Geant4 Simulation of a Packaging for Solid-State Radiation Monitoring Sensors

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Project vision

- The CERN RADMON group has selected and cataloged semi-conductor sensors to be used for radiation monitoring purposes.
- These sensors will be used in the LHC environment as radiation monitoring devices.
- However, the use of inappropriate materials around the sensors can modify the chips response.
- This can induce errors in the measurement.
- They are interested to have a study of the effect of the packaging on the sensor response as a function of materials and thicknesses.
Primary candidate

- Chip packaging is done in house at CERN
- CERN has already available 2000 parts of a packaging with the following features
  - ~ 1 cm × ~ 1 cm × ~ 1.5 mm
  - 36 pins
  - Al$_2$O$_3$ carrier
  - Tungsten metalization
  - Gold-plated
Main objectives

The main objectives are

- A quantitative analysis of the energy cut-off introduced by the packaging as a function of the particle type
- A quantitative analysis on how the materials and thicknesses affect the cut-off thresholds
- A quantitative analysis of the spectrum of particles (primaries and secondaries) arriving on the dosimeter volume as a function of the incoming spectrum

For physics validation purposes I will use experimental data taken in the past years by the RADMON group

This validation process is essential to provide sound results
Software process

- The project is developed as a Geant4 advanced example
- A rigorous software process based on the RUP
  - Requirements
    - Vision document
    - User requirements document
      - Both available in the Geant4 documentation CVS repository
  - Analysis and Design
    - Design model (Available in the Geant4 documentation CVS repository)
  - Implementation
    - Developed code is available in the Geant4 CVS repository
  - Testing
    - Validation against experimental data (planned)
  - Traceability
    - In progress
- The project is documented in
  - http://www.ge.infn.it/geant4/hep/radmon
Requirements

- **Geometry**
  - Define objects made up of several layers with different geometries
  - Define thicknesses, materials and other geometrical parameters of each layer
  - Define more than one multi-layer object and place them in a environment
  - Define a realistic environment like the CERN facility they use for their tests/measurements

- **Event generation**
  - Isotropic flux of monochromatic particles
  - Isotropic flux of particles according to tabulated spectra
  - Directional monochromatic beam
Requirements^{2/2}

- **Physics**
  - Handle protons, neutrons, electrons, gammas, and pions
  - Electromagnetic and hadronic processes for primaries and secondaries particles

- **Event**
  - Be able to obtain
    - The particles flux into the sensor volume
    - The energy deposited into the sensor volume
    - Attenuation effect of the packaging on the particle flux
    - Spectra of the particles arriving to the sensor volume

- **User interface**
  - Be able to interactively change the geometrical parameters and the materials of the multi-layers objects and of the environment (test-beam setup)
Development schedule

- The project started on the 1st of August and will be completed in January
- The Geometry & User interface design, implementation and testing was completed in September
- Next phase will be the development of the event generators, the physics list and the sensible volumes
  - In the next months the RADMON group will take some experimental data
  - It is possible to directly compare the measures taken from the RADMON group with the simulation
- This will allow validating the physics processes involved
- It is expected to have the example fully functional for the December release
The geometry & user interface design and implementation is almost completed.

Key features are:
- Document-view for geometrical data management
- Observer pattern for geometrical changes notification to the detector constructor
Geometry design key features\(^2/3\)

- Solids, physical volumes and logical volumes created using an Abstract Factory pattern.
- As layers have partial similar features, layer creator classes use a Decorator pattern (template = compile bound).

```
RadmonVDetectorEntitiesConstructorFactory -> RadmonVDetectorEntityConstructor
RadmonDetectorLabelledEntitiesConstructorFactory
RadmonDetectorFlatVolumeComponent
LayerVolumesComponent
RadmonVDetectorLabelledEntityConstructor
RadmonTDetectorLayerConstructor
LayerVolumesComponent
RadmonTDetectorVolumesWithHolesDecorator
```

RadmonDetectorFlatVolumeComponent
Geometry design key features

At construction time, according to the layer type, several parameters must be provided in order to define the geometrical features of the layer and its materials.

To have a common and extensible way to manage these features, a list of attributes can be attached to each layer.

Attribute means a pair of strings (the attribute name and the attribute value).

In that way the definition of the layer type features through user interface commands comes for free.
Layer types\(^{1/2}\)

- A simple box with a hole
- A simple box with tracks
- A simple box with a hole and carved borders
- A simple box with tracks, a hole and carved borders
Layer types^{2/2}

- A simple box with pins
- A simple box with pins and carved borders
- A simple box with ground plane and marks
- A simple box with ground plane and marks, a hole and carved borders
Final packaging and sensors geometry

- Packaging has been tested against volumes overlapping
Interactivity

- The user can interactively
  - Select/change the type of environment
    - Set the attributes of the environment
  - Create one or more types of multi-layer object
    - Define the multi-layer dimension
    - Define each layer type and its thickness
    - Define the parameters of the layer type (attributes)
  - Position the multilayer object
    - There can be more than one instance of the same multilayer object
  - Define the materials
  - A non exhaustive list of parameters is
    - Plating thickness and material
    - Number of holes carved on the border
    - Radius of the holes
    - Spacing between holes
    - Dimensions of the central hole
    - Dimensions of the ground plane
    - Visual attributes
# Macro example

## Materials

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<tr>
<th>Line</th>
<th>Description</th>
<th>Value</th>
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## Geometry definition

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<th>Value</th>
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Documentation

- Documentation on the web page and on CVS will be provided for
  - Custom user interface commands
  - List of layer types and their features
  - Attributes of each layer type
Summary

- A new advanced example is in progress
- The aim of this example is to study the effects of a packaging on the sensor response to radiation
- The packaging has been described in great detail adopting a rigorous software process and taking advantage of the Decorator pattern

Next steps are:
- Develop the primary generators and the physics list
- Compare the results obtained from the simulation with the data that will be taken by the RADMON group
- Validate the physics and deliver the studies needed by the RADMON group
- The example will be released in December, probably fully functional