Muon and Neutrino Energy Reconstruction for KM3NeT
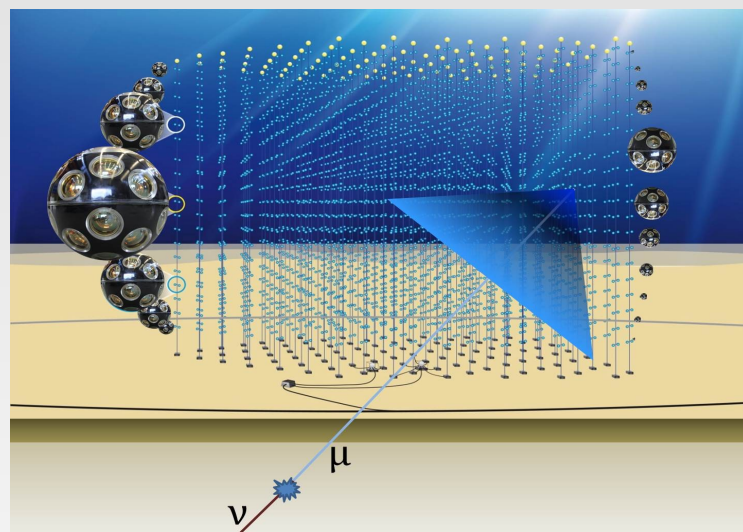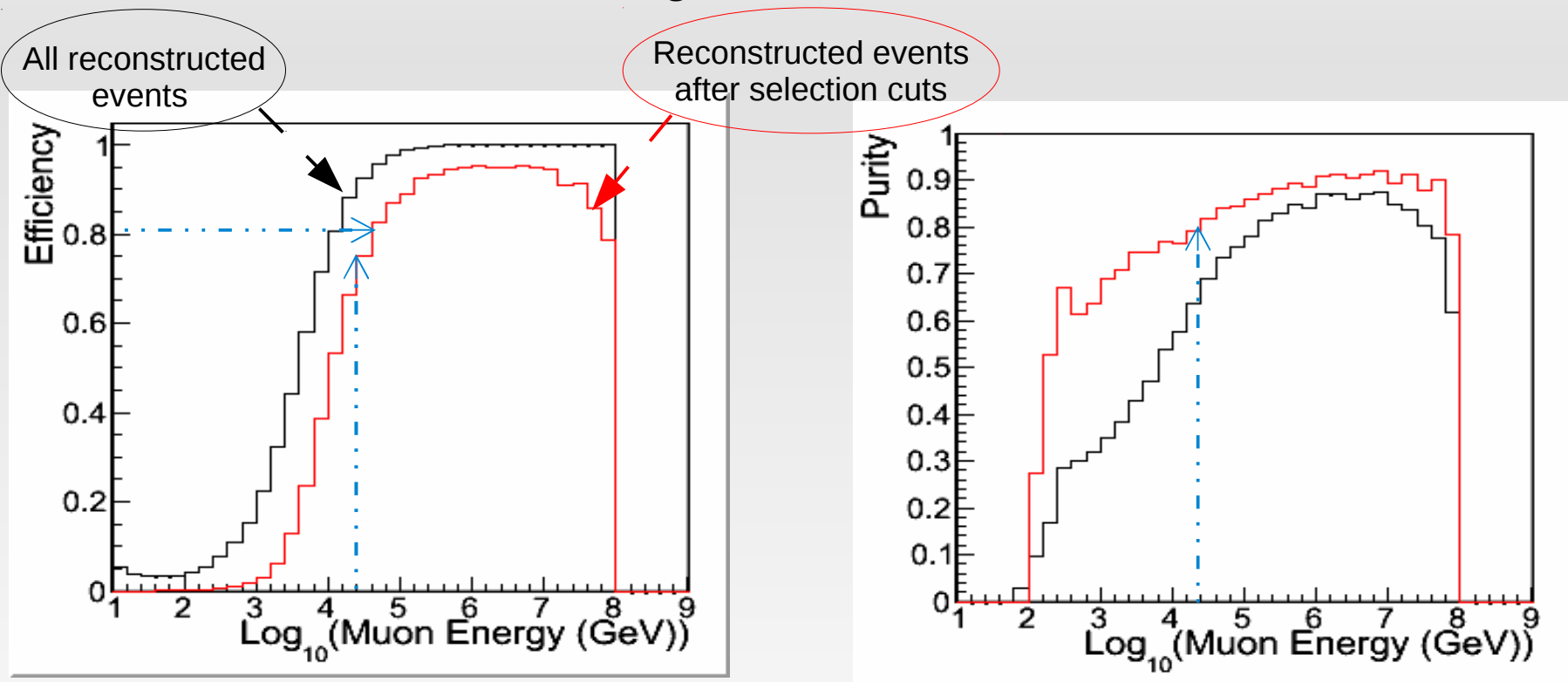
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- Muons produced by neutrinos via Charged Current interactions were reconstructed and used for the energy estimation study. Hits from signal and K^{40} background are considered. The muon tracks under consideration are crossing the detector volume.
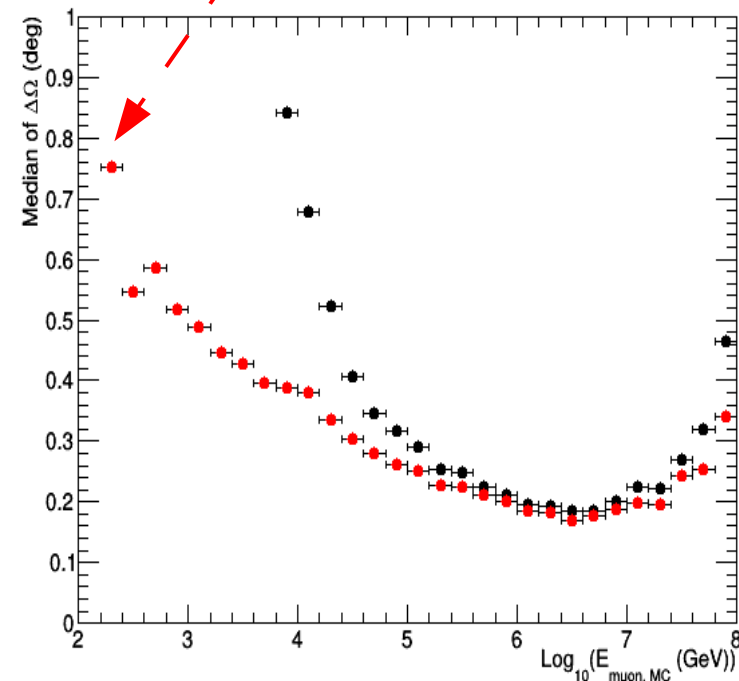
All reconstructed events

Reconstructed events after selection cuts

- A good purity ($\geq$ **80%**) of the reconstructed events for $E_\mu \geq 25\,TeV$ can be attained, with an efficiency of 7**5%** for $E_\mu \geq 25\,TeV$.

- The efficiency is $\geq$ **80%** for $E_\mu \geq 40\,TeV$ rising with energy to ~ **95%** for $E_\mu \geq 100\,TeV$.
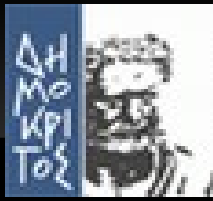
All reconstructed events
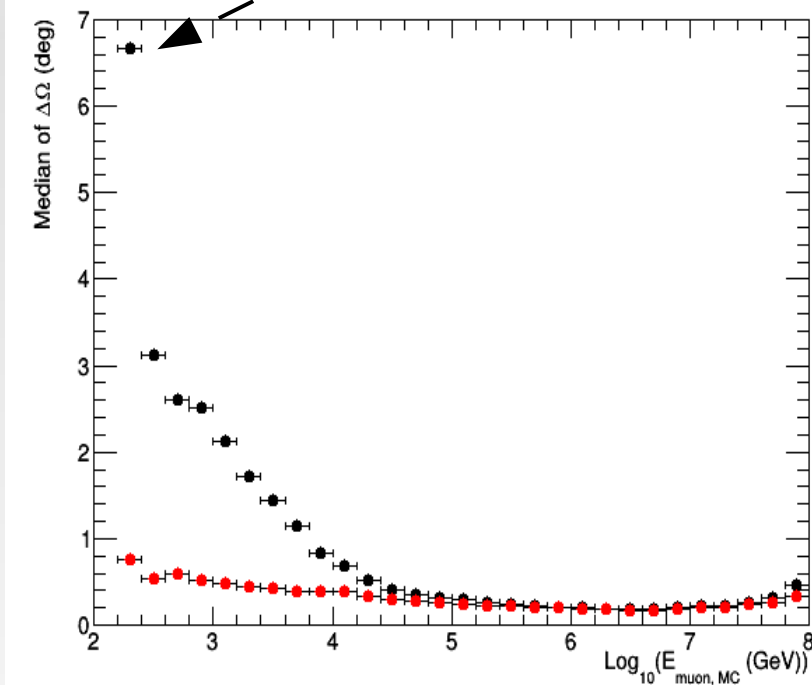
Reconstructed events after selection cuts

- $\Delta\Omega < 0.5°$ for $E_\mu > 1\,TeV$
- $\Delta\Omega < 0.33°$ for $E_\mu > 25\,TeV$
- <u>Very good angular resolution</u> in the high energy regime.

MultiVariate Analysis

- **Muon and Neutrino Energy Estimation:** a Multi-Layer Percepton (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 estimate muon and neutrino energy.
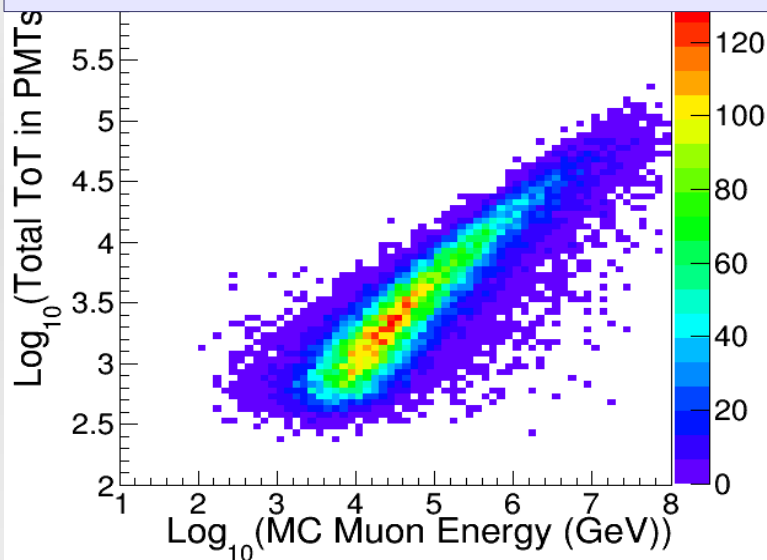
We consider the PMTs with signal used by the fitting procedure
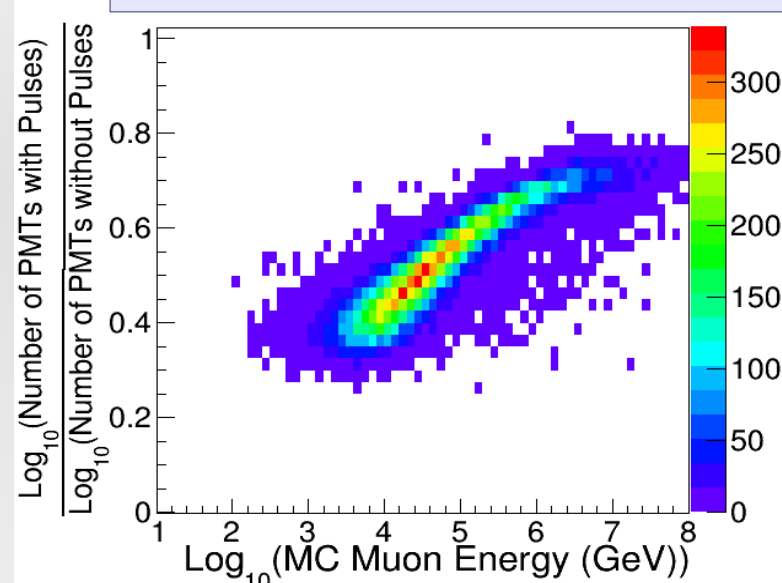
→ reduction of K^{40} contribution

reconstructed muon track

● PMTs with signal

● PMTs without signal

Amplitude of Signal

Threshold

Time (ns)
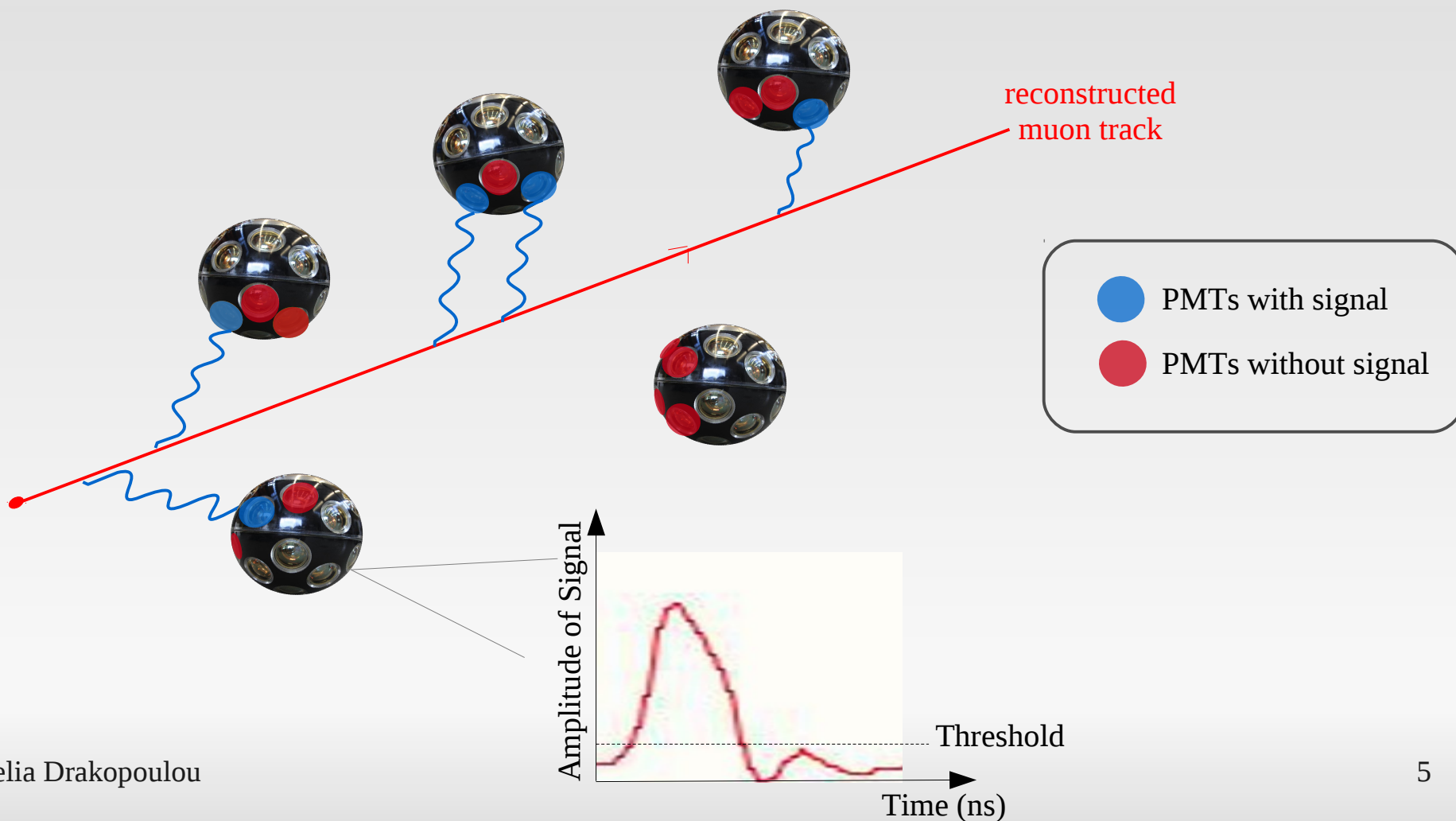
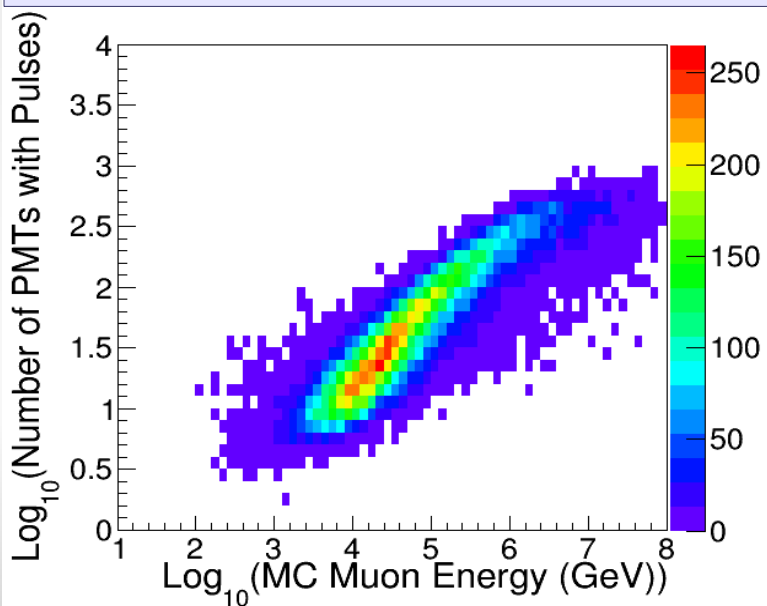# Muon Energy Estimation
Neural Network Input Variables

Total Time over Threshold (ToT) in PMTs

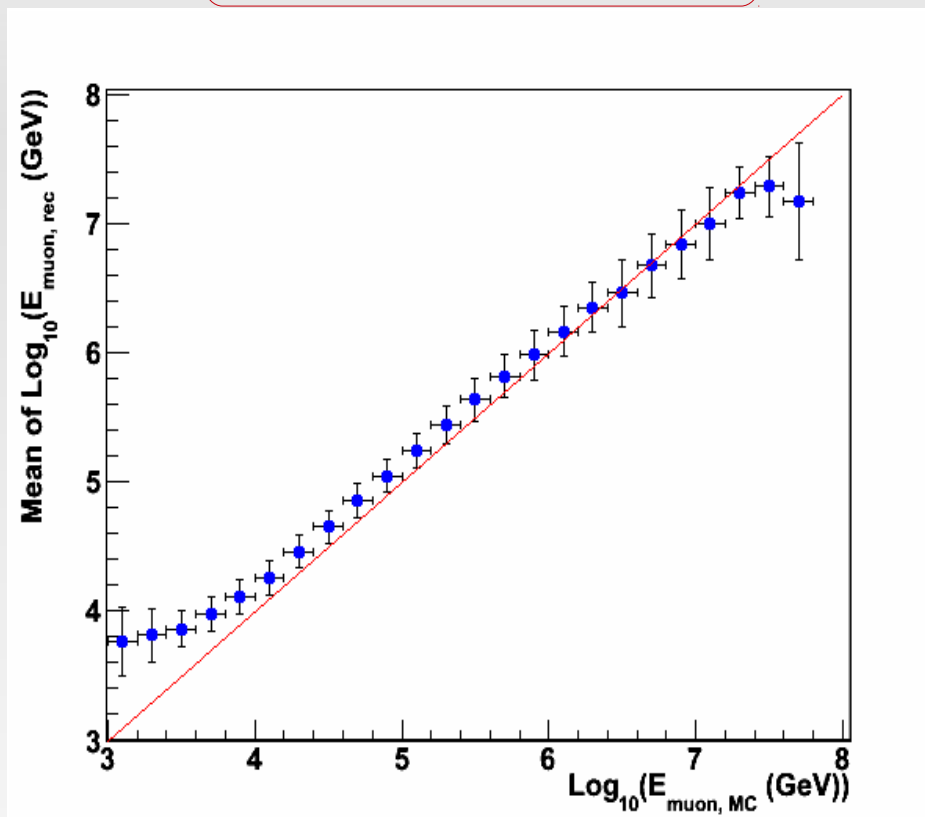## Number of PMTs without signal

Number of PMTs with signal

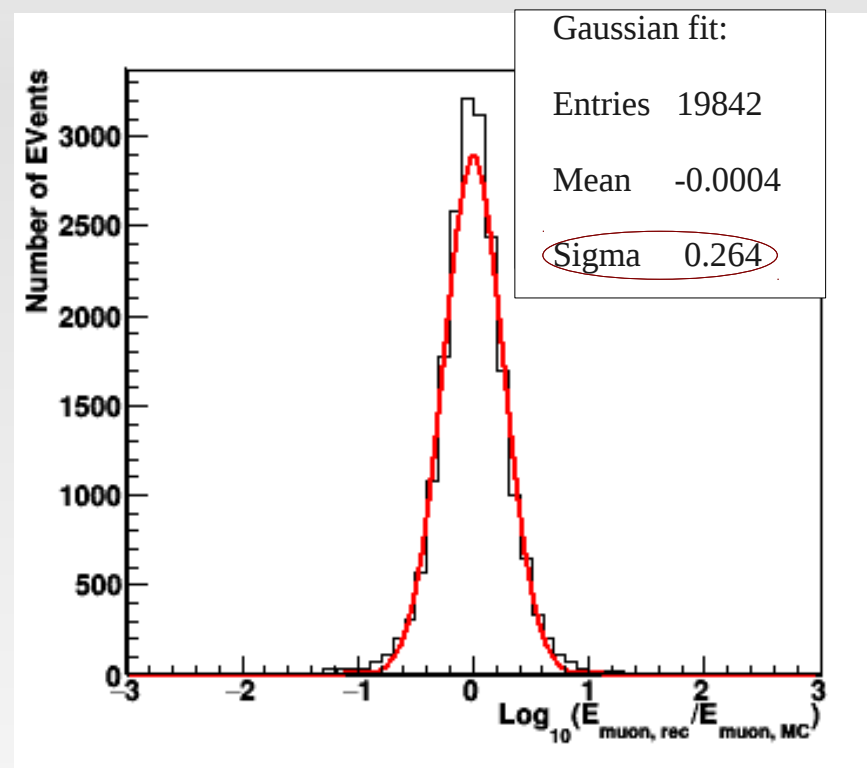## Number of OMs with signal

HEP-2015

6
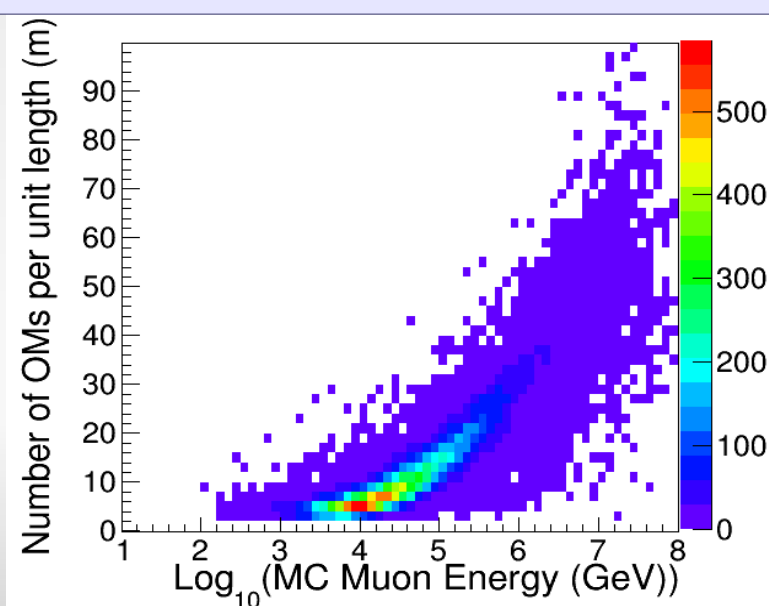
Muon Energy Reconstruction
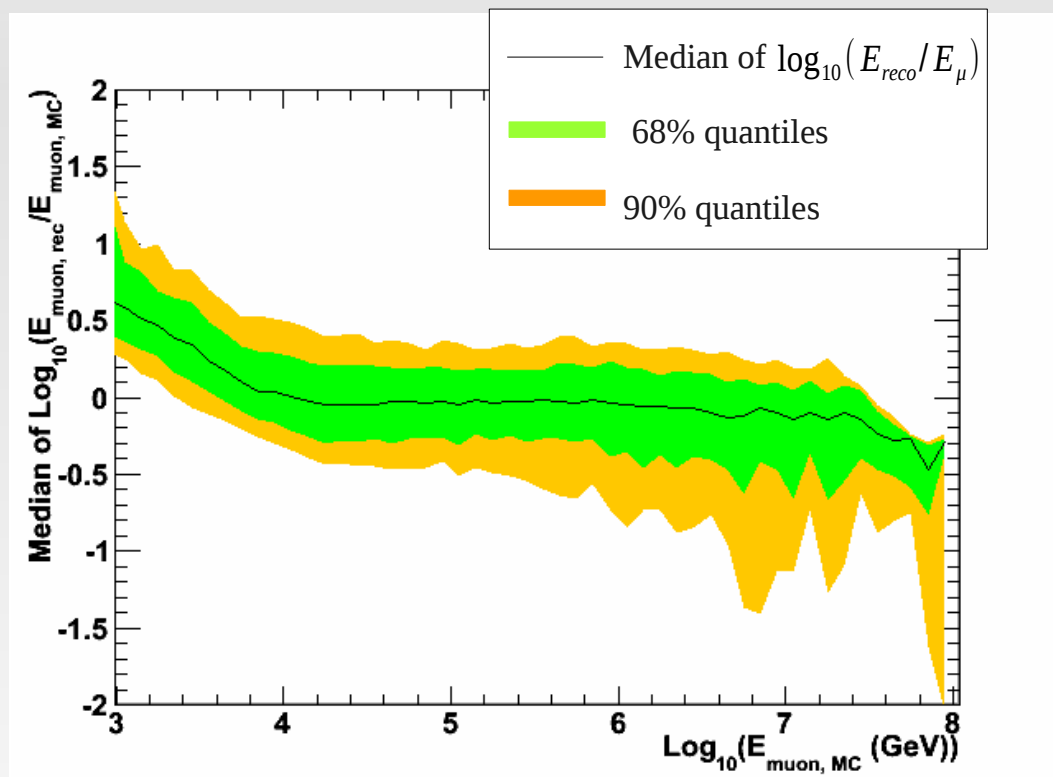
$$1\,TeV \leq E_\mu \leq 100\,PeV$$

- There is a very good linear relation between the reconstructed and the simulated muon energy for $E_\mu \geq 10\,TeV$.

Muon Energy Reconstruction

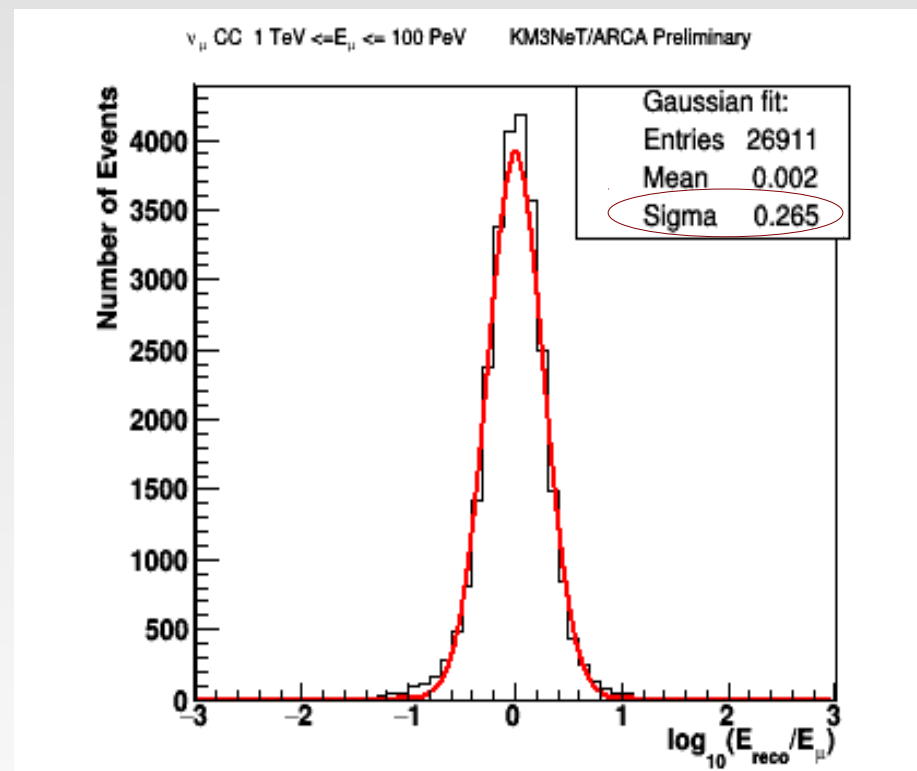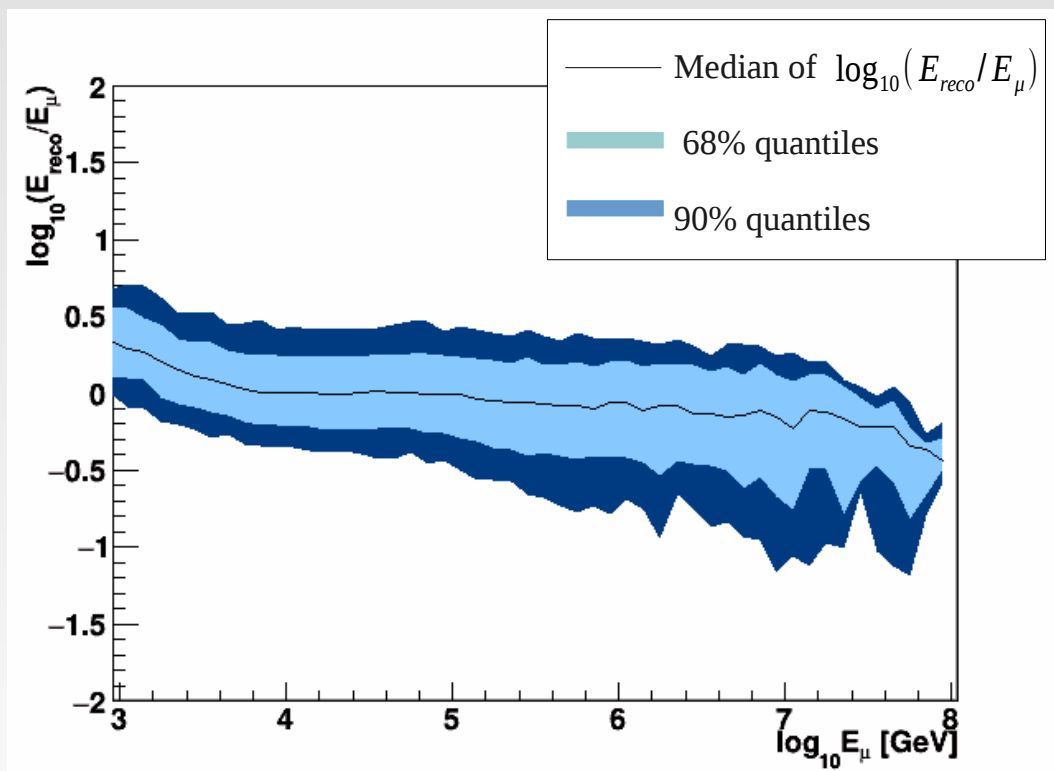$$1\,TeV \leq E_\mu \leq 100\,PeV$$

- The energy resolution is **~ 0.26** for $E_\mu \geq 1\,TeV$.

- This method for muon energy reconstruction was also applied to other track reconstruction algorithm (based on a pdf fit).

$$1\,TeV \leq E_\mu \leq 100\,PeV$$

- The energy resolution is **~ 0.26** for $E_\mu \geq 1\,TeV$.

$$Efficiency = \frac{Number\ of\ Events\ that\ pass\ the\ energy\ selection}{Number\ of\ events\ that\ pass\ the\ reconstruction\ selection}$$
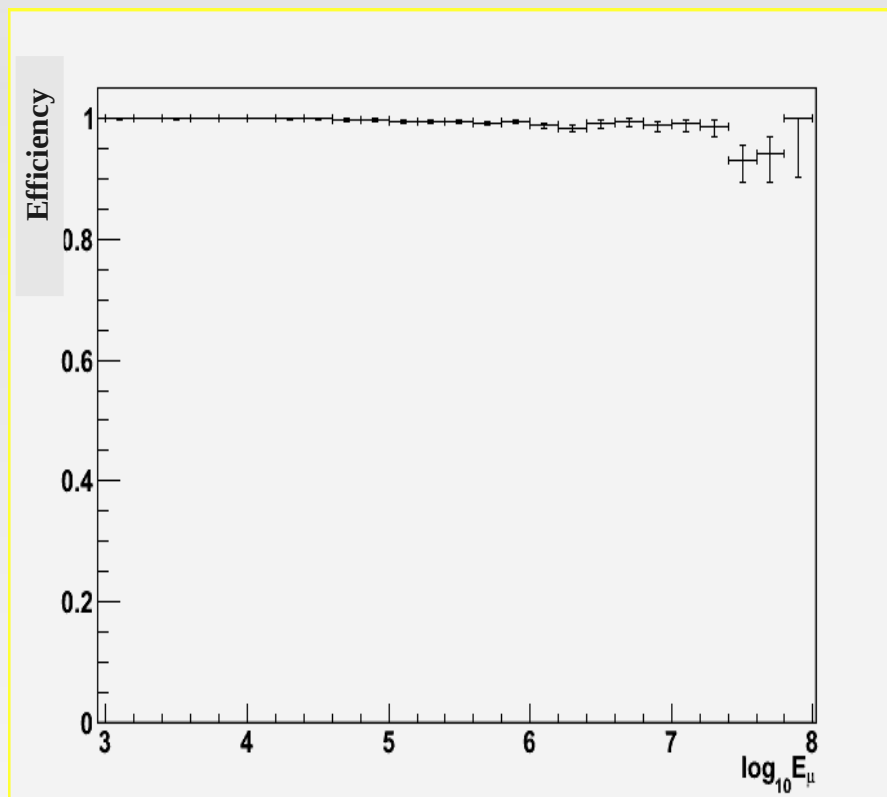
- A very high efficiency for the energy reconstruction is achieved for all events crossing the detector volume.

- Improvements were made to the existing track reconstruction algorithm leading to $\Delta\Omega < 0.5°$ for $E_\mu \geq 1\,TeV$.

- A new method for the muon and neutrino energy estimation using a Multi-Layer Percepton Neural Network with appropriate input variables was presented.

- <u>The performance of the energy estimator is very good</u>, particularly in the high energy region ($E_\mu \geq 10\,TeV$) which is the energy regime we are mostly interested in.

- This method was successfully applied to two different track direction reconstruction algorithms with comparable results.

- The energy resolution is **~ 0.26** for $E_\mu \geq 1\,TeV$.

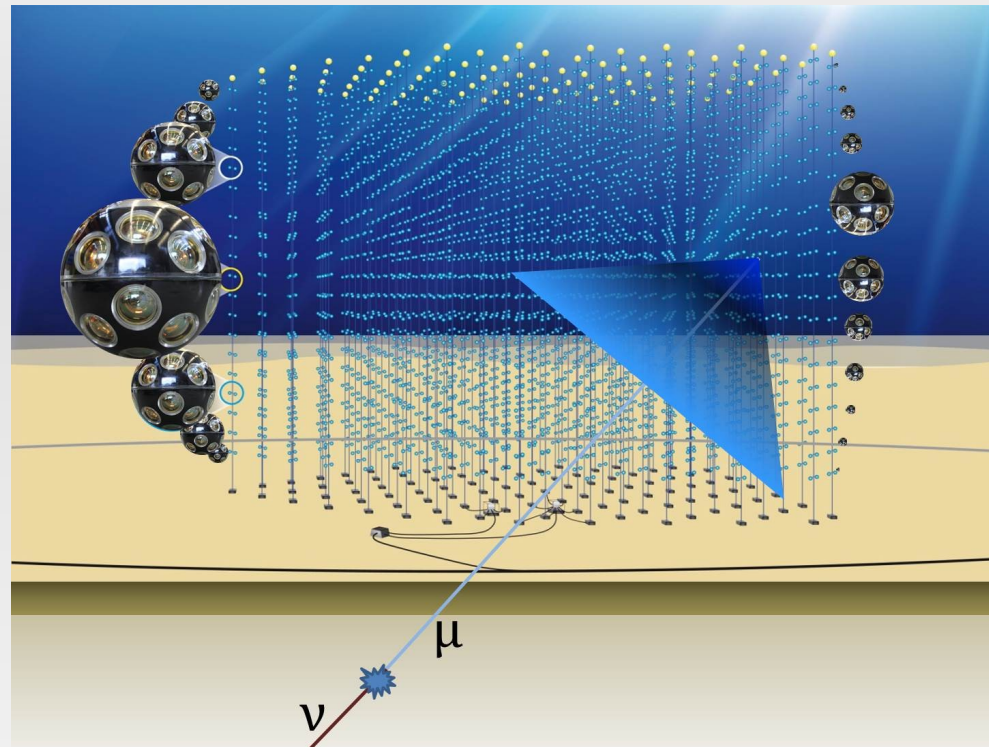- This method will be used for the Letter of Intent of the experiment.

Backup Slides

KM3NeT ➝ Neutrino Telescope with volume of **several km^3** which will be placed in the Mediterranean Sea.

The telescope will search for **neutrinos** from <u>galactic</u> and <u>extragalactic</u> astrophysical sources (like Gamma Ray Bursts, Supernovae, Colliding Stars).
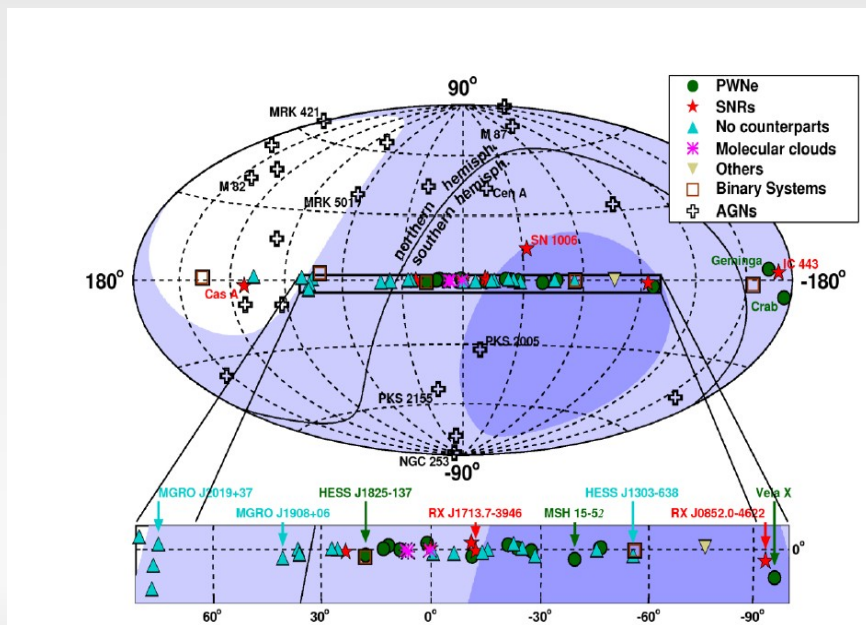

Sky coverage in galactic coordinates for a detector located in the Mediterranean Sea.

Dark (light) areas are visible at least 75% (25%) of the time.
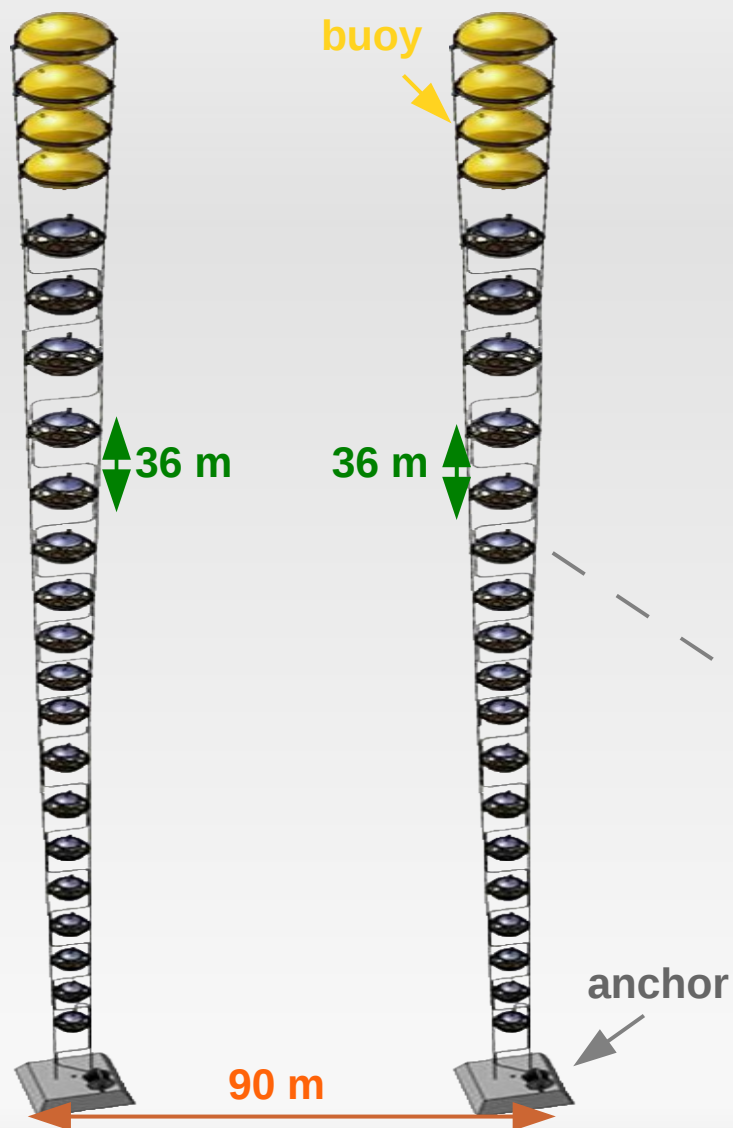
KM3NeT - Backgrounds

- **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 rays interactions in the atmosphere.

- K^{40} **:** radioactive potassium isotope

- **Bioluminescence :** life forms that inhabit in the deep sea emit light.

buoy

36 m   36 m

anchor

90 m
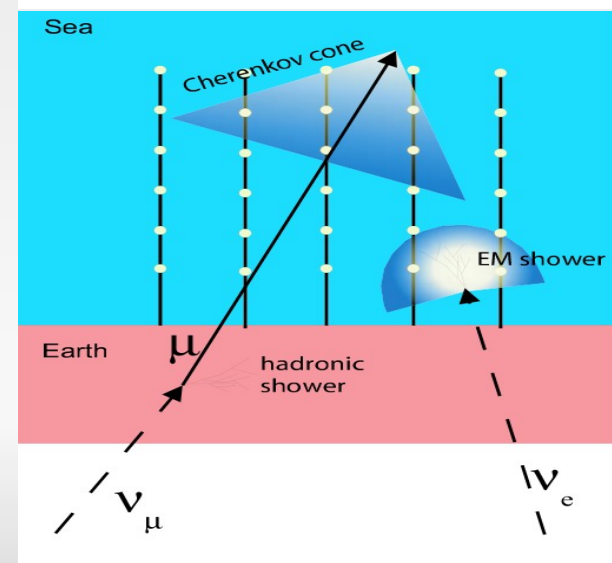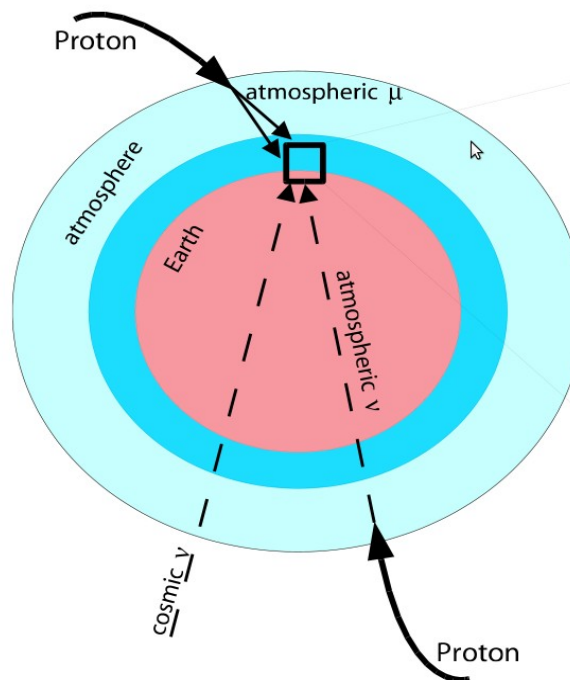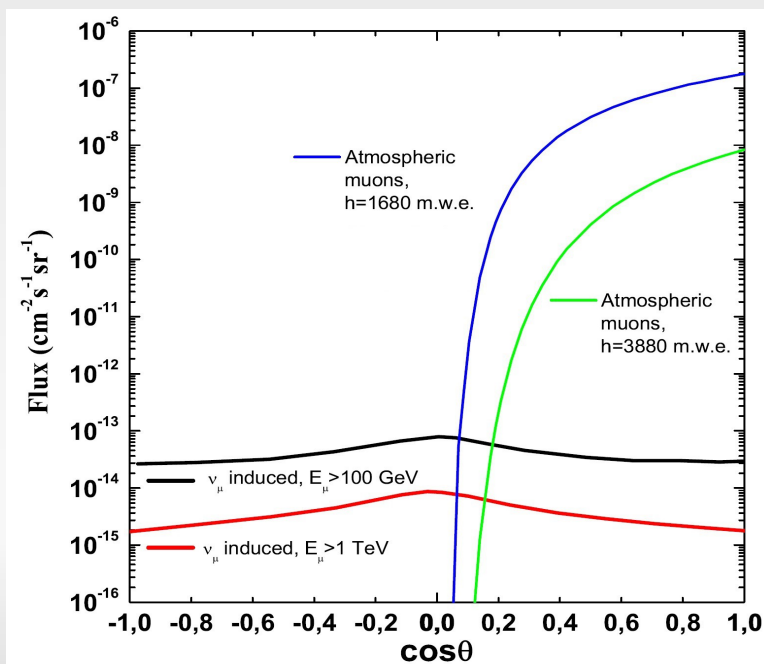
- Each of the 6 blocks has an almost hexagonal geometry with **115 strings** at **90m** distance. Each string has **18 floors** and each floor has **1** Optical Module (OM).

- 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 inches photomultipliers**.

- *Minimum Expected Path* = 0.5***h** + (**R** – 0.5***h**) * sin (**θrec**)

  <u>where</u>: **h**: string's height, **R**: detector radius, **θrec**: reconstructed muon angle

- For <u>Horizontal Muons</u> Minimum Expected Path is the <u>Detector Radius</u>

- For <u>Vertical Muons</u> Minimum Expected Path is <u>0.5*String height</u>

- *PMT Distance* : distance between first and last PMT positions

- The PMT Distance should be more than the half of minimum expected path or at least:

$$\frac{PMT\ Distance}{Minimum\ Expected\ Path} \geq 0.3$$

detector
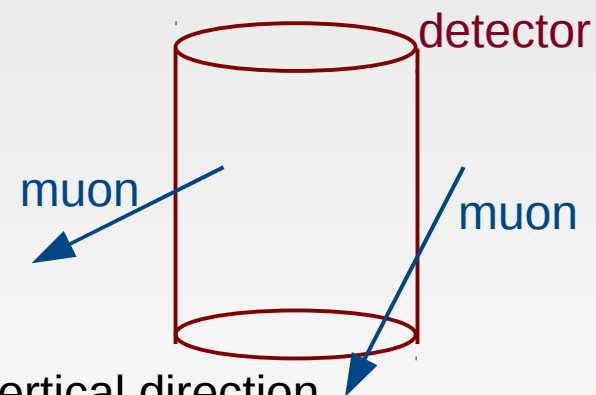
muon

muon

- The distances between OMs are different in horizontal and vertical direction

- minimum expected path length should change with respect to the muon zenith