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CMS DPS -2010/025

The Compact Muon Solenoid Experiment

Detector Performance Summary

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HCAL performance from first collisions data

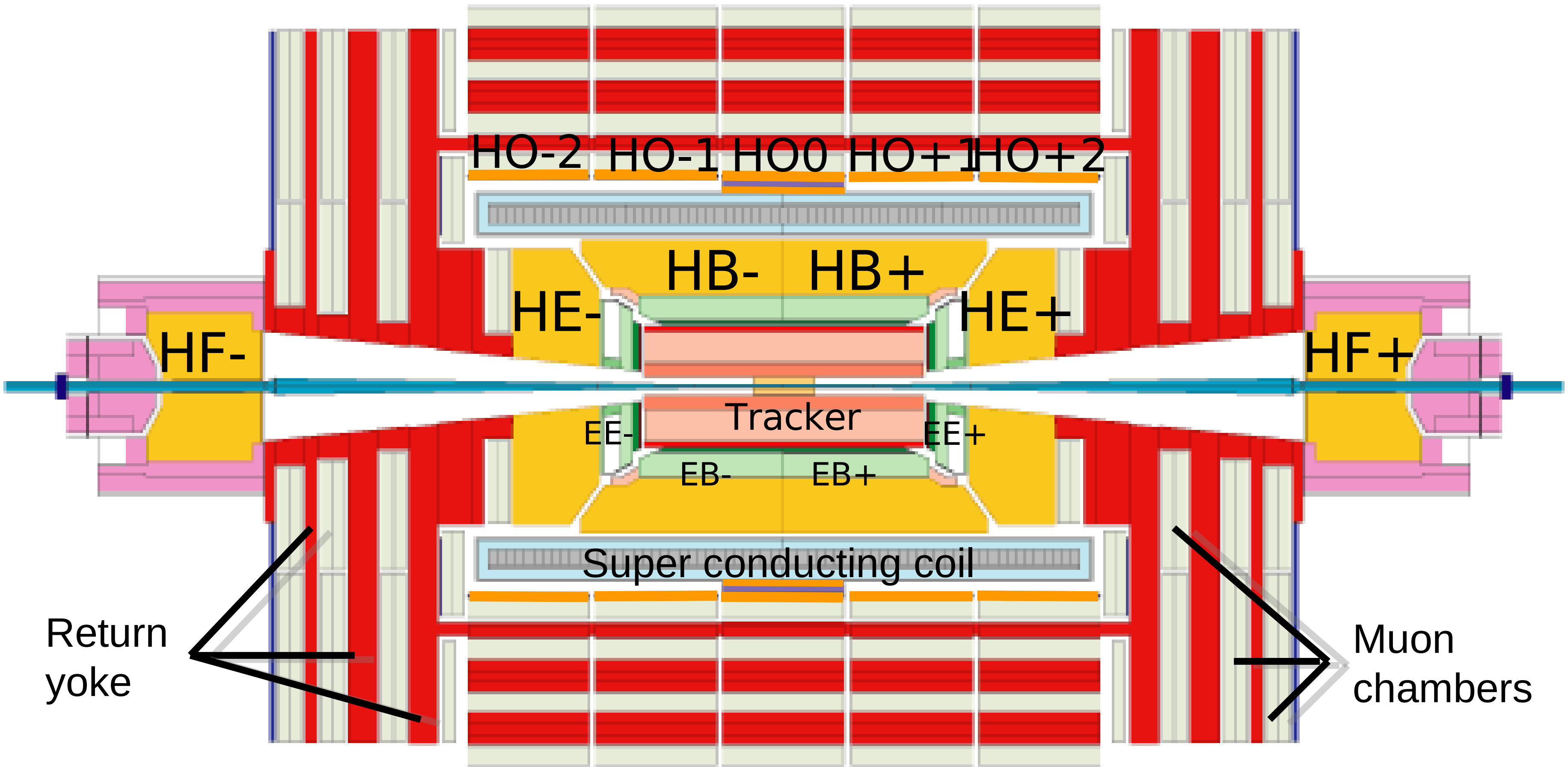
CMS Collaboration

Abstract

HCAL performance from first collisions data. It includes: particle response in HCAL, anomalous signals and timing.

CMS Calorimeter

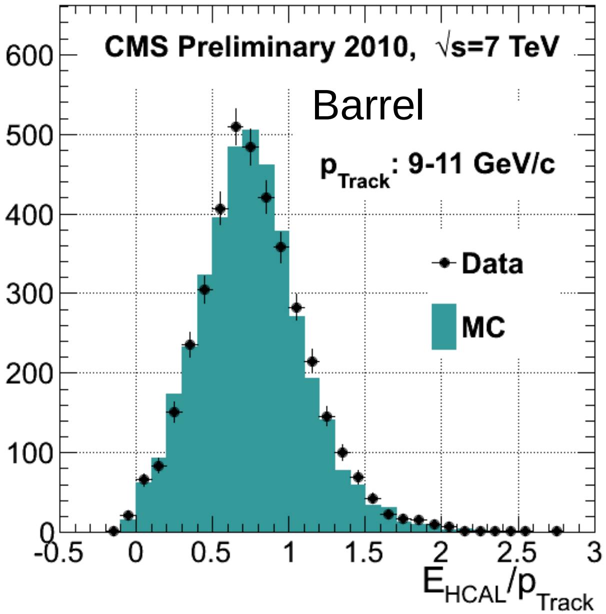
CMS Calorimeter (ECAL+HCAL) - Very hermetic (>10λ in all η, no projective gap)

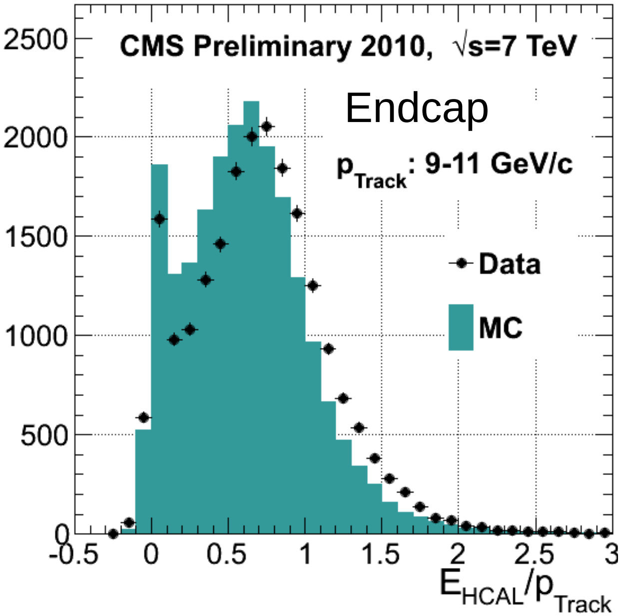


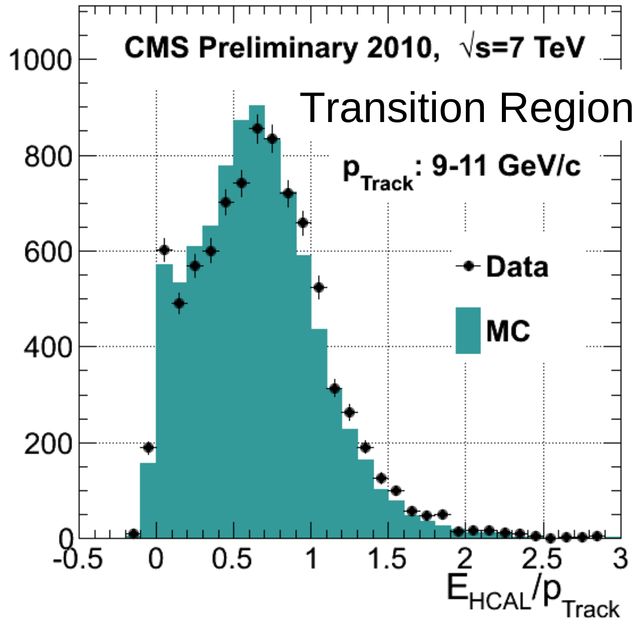
HB	Brass Absorber (5cm) + Scintillator Tiles (3.7mm)	Photo Detector (HPD)	|η| 0.0 ~ 1.4
HE	Brass Absorber (8cm) + Scintillator Tiles (3.7mm)	Photo Detector (HPD)	|η| 1.3 ~ 3.0
HO	Scintillator Tile (10mm) *outside of solenoid*	Photo Detector (HPD)	|η| 0.0 ~ 1.3
HF	Iron Absorber + Quartz Fibers	Photo Detector (PMT)	|η| 2.9 ~ 5.2

HCAL Response Shape

Barrel: |η| < 1.1
Transition region: 1.1 < |η| < 1.7
Endcap: 1.7 < |η| < 2.2





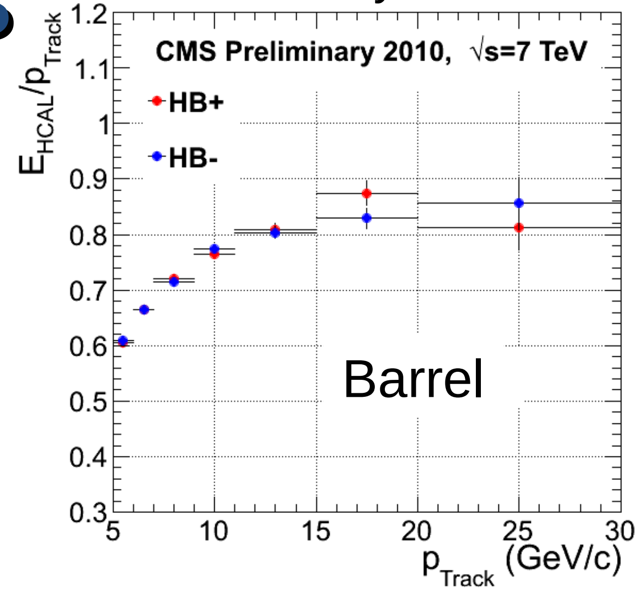


The HCAL response for tracks with a momentum between 9 and 11 GeV/c for three differeent regions of HCAL

The data is shown compared with the Geant4 based MC simulation of minimum bias events

HCAL Mean Response

DATA only +/- sides

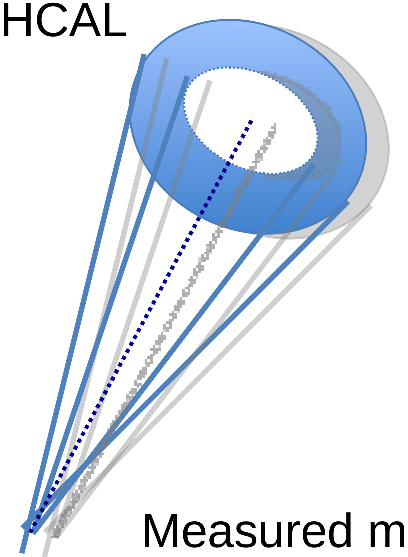


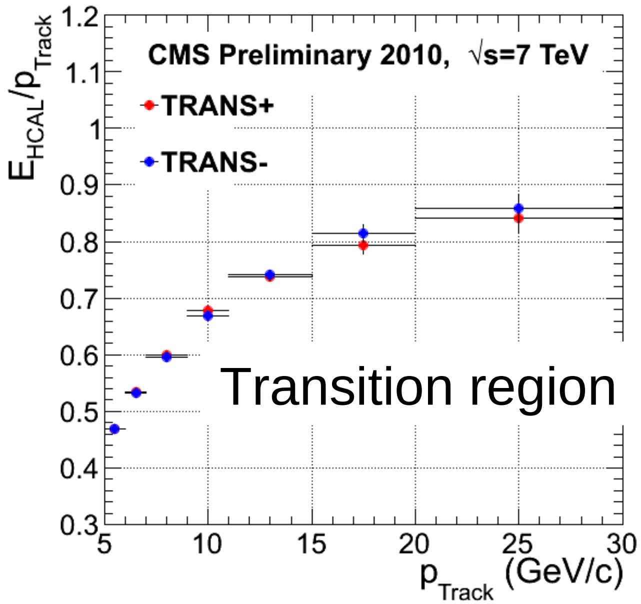
<Response> = <E_{HAD}/p_{track}>

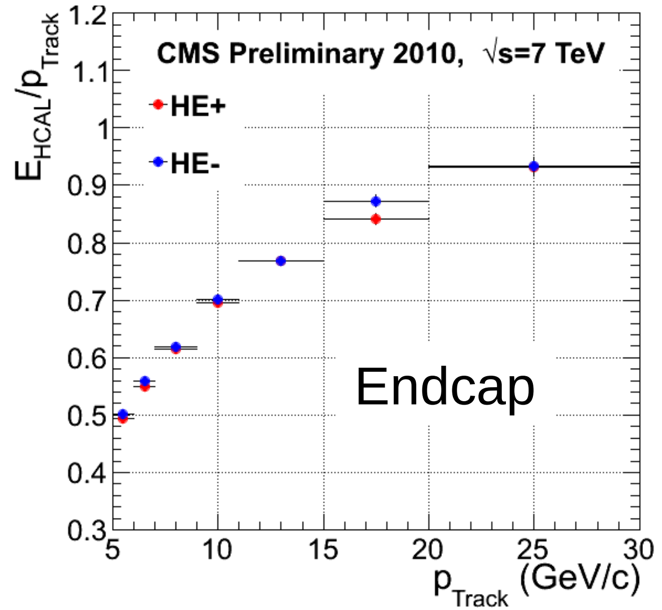
- √s= 7 TeV min-bias data, ~10 nb^{-1}
- MIP in ECAL
- Isolated tracks > 5 GeV/c

Barrel:	$|\eta| < 1.1$
Transition region:	$1.1 < |\eta| < 1.7$
Endcap:	$1.7 < |\eta| < 2.2$

Cone based isolation zone at the surface of the HCAL

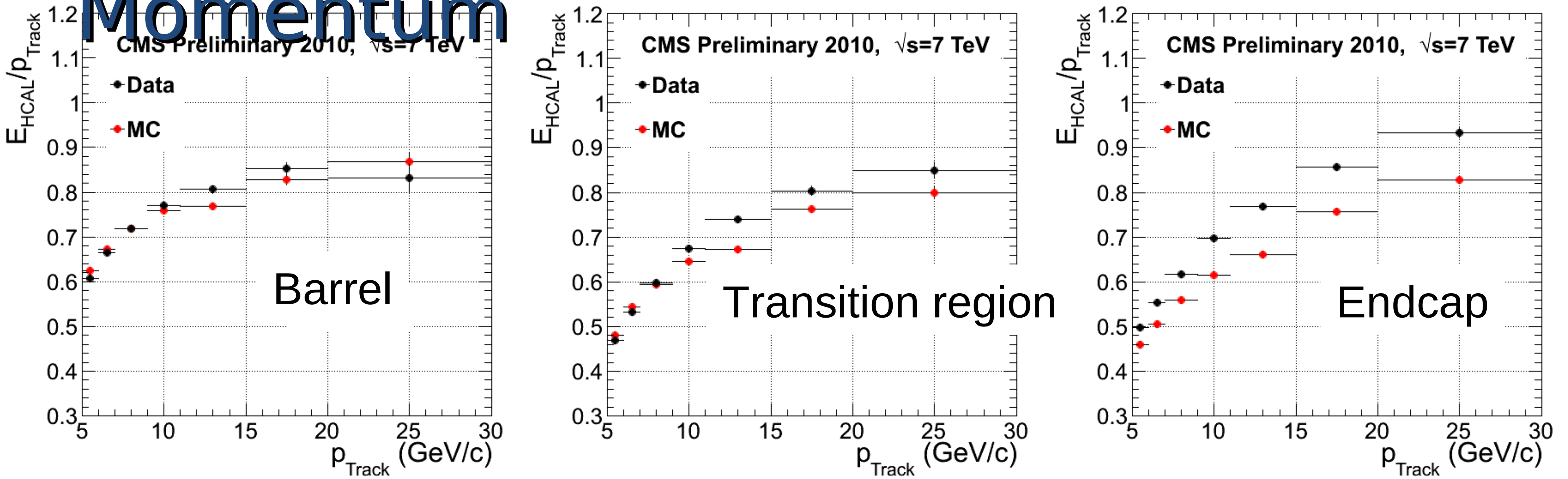






Measured mean response as a function of track momentum in three different regions of the hadron calorimeter; + and – data are overlaid

HCAL Mean Response vs Track Momentum



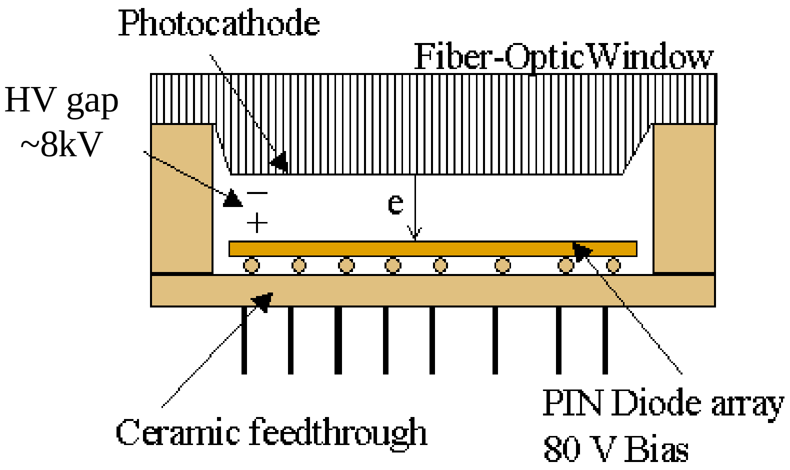
The measured mean response as a function of the track momentum in three different regions of the hadron calorimeter.

Barrel:	$|\eta| < 1.1$
Transition region:	$1.1 < |\eta| < 1.7$
Endcap:	$1.7 < |\eta| < 2.2$

The full calibration will use tracks with a momentum of ~50 GeV and will require ~10 pb-1 of data in order to get the desired precision.

We observe two classes of anomalous signals in HCAL

1) Electronics noise from the Hybrid Photo Diode (HPD) and Readout BoX (RBX) used for the Hadronic Barrel (HB), Outer (HO), and EndCap (HE) calorimeters

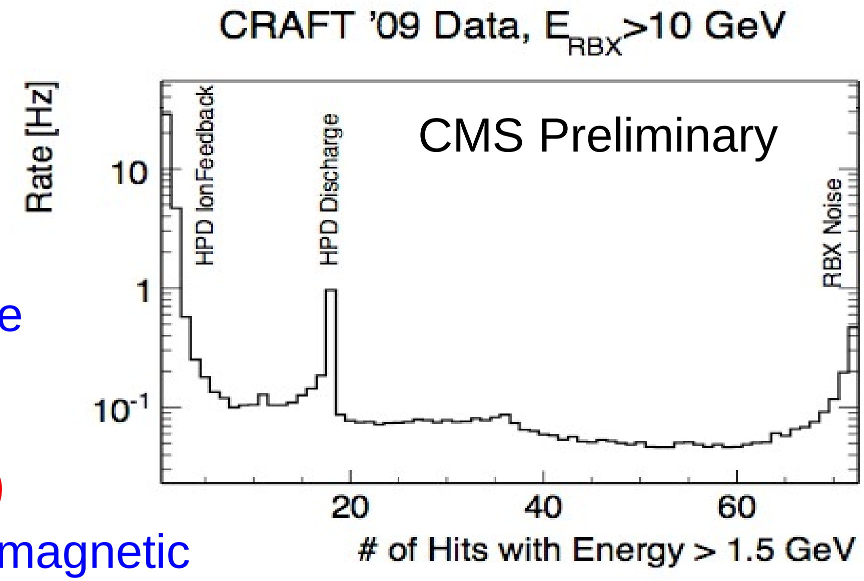


The HPD has 18 channels/device
There are 4 HPDs in a RBX

2) Cherenkov light produced by interactions in the window of the Forward Calorimeter PMTs

Glass window thickness in the center is ~1mm increasing to ~6.1mm on the edges

HPD and RBX Noise



HPD Ion Feedback *(~1 HPD channel)*

Photoelectron induced liberation of ions from the silicon diode which accelerate across the HV gap and interact with the photocathode freeing additional photoelectrons

HPD Discharge *(up to 18 HPD channels)*

With the HPD operating at ~8kV in the CMS magnetic field, dielectric flashover from the wall can produce large signals in many channels

RBX Noise *(up to 72 channels)*

Source unknown, possibly due to external noise coupling to HV of many channels across the whole RBX

For the HB and HE the total rate of HPD and RBX noise is 10-20 Hz for E>20 GeV which includes the contribution from the OR of 288 HPDs

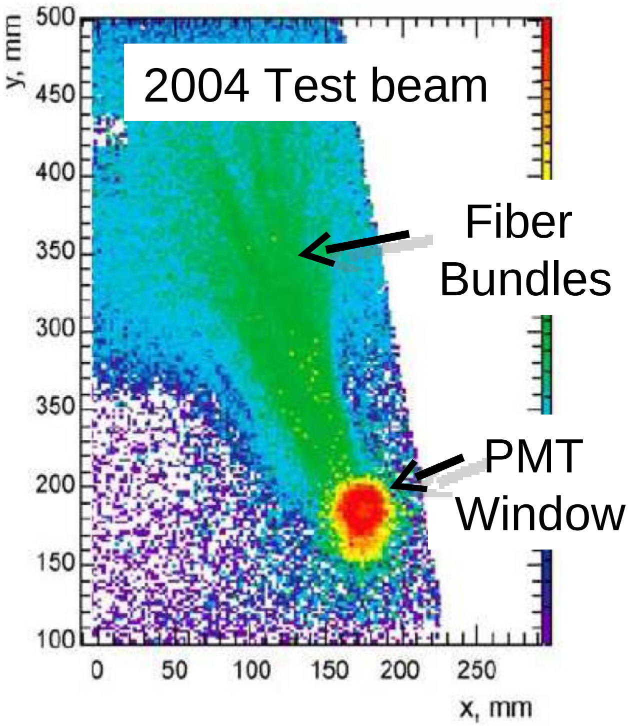
HPD and RBX noise is random and the overlap with physics is very low

HPD/RBX noise produce distinct patterns in HCAL

Filters have been developed making use of hit patterns, timing, pulse shape, and EM fraction ignals from interactions in the HF PMT windows and

n the fiber bundles were observed in the testbeam

nd published in: *Eur. Phys.J. C53, 139-166 (2008)*



ong fibers: extends for the full length of HF

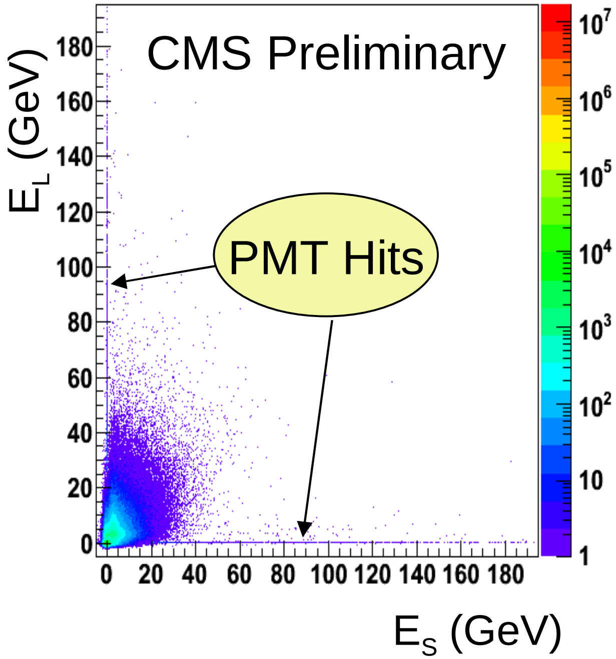
hort fibers: start at a depth of 22cm from the front of HF

ost of the HF PMT hits can be identified based on the

nergy sharing between the Long and Short fibers using

$= (E_L - E_S)/(E_L + E_S)$. Filters have been developed to effectively remove anomalous signals with little impact

n real energy deposits.



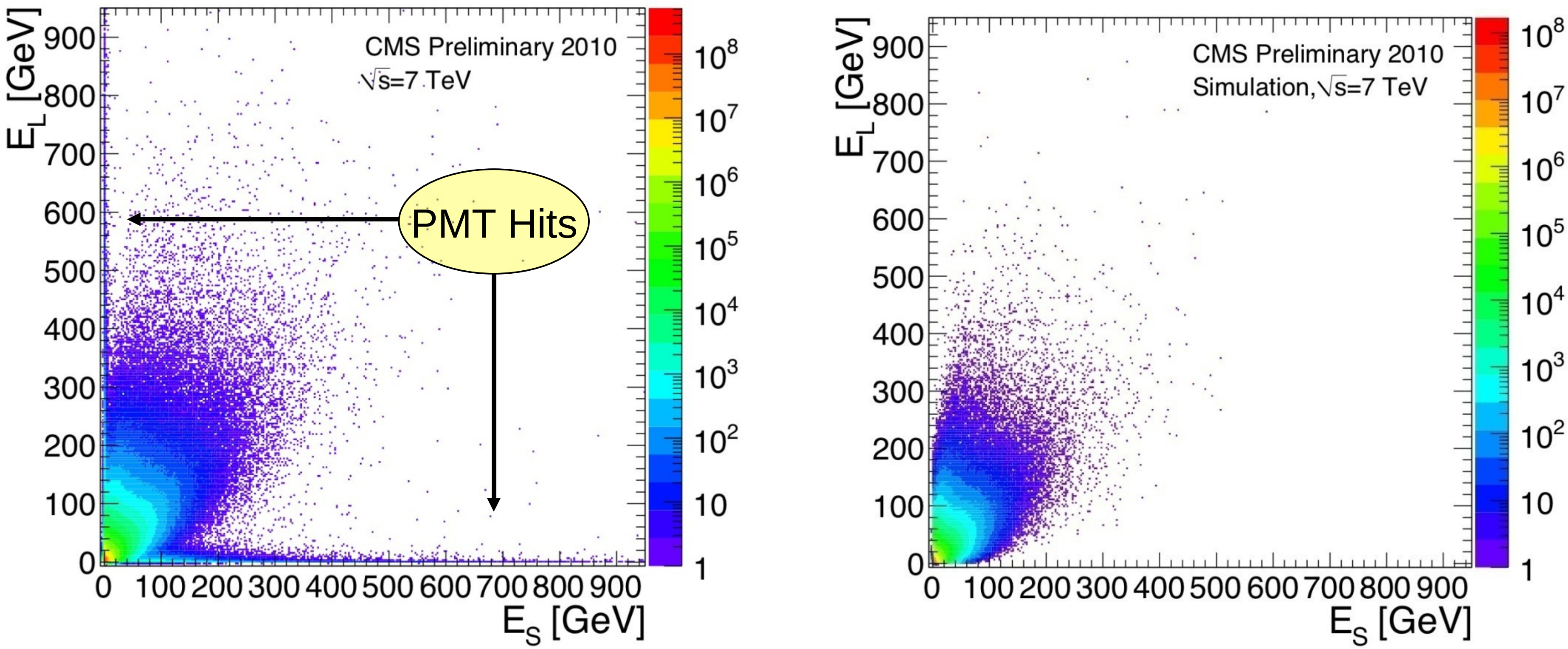
ates in 2009 minimum bias data (~1720 PMTS)

HF PMT Hits: Topological Filter

Long fiber channel energy vs. short fiber channel energy from the same HF tower in 7 TeV collision data (left) and 7 TeV MinBias Monte Carlo simulation (right). High energy entries close to either of the two axes only present in collision data (left plot) are the HF PMT window

$$R = \frac{E_L - E_S}{E_L + E_S},$$

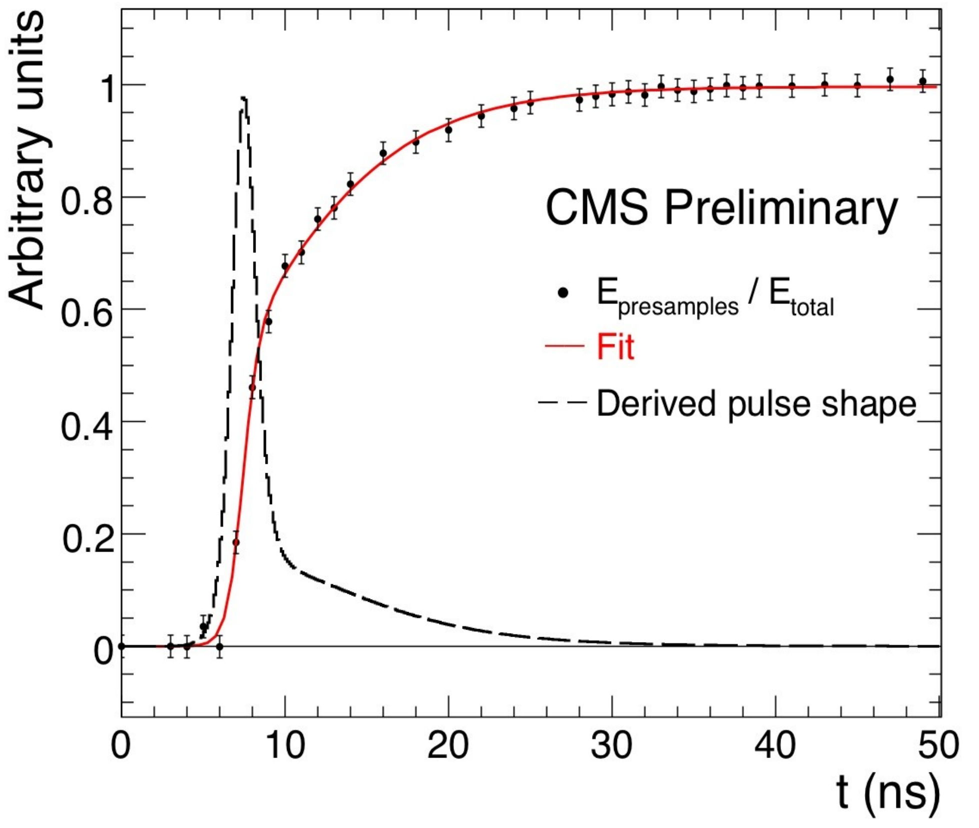
R is used to identify PMT hits in the short fibers. For long fibers an isolation criterion is used to avoid mis-identifying EM showers as PMT hits



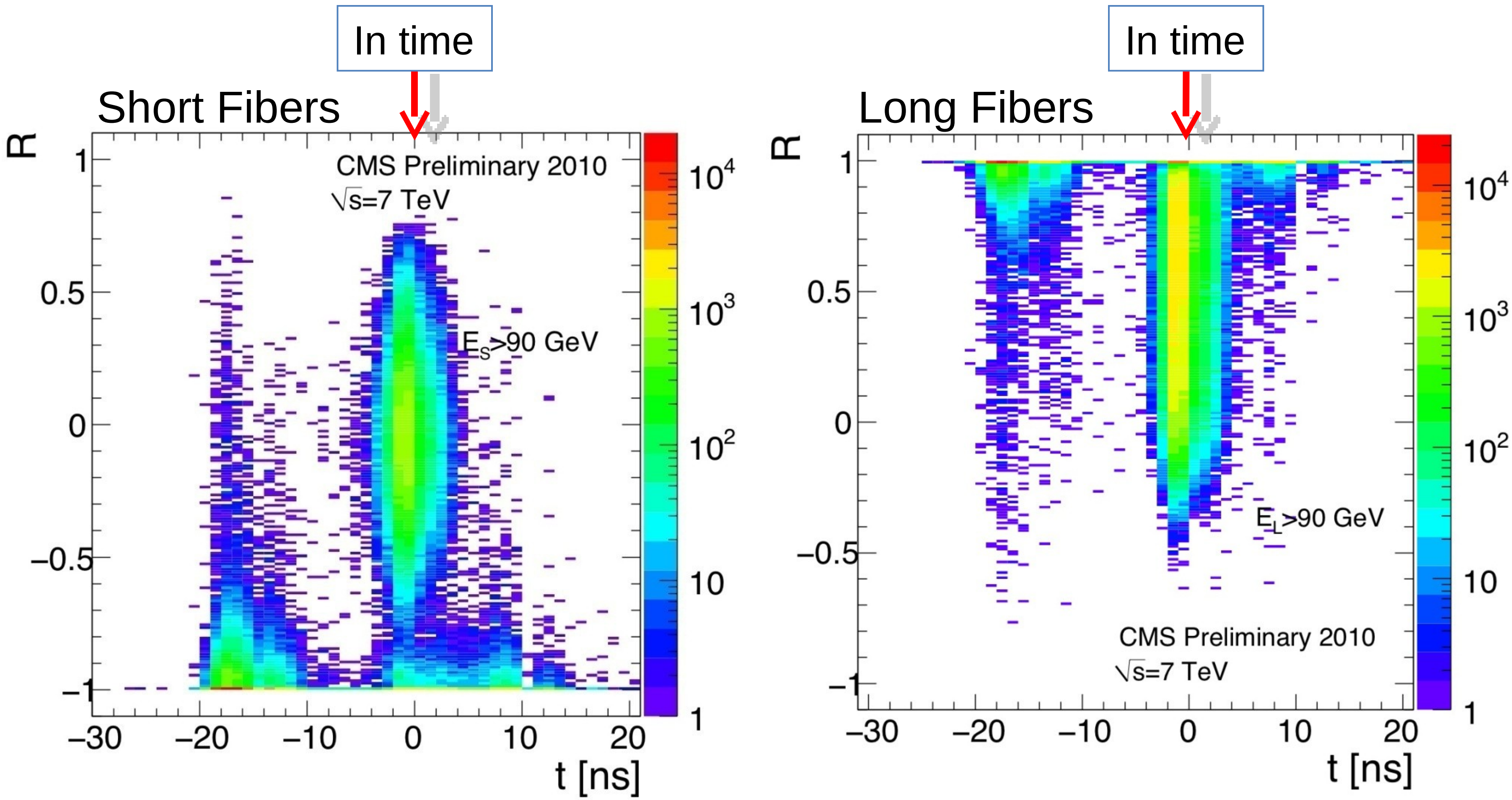
Energy depositions of 100 GeV correspond to E_T of 10 (1.3) GeV at h=3 (5)

Measured HF Pulse Shape

A QIE phase scan was performed for HF in a series of runs. The fit is the integrated pulse shape determined from this scan for one HF channel with a threshold E > 40 GeV applied. The dashed curve is the derived pulse shape. The data points are the average fraction of charge in the first 4 (5 above 25 ns) of the 10 time slices read out, as a function of the phase setting.



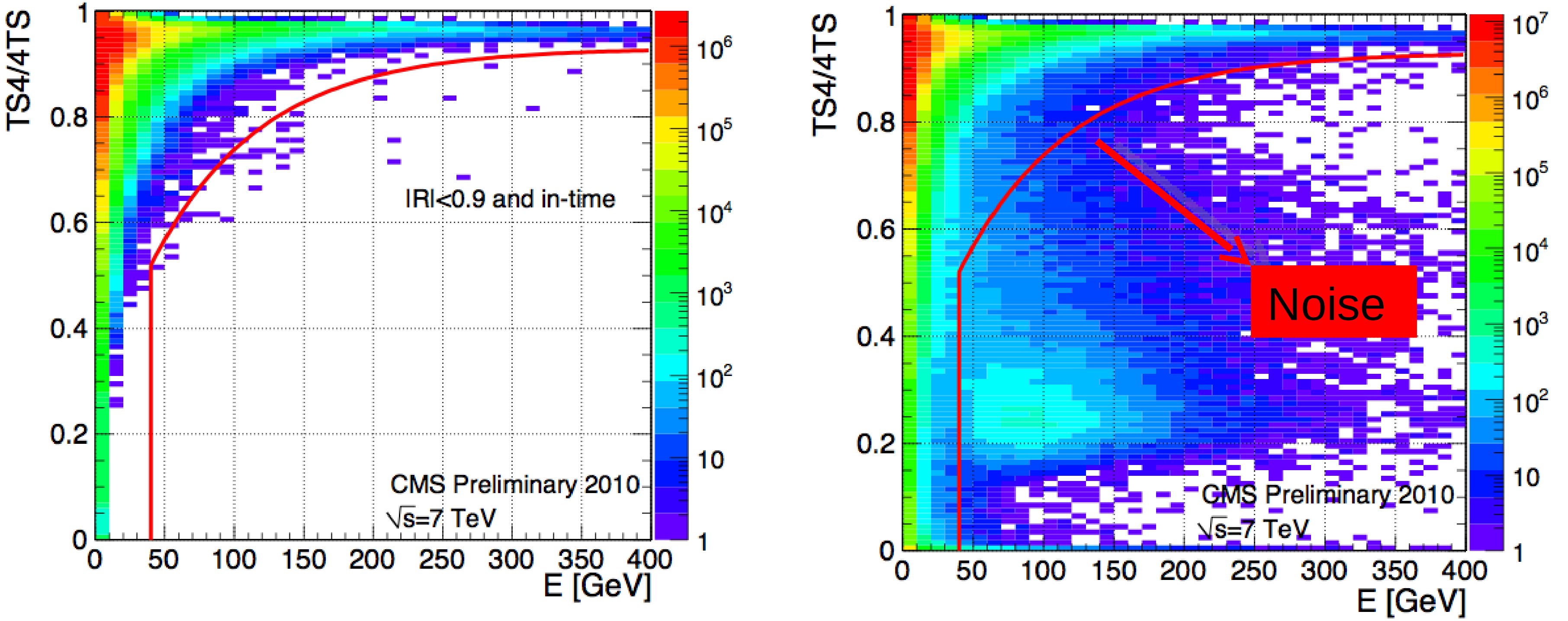
Timing of HF PMT Hits



R ratio versus reconstructed time for short (left) and long (right) fiber hits having E > 90 GeV in 7 TeV collision data (~1 nb^{-1} minimum bias data).

Hits having out-of-time (early) energy in the HF long and short fibers are identified as “PMT hits”.

HF PMT Hits: Pulse Shape Filter

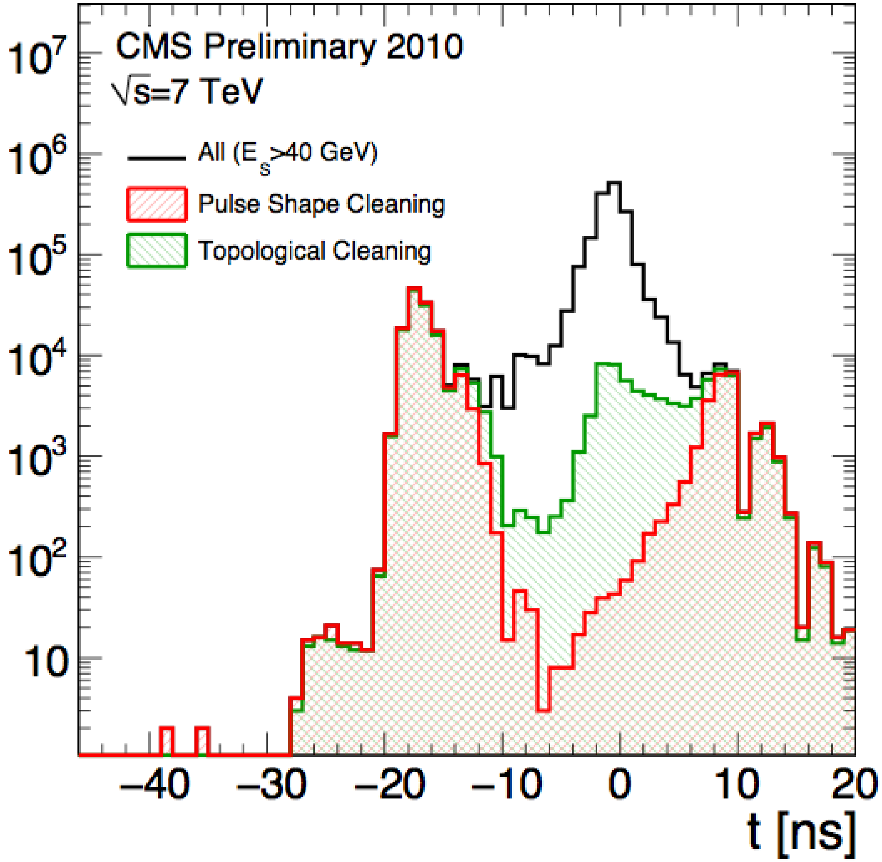


TS4/4TS is the ratio of the nominal in-time signal charge (4th time-slice) over the total charge in time slices 3 to 6. Channels below the red curve are identified as PMT Hits.

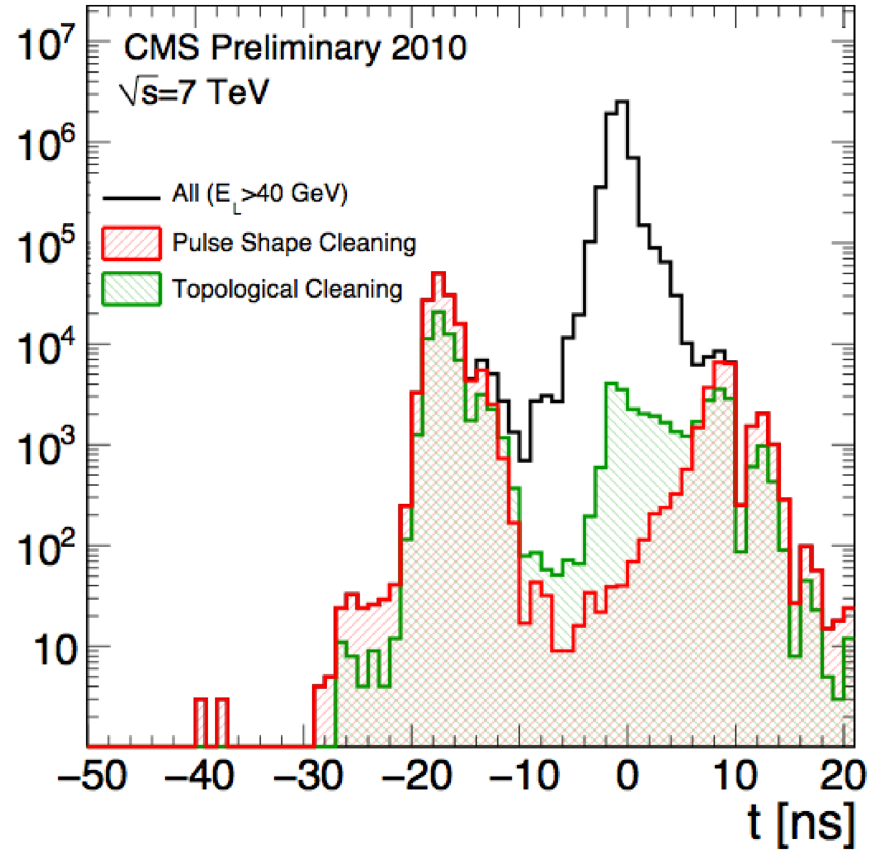
The left plot shows good in-time channels and the right plot includes all channels having E>40 GeV. (~0.1 nb^{-1} min-bias)

HF Timing

Short Fibers

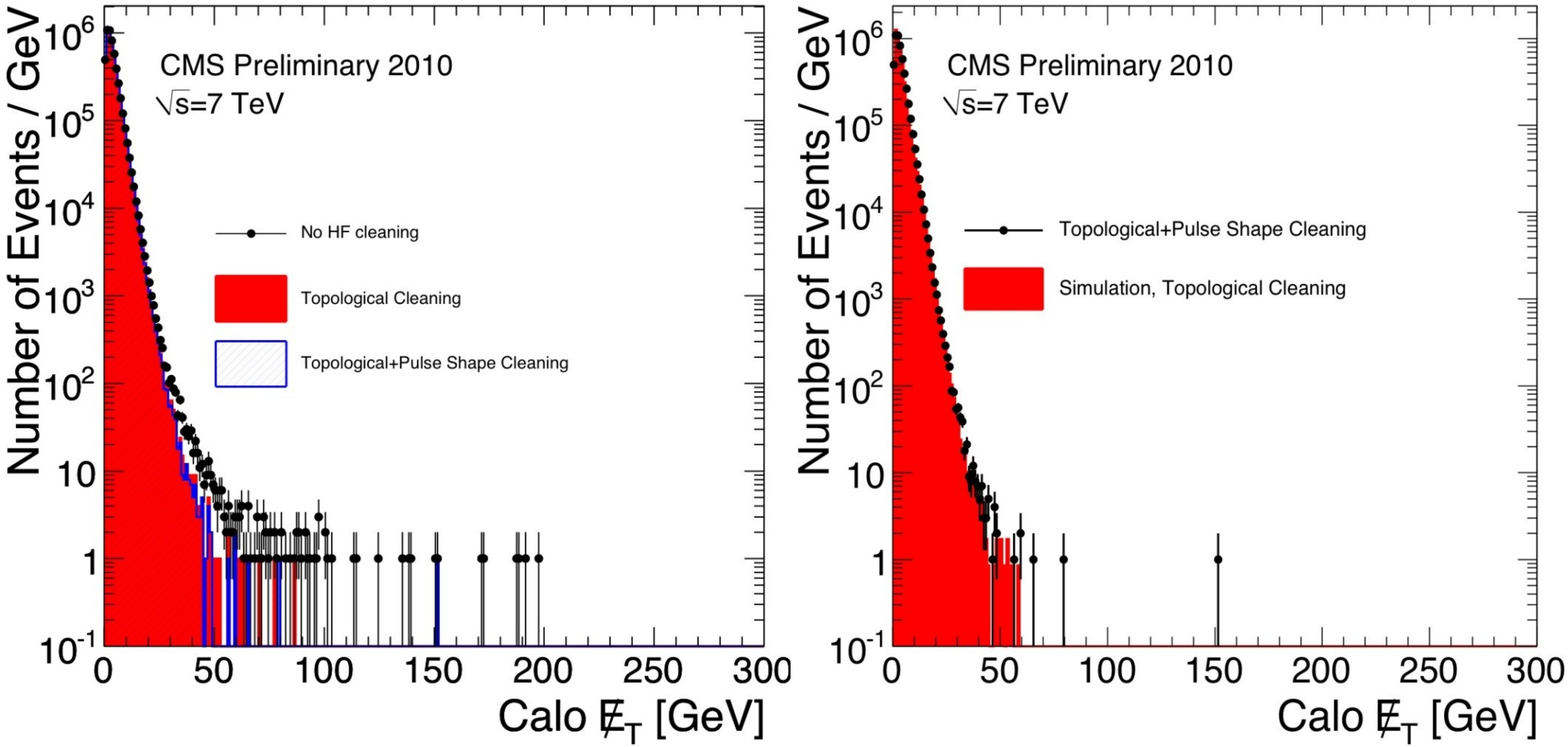


Long Fibers

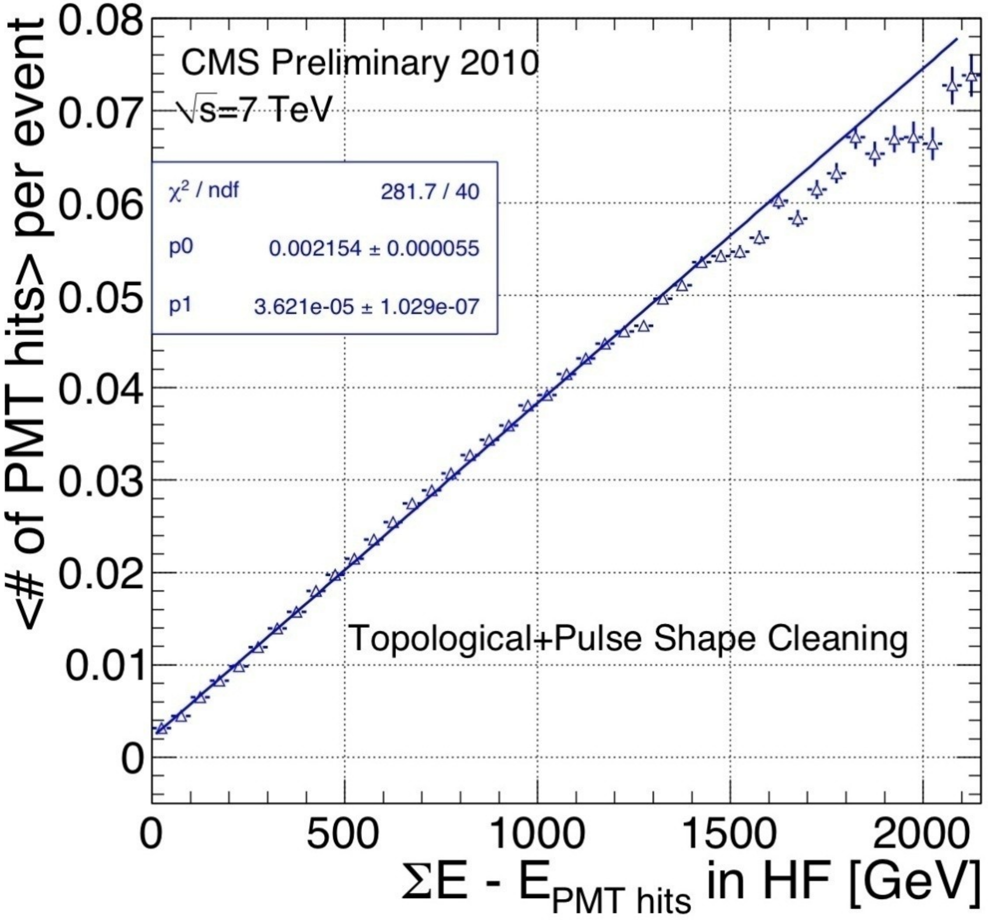


Time distributions for short (left) and long (right) fiber HF channels having energy greater than 40 GeV. The time distribution of channels tagged as "PMT hits" with topological and pulse shape "noise filters" are overlaid. (~1 nb^{-1} minimum bias)

HF PMT Hit Filters: Performance on the MET



Calorimetric Missing Transverse Energy before and after the HF PMT hit cleaning using the topological and pulse shape PMT hit noise filters (left) and comparison of the cleaned spectrum with the MC G4-based CMS simulation (right). All other calorimetry noise removal algorithms are applied prior to the HF PMT cleaning.

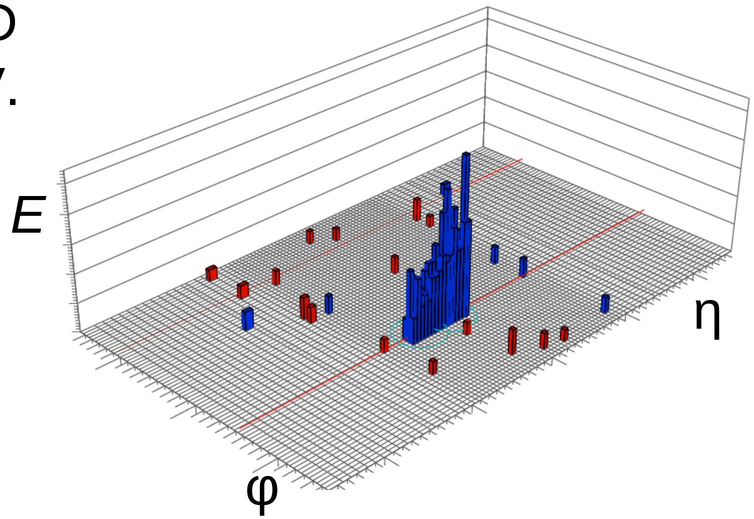


Average number of HF PMT hits per event as a function of E in HF in 7 TeV data (excluding the energy of the “PMT hits”).

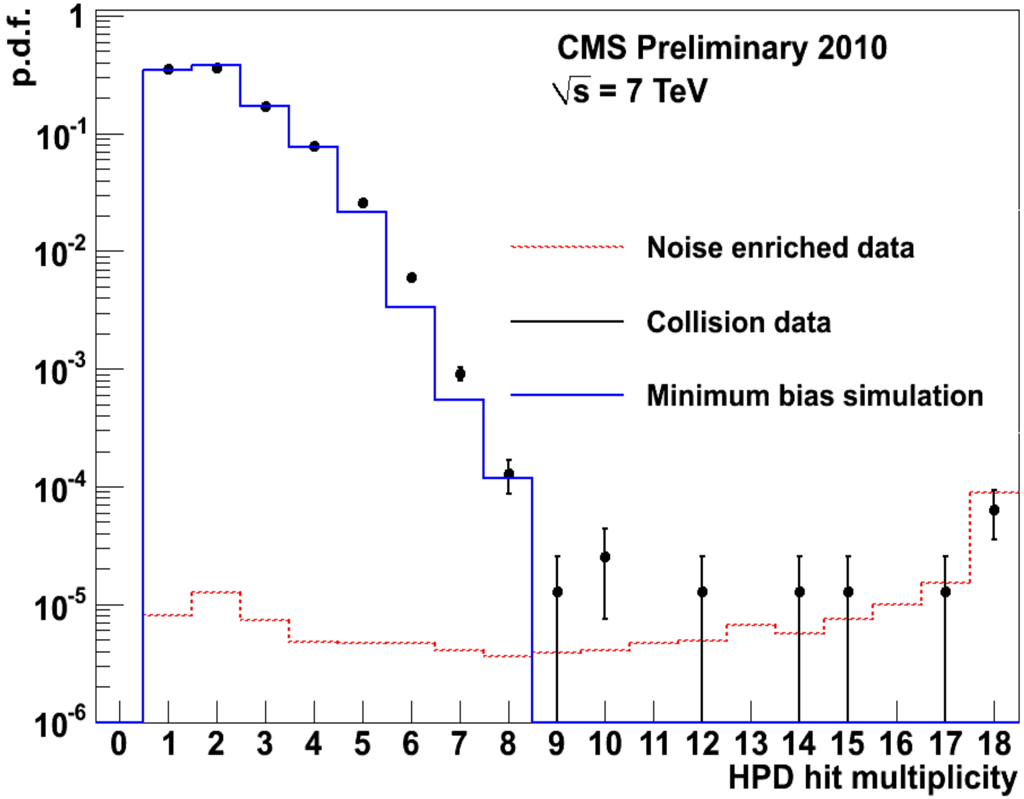
HB/HE HPD/RBX "Topological" Noise Filter

Event display of RBX noise

Events are identified as noise if there is an HPD with more than 17 channels having E>1.5 GeV.



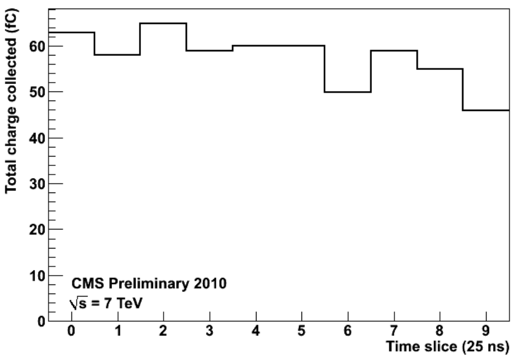
Plot shows the probability versus the hit multiplicity.

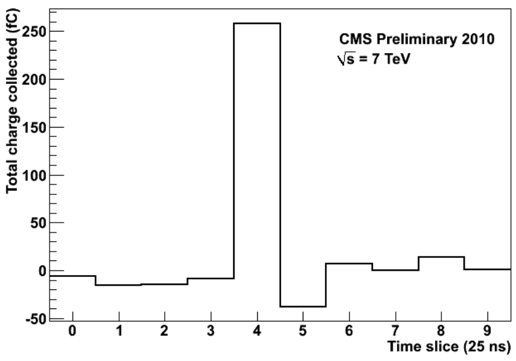


7 TeV collision data (points) are compared with HCAL noise-runs (noise enriched data, dashed red). MC simulation of minimum-bias and other signal events are used to assess the performance of the filter that uses the HPD hit multiplicity to discard such events. (~1 nb^{-1} min-bias)

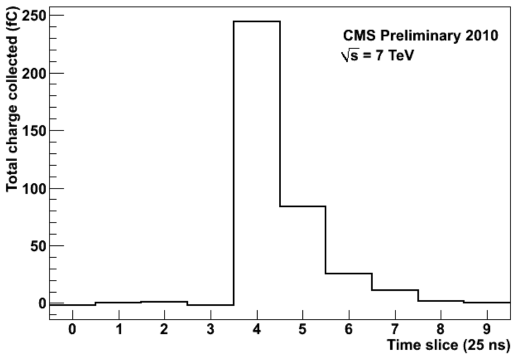
HB/HE HPD/RBX Noise Filter Using the Pulse Shape)

Examples of Anomalous Pulse Shapes

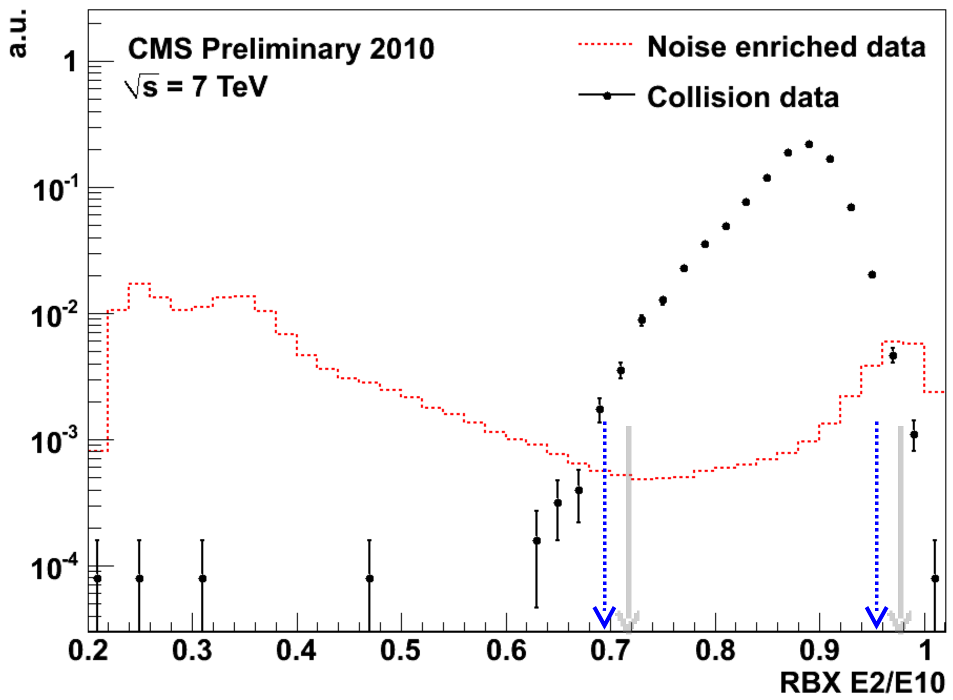




Nominal Pulse Shape



E2/E10 for E_{RBX} > 50 GeV

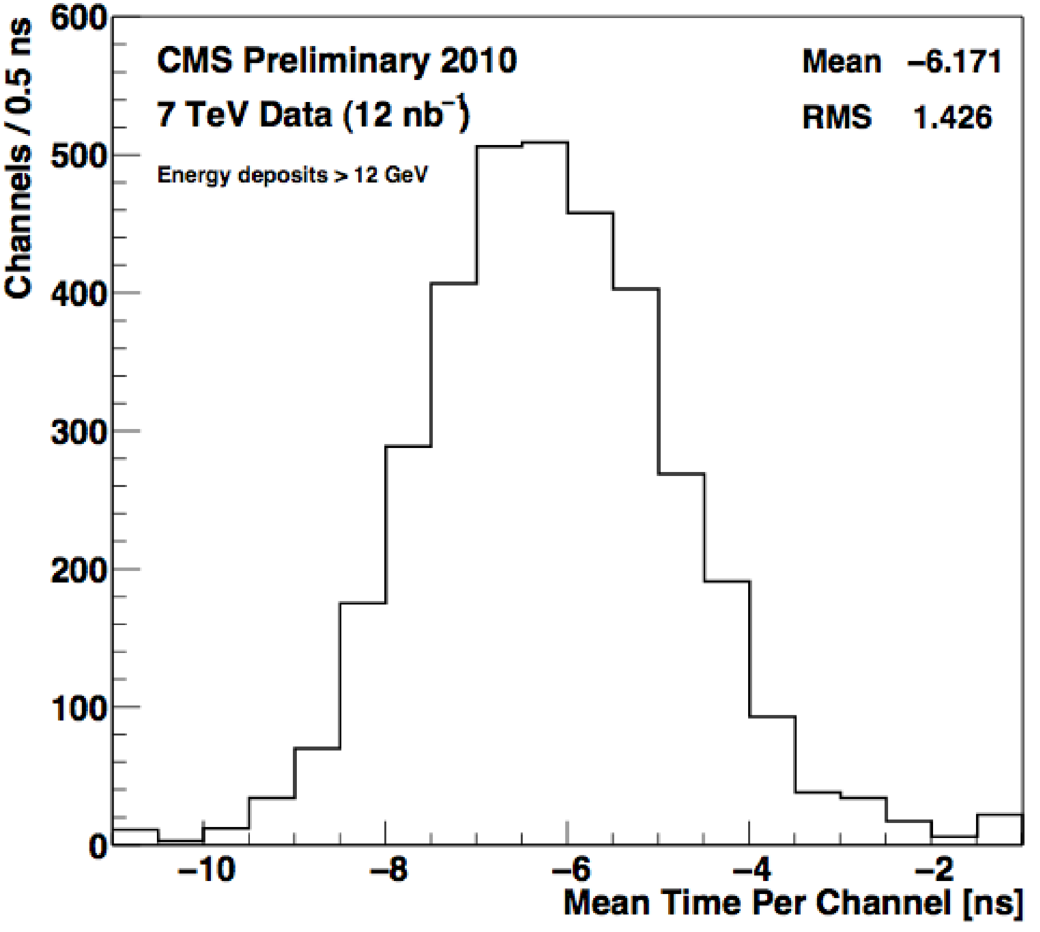


Noise can be identified by the pulse shape

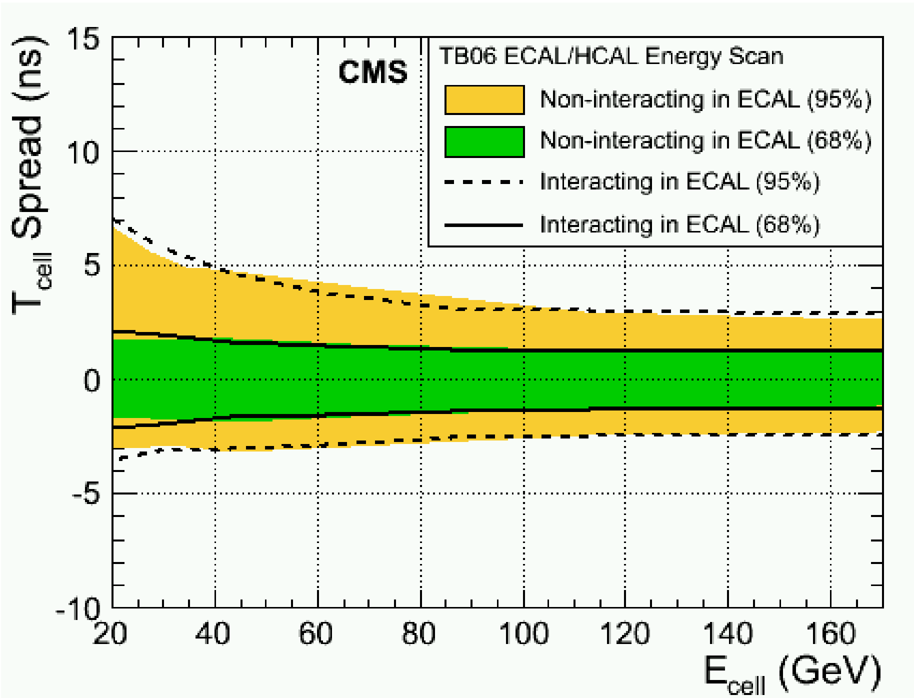
- ➢ RBX E2/E10: the charge in the first two signal TS versus the total charge in the 10 TS over all channels in an RBX
- ➢ The structure in the noise is due to flat pulse shapes(0.2) and 1 or 2 TS spikes (1)

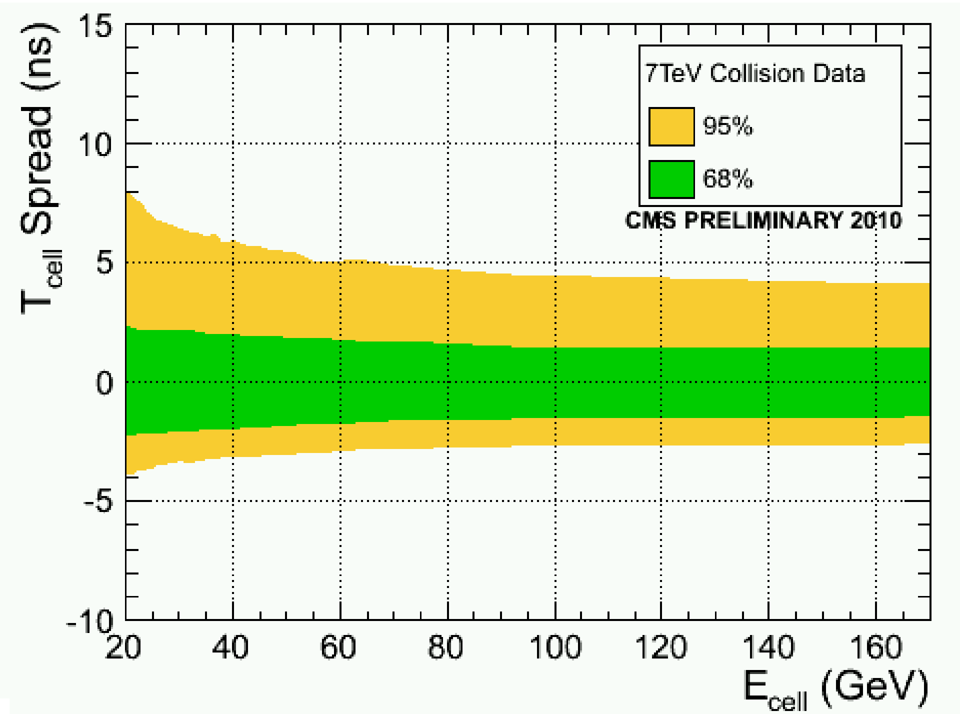
HB/HE Timing

The time-synchronization of all the 5184 HB/HE channels
(12 nb^{-1} 7 TeV data used)



HB/HE Timing Resolution





Left: Timing resolution as a function of energy measured during test beam runs in 2006, showing the consistency of time reconstruction for particles that begin showering in the ECAL (lines) and those that do not (areas) (Test Beam Setup).

Right: The corresponding results using 7 TeV data (~ 40 nb^{-1} from the jet-MET-Tau Primary Dataset) after appropriate noise cleanings are applied (full detector).