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# Übungen zu Teilchenphysik I

## Wintersemester 2023/24

**Exercise 4** To be worked on until November 23, 2023

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# Introduction to GEANT, Part 2

## Working principle of calorimeters

Calorimeters used to measure the energies of particles are crucial components of many high-energy-physics experiments. They consist essentially of blocks of dense matter in which incoming high-energy particles induce particle showers, i.e. cascades of secondary particles with successively less energy. The low energetic, charged shower particles generate photons or free charges in the detector material, that can be converted into a measurable signal. Their number depends on the incident particle's energy $E_{\text{in}}$ and is measured to determine $E_{\text{in}}$. To achieve a precise measurement, the calorimeter should be dimensioned such that the incoming particle deposits a large fraction (ideally all) of its energy in the material, i.e. that the shower is contained within the calorimeter. Since calorimeters are typically segmented, they can also be used to measure the direction of the incident particle.

Calorimeters are usually optimised either to measure electromagnetic showers initiated by incoming electrons, positrons, or photons (such a calorimeter is frequently called "ECAL") or to measure hadronic showers caused by hadrons (such a calorimeter is called "HCAL"). The dimensions of electromagnetic and hadronic showers can be characterised in a material-independent way in terms of the radiation length $X_0$ and hadronic interaction length $\lambda$, respectively, which are properties of the material. Since the nuclear interaction length $\lambda$ is much larger than the electromagnetic radiation length $X_0$ in typical materials, an HCAL has to be thicker than an ECAL to contain the same energy fraction of a shower.

Two basic calorimeter designs exist:, *sampling* and *homogeneous* calorimeters. The former consists of separated layers of a passive, high-density absorber material, e.g. lead, brass, or uranium, and an active material generating the signal, e.g. a scintillator, a liquid noble gas, or a semiconductor. The latter is composed of one material, e.g. lead tungstate ($PbWO_4$), which both absorbs the particles and generates the signal.

In this exercise, a sampling calorimeter will be simulated with GEANT4, so we will use the **Geant4** image on the jupytermachine. As usual, you can find the corresponding Jupyter Notebook at:

`https://gitlab.etp.kit.edu/Lehre/tp1_forstudents`