DOE REPORT

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One of the main interests of the Caltech group are searches of signatures of physics beyond standard model (SM) in final states involving jets and missing transverse energy (MET). Such signatures arise in e.g. R-parity conserving scenarios, where MET in the final state is due to the stable lightest supersymmetric particle (LSP) escaping detectors. Since cross-sections for sparticle production at LHC are dominated by squark and gluino production, the final states with jets and MET offer the greatest early reach in many searches.

However, MET is also one of the most challenging experimental observables to measure, since various sources of noise or instrumental effects can "fake" MET signatures of new physics. An in-depth understanding of the performance of all parts of the detector is therefore crucial for the searches. Caltech has leading roles in commissioning and monitoring the hadronic and electromagnetic calorimeteres (HCAL and ECAL), as well as developing, calibrating and optimizing the measurement of jets and MET.

A.Apresyan has been actively participating in the commissioning of ECAL, HCAL, jets and MET reconstruction since the beginning of collisions at LHC in 2009. Several sources of anomalous signals in CMS calorimeters were identified in the analysis of the first collision data in 2009, and these studies continued with 7TeV data taking. Anomalous signals were identified in the electromagnetic calorimeter barrel (EB) and hadron calorimeter barrel (HB), end-cap (HE), and forward (HF) sections.

The basic strategy for the identification and removal of anomalous signals in EB and HF is based on unphysical charge sharing between neighbouring channels in space and/or depth, as well as timing/pulse shape information. Once a "hit" in an HF tower or EB crystal is determined to be unphysical, it is excluded from the reconstruction of higher level objects like jets or MET, thus arriving at a reconstruction of jets and MET that are consistently "cleaned" of anomalous detector effects. A.Apresyan has played a leading role in the development and commissioning of these algorithms, and these algorithms are currently used in the default event reconstruction by CMS. As a result of these cleanings, the default MET reconstruction within CMS framework shows a very good agreement with MC simulation (which does not include anomalous energies), as can be seen in Fig. 1.

In HB and HE, electronics noise from the Hybrid Photo Diode (HPD) and Readout BoX (RBX) is rarely observed, and can affect from one up to all 72 channels in an RBX. Y.Chen, A.Apresyan and M.Spiropulu have developed a set of algorithms to identify and remove the HBHE noise rechits from event reconstruction [5]. These algorithms are based on discriminating the noise from expected signal pulse shape in HCAL, comparing the χ^2 fit from ideal pulse shape to both hypothesis using a log-likelihood ratio. The LHC

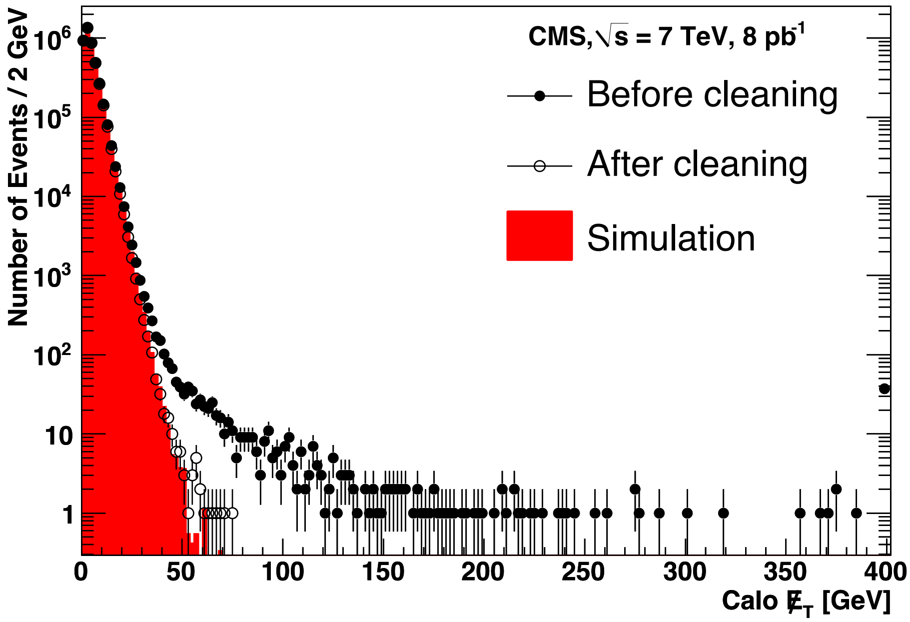

FIGURE 1. MET distributions in a minimum bias data sample without (black dots) and with (open circles) removal of anomalous energies, compared to Monte Carlo simulation.

has recently changed from 150ns bunch-spacing (used in 2010) to 50ns, and since the energy reconstruction in HBHE integrates over 100ns, there is non-negligible effect on the signal pulse-shape from the signals from early and late (compared to the triggered) bunch-crossings. As can be seen in Yi's section of this report, these algorithms perform very well even in 50ns bunch-spacing, and will soon be enabled in the default reconstruction. Together with the anomalous noise cleaning in EB and HF, the removal of anomalous noise in HBHE results in a dramatically improved reconstruction of jets and MET, and the Caltech team has played a leading role in all aspects of the studies leading to this results. Additionally, many of these algorithms are now being implemented at the CMS high level trigger (HLT), in order to reduce the rates of MET and jet triggers that are contaminated by noise (Alex's section). This effort is led by members of the Caltech team (M.Spiropulu, A.Mott, Y.Chen, A.Apresyan) [4].

In order to identify any remaining sources of residual noise in CMS that can affect the MET reconstruction, a "MET scanners" team was formed within the MET working group. Apresyan is one of the leaders of this group, which is charged to monitor the tails of MET distributions using different MET algorithms available in CMS (CaloMET, tcMET, pfMET). These studies provide fast feedback on commissioning any new noise cleaning algorithm or changes of the existing ones.

A.Apresyan played a leading role in the characterization of the performance of MET reconstruction in CMS. Using data collected by CMS up to fall 2010 (corresponding to up to $0.5pb^{-1}$ of integrated luminosity), Apresyan lead the studies of MET reconstruction using photon+jets and Z/W+jets events. These studies focused on first measurements of the MET scale and resolution, studies of degradation to MET resolution due to "pileup", and performance studies. These studies resulted in the first CMS public note on MET performance in $\sqrt{s} = 7$TeV data in events containing an identified vector boson, W or γ [1], and A.Apresyan was one of the two editors of this note. The studies performed in [1] were continued and expanded with the full data sample collected in 2010 ($36pb^{-1}$), and we are currently in the final stages of collaboration-wide review of the paper to be submitted for publication in JINST [2].

One of the critical aspects of any successful analysis program is to ensure that the data-sample used in the analysis (e.g. search for SUSY signatures) does not contain events where a critical sub-detector is not fully functional, or experiences problems. Data taken in periods where e.g. a hot channel is present in HCAL, or HCAL contains channels that have operational problems could affect the searches in MET+jets final states, causing a bias in Jets and MET distributions. A.Apresyan is leading the HCAL "Monitoring and Data Certification" group. One of the tasks of this group is to perform weekly "certification" of data collected in the previous week, identifying the list of runs free from HCAL detector problems. This is list is then combined with the similar one from other subdetectors, and all CMS physics analysis only use runs present in this list. The certification is done using the HCAL DQM (Data Quality Monitoring), and A.Apresyan is the main developer of this framework. A.Apresyan is currently leading the effort to migrate the semi-manual certification procedure that is currently used in HCAL (experts run a set of scripts and look at the output) to an automated, central work-flow. The certification will then be done automatically by performing the quality checks in every 23sec fragment of CMS data (by-"lumisection"), and all the essential tasks for data certification (number of dead or hot channels, data corruption, trigger primitive quality, etc...) are performed for each lumisection. Apresyan has developed an additional quality check for HCAL data quality, where the database values for HCAL detector conditions (e.g. bias and high voltages) are read from a central database to spot any deviations from nominal values, per lumisection. Together with the DQM output these checks allow one to check for a very wide range of failures in an automatic fashion. The migration to automated framework is progressing very well, and we expect that in May-June HCAL will fully switch to automated framework by default. This will not only make the certification results less (human)error-prone, but also allow to sustain the high level of data quality monitoring with a reduced amount of dedicated experts.

An important aspect of HCAL monitoring is to ensure that when an error occurs, the shift crew immediately notices the problem and notifies the experts who can fix it. It was noticed in 2010 runs that occasionally a full RBX in HCAL (72 channels) will lose the data link, resulting in all data from those channels being lost. This would later cause that section

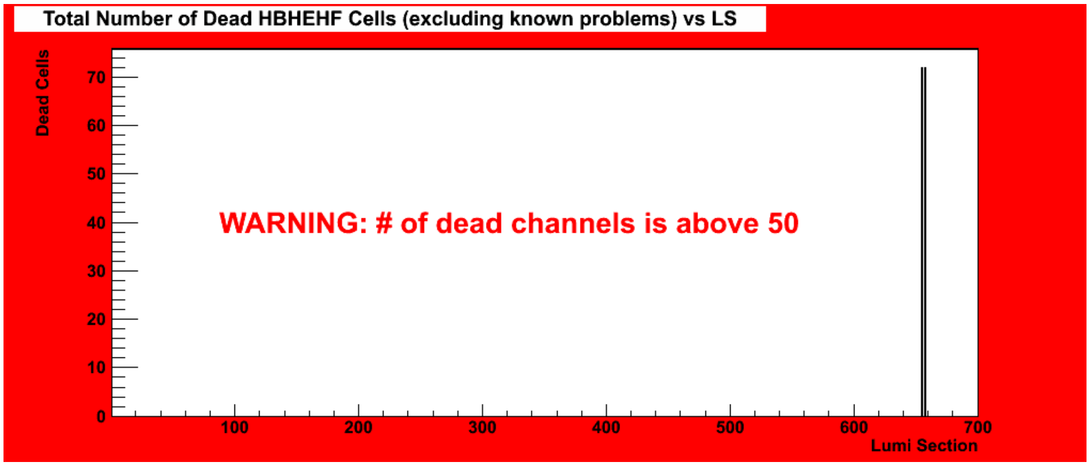

FIGURE 2. Distribution of dead cells in HCAL as function of lumisections. To ensure that the DQM shifters immediately notice the RBX data loss, the histogram changes the background color and displays a warning message.

of data be declared bad for analysis (i.e. excluded from the good run list described in the previous paragraph). Apresyan developed an improved notification system for monitoring this type of problems, as shown in Fig. 2, which resulted in a much faster response time from P5 shifters: on average less than 5 minutes, instead of the previous 0.5-2.0 hours. An audio alarm system is also being commissioned in CMS control room, to ensure fast response to this and other types of problem that require an immediate action by the detector experts.

Yet another area of monitoring the HCAL performance is the monitoring of anomalous HCAL noise, and the monitoring of the rates of anomalous noise. This is covered in Yi's section on HCAL noise DQM, which once it goes online (after May 9) will also provide invaluable feedback to HCAL certification team.

In addition to monitoring the performance of HCAL detector from operational point of view, it is critical to continuously monitor the jets and MET reconstruction. A.Apresyan was appointed a co-convener of the JetMET data monitoring and validation group since the beginning of 2011. While jets and MET reconstruction are being monitored in the DQM similar to HCAL and other subsystems, the data certification has been largely a manual effort, which as a result is very time consuming. Apresyan is now leading the effort to move JetMET certification to an automated procedure. In addition to monitoring the data quality, Apresyan is also leading the group responsible for monitoring software changes (e.g. new calibration constants in HCAL, new jet energy corrections, changes in reconstruction algorithms, etc. . .) and their effects on jets and MET reconstruction. Every new CMS software version (including development versions, that are produced once a week) is checked for consistency with expectations. These checks have been until recently done by a group of experts within the JetMET monitoring and validation team, and need them to submit jobs to GRID and analyze the output manually. Apresyan is now leading

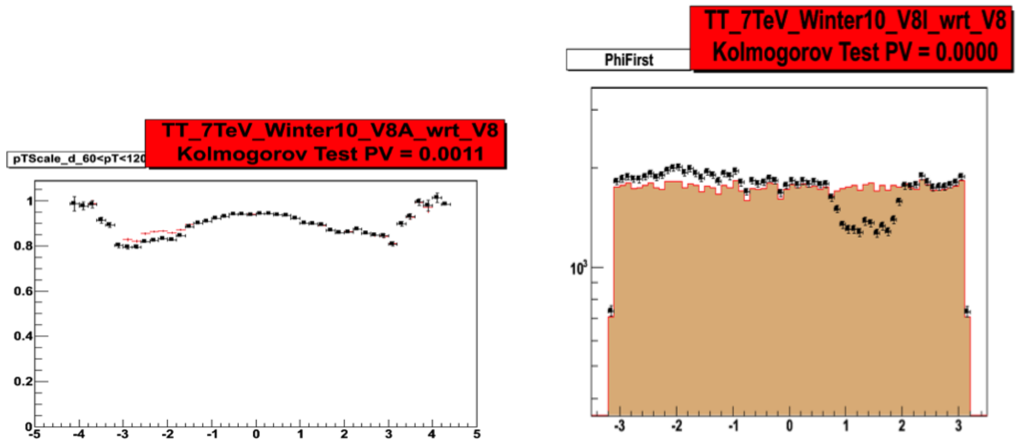

FIGURE 3. The effects of ECAL and HCAL failure scenarios on jets and MET reconstruction. (Left) the distribution of the jet response as a function of η, black histogram is for the scenario when on ECAL FED in EE is lost, and the red histogram is the normal configuration. (Right) the distribution of the jet η, black histogram is for the scenario when an HCAL RBX in HB is lost, and the red histogram is the normal configuration.

the effort to migrate the release validation task to an automated procedure, still within the DQM infrastructure. This automated work-flow will allow the code developers to get faster feedback on their proposed changes, without having to wait for the results of manual certification.

It occasionally happens that some part of the CMS detector experiences a problem, resulting in a loss of e.g. a single channel in ECAL or HCAL. In order to ease the certification procedure in judging the importance of a detector failure mode on the physics analysis, Apresyan performed a study of the effects of several scenarios on the jets and MET reconstruction. Apresyan considered twelve different scenarios, ranging from a single channel in ECAL or HCAL, and up to losing a full ECAL quadrant or and HPD/RBX in HCAL. All the effects on jets and MET reconstruction, jets and MET response and resolution were studied and quantified. Some examples can be seen in Fig 3. These studies now allow the detector operation teams in deciding on how to act when these problems occur during data-taking (e.g. if it is non-noticeable problem, they may choose to keep collecting data until the LHC fill is dumped). Additionally, these studies allow the data certification teams from ECAL and HCAL on deciding whether or not to consider the runs good or bad for physics. For example, it was shown that the effect of having a single (or even up to 18 in HCAL) missing channels has no noticeable effect on jets and MET response or resolution, and no effect on $H \to WW$ signal acceptance.

In 2011 running the LHC accelerator is running with 50ns bunch-spacing, as opposed to 150ns spacing used last year. Since the calorimeters use several 25ns time samples to integrate the energy deposits, the 50ns running poses a complication of the contamination from "out-of-time pileup" (OOT PU), where the energy from the next or previous bunch-crossing contaminates the energy reconstruction in the triggered bunch-crossing. Several scenarios are being considered to reduce the effect on HCAL energy reconstruction, one of which is to reduce the energy reconstruction window to use only 50ns (in which case HCAL will be insensitive to OOT PU) and use a parameterized function to correct for the energy leakage out of the 2 time slices. It is known that approximately 90% of energy is contained in the first two time slices. Apresyan is leading the effort on developing and commissioning these correction functions in default CMS reconstruction.

Apresyan has served as a member of the analysis review committee ARC on the SUSY search in events with a lepton, photon and MET, which is going through its final collaboration wide review as of mid-April and is planned to be submitted to JHEP. It is the first search in this final state in LHC, and finding no evidence for SUSY, an upper limit on SUSY particle masses were placed.

Having an extensive knowledge and understanding of the calorimeters and jets and MET reconstruction, Apresyan is implementing these knowledge in the physics analysis level. Apresyan, Y.Chen and M.Spriropulu continue the program of searches of physics beyond standard model in hadronic final states, using the MET + b-jets final state for a search of a 3-rd generation Leptoquarks (LQ). This would be the first search for 3-rd generation LQ in CMS. The analysis is progressing well, and we plan to have the first results on this analysis in time for summer conferences. The current plan is to expand this search into other searches including searches for Higgs boson and SUSY.

References

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