**The Initial Run of the High Granularity Calorimeter Test Beam System**

**Rajdeep M. Chatterjee** on behalf of the CMS Collaboration

**University of Minnesota, USA**

---

**HL-LHC environment: need for HGCAL**

To operate in the high radiation levels of the HL-LHC the CMS endcap calorimeter will need replacement.

- With 25 ns bunch crossing the pileup is expected to be ~140 at a luminosity of 5*10^{33} cm^{-2} s^{-1} from 4-32 GeV, as well as protons at 120 GeV.

There will be further tests at CERN where we will have access to beams at higher energies.

**Overview of the HGCAL test beam campaign**

- The primary goal of the test beam program at FNAL and CERN are:
  - Proof of concept of the baseline design with a closely spaced stack-up of modules.
  - Test the proposed design of a compact detector module with deep access wire-bonding.

The test beam prototype will comprise of:

- A 28 layer ECAL section with a single 6'' sensor module per layer.
- A 12 layer FH section with 7x6'' sensor modules per layer.
- A realistic readout system to acquire data from the ECAL system with ~4000 channels.

We study the calorimeter performance:

- Calibration with MIPs, measurement of signal-to-noise ratio.
- Response to electrons/hadrons.
- Position, timing and angular resolutions.
- Comparison of test beam results with simulation.

In 3 rounds of test beams at FNAL we have made measurements with electrons at energies ranging from 4-32 GeV, as well as protons at 120 GeV.

There will be further tests at CERN where we will have access to beams at higher energies.

---

**The HGCAL detector module**

- For the most recent tests we have used, 200 µm active thickness silicon sensors and a dual board readout shown in the schematic.
  - One passive board glued to the sensor.
  - Connected to a second board with the SKIROC2 chip mounted on top, with connectors between the two board.

We have used the 64-channel SKIROC2 ASIC developed by the OMEGA group for the CALICE collaboration as a starting point. This is not the final front-end chip.

- Shaping time 200 ns.
- Two 12-bit ADCs, with selectable low and high gain.
- Programmable gain, max sensitivity 0.02 fC (325 e-) (ADC count).

**The DAQ system is designed to be scaleable, largely using commercial components**

- Each sensor module is connected to the data collection FPGA (Artix on the FMCIO) that stores data during a spill.

A second FPGA based system (The ZedBoard) collects data from all FMCIOs between spills.

The mechanics consists of a hanging file structure for flexibility:

- Enables easy insertion of detector modules as well as absorbers of different thicknesses.

It is easy to have different distances between the layers.

---

**Data Acquisition System**

The DAQ system is designed to be scaleable, largely using commercial components mounted on custom PCBs:

- Each sensor module is connected to the data collection FPGA (Artix on the FMCIO) that stores data during a spill.

A second FPGA based system (The ZedBoard) collects data from all FMCIOs between spills.

**Calibration with 120 GeV protons**

- The plot on the left shows the response of a cell to 120 GeV protons.
- The distribution is modelled with a Gaussian + Landau convoluted Gaussian function.
- The MPV of the Landau is the response to a 120 GeV proton.
- The plot on the right shows the MPV of the peak for each of the 16 layers.

We use the response to 120 GeV protons (1.3 MIPs) to obtain the ADC → MIP translation factor for each of the 16 detector layers.

**Detector response versus beam energy**

- The energy deposited in each of the 16 layers, expressed in terms of MIPs, for 6 different beam energies is plotted above.

- The evolution of the shower maximum towards higher depths for higher beam energies can be seen.

2016:

- Setup in the H2 beamline at CERN
- Investigate high energy response and the constant term of the energy resolution.
- Replace the current readout ASIC with a custom ASIC for tests with precision timing

2017:

- Test with EE & FH prototype.