KEK_J-PARC-PAC2010-05

Test of TOP counter for B-factory upgrade

Belle-II PID group

K. Inami [a], T. Mori [a], K. Suzuki [a], K. Hara [a], T. Iijima [a], G. Varner [b], T. E. Browder [b], M. Rosen [b], A. J. Schwartz [c], S. Korpar [d], P. Križan [d], M. Starič [d], and I. Adachi [e]

[a] *Nagoya University, Nagoya, Japan*

[b] *University of Hawaii, Honolulu, HI, USA*

[c] *University of Cincinnati, Cincinnati, OH, USA*

[d] *J. Stefan Institute, Ljubljana, Slovenia*

[e] *High Energy Accelerator Research Organization (KEK), Tsukuba, Japan*

Abstract

We propose a beam test of TOP counter for Belle-II upgrade, in order to demonstrate the particle identification performance using $K^{\pm}$ and $\pi^{\pm}$ beam. In the test, we will confirm the Cherenkov ring image, the number of detected photons and the time resolution for the ring image reflected by a focusing mirror, using the prototype with the new electronics and expansion block.

1 Introduction

To extend the physics reach at the Belle-II experiment, which plans to start from 2014, we would like to improve the K/π separation capability of the spectrometer by upgrading the particle identification (PID) system [1]. An upgrade of the system is also compulsory to cope with the higher background environment.

In the barrel region of the spectrometer, the present time-of-flight and aerogel Cherenkov counters are replaced with a Time-Of-Propagation (TOP) counter [2], whose conceptual overview is shown in Fig. 1. In this counter the time of propagation of the Cherenkov photons internally reflected inside a quartz radiator is measured (Fig. 2). The Cherenkov image is reconstructed from the 3-dimensional information provided by two coordinates (x, y) and precise timing, which is determined by micro-channel plate (MCP) PMTs at the end

Preprint submitted to *14 June 2010*

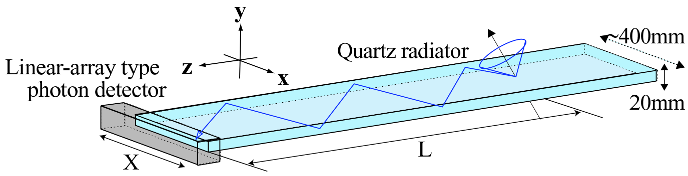


Fig. 1. Conceptual overview of TOP counter.

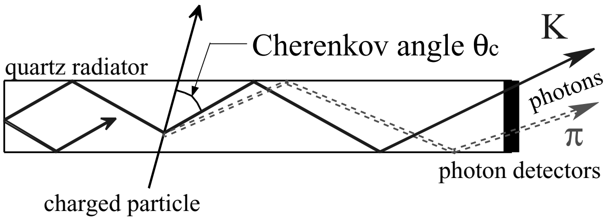


Fig. 2. Schematic side-view of TOP counter and internal reflecting Cherenkov photons.

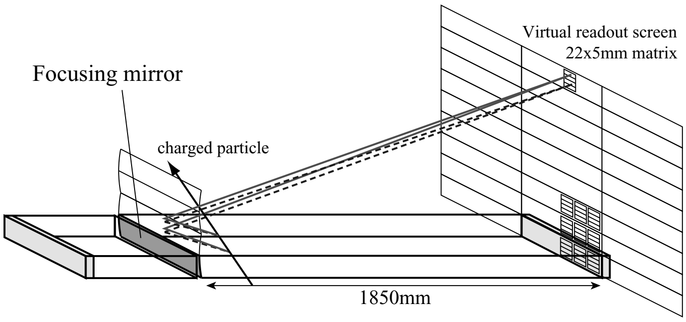


Fig. 3. The principle of the focusing scheme in the TOP counter. The virtual extension of the focal surface and of the photon detector plane are shown by the dashed curves and dashed lines.

surfaces of the quartz bar. The array of quartz bars surrounds the outer wall of the central drift chamber in the Belle-II detector; they are divided into 16 modules in ϕ in the baseline geometry.

The PID power is limited by the broadening of the time resolution due to the chromaticity of Cherenkov photons. To minimize the chromatic effect, we introduce a focusing system.

Figure 3 shows the schematic set-up. A focusing mirror is introduced at the end of the quartz bar. The PMT is aligned to measure the position of the photon impact in x and y. The cross section of the quartz bar is a rectangle. We can therefore expand the light trajectory into the mirror-image region and create a virtual readout screen. The Cherenkov photons with different θ_c will focus onto the different PMT channels and we thereby obtain λ information from the y detection position through θ_c. The focusing TOP reconstructs the ring image from 3-dimensional information of time, x and y.

2 Prototype

We have produced a prototype TOP counter to check the effects of chromatic dispersion effect and demonstrated overall timing performance [3]. The prototype consists of $1830 \times 400 \times 20\text{mm}^3$ quartz radiator with a spherical focusing mirror (5m radius) and the 14 MCP-PMT array, which are shown in Figure 4. In order to reduce chromatic dispersion effects, a wavelength high-pass filter of $\lambda > 400$ nm was inserted between the radiator and the MCP-PMTs. Operation of the MCP-PMTs demonstrated stable gain ($\sim 10^6$) and good time resolution (< 40 ps) for all channels.

Using a prototype counter, we performed beam tests with 2 GeV/c electrons at the KEK Fuji test beam line in June and December 2008. The TOP counter was located between trigger scintillation counters and tracking chambers. To determine the beam timing precisely, we put the timing counter [4] along the beam line, which consisted of a small quartz radiator (10 mm$^\phi$ $\times$10 mm^L) and a round MCP-PMT (Hamamatsu R3809-50-11X). The time resolution obtained for these start counters was determined to be 14.8 ps during the beam test.

Figure 5(a) shows a partial ring image obtained during the beam test. The beam was normally incident at the center of the radiator. The distance between this incident position and the nearest MCP-PMT was 358 mm. A clear partial ring image was obtained, as predicted by simulation. Figure 5(b) shows the number of detected photons for the normal-incidence case, which also matched Monte-Carlo expectations for the number of photons. Figure 5(c) is the TDC distribution for an anode at the center of the readout plane. The distance between the incident position and this MCP-PMT was 875 mm. A comparison was made of the time resolutions obtained during the beam test with the resolution expected from simulation, which included PMT resolution and the effect of chromatic dispersion. The time resolution of the first peak was 76.0 ± 2.0 and 77.7 ± 2.3 for data and simulation, respectively, indicating consistent results between data and simulation.

3 Next beam test

3.1 Aim

In the next beam test, we want to demonstrate the performance of TOP counter prototype with an expansion block and new electronics. We want to confirm that the ring image, number of detected Cherenkov photons and the time resolution for the ring image reflected by a focusing mirror is consistent with the prediction by the simulation program, using the $K^{\pm}$ and $\pi^{\pm}$ beam. In the previous beam test, we found a small amount of background photons in the time distribution under signal peaks. It looks due to the electron shower at upstream beam line. In order to avoid such a effect, we want to use hadron beam.

3.2 Set up

Figure 6 shows the schematic view of the setup of our test. The located devices are following:

- Trigger counter: two scintillation counters located on the most upstream and downstream construct this device. The coincidence of signals from the both counters generate the trigger.
- MWPC: the sensitive area is $50 \times 50\text{mm}^2$. The resolution is 1mm for both of the horizontal and vertical axis. Two MWPCs are located for the tracking, in the case that the distance of two MWPCs is 1m, the angle resolution is 1mrad.
- TOP counter prototype: our test target. Basically, we use the prototype described in Section 2, but we will upgrade the readout electronics and add the expansion block.
- Veto counter: multi-track events make the number of detected photons double, they should be subtract.
- Timing counter: it is important to establish the standard time with the narrow TTS; this device decides the timing with the jitter less than 20ps.

As shown in the Fig. 6, the TOP counter can be slided horizontally (z) or vertically (x), or be rotated in the polar (θ) or azimuthal (ϕ) direction. Therefore, not only the normal irradiation, but also the slanting irradiation can be done on the certain region of the quartz.

New readout system developed by Hawaii group will be implemented. The ASIC based waveform sampling device [5–7] is used. Digitized data are send to the computer via the interface card.

3.3 Beam request

We request to have a beam test at around October 2010, because we want to demonstrate the prototype performance before starting the mass production for Belle-II experiment. We want to use the $\pi^{\pm}$ and $K^{\pm}$ beam of $p = 1 \sim 3\text{GeV}/c$. Considering the beam intensity ($10^{6\sim7}$/hour), we can obtain enough data for a few hours running. We want to take data sets for several incident conditions, by changing the θ angle and z position shown in Fig. 6 to check the performance for whole coverage region (5 conditions), the ϕ angle, which corresponds to change the momentum in the Belle-II detector (3 conditions), and the x position to check the effect of side edge (3 conditions). In total, we need about 45 conditions. Including the setup change, we need about $4 \sim 5$ hours for each condition. Therefore, we request the run time for about two weeks including the beam-line setup and detector tuning. (Depending on the beam condition, we can reduce the number of conditions.)

References

[1] I. Adachi *et. al.*, arXiv:0810.4084.

[2] K. Inami *et. al.*, Nucl. Instrum. Meth. **A 595** (2008) 96.

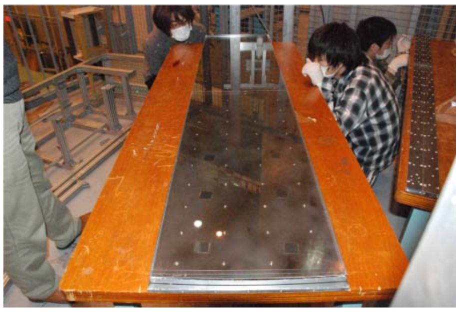
[3] K. Inami *et. al.*, Journal Instr. 5 P03006 (2010).

[4] K. Inami *et. al.*, Nucl. Instrum. Meth. **A 560** (2006) 303.

[5] G. Varner *et. al.*, Nucl. Instrum. Meth. **A 583** (2007) 447.

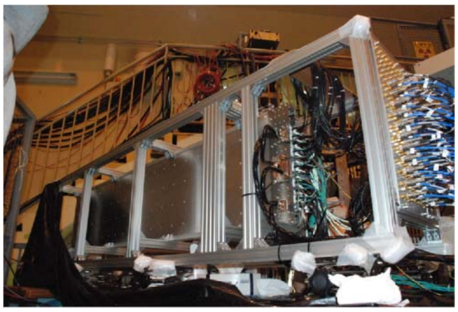
[6] G. Varner *et. al.*, Nucl. Instrum. Meth. **A 554** (2005) 437.

[7] G. Varner *et. al.*, Proc. SPIE Int. Soc. Opt. Eng. 4858-31 (2003).



(a) Quartz

(b) PMT-BOX



(c) Prototype

Fig. 4. Pictures of TOP counter prototype.

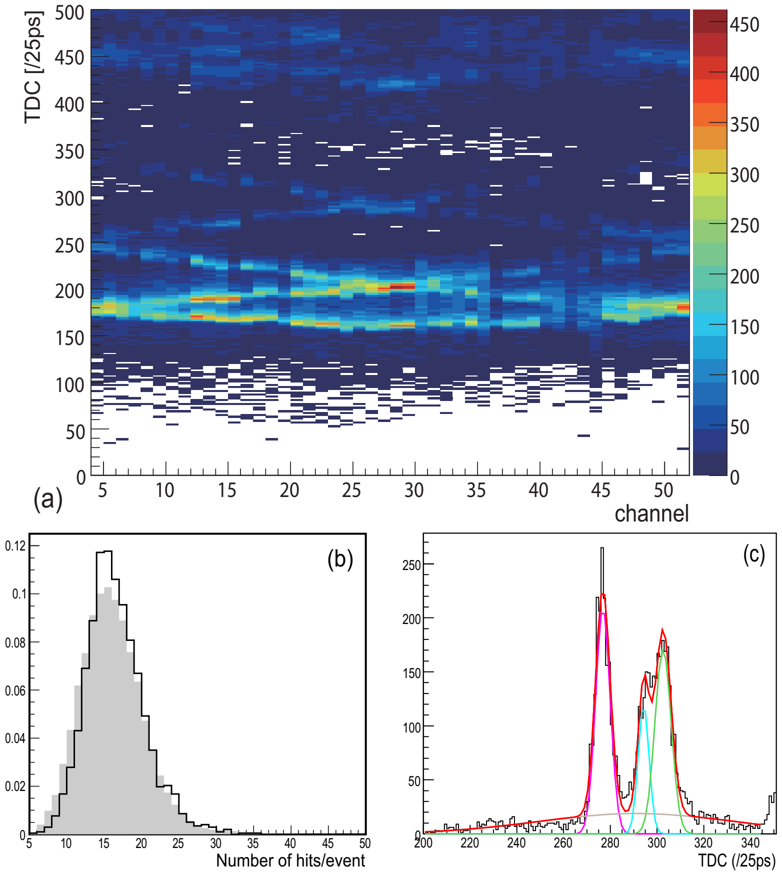


Fig. 5. (a) Partial ring image, (b) number of detected photons, and (c) TDC distribution of an anode at the center of the readout plane, obtained during the beam test. In (b), the solid and shaded histograms correspond to data and simulation, respectively. In (c), the histogram is the data, and the curves show the fitted Gaussian and background functions.

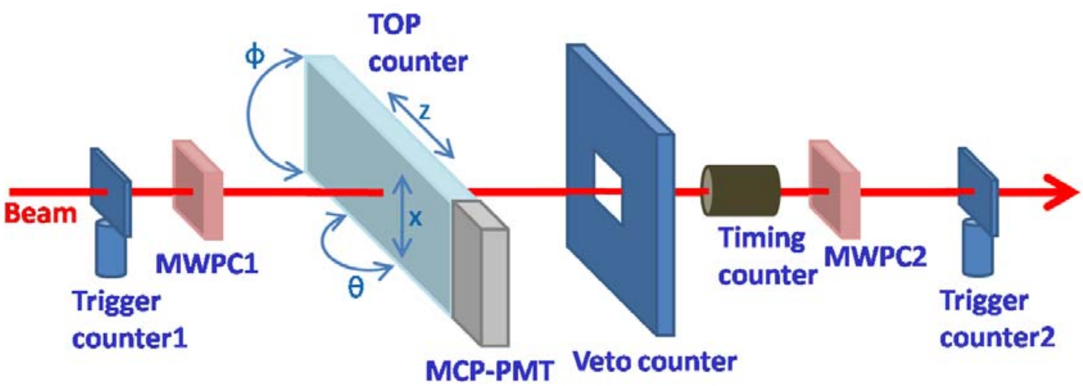


Fig. 6. The schematic view of the test. Red line shows the π or K beam line. From the upstream of the beam, following devices are placed: the 1st MWPC, the TOP counter prototype, the veto counter, the timing counter, the 2nd MWPC, the trigger counter.