Performance of 8- and 12- Dynode Stage Multianode Photo Multipliers

R. Chamonal , S. Eisenhardt

School of Physics, University of Edinburgh
Mayfield Road, Edinburgh, EH9 3JZ, Scotland/UK

On behalf of the LHCb RICH MaPMT Group

Abstract

We report on studies of 64-channel Multianode Photo Multiplier Tubes (MaPMTs) as photo detectors for Ring Imaging Cherenkov (RICH) counters. The newly available 8-dynode stage MaPMT was tested in particle beams at CERN. The MaPMT signals were read out directly with the Beetle1.2 chip which was designed for the LHCb environment and operates at 40 MHz. The photon yield and signal losses were determined for a cluster of 3×3 close-packed MaPMTs. The performance of the 8-dynode stage MaPMT was compared to that of the 12-dynode stage MaPMT which has a larger intrinsic gain.

Key words:
PACS: 85.60.H, 29.40 K

1 Overview

We report on the studies of 64-channel Multianode PhotoMultiplier Tubes (MaPMTs) as an option for the Ring Imaging CHerenkov (RICH) detectors of the LHCb experiment. Of the R7600-03-M64 series, manufactured by Hamamatsu, we compared two different types of dynodes chains: (1) the newly available 8-dynode stage with a gain of $0.5 \times 10^5\, e^-$ at -800 V and (2) the 12-dynode stage with a gain of $3 \times 10^5\, \mathrm{e}^-$ at -800 V. Both have a bi-alkali photocathode with a QE of 25% at $\lambda = 360\, mm$ deposited on the inside of a semi-transparent UV glass window.

Email address: `chamonal@ph.ed.ac.uk` (R. Chamonal).

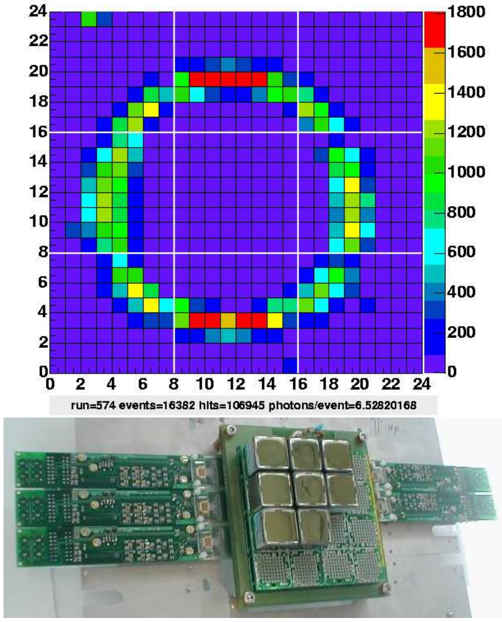

Fig. 1. *Top: Cherenkov Ring on the MaPMT array. Bottom: 3×3 MaPMT array with its Beetle1.2 Front-end boards. One MaPMT is missing.*

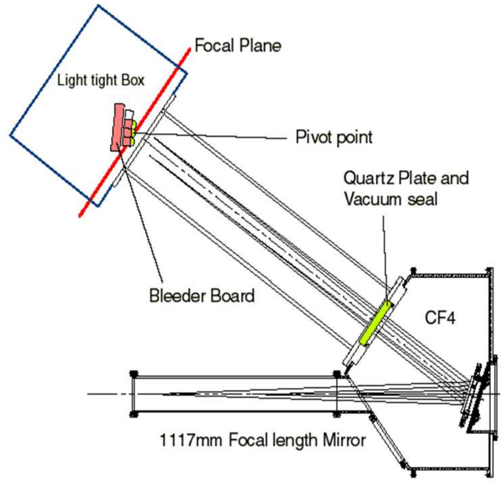

Fig. 2. *Schematic of the RICH1 prototype with the beam coming from the left. The Cherenkov photons are reflected out to the MaPMT Bleeder board plane using a spherical mirror.*

2 8-Dynode Stage MaPMTs measured in a Testbeam

8-dynode stage MaPMTs have been tested in the T9 PS particle beam at CERN. The tubes were close-packed as a 3×3 array, shown in Figure 1, to detect the Cherenkov photons with the LHCb RICH1 prototype shown in Figure 2. The active area of a MaPMT is only 38%. Silica lenses were mounted to focus the incident light onto the active area and achieve a 85% active area fraction. The MaPMTs were read out by the Beetle1.2 chip mounted on a front-end board capable of reading out two MaPMTs at a rate of 40 MHz. The beam consisted of 95% pions and 5% electrons with a momentum of 10 GeV/c. The 1 m long radiator vessel was filled with CF4 gas at 800 mbar.

The photon yield was evaluated from data taken in the range -750 V to -1 kV in steps of 50 V. Figure 1 shows a detected ring at -900 V where a hit, or photoelectron (p.e) is defined as a pixel with a pulse height larger than 5σ above the Gaussian pedestal. The yields were then compared to a Geant4 Monte Carlo simulation. The simulation predicts 6.2 p.e per event assuming no signal loss correction. Figure 3 shows the photon yield as a function of MaPMT high voltage before and after cross-talk correction. The corrected yield of 6.5 p.e, at the nominal operating voltage of -900 V, is in good agreement with the simulation. The signal loss shown in Figure 4 is 7% at -900V which is below the 15% maximum limit imposed by LHCb. These measurements are

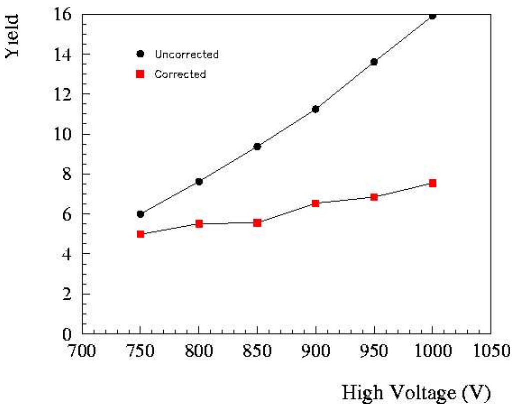

Fig. 3. *Photon Yield against High Voltage. Before (circles) and after cross-talk and background correction (squares).*

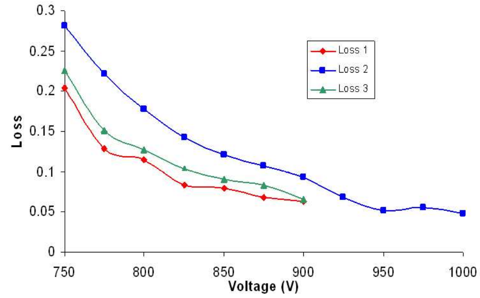

Fig. 4. *Determined signal loss against High Voltage for three different algorithms applied to measurements. Loss1 estimates an upper limit.*

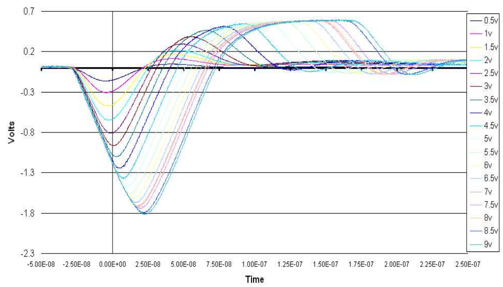

Fig. 5. *Measurements of the signal shape after the amplifier and shaper of the Beetle1.2 chip.*

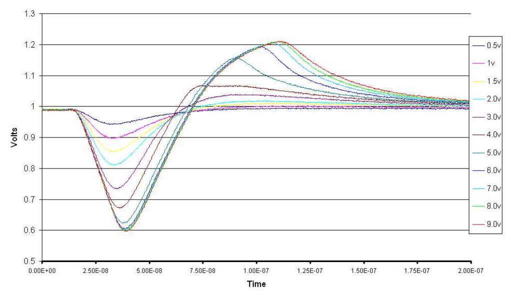

Fig. 6. *Measurement of the signal shape after the amplifier and shaper of the Beetle1.2MA0 chip.*

in agreement with the 12-stage dynode MaPMTs made in earlier studies [1].

3 Comparison of 8- and 12-Dynode Stage MaPMTs

The 8-dynode stage MaPMTs were read out with the Beetle1.2 chip designed for silicon sensors in the LHCb environment. The low gain matches well the amplification range of the chip with a single photon signal equivalent to two minimum ionising particles (60 mV). However the signal suffers from signal walk and a long lived overshoot as the number of p.e increases, see Figure 5. The Beetle1.2MA0 chip features a custom designed input circuit to match the high gain of the 12-dynode stage MaPMT. This leads to a single photon signal of 30 mV as can be seen in Figure 6. The 12-dynode stage have a better overshoot behaviour and suffer less signal walk than the 8-dynode stage. In addition the signal overshoot can be traded off against the spill over to subsequent samples. High voltage scans were taken with a LED light source at 470 nm. Figure 7 compares the pulse height spectra for the 8-dynode stage

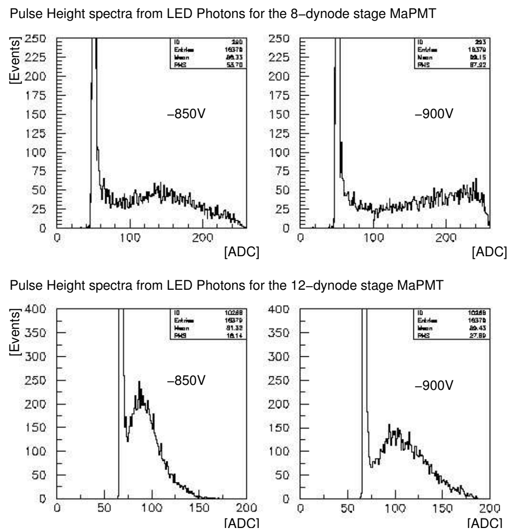

Fig. 7. *Pulse height spectra for the 8-dynode (top) and 12-dynode stage (bottom) for -850V (left) and -950V (right).*

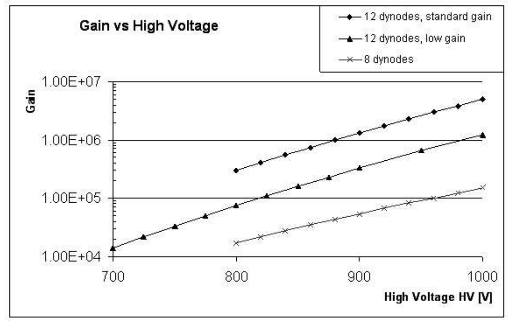

Fig. 8. *MaPMT gain against high voltage. 12-dynode stage with standard (diamonds) and low gain (triangles), 8 dynode stage with standard gain (triangles).*

and 12-dynode stage MaPMTs. For both MaPMT options the gain doubles every 50 Volts. Both have a clear separation between the photon signal and the pedestal. However the 12-dynode stage option has a lower noise than the 8-dynode stage (1.0 vs. 1.3 ADC channels) and a better separation from the pedestal. Figure 8 shows the gain variation with high voltage for the 8-dynode and 12-dynode stage using the default voltage divider chain. The 12-dynode stage MaPMT was also operated with a low gain divider chain but the signal-over-noise ratio was poor at gains matching the Beetle1.2 dynamic range.

4 Conclusions

Both options, the 8-dynode using the Beetle1.2 chip and the 12-dynode stage MaPMT using the Beetle1.2MA0 chip are viable solutions for the LHCb RICH detectors. However the 12-dynode stage option would be preferred as it exhibits less noise and has a better signal/pedestal separation.

References

[1] E. Albrecht et al., "Performance of a cluster of Multi-anode Photomultipliers equipped with lenses for use in a prototype RICH detector", Nucl. Instrum. Meth. A **488**, (2002) 110-130.