Exercises: Particle Detectors WS 2016/17
Prof. Dr. Ulrich Landgraf, Dr. Susanne Kühn
Problem Set No.5

Solutions have to be handed in by Wednesday 3pm, 23.11.2016 in letter box no. 3, in the ground floor of Gustav-Mie building!

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1. Efficiency calculations

You have built a detector, whose efficiency you measure to be 95%. You also measure the fake rate of the detector, i.e. how many times you have signal without any incoming particle, and find it to be 1%. Instead of further improving the efficiency, you decide to stack multiple identical detector layers. Assume you are using three layers. Calculate your total efficiencies if your signal is defined as:

- a logical OR of the three detector layers
- a logical AND of 2 or more layers

What happens to the fake rate in the two cases? **[3 points]**

2. Calculation of integrals with the Monte-Carlo method

Use the ROOT class `TF1` to plot the function $y = 2x - x^2$ in the interval $[0, 2]$. Please use the methods `SetMinimum` and `SetMaximum` to adjust the coordinate system such that the graphics exactly displays only the function values in the interval $[0, 1]$.

We will now get to learn a method to calculate the area A under this curve without using integrals. If you cover the area in your plot evenly with random dots, the fraction of points inside the area A under the curve (N_{inside}/N_{total}) will correspond to the ratio of the wanted area A to the total area of the rectangle that is spanned by the coordinate axes:

$$\frac{N_{inside}}{N_{total}} = \frac{A}{(y_{max} - y_{min}) \cdot (x_{max} - x_{min})} \, .$$

So we have found a simple method to calculate the area A:

$$A = \frac{N_{inside}}{N_{total}} \cdot (y_{max} - y_{min}) \cdot (x_{max} - x_{min}) \, .$$

Use this so-called „Monte Carlo Method“ to calculate the integral

$$\int_0^2 (2x - x^2) \, dx \, .$$

Vary the number of random dots to try how much points are necessary to get the correct result (which you get from explicit calculation) to a precision of 0.1%. **[4 points]**

3. Deterioration of particle tracks

A muon is generated at the interaction point of a LHC detector. It traverses several inner detectors before it arrives at the muon detector.

Assume the muon has a momentum of 50 GeV/c at the interaction point and crosses 80 cm of lead ($11.3\,\mathrm{g/cm^3}$) and 4 m of iron ($7.9\,\mathrm{g/cm^3}$). It hits the first layer of material at an angle of 90°. What will be the average energy of the muon when it arrives at the muon detector?

In the muon detector you will measure also precisely the direction of the muon. Unfortunately the direction information has been degraded also by the traversal of the material. Quantify the error on the angular variable due to multiple scattering.

Repeat the calculations for muons with a momentum of 10 GeV/c, 100 GeV/c, 500 GeV/c and 1 TeV/c. Plot the dependency of the energy loss and of the track angle as a function of the initial muon momentum. [**4 points**]