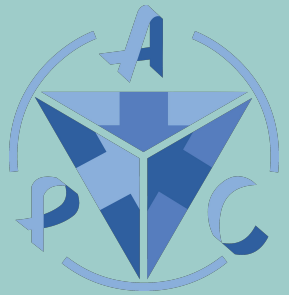
Energy reconstruction using PIDA

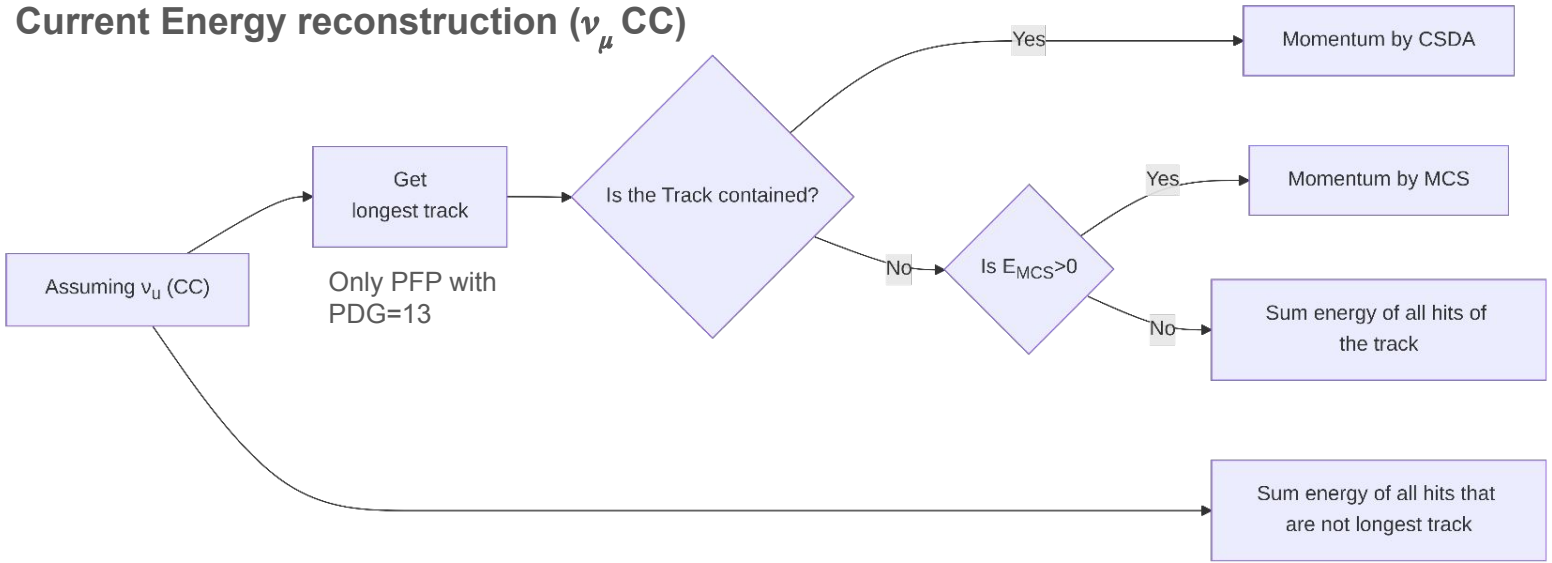
Henrique Souza for the APC group

18/11/2024



Context

Current Energy reconstruction (ν_μ CC)



Pros: Very simple and direct approach

Cons:

1. Longest track is not always muon
2. If MCS fails, the mass of the muon is not taken into account
3. **Does not use PID capability of LArTPC**

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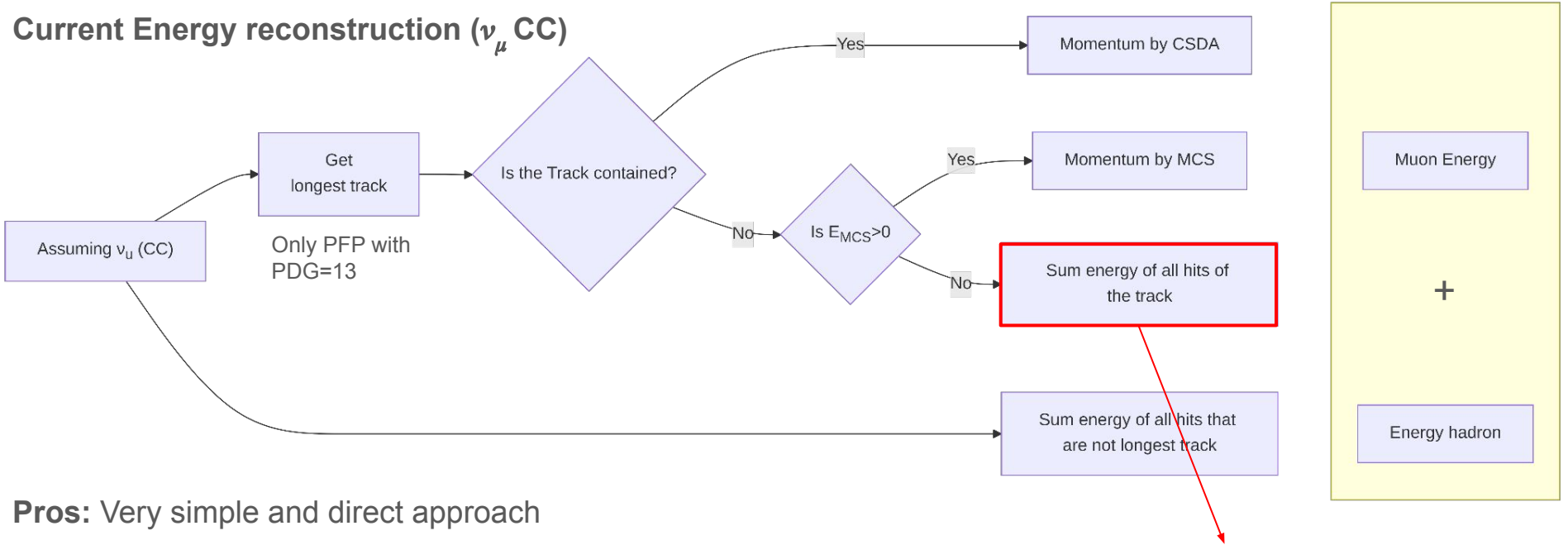


Pros: Very simple and direct approach

Cons:

1. Longest track is not always muon
2. If MCS fails, the mass of the muon is not taken into account
3. **Does not use PID capability of LArTPC**

In this case, the mass of the muon is not added. I changed that

Full method description: https://iopscience.iop.org/article/10.1088/1748-0221/8/08/P08005

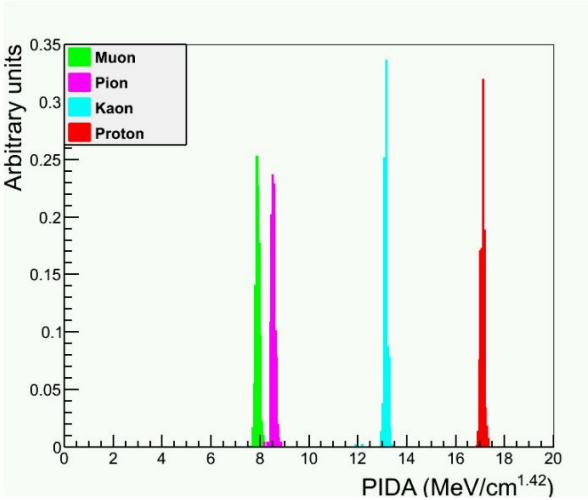
Main points:

- Utilize the theoretical power-law dependence of dEdx on the particle velocity as it reaches the end of its travel.
- Weak dependence on b

$$(dE/dx)_{hyp} = A\,R^{b}$$

$$A_i = (dE/dx)_{calo,i} R_i^{0.42}$$

- Average of Ai is used for last 30 cm of track



Particle	A MeV/cm^{1-b}	b
pion	8	-0.37
kaon	14	-0.41
proton	17	-0.42
deuteron	25	-0.43

PIDA

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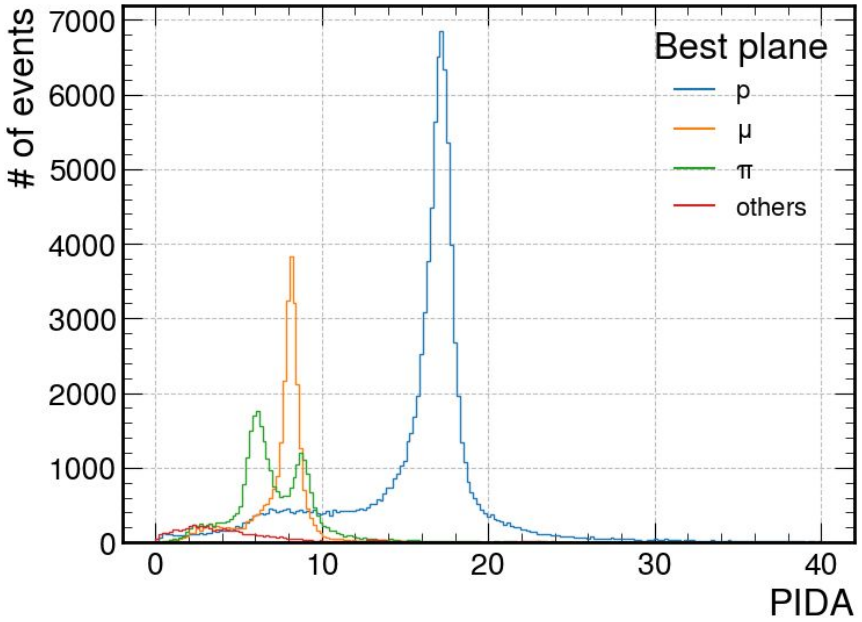
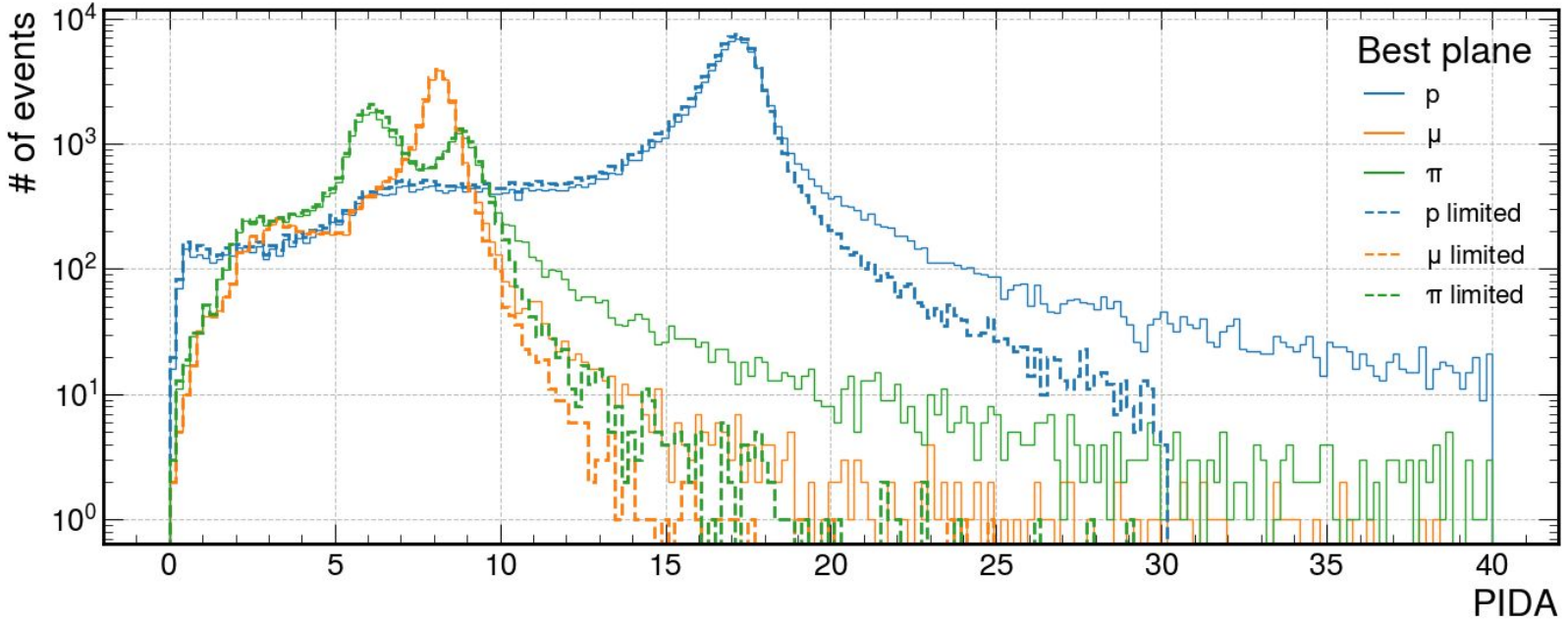


PIDA - My changes

- Changed from Median to Mean
- Avoid values in which dE/dx > 1000
- Avoid values of PIDA > 30 (before mean)

- **Better separations protons <-> muons,pions**



Metrics

- In the analysis, I take into account:
  - PFP calorimetric energy
  - PFP hits to G4 matching
  - Total calorimetric energy of event (Including all PFPs)
  - PIDA
- Define best plane by:
  - Most hits of PFP
  - Most hits of entire event
  - Most hits used in computation

They are all calculated in each plane view (U, V and W).

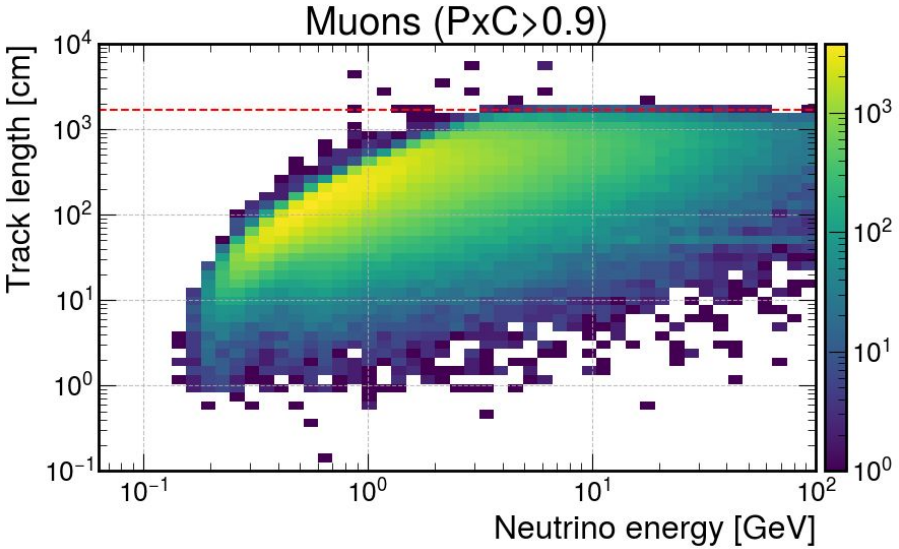
Using only “W” plane does not work for atmospheric events: not in beam direction

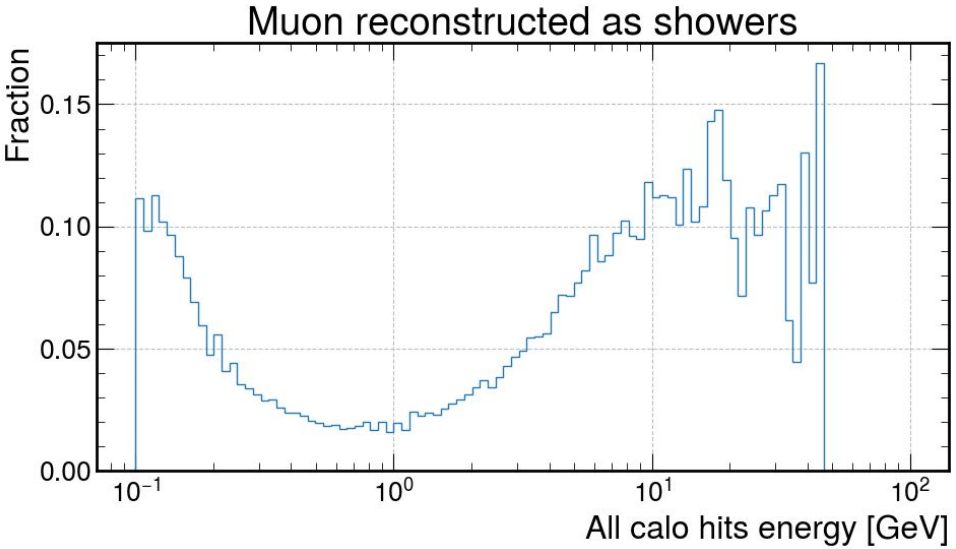
G4 matching can sometimes be fail ! Planes can give different results. Using the plane with most hits seemed better than taking all planes together.

Specially for PIDA, taking the plane with most (valid) hits make a good difference.

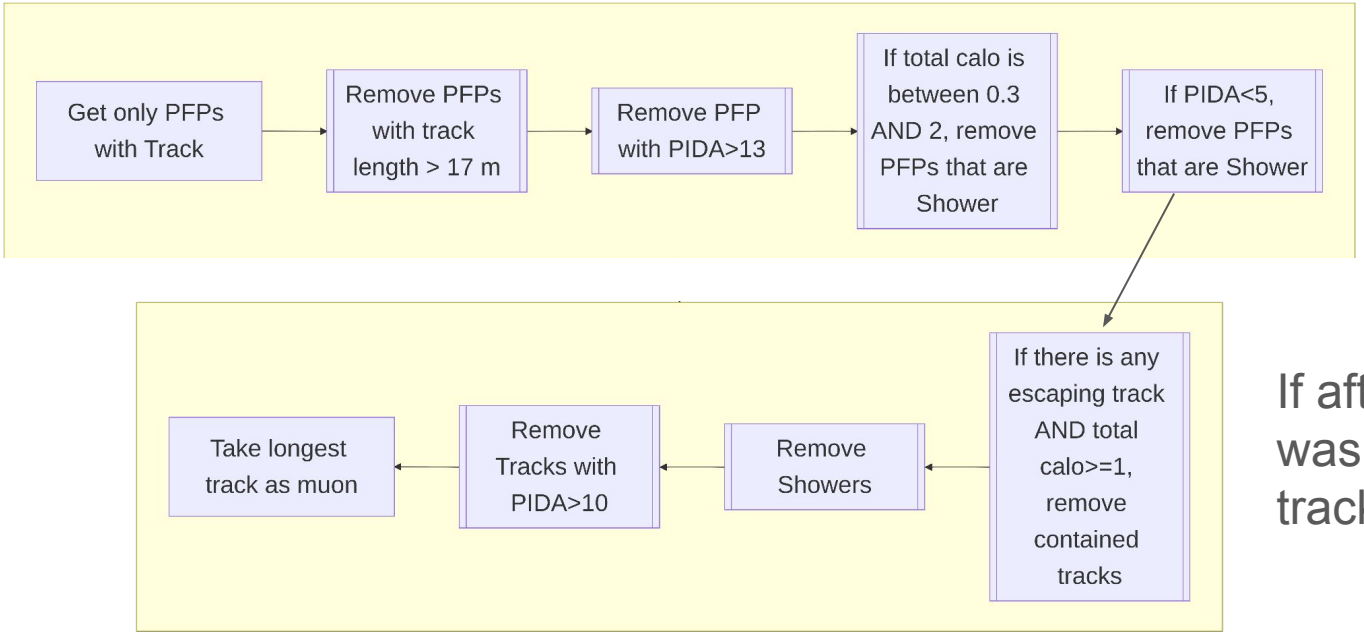
Metrics

- My method was based on trial and error.
- For muon and proton selection, I tried to maximize purity and completeness, focusing on purity.
- Same for pions at the beginning (changed later and got better results)
- **Some things I have noticed:** (1) cut can be applied to track length; (2) can search for muons that are reconstructed as showers (PFP PdgCode=11) depending on all hits calorimetry





Muon selection



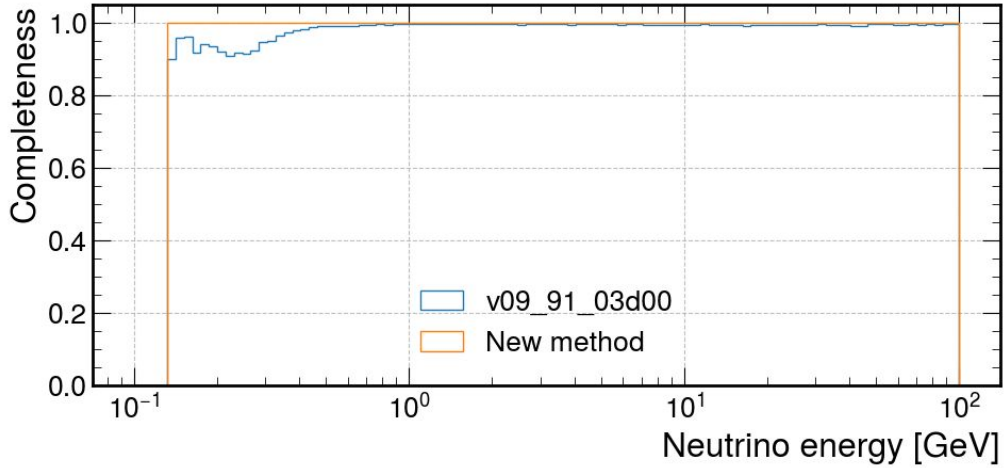
Definition

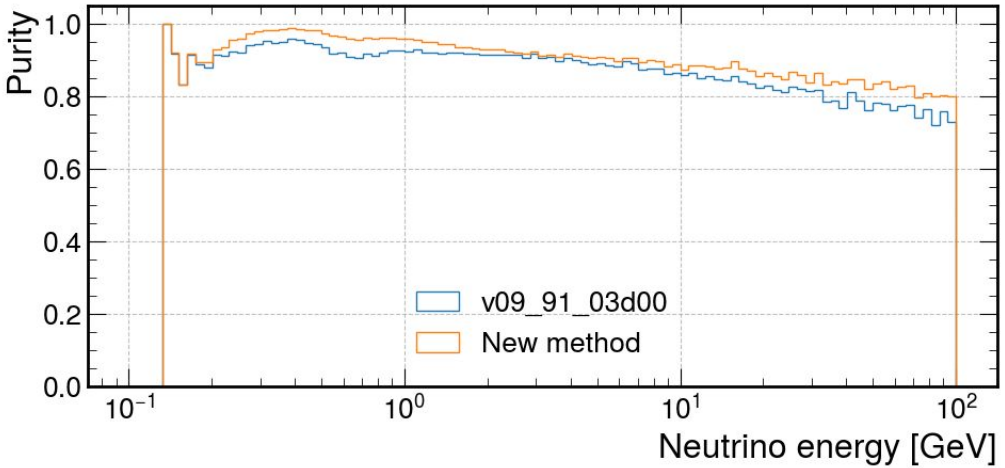
If there is only one option, take as muon, otherwise, apply cut

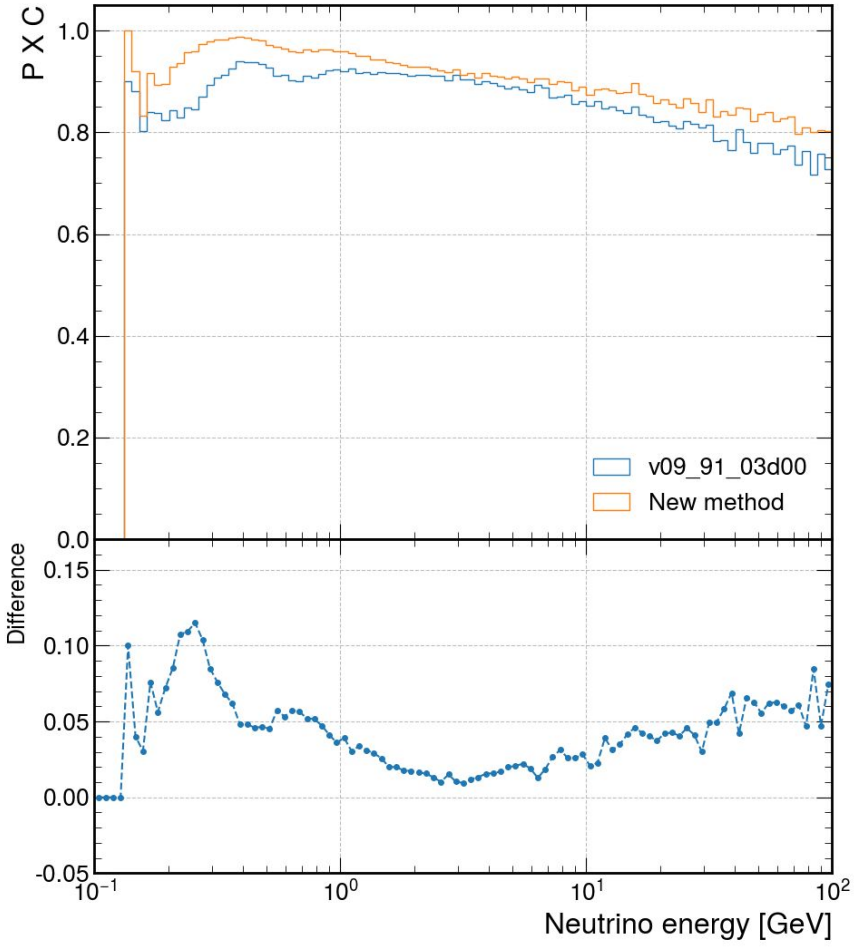
If after any step, no muon was taken, take the longest track instead

*Only analysing events in which 1 PFP is tagged as muon and has a track associated.
I am skipping ~6% of the dataset like this.

Muon selection







Muon selection

Note:

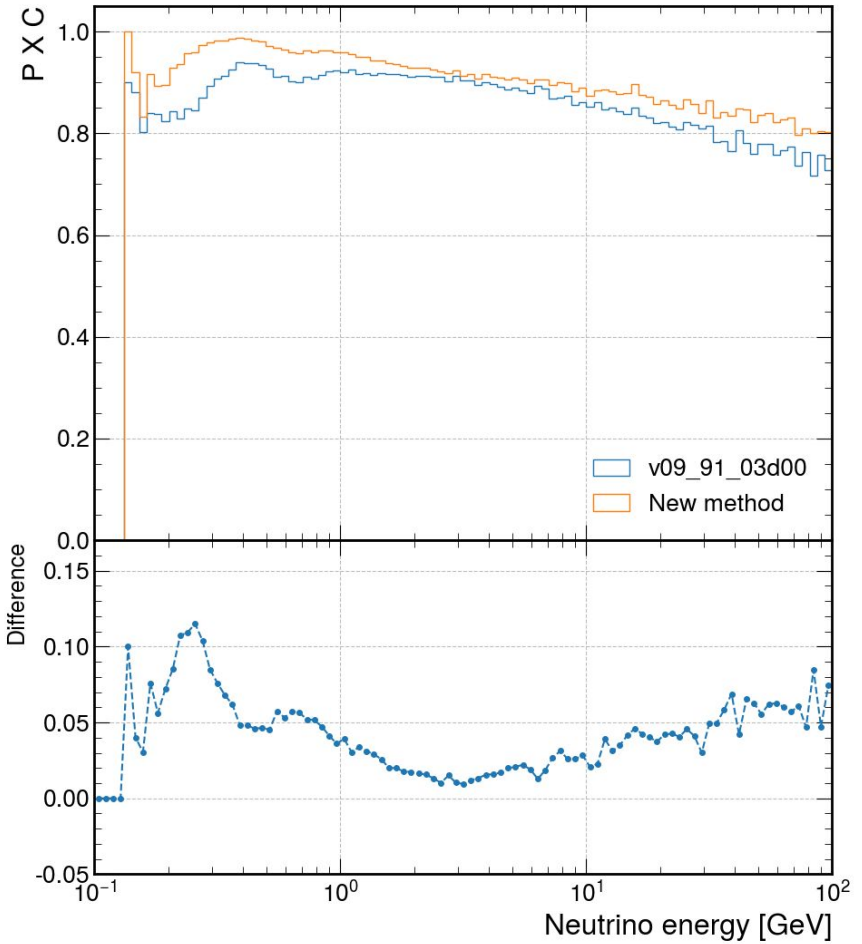
Total events: 472153

# of events with **no muon reconstructed** (in which PFP has a track): 30007 (6.4%)

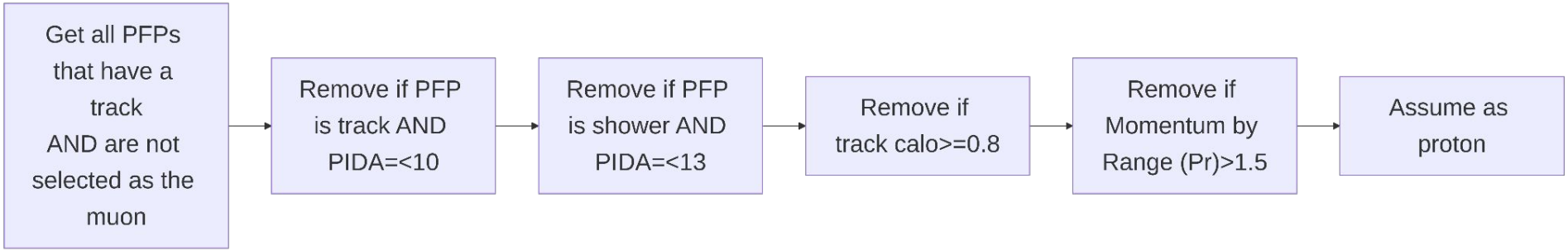
This number changes if I ask that the reconstructed muon has a purity x completeness bigger than X

PFP PnC > 0.25: 33227 (7.0%)
PFP PnC > 0.64: 63258 (13.3%)
PFP PnC > 0.81: 105574 (22.3%)

In backup: plot of difference for different cuts of PnC



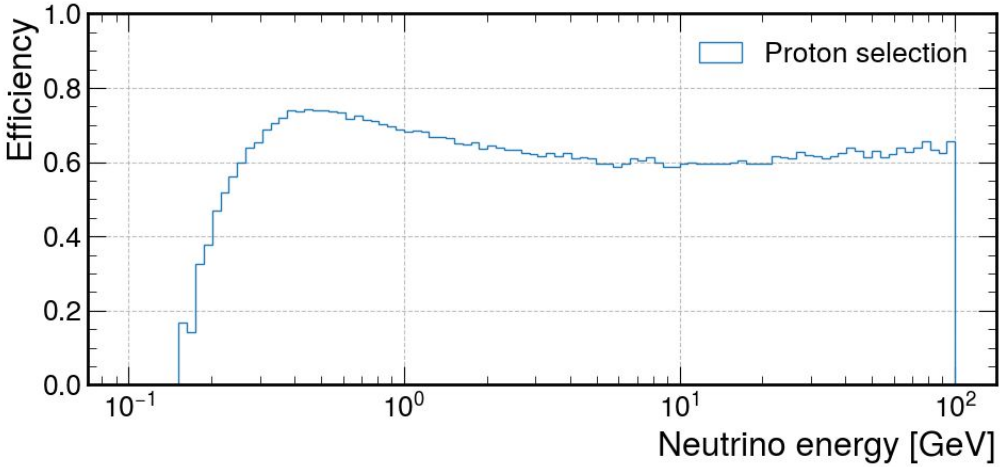
Proton selection

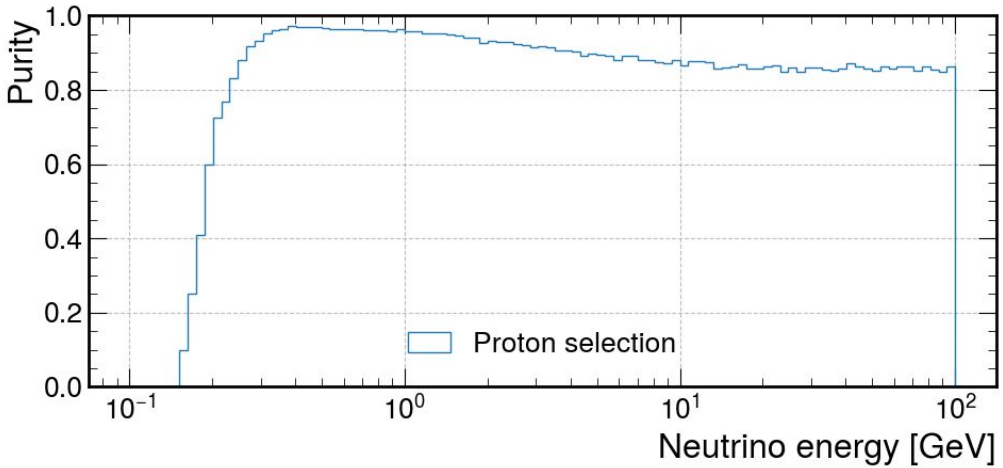


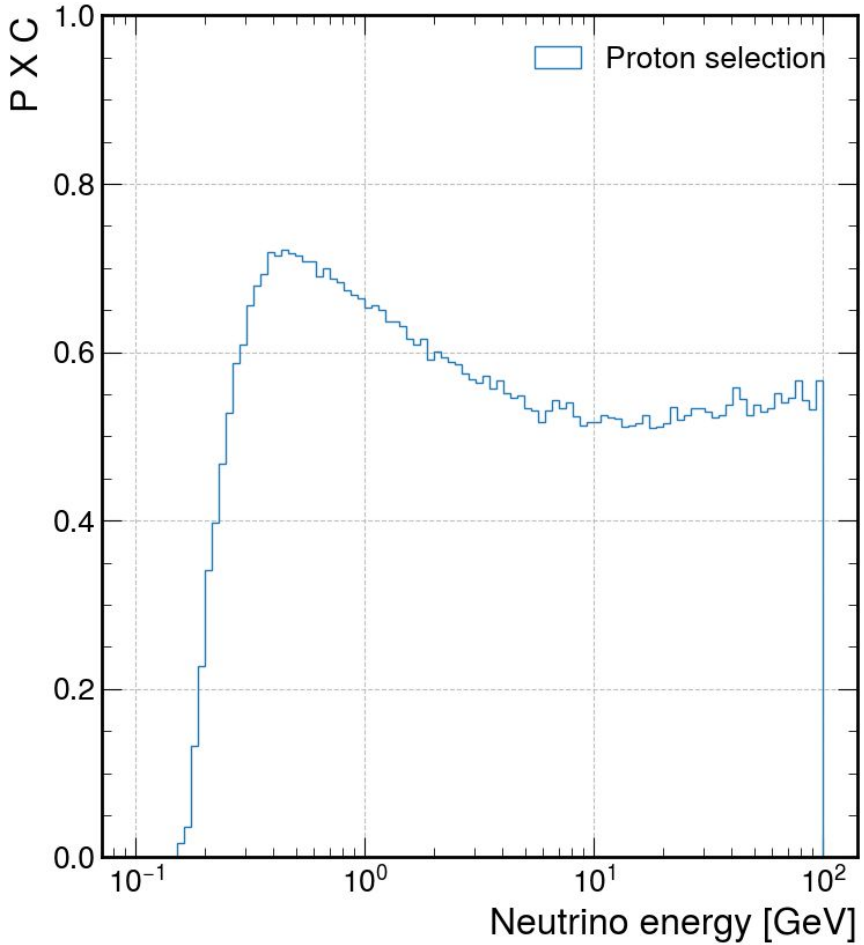
As protons have a good PIDA score, cutting was easy.

- Different thresholds for protons reconstructed as track or shower increases purity
- Cuts in calorimetry and momentum by range also improves purity

Proton selection





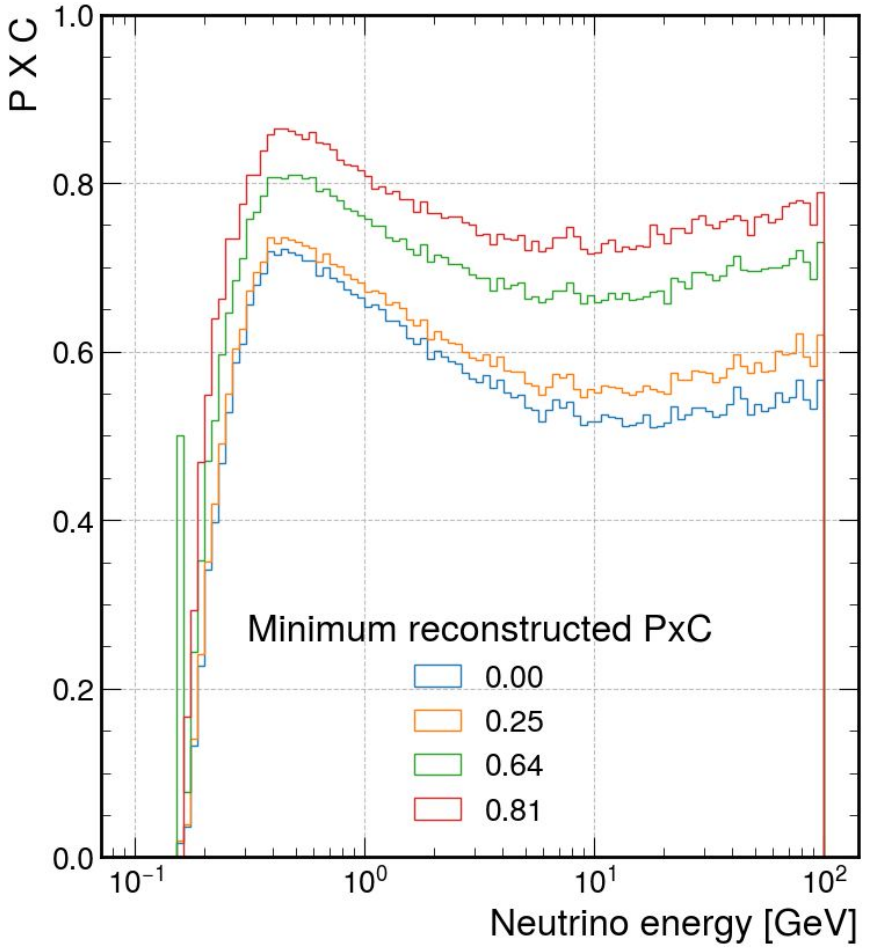


Proton selection

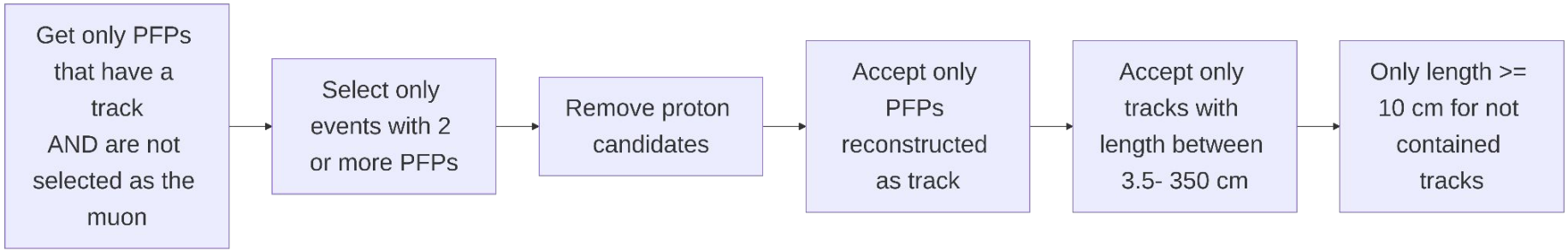
Note:

Purity and (specially) efficiency increases when analysing only tracks with PxC > X

This is caused by particles that are pointed as being a proton, but with a poor PxC

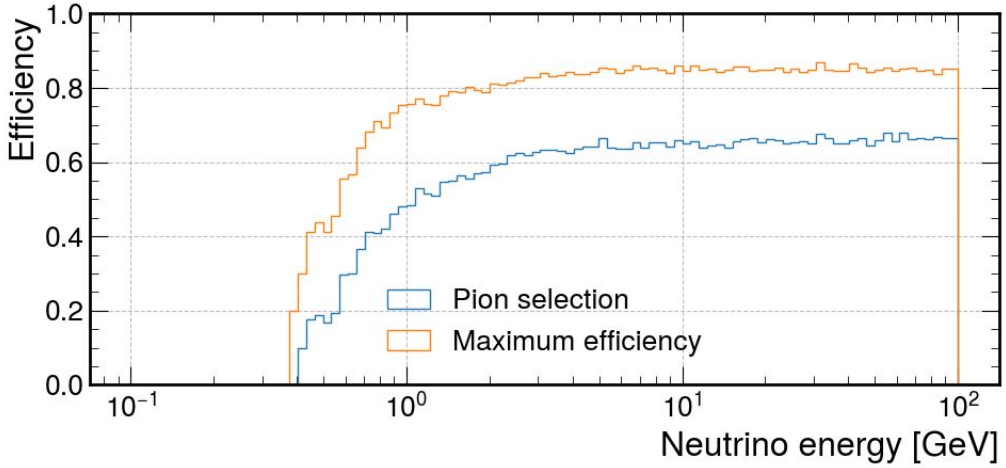


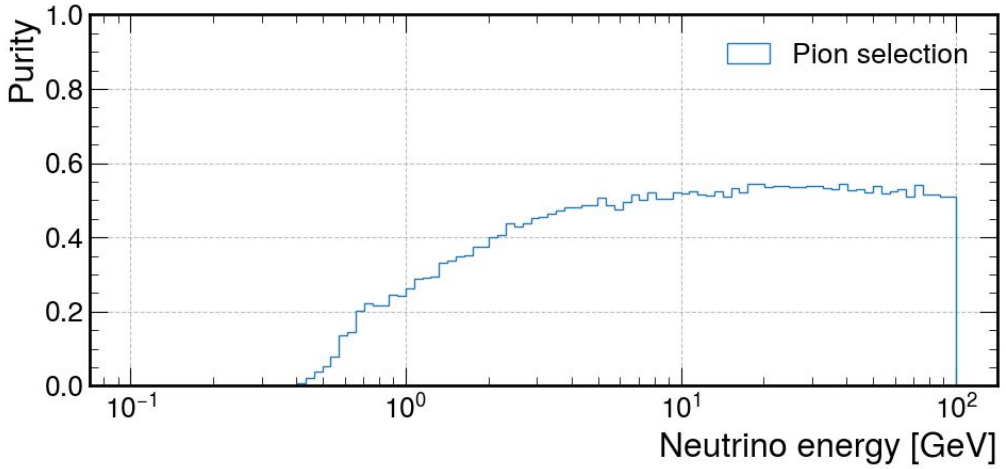
Pion selection

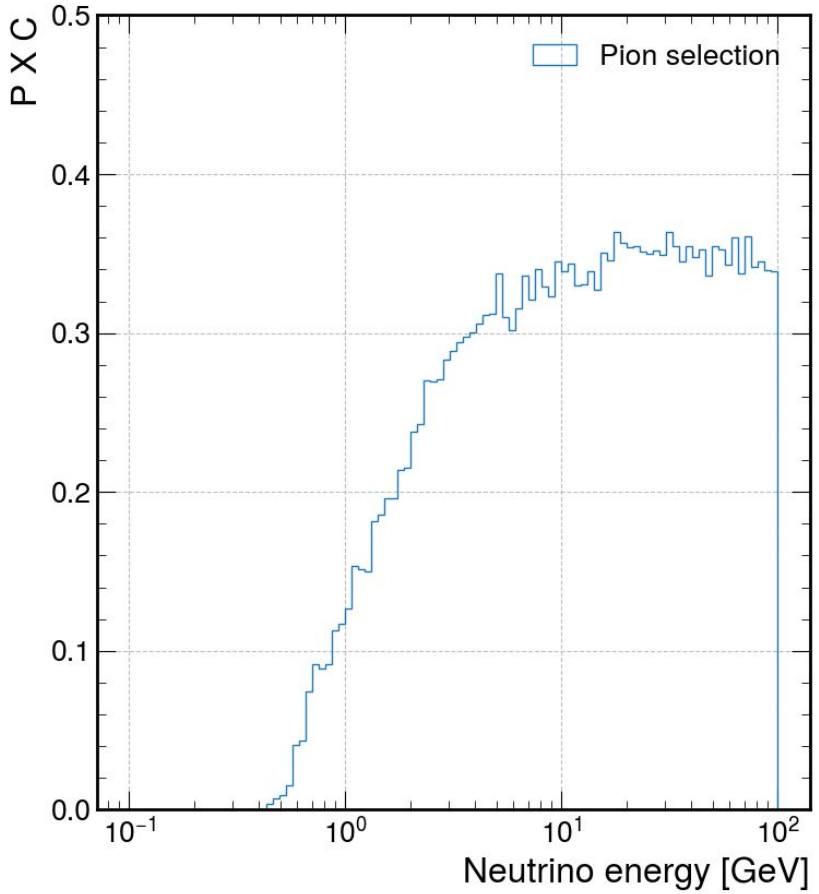


- For pions, I could not find a good parameter that would keep a good purity with good efficiency. If I increased purity, efficiency drops a lot

Pion selection

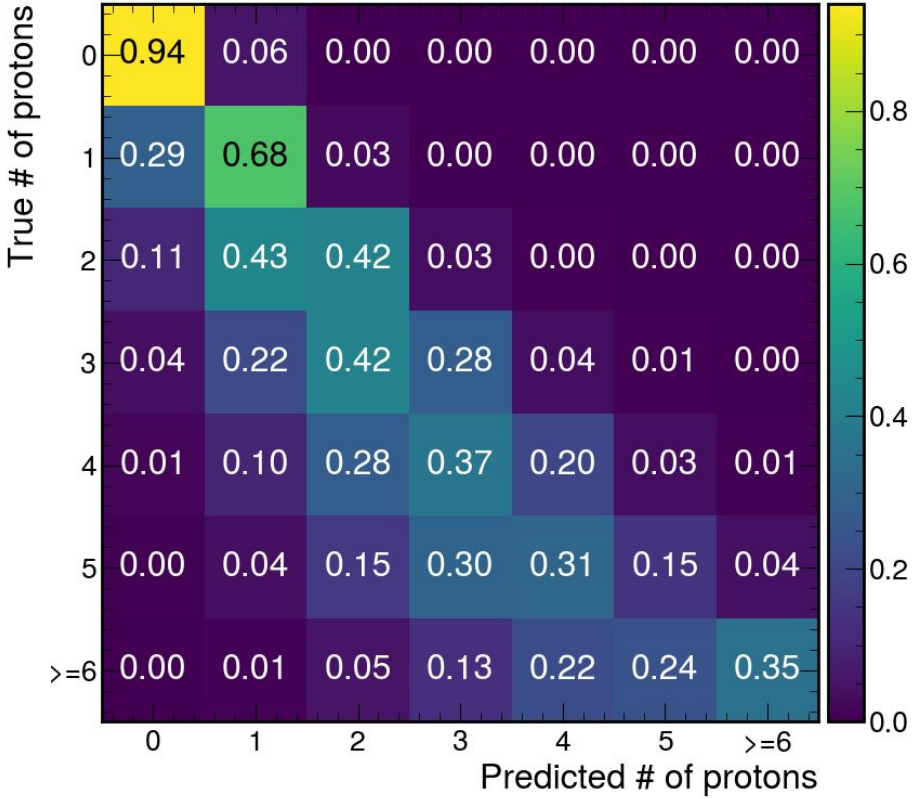


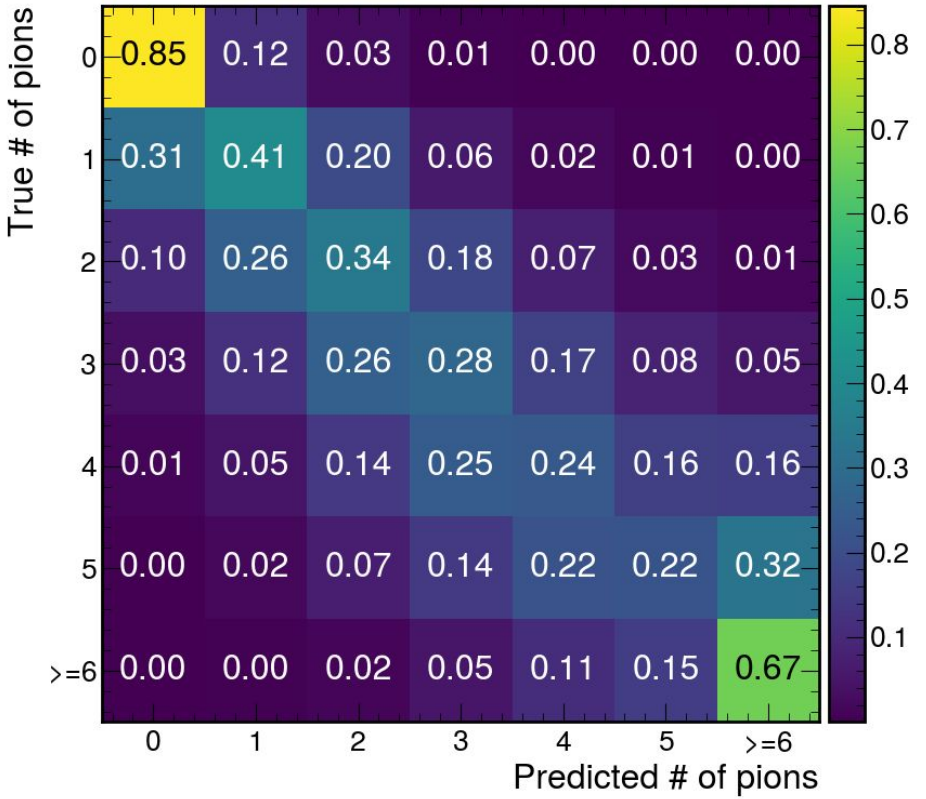




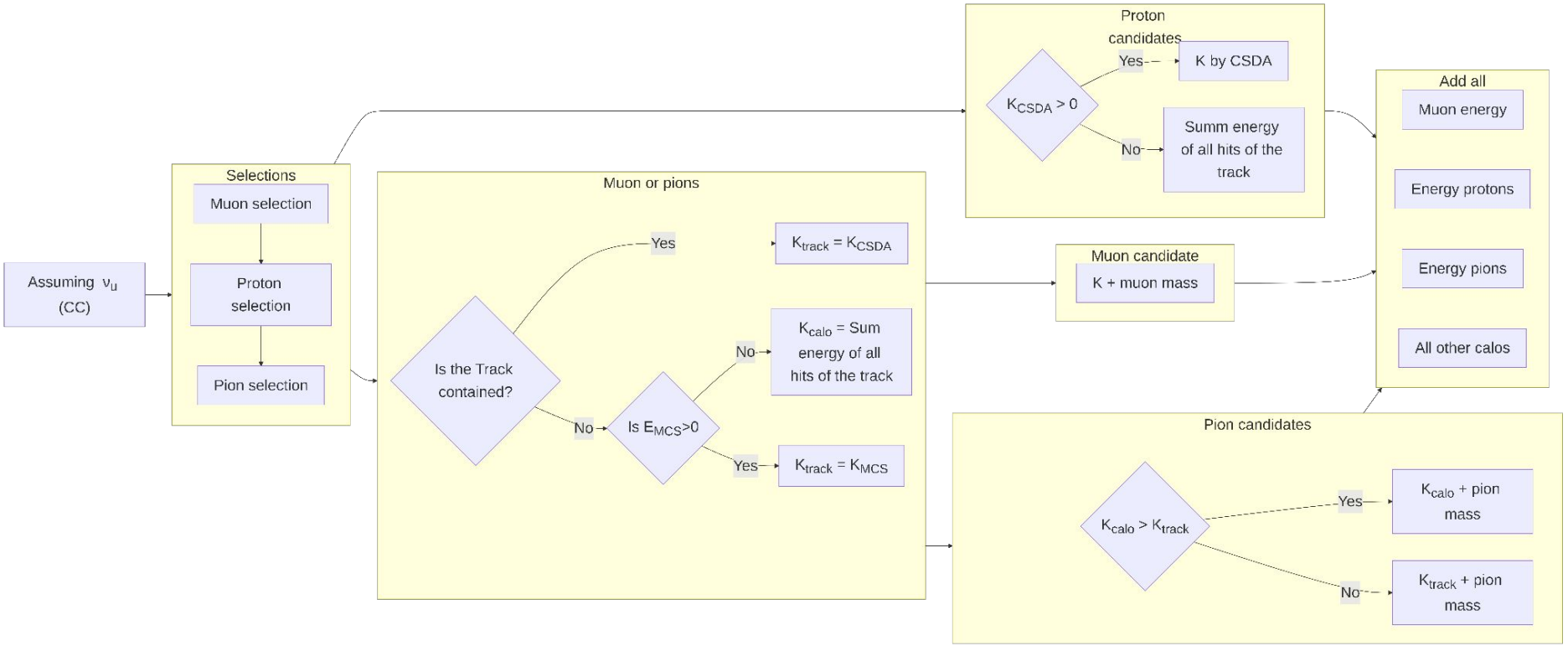
Proton and Pion selection

High purity for protons -> higher number of pions





Energy reconstruction



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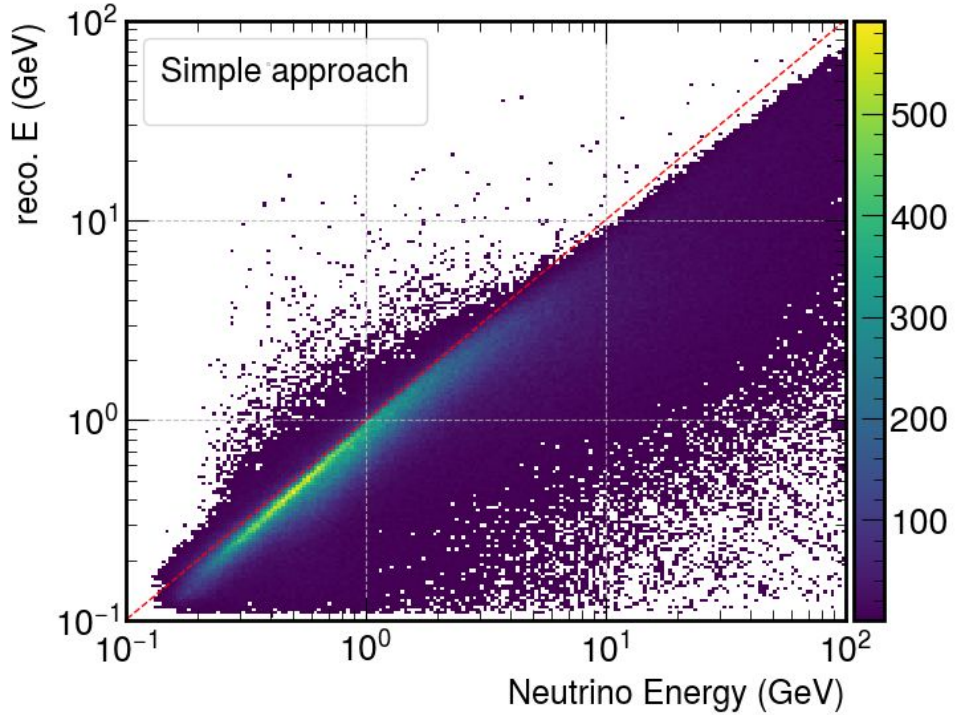
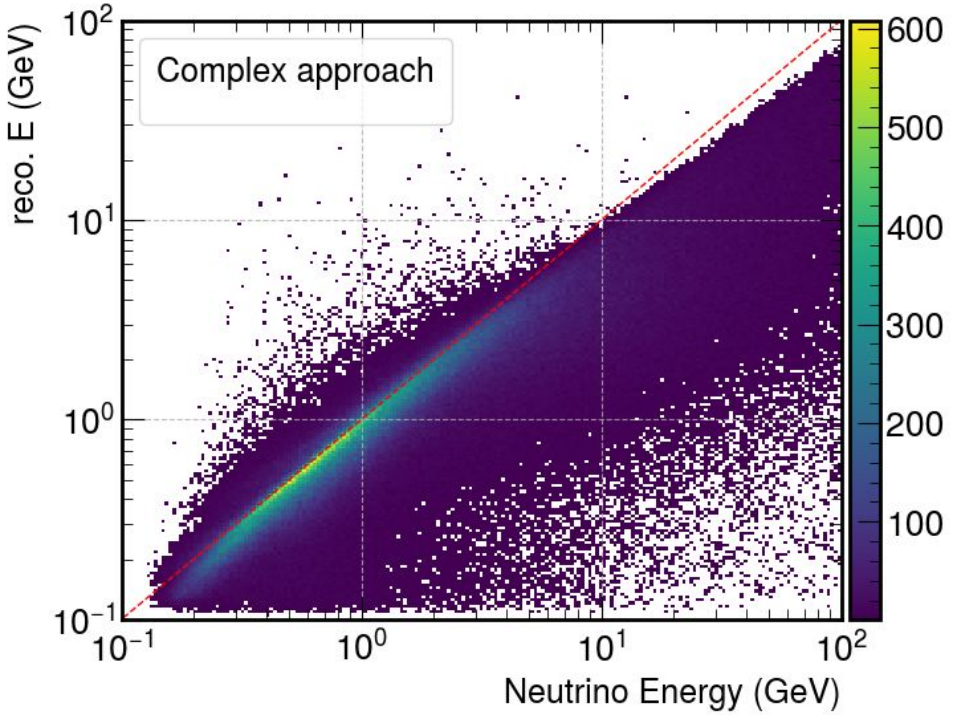
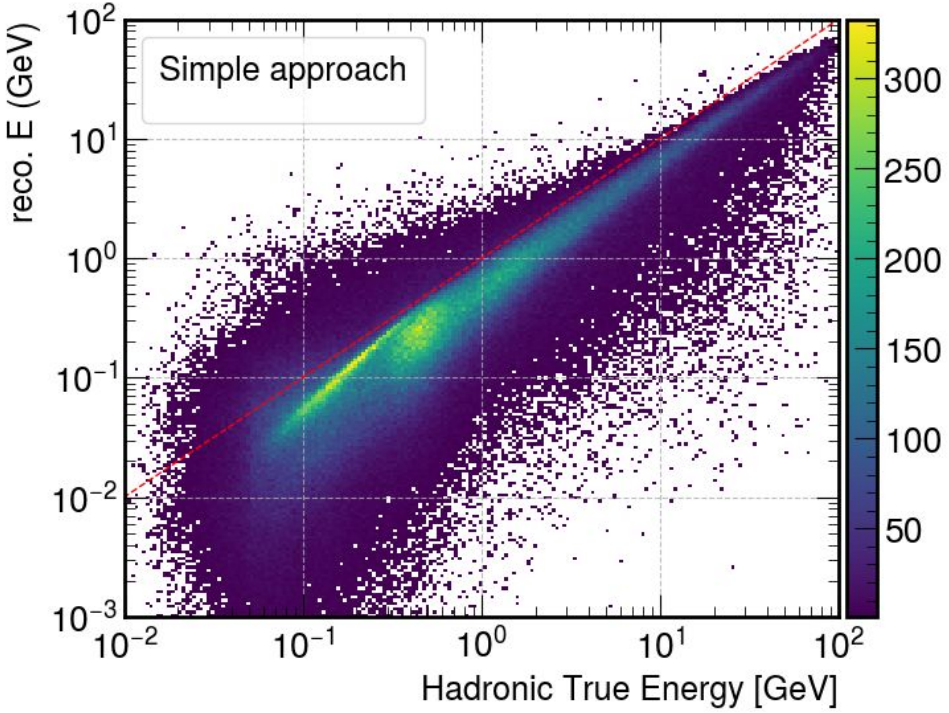
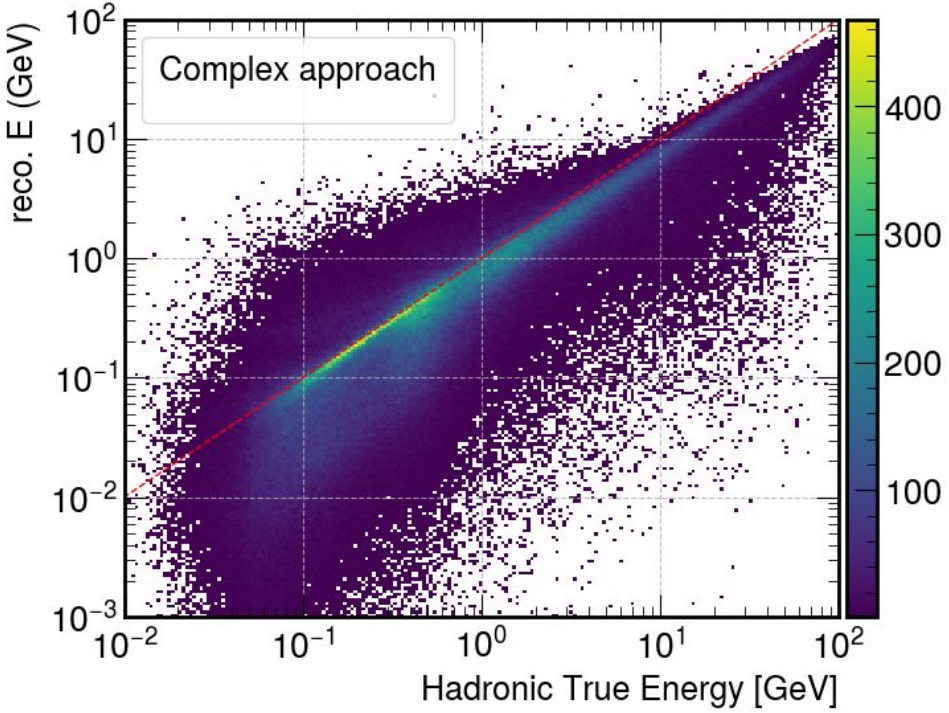




Energy reconstruction

$E_{had} = E_{\nu} - E_{LEP}$

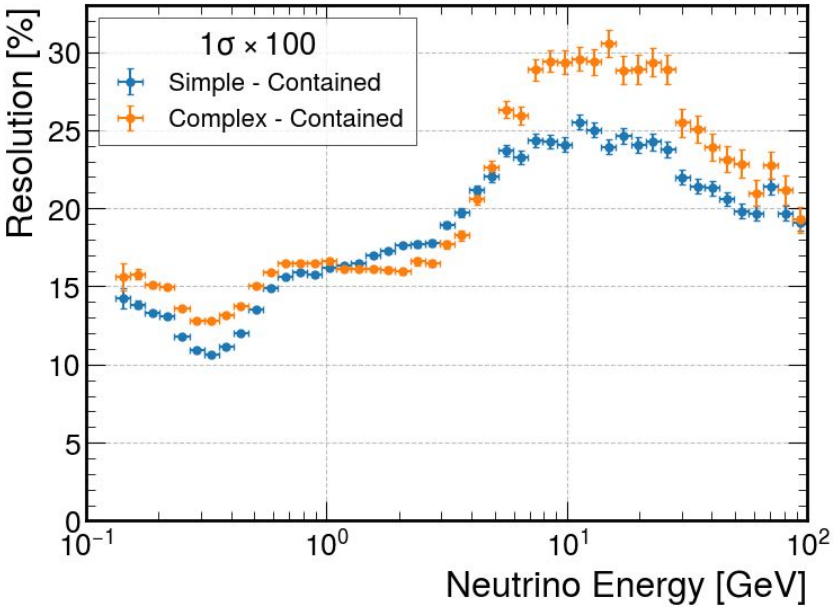


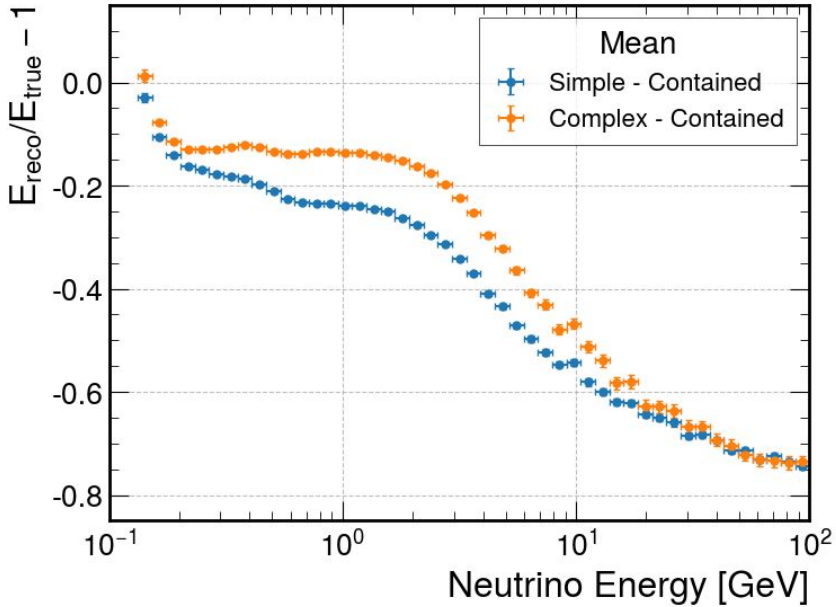


Energy reconstruction

To compare between the two methods:

- When track tagged as muon **is contained**
- When track tagged as muon is not contained





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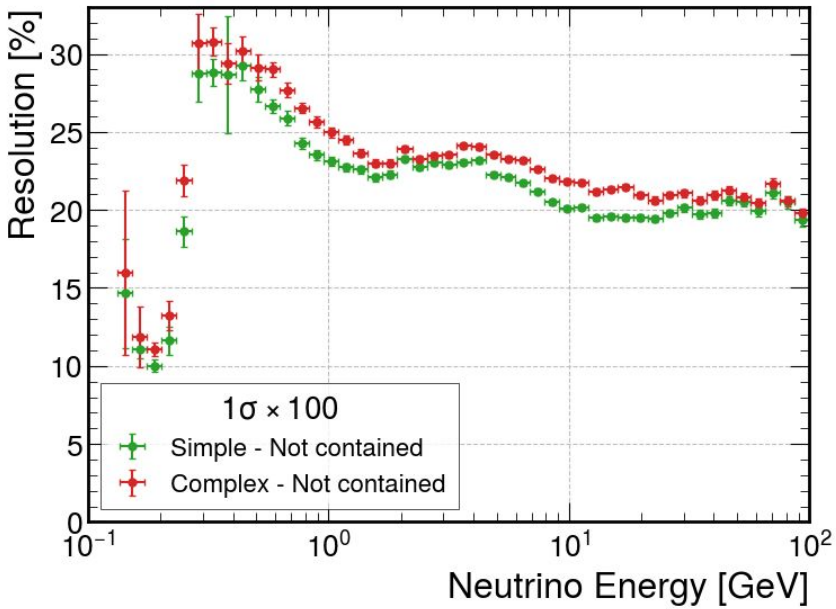

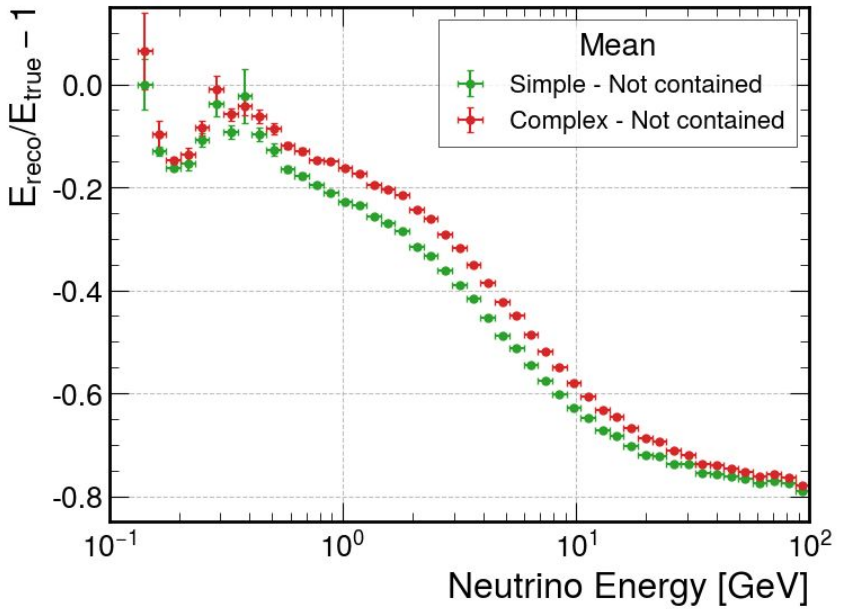

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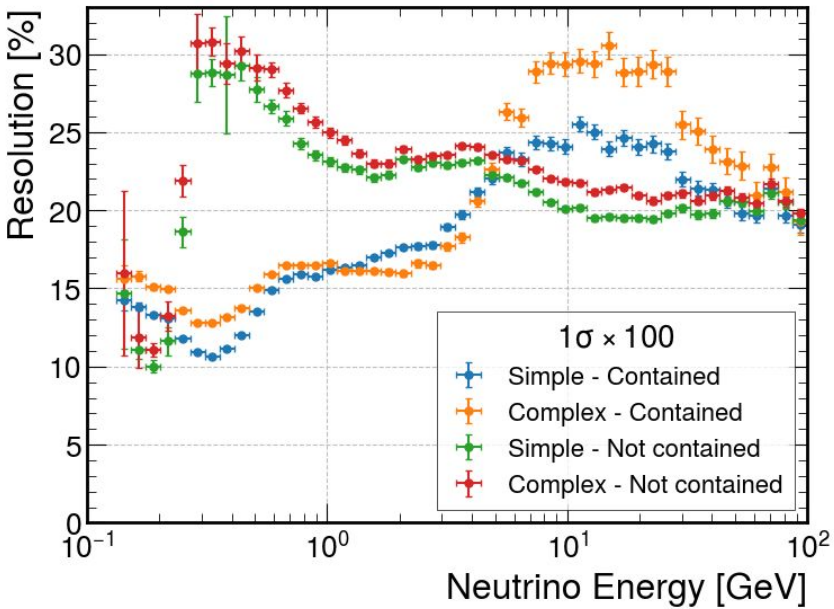
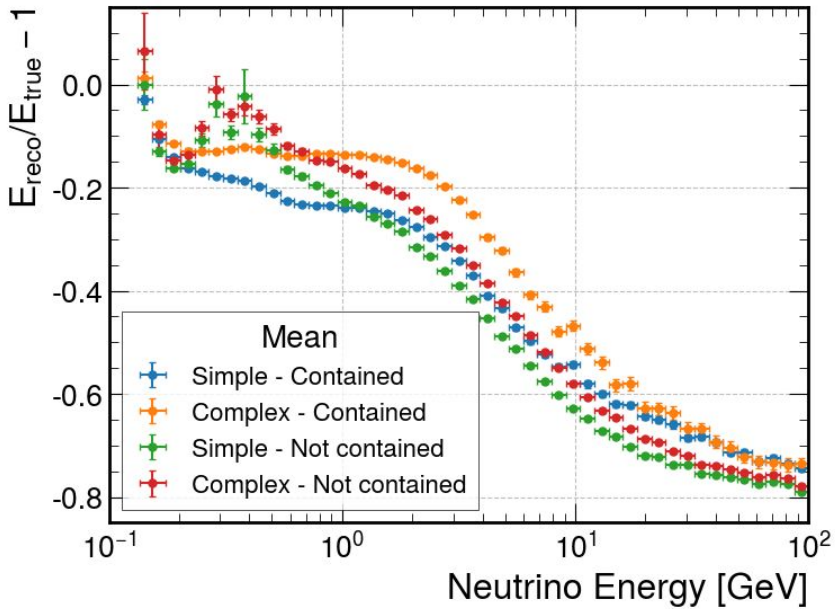




Conclusions

First method using PIDA

Pros:

- Uses pid :)
- If rescaled, resolution is better (check backup)

Cons:

- Needs a lot of selections that will change depending on simulation, reconstruction and detector geometry.
- … others

Next steps:

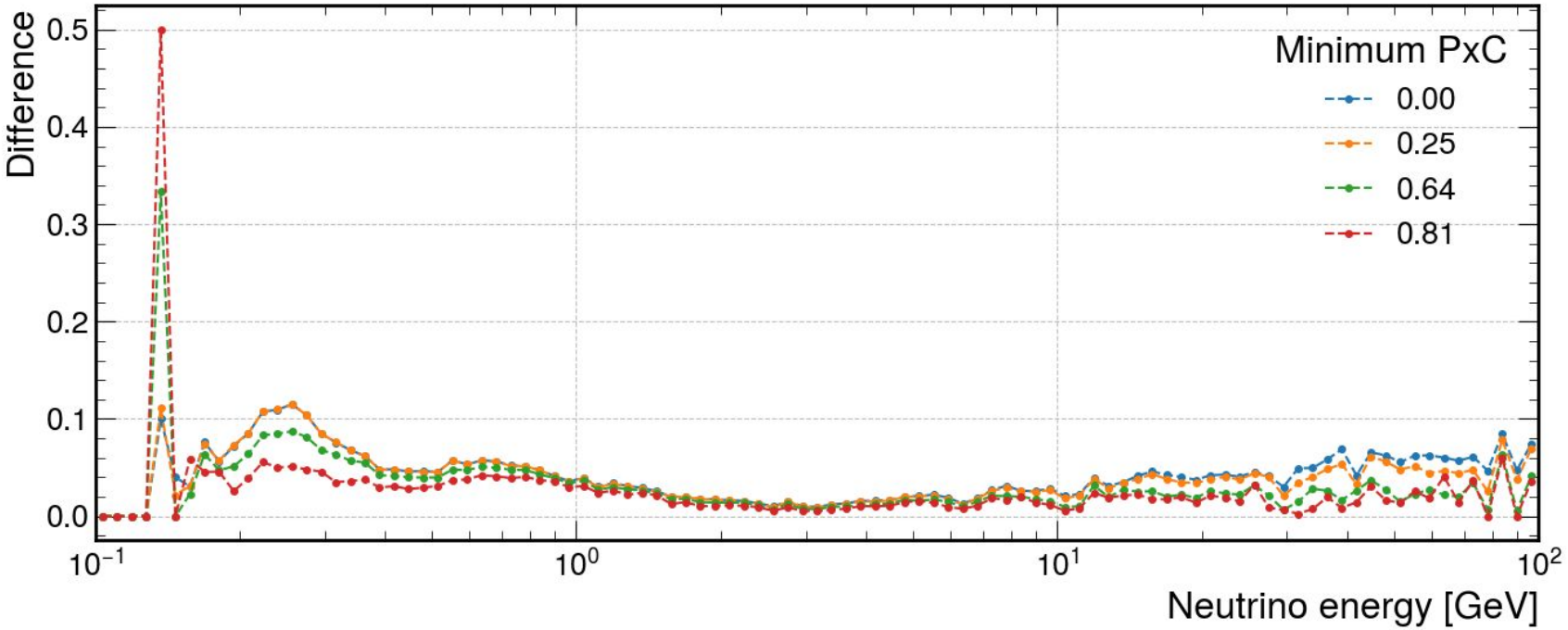
- Any suggestions? -> try/add
- Implement similar approach for nue
- Implement methods in dunereco

What can/need to be improved:

- Maybe pion selection for low energies can be improved
- Energy for pions can be improved.
  - Use proper CSDA “table”
  - Tune MCS for not contained
- Any “Shower PID” ?

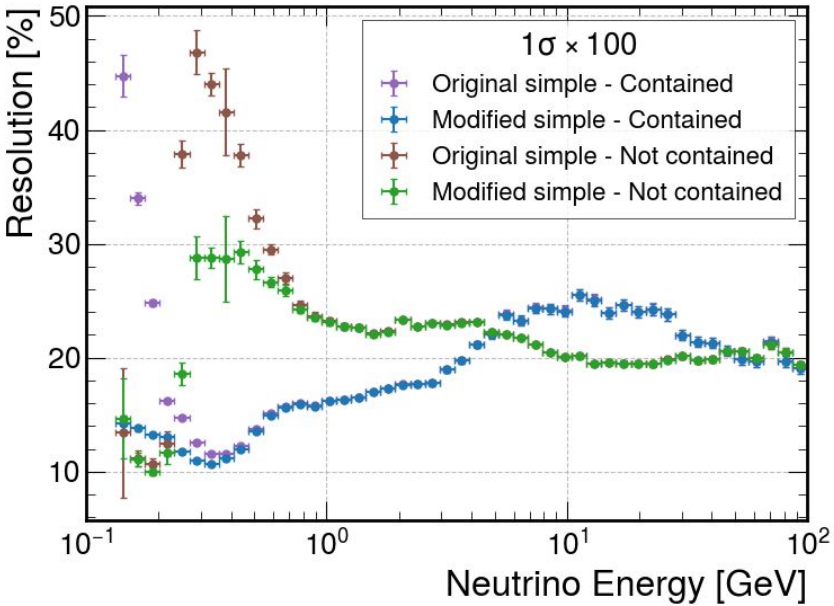
Backup

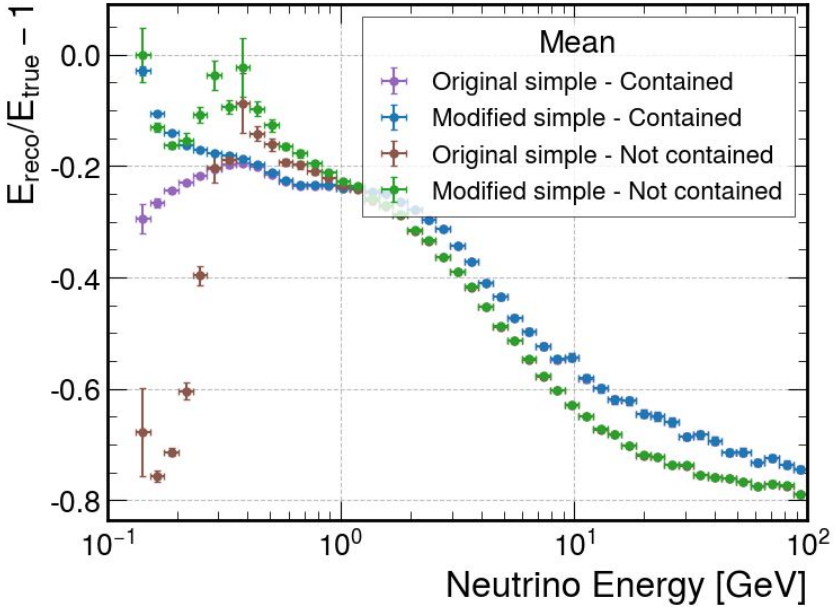
Muon selection improvement when asking minimum PxC over the muon



Backup

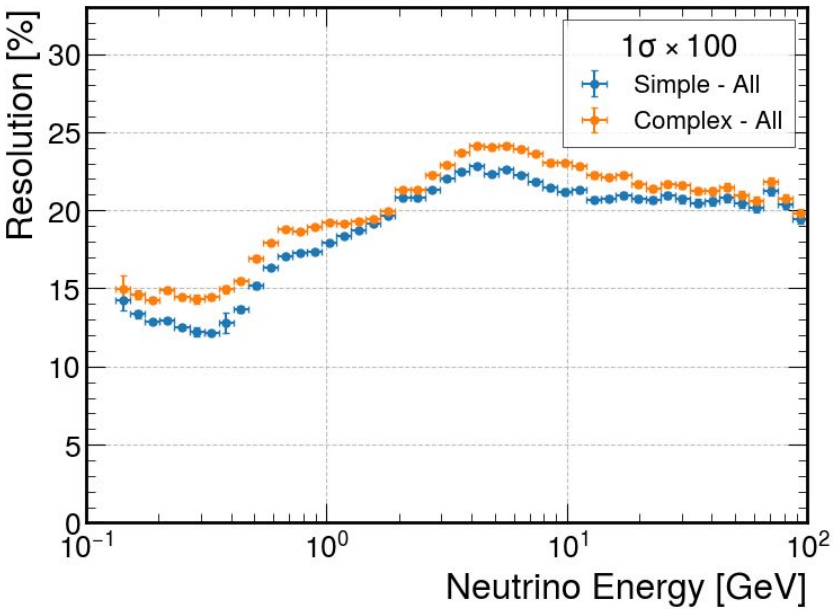
- Changes in simple approach

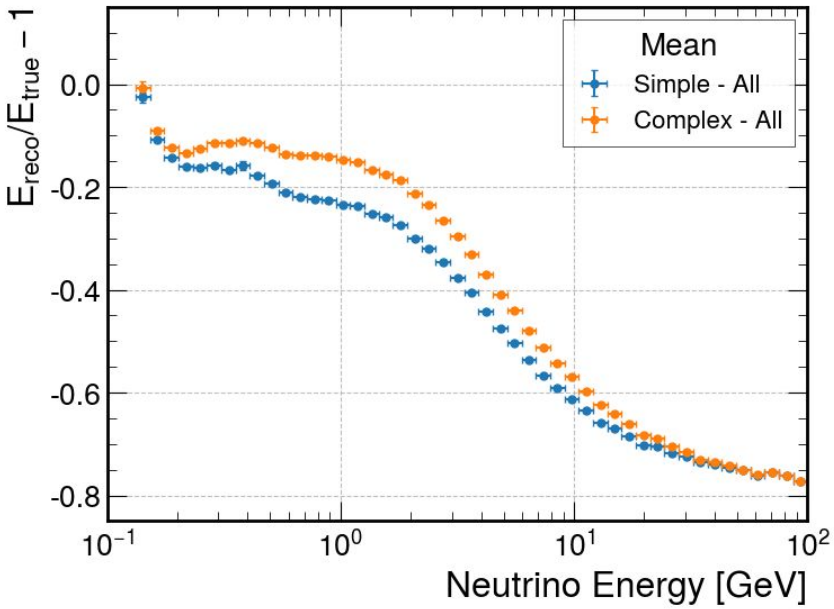




To compare between the two methods:

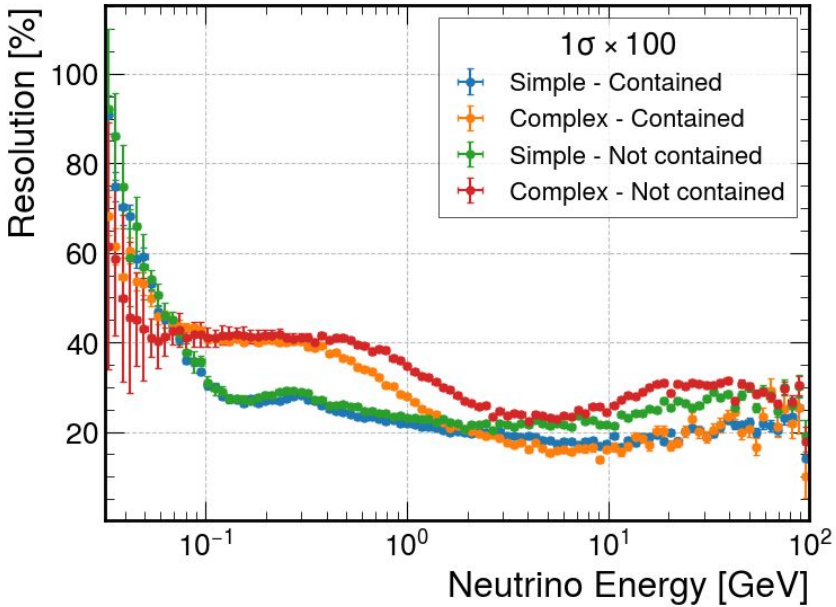
- All events

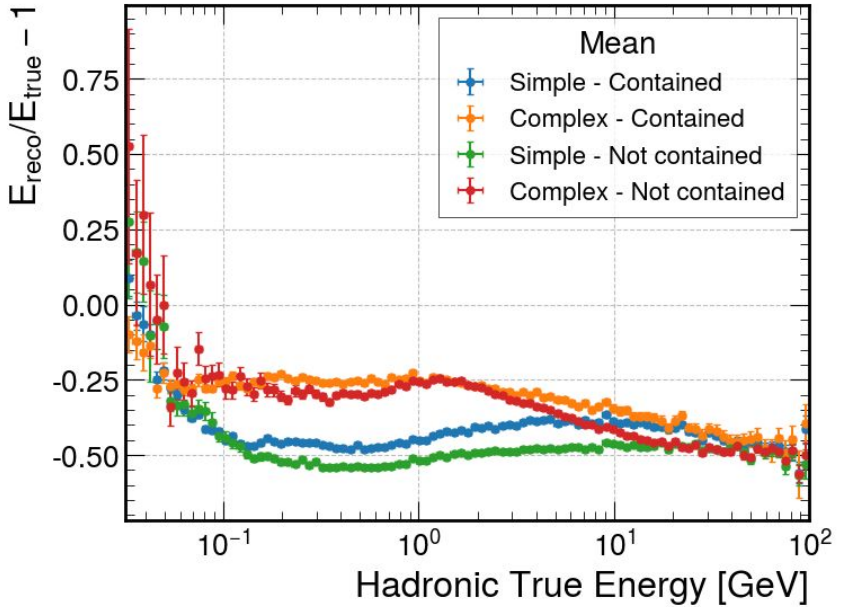




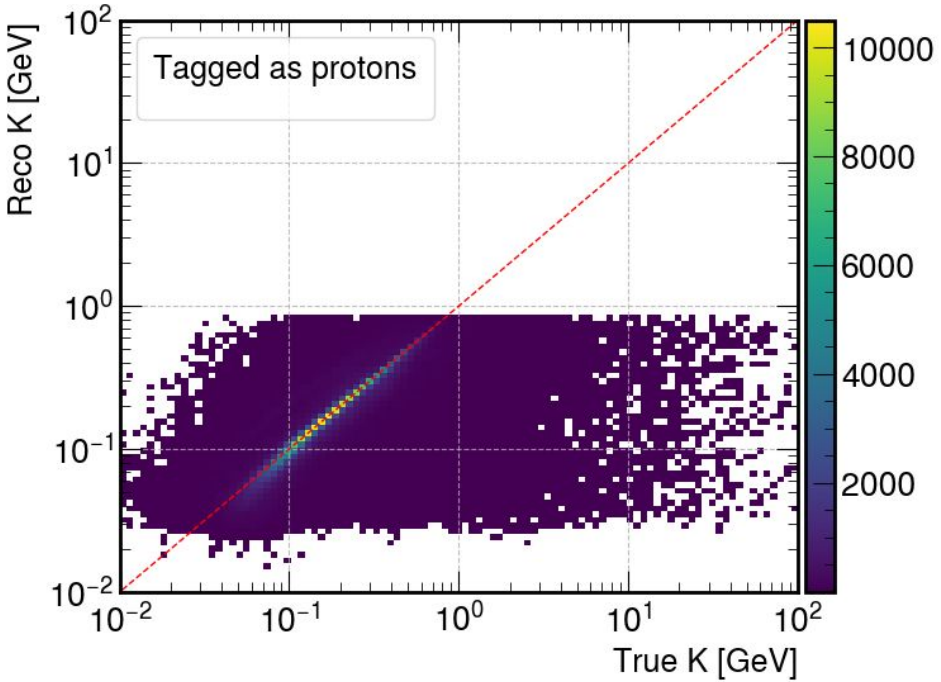
To compare between the two methods:

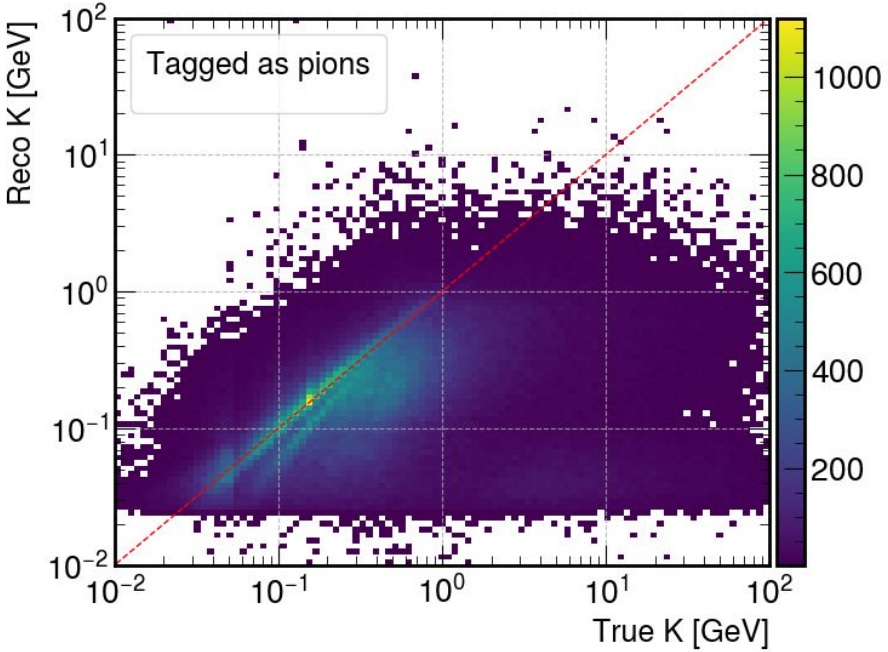
- Hadronic energy





Backup


Tagged as protons
Reco K [GeV]
True K [GeV]
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10000
8000
6000
4000
2000


Tagged as pions
Reco K [GeV]
True K [GeV]
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
1000
800
600
400
200

What if we try to rescale:
(Esimple (con.) ^ 1.05)*1.3 (Ecomplex (con.))*1.14
(Esimple (not cont.) ^1.2)*1.3 (Ecomplex (not cont.) ^1.15)*1.18