Development of Versatile Calibration Method for Electro-Magnetic Calorimeters using a stopped Cosmic-ray beam

H. Ito[1], K. Horie[2], H. Kawai[1], S. Kodama[1], S. Shimizu[2] for the J-PARC TREK collaboration

[1]Graduate School of Science, Chiba University, 1-33, Yayoicho, Inage, Chiba, Japan

[2]Graduate School of Science, Osaka University, 1-1, Machikaneyamacho, Toyonaka, Osaka, Japan

abstract

A new method using a stopped Cosmic-ray beam for a calibration of an electro-magnetic calorimeter which consists of several hundreds of modules has been established. Cosmic muons stop in the calorimeter, and positrons (and electrons) from the muon decays with the maximum energy of 53 MeV are used for the energy calibration. These events could be identified as double pulses observed by a flash ADC. It has some advantages, (1) intermediate energy scale (<53 MeV) to interpolate a few MeV by radioactive sources and 153 MeV of the muon from $K^+ \to \mu^+\nu_\mu$, (2) efficient procedure to calibrate all modules at the same time and (3) versatile method applied for many types of electro-magnetic calorimeters. Then, this method was checked in the J-PARC E36 experiment which was performed to precisely measure the ratio of $\Gamma(\mathrm{K}^+ \to \mathrm{e}^+\nu_\mathrm{e})/\Gamma(\mathrm{K}^+ \to \mu^+\nu_\mu)$. Double pulses from the CsI(Tl) photon detector were successfully observed and the waveform function was carefully studied to decompose the second pulse generated by the decay positron. In this talk, (1) mechanism of this calibration procedure, (2) experimental method using Cosmic rays, (3) development of the waveform function to fit the flash ADC data, (4) experimental results and (5) confirmation of the new calibration method, will be presented.

1. Introduction

In nuclear and particle physics, conventional energy calibration methods using a radioactive source of ^{60}Co (1.1 or 1.3 MeV) and deposit energy of Cosmic rays [1] have been well known. Here we would like to propose a versatile calibration method for an electro-magnetic calorimeter using a stopped Cosmic-ray beam. Instead of normal usage of Cosmic muons, they are stopped in the calorimeter and positrons (and electrons) from the muon decays ($\mu^+ \to e^+\,\nu_e\,\overline{\nu_\mu}$) with the maximum energy of 53 MeV [2] are used for the energy calibration. It has some advantages, (1) intermediate energy scale (<53 MeV) to interpolate a few MeV by radioactive sources and 153 MeV of the muon from $K^+ \to \mu^+\nu_\mu$ ($K_{\mu 2}$), (2) efficient procedure to calibrate all modules at the same time and (3) versatile method applied in many types of electro-magnetic calorimeters. This paper presents a mechanism of the new method and confirmation based on the experimental data.

2. Results obtained in the J-PARC E36 experiment

In order to verify the validity of the above calibration procedure, the test experiment to calibrate the CsI(Tl) photon detector used in the J-PARC E36 experiment [3] was performed. The E36 experiment was performed to precisely measure the ratio of $\Gamma(\mathrm{K}^+ \to \mathrm{e}^+\nu_\mathrm{e})/\Gamma(\mathrm{K}^+ \to \mu^+\nu_\mu)$, and the CsI(Tl) calorimeter was introduced for the radiative decay measurement such as $\mathrm{K}^+ \to \mathrm{e}^+\nu_\mathrm{e}\gamma$ and $\mathrm{K}^+ \to \mu^+\nu_\mu\gamma$. The calorimeter has a barrel-shape structure and consists of 768 modules of CsI(Tl) crystal with PIN diode readout [4, 5]. Signals form the Cosmic rays were recorded by a flash ADC (25 MHz and $10\ \mu\mathrm{s}$ time range) [6] and the energy information was obtained by analyzing the pulse waveform.

(a) Waveform Function

In the analysis, the specific waveform model function has been developed to decompose the pulses generated from Cosmic muons and positrons from the muon decay. The model function was successfully studied using single pulse event samples (red line in Fig. 1 (left)) and considered to have good performance for the positron identification, since the residual differences from the flash ADC data for amplitude, integration and peak time were achieved to be 0.45%, 0.095% and 2.0%, respectively. Then, events with double pulses were selected, and the double-pulse waveform was here introduced. Fig. 1 (right) shows the waveform data (black dots) and the typical fitting result, where blue, green and red lines correspond to muon, positron and total signals, respectively.

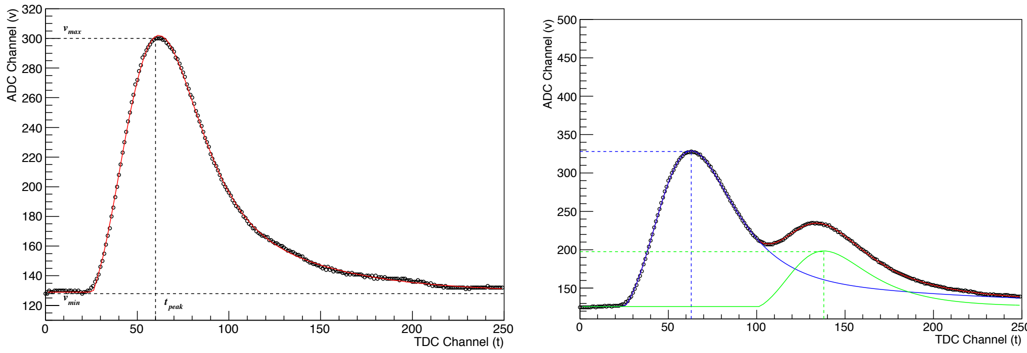

Fig. 1. Typical waveform of a single pulse (left) and a double pulse (right). The black dots denote the data by flash ADC. The typical fitting result of blue, green and red lines correspond to muon, positron and total signals, respectively.

(b) Results

The positron energy spectrum is shown in Fig. 2 (left). The endpoint of 53 MeV is consistent with the gain coefficient determined using the monochromatic muons from the $K_{\mu2}$ decays. The time difference between the two pulses is also shown in Fig. 2(right) which has an exponential function structure with the mean life time of 2.0 ± 0.3 μs. For the reliable event selection, the time difference was imposed to be larger than 4 μs.

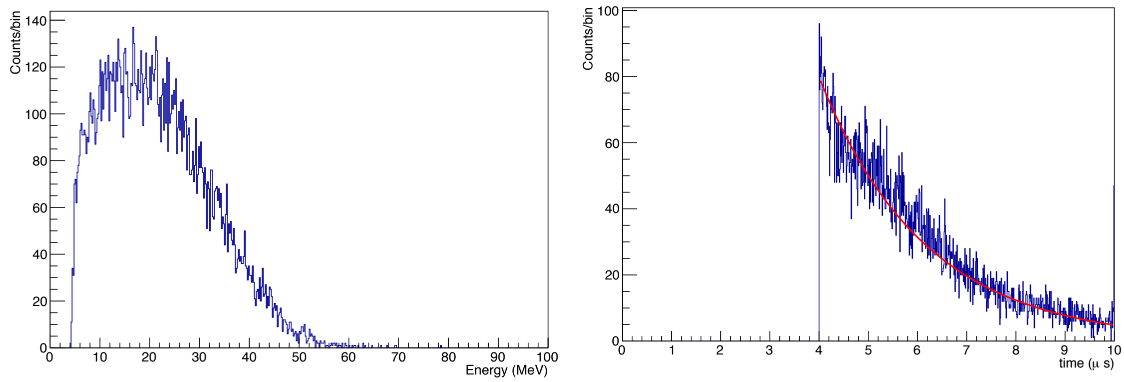

Fig. 2. The second pulse height distribution (left) and the time difference distribution (right).

Conclusion

We have proposed a new and versatile calibration method using a stopped Cosmic-ray beam for various electromagnetic calorimeters. This method was confirmed using the CsI(Tl) photon detector used in the J-PARC E36 experiment. The specific waveform model function has been developed to decompose the pulses generated from Cosmic muons and positrons from the muon decay. The endpoint of the observed positron energy spectrum was consistent with the calibration results obtained by using the $K_{\mu2}$ events.

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