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Status of ALICE: Report to the March 2013 RRB

Introduction and Organization

ALICE is a general-purpose heavy-ion experiment designed to study the physics of strongly interacting matter and the quark-gluon plasma in nucleus-nucleus collisions at the LHC. The collaboration currently includes over 1300 members from 138 institutions in 36 countries. The ALICE detector consists of a central part, which measures hadrons, electrons and photons, and a forward spectrometer to measure muons. The central part, which covers polar angles from 45^0 to 135^0 over the full azimuth, is embedded in the large L3 solenoidal magnet. It consists of an inner tracking system (ITS) of high-resolution silicon tracking detectors, a cylindrical Time Projection Chamber (TPC), three particle identification arrays of Time-of-Flight (TOF), Cerenkov (HMPID) and Transition Radiation (TRD) counters and two electromagnetic calorimeters (high resolution PHOS and large acceptance EMCAL+DCAL). DCAL, a second arm complementing EMCAL at the opposite azimuth and thus enhancing ALICE jet and especially di-jet has been approved in 2010 and will be installed in the current Long Shutdown. The forward muon arm (2^0-9^0) consists of a complex arrangement of absorbers, a large dipole magnet, and 14 stations of tracking and triggering chambers. Several smaller specialized detectors (ZDC, PMD, FMD, T0, V0) are located at small angles. A scintillator array to trigger on cosmic rays (ACORDE) is installed on top of the L3 magnet.

In 2012 ALICE has taken data mostly with proton beams at a centre-of-mass energy of 8 TeV. After considerable difficulties in the first part of the year, the luminosity and background conditions improved for the last weeks of run, allowing to collect a significant fraction of the desired integrated luminosity. A very short (one fill) low luminosity run of p-Pb collisions, conceived primarily as a test run, provided a first glance at this very interesting system. In 2013, ALICE took data with pPb and Pbp collisions. The run was very successful, and the full program, which included 100 million minimum bias events and 30 nb-1 for rare triggers evenly split among the two systems, could be achieved. A short pp run at 2.76 TeV at the end of the pPb one allowed to increase by a factor of four the statistics for comparison with the PbPb data taken in 2011.

The experiment has performed well throughout the year, and so did the data analysis. The ALICE performance during the pPb data taking was particularly satisfactory, with efficiencies reaching 96% in the minimum bias period.

Exciting scientific results have been produced and continue to come at a fast pace. The number of ALICE presentations at International Conferences continues at a constant rate, and so does the number of papers in refereed journals. The results currently in review in the collaboration let expect an even higher rate of presentations of new results and publication in the course of 2013.

The papers published by the ALICE Collaboration continue to raise considerable interest in the scientific community, as visible from the very high number of citations received.
Since the last RRB meeting of October 2012, the following institutes have joined the Collaboration: Inha University (Korea) and INSER (India) have joined as full members, Konkuk University (Korea) has joined ALICE as part of Bergen University. Discussions

to join the Collaboration are ongoing with several institutions in China, Brazil, Chile Pakistan, Indonesia, Germany, Austria and other countries.

<u>Detector status:</u>

Tracking Detectors (ITS, TPC):
The ITS subsystems - silicon pixels (SPD), silicon drift (SDD) and silicon strip (SSD) – showed excellent performance during this year's p-Pb run, with detector channel efficiencies in excess of 95%, with specific changes to be reported with respect to the Oct. 2012 RRB report.
The TPC detector performed well at p-Pb collision rates in excess of 200kHz with good stability and reasonable chamber trip rates. It is worth mentioning that all readout chambers (inner and outer) were operated at nominal gain, therefore providing excellent particle identification performance. Consolidation efforts that will continue during the entire Long Shutdown 1 (LS1) have started. The main focus is on the migration of the readout to the latest version of the DAQ link, the DDL2.

Particle Identification Detectors (TOF, HMPID, TRD):
The TOF detector performed excellently up to the maximum p-Pb collision rates. The HMPID detector performs with nominal resolution. The original coverage is reduced by about 25% due to leakage of a number of radiators. The effort for repairing these elements was considered too large when considering the relatively modest impact on the physics, so the detector will not be removed during LS1. The TRD contributed to the trigger during the p-Pb run early this year, and currently HV consolidation efforts on a few modules are ongoing.

Calorimeters (PHOS, EMCAL, ZDC):
The EMCAL system continues to show extremely stable performance. Preparations for the installation of the calorimeter extension during LS1 are ongoing. The new support structures and installation tools are sitting in the ALICE surface building and final tests are currently performed. The PHOS detector performed well during the p-Pb run and all PHOS modules are now taken to the surface building for consolidation and repair of broken channels. The ZDC performed excellently during the p-Pb run and is presently sitting on the surface for improvements of the moving table.

Muon Spectrometer:
The Muon Trigger Chambers also showed excellent performance during the p-Pb run. Presently a study for a recirculating gas system for this detector is ongoing, with possible implementation during LS1. The Muon Tracking Chambers showed good performance, with some difficulties on the readout electronics stability. Consolidation efforts are planned and being carried out during L1.

Other detectors (PMD, FMD, V0, ACORDE, T0):
The PMD detector was able to collect the required p-Pb statistics efficiently. The FMD, V0 and T0 detectors are operating very stably. In an efforts to tackle the ageing of the photomultipliers, new devices with more dynodes and therefore less gain per stage, are presently being evaluated. ACORDE is used routinely for triggering in cosmic ray data taking.

LS1 shutdown activities:
The first long LHC shutdown started on Feb. 15th 2013 and will last approximately 2 years. After opening of the detector in February, the activities around the installation of the EMCAL

extension (DCAL) have started. The PHOS modules and cradle were removed from the cavern and the modification of the service infrastructure is ongoing. The new support structures and installation tools are prepared on the surface. The infrastructure for consolidation of the TRD modules has started as well. Many of the LS1 activities are concerned with infrastructure consolidation. The replacement of the UPS system and electrical infrastructure in the ALICE control rooms has started and is well advanced.

Online Systems (DAQ, CTP, HLT, DCS):

In 2012 and 2013, the ALICE online systems have worked well above their design specifications and have delivered a smooth service to the whole experiment. The Long Shutdown 1 is the occasion to consolidate the systems, investigate how to improve them and make the adaptations required by the running conditions of Run 2 and replace obsolete hardware.

A systematic investigation of the sources of inefficiency has been performed and ways to address them are being worked on. This will in particular involve the overall experiment control scheduling by the Experiment Control System (ECS) and the independent operations performed by the other online systems and the detectors

A new version of the CTP L0 board is being designed in order to accommodate more L0 inputs, extended functionality for L0 trigger logic, integrated L0 trigger input multiplexer, integrated pre-trigger logic for TRD as LM trigger level, bigger memory and to provide an additional output channel to the DAQ for the interaction records and L0 trigger input status at interaction. In addition to automatic downscaling of classes and the class downscaling factors included in elogbook, the software will be improved for the downscaling and the monitoring via the eLogbook.

After the last detector tests, the DAQ system will be stopped in May and entirely dismounted. The racks (inherited from L3) will be replaced in accordance with today's mechanical standards and the cooling capacity will be increased in view of the LS2 upgrade.

The ALICE HLT system has been the first one at LHC using GPUs in production for TPC tracking. The tracker software will be ported from CUDA to OpenCL to gain vendor independence. This is particularly important during LS1 because the DAQ and HLT computing hardware will be replaced after 5 years or more of continuous operation.

The DCS will upgrade the SCADA to the latest version (including a rebranding from PVSS to WinCC OA); obsolete computing infrastructure will be replaced and operating systems will be brought to the latest versions. The DCS will evolve to cater for the new requirements (e.g. the installation of new detectors during LS1). We will also upgrade the databases and improve data exchange and communication with systems external to DCS. A thorough review will be done of the core applications (FSM, alerts, User Interface, etc.) based on the operational experience obtained over the last years, to come to a more coherent operation environment with further automation in view of a simpler and more efficient operation.

In addition to the LS1 developments, a large common effort has been initiated by the DAQ, HLT and Offline project in view of the LS2 upgrade: the so-called O2 project. A dozen Computing Working Groups (CWGs) have been formed with participants from the 3 projects. These CWGs work on different architectural, technological or procedural topics related to the future common computing system that will be used for the online and offline computing for Run 3. The Online-Offline computing TDR for the LS2 upgraded is scheduled for September 2014.

Offline and Computing:

Data statistics, processing and analysis strategies

In the reporting period ALICE completed the p-p and p-A data taking and has fully processed substantial amount of the collected statistics. In 2012/2013 there were 8 p-p periods at nominal LHC collision energy, 6 p-A periods and at the end of data taking, one short p-p run @2.7GeV as reference data for the p-A periods.

All p-p data from 2012 has been fully calibrated. All periods, with the exception of the last 2 (LHC12i and LHC12h) have been processed. The 2 last periods represent about 10% of the entire 2012 data sample are scheduled for processing after the end of the p-A processing.

The collected RAW samples are as follows: total of 1.7PB of which 1.35 p-p and 0.35PB p-A. For the p-A data taking period, the reconstruction strategy of ALICE was modified to allow for a fast analysis of specific trigger sets, thus the calibration periods were shortened, allowing a full production cycle shortly after the completion of the data taking. So far, 100% of the collected data for specific trigger sets has been reconstructed as well as 100% of the minimum bias data sample. The calibration of the remaining rare trigger data is completed and the processing is ongoing. We expect to complete the full processing by the end of April and to complete the processing of the remaining 2012 p-p data by 15 of May.

It is worth mentioning the very successful operation during the Christmas break. As in the previous years, it was very productive for ALICE - the number of concurrently running jobs was steadily over 40000 and we were able to complete a large Pb-Pb MC production in preparation for the 3rd pass of the LHC11h data sample. We congratulate all computing centers for the excellent operation.

By increasing the share of analysis trains over individual user analysis, improving analysis tools quality and introducing data caching (enabling of ROOT TTree cache) in October 2012 for all ALICE analysis jobs, the overall CPU/WALL efficiency of ALICE grid jobs has increased to ~85% and now is compatible with the other LHC VOs. There are few remaining T2 sites where tuning the local network and storage setups can further increase the efficiency. The improvement plans are being discussed with the local system administrators.

The repartition of Grid resources during the accounting period was as follows: from the total of 37K parallel jobs, 25K (68%) were simulation, 4.1K (11%) were RAW data reconstruction, 3K (8%) were organized analysis and the remaining 13% were individual user analysis jobs. The latter figure was heavily influenced by an uptick of individual user analysis during the p-A data taking in February, driven by the fast QA and preliminary analysis programme. This has influenced downward (few percent) the job efficiency figure for the month.

Several tests were performed to address the issue of high memory consumption in Pb-Pb reconstruction and MC jobs. In addition to extensive code optimization, we have tested the memory allocator jemalloc, which substantially decreases memory fragmentation and indirectly, the total memory utilization. The use of jemalloc already shows improvement in SLC5, however under SLC6 and more advanced kernels, the positive effect is higher. The overall effect is that the memory profile and job completion rate even for the most demanding RAW data reconstruction is now well within the memory budget of all sites.

Issues

• Finalization of efficiency-improvement programme at all sites. The goal is to achieve minimum ~85% CPU/Wall ratio at all centres. The necessary central analysis framework improvements are now completed and the programme is focusing on specific centres, which show lower efficiencies as well as on individual user analysis, which has the strongest impact on the overall efficiency.

• The in-depth review of the information contained in the AODs in order to reduce the size and therefore the read time is continuing. The adoption of longer analysis "trains" more CPU-heavy is also explored, although this is limited by the memory footprint and by the compatibility of the analysis tasks.

<u>Operation & Data taking:</u>

Based on the main-satellite collision scheme adopted by ALICE for the proton physics data taking in 2012 we were delivered for the largest fraction of the time a peak luminosity of 1-2 Hz/μb corresponding to an average instantaneous luminosity of 0.6 Hz/μb over an entire fill. Following a long and constructive interaction with the machine experts of both the PS and LHC it was possible to increase the satellite population in two steps by increasing the longitudinal blow-up in the PS during the final phase of the 2012 p-p data taking. Peak luminosities of 15 to 18 Hz/μb corresponding to an average instantaneous luminosity of 7.0 Hz/μb for a fill were achieved and allowed efficient ALICE operation.

In spite of the difficult background situation in ALICE during the 2012 proton physics data taking period, ALICE collected approximately 300 million of good minimum bias events using a downscaled minimum bias trigger mixed with rare triggers, keeping ~80% trigger live-time. The rare triggers consist mainly of jet triggers with the EMCal, di-muon triggers, and the new TRD electron and charged jet triggers introduced in a later stage of the year. The final collected p-p statistics are 4 pb^{-1} for the di-muon triggers, 3 pb^{-1} for the EMCal jet and gamma triggers with the TPC in data taking, and 0.2 pb^{-1} for the TRD triggers.

At the beginning of January 2013 a new phase of the LHC started because for the first time the machine succeeded to provided, after a very short commissioning period, p-Pb asymmetric beams with hundreds of bunches.

ALICE successfully collected data in both p-Pb and Pb-p configurations at its maximum foreseen luminosity. The trigger was setup, in the first few days, only with a minimum bias trigger by using the VZERO detector, with above 90% of trigger saturation. LHC leveled the interaction rate to a value of 10 kHz by beam separation, to minimize pile-up in the TPC and to have the maximum data taking rate for minimum bias events. ALICE collected 100 million of minimum bias events in the first 4 days of the p-Pb period.

After that, LHC increased the peak interaction rate at ALICE to 200 kHz. Accordingly ALICE changed the trigger strategy to the rare trigger mode, with higher trigger live-time. The trigger mixture was similar to pp data taking, with EMCal triggers, muon triggers and TRD triggers. In addition to that, high-multiplicity trigger, muon-central barrel correlation trigger, ultra-peripheral collision triggers were added in the trigger mixture. The LHC was able to deliver the requested 30nb-1 of p-Pb collisions to ALICE.

In February 2013, after the p-Pb/Pb-p campaign, ALICE participated also to the pp data taking at 2.76 TeV. During the few days dedicated to the pp low energy reference data taking, ALICE successfully collected additional 20 million of minimum bias triggered events and above 70 nb^{-1} of rare triggers that corresponds to a factor 4 more integrated luminosity compared to the 2011 low energy run for rare triggers.

Physics & Analysis:

During the last five months, the physics analysis activity concentrated on the following areas:

- the p-Pb run: this has been at the top of the PWG priorities during the winter (definition and optimisation of the trigger mix for the data taking, control of the data quality during the run, calibration, MC productions, data analysis). The discovery of an as-yet unexplained "double ridge" structure in the di-hadron angular correlations in high multiplicity p-Pb collisions was announced in a PH seminar and posted to the arXiv on 10 December
- finalisation of physics analyses for publication: besides the double ridge paper mentioned above, several final results were published on the analysis of Pb-Pb data (centrality determination in Pb-Pb collisions, centrality dependence of the charged particle pseudorapidity distribution, centrality dependence of the production of identified pions, protons and kaons, charge correlations, azimuthal asymmetry of J/ψ production) and pp data (jet spectrum and charged kaon correlations). Besides these, during the period in question, seven other analyses have been completed down to the approval of the final results, with the corresponding papers currently in the final editorial stages
- production of new results: the collaboration has decided to concentrate the bulk of the approvals of new results around three main releases in spring, summer and autumn. As a result, only three new preliminary results were approved during the last five months (all on pp data: multiplicity dependence of the production of J/ψ from B decays and of D mesons and p_T-differential cross section of electrons from B decays); the preliminary results of sixteen new analyses are being finalised and will be up for approval in two weeks time
- in addition, about thirty conference proceedings were produced during the period in question, the majority of them relative to the Quark Matter 2012 and Hot Quarks 2012 conferences.

Upgrades:

The long term goal of the ALICE experiment is to provide a precision characterization of the high-density, high-temperature phase of strongly interacting matter. To achieve this goal, high-statistics measurements are required, which necessitate upgrading the ALICE detector. The general upgrade strategy is conceived to deal with this challenge with expected Pb-Pb interaction rates of up to 50 kHz aiming at an integrated luminosity above 10 nb^{-1}. With the proposed timeline, starting the high-rate operation progressively after the 2018 shutdown, the goals set up in our upgrade plans should be achieved collecting data until the mid-2020's. In the Letter of Intent presented to LHCC at its September session we described the main physics motivations for running the LHC with heavy ions at high luminosities and discussed the modifications and replacements needed in the ALICE detectors, the online and offline systems.

The proposed program will allow to understand the dynamics (transport, thermalisation, hadronization) of heavy quarks in the QGP, to study the production of quarkonia especially in the most interesting low-transverse momentum region and, for the first time, to study in an exhaustive way the production of low-mass lepton pairs. In addition, the capabilities of ALICE to study the properties of jets in the hot and dense medium and the production of exotic nuclear and antinuclear states will be substantially enhanced. The schedule, cost estimate and organization of the upgrade programme were presented as well. The letter was accompanied by a Conceptual Design Report for the proposed Inner Tracking System, including results from R&D and an advanced design study of the new detector.

The committee endorsed the upgrade plan of the ALICE collaboration, which is now working on the preparation of Technical Design Reports for the various elements of the upgraded detector. The TDRs are expected to be submitted in the summer. In parallel, a vigorous R&D program addressing all relevant technical issues is rapidly progressing.

The upgrade program has the full commitment of the entire existing collaboration, and continues to attract new institutions, motivated by both the excellence of the scientific program and the interest of the technological challenges involved. In the March Collaboration meeting, ALICE has decided to submit to the LHCC a Letter of Intent for the addition of a silicon pixel tracker in front of the muon absorber (Muon Forward Tracker), improving the angular and impact parameter resolution of muons, thus improving the measurement of dimuon resonances and allowing the separation of non-prompt muons. Studies on a Forward CALorimeter will continue in view of a discussion for a possible submission to the LHCC at a later stage.