Prototype tests for a highly granular scintillator-based hadron calorimeter

This content has been downloaded from IOPscience. Please scroll down to see the full text.


(http://iopscience.iop.org/1742-6596/587/1/012033)

View the table of contents for this issue, or go to the journal homepage for more

Download details:

IP Address: 188.184.3.52
This content was downloaded on 24/06/2015 at 12:17

Please note that terms and conditions apply.
Prototype tests for a highly granular
scintillator-based hadron calorimeter

K Krüger (for the CALICE collaboration)
DESY Hamburg, Notkestrasse 85, 22607 Hamburg, Germany
E-mail: katja.krueger@desy.de

Abstract. Within the CALICE collaboration, several concepts for the hadronic calorimeter of a future linear collider detector are studied. After having demonstrated the capabilities of the measurement methods in “physics prototypes”, the focus now lies on improving their implementation in “technological prototypes”, that are scalable to the full linear collider detector. The Analog Hadron Calorimeter (AHCAL) concept is a sampling calorimeter of tungsten or steel absorber plates and plastic scintillator tiles read out by silicon photomultipliers as active material. In the AHCAL technological prototype, the front-end chips are integrated into the active layers of the calorimeter and are designed for minimal power consumption. The versatile electronics allows the prototype to be equipped with different types of scintillator tiles and SiPMs. The current status of the AHCAL engineering prototype is shown and recent beam test measurements as well as plans for future hadron beam tests with a larger prototype will be discussed.

1. Introduction
At a future linear collider, one of the physics goal is the distinction of the hadronic decays of $W$ and $Z$ bosons which requires an unprecedented jet energy resolution of $3 - 4\%$ in a wide range of jet energies from 40 to 500 GeV. These values can be reached by using particle flow algorithms (PFAs) which reconstruct each particle within a jet from the detector part with the best energy resolution. In this way only neutral particles are reconstructed in the calorimeter, while for charged particles the information from the tracker is used. A good performance of the PFA requires a fine detector granularity and a compact calorimeter layout contained within the magnet coil. The CALICE collaboration develops such highly granular options for the electromagnetic and the hadronic calorimeter for a future linear collider detector.

The Analog Hadron Calorimeter (AHCAL) is a sampling hadron calorimeter concept based on scintillator tiles coupled to silicon photomultipliers (SiPMs) as active component. Iron and tungsten have been used as absorber material in beam tests of a large “physics prototype” which have demonstrated the capabilities of the AHCAL concept. Now the focus lies on improving the implementation in a “technological prototype”, that is scalable to the full linear collider detector.

2. AHCAL physics prototype
The $\sim 1 \text{ m}^3$ large AHCAL physics prototype was operated between 2006 and 2012 in several beam test campaigns in electron, muon and hadron beams at DESY, CERN and Fermilab. It
has been used to measure the AHCAL energy resolution for electrons [1] and hadrons [2]. Its high granularity and good energy resolution allow for detailed studies of hadronic showers [3] which are used also to validate the simulation of hadronic showers in the GEANT4 toolkit [4]. Recent results from the beam tests of the AHCAL physics prototype include the measurement of longitudinal and radial shower profiles of pions [5] (figure 1) and the validation of the performance of the PandoraPFA algorithm [6] by overlaying pion showers measured in beam tests [7] (figure 2). Overall, the studies show a good performance of the AHCAL concept and a reasonable to good agreement of the simulation with data if a modern physics list like FTFP_BERT or QGSP_BERT is used in GEANT4.

**Figure 1.** Mean longitudinal shower profiles from shower starting point for 18 GeV pions for data and for GEANT4 simulated data for the FTFP_BERT physics list.

**Figure 2.** Probability of recovering a neutral 10 GeV hadrons energy within 3 standard deviations from its real energy as a function of the distance from charged 10 GeV and 30 GeV hadrons for beam data and for GEANT4 simulated data for two physics lists.

### 3. AHCAL technological prototype

The goal of the development of the AHCAL technological prototype is the scalability to a full linear collider detector. It is based on a fully integrated design with front-end readout electronics embedded in the active layers to cope with the high channel density without dead zones. In order to avoid cooling in the active layers, this imposes stringent requirements on the power consumption of the electronics that can only be realized by switching off parts that are not needed during some data taking phases (power-pulsing). For the calibration and monitoring of all individual channels an LED system is also integrated into the layers.

The AHCAL technological prototype is based on $3 \times 3 \times 0.3 \text{ cm}^3$ tiles of plastic scintillator, resulting in $\sim 8$ mio. channels for the complete hadronic calorimeter. The availability of new SiPMs with reduced noise and very small device-to-device variations opens up new possibilities for the tile design. Several different tile options with and without wavelength shifting (WLS) fiber for the coupling of the tile to the SiPM are studied. One goal of the optimisation of the tile design is an easier and faster production and assembly of the detector. The design with a WLS fiber (figure 3) offers a better signal uniformity across the tile, while the design without
WLS fiber (figure 4, design based on [8]) is easier to produce. Changing the SiPM position from the side of the tile to the top would allow for the use of large scintillator plates [9] (“megatiles”) which cover several SiPMs (figure 5). These different tile options also have implications for the assembly and calibration procedure which are currently investigated.

The layout of the AHCAL for the International Linear collider Detector (ILD) [10] is planned to consist of two endcaps and a barrel, which is segmented into two rings along the beam direction. Each of the half-barrels is further segmented into 16 half-octants with a thickness of 40 to 48 layers (figure 6). The layers in turn are segmented into 18 HCAL Base Units (HBUs) arranged into 3 slabs with a length of 6 HBUs each (figure 7).

Several configurations with small numbers of HBUs have been operated successfully in the lab and studied in beam tests. A slab with the full length of 6 HBUs (figure 8) was tested with and without power pulsing in the lab and showed good signal uniformity over the full length of the slab of 2.1 m. A layer of 2*2 HBUs was calibrated with electrons from the DESY test beam used as minimal-ionising particles (MIPs) and used to measure hit times in hadron showers in the SPS test beam at CERN. Most recent, a stack of 8 HBUs (figure 9) was calibrated with MIPs in the DESY test beam (figure 10) and then used to measure electron showers. The active layers as well as the steel absorber have the geometry planned for ILD. As next step we plan to partly equip an ILD sector such that a few layers can be used to identify the shower start and a few larger layers can be used to measure the correlation of the size and the time of hits in a
hadronic shower. This configuration will be tested in muon and hadron beams at CERN. These tests are important steps toward the realisation of a large AHCAL technological prototype that demonstrates the feasibility of building a hadronic calorimeter according to the AHCAL concept for a future linear collider detector.

Figure 8. Slab of 6 HBUs tested in the lab.

4. Acknowledgments
The research leading to these results has received funding from the European Commission under the FP7 Research Infrastructures project AIDA, grant agreement no. 262025.

References

Figure 9. Steel stack with 8 layers of 1 HBU each.

Figure 10. Energy deposition of a MIP traversing several HBUs before (blue) and after cuts on the hit times (red). The noise peak at very low amplitudes is reduced significantly.


