Strip-based Scintillation Detector for Dual-readout High-granularity Calorimetry

Hiroyasu Ogawa[1,*], *James* Freeman[2], *Corrado* Gatto[3], *Daniel* Jeans[4], *Taiki* Kamiyama[1], *Weiyuan* Li[1], *Kodai* Matsuoka[4], *Wataru* Ootani[1], *Taikan* Suehara[1], and *Tohru* Takeshita[5]

[1]International Center for Elementary Particle, the University of Tokyo
[2]Fermi National Accelerator Laboratory
[3]Department of Physics, Northern Illninois University
[4]High Energy Accelerator Reseach Organaization(KEK)
[5]Department of Physics, Shinshu University

Abstract. New calorimeter technology is being developed for future collider experiments. We are developing a calorimeter that integrates two technologies, a high-granularity calorimeter and a dual-readout calorimeter, and has high time resolution at a picosecond level. The proposed calorimeter is a sampling calorimeter based on scintillation and Cherenkov detectors with high-granularity readout. The Cherenkov detector has a picosecond level time resolution. For the high-granularity scintillation detector, scintillator strips of 300mm × 30mm ×3mm-thick are aligned horizontally and vertically to realize an effective 30mm-square-cell segmentation. Prototype strips with different designs and scintillator materials were tested to compare the performance.

1 Introduction

For future collider experiments, precise jet energy measurement is required. The dual-readout calorimeters [1] and the high-granularity PFA calorimeters [2] are being developed as possible calorimeter technologies. We are developing a new sampling hadronic calorimeter that combines dual-readout calorimeter and high-granularity calorimetr with high time resolution [3] [4]. The dual readout is achieved by reading out signals from both a scintillation detector and a Cherenkov detector. The development of a strip-based scintillation for this new calorimeter is presented.

2 Strip scintillation detector

2.1 Concept of scintillation detector

Strip-shaped scintillators are alternately aligned horizontally and vertically to have an effective square-cell segmentation. The number of readout channels can be significantly reduced in this strip configuration compared to the real square cell segmentation. The scintillator strips are read out by SiPMs.

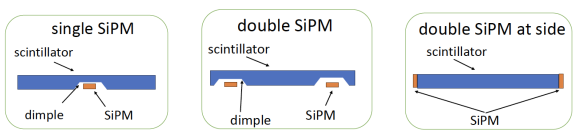
2.2 Prototypes of scintillator strip

We produced prototype detectors with different scintillator materials and SiPM readout schemes.
Two types of the scintillator materials are used: ELJEN's EJ200 [5] and EJ232 [6]. Table 1 shows the properties of the two types of the scintillation materials. EJ200 is a scintillator of standard type and EJ232 is a fast type. EJ200 has a higher light yield and longer attenuation length than EJ232.
The dimensions of the strip are 300mm × 30mm × ^{t}3mm. The strip is wrapped with a reflective film (3M ESR). The scintillation light is read tout by SiPM (Hamamatsu MPPC S13360-2050VE).

Table 1. Properties of scintillator materials

	EJ200	EJ232
light yield[photons/1MeV]	10,000	8,400
attenuation length[cm]	380	17
rise time[ns]	0.9	0.35

Three SiPM readout schemes were tested (Figure1).



(a) (b) (c)

Figure 1. SiPM readout schemes tested in the prototypes

There are dimples in (a) and (b). The shape of dimple is like a cone cut in the middle(Figure2).

*e-mail: hogawa@icepp.s.u-tokyo.ac.jp

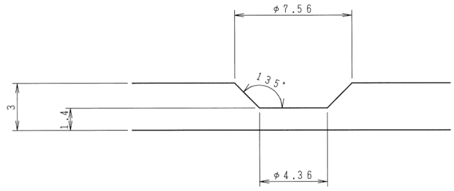


Figure 2. The shape of dimple

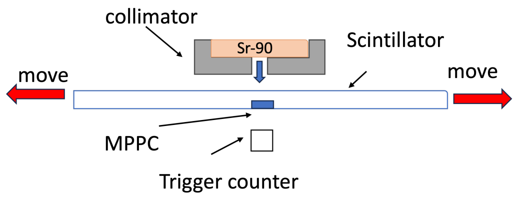


Figure 3. Setup for the performance measurements

Single SiPM (Figure1(a)) :
The strip is readout by a SiPM ihoused in a dimple (Figure2) at the center of the strip.
This can be a minimal design with a minimum number of sensors.

Double SiPMs (Figure1(b)):
The strip is read out by two SiPMs in two dimples at strip ends. The dimple is located from 15mm from each strip edge. This design is that higher light yield is expected and the hit position can be reconstructed using the charge ratio and the time difference between the two SiPMs.

Double side-SiPM (Figure1(C)):
Two SiPMs are attached to both sides of the strip. The possible advantage of the design is a better time resolution.

2.3 Performance measurements

The setup for the performance measurements is shown in Figure3. The origin is center of the scintillator, the longitudinal direction is the Y-axis and the direction of the minor axis is the X-axis. The light yield was measured on different positions on the strip at 10mm intervals. The strip on a X-Y stage was moved in the Y-axis from -140mm to 140mm, in the X-axis from -10mm to 10mm (Figure4).

2.4 Result and discussion

Figure 5 shows the measured light yields. The single SiPM readout with EJ-200(Figure 5(a)) shows a sufficient light yield above 20 p.e., which is comparable to the one obtained by the previous study in the CALICE-AHCAL [7]. On the other hand, the light yield for the single SiPM readout with EJ232(Figure 5(b)) shows much lower light yield than expected from the catalogue value (Table1). This is not understood yet. Except around the SiPM position, a reasonably good uniformity is obtained over the strip length.
The double SiPM readout with EJ-200 (Figure 5(c)) shows even higher light yiled and more uniform response for the sum of the light yields of the two SiPMs. The uniformy is even better for the geometric mean which compensates the effect of the attenuation. There is an asymmetry between the left and right SiPMs, which is under investigation. The

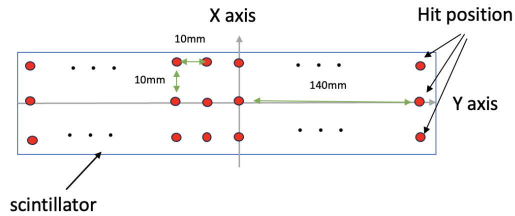


Figure 4. The positions where the light yield was measured on the scintillator strip

position dependence is larger for the double SiPM readout with EJ-232 (Figure 5(d)) due to the shorter attenuation length of the EJ-232.
The double side SiPM with EJ-200 shows even higher light yield and better uniformity, although there are blind spots at the corner of the strip where the light yield is lower.

3 Summary and prospect

We are developing a new calorimeter technology where dual-readout calorimeter, high-granularity calorimeter, and excellent timing resolution are combined. A strip-based scintillation detector is being developed for the new calorimeter. The performance of the scintilltor strip was measured for different strip designs. We found that the strip with the standard scintillator material (EJ-200) shows a good performance such as sufficient light yield and uniform response. The permanence is expected to be improved by further design optimization. The peaky response near the SiPM can be mitigated by optimizing the dimple shape. The possibility of the hit position reconstruction will also be studied.

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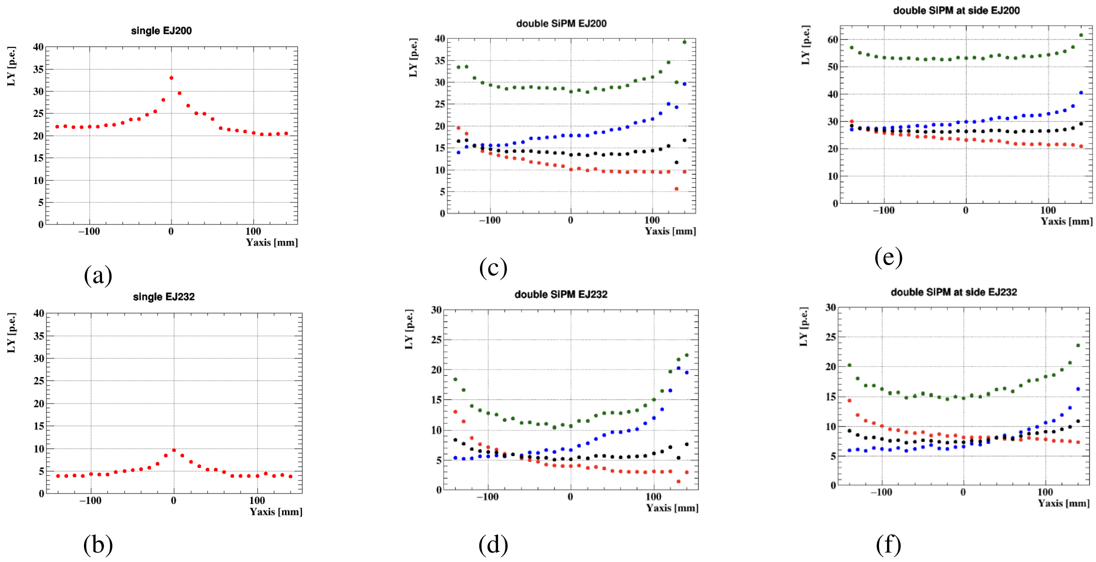

Figure 5. Measured light yields for (a) Single SiPM(EJ200), (b) Single SiPM(EJ232), (c) Double SiPMs(EJ200), (d) Double SiPMs(EJ232), (e) Double SiPMs at side(EJ200), (f) Double SiPMs at side (EJ232). The light yield measured by each of the left (red) and right (blue), the sum (green), and the geometric mean of the light yields at two SiPMs(black) are shown.

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