Modifying the detector geometry

The dangers of volume overlaps in GEANT

Detector performance and MDI meeting - 09/05/2023

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Introduction

I started building a modified detector geometry to explore 10 TeV concepts and learned many things (i.e. generated a ton of buggy samples)

This presentation could be summarised by one sentence:
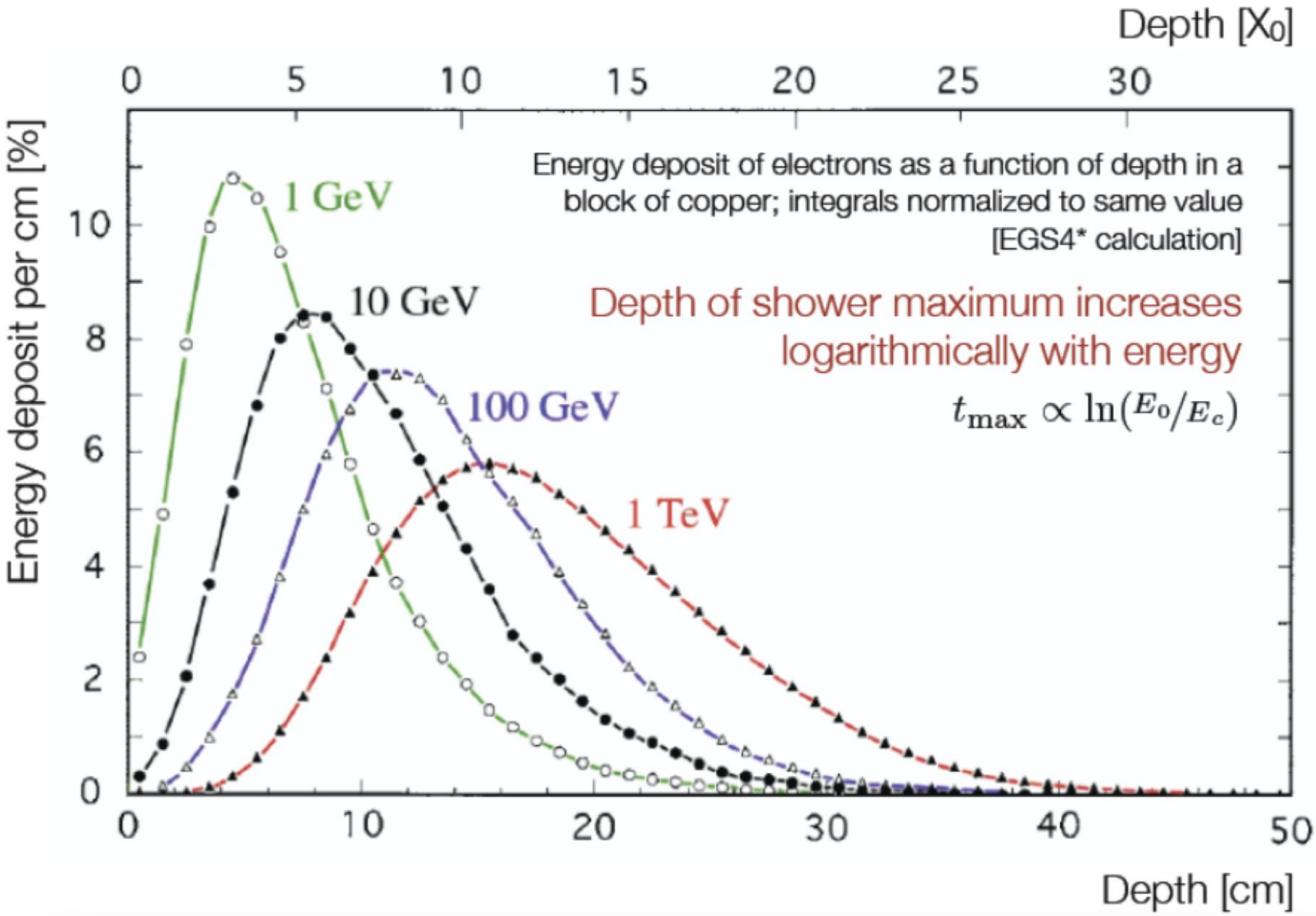**always check for overlaps when modifying a detector xml descriptor**

I'll take a few more minutes of your time to:
- Show what kind of things could happen to you
- Explain how to find the overlaps (solving them is, in general, far less trivial)

Focus today:

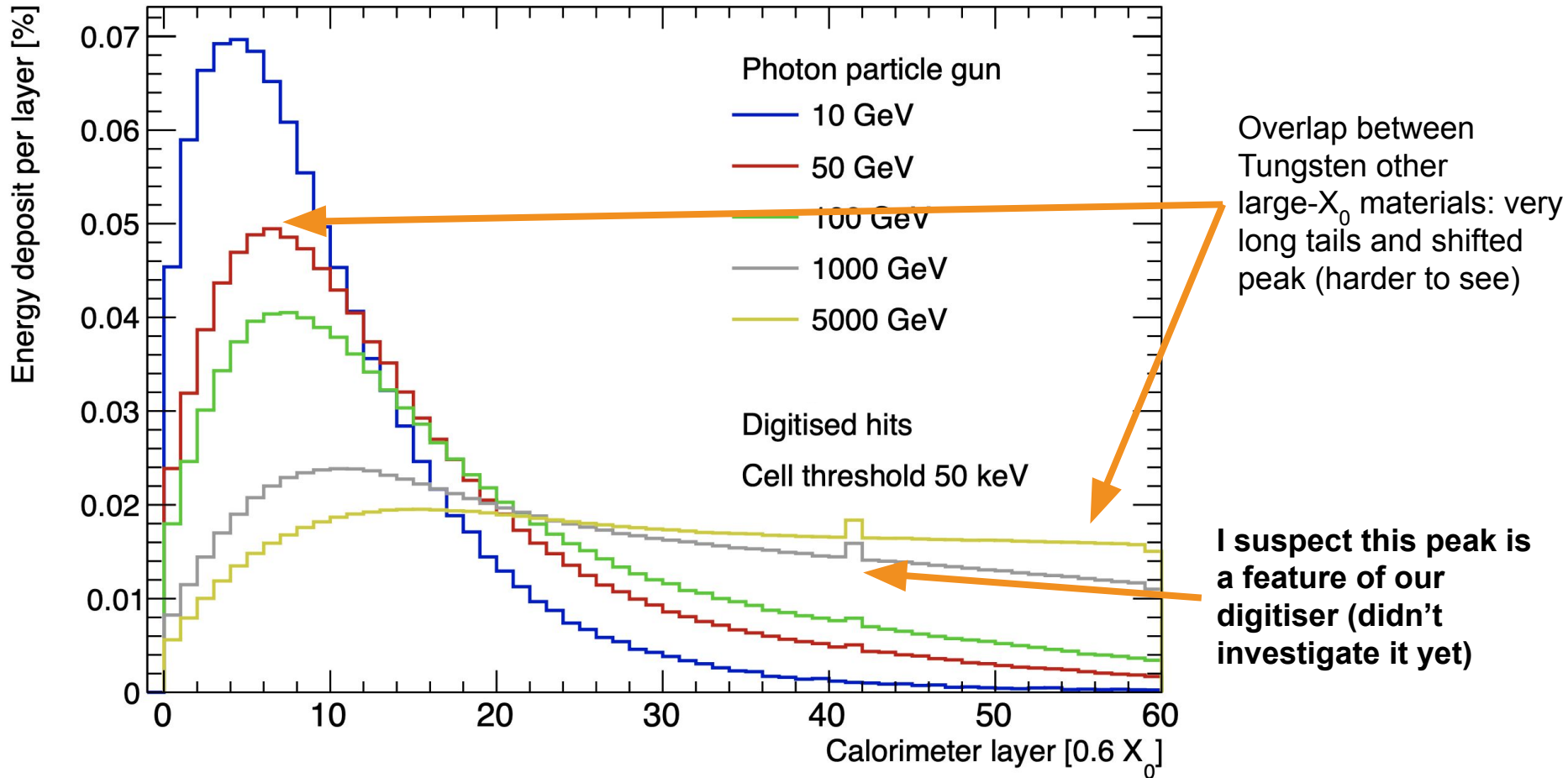- effects of overlaps on photon shower development in calorimeters

Reference result

Energy deposit of electrons as a function of depth in a block of copper; integrals normalized to same value [EGS4* calculation]

Depth of shower maximum increases logarithmically with energy
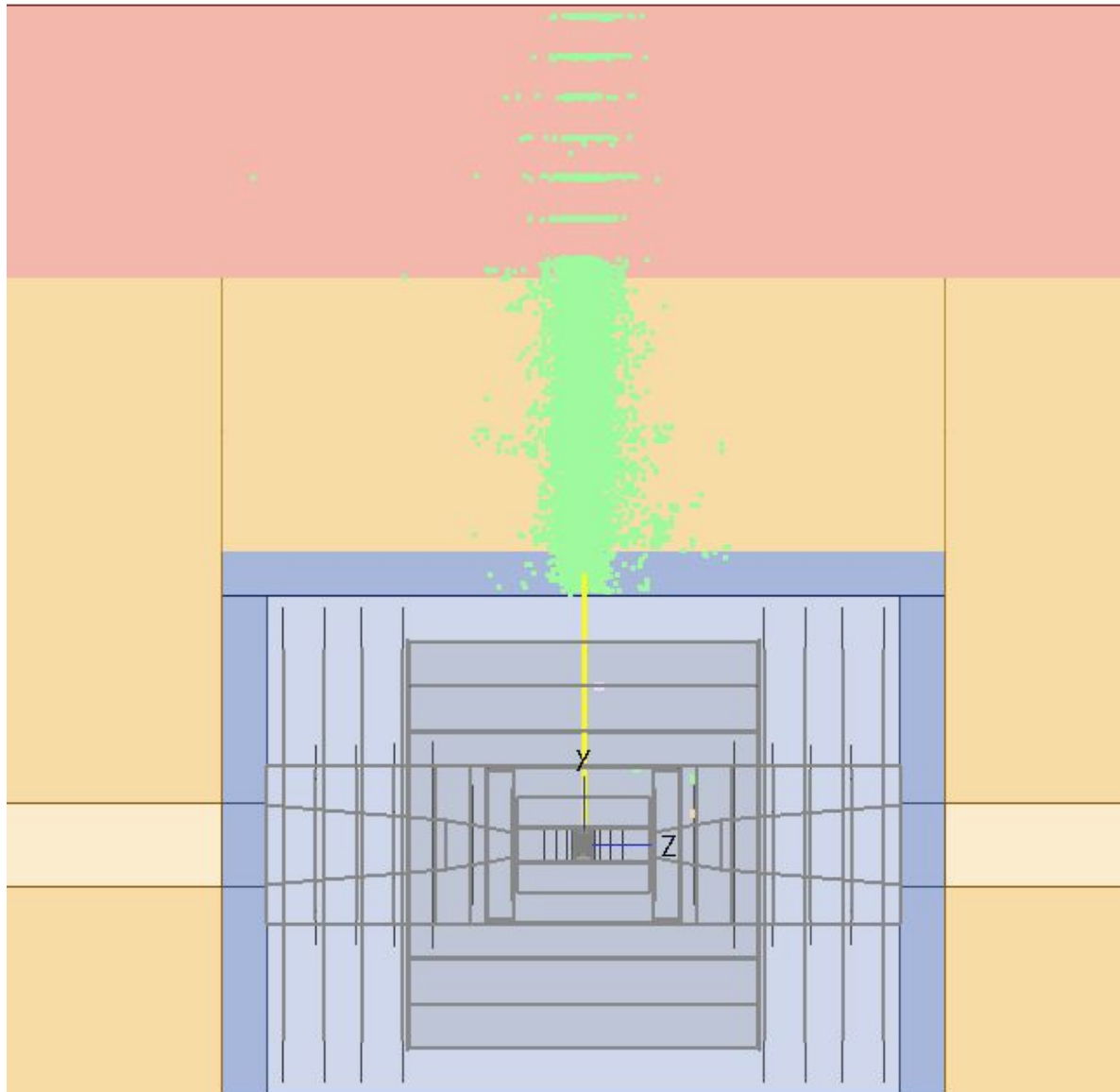
$$t_{max} \propto \ln(E_0/E_c)$$

Accident #1: large overlap

Maximum radius of inner detector > minimum radius of outer detector

- Part of the shower develops in one medium, part in another

Overlap between Tungsten other large-X_0 materials: very long tails and shifted peak (harder to see)

I suspect this peak is a feature of our digitiser (didn't investigate it yet)
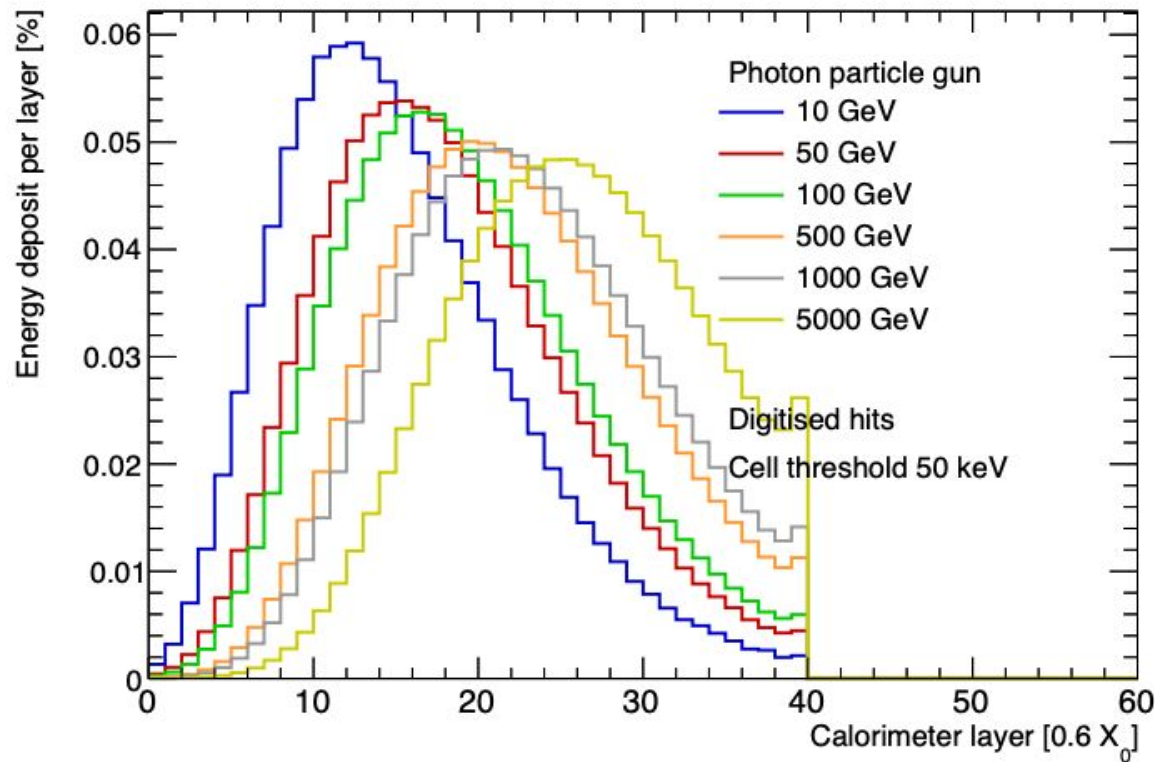
Visual inspection

Accident #2: pocket dimension

There are places that can capture a particle.

Happened to me shooting a photonGun in the direction (1,0,0).

- The MC particle will get captured, and after 10 steps GEANT will start increasing the step size to get free.

- In this particular case, the photon would be released after it "teleported" through the whole ECAL

How to detect:

- DD4hep prints a (very easy to miss) warning when increasing the step size

Minor note: the plots are not fully consistent as I saved them at different time while investigating different things.

Accident #3: volume subtraction

Similar problem of accident #1, but this time with subtraction volumes (like those used to carve the beampipe/nozzle hole in the HCAL)

Need to be extra careful, because subtraction volumes can act on other detectors, they are not limited to the xml where they are specified in

- Accidentally subtracted away ⅔ of the tracker + the whole ECAL
- **Other cases might be harder to spot**
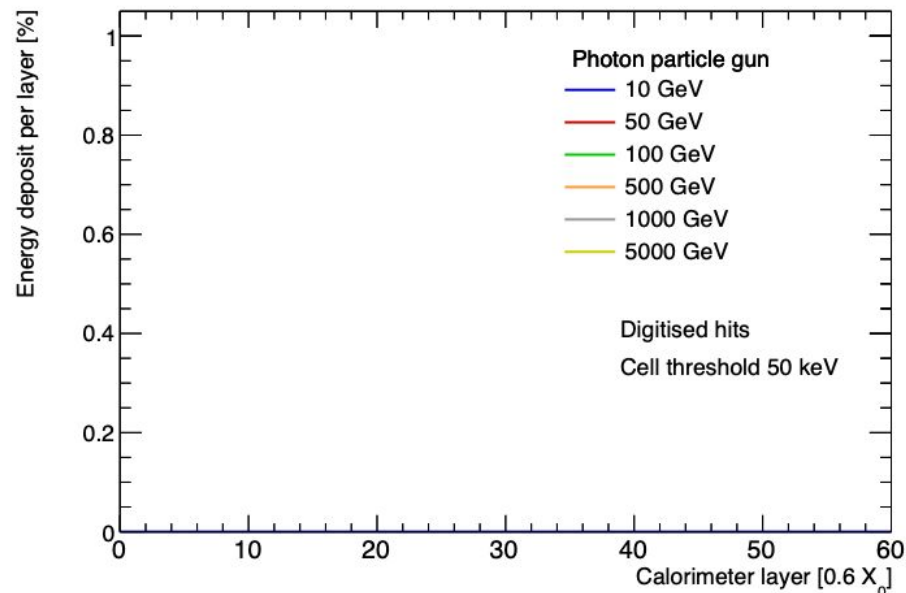
Always check for overlaps!

Overlap Checking

Whenever you change the geometry in a non-trivial way there are the possibilities of overlaps and the following things should be kept in mind

1. There are no trivial changes
2. See point 1
3. Run the overlap check

(Excellent) slides from A. Sailer at Key4hep Software Tutorial for Future Collider studies

How to check for overlaps

Running the Geant4 Overlap Check

Create the following file as `overlap.mac`

```
/geometry/test/run
exit
```

And then we run `ddsim` with this macro file, and dump the output to a text file for easy browsing

```
ddsim --compactFile FCCee_o1_v05/FCCee_o1_v05.xml \
      --runType run \
      --macroFile overlap.mac > overlapDump &
```

▶ With the full detector model including the tracker this would take about 30 minutes

(Excellent) slides from A. Sailer at Key4hep Software Tutorial for Future Collider studies

Conclusions

Ran the overlap checker on v1 and v1.3.1 geometry (not sure if we changed the default in the latest sw release).

- Found 104 overlaps (in InnerTracker, Support structures, Nozzle, Beampipe, Vertex Endcap, HCalEndcap, Yoke Endcap)

Example

```
Checking overlaps for volume av_35_impr_6_InnerTrackerEndcapModule_2x2_Out_pv_0 (G4Box) ...
--------- WWWW -------- G4Exception-START -------- WWWW --------
*** G4Exception : GeomVol1002
      issued by : G4PVPlacement::CheckOverlaps()
Overlap with volume already placed !
        Overlap is detected for volume av_35_impr_6_InnerTrackerEndcapModule_2x2_Out_pv_0:108 (G4Box)
        with av_35_impr_11_section_ConeSupport1_pos_pv_0:608 (G4Cons) volume's
        local point (-95,-4.16501,-220.759), overlapping by at least: 100.452 um
NOTE: Reached maximum fixed number -1- of overlaps reports for this volume !
*** This is just a warning message. ***
--------- WWWW --------- G4Exception-END -------- WWWW --------
```

Saved dump files and happy to share them if anybody would like to take a look.

Always check for overlaps when modifying a detector xml descriptor!