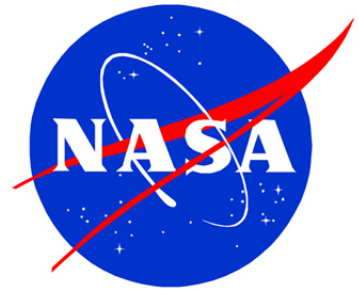


A new advanced example :

GORAD
(Geant4 Open-source Radiation Analysis and Design)

Makoto Asai (SLAC)

Introduction

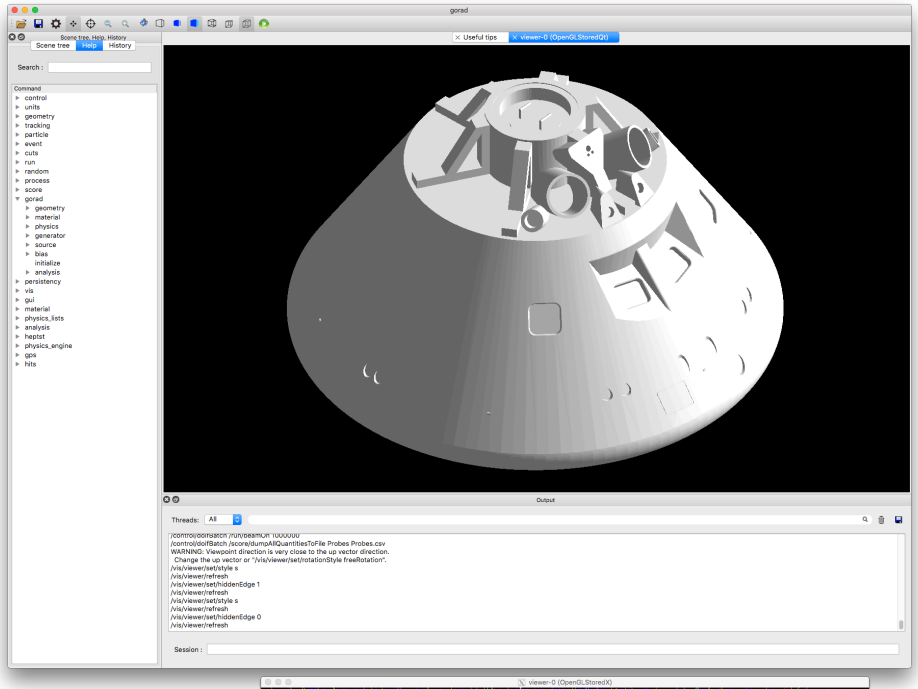
- ***Gorad*** (Geant4 Open-source Radiation Analysis and Design) is a new Advanced Example to be released with Geant4 version 10.7.
- ***Gorad*** is developed as a turn-key application for radiation analysis and spacecraft design built on top of Geant4.
  - ***Gorad*** is developed under the NASA JSC contract NNJ15HK11B to be used primarily for radiation shielding studies of Orion spacecraft.
- As a turn-key application, user of ***Gorad*** does not need to write any C++ source code.
  - Simulation geometry should be provided in the form of GDML.
  - Radiation environment can be specified as an ascii input file.
  - ***Gorad*** is controlled by UI commands, and it works both in interactive mode (Qt recommended) and in batch mode with an input macro file.
  - It runs in multithreaded mode with automatic data reductions.
- ***Gorad*** utilizes some of new developments in Geant4 version 10.7 so that it does not work with earlier version of Geant4.
  - For example, “probe” scoring, filling histogram directly from scorer.

How ***Gorad*** works

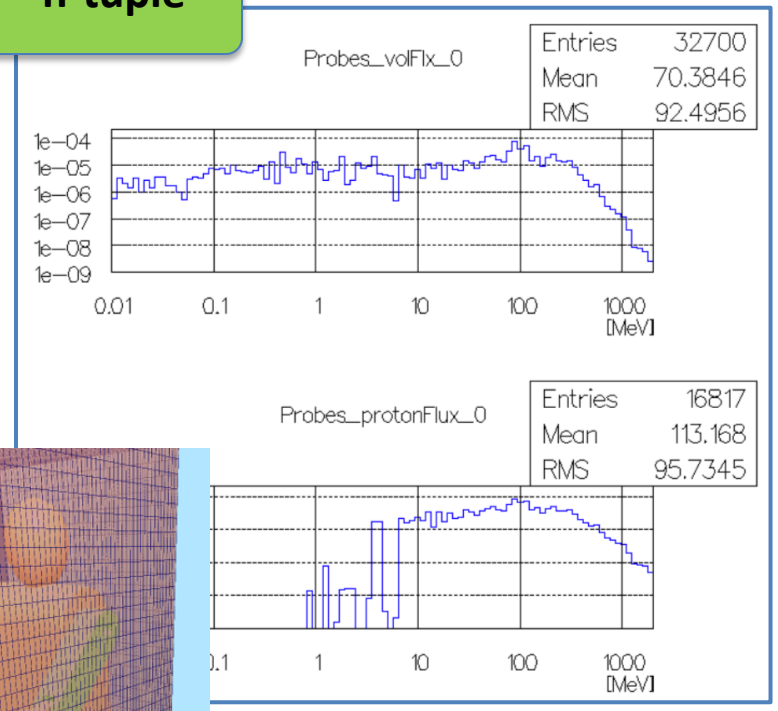
GDML

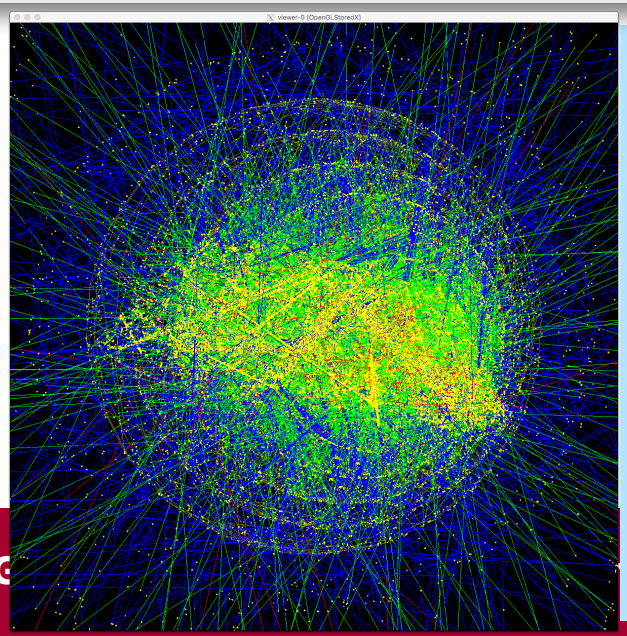
Radiation spectrum

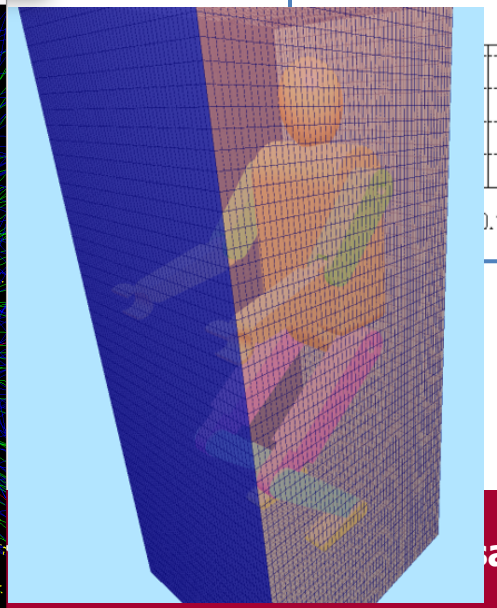
Macro file
or
interactive command



Scores
histos
n-tuple



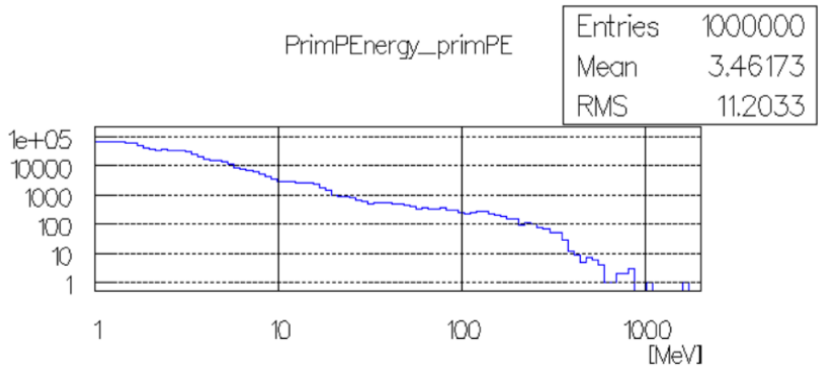




Primary radiation spectrum

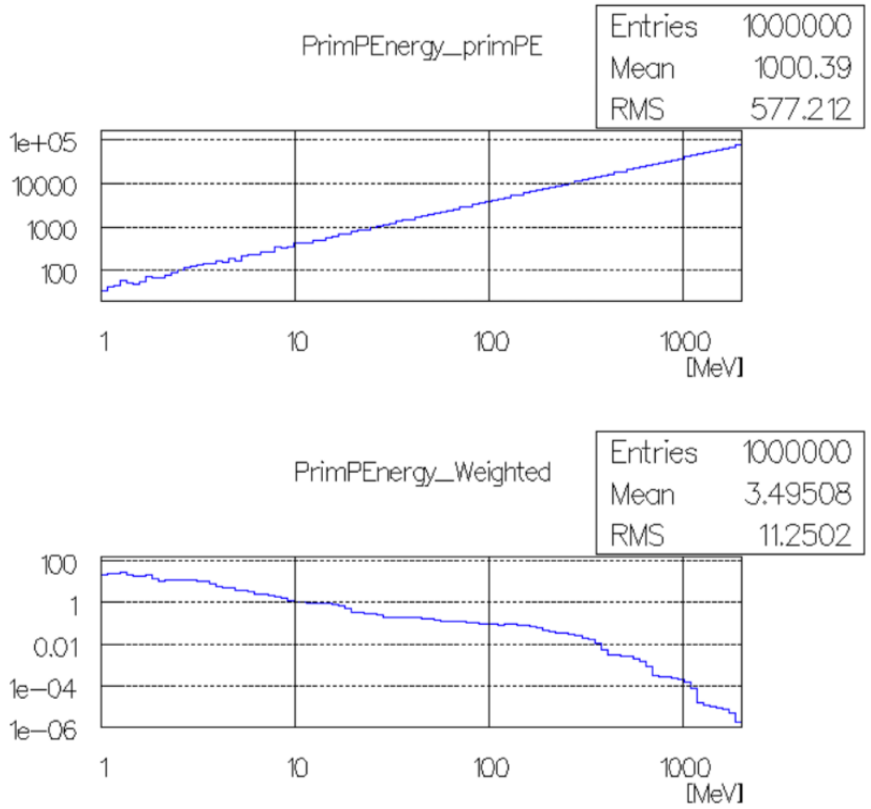
- ***Gorad*** provides two differential radiation spectra (King and trapped proton) as ascii input files.
  - User may use other spectra as well as Geant4 general particle source commands.
- Primary particle biasing option is available.

analogue mode



Please note that despite the trapped proton spectrum file having data up to 2 GeV, analog mode plot does not have many entries higher than 1 GeV due to insufficient statistics, i.e. 1 million events are not enough to have tracks higher than 1 GeV. And most of lower-energy tracks do not penetrate the spacecraft shield.

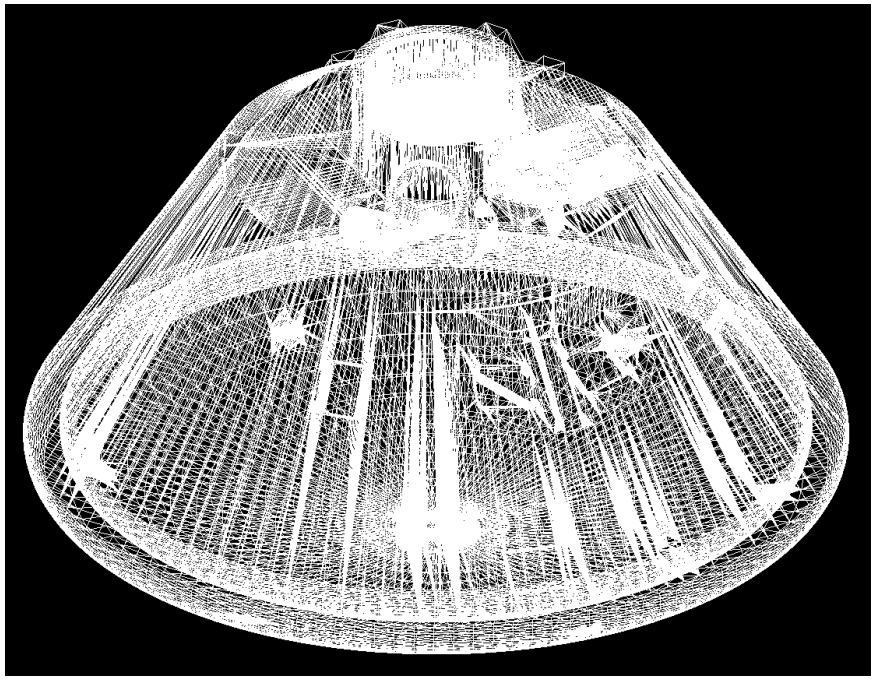
biasing mode

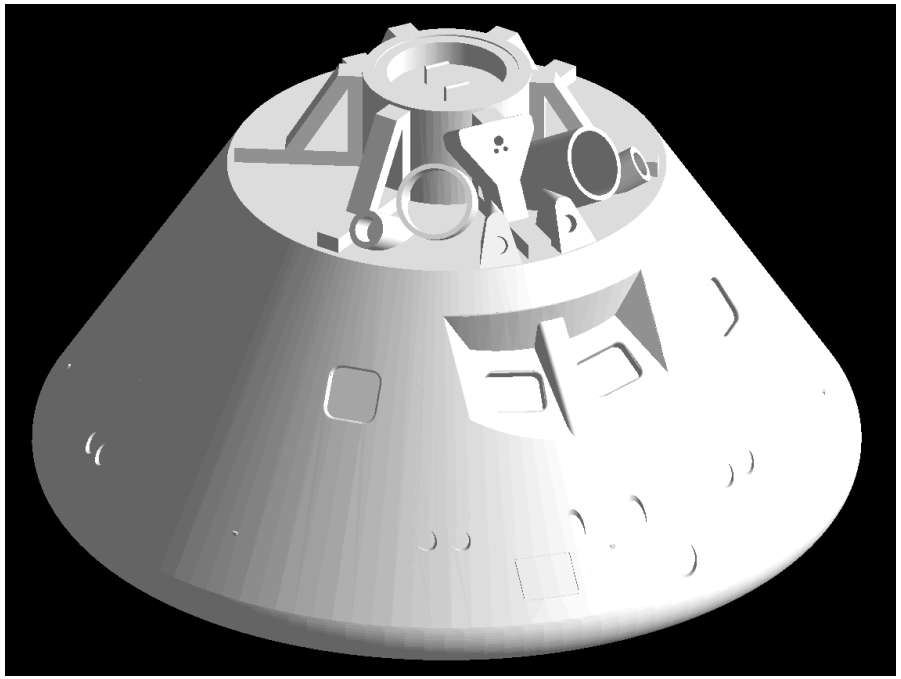


Here, the upper plot shows the energy spectrum of the generated primary tracks without their weights, while lower plot shows the same energy spectrum of the generated primary tracks with weights. This option can statistically enhance higher-energy tracks that are rare but contribute largely to the scores.

Geometry

- Simulation geometry should be provided in the form of GDML.
- ***Gorad*** offers some utility commands.
  - Setting/changing material of a volume
  - List volumes with their properties such as mass
  - Define a region and set cuts for it
- As a sample geometry, partial and simplified shielding structure of Orion Spacecraft is available (~22 MB).



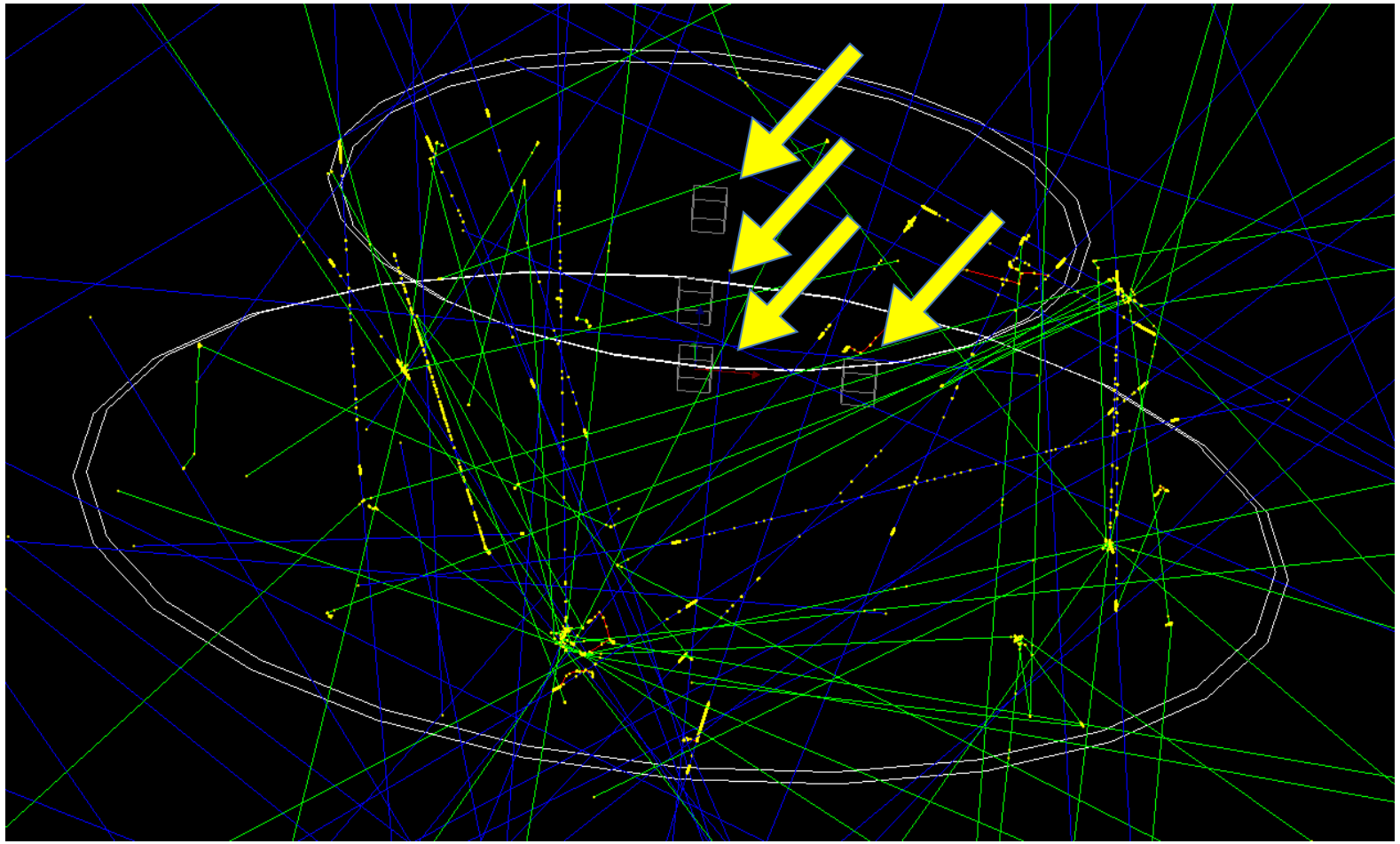


Scoring

- In addition to the conventional scoring mesh, ***Gorad*** uses two newly developed scoring functionalities.
- Command-based real-world scorer
  - User may assign scorer to a logical volume defined in the mass world.
- Command-based “probe” scorer
  - User may locate scoring “probes” at arbitrary locations. A “probe” is a virtual cube, to which any Geant4 primitive scorers could be assigned.
  - Given these probes are located in an artificial “parallel world”, probes may overlap to the volumes defined in the mass geometry, as long as probes themselves are not overlapping to each other or protruding from the world volume.
  - In addition, the user may optionally set a material to the probe. Once a material is set to the probe, it overwrites the material(s) defined in the mass geometry when a track enters the probe cube.
    - Because of this overwriting, physics quantities that depend on material or density, e.g. energy deposition or dose, would be measured accordingly to the specified material.
    - Please note that this overwriting material obviously affects to the simulation results, so the size and number of probes should be reasonably small to avoid significant side effects.
- Once a real-world scorer or a probe is defined, user can associate arbitrary number of primitive scorers and filters like the conventional scoring mesh.
  - All physical volumes or probes have the same scorers but score individually.

Command-based probe scorer

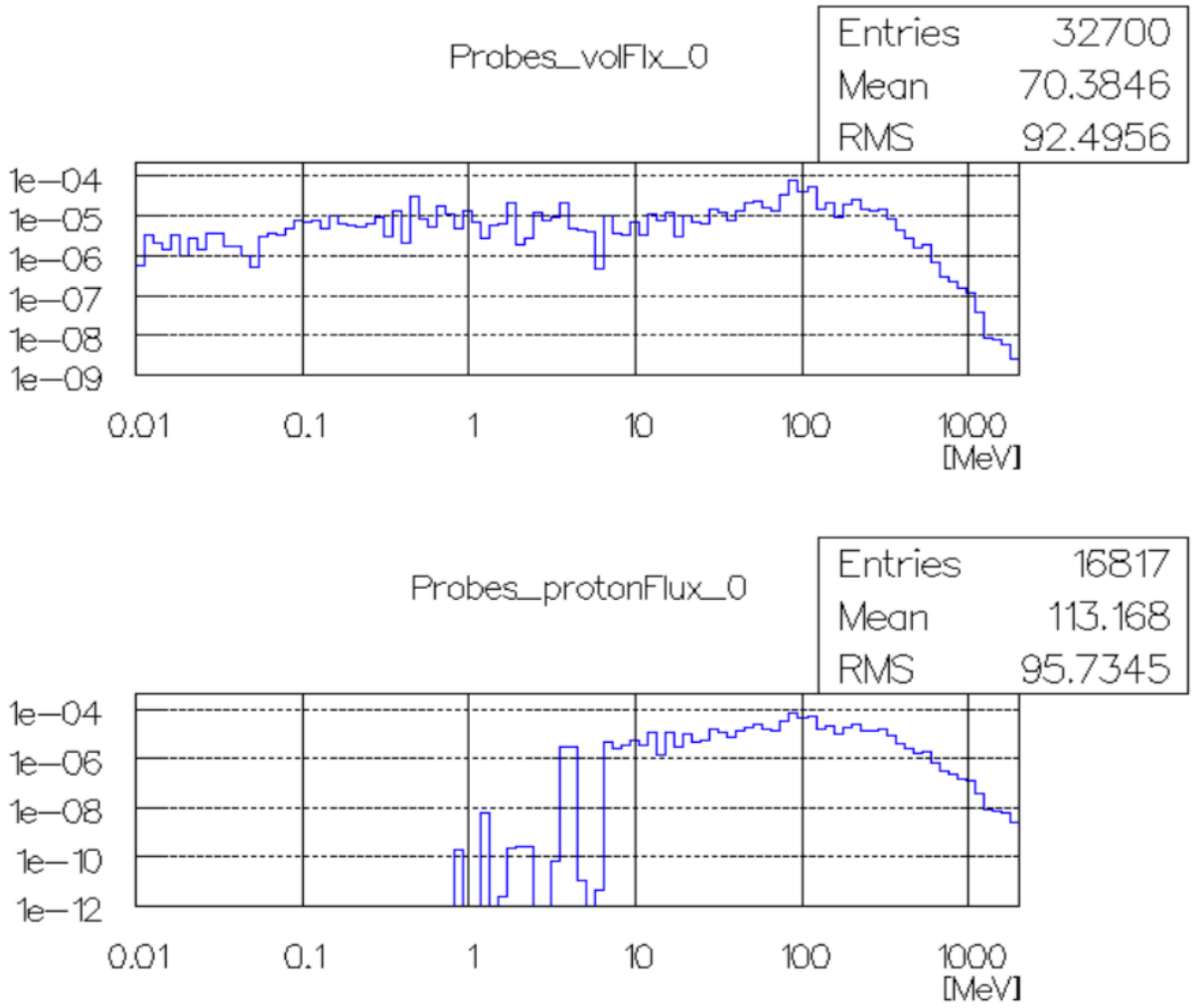
```
/score/create/probe Probes 5. cm
/score/probe/material G4_WATER
/score/probe/locate 0. 0. 0. cm
/score/probe/locate 25. 0. 0. cm
/score/probe/locate 0. 25. 0. cm
/score/probe/locate 0. 0. 25. cm
/score/quantity/energyDeposit eDep MeV
/score/quantity/doseDeposit dose mGy
/score/quantity/volumeFlux volFlx
/score/quantity/volumeFlux protonFlux
/score/filter/particle protonFilter proton
/score/close
```



Note: To visualize the probes defined in a parallel world, the following command is required.
/vis/drawVolume worlds

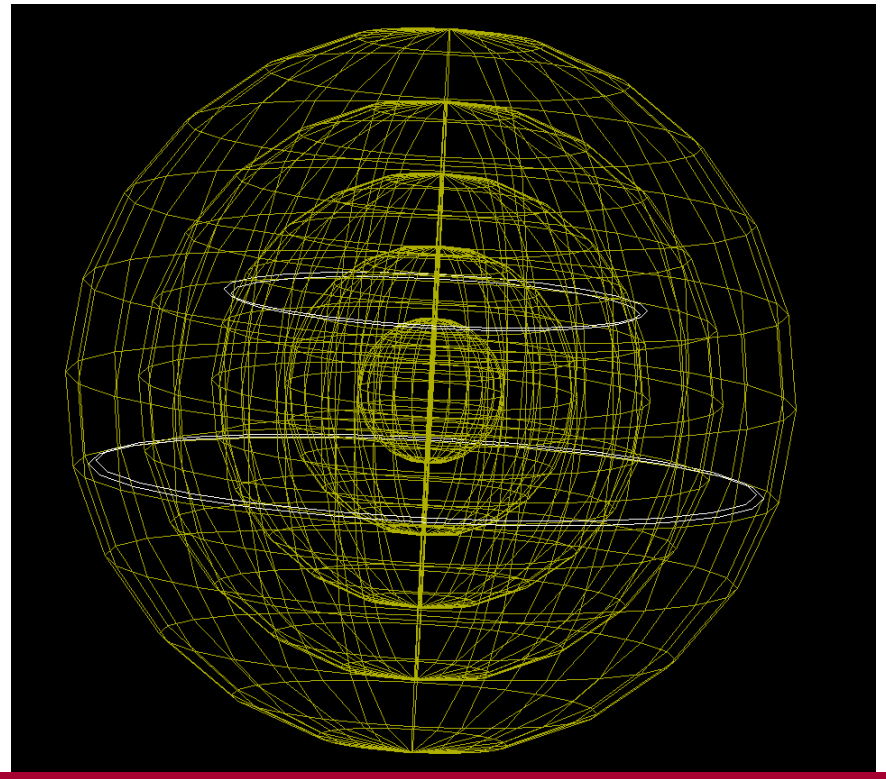
1-D histogram directly filled by a primitive scorer

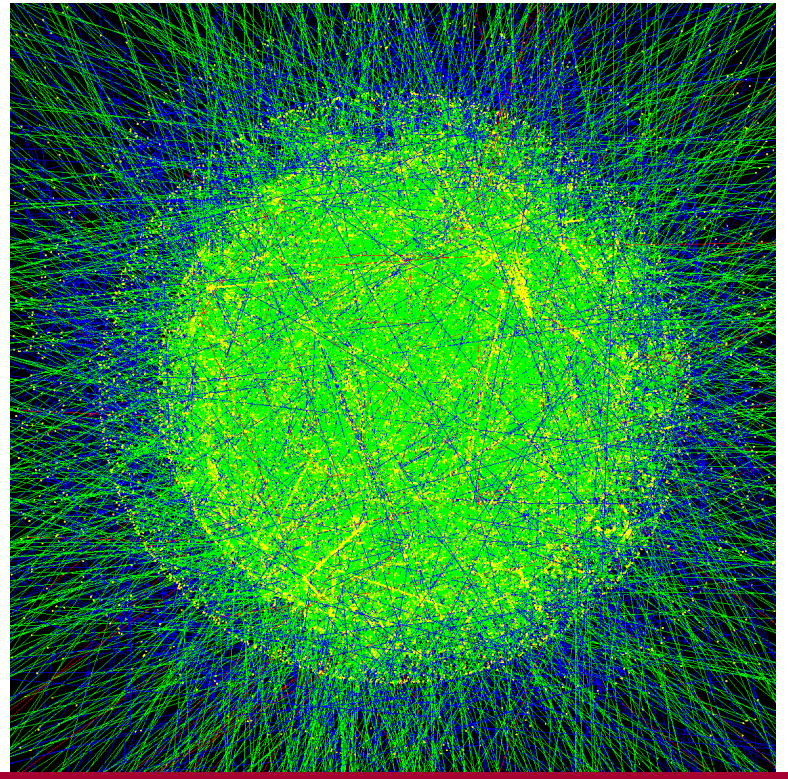
- Through a newly introduced interface class (G4TScoreHistFiller) a primitive scorer can directly fill a 1-D histogram defined by G4Analysis.
  - Track-by-track or step-by-step filling allows command-based histogram such as energy spectrum.
  - Event-by-event score may also be filled to histogram.
- ***Gorad*** allows user to define an n-tuple with UI commands.
  - User may specify primitive scorers (and copy numbers) as column of the n-tuple data row.

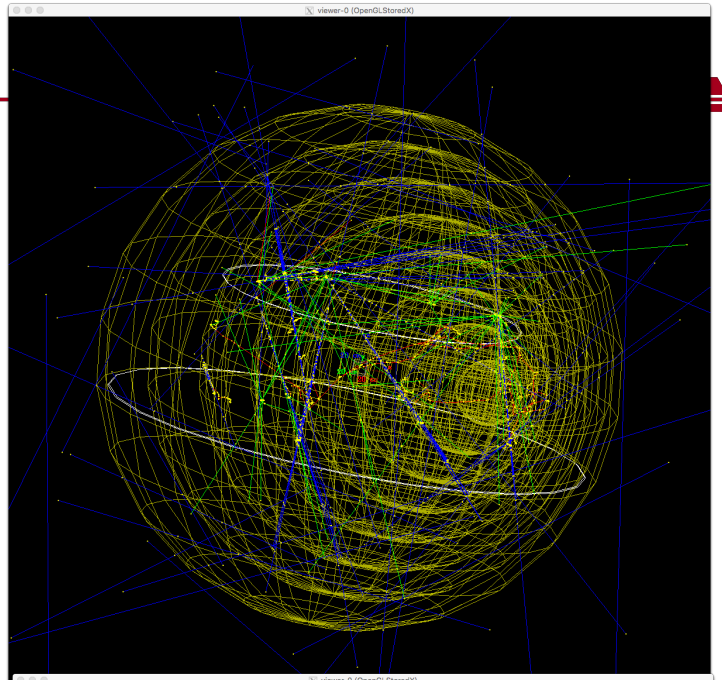


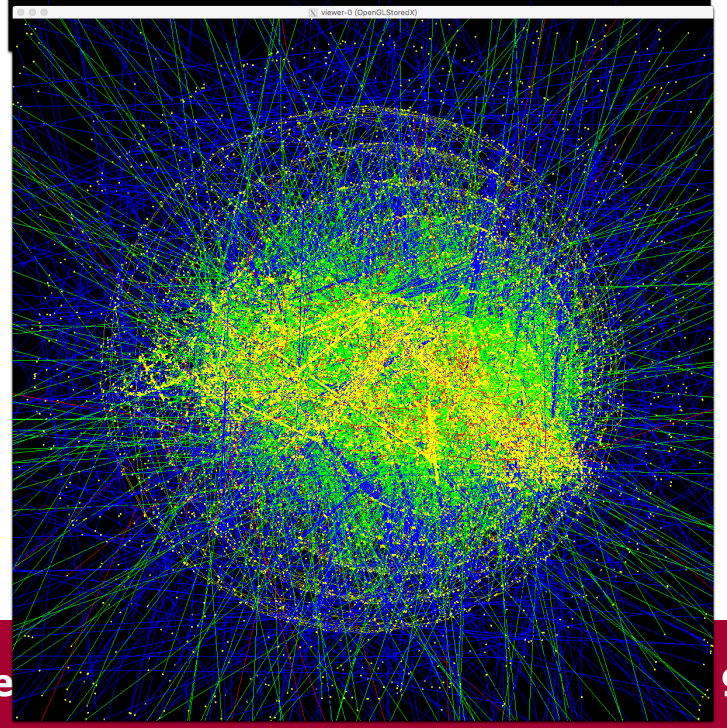
Geometry importance biasing

- ***Gorad*** offers UI commands to define geometry importance biasing.
  - Virtual spheres are created in a dedicated parallel world.
  - Each sphere has its importance.
  - Tracks are enhanced toward the center of the geometry.









To sum up

- ***Gorad*** (Geant4 Open-source Radiation Analysis and Design) is a new Advanced Example to be released with Geant4 version 10.7.
  - Full manual is also available.
    - https://geant4.web.cern.ch/node/1925
  - ***Gorad*** is developed as a turn-key application for radiation analysis and spacecraft design built on top of Geant4.
  - ***Gorad*** is developed under the NASA JSC contract NNJ15HK11B to be used primarily for radiation shielding studies of Orion spacecraft.
- ***Gorad*** is now available in /examples/advanced/gorad.
  - ***Gorad*** may also be used as an example for other applications of the use of newly developed Geant4 scoring functionalities.
    - Command-based real-world scorer and command-based probe scorer
    - 1-D histograms filled by scorers