Particle Identification (PID) in FairShip

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Outline

1) PID criteria and selections.
2) Explaining the structure of the PID code.
3) How to use the PID information in data analyzing (for all users).
4) As an example I'll show the application of the particle identification using "simple" cuts for Muons, Hadrons and Electrons.

Introduction

- The aim is to explain how PID is implemented in FairShip.
- I've adopted a step by step approach; therefore, any modification and using specific cuts easily can be implemented to the code.
- However, in order to have a unique PID information to be used by other users, please send your commends and modifications to us to implement them into the code.

PID criteria and selections

PID criteria and selections

- Selection variables for the muonid:
  - Difference in position of extrapolated tracks and the position of hits (inside each pad).
  - Depth in 4 layers of the muon detector due to the momentum of tracks.
  - Number of related hits.
- Field of interests for mounid:
  - Each layer digitized with the pads, each of them having a size of 5x5 cm^2.
  - MuonPoint hits related to each pad, are merged together. Therefore, there is one single hit per each pad.
  - PID depends on momentum and for each momentum is interval (which is customizable); then, I ask for hits to be present at a given depth around a number of pad area depending on the momentum of the track. If the number of hits around these number of pad area are 1 or 2, the track is identified as a muon.

PID criteria and selections

- Selection variables for electron:
  - Difference in position of extrapolated tracks and the clusters in Ecal detector.
  - Value of E/P.
- Hadron detector:
  - The Hcal information also will be add to this work when this information will be ready.

PID criteria and selections

- The main strategy is:

1) First extrapolate tracks up to the end of the detector.

2) Using the information of muon detector check if the track is a muon.

3) If not, Check the electronid by using the Ecal information.

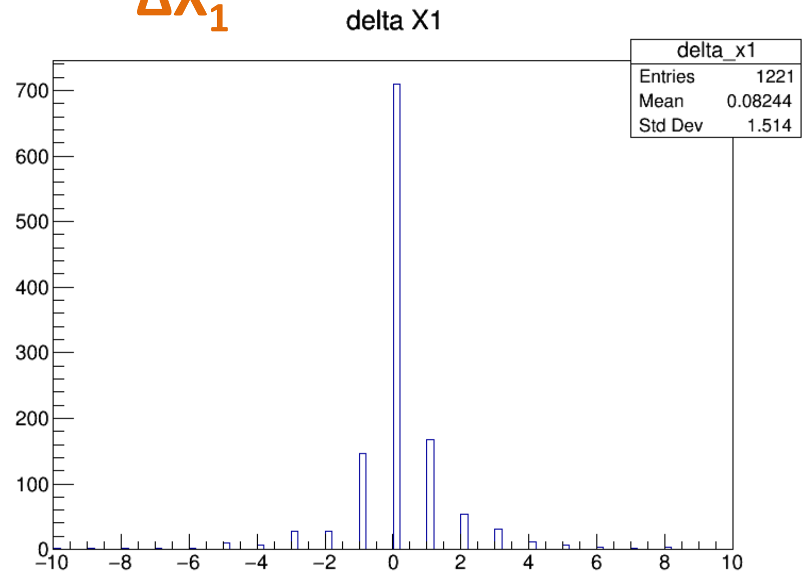
4) If it is not muon and electron, it is a hadron.

The muon identification using some simple cuts

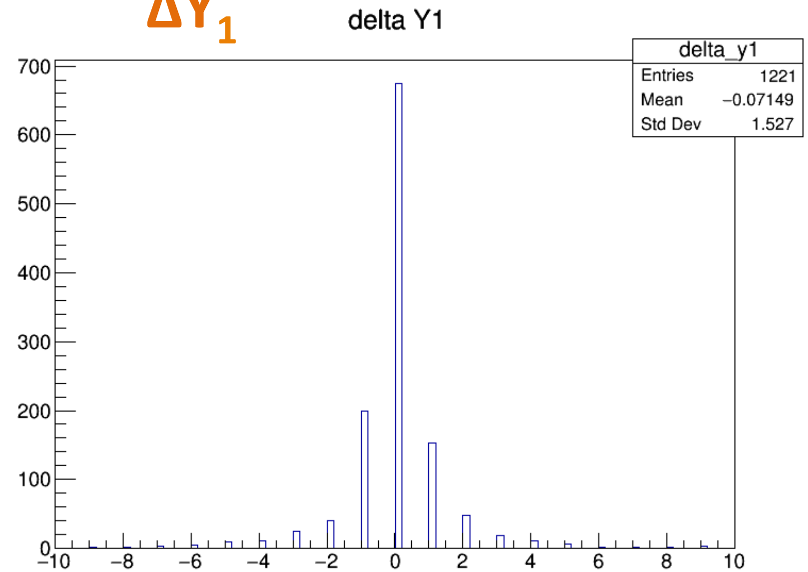
1000 events with a single muon are generated using Pgun with momenta in the range of (1-50 GeV).

Difference in position of Muon detector hits and extrapolated tracks (layer 1)

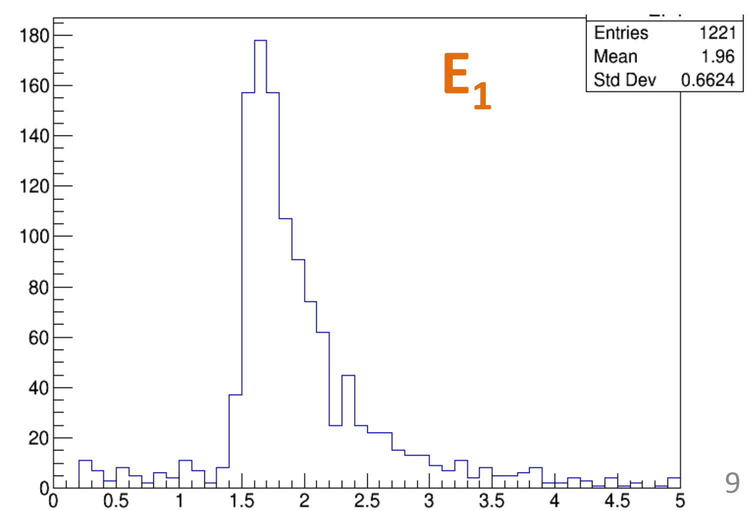
ΔX_1



ΔY_1



E_1



Each layer digitized with 5x5 cm^2 pads

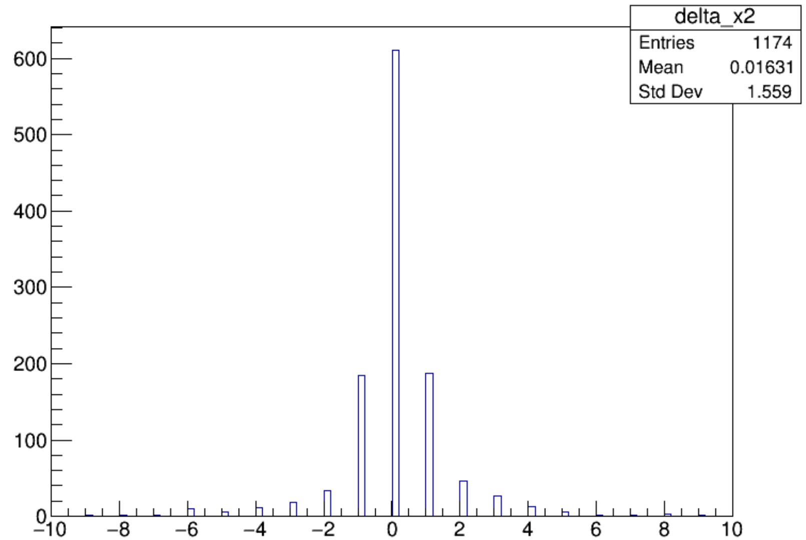
$\Delta X = X_{extrapolated} - X_{hit}$

$\Delta Y = Y_{extrapolated} - Y_{hit}$

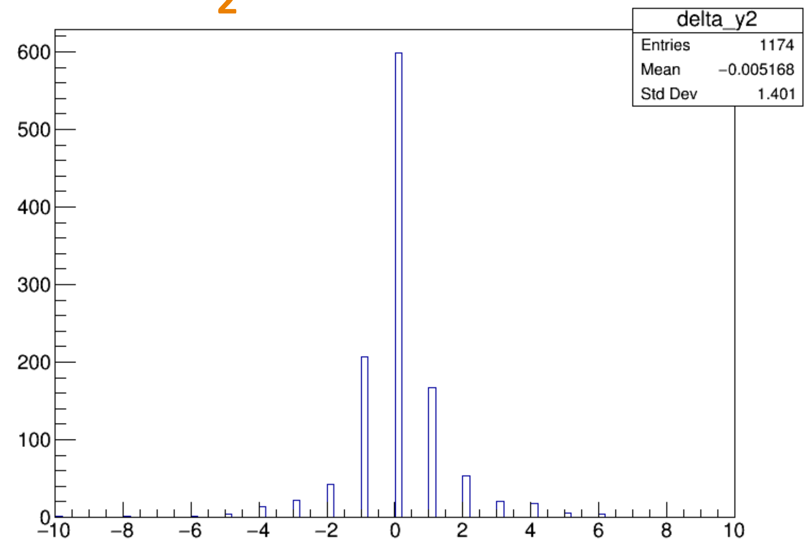
E = sum of the energy of hits in one pad

Difference in position of Muon detector hits and extrapolated tracks (layer 2)

ΔX_2



ΔY_2

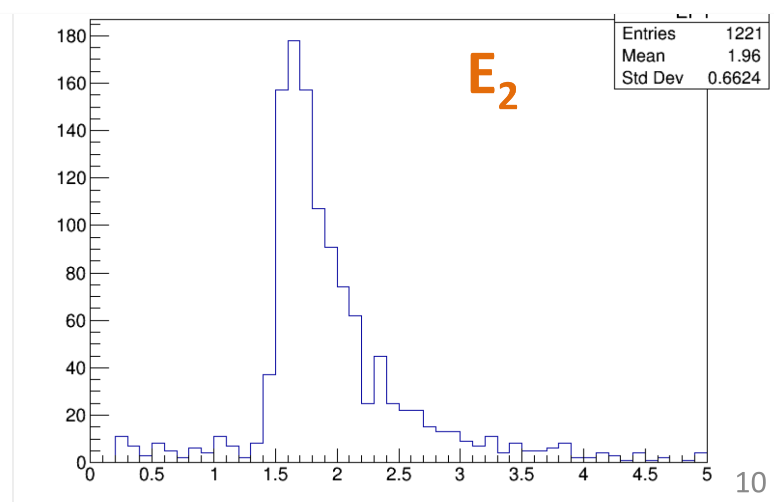


$$\Delta X = X_{extrapolated} - X_{hit}$$

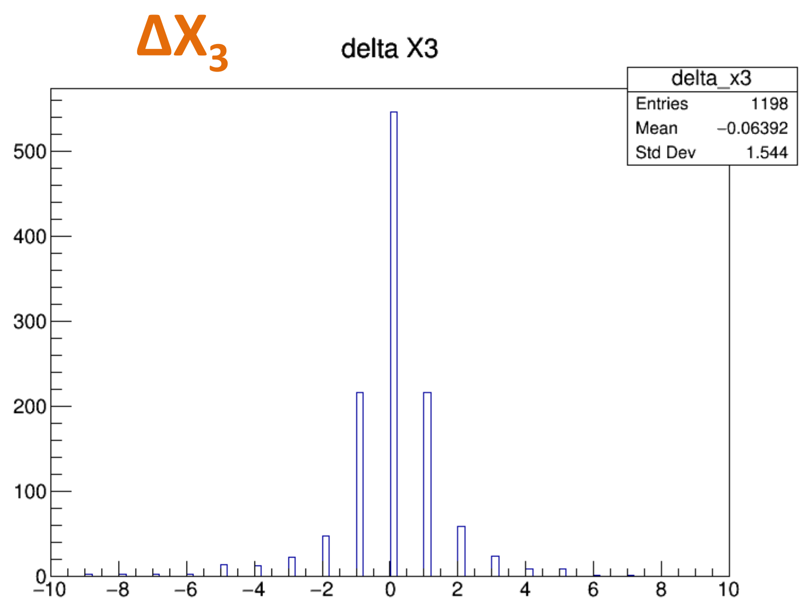
$$\Delta Y = Y_{extrapolated} - Y_{hit}$$

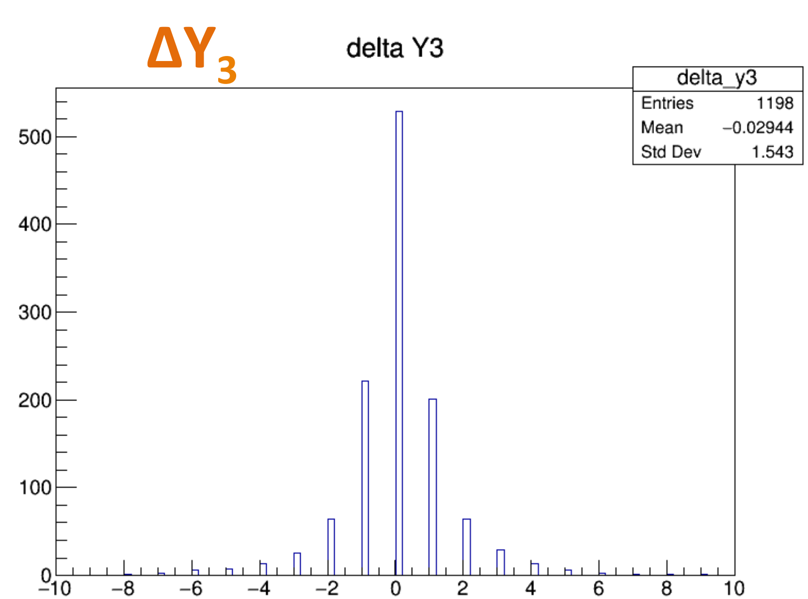
E = sum of the energy of hits in one pad

E_2



Difference in position of Muon detector hits and extrapolated tracks (layer 3)

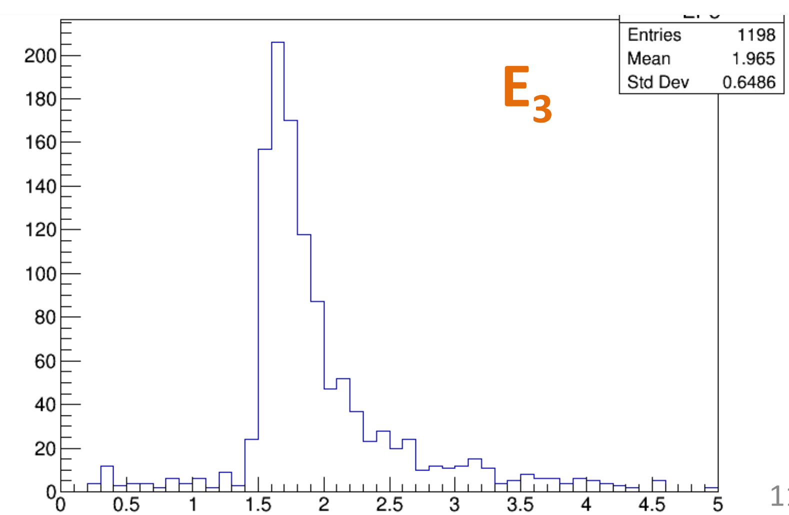




$\Delta X = X_{extrapolated} - X_{hit}$

$\Delta Y = Y_{extrapolated} - Y_{hit}$

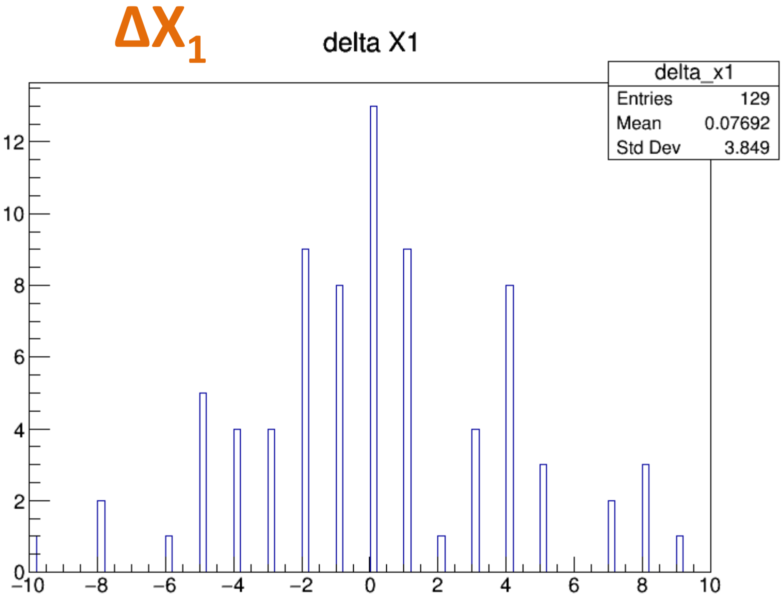
E = sum of the energy of hits in one pad

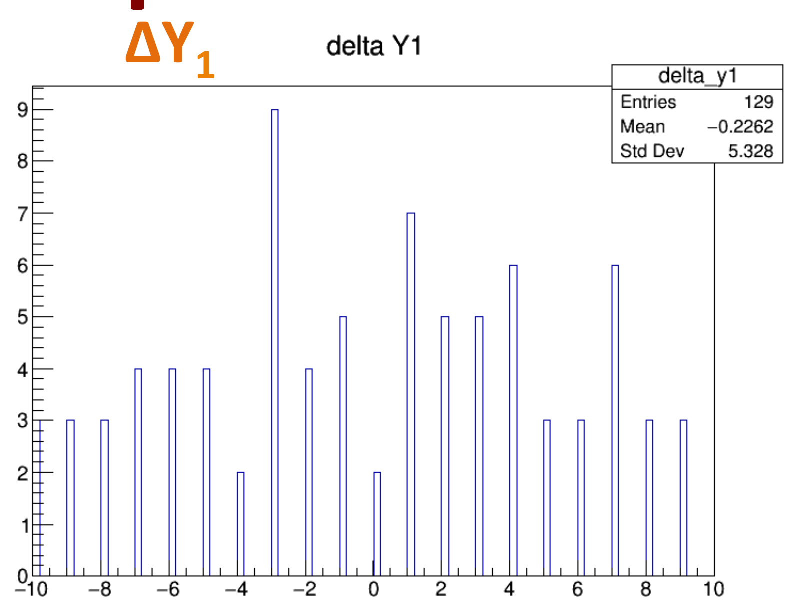


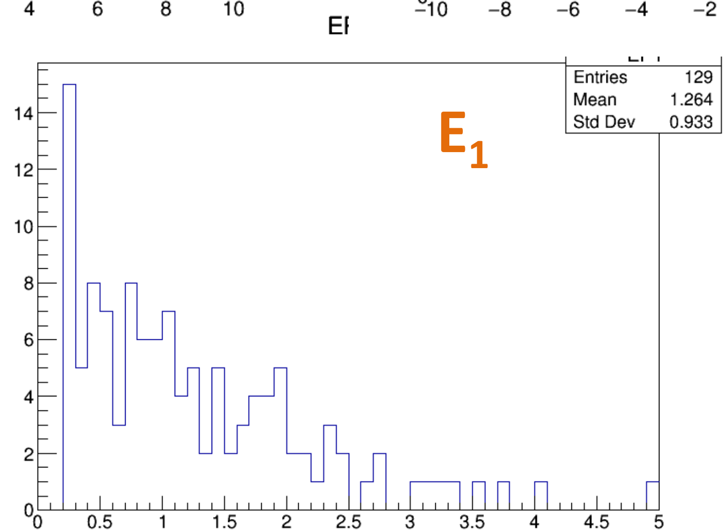
The hadron identification using some simple cuts

1000 events with a single proton are generated using Pgun with momenta in the range of (1-50 GeV).

Difference in position of proton detector hits and extrapolated tracks

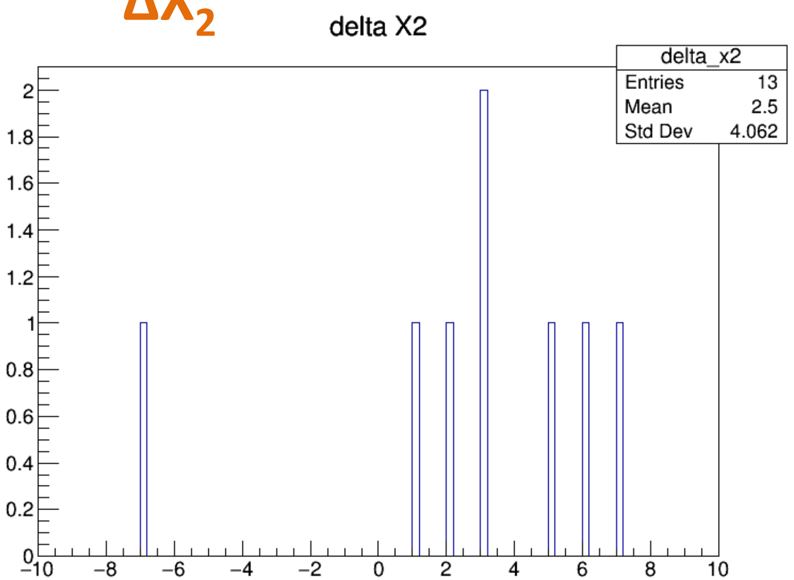




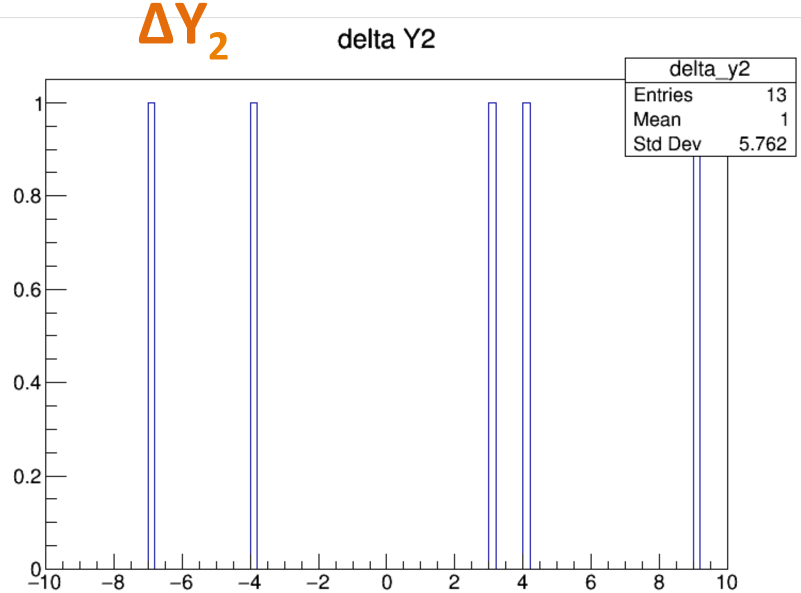


Difference in position of proton detector hits and extrapolated tracks

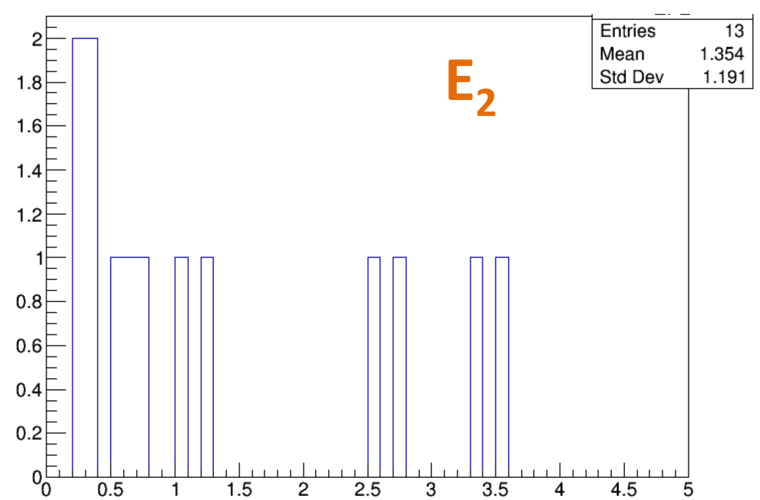
ΔX_2



ΔY_2



E_2

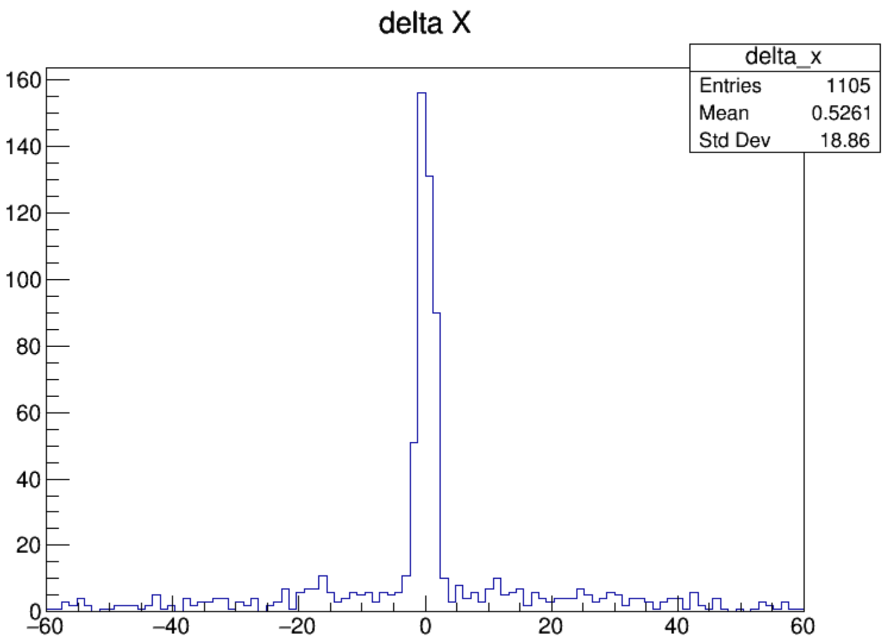


The electron-pion identification using some simple cuts

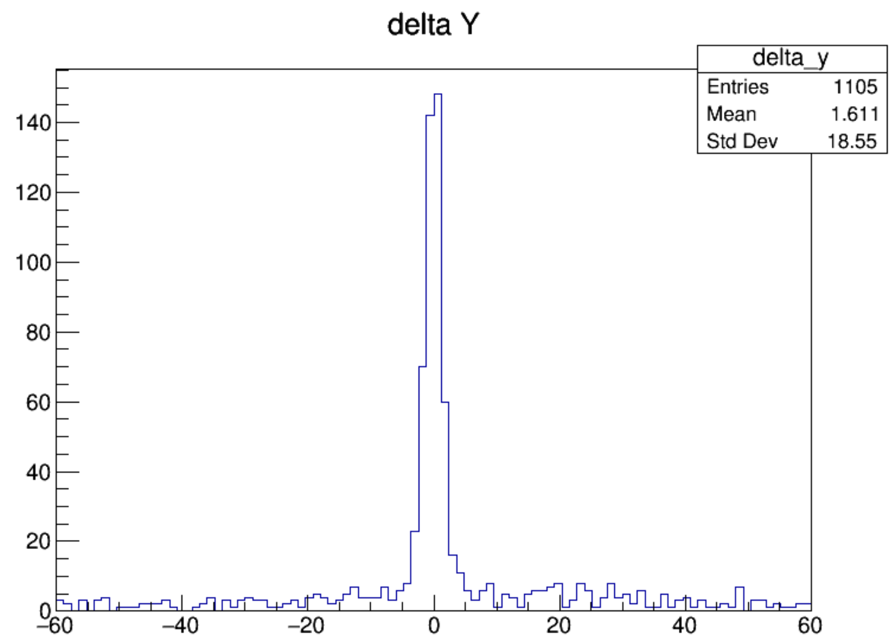
1000 events with a pion and electron in their final state are generated with momenta in the range of (1-50 GeV).

Difference in position of cluster and extrapolated tracks

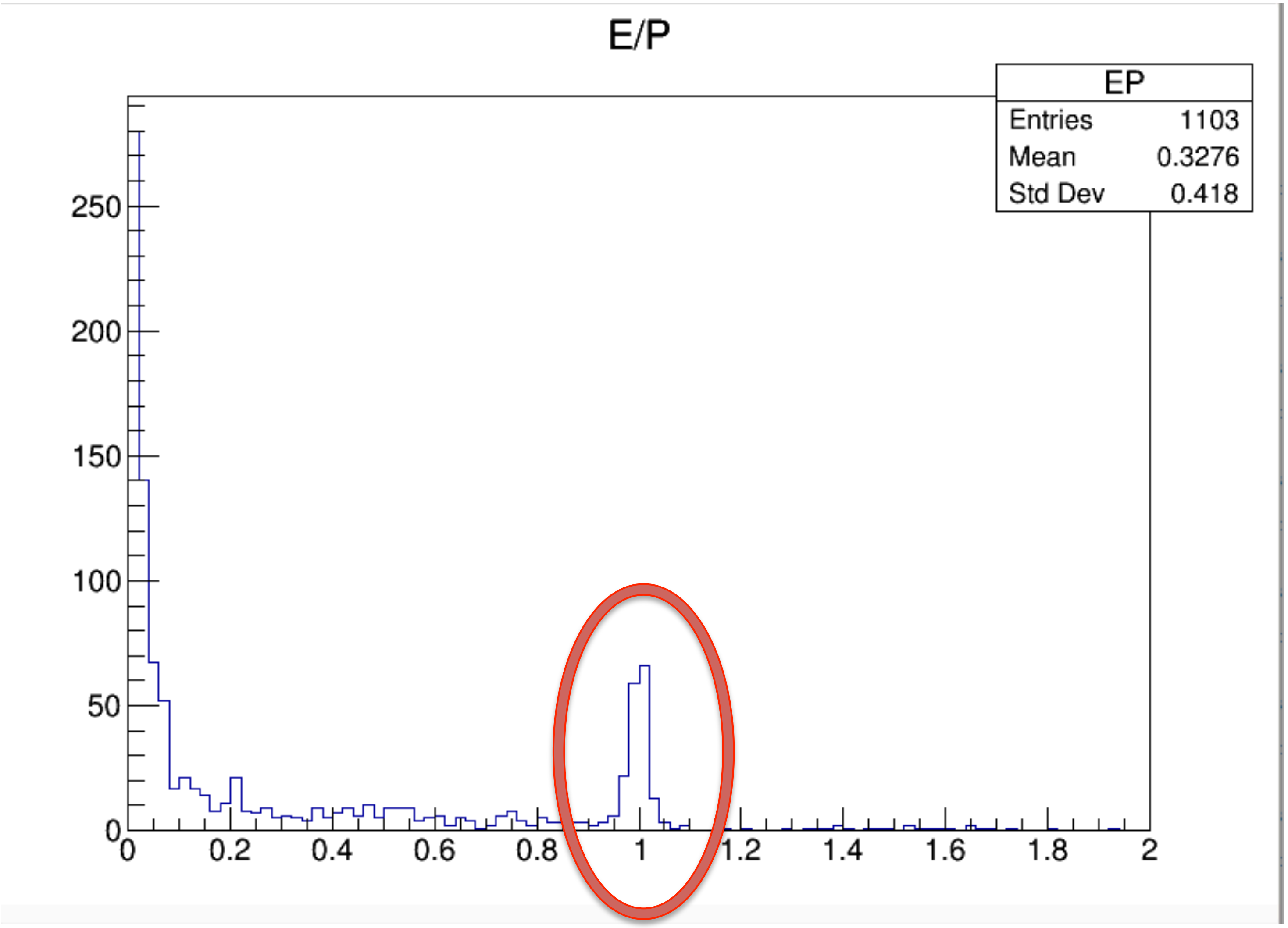
ΔX position



ΔY position



Energy over Momentum



Structure of the Code

The structure of our code

- A Pid folder is created under Fairship and the Pid Class is written under C++

- The Particle identification code is written under "python folder" using python program which includes different parts such as executing part and analysis part that it will be executed in ShipReco

- Then it brings us to have a Pid container in "ship.10.0.Pythia8-TGeant4_rec.root" file

```
#
 def execute(self):
  # make particles persistent
  self.PID()
  self.pID.Fill()

#
 def PID(self):
  self.fpidArray.Delete()
  fittedTracks = self.sTree.FitTracks
  ppid     = self.fpidArray
```

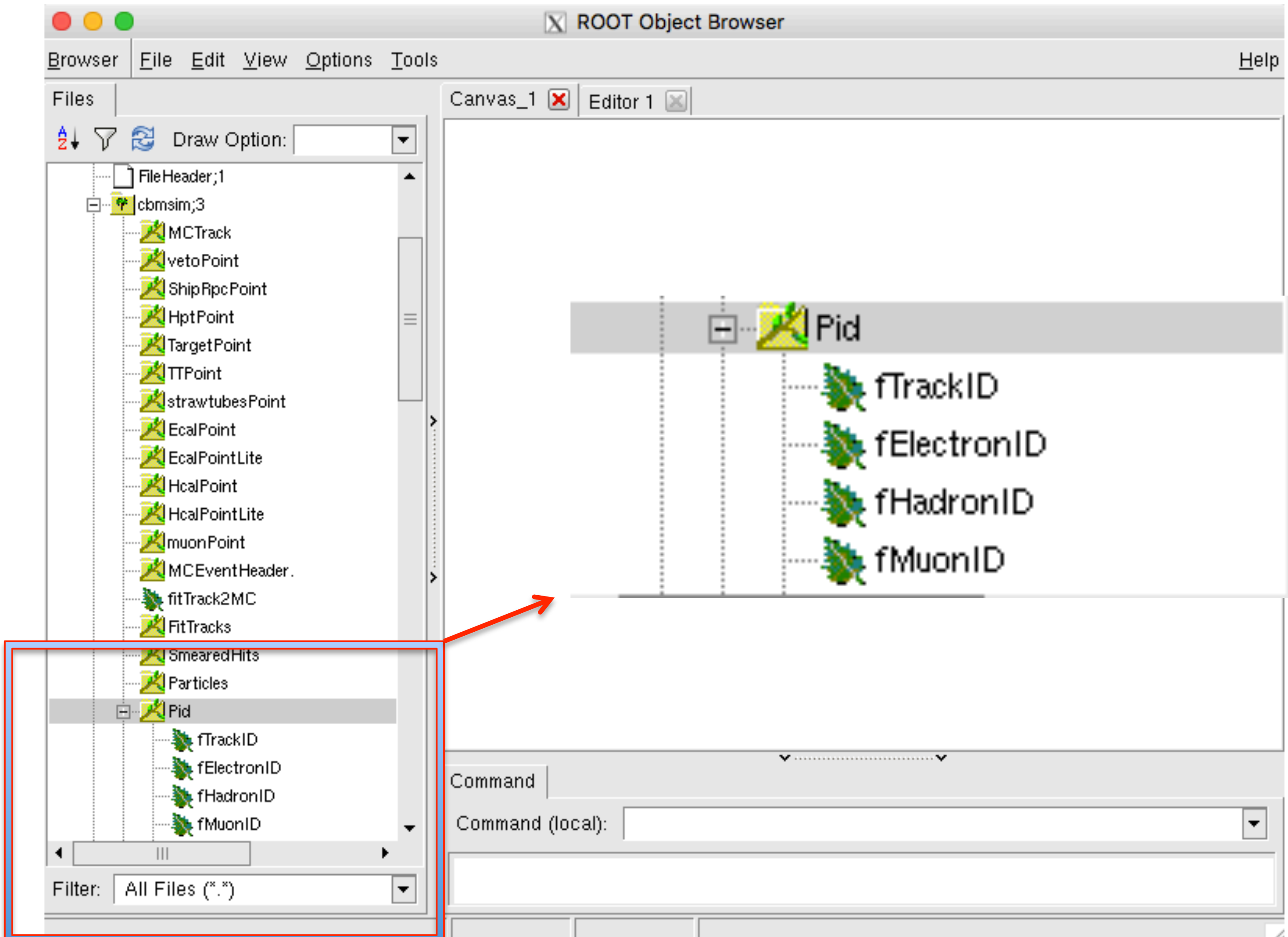
Commends used in ShipReco:

```
#
import shipPid

#
SHiP.Pid.execute()
```

Many thanks to Thomas for his support and his infinite help.

Pid container



Is it an Muon?

- As a first step, the code checks if the track is a Muon using the information given by Muon detector.
- This has been done based on:
  - Difference in position of extrapolated tracks and the position of hits (inside each pad).
  - Depth in 4 layers of the Muon detector due to the momentum of tracks.
  - Number of related hits.
- Is it a muon?
  - Yes => MuonID = 1
  - No => MuonID = 0 (and check the Electron)
  - If the information is not enough => MuonID = -1
  - If it is out of the Muon detector acceptance => MuonID = -2

Electron and Hadron

- Check if it is an Electron using the Ecal information:
- If it is electron => ElectronID = 1
- If it is not muon and not electron=> HadronID = 1

Using the PID information

Using Pid in ShipAna

The data analysis experts who do the physics analysis regarding the HNL events, such as Nico, now easily can extract the PID informationin the ShipAna.

```
for apid in sTree.Pid:
 trackid=apid.TrackID()
 if apid.MuonID():
   track = sTree.FitTracks[trackid]
   ...
 if apid.ElectronID():
   track = sTree.FitTracks[trackid]
   ...
 if apid.HadronID():
   track = sTree.FitTracks[trackid]
   ...
```

Add versioning

- We are planning to add a versioning to this work. in this way there will be no confusion to which PID version people refers in her/his analysis. It will be printed when running ShipAna so that users will know which version are they using; as example “PIDv1.0”.
- Also an “history file” will be created in order to store all changes that applied to the PID code during the time.

The application of muon, electron and hadron identification by applying simple cuts

Electron, Hadron and Muon identification

1) 1000 events with a single muon are generated using Pgun with momenta in the range of (1-50 GeV).

- 996 muon tracks have been reconstructed.
- Using our code, 960 tracks are selected correctly as Muon.
- 36 tracks misidentified as hadron which they mostly have momentum lesser then 3 GeV.

Electron, Hadron and Muon identification

2) 1000 events with a single proton are generated using Pgun with momenta in the range of (1-50 GeV).

- 997 protons have been reconstructed.
- 994 protons are selected correctly as Hadron.
- 3 tracks misidentified; 2 of them as electron and one as muon.

Electron, Hadron and Muon identification

3) 1000 events with a single electron are generated using Pgun with momenta in the range of (1-50 GeV).

- 995 electrons have been reconstructed.
- 978 tracks are selected correctly as Electron.
- 17 tracks misidentified as hadron.

Conclusion and Future Plans

- Particle Identification works very well and it is in the level to be committed in fairShip and be checked and used by the collaboration.
- In addition, Hcal information could be also added to this work and for that we will need the help of Hcal experts.
- The next step will be to improve our work by using the more advanced analysis methods such as BDT, Likelihoods or NN.
- We also plan to add the related histograms to ShipAna.