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

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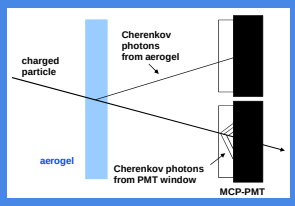
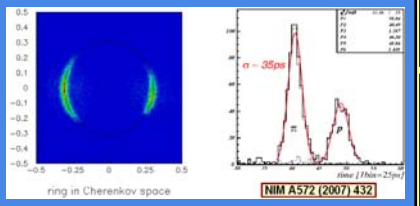
Abstract

We report on 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 also used as a time-of-flight counter, and thus complement the kinematic range of the RICH counter.

Motivation

For the Belle particle identification system upgrade, 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 (left). A prototype of this novel device using two 64-channel Photonis 85011 microchannel plate PMTs was tested in a test beam at KEK. Excellent performance of the counter could be demonstrated (middle). In particular, a good separation of pions and protons was observed in the test beam data with a time-of-flight resolution of 35ps (right).





Present study:

-measure performance in high magnetic field

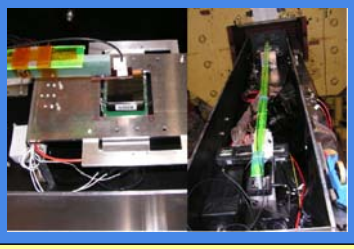
-determine timing properties of the common electrode, second stage MCP

-measure ageing properties (operation after long term high rate illumination)

Tests in magnetic field

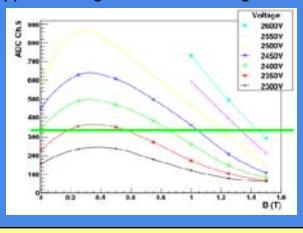
Measurements of gain, uniformity of response snd cross talk

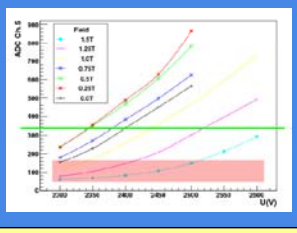
Magnet at KEK with B field up to 1.5 T
Light source - laser:
•wavelength 439 nm
•spot size < 0.5 mm
•pulse timing 90 ps (FWHM)



Gain in magnetic field

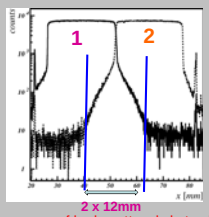
Gain as a function of magnetic field for different operation voltages and as a function of applied voltage for different magnetic fields.





Uniformity of response at B=0T and B=1.5T

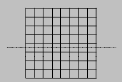
Surface response of PMTs is fairly uniform. Multiple counting is observed at pad boundaries due to charge sharing.



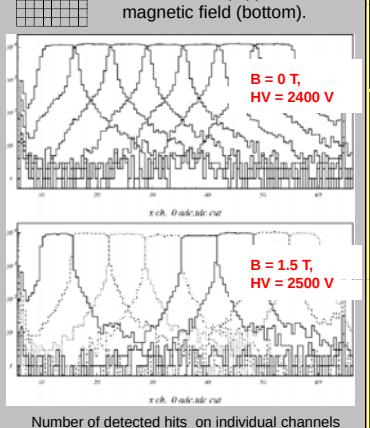
B = 0 T

2 x 12mm
= range of back-scattered photo-electrons in absence of magnetic field

Slice of 2D distribution shows a uniform response within the pads, and the long range cross talk due to photoelectron back-scattering and photon reflection.



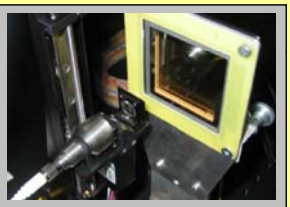
Scans across a 64 channel PMT without (top) and with magnetic field (bottom).



Number of detected hits on individual channels as a function of light spot position.

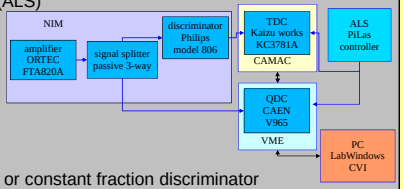
In the presence of magnetic field, charge sharing and cross talk due to long range photoelectron back-scattering are considerably reduced.

Experimental set-up for on the bench tests



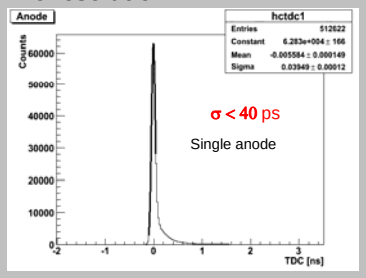
Photonis/BURLE 85011 MCP-PMT:
- multi-anode PMT with two MCP steps, 10 μm pores
- 8x8 anode pads
- bialkali photocathode
- gain ~ 0.6 x 10^6, collection efficiency ~ 60%

Light source:
- PiLas diode laser system EIG1000D (ALS)
- laser rate 2kHz (~DAQ rate)
- neutral density filters
- optical fiber (single mode,~4μm core)
- focusing lens (spot size σ ~ 10μm)



Signal processing:
- amplifier: 350MHz (<1ns rise time)
- discriminator: leading edge, 300MHz, or constant fraction discriminator
- TDC: 25ps LSB (σ~11ps)
- QDC: dual range 800pC, 200pC

Time resolution

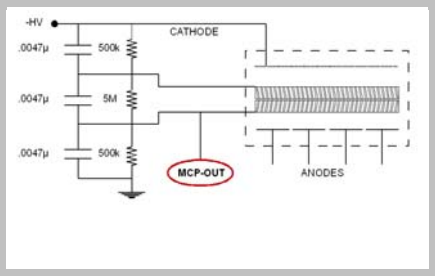


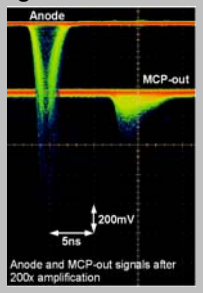
Anode output: excellent timing properties for single photons, σ<40 ps, well understood (NIM A595 (2008) 169).

MCP PMT for time-of-flight measurements: if a charged particle passes the PMT window, ~10 Cherenkov photons are detected in the MCP PMT; they are distributed over several anode channels.

Idea: read timing for the whole device from a single channel (second MCP stage), while 64 anode channels are used for position measurement

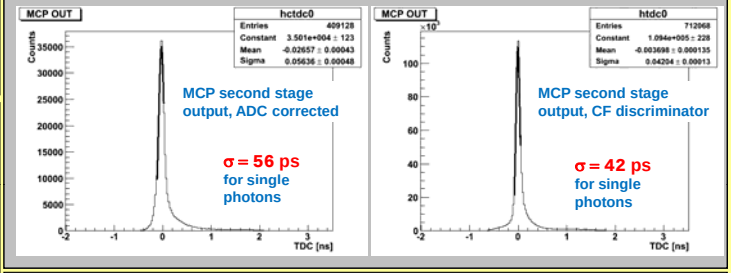
Timing with a signal from the second MCP stage





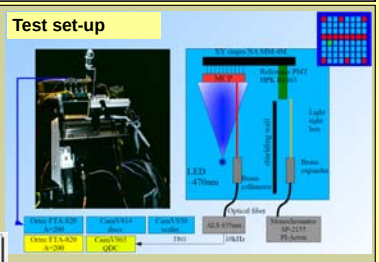
Time walk corrected signals from the second MCP stage

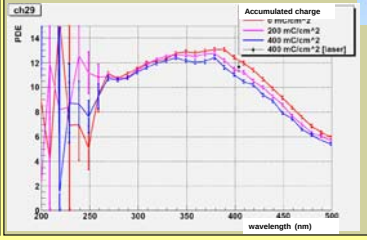
Constant fraction discrimination gives **σ=42 ps** for MCP-out signals in case of single photons



Ageing studies

Test set-up: high rate illumination of the whole photosensitive surface by LED, pulsed laser monitoring of the amplification. Reference PMT is used for periodic QE measuemnets with a monochromator in the same set-up.





Results: after 400 mC/cm² (= Belle II lifetime) the efficiency drops by about 10% → no problem for operation.