Proximity focusing RICH with TOF capabilities

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A proximity focusing RICH with aerogel radiator has been studied to extend the pion-kaon separation power in the forward region of the Belle spectrometer. Such a proximity focusing RICH counter is also a very fast detector, in particular if a micro-channel plate (MCP) PMT is used as the photon detector. With its excellent timing properties, the same device could also serve as a time-of-flight counter and thus supplement other identification methods, in particular for low momentum tracks. Cherenkov photons emitted in the radiator medium (aerogel) as well as in the entrance window of the PMT could be used for the time-of-flight measurement. A prototype of this novel device using BURLE 85011 64-anode, microchannel plate PMT, was tested on the bench and in the test beam at KEK. Excellent performance of this 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 about 35 ps (rms) for Cherenkov photons produced in the PMT window.

1. Introduction

The present paper reports on ane perimental investigation of a novel type of particle identification device, a proximity focusing RICH counter with time-of-flight capabilities.

A proximity focusing RICH with aerogel radiator (Fig. 1) has been studied to extend the pion-kaon separation power in the forward region of the Belle spectrometer [1]. To further improve its performance, a novel technique was developed where multiple aerogel layers of different refractive indices are combined in such a way that the Cherenkov ring images from individual layers overlap on the photon detector plane. In this innovative approach, the uncertainty in the Cherenkov angle measurement from the radiator thickness is suppressed. A thicker aerogel radiator can therefore be used, resulting in an increased number of observed photoelectrons, and consequently a better Cherenkov angle resolution [2,3].

Such a proximity focusing RICH counter is also a very fast detector, in particular if a micro-channel plate (MCP) PMT is used as the photon detector. With its excellent timing properties, the same device could also serve as a time-of-flight counter and thus supplement other identification methods, in particular for low momen-

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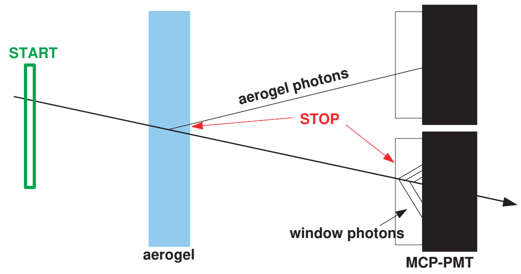

Figure 1. Schematic view of a combined RICH and TOF counter.

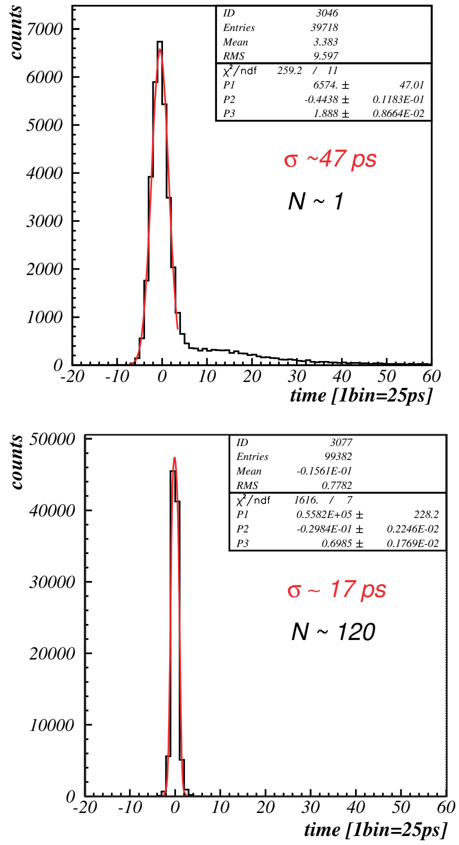

Figure 2. Single photon (top) and multiple photon (bottom) TDC distributions obtained by the laser pulse illumination.

tum tracks. Cherenkov photons emitted in the radiator medium as well as in the entrance window of the PMT can be used for the time-of-flight measurement (Fig. 1). This allows to positively identify also particles that would be below the Cherenkov threshold in the aerogel radiator (kaons and protons in the region around 1 GeV). Consequently, a good separation of kaons and protons would be possible in this region as well.

While we have already discussed the performance of the BURLE 85011 MCP PMT [4], a multichannel device with 8x8 channels and 6 mm $\times$ 6 mm large pads, as the detector of Cherenkov photons in a RICH counter [5], the present paper describes measurements and results obtained with a modified configuration in which we have registered both the hit position and its time in the same π2 beam at KEK.

2. The bench test

Timing properties of BURLE 85011 MCP PMT were first measured on the bench. The PMT was mounted in the dark box and illuminated by the short light pulses from a picosecond laser (PLP-02-SLDH-041) with the repetition rate of 1 kHz. The light was guided from the laser into the box by an optical fiber; its intensity was controlled by filters between the end of the fiber and PMT. A screen with a 2 mm hole was placed in front of the PMT window so that only the center of a single pad was illuminated.

The signal from the PMT was first amplified by an ORTEC FTA820A NIM module and was split by a resistor network into two branches. One was fed to the CAMAC charge sensitive ADC while the other was first discriminated by a PHILIPS 708 NIM module and used as a stop signal for a CAMAC TDC module. As a start signal for the TDC we used the trigger signal from the laser.

From measured TDC and ADC values the time-walk correction function was determined and used to correct the TDC data. The corrected TDC distributions for single and multiple photon signals are shown in Fig. 2. The time resolution for the prompt peak of the single photon distribution is 47 ps, while for a large number of photons in the pulse the resolution is better than 20 ps. Note that the expected number of Cherenkov photons emitted by a minimum ionizing particle in the PMT window is 12, such that from the measured dependence of time resolution as a function of the pulse intensity we deduce that the expected time resolution is 30 ps.

3. The beam test

The beam test set-up is shown in Fig. 3. After passing through the first multi-wire proportional chamber (MWPC) and the start counter, a charged particle hits the aerogel radiator in which it emits Cherenkov photons. It also emits Cherenkov photons in the window of the position sensitive detector of Cherenkov photons which is situated 20 cm downstream of the aerogel. The hits on the photon detector provide the stop for the time-of-flight measurement, and the start is provided by another MCP PMT (Hamamatsu R3890) 65 cm upstream.

The distributions of hits, depending on their time of flight for Cherenkov photons from aerogel, is plotted in Fig. 4. Fitting this distribution with a Gaussian function yields a standard deviation of about 50 ps. For 10 detected hits per track this would correspond to a time-of-flight resolution of 20 ps.

An excellent resolution is also found from the distribution over time of flight as determined by the Cherenkov photons from the PMT window. As can be seen in Fig. 5, the standard deviation of the distribution for pions is 37 ps. We can also see that pions are clearly separated from protons even in this very compact set-up with a very short flight path. In the Belle spectrometer, where the typical flight path is about 2 m, the measured performance would correspond to a 6 σ separation between pions and kaons at 2 GeV/c, and a 3.5 σ separation between protons and kaons at 4 GeV/c.

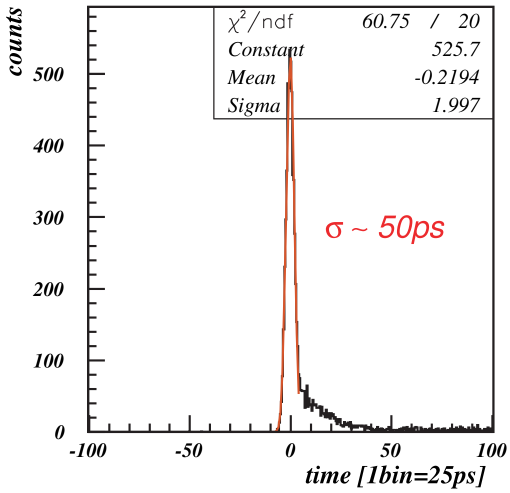

Figure 4. The distribution of the time of flight as measured by single Cherenkov photons from the aerogel radiator.

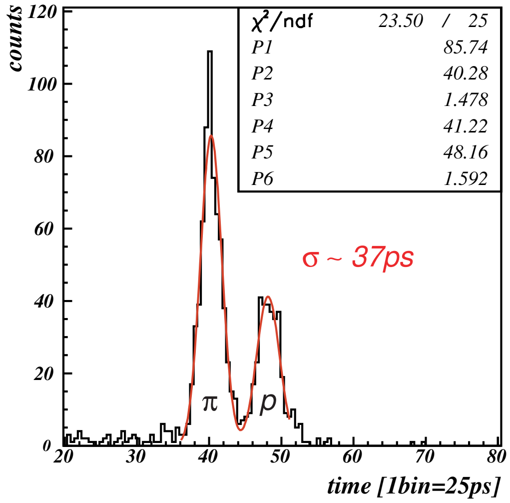

Figure 5. The distribution of the time of flight as measured by Cherenkov photons from the PMT window, shown for 2 GeV/c pions and protons.

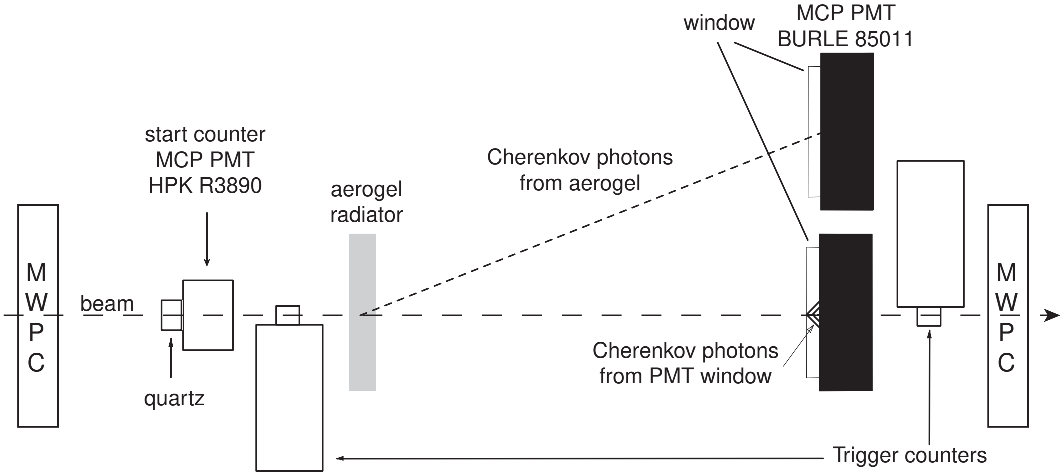

Figure 3. The experimental set-up used for the beam tests. Cherenkov photons emitted in the aerogel radiator and in the window of the PMT are used for measuring the time of arrival. The start signal is provided by another MCP PMT.

4. Conclusion

In the present study we have investigated time of flight capabilities of a proximity focusing RICH with aerogel radiator and a fast micro-channel plate PMT photon detector. Such a device could also serve as a time-of-flight counter and thus supplement other identification methods, in particular for low momentum tracks. A prototype of this novel device using BURLE 85011 64-anode, microchannel plate PMT, was tested on the bench and in the test beam at KEK. Cherenkov photons emitted in the radiator medium (aerogel) as well as in the entrance window of the PMT were used for the time-of-flight measurement. Resolutions of 50 ps for single photons from the aerogel radiator and 35 ps for multiple photon pulses from the PMT window were measured. A good separation of pions and protons was observed in the test beam data.

One of the problems which deserves further attention is the operation in high magnetic fields. The present BURLE 85011 PMT with 25 μm pores works well in the fields up to 0.8 T [6], whereas operation in 1.5 T is ultimately required. Hopefully this could be achieved with 10 μm pore microchannel plates. Further investigations are in progress with the aim of reaching the required performance of the proximity focusing RICH detector, as planned for the Belle upgrade.

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