Data Quality Monitoring Display for ATLAS experiment

Y Ilchenko[1], C Cuenca Almenar[2], A Corso-Radu[2], H Hadavand[1], S Kolos[2], K Slagle[2], A Taffard[2]

[1] Southern Methodist University, Dept. of Physics, Dallas, TX 75205, USA

[2] University of California, Dept. of Physics, Irvine, CA 92697, USA

Abstract. The start of collisions at the LHC brings a new era of particle physics and much improved potential to observe signatures of new physics. Some of these may be evident already from the very beginning of collisions. It's essential at this point in the experiment to be prepared to quickly and efficiently determine the quality of the incoming data. Easy visualization of data for the shift crew and experts is one of the key factors in the data quality assessment process. This paper describes the design and implementation of the Data Quality Monitoring Display and discusses experience from its usage and performance during ATLAS commissioning with cosmic ray and single beam data.

1. Introduction

ATLAS is a particle physics experiment at the Large Hadron Collider (LHC) at CERN. The LHC will produce proton-proton head-on collisions with center-of-mass energy of 14 TeV at a rate of 40 MHz. The detector is composed of more than 140 million electronic channels. Data Quality Monitoring is an important and integral part of the data taking process in High Energy Physics experiments. It is performed throughout the data acquisition (DAQ), the offline processing of real data in two computing tiers, and during production of Monte Carlo data. Assessment of the quality of incoming data will be made during continuous monitoring and will be archived for retrieval at the physics analysis stage.

Due to the complexity of the ATLAS experiment, a framework for automatic data quality assessments of incoming data and a visualization tool for easy identification of problems are essential. A highly scalable distributed Data Quality monitoring framework (DQMF) has been developed and is being used to monitor the quality of the data as well as operational conditions of hardware and software elements of the detector, trigger, and data acquisition systems. It is provided to avoid taking faulty data in the online environment, reject bad runs before offline processing, and categorize good runs for the various physics groups. The monitoring algorithm identifies problems automatically as they occur and alarms the shift crew. The framework allows to check and archive the quality of the data as well as to re-assess it at a later stage.

The shift crew interacts with the data quality monitoring framework and other online services via the Data Quality Monitoring Display (DQMD), which serves as the platform to debug problems and perform the data quality assessment. The Display enables quick and efficient resolution of problems. It enables the shift crew to assess the data quality assessment by displaying the data quality status flags,

the monitored histograms, etc. It provides to the expert the debugging tools to efficiently resolve the issue and recover the system either online or offline.

2. Data Quality Monitoring Framework

The DQMF executes specific analysis algorithms on various types of data (e.g. histograms, messages, etc) and produces color coded Results relaying the quality of data according to a particular configuration specified by the user. A summary of these results is displayed to the shifter and is also archived for future retrieval. The ATLAS data quality monitoring system, provided as part of the ATLAS trigger and data acquisition [1] software infrastructure, is depicted in Fig. 1. Incoming data from the detector in form of histograms is being processed by DQMF and the assessment made about its quality is being published to the online Information Service that stores the data quality results. Those results are being used by Data Quality Monitoring Display for visualization.
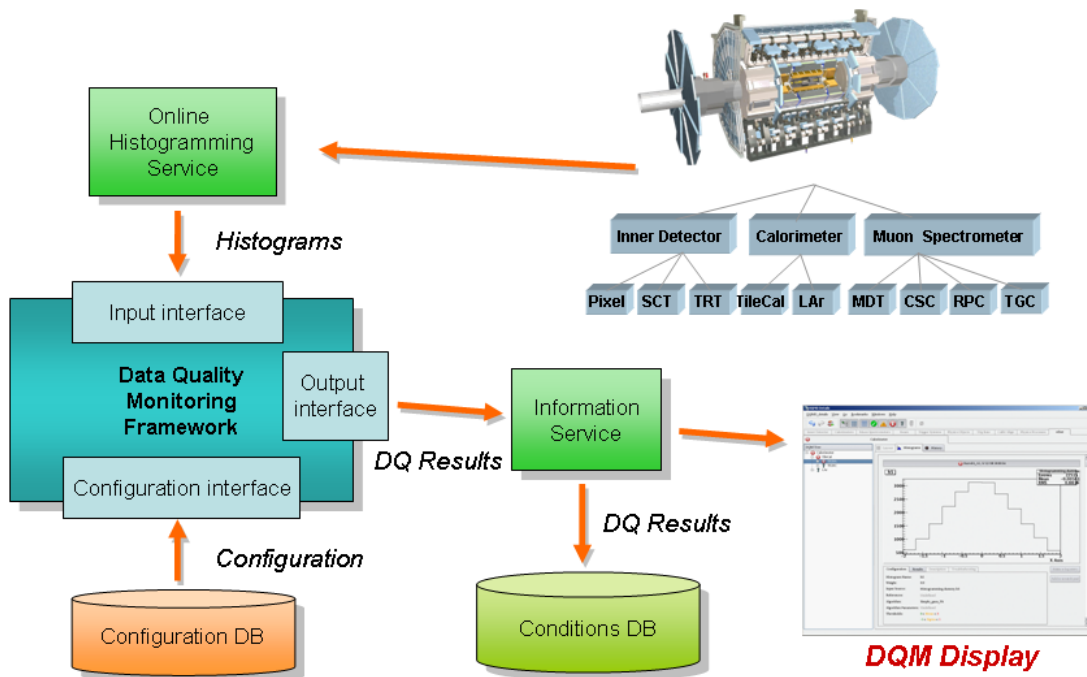

Figure 1. DQMF online regime.

The central part of the DQMF consists of the following core components as described in [2] – Parameter, Region, Algorithm, Result. Parameter object represents the element of the DAQ system (it could be single physical element of the detector or a set of such elements) whose state can be assessed using single monitoring data (i.e. histogram). Parameter applies predefined algorithm to that data in order to obtain the assessment which will come in the form of a Result. Region object represents a certain subset of the DAQ system elements and contains a set of Parameters or low-level Regions, which correspond to these elements. Algorithm is responsible for producing the Result object being applied to the monitoring data in order to evaluate a status of the corresponding DAQ system elements. Result objects represent the status of DAQ system elements, and contain color code value (Red, Yellow, Green or Grey) that shows the state of elements.

3. Data Quality Monitoring Display

The display must assist efficient recording and processing of good quality data. A software prototype was initially implemented in Java using JAIDA package [3] to display histograms. Good functionality was obtained and used from 2007-2008. However, performance was not scalable, which led to a reimplementation of the display using a QTROOT library [4]. The strengths of this implementation are that performance is scalable, and we have complete functionality of ROOT histograms readily available for an interactive display.

It allows easy navigation between Regions and Parameters providing great flexibility for visualization of Results produced by DQMF. For any particular data acquisition configuration, all the available Regions and Parameters are organized into a tree where Parameter leaves are colored in corresponding Result status colors made by custom Algorithms applied to them. Region status color is inferred from the Results of underlying Parameters taken with some weight coefficients defined in configuration that determine importance of those Parameters for that Region. Each Region being defined to represent a particular set of Parameters and/or Regions stands in the tree as a branch node with a summary Result status for that set. For any Parameter, DQMD displays histograms used for the check (overlaid by corresponding reference histograms if applicable), configuration parameters of the Algorithms used to run the DQMF Algorithm, history graph of the data quality results. The Display also supports visualization of the Results in graphical form, i.e. a hardware view of the detector to easily detect faulty channels or modules by eye. The graphical representation of the detector and its subsystems allows for navigation functionality. The display provides the shift crew with a checklist before the final assessment of the data is saved to the database, a list of experts to contact in case of specific problems, and actions to perform in case of failure.

4. The Display Graphical User Interface

The DQMD graphic user interface consists of two windows – Summary and Detailed panels – which implement its functionality. The Summary panel is used to show the overall status of current Run and detector sub-systems while Detailed Panel allows shifter to see all necessary details of data quality assessment. The Display is also provided with a supplementary tool – Data Quality Display Configurator – that greatly simplifies development of graphical configurations.

4.1. Summary panel

The Summary panel (Fig. 2) shows Run Control conditions such as the name of the partition being used, Run number, event number, etc. It provides overall status per sub-system (each sub-system defined as a Region) in the form of buttons painted with the color of corresponding Results. Buttons are collected into sub-detector categories. The Summary panel also contains log information for the current Run. Left clicking on the sub-system button opens the Detailed panel of the corresponding tab with the root element of the tree set to the sub-system Region while Regions of other sub-systems are hidden.
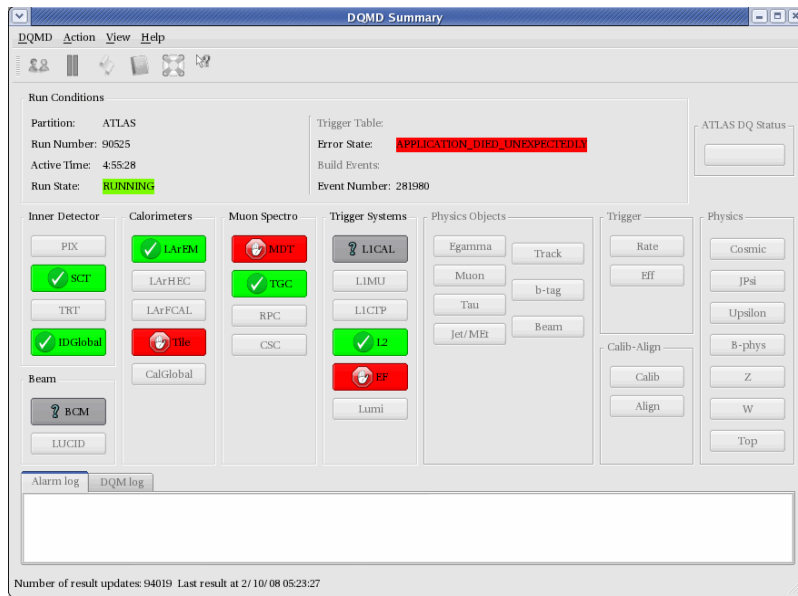
Figure 2. Summary panel widow of the Display with Run Conditions and painted sub-system buttons

4.2. Detailed panel

The Detailed panel organizes underlying sub-system structure in a tree of Regions and Parameters to simplify navigation. It provides essential information related to data quality by means of three tabs. Upon the left mouse click on the Region or Parameter in the tree one can see in the Histogram tab (Fig. 3) monitored and reference histograms, current color status, Result values, Algorithm parameters etc. Buttons on the toolbar allow to hide/show parameters by Result color assigned to them providing greater flexibility in selecting only necessary Parameters to display (e.g. one can select to display only red or red and yellow Parameters etc).
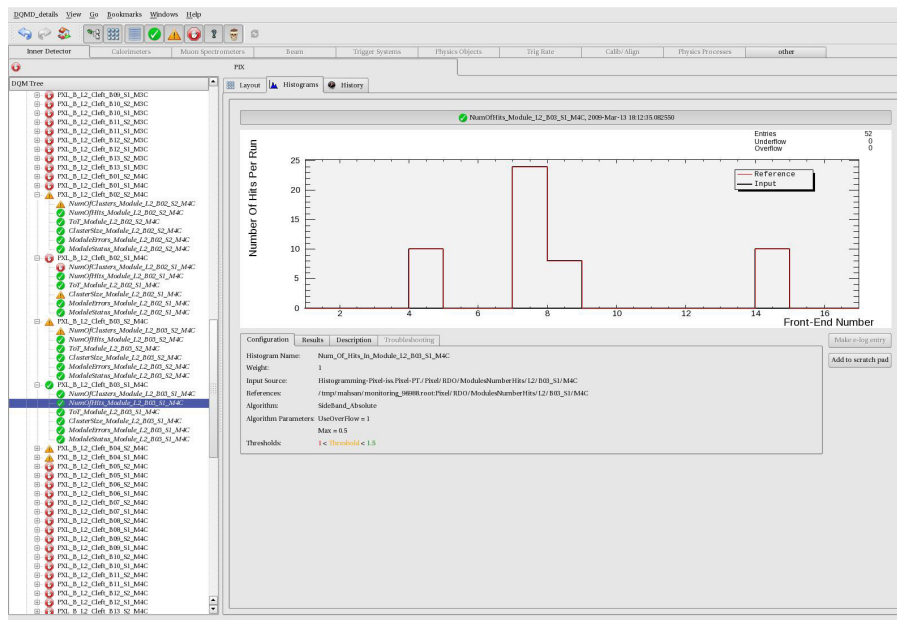

Figure 3. Detailed panel widow with histogram tab open. Tree with Parameters and Regions painted with the corresponding Result color. Parameter histogram with overlaid reference histogram. Active Algorithm configuration tab under histogram.

The history tab (Fig. 4) provides graphs with values of Results and colors plotted versus time so that shifter can navigate back in time to see how Results were changing. Plots are updated automatically upon a new Result is published continuously keeping history graphs up-to-date.
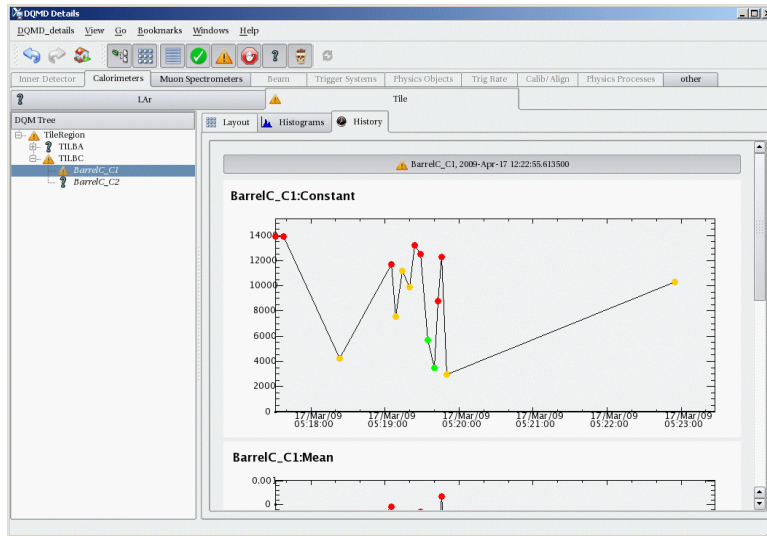

Figure 4. Detailed panel widow with history tab open. Result history plot with color codes at the moment Result has been produced.

To facilitate "at a glance" status summary of detector sub-systems in a more convenient and natural way, the Detailed panel provides a Layout tab (Fig. 5) which allows for a graphical representation with dive in sub-level functionality. One can easily get underlying graphical representation for each element by left clicking on a given element until one reaches the necessary level of granularity. The colors assigned to elements are Result colors of corresponding Parameters. The Display builds graphical representations on the fly using user specified configurations from the configuration database.
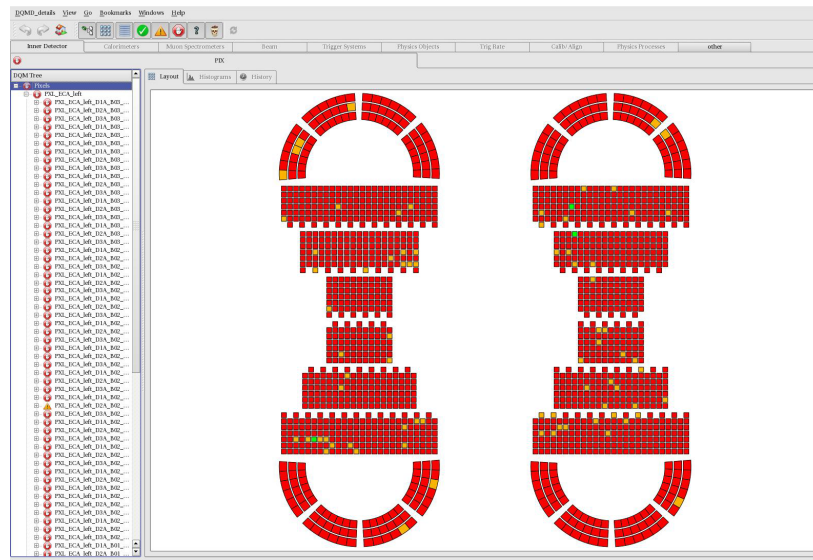

Figure 5. Detailed panel widow with layout tab open. Graphical representation of the detector sub-system.

4.3. Data Quality Display Configurator

The Data Quality Display Configurator (DQMC) (Fig. 6) provided with the Display allows experts to create new configurations or modify the existing configuration database by specifying various layouts and shape parameters of the detector sub-system until it reaches a desired look. Configuration database is written in platform-independent extensible markup language (XML). XML allows storing hierarchically structured data and provides ability to validate it with respect to the schema. Using the set of basic shapes and layouts, experts can easily create advanced graphical representation of any detector sub-system or any part of the sub-system and then save it to the configuration database for future use in the Data Quality Monitoring Display.
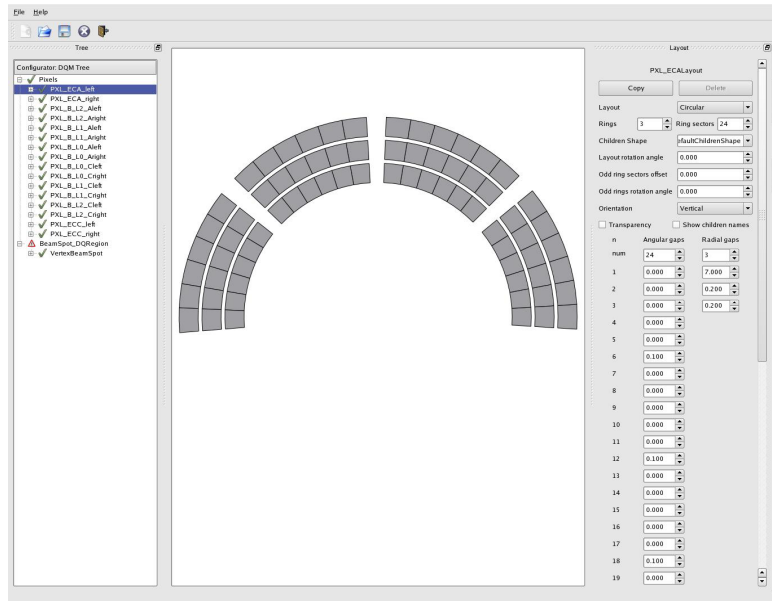

Figure 6. Data Quality Display Configurator. Graphical representation for selected Region with layout panel to modify settings.

5. Results

The DQMD was developed and first used in cosmic-ray running in September 2008. It has been employed since that time in all commissioning exercises using the online trigger and data acquisition systems. It as also relied upon during the single beam running in fall 2008. The standard mode of usage is both by the overall ATLAS Data Quality shifter in the online control room, but also by sub-detectors systems for data quality assessment work.

During the commissioning period 3,173 Regions and 16,945 Parameters were successfully running with the Display. The Data Quality Monitoring Configurator has also been used by different ATLAS detector sub-groups for development of graphical representations of ATLAS sub-systems.

6. Conclusion

The DQMD is a visualization application for the ATLAS automated data quality monitoring assessment. We designed it to work with the Data Quality Monitoring Framework, allowing for both online and offline usage. Several panels present various information about data quality evaluations, including the input histograms, the configuration used, and the results. Navigation is provided from the Results to the inputs, and sophisticated and flexible geographical and time-dependent presentations

of these results are enabled. Performance achieves the needs of the experiment. It has been used extensively online across many subsystems since summer 2008.

References
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