

Problem set for the lecture  
**Particle Detectors, WS 2015/16**

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**PROBLEM SET 10**

Deadline: Thursday January 21, 10am

(Please drop into mailbox number 1 on the ground floor of the Gustav-Mie building.)

**1. NUMERICAL SIMULATION - GEANT4 - Sampling Calorimeter**

This exercise relies on the Geant4 simulation framework, and a basic main program is provided on the homepage of the lecture. A README file is included featuring

- a link on how to install Geant4 on Linux, OSX or Windows systems
- information how to alternatively use a pre-installed version of Geant4 on a linux machine, reachable via ssh using an University of Freiburg RZ login
- a short introduction to the structure of the main program
- examples of the usage of the main program in both interactive and batch mode
- pointers on how to use ROOT for analysis of the output produced by the main program

The main program provided describes a detector consisting of 30 layers of plastic scintillator, each with a width of 5 mm, and the option to insert lead absorber layers in between the scintillators. A "particle gun" can shoot a single particle with a fixed energy into the detector, by default an electron with 10 GeV, but the particle type and energy can be changed interactively. For such "events" the path through the detector of the primary particle and all secondaries is visualized, and the total energy deposited in the scintillators is written out. In addition, simple histograms are filled and saved, and an "event record" is saved as a root tree inside a root file for further analysis.

- (a) With the detector setup as given, at first familiarize yourself with the program and its outputs by shooting particles of varying energies at the detector. Is it appropriate to call the detector a calorimeter?
- (b) Introduce sufficiently wide lead absorber layers to, on average, fully contain the electromagnetic shower from a 10 GeV electron, by modifying the DetectorConstruction class. Study the fraction of the electron energy (in respect to the incident energy) deposited in the active material (scintillator) as a function of incident particle energy, for  $E = 100 \text{ MeV}$ ,  $300 \text{ MeV}$ ,  $1 \text{ GeV}$ ,  $3 \text{ GeV}$  and  $10 \text{ GeV}$ .
- (c) The energy deposited in the active material fluctuates from event to event. The

standard deviation of its distribution is called the energy resolution. Optimize the lead layer width to get the best possible energy resolution for a 10 GeV electron. How does the resolution depend on the incident particle energy?

- (d) Implement readout of individual scintillator layers. The EventAction class already includes basic functionality to keep track of the deposited energy per layer, but this is not used yet. Modify the SteppingAction class to record deposited energies per layer and the EventAction class to write them out to histograms and the ROOT output file. Study the shower development, both in deposited energy as well as length of charged tracks. How does the result compare to a simple shower model, e.g. of problem set 9?

(10 Points)