Measurement of the atmospheric muon neutrino flux with KM3NeT/ORCA6

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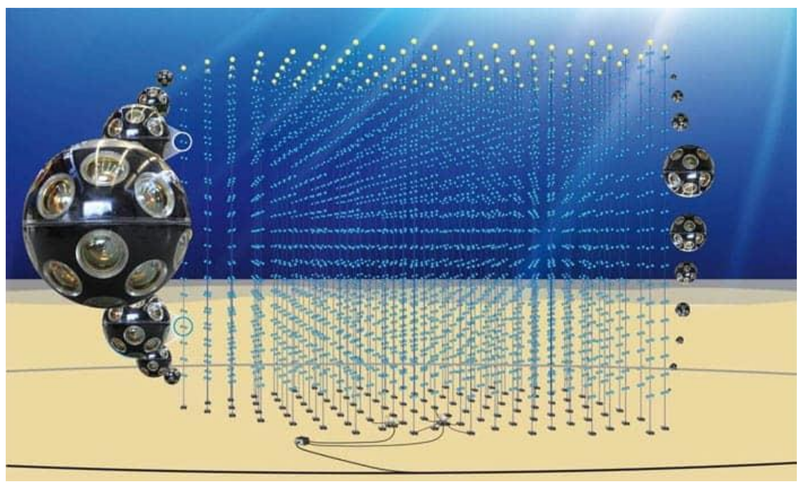
The KM3NeT/ORCA detector



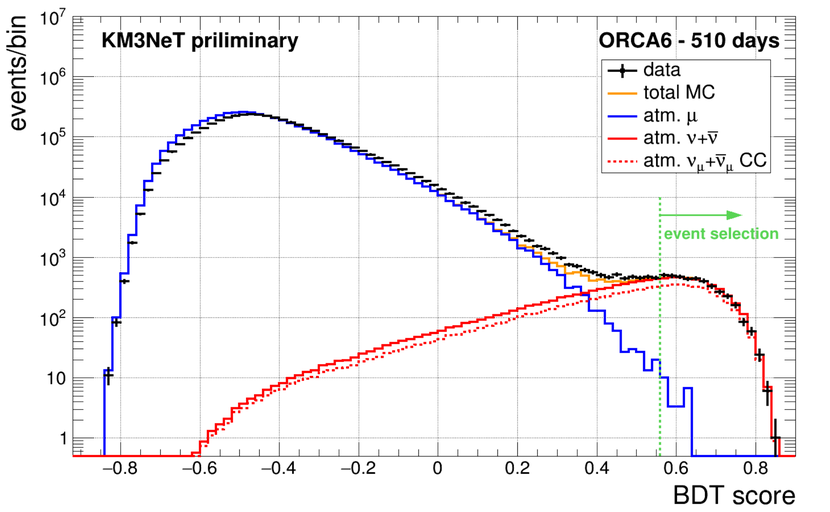
Artist view of the completed ORCA detector

The KM3NeT/ORCA detector [1] is an array of Digital Optical Modules, each containing 31 photomultiplier tubes, currently being constructed at a depth of approximately 2450 meters offshore from Toulon, France. The primary physics goal of the detector is to determine the Neutrino Mass Ordering.

This array configuration is designed to detect neutrino events by capturing the Cherenkov radiation emitted by secondary particles from neutrino interactions in the deep waters of the Mediterranean Sea.

The Digital Optical Module of KM3NeT (bottom side)

Neutrino event selection with high purity

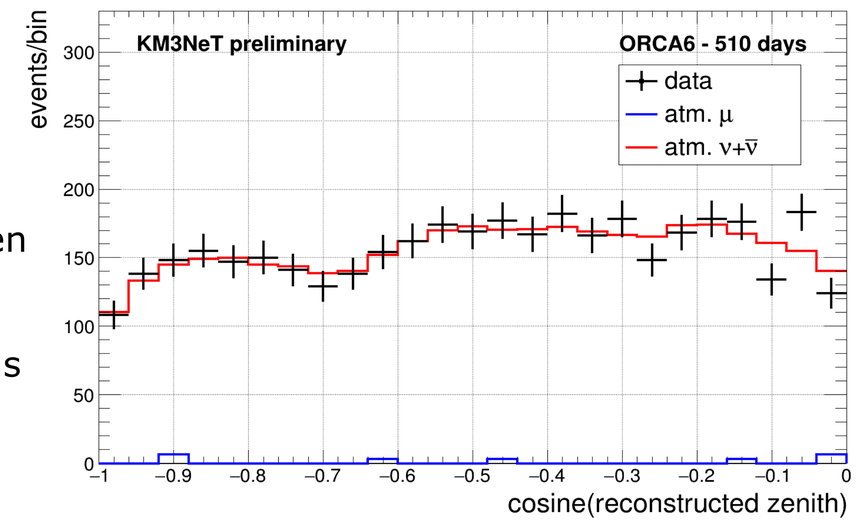


Boosted Decision Tree ML classification score for the reconstructed as upgoing events that pass soft anti-noise cuts; The ability to identify neutrino events is clear.

Data corresponding to 510 days, collected with a 6-Detection Unit configuration (ORCA6) have been used for this measurement.

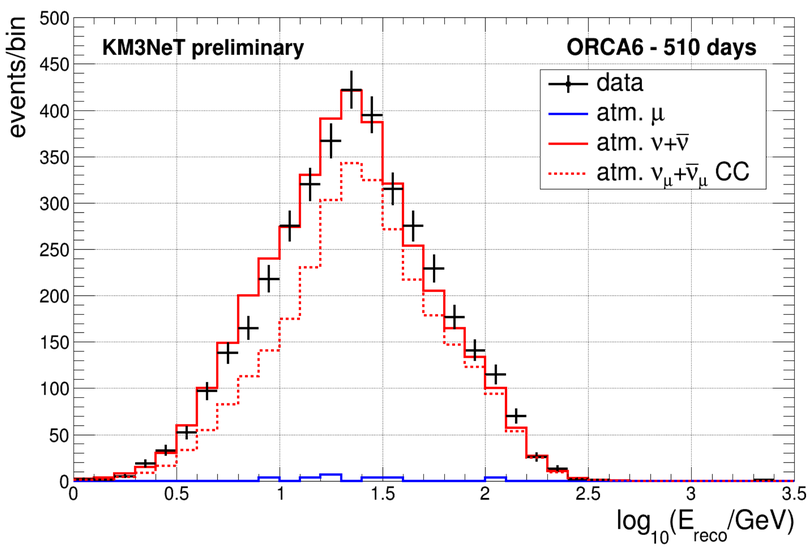
Sophisticated event variables have been developed and used as features in a BDT classifier (*TMVA*) to discriminate atmospheric neutrinos reconstructed as upgoing from the misreconstructed atmospheric muon background.

A high purity neutrino event selection is achieved, with and a nice agreement between data and MC.



Distribution of the reconstructed cosine zenith for data and MC selected events. A good data/MC agreement is illustrated.

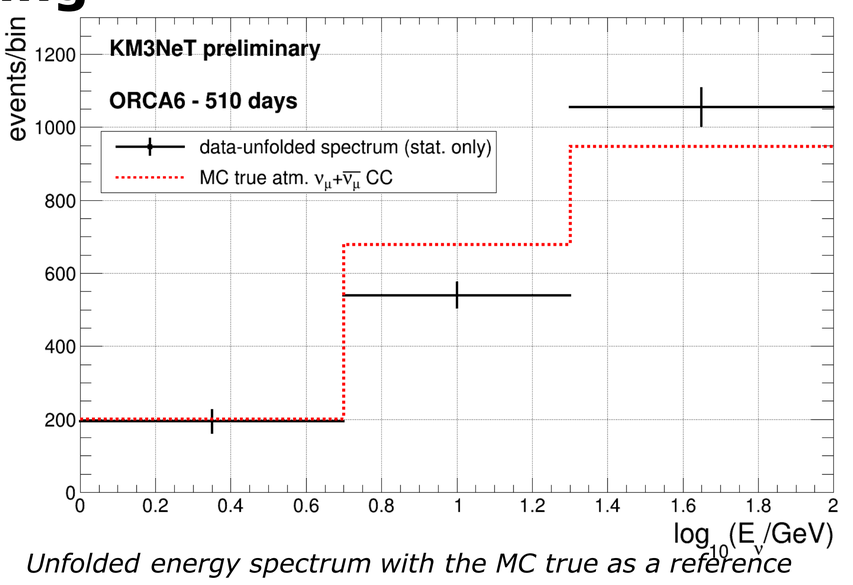
Energy spectrum unfolding



Shower reconstructed energy for the event selection

An unfolding scheme (*TUnfold*) is used in order to deconvolve the muon (anti-)neutrino CC energy distribution from the experimentally measured one (*left*).

The binning schemes for the true and reconstructed phase spaces have been defined according to the bin purity; the robustness of the procedure is tested using toy MC experiments.



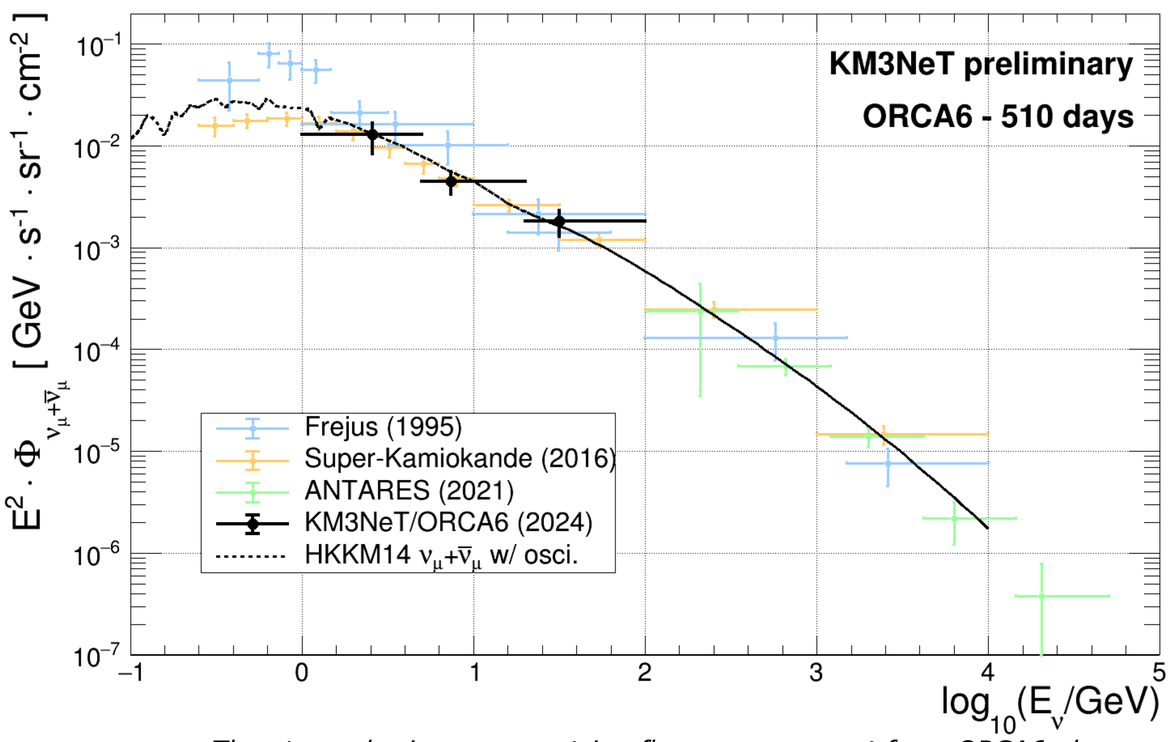
Unfolded energy spectrum with the MC true as a reference

Flux measurement

The unfolded numbers of events per bin are converted to flux values using the HKKM14 conventional flux model [2] and the NuFIT v5.2 oscillation probabilities [3].

$\log_{10}(E_\nu/GeV)$	$\log_{10}(\tilde{E}_i/GeV)$	$\tilde{E}_i^2\Phi_i$	stat. error [%]	syst. error [%]
$0.0-0.8$	0.41	$1.29\cdot10^{-2}$	±15.7	$+26.3\ /\ -32.2$
$0.7-1.3$	0.87	$4.49\cdot10^{-3}$	±6.3	$+23.1\ /\ -25.0$
$1.3-2.0$	1.50	$1.83\cdot10^{-3}$	±4.8	$+25.3\ /\ -29.2$

From left to right: Bin energy range; weighted energy bin center; flux measurement multiplied by the weighted energy bin center squared; statistical error; systematic error.



The atmospheric muon neutrino flux measurement from ORCA6 along with the ones from Frejus [4], Super-Kamiokande [5] and Antares [6].

References
1: *S. Adrián-Martínez et al. (KM3NeT Collaboration), 2016 J. Phys. G43084001.*
2: *M. Honda et al., Phys. Rev. D 92, 023004 (2015)*
3: *HEP 09 (2020) 178 [arXiv:2007.14792], NuFIT 5.2 (2022), www.nu-fit.org.*
4: K. Daum (Frejus Collaboration), Z. Phys. C 66, 417 (1995).
5: E. Richard, et al. Phys. Rev. D, 94 (2016) 052001
6: *Albert A., et al., ANTARES Collaboration Phys. Lett. B, 816 (2021) 136228*