SPENVIS Tutorial: Geant4 package

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Outline

- Introduction - Geant4 tools available in SPENVIS
- Geant4 tools SPENVIS interface
- Updates & current developments
  - Gras Interface
- Discussion/Conclusions

1. Geant4 Tools in SPENVIS

Geant4 Tools in SPENVIS: Motivation

- User friendly interface - No prior knowledge of Geant4.
- Generation of a g4mac file that can be used directly in a locally installed Geant4 application.
- Applications use outputs from other SPENVIS applications.
- Applications provide input to other SPENVIS applications.

Currently implemented models:

- Mulassis, GEMAT, SSAT, Magnetocosmics & Planetocosmics - MarsREM (third party).

Geant4 Tools in SPENVIS: A brief tour

Multi-Layered Shielding Simulation (Mulassis)

- Developed by QinetiQ
- Definition of a multi-layered, one-dimensional shield and incident particle source.
- Simulates radiation transport through the geometry, treating electromagnetic and nuclear interactions.
- Can directly include radiation environment spectra (Earth & Jupiter)
- **Outputs:**
  - Mulassis g4 macro file ← SPENVIS
  - Report file
  - CSV file (outputs from all analysis modules)
  - Mulassis log file
  - Plot of analysis results ← SPENVIS

Geant4 Tools in SPENVIS: A brief tour

Geant4-based Microdosimetry Analysis Tool (GEMAT)

- Developed by QinetiQ
- Microdosimetry effects of space radiation on micro-electronics and micro-sensors.
- **Outputs:**
  - GEMAT g4 macro file ← SPENVIS
  - Report file
  - CSV file (outputs from analysis modules)
  - GEMAT log file
  - VRML representation geometry ← SPENVIS
  - Plot of analysis results ← SPENVIS

Geant4 Tools in SPENVIS: A brief tour

Sector Shielding Analysis Tool (SSAT)

- Developed by QinetiQ
- Ray tracing from user defined point within geometry to determine shielding levels and shielding distributions.
- Upload GDML file or create one using the geometry definition tool.
- Shielding distributions can be folded with flux and dose models (e.g. from SHIELDOSE or NIEL)
- **Outputs:**
  - SSAT g4 macro file ← SPENVIS
  - SSAT output (1D & 2D shielding distribution)
  - SSAT log file
  - VRML view of geometry ← SPENVIS
  - Plots of dose distribution & shielding distribution as a function of shielding thickness, etc ← SPENVIS

Geant4 Tools in SPENVIS: A brief tour

MAGNETOCOSMICS

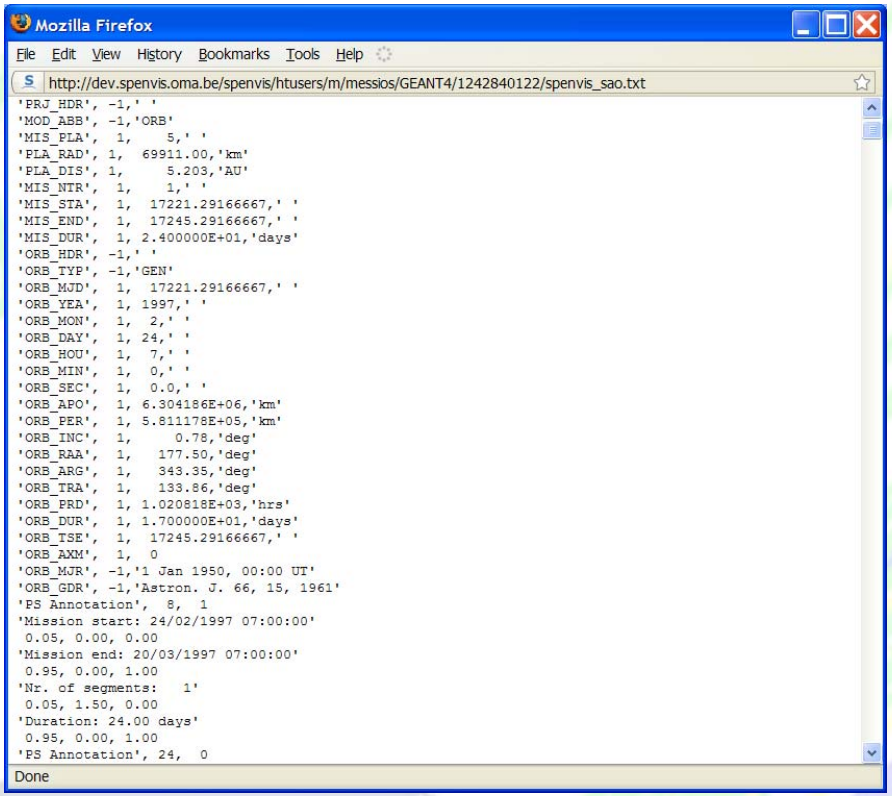
- Developed at the University of Bern
- Using the Geant4 toolkit to simulate the motion of charged particles:
  - computation and visualisation of charged particle trajectories & magnetic field lines
  - computation of cut-off rigidities as a function of position
- Can directly include SAPRE orbit generator and/or geographical coordinate grid outputs.
- **Outputs:**
  - MAGNETOCOSMICS g4 macro file ← SPENVIS
  - CSV result file
  - Program log file
  - VRML representation of particle trajectories or magnetic field lines
  - Plot of rigidity cut-offs ← SPENVIS

Geant4 Tools in SPENVIS: A brief tour

PLANETOCOSMICS

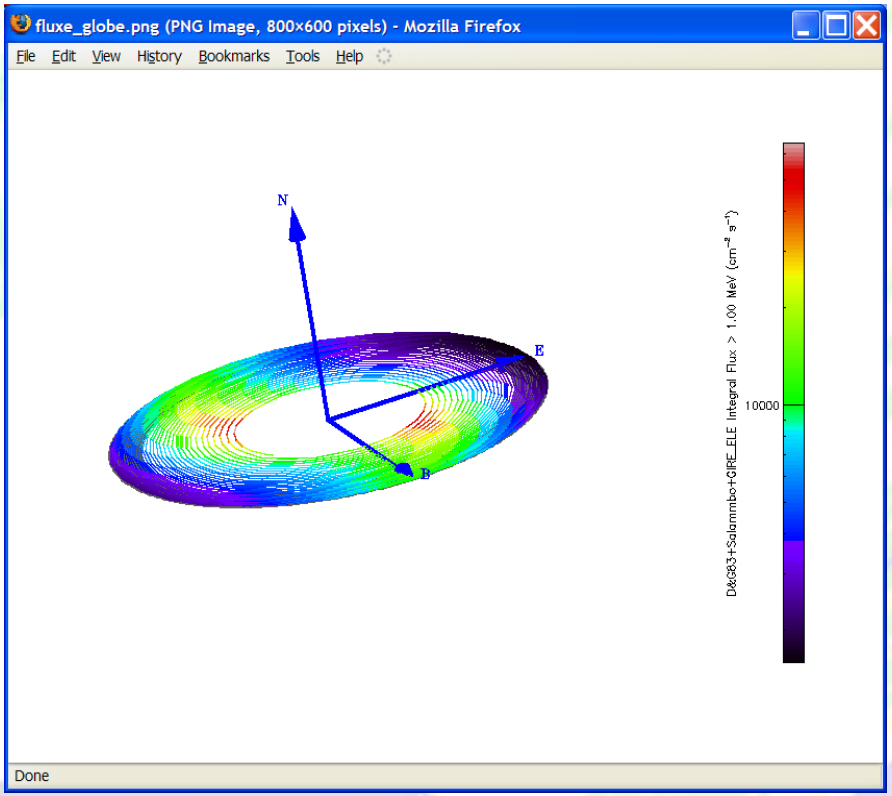
- Developed at the University of Bern
- Hadronic and electromagnetic interactions of particles with planetary environment (Mercury, Earth & Mars)
- Fluence & Energy deposition analysis.
- SPENVIS trapped particle or solar proton spectrum.
- **Outputs:**
  - PLANETOCOSMICS g4 macro file ← SPENVIS
  - CSV result file
  - Program log file
  - VRML representation of particle trajectories

Example 1: NIEL analysis for Galileo encounter with Europa (24 Feb 1997)



- Run SAPRE (17 days)

Example 1: NIEL analysis for Galileo encounter with Europa (24 Feb 1997)



- Run SAPRE (17 days)
- Run Jovian trapped radiation models

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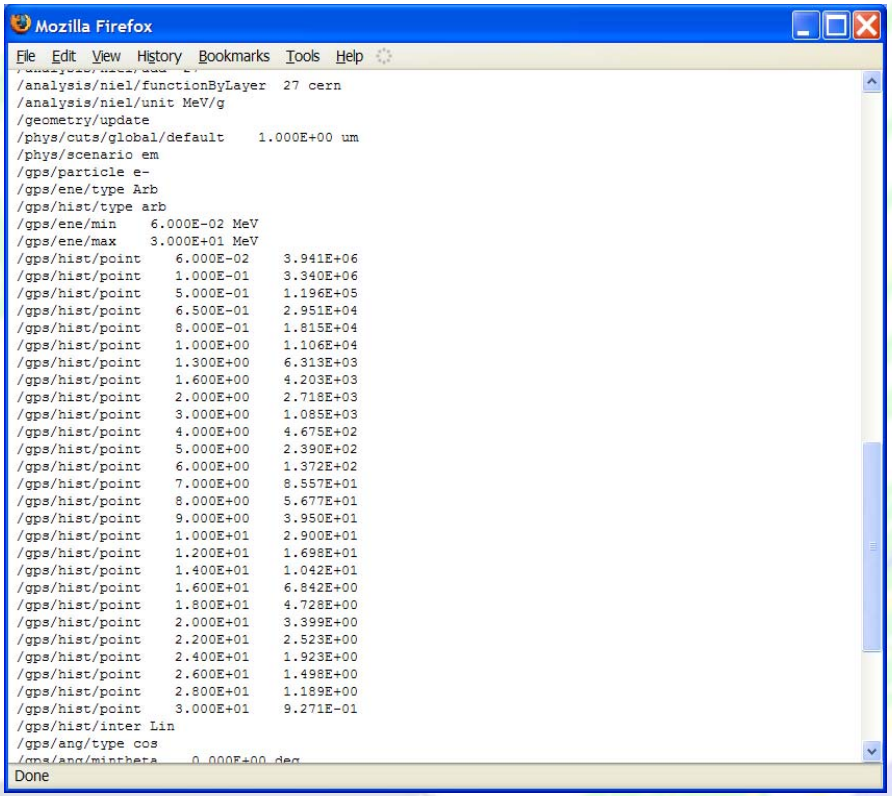
Example 1: NIEL analysis for Galileo encounter with Europa (24 Feb 1997)



- Run SAPRE (17 days)
- Run Jovian trapped radiation models
- Use trapped e- spectrum

  as input for Mulassis

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Example 1: NIEL analysis for Galileo encounter with Europa (24 Feb 1997)

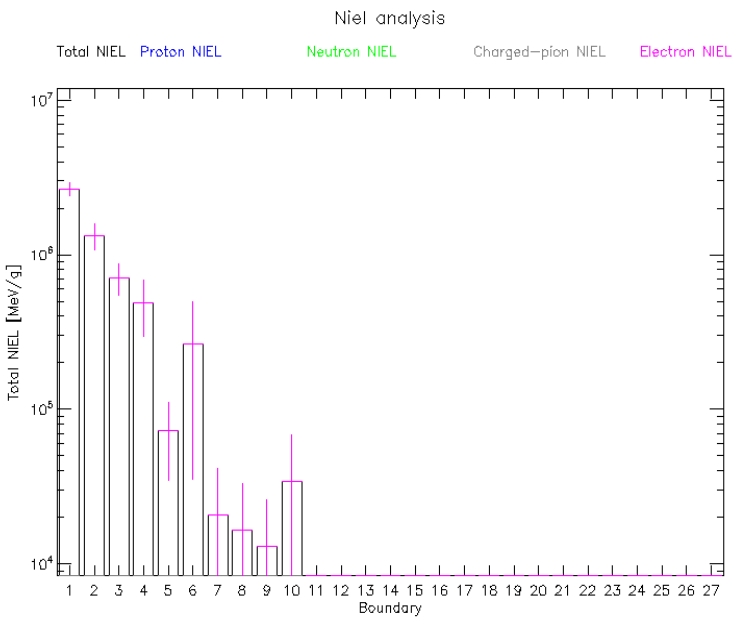
Mozilla Firefox

File Edit View History Bookmarks Tools Help

```
/analysis/niel/functionByLayer  27 cern
/analysis/niel/unit MeV/g
/geometry/update
/phys/cuts/global/default    1.000E+00 um
/phys/scenario em
/gps/particle e-
/gps/ene/type Arb
/gps/hist/type arb
/gps/ene/min    6.000E-02 MeV
/gps/ene/max    3.000E+01 MeV
/gps/hist/point    6.000E-02    3.941E+06
/gps/hist/point    1.000E-01    3.340E+06
/gps/hist/point    5.000E-01    1.196E+05
/gps/hist/point    6.500E-01    2.951E+04
/gps/hist/point    8.000E-01    1.815E+04
/gps/hist/point    1.000E+00    1.106E+04
/gps/hist/point    1.300E+00    6.313E+03
/gps/hist/point    1.600E+00    4.203E+03
/gps/hist/point    2.000E+00    2.718E+03
/gps/hist/point    3.000E+00    1.085E+03
```

mulassis_niel.png (PNG Image, 800×600 pixels) - Mozilla Firefox

File Edit View History Bookmarks Tools Help



Done

- Run SAPRE (17 days)
- Run Jovian trapped radiation models
- Use trapped e- spectrum as input for Mulassis
- Run Mulassis

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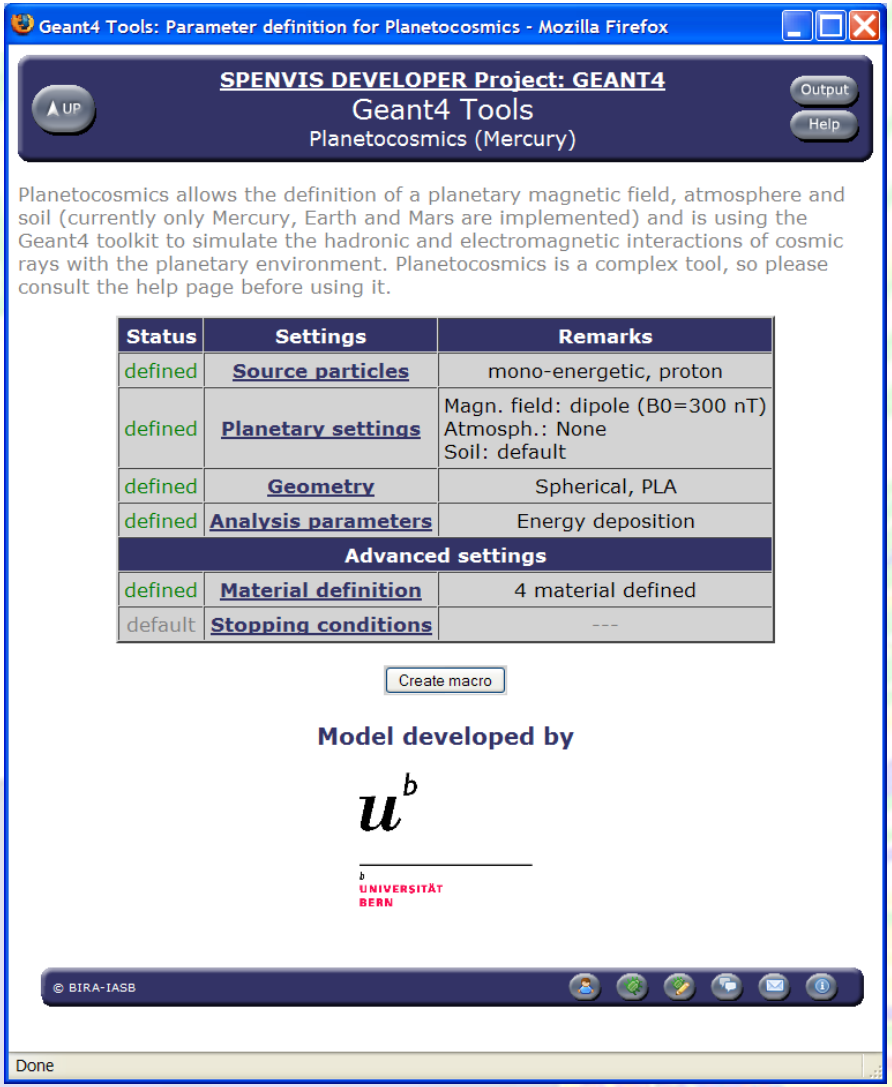
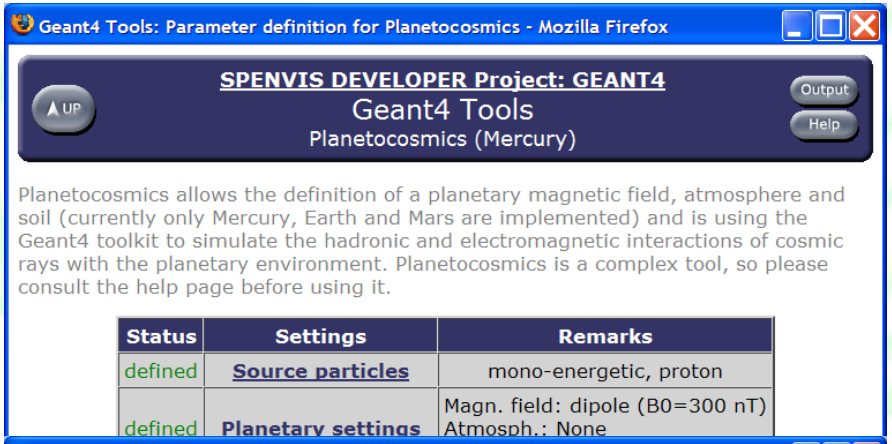
Example 2: Proton interaction with Mercury's soil

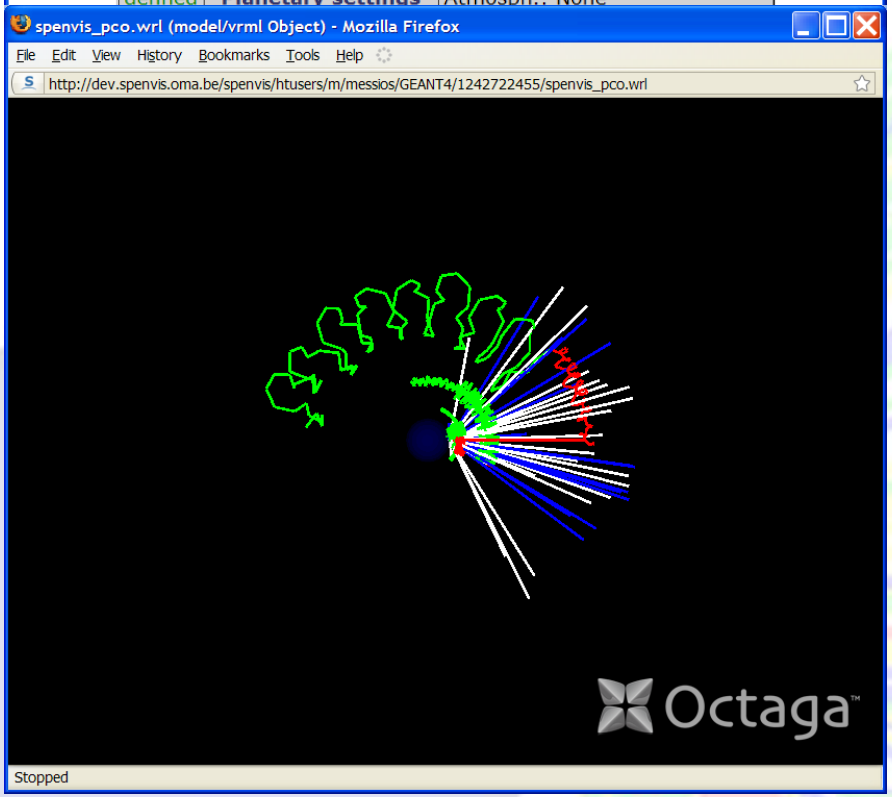


Run PLANETOCOSMICS:

- 5 GeV primaries
- 10 events
- 10 m thick layer with 1.3 [g/cm3] density
- Layer composition: SiO2(45%), MgO(35%), Al2O3(7%), CaO (7%), FeO(5%), Na2O(0.7%), TiO2(0.3%)

Example 2: Proton interaction with Mercury's soil





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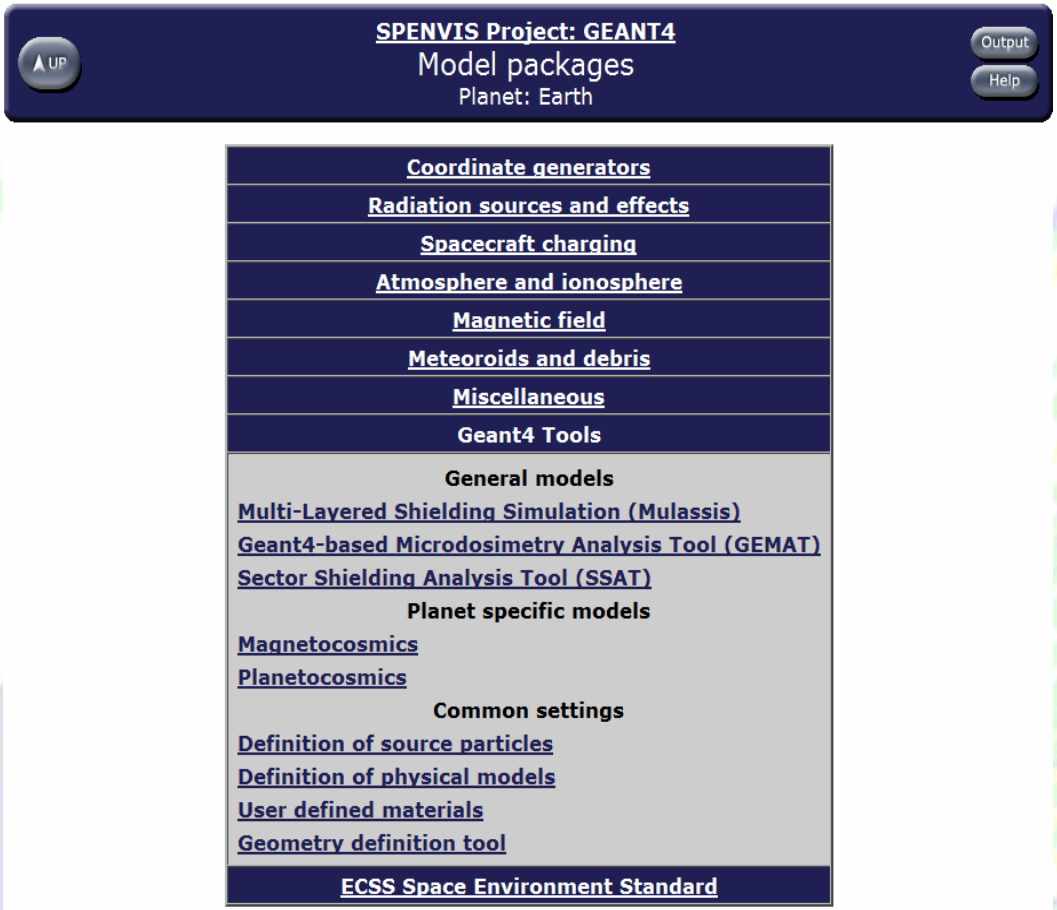
Geant4 Tools in SPENVIS: Limitations

- Simulations can be highly time-consuming.
- CPU time available on SPENVIS for a single user is limited and calculations are stopped if program exceeds a limit.
- This can be often the case for calculations on maps or orbit trajectories.
- Users are welcome to utilise SPENVIS to produce and download the macro-file but is recommended that they download the stand-alone version of the Geant4 application to make a run.

2. SPENVIS Geant4 Tools Interface

Geant4 tools interface: entry point



The models implemented in SPENVIS are combined in the packages listed above. Clicking on a package name will expand the table with a list of models. Some model suites have to be executed in a prescribed order. Model links will not be available when pre-required runs have not been executed yet. Most models run on both a spacecraft trajectory and a geographical coordinate grid. Clicking on the coordinate generator links and returning to this page toggles between the two sets of coordinates. The model links will adapt to the choice of coordinates.

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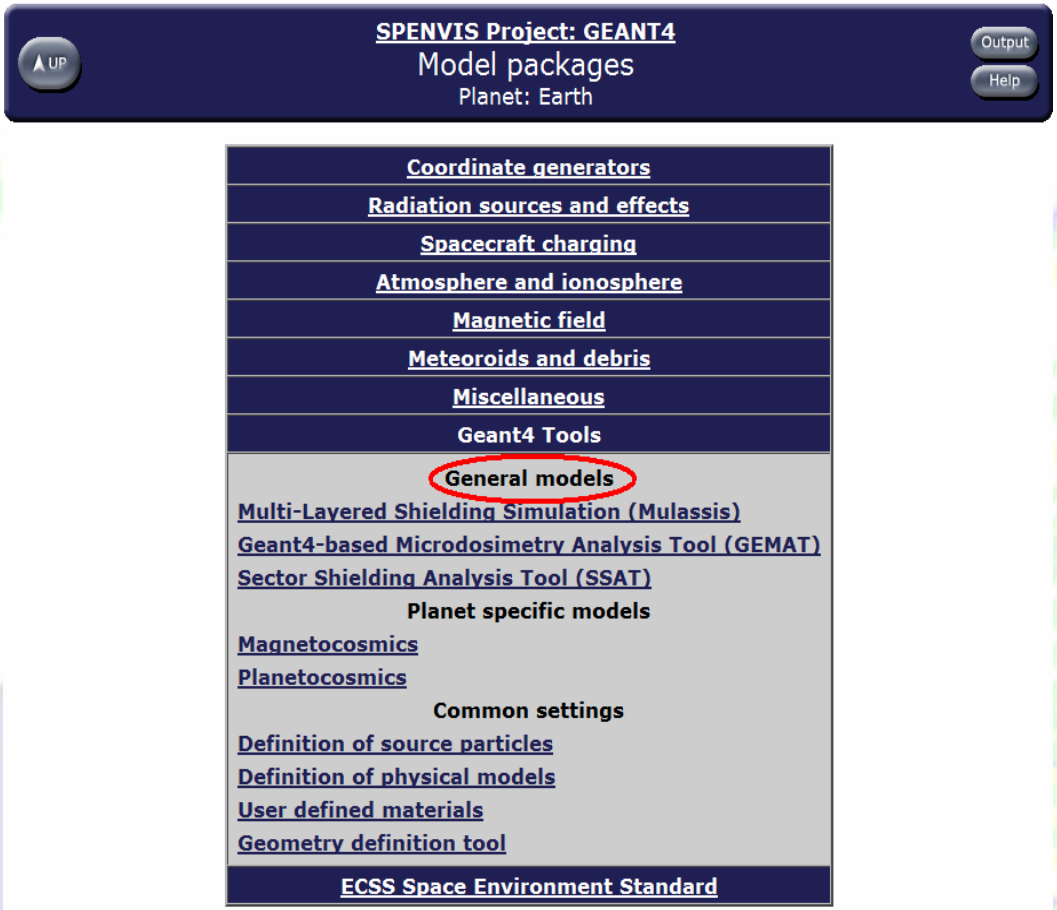

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- **General models:**
  Accessible for all planets included in SPENVIS

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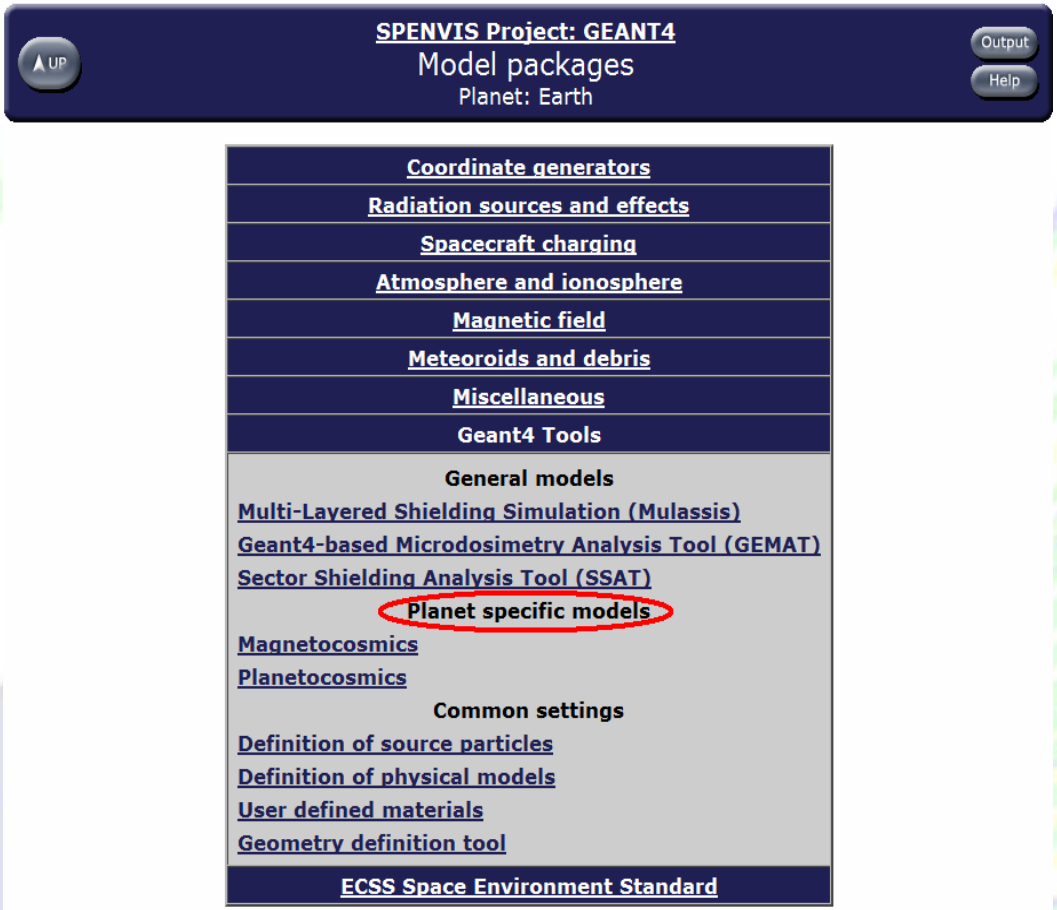
Geant4 tools interface: entry point



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- **General models:** Accessible for all planets included in SPENVIS
- **Planet specific models:** Appear only for a specific planet

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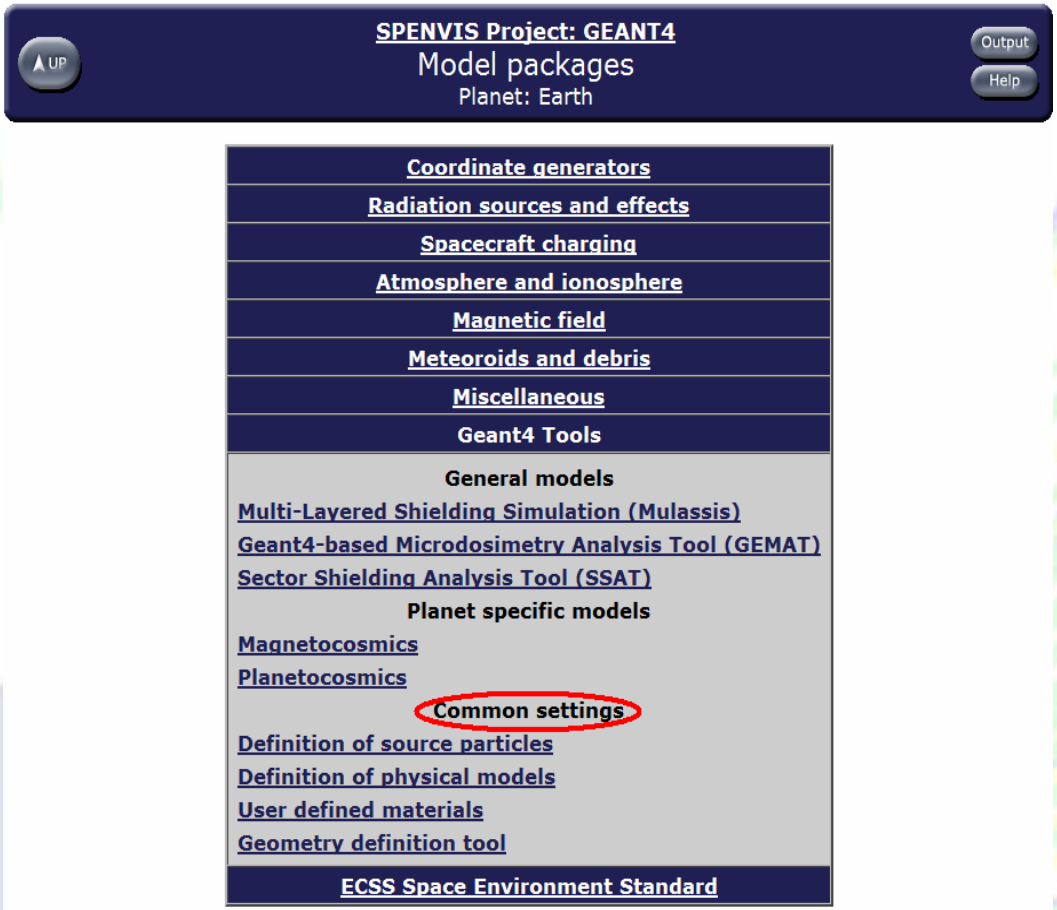
Geant4 tools interface: entry point



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- **General models:** Accessible for all planets included in SPENVIS
- **Planet specific models:** Appear only for a specific planet
- **Common settings:**
  - Defined for various Geant4 tools
  - Available for all planets

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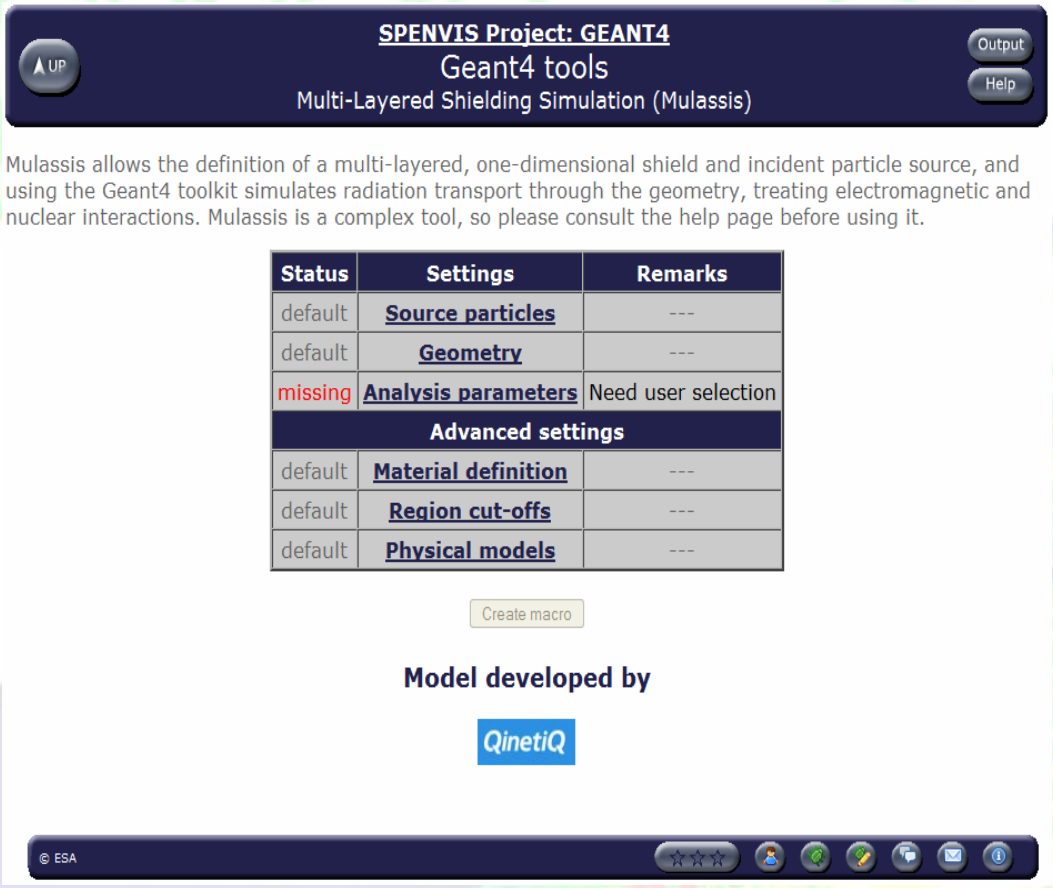
Geant4 tools interface: navigation



- Model main page:
  - summary of setting status
  - access to different setting sections
- Users can modify the settings by clicking on a particular section.
- Automatic check of the user's input.
- Create macro & run model

Geant4 tools interface: navigation

UP

SPENVIS Project: GEANT4

Geant4 tools

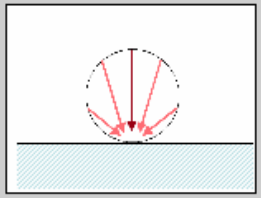
Source particles

Output

Help

These settings are used as an input by Multi-Layered Shielding Simulation (Mulassis), Geant4-based Microdosimetry Analysis Tool (GEMAT), Geant4 Radiation Analysis for Space (Gras) and Planetocosmics.

Source particle type and spectrum		
Incident particle type: electron		
Number of primary particles to simulate: 1,000		
Warning: Particle track visualisation will be disabled!		
Incident energy spectrum: mono-energetic (mono-energetic / trapped electrons / linear / power law / exponential / user-defined)		
Mono-energetic energy:	100.0	
Fluence/(Flux) intensity:	1.0	)]
Angular distribution (1D):		
Minimum angle:	0.0	[degrees]
Maximum angle:	90.0	[degrees]



Reset Save >>

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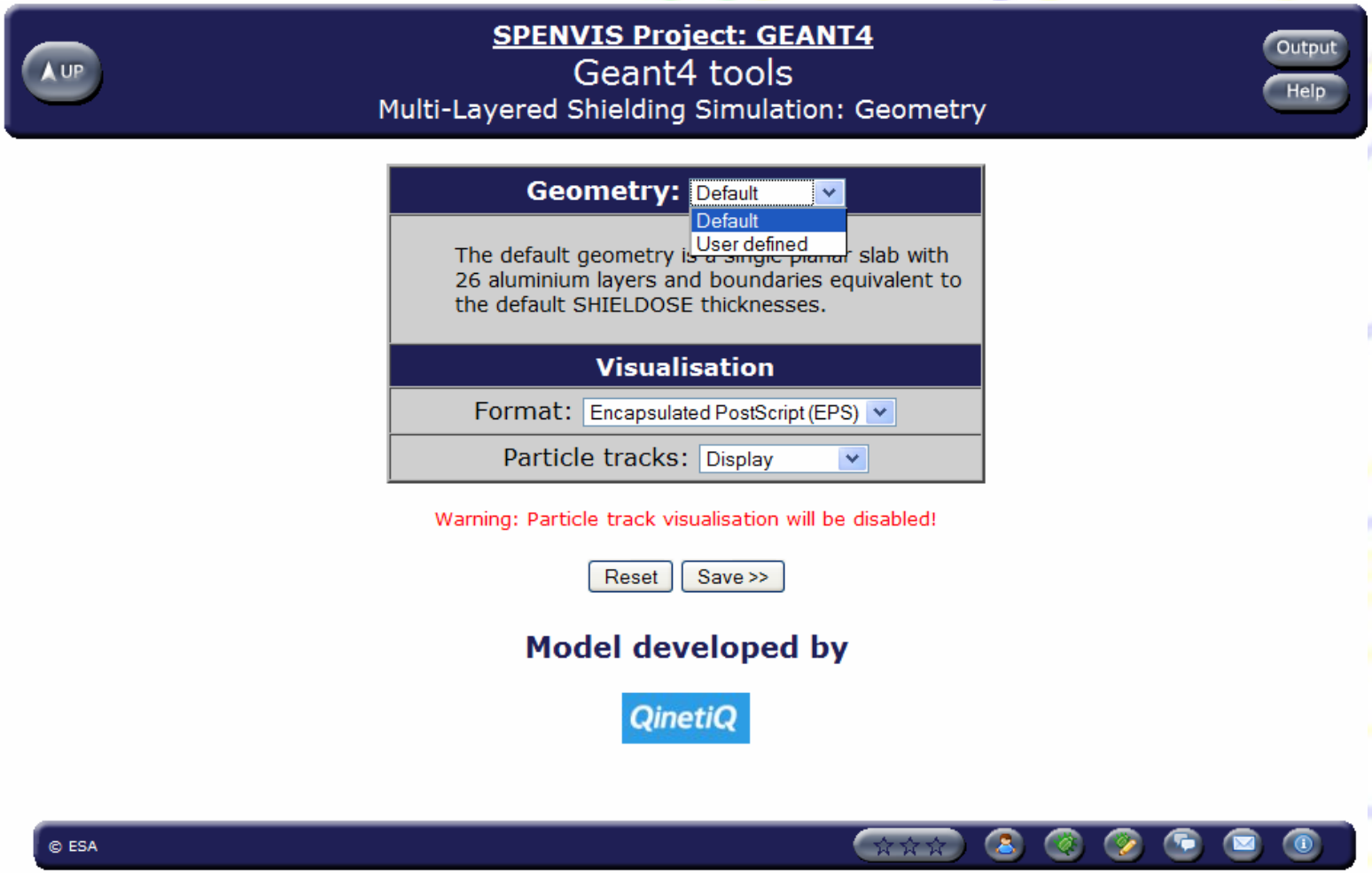
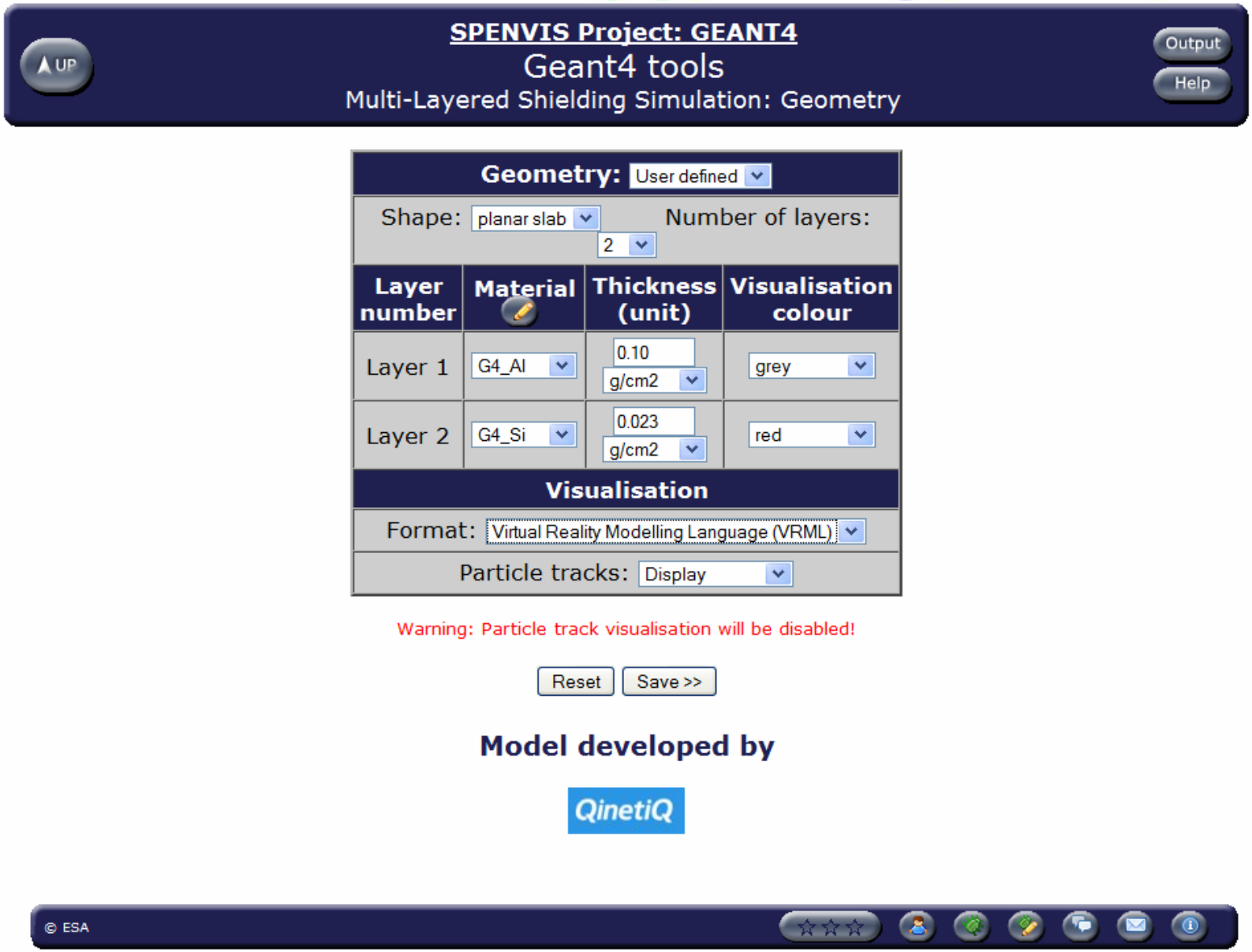
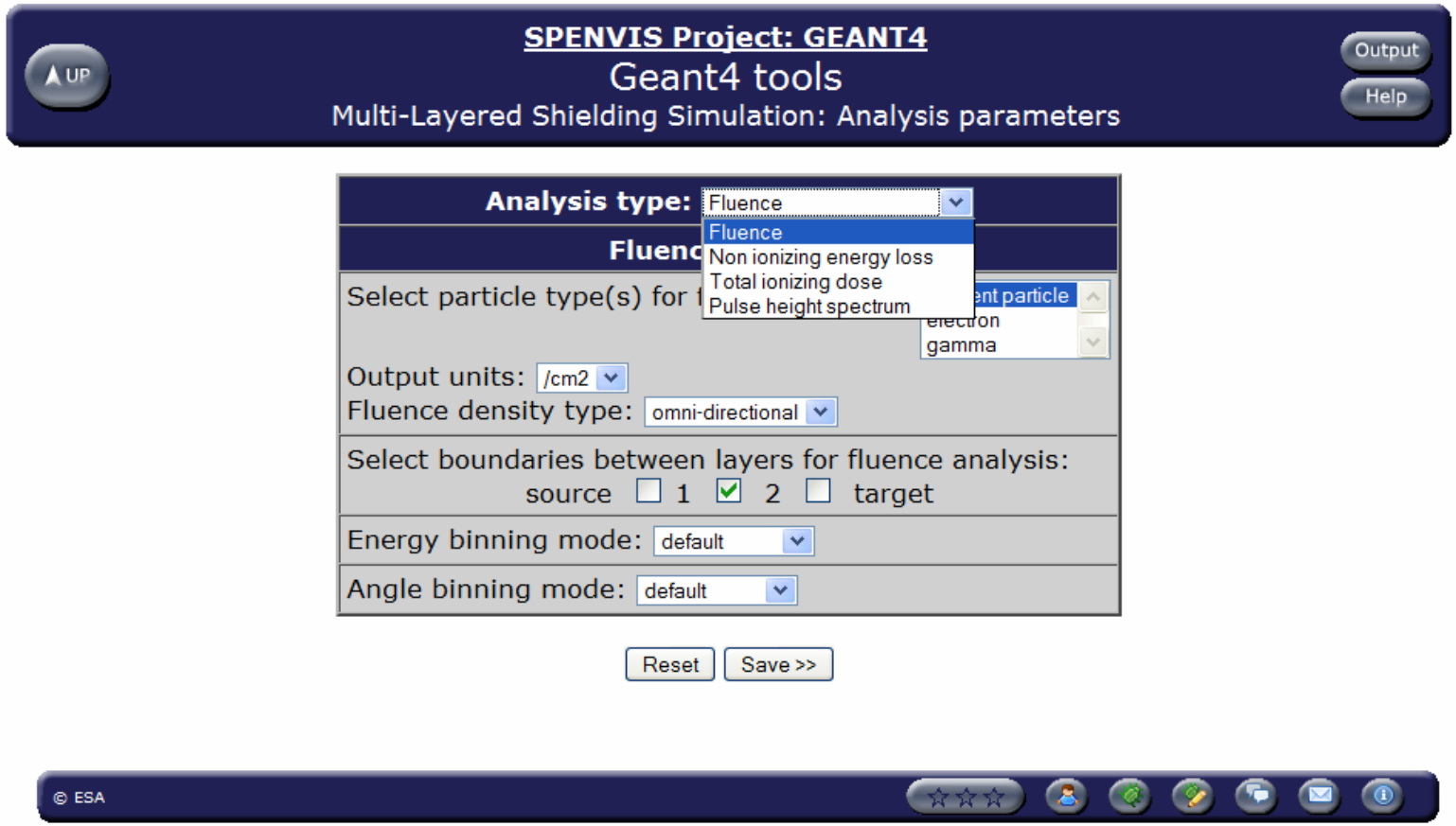
Geant4 tools interface: navigation



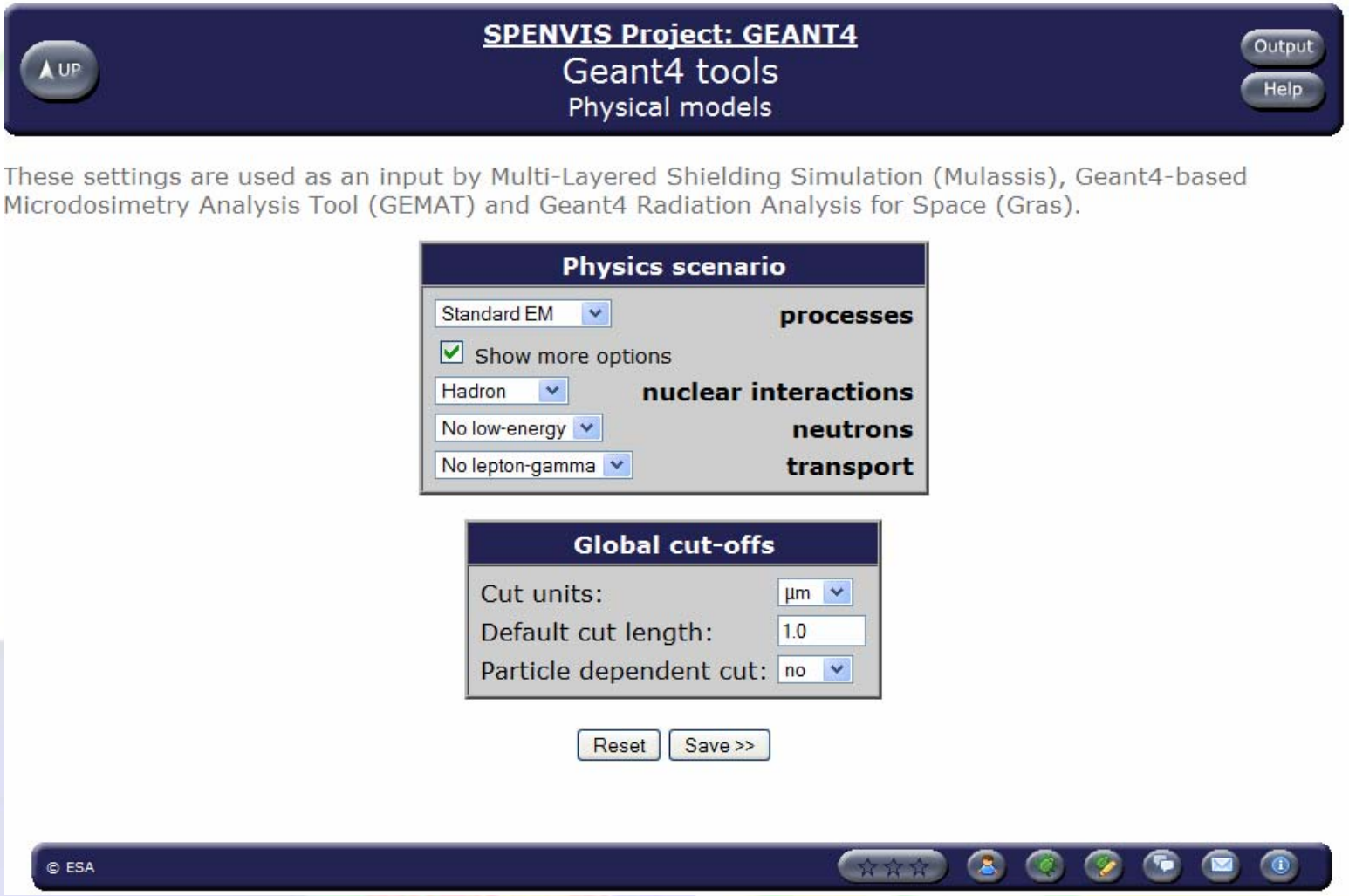
Geant4 tools interface: navigation



Geant4 tools interface: navigation



Geant4 tools interface: navigation



Geant4 tools interface: navigation

UP

SPENVIS Project: GEANT4

Geant4 tools

Multi-Layered Shielding Simulation (Mulassis)

Output

Help

Mulassis allows the definition of a multi-layered, one-dimensional shield and incident particle source, and using the Geant4 toolkit simulates radiation transport through the geometry, treating electromagnetic and nuclear interactions. Mulassis is a complex tool, so please consult the help page before using it.

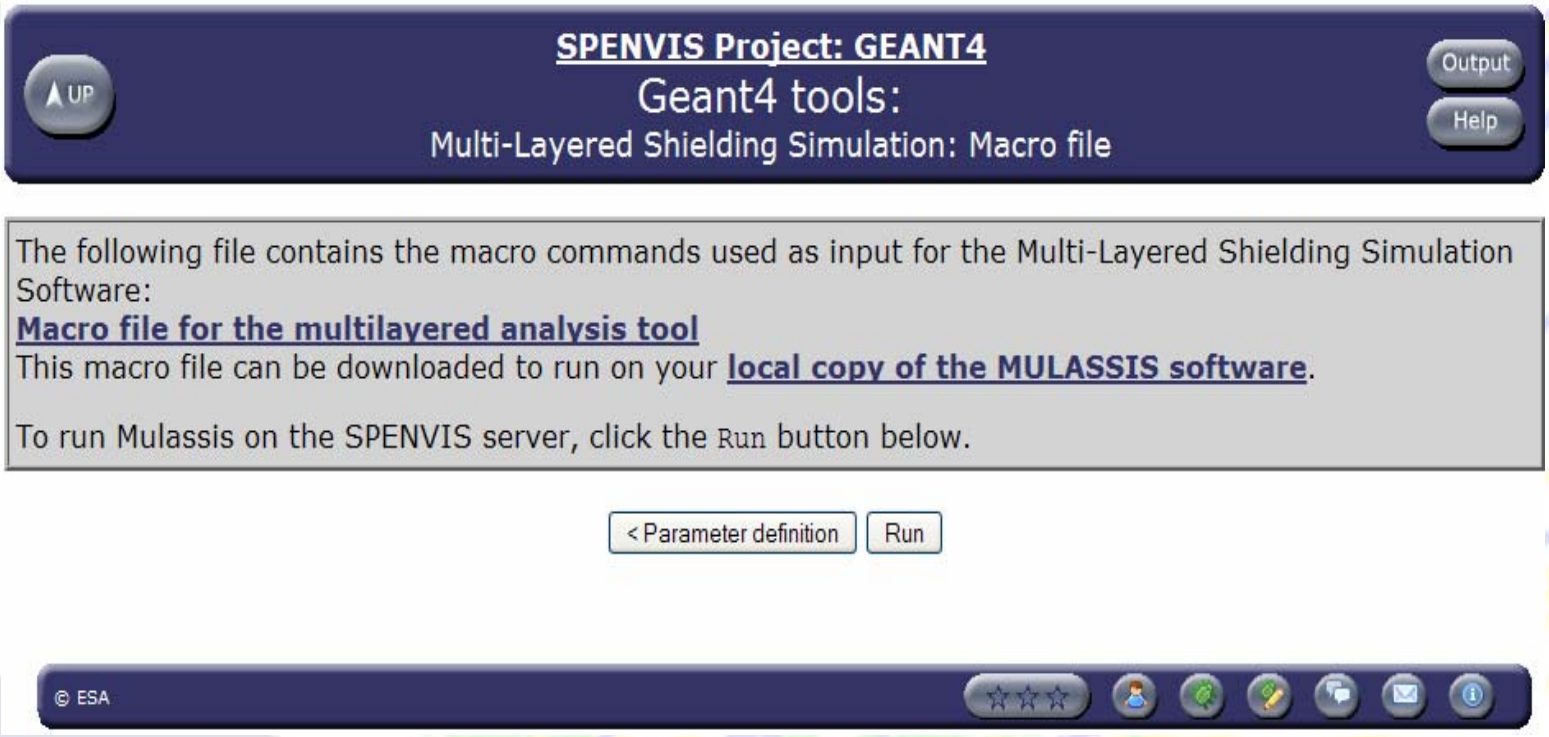
Status	Settings	Remarks
defined	Source particles	mono-energetic, e-
defined	Geometry	Planar slab, 2 layers
defined	Analysis parameters	Fluence
Advanced settings		
defined	Material definition	2 material defined
default	Region cut-offs	---
defined	Physical models	Standard EM, Hadron

Create macro

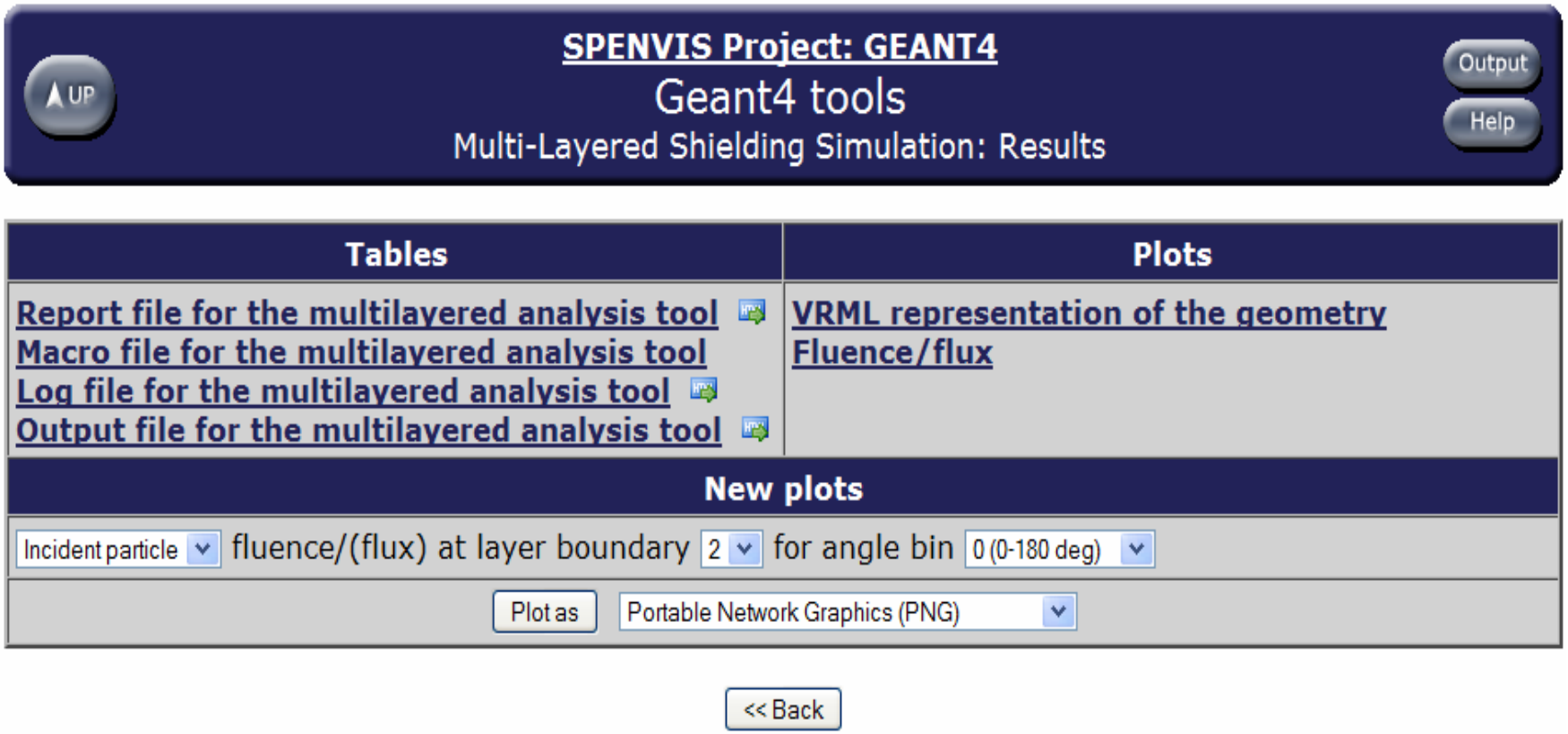
Model developed by

QinetiQ

Geant4 tools interface: navigation



Geant4 tools interface: navigation



Geant4 tools interface: help page

The Geant4 source code is freely available, accompanied by an Installation Guide and an extensive set of documentation.[2] In general, one needs to install the Geant4 source code in order to recompile code for a particular Geant4 application. However, this is not necessary when a static version of this program is available (e.g. the SPENVIS version of MULASSIS).

Geant4 tools in the SPENVIS environment

The following table gives an overview of the various Geant4 tools available in SPENVIS.

Tool name	Version (Geant4 version)	Home page
MULASSIS	V1.19 (4.9.0)	http://reat.space.qinetiq.com/mulassis/
GEMAT	V2.4 (4.9.0)	http://reat.space.qinetiq.com/gemat/
SSAT	V2.1 (4.9.0)	http://reat.space.qinetiq.com/ssat/
MAGNETOCOSMICS	(4.7.1)	http://cosray.unibe.ch/~laurent/magnetocosmics/
PLANETOCOSMICS	(4.8.1)	http://cosray.unibe.ch/~laurent/planetocosmics/
GRAS	(4.9.1)	http://space-env.esa.int/index.php/geant4-radiation-analysis-for-space.html

The SPENVIS interface of all these tools simplifies the process of defining run parameters using a number of input pages (see the detailed tool help pages for more information).

Advanced users have the option to input a number of fine-tuning parameters.

The Geant4 tools use a Monte-Carlo simulation-based code and execution times can be very long. In order to guarantee the consistency between the different models available in the SPENVIS system (e.g. particle spectrum vs. total ionising dose), the user project is 'blocked' while running any simulation. However, navigation remains possible. The excution is limited to ten minutes of CPU-time on the simulation machine. If the application run exceeds this limit, the simulation will be terminated and intermediate results returned to the user.

References

1. QinetiQ website
2. Geant4 website
3. Geant4 Space Users Page
4. Geant4 Physics Reference Manual

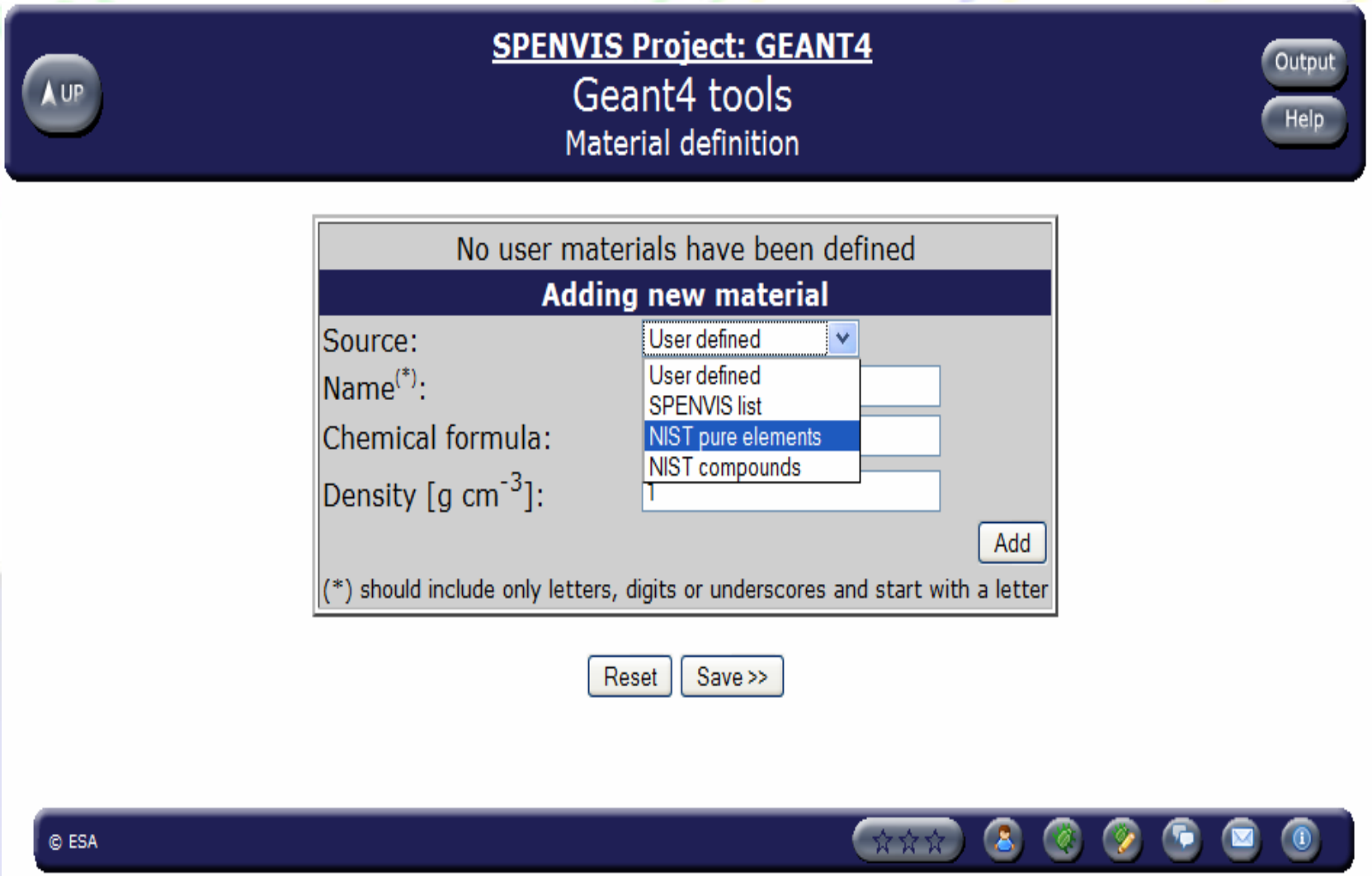
- Geant4 background information
- Overview of Geant4 tools in SPENVIS
- Links & references

Geant4 tools interface: Common tools

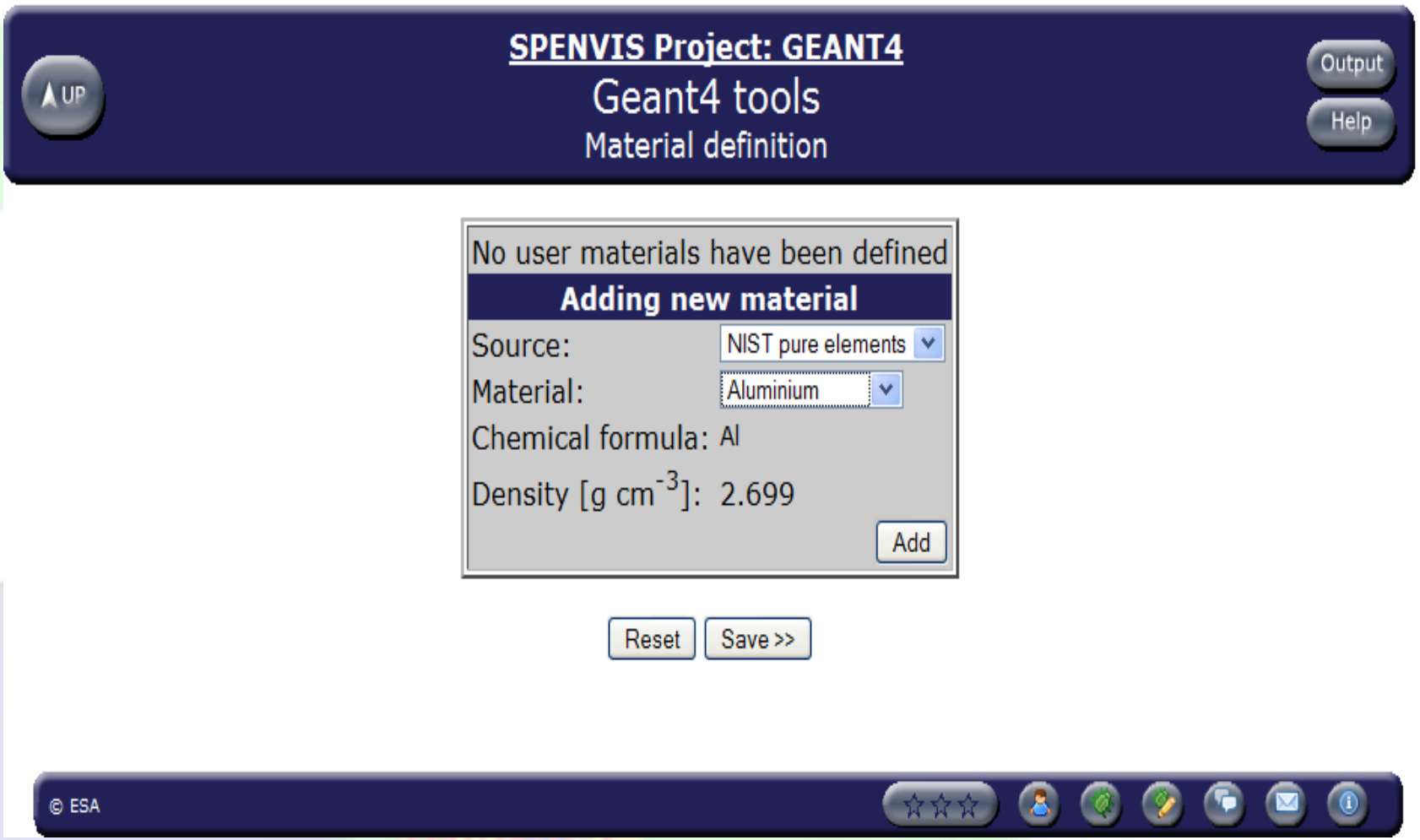
Material definition

- Define own material or choose from predefined lists.
- User defined material input fields:
  - material name (unique)
  - chemical composition (special syntax)
  - density
- Defined material available for all Geant4 applications.

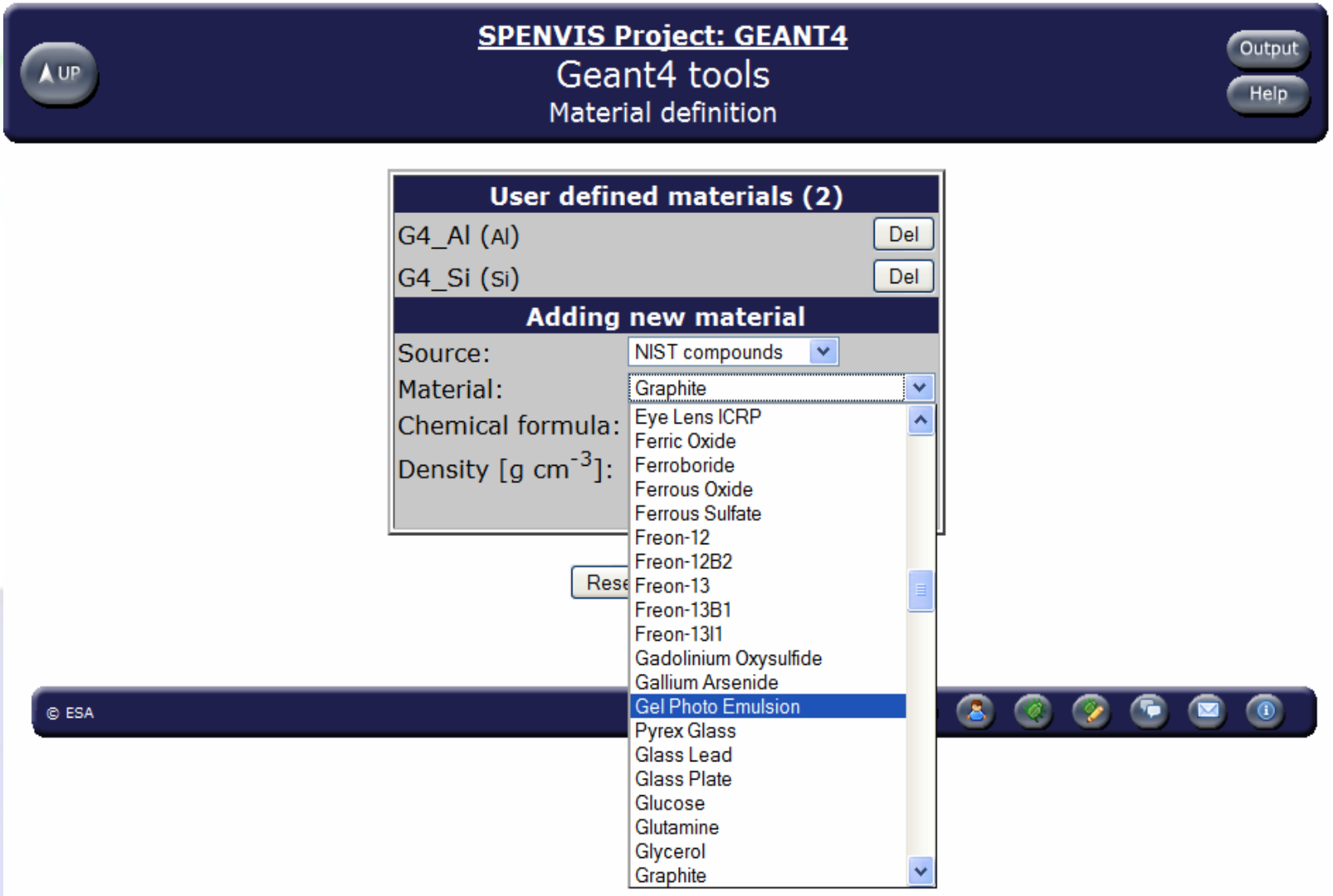
Geant4 tools interface: Common tools



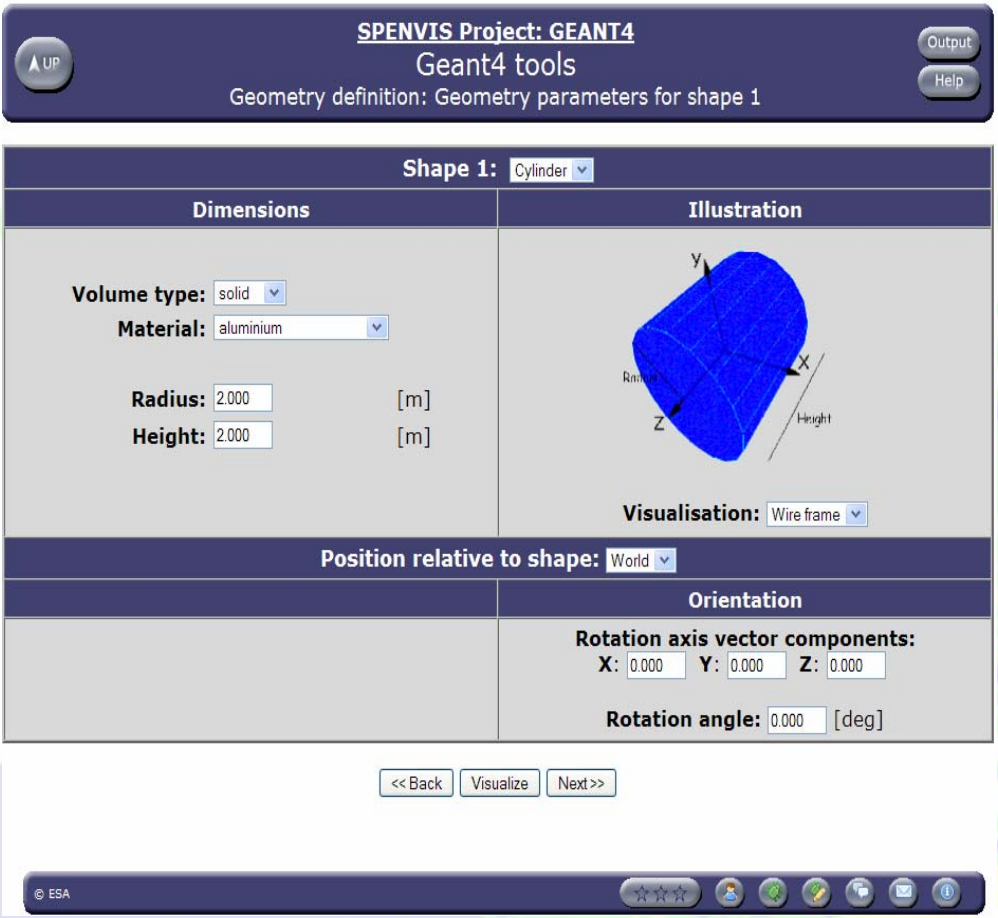
Geant4 tools interface: Common tools



Geant4 tools interface: Common tools

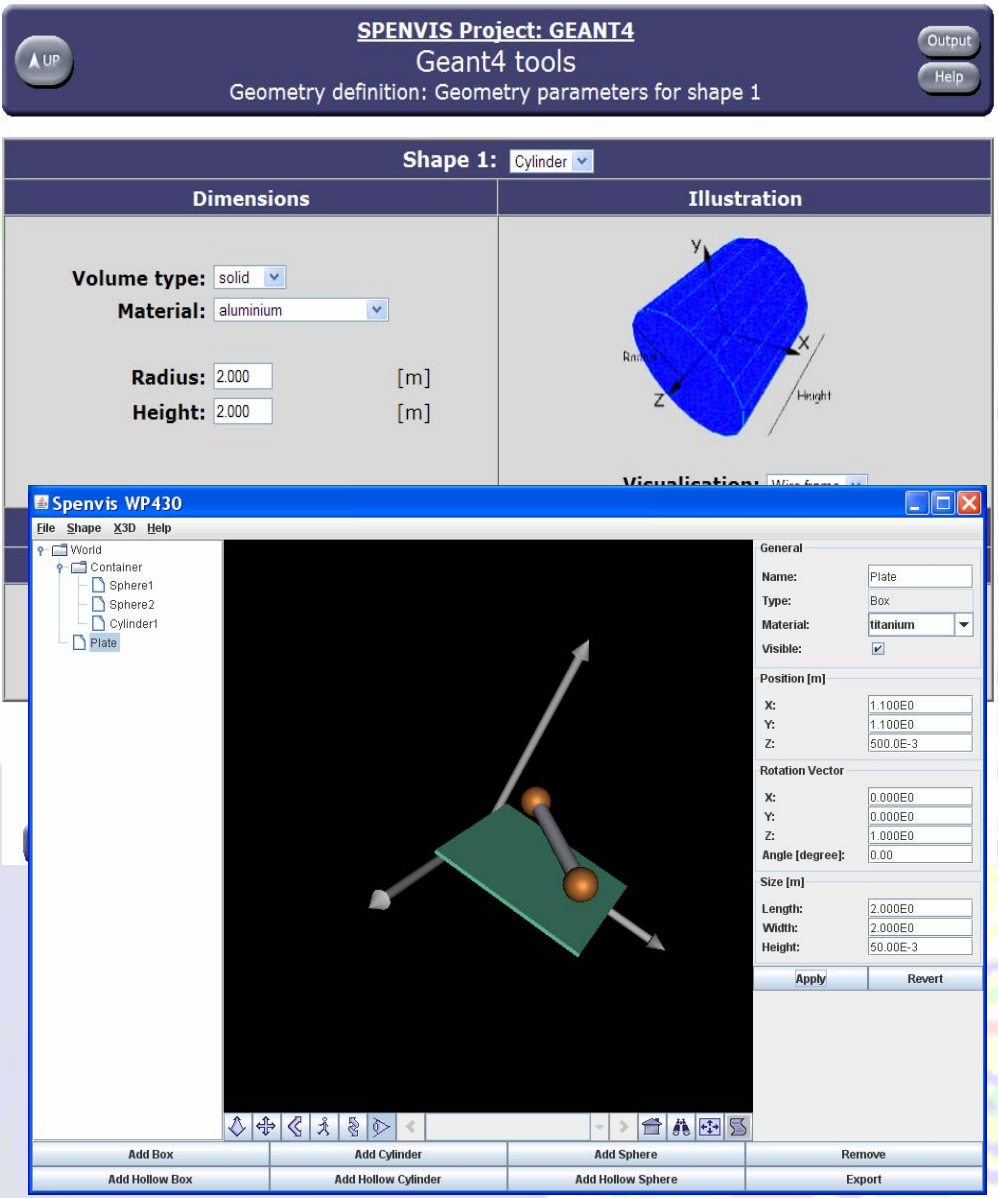


Common tools: Geometry definition tool



- Basic building blocks (sphere, box, cylinder) to construct 3D model.
- Create GDML file and VRML visualisation of the geometry definition.
- GDML upload SSAT only.

Common tools: Geometry definition tool



- Basic building blocks (sphere, box, cylinder) to construct 3D model.
- Create GDML file and VRML visualisation of the geometry definition.
- GDML upload SSAT only.
- Java version of geometry definition tool.

Future:

- Extension of GDML upload.

3. Updates & Current Developments

Updates & Current Developments: Overview

- Some recent modifications of the new user interface for Geant4 tools in SPENVIS
- JoveREM (third party)
- Implementation of Gras

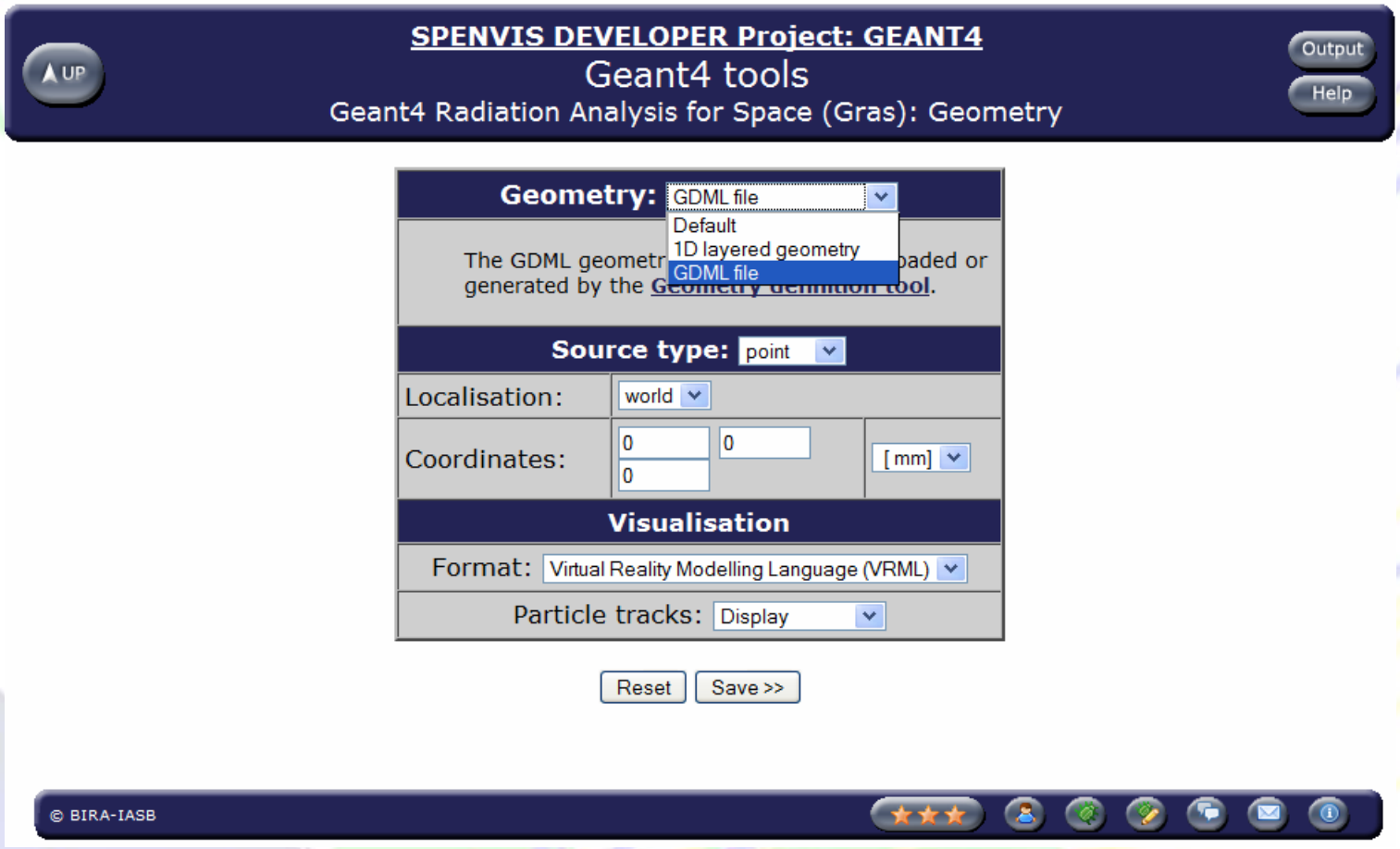
Updates & Current Developments : Gras

Geant4 Radiation Analysis for Space (Gras)

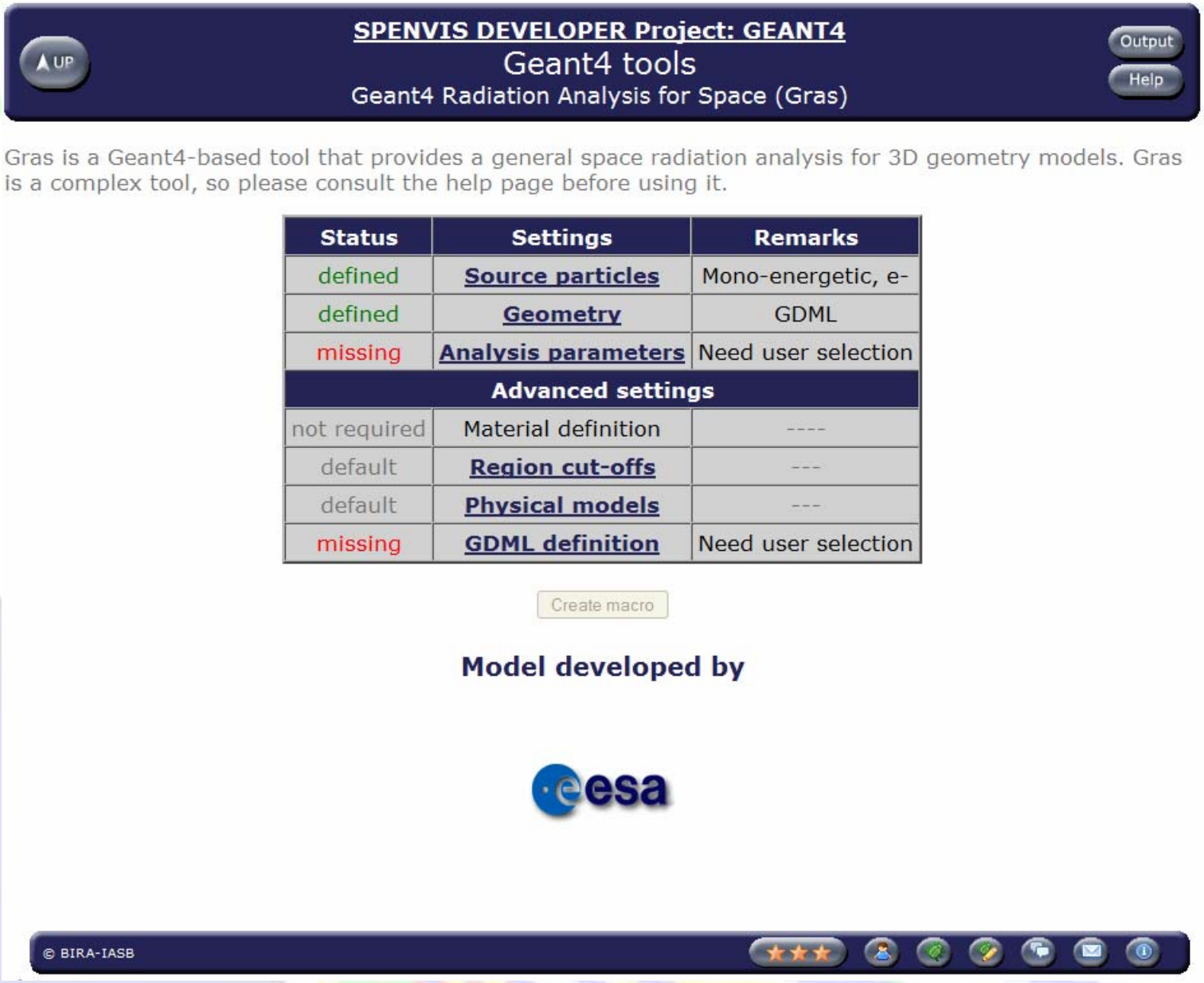
- Developed by ESA.
- Provides a general space radiation analysis for 3D geometry models.
- SPENVIS: Mulassis-like or GDML geometry
- Can directly include SPENVIS trapped particle or solar proton spectrum.
- **Outputs:**
  - Gras g4 macro file← SPENVIS
  - CSV result file
  - Gras log file
- Upload GDML file

Updates & Current Developments : Gras

Updates & Current Developments : Gras



Updates & Current Developments : Gras



UP

SPENVIS DEVELOPER Project: GEANT4

Geant4 tools

Geant4 Radiation Analysis for Space (Gras)

Output

Help

Gras is a Geant4-based tool that provides a general space radiation analysis for 3D geometry models. Gras is a complex tool, so please consult the help page before using it.

Status	Settings	Remarks
defined	Source particles	Mono-energetic, e-
defined	Geometry	GDML
missing	Analysis parameters	Need user selection
Advanced settings		
not required	Material definition	----
default	Region cut-offs	---
default	Physical models	---
missing	GDML definition	Need user selection

Create macro

Model developed by

esa

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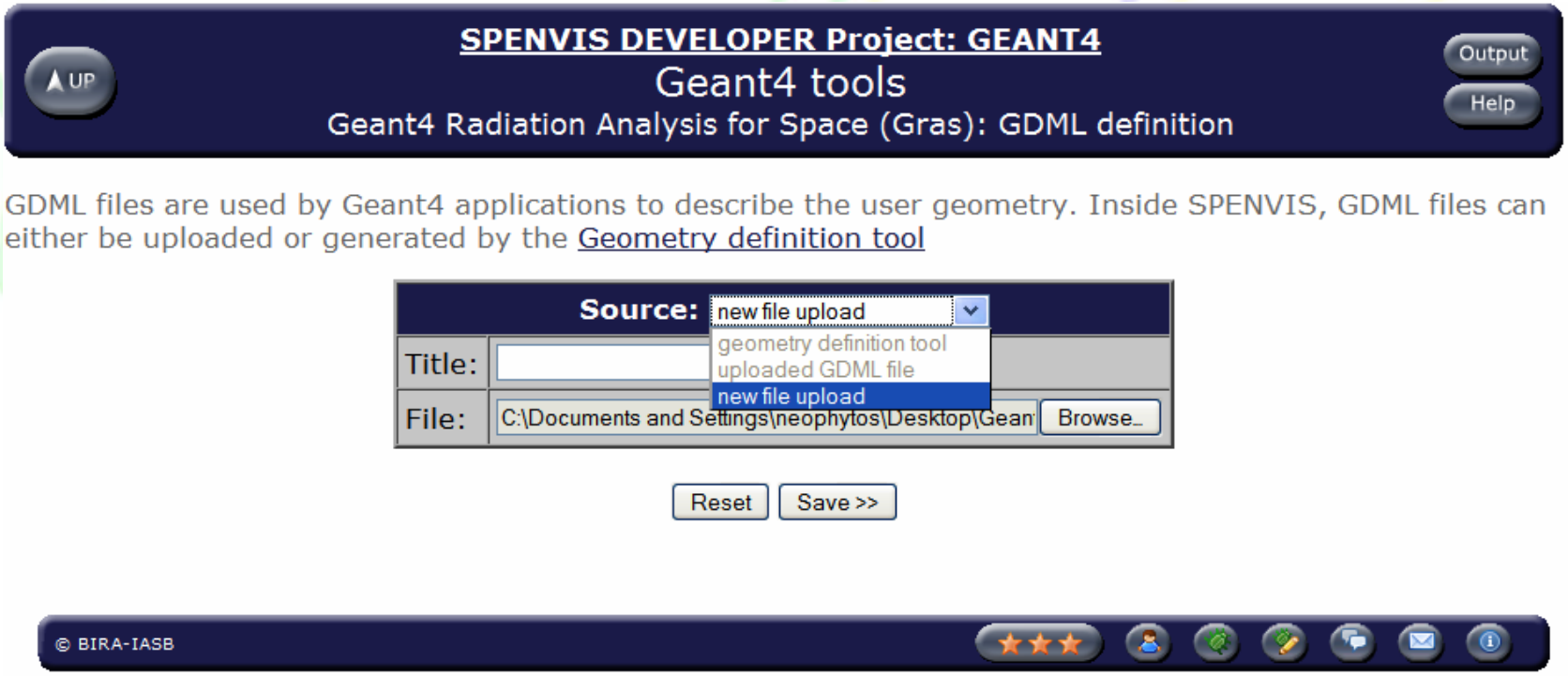
Updates & Current Developments : Gras



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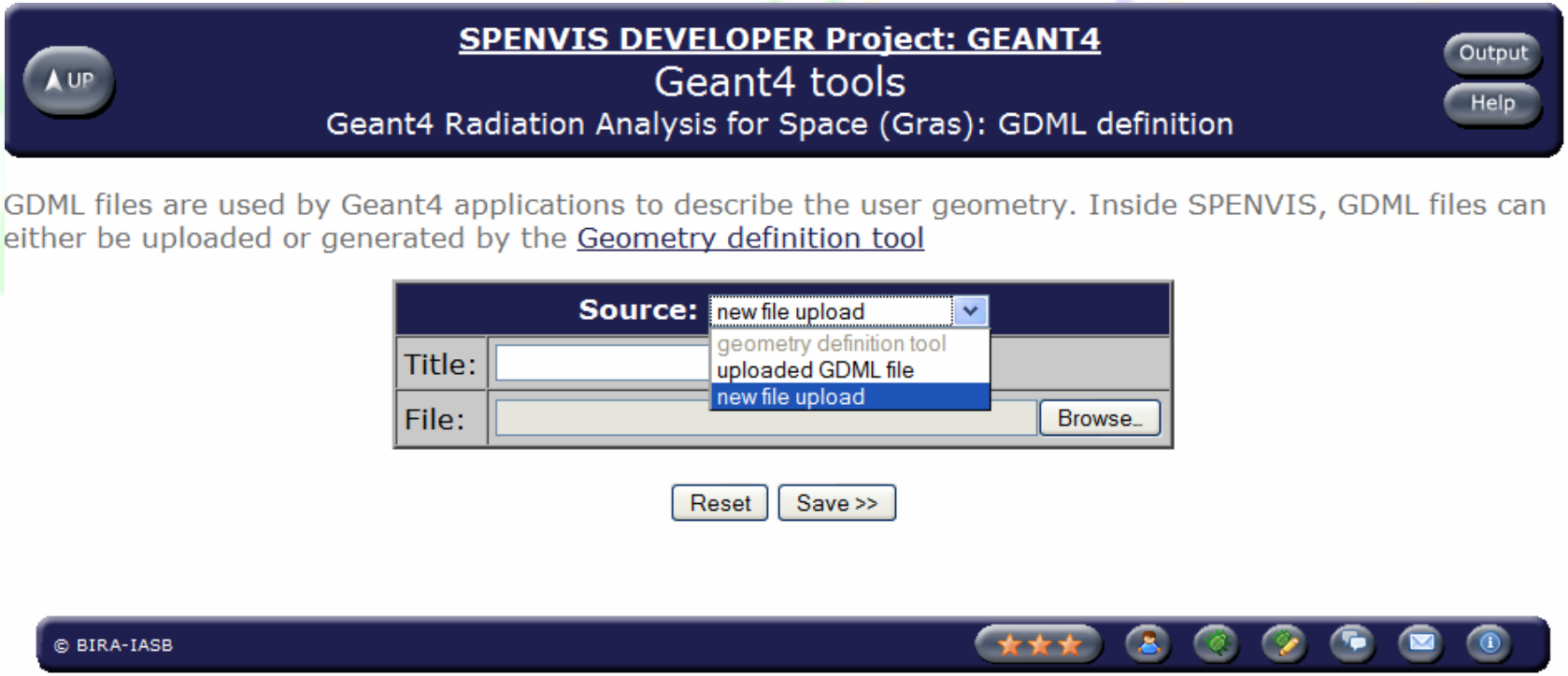

Updates & Current Developments : Gras

UP

SPENVIS DEVELOPER Project: GEANT4

Geant4 tools

Geant4 Radiation Analysis for Space (Gras)

Output

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Gras is a Geant4-based tool that provides a general space radiation analysis for 3D geometry models. Gras is a complex tool, so please consult the help page before using it.

Status	Settings	Remarks
defined	**Source particles**	Mono-energetic, e-
defined	**Geometry**	GDML
missing	**Analysis parameters**	Need user selection
Advanced settings		
not required	Material definition	----
default	**Region cut-offs**	---
default	**Physical models**	---
defined	**GDML definition**	upl, **Report file**

Create macro

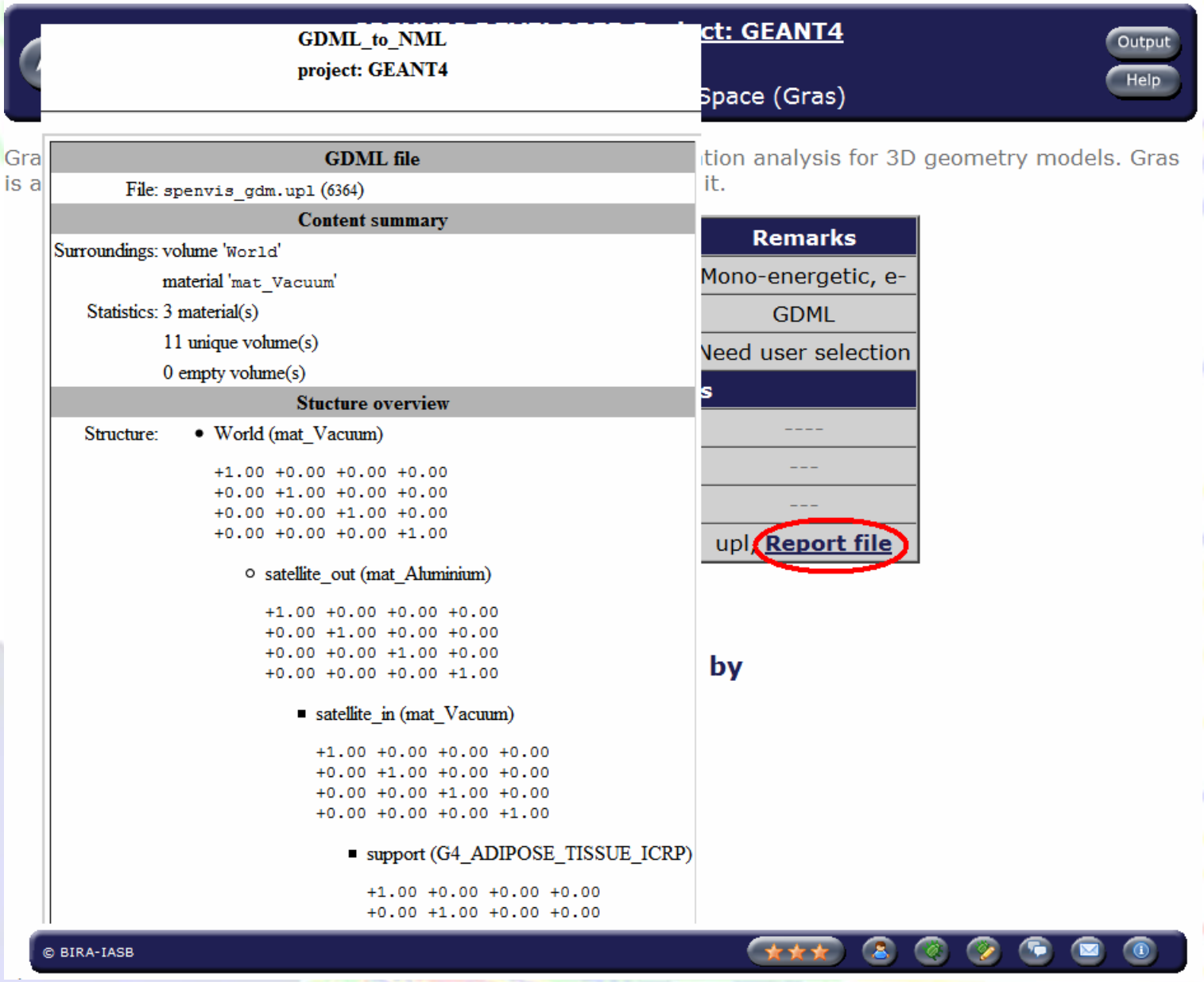
Model developed by

esa

aeronomie.be

.be

Updates & Current Developments : Gras



GDML_to_NML
project: GEANT4

ct: GEANT4
Space (Gras)
Output
Help

Gra ... tion analysis for 3D geometry models. Gras is a ... it.

GDML file

File: `spenvis_gdm.upl` (6364)

Content summary

Surroundings: volume '`World`'
material '`mat_Vacuum`'
Statistics: 3 material(s)
11 unique volume(s)
0 empty volume(s)

Stucture overview

Structure:
- World (mat_Vacuum)

```
+1.00 +0.00 +0.00 +0.00
+0.00 +1.00 +0.00 +0.00
+0.00 +0.00 +1.00 +0.00
+0.00 +0.00 +0.00 +1.00
```

  - satellite_out (mat_Aluminium)

```
+1.00 +0.00 +0.00 +0.00
+0.00 +1.00 +0.00 +0.00
+0.00 +0.00 +1.00 +0.00
+0.00 +0.00 +0.00 +1.00
```

    - satellite_in (mat_Vacuum)

```
+1.00 +0.00 +0.00 +0.00
+0.00 +1.00 +0.00 +0.00
+0.00 +0.00 +1.00 +0.00
+0.00 +0.00 +0.00 +1.00
```

      - support (G4_ADIPOSE_TISSUE_ICRP)

```
+1.00 +0.00 +0.00 +0.00
+0.00 +1.00 +0.00 +0.00
```

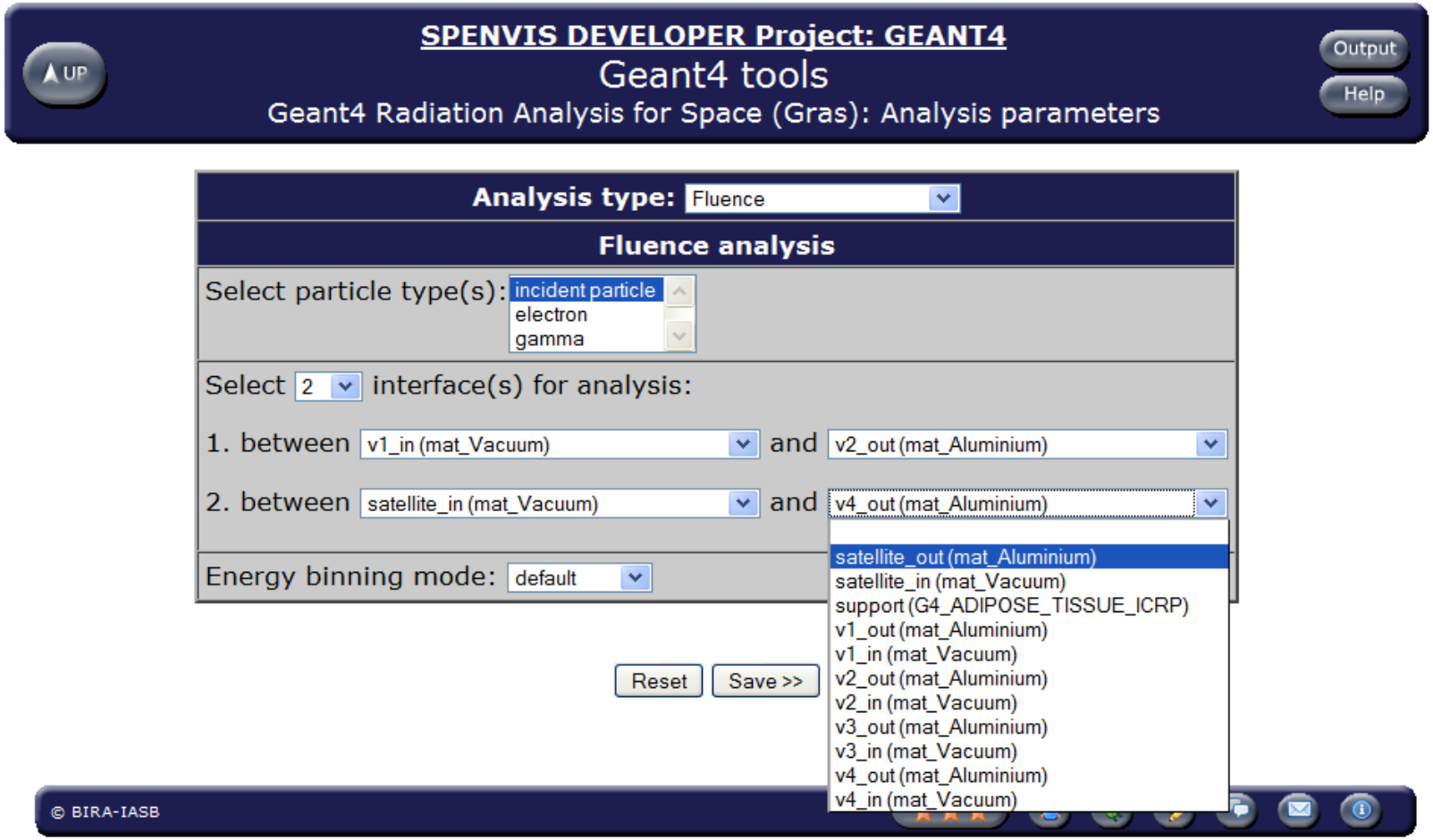
Remarks
Mono-energetic, e-
GDML
Need user selection
s

---
upl Report file

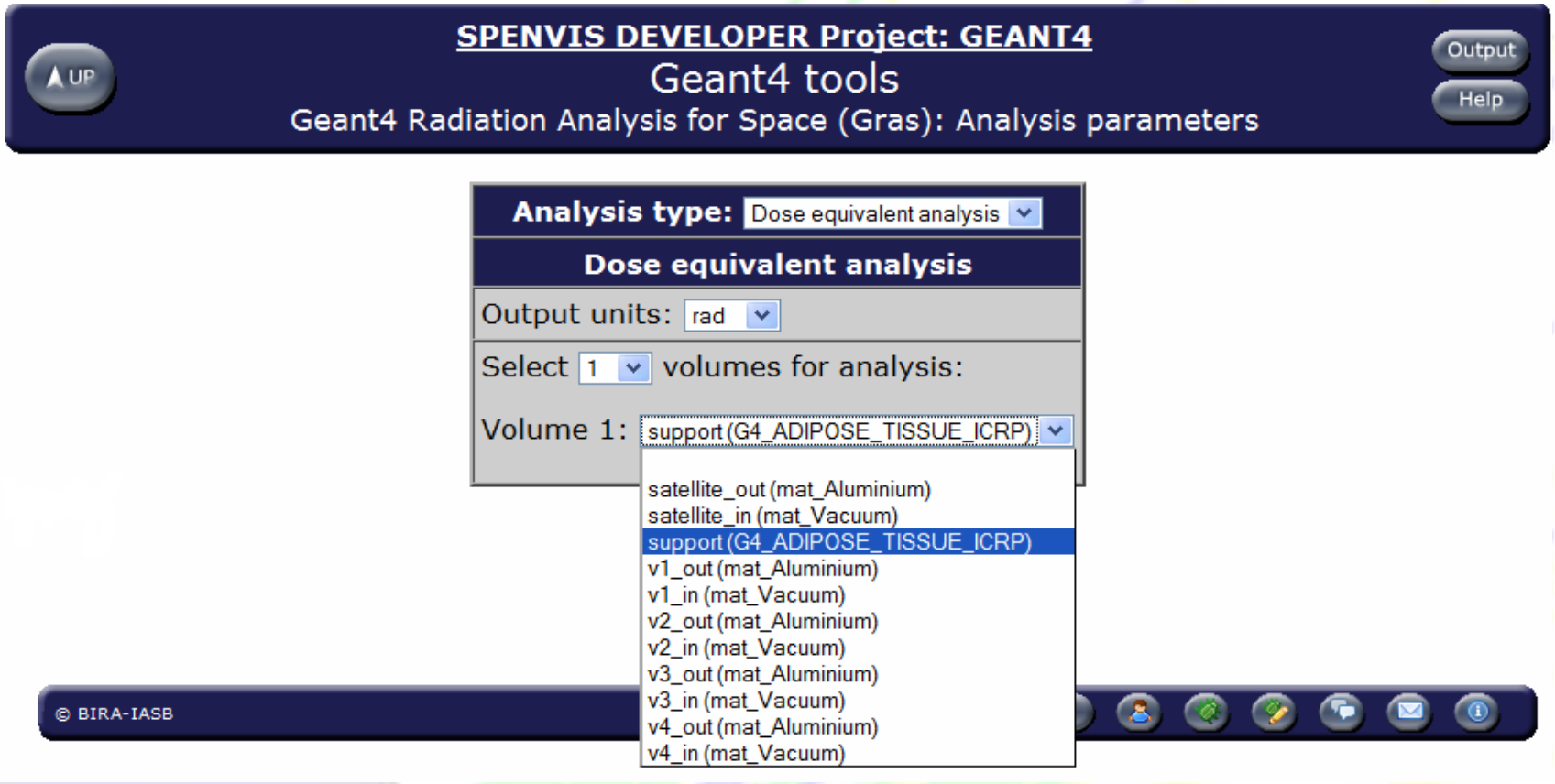
by

© BIRA-IASB

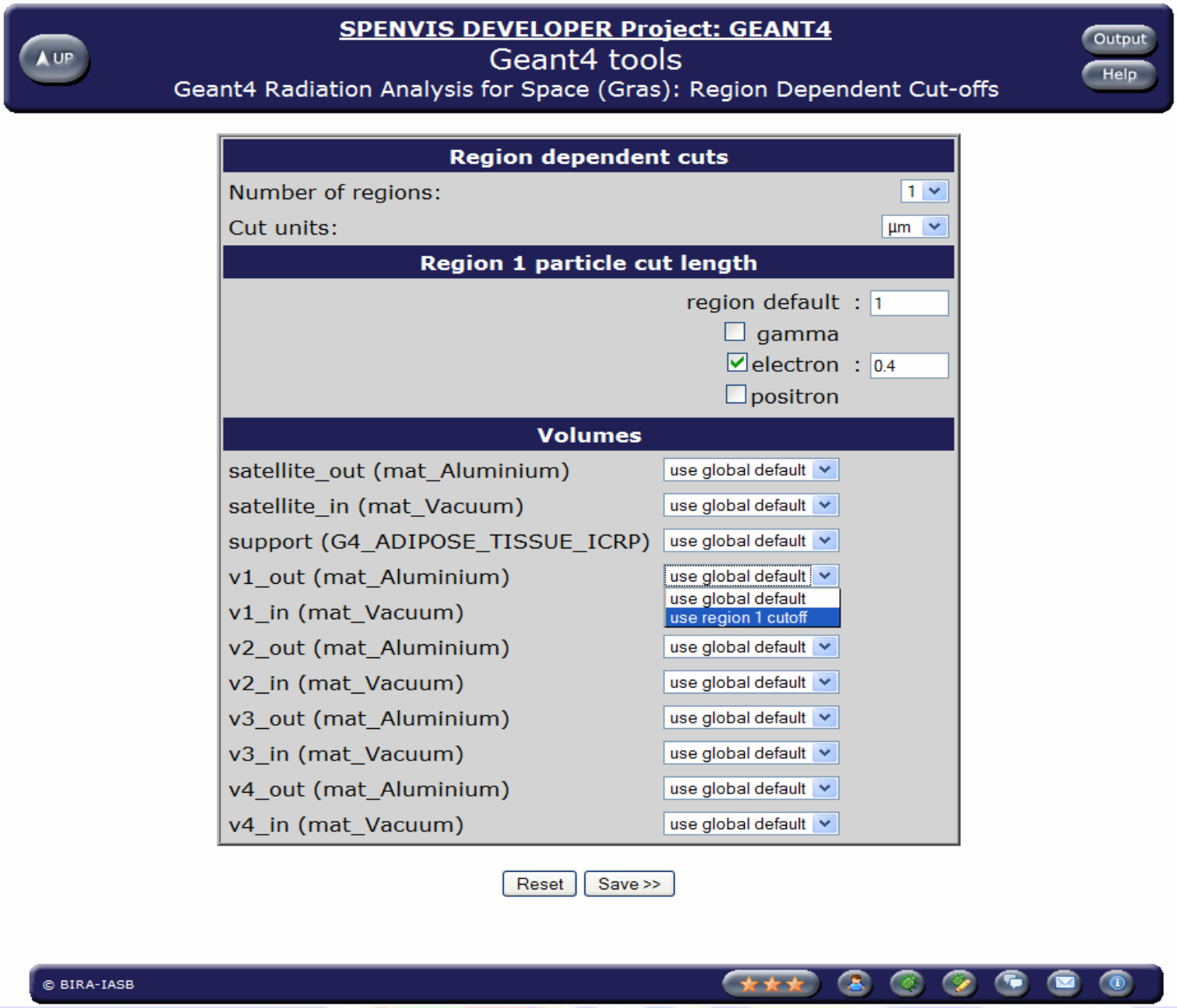
Updates & Current Developments : Gras



Updates & Current Developments : Gras



Updates & Current Developments : Gras



Updates & Current Developments : Gras

UP

SPENVIS DEVELOPER Project: GEANT4

Geant4 tools

Geant4 Radiation Analysis for Space (Gras)

Output

Help

Gras is a Geant4-based tool that provides a general space radiation analysis for 3D geometry models. Gras is a complex tool, so please consult the help page before using it.

Status	Settings	Remarks
defined	**Source particles**	Mono-energetic, e-
defined	**Geometry**	GDML
defined	**Analysis parameters**	Dose equivalent analysis
Advanced settings		
not required	Material definition	----
defined	**Region cut-offs**	1 region
defined	**Physical models**	Standard EM, No hadron
defined	**GDML definition**	upl, **Report file**

Create macro

Model developed by

esa

aeronomie.be

.be

Conclusions

- User friendly interface to Geant4 applications.
- Some difficulties during implementation:
  - macro command dependencies
  - model specific commands
  - static version of the model
- Interaction with Geant4 developers community.
- Gras will be available with a forthcoming release of SPENVIS!