The Liquid Argon Calorimeters Online Monitoring

Draft 1.5

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The monitoring of the Liquid Argon Calorimeters will be done in different places. This document updates the document of the DSP-monitoring (Ref [1]) including a more general monitoring and describing the information to be monitored, the place, the time when is to be monitored, the data size and the estimated frequency.

Four different places are foreseen so far:

- At the receivers
- At the ROD level
- At the ROS level
- At Level 2, Event Filter or Stream0 within Athena

This document will be revisited after the experience in the testbeams of 2004 and also after the experience in the FE and BE crate tests.

1 At the receivers

The receiver/monitor system of the LAr calorimeters is the only place where analog signals from individual trigger towers of the calorimeter can be monitored. Up to 16 individual channels from each crate can be monitored simultaneously. Including the tile calorimeter, the total number of channels that can be simultaneously monitored amounts to 128.

The selection of channels to monitor from each crate is determined by USB commands received by the control board in each receiver crate. These commands arrive either from a dedicated VME processor located in the monitoring crate or from a laptop connected to this controller via a USB interface. These control signals can be sent to the system during regular data taking and no interference is caused by this monitoring to the L1 trigger operations and data taking.

Originally there were no plans to digitize the signals from the channels being monitored for remote use. The only monitoring foreseen in the past was with an oscilloscope connected to a few channels. This would require a physicist working for some extended period of time down in the cavern.

Concerns about possible radiation environment in the USA15 cavern introduced the need to multiplex, digitize and make use of remote monitoring of individual channels of the calorimeter. The system is being designed to allow for such remote operations. This system, consisting of some multiplexers and ADC(s) will be a part of the existing Receiver/monitor system. Physical space for this system has been already allocated.

The ability to monitor calorimeter signals from individual trigger towers on a workstation dedicated to monitoring would be a valuable asset and of great help for calorimeter experts.

It is not foreseen to add this monitoring information to the data stream and to make automated decisions for resetting the FEBs and/or receiver crates when abnormalities are observed. In principle, this system should allow to cycle over some predetermined set of channels, collect information about digitized waveforms, do some statistical analysis and prepare some histograms and scatter plots for calorimeter experts. This information would be available on a dedicated workstation. Archiving monitoring results in some database for later use should also be possible.

The workstation will communicate with the receiver VME processor using TCP/IP. This VME processor will send control signals to the receiver crates via USB interface.

Notice that the identification of suspicious channels using this system alone would take too long because of the degree of multiplexing involved in cycling over all calorimeter channels. This multiplexing is being done on the receiver boards, in crate controller boards and in the monitoring crate before digitization.

2 At the ROD level

Different kind of information will be monitored at the ROD level through VME:

- Information available in the SPAC masters and the ROD boards that will end up in the ATLAS DCS (temperatures, etc).
- Information gathered in the ROD boards (DSP histograms and sub-samples of ROD output data).
- Information gathered in the LAr WorkStations in USA15 (histograms involving various ROD crates).

2.1 Information from the SPAC and ROD boards to the ATLAS DCS

A table with the monitoring information, the reason for monitoring, the place where is to be implemented, the period when is to be monitored (commissioning, debugging, calibration or physics phases), the data size for each full ROD board and the frequencies at which the information is sent to the LAr WorkStation and later to DCS follows. The following information is gathered in the ROD or SPAC master boards and monitored for each event. This information is retrieved through VME by the CPU VME and sent to the LAr WorkStation (WS) at a given frequency. The frequency at which the collected information is sent to DCS is also given below.

The information coming from the SPAC would be needed in the commissioning phase and most probably not during physics data taking.

Information	*Reason*	*Place*	*Period*	*Data size*	*Frequency board→WS*	*Frequency WS→DCS*
Glink temperature	Alarm in case T>35°C	ROD MB	All times	32 bits*8	1 min	10 min
Maximum Glink temperature		ROD MB	All times	32 bits*8	1 min	10 min
Minimum Glink temperature	Water cooling monitoring	ROD MB	Commis-sioning	32 bits*8	1 min	10 min
SPAC info		SPAC master	Commis-sioning			

Additionally, other DCS information of the LAr calorimeters is monitored. Here, only the information going through the ATLAS DAQ system to DCS is described. A full description of the LAr DCS system and the information provided can be found in ref [2].

2.2 Information gathered in the ROD boards

Different types of information are filled per event, if applies, and gathered in the ROD boards. At a later stage, they are retrieved through VME at a given frequency to the local LAr WorkStations (WS).

2.2.1 Digital part of the FEB and link to ROD

The following information is gathered in the ROD board, specifically in the PU (DSP or Input FPGA). It is retrieved through VME by the VME CPU at the given frequency and sent to the LAr Workstation (WS) where is monitored and sent to the Data Acquisition (DAQ) system or DCS. Part of this information is already implemented in the firmware.

Information	*Reason*	*Place*	*Period*	*Data size*	*Frequency ROD→WS*	*Frequency WS→DAQ*
# Parity errors	Pin down FEB-ROD link problems	PU (InFPGA)	All times		1 min	10 min
# Format errors		PU (InFPGA)	All times		1 min	10 min
“link-down” rate			All times	32 bits*8	1 min	10 min
“link-down” time			All times	32 bits*8	1 min	10 min
# BCID errors	BCID mismatch with L1 trigger	PU (DSP)	All times		1 min	10 min
Two histograms (one per SCA-controller) per FEB of the SCA cell numbers (0-143).	Find dead cells or wrong cell number	PU (DSP)	All times	Histogram	1 min	10 min
# non-consecutivity of capa-addresses	Pin down FEB problems	PU (InFPGA)	Low trigger rate		1 min	10 min
# desynchronization of the two FEB halfs.		PU (InFPGA)	All times		1 min	10 min

Additionally, it would be worth monitoring the frequency of FEB resets for each FEB and storing this information in the database for future use in efficiency studies, detector simulation and physics analysis.

2.2.2 Signal and timing related tasks (per channel)

a) **Information implemented in the hardware (size per full ROD: 8*128 channels).**

Information only filled per cells with **E > Ethreshold**. The following information is filled per each event in the DSP. It is retrieved by the VME CPU each 10 minutes. It is monitored in the LAr WorkStations and sent to the DAQ each hour. Until now, these histograms are implemented in linear scale.

Information	*Reason*	*Place*	*Period*	*Data size*	*Frequency ROD→WS*	*Frequency WS→DAQ*

Energy cell low gain	Monitoring of energy deposition, time in the peak and chi2 calculations per cell (output of the OF calculation) at each gain	PU (DSP)	All times	Histogram 32 bins of 32 bits	10 min	1 hour
Energy cell medium gain		PU (DSP)	All times	Histogram 32 bins of 32 bits	10 min	1 hour
Energy cell high gain		PU (DSP)	All times	Histogram 32 bins of 32 bits	10 min	1 hour
Energy cell		PU (DSP)	All times	Histogram 128 bins of 32 bits	10 min	1 hour
Reconstructed time cell low gain		PU (DSP)	All times	Histogram 32 bins of 32 bits	10 min	1 hour
Reconstructed time cell medium gain		PU (DSP)	All times	Histogram 32 bins of 32 bits	10 min	1 hour
Reconstructed time cell high gain		PU (DSP)	All times	Histogram 32 bins of 32 bits	10 min	1 hour
Reconstructed time cell		PU (DSP)	All times	Histogram 128 bins of 32 bits	10 min	1 hour
2 (1)		PU (DSP)	All times	Histogram 32 bins of 32 bits	10 min	1 hour

b) Additional information in the “Wish list“ during physics running.

- Histogram of the ADC bit frequency in order to detect bit problems.

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[10] The ^{2} is defined: $^{2} = ((S_i – ped) – Eh_i)^2$ where i runs from 1 to 5, S_i is the ith sample, E is the calculated energy, h_i are the optimal filtering weights and *ped* is the pedestal value.

- Record thresholds of the different gains (cross-check for correct gain selection): minimum and maximum ADC-count for each gain.
- Histogram of the first sample (in time) as a measure of the pedestal (separate for each gain). Random triggers do only populate the high gain histogram!
- Histogram of measured energy for each gain. A log x-axis might be desirable. In order to be able to observe problems close to the pedestal, a special histogram for values around zero might be needed (high gain only).
- Histogram of the ^{2} (how is it defined? Normalization?) for each gain.
- Histogram of the average residual for each sample and gain (5 bins per gain). This allows distortions of the signals with respect to the sample weights determined from the calibration to be seen.
- Specialized Software to optimize the signal timing might be needed during a start-up of the system after a longer shutdown period.
- Histogram of the busy time. It is important to know who sets the busy and how often in order to spot potential noisy cells or problems.
- It would be useful to look at different distributions according to the cables or according to crates in order to spot possible mis-cablings in the installation. Especially for the trigger system as it is most probably not tested with calibration.

2.2.3 Proposed list of monitoring tasks in special runs or triggers

The following tasks should be shared between the DSP and the WS. The actual implemented has not been discussed yet.

Pedestal related tasks

- Pedestal for each channel and each gain.
- Noise for each channel and each gain.[2]
- Coherent noise per FEB and gain calculated from the coherent sum and incoherent sums over the channels of the FEB.
- Fixed sequence noise for each channel and each gain. It measures the spread of the pedestals of the 144 capas in the pipeline. It can spot problems on the pulser.
- Scatter plot of $\sum A_1$ versus $\sum A_i$ (i from 2 to 5). Where A_i is the amplitude in time sample i and the sum is over all channels of a given FEB. These four scatter plot per FEB would allow to see correlations within the five samples(e.g. pickup of certain frequencies).
- Autocorrelation function for each channel and gain.

Calibration related tasks

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[2] For a detailed description of the calculation of noise and pedestal, see refs [3] and [4].

In this part, it is assumed that the DAC, calibration line and delay value are available inside the DSP, in order to be able to do the calibration procedure in the event stream if needed.

- Delay run (per FEB and gain): signal as function of the time for pulsed channels in order to monitor the continuity of the delay chip in time and that the calibration board is actually pulsing. Possibly for individual calibration lines.
- Ramp run (per FEB and gain): peak sample (ADC-pedestal) as function of the DAC value for the pulsed channels, possibly subdivided by calibration line. This allows the correct functioning of the pulsers to be monitored and to pin down problems in the calibration lines.

Ramp fitting

A priori, the ramp fitting will not be done in the DSP but either in the VME CPU or in the local WorkStations.

- Residuals of fit per channel.
- Histogram of the linear and quadratic term per channel.

2.3 Information gathered in the LAr WorkStations

A list of histograms and counters will be monitored in the LAr WorkStations installed in USA15. There will be one WorkStation per partition. Each WorkStation will gather all the information from several ROD crates, depending on the partition:

Partition name	# ROD crates	# ROD boards
EMB A	4	14 * 4
EMB C	4	14 * 4
EMEC A	3	13*2 + 9
EMEC C	3	13*2 + 9
FCAL	1	4
HEC	1	6

Randomly, the output of the ROD board is stored in the SDRAMs of the ROD board. This information is only accessible through VME. Depending on the running conditions, the output of the ROD will include only the Energy cell or the samples as well.

A list of information to be monitored is included in the following table (the data size is for a full ROD board):

Information	*Reason*	*Origin of information*	*Period*	*Data size*
# S-link errors	Spot ROD-TM problems	ROD MB	All times	32 bits*4
Energy per cell	Spot noisy and dead cells	PU histos and raw data	All times	Histogram
Cell activity over time			All times	Histogram
vs plot of cell activity integrated over time (for different energy thresholds)			All times	Histogram
Noise and baseline value of those non detector connected channels over time (in ADC counts if possible)	Spot baseline shifts and noise conditions changes (specially if the SPAC is not working during physics)		Commissioning	Histogram
Pedestal drift over time for randomly triggered events	Spot potential problems of noise		All times	Histogram
Reconstructed time per cell over time	Spot potential problems in the TTC system	PU histos	All times	Histogram
Number of events per gain	Spot potential problems in gain selection	From the number of entries of the DSP histograms	All times	32 bits * 3 * 128 * 8
Data quality flag	Spot any problem		Physics	32 bits

It would be worth monitoring some of these quantities per receiver board, as for example the occupancy in order to spot any malfunctioning.

For the randomly monitored events that include the samples, one should foresee to redo the optimal filtering algorithm and compare the result to the DSP output. If possible, one should also extract the timing information.

An automatic expert system which analyses the actual histograms, compares them with histograms of previous runs (so-called reference histograms), spots potential problems and writes the Data quality flag more or less every hour to the ATLAS database system should be foreseen. The noise conditions should also be extracted and stored in the database.

3 At the ROS level

At the level of the ROS, the functions of the ROD itself should be monitored, i.e. the number of errors that have occurred, the dead times, the busy links, etc. The advantage is the decoupling to the rest of the DAQ and the possibility to do monitoring in a point physically connected to the RODs and before data is sent out on the network. This is needed at least during the commissioning phase.

4 Athena-based Monitoring

In the data stream after the RODs, the full precision, digitally filtered readout becomes available at Level 2 and beyond. This readout can be accessed by Athena tasks which can examine the quality of part or all of the calorimeter. Although some information available in the RODs is not generally available at this new layer, many of the examinations described for ROD monitoring can be performed in Athena processes. The advantage is that resources are considerably less limited than in the RODs. The availability of this readout means also that reconstruction algorithms can be applied to the data which anticipate the behavior of physics objects in a final offline physics analysis. Our goals will be to provide functioning, extensible LAr monitoring which can perform useful Athena-based monitoring at the beginning of cosmic running, and be improved over time to contribute to monitoring during first collisions. We also intend to learn lessons already gleaned from test beam and what cosmic running has to teach us for developing ideas for the most useful monitoring during first collisions. Our direction is to prepare the way for hardware and physics monitoring during first collisions. We discuss in this section first the places in the DAQ and trigger systems where such monitoring may be appropriate, a sketch of the tiers of monitoring anticipated for cosmics and normal running, and some specifics of what we will monitor.

Monitoring Levels

At Level 2, the full readout is available in regions of interest and basic algorithms are available which find basic physics objects. One parameter which is available is a 32-bit status word which checks data chain integrity. While the potential for useful plots definitely exists at Level 2, the processing budget is limited. Studies which would indicate the impact of various monitoring loads on functioning of the trigger have not been done, so for now we will consider monitoring in Level 2 only if it is necessary.

It is also envisioned to have a streamed data sample which undergoes a first pass of the event reconstruction. Such a pipeline, which would run approximately 24 hours after the data is taken, would provide the first sample in which energy scales, resolutions and efficiencies directly relevant to physics analyses could be estimated. The first pass reconstruction, while having no major CPU limitations, comes too late for effective turn-around of observed problems. However, it will be invaluable for the first look at the ability to make physics measurements with ATLAS data. As such, we will consider this stream as the final stage in our monitoring strategy.

The Event Filter permits analysis of the whole event at full precision. More advanced algorithms to find physics objects are run, and event-wide variables such as Etmiss and total Scalar Et. A system employing histogram generating processes in multiple Event filter nodes has been created and used in the 2004 test beam. This scheme causes similar histograms to be summed by a ‘Gatherer’ process which then transmits them to a presentation task. This scheme permits a wide range of the monitoring tasks which we require, and will be the default method that will be pursued to most Athena-based monitoring for now.

Monitoring Tiers

To best accomplish our goals of monitoring the performance of the calorimeter, while also providing detailed information useful for locating potential problems, we will employ two tiers of monitoring. The first consists of those plots and numbers which are used at all times by a shifter to verify proper function in normal operating conditions. Here, we will keep things simple and employ very few plots to provide a concise estimation of detector performance and will be sensitive to many basic problems. It may be necessary or desirable to monitor more than this, but not to present it to shifters except when an error condition is satisfied. Even if we display a large number of histograms in the beginning of the cosmic or collider run, eventually there will be a desire to shorten the list of plots a shifter must view. To accommodate this, we will begin early to define reference histograms for many of our plots such that it is possible to compare these histograms to those observed at any moment in data-taking. Ultimately, one can envision an alerting mechanism based on this comparison which only displays these plots when there is a problem. However, it will take some time before the appropriate thresholds for such alerts is understood.

While the shifter plots may provide an indication of many problems, they will not completely characterize the calorimeter detector and electronics performance, and they will likely fal short of being able to conclusively identify the source of many types of problems. The performance characterization is important to identify subtle problems, or non-optimal performance of particular components. It is also crucial when more basic monitoring identifies a problem but is not sufficiently incisive to isolate the cause. The list of potential quantities to plot or examine will eventually be quite long. It will be important to look at individual channels, or groups of channels. We will want to journal or record the time history of important hardware parameters. We will also want some ability to script or configure what is examined at run-time.

Hardware Monitoring

There are two broad tasks to address: hardware monitoring, and physics monitoring. The former should be able to serve the purposes of commissioning the detector and electronics and maintaining their proper performance. This effort should compliment the similarly directed efforts described in previous sections. Hardware failures could occur at one of several levels, including preamps, FEB boards, RODs, and trigger electronics. Performing cross-correlations of different detector regions can identify subtle problems which may not be obvious from ROD monitoring. Also, considering some parameters, such as the locations of high energy cells, may provide most useful information if taken for certain kinds of triggers, for example an Etmiss trigger.

It will be important to thoroughly characterize the noise of the LAr calorimeter. Quantification of means, RMS’s and stability for all channels will be important. By quantification we mean these properties are calculated regularly, databased, and analyzed for hardware problems. A schedule of regular pedestal runs to implement these will be maintained, but this monitoring should also be part of normal data-taking.

Calibration of cells and monitoring of related quantities will also be an important element of monitoring. Both pulser runs and the study of muon MIP traces in the calorimeter during cosmic running can comment on the calibration.

At shifter level, some plots which would be relevant to understanding the detector at the hardware level would be:

- Cell Et for EM and HAD (perhaps by detector)
- Readout chain status

However, many more studies will be useful at least for experts:

- Noise calibration among similar cells
- Statistical measures of noise correlations across detector elements
- # cells above some thresholds
- cell energy distributions integrated over detector regions

A further list of histograms might include:

A list of histograms follows:

- Total E_T distribution (vectorial)
- Total E_T distribution (scalar)
- Total hadronic E_T
- Total electromagnetic E_T
- E_T per event as function of for all
- E_T per event as function of for all only hadronic
- E_T per event as function of for all only electromagnetic
- Hit rate as function of for all
- Hit rate as function of for all only hadronic
- Hit rate as function of for all only electromagnetic
- Hit rates as above, but for a certain E_T threshold (5GeV ?)
- E_T and hit rates as above, but for individual longitudinal segments

List of Lego plots:

- E_T per event as function of and
- E_T per event as function of and only hadronic
- E_T per event as function of and only electromagnetic
- Hit rate as function of and
- Hit rate as function of and only hadronic
- Hit rate as function of and only electromagnetic
- Hit rates as above, but for a certain E_T threshold as function of and
- E_T and hit rates as above, but for individual longitudinal segments as function of and .

Level 1 Trigger Monitoring

Calorimeter signals which reach the FEB boards are sent down to independent readout paths. One is the Level 1 trigger readout where signals are summed and sent to trigger electronics where they are digitized. The other comprises the full readout of the calorimeter. An important issue in the area of monitoring is the crosscheck between the standard read-out of the calorimeter and the trigger towers. Of interest is the comparison of the trigger tower energy compared to the sum of the signals in the involved cells. This helps to check the calibration of the trigger towers and find problems for example in the timing between trigger and read-out. Additional monitoring allows to pin down faults in the trigger read-out chain, or hot cells, which are causing high trigger rates. Additionally, it would be worth detecting a malfunctioning of the TTC clock.

Many problems in the electronics operating after this split can be diagnosed by comparing trigger and full readout consistency. For instance, SCA failures will affect full readout, but not the trigger. Failure of summing electronics will affect the trigger only.

Comparison of these readouts across a whole event can provide information about coherent noise. (did you check it is possible to do it event by event with Vladimir?) Here I guess, more detailed things will be needed in the future. Do you know the status of this implementation? Where will the comparison take place? Coherent noise studies across detector components can be facilitated by checking the consistency of the trigger and full readouts.

The list of histograms is very much like the one above, but for trigger towers instead of the actual cells. The same applies to the Lego plots.

- L1Cal – full readout for all towers
- L1Cal/full readout for all towers with significant energy
- Difference and ratio readout comparisons for similar channels

Additional monitoring histograms would be:

- Ratio of Level-1 trigger tower energy and the sum of the corresponding cells
- Rate for each trigger tower actually causing a calorimeter trigger (probably not easy to get)

Physics Monitoring

Another job of online monitoring, and one uniquely addressed by Athena-based monitoring, concerns the measurement and tracking of the properties of physics objects in the incoming data. Prompt physics validation will be extremely important. It will be important to examine raw kinematic distributions [pt, eta, phi] of jets, electrons, topo clusters and Etmiss. As such, algorithms which find these objects will need to be in place. We will want to look at the time-dependence of these distributions. The goal is to make first measurements of these objects to ensure that the distributions are a) physical and b) don't change with time. In particular, consideration of possible failure modes which would limit searches indicates that relationships among objects (eg. Electron eta-phi after Etmiss selection) can better isolate the problem. Looking at higher-level quantities like raw energy scales, resolutions and tails to these distributions can also provide valuable input on the performance of the detector as it directly impacts analyses.

- Scalar Et, Etmiss, Etmiss phi
- Jet, egamma #, Pt, eta , phi\
- Eta vs. phi for physics objects
- Object distributions with >= 1 Etmiss thresholds
- Object scale, resolution, efficiency, tails
- At Calorimeter energy response to electrons as function of .
- Calorimeter energy response to electrons as function of .
- Z-mass as function of .
- Z-mass as function of .

- For a Z-mass window, multiplicity of Z as function of .
- For a Z-mass window, multiplicity of Z as function of .

5 Some additional remarks

- All histograms should have over- and underflow bins.
- The binning of histograms will depend strongly on the actual distribution (flat or exponential) and should be chosen accordingly.
- For some histograms (especially some energy distributions) it might be desirable to have a logarithmic x-axis.
- The question of how to handle the saturation of counters/histograms has to be addressed.
- In order to pin down problems, the possibility to set the range of histograms and thresholds via software, without changing the actual run conditions would be desirable.
- In order to be able to pin down problems, the possibility should be foreseen to send signal samples via the VME-bus to some *offline monitoring*, which would allow a more detailed analysis. This action should be triggered by thresholds on quality criteria like the ^{2} of the signal fit or the energy.
- After the commissioning phase of the ROD system, some of the histograms could be replaced by the calculation of moments of the distribution (e.g. mean, rms, skewness and kurtosis).

6 References

[1] J.Beck-Hansen et al, “Report of the DSP-Monitoring Task Force”.

[2] ATLAS LAr DCS Steering Group, “**ATLAS LAr DCS**”, http://atlas.web.cern.ch/Atlas/GROUPS/LIQARGON/Electronics/Monitoring/largdcs.pdf

[3] Robert Zitoun, "**Study of noise in the November 1998 barrel run**", ATL-Larg-99-006.

[4] Remi Lafaye, "**EMTB user guide**", http://atlas.web.cern.ch/Atlas/GROUPS/LIQARGON/EM_Calo/TestBeam/www_emtb/manual-1-9.ps