Project on High Energy Physics

In this article we will work on the efficiencies of the different selection criteria that are applied in filtering the potential electron candidates from a Monte Carlo collision model and reconstructing a Z Boson from the electrons.

INTRODUCTION

The Standard Model of particle physics is the most rigorous and well tested model known till date. The model is still incomplete, but it can give definite correct predictions to most of our questions.

The Standard model describes three fundamental forces of nature and classifies the elementary particles that interact with the forces. The fundamental forces are Electromagnetic, Strong and Weak force (excluding gravitational force) and the fundamental particles are divided into Bosons and Fermions.
The Fermions are called matter particles and consists of two classes of particles : quarks and leptons. The Bosons are particles which are called Force carriers consist of Photons(Electromagnetic), Z and W Bosons(Weak Interactions) and Gluons(Strong Interactions).

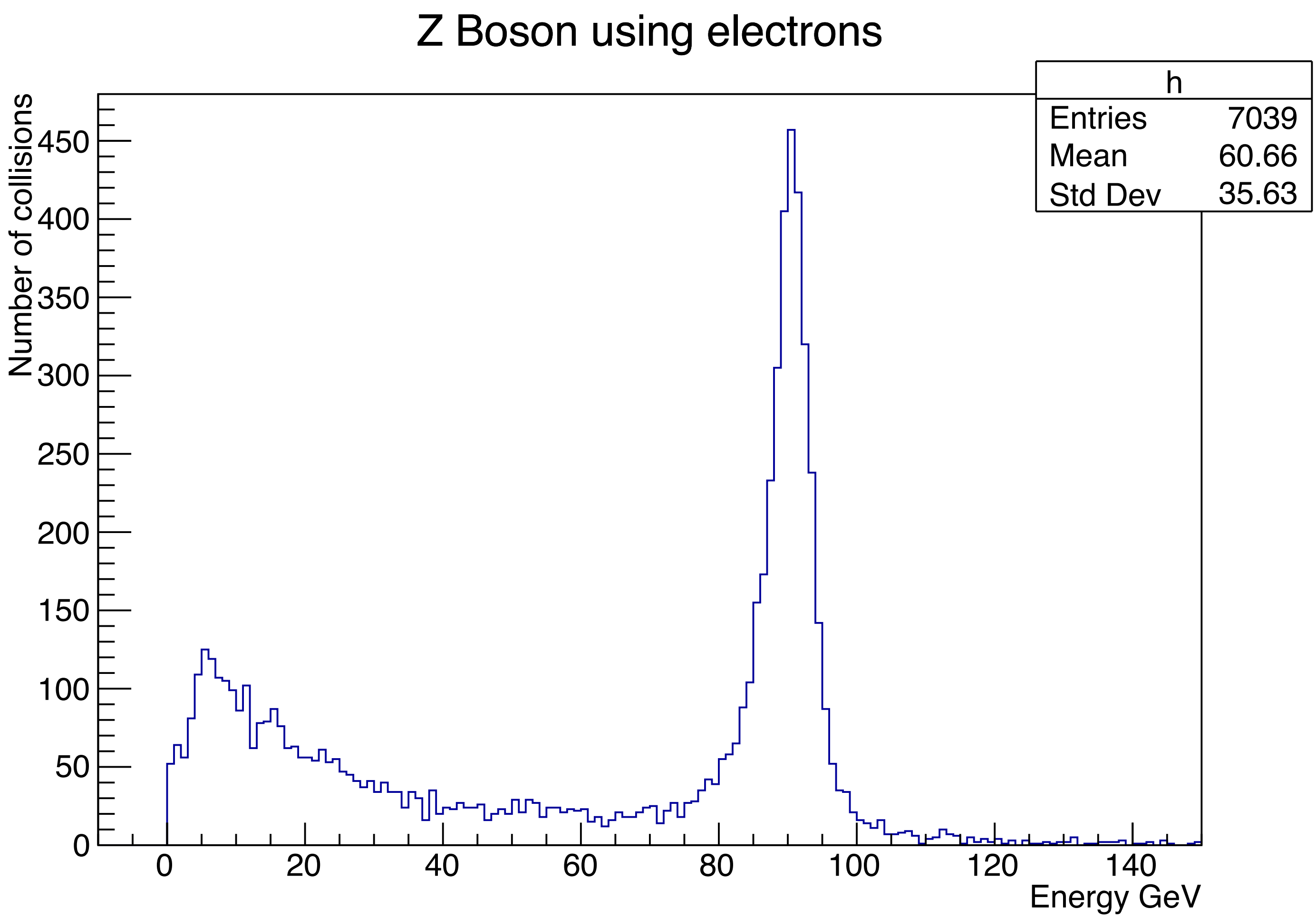
The protons are composed of (uud) up up down quark combination; high energy collisions force the formation of several particles, Z boson being one of them. The decay product of the Z Boson(electrically neutral) can be an electron and a positron or a negatively charged muon and a positively charged muon.

The electrons and muons are fundamental particles and will not decay. These fundamental particles can be detected by the detectors. The detectors can give us the momentum and the energy of the fundamental particles which can be used to derive the invariant of the particle from which they originated from.

Z BOSONS RECONSTRUCTED FROM ELECTRONS WITHOUT USING SELECTION CRITERIA

Two electrons with highest transverse momentum is taken from every collision, without using any selection criteria their invariant mass is filled in a histogram.

The Histogram we get is follows:



From the histogram we can say that there is a distinct peak near ~90 GeV and there is another small peak near 5-10 GeV.

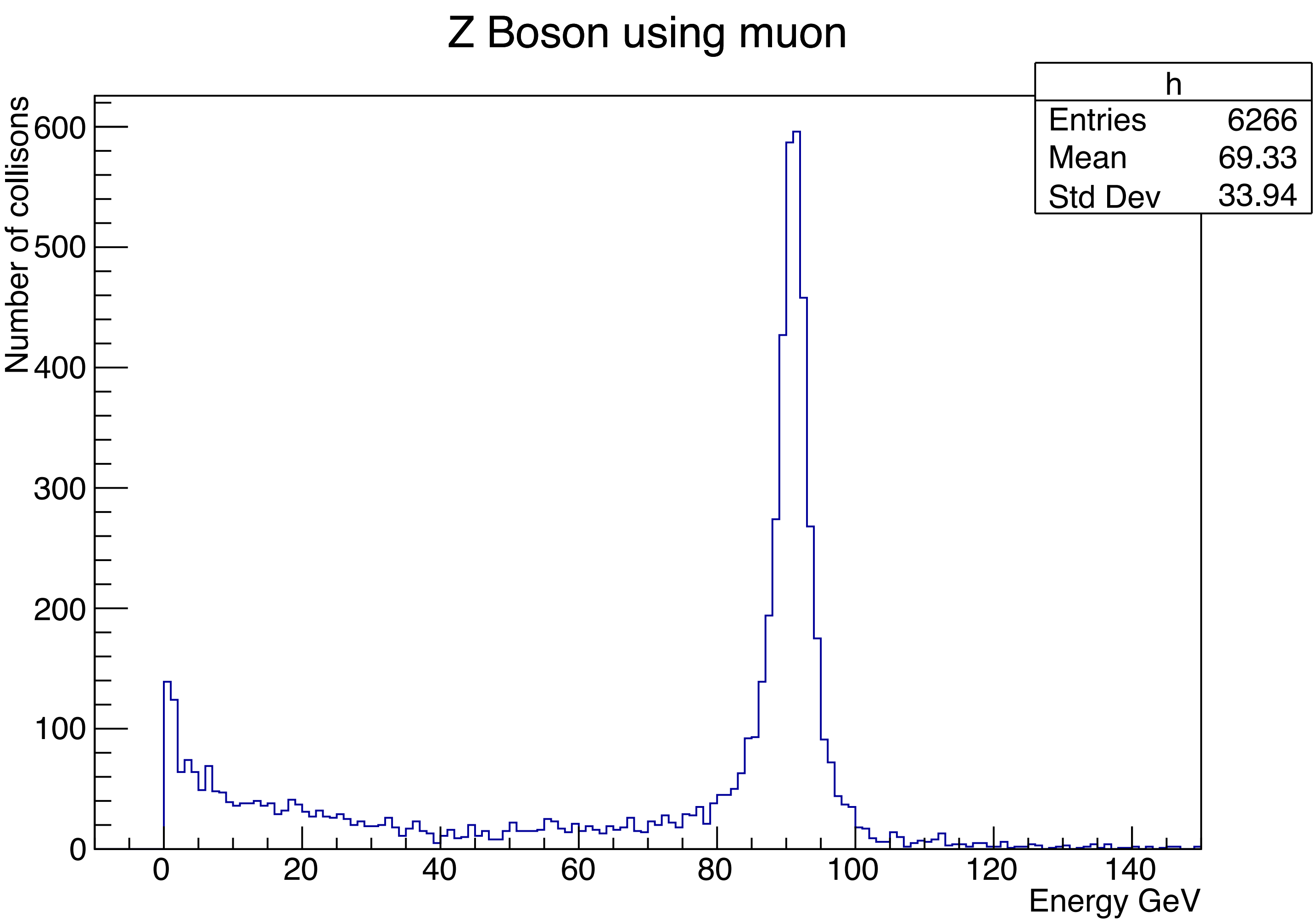
Note : The Large Hadron Collider is not very accurate near the lower energy levels.

There are 7039 events that are considered in this histogram.

Z BOSONS RECONSTRUCTED FROM MUONS WITHOUT USING SELECTION CRITERIA

Two muons with highest transverse momentum is taken from each collision, without using any selection criteria their invariant mass is filled in a histogram.

The Histogram we get is follows:



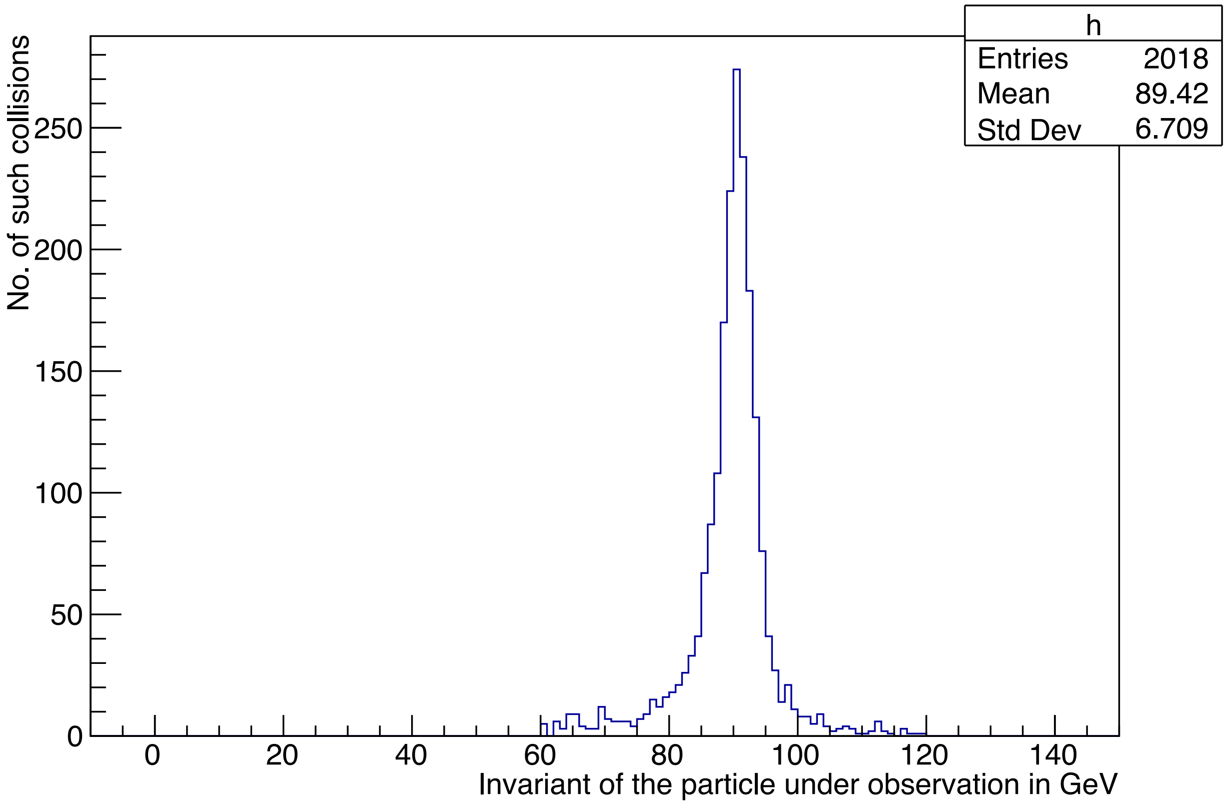
From the histogram distribution we can again clearly see that there is a peak at ~90GeV and another at the lower energy level.

There are 6266 events that are considered in this histogram.

Z BOSONS RECONSTRUCTED FROM ELECTRONS USING SELECTION CRITERIA

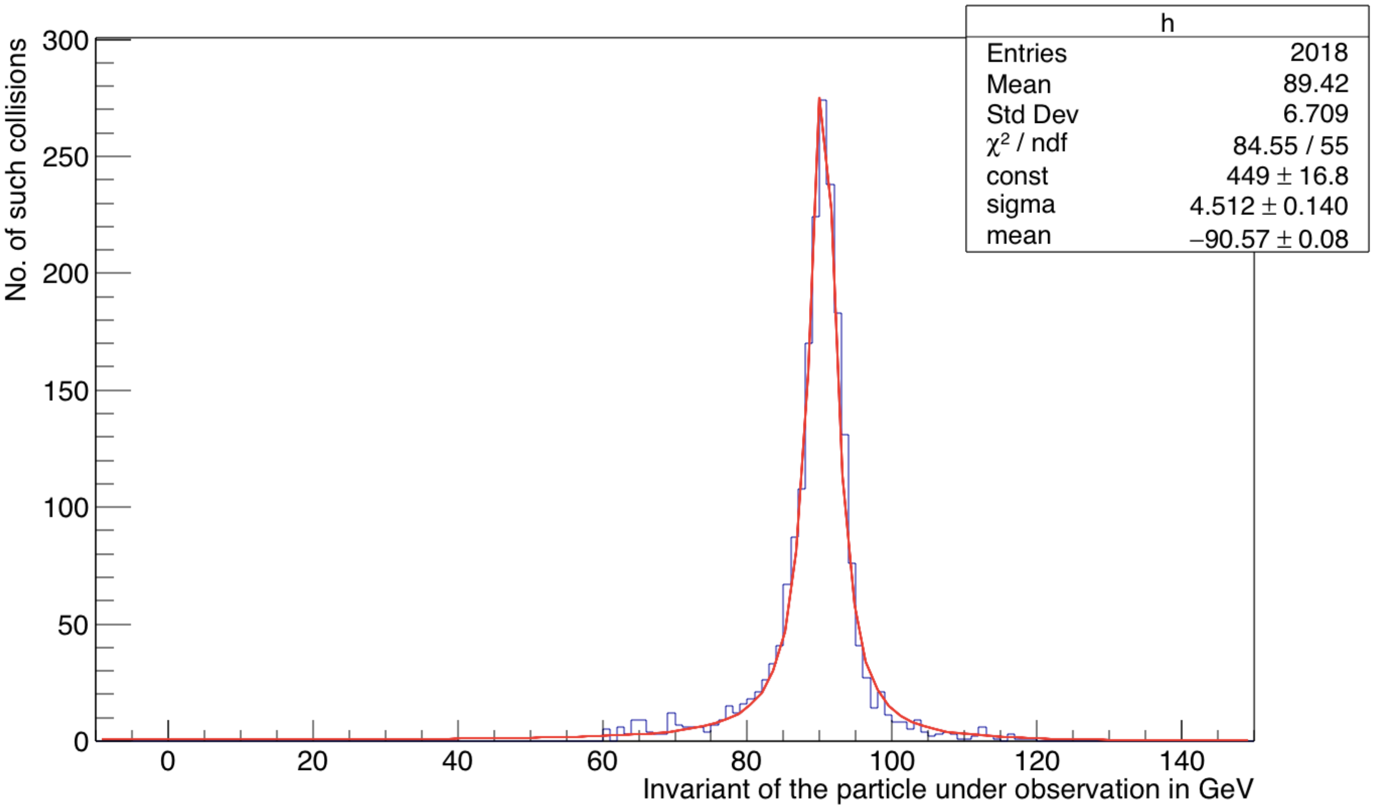
The cuts(selection criteria) that are used to determine true electrons are as follows :

1. eleHoverE
2. eleSigmaIEtaIEtaFull5x5
3. eleMissHits
4. eleConvVeto
5. eleEoverPInv
6. eledEtaAtVtx
7. eledPhiAtVtx



There was a cut which was applied on the magnitude of the invariant mass which is invariant of the composite particle has to be less than 120 and greater than 60 (Since we know that the invariant mass of Z Boson is ~92 GeV, from theory)

The histogram of the invariant mass was fitted with a Breigt Weigner.



We know the theoretical value of invariant mass of Z Boson to be ~91.2 .

From the fitted histogram we can see the mean to be ~90.5 .

STUDYING THE DIFFERENT SELECTION CRITERIA OF ELECTRONS

The data collected from the collisions in large hadron collider are stored in data structures called TTrees.
ROOT data analysis software is used to access the TTrees and the data stored in it.

We will use the electron and positron data stored in it to differentiate real from false electrons and positrons(other particles which behave like electrons and positrons).

Procedure of calculating the efficiency of different selection criteria:

I have used the Tag and Probe method to calculate the efficiencies.
The Tag particle is chosen such that it has high probability of being a true particle; a tight particle.

For determining the second particle all the cuts(selection criteria) are applied except the cut which is under consideration.

Then the tag particle and the second particle are reconstructed to get the invariant mass of the original particle from which they generated. If the particle has an invariant mass ranging between 70 and 110 GeV then the second particle is considered to be a true particle.

Now the second particle is passed through varying values of the cut which is under consideration.
The efficiency of selection criteria = (number of particles that passed the criteria / total number of particles)

A graph is plotted : efficiency vs value of the cut.

Note : If the cut is loose(the value of the criteria is relaxed) there is a chance of including false electrons. But if the cut is tight we might exclude some true particles.

The selection criteria that are considered are as follows:

1. eleHoverE
2. eleSigmaIEtaIEta5x5Full
3. fabs(eleEoverPInv)
4. fabs(eledEtaAtVtx)
5. fabs(eledPhiAtVtx)
6. eleConvVeto
7. eleMissHits

The X axis represents the value of the cut and the Y axis is the efficiency of the cut at that value. The efficiencies of the cuts are calculated separately for the barrel and the end cap.

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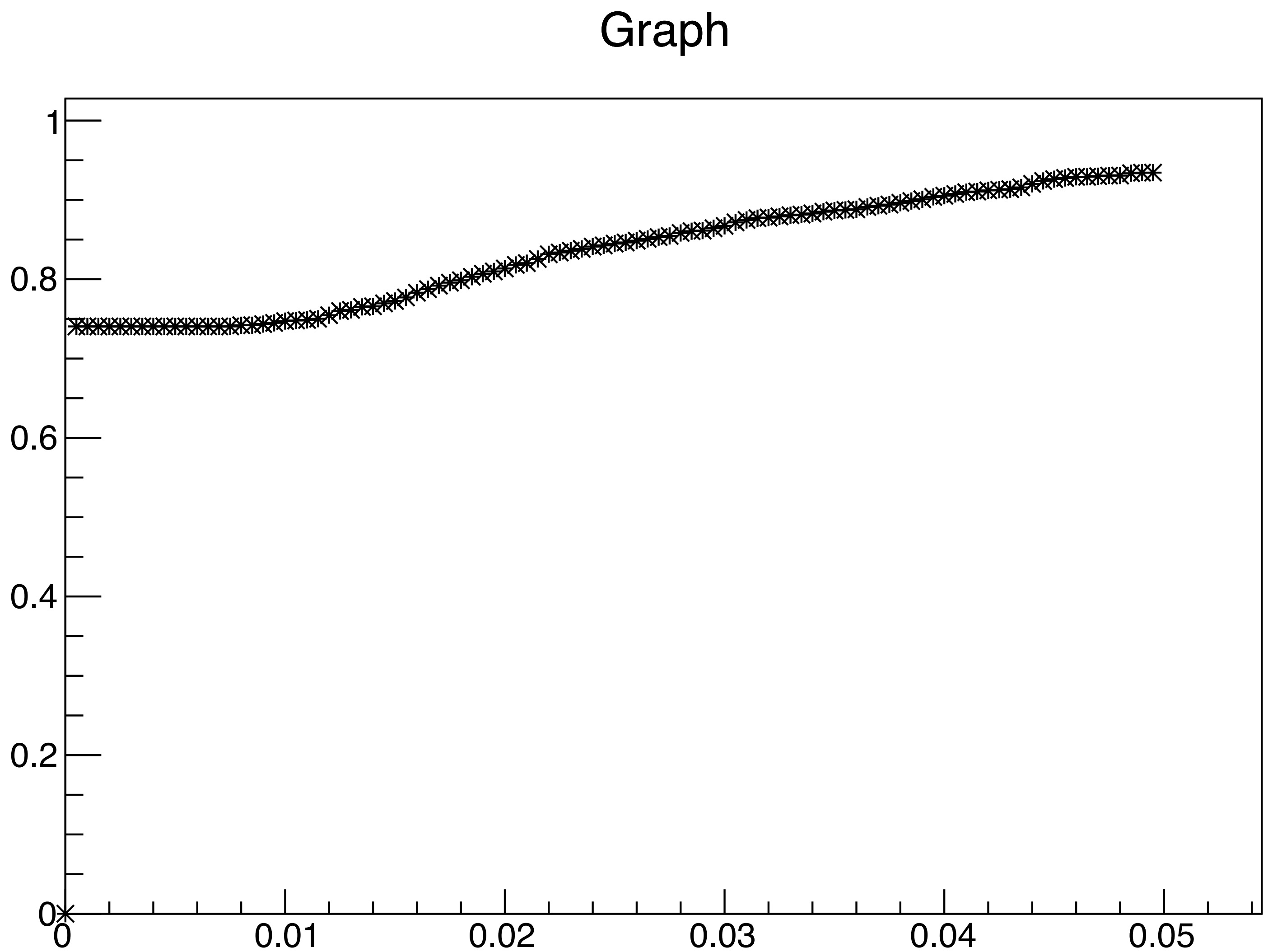
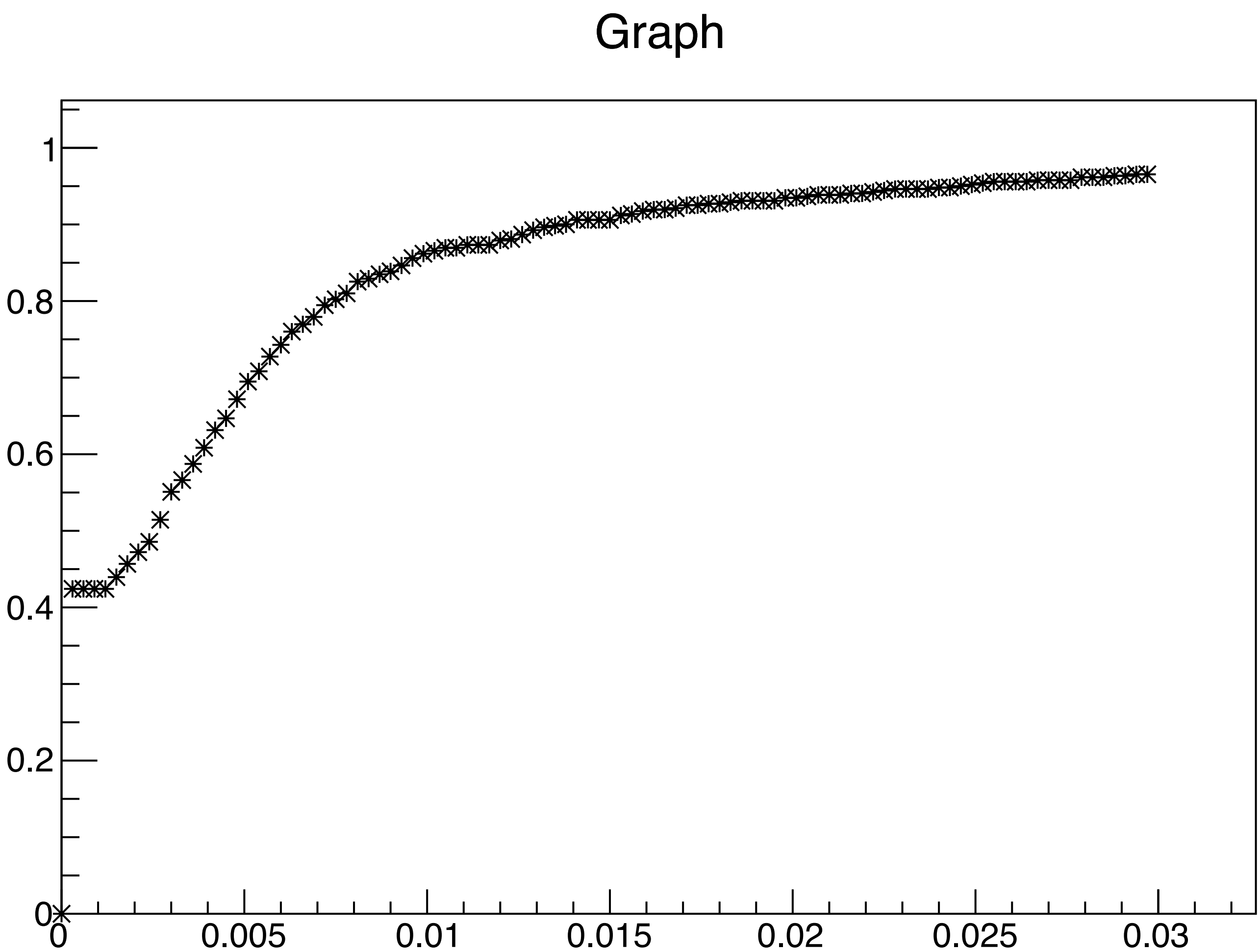
eleHoverE

Barrel region :



The provided value of the cut is <0.0414. The efficiency at that value of the cut is 0.910515.

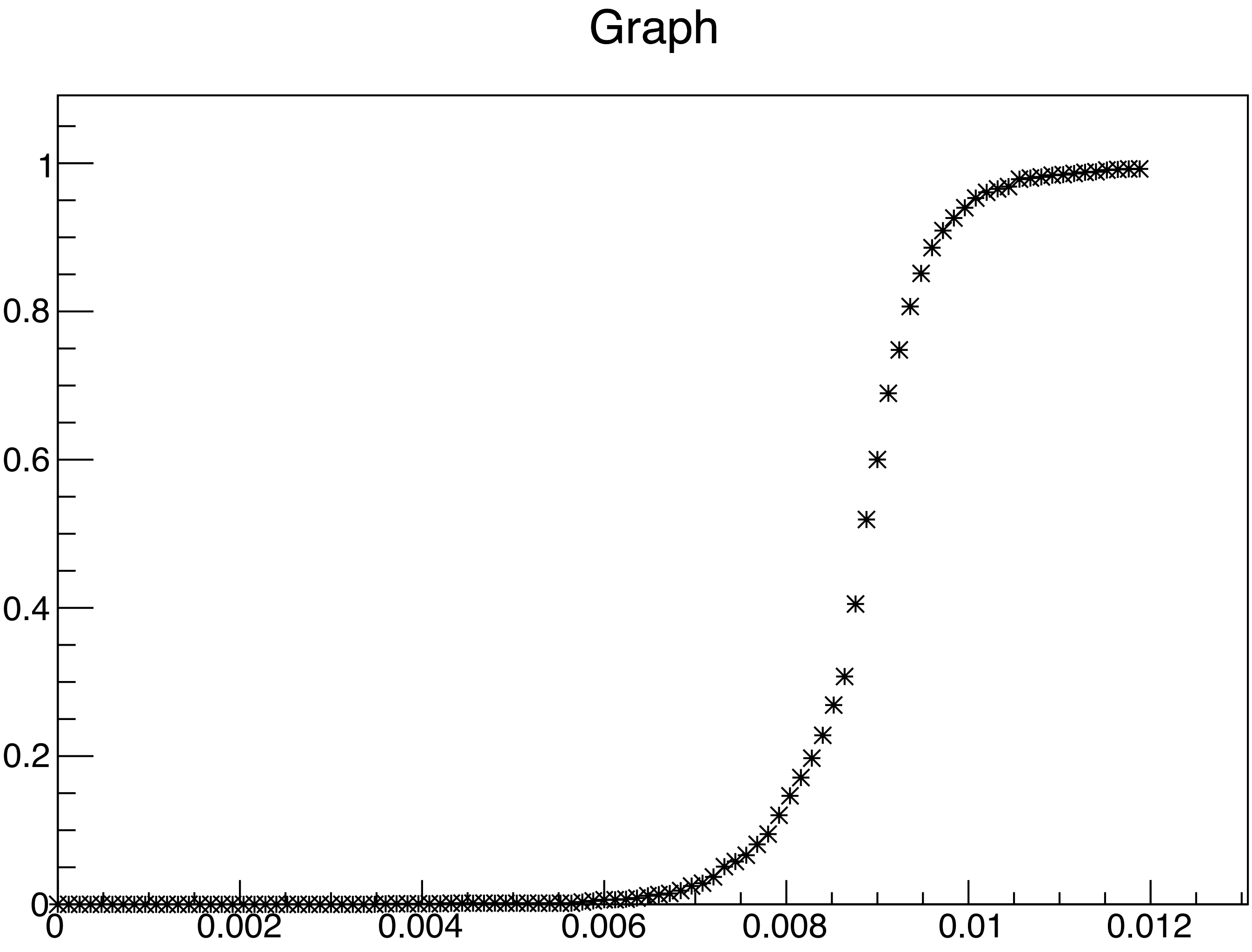
End cap region :



The provided value of the cut is <0.0641. The efficiency at that value of the cut is 0.930902.

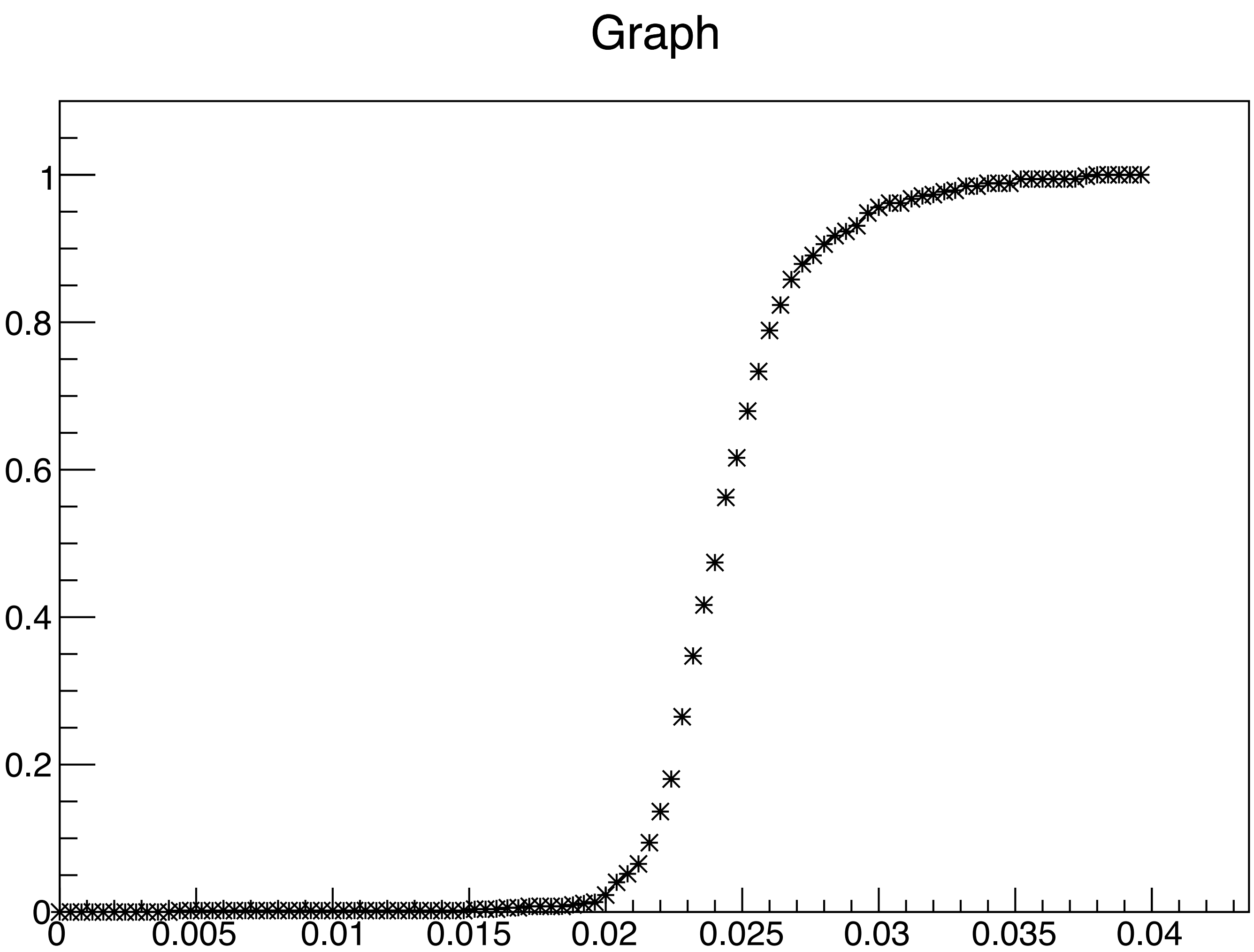
eleSigmaIEtaIEtaFull5x5

Barrel region :



The provided value of the cut is <0.00998. The efficiency at that value of the cut is 0.940678.

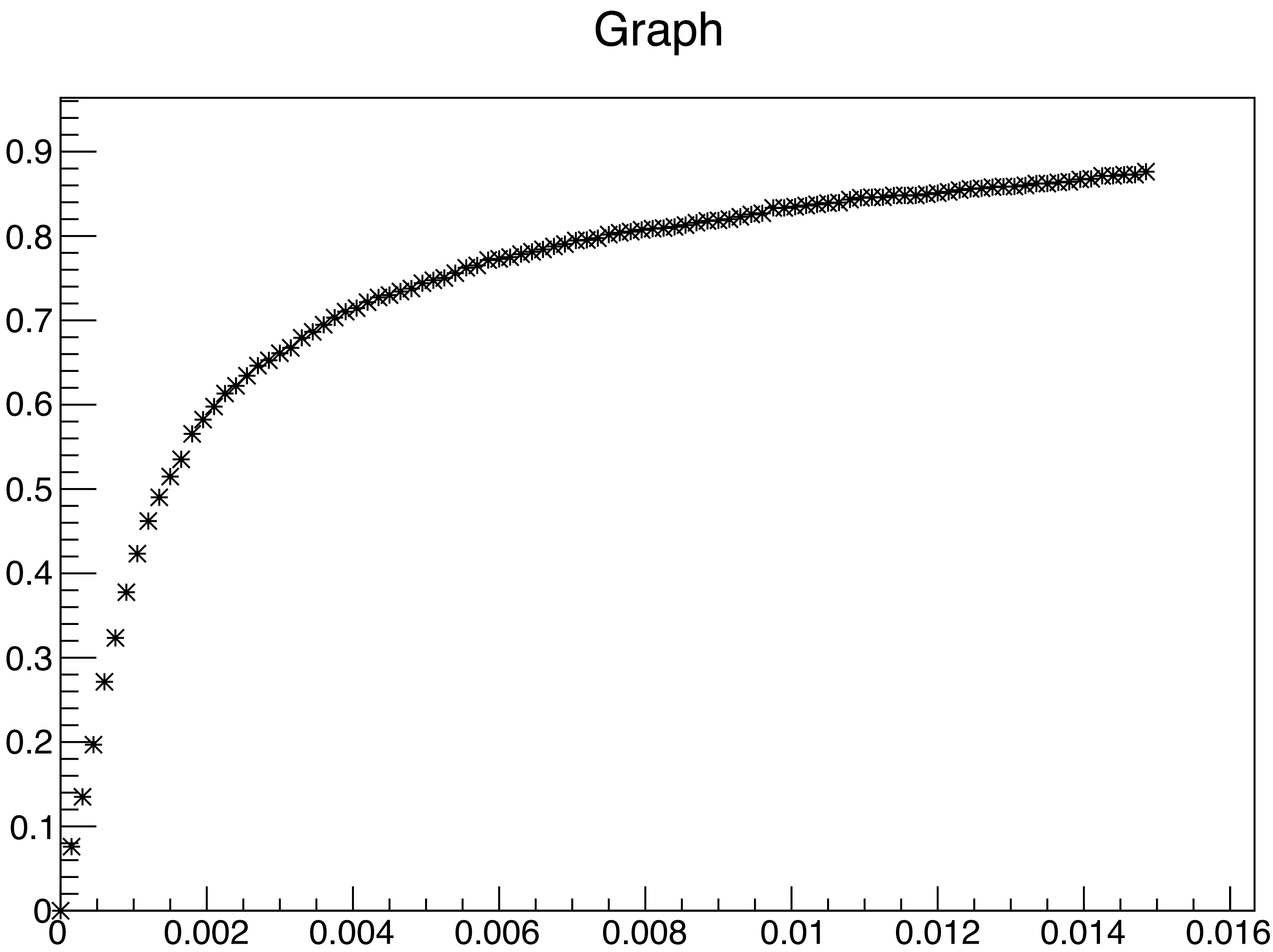
Endcap region :



The provided value of the cut is <0.0292. The efficiency at that value of the cut is 0.930902

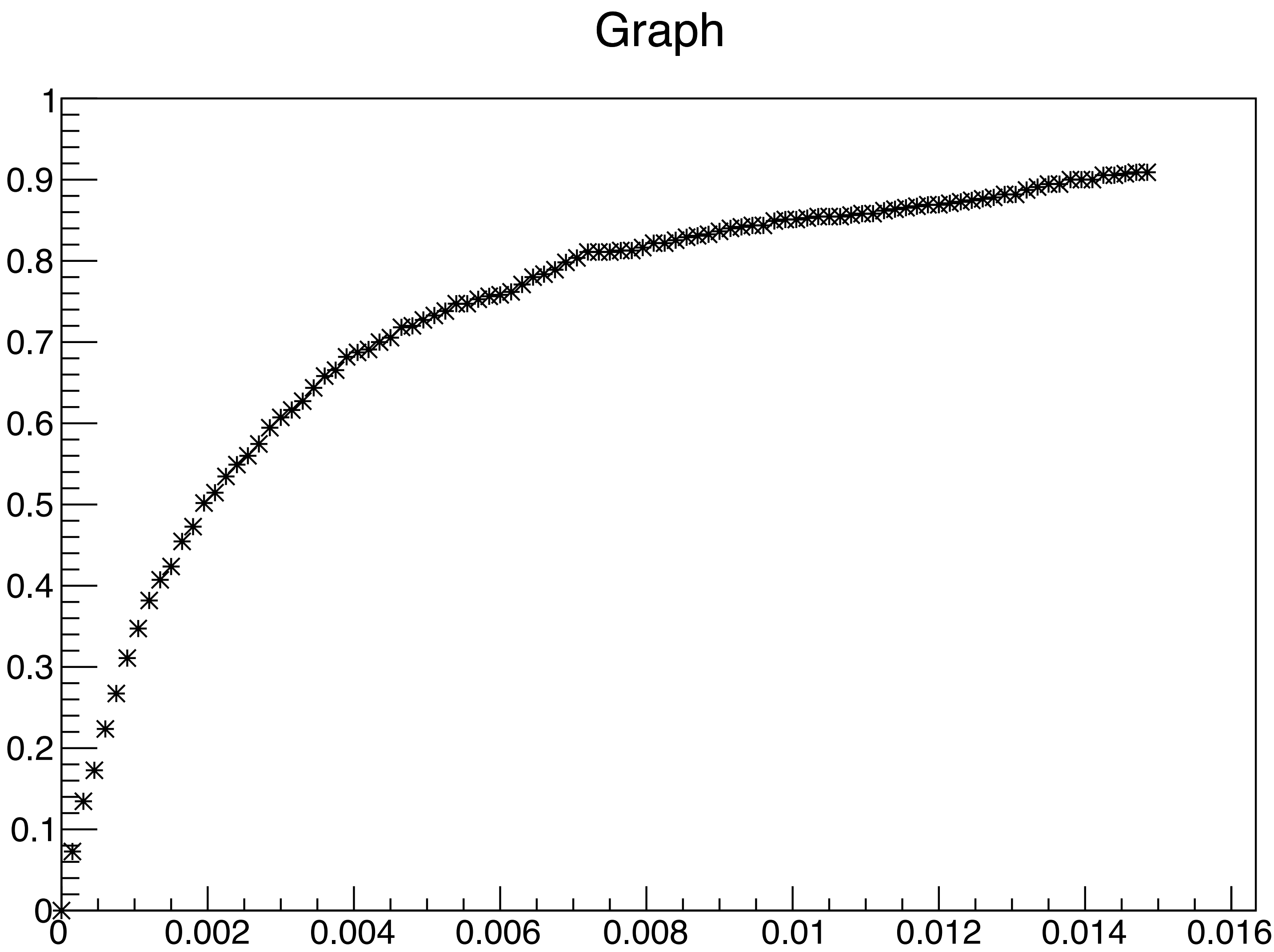
fabs(eleEoverPInv)

Barrel region :



The provided value of the cut is <0.0129. The efficiency at that value of the cut is 0.85865.

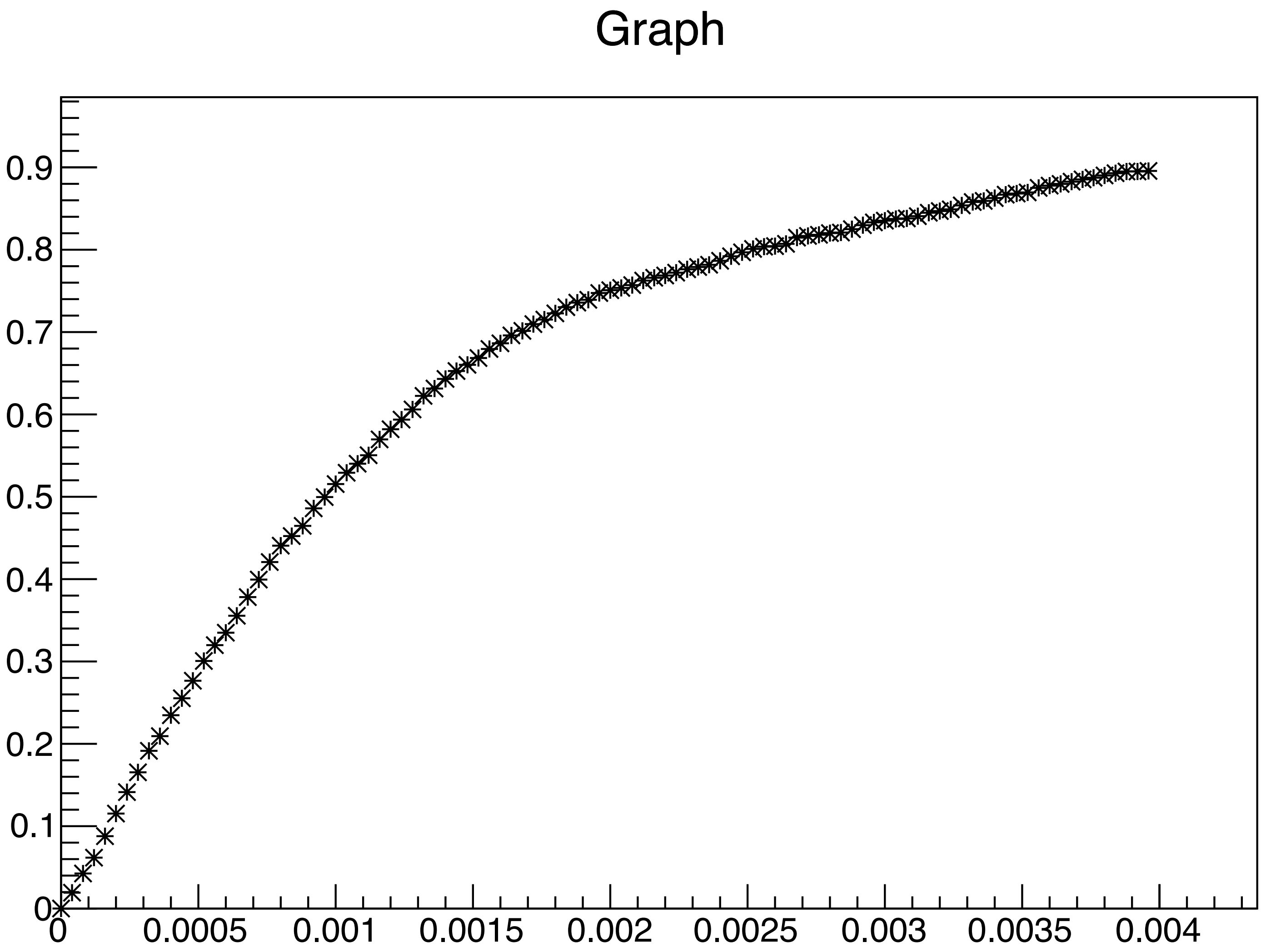
Endcap region :



The provided value of the cut is <0.0129. The efficiency at that value of the cut is 0.881818

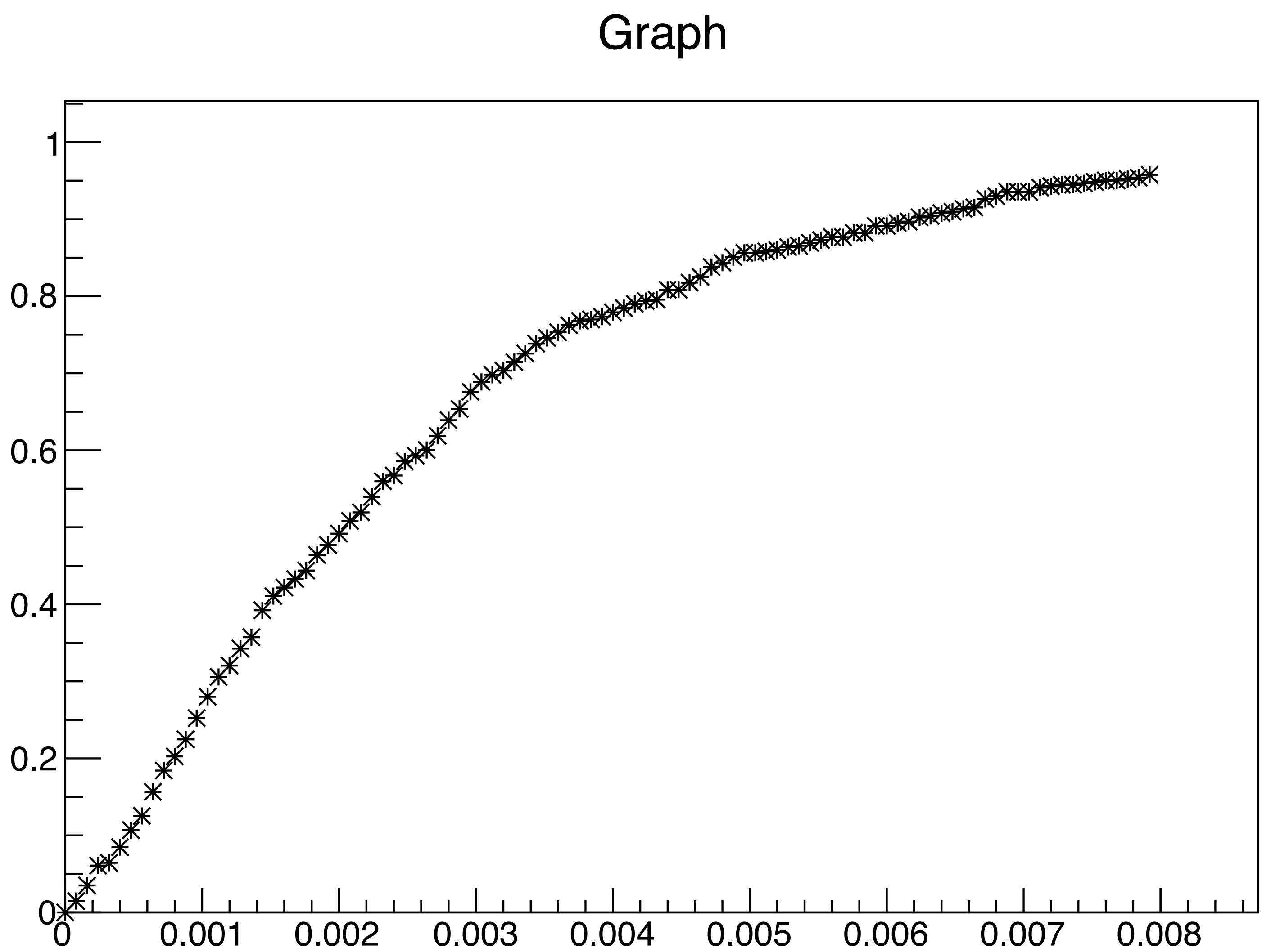
eledEtaAtVtx

Barrel region :



The provided value of the cut is <0.00308. The efficiency at that value of the cut is 0.838023

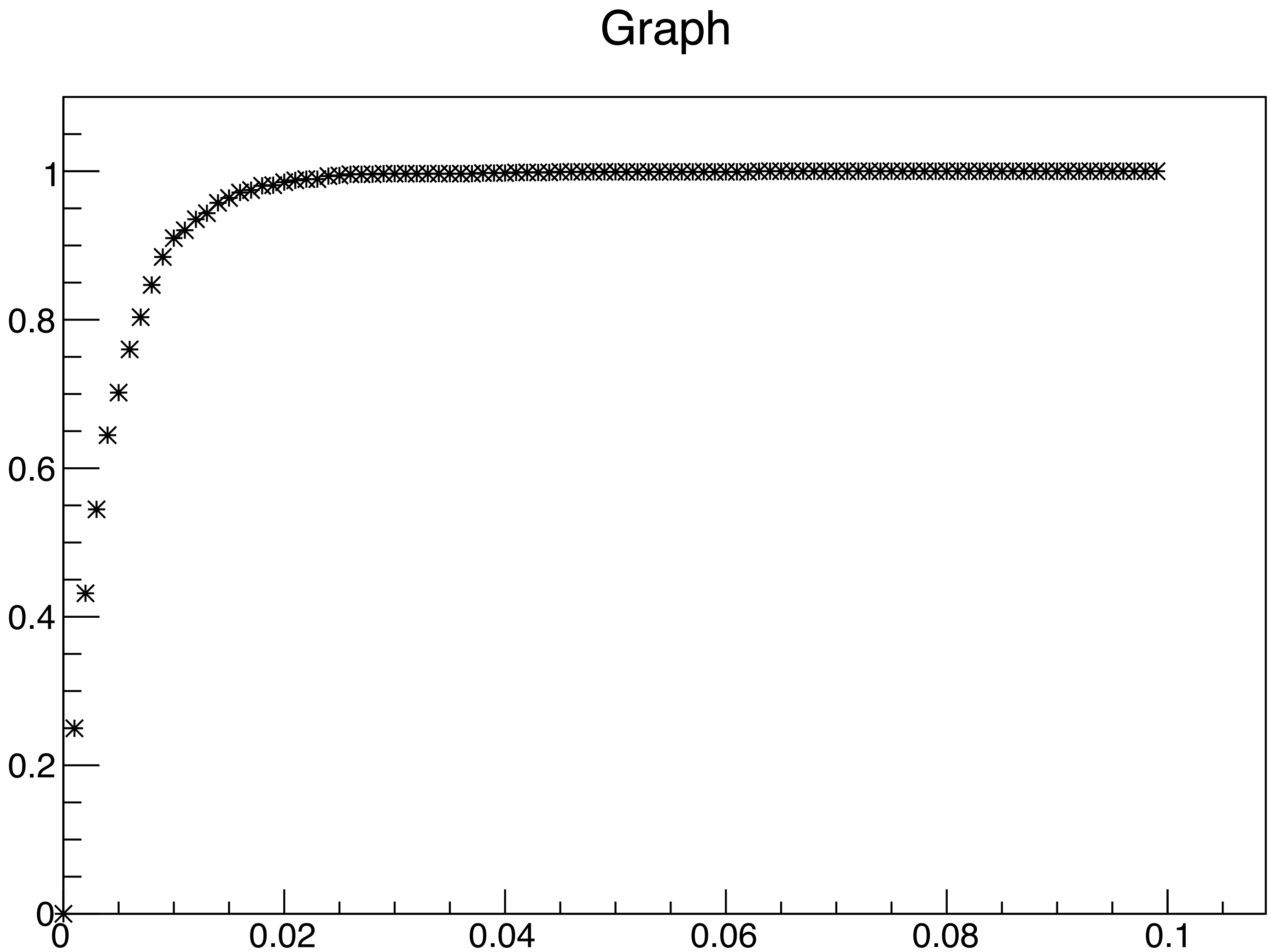
Endcap region :



The provided value of the cut is <0.00605. The efficiency at that value of the cut is 0.893186

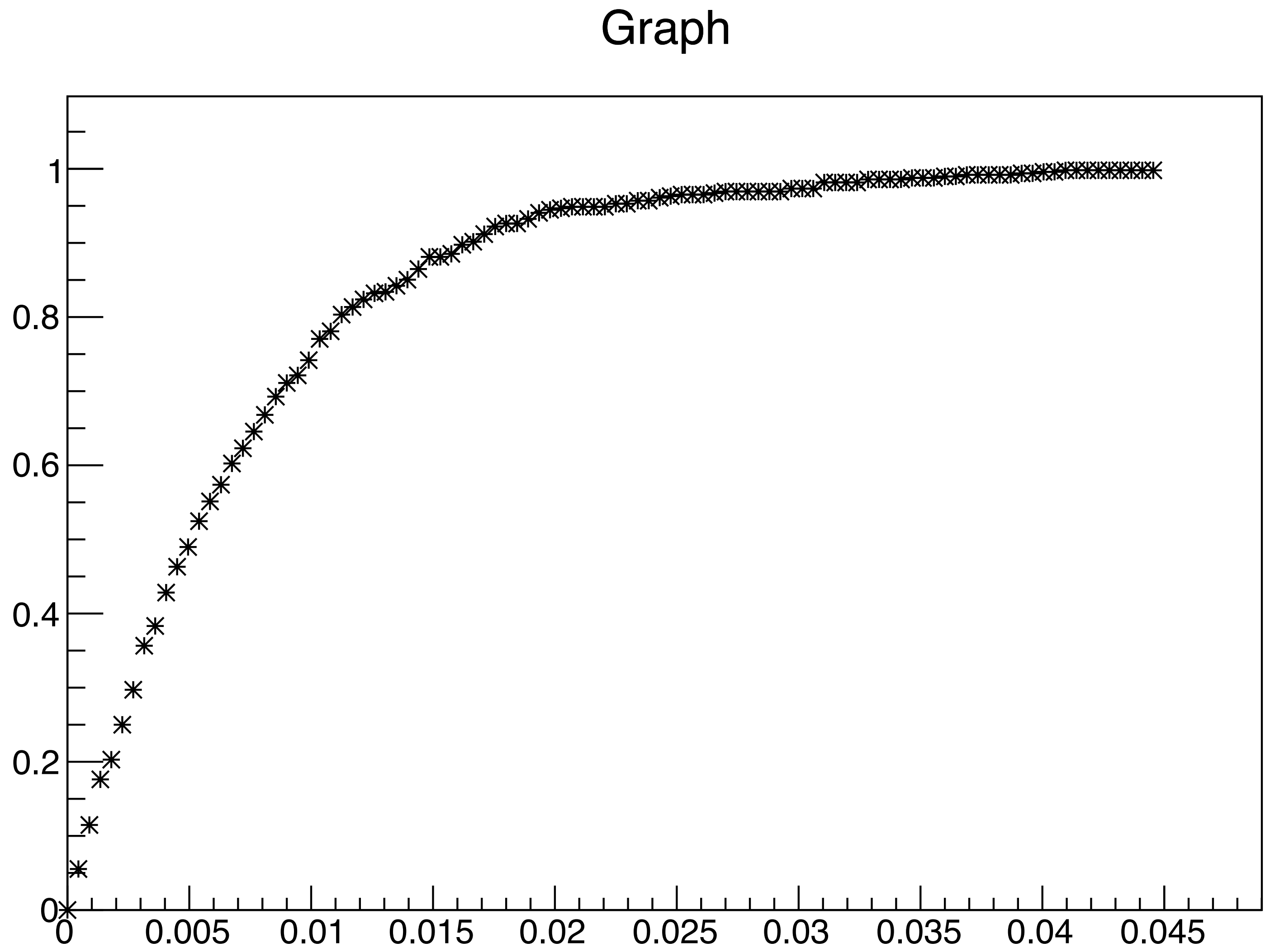
eledPhiAtVtx

Barrel region :



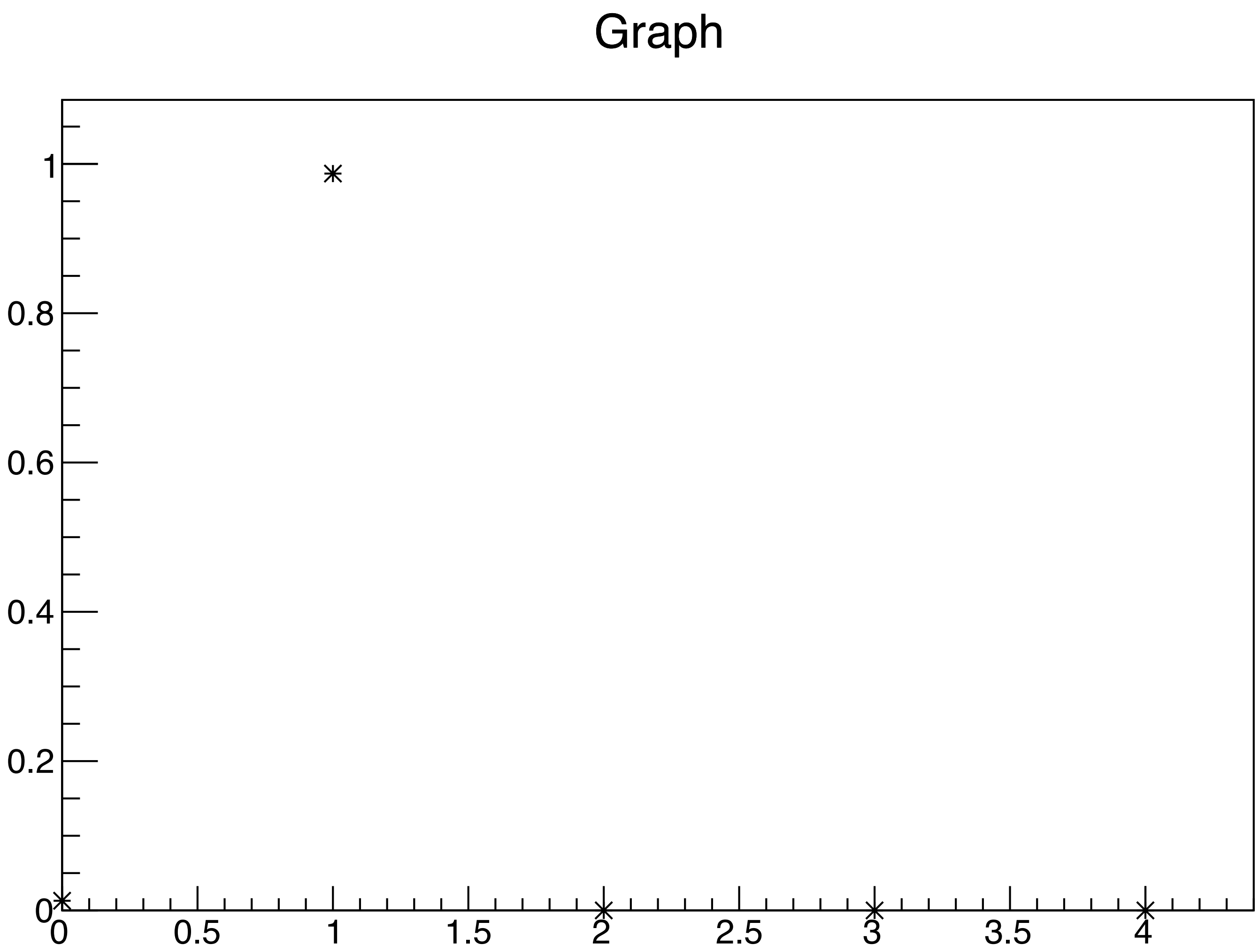
The provided value of the cut is <0.0816. The efficiency at that value of the cut is 1.0.

Endcap region :



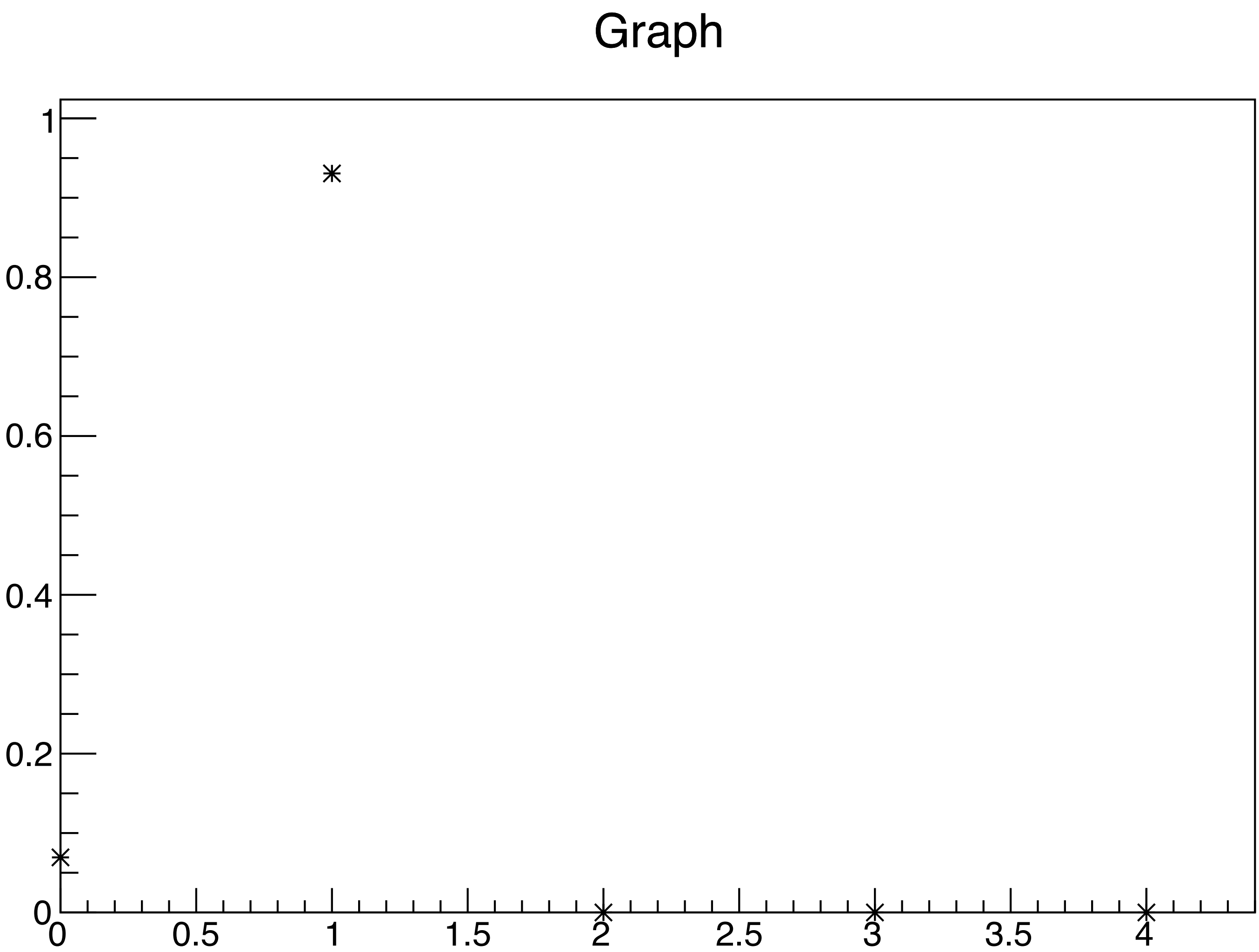
The provided value of the cut is <0.0394. The efficiency at that value of the cut is 0.993852.

Barrel region:



The provided value of the cut is =1. The efficiency at that value of the cut is 0.987065.

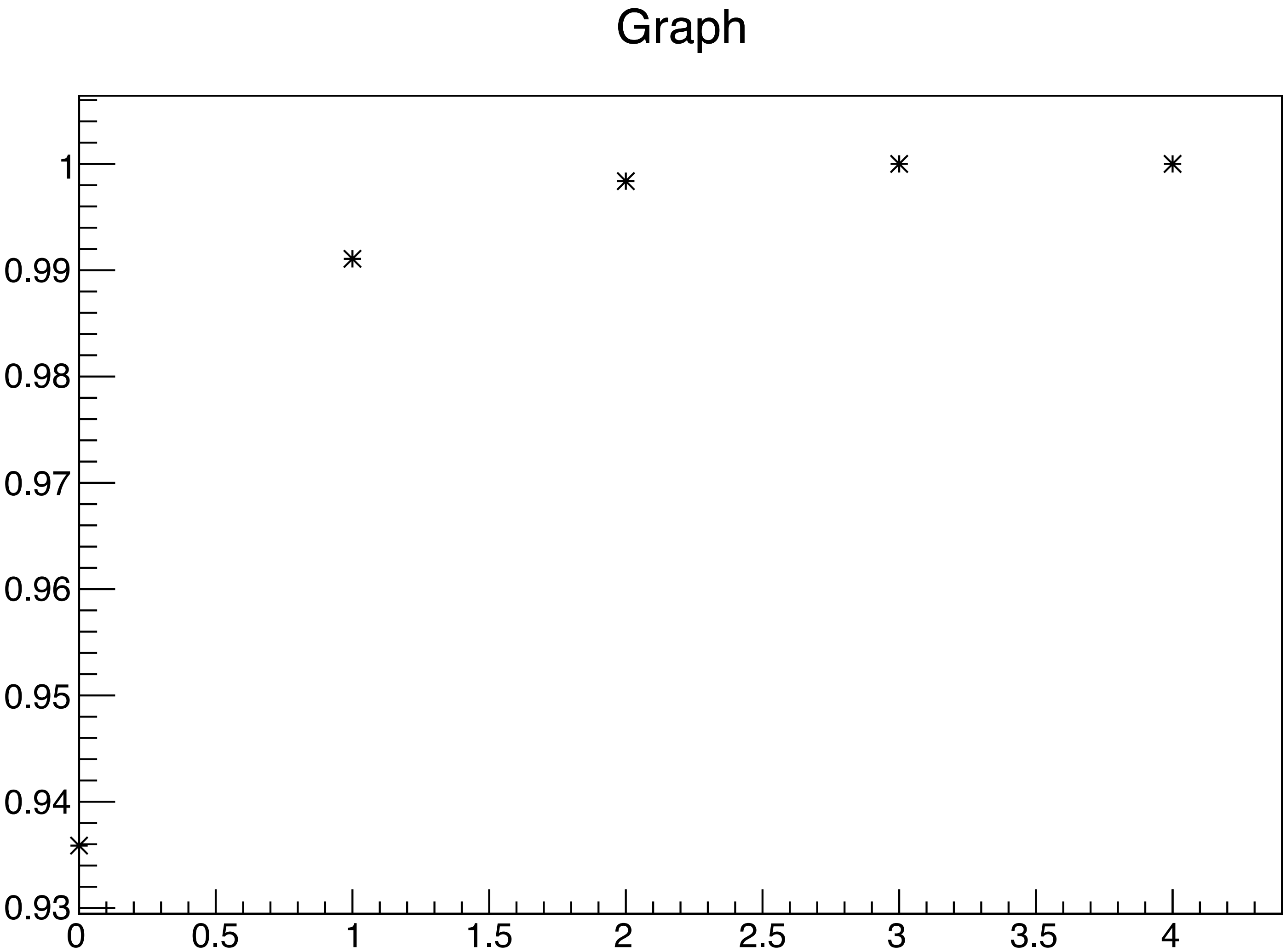
endcap region :



The provided value of the cut is =1. The efficiency at that value of the cut is 0.934489.

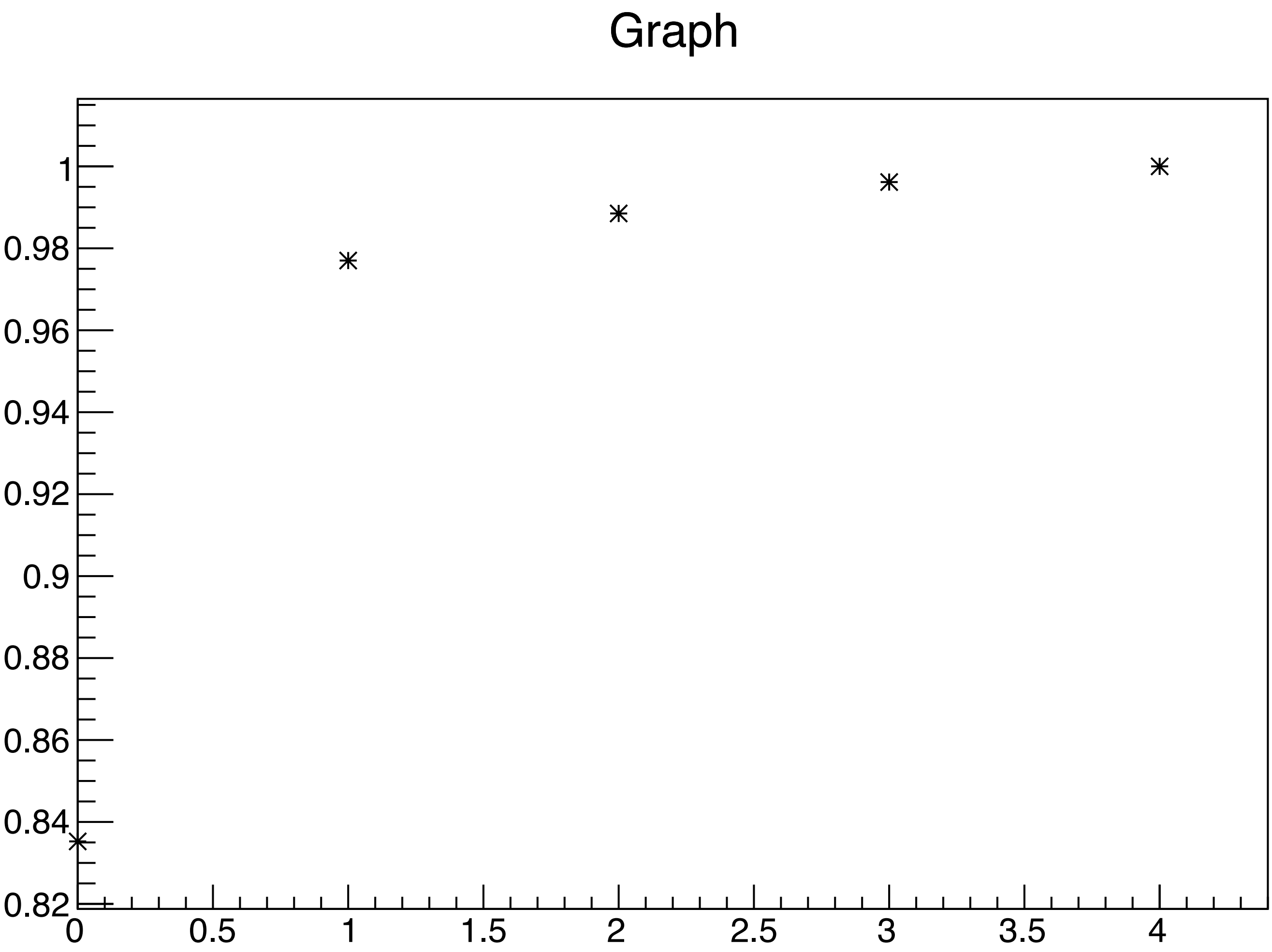
eleMissHits

Barrel region :



The provided value of the cut is <=1. The efficiency at that value of the cut is 0.991071.

Endcap region :



The provided value of the cut is <=1. The efficiency at that value of the cut is 0.971944.

Acknowledgement

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Reference

- Introduction to Elementary Particles - David Griffiths
- C++ by Dissection - Ira Pohl
- A ROOT Guide For Beginners