Recent Developments in the FullSimLight Simulation Tool from ATLAS

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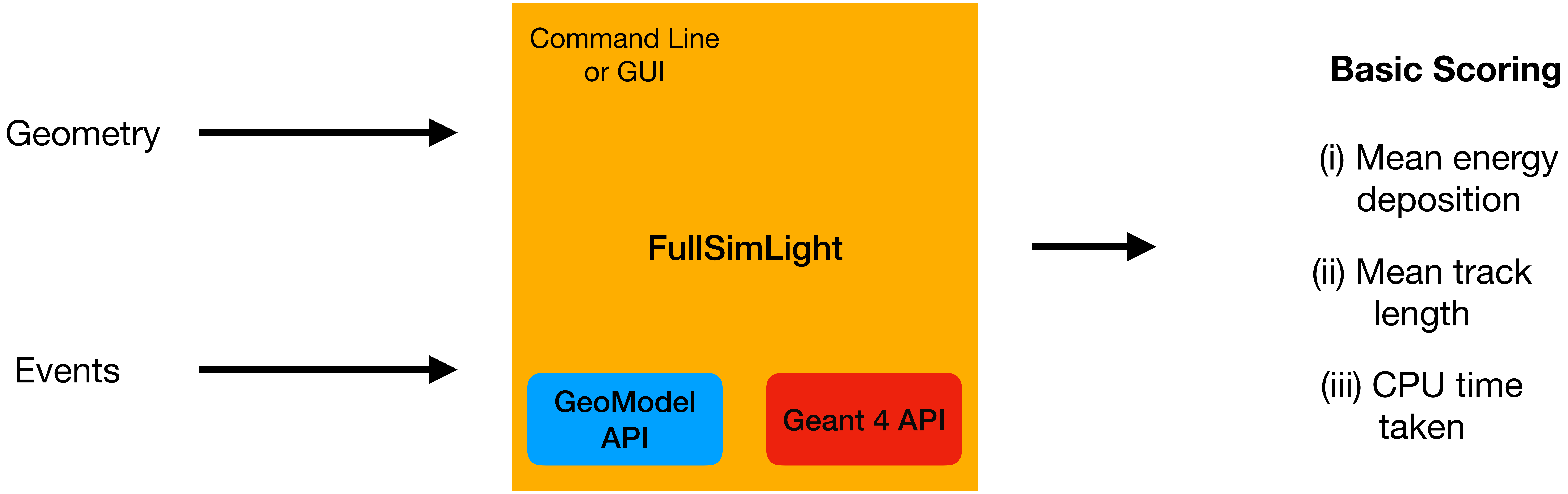
FullSimLight

- FullSimLight brought to you by the ATLAS collaboration is an experiment independent tool used for lightweight full Geant4 simulation.

- FullSimLight reads in events **and geometries**.

- The goal of FullSimLight is to simplify studies of Geant4 tracking and physics processes, including tests on novel architectures as well as optimization studies.

FullSimLight



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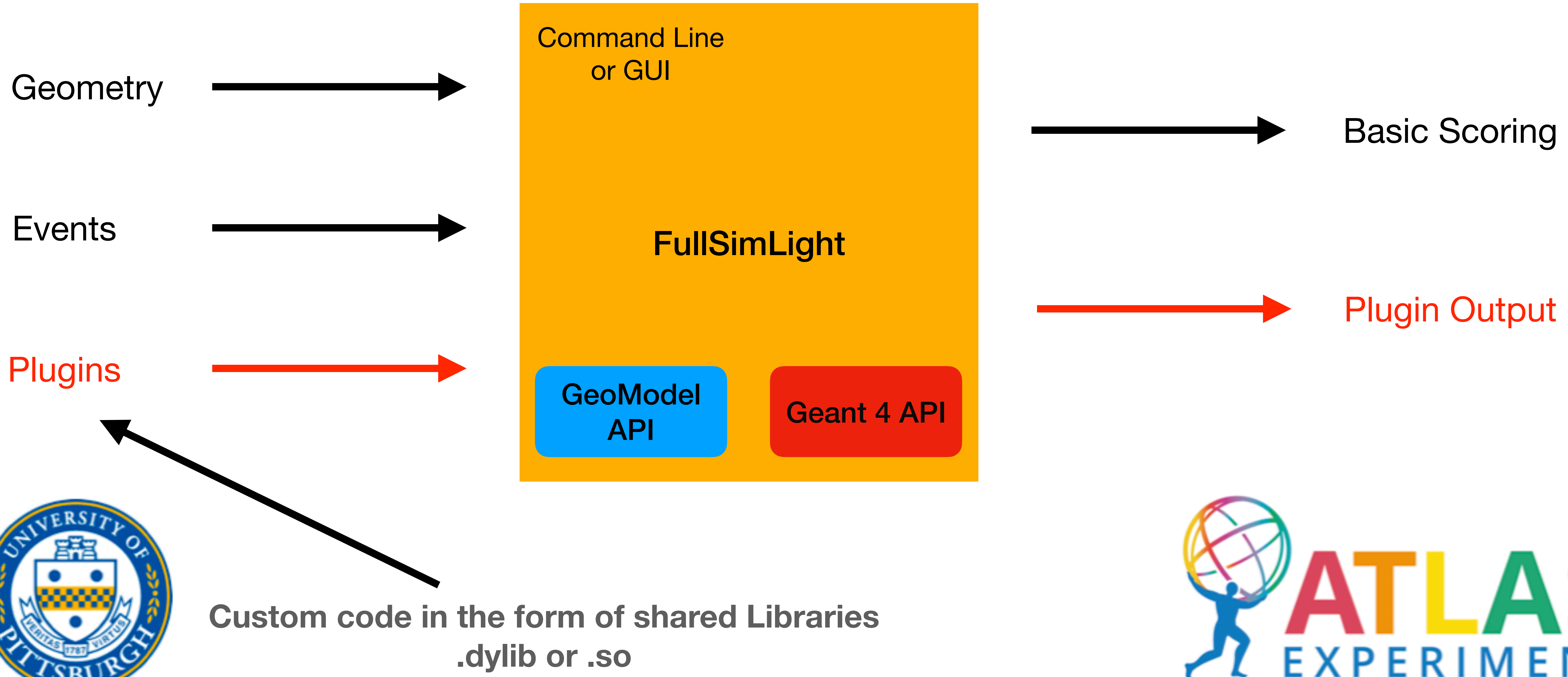
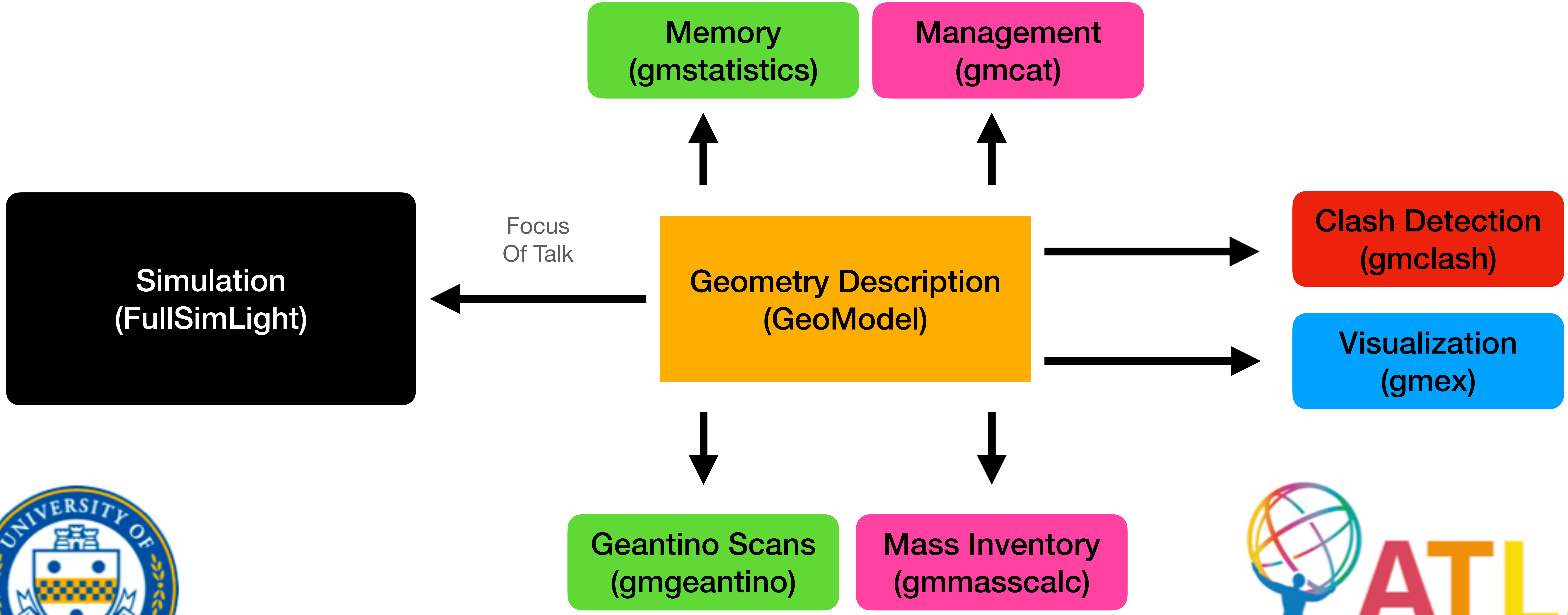
Customized FullSimLight



Geant 4

- Geant4 is a toolkit to create simulations of the passage of particles or radiation through matter.
  - Tracking of charged and neutral particles through geometry in a magnetic field.
  - Decay of unstable particles and interaction with detector materials.
    - Customizable (Physics Lists).
  - Customizable simulation of detector response (Sensitive Detectors).
  - User hooks allowing one to intercept processing at various stages (User Actions).
    - Run Actions
    - Event Actions
    - Tracking Actions
    - Stepping Actions
    - Stacking Actions

- The **GeoModel Toolkit** (geomodel.web.cern.ch) offers classes that provide geometrical primitives for describing detectors, and a set of **command line tools** for accessing, handling, manipulating, dumping, restoring, visualizing, inspecting, and debugging the detector geometry.



- Installation Instructions

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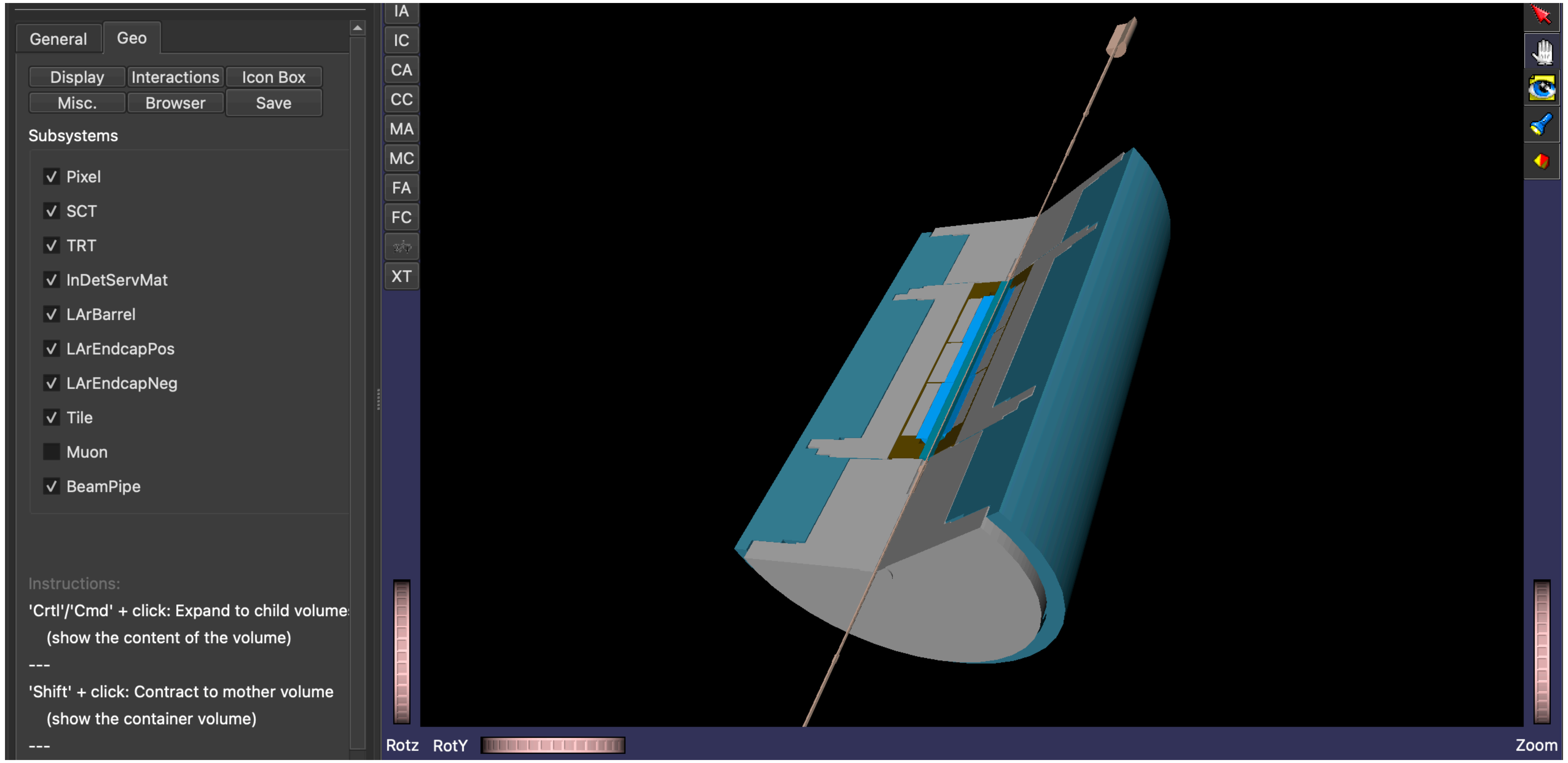
Gmex

- Gmex is an interactive 3d geometry visualization tool which is part of the GeoModel toolkit.

- Useful in developing a software description of a geometry.

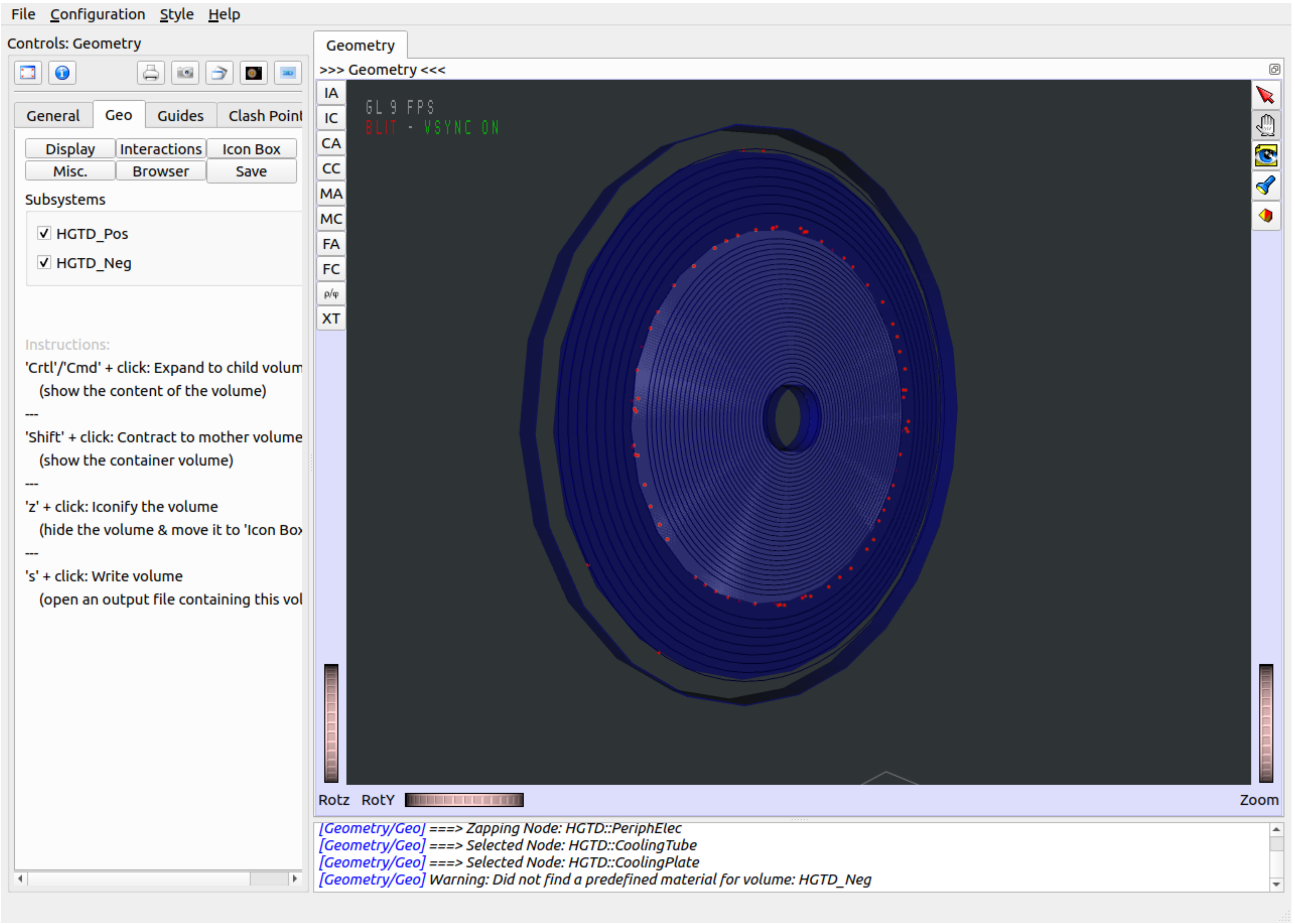


ATLAS Detector visualized in gmex.

Clash Detection

Clash report

```
{
  "ClashesReport": [
    {
      "distance[mm]": 2.2229113814991024,
      "typeOfClash": 0,
      "volume1CopyNo": 16969,
      "volume1EntityType": "G4Box",
      "volume1Name":
"HGTDModule3_layer_8_8_12",
      "volume2CopyNo": -1897956176,
      "volume2EntityType": "G4Tubs",
      "volume2Name": "HGTD::ModuleLayer3",
      "x": 3.8780568483553015,
      "y": -20.659230748619382,
      "z": 3491.78
    },    ....
```



Clash points visualized in gmex.

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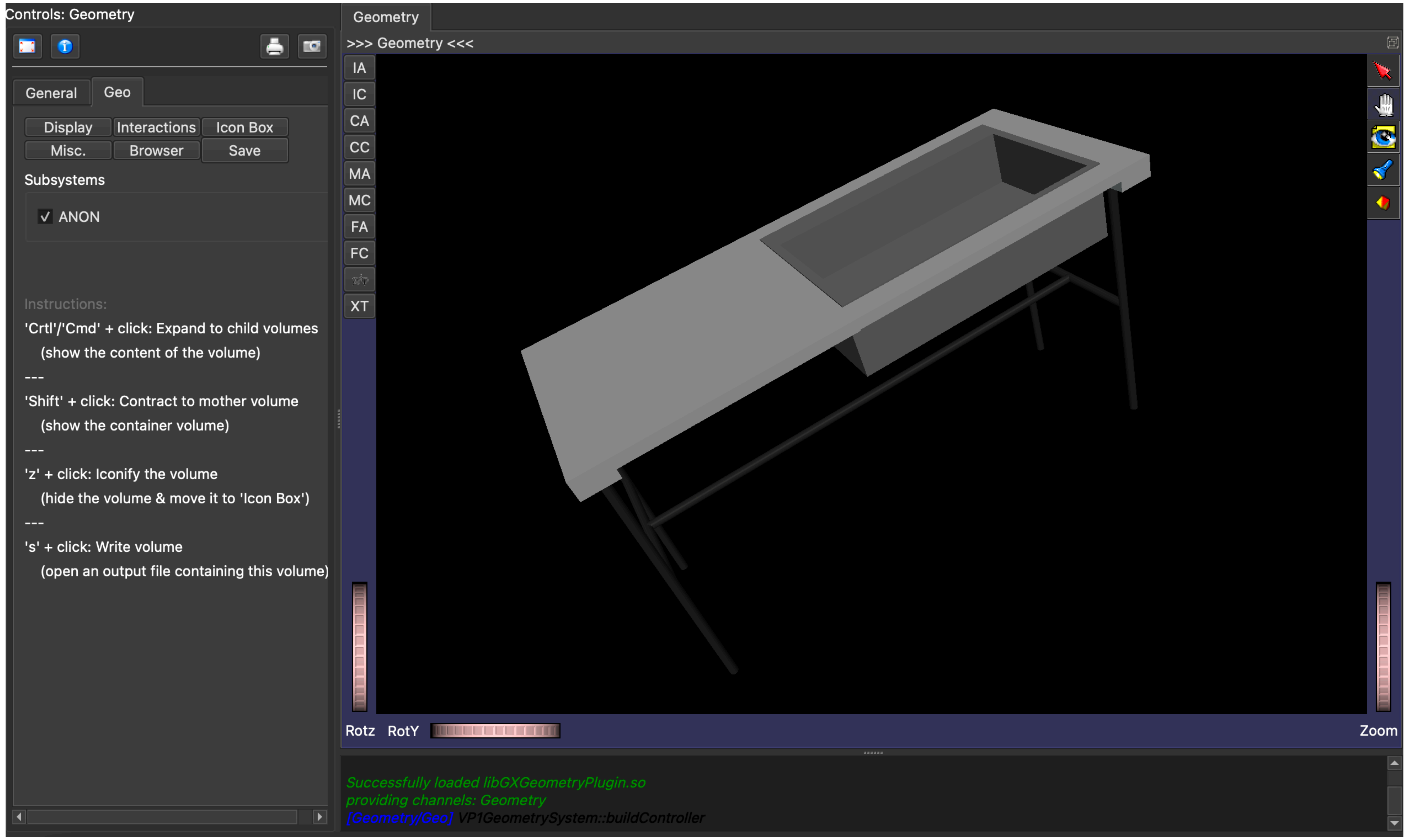
Geometry Example (Kitchen Sink)

```
void KitchenSinkPlugin::create(GeoPhysVol *world, bool /*publish*/)
{
  const double degree=M_PI/180.0;

  // Define elements used in this example:
  GeoElement  *oxygen        = new GeoElement("Oxygen",    "O",   19,  39*gram/mole);
  GeoElement  *nitrogen      = new GeoElement("Nitrogen",  "N",    7,  14*gram/mole);
  GeoElement  *argon         = new GeoElement("Argon",     "Ar", 18,  40*gram/mole);
  GeoElement  *aluminium     = new GeoElement("Aluminium", "Al", 13,  26*gram/mole);
  GeoElement  *iron          = new GeoElement("Iron",      "Fe", 26,  55.8*gram/mole);
  GeoElement  *chromium      = new GeoElement("Chromium",  "Cr", 24,  52*gram/mole);



  // Some dimensions used below:
  double platformHeight=34.5;                            // Height to the top of the flanges
  double flangeDiameter=3.375;                           // Diameter of the flanges
  double flangeThickness=3.0/16.0;                       // Thickness of the flanges
  double t1TubeLength = platformHeight-flangeThickness;  // Overall length of tube t1;
  double innerRadius=0.75/2.0;                           // 3/4 inch (inner diameter) pipe


  const GeoTube      *t1Tube    = new GeoTube(innerRadius,outerRadius, t1TubeLength/2.0);
  const GeoLogVol    *t1Log     = new  GeoLogVol("T1Log", t1Tube, Iron);
  GeoPhysVol         *t1Phys    = new GeoPhysVol(t1Log);


  world->add(xform1);
  world->add(t1Phys);
  world->add(xform2);
  world->add(t1Phys);
```

Build Into Plugin →



GeoModel Description

Gmex visualization

- [Check Out Kitchen Sink Plugin]

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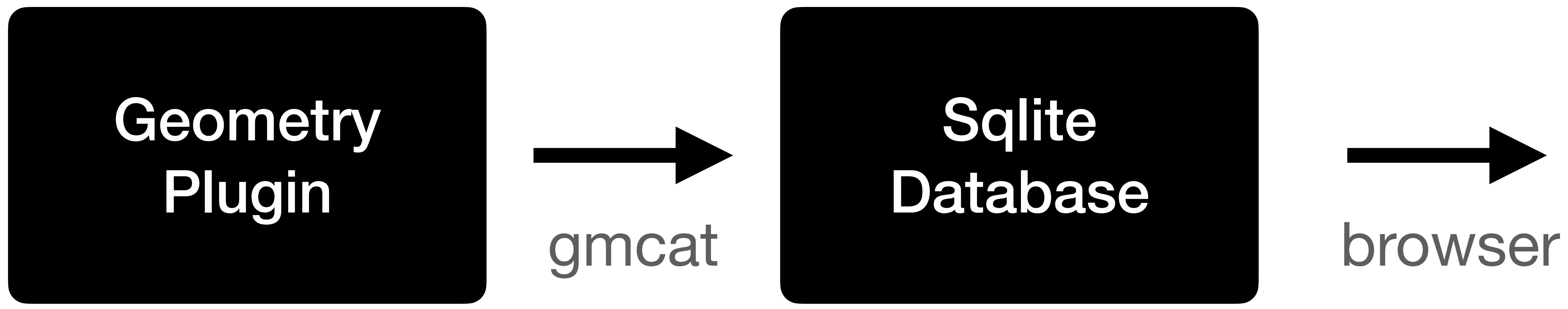
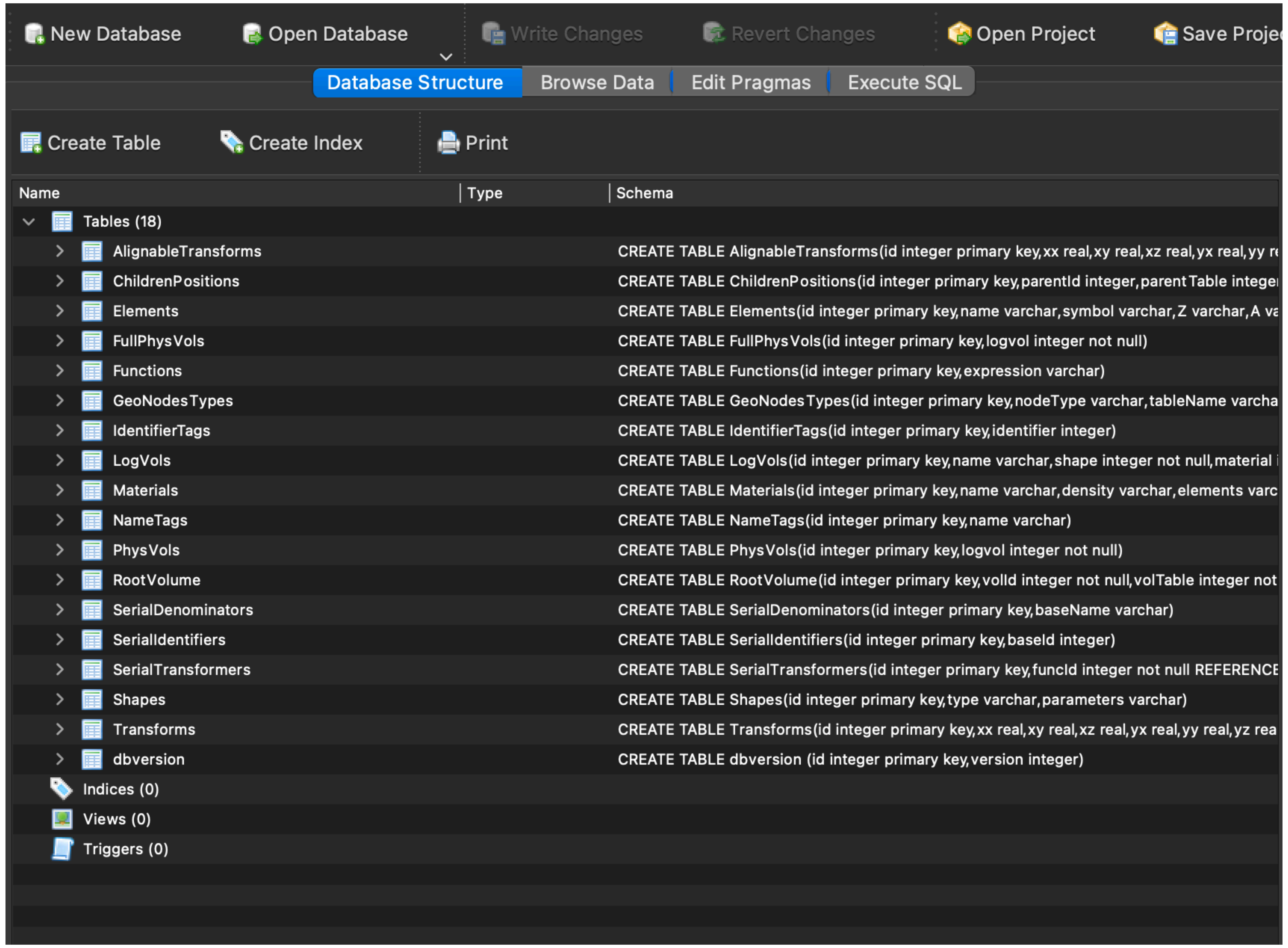
Dump into Database file





Geometry Database

Back to FullSimLight (Command Line)

```
./fullSimLight -g mygeometry.db
```

```
./fullSimLight  -g libHGTDPlugin.1.0.0.dylib
```

```
./fullSimLight -c myconfig.json
```

New way of running FullSimLight

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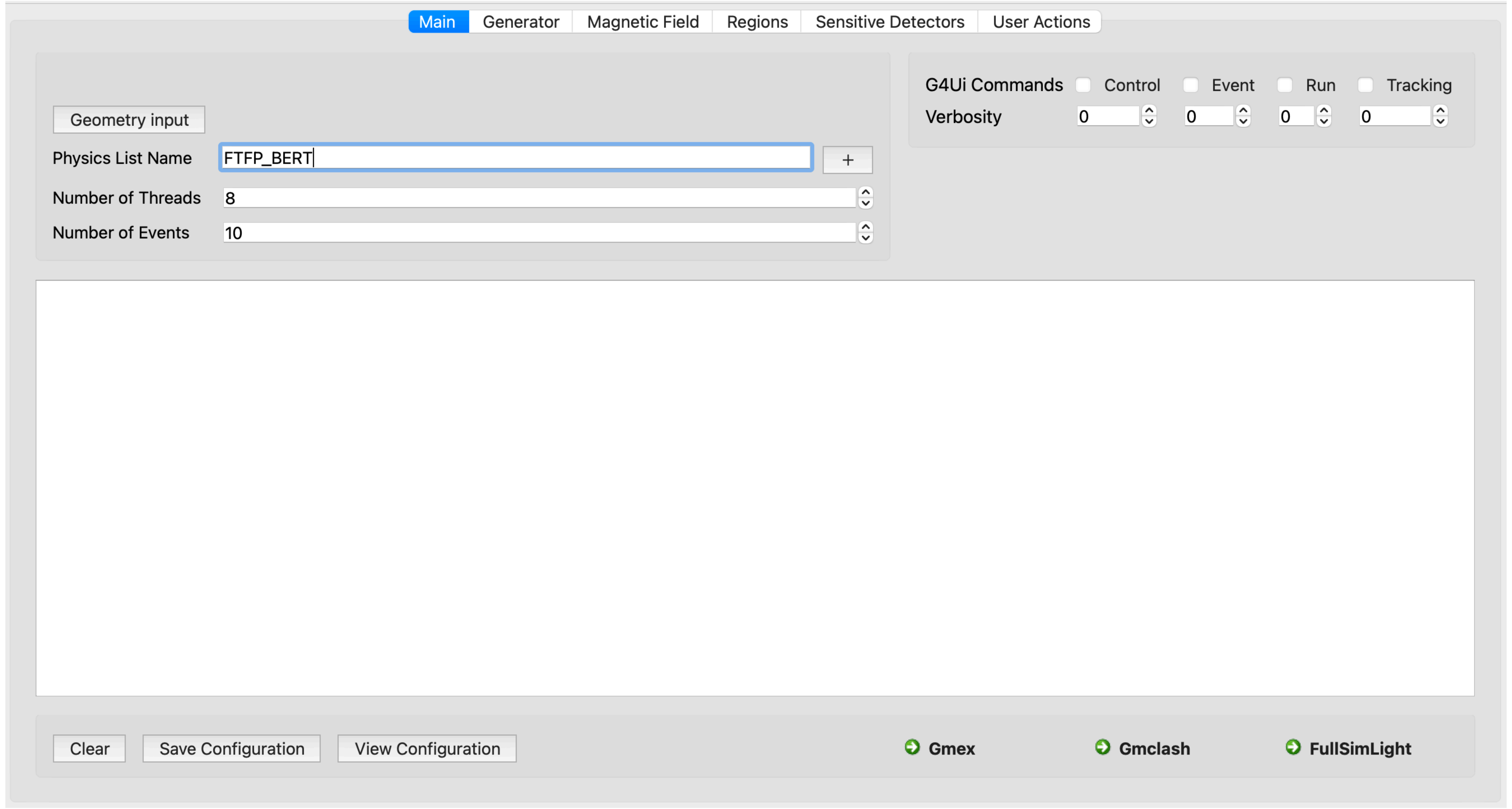
FSL

- FSL is the GUI to FullSimLight.
- Produces a fool-proof configuration file which can be ran with FullSimLight through the -c flag.
- FullSimLight and other GeoModel tools can also be run right within the FSL interface.



FSL GUI

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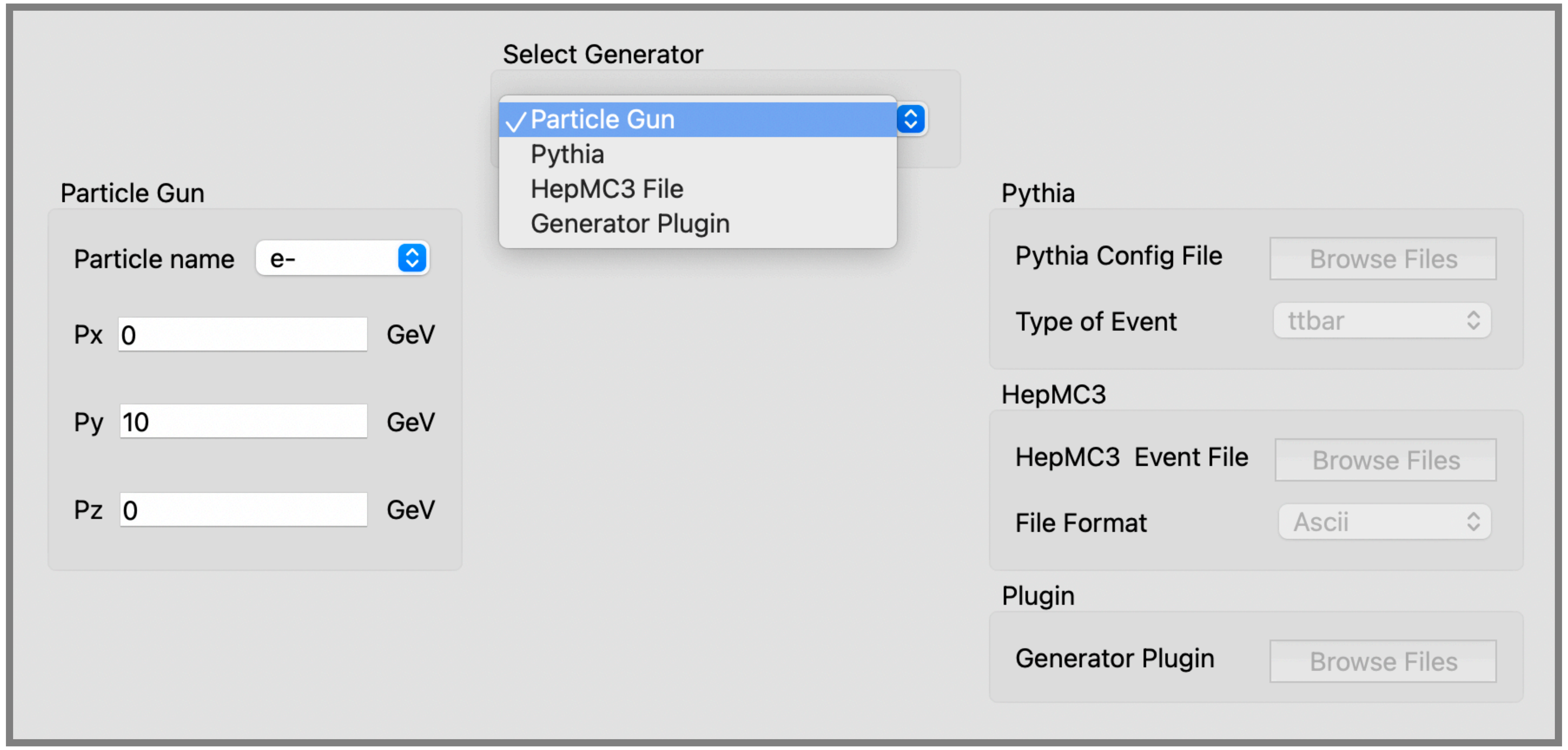
Event Generation

Particle gun.

Pythia

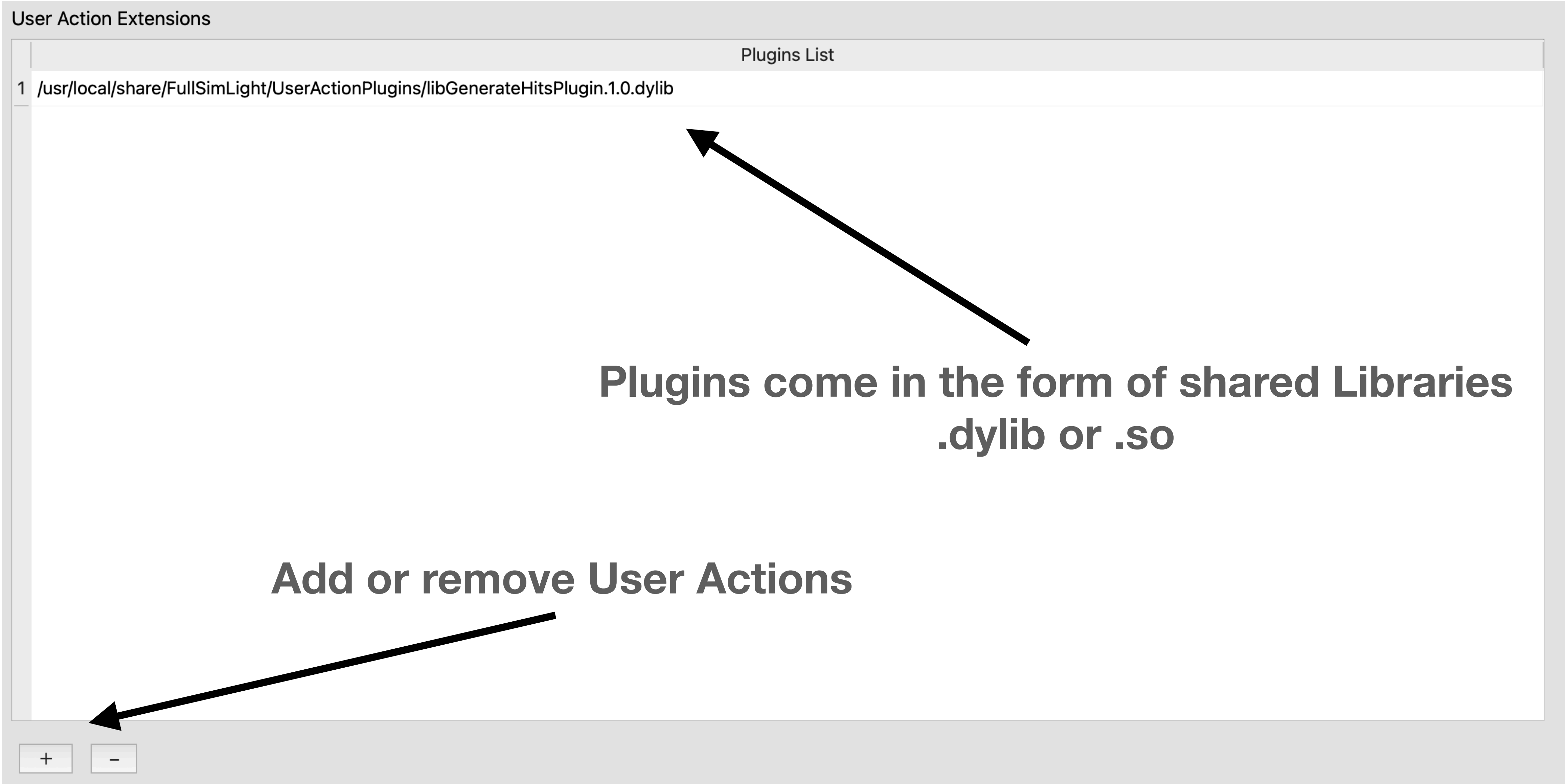
HepMC3 Files (New)

Event Generator Plugin (New)



Generator Menu on GUI

Plugin Architecture



User Action Plugin Menu

Magnetic Field Plugin Menu

- Plugins which come in the form of shared libraries are the mechanism for users to extend their simulations. Plugins can be used to add
    - User Actions
    - Sensitive Detectors
    - Magnetic Field
    - Physics Lists
    - Event Generators
- FSL provides a simple interface to add the plugins through various menus, some of which are shown on the right.
- FullSimLight comes with a number of custom plugins to do various things such as record hits, generate the ATLAS magnetic field, etc.

ATLAS EXPERIMENT

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Writing Plugins

Geant4 provides User Actions to interrupt processing at specific points. → FullSimLight provides Abstract classes to interface with this mechanism via plugins. → The Plugin instantiates and uses user customized G4UserActions. → Example: Hits Plugin (produces record of Geant4 Stepping points)

Plugin

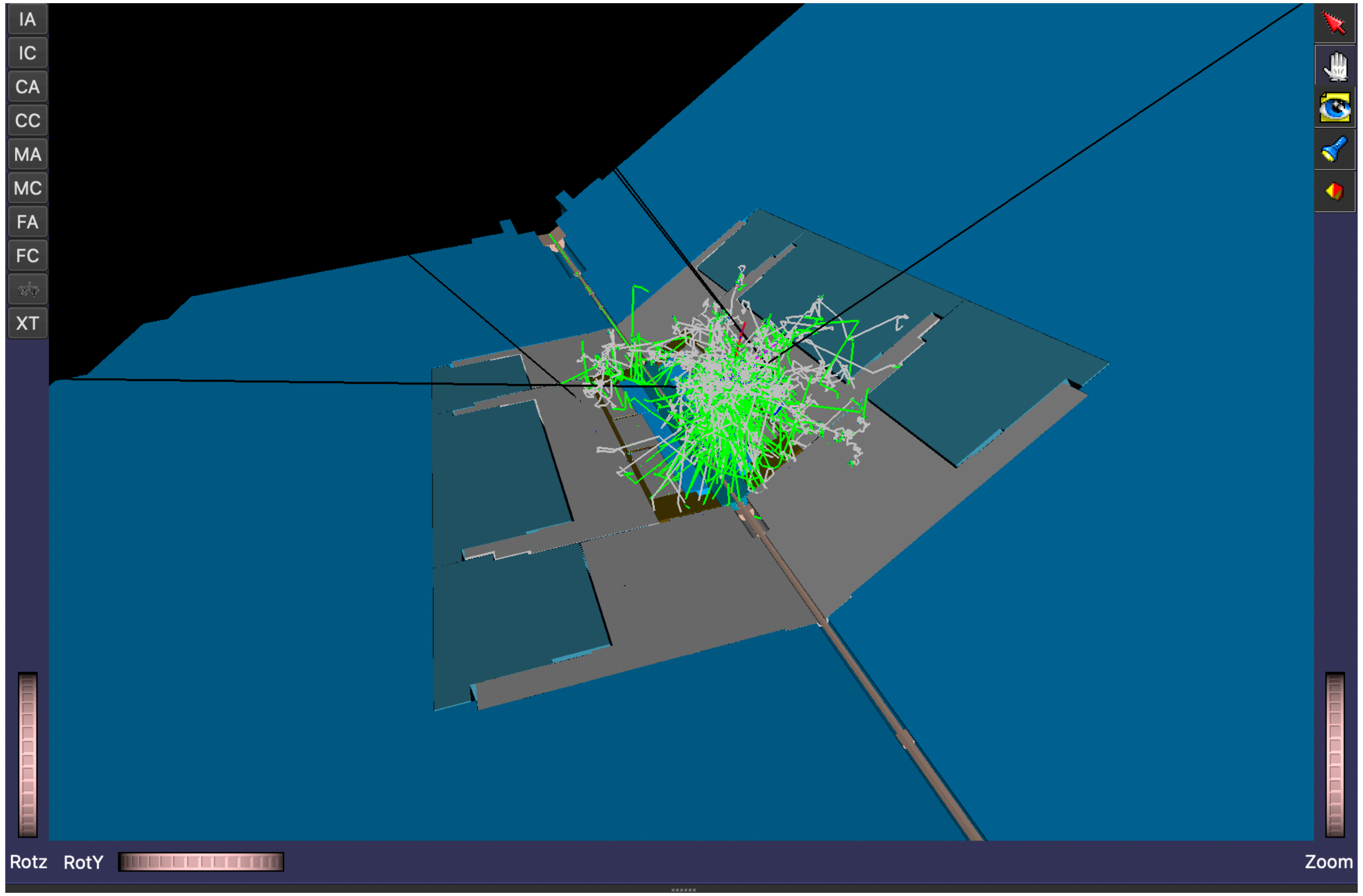
User Actions

Abstract Class

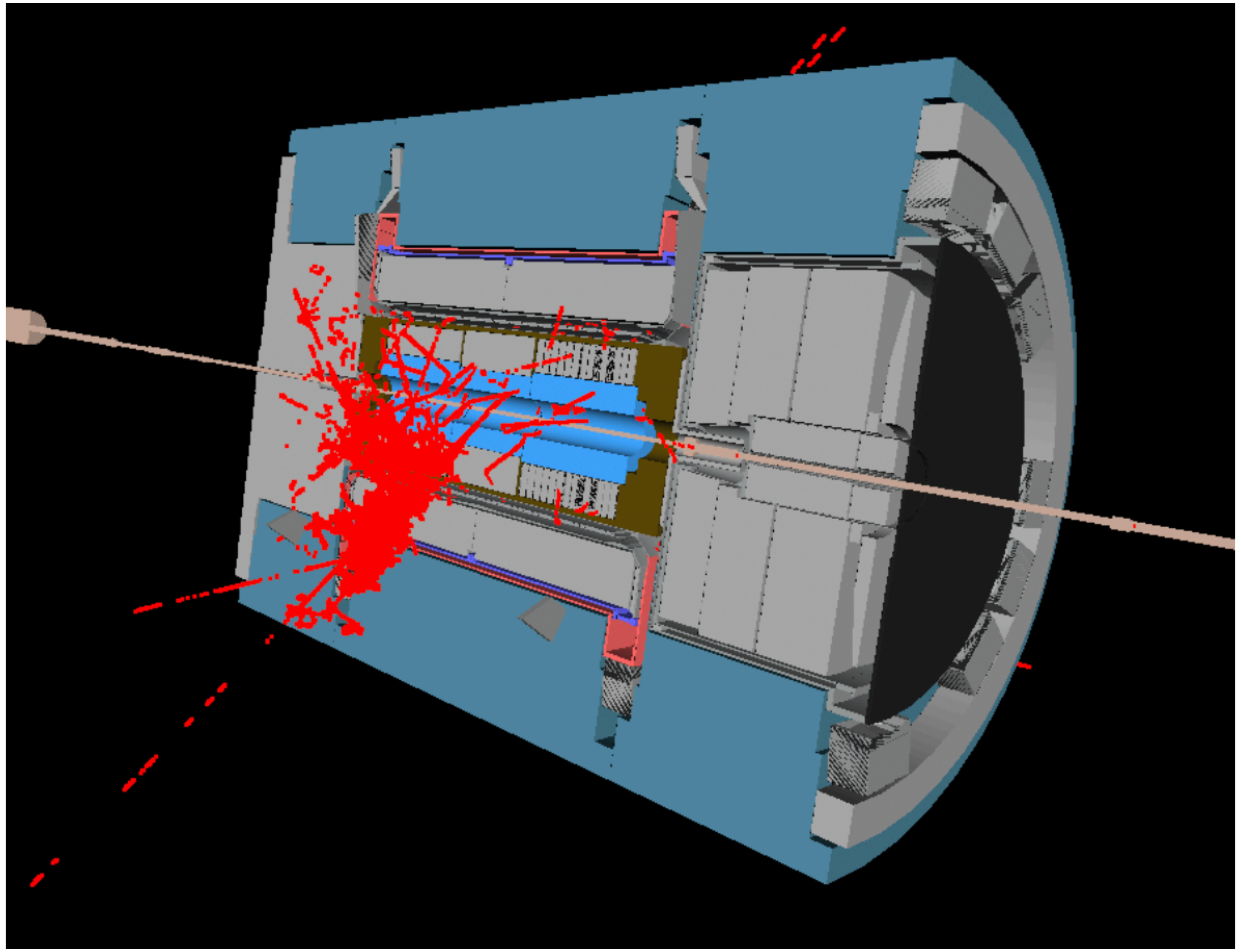
```
class GenerateHitsPlugin:public FSLUserActionPlugin {

public:

    GenerateHitsPlugin();
    virtual G4UserSteppingAction *getSteppingAction() const final override;
    virtual G4UserEventAction *getEventAction() const final override;

    GenerateHitsEvent* eventaction = new GenerateHitsEvent();
    GenerateHitsStep* stepaction = new GenerateHitsStep();

};
```

- Check Out Hits Plugin

Step and Tracks Visualization in gmex



Tracks Visualization in gmex

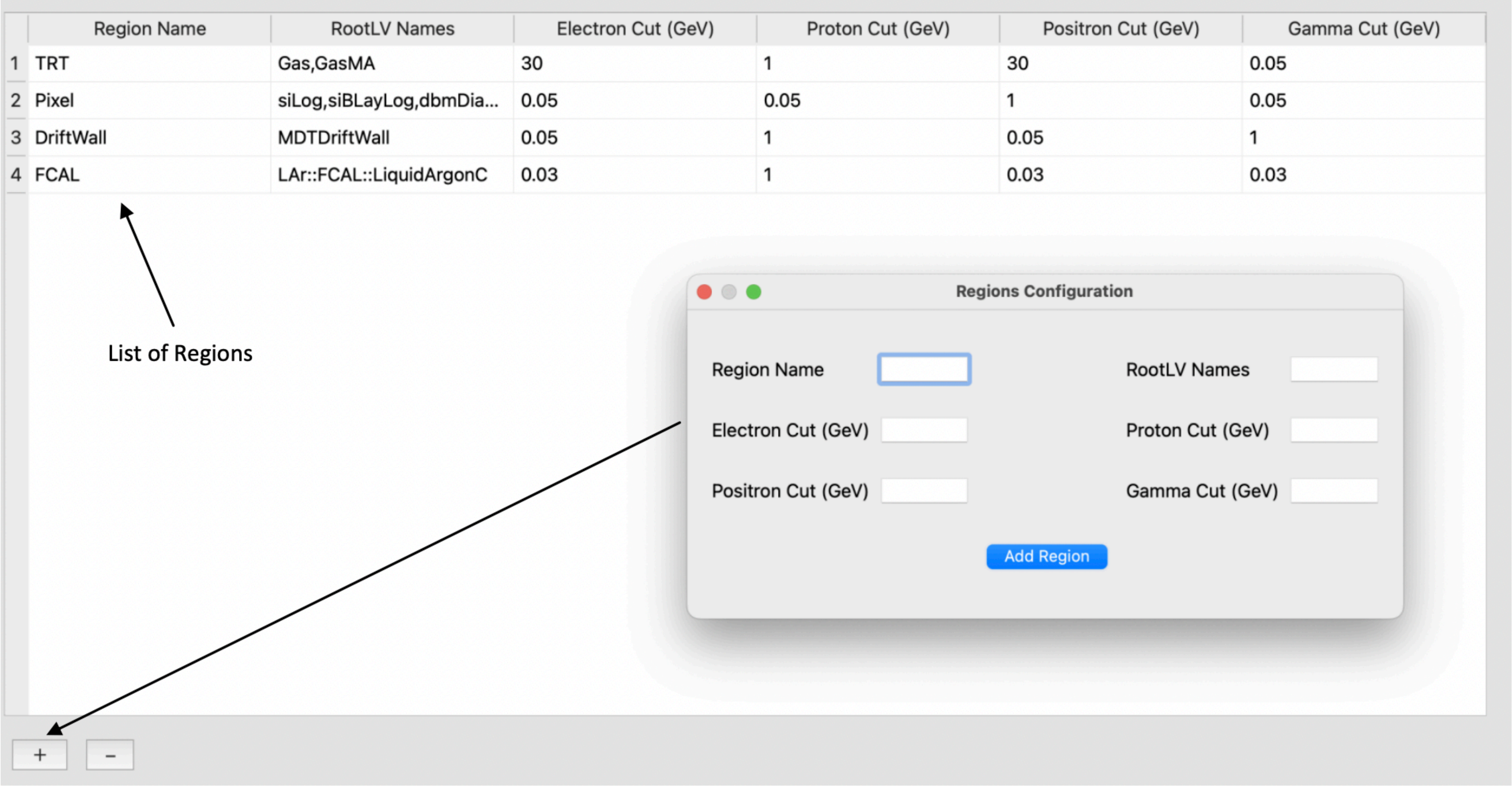


Steps Visualization in gmex

Regions

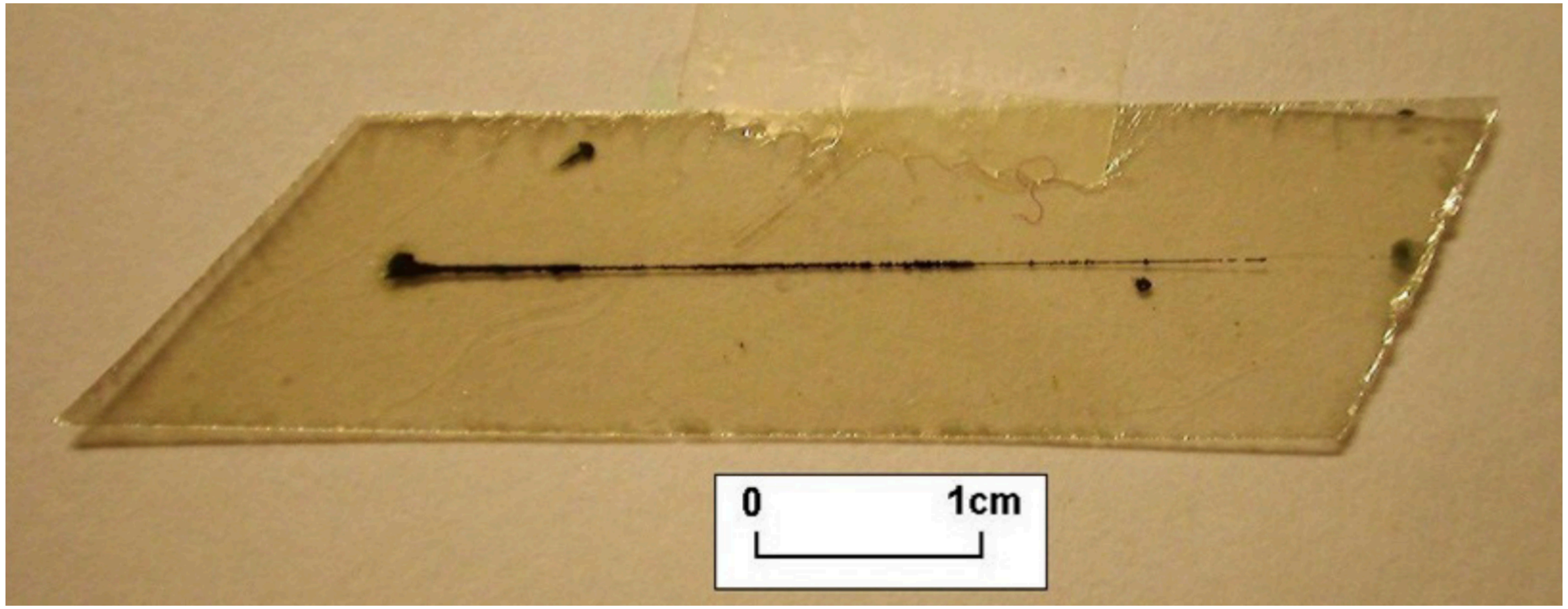
- The mechanism to configure regions is found on the Regions tab in FSL.

- Root Logical volumes and cuts can be specified as required.



Practical Example

- It is commonly believed that grand unified theories (GUTs) predict proton decay.
- Muscovite Mica is one possible place to look for evidence of such proton decay by analyzing positron tracks.
- Easy to simulate using FullSimLight.

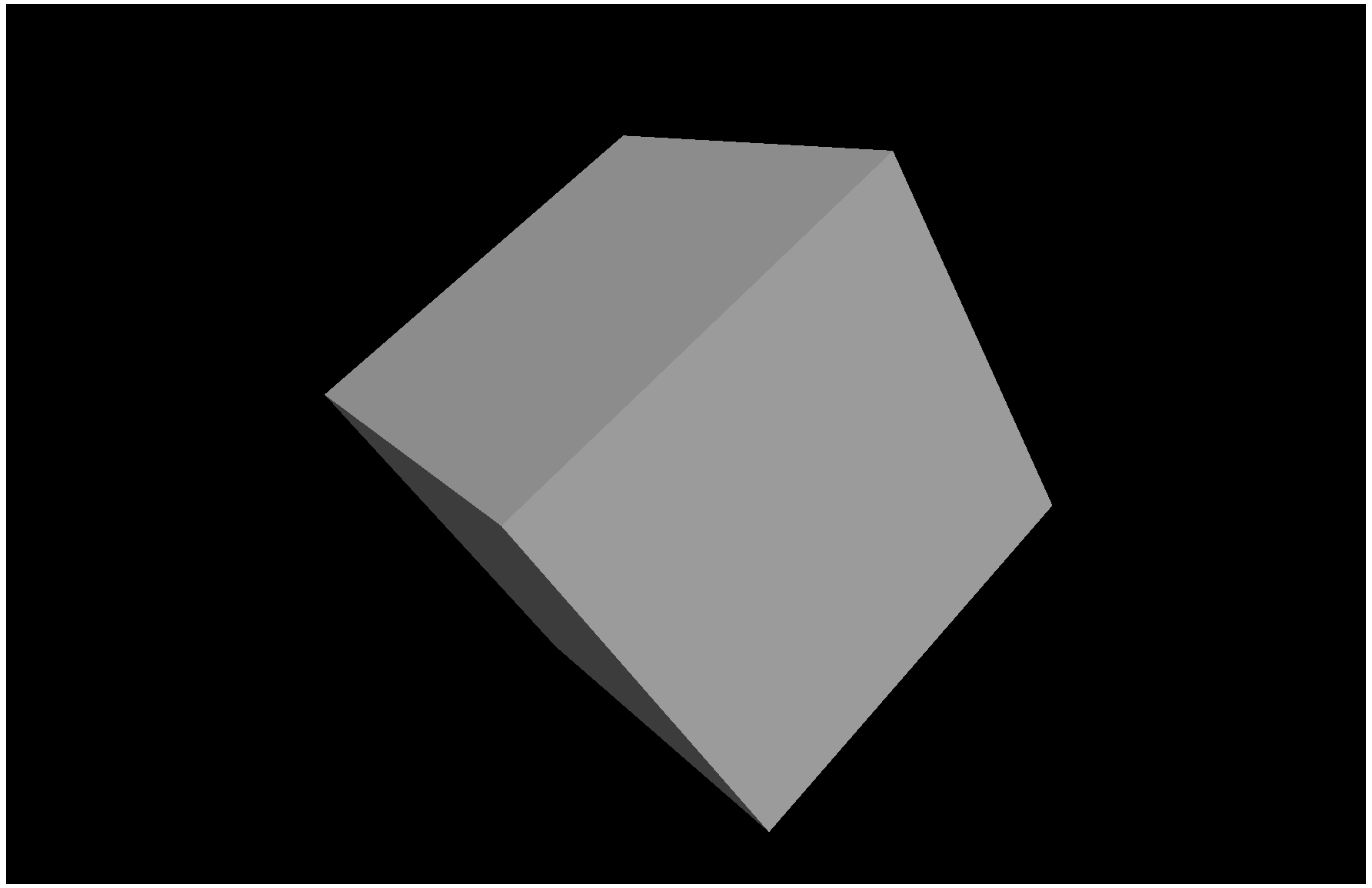


Positron track in muscovite mica (*F.M. Russell. In Quodons in Mica, J.F. R. Archilla et al, eds., Springer (2015) pp. 474–559.*)

Cube of Mica

```
void MicaPlugin::create(GeoPhysVol *world, bool /*publish*/)
{
    GeoElement  *potassium = new GeoElement("Potassium",    "K",   19,  39*gram/mole);
    GeoElement  *oxygen    = new GeoElement("Oxygen",     "O",   8,  16*gram/mole);
    GeoElement  *aluminium = new GeoElement("Aluminium", "Al", 13,  26*gram/mole);
    GeoElement  *silicon   = new GeoElement("Silicon", "Si", 14,  28*gram/mole);
    GeoElement  *hydrogen  = new GeoElement("Hydrogen", "H", 1,  1*gram/mole);
    GeoElement  *fluorine  = new GeoElement("Fluorine", "F", 9,  19*gram/mole);

    //Defining Mica
    double densityOfMica = 2.82*gram/cm3;
    GeoMaterial *Mica = new GeoMaterial("Mica",densityOfMica);
    Mica->add(potassium,1);
    Mica->add(oxygen,11.8);
    Mica->add(aluminium,3);
    Mica->add(silicon,3);
    Mica->add(hydrogen,1.8);
    Mica->add(fluorine,0.2);
    Mica->lock();


    const double barWidth1=4.0;
    const double barWidth2=3.0;
    double barThickness   =1.25;
    double cutoutDepth    = 21.5;
    double cutoutWidth    = 32.375;


    const GeoBox       *MicaBox  = new GeoBox(100*cm, 100*cm,100*cm);
    const GeoLogVol    *MicaLog  = new  GeoLogVol("MicaLog", MicaBox, Mica);
    GeoPhysVol         *MicaPhys = new GeoPhysVol(MicaLog);
    world->add(MicaPhys);
```

GeoModel Description

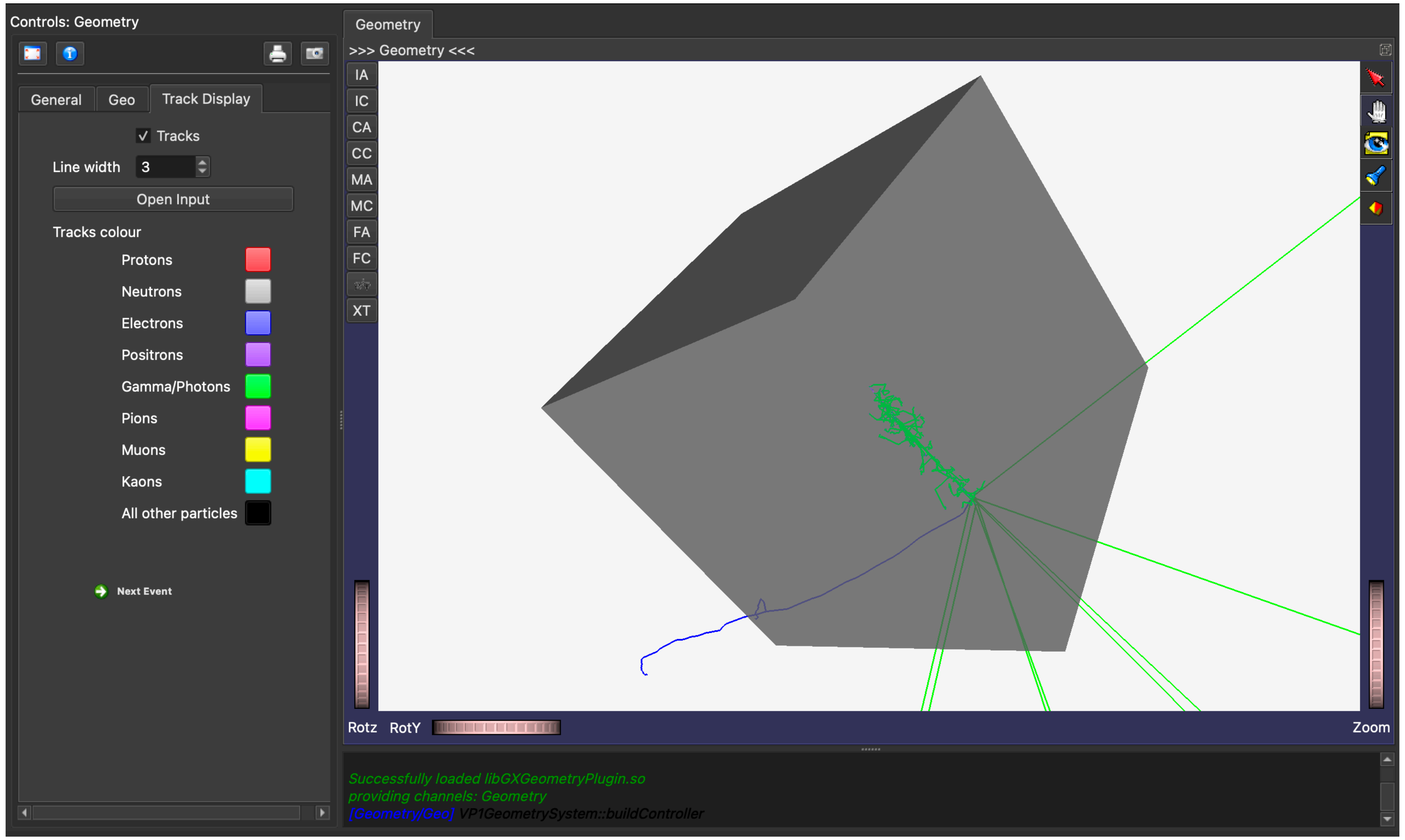


Gmex visualization

Simulation

```
==================================   Run summary   ===============

   Number of events  = 10

------------------------------------------------------------------

 Mean energy deposit per event = 0.4981 +- 0.006169 [GeV]

 Mean track length (charged) per event = 115.4 +- 49.83 [cm]
 Mean track length (neutral) per event = 4568 +- 6626 [cm]

 Number of steps (charged) per event = 1002 +- 106.6
 Number of steps (neutral) per event = 719.1 +- 105.4

 Number of secondaries per event :
    Gammas    =  108.5 +- 11.49
    Electrons =  712.5 +- 96.47
    Positrons =  7.1 +- 2.119
..................................................................
```

FullSimLight Basic Scoring



Particle shower inside Mica Cube

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Summary of Recent Developments in FullSimLight

- Plugin Mechanism to allow users and developers with diverse goals to extend and customize the simulation.
- A GUI for fast, transparent, and foolproof configuration.
- Reading in events from HepMC3 files and region configuration.
- Built in visualization of steps and tracks in gmex.
- Source code can be found at GeoModel and documentation/installation instructions at Documentation.