Nuclear Instruments and Methods in Physics Research A 766 (2014) 255–258

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

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

Performance tests of a full scale prototype of the Belle II TOP counter with cosmic muons and 2.1 GeV/c positron beam

Tomokatsu Hayakawa

Graduate School of Science, Nagoya University, Nagoya, Japan

On behalf of the Belle II PID Group

ARTICLE INFO

Available online 11 July 2014

Keywords:
Cherenkov radiation
TOP counter
Particle identification

ABSTRACT

A time-of-propagation detector named TOP is a hadronic particle identification system for the Belle II experiment. We have produced a full scale prototype of the Belle II TOP counter and tested with cosmic muons at KEK and the 2.1 GeV/c positrons at SPring-8 LEPS beamline. The procedures for the quartz acceptance test and assembly worked well and the first quartz radiator was successfully fabricated. The obtained test data shows good agreement with Monte Carlo expectation.

1. Introduction

The time-of-propagation (TOP) counter [1–3] is a totally internally reflecting Cherenkov imaging detector proposed for charged particle identification (PID) in the barrel region of the Belle II detector [4]. The TOP counter measures about 20 Cherenkov photons produced inside a quartz radiator with position sensitive photo detectors attached to the end of the radiator. Using the position and timing information of arriving the Cherenkov photons, Cherenkov ring image is reconstructed and the velocity of the charged particle is determined by comparing the time-of-propagation spectra with probability density functions.

A full scale prototype of the Belle II TOP counter was produced to evaluate the performance in 2013. It comprises about 2.7 m quartz radiator with a spherical focusing mirror (radius of curvature: 5 m) and a prism-shape expansion block viewed by 32 square-shape MCP-PMTs [5,6] as shown in Fig. 1.

Two raw fused silica materials have been selected for this prototype. One quartz material provided by ShinEtsu Quartz (SUPRASIL-P20) was grinded by Okamoto Optics Works. Zygo polished another material from Corning (Corning 7980). The primary quality control of the quartz optics was performed by the quartz vendors. Both prototype quartz bars have high quality surfaces whose roughness is less than 0.5 nm and the flatness is about 5 μm/m. When a shipment of the quartz components was received, edge damage was inspected visually. The position and size of each chip should be measured precisely since chips on quartz bars cause the scattering of Cherenkov photons. Therefore, chips and scratches also have been searched using a single-lens reflex camera attached on a rail system and a coaxial illumination method has been employed in order to get high-contrast chip images from transparent objects like quartz bars.

In order to confirm the optical quality, the bulk transmittance (τ) and internal surface reflectance (α) have been measured by scanning the quartz optics with a laser beam at 405 nm and photodiodes. The obtained results are $\tau = 99.6 \pm 0.2\%/\text{m}$ and $\alpha = 0.9998 \pm 0.0002/\text{bounce}$ at 405 nm, which meet our specifications.

Since the emission angle of the Cherenkov light must be preserved, angular misalignments of the quartz parts must be minimized. To align and glue the quartz parts precisely, they were mounted on the special optical stages and the relative position and angle were adjusted using an autocollimator and laser displacement sensors by $\mathcal{O}(10)$ μm and $\mathcal{O}(10)$ μrad. A UV-cured glue (Norland NOA63) was used for the bar–bar and bar–prism joints for this prototype. On the other hand, another UV-cured glue (Norland NBA107) which is removable using aceton was used for the bar–mirror joint for the future mirror studies. The total relative angle and displacement of the glued quartz radiator are less than 0.1 mrad and less than 100 μm respectively. In addition, a wavelength-cut filter of $\lambda > 340$ nm (Isuzu Glass IHU340) was also put between the quartz radiator and the MCP-PMTs to avoid deteriorating the time resolution.

For this prototype, two Front-End Electronics were prepared as shown in Fig. 2. One is based on a waveform-sampling ASIC (IRS) developed by Hawaii University [7,8], which is the baseline for the Belle II TOP counter. The other is based on a home-made constant fraction discriminator (CFD). The time resolution of the conventional readout electronics is about 50 ps. Using the Front-End Electronics, we have evaluated the expected performance of the

http://dx.doi.org/10.1016/j.nima.2014.07.009
0168-9002/

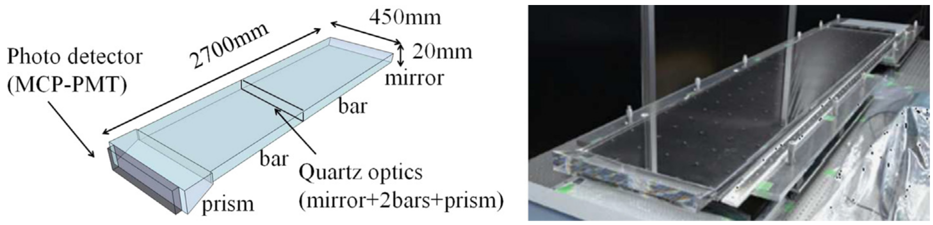

Fig. 1. Overview of the Belle II TOP counter (left). The quartz radiator of the first full scale prototype assembled in the cleanroom at KEK (right).

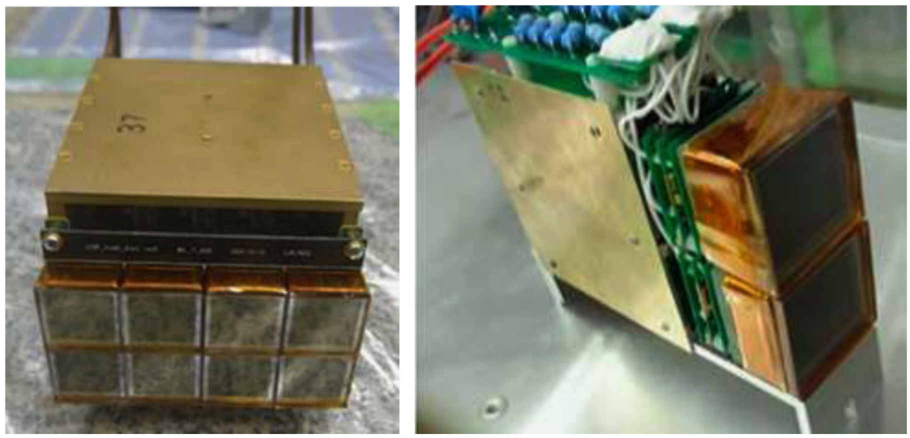

Fig. 2. IRS front-end electronics (left). CFD front-end electronics (right).

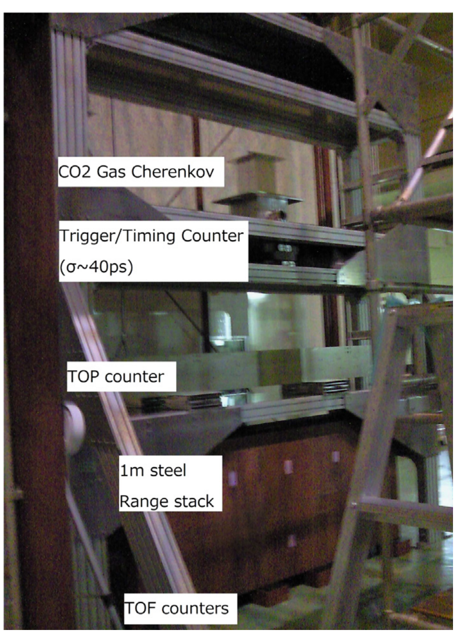

Fig. 3. Overview of the cosmic ray telescope.

Belle II TOP counter based on the specification parameters for the optical components and the photon detector, MCP-PMT.

2. Cosmic ray telescope (CRT)

High momentum cosmic muons are proposed to be used as the source for measurements over the whole detection area of the TOP counter. A dedicated Cosmic Ray Telescope (CRT) facility has been constructed at KEK Fuji hall [9]. The CRT consists of five layers of plastic scintillation hodoscopes for triggering cosmic ray muons, four arrays of SciFi trackers for muon track, CO_2 Gas Cherenkov counters for eliminating low momentum muons, and a wide steel range stack for vetoing shower events as shown in Fig. 3. In addition, large acceptance drift tubes for muon track are being integrated.

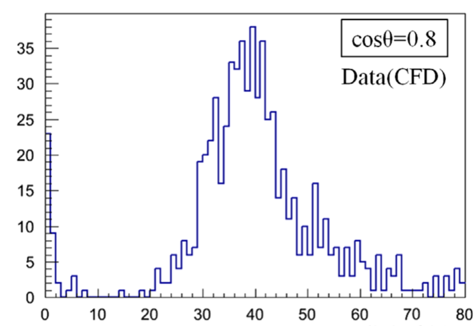

Fig. 4. Number of photon hits distribution with about 37° tilted incident condition. The expected average value of the number of photon hits from Monte Carlo is 38.

The prototype TOP counter has been tested using this CRT facility. Three large plastic counters tag cosmic muons passing through the wide steel range stack. Data with about 37° tilted incident condition was taken with CFD readout electronics. The obtained number of photon hits distribution has good agreement with Monte Carlo expectation as shown in Fig. 4. Further performance studies will be carried out using large acceptance tracking detectors. Data taking with new IRS readout electronics will also start soon.

3. Beam test at SPring-8 LEPS beamline

In order to evaluate the full scale prototype of the Belle II TOP counter, a beam test has been carried out at SPring-8 LEPS