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Performances of the SDHCAL hadronic calorimeter for future lepton collider experiments

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Hadronic calorimeter using GRPC as active medium is proposed in the ILD project of the future ILC experiments. A prototype of 1.3 m3 was built within the CALICE collaboration to validate the option proposed for ILD. The prototype is made of 50 GRPC detector of 1m2 size and 3 mm thickness each. They are fully equipped with a semi-digital electronic readout embedded on the detectors. A new genuine gas distribution design is elaborated to optimize the gas circulation within the detectors. The detectors are placed in a self-supporting mechanical structure playing the role of the absorber.
The prototype was exposed to pion and electron beams at CERN in 2012 and in 2014 using the triggerless and the power-pulsing modes. This is the first time a prototype of this size is run with these both modes and until now the unique one.
New techniques were developed to extract the energy of the hadron producing the hadronic showers in the prototype. An excellent energy resolution was obtained by analyzing the collected data during the Test Beams at different energies.
The ultra-granularity of the SDHCAL allows also a better understanding of the hadronic showers. In addition MIPs produced within the hadronic showers are easily extracted using Hough Transform and used for the insitu study of the detector.
The results obtained so far show the big potential of such a high granular calorimeter and pave the way for the use of this new generation of calorimeters in the future experiments

Collaboration

SDHCAL groups of the CALICE collaboration

Summary

The SDHCAL prototype is the first technological prototype of the new generation of the PFA-based compact hadronic calorimeters proposed for the future ILC. It is made of 50 units. Each unit is a cassette containing 1 m2 GRPC detector and its embedded electronics providing a lateral segmentation of 1 cm2. The cassettes are inserted in a self-supporting mechanical structure that, with the cassettes, plays the role of the absorber.
The detectors of 1 m2 were developed with the spirit of having excellent homogeneity, and reducing the dead zones while increasing the gas circulation efficiency.
A semi-digital electronic readout was used to read out the signal produced by the passage of charged particles in the prototype.
7200 ASICs were used. All of them were previously controlled and calibrated using a customized robot.
50 Electronics boards of 1 m2 each were built. Each unit was made of 6 Active Sensor Unit (ASU) hosting each 24 ASICs on one face and the pick-up pads of the other face of a 8-layer Printed Circuit Board (PCB). All the PCBs were controlled before to get assembled together by sets of 6 to build the large board of 1 m2.
Two ILC related modes were developed and successfully used: the triggerless mode and the power-pulsed mode. The first allows to keep all the events during the data taking and the second is necessary to reduce the power consumption of the more than 460000 electronic channels of the SDHCAL.
A genuine acquisition system was developed to deal with the data collected from the 48 units. The system

uses both USB and HDMI transmission protocols. The first protocol allows to transmit to each of the ASICs the 872 configuration parameters (6278400 in total) and to collect the data recorded by the ASICs during the data taking. The HDMI was used to synchronize the ASICs and for fast commands (RAMFULL, BUSY..)
The management of data was performed using Xdaq system developed for the CMS tracker. This allows a full control of the data collected and its consistency.
A dedicated Oracle database was developed to deal with the configuration parameters. It allows to keep track of the used configurations in a given run. It facilitates the access to access to the parameters and to modify them quickly.
The prototype was commissioned using comic rays before to exposed pion, electrons and muon beams at CERN.
The performance of the different units of the prototype was studied using muons. The average efficiency of 96% of the 50 chambers made it possible to study hadronic shower produced with pions and electromagnetic showers produced by electrons.
The study of hadronic showers shows very good energy. Improvement is ongoing by applying calibration procedures.
The low noise of the calorimeter and its high granularity were used to demonstrate the capability of such calorimeter to apply PFA algorithms and to study the hadronic shower as well.

To validate completely the SDHCAL concept for the ILD project, development of larger GRPC detectors equipped with the next generation of ASICs and new DAQ system are being pursued.

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