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Results of 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 (Calo$\not\!\!E_{\mathrm{T}} > 45$ GeV OR tc$\not\!\!E_{\mathrm{T}} > 45$ GeV OR pf$\not\!\!E_{\mathrm{T}} > 45$ GeV) in a sample of 12 nb^{-1} of 7 TeV pp collision data, after applying the official noise clean-up. The CMS software *Fireworks* has been used to produce the event displays. The high $\not\!\!E_{\mathrm{T}}$ events have been visually inspected and classified in different cathegories. The resuls of this scan can be used to further improve the noise cleaning algorithms and identify possible problems in the three 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 produce solely from expected fluctuations in the electronics) in the calorimeters of the CMS experiment:

- *ECAL barrel spikes* - Energy deposits in individual channels affected by the noise are cleaned using both topological and timing information of the reconstructed hits. Noise correlated with collisions. More details are available at XXX.
- *HF PMT hits* - Energy deposits in individual channels affected by the noise are cleaned using both topological and timing information of the reconstructed hits. Noise correlated with collisions. More details are available at XXX.
- *HPB/RBX noise in HCAL barrel and endcaps* - Events with identified HPD/RBX noise are removed from the analysis using a filter based on both topological and timing information of the reconstructed energy deposits. Noise not correlated with collision. More details are available at XXX.

In addition, machine-induced background, in the form of beam halo [XXX] and beam scraping events [XXX], 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.

In this note, we present the results of a visual scan of high $\not\!\!E_{\mathrm{T}}$ events (> 45 GeV) in a sample of 7 TeV pp collision data, after applying the noise clean-up developed by joint effort of several groups in the CMS collaboration, and described in Section 2. The CMS software *Fireworks* [XXX] has been used to produce the event displays. The high $\not\!\!E_{\mathrm{T}}$ events have been visually inspected and classified in different cathegories. The resuls of this scan can be used as a starting point to further improve the noise cleaning algorithms and to identify possible problems and inconsistencies in the three algorithms employed in CMS for the $\not\!\!E_{\mathrm{T}}$ reconstruction.

2 Datasample, Event Selection, and Noise Cleaning

Information on the dataset and CMSSW release used to reconstruct the data:

- dataset: /MinimumBias/Commissioning10-May6thReReco-v1/RECO
- CMSSW release: CMSSW_358p3

Event selection (reject events):

- BPTX
- GOOD VERTEX
- BEAM SCRAPING FILTER
- etc..

Noise cleaning (reject RecHits):

- ECAL barrel spikes: topology (swiss cross variable) + timing (kOutOfTime flag) [XXX]
- HF PMT hits: topology (“v2”: PET+S9S1) + timing (rechit-time window cut) = “v4” cleaning [XXX]
- HPD/RBX noise in HBHE: topology (cut on hit multiplicity in an HPD) [XXX]

See details at https://twiki.cern.ch/twiki/bin/view/CMS/METNoiseCleanup.

Figure 1 shows the cleaned Calo$\not\!\!E_{\mathrm{T}}$ distribution for ≈ 19.6 M events passing the event selection described above.

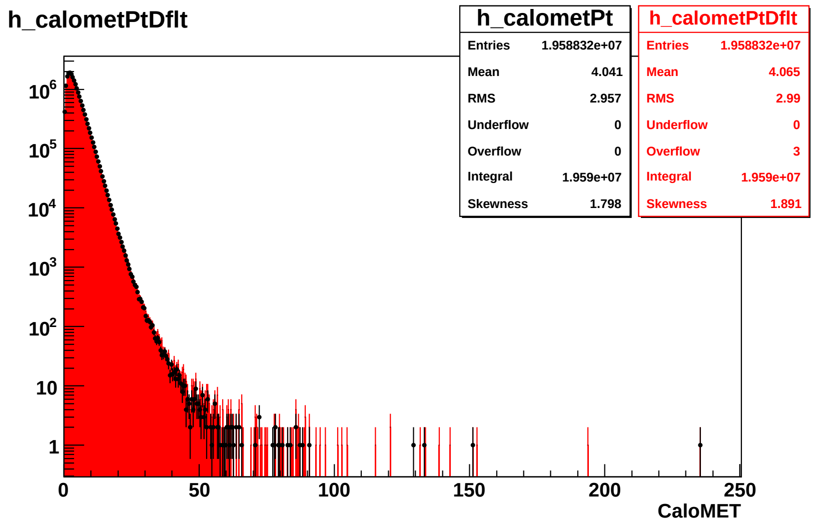

Figure 1: Calo$\not\!\!E_T$ distribution of 7 TeV collision data after applying the event selection described in this section. Red filled histogram is obtained using the $\not\!\!E_T$ value coming from default CMS reconstruction in CMSSW_358p3. The black dotted histogram is the $\not\!\!E_T$ after applying the full noise cleaning procedure described in this section.

3 Scan of high $\not\!\!E_T$ events

The high $\not\!\!E_T$ events have been divided in three mutually exclusive categories and stored in the directory SKIMDIR = /castor/cern.ch/user/s/santanas/MET/Skims/METtails_45GeVcut_May27_2010/ :

- Category 1 - Calo$\not\!\!E_T > 45$ GeV AND tc$\not\!\!E_T > 45$ GeV
  Root file in RECO format at:
  SKIMDIR/picked_events_CaloMET_and_tcMET_gt_45GeV_Artur.root
- Category 2 - Calo$\not\!\!E_T > 45$ GeV AND tc$\not\!\!E_T < 45$ GeV
  Root file in RECO format at:
  SKIMDIR/picked_events_CaloMET_gt_45GeV_Artur.root
- Category 3 - Calo$\not\!\!E_T < 45$ GeV AND tc$\not\!\!E_T > 45$ GeV
  Root file in RECO format at:
  SKIMDIR/picked_events_tcMET_gt_45GeV_Artur.root

A visual scan of these events have been performed using the CMS event display software “Fireworks”. It should pointed out that the results of a visual scan are subject to personal judgment. Nevertheless, they should provide with good approximation a realistic picture of which are the events that populates the tails of the $\not\!\!E_T$ after applying the current noise clean-up.

The result of the scan for Category 1, 2, and 3 are summarized in the Tables 1, 2, and 3, respectively.

Category		Number of events	Comments
ECAL TOTAL		**3**	-
EB	spike at EB-EE boundary	3	all removed by Particle-Flow cleaning
HCAL TOTAL		**43**	-
HF	multi-PMT-hits or phi-strip events	7	2 partially cleaned by Particle-Flow cleaning
HF	double-PMT-hits	22	11 cleaned by Particle-Flow cleaning
HF	PMT hit embedded in a jet	4	-
HF	single jet in HF	4	-
HF	not isolated PMT hit	1	-
HB	HPD/RBX noise	3	2 removed by HPD/RBX event filter
HE	HPD/RBX noise	2	2 removed by HPD/RBX event filter
PHYSICS TOTAL		**43**	-
Physics	1 jet	0	-
Physics	2 jets	4	-
Physics	3 jets	4	-
Physics	4 jets	3	-
Physics	5 jets	1	-
Physics	6 jets	0	-
OTHERS TOTAL		**43**	-
Others	cleaning issue	1	smaller Calo$\not\!\!E_{\mathrm{T}}$/tc$\not\!\!E_{\mathrm{T}}$ before cleaning, larger after cleaning.
TOTAL		**59**	-

Table 1: Results of visual scan of high $\not\!\!E_{\mathrm{T}}$ events in the skim “Category 1”.

Category		Number of events	Comments
ECAL TOTAL		**0**	-
HCAL TOTAL		**14**	-
HF	multi-PMT-hits or phi-strip events	2	-
HF	double-PMT-hits	2	-
HF	PMT hit embedded in a jet	5	-
HF	single jet in HF	5	-
PHYSICS TOTAL		**62**	-
Physics	1 jet	3	-
Physics	2 jets	31	-
Physics	3 jets	13	-
Physics	4 jets	9	-
Physics	5 jets	5	-
Physics	6 jets	1	-
OTHERS TOTAL		**1**	-
Others	cleaning issue	1	smaller Calo$\not\!\!E_{\mathrm{T}}$/tc$\not\!\!E_{\mathrm{T}}$ before cleaning, larger after cleaning.
TOTAL		**77**	-

Table 2: Results of visual scan of high $\not\!\!E_{\mathrm{T}}$ events in the skim “Category 2”.

Category		Number of events	Comments
ECAL TOTAL		**0**	-
HCAL TOTAL		**4**	-
HF	multi-PMT-hits or phi-strip events	2	-
HF	single jet in HF	1	-
HB	HPD/RBX noise	1	-
PHYSICS TOTAL		**16**	-
Physics	1 jet	2	-
Physics	2 jets	6	-
Physics	3 jets	4	-
Physics	4 jets	3	-
Physics	5 jets	1	-
Physics	6 jets	0	-
OTHERS TOTAL		**12**	-
Others	possible issues with tc$\not\!\!E_{\mathrm{T}}$	6	small Calo$\not\!\!E_{\mathrm{T}}$/pf$\not\!\!E_{\mathrm{T}}$, large tc$\not\!\!E_{\mathrm{T}}$
Others	cleaning issue	6	smaller Calo$\not\!\!E_{\mathrm{T}}$/tc$\not\!\!E_{\mathrm{T}}$ before cleaning, larger after cleaning
TOTAL		**32**	-

Table 3: Results of visual scan of high $\not\!\!E_{\mathrm{T}}$ events in the skim “Category 3”.

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

4.1 EB, spike at EB-EE boundary

The topological cuts are not currently applied to identify "spikes" candidates occuring at the boundary between ECAL barrel and endcaps. Most of such events can be removed by the timing cuts. Nevertheless, some of them still survives after the noise clean-up, as the event shown in Figure 2.

Figure 2: Example of "EB spike at EB-EE boundary" event

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

These events are characterized by more than two or more PMT hits, in adjecent cells; typically they show up as a strip of hits at the same $i\phi$ location, as the one reported in Figure 3. 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.

Figure 3: Example of "HF multi-PMT-hits or phi-strip" event

4.3 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 6. This type of noise cannot be cleaned by current topological algorithm 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 [XXX]. This type of cleaning is not expected to be fully safe for isolated particles, in particular for physically bigger towers at lower η values, and therefore should only be applied for certain analyses at the analysis level. Preliminary studies on the use of S8/S1 isolation variable have been performed. More information will be available in the "HCAL reflagger" Twiki: https://twiki.cern.ch/twiki/bin/viewauth/CMS/HcalRecHitReflagger .

Figure 4: Example of "HF double-PMT-hits" event

4.4 HF, PMT hit embedded in a jet

These events are characterized by one or more anomalous hits embedded inside a jet,as shown in Figure 5. 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.

4.5 HF, single jet in HF

These events are characterized by the presence of an apparently good jet reconstructed in HF and no other jet in the rest of the detector; in addition, the energy in the transverse plane is not balanced, producing large $\not\!\!E_{\mathrm{T}}$. See Figure 6. The source of the large $\not\!\!E_{\mathrm{T}}$ is not yet fully understood. A few possible explanations are given: i) some kind of mis-measurement of the unclustered energy, ii) energy missing due to particles lost in the beam pipe, or iii) some kind of HF noise overlapping with a real jet (in the latter case such events would fall in the category discussed in Section 4.4).

Figure 5: Example of “HF PMT hit embedded in a jet” event

Figure 6: Example of “single HF jet in HF” event