How beam driven operations optimize ALICE efficiency and safety

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Abstract. ALICE is one of the experiments at the Large Hadron Collider (LHC), CERN (Geneva, Switzerland). The ALICE DCS is responsible for the coordination and monitoring of the various detectors and of central systems, for collecting and managing alarms, data and commands. Furthermore, it’s the central tool to monitor and verify the beam status with special emphasis on safety. In particular, it is important to ensure that the experiment’s detectors are brought to and stay in a safe state, e.g. reduced voltages during the injection, acceleration, and adjusting phases of the LHC beams. Thanks to its central role, it’s the appropriate system to implement automatic actions that were normally left to the initiative of the shift leader; where decisions come from the knowledge of detectors’ statuses and of the beam, combined together to fulfil the scientific requirements, keeping safety as a priority in all cases. This paper shows how the central DCS is interpreting the daily operations from a beam driven point of view. A tool is being implemented where automatic actions can be set and monitored through expert panels, with a custom level of automatization. Some routine operations are already automated, when a particular beam mode is declared by the LHC, which can represent a safety concern. This beam driven approach is proving to be a tool for the shift crew to optimize the efficiency of data taking, while improving the safety of the experiment.

1. The ALICE DCS
The ALICE experiment [1] has been running for about 10 years, with different levels of completeness and functionality, and the DCS (Detector Control System) was operational from the beginning and constantly evolving with the experiment.
The DCS is an online system [2], based on PVSSII [3], a commercial software that is capable of interfacing different devices through several protocols, while providing a graphical environment for developers, and a friendly user interface for users.

In order to satisfy a wide variety of needs a strong customization has been performed by the CERN JCOP service, with the implementation of a complex framework [4] to expand the functionality of PVSSII.

The components integrated into the new framework include a general purpose client server protocol (DIM) [5] and the DIM based FSM (Finite State Machine) logic [6]. These tools have already proven their strength in LEP experiments.

The main ALICE DCS backbone was in planning for a long time [7], in close collaboration with the other LHC experiments. All the detectors operations were based on the well defined FSM logic, as was designed many years ago. Being rather complex and deeply interconnected among systems, it was necessary to avoid changes on it during data taking periods and to postpone upgrades to the long LHC shutdown periods.

This is one of the reasons that forced the DCS team to introduce new abstraction layers more compliant with the evolving operational logic of the ALICE experiment. To cope with the evolution of operational procedures related to beams, beam driven operations have been introduced, which guarantee a high degree of flexibility while maintaining the levels of safety and efficiency required for the routine operation of the experiment.

2. Control room activity

In the last few years (since the LHC started) the control room activities have strictly followed the beam mode timing. Furthermore, with a growing operational experience it has become possible to rationalize the shifters presence, to combine together the operations of groups of detectors or systems, and to simplify the routine operations as much as possible.

The routine DCS tasks include monitoring and controlling the detectors and associated electronics, and all environmental parameters required to ensure stable and safe operation of the experiment. Thanks to this central role, and to its interface with several systems, the DCS is able to control the detectors’ safety, centralizing controls and commands, while delegating the custom definition of “safety”, in particular of “beam safety”, to the detector side. With the increase of the beam intensity, new factors have entered into the game, such as the beam background level. These represent a severe limiting factor for several categories of detectors, especially the gaseous ones. It is important therefore, from the engineering point of view, to foresee a certain level of flexibility in the safety condition definitions.

The shifters’ activity is coordinated by the Shift Leader, who takes care of the data taking organization. While the DAQ shifter is responsible for smooth physics data taking, the DCS shifter deals with the detectors’ and central systems conditions, reacting quickly to alarms or changes of state, and preparing the detectors for the data run, whenever the beam and environment conditions are compatible. Therefore, safety must be ensured in the sense that detectors must be promptly brought to, and kept in a safe state whenever the beam mode may require so. Efficiency is enhanced by readily bringing the detectors to a condition where they are ready to take data once the beams are stable. In addition, unnecessary interlocking of the machine operation by the experiment can be minimized.
3. Beam driven operations

The first beam driven operation, called as the handshake, was implemented some time ago. The handshake procedure is a dialog between the LHC control room and the experiment control rooms, following a predefined protocol to announce imminentness of certain beam operations, e.g. beam injection into the machine, that could be dangerous for some kinds of detectors under particular configurations. The aim is to alert the experiments so that they have the time to protect their instruments by lowering voltages, switching off sensitive parts, or activating different protections.

When the LHC opens the INJECTION HANDSHAKE, announcing an imminent injection, the ALICE experiment moves to an operation mode called simply SAFE. ALICE SAFE requires that all detectors are in a similarly called SAFE state, which is a specific condition for every detector. The operator is guided throughout the handshake procedure with a combined set of PVSS II panels and scripts, to guarantee the success of the actions within the time limits, as requested in the protocol definition. In a first phase the handshake has been designed as a non-fully automatic action, requiring at the end a manual confirmation from a human operator.

The introduction of a GO_SAFE mechanism can be considered as an abstraction layer to hide from the shifter the complexity and variety of configurations required on the detectors’ side. When the shifter issues the command by clicking the GO_SAFE button, the different detectors perform different actions which were predefined by the detector experts, e.g. reduce or switch off the HV, or do nothing.

At the end of the beam injection, the LHC beam mode is changed to PREPARE_RAMP. At this point, a particular set of detectors (the luminometers) is activated, but the other detectors stay safe. A dedicated panel helps the shifter, allowing changing the detector conditions to a state compatible with data taking (GO_READY: switch on and prepare for data taking). This particular set of detectors is grouped under one button, thus reducing the risk of manipulating the wrong detector at this stage, while simplifying the shifter’s work.

The transition to LHC beam mode RAMP automatically triggers DCS and CTP (the Central Trigger Processor system) to check the LHC clock quality, and to raise a DCS alarm and perform an automatic resynchronization in case of jitter.

When the beam mode is FLAT_TOP, SQUEEZE, or ADJUST the shift crew perform the calibration runs in preparation for the imminent data taking. Whenever the STABLE BEAMS condition is declared, the remaining detectors shall be promptly send to READY, if the background conditions allow.

If a BEAM DUMP occurs, programmed or not, the data taking is stopped and the DCS shifter brings the ALICE experiment to the condition requested by the daily program, or to a SAFE condition in case a new injection is expected.

The introduction of the beam SAFE concept solved a problem appearing in the last few years: the detectors’ interpretation of the beam safety was evolving over time, and simple FSM states proved not to be flexible enough to define the beam safety condition. This made it difficult for the DCS operator to interpret the beam safe condition of the detector when dealing with the FSM only.

Furthermore, the SAFE concept is different for different detector technologies: calorimeters like EMCAL and PHOS are considered always SAFE, i.e. they are not critically sensitive to beam conditions. However, the main gaseous detectors (TPC, TRD, TOF, HMPID, muon detectors) suffer from over-current trips in case of beam losses, which are expected before the beams are brought into collisions (STABLE BEAMS).
4. **ALICE tools for the beam driven operations**

Several tools have been prepared to support the shifter, guiding him/her to perform the correct operations in due time and suggesting the next expected operation: the handshake popup panels, which are especially designed to force the shifter to follow a precise protocol, acting correctly and within the time limits; a sound system, which produces an audible gong as soon as some relevant beam modes are declared; a panel with an overview of all the programmed actions, embedded in the LHC cycle schema [Figure 1].

**Figure 1. Panel showing LHC cycle and automatic operations**

Beam driven operations are defined by the Run Coordination, in agreement with the System Run Coordinators, and are implemented in DCS through expert panels managed by the DCS experts [Figure 2]. Technically, a script is executed when a certain beam mode is declared, or when a certain parameter assumes a predefined value, e.g. beam-gas background rate. The operations themselves are implemented in PVSSII as datapoints (elementary structures similar to the Objects in object-oriented terminology), as are all the other parameters and configurations that are handled by the DCS.
Each operation can be activated in DEBUG mode, SEMIAUTOMATIC mode, or fully AUTOMATIC. The DEBUG mode is active during the test period: the action is actually not executed and the shifter continues the manual operations following the shift leader instructions, but the conditions and the actions are logged to allow the DCS experts and developers to evaluate the robustness of the procedure. In a SEMIAUTOMATIC operation mode, a popup panel is proposed to the shifter, which contains the description of the conditions determining the operation activation, a description of the actions to be performed, and a YES/NO choice requesting a manual intervention from the shifter. An AUTOMATIC operation is performed by the system without requiring the shifter intervention; a log entry is visible in a special area of the central operation panel.

5. Conclusions and outlook

Moving to automatic routine operations has been promoted by the ALICE Run Coordination for a few years already, addressing and supporting the DCS experts in this direction [8].

The aim is to optimize the operations: increase the data taking efficiency by minimizing the time to move the experiment to READY, and guarantee the detector’s safety under various beam modes and background conditions, in addition to the usual parameters handled by the DCS.

The ALICE DCS is now starting a stress test campaign, where the robustness of the procedures is aimed to be established by spotting and fixing software errors and bugs. After this validation campaign, ALICE shall move to a semiautomatic mode, to gain confidence before fully automatic operation.

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