Presentation of the validation case performed with the SPIS Services IC application
-
Geant4 Space users workshop

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Context

- Increase of complexity of future commercial mission
  - For sample increasing of power

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- Space environment more and more hostile for scientific mission
  - Jovian environment for example

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New spacecraft design must be considered

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Use of COTS components

New spacecraft design must be considered

Mass optimization

Context

- Increase of complexity of future commercial mission
  - For sample increasing of power
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Use of COTS components

New spacecraft design must be considered

Mass optimization

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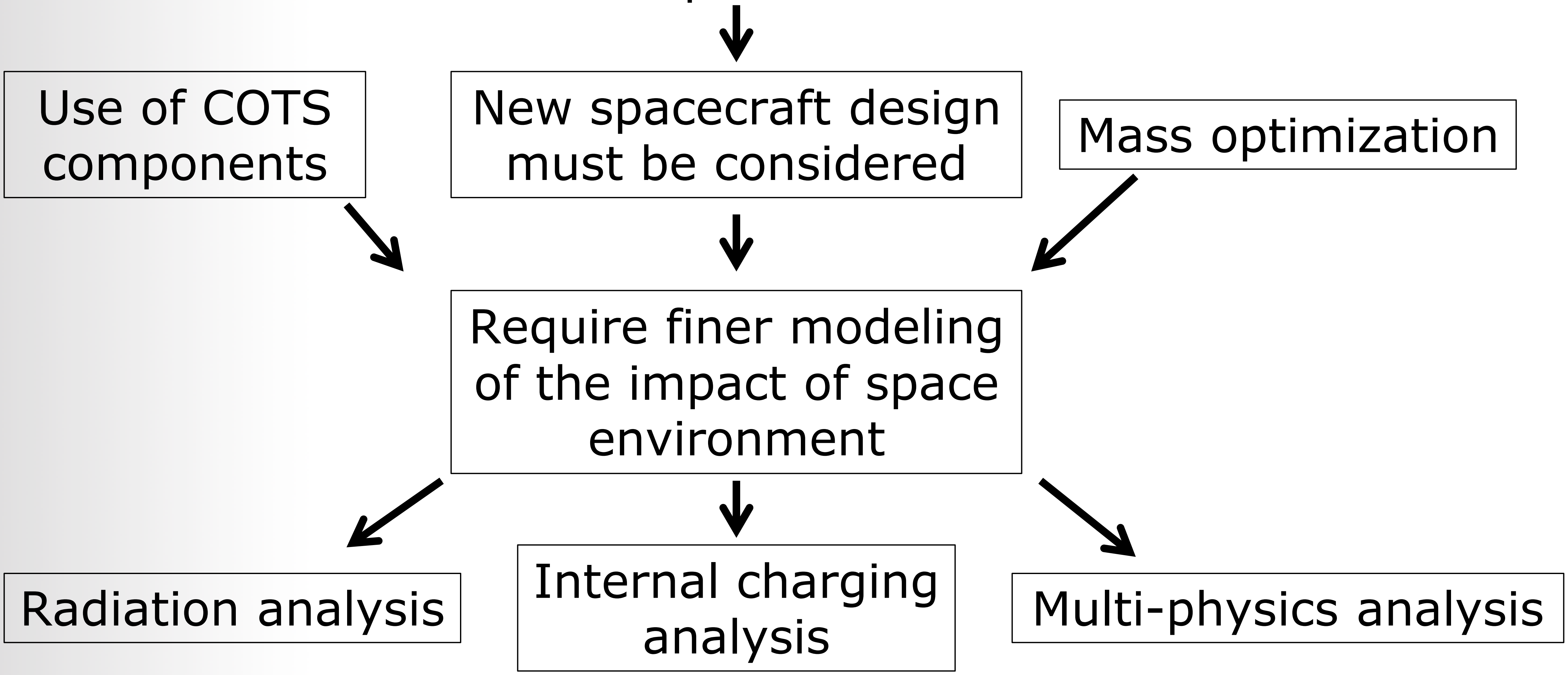
Require finer modeling of the impact of space environment

Context

- Increase of complexity of future commercial mission
  - For sample increasing of power
- Space environment more and more hostile for scientific mission
  - Jovian environment for example



Context

Presentation of existing simulation tools

- GRAS: radiation analysis tools based on Geant4
  - 3D Monte-Carlo
  - Initiated and developed by G. Santin from ESTEC
  - Supported by a large community of experts
  - Allow to compute deposited dose, deposited energy, charge, …
  - Allow to model complex 3D geometries and sources
  - Available on the ESA website:

space-env.esa.int/index.php/geant4-radiation-analysis-for-space.html

Context

Presentation of existing simulation tools

- Current limitations of GRAS:
  - Limits to create CAD geometry in a dedicated 3D tool
  - Limits to load and edit an existing geometry in a dedicated 3D tool
  - Limits to create materials in a dedicated graphical tool
  - Limits to attribute a material to a specific shape in a dedicated 3D tool
  - Limits to create and visualize a source in a dedicated 3D tool with the visualization of the global geometry
  - Limits to perform 3D post-processing operations on GRAS 3D results (cutting plane, clipping, …)

Context

Presentation of existing simulation tools

- SPIS IC: 3D PIC code used to perform internal charging analysis:
  - SPIS is initially used to model the spacecraft plasma interactions
  - SPIS is an open source software freely available through the SPINE community:
    http://dev.spis.org/
  - Initiated by the ESA and CNES agencies
  - Became the de facto reference tools in the plasma-spacecraft interactions
  - Recently extended to the internal charging

  - Internal charging analysis needs radiation analysis as input (deposited dose and charge)
  - More details in the Pierre Sarrailh’s presentation called “Internal charging simulation at a Galileo like orbit – effect of the anisotropic shielding and of the environment definition”

Outline

Presentation of a new single modelling chain able to manage radiation analysis and internal charging analysis

Currently finalization of the validity of this modelling chain

- Presentation of the validity of this new modeling chain with a realistic test case
  - Presentation of the test case
  - Presentation of the whole modeling chain
  - Use the modeling chain with a realistic test case

Test case presentation

Consider a realistic Raspberry Pi card

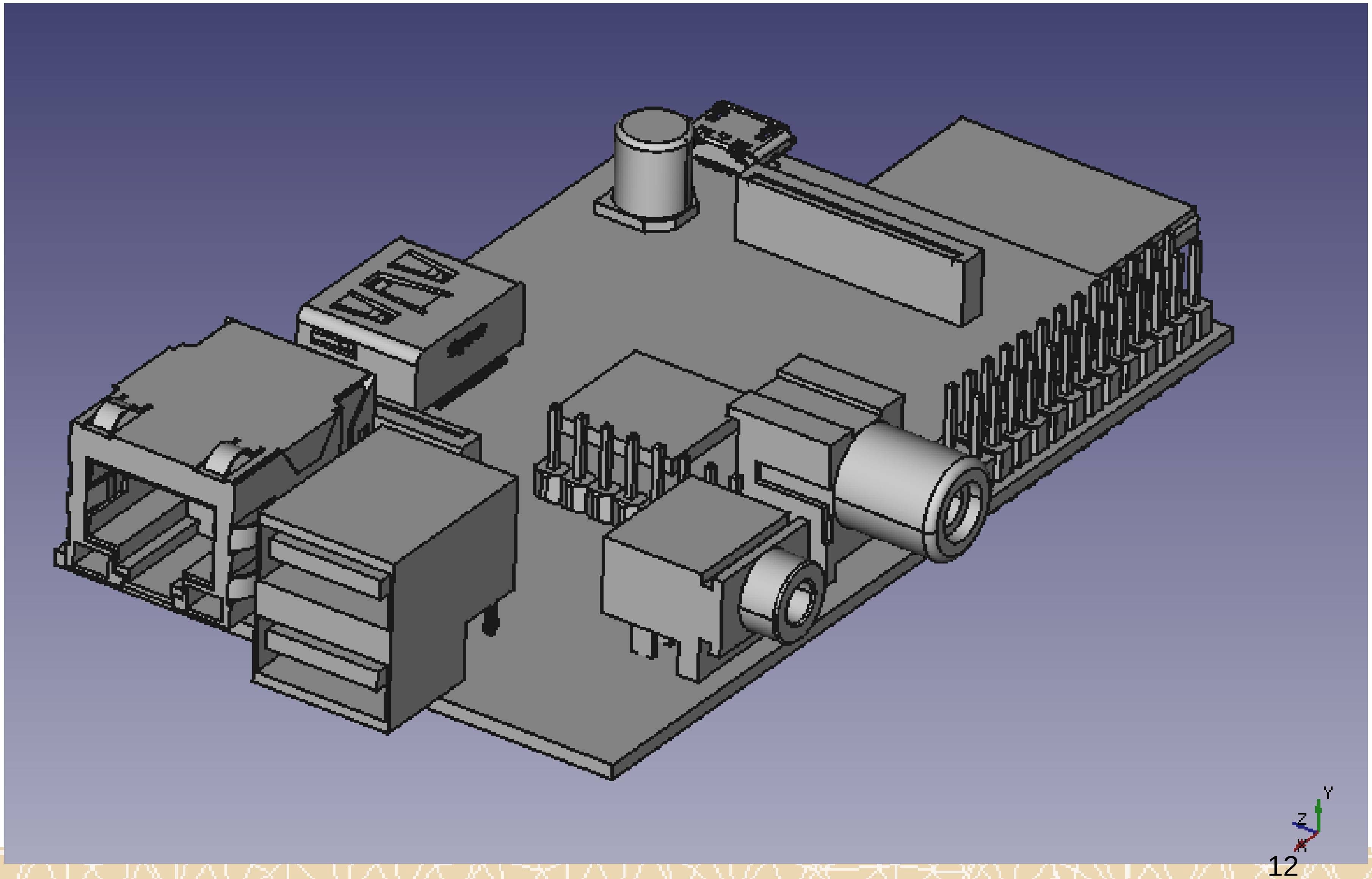
- Non space validated example even if AstroPi project may be also considered:

https://astro-pi.org/about/hardware/

- Realistic in term of complexity

Objective: Check the validity of the whole modelling chain

Still need to adapt 3D CAD model-> expertise needed



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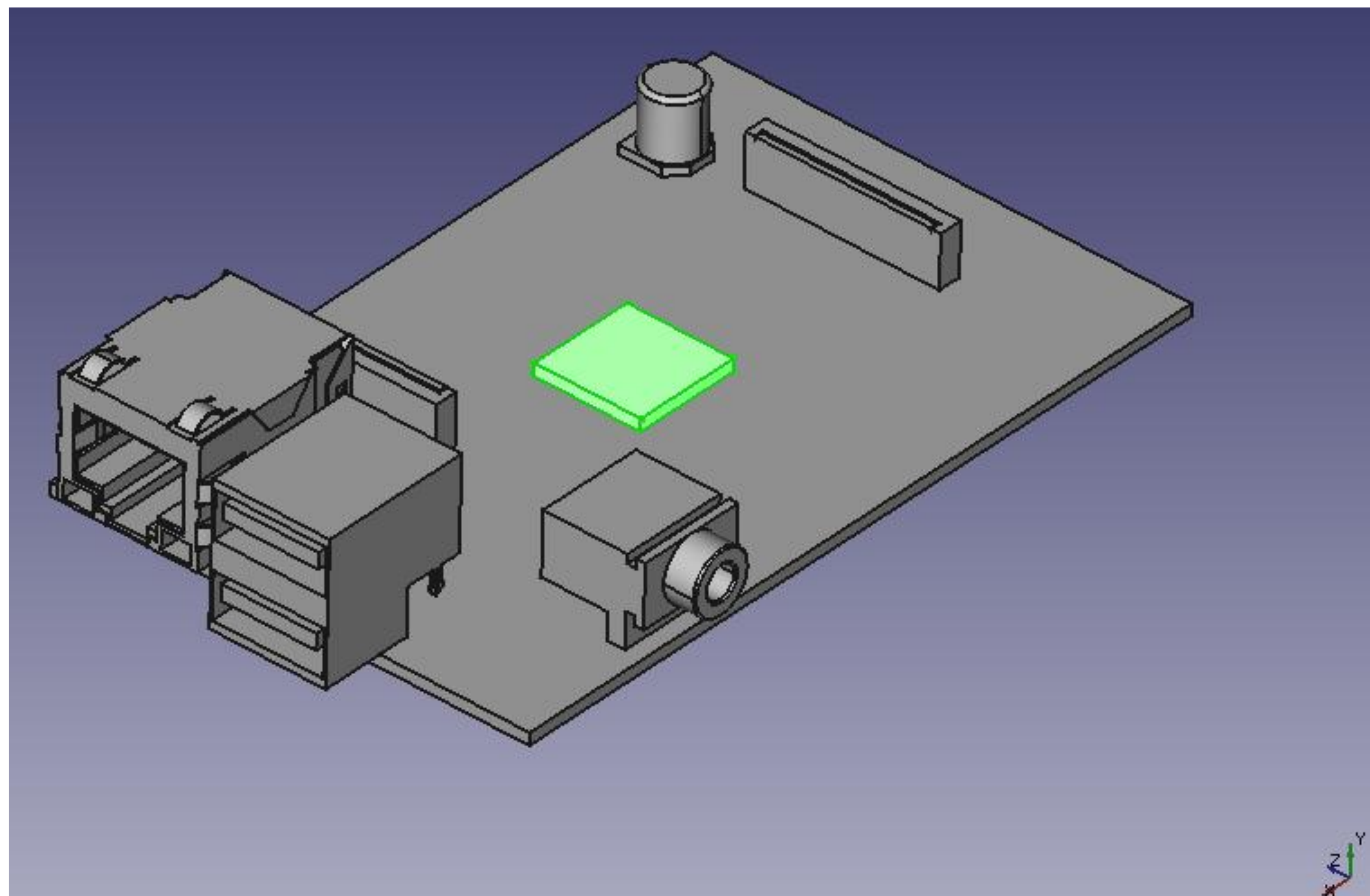
Test case presentation

Objective: perform a radiation analysis and an internal charging analysis on a component considered as a sensitive component

CPU is considered as the sensitive component

Inputs:

- MEO worst case during 1 hour (data from CNES/ONERA)
- Industrial complex STEP-AP geometry file
  - Capacitor
  - Microprocessor/CPU
  - Ethernet port
  - …



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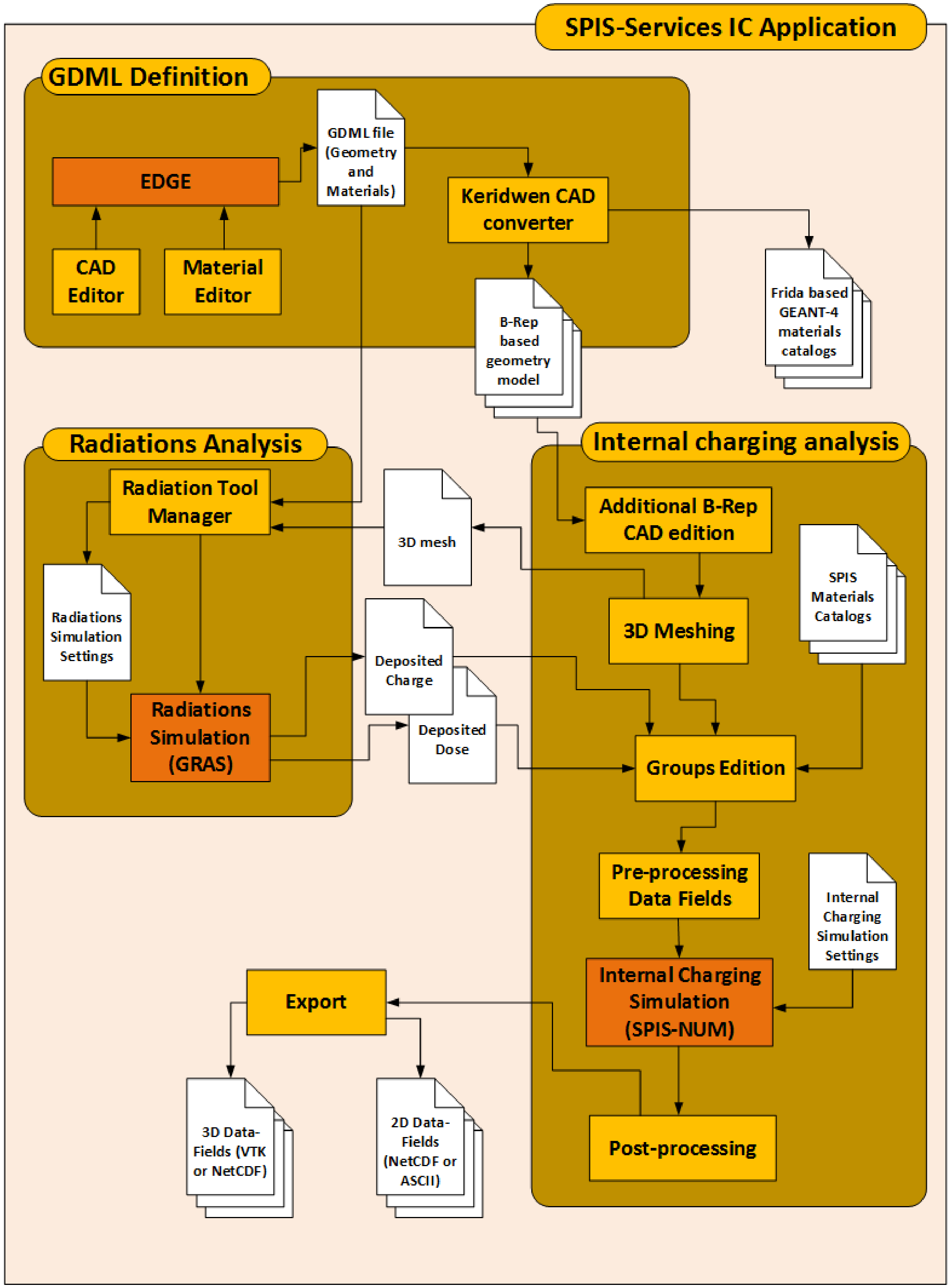
Modelling chain presentation

- Complex modeling chain presented later with the test case
- Thanks to the experience acquired during the ESA projects and previous works realised with G. Santin (CIRSOS, ELSHIELD, 3DMICS, ...)



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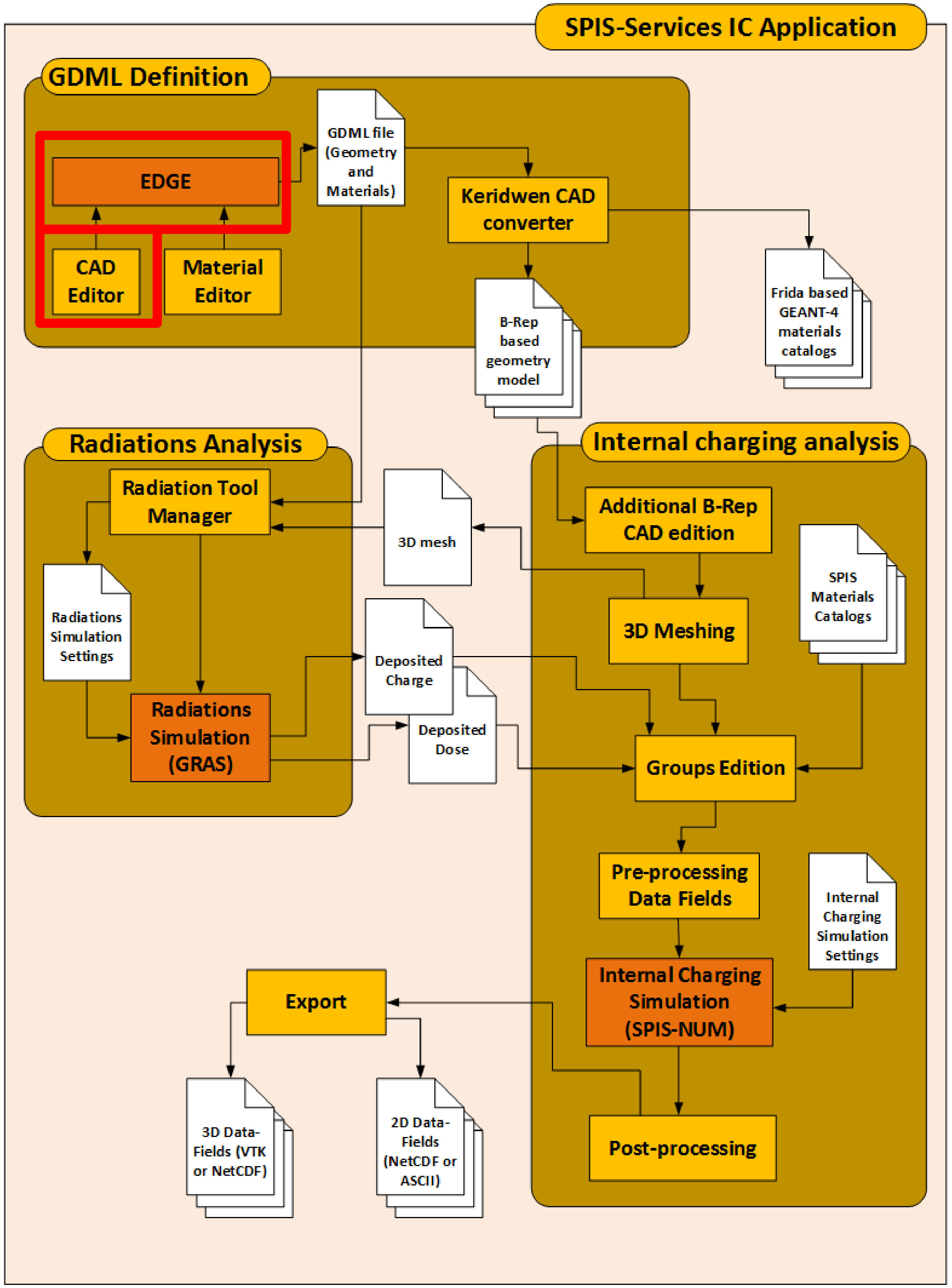
Sample of use of the modelling chain with a realistic test case

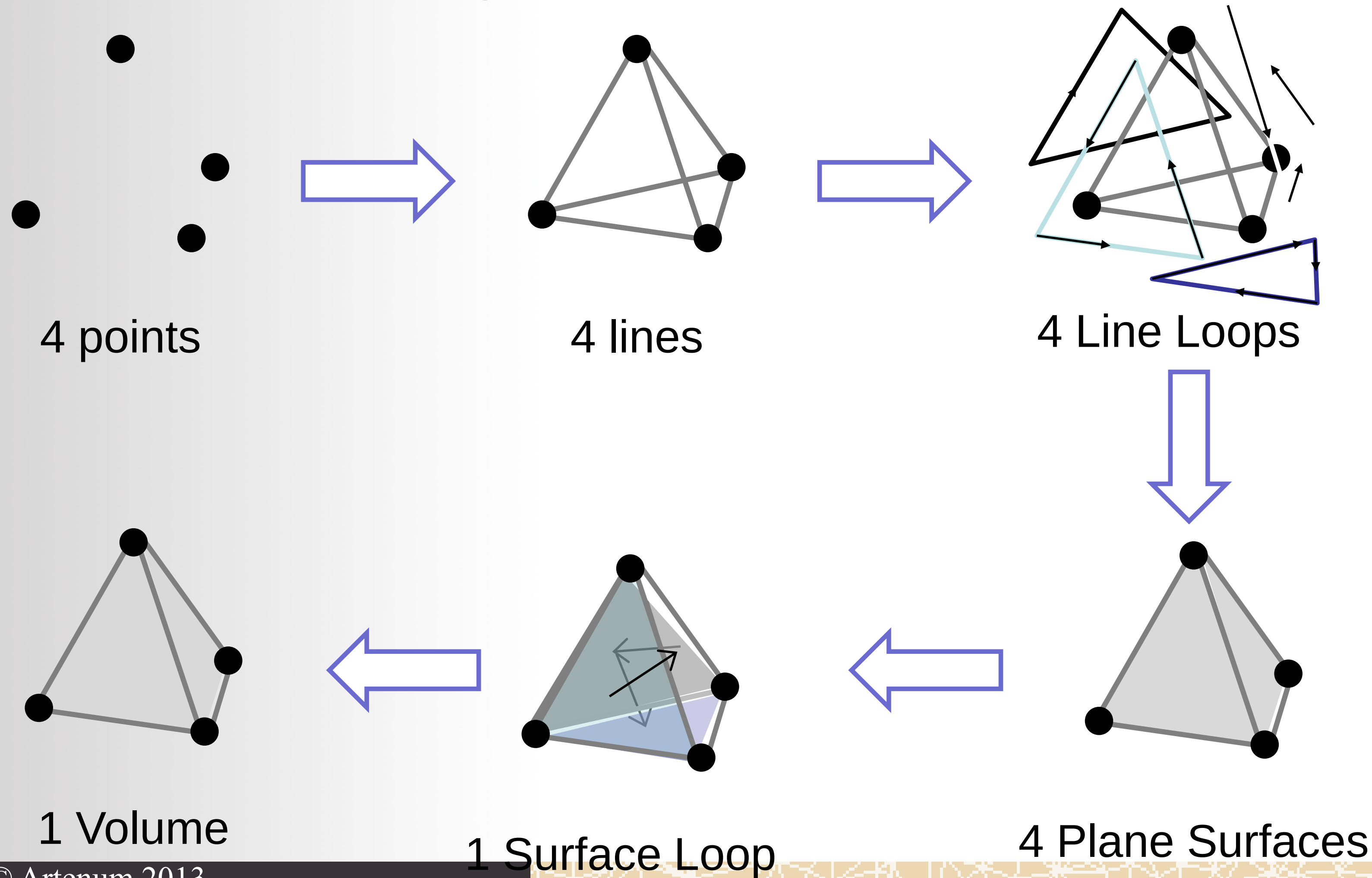
- Convert the input STEP-AP geometry file in GDML file compatible with Geant4/GRAS software
- Problem: STEP-AP geometry format is a B-Rep geometry representation and GDML geometry file is a CSG geometry representation



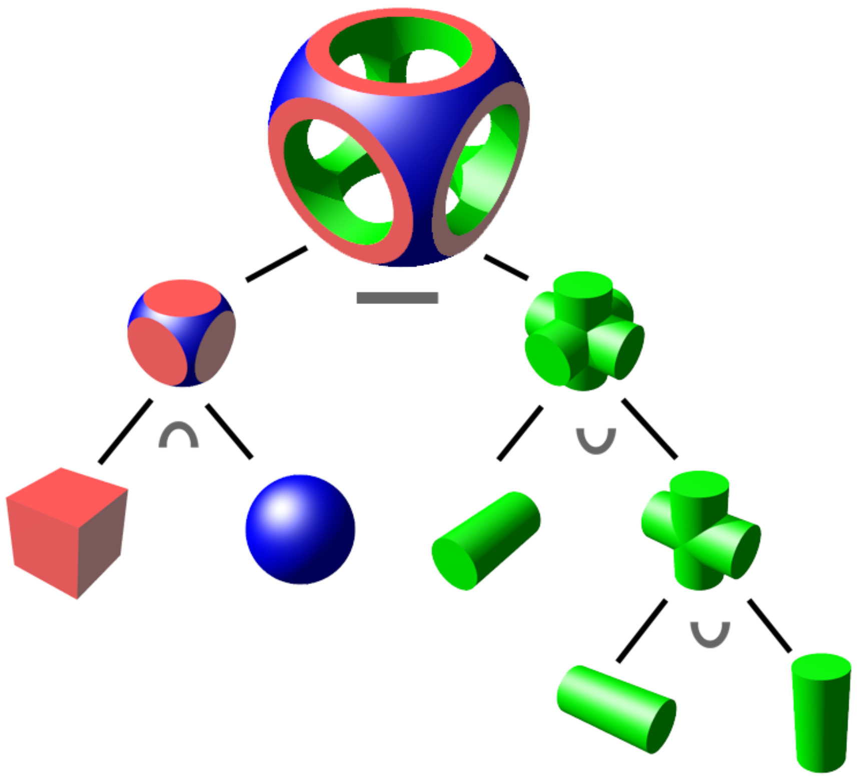
Sample of use of the modelling chain with a realistic test case

Presentation of B-Rep geometry representation and the CSG geometry representation

B-Rep geometry representation (STEP-AP geometry file and SPIS geometry file):



CSG geometry representation (GDML GRAS/Geant4 file):



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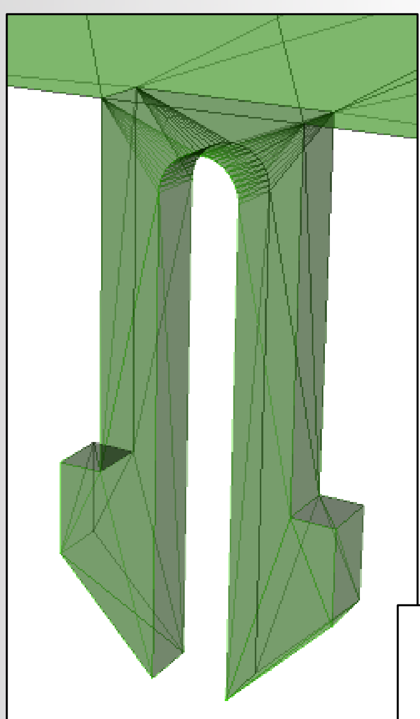
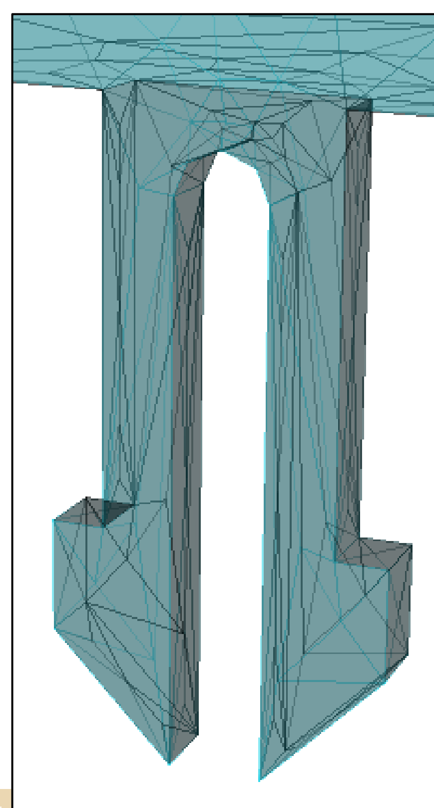
Sample of use of the modelling chain with a realistic test case

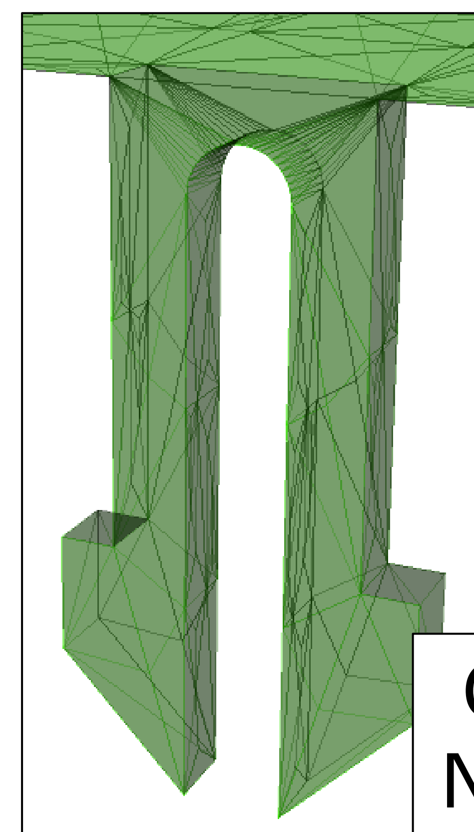
- Solution: The conversion from the STEP-AP geometry file to the geometry GDML file is performed by a tessellation
- Several approach can be considered to perform tessellation in **EDGE** software
  - OCC mesher
  - Netgen mesher
  - Combination of OCC mesher and Netgen Mesher
- The Netgen mesher seems to be the better approach to limit the overlaps problem considered by Geant4



OCC mesher



Netgen mesher



OCC+ Netgen mesher

Sample of use of the modelling chain with a realistic test case

EDGE software presentation

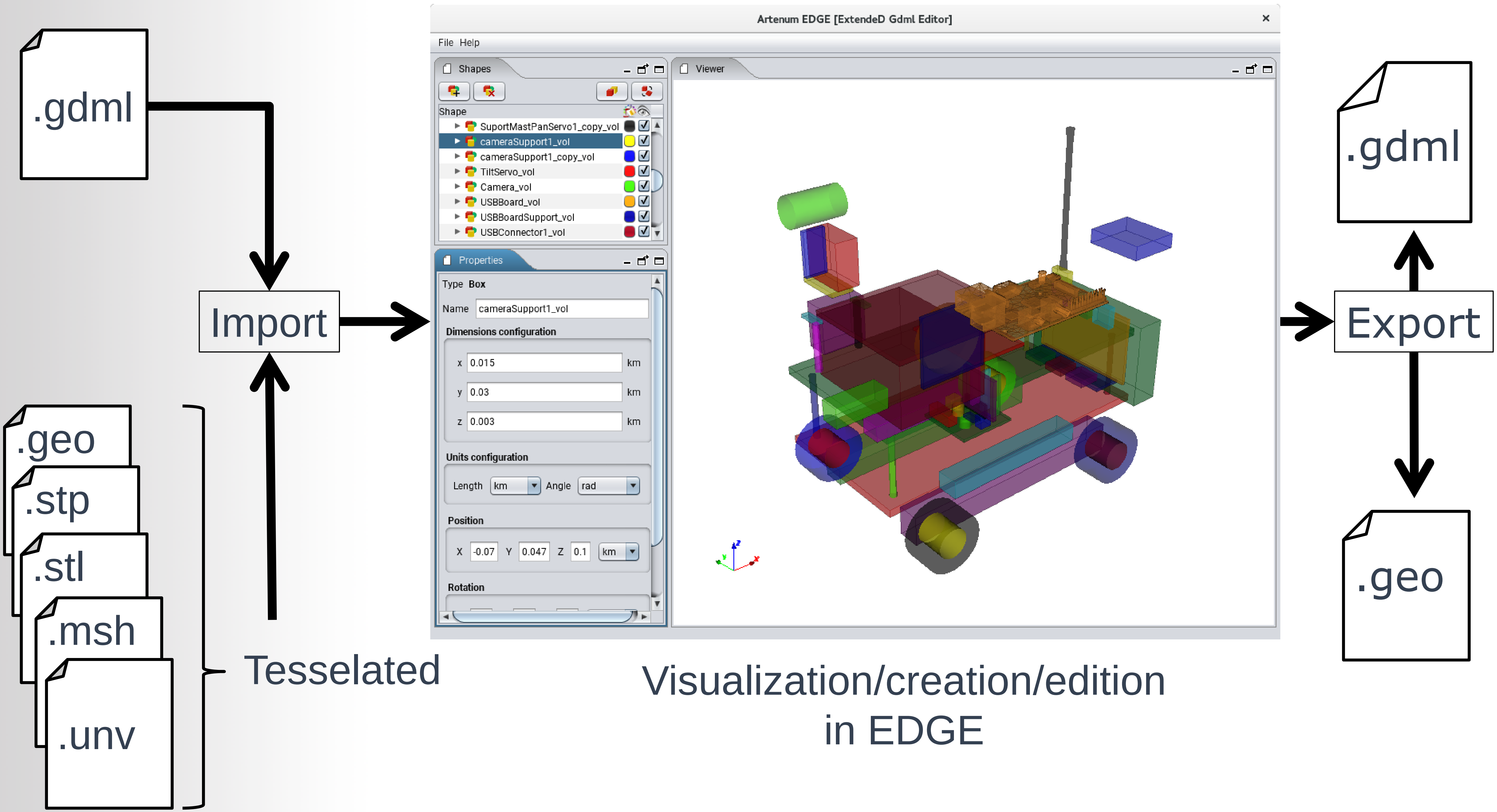
- EDGE= **E**xtende**D** **G**dml **E**ditor

- Geometric feature
  - Create a GDML geometry from scratch
  - Load and visualize an existing GDML file
  - Edit existing GDML "solids"
  - Add GDML "solids" to an existing GDML geometry
  - Support of several GDML shapes (box, cone, cylinder, …)
  - Support geometry hierarchy

- Material feature:
  - Create a GDML material from scratch
  - Load and visualize an existing GDML material file
  - Edit existing GDML material
  - Attribute GDML material to an existing GDML geometry

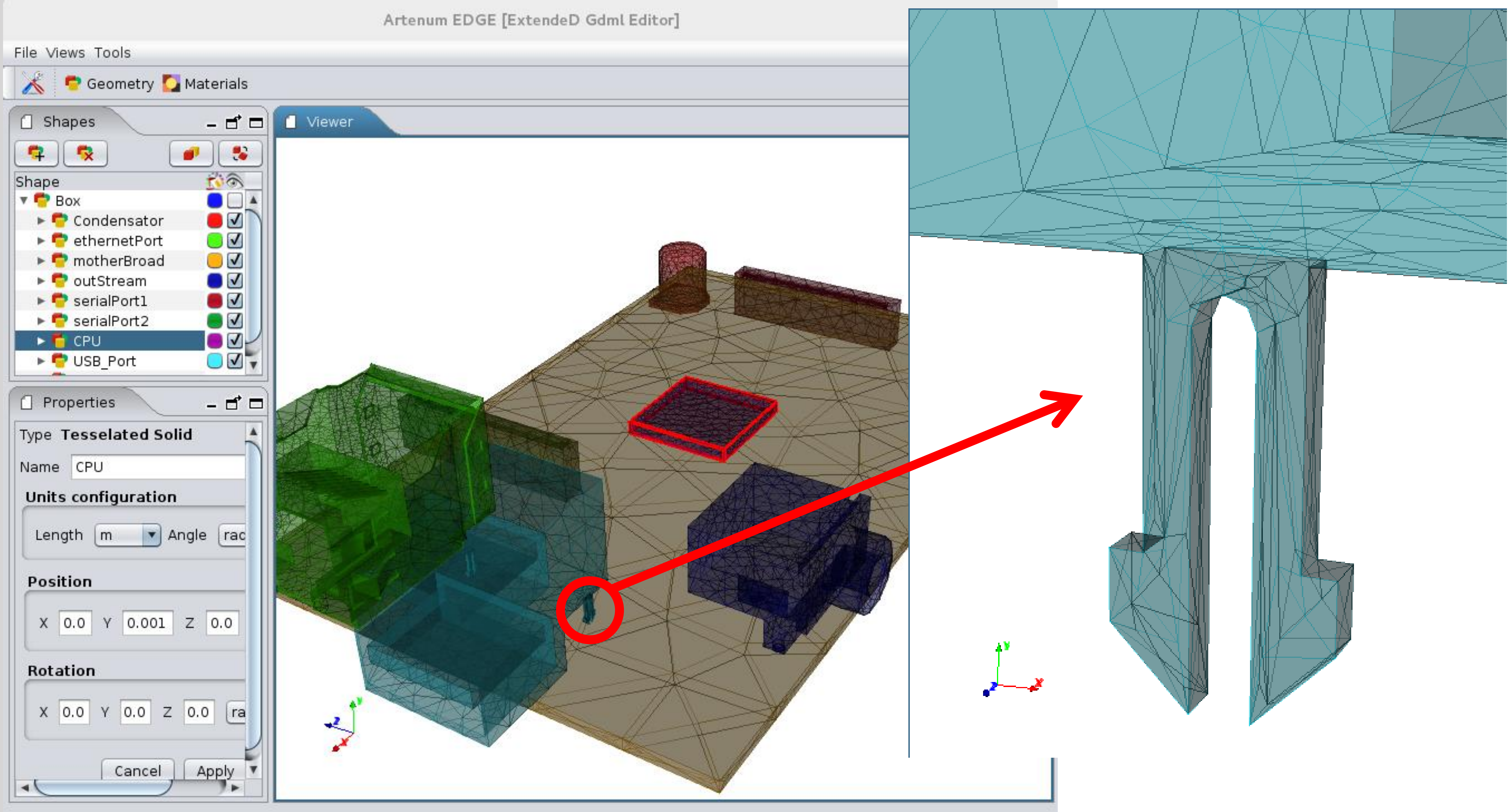
Sample of use of the modelling chain with a realistic test case

EDGE presentation



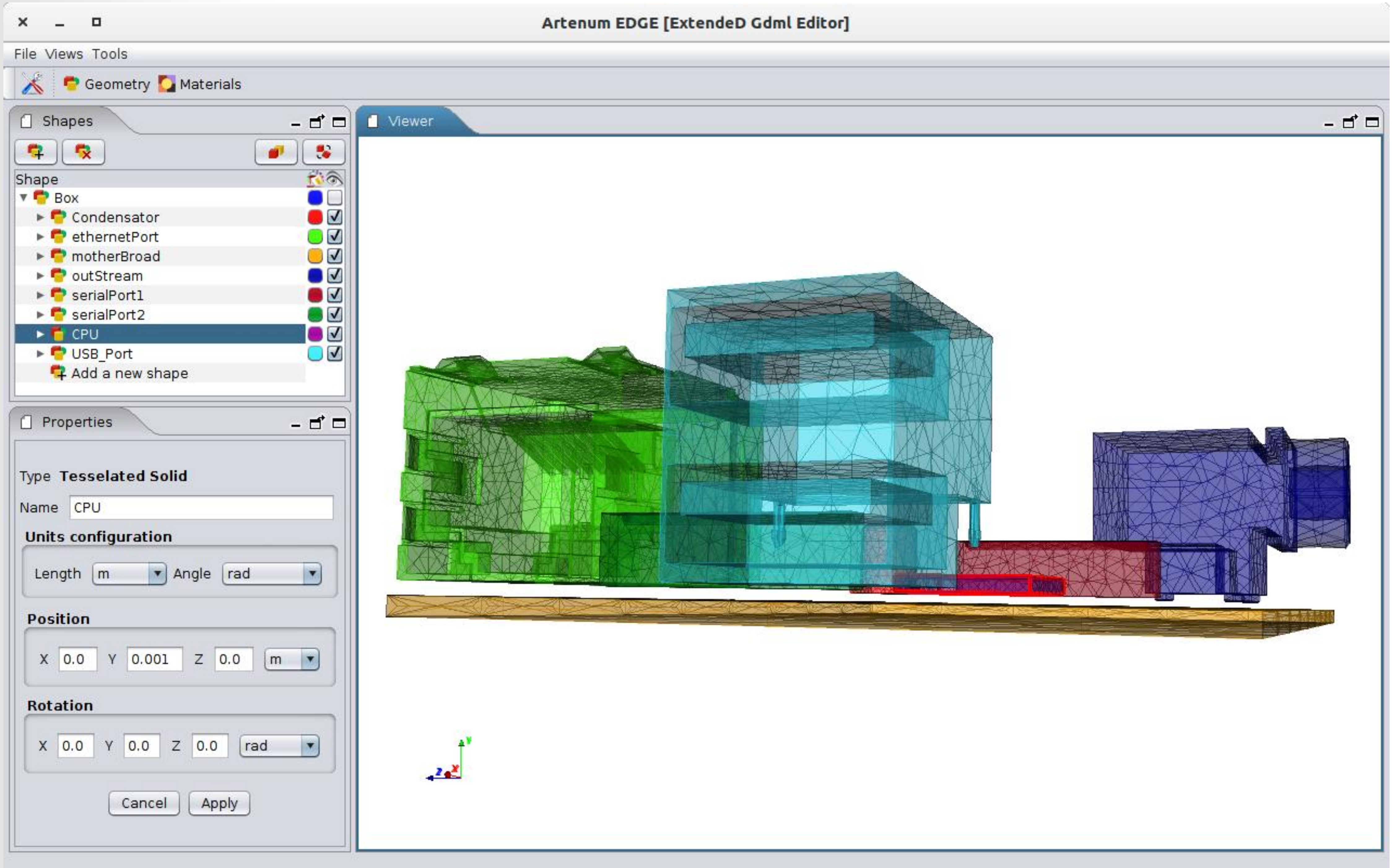
Sample of use of the modelling chain with a realistic test case

Import the STEP-AP file through a Netgen tessellation in EDGE



Sample of use of the modelling chain with a realistic test case

Perform some geometric operations like translations to GDML solids to avoid Geant4 overlaps

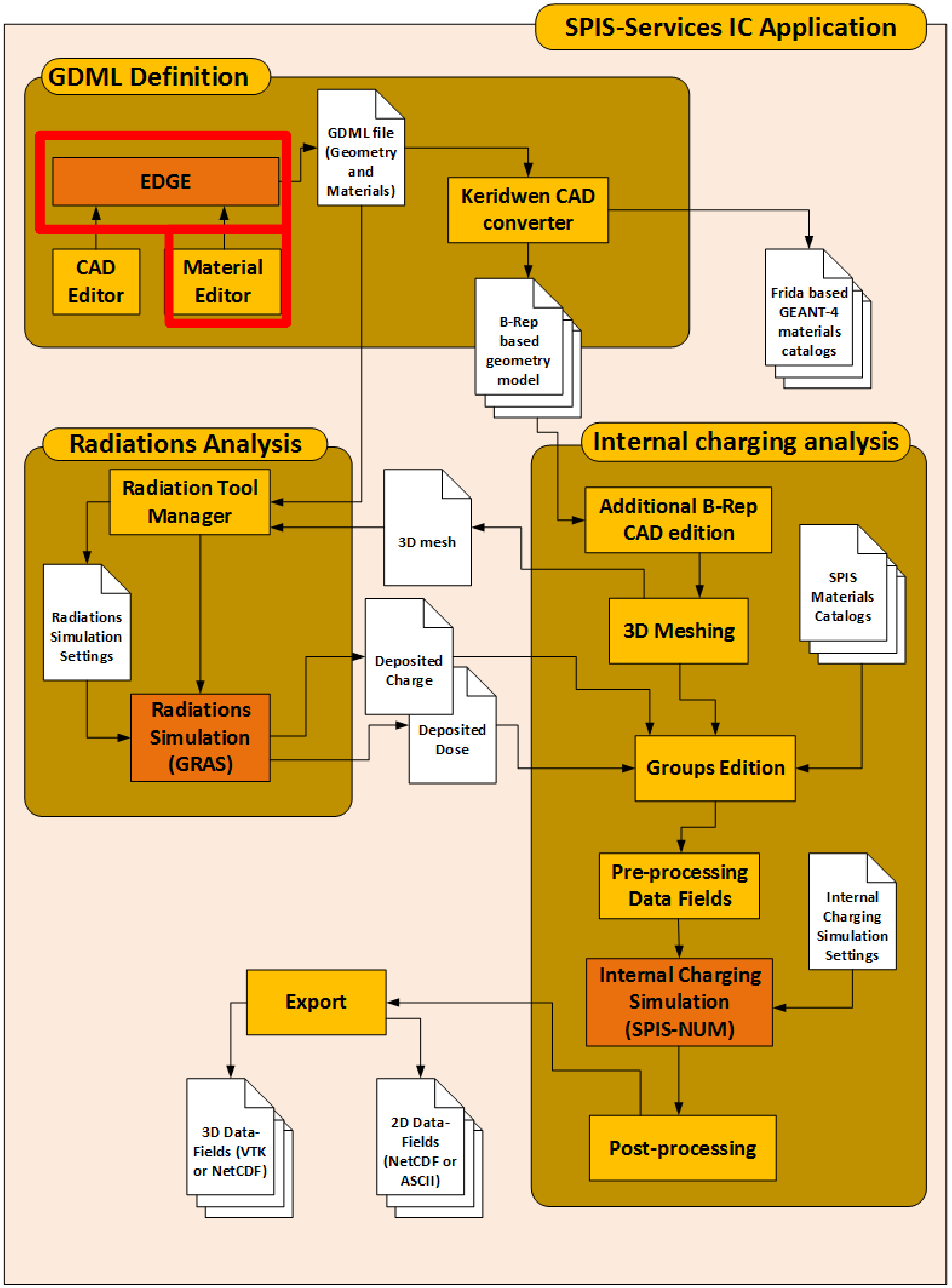


Sample of use of the modelling chain with a realistic test case

- GDML material description fully compliant with Geant4

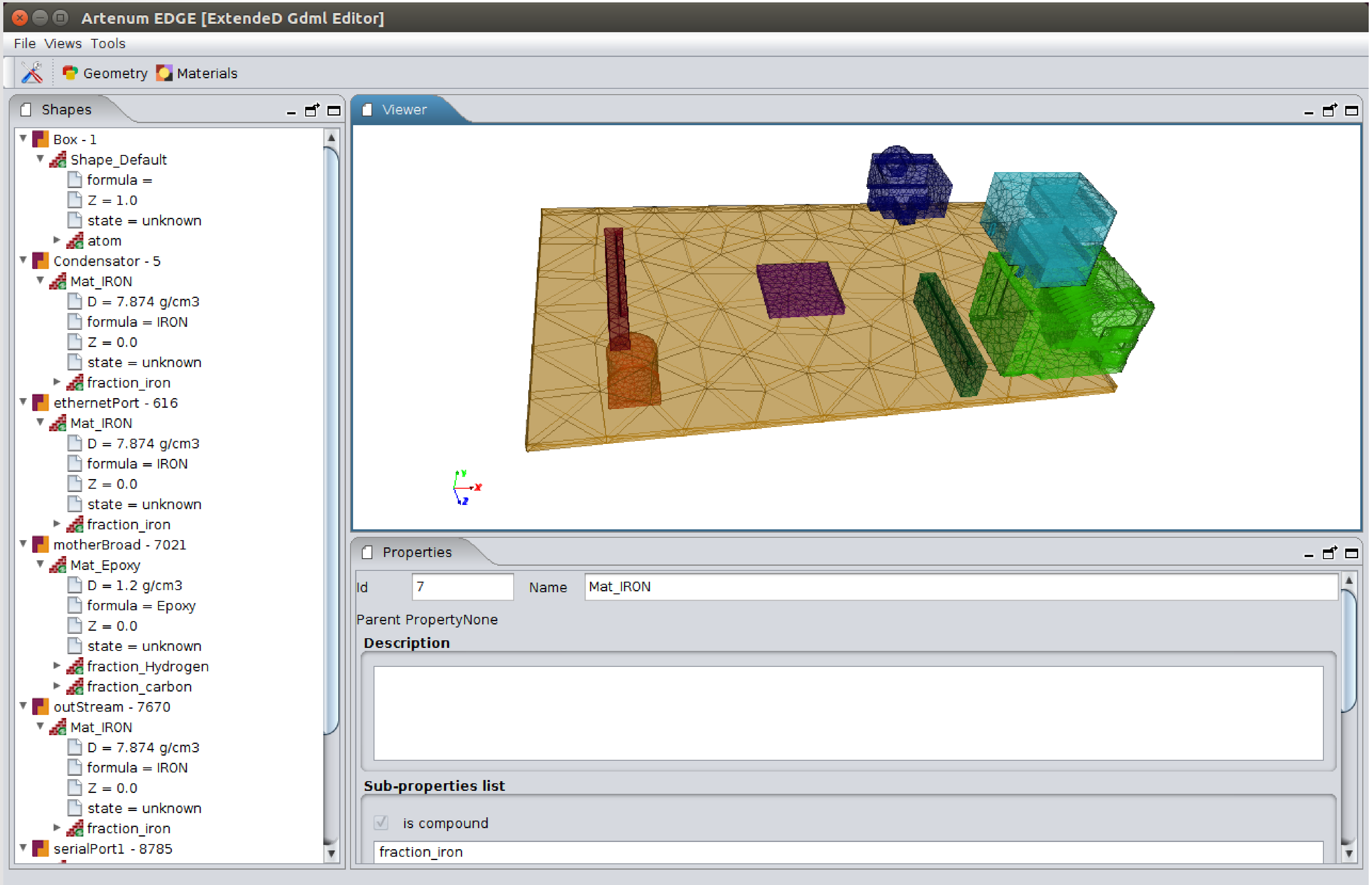
- Material edition
  - Creation of a complex material from scratch
  - Use of a built-in pre-defined material in the EDGE data base

- Possibility to attribute a material to an existing GDML solid through WYSIWYG GUI



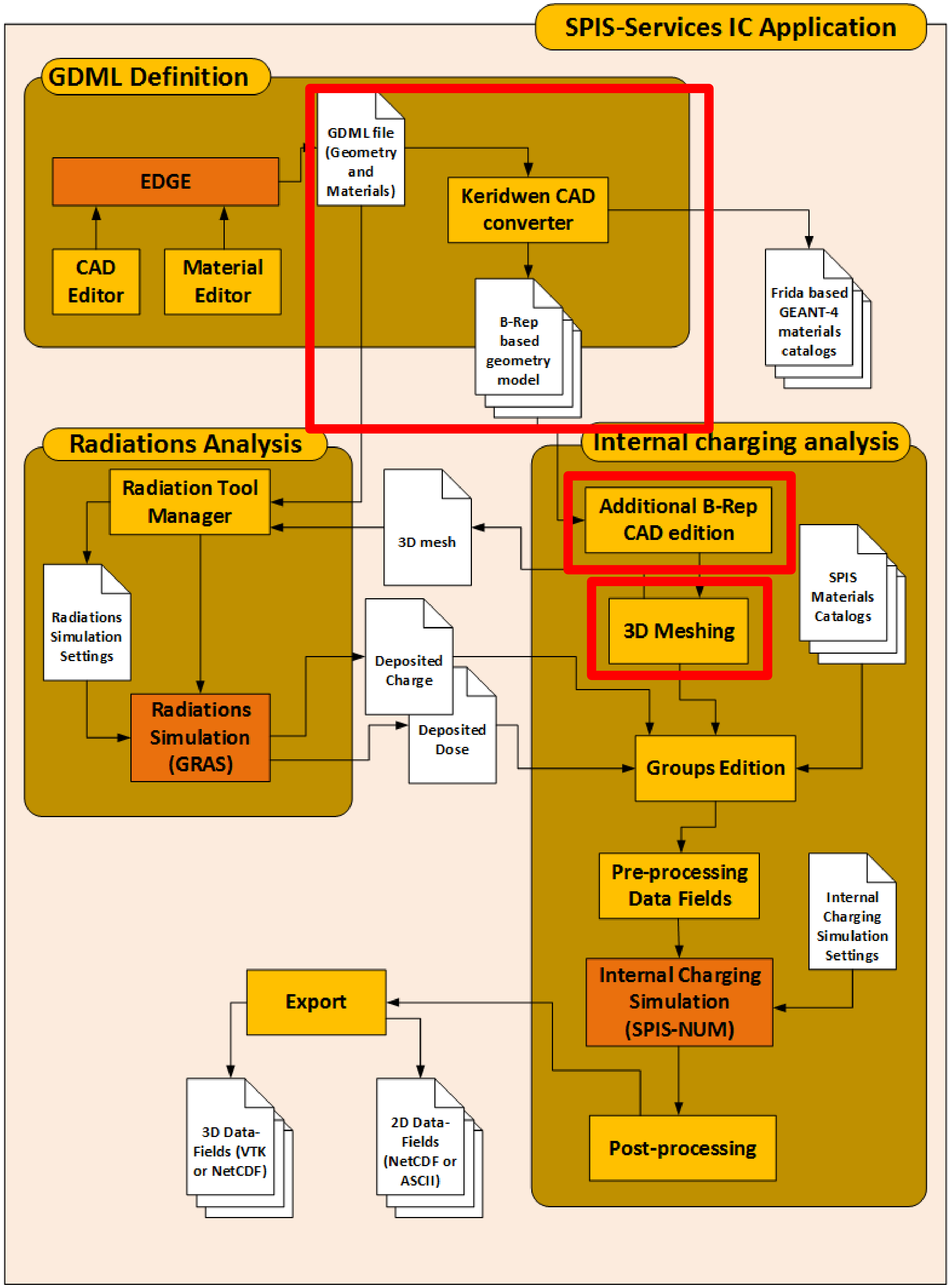
Sample of use of the modelling chain with a realistic test case

Define and attribute materials to GDML solids in EDGE



Sample of use of the modelling chain with a realistic test case

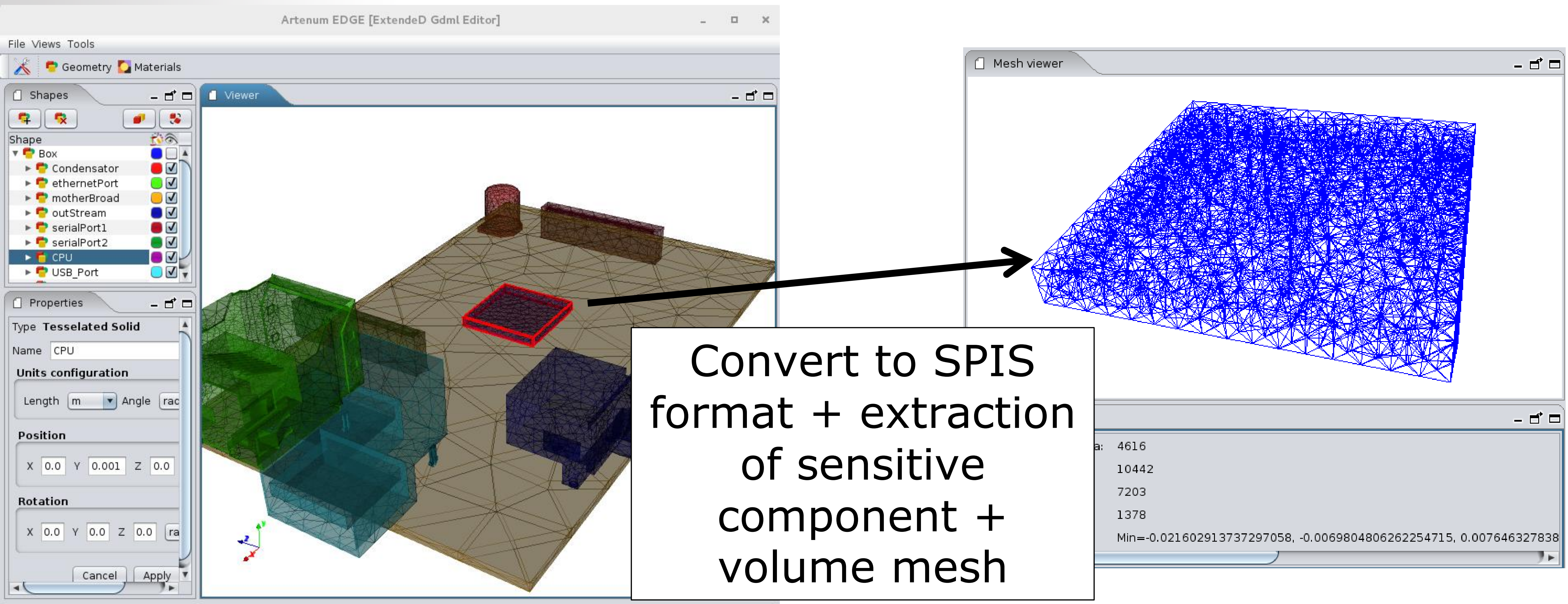
- Saving of geometric description and material attribution in GDML file
- Possibility to convert the geometry to a SPIS compliant CAD model
  - CSG to B-Rep decomposition
  - Exact geometrical conversion (without tessellation)
- Extraction of the sensitive components to consider
  - For dose and charge calculation
  - For internal charging analysis
- Volume mesh of this sensitive components



Sample of use of the modelling chain with a realistic test case

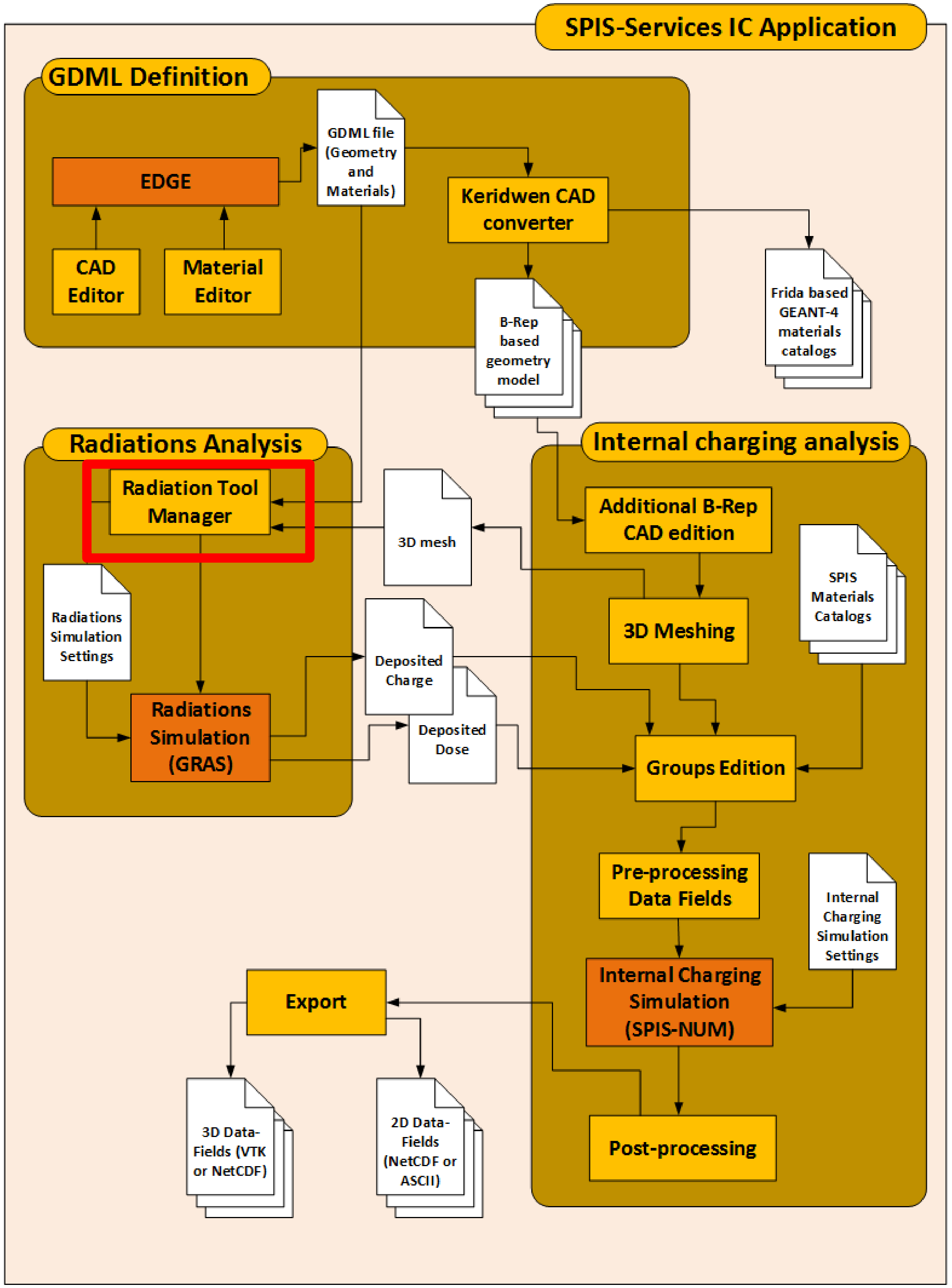
As example, ARM/CPU is considered as sensitive volume

- volume mesh used to define the mesh input for the internal charging analysis
- volume mesh used as support of GRAS scoring



Sample of use of the modelling chain with a realistic test case

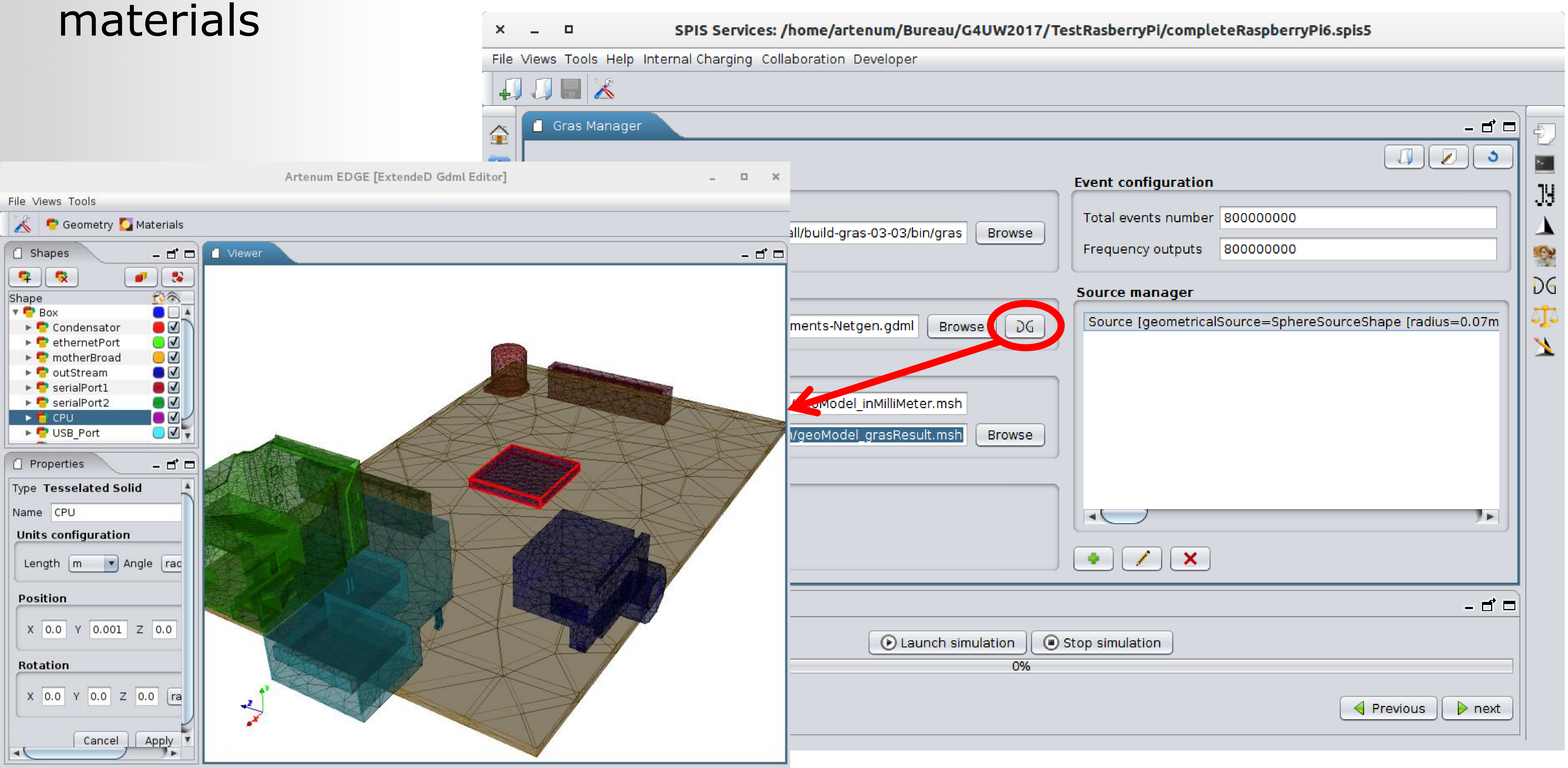
- Aim of the radiation manager: fully set-up the Geant-4 simulation
  - Set the geometry
  - Set the material attribution
  - Set the particle sources
  - Set the simulation parameters
- Generation of a G4 .mac script and of the various geometrical supports for scorings and data exchanges
- Possibility to create a G4 .mac file from the UI or import an external one
- Integrated as a new OSGi bundle into SPIS-IC IME
  - Fully integrated approach
  - Handling of all needed data conversion



Sample of use of the modelling chain with a realistic test case

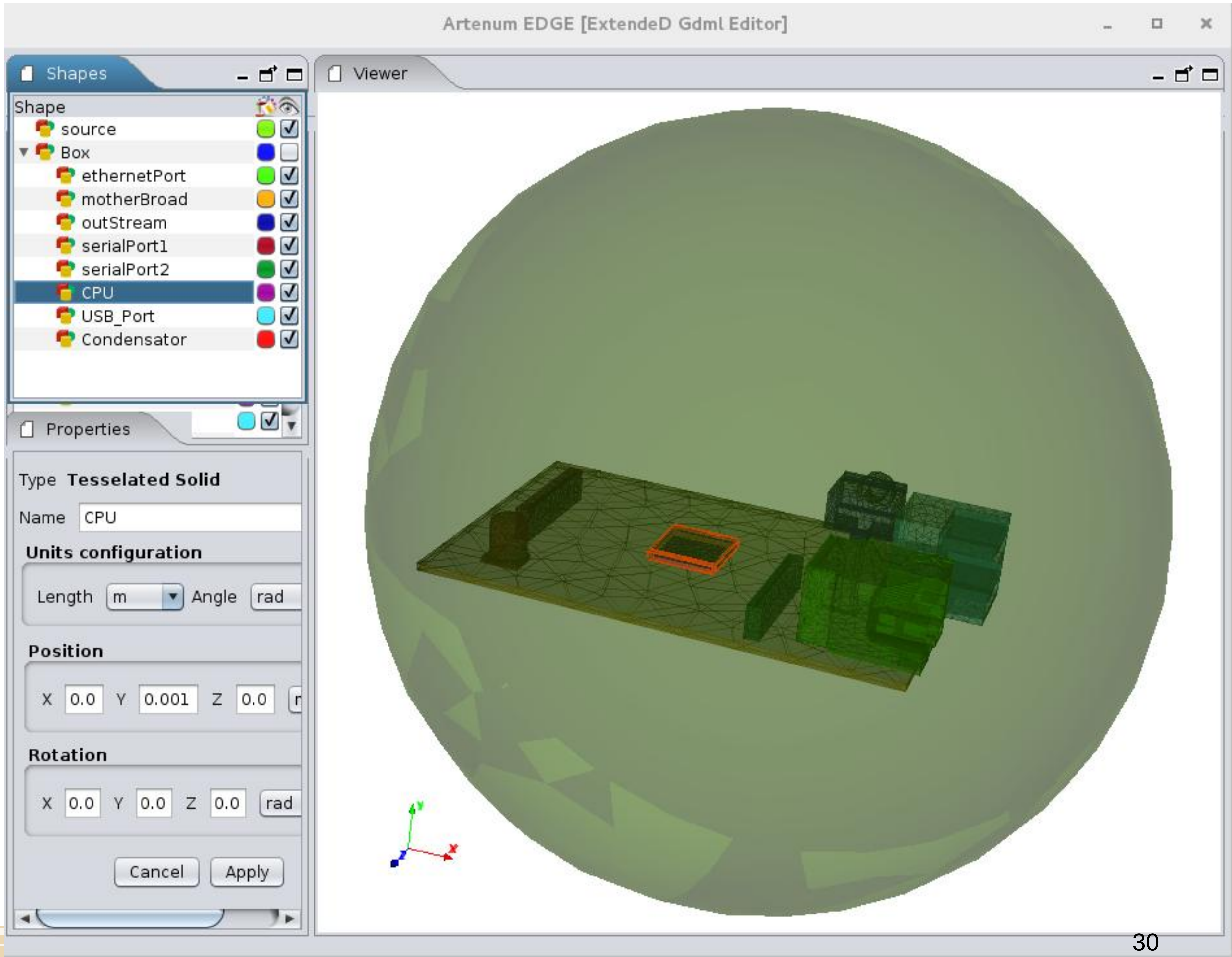
Radiation manager: fully WYSIWYG GUI to define settings of G4 based simulation

- Access to EDGE to create/edit/visualize the geometry and the materials



Sample of use of the modelling chain with a realistic test case

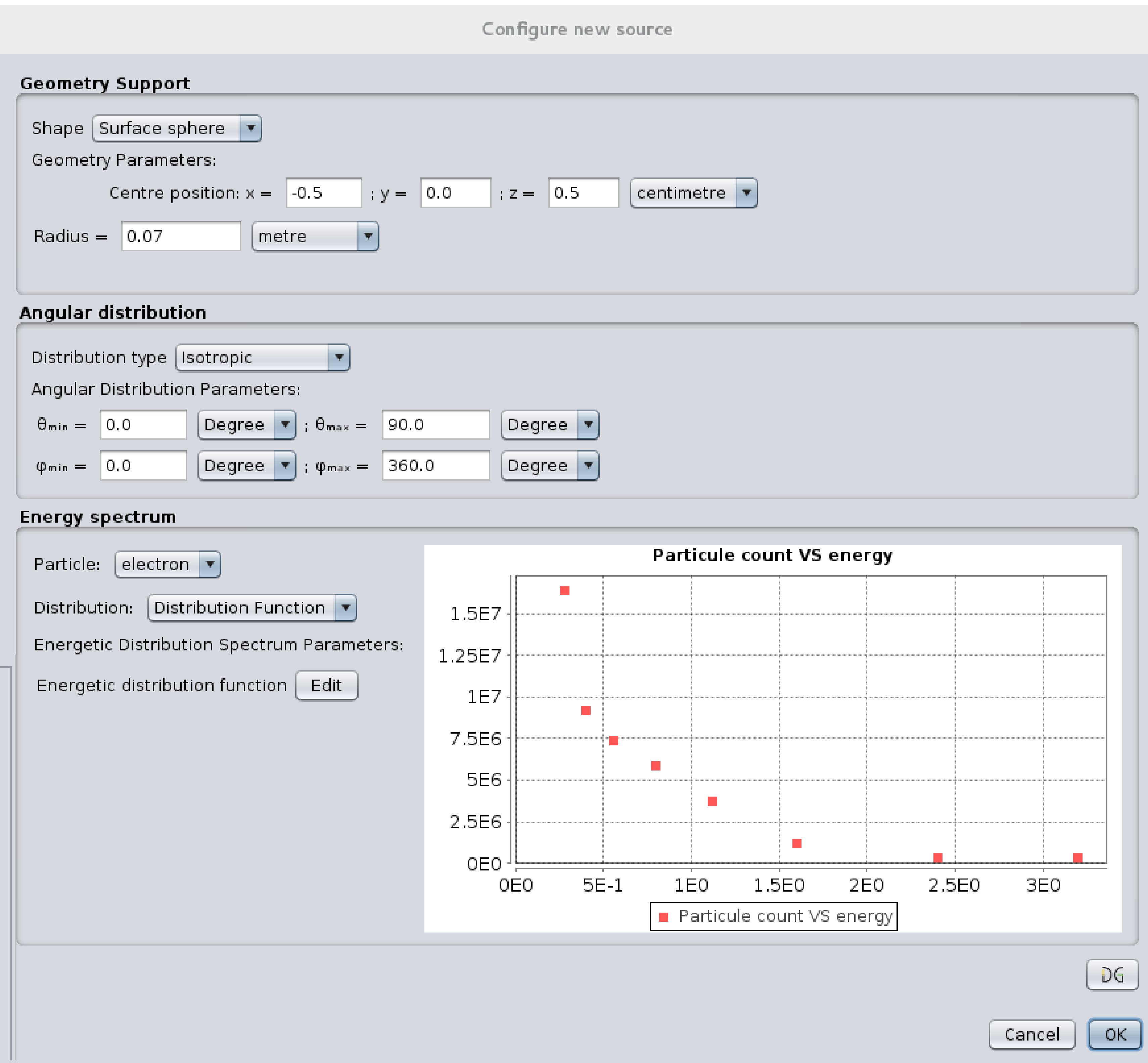
- Possibility to define one or several sources
- Possibility to visualize sources
- Source shape
  - Surface sphere



Sample of use of the modelling chain with a realistic test case

- Angular distribution
  - Isotropic
  - Inside sphere
- Energy spectrum
  - electron
  - energetic distribution function to model MEO worst case during 1 hour flux

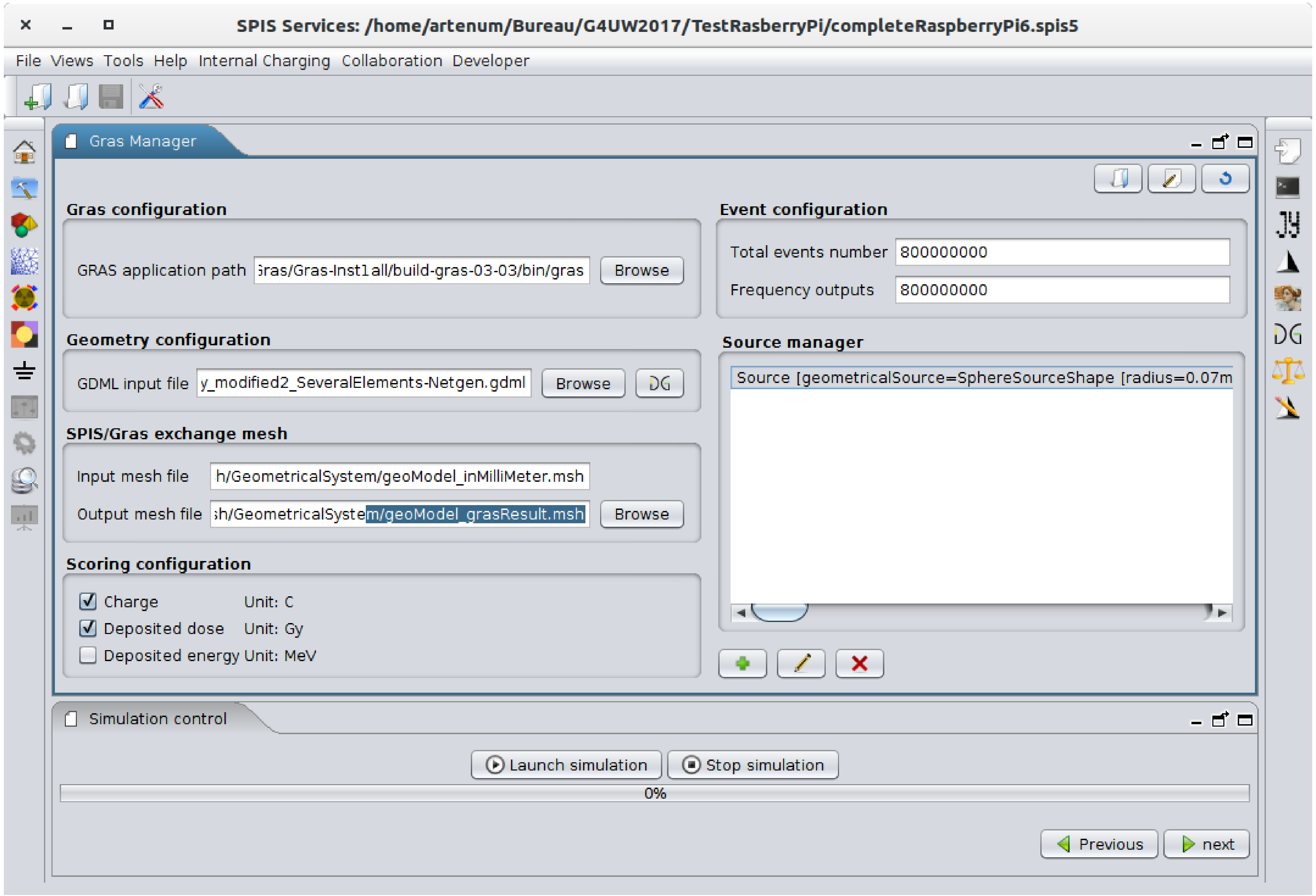
	Energy	Weight
	[MeV]	[-]
1	0.28	1.64E7
2	0.4	9170000.0
3	0.56	7410000.0
4	0.8	5900000.0
5	1.12	3730000.0
6	1.6	1190000.0
7	2.4	350000.0
8	3.2	329000.0



Sample of use of the modelling chain with a realistic test case

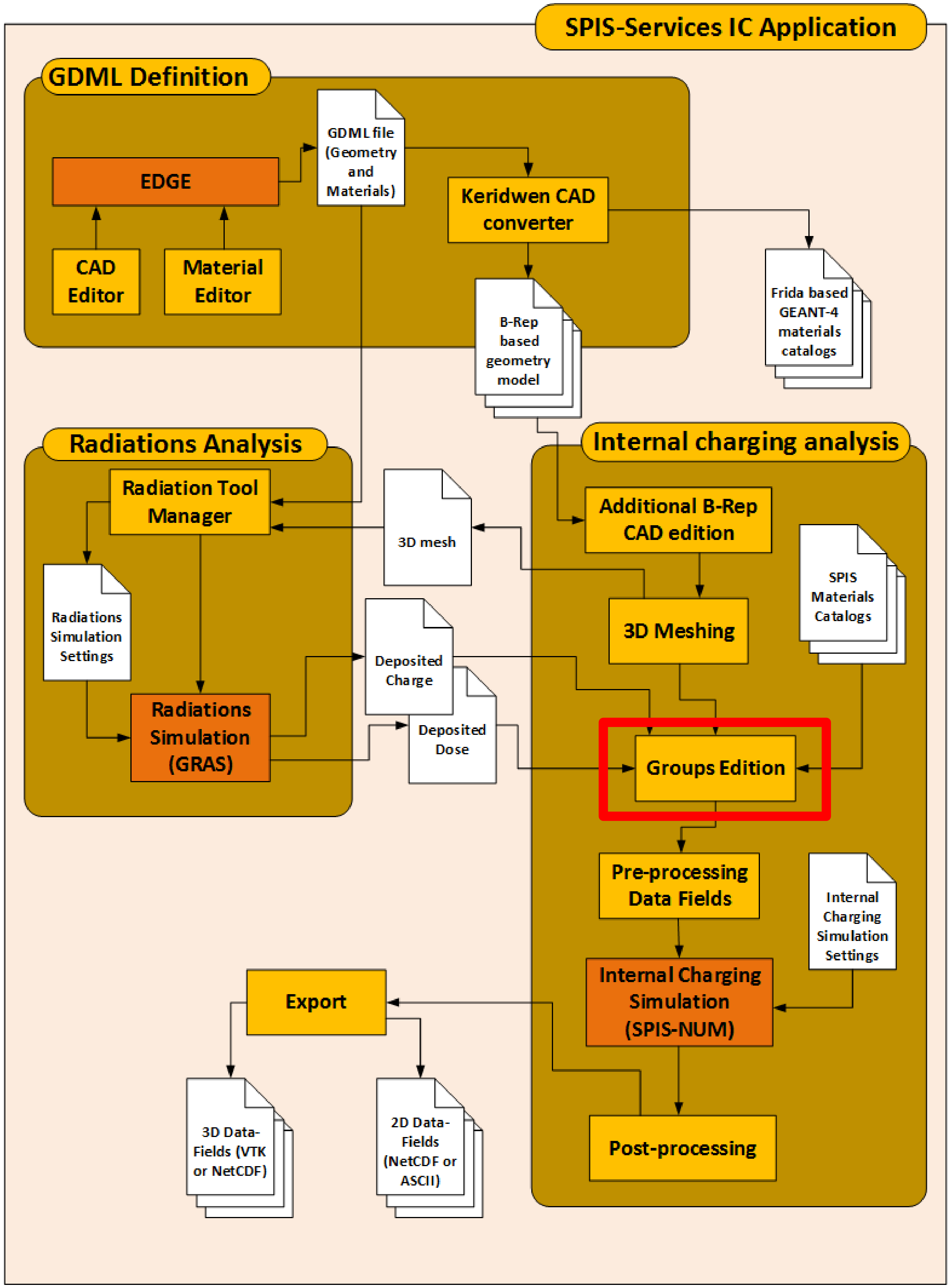
Use the WYSIWYG radiation manager to define settings of gras simulation

- Generate the G4 .mac file used to launch the GRAS simulation
- Edit it (optional)
- Launch the GRAS simulation
- Access to the GRAS log through the log console application



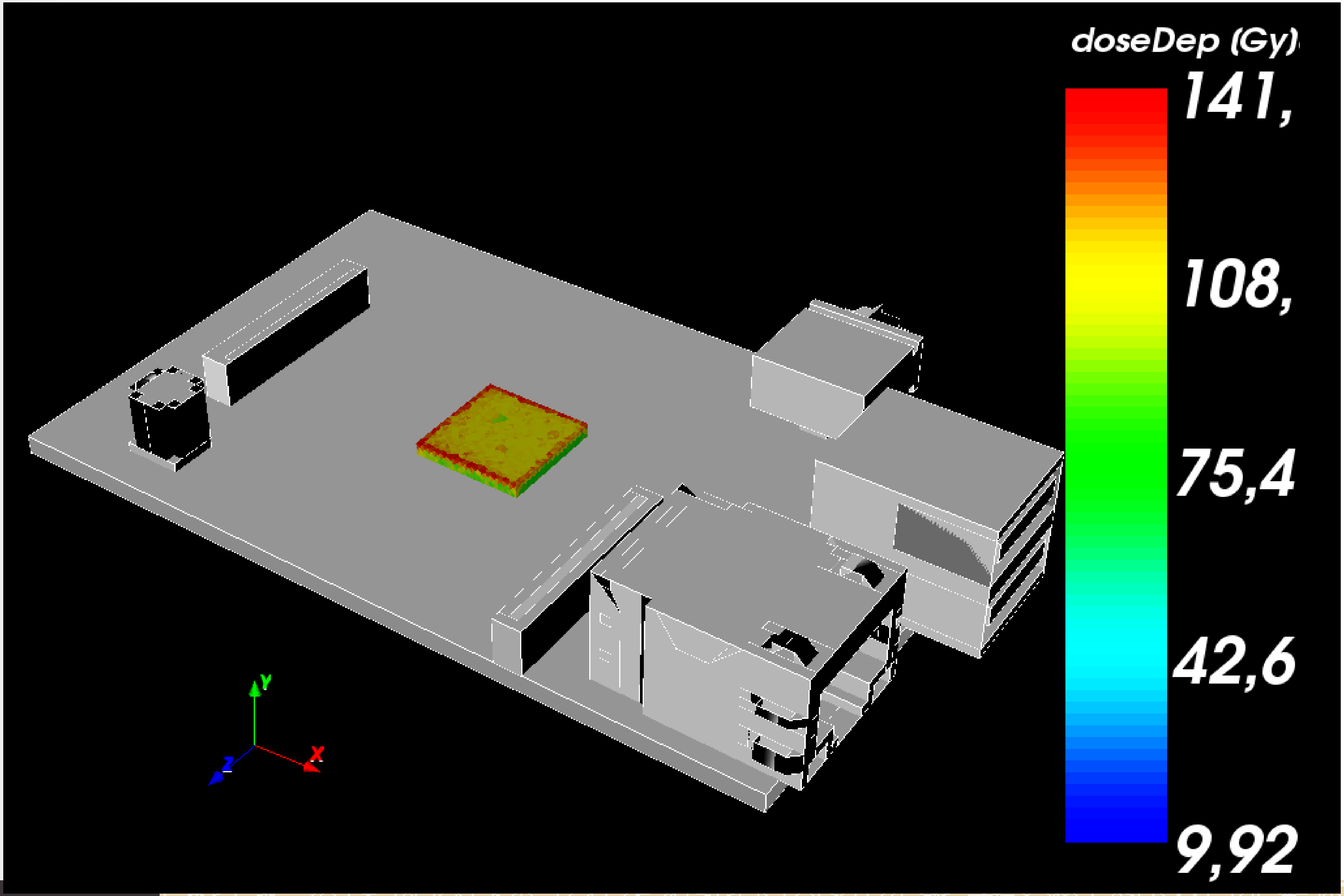
Sample of use of the modelling chain with a realistic test case

- The GRAS results are loaded in the group editor of SPIS able to define the internal and boundary condition
- Users have to attribute the SPIS material to consider in the internal charging analysis
- Users have to set the global parameters as usual in SPIS simulation



Sample of use of the modelling chain with a realistic test case

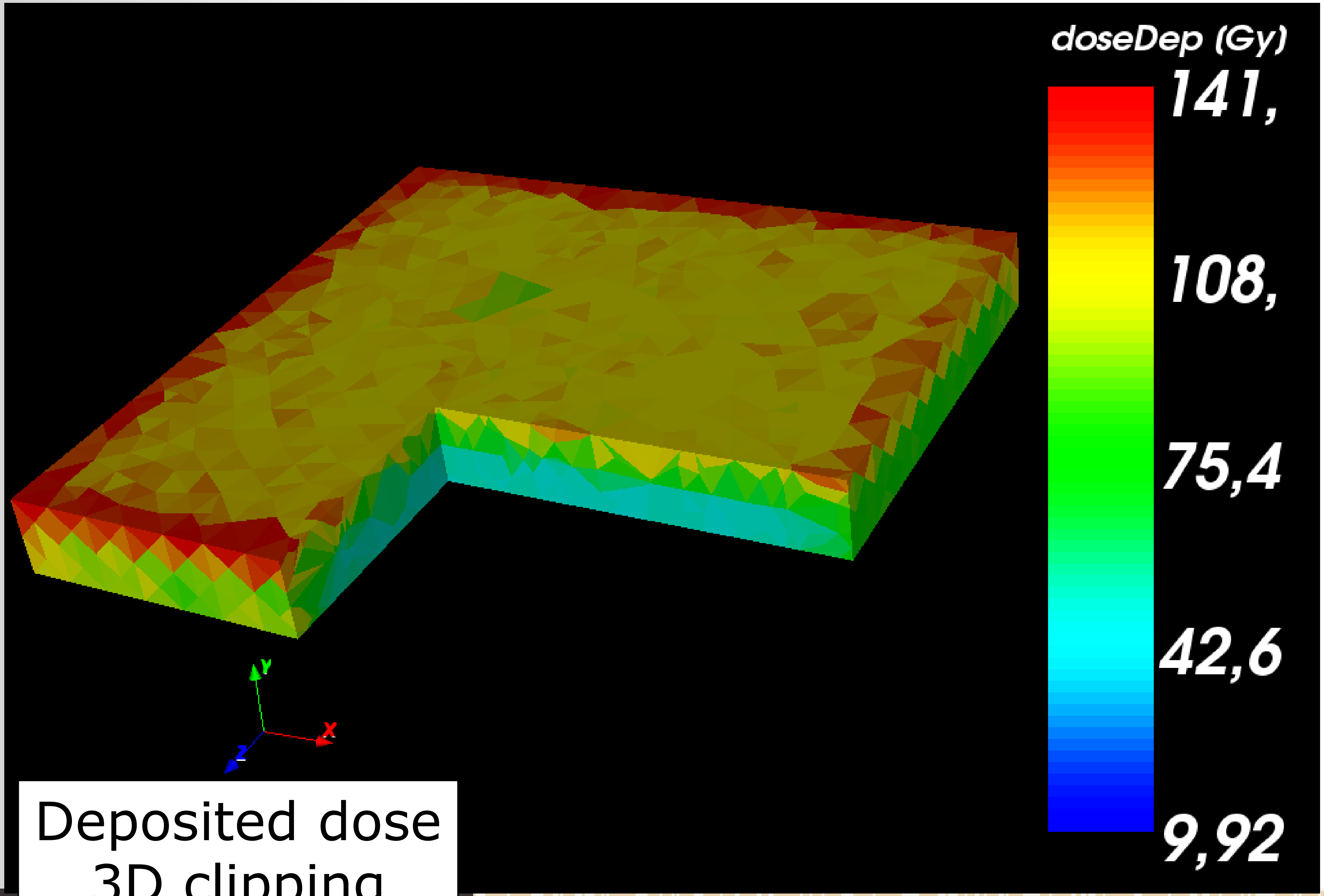
Visualization of GRAS results in the SPIS Group editor with powerful 3D filter



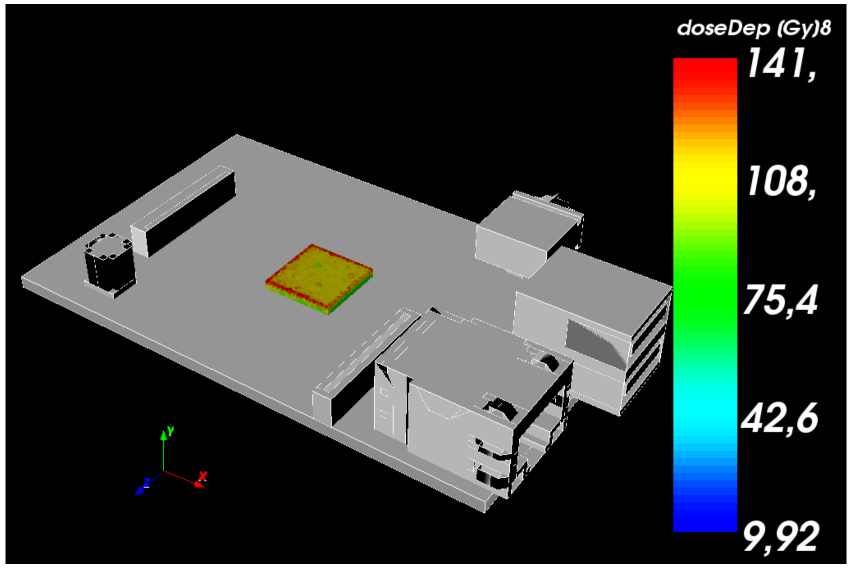
Sample of use of the modelling chain with a realistic test case

3D deposited dose results:

- Strong asymmetry along the Y-axis direction cause to epoxy mother broad solid
- Light asymmetry along the X-axis direction cause to iron solids



Deposited dose 3D clipping

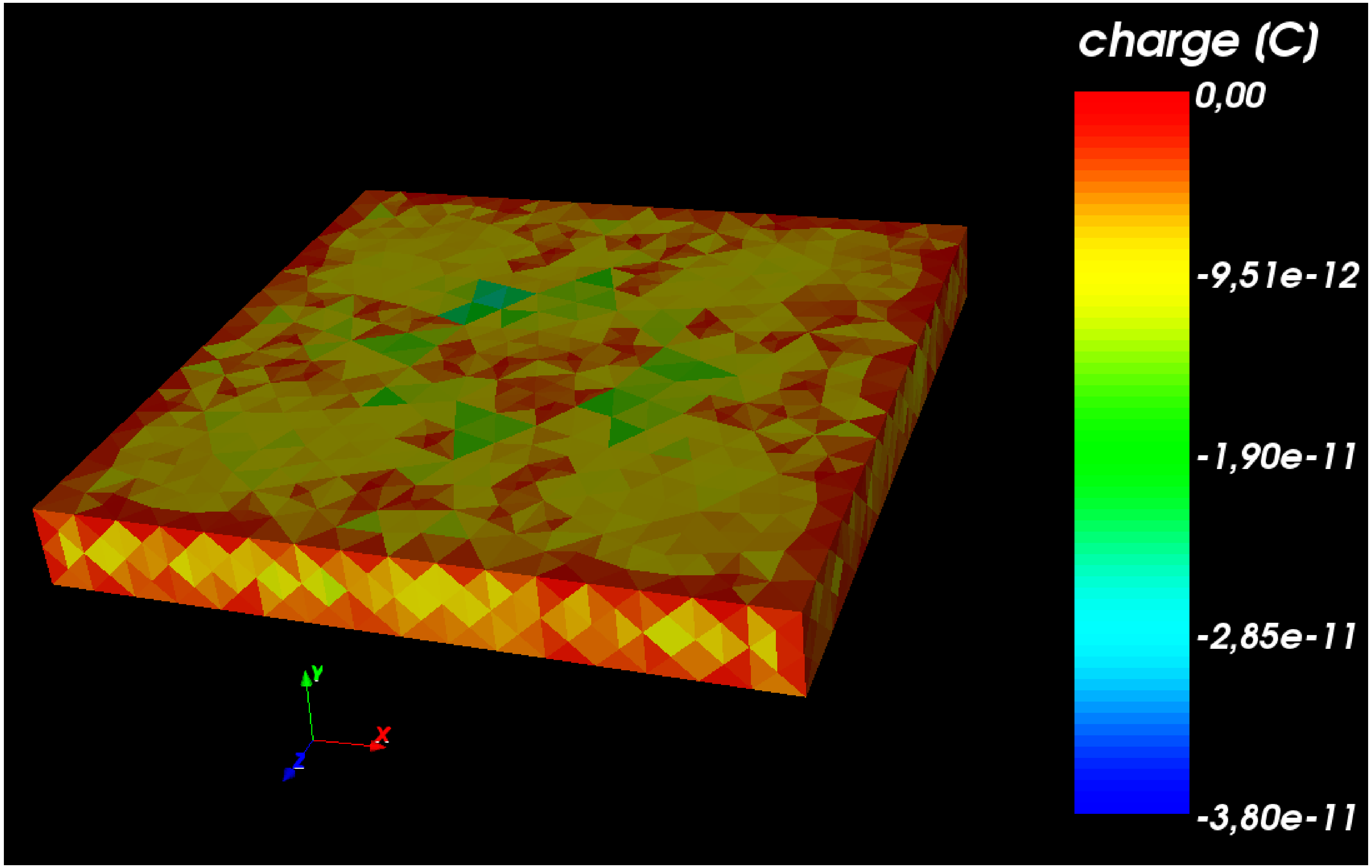


Sample of use of the modelling chain with a realistic test case

Visualization of GRAS results in the SPIS Group editor with powerful 3D filter

3D deposited charge results

- Charge are more important in the centre of the CPU



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3D deposited charge results

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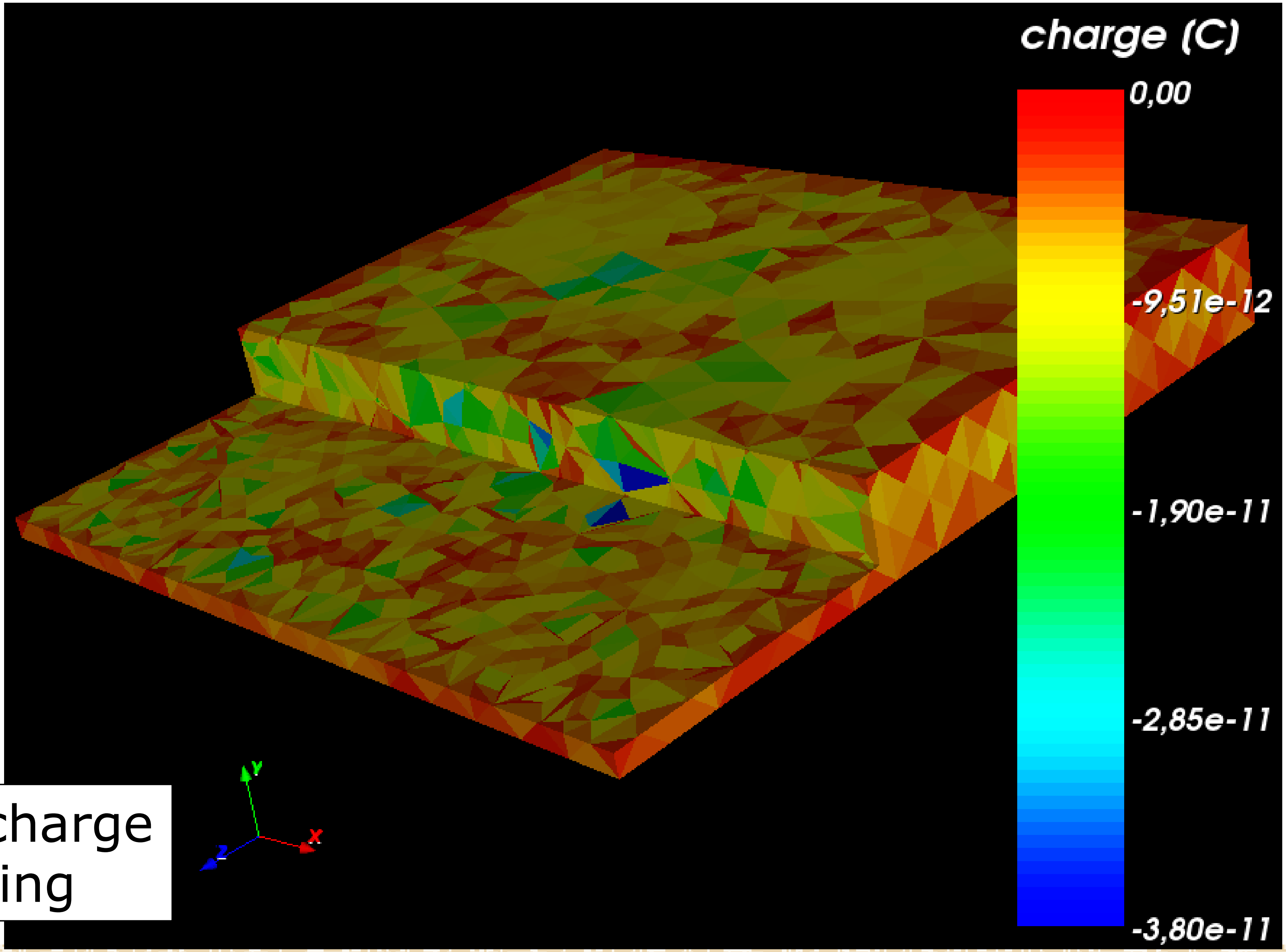
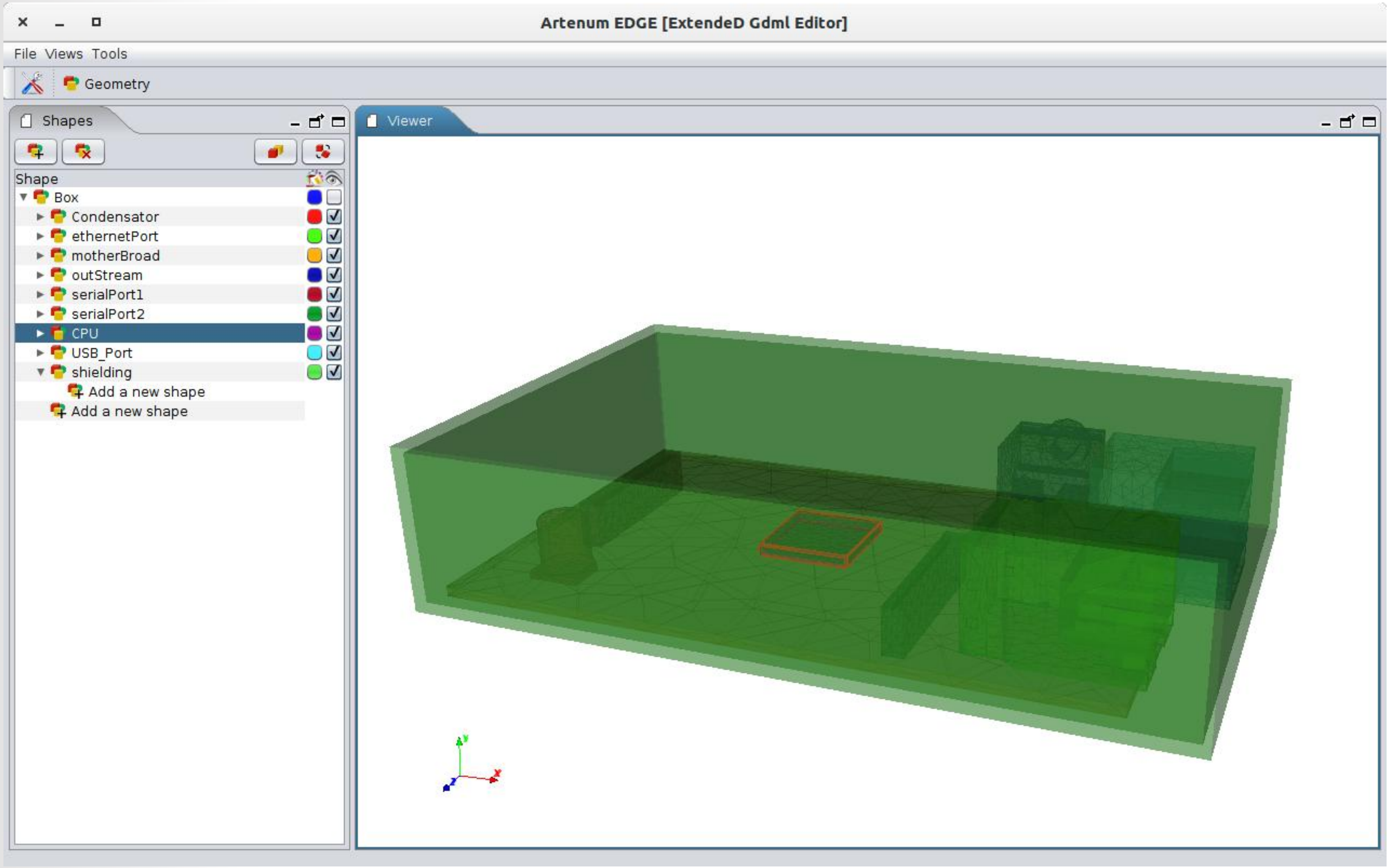


Deposited charge
3D clipping

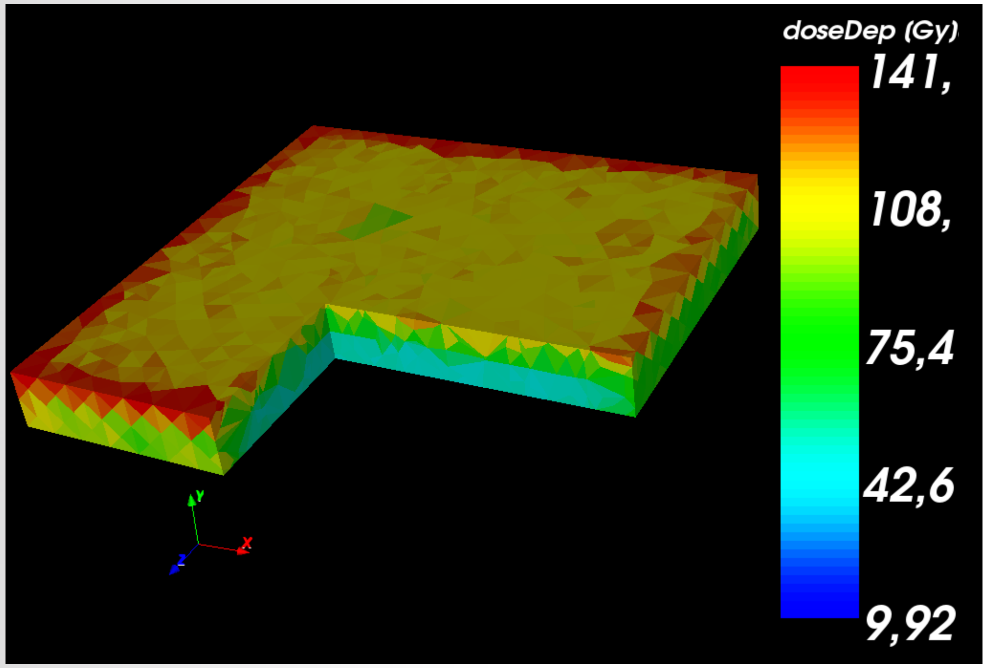
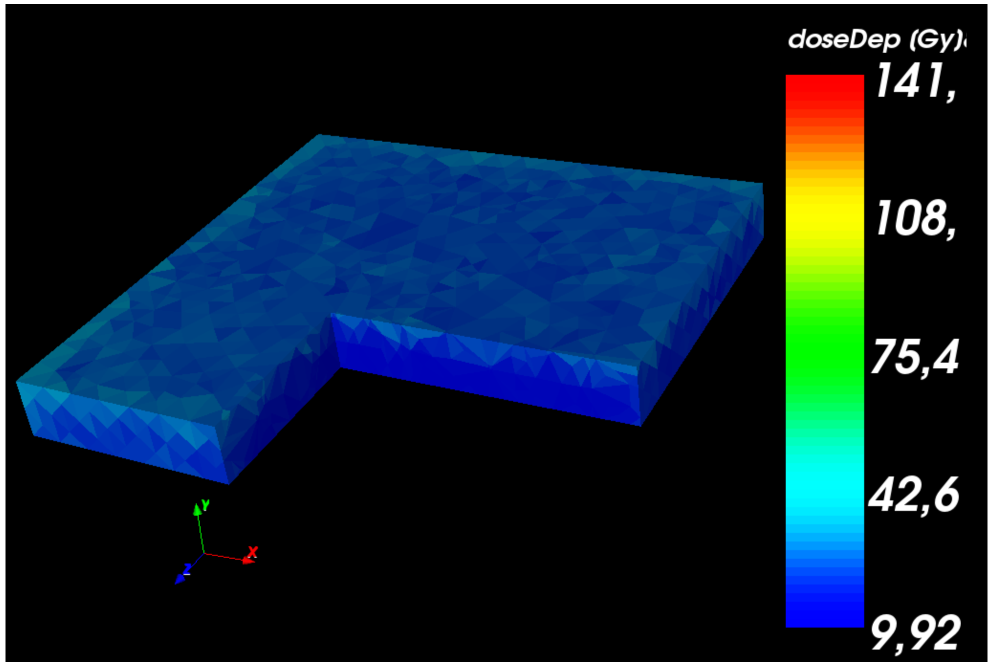
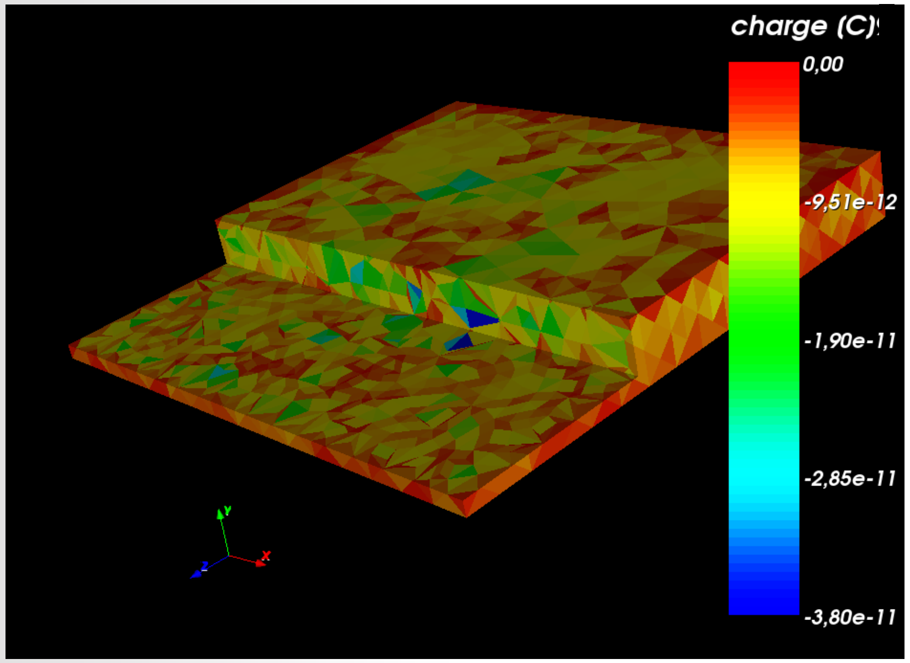
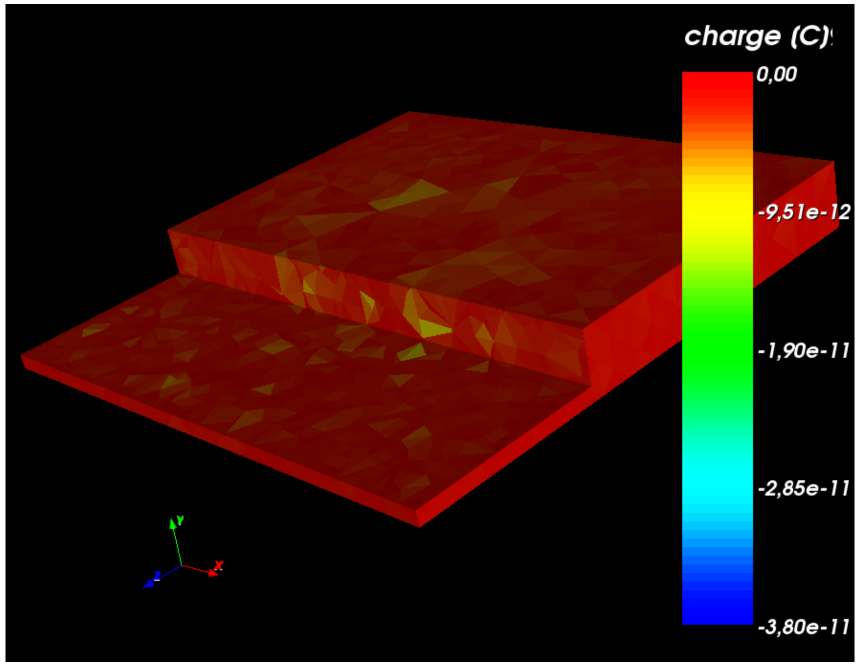
Sample of use of the modelling chain with a realistic test case

- Thanks to the modeling chain, it is easy to edit the geometry to add an aluminum shielding and compare the final results



Sample of use of the modelling chain with a realistic test case

- Results comparison during one hour

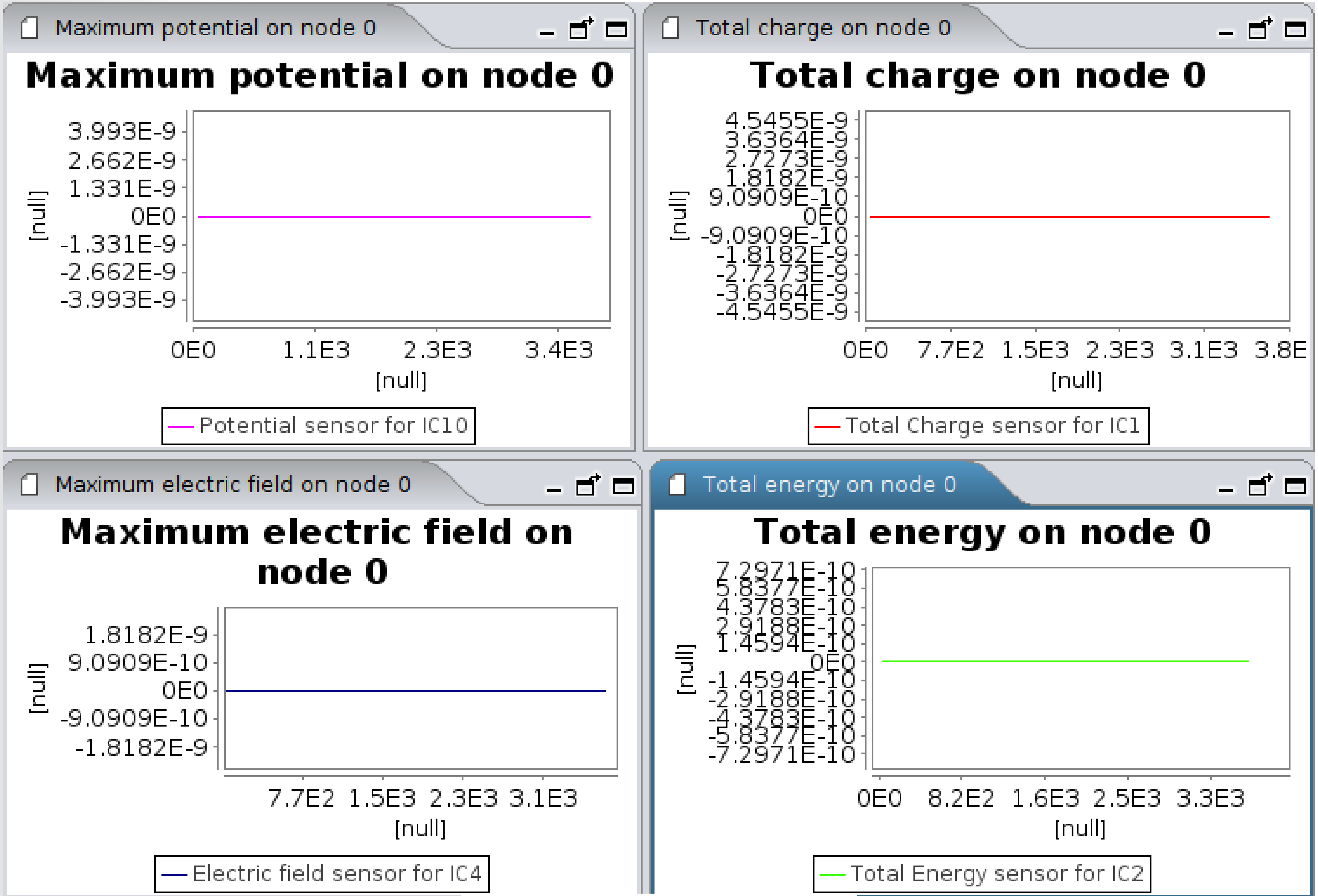
Without shielding	**With shielding**
	
	

Sample of use of the modelling chain with a realistic test case

Thanks to the modeling chain, users can consider several test cases:

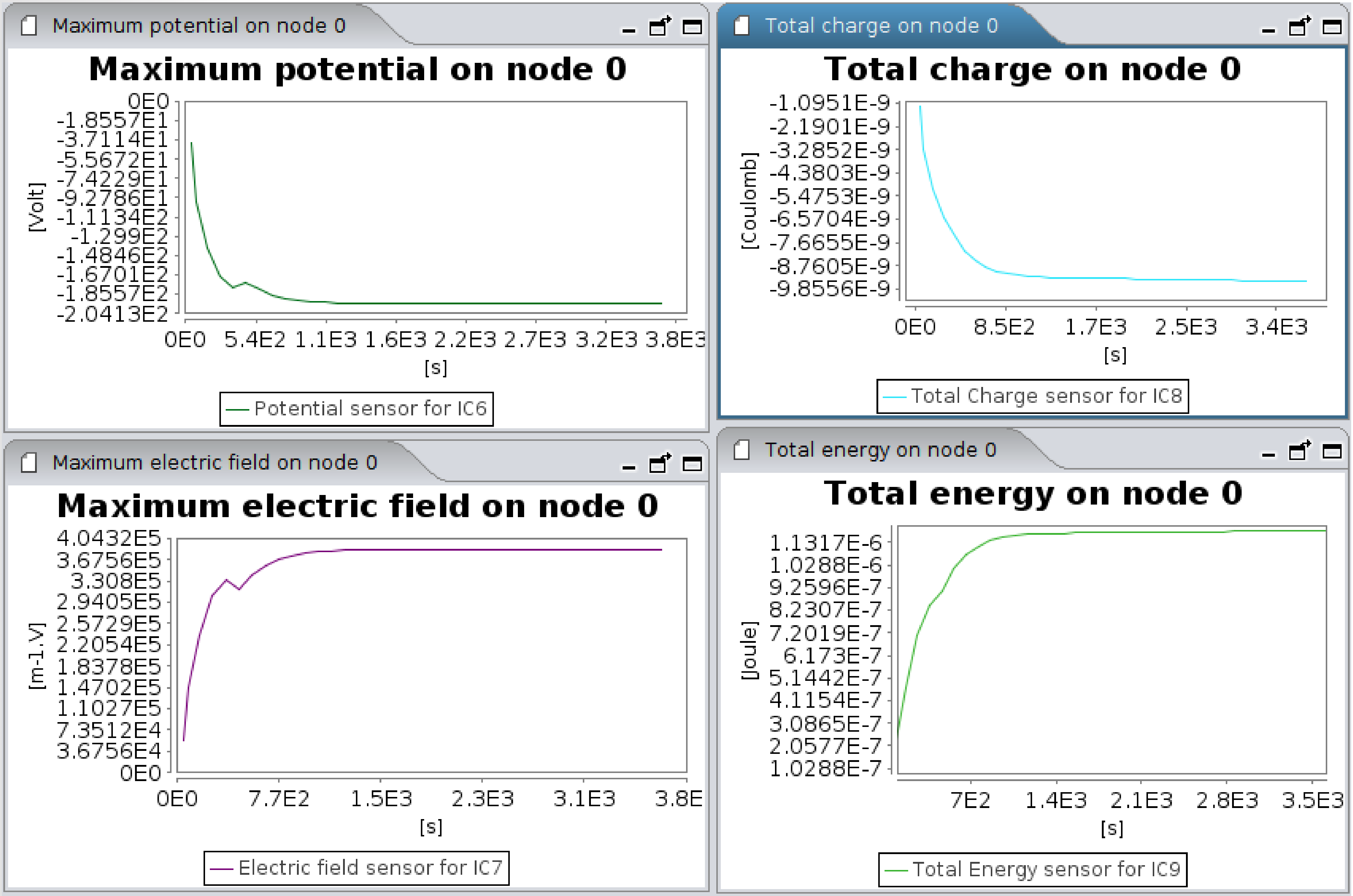
- Test case 1: Internal charging analysis where the CPU is considered as a conductor
  - Expected results: no charge because conductive material
- Test case 2: Internal charging analysis where the CPU is considered as the dielectric glass protection
  - Expected results: The glass will be charged

Sample of use of the modelling chain with a realistic test case



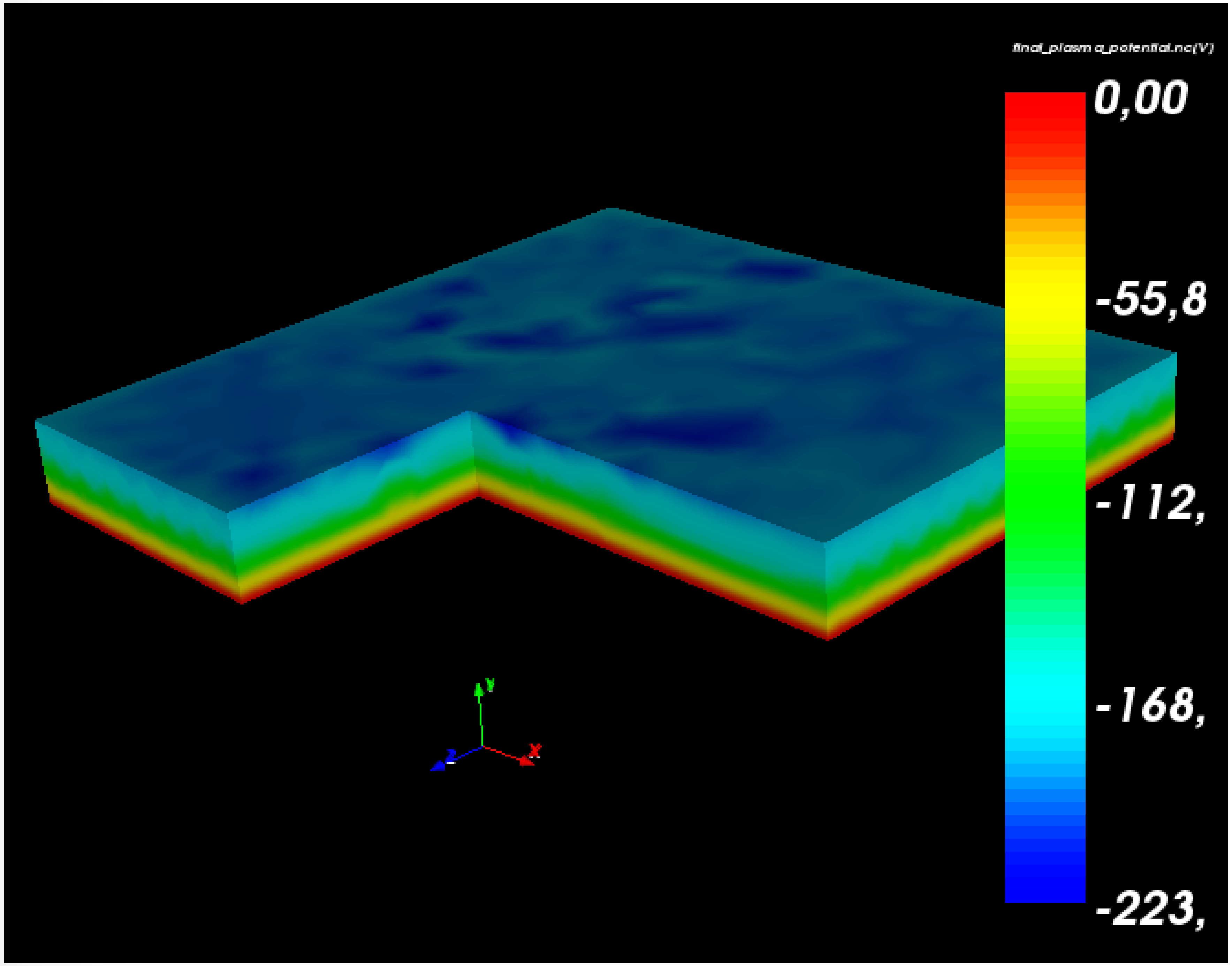
Conductor material

Sample of use of the modelling chain with a realistic test case



Dielectric glass material

Sample of use of the modelling chain with a realistic test case



Dielectric glass material: CPU potential (Volt)

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Conclusion

- A new modeling chain able to configure radiation and internal charging simulations in one application through 3D dedicated tools
  - Create GDML CAD geometry
  - Load and edit an existing GDML CAD geometries
  - Create GDML materials
  - Attribute a material to a specific shape
  - Create and visualize a radiation source
  - 3D post-processing operations on GRAS 3D results (cutting plane, clipping, …)
- This modeling chain does not reduce the CPU time to launch G4 radiation or internal charging simulation but save "human" engineer time through a WYSIWYG tool
- This modeling chain is available in the SPIS-services context provides by Artenum and ONERA companies

Questions?

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Thanks for your attention