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Large sensitive area photodetectors for underwater neutrino telescopes: PMT vs HPD

We review large sensitive area photodetectors developed for underwater neutrino telescopes - classical photomultipliers (PMTs) and hybrid phototubes (HPDs). We present results of studies of recently developed large sensitive area hemispherical PMTs including PMTs with high quantum efficiency photocathodes. Despite substantial achievements they have still significant shortcomings like poor collection efficiency, narrow angular acceptance, afterpulses etc. There is an alternative solution to all such problems - hybrid phototubes with luminescent screens like XP2600 and QUASAR-370 phototubes. The latter is a basic photodetector of the lake Baikal neutrino experiment and TUNKA-25 EAS Cherenkov detector. Modifications of QUASAR-370 have excellent time and amplitude resolutions, competitive to parameters of the best small PMTs. High time and amplitude resolutions, wide angular acceptance (˜2pi) along with independence of the phototube parameters from the terrestrial magnetic field make the phototube very close to the ideal photodetector for underwater neutrino telecopes. The only shortcoming of the phototube is a slow time response due to scintillator decay time. New promising very fast scintillators like ZnO:Ga allow to overcome the shortcoming making the phototube very attractive for the next generation large scale neutrino experiments. First pilot sample of recently developed HPD with ZnO:Ga scintillator has <1ns time resolution (fwhm) and a few ns pulse width. (fwhm).

Summary (Additional text describing your work. Can be pasted here or give an URL to a PDF document):

Large sensitive area conventional PMTs, recently developed by Hamamatsu (13 in. R8055 and 10 in. R7018 with high quantum efficiency photocathode) and Photonis (12 in. XP1807) demonstrate good performances. Due to high secondary electron emission coefficient of their first dynode the rate of prepulses are suppressed. The late pulses rate is at 3-5% level, the rate of afterpulses varies significantly from a few percents to more than 10%.

A HPD with luminescent screen is a combination of electron-optic preamplifier with large hemispherical photocathode and small conventional type PMT. Such approach allows to achieve excellent time and amplitude resolutions. QUASAR-370Y phototube, the basic photodetector of the lake Baikal neutrino experiment, has 1.8-2.2 ns (fwhm) jitter and 70-85% single electron resolution (fwhm). The best modification of QUASAR-370 phototube with LSO scintillator reaches 1ns (fwhm) jitter and 30% single electron resolution. The phototubes have no prepulses, late pulses and very low rate of afterpulses (<1%). So far scintillators used in QUASAR-370 phototubes have 27-50 ns decay time making the time response of the phototube rather slow. We have developed a pilot sample of small HPD with relatively new scintillator ZnO:Ga as a monocrystal. The scintillatior has ˜700 ps decay time and ˜1000 photons per MeV light yield. The developed HPD has <1 ns jitter (fwhm). The time response of the HPD is restricted by the time response of the small PMT used in the HPD readout. In our case the HPD has a 3-4 ns pulse width (fwhm). One can compare it with ˜20-30ns pulse width (fwhm) of large sensitive area PMTs like R8055, R7018 and XP1807.

So, using new fast and effective scintillators, like ZnO:Ga, in the HPDs with luminescent screens will remove their only shortcoming - slow time response. It will make them practically ideal photodetectors for the next generation giant neuttrino experiments.

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