PROCEEDINGS OF SCIENCE

New PID detector -TOP counter- for Belle II experiment

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We have been developing a Cherenkov ring-imaging counter, named TOP counter, as a barrel particle identification device of the Belle II detector for the super B-factory at KEK. Recently, we have started the module production with 2.7m long quartz radiator, honeycomb panel box, MCP-PMTs and the fast electronics. In the performance tests, we have evaluated the number of detected photons, time resolution and the related performance for each component. In this presentation, we show the overview of the TOP counter, test results, module production status and prospects.

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1. Introduction

New ring imaging Cherenkov detector, named TOP counter [1], will be used for K/π particle identification in the Belle II [2] barrel region, which measures the time-of-flight of the particles from the interaction point and the time-of-propagation of internal reflected Cherenkov photons. TOP counter consists of the quartz radiators, a focusing mirror, an image expansion block, in order to correct for chromaticity and increase the number of effective detected photons, and the micro-channel-plate (MCP) PMTs/fast electronics. The schematic view and optics size is shown in Figure 1.

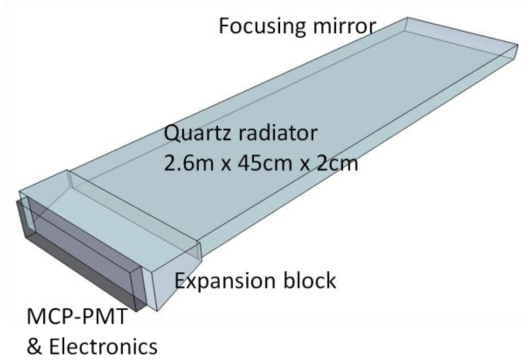

Figure 1: Schematic view of TOP counter configuration

Cherenkov photons are emitted in the quartz bar, and propagate to the MCP-PMT. Cherenkov ring image is reconstructed not only by x-y position but also with time information. TOP counter utilizes the time-of-flight information additively. Because of this characteristic, TOP counter requires a good time resolution, which is less than an order of 100ps for single photon detection.

Particle identification is performed using a likelihood calculation with complicated ring image. To demonstrate the performance, we have carried out the beam test using 2 GeV electrons at the Spring-8 LEPS beam line. The obtained ring image is shown in Figure 2 with the Monte Carlo (MC) expectation. The data is obtained as expected, with the sufficient number of photons (Figure 2 right) and precise time resolution (~100ps depending on the propagation length).

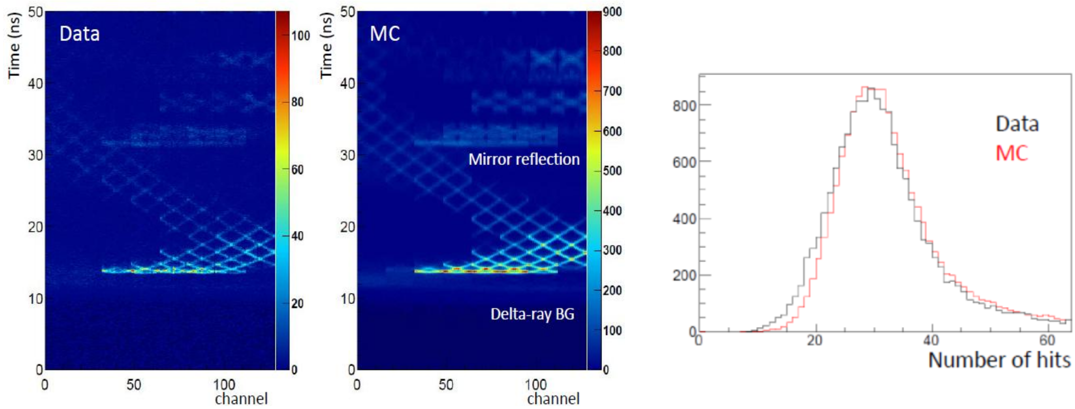

Figure 2: Ring image obtained by beam test. Left figure shows the data and center is MC expectation. Right figure shows the number of detected photons.

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2. Detector components

The status of the main detector componets is described here.

2.1 Quartz radiator

The Cherenkov radiator is made of high quality quartz with a polishing accuracy of 2λ flatness and 5Å surface roughness. Two quartz bars (2mm^{t} x 45cm^{w} x 125cm^{l}), a focusing mirror and an image expansion block are glued with a reletive angle accuracy of ~0.02mrad, ~10mm by the optical epoxy glue (EPOTEK301-2). The gluing process and optics are shown in Figure 3.

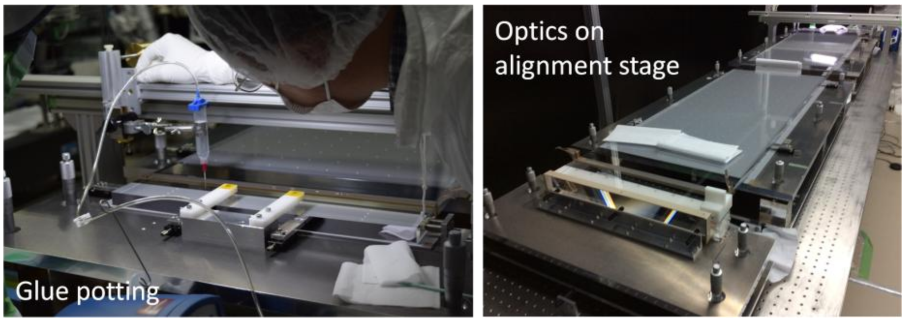

Figure 3: Photo of glue potting process (left) and optics on the alignment stage (right).

2.2 Mechanics

Radiator is supported by honeycomb panel and buttons with the flatness of ~40μm. The stiffness of the assembled TOP module is improved by the round shaped honeycomb panel (Figure 4 right) and the barrel connection with the adjacent module. During the production, "strong back" is attached to the quartz-bar-box (QBB) to keep the flatness (Figure 4 left).

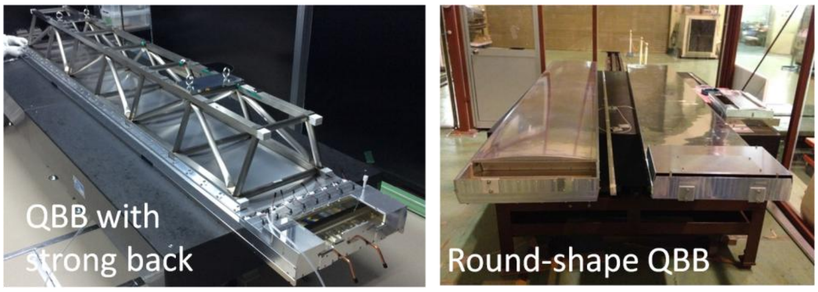

Figure 4: Photo of QBB with the strong back (left) and round-shape honeycomb panel (right).

2.3 MCP-PMT and frontend electronics

MCP-PMTs work for single photon detection even under a 1.5T magnetic field, with a transit-time-spread (TTS) of <40ps [3]. An enhanced photocathode has been adopted to increase the number of detected photons. The mass production for the Belle II has been carried out with the stable performance of TTS<40ps and the quantum efficiency (QE)~28.5%, as shown in Figure 5 left. The photo-cathode lifetime was improved by adopting coated MCP, as shown in Figure 5 right.

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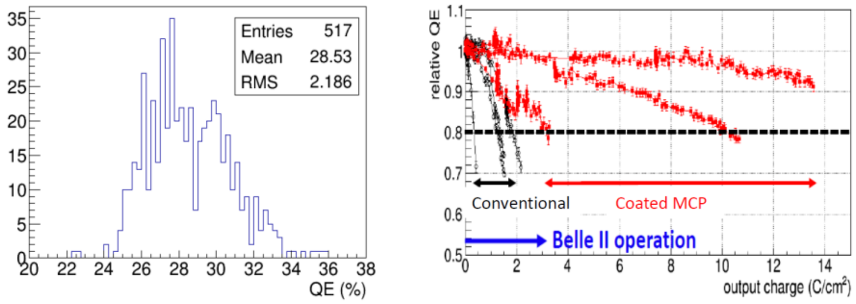

Figure 5: Obtained QE distribution at 360nm for the mass-production PMTs (left) and the relative QE degradation as a function of output chage from PMT for conventional and coated MCP-PMTs (right)

The PMT signal is read out by a newly developed ASIC, named IRS, with GHz analog bandwidth, high speed waveform recording, to achieve pico-second level timing measurement. Prototypes are developed and show the performance as expected; time resolution with PMT is ~50ps. The final model is in mass production.

3. TOP module production

Finally, TOP module production has been started from December 2014, following the practices of 4 prototype productions. In the production, first we glue optics and tune QBB parts, then we lift up the optics from the glue stage to QBB, and assemble QBB, PMT modules and frontend electronics, as shown in Figure 6. Currently, the production goes successfully, although we improve the procedure gradually. We could produce about 2.5weeks per module and plan to finish all modules by the end of JFY2015.

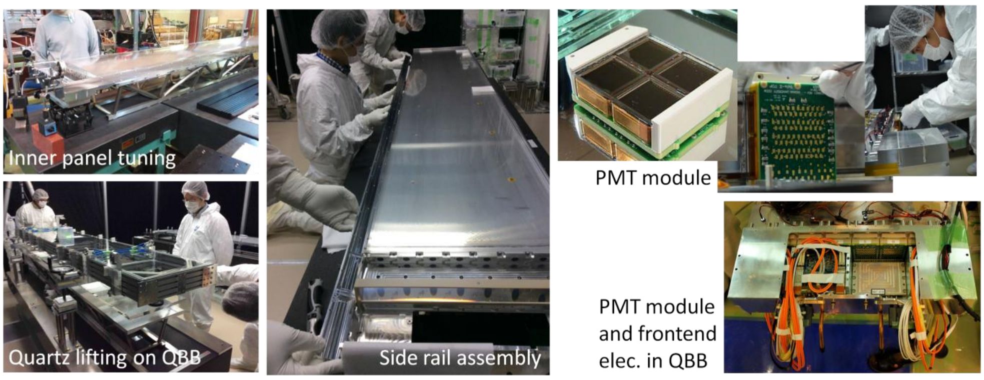

Figure 6: Photos for the TOP module production.

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