Tutorial 1 – An Introduction to Detector Geometries in rat-pac

Introduction:

rat-pac is an open source toolkit developed by a consortium of high energy physics experimental groups, namely ASDC, WATCHMAN, and ANNIE. The package is a plain text wrapper for GEANT4 that uses the human readable JavaScript Object Notation (JSON) standard to provide detector descriptions.

Prerequisites:

These tutorials are designed to be a step by step tutorial to get new users familiar with the rat-pac toolkit. I will reference the user manual, http://rat.readthedocs.org/en/latest/index.html, to guide the user to broader material than the specific examples covered in this tutorial series.

Prerequisites:

1) Required: Installation of rat-pac and all dependencies as covered at http://rat.readthedocs.org/en/latest/installation.html
2) Required environmental variable setup
    a. source [Path to geant4 installation]/geant4.10.01.p02/geant4.10.01.p02-build/bin/geant4.sh
    b. source [Path to geant4 installation]/geant4.10.01.p02/geant4.10.01.p02-build/geant4make.sh
    c. source [Path to rat-pac installation]/rat-pac/env.sh
    d. if running scientific linux or centos:
        i. PATH=[Path to python 2.7 installation]/Python-2.7.6/:$PATH
        ii. LD_LIBRARY_PATH=[Path to python 2.7 installation] /python/lib:$LD_LIBRARY_PATH
3) Suggested: Open GL with Qt – Qt allows for simple mouse driven rotation and panning of the detector geometry. Without Qt this can be accomplished via the command line which will be discussed.

Navigating rat-pac:

Let us start by running the example watchboy_movie. At the command prompt type:

```
rat mac/tutorials/tutorial_001/watchboy_movie.mac
```

This will run the macro `watchboy_movie.mac` (**Figure 1**) which opens an OpenGL window, displays and rotates the detector, runs 1 7MeV electron, and closes (link to movie). Additional macro files can be found in the [rat-pac installation]/mac/ directory

For those new to rat-pac with Geant4 experience, you will notice two commands at the top of the file not native to Geant4.

```
/rat/db/set DETECTOR experiment "Watchboy"
/rat/db/set DETECTOR geo_file "Watchboy/Watchboy.geo"
```

By default `/rat/db/set` looks in the [rat-pac installation]/data directory. The first line points rat-pac to the directory that contains all the experiment files

MATERIALS_Watchboy.ratdb
Watchboy.geo

Calib.geo

PMTINFO_inner.ratdb

PMTINFO_innerveto.ratdb

PMTINFO_outerveto.ratdb

Figure 1 `rat-pac/mac/tutorials/tutorial_001/watchboy_movie.mac`

```
#set the detector parameters
/rat/db/set DETECTOR experiment "Watchboy"
/rat/db/set DETECTOR geo_file "Watchboy/Watchboy.geo"

/run/initialize

#initialize the visualizer
/vis/open OGLIQt
/vis/scene/create

/vis/scene/add/volume
/vis/scene/add/trajectories
/vis/viewer/reset
/vis/viewer/set/style surface
/vis/viewer/set/upVector 1 0 0
/vis/drawVolume

# remove the # from the following to lines to export the detector geometry to a .png file
#/vis/ogl/set/exportFormat png
#/vis/ogl/export

/control/loop mac/tutorials/tutorial_001/movieStep001.loop theta -90 0 5
/control/loop mac/tutorials/tutorial_001/movieStep003.loop theta 0 -90 -5

/generator/add combo gun:point
/generator/vtx/set e-  0 0 1 7 # pname dir_x dir_y dir_z energy
/generator/pos/set 0 0 0       # x y z

/run/beamOn 1
```

rat-pac Geometries:

basic geometries:

Let's take a look at the Watchboy.geo file. You can find it at [rat-pac installation]/data directory/Watchboy/Watchboy.geo. You will notice the file is structured as many JSON objects. The first of these is shown in Figure 2. The individual keys and values for this object are described in the table below:

key	value description
name:	object type
index:	name of this volume
valid_begin:	not currently used
valid_end:	not currently used
mother:	mother volume for this object "" denotes the world volume (i.e. the volume that contains all others)
type:	geometry type tube for this example)
r_max:	tube outer radius, if r_min is not defined then the tube is a cylinder
size_z:	tube half length
position:	location of the center of the tube
material:	material (predefined and custom materials will be discussed later)
color:	color for rendering RGB or RGBA
drawstyle:	style to draw, i.e. "solid", "wireframe"

Figure 2

```
{
name: "GEO",
index: "world", //this is
the tank
valid_begin: [0, 0],
valid_end: [0, 0],
mother: "",
type: "tube",
r_max: 1980.2,
size_z: 1651.2,
position: [0.0, 0.0, 0.0],
material: "stainless_steel",
color: [1.0, 0.0, 0.0, 0.1],
drawstyle: "solid"
}
```

To illustrate the modification of the geometry, let's replace the mother volume with a cube 4000 mm on a side. This is done by simply replacing

```
type: "tube",
r_max: 1980.2,
size_z: 1651.2,
```

with

```
type: "box",
size: [2000, 2000, 2000]
```

in [rat-pac installation]/data directory/Watchboy/Watchboy.geo. Now rerun:

rat mac/tutorials/tutorial_001/watchboy_movie.mac

When the volume rotates downward, you will notice it now has a square cross-section (link to movie).

Before moving on, change the geometry file back to a tube.

You can read about additional key and value fields for other geometries at http://rat.readthedocs.org/en/latest/geometry.html#geo-table-fields

pmtarray geometries

Continuing with the Watchboy.geo file. The last three JSON objects are defining PMT arrays. Of these three the first is shown in Figure 3. The individual keys and values for this object are similar to those above. I will focus on `pmt_model, sensitive_detector, pos_table, and orientation` Other perameters ill later tutorials.

Figure 3

```
{
name: "GEO",
index: "inner_pmts",
enable: 1,
valid_begin: [0, 0],
valid_end: [0, 0],
mother: "mid_water",
type: "pmtarray",
pmt_model: "r7081_hqe",
pmt_detector_type: "idpmt",
sensitive_detector: "/mydet/pmt/inner",
efficiency_correction: 1.000,
pos_table: "PMTINFO_inner",
orientation: "manual",
}
```

`pmt_model` is the model of the pmt to use. The individual PMT models are defined in [rat-pac installation]/data/PMT.ratdb. A list of those PMTs with existing definitions is below.

- r5912
- r1408
- r11065
- r11780_hqe
- r7081_hqe
- r7081
- et9390b

`sensitive_detector` provides the name of sensitive detector if this volume should register hits. Limited to "/mydet/pmt/inner" and "/mydet/pmt/veto"

Figure 4 PMTINFO_inner.ratdb

```
{
name: "PMTINFO_inner",
valid_begin: [0, 0],
valid_end: [0, 0],
//These positions are relative to the GLOBAL origin
x: [305.5000, 94.4250, -246.6750, -246.6750, 94.4250, 584.4000, 472.2465, 180.0465, -180.0465,
-472.2465, -584.4000, -472.2465, -180.0465, 180.0465, 472.2465, 0.0000, ],
y: [0.0000, 290.0072, 179.9274, -179.9274, -290.0072, 0.0000, 343.3266, 555.5417, 555.5417,
343.3266, 0.0000, -343.3266, -555.5417, -555.5417, -343.3266, 0.0000, ],
z: [-482.2500, -482.2500, -482.2500, -482.2500, -482.2500, -482.2500, -482.2500, -482.2500, -
482.2500, -482.2500, -482.2500, -482.2500, -482.2500, -482.2500, -482.2500, -482.2500, ],
dir_x: [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, ],
dir_y: [0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, ],
dir_z: [1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0,
1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, 1.0, ],
type: [0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, ],
}
```

`pos_table` provides the file name with the PMT positions and `orientation` specifies how to orient the PMTs. If `orientation` is defined as "point" then the PMTs will all point towards a single point in space. If `orientation` is defined as manual then the pos_table must contain arrays for x, y, and z, pointing vectors for each PMT. An example PMT pos_table file is shown in Figure 4

Let us make a new simple pmt post_table file called `PMTINFO_innerSingle.ratdb` that contains the following object.

```
{
name: "PMTINFO_innerSingle",
valid_begin: [0, 0],
valid_end: [0, 0],
//These positions are relative to the GLOBAL origin
x: [0.0000],
y: [0.0000],
z: [-482.2500],
dir_x: [0.0],
dir_y: [0.0],
dir_z: [1.0],
type: [0],

}
```

In the Watchboy.geo file change `PMTINFO_inner` to `PMTINFO_innerSingle`.

in [rat-pac installation]/data directory/Watchboy/Watchboy.geo. Now rerun:

`rat mac/tutorials/tutorial_001/watchboy_movie.mac`

You will notice, the detector now contains a single PMT in the central volume as seen here