

User manual

# **EDGE 2.2.0 User Manual**

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## Summary

### Objectives


The objective of this document is to describe the aim of EDGE, how to use it and the main concepts behind it.

### Diffusion

Nom	Organization
Users of Edge	-

### Changes record

Version	Revision	Date	Author / Modification
1	0	03/09/2015	Arnaud Trouche / Document creation
1	1	06/06/2016	Arnaud Trouche / Update with latest developments
1	2	10/06/2016	Elsa Kress / Update
2	0	05/08/2016	Arnaud Trouche / Add the material edition, rearrangement
2	1	05/08/2016	Elsa Kress / Update
2	2	02/11/2016	Arnaud Trouche / Update
3	0	05/10/2017	Amandine Champlain / Update to the new version of the software
3	1	09/04/2018	Arnaud Trouche / Updates for EDGE 2.1.1

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## 1. Introduction

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### 1.1. Scope of the document

This document describes the EDGE CAD editor, the context and the concepts behind its conception, as well as its use.

### 1.2. Reference documents

[RD1] GDML Web page, <http://gdml.web.cern.ch/GDML/>

[RD2] GEANT-4 Web page, <https://geant4.web.cern.ch/geant4/>

[RD3] SpaceSuite Web site, [www.space-suite.com](http://www.space-suite.com)

[RD4] Santin G. et al., "GRAS: A General-Purpose 3-D Modular Simulation Tool for Space Environment Effects Analysis", IEEE Trans. Nucl. Sci., Vol. 52, No. 6, December 2005

[RD5] Jeanty-Ruard B. et al, "Advanced CAD Tool and experimental integration of GRAS/GEANT-4 for internal charging analysis in SPIS", Proceedings, 14th Spacecraft Charging Technology Conference, ESA/ESTEC, Noordwijk, NL, 04-08 APRIL 2016

[RD6] Keridwen open-source IME Web site, [www.keridwen.org](http://www.keridwen.org)


[RD7] SPINE community Web site, [www.spis.org](http://www.spis.org)

[RD8] EDGE project Web page, [http://dev.artenum.com/projects/edge\\_extended\\_gdml\\_editor](http://dev.artenum.com/projects/edge_extended_gdml_editor)

### 1.3. Acronyms and abbreviations

- B-Rep: Boundary Representation
- CAD: Computer Assisted Design
- CSG: Constructive Solid Geometry
- EDGE: ExtendedD Gdml Editor
- GDML: Geometry Description Mark-up Language
- GUI: Graphical User Interface
- IME: Integrated Modelling Environment
- STL: STereo-Lithography
- UNV: Universal File Format
- XML: Extensive Markup Language

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## 2. EDGE objectives

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EDGE — for Extended Gdml Editor — is an easy-to-use GDML-based CAD editor. It provides a powerful and flexible CSG model fully compliant with the GDML CAD format [RD1], used by numerous particle-matter interactions analysis tools based on the GEANT-4 library [RD2]. EDGE provides also various import/export capabilities from/to B-Rep based CAD formats.

EDGE has been developed by Artenum in the frame of its internal R&D activities and is available through several of its commercial services offers, like SpaceSuite [RD3].

### 2.1. About GDML

Based on XML syntax, the **Geometry Description Markup Language (GDML)** is the reference language used to describe geometrical models (i.e. CAD models) for radiation modelling tools like [GEANT-4](#) [RD2], [ESA/GRAS](#) [RD4] or SPIS-IC [RD5]. GDML is based on a rich CSG approach and can be used to create complex and realistic geometrical systems to be used for various purposes.

As an XML-based language, it can be fairly well read by humans and it is quite simple to parse it. However, one of its limits is that it is difficult to visualise what a GDML file is going to produce just by looking at it in a tailored sense, i.e. as a 3D geometrical system. Although some viewers or editors exist, only a few of them are publicly available, and they are not user-friendly or incomplete. Moreover, most GDML editors so far can not handle the depth hierarchy used in GDML.

Therefore, Artenum decided to develop a GDML editor based on the IME Keridwen [RD6]. Its aim is to propose a simple-to-use, cross-platform editor with good capacities of visualization.

### 2.2. Main functionalities

EDGE can either create or load a complete GDML model. In both cases, the user can modify the properties of all the shapes or add new shapes. Moreover, shapes also have position and orientation properties that allow placing them correctly. To facilitate the work for the user, position and orientation can be applied to several objects at the same time. EDGE handles complex hierarchies with several levels of depth.

EDGE also allows editing and attributing material properties to each shape individually.

At any time, the user can see the results of his work thanks to the real-time 3D.

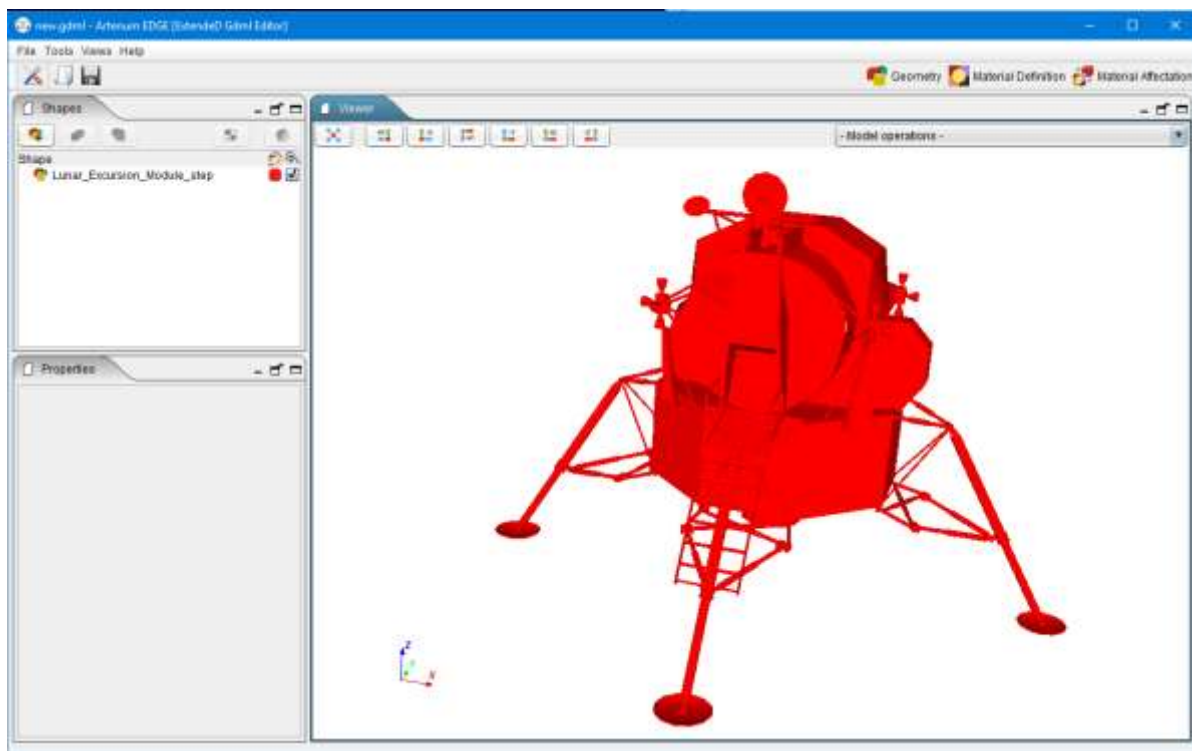
<b>Status:</b> final	<b>Date:</b> 09/04/2018
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After editing his file, the user can save the result back to GDML but he can also export it to the B-Rep .geo format (the file format of Gmsh)<sup>1</sup>.

## 2.3. Supported formats

### 2.3.1. Import

EDGE support natively the GDML format in reading and writing, but is also able to import numerous B-Rep CAD formats like Gmsh's geo or STEP-AP 203/214 and tessellated solids in STL or UNV files. These import/export capabilities open interoperability bridges with other CAD tools and multi-physics simulation software.

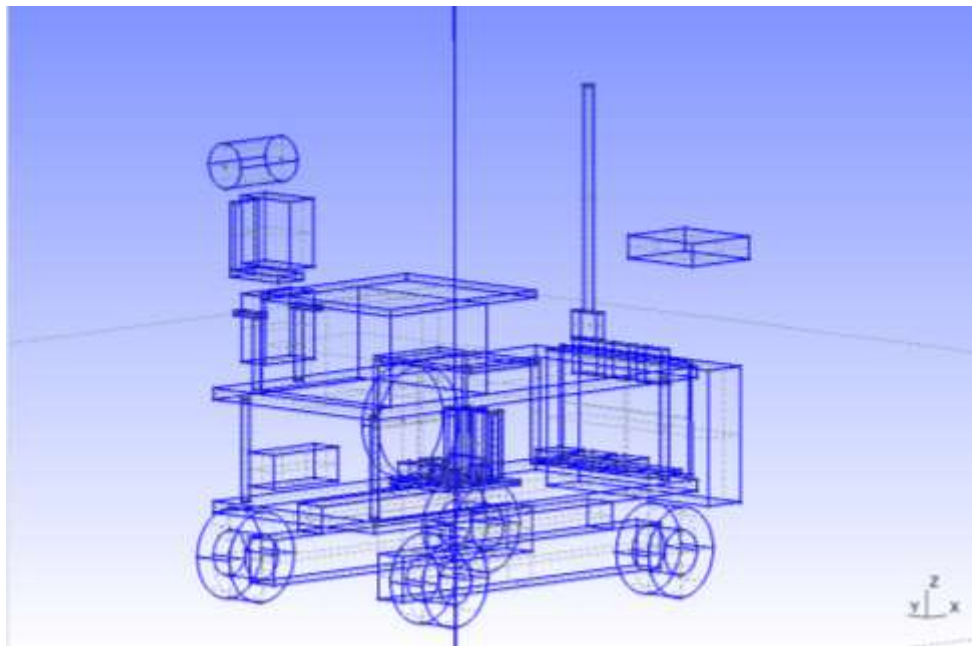
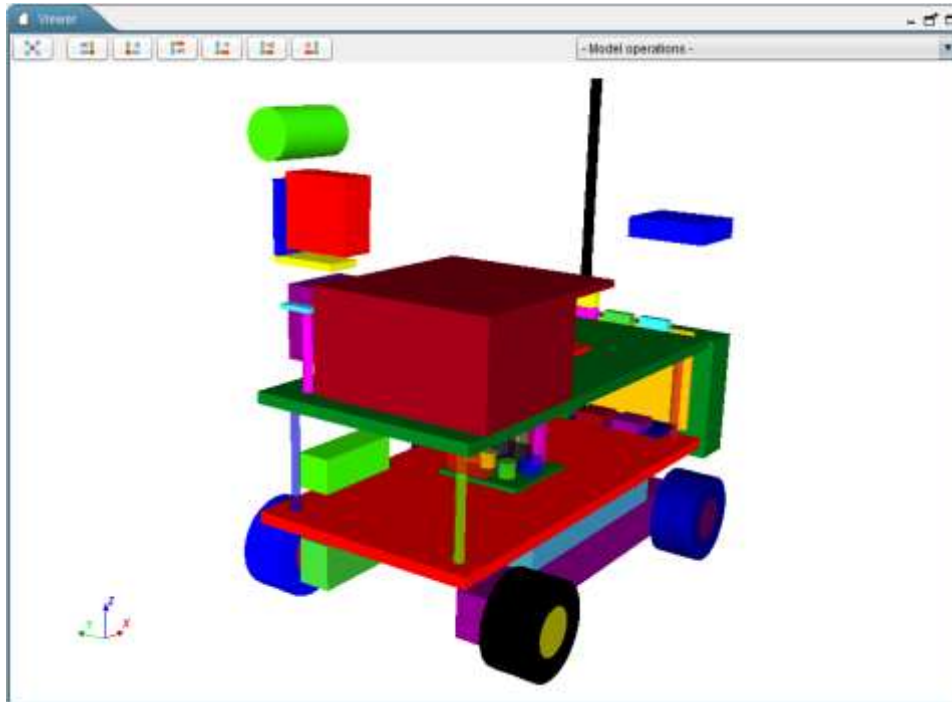


**Figure 1: Example of imported STEP-AP model inside EDGE**


### 2.3.2. Export and CSG-to-B-Rep decomposition

EDGE is able to convert GDML models into an equivalent Gmsh's geo file, fully compliant with tailored applications like SPIS [RD7]. This conversion is not done by tessellation but by a proper CSG to B-Rep decomposition with the view in Gmsh (on the top of Figure 2) of a model initially defined in EDGE (on the bottom of Figure 2).

<sup>1</sup> <http://geuz.org/gmsh/>



**Figure 2: CSG to B-Rep decomposition of a GDML model defined in EDGE (top) visualized in Gmsh (bottom)**

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## 3. Using EDGE

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### 3.1. Supported platforms

Currently, EDGE can be used on most 64bits Linux platforms, Microsoft Windows-7-8-10 32/64bits and OSX/macOS 64bits.

### 3.2. Starting Edge

The application as well as the present User Manual can be downloaded from the [Artenum/EDGE](#) Web page [RD8].

Once downloaded, the zip file containing the EDGE snapshot has to be extracted on the machine where it will be used on to ensure that the software is executable.

To start the application, open a terminal and just execute the Edge.sh/Edge.bat file, respectively for Linux-OSX/Windows systems.

On recent Linux distributions with Gnome, a double-click on the Edge.sh displays the content of the file instead of launching it. You can modify this behaviour by going to the file manager preferences and changing the way executable files are handled.

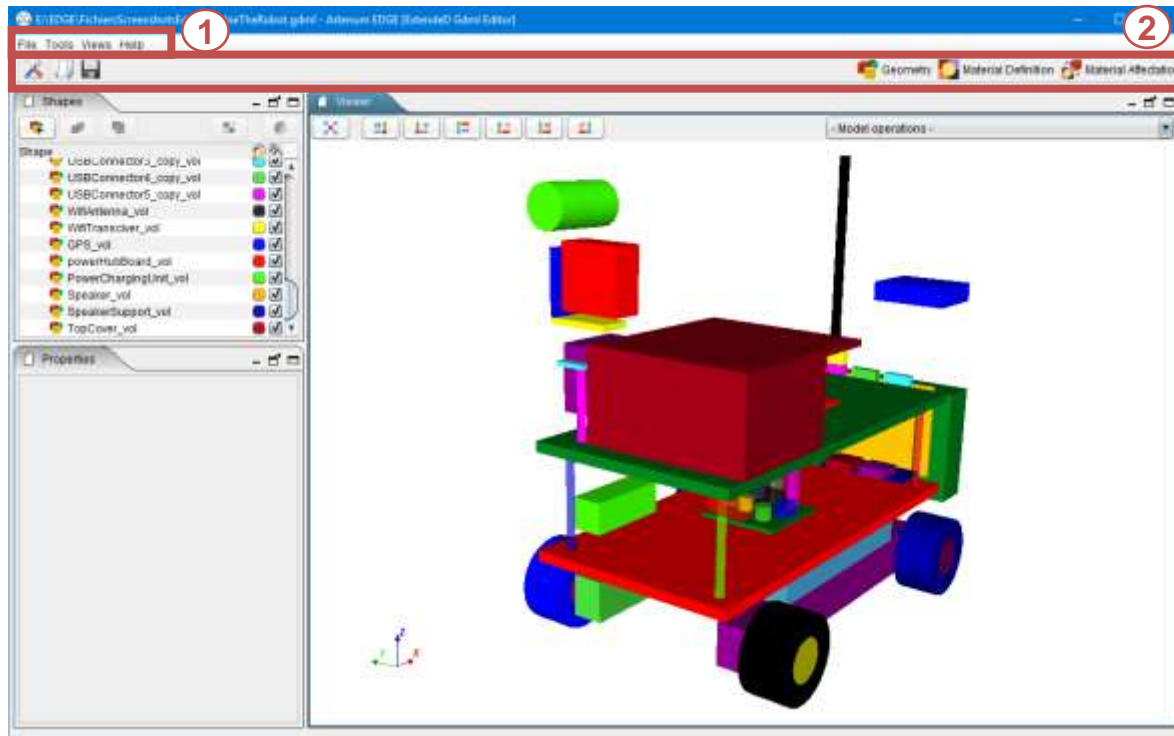
### 3.3. EDGE Main Window

The GUI of EDGE is very intuitive and based on the concept of “perspectives”, where the modelled system can be viewed and handled from different approach or points of view, like the edition of the geometrical model, the definition of material properties or the affectation of these materials.

Even if EDGE has three main different perspectives (geometrical edition, material edition and material affectation), some elements are common in all views as shows the Figure 3:

- **(1) Main Menu** corresponds to main control menu of the application. It is always available.
- **(2) General Toolbar** presents shortcut buttons to open and save a file and also allows switching from a perspective to another (e.g. preferences, geometry, material definition and material affectation). It is always available. These elements are described in further details in the following sections.





**Figure 3: Main elements of EDGE window (here in the geometry perspective)**

### 3.3.1. Main Menu

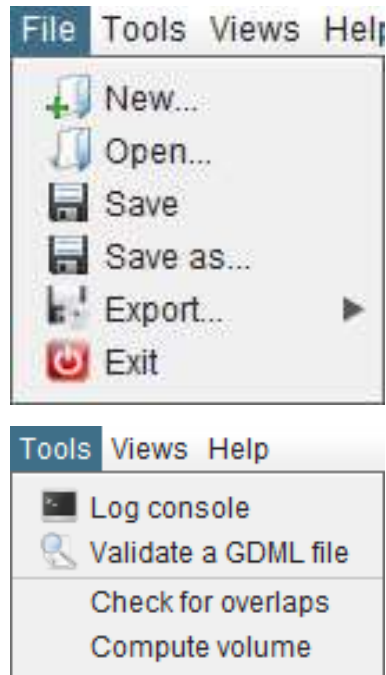
The File menu shown on Figure 4 (top) allows opening from GDML, saving in GDML and exporting to .geo format. When opening a GDML file, if this file contains for example two solids with the same name, EDGE will only consider the last element with this name. A warning will be displayed, informing the user that several shapes have the same name.

**Remark:** Please note that only one GDML file can be opened at a time in EDGE. Opening another GDML file will delete all unsaved previous work.

The Tools menu shown on Figure 4 (bottom) allows opening a console log, mainly for advanced users, and checking the validity of any GDML file, not only the one opened in EDGE, against the different versions of GDML format specifications. This tool only notes the first error in the file, even if there are several of them, and warns the user about it. This menu also offers access to the various model computations, described in more details in section 5.5.

The Views menu allows switching from one of the perspectives presented earlier to another, except for the Preferences.

The Help menu is useful to access the EDGE User Manual and to obtain information about the software.



**Figure 4: EDGE file menu (top) and tools menu (bottom)**


### 3.3.2. General Toolbar

The left part of this toolbar allows the user, thanks to three buttons, to access the Preferences, presented in section 4, and to easily open and save a file without opening the File menu presented in 3.3.1 (cf. Figure 4).

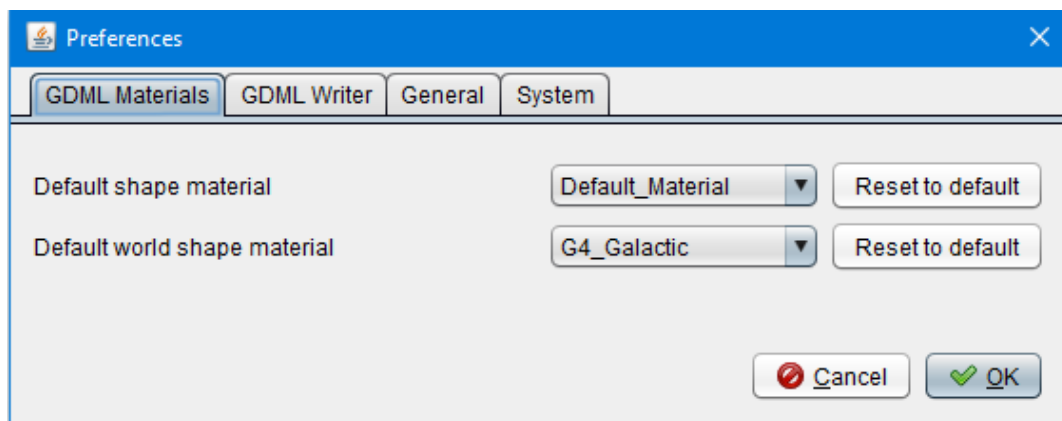
The right part of this toolbar presents three buttons allowing the user to switch between the three main perspectives of EDGE: the Geometry edition (visible in the Figure 9, see section 5), the Material definition (see section 6) and the Material affectation one (see section 7 for more information).

## 4. Preferences

The Preferences dialog box is automatically displayed during the first launch of EDGE. The user can access it afterwards thanks to the Perspective selection toolbar.

By clicking on the button , the user can access to a panel allowing the setting of general options, as shown on Figure 5. On each tab, the “Reset to default” buttons allow switching back to the initial preferences.

*NB: Every modal window, such as the preferences dialog, the addition of a new shape or the application of a transformation, can be closed by typing on the “ESC” key.*

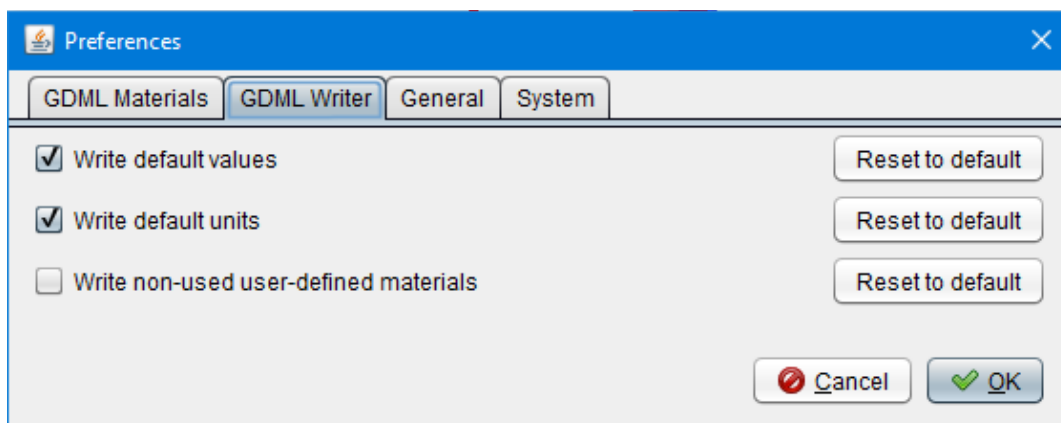


**Figure 5: Preferences dialog box**

The first tab, see Figure 5, offers options concerning the GDML materials. The user can choose the default shape material, which is the material attributed by default to all shapes created in the geometry. The user can also select which default material he wants to attribute to the world shape.

The second tab, shown on Figure 6, sets parameters for the GDML writer:

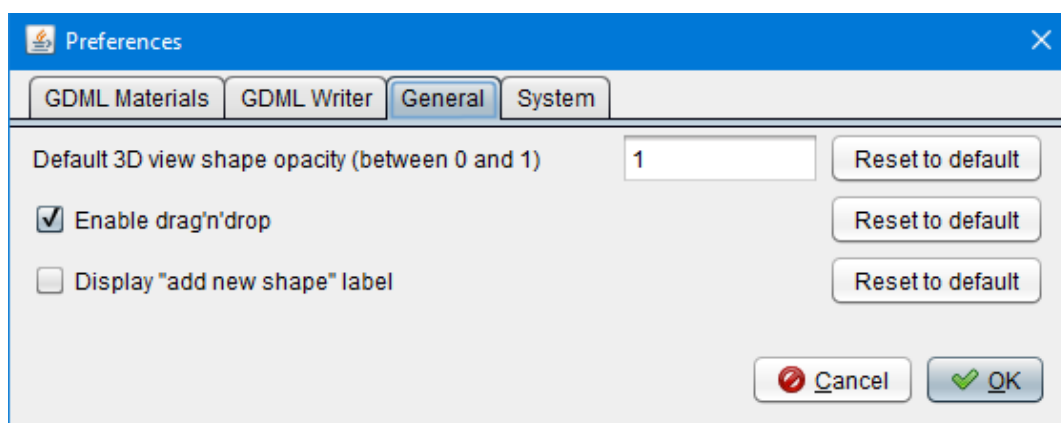
- The writing of default values or not: if this option is selected, the default values chosen in EDGE (mainly zeros) will be written inside the GDML file;
- The writing of default units: if this option is selected, the units will be specified inside the GDML file;
- The writing of non-used user-defined materials: if this option is selected and that the user has defined materials which are not attributed to a geometric shape, those materials will be stored in the GDML file anyway.



**Figure 6: GDML writer options**

The third tab offers more general usability preferences, as shown on Figure 7:

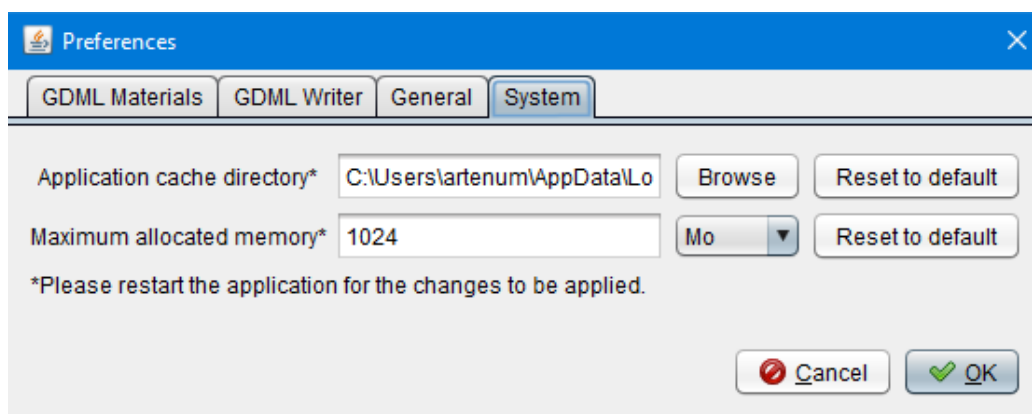
- The user can choose the default opacity used when adding a new shape to the 3D view. Indeed, a colour is automatically chosen for every new shape and this setting will choose the opacity for this colour. Please note that this setting will not change the opacity of the shapes already displayed in the 3D view;
- The option “enable drag’n’drop” allows to enable the possibility to move the elements in the Shapes tree using drag’n’drop. It facilitates the modification of the hierarchy. This option is disabled by default;
- It is also possible to display “Add new shape” shortcut labels in the shapes tree of the Geometry Edition perspective. These labels help to gain time to add new shape but this option is disabled by default to gain cleanliness, see section 0.



**Figure 7: General options**

The last tab sets preferences for the system, as shown on Figure 8. The user can choose:

- The application cache directory: by clicking on the “Browse” button, the user can choose the path where the application stores its temporary files. It may be useful to change this setting if you do not have write access to your temporary folder (by default EDGE uses the operating system default temporary folder);
- The maximum allocated memory: the user can choose the value and unit (Mo or Go) of the available memory for EDGE. It can be useful to increase this value when loading very big files, without exceeding the system maximum capabilities.



**Figure 8: System options**

## 5. Geometry Edition

The Geometry perspective is the main perspective of EDGE since it allows the creation and the edition of geometrical elements.

### 5.1. The Geometry edition perspective

It is the main perspective of EDGE displayed by default at the launching. It has two main panels to edit the geometry, as shows Figure 9:

- **(1) Shapes Tree** panel, to visualise and edit the list of geometric shapes;
- **(2) Properties** panel, to edit the properties of the currently selected shape;
- **(3) 3D Viewer** panel, present only for the geometrical edition and material affectation perspectives, provides a 3D view of the modelled system.

These panels, as well as the 3D View panel, can be moved, detached or maximized at the user's liking using the buttons on their top right corner.

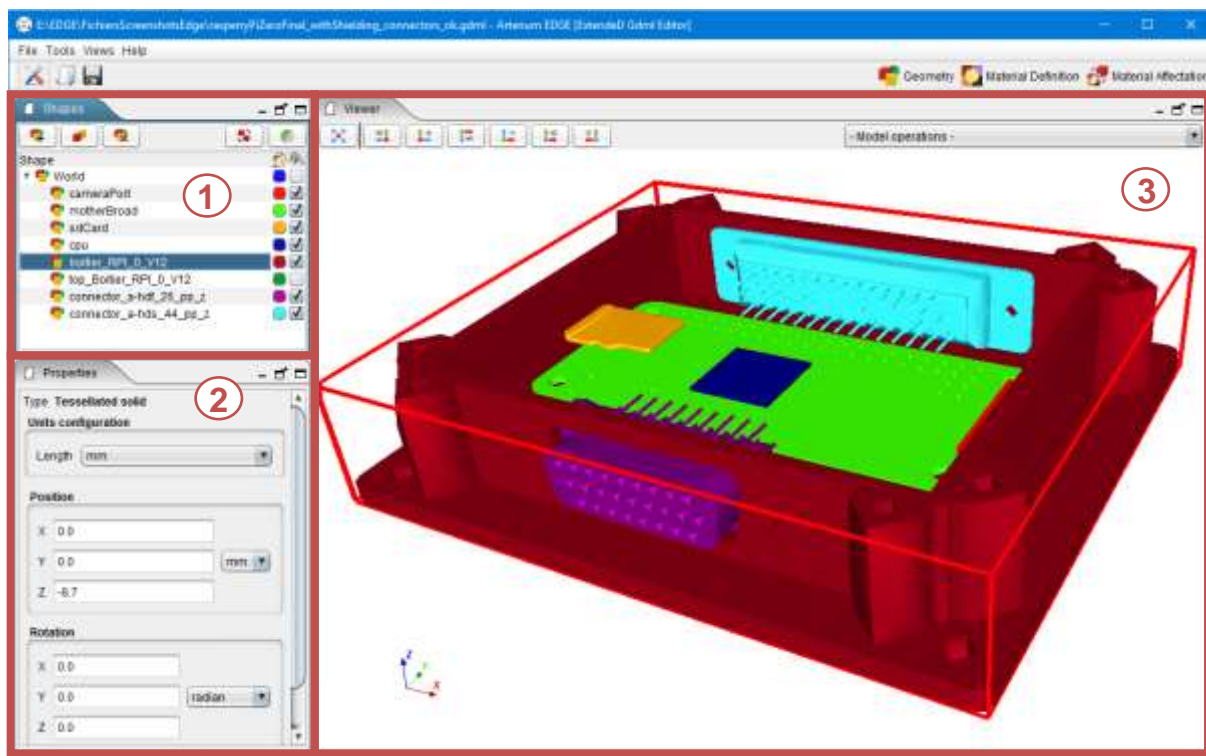
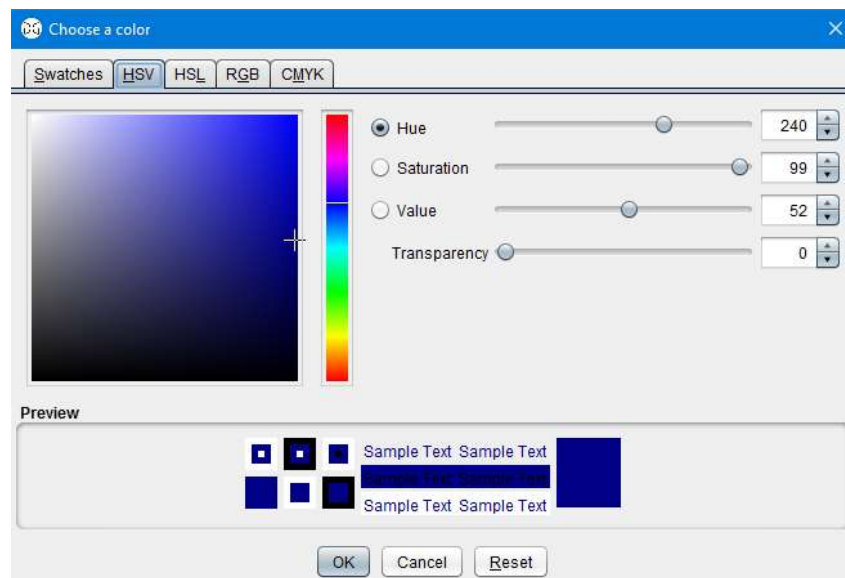


Figure 9: EDGE geometry edition view

### 5.1.1. Shapes tree






The Shapes tree lists all the shapes currently defined in the geometrical model and displayed in the 3D scene. It also shows the hierarchy of the shapes. The shape(s) currently selected is highlighted in the 3D view on the right with a red box. It is also possible to move one geometry element and all its children elements to another logical location in the geometry tree. This feature is available only if the drag'n'drop option has been enabled in the Preferences, see section 4.

On the right of each shape, a click on the coloured box opens a dialog that allows changing the colour of the shape in the 3D view. It is also possible to change the transparency of the selected element in this dialog box, as shown on Figure 10. A checkbox at right controls the visibility of the object in the 3D view.



**Figure 10: Colour changing dialog box**

On top of the tree, five buttons are used to control the shapes:

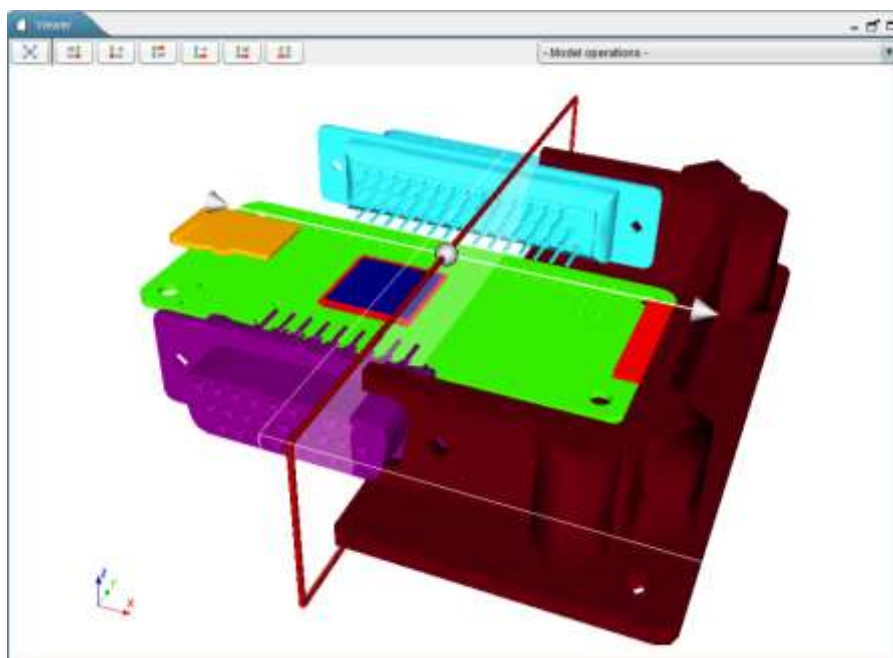
- The three buttons on the left side allow adding, duplicating and/or removing shapes. The first one (  ) opens a dialog box to add a new shape to the tree (more details in section 5.4.1). The second one (  ) duplicates the selected shape(s) and the third one (  ) deletes all the shapes currently selected in the tree.
- The two buttons on the right side allow performing actions on the currently selected shape(s). The first one (  ) opens a dialog box to apply a transformation to all the elements currently selected (more details in section 5.4). The second one (  ) offers the possibility to use a clipping filter. This button triggers the apparition of a dialog box allowing the user to set the



parameters of the clipping filter, see Figure 11. This filter performs a cut in the geometry to view more precisely the inner geometry of the modelled system. The clipping is set with the coordinates of a centre point and a normal direction. It will keep the geometric representation of the selected element in the half-space defined by this point and the normal. To get a more interactive setting, you can selected the “Display 3D control widget” that will display an interactive control in the 3D view to change the clipping. This 3D control of the filter are materialised by a sphere (representing the centre of the clipping operation) and an axis with two arrows (representing the normal direction), see Figure 12.



**Figure 11: Clipping dialog box**



**Figure 12: Clipping filter applied on a Raspberry Pi Zero housing with the 3D control widget enabled**



### 5.1.2. Properties panel

This panel shows the properties of the shape currently selected in the Shapes tree. It shows properties only if there is one — and only one — shape selected. Depending on the shape selected, the properties displayed change accordingly.

The user can thus define the dimensions of the shape and also — for box, cylinder and cone shapes — an additional useful parameter (not present in GDML) the thickness. If a shape has a thickness defined (different from 0), then the export of this shape will be done using Boolean operations (a subtraction between the outer element and the inner element). This kind of shape can be very useful during the definition of radiation analysis. The user shall be aware that this thickness value is not a GDML parameter, which means that setting this parameter to a value different from zero will result, in the GDML file, to the corresponding Boolean operation.

This panel shows also fields to choose the position and orientation of the object and the unit of measure. The position (0, 0, 0) corresponds to the barycentre of the World shape (see section 5.4.1).

The unit can be changed and it is proposed to convert all the relevant data to the new unit format. The default units are millimetres (mm) and radians (rad).

### 5.1.3. 3D View








The 3D view is showing in real-time the product of the GDML model. It is possible to interact with the view using the mouse to control it:

- Left click (hold) and movement: rotate the scene;
- Wheel (hold) and movement: translate the scene;
- Right click (hold) and movement: zoom;

Or the keyboard:

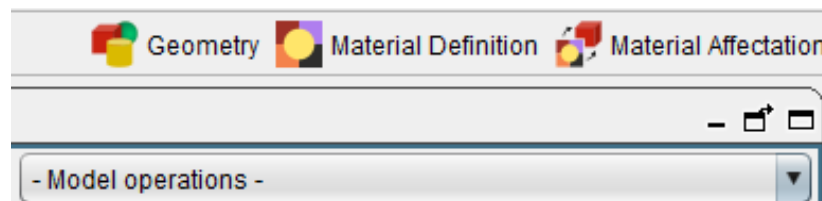
- “R” resets the view and shows all the shapes of the scene;
- “I” to zoom in;
- “O” to zoom out;
- “W” displays the shapes as wireframes;
- “S” displays the shapes as solid;
- The up/down/left/right arrows rotate the scene.

The buttons at the top of the view also facilitate its handling:

-  resets the view and shows all the shapes of the scene (equivalent to the “R” key shortcut);
-  aligns the view along +X axis;
-  aligns the view along -X axis;
-  aligns the view along +Y axis;
-  aligns the view along -Y axis;
-  aligns the view along +Z axis;
-  aligns the view along -Z axis.

*NB: sometimes, at the launch of the software, the 3D view is not correctly initialised. To refresh it, change perspective to another one and come back to the initial perspective, the 3D view is now correctly initialised. It can also happen when using several screen and moving the application from one screen to another one.*

On top of the 3D view, a drop-down menu (cf. Figure 13) allows the user to choose a model operation to launch (cf. section 5.5). These operations are also available through the Tools menu presented on Figure 4.



**Figure 13: Drop-down menu “Model operations” of the 3D view**

## 5.2. Available geometric shapes

EDGE is currently handling the following shapes: cone, ellipsoid, elliptical cone, elliptical tube, box, orb, paraboloid, sphere, and tube (see Figure 14). Other kind of shapes are also supported and presented in section 5.3.



**Figure 14: Available shapes**

### 5.2.1. Cone

A segmented or complete cone with a thickness and the possibility to have only a portion of its circumference.

**rmin1** inner radius at base of cone

**rmax1** outer radius at base of cone

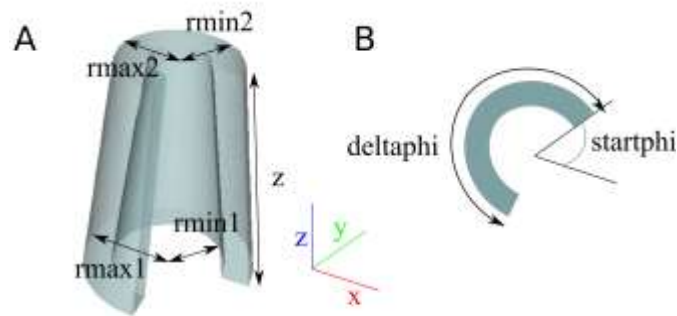
**rmin2** inner radius at top of cone

**rmax2** outer radius at top of cone

**z** height of cone segment

**startphi** start angle of the segment relative to the x axis

**deltaphi** angle of the segment



**Figure 15: Geometrical properties of the cone (A: whole view; B: basal section)**

### 5.2.2. Ellipsoid

An ellipsoid, where half-axis dimensions can be different along the three axes and which can be cut at the top and/or the bottom.

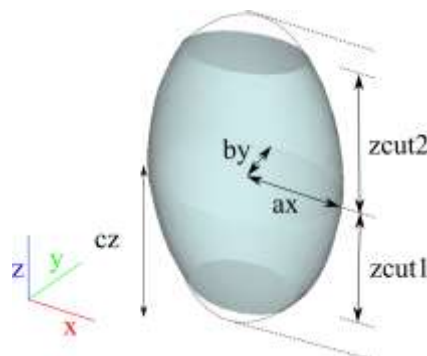
**ax** x semi axis

**by** y semi axis

**cz** z semi axis

**zcut1** height from the centre to the truncated base

**zcut2** height from the centre to the truncated top



**Figure 16: Geometrical properties of the ellipsoid**

### 5.2.3. Elliptical Cone

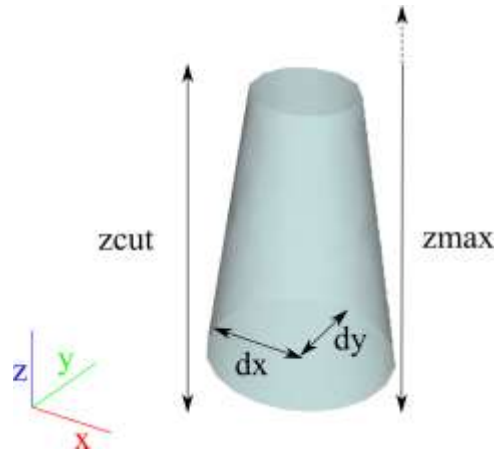
A segmented or complete cone that can have a different radius along the x and y radius.

**dx** x semi axis

**zmax** total z length without cut

**dy** y semi axis

**zcut** upper cut in Z



**Figure 17: Geometrical properties of the elliptical cone**

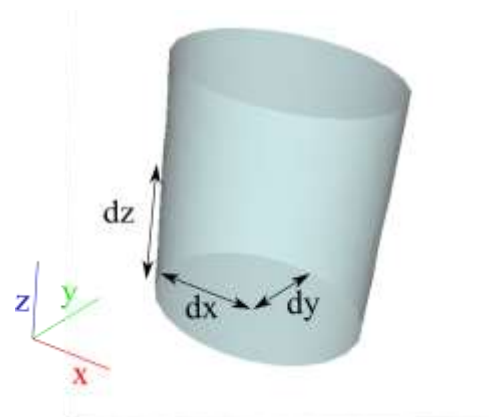
### 5.2.4. Elliptical Tube

A complete tube that can have a different radius along the x and y radius.

**dx** x semi axis

**dz** z semi axis

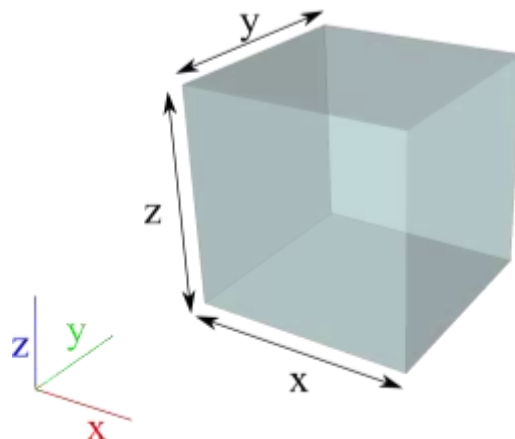
**dy** y semi axis



**Figure 18: Geometrical properties of the elliptical tube**

### 5.2.5. Box

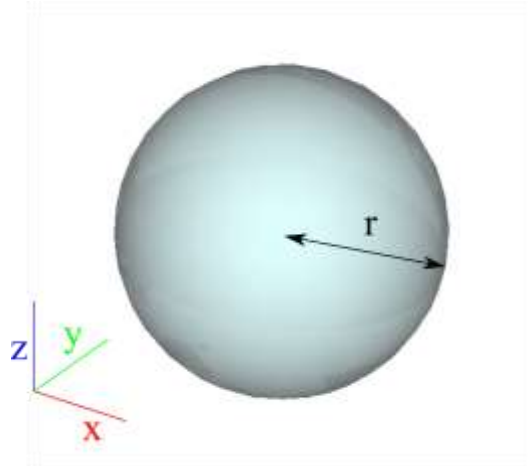
A simple box with the possibility to edit the **x**, **y**, **z** dimensions. This allows only to draw rectangular solids.



**Figure 19: Geometrical properties of the box**

### 5.2.6. Orb

A simple complete sphere with only one parameter,  $r$ , as the radius.



**Figure 20: Geometrical properties of the orb**

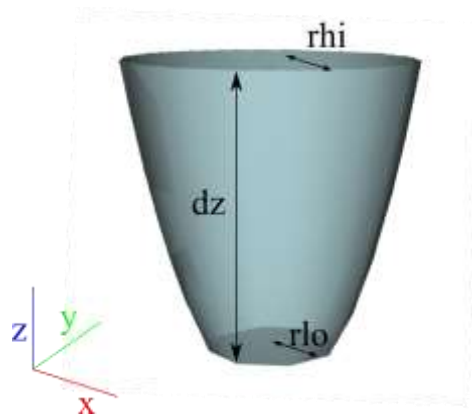
### 5.2.7. Paraboloid

A portion of a paraboloid, which can be cut at the top.

**rlo** radius at  $-z$

**dz** z length

**rhi** radius at  $+z$



**Figure 21: Geometrical properties of the paraboloid**

### 5.2.8. Sphere

A fully customizable sphere, with a thickness.

**rmin** inner radius

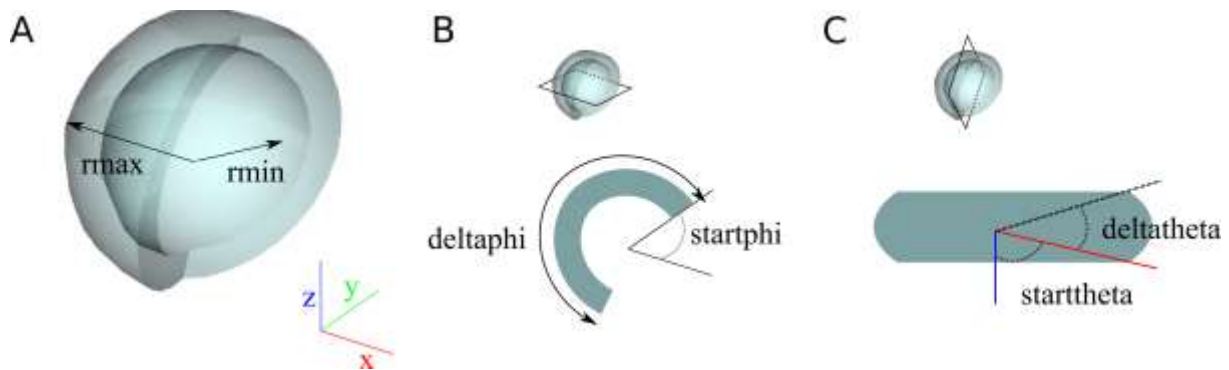
**rmax** outer radius

**startphi** starting angle of the “horizontal” segment

**deltaphi** delta angle of the “horizontal” segment

**starttheta** starting angle of the “vertical” segment

**deltatheta** delta angle of the “vertical” segment



**Figure 22: Geometrical properties of the sphere  
(A: whole view; B: horizontal section; C: Vertical section)**

### 5.2.9. Tube

A segment or complete tube, with a circular basis only, a thickness and the possibility to have only a portion of its circumference.

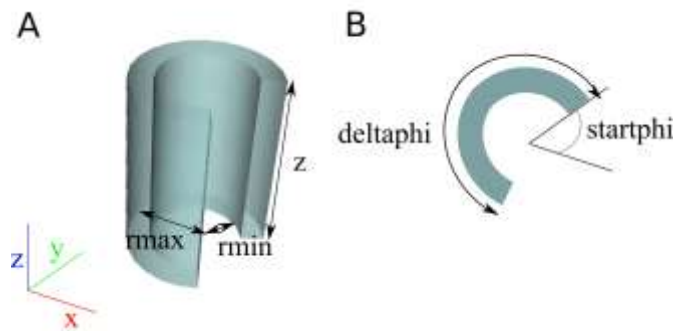
**rmin** inside radius of segment

**rmax** outside radius of segment

**z** z length of tube segment

**startphi** starting phi position angle of segment

**deltaphi** delta angle of segment



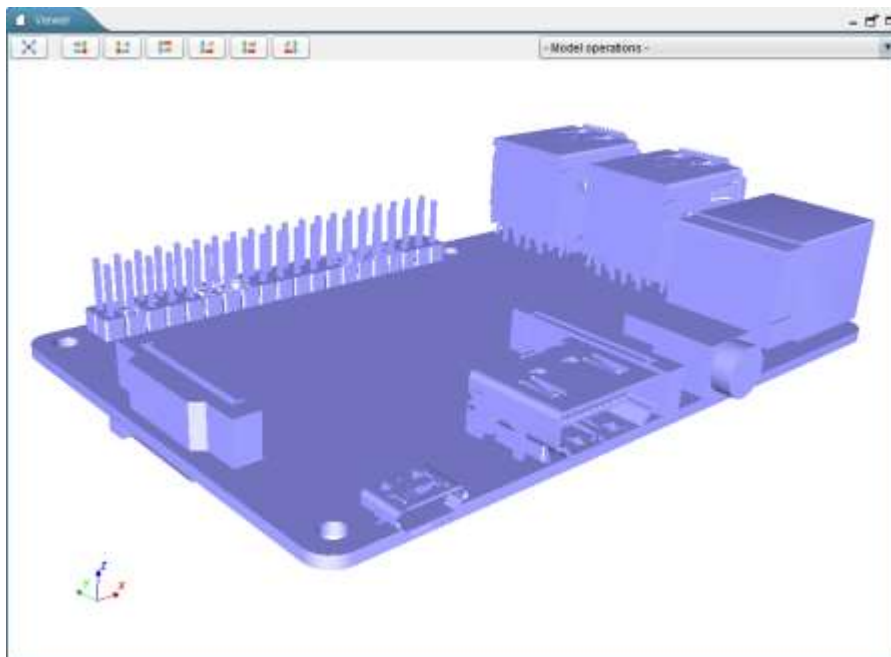
**Figure 23: Geometrical properties of the tube (A: whole view; B: section)**

### 5.3. Other shapes available

#### 5.3.1. Tessellated Solid

Solids with complex geometries can be constructed by importing tessellated surfaces, including initially B-Rep based models. Numerous formats are supported (.geo, mesh file, STEP AP 203 – 214 ...). Those tessellated surfaces are converted into an equivalent GDML tessellated solid object.

Please notice that the imported tessellated surface must imperatively be a close surface. EDGE displays a warning message to the user if it is not the case.



**Figure 24: Example of an imported tessellated solid**



### 5.3.2. Assemblies

In EDGE, the user has the possibility to handle “assembly” elements. Those elements are grouping several shapes without being attached to a geometric shape.

### 5.3.3. GDML file

EDGE also allows importing all the geometry concepts from another GDML file and including them as a child of the currently selected element. This option can be very useful if users want to check the position of a specific subsystem (defined in the imported GDML file) in the whole system (main GDML file).



## 5.4. Edition of the geometry

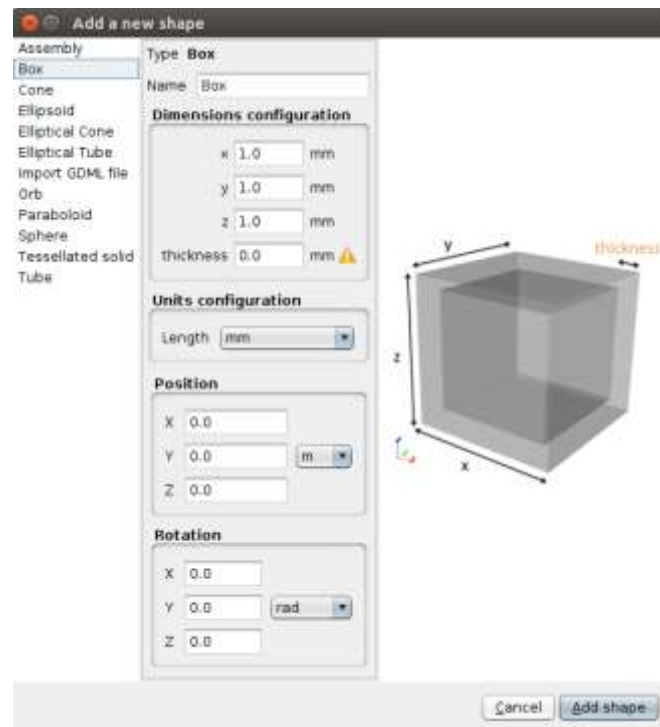
### 5.4.1. Creating/adding a new shape

The user has first to create a “world” shape that will include all subsequent shapes. Even if technically GDML allows creating a world smaller than the final object, it is not recommended. The world shape typically corresponds to the computational domain of numerous of simulation software using GDML files in input. And most of these tools will not work properly nor give relevant results if the world shape does not encapsulate all other elements. The relevant definition of the world shape remains on the responsibility of the user and with respect to the final targeted application.

The position (0, 0, 0) corresponds to the barycentre of this world shape.

Once this is done, it is possible to start the construction of the desired object.

Clicking on the  button (or the Add the world shape /  Add a new shape ” link if the corresponding option in the Preferences is enabled, see section 0), calls the New Shape Wizard (Figure 25). On the left panel of the dialog box, all the available shapes are represented. A click on a shape selects it and shows its properties on the right panel. Properties requirement varies with the different shapes, but for each ones the Name, Unit Configuration, Position and Rotation can be informed. All the properties can be edited via the Properties Panel (Figure 9, box 3).




**Figure 25: New shape dialog box**

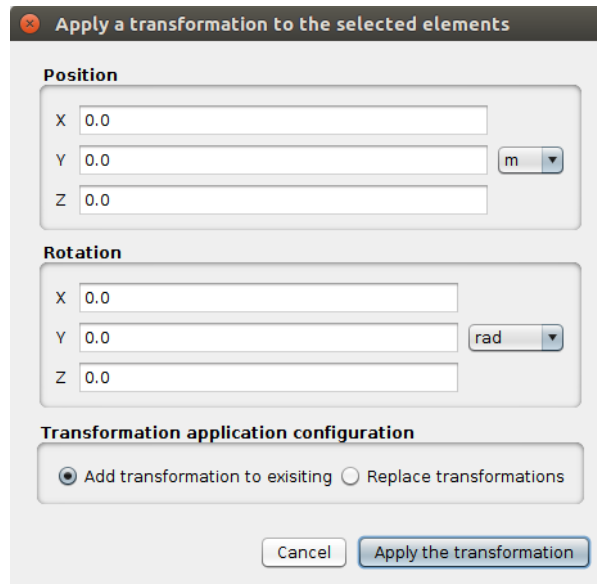
If the tree is empty, the first new shape will become the “world” shape. After that, each new shape will be added to the tree as a child of the current selected element. If no element is selected, the new element will be added as a child of the “world box”. This feature makes possible the creation of objects with a complex hierarchy of objects.

The new shape dialog box allows the import of B-Rep format files, as tessellated shapes, or GDML files as children of an existing shape, see section 5.3.

#### 5.4.2. Transforming several elements

Position and orientation can be directly edited in the properties panel. However, as it is not convenient to use this feature on each element to move, a multi-transformation tool has been implemented, accessible via the “Transform” icon of the Shapes tree panel (see section 0).

Once the elements to modify in the tree are selected, click on the Transform button (). The dialog box showed in Figure 26 then appears.



**Figure 26: Multi-element transformation dialog**

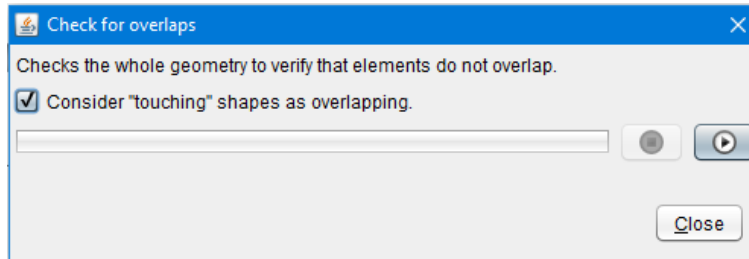
This dialog allows setting the translation and rotation to apply to the elements. These transformations can replace the current position and orientation properties of the objects or be added to any existing placement information. For example, for an object at a (1, 1, 1) position, a transformation of (2, 0, 0) with “Add” will displace the object to (3, 1, 1), when “Replace” will displace it to (2, 0, 0).

## 5.5. Model operations

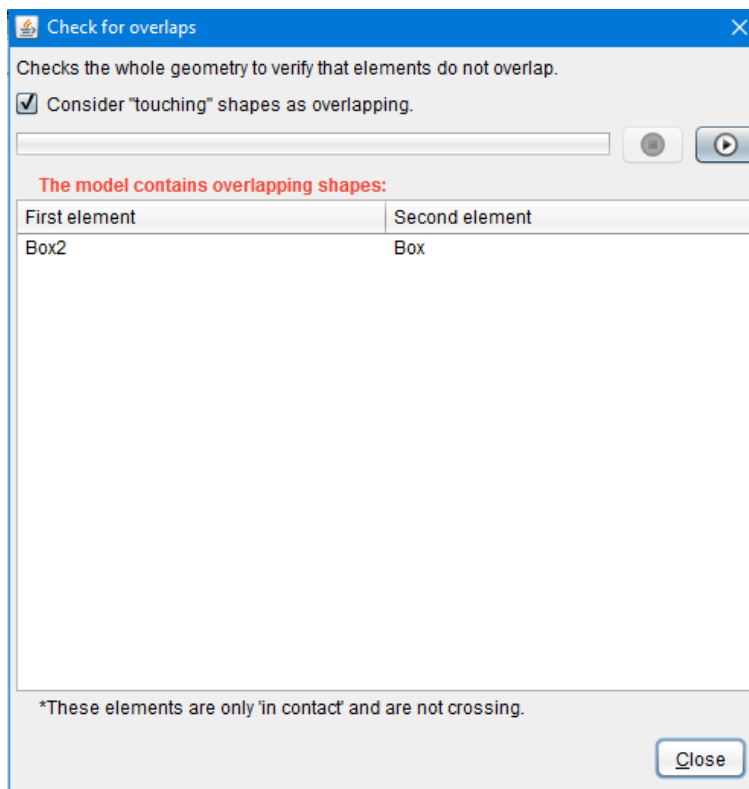
The user can obtain information about the created shapes thanks to the drop-down menu “Model operations”, as shown on Figure 13. The list of available operations may be subject to changes.

Available operations are:

- “Check for overlaps”: allows the user to check if there are no overlaps inside the geometry, meaning that there are no shapes overlapping each other. The user can choose if “touching” shapes should be considered as overlapping or not. To launch the calculation, the user can click on the “Play” button. The “Stop” button allows the user to stop the calculation at any time. The results of the operation are presented on Figure 28;

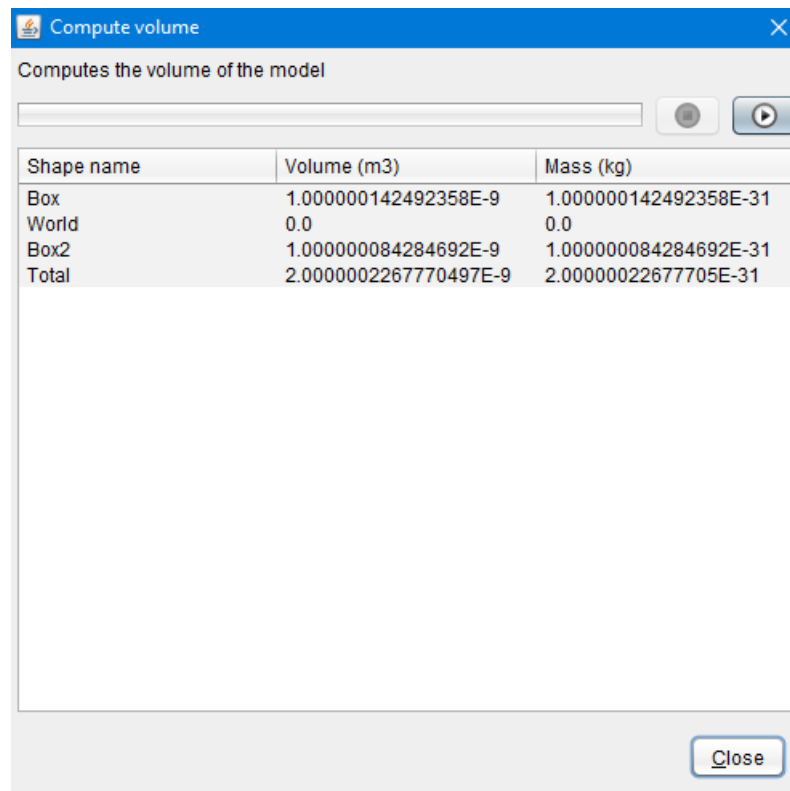


**Figure 27: Overlaps checking dialog box**



**Figure 28: Overlaps calculation results (indicates that the Box2 and Box elements are overlapping)**

- “Compute volume”: allows the user to obtain the volume of the geometry. The computed value is an approximation of the real volume value based on 3D meshing of the shapes. As for the previous operation, the calculation is launch with the “Play” button and can be stopped with the “Stop” button (cf. Figure 29).



**Figure 29: Volume computation results**

- “Reorganise model”: allows the user to check the consistency of the hierarchy of the model. Indeed, to get proper radiations results, elements that are included in other ones (geometrically) should be placed as child of the geometrical shapes they are in. This tool computes the real hierarchy, displays the results to the user and proposes to modify the model accordingly. NB: due to current limitation on this tool, it will remove all assemblies from the model.

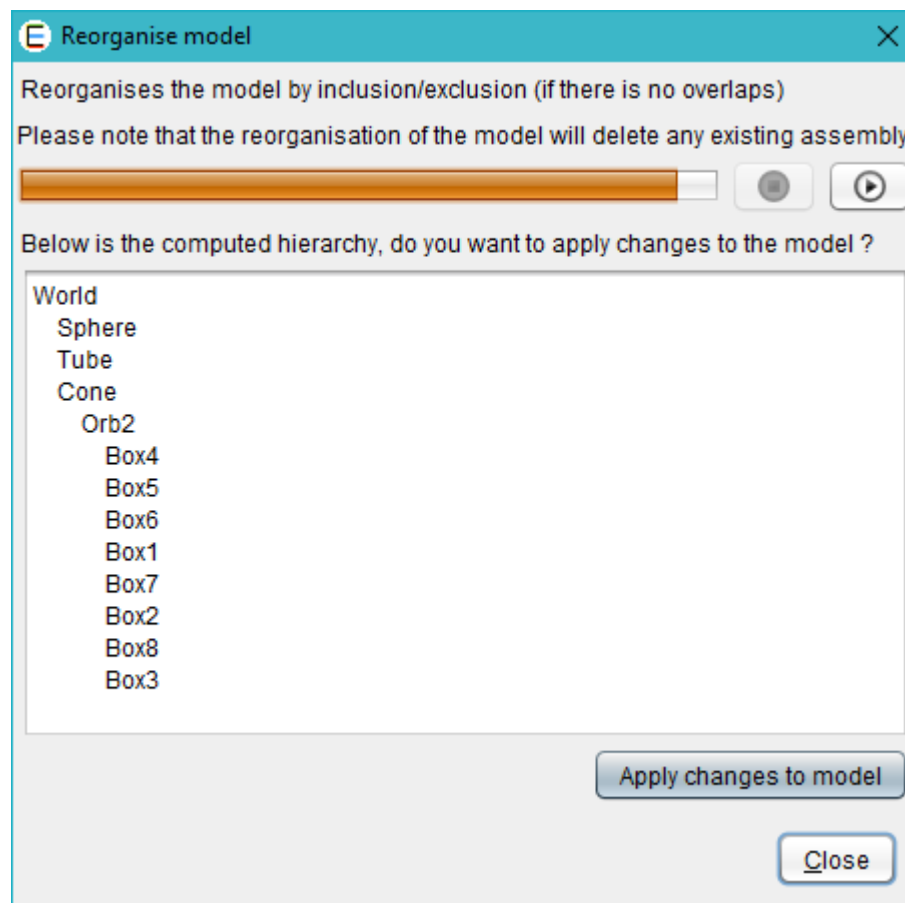


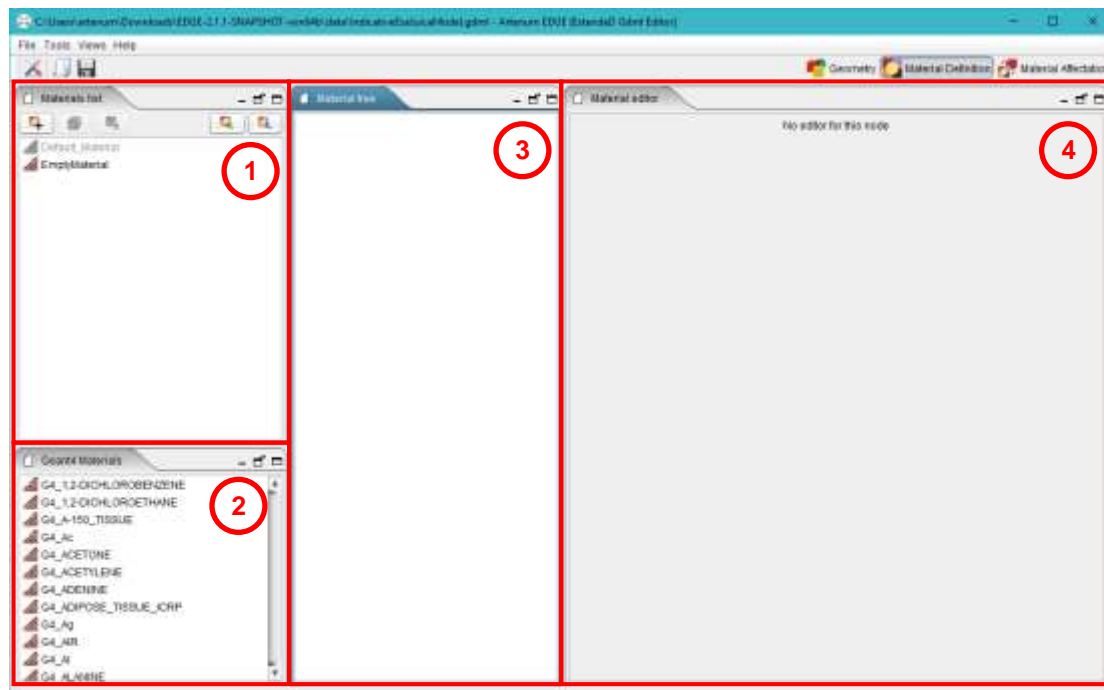
Figure 30: Exemple of hierarchy reorganisation results.

## 6. Material definition

The aim of this perspective is to define materials that will be attributed later to a geometric shape.

The Material definition perspective has no 3D view but is composed of four main panels, as shown on Figure 31:


- 1- Materials list
- 2- Available GEANT-4 materials
- 3- Material tree
- 4- Material editor



**Figure 31: EDGE material definition view**

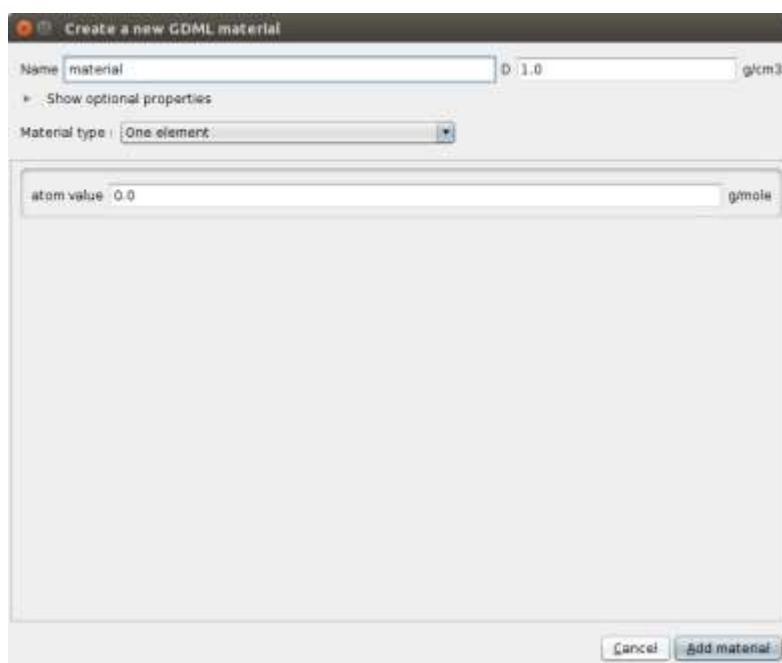
### 6.1. Materials list

This panel displays a list of all the materials, created by the user or not, as shown on Figure 33. EDGE contains one default material, named Default Material. This material is not editable (but may be duplicated).

In order to edit a material, the user can create a new one by clicking on (). The dialog box shown on Figure 34 then appears and asks the user to fill in the material name and density in  $\text{g/cm}^3$ , before choosing the type of material (see below).

General optional properties can be set by clicking on the “Show optional properties” and are:

- The choice of the atomic number Z;
- The formula;
- The state (liquid, solid, gaseous);
- The absorption length (AL);
- The mean excitation energy (MEE);
- The pressure (P);
- The radiation length (RL);
- The temperature (T).



**Figure 32: Material creation dialog box**

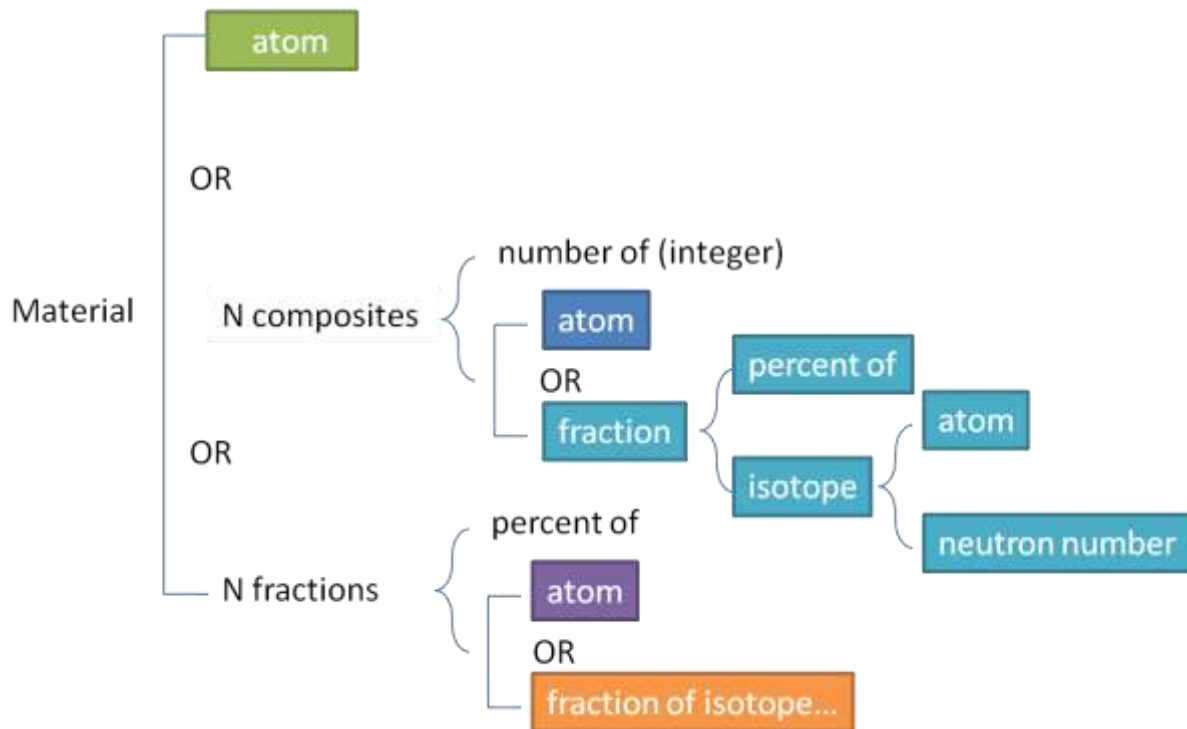
The user can then choose a material type. As shows Figure 33, a material can be defined by three different ways.

The first way simply consists in defining the material as one atom. For example, helium is defined as a single atom of helium.

The other possible definitions consist in defining an association of different elements. The difference is that a composition uses *integer* to indicate the repartition (2 atoms of X, 1 atom of Y ...) whereas the fraction uses *percentages* to indicate the repartition (0.4 of the total is made of X and 0.6 of the total is made of Y). Then, each fraction or composition can contain an atom or a fraction of composites.

Figure 34 presents different examples of material defined using the GDML formalism.





**Figure 33: Material definition in GDML**

<p>Helium</p> <p>0.01 of Carbon</p> <p>0.17 of Chromium</p> <p>0.82 of Iron</p>	<p>2 Hydrogen</p> <p>1 Oxygen</p> <p>0.01 of (0.9893 of <sup>12</sup>C and 0.0107 of <sup>13</sup>C),</p> <p>0.17 of (4.34% of <sup>50</sup>Cr, 83.79% of <sup>52</sup>Cr, 9.5% of <sup>53</sup>Cr and 2.37% of <sup>54</sup>Cr)</p> <p>0.82 of (5,85 % of <sup>54</sup>Fe, 91,75 % of <sup>56</sup>Fe 2,12 % of <sup>57</sup>Fe and 0,28 % of <sup>58</sup>Fe)</p>	<p>2 (0.99988 of <sup>1</sup>H and 0.00012 of <sup>2</sup>H)</p> <p>1 (0,9975 of <sup>16</sup>O, 0.0004 of <sup>17</sup>O and 0,0021 of <sup>18</sup>O)</p>
---	---	---


**Figure 34: Examples of different ways of defining a material in GDML**

Finally, the user can choose the atom value in g/mol of the newly created material. The material is created when the user clicks on “Add material”. This new material appears at the end of the Material list.

**Warning: If the user creates a new material which is not attributed to a geometrical shape in the Materials affectation perspective, this material will not be saved inside the .gdml file when the user saves the file to GDML in EDGE. In order to save materials which are not attributed inside the .gdml file, the user needs to activate the corresponding option, see section 0.**

The user can also duplicate a material by clicking on (  ). Those new materials are added at the end of the materials list and their names are incremented in order to not confuse them with the initial materials.

The user has also the possibility to delete a selected material by clicking on (  ).

By clicking on () , the user will be able to import materials from another GDML file or from a GDML materials XML file. In the case of a GDML file, this mechanism will import all materials written inside the GDML file. We remind that in order to write in a GDML file all materials, even the ones which are not affected to a geometry shape, the user must enable the corresponding option in the Preferences (see section 0).

Finally, by clicking on the export button () , it is possible to export the materials into a GDML material file (.xml). All the user-defined materials will be exported.

## 6.2. Available GEANT-4 materials



Several pre-existing GEANT-4 materials are listed in EDGE and are available for the material affectation, see section 7. The complete list is displayed in the GEANT-4 materials panel, as shown on Figure 31. Those materials are displayed here to inform the user that they will be available during the material affectation, see section 7.

## 6.3. Material tree

This panel displays the current material selected in the Materials list, this one being either newly created by the user or pre-existing in EDGE. It shows the entire tree view of the material, as shown on Figure 35.

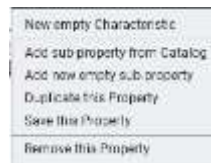


**Figure 35: Tree view of a material**

Once a material is created or selected in the materials list and displayed in the material tree, it is possible to edit it by selecting the properties ( or ) and

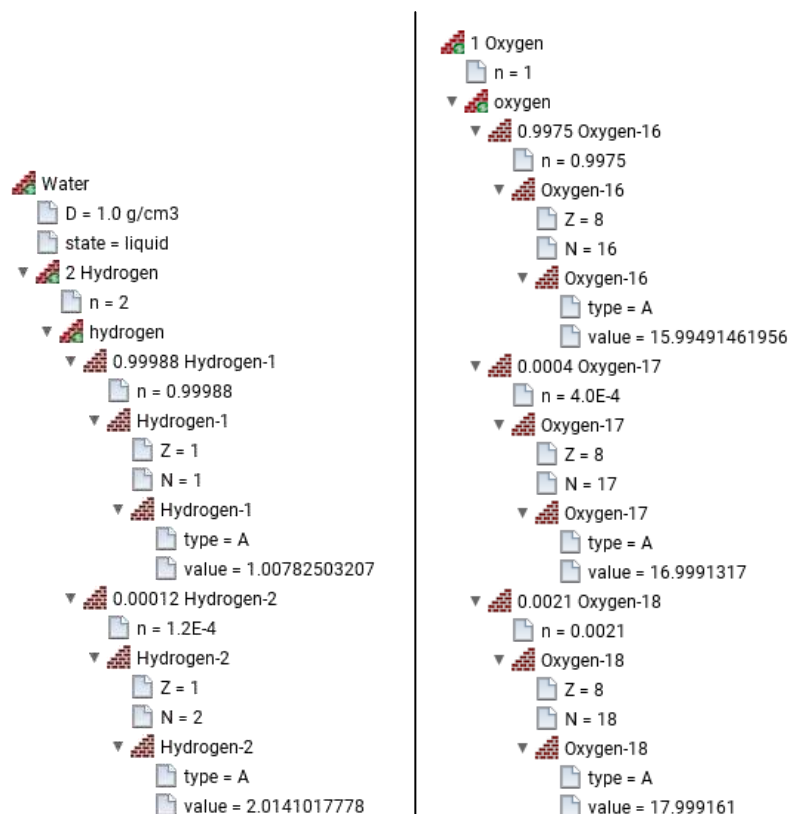
characteristics (📄) in the material tree on the left. Once selected, the correct editor is displayed in the material editor where the different values can be modified.

The properties can be duplicated by selecting them, right-clicking and selecting *Duplicate this property* as shown on Figure 36. The duplicate function will duplicate the property as well as its characteristics and its sub-properties recursively. This menu also allows deleting a property. The same actions can be applied to characteristics.



**Figure 36: Right-click on a selected property**

The following example, described in Figure 37, consists in the creation of the water material with the isotopes repartition explicated. To do so, the custom material has been filled with two “composites of isotopes”. The template obtained is then expanded by duplicating the template isotope. After that, all the characteristics are filled up with correct value and the different element are renamed to make the created hierarchy understandable.

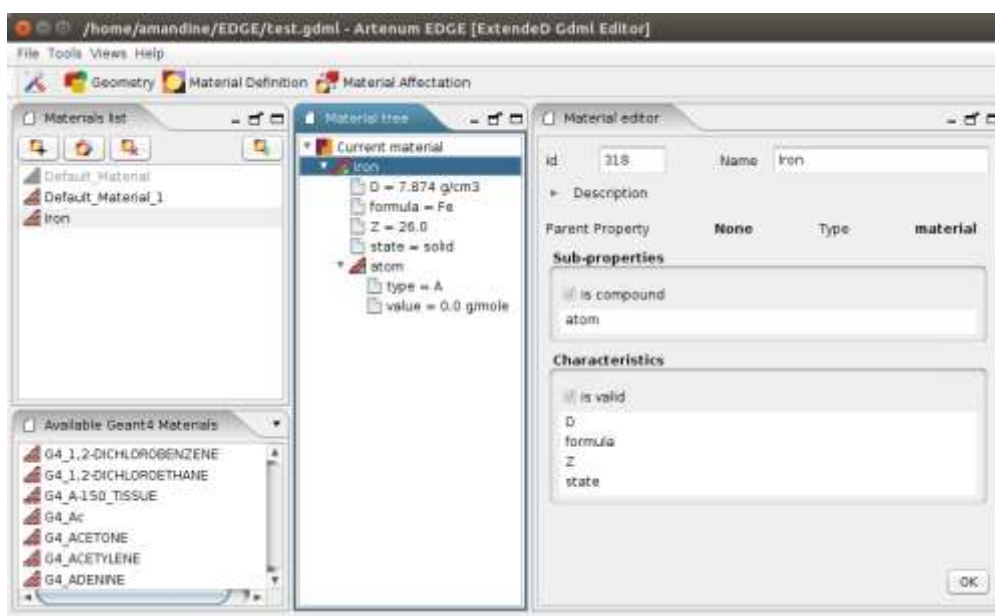


**Figure 37: Example of complex material in EDGE (water with the natural isotopes repartition)**

## 6.4. Material editor

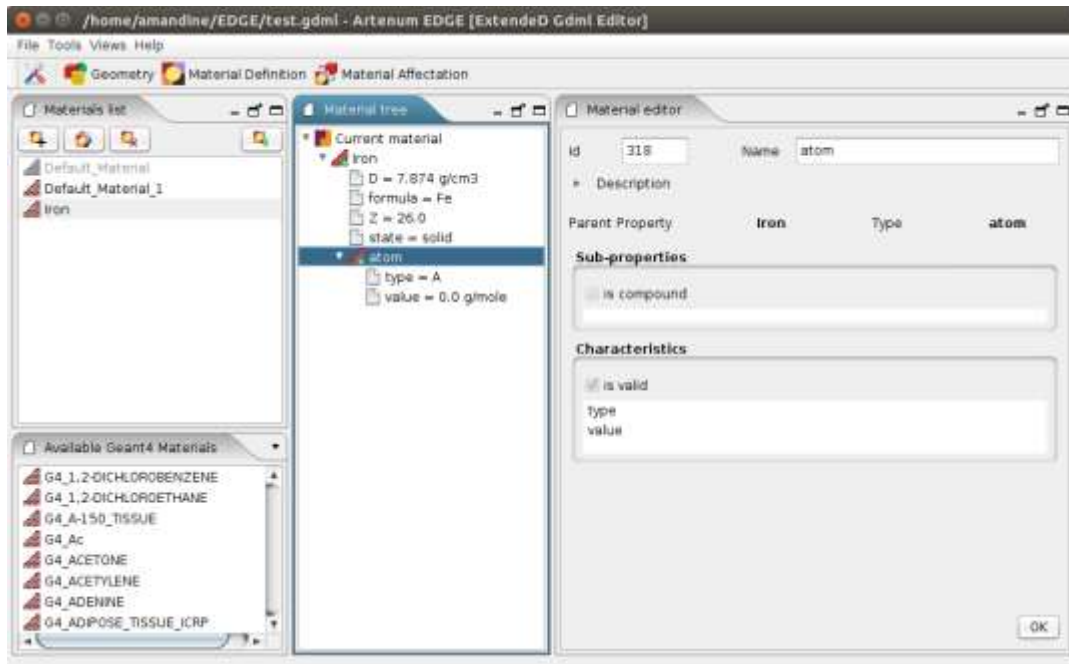
This panel allows the user to edit the values of the material tree displayed on the Material tree panel.

When the name of the material is selected in the Material tree panel, the Material editor panel is the one shown on Figure 38. The user can find on this panel the Id of the material, its name, its description, its sub-properties and its characteristics. The user can change the values of all these fields and validate them by clicking on the “Ok” button at the bottom of this panel.



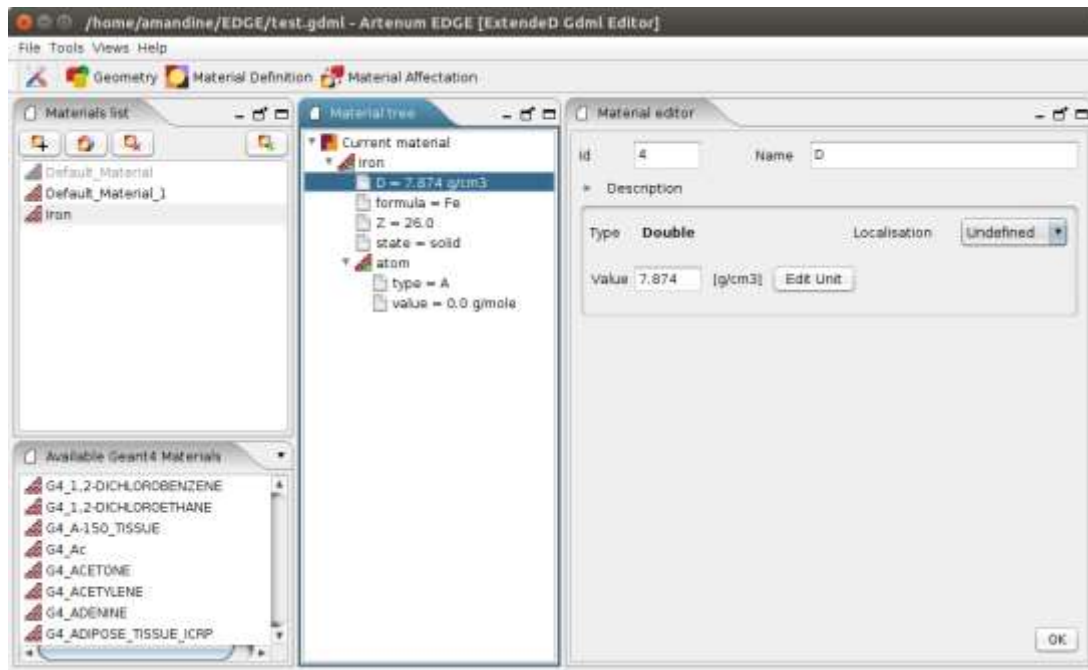
**Figure 38: Material editor when the material name is selected**

When a sub-property of a material is selected in the material tree, the Material editor panel changes accordingly, as shown on Figure 39. This new panel displays the Id of the material, the name of the sub-property, its description, its parent property, its sub-properties and its characteristics. As for the previous panel, all fields are editable.



**Figure 39: Material editor when a sub-property is selected**

When a characteristic is selected in the material tree, the corresponding material editor panel is as shown on Figure 40. It displays the Id of the characteristic, its name, its description and its value. The user can also change the unit of the characteristic by clicking on “Edit unit”.



**Figure 40: Material editor when a characteristic is selected**

## 7. Materials affectation

The aim of this perspective is to apply the materials defined in the material definition view to the geometry defined in the geometry edition view. Thus, this view only makes sense when at least one shape has been defined in the geometry perspective.

The materials affectation perspective has the same 3D view as the geometry one (like shown on Figure 41):

- 1- Materials list
- 2- Material selection

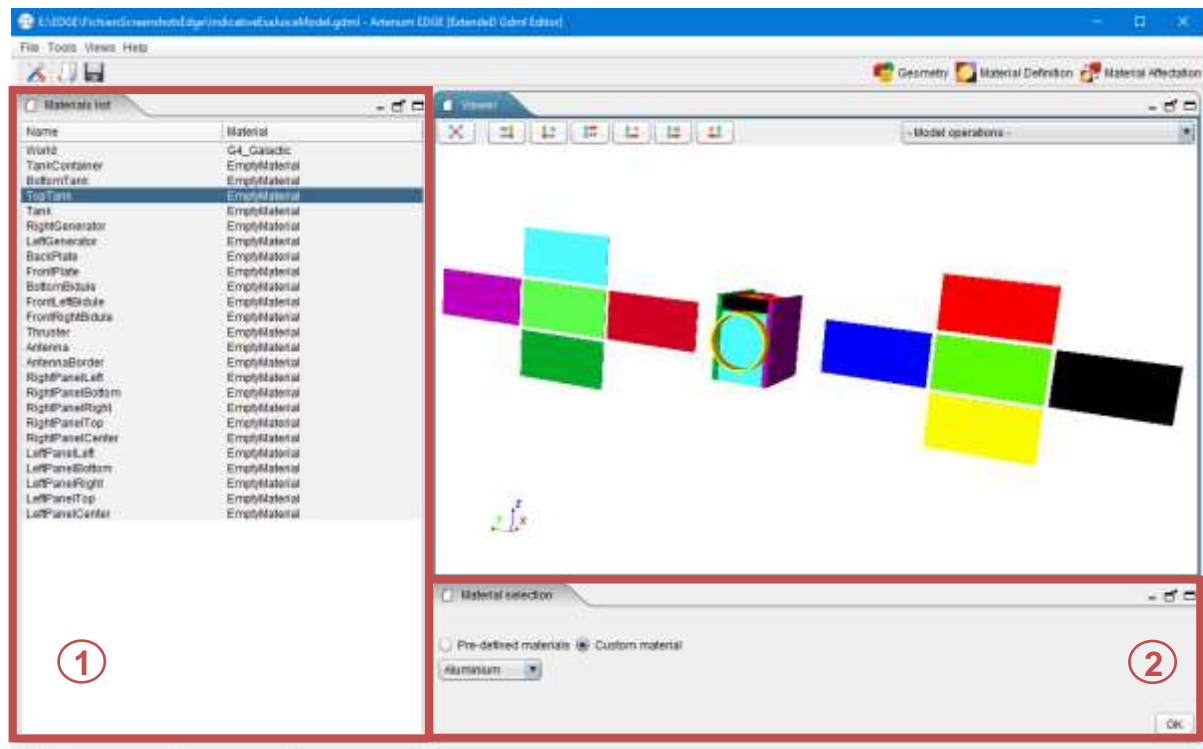



Figure 41: EDGE material edition view

### 7.1. Materials list

This panel contains a table with two columns. The first column (on the left) lists the geometry shapes created in the Geometry edition perspective. The second column (on the right) lists the materials attributed to each corresponding geometry shape. By default, the GEANT-4 material G4\_Galactic (i.e space environment) is attributed to the geometry shape representing the world. All other geometry shapes created are, by default, composed of Default\_Material.

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## 7.2. Material selection

The Material selection panel allows the user to select the material to attribute to a geometry shape, defined in the Geometry edition perspective.

When a geometry shape is selected in the Material list panel, the Material selection panel displays several choices for the user:

- *Pre-defined materials*: some pre-defined materials exist (see section 6) and can be directly used to define the material for the selected shape. When this option is selected, a drop down list appears, displaying all default materials already available in EDGE (Default\_Material and all GEANT-4 materials presented in section 6).
- *Custom materials*: When this option is selected, a drop down list appears, displaying all the materials created by the user in the Material definition perspective.

When the chosen materials are selected in the drop down list, the user must click on the “Ok” button of the Material selection panel in order to validate the choice and update the table in the Material list panel.

## 8. Annex A: Example of materials description

Here after is presented an example of material definition in GDML format (partial description).

```
<materials>

<!-- Examples of basic or fundamental materials -->

<element name="videRef" formula="VACUUM" Z="1">
  <atom value="1"/>
</element>

<element name="aluminum" formula="Al" Z="13">
  <atom value="26.9815"/>
</element>

<element name="carbon" formula="C" Z="6">
  <atom value="12.0107"/>
</element>

<element name="Hydrogen" formula="H2" Z="1">
  <atom value="1.01"/>
</element>

<element name="Nitrogen" formula="N2" Z="7">
  <atom value="14.01"/>
</element>

<element name="Oxygen" formula="O2" Z="8">
  <atom value="16.0"/>
</element>

<!-- Examples of complex or composite materials -->

<material name="Mat_ALUMINUM" formula="ALUMINUM">
  <D value="2.7000" unit="g/cm3"/>
  <fraction n="1.0000" ref="aluminum"/>
</material>
```



```
<material name="Mat_Kapton" formula="Kapton">  
  <D value ="1.42" unit="g/cm3"/>  
  <fraction n="0.0273" ref="Hydrogen"/>  
  <fraction n="0.7213" ref="carbon"/>  
  <fraction n="0.0765" ref="Nitrogen"/>  
  <fraction n="0.1749" ref="Oxygen"/>  
</material>
```

```
</materials>
```

**END OF DOCUMENT**