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Digital Multi-PMT optical module for the KM3NeT neutrino telescope

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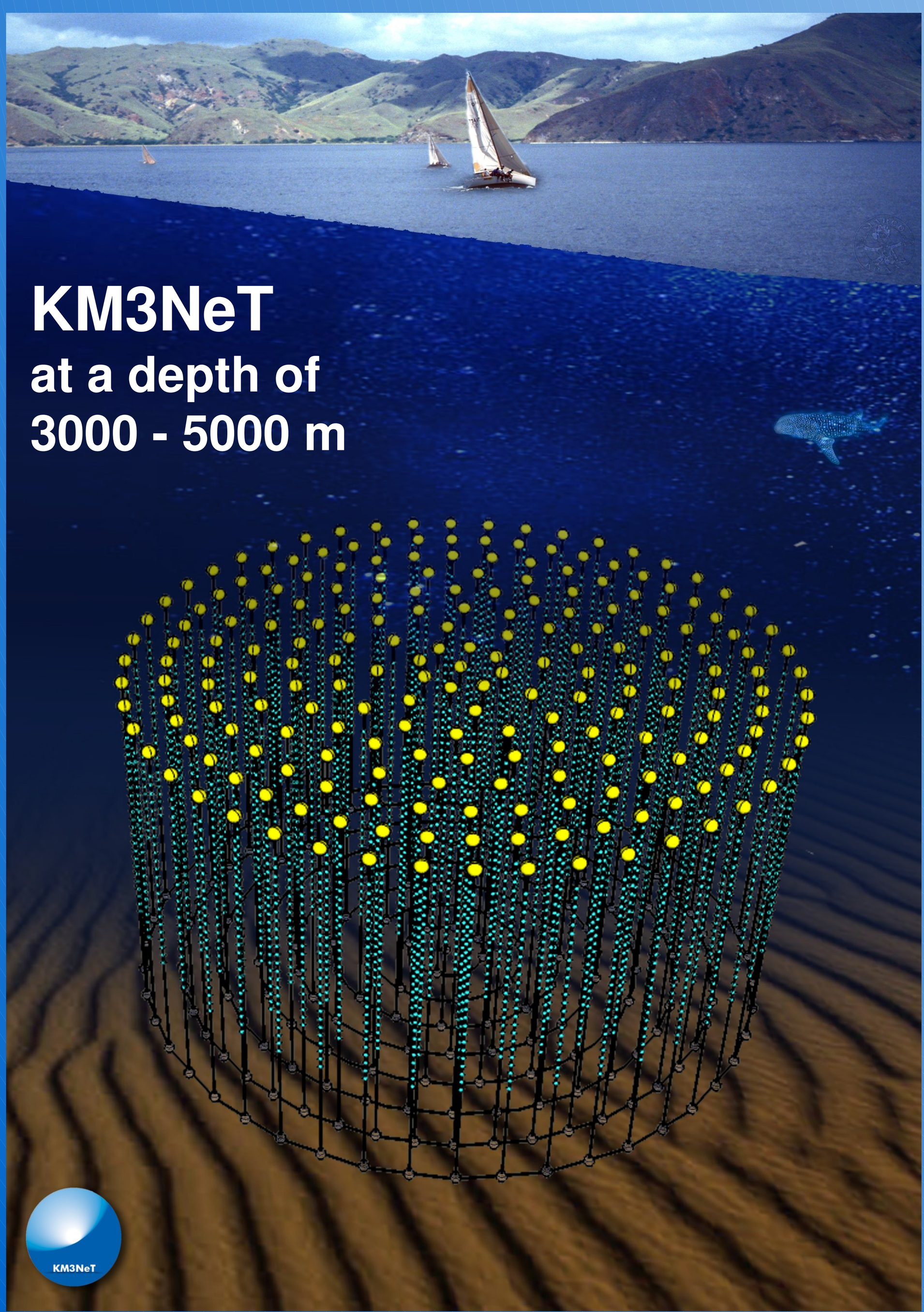
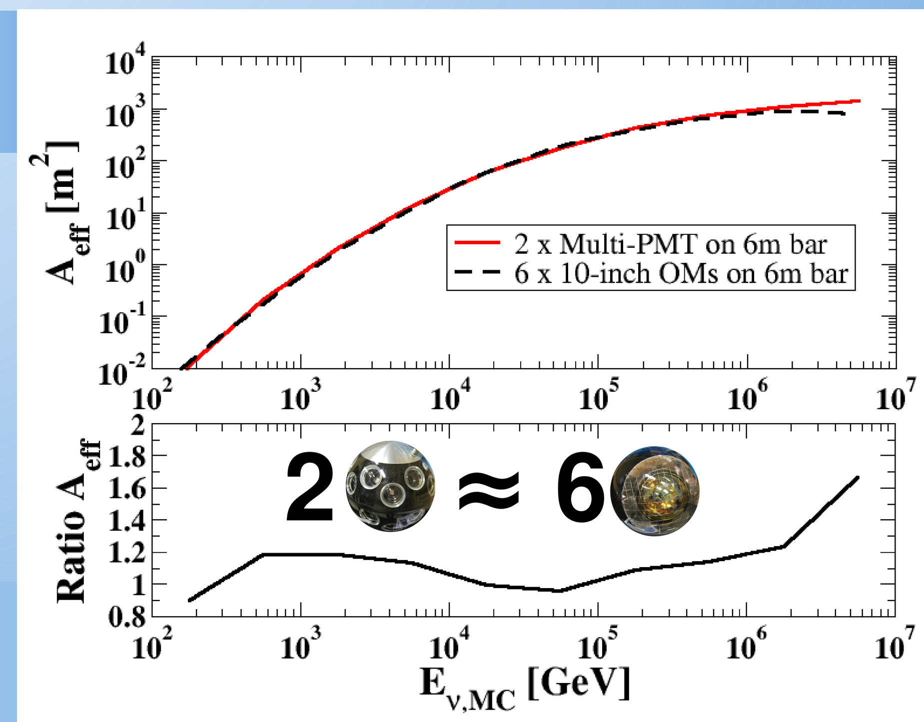


KM3NeT

KM3NeT [1] is a future European research facility in the Mediterranean Sea that will house a neutrino telescope of multi-cubic-kilometer scale. Cherenkov light from neutrino-induced secondary charged particles will be detected by an array of optical modules (OMs) – high-pressure resistant glass spheres containing photomultiplier tubes.



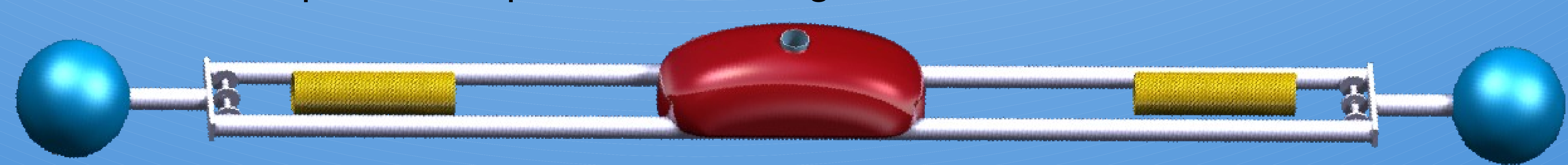
Monte-Carlo generated [2] effective area for neutrino detection as function of the neutrino energy after full reconstruction for the KM3NeT design option with multi-PMT OMs (solid red curve) and with conventional OMs hosting 10-inch PMTs (black dashed curve). Ratio is shown in the bottom panel.

Detection unit (DU)

The DU is a **flexible tower** of 900 m height with 20 storeys (floors) at 40 m distance.

Bar

Storey: 6m long bar equipped with 2 multi-PMT OMs.
Multi-PMT OM: pressure sphere containing 31 3-inch PMTs.



Required characteristics for 3-inch PMTs

Cathode (CsK) quantum efficiency	>32% at 404 nm >20% at 470 nm
Inhomogeneity of cathode response	< 10%
Dark count rate	< 3 kHz at 15°C
Transit time spread	< 2 ns (σ)
Peak-to-valley ratio	> 3
Operation Temperature	10 – 25°C

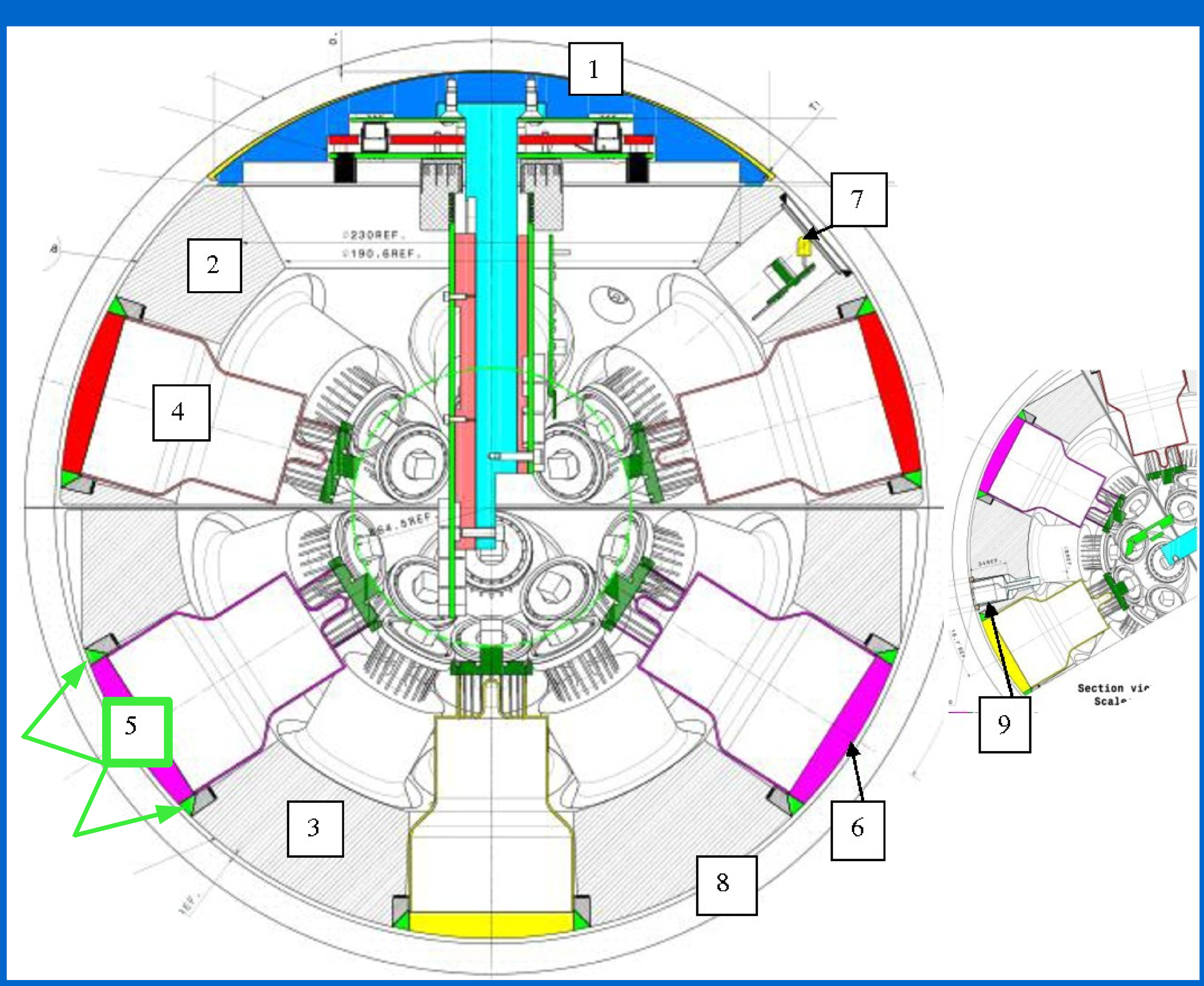
Digital Multi-PM Optical Module

The multi-PMT OM is designed to:
- minimize the number of connectors in the detection system;
- measure optical photons at the single-photon level

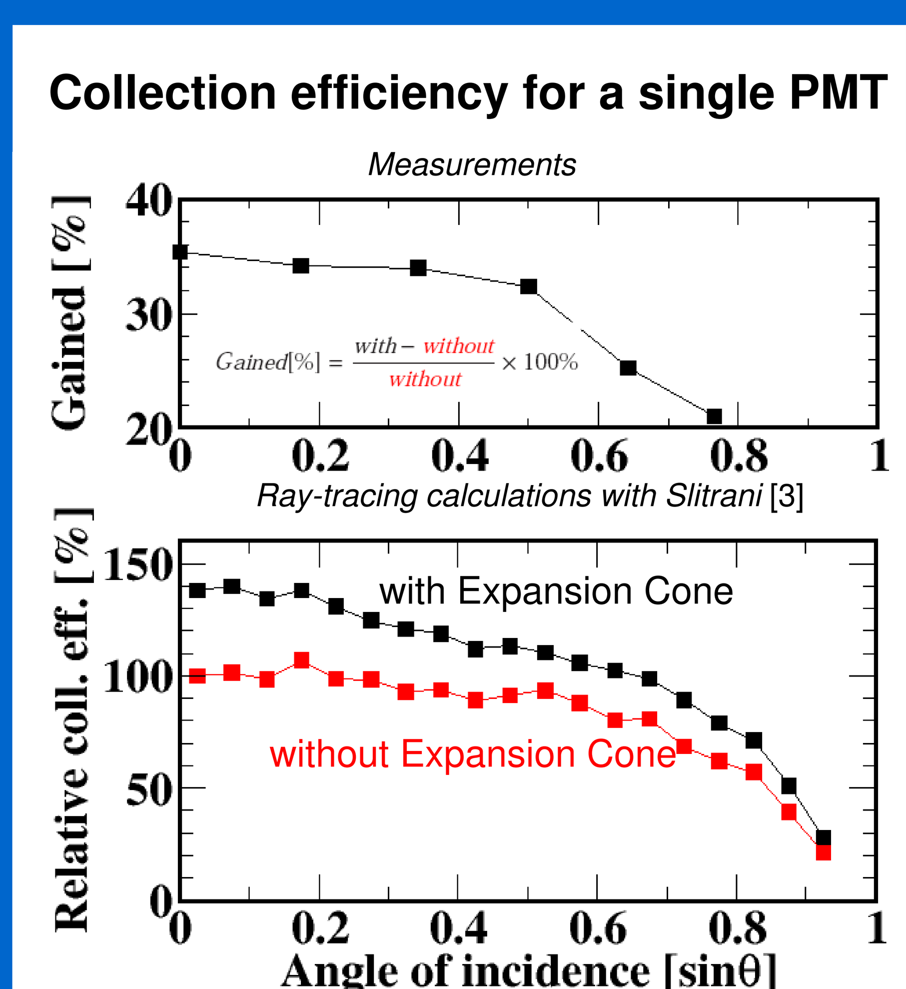
Advantages

+ Very good one-vs.-two photoelectron separation
+ Wide-angle photon acceptance
+ Reduced environmental background by requiring local coincidences
+ Good QE and transit time spread
+ Increased photo sensitivity by reflective rings surrounding PMTs
+ Longer PMT lifetime (smaller photo cathode and less collected charge per year)
+ No magnetic shielding needed

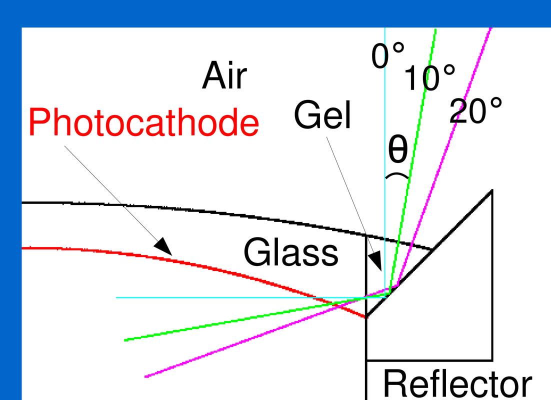
➡ **31 PMTs, 19 (12)** in lower (upper) hemisphere, suspended in foam support
➡ **Optical gel** (optical contact)
➡ **OM-logic board**
converts signals from the PMTs to: time, amplitude and PMT (OM) identification; contains electronic and photonic components for an optical serial link to the shore
➡ **Signal collection boards**
link the PMTs and the OM-logic board
➡ **Printed circuit (converter) board**
provides all necessary DC power
➡ **Adjustable HV supply for each PMT**
➡ **Aluminium structure**
provides heat conduction between the electronics and the exterior of the sphere
➡ **Overall power consumption: 7 W / OM**
➡ **Colour point-to-point connections**
of individual OMs to shore station



Cross section A-A
*1-Heat conductor, **2,3**- Foam cores, **4**-PMT with PMT base, **5**-Expansion cone, **6**-Optical coupler, **7**-Nanobeacon, **8**-Glass sphere, **9**-Piezo element.*



Expansion Cone



➡ The photon collection area will be extended by a bevelled reflective aluminium collar, the expansion cone (filled with silicon gel)

➡ Measurements reveal an increase in collection efficiency by 30 % on average for angles of incidence from -50° to +45°, with a maximum of 35 % for perpendicular incidence

➡ Ray-tracing calculations were performed with SLitrani, a general purpose Monte-Carlo program simulating light propagation [3], resulting in an overall photocathode acceptance increase of 27 % integrated over all angles of incidence

Acknowledgements

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References

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