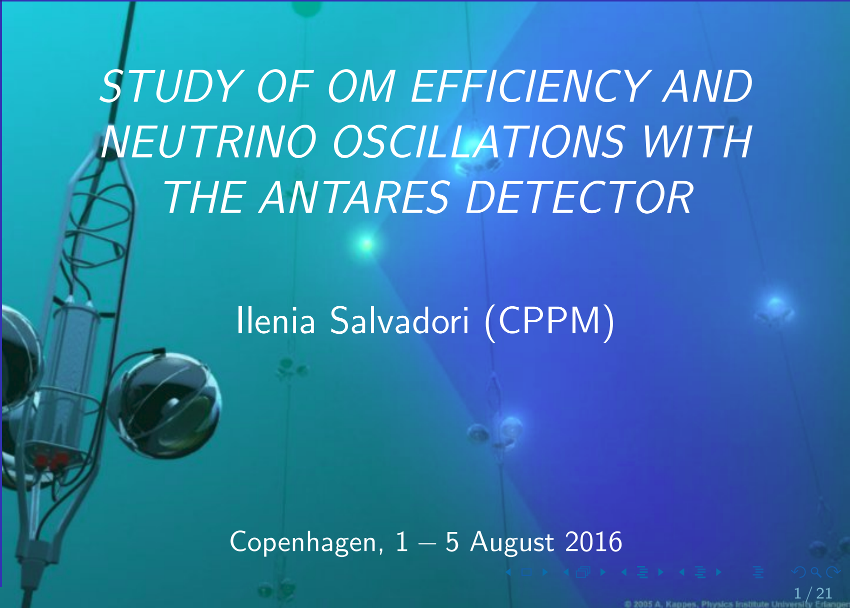
NBIA PhD School: Neutrino Underground & in the Heavens II



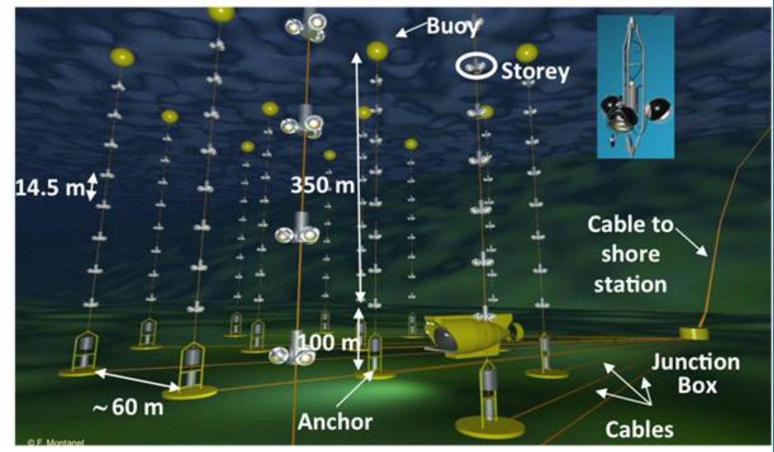
STUDY OF OM EFFICIENCY AND NEUTRINO OSCILLATIONS WITH THE ANTARES DETECTOR

Ilenia Salvadori (CPPM)

Copenhagen, 1 – 5 August 2016

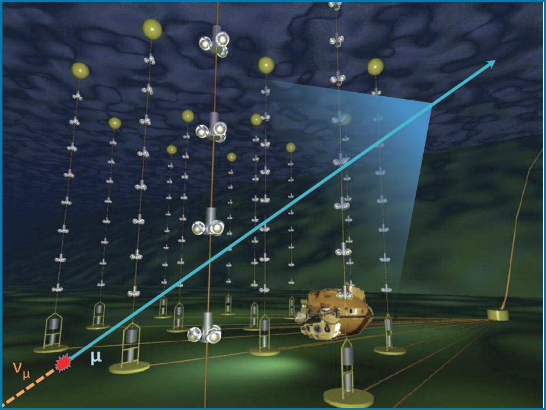
The ANTARES Detector

Completed in 2008!



The ANTARES Detection Method

Using Cherenkov light emitted by ultra relativistic particles produced by neutrino interactions under water!

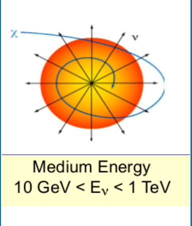


ANTARES Physics Goals

The main goals of ANTARES are:

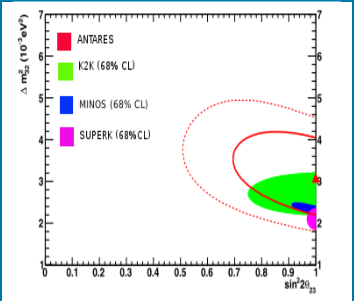
- the study of particle acceleration mechanisms in energetic astrophysical objects;

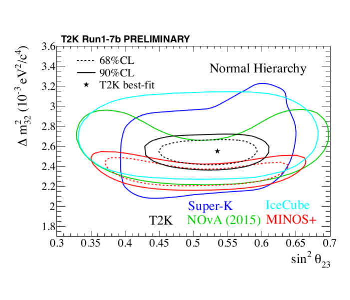
- the detection of non-baryonic dark matter (WIMPs) through the neutrinos produced by annihilation of WIMPs in the cores of the Earth and the Sun;



ANTARES Physics Goals

- the study, at energies below 100 GeV, of neutrino oscillations by analyzing distortions in the energy/angular spectrum of upward-going atmospheric neutrinos.



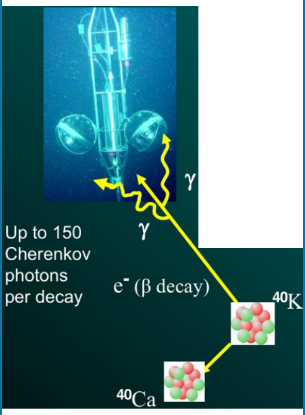


Physics Letters B 714 (2012) H. A. Tanaka (Neutrino 2016)

STUDY OF THE OPTICAL MODULES EFFICIENCY WITH THE ^{40}K TRIGGER METHOD

OM Efficiency Study

- ^{40}K is the most abundant radioactive isotope in sea water;

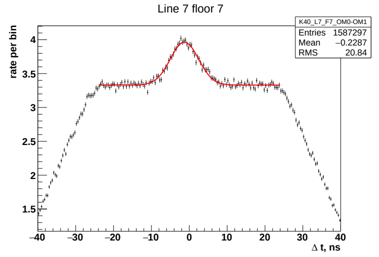


- GENUINE COINCIDENCES (a ^{40}K decay is recorded by two OMs)
- RANDOM COINCIDENCES (two distinct ^{40}K decays are recorded by two OMs)

OM Efficiency Study

The histograms of the hit time differences between hits from adjacent PMTs can then be fitted with a Gaussian plus a flat distribution, and the fit parameters can be stored for further analysis:

$$f(t) = p + a\exp(-\frac{(t-t_0)^2}{2\sigma^2})$$



OM Efficiency Study

- From the fit parameters we can obtained three correlated coincidence rates for each storey;
- From those rates we can analytically deduce the three OM efficiency.

Why is the OM efficiency so important?

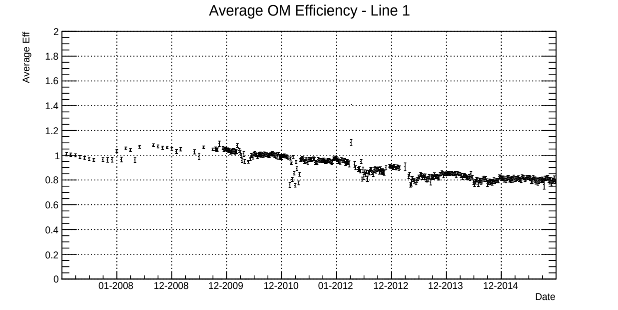
- The sensitivity of OMs can vary from module to module and can also vary in time;
- All these variations may affect track and energy reconstructions, as well as the overall detector efficiency.

OM Efficiency Study

My work consisted in:

- Rewriting the script which produces the coincidence histograms;
- Fitting them and finding a proper set of sanity cuts to get rid of the bad fitted histograms;
- Computing the OM efficiency as a function of time, both for each OM and for each detector line.

OM Efficiency Study



Ten years in the water!!

- The efficiency decreases with time due to biofouling and PMT ageing;
- Steps are due to HV tuning.

NEUTRINO OSCILLATIONS

WITH ANTARES

Neutrino Oscillation Analysis

Old Analysis	New Analysis
2007-2010 data	2007-2015 data
muon track length	vertex + containment + muon length + shower energy
$1D$ fit in L/E	$2D$ fit in L and E

Energy Reconstruction Algorithm

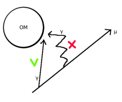
The basic idea is:

- Reconstruct the muon energy by the estimation of the muon track length and the interaction vertex;
- Reconstruct the neutrino energy from the reconstructed muon track length and the hits used by the track reconstruction algorithm.

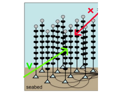
Energy Reconstruction Algorithm

The first step is try to select the hits from the muon track:

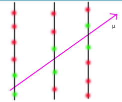
Low Energies



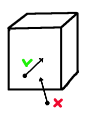
Direct Photons



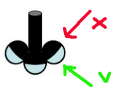
Up-going tracks



OMs around track



Containment

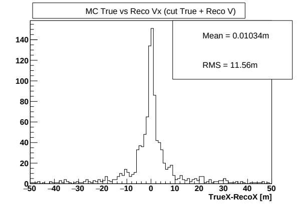


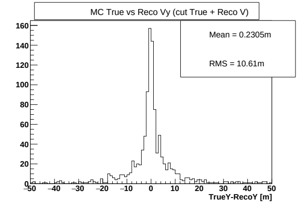
Facing Photons

Energy Reconstruction Algorithm

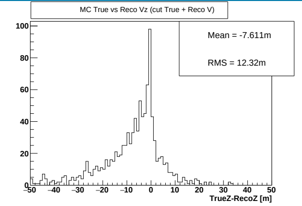
- We projected back to the track the Cherenkov photons selected;
- Using the first hit (based on the photon emission time) we can estimate the interaction vertex;
- Then we kept only those events for which the containment condition was satisfied also by the reconstructed vertex.

Energy Reconstruction Algorithm





MC Hits - $X_{true} - X_{reco}$ MC Hits - $Y_{true} - Y_{reco}$

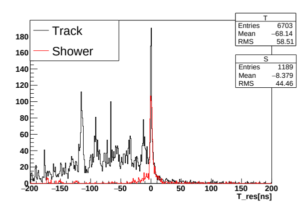


MC Hits - $Z_{true} - Z_{reco}$

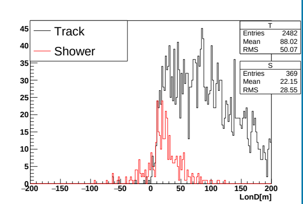
Energy Reconstruction Algorithm

- We tried to study whether we can distinguish between track and shower hits;
- For the events for which the first vertex estimation, (V'), succeeded, I computed both for track and shower hits:
  - the time residual with respect to the the time of V';
  - the longitudinal (l) and orthogonal (k) projections of the distance between V' and the OM in which a hit has been seen.

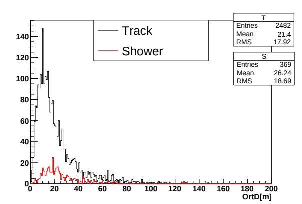
Vertex Estimation - Track vs Shower Hits



Time Residual



Long Projection



Ort Projection

Energy Reconstruction Algorithm

Work in progress:

- Obtain a second vertex estimation from a shower reconstruction algorithm;
- Study the correlation with the true neutrino energy;
- Determine the most suitable track reconstruction algorithm.

Thank you for your attention!