

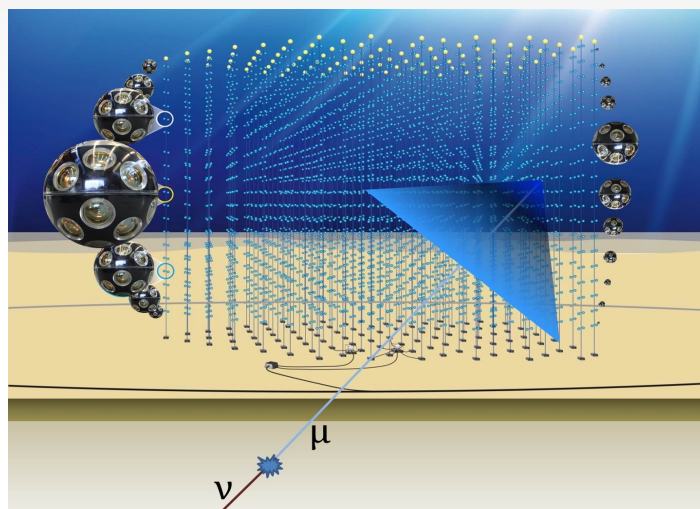


European Union
European Social Fund



Energy reconstruction of high energy muon and neutrino events in KM3NeT

for the KM3NeT collaboration



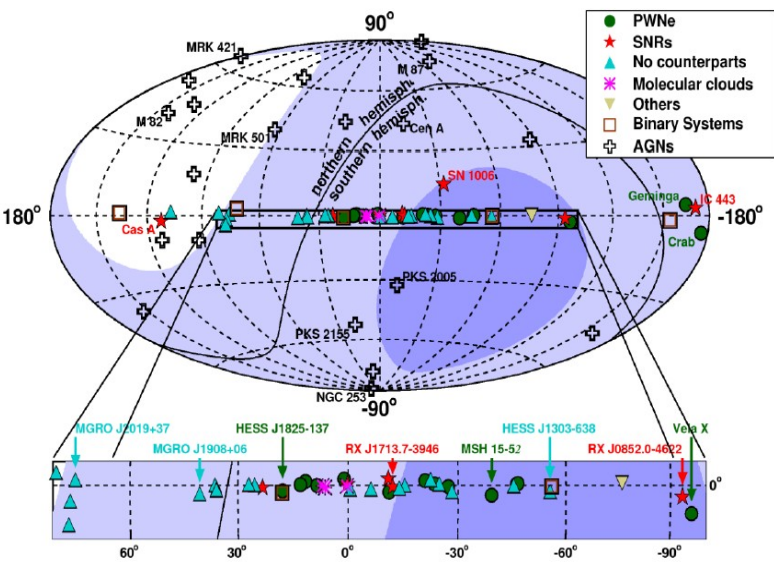
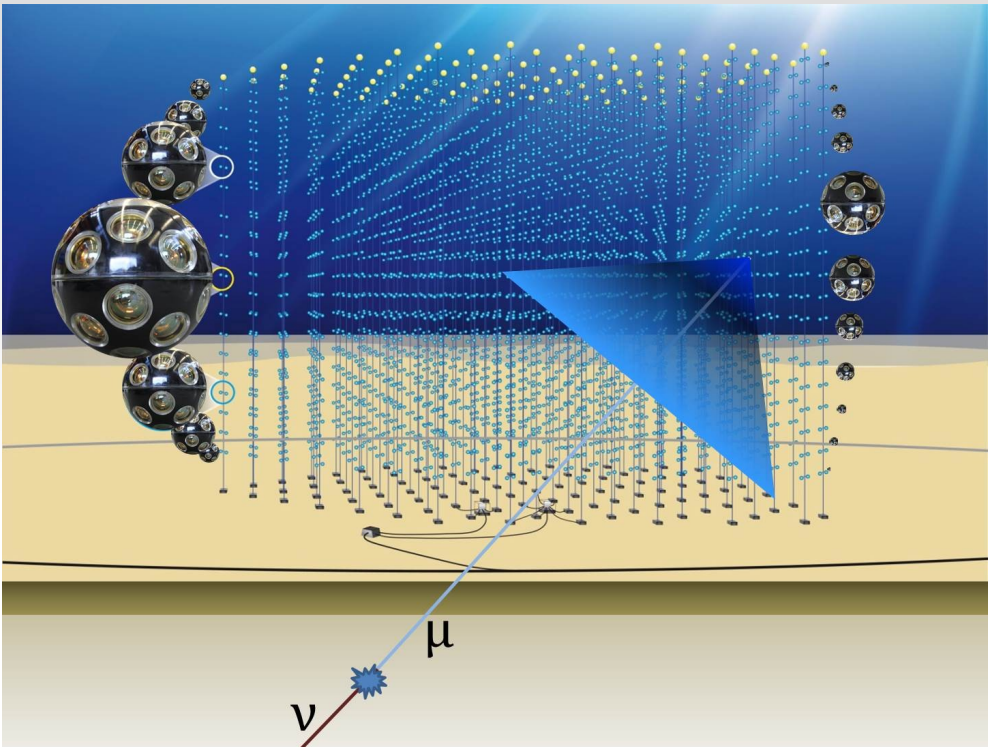
Drakopoulou Evangelia
N.C.S.R. Demokritos



KM3NeT



- **KM3NeT** → Neutrino telescope with volume of **several km³** which will be placed in the Mediterranean Sea.
- The telescope will search for **neutrinos** from galactic and extragalactic astrophysical sources (like Gamma Ray Bursts, Supernovae, Colliding Stars).



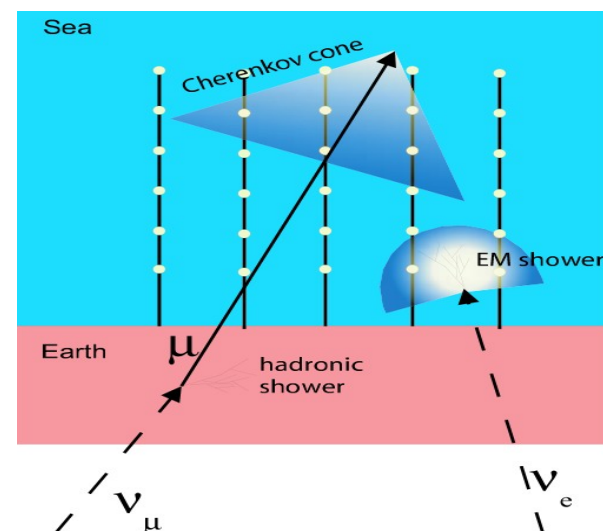
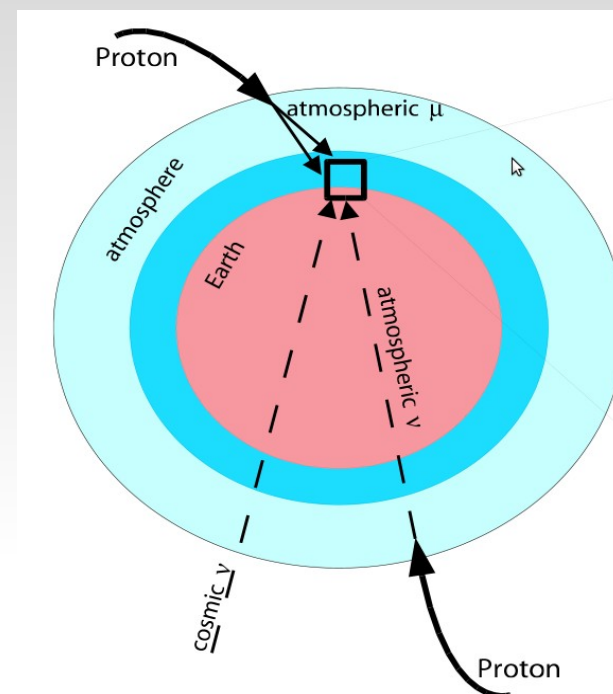
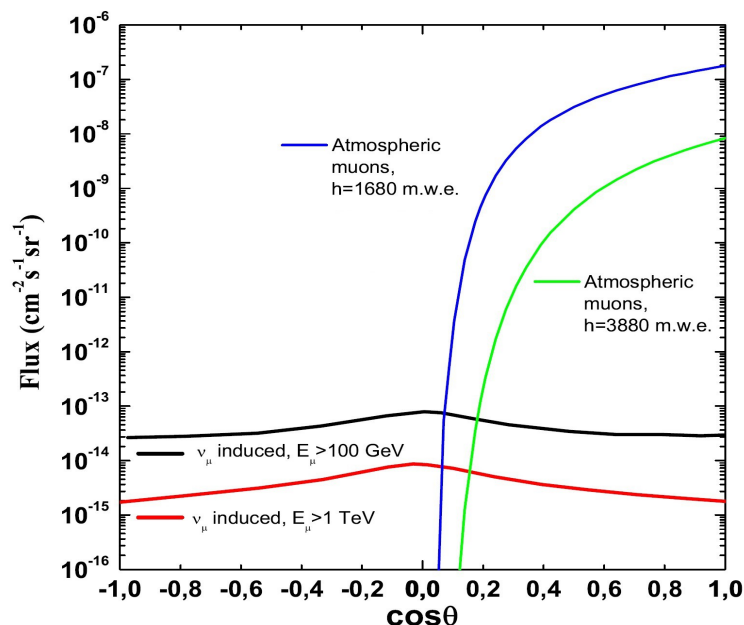
- Sky coverage in galactic coordinates for a detector located in the Mediterranean Sea.
- Dark (light) areas are visible at least 75% (25%) of the time.



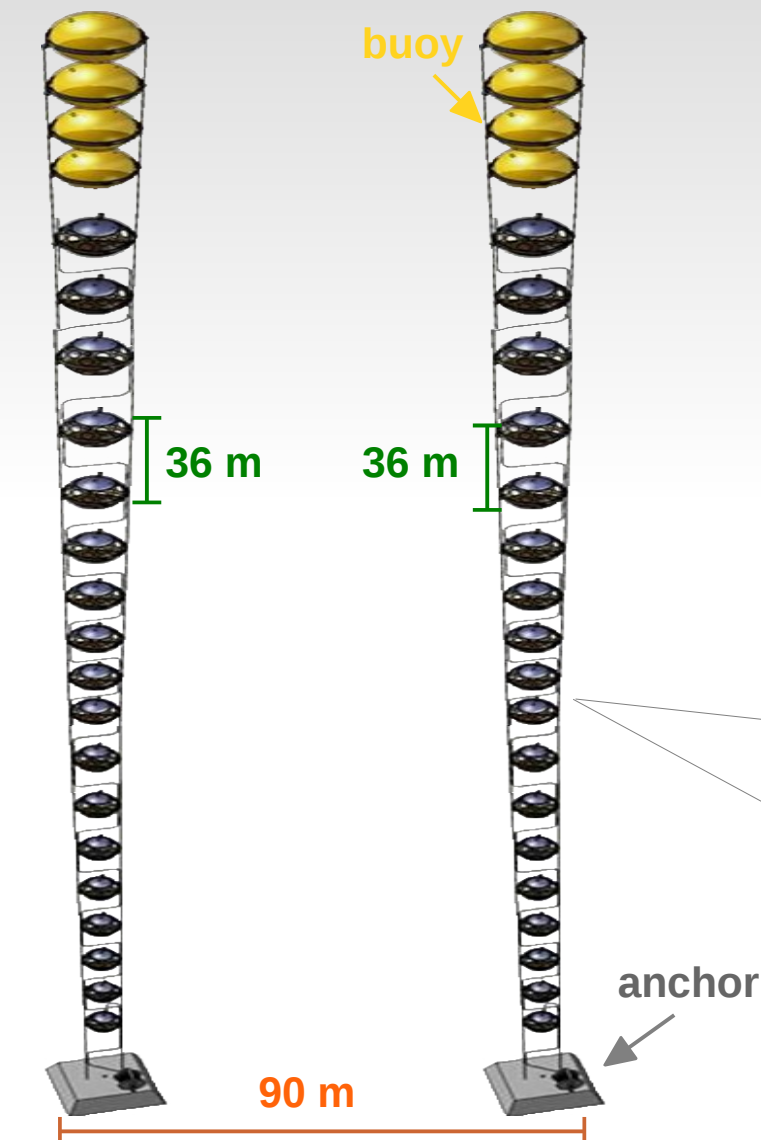
KM3NeT - Backgrounds



- **Atmospheric Muons** : contained in the extensive air showers produced by cosmic rays in the atmosphere.
- **Atmospheric Neutrinos** : produced by charged kaons or pions in cosmic ray interactions in the atmosphere.
- K^{40} : decays of radioactive potassium isotope
- **Bioluminescence** : life forms that inhabit the deep sea emit light.



Detector Configuration



- Each of the 6 blocks has an almost hexagonal geometry with **115 strings** at **90m** distance. Each string has **18 floors** and each floor has **1 Optical Module (OM)**.
- The optical modules are arranged in **vertical strings** with a height of almost **600m**.
- All data are transmitted to shore via an optical fibre network.
- Each optical module consists of a **17" glass sphere**, equipped with **31 3" photomultipliers**.



Muon Energy Reconstruction

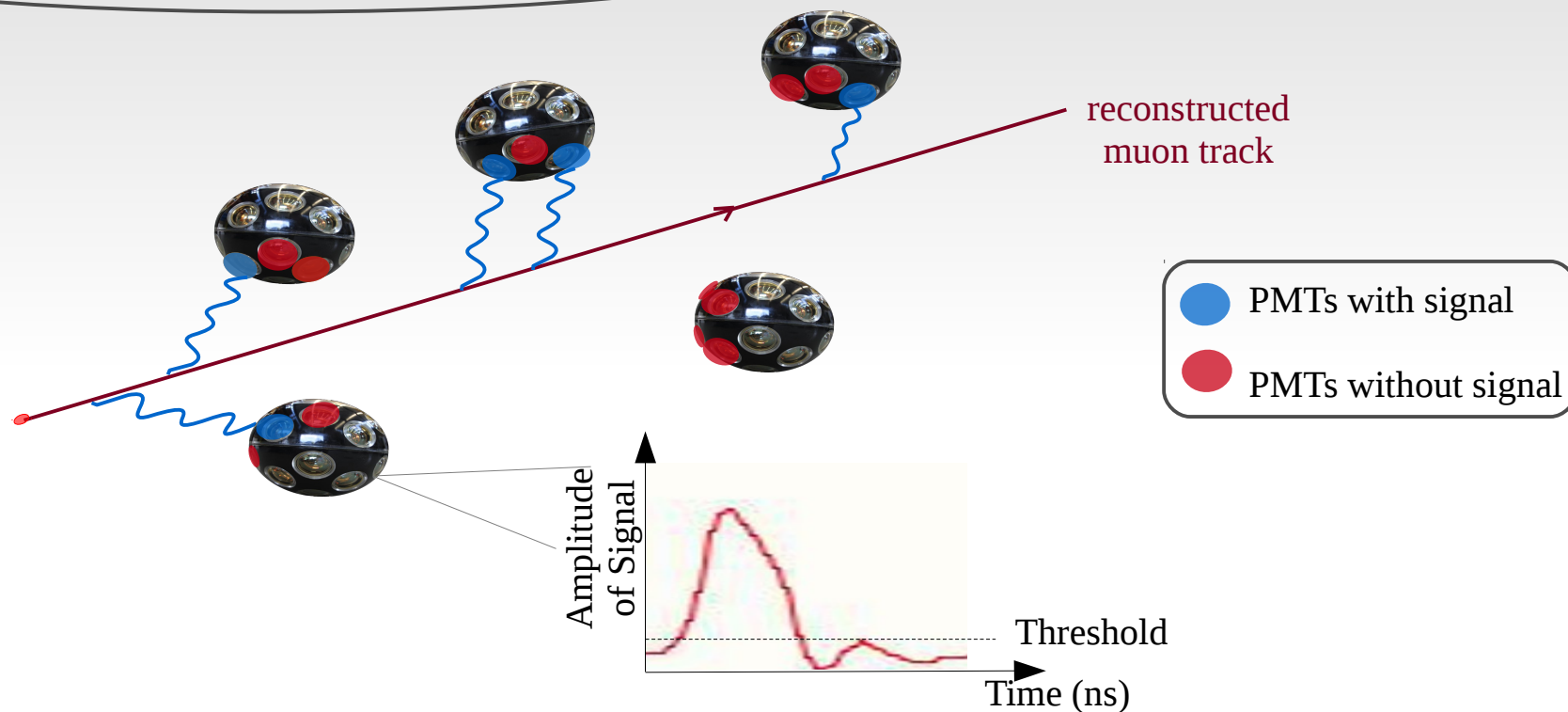
MultiVariate Analysis

- **Muon and Neutrino Energy Estimation:** a Multi-Layer Perceptron (MLP) Neural Network has been trained using information referring to:
 - ➔ Number of photomultipliers (PMTs) with signal
(weighted considering the PMT distance from the reconstructed muon track)
 - ➔ Total Time over Threshold (ToT) in PMTs (as a measure of charge in PMTs)
 - ➔ Number of OMs with signal
(weighted taken into account that muons with lower energies travel shorter distances inside the detector than muons with higher energies)
 - ➔ Number of PMTs without signal
(weighted considering that the number of PMTs that have no signal is larger for muons with lower energies)
- ♦ A minimum muon track length inside the detector volume is required in order to reliably estimate the muon energy (**containment selection**).

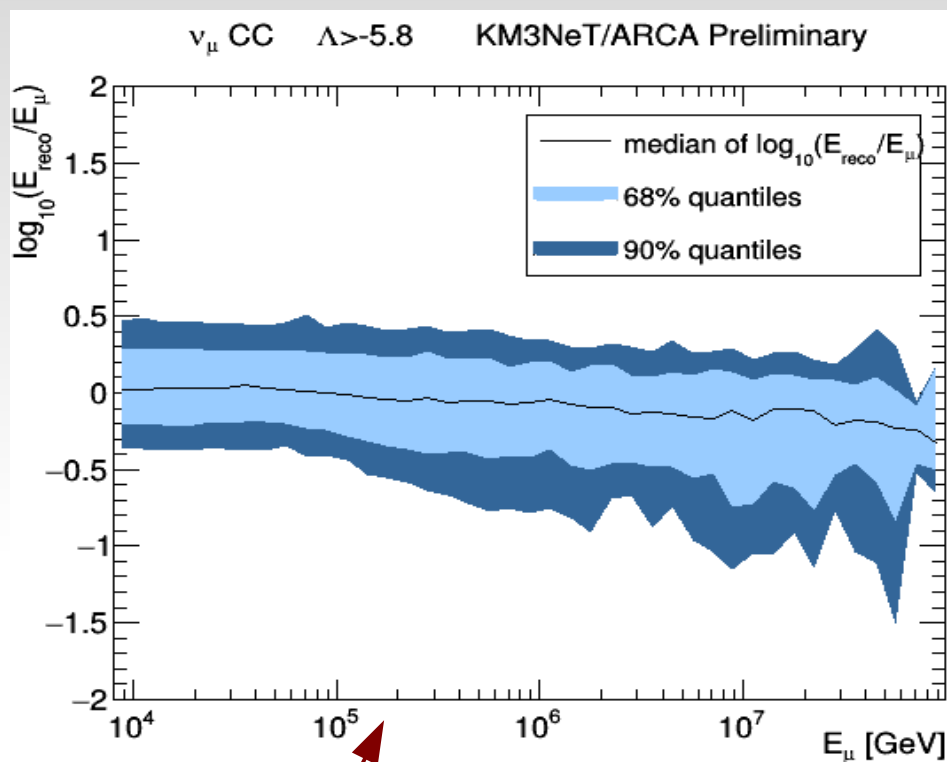
Muon Energy Reconstruction

MultiVariate Analysis

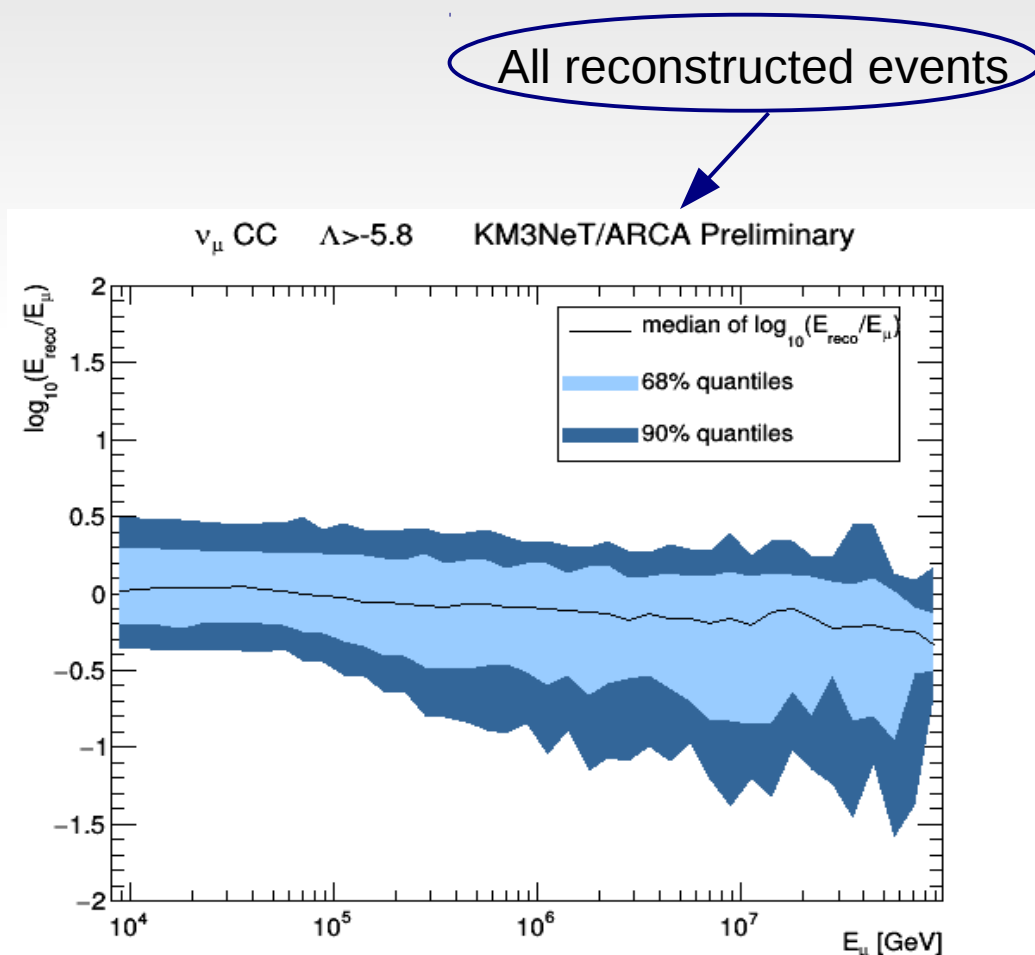
We consider the PMTs with signal used by the fitting procedure → reduction of K^{40} contribution



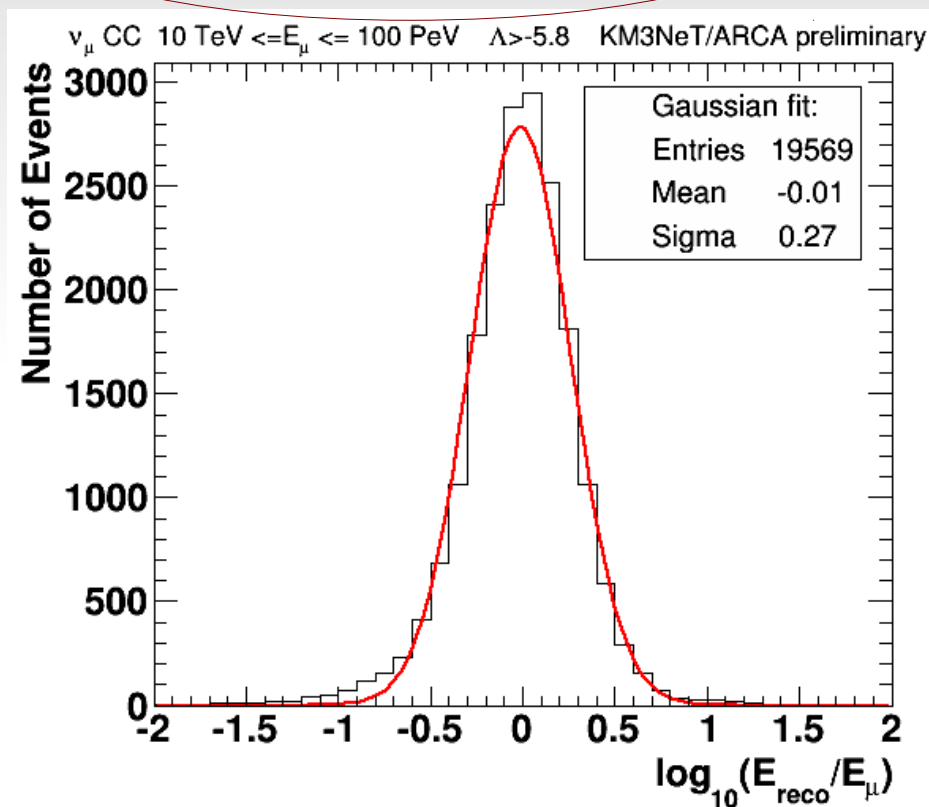
- For events that satisfy the containment selection the muon energy is estimated.
- For events that do not satisfy the containment selection a lower limit of the energy is calculated.



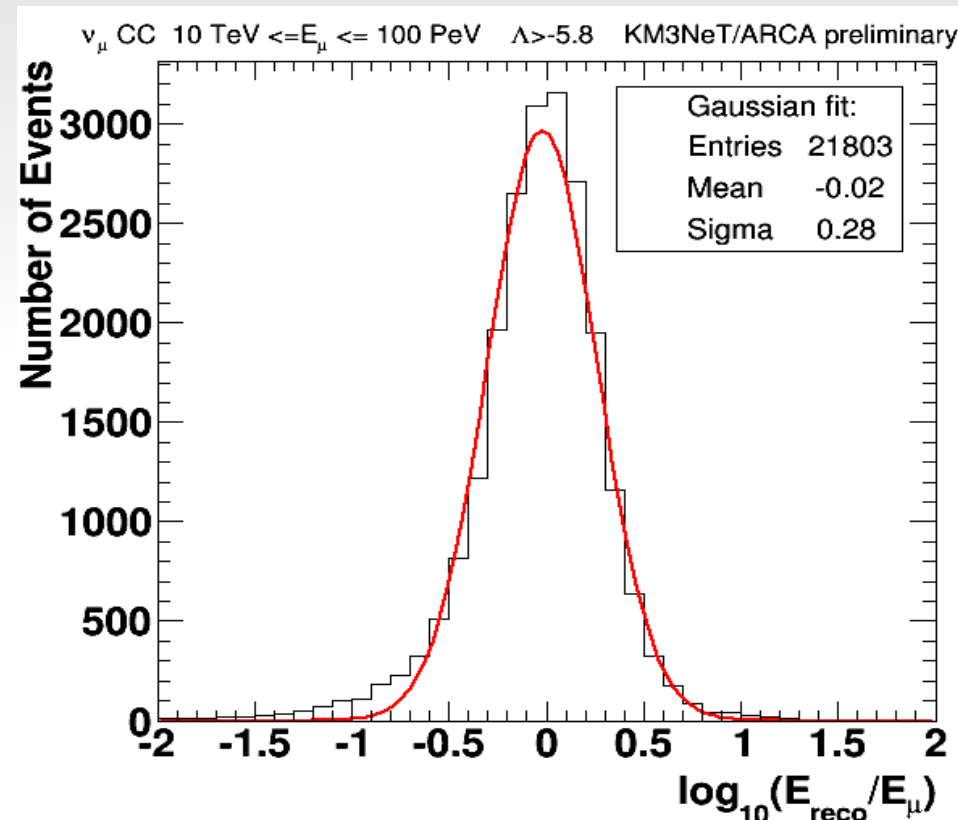
Reconstructed events that satisfy the containment selection



Reconstructed events that satisfy the containment selection



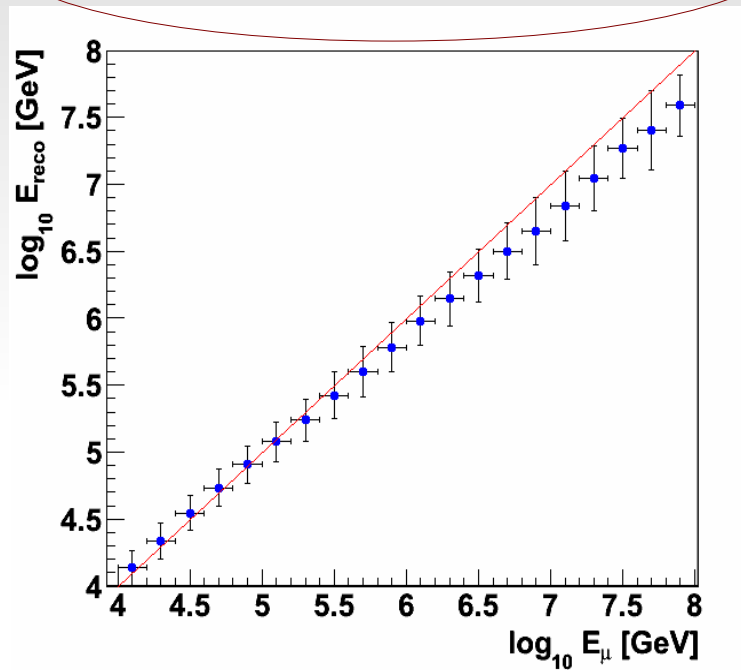
All reconstructed events



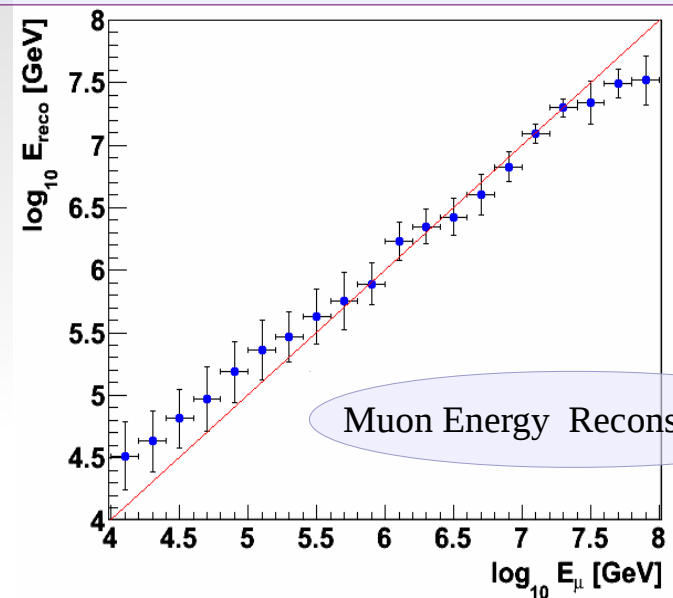
- An energy resolution of ~ 0.27 has been achieved for events that satisfy the containment selection.
- The energy resolution is ~ 0.28 for all reconstructed events.

Muon and Neutrino Energy Reconstruction

Reconstructed events that satisfy the containment selection



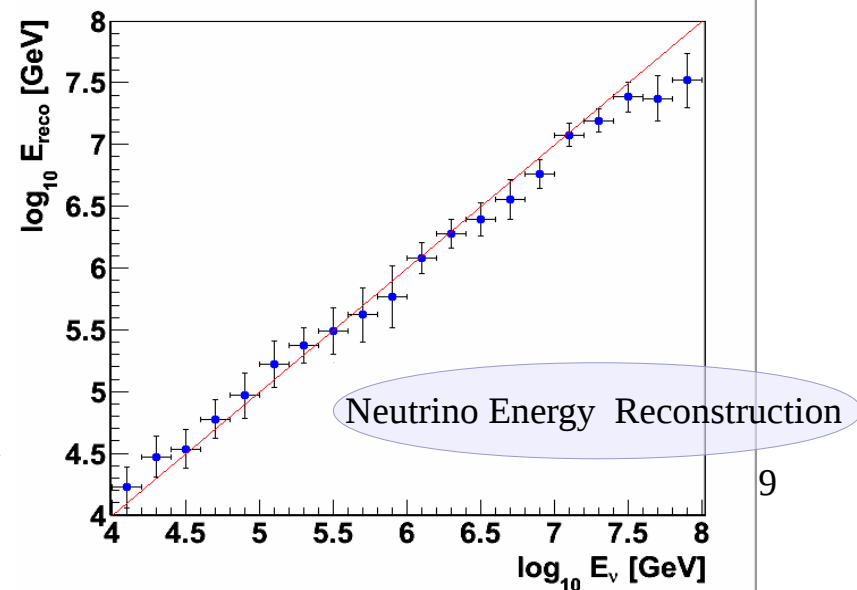
Events with the reconstructed vertex inside the instrumented volume



Muon Energy Reconstruction

→ The neutrino energy can be reliably estimated if the interaction vertex is close to or inside the instrumented volume.

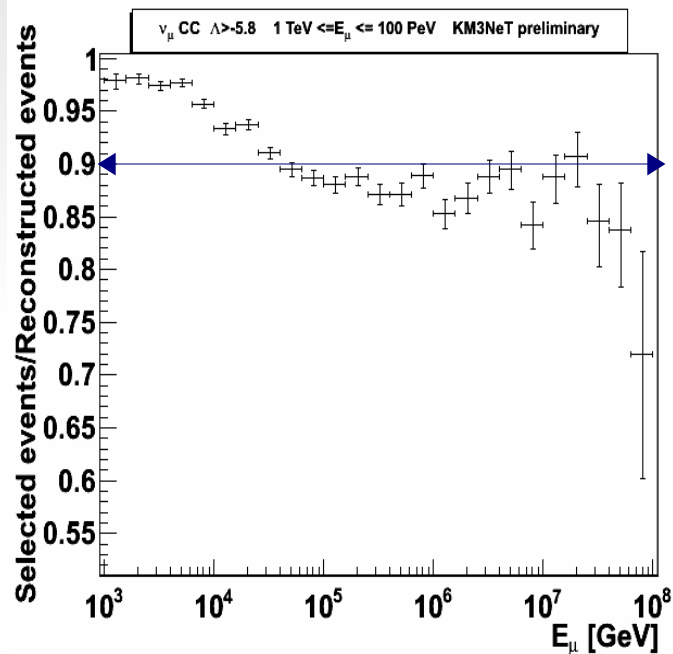
→ Very good linear correlation of the reconstructed and the simulated E_{ν} .



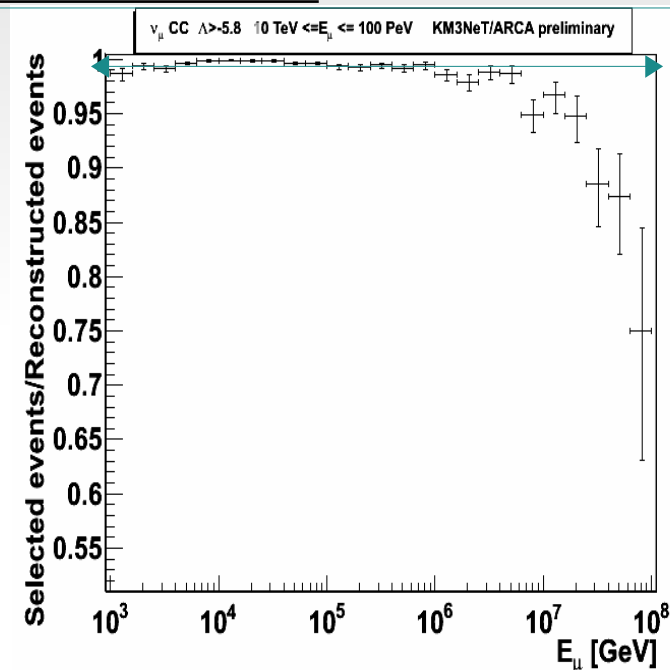
Neutrino Energy Reconstruction

Efficiency of the Muon Energy Reconstruction

Efficiency of this energy estimator for all reconstructed events.



Efficiency of this energy estimator for reconstructed events that cross the detector volume.



Energy Reconstruction:

- A very high efficiency of **~ 90%** for $E_\mu \geq 10 \text{ TeV}$ is achieved.
- The efficiency is **~ 99.5%** for $E_\mu \geq 10 \text{ TeV}$ for events that cross the instrumented volume.

Evaluating the systematics

- The systematics were evaluated for the reconstructed tracks that satisfy the containment selection.

$\nu_{\mu} CC \ 10 TeV \leq E_{\mu} \leq 100 PeV \ KM3NeT / ARCA Preliminary$

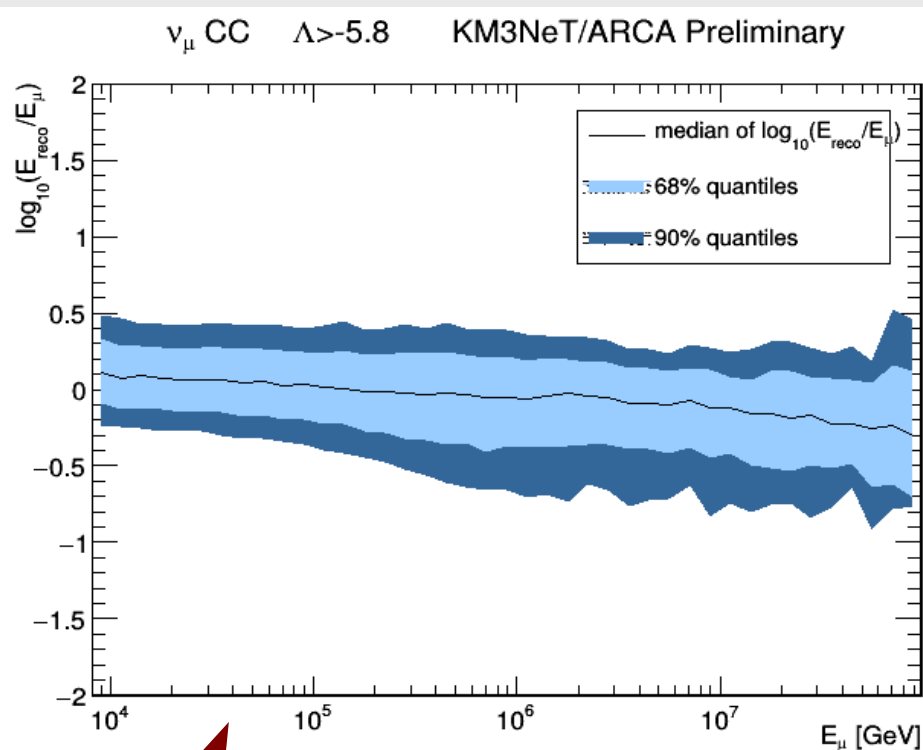
Energy Resolution

$\Lambda > -5.8$	Gaussian fit: Mean (%)	Gaussian fit: σ (%)
Simulation Values:	-1.0%	27%
Absorption Length: -10%	-9.5%	26%
Absorption Length: +10%	5.3%	27%
Scattering Length: -10%	-2.4%	27%
Scattering Length: +10%	-0.8%	27%
PMT Effective Area: -10%	-6.0%	27%
PTM Effective Area: +10%	2.0%	27%

Muon Energy Reconstruction

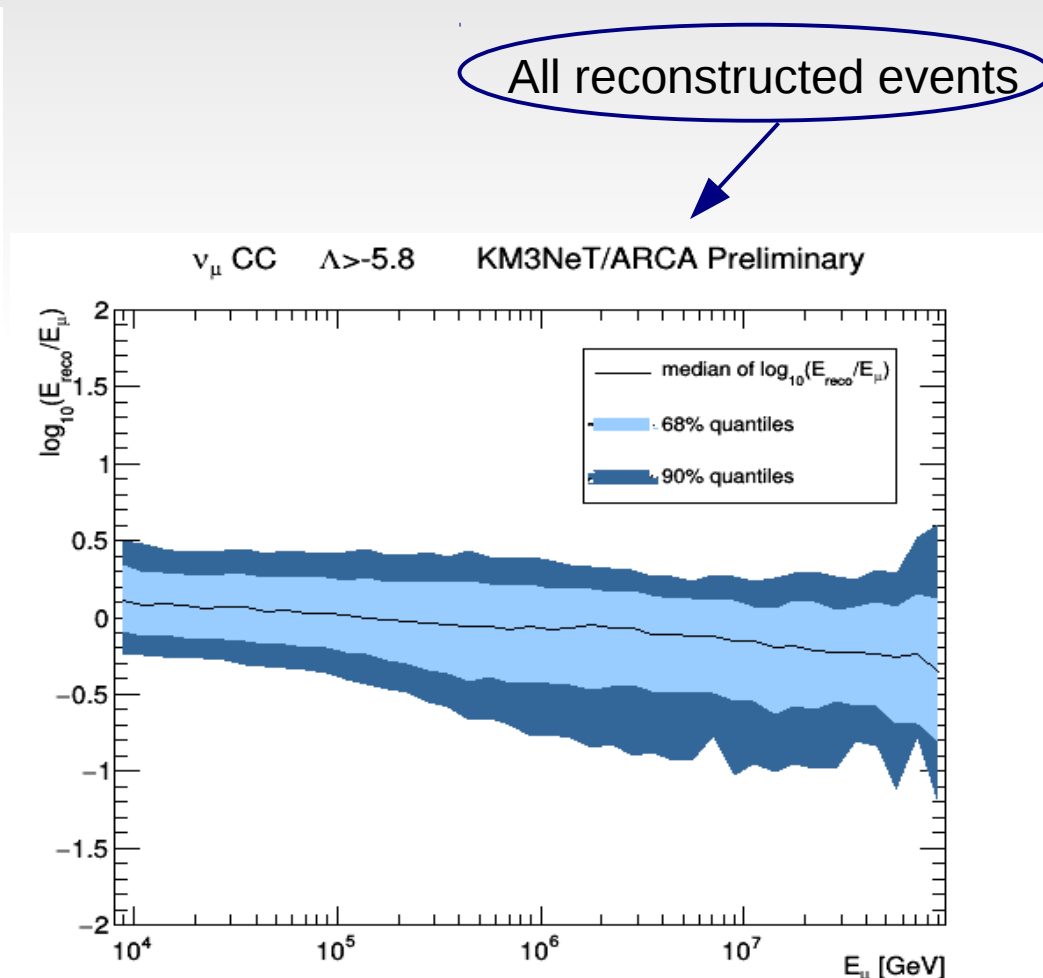
Alternative detector configuration

- The performance of this energy reconstruction has also been tested for a detector configuration with a larger average horizontal distance between strings, i.e. **120 m** instead of **90 m** corresponding to an instrumented volume of $\sim 0.8 \text{ km}^3$ per block.



Reconstructed events that satisfy containment selection

E. Drakopoulou

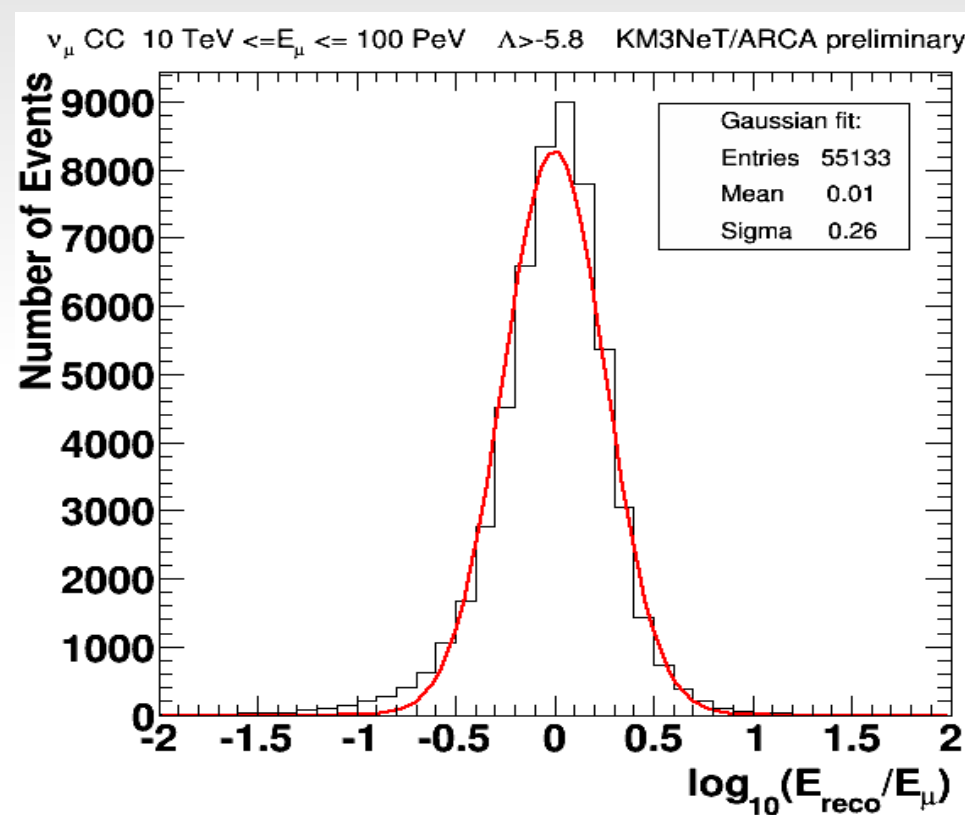
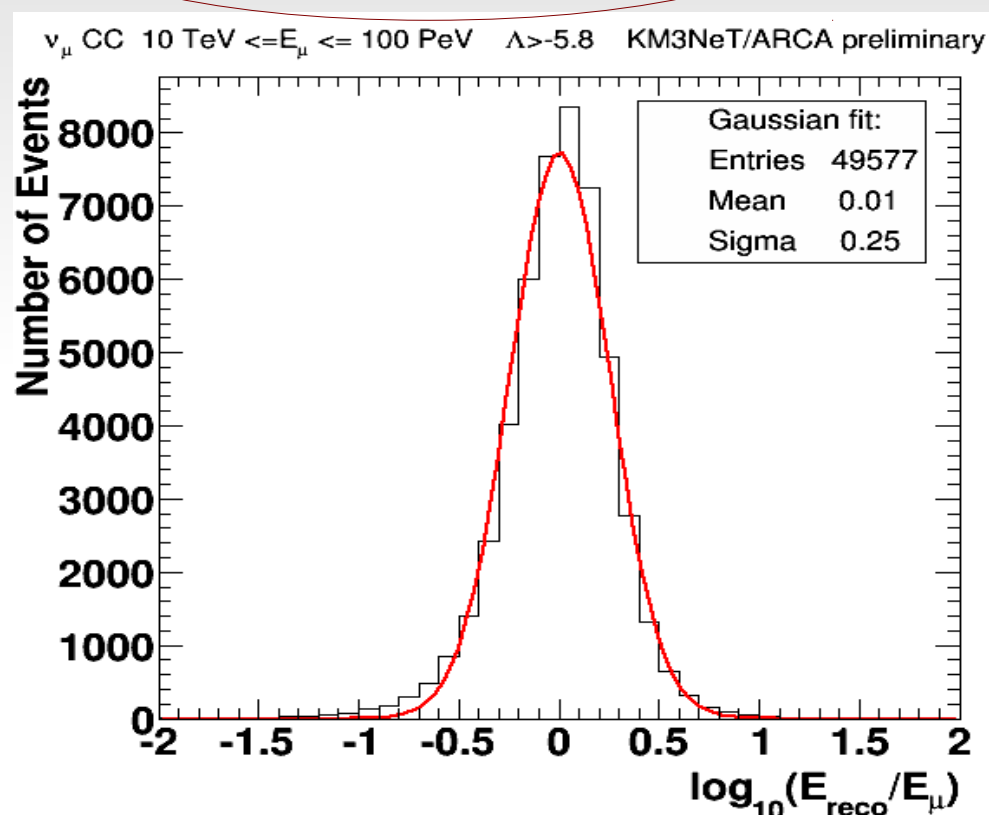


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Reconstructed events that satisfy the containment selection

All reconstructed events



- An energy resolution of ~ 0.25 has been achieved for events that satisfy the containment selection.
- The energy resolution is ~ 0.26 for all reconstructed events.



Conclusions



- A new method for the muon and neutrino energy reconstruction employing a Multi-Layer Perceptron Neural Network with appropriate input variables was developed.
- The performance of this energy estimator is very good for muons in the high energy region ($E_\mu \geq 10 \text{ TeV}$) which is the energy regime we are mostly interested in.
- The energy resolution is ~ 0.27 for events that satisfy the containment selection and ~ 0.28 for all reconstructed events.
- For an alternative detector configuration with larger distance between strings leading to a larger instrumented volume, the energy resolution is ~ 0.25 for events that satisfy the containment selection and ~ 0.26 for all reconstructed events.



Thank you !