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# The ALICE data acquisition system

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ABSTRACT

In this paper we describe the design, the construction, the commissioning and the operation of the Data Acquisition (DAQ) and Experiment Control Systems (ECS) of the ALICE experiment at the CERN Large Hadron Collider (LHC).

The DAQ and the ECS are the systems used respectively for the acquisition of all physics data and for the overall control of the experiment. They are two computing systems made of hundreds of PCs and data storage units interconnected via two networks. The collection of experimental data from the detectors is performed by several hundreds of high-speed optical links.

We describe in detail the design considerations for these systems handling the extreme data throughput resulting from central lead ions collisions at LHC energy. The implementation of the resulting requirements into hardware (custom optical links and commercial computing equipment), infrastructure (racks, cooling, power distribution, control room), and software led to many innovative solutions which are described together with a presentation of all the major components of the systems, as currently realized. We also report on the performance achieved during the first period of data taking (from 2009 to 2013) often exceeding those specified in the DAQ Technical Design Report.



## 1. Introduction

The main goal of the ALICE [1,2] (A Large Ion Collider Experiment) experiment at the CERN Large Hadron Collider (LHC) is a precise characterization of the Quark-Gluon Plasma (QGP), the state of deconfined matter produced in high-energy heavy-ion collisions. This QGP is, in the standard Big Bang model, the state of matter which existed in the early universe from picoseconds to about 10 microseconds after the Big Bang. A precise determination of its properties would be a major achievement. The study of the QGP is performed by investigating the result of heavy ion collisions at a center-of-mass energy of 5.5 TeV per nucleon pair.

*Acronyms:* ACT, ALICE configuration tool; AMORE, Automatic MOnitoRing Environment; API, application programming interface; BIST, Built-In Self-Test; CASTOR, CERN Advanced STORage manager; CTP, central trigger processor; CVS, concurrent versions system; D-RORC, DAQ Read-Out Receiver Card; DA, Detector Algorithm; DAQ, data acquisition system; DATE, data acquisition and test environment; DB, database; DCS, detector control system; DDD, DCS Dedicated Daemon; DDL, detector data link; DIM, distributed information system; DIU, destination interface unit; DMA, direct memory access; DQM, data quality monitoring; DSS, DAQ services servers; ECS, experiment control system; EDD, ECS dedicated daemon; EDM, event destination manager; FEE, front-end electronics; FERO, front-end and read-out; GDC, global data collector; GUI, graphical user interface; H-RORC, HLT Read-Out Receiver Card; HI, human interface; HLT, high level trigger; HOMER, HLT Online Monitoring Environment; HW, hardware; LDC, local data collector; LHC, Large Hadron Collider; LTU, local trigger unit; NTP, network time protocol; NVRAM, non-volatile random access memory; PDS, permanent data storage; QGP, Quark-Gluon plasma; RCS interface, MISSING; RCT, run control tool; RORC, Read-Out Receiver Card; SAN, storage area network; SIU, source interface unit; SL, shift leader; SMI, state management interface; SSH, Secure SHell; SW, software; TDS, transient data storage; TDSM, transient data storage manager; TRG, trigger system; TTC, trigger timing and control

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Collisions of lower-mass ions will also be observed as a mean of varying the energy density and of pp or p–nucleus to provide reference data for the nucleus–nucleus collisions.

The LHC includes two adjacent parallel beamlines (or beam pipes) that intersect at four points, each containing a particle beam, which travel in opposite directions around the ring. The particle beams are made of either protons, ion nuclei, or proton and ion nuclei. A beam in the LHC is not a continuous string of particles, but is divided into hundreds of bunches, each a few tens of centimetres long. Each bunch contains more than a hundred billion protons or tens of millions lead nuclei. The LHC has been designed in order to maximize the chances of interaction between the particles in the four intersection points, where the bunches of the two beams cross each other.

Experiments have been installed at the four LHC intersection points to observe the interactions between the particles of the two beams. An interaction is often referred to in this paper as an event and, by extension, the data produced by an experiment when observing this interaction are also designated as an event.

The ALICE experiment has operated since 2008 in several different running modes with significantly different characteristics. ALICE has been primarily designed to run with heavy-ion beams (PbPb) which are characterized by a relatively low interaction rate ( $\leq$ 10 kHz), a relatively short running time (a few weeks per year) but with a very large event size produced by the large number of charged particles traversing the detectors. In proton–proton (pp) or proton–nucleus (pPb) running modes, the interaction rates are much higher (up to hundreds of kHz) whereas the event size is smaller and the running time of several months per year in pp. These running modes and the corresponding expected event rates and data throughput constitute the main requirements that have been used to design the online systems as reported in the ALICE Technical Design Report on Trigger, Data Acquisition, High-Level Trigger and Control System [3].

### 1.1. ALICE online systems

The ALICE experiment includes five online systems: Trigger, Data Acquisition, High-Level Trigger, Detector Control System and Experiment Control System. The functions of these systems are the following:

- The Trigger system (TRG) is combining the information from all triggering detectors and, for every bunch-crossing of the LHC, makes a decision within microseconds whether the resulting data are worth being collected. For each positive decision, it sends a sequence of trigger signals to all detectors in order to make them read out synchronously.
- The core function of the Data Acquisition (DAQ) system is to realize the data-flow from the detector up to the data storage. The DAQ system also includes software packages performing the data quality monitoring and the system performance monitoring.
- The High-Level Trigger (HLT) reduces the volume of physics data by selection and compression of the data.
- The Detector Control System (DCS) is in charge of controlling all the detector services (high and low-voltage power supplies, gas, magnet, cooling, etc.).
- The Experiment Control System (ECS) is coordinating the activities of all the online systems to fulfil their common goal.

This paper describes the DAQ and ECS systems who are in charge of the overall experiment data-flow and control, the detector software, the infrastructure and the data quality monitoring.

### 1.2. Data-flow

The data-flow from the detector electronics up to the data storage in the CERN computing center is organized as a sequential data-driven pipeline. Upon reception of a sequence of trigger signals requesting the data collection, the selected elements of the detectors generate data fragments that are transferred to computers via optical links. A computing farm is used to check, label, format and record the data. The data-flow has been implemented as a hardware system and a set of software packages described respectively in Sections 3 and 4.1.

### 1.3. Control

The ECS has several roles. It has to provide the operators with a unified view of the experiment and a central point from where to steer the experiment operations. Second, it also has to permit independent concurrent activities on parts of the experiment (at the detector level) by different operators. Finally, it has to coordinate the operation of the control systems active on each detector: the TRG, DCS, DAQ and HLT control. The ECS and the other software packages used to configure and control the experiment are presented in Section 4.2.

The ALICE Configuration Tool (ACT) serves as a configuration repository to which the different ALICE systems can access to extract their currently selected configuration. It is described in Section 4.2.3.

### 1.4. Monitoring, metadata, detector software and data quality monitoring

The ALICE DAQ and ECS are complex systems operated by a single person. It is therefore of paramount importance to have good services to monitor the system itself. The software packages used for the infrastructure monitoring are presented in Section 4.3: Lemon for the fabric monitoring, the infoLogger for all the operations related to the log messages generated by all the other software packages and Orthos for the alarm handling.

One package is playing a special role: the electronic logbook presented in Section 4.3.4. This package implements the bookkeeping of all the operational activities and is the only software of the DAQ and ECS systems directly used by all the members of the collaboration.

The DAQ system also includes two facilities to execute detector related algorithms such as calibrating a detector or monitoring the data quality. The Detector Algorithms package (DA) has implemented a controlled and reliable environment for the execution of detector related tasks and is presented in Section 4.4. AMORE (Automatic MOnitoRing Environment) is the environment used by all the detectors and systems for the monitoring of the data quality. It is presented in Section 4.5.

### 1.5. The DATE software package

The coherence of the whole DAQ and ECS systems is given by a common software framework composed of different layers of modules. The bottom layer includes the memory handling, the process synchronization and the communication layers. The application layers includes the data-flow and the control applications. This framework is called DATE (Data Acquisition and Test Environment) and has been used during all the phases of development and operation of the ALICE experiment.