Studying neutrino absorption through the Earth with ANTARES and KM3NeT/ARCA

Luigi Antonio Fusco – luigi.fusco@apc.in2p3.fr
Véronique Van Elewyck - elewyck@apc.univ-paris7.fr
Laboratoire APC, Paris

on behalf of the ANTARES and KM3NeT Collaborations

Neutrino telescopes collect large statistics of high-energy (> TeV) atmospheric neutrinos, using the Cherenkov radiation produced by charged particles induced by neutrino interactions in the surrounding medium to reconstruct the direction and energy of the incoming neutrino.

Underwater neutrino telescopes such as ANTARES and the future KM3NeT/ARCA, taking advantage of the transparent waters of the Mediterranean Sea provide the best reconstruction performances for high energy neutrinos.

Atmospheric neutrinos are present in the particle showers produced by the interaction of primary cosmic rays in the atmosphere. The largest source of these neutrinos are the decays of charged pions and kaons in the air shower. Above ~100 TeV the atmospheric muon neutrino flux is dominated by the prompt component due to charmed mesons decay; at these energy a cosmic component should play a significant role as well.

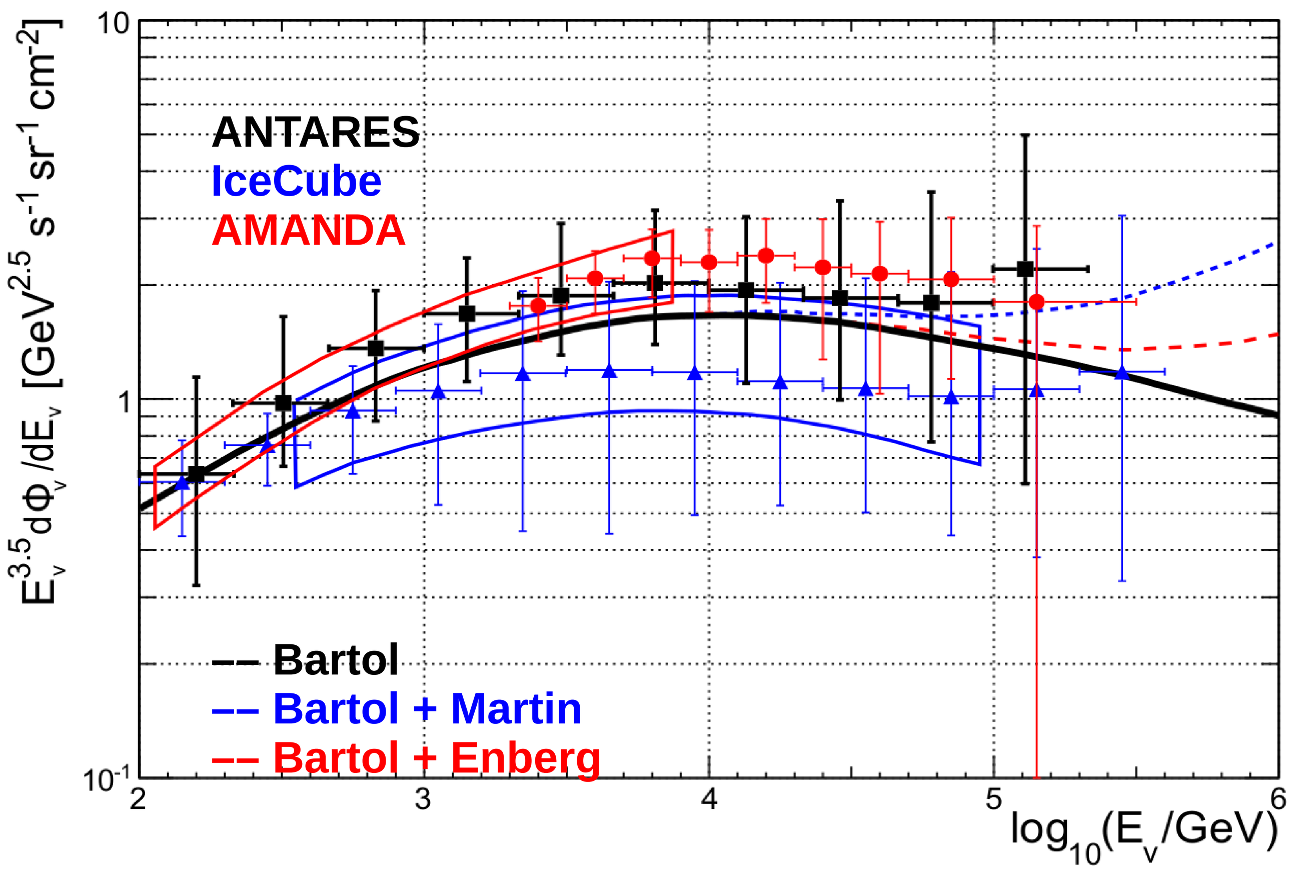

Figure 1. Atmospheric muon neutrino energy spectrum as measured by the ANTARES, IceCube and AMANDA neutrino telescopes and

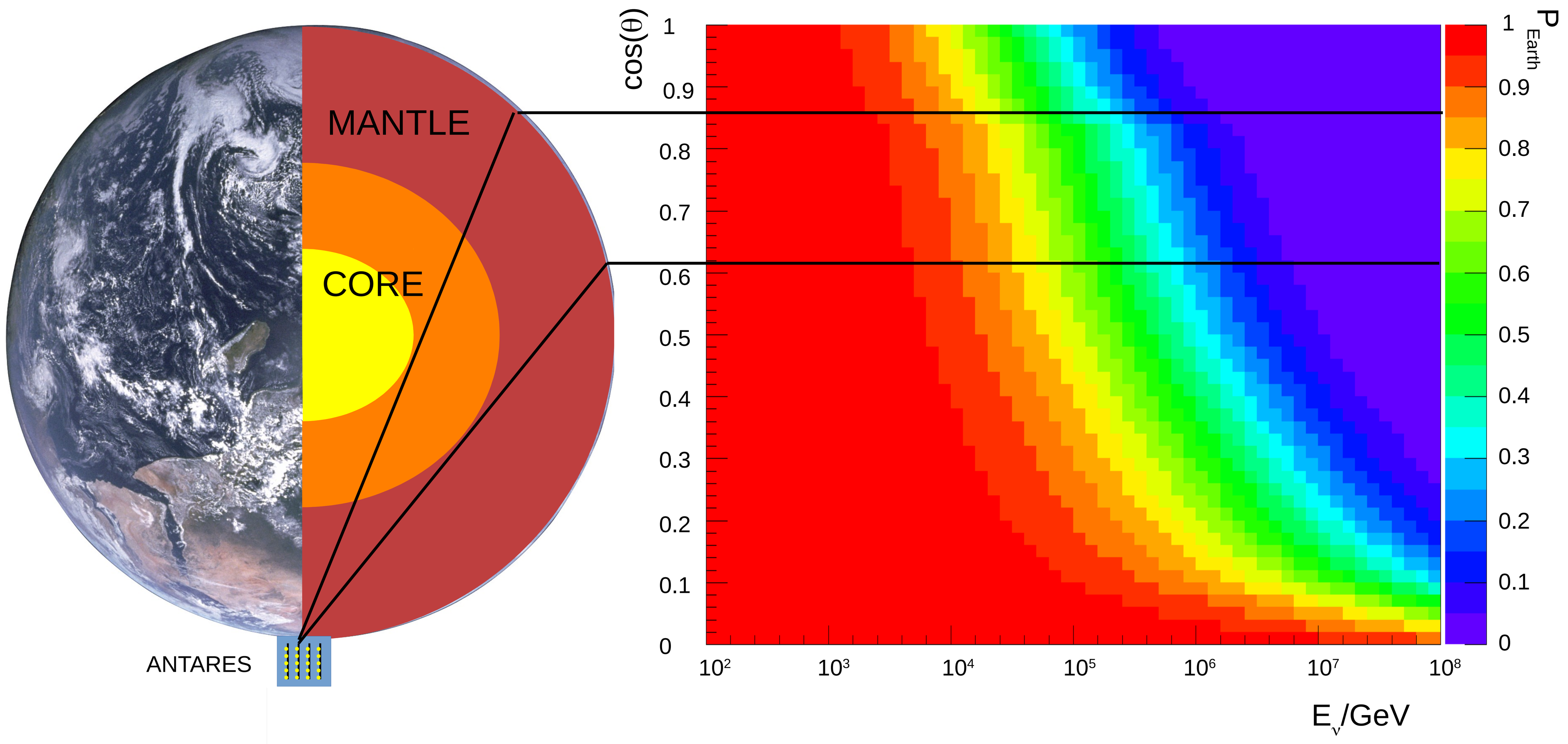

Figure 2. Neutrino absorption effects are due to the amount of traversed matter, which is zenith dependent, and to the neutrino cross section, which is energy dependent

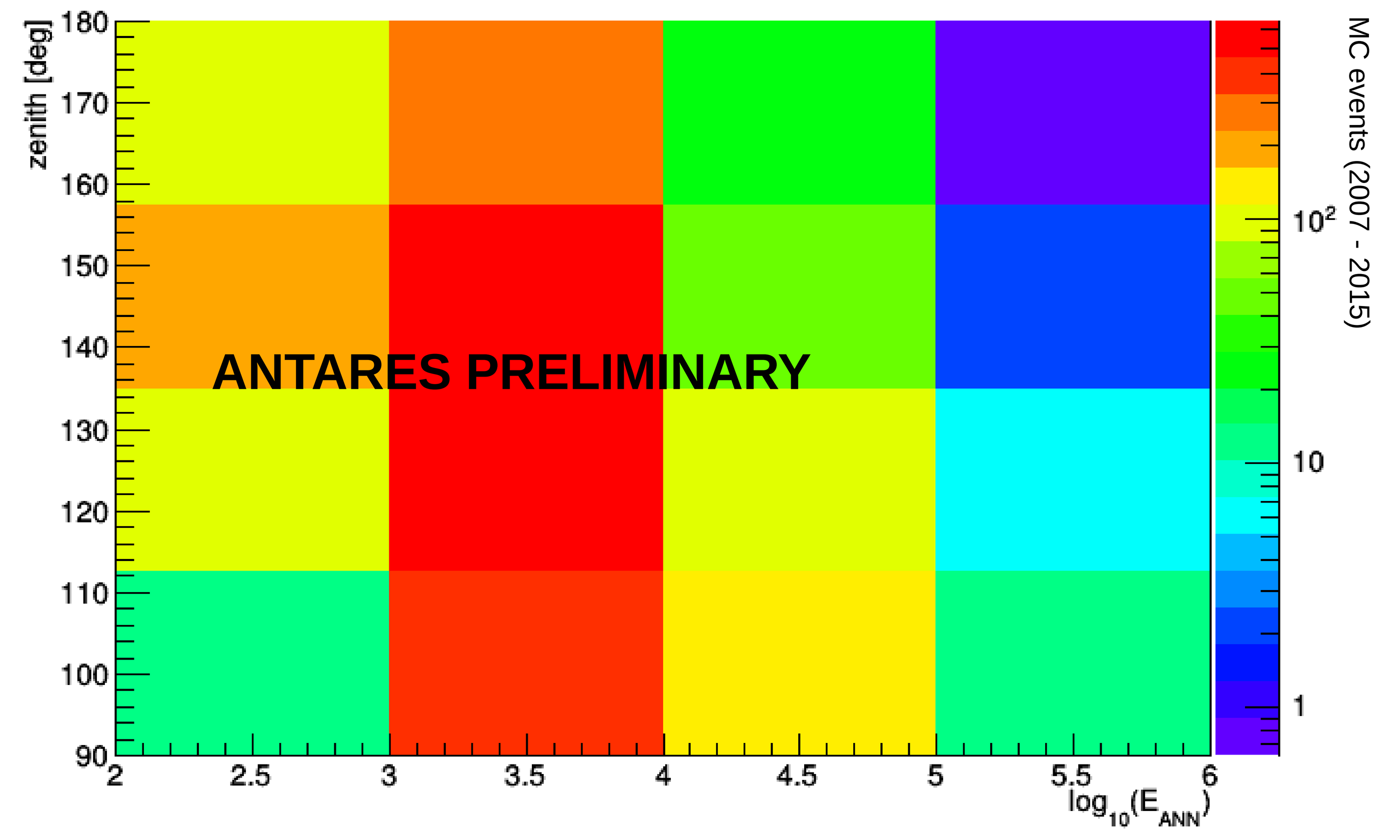

Figure 3. Event rate at the ANTARES detector once the detection efficiency, the steeply falling atmospheric neutrino spectrum and the Earth crossing probability are convoluted – for standard atmospheric spectrum and the SM ν-N cross section

Neutrino absorption is driven by the ν-N CC cross section and by the amount of matter traversed by the neutrino. The former is increasing with the neutrino energy, the latter depends on the zenith of upward going neutrinos – both because of the longer path traversed through the Earth and because of the higher density in the core.

The muon neutrino cross section can be measured fixing the model for the inner Earth, and measuring the zenith-energy distribution of reconstructed events.

The limited energy resolution, the steeply falling neutrino spectrum and the detection efficiency worsen significantly the capability to observe neutrino absorption, smoothing-out the features of the Earth crossing probability (P_{Earth}) distribution.

A maximum-likelihood fit [2] can be performed on the binned zenith-energy distribution to obtain the neutrino cross section simultaneously and the atmospheric neutrino spectrum, the cosmic neutrino spectrum as well as possible nuisances – kaon-to-pion ratio, ν-to-antiν ratio, detector systematics etc.

As the event rate at the detector is linearly dependent on the cross section value, the fitted atmospheric normalisation and the cross section value are correlated

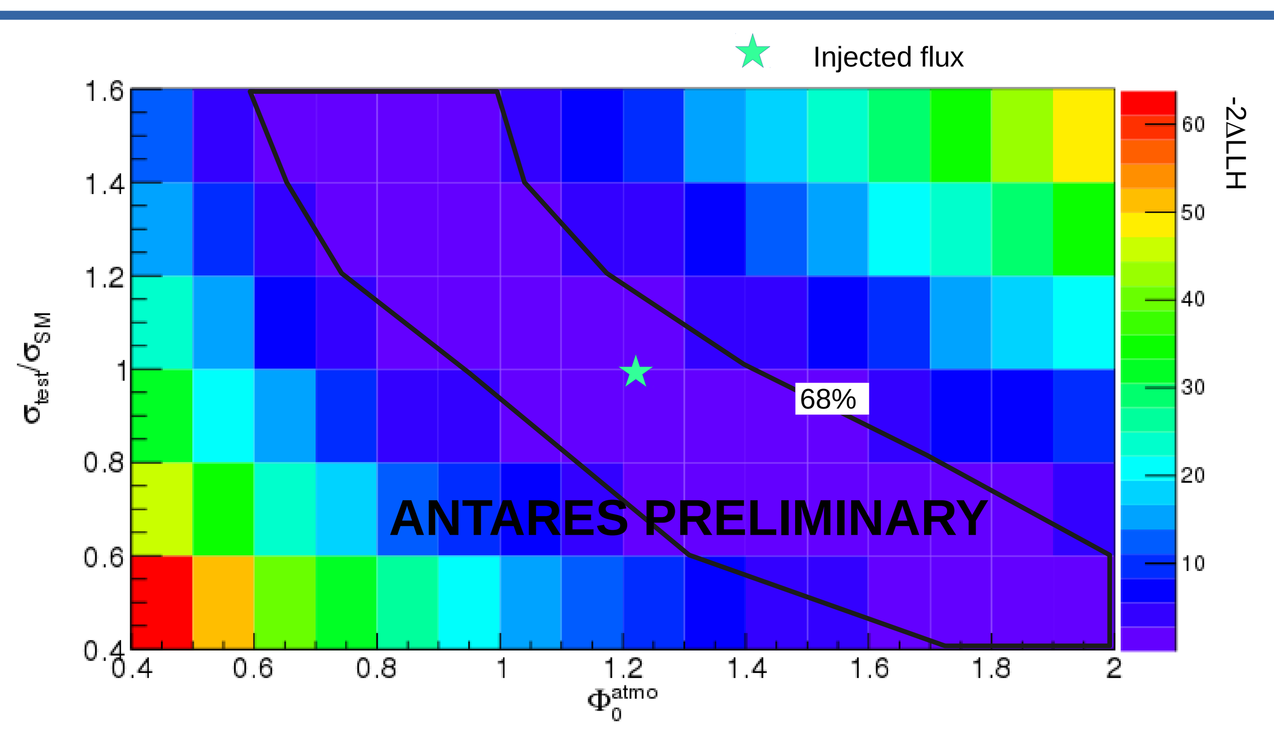

Figure 4. -2ΔLLH profile for pseudo-data fitting for SM cross section assumption and an atmospheric neutrino flux 25% higher than the conventional models. The 1σ confidence region for the measurement is shown.

$$L = \prod_{S\in\{sh,tr\}} \prod_{i=0}^{N_S} L_{i,S} \quad \text{with} \quad L_{i,S} = e^{-\mu_{i,S}} \cdot \frac{\mu_i^{k_{i,S}}}{k_{i,S}!}$$

μ_i - MC expectations for each bin, according to MC template of the cross section and the atmospheric neutrino properties

k_i - observation

-2ΔLogLikelihood estimator

References

[1] S. Adrian-Martinez et al., EPJC **73**:2606 (2013)

[2] A. Albert et al., ApJL **853:** L7 (2018)