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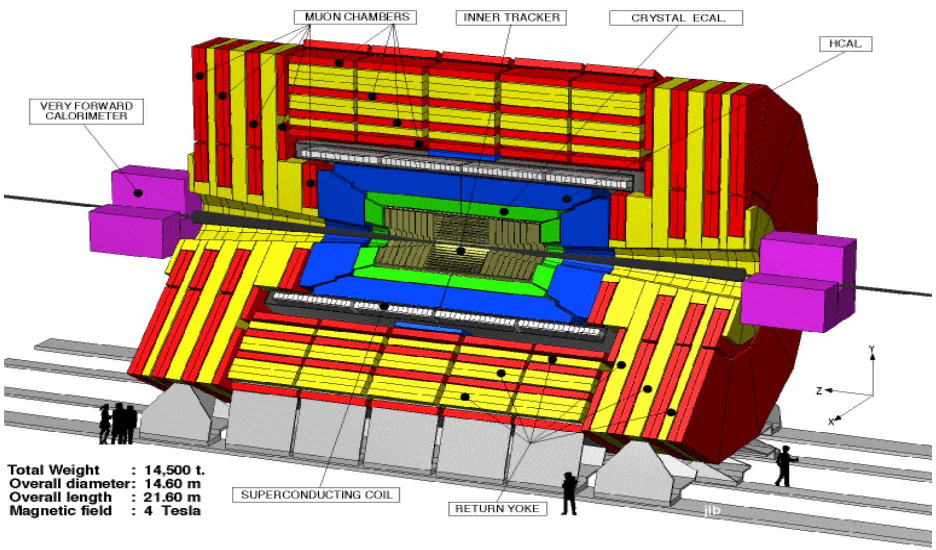
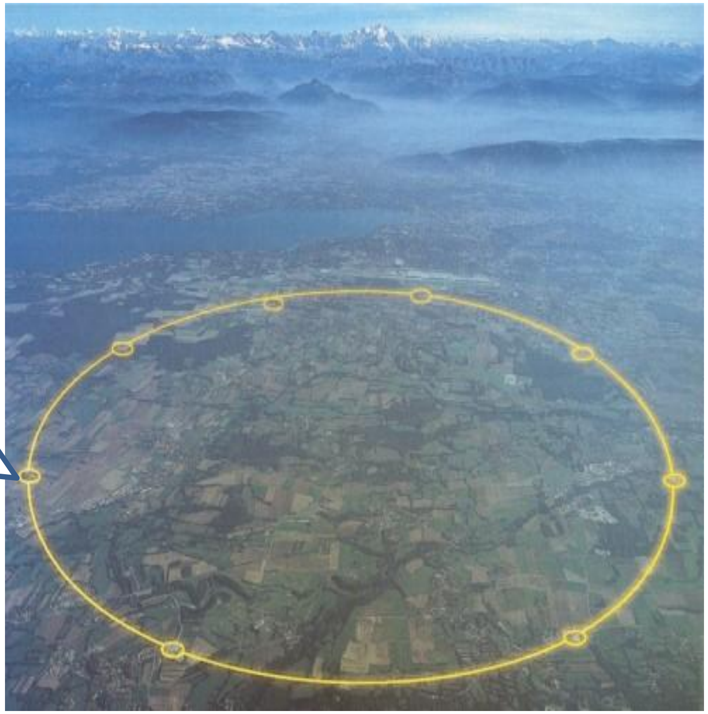
CMS HF Calorimeter and perspectives for it's upgrade

On behalf of CMS collaboration

CMS experiment at LHC

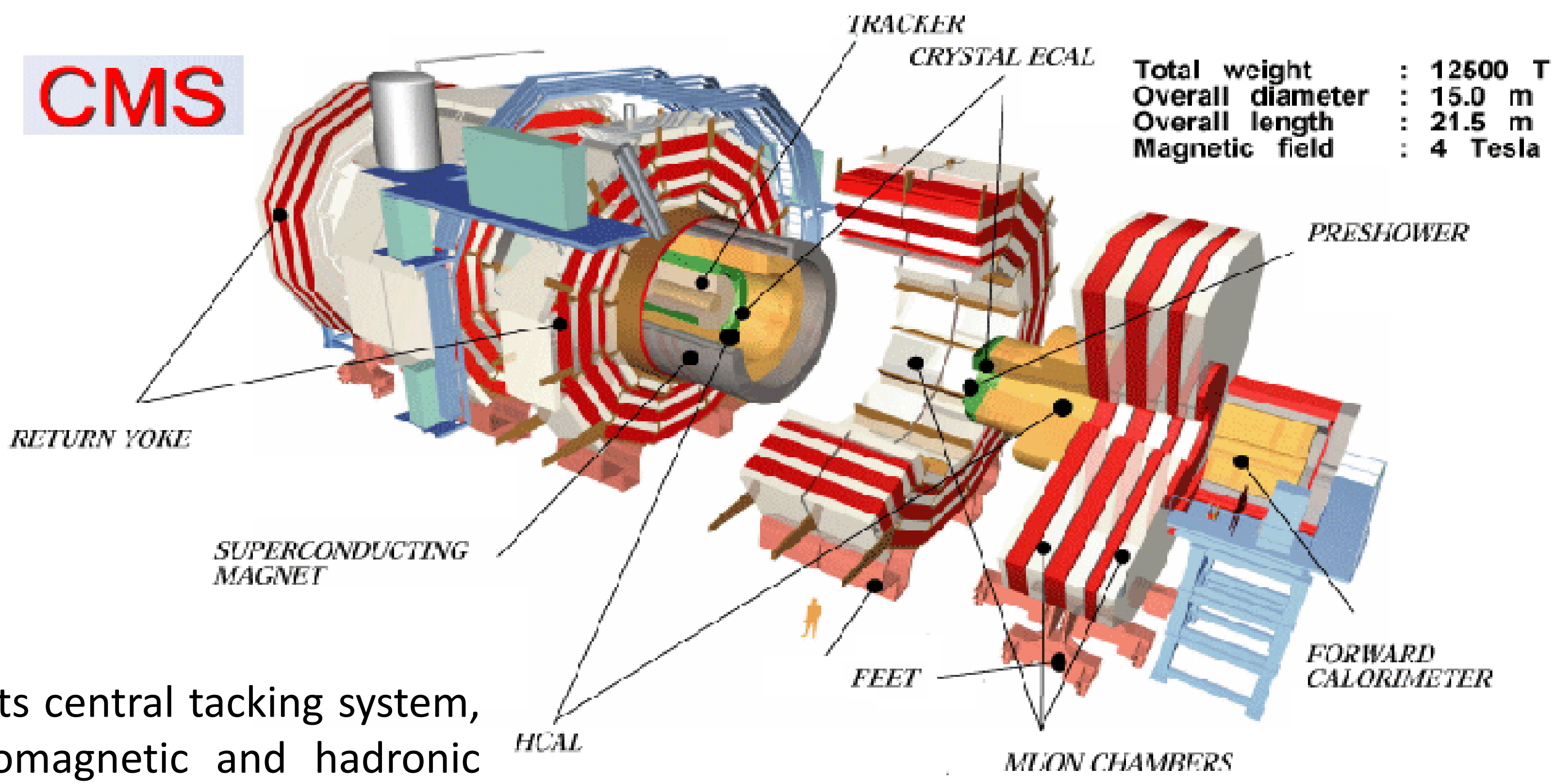
A multipurpose detector to study a vide variety of HEP tasks





located at point 5 of LHC is second largest among four LHC experiment

CMS experiment at LHC



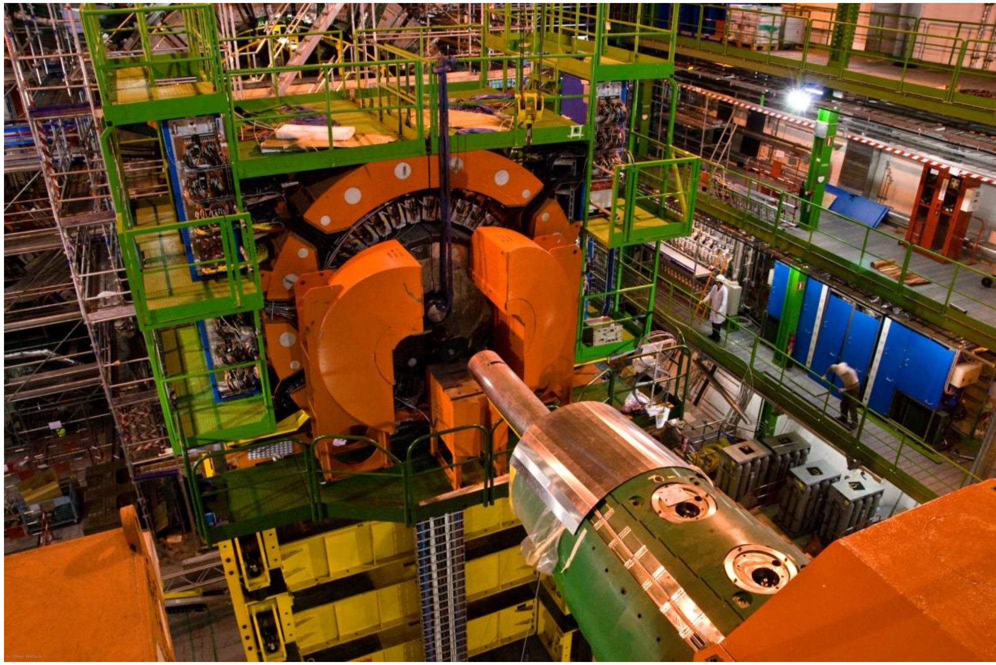
consists central tacking system, electromagnetic and hadronic calorimeters, superconducting magnet providing 4 Tesla magnetic field and muon system.

HF (Hadron Forward)d calorimeter is a part of the HCAL and covers pseudo rapidity region 3 - 5

HF Calorimeter

While lowering – first lowered in to the cavern

On four risers – at beam position



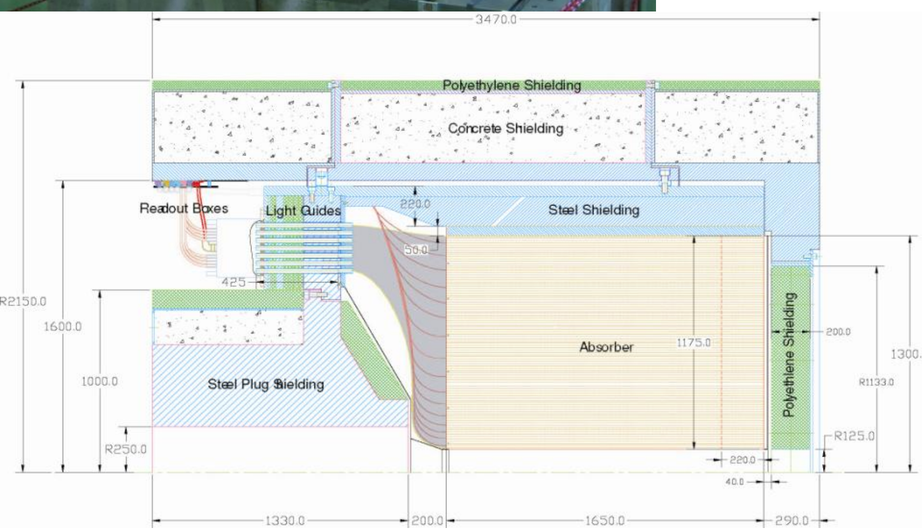
HF calorimeter is composed with two identical parts located at the + and – ends of the CMS detector

HF calorimeter operation principles and construction

- The signal is generated when charged shower particles above the Cherenkov threshold (E > 190 KeV for electrons) generate Cherenkov light, so calorimeter is mostly sensitive to the electromagnetic component of showers
- CMS forward calorimeter during the collisions at nominal LHC energies will experience huge particle fluxes – on average 760 GeV per *pp* collision, which during 10 years of LHC operation translates to ~1Grad radiation
- Successful operation in such a harsh radiation conditions critically depends on the radiation hardness of the active material. This was the principal reason why quartz fibers (fused-silica core and polymer hard-clad) were chosen as the active medium.
- The forward calorimeter is essentially a cylindrical steel structure with an outer radius of 130.0 cm. The front face of the calorimeter is located at 11.15 m from the interaction point. A cylindrical hole with a radius of 12.5 cm accommodates the beam pipe. Thus, the effective sensitive radial interval is 117.5 cm. This structure is azimuthally subdivided into 20-degree modular wedges

HF calorimeter operation principles and construction

Calorimeter wedges



Two compartments ElectroMagnetic and HADronic defined by the embedded fiber length

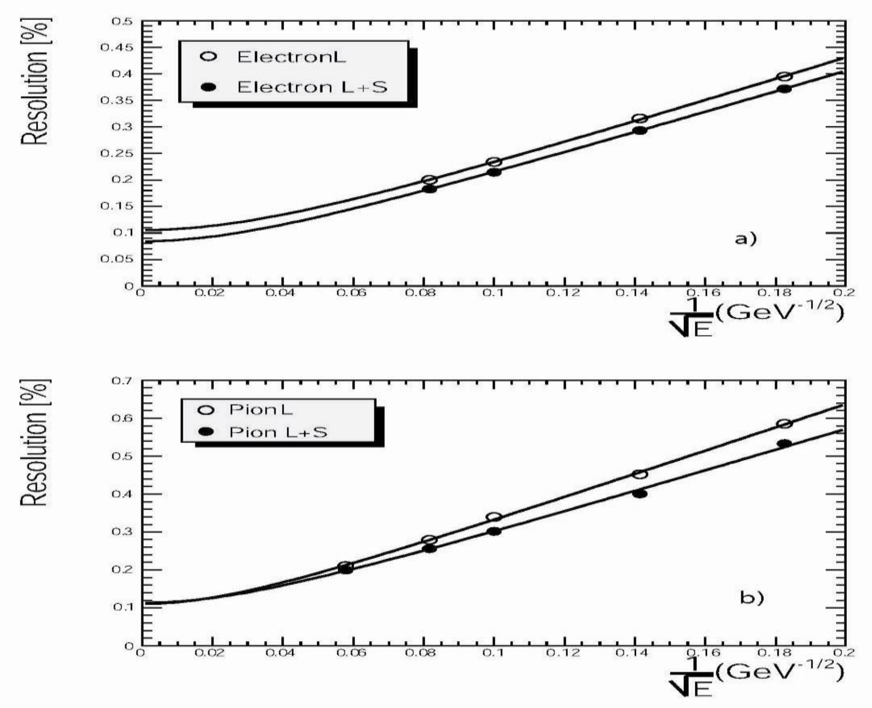
EM - fibers run all the way to the front face of the calorimeter, referred as **Long** fibers

HAD – fibers stops 22cm before front face of the calorimeter, referred as **Short** fibers

Fibers run parallel to the beam line and are bundled to form 0.175•0.175 (Δϕ•Δη) towers. Optical read out – Hamamatsu R7525 Photomultiplier. PMT's and fibers are looking to the aluminum tube housed air core light guides from either side. LG's and PMT's are coupled with small reflective sleeves to prevent corona under HV operation. The detector is housed in a hermetic radiation shielding

Detailed description of HF calorimeter can be found at – EPJ, C53, N 1 (2008)

Energy resolution



If we parameterize hadronic energy resolution as

$$\frac{\sigma}{E} = \frac{a'}{\sqrt{E}} \otimes b'[\frac{E}{0.7}]^{-0.28} \otimes c'$$

and determine b' = 0.83±0.03, then this means that , calorimeter is highly non compensated

The electromagnetic energy resolution (a) is dominated by the photoelectron statistics and is parameterized as

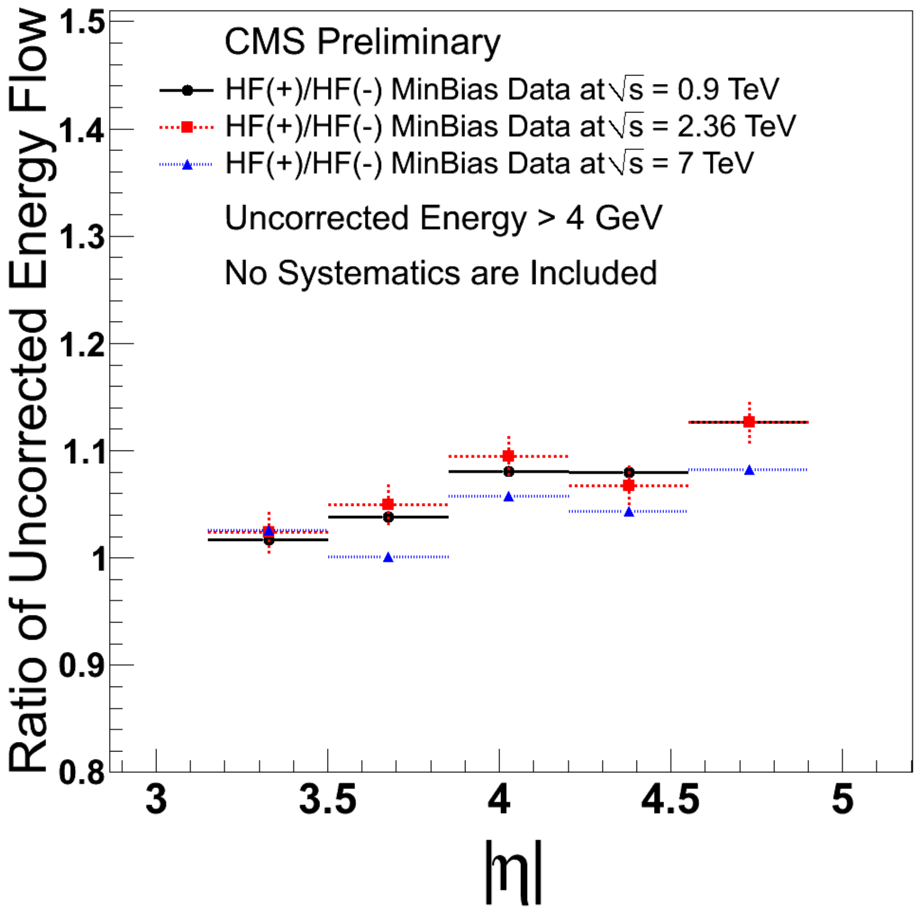
$$\frac{a}{\sqrt{E}} \otimes b$$

The energy resolution due only to the long (L) fibers results in 198% for the stochastic term a and 9% for the constant term b.

The hadronic energy resolution is largely determined by π^0 fluctuations in showers .At low energies, 30 GeV and less, photoelectron statistics also contribute significantly.

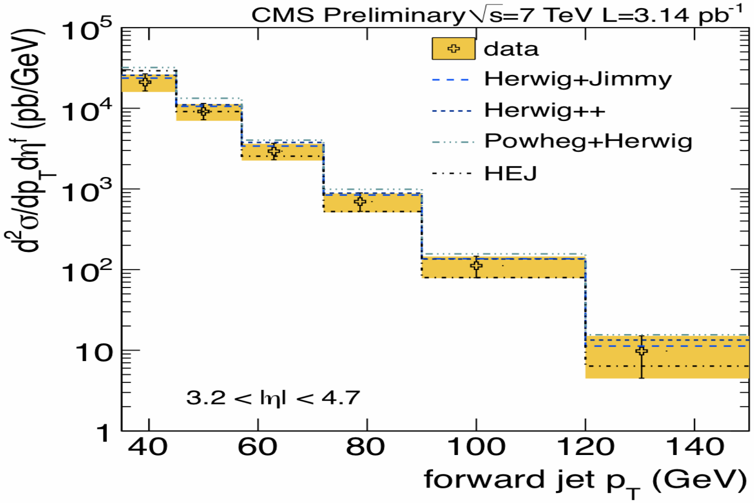
When parameterized as above a = 314% and b =11% for the L fibers. For (L+S), the values are a = 280% and b = 11%

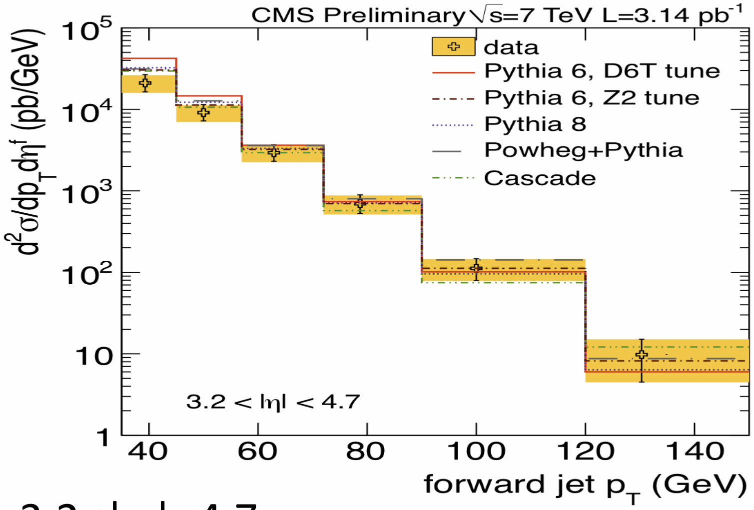
Energy Flow in HF(+) vs. HF(-)

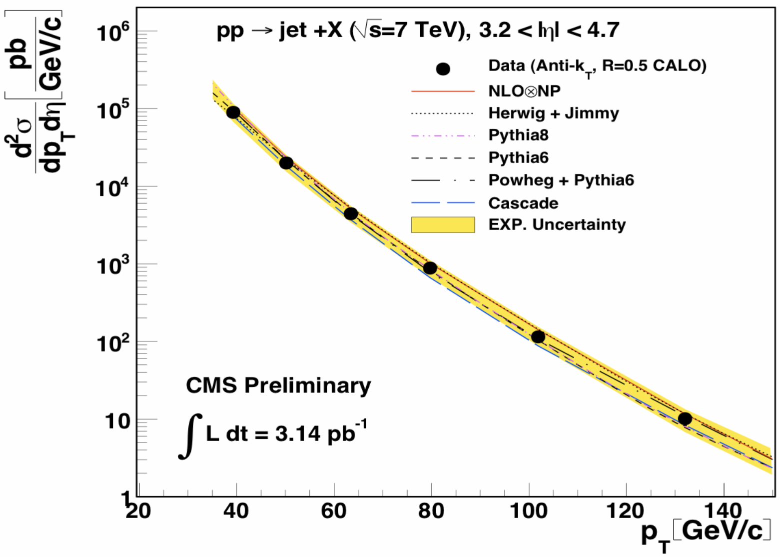


In the figure the ratio of energy flow from HF(+) to energy flow from HF(-) is shown. Uncorrected energy measurements are used and systematic uncertainties are under study

HF performance during beam operation







Jet $P_t > 35$GeV, $3.2<|\eta|<4.7$

Two upper pictures – forward jet P_t compared to various theoretical models.

Bottom left forward jet cross section is compared to several modes. In all cases agreement is excellent

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsFWD

Anomalous events in HF calorimeter

Anomalous signals in HF

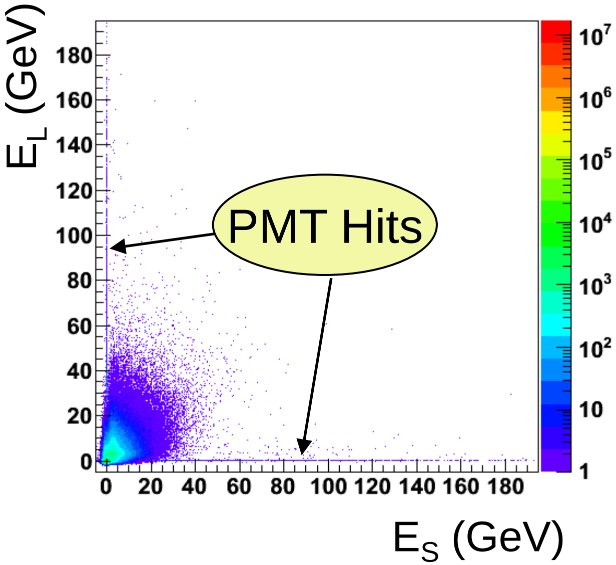
Cherenkov light produced by interactions in the window of the Forward Calorimeter PMTs

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

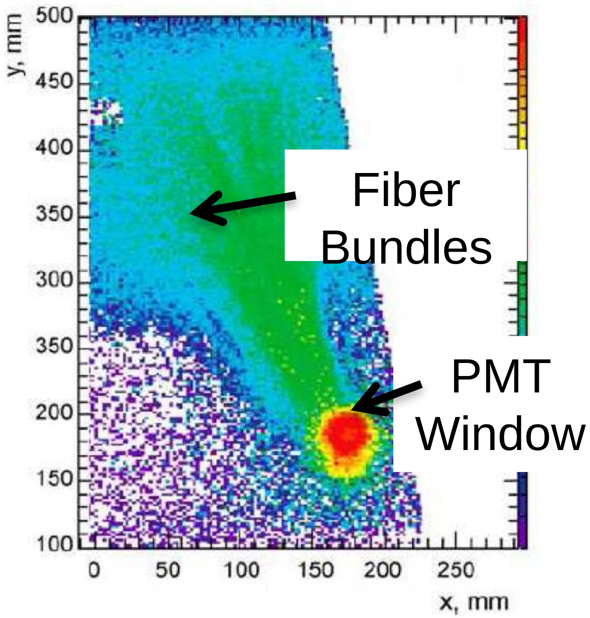
HF PMT hit identification – compare signals from the Long and Short fibers using relation

$$R = (E_L - E_S)/(E_L + E_S)..$$

Dominant sources are muons from decays in flight and hadron shower punch through

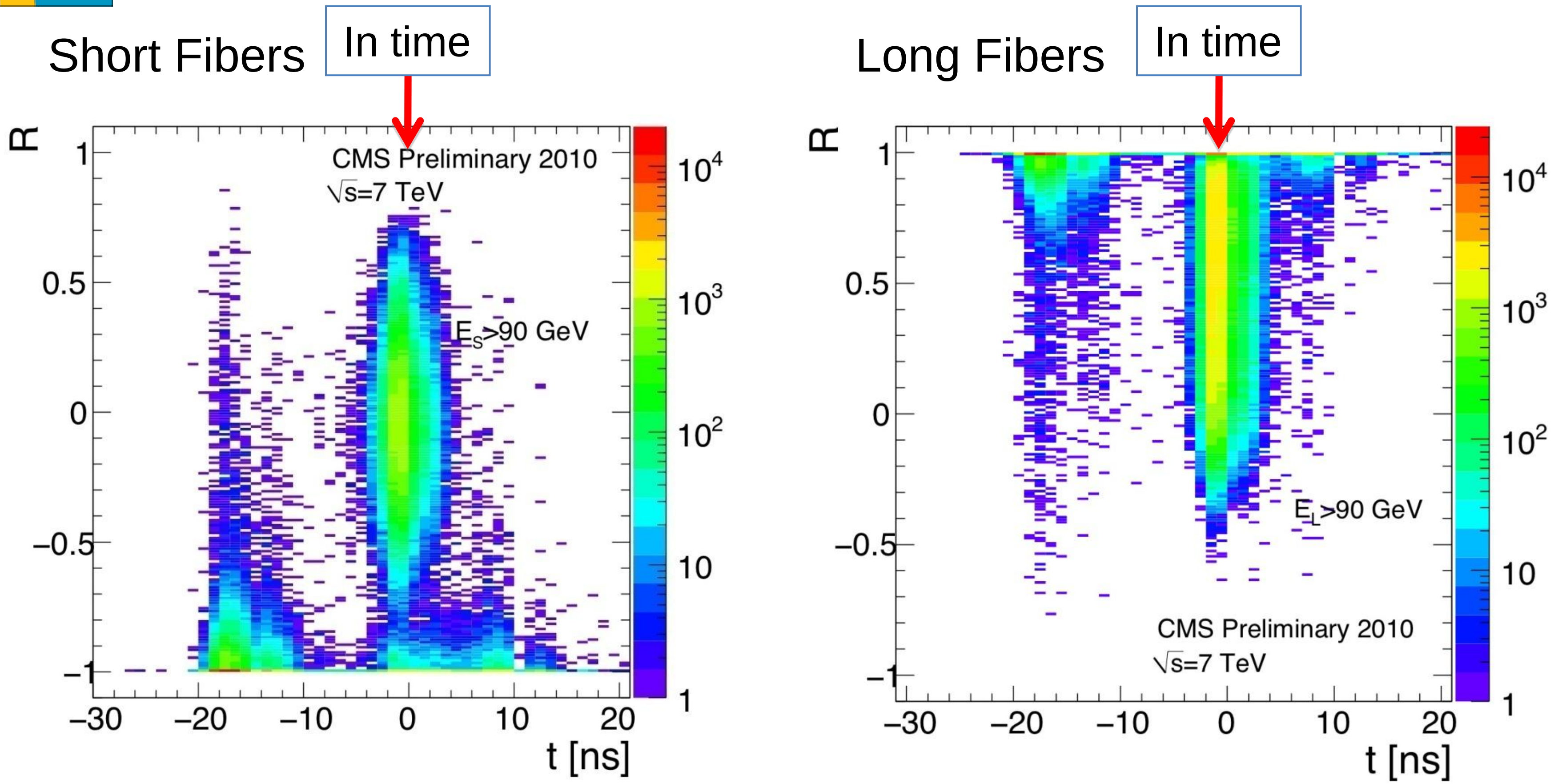


R is used to identify PMT hits in the short fibers. For long fibers an isolation criterion is used to avoid misidentifying EM showers as PMT hits



Eur. Phys.J. C53, 139-166 (2008),JINST 5 T03014

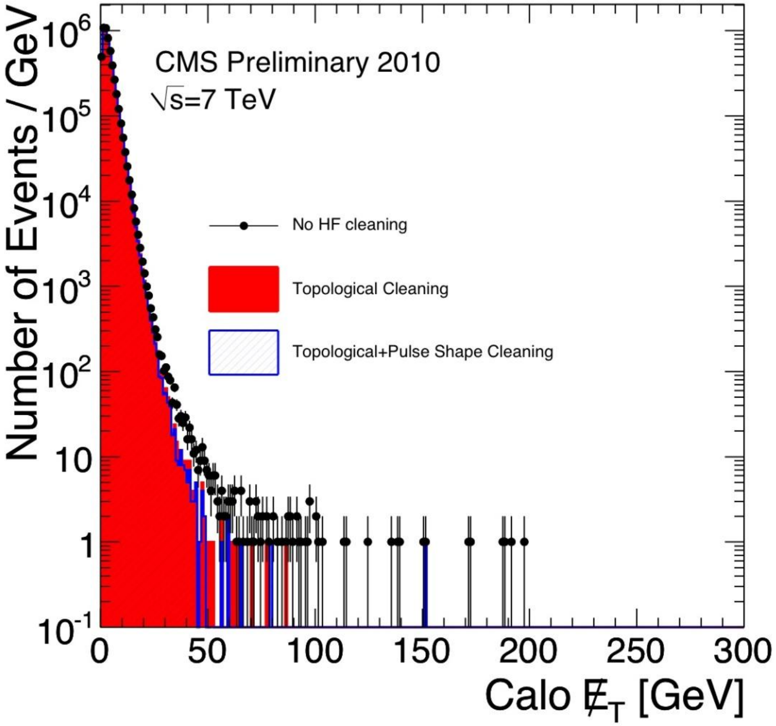
Anomalous signals in HF

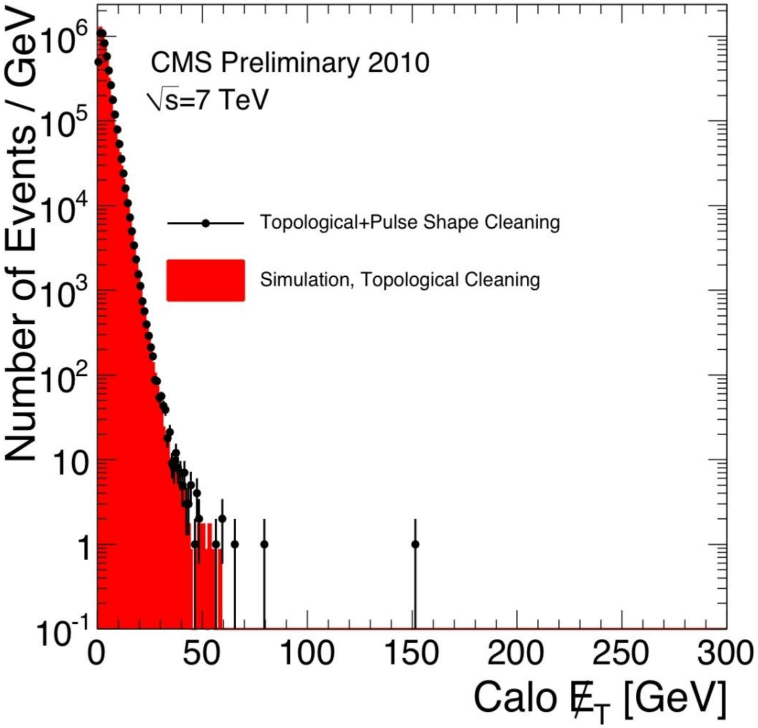


R ratio versus reconstructed time for short (left) and long (right) fiber hits having E > 90 GeV in 7 TeV collision data (~1 nb^{-1} minimum bias data).

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

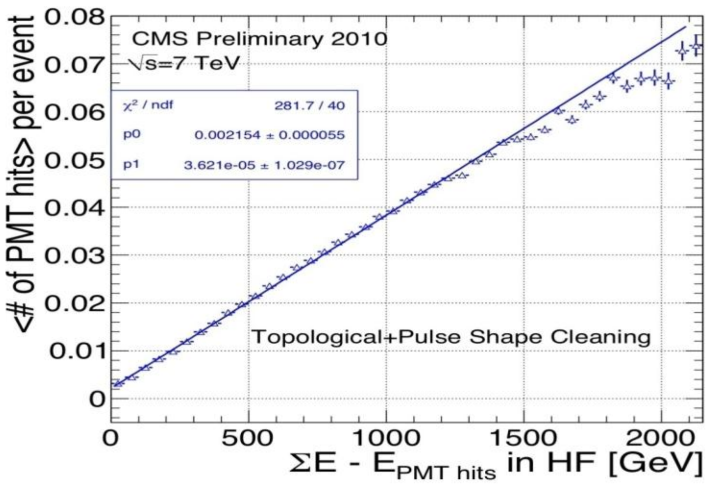
HF PMT Hit Filters: Anomalous event





Transverse Energy before and after the HF PMT hit cleaning PMT hit noise filters (left) and comparison of the cleaned spectrum with the MC CMS simulation (right).

HF PMT Hit Filters: Anomalous event

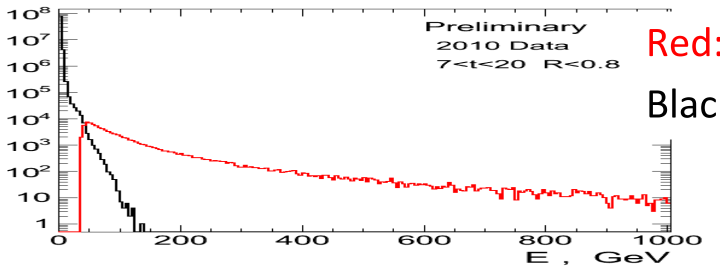


Rates in 2009 minimum bias data (~1720 PMTS)

~6x10^{-3} per event identified for 900 GeV data

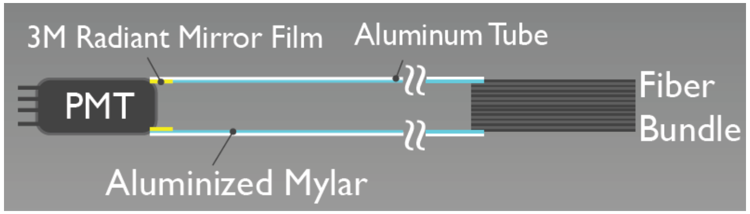
~8x10^{-3} per event identified for 2.36 TeV data

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").



Red: flagged by noise filter

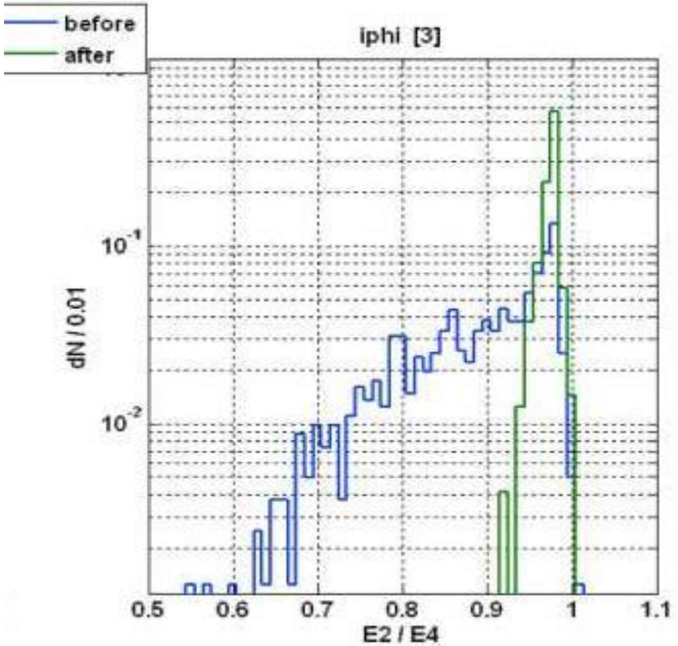
Black: not flagged



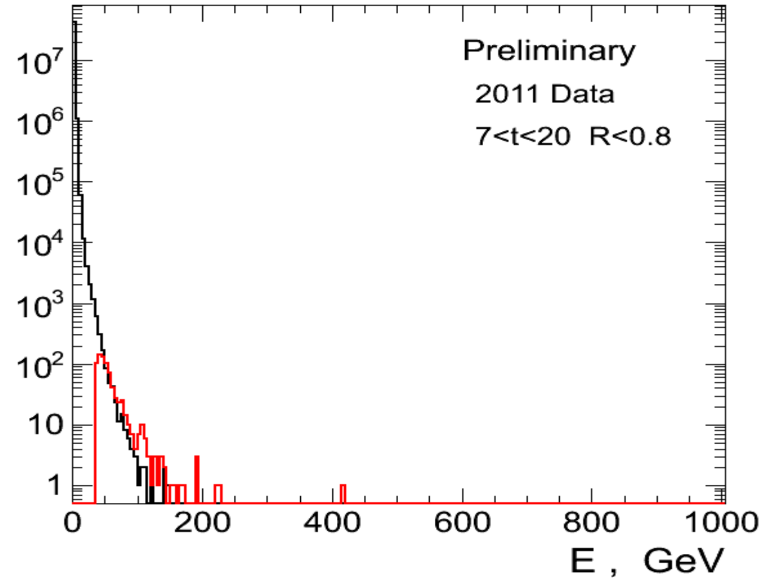
Motivation for upgrade

Upgrade

Quick upgrade– 3M radiant mirror sleeves exchanged to tyvek ones



Ratio of signals in two TS – E2 over the signal in four TS - E4 before and after sleeve exchange



HF noisy event filter performance after sleeves replaced

PMT upgrade

<u>Basic requirements for a PMT</u>

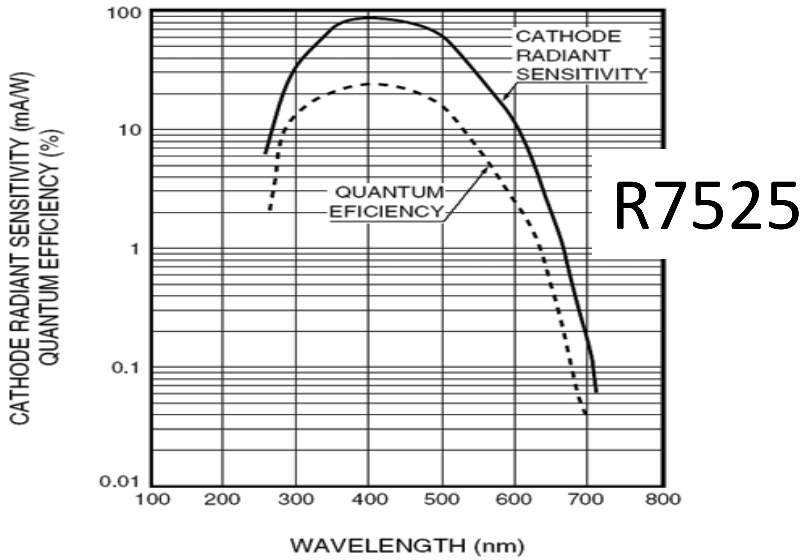
- Thin front window
- Good quantum efficiency
- Gain at least comparable with present ones (Hamamatsu R7525)
- Multichannel, to effectively suppress muon hits in a window

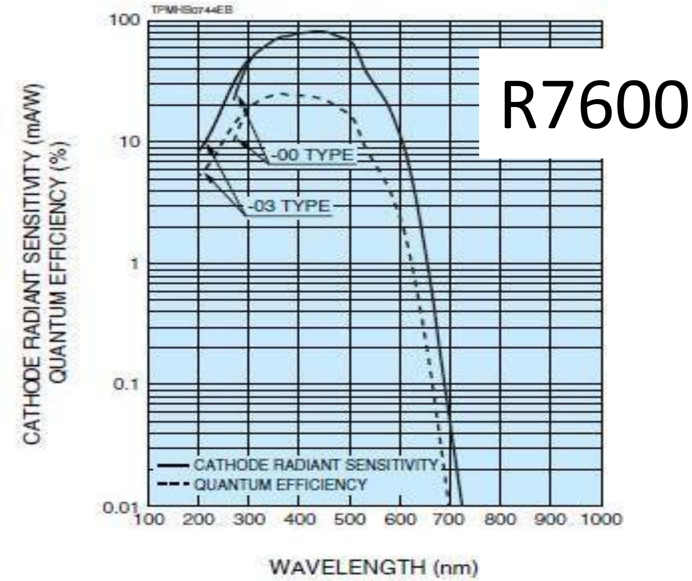
Hamamatsu R7600 – 4 anode PMT's were chosen to change old R7525 PMT's

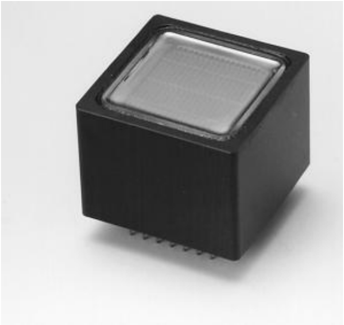
PMT upgrade

Part Number	**R7600**	**R7525**
Peak Sens.	420nm	420nm
Cathode Radiant Sensitivity	72mA/W	88mA/W
Window	Borosilicate	Borosilicate
Cathode Type	Bialkali	Bialkali
Cathode Luminous Sensitivity	70µA/lm	95µA/lm
Anode Luminous Sensitivity	140A/lm	45A/lm
Gain	2.0E+06	5.0E+05
Dark Current after 30 min.	0.5nA	5nA
Rise Time	2.2ns	1.3ns
Transit Time	8.8ns	14ns
Number of Dynodes	10	8
Applied Voltage	800V	1750V

Hamamatsu R7600 vs R7525

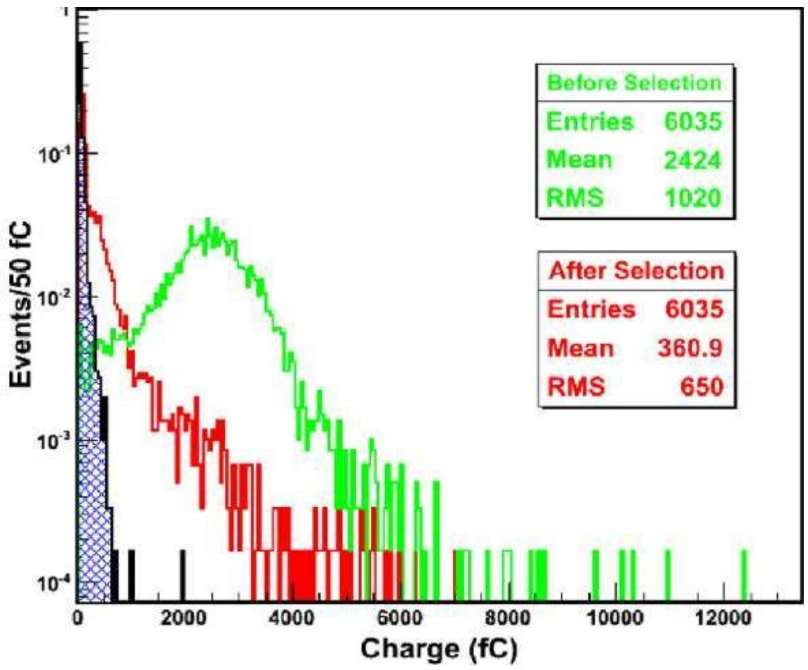






Typical spectral response and quantum efficiency for R7525 and R7600 PMT's

Hamamatsu R7600 performance



Reduction of the unwanted window events after selecting those signals with high correlation between the channels (right-red distribution). Window events will produce signals in some of the channels but not all of them (uncorrelated) as seen in the event distribution before the selection (green).

Hamamatsu 4-anode PMTs (R7600) are chosen to be the replacement PMTs for the HF

Summary

- HF (hadron forward) calorimeter of CMS experiment, covering very forward region, was discussed.
- It showed excellent performance during 2010 run and performs perfectly during 2011 run as well
- Some anomalous events were observed to happen during operation, such as window hit events.
- The event filters developed to distinguish good and anomalous events.
- In parallel significant effort is going on to upgrade the calorimeter in order reduce as possible unwanted event activity
- Upgrade work of HF calorimeter is quite big effort, since it requires to exchange Front End electronics, cables and some services