant4 COILs
4. Integration conflict checking

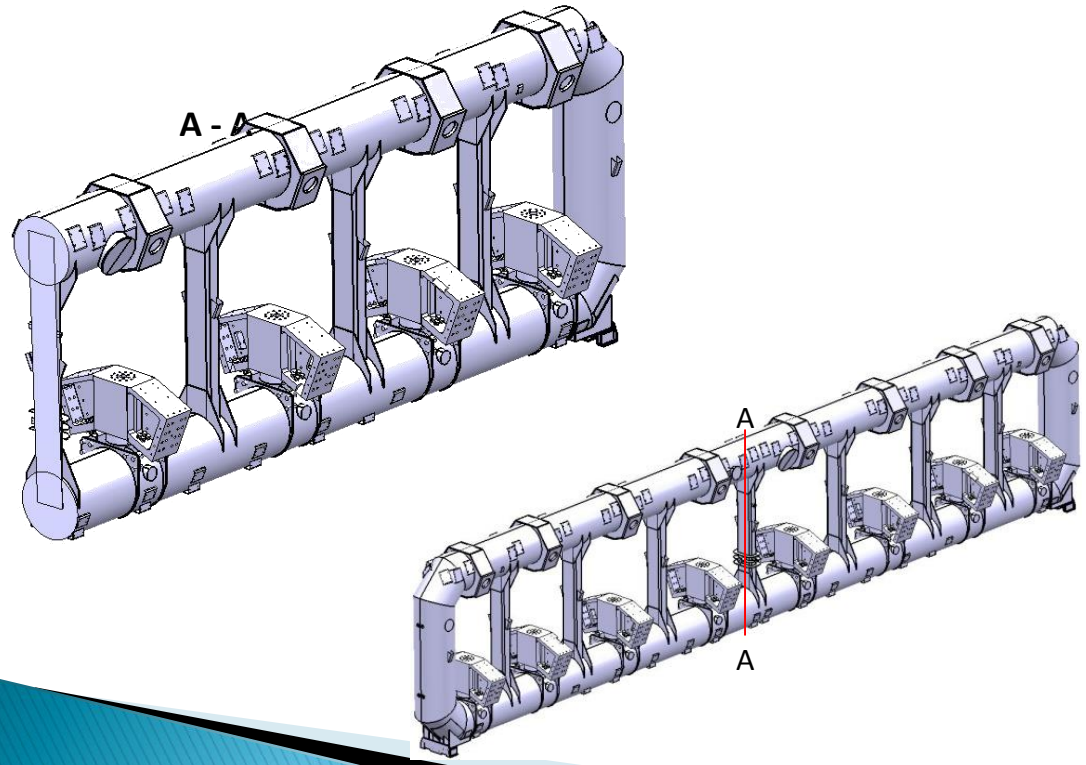
I. Reproduction of Geometrical Model of COIL in CATIA

Reproduction of Geometrical Model of COIL in CATIA

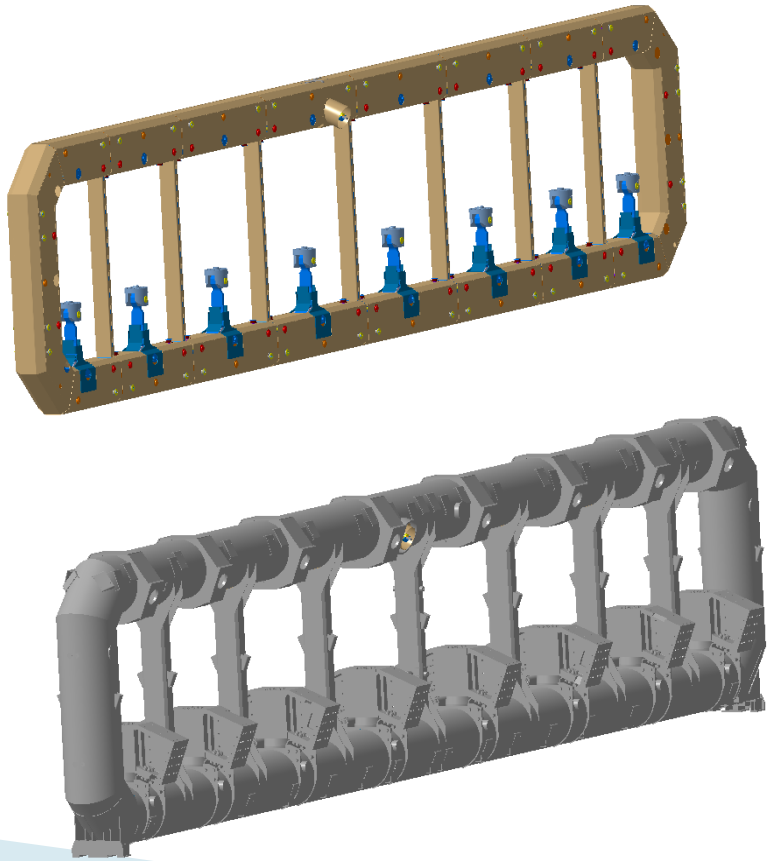
1. Source geometry has been taken from Smarteam Engineering Database

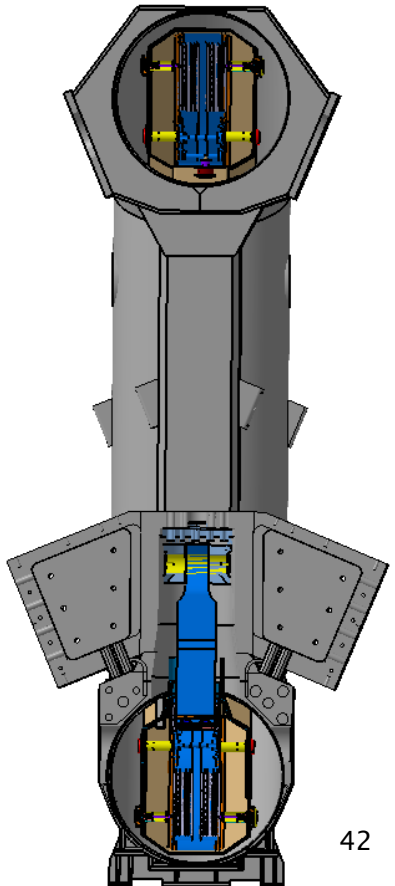
2. 225 manufacturing drawings have been founded on CDD and missing parts was added to primary Smarteam geometry

SmarTeam Model



CATIA Model



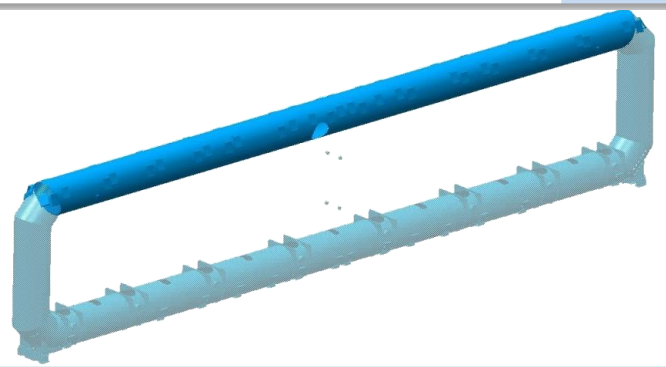


II. Decomposition and Mass analysis of COIL

Decomposition and Mass analysis of COIL

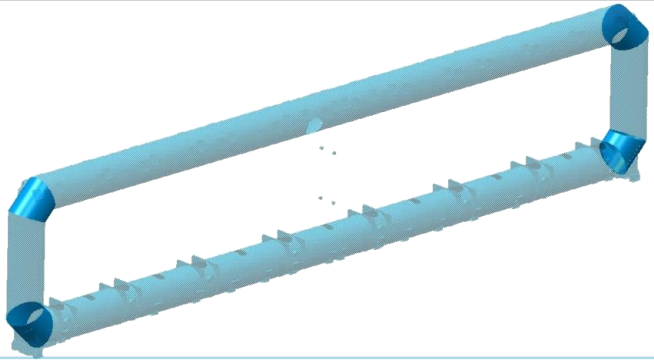
Volume 1. Cryostat Long (Top)

Number of Items	Material	Density (kg/m³)	Volume (m³)	Total Volume (m³)	Total Mass (kg)
1	Stainless Steel 304L	8000	1.261	1.261	10088
				Total Mass (kg): **10088**	



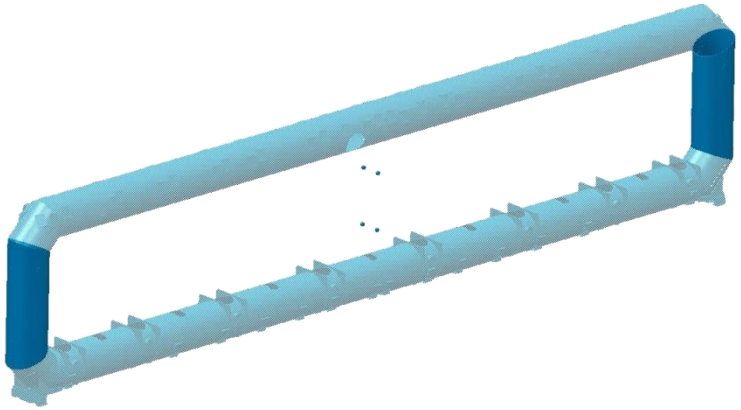
Volume 2, 4, 6, 8. Cryostat Corner

Number of Items	Material	Density (kg/m³)	Volume (m³)	Total Volume (m³)	Total Mass (kg)
4	Stainless Steel 304L	8000	0.042	0.168	1344
				Total Mass (kg): **1344**	



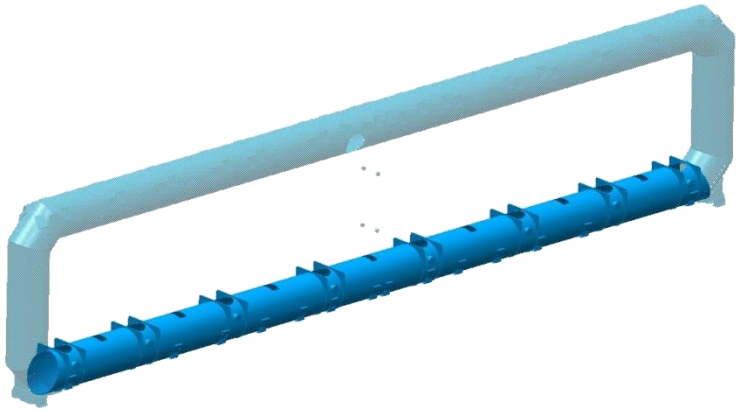
Volume 3, 7. Cryostat Short

Number of Items	Material	Density (kg/m³)	Volume (m³)	Total Volume (m³)	Total Mass (kg)
2	Stainless Steel 304L	8000	0.169	0.338	2704
				Total Mass (kg): **2704**	



Volume 5 Cryostat Long (bottom)

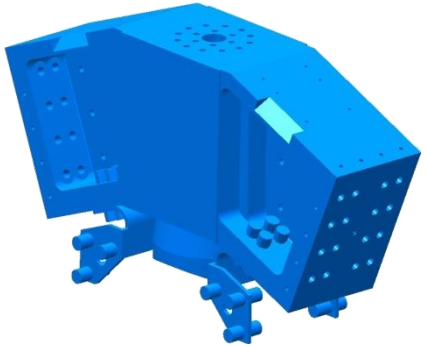
Number of Items	Material	Density (kg/m³)	Volume (m³)	Total Volume (m³)	Total Mass (kg)
1	Stainless Steel 304L	8000	1.421	1.421	11368
				Total Mass (kg): **11368**	



Decomposition and Mass analysis of COIL

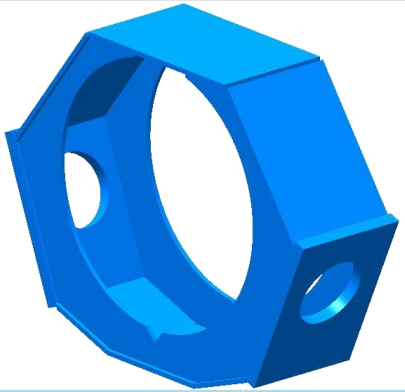
Volume 9. Voussoirs

Number of Items	Material	Density (kg/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kg)
8	Aluminum/Stainless Steel 304L	2650	0.552	4.416	12344.4
				Total Mass (kg): **12344.4**	



Volume 10. STEFFENERS

Number of Items	Material	Density (kg/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kg)
8	Stainless Steel 304L	8000	0.083	0.667	5336
				Total Mass (kg): **5336**	

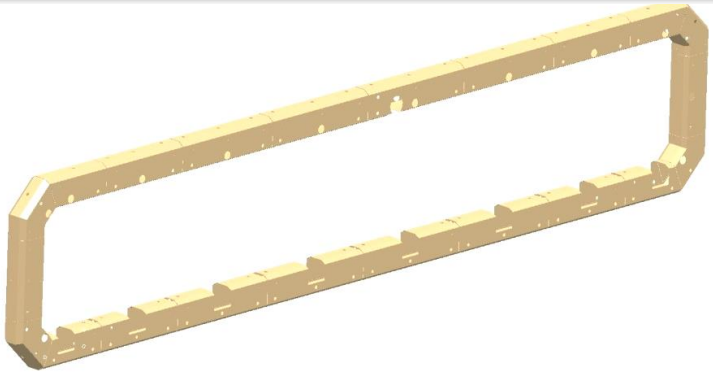


Volume 11. Ribs

Number of Items	Material	Density (kg/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kg)
7	Stainless Steel 304L	8000	0.086	0.603	4824
				Total Mass (kg): **4824**	

Volume 12. Thermal Shielding

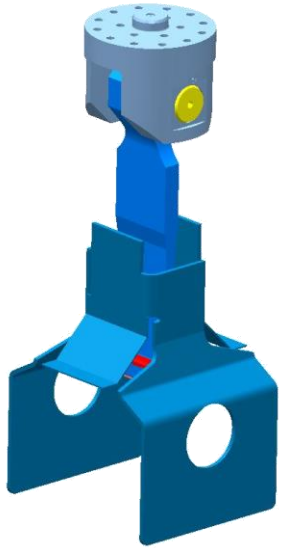
Number of Items	Material	Density (kg/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kg)
1	Aluminum 3003.H22	2740	0.7373	0.7373	2020
				Total Mass (kg): **2020**	



Decomposition and Mass analysis of COIL

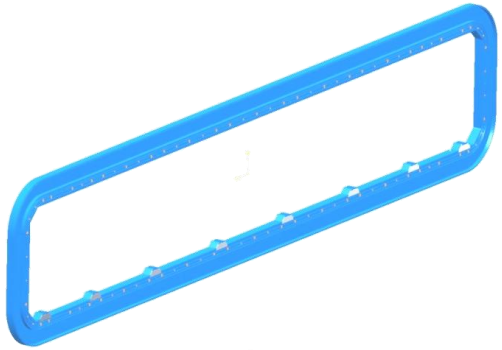
Volume 13. Tie Rod

Number of Items	Material	Density (kgs/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kgs)
8	Titan TA5E-ELI	4480	0.016	0.1280	573.44
8	Stainless Steel Z3 CN18-10	8000	0.028	0.2240	1792.0
8	Titan TA5E-ELI	4480	0.005	0.0400	179.2
8	Stainless Steel Z3 CN18-10	8000	0.0002946	0.0024	18.9
16	Stainless Steel Z3 CN18-10	8000	0.00007062	0.0011	9.0
16	Stainless Steel Z3 CND 17-12 Az	8000	0.00008187	0.0013	10.5
16	Stainless Steel Z3 CND 17-12 Az	8000	0.0001569	0.0025	20.1
8	Al uminum 1050 H22	2705	0.015	0.12	324.6
				Total Mass (kg): **2928**	



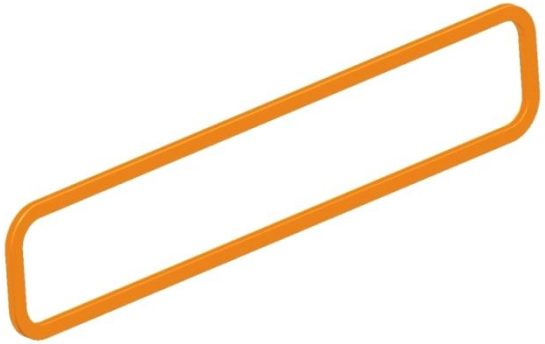
Volume 14. Coil casing

Number of Items	Material	Density (kg/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kg)
1	Aluminum 5083	2650	6.959	6.959	18440.82
86	Aluminum 7075 T73	2810	0.00022	0.0189	53.1
16	Aluminum 5083	2650	0.0002	0.032	84.8
				Total Mass (kg): **18578.7**	



Volume 15. Coil casing part

Number of Items	Material	Density (kg/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kg)
1	Aluminum 5083 h112	2660	1.866	1.866	4963.6
				Total Mass (kg): **4963.6**	



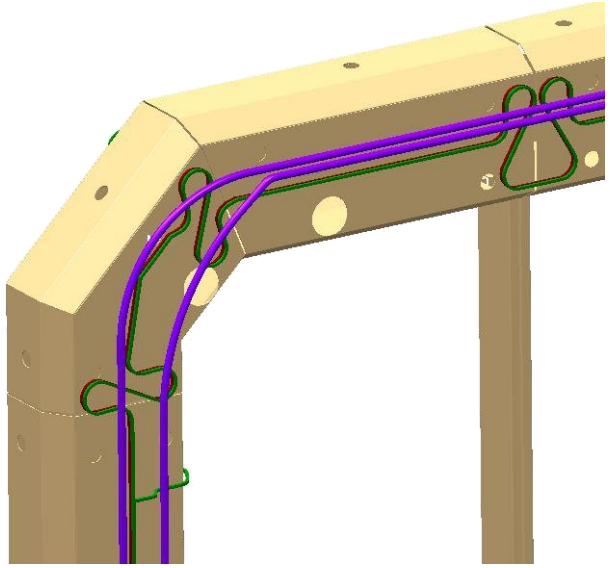
Decomposition and Mass analysis of COIL

Volume 16

Number of Items	Material	Density (kg/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kg)
1	Aluminum	2650	4.367	4.367	11572.55
				Total Mass (kg): **11572.55**	

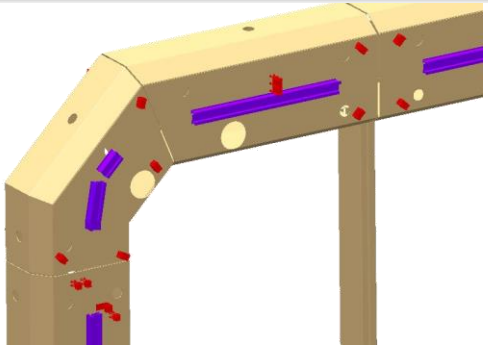
Volume 17. Services

Number of Items	Material	Density (kg/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kg)
1	Aluminum 1050	2705	0.0640	0.0640	173.1
1	Stainless Steel 304L	8000	0.0040	0.0040	32.0
1	Stainless Steel 304L	8000	0.0040	0.0040	32.0
1	Stainless Steel 304L	8000	0.0006	0.0006	4.6
2	Stainless Steel 304L	8000	0.0003	0.0005	4.1
1	Stainless Steel 304L	8000	0.0005	0.0005	4.1
1	Stainless Steel 304L	8000	0.0004	0.0004	3.2
				Total Mass (kg): **253**	



Volume 18. Supports of Services

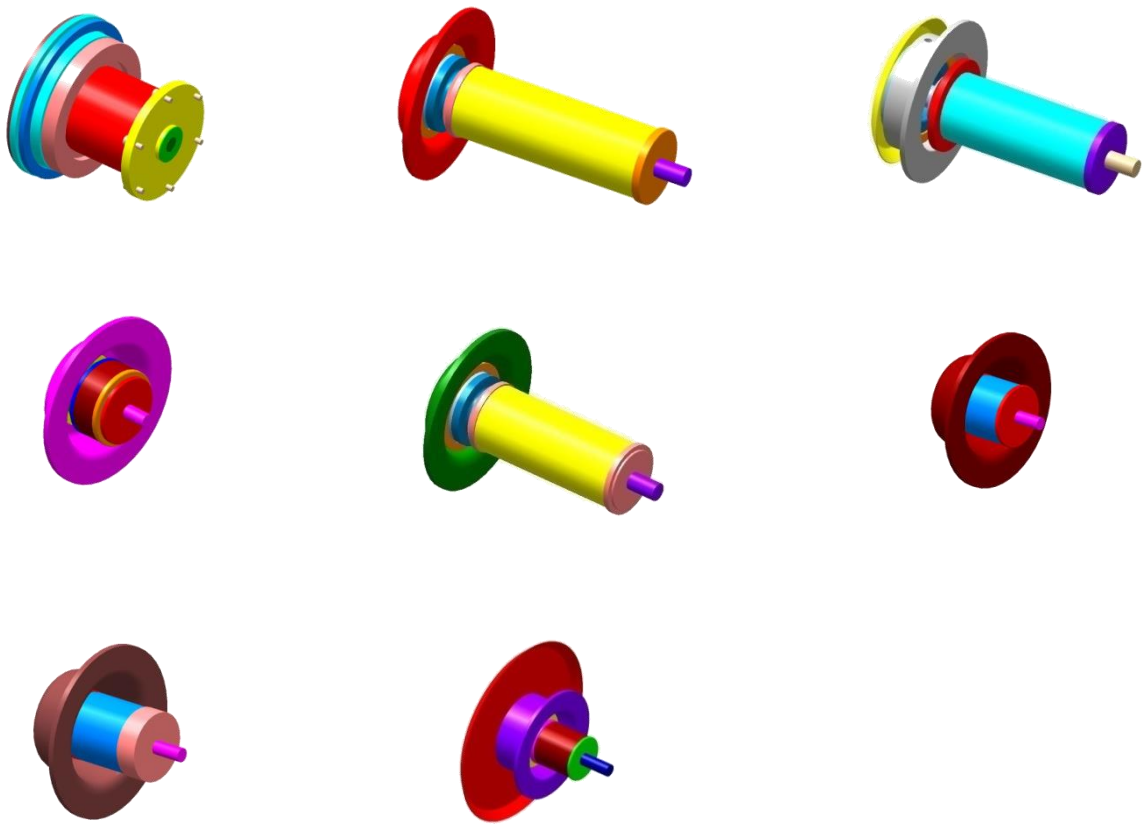
Number of Items	Material	Density (kg/m^3)	Volume (m^3)	Total Volume (m^3)	Total Mass (kg)
139	Multiple*		0.000085	0.01	31.72
81	Multiple*		0.00018	0.01479	22.1
1	Aluminum 1050	2705	0.179	0.179	484.2
				Total Mass (kg): **538**	



Decomposition and Mass analysis of COIL

Volume 19. Supports of Coil

Number of Items	Material	Density (kg/m³)	Volume (m³)	Total Volume (m³)	Total Mass (kg)
108	Aluminum 5083 F	2660	0.0001048	0.0113184	30.1
108	Stainless Steel 304L	8000	0.00004723	0.00510084	40.8
108	Stainless Steel 304L	8000	0.00006412	0.00692496	55.4
100	Stainless steel AISI 304 L	8000	0.00002734	0.002734	21.9
52	Aluminum 5083 F	2660	0.0001228	0.0063856	17.0
58	Stainless Steel 304L/316L	8000	0.0000223	0.0012934	10.3
58	Stainless Steel 304L/316L	8000	0.00002888	0.00167504	13.4
28	Stainless Steel 304L/316L	8000	0.00005369	0.00150332	12.0
28	Aluminum 2024 T3	2780	0.0001857	0.0051996	14.5
44	Stainless Steel AISI 304 L	8000	0.0004261	0.0187484	150.0
44	PERMAGLAS TE630	1850	0.0005058	0.0222552	41.2
44	Aluminum	2700	0.0007714	0.0339416	91.6
44	Aluminum	2700	0.0005786	0.0254584	68.7
44	Aluminum	2700	0.0006777	0.0298188	80.5
44	Aluminum	2700	0.0001206	0.0053064	14.3
44	Aluminum	2700	0.0005685	0.025014	67.5
72	Stainless Steel 304L/316L	8000	0.00008567	0.00616824	49.3
72	Aluminum 2024 T3	2780	0.0001163	0.0083736	23.3
72	Stainless Steel 304L/316L	8000	0.00003998	0.00287856	23.0
72	Stainless Steel 304L/316L	8000	0.00009161	0.00659592	52.8
72	Stainless Steel AISI 304L	8000	0.00002725	0.001962	15.7
72	PERMAGLAS TE630	1850	0.00007735	0.0055692	10.3
				Total Mass (kg):	**903.7**



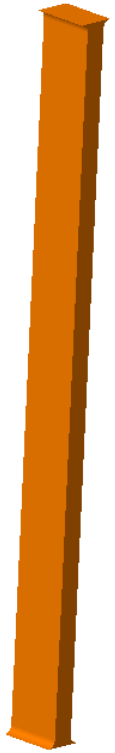
Decomposition and Mass analysis of COIL

Volume 20. Ribs of Thermal Shielding

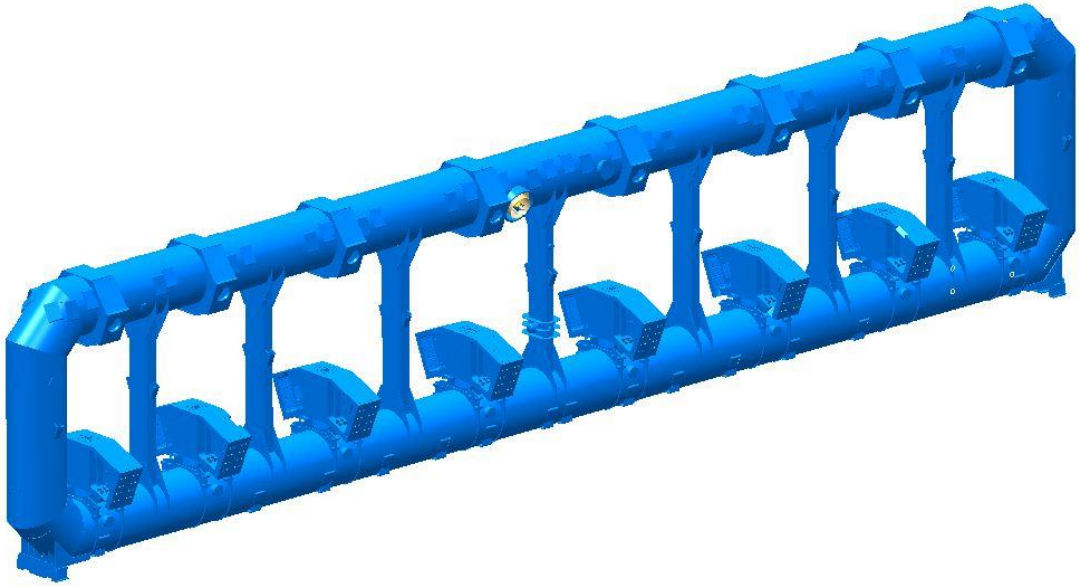
Number of Items	Material	Density (kg/m³)	Volume (m³)	Total Volume (m³)	Total Mass (kg)
7	Aluminum 3003.H22	2740	0.0144	0.101	276
				Total Mass (kg): **276**	

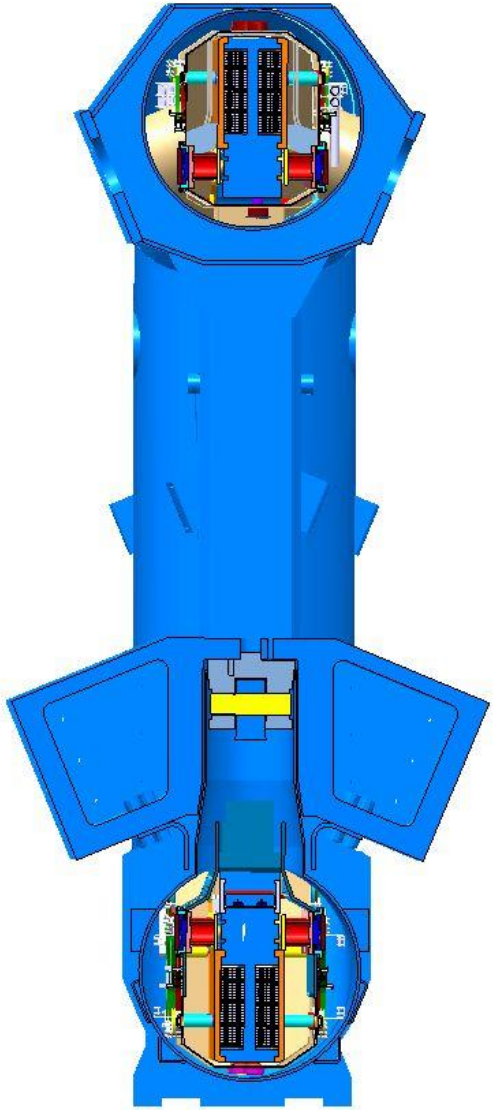
Volume 21. Ribs of Coil casing

Number of Items	Material	Density (kg/m³)	Volume (m³)	Total Volume (m³)	Total Mass (kg)
7	Aluminum 5083	2650	0.101	0.707	1873
				Total Mass (kg): **1873**	



Decomposition and Mass analysis of COIL

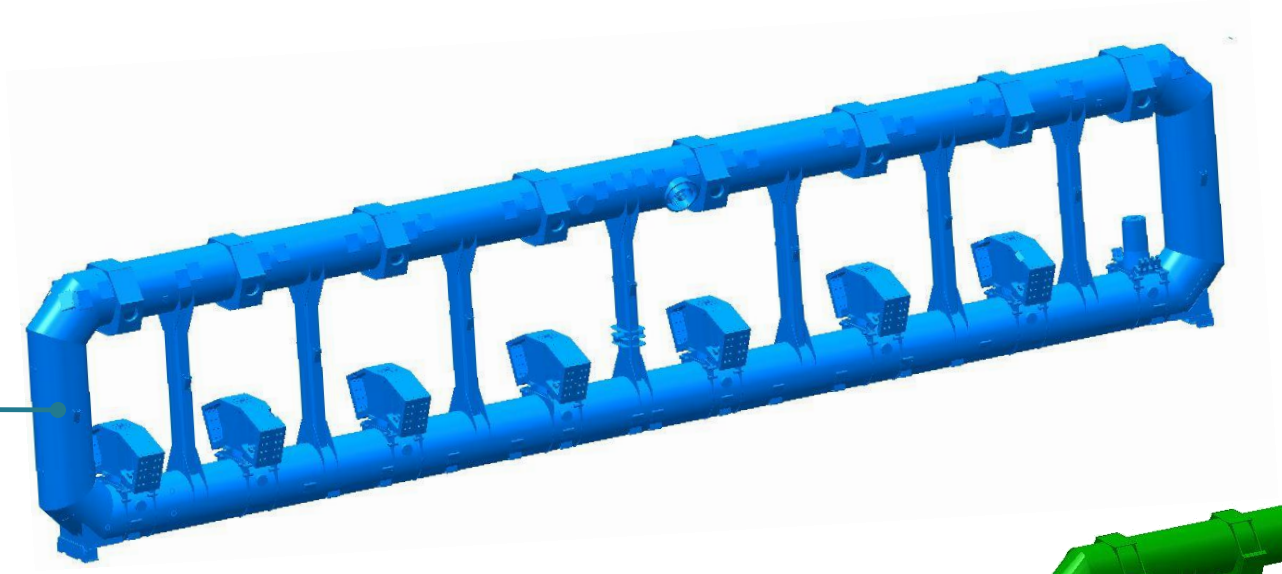


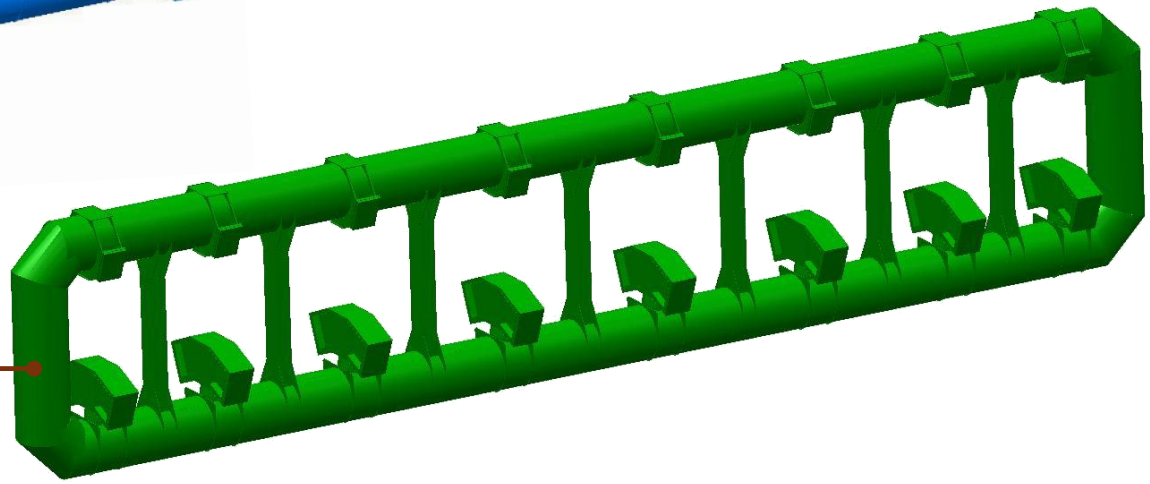


91’914 kg = 10’088 kg + 1’344 kg + 2704 kg + 11’368 kg + 12’344 kg + 5’336 kg + 4’824 kg + 2’020 kg + 2’928 kg + 18’578.7 kg + 4963.6 kg + 11’572.55 kg + 253 kg + 538 kg + 903.7 kg + 276 kg + 1’873 kg

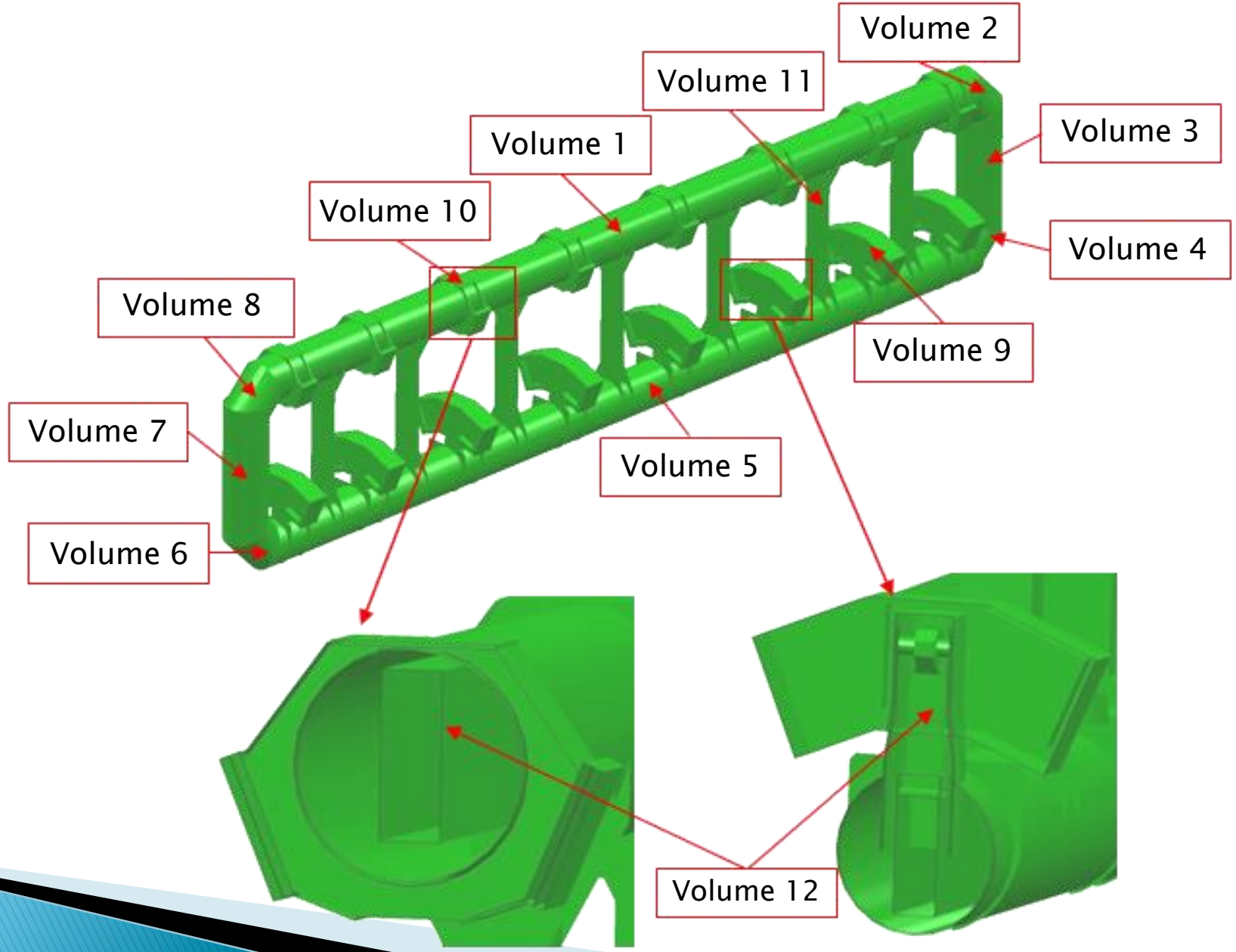
Total mass of COIL- 91’914 kg

III. Compare analysis between CATIA and Geant4 COILs





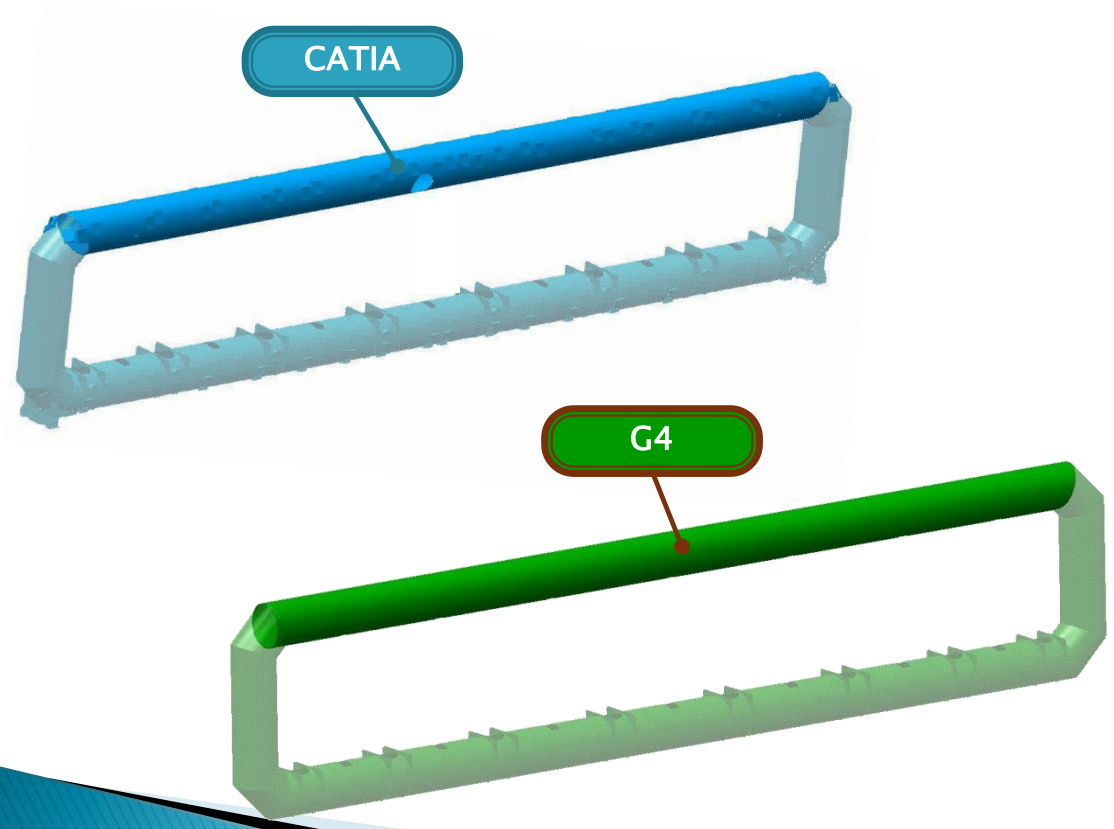
Compare analysis between CATIA and Geant4 COILs



Compare analysis between CATIA and Geant4 COILs

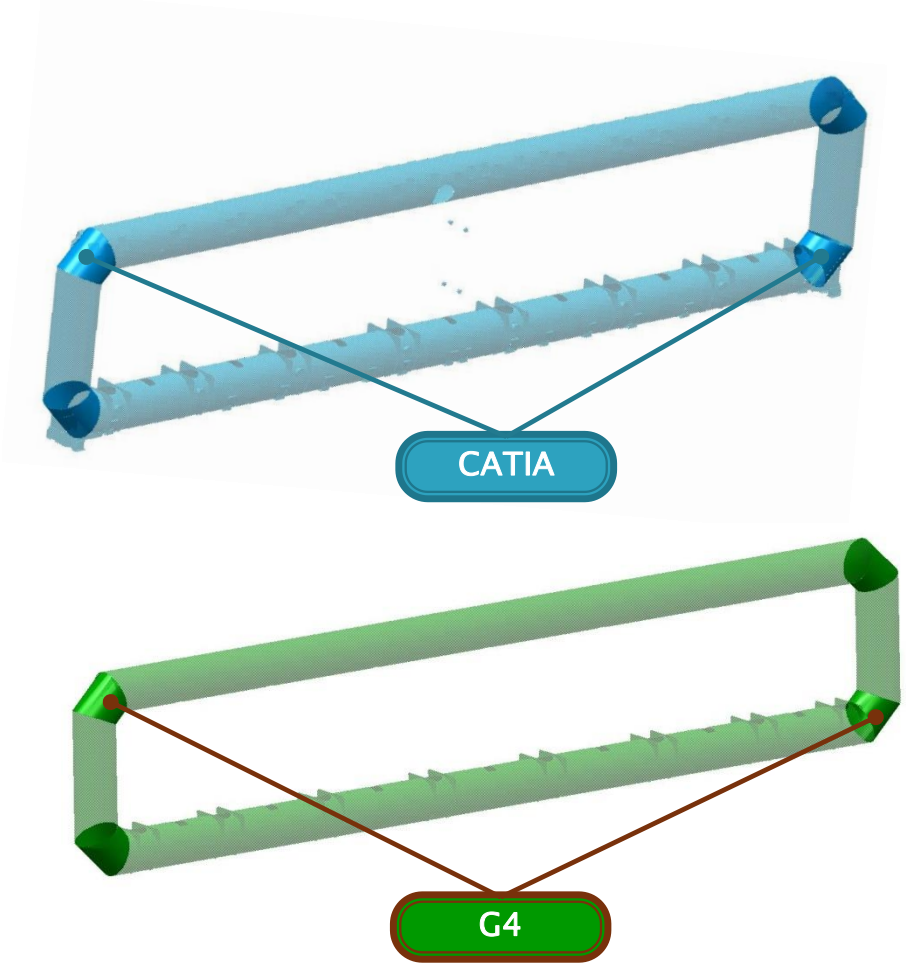
Volume 1. Cryostat Long (Top)

Model	Material	Density (kg/m3)	Volume (m3)	**Mass (kgs)**	Difference (kgs)
CATIA	SSteel 304L	8000	1.261	**10088**	
G4	Iron	7870	1.137	**8950**	-1138



Volume 2, 4, 6, 8. Cryostat Corner

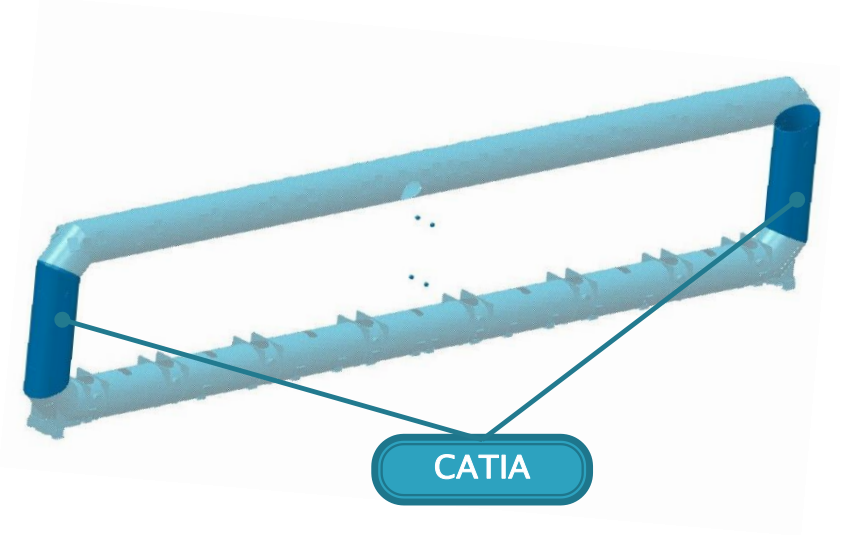
Model	Material	Density (kg/m3)	Volume (m3)	**Mass (kgs)**	Difference (kgs)
CATIA	SSteel 304L	8000	0.168	**1344**	
G4	Iron	7870	0.169	**1330**	-14

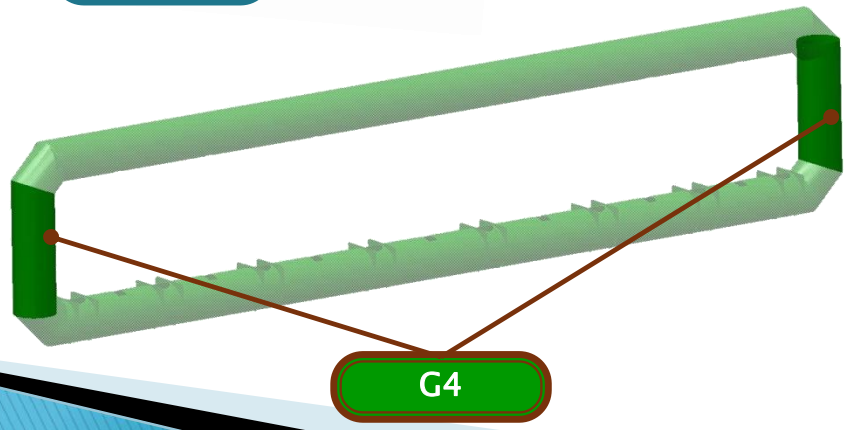


Compare analysis between CATIA and Geant4 COILs

Volume 3, 7. Cryostat Short

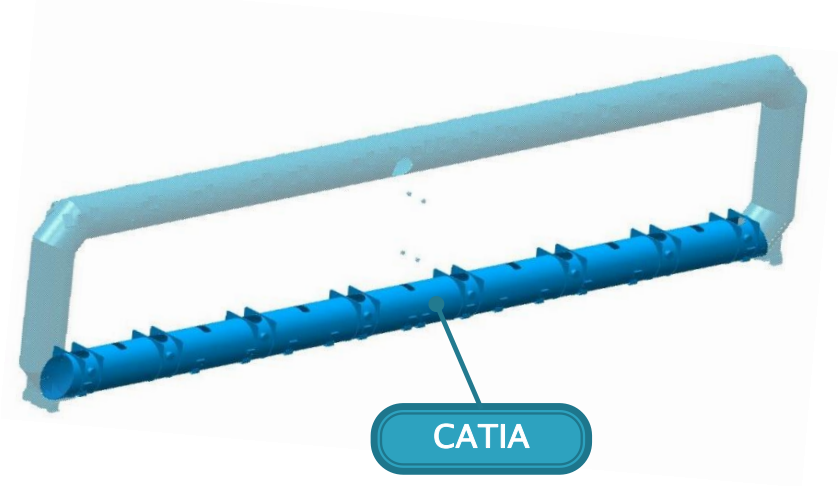
Model	Material	Density (kg/m3)	Volume (m3)	**Mass (kgs)**	Difference (kgs)
CATIA	SSteel 304L	8000	0.338	**2704**	
G4	Iron	7870	0.162	**2546**	-158

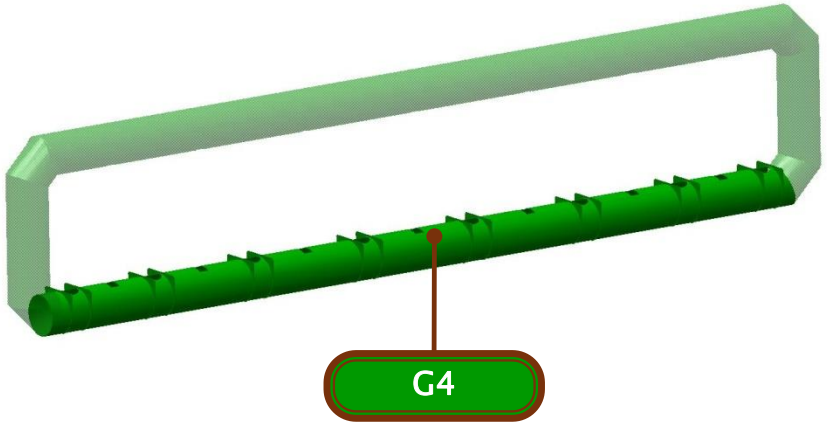




Volume 5 Cryostat Long (bottom)

Model	Material	Density (kg/m3)	Volume (m3)	**Mass (kgs)**	Difference (kgs)
CATIA	SSteel 304L	8000	1.421	**11368**	
G4	Iron	7870	1.223	**9630**	-1738

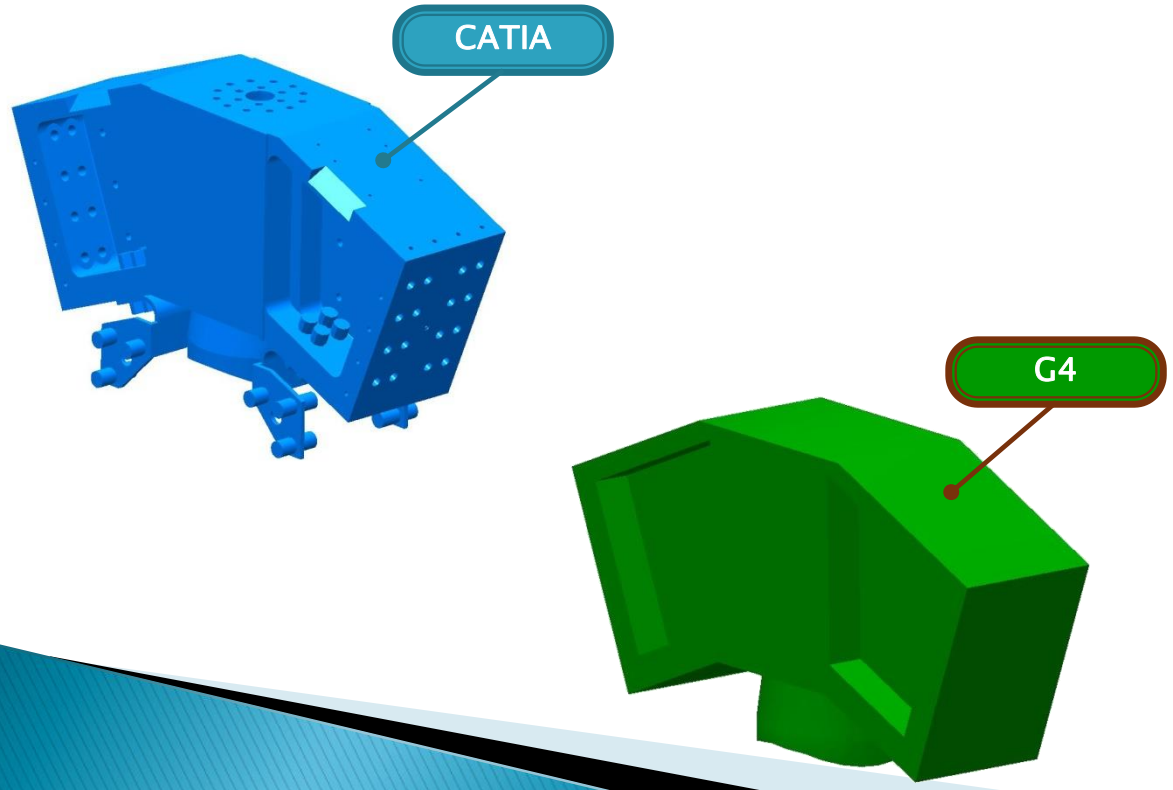




Compare analysis between CATIA and Geant4 COILs

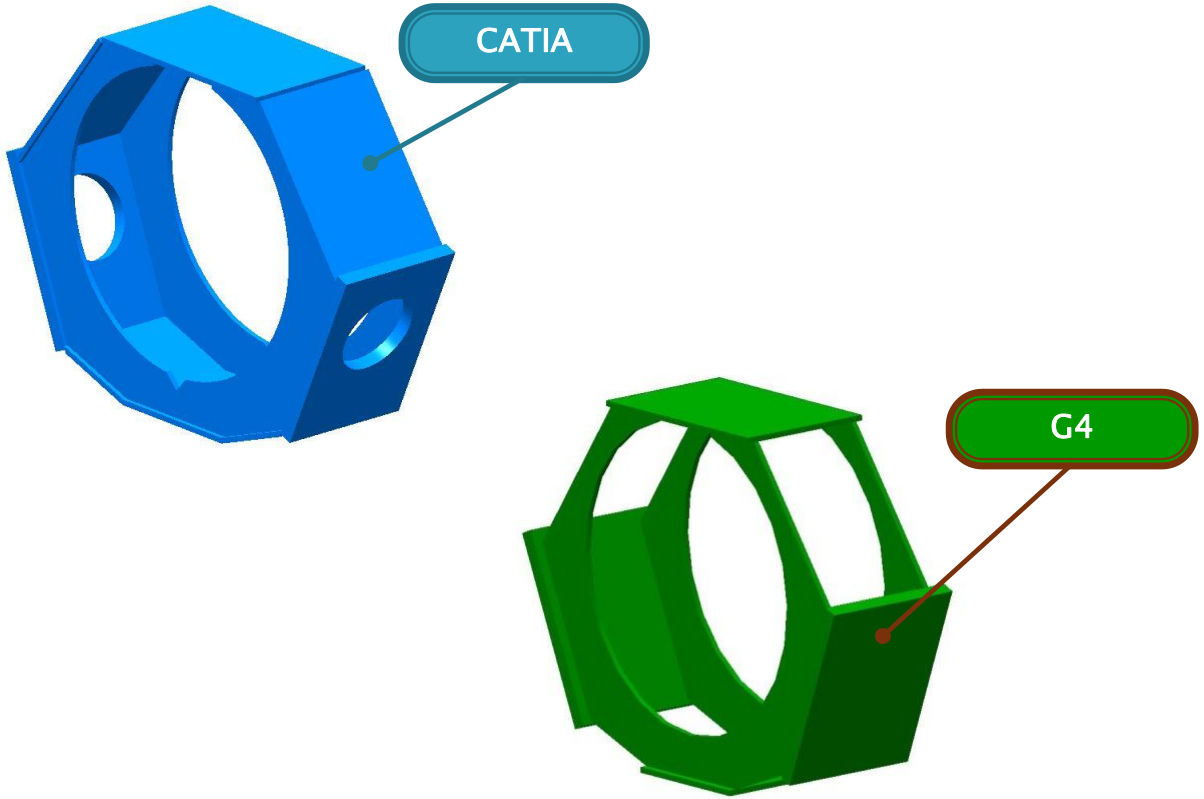
Volume 9. Voussoirs

Model	Material	Density (kg/m3)	Volume (m3)	**Mass (kgs)**	Difference (kgs)
CATIA	Ssteel 304L/Al	8000/2650	4.416	**12344**	
G4	Iron/Al	7870/2700	4.573	**13255**	+911



Volume 10. STEFFENERS

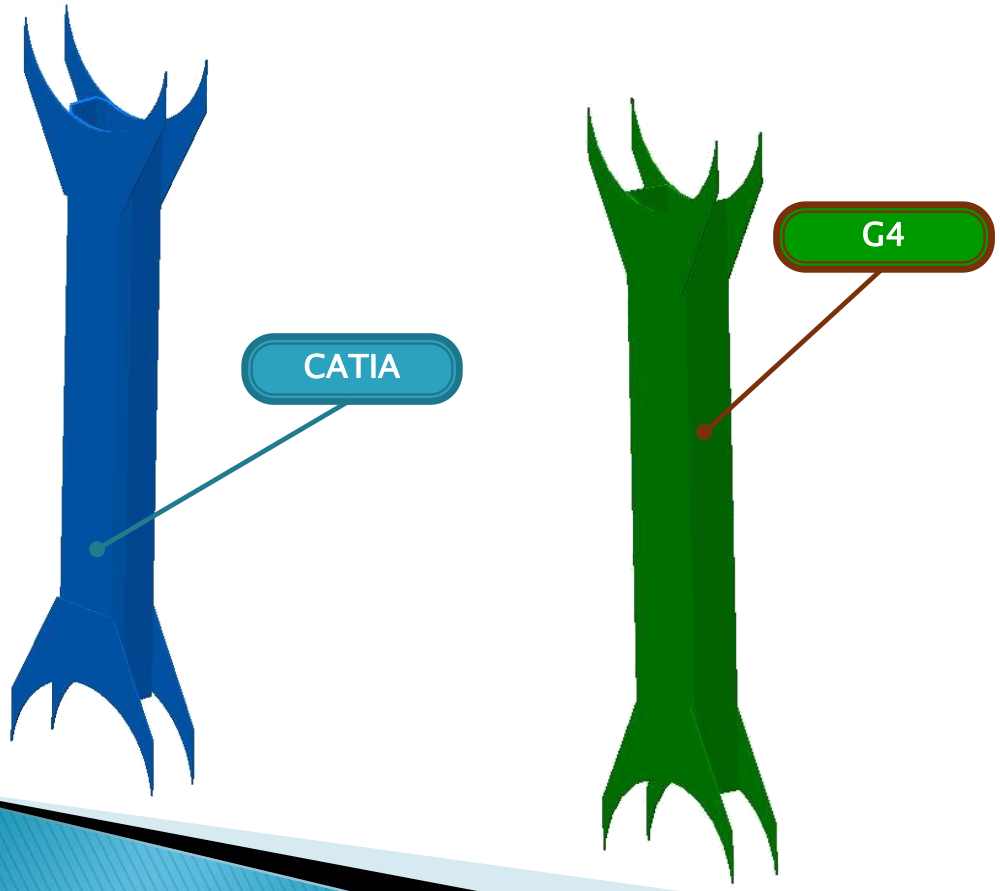
Model	Material	Density (kg/m3)	Volume (m3)	**Mass (kgs)**	Difference (kgs)
CATIA	Ssteel 304L	8000	0.667	**5336**	
G4	Iron	7870	0.579	**4558**	-778



Compare analysis between CATIA and Geant4 COILs

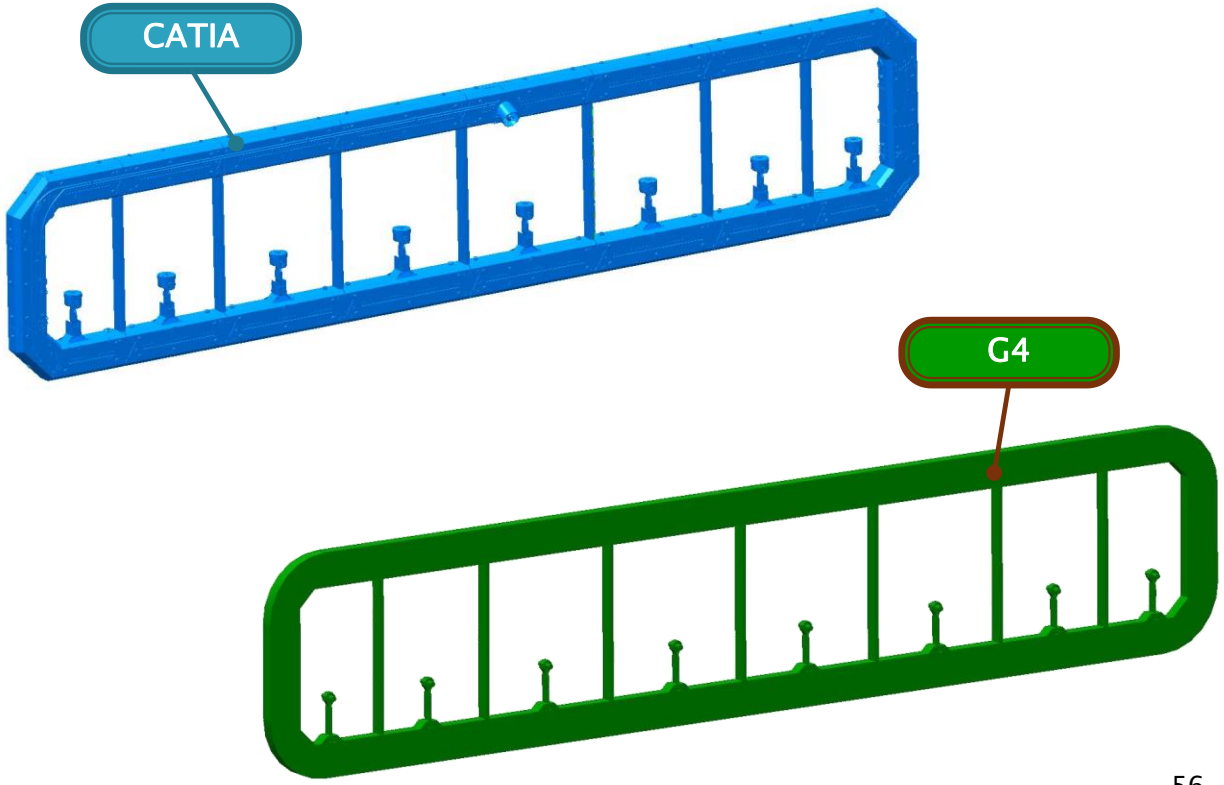
Volume 11. Ribs

Model	Material	Density (kg/m3)	Volume (m3)	**Mass (kgs)**	Difference (kgs)
CATIA	Ssteel 304L	8000	0.603	**4824**	
G4	Iron	7870	0.454	**3576**	-1248



Inner Parts

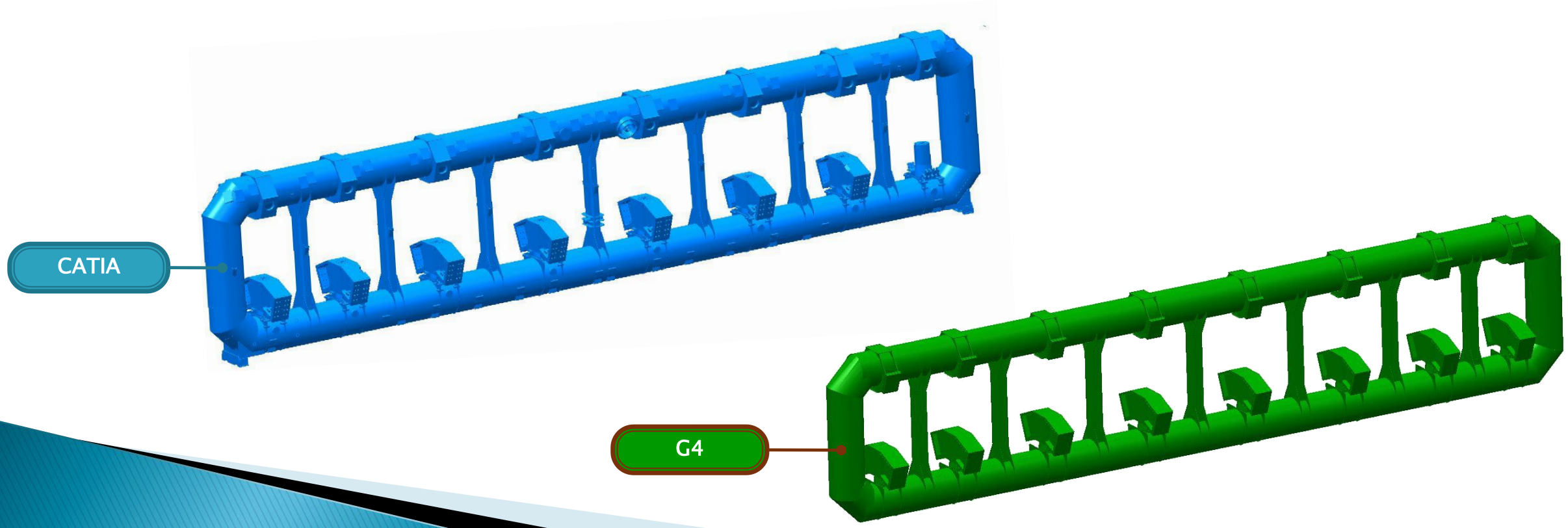
Model	Material	Density (kg/m3)	Volume (m3)	**Mass (kgs)**	Difference (kgs)
CATIA	Materials*		15.885	**44122**	
G4	Aluminum	2700	13.558	**36607**	-7299.5



Compare analysis between CATIA and Geant4 COILs

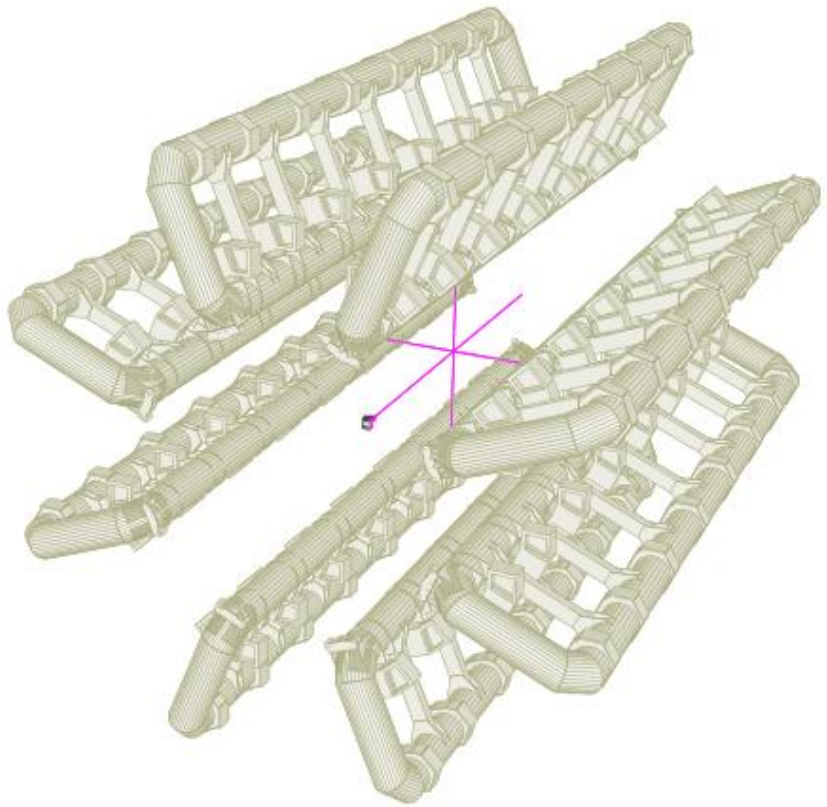
Model	Volume (m3)	**Mass (kgs)**	Difference (kgs)
CATIA	24.75	**91'914.5**	
G4	22.13	**80'452**	-11'462.5

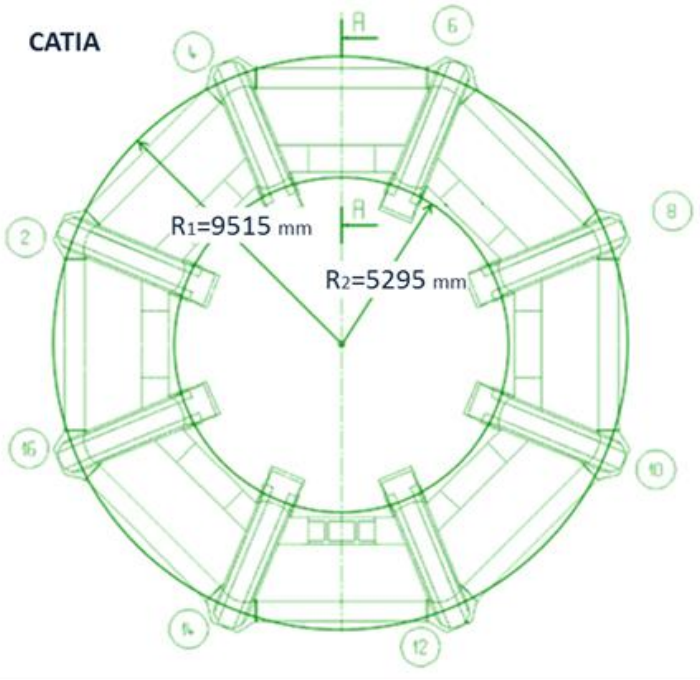
$$\Delta_{\Sigma/Dif} = \Delta_1 + \Delta_2 + \Delta_3 + \Delta_4 + \Delta_5 + \Delta_6 + \Delta_7 + \Delta_8$$
$$= 1'138\ kg + 14\ kg + 158\ kg + 1'738\ kg - 911\ kg + 778\ kg + 1'248\ kg + 7'299.5\ kg = 11'462.5 kg$$

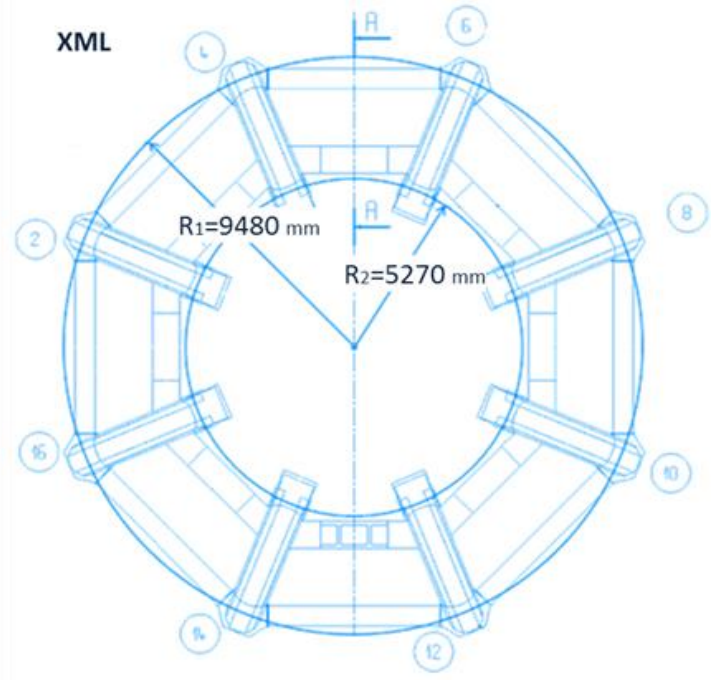


IV. Integration conflict checking

Integration conflict checking







$$\Delta_{R1} = R1_{Catia} - R1_{Geant4} = 9'515\ mm - 9'480\ mm = 35\ mm$$

$$\Delta_{R2} = R2_{Catia} - R2_{Geant4} = 5'295\ mm - 5'270\ mm = 25\ mm$$

Conclusion of Hypothesis II

1. Hypothesis #02 has been confirmed: The geometry descriptions in the simulation are not consistent with design geometry description
2. The COIL was divided into 21 separate volume
3. Volume and Weight analyses of the COIL have been implemented; Comparison of the volume and weight between CATIA and XML descriptions have been implemented
4. Important differences have been discovered for the following volumes: Cryostat Bottom missing 1’738 kg., Rib missing 1’248 kg., Thermal Shielding missing 2’020 kg., Inner parts of the COIL missing 5’297.5 kg
5. It is was found that there was not Thermal Shielding in the Geant4 description
6. 11.5 tones missed materials were discovered for Geant 4 geometry
7. 35mm dispositioning of the COIL has been discovered

Evaluation of Research

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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
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European Laboratory for Particle Physics

ATLAS EXPERIMENT

Report on the presentations by Niko TSUTSKIRIDZE
(Technical University of Georgia) on

Development of Loop for ATLAS Simulation Packages

We attended Niko Tsutskiridze's presentations at CERN on 2 and 15 July 2014 and discussed the material that was shown. This work was performed during his stay at CERN from 1st February to 31st July 2014, and in the context of the PhD thesis activity on the development of methods and tools for the investigation of the Geant4 geometry in ATLAS simulation packages. This work is needed by the ATLAS Collaboration in order to have an accurate geometrical representation of the detector and therefore the best possible simulation and reconstruction results.

The "Simulation Loop" is a way to cross-check the geometry representations used by several packages: Geant4, GeoModel, AGDD/Persint (XML representation), SmartTeam. Converters have been developed to and from each of these applications with respect to the CATIA geometrical database. They are used to bring all the geometries into the same framework in order to compare them for mismatches, overlaps, and differences in total dimensions and/or mass of the components.

The presentations covered the development of the necessary geometrical transformations and showed several examples of the application of this code to geometrical shapes that are part of the ATLAS Muon System description. Each geometrical shape is first assigned to one of a small number of topological categories according to its geometrical properties, whether it is isolated or part of a composite structure, and if there are cut-outs or not. Then for each category automatic comparisons have been developed and can be performed systematically.

We consider Niko Tsutskiridze's work of the highest quality and wish him a successful career in computational engineering after the completion of his PhD thesis work.

Geneva, 23 July 2014

Dr. Richard Mount (SLAC, Stanford, USA), Computing Coordinator

Dr. Eric Lançon (CEA, Saclay, France), Deputy Computing Coordinator

Dr. John Apostolakis (CERN, Geneva, Switzerland), Geant4 Geometry

Dr. Dario Barberis (Genova University/INFN, Genova, Italy), Database Coordinator

Dr. John Chapman (Cambridge University, Cambridge, UK), Simulation Technical Coordinator

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Dr. Jochen Meyer (CERN, Geneva, Switzerland), Muon Software Coordinator

European Organization for Nuclear Research
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ATLAS EXPERIMENT Nikhef

Statement on the PhD thesis with the subject

Development of the Geometrical Description of the ATLAS Detector for the Simulation and Reconstruction Software Packages

submitted by
Niko TSUTSKIRIDZE (Technical University of Georgia)

The developed and actually realized procedures presented in the above-mentioned thesis are of high interest in themselves, as well as making further investigations possible. With the newly implemented ability to load geometrical representations as used inside the ATLAS simulation workflow into a program which is also capable of displaying the models designed for construction, it is possible for the first time to perform direct comparisons of these two descriptions. As a matter of principle the simulated detector geometry does not match what can be found in the technical drawings, however, the amount of discrepancies should be rather low or at least be well motivated.

The work done in this thesis allowed the identification of various examples for which this is not the case. In order to achieve a better agreement between simulated and real data, the differences listed in the thesis were reduced in later implementations of the detector description used during simulation. Therefore the results of this part of the thesis could even have impact on Physics results published by the ATLAS collaboration because they potentially contribute to a reduction of systematic uncertainties. Furthermore the applied techniques suggested that unexpected precision issues were occurring at some point during the geometry parsing. Additional checks are required to identify their source.

Even though the second major outcome of the performed studies is of a purely technical nature it has quite some relevance as well. The categorization of volume types employed in the simulation and investigation into different methods of implementing them is a strong basis for future research to follow. The presented result will be greatly helpful for studies regarding the stability and technical performance of the simulation software. Modifying the implementation of volumes in the various ways pointed out in this thesis and monitoring for example the resulting changes in CPU time could lead to interesting conclusions about the performance.

In summary, the research done in the context of this thesis uncovered some flaws which required immediate improvement. Additionally there were interesting indications for unexpected features to be followed up on. Finally it gives a good basis for further studies within the ATLAS simulation software environment.

Dr. Jochen Meyer (Nikhef, Amsterdam, Netherlands)
ATLAS Muon Software Coordinator

Thank you for your attention!

Niko Tsutskiridze

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