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Performance of 8- and 12-dynode stage multianode photo-multipliers

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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.

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Keywords: Multianode photo-multiplier tubes; Ring Imaging Cherenkov (RICH) counters; Beetle readout chip

1. Overview

We report on the studies of 64-channel Multianode Photo-Multiplier 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 dynode chains: (1) the newly available 8-dynode stage with a gain of $0.5 \times 10^5 e^-$ at a voltage of -800 V and (2) the 12-dynode stage with a gain of $3 \times 10^5 e^-$ at -800 V. Both have a bi-alkali photo-cathode with a quantum efficiency of 25% at $\lambda = 360$ mm deposited on the inside of a semi-transparent UV glass window.

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2. 8-Dynode stage MaPMTs measured in a testbeam

The 8-dynode stage MaPMTs have been tested in the T9 PS particle beam at CERN. The tubes were close packed into a 3×3 array, shown in Fig. 1. The array detected Cherenkov photons from the LHCb RICH1 prototype, shown in Fig. 2. The active area of an MaPMT is only 38%. Silica lenses were, therefore, mounted to focus the incident light onto the active area in order to achieve a 85% active area fraction. The MaPMTs were read out by the Beetle1.2 chip [1] mounted on a front-end board which reads out up to 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 MaPMT voltage range from -750 V to -1, kV in steps of 50 V. Fig. 1 shows an accumulation of detected Cherenkov

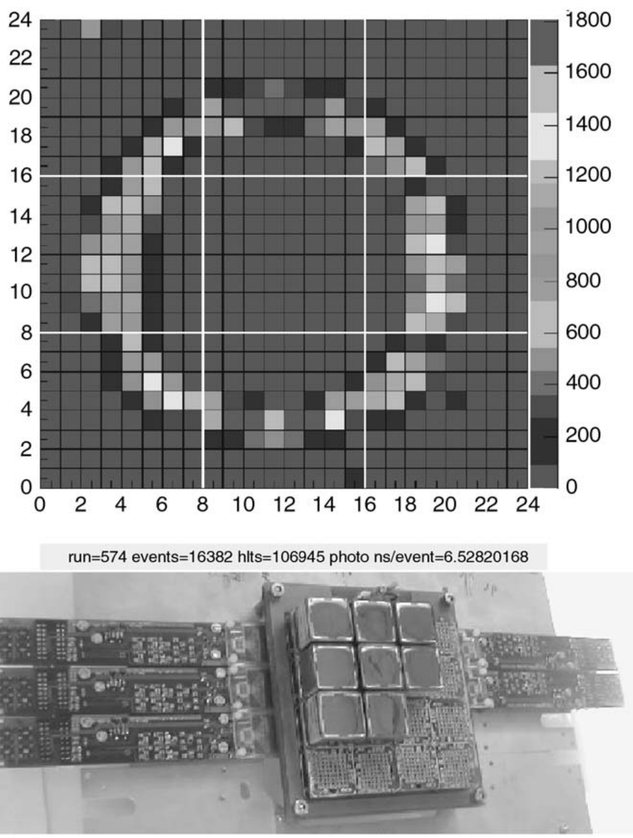

Fig. 1. Top: Cherenkov ring, integrated over many events, displayed on the MaPMT array. Bottom: 3×3 MaPMT array with the Beetle1.2 front-end boards. One MaPMT is missing.

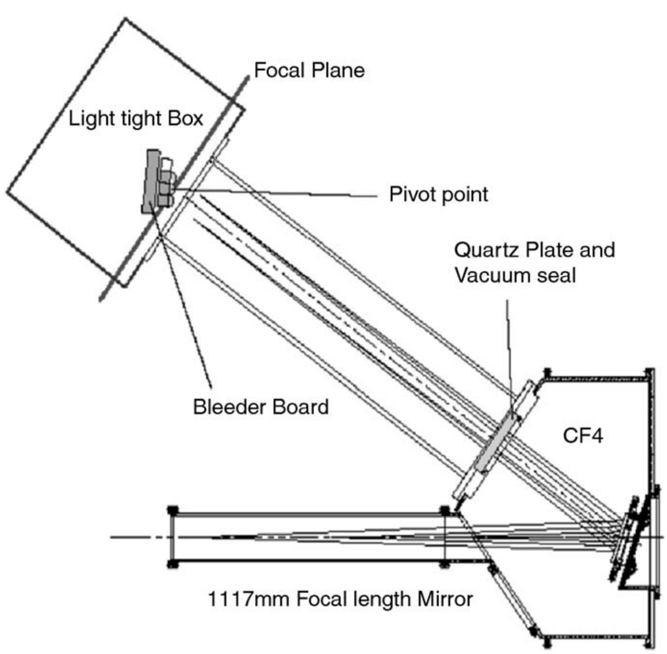

Fig. 2. Schematic of the RICH1 prototype with the beam entering from the left. The Cherenkov photons are reflected out to the MaPMT plane from a spherical mirror.

rings at -900 V where a hit, or photo-electron (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. In the data, significant cross-talk was observed which was isolated to the MaPMT front-end electronics board. Fig. 3 shows the photon yield as a function of MaPMT high voltage before and after cross-talk correction. The cross-talk 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, measured by fitting the signal spectrum to a Gaussian-smeared Poisson distribution, is shown in Fig. 4. The loss is 7% at -900 V. These measurements are in agreement with 12-stage dynode MaPMTs results made in earlier studies [2].

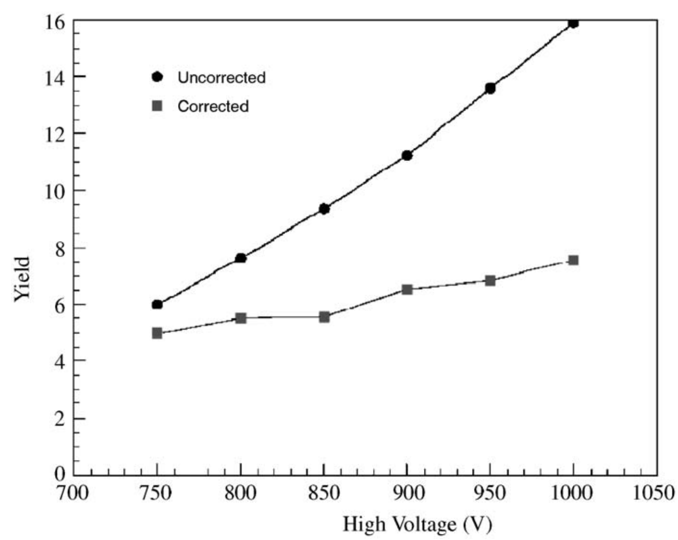

Fig. 3. Photon yield as a function of high voltage. Before (circles) and after (squares) cross-talk and background correction.

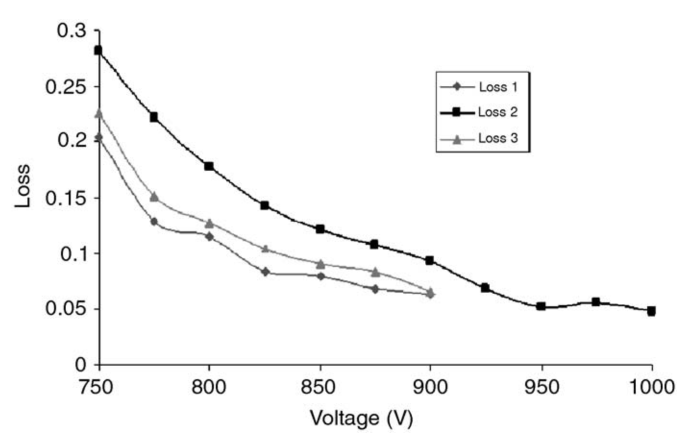

Fig. 4. Determined signal loss as a function of high voltage for three different algorithms applied to measurements. Loss1 is an upper-limit estimate.