EDGE: new GDML CAD tool for Geant4 based analysis and interoperability bridge for high-energy particle modelling tools

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Introduction: Geant4 has fully confirmed is capability to model 3D complex high-energy particles/matter processes and handle realistic geometries. To define them, the usual approaches consist in using Geant4 built-in classes, or through the GDML format. GDML, for Geometry Description Markup Language, is a rich XML based CAD format, following a CSG approach, to define detailed geometrical systems and their material characteristics. However up-to-know, the lack of WYSIWYG dedicated tools, easily available, made the adoption of GDML still limited in the community. EDGE through a user-friendly GUI, including real-time 3D visualisation aims to help GDML usage in the Geant4 community.

Importing complex GDML geometries

GDML is used by Geant4 to define detailed geometries and applied material properties. EDGE supports most of the GDML features. It especially handles most of the available shapes. An internal EDGE tool allows checking any GDML file compatibility with the standard.

Industrial formats import

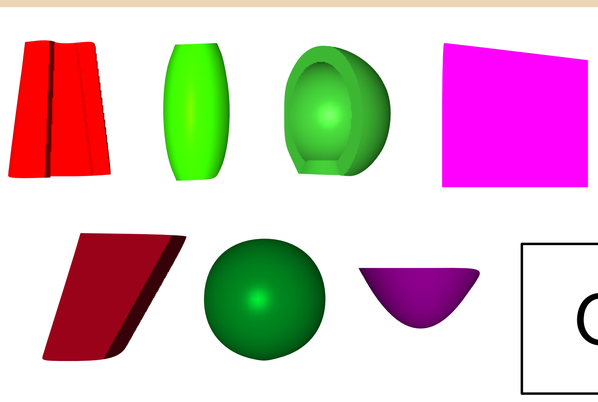
A **STEP-AP** reader allows importing and simplifying geometrical models from tools more generally used in the industry. EDGE can also import various B-Rep based formats such as: Gmsh **.geo** geometry format and **.msh** mesh format as well as others B-Rep formats like **.stl** and **.unv**.

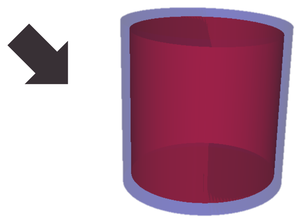
Bridge towards interoperability

As a first step towards interoperability, EDGE is now able to **load geometries from** the **MCNP** file format, currently limited to macro-bodies. It can help visualise MCNP geometry definition. This first step demonstrates the capabilities of the software as an interoperability bridge.

```
c  ***************** BLOCK 1 -- cells
8  0          -18          IMP:P,N=1     $ inside the cask
7  5  -7.86    18  -17     IMP:P,N=1     $ cask iron shell
9  0           17          IMP:P,N=0     $ void outside cask

c ***************** BLOCK 2  -- surfaces/macrobodies
17 RCC  5 5 40    0 0 20    10          $ outer cylinder
18 RCC  5 5 41    0 0 18    9           $ inner cylinder
```





STEP-AP

MSH, STL, UNV, …

GDML

MCNP

EDGE

ExtendeD Gdml Editor

A fully functional editor

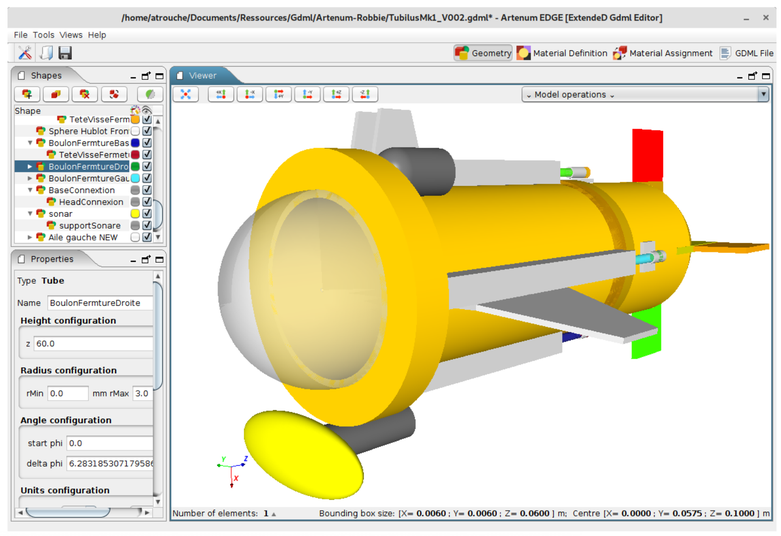
EDGE has been designed with the idea to facilitate the creation or edition of GDML files. With this software, users can **create/load/edit GDML files** and save them with real-time 3D visualisation.

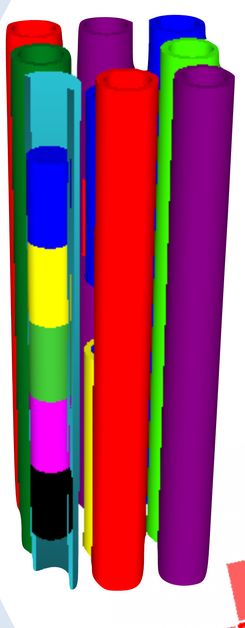
EDGE allows the creation of complex GDML files by handling **several-layer hierarchy** with most of the GDML simple shapes, such as:

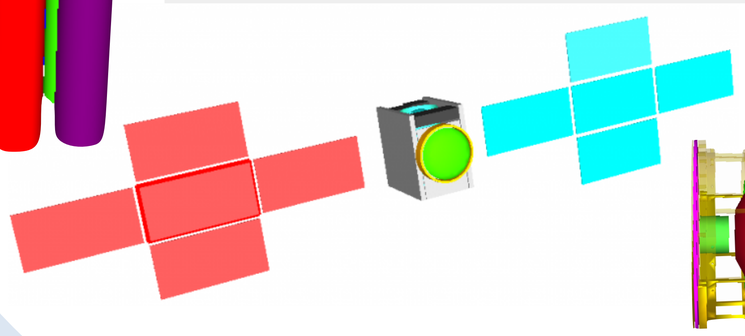
- Boxes and Parallelepipeds;
- Paraboloid;
- Spheres and Ellipsoids;
- Tessellated Elements;
- Trapezoids;
- Tubes and Cones.

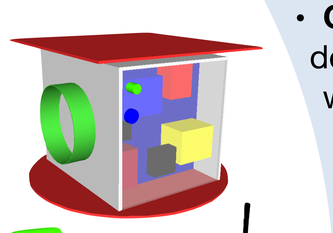
EDGE allows to **edit** and **assign material** properties on each geometrical elements in a simple way. Materials can be defined:

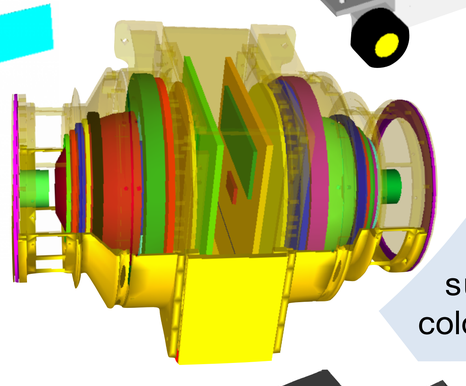
- From Geant4 predefined materials;
- From existing GDML defined materials;
- Manually by defining the various isotopic and stoichiometric compositions using an easy-to-use graphical editor.











Geometry checking and statistics

Based on a modular design, following an OSGi approach, EDGE also includes numerous extra functionalities to help configuring Geant4 simulations:

- **Overlapping detection module:** it detects overlaps that cause issues with Geant4 analysis.
- **Volume and mass computation module:** computes the **total volume and mass** (using assigned material densities) of the system.
- **Sector Shielding Analysis Module SSAM:** this plug-in allows through a simple GUI to perform quick sector shielding analysis and **deposited dose computations**. SSAM is perfectly adapted for quick radiations analysis, in a simplified engineering approach or as pre-processing for Monte-Carlo models. SSAM offers various results visualisation such as “sectorised geometry views”, colorised spheres and angular maps.

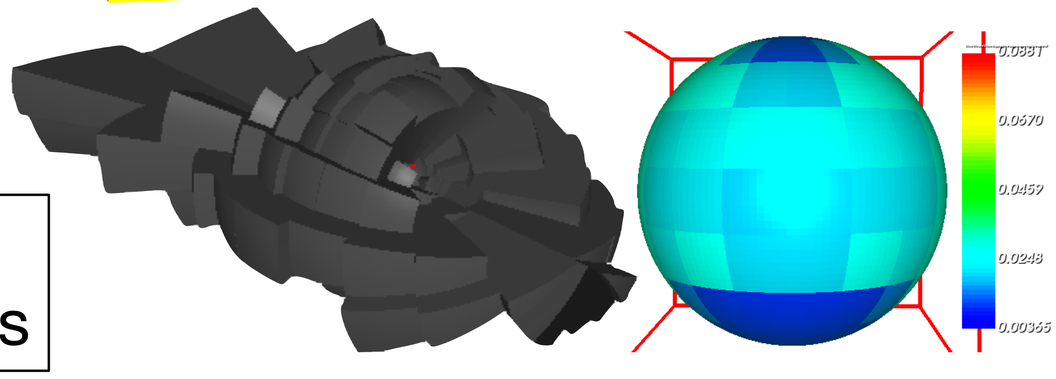
Pre-processing tool for other physics

EDGE can also **export** the modeled system to **other geometrical** formalisms such as B-Rep ones.

An existing one exports the geometry definition to the Gmsh geometry file .geo. It is for example used by the SPIS software to model **spacecraft charging**.

Export to B-Rep format

GDML for Geant4 analysis

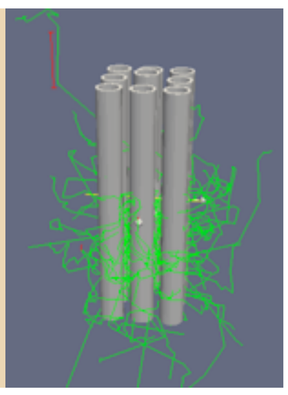


Using GDML with Geant4 for space environment effects analysis

In space environment effects, and especially in radiations analysis, GDML has already be used to model numerous space systems and scientific payloads in a realistic way, like CNES/AMBRE instrument. In this frame, a detailed **radiations and internal charging analysis** have been performed with the ESA/GRAS tool, through the **MoORa** (Modelling Of Radiations) software, a user-friendly frontal for Geant4 based applications, developed by Artenum. Here the key aspect is to obtain the right balance for the geometry: at the same time accurate and simplified enough to obtain exact dose and charge computations in direct Monte-Carlo at a reasonable cost.

Using GDML with Geant4 for neutron transport

For neutron transport and nuclear criticality applications, EDGE has been used to define fuel-assembly models to explore the possibility to compute effective multiplication factor K_{eff} with Geant4. Here the challenging aspects were the definition of geometries presenting numerous **repetitive elements** (assemblies) and **accurate material definitions** (stoichiometric and isotopic). In high-energy particles physics, EDGE can also be used to define complex instruments geometries.



Conclusion: EDGE is a fully operational GDML CAD editor especially designed for Geant 4 applications. Easy to use, integrating several additional pre-processing tools, it is already used for numerous scientific and industrial applications. Initially mainly used in space environment analysis, EDGE is available through the **SpaceSuite** service (**www.space-suite.eu**). But it sees its application scope progressively extended to ground applications, in neutrons transport, radiological protection and high-energy particles. Nevertheless, current EDGE version is not optimised enough to produce smart constructions for big assemblies (using replicas and loops). To handle complex systems, the editor needs to handle such GDML features.

ENSAR2 workshop: GEANT4 in nuclear physics – 24-26 April 2019 – Madrid (Spain)