

# Introduction to the FreeCAD GDML Workbench

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# GDML

GDML: Geometry Description Markup Language.

- A specialized XML-based language designed for describing the geometries of detectors for physics experiments.
- Integrated into Geant4 since release 9.2
- Need to set `GEANT4_USE_GDML = 1` when compiling
- GDML Workbench: A tool for importing GDML files into (Free)CAD geometries and exporting FreeCAD geometries to GDML

## Abbreviated GDML file structure

```
<?xml version="1.0" encoding="UTF-8"?>
<gdml xsi:noNamespaceSchemaLocation="schema/gdml.xsd">
  <define>
    ...
    <position name="TrackerinWorldpos" unit="mm" x="0" y="0" z="100"/>
  </define>
  <materials>
    ...
    <element name="Nitrogen" formula="N" Z="7.">
      <atom value="14.01"/>
    </element>
    <material formula=" " name="Air" >
      <D value="1.290" unit="mg/cm3"/>
      <fraction n="0.7" ref="Nitrogen" />
      <fraction n="0.3" ref="Oxygen" />
    </material>
  </materials>
  <solids>
    ...
    <box lunit="mm" name="Tracker" x="50" y="50" z="50"/>
  </solids>
  <structure>
    ...
    <volume name="World" >
      <materialref ref="Air" />
      <solidref ref="world" />
      <physvol>
        <volumeref ref="Tracker" />
        <positionref ref="TrackerinWorldpos"/>
        <rotationref ref="TrackerinWorldrot"/>
      </physvol>
    </volume>
  </structure>
  <setup name="Default" version="1.0" >
    <world ref="World" />
  </setup>
</gdml>
```

# FreeCAD – an Open Source CAD Application


freecad.org

FreeCAD

Features Download Blog Documentation Contribute Community

## Current stable version: 0.21.1


Select your desired platform (note that all downloads are for 64-bit systems):



### Windows


- 64-bit installer
- 64-bit portable (.7z)

Windows 7 is the minimum supported version. For more info



### Mac

- ARM (M1/M2) disk image
- Intel disk image
- MacOS 12 and older (unsigned)

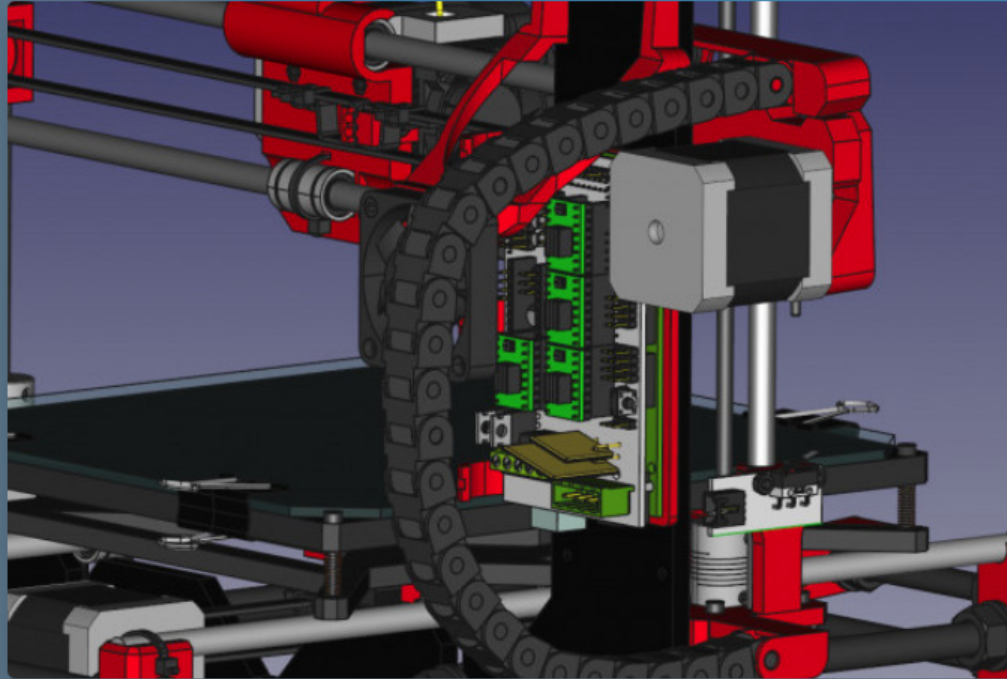


### Linux

- x86\_64 Appliance Image
- aarch64 Appliance Image

For distro-specific instructions, such as Ubuntu PPA, and other

# Some Features(from the FreeCAD web site):

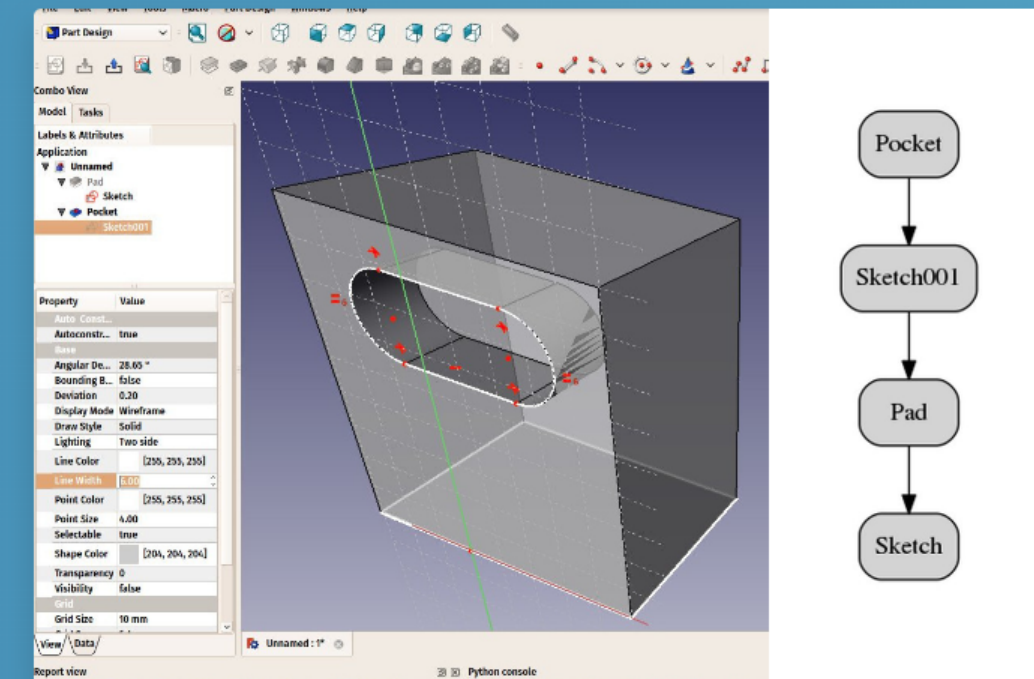


## A powerful solid-based geometry kernel

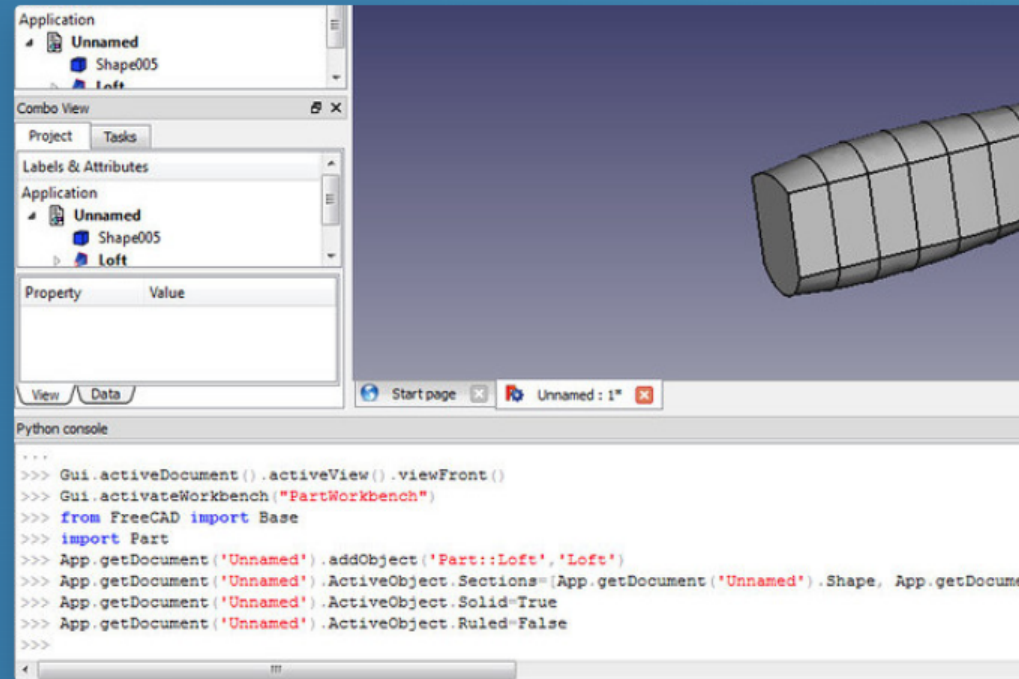
FreeCAD features an advanced geometry engine based on Open CASCADE Technology. It supports solids, Boundary Representation (BRep) objects, and Non-uniform rational basis spline (NURBS) curves and surfaces, and offers a wide range of tools to create and modify these objects, including complex Boolean operations, fillets, shape cleaning and much more.

## A wi(l)dly parametric environment

All FreeCAD objects are natively parametric, meaning their shape can be based on properties such as numeric values, texts, on/off buttons, or even other objects. All shape changes are recalculated on demand, recorded by an undo/redo stack, and allow to maintain a precise modelling history. Properties of one object can drive the value of properties of other objects, allowing complex, custom parametric chains that could only exist in your wildest dreams. New parametric objects are easy to code.



# FreeCAD features, continued



## Python everywhere

While the FreeCAD core functionality is coded in C++ for robustness and performance, large parts of the external layers, workbenches and almost all the communication between the core and the user interface is coded in **Python**, a flexible, user-friendly, easy to learn programming language. From Python code, you are able to do just **anything in FreeCAD**, from simple one-line commands in the integrated Python console to recording macros,

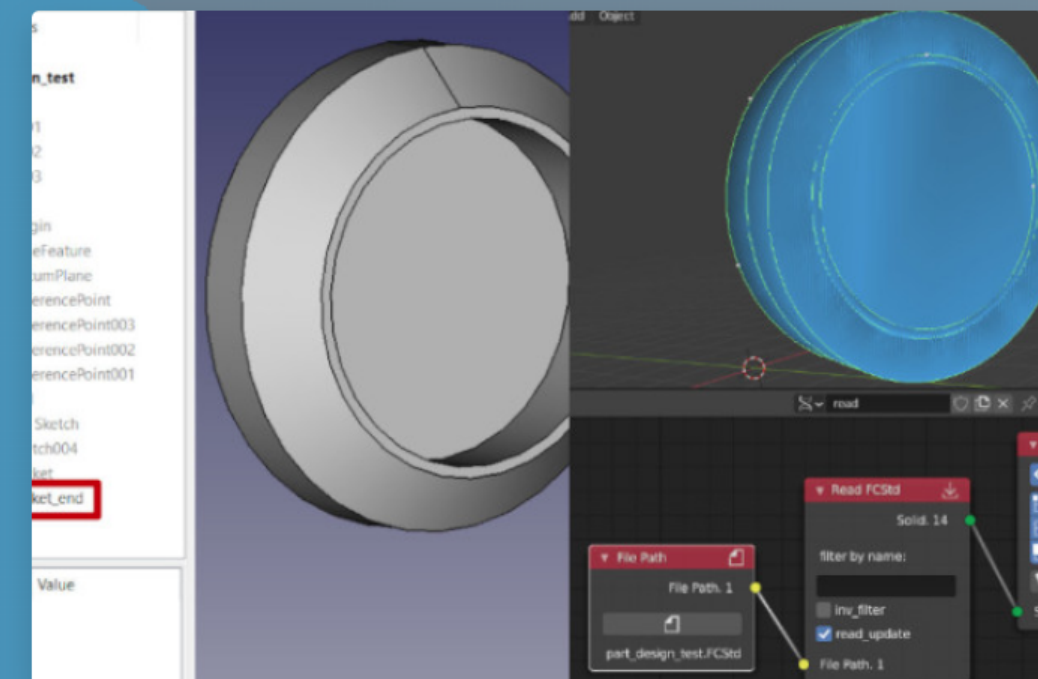
coding your own tools up to full custom workbenches.

GDML Workbench

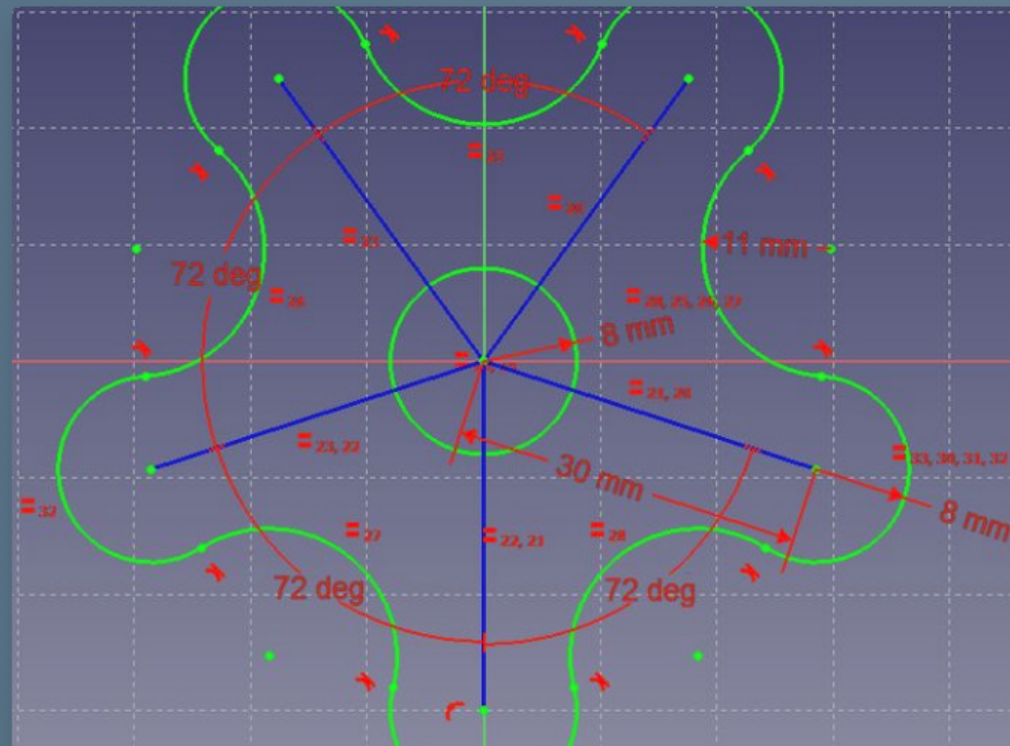
## File formats frenzy

FreeCAD allows you to import and export models and many other kinds of data from your models such as analyses results or quantities data to dozens of different **file formats** such as **STEP, IGES, OBJ, STL, DWG, DXF, SVG, SHP, DAE, IFC** or **OFF, NASTRAN, VRML, OpenSCAD CSG** and many more, in addition to FreeCAD's native **FCStd** file format. Add-on workbenches can also add more file formats.

GDML Workbench adds import/export of gdml files



# FreeCAD features, continued



## A parametric constraints-based 2D sketcher

FreeCAD features a state-of-the-art Sketcher with integrated constraint-solver, allowing you to sketch geometry-constrained 2D shapes. Sketches are the main building block of FreeCAD, and the constrained 2D shapes built with it may then be used as a base to build other objects throughout FreeCAD, be it either with the dedicated Part Design workbench or any other workbench.

- Sketch parameters can have numeric values (with units) or come from a FreeCAD supported spreadsheet. As usual, cells can have aliases and reference other cells.
- Sketches can be converted to 3D solids by (a) extruding them (b) revolving them, (c) sweeping them along paths.




```

Windows Help
...
zing /home/hindi/.local/share/FreeCAD/Mod
ot found)... ignore
zing /home/hindi/.local/share/FreeCAD/Mod
... done
zing /home/hindi/.local/share/FreeCAD/Mod
zing /home/hindi/.local/share/FreeCAD/Mod
workbench ThreadProfile specified icon in
... replacing with icon from package.xml
zing /home/hindi/.local/share/FreeCAD/Mod
... ignore
zing /home/hindi/.local/share/FreeCAD/Mod
zing /home/hindi/.local/share/FreeCAD/Mod
zing /home/hindi/.local/share/FreeCAD/Mod
workbench specified icon in class
ing with icon from package.xml data.
Is using InitGui.py are now initialized
freecad.gdml
module... done
dule... done
cher module... done
... done
module... done
Part module... done
re not available

```

- Start
- Arch
- Assembly 4
- BIM
- Draft
- Drawing
- Fasteners
- FEM
- GDML**
- Gear
- Image
- Inspection
- Manipulator
- Mesh Design
- <none>
- OpenSCAD
- Part Design
- Part
- Path
- Points
- Pyramids-and-Polyhedrons
- Raytracing
- Reverse Engineering
- Robot
- Sketcher
- Spreadsheet
- Start
- Surface

● Functionality of FreeCAD accessed through **Workbenches**:  
 Workbench: a set of tools + GUI grouped for a certain task.

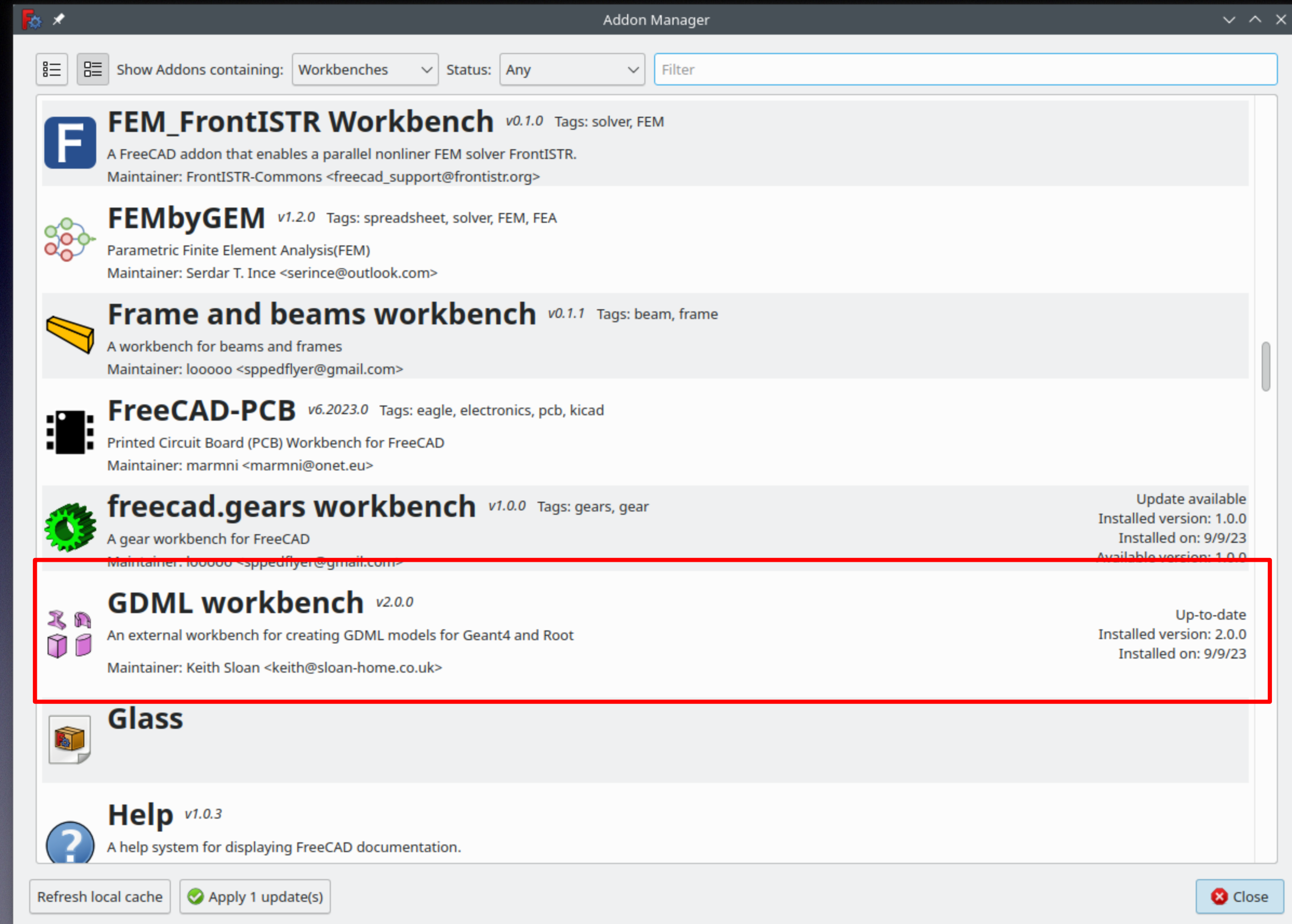
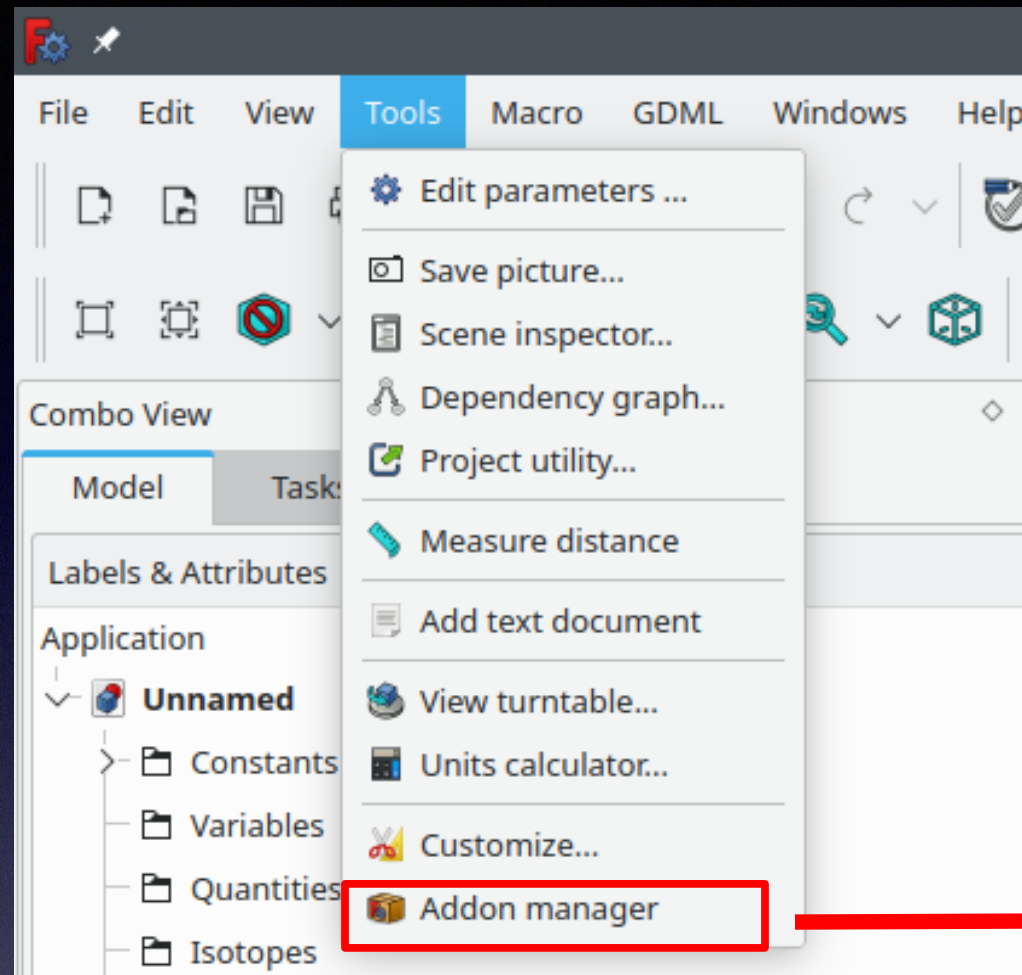
-  Base Workbenches: installed with FreeCAD and maintained by them
-  External Workbenches: Developed by the community and maintained outside FreeCAD
-  GDML: An external Workbench

Examples

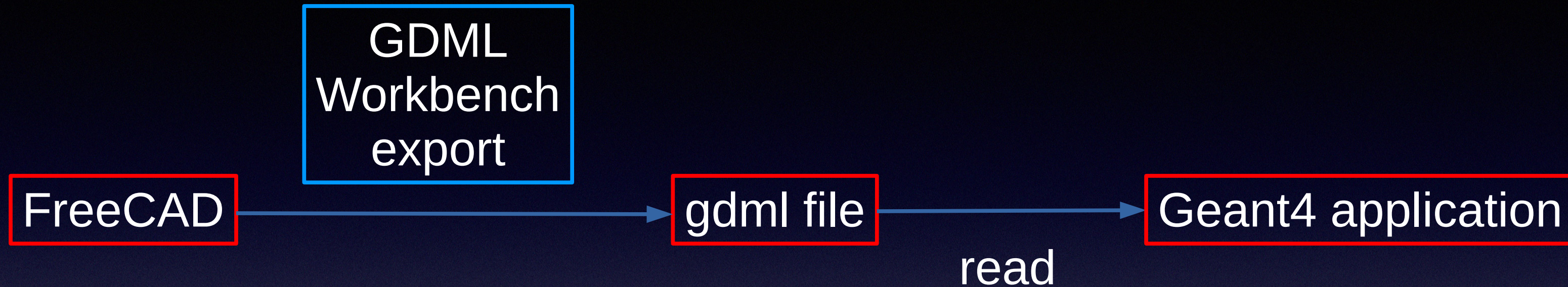




# External Workbenches Installed Via Tools→Addon Manager



In this presentation we concentrate on going from FreeCAD to gdml/Geant4:

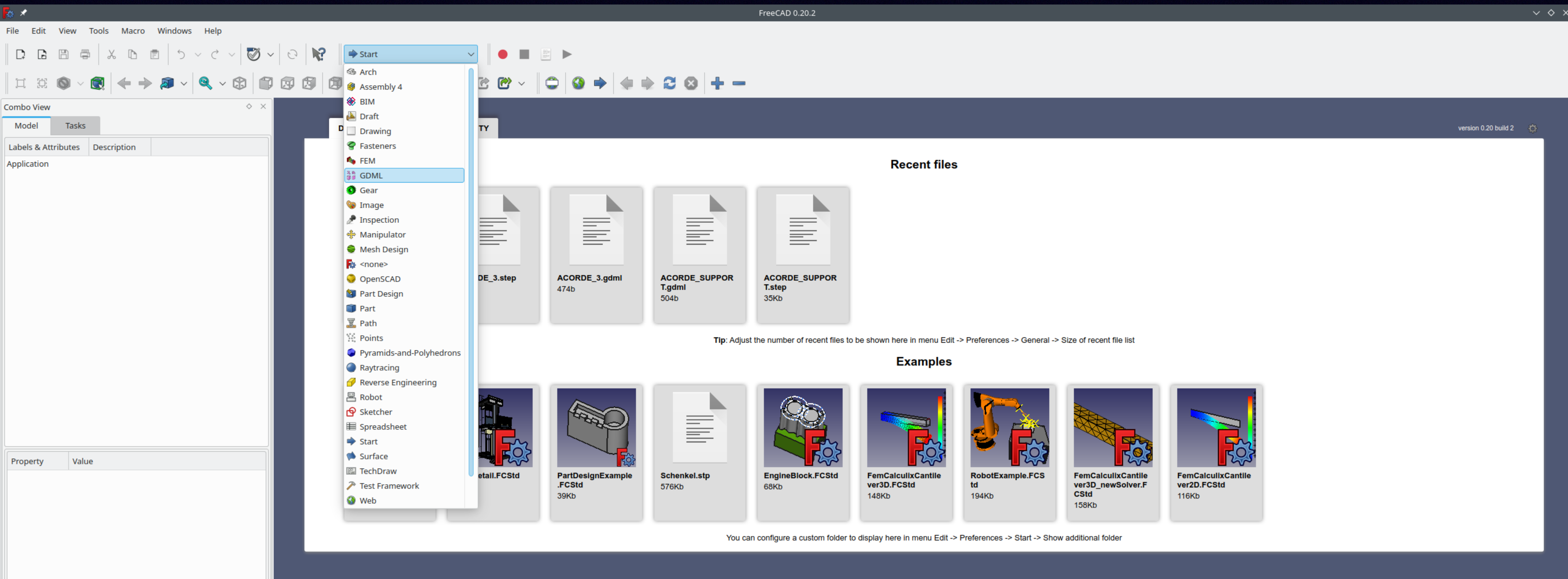


But one can also go from a Geant4 geometry to FreeCAD (see *example G01*):



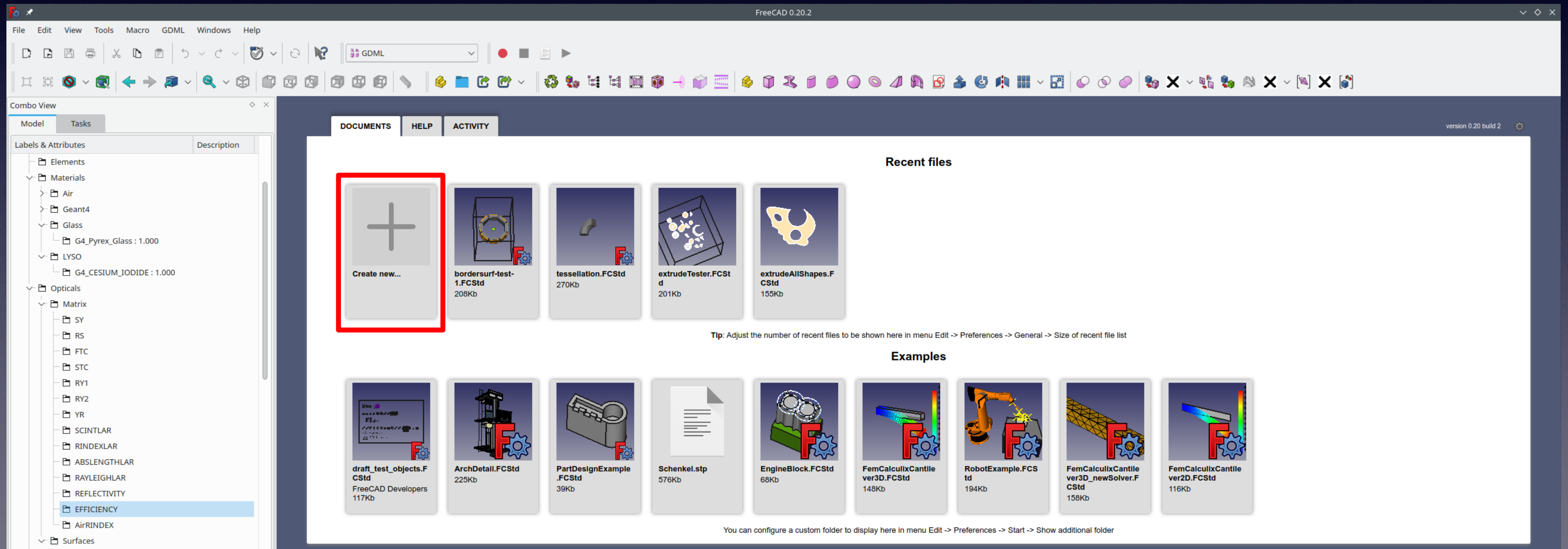
# Creating a gdml file from scratch

1. Launch FreeCAD
2. Select GDML Workbench



# Creating a gdml file from scratch, continued

## 3. Create New document

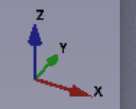
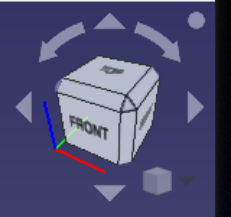
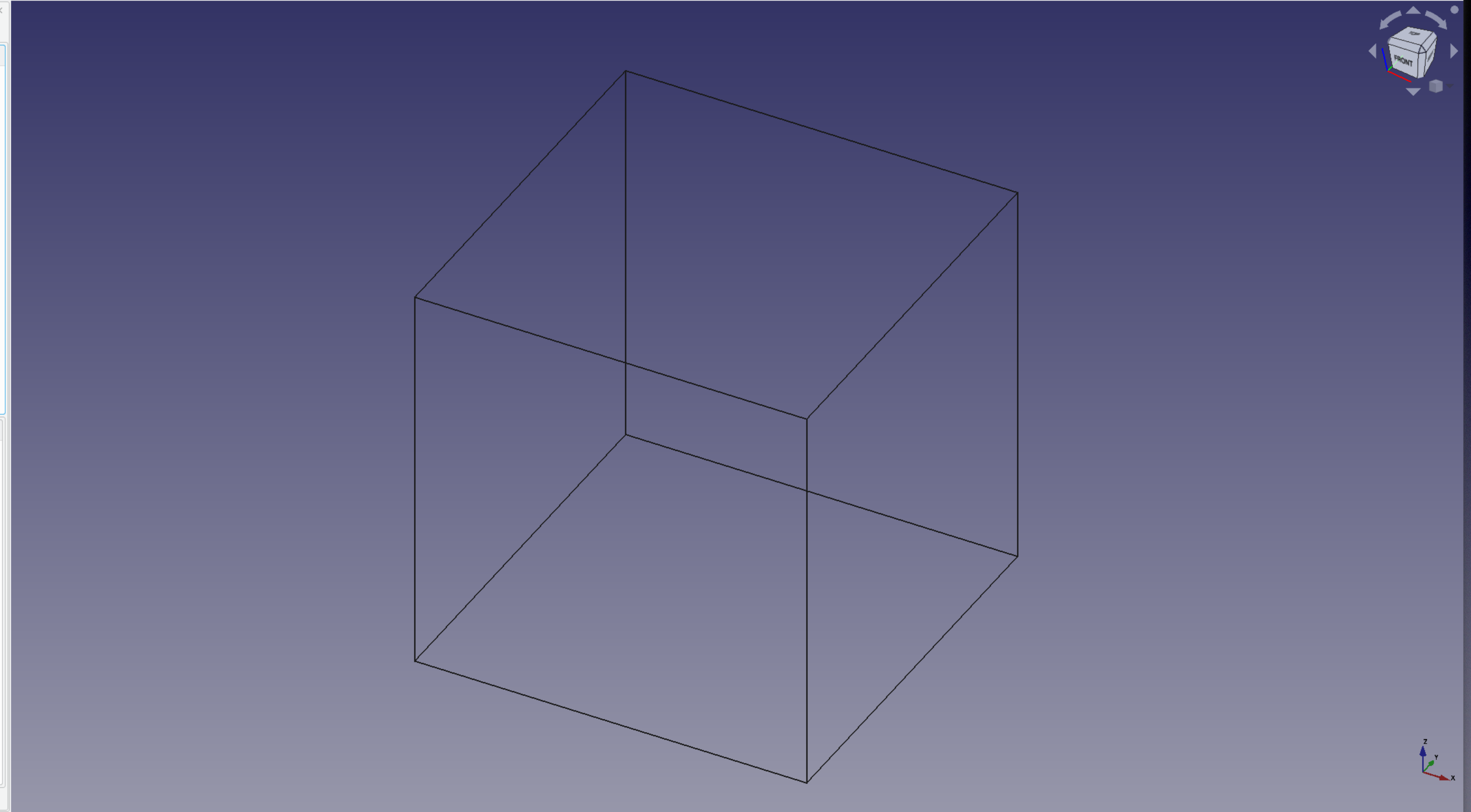


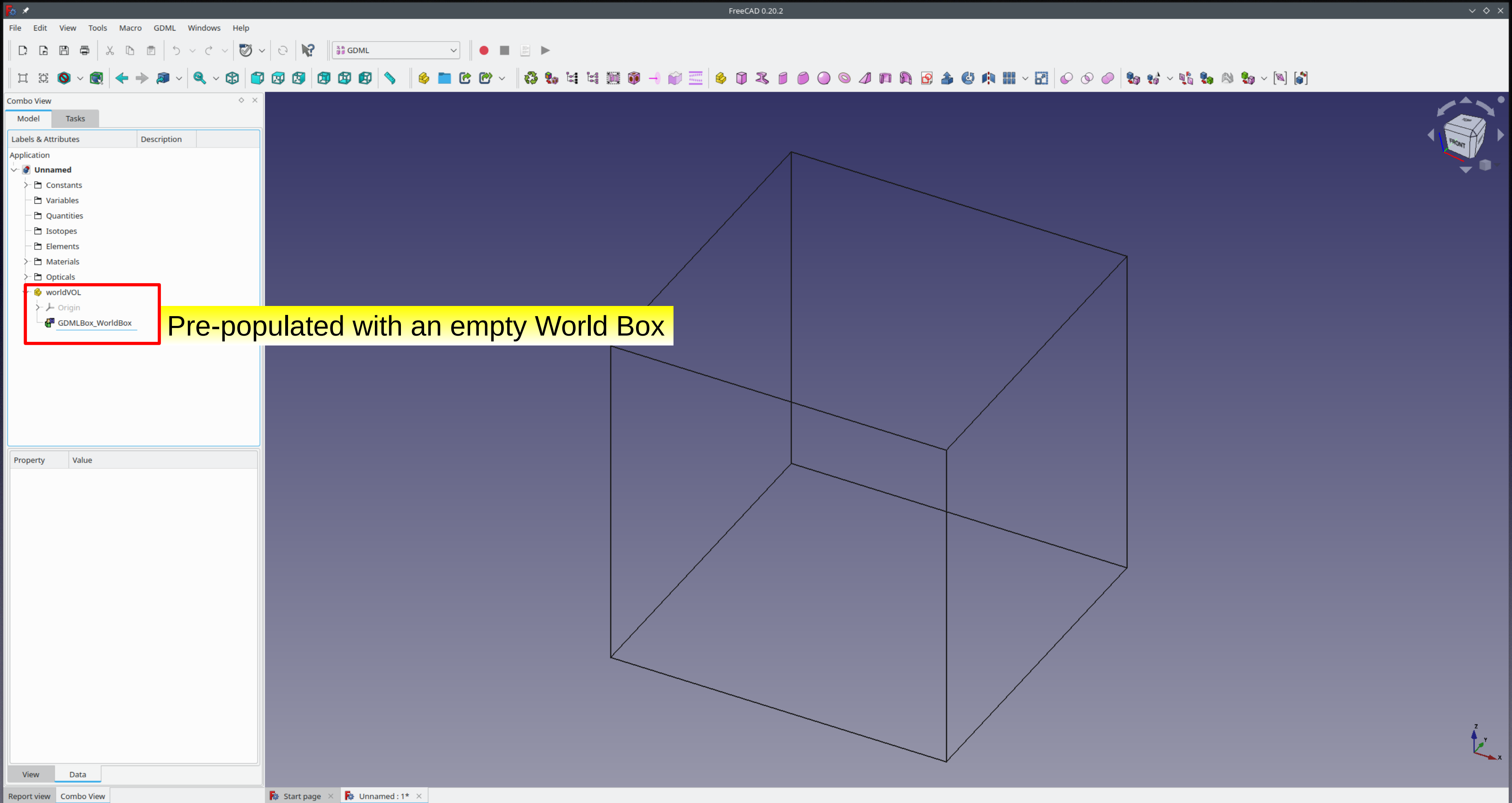
Combo View

Model Tasks

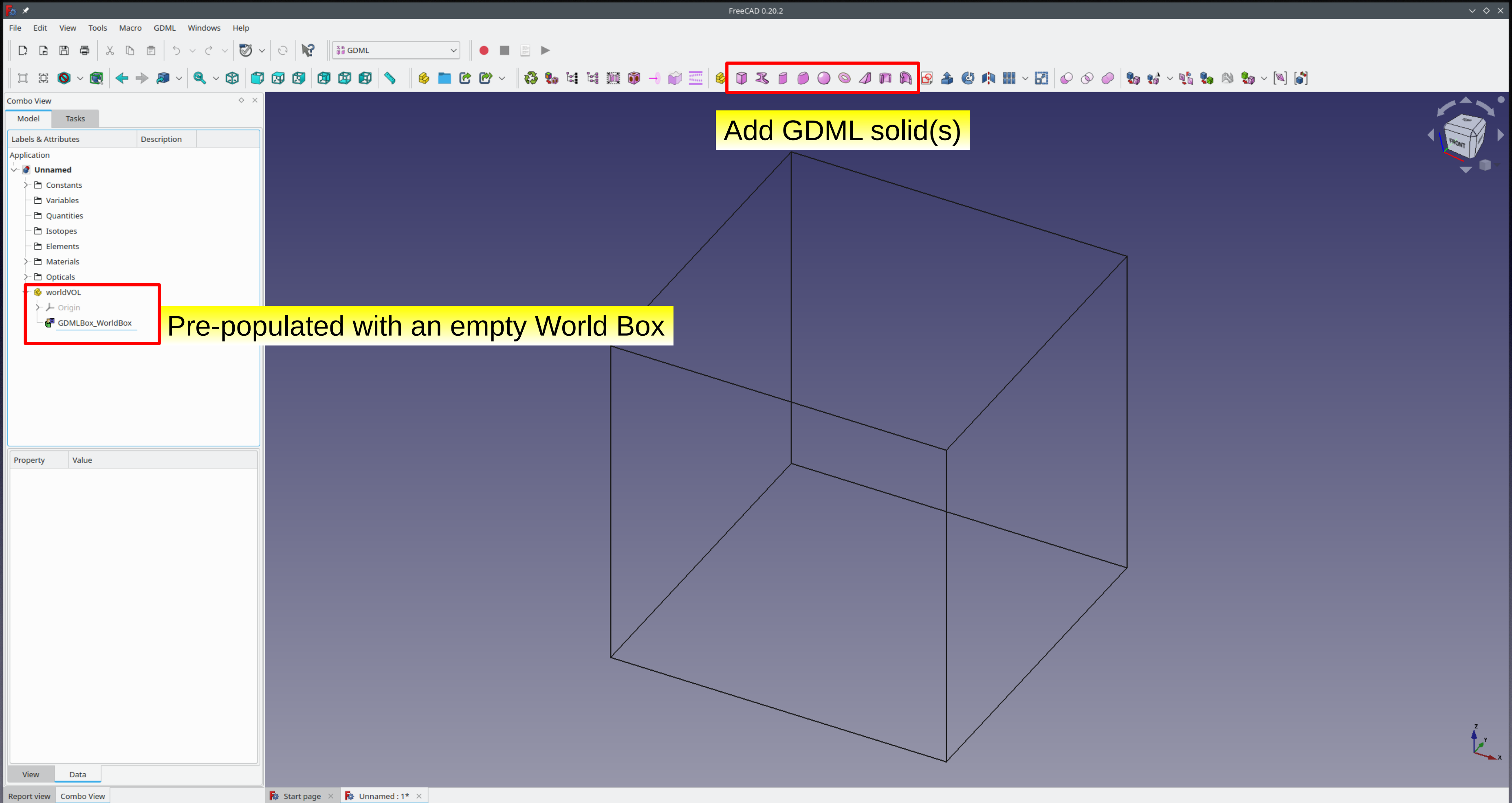
Labels & Attributes	Description
Application	
<ul style="list-style-type: none"> <li>Unnamed           <ul style="list-style-type: none"> <li>Constants</li> <li>Variables</li> <li>Quantities</li> <li>Isotopes</li> <li>Elements</li> <li>Materials</li> <li>Opticals</li> <li>worldVOL               <ul style="list-style-type: none"> <li>Origin</li> <li>GDMLBox_WorldBox</li> </ul> </li> </ul> </li> </ul>	

Property	Value





Pre-populated with an empty World Box



Add GDML solid(s)

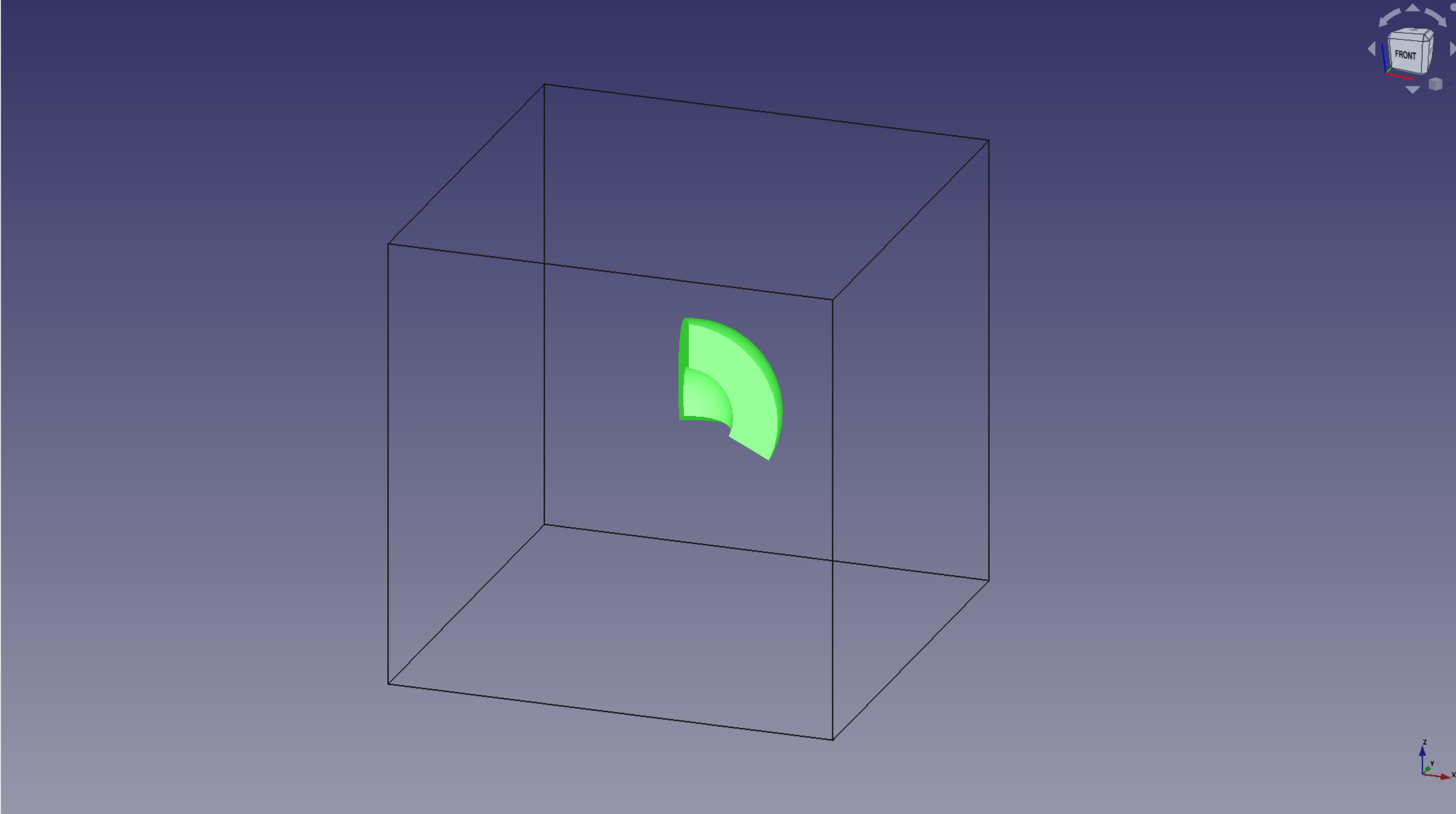
Pre-populated with an empty World Box

Combo View

Model Tasks

Labels & Attributes	Description
Application	
↳ <b>Unnamed</b>	
↳ Constants	
↳ Variables	
↳ Quantities	
↳ Isotopes	
↳ Elements	
↳ Materials	
↳ Opticals	
↳ worldVOL	
↳ Origin	
↳ GDMLBox_WorldBox	
↳ LV_Sphere	
↳ Origin001	
↳ <b>GDMLSphere</b>	

Property	Value
<b>Base</b>	
↳ Placement	[[0.00 0.00 1.00]; 0.00 °; (0.00 mm 0.00 mm 0.00 ...
↳ Label	GDMLSphere
<b>GDMLSphere</b>	
↳ aunit	rad
↳ deltaphi	2.02
↳ deltatheta	2.02
↳ lunit	mm
↳ material	G4_A-150_TISSUE
↳ rmax	20.00
↳ rmin	10.00
↳ startphi	0.00
↳ starttheta	0.00





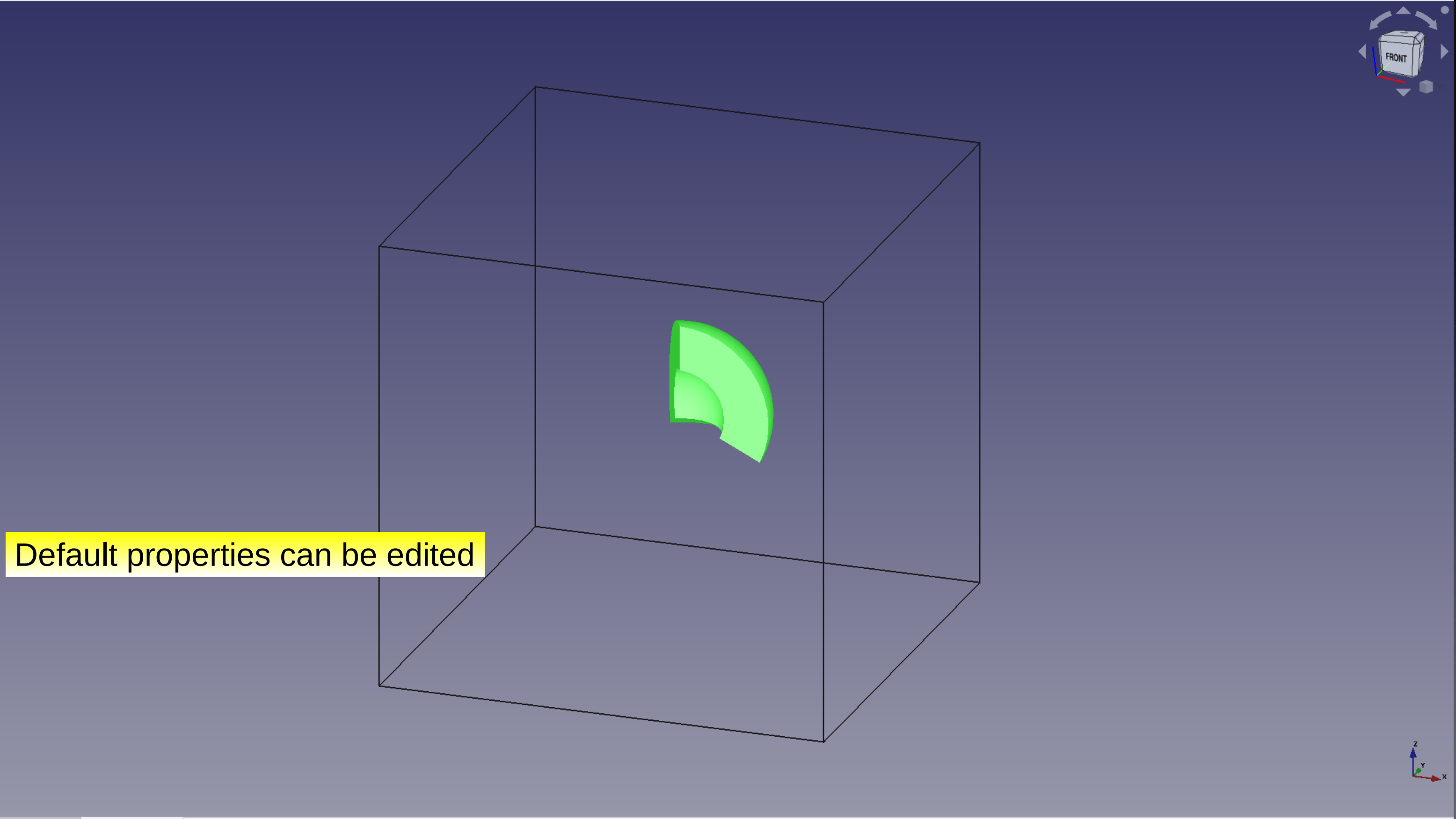


Combo View

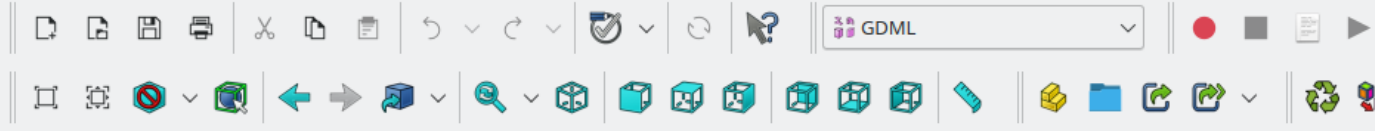
Model Tasks

Labels & Attributes	Description
Application	
▼ <b>Unnamed</b>	
> Constants	
> Variables	
> Quantities	
> Isotopes	
> Elements	
> Materials	
> Opticals	
> worldVOL	
> Origin	
GDMLBox_WorldBox	
> LV_Sphere	
> Origin001	
<b>GDMLSphere</b>	

Property	Value
<b>Base</b>	
> Placement	[[0.00 0.00 1.00]; 0.00 °; (0.00 mm 0.00 mm 0.00 ...
Label	GDMLSphere
<b>GDMLSphere</b>	
- aunit	rad
- deltaphi	2.02
- deltatheta	2.02
- lunit	mm
- material	G4_A-150_TISSUE
- rmax	20.00
- rmin	10.00
- startphi	0.00
- starttheta	0.00



Default properties can be edited



Combo View

Model Tasks

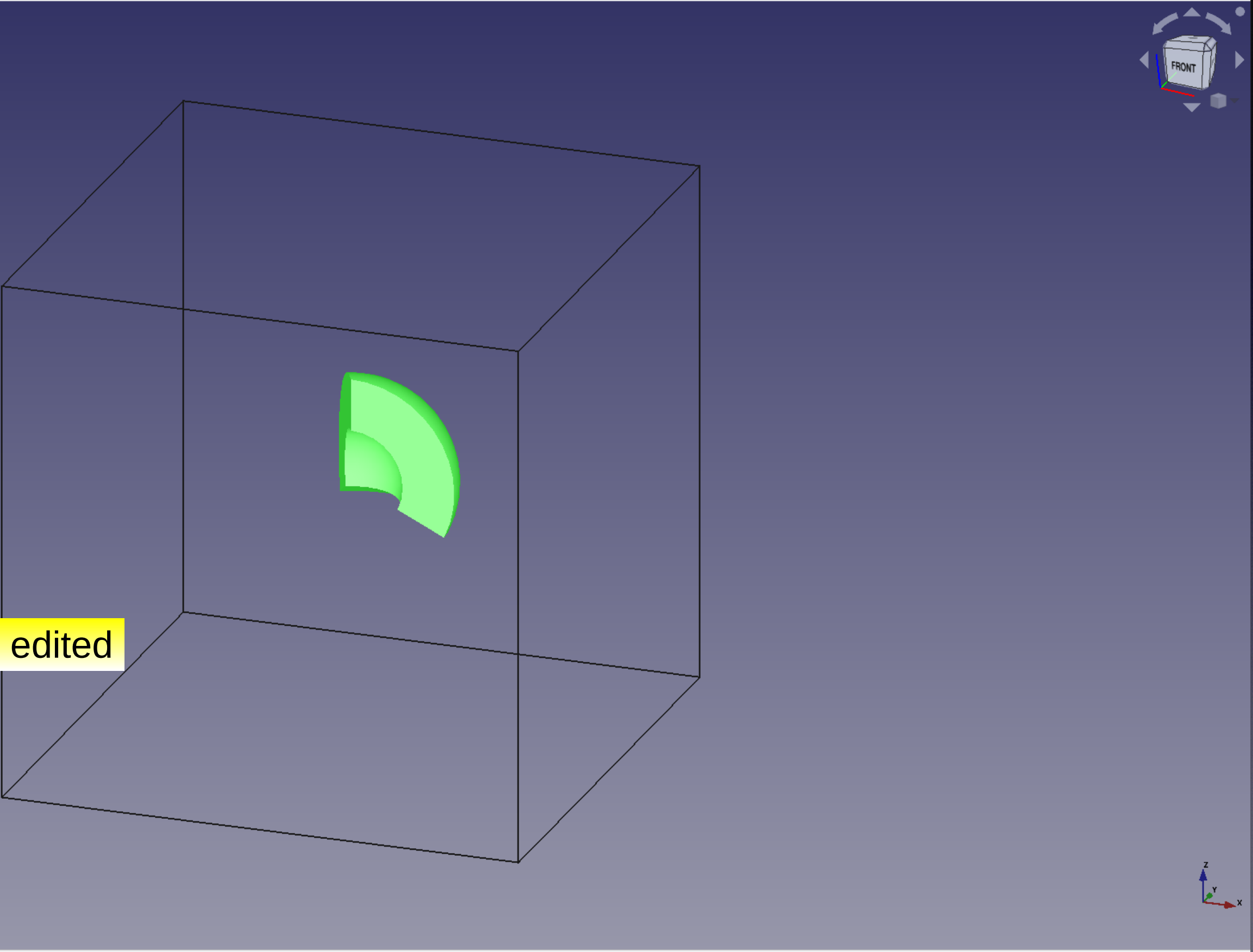
Labels & Attributes	Description	
Application		
<ul style="list-style-type: none"> <li>Unnamed           <ul style="list-style-type: none"> <li>Constants</li> <li>Variables</li> <li>Quantities</li> <li>Isotopes</li> <li>Elements</li> <li>Materials</li> <li>Opticals</li> <li>worldVOL               <ul style="list-style-type: none"> <li>Origin</li> <li>GDMLBox_WorldBox                   <ul style="list-style-type: none"> <li>LV_Sphere                       <ul style="list-style-type: none"> <li>Origin001                           <ul style="list-style-type: none"> <li>GDMLSphere</li> </ul> </li> </ul> </li> </ul> </li> </ul> </li> </ul> </li> </ul>		

This tree element in the document exports to:

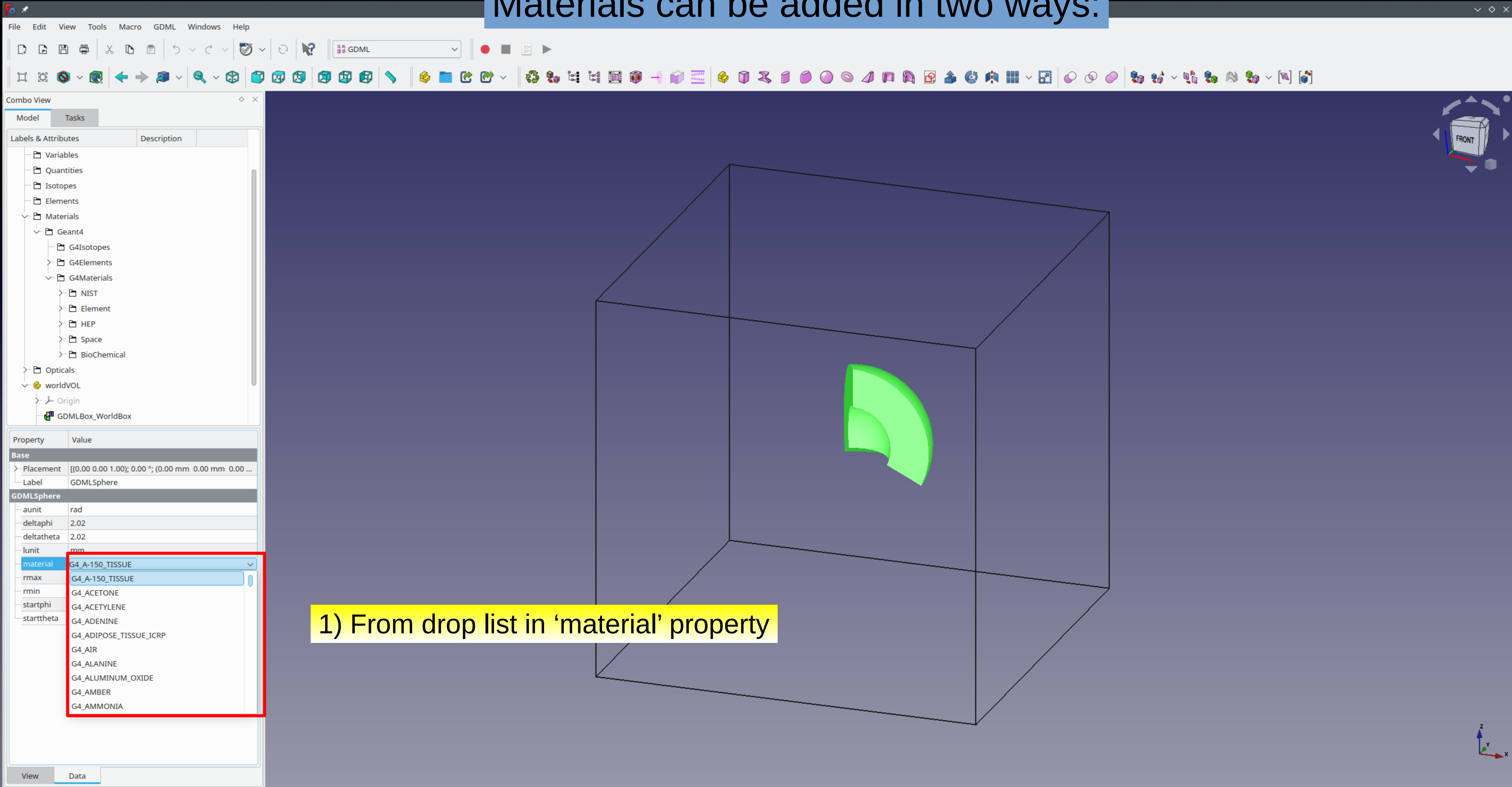
- a) a <solid
- b) a <volume
- c) a <physvol

Property	Value
Base	
Placement	[[0.00 0.00 1.00]; 0.00 °; (0.00 mm 0.00 mm 0.00 ...
Label	GDMLSphere
GDMLSphere	
-aunit	rad
-deltaphi	2.02
-deltatheta	2.02
-lunit	mm
-material	G4_A-150_TISSUE
-rmax	20.00
-rmin	10.00
-startphi	0.00
-starttheta	0.00

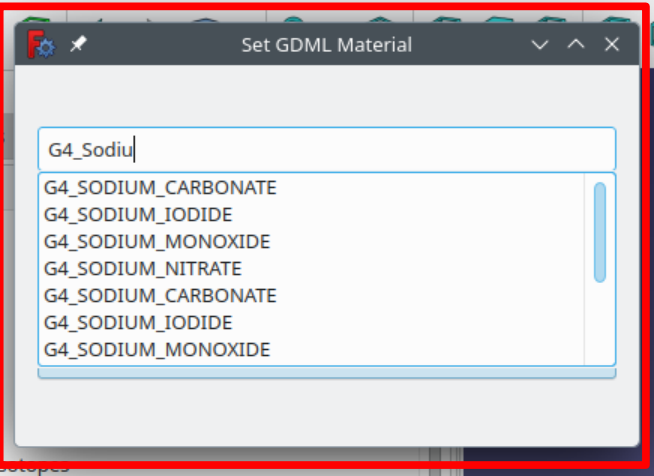
Default properties can be edited



# Materials can be added in two ways:



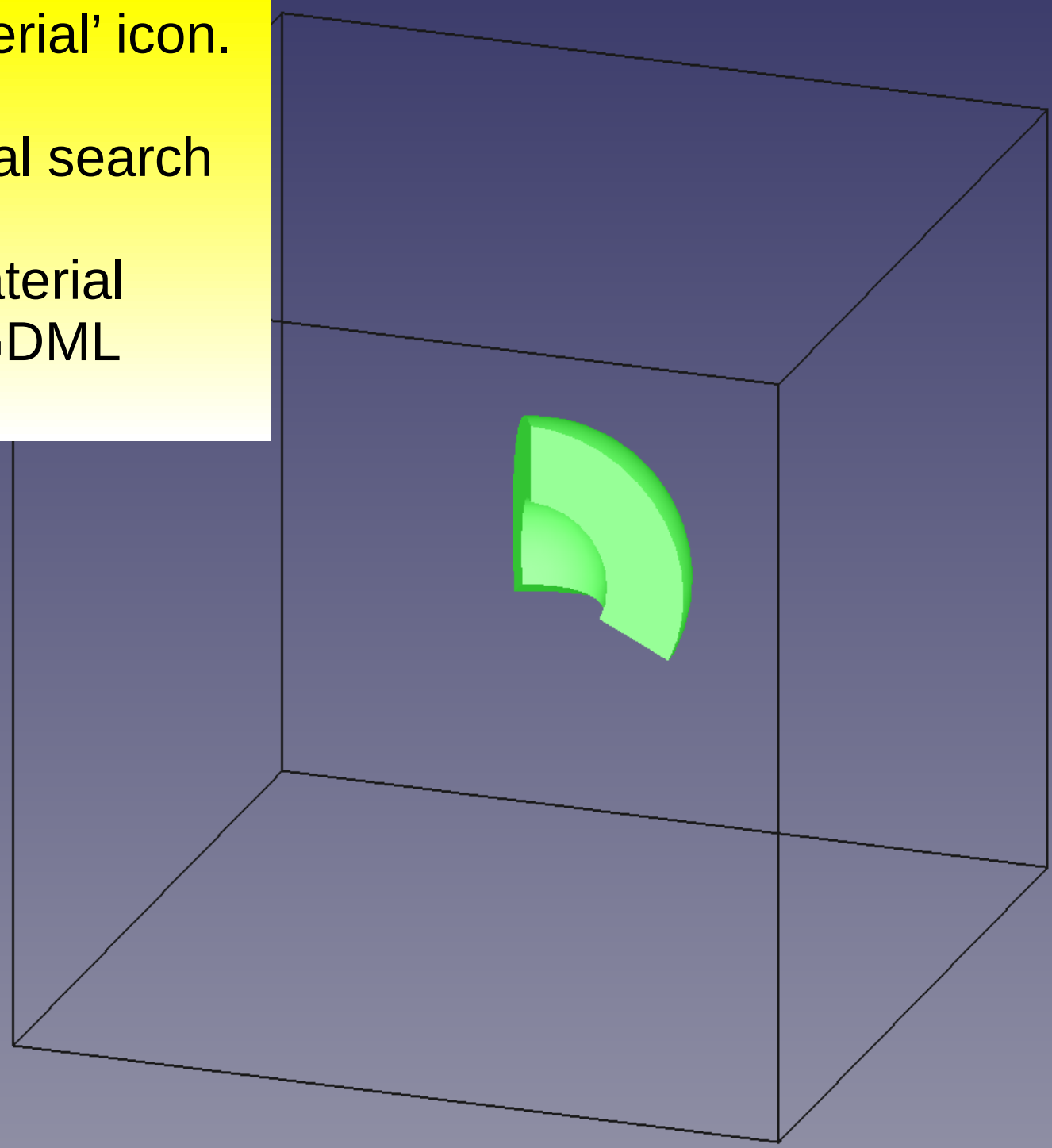
# Materials can be added in two ways:



2) Using 'set material' icon.

Allows incremental search

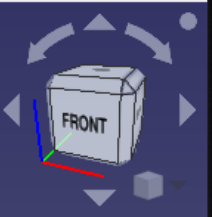
Allows adding material property to non-GDML solids.



# Materials



- When a new document is created, a file supplied with the GDML Workbench (Geant4Materials.xml) is loaded. This file contains the Geant4 and NIST list of materials. The materials are displayed as a group with subgroups in the FreeCAD document.
- At present new materials cannot be defined from within the GDML Workbench
- New materials can be added directly to the supplied Geant4Materials.xml file, or read by opening or importing a user supplied gdml file.
- Opening a gdml file creates a new document; importing it adds its contents to the currently open document





Can add booleans (Cuts, Intersections, Unions) of inserted solids: select two solids then select the operation using the icons above.

# Export the document to gdmf:

The screenshot shows the FreeCAD 0.20.2 interface. The main 3D view displays a green rectangular block with a cylindrical hole, enclosed within a green wireframe bounding box. The Combo View panel on the left is open to the 'Model' tab, showing a tree structure. The 'worldVOL' object is highlighted with a red rectangle. Below the tree is a property table.

Property	Value
<b>Display Optio...</b>	
Display M...	Group
Show In T...	true
Visibility	true
<b>Selection</b>	
On Top W...	Disabled
Selection ...	Shape

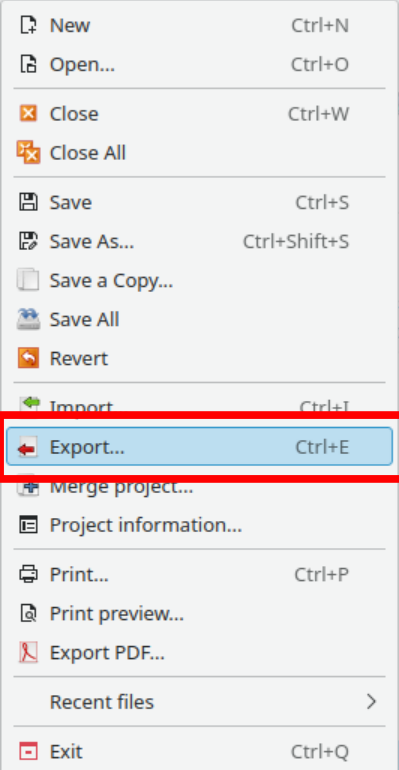
1) Select the worldVOL

Report view Combo View

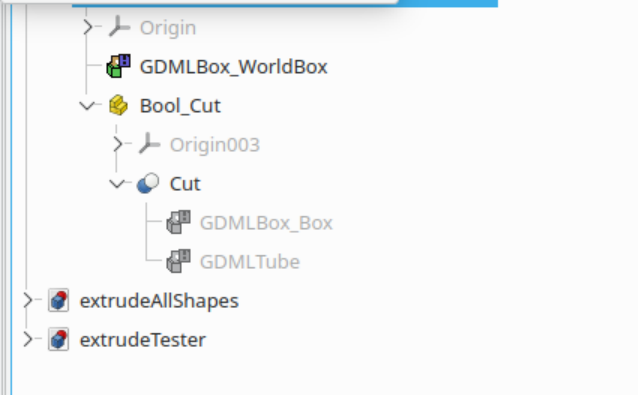
Start page booleans : 1 extrudeAllShapes : 1\* extrudeTester : 1

Preselected: Unnamed.worldVOL.Bool\_Cut.Cut.Face3 (-23.047634 mm, -10.149405 mm, 25.000000 mm)

CAD 323.04 mm x 173.21 mm

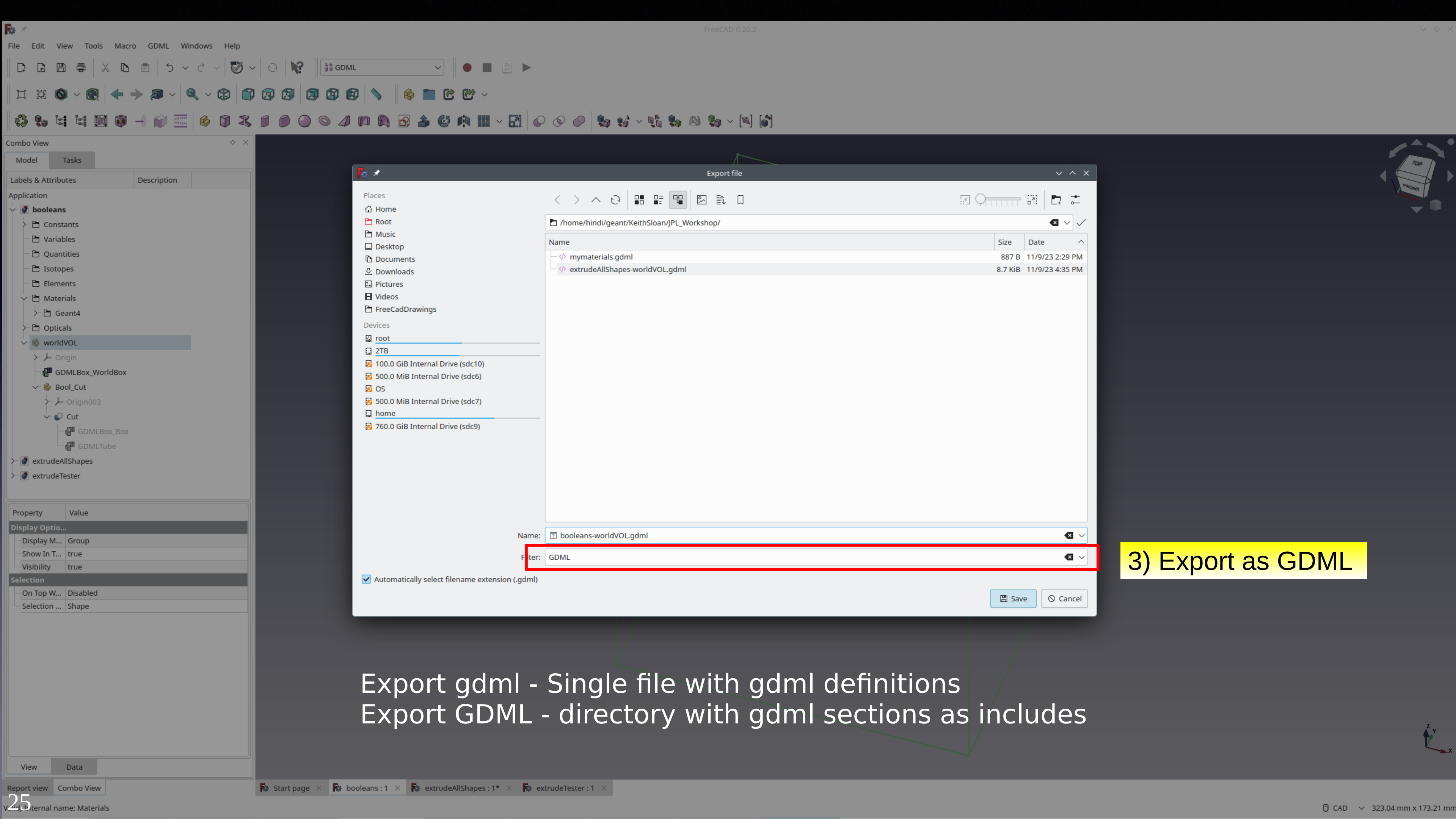


2) File → Export...



Property	Value
<b>Display Optio...</b>	
Display M...	Group
Show In T...	true
Visibility	true
<b>Selection</b>	
On Top W...	Disabled
Selection ...	Shape





Export gdml - Single file with gdml definitions  
Export GDML - directory with gdml sections as includes

3) Export as GDML

Can view the exported file using the `load_gdml` application provided with Geant4 in `examples/persistency/gdml/G01`

We export the FreeCAD color of solids by adding an `<auxiliary auxtype="Color">` tag to each of the `<volumes>` in the gdml file.

We have a modified version of `load_gdml`, `load_gdml_color` that processes that auxiliary tag. We can add the modified file to the github if there is interest.

The screenshot displays the `load_gdml_color` application interface. The main window shows a 3D visualization of a detector component, which is a blue rectangular block with a circular hole in the center. A red arrow points to the right side of the block. The interface includes a scene tree on the left, a search bar, and a command list. The output window at the bottom shows the following text:

```
# Abbreviations: PV = Physical Volume, LV = Logical Volume,
#                SD = Sensitive Detector, RO = Read Out Geometry.
"worldVOL_PV":0 / "worldVOL" / "WorldBox" (G4Box), 1 L , 1.20479 mg/cm3 (G4_AIR)
"PV-Bool_Cut":0 / "Bool_Cut" / "Cut" (G4SubtractionSolid), 1.09314 dL , 1.127 g/cm3 (G4_A-150_TISSUE)
Calculating mass(es)...
Overall volume of "worldVOL_PV":0, is 1 L and the daughter-included mass to unlimited depth is 124.27 g
G4ASCIITreeSceneHandler::EndModeling
/vis/viewer/update viewer-1
Reverting to viewer-0 (OpenGLImmediateQt)
# Adjust trajectory colors
/vis/modeling/trajectories/create/drawByParticleID myModel
```

# Adding non-GDML solids to the GDML document

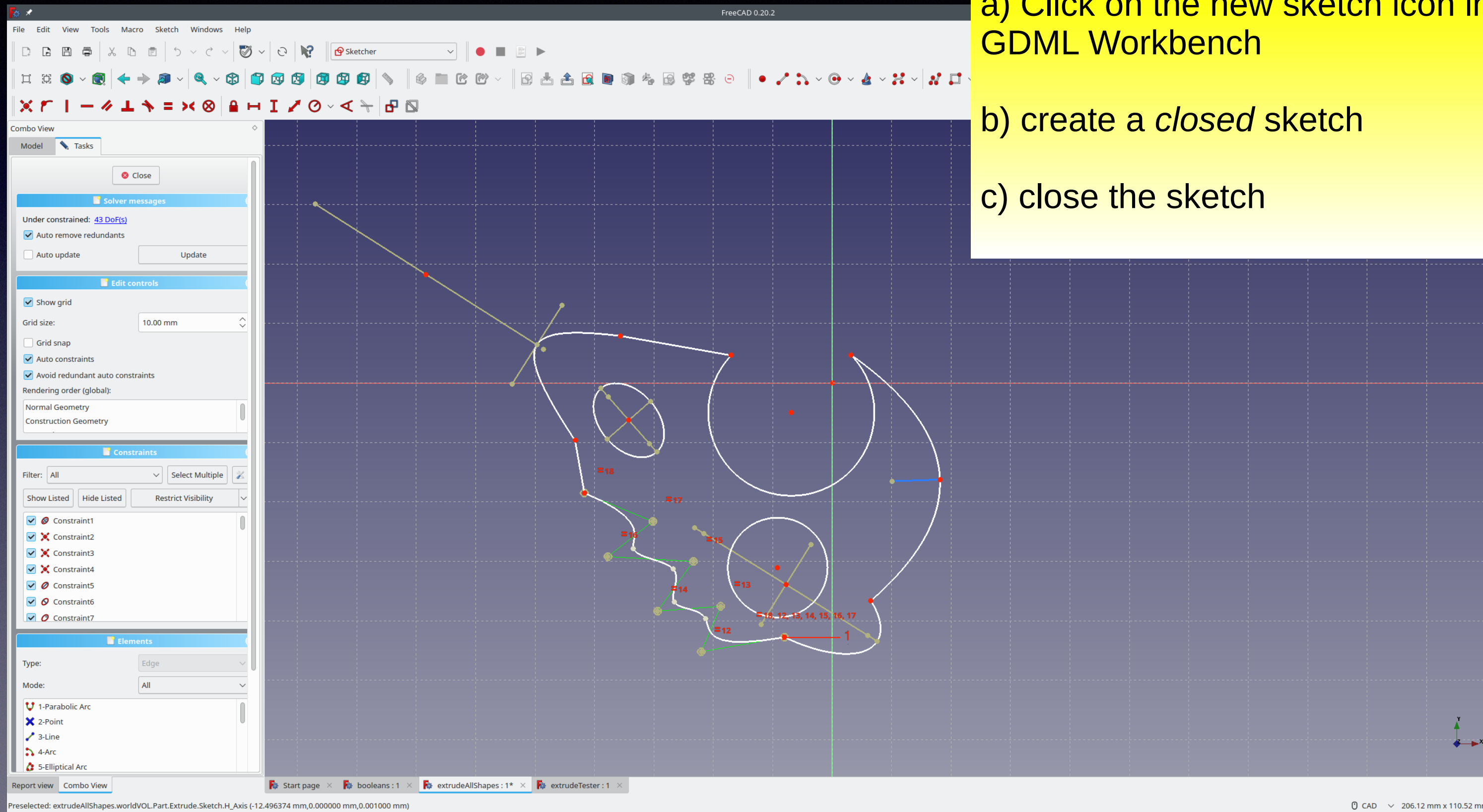
## 1. Extrusions

a) Click on the new sketch icon in the GDML Workbench



b) create a *closed* sketch

c) close the sketch



The toolbar contains various icons for file operations, editing, and modeling. The Extrude icon, which depicts a 3D rectangular block with a blue arrow, is highlighted with a red rectangular box.

d) Select the sketch and extrude it to the desired height

Combo View

- Model
- Tasks
- Labels & Attributes
- Description

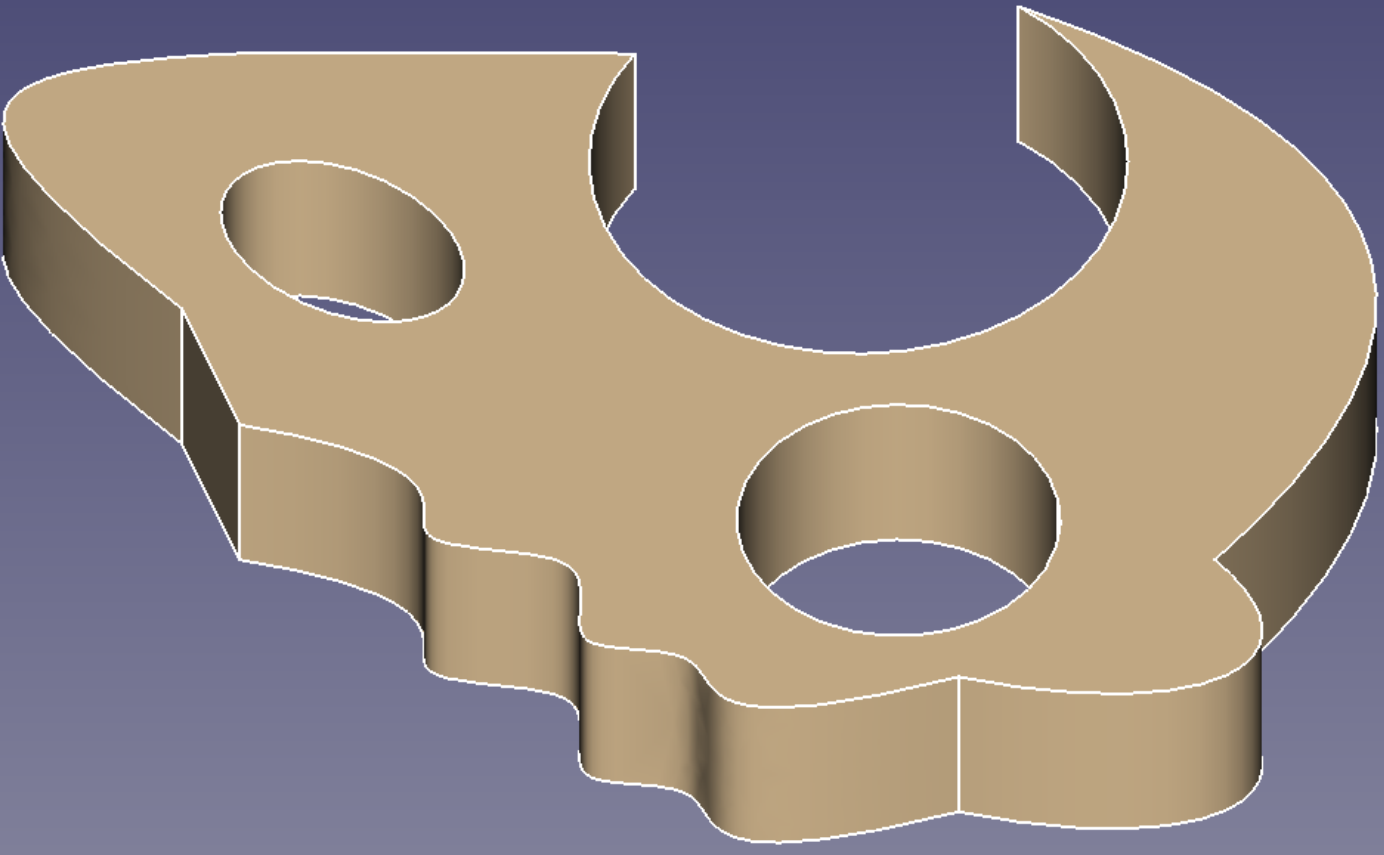
Application

- booleans
- extrudeAllShapes
  - Constants
  - Variables
  - Quantities
  - Isotopes
  - Elements
  - Materials
  - worldVOL
    - Origin
    - GDMLBox\_WorldBox
    - Part
      - Origin001
        - Extrude
          - Sketch
- extrudeTester

Property

Property	Value
----------	-------

View Data





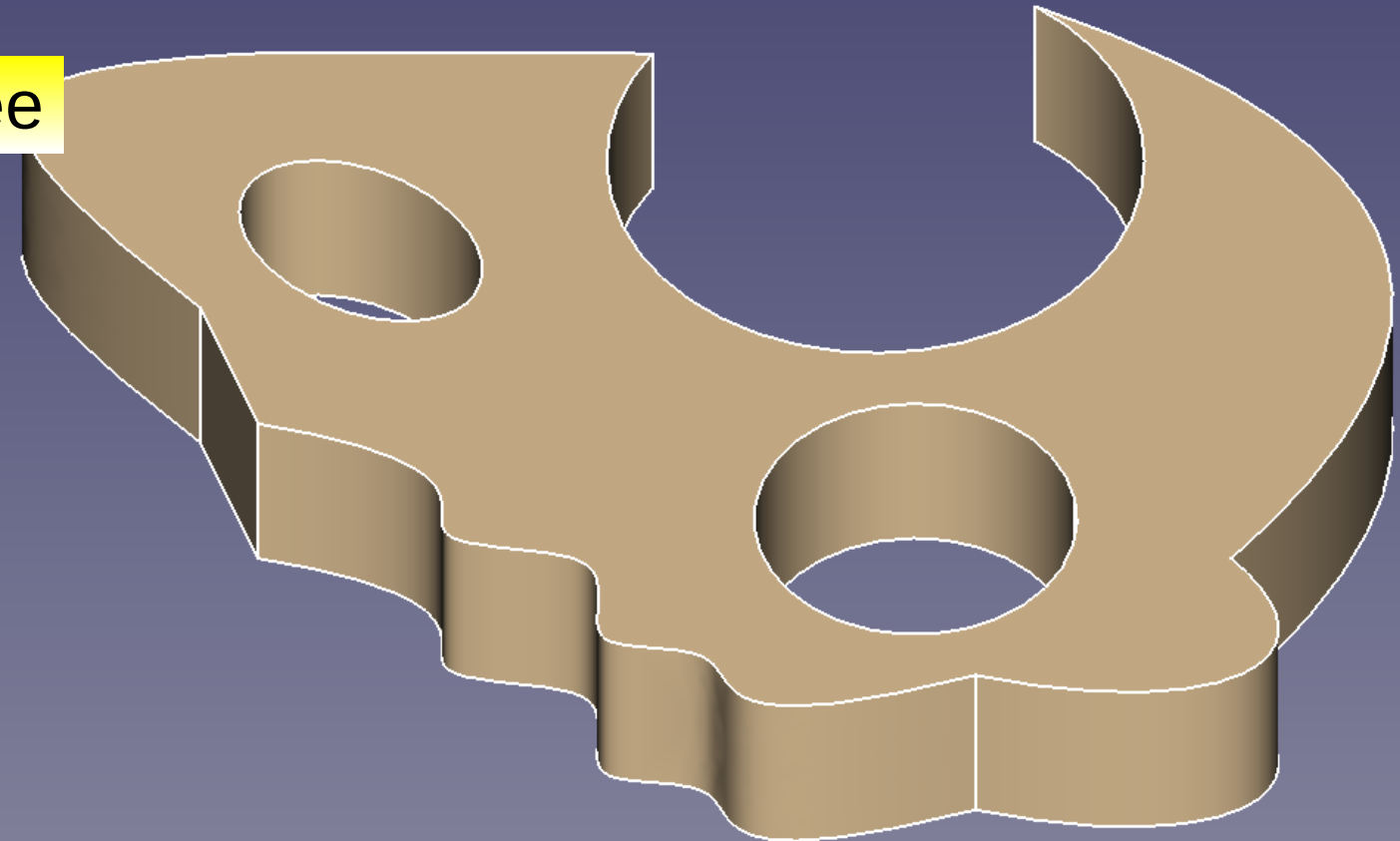
Combo View

Model Tasks

Labels & Attributes	Description
Application	
booleans	
extrudeAllShapes	
Constants	
Variables	
Quantities	
Isotopes	
Elements	
Materials	
worldVOL	
Origin	
GDMLBox_Work	
Part	
Origin001	
Extrude	
Sketch	
extrudeTester	

d) Select the sketch and extrude it to the desired height

e) Add a Part to the worldVOL tree



Property Value

Property	Value
----------	-------

View Data



Combo View

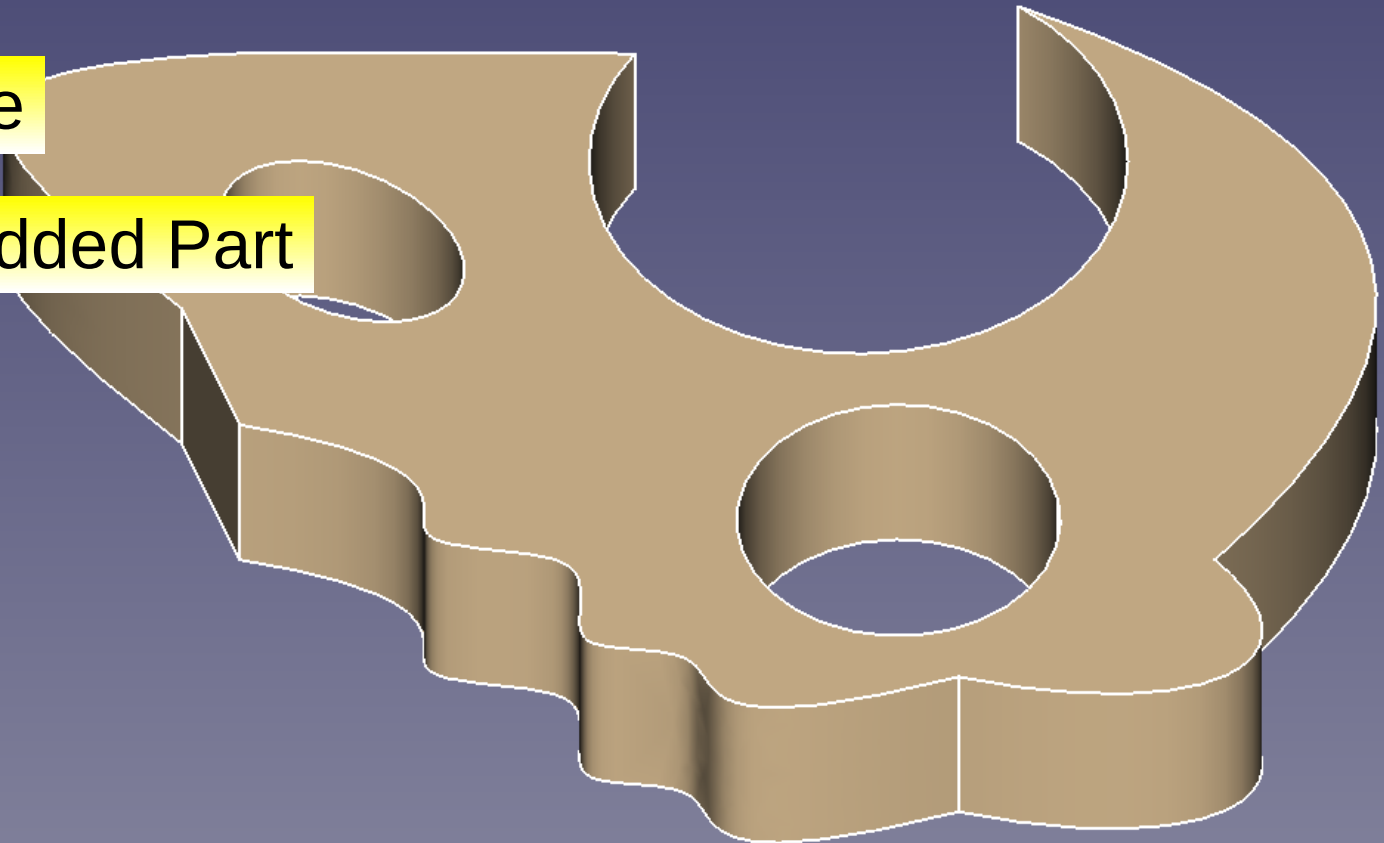
Model Tasks

Labels & Attributes	Description
Application	
booleans	
extrudeAllShapes	
Constants	
Variables	
Quantities	
Isotopes	
Elements	
Materials	
worldVOL	
Origin	
GDMLBox_Work	
Part	
Extrude	
Sketch	
extrudeTester	

d) Select the sketch and extrude it to the desired height

e) Add a Part to the worldVOL tree

f) Drag the Extrusion under the added Part



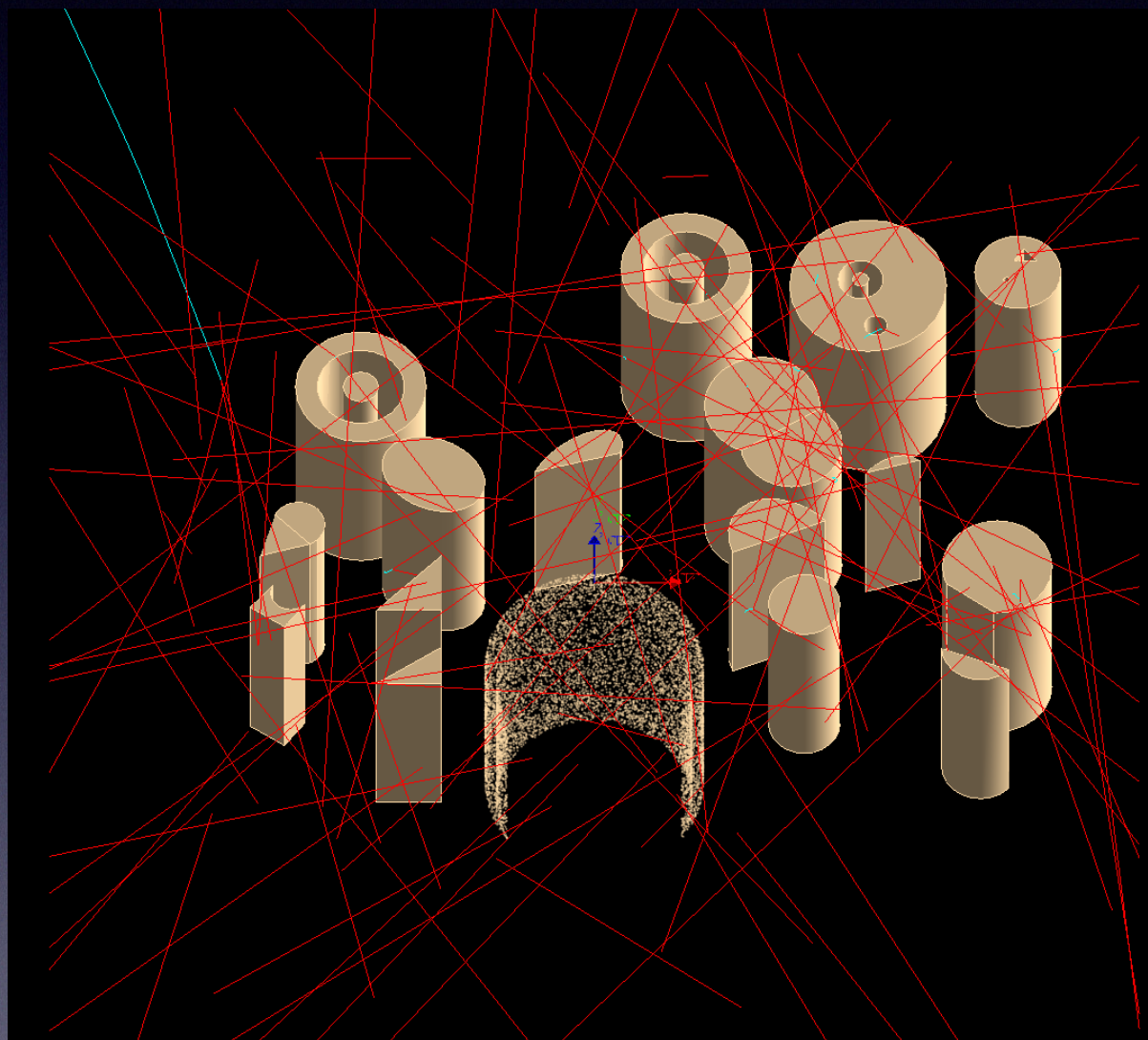
Property	Value

View Data

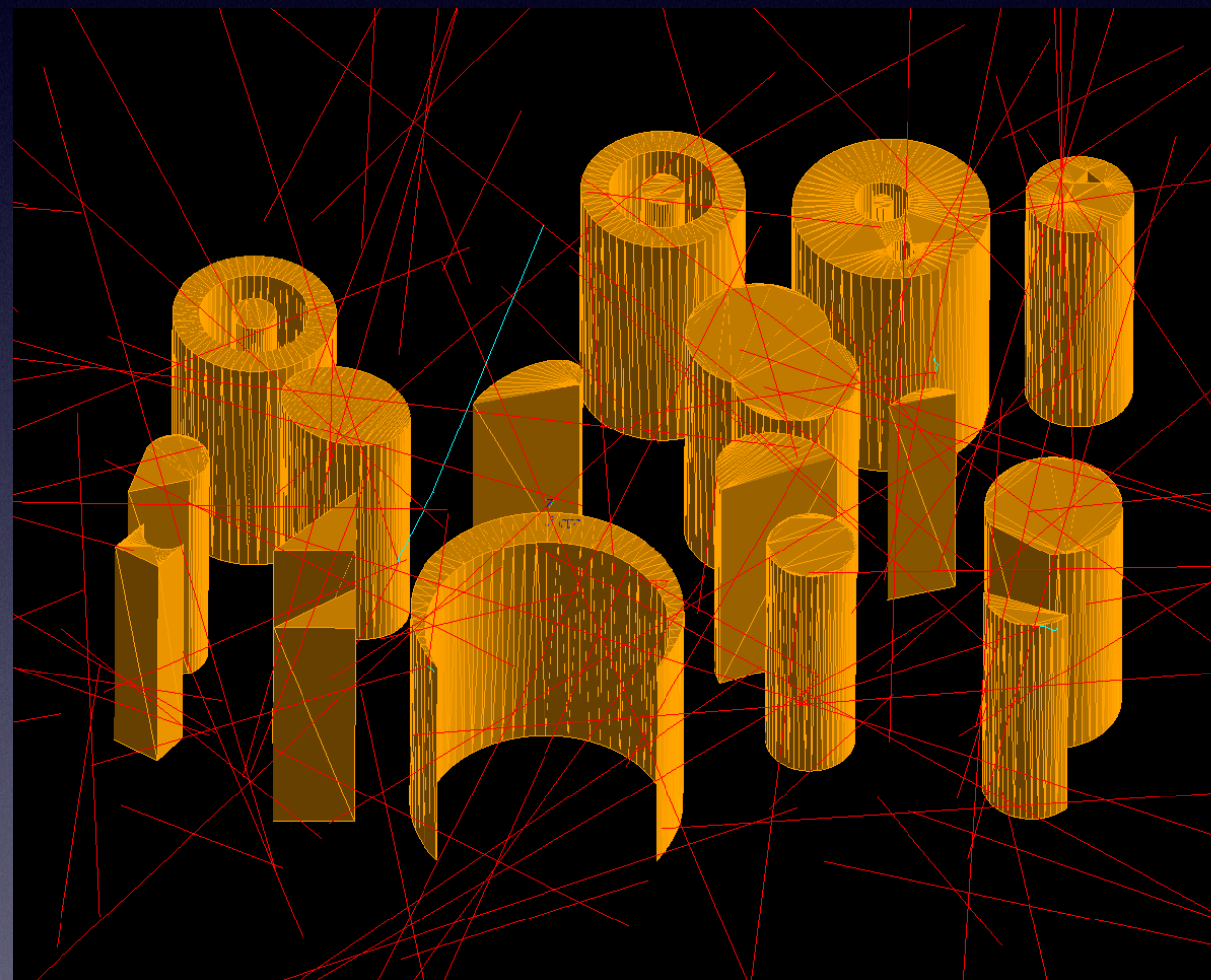
# Adding non-GDML solids to the GDML document

## 1. Extrusions

To the extent possible, extrusions are exported as booleans of GDML solids (Circles → Tubes, Polygons → Xtru, Ellipses → ElTube, ...). We believe this produces faster Geant4 simulations than conversion to a Tessellation:



Exported as booleans of Solids



Exported as tessellations

**With  $10^6$  geantinos:**


**extrusions: 7.25 s**  
**tessellation: 17.35 s**  
**(Factor of 2.4 faster with booleans)**

**With  $10^6$  2 MeV gamma rays:**

**extrusion: 17.35 s**  
**tessellation: 146 s**  
**(Factor of 8.4 faster with booleans)**

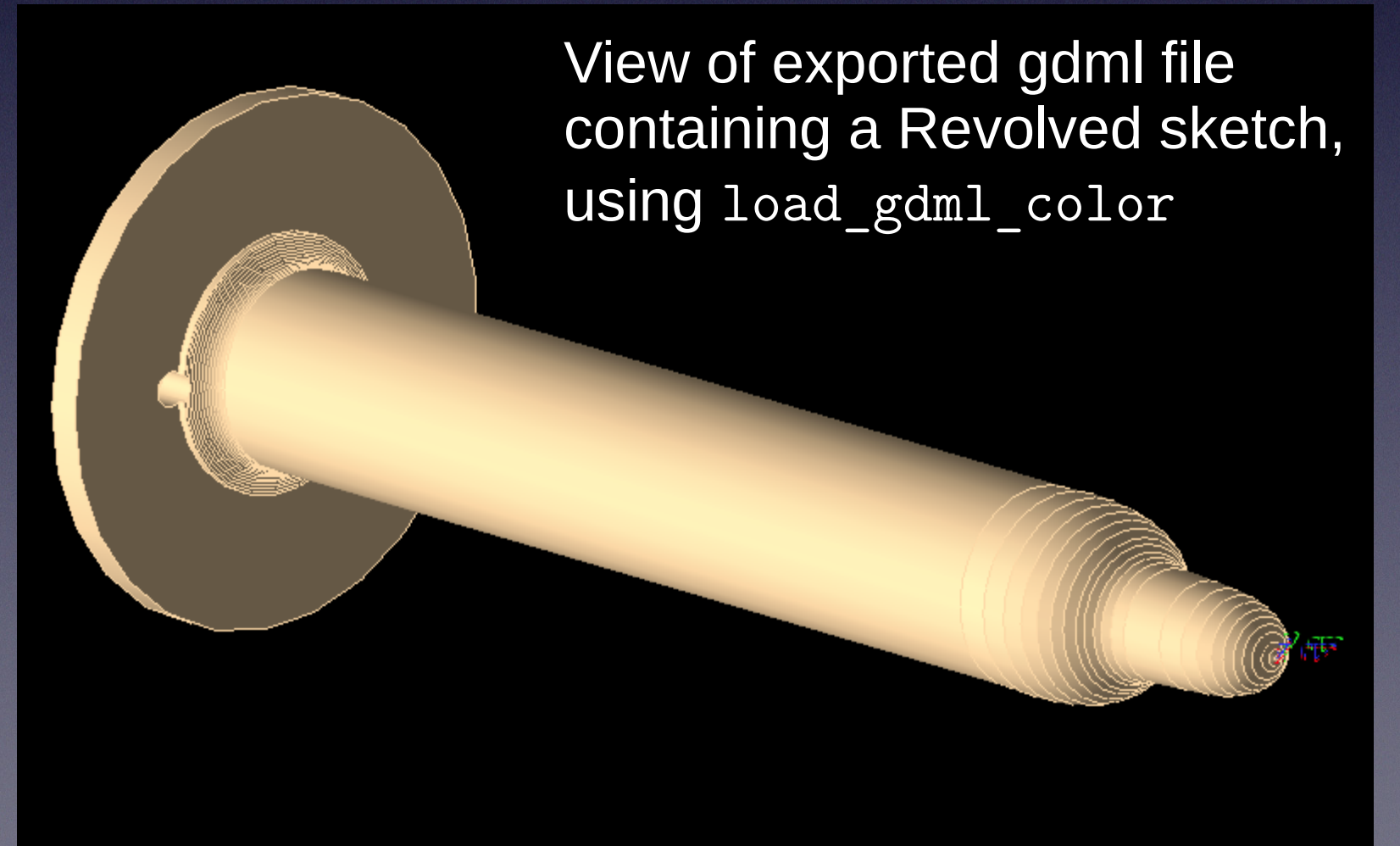
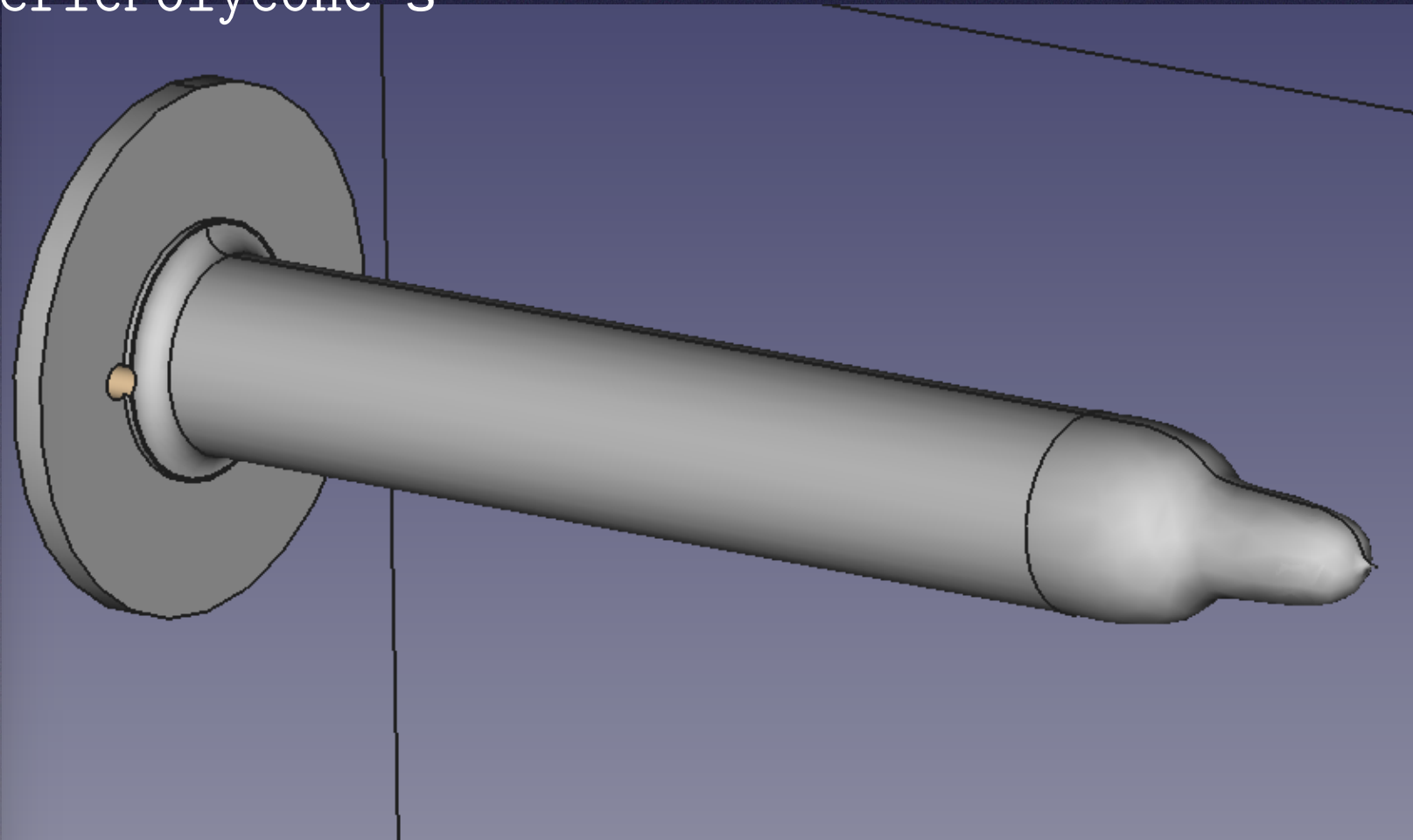
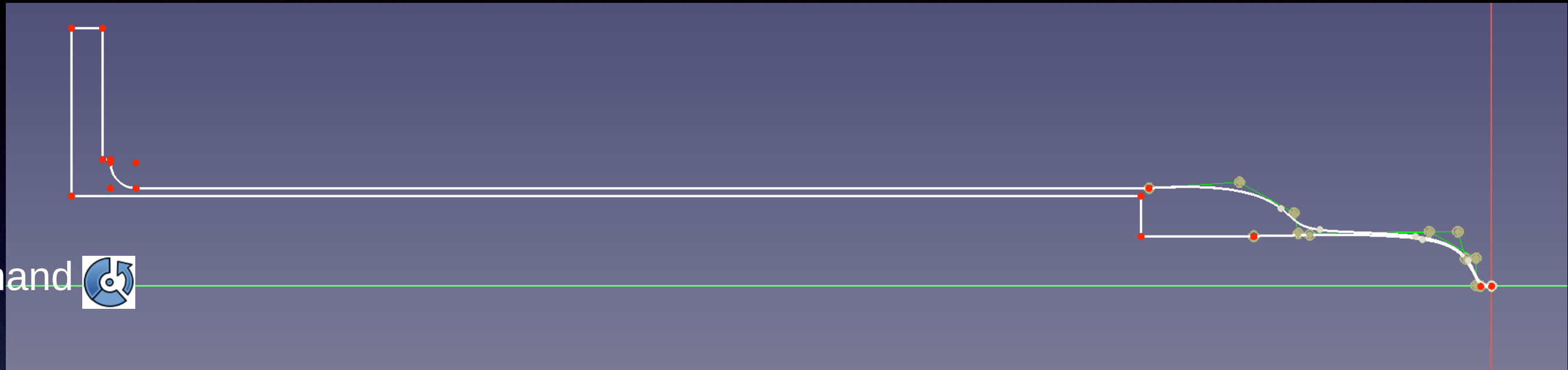
# Adding non-GDML solids to the GDML document

## 2. Revolve

Surfaces of revolution added by creating curve(s) in Sketcher, 

and then using the revolve command 

Revolves are exported as gdml genericPolycone's






# Adding non-GDML solids to the GDML document

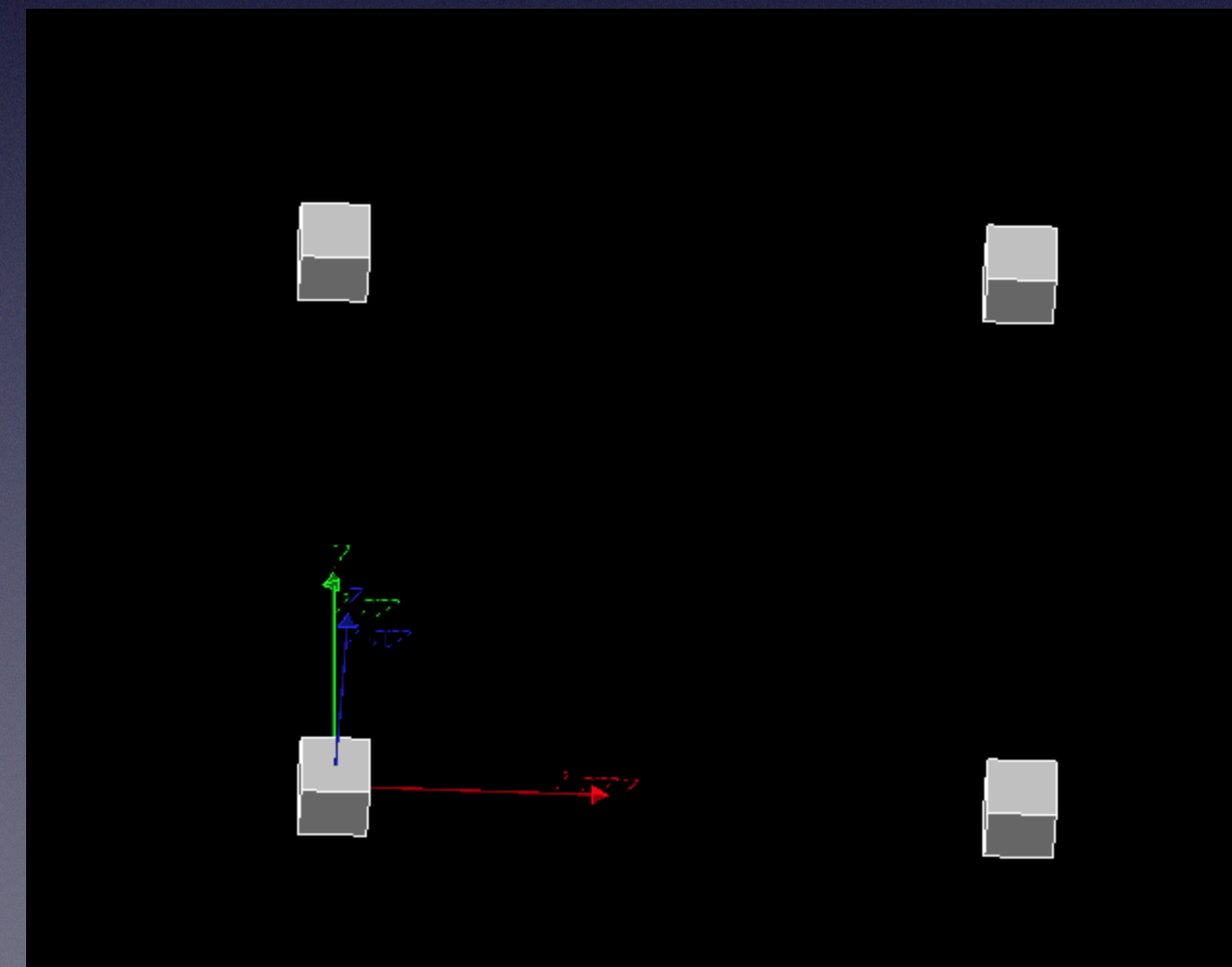
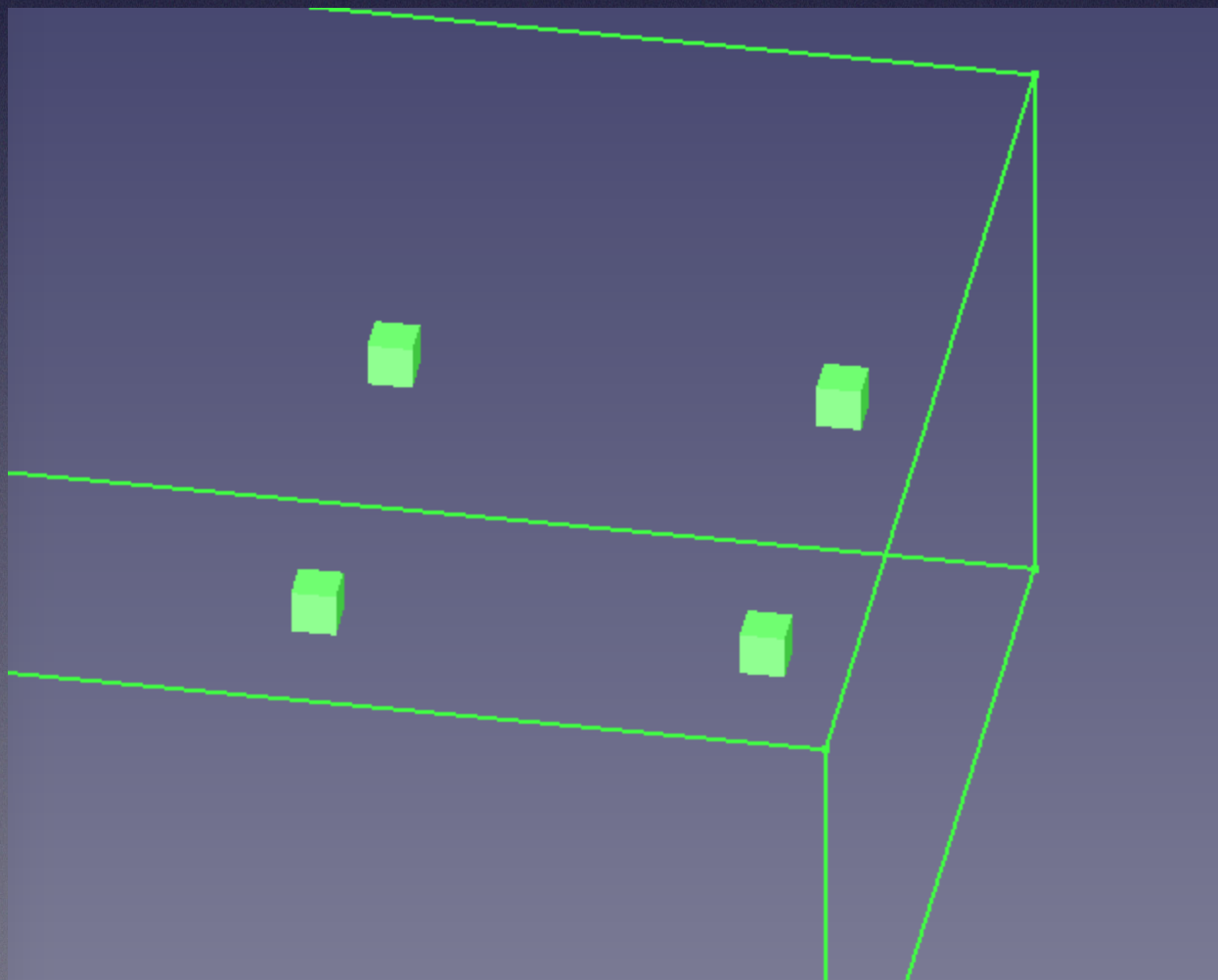
## 3. Arrays

### a. Orthogonal Arrays

Orthogonal arrays are added by selecting the object and executing the orthogonal array command 

Note: Arrays of solids are exported as a single `multiunion` solid and will all have the same material


View of exported gdml file containing an orthogonal (rectangular) array, using `load_gdml_color`

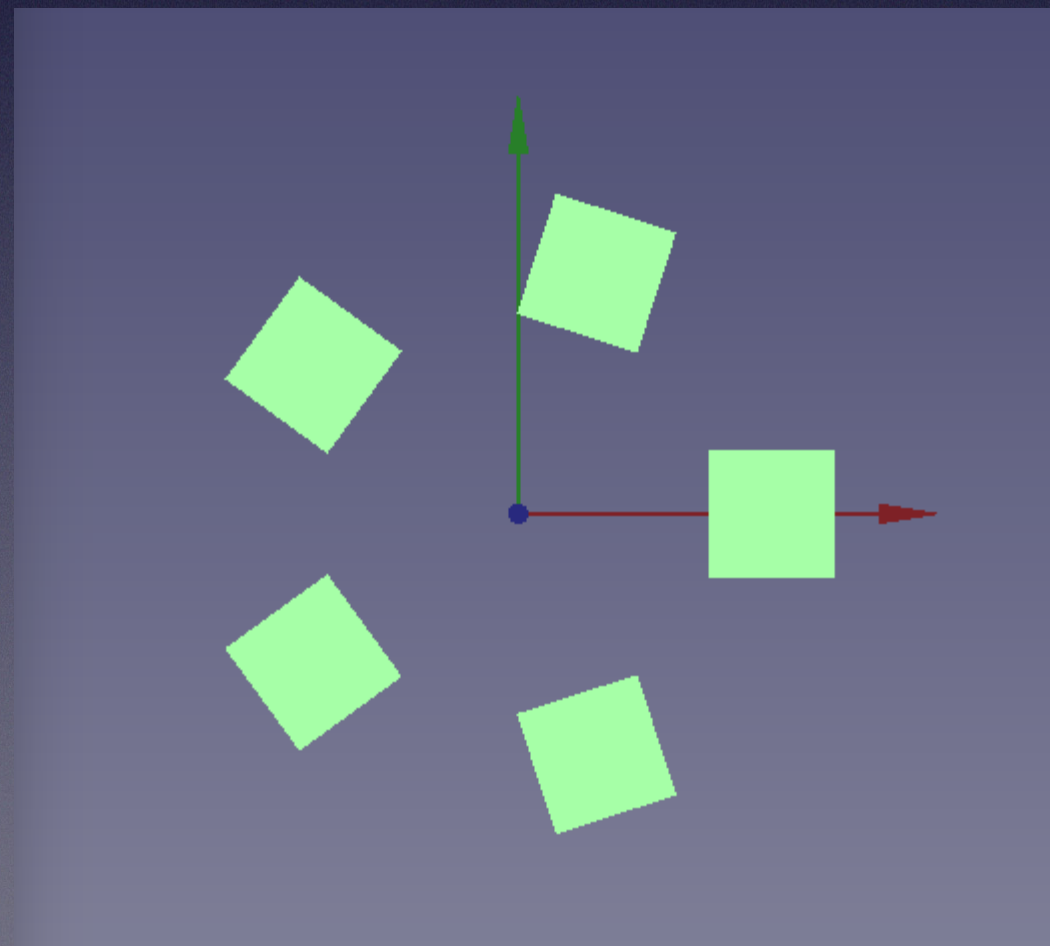


# Adding non-GDML solids to the GDML document

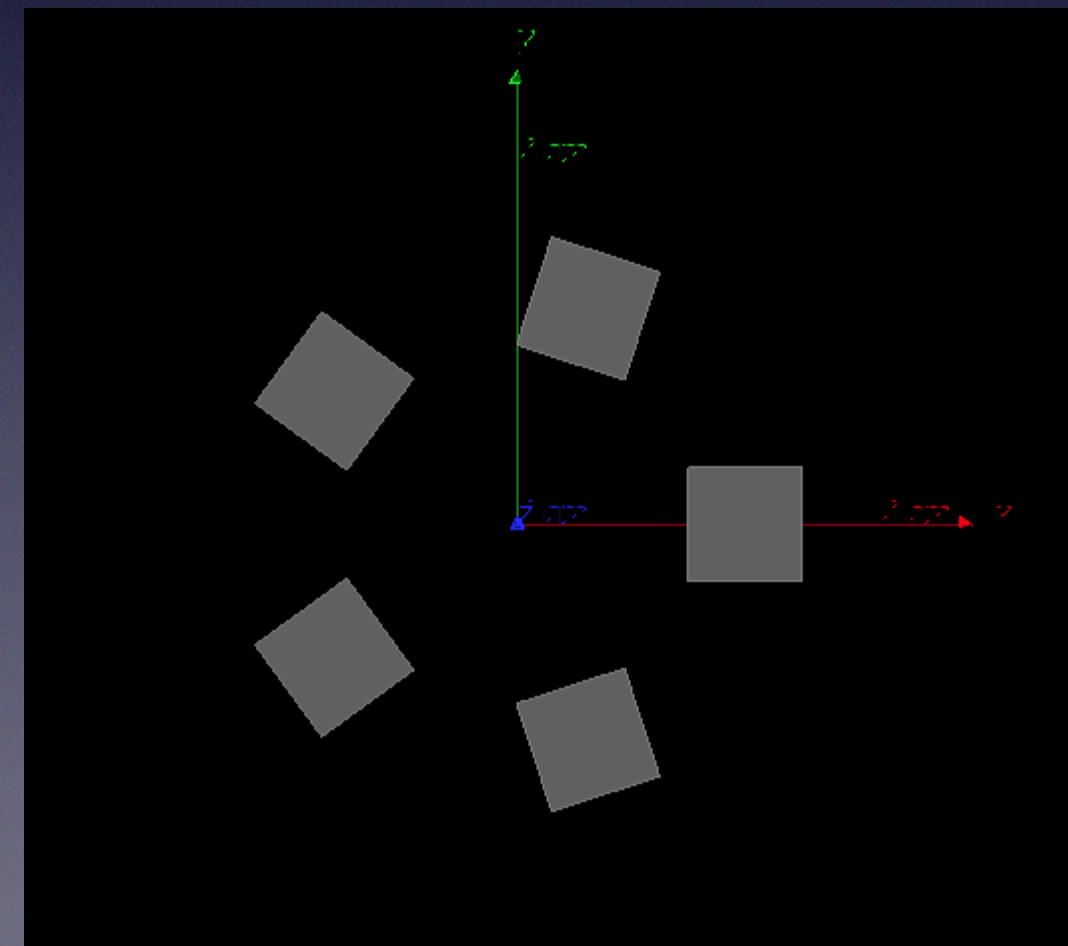
## 3. Arrays

### b. Polar Arrays

Polar arrays are added by selecting the object and executing the polar array command 




View of exported gdml file containing a polar array, using `load_gdml_color`



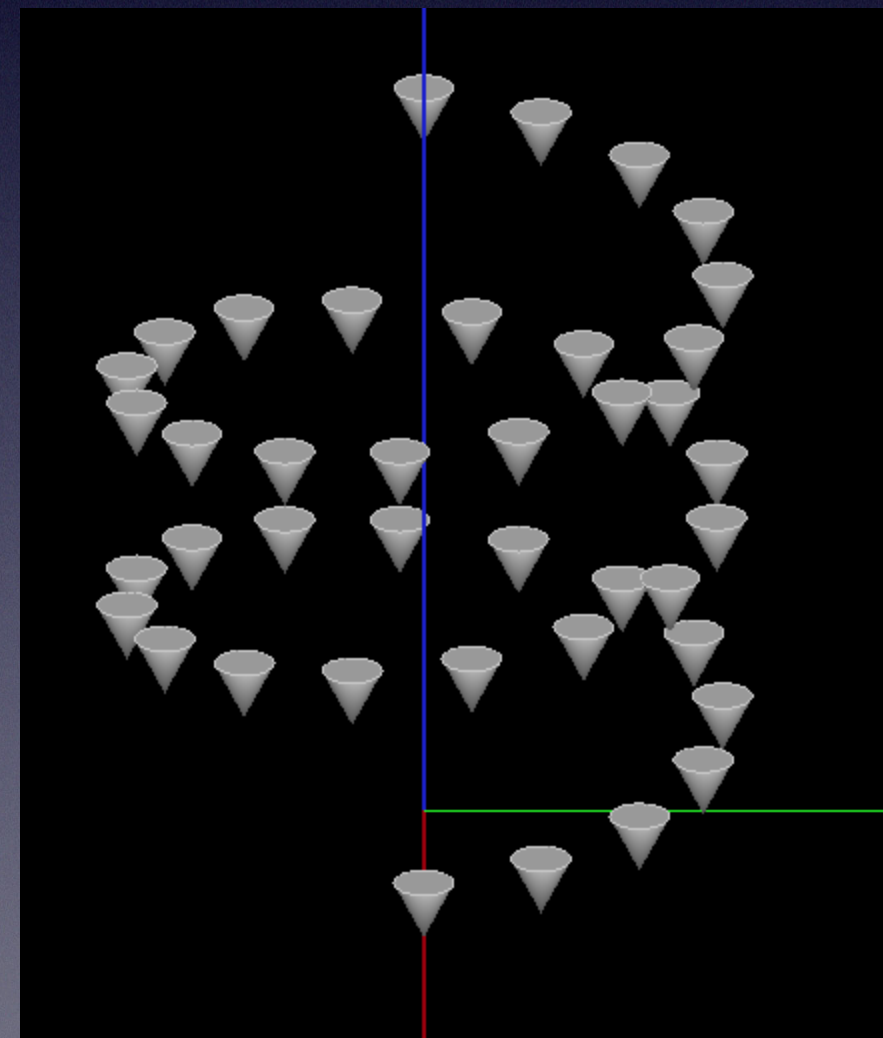
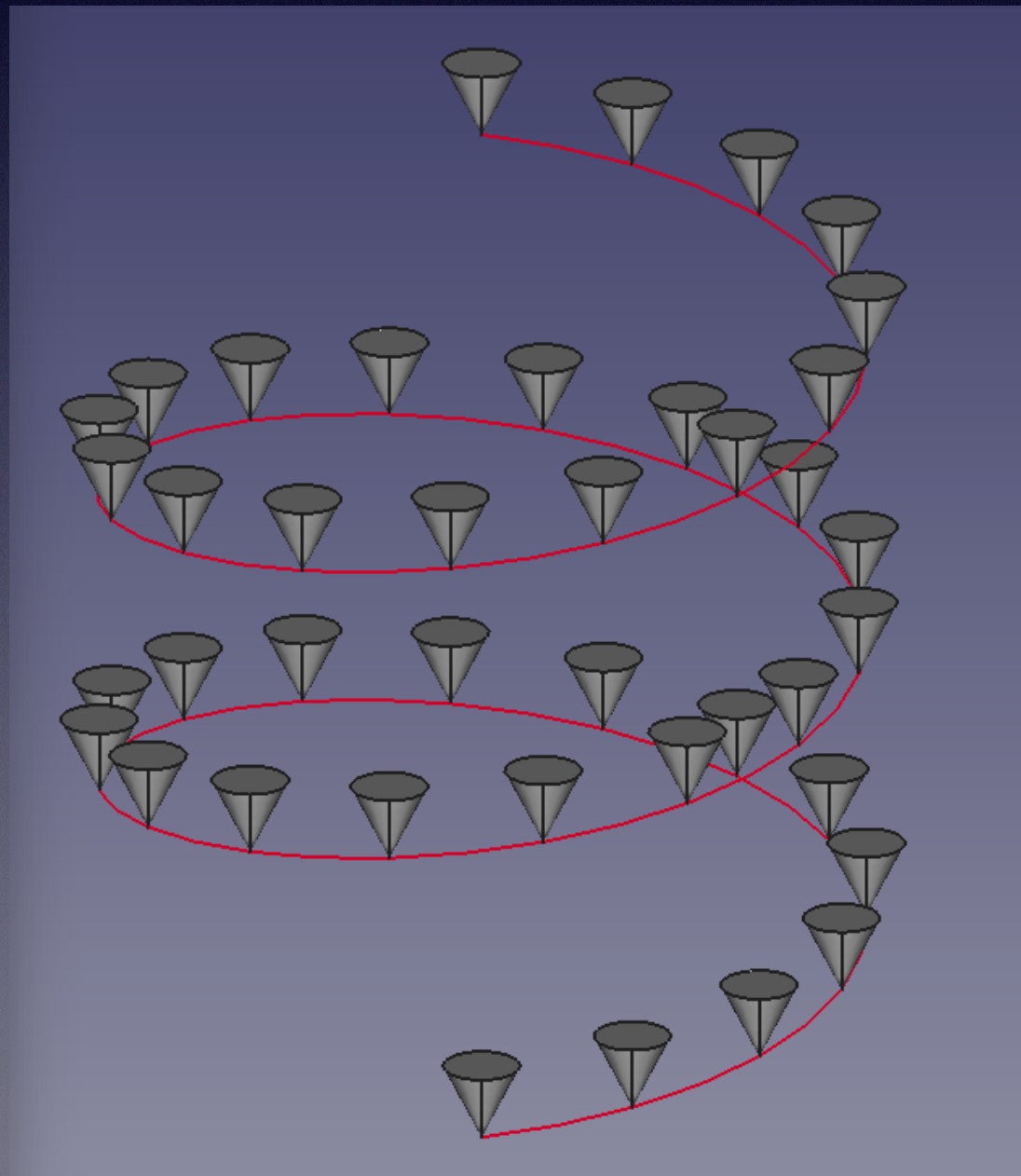
# Adding non-GDML solids to the GDML document

## 3. Arrays

### c. Arrays of objects distributed along a path

Path arrays are added by selecting the object, a curve (path) in 3D and executing the path array command 

View of exported gdml file containing a path array, using `load_gdml_color`



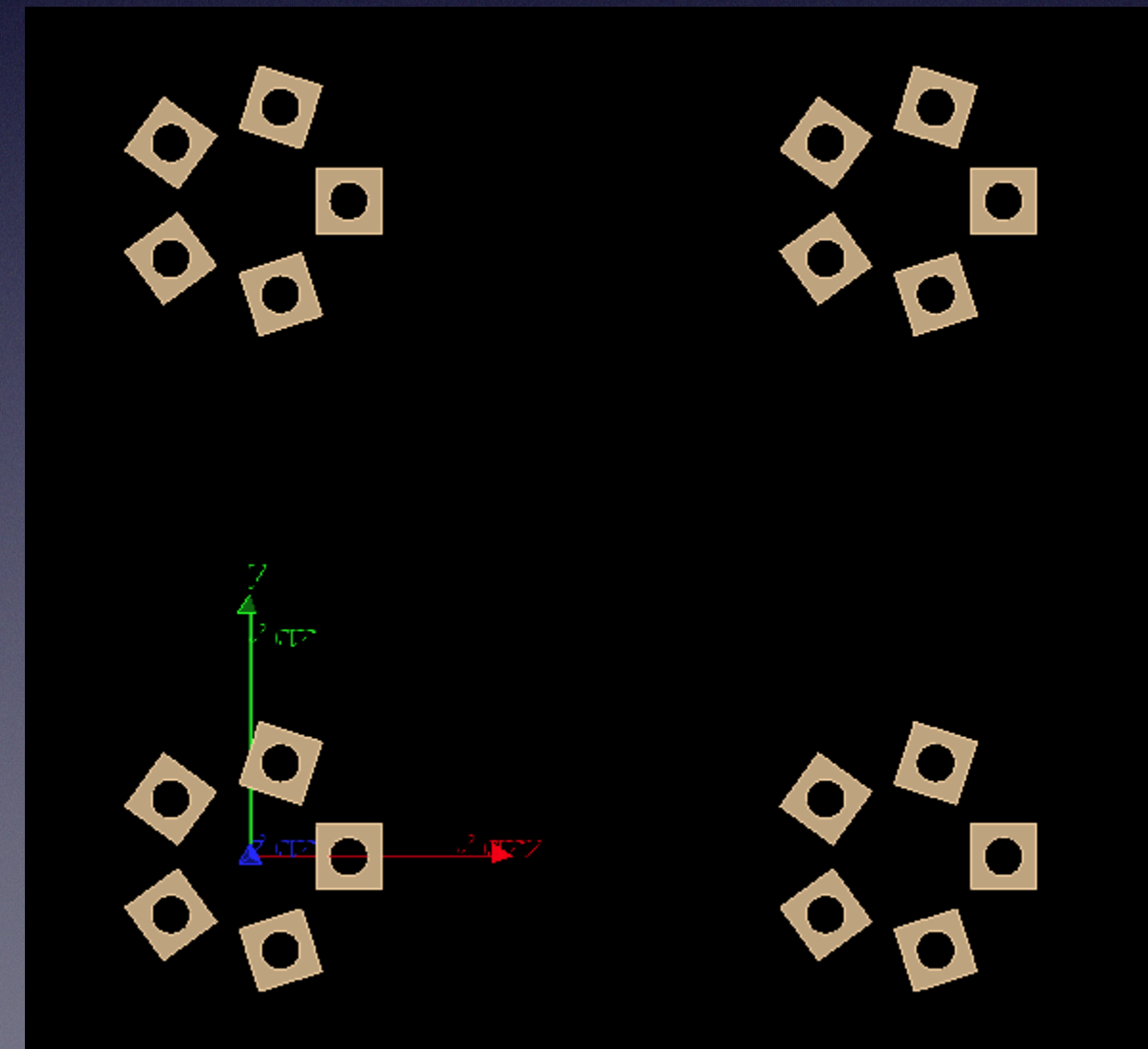
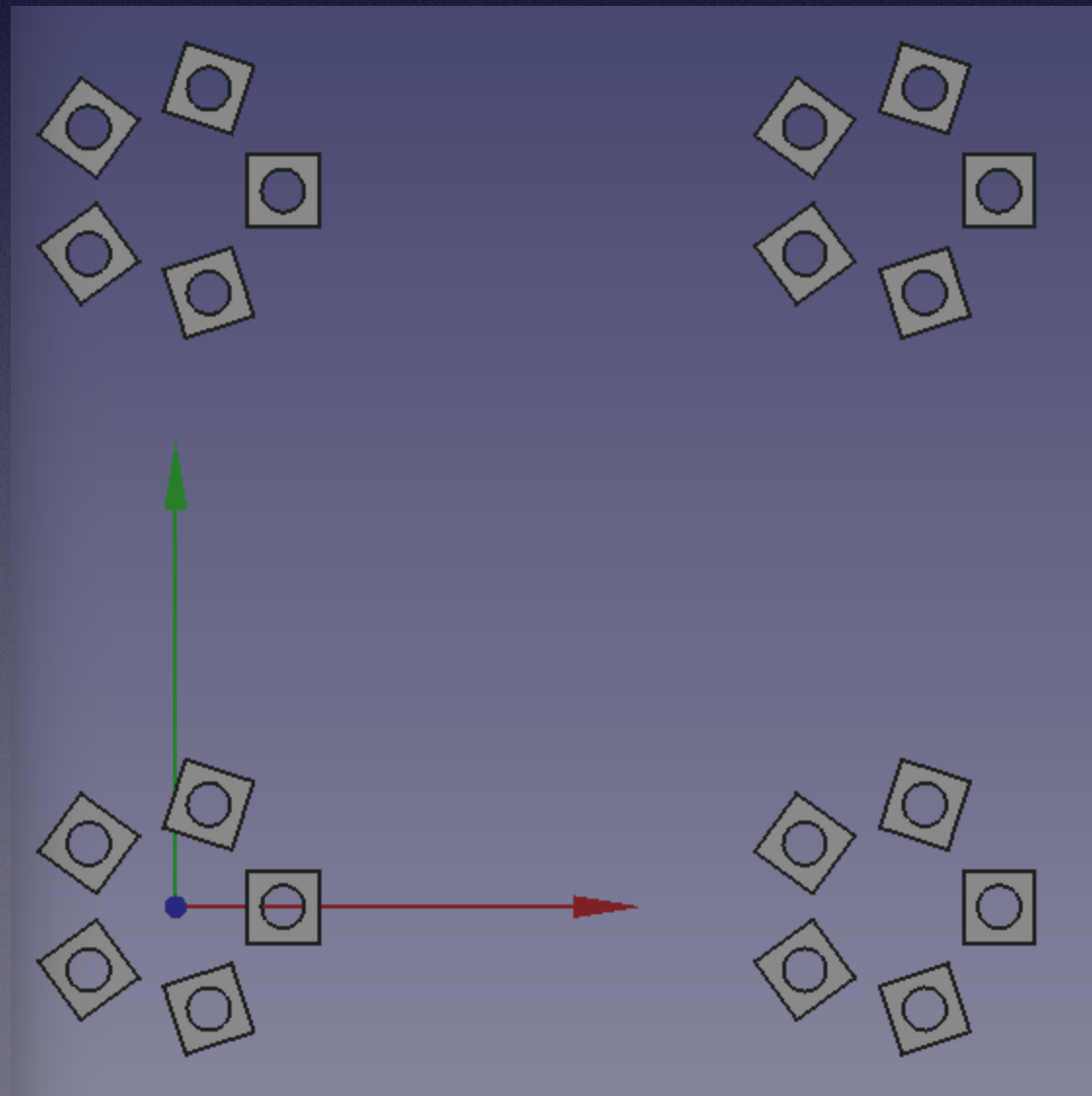
# Adding non-GDML solids to the GDML document

## 3. Arrays

### e. Arrays of arrays

Any object that can be exported to GDML by the Workbench can serve as the base of an array. Below shows an orthogonal array of a polar array of a Cut of two solids in FreeCAD.

View of the exported gdml file containing an orthogonal array of a polar array, using `load_gdml_color`



## Adding non-GDML solids to the GDML document

Any solid can be exported to a gdml file by meshing it then tessellating the mesh

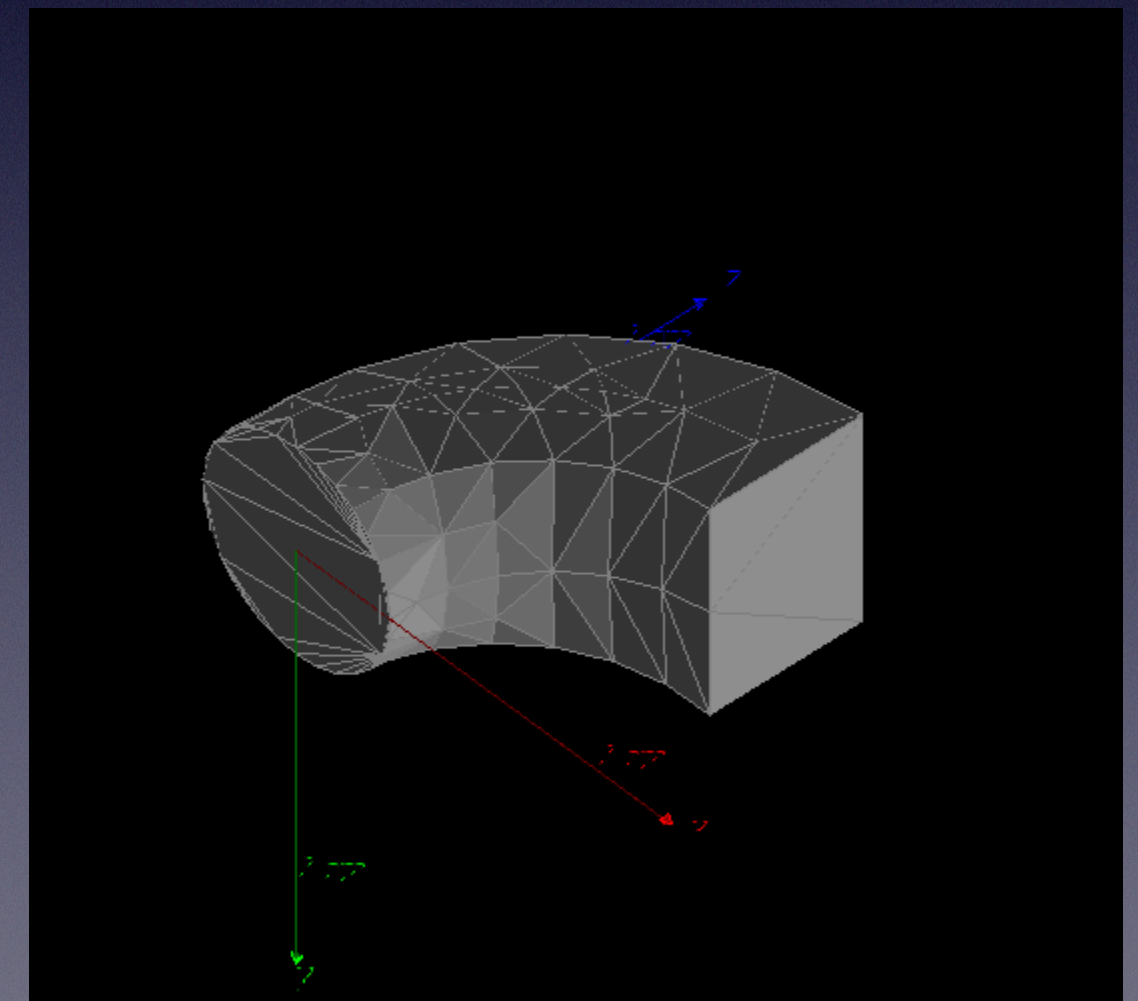
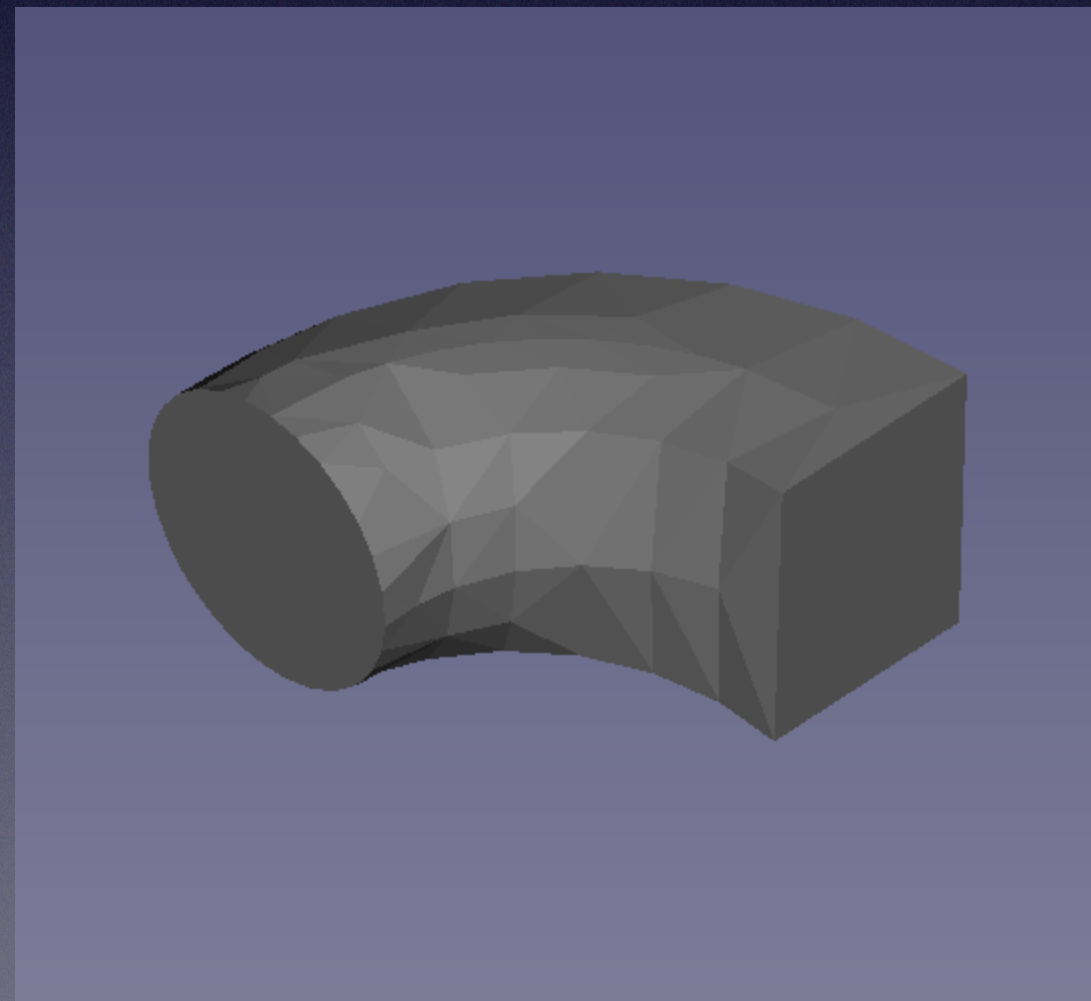
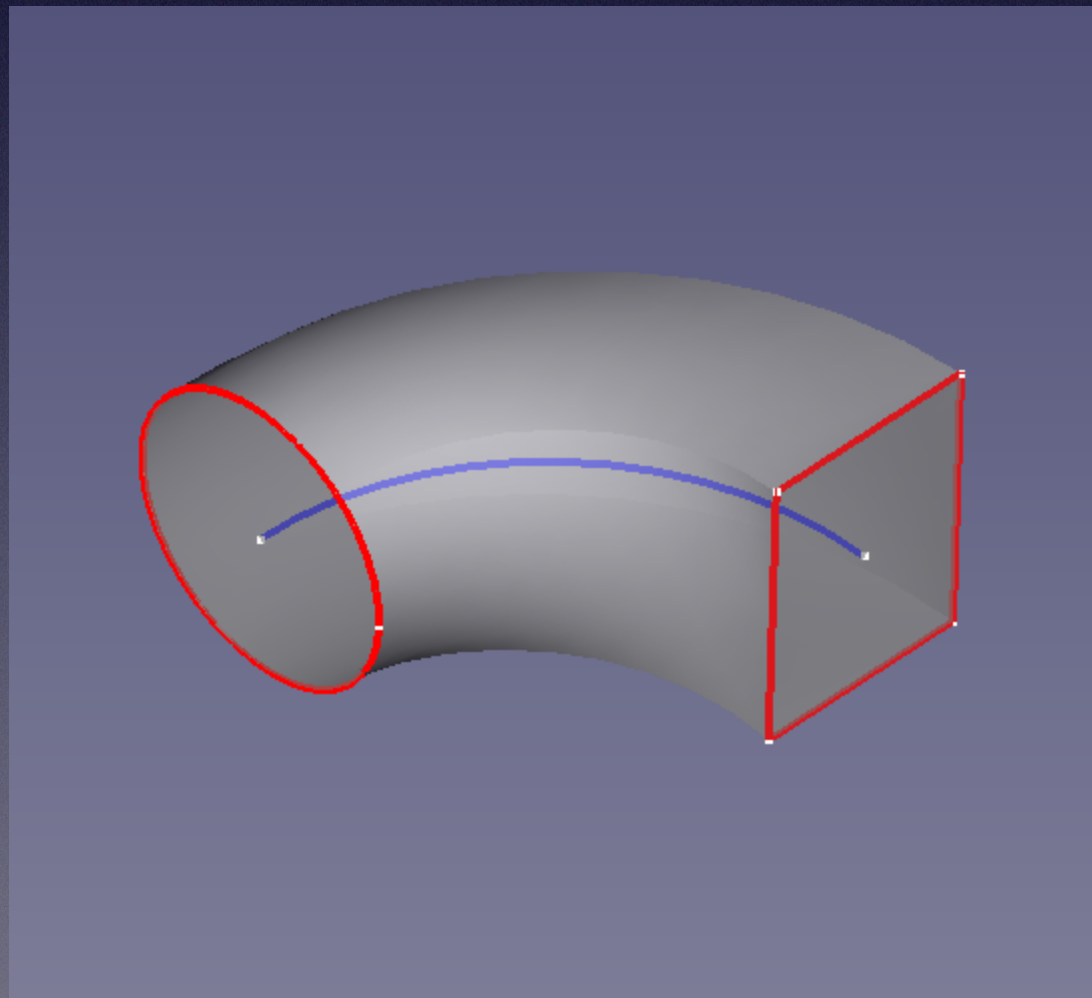
Example:

Part Workbench can create a solid by sweeping one sketch to another along a path. GDML Workbench currently cannot export a sweep.



Can convert the sweep shape to a tessellated solid using the Part to Mesh command

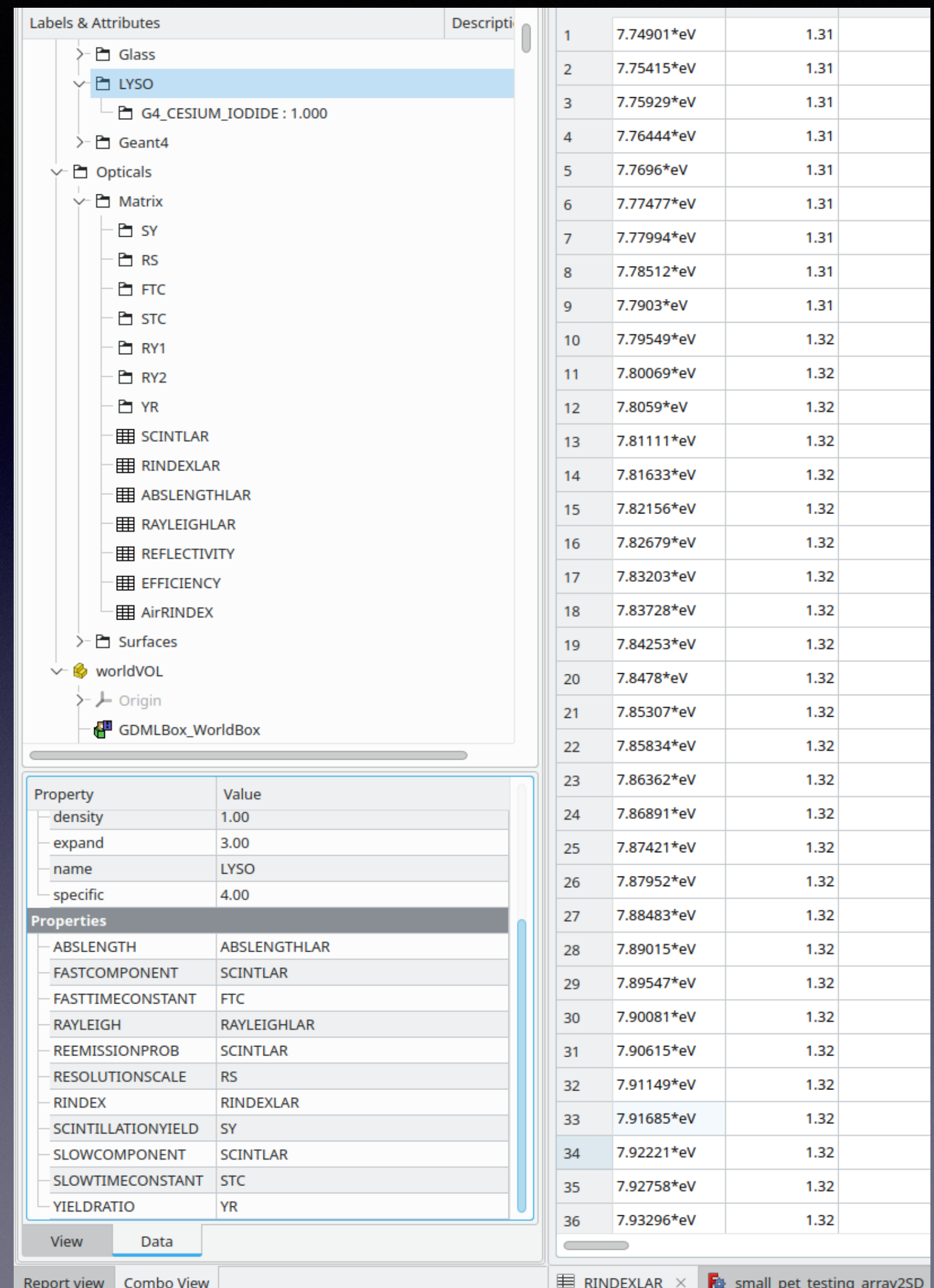


View of exported gdml file containing a tessellation, using `load_gdml_color`



# Opticals Support

- With GDML workbench activated, open new file
  - Creates GDML file structure
    - Matrix
    - Surfaces
- Import matrix.xml file see example <freecad/gdml/Resources/matrix.xml>
  - Matrix is a number of FreeCAD spreadsheets within the Opticals/Matrix Group
- Import optical.xml file see example <freecad/gdml/Resources/optical.xml>
  - Definition of a number of surfaces
- Icons/Commands
  - Set Skin Surface 
  - Set Border Surface 



The screenshot shows the FreeCAD GDML workbench interface. The 'Labels & Attributes' tree on the left shows the hierarchy: Glass > LYSO > G4\_CESIUM\_IODIDE : 1.000 > Geant4 > Opticals > Matrix. The 'Matrix' group contains several spreadsheets: SY, RS, FTC, STC, RY1, RY2, YR, SCINTLAR, RINDEXLAR, ABSLENGTHLAR, RAYLEIGHLAR, REFLECTIVITY, EFFICIENCY, and AirRINDEX. Below the tree, the 'Properties' table is visible, showing properties for the selected 'LYSO' object.

Property	Value
density	1.00
expand	3.00
name	LYSO
specific	4.00

Property	Value
ABSLLENGTH	ABSLLENGTHLAR
FASTCOMPONENT	SCINTLAR
FASTTIMECONSTANT	FTC
RAYLEIGH	RAYLEIGHLAR
REEMISSIONPROB	SCINTLAR
RESOLUTIONSCALE	RS
RINDEX	RINDEXLAR
SCINTILLATIONYIELD	SY
SLOWCOMPONENT	SCINTLAR
SLOWTIMECONSTANT	STC
YIELDRATIO	YR

Index	Energy (eV)	Value
1	7.74901*eV	1.31
2	7.75415*eV	1.31
3	7.75929*eV	1.31
4	7.76444*eV	1.31
5	7.7696*eV	1.31
6	7.77477*eV	1.31
7	7.77994*eV	1.31
8	7.78512*eV	1.31
9	7.7903*eV	1.31
10	7.79549*eV	1.32
11	7.80069*eV	1.32
12	7.8059*eV	1.32
13	7.81111*eV	1.32
14	7.81633*eV	1.32
15	7.82156*eV	1.32
16	7.82679*eV	1.32
17	7.83203*eV	1.32
18	7.83728*eV	1.32
19	7.84253*eV	1.32
20	7.8478*eV	1.32
21	7.85307*eV	1.32
22	7.85834*eV	1.32
23	7.86362*eV	1.32
24	7.86891*eV	1.32
25	7.87421*eV	1.32
26	7.87952*eV	1.32
27	7.88483*eV	1.32
28	7.89015*eV	1.32
29	7.89547*eV	1.32
30	7.90081*eV	1.32
31	7.90615*eV	1.32
32	7.91149*eV	1.32
33	7.91685*eV	1.32
34	7.92221*eV	1.32
35	7.92758*eV	1.32
36	7.93296*eV	1.32

## Other Information

- Information on the GDML workbench can be found on Keith's github page: <https://github.com/KeithSloan/GDML>
- Installation - see README in github
  - Gmsh shared library needs to be installed in FreeCAD Resources/lib see README
- Use instructions and example files are on the wiki page <https://github.com/KeithSloan/GDML/wiki>

## Future

- Command line scripts
- User defined materials in FreeCAD
  - User-defined materials can be imported into the Workbench, but not defined in it
- GUI creation of more solids
  - Although all solids defined under GDML are implemented, the lesser common ones do not have corresponding commands/icons to create them in the GDML Workbench. Currently can import all solids, so one without an icon can be imported into a document from a gdml file
- Check for overlapping solids in FreeCAD itself
- Closer match between exported and imported GDML files
- Need Help! Both Keith and I are in our early 70's and probably cannot continue to maintain the project far into the future. Would like to get younger people who are competent in python involved in the project with a view to eventually taking over the maintenance. We would be willing to mentor anyone who is interested!

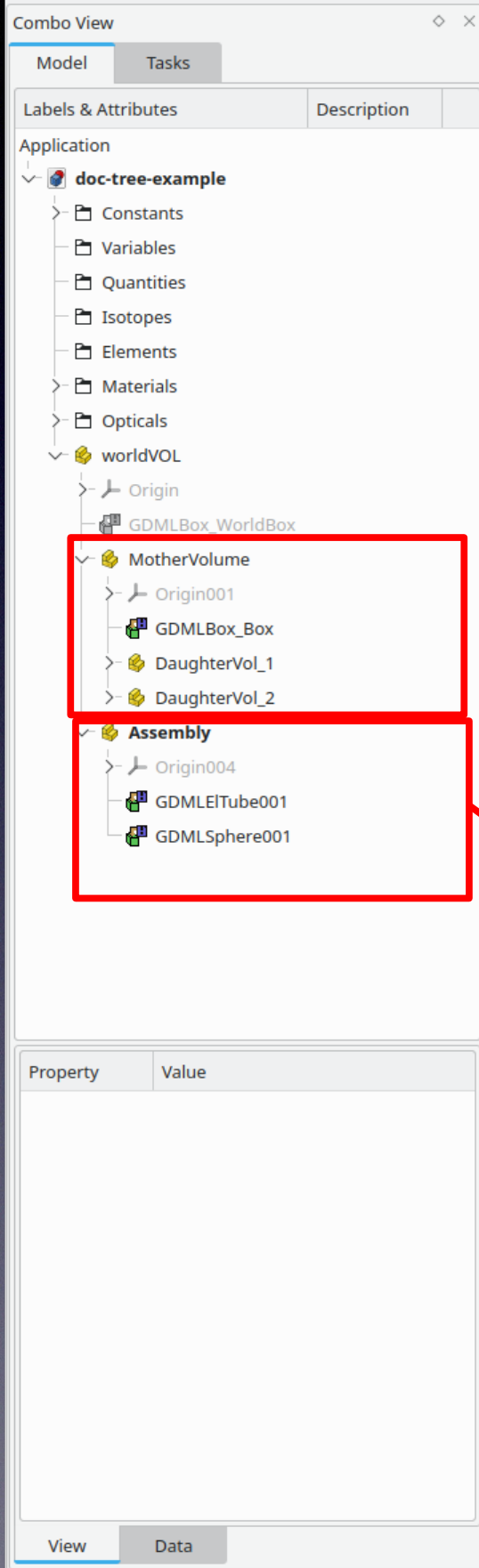


# Thanks

- Jim Austin (icon designs)
- Emmanuel Delage, Wouter Deconnick, Louis Helary
- Damian Lambert, Paulo Dondero, Ami Hashemi
- John Watts, Frederico-Carminati
- Hilden Timo, Atanu Quant, Masaki Morita
- Large number from the FreeCAD community  
Please see github README
- See also GitHub Contributors

# Extra Slides

# Correspondence between FreeCAD document structure and GDMML document structure



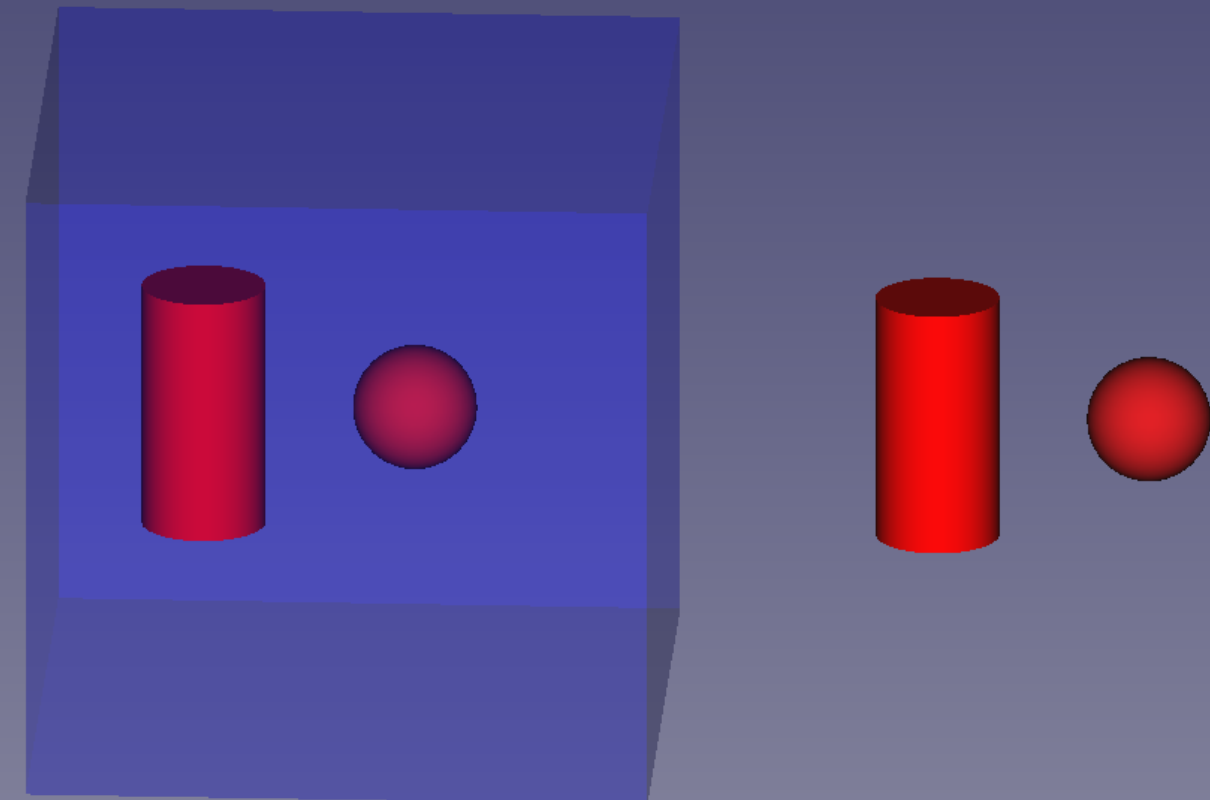
The image shows the FreeCAD Combo View window. The 'Model' tab is active, displaying a tree view of the document structure. The tree is organized as follows:

- Application
  - doc-tree-example
    - Constants
    - Variables
    - Quantities
    - Isotopes
    - Elements
    - Materials
    - Opticals
    - worldVOL
      - Origin
      - GDMMLBox WorldBox
        - MotherVolume
          - Origin001
          - GDMMLBox\_Box
          - DaughterVol\_1
          - DaughterVol\_2
        - Assembly
          - Origin004
          - GDMLE1Tube001
          - GDMMLSphere001

Two red boxes highlight the 'MotherVolume' and 'Assembly' sub-structures. Red arrows point from these boxes to the corresponding XML code blocks on the right.

```
<volume name="DaughterVol_1">
...
<volume name="DaughterVol_2">
...
<volume name="MotherVolume">
  <materialref ref="G4_A-150_TISSUE"/>
  <solidref ref="Box"/>
  <physvol name="PV-DaughterVol_1">
    <volumeref ref="DaughterVol_1"/>
    ... (position+rotation)
  <physvol name="PV-DaughterVol_2">
    <volumeref ref="DaughterVol_2"/>
    ... (position+rotation)
</volume>
```


```
<volume name="V-GDMLE1Tube001">
...
<volume name="V-GDMMLSphere001">
...
<assembly name="Assembly">
  <physvol name="PV-GDMLE1Tube001">
    <volumeref ref="V-GDMLE1Tube001"/>
    ... (position+rotation)
  <physvol name="PV-GDMMLSphere001">
    <volumeref ref="V-GDMMLSphere001"/>
    ... (position+rotation)
</assembly>
```



# Adding non-GDML solids to the GDML document

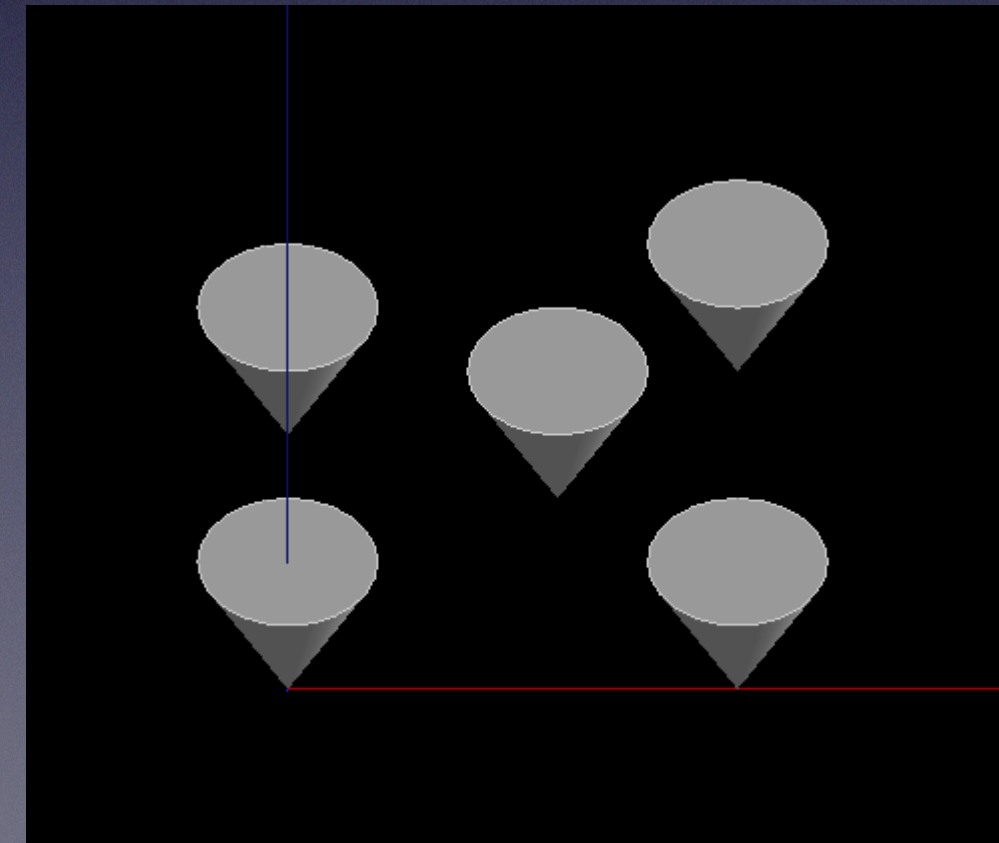
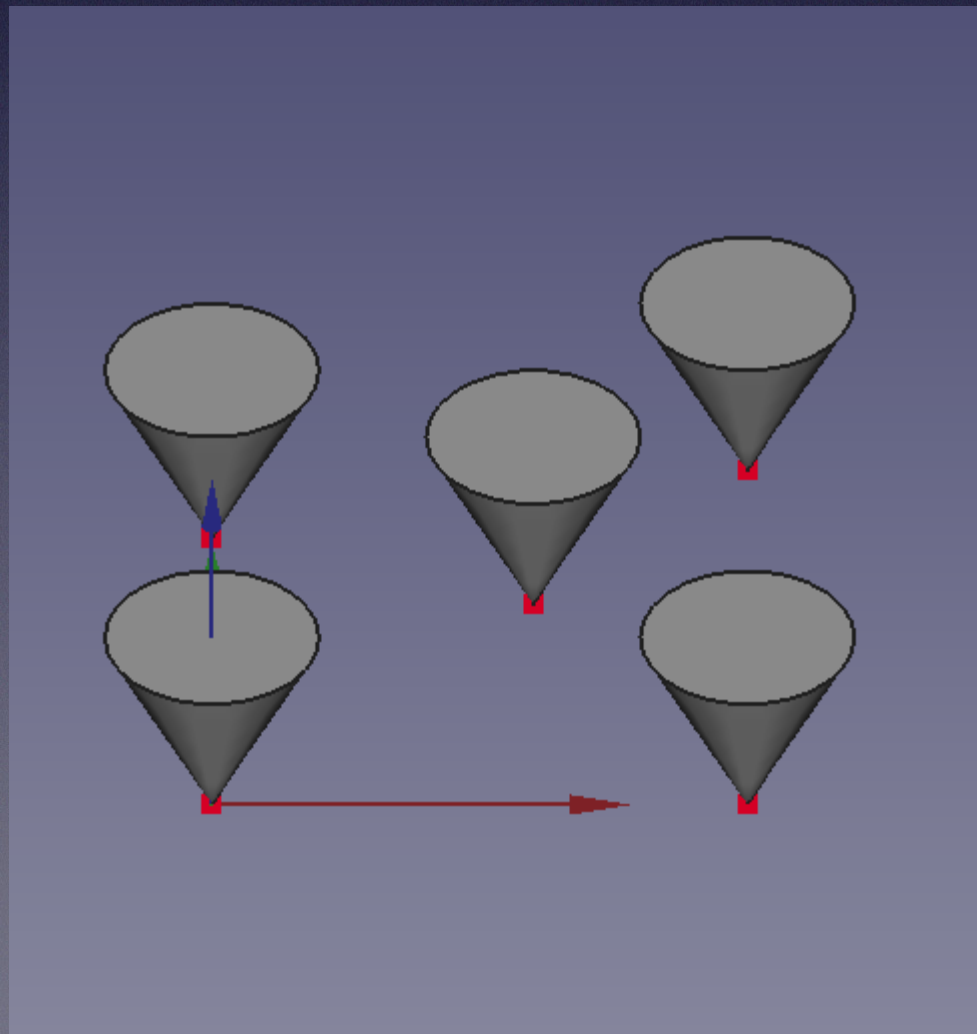
## 3. Arrays

### d. Arrays of objects placed at arbitrary points

Point arrays are added by selecting the object, a set of points in 3D and executing the point array command. 


Points can be entered in a variety of ways, including using the Points Workbench to read a variety of file formats.

View of exported gdml file containing a point array, using `load_gdml_color`

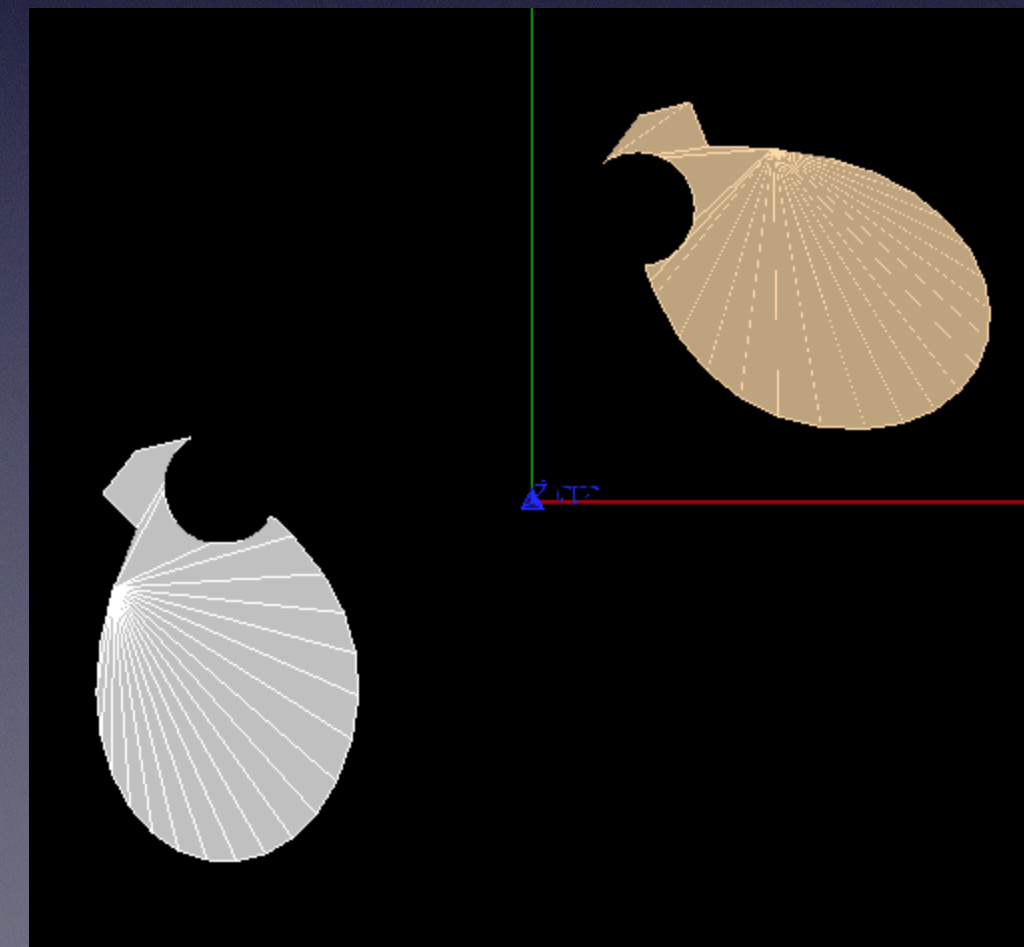
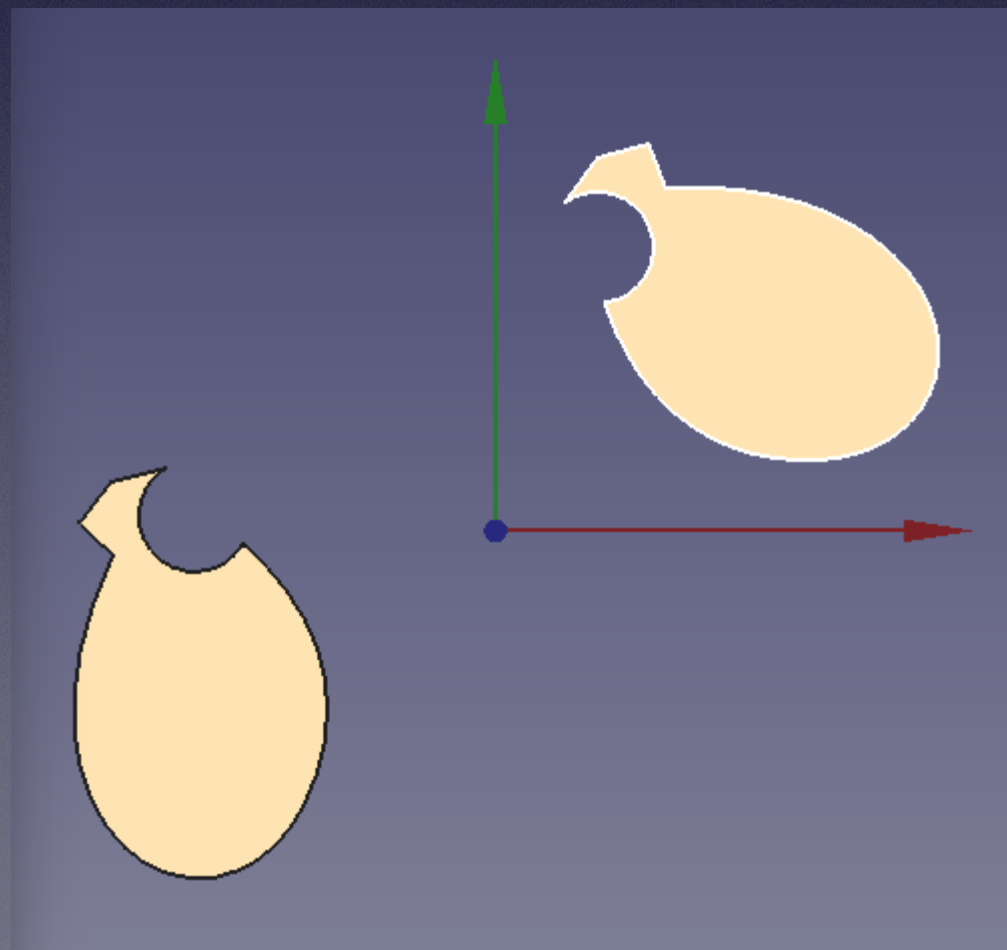


# Adding non-GDML solids to the GDML document

## 4. Mirrored object

Mirrored objects are added by selecting the object, a reflection plane and executing the mirror command. 

View of exported gdml file containing a path array, using `load_gdml_color`



# GDML Workbench History

- CAD-GDML - Meeting at SLAC Sept 2011
  - C++ Workbench started by Emmanuel Delage
- Initial Workbench FreeCAD\_Python\_GDML
  - Geant4 python library which at the time was still under development
  - Now GitHub retired / archived
- GDML workbench – Created and maintained by **Keith Sloan**  
<https://github.com/KeithSloan/GDML>
  - Different approach
  - GDML Solids implemented as FreeCAD FeaturePython Objects
  - Recent enhancements - Thanks to Munther Hindi (joined the project November 2021)
    - Arrays, Mirrors
    - Extruded and Revolved Sketches