Engineering Prototypes for the CALICE Hadron Calorimeters

Angela Lucaci-Timoce[1]

[1]DESY, Notketraße 85, 22607 Hamburg, Germany

The engineering prototypes of the hadron calorimeters proposed by the CALICE collaboration as a solution for the physics requirements of the International Linear Collider (ILC) are presented. Two different technologies are currently under study: an analog hadronic calorimeter, based on scintillating tiles that are read out by silicon photo-multipliers (SiPMs), and a digital hadronic calorimeter, using gaseous detectors.

1 Introduction

The International Linear Collider [1] is a planned electron-positron collider, that will reach energies of up to 1 GeV, and which will perform precision measurements complementary to the Large Hadron Collider program. The goal for the jet energy resolution at ILC is to cleanly separate W and Z decays. The most promising approach to achieve this is considered to be the particle flow algorithm (PFA), that requires the reconstruction of all visible particles in an event, and imposes stringent requirements on the granularity of the ILC calorimeters.

Below, the work of the CALICE collaboration [2] towards a realistic mechanical structure and calibration concept of the hadron calorimeter prototypes for the ILC is presented. The hadron calorimeter (HCAL) consists of 48 layers in a cylindrical structure with an inner radius o 2.0 m, and an outer radius of 3.1 m, respectively, surrounded by a magnet. Inside the HCAL, the electromagnetic calorimeter will be placed. The front-end electronics has to be highly integrated. In section 2, the mechanical integration and the calibration procedure of the Analogue Hadron Calorimeter (AHCAL) are presented. In section 3, the options for the digital hadron calorimeter are shortly described.

2 The Analogue Hadron Calorimeter

A possible analogue realization of the hadron calorimeter for the ILC is using 3×3 cm^2 scintillator tiles, which are readout by novel silicon photomultipliers. The circular structure of the AHCAL will be divided into 16 sectors, one of which is shown in Fig. 1, with one detector layer. Each layer contains the scintillating tiles, the front-end electronics which is integrated into the absorber structure, and a 2 cm thick stainless stell absorber plate, such that the typical size of a sector's layer is 1×2.2 cm^2.

All electronics connections and interfaces can be placed at the two end-faces, which are thus easy to access for maintenance and service lines. In order to keep the single modules at reasonable size, the detector's electronics is divided into basic units (HCAL base unit: HBU), each with a typical size of 36×36 cm^2, integrating 144 tiles, together with the corresponding

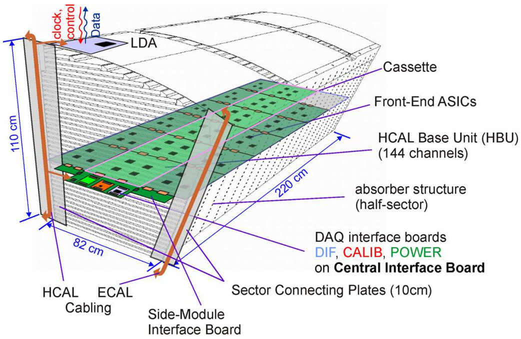

Figure 1: Structure of 1/16th part of the AHCAL's barrel, with only one detector layer shown. The electronics is integrated into the absorber structure.

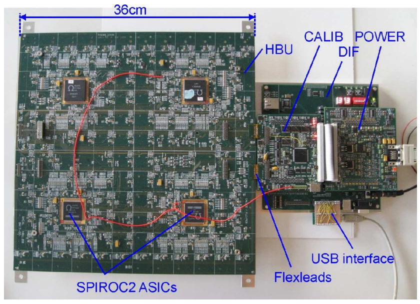

Figure 2: Top view of the HCAL Base Unit (left) connected to the data acquisitions modules (right). The scintillation tiles with SiPMs are assembled on the HBU back-side.

SiPMs, front-end electronics and the light calibration system. The analogue signals of the SiPMs are read out by 4 front-end ASICs of type SPIROC, developed by LAL/Omega.

The first prototype module with 144 detector channels connected to a preliminary data acquisition system has been realised within the EUDET framework (see Fig. 2). The interface to a Labview user PC is done via an USB module. The first results (see Fig. 3) indicate that the full operation chain of the system (including data taking with internal or external trigger, data read out, light calibration and preliminary data acquisition) has been established. More details can be found in [3]. The SiPMs response varies strongly with temperature and voltage:

$$\frac{dG}{dT} = \frac{-1.7\,\%}{K} \quad \text{and} \quad \frac{dG}{dV} = \frac{2.5\,\%}{100\text{ mV}}, \tag{1}$$

therefore a gain calibration and monitoring system is needed. The calibration system offers several functionalities: at low light, the SiPMs show single photon peaks, and the distance between the peaks is a measure for the SiPM gain; at high light, the SiPM shows saturation behaviour, and the SiPM response function can be checked. For the calibration system, two concepts are currently under investigation: the first one, using one LED per tile (integrated into the detector gap), and a second one, developed by ASCR Prague, with strong LEDs outside the detector, which distribute the light via cleaved fibers [4]. For the first concept, an LED testboard has been realized, with ultraviolet LEDs mounted up-side down, and is being investigated at the University of Wuppertal.

In order to test the mechanical stability, tolerances and deformations, a real size prototype of $1/16^{\text{th}}$ of an HCAL barrel structure was build at DESY Hamburg (see Fig. 4). The module consists of stainless steel plates of 16 mm thickness, which are supported only by 5 mm thick side pannels. Flatness measurements of the steel plate indicated deviations up to 8 mm. After roller leveling of the plate, the deviation reduced to less than 1 mm.

3 Digital Hadron Calorimeter

The high granularity of the ILC calorimeters required in the particle flow approach implies readout of a high number of channels, which is in general impractical. Monte Carlo simulations

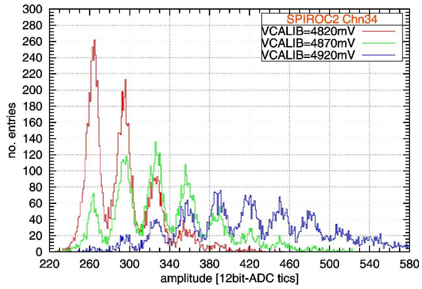

Figure 3: Single photon spectrum of a SiPM for three LED light intensities (VCALIB settings).

Figure 4: The vertical mechanical structure for the technical HCAL prototype.

have shown that it is possible to preserve the energy resolution of single hadronic particles using a simple discriminator with only one threshold. This lead to the idea of developing digital hadron calorimeters (DHCALs), with 1 bit per pad, and so-called semi-digital hadron calorimeters, with 2-3 bits per pad. The latter allows to distinguish between the simple case with one particle going through one pad of the detector, and the cases where several particles traverse the detector pad (important at high energies). The digital calorimeters are based on gaseous active layers with 1×1 cm^2 pad readout, and iron as absorber material. The CALICE DHCAL group investigates three different active media: rezistive plate chambers (RPCs) [5], gas electron multipliers (GEMs) and micromegas. In addition, two readout schemes, one based on the DCAL chip (developed by Argonne and Fermilab), and another one based on the HARDROC chip (developed by the French groups of LAL, LLR and IPNL) are developed.

4 Conclusions

The mechanical and electrical integrations of the hadron calorimeters for the ILC, proposed by the CALICE collaboration, have been presented. For the tile hadron calorimeter, mechanical tests of a real size module have been done. The various efforts provided valuable experience towards building an optimal calorimeter for the ILC environment.

References

[1] http://www.linearcollider.org/cms/

[2] https://twiki.cern.ch/twiki/bin/view/CALICE/CaliceCollaboration

[3] P. Goettlicher, *First Results of the Engineering Prototype of the CALICE Tile Hadron Calorimeter*, proceedings of the 2009 IEEE NSS conference

[4] Ivo Polak, *Calibration System of CALICE AHCAL Detector*, ALCPG 2009, Albuquerque, 29th Sept-3rd Oct 2009

[5] B. Bilki et al., *Hadron Showers in a Digital Hadron Calorimeter*, JINST **4**, P10008 (2009) [arXiv:0908.4236 [physics.ins-det]].