# KM3NeT performance on oscillation and absorption tomography of the Earth

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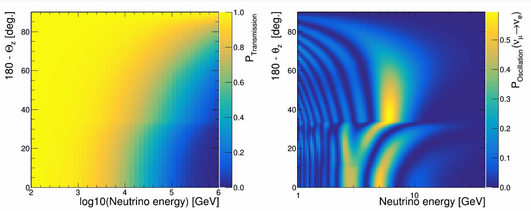
## Introduction

The two KM3NeT detectors ORCA and ARCA [1] will detect atmospheric neutrinos from the GeV to PeV energy range. Neutrinos that traverse the Earth will be affected by the matter along their path in two possible ways:

>30 TeV neutrinos (ARCA): Absorption

GeV neutrinos (ORCA): Resonance matter oscillations




By studying these effects, KM3NeT will be able to provide insights about the Earth's interior **independent from seismic measurements**.

## Objectives

The absorption tomography with ARCA is sensitive to the matter density of the Earth. We are trying to measure a **density profile** like the Preliminary Earth Model (PREM [2]) coming from geoscience.

The oscillation tomography is sensitive to the electron density $n_e$, which is proportional to the proton-to-nucleon ratio Z/A and the matter density ρ:

$$n_e \sim \mathrm{Z/A} \times \rho$$

The determination of Z/A is of special interest for geophysicists, since it can be used to constrain the **chemical composition** of the outer core, which is not possible with seismic measurements.

Sources:

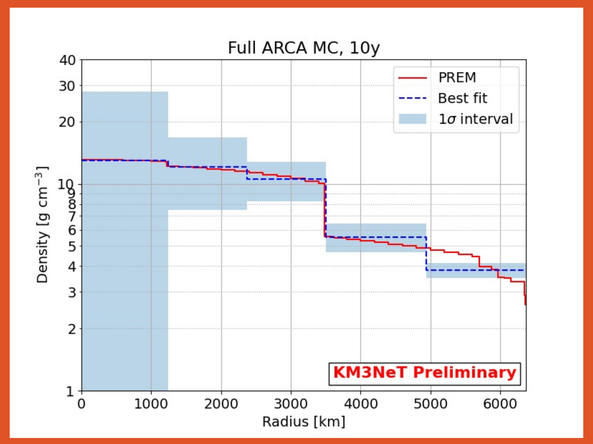
[1] S.Adrián-Martinézetal."Letter of intent for KM3NeT2.0".In: Journal of Physics G: Nuclear and Particle Physics (2016).

[2] M. Dziewonski and D. L. Anderson, Physics of the Earth and Planetary Interiors **25** 297 (1981).

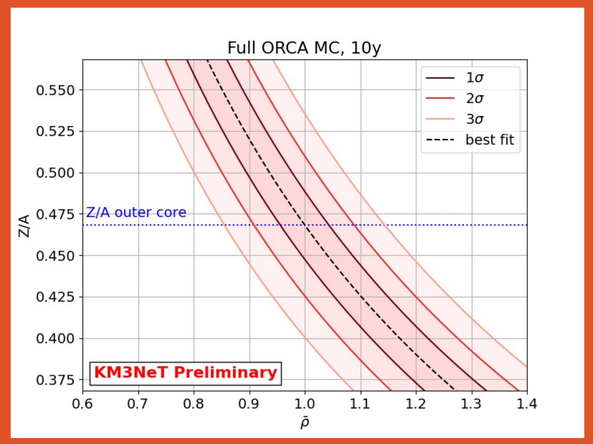
[3] https://github.com/joaoabcoelho/OscProb

# KM3NeT can measure the density and chemical composition of the deep Earth with atmospheric neutrinos

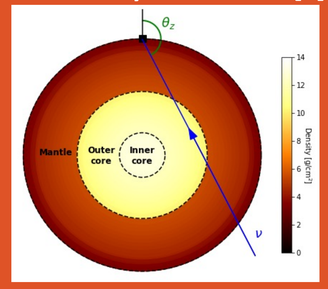
## Absorption tomography with ARCA: Density profiling




## Oscillation tomography with ORCA: Measure electron density




## Preliminary Earth model[1]

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## Methods

Our analysis calculates **log-likelihood-ratios on pseudo-experiments** to determine the sensitivity of KM3NeT for measuring Earth's parameters. We create the pseudo experiment by combining input models of the flux, neutrino cross-section with **oscillation and absorption probabilities** (these depend on the used Earth model) to calculate the interacting event rates at the respective detector-site. Both probabilities are calculated with *OscProb* [3], assuming an exponential attenuation of the neutrino flux. In order to model the **detector response**, we use event-by-event Monte Carlo simulations to create PDFs that will smear the true energy and direction of the neutrinos.

## Results

Absorption tomography with ARCA:

We use here an Earth model with 5 layers of constant matter densities according to the average over the density of the corresponding layers of PREM. We fit the densities of each layer and determine the $1\sigma$ errors, respectively. We find that we can **distinguish between the core and the mantle** with a density profile measured with neutrinos. Overall, the accuracy of density measurement with neutrinos are not compatible with seismic methods (PREM uncertainties are only a few percent). The presented result is calculated for 10 years of data taking with two ARCA building blocks, without taking into account any systematic uncertainty.

Oscillation tomography with ORCA:

For the analysis on the outer core with neutrino oscillations, we perform a fit of the Z/A and draw the $1, 2$ and $3\sigma$ contour lines, that correspond to equal values of the electron density $n_e$. For our fit we do not apply any priors to remain independent from seismic measurements. Results from absorption tomography could be used as priors in future. If we would assume the PREM density ($\bar{\rho} = 1$), we could **determine the Z/A with +0.020,-0.021 accuracy**. Realistic Z/A values from theoretical Earth models vary between 0.4661 and ~0.4714 and are thus not yet distinguishable by oscillation tomography.

## Summary

Although the measurements of the Earth's interior with neutrinos are not yet competitive with seismic experiments, we showed here that tomography studies with neutrinos are feasible. **KM3NeT is an experiment capable of performing both oscillation and absorption tomography** and provide independent measurements of Earth parameters.

## Acknowledgements

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