



Feasibility of Tau Appearance with ANTARES

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Erlangen, 07/12/2023
Oscillation WG Meeting @ ECAP

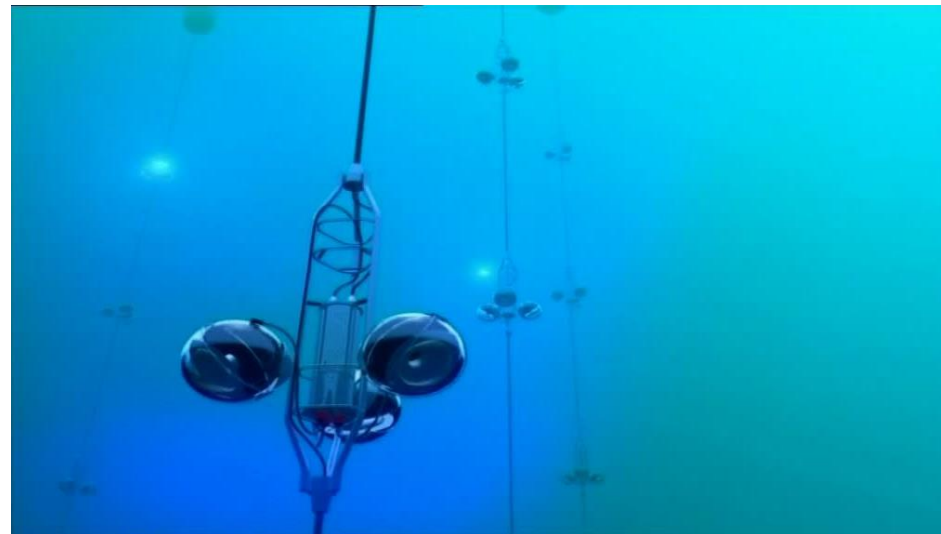
01 ANTARES Detector

02 ANTARES Datafiles

03 Event Selection Criteria

04 Signal

05 Conclusion & Next Steps



Courtesy: ANTARES Collaboration

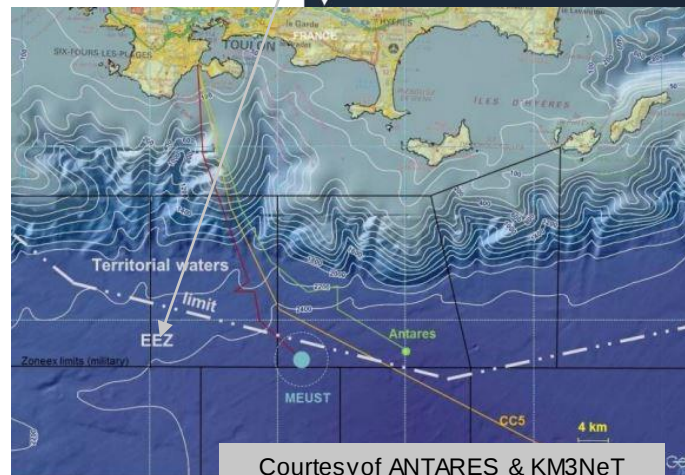
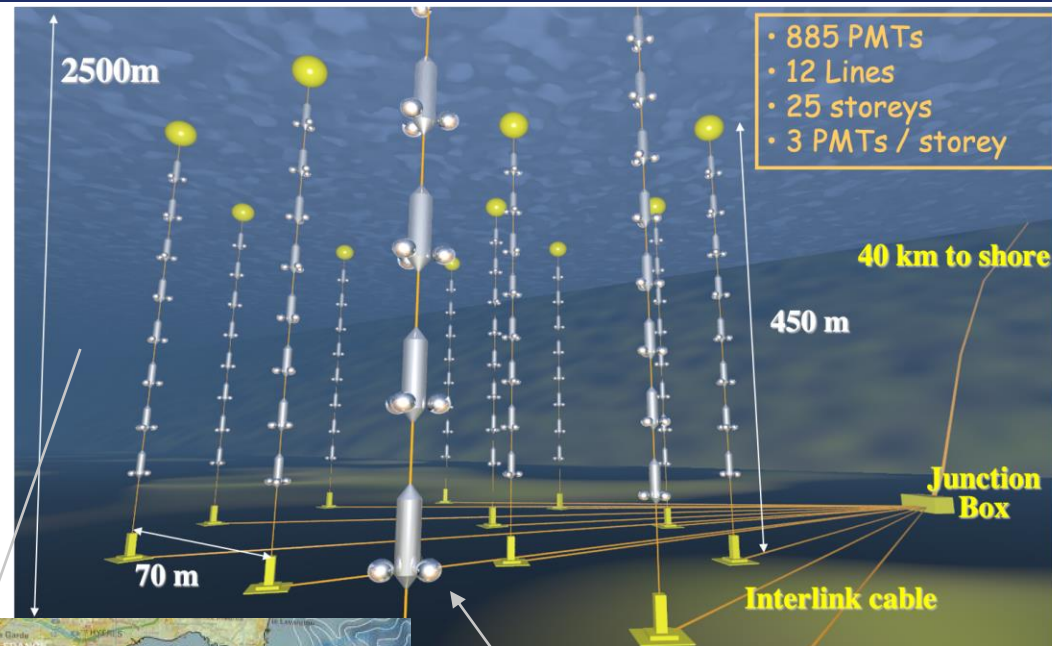
- Alternative approach to the legacy data of ANTARES.
- Utilization of the whole ANTARES data set, which can compensate with its long lifetime.
- Possibility of adding statistics to the already ongoing analysis currently being active in the KM3NeT collaboration.

Drawbacks:

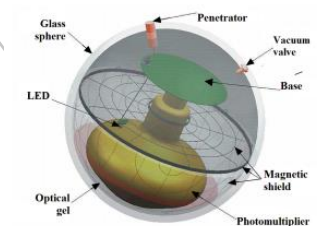
- Energy region of the analysis very close to the energy threshold of the detector.
- ANTARES was not designed for this purpose, thus energy resolution and reconstruction in this region a definite challenge!

Key points:

- Completed: 05/2008
- Last Measurement: 02/2022
- Volume: 0.03 km^3
- Energy Threshold: 5 GeV
- Vertical Spacing: 14.5 m
- Horizontal Spacing: 70m
- Storey Height: 2m
- Num. Runs: 24854



Nucl. Instrum. Meth. A 656 (2011) 11-38

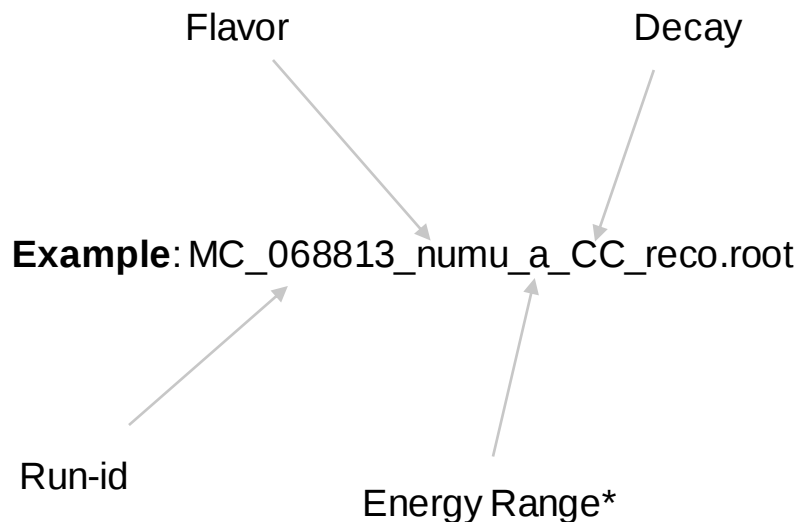


Data concept run-by-run, for each run:

- Muon files (mupage)
- Neutrino files (per interaction and energy range)
 - (a)nue_CC
 - (a)nue_NC
 - (a)numu_CC
 - (a)numu_NC
 - (a)nutau_CCshow
 - (a)nutau_CCmu
 - (a)nutau_NC

Energy range:

- a for 5 GeV to 20 TeV
- b for 20 TeV to 100 PeV



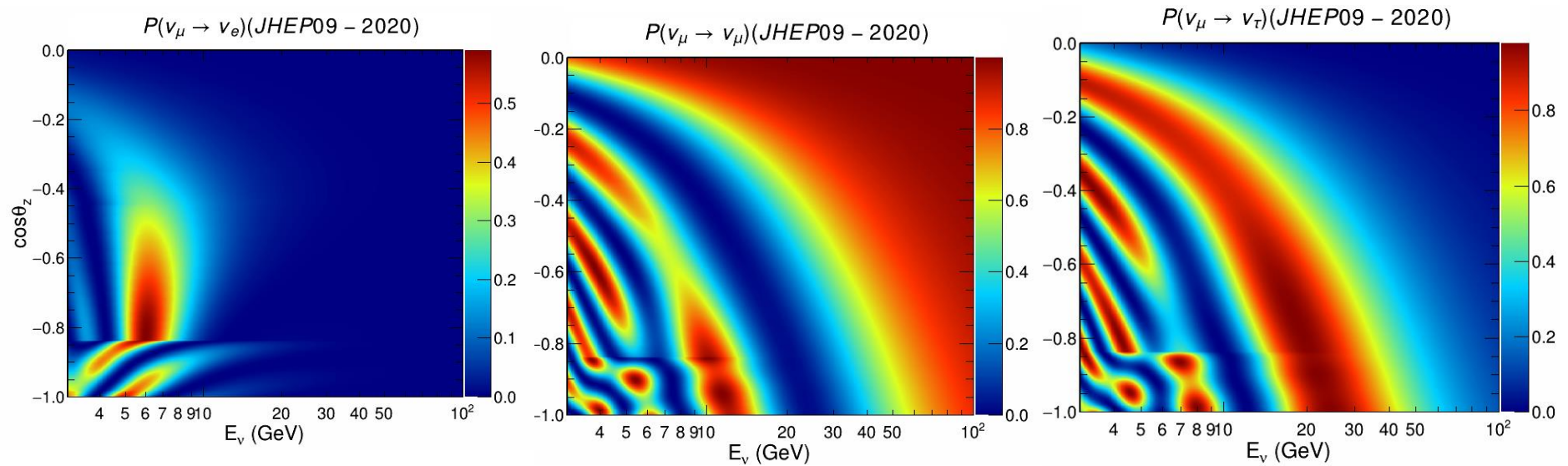
Summary: for each run neutrino 8 electron neutrino, 8 muon neutrino, 12 tau neutrino files

Information in each root file:

- Run Quality
 - Run id, Run Duration,
 - Data Quality Factor
- Monte Carlo True Information
 - Vertex Position (x,y,z)
 - Cosine Zenith
 - Energy
 - Weights
- Reconstruction (AAfit, BBfit, Showerdusj, Showertantra, etc.)
 - Reco Quality
 - Vertex Position (x,y,z)
 - Cosine Zenith
 - Energy
 - N of used lines, N of used hits



- event_id
- run_id
- type
- is_neutrino
- is_cc
- rdur
- mc_id
- ngen
- w2
- w3
- w_honda
- w_bartol
- DataMCratio
- w_muon
- wevt
- wevt_bartol
- wevt_honda
- pos_x_true
- pos_y_true
- pos_z_true
- energy_true
- cos_zenith_true
- bjorken_y_true
- n3N
- nT2
- nT3
- nTQ
- run
- mean_trigger_rate
- baseline_rate
- ratio_active
- burst_fraction
- run_duration
- run_quality
- run_duration_calc
- aafit_lambda
- aafit_bij
- aafit_pos_x
- aafit_pos_y
- aafit_pos_z
- aafit_angen_deg
- aafit_zenith_deg
- aafit_cos_zenith
- aafit_azimuth_deg
- aafit_nusedlines
- aafit_nusedhits



Oscillation Probabilities from muon neutrino to all the other flavors

Atmospheric Oscillated Weight

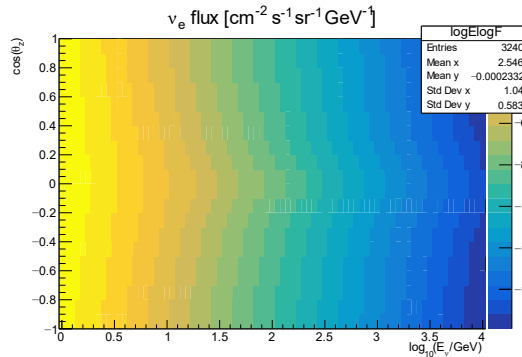
Weight Calculation



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The calculation of the oscillated atmospheric weight is given by the following equation:



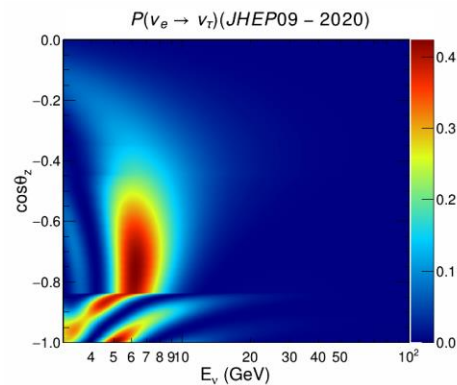
Given by Honda and taken from SWIM repository

Atmospheric Flux

Run Duration

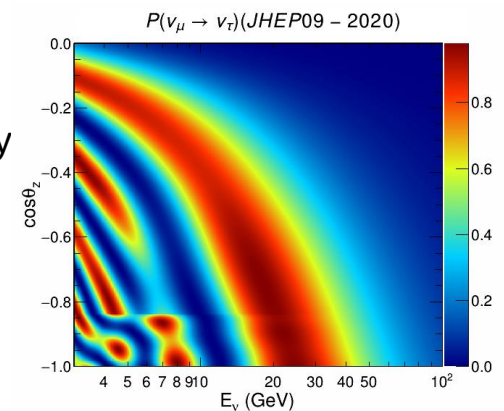
$$W_{\nu_i}^{\text{atm}} = w_2 / n_{\text{gen}} \cdot (\Phi_{\nu_e} \cdot P_{\nu_e \rightarrow \nu_i} + \Phi_{\nu_\mu} P_{\nu_\mu \rightarrow \nu_i}) \text{rdur}$$

Generated weight normalized



Oscillation Probability

Calculated with OscProb



- Pre-selection Criteria

- $\text{aafit_cos_zenith} < 0$ - reconstructed upgoing from AAFit

OR

- $\text{showertantra_cos_zenith} < 0$ - reconstructed upgoing from ShowerTanta

- Selection Criteria

- aafit cos_zenith
- aafit lambda
- aafit nusedlines
- aafit nusedhits
- $\text{showertantra cos_zenith}$
- $\text{showertantra lambda}$
- $\text{showertantra nusedlines}$
- $\text{showertantra nusedhits}$

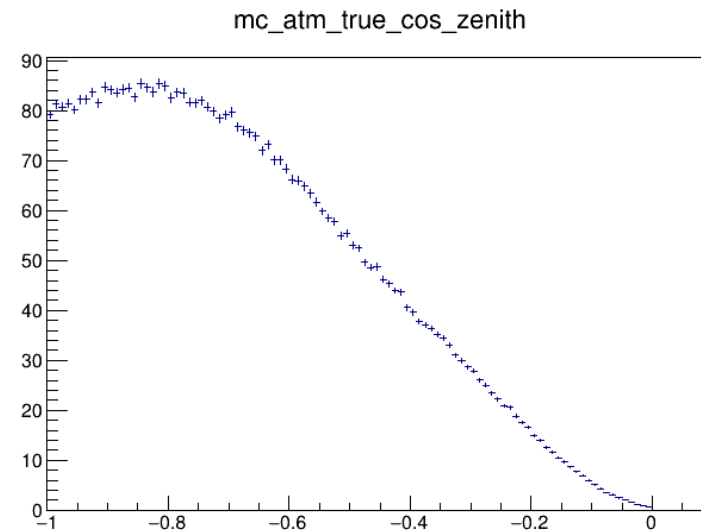
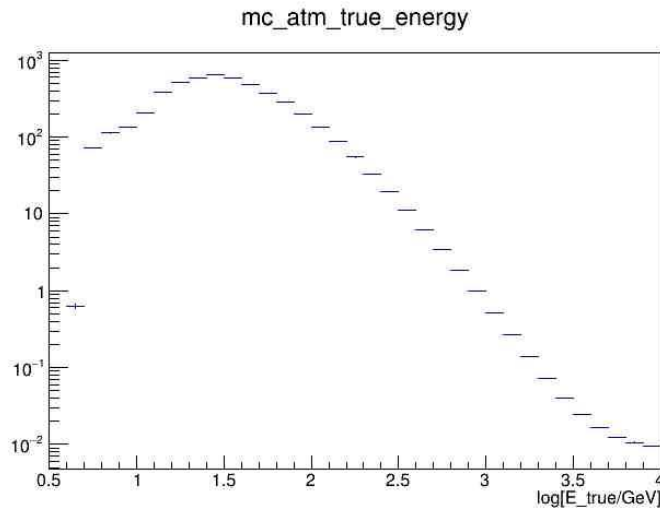
How about reco vertex?

1) Detector too small to have a fiducial volume :(

2) Initial results: reco vertex position reconstruction not sufficient.

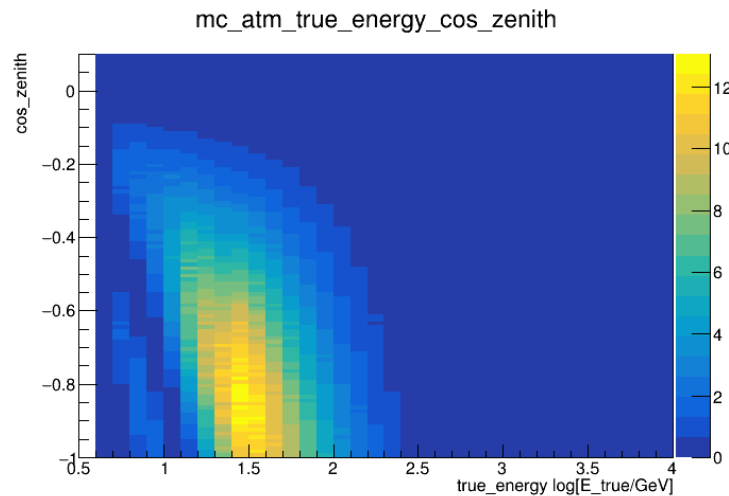
Plots with only pre-selection cuts

MC true information

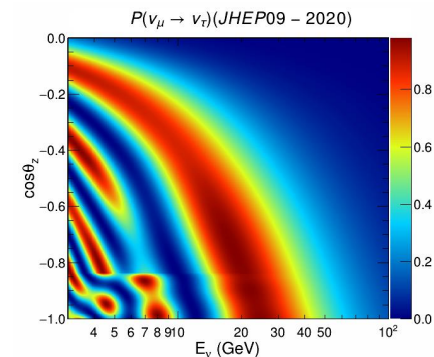


Nutau events

Integral up to
100 GeV: 4759

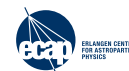


Remember oscillograms!

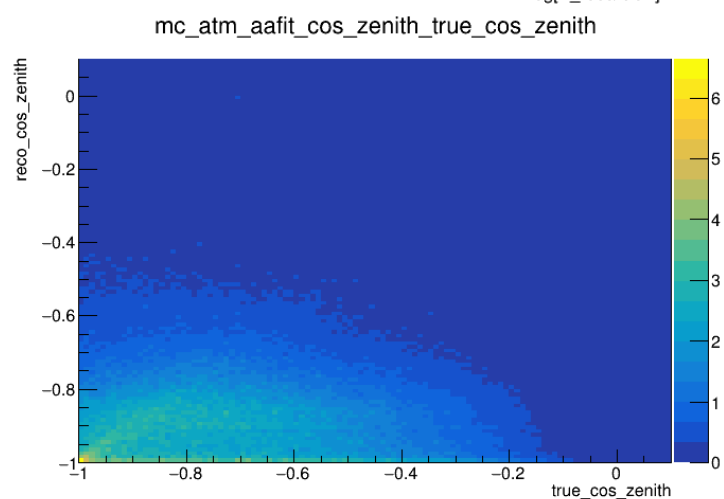
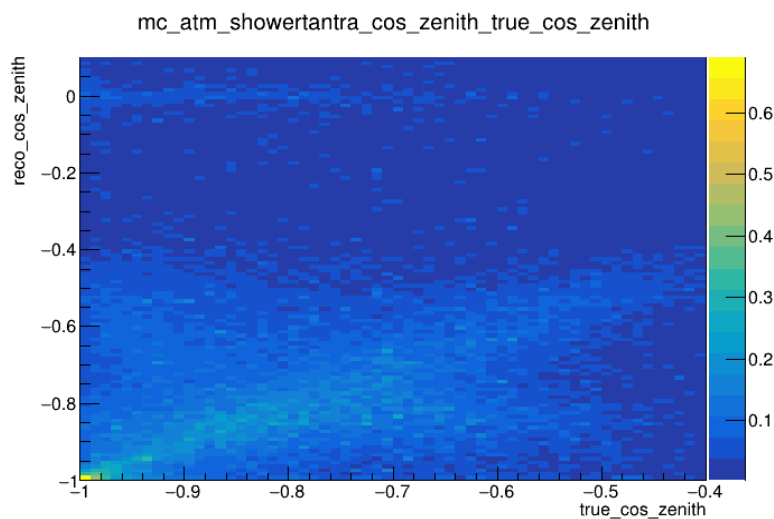
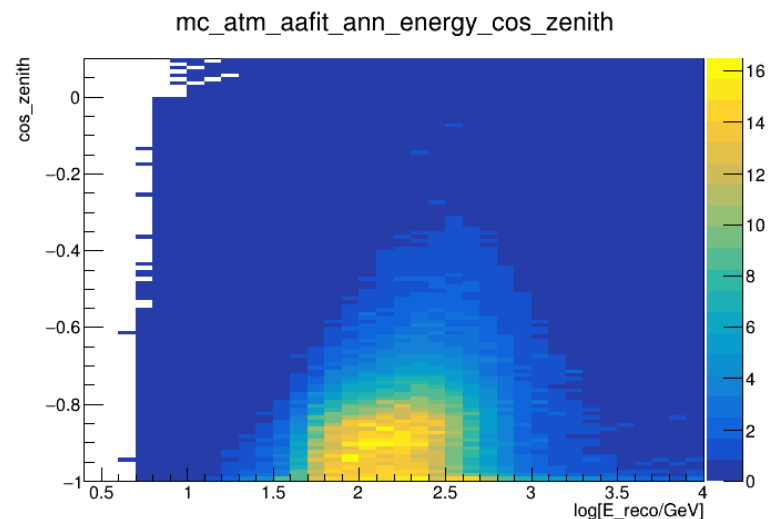
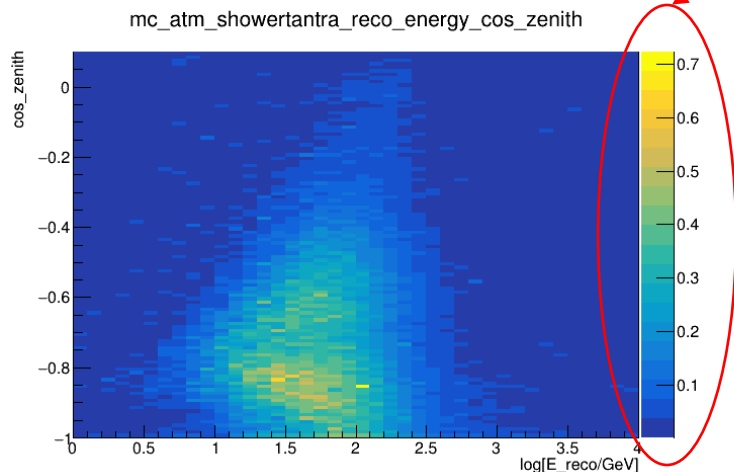


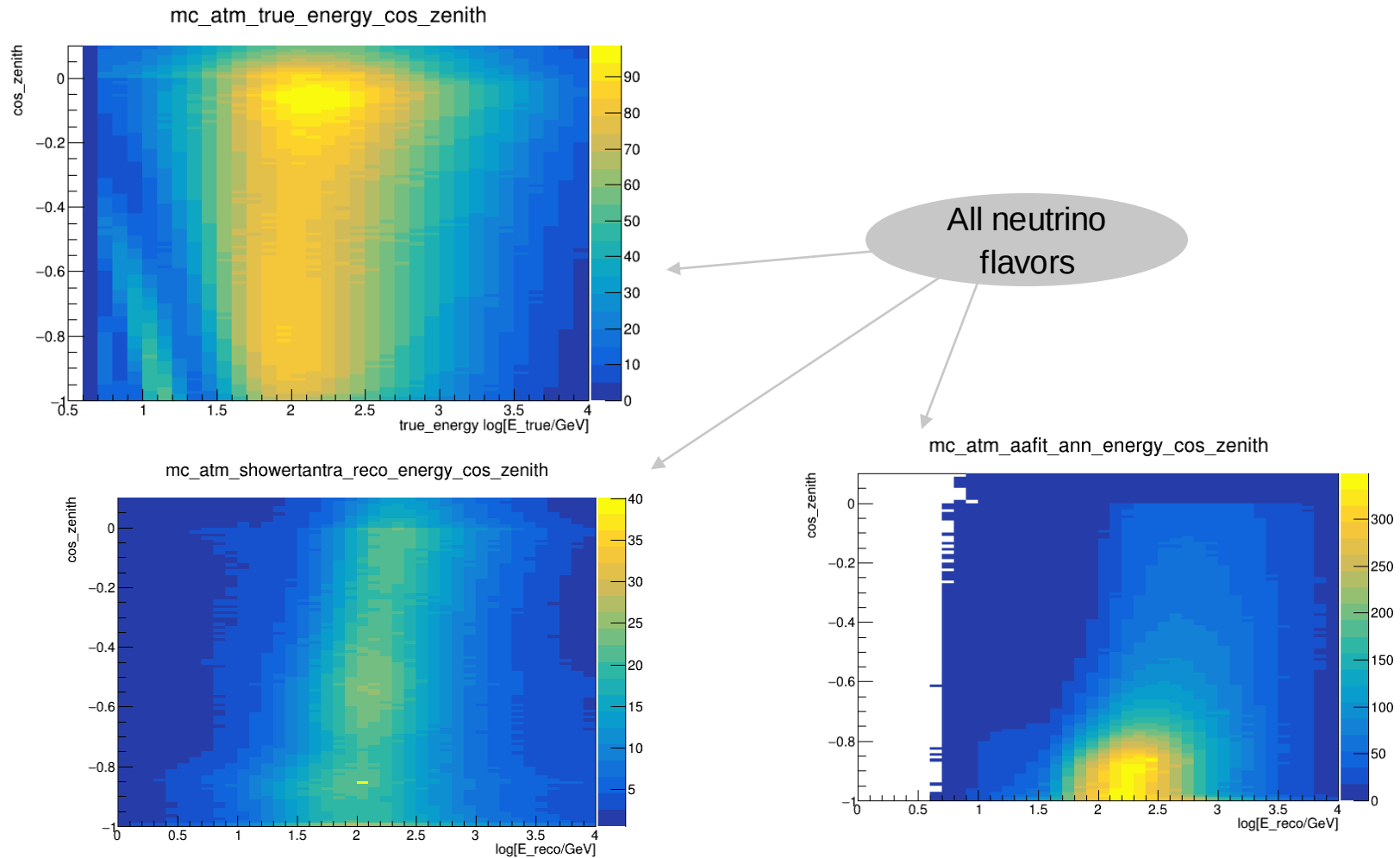
Plots with only pre-selection cuts

Reconstructions



Low number of events!





MC true upgoing low energy sample (100 GeV <)

Look into the behavior of reconstructed variables.



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Flavor	Events(weighted)	Events (%)
Total MC	63627	
Nue CC	9286	14.6
Numu CC	44921	70.6
Nue+Numu NC	3317	5.2
Nutau CC+NC	6103	9.5
Nutau CC shower	3609	5.8
Nutau CC track	1135	1.9
Nutau NC	1359	1.8

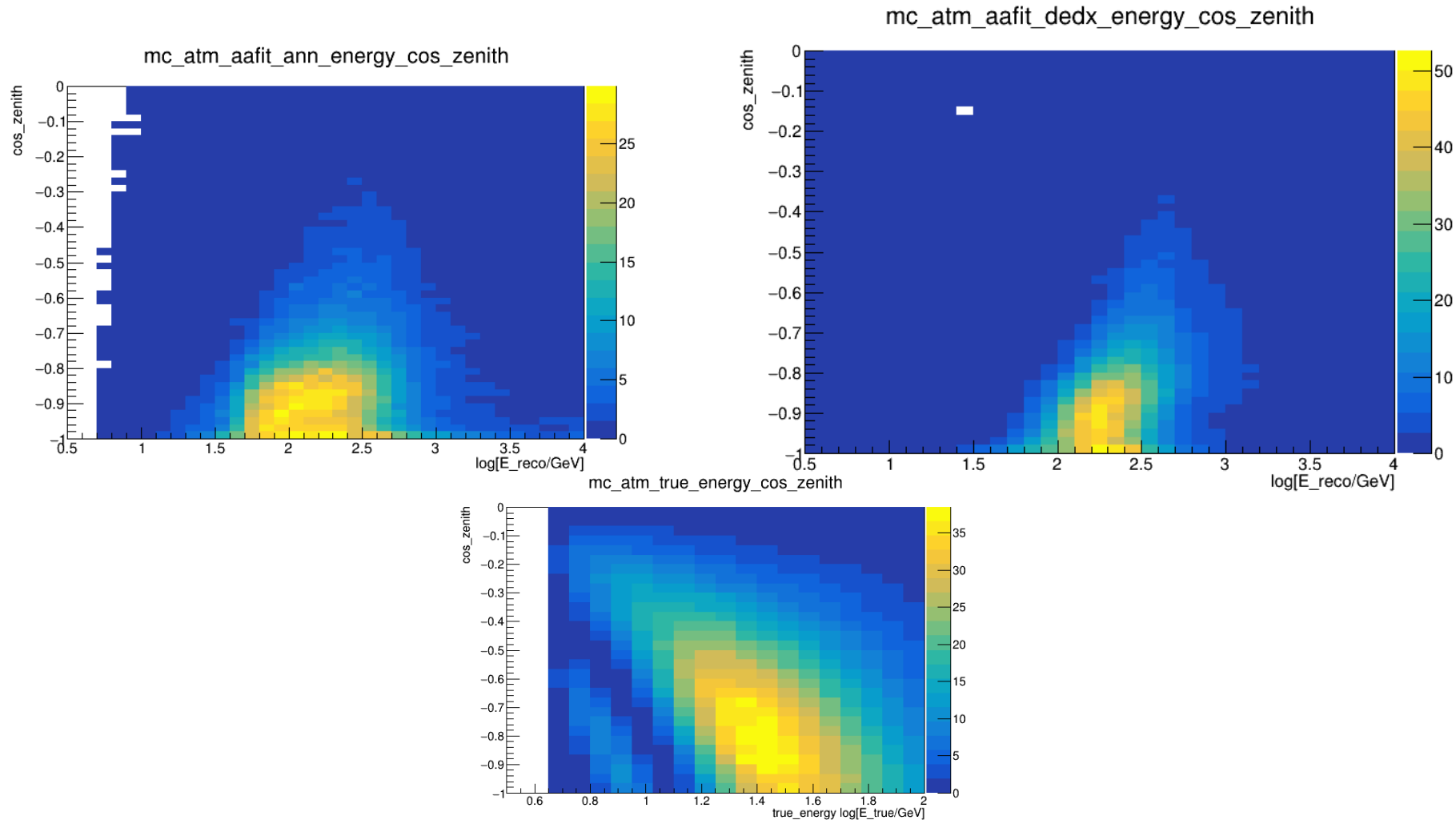
Summary of number of weighted events

MC true upgoing low energy sample ($100 \text{ GeV} <$)

Look into the behavior of reconstructed variables.

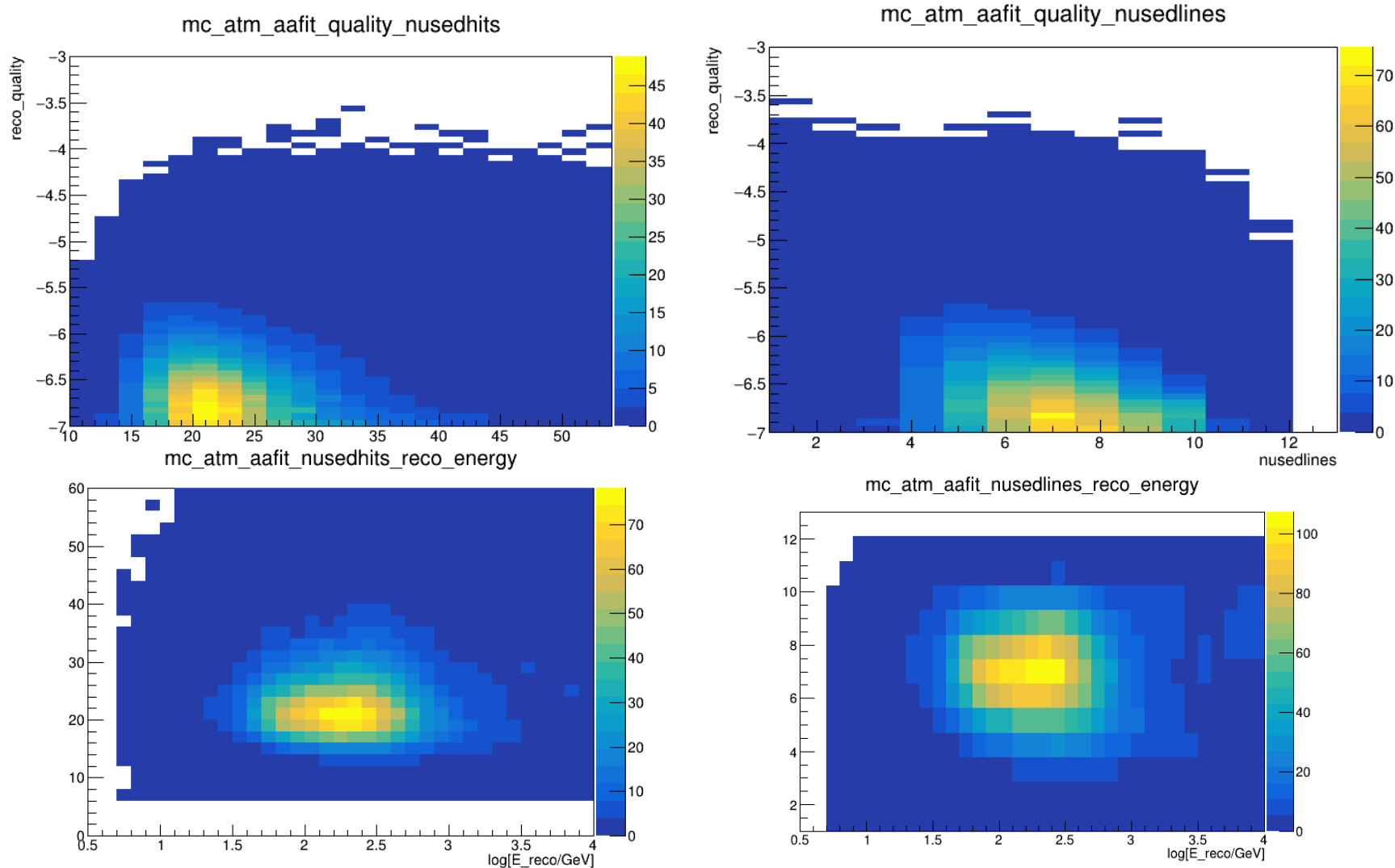


Looking to the whole signal:



MC true upgoing low energy sample (100 GeV <)

Look into the behavior of reconstructed variables.

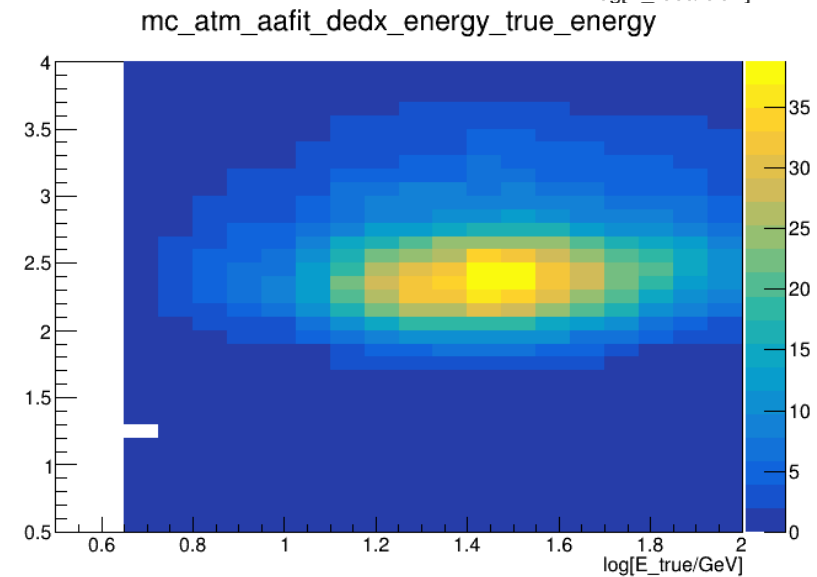
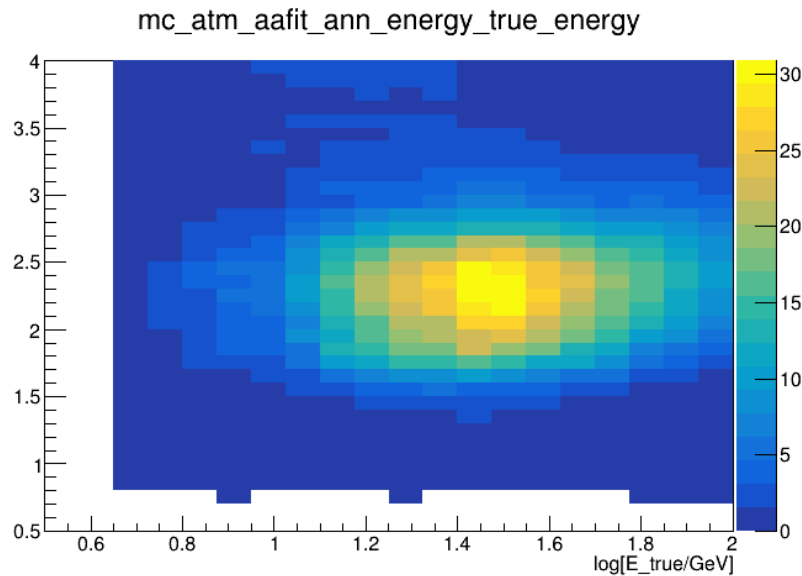
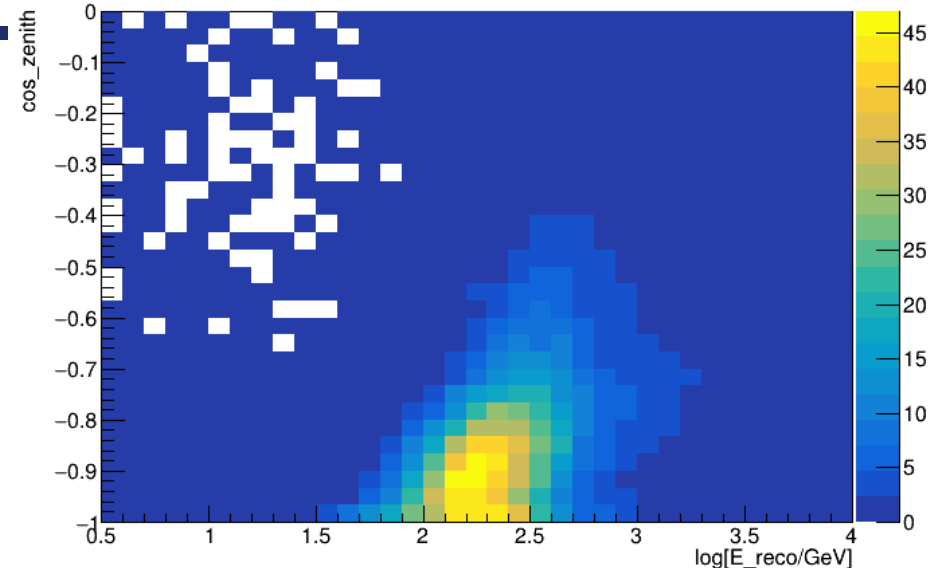
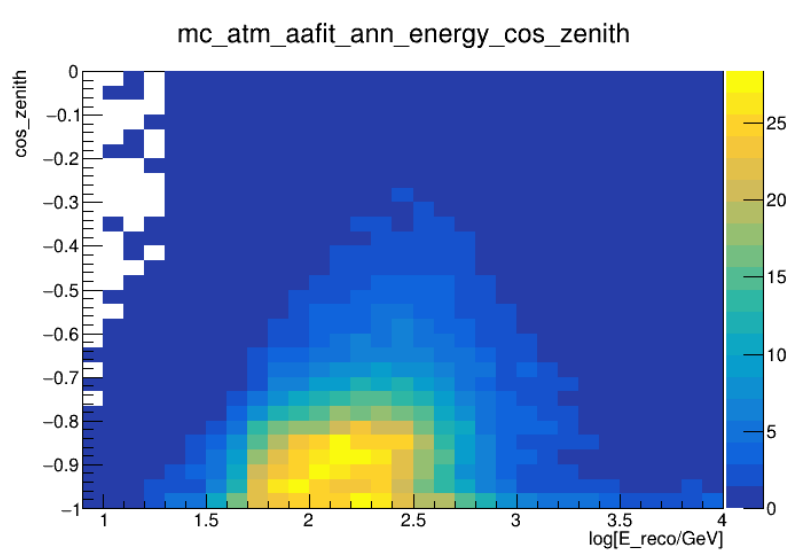


MC true low energy sample ($100 \text{ GeV} <$)



Looking into our shower signal:

mc_atm_aafit_dedx_energy_cos_zenith



MC true low energy sample ($100 \text{ GeV} <$)

Look into the behavior of reconstructed variables.

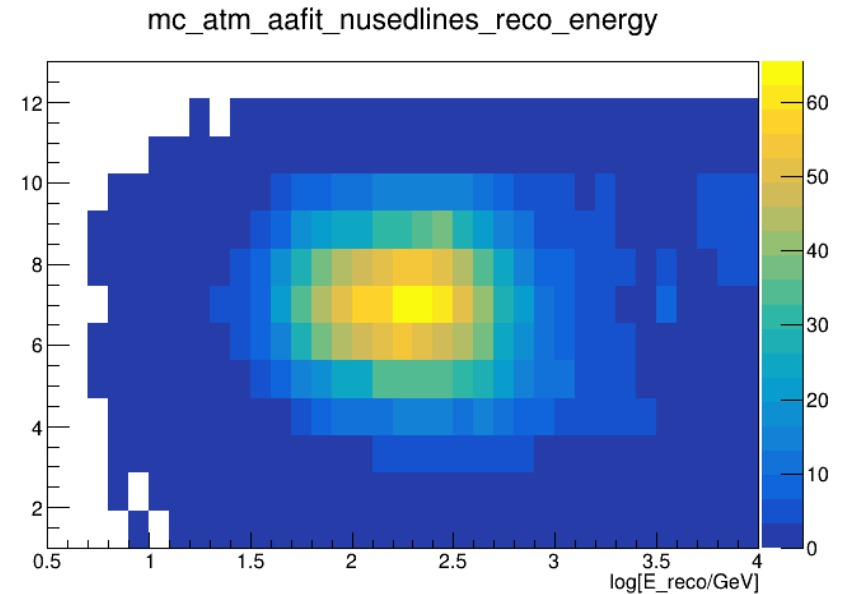
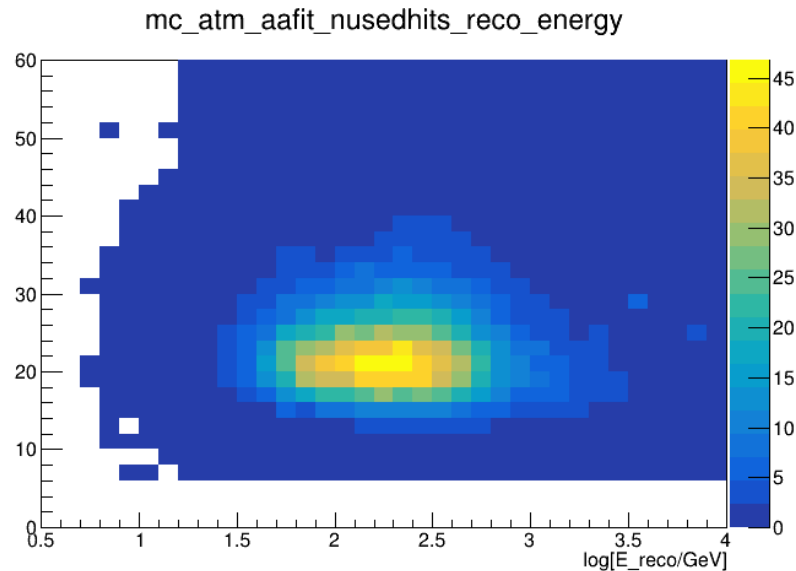
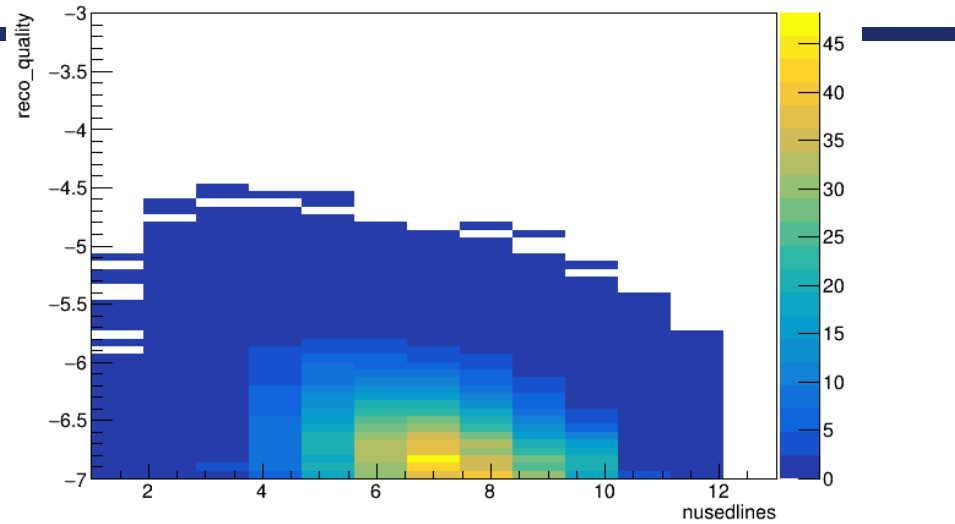
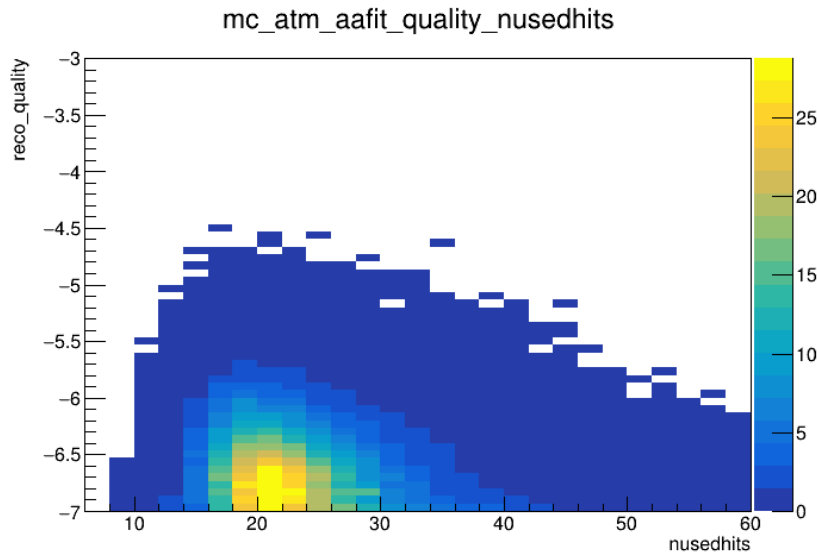


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Looking into our shower signal:

mc_atm_aafit_quality_nusedlines



Summary:

- Tau neutrinos can be found in the mc files
ANTARES!
- Normal reconstruction algorithms not designed for this energy range!
- Some apparent missing reconstructed parameters from the MC production.

Next Steps:

- Study the performance further of different reconstruction algorithms that could be provided by the AntDSTs.
- Look into other possible reconstruction algorithms (maybe NNfit from Juan Garcia Mendez...)



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Thanks a lot for your attention!

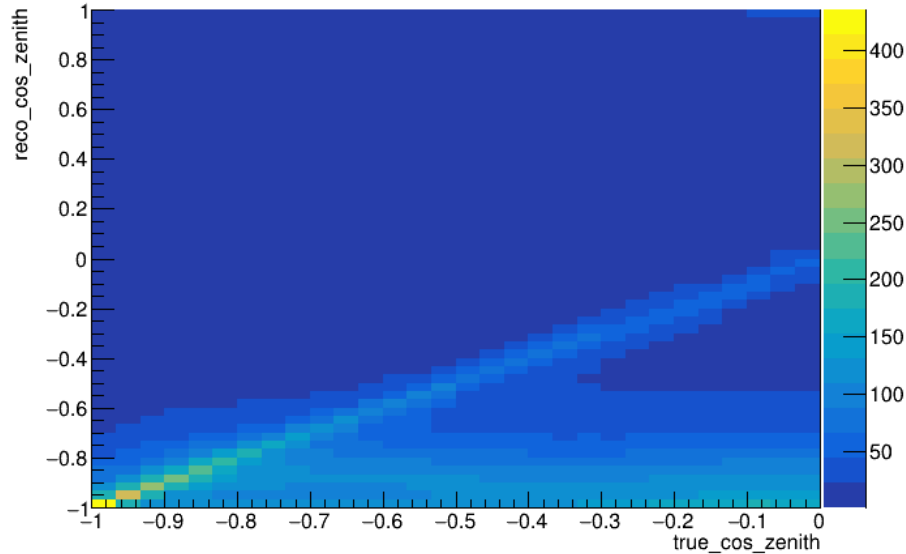
AAfit performance with muon neutrinos



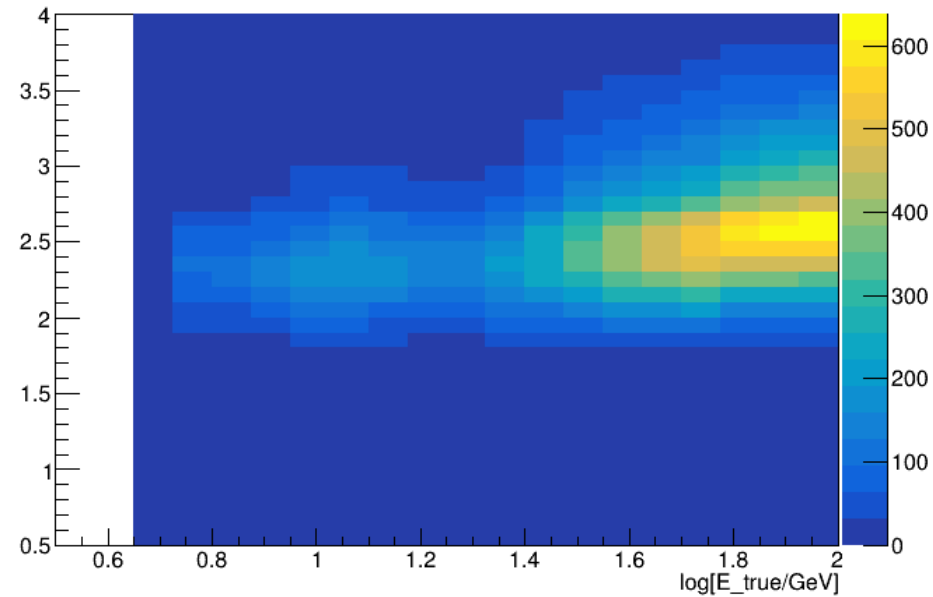
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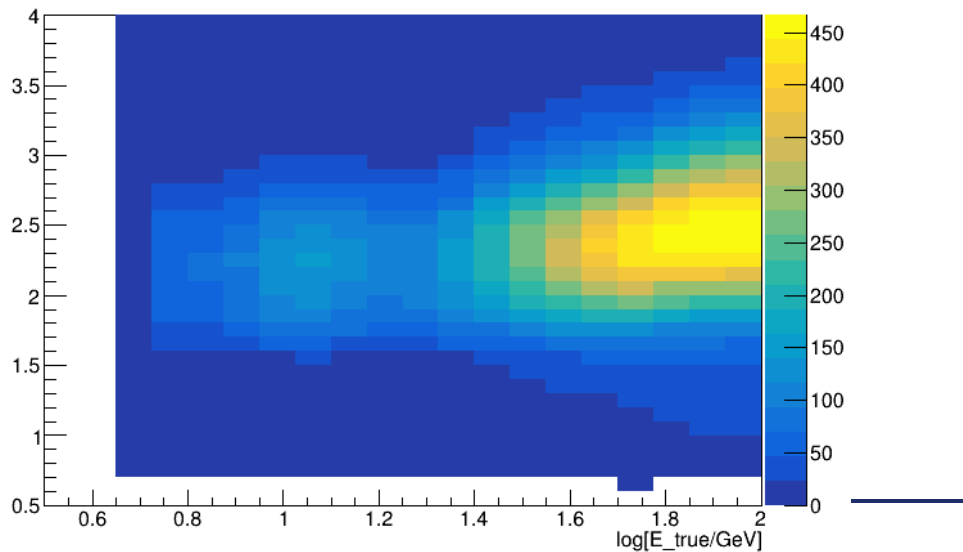
mc_atm_aafit_cos_zenith_true_cos_zenith



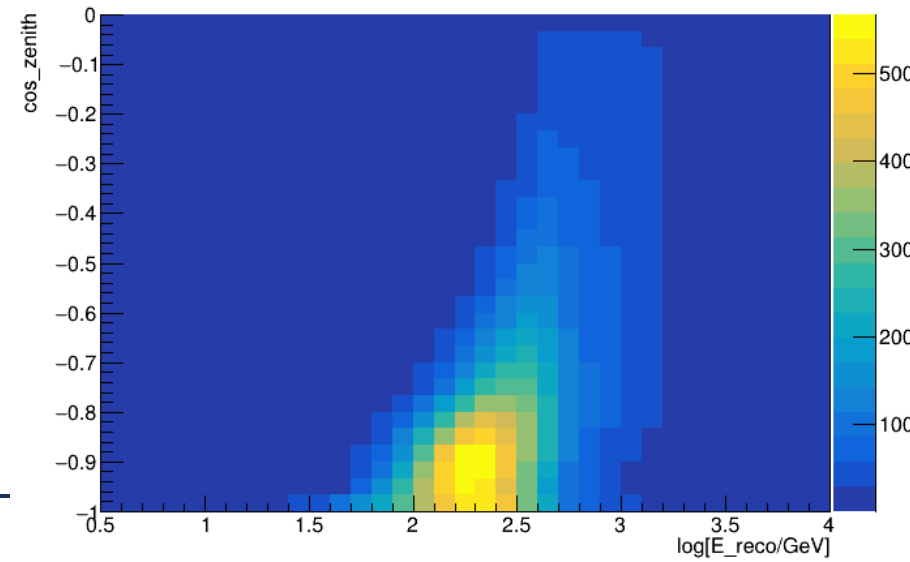
mc_atm_aafit_dedx_energy_true_energy



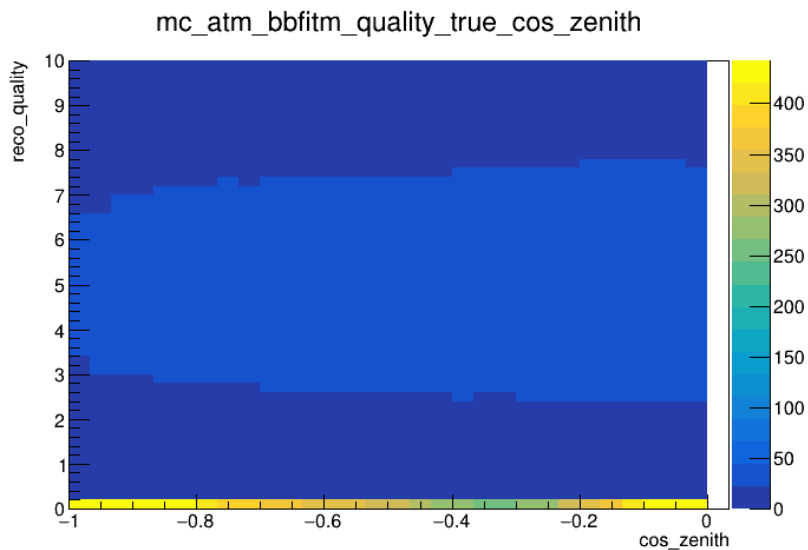
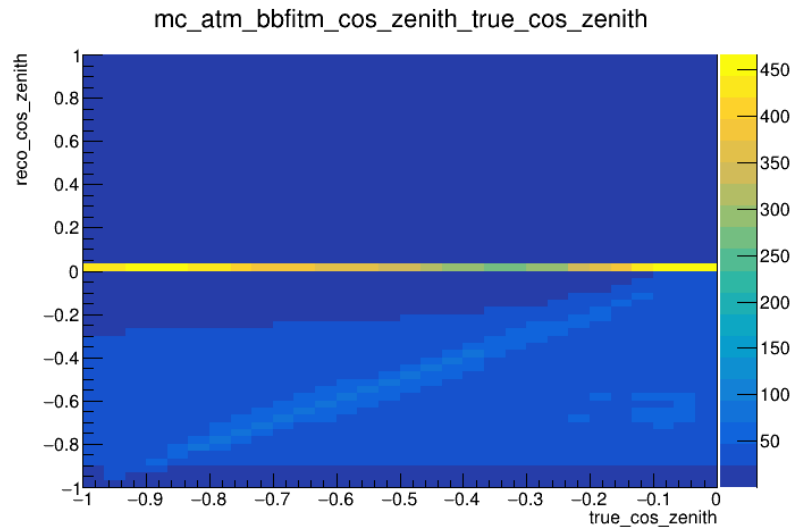
mc_atm_aafit_ann_energy_true_energy



mc_atm_aafit_dedx_energy_cos_zenith



Muon neutrinos



Tau neutrinos shower signal

