Integration Prototype of the CALICE Tile Hadron Calorimeter for the International Linear Collider

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1 Introduction

A new prototype of a tile hadron calorimeter (HCAL) for the International Linear Collider (ILC) detector is currently developed within the CALICE collaboration. The aim is to improve the energy resolution by measuring details of the shower development (particle flow). The prototype is based on scintillating tiles that are read out by novel Multi-Pixel Geiger-Mode Photo Diodes (MGPDs). The concept is based on the experience with a 7608-channels physics-prototype that has been extensively tested at the H6 beam line of CERN SPS in 2006 and 2007 and which is currently installed at FNAL MTBF. As a further development, this new prototype will take into account all design aspects that are demanded by the intended operation at the ILC. It will contain about 2200 detector channels. Main focus of this contribution will be the mechanical and electrical integration of the front-end electronics into the HCAL absorber structure maintaining a high-density calorimeter. The proposal for an integrated light-calibration system for calibration and gain monitoring will be presented, addressing temperature and bias dependence of the MGPD gains. This is the first calorimeter design which makes full use of the high integration potential of the novel photo-sensor technology.

The CALICE collaboration consists of 42 institutes from 12 countries. Within CALICE new concepts of electromagnetic and hadronic calorimeters for the ILC are developed.

2 HCAL Structure

The HCAL barrel for the ILC is a cylindrical structure with an inner and outer radius of 1.8m and 2.8m, respectively. Inside the HCAL the electromagnetic calorimeter (ECAL) will be placed, while the HCAL is surrounded from the outside by the magnet. The current proposal foresees only one subdivision perpendicular to the beam line, such that all electronics connections and interfaces can be placed at the two end faces which are easily accessible for maintenance and service lines. The circular structure of the HCAL will be divided into 16 sectors. There are 38 detector layers foreseen; each HCAL layer consists of the tiles, the front-end electronics and a ~2cm-thick stainless steel absorber plate. The typical size of a segment’s layer is 1x2.2m². With a size of the scintillating tiles of 3x3cm², a layer contains about 2200 channels. The total number of channels of the HCAL barrel adds up to about 2.5 million.

2.1 Absorber Structure Design

The design of the absorber structure minimizes the amount of dead material which would compromise energy resolution and pattern recognition capabilities. There are no spacers in the active detector area, the absorber plates are supported only by a 3mm steel sheet at the boundary to the neighbouring sector. This guarantees that a maximum area in the gap can be instrumented with active elements, and a modular structure with easy insertion and removal of the layers can be realized, which facilitates assembly and maintenance.

Using finite element methods first analyses of the mechanical stability of this ambitious design have been performed. Depending on the fixing points of the AHCAL sectors and their position within the barrel, the bending of the absorber plates has been calculated and was shown to meet the requirements for the insertion of thin absorber layers with minimum tolerances such that a very compact structure can be realized in the given radial boundary conditions.

2.2 HCAL Detector Modules

The electronics of the 1x2.2m² large segment layers will be divided into base units (HBUs) in order to keep the single modules at reasonable sizes. A possible HBU setup is shown in Fig. 1. The HBU with a size of 36x36cm² integrates 144 scintillating tiles each with MGPDs together with the front-end electronics and the light calibration system. The tiles are connected to the HBU's printed circuit board (PCB) by a new concept using alignment pins that are plugged into holes of the PCB. The analogue signals of the MGPDs are read out by four 36-input-channel ASICs. The HBUs of a detector layer are interconnected by flexleads and ultra-thin connectors with a stacking height of 0.8mm. The signals are guided to the DAQ interface at the end of the segment layer, where an interface electronics collects the readout data and controls the detector's run configuration and power-pulsing.

Since the HCAL is surrounded by the ILC magnet, the detector modules have to be as thin as possible for cost reasons. This optimization will be achieved by the placement of the largest electronics components into cutouts of the HBU's PCB. The HBU electronics together with the tiles is placed into a steel cassette, of which top- and bottom plates are of the same material as the absorber plates. By this, the non-absorber material of the HBUs can be placed into 5.3mm.

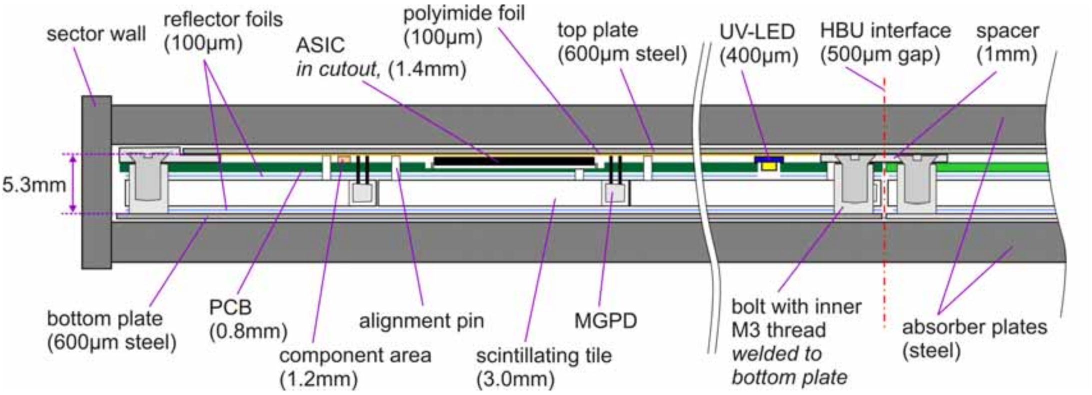

Fig. 1: Cross Section of one HCAL detector layer. The numbers in brackets show the heights of the parts.

2.3 ILC Power Budget and Light Calibration System

For the MGPDs a gain dependence on the operating temperature (in the order of -1.7%/K) and the bias voltage has to be assumed. No active cooling system is foreseen for the HCAL, which on one hand demands a calibration and gain monitoring system, on the other hand puts stringent restrictions to the power budget of the HCAL electronics. Switching with the 0.5% duty cycle of the ILC bunch structure, a power dissipation of about 25µW per channel for the electronics (mainly the front-end ASIC) and additional 15µW per channel for the MGPD bias is expected.

For the gain calibration and monitoring a new concept has been set up, based on one surface-mount UV LED (λ=395nm) per channel, that is mounted up-side-down on the HBU PCB and irradiates UV light directly into the tile (see Fig. 1). Thereby the complication of light distribution is avoided. At low light intensities, the MGPD response shows a characteristic single-photon-peak spectrum, corresponding to no, one or more pixels of the MGPD firing. The distances of the peaks in the spectrum are a measure of the channel's overall gain. This concept has already been verified with a testboard (see Fig. 2), showing very fast optical pulses of the LEDs (~5ns pulse width) and lowest crosstalk of the LED drivers to the MGPDs. The dynamic range covers about 10MIP (MIP: minimum ionizing particle). The problem of component-to-component spread of the LED's optical output at a specific biasing and optimization of dynamic range is under study. The in-detector power dissipation of the LED driving electronics adds up to 23µW per channel (assuming 1% duty cycle, worst case).

Fig. 2: Assembled UV LEDs (V3, V5) of the proposed calibration system.

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