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Analysis Note

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Results of a visual scan of high $\not\!\!E_{\mathrm{T}}$ events in 7 TeV pp collision data

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Abstract

We present the results of a visual scan of high $\not\!\!E_{\mathrm{T}}$ events (tc$\not\!\!E_{\mathrm{T}} > 60$ GeV OR pf$\not\!\!E_{\mathrm{T}} > 60$ GeV) in a large inclusive sample of 7 TeV pp collision data, after applying the official noise clean-up available in CMSSW_3_7_0_patch2. The scan is performed separately for events with tc$\not\!\!E_{\mathrm{T}} > 60$ GeV and pf$\not\!\!E_{\mathrm{T}} > 60$ GeV since two different noise cleaning algorithms are employed. The CMS software *Fireworks* and *PFRootEvent* have been used to produce the event displays. The high $\not\!\!E_{\mathrm{T}}$ events have been visually inspected and classified in different categories. The results of this scan can provide hints to further improve the noise cleaning and to identify possible problems and inconsistencies in the algorithms employed in CMS for the $\not\!\!E_{\mathrm{T}}$ reconstruction.

Contents

1 Introduction

Commissioning studies performed with test beams, cosmic runs and early 0.9 TeV, 2.36 TeV and 7 TeV pp collision data have identified several sources of anomalous noise (i.e. noise not produced solely from expected fluctuations in the electronics) in the calorimeters of the CMS experiment:

- *ECAL barrel spikes* - More details are available at [1].
- *HF PMT hits* - More details are available at [2, 3]
- *IonFeedback/HPD/RBX noise in HCAL barrel and endcaps* - More details are available at [2, 4].

In addition, machine-induced background, as beam halo events [5] and beam-gas interactions producing large pixel cluster multiplicity [6], have been observed.

The overlap of either anomalous noise or machine-induced background with a pp collision event produces an unbalance in the reconstructed missing transverse energy in the event, which can produce large tails in the $\not\!\!E_{\mathrm{T}}$ distribution.

We present the results of a visual scan of high $\not\!\!E_{\mathrm{T}}$ events (tc$\not\!\!E_{\mathrm{T}} > 60$ GeV OR pf$\not\!\!E_{\mathrm{T}} > 60$ GeV) in a large inclusive sample of 7 TeV pp collision data, after applying the official noise clean-up available in CMSSW_3_7_0_patch2. The scan is performed separately for events with tc$\not\!\!E_{\mathrm{T}} > 60$ GeV and pf$\not\!\!E_{\mathrm{T}} > 60$ GeV since two different noise cleaning algorithms are employed (see more details in Section 2).

The CMS software *Fireworks* [7] and *PFRootEvent* [8] have been used to produce the event displays and study the events (for illustration purpose, only *Fireworks* event displays are shown in Section 4). The high $\not\!\!E_{\mathrm{T}}$ events have been visually inspected and classified in different categories. The results of this scan can provide hints to further improve the noise cleaning and to identify possible problems and inconsistencies in the algorithms employed in CMS for the $\not\!\!E_{\mathrm{T}}$ reconstruction.

2 Datasample, Event Selection, and Noise Cleaning

Dataset and CMSSW release:

- dataset: /MinimumBias/Commissioning10-GOODCOLL-Jun9thSkim_v1/RECO
- CMSSW release: CMSSW_3_7_0_patch2

Event selection:

- BPTX bit 0
- Removal of events with large pixel cluster multiplicity
- Good primary vertex
- Good Run/LS selection. JSON file: Cert_132440-136119_7TeV_May27thReReco_Collisions10_JSON.txt

Noise cleaning

"Calotower cleaning" (employed by tc$\not\!\!E_{\mathrm{T}}$):

- ECAL barrel spikes (reject RecHits): topology (kWeird flag = swiss cross variable) + timing (kOutOfTime flag) [1];
- HF PMT hits (reject Rechits): topology (HFLongShort flag = PET+S9/S1) + pulse shape (HFDigiTime flag) [3];
- HPD/RBX noise in HBHE (reject events): combination of pulse shape and topological variables [4].

"Particle-Flow PF cleaning" (employed by pf$\not\!\!E_{\mathrm{T}}$):
PF cleaning [9] is applied on the PFRechits which are used to reconstruct all PF objects (including pf$\not\!\!E_{\mathrm{T}}$). Timing and topology are used to reject RecHits affected by ECAL and HF noise. Topology only is used to reject rechits affected by HBHE noise. In addition an *a posteriori* recovery algorithm is applied, targeted to recover real HF energy deposits incorrectly flagged by the cleaning procedure. No events are rejected.

NOTE: The HPD/RBX noise filter is applied for the scan of both tc$\not\!\!E_{\mathrm{T}}$ and pf$\not\!\!E_{\mathrm{T}}$ tails presented in this note, in order to have the same number of events passing the selection.

Figure 1 shows the cleaned tc$\not\!\!E_{\mathrm{T}}$ and pf$\not\!\!E_{\mathrm{T}}$ distributions for ≈ 60 M events (precisely 58821832 events) passing the event selection described above.

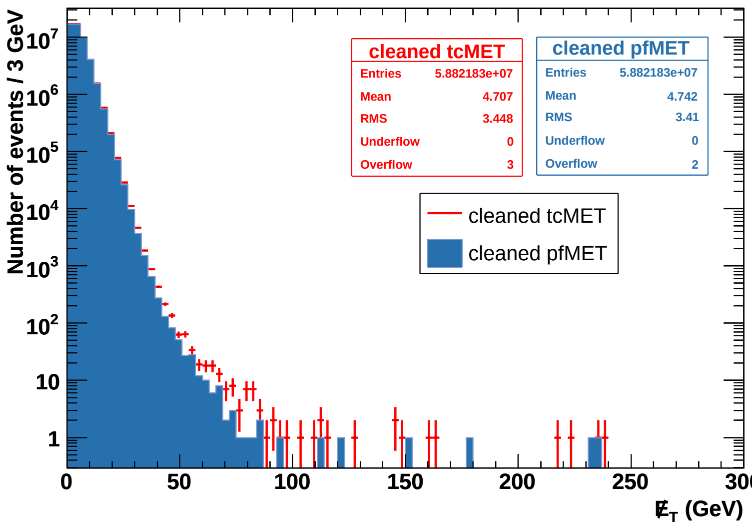

Figure 1: tc$\not\!\!E_{\mathrm{T}}$ and pf$\not\!\!E_{\mathrm{T}}$ distributions of 7 TeV collision data after applying the full event selection and noise cleaning.

3 Scan of high $\not\!\!E_{\mathrm{T}}$ events

Two high $\not\!\!E_{\mathrm{T}}$ skims have been produced and stored in the directory
SKIMDIR = /castor/cern.ch/user/s/santanas/MET/Skims/ScanMETtails60GeV_June2010 :

- tc$\not\!\!E_{\mathrm{T}}$ skim: tc$\not\!\!E_{\mathrm{T}} > 60$ GeV
  Root file in RECO format at:
  SKIMDIR/tcMetSkims.root
- pf$\not\!\!E_{\mathrm{T}}$ skim: pf$\not\!\!E_{\mathrm{T}} > 60$ GeV
  Root file in RECO format at:
  SKIMDIR/pfMetSkims.root

A visual scan of these events has been performed using the CMS event display software *Fireworks* and *PF-RootEvent*. The result of the scan for tc$\not\!\!E_{\mathrm{T}}$ skim and pf$\not\!\!E_{\mathrm{T}}$ skim are summarized in the Tables 1 and 2, respectively.

4 Description and event displays of high $\not\!\!E_{\mathrm{T}}$ events

4.1 EB, spike at EB-EE boundary

We see EB spikes occurring at the boundary between ECAL barrel and endcaps.

The ECAL spikes topological cuts employed in the calotower-based cleaning for tc$\not\!\!E_{\mathrm{T}}$ are not currently applied to identify "spikes" candidates occurring at the boundary between ECAL barrel and endcaps. Spikes at the EB-EE

Category		Number of events	Comments
ECAL		**25**	
EB	spike at EB-EE boundary	22	all removed by Particle-Flow cleaning
EB	spike	1	removed by Particle-Flow cleaning
EE	spike	2	removed by Particle-Flow cleaning
HCAL		**45**	
HF	multi-PMT-hits or phi-strip events	12	5 cleaned by Particle-Flow cleaning
HF	double-PMT-hits	22	17 cleaned by Particle-Flow cleaning
HF	PMT hit embedded in a jet	4	1 cleaned by Particle-Flow cleaning
HB	IonFeedback/HPD/RBX noise	6	low-multipl. noise, not cleaned by PF
HE	IonFeedback/HPD/RBX noise	1	low-multipl. noise, not cleaned by PF
PHYSICS		**35**	
Physics	1 jet	1	large pf$\not\!\!E_{\mathrm{T}}$ as well
Physics	2 jets	9	5 of them have pf$\not\!\!E_{\mathrm{T}}$ $<$ OR $<<$ than tc$\not\!\!E_{\mathrm{T}}$
Physics	3 jets	12	5 of them have pf$\not\!\!E_{\mathrm{T}}$ $<$ OR $<<$ than tc$\not\!\!E_{\mathrm{T}}$
Physics	4 jets	9	4 of them have pf$\not\!\!E_{\mathrm{T}}$ $<$ OR $<<$ than tc$\not\!\!E_{\mathrm{T}}$
Physics	5 jets	2	1 of them has pf$\not\!\!E_{\mathrm{T}}$ $\approx$1/2$\times$ tc$\not\!\!E_{\mathrm{T}}$
Physics	6 jets	2	both have pf$\not\!\!E_{\mathrm{T}}$ $\approx$1/2$\times$ tc$\not\!\!E_{\mathrm{T}}$
OTHERS		**2**	
Others	HB activity + muon	1	large pf$\not\!\!E_{\mathrm{T}}$ as well
Others	Noise in both HB and HE	1	2 “jets” with EMF=0 (cleaned by pfMET)
TOTAL		**107**	

Table 1: Results of visual scan of events with tc$\not\!\!E_{\mathrm{T}} > 60$ GeV.

Category		Number of events	Comments
ECAL		**0**	
HCAL		**19**	
HF	multi-PMT-hits or phi-strip events	4	large tc$\not\!\!E_{\mathrm{T}}$ as well
HF	double-PMT-hits	4	large tc$\not\!\!E_{\mathrm{T}}$ as well
HF	PMT hit embedded in a jet	3	large tc$\not\!\!E_{\mathrm{T}}$ as well
HB	IonFeedback/HPD/RBX noise	7	low-multipl. noise, large tc$\not\!\!E_{\mathrm{T}}$ as well
HE	IonFeedback/HPD/RBX noise	1	low-multipl. noise, large tc$\not\!\!E_{\mathrm{T}}$ as well
PHYSICS		**18**	
Physics	1 jet	1	large tc$\not\!\!E_{\mathrm{T}}$ as well
Physics	2 jets	5	large tc$\not\!\!E_{\mathrm{T}}$ as well
Physics	3 jets	6	large tc$\not\!\!E_{\mathrm{T}}$ as well
Physics	4 jets	3	large tc$\not\!\!E_{\mathrm{T}}$ as well
Physics	5 jets	1	large tc$\not\!\!E_{\mathrm{T}}$ as well
Physics	6 jets	1	pf$\not\!\!E_{\mathrm{T}}$ $\approx$2$\times$ tc$\not\!\!E_{\mathrm{T}}$
Physics	jet + muon	1	large tc$\not\!\!E_{\mathrm{T}}$ as well
OTHERS		**6**	
Others	large muon-induced pfMET	5	very small tc$\not\!\!E_{\mathrm{T}}$
Others	HB activity + muon	1	large tc$\not\!\!E_{\mathrm{T}}$ as well
TOTAL		**43**	

Table 2: Results of visual scan of events with pf$\not\!\!E_{\mathrm{T}} > 60$ GeV.

boundary could anyway be removed by the timing cuts. Nevertheless, some of them still survives after the noise clean-up, as the event shown in Figure 2. It has been verified that all 22 spikes at EB-EE border reported in the tc$\not\!\!E_{\rm T}$ scan are in fact reconstructed in-time, and therefore not removed.

All the observed EB spikes at EB-EE boundaries are instead cleaned by PF cleaning. The topological cuts applied at the EE/EB boundaries and in the vicinity of intermodule cracks are tighter than elsewhere, such that they are as selective as in the fiducial ECAL region.

4.2 EB, EE spikes

We see one event with an isolated spike in ECAL barrel (EB) far from the EB-EE boundaries (Figure 3, left plot) and two events with an isolated spike in ECAL endcap (EE) (Figure 3, right plot).

Calotower-based cleaning for spikes is not applied in EE (it is understood that spikes are due to particles hitting an APD, which are mounted only in the ECAL barrel). The case of EB spike, far from the EB-EE boundary and not cleaned, should be investigated.

All events are cleaned by PF; note that a topological cleaning for spikes is applied by default also in EE.

4.3 HF, multi-PMT-hits or phi-strip events

These events are characterized by several anomalous hits in adjacent cells; sometimes they show up as a strip of hits at the same $i\phi$ location, as the ones reported in Figure 4. This type of noise cannot be cleaned by the existing topological algorithms but could be cleaned by the timing or pulse shape based cleaning if hits are out-of-time or have a malformed pulse shape. A topological cleaning based on the multiplicity of hits above certain energy threshold at the same $i\phi$ location might be effective at identifying such noise. The source of such events is not yet fully understood.

Some of these events are identified by PF cleaning but not by calotower cleaning. Such events are removed by PF cleaning mainly for two reasons:

- the use of the E_S/E_L-type variable also for long fibers (note: this cut, even being more aggressive on isolated photons than the S9/S1-type variable, it's still safe for physics thanks to the presence of the *a posteriori* recovery algorithm implemented in PF cleaning);
- the timing cleaning is first applied, and the topological cleaning is applied once the timing-cleaned hits are removed, making it efficient for multi hits as well.

4.4 HF, double-PMT-hits

These events are characterized by significant energy in both long and short fibers in a single isolated tower, as shown in Figure 5. For high $\not\!\!E_{\rm T}$ events, this noise often shows up in the towers located at the smallest η value in HF (η=3). This can be explained by the fact that, for a given energy, a noise occurring at smaller η produces a larger transverse energy, and therefore is more visible at high $\not\!\!E_{\rm T}$. Anyway it's not excluded that double-hits occurs also at larger η; but in this case such events might fall in the bulk of $\not\!\!E_{\rm T}$ distribution.

This type of noise cannot be cleaned by current calotower-based topological algorithms (PET or S9/S1) but can be cleaned by the timing or pulse shape based cleaning if hits are out-of-time or have a malformed pulse shape. However, cases of in-time double-hits with good pulse shape have been observed. In such cases, a cleaning based on S8/S1 isolation variable could be effective, where S8/S1 is defined in a similar way to S9/S1 with the companion RecHit energy from the same HF tower left out from the sum.

PF cleaning flags most of these noise events. The HF double-hits removed by PF cleaning are characterized by having energy in the short fiber larger than the energy in the long fiber. If, in addition to this condition, the HF tower is also isolated (i.e. small energy in the adjacent towers), the double-hit is identified by the PF cleaning algorithm. No such algorithm is implemented for calotower cleaning in the release CMSSW_3_7_0_patch2; work ongoing to include it in CMSSW_3_8_X.

4.5 HF, PMT hit embedded in a jet

These events are characterized by one or more anomalous hits embedded inside a jet (or simply not isolated), as shown in Figure 6. This type of noise could arise from muons coming from in-flight decays of hadronic particles or from a jet punch-through. In both cases such jets could be identified using the JetID variables since it is expected that a large fraction of the total jet energy would come from only one or two HF towers. Due to an overlap between real and anomalous signal there are two cleaning strategies possible: an entire event could be rejected or a more sophisticated anomalous energy subtraction algorithm would have to be developed.

Neither calotower-based cleaning nor PF cleaning are able to identify these noise events (with the exception of one event removed by PF cleaning and not by calotower-based cleaning).

4.6 HBHE, IonFeedback/HPD/RBX noise

These events are characterized by low multiplicity noise or single noisy channels in HCAL barrel or endcap. Two examples are shown in Figure 7. Improved timing cuts could be employed to identify these residual noise events.

Neither calotower-based cleaning nor PF cleaning are able to identify these residual HBHE noise events.

4.7 Physics

It is observed that approximately 30% of the high $\not\!\!E_{\mathrm{T}}$ events don't contain an obvious source of noise (and therefore are classified as "Physics"). They are typically multi-jet events where the large fake $\not\!\!E_{\mathrm{T}}$ is produced by jet energy mis-measurements or jets at the boundaries between sub-detectors, but can also be events with real $\not\!\!E_{\mathrm{T}}$. Figure 8 shows some examples of physics events with large $\not\!\!E_{\mathrm{T}}$.

In about 50% of high tc$\not\!\!E_{\mathrm{T}}$ events with multi-jet topology, pf$\not\!\!E_{\mathrm{T}}$ values are smaller than tc$\not\!\!E_{\mathrm{T}}$ values. More details can be found in the Tables 1 and 2, and in the list of events posted at the end of the note. The events are classified based on the jet multiplicity using caloJets with uncorrected $p_T > 10$ GeV.

4.8 Others, large muon-induced pf$\not\!\!E_{\mathrm{T}}$

We observed 5 events with large pf$\not\!\!E_{\mathrm{T}}$ (sometimes a few hundreds GeV) but very small tc$\not\!\!E_{\mathrm{T}}$. The muon is reconstructed as "global muon" and "standalone muon", but not as "tracker muon". An example is shown in Figure 9.

Info from PF group:

4 events with pf$\not\!\!E_{\mathrm{T}} > 80$ GeV, with pf$\not\!\!E_{\mathrm{T}}$ = 83, 242, 337 and 528 GeV, respectively, and a muon with $|\eta| > 2.2$. These muons have all a central tracker track associated to them. They are indeed not "tracker muon", meaning that they fail the tracker-muon criteria, but they are all global muons (with a track and a stand-alone muon part) for which the reco::muon pt is not correct. What is interesting is that such poorly reconstructed muons are not seen in the simulation, which points to something odd in the muon and or tracker alignment or geometry in this large eta region.

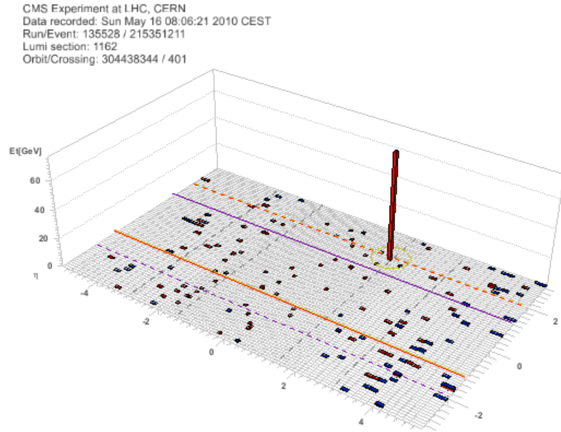

Figure 2: Example of an “EB spike at EB-EE boundary” event

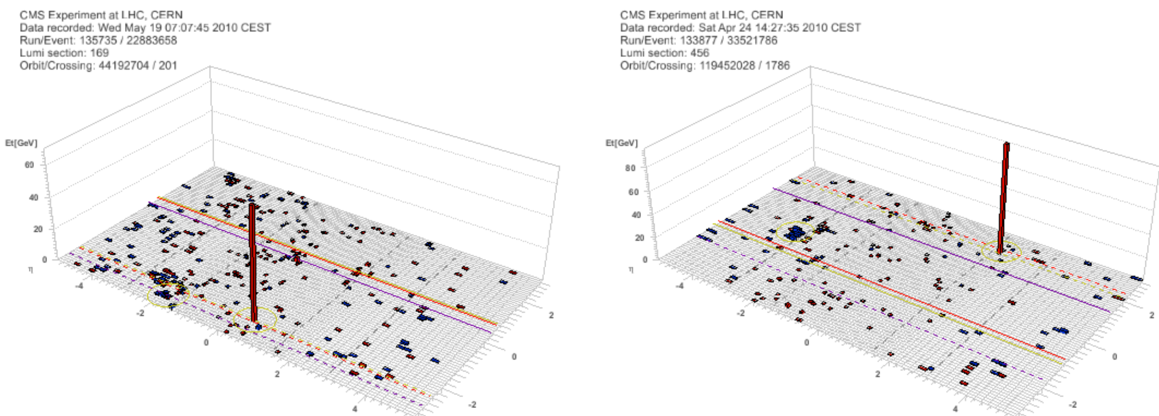

Figure 3: Example of an “EB spike” (left) and an “EE spike” (right) event

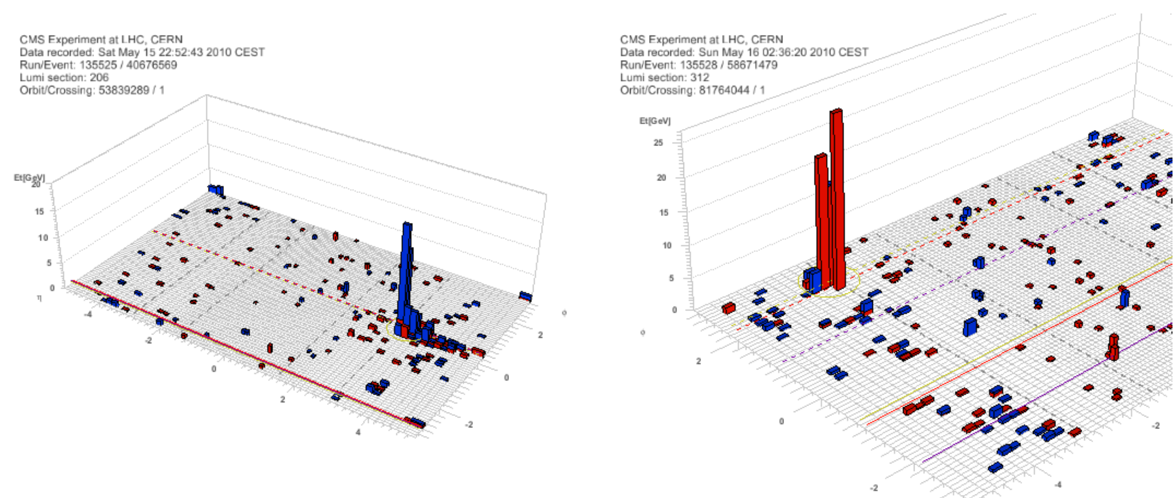

Figure 4: Example of two “HF multi-PMT-hits or phi-strip” events

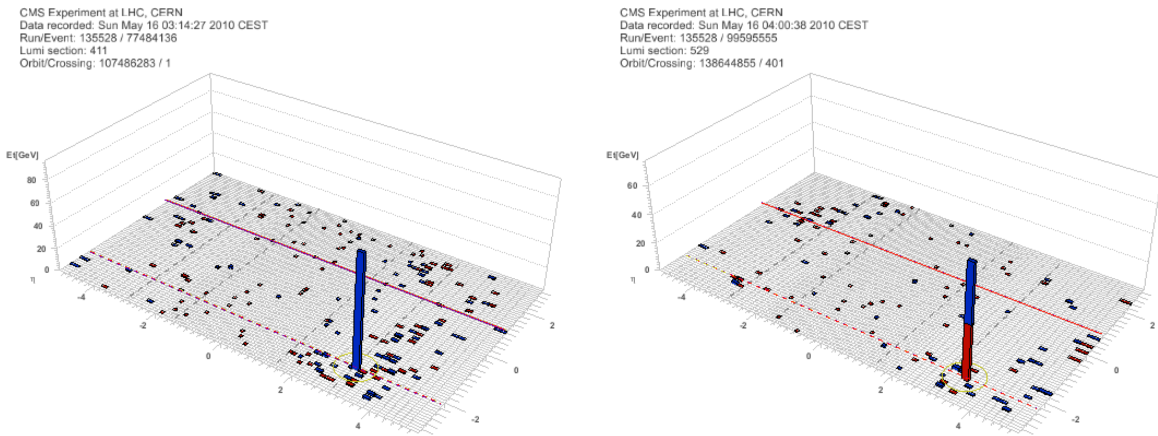

Figure 5: Example of two "HF double-PMT-hits" events. Event in left plot is cleaned by PF and not by calotower-based cleaning; the event on the right is not cleaned by any of the two. NOTE: The event display for the left plot is mis-leading since the hit is not single, as it seems, but double. In fact, in this event display (produce with Fireworks) the following convention is used for HF towers: blue=2*E_S=hadEnergy, while red=$E_L - E_S$=emEnergy. In this event the emEnergy ("red") is negative, but both energies in long and short fibers, E_L and E_S, are large (several hundreds of GeV). The event display only shows positive quantities (only the hadEnergy = "blue"), so the "negative" red spike is not visible and it gives the illusion of a single hit. It is observed that most of double-hits cleaned by PF cleaning have negative emEnergy, i.e. $E_S > E_L$.

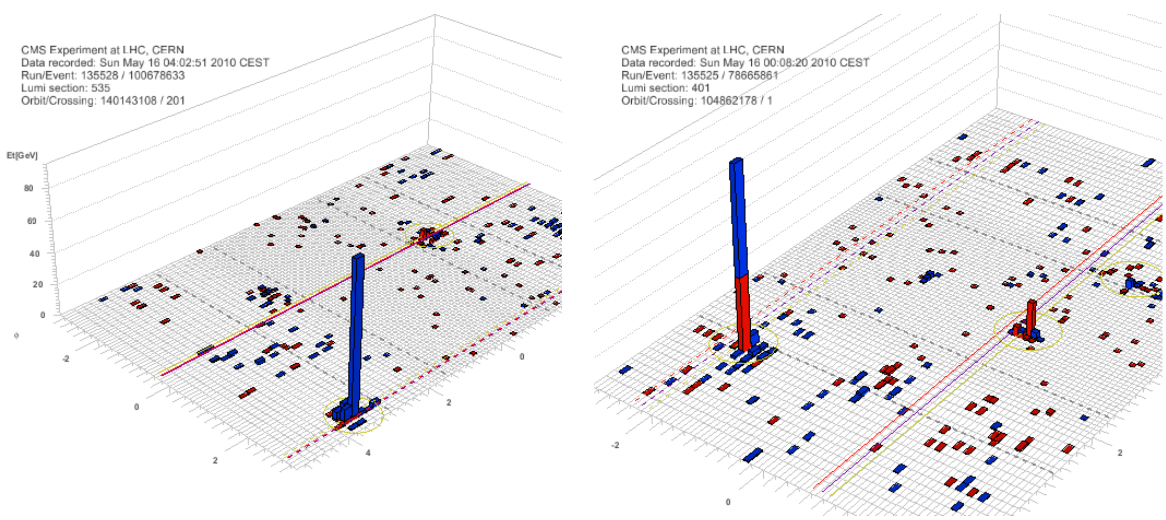

Figure 6: Example of two "HF PMT hit embedded in a jet" events

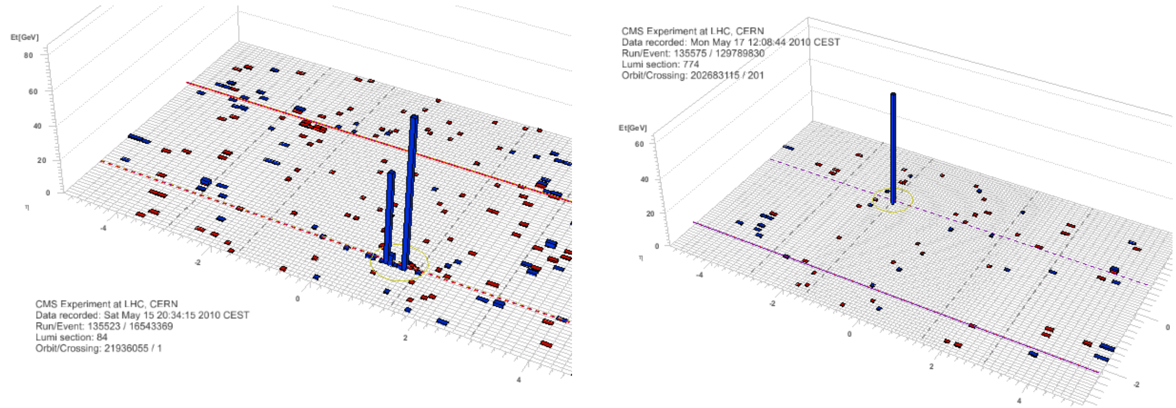

Figure 7: Example of two “HBHE IonFeedback/HPD/RBX” noise events. The left plot shows an HPD/RBX noise event with low hit multiplicity. The right plot show instead an isolated spike, probably IonFeedback noise affecting an individual channel.

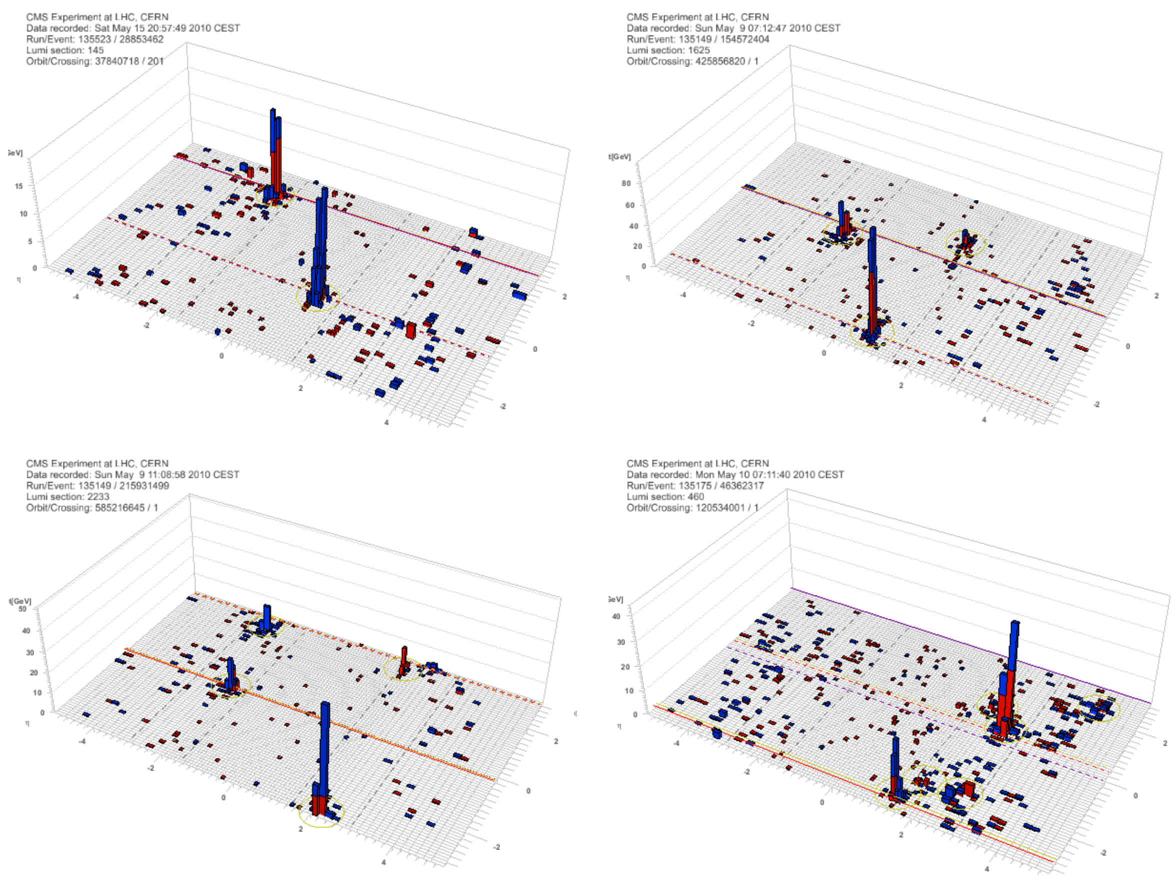

Figure 8: Example of “Physics” events with multi-jet topology

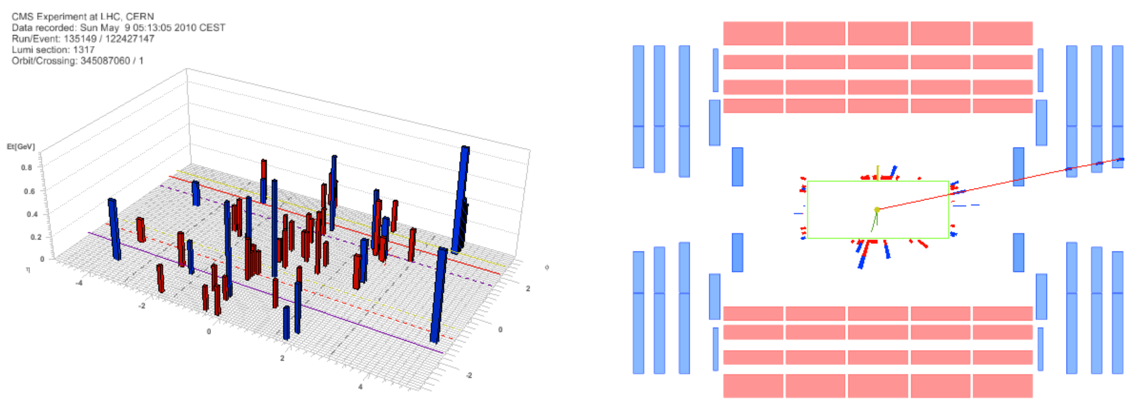

Figure 9: Example of a “large muon-induced pf$\not\!\!E_{\rm T}$” event shown in the eta/phi view (left) and in the transverse plane view (right). There is an high p_T muon reconstructed as “global muon” and “standalone muon” , but not as “tracker muon”.

5 List of high $\not\!\!E_{\mathrm{T}}$ events

In this section, the complete list of high $\not\!\!E_{\mathrm{T}}$ events is provided, for both tc$\not\!\!E_{\mathrm{T}}$ (Table 3, 4, 5) and pf$\not\!\!E_{\mathrm{T}}$ (Table 6) skims.

Run	Event	LS	tc$\not\!\!E_{\mathrm{T}}$ (GeV)	category
132599	4345895	183	78.2843	HF multi-PMT-hits or phi-strip events (tcMET $\approx$ pfMET)
132601	166842	7	81.8343	HF double-PMT-hits (small pfMET)
132601	4585263	188	237.387	EB spike at EB-EE boundary (small pfMET)
132658	892391	37	68.8251	Others, noise in both HB and HE (2 “jets” with EMF=0) (small pfMET)
133046	3187891	138	148.51	EB spike at EB-EE boundary (small pfMET)
133321	14516033	238	60.4839	HF double-PMT-hits (small pfMET)
133874	41569953	528	81.4559	HE noise (tcMET $\approx$ pfMET)
133874	66583217	826	85.6937	HF double-PMT-hits (tcMET $\approx$ pfMET)
133877	21558793	299	83.5564	HF double-PMT-hits (small pfMET)
133877	33521786	456	90.3345	EE spike (small pfMET)
133877	83377798	1130	63.9341	HF double-PMT-hits (tcMET $\approx$ pfMET)
133885	335989	5	62.133	Physics 3 jets (1 “jet” is an electron of 25 GeV) (tcMET $\approx$ pfMET)
133927	369683	6	93.0333	HF double-PMT-hits (small pfMET)
133928	22682366	319	63.7869	HF multi-PMT-hits or phi-strip events (tcMET $\approx$ pfMET)
133928	36620099	517	66.8677	Physics 1 jet (in endcap) (tcMET $\approx$ pfMET)
135149	63603939	753	66.9592	Physics 2 jets (2 electrons of 7 and 3 GeV) (small pfMET=15.9 GeV)
135149	116927949	1265	63.1608	Physics 3 jets (low p_T electrons) (tcMET $\approx$ pfMET)
135149	154572404	1625	98.3469	Physics 3 jets (low p_T electrons) (tcMET $\approx$ pfMET)
135149	155186256	1631	60.8672	Physics 3 jets (20 GeV muon) (tcMET $\approx$ pfMET)
135149	156347129	1642	65.4799	HF double-PMT-hits (small pfMET)
135149	162208514	1699	78.278	HF multi-PMT-hits or phi-strip events (tcMET $\approx$ pfMET)
135149	214116071	2215	66.5431	HF PMT hit embedded in a jet (tcMET $\approx$ pfMET)
135149	215931499	2233	71.0733	Physics 4 jets (27 GeV electron) (tcMET $\approx$ pfMET)
135149	217153658	2245	81.4574	Physics 3 jets (26 GeV and 6 GeV muons)(tcMET $\approx$ pfMET)
135149	222730662	2307	418.801	EB spike at EB-EE boundary (small pfMET)
135149	233103931	2411	74.2742	EB spike at EB-EE boundary (small pfMET)
135149	267019811	2758	66.3561	Physics 4 jets (low p_T electron)(small pfMET=19.8 GeV)
135149	318396401	3297	542.981	EB spike at EB-EE boundary (small pfMET)
135175	17812005	191	64.2943	HB noise (tcMET $\approx$ pfMET)
135175	42757899	426	92.0741	HF double-PMT-hits (small pfMET)
135175	46362317	460	69.9842	Physics 6 jets (tcMET 2 * pfMET)
135175	57982991	574	73.1318	HF double-PMT-hits (small pfMET)

Table 3: List of events with tc$\not\!\!E_{\mathrm{T}} > 60$ GeV - Part 1.

Run	Event	LS	tc$\not\!\!E_{\mathrm{T}}$ (GeV)	category
135175	64940222	641	62.4991	EB spike at EB-EE boundary (small pfMET)
135175	72861680	718	116.591	EE spike (small pfMET)
135175	94014613	926	145.352	Physics 4 jets (low p_T electrons) (tcMET 2 * pfMET)
135175	100575970	990	61.3085	HF double-PMT-hits (tcMET ≈ pfMET)
135521	22453149	203	71.9826	Physics 3 jets (18 GeV electron)(tcMET ≈ pfMET)
135521	32219215	251	69.445	Physics 2 jets (both in HF) (tcMET ≈ pfMET)
135521	40089571	289	77.7739	EB spike at EB-EE boundary (small pfMET)
135521	66824775	420	80.9651	EB spike at EB-EE boundary (small pfMET)
135521	69919879	435	80.0659	HF multi-PMT-hits or phi-strip events (small pfMET), eta strip
135523	9879701	50	61.4423	HF double-PMT-hits (small pfMET)
135523	16543369	84	164.131	HB noise (tcMET ≈ pfMET)
135523	28853462	145	64.5248	Physics 2 jets (4.5 GeV muon) (tcMET ≈ pfMET)
135525	17433547	87	68.2453	Physics 3 jets (small pfMET = 7 GeV)
135525	40676569	206	62.4033	HF multi-PMT-hits or phi-strip events (tcMET ≈ pfMET), 2-4 phi strip
135525	45035068	228	70.4362	EB spike at EB-EE boundary (small pfMET)
135525	48804509	247	62.6639	Physics 4 jets (tcMET ≈ pfMET)
135525	63386076	320	77.1017	HF multi-PMT-hits or phi-strip events (tcMET ≈ pfMET)
135525	78665861	401	62.0925	HF PMT hit embedded in a jet (tcMET ≈ pfMET)
135525	80550953	410	65.2472	Physics 2 jets (back-to-back) (tcMET 2 * pfMET)
135525	87558102	448	110.215	Physics 5 jets (tcMET ≈ pfMET)
135525	88031668	450	64.1569	Physics 4 jets (tcMET 3 * pfMET)
135528	884119	5	62.3458	HF double-PMT-hits (tcMET ≈ pfMET)
135528	19813983	105	61.8938	HF multi-PMT-hits or phi-strip events (tcMET ≈ pfMET)
135528	32603499	174	63.8757	EB spike at EB-EE boundary (small pfMET)
135528	58671479	312	64.5086	HF multi-PMT-hits or phi-strip events (small pfMET)
135528	60003196	319	74.3878	Physics 2 jets (back-to-back) (small pfMET = 17 GeV)
135528	77484136	411	89.8829	HF double-PMT-hits (small pfMET)
135528	80490418	426	73.026	Physics 3 jets (8 GeV muon) (tcMET 2 * pfMET)
135528	99595555	529	82.2867	HF double-PMT-hits (tcMET ≈ pfMET)
135528	100678633	535	78.523	HF PMT hit embedded in a jet (tcMET ≈ pfMET)
135528	102808626	546	68.4343	Physics 6 jets (6 GeV electron) (tcMET 2 * pfMET)
135528	115447830	618	62.2738	HB noise (tcMET ≈ pfMET)
135528	130731462	699	127.18	HF double-PMT-hits (small pfMET)

Table 4: List of events with tc$\not\!\!E_{\mathrm{T}} > 60$ GeV - Part 2.

Run	Event	LS	tc$\not\!\!E_{\mathrm{T}}$ (GeV)	category
135528	150342996	808	66.7701	Physics 5 jets (tcMET 2 * pfMET)
135528	153336127	824	63.8531	Physics 4 jets (28.5 and 14 GeV electrons) (tcMET ≈ pfMET)
135528	162079374	871	111.931	HF multi-PMT-hits or phi-strip events (small pfMET)
135528	172155075	927	216.754	EB spike at EB-EE boundary (small pfMET)
135528	178385490	960	113.215	HF multi-PMT-hits or phi-strip events (small pfMET)
135528	194937806	1049	61.32	Physics 4 jets (10 GeV electron) (tcMET ≈ pfMET)
135528	195017684	1050	65.1985	HF double-PMT-hits (small pfMET)
135528	204463628	1103	69.0627	Physics 2 jets (small pfMET = 14 GeV)
135528	207348623	1118	75.5706	HF multi-PMT-hits or phi-strip events (tcMET ≈ pfMET)
135528	215351211	1162	68.9099	EB spike at EB-EE boundary (small pfMET)
135528	226804792	1227	575.609	EB spike at EB-EE boundary (small pfMET)
135528	227722743	1232	159.545	EB spike at EB-EE boundary (small pfMET)
135528	238836923	1292	69.2778	EB spike at EB-EE boundary (small pfMET)
135528	256160509	1388	74.4981	EB spike at EB-EE boundary (small pfMET)
135535	15564358	92	224.509	HB noise (tcMET ≈ pfMET)
135535	18401448	109	79.3533	HF double-PMT-hits (small pfMET)
135535	31027189	182	67.2768	Others - HB activity + muon (tcMET ≈ pfMET)
135573	13003948	151	81.3199	HF double-PMT-hits (small pfMET)
135575	5342229	38	63.8363	Physics 3 jets (2 GeV muon) (tcMET 2 * pfMET)
135575	11156890	79	61.2564	Physics 3 jets (6 GeV muon) (tcMET ≈ pfMET)
135575	13695733	97	235.509	EB spike at EB-EE boundary (small pfMET)
135575	64338278	393	68.2189	Physics 2 jets (1 jet at barrel-endcap border)(tcMET ≈ pfMET)
135575	67135767	408	68.972	HF multi-PMT-hits or phi-strip events (small pfMET)
135575	67221216	409	78.3203	EB spike at EB-EE boundary (small pfMET)
135575	69788619	423	63.2861	Physics 4 jets (27 and 10 GeV electrons) (tcMET ≈ pfMET)
135575	93340831	559	146.205	Physics 2 jets + 65 GeV muon in jet + EB activity at border? (tcMET ≈ pfMET)
135575	96504815	577	60.6013	EB spike at EB-EE boundary (small pfMET)
135575	117083855	698	86.9326	HF double-PMT-hits (small pfMET)
135575	126932629	757	72.2135	HF double-PMT-hits (small pfMET)
135575	128277130	765	64.6596	Physics 3 jets (tcMET 2 * pfMET)
135575	129789830	774	66.7404	HB noise (tcMET ≈ pfMET), Ion Feedback?
135575	130735782	779	64.1565	EB spike at EB-EE boundary (small pfMET)
135575	134419161	805	61.4918	HF PMT hit embedded in a jet (small pfMET)
135575	144805158	870	86.8711	HF double-PMT-hits (small pfMET)
135575	149874280	901	61.6245	EB spike at EB-EE boundary (small pfMET)
135575	180503581	1110	64.2686	HF double-PMT-hits (small pfMET)
135575	189427985	1175	61.6306	Physics 2 jets (23, and 2 GeV electrons)(tcMET 2 * pfMET)
135575	190898956	1186	73.6522	EB spike at EB-EE boundary (small pfMET)
135575	192395010	1197	64.455	Physics 3 jets (tcMET 2 * pfMET)
135575	193746493	1207	104.321	HB noise (tcMET ≈ pfMET)
135735	8376298	103	72.7973	Physics 4 jets (2.6 GeV electron) (small pfMET=18 GeV)
135735	22883658	169	83.7303	EB spike (small pfMET)

Table 5: List of events with tc$\not\!\!E_{\mathrm{T}} > 60$ GeV - Part 3.

Run	Event	LS	pf$\not\!\!E_{\mathrm{T}}$ (GeV)	category
132599	4345895	183	67.483	HF multi-PMT-hits or phi-strip events (pfMET $\approx$ tcMET)
133874	41569953	528	85.4173	HE noise (pfMET $\approx$ tcMET)
133874	66583217	826	94.6307	HF double-PMT-hits (pfMET $\approx$ tcMET)
133877	9967629	147	63.2921	Physics 2 jets (pfMET $\approx$ tcMET)
133877	83377798	1130	62.5759	HF double-PMT-hits (pfMET $\approx$ tcMET)
133885	335989	5	65.6229	Physics 3 jets (1 “jet” is an electron of 25 GeV) (pfMET $\approx$ tcMET)
133928	36620099	517	67.8891	Physics 1 jet (in endcap) (pfMET $\approx$ tcMET)
135149	116927949	1265	72.6891	Physics 3 jets (low p_T electrons) (pfMET $\approx$ tcMET)
135149	122427147	1317	528.658	Others large muon-induced pfMET, very small tcMET
135149	154572404	1625	63.0696	Physics 3 jets (low p_T electrons) (pfMET $\approx$ tcMET)
135149	162208514	1699	70.1507	HF multi-PMT-hits or phi-strip events (pfMET $\approx$ tcMET)
135149	215931499	2233	86.0465	Physics 4 jets (27 GeV electron) (pfMET $\approx$ tcMET)
135149	217153658	2245	67.7884	Physics 3 jets (26 GeV and 6 GeV muons)(pfMET $\approx$ tcMET)
135175	57397642	568	337.561	Others large muon-induced pfMET, very small tcMET
135175	94014613	926	61.3586	Physics 4 jets (low p_T electrons) (tcMET 2 * pfMET)
135175	100575970	990	61.8675	HF double-PMT-hits (pfMET $\approx$ tcMET)
135521	22774568	205	60.8714	Physics 3 jets (pfMET $\approx$ tcMET)
135521	32219215	251	62.8553	Physics 2 jets (both in HF) (pfMET $\approx$ tcMET)
135523	16543369	84	179.233	HB noise (pfMET $\approx$ tcMET)
135525	48804509	247	60.366	Physics 4 jets (pfMET $\approx$ tcMET)
135525	63386076	320	67.772	HF multi-PMT-hits or phi-strip events (pfMET $\approx$ tcMET)
135525	78665861	401	62.6467	HF PMT hit embedded in a jet (pfMET $\approx$ tcMET)
135525	87558102	448	121.168	Physics 5 jets (pfMET $\approx$ tcMET)
135528	32056404	171	231.068	Others large muon-induced pfMET, very small tcMET
135528	99411269	528	62.2593	HB noise (pfMET $\approx$ tcMET) , Ion Feedback?
135528	99595555	529	80.0732	HF double-PMT-hits (pfMET $\approx$ tcMET)
135528	99860976	531	69.2713	Physics 6 jets (pfMET 2*tcMET)
135528	100678633	535	67.2221	HF PMT hit embedded in a jet (pfMET $\approx$ tcMET)
135528	109847963	584	83.8501	Others large muon-induced pfMET, very small tcMET
135528	115447830	618	72.7202	HB noise (pfMET $\approx$ tcMET)
135528	190129212	1023	64.6779	Physics 2 jets + muon (pfMET $\approx$ tcMET)
135528	192636869	1037	66.284	HF PMT hit embedded in a jet (pfMET 2 * tcMET)
135528	207348623	1118	68.2922	HF multi-PMT-hits or phi-strip events (pfMET $\approx$ tcMET)
135528	208274999	1123	60.6407	Others large muon-induced pfMET, very small tcMET
135535	15564358	92	235.597	HB noise (pfMET $\approx$ tcMET)
135535	31027189	182	72.7387	Others - HB activity + muon (pfMET $\approx$ tcMET)
135575	11156890	79	66.5948	Physics 3 jets (6 GeV muon) (pfMET $\approx$ tcMET)
135575	64338278	393	64.4694	Physics 2 jets (1 jet at barrel-endcap border)(pfMET $\approx$ tcMET)
135575	75318623	455	60.9222	Physics jet + muon (pfMET $\approx$ tcMET)
135575	93340831	559	152.727	Physics 2 jets + 65 GeV muon in jet + EB activity at border? (pfMET $\approx$ tcMET)
135575	129789830	774	76.5243	HB noise (pfMET $\approx$ tcMET) , Ion Feedback?
135575	136780600	820	64.009	HB noise (pfMET $\approx$ tcMET) , Ion Feedback?
135575	193746493	1207	112.707	HB noise (pfMET $\approx$ tcMET)

Table 6: List of events with pf$\not\!\!E_{\mathrm{T}} > 60$ GeV.

6 Conclusions

We have performed a visual scan of high $\not\!\!E_T$ events (tc$\not\!\!E_T > 60$ GeV OR pf$\not\!\!E_T > 60$ GeV) in a large inclusive sample of 7 TeV pp collision data (about 60M events), after applying the official noise clean-up available in CMSSW_3_7_0_patch2.

We observe that the main difference between calotower cleaning and PF cleaning, in terms of removal of noise events in the $\not\!\!E_T$ tails, consists in the ability to identify:

- in-time EB spikes occurring at the border between EB and EE, and EE spikes;
- in-time HF double-hits.

In particular, PF cleaning is able to reject all the ECAL spikes (25 events with tc$\not\!\!E_T > 60$ GeV), and the majority of the HF double-hits (17 out of 22 events with tc$\not\!\!E_T > 60$ GeV) identified by the visual scan of $\not\!\!E_T$ tails. Work is ongoing to include similar identification criteria also in the calotower cleaning.

After the cleaning, some residual noise events are still present in the tails of the $\not\!\!E_T$ distribution at an approximate rate of 10^{-6}-10^{-7} (e.g., in the pf$\not\!\!E_T$ tails there are 19 HCAL noise events with pf$\not\!\!E_T > 60$ GeV out of approximately 60M of collision events from the /MinimumBias/Commissioning10-GOODCOLL-Jun9thSkim_v1/RECO dataset).

It should be pointed out that the results of a visual scan are always subject to a personal judgment and cannot guarantee the consistency and reproducibility of a rigorous statistical analysis. Nevertheless, they should provide with good approximation a realistic picture of the events populating the $\not\!\!E_T$ tails after applying the current noise clean-up.

References

[1] **CMS** Collaboration, "Electromagnetic calorimeter commissioning and performance with 7 TeV data," *CMS PAS* **EGM-10-002** (2010).

[2] **CMS** Collaboration, "Identification and Filtering of Uncharacteristic Noise in the CMS Hadron Calorimeter," *CMS-CFT* **09-019** (2009) `arXiv:0911.4881`.

[3] **CMS** Collaboration, e. a. F. Chlebana, "Optimization and Performance of HF PMT Hit Cleaning Algorithms Developed Using pp Collision Data at sqrt(s)=0.9, 2.36 and 7 TeV," *CMS Detector Note* **DN-2010/008** (2010).

[4] **CMS** Collaboration, T. H. D. noise WG members, "HCAL Noise Working Group Summary for CMS Summer 2010 analyses," *CMS Analysis Note* **AN-2010/165** (2010).

[5] **CMS** Collaboration, e. a. D.Acosta, "Beam Halo Event Identification in CMS Using the CSCs, ECAL, and HCAL," *CMS Analysis Note* **AN-2010/111** (2010).

[6] **CMS** Collaboration, "Tracking and Primary Vertex Results in First 7 TeV Collisions," *CMS PAS* **TRK-10-005** (2010).

[7] **CMS** Collaboration, "Physics Analysis Oriented Event Display (Fireworks / cmsShow)," *CMS Twiki* **https://twiki.cern.ch/twiki/bin/viewauth/CMS/WorkBookFireworks**.

[8] **CMS** Collaboration, "The PFRootEvent ROOT interface," *CMS Twiki* **https://twiki.cern.ch/twiki/bin/view/CMS/WorkBookParticleFlowPFRootEvent**.

[9] **CMS** Collaboration, "Commissioning of the Particle-Flow reconstruction in Minimum-Bias and Jet Events from pp Collisions at 7 TeV," *CMS PAS* **PFT-10-002** (2010).