# Underwater pressure tests of photomultiplier tubes and assembly of a demonstrator for PMm²

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*PMm² est un projet de recherche-développement destiné à répondre aux besoins des futures expériences sur les neutrinos de type « Mégatonne ». Il s'agit de placer dans l'eau sous une pression pouvant aller jusque 7 bars des tubes photomultiplicateurs, leur polarisation et l'électronique. Le Service Détecteurs a conçu une embase et une connexion à l'électronique, étanche jusqu'à une pression de 10 bars, qui a été vérifiée avec des petits tubes photomultiplicateurs. Le dialogue avec la société Photonis a permis d'aboutir à produire des verreries de tubes photomultiplicateurs de 12 pouces tenant plus de 20 bars de pression. La mécanique d'un démonstrateur d'un module constitué de 16 photomultiplicateurs de 8 pouces de diamètre a été réalisée. Ce projet a permis à l'IPN d'acquérir des compétences pour d'autres futurs projets aux conditions environnementales sévères. Il est financé par le contrat ANR-06-BLAN-0186.*

The next generation of neutrino experiments [1], the post-SuperKamiokande detectors will need megaton size water tanks. Therefore they will require very large surfaces of photodetection and will produce a large volume of data. Even with large hemispherical photomultiplier tubes (PMT), the expected number of channels should reach hundreds of thousands. As a consequence, the costs are a major issue, and the design must take into account the production processes and the reliability. Those photodetectors will be directly in contact with water, and will therefore have to sustain pressure of several bars. The requirement has been put to 10 bars.

## The PMm² proposal

A R&D program called PMm² [2, 3] was set-up by the LAL, the IPN, the LAPP and the Photonis company to implement a solution. It consists in segmenting the large photodection surface in macro pixels made of 16 hemispherical (12 inches) PMTs connected to an autonomous front-end electronics. Only the relevant data will be sent out by cable to the central data storage unit in a triggerless mode. The LAPP carried out this study in order to transmit data at a rate of 5 Mb/s per cable. This allows then to reduce considerably the cost of these detectors and facilitate their industrialization.

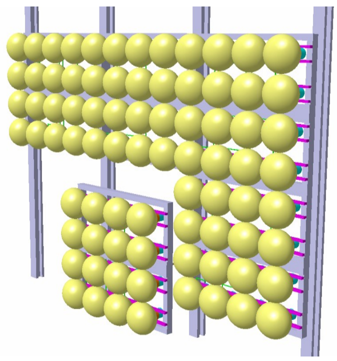

Figure 1: Principle of the modular architecture.

The main goal of this project is the study, implementation and test of a demonstrator made of 16 PMTs, the front-end electronics, a cable and its readout. Within this collaboration, the Detector department of IPN Orsay has discussed the requirements on the new PMTs with Photonis, studied the water tightness of the PMT, its base circuit and the front-end enclosure. It has also assembled a demonstrator for 16 large PMTs

## A single high voltage for 16 PMTs

In the proposed design, the PMTs are biased by a resistive voltage divider. In order to reduce the connection costs, the same coaxial cable carries the high voltage and the signal. The high voltage is common for the 16 PMTs. The bases are to be put underwater and therefore need to be potted. The first tests were made with the Photonis XP3102 PMT, which diameter is one inch. The base was potted at the detector department (see Figure 2).

Figure 2: Potting of 1-in PMTs. The PMT base can be seen on the right side of the picture. The potted circuits are on the left side.

The signals are readout with an ASIC achieving amplification, shaping, discrimination, time stamping and charge digitization. This ASIC is developed at LAL [4] and tested at IPN Orsay with PMTs.

A prototype of front-end electronics was successfully tested at Orsay with 16 1-in PMTs supplied by a single high voltage, with the analog board developed at the IPN Orsay electronics department, the water-tight cables and connections validated by the Detector Department, the digital readout electronics developed by the LAPP and the data acquisition software developed at ULB. The analysis of the data is performed by the Detector Department by monitoring the charge of the single electron obtained from the PMT noise and estimating the noise and the cross-talk between the channels from the time stamp analysis.

## Water tightness and resistance to pressure

The water tightness and the resistance to the pressure was tested with a pressure vessel designed to sustain pressures up to 100 bars, which is shown in Figure 3. This type of tank has already been used for equivalent tests at Brookhaven National Laboratory (BNL, USA) by M. Diwan and coworkers, and one of them was sent to Orsay in 2008. This tank is equipped with feed-through for instrumentation.

The potted 1-in tubes and the front-end electronics are planned to be tested with this tank, which is large enough to contain 16 1-in tubes, the front-end enclosure and the rolled 100-m cable of data transmission.

Figure 3: Closing the pressure vessel before a test.

## Design and test of a new 12-in PMT envelope

The first calculations made at Orsay on the glass envelope of existing PMTs showed they could not sustain the 10 bar pressure required for the experiment because of weaknesses due to sharp bending of curvature at the bulb level and close to the pins. We validated the calculations by testing 20 tubes from Photonis and Hamamatsu with stress gauges in the pressure vessel (see Figure 4). We found a good agreement with our model and the experience, especially to predict where the tube would break. Photonis designed a new glass envelope of 12-inch PMT which was simulated and tested on two samples, which sustained more than 20 bars.

## Implementation of a demonstrator

A demonstrator was designed to test 16 hemispherical PMTs and the front-end electronics under water over a long period of time. Its sketch is shown in Figure 5.

Figure 4: Left: PMT equipped with stress gauges. Right: PMT cracked after a pressure test.

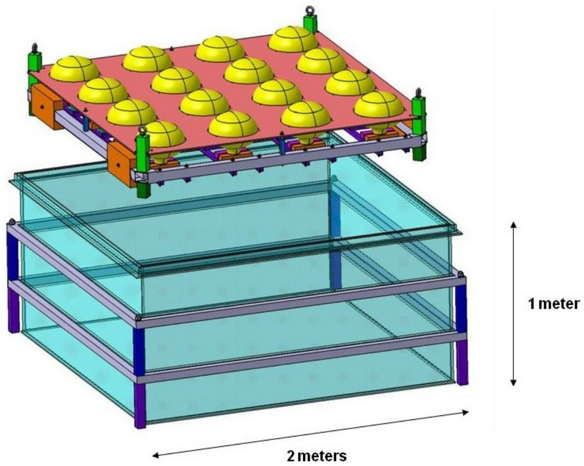


Figure 5: Drawing of the demonstrator for the test of 16 large PMTs under water with the front-end electronics.

Since the Photonis company halted its production of PMTs, we bought 16 8-in PMTs from Hamamatsu (R5912) after a compromise between the costs and the specifications. The design of the demonstrator was adapted to those tubes, and completed in November 2009. The bases of those tubes will be potted in 2010, and then they will be tested under water with the front-end electronics in this tank.

## References

[1] D. Autiero et al., *Large underground, liquid based detectors for astro-particle physics in Europe: scientific case and prospects*, JCAP 0711:011 (2007) , arXiv:0705.0116 [hep-ph]

[2] http://pmm2.in2p3.fr/

[3] B. Genolini for the PMm2 collaboration, *PMm2: Large Photomultipliers and innovative electronics for the next-generation neutrino experiments* , Nucl. Inst. Meth. A 610 (2009) 249-252, doi:10.1016/j.nima.2009.05.135

[4] S. Conforti Di Lorezo et al, *PARISROC: a Photomultiplier Array Integrated Read Out Chip*, IEEE Nuclear Science Symposium Conference Record (NSS/MIC), (2010) 1074 -1081, doi:10.1109/NSSMIC.2009.5402430, Hal00433090., ArXiv 0912.1269