

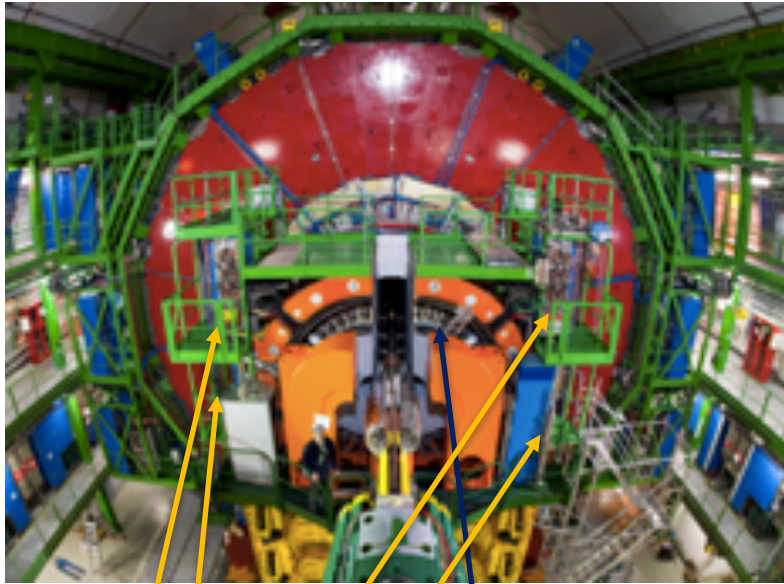
# Commissioning of the CMS Hadron Forward Calorimeters Phase 1 Upgrade

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On Behalf of the CMS Collaboration

International Conference on Technology and Instrumentation in  
Particle Physics  
May 22-26, 2017  
Beijing

# CMS Hadron Forward (HF) Calorimeters



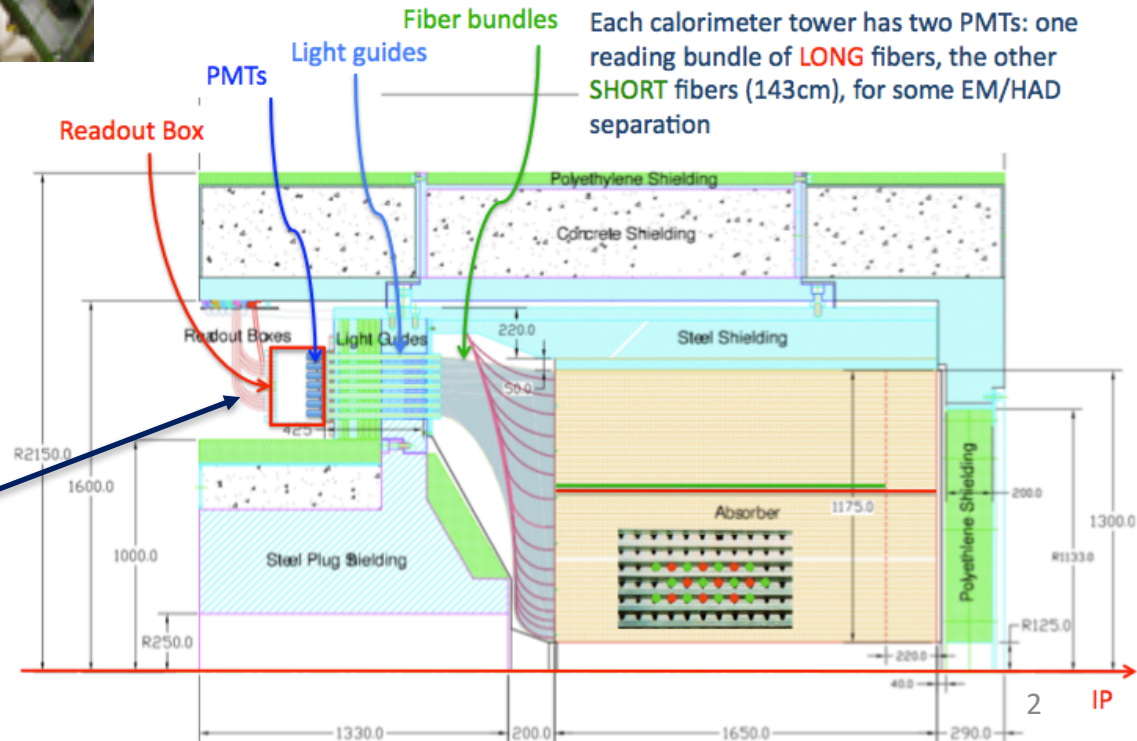
- Čerenkov Calorimeter – Quartz fibers
- ~ 250 tons iron absorber ( $8.8 \lambda_I$ )
- ~ 1000 km quartz fibers (0.8 mm diam)
- ~ 2000 Photomultiplier tube (PMT) read-out
- 36 wedges azimuthally; 18 rings radially  
(Segmentation  $\Delta\eta \times \Delta\phi = 0.175 \times 0.175$ )

$[\Delta\eta \sim 0.03, \Delta\phi \sim 0.03 \text{ rad}]$

Front-end  
electronics racks

PMT Boxes

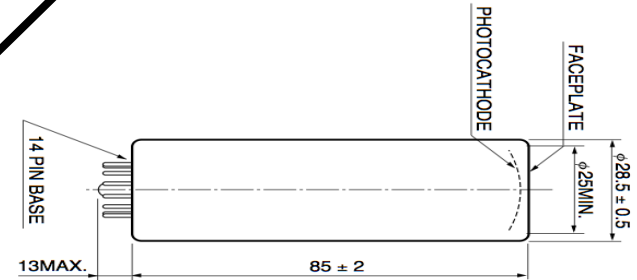
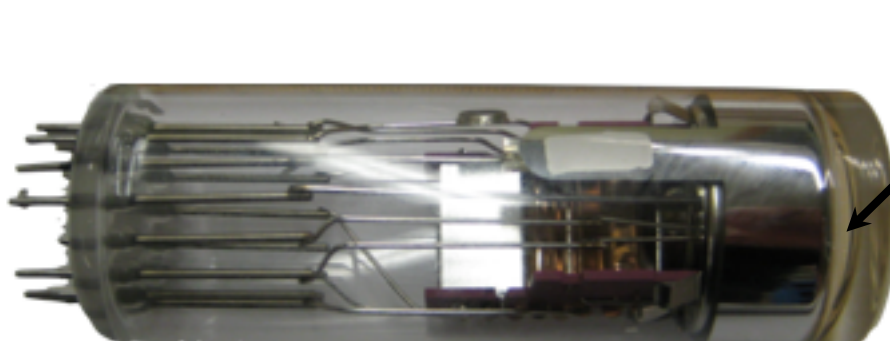
HF side view





# HF Noise Due to PMT Hits

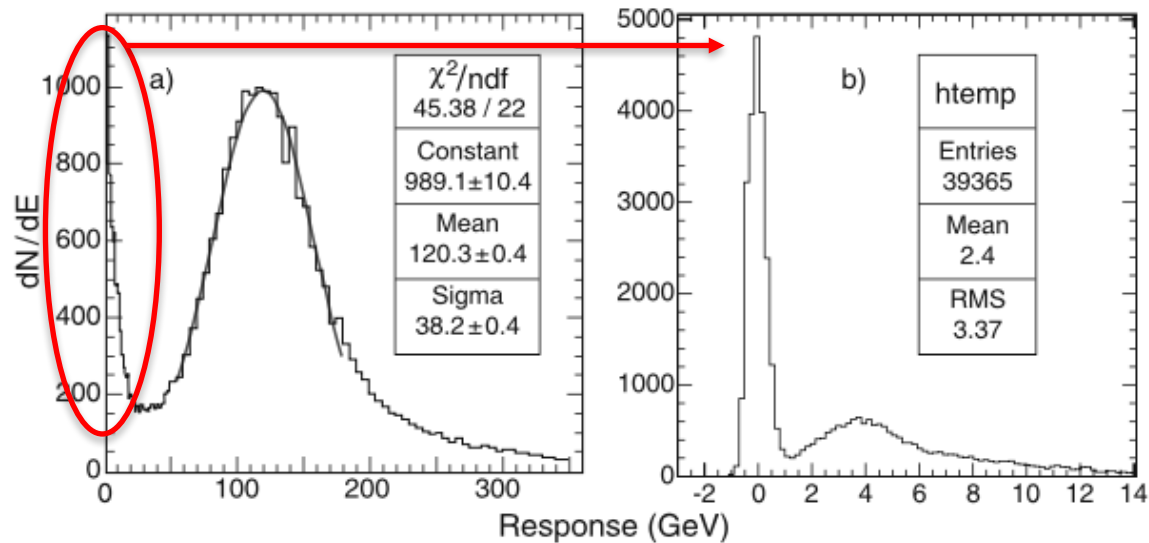
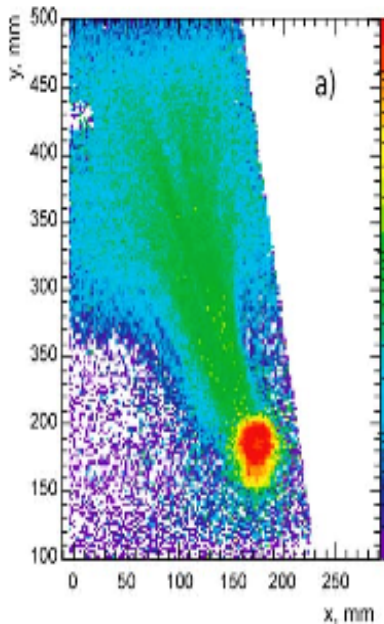
Large energy events detected by the Run I (2004 – 2012) R7525HA type HF PMTs due to particles hitting PMT windows.



Plano-concave shape

$t_{\text{thin}}$ : 1.12 mm

$t_{\text{thick}}$ : 5.92 mm



# HF Upgrade: PMT Replacement

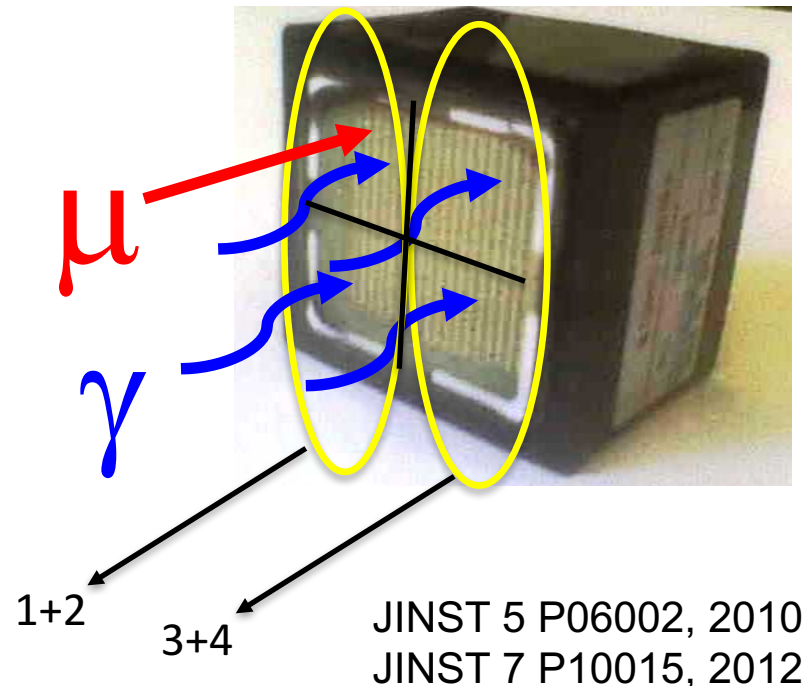
Replace R7525 with a new multi-anode PMT which has

- ❖ 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).

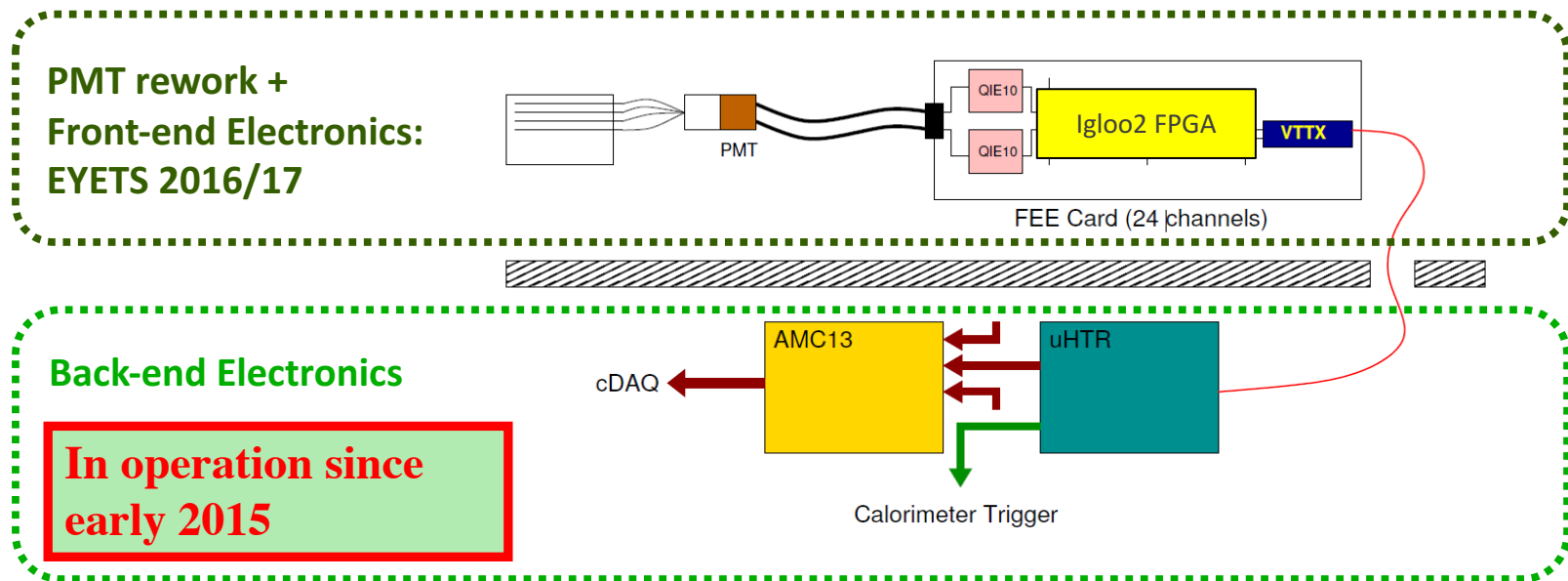
R7600U-200-M4

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

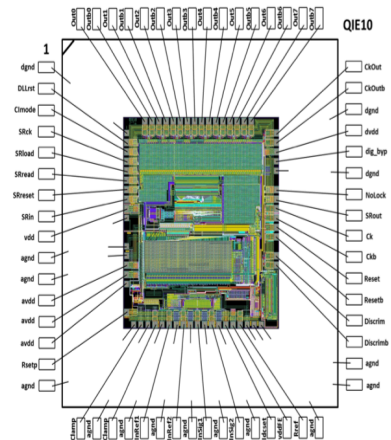


## New front-end electronics

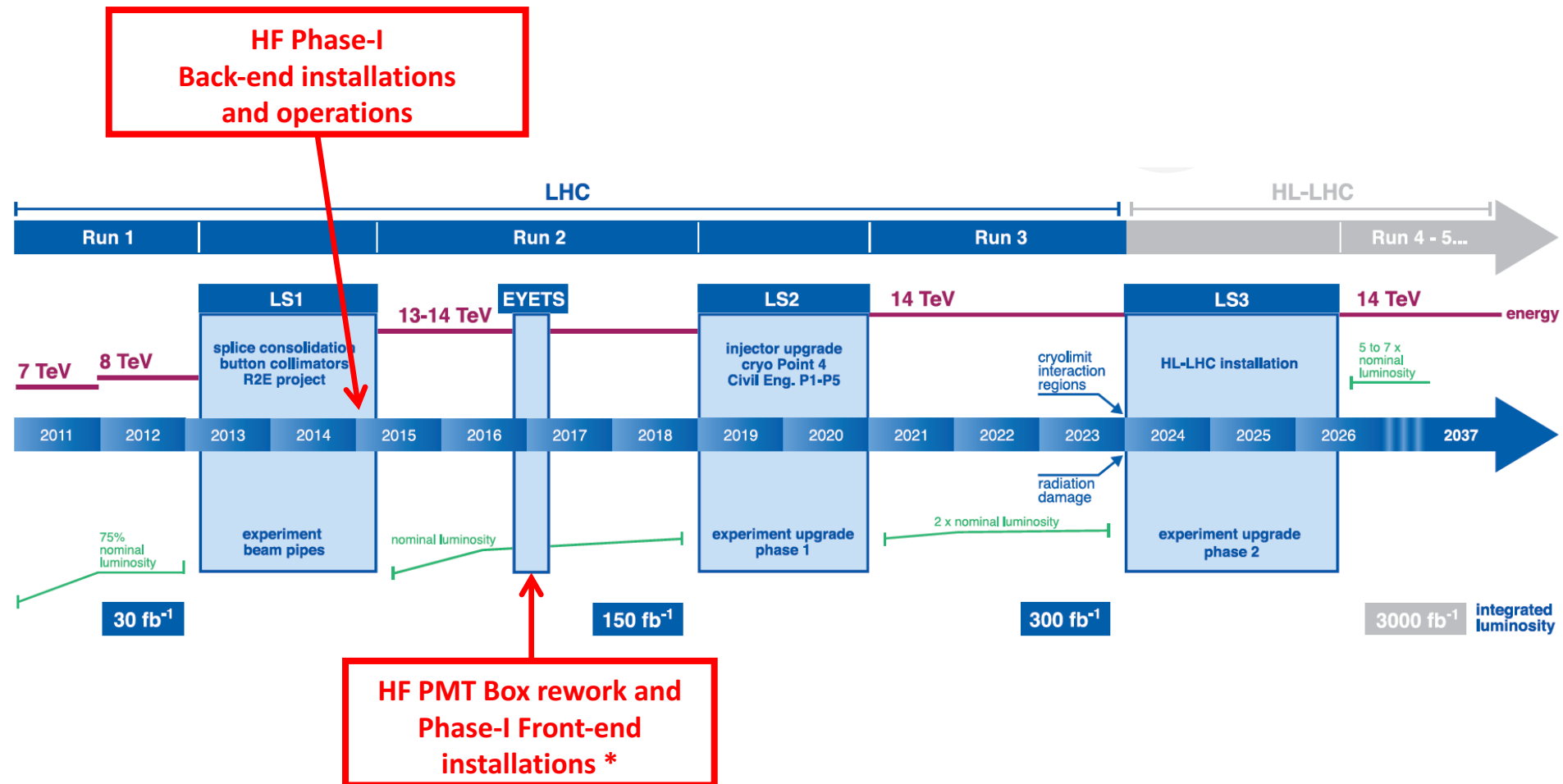
- supports increased number of channels
- QIE8 (7-bit ADC) → **QIE10** (8-bit ADC, embedded 6-bit **TDC**)

## New back-end electronics ( $\mu$ TCA)

- supports larger data volumes, new trigger primitives



# HF Phase I Upgrade Timeline

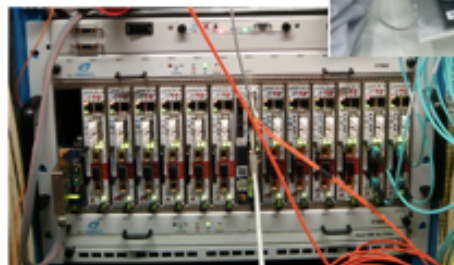
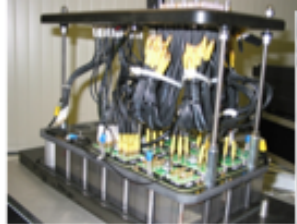
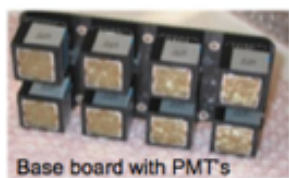


\* Postponed from YETS 15/16 (benefit: it allowed installing improved QIE10 chips on HF front-end cards)

# HF Phase I Upgrade Components

## Pre-Run II installation

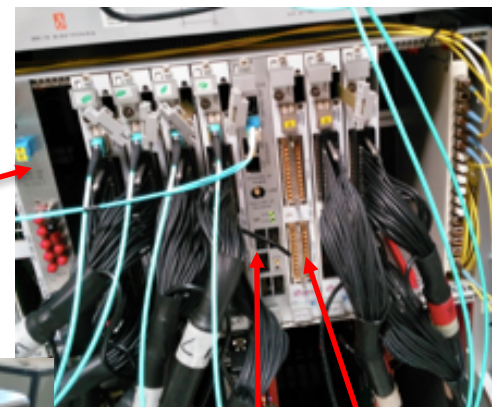
- PMTs
- Base boards
- 1-channel adapter boards
- Winchester cables
- Light guides and sleeves
- Back-end electronics



## EYETS 16-17 installation/modification

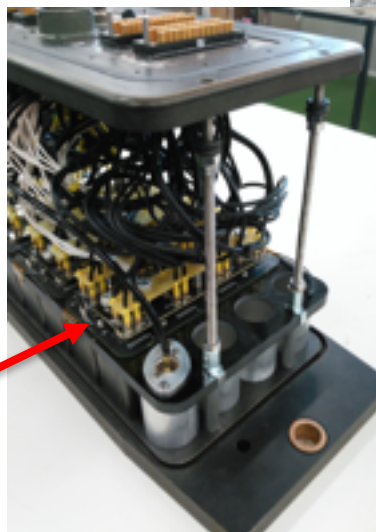
- 2-channel adapter boards
- Front-end electronics

Calibration unit



ngCCM

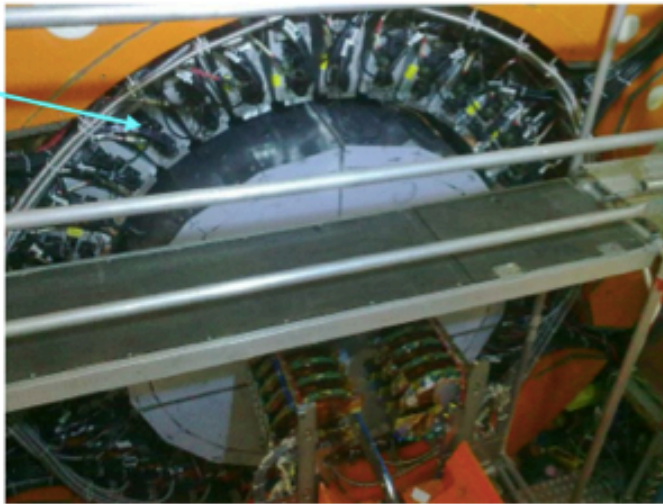
QIE10 cards



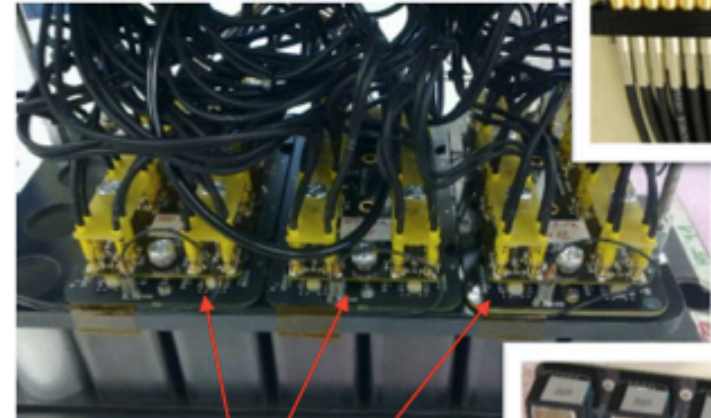


# PMT Box Rework: 1-channel → 2-channel Readout

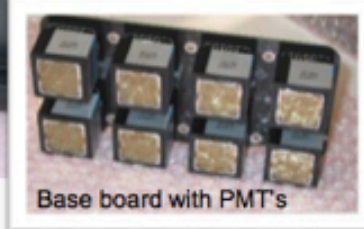
36 PMT boxes  
each end



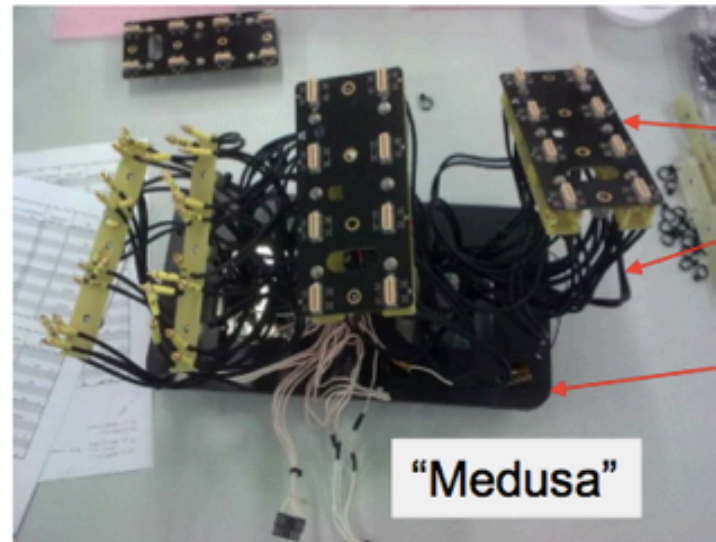
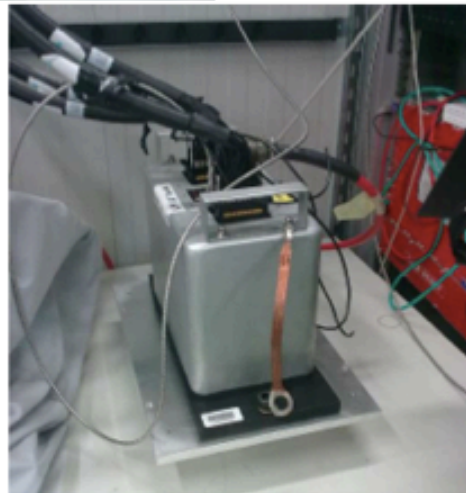
PMT box insides



Adapter boards attached to  
base boards



Base board with PMT's



Adapter board, gangs anodes

Winchester to MMCX coax  
cables (96 per box)

"plate 3" holding connectors

"Medusa"



# 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,  $\mu$ TCA back-end)

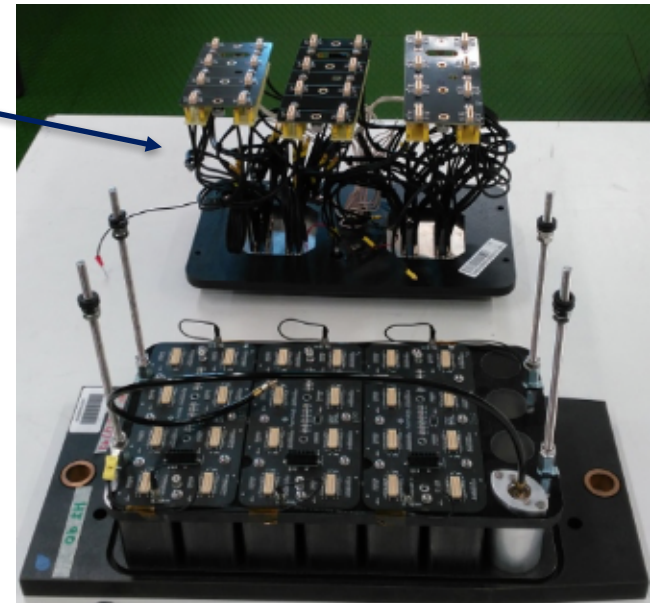
## Rework:

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

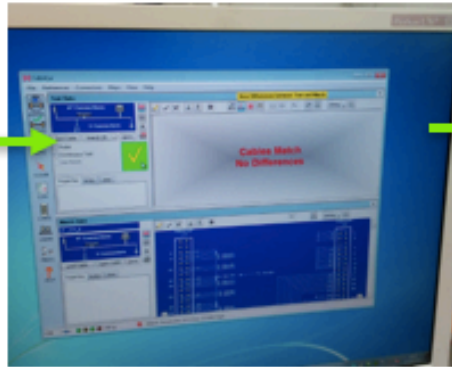
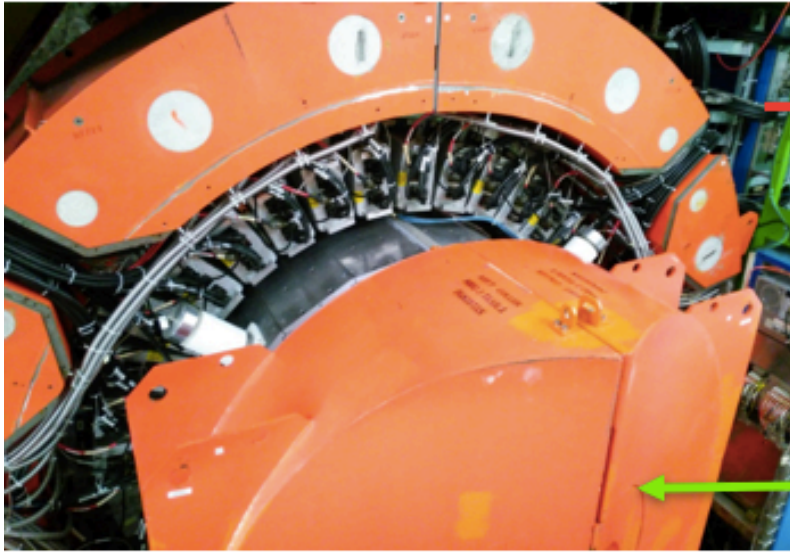
## Testing:

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

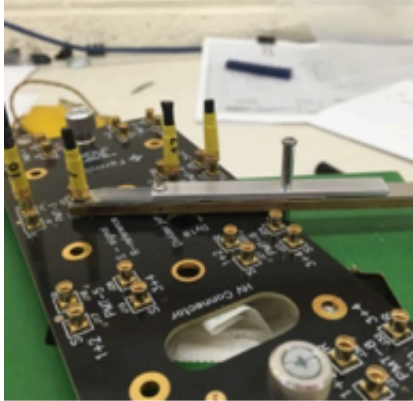
## Reinstallation on detector and commissioning



# PMT Box Rework: Workflow Overview (with Pictures)



# 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.

**CMS HCAL Phase I Upgrade**

**PMT Box Rework Operations**

**Admin Site**

[PMT Box Tracking](#) [Test Bench](#) [Run List](#) [Re-Rework](#)

PMT Box Barcode	PMT Box Name	Location	Status	Reworked by	Tested at
3040000000000600637	HFP_34_Q4	HFP.Q4.4	Sign Off	Pascal	Station 3
343970000000001	HFP_36_Q4	HFP.Q4.5	Sign Off	Olga	Station 1
343970000000002	HFP_03_Q1	HFP.Q1.3	Sign Off	Fan	Station 2
343970000000003	HFP_02_Q1	HFP.Q1.2	Sign Off	Olga	Station 3
343970000000004	HFP_05_Q1	HFP.Q1.5	Sign Off	Svetlana	Station 1
343970000000005	HFP_04_Q1	HFP.Q1.2	Sign Off	Fan	Station 2
343970000000006	HFP_07_Q1	HFP.Q1.1	Sign Off	Olga	Station 3
343970000000007	HFP_06_Q1	HFP.Q1.4	Sign Off	Pascal	Station 1
343970000000008	HFP_09_Q1	HFP.Q1.3	Sign Off	Fan	Station 2
343970000000009	HFP_08_Q1	HFP.Q1.4	Sign Off	Svetlana	Station 3
343970000000010	HFP_11_Q2	HFP.Q2.4	Sign Off	Pascal	Station 1
343970000000011	HFP_10_Q2	HFP.Q2.5	Sign Off	Svetlana	Station 2
343970000000012	HFP_13_Q2	HFP.Q2.2	Sign Off	Fan	Station 3
343970000000013	HFP_12_Q2	HFP.Q2.3	Sign Off	Svetlana	Station 1
343970000000014	HFP_15_Q2	HFP.Q2.2	Sign Off	Fan	Station 2
343970000000015	HFP_14_Q2	HFP.Q2.1	Sign Off	Olga	Station 3
343970000000016	HFP_17_Q2	HFP.Q2.1	Sign Off	Fan	Station 1
343970000000017	HFP_16_Q2	HFP.Q2.3	Sign Off	Svetlana	Station 2
343970000000018	HFP_19_Q3	HFP.Q3.4	Sign Off	Pascal	Station 1
343970000000019	HFP_18_Q2	HFP.Q2.4	Sign Off	Pascal	Station 3



**CMS HCAL Phase I Upgrade**

**PMT Box Rework Operations**

**Results Site**

**PMT Box: HFP\_19\_Q3 Barcode: 343970000000018**

[Initial Pedestal](#)

[Initial LED](#)

[Initial Pedestal Histograms](#)

[Initial Pedestal Histograms at OV2+100 V](#)

[Initial LED at OV2+100 V](#)

[Final Pedestal 1](#)

[Final LED 1](#)

[Final Pedestal 2](#)

[Final LED 2](#)

[Final Pedestal Histograms](#)

[Final Pedestal Histograms at OV2+100 V](#)

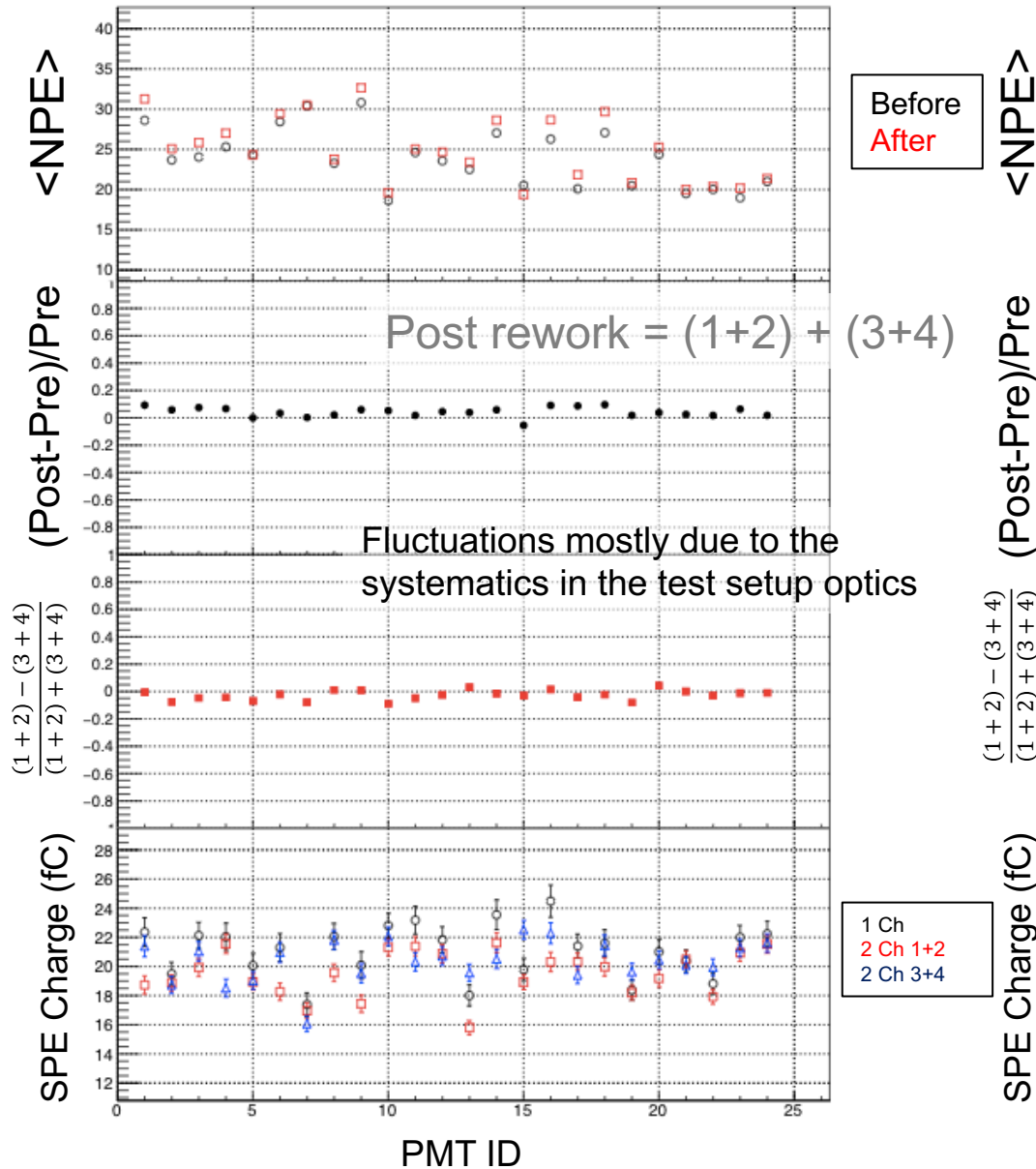
[Final LED at OV2+100 V](#)

[Initial-Final Comparison](#)

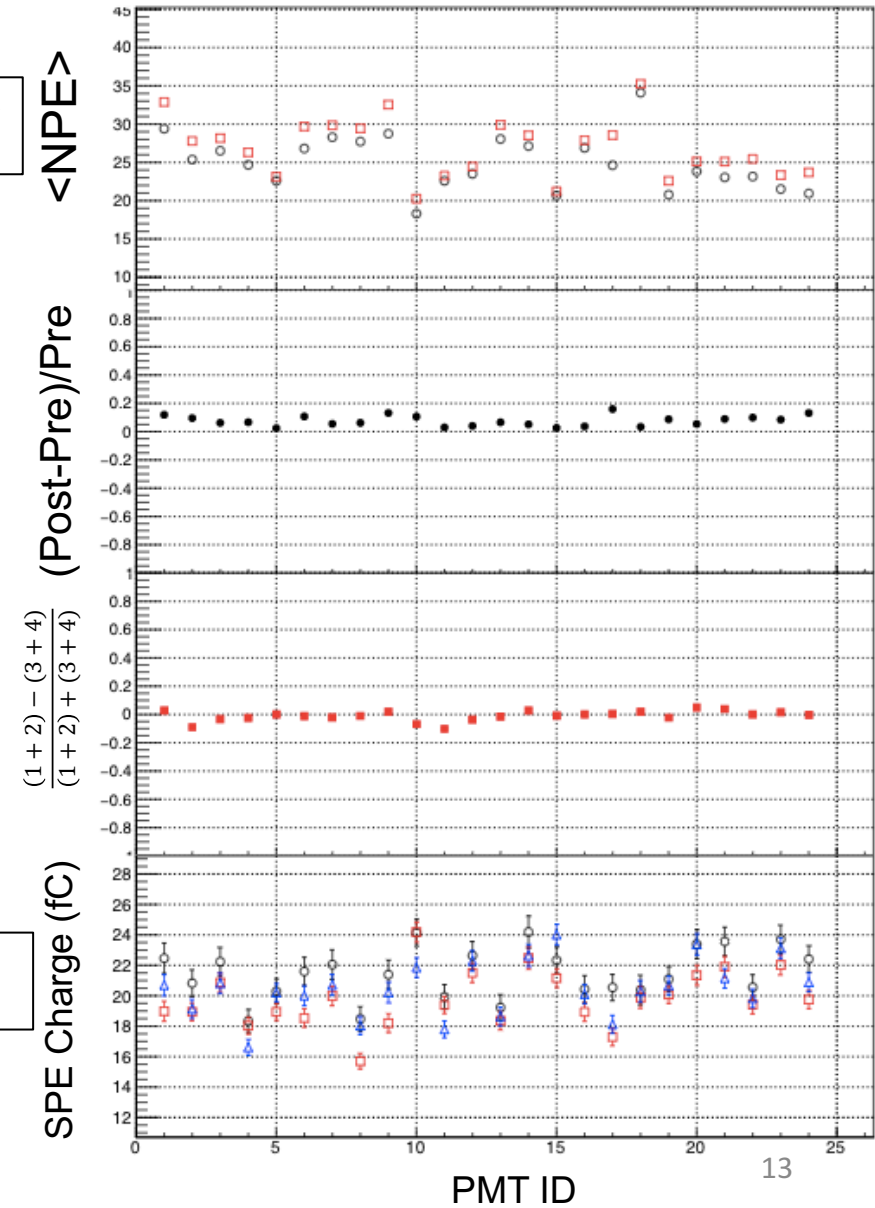
Links to multi-page pdf documents with plots

# PMT Box Rework: Examples of Rework Test Results

## HFP\_25\_Q3



## HFM\_23\_Q3



# 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

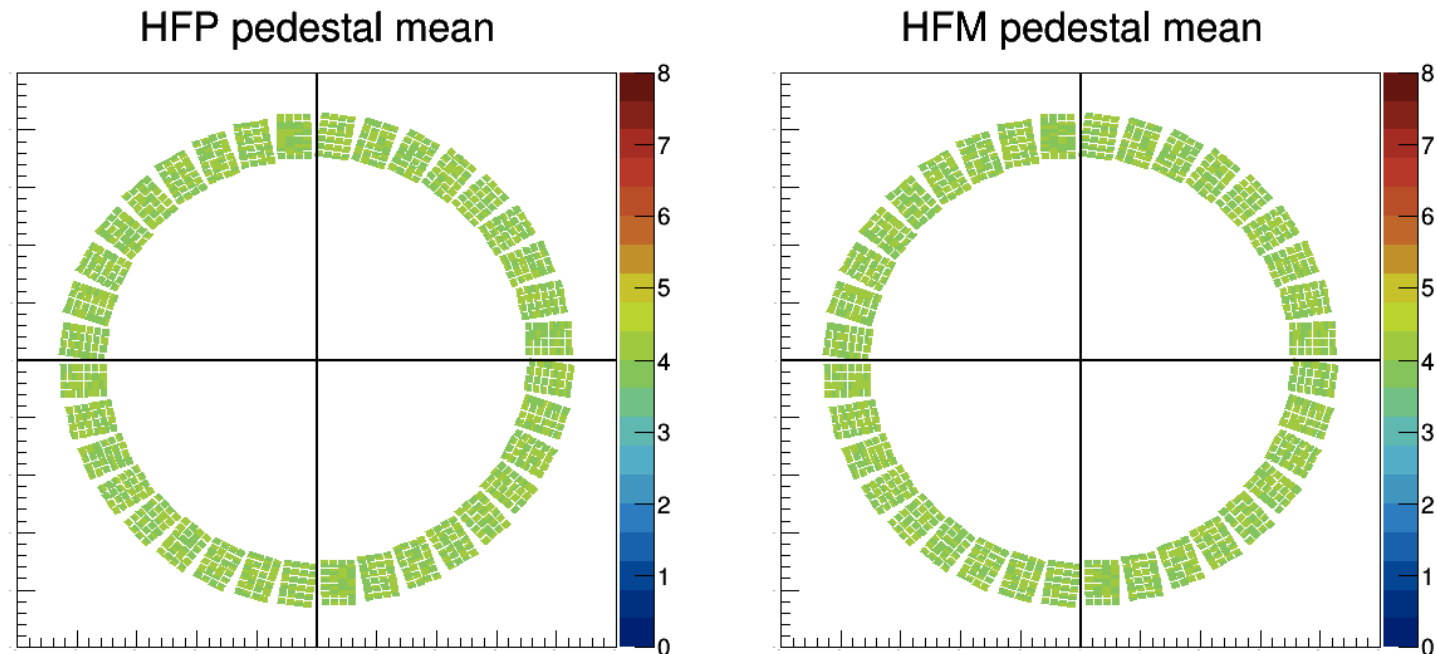
- Testing of control and data links to each crate
- Testing data readout with local pedestal and charge injection runs



# Commissioning of HF Phase I Upgrade with Local Data Taking

Local data taking types are:

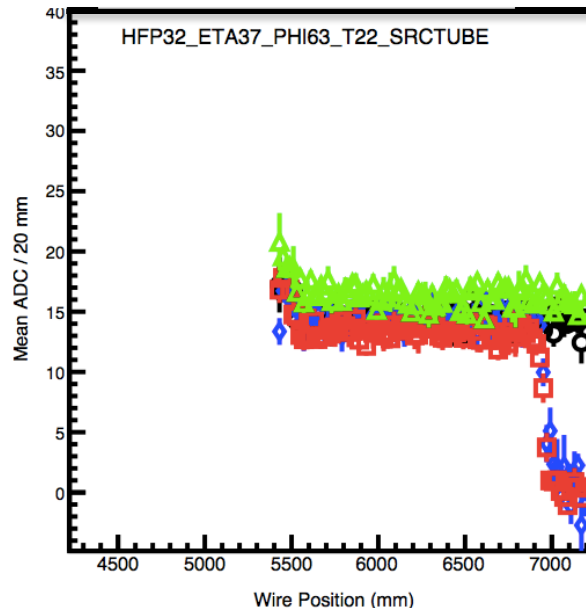
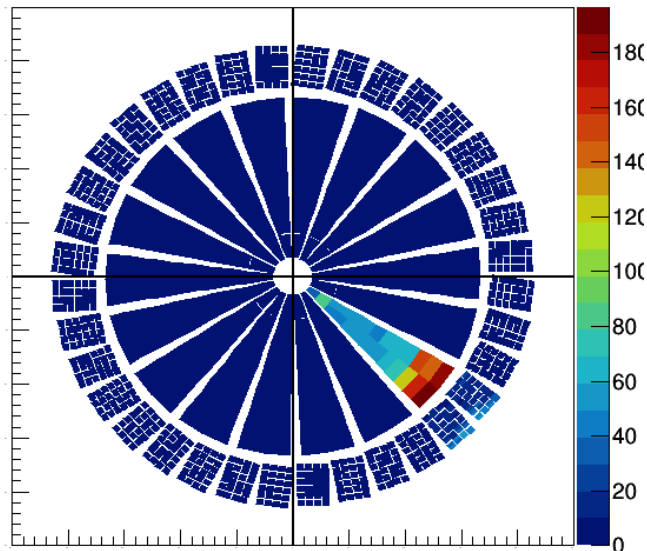
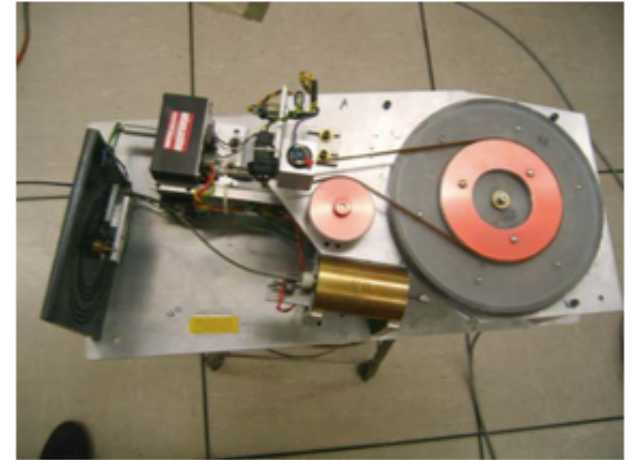
- Pedestal
- Internal Charge Injection (QIE10 has the ability to inject pulse internally)
- LED (LED light with tunable intensity is provided by the upgrade calibration unit)
- Laser (laser light is centrally injected into the HFs)



# Commissioning of HF Phase I Upgrade with $^{60}\text{Co}$ 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 - Em (1+2)**
- 2 - Had (1+2)**
- 3 - Em (3+4)**
- 4 - Had (3+4)**

# Summary

PMT box rework started – December 7<sup>th</sup> 2016

PMT box rework completed – February 10<sup>th</sup> 2017

Front-end electronics installation completed – February 13<sup>th</sup> 2017

All PMT boxes installed – February 16<sup>th</sup> 2017

First commissioning runs were taken – February 17<sup>th</sup> 2017

First radioactive sourcing runs were taken – March 10<sup>th</sup> 2017

HFs fully commissioned and in place – end of April 2017

**HF Phase I is ready for data taking.**