Nuclear Instruments and Methods in Physics Research A 639 (2011) 162–164

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Photonis MCP PMT as a light sensor for the Belle II RICH

S. Korpar [a,b], I. Adachi [c], R. Dolenec [b], P. Križan [d,b,*], R. Pestotnik [b], A. Stanovnik [e,b]

[a] Faculty of Chemistry and Chemical Engineering, University of Maribor, Maribor, Slovenia
[b] J. Stefan Institute, Ljubljana, Slovenia
[c] KEK, Tsukuba, Japan
[d] Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
[e] Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia

ARTICLE INFO

Available online 7 November 2010

Keywords:
Microchannel plate photomultipliers
Cherenkov detectors

ABSTRACT

We report about on-the-bench studies of Photonis multi anode micro-channel plate (MCP) PMTs, as candidate photodetectors for the aerogel RICH counter of the Belle II spectrometer. This photosensor is fast enough to be used also as a time-of-flight counter, which would complement the kinematic range of the aerogel RICH counter.

1. Introduction

For the particle identification system of the Belle II spectrometer [1], a proximity focusing RICH detector with aerogel as radiator is being considered. One of the candidates for the detector of Cherenkov photons is a microchannel plate PMT. With its excellent timing properties, such a counter could serve in addition as a time-of-flight counter. In this latter case, precise timing would be provided by Cherenkov photons emitted in the PMT window as illustrated in Fig. 1. A prototype of this novel device using two 64-channel Photonis 85011 [2] microchannel plate PMTs was tested several years ago in a test beam at KEK. Excellent performance of the counter could be demonstrated. In particular, a good separation of pions and protons was observed in the test beam data with a time-of-flight resolution of 35 ps [3,4].

The present study was devoted to measuring the performance in high magnetic fields, determining timing properties of the common electrode signal, the second stage MCP output, and to measuring ageing properties (operation after long term and high rate illumination), and thus complements our previous on-the-bench studies of this sensor type [3,5], as well as the studies by Jerry Va'vra et al. [6]. The tube used in the present tests had 64 channels (8×8) and microchannel plates with 10 μm pores.

2. Tests in magnetic field

Since the sensor is required to operate in a high magnetic field of 1.5 T, we have performed measurements of gain, uniformity of response and cross talk in a magnet at KEK with a magnetic field of up to 1.5 T. As a photon source we used a picosecond laser with a 439 nm head (Hamamatsu Picosecond Light Pulser). The laser light was first attenuated by neutral density filters and guided into a light tight box along an optical fiber (Fig. 2). The light was collimated onto the photocathode of a MCP-PMT to a spot diameter of ≈ 500 μm. The position of the light spot was set by a computer controlled 2D stage. Signals from the anodes were amplified by an Ortec FTA820 amplifier, and recorded by a CAMAC charge sensitive ADC.

The MCP PMT gain as a function of magnetic field for different operation voltages and as a function of applied voltage for different magnetic fields is shown in Fig. 3. At 1.5 T, the operating voltage has to be increased by roughly 200 V to achieve the same gain as without magnetic field.

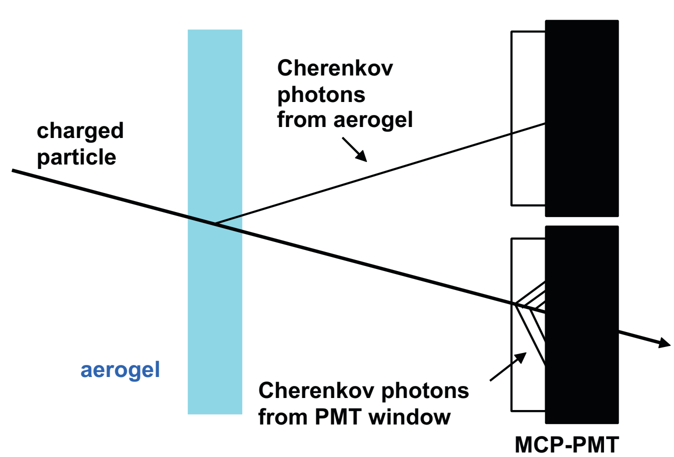

Fig. 1. MCP PMT as a photon detector in a proximity focusing Cherenkov counter.

* Corresponding author at: Faculty of Mathematics and Physics, University of Ljubljana, Jadranska 19, Ljubljana, Slovenia.
E-mail address: peter.krizan@ijs.si (P. Križan).

0168-9002/$ - see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.nima.2010.10.148

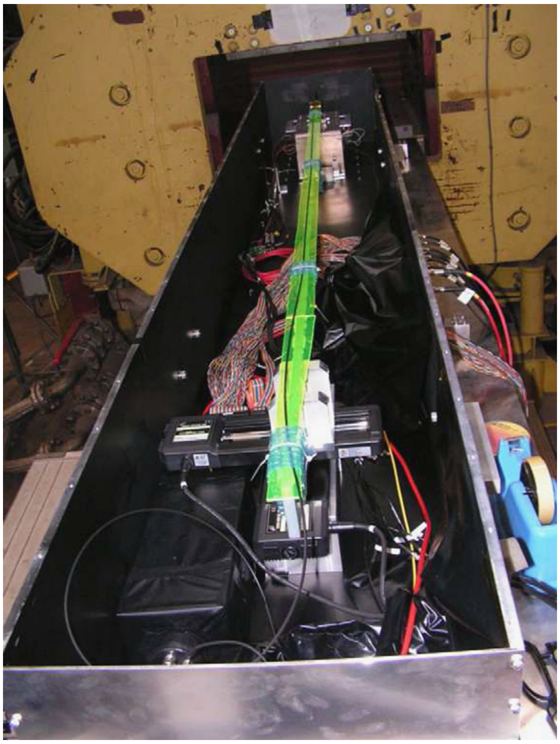

Fig. 2. Apparatus for the measurement of MCP-PMT properties in magnetic field: from the 2d stage, laser light is led over a long lever arm to the MCP PMT front window inside the magnet gap.

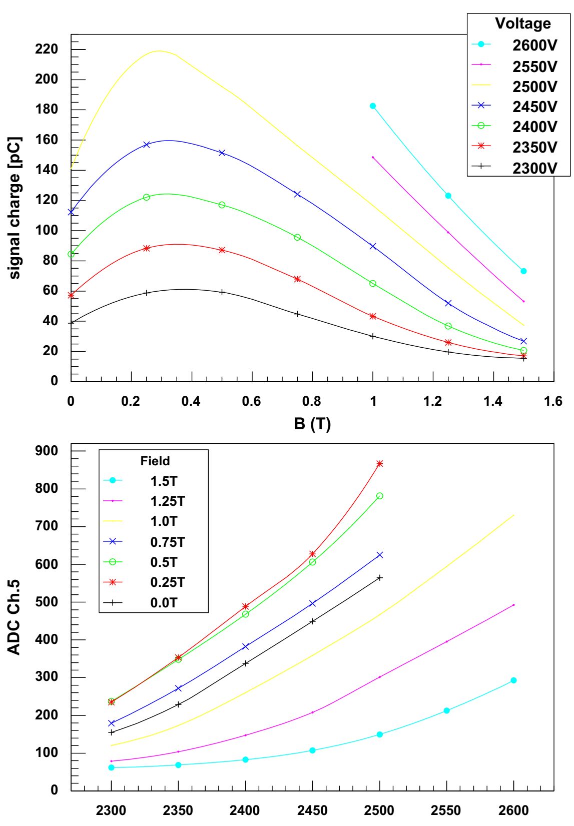

Fig. 3. MCP PMT operation in magnetic field: gain (arbitrary units) as a function of magnetic field (top) and as a function of high voltage for different magnetic fields (bottom).

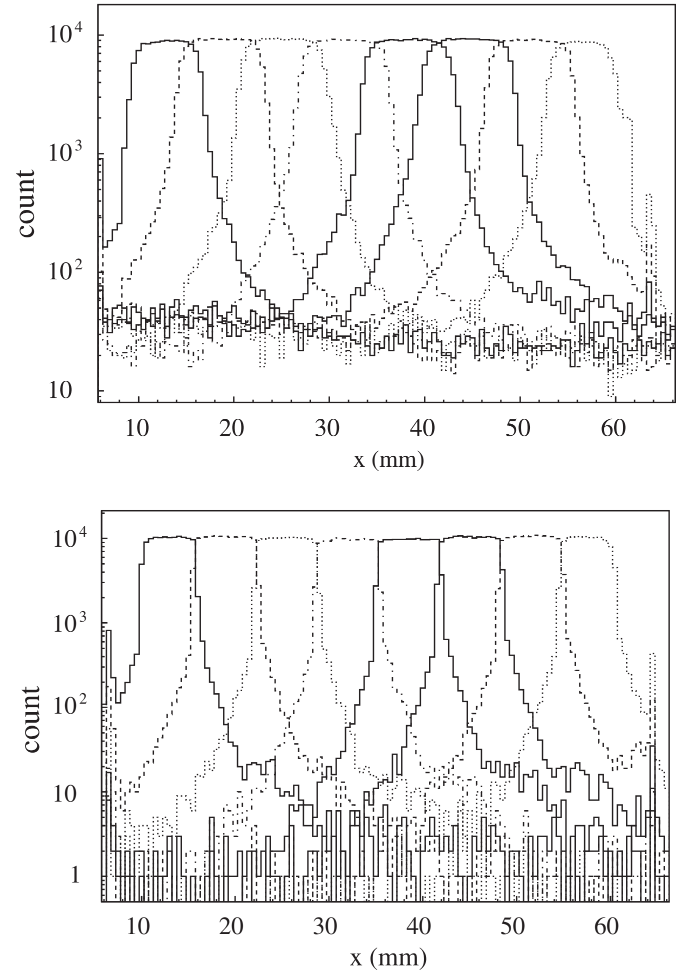

Fig. 4. Scans across a 64 channel PMT without (top) and with magnetic field (bottom). Number of detected hits on individual channels is shown as a function of the light spot position.

By scanning the laser spot across the PMT surface, the position dependence of sensitivity could be studied. As can be seen from Fig. 4, the response of the PMT is fairly uniform. Multiple counting is observed at pad boundaries due to charge sharing. In addition, a long range cross talk can be observed due to photoelectron back-scattering. The origin of the cross talk between the channels was investigated in several preceding studies by studying the correlations between signals on neighboring pads, their amplitudes and time of arrival [5]. The contributions of cross talk are relatively small, but extend to about 12 mm beyond the pad boundary in accordance with the estimated maximum range of photoelectrons backscattered on the multichannel plate (Fig. 4, top). In the presence of a magnetic field, however, charge sharing and cross talk due to long range photoelectron back-scattering are considerably reduced because of the curling up of electron trajectories along the axial magnetic field, as demonstrated in the bottom plot of Fig. 4.

3. Precise timing with the common output from the second MCP stage

As reported in previous studies of this sensor type, the anode output has excellent timing properties for single photons, with r.m.s. resolutions better than 40 ps [5]. If, however, the MCP PMT is employed for time-of-flight measurements (Fig. 1), use is being made of the fact that if a charged particle passes the 2 mm thick

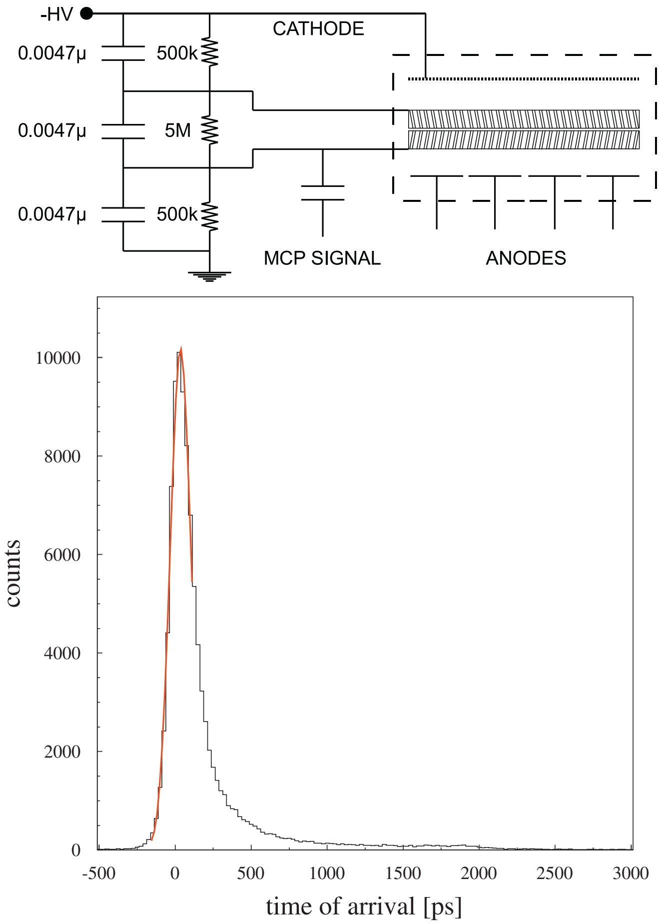

Fig. 5. Timing with a signal from the second MCP stage: schematics (top), distribution of signals from the second MCP stage (bottom).

quartz PMT window, about 10 Cherenkov photons are detected in the MCP PMT. They are distributed over several anode channels. It would be advantageous, if the time of arrival of these photons were read out for the whole device from a single common electrode of the second MCP stage, while 64 anode channels are used for position measurement of Cherenkov photons from the aerogel.

To test this idea, we have studied the timing properties of this common electrode. Signals from the second MCP stage were amplified by an Ortec FTA820 amplifier. After amplification, each signal was split in two branches; one for the timing and the other for the signal amplitude measurement. The timing signal was discriminated either by a Phillips 708 leading edge or an Ortec 9327 constant fraction discriminator, and used as a stop signal. The time of the pulse was measured by the Kaizu Works KC3781A TDC (CAMAC) with 25 ps per channel. A common start signal was determined by the laser control unit. The signal pulse height was registered in a CAEN V965 charge sensitive ADC (VME). In such a set-up, a σ of 65 ps for the MCP signals was observed with a constant fraction discriminator in case of single photons, as shown in Fig. 5; the resolution includes the time jitter of the laser source and the electronics. With 10 detected photons, a time-of-flight resolution of around 30 ps is expected [7], which would allow a $3\sigma\,\pi/K$ separation up to about 2.8 GeV/c at a flight length of 2 m.

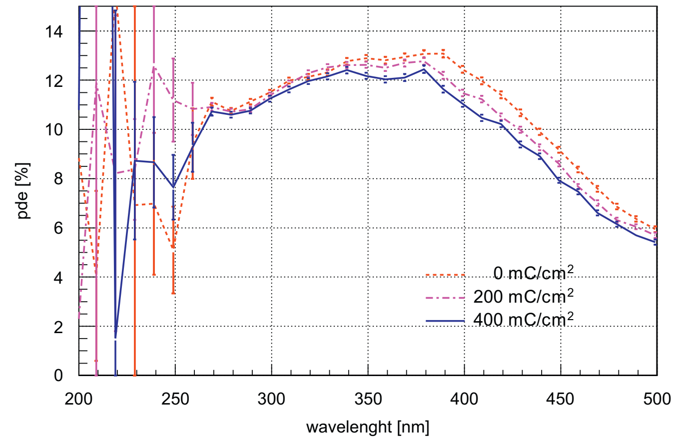

Fig. 6. MCP ageing studies: photon detection efficiency as a function of wavelength at the start of the study, after 200 and 400 mC/cm^2 of accumulated charge on the anode.

4. MCP PMT ageing studies

To ensure stable, long term operation of the photon sensor in a high luminosity experiment like Belle II, it is mandatory to check its ageing properties. In a dedicated test set-up, the whole photo-sensitive surface was exposed to high rate illumination by a LED. A pulsed laser was used to monitor the amplification, and a reference PMT is used for periodic QE measurements with a monochromator in the same set-up. As shown in Fig. 6, the results of this test are quite promising. After the charge accumulated at the anode reached 400 mC/cm^2, corresponding to the dose expected for the full Belle II lifetime, the efficiency dropped only by about 10% which is of no problem for the operation of the experiment.

To conclude we note that the observed properties of the MCP PMT are in very good agreement with expectations. They show that the present tube is an excellent candidate for the photon sensor of the aerogel RICH detector in the Belle II spectrometer, capable of successful operation in the high magnetic field throughout the full duration of the experiment.

References

[1] K. Abe, et al., in: S. Hashimoto, M. Hazumi, J. Haba, J.W. Flanagan, Y. Ohnishi (Eds.), Letter of Intent for KEK Super B Factory, KEK Report 2004-04 〈http://superb.kek.jp/documents/loi/img/LoI_detector.pdf〉, 2004.
[2] BURLE 85011 data sheet: 〈http://www.burle.com/cgi-bin/byteserver.pl/pdf/85011-501.pdf〉.
[3] S. Korpar, et al., in: Proceedings of the IEEE Nuclear Science Symposium, Rome, Italy, October 17–22, 2004; P. Križan, et al., Nucl. Instr. and Meth. A 567 (2006) 124.
[4] S. Korpar, et al., Nucl. Instr. and Meth. A 572 (2007) 432.
[5] S. Korpar, et al., Nucl. Instr. and Meth. A 595 (2008) 169.
[6] C. Field, et al., Nucl. Instr. and Meth. A 518 (2004) 565;
J. Va'vra, et al., Nucl. Instr. and Meth. A 572 (2007) 459;
J. Va'vra, C. Ertley, D.W.G. Leith, B. Ratcliff, J. Schwiening, Nucl. Instr. and Meth. A 595 (2008) 270.
[7] R. Dolenec, et al., in: Proceedings of the IEEE Nuclear Science Symposium, Orlando, Florida, October 25–31, 2009.