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# Development of the ARICH monitor system for the Belle II experiment

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A B S T R A C T

The Belle II detector is under construction at KEK in Japan. In the forward endcap region of the Belle II detector, particle identification (PID) is performed by the Aerogel Ring Imaging Cherenkov (ARICH) counter composed of aerogel tiles and 144-channel Hybrid Avalanche Photo-Detectors (HAPDs). The photon detection efficiency of the photosensor is important for a stable operation of the ARICH. To examine the performance of the HAPDs periodically, a monitor system using scattered photons injected by optical fibers is being developed. In this paper, we report the test using the prototype monitor system and the tests with a partially built ARICH detector.

## 1. Introduction

The Aerogel Ring Imaging Cherenkov (ARICH) counter is the particle identification device in the endcap region of the Belle II detector. The ARICH is designed to discriminate charged pions from kaons using the difference in radiation angle of Cherenkov light, aiming to obtain a discrimination power of $4\sigma$ up to 4 GeV/c [1]. It is composed of aerogel tiles as the Cherenkov radiators and Hybrid Avalanche Photo-Detectors (HAPDs) as the photon detectors. The HAPD has a two-step amplification mechanism: (1) photo-electron acceleration in a high-voltage gap, and (2) avalanche amplification in the Avalanche Photo-Diode (APD). Each HAPD has 144 channels. ARICH is equipped with 420 HAPDs, corresponding to 60,480 channels in total.

To keep a high photon detection efficiency of the HAPDs, a periodical check of the photon detection efficiency and in-situ calibration of the HAPDs is necessary. We have been developing a monitor system that checks performance of each channel of the HAPDs.

## 2. The monitor system for ARICH

The monitor system is required to be installed in the limited space of the ARICH. Light pulses produced by an LED are introduced into the ARICH using optical fibers and emitted at the end of the fiber towards the aerogel tiles. A portion of the emitted photons are reflected by Rayleigh scattering in the aerogel tiles as shown in Fig. 1. Using scattered photons that enter the windows of the HAPDs, the performance of the HAPD is examined.

The ARICH counter is divided into six sectors. Each sector has 15 holes in the support structure for installing optical fibers. Fifteen optical fibers are used to uniformly illuminate all the HAPDs in one sector.

In the early stage of the Belle II experiment, it is expected to be difficult to detect a possible change of the performance of the HAPDs using the beam data as the quantity and quality of the beam data will be

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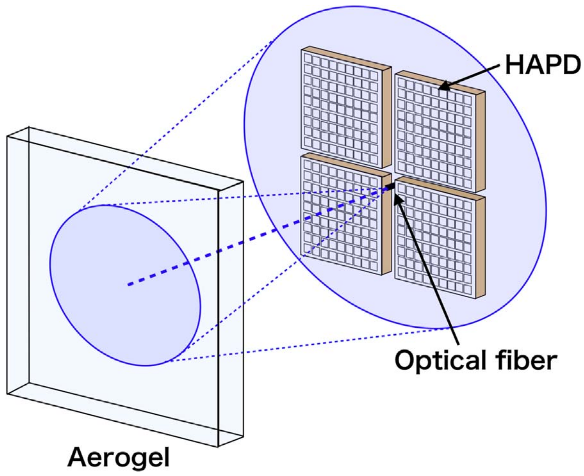


**Fig. 1.** The scheme of the ARICH monitor system. The light pulses emitted at the end of the optical fiber are scattered in aerogel tiles and enters each channels of the HAPDs.

low. The monitor system will be useful to assure whether individual channels of the HAPDs are dead or alive. After the early stage of the Belle II experiment, the system can be used as the in-situ calibration source for the HAPDs and their front-end electronics.

## 3. Test of the prototype monitor system

The prototype monitor system consists of an HAPD, dual layered silica aerogel tiles with refractive indices of 1.045 and 1.055 for the upstream and downstream radiator respectively, and an optical fiber as shown in Fig. 2.

Light pulses generated by an LED with a wave length of 470 nm, are transmitted through the optical fiber. A diffusing lens is placed at the end of the fiber. Thus, diffused light illuminates the aerogel tiles with the angle of about 24 degrees.

Photons that are back-scattered by the aerogel tiles are detected by the HAPD. By varying the HAPD position, we measure the hit rate, which is defined as the hit count divided by number of triggers, as function of the distance between the optical fiber and the center of the HAPD.

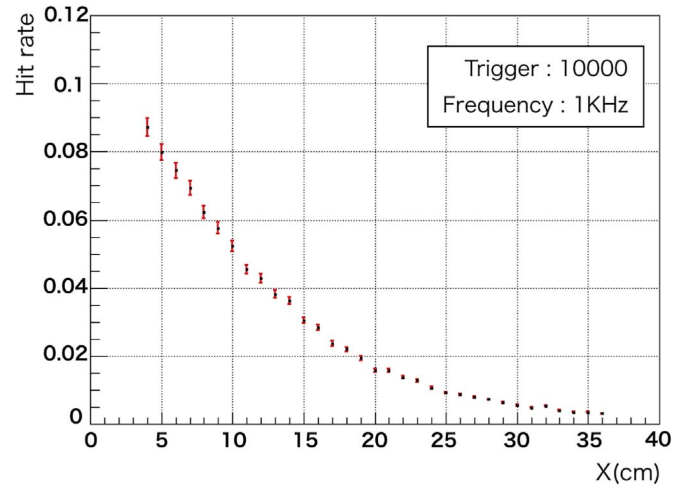


**Fig. 3.** The distribution of the scattered light. The detected LED light is distributed to a distance of about 30 cm. Horizontal axis is the distance between the optical fiber and the center of the HAPD.

Fig. 3 shows the distribution of the hit rate as a function of the distance. We confirmed that the light spreads to about 30 cm in radius from the position of the optical fiber. In the ARICH, the intervals between the optical fibers is designed to be about 15 cm, and thus the area illuminated by light from an optical fiber is sufficiently large. So, we expect the monitor system we designed can illuminate all the HAPDs of the ARICH.

In addition, we periodically measured the hit rate every hour up to 471 h. As the result, we found the system can monitor the long term stability of all the HAPD channels simultaneously. We also confirmed that it is possible to detect the dead channels in long term operation.

We can measure hit rate of light signal by varying the threshold voltage of the readout electronics. This procedure is called a threshold scan. It can be used for in-situ calibration of the HAPDs. We confirmed that we can obtain the gain and noise level of each channel of the HAPDs using the threshold scan. Together with the measurement of

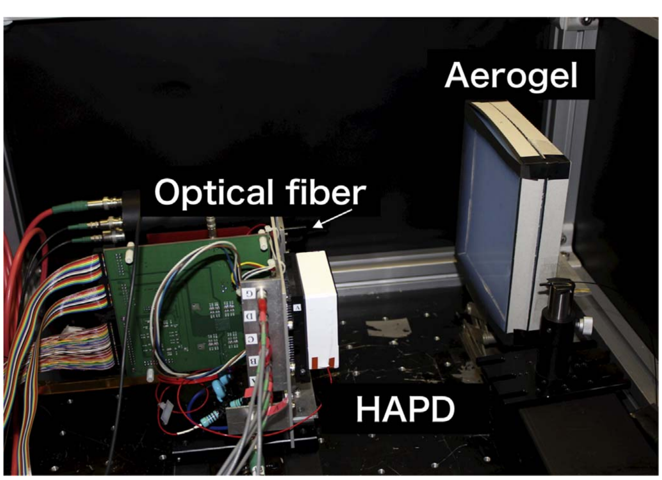


**Fig. 2.** The prototype monitor system setup. The two-layered aerogel tiles, one HAPD module and one optical fiber are set up in the same way as in the final detector. The LED light is emitted from the optical fiber in front of the center of the aerogel tile.

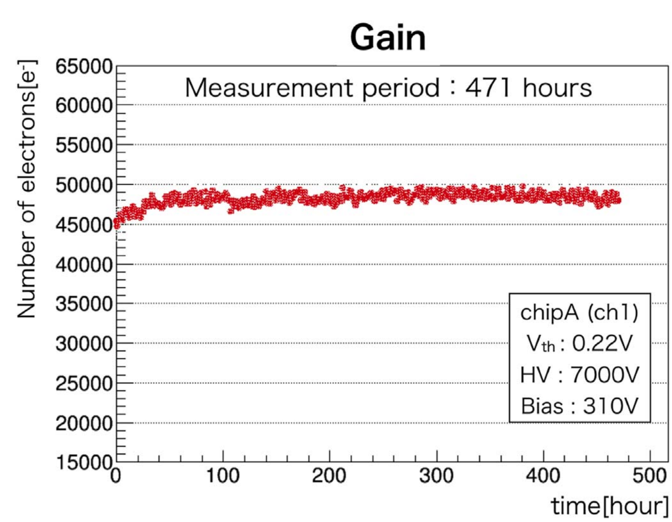


**Fig. 4.** Long term stability of the gain of a channel of a HAPD.