Anomalous Events in HF

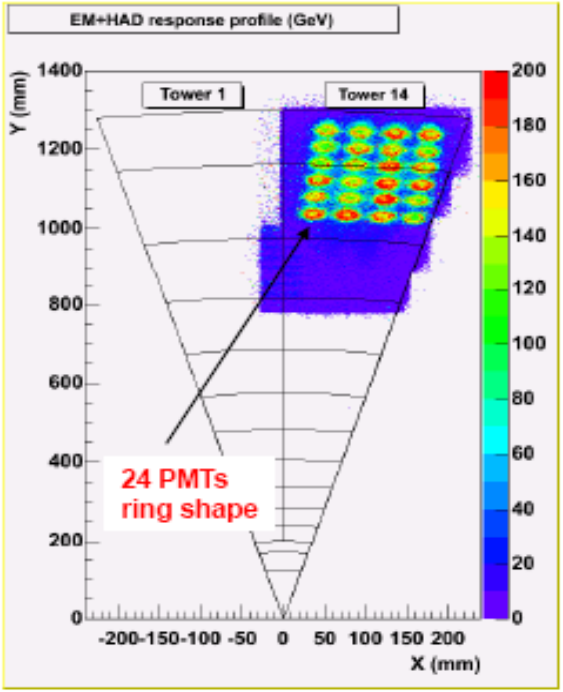
Frank Chlebana

HF Upgrade Review Practice Talk

August 10, 2010

HF PMT Window Hits

150GeV Muon / Wedge 2-6

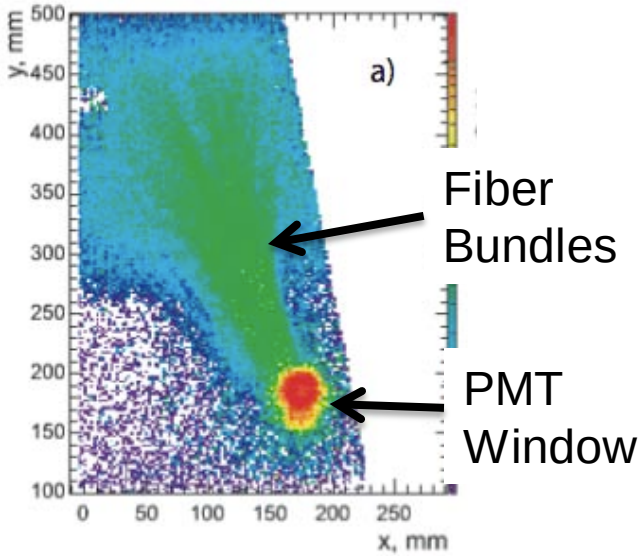


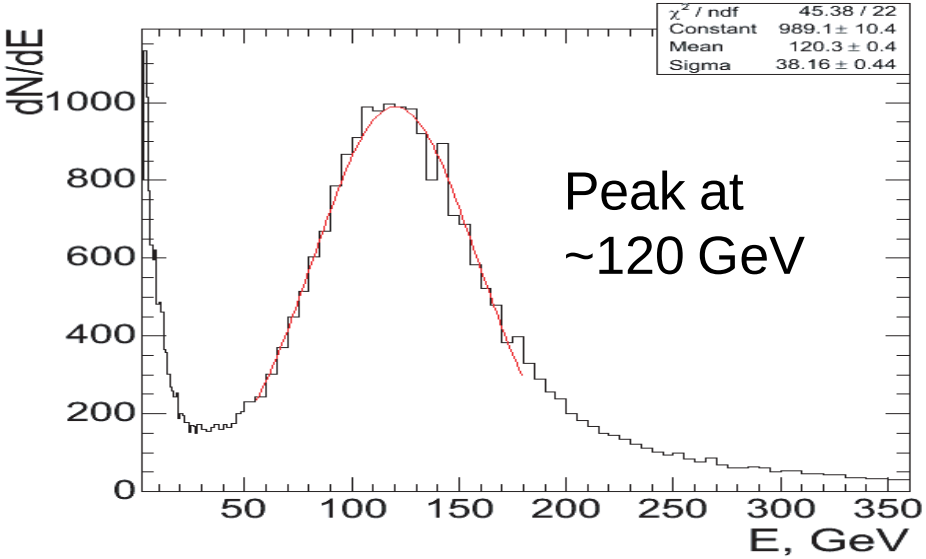
TB2004 elog 3601 Aug. 2, 2004

Anomalous signals were first observed in the 2004 test beam

Signals in HF L or S sections observed from particles interacting in the PMT window.

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





TB calibration for 100 GeV electrons set so L energy = 100 GeV; L+S = 130 GeV

For current calibration peak would occur at 120 / (130/100) = 92 GeV

Anomalous Events in HF

Two main sources of anomalous events in HF

HF PMT Window Events *(topic of this review)*

- Replace PMTs with thinner window
- Additional handles to identify anomalous events
  - *Multi-channel readout*
  - *Finer time resolution*

Late hits from scintillation light

- Plan to replace light guides
- *More details in Taylan's talk*

Noise Working Groups

The software infrastructure to treat anomalous events was started when they were first observed

HCAL DPG Noise Task Force was established to study the properties of Noise

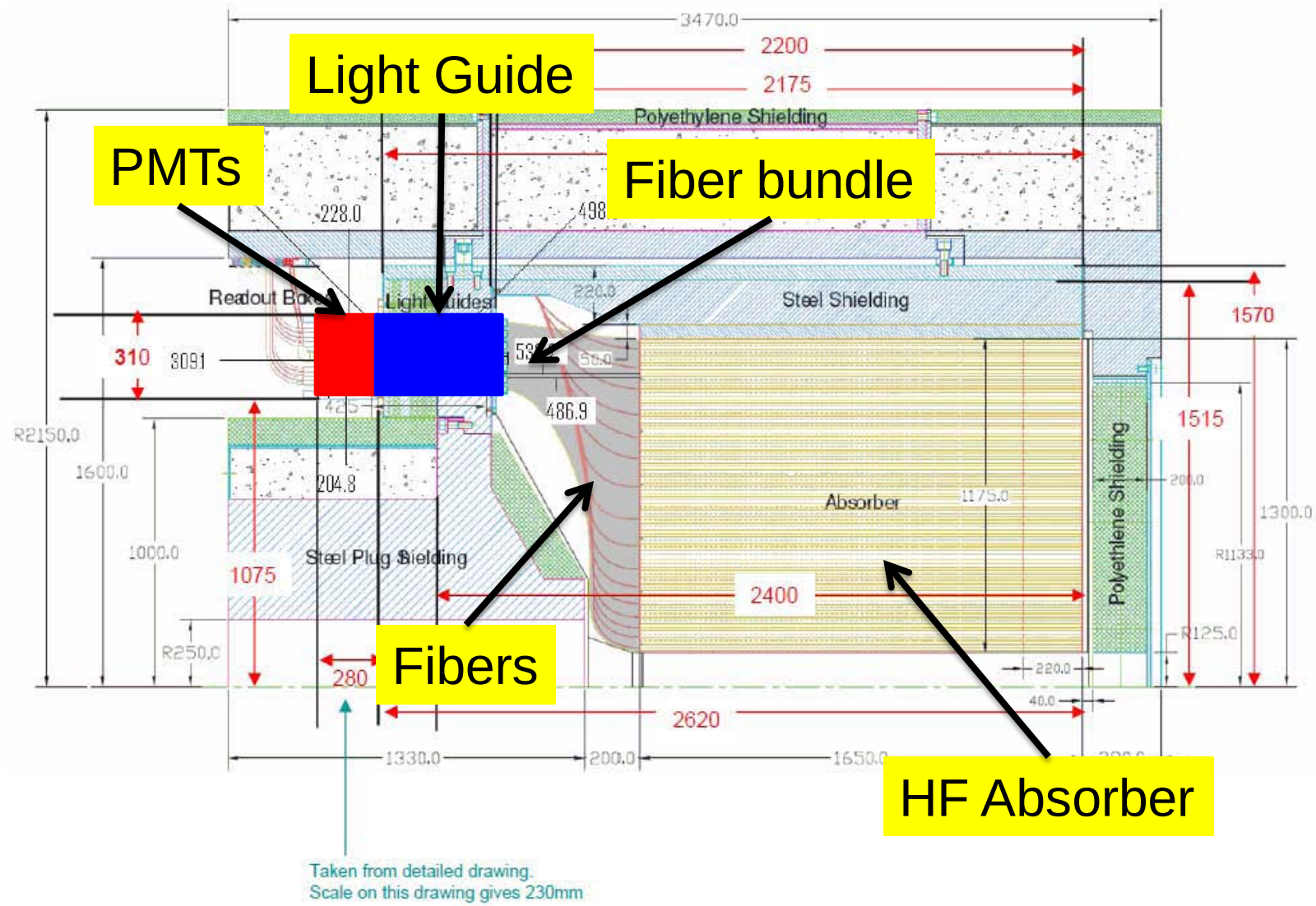
CMS established the Anomalous Signals in Calorimeters Task Force (ASCTF) to coordinate the treatment of noise filtering and to provide official recommendations to CMS

Provided recommendations for the ICHEP dataset

HCAL DPG Noise Working Group established to develop filters to treat residual noise

Represents the work of many people… including work needed to develop the software framework

Hadronic Forward Calorimeter

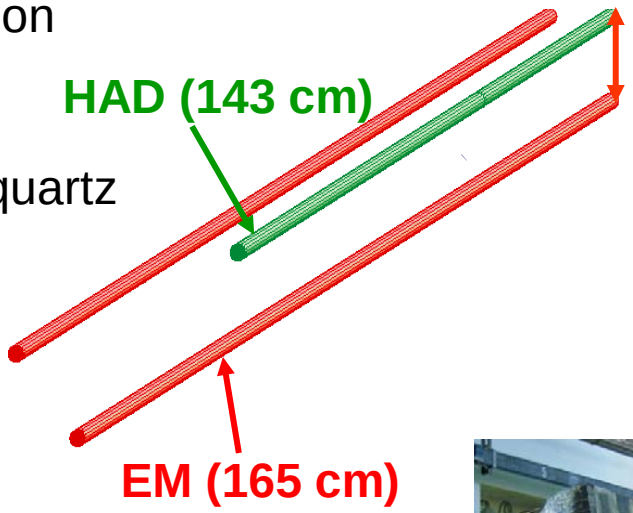


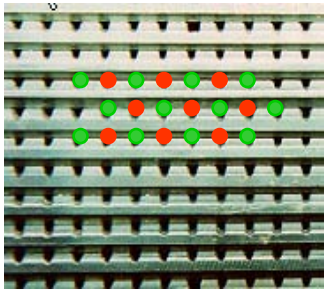
Forward Calorimeter (HF)

HF is located about 11 m from the interaction point, covers 3 < |η| < 5 with depth 10 λ_{int}

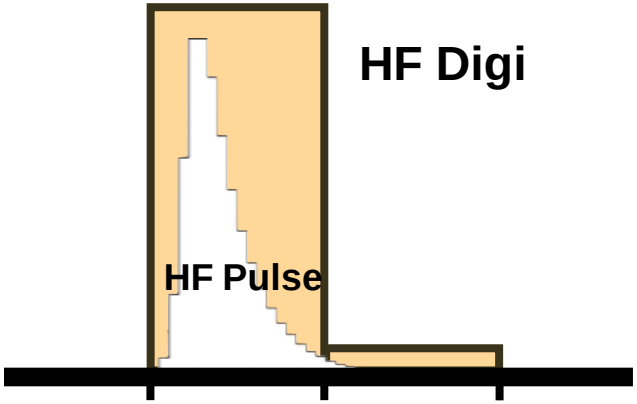
Consists of iron absorber embedded with quartz fibers parallel to the beam direction in a 5x5 mm matrix

Charged particles from showers produce Cherenkov light

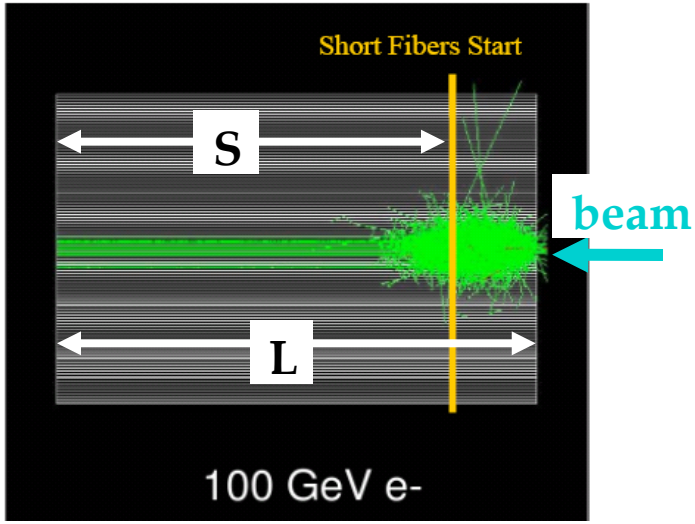




HF signal generation and collection is very fast ~10 ns



25 ns time samples



20° wedges

Filters to Remove HF Anomalous Events

Filters based on topology (isolation)

PMT window events typically have large energy in either the long or short sections with no significant energy in the corresponding short or long sections

Filters using timing or pulse shape

PMT window events produce pulses that arrive earlier than the scintilation light produced in the absorber

Details of the filters can be found in: CMS DN-2010/008

Evolution of the Topological Algorithm

Algo 1) *HCAL DPG, tcMET*

R = |L-S|/(L+S) > R_Th

E or Et > E_Th

Original algorithm

E, ET thresholds were too low

Algo 2) *HCAL DPG*

Polynomial Energy Threshold (PET)

R = (L-S)/(L+S)

E > E_Th(iEta)

Optimization of E threshold

Algo 3) *PFlow, HCAL DPG*

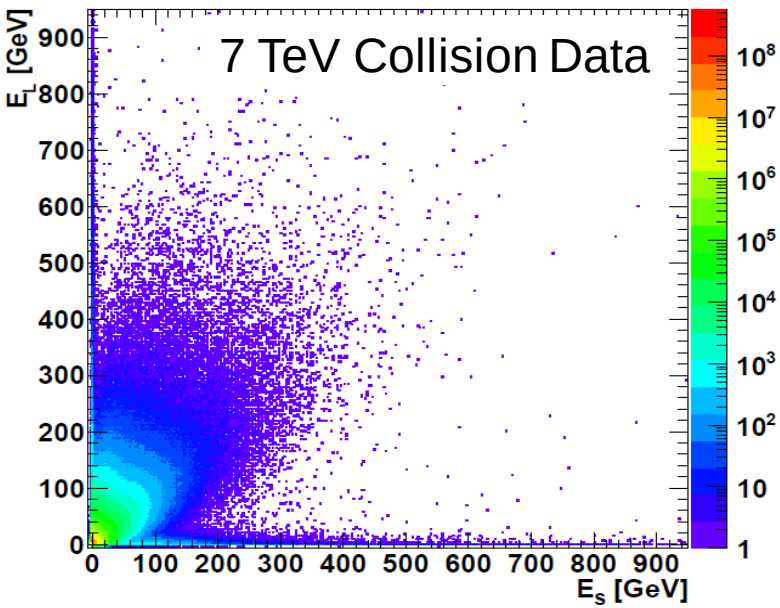
Short: S/L

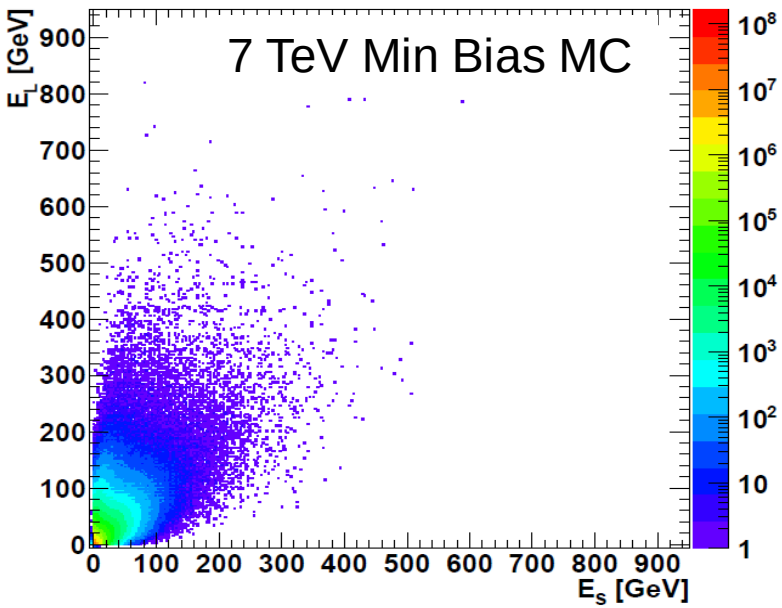
Long: S9/S1

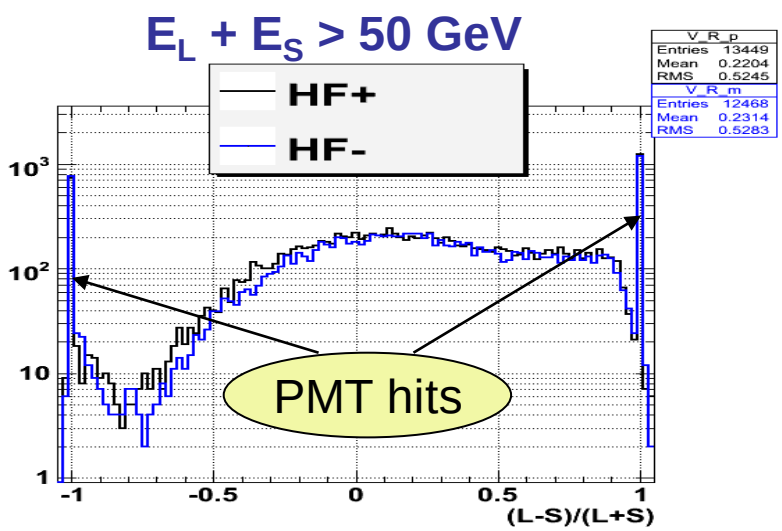
Simple cuts (Algo 1) were removing energy in physics MC

Isolation criteria introduced by PFlow

Topological Filter

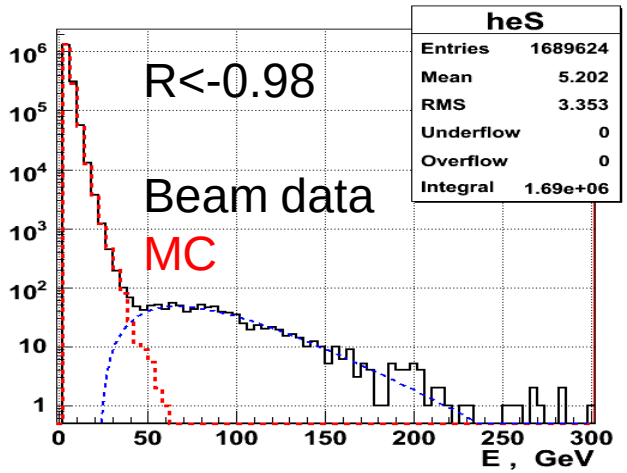


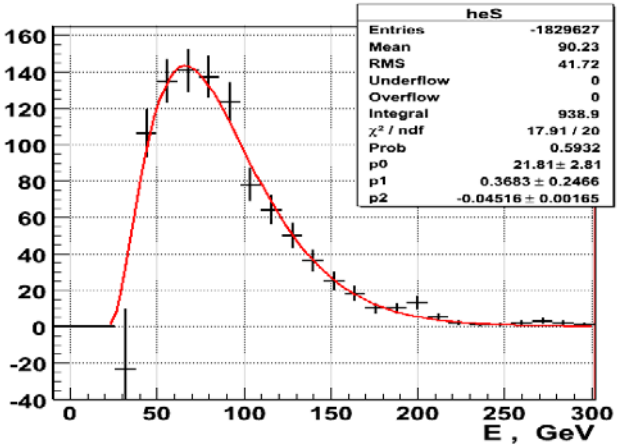




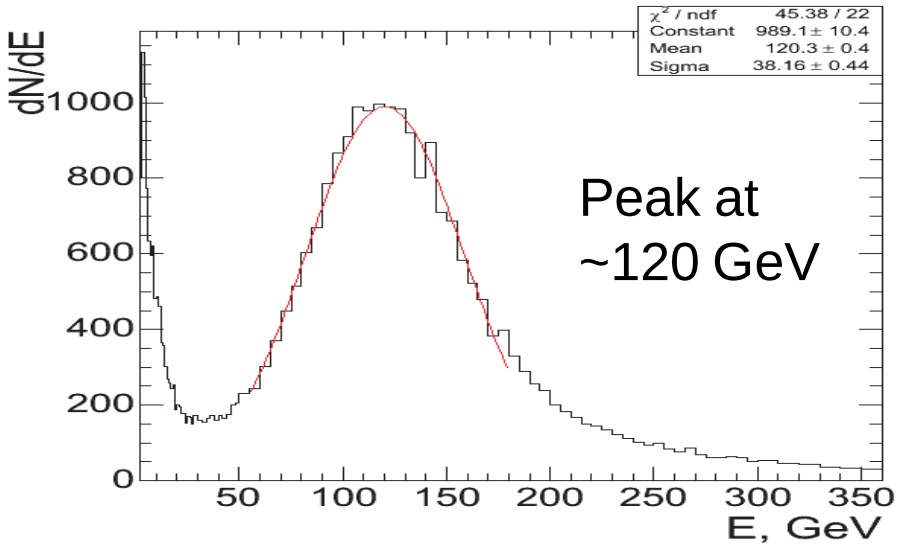
Can identify HF PMT Window events by looking at the ratio R = (L – S)/(L + S) and require *E* or E_T > Threshold

HF PMT Window Events





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



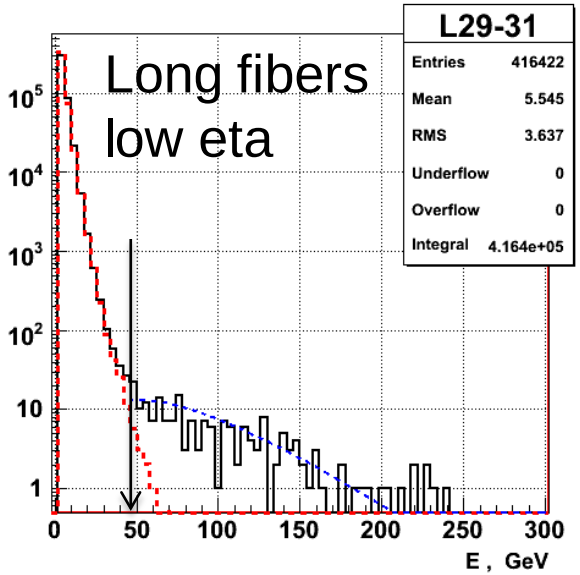
Spectra of PMT Hit events does not extend to very high energies

Forward region → Low E_T

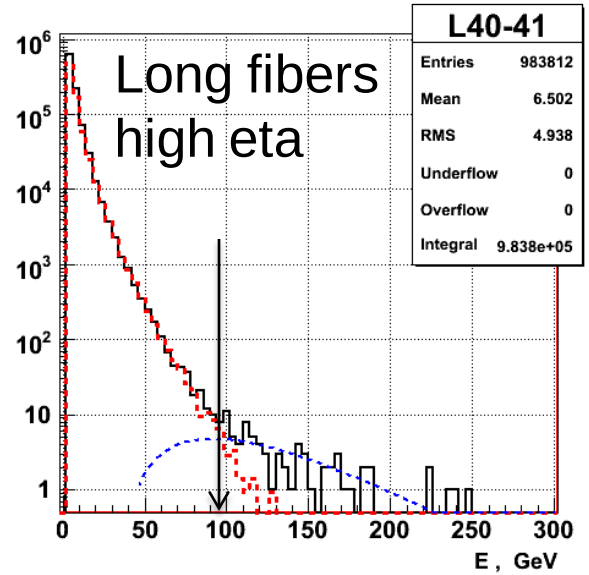
TB calibration for 100 GeV electrons set so L energy = 100 GeV; L+S = 130 GeV

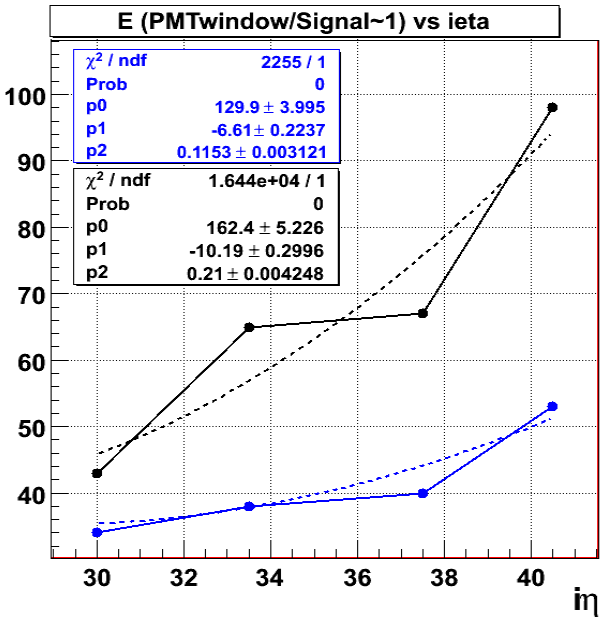
For current calibration peak would occur at 120 / (130/100) = 92 GeV

Algorithm 2: E > E_Th(iEta)



Increasing iEta





More energy deposited at higher eta

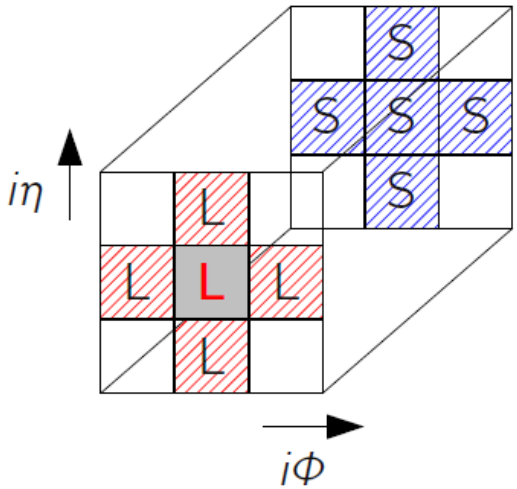
Can use a sliding energy threshold in order to avoid rejecting physics

Set threshold at energy where physics rate = noise rate

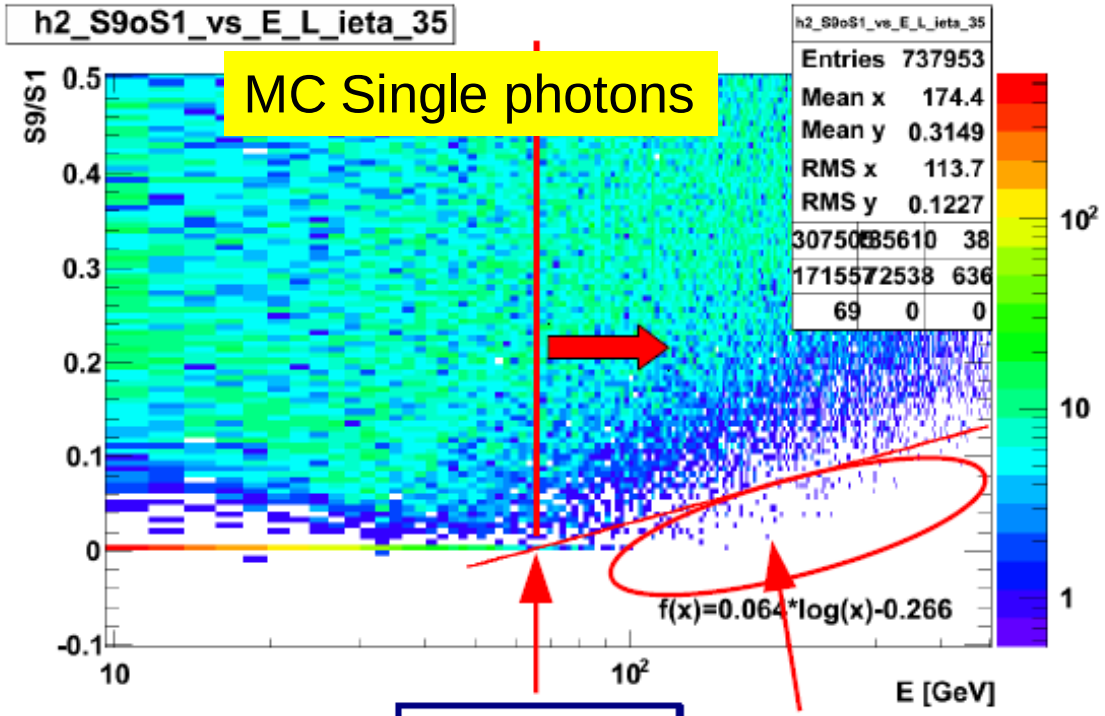
Algorithm 3: S9/S1

Introduce isolation to make the algorithm "safer"

E > E_PET(iEta)
S9/S1 < f(E, iEta)



$$\left(\frac{S9}{S1}\right)_L = \frac{S + L_{(4)} + S_{(4)}}{L}$$

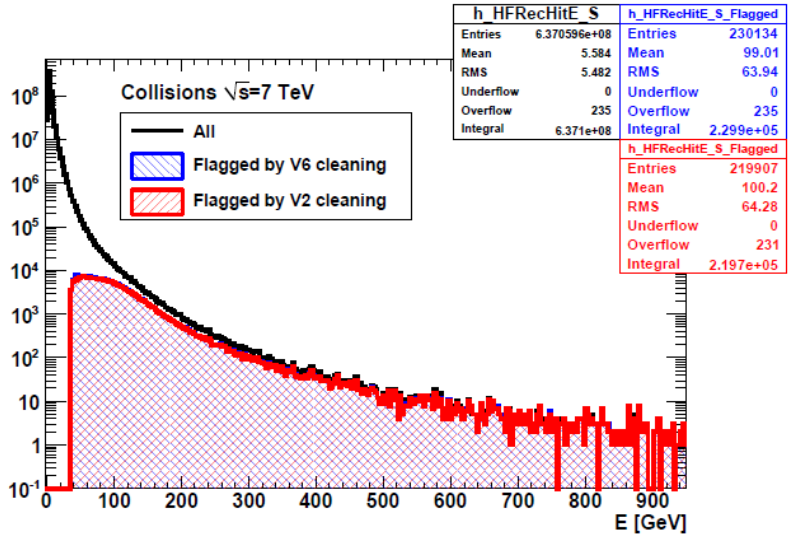


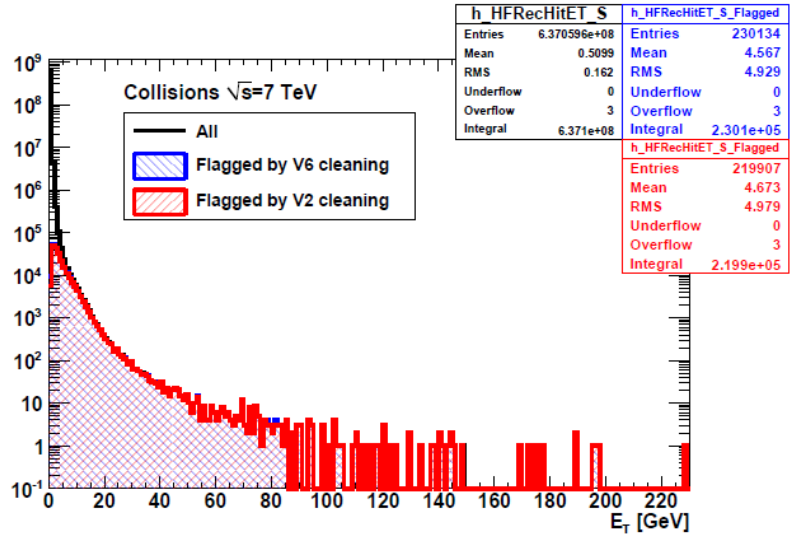
$E_{PET}(35)$ cut

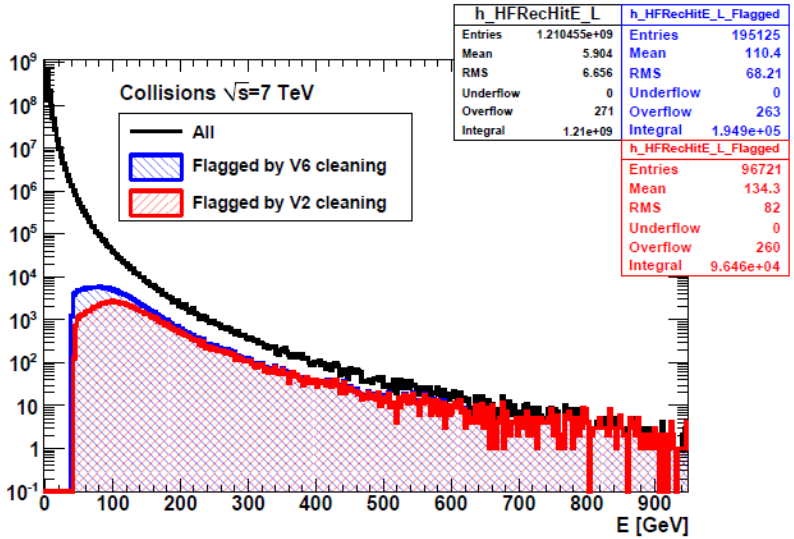
Flagged RecHits are those below the cut line

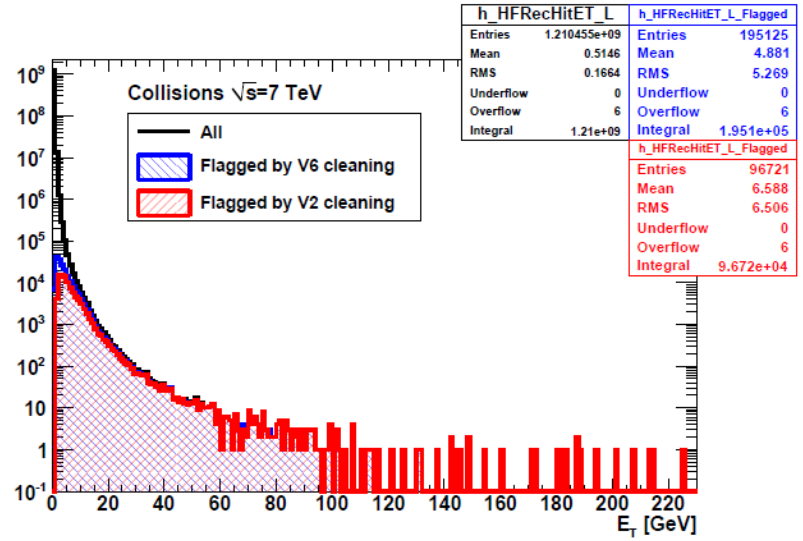
Slope optimized such that only 0.1% of the simulated photons above the E_PET(iη) threshold is flagged

Flagged Noise in the 7 TeV Data

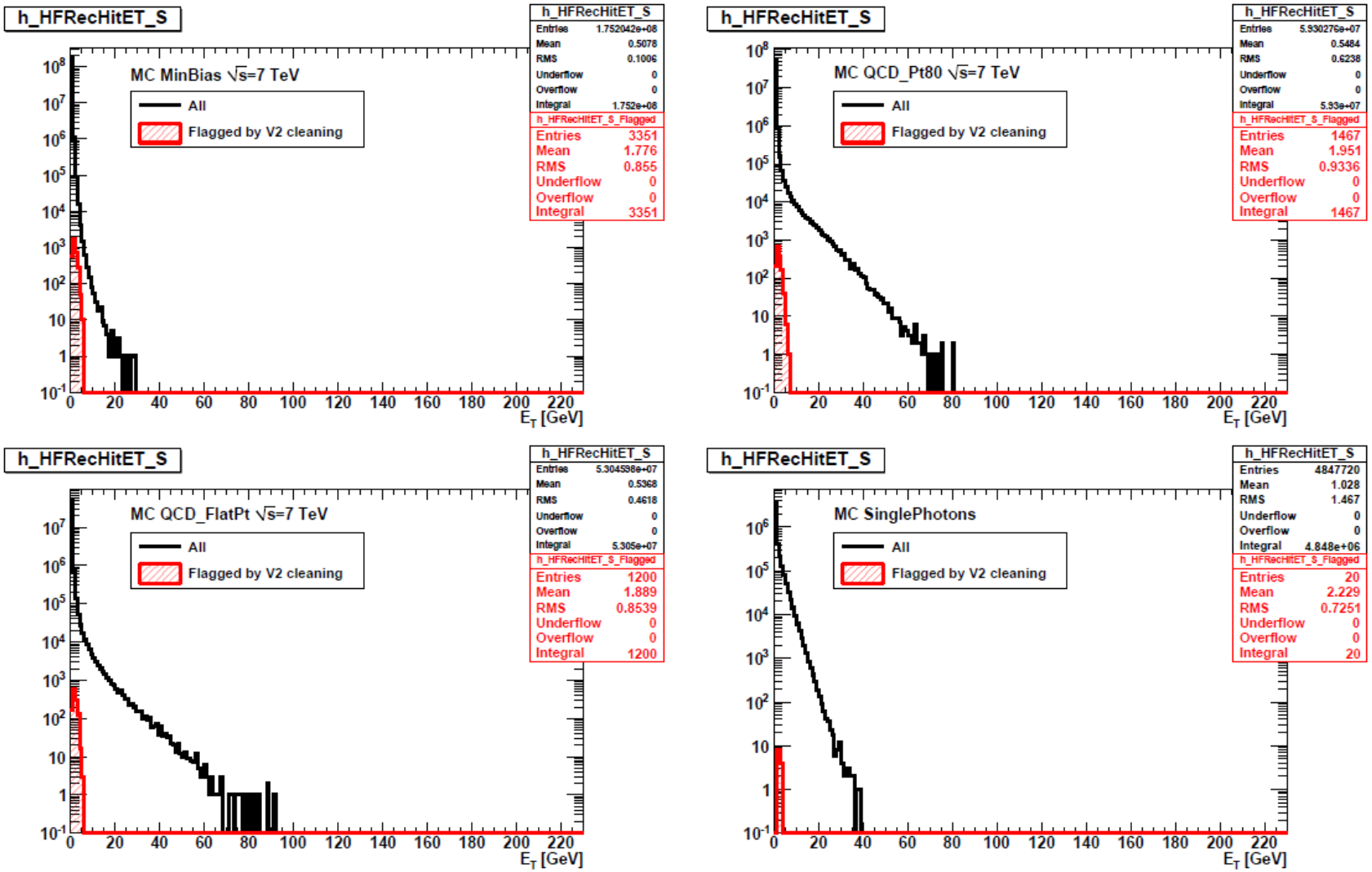






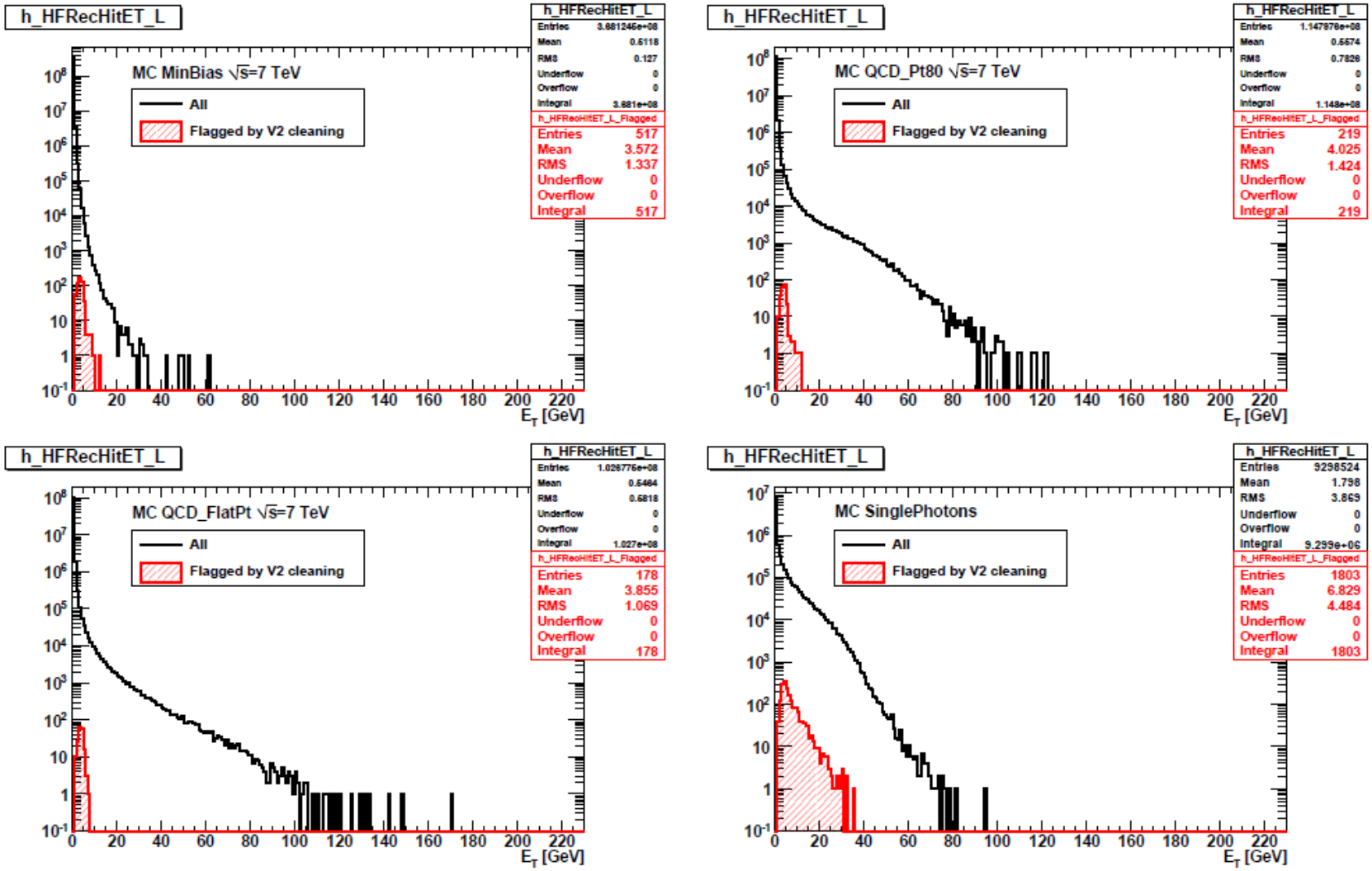


Mis-Identified Noise in MC Samples



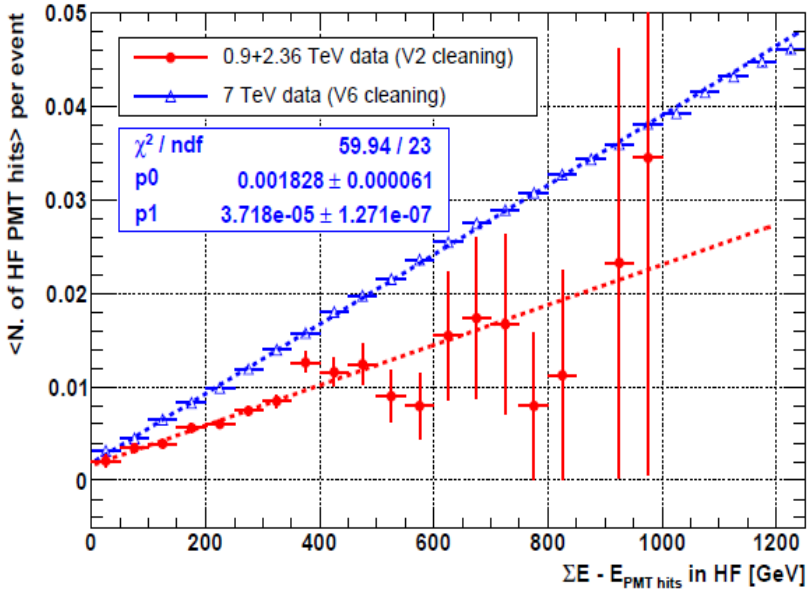
E_T of mis-flagged rechits is very small…

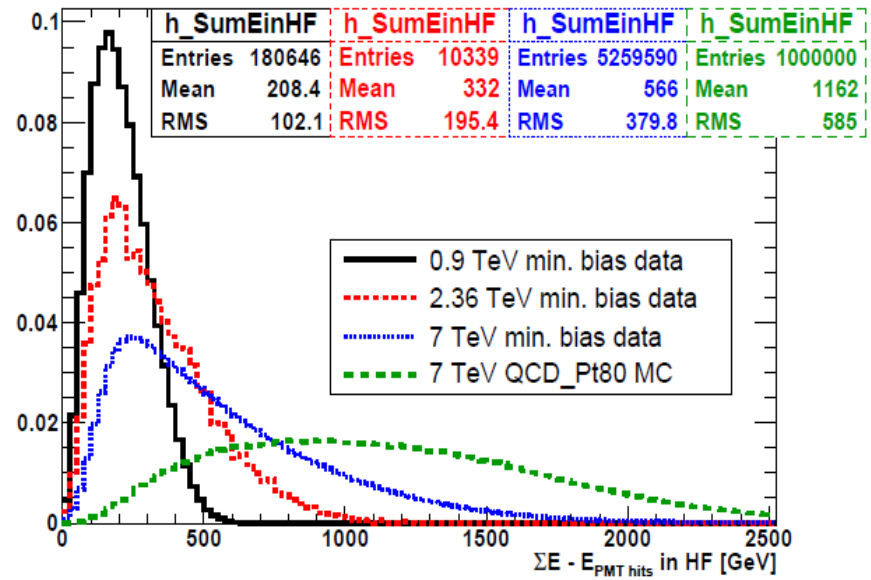
Mis-Identified Noise in MC Samples

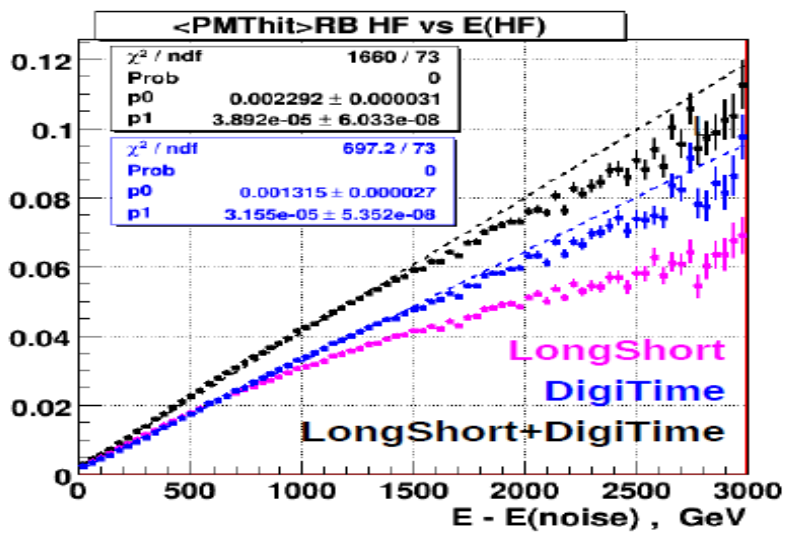


E_T of mis-flagged rechits is very small…

Expected HF PMT Hit Rate







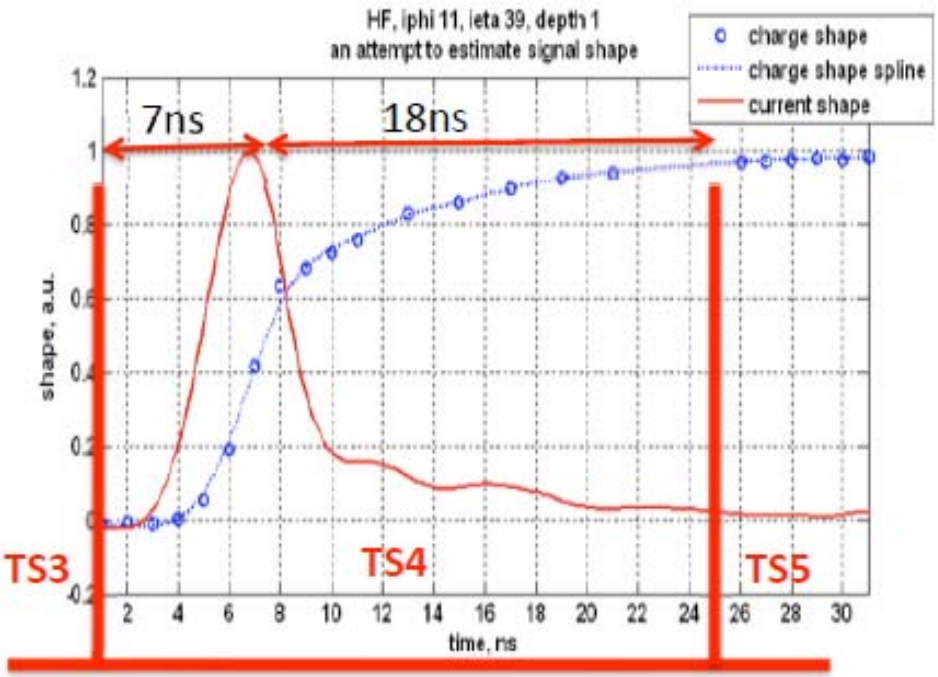
4% of events will have a HF anomalous event for HF E~1000 GeV

For QCD with p_T > 80 GeV we see HF Energy ~1162 GeV

The topological filter becomes less effective as the energy in HF increases

HF Timing Global Phase

50/50 – 7ns Setting



The HF channels have been aligned to ~1ns

Pulse shifted so that 50/50 point is 7 ns from front edge of TS

For this setting the nominal pulse does not have any signal in previous TS

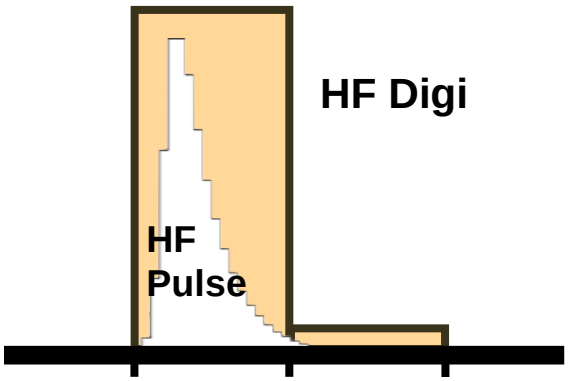
Early pulses will have some signal in previous TS

HF Timing to Identify Early Hits

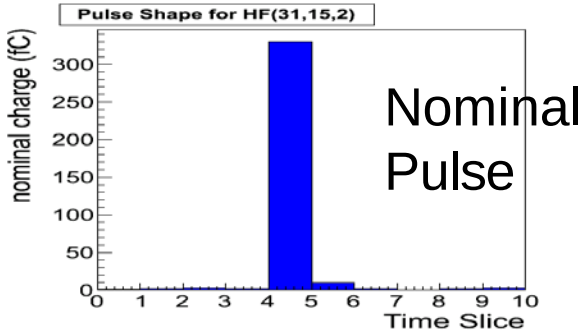
7 TeV collision data was used to align the phase of the HF channels to within a few ns

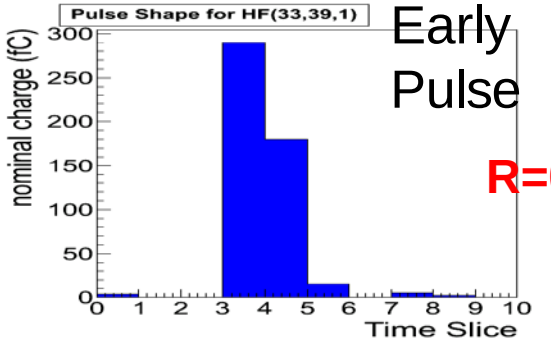
Particles hitting the PMT window can arrive earlier than the light signal from showing particles in HF

Phase is adjusted so that the nominal pulse is contained in TS4 while part of the early pulse will sits in the earlier TS

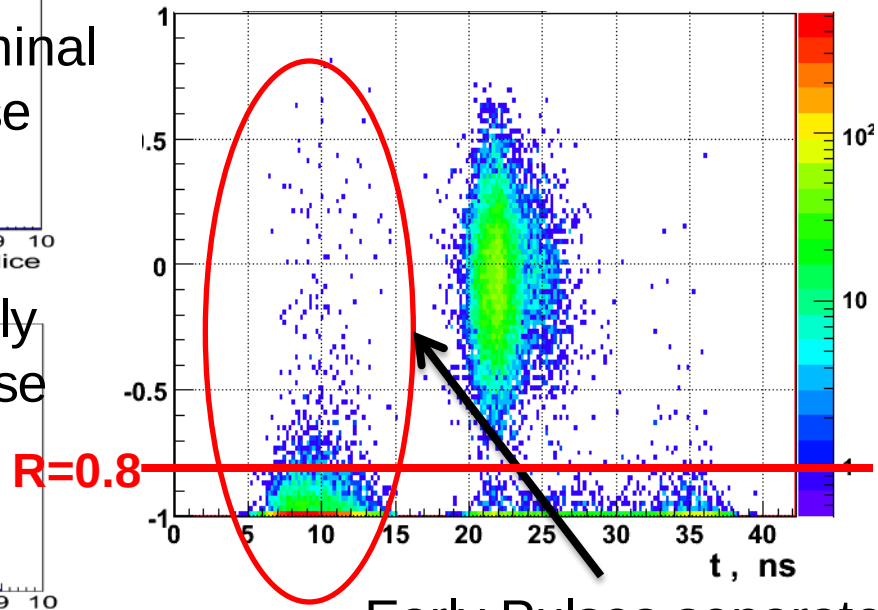


25 ns time samples





Energy > 90 GeV



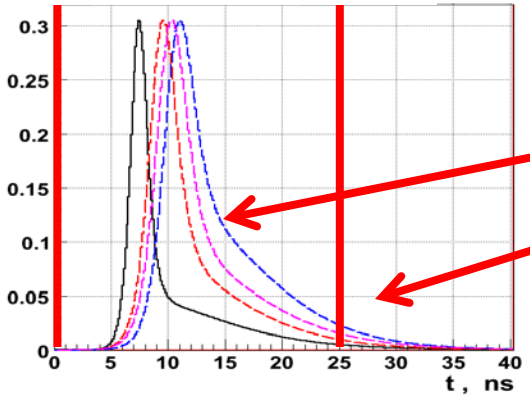
Anomalous signals can be identified by looking at the energy sharing in the Long and Short sections, R=(L-S)/(L+S), and requiring isolation

Timing is still being commissioned….

Early Pulses separated from physics

Time vs Pulse Shape

Pulse Shape



TS=N TS=N+1

Timing algorithm is still being commissioned

Uses:

- Average pulse shape (obtained from scans)
- Charge in N+1 TS

Pulse shape will depend on energy and varies from channel to channel

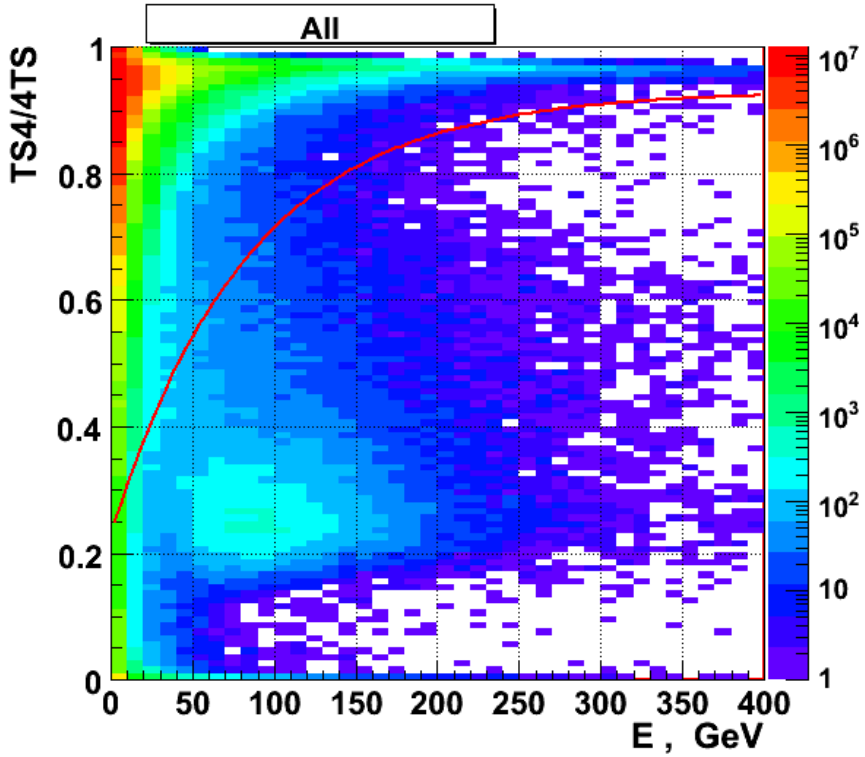
Can use a pulse shape variable to identify anomalous signals in HF (TS4/4TS)

TS4	Charge in nominal TS
4TS	Sum of 4 TS (N -1 … N+2)

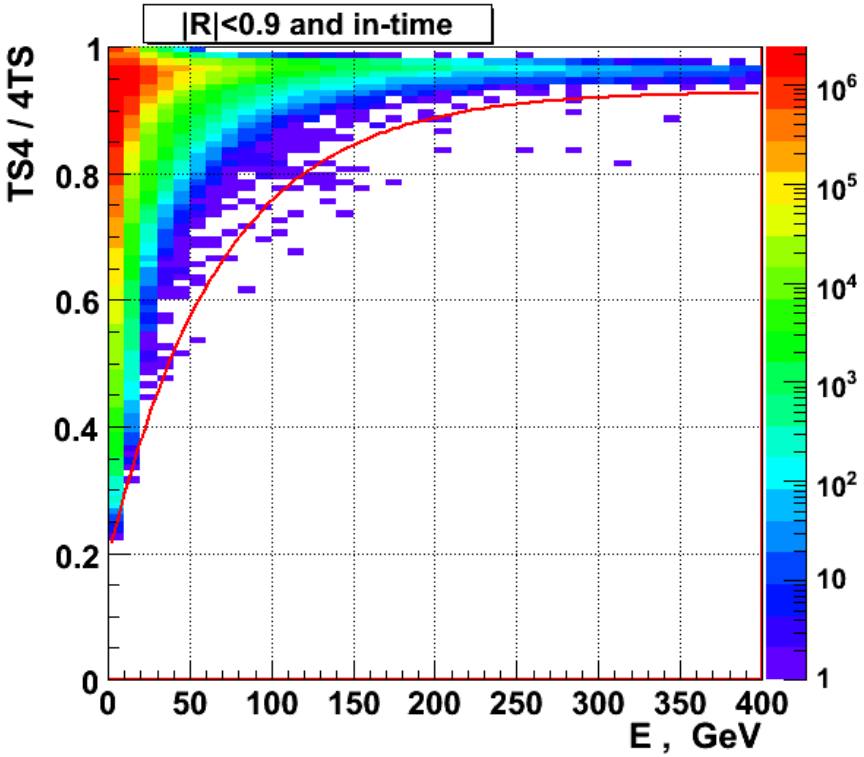
Less sensitive to some assumptions used in the time algorithm

Pulse Shape

All events



Events surviving topological cut and timing cut



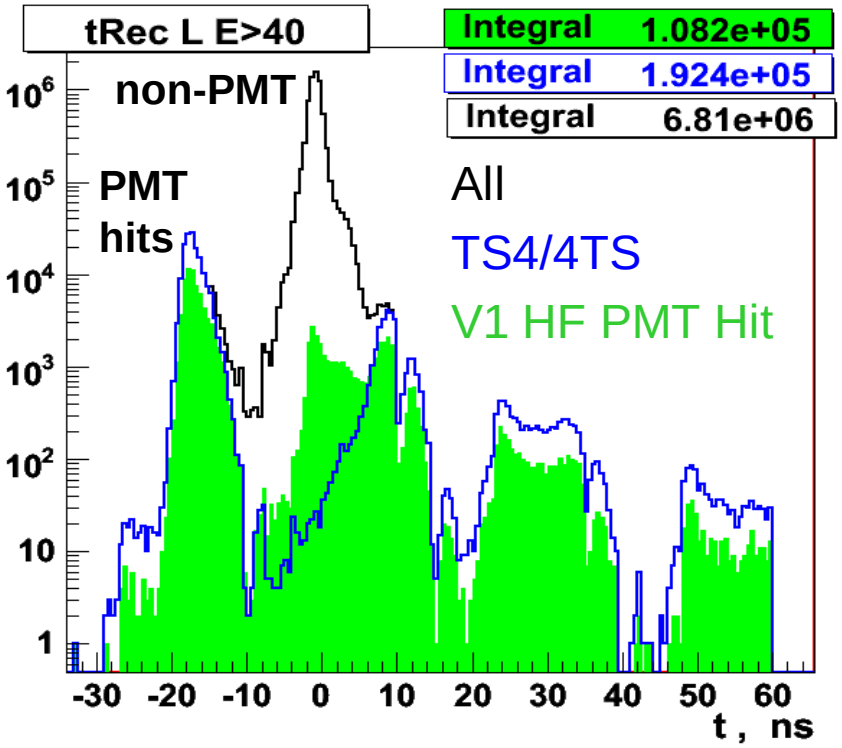
Pulse shape filter uses TS4/4TS and requires that the rechit energy is above cut contour shown on the plots

HF Anomalous Event Filter Performance

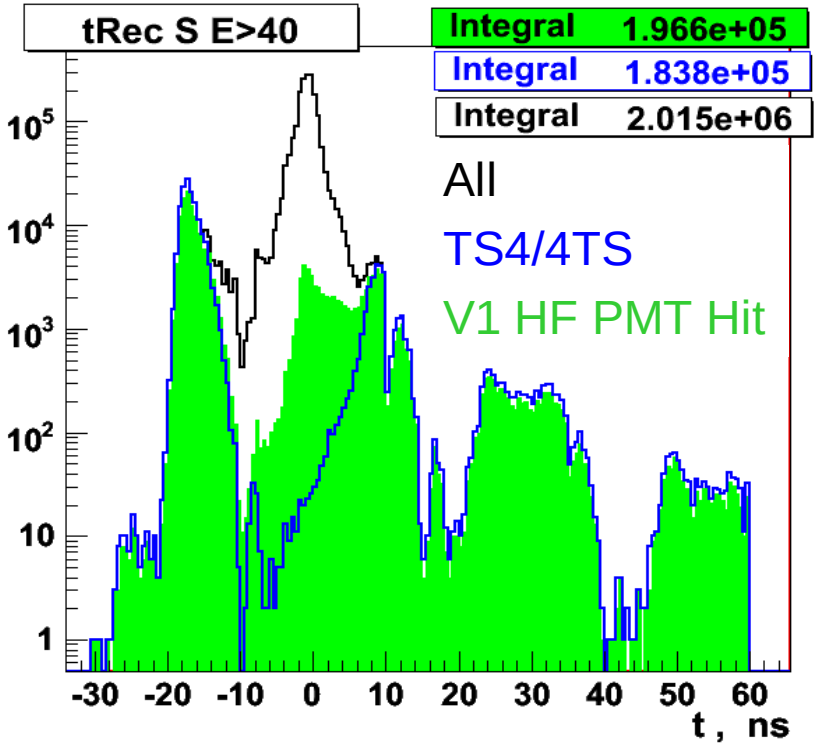
Pulse Shape filter (TS4/4TS) has similar rejection power as a time based cut

Apply both the topology and pulse shape filters

Long fibers



Short fibers



Filter Development/Software Infrastructure

A flexible software framework was developed to flag/remove channels (rechit) that have been identified as noise

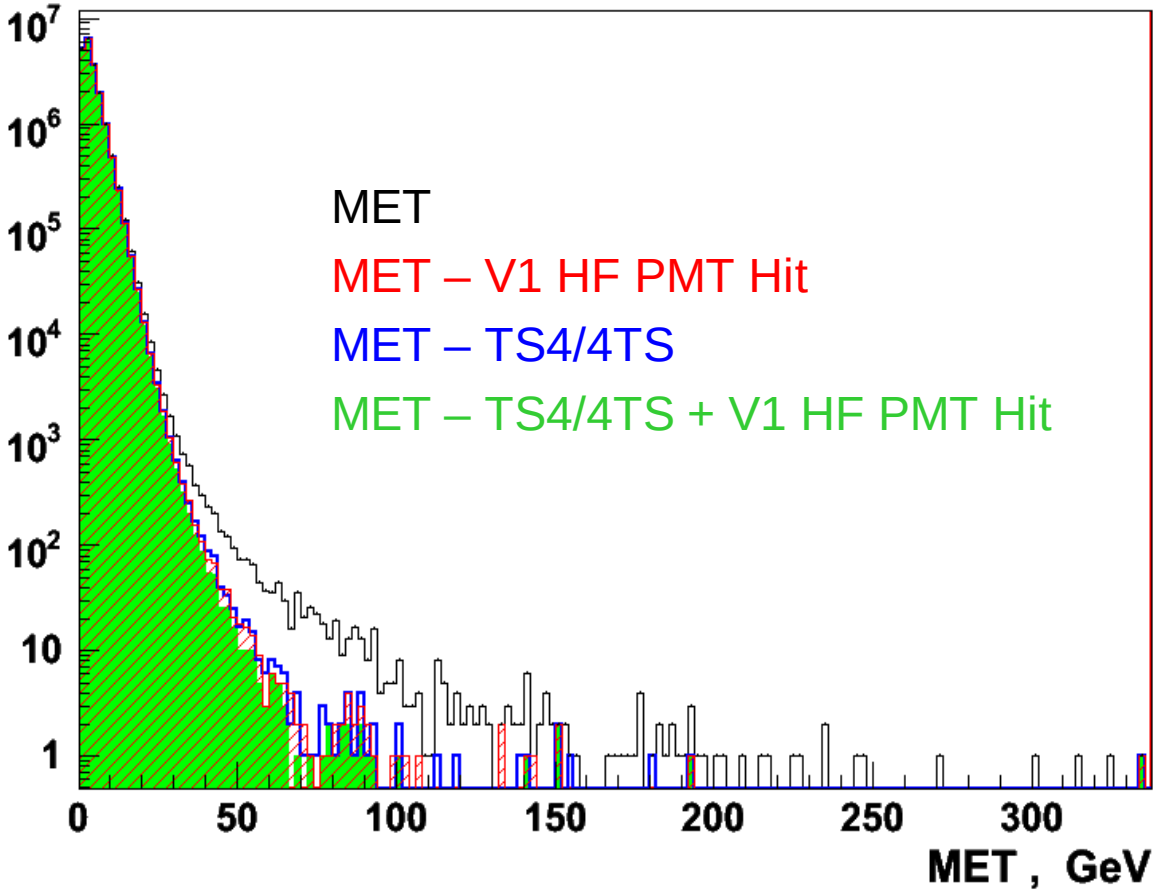
Flagged channels are removed from the basic reconstructed object (CaloTower) from which the physics objects using Calorimeter information are derived (jets, MET, …)

Digitized Data → Reconstructed Energy → Calorimeter Towers → Physics Objects

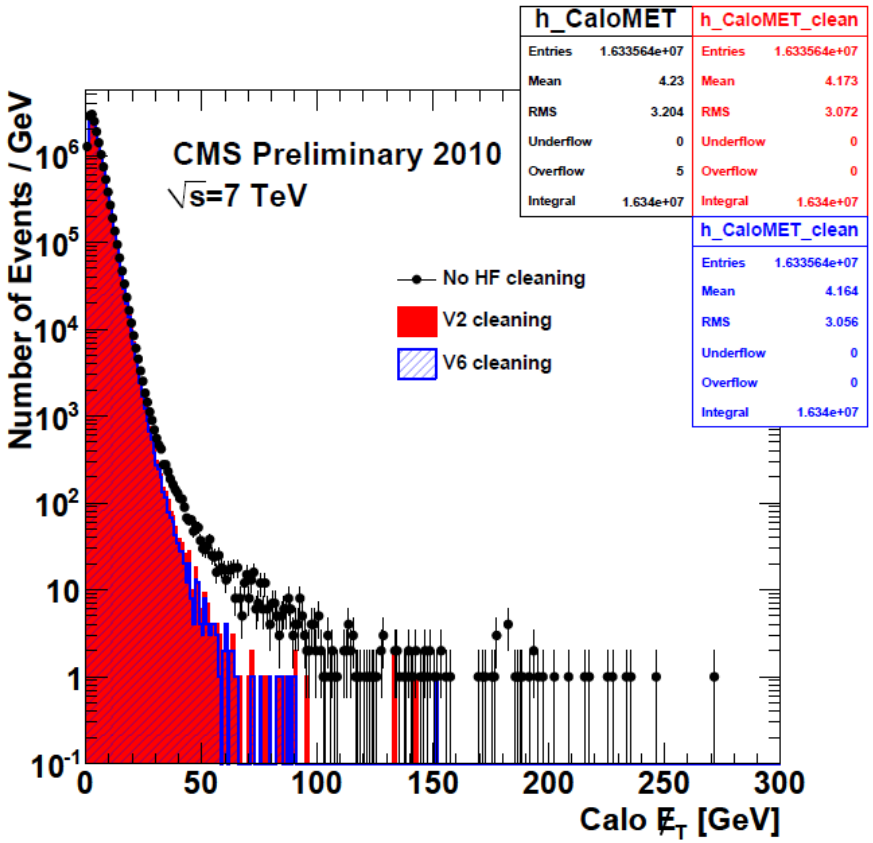
Filter development included feedback from the physics objects groups and their approval

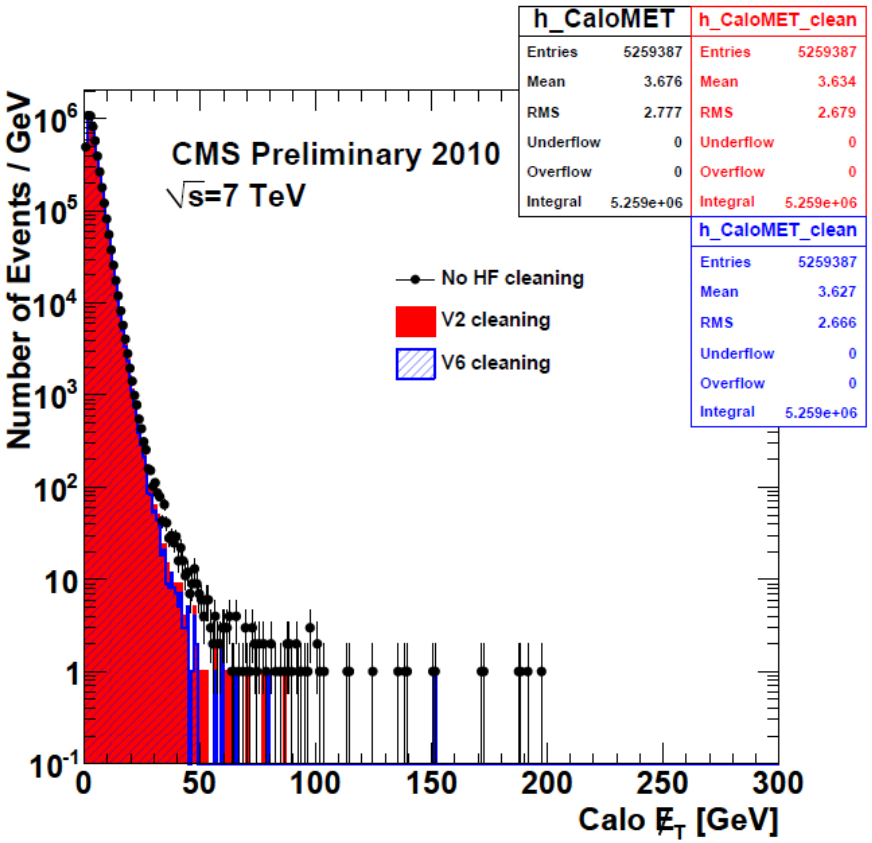
HF Filters are applied during data processing and all analyses start from the same cleaned objects…

Combined Filter Performance



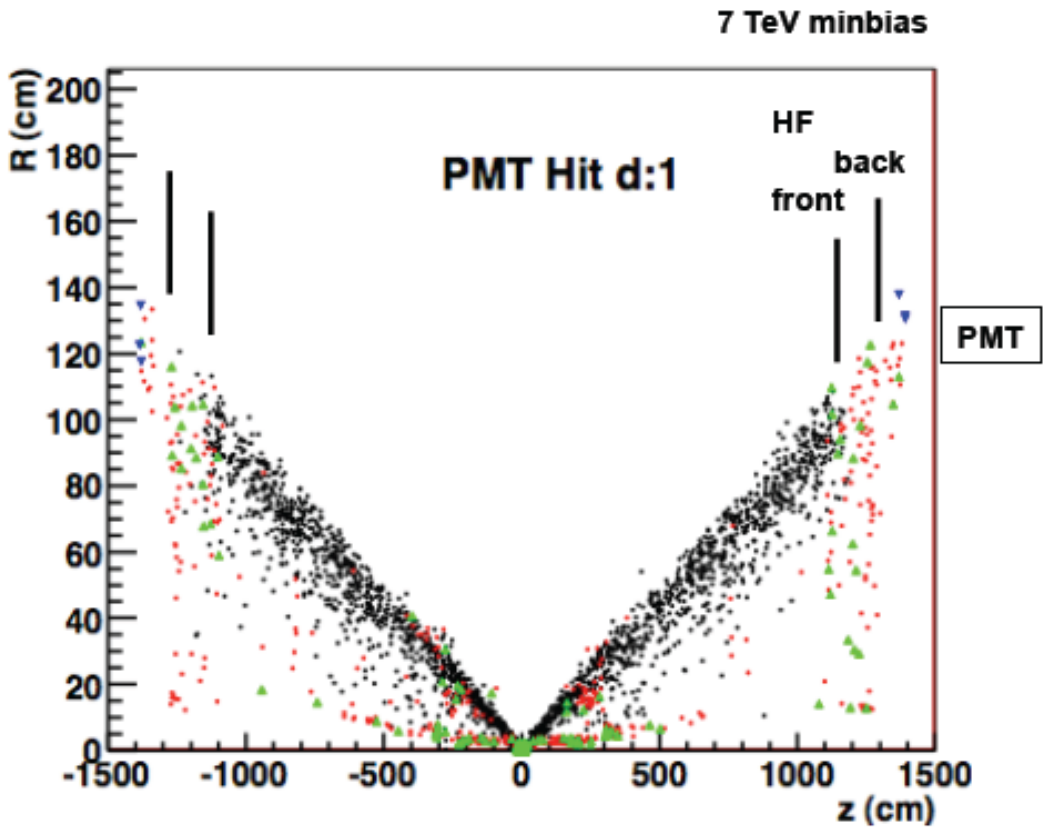
Recommend to apply both the HF PMT Hit filter and the new pulse shape filter to remove anomalous HF signals


h_CaloMET
Entries 1.633564e+07
Mean 4.23
RMS 3.204
Underflow 0
Overflow 5
Integral 1.634e+07
h_CaloMET_clean
Entries 1.633564e+07
Mean 4.173
RMS 3.072
Underflow 0
Overflow 0
Integral 1.634e+07
h_CaloMET_clean
Entries 1.633564e+07
Mean 4.164
RMS 3.056
Underflow 0
Overflow 0
Integral 1.634e+07
CMS Preliminary 2010
√s=7 TeV
No HF cleaning
V2 cleaning
V6 cleaning
Number of Events / GeV
Calo E̸T [GeV]


h_CaloMET
Entries 5259387
Mean 3.676
RMS 2.777
Underflow 0
Overflow 0
Integral 5.259e+06
h_CaloMET_clean
Entries 5259387
Mean 3.634
RMS 2.679
Underflow 0
Overflow 0
Integral 5.259e+06
h_CaloMET_clean
Entries 5259387
Mean 3.627
RMS 2.666
Underflow 0
Overflow 0
Integral 5.259e+06
CMS Preliminary 2010
√s=7 TeV
No HF cleaning
V2 cleaning
V6 cleaning
Number of Events / GeV
Calo E̸T [GeV]

HF PMT Hits Simulation

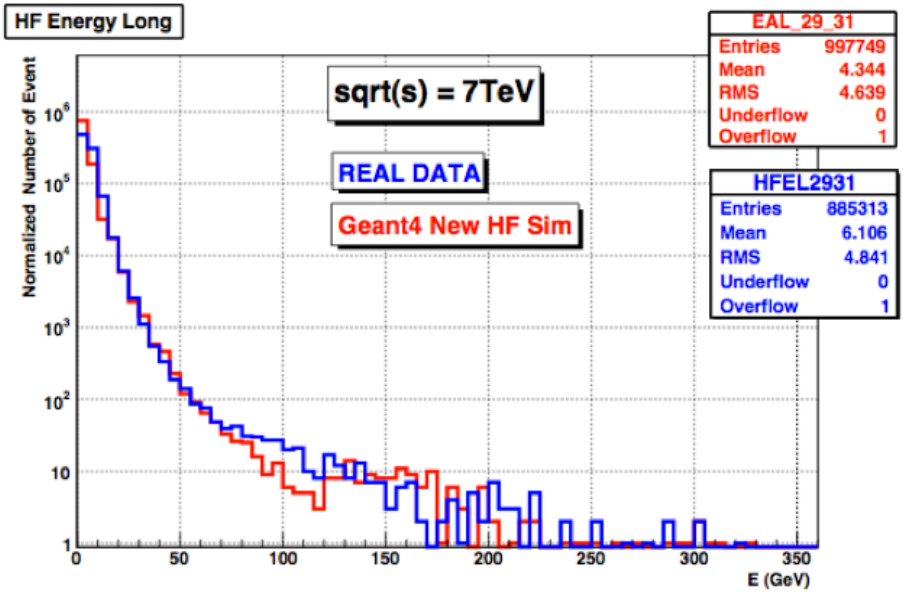
G4 Simulation - Production points of (parent) particles hitting PMT Windows and leaving signal > 50GeV

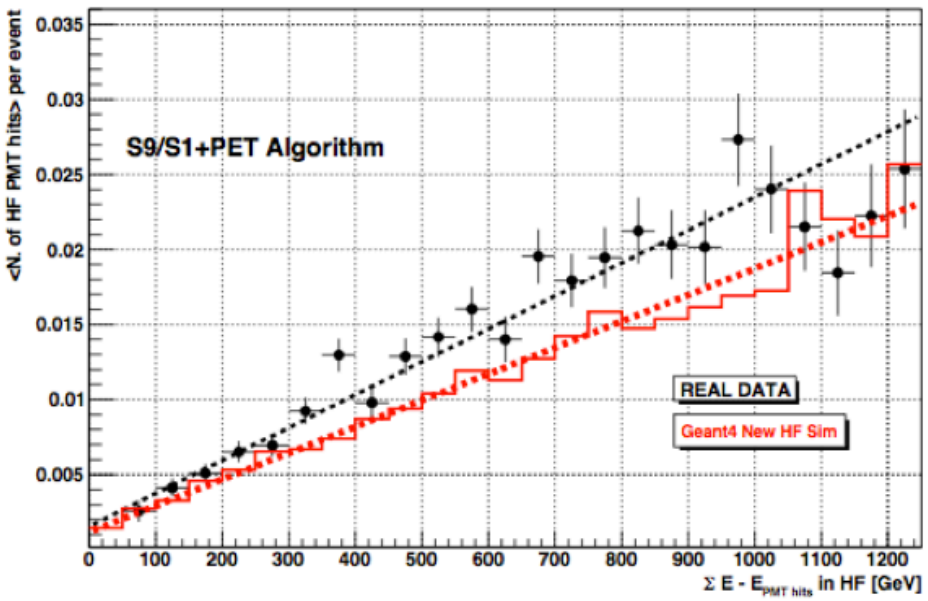


Black	muons	62%
Red	pion	26%
Green	kaon	12%
Blue	electron	0%

Most HF Window Hits are from muons produced by decays in flight (62%) and hadronic shower punch through (38%)

HF PMT Hit Simulation





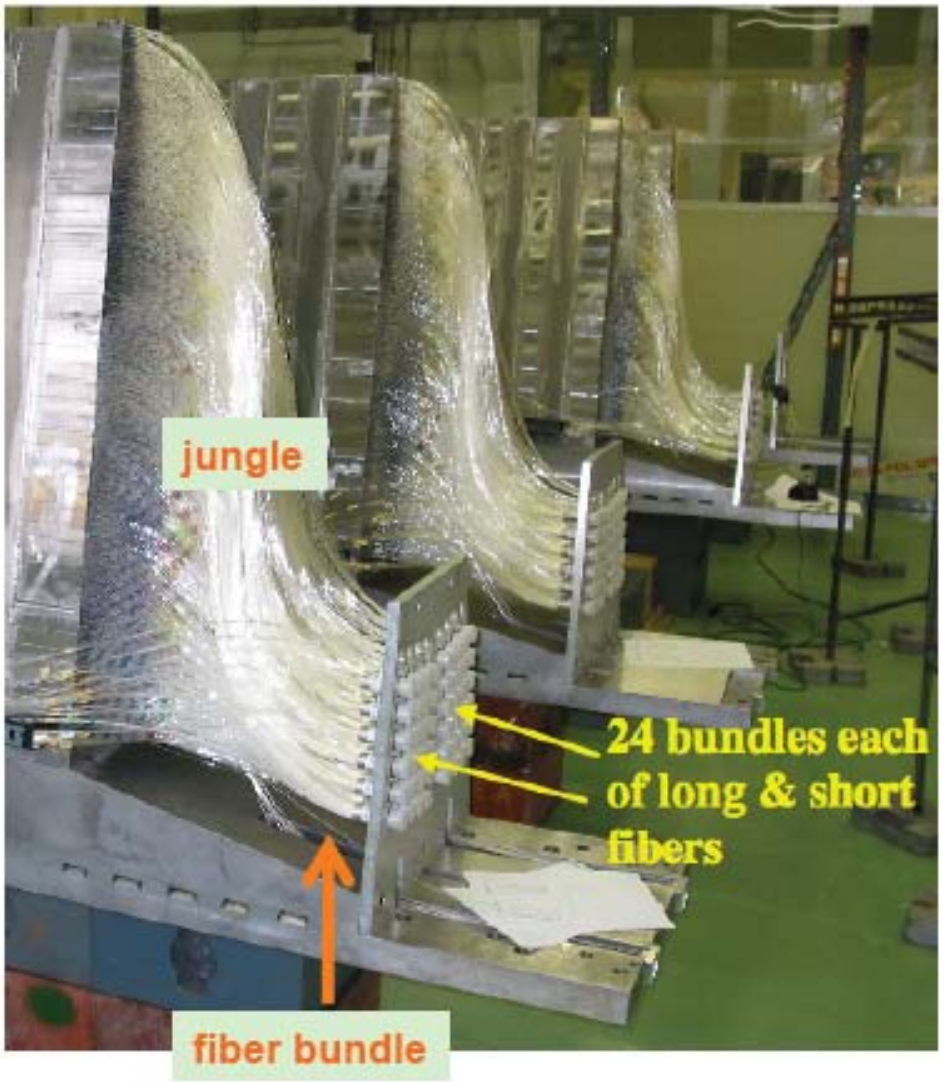
http://indico.cern.ch/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=97260

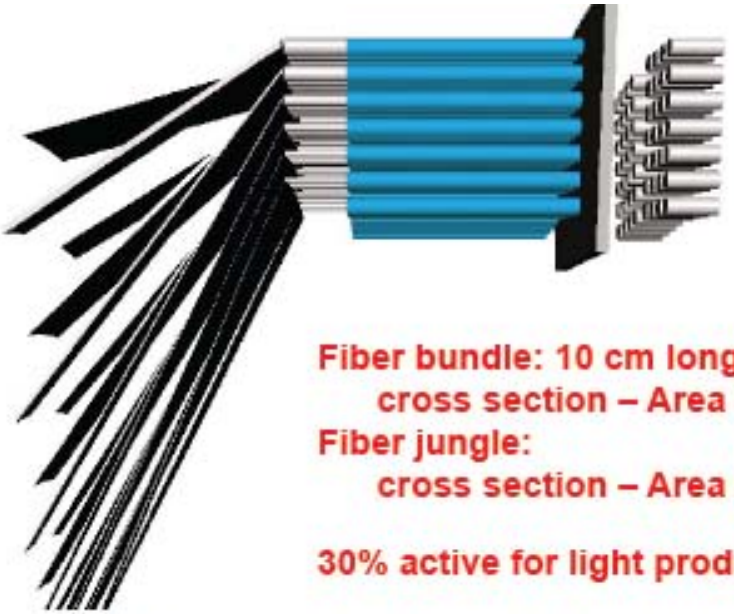
For events with irreducible noise, e.g. jets with PMT hits another approach maybe needed: Simulate the noise production mechanism.

Substantial effort to put HF PMT hits in simulation. Preliminary results are very encouraging. Fiber bundles are being put into simulation.

Similarly HPD ion feedback noise simulation, HPD/RBX noise data mixing with MC data are being developed

Fiber Bundle Jungle





Fiber bundle: 10 cm long
cross section – Area below
Fiber jungle:
cross section – Area below

30% active for light production

Table 1. The tower sizes, number of fibers, fiber bundle area (A_b) and the percentage of photocathode area (A_{ph}) utilized are listed below for each tower. The air-core light guides are tapered to better match the photocathode area for towers 1–3

Area

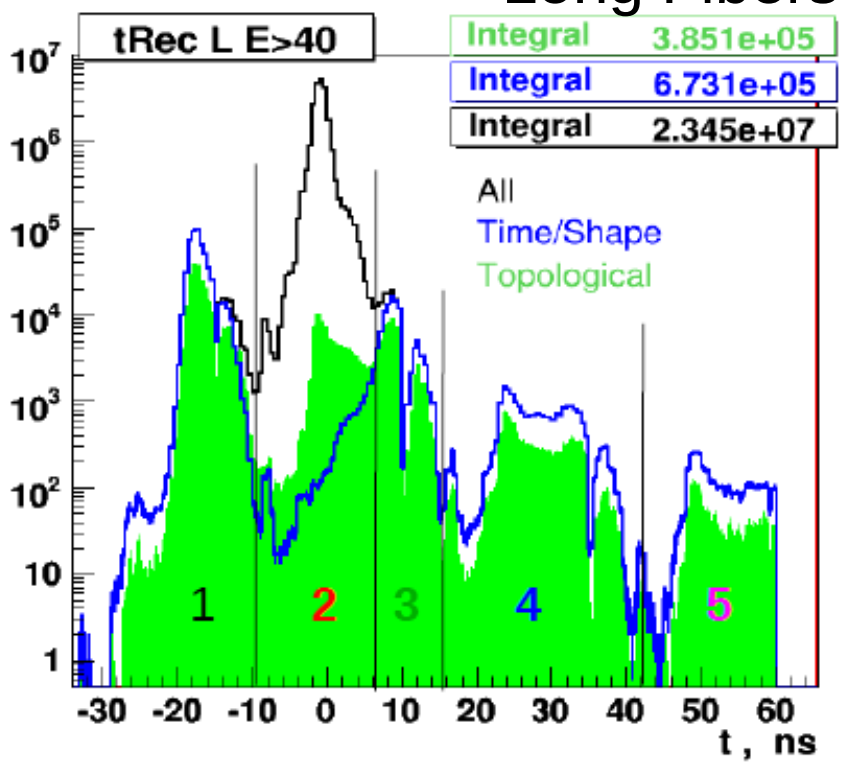
Ring	(r_{in}, r_{out}) [mm]	$\Delta\eta$	$\Delta\phi$ [degree]	N_{fib}	A_b [mm^2]	A_b/A_{ph}
1	(1162–1300)	0.111	10	594	551	1.14
2	(975–1162)	0.175	10	696	652	1.33
3	(818–975)	0.175	10	491	469	0.96
4	(686–818)	0.175	10	346	324	0.66
5	(576–686)	0.175	10	242	231	0.47
6	(483–576)	0.175	10	171	167	0.34
7	(406–483)	0.175	10	120	120	0.25
8	(340–406)	0.175	10	85	88	0.18
9	(286–340)	0.175	10	59	63	0.13
10	(240–286)	0.175	10	41	46	0.94
11	(201–240)	0.175	10	30	35	0.71
12	(169–201)	0.175	20	42	52	0.11
13	(125–169)	0.300	20	45	56	0.16

RecHit Time Distribution

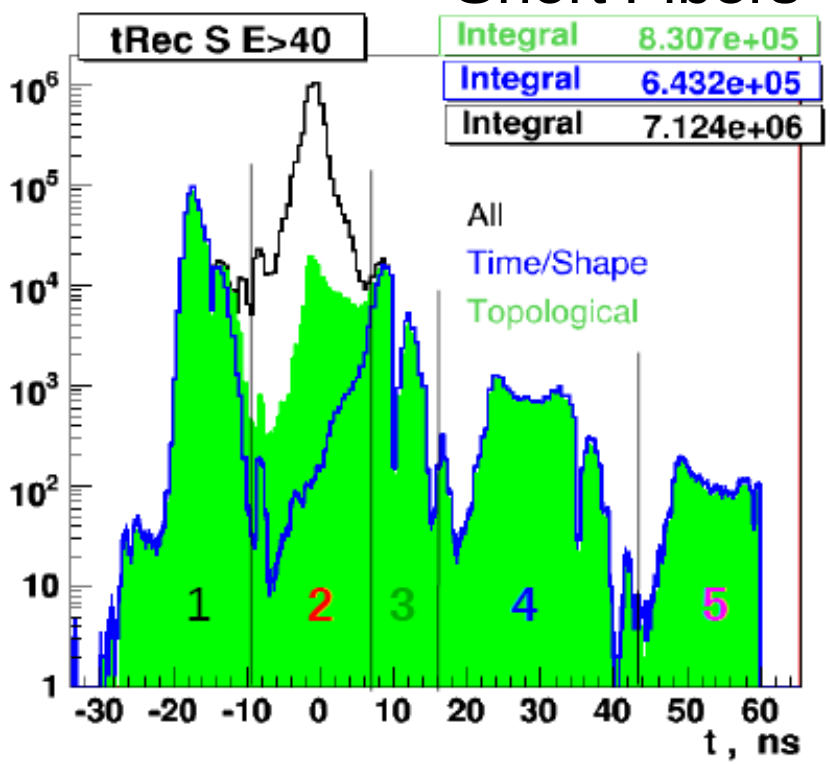
Reconstructed timing distribution has several time bands:

1. 3.7% PMT hits
2. 96% HF absorber hits mostly
3. 0.65%
4. 0.14%
5. 0.02%

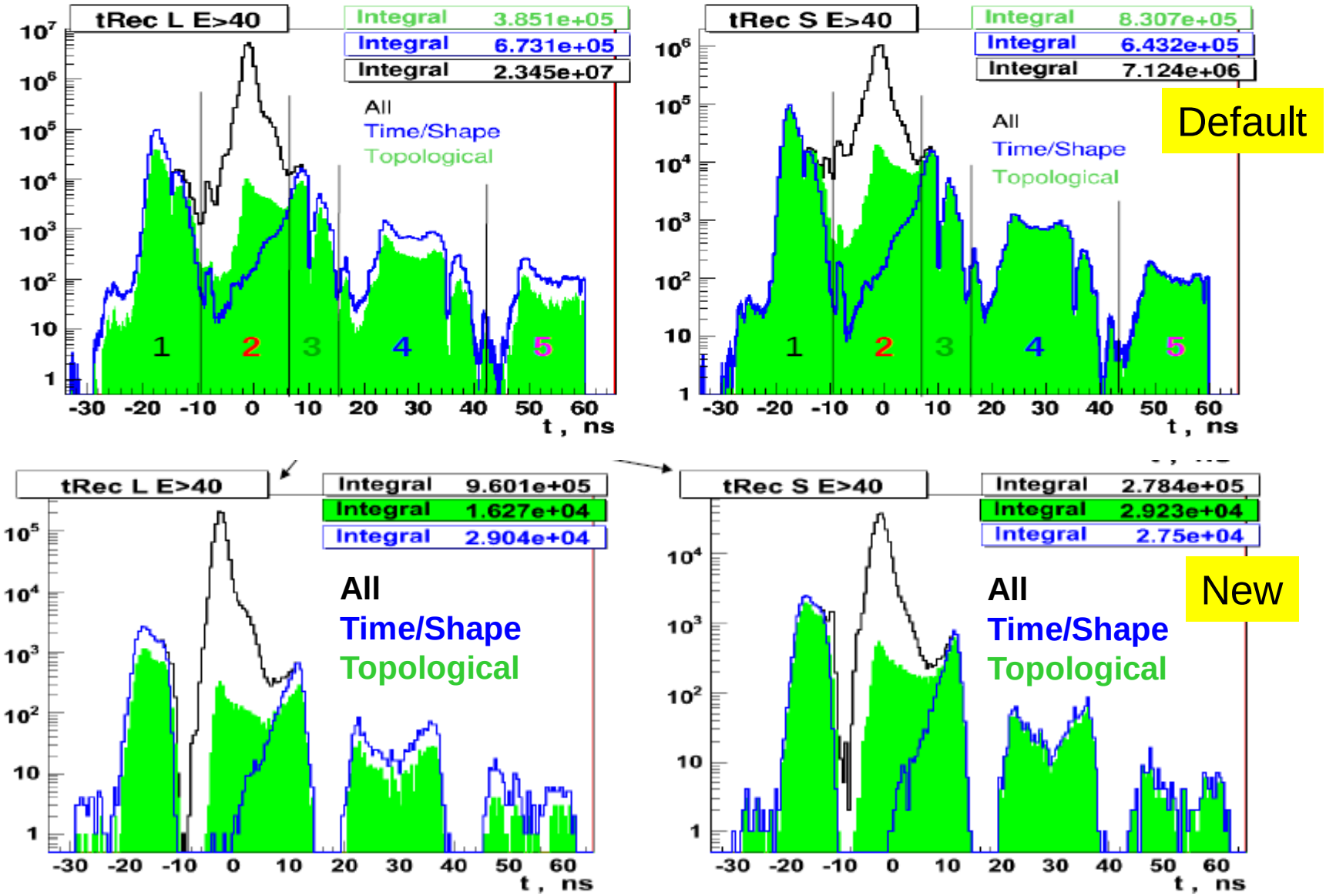
Long Fibers



Short Fibers



Default vs New Time Reconstruction



New Time Reconstruction Algorithm

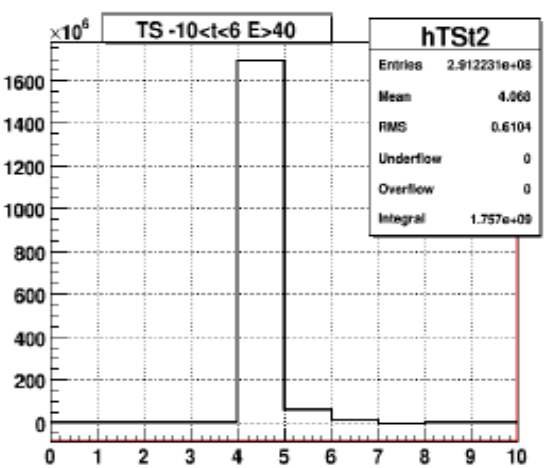
Structure in the time distribution is an artifact of the time algorithm, pulse shape (10 ns), and wide sampling window (25 ns)

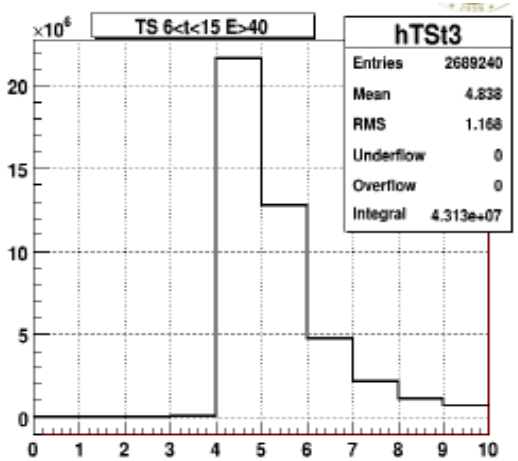
Default time reconstruction algorithm uses correction function based on old pulse shape from test beam data and 3TS

TSMax-1, TSMax, TSMax+1

The new time reconstruction algorithm uses a fit to the measure pulse shape from collision data and 2TS

2 adjacent Maximum TS



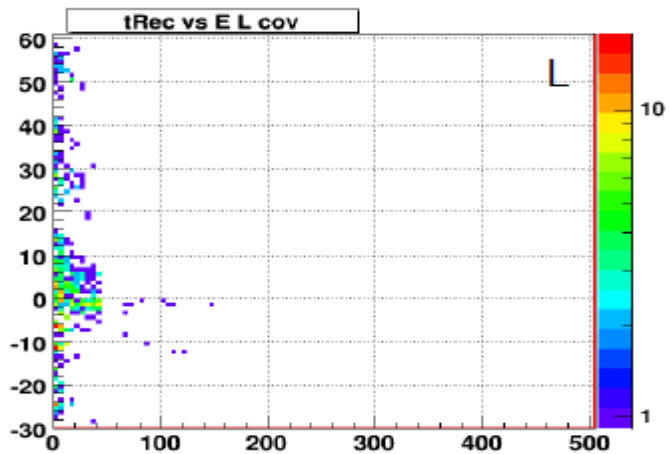


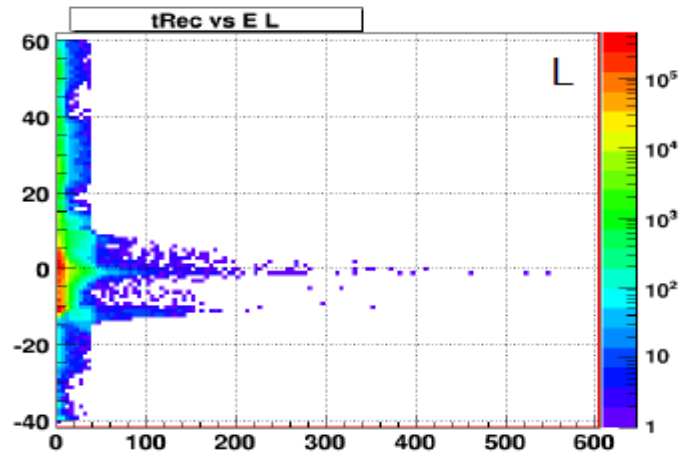
Would introduce biases for pulses with non-ideal shape

Late Energy Deposits in HF

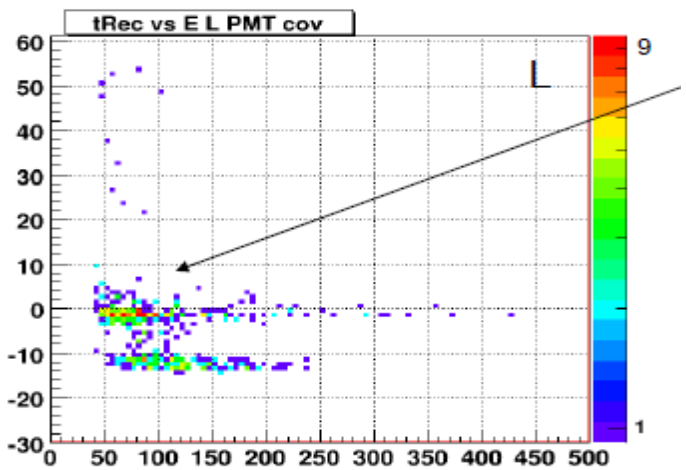
Covered PMTS (iEta=29)

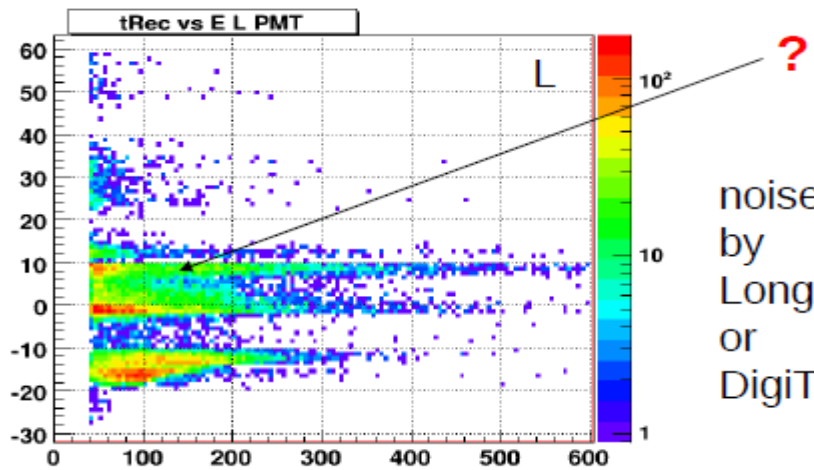
Non-covered PMTS (iEta=29)





non-noise hits by LongShort and DigiTime



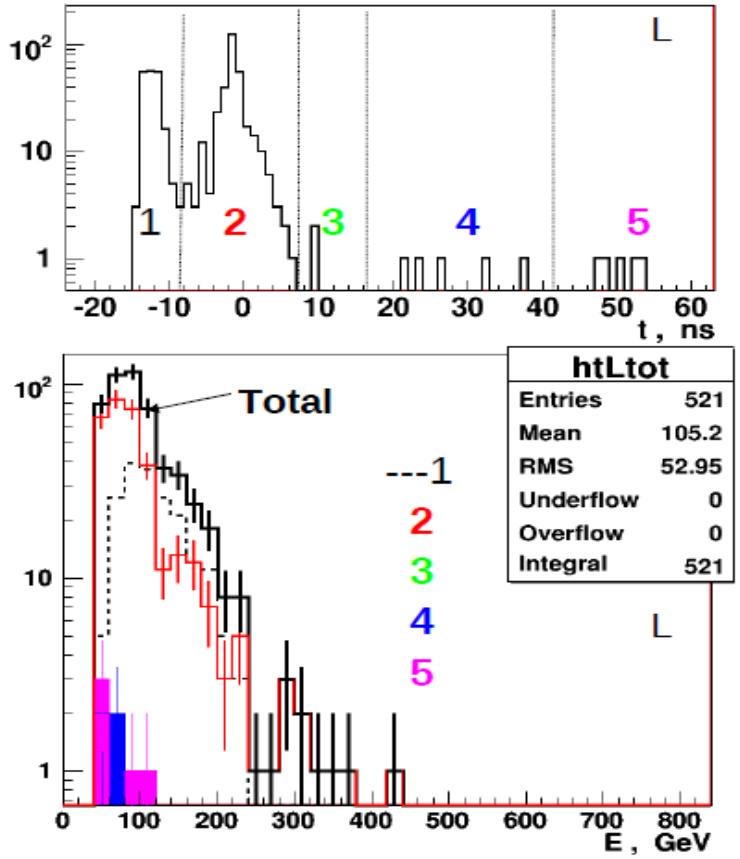


noise hits by LongShort or DigiTime

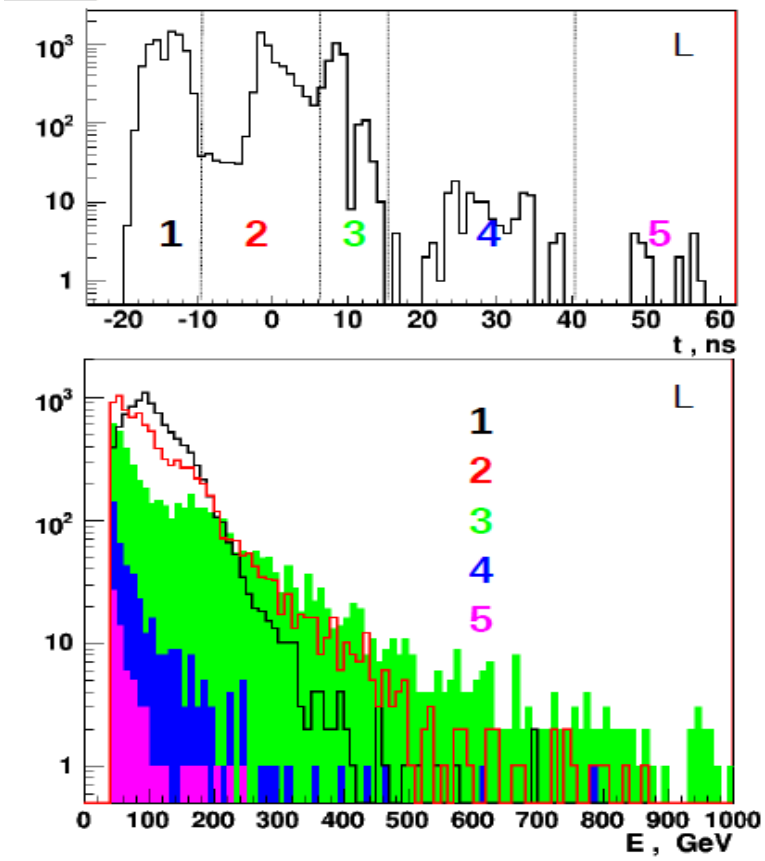
Late hits are not present for the covered PMTs

RecHits Flagged as Noise in HF

Covered PMTS (iEta=29)



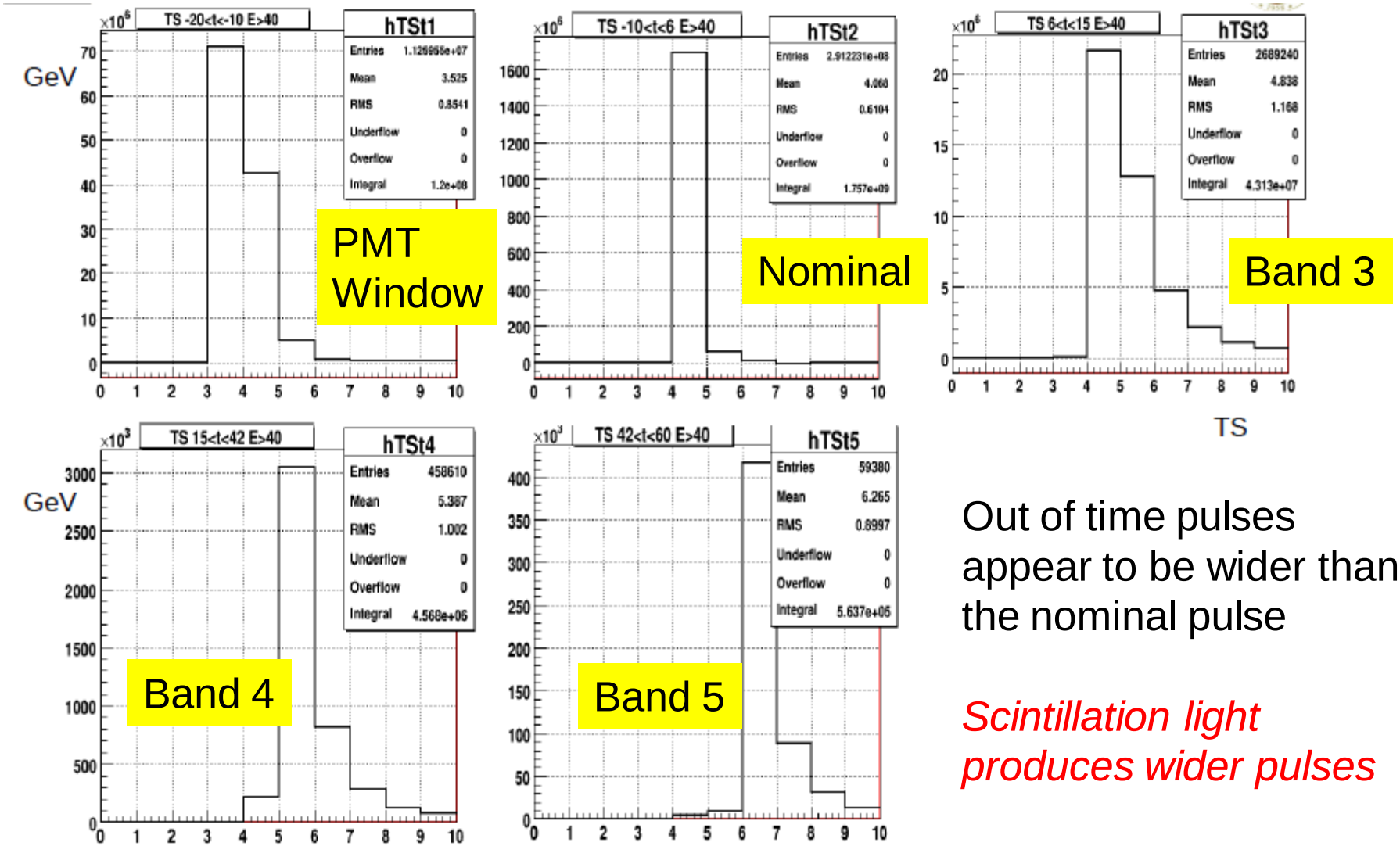
Non-covered PMTS (iEta=29)



Late hits in “band 3” do not appear in the covered PMTs

Band 3 events have a harder energy spectrum

Pulse Shape for Different Time Bands

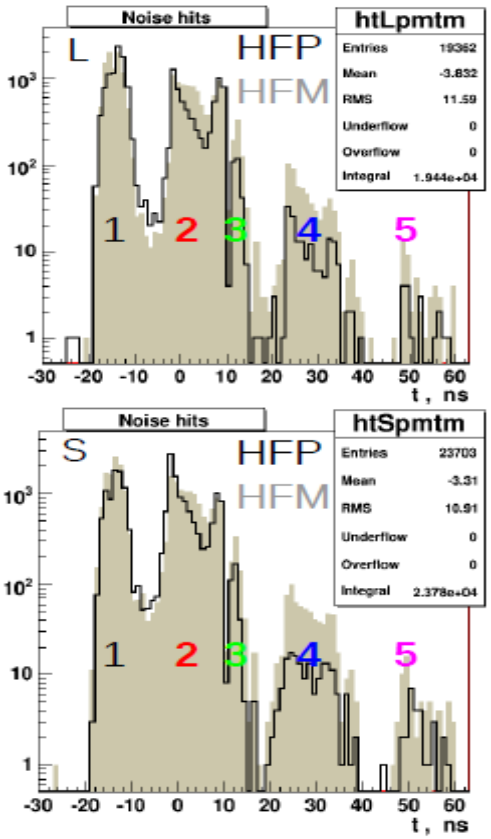


Out of time pulses appear to be wider than the nominal pulse

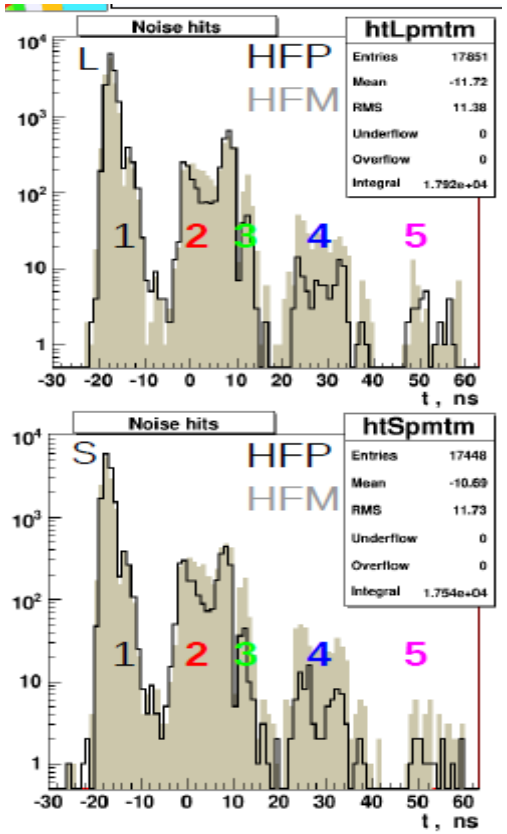
Scintillation light produces wider pulses

Time for RecHits Identified as Noise

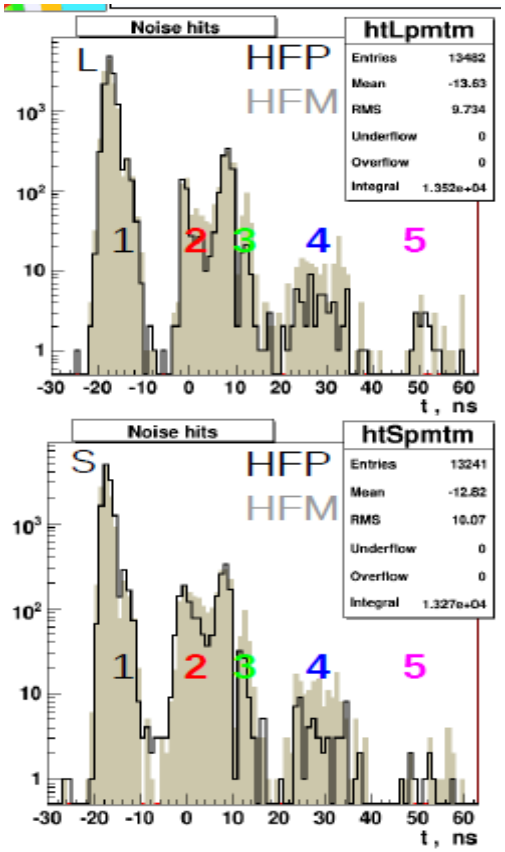
iEta = 30



iEta = 35



iEta = 41

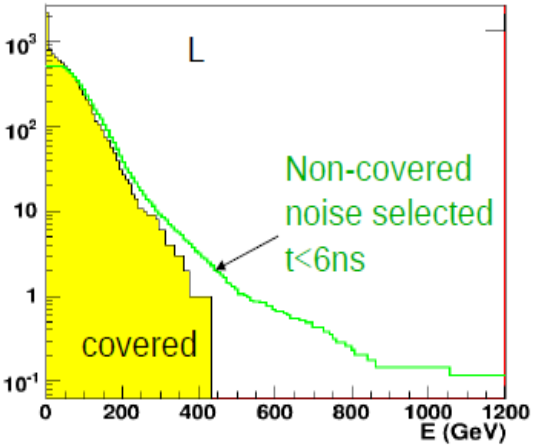


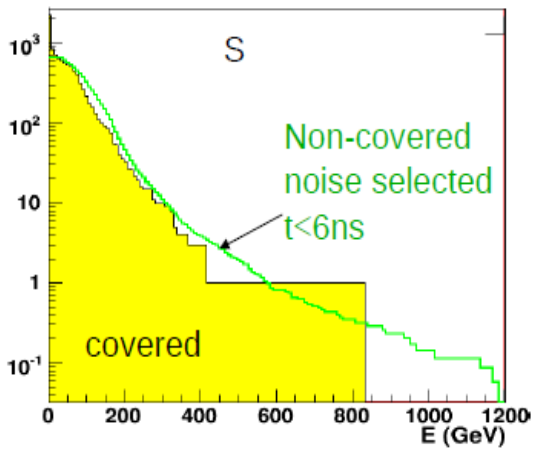
Better separation of early/nominal pulses for larger iEta

Fiber path length is shorter for low iEta

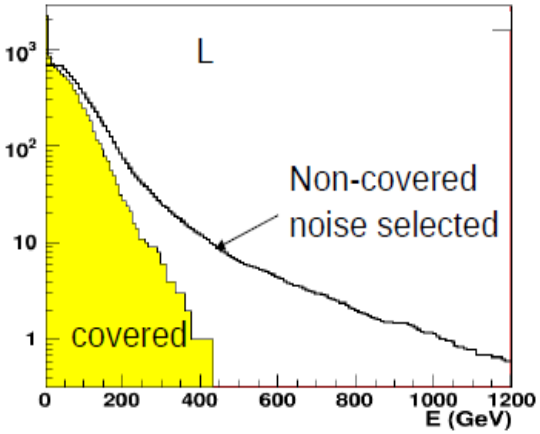
Higher rate of late hits for HFM

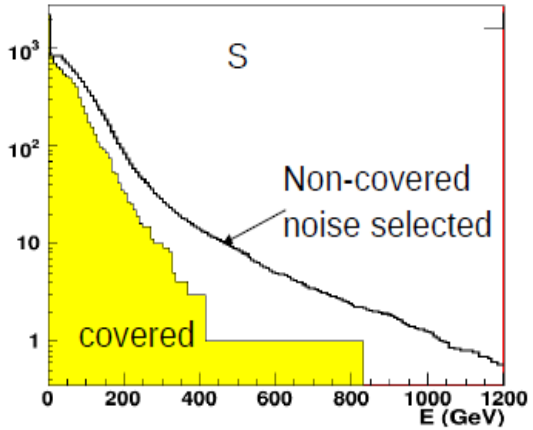
Number of Noise Events for E>Ex





Spectra for covered PMT and early events (Time Band 1) are similar

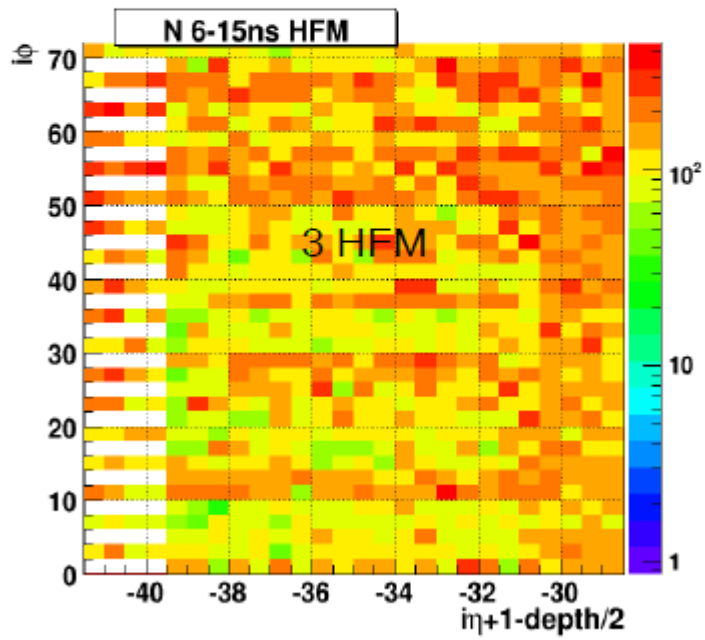


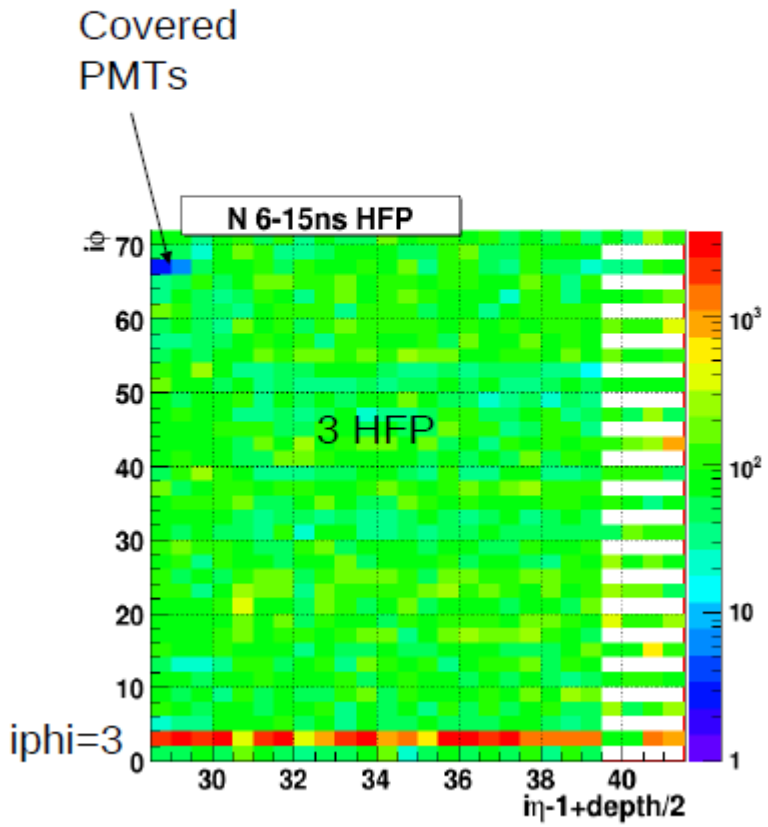


Spectra for all noise has a non-PMT window component that extends to higher E

HF Late Energy

We observe a higher rate of late hits for HFM
Light guide different in iphi=3





Igor Vodopiyanov, HF noise hits, July 2010

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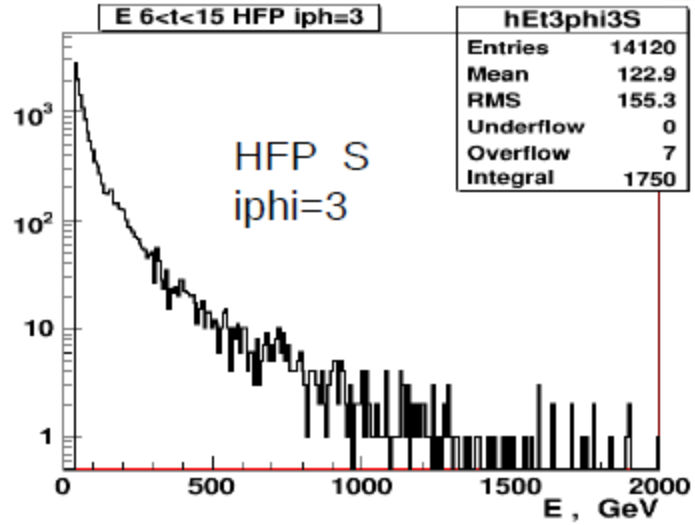
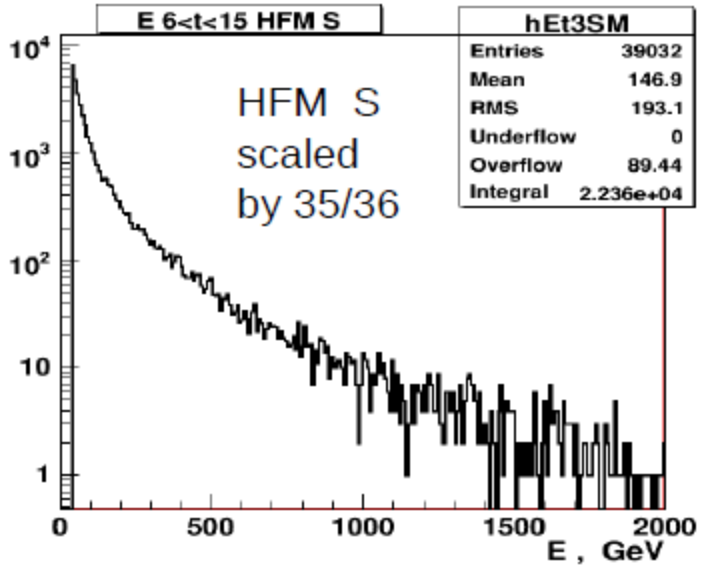
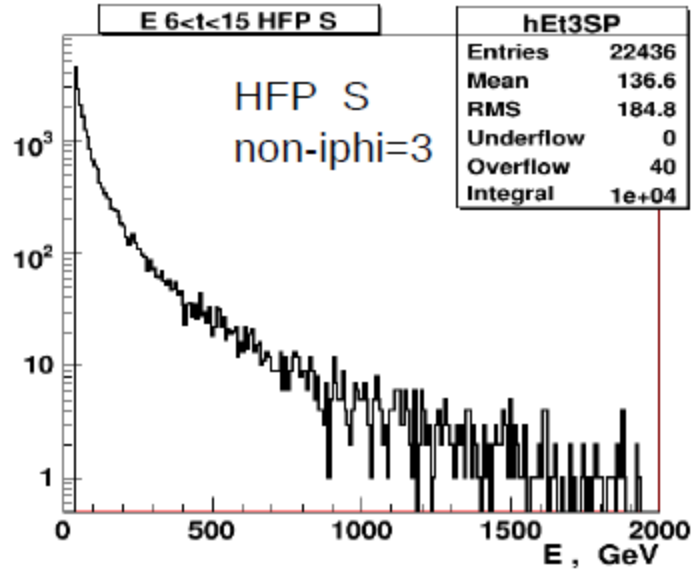
E Spectra for Band 3 Events (E>40 GeV)

HFM/HFP = 39032/22436 = 1.7x
iEta=3: 14120/(22436/35) = 22x







Summary of HFM/HFP Rates

	HFM/HFP	Error
Time Band 1	1.02	0.01
Time Band 2	0.96	0.01
Time Band 2 (noise)	1.23	0.01
Time Band 3	1.58	0.01
Time Band 4	3.74	0.06
Time Band 5	2.45	0.10

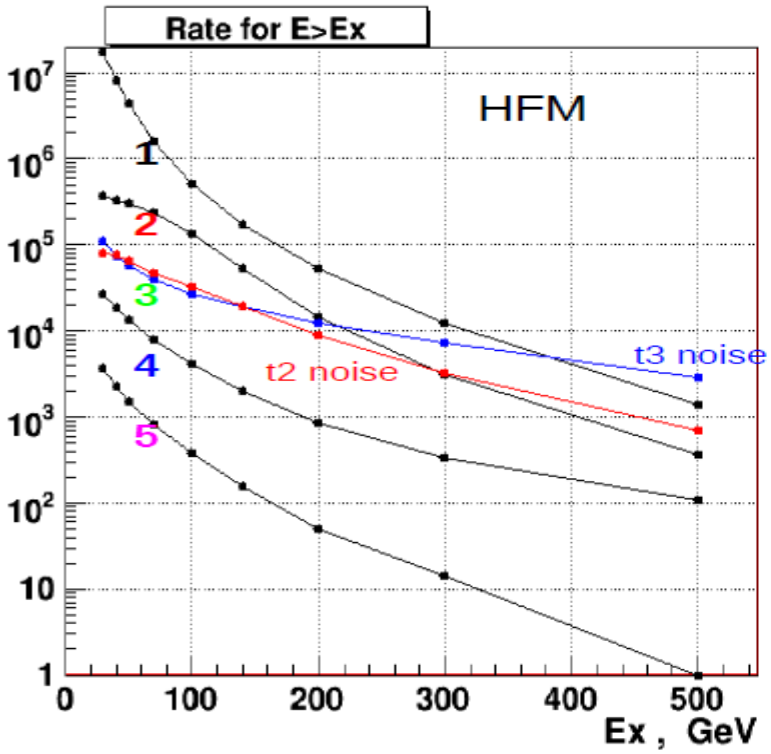
Similar rate of PMT Window events (Time Band 1) for HFM and HFP

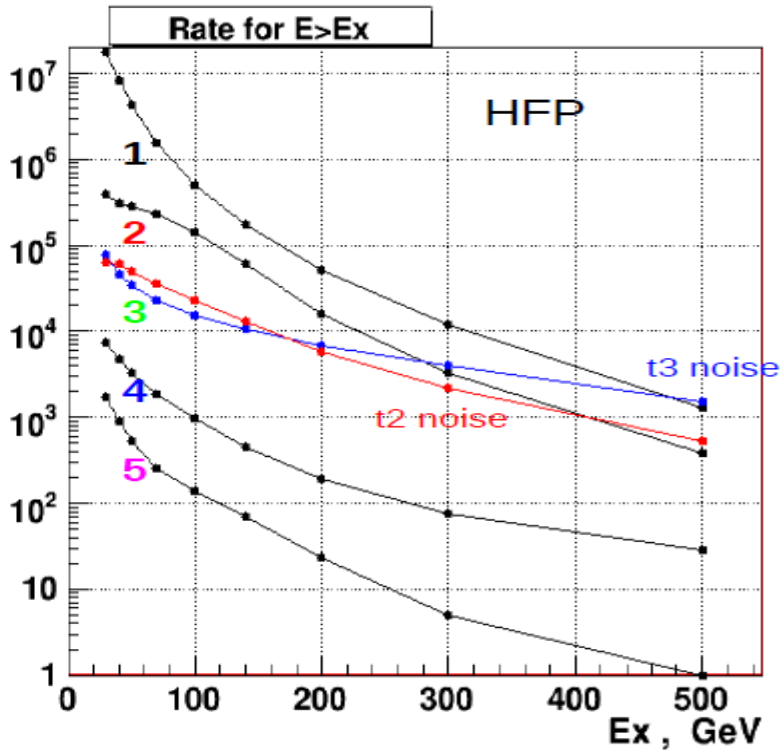
Similar rate of in-time physics signal (Time Band 2) for HFM and HFP

We observe a higher rate of in-time noise (Time Band 2) for HFM

We observe a higher rate of late noise (Time Band 3-5) for HFM

Rates for Events in Different Time Bands





Band 3 noise has a harder E spectrum and will dominate at higher energies

Triggers

HF does not participate in the trigger

Anomalous events in HF mostly have a low E_T with a low rate of events extending to higher E_T

Early hits could lead to an early trigger

Do not see any evidence that this happens a

If needed we can enable HF cleaning in the HLT

Same cleaning as is done during offline processing

Limitations of Current Filters

Topological filter becomes less effective as occupancy increases

Pulse shape filters will have to be reexamined once we have significant pileup

Difficult to treat punch through or hits in a jet

In time noise cannot be removed

Difficult to model precisely

Reduce bunch spacing

May start seeing late hits from previous collision

Summary

We have multiple contributions to the HF anomalous events

HF PMT Window events (early hits)

Late pulses (thought to originate from scintillation in the light guide)

HF PMT Hits is the dominant source of anomalous events in HCAL (for E>40 GeV)

Topological and Pulse shape filters have been developed and are used by default to remove HF anomalous events

We have some residual in-time noise

Topological filter is more effective at tagging in-time noise

becomes less effective as occupancy increases

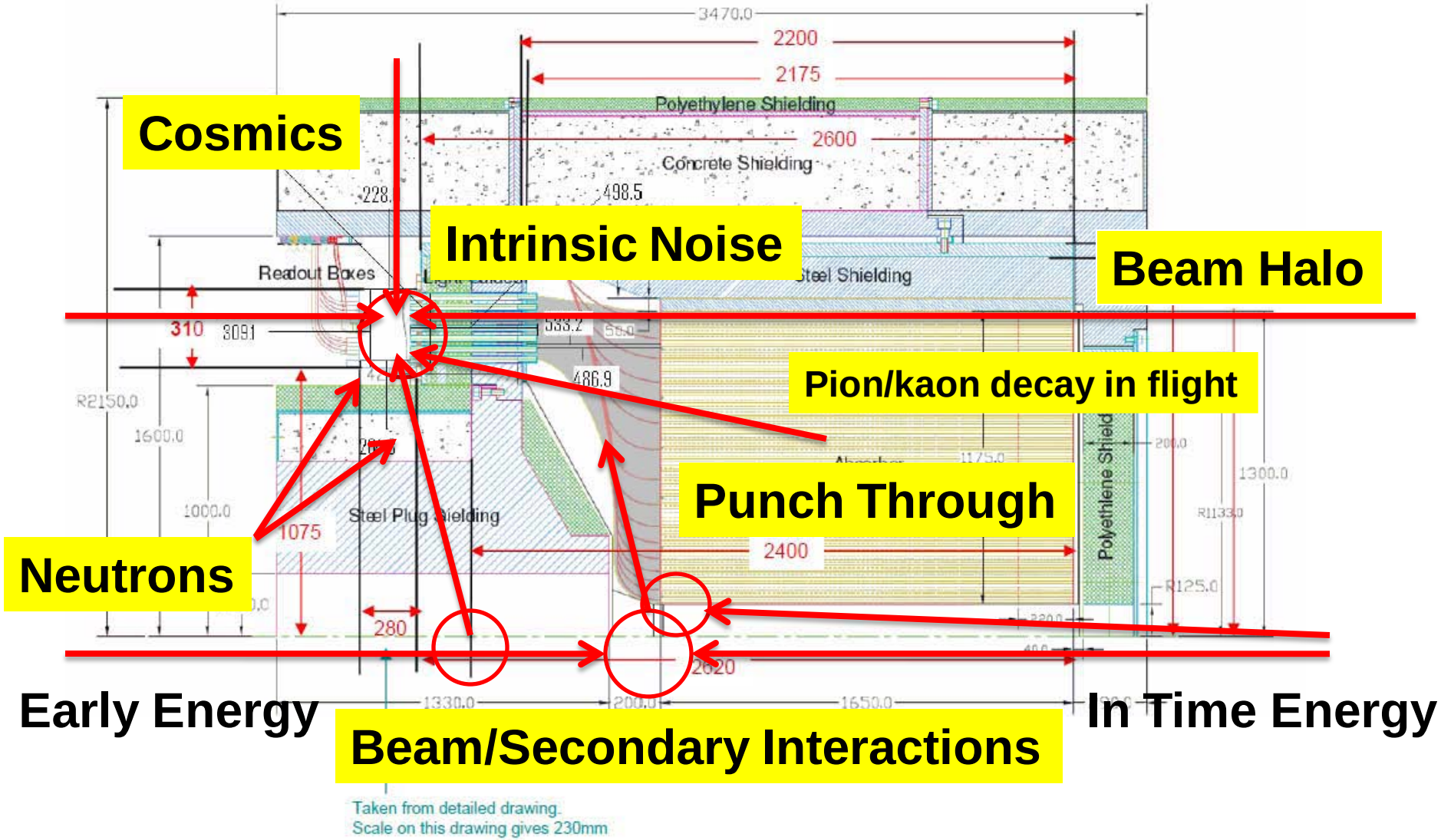
HF PMT thin window will help with the in-time PMT hit events

We still have to contend with in-time broad pulses…

Plan to replace light guide to mitigate late pulses

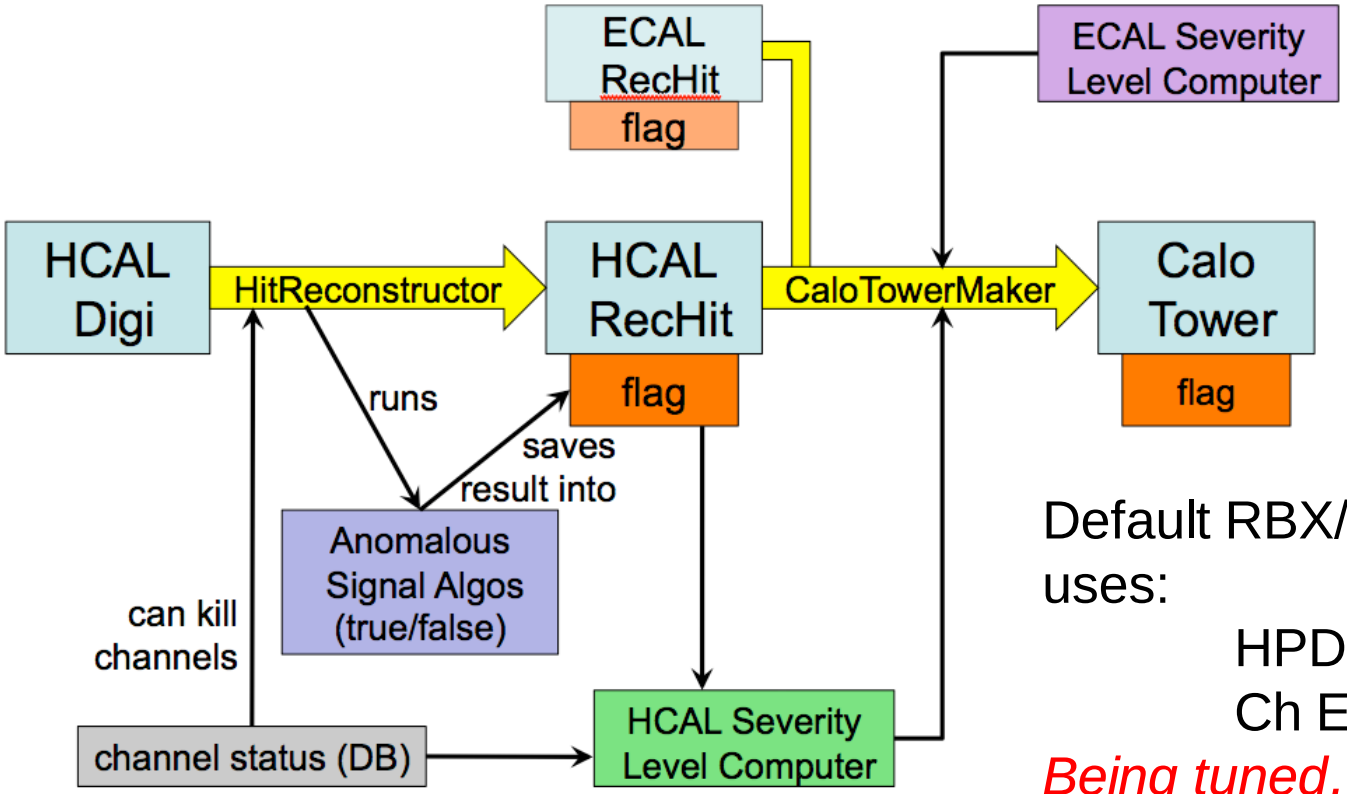
Backup Slides

Possible Sources of HF Anomalous Signals



RBX/HPD Noise RecHit Removal

Uses existing software framework (same as for HF PMT Hit Filter) to flag and eventually remove rechit from the CaloTower



Default RBX/HPD rechit filter uses:

HPD channels >= 17

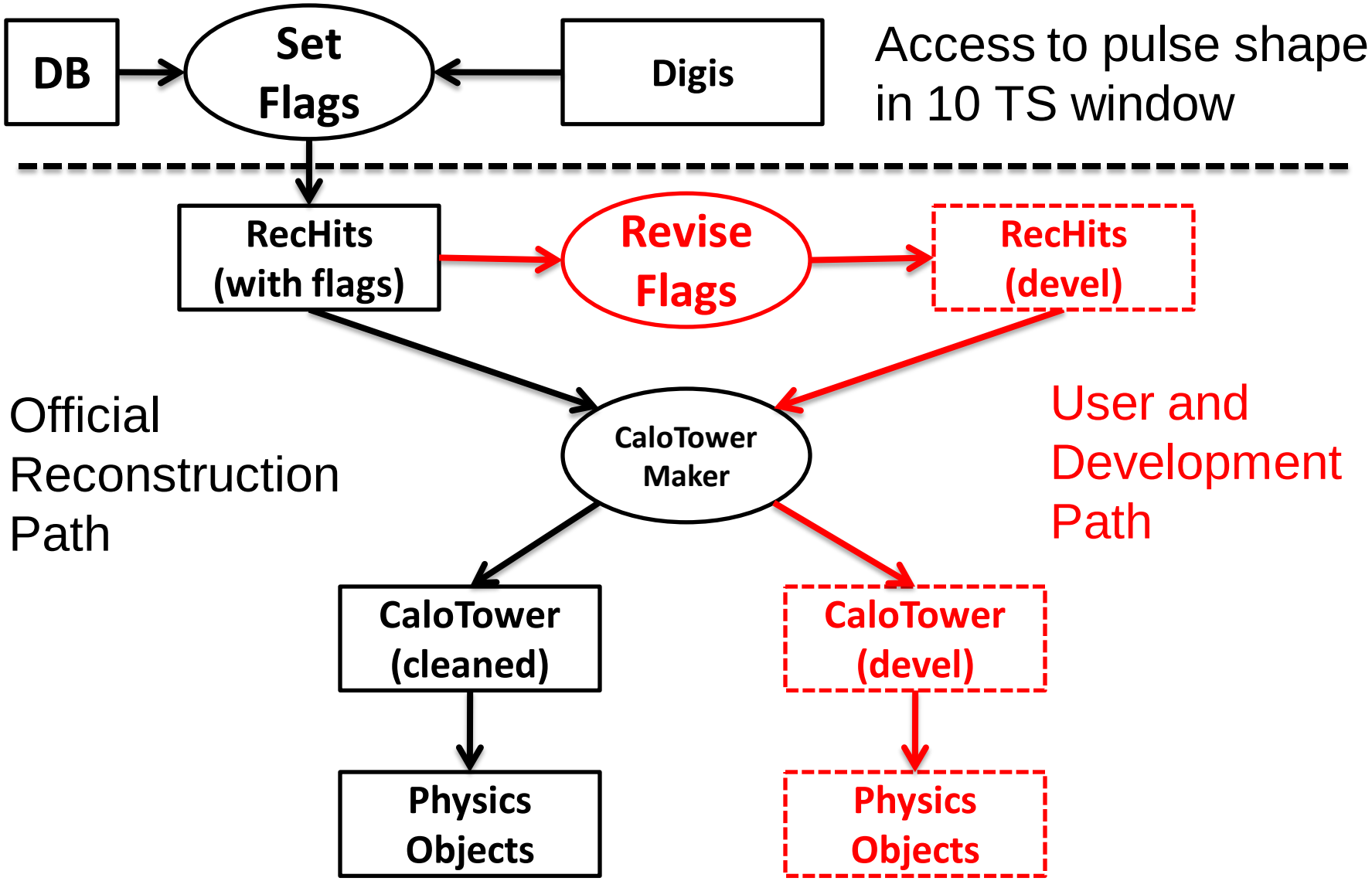
Ch Energy > 1 GeV

Being tuned….

This is *not* being applied as a default for everyone…

Users have to reconstruct CaloTower and downstream physics objects

Development Framework to Treat Noise



HCAL DPG Recommendations

HCAL DPG recommendations for cleaning up Anomalous HCAL Signals

1) V2 of HF PMT Filter *Applied by default*
2) V1 of HF Pulse Filter *Applied by default in CMSSW370p2*
3) V1 of RBX/HPD Event Filter *To be applied at analysis level*
4) *Additional cleaning algorithms available at the user analysis level*

Details can be found at:
https://twiki.cern.ch/twiki/bin/view/CMS/HcalDPGAnomalousSignals

General framework allows possibility to explore more aggressive cleaning

In addition to the recommended filters

- HF rechit filter using the timing information is available
- RBX/HPD rechit filter is available
- More aggressive event filters using the Noise Summary Object