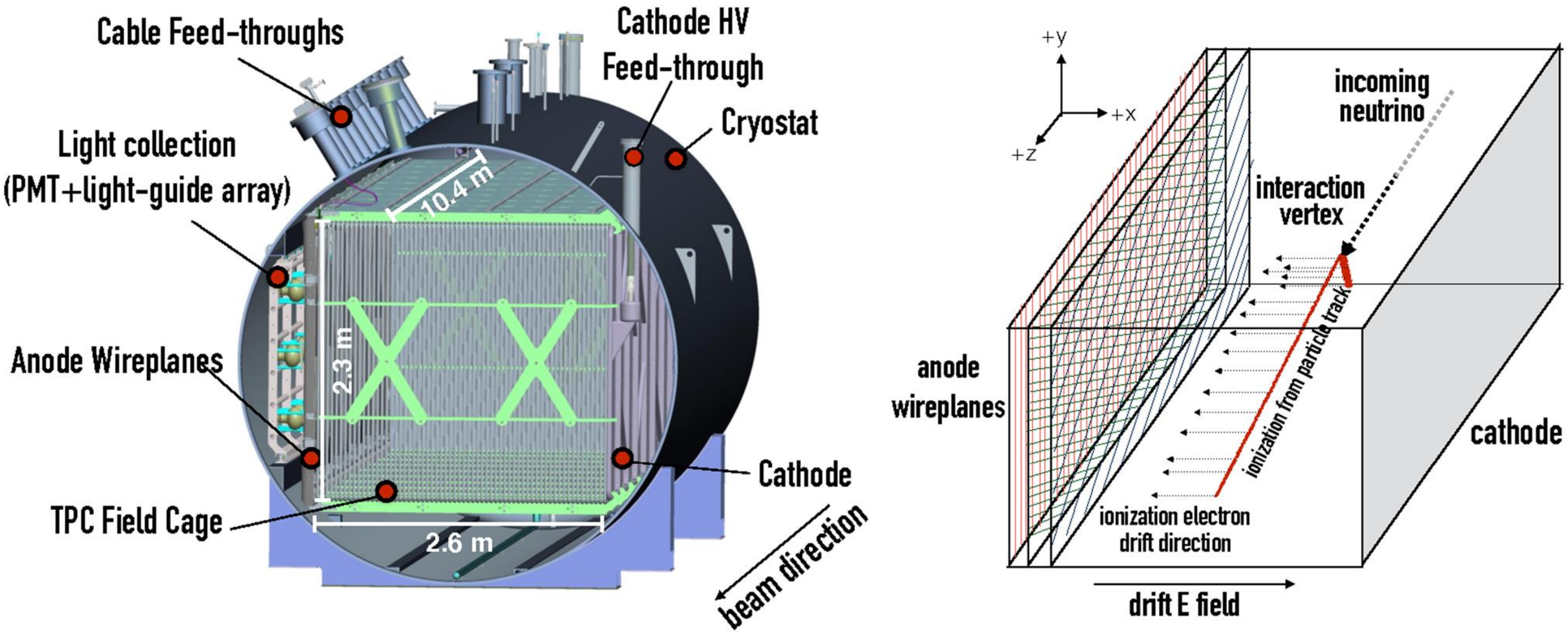
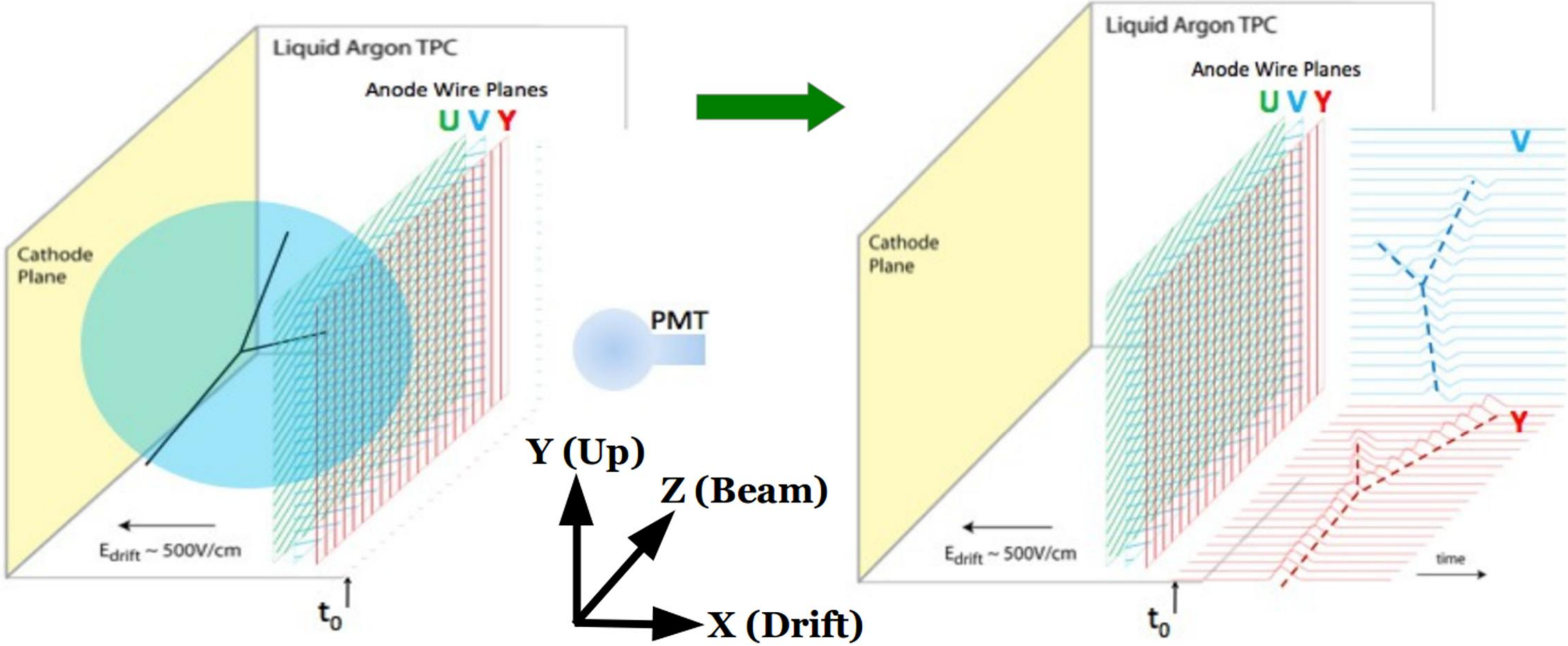
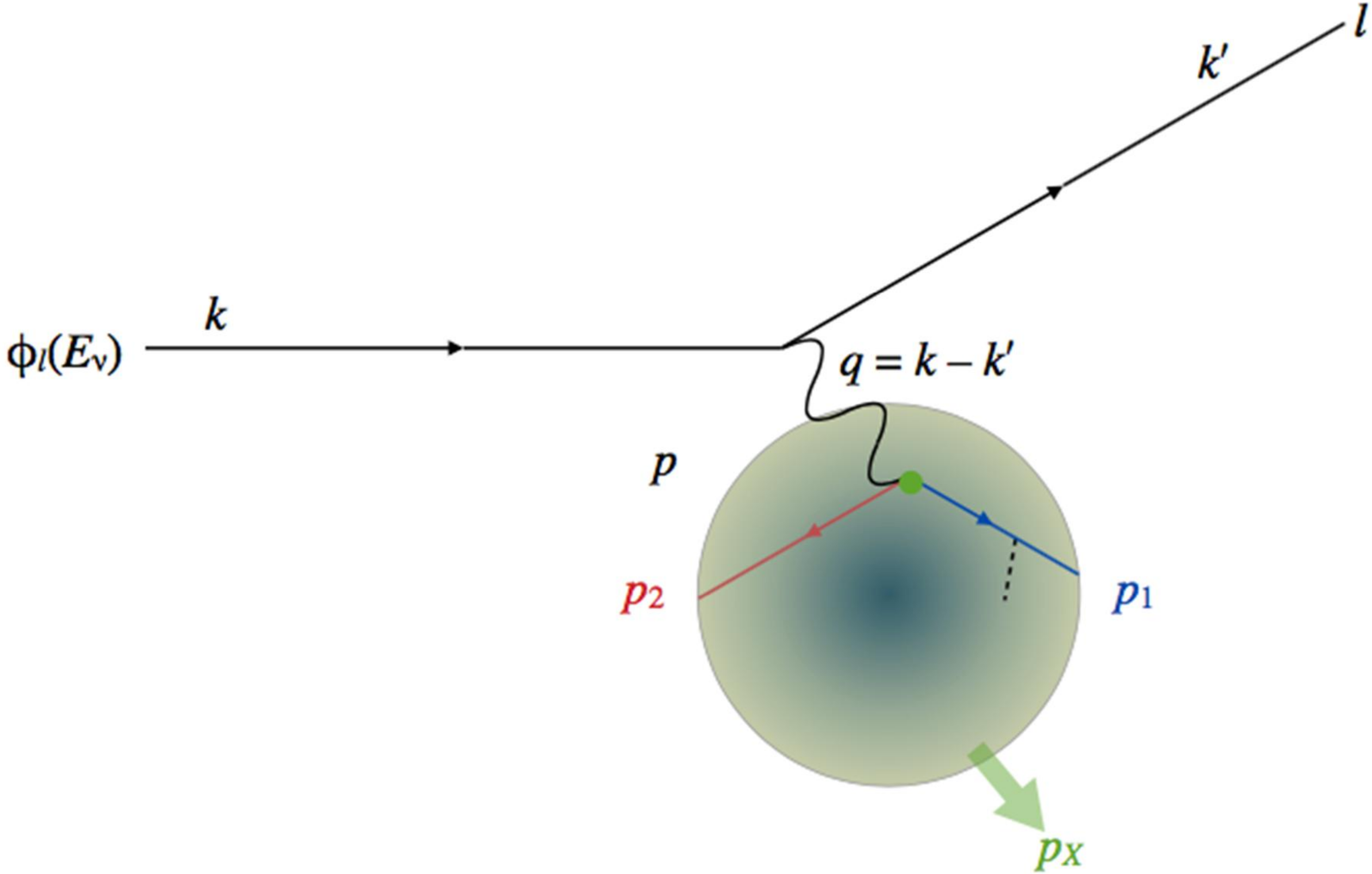
Reconstruction efficiency study


Cable Feed-throughs
Cathode HV
Feed-through
Cryostat
Light collection
(PMT+light-guide array)
10.4 m
2.3 m
Anode Wireplanes
Cathode
TPC Field Cage
2.6 m
beam direction
+y
+x
+z
incoming
neutrino
interaction
vertex
ionization from particle track
anode
wireplanes
cathode
ionization electron
drift direction
drift E field


Liquid Argon TPC
Anode Wire Planes
U V Y
Cathode Plane
PMT
E_drift ~ 500V/cm
t0
Y (Up)
Z (Beam)
X (Drift)
Liquid Argon TPC
Anode Wire Planes
U V Y
V
Cathode Plane
Y
E_drift ~ 500V/cm
time
t0



l
k′
k
ϕl(Eν)
q = k − k′
p
p2
p1
pX

Sample

The sample consist of simulated 2-tracks events (1 muon+1 proton) reconstructed using Larsoft v06_45_01 (standard reconstruction).

The kinematic of the events generated consist of:
Proton:

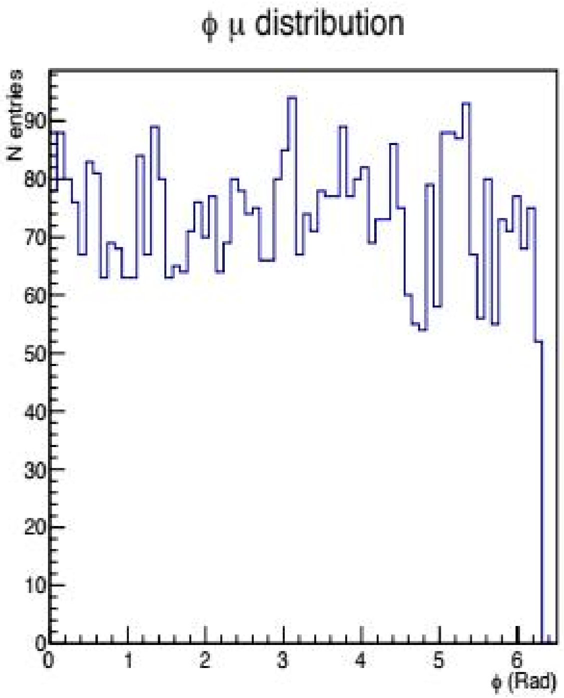
- Cos($\boldsymbol{\theta}$) distribution flat between -1 and 1
- $\boldsymbol{\varphi}$ distribution flat between 0-2$\boldsymbol{\pi}$
- Momentum distribution flat between 0.2 GeV and 0.65 GeV

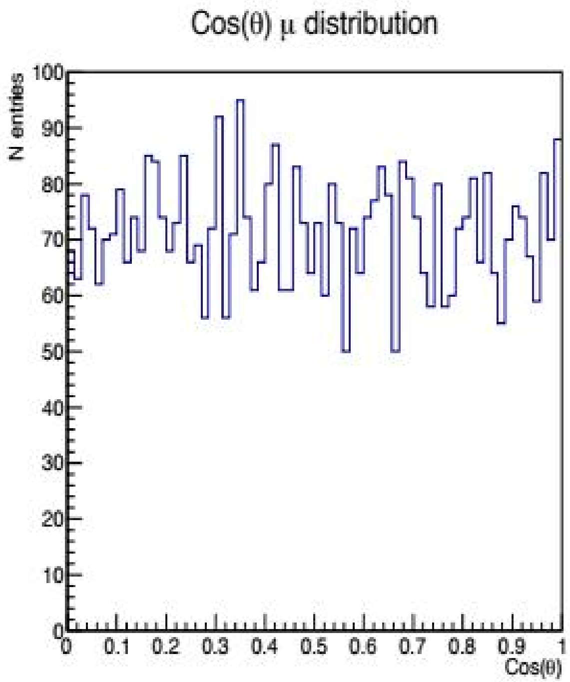
Muon:

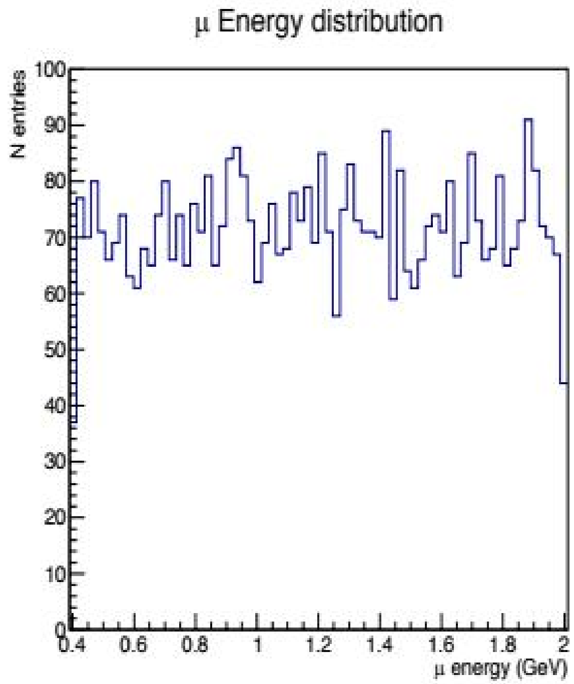
- Cos($\boldsymbol{\theta}$) distribution flat between 0 and 1
- $\boldsymbol{\varphi}$ distribution flat between 0-2$\boldsymbol{\pi}$
- Energy distribution flat between 0.4 GeV and 2 GeV

The primary vertex is generated so that:

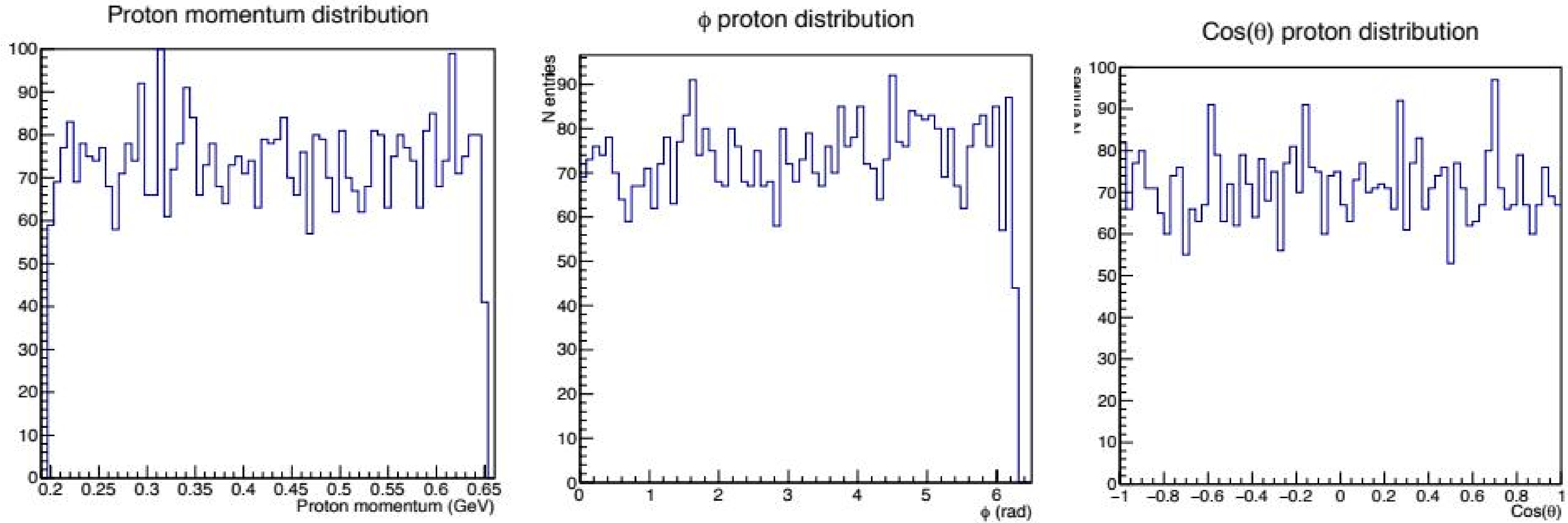
- x position ranges from 25 cm to 231.35 cm
- y position ranges from -91.5 cm to 91.5 cm
- z position ranges from 35 cm to 1011 cm



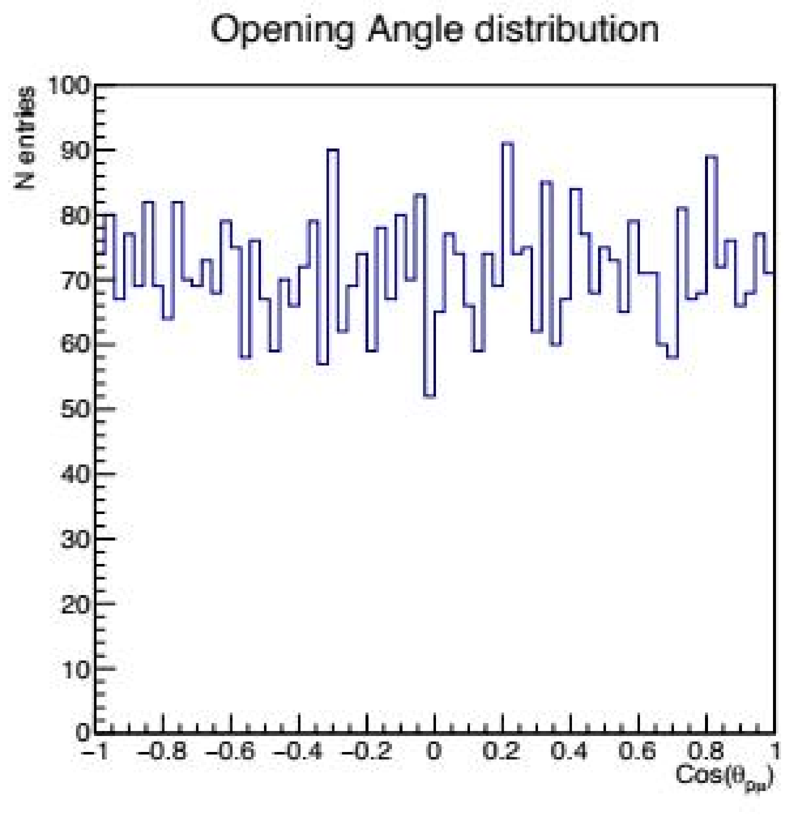




Muon's parameter distribution (true information)



Proton's parameter distribution (true information)



Opening Angle distribution
N entries
Cos(θ_pμ)

- With this study we aim to understand the efficiency of pattern recognition or reconstruction, with particular interest on the short-track proton type events, about which we expect worse results.

The two considered parameters for this job are: **Completeness** and **Purity**.

Completeness

- Gives a measure of how much of the true particle is on the matched track.

- It's given by number of hits shared between the reconstructed particle and the MC Particle, over the number of hits of the MC Particle

$$\text{Completeness} = \frac{N_{MC \cap PF}}{N_{MC}}$$

Purity

- Gives a measure of how much of the PF particle is due to the matched MC Particle.
- It's given by the number of hits shared between the MC Particle and the reconstructed particle over the number of hits associated to the PF Particle.

$$\text{Purity} = \frac{N_{MC \cap PF}}{N_{PF}}$$

PFParticles to MCParticles Matching

MCParticle → Charge deposition on a wire at a certain time (MCHit) → reconstructed hit (Hit) → PFParticles

(truth information)

(matching by the wire and timing)

(pattern recognition, pandora in this case)

Muon

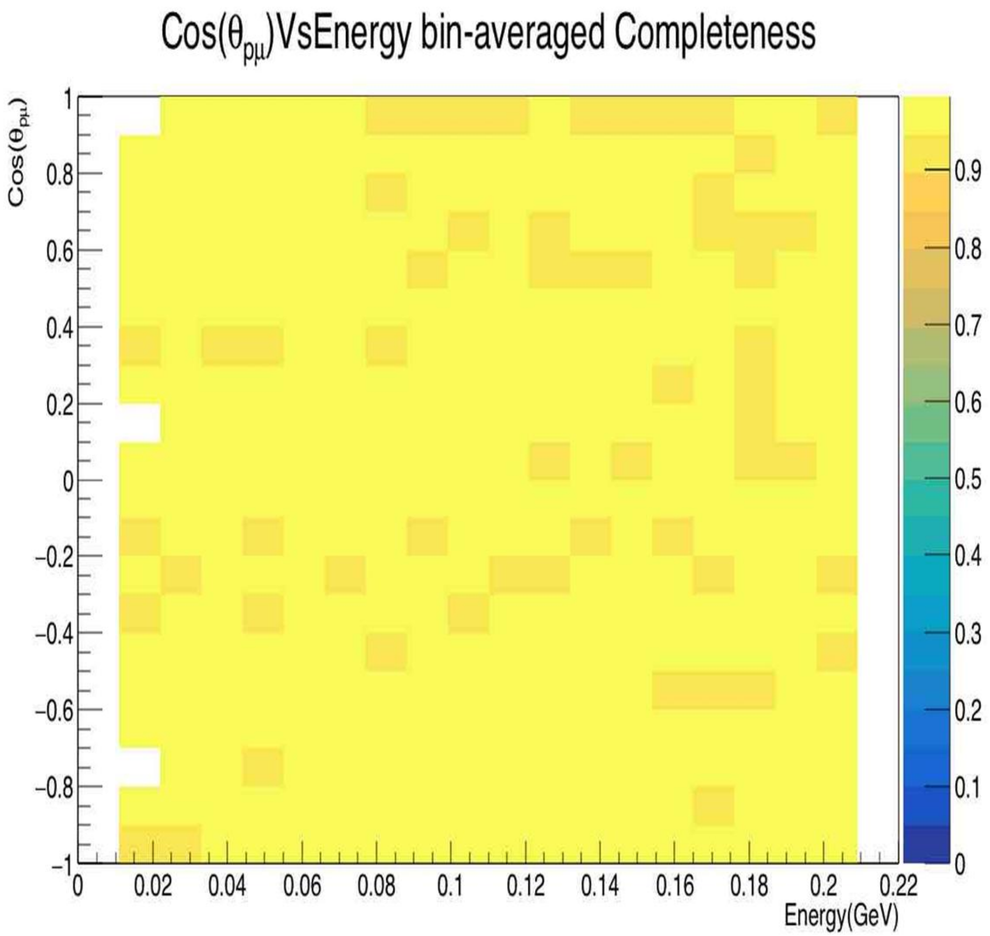


Figure 1

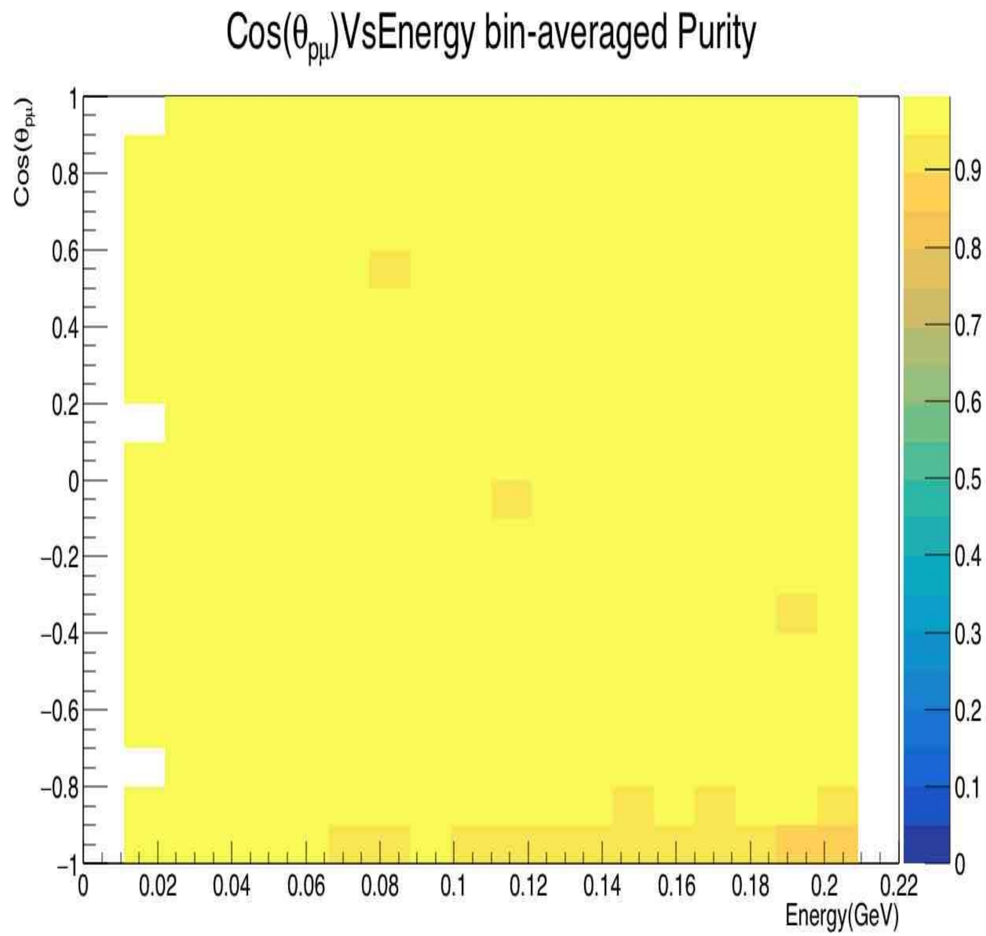


Figure 2

Proton

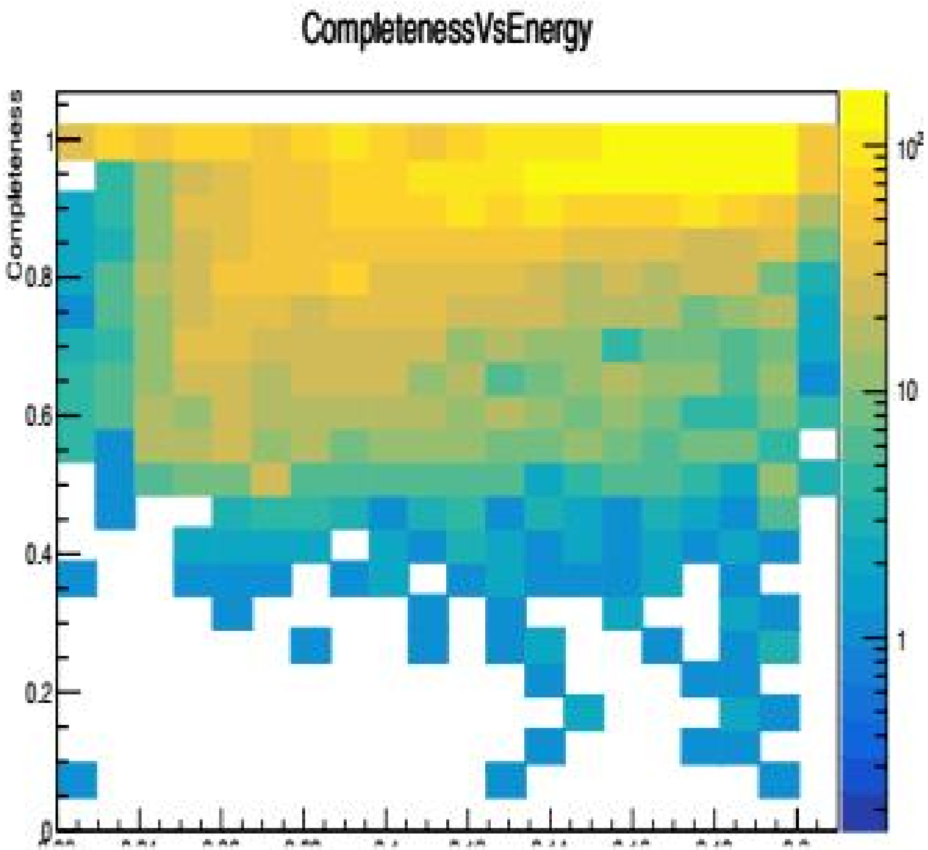


Figure 3

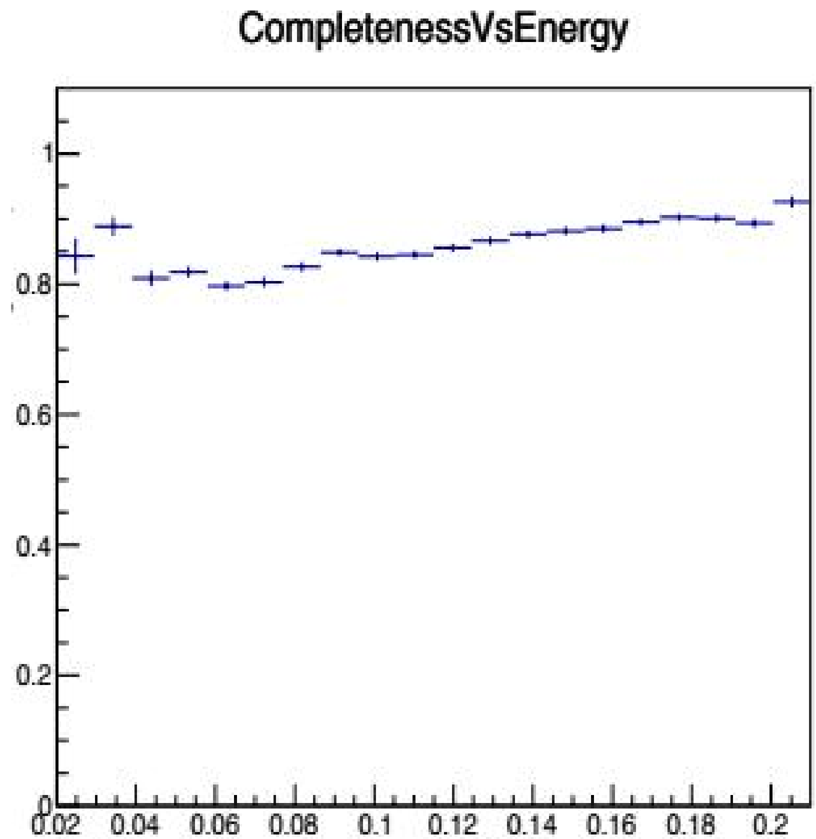


Figure 4

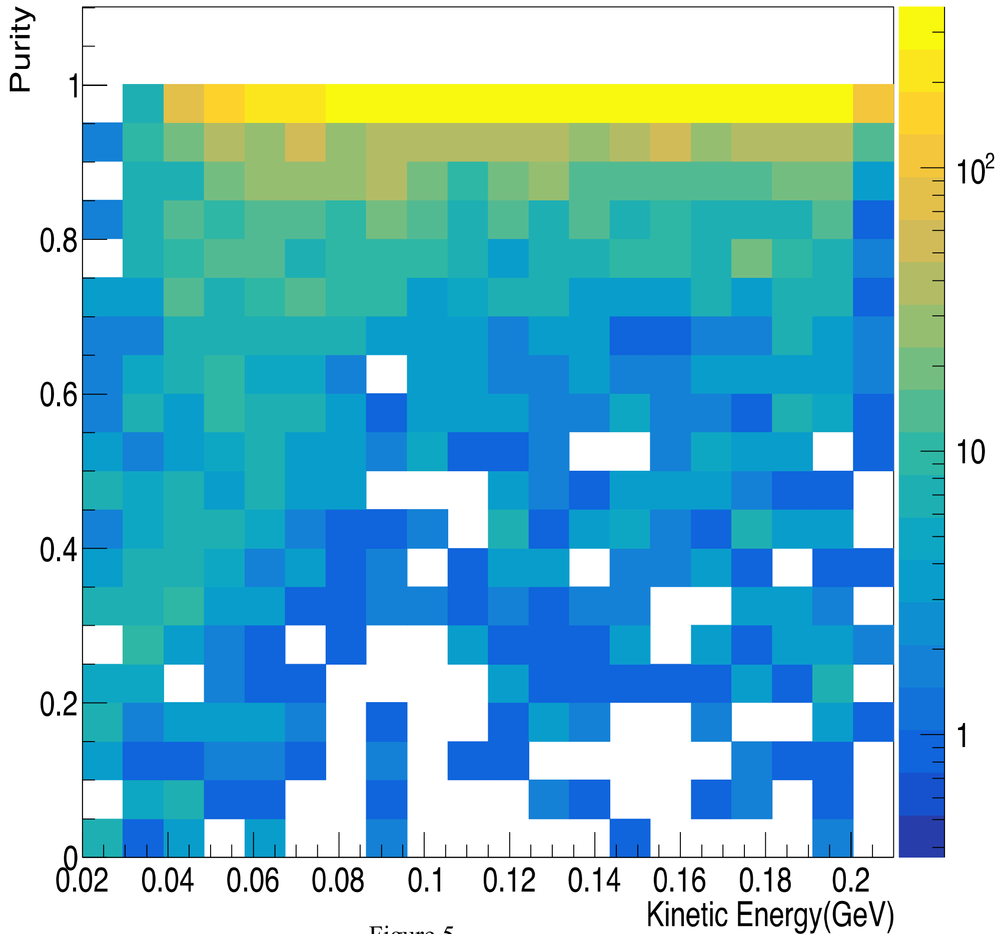


Figure 5

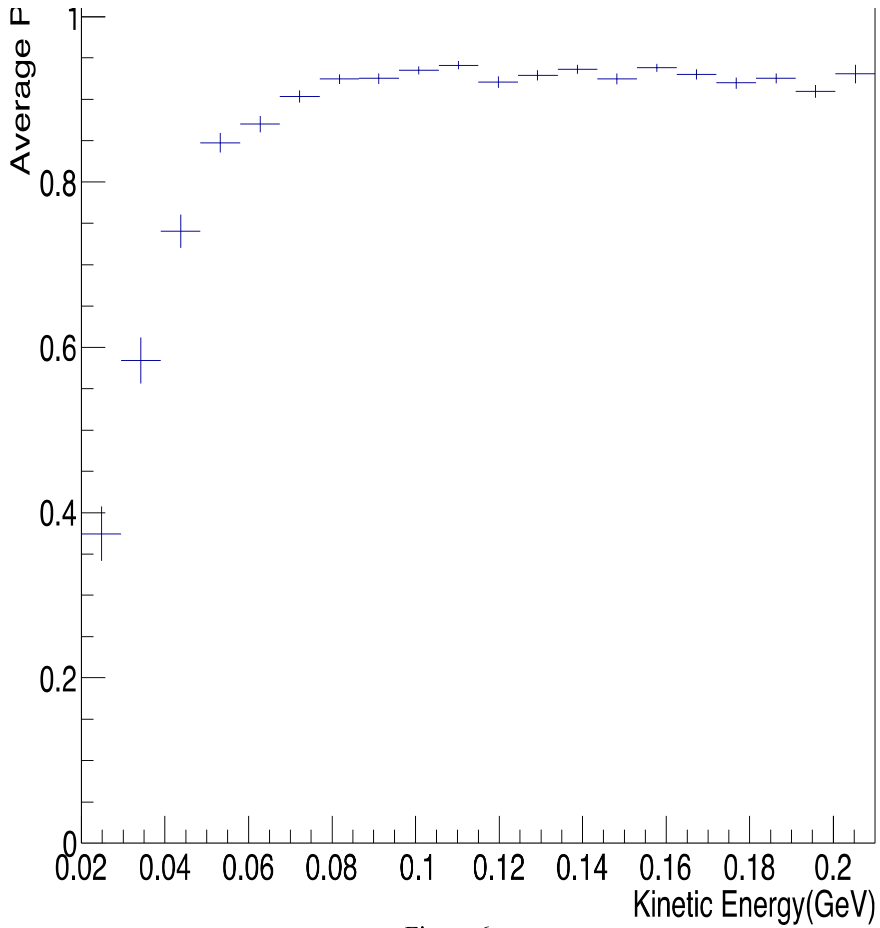


Figure 6

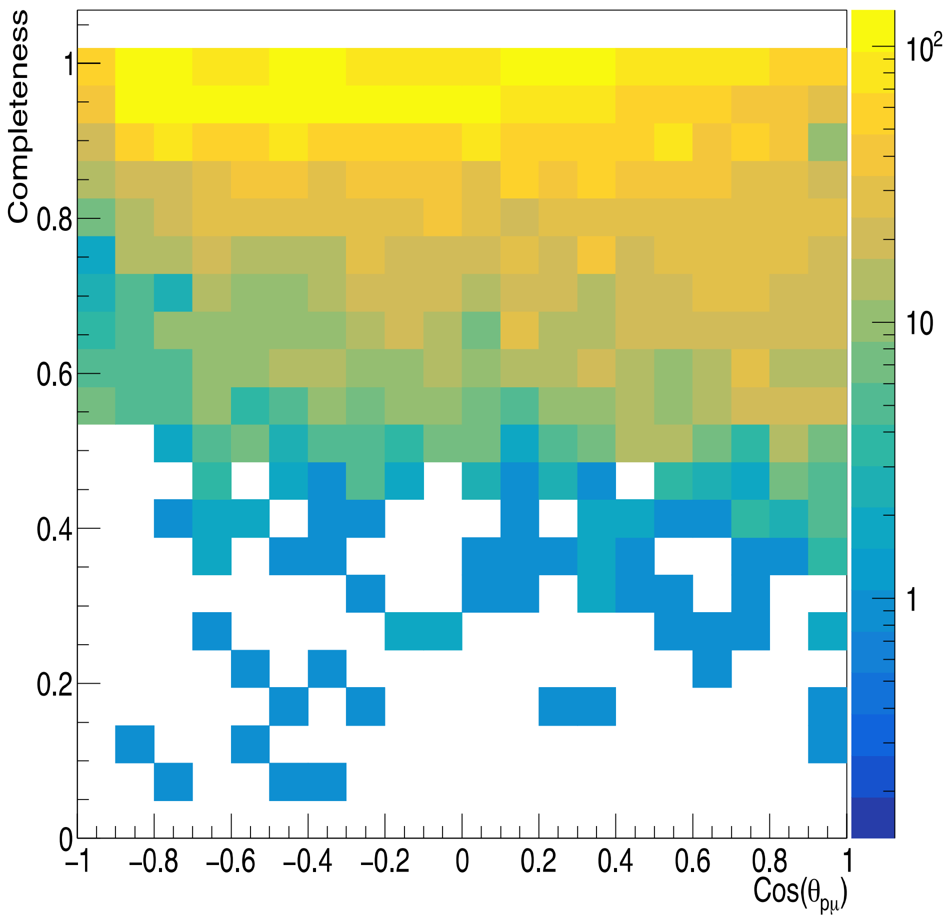


Figure 7

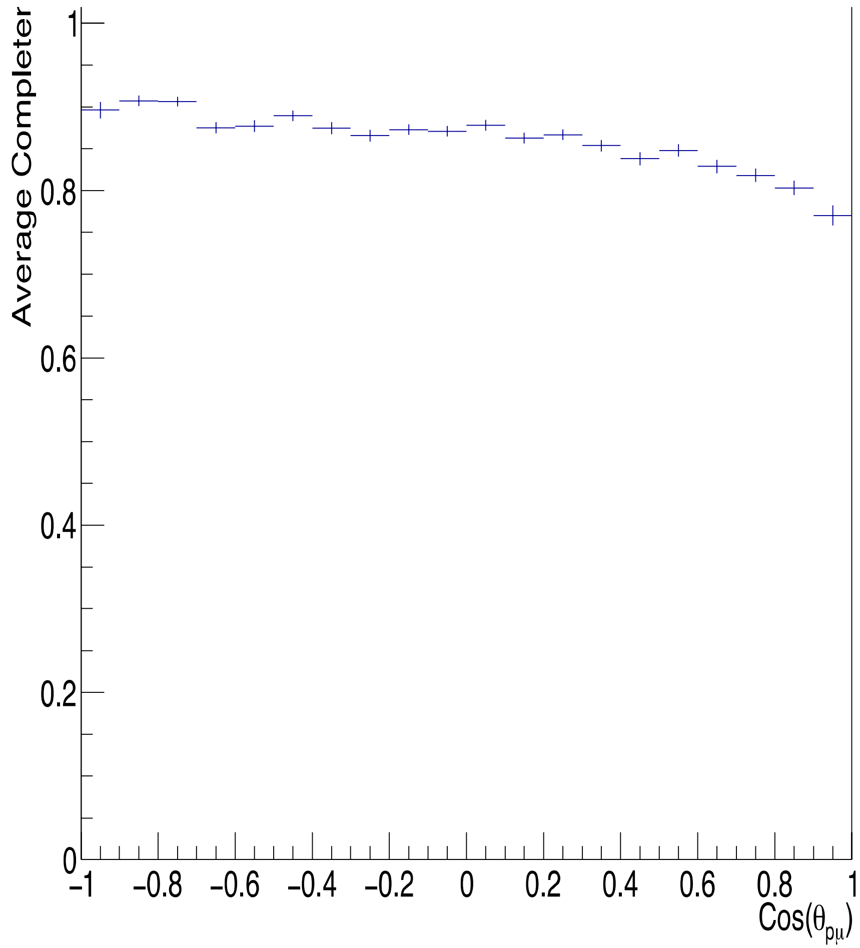


Figure 8

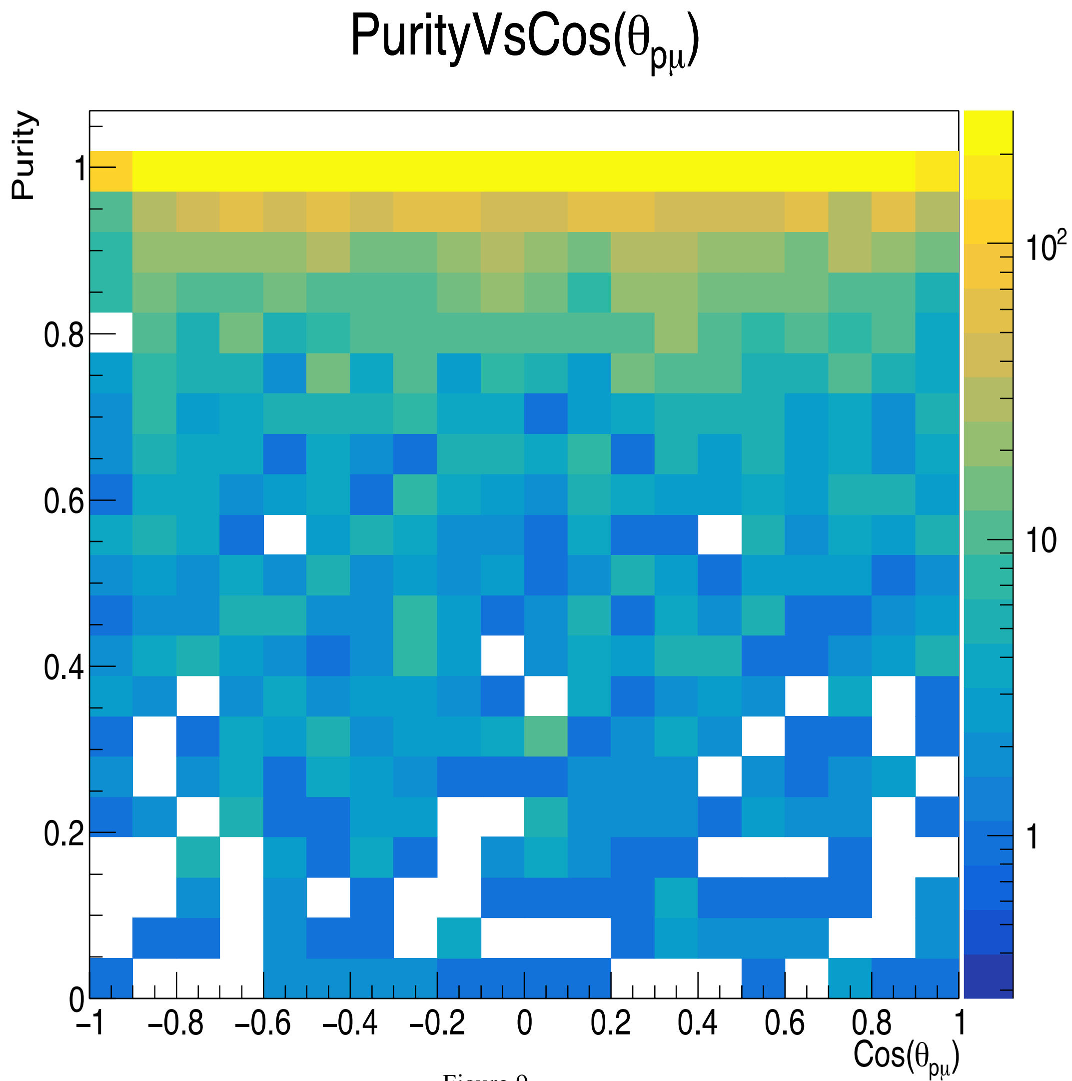


Figure 9

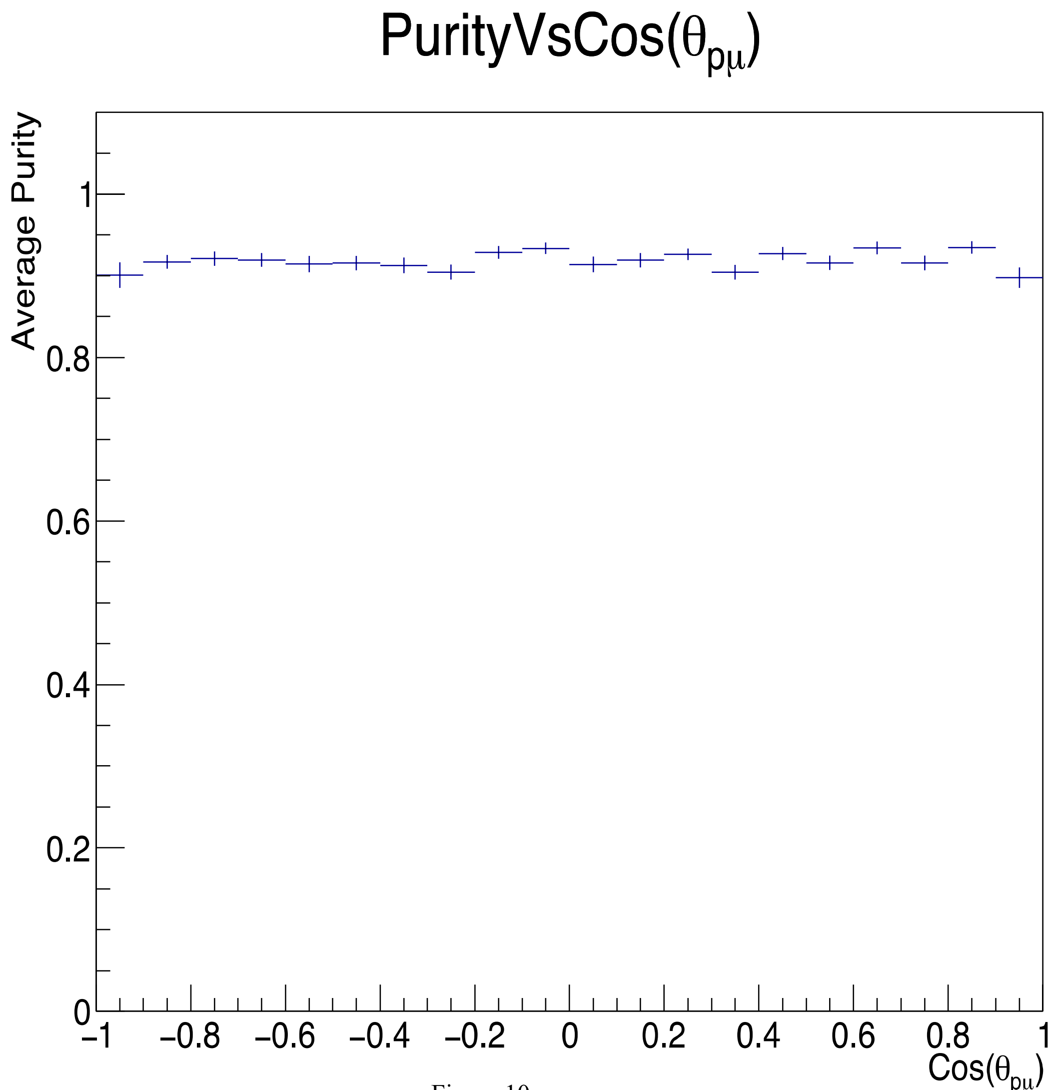


Figure 10

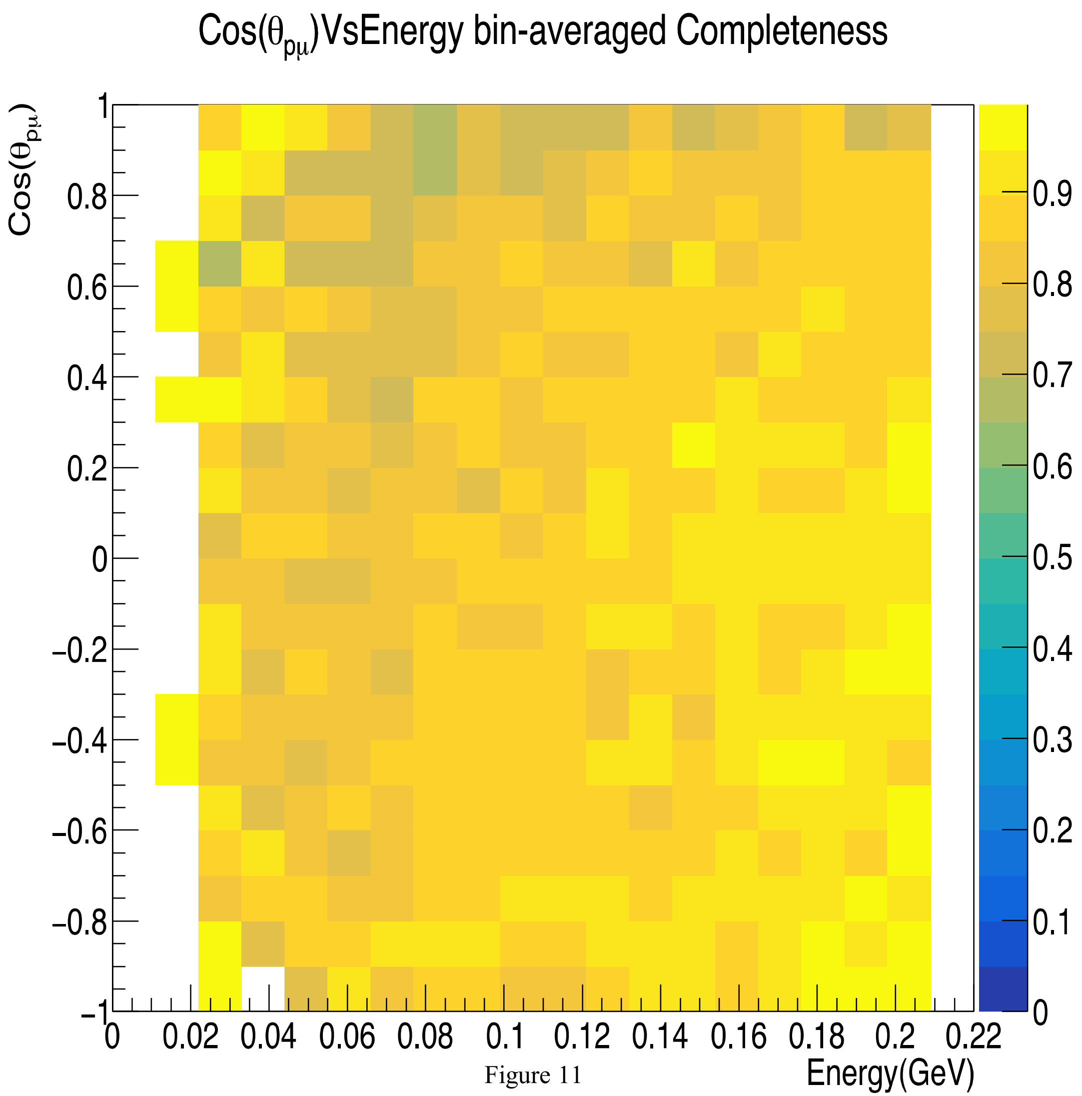


Figure 11

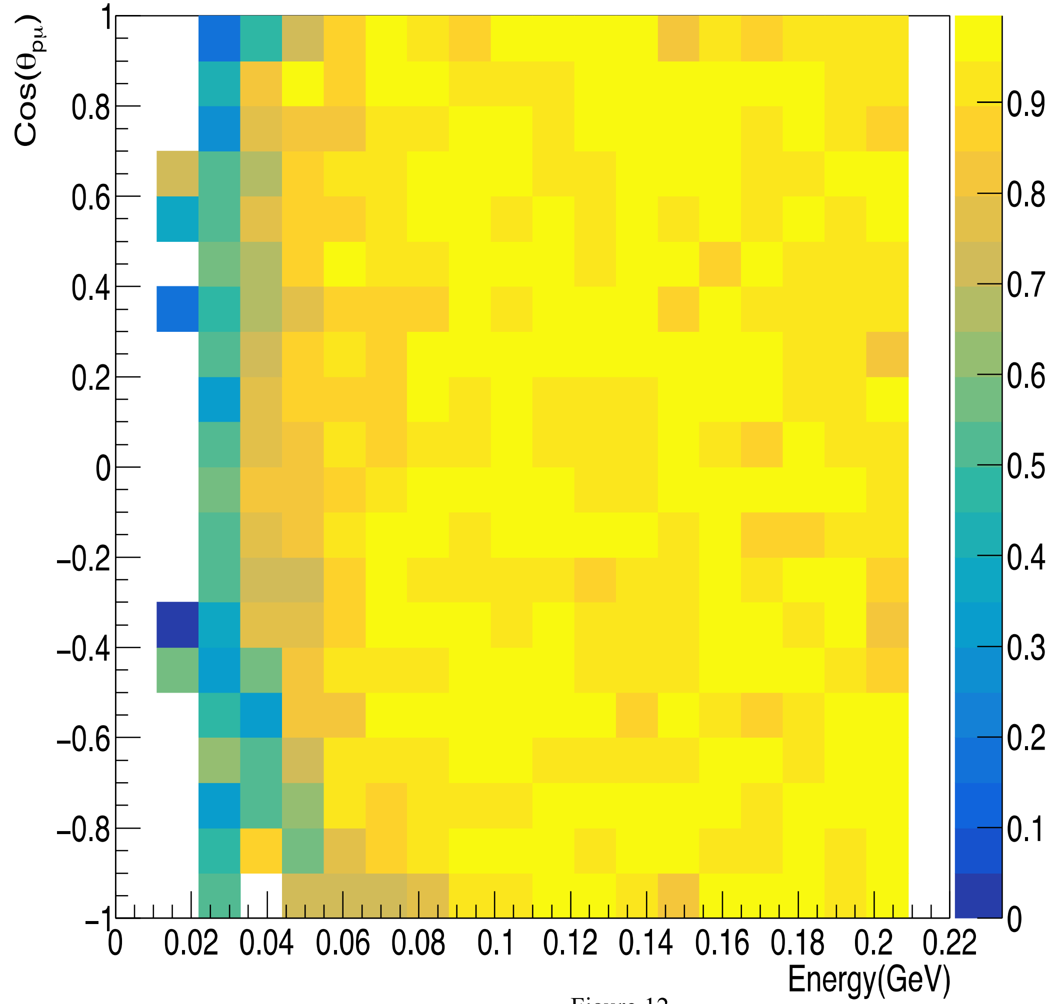


Figure 12

Tracking efficiency

$$e_t = \frac{N_{tracked}(E_p, \theta_{\mu p}, ..)}{N_{total}(E_p, \theta_{\mu p}, ..)}$$

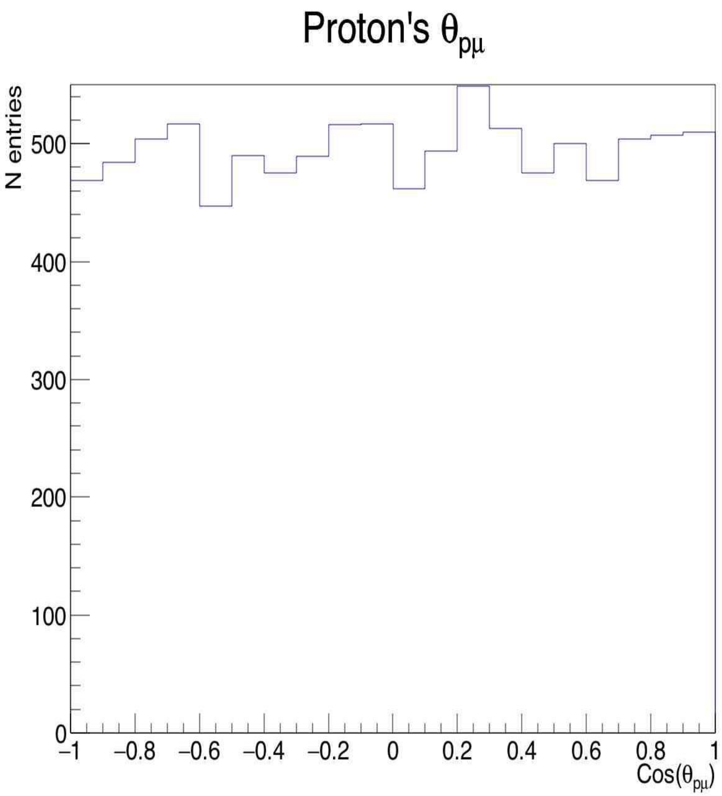


Figure 16

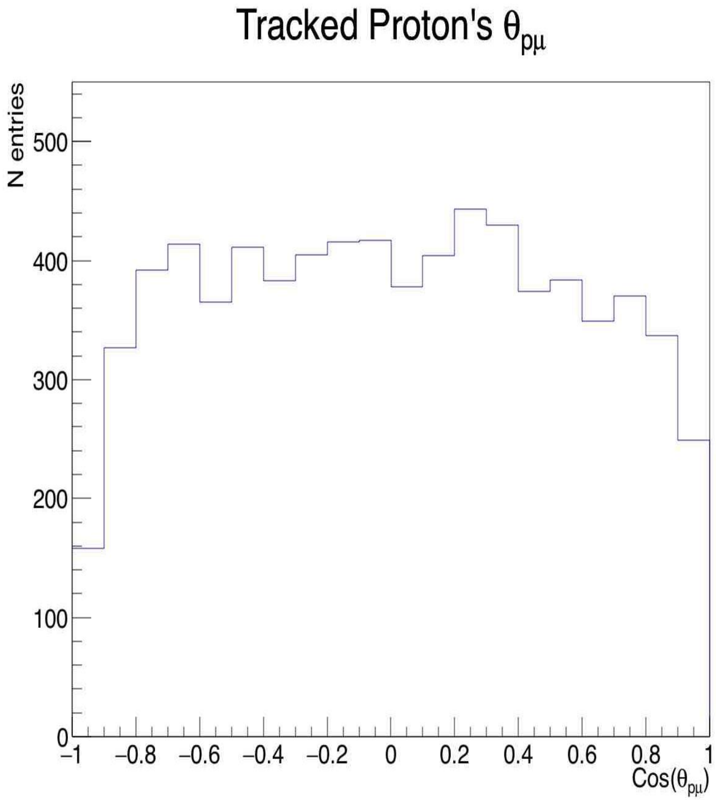


Figure 17

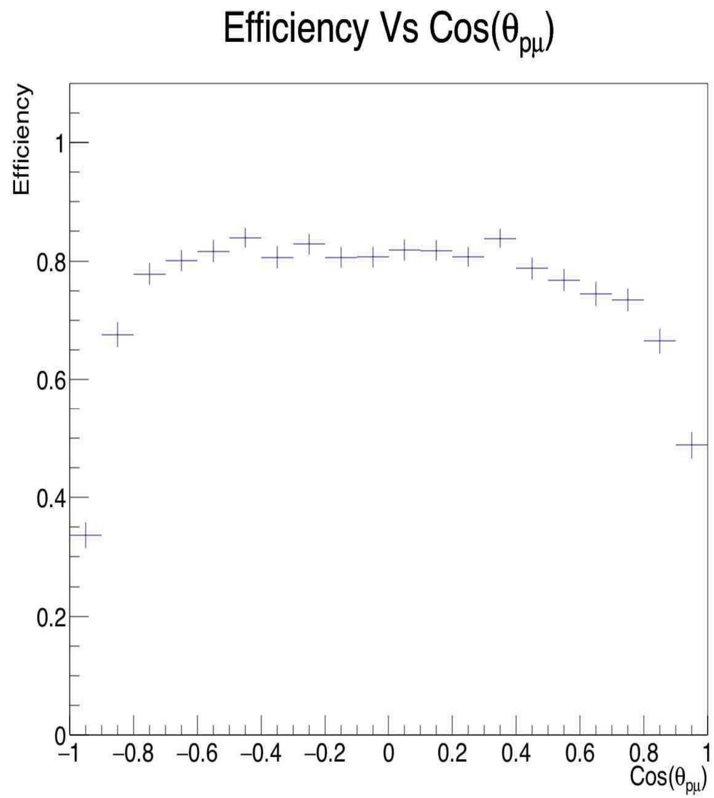


Figure 18

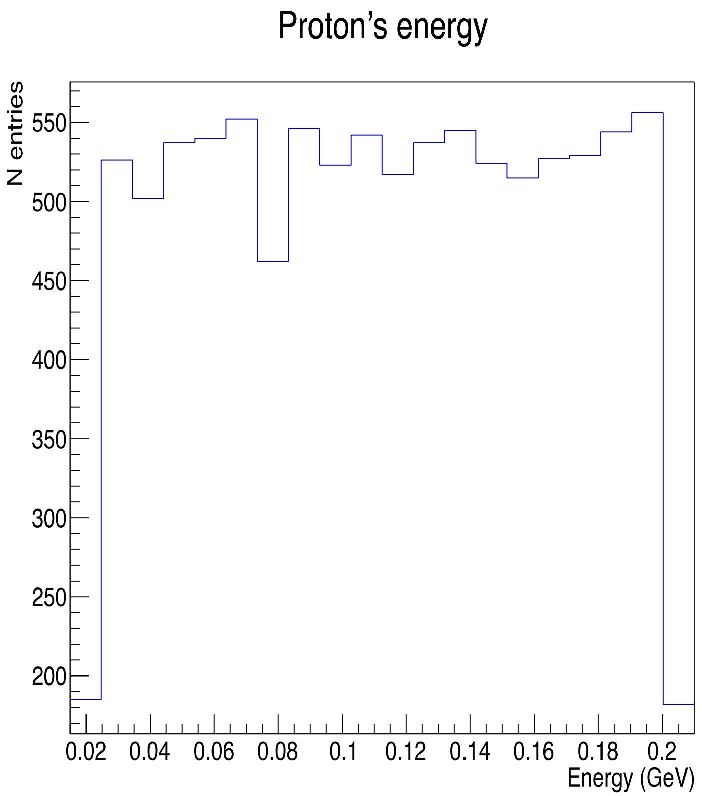


Figure 13

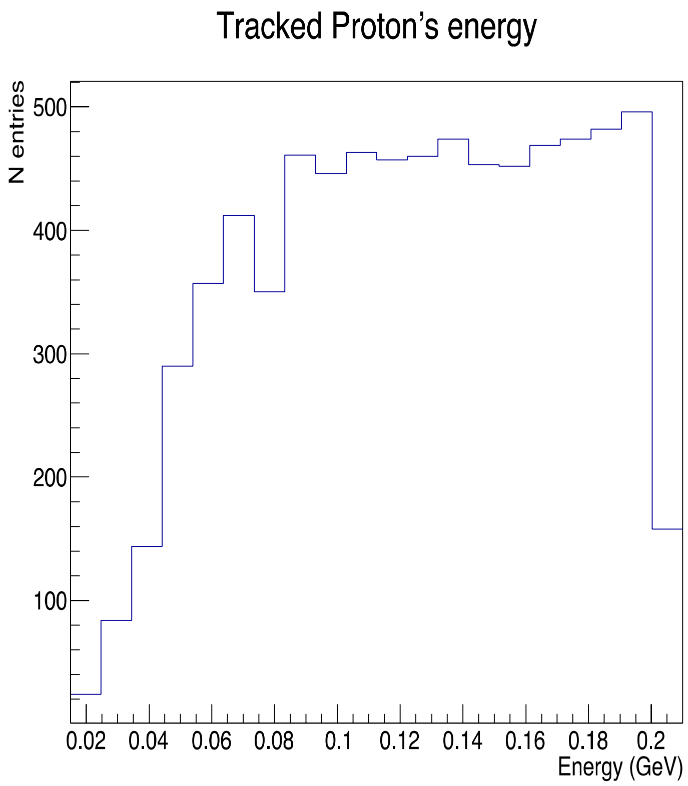


Figure 14

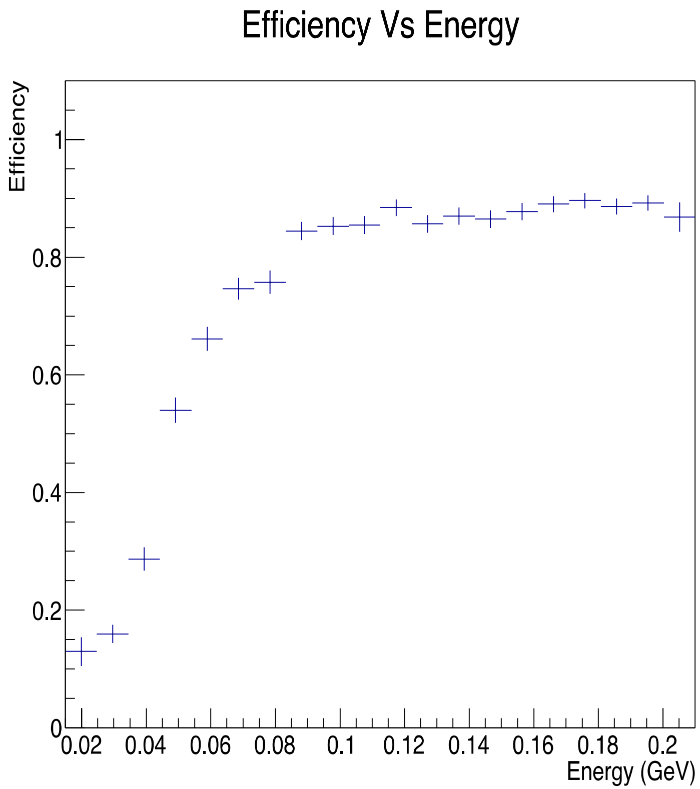


Figure 15

09/15

Conclusions

- Completeness seems to be pretty good at every energy and angle, both for muon and proton, but has for the proton, has a strange bump near kinetic energy=0.
- ~~Purity is almost always exactly 1, both for muon and proton and this look very suspicious.~~
- The efficiency is good, 73% on average, and get better with growing energy and opening angle near 90 degrees, where the two track separation should be better, as one would expect. (We got 97% on a sample generated with opening angle equals to 90 degrees and high proton energy).

Next step

09/15

- Look at the event display to try to understand the problem with purity.
- Try to understand the problem with the events that don't seem to show the MC proton track in the display
- Suggestions..

New event sample:

- Same spatial distribution and kinematic for the muon.
- Same spatial distribution for the proton, but fixed momentum of 50 MeV.
- Fixed $\theta_{\mu p}$ of 90°.
- 100 events.

A region of the opening angle-energy space where we expect to miss the proton 1 time out of to, mostly due to the fact of being low energetic

- **Too few wire crossings:** manually counting the number of wires crossed by each proton, summing over all the planes, I found that 7 of them crossed less than 10 wires cumulatively, that is approximately the threshold the reconstruction software has to being able to identify a particle.

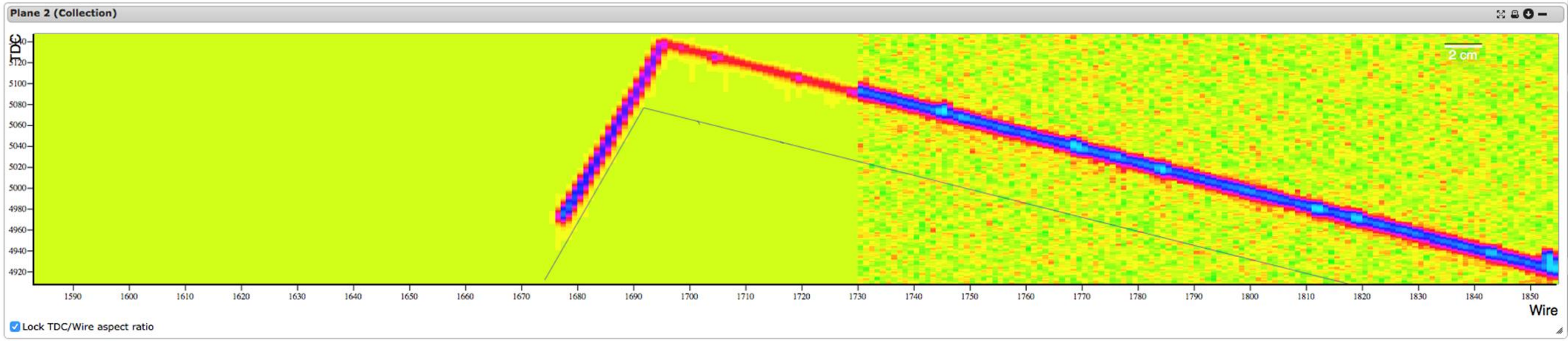
- **Dead/misconfigured regions:** 15 of them had a sufficient number of wires crossed, but it happened that in one or more plane the vertex fell in a dead or misconfigured region, i.e. a part of the detector for which a certain number of wires doesn’t work (dead), or is working in a wrong way (misconfigured). The reconstruction software actually has a way to recover information from misconfigured wires, but, as far as I could see, many time it doesn’t work very well, and lot of information is lost.

- **Other:** for 10 events I wasn't able to find an explanation for the reason of bad-tracking.

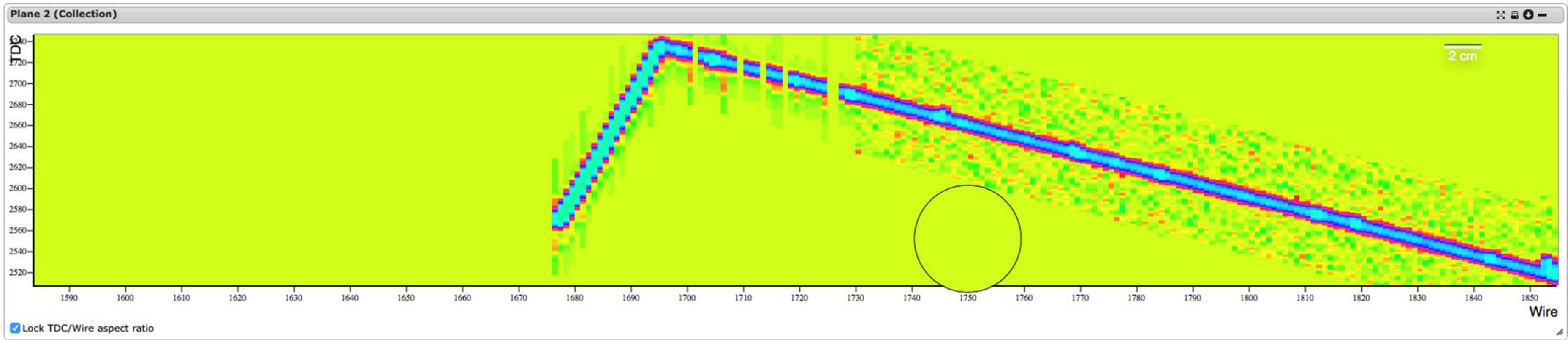
Of the 32 bad tracked proton I found:

Category:	Number of events:
Too few WC	7
Dead/mis region	15
Other	10

Raw wire data



Calibrated wire data



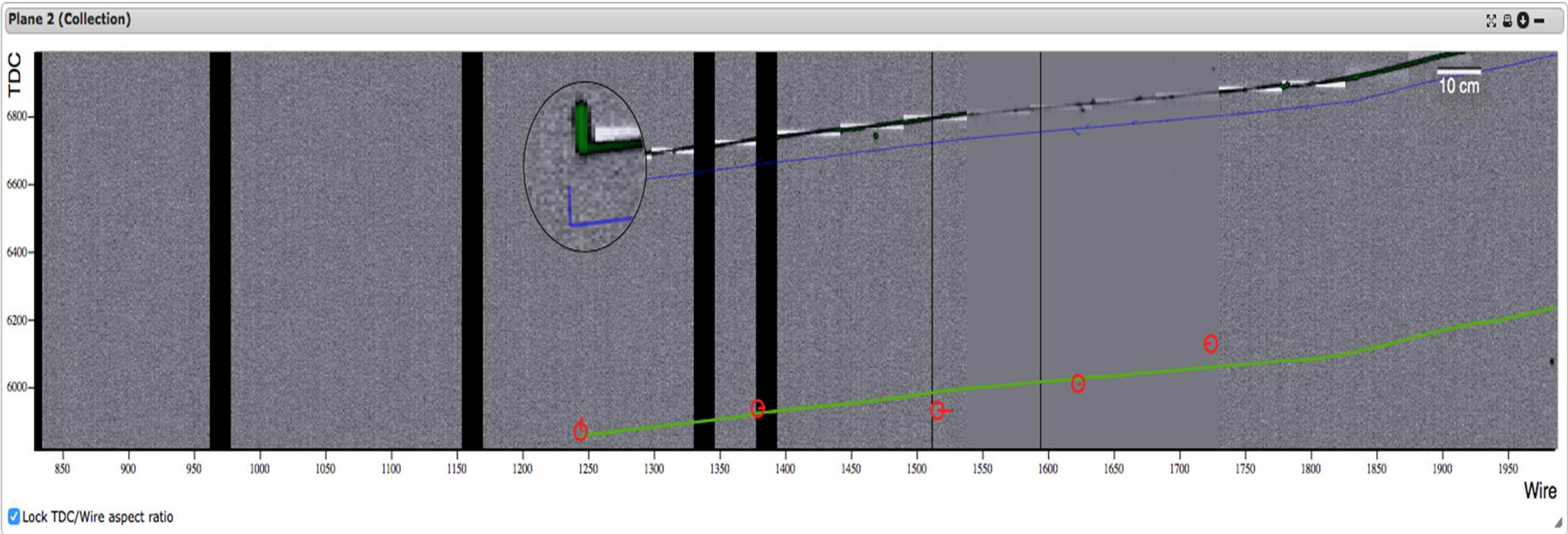


Figure 19 Entry 61 of the file; example of a proton that cross too few wires in the Y plane(collection) to be tracked. From the bottom to the top we can see: in green the reconstructed track, in blue the MCParticles, in different colors what is obtained from raw wire data. The black vertical bands represent dead regions. Wires crossed from the proton summing over all planes: 4/8.

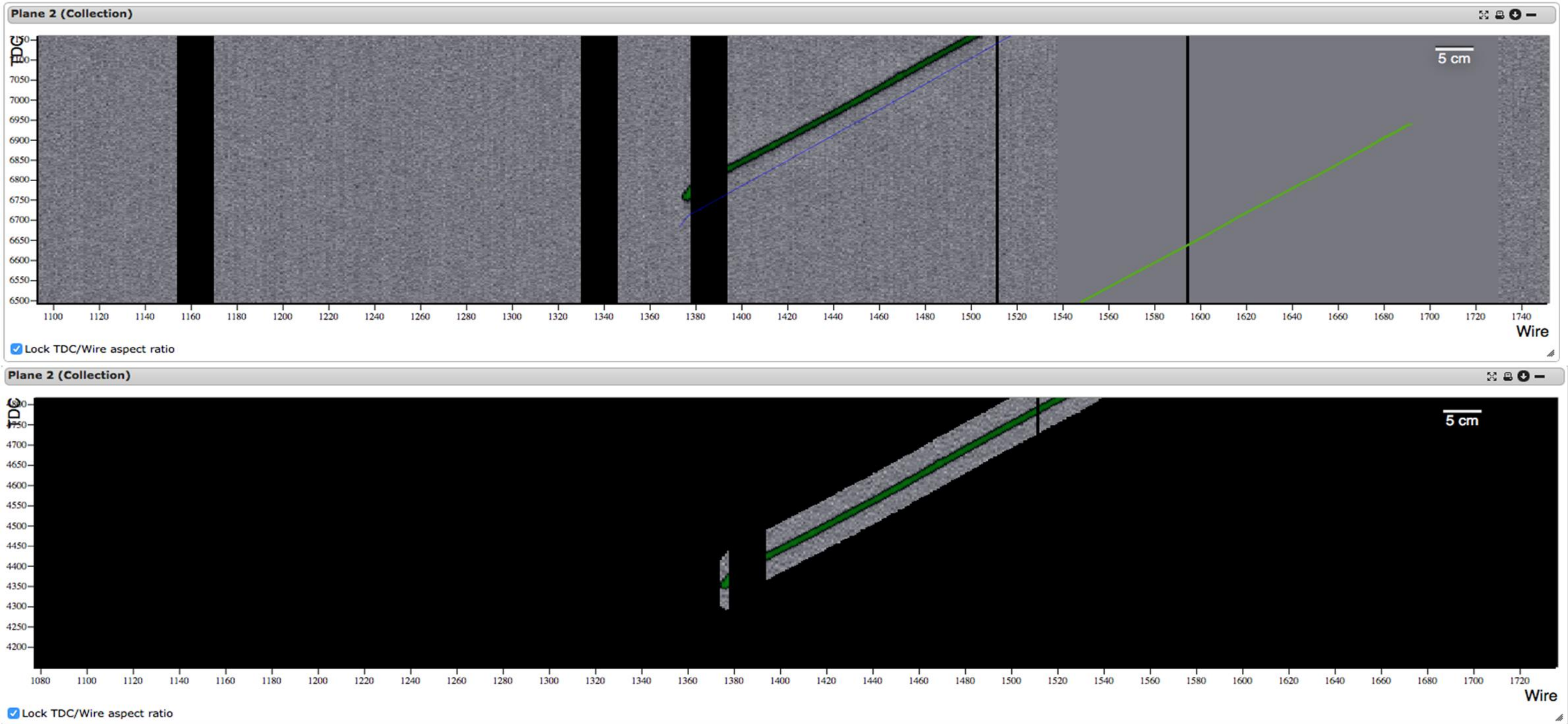


Figure 20 Entry 46 of the file; example of vertex fallen in a dead region in plane Y (collection). Top: raw wire data; bottom: calibrated wire data mode (i.e. wire data processed to recover information from misconfigured wires). In calibrated data the black doesn't represent dead wires. Wires crossed from the proton summing over all planes: 13/13. Not counting this one: 9/9.

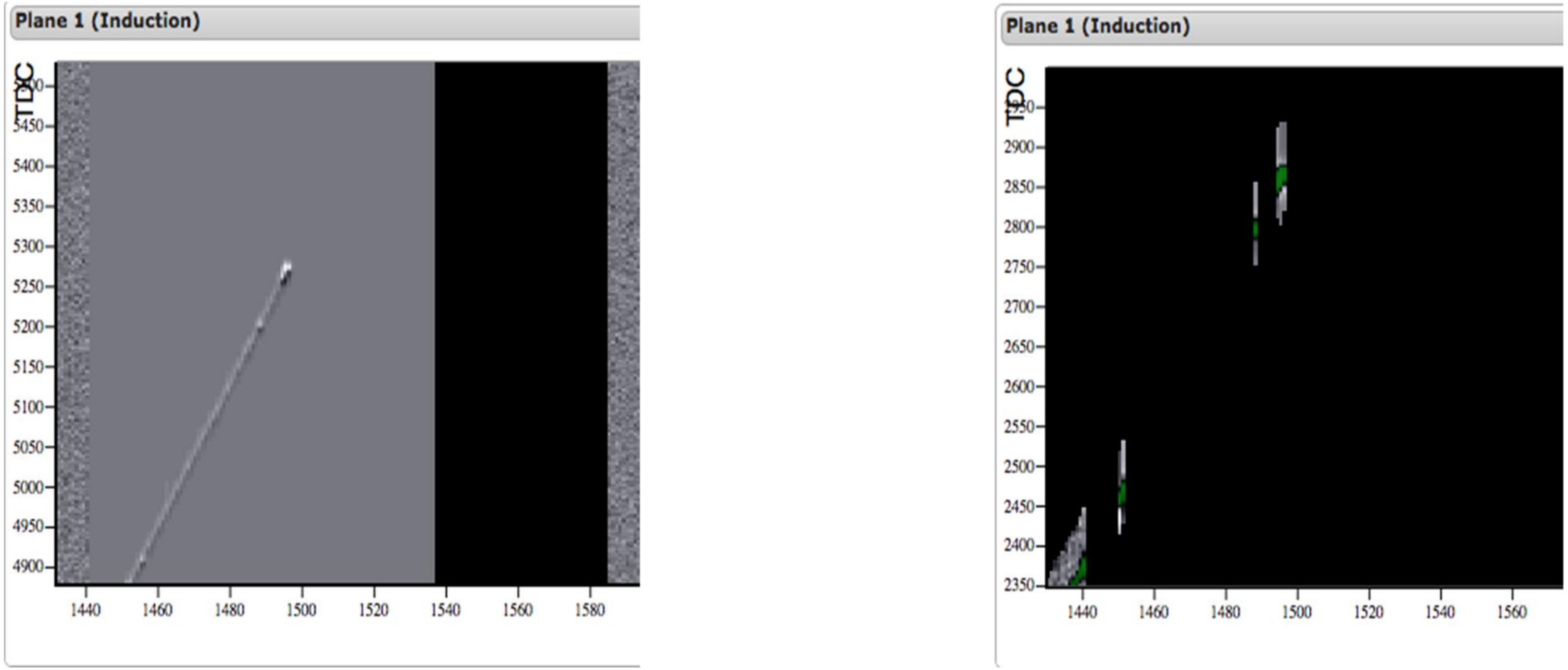


Figure 21 Entry 31 of the file; example of the calibration operation failure for a vertex fallen in a misconfigured region in plane V (induction). Left: raw wire data; right: same vertex in calibrated wire data mode. Wires crossed from the proton summing over all planes: 12/17. Not counting this one: 9/13.

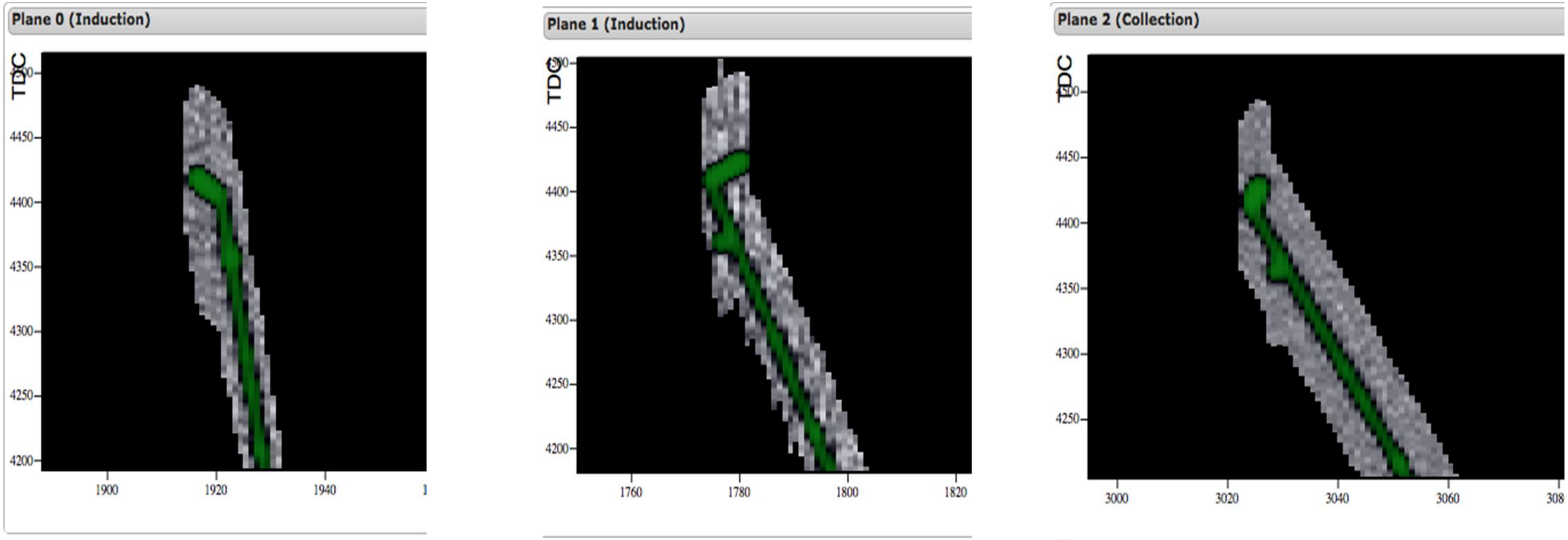


Figure 21 Entry 16 of the file; example of event not tracked for some unknown reason. Left: plane U calibrated wire data view; center: plane V calibrated wire data view; plane Y calibrated wire data view. Wire crossed: 14/17

Conclusions

- The reason why completeness seems to have a peak at very low energies isn't very clear, and needs some further investigation. The first guess was that, at low energy, the proton starts to be associated to the muon because of the shortness of his track, resulting in a fake increase in completeness accompanied by a bad purity. This behavior though, should be avoided requiring the "well-tracked protons" condition (first plots, that showed the same trend, didn't include this condition).
- What we think right now, not yet verified, is that the little bump in completeness, as well as the average purity below 0.5 in the first bin (proton with purity under 0.5 should be labeled as not tracked by the software), could be due to the secondary scattering of the proton. This would reproduce this behavior, the only problem being that low energetic scattering proton are less likely to be tracked, and so it's difficult to guess how much they affect the analysis.

- For events falling in dead region there isn’t much that can be done, but fixing the recalibration of raw data, could be a way to slightly improve the efficiency.
- Obviously, understand why the protons falling in the “other” category are not tracked, is an handle to improve tracking efficiency.