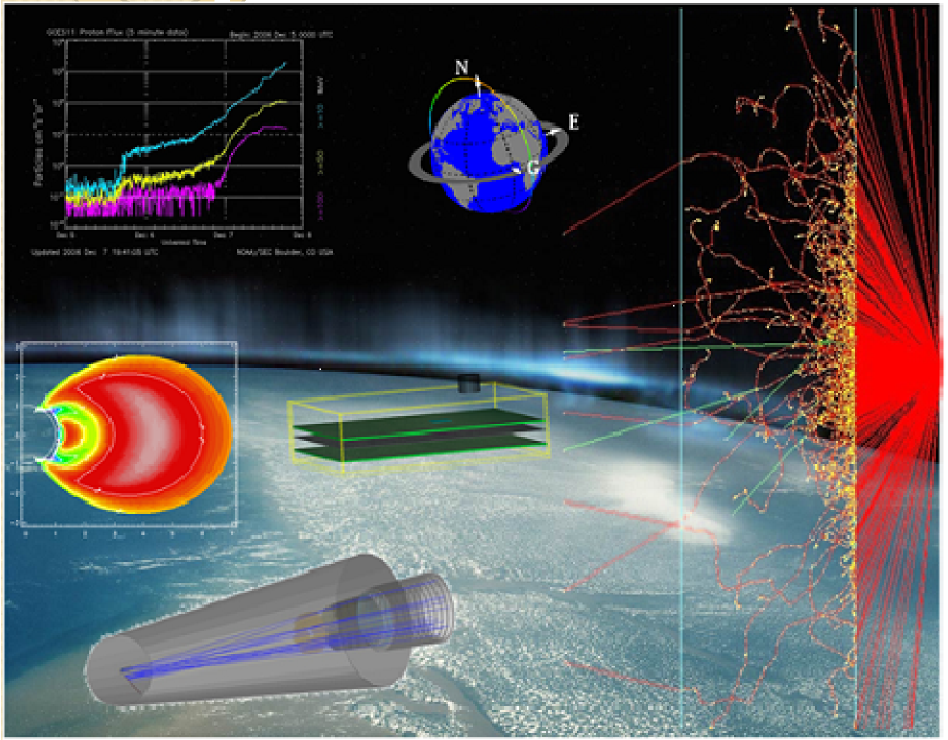

An Introduction to the REST-SIM Simulation Framework

Fan Lei
RadMod Research

(and the REST-SIM project team)

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Contents

Cosmic Vision Missions programme

ESA's science missions for 2015-2025:

- Over 150 missions have been proposed
- 4 missions have been selected so far:
  - L class: JUICE (L1,2022)
  - M class: Solar Orbiter (M1, 2017), Euclid (M2, 2020)
  - S class: CHEOPS (S1,2017)
- Other L class candidates:
  - IXO/ATHENA: Advanced Telescope for High Energy Astrophysics
  - LISA/NGO: New Gravitational wave Observatory
- New M3 studies:
  - EChO (Exoplanet Characterisation Observatory)
  - STE-QUEST (Space-Time Explorer and Quantum Equivalence Principle Space Test)
  - MarcoPolo-R (Asteroid sample return)
  - LOFT (Large Observatory For X-ray Timing)
  - PLATO (PLAnetary Transits and Oscillations of stars)

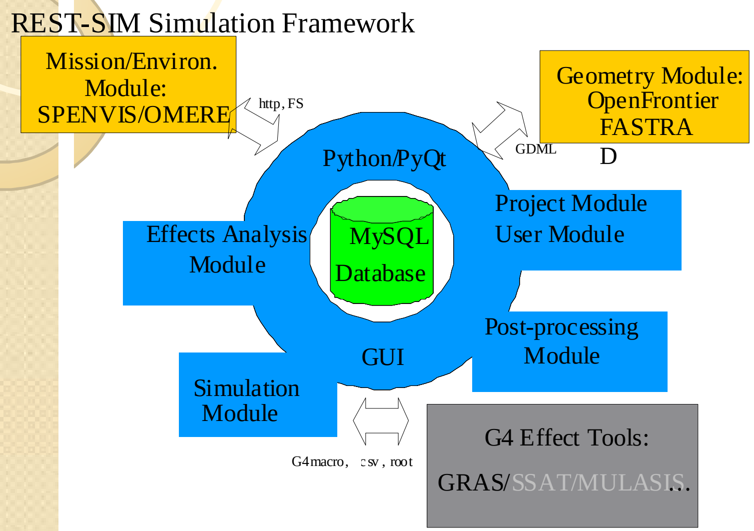
REST-SIM Project

Radiation Effects on Sensors and Technologies for Cosmic Vision Missions (CVM)

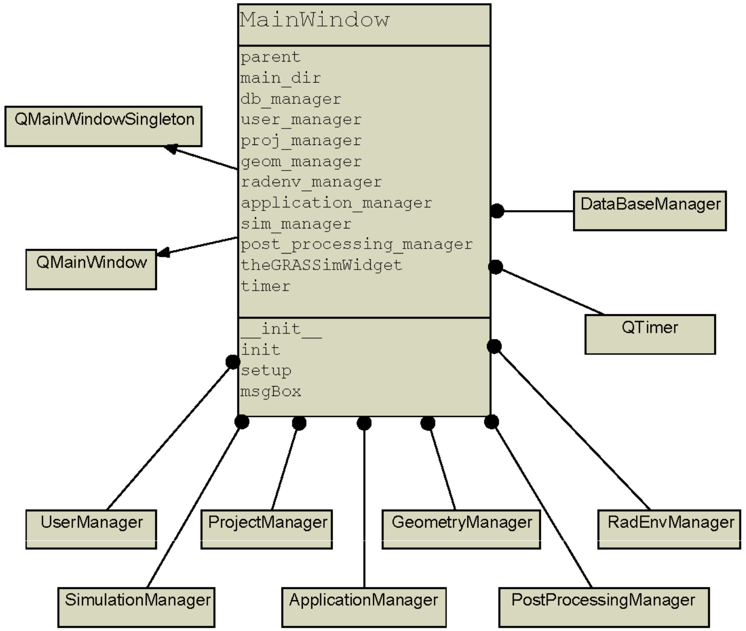
- Main objectives:
  - Survey of the proposed CVM technologies and review their radiation susceptibility
  - Review existing radiation effects analysis tools and capture the SF requirements
  - Design and implement the SF
  - Demonstrate the SF capabilities
- The project team:
  - QinetiQ (now RadMod), etamax, SpaceIT, DHC and UCL/CSR
  - ESA technical officers: Giovanni Santin & Petteri Nieminen
- Main development activities have been completed in 2012

http:/spitfire.estec.esa.int/trac/REST-SIM

REST-SIM Simulation Framework



Top level design



Main class diagram

Key s/w technologies:

- Python and PyQT – main programming lang. and GUI
- GRAS/Geant4 – particle transport and effects simulation tool
- OpenCascade – geometry modelling
- NumPy, SciPy & Matplotlib – post-processing
- MySQL – internal database

Main tools:

- Eclipse/Pydev, QtDesigner

REST-SIM SF Components

- **User manager**: sets up a single user (anonymous, without login) or multi user environment (with registration and login)
- **Project manager**: all configuration and run parameters, user inputs, run results, post-processing products, ... are organised in projects.
- **Environment manager:** set up connections to a SPENVIS server and import environment spectra from SPENVIS, OMERE or via direct user file import.
- **Geometry manager:** import GDML files or set up, run and import files from ESABASE2 and FASTRAD.
- **Application manager:** set up the parameters for the selected effects tool.
- **Simulation manager:** define host environments for simulation runs and schedule the run execution
- **Post-processing manager:** visualise and plot results, apply response functions and user defined functions.
- **Database:** storage of user defined parameters, imported and generated files, simulation setup and progress, ...

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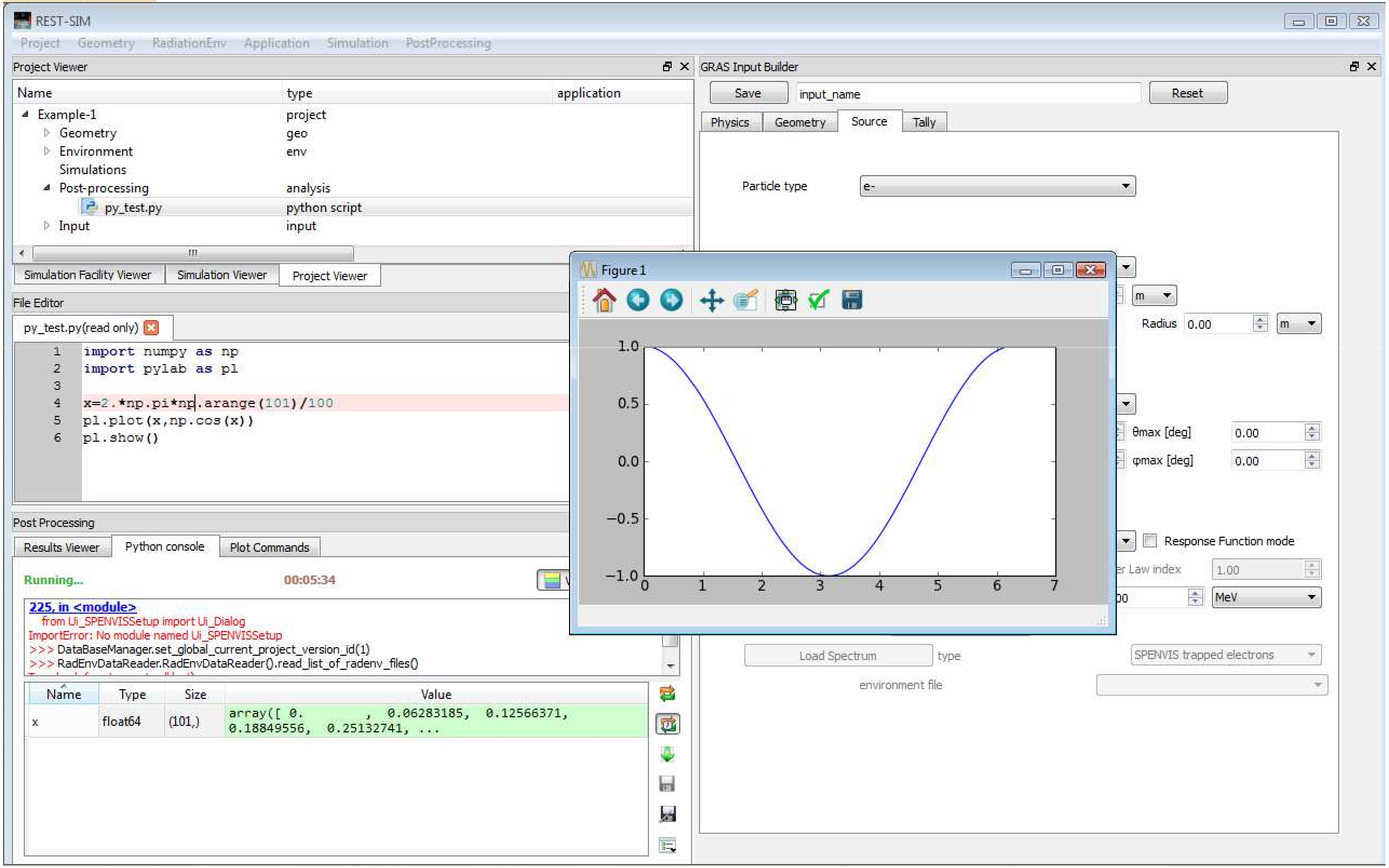
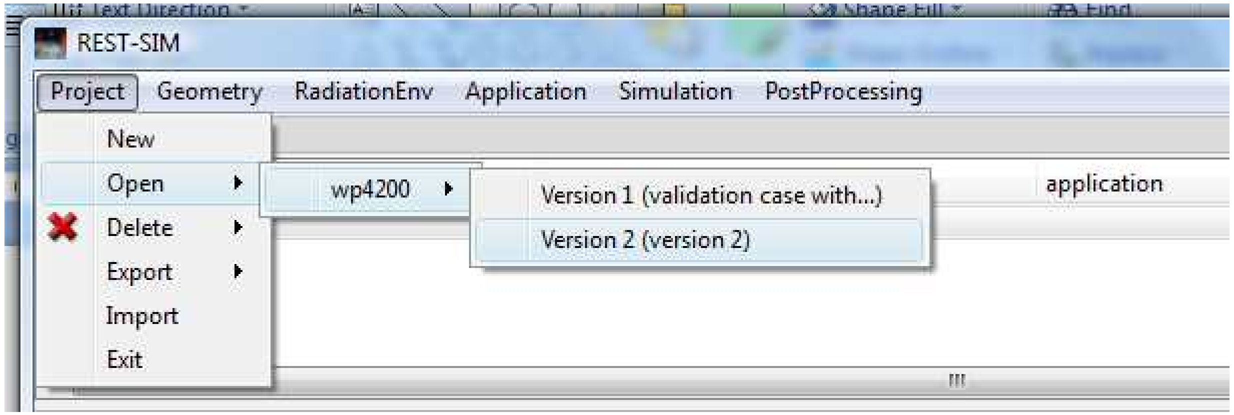
REST-SIM SF GUI

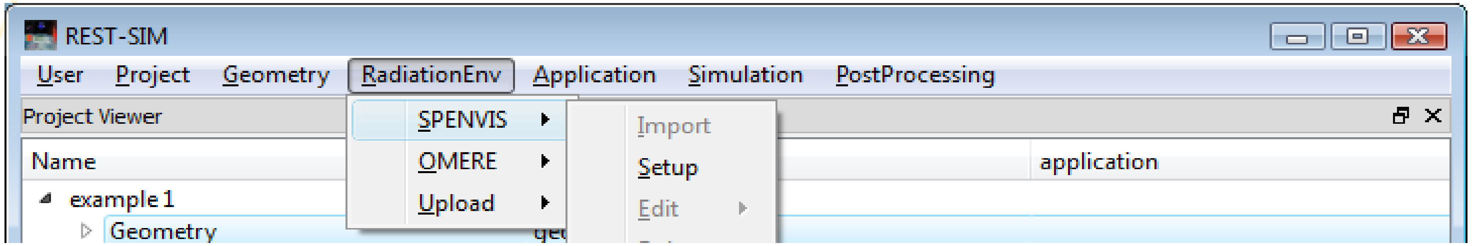


Project manager



- Create new and delete existing projects
- Create and delete project versions: creates a copy from a selected base version
- Share/unshare project versions with other users
- Block/unblock project versions
- Export/import projects: write/read all project files into/from a directory tree on disk
- Project viewer: GUI panel listing project version files with right-click actions: view, edit, delete, run, ...

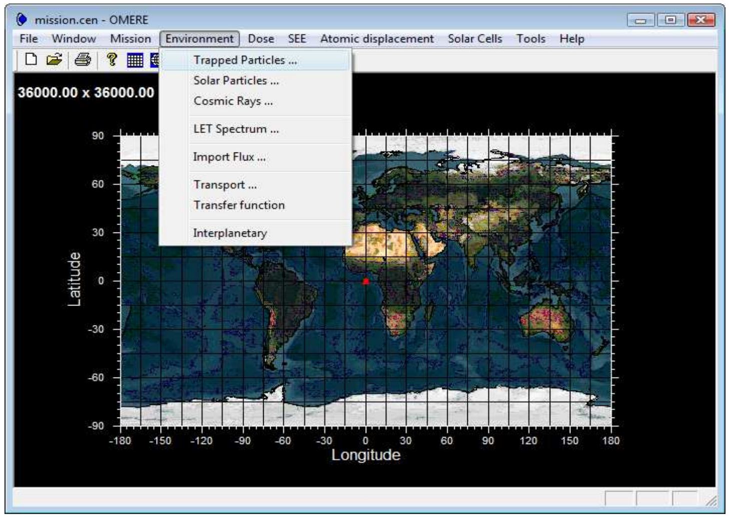
RadEnv Manager

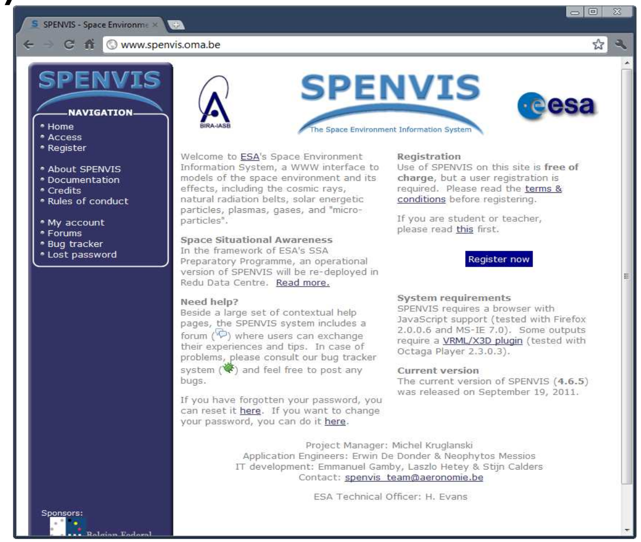


Mission environments can be modelled using SPENVIS and OMERE

- run from REST-SIM
- environ. data are imported and saved in the project database

User can also upload environ. specifications directly





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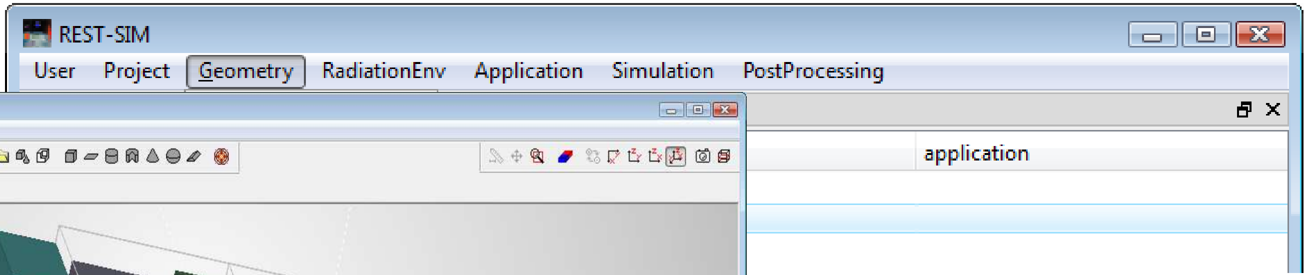
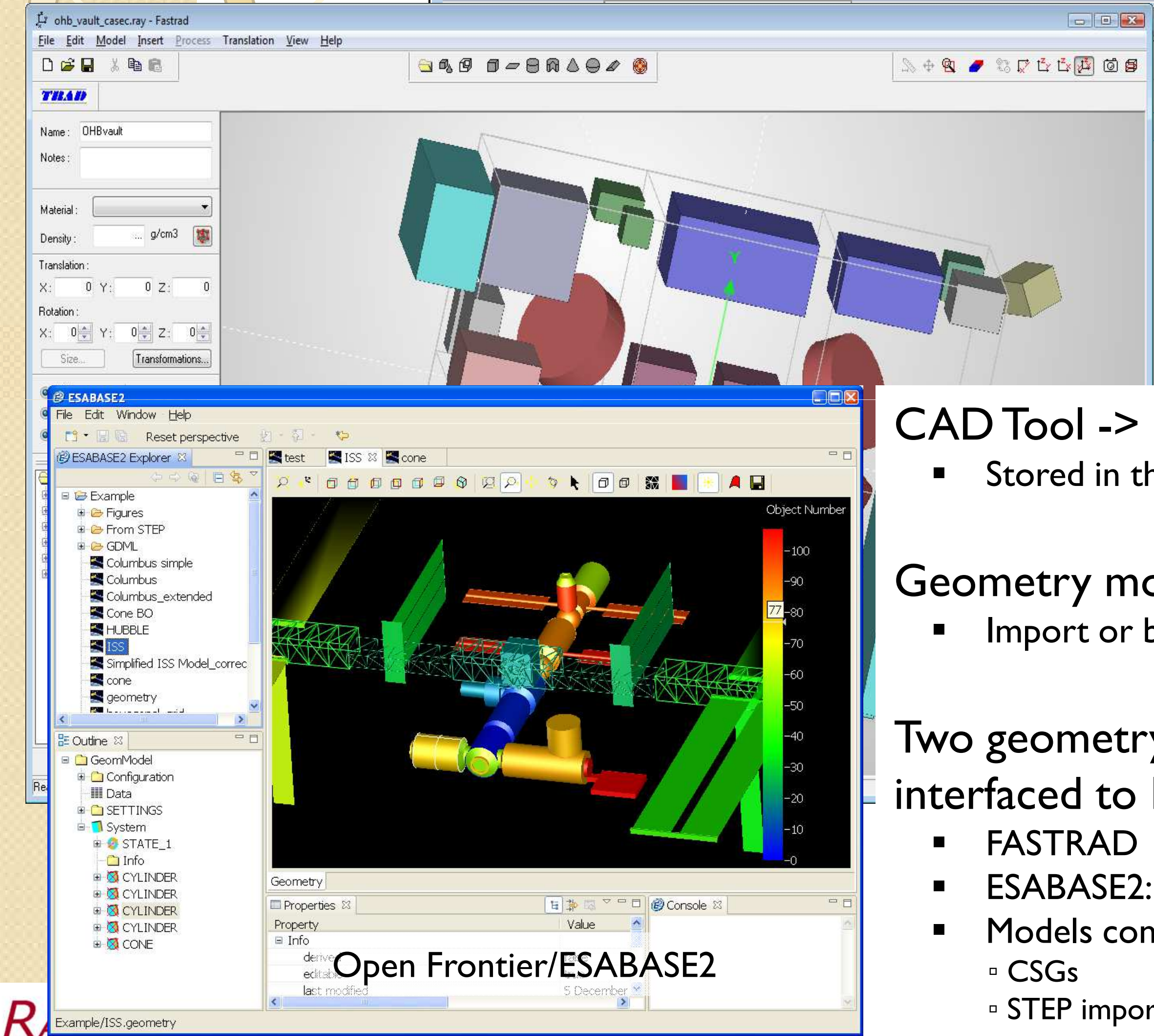
Geometry Manager





CAD Tool -> GDML -> Geant4:

- Stored in the database in GDML format

Geometry modelling:

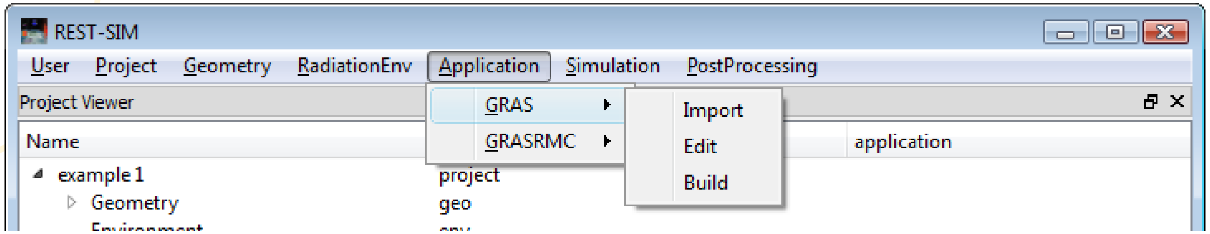
- Import or building from scratch

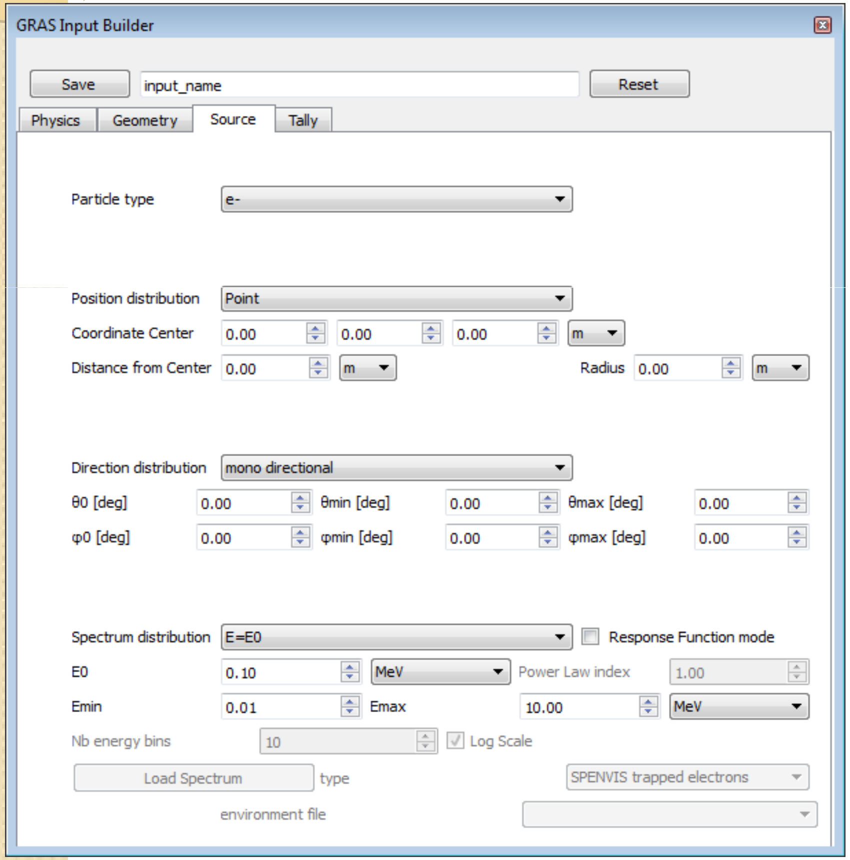
Two geometry modelling tools have been interfaced to REST-SIM:

- FASTRAD
- ESABASE2: many new developments for REST-SIM
- Models constructed from
  - CSGs
  - STEP import

Research

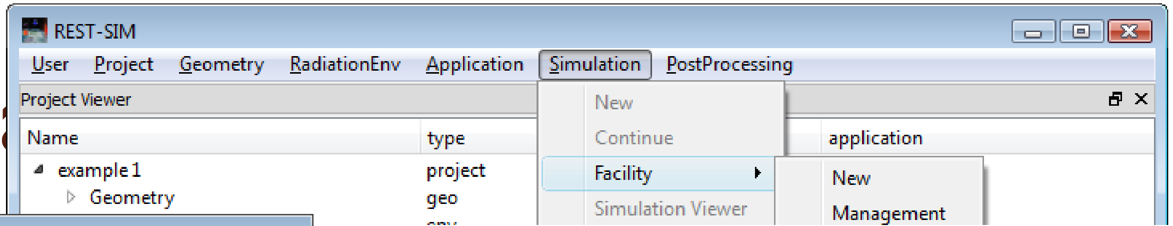
Application/Effects Analysis Manager

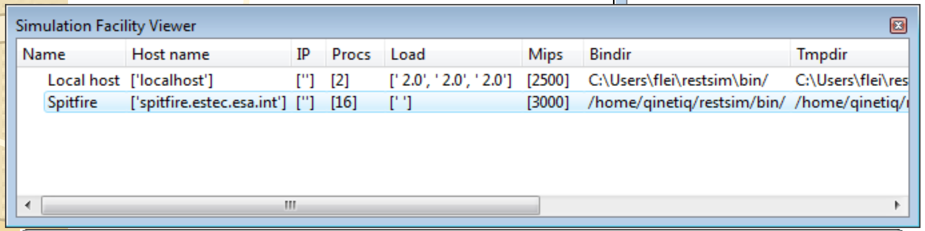


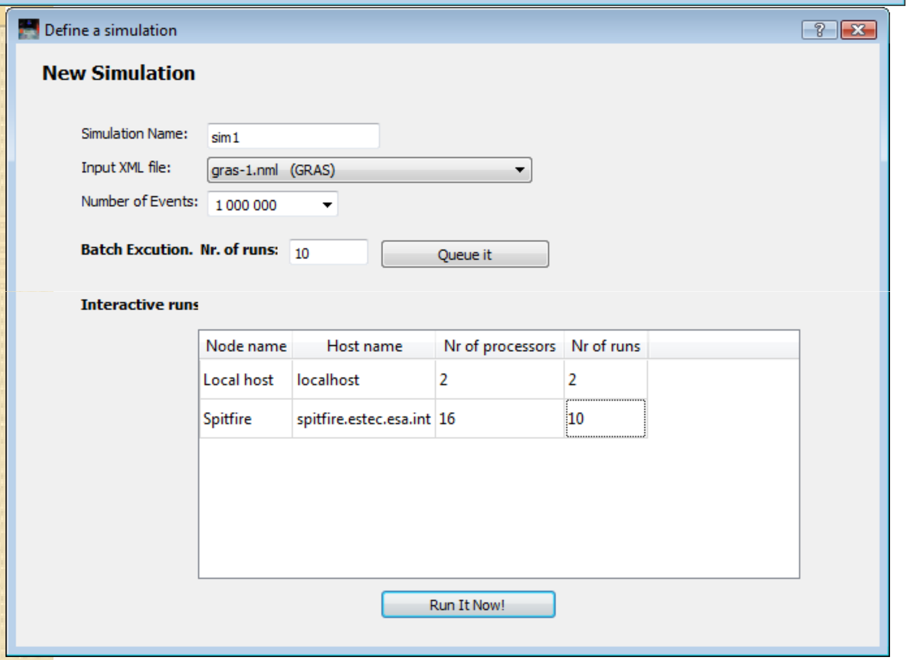


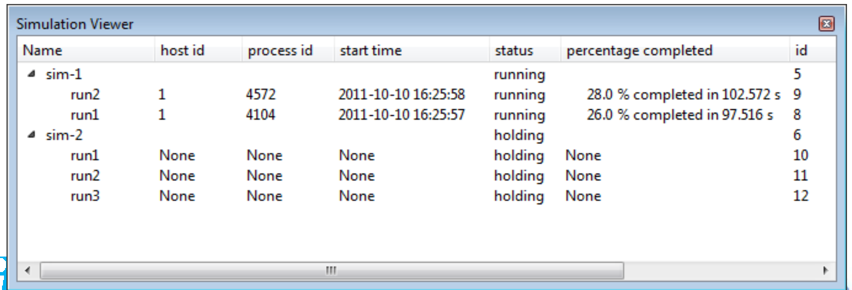
- Geant4 based analysis tools:
  - GRAS
  - GRASRMC
  - (MULASSIS, SSAT, PLANETOCOSMICS)
- Geometry and Environment from the database
- Full control of Geant4 physics
- Type of effects/analysis:
  - Fluence/Current -- Dose
  - PHS -- Dose_equivalent
  - Equivalent_dose -- LET
  - NIEL -- Path_Length
  - Charging -- Charge_collection
- Parametric and Templated analysis

Simulation Man



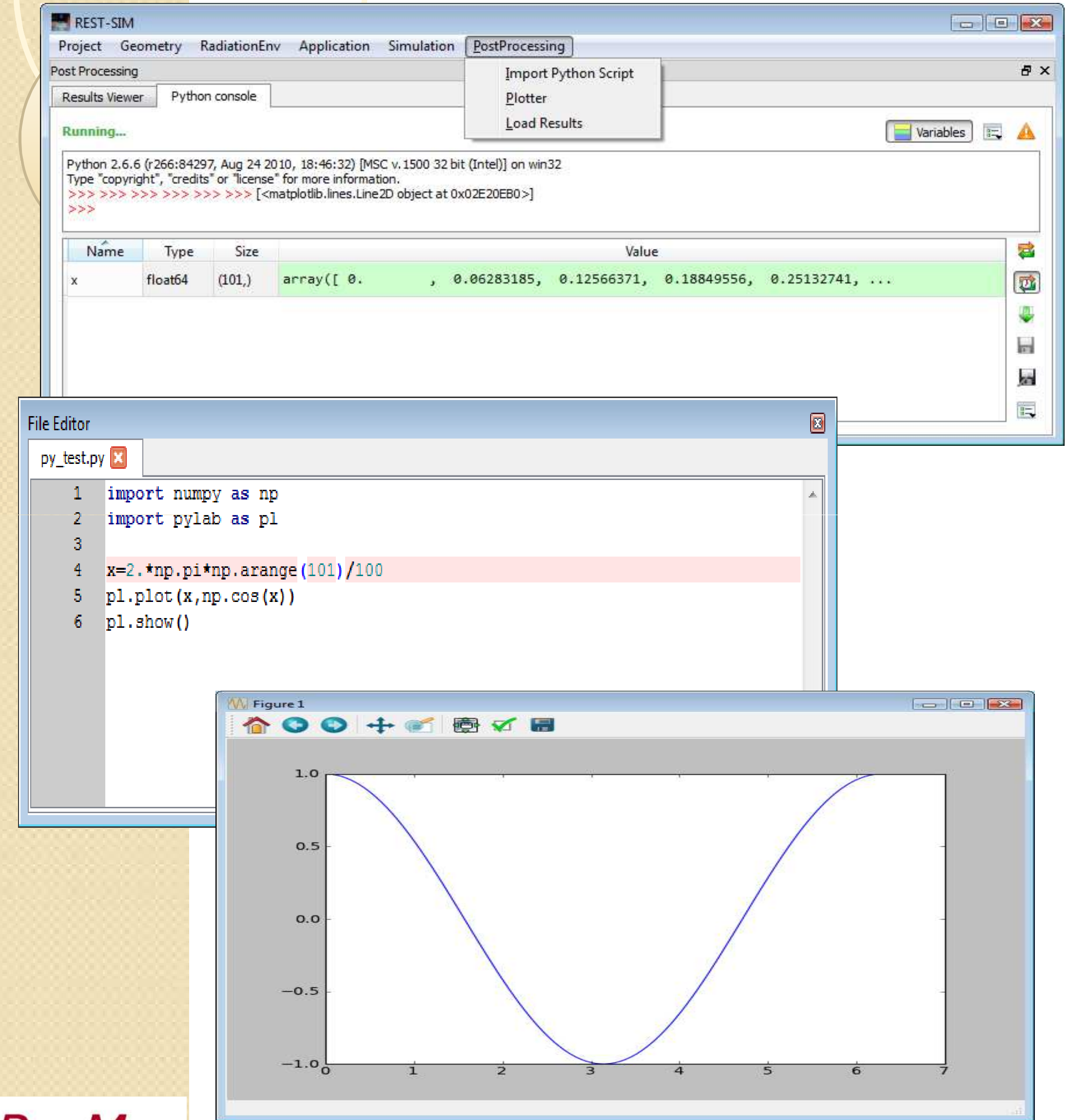






- Simulation facilities:
  - Local host, or/and remote (SSH)
  - Linux, or/and Windows (local)
- Two execution modes:
  - Interactive, forced runs
  - Batch queue
- Automated parallelisation:
  - Load balance
  - Results - auto collection, merge
- Execution monitoring/management:
  - Check progress: % completed
  - Stop/Kill/Remove

Post-processing manager



Interactive Python scripts

- NumPy, SciPy, Matplotlib
- Python console and editor

Plotting:

- 1d/2d histograms

Post-processing:

- Operation on histograms
- Derivative parameter analysis
- Analysis based on response functions
- …

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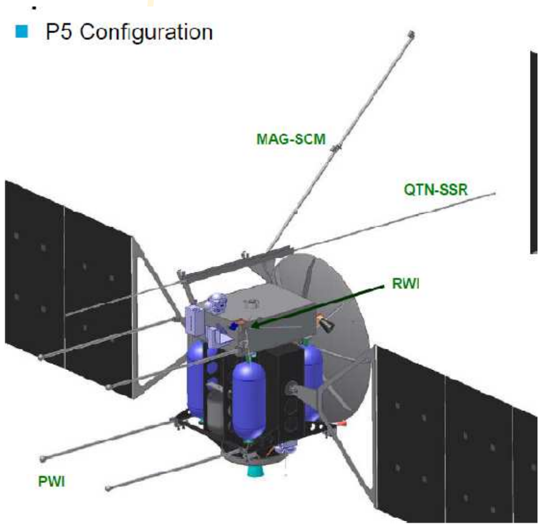
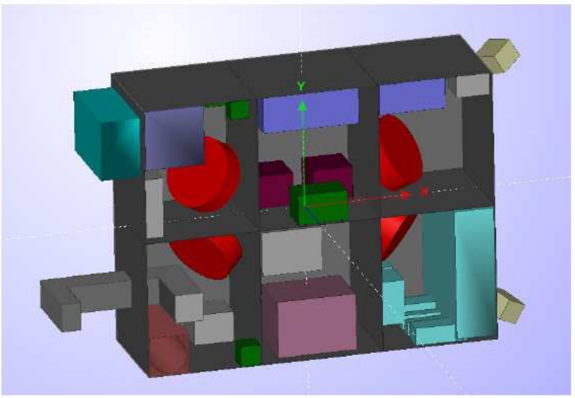
Demonstration Application: JUICE



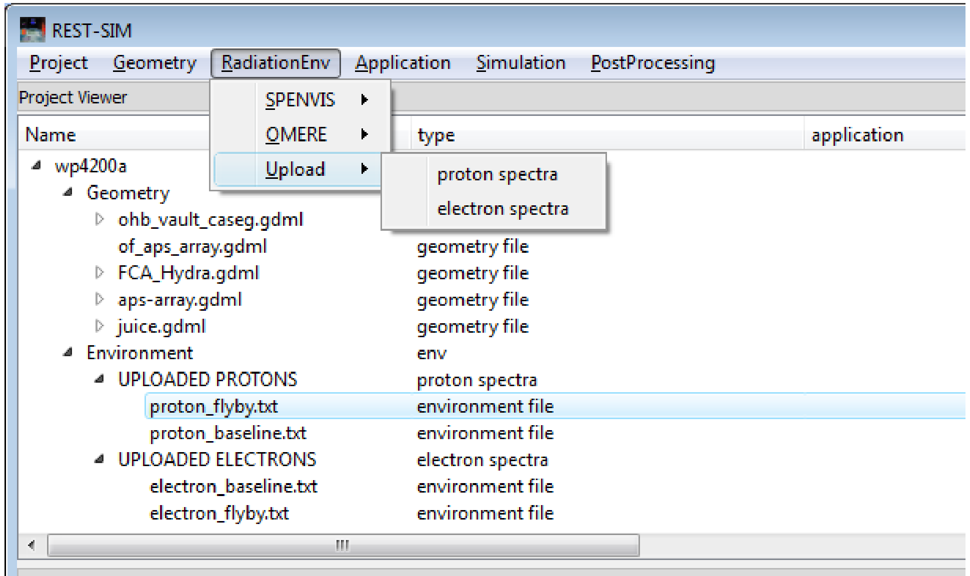


- Two demonstration applications:
  - JUICE
  - Solar Orbiter
- JUICE:
  - Environments: ESA specifications
  - Geometry Model:
    - Simplified OHB study configuration
    - Detailed geometry model of the StarTracker/APS
    - Modelled with FASTRAD
  - Analysis:
    - TID the APS/StarTracker, and others
    - Comparison with SSAT results

JUICE - Environments

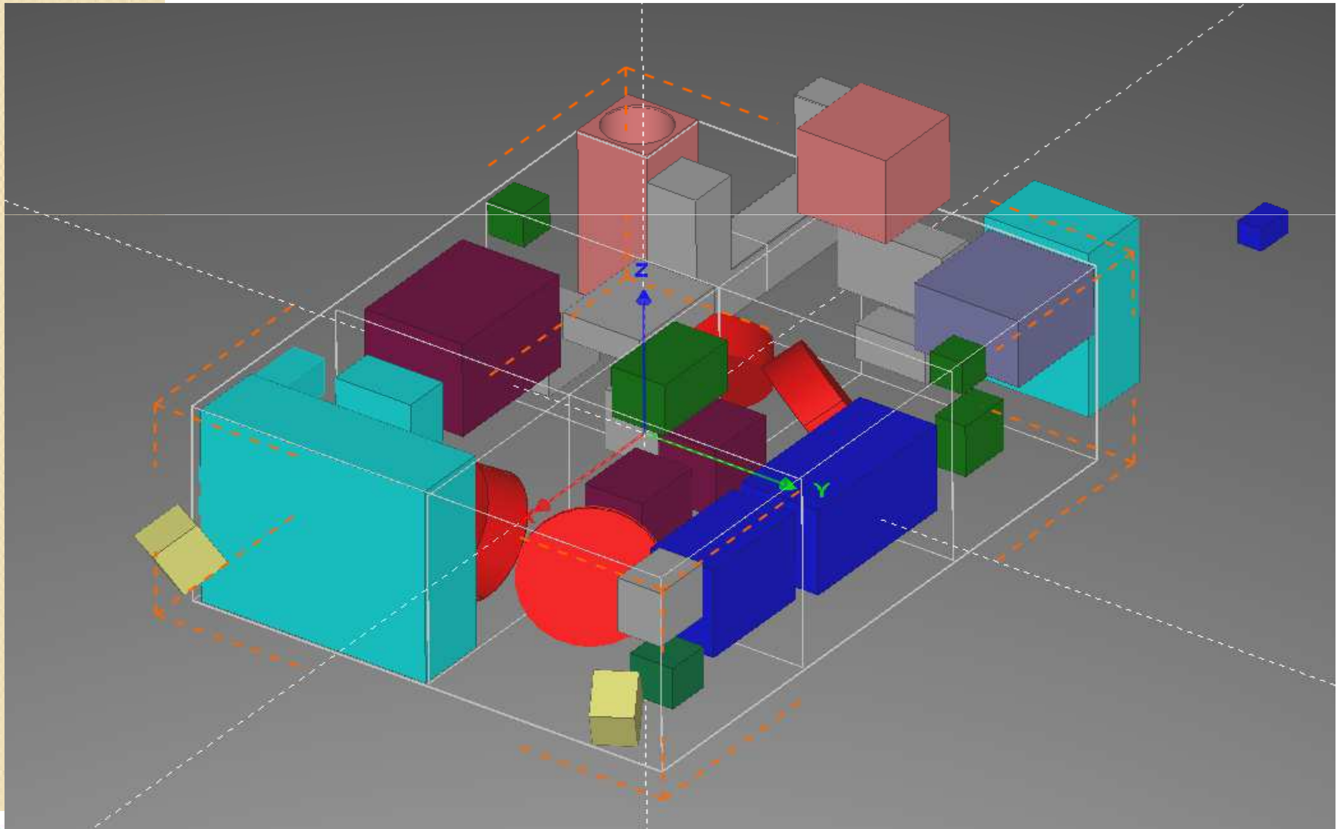
- ESA Specification:
  - Memorandum on ‘Radiation Environment Specification for Jupiter Mission Reformulation Activities’ (SRE-PA/2011.050/CE issue 1.3, 10/08/2011)
- Two mission scenarios:
  - Baseline: Callisto + Ganymede
  - Flybys: No Callisto + 2 Europa flybys
- Total proton and electron fluence spectra
  - proton_basline.txt
  - proton_flyby.txt
  - electron_basline.txt
  - electron_flyby.txt

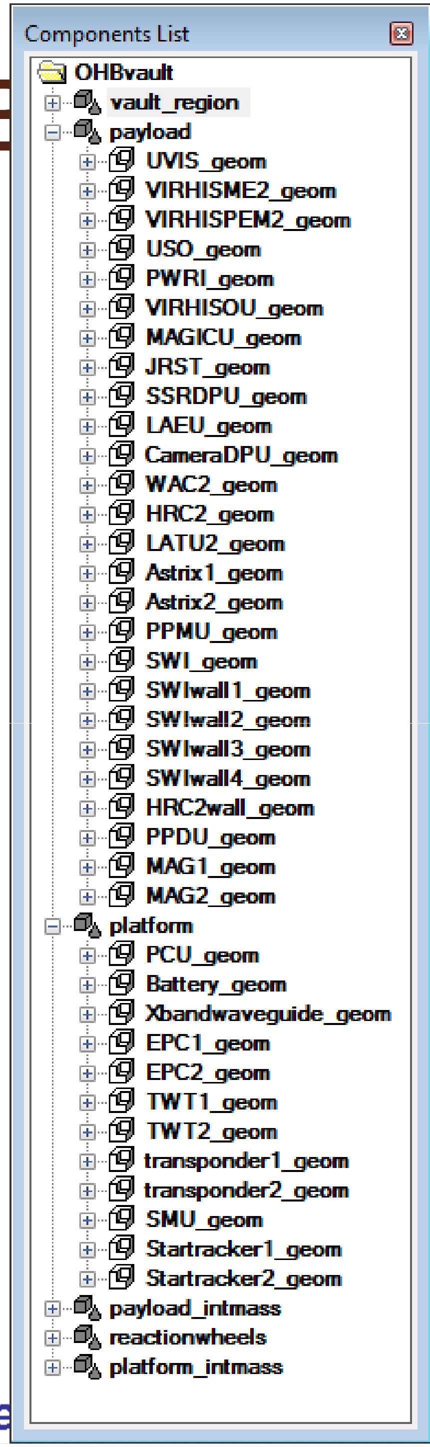
- proton_flyby.txt
- # JUICE flyby proton fluence
- # Energy spectrum
- #   Energy   Differential_flux   Integrated_flux
- #   (MeV)   (MeV-1.cm-2.sr-1)   (cm-2.sr-1)
- 0.1   1.17E+14   2.48514E+13
- 0.2   4.79E+13   1.56082E+13
- ….
- ….
- 400   5.45E+04   7812679.029
- 500   2.34E+04   4144082.801
- 700   6.61E+03   1751316.074
- 1000   1.57E+03   716314.2436



JUICE Geometry: QinetiQ/OHB

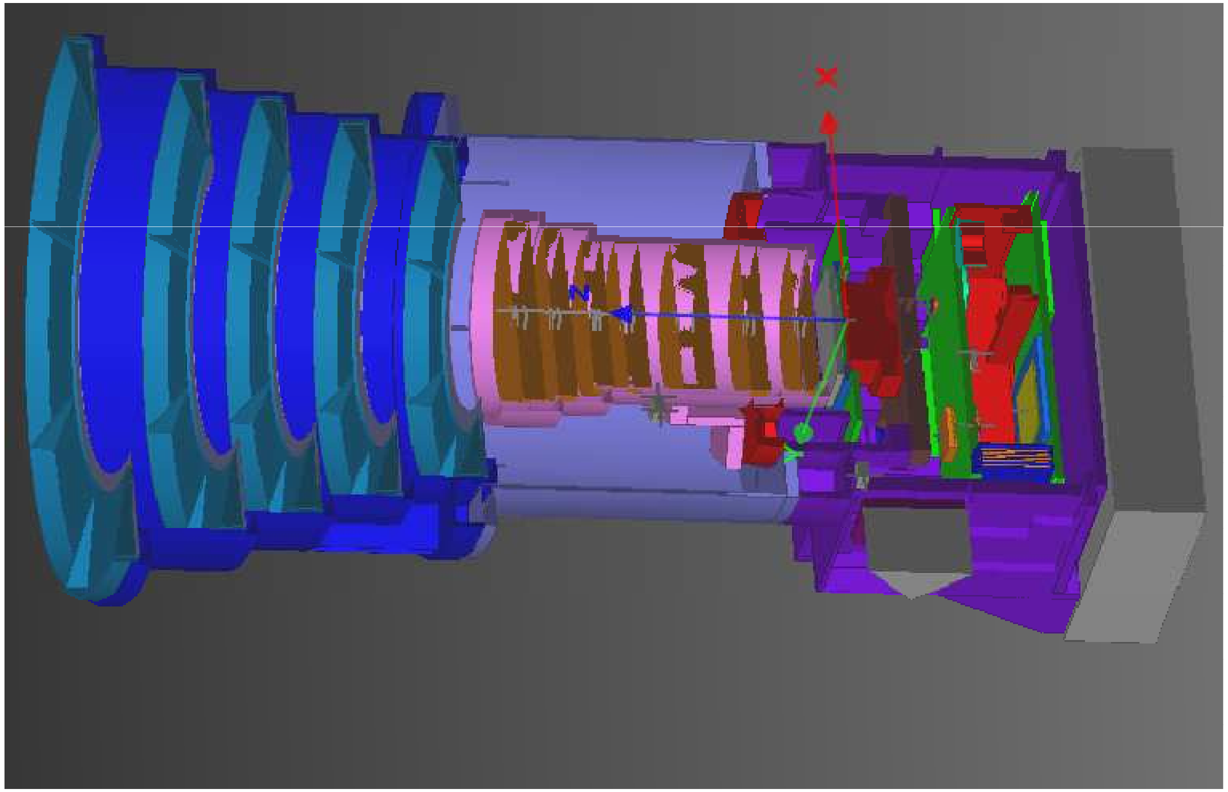
- A FASTRAD model of the service and payload modules of JUICE have been created using FASTRAD, based on the results of a separate study by OHB/QINETIQ
  - Most components are housed in a vault which is not shown



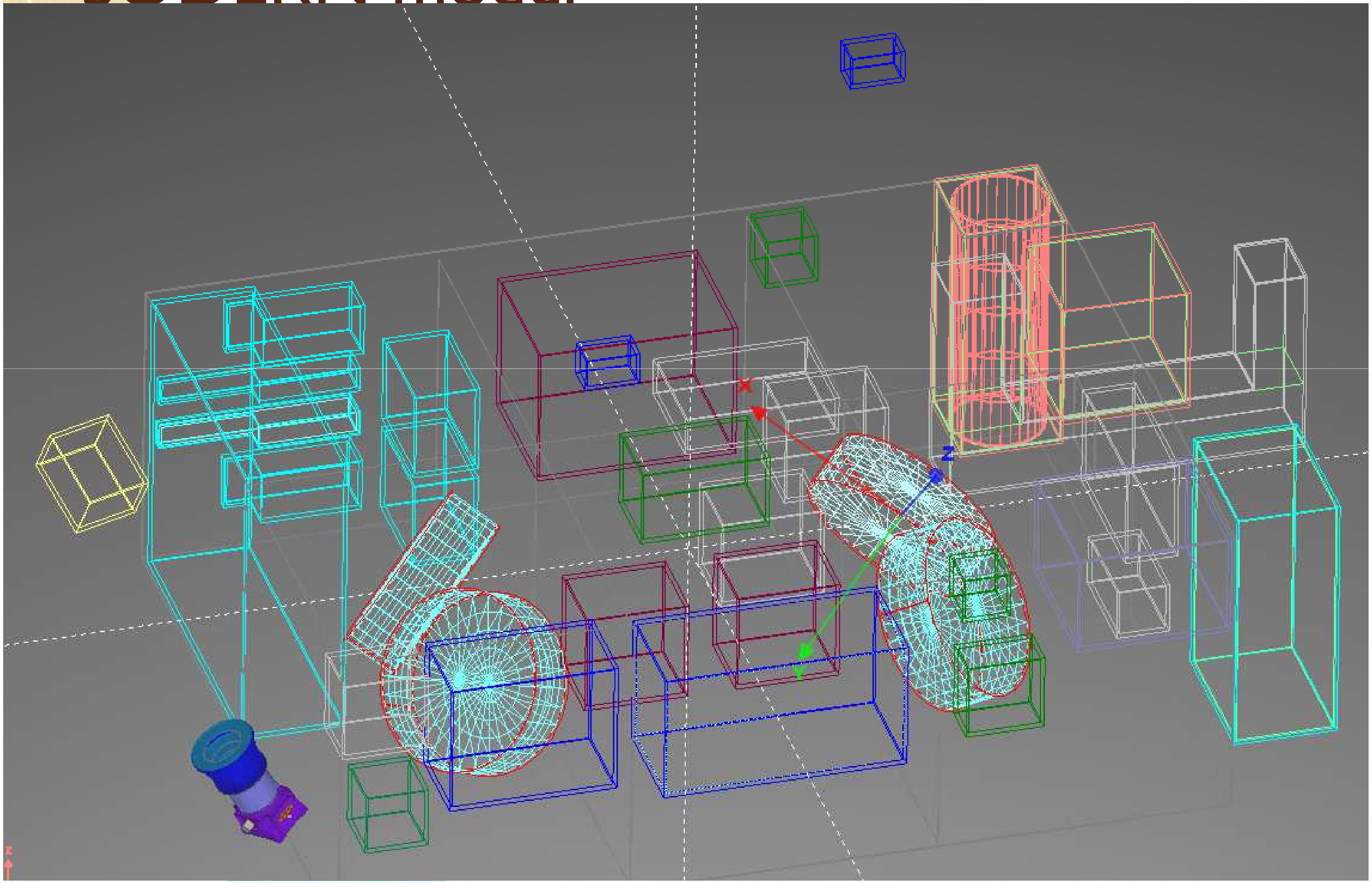


JUICE Geometry: Detailed model of the Star Tracker

A FASTRAD model of the Star Trackers has been developed by SODERN and made available to the REST-SIM project.



JUICE Geometry: QinetiQ/OHB + SODERN model

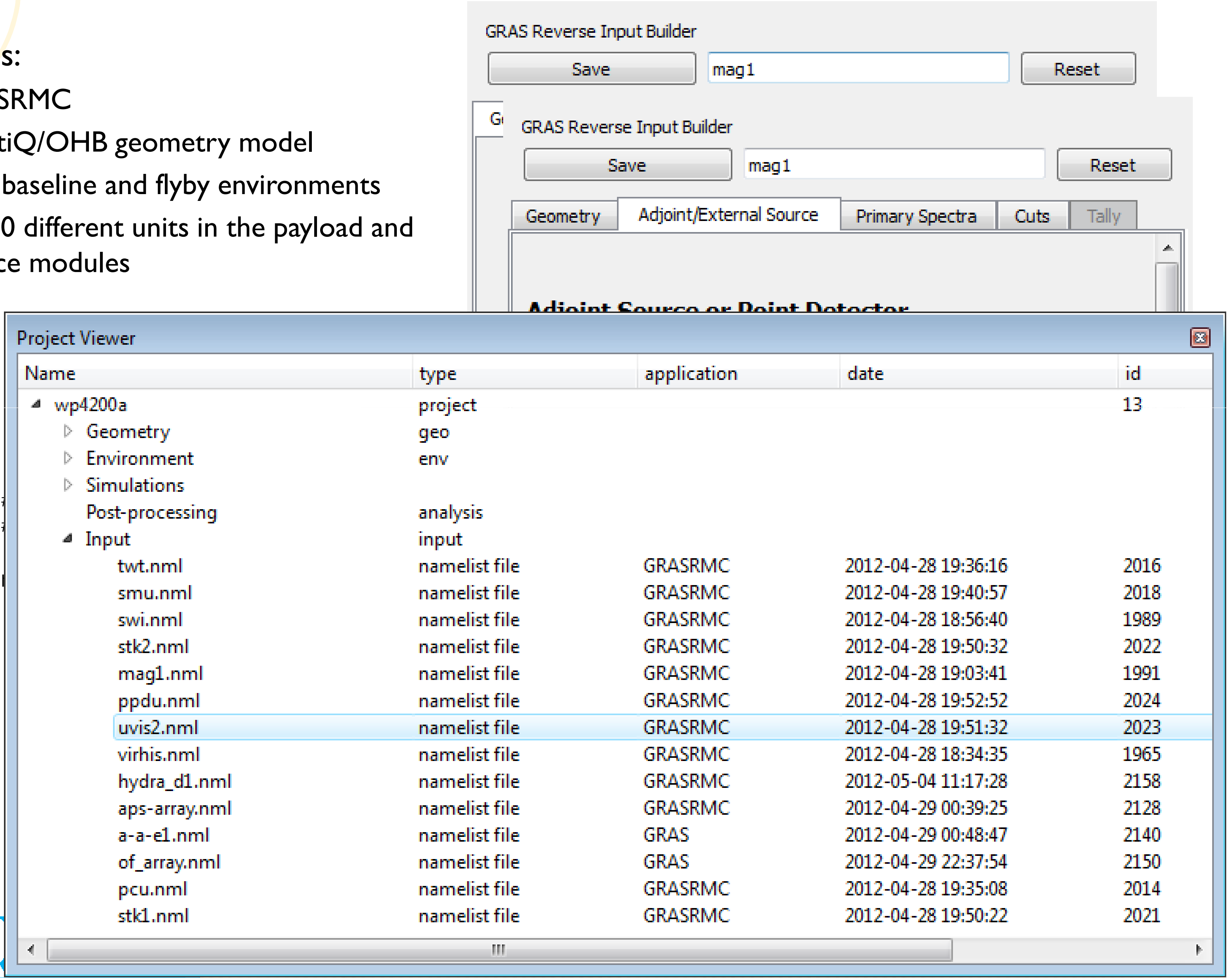


TID Analysis with GRASRMC

- TID analysis:
  - GRASRMC
  - QinetiQ/OHB geometry model
  - Both baseline and flyby environments
  - For 10 different units in the payload and service modules

Platform/Poayload

PCU
TWT #1
SMU
SG ACS STS AA STR
SG ACS STS AA STR
UVIS2
VIRHIS OU (outside vau
SWI (outside vault)
PP DU (outside vault)
MAG #1 (outside vault)



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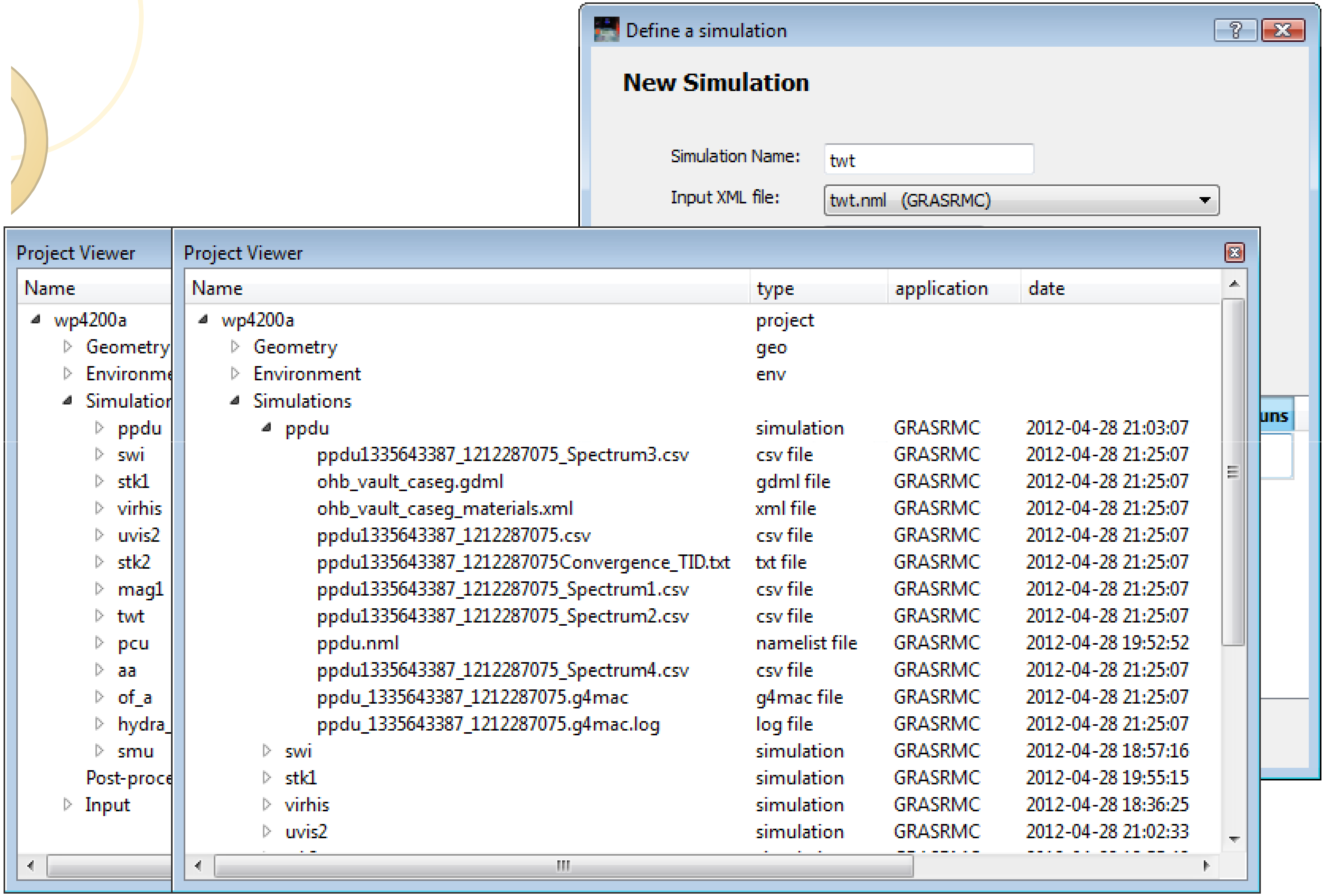
Simulation executions



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GRASRMC Simulation Results

		baseline			flyby		
		electron	proton	total	electron	proton	total
Platform	PCU	3.03±0.01	67.1±3.1	70.1±3.1	3.04±0.01	81.1±4.1	84.1±4.1
	TWT #1	3.07±0.01	71.1±3.1	74.1±3.1	3.12±0.01	86.1±3.1	89.1±3.1
	SMU	3.01±0.01	63.1±2.1	66.1±2.1	3.05±0.01	78.1±1.1	81.1±1.1
	Star Tracker 1	3.82±0.02	88.1±2.1	92.1±2.1	3.81±0.02	107.1±2.	111.1±2.1
	Star Tracker 2	3.78±0.02	90.1±2.1	93.1±2.1	3.83±0.02	109.1±2.	112.1±2.1
Payload	UVIS2	3.17±0.04	62.1±1.1	65.1±1.1	3.2±0.01	76.1±2.1	80.1±2.1
	VIRHIS OU	3.38±0.02	124.1±4.1	127.1±4.1	3.42±0.02	142.1±4.	145.1±4.1
	SWI	3.62±0.02	129.1±13.	133.1±13	3.66±0.02	153.1±15	156.1±15.
	PP DU	2.15±0.01	43.1±2.1	45.1±2.1	2.18±0.01	53.1±3.1	55.1±3.1
	MAG #1	4.23±0.03	67.1±1.1	71.1±1.1	4.3±0.03	84.1±1.1	88.1±1.1

TID in krad(Si)

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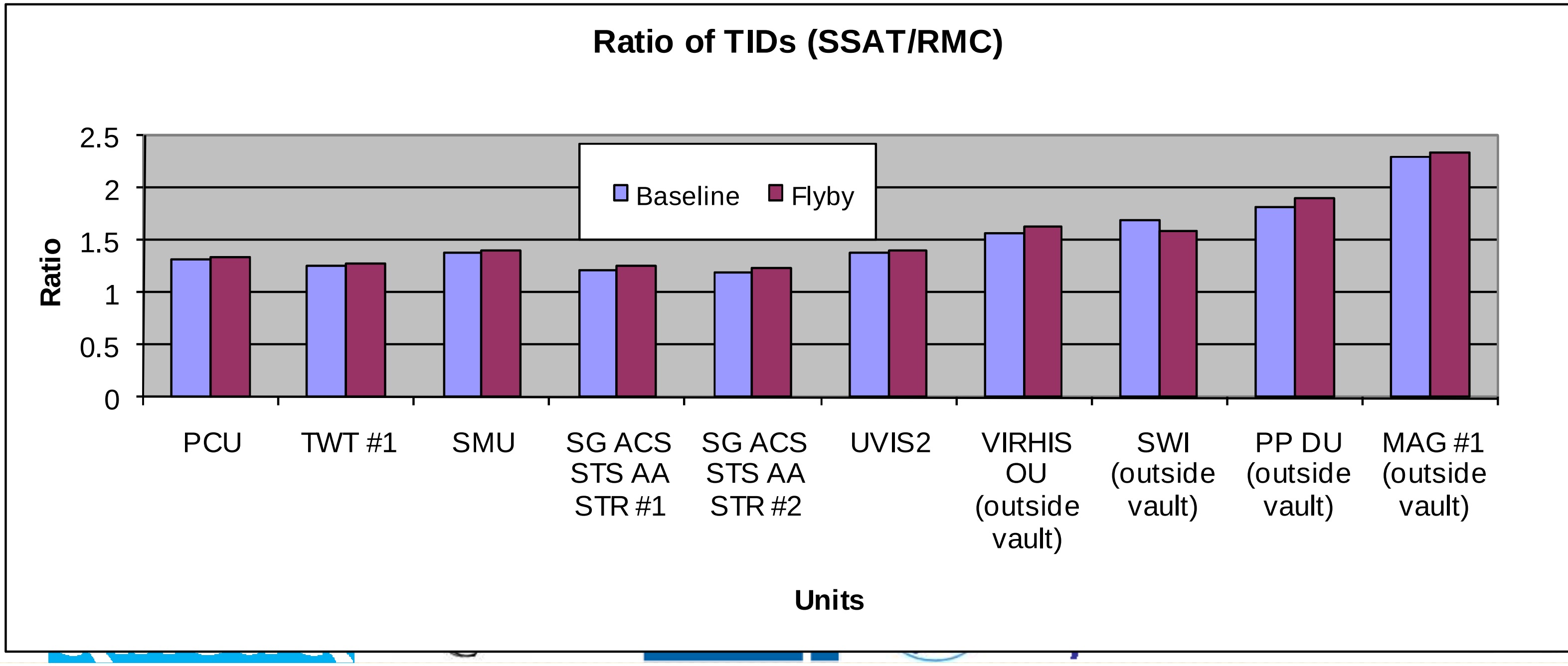
Comparison with SSAT Results

- SSAT analysis were carried out for the same locations with the same geometry model. The calculated TID in krad(Si)

		Baseline	Flybys
Platform	PCU	90.69	112.83
	TWT #1	92.27	113.53
	SMU	90.83	113.03
	Star Tracker 1	111.52	138.06
	Star Tracker 2	111.2	138.17
Payload	UVIS2	89.53	111.64
	VIRHIS OU	197.39	237.55
	SWI	225.53	248.87
	PP DU	82.52	103.52
	MAG #1	163.01	204.89



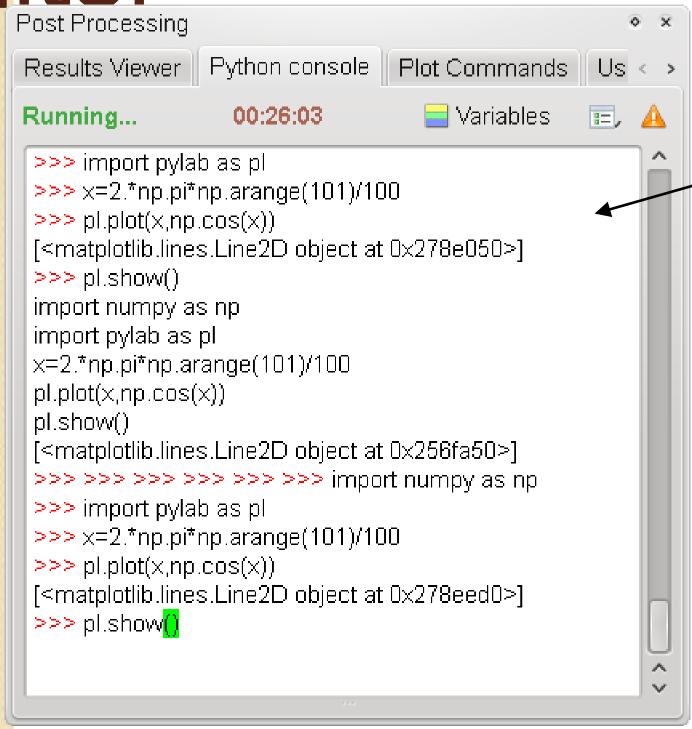
Future Developments

A new team has been assembled in response to new ESA ITT (CIRSOS):

- New Integrated Modelling Environment (IME)
  - collaborative and iterative modelling approach, operational s/w for CVMs
- Geometry manager
  - Model configuration tool: GDML – modular schema
  - New visualisation tool
- Application tools
  - Internal Charging (IC) analysis
    - Based on the ELSHIELD work
    - Build-in libraries of materials and components at risk
  - SSAT
  - 2-stage analysis approach
    - FMC and RMC in both stage
  - General parametric analysis
    - Template based solution
- Simulation manager
  - Utility to use commercial cloud computing facilities, e.g. EC2
- Lots of enhancement to post-processing and many more…

Backup slides

Interactive Python console/ Python editor

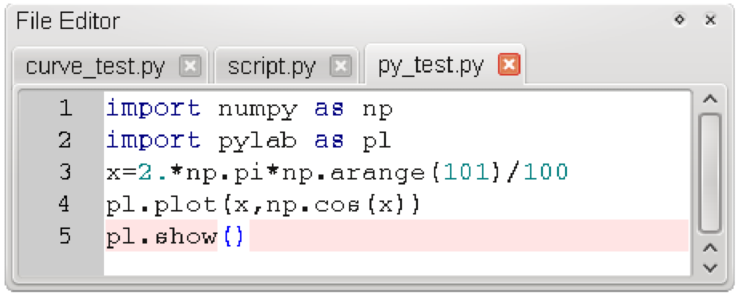


Interactive Python console

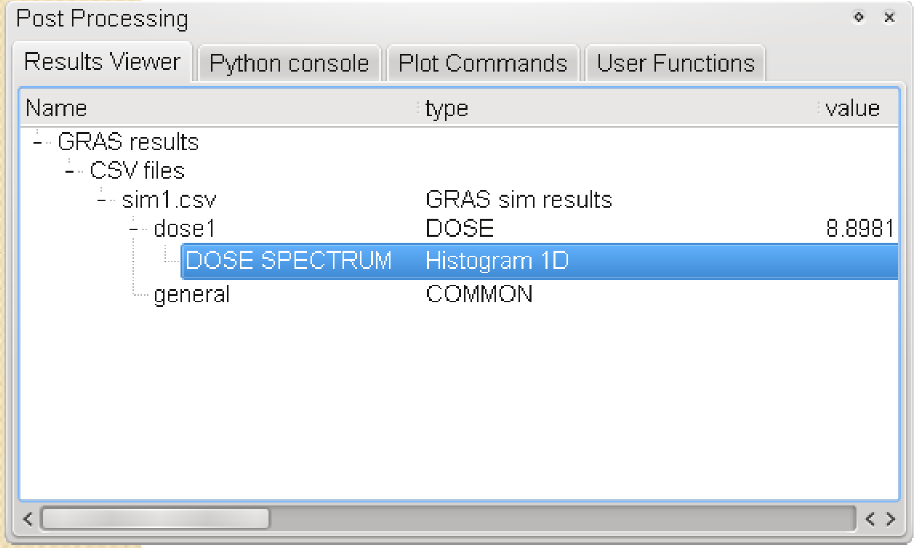
- Using the Spyder python library
- Run of user script from popup menu of the PYTHON editor
- Visualisation of python command send by the GUI
- Pre imported modules : numpy, pylab, DataManager, function loading

Python script editor

- Syntax recognition based on QScintilla
- menu for run, save, edit, add commands



Reading/Viewing/Access of simulation results

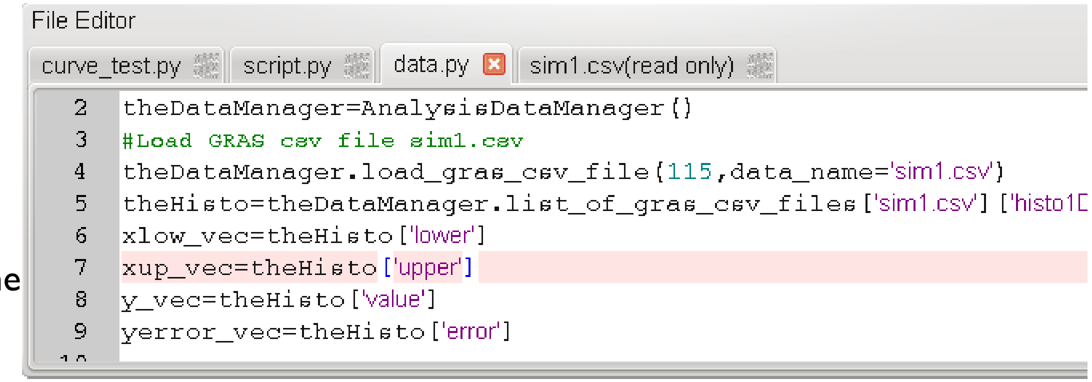


Reading/Viewing of simulation results

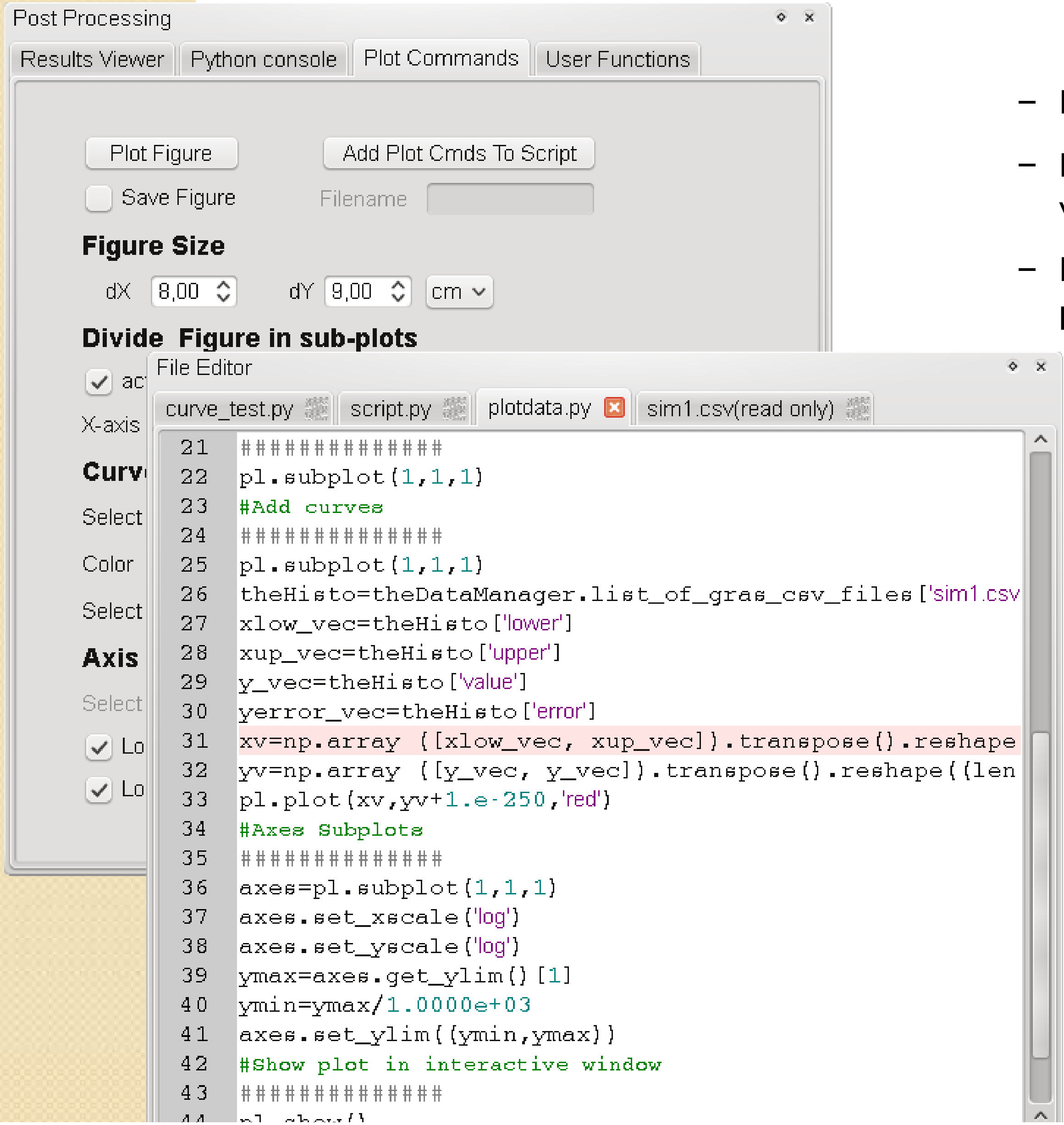
- PYTHON interface to Spenvis CSV C++ code to read CSV files
- Direct View of GRAS CSV file in Editor
- Results viewer widget as a file structure viewer

Access of data in user script

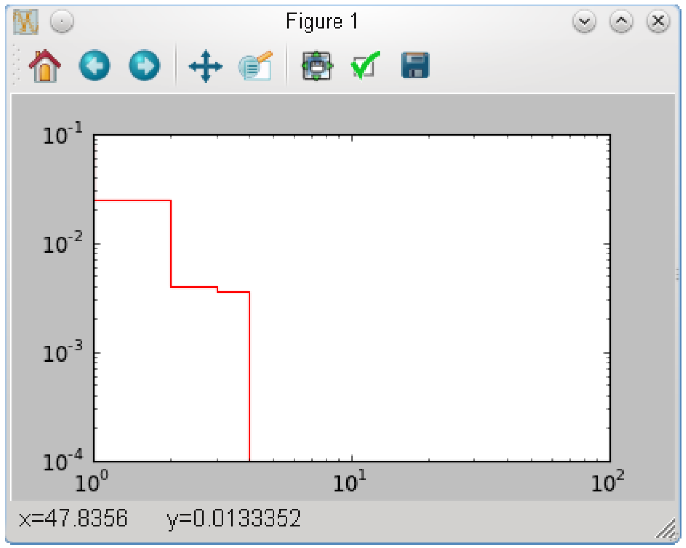
- Access of DataManager in user script
- Python Cmds to acess Histograms directly added in the script from a popup menu of the results viewer



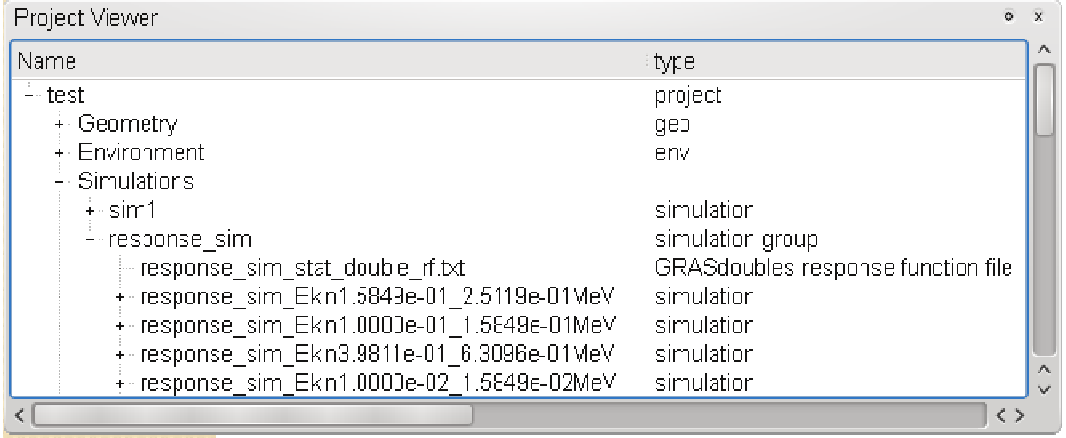
Plotting of simulations results



- Direct plotting of single 1D histogram
- Multi curve plottings using a plotting widget
- Interactive adding of plotting cmds from plotting widget to user script



Response function analysis

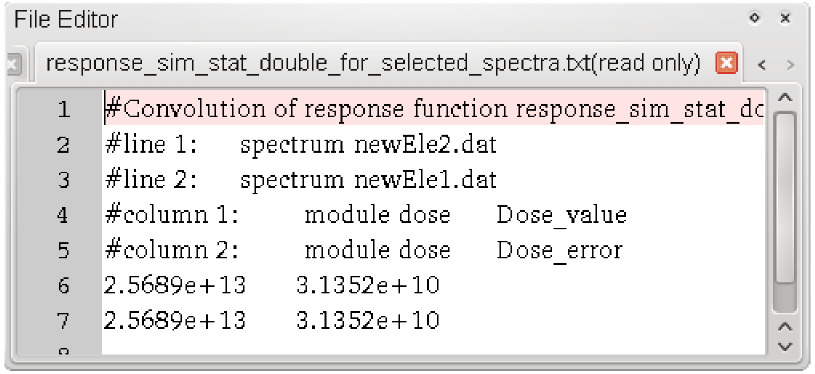


<u>Response functions vs primary energy</u>

- Multiple simulations vs primary energy
- Log or linear energy bins
- General concept of simulation group for all type of parametrized simulations
- End of simulations: production of an ASCII table containg all scalars (TID,NIEL,...) in function of primary energy bins

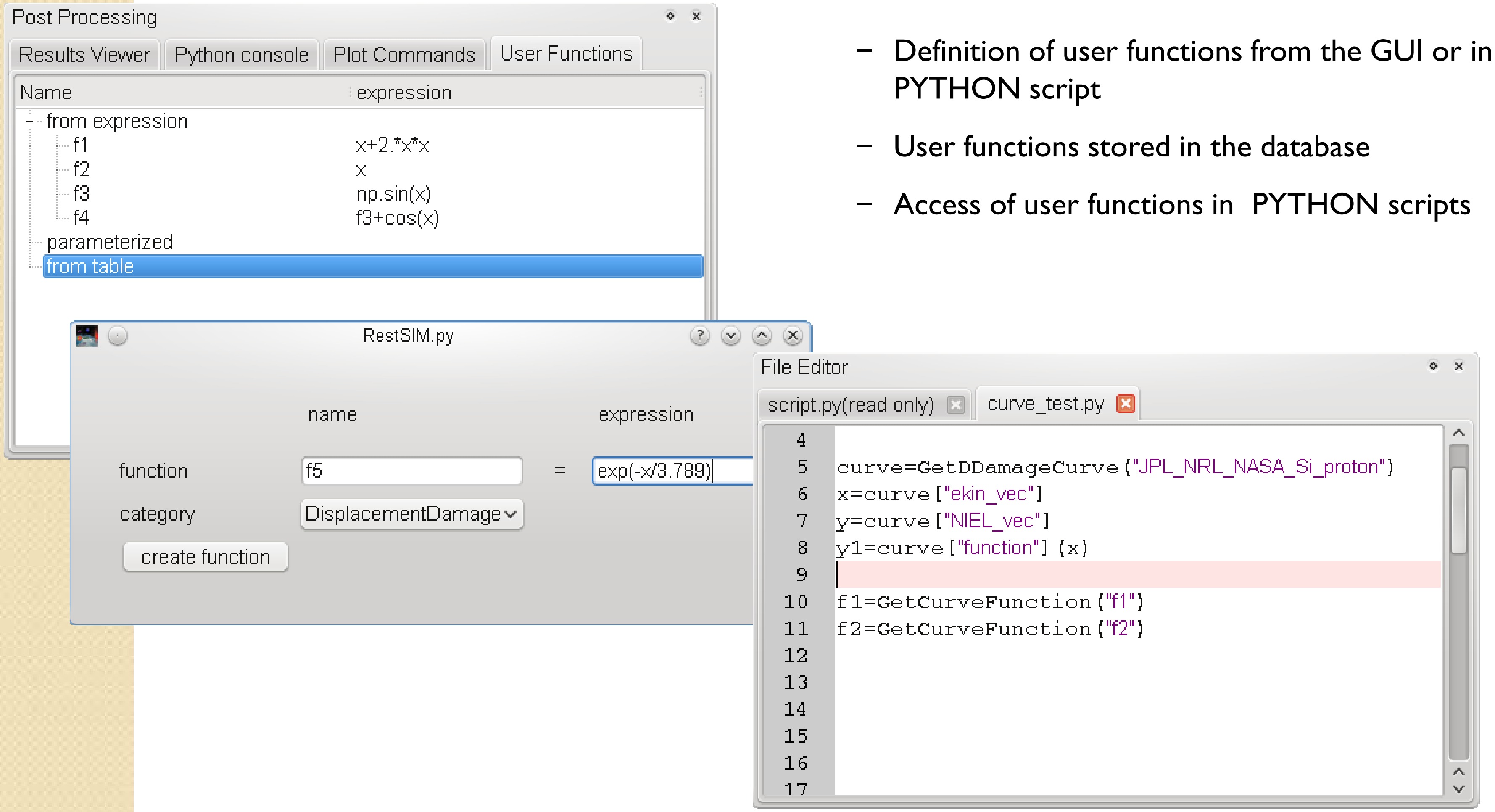
•<u>Signals vs primary spectrum</u>

- Convolution of response functions with user selected spectra
- Use of SciPy library
- ASCII table of scalar signals in function of user selected spectra

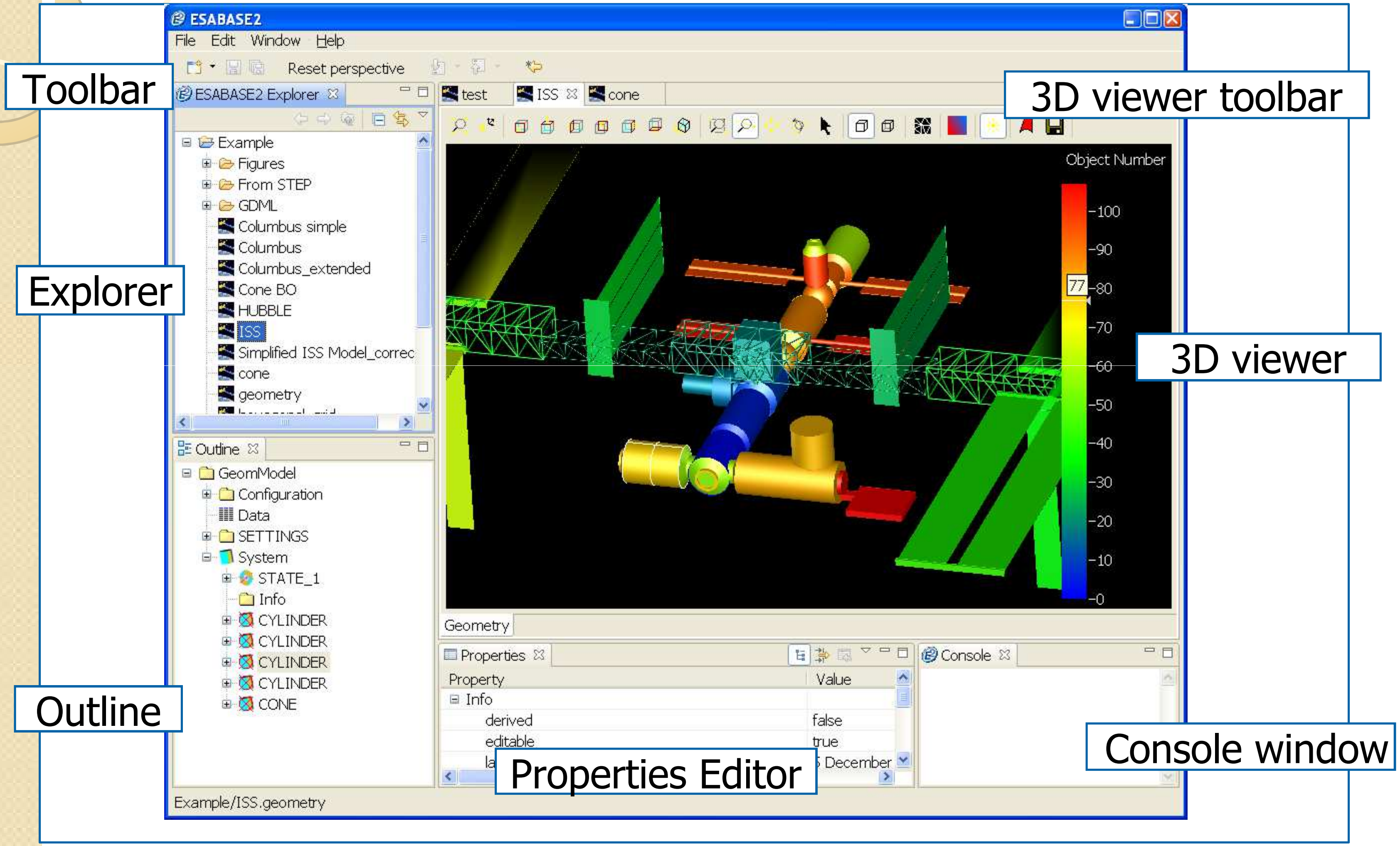


Definition/loading of user functions for radiation effect analysis

- Definition of user functions from the GUI or in PYTHON script
- User functions stored in the database
- Access of user functions in PYTHON scripts



ESABASE2 GUI Overview



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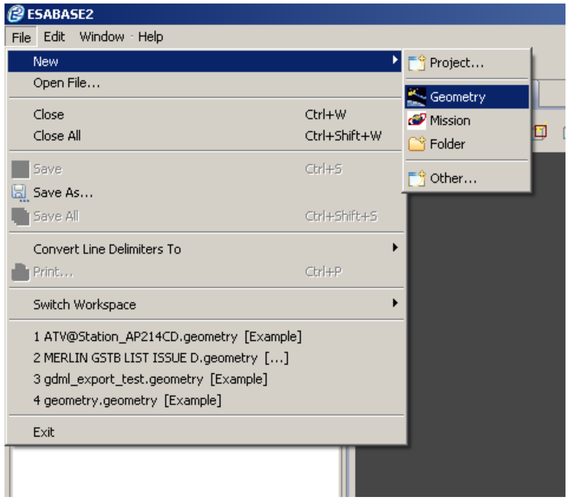
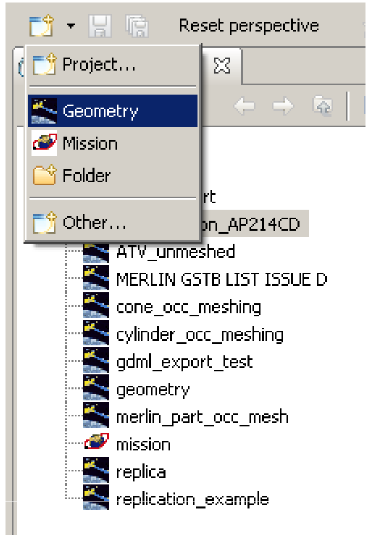
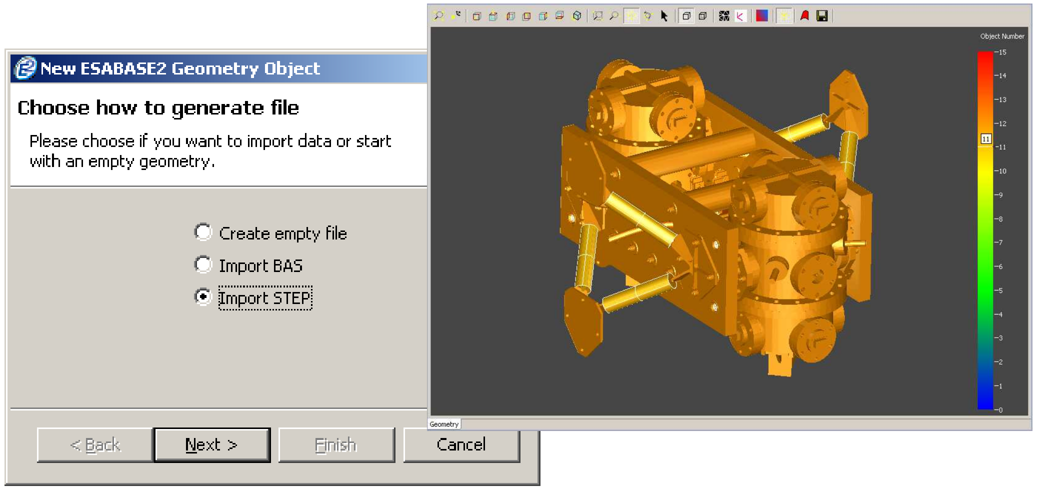
STEP AP203/214 Import

- Import of any STEP AP203/214 files, also of high complexity.
- Tested with a large number of files originating from various CAD tools.
- Accessible via the respective open file menu or toolbar entry.



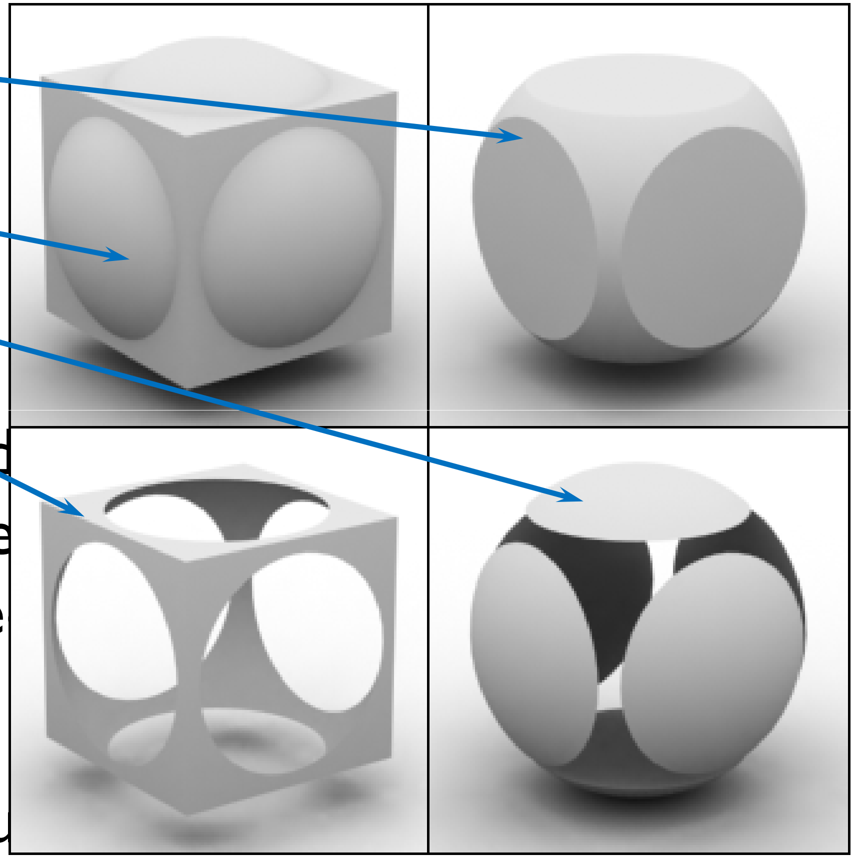


- Opens a file selection dialogue
- Can take a while, depending on the complexity of the geometry...



Boolean Operations (1)

- Three types of Boolean Operations (BO) implemented:
  - intersection
  - union
  - subtraction



- After the operation is performed, the child shape is stored under the BOP-nod
- It can be edited via the shape
- Any changes made are applie Boolean shape.
- If a BO is removed from the BOP node, the operation is u

Boolean Operations (2)

- Series of Boolean Operations can be performed following the defined workflow:
  - Add child to Boolean shape parent
  - Execute next BO

ttr Bo

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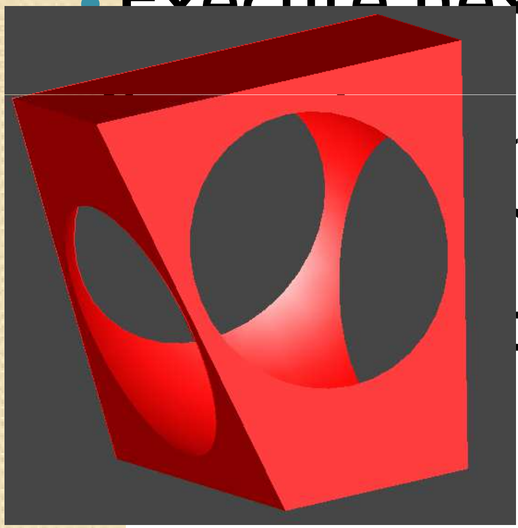
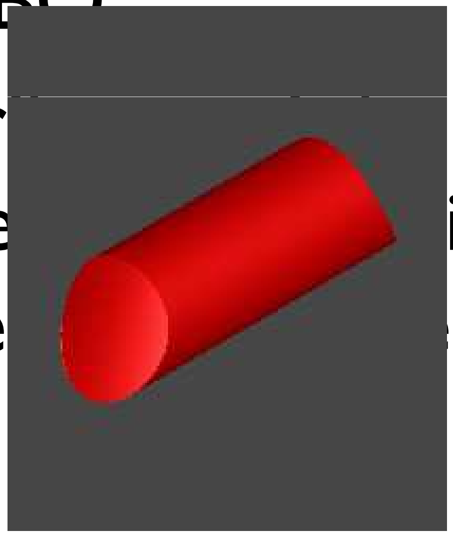
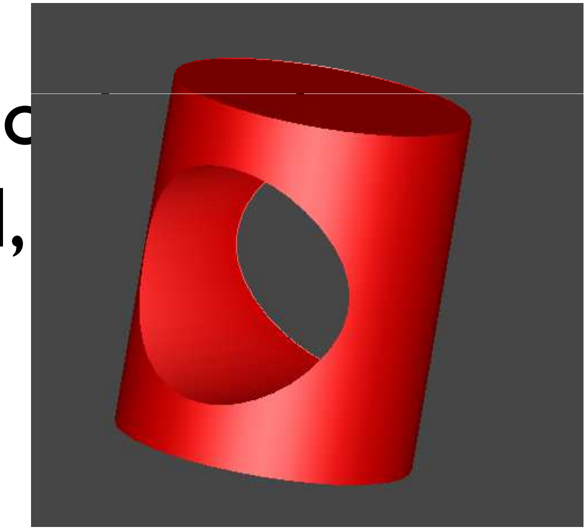
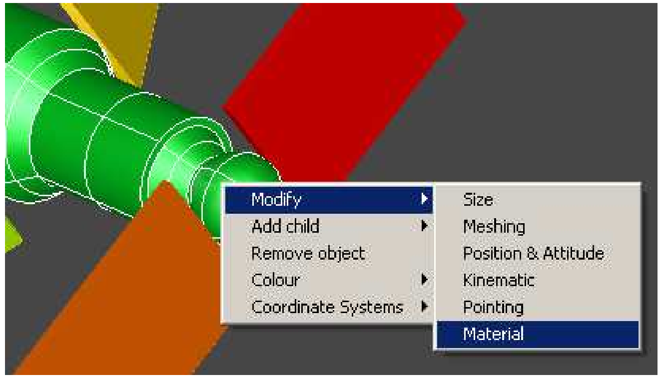


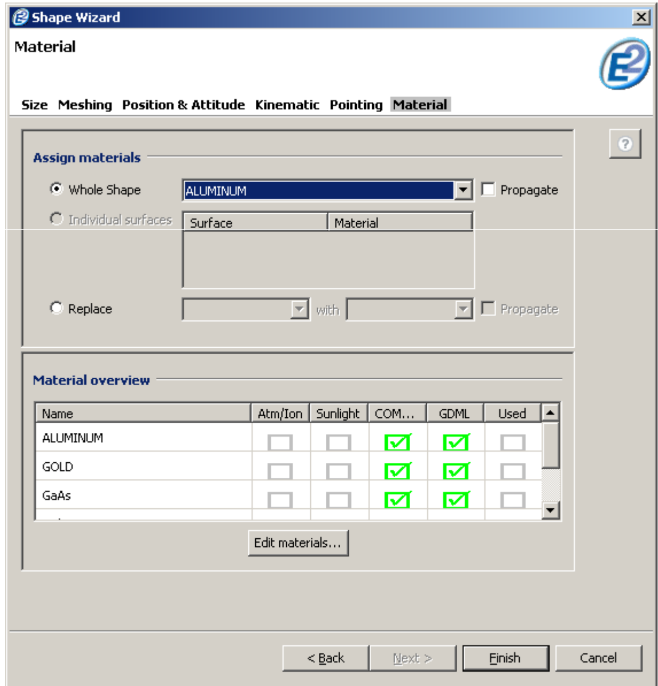




Material Editor

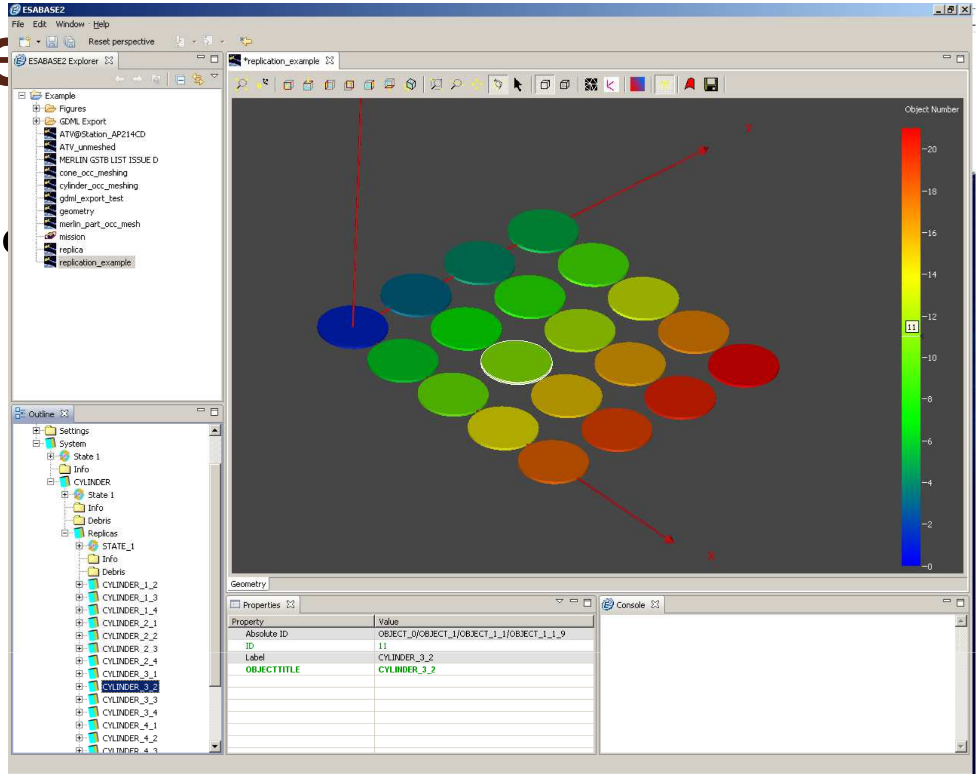
- Objective: Assignment of materials to geometrical objects.
- Underlying comprehensive material database.
- Part of the shape wizard.
- Accessible via
  - the Outline context menu,
  - the 3D view context menu ('Modify --> Material').
- Allows
  - editing of material properties,
  - creation of user defined materials.
- Materials can be assigned only, if they are copied from the material database to the geometry.
- The elements a material is consisting of are automatically copied to the geometry, when the material is copied to the geometry.



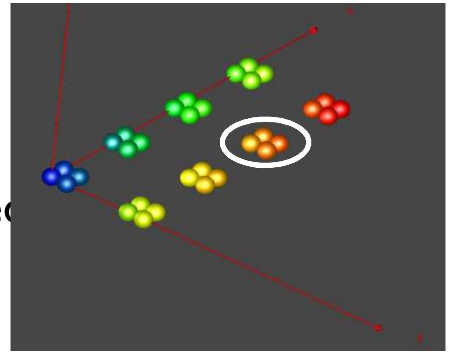


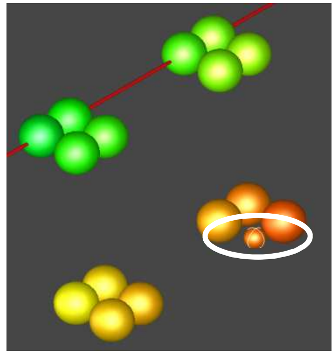
Replicated Structure

- Objective: enable the replication of geometrical objects in x- and y-dire with user defined different off-sets.
  - Example:
    - replicated cylinders
    - 5 in x-direction
    - 4 in y-direction
    - different off-sets in x- and y-direction
    - index of the replica is given in its name
    - here: *cylinder_3_2* :
      - 3rd in x-direction
      - 2nd in y-direction



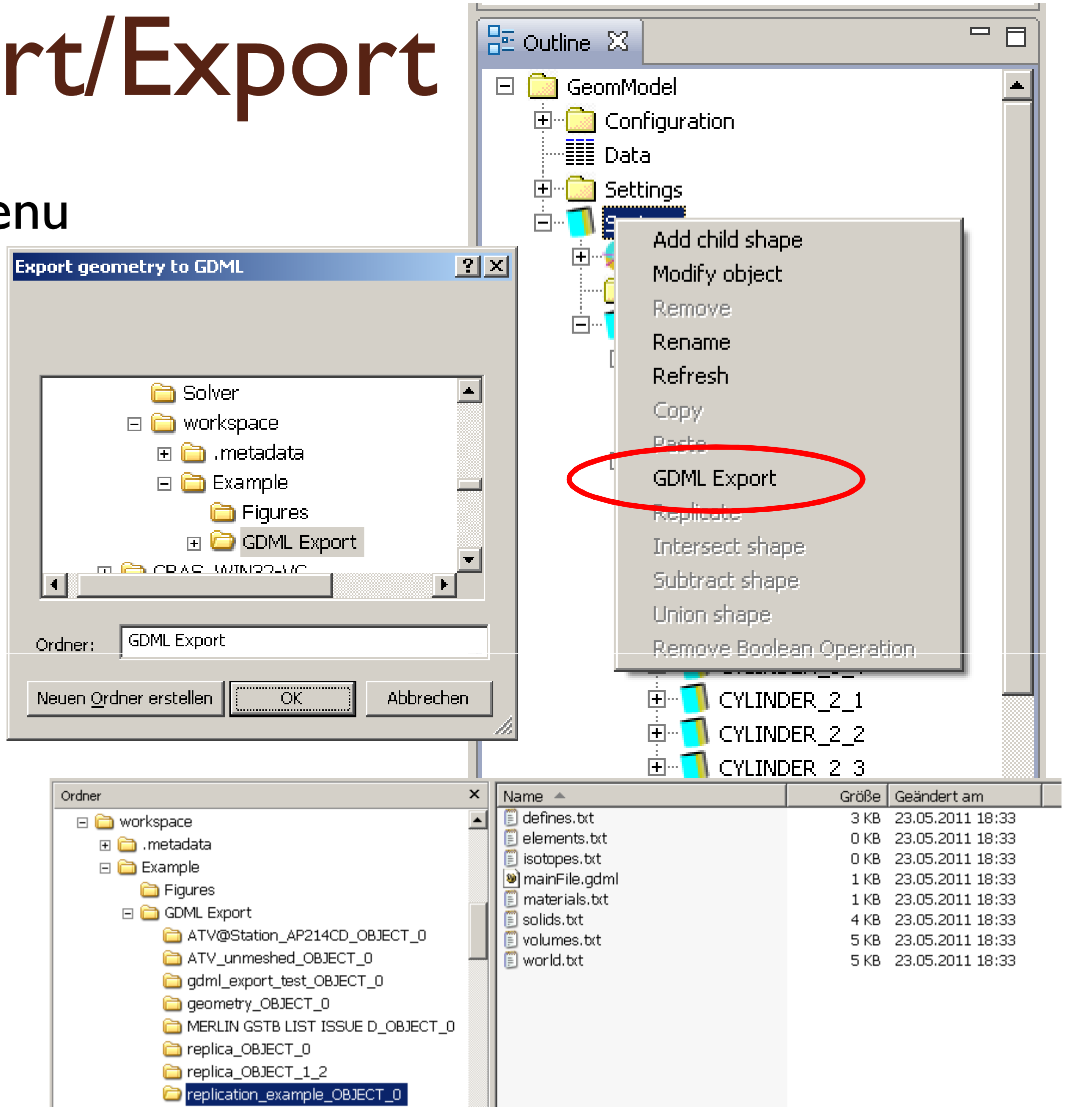
  - Replication of the parent object of a replicated structure replicates the entire structure.
  - The properties each object of the replicate structure can be edited individually.





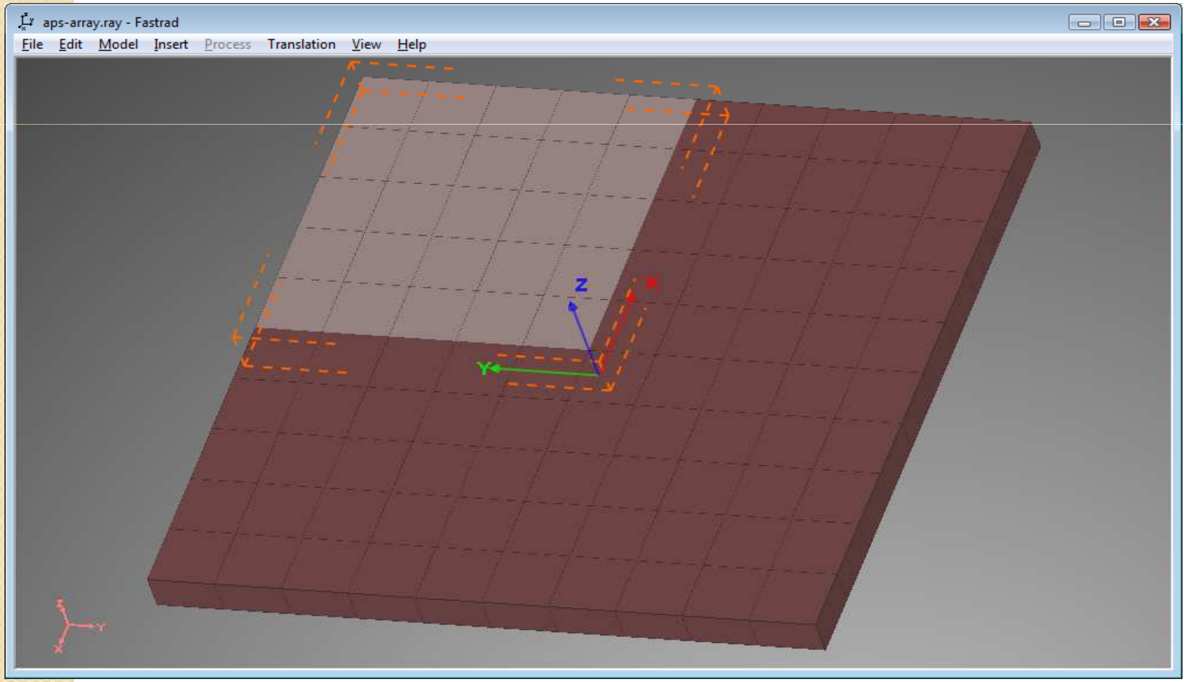
GDML Import/Export

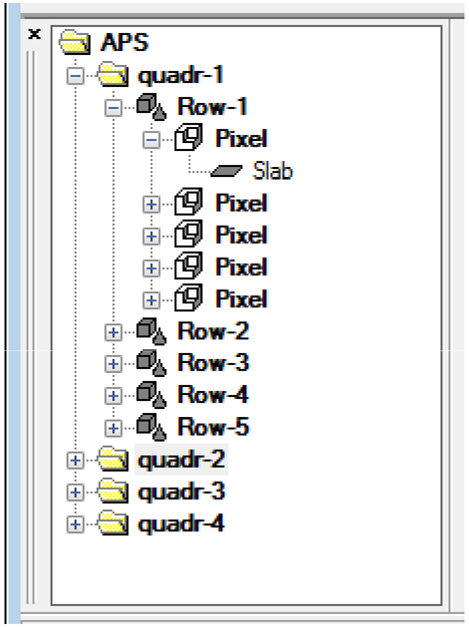
- via the Outline context menu
  - entire system
  - parts of the geometry tree
  - single objects
- opens a dialogue for the selection of the target folder
- creates a sub-folder in the target folder with the name of the geometry file, which contains the 'main.gdml' file and the include files



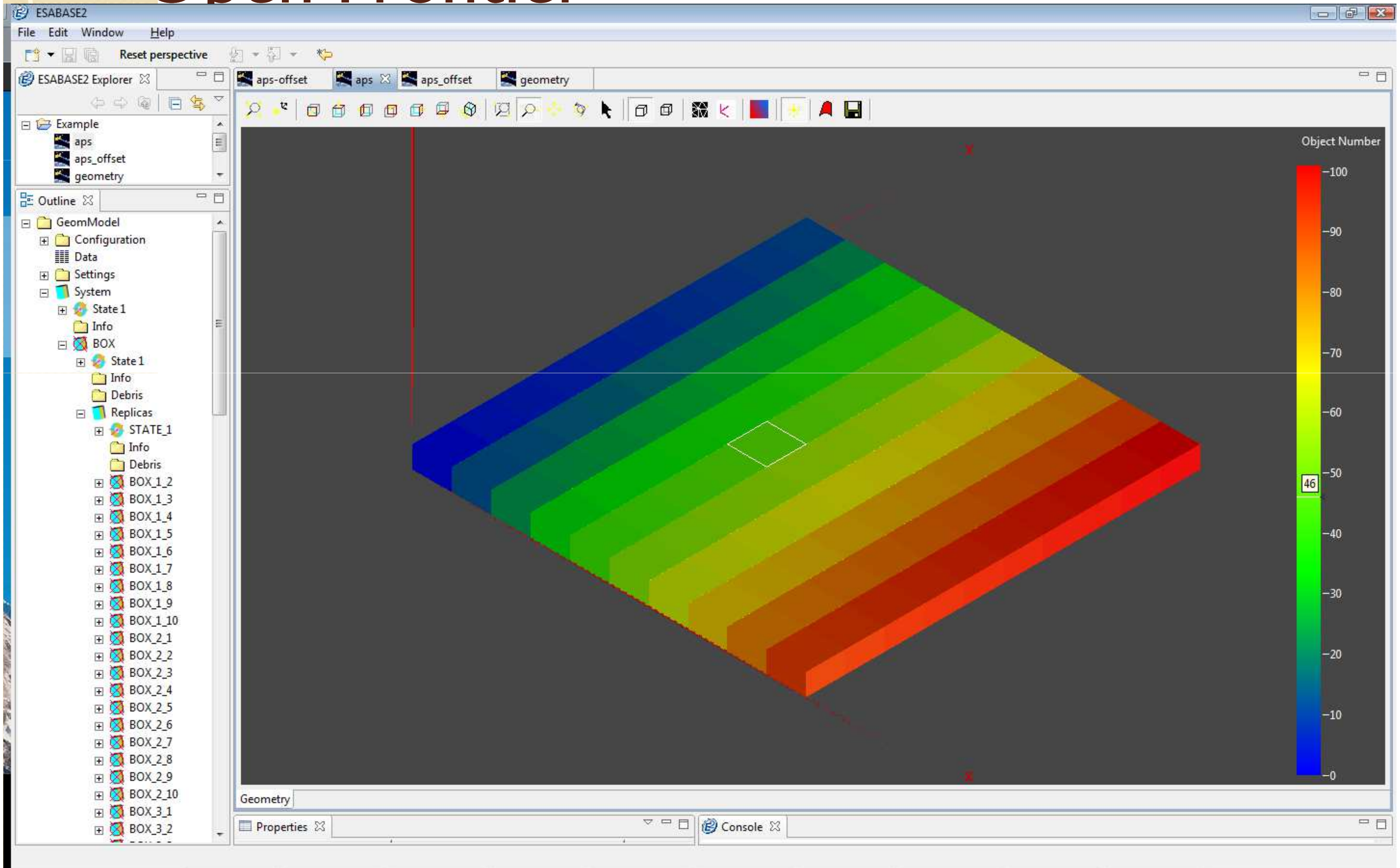
JUICE Geometry: Pixellated APS Model - FASTRAD

- Repeated APS pixels can be modelled using the combined functions of copy/paste and transformation
- But volume names have to be changed manually
  - This is required if each pixel needs to be identified uniquely
  - Impractical for large arrays such as the APS (1024x1024)





JUICE Geometry: Pixellated APS Model – Open Frontier



Research