

# Measurement of the atmospheric muon neutrino flux with KM3NeT/ORCA6

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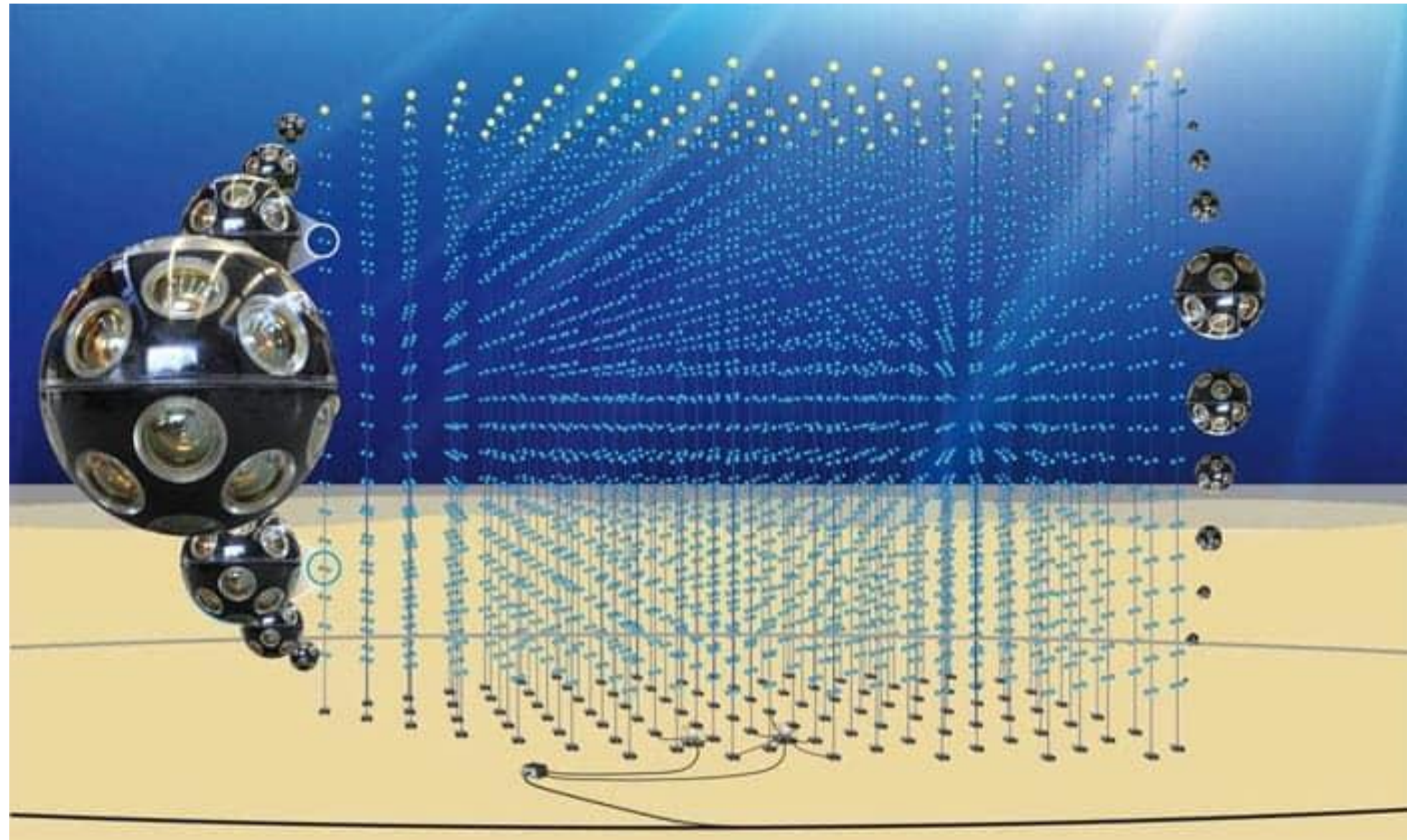
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## The KM3NeT/ORCA detector



Artist view of the completed ORCA detector

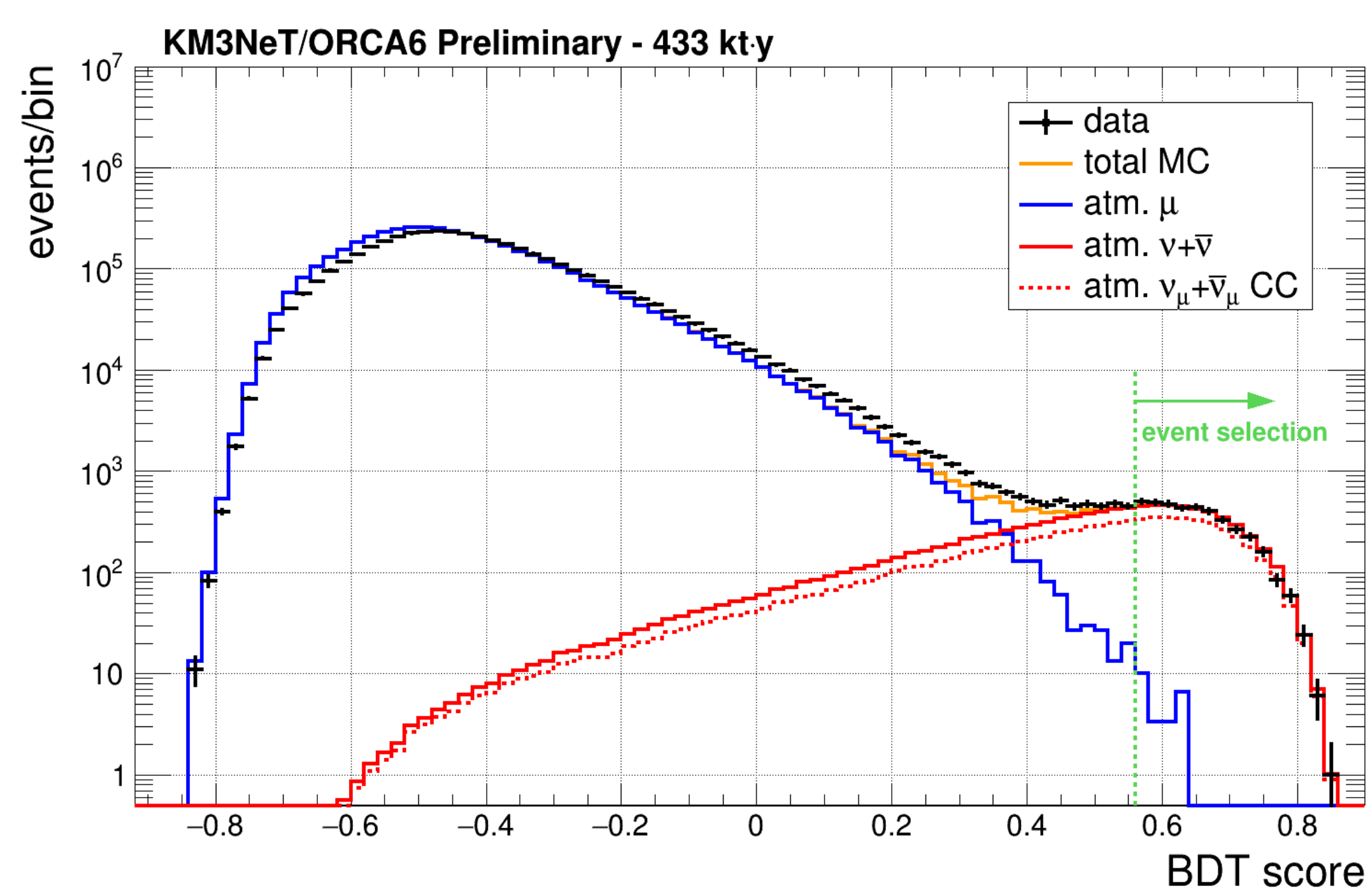
The KM3NeT/ORCA detector [1] is an array of Digital Optical Modules, each containing 31 photomultiplier tubes, currently being deployed at a depth of approximately 2450 meters South of Toulon, France. The main physics goal of the detector is to determine the Neutrino Mass Hierarchy.

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

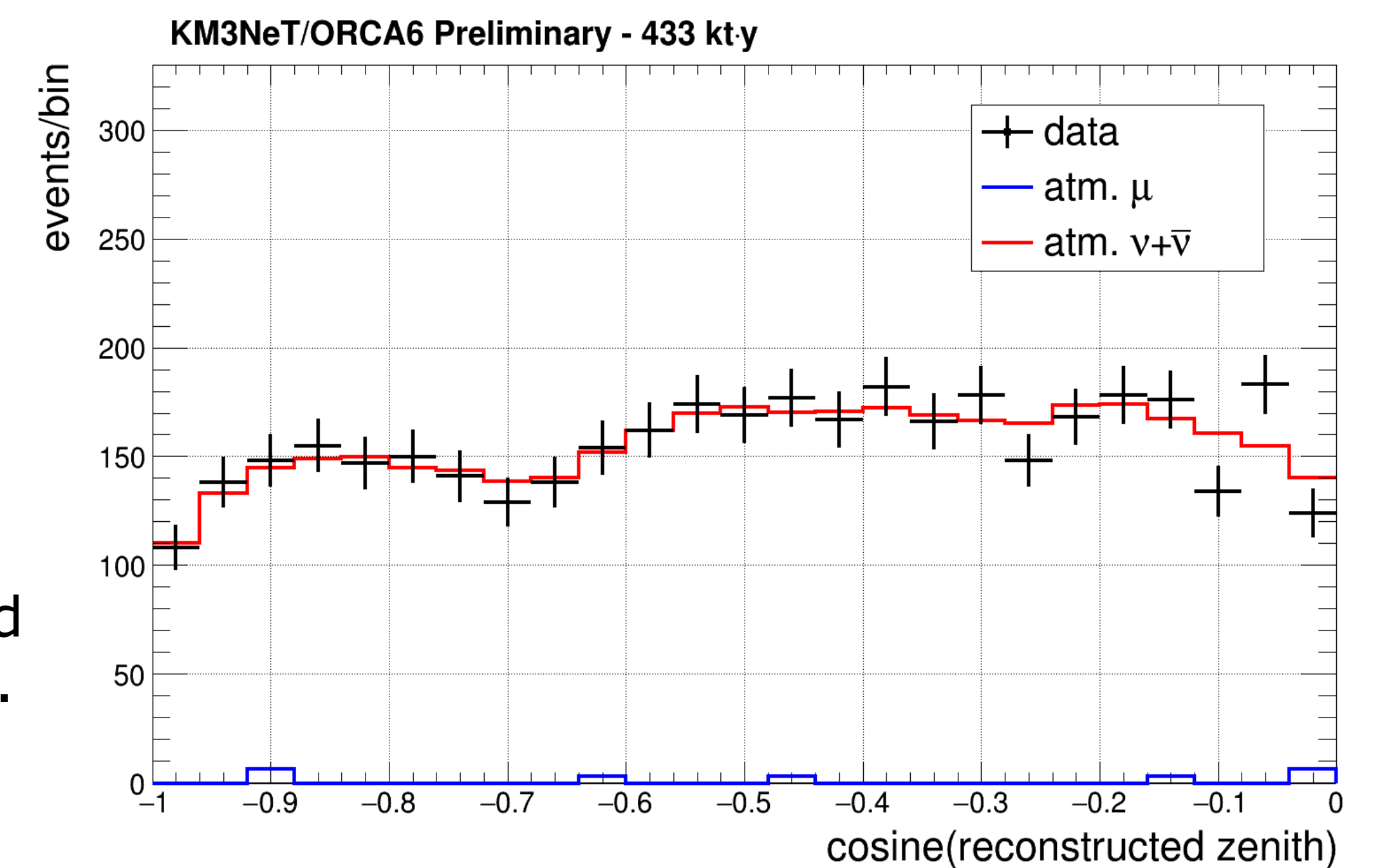


Boosted Decision Tree ML classification score for the reconstructed as upgoing events that pass soft anti-noise cuts; The ability to identify neutrino events is clear.

Data corresponding to 510 days, collected with a 6-Detection Unit configuration (ORCA6) were used.

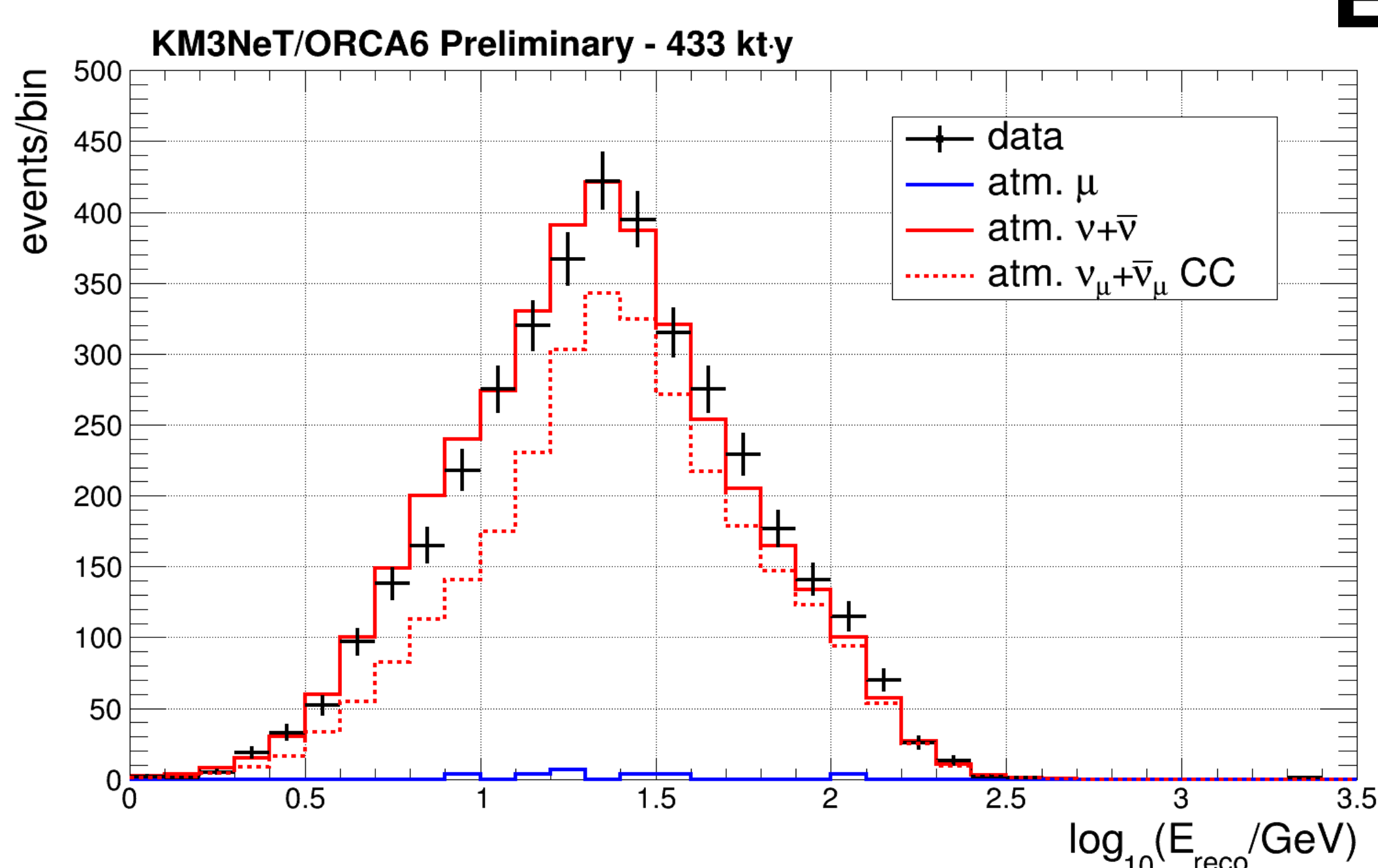
Event variables developed and were exploited as features in a BDT classifier (*TMVA*) to discriminate atmospheric neutrinos reconstructed as upgoing from the misreconstructed atmospheric muon background (*left*).

An event selection is achieved (*right*), with high purity 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.

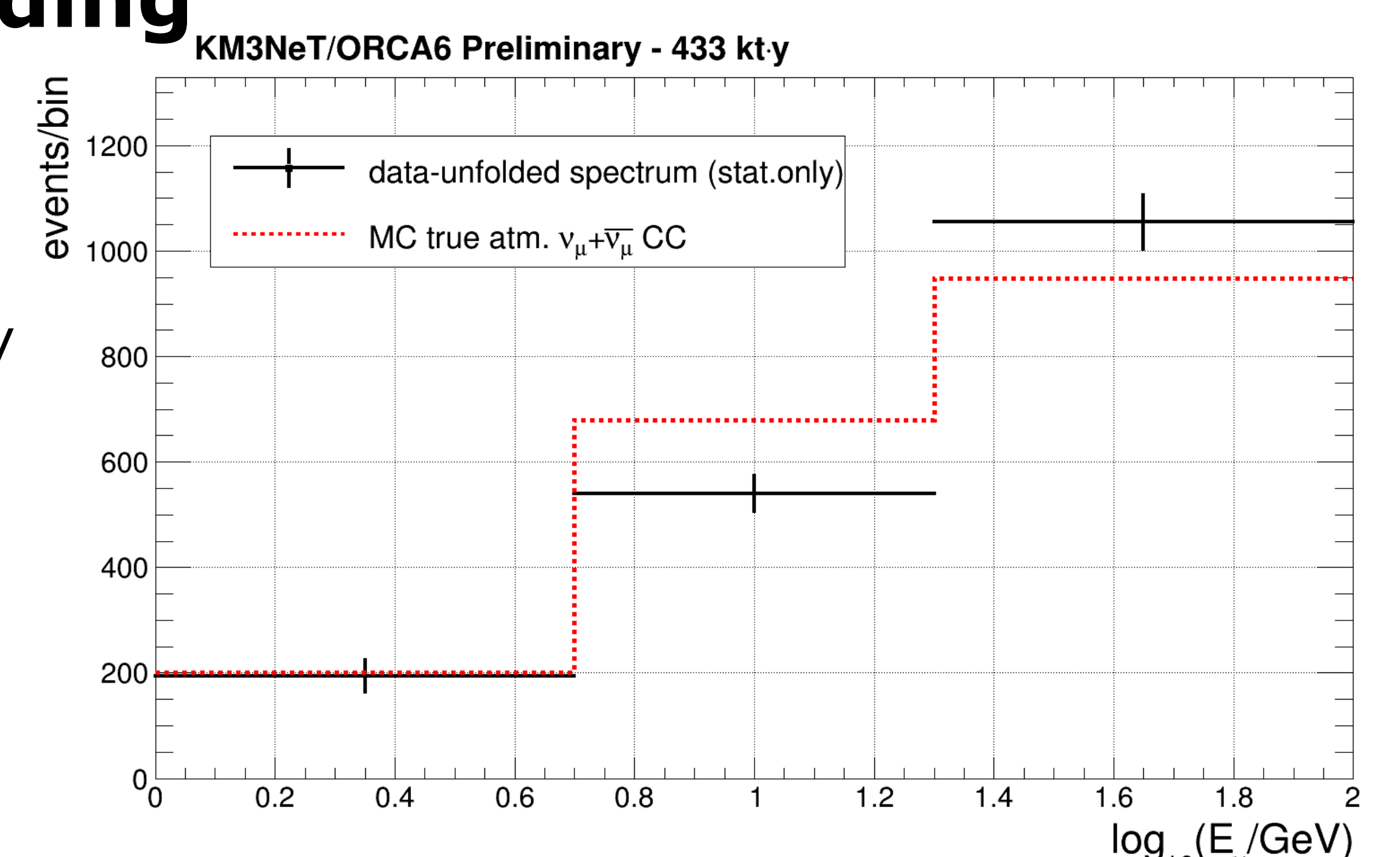
## Energy spectrum unfolding



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

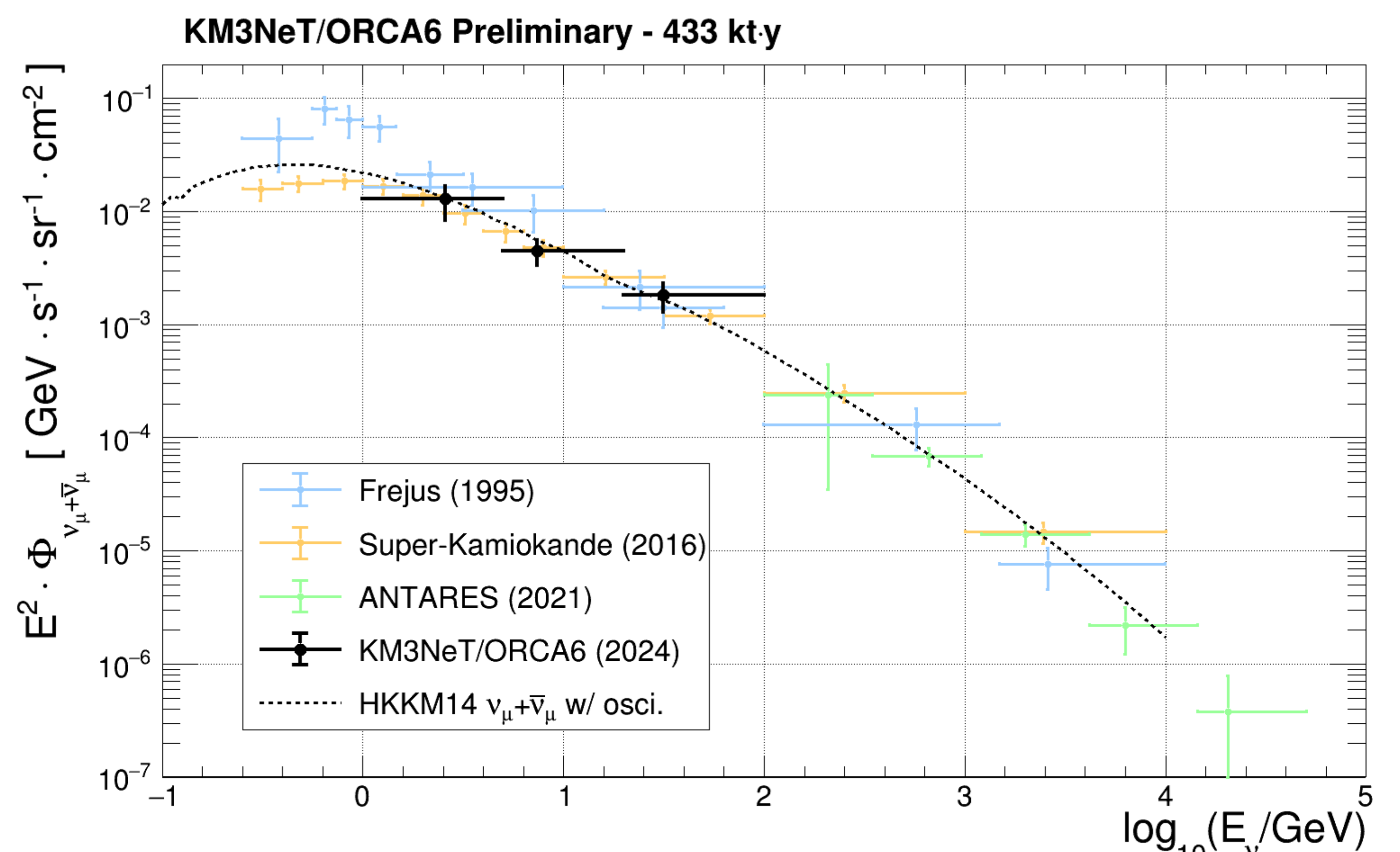
The flux values are derived from the unfolded number of events per bin are using the HKKM14 conventional flux model [2] and the NuFIT v5.2 oscillation probabilities [3].

$\log_{10}(E_\nu/GeV)$	$\log_{10}(\tilde{E}_i/GeV)$	$\tilde{E}_i^2 \Phi_i$	stat. error	syst. error
0.0 – 0.7	0.41	$1.29 \cdot 10^{-2}$	$\pm 16\%$	+26% -32%
0.7 – 1.3	0.87	$4.49 \cdot 10^{-3}$	$\pm 6\%$	+23% -25%
1.3 – 2.0	1.50	$1.83 \cdot 10^{-3}$	$\pm 5\%$	+25% -29%

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.

### 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



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