Commissioning of the CMS Hadron Forward Calorimeters Phase 1 Upgrade

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CMS Hadron Forward (HF) Calorimeters

- Čerenkov Calorimeter – Quartz fibers
- ~ 250 tons iron absorber (8.8 λ_i)
- ~ 1000 km quartz fibers (0.8 mm diam)
- ~ 2000 Photomultiplier tube (PMT) read-out
- 36 wedges azimuthally; 18 rings radially
  (Segmentation ΔηxΔφ = 0.175 x 0.175)
  \[Δη \sim 0.03, Δφ \sim 0.03 \text{ rad}\]
HF Noise Due to PMT Hits

Large energy events detected by the Run I (2004 – 2012) R7525HA type HF PMTs due to particles hitting PMT windows.

Plano-concave shape

- $t_{\text{thin}}$: 1.12 mm
- $t_{\text{thick}}$: 5.92 mm

HF Upgrade: PMT Replacement

Replace R7525 with a new multi-anode PMT which has

❖ thinner window,
❖ no glass other than the window per se,
❖ multiple channels that view the same well-mixed light from the light guide
   NOT ONLY to tag fake PMT hit events BUT ALSO to CORRECT the energy
   (this will enable us to recover energy imbalance).

The new PMTs have been operational in 1-channel readout mode since the
beginning of Run II (2015 -).

HF Phase I Upgrade – Implementation of the 2-channel readout: During
EYETS 16-17, the PMT boxes were reworked to provide 2 channels per
PMT, which exploits the benefits of multi-anode feature.
HF Phase I Upgrade: Front-End and Back-End Electronics

PMT rework + Front-end Electronics: EYETS 2016/17

In operation since early 2015

Back-end Electronics

New front-end electronics
- supports increased number of channels
- QIE8 (7-bit ADC) ➔ QIE10 (8-bit ADC, embedded 6-bit TDC)

New back-end electronics (μTCA)
- supports larger data volumes, new trigger primitives
HF Phase I Upgrade Timeline

HF Phase-I Back-end installations and operations

* Postponed from YETS 15/16 (benefit: it allowed installing improved QIE10 chips on HF front-end cards)
HF Phase I Upgrade Components

**Pre-Run II installation**
- PMTs
- Base boards
- 1-channel adapter boards
- Winchester cables
- Light guides and sleeves
- Back-end electronics

**EYETS 16-17 installation/modification**
- 2-channel adapter boards
- Front-end electronics

Calibration unit
ngCCM
QIE10 cards
PMT Box Rework: 1-channel → 2-channel Readout
PMT Box Rework: Workflow Overview

Removal:
1. Removal of boxes from detector
2. Radioprotection screening
3. Transport PMT boxes to SX5 work area (temporary radiation zone)

Pre-Rework Testing:
1. Three boxes at a time connected to test-stand electronics (HF front-end, μTCA back-end)

Rework:
1. Open box
2. Remove “Medusa” (assembly consisting of Winchester connectors, coax cables and adapter boards)
3. Change adapter boards
4. Electrical and mapping test of Medusa
5. Reinstallation of Medusa onto PMT box
6. Close box

Testing:
1. Three boxes at a time connected to test-stand electronics (HF front end, μTCA backend)
2. Testing overnight
3. Sign off or re-work.

Reinstallation on detector and commissioning
PMT Box Rework: Rework Tools

MMCX connector removal tools

Crucial instruments of the rework!

Winchester-MMCX cable replacement tools
PMT Box Rework: SX5 Operations

Specially developed online tracking and logging system:

- efficient and reliable tracking of several boxes at different stages of the rework.
- immediate online publication of the test results for collaboration view.

Links to multi-page pdf documents with plots
PMT Box Rework: Examples of Rework Test Results

HFP_25_Q3

Fluctuations mostly due to the systematics in the test setup optics

\[
\text{Post rework} = (1+2) + (3+4)
\]

HFM_23_Q3

SPE Charge (fC)

1 Ch
2 Ch 1+2
2 Ch 3+4
Front-End Electronics: Testing, Installation and Commissioning

All front-end electronics have been fully tested and commissioned in building 904.

A full testing suite of all channels on all cards to ensure they are fully operational:

- Testing communications with cards
- LED test with PMT Box
- Calibration of response of QIE10s

Work on installation and commissioning of FE happened in parallel between HFP and HFM.

Front-end electronics were commissioned as they were installed:

- Testing of control and data links to each crate
- Testing data readout with local pedestal and charge injection runs
Commissioning of HF Phase I Upgrade with Local Data Taking

Local data taking types are:

- Pedestal
- Internal Charge Injection (QIE10 has the ability to inject pulse internally)
- LED (LED light with tunable intensity is provided by the upgrade calibration unit)
- Laser (laser light is centrally injected into the HFs)
Commissioning of HF Phase I Upgrade with $^{60}$Co Radioactive Source

Permanently installed radioactive source drivers insert the source into the source tubes inside the calorimeter towers.

Very useful tool to verify mapping, optical path quality and calibration.

Color index:

1 - $\text{Em (1+2)}$
2 - $\text{Had (1+2)}$
3 - $\text{Em (3+4)}$
4 - $\text{Had (3+4)}$
Summary

PMT box rework started – December 7th 2016

PMT box rework completed – February 10th 2017

Front-end electronics installation completed – February 13th 2017

All PMT boxes installed – February 16th 2017

First commissioning runs were taken – February 17th 2017

First radioactive sourcing runs were taken – March 10th 2017

HF Phase I is ready for data taking.