Exercises for the Calorimeter Reconstruction and Machine Learning Workshop 2023

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1 Day 1

1. X_0 is the radiation length of an electromagnetic shower given by

$$X_0 = \frac{A}{4\pi N_A Z^2 r_e^2 \ln\frac{183}{Z^{1/3}}} \quad . \tag{1}$$

   Plot X_0 as a function of A and Z and put points for the materials in our simulation.

2. E_c is the critical energy at which the bremsstrahlung and ionization rates are equal and can be approximated by

$$E_c = \frac{800\,\mathrm{MeV}}{Z + 1.2} \quad . \tag{2}$$

   Verify this approximation for 3 - 4 choices of energies using simulation. How can we do this with our given tools?

3. The maximum time an electromagnetic particle travels in a material follows the relation

$$t_{max} \propto \ln E_0/E_c \quad . \tag{3}$$

   A rule of thumb for the length in which 95 % of the initial energy is deposited in the material is

$$L(95\%) = (t_{max} + 0.08Z + 9.6)[X_0] \quad . \tag{4}$$

   a) Verify this in simulation

   b) How many X_0 are need to capture 99 % of the initial energy? (Careful: this also includes processes such as ionisation / excitation / Compton Scattering / Rayleigh Scattering)

4. The Moliere radius describes the transversal expansion of an electromagnetic shower, mostly by low-energy electrons. What is the Moliere radius of Pb or PbWO4? What does that mean for our calorimeter?

5. Compare the energy deposition in the same thickness for different scintillator materials in our G4Calo simulation package.

6. CMS and ATLAS have two different approaches when it comes to calorimeter designs.

   a) Verify qualitatively the two calorimeter designs in simulation with a simple energy sum and a DNN regression for energy reconstruction.

   b) Reproduce the plots made by ATLAS and CMS for their calorimeter reconstruction.

   c) Store your code in a module that is callable, you will need it again later.

7. Create a class inheriting from ConstructionWrapper that also tracks the total material cost of the calorimeter.

8. Build an optimal EM calorimeter for showers between 1 and 100 GeV (no transversal granularity). Don't spend more than 50k CHF.