Analysis of Reconstructed Single Muon in ICAL detector

Introduction

The aim of this simulation is to study the single particle response of a detector. In this exercise, the detector in concern is a magnetized iron calorimeter (ICAL) with active detector element as resistive plate chamber (RPC). The benefit of ICAL detector is that we can study its response to both leptons as well as hadrons, also distinguish their charges.The detector is designed to consist of 150 alternate layers of 5.6 cm thick iron plates and glass RPCs stacked on top of each other.Iron will be magnetized to a field of about 1.4T. The iron plates act as the target mass for particle interaction and RPCs will give the trajectory of leptons and hadrons passing through them.

In this session we will be focusing on the detector response to muons. For this we first have to find the efficiency of the detector in detecting muons, also its momentum and direction resolution. In order to do this, we generate a single muon of fixed energy and charge and pass it through the detector. We also specify its direction and vertex where it's generated in the detector. The detector geometry is specified in GEANT4. The number of layers muons hit will depend on its initial parameters defined and these hits will form a curved trajectory.The efficiency of the detector is given by how well it can reconstruct these tracks, which will provide us with muon momentum and direction.The momentum is determined from the radius of the curved path which is a result of the applied magnetic field (Lorentz force). Generating a single muon and getting back its track is defined as a single event. To reduce the statistical uncertainty we generate a large number of events (10,000 in this case). Another study which can be done is to find out how the detector behaves to differently charged muons, *i.e.* μ^+ and μ^-.The charge of the muon is determined from the direction of bending of the track in presence of the magnetic field. Mass of muon is 104 MeV/c^2 and since it is very small, energy and momentum can be regarded as almost equal.

Exercise

- You have been provided with reconstructed muon root files, which has been sorted into various energies each containing three angles (cosθ). The list of parameters and its definition is attached along with this.
- Check the initial parameters like charge (pidin is -13 for μ^+ and +13 for μ^-), generated momentum and direction(cosθ).
- *Reconstruction efficiency* : Analyze the reconstructed momentum (abs(trkmm[0])) and parametrize it using guassian. Once the sigma(σ) and mean are obtained apply the cut, mean $\pm$ 5σ. The entries obtained are the number of reconstructed muon events. Reconstruction efficiency is given as

$$\varepsilon_{reco} = \frac{No.\ \ of\ \ reconstructed\ \ \mu}{No.\ \ of\ \ generated\ \ \mu^{\pm}} \times 100 \tag{1}$$

- *Charge id efficiency*: To understand how well the detector can distinguish between charges, we find its charge id efficiency. We analyse the reconstructed momentum (trkmm[0]) and repeat the above step. The charge id efficiency is given as

$$\varepsilon_{recocid} = \frac{No.\ \ of\ \ reconstructed\ \ \mu^{\pm}}{No.\ \ of\ \ reconstructed\ \ \mu} \times 100 \tag{2}$$

- *Momentum resolution*:

$$\sigma_p = \frac{\sigma_{fit}}{P_{in}} \times 100 \tag{3}$$

where σ_{fit} is the standard deviation obtained from the Gaussian fit and P_{in} is the input momentum.

- *Direction resolution*: We can also try to study how the measured direction(trkth[0]) varies as function of momentum of the particle.

$$\sigma_{cos\theta} = \frac{\sigma_{fit}}{cos\theta_{in}} \times 100 \tag{4}$$

where σ_{fit} is the standard deviation obtained from the Gaussian fit and $\cos(\theta)_{in}$ is the input direction.

- Once this is done, the same procedure can be repeated for other energies assigned to you. Graphs can be plotted for each of four analyses mentioned above.
- This whole procedure can be repeated for other angles as well.