PMT Characterisation for the KM3NeT Project

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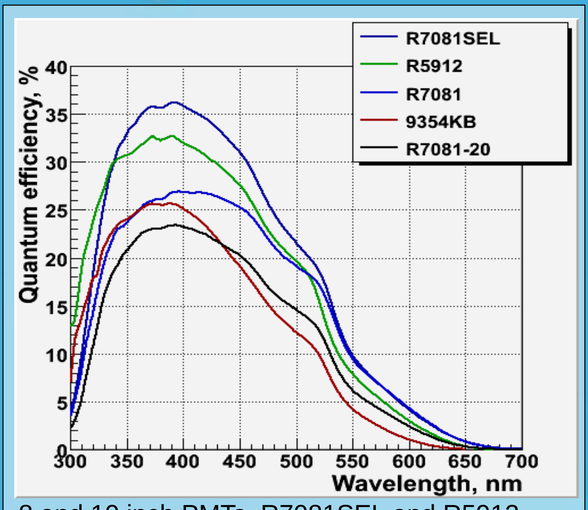
Abstract. The KM3NeT project[1] aims to design and to construct at least a cubic-kilometre scale neutrino telescope in the Mediterranean Sea. The main task is to instrument this deep-sea water volume with optical modules, each housing one or several photomultiplier tubes (PMTs). 3-, 8- and 10-inch PMTs from ET Enterprises, Hamamatsu and MELZ-FEU have been investigated as candidates for the telescope's optical modules. Various parameters of these photomultiplier tubes have been measured in a test bench at the Erlangen Centre for Astroparticle Physics. These results are presented.

PMTs. Tested PMTs: Hamamatsu R7081 (10in), R5912 (8in), R6233 (3in); ET Enterprises ET9354 (8in), ET9822 (3in); MELZ FEU FEU184TD (3in).
All PMTs have bialkali photocathodes . Spectral sensitivity of this photocathode type is well suited for the spectral distribution of incoming Cherenkov photons. Newer enhanced “super bialkali “ photocathodes are claimed to achieve up to 36% quantum efficiency compared to around 25% of standard bialkali. Both photocathode’s types were available for all Hamamatsu PMTs.

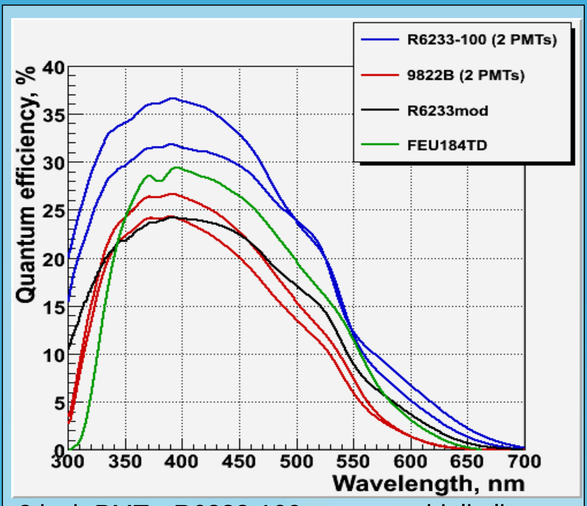
3 inch PMTs FEU184TD, R6233, ET9822 (left to right)

8 inch ET9354 and 10 inch Hamamatsu R7081 hemispherical PMTs

Quantum efficiency. QE is measured in a DC mode. Light from the halogen lamp is guided through a monochromator to a light-tight box containing a PMT. The Dynode-Anode structure is shortcut with a special PMT base and the typical recommended photocathode-1st dynode voltage increment is applied between the combined structure and the photocathode. PMT’s photocathode is connected via a picoamperemeter to ground. An absolute-calibrated photodiode is used as a reference photodetector to provide an absolute calibration of PMTs.

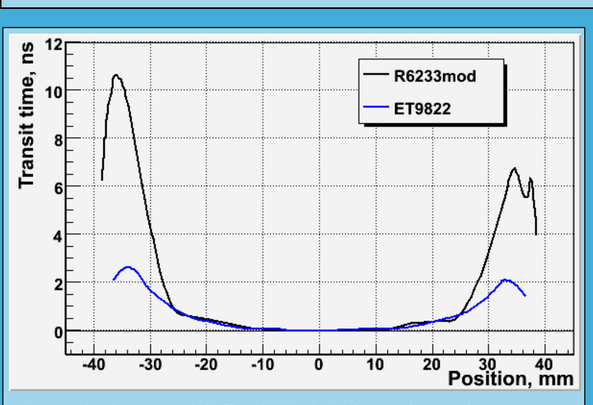


8 and 10 inch PMTs. R7081SEL and R5912 have super bialkali photocathodes

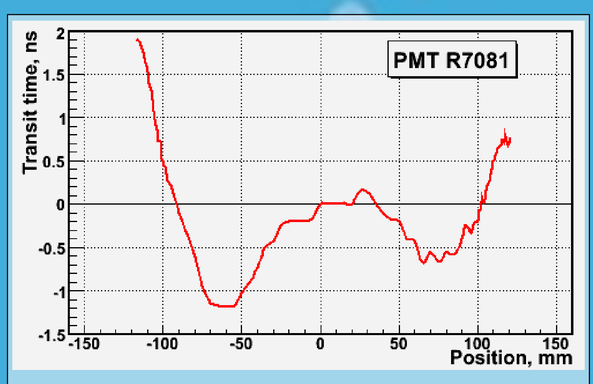


3 inch PMTs. R6233-100 are super bialkali

Transit time spread over photocathode. TTS is measured simultaneously with an effective area. 3in PMTs with flat photocathode have TTS exceeding the 2ns figure specified by KM3NeT. Modification of these PMTs toward a concave photocathode will improve TTS to a suitable value.

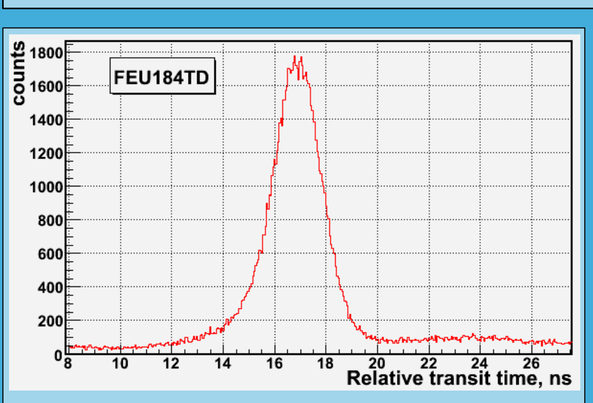


Transit times of fully (ET9822) and partly (R6233MOD) concave photocathodes

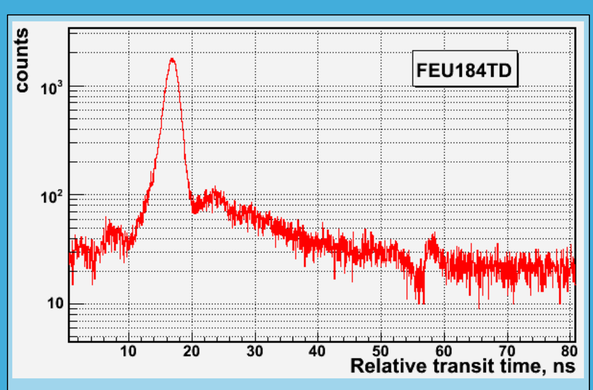


Transit time of 10in hemispherical PMT R7081

Single photoelectron jitter. This parameter is measured with fast (σ=14ps) laser pulses. Transit time distribution of single photoelectrons shows a main peak and a long tail of electrons scattered from the 1st dynode Only the main peak is taking into account to calculate jitter.



Single photoelectron jitter of PMT FEU184TD, main peak

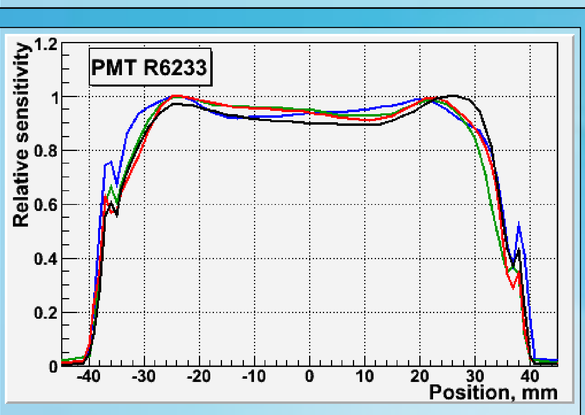


Single photoelectron jitter of PMT FEU184TD, main peak and tail

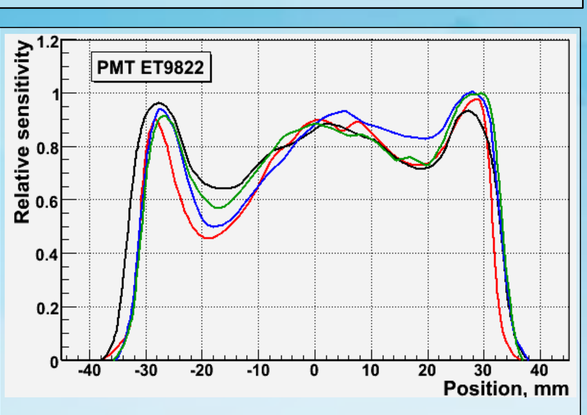
Summary of tests

PMT	TTS,ns	Jitter,ns	Area, cm²	Diameter,mm
R7081	1.0	1.2	380	220
R5912		0.57		
ET9354	0.62	0.67	264	183
R6233mod	3.1	1.5	35	67
FEU184TD	4.0	1.0	33	65
ET9822	0.73	0.55	27	58

Effective photocathode area. Through the scanning of the PMT surface with a pulsed light source, both the inhomogeneity of the photocathode deposition and variations in collection efficiency are measured simultaneously. To perform such tests, an X-Y scanner was built at ECAP. In the presented results, PMTs are scanned radially . Normalizing sensitivity to a maximal value, one can calculate an effective photocathode area.

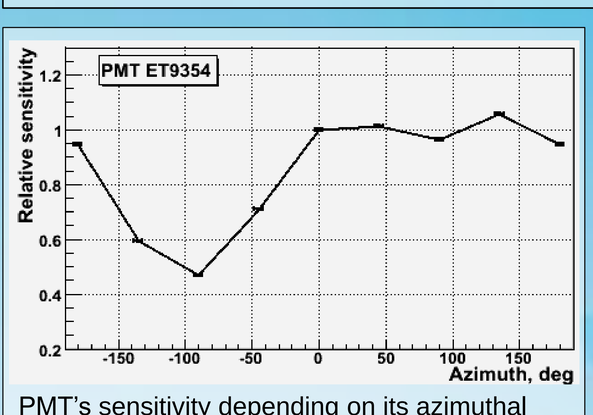


For most of the measured PMTs, the variation in relative sensitivity does not exceed 10%

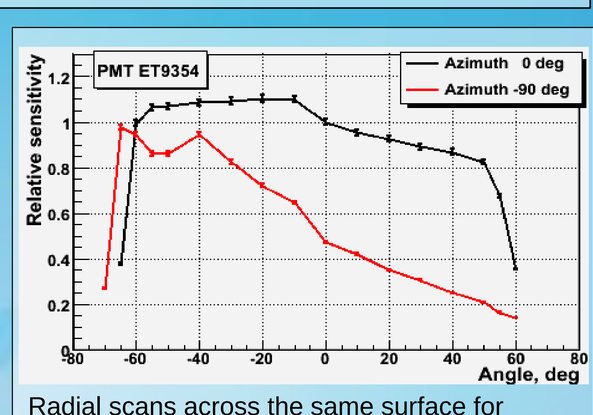


ET9822 has large variations of collection efficiency

Influence of the Earth’s magnetic field. These tests are ongoing in ECAP. First measurement of the 8in PMT ET9354 shows very strong dependence of the PMT response on the azimuthal orientation of the vertically installed PMT. Because of illuminations on a few tens photoelectron level, decreases of collection efficiency and/or amplification are not distinguished. The same tests on a single photoelecton level to be analysed.



PMT’s sensitivity depending on its azimuthal orientation. Photocathode’s centre is illuminated.



Radial scans across the same surface for different PMT orientations.

Acknowledgement and references.
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[1] KM3NeT Consortium, P. Bagley et al., *KM3NeT Conceptual Design for a Deep-Sea Research Infrastructure Incorporating a Very Large Volume Neutrino Telescope in the Mediterranean Sea*, 2008, http://www.km3net.org/CDR/CDR-KM3NeT.pdf;