Development of Threshold-Type Aerogel Cherenkov Counter with A Low Mis-PID Rate

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Introduction

Four-pi Omnidirectional-Response Extended Spectrometer Trio (FOREST) is a multiple gamma-ray detector group at GeV Gamma room in Research Center for ELectron PHoton Science (ELPH), Tohoku University. Present FOREST does not have any instrument for measuring charged particles, and plans to install an instrument for measuring incident charged particles downstream. This instrument consists of two sets of position detectors for charged particles, a silica aerogel Cherenkov counter for pion-kaon separation and a Time-of-Flight (TOF) scintillator for kaon-proton separation using a dipole magnet used in KEKB synchrotron as shown in Fig. 1. The bending electromagnet is for bending the incident charged particles slightly in the horizontal direction. We are researching and developing this Cherenkov counter. The momentum of the charged particles incident on this Cherenkov counter is 0.6 to 1.3 GeV/c. therefore, here we use silica aerogels with a refractive index of approximately 1.06.

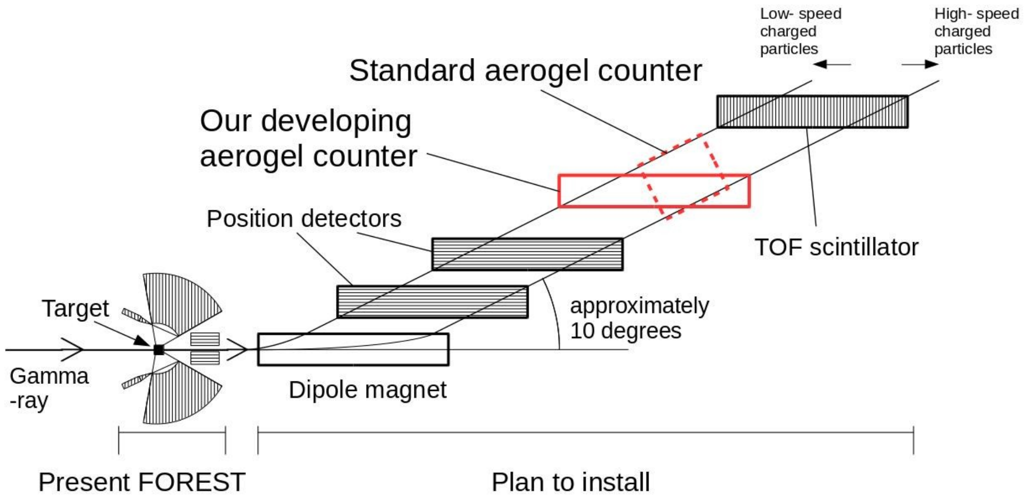

Fig. 1. Generally, an aerogel counter is installed at the position as shown by the dashed red line. We plan to install at the position as shown by the solid red line at FOREST.

Standard Cherenkov counter

As shown by the dashed red line in Fig. 1, standard threshold-type Cherenkov counters are generally installed so that the charged particles enter the radiator perpendicularly. For example, the radiator of a standard counter has the horizontal length of 20 cm, the vertical length of 10 cm and the thickness of 2 cm as shown in Fig. 2. Four photomultiplier tubes (PMTs) with a diameter of 2 inch are installed above and below the radiator, respectively. Knock-on electrons (high-speed electrons produced by incident particles in the radiator) are generally emitted in the direction perpendicular to the incident direction of charged particles. In Fig. 2, knock-on electrons emitted in the horizontal direction pass through the radiator with an average of 10 cm approximately and that in the vertical direction pass through the radiator with an average of 5 cm approximately. As shown in Fig. 2, sometimes both Cherenkov light produced by original charged particles and Cherenkov light produced by knock-on electrons enter the same PMT, which causes error of particle identification (PID).

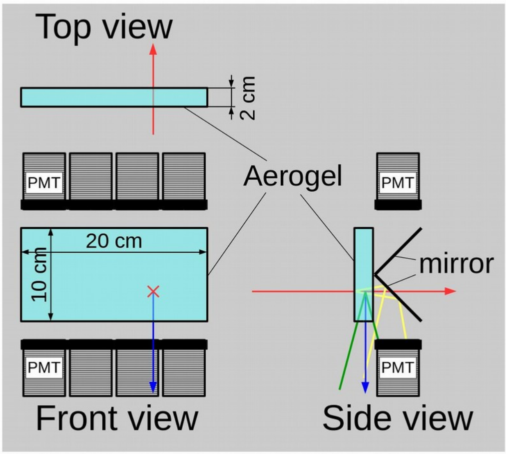

Fig. 2. Standard threshold-type Cherenkov counter. In this figure, the red arrows show incident charged particles, the yellow lines show Cherenkov light produced by incident charged particles, the blue arrows show knock-on electrons emitted in the horizontal direction, and the green lines show Cherenkov light produced by the knock-on electrons.

Our developing Cherenkov counter

We plan to install a threshold-type Cherenkov counter at the position shown by the solid red line in Fig. 1. Our plan of arrangements is shown in Fig. 3. The charged particles obliquely enter the radiator at a small incident angle of approximately 10 degrees to the radiator. For example, the radiator of our counter has a horizontal length of 100 cm and a vertical length of 10 cm. If the thickness is 0.4 cm, charged particles pass through the radiator with approximately 2cm. Therefore, the amount of Cherenkov light emission and the required volume of the radiator of our counter are the same as that of standard counters. In the front view of Fig. 3, four PMTs with a diameter of 2 inch are obliquely installed above and below the radiator respectively at an angle of approximately 10 degrees to the horizontal direction. Knock-on electrons emitted in the horizontal direction pass through the radiator with an average of only 0.2 cm approximately. Knock-on electrons emitted in the vertical direction pass through the radiator with the same average of 5 cm approximately as standard counters. It is easy, however, to identify the Cherenkov light produced by knock-on electrons as shown below. As shown in the front view of Fig. 3, the PMT which Cherenkov light produced by original charged particles enters differs from the PMT which Cherenkov light produced by knock-on electrons enters. Therefore we expect our counter that the error rate of PID caused by knock-on electrons is greatly reduced compared with standard counters. According to a simple simulation calculation, the error rate of our counter is less than one tenth of the error rate of standard counters.

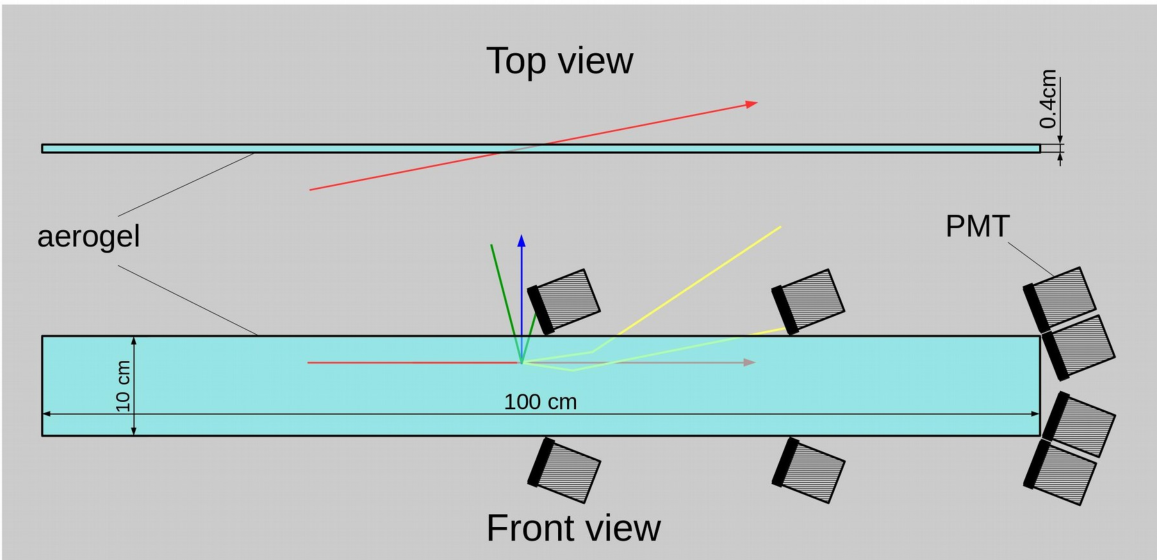

Fig. 3. Our developing threshold-type Cherenkov counter. In this figure, the red arrows show incident charged particles, the yellow lines show Cherenkov light produced by incident charged particles, the blue arrow shows knock-on electrons emitted in the vertical direction, and the green lines show Cherenkov light produced by the knock-on electrons.

Future view

We are developing this Cherenkov counter now. In September this year, we are going to conduct performance evaluation experiment using positron beam with ELPH, Tohoku University and proton beam with the Heavy Ion Medical Accelerator in Chiba (HIMAC) at National Institute of Radiological Sciences. I would like to present the shape and the performance of our PID instrument including these experimental results in October.