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The Water Properties of the Site in Capo Passero using the LED Beacon of the Prototype Tower

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Abstract

In that work we study the scattering parameters of the water on the KM3Net site in Capo Passero. To this purpose we compare the real data from the time calibration runs of the detector to the results of a simulations of the light emission, propagation and detection according to the expeimental apparatus.

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1 Introduction

One of the two detection infrastructures of KM3NeT [1] is located near Sicily, Italy. It uses the Cherenkov light method to detect high energy neutrinos and requires a precise knowledge of the light propagation in the water. So, in this note we will present some steps that are leading to that knowledge. For this purpose we used a comparison between the GEANT4 simulation [2] with different parameters and the real experimental data from the prototype tower [3]. These data are the arrival time distributions of the photons emitted by one LED in one beam of the tower and detected by an upper optical module. The peak of the distribution is used for timing calibration purposes while the tail mostly depends on the scattering properties of the water as discussed in this note. We expect that this approach can be extended to the analysis of the data from the new prototype strings [4].

2 Experimental facilities

The test line used in this work is shown in fig.1. It had 8 floors, each level is an 8-meter-long beam, which are separated by the distance of 40 meters, the bottom one is 100 meters above from the sea bottom. Each beam is perpendicular to its nearest neibourghs.

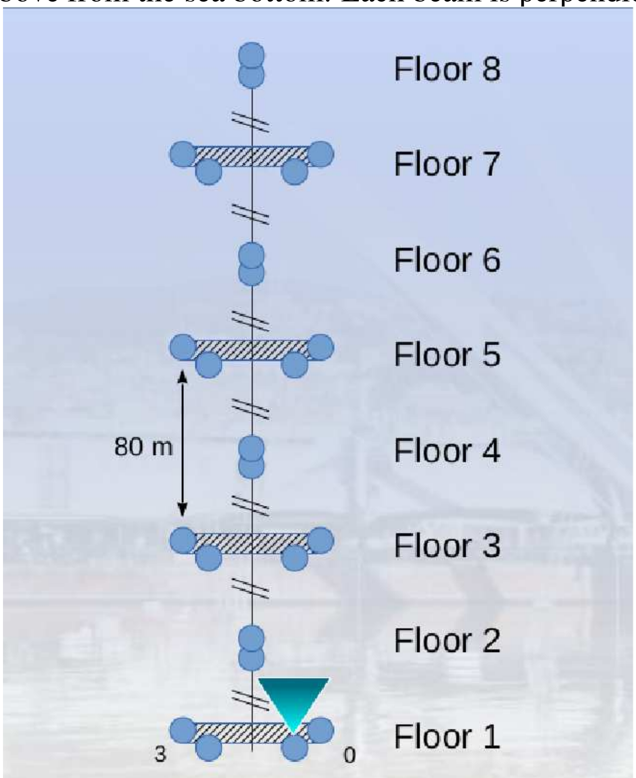

Figure 1: The Tower Prototype

On each end of each beam there are two optical modules [5], one of which looks downward, another is turned sidewards. The structure of the optical module is shown in fig.2: a glass sphere contais one 8” Hamamatsu photomultiplier, electronic boards for the PMT’s operation, read out and for time calibration. The optical gel provides mechanical and optical contact between the sphere and the PMT, and a μ-metal net protects the system from the magnetic field.

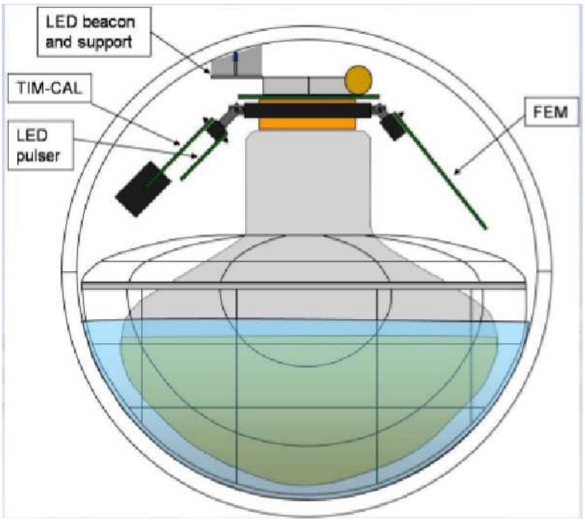

Figure 2: The Optical Module

As it is shown in fig.2, the upper side of the OM contains a support with an LED. The LED has a wavelength equal to 470 nm (that is blue, closer to the Cherenkov radiation’s higher intensity region) pointing upward. Three of them on the lower floors are used in the calibration runs. During the calibration runs, these beacons are blinking with the frequency of 2 kHz.

The analised data includes empty runs with background noise as well as the runs with active LEDs on different floors. Some of them have lower intensity, and suites better for our purpose. The reason for that will be explained later in the Scattering section.

As an example fig.3 represents the charge detected in one OM as a function of the time. In the same OM an LED was activated with different intensities corresponding to the different charge levels. Noise level is represented by the few counts above t=700 while a more detailed view of the background behavior is reported in fig.4. Here the spikes correspond to bioluminescence activity close to the OM.

We determined the charge calibration procedure using the noise runs. These runs contains mostly one-photon events, produced by biological activity or 40K decay, so if we

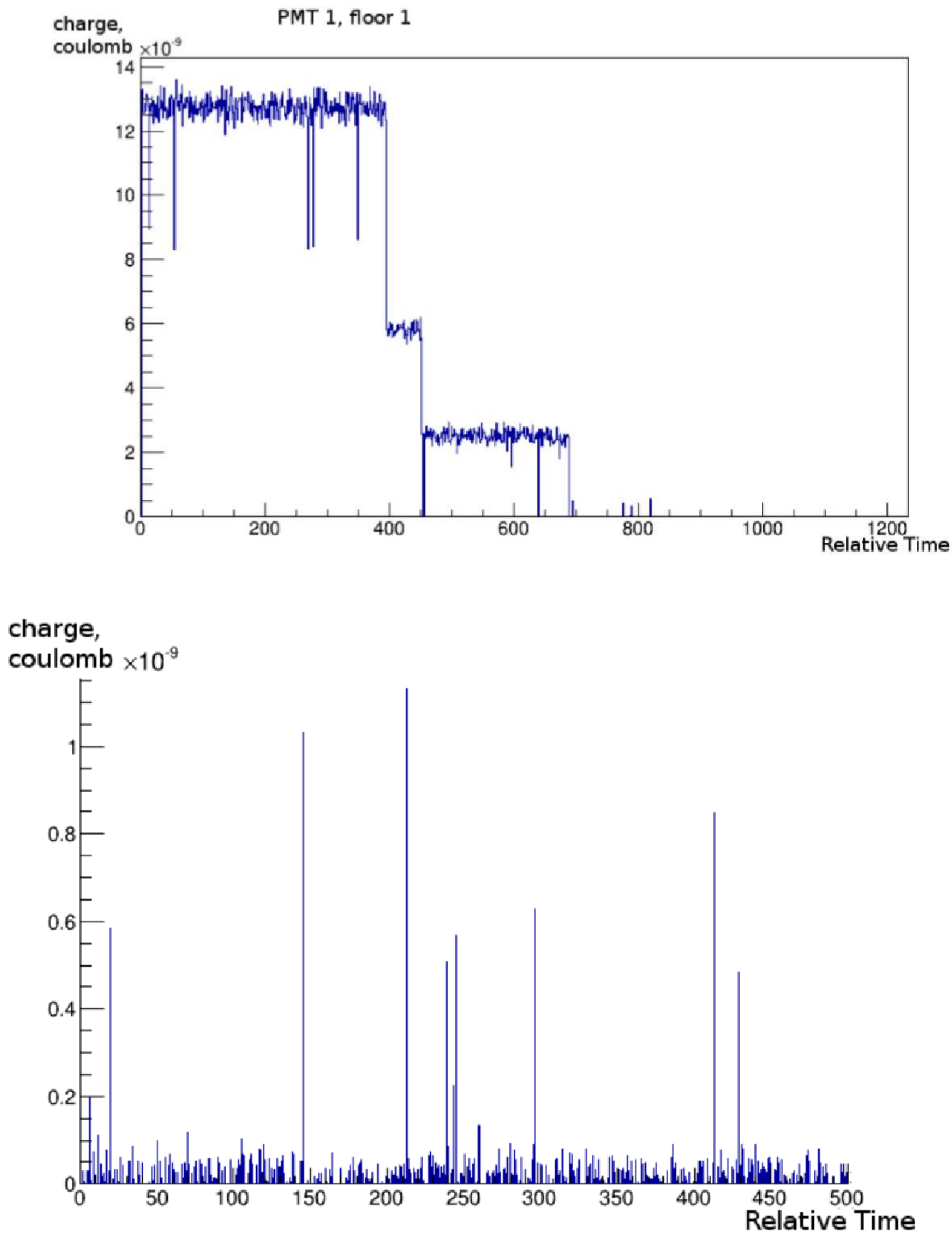

Figure 4: The Run with Noise

plot the hystogram of the number of the events with different charge, the plot's maximum will correspond to the most probable charge produced by a single photon. So, the plot's peak was approximated by a gaussian curve and the charge was taken from the position of the maximum of the curve, as shown in fig.5. The charges were quite similar, as expected, but not exactly the same, so we had to consider that.

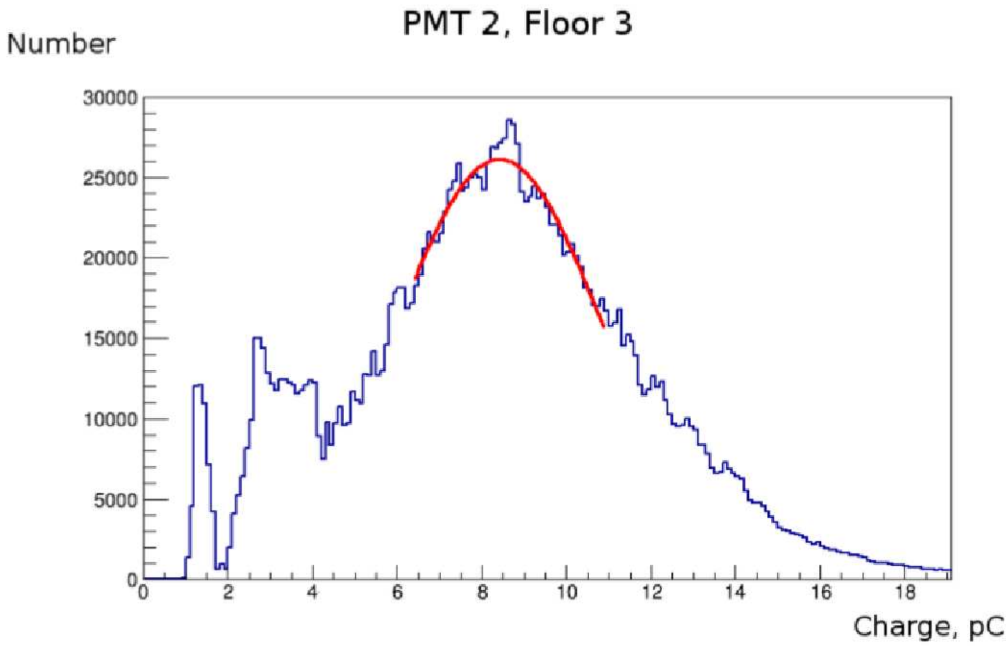

Figure 5: Calibration

3 Scattering

The scattering is studied here using the Kopelevich model [6] that uses two sizes of particles, large and small, instead of a variety of sizes. The resulting scattering probability from the particle is the following:

$$b_p = 1.34\nu_s\Big(\frac{550nm}{\lambda}\Big)^{1.7} + 0.312\nu_l\Big(\frac{550nm}{\lambda}\Big)^{0.3} \tag{1}$$

where the suffix s stands for small, l for large and λ is the wave length. There is also a part that is related to the molecule scattering. The angular distributions for these two variants of scattering are different, the particle one has forward going angular distribution, while the molecule scattering has isotropic distribution. The scattering distribution from the molecules is, however, relatively well known, while the parameters of the particles vary from one location to the other.

In the next stage of the work we developed a method to select the LED pulses and we accumulated statistics to well determine the arrival time distribution as detected in one

PMT. The LED was blinking in a regular manner, so it was possible to sum the signal from all the flashes. As these flashes had the same duration and the same intensity, it was possible to do that. The intervals of 500 μs that includes a shorter flash of light together with all the scattering effects, were summed together to collect a significant data array.

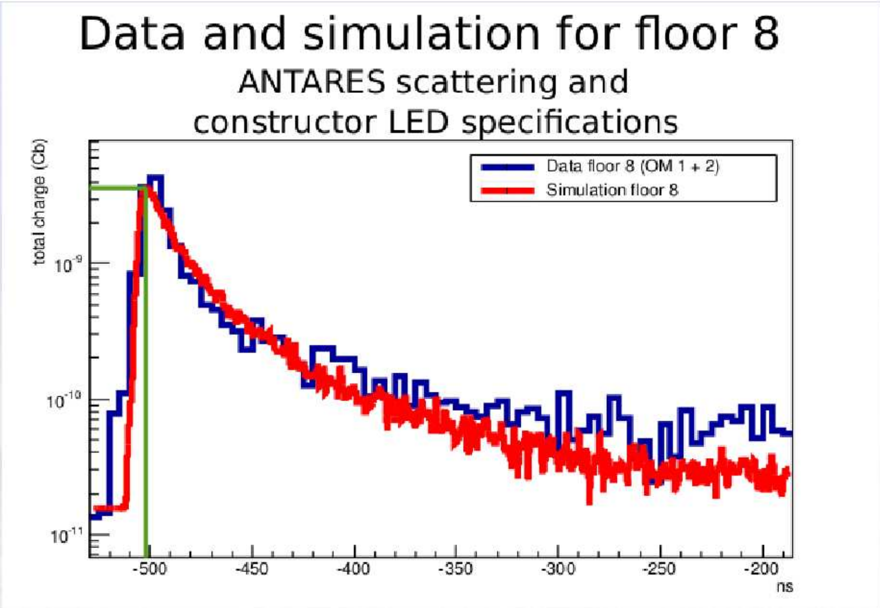

Figure 6: An example of the time arrival distribution of the photons from the LED located in floor 1 and detected in floor 8 compared to the GEANT4 calculation

In this analysis we considered only the runs at low intensity to guarantee that only one photon at time reach the PMT

The simulation uses GEANT4 to model of the propagation of the photons through the water. That model works only with the assumption that only one photon is detected at the same moment. That assumption is quite rough, of course, but without it the diffilcuties of creating the simulation will increase significantly. So, instead of doing that, we selected a low-intensity run.

An example of the time arrival distribution of the photons from the LED located on floor 1 and detected in floor 8 is reported in fig. 6. The measurement (blue line) is compared to the GEANT4 simulation (red line).

4 Analysis

The simulation was repeated several times, with two parameters varied. One was a scalig factor which was applied to the total scattering legth that is the primary aim of that study, another was the aperture angle of the LED which was varied within its specifications $\pm 5\%$. The results of the simulation of the arrival time distribution was at first approximated by an exponential decay, and after this smoothing it was compared with real data. That was done to simplify the analysis.

The analysis was made at first using the data only from the seventh floor of the system, but afterwards the study was extended to the three highest floors.

From each value of the scattering factor and of aperture angle we performed the simulation and compared to the real data. Some parameters, like height of the peak or the start time of the signal, were changed to fit the real values better (so there was a time shift and vertical scaling). After that we took chi-square for each pair of parameters. Finaly, a plot representing the dependency of χ-square from the scattering lenght and the apperture angle was made. The result of the two-dimensional χ-square distribution is reported in fig.7. The darker color represents lower χ-square values , that is better fit to the data. The chisquare distribution does not show a clear behavior but there is an evidence that and LED angular aperture close to the nominal values together with a scaling factor of 0.9 better fit the experimental distributions. The scaling factor 0.9 is applied to the total scattering length used in the simulation indicated in the figure as '0.9 ANTARES sca.' This result indicates that the method we have described is potentially usable to determine the scattering properties of the environment. We are confident that the application of this procedure to the new data from the strings will give more results.

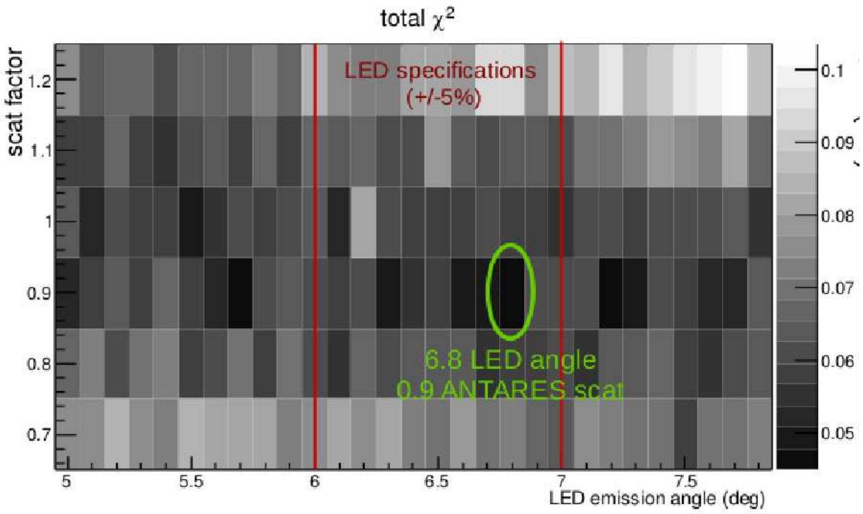

Figure 7: The Result of the χ-square definition for different parameters

5 Conclusion

To sum up, the main result of this work is the development of a method to determine the scattering length of enviromental water in the Capo Passero site. Unluckily, the data from the tower prototype does not seem to be sufficiently accurate for the task, so the water parameters should be re-evaluated using the data from the string, that seems to provide more accurate information.

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