Performance of a Highly Granular Scintillator-SiPM Based Hadron Calorimeter Prototype in Strong Magnetic Fields

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- Overview
- Technologies used
- Test-beam performance
- Outlook - full technical prototype
**Aim**: Development of new technologies for calorimetry with highly granular detectors

- Several technologies under study
- This talk: focus on **analog hadronic calorimeter** (AHCAL)
Highly Granular Calorimeters - Motivation

- Future linear accelerator e.g., ILC or CLIC
- Detectors rely on Particle Flow algorithm to achieve ~ 3% jet energy resolution
- Highly granular calorimeters needed to resolve single particles in a jet
  - $\Rightarrow$ 8 Mio channels
- Other applications:
  - LHC (CMS), neutrino experiments, …
**AHCAL - Physics Prototype**

- Show principle of highly granular calorimeters (~8000 channels)
- Successfully tested in DESY, CERN, FNAL test-beam campaigns
- Proved competitive single hadron energy resolution and two particle separation

![AHCAL prototype setup](image)

**Figure 24.** CALICE calorimeter system setup at CERN in 2006 (left) and 2007 (right).

**Figure 25.** Event collection rate during test beam in 2006 (left) and 2007 (right).

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**9.3 MIP Calibration**

The calibration of each cell is accomplished with muons from a beam that has a sufficiently broad distribution to cover the entire front face of the AHCAL. A minimum of 2000 muon events per cell is necessary to obtain a reliable fit to the pulse height spectrum that is parameterized as a convolution of a Landau distribution and a Gaussian function. For a uniform beam distribution this amounts to a total of $5 \times 10^5$ events. Since the beam...
• Prove scalability to full detector
• Steel and tungsten absorbers - partially instrumented
• Time measurements possible
• Small steel stack:
  • Precision measurements of em showers
  • Test of temperature compensation / power-pulsing
• Data analysis still ongoing
• Sampling calorimeter based on scintillators and silicon photomultipliers (SiPMs)

• Scintillator tiles of size 3 x 3 x 0.3 cm³, dimple for light focusing, wrapped in reflecting foil

• HCAL base unit (HBU) with fully integrated electronics
Readout

• Readout ASIC: Spiroc2b
• 36 channels (ext. trigger or auto-trigger)
• 12 bit ADC for energy and time measurement
• 16 memory cells per channel
• Central Interface Board (CIB)
  • fitted for space constraints in real detector
  • Contains: Detector Interface (DIF), Calibration, Power
• Power board capable of power pulsing and software adjustment of SiPM power voltage
**Power Pulsing**

- **Power pulsing**: 8 Mio channels, no active cooling → reduce power consumption

- Rapidly cycling the power according to the beam structure of a linear accelerator

- 1ms train of bunches spaced ~300ns apart, 199ms idle time

- SiPM gain stays stable with power pulsing
AHCAL Test-beam with Magnetic Field

- 15 Layers in small steel stack, > 2000 channels
- Taking data with and without 1.5T magnetic field
- Muons, 10-60GeV Electrons
- Detector survived 2.4T
First Results (Work in Progress)

Magnet off

10 GeV Electrons

Hit Position Y

Hit Position X

Normalized Entries

CALICE AHCAL Work in progress

Electrons 10GeV

Magnet Off

Magnet On
First Results (Work in Progress)

Hit Position Y

Hit Position X

Magnet on

10 GeV Electrons
First Results (Work in Progress)

- Energy sum increases with magnetic field for electrons
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- Effect is two-fold:
  1. increase in MIP scale
  2. increase in number of hits
First Results (Work in Progress)

• Energy sum increases with magnetic field for electrons

• Effect is two-fold:
  1. increase in MIP scale
  2. increase in number of hits

• Time distributions stay stable with slight broadening of distribution during / after magnetic field
Outlook

- Construction of large technological prototype
- 40 Layers, 160 HBUs, 23000 channels
- Mass production:
  - SiPM testing and characterization
  - AISIC tests
  - PCB construction and testing
  - Automatic scintillator tile wrapping and assembly
  - Cosmic ray tests
- Towards hadronic test-beam at SPS in 2018
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Summary

- Successful test-beam campaign with 1.5T magnetic field
- Power pulsing and temperature compensation established
- Data analysis of various test-beam campaigns ongoing
- Construction of new fully instrumented AHCAL technological prototype ongoing
Backup