

The Tail-Catcher/Muon Tracker for the CALICE Test Beam

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We summarize the design, construction, and testing of the “tail-catcher/muon tracker”, or “TCMT”, section of the CALICE collaboration’s calorimeter module prototype, which is scheduled for beam tests during 2006-2009.

1. INTRODUCTION

The CALICE (CAlorimeter for the Linear Collider with Electrons) collaboration [1] plans to examine several technology and geometry options for electromagnetic and hadronic calorimetry at the proposed International Linear Collider. Since in many geometries the total material thickness of the calorimeter is too little to fully contain highly energetic hadronic showers, it is important to gain a good understanding of how to estimate the leakage. In real life, the substantial amount of uninstrumented material in the magnet enveloping the barrel calorimeter will prevent a direct measurement of the energy punching through the calorimeter. The NIU group is responsible for building a detector subsystem consisting of alternating layers of scintillator strips and steel plates to serve the dual purpose of measuring the tail of showers escaping the hadronic calorimeter module, as well as supplement the muon-tracking capability. This section of the detector, dubbed the “tail-catcher/muon tracker”, or “TCMT”, is rapidly approaching completion. The project involved specification of performance criteria, careful evaluation of available options including emerging technologies, testing of individual components, as well as considerations of costs and other constraints. These are described briefly in the following sections.

2. MOTIVATION

Figure 1 shows how the energy resolution depends on the estimation of the leakage past the ECal and HCal for a range of single pion energies. The study is based on GEANT4 simulation of the detector. Although not an exact model of the full detector or the test beam module, it demonstrates clearly the importance of studying the energy leakage. Figure 2 shows a GEANT4 simulation of a 50 GeV single pion interacting in the CALICE test beam module. Most of the energy is deposited in the latter part of the HCal (middle), and almost the entire remainder in the TCMT (right).

The primary goal of the TCMT is to provide a reasonable snapshot of the tail-end of showers for simulation validation at the test beams. Thus, it will allow us to compensate for the leaked energy and understand the pattern of energy deposited in the coil. The TCMT also serves as a prototype detector for a generic LCD muon system. In this role it can be useful in developing muon reconstruction and identification algorithms and in estimating the fake rates.

3. THE TCMT DESIGN

The TCMT measures $109\text{ cm} \times 109\text{ cm}$ perpendicular to the beam and 142 cm along, and weighs nearly 10 tons. It consists of a “fine” and a “coarse” section. Each section has 8 layers of scintillating strips interspersed with steel absorbers. The absorber plates are 2 cm thick in the “fine” section and 10 cm in the “coarse”. Figure 3 shows a

Single particle E Resolution

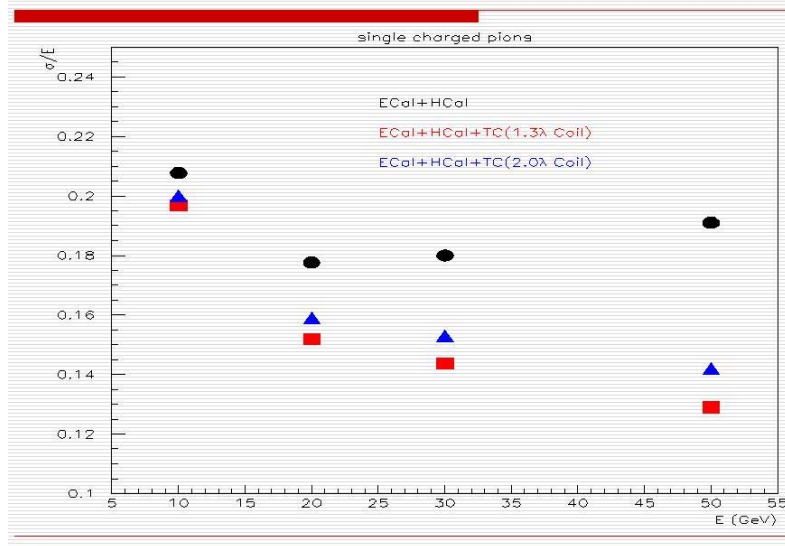


Figure 1: Single π^+ energy resolution with and without the tailcatcher behind an ECal and HCal of combined thickness 4.2λ and the central magnet coil: no tailcatcher (circles), tailcatcher behind a 2.0λ thick coil (squares), and tailcatcher behind a 1.3λ thick coil (triangles).

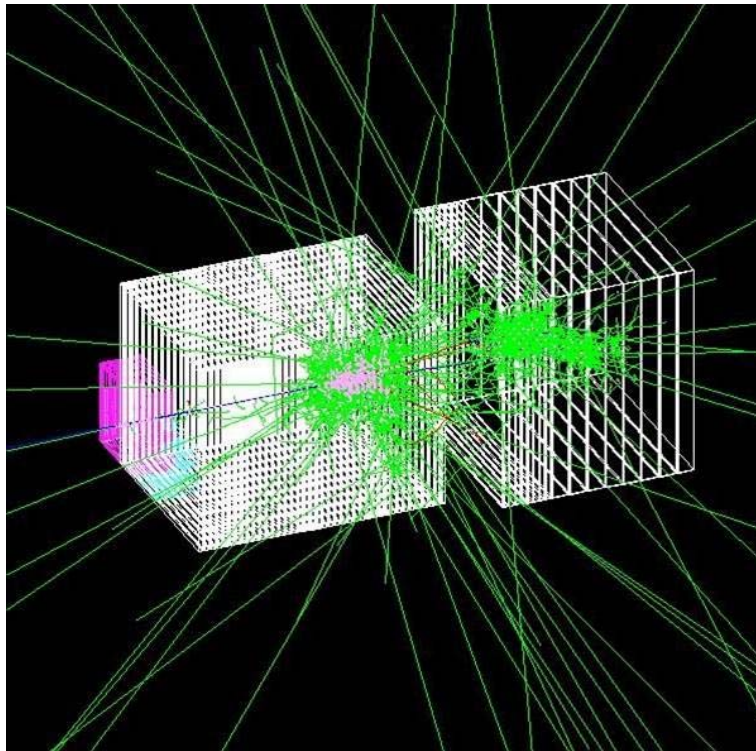


Figure 2: Simulation of a 50 GeV π^+ interacting in the CALICE test beam module.

drawing of the TCMT mounted at the test beam facility. The active layers of the TCMT are made of 5 cm wide, 0.5 cm thick plastic scintillators strips produced at the NICADD/FERMILAB extrusion facility [2] and read out with 1.2 mm diameter Kuraray Y11 wavelength shifting fibers embedded in a coextruded hole along the length of each strip. The photons from the fiber are detected using pixelated silicon photodetectors called “SiPM”s. Each pixel is essentially an Avalanche Photo-Diode (APD) operated in the limited Geiger mode with a step-function response to photons. However, because of the large number of pixels ($O(1000)$), typically, the number of pixels registering hits is, on average, proportional to the energy deposited by up to 30 minimum ionizing particles traversing the 5 mm

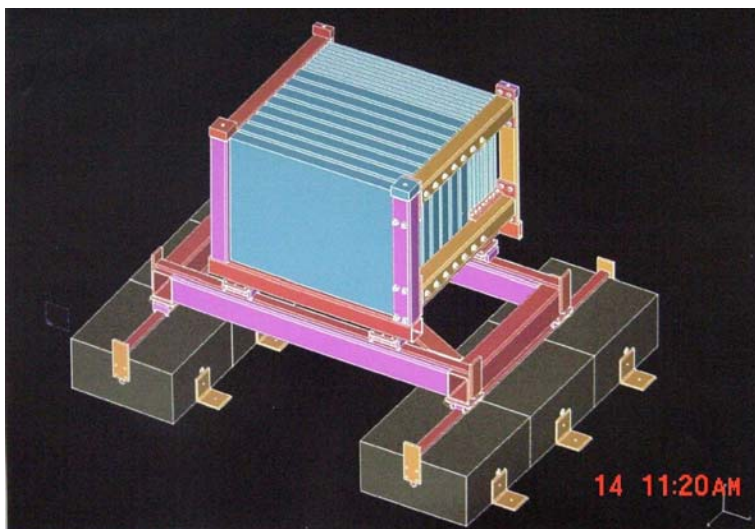


Figure 3: The Tail-Catcher/Muon-Tracker for the CALICE test beam module.



Figure 4: A pair of extruded scintillator strips for the TCMT.

thickness of the strip. We have carried out detailed studies of the characteristics of these devices [3]. Each strip is wrapped with Tyvek paper and VM2000. Strips in alternate layers are oriented normal to each other. The readout electronics is common with the HCal [4].

4. CONSTRUCTION, TESTING, AND CALIBRATION

The strips are produced in pairs from a 10 cm wide extruded strip cut in two. In each half is a coextruded hole to hold the fiber running along the length of the strip, as shown in Fig.4. Each strip has been calibrated against standard reference cells by placing a Sr-90 radioactive source at a number of predetermined positions on its surface and measuring the response with a PMT. The details of this procedure can be found in Ref. [2].

The extruded scintillator has many advantages. Our studies under the FNAL-NICADD Extruded Scintillator Project [5] over the past 3 years confirm that

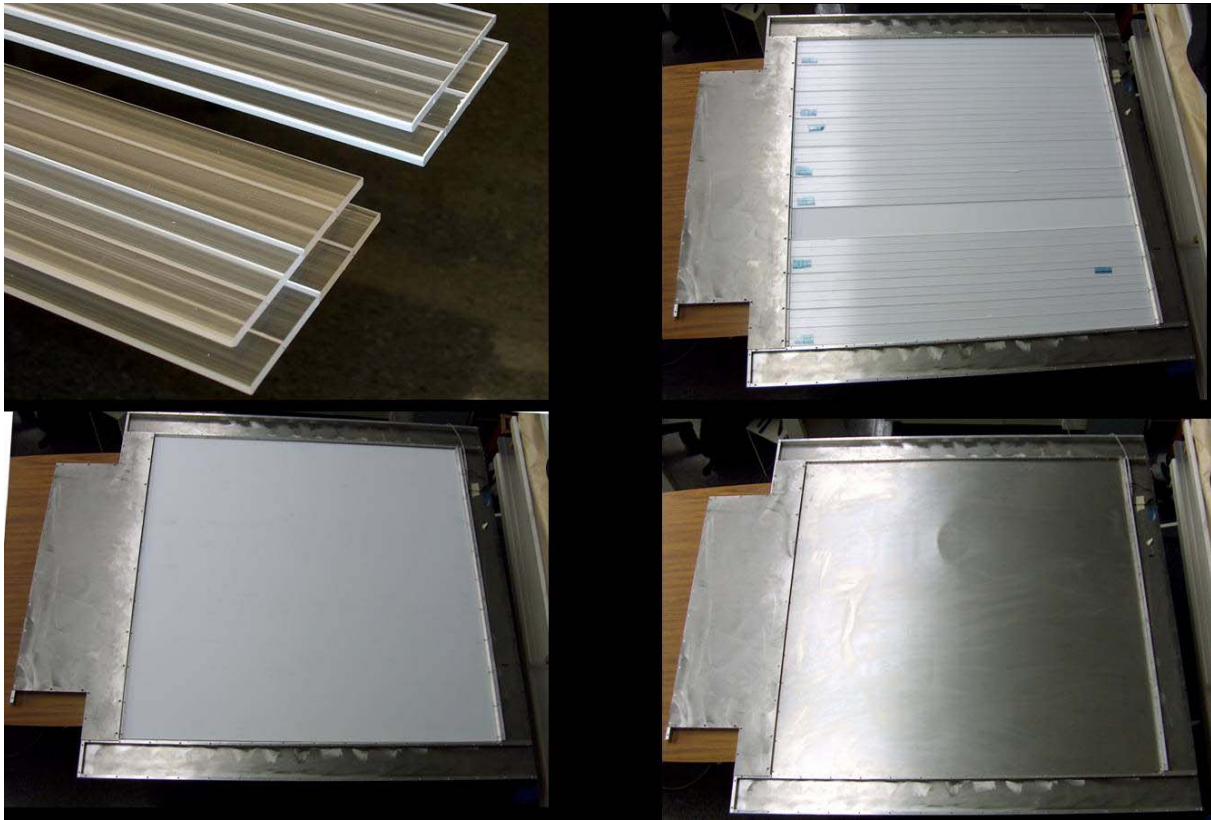


Figure 5: Scintillator strips are laid side-by-side in a cassette frame.

- the significant savings in cost compared to commercially available cast scintillator does not compromise performance,
- the response and clarity are adequate that they do not limit segmentation,
- uniformity is excellent in both spatial geometry and response.

The strips are laid side-by-side in a “cassette” frame, which can slide in the gap between the fixed absorber plates. Some stages of the cassette assembly are shown in Fig. 5, while Fig. 6 shows a SiPM with its holder, which is mounted on the frame on the side where the wavelength-shifting fibers emerge from the scintillator strips.

For real-time calibration, a LED with an independent driver is embedded in each strip. The driver design and readout schema are going through prototyping and iterations.

5. SUMMARY AND PLANS

Quality certification has been completed for all the strips and WLS fibers, assembly of the full cassettes is progressing well. The absorber plates have been cut. The timescale for full-chain commissioning followed by extensive calibration and collection of cosmic ray data with all cassettes in place will be determined by the availability of the full number of SiPMs - probably by early 2006.

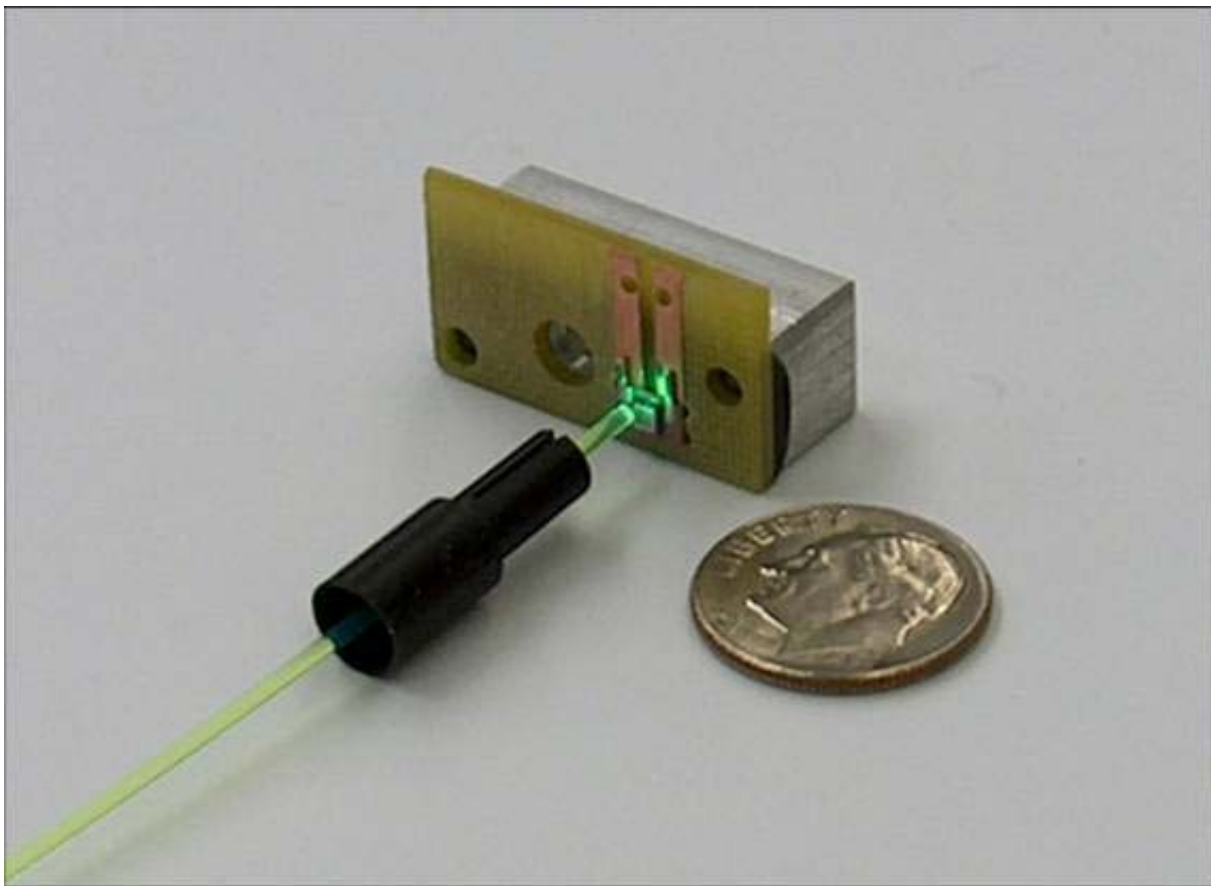


Figure 6: A WLS fiber shining green light on the 1 mm×1 mm SiPM with ~ 1000 pixels.

Acknowledgments

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References

- [1] <http://polywww.in2p3.fr/tesla/calice.html>
- [2] Talk by A. Dychkant, this workshop.
- [3] D. Bezhnosko et al, NIM A vol. 545, issue 3 (2005) p 727-737. Also, talk by G. Blazey, this workshop, and by D. Chakraborty at the 4th International Conference on New Developments in Photodetection, Beaune, France, 19-24 June, 2005 (<http://beaune.in2p3.fr/>)
- [4] Talk by F. Sefkow, this workshop.
- [5] <http://nicadd.niu.edu/> → Research Projects → FNAL-NICADD Extruded Scintillator Project (FNESP)