Total Measurement Calorimeter TMC

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Abstract. A new type of total absorbing calorimeter with active absorber is investigated . Some initial results are presented and further activities are also discussed to archive TMC.

1. Introduction

The total absorption calorimeter had been constructed and played relevant role in many high energy experiments for the electro-magnetic calorimeter (ECA). However, at higher energy experiments, the crucial physics will be derived by measuring the energy of jets, where those jets are the final states of heavy relevant particles, such as Higgs, W/Z, and top quarks. The jet energy measurement is dominated by the energy measurement of hadrons in jets.

There are two ideas to resolve the jet measurement. One is called the PFA approach, which is divided into sum of three measurements, say, track momentum, photon energy, and neutral hadron energy[1]. The other one is so called dual read out solution. There are several approaches to achieve the dual read out system to have energy measurement in two ways [2]. This work is classified into the dual read out approach.

In the context of the dual read out scheme, two kinds of non-independent measurement are extracted from the calorimeter. They are charged hadron interactions and neutral pion EM shower. Moreover we add here additional factor of the total measurement in the absorber in this work.

In the sandwich calorimeter detector, usually we lose information from the absorber, However, we introduce an active absorber system which leads to a total measurement calorimeter with longitudinal shower profile, since the calorimeter composed of sandwich type. A sort of information from the absorber energy measurement reflects a specific part the hadron interactions. The hadrons drop energy in the absorber material through hadronic interaction, which mostly create charged and neutral pions. The charged hadrons lose their energies by electro-magnetic (EM) interaction with the electrons though their tracks. However, the neutral pions decay in short time and generate two photons, which emerge as the EM showers.   This shower is easily detected and measured in the heavy transparent absorber such as lead glass, by producing Cherenkov lights.

2. Hadron interaction and the calorimeter

The hadron interaction consists of mainly the strong interaction as well as the electromagnetic interaction. The strong interaction, furthermore, include the nuclear breakup or nuclear fusion. This makes the hadron interactions to be complicated phenomena. The calorimeter construction is difficult due to those facts, as well. Furthermore, those ejected neutrons from the nuclear interactions, will be detected as a scattered protons after some time in widely spread out areas.

2.1. Hadron energy measurement

Jet final states should be identified and measured to determine the physics interaction process, therefore measurement of the jet energy plays a crucial role on the physics analysis. The jets are composed of mostly hadrons at the fragmentation level, then the neutral pions decay into two photons immediately. Thus a jet is detected as a group of charged hadrons and photons. A common idea to

measure the jet energy effectively is to equip two calorimeters to fit the photon and hadron energy measurement. They are called the electromagnetic calorimeter (ECAL) and the hadronic calorimeter (HCAL) , being optimize the absorber and active material for both interactions.

In some ECAL, total absorption electromagnetic calorimeter which composed of the lead glass and photo-sensor only has been constructed and employed widely. The electromagnetic (EM) shower is detected and measured by the Cherenkov lights. The total absorption calorimeter, generally speaking, has a good energy resolution, since total EM-shower track length is affecting for the measurement of the EM shower energy [3].

On the other hand the hadron energy measurement has a relatively poor resolution, because of shorter track length of charged hadrons passing through the HCAL Furthermore the production of neutral pions generates EM showers in the hadronic shower. The contribution in the hadronic energy measurement of the neutral pions is sometimes dominating, because the energy deposit of the EM shower is much bigger than that of charged hadron passing. The fluctuation of the production of the neutral pions makes the hadron energy resolution poor.
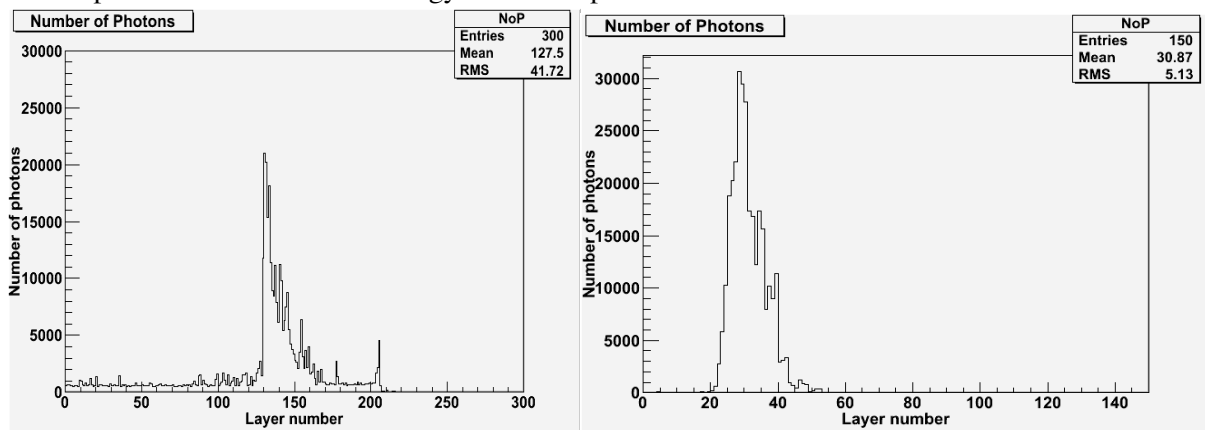

Figure1. (left) A simulated 20GeV char4ged pion interactions in the fine segmented HCAL in the longitudinal direction. A energy peak around 130th layer is thought to be a production of a neutral pion.

Figure2. (right) A simulated 5GeV neutral pion at 20th layer. The pulse hight profile in the longitudinal direction looks similar to the figure1.

By introducing the fine segmentation in the longitudinal direction of the HCAL, we are able to find the neutral pion production event by event basis. An example event, which contains a clear production of neutral pion is shown in figure 1 in a simulation of a 20 GeV pion shower. In figure 1 right, we add and a 5GeV neutral pion generated at 20th layer. One can find the sequential large pulse height in successive layers in the longitudinal segmentation.

2-2 Total energy measurement

In order to improve the hadron energy measurement, avoiding the big fluctuation due to the EM shower production is apparent. Thus we need to identification and precise measurement of the neutral pions. To achieve this, we introduce active absorber which is made of such as lead glass or other transparent , high Z , heavy material by detecting the Cherenkov light. Those heavy material is used as an absorber of the charged hadrons, as well.

The figure 3 shows an idea of such detector with fine longitudinal segmentation. In this scheme, lead glass block is employed for the absorber and active Cherenkov radiator with a small photo-sensor. For the charged energy measurement, as usual hadron calorimeter, we set scintillator layers. This scintillator will work as a neutron radiator as well, so as to detect really the total energy measurement in the hadronic interaction.

Since this detector works as a combination of ECAL and HCAL, we need to test the performance in electrons and pions. In figure 4, a scatter plot of simulated 1GeV electron are shown. The total number of photons generated in the lead glass absorbers and that of scintillators are scatter-plotted. A clear anti-correlation is visible, in addition to showing better energy resolution in the Cherenkov light detection. The end point of the anti-correlation plot at lowest energy corresponds to the initial energy ; 1 GeV, in this case.
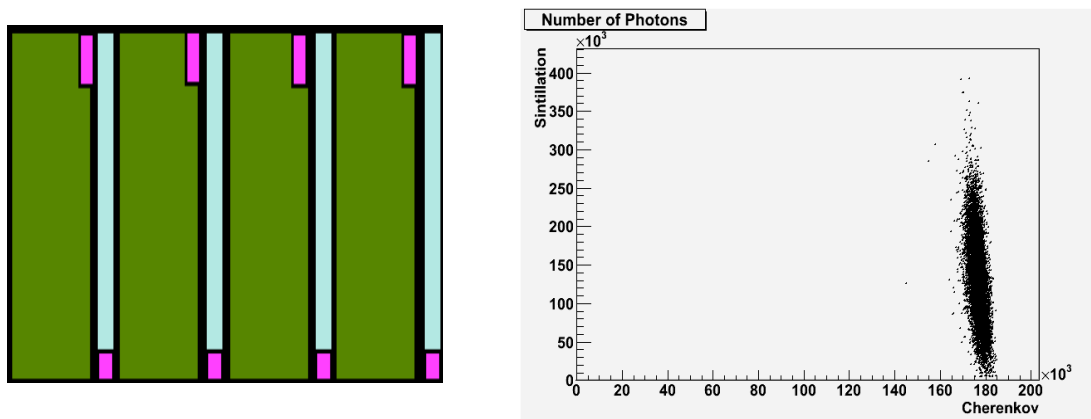
Figure 3 (left) An example TMC detector, which composed of a sandwich calorimeter with the lead glass (in green) and the scintillator (in light blue). The small blocks (in pink) indicate the photo-sensors for Cherenkov and scintillation lights.

Figure 4 (right) A simulated scatter plot with number of Cherenkov photon vs number of scintillator photons.
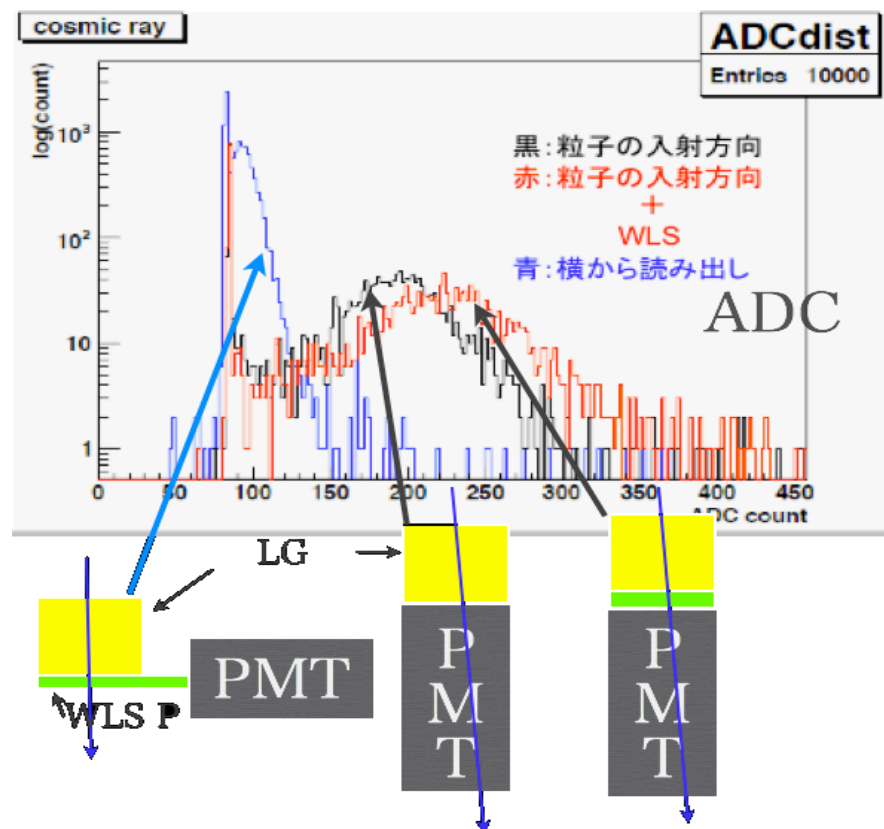

Figure 5; ADC distribution of cosmic muons, the blue line indicates with using a wave length shifting plate (WLSFP) , the black with direction connection and the red with a WLSP on the PMT between the lead glass.

3．Cherenkov measurement

   With using a lead glass block of 60mm long, we detected the cosmic ray muons under different photo-coupling to a photo-multiplier. It is shown in figure 5.

   Although the accumulation of Cherekov light is not sufficient, further trial will be carried out, soon. However, if we give up to detect MIP particles, such as muons, the EM shower detection is quite easier. We have carried out a test beam experiment with 3GeV electrons. There we found a much

bigger number of Cherenkov light by passing the electron shower, even in a slice of a EM shower. At this test experiment, we used the same thickness of 5cm for the lead glass blocks. On the other hand the calibration scheme must be resolved by other than high energy muons.
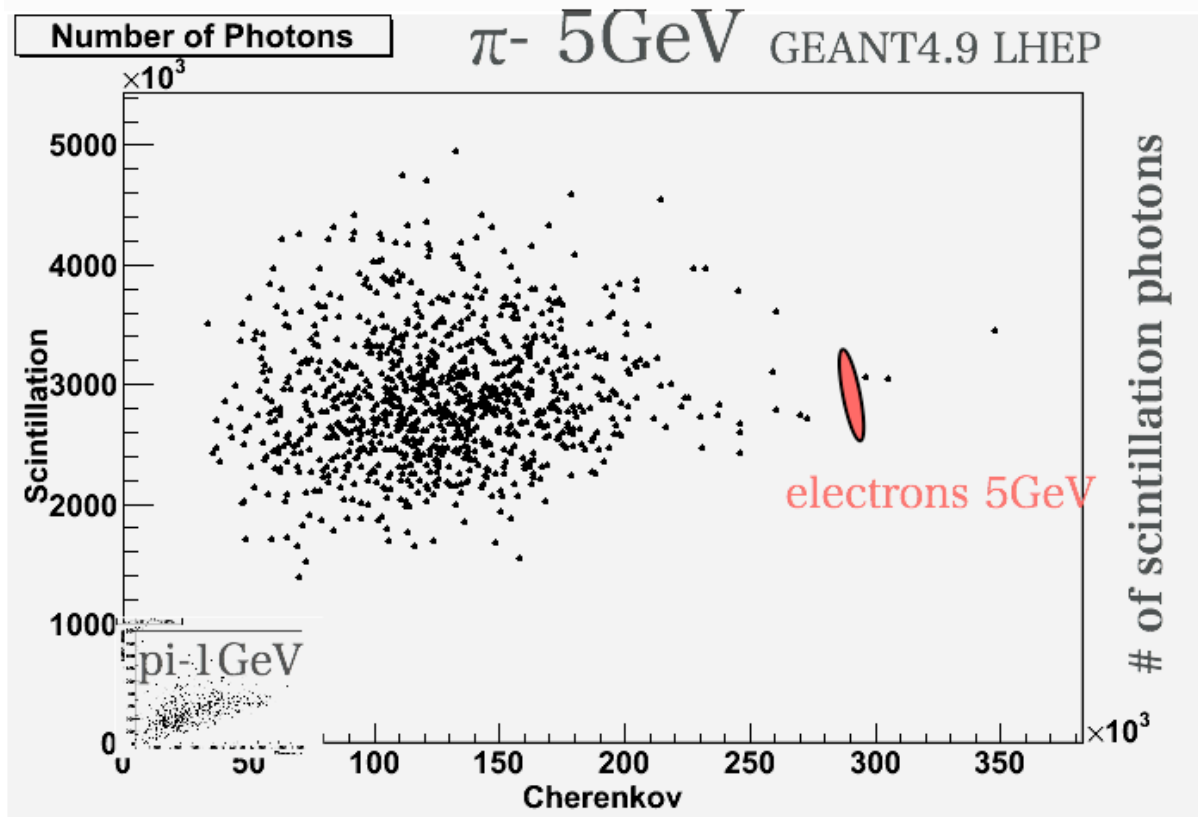

Figure 6; A simulated results of 5GeV charged pions in scattered plot. The red area is corresponding area for the 5 GeV electrons. A clear separation is seen. More over, 1GeV pions are added with the same scale in it.

4 Hadron measurement in the TMC

Hadron response is simulated with 5 GeV charged pions. The electron signal area is added by hand in the same energy with red. The same energy electrons and charged pions are clearly separated in the plot, once we measure Chrenkov and scintillator signal simultaneously in a event. The figure 6 shows also contribution from the charged pions of 1 GeV at the bottom end of the smallest region in the plot. This indicates separation between 5 GeV and 1 GeV pions is easily done in the TMC.

5 Summary

An idea of Total Measurement Calorimeter (TMC) is described. Fine segmented HCAL will give us active neutral pion generation in the hadronic interactions. To detect neutral pions effectively, active absorber with lead glass system is introduced, tested and simulated. The initial trials look fine and promising for the bigger and deeper calorimeter test.

References
[1] Performance of the ALEPH detector at LEP. ALEPH collaboration, Nucl. Inst. and Meth. A360 (1995) 481.
[2] Hadron and jet detection with a dual-readout calorimeter. N. Akchurin et al. Nucl. Inst. and Meth. A 537 (2005) 537
[3] The OPAL detector at LEP. OPAL collaboration, Nucl. Inst. and Meth. A305 (1991) 275-319.