Multi-PMT optical module

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Abstract

In this paper we discuss the advantages of using many small photomultiplier tubes inside a cylindrical or spherical pressure vessel as an alternative to the "standard" large (10") photomultiplier. The tube used for the test is the Photonis XP53x2 tube which has a diameter of 3". We show that in terms of signal to noise the small phototube solution is superior to the large tube. Tests show that the small tubes can be successfully operated feeding twelve tubes from a single High Voltage power supply, using individual high resistance bases. The readout using a time over threshold technique has also been investigated and shows very promissing results.

Key words:
PACS:

1 Introduction

Simulations done for the Antares detector have shown that the major criterion for distinguishing signal (passing muon) from background (^{40}K and bioluminescence) is the identification of a coincidence of two or more photons at a single position in space. This can be achieved by either selecting coincidences between two tubes or selecting large pulseheights. The latter is problematic due to the signifficant pulseheight spread in the 10" tubes. Cutting at pulseheights above 1.5 photoelectron equivalent (spe) still allows a significant fraction of single photons to pass, whereas raising the cut to 2 spe reduces the false count to an acceptable level but obviously removes 50% of the genuine 2 photon events. An alternative investigated in this paper is to segment the photocathode area in order to **count** the number of photons. We do this by replacing the single 10" PMT by 12 3" PMTs. This is an equal photocathode area. In this case a two photon event will in more than 90% of the cases be registered as a coincidence between two separate PMTs. Each of the PMTs can be set to a low threshold of about 0.3 spe. The purity of the coincidence signal is close to 100% as the backgrounds are entirely composed of single photons for the 500 cm^2 photocathode area. Figure 1 shows

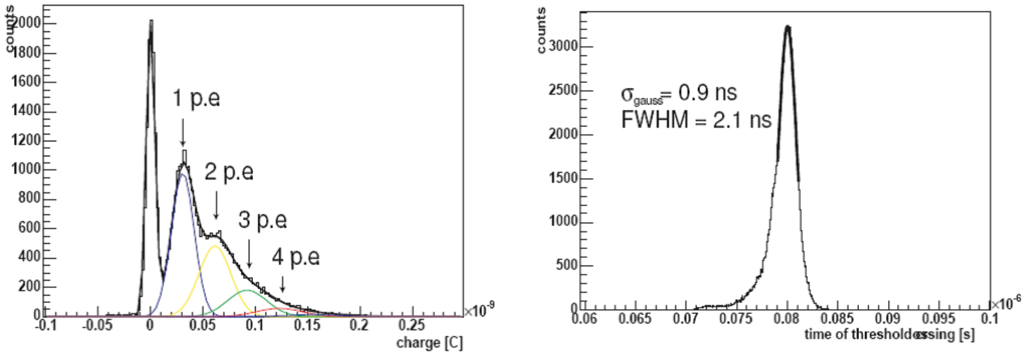

Fig. 1. Time resolution and pulseheight distributions for the Photonis XP53x2 PMT.

a typical pulseheightspectrum from the Photonis tube, clearly showing the single photoelectron peak separated from the noise. The figure also shows the time resolution. An RMS width of about 0.9 ns is obtained, which is equally attributable to the width of the photon source and the tube. Both results are more than sufficient for the use in an optical module. An added advantage of the small PMTs is the signifficantly smaller integrated charge expected for 10 years of operation. Whereas the 10" tube collects of the order of 60 C of charge and will thus suffer degradation of the gain for fixed HV of anywhere from 25 to 50%, the 3" tubes collect only 0.25 C, which should lead to only a few percent decrease in gain at fixed HV over the 10 year lifetime.The variation between tubes is expected to be even less. This allows us to envisage a system of 12 tubes, selected for equal gain, to be run for the lifetime of the experiment from a single HV supply. A setup of 12 tubes, each with individual resistive bases of 25 $M\Omega$, has been succesfully tested. The power consumption is about 0.5 W for the twelve tube set-up.

2 Possible arrangements

We have investigated the arrangements of the 3" PMTs inside pressure vessels. One possibility, that has not been worked out completely yet, is the maximum packing of the PMTs inside a sphere. It seems possible to pack of the order of 40 PMTs into a 17" Benthos sphere. Although this is clearly a very attractive solution (the equivalent of four 10" tubes inside a single pressure vessel) it still needs more detailed investigation on the practicallities in terms of production. An alternative is to place 12 PMTs inside a pressure resistant glass cylinder. Such cylinders are produced by Nautilus GmbH and have a length of up to 1.5 m and an inner diameter of 160 mm. It is just possible to place 18 tubes in the 1.5 m length or 12 tubes inside a 1m length. Two half spheres, which close off the ends of the cylinder are available for HV and readout electronics. One can place three of these cylinders closely packed around a central cable. The costs of the single cylinder with 12 3" tubes are estimated to be of the same order of that of the sphere with a single 10" tube. The sphere with 40 tubes is estimated to be slightly less expensive than four spheres with 10" tubes (i.e.

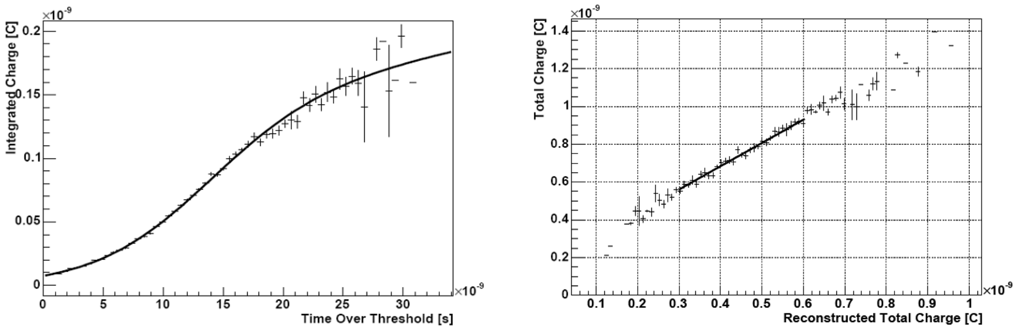

Fig. 2. (a)Time over threshold versus integrated charge for a single PMT.(b) Charge reconstructed from the analogue sum of time over threshold signals versus the sum of the charges in each pulse.

for the same fotocathode area).

3 Results

Results of simulations show that the angular acceptance of a three cylinder arrangement with 12 3" PMTs, is signifficantly larger than that of the three spheres with 10" tubes, except in the exactly vertical directions where the response is about 20% less. It varies less than 20% over the full range of θ. The random coincidence or large pulseheight rate has been determined for both a single 10" tube and for a single cylinder containing 12 3" tubes. The background singles rate is assumed to be 100 kHz for a 10" PMT. For the cylinder the random rate of coincidences is at 130Hz, while retaining 95% of true coincidences (20 ns window). The 10" tube produces a rate of around 8 kHz if a cut is made at 1.5 spe. This cut retains 80% of the true 2 photon signal. This rate can be reduced to 60 Hz by raising the threshold to 2 spe, but only at the cost of a reduction in efficiency for true two photon events to 50%. We have also investigated the readout scheme using analogue sums of time over threshold signals. Figure 2a shows the measured time over threshold versus the integrated charge of a single tube. The functional behaviour is smooth and after a turnon region the behaviour becomes logarithmic. The analogue sums of several signals have then been analysed assuming that the first rising edge of the signal is correlated to the first trailing edge. The reconstructed charge from these signals versus the true charge sum is shown in Fig. 2b. A linear behaviour is observed however with a slope of slightly less than unity. Alternative ideas of registering the time over threshold signal rising and falling edge for each tube individually are also being investigated.

In conclusion the multi-PMT optical module seems to be a viable solution. In terms of signal to noise it has superior performance. Specific details of PMT support, HV distribution and readout are presently being investigated.