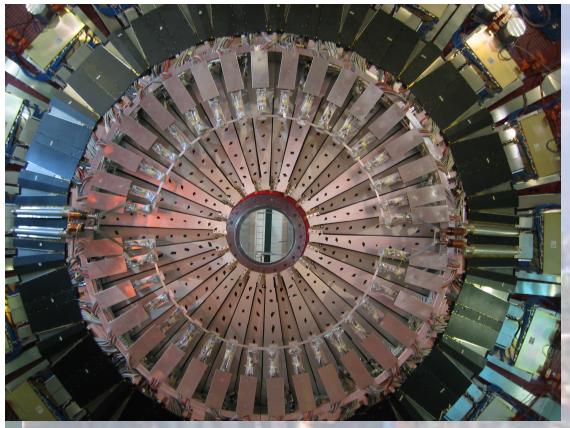


Performance and Upgrade plans for the CMS Hadron Calorimeter @ LHC

Sudan Paramesvaran (UC Riverside), on behalf of the CMS Collaboration

International Conference on High Energy Physics (ICHEP) 2012

Melbourne, AUS

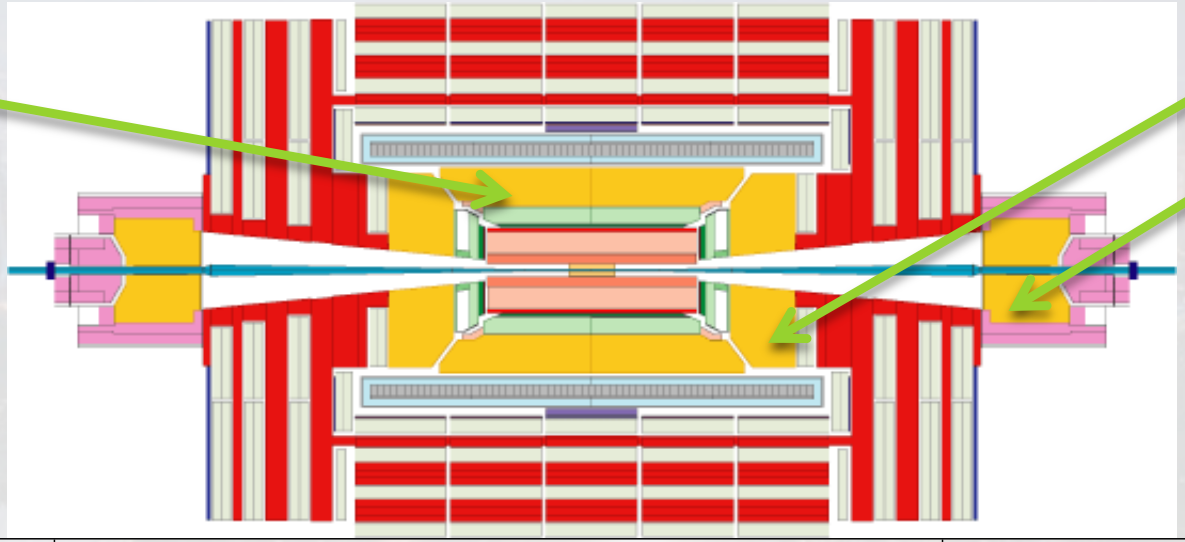
Introduction/Overview

- *Unprecedented conditions for CMS to operate in…will take a closer look at the performance in HCAL in this regime and then move on to the upgrade plans*

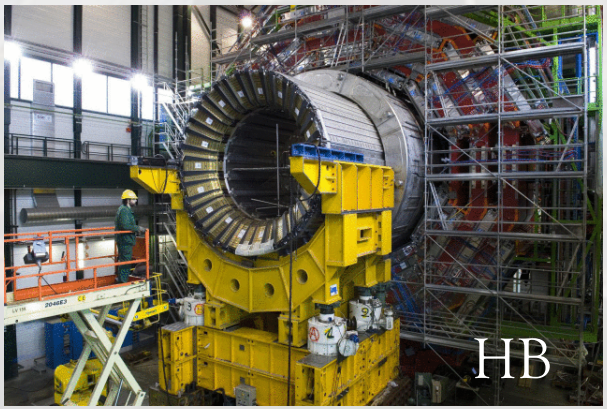
- *Performance:*
  - *HCAL overview*
  - *Signal Readout*
  - *Calibration*

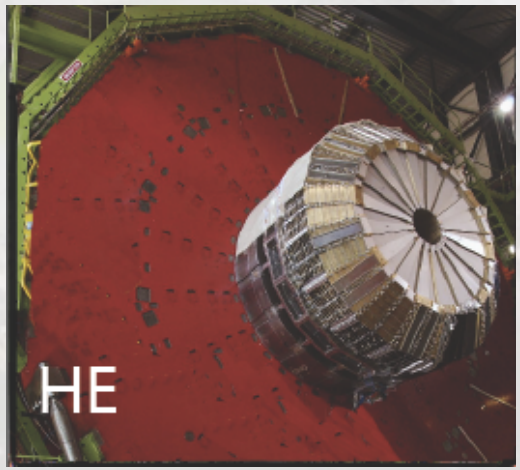
- *Upgrade plans*
  - *Motivation*
  - *Photodetectors*
  - *Back-end electronics*
  - *Testing at CMS*

HCAL Overview



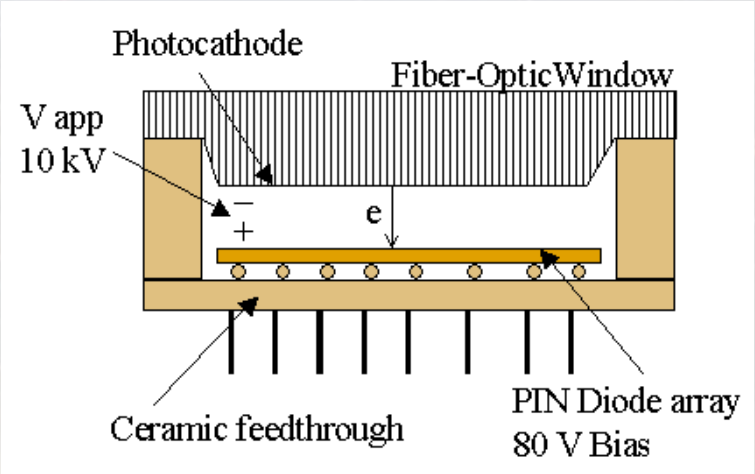
	Active Material	Absorber	Readout	No.of Channels
HB/HE	Scintillator Tile	Brass	Hybrid photo-diode	2592/2592
HO	Scintillator Tile	Brass	Hybrid photo-diode	2160
HF	Quartz Fibre	Steel	Photomultiplier tube	1728





HCAL Signal Readout

- Hybrid photo-diodes:
  - Designed to operate at magnetic fields up to 4T
  - HV of up to 8kV for 18 pixels
  - Gain of 2k – linear response over large dynamic range



- Photo-multiplier tubes:
  - Magnetic field strength less in forward regions – so can use conventional PMTs - Single anode

HCAL Calibration

• We monitor the stability of the gains of HPD's and PMT's using an LED system. This data is taken in the periods between fills.

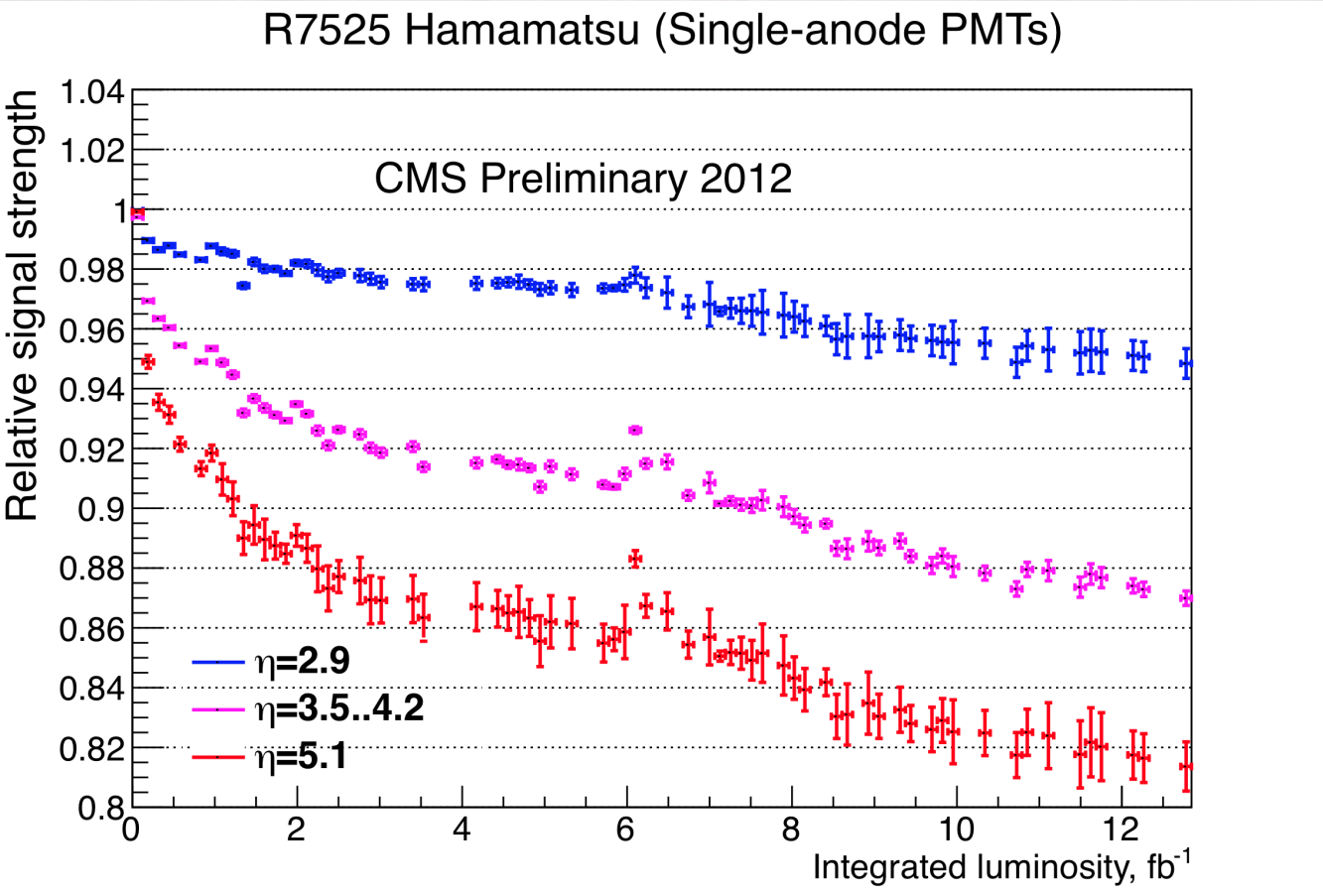
•Pedestals and signal timing is monitored using a Laser system – operates in the abort gap in the LHC orbit structure.

•We use collision data to obtain calorimeter response corrections

•This LED/Laser system has been essential in monitoring HPD and PMT affects to data-taking

Corrections are made to calibration coefficients to ensure the effect of gain shift and pixel response drift is accounted for.

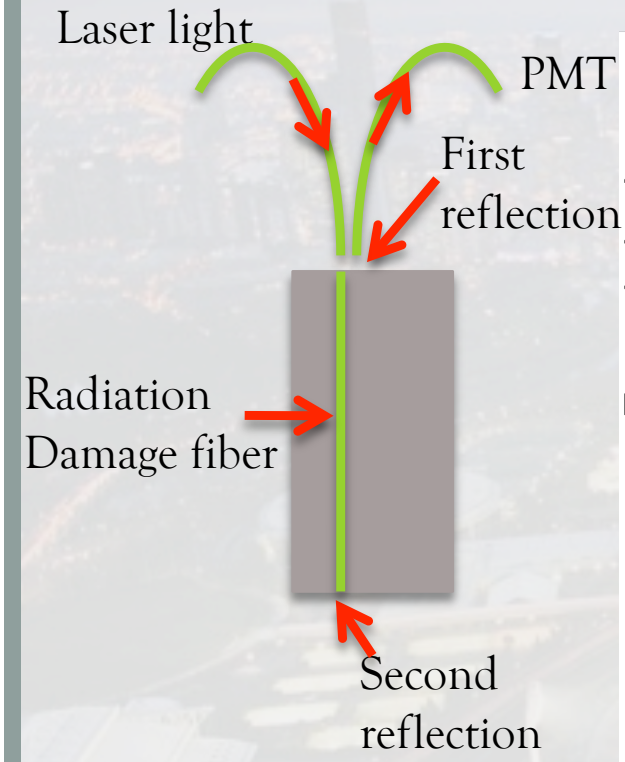
HCAL Calibration – HF PMT Gain Shift

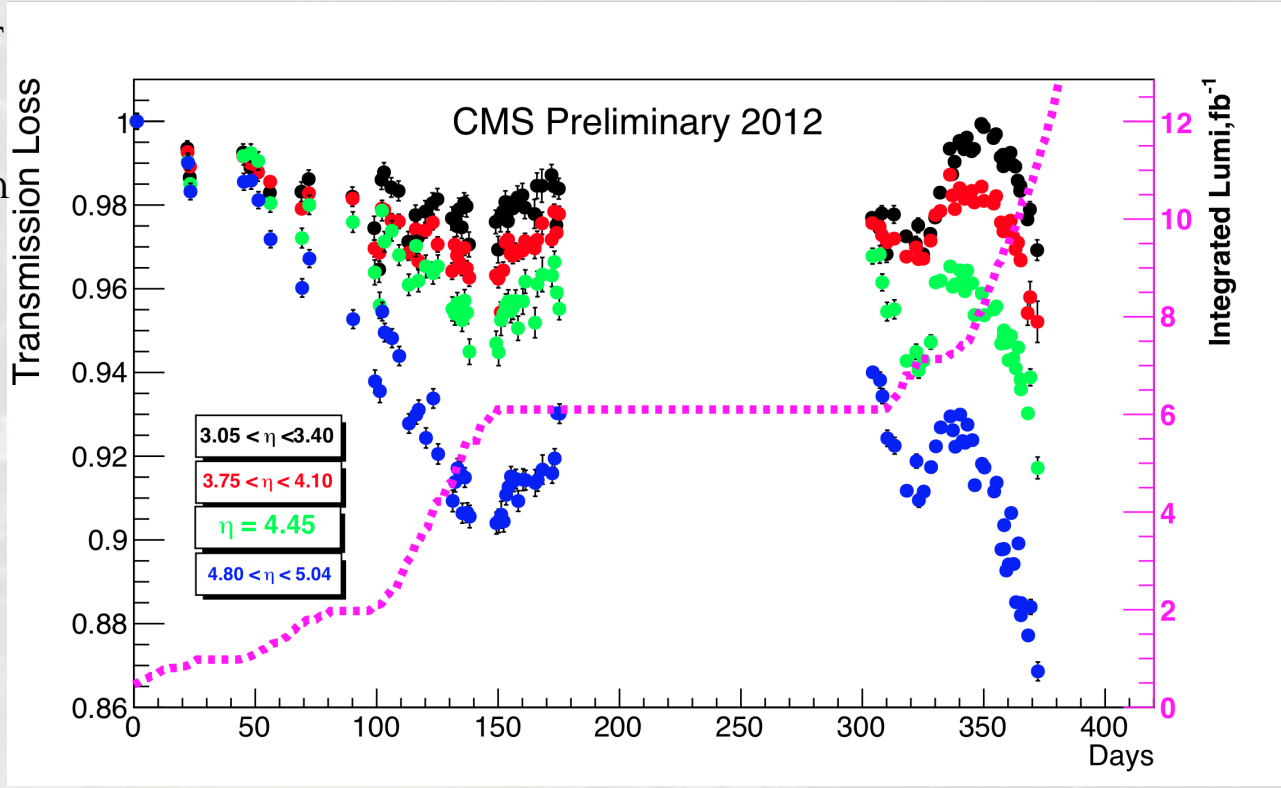


- Gain shift of HF PMT's as a function of integrated luminosity.
- The recovery is in line with periods of no beam in the LHC machine, i.e Technical Stops

The PMT gain stabilises as the rate of current drawn stabilises, with some delay.

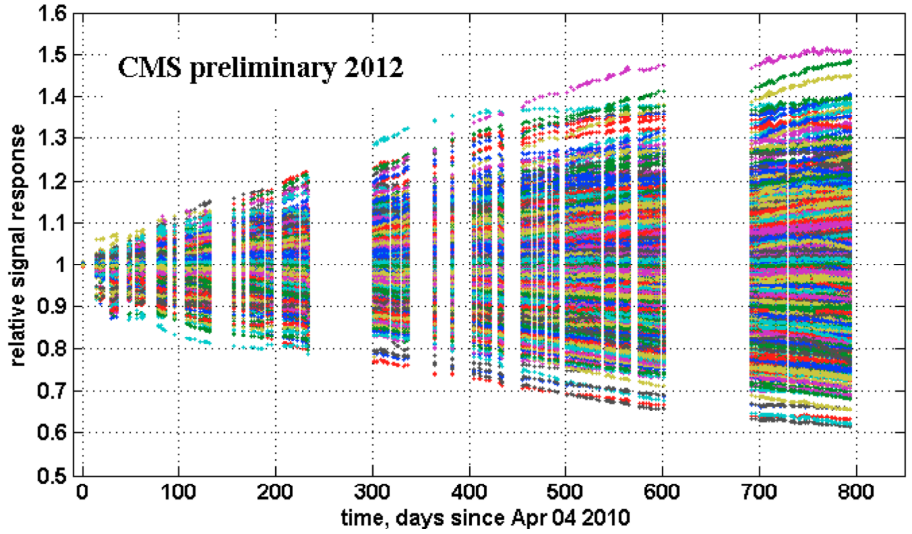
HCAL Calibration – Radiation Damage

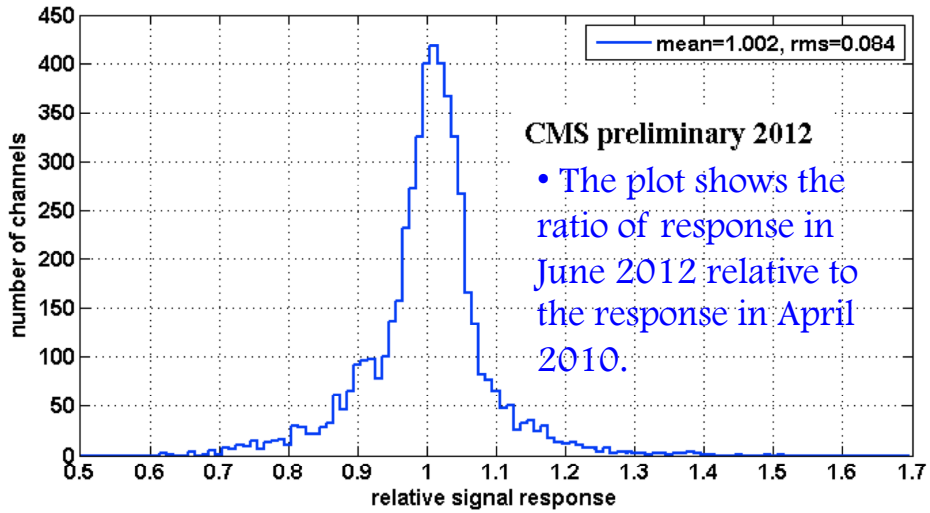




- This plot shows the transmission loss in the HF quartz fibers from 2011 to present, as a function of time.
- The recovery corresponds to periods without beam in the machine.

HCAL Calibration – HPD Response Drift





• The plot shows the relative response of HPD pixels in HBHE as a function of time, from April 2010 till June 2012. Response is normalized to its value in April 2010.

• This drift is an effect of the photo-cathode in the HPD, and is not luminosity dependent

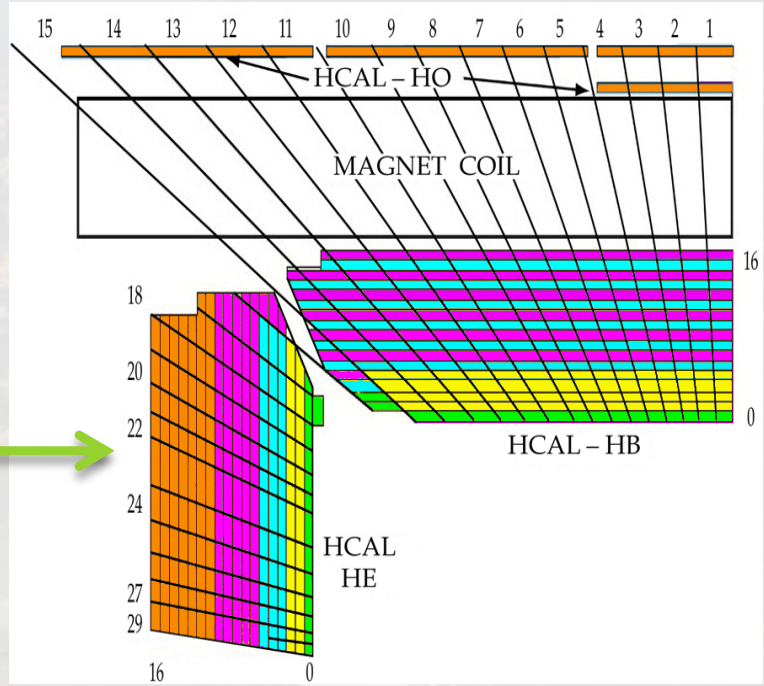
HCAL Upgrade Overview

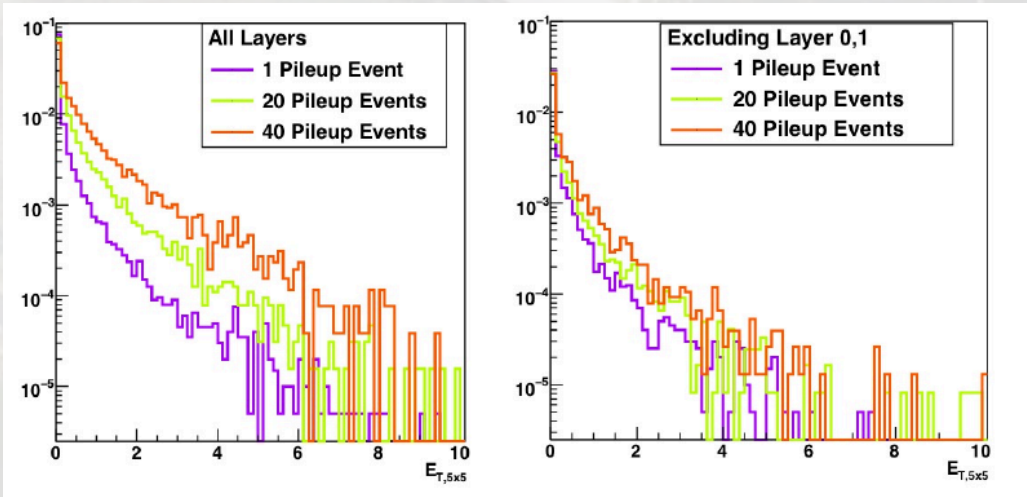
See:
J. Mans "Status and Plans for the Upgrades of the CMS detector"
F. Giordano "The status of the CMS Pixel upgrade detector"
I. Furic "Evolution of the CMS Trigger system"

CMS Upgrade

HCAL Upgrade Overview – HB, HE, HO

- HPD's to SiPM's
- Depth segmentation to cope with higher luminosities
- New backend electronics designed to provide enhanced information for the Trigger

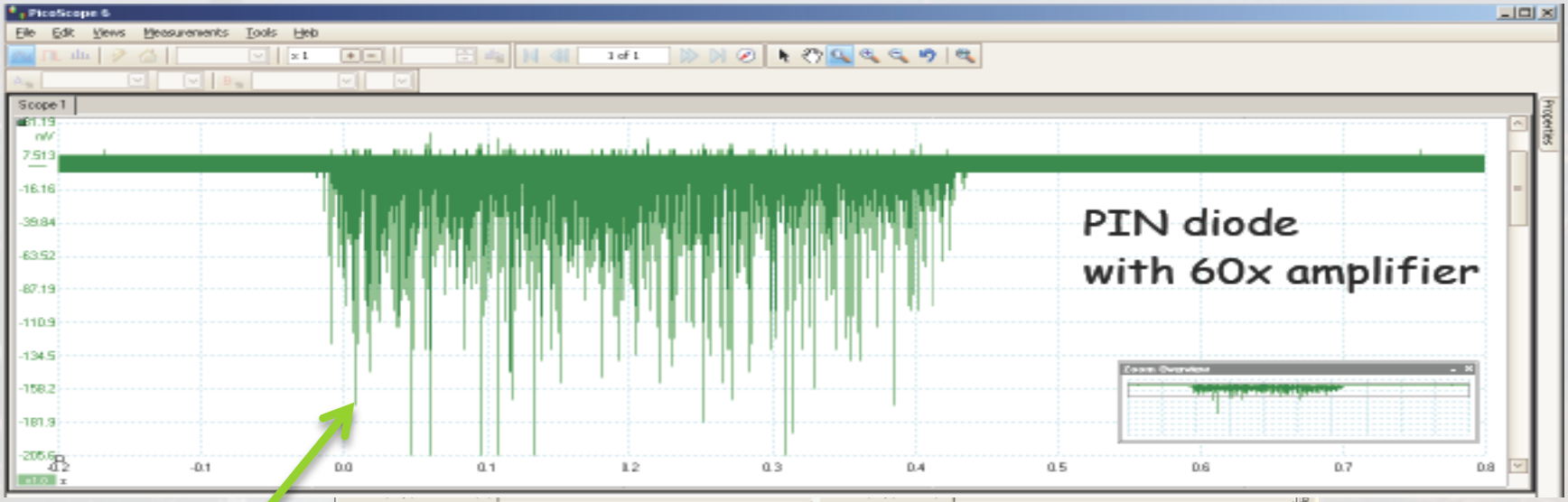




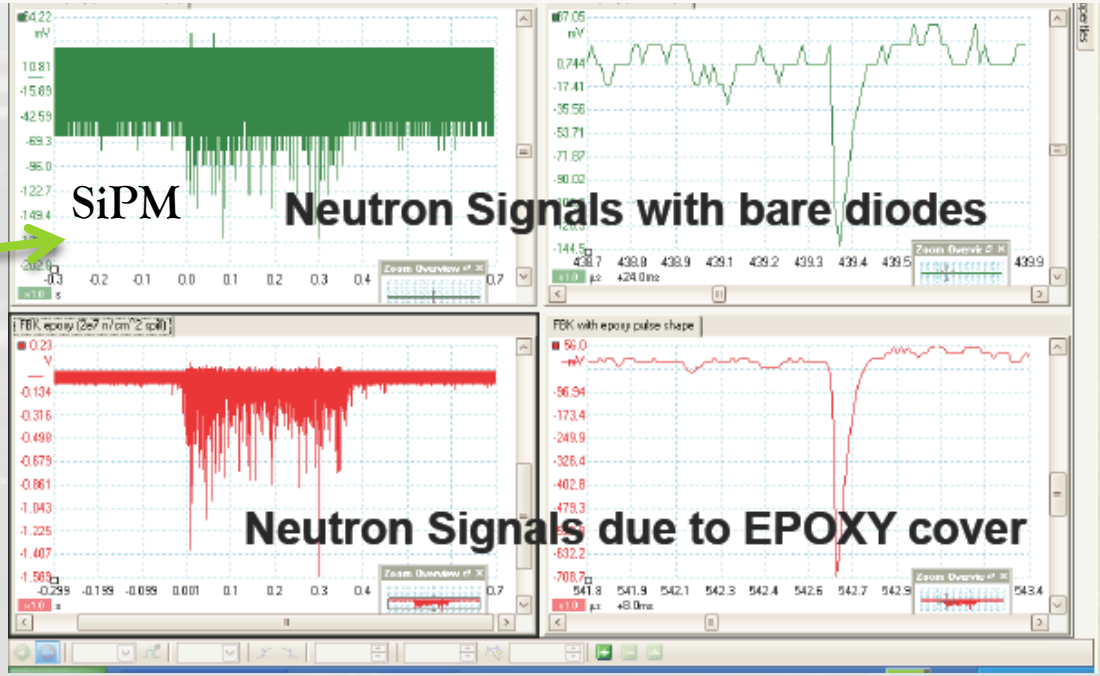
HCAL Upgrade : SiPM's

- SiPM's are pixelated avalanche photo diodes and run in Geiger mode
- Compact, can get 5k pixels per mm^2
- x10 improvement in signal to noise ratio, x2-3 in quantum efficiency, x100 higher gain
- Can operate at relatively low voltage < 100V (compare to 10kV for HPD's) – so no discharging
- Have operated prototype SiPM's on a section of the Outer Calorimeter for the last 2 years – have been stable in real running conditions.

HCAL Upgrade : SiPM's



Neutrons interacting and causing signal spikes; but in SiPM's these are limited to being in a single pixel

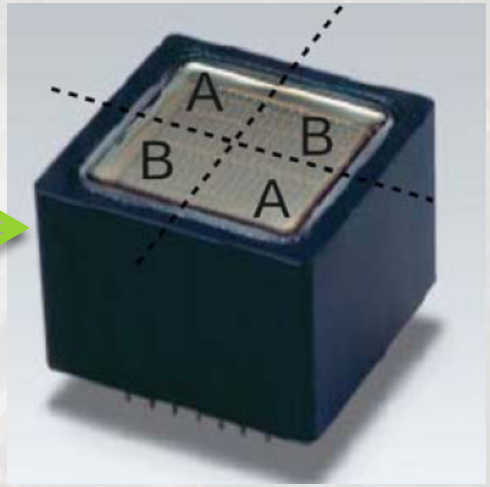


HCAL Upgrade Overview – HF

For the forward calorimeters:

- Single anode PMT's to multi-anode PMT's
  - Thinner glass windows
  - Metal envelopes
  - Increase in Quantum Efficiency – will improve S/N ratio

- The multi-anode design ensures superior identification and/or reduction in anomalous hits by comparing readouts from A and B



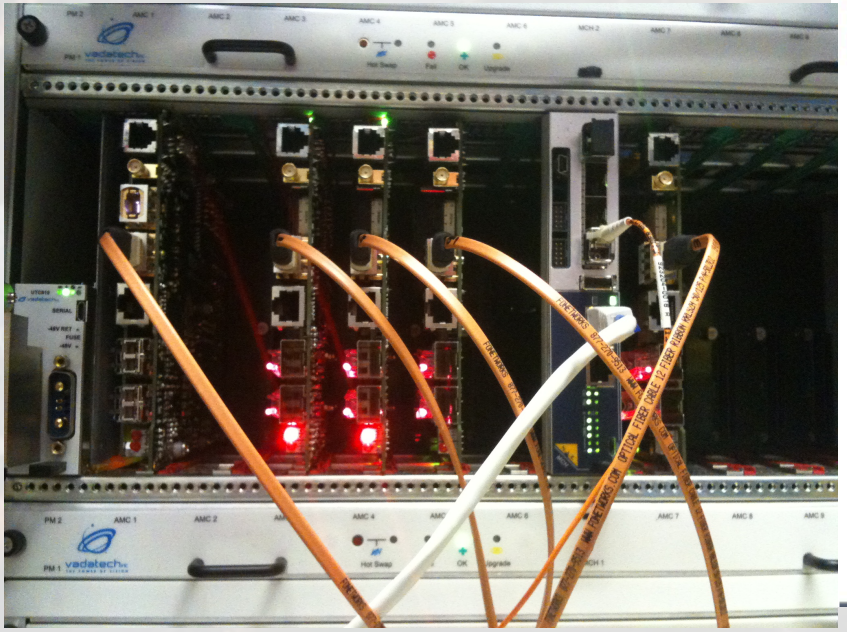
Have installed multi-anode PMT's in CMS in a section of HF – tried and tested in running conditions

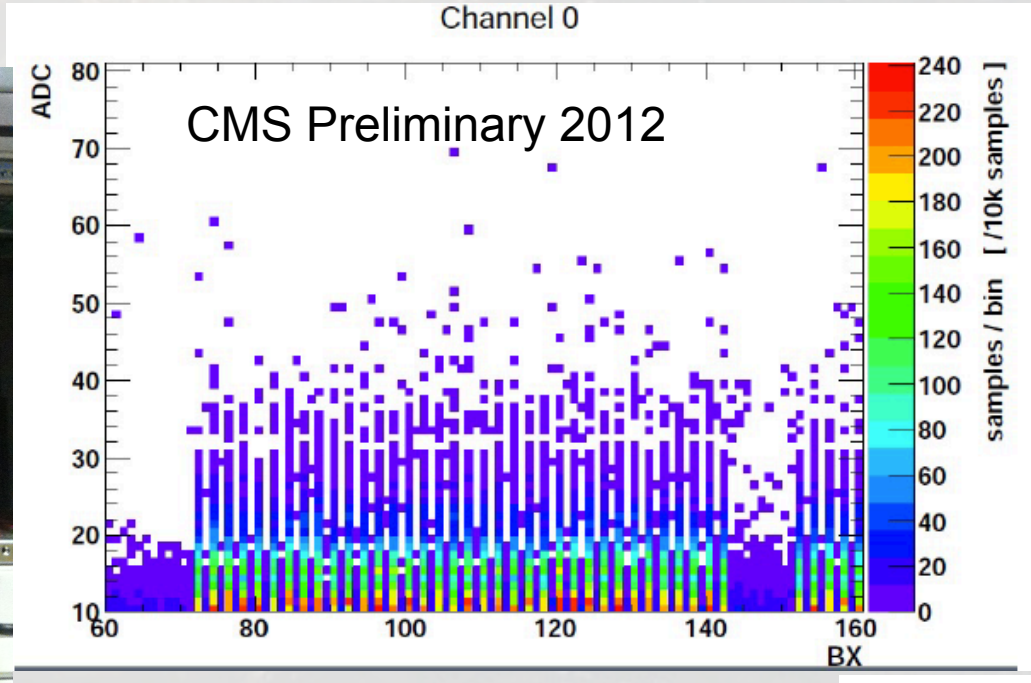
HCAL Upgrade : Backend - microTCA

- To handle the large volumes of data expected with higher luminosity have developed custom back-end electronics for readout system

- Based on the micro Telecommunication Architecture – new standard.

- Operation undertaken this year at CMS by using optical splitters on front-end signals from HCAL





Summary of performance & upgrade

- The CMS HCAL is a very stable detector delivering excellent quality data with high efficiency, and >99% of live channels

- The calibration system was used to identify potential affects with the photodetectors, which are now understood and accounted for in data-taking

- A comprehensive and detailed upgrade plan is underway to cope with
  - Increasing luminosity and high pile-up conditions
  - Existing limitations of current photodetectors

- Custom back-end and front-end electronics has been developed

- SiPM's tested in HO, m-anode PMT's tested in HF, microTCA crate reading out in CMS now.

Summary of proposed timescale

- LS1 (2013/2014), Year End Technical Stop (YETS 2015/2016), LS2 (2018)
- New multi- anode PMT's: for HF - LS1
- Replace HPD's with SiPM's
  - HO during LS1
  - HBHE during LS2
- Improve depth segmentation
  - HB/HE during LS2
- New Front-Ends – moving from ADC to TDC
  - HF during YETS
  - HBHE during LS2
- New Back-Ends (microTCA etc)
  - HF during LS1
  - HBHE during LS2

Back -Up

HCAL Upgrade : multi-anode PMT's

- Have installed multi-anode PMT's in CMS in a section of HF – tried and tested in running conditions

- Have seen stable gains after exposing them to over 6 fb^{-1} of integrated luminosity