A systematic study to characterize fine-mesh PMTs in high magnetic fields

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Available online 20 November 2006

Abstract

The performance of fine-mesh Hamamatsu photomultipliers with 1, 1.5, and 2 in. diameters has been measured in magnetic fields (up to 1.2 T) to determine gain and timing properties. Rate capabilities have also been studied.

PACS: 85.60.Ha

Keywords: Photomultipliers

1. Introduction

Hamamatsu fine-mesh PMTs have good gain and timing behavior in high magnetic fields. To avoid dynode damage and pulse amplitude reduction (loss of linearity), a limit on the average anode current ($\sim$100 $\mu$A) must not be exceeded. Systematic studies have been done for 1 in. (R5505), 1.5 in. (R7761) and 2 in. (R5924) Hamamatsu fine-mesh PMTs, using a resistive dipole magnet at LASA (INFN Milano), with magnetic fields up to 1.2 T and an open gap of 12 cm. A fast light pulse from a PLP-10 Hamamatsu laser ($\sim$405 nm, 60 ps FWHM pulse width, max repetition rate 100 MHz) is sent to the photocathode of the PMT under test via a multimode CERAM OPTEC UV 100/125 optical fiber (with a measured dispersion of $<15$ ps/m, see Ref. [1]). At the end of the fiber a small plexiglass prism, inserted in a black plastic cover in front of the PMT window, allows illumination at the center of the photocathode. Tests were usually done with a signal corresponding to about 300 photoelectrons (p.e.), that is typical for a minimum ionizing particle (MIP) crossing a scintillator 1–2 in. thick, 6–10 cm wide, at a distance of 1–2 m. The optical power was periodically monitored with an OPHIR PD-2A laser power meter. Data were acquired in VME standard, both for amplitude measurements (via a CAEN V465QADC) and timing measurements (via a CAEN V480 TDC). In part of the measurements an Ortec TRUMP-8 K MCA was used instead.

2. Experimental results

The PMTs under test were inserted in the central region of the test magnet, where the field had a uniformity of $\sim$1%. Measures were done to see gain reduction, timing resolution and rate capability as a function of magnetic field and relative orientation angle $\theta$ for the three types of fine-mesh PMTs under study. Due to the effect of magnetic field on the accelerated electrons inside the PMTs, we can expect a reduction of gain as the $B$ field increases and also a...
marked dependence of the relative gain as a function of the inclination angle $\theta$. Fine-mesh PMTs are well behaving up to a critical orientation $\theta_C$ depending on the photocathode size: typically $\theta_C = 30–45^\circ$, up to the measured maximum magnetic field $B \sim 1.2$ T. Some results (for a standard HV of 2000 V) are shown in Fig. 1 for a typical 2 in. PMT.

The rate capability of fine-mesh PMTs is limited by the maximum allowable average anode current $I_a$. Keeping this in mind, all the following plots can be easily understood. Fig. 2 shows the PMT response (P.H. in mV) as a function of the laser shot repetition rate $R$, in different conditions of the external magnetic field $B$ for two typical 1 and 1.5 in. fine-mesh PMTs. Results include a correction to account for the dependence of the laser shot intensity from the laser repetition rate $R$, as measured with a Thorlabs DET210M photodiode.

Timing studies were conducted with laser signals corresponding to $\sim 300$ photoelectrons. In this, timing characteristics of fine-mesh PMTs show a weak dependence on field strength and direction, in spite of the large reduction in gain (up to a factor of 100). Only at fields $\sim 1$ T, the multiphoton timing resolution $\sigma_{TDWC}$ seems to begin to be affected, as shown in Fig. 3 for a typical 2 in. fine-mesh PMT.

3. Conclusions

Fine-mesh PMTs show good timing properties for a simulated signal of $\sim 300$ p.e. (corresponding to a typical MIP signal) even in magnetic fields up to 1 T. Rate capabilities are driven by the mean flowing anode current and linearity is good if the maximum allowable value is not exceeded (typically 100 $\mu$A or a 2 in. PMT). Gain behavior turns to be problematic only if the inclination of the PMT axis with respect to the $B$ field exceeds a critical value $\theta_C \sim 30–45^\circ$ depending on the PMT size.
Fig. 3. Transit time ratio at magnetic field $B$ and $B = 0$ T (a), timing resolution $\sigma_{TDWC}$ in 25 ps units as a function of the magnetic field $B$ for typical 2 in. Hamamatsu R5924 fine-mesh PMT (b).

Reference