Development of Micro-channel Plate based Photo-multiplier Tube(MCP-PMT) for photon detection

P. C. Rout[1,2,*] K. Singh [3], S. Santra[1,2], S. Malhotra [3], A. K. Gupta [1,2], and V.M. Datar [4]
[1] *Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[2] *Homi Bhabha National Institute, Anushaktinagar, Mumbai- 400094, INDIA*
[3] *EmA&ID, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and*
[4] *Institute of Mathematical Sciences (IMSc), Chenai - 600113 INDIA*

Introduction

Photomultiplier tubes (PMTs) are generally used as photo-detectors because of high gain, high quantum efficiency (QE), single photon response capability and low cost/unit areal coverage. The development of multi-anode PMTs have similar performances and also offered good spatial resolution. PMTs have a complex dynode configuration for electron multiplication that limits the size and the spatial resolution and it is also susceptibility to magnetic field. An alternate to the PMTs was developed by replacing the dynode by a microchannel plate(MCP). The MCP base PMTs (MCP-PMTs) are compact photodetectors capable of picosecond time resolution and sub-millimeter position resolution [1, 2]. The transit times are small (∼ ns) due to its compact size. Moreover, the small size makes MCP-PMTs much less sensitive to magnetic fields. Chang et al. [3] has developed a 20-inch dia. MCP-PMT for next generation neutrino experiments at JUNO.

Design of the MCP-PMT

We present the design and fabrication of the indigenous MCP based PMT (MCP-PMT) which is the future photodetector having wide applications in fundamental and applied sciences. A micro-channel plate based photo multiplier tube (MCP-PMT), has (i) a cathode window which transmits the radiation to photocathod (ii) a cathode fitted inside the tube producing photoelectrons by photoelectric effect (iii) an MCP for electron multiplier and (iv) an anode for collection of photoelectrons. A design of the MCP-PMT is shown in Fig 1. The MCP-PMT is fabricated inhouse by encapsulating and sealing the photocathode, a Single Micro Channel Plate (MCP) and an Aluminized Anode under a high vacuum system.

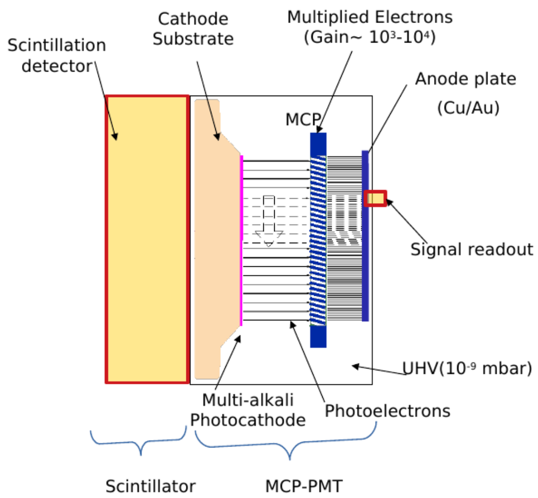

FIG. 1: Design of MCP-PMT depicted with different parts and its coupling to the scintilltor.

The signal read-out is provided through a BNC Connector electrically connected to the Anode. A Power Supply Unit has been integrated with the MCP-PMT and encapsulated in a plastic housing. Fig 2 shows a photograph of indigenously developed MCP-PMT. It may be noted that the MCP used for the present development has the gain of ∼1000.

*Electronic address: `prout@barc.gov.in`

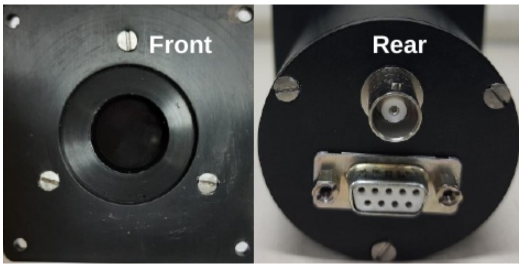

FIG. 2: The indigenously developed MCP-PMT showing front view (window of the PMT) and rear view (BNC connector for anode signal).

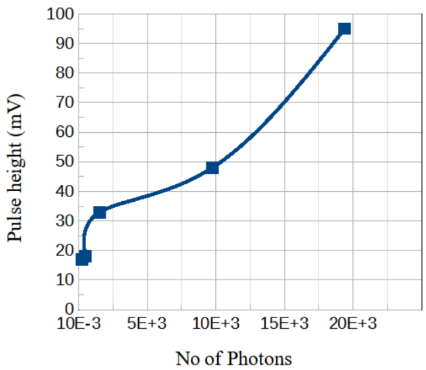

FIG. 3: The measured anode signal when the photons from a light source incident on the MCP-PMT.

Results and Discussion

The response of the MCP-PMT was tested after fabrication using a lamp with different filters to vary the number of photons incident on it. The anode pulse (mV) measured across a 1GΩ resistor. The typical anode signal at different luminosity(related to no of photons) is shown in Fig 3. When the PMT was coupled to a plastic scintillator, the anode signal is very small across 50Ω resistor. It is due to low gain of the MCP used in this PMT. A possible improvement with high gain MCP and also cascading of MCPs in chevron configuration may obtain the good signal to noise ratio.

The indigenous development of MCP-PMT built the confidence to develop high gain and larger area PMTs with improved process setup and infrastructure. The challenge in such a development is the large area and high gain MCP to achieve the desired gain of the MCP-PMTs to match traditional PMTs. In future the MCP-PMT will replace the traditional PMTs due to its superior time resolutions and spatial resolutions.

Acknowledgments

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References

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