Phase 1 Upgrade of the CMS Forward Hadronic Calorimeter

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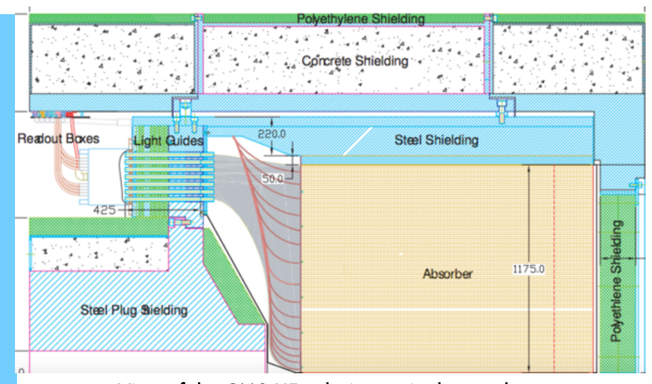
for the CMS collaboration

Abstract :

The CMS experiment at the Large Hadron Collider at CERN is upgrading the photo-detection and readout system of the forward hadronic calorimeter (HF). The phase-1 upgrade of the CMS forward calorimeter requires the replacement of the current photomultiplier tubes, as well as the installation of a new front-end readout system. The new PMTs contain a thinner window as well as multi-anode readout. The front-end electronics will use the QIE10 ASIC which combines signal digitization with timing information. This talk will describe the major components of the upgrade as well as the current status.



View of the CMS HF calorimeter in the r-z plane

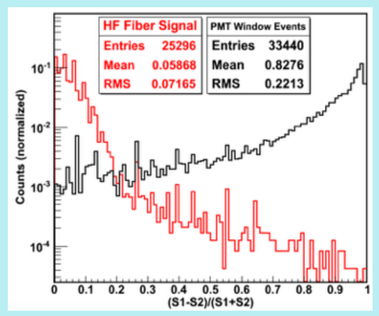
Overview :

Both the front end electronics and photomultiplier tubes (PMT) are being upgraded as part of the Phase 1 upgrade.

- New PMTs (Hamamatsu R7600U-200-M4 multi-anode tubes) will be read out in a dual anode configuration
  - Dual anode readout doubles the number of output channels, requiring an upgrade to the front end electronics
- New front end electronics perform charge integration using QIE10 ASIC
  - Provides charge integration and digitization of signals from PMT
- PMTs were installed in the detector during LS1 (2013)
- Front end electronics are being commissioned and will be installed during LHC shutdown at the end of the year

Motivation:

Anomalous hits caused by particles hitting PMT windows or housing cause large isolated signal. New PMT's have been installed, and front end electronics will be installed to mitigate this problem. PMTs have a thinner window to reduce interactions, and multiple anodes to measure asymmetric charge from direct hits. New QIE cards provide timing information, to detector the early arrival of anomalous hits.



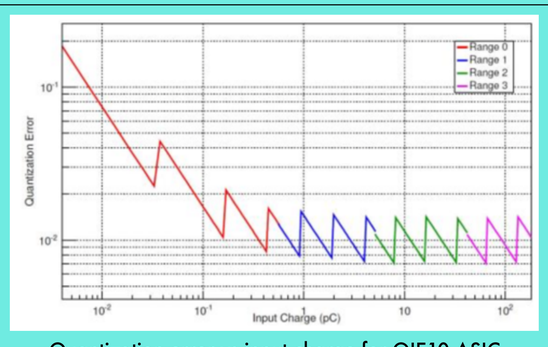
Asymmetry in charge measurement between PMT anodes for real signals (red) and anomalous hits (black).

QIE10 ASIC

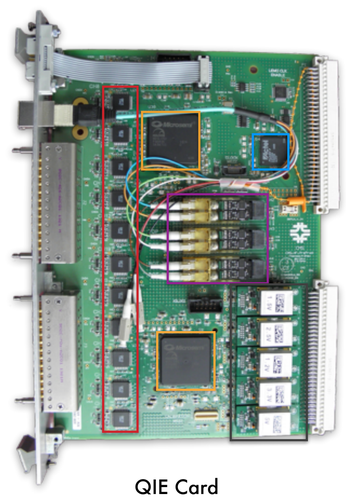
The QIE10 is used for integrating the charge coming from the PMT.

- Provides charge integration and digitization at 40 MHz
- 8-bit pseudo-logarithmic ADC provides 1% resolution between +50 fC and -350 pC in four ranges
- Rotates between four identical integrators for deadtimeless operation
- Provides 6-bit TDC (0.5 nS resolution) of pulse arrival time

QIE10 ASICs are organized on QIE cards, with 24 chips per card.
A total of 144 QIE cards will be needed for the readout of the upgraded HF.



Quantization error vs input charge for QIE10 ASIC

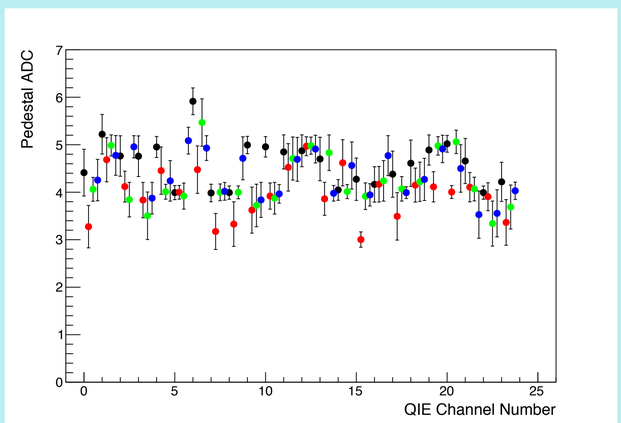


QIE10 ASIC
Microsemi Igloo2 FPGA
Microsemi ProAsic3 Bridge FPGA
Versatile Twin-Transmitter modules (VTTx)
FeastMP DC/DC converters

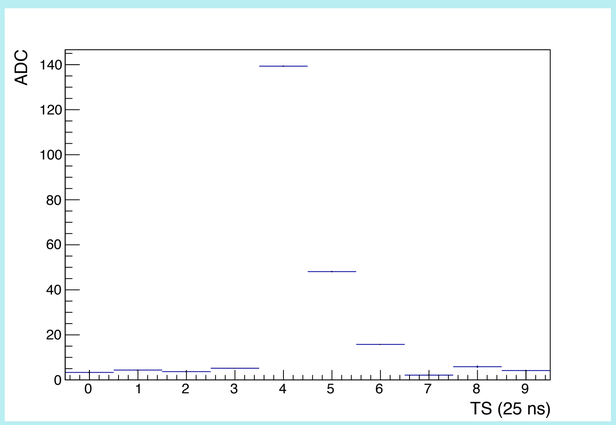
QIE Card

QIE card qualification testing

All QIE cards undergo testing and commissioning to prepare for installation. Check the functionality of all chips (pedestal values, response to internally and externally supplied pulses, TDC response, etc.)



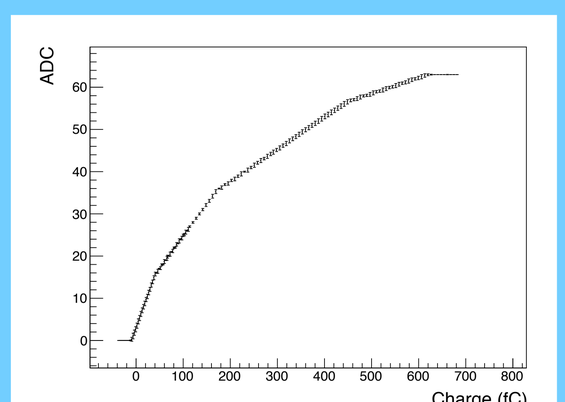
Pedestal values, separated by integrator, for the 24 chips on a QIE card



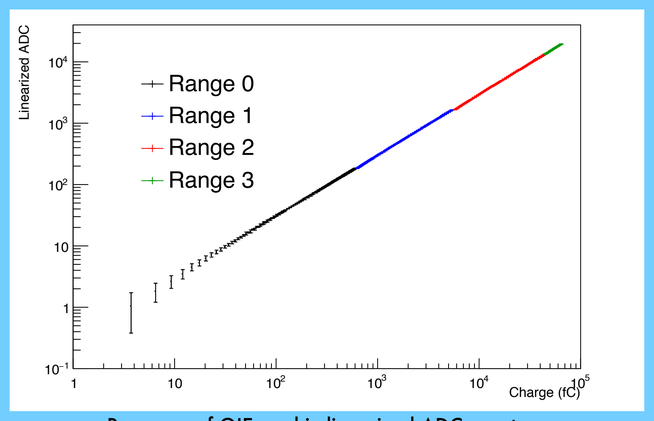
Shape of pulse injected by LED into PMT, measured by QIE chip. Figure shows ADC counts measured in each 25 ns time slice

QIE Calibration

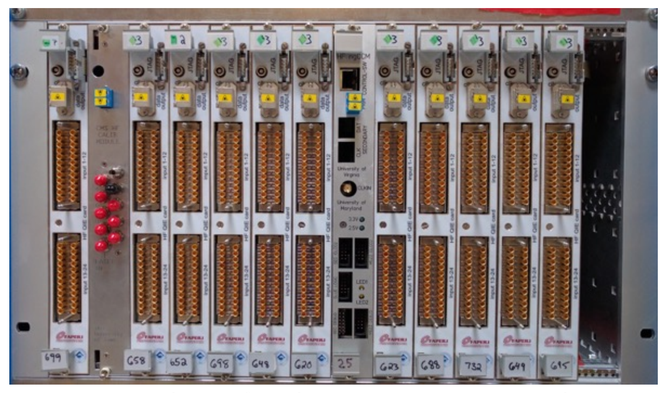
Response of QIE card to charge values is necessary to calibrate to ensure accurate reconstruction of collision data. DC current is injected into the QIE at a variety of values, and the output ADC is measured. Each individual QIE10 chip is calibrated separately, with calibration constants measured for each range and capID.



Injected charge vs ADC response for lowest range of QIE 10



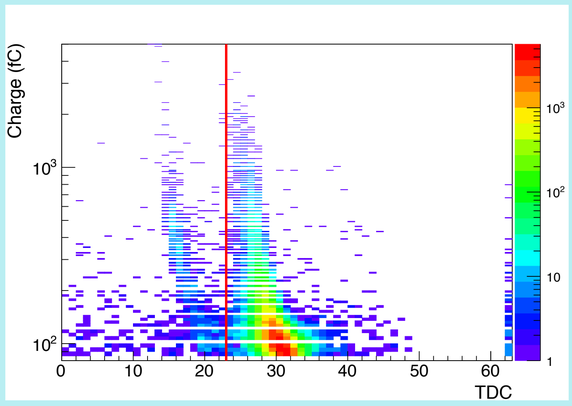
Response of QIE card in linearized ADC counts vs injected charge for all 4 ranges, covering the dynamic range of the QIE 10



Front end crate of HF electronics, containing QIE cards

QIE10 pilot system

Two QIE cards have been installed in the detector during 2016 data taking, to verify the performance in collision data. Operation of the QIE10 has been successful, and provided useful insight and preparation for operating the full system beginning next year.



TDC vs measured charge for QIE10 chip in LHC collision data. Points to the left of the red line represent early hits, likely coming from particles interacting directly with the PMT

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