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Atmospheric neutrinos with the first KM3NeT/ORCA data and prospects for measuring the atmospheric neutrino flux

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Introduction

KM3NeT is a research infrastructure aiming to study astrophysical sources as well as to perform particle physics studies, through the detection of neutrinos in the abyssal depths of the Mediterranean Sea [1]. The *KM3NeT/ORCA* detector (Oscillation Research with Cosmics in the Abyss), currently under construction, is deployed at 2450m depth near Toulon, France. It consists of vertical structures (Detection Units) equipped with spherical Digital Optical Modules, each hosting a set of photomultiplier tubes capable of detecting neutrino events from the Cherenkov radiation induced by the daughter particles.

ORCA detects neutrinos with energy above a few GeV and will be able to measure the atmospheric neutrino flux in an energy range for which only few measurements exist, providing valuable input for testing Cosmic Ray models.

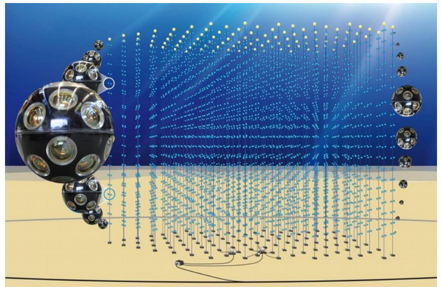

Figure 1: Artistic view of the KM3NeT/ORCA detector, highlighting the Digital Optical Module.

Data & Simulation

Data collected from February 2020 to March 2021 with the first 6 detection units of the *KM3NeT/ORCA* detector are used in this analysis. The data exposure is equivalent to 354.6 days, resulting in a 92% time-efficiency during this period.

Simulated atmospheric neutrino events have been generated with the *gSeaGen* Monte Carlo software [2] to evaluate the detector response. Neutrino & antineutrino CC interactions for each flavor have been simulated, as well as NC interactions. The neutrino events have been weighted with the HKKM2014 neutrino flux, computed for the Frejus location [3].

For the atmospheric muon background simulation, the *MUPAGE* Monte Carlo generator has been used [4].

All events have been reconstructed under the track hypothesis using the Jpp software package[5].

Analysis & Results

Atmospheric neutrino events are discriminated from the background by applying several selection criteria. As a first step, events reconstructed as upgoing are selected, since for these events the contribution of atmospheric neutrinos is proportionally the largest.

The remaining background consists of atmorpheric muons, misreconstructed as upgoing. These are rejected according to the following event characteristics :

- Agreement between the track hypothesis and signal-like hits
- Reconstruction quality
- Containment

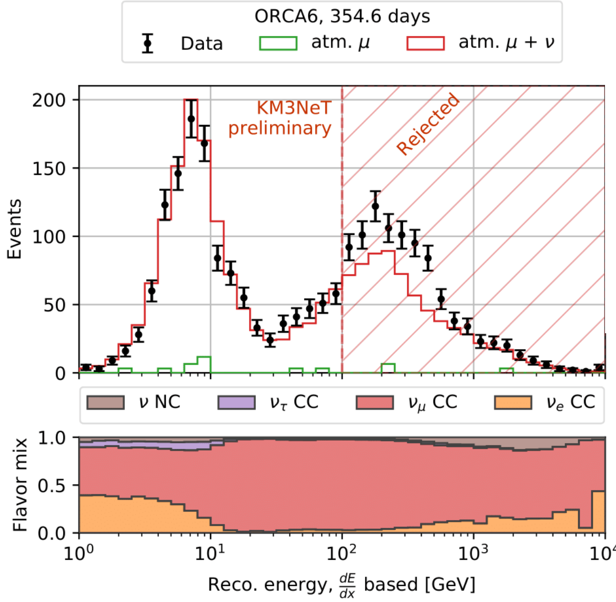

Figure 2: Distribution of the reconstructed energy for data and MC simulated events, after applying the selection criteria described above. The flavor mix for each energy bin is also depicted.

Moreover, as the KM3NeT/ORCA detector is in the construction phase, to account for the limited instrumented volume, events reconstructed with an energy above 100 GeV are rejected (fig.2).

Application of the selection criteria and of the reconstructed energy cut to the data leads to ***1247*** events, while ***1240 ± 35*** are predicted by the atmospheric neutrino simulation. A small contamination of atmospheric muon events exists, with ***31 ± 10*** events surviving the selection requirements (fig.3).

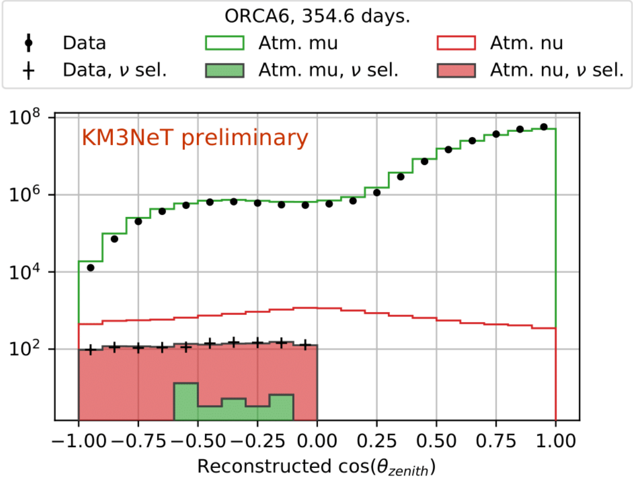

Figure 3: Distribution of the cosine of the reconstructed zenith angle for data and MC simulated events, before and after applying the selection criteria.

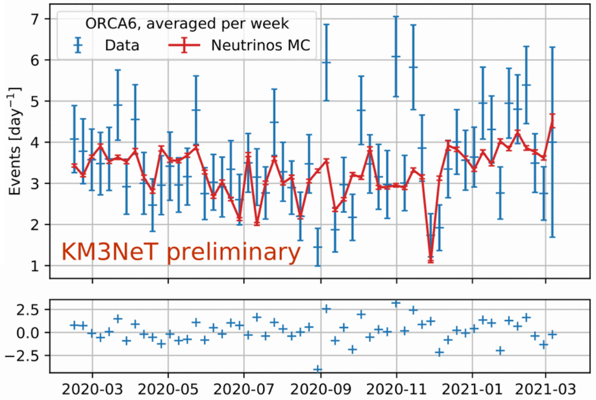

Figure 4: Detection rate for the selected events and the respective residual plot.

Conclusions & Prospects

The analysis presented here results in a selection of neutrino event candidates with a good reconstruction performance (fig.5). An angular resolution of less than 10 degrees for neutrino energies higher than 20 GeV is obtained.

With increasing energy, the reconstruction performance is limited by the instrumented volume as shown in fig.6. With the upcoming deployment of more Detection Units, the energy range will be increased and the quality of the energy reconstruction, which is a key factor for measuring the atmospheric neutrino flux, will be improved.

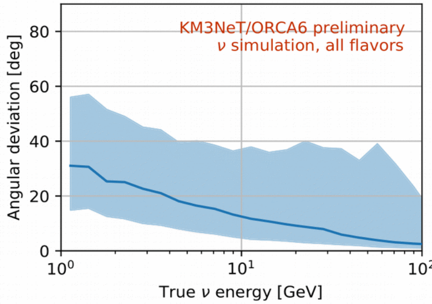

Figure 5: Angular resolution as a function of the true neutrino energy for MC selected events.

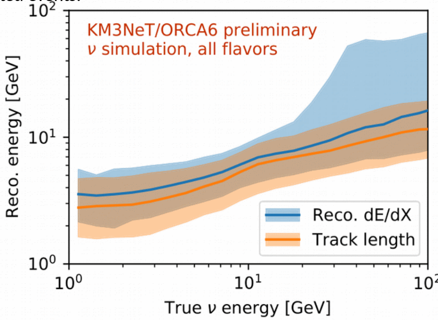

Figure 6: Median reconstructed energy as a function of the true neutrino energy for MC selected events, using two energy estimators. One that use the detected light around the reco track (blue), and another using the length of the reco track (orange).

References:
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