Simple Tracker Geometry

• Started with a simple geometry:
  • 75 silica optical fibres stacked together (38, 37 → double layers)
  • Two double-layered trackers

• Will improve the geometry as we go ahead.

• Looking at DD4hep as well. We’ll probably need an xml of the drawing.
4 GeV muons ($\mu^+, \mu^-$)
Incident with a moving particle gun
CRY (Cosmic-ray Shower Library)

• Installed it on my virtual machine running Ubuntu 20.04.
• Tested out some included examples, installation seems to be fine.
• Looking into more details.

Importing CAD geometry in DD4hep

• Documentation says it is possible with the assimp package (available on git). Supports import from ~53 filetypes.
• I haven’t tried this yet. What filetypes can the geometry be exported in with Solid Edge or SOLIDWORKS? Is XML supported?
• Do we want to import everything in black box for Geant4 simulations?
Scintillating Fiber Geometry & Material
(Single-clad fibers - confirmed)

**Core**
- Material: Polystyrene
- Refractive index: 1.60
- Density: 1.05 g/cc
- Diameter: 1.94 mm

**Cladding**
- Material: Acrylic (PMMA)
- Refractive index: 1.49
- Density: 1.2 g/cc
- Thickness: 60 μm
Importing CAD files in DD4hep

• Start from a very simple CAD file, maybe collada export (.dae) – similar to xml
• Looking into assimp package examples
• Would like to try out a few different filetypes:

  **STL, STEP → DAE, 3DXML, IFC, XAML**
Supported filetypes with ASSIMP package

### Collada
- *.dae
- *.xml

### Blender
- *.blend

### Biovision BVH
- *.bvh

### 3D Studio Max 3DS
- *.3ds

### 3D Studio Max ASE
- *.ase

### Wavefront Object
- *.obj

### Stanford Polygon Library
- *.ply

### AutoCAD DXF
- *.dxf

### IFC-STEP, Industry Foundation Classes
- *.ifc

### Neutral File Format
- *.nff

### Sense8 WorldToolkit
- *.nff

### Valve Model
- *.mdl
- *.vta

### Quake I
- *.md1

### Quake II
- *.md2

### Quake III
- *.md3

### Quake 3 BSP
- *.pk3

### RtCW
- *.mdc

### Doom 3
- *.md5mesh
- *.md5anim
- *.md5camera

### DirectX X
- *.x

### Quick3D
- *.q3o
- *.q3s

### Raw Triangles
- *.raw

### AC3D
- *.ac

### Stereolithography
- *.stl

### Autodesk DXF
- *.dxf

### Irrlicht Mesh
- *.irrmesh
- *.xml

### Irrlicht Scene
- *.irr
- *.xml

### Object File Format
- *.off

### Terragen Terrain
- *.ter

### 3D GameStudio Model
- *.mdl

### 3D GameStudio Terrain
- *.hmp

### Ogre
- *.mesh.xml
- *.skeleton.xml
- *.material

### Milkshape 3D
- *.ms3d

### LightWave Model
- *.lwo

### LightWave Scene
- *.lws

### Modo Model
- *.lxo

### CharacterStudio Motion
- *.csm

### Stanford Ply
- *.ply

### TrueSpace
- *.cob
- *.scn

### XGL
- *.xgl
- *.zgl
Importing CAD geometry in DD4hep

• Open .STEP file in FreeCAD software and export selected parts to a Collada .dae file.
• Import this .dae file (detector assembly) in DD4hep with DDCAD and then, root may be used for visualization.

In FreeCAD (STEP file) → Collada (.dae)  Import in DD4hep  Visualize with root
Tested XML (simple layout):

```
<lcdd>
    <includes>
    </includes>
    <detectors>
        <detector id="1" name="HMB_STL" type="DD4hep_TestShape_Creator">
            <check vis="T1_Fiber">
                <shape type="CAD_Assembly" ref="/mnt/hgfs/VMShared/HMB/allGeo.stl"/>
            </check>
        </detector>
    </detectors>
</lcdd>
```

Auxiliary detector model information

- `<includes>` ... `<includes>` Section defining GDML files to be included
- `<define>` ... `<define>` Dictionary of constant expressions and variables
- `<materials>` ... `<materials>` Additional material definitions
- `<display>` ... `<display>` Definition of visualization attributes
- `<detectors>` ... `<detectors>` Section with sub-detector definitions
- `<readouts>` ... `<readouts>` Section with readout structure definitions
- `<limits>` ... `<limits>` Definition of limit sets for Geant4
- `<fields>` ... `<fields>` Field definitions

```
geoDisplay -compact test.xml
```
CAD drawings from STL → GDML

geoConverter -compact2gdml -input test.xml -output test.gdml

• GDML: XML like syntax, compatible with Geant4
• This can be used in an independent Geant4 simulation (independent of DD4hep)
• Material info in CAD files, perhaps lost in translation! Does STL have material info?
• The resulting GDML file might not be efficiently processed with Geant4 though, especially for complex detector geometries.
GENERATION OF PARTICLES WITH CRY LIBRARY

CRY: Cosmic-ray Shower Library (v1.7)

~/cry/test/testOut.cc setup.file 100000

Output file → shower.out:

<table>
<thead>
<tr>
<th>#</th>
<th>nEvent</th>
<th>nSecondary</th>
<th>KE</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>u</th>
<th>v</th>
<th>w</th>
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<td>-0.88309</td>
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<tr>
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<td>0</td>
<td>4</td>
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<td>-0.59347</td>
<td>0</td>
<td>0.22576</td>
<td>0.29066</td>
<td>-0.01675</td>
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</table>

Altitude: 0 m, 2.1 km, 11.3 km
Incident Muon’s Zenith Angle vs KE

Zenith angle: $\cos^{-1}(-w)$

$w$ is the z-component of the particle velocity.
# CRY Library Data File

### Primary binning

% bin boundaries for Energy (MeV) of primary cosmic ray proton

<table>
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<th>% bins</th>
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<tr>
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<td>7000 8000 9000 10000 11000 12000</td>
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<tr>
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<td>];</td>
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### Secondary binning

% bin boundaries for Energy (MeV) of secondary particles produced in the shower

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</tr>
</tbody>
</table>

| 33 primary bins |

| 85 secondary bins |

| 85x33 values |
CRY DATA FILE: ORGANIZATION OF PARTICLE PDFs

- **Primary cosmic ray proton energies** (33 primary bins)
  - 1500
  - 2500
  - 5.14 \times 10^7
  - 8.15 \times 10^7

- **85 secondary bins** (sBins)

- Increasing sBins require interpolation of:
  - **Energy** distribution
  - **Time** distribution
  - **cos \theta** distribution
  - **Charge** distribution

For all secondary particles.
Muon Energy Distribution
(After interpolation of almost all distributions in CRY data files)

1M muons

4x more points in KE dist.
More details on NaI Calorimeter

**Good references:**

- **Product list:** https://www.crystals.saint-gobain.com/products/radiation-detection-products/standard-scintillation-product-list
- **Similar product drawings:**
Nal Scintillator Slab (Calorimeter)

**Missing details:**
- Spacing between various elements
- Placement/Alignment of Nal Slab inside the HMB Box
Change in Muon KE due to Concrete & Rebars

- Concrete thickness: 8.25 in
- Material: G4_CONCRETE
- Estimated thickness of rebars: 1 in.
- Material: G4_Fe
Including building structures in simulation

Concrete slabs (no rebars yet)

HMB black box

Nal Slab

Color codes:
- Default color: grey
- $e^+$ : blue
- $e^-$ : red
- Gamma : green
- Neutron : yellow
- $\pi^+$ : magenta
- $\pi^-$ : magenta
- Proton : cyan
- $\mu^+$ : orange
- $\mu^-$ : pink