DAMIC-M Kick Off Meeting
Geant 4

João Da Rocha (LPNHE) for the simulation working group
Part 1: The DAMIC Geant4 Simulation
Why do we need a Geant4 simulation?

- **Principal aim**: simulate the different components of the background and compare the results with the real data.

- **Others aims**: Calibrations Studies, Production of simulations to simulate some tests for the analysis.

- Geant4 simulation developed by the LPNHE group

- Used by the collaboration
Geometry

- DAMIC-SNOLAB geometry simulated = \(\sim 100\) volumes
- The polyethylene isn’t used in the contaminant studies
- DAMIC-SNOLAB: 8 CCDs, 2 Lead blocs.
Muon tomography

Top of the copper Box

Copper top plate

Copper Mount Bar

Coppe Base Plate

Bottom of the copper Box

6 CCDs

<table>
<thead>
<tr>
<th>YZ</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Entries</td>
<td>404537</td>
</tr>
<tr>
<td>Mean x</td>
<td>-5.987</td>
</tr>
<tr>
<td>Mean y</td>
<td>-267</td>
</tr>
<tr>
<td>Std Dev x</td>
<td>29.48</td>
</tr>
<tr>
<td>Std Dev y</td>
<td>46.37</td>
</tr>
</tbody>
</table>
Physics Lists and Parameters

Three physics lists:
- **Livermore**: validated down to 100 eV
- **MicroElectronics**: validated down to 16.7 eV
- **Penelope**: validated down to 250 eV

Parameters:
- Length range cut (LRC)* for different volumes
- Multiple Scattering Model
- Ionization Model
- ...

*Cut in range for the production of secondaries in all processes

Electrons going through a 2µm silicon cube

True Range step by step in nm Liv with electrons of 8keV

<table>
<thead>
<tr>
<th>TDLiv</th>
<th>Entries</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100000</td>
<td>811.8</td>
<td>231.3</td>
</tr>
</tbody>
</table>

Problem MicroElectronics (G4collaboration) Fixed

True Range: the sum of all step length of an electron trajectory
Simplified Case: Understanding of G4

Pixel where e- are injected

Additional pixels for charge collection

Total energy deposit and conservation

10 keV, e⁻ injected on surface

- sum_Edep
  - Entries: 9999
  - Mean: 0.008988
  - RMS: 0.002432

- sum_Edep + sum_Elost
  - Entries: 9999
  - Mean: 0.01
  - RMS: 6.162e-09

total Energy (keV)
Simulation Chain

Macros
- Primary
- Energy
- Direction
- Number

Geant4 Simu

Diffusion

G4 Output
- Energy Deposit
- Coordinates
- Interaction
- ...

Images
- Electrons per Pixel
- Informations from Simulation

Image Analysis

Clusters File
Part 2 : Applications
The energy spectrum DAMIC

- **Goal:** Understand the energy spectrum of DAMIC-SNOLAB.
- Production of simulations of different isotopes in the geometry of DAMIC-SNOLAB.
- 22 beta ± decays
- 5 Millions decays per isotope and per volume.
- In total ~2200 simulations need to be produced: **110 billions of decays.**
Tritium Experiment

The goal is to compare simulations with data

Data from two CCDs (at Chicago):
• Old Experiment - 2016
• New Experiment - May 2018

From the results we choose:
• A physics list
• A top dead layer thickness
Comparison of the old tritium data and the simulations

Old Experiment
(Dead layer is ~1.5µm thick expected from factory)

The best estimated value of the dead layer from simulation is 1.5µm

New Experiment
(Dead layer is ~2µm thick expected from factory)

The best estimated value of the dead layer from simulation is 2.2µm
**Other dead layer Studies**

**Lead210 produced at the surface of the protection**

<table>
<thead>
<tr>
<th>Size of the protection</th>
<th>DRU produced by Si 32 (0-1keV)</th>
<th>Increase of Si 32 contamination (0-1 keV).</th>
<th>Decrease of Pb210 contamination (0-1 keV).</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 um</td>
<td>0.8±0.05</td>
<td>0 %</td>
<td>0 %</td>
</tr>
<tr>
<td>1 um</td>
<td>0.804</td>
<td>0.50 %</td>
<td>12 %</td>
</tr>
<tr>
<td>10 um</td>
<td>0.813</td>
<td>1.31 %</td>
<td>49 %</td>
</tr>
<tr>
<td>30 µm</td>
<td>0.825</td>
<td>1.62 %</td>
<td>64 %</td>
</tr>
</tbody>
</table>

**Silicon 32 produced inside the silicon protection**

Size of the CCD: 675 µm  
Top layer depth (simulation): 1 µm
Parameters and calibration of the CCDs

Goals:

- Verify the calibration and the parameters of the CCDs
- Illuminate our CCDs without changing our setup

- Two gases can be used:
  - Radon 222 -> Lead 210 (half-life 22.3 years)
  - Radon 220 -> Lead 208 (Stable)

- Mainly Compton, and there is no fluorescence that can be identified.

- For 5 kBq of Radon 220, we will have $\sim 1620$ clusters/heure in the CCDs

![Energy deposit on all CCD's between 0 and 300 keV](Image)

<table>
<thead>
<tr>
<th>Spectrum All</th>
<th>Energy (keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>50</td>
<td>80</td>
</tr>
<tr>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td>150</td>
<td>40</td>
</tr>
<tr>
<td>200</td>
<td>20</td>
</tr>
<tr>
<td>250</td>
<td>10</td>
</tr>
<tr>
<td>300</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SpectraAll</th>
<th>Entries 1383</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>98.57</td>
</tr>
<tr>
<td>Std Dev</td>
<td>81.66</td>
</tr>
</tbody>
</table>

Little Space for the radioactive gas
Conclusion

• Geant4 extremely useful for DAMIC: Analysis, studies.

• One must pay attention to the way, one uses Geant4: Geometry, Cuts.

• In the next months, Geant4 will be used to implement the DAMIC-M setup:
  • Study on the CCD packaging
  • Muons