

# ANTS2 toolkit

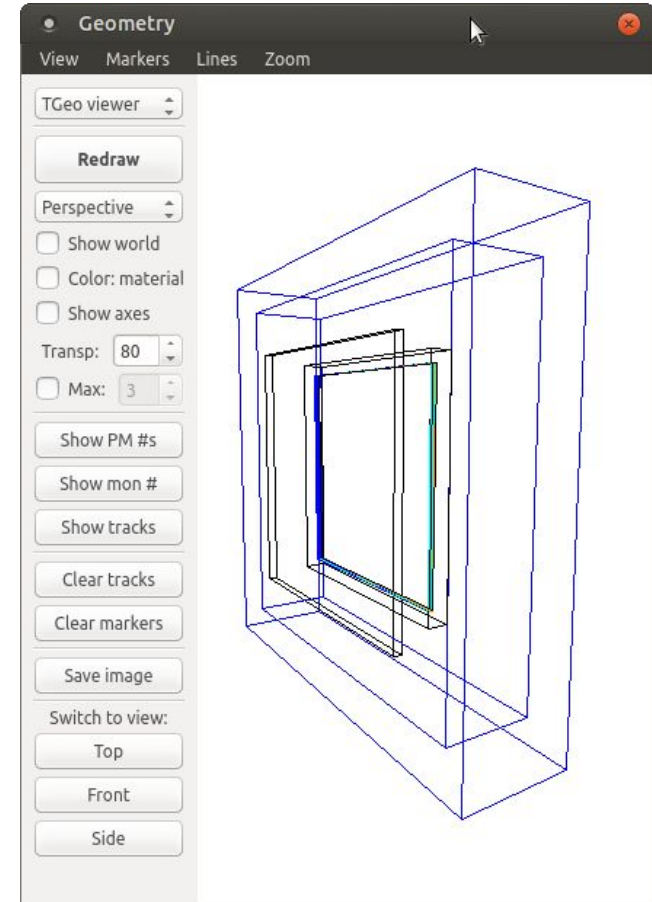
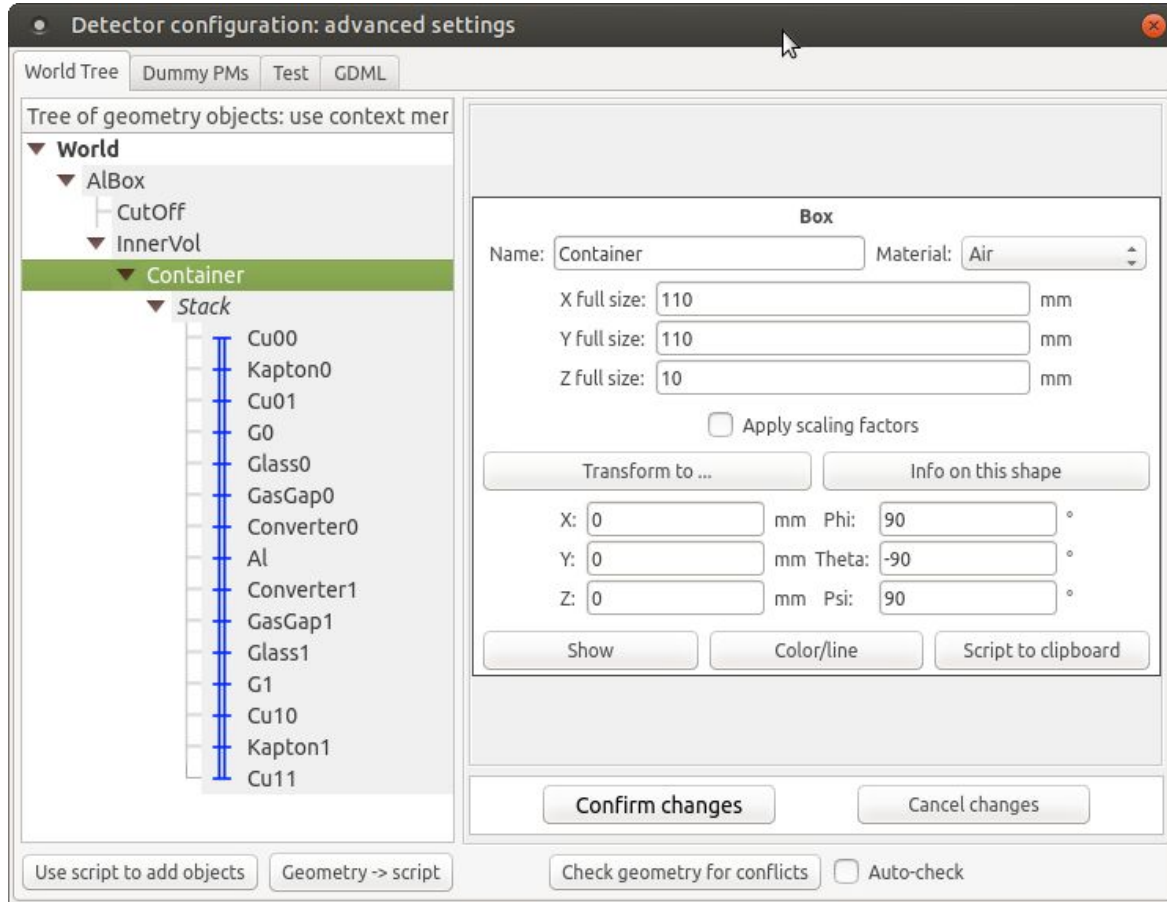
Interface to Geant4, event analyzer and  
semi-automatic detector optimization

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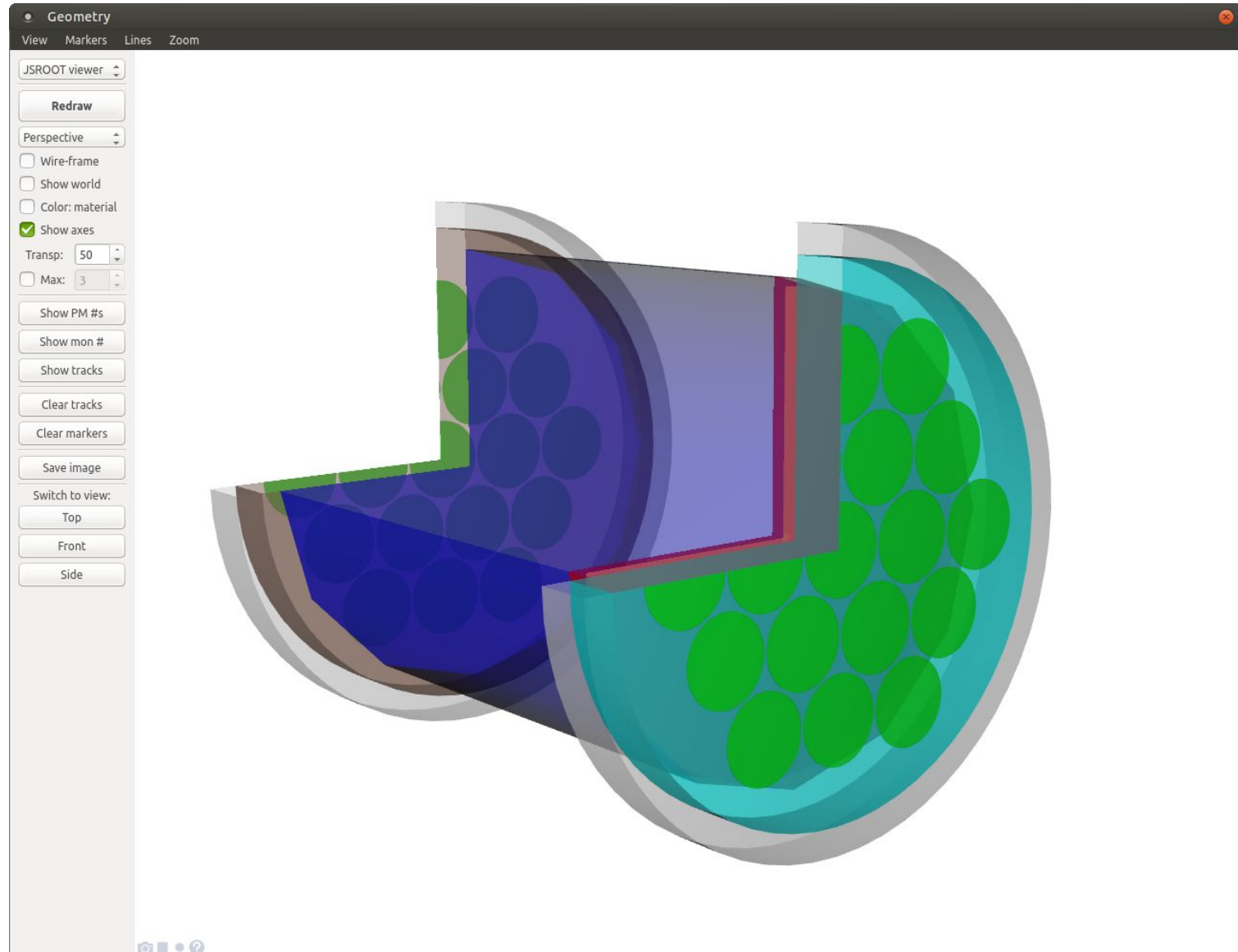
- Geometry: advanced GUI tools
- ANTS2 - Geant4 interface
- Event viewer and history analyzer
- Semi-automatic detector optimization

# Geometry: advanced GUI tools

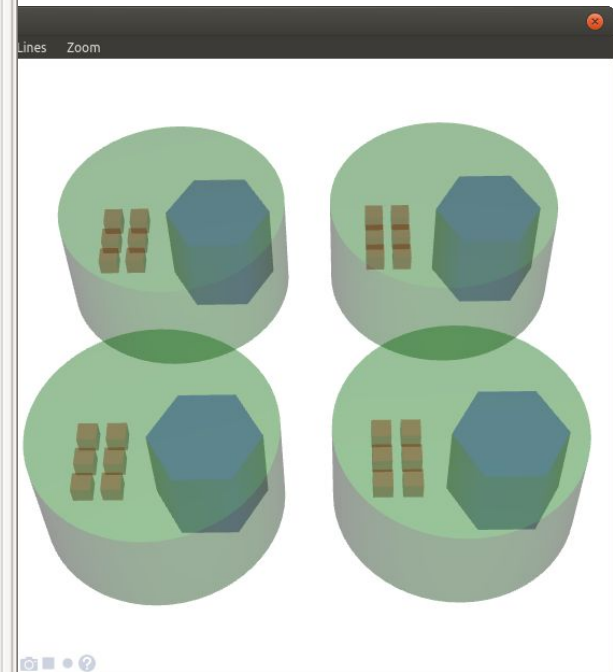
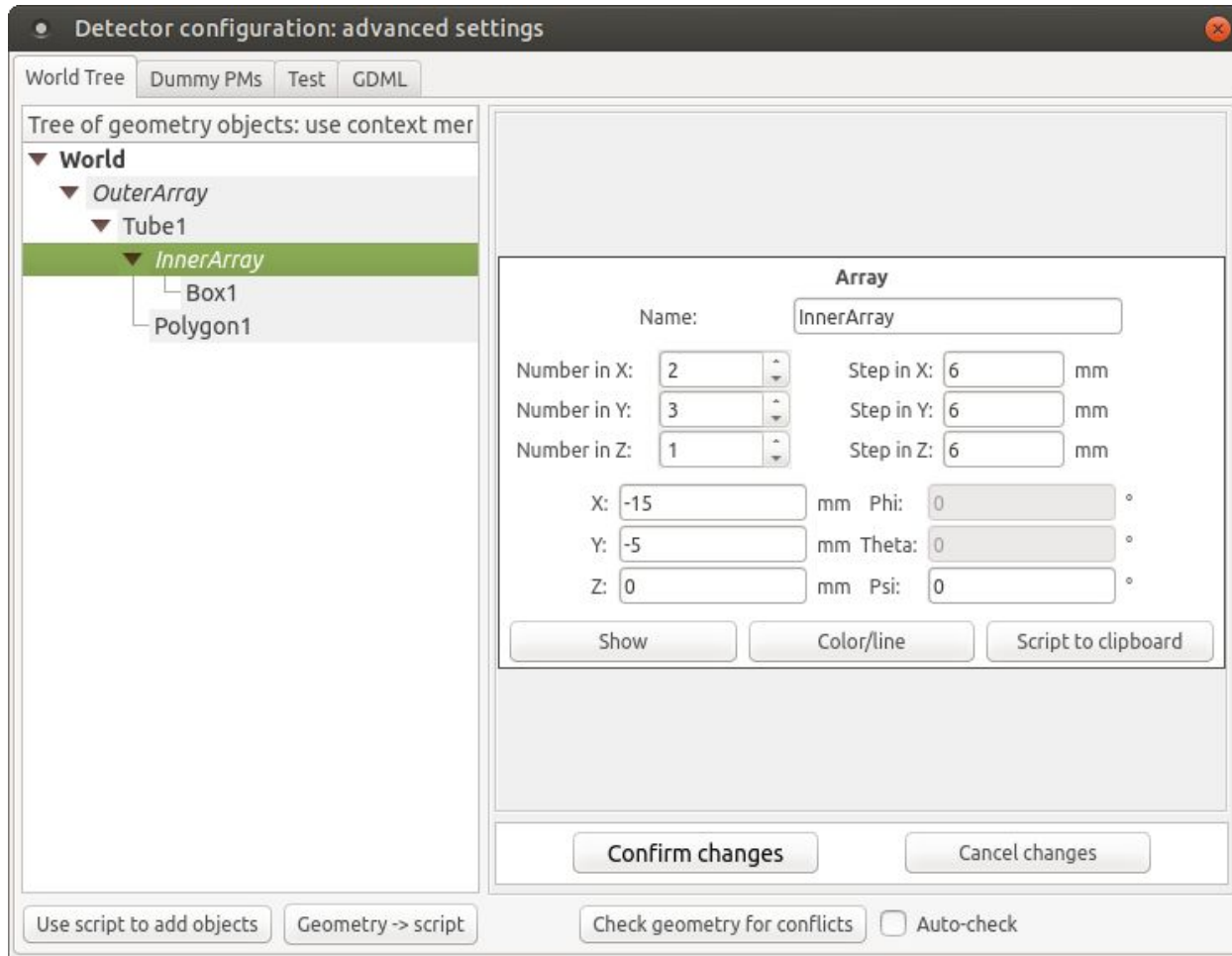


- Tree view of the detector volume hierarchy
- Context menu to add / remove / duplicate / disable volumes
- Drag-and-drop to move or reorder objects
- Property edit box for the selected object

## JSROOT visualization

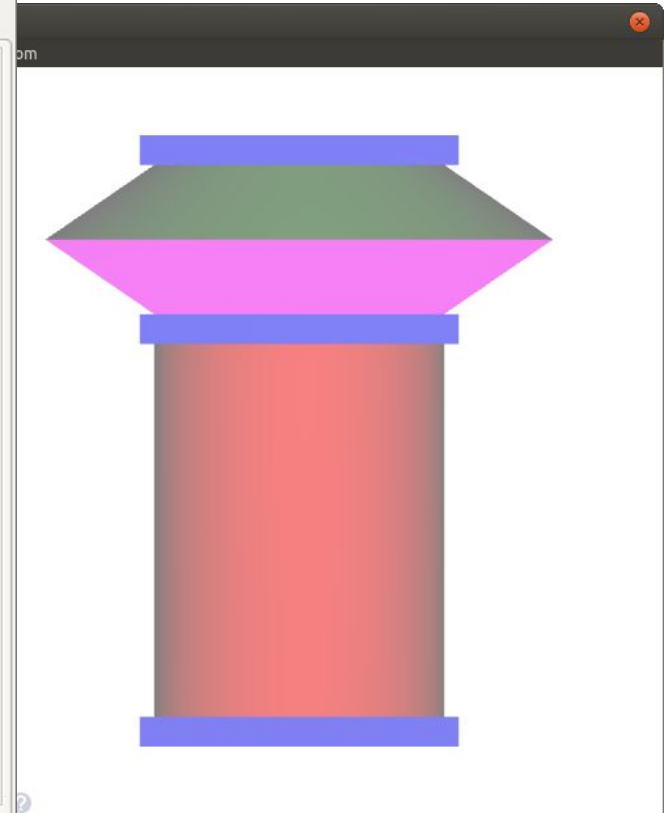
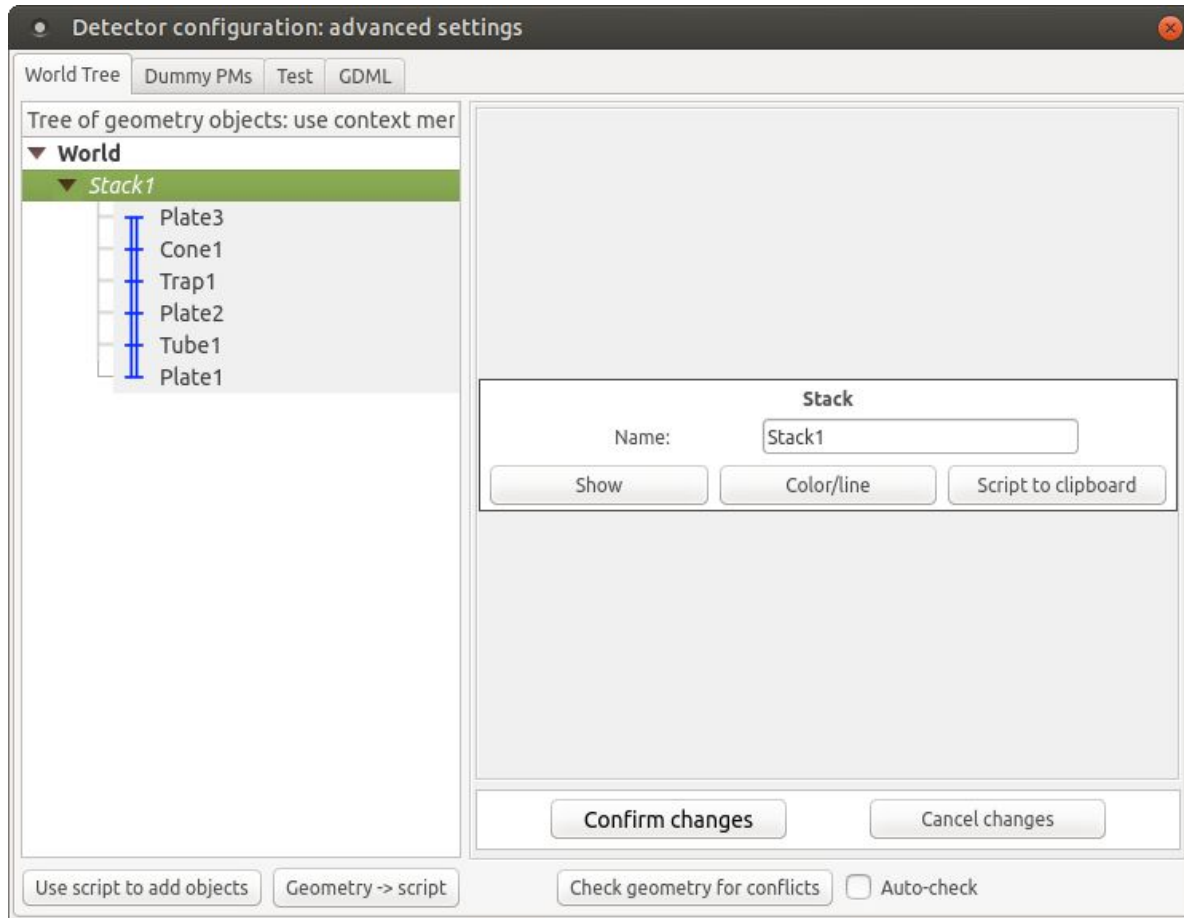


## Arrays of objects



# Geometry: advanced GUI tools

## Stacks of objects



# Geometry: advanced GUI tools

## Monitor objects

The image displays two windows from a software interface. The left window, titled "Detector configuration: advanced settings", shows a "Tree of geometry objects" on the left with "PrScint" and "Monitor\_gamma" selected. The main panel is for configuring a "Monitor" object. The "Name" is "Monitor\_gamma", "Shape" is "Rectangular", and "Size X" and "Y" are both 8 mm. Position coordinates (X, Y, Z) and orientation angles (Phi, Theta, Psi) are all set to 0. The "Sensitive" direction is "From top and bottom". The "Monitoring" is set to "Particles" for "gamma" particles. The "Position" section has X and Y bins of 50. The "Time" section has bins of 100 ns from 0 to 100. The "Angle" section has bins of 100 degrees from 0 to 90. The "Energy" section has bins of 100 keV from 0 to 200. Buttons for "Show", "Color/line", and "Script to clipboard" are present. The right window, titled "Results/Output", shows the "Monitors" tab. The "Selected monitor" is "Monitor\_gamma index=0" with a value of 0. A "Show monitor settings" button is visible. Below, the "Detections" count is 31083. The "Distributions" section includes buttons for "Spatial (XY)", "Time", "Angle", and "Energy". A red arrow points from the "Spatial (XY)" button to a third window at the bottom right. This window shows a 2D heatmap of the detector response, with axes X and Y in mm ranging from -4 to 4. A color scale on the right indicates intensity from 0 to 100. A statistics panel in the top right corner of the heatmap displays: Entries: 31083, Mean x: 0.00381, Mean y: -0.009615, Std Dev x: 0.9378, Std Dev y: 0.9389. The left side of this window contains various plot controls like "Range", "Grid", "Log", and "Show stats panel".

## Goal:

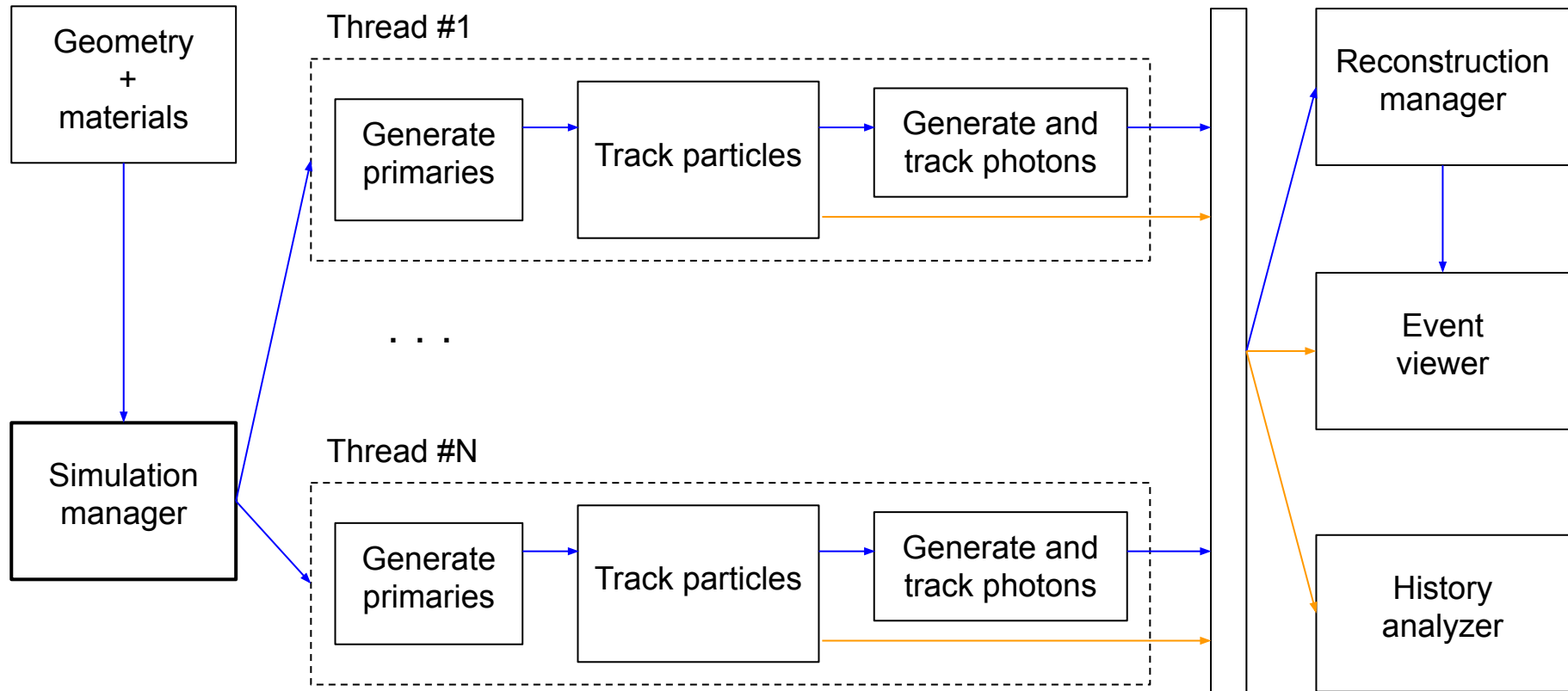
Delegate particle simulations from ANTS2 to Geant4 and import back the energy deposition data (optionally also data from monitors / tracking history)

## Challenges:

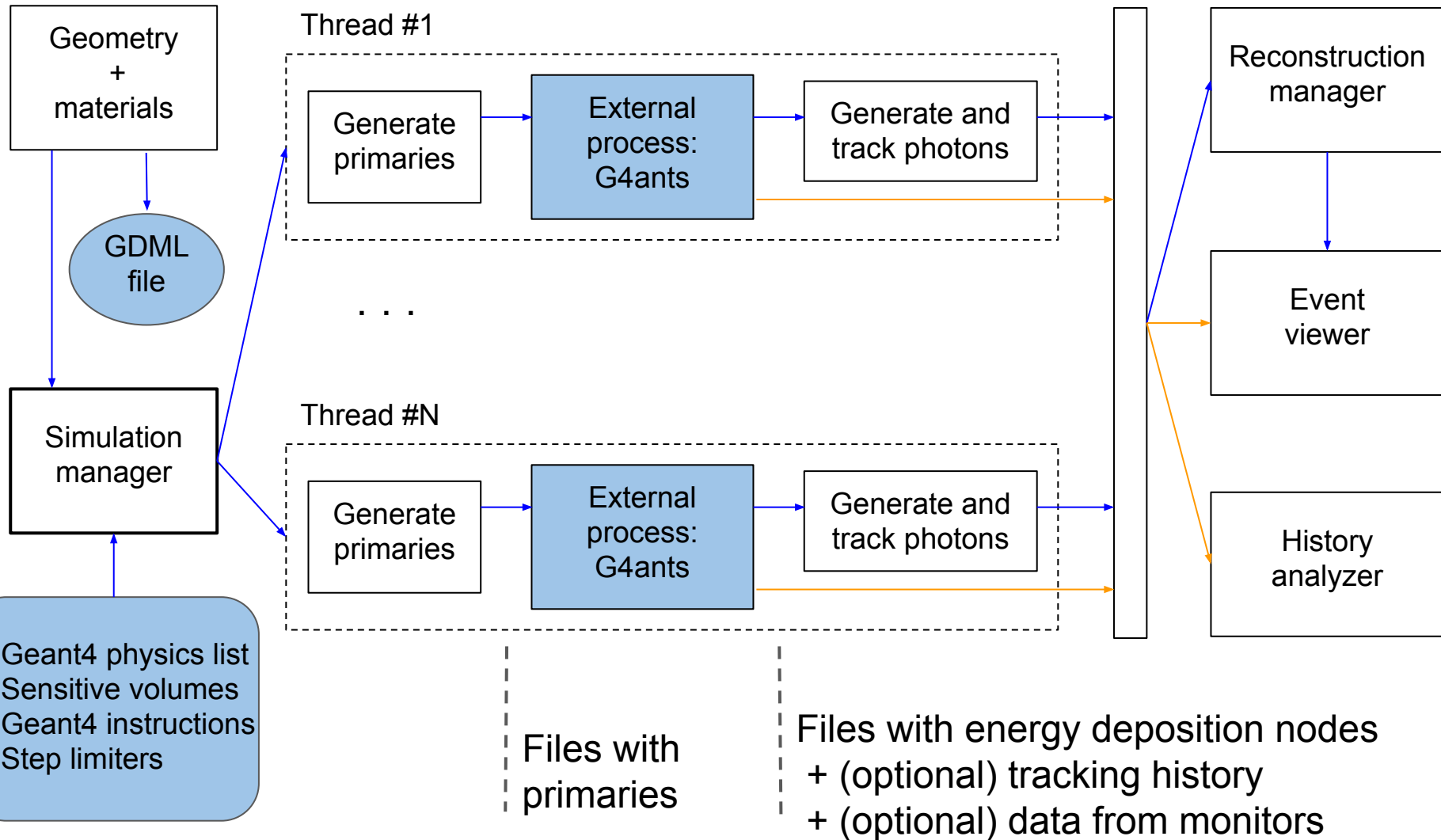
- ANTS2 uses TGeoManager 3D navigator from CERN ROOT, so detector geometry is configured in TGeo format
  - ANTS2 also uses custom system of materials
- ANTS2 have many options for primary particle generation (e.g., models of radioactive sources and script-based generator)
- Need to configure Geant4 simulation without C++ code re-compilation
- Need compatibility with ANTS2 multithreading and simulations on ANTS2 grid



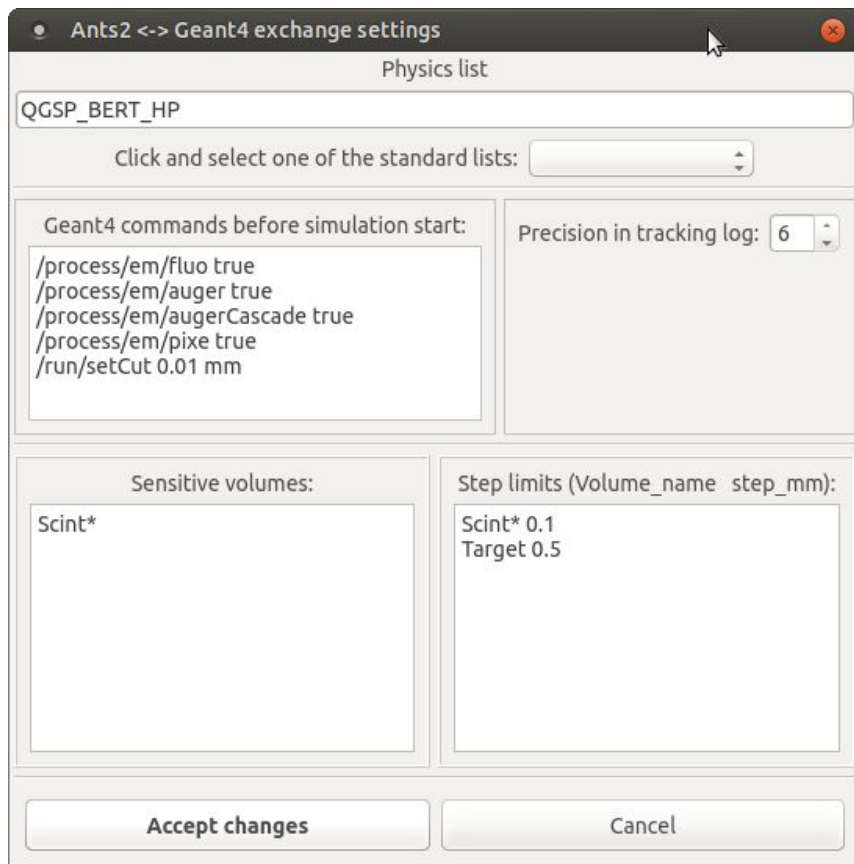
## ANTS2 without Geant4:



## ANTS2 with Geant4:



## ANTS2 GUI: configuration of Geant4 simulation settings

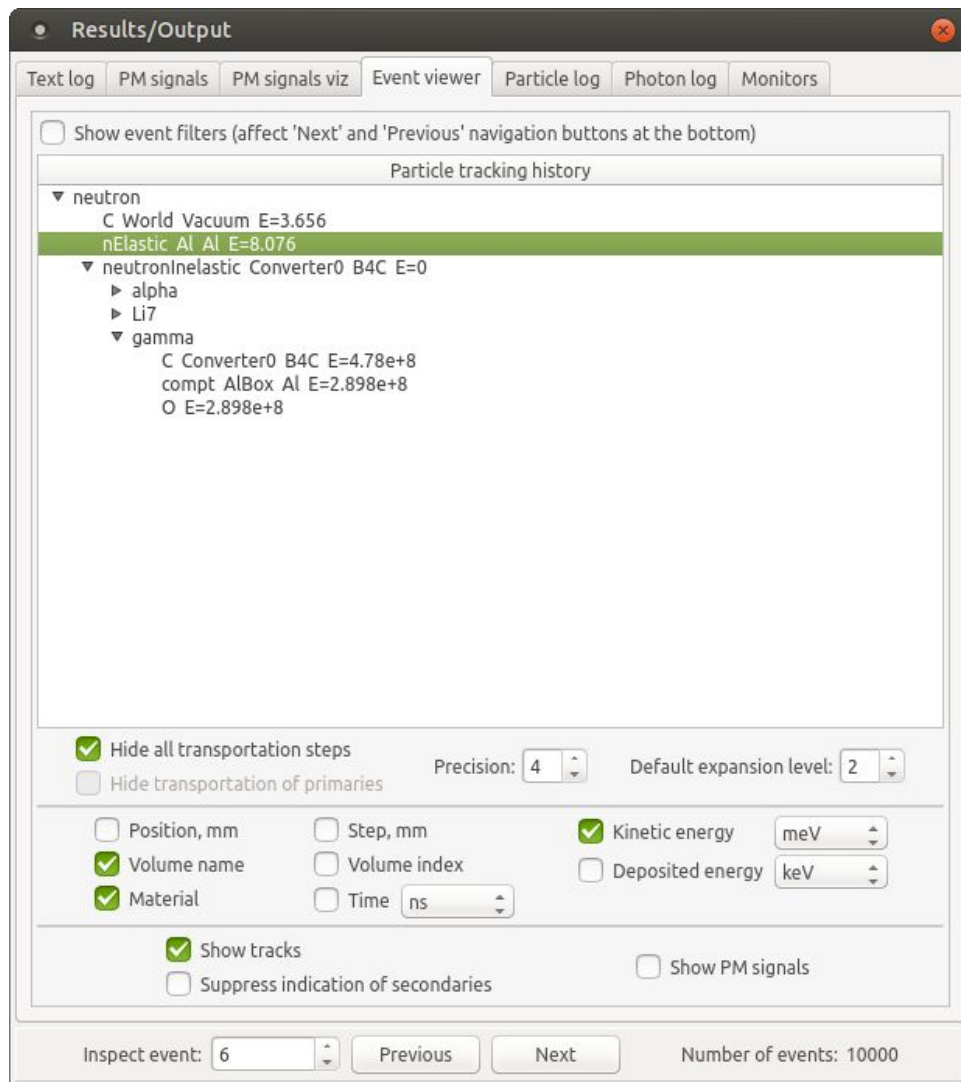


## G4ants executable:

- Reads configuration file
- Generates Geant4 detector geometry and materials described in the GDML file
- Configures physics list and sets step limiters
- Creates Geant4 SensitiveDetectors
  - for each sensitive volume: to collect energy deposition data
  - for each monitor object (if present)
- Configures SteppingAction (if tracking history collection is activated)
- Executes additional Geant4 configuration instructions given by the user
- For each event, reads records of the primaries from the file and simulates them one by one

# Event viewer and history analyzer

**Event Viewer:** tree view of all transportation and interaction history. Flexible configuration to show only relevant information. Track view with step indication.



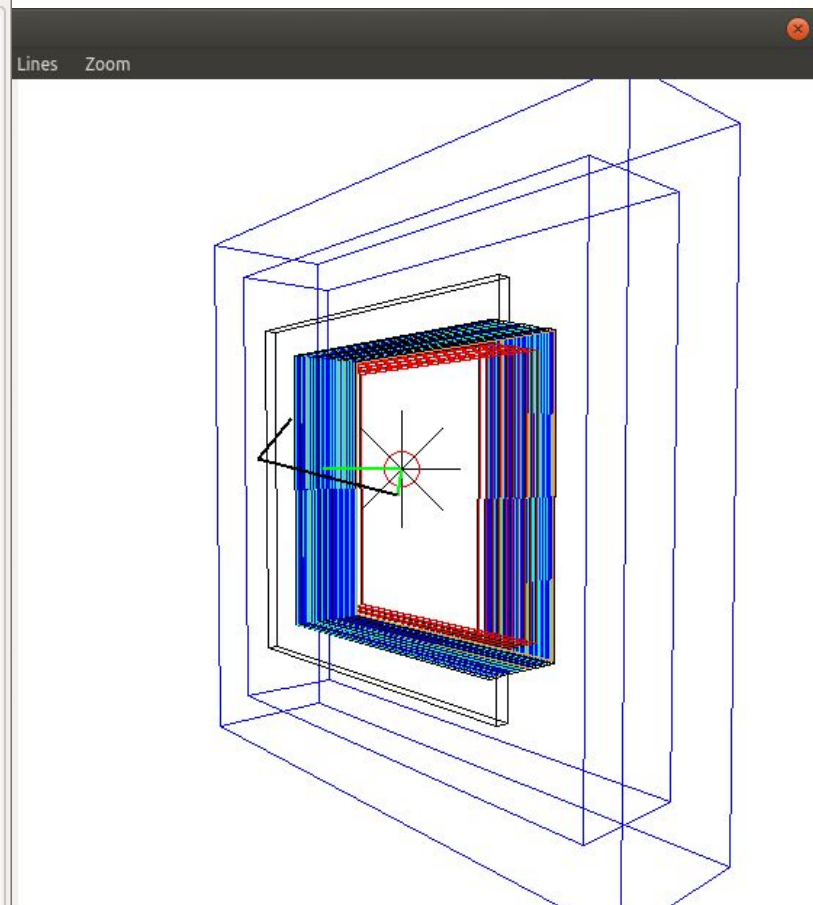
The screenshot shows the 'Results/Output' window with the 'Event viewer' tab selected. The main area displays a tree view of particle tracking history. The selected event is a neutron interaction with the following details:

- neutron
  - C World Vacuum E=3.656
  - nElastic Al Al E=8.076
  - neutronInelastic Converter0 B4C E=0
    - alpha
    - Li7
    - gamma
      - C Converter0 B4C E=4.78e+8
      - compt AlBox Al E=2.898e+8
      - O E=2.898e+8

Configuration options at the bottom include:

- Hide all transportation steps
- Hide transportation of primaries
- Precision: 4
- Default expansion level: 2
- Position, mm
- Step, mm
- Kinetic energy (meV)
- Volume name
- Volume index
- Deposited energy (keV)
- Material
- Time (ns)
- Show tracks
- Suppress indication of secondaries
- Show PM signals

At the bottom, 'Inspect event:' is set to 6, and 'Number of events:' is 10000.



## Event analyzer: “In volumes” tab



### Statistics on:

- Particles seen
- Processes seen
- Traveled distance
- Deposited energy

Very flexible cuts!

# Event viewer and history analyzer

## Event analyzer: “In volumes” tab

**Results/Output**

Text log PM signals PM signals viz Event viewer Particle log Photon log Mor...

Before simulation activate acquisition of particle tracking log!

Limit to particle:

Only primaries  Limit to the first interaction of the primary

Only secondaries

**In volumes** On the borders

Request what:

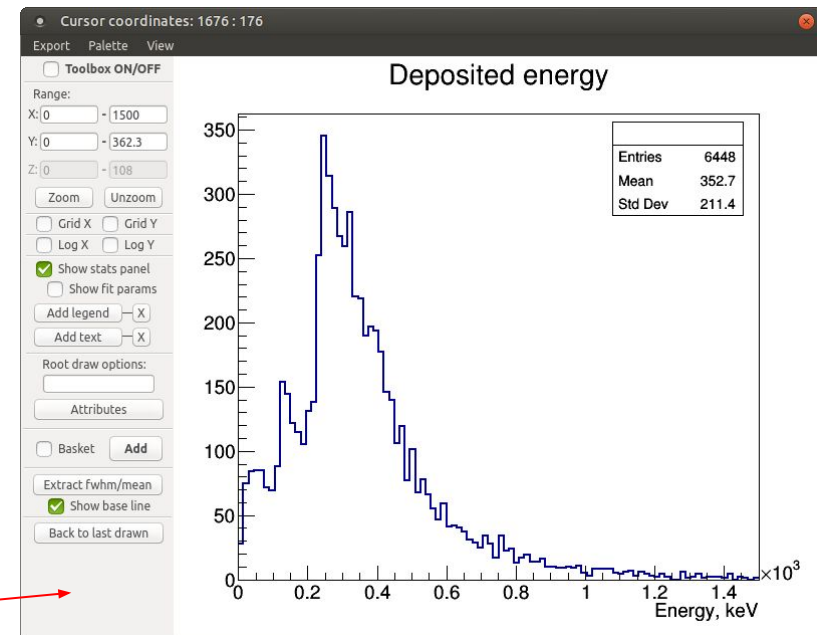
Limit to material:

Limit to volume:

Limit to volume index:

- Bins:  from:  to:

**Request**



# Event viewer and history analyzer

Event analyzer: “On the borders” tab. Statistics for particles crossing volume borders

Results/Output

Text log PM signals PM signals viz Event viewer Particle log Photon log Monitors

Before simulation activate acquisition of particle tracking log!

Limit to particle: neutron

Only primaries  Limit to the first interaction of the primary

Only secondaries

In volumes On the borders

Y  vs: Z

average per bin  and vs (3D):

Conditions:  $X < -20 \ \&\& \ (Energy < 2.49e-5 \ || \ Energy > 2.51e-5)$

Limit material from: Al  Limit material to: Vacuum

Limit volume from:  Limit volume to:

Limit vol index from: 0  Limit vol index to: 0

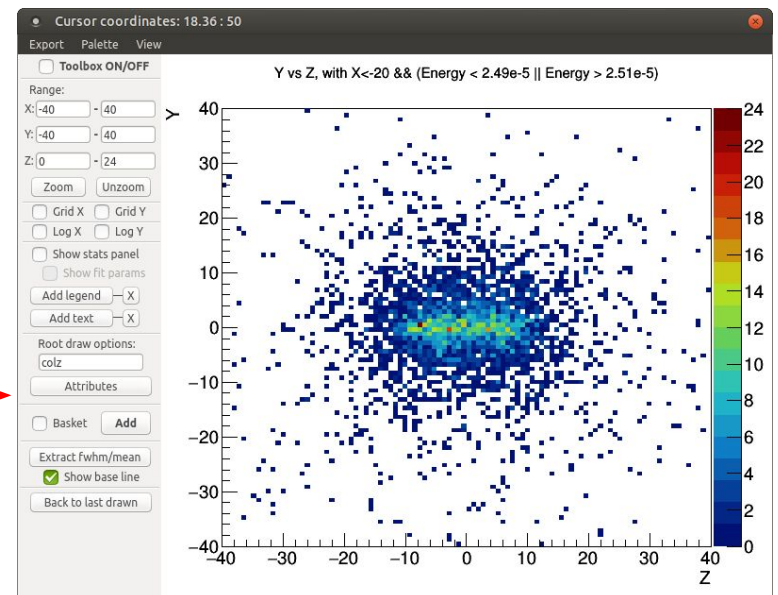
- Bins: 100 from: -40 to: 40

| Bins: 100 from: -40 to: 40

Request

Requests / cuts:

Arbitrary combination of parameters, including position ( $X$ ,  $Y$ ,  $Z$ ), **Energy**, **Time**, and direction vector components ( $V_x$ ,  $V_y$ ,  $V_z$ ) and **mathematical expressions** and **logical operations** supported by TFormula class of ROOT, e.g.,  $2 * \pi * \sqrt{X^2 + Y^2}$



Spatial distribution of back-scattered neutrons

Detector optimization over several “entangled” parameters:

- **Brute force approach:** perform simulations covering a large grid in a multi-dimensional parameter space
- A smarter approach: implement a **minimization algorithm** operating with a custom cost function

On each call from the minimizer, the function

- receives a value for each optimization parameter
- modifies the detector model according to the parameter values
- runs a simulation
- processes the results
- calculates the value of a user-defined *goodness parameter* and returns it to the minimizer



In ANTS2 this minimization-based approach is realized using the scripting system (JavaScript or Python):

- Access is provided to a CERN ROOT minimizer
- An arbitrary number of parameters can be configured
  - These parameters can have a defined upper and/or lower bounds
- Custom cost function is defined directly in the script (no compilation is needed)
  - It is straightforward to change any detector property: configuration is stored in a JSON object (collection of key/value pairs)
  - Scripting gives access to the simulation and reconstruction managers, the data hub and the history analyzer

# Semi-automatic detector optimization

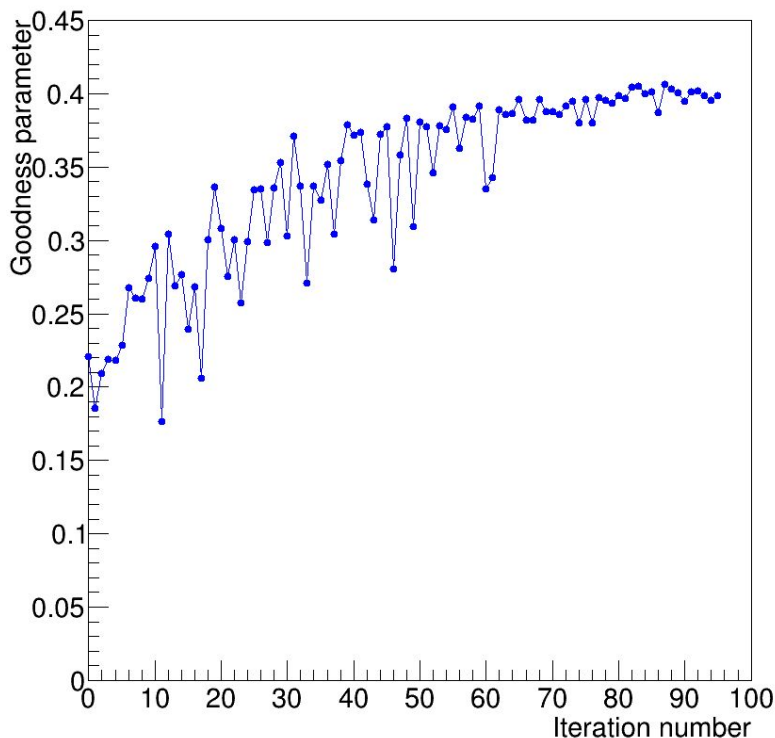
An example: Optimization of an RPC neutron detector

**Parameters:** 5 thicknesses of neutron converter layers



**Cost function:** A product of an *equality parameter* and the total detection efficiency:

we target to equalize the count rate of all individual RPCs as much as possible maintaining high detection efficiency



- Optimization started from converter layer thickness of  $1\ \mu\text{m}$  for all RPCs
- After 87 iteration (20 minutes) an optimum was found with layer thicknesses of  $0.36$ ,  $0.46$ ,  $0.72$ ,  $1.23$  and  $2.54\ \mu\text{m}$
- Compared to the detector prototype, we were able to improved the equality parameter by a factor of 2.5

- Develop web interface for ANTS2 targeting didactic / outreach activities
- Implement VecGeom geometry manager and navigator for direct compatibility with Geant4
- Implement tracing of optical photons on GPU (ambitious!)
- ANTS2 as a Python package?

Open source at Github:

<https://github.com/andrmor/ANTS2> (use Dev branch for the latest features)

<https://github.com/andrmor/G4ants>

If you have questions, send them to [andrei@coimbra.lip.pt](mailto:andrei@coimbra.lip.pt)