CMS HCAL

- Hadron Calorimeter -

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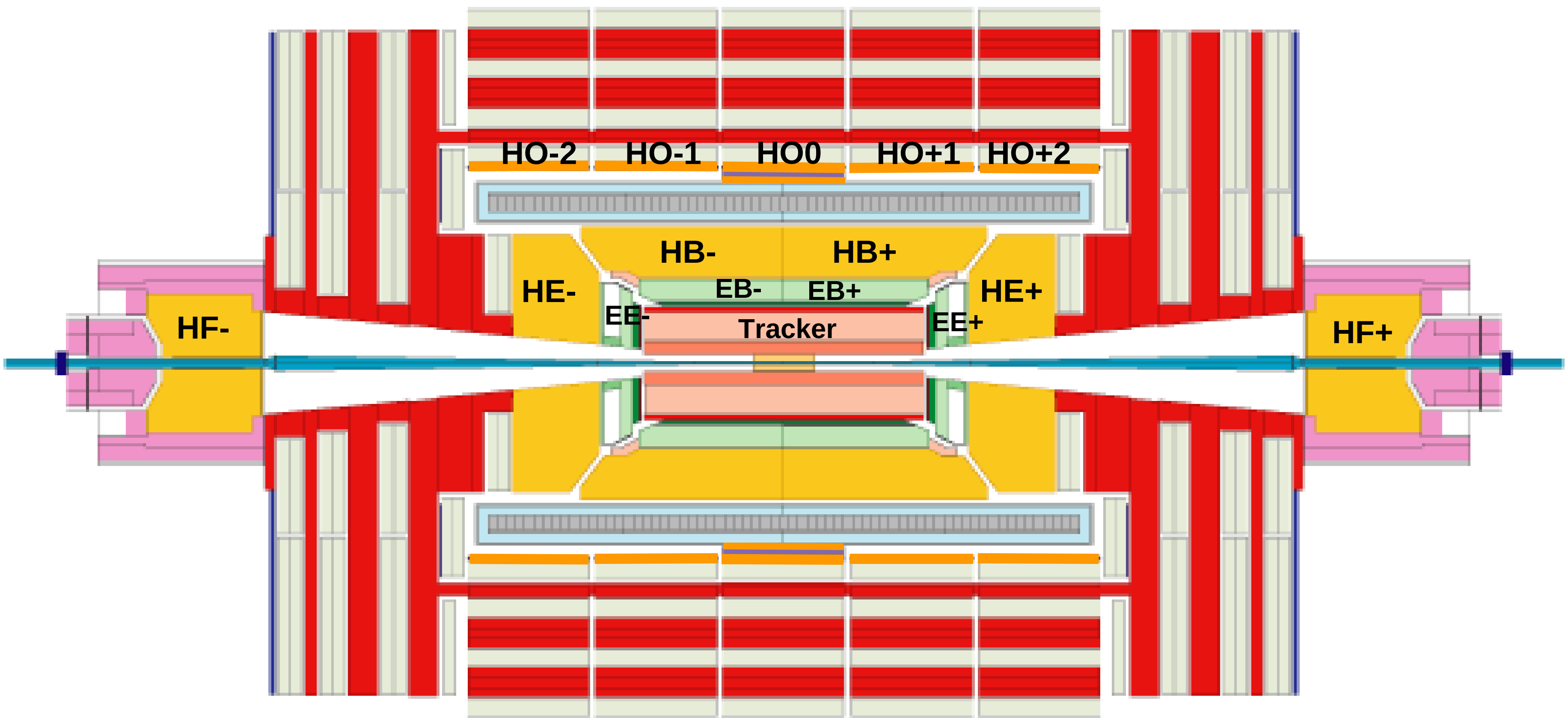
CMS Calorimeter

CMS Calorimeter (ECAL+HCAL) - Very hermetic (>10λ in all η, no projective gap)



HB Brass Abosber (5cm) + Scintillator Tile (3.7mm) Photo Detector (HPD) |η| 0.000 ~ 1.393
HE Brass Absober (8cm) + Scintillator Tils (3.7mm) Photo Detector (HPD) |η| 1.305 ~ 3.000
HO Scitillator Tile (10mm) outside of solenoid Photo Detector (HPD) |η| 0.000 ~ 1.305
HF Iron Absober + Quaartz Fibers Photo Detector (PMT) |η| 2.853 ~ 5.191

HCAL Barrel (HB)

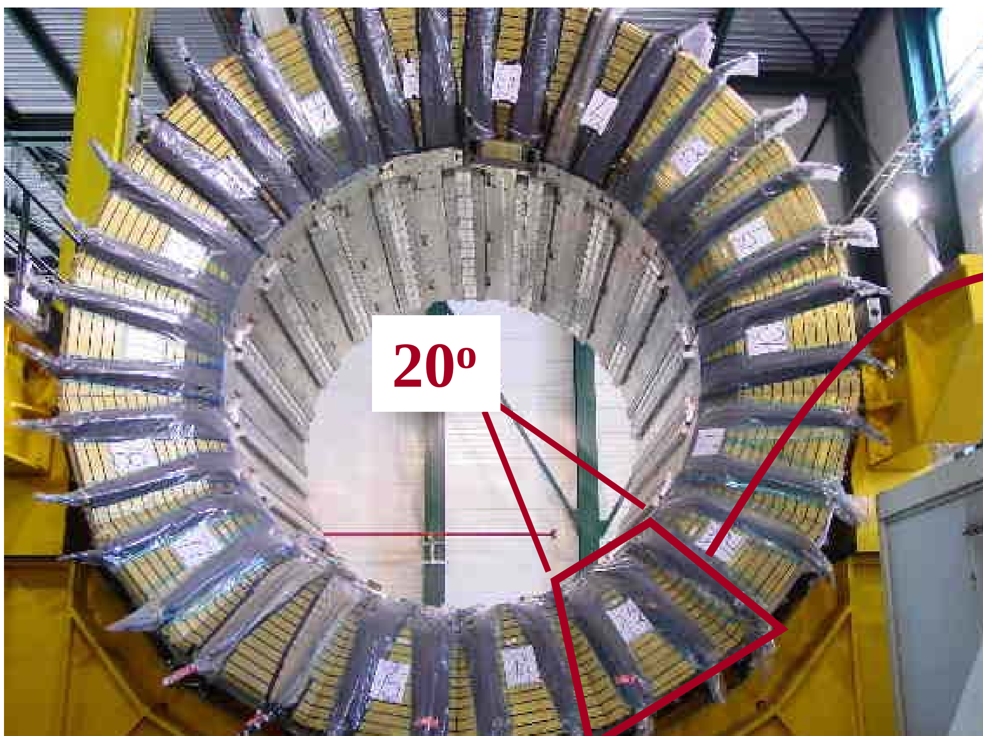
Sampling calorimeter: brass (passive) & scintillator (active)

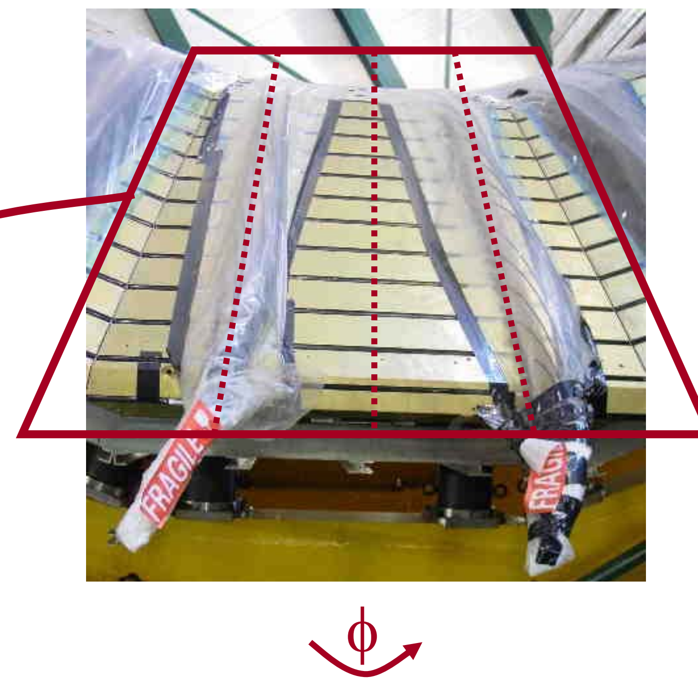
Coverage: $|\eta|<1.3$ segmentation: $\phi \times \eta$ = 0.087x0.087

Depth: 5.8 λ_{int} (at η=0)

π resolution: ~ 90 %/ $\sqrt{E}$

17 longitudinal layers





HCAL Endcap (HE)

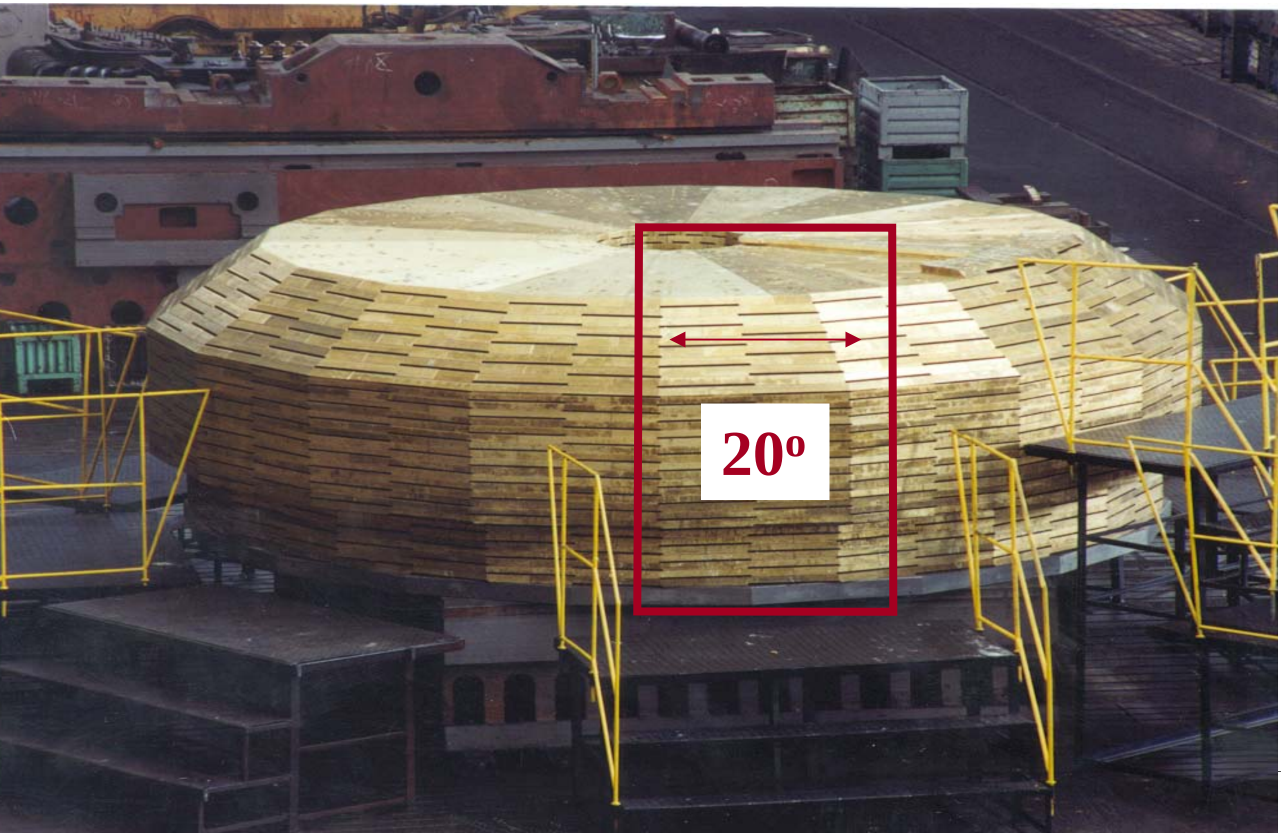
Sampling calorimeter: brass (passive) & scintillator (active)

Coverage: $1.3<|\eta|<3$

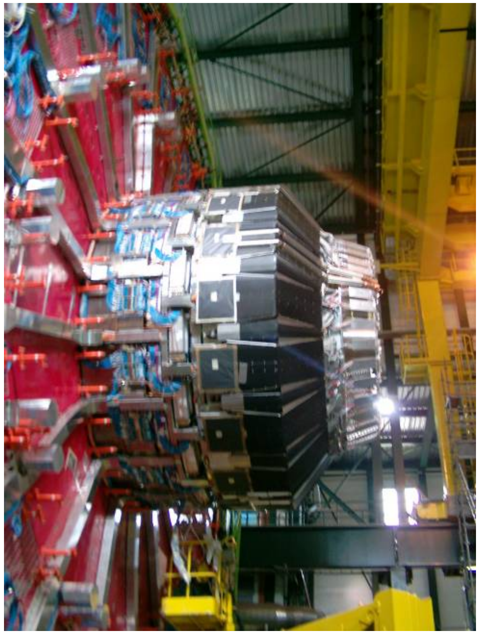
Depth: $10\ \lambda_{int}$

segmentation: $\phi \times \eta =$ 0.087x0.087 (larger at high eta)

π resolution: ~ $100\%/\sqrt{E}$



19 longitudinal layers



HCAL Outer (HO)

Sampling calorimeter: magnet+yoke (passive) & scintillator

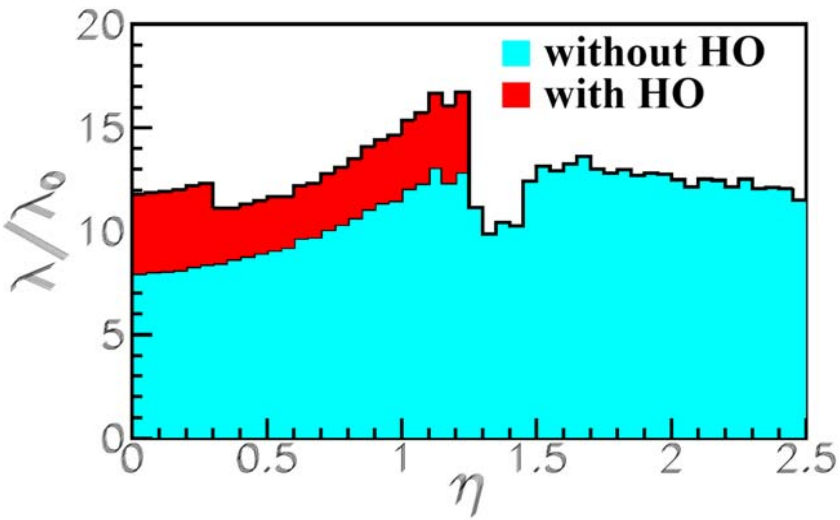
Coverage: $0 < |\eta| < 1.3$

1 or 2 longitudinal layers

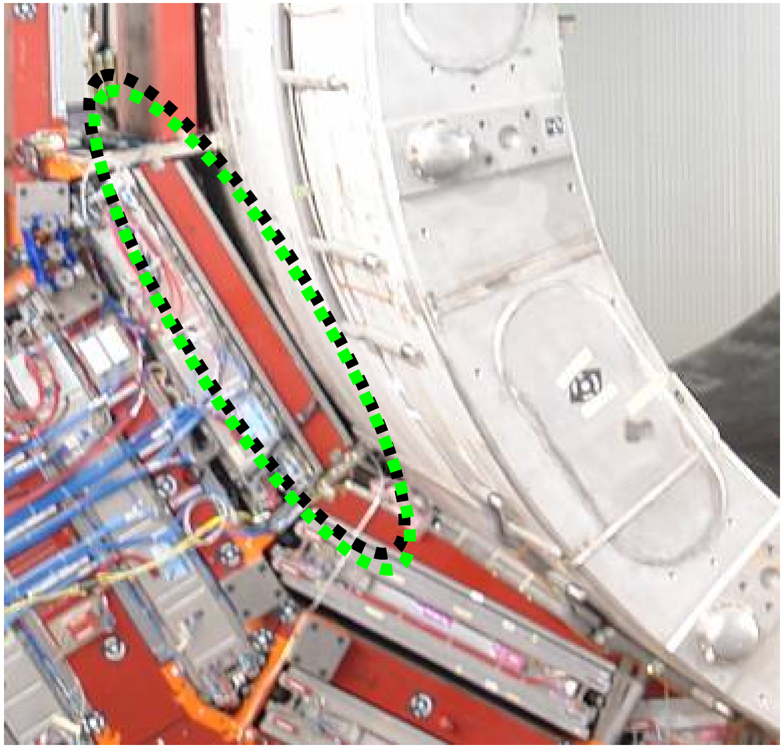
Depth: $10\ \lambda_{int}$

segmentation: $\phi \times \eta =$ 0.087x0.087

π resolution: $\sim 120\%/\sqrt{E}$



HO captures energy leakage from HB due to late shower.



Forward Calorimeter : HF

Iron absorbers, embedded quartz fibres, parallel to the beam

Fast (~10 ns) collection of Cherenkov radiation.

Coverage: $3<|\eta|<5$

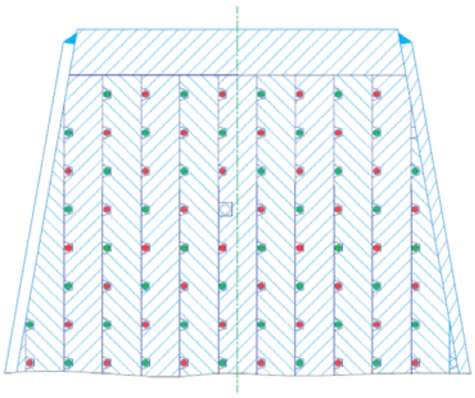
Depth: $10\ \lambda_{int}$

segmentation: $\phi \times \eta =$ $10^{o} \times 13\ \eta$ towers

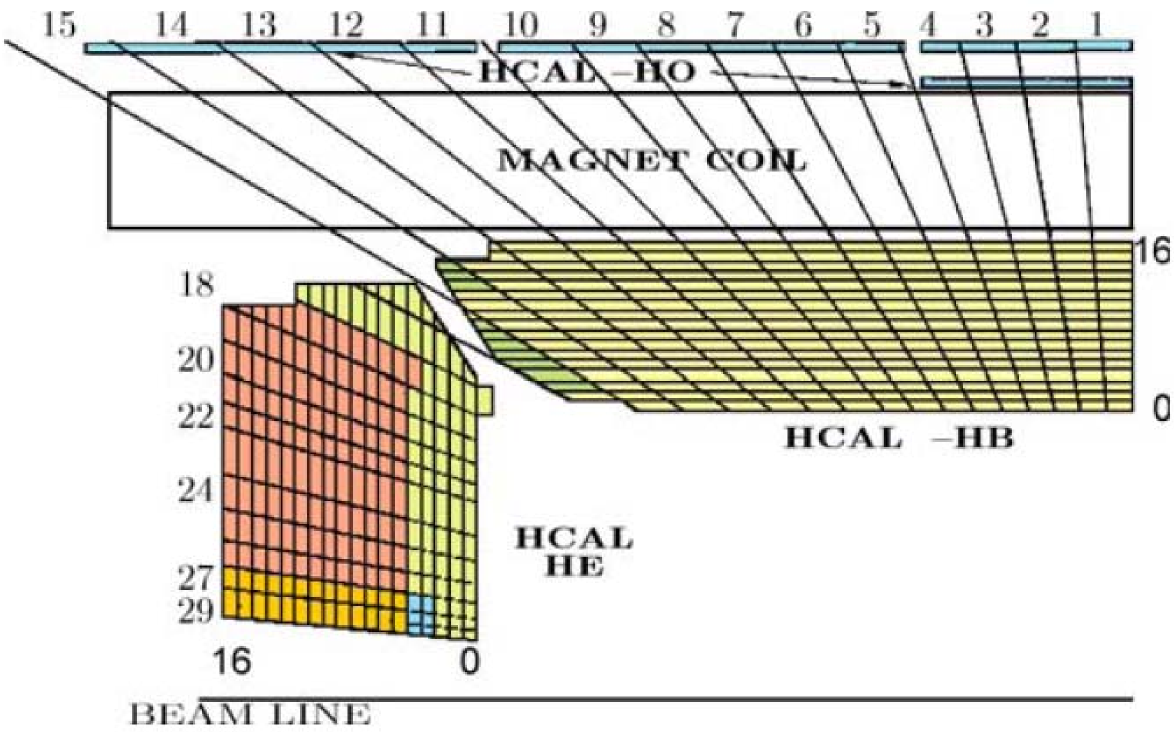
Depth Segmentation

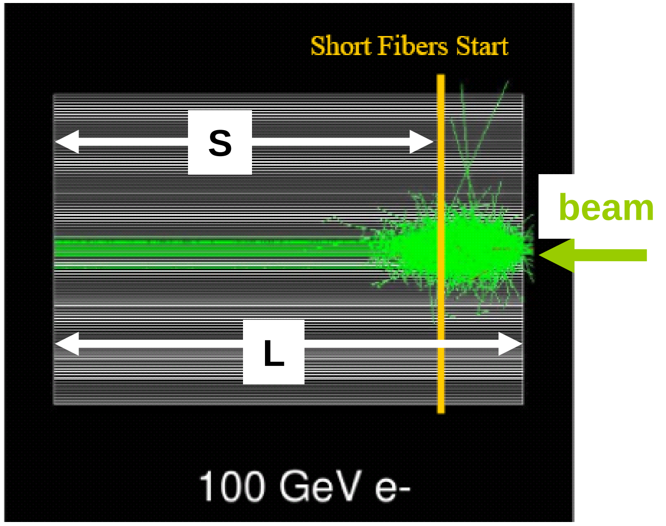
HB: Single depth
except iη 15, 16
HE: 1-3 depths
HO: single depth

HF view along beam



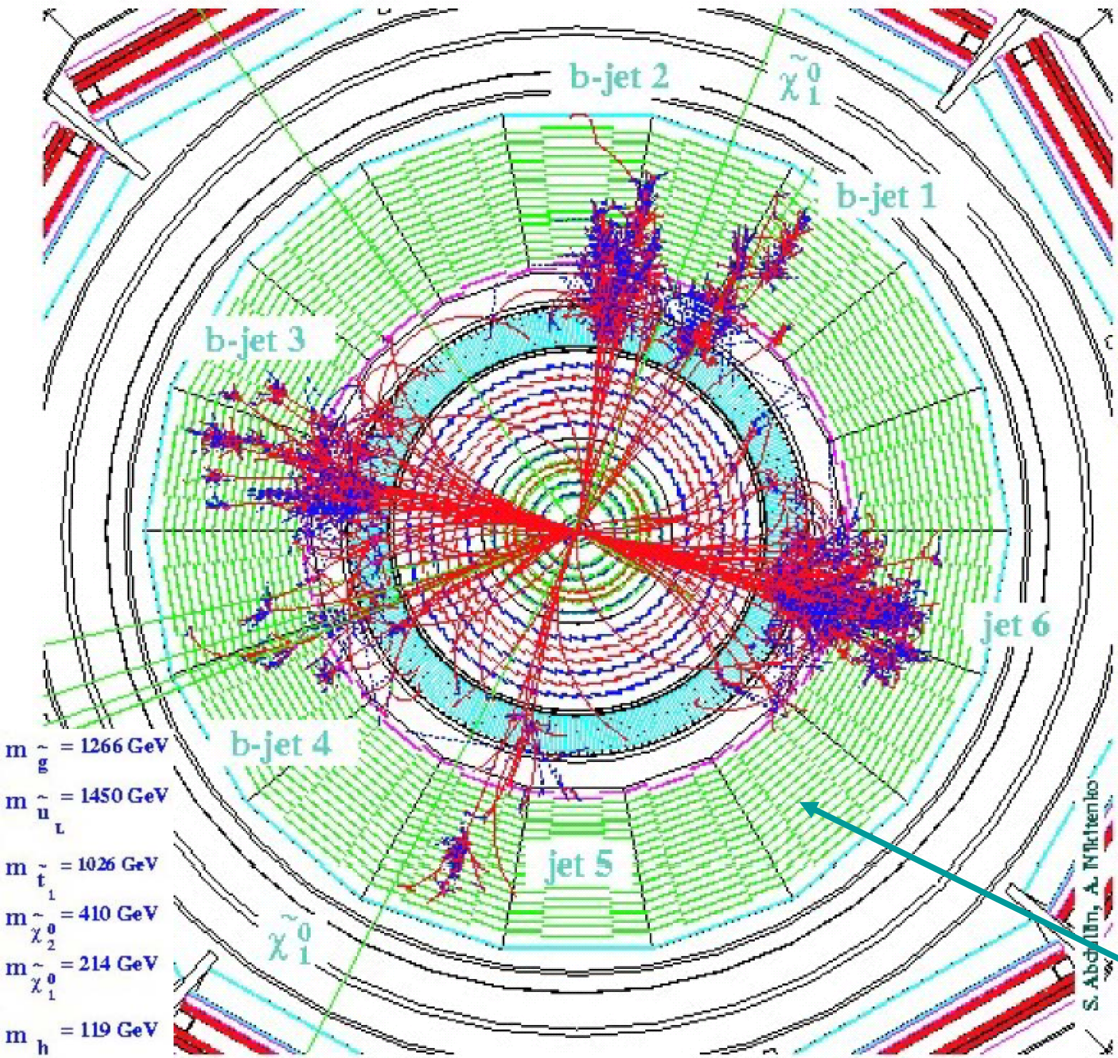
Long (full length) –green
Short (22cm shorter) – red
In 5x5mm grid





Goal of HCAL with ECAL

a SUSY event in CMS



Primary goal

Measure quarks and gluons
→ Jets

Measure "neutrino"s
→ Missing ET

Additional goal

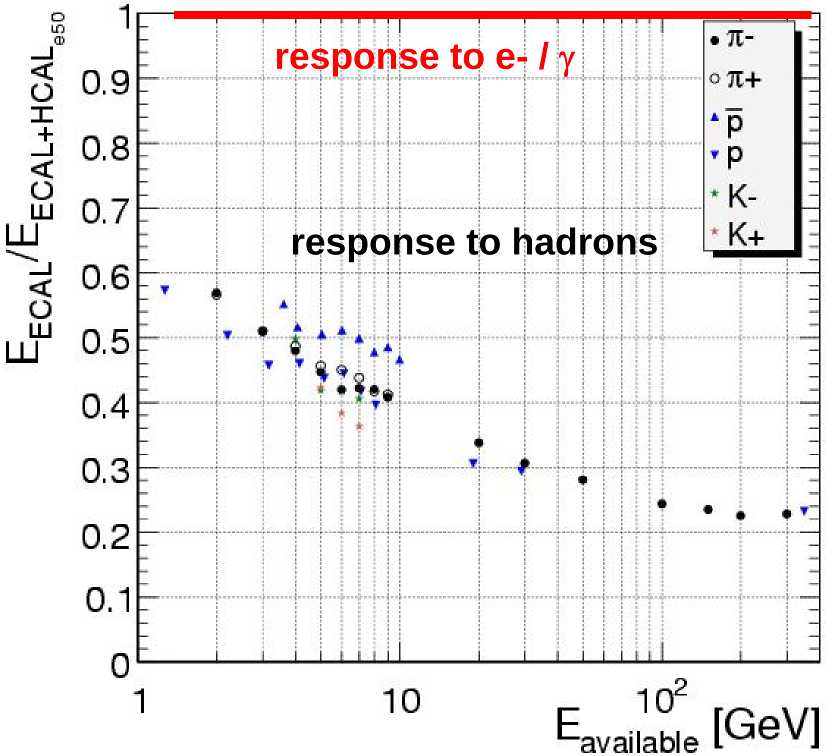
Electron/photon ID
→ energy only in ECAL, not in HCAL

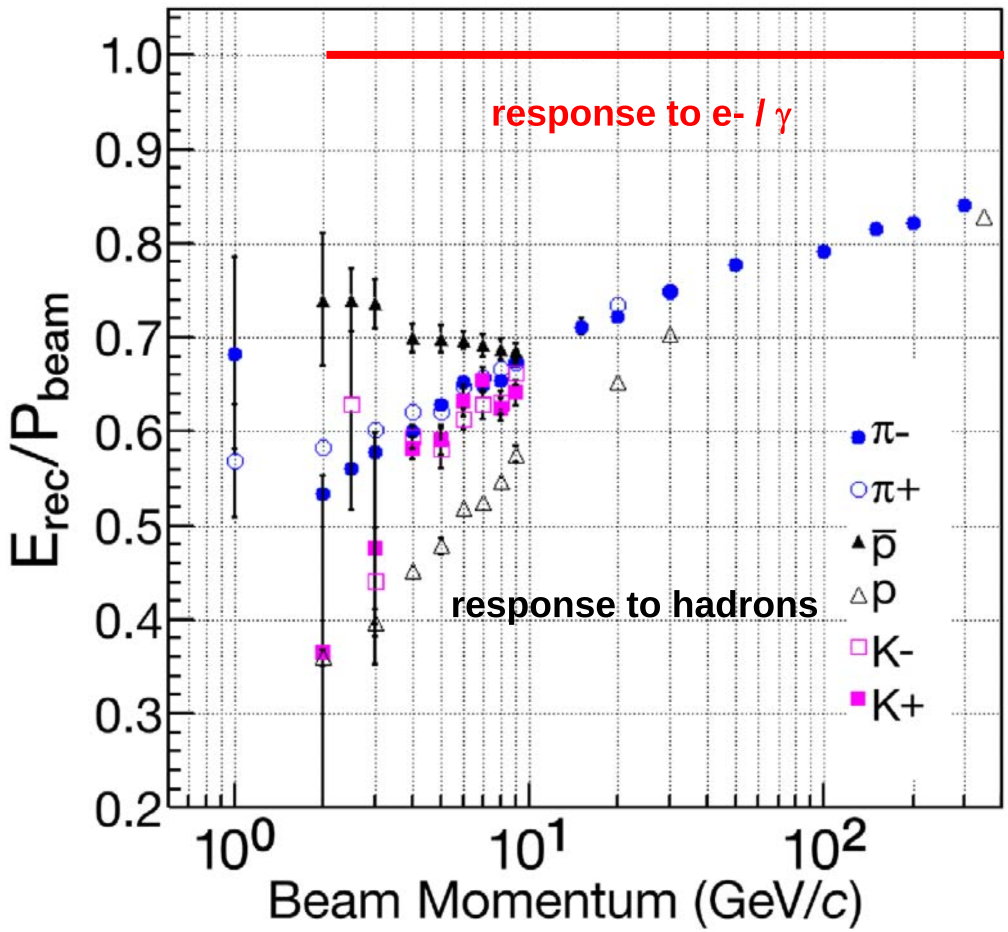
Muon ID
→ MIP signal or EM shower in HCAL

Tau ID
→ very narrow jets
(for hadronic tau decay)

Scintillators shown in green

EB+HB response to hadrons (TB2006)

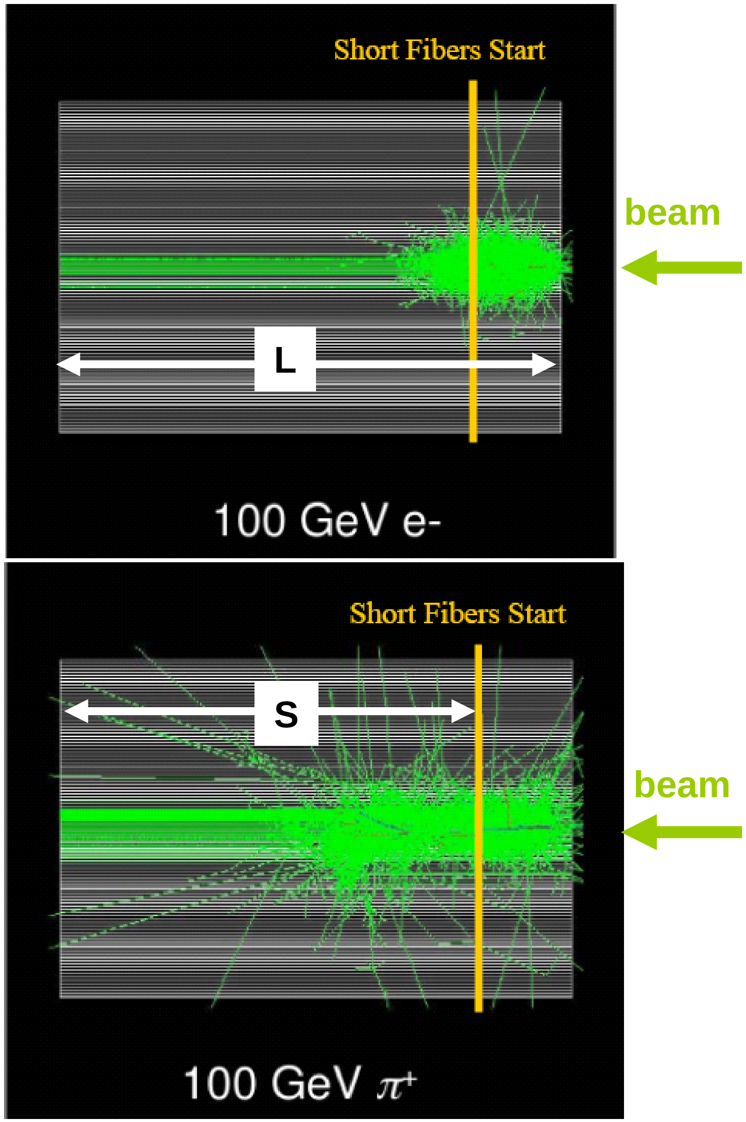


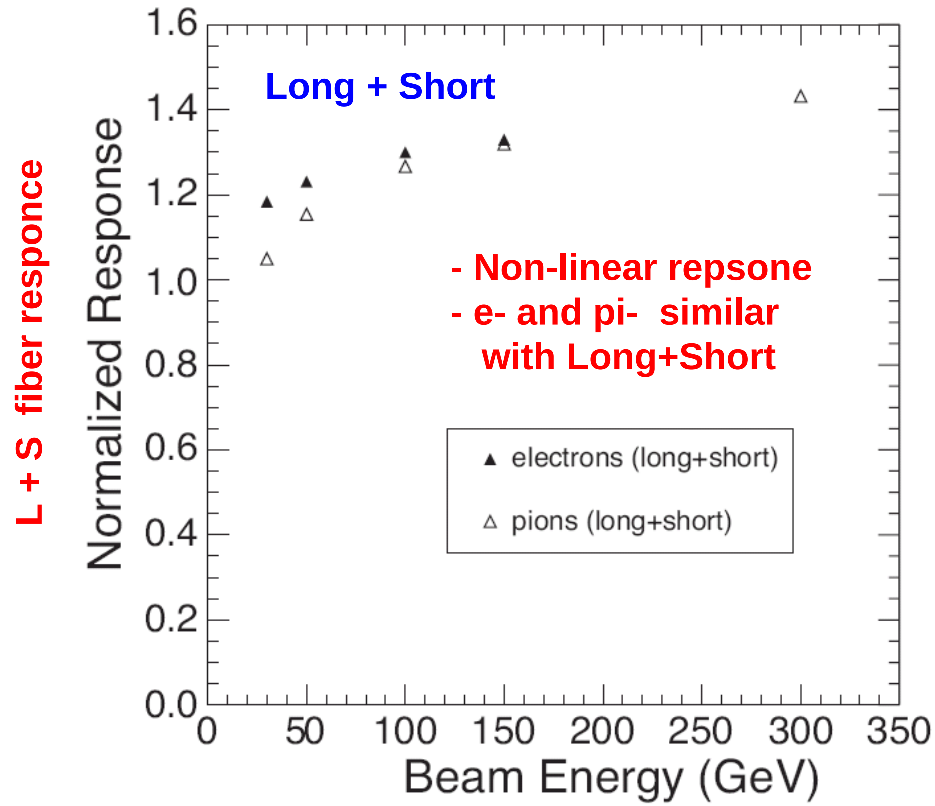


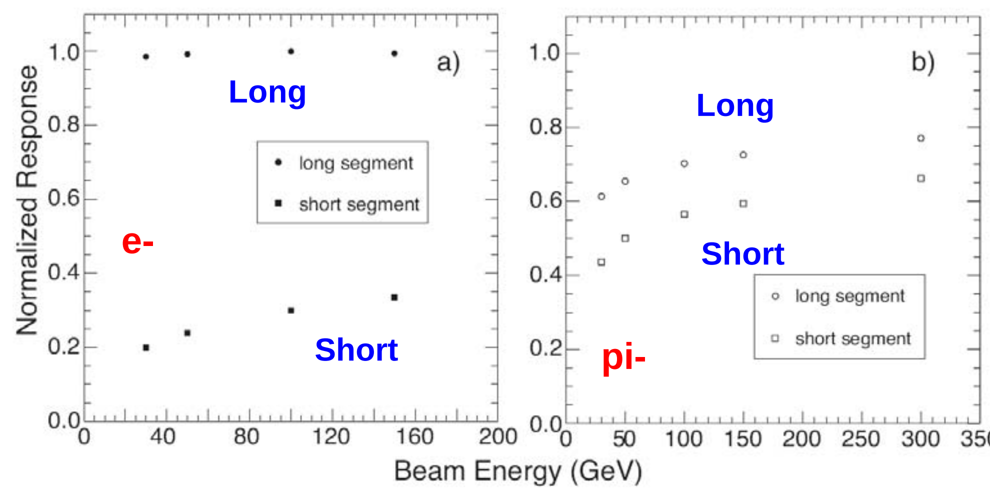
Reponse to hadrons:
- **20-60% of observed energy in EB**
- **non-linear response**

→ e/pi correction
→ jet & MET energy correction

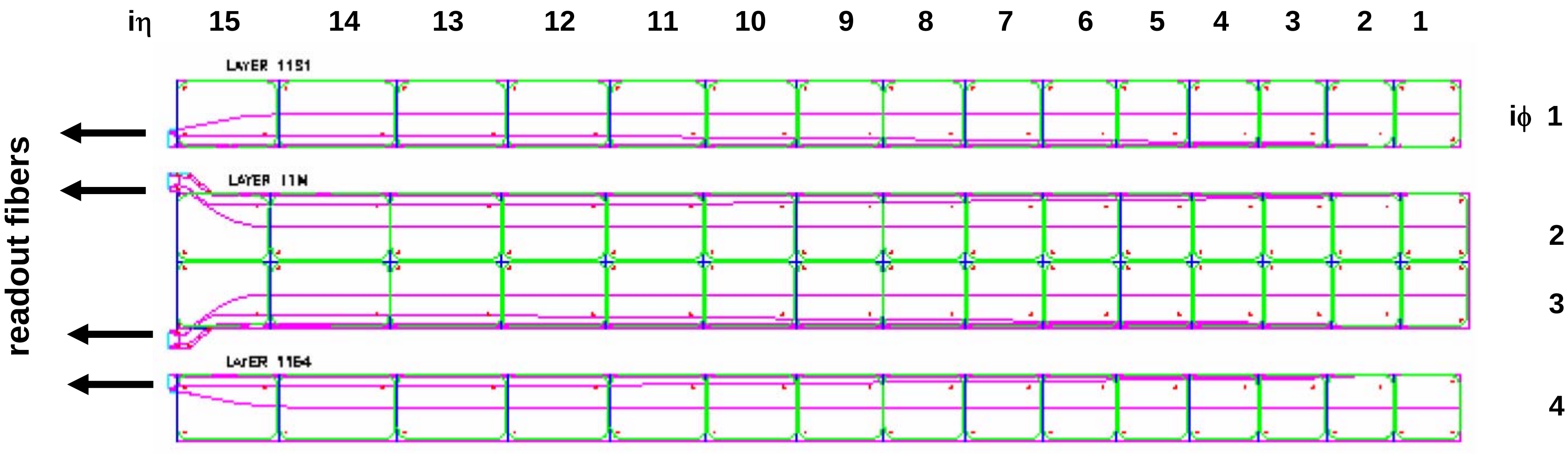
HF response (TB2004)



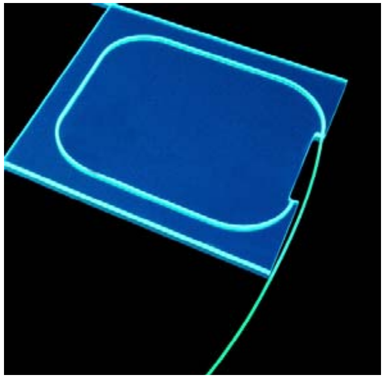




HB Scintillator Megatile (layer 11)

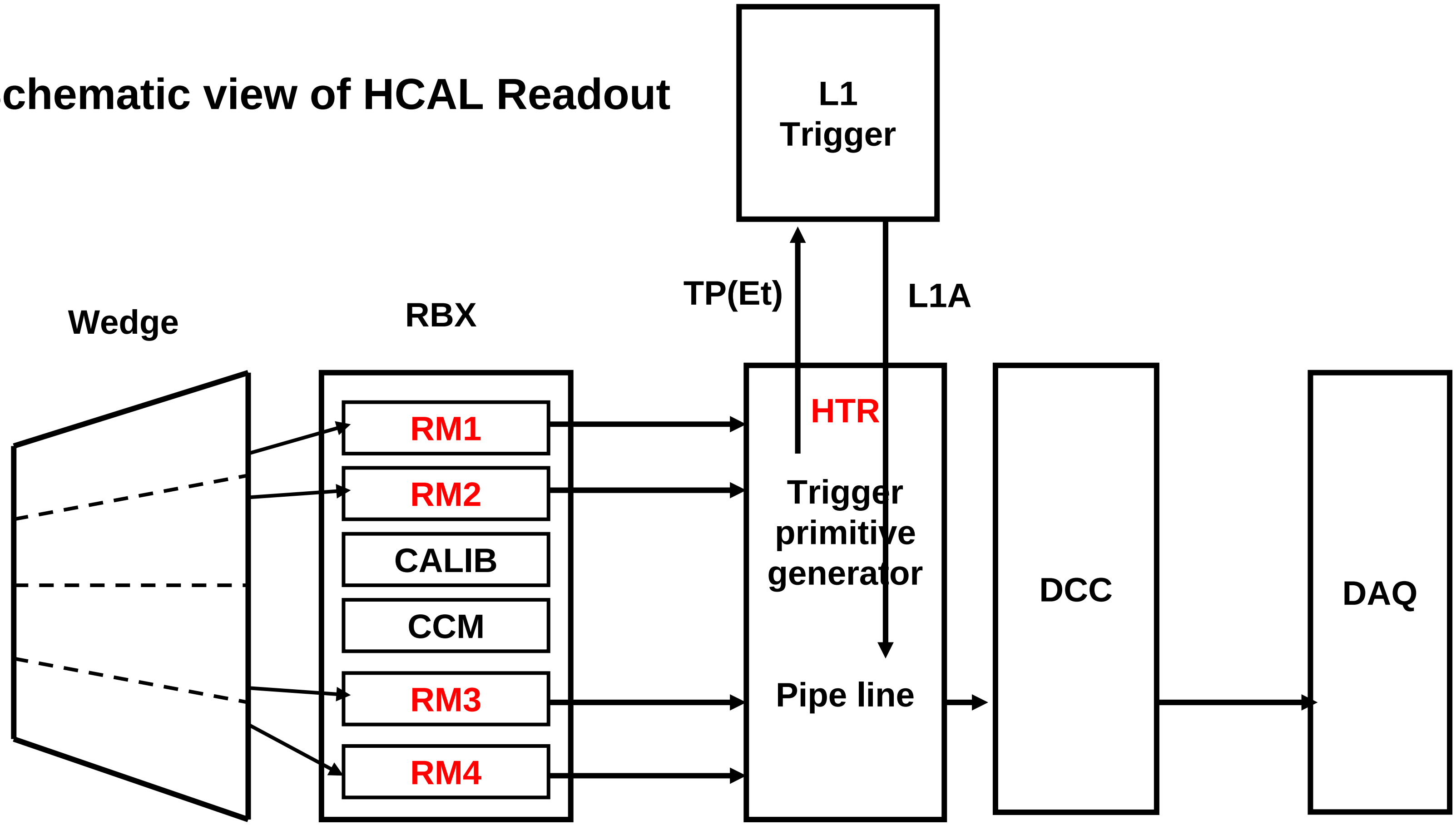


Installation of a central megatile



Wave length shift fiber is placed in a groove in each scitillator tile. About 5% of light is captured in the fiber.

Schematic view of HCAL Readout

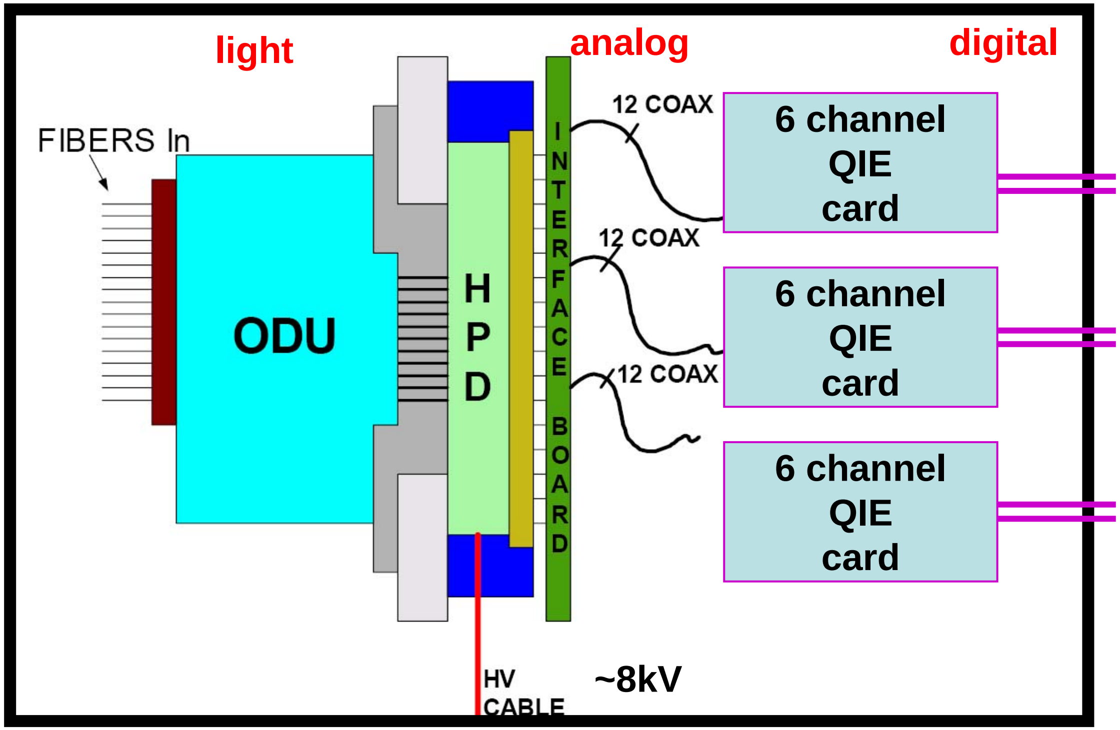


On Detector (UX5) | **Counting Room (UXC55)**

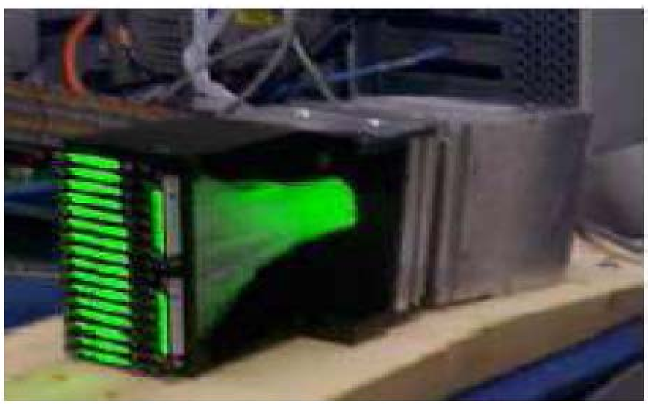
One wedge: 4 f-slices, 16 h
RBX: Readout Box (one per wedge)
RM: Readout Module (four per RBX)
1 HPD and 18 ch QIE(ADC)

HTR: Hcal Trigger Readout module
DCC: Data Concentrator Card

RM
readout module



ODU: optical decoder unit
16 fibers from each layer (HB)

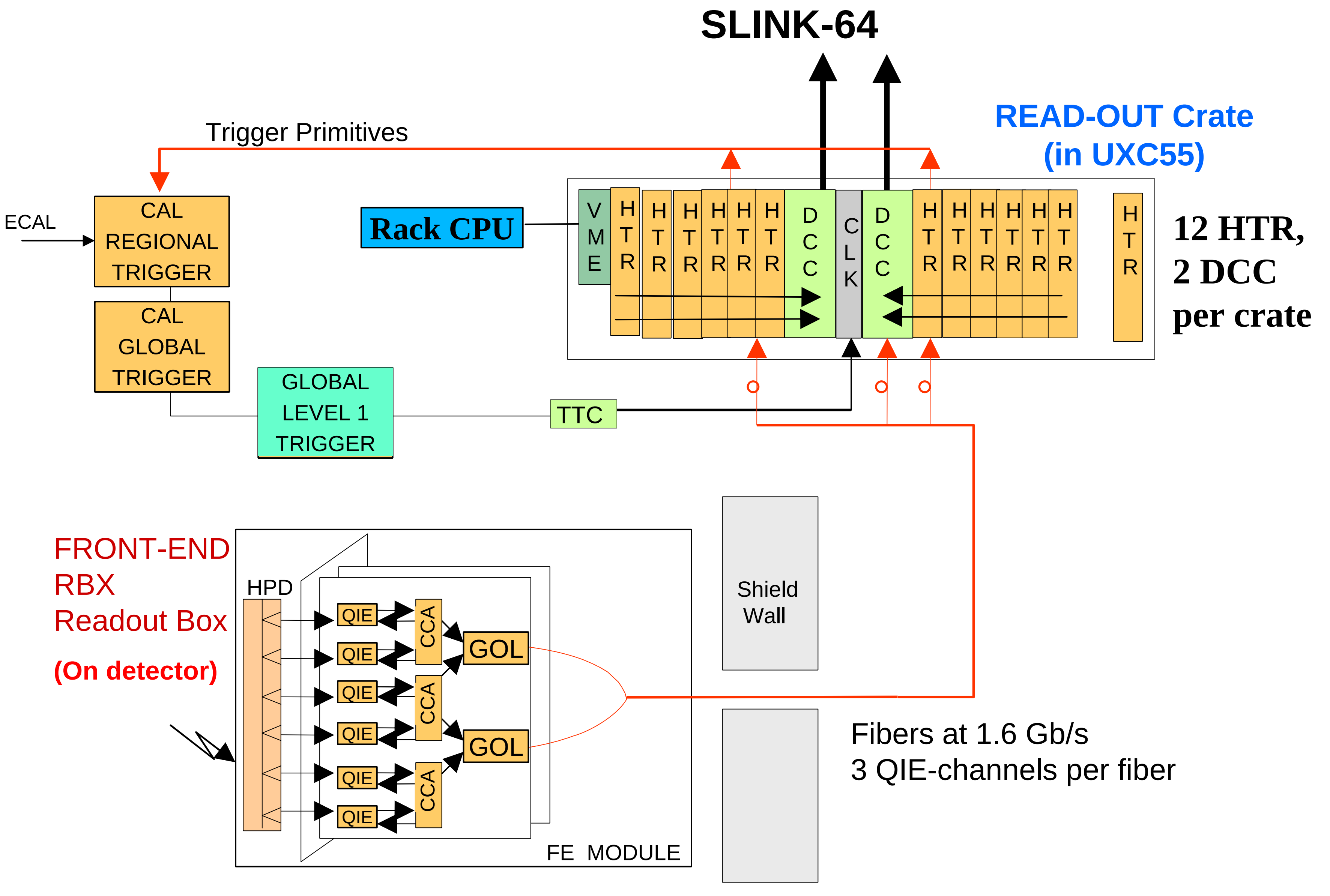


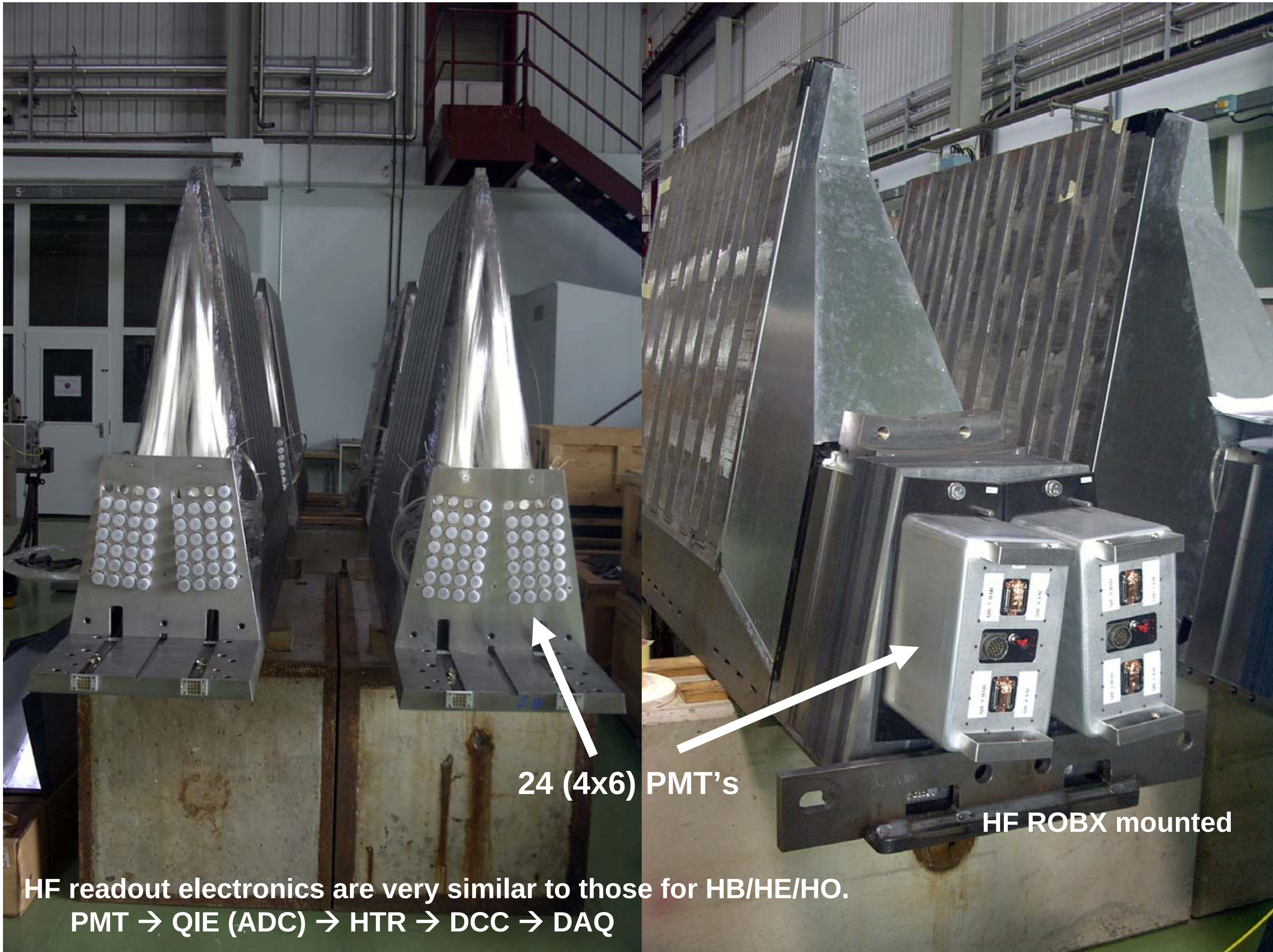
Fibers on HPD face

19 pixel HPD
(16 η + 2 depths)

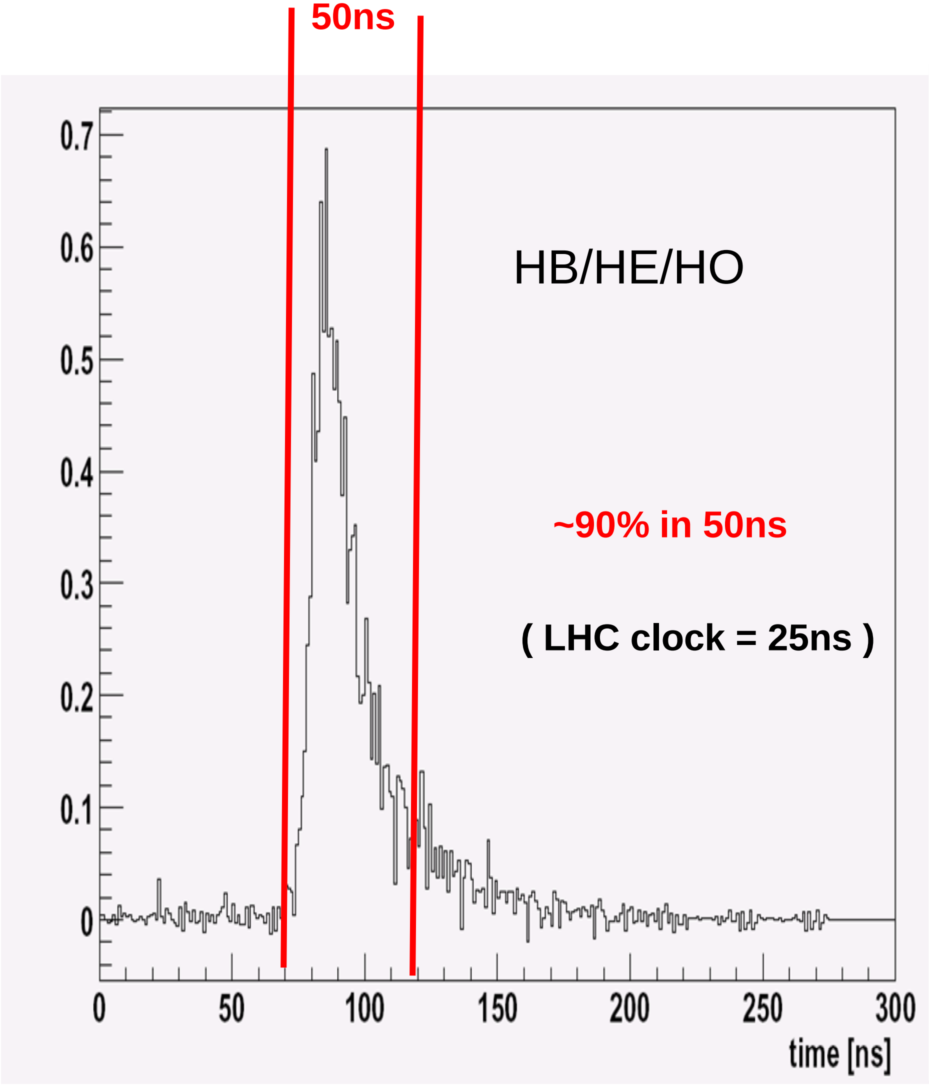
cm

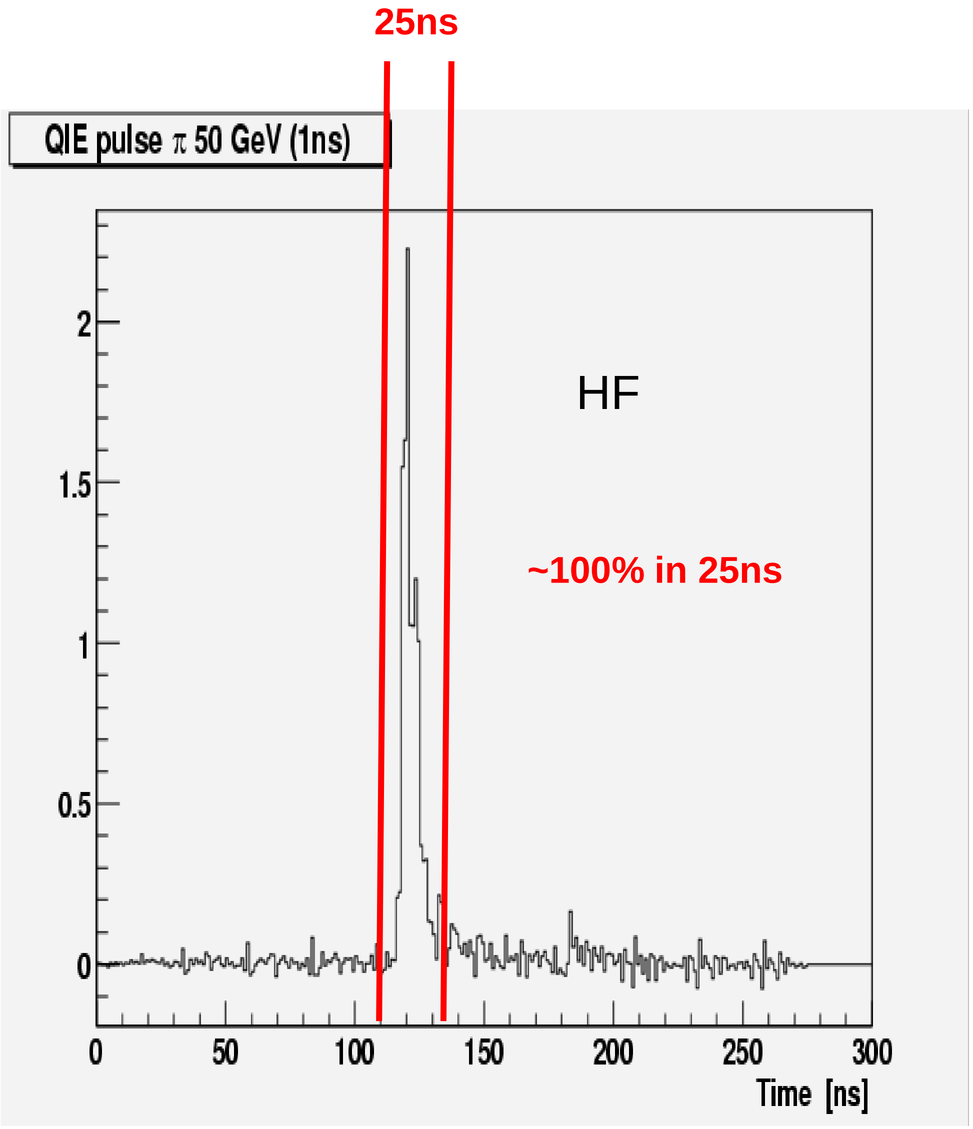
HCAL Readout and Trigger Electronics




24 (4x6) PMT's
HF ROBX mounted
HF readout electronics are very similar to those for HB/HE/HO.
PMT → QIE (ADC) → HTR → DCC → DAQ

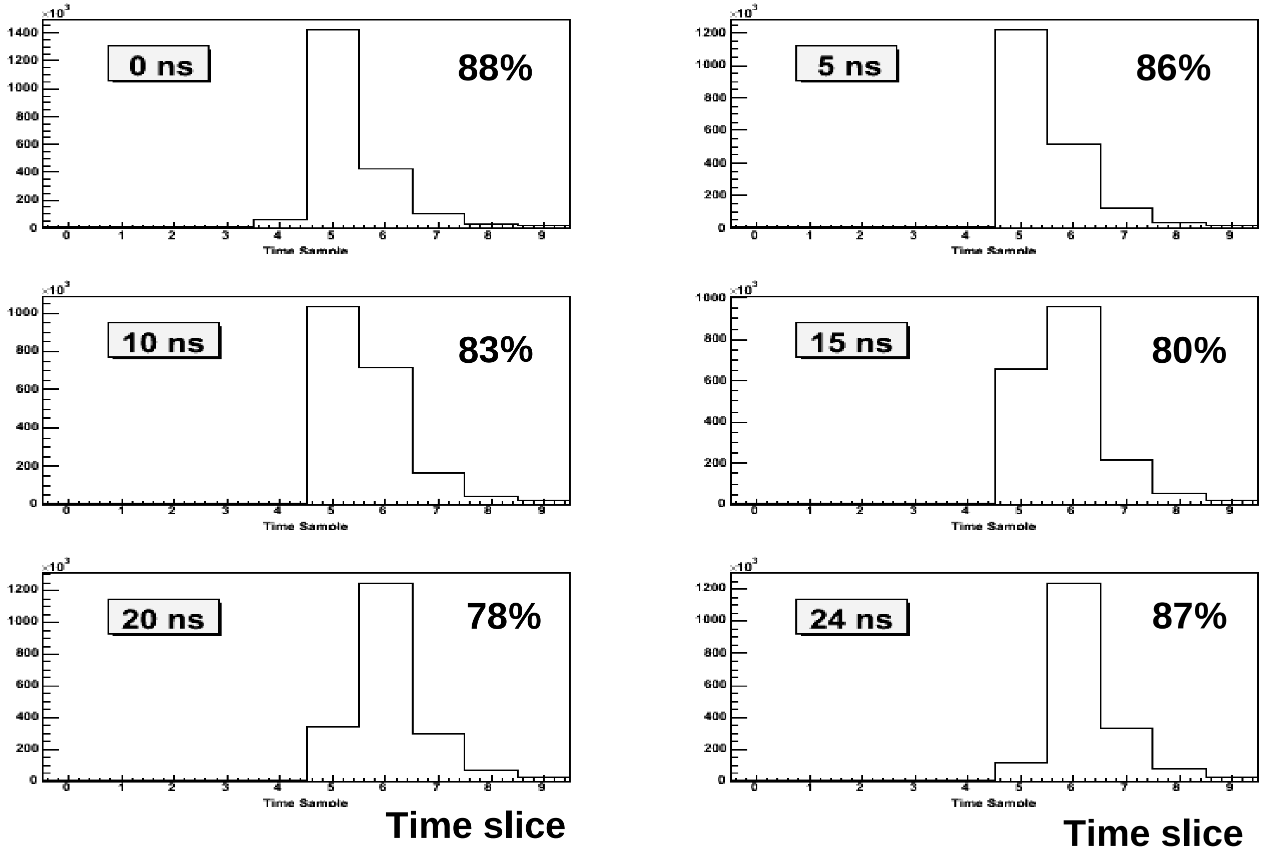
Pulse Shapes to QIE





QIE Output (Digi)

ADC count (linearized) in 10 time slice with different Phase setting (HB)



HTR uses 2 time slices to calculate TP (Trigger Primitive in Et).

Reco uses also 2 (or 4) time slice sto calculate RecHit (E and timing).

Containment of signal in 2 time slices (50ns) depends on the phase setting.

Rejection of cosmic muon background uses timing information.

Rejection of some HCAL noise is done using timing and “pulse shape”.

→ Important to have stable phase setting (synchronization).

CRAFT Data Analysis

- **CRAFT**
  - 4 weeks of continuous CMS running (370M cosmic events)
    - 290M events with B=3.8T and Strip tracker/DT
    - 194M events with all components
- **What can we do with those data?**
  - For Tracker and Muon system- Alignment
  - For HCAL?
    - Measurement of HCAL parameters for all channels.
      - Energy calibration constants
      - Pulse shape, timing (synchronization)
      - Noise spectrum and rate
    - Development of algorithms
      - rejecting fake-jets and fake-MET due to HCAL noise (and cosmic background).
      - monitoring HCAL performance in longer term, especially slow changes.
    - Test of CMSSW
    - Opportunity
      - To understand real CMS detector
      - To gain experience of data handling and data access for data analysis, e.g. skim job, re-processing, distributed data access/analysis, etc.
  - Work has started, but a lot of tasks to do- new people are welcome!

CRAFT data

L1 triggers during CRAFT

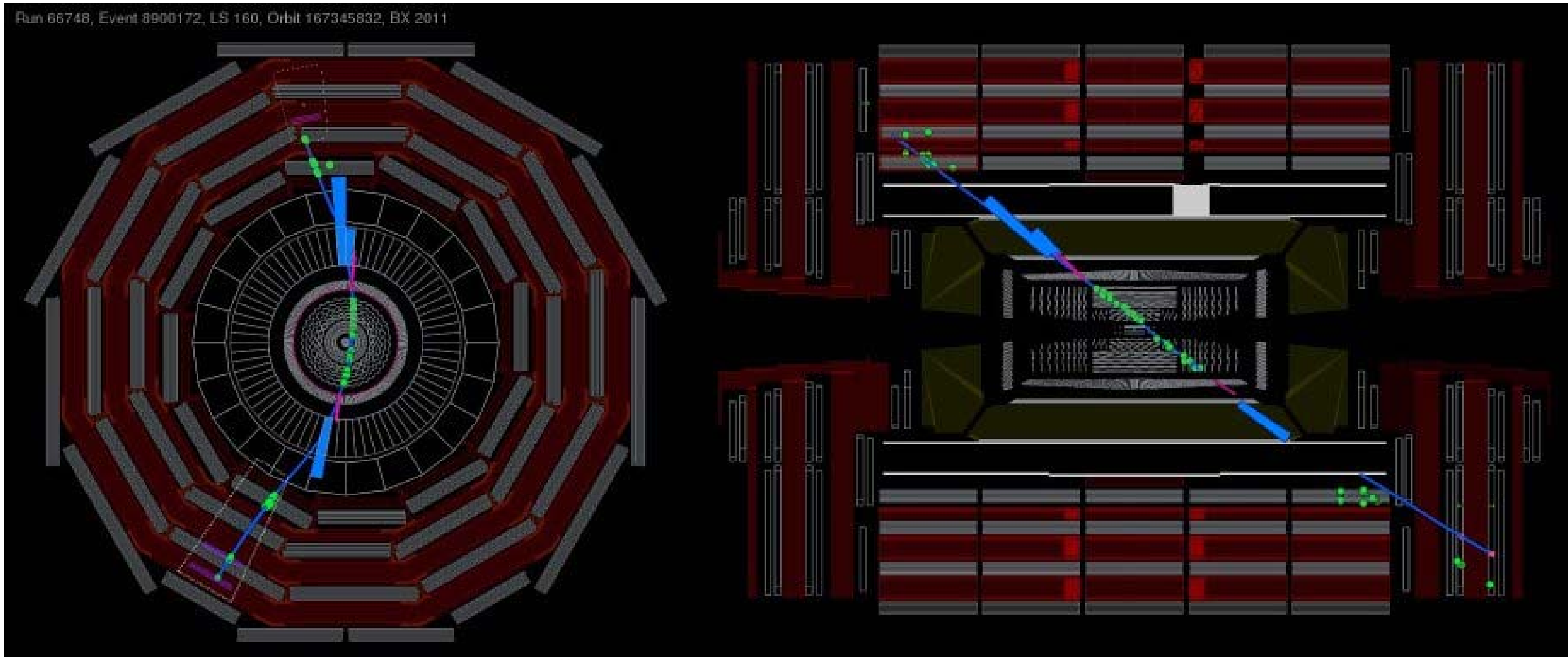
- Using L1Menu_startup2_v2
  - L1_SingleMuOpen – bit 55 - (all runs)
  - L1_SingleMuBeamHalo – bit 54 – (~90% of runs)
  - L1_SingleEG1 – bit 46 – (~35% of runs)
    - Mainly for ECAL e/gamma trigger studies
  - L1_SingleEG5_00001 – bit 47 – (~20% of runs)
    - Mainly for HCAL HPD noise studies
  - L1_SingleJet10_00001 – bit 16 – (~20% of runs)
- Additional triggers
  - HO technical trigger – TT bit 11 – (~40% of runs)
  - Calibration – (~70% of runs)
  - Random – (~80% of runs) – usually prescaled to 6Hz

300M muon events (L1_SingleMuOpen, L1_SingleMuBeamHalo): Energy scale, Pulse shape, Timing

Calo Trigger (L1_SingleEG5_00001, L1_SingleJet10_00001): Large "fake" MET sample

I. Mikulec 3

CRAFT data analysis jamboree, 12-Nov-2008.

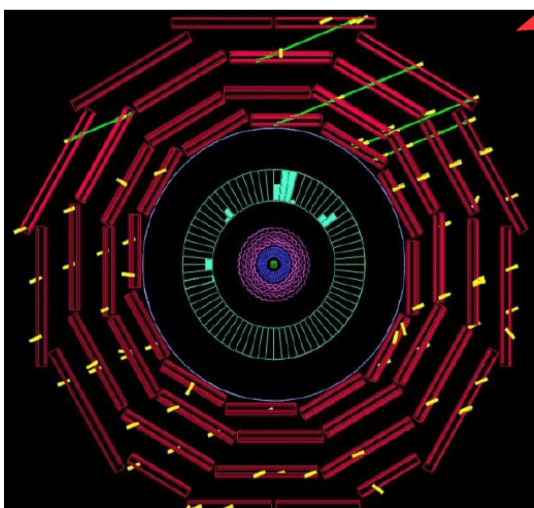


MET = 368 GeV

μ

MET = 1119 GeV

μ

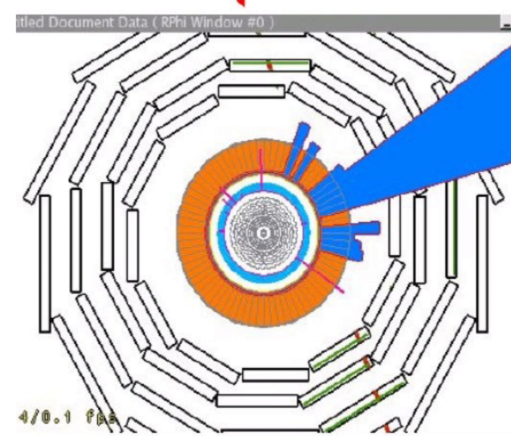


Run 51047 Event 4497905 (HB)

CRUZET3

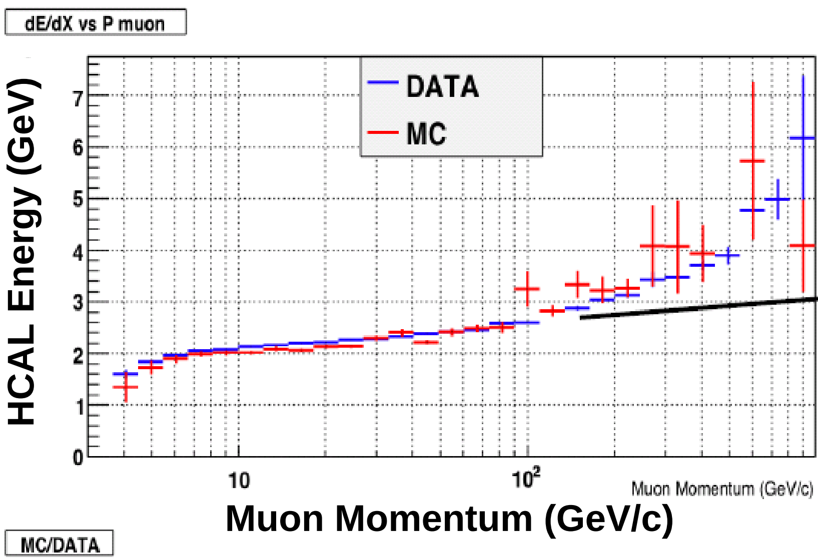
← **Multi muon event**

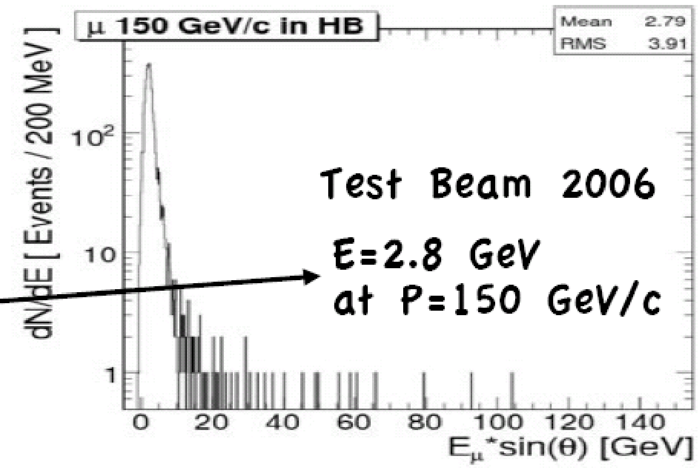
Large MET 1.1 TeV →



Run 51047 Event 5730838 (HB)

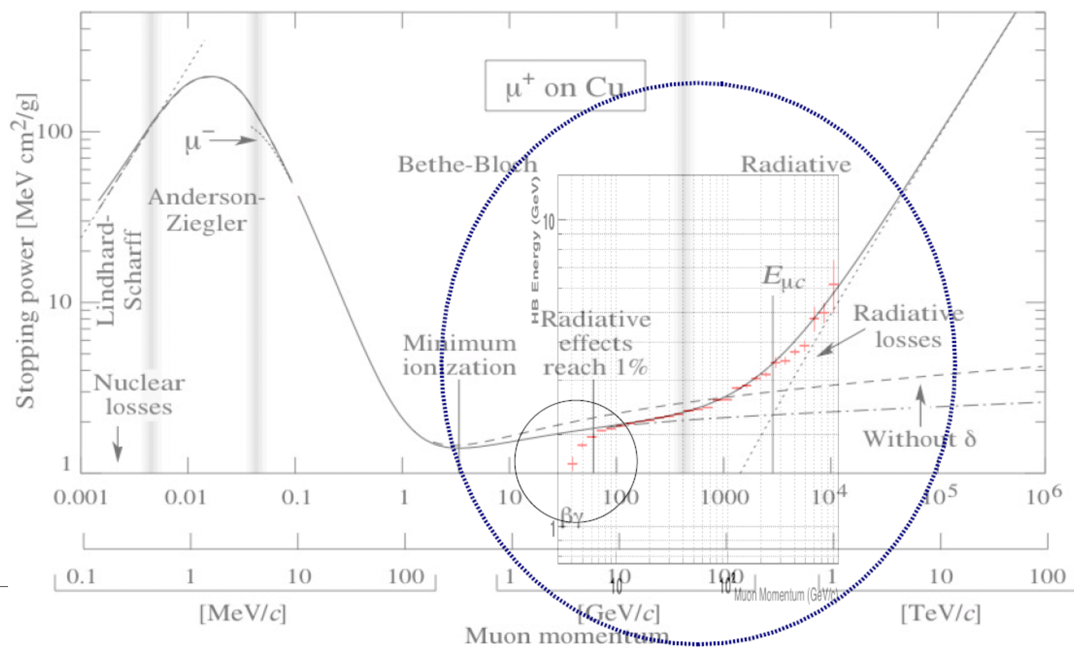
Muon Response in HB vs Momentum (tracker)





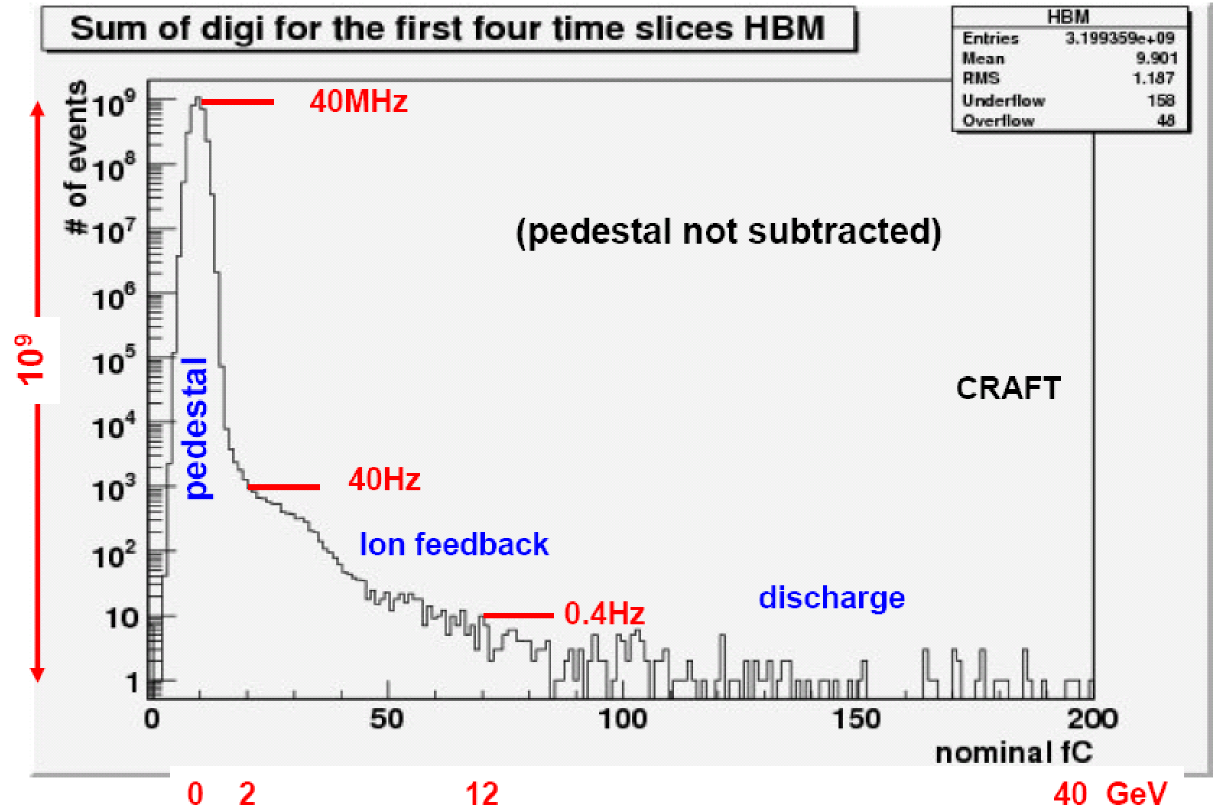
Very good match with Test
Beam 06 data (scale ~OK)

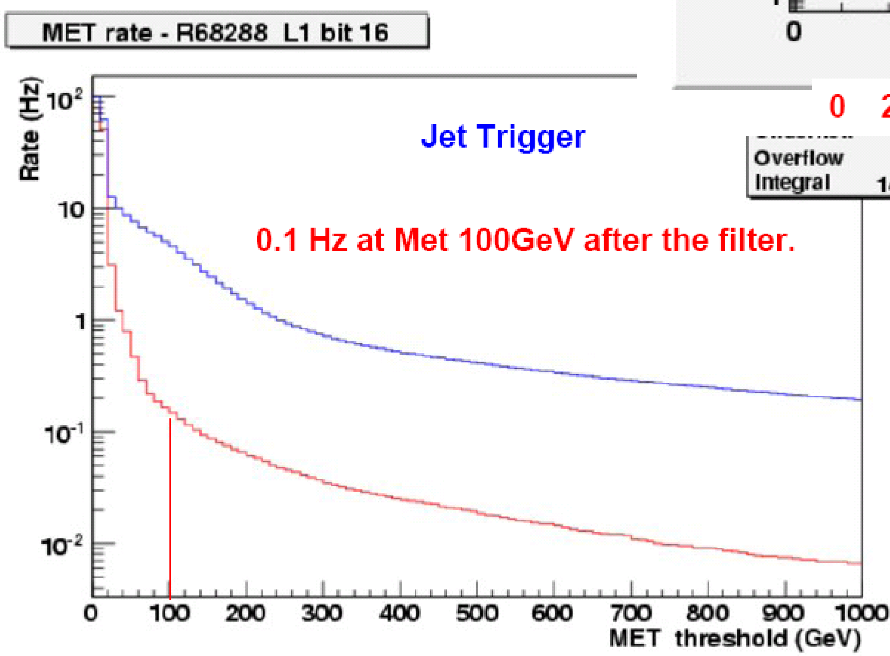
PDG muon
vs
Data (red)



HCAL Noise Spectrum

Rate of large noise (>12GeV) Is ~10^{-8} per cahnnel.

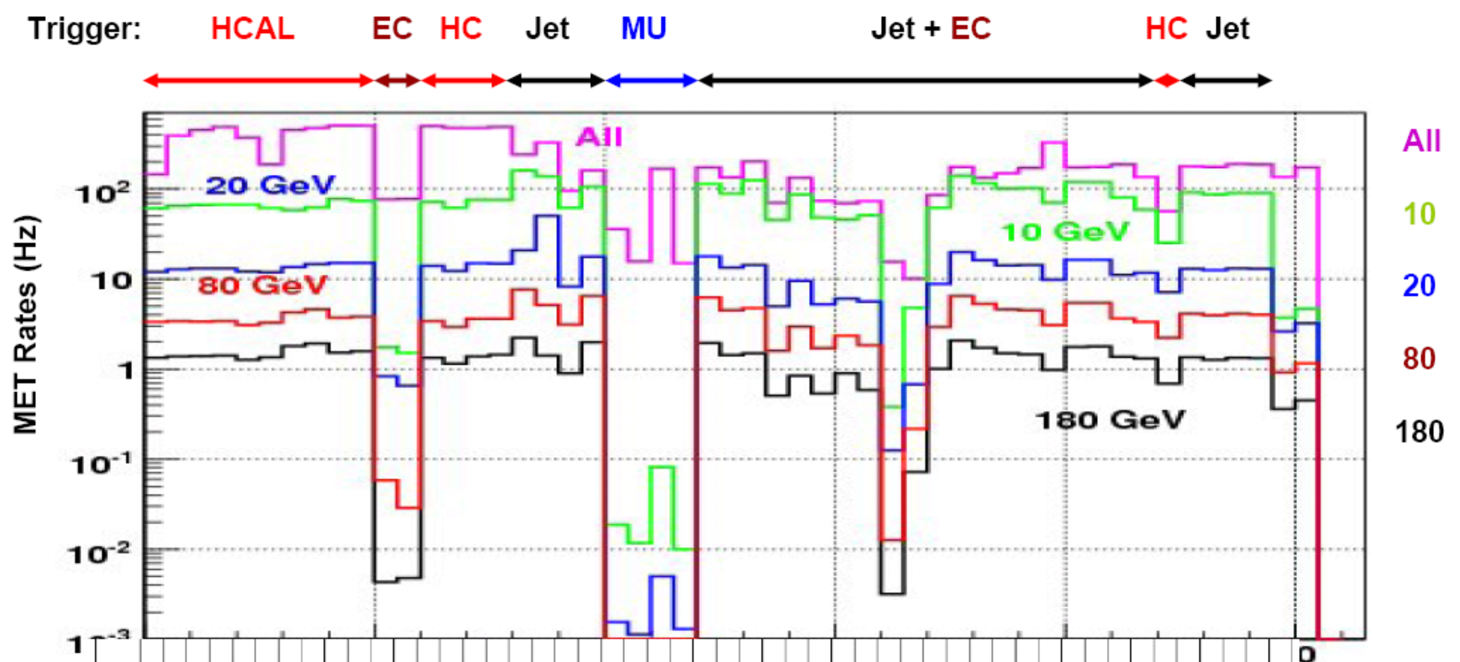




MET rate before / after a HCAL noise filter using HCAL pulse shape. (our first try).
→ development of filter is in progress.

Development of Monitoring Tool

Use CRAFT data to develop a tool to monitor HCAL noise/Anomalous events in MET events.



Preliminary Listing →

Run Number	Trigger Bit
66714	--------
66722	47, 54, 55
66739	47, 54, 55
66740	47, 54, 55
66746	47, 54, 55
66748	47, 54, 55
67039	54, 55
67043	54, 55
67141	47, 54, 55
67147	47, 54, 55
67173	46, 54, 55
67225	46, 54, 55
67539	--------
67573	47, 54, 55
67647	47, 54, 55
67818	47, 54, 55
68021	16, 46, 54, 55
68094	16, 46, 54, 55
68100	16, 46, 54, 55
68129	16, 46, 54, 55
68141	54, 55
68264	54, 55
68276	54, 55
68279	54, 55
68288	16, 46, 54, 55
68958	--------
69046	--------
69240	16, 46, 54, 55
69243	16, 46, 54, 55
69251	16, 46, 54, 55
69256	16, 46, 54, 55
69261	16, 46, 54, 55
69276	16, 46, 54, 55
69310	16, 46, 54, 55
69333	16, 46, 54, 55
69335	16, 46, 54, 55
69343	16, 46, 54, 55
69357	16, 46, 54, 55
69364	16, 46, 54, 55
69365	16, 46, 54, 55
69382	16, 46, 54, 55
69396	16, 46, 54, 55
69522	16, 46, 54, 55
69609	47
69671	47
69750	16, 46, 55
69788	16, 46, 55
69797	16, 46, 55
69800	16, 46, 55
69997	47, 55

Runs with > 5M events

L1 bits

- 16 jet
- 46 ECAL
- 47 HCAL
- 55 MU

Oct.18 ← 3 weeks → Nov.08

Summary

- **CMS HCAL is sampling calorimeter.**
  - **HB/HE: brass + scintillator tile with HPD**
  - **HO: scintillator tiles with HPD behind solenoid**
  - **HF: ion abosrber + quartz fibers with PMT (cerenkov light)**
- **We have high statistics CRAFT data**
  - **Data with 3.8T field and all components.**
  - **Tasks for HCAL.**
    - **Verify and improve the calibration constants.**
    - **Develop algorithms to identify and reject “noise events” due to detector noise and cosmic background. LHC machine related background will come next.**
    - **Develop and/or improve software tools for short-term and long-term monitoring.**
    - **Test CMSSW.**
    - **Develop and/or improve our (computing) plan for analysis of real data.**
  - **Opportunity to learn real detector.**

Some References

CMS physics: Technical design report.
By CMS Collaboration (G.L. Bayatian *et al.*). CERN-LHCC-2006-001, CMS-TDR-008-1, 2006. 521pp (Volume 1, Chapter 5, Hadron Calorimeter)

Design, performance, and calibration of CMS hadron-barrel calorimeter wedges.
By CMS HCAL Collaboration (S. Abdullin *et al.*). FERMILAB-PUB-08-246-CMS, 2008. 13pp.
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G. Bayatian *et al.* CERN-CMS-NOTE-2006-044, Feb 2006. 42pp.
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Talks in past CMS101 and JTerms