Geometry Infrastructure Quality Analyses

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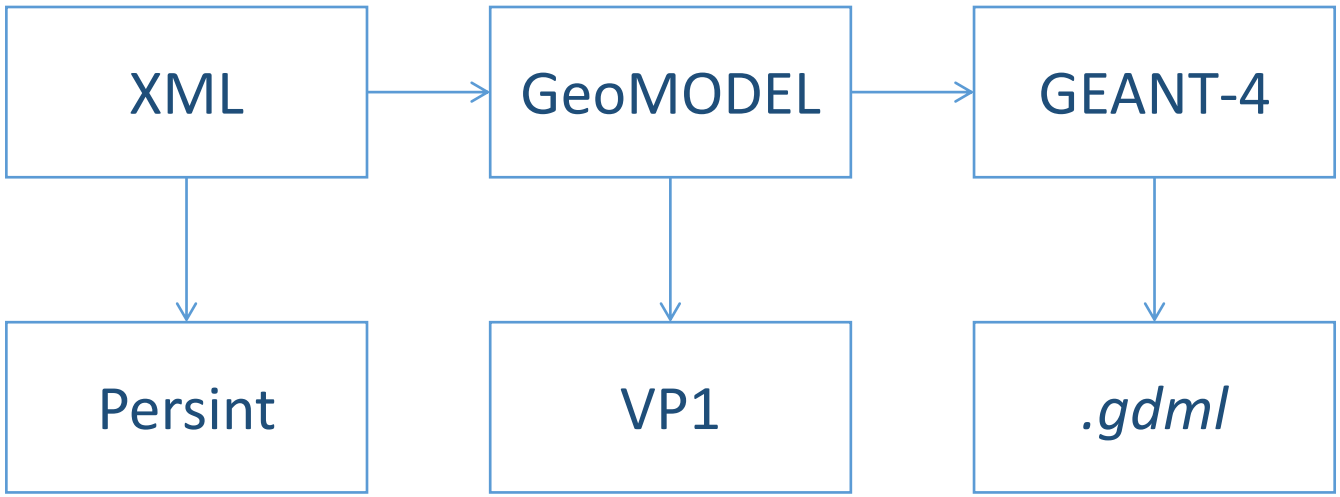
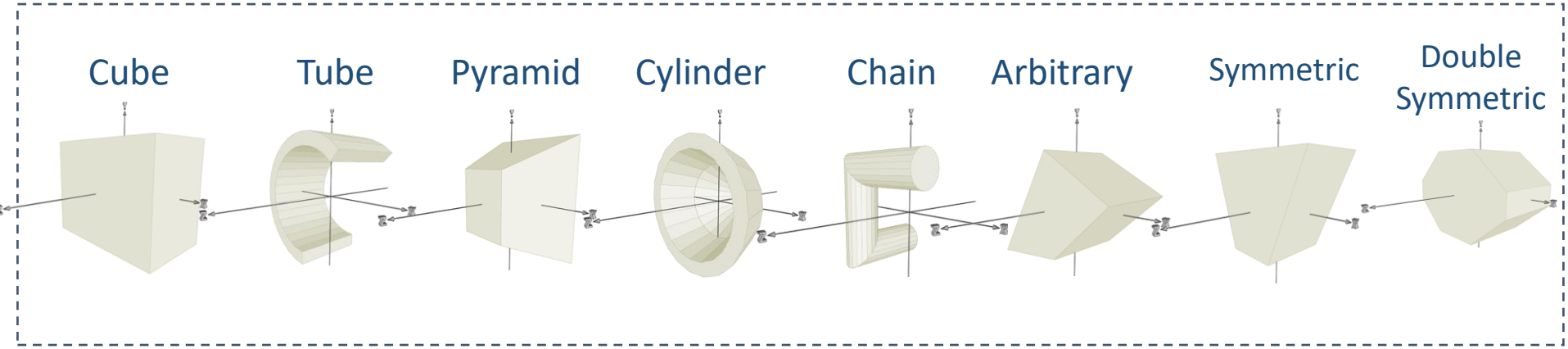
Structure of Geometry Infrastructure



XML Platform

- Standard Primitives and Polygon Methods

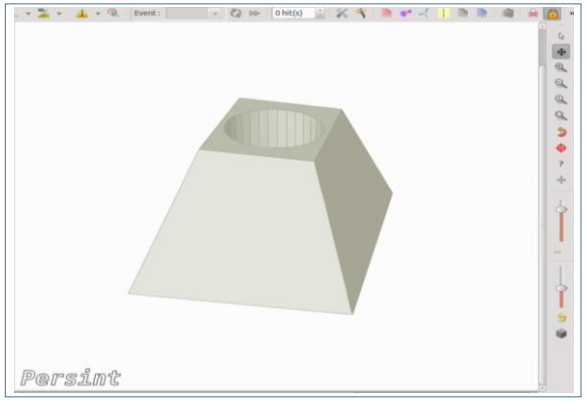


- Transactions: Move, Rotate
- Boolean Operations: Subtraction, Union, Intersection

Code Example for *Pyramid* with cut

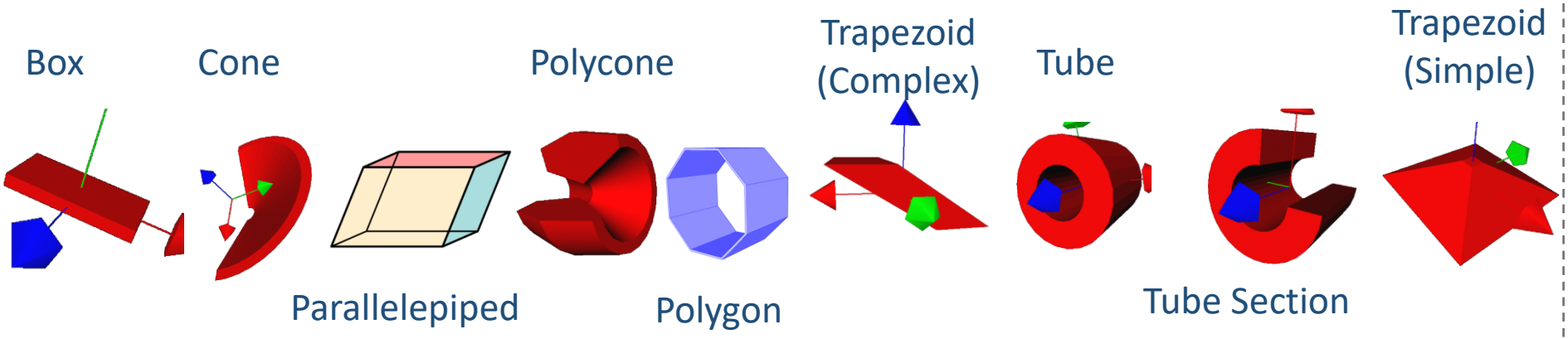
```
<trd name="Pyramid"  material="Aluminium"  Xmp_Ymp_Z="4000.; 2000.; 5000.; 2500.; 3000." />
<tubs name="Tube" material="Aluminium" Rio_Z="0.; 900.; 5200."   nbPhi="32" />

<subtraction name="Pyramid_Test" >
   <posXYZ  volume="Pyramid"   X_Y_Z=" 0; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube"  X_Y_Z=" 0. ; 0. ; 0. "  rot=" 0. ; 0. ; 0. "/>
</subtraction>
```

Persint Screenshot



GeoMODEL Platform

- Standard Primitives and Polygon Methods

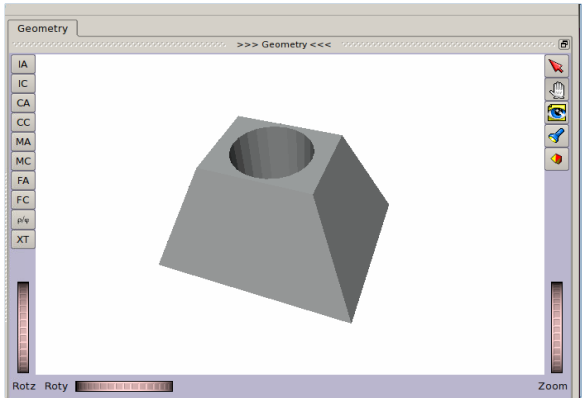


- Transactions: Move, Rotate
- Boolean Operations: Subtraction, Union, Intersection

Code Example for *Pyramid* with cut

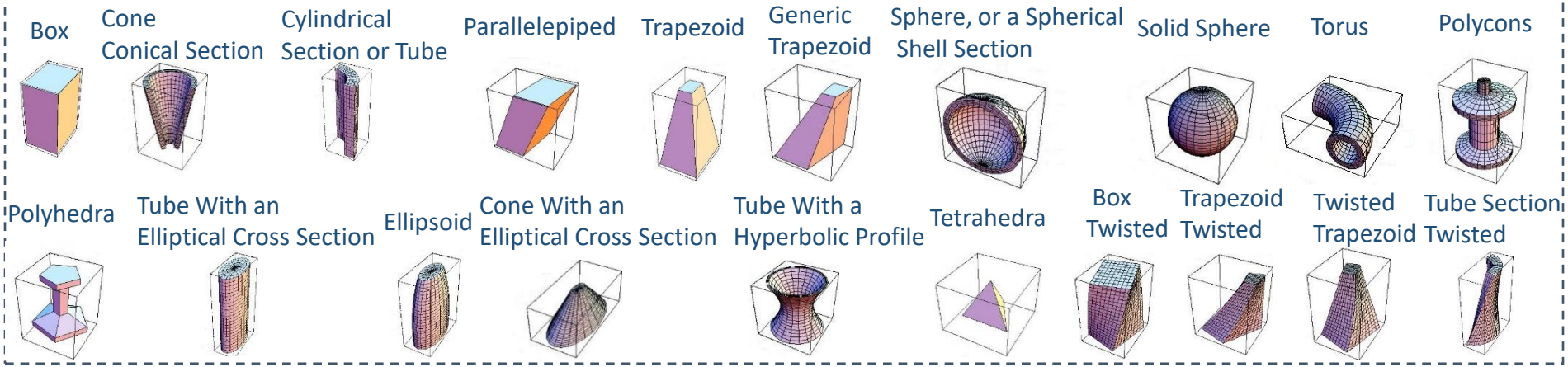
```
129
130 GeoTrd * Trapezoir_Pr = new GeoTrd(2000.*CLHEP::mm, 1000.*CLHEP::mm,2500.*CLHEP::mm,
131                                    1250.*CLHEP::mm, 1500.*CLHEP::mm );
132 GeoTube * Tube = new GeoTube( 0.*CLHEP::mm, 900.*CLHEP::mm, 2600.*CLHEP::mm);
133
134 const GeoShape & ExampleN55_subtr = Trapezoir_Pr->subtract((*Tube));
135
136 GeoLogVol* ExampleN55_Log = new GeoLogVol("ExampleN55",&ExampleN55_subtr,Aluminium);
137 GeoPhysVol* ExampleN55_Log_Phis = new GeoPhysVol(ExampleN55_Log);
138
```

VP1 Screenshot



GEANT-4 Platform

- Standard Primitives and Polygon Methods

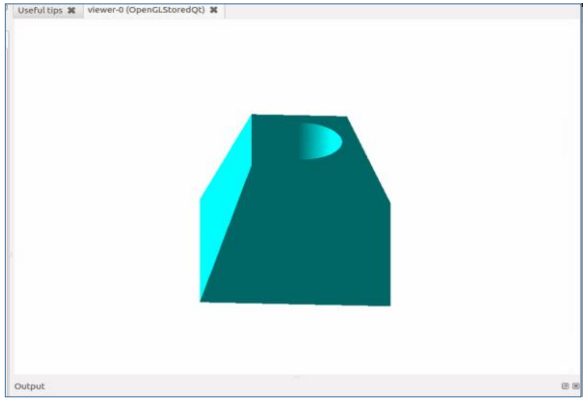


- Transactions: Move, Rotate
- Boolean Operations: Subtraction, Union, Intersection

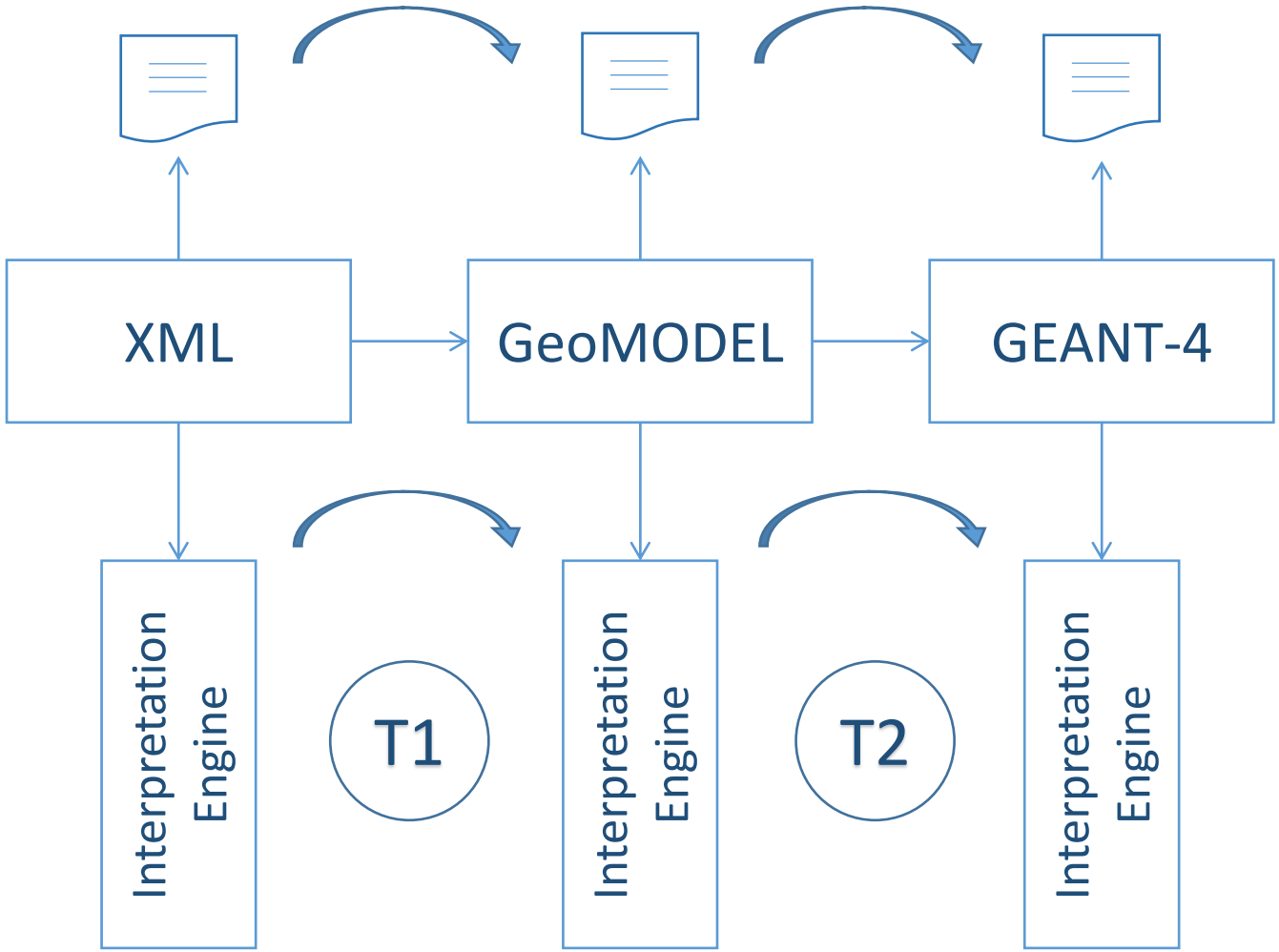
Code Example for *Pyramid* with cut

```
150
151
152 G4Tubs* solidShape1 = new G4Tubs("Shape1", 0.*mm, 900.*mm,  5200.*mm, 0.*deg, 360.*deg);
153
154 G4Trd* solidShape2 = new G4Trd("Shape2",
155              2000.*mm, 1000*mm,
156              2500*mm, 1250*mm, 1500*mm);
157 G4SubtractionSolid* b1minusC12 =   new G4SubtractionSolid("Box-Cylinder", solidShape2, solidShape1);
158
159 G4LogicalVolume* b1minusC1 = new G4LogicalVolume(b1minusC12,
160                         shape2_mat,
161                         "Shape2");
162
163 new G4PVPlacement(0, pos2, b1minusC1,"Shape2", logicEnv, false, 0, checkOverlaps);
164
```

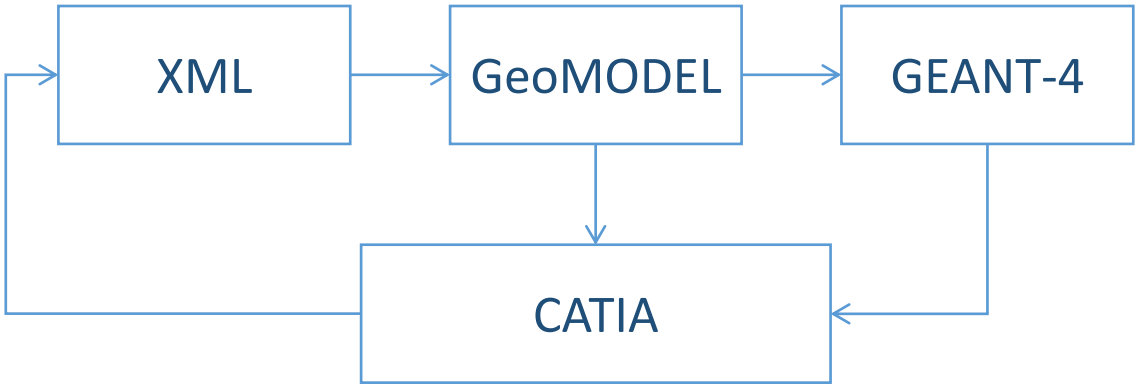
OpenGL Screenshot

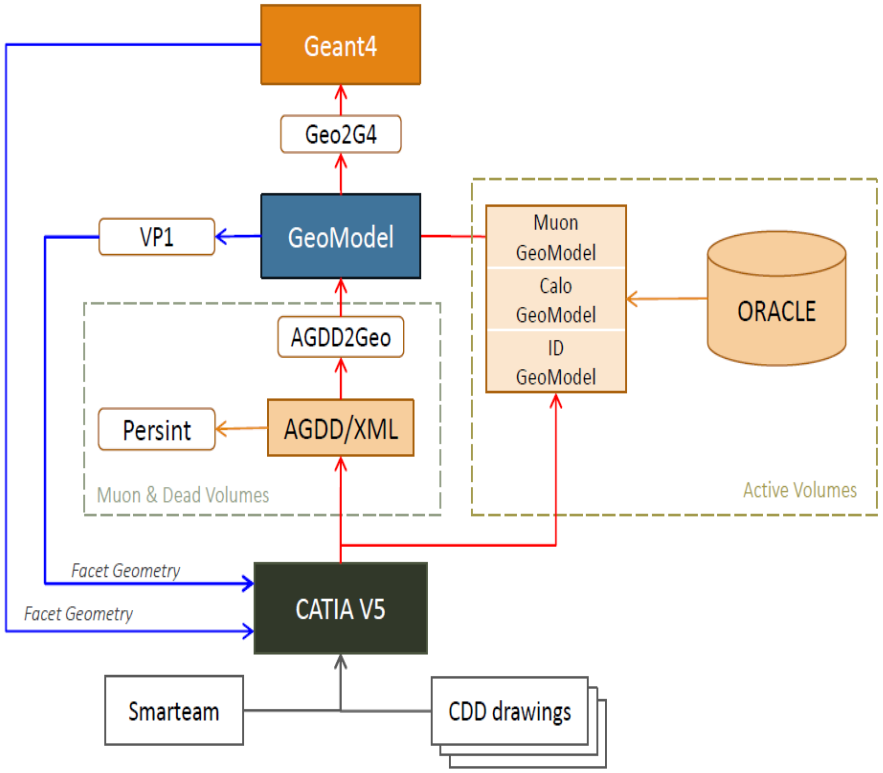


Geometry Transformations



Geometry Infrastructure with CATIA





Several Chains have been developed:

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

Objectives of Analyses

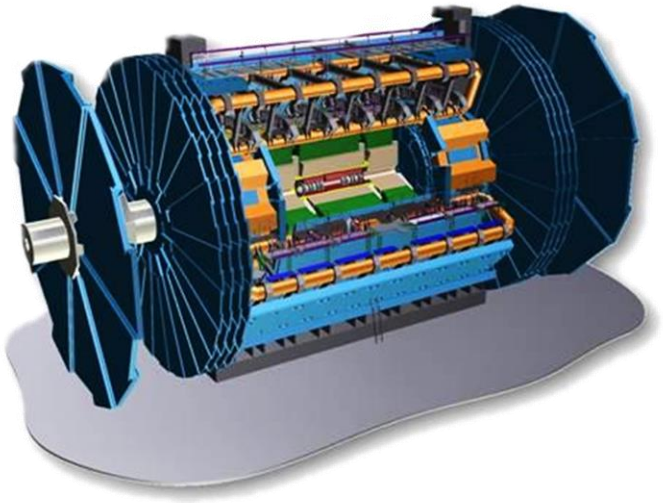
- Investigation quality of T1/T2 geometry Transformations

Methodology of Analyses

1. Typization of geometry of Detector components
2. Selection Methods for description
3. Test runs of test examples
4. Case study of transactions
5. Systematization of results
6. Making Conclusions

Part I. Typization of Geometry

I. Typization of Geometry



- Total number of Mechanical assemblies > 3’700
- Total number of Mechanical features > 10’000’000
- Disk size of geometry 62Gb

- **Purpose** of typization is finding groups of detector components similar by geometry and identification of typical group representatives.

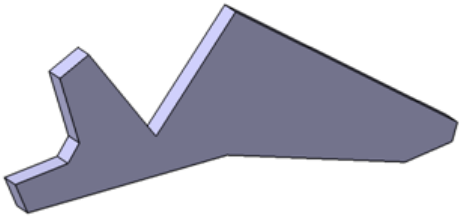
- **3 criteria** can be implemented for typization of detector geometry:

  1. Correspondence of detector components to standard geometry primitives – shapes with vertex; shapes without cuts; both, regular and irregular shapes; both, convex and concave shapes
  2. Grouping components with typical joining’s
  3. Grouping components with cuts

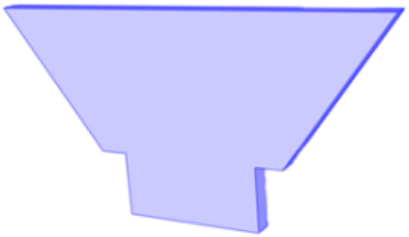
I. Typization of Geometry

- 22 typical primitives have been separated in 1st class of objects

Dodecagonal Prism

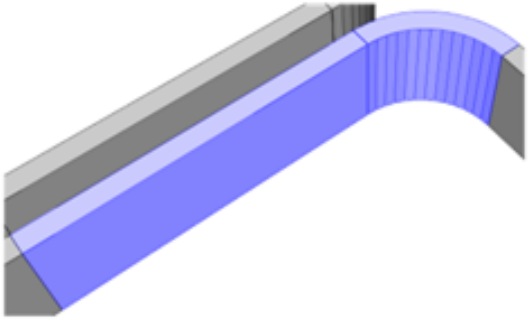


Octagonal Prism

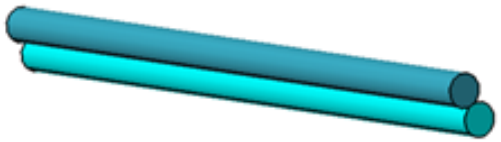


- 29 combined objects with typical joining's have been found for 2nd class

Cube and Tube Joining



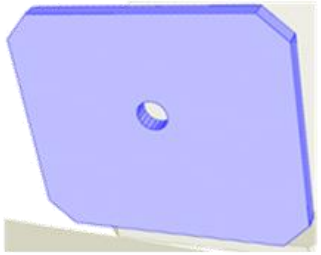
: Tubes Joining



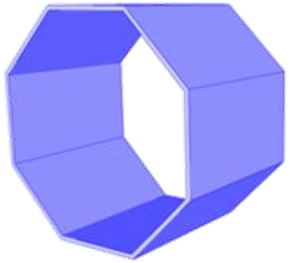
Typization of Geometry

- 3. 33 objects with cuts were separated for 3rd class

Octagonal Prism with cut



Octagonal prism with cut



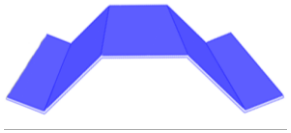
Conclusion: ATLAS detector geometry can be described by 84 typical representors of class of objects

Muon & Dead Volumes	Geometry Primitives	19	Total: 58
	Typical Joining	13	
	Combined Objects	26	
Active Volumes	Geometry Primitives	3	Total: 26
	Typical Joining	16	
	Combined Objects	7	

I. Typization of Geometry

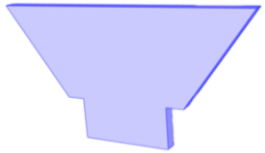
Conclusion: ATLAS detector geometry can be described by 84 typical representors of class of objects

#01: Dodecagonal Prism



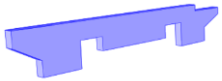
#02: Heptagonal Prism

#03: Octagonal Prism

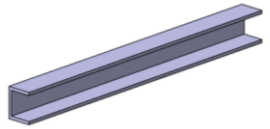


#04: Pentagonal Prism

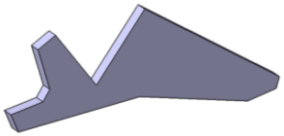
#05: Octadecagonal Prism



#06: Octagonal Prism



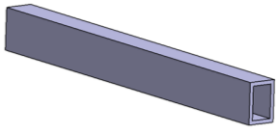
#07: Dodecagonal Prism



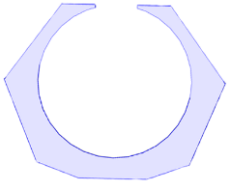
#08: Pentagonal Prism

#09; #10: Dodecagonal Prism with Cuts

#11; #12: Cube with Cut

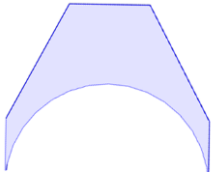


#13; #14: Octagonal Prism with Cuts

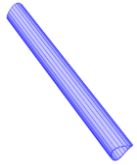


#15: Quadrilateral Prism with Cut

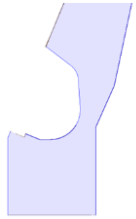
#16: Quadrilateral Prism with Cut



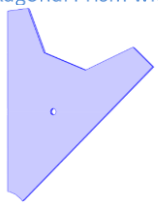
#17: Tube with Cut



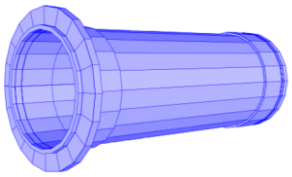
#18: Octagonal Prism with Cuts



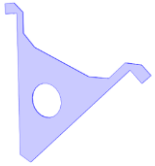
#19; #20: Hexagonal Prism with Cuts



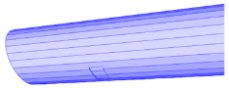
#21: Polycone



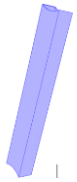
#22; 23: Hexadecagonal Prism with cut



#24: Tube with Cut

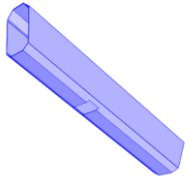


#25; #26: Cube with Cuts



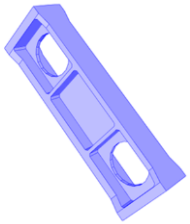
I. Typization of Geometry

#27; #28: Octagonal Prism with Cuts

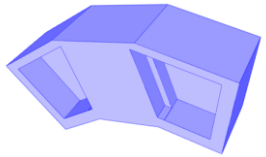


#29: Octadecagonal Prism with Cuts

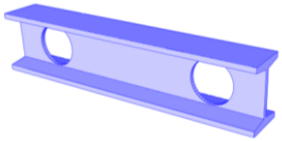
#30; #31: Dodecagonal Prism with Cuts



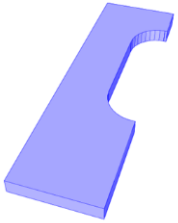
#32; #33: Octagonal Prism with Cuts



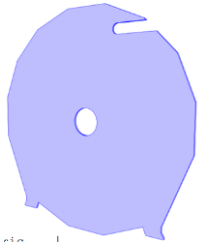
#34; #35: Dodecagonal Prism with Cuts



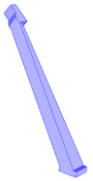
#36; #37: Octagonal Prism with Cuts



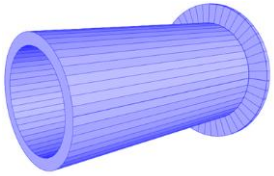
#38; #39: Icositetragonal Prism with Cuts



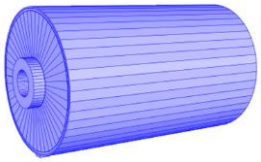
#40; #41: Cube with Cuts



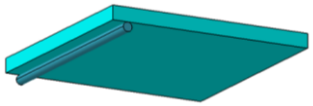
#42: Tubes Joining



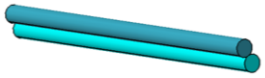
#43: Tubes Joining



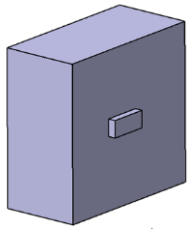
#44; #45: Cylinder and Cube Joining



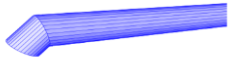
#46: Tubes Joining



#47; #48: Cubes Joining

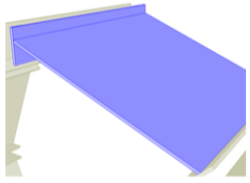


#49: Tubes Joining

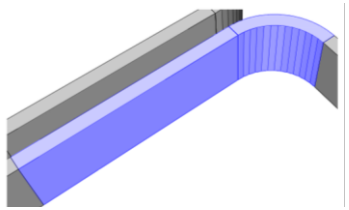


#50: Tubes and Cone Joining

#51: Cubes Joining

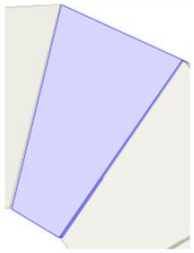


#52 #53: Cube and Tube Joining

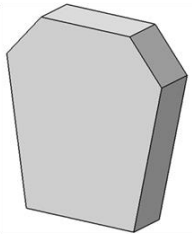


I. Typization of Geometry

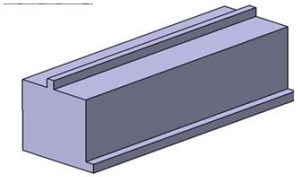
#54: Trapezoid



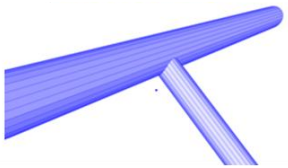
#55: Hexagonal Prism



#56: Decagonal Prism

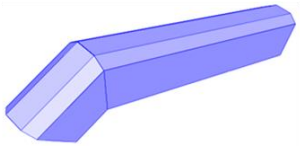


#57: Tubes Joining

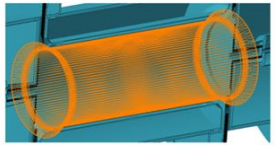


#58 #59: Cube and Tube Joining

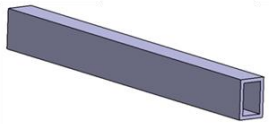
#60 #61: Octagonal Prisms with Cuts Joining



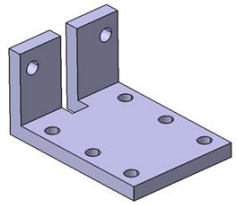
#62: Polycone



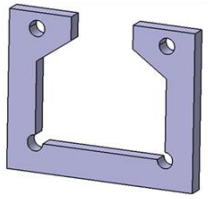
#63: Cube with Cut



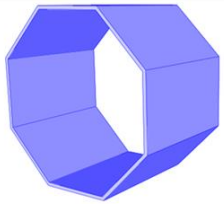
#64: Box with cuts



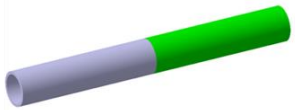
#65: Box with cuts



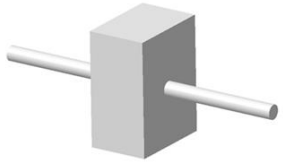
#66: Octagonal prism with cut



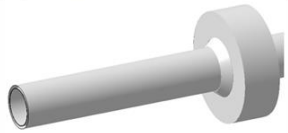
#67: Tubes joining



#68: Tube and Box joining

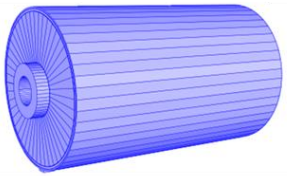


#69: Tubes and Cone Joining

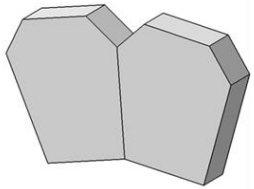


I. Typization of Geometry

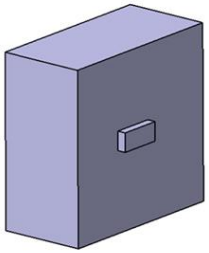
#70: Tubes Joining



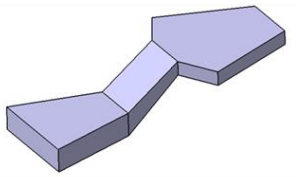
#71: Hexagonal Prism Joining



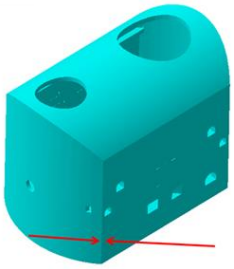
#72: Boxes Joining



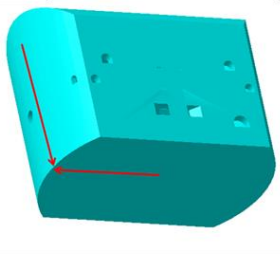
#73: Trapezoid, tetragonal and Hexagonal Prism Joining



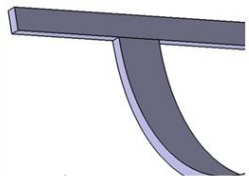
#74: Tubs and Box Joining



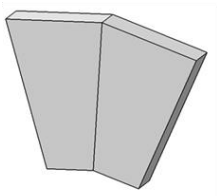
#75: Tubs and Box Joining



#76: Tubs and Box Joining



#77: Trapezoids Joining

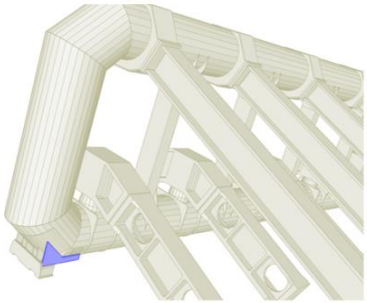


Part II. Selection of Methods for Description

II. Selection of Methods for Description

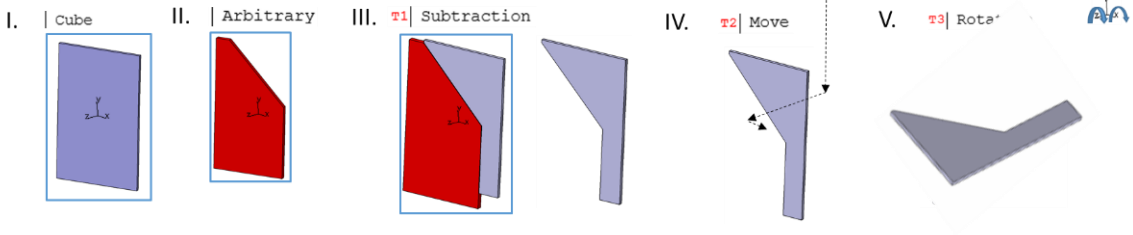
- Several Methods can be implemented for description of one single object

Pentagonal Prism



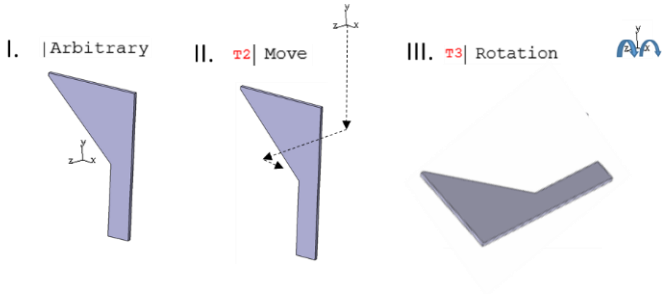
Method 01

	Cube
	Arbitrary
T1	Subtraction
T2	Move
T3	Rotation



Method 02

	Arbitrary
T1	Move
T2	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 22 objects: 4'636 methods

3rd class of 33 objects: 6'579 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
```

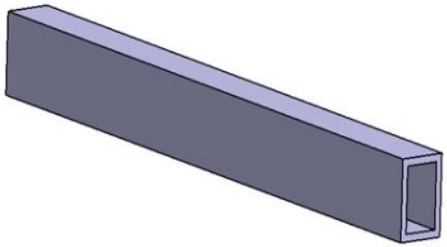
Conclusion: Exclude Methods II and III

II. Selection of Methods for Description

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

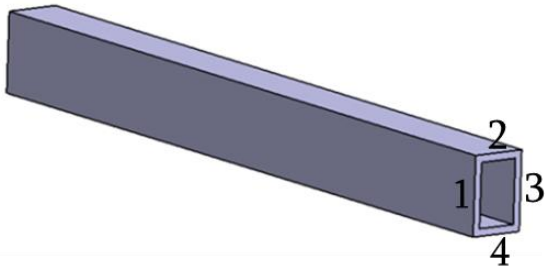
1. Ensure compactness of code
2. Reduce number received clashes, contacts and inaccuracies of positioning
3. Ensure better performance by reducing number of regions for consideration during the tracking

Example: Descriptions of Cube with Cut



I.

```
Cube
Cube
Subtraction
Move
Rotation
```



II.

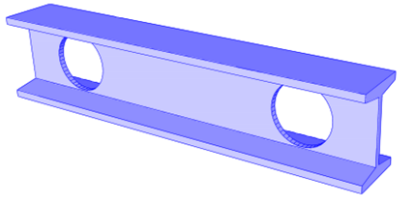
```
Cube
Move
Cube
Move
Cube
Move
Cube
Move
Union
Move
Rotation
```

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.

```
Cube
Symmetric
Move
Subtraction
Move
Subtraction
Arbitrary
Subtraction
Tube
Move
Subtraction
Cube
Move
Subtraction
Tube
Move
Subtraction
```

II.

```
Pyramid
Symmetric
Move
Subtraction
Move
Subtraction
Arbitrary
Subtraction
Tube
Move
Subtraction
Cube
Move
Subtraction
Tube
Move
Subtraction
```

Conclusion: Either I or II should be excluded

II. Selection of Methods for Description

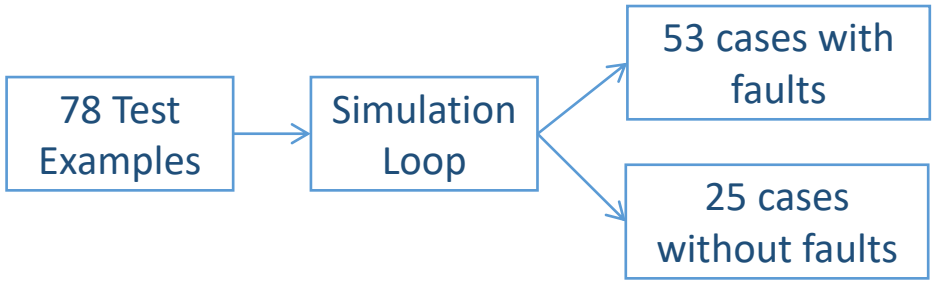
- Total number of methods has been analysed and just unique cases of descriptions were selected:

Before Separation	After Separation
1st class of 22 objects: 4'460 methods	*1st class* of 22 objects: 11 methods
2nd class of 22 objects: 4'636 methods	*2nd class* of 22 objects: 29 methods
3rd class of 33 objects: 6'579 methods	*3rd class* of 33 objects: 38 methods
Total: **15'675** methods	Total: **78** methods

Conclusion: 78 unique examples have been formed for the investigation of quality of geometry transformations doing by simulation software.

Part III. Test Runs

III. Test Runs



#	TestExample N	Inaccuracies	Comment
1	1	Yes	Maximal Inaccuracy 0.23 mm
2	2	Yes	Maximal Inaccuracy 0.03 mm
3	3	No	
4	4	Yes	Maximal Inaccuracy 0.51 mm
5	5	No	
6	6	Yes	Maximal Inaccuracy 0.2 mm
7	7		
8	8	Yes	Maximal Inaccuracy 0.01 mm
9	9	Yes	Maximal Inaccuracy 0.01 mm
10	10	Yes	Maximal Inaccuracy 0.03 mm
11	11	Yes	Maximal Inaccuracy 0.09 mm
12	12	Yes	Maximal Inaccuracy 0.09 mm
13	13	Yes	Maximal Inaccuracy 0.04 mm
14	14	Yes	Maximal Inaccuracy 0.05 mm
15	15	Yes	Maximal Inaccuracy 0.01 mm
16	16	Yes	Maximal Inaccuracy 0.03 mm
17	17	Yes	Maximal Inaccuracy 0.04 mm
18	18	Yes	Maximal Inaccuracy 0.19 mm
19	19	Yes	Maximal Inaccuracy 0.06 mm
20	20	Yes	Maximal Inaccuracy 0.15 mm
21	21	No	
22	22	Yes	Maximal Inaccuracy 0.03 mm
23	23	Yes	Maximal Inaccuracy 0.22 mm
24	24	Yes	Inaccuracies on the X and Y Z axes
25	25	Yes	Maximal Inaccuracy 0.18 mm
26	26	Yes	Maximal Inaccuracy 0.19 mm
27	27	Yes	Maximal Inaccuracy 0.12 mm
28	28	Yes	Maximal Inaccuracy 0.12 mm
29	29	Yes	Maximal Inaccuracy 0.05 mm
30	30	Yes	Maximal Inaccuracy 0.03 mm
31	31	Yes	Maximal Inaccuracy 0.03 mm
32	32	Yes	Maximal Inaccuracy 0.06 mm
33	33	Yes	Maximal Inaccuracy 0.06 mm
34	34	Yes	Maximal Inaccuracy 0.01 mm
35	35	Yes	Maximal Inaccuracy 0.01 mm
36	36	Yes	Maximal Inaccuracy 0.01 mm
37	37	Yes	Maximal Inaccuracy 1.52 mm
38	38	Yes	Maximal Inaccuracy 0.03 mm
39	39	Yes	Maximal Inaccuracy 0.04 mm
40	40	Yes	Maximal Inaccuracy 0.14 mm
41	41	Yes	Maximal Inaccuracy 0.14 mm
42	42		
43	43	No	
44	44	Yes	Maximal Inaccuracy 0.01 mm
45	45	Yes	Maximal Inaccuracy 0.01 mm
46	46		
47	47	No	
48	48	No	
49	49		
50	50	No	
51	51	Yes	Maximal Inaccuracy 1.05 mm
52	52	No	
53	53	No	
54			
55	54	No	
56	55	Yes	Maximal Inaccuracy 0.08 mm
57	56	Yes	Maximal Inaccuracy 0.03 mm
58	58	No	
59	59	No	
60	60	No	
61	61	No	
62	62	No	
63	63	Yes	Maximal Inaccuracy 0.12 mm
64	65	No	
65	66	Yes	Maximal Inaccuracy 0.01 mm
66	67	No	
67	68	No	
68	69	No	
69	70	No	
70	71	Yes	Maximal Inaccuracy 0.38 mm
71	72	No	
72	73	No	
73	74	No	
74	75	Yes	Clash 0.89 mm
75	76	Yes	Clash 2.27 mm
76	77	Yes	Clash 0.04 mm
77	78	No	
78	79	No	

T1: XML->GeoMODEL transformation : 44 cases

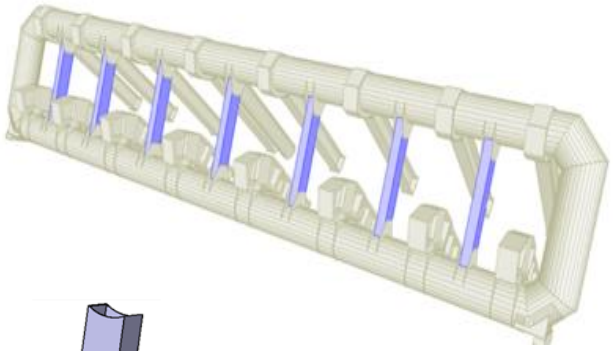
T2: GeoMODEL->GEANT-4 transformation : 9 cases

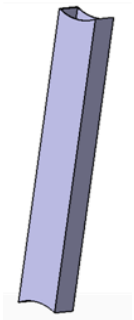
Part IV. Case Study of Transactions

IV. Case Study of Transactions

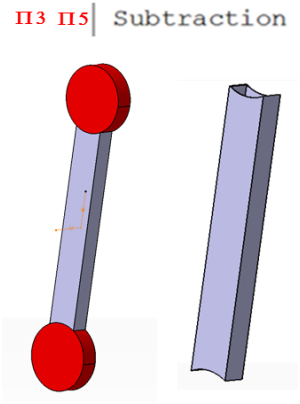
- Further investigations have done in order to understand reasons which caused inaccurateness
- Geometry transactions *move/rotation* and *Boolean* operations were considered separately and together to discover any kind of correlations between them

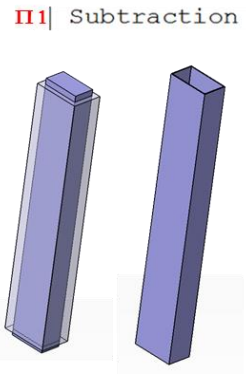
Example: Case study of transactions for Tube with cuts

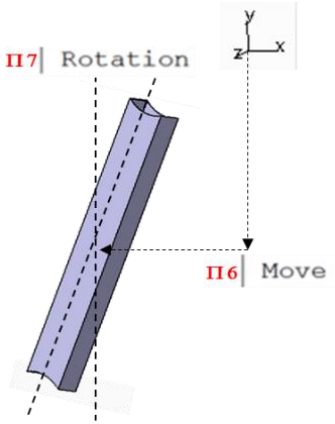




	Cube
	Cube
П1	Subtraction
	Tube
П2	Move
П3	Subtraction
П4	Move
П5	Subtraction
П6	Move
П7	Rotation

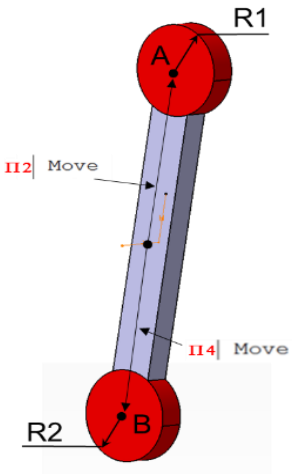






IV. Case Study of Transactions

Sub-Case #01: Π2/Π4 movement of A and B center points of auxiliary tubes along Y axis from origin



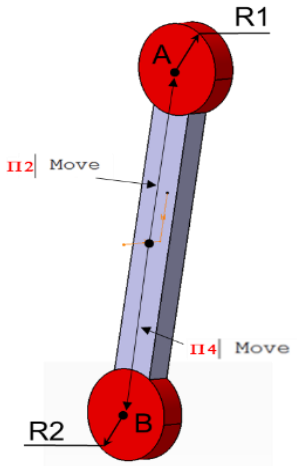
	Cube
	Cube
Π1	Subtraction
	Tube
Π2	Move
Π3	Subtraction
Π4	Move
Π5	Subtraction
Π6	Move
Π7	Rotation

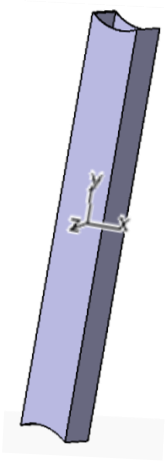
```
<gvxy name="Box1" material="Aluminium" dZ="290.">
    <gvxy_point X_Y="-250.; -8947."/>
    <gvxy_point X_Y="-250.; -5707."/>
    <gvxy_point X_Y="250.; -5707."/>
    <gvxy_point X_Y="250.; -8947."/>
</gvxy>

<gvxy name="Box2" material="Aluminium" dZ="270.">
    <gvxy_point X_Y="-240.; -8977."/>
    <gvxy_point X_Y="-240.; -5677."/>
    <gvxy_point X_Y="240.; -5677."/>
    <gvxy_point X_Y="240.; -8977."/>
</gvxy>

<tubs name="Tube1" material="Aluminium" Rio_Z="0.; 544.5; 300." nbPhi="32" />

<composition name="TestExampleN25" >
   <posXYZ  volume="Box1"   X_Y_Z=" 0. ; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Box2"   X_Y_Z=" 0. ; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -5227. ; 0. "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -9427. ; 0. "  rot=" 0. ; 0. ; 0. "/>
</composition>

<composition  name="ECT_Toroids" >
  <posXYZ  volume="TestExampleN25" X_Y_Z=" 0. ; 0. ; 0." rot=" 0.; 0.; 0. " />
</composition>
```

Results: There are no inaccuracies

IV. Case Study of Transactions

Sub-Case #02: Π2/Π4 movement together with Boolean subtractions





	Cube
	Cube
Π1	Subtraction
	Tube
Π2	Move
Π3	Subtraction
Π4	Move
Π5	Subtraction
Π6	Move
Π7	Rotation

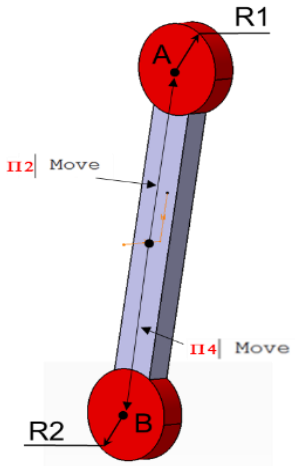
```
<gvxy name="Box1" material="Aluminium" dZ="290.">
    <gvxy_point X_Y="-250.; -8947."/>
    <gvxy_point X_Y="-250.; -5707."/>
    <gvxy_point X_Y="250.; -5707."/>
    <gvxy_point X_Y="250.; -8947."/>
</gvxy>

<gvxy name="Box2" material="Aluminium" dZ="270.">
    <gvxy_point X_Y="-240.; -8977."/>
    <gvxy_point X_Y="-240.; -5677."/>
    <gvxy_point X_Y="240.; -5677."/>
    <gvxy_point X_Y="240.; -8977."/>
</gvxy>

<tubs name="Tube1" material="Aluminium" Rio_Z="0.; 544.5; 300." nbPhi="32" />

<subtraction name="TestExampleN25" >
   <posXYZ  volume="Box1"   X_Y_Z=" 0; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Box2"   X_Y_Z=" 0; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -5227. ; 0. "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -9427. ; 0. "  rot=" 0. ; 0. ; 0. "/>
</subtraction>

<composition  name="ECT_Toroids" >
  <posXYZ  volume="TestExampleN25" X_Y_Z=" 0. ; 0. ; 0.." rot=" 0.; 0.; 0. " />
</composition>
```

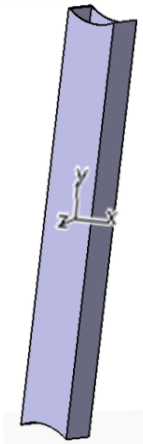
Results:

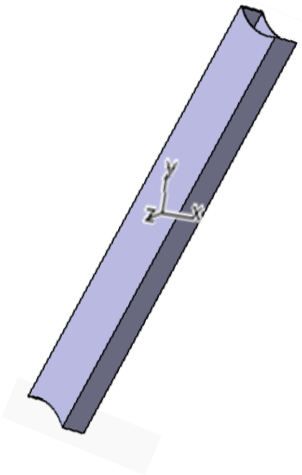
		GeoM Δ_1	G-4 Δ_2	Total Δ
A	*x*	0.03	0	0.03
	y	0.02	0.2	0.22
	z	0	0	0
B	*x*	0.03	0	0.03
	y	-0.02	0.1	0.08
	z	0	0	0
	R1	0	-0.19	-0.19
	R2	0	0.1	0.1
Volume		-0.0005	0.0004	-0.0001

IV. Case Study of Transactions

Sub-Case #03: Π7 rotation together with Π2/Π4 movement and Π1/Π3 subtractions







	Cube
	Cube
Π1	Subtraction
	Tube
Π2	Move
Π3	Subtraction
Π4	Move
Π5	Subtraction
Π6	Move
Π7	Rotation

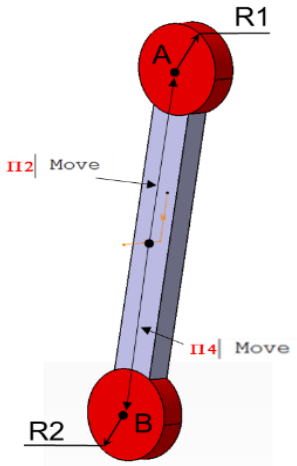
```
<gvxy name="Box1" material="Aluminium" dZ="290.">
    <gvxy_point X_Y="-250.; -8947."/>
    <gvxy_point X_Y="-250.; -5707."/>
    <gvxy_point X_Y="250.; -5707."/>
    <gvxy_point X_Y="250.; -8947."/>
</gvxy>

<gvxy name="Box2" material="Aluminium" dZ="270.">
    <gvxy_point X_Y="-240.; -8977."/>
    <gvxy_point X_Y="-240.; -5677."/>
    <gvxy_point X_Y="240.; -5677."/>
    <gvxy_point X_Y="240.; -8977."/>
</gvxy>

<tubs name="Tube1" material="Aluminium" Rio_Z="0.; 544.5; 300." nbPhi="32" />

<subtraction name="TestExampleN25" >
   <posXYZ  volume="Box1"   X_Y_Z=" 0; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Box2"   X_Y_Z=" 0; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -5227. ; 0. "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -9427. ; 0. "  rot=" 0. ; 0. ; 0. "/>
</subtraction>

<composition  name="ECT_Toroids" >
  <posXYZ  volume="TestExampleN25" X_Y_Z=" 0. ; 0. ; 0." rot=" 0.; 0.; -22.5 " />
</composition>
```

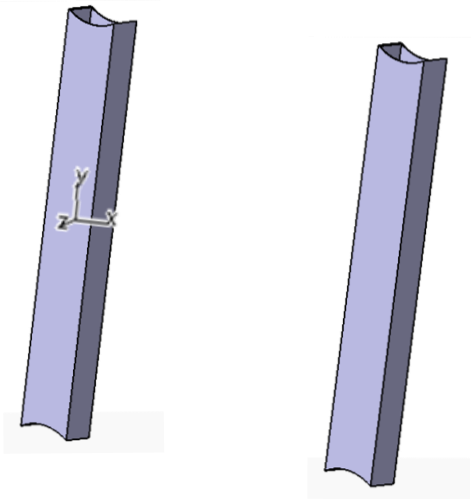
Results:

		GeoM Δ_1	G-4 Δ_2	Total Δ
A	x	0.05	0.09	0.14
	y	0.01	0.23	0.24
	z	0	0	0
B	x	0.01	0.01	0.02
	y	-0.03	0.02	-0.01
	z	0	0	0
	R1	0	-0.24	-0.24
	R2	0	0.02	0.02
Volume				-0.0001

IV. Case Study of Transactions

Sub-Case #04: Π6 movement together with Π2/Π4 and Π1/Π3 subtraction





	Cube
	Cube
Π1	Subtraction
	Tube
Π2	Move
Π3	Subtraction
Π4	Move
Π5	Subtraction
Π6	Move
Π7	Rotation

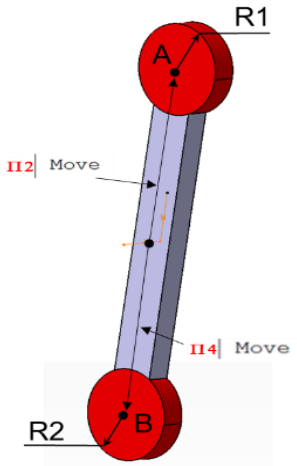
```
<gvxy name="Box1" material="Aluminium" dZ="290.">
    <gvxy_point X_Y="-250.; -8947."/>
    <gvxy_point X_Y="-250.; -5707."/>
    <gvxy_point X_Y="250.; -5707."/>
    <gvxy_point X_Y="250.; -8947."/>
</gvxy>

<gvxy name="Box2" material="Aluminium" dZ="270.">
    <gvxy_point X_Y="-240.; -8977."/>
    <gvxy_point X_Y="-240.; -5677."/>
    <gvxy_point X_Y="240.; -5677."/>
    <gvxy_point X_Y="240.; -8977."/>
</gvxy>

<tubs name="Tube1" material="Aluminium" Rio_Z="0.; 544.5; 300." nbPhi="32" />

<subtraction name="TestExampleN25" >
   <posXYZ  volume="Box1"   X_Y_Z=" 0; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Box2"   X_Y_Z=" 0; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -5227. ; 0. "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -9427. ; 0. "  rot=" 0. ; 0. ; 0. "/>
</subtraction>

<composition  name="ECT_Toroids" >
  <posXYZ  volume="TestExampleN25" X_Y_Z=" 0. ; 0. ; 9540." rot=" 0.; 0.; 0. " />
</composition>
```

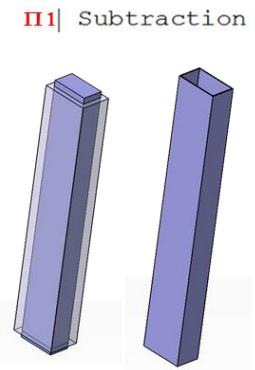
Results:

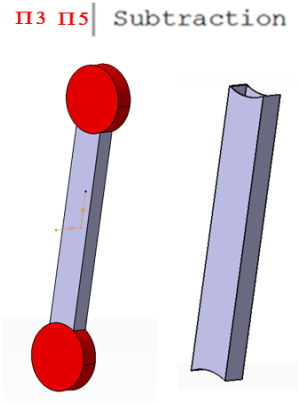
		GeoM Δ_1	G-4 Δ_2	Total Δ
A	x	0.03	0.01	0.04
	y	0.02	0.2	0.22
	z	0	0	0
B	x	0.03	0	0.03
	y	-0.03	0.1	0.07
	z	0	0	0
	R1	0.01	-0.2	-0.19
	R2	-0.01	0.1	0.09
Volume				-0.0001

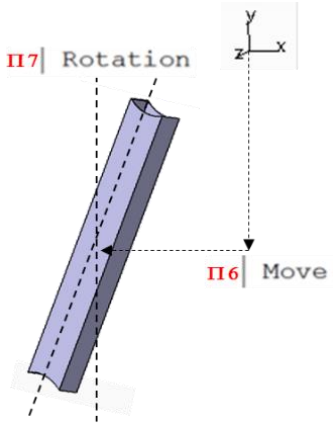
IV. Case Study of Transactions

Sub-Case #05: Π6 movement together with Π2/Π4 ; Π1/Π3 subtractions and Π7 rotation










```
    Cube
    Cube
Π1  Subtraction
    Tube
Π2  Move
Π3  Subtraction
Π4  Move
Π5  Subtraction
Π6  Move
Π7  Rotation
```

```
<gvxy name="Box1" material="Aluminium" dZ="290.">
    <gvxy_point X_Y="-250.; -8947."/>
    <gvxy_point X_Y="-250.; -5707."/>
    <gvxy_point X_Y="250.; -5707."/>
    <gvxy_point X_Y="250.; -8947."/>
</gvxy>

<gvxy name="Box2" material="Aluminium" dZ="270.">
    <gvxy_point X_Y="-240.; -8977."/>
    <gvxy_point X_Y="-240.; -5677."/>
    <gvxy_point X_Y="240.; -5677."/>
    <gvxy_point X_Y="240.; -8977."/>
</gvxy>

<tubs name="Tube1" material="Aluminium" Rio_Z="0.; 544.5; 300." nbPhi="32" />

<subtraction name="TestExampleN25" >
   <posXYZ  volume="Box1"   X_Y_Z=" 0; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Box2"   X_Y_Z=" 0; 0. ; 0.  "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -5227. ; 0. "  rot=" 0. ; 0. ; 0. "/>
   <posXYZ  volume="Tube1"  X_Y_Z=" 0. ; -9427. ; 0. "  rot=" 0. ; 0. ; 0. "/>
</subtraction>

<composition  name="ECT_Toroids" >
  <posXYZ  volume="TestExampleN25" X_Y_Z=" 0. ; 0. ; 9540." rot=" 0.; 0.; 0. " />
</composition>
```

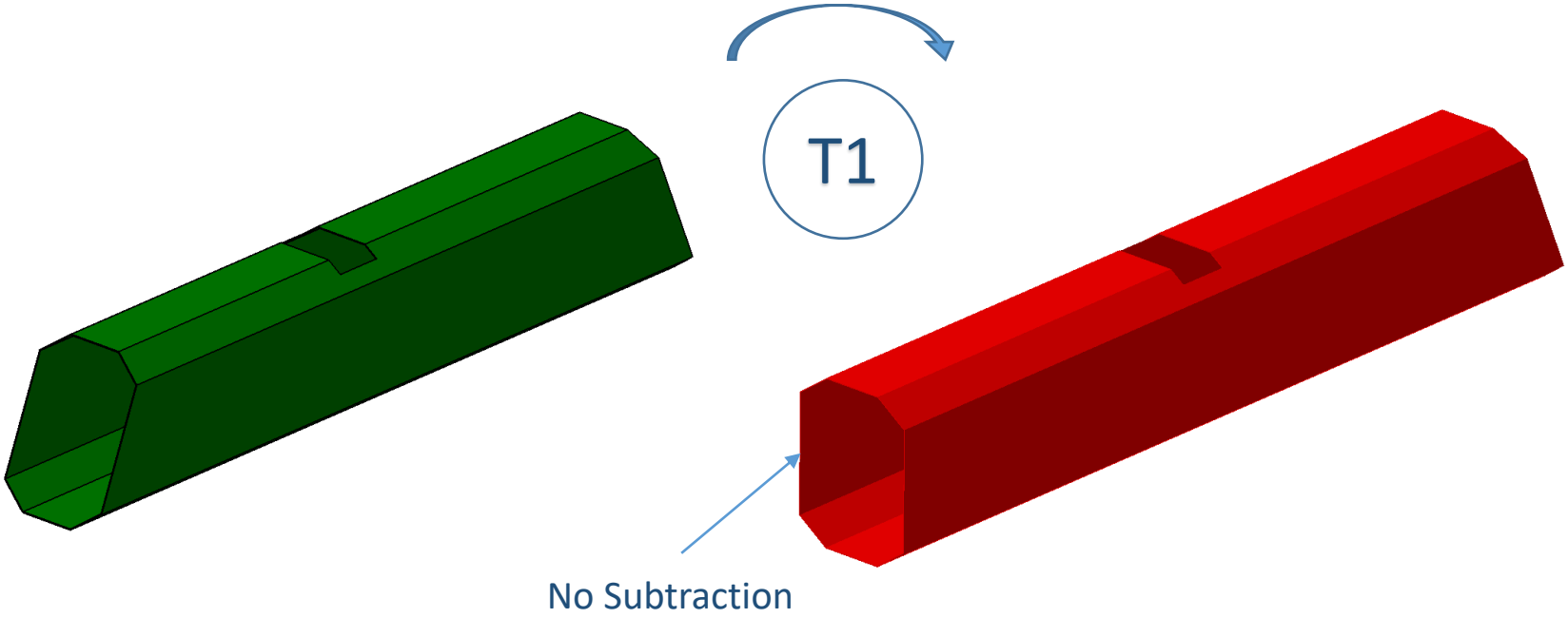
Results:

		GeoM Δ_1	G-4 Δ_2	Total Δ
A	*x*	0.03	0	0.03
	y	0	-0.02	-0.02
	z	0	0	0
B	*x*			0.02
	y			0
	z			0
	R1	-0.01	0.18	0.17
	R2			-0.03
Volume		-0.0005	0.0004	-0.0001

IV. Case Study of Transactions

- Direct Faults have been detected

Example: GeoMODEL Boolean Subtraction failure



Part V. Systematization of Results

V. Systematization of Results

	Geometric Primitives										Transactions					Inaccuracies of **T1** Transformation						Inaccuracies of **T2** Transformation					
№	Cube	Tube	Pyr.	Trap.	Cone	PolyC.	PolyG.	Arbit.	Sym.	DSym	M	R	Subt.	M	R	M	R	Subt.	M	R	Conf.	M	R	Subt.	M	R	Conf.
1			3X								5X	4X	5X	X	X	0	0	ΔX=-0.02 ΔY=0.01 Δ_V=0.0014	ΔX=-0.03 ΔY=0.03	ΔX=-0.03 ΔY=0.06		0	0	0	ΔX=-0.01 ΔY=0.01	ΔX=0.01 ΔY=0.02	
2	2X										2X	X	2X	X	X	0	0	ΔY=0.01 ΔZ=-0.02	0	ΔX=-0.01 ΔY=0.01		0	0	0	ΔZ=0.03	ΔX=-0.01	
4	X							X					X	X	X			ΔX=-0.03 ΔY=-0.02	0	ΔX=0.02 ΔY=-0.02				0	0	ΔZ=0.02	
6	2X										X		X	X	X	0		ΔX=0.23 ΔZ=-0.13	0	ΔX=0.03 ΔY=0.1		0		0	ΔZ=0.03	0	
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=0.01 ΔY=0.01	ΔX=-0.01 ΔY=-0.01	ΔX=0.05 ΔY=0.01	
8	2X										X	X	X	X	X	0	0	ΔY=0.01 ΔZ=0.01	0	0		0	0	0	0	0	
9								2X			2X		2X	X	X	0		0	0	ΔX=0.01 ΔY=0.01		0		0	0	ΔX=0.01 ΔY=0.01	
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		0	0	ΔX=0.01 ΔY=0.01	
11	2X												X	X	X	0		ΔY=-0.1 ΔZ=-0.06	0	ΔX=0.04 ΔY=0.01		0		0	ΔZ=0.01	0	
12								2X					X	X	X			ΔX=0.09 ΔY=0.06	0	ΔX=0.04 ΔY=0.01				0	ΔY=0.01	ΔZ=0.01	
13	X	X						X			X		2X	X	X	0		ΔX=0.01 Δ_V=0.0002	ΔX=-0.03 ΔY=-0.03	ΔX=-0.01 ΔY=0.03		0		0	ΔY=-0.01	ΔX=-0.01 ΔY=0.01	
14	X	X						X			2X		2X	X	X	0		ΔX=-0.03 ΔY=-0.02 Δ_V=0.0002	0	ΔX=-0.01 ΔY=-0.01		0		ΔX=0.01	0	ΔX=0.01	
15	X	X									X		X	X	X	0		0	0	ΔX=0.01 ΔY=-0.01		0		0	0	0	

V. Systematization of Results

	Geometric Primitives										Transactions					Inaccuracies of **T1** Transformation						Inaccuracies of **T2** Transformation					
№	Cube	Tube	Pyr.	Trap.	Cone	PolyC.	PolyG.	Arbit.	Sym.	DSym	M	R	Subt.	M	R	M	R	Subt.	M	R	Conf.	M	R	Subt.	M	R	Conf.
16		X						X			X		X	X	X	0		ΔX=-0.03 ΔY=-0.02	ΔZ=0.01 R=0.01	ΔX=-0.01 R=0.01		0		ΔX=-0.01 ΔY=-0.01	0	ΔX=-0.01 ΔY=-0.01	
17		2X									2X	2X	2X	X	X	0	0	ΔX=0.04 ΔY=0.02 R=0.02	ΔX=0.01	ΔX=0.02 ΔY=-0.02 R=0.01		0	0	ΔY=-0.02 R=0.02	0	ΔX=-0.01 ΔY=-0.05 R=0.04	
18		2X						X	X		2X		3X	X		0		ΔX=-0.11 ΔY=-0.08 Δ_V=0.0009	0			0		ΔX=-0.01 R=0.01	ΔX=-0.07 ΔY=-0.04 R=0.08		
19		2X						X			2X		2X	X	X	0		ΔX=0.06 ΔY=0.04	0	ΔY=-0.03		0		ΔY=-0.03	ΔX=-0.03 ΔY=-0.04 R=0.05	ΔX=0.04 ΔY=0.06 R=0.09	
20		2X	X						X		3X	X	3X	X	X	0	0	ΔX=-0.14 ΔY=-0.08 Δ_V=0.0003	ΔX=0.01	ΔX=-0.03 ΔY=0.06		0	0	R=0.03	ΔX=0.01 R=0.03	ΔX=-0.01 ΔY=0.02 R=0.01	
22		X						X			X		X	X	X	0		ΔX=-0.03 ΔY=-0.02 Δ_V=0.0001	0	ΔY=0.02		0		0	0	0	
23		X	X					2X			X	2X	4X	X	X	0	0	ΔX=-0.12 ΔY=-0.09 Δ_V=0.0001	0	ΔX=-0.03 ΔY=-0.06		0	0	0	0	0	
24	X	X									X		X	X	X	0		ΔX=-0.02 ΔY=-0.01 ΔZ=-0.01	0	ΔX=0.01 ΔY=0.01		0		0	ΔY=0.01	ΔX=0.01 ΔY=0.01	
25		X						2X			2X		3X	X	X	0		ΔX=0.03 ΔY=0.02 Δ_V=0.0005 R=0.01	0	ΔX=-0.02		0		ΔY=0.19 Δ_V=0.0004 R=0.18	0	ΔY=0.21	
26	2X	X									2X		3X	X	X	0		ΔX=0.03 ΔY=0.02	ΔY=0.01 R=0.01	ΔX=0.02 ΔY=0.01		0		ΔY=0.1 R=0.02	ΔX=0.01 R=0.01	ΔX=0.09 ΔY=0.03 R=0.05	
27								4X			3X	2X	4X	X	X	0	0	ΔX=0.15 ΔY=-0.22 ΔZ=-0.06	ΔX=-0.02 ΔY=0.01	ΔX=-0.09 ΔY=0.07		0	0	ΔX=0.26 ΔY=-0.23 ΔZ=0.02	ΔZ=0.01	ΔX=-0.09 ΔY=-0.09	
28	2X									2X	3X	2X	4X	X	X	0	0	ΔX=0.15 ΔY=-0.22 ΔZ=-0.06	ΔX=-0.02 ΔZ=0.01	ΔX=-0.09 ΔY=0.07		0	0	ΔX=0.26 ΔY=0.23 ΔZ=0.02	ΔZ=0.01	ΔX=-0.09 ΔY=-0.09	
29		X						2X			X	2X	3X	X	X	0	0	ΔX=0.01 ΔY=-0.03 ΔZ=0.01 Δ_V=0.0002	0	ΔX=-0.01 ΔY=0.01		0	0	ΔY=0.01	ΔZ=0.03	ΔX=0.01 ΔY=0.03 ΔZ=0.01 R=0.01	

V. Systematization of Results

	Geometric Primitives										Transactions					Inaccuracies of **T1** Transformation						Inaccuracies of **T2** Transformation					
№	Cube	Tube	Pyr.	Trap.	Cone	PolyC.	PolyG.	Arbit.	Sym.	DSym	M	R	Subt.	M	R	M	R	Subt.	M	R	Conf.	M	R	Subt.	M	R	Conf.
30		X						2X			8X	7X	8X	X	X	0	0	ΔX=0.03 ΔY=-0.03 ΔZ=-0.02 Δ_V=0.00031	ΔY=-0.03 ΔZ=0.03	ΔY=0.01 ΔZ=0.04		0	0	ΔZ=0.03	ΔX=-0.01 ΔY=0.03 ΔZ=0.03 R=0.01	ΔX=0.01 ΔY=-0.03 ΔZ=0.04 Δ_V=0.00002 R=0.01	
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	0	ΔX=0.02 ΔY=0.03 R=0.01	ΔX=-0.02 ΔY=-0.03 ΔZ=0.04 Δ_V=0.00002 R=0.01	
32					X			3X			7X	5X	7X	X	X	0	0	ΔX=0.03 ΔY=-0.03 ΔZ=0.03 Δ_V=0.00163	ΔX=-0.03 ΔZ=-0.02 Δ_V=0.0033	ΔX=0.01 ΔZ=0.02		0	0	ΔX=0.06 ΔY=-0.05 ΔZ=-0.03 Δ_V=0.00001 R=0.01	ΔX=0.07 ΔY=0.06 ΔZ=0.02 Δ_V=0.00002 R=0.02	ΔX=0.05 ΔY=-0.09 ΔZ=-0.02 Δ_V=0.00002 R=0.04	
33					X			2X	X		7X	5X	7X	X	X	0	0	ΔX=0.03 ΔY=0.03 ΔZ=0.03 Δ_V=0.00163	ΔX=-0.03 ΔZ=-0.02 Δ_V=0.0033	ΔX=0.01 ΔY=0.02		0	0	ΔX=0.06 ΔY=0.05 ΔZ=-0.03 Δ_V=0.00001 R=0.01	ΔX=0.07 ΔY=0.06 ΔZ=0.02 Δ_V=0.00002 R=0.02	ΔX=0.05 ΔY=-0.09 ΔZ=-0.02 Δ_V=0.00002 R=0.04	
34		X						X			2X	2X	2X	X	X	0	0	ΔX=0.01 ΔY=0.01 Δ_V=0.0001	0	0		0	0	0	0	0	
35		X							X		2X	2X	2X	X	X	0	0	ΔX=0.01 ΔY=0.01 Δ_V=0.0001	0	0		0	0	0	0	0	
36		X						X			2X		2X	X	X	0		ΔX=0.02 ΔZ=0.01 Δ_V=0.00001	0	0		0		ΔX=0.01	0	0	
37	2X	X									3X		3X	X	X	0		ΔX=0.01 ΔZ=0.01 Δ_V=0.00007	0	ΔZ=-0.02		0		ΔX=0.01 ΔZ=0.02	ΔX=0.03 ΔZ=0.05 R=0.05	ΔX=-0.16 ΔZ=-0.19 R=-0.19	
38		2X						X			X		2X	X		0		ΔX=-0.02 ΔY=-0.03 Δ_V=0.0009	0			0		ΔY=-0.01	0		
39	X	2X						X	X		2X		4X	X		0		ΔX=-0.24 ΔY=-0.18 Δ_V=0.0009	0			0		ΔY=-0.01	0		
40								5X				2X	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	0	0	0	

V. Systematization of Results

	Geometric Primitives										Transactions					Inaccuracies of **T1** Transformation						Inaccuracies of **T2** Transformation					
№	Cube	Tube	Pyr.	Trap.	Cone	PolyC.	PolyG.	Arbit.	Sym.	DSym	M	R	Subt.	M	R	M	R	Subt.	M	R	Conf.	M	R	Subt.	M	R	Conf.
39	X	2X						X	X		2X		4X	X		0		ΔX=-0.24 ΔY=-0.18 Δ_V=0.0009	0			0		ΔY=-0.01	0		
40								5X				2X	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	0	0	0	
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	0	0	0	
49	X	2X									3X	3X	2X	X	X	0	0				0	0	0				0
57		2X									2X	2X	X	X	X	0	0	ΔX=0.04 ΔY=0.02 R=0.02	ΔX=0.01	ΔX=0.02 ΔY=-0.02 R=0.01	-	0	0	ΔY=-0.02 R=0.02	0	ΔX=-0.01 ΔY=-0.05 R=0.04	-
58	2X	X									X		2X	2X	X	0		ΔX=0.03 ΔY=0.02	ΔY=0.01 R=0.01	ΔX=0.02 ΔY=0.01	-	0		ΔY=0.1 R=0.02	ΔX=0.01 R=0.01	ΔX=0.09 ΔY=0.03 R=0.05	-
59	2X	X									X		2X	2X	X	0		ΔX=0.03 ΔY=0.02 Δ_V=0.0005 R=0.01	0	ΔX=-0.02	-	0		ΔY=0.19 Δ_V=0.0004 R=0.18	0	ΔY=0.21	-
60	X									2X	X	X	2X	2X	2X	0	0	ΔX=0.15 ΔY=-0.22 ΔZ=-0.06	ΔX=-0.02 ΔZ=0.01	ΔX=-0.09 ΔY=0.07	-	0	0	ΔX=0.26 ΔY=0.23 ΔZ=0.02	ΔZ=0.01	ΔX=-0.09 ΔY=-0.09	-
61								3X			X	X	2X	2X	2X	0	0	ΔX=0.15 ΔY=-0.22 ΔZ=-0.06	ΔX=-0.02 ΔY=0.01	ΔX=-0.09 ΔY=0.07	-	0	0	ΔX=0.26 ΔY=-0.23 ΔZ=0.02	ΔZ=0.01	ΔX=-0.09 ΔY=-0.09	-
55	X			X							2X	2X	2X	X	X	0	0	ΔX=0.02 ΔY=0.08	ΔY=0.02	ΔX=-0.01 ΔY=0.01	-	0	0	0	0	ΔX=0.01	-
56	2X										3X		3X	X	X	0		ΔX=0.03 ΔY=0.02	0	ΔX=0.01 ΔY=0.01	-	0		0	0	0	-
63	2X												X	X	X	0		ΔY=-0.09 ΔZ=0.06	0	ΔX=0.03 ΔY=0.01	-	0		0	ΔY=-0.01	ΔY=-0.03	-
66	2X	X		X							7X	2X	7X	X	X						-						-
69	X	X									X		X	X		0		ΔX=-0.06 ΔY=-0.05	0	0	-	0		0	0	0	-

V. Systematization of Results

	Geometric Primitives										Transactions					Inaccuracies of **T1** Transformation						Inaccuracies of **T2** Transformation					
№	Cube	Tube	Pyr.	Trap.	Cone	PolyC.	PolyG.	Arbit.	Sym.	DSym	M	R	Subt.	M	R	M	R	Subt.	M	R	Conf.	M	R	Subt.	M	R	Conf.
72	X			X							3X	3X	2X	X	X	0	0	ΔX=0.02 ΔY=0.08	ΔY=0.02	ΔX=-0.01 ΔY=0.01	0	0	0	0	0	ΔX=0.01	0
74	4X			2X							6X	6X	5X	2X	2X	0	0	ΔX=0.02 ΔY=0.08	ΔY=0.02	ΔX=-0.01 ΔY=0.01	-	0	0	0	0	ΔX=0.01	-
75	2X	X									2X		X		X	0		ΔX=-1.34 ΔZ=0.94 Δ_V=0.175		ΔX=-0.47 ΔZ=0.3	Clash=1.28	0		ΔX=0.14 ΔZ=-0.14		ΔX=-0.47 ΔZ=-0.33	Clash=0.37
77	X	2X									X	X	X	X	X	0	0	ΔX=-1.71 ΔZ=-1.25 Δ_V=34.45	0	0	-	0	0	ΔX=-0.04 ΔZ=0.01 R=0.05	0	0	-

Part VI. Conclusions

VI. Conclusions

1. *Arbitrary* Polygon method is most reliable way to simulate detector geometry in ATLAS simulation software infrastructure
2. For all type of detector geometries dimensional, form and positioning faults are caused by *Boolean* operations
3. *Boolean* operation correlated with *Move/Rotation* transactions in GEANT. Once *Boolean* operation is implemented transactions generating geometry displacements of support points of geometry created by *Boolean* procedures
4. *Boolean* operation damage total volume of geometry mainly for **T1** transformation – 23 cases. For **T2** transformation – 3 cases
5. *Boolean* operation cause clashes (~1.28mm) inside geometry which is “visible” for large size volumes and not visible for smaller because of limitations of CATIA tool using for analyses

VI. Conclusions

6. For complex geometries with number of cutouts and rounding, for **T2** transformation - total value of inaccuracies added by *Rotation* is substantial
7. Increasing of dimensional values of geometry are exponentially increase values of inaccuracies added by *Boolean* operations

Thanks for your attention!

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