Status of ALICE: Report to the October 2012 RRB CERN-RRB-2012-067

Introduction and Organization

ALICE is a general-purpose heavy-ion detector designed to study the physics of strongly interacting matter and the quark-gluon plasma in nucleus-nucleus collisions at the LHC. It currently includes over 1300 members from 138 institutions in 36 countries. ALICE 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 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 so far taken data mostly with proton beams at 8 TeV, but with a very important short run (one fill) of p-Pb collisions, conceived primarily as a test run in view of the p-Pb run of Jan-Feb 2013. Still, this short run already provided a first glance at this most interesting system. Two publications have already been submitted, based on the data taken during the test run, which constitute a fundamental reference for the interpretation of the results obtained in PbPb collisions. During the 2012 run, ALICE has operated colliding main bunches against so-called satellite bunches, which have much lower population, in order to attain the optimum collision rate in the experiment. The 2012 pp run has been plagued by a high level of background, caused by the coupling of vacuum problems with the very high intensity of the beams in the LHC, and by difficulties in providing adequate population in the satellite bunches. The problems have been attacked by ALICE and the LHC on several fronts: increasing the rate capability of the ALICE detectors to cope with the higher rate induced by the background, applying mitigating measures to reduce the background levels and finally increasing the satellite population. The overall result is that ALICE is now finally operating in a satisfactory way and should be able to achieve most of its planned program of data taking foreseen for the year. The experiment has performed well throughout the year, and so did the data analysis. 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 similar pace as in 2011, and has already reached reached over 250 , (57 at the two main Heavy Ion conferences of 2012, Quark Matter and Hard Probes), while the number of publications in refereed journals has reached 50 (including the latest submissions). Many more papers are currently in preparation. The papers published by the ALICE Collaborations 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 March 2012, the following institutes have joined the Collaboration: Karatay University (Turkey) as full member, Rutherford Appleton Laboratory (UK), TU München, (Germany), TU München - Excellence Cluster 'Universe', (Germany), BARC (India), ASRT (Egypt) and Technical University in Kosice, (Slovakia) as associate members. Suranaree University of Technology (Thailand) has changed its status from associate to full member. Vestfold University College (Norway) has joined ALICE as part of Bergen University. Discussions to join the Collaboration are ongoing with several institutions in China, Italy and other countries.

Detector status:

Tracking Detectors (ITS, TPC):

The ITS subsystems - silicon pixels (SPD), silicon drift (SDD) and silicon strip (SSD) – have continued to show very stable performance during this year. After another remote intervention on the SPD cooling system the detector shows excellent performance at >95% efficiency. The increased leakage currents on the SSD detector, which were traced to high sensitivity to humidity, were eliminated by the installation of a new ventilation machine that allows a precise control on the humidity and temperature environment for the ITS. The detectors are now operated at proton collision rates of up to 1MHz.

For the TPC detector, the installation of new HV supplies with strongly increased control of chamber trip conditions allows very much improved detector operation. The inner readout chambers that were operated at about 65% of the nominal gain due to high trip rates are now operating stably at nominal gain. The rate at which the TPC is operated was increased from 100 kHz to more than 400 kHz at very reasonable trip rate on the order of 1/day.

Particle Identification Detectors (TOF, HMPID, TRD):
The TOF detector continues to provide excellent performance even at this year's elevated p-p collision rates of more than 400 kHz. The HMPID detector performs with nominal resolution, it did however experience the breakage of a radiator that forced the exclusion of part of a detector module. The reduction in efficiency has however negligible impact on the physics exploitation. The TRD modules installed during the winter stop were commissioned and the TRD system is now also contributing to the L1 trigger both for jets and electrons.

Calorimeters (PHOS, EMCAL, ZDC):
The EMCAL system continues to show very stable performance. Preparations for the installation of the calorimeter extension during LS1 are on track. The PHOS detector shows very stable operation. A major leak in the PHOS cooling plant, which did not allow operation of PHOS during a period of 3 weeks, was fixed. The ZDC detector does not participate in the present proton physics runs in order to limit the ageing of the photomultipliers that was observed over the course of last year. Otherwise the detector is in perfect shape for the upcoming p-Pb run.

Muon Spectrometer:
An automated recovery procedure from single event upsets in the muon chamber readout electronics is now in operation and allows efficient data taking. The system is currently operated at p-p collision rates of up to 700 kHz. The muon trigger chambers continue to show stable performance in accordance with specifications.

Other detectors (PMD, FMD, V0, ACORDE, T0):
The PMD detector collected enough statistics from pp collisions and is currently off.
The FMD, V0 and T0 detectors are operating very stably. The reduction of pulse-height that was observed in the V0 detector during the course of the 2011 run was traced to the pPhotomultipliers, which are fortunately accessible during LS1 and the issue will be addressed then.
ACORDE is used routinely for triggering in cosmic ray data taking.

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

In 2012, the ALICE online systems have worked smoothly and have further improved the tools to improve the experiment efficiency and to smooth the experiment operation.
The Experiment Control System (ECS), the other online systems and the detectors have joined forces for detecting and automatically correcting some of the most frequent error conditions from some detectors (such as a single-event upset of the front-end electronics or a trip of the high-voltage power supply of a chamber).
The synchronous downscaling has been implemented on the L0 board. A batch of 40 new LTU boards has been manufactured in view of the detector R&D for the upgrade. The CTP has been upgraded with more counters for a better monitoring of the trigger rates and trigger aliases have been introduced.
The DAQ system is being equipped with a software alarm tool to detect and guide the operation in case of hardware or software faults. The eLogBook has been extended to archive all the trigger conditions used during data taking.
The HLT usage has been increased with the usage of the cluster finder for the pp data taking. The tracking has also been put into production and R&D is on-going to use the online tracks as seeds to the offline processing.
After migrating the ALICE DCS system to new hardware and operating system early 2012, DCS operation resumed without major problems. Development throughout the year concentrated on the operator interface, tools, training and procedures; with the aim to further improve the operation. Another main area of development covers a range of monitoring tools, mainly for experts, to allow a close monitoring of hardware and processes; to assure an early detection of anomalies. The databases have been migrated to new hardware, the upgrade to Oracle 11g allowed the use of 'active dataguard', providing a synchronized replica outside ALICE. This opens up the way for accessing the DCS data without the need to connect to ALICE production network and avoiding a risk of perturbing the production server.

Offline and Computing:

Data statistics, processing and analysis strategies

Since May 2012, ALICE has collected 550 TB RAW data, pp@4TeV. The periods LHC12a and LHC12b were fully reconstructed after a complete calibration and validation procedure. The standard AOD's were also produced for these two LHC periods. The calibration procedure and validation for the remaining 2012 LHC periods is ongoing. Another important activity was re-processing of LHC11h, Pb-Pb collisions (pass2) and LHC11c,d p-p collisions (pass2) for the MUON detector.
The short test run of pPb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV in September allowed collecting about one million events. These events have been swiftly reconstructed and analyzed, leading to the publication of two papers, probably the two first ones on pPb at LHC.
A large part of the GRID productions were focused on producing Monte Carlo events for Pb-Pb LHC11h for the QM2012 conference. In average there were about 20K production jobs (calibration, reconstruction and MC) running at any time during this period, peaking at 50K jobs mid July. Besides these central productions, about 39% of the grid resources were used for end-user analysis and organized analysis (LEGO trains) submitted by physics working groups.
While the average ratio CPU over wall time for simulation and reconstruction jobs is well under control at about 82%, we conducted a series of investigations of the much lower values observed in analysis. The preliminary conclusions pointed to the large input/output rate as main source for the drop of the ratio CPU over wall. To better understand the sources contributing to this, we developed and deployed simple utility collecting information at ROOT level about the data size read, the total size in memory and run time, correlated with the analysis job type, file open time, PFN and storage element. In addition, we are able to collect the same information for the analysis trains running in test mode on the LEGO train facility so it is possible to factorize the contribution of the input read rate to the ratio CPU over wall. The throughput-related utility is now being fully deployed and the analysis jobs will be instrumented to collect this information, which will help us understanding the data flow at the level of grid nodes to get a better grasp of the main causes of observed effect. A marked increase of the use of organized (train) analysis was observed for the preparation of Quark Matter 2012 conference which required increasing the job quotas for the power user running the LEGO trains with respect to other production types.
A major upgrade of the Grid middleware was executed with minimal disturbance to the production jobs.

Issues

• The disk space available for storing additional AOD datasets for PbPb is extremely limited, so any new massive re-filtering requires cleaning-up older AOD's. This affects especially the LHC11h period for which the re-filtering was already approved by the physics board.
• The large traffic and saturation at the level of disk storages remains an important factor that further decreases the ratio CPU over wall of the analysis jobs. This translates into large drops in the throughput or timeouts that trigger accessing non-local file replicas. We are trying to understand and minimize the inter-site communications with large latency due to temporary unavailability of files.
• Another vigorous disk-cleaning campaign is going on. We are also considering reducing the number of replicas for AODs and ESDs. Unfortunately, these two measures, although leading to some short-term relief of the constrained storage situation, risk to introduce further inefficiencies when data will have to be recalled from tape or when non-local access will be needed to read AODs and ESDs because there will be CPU resources available but no local data. A further data reduction step is an in-depth review of the information contained in the AODs in order to reduce the size and therefore the read time. The adoption of longer analysis "trains" more CPU-heavy is also being explored, although the memory footprint of the analysis tasks limits this.

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

Since May ALICE was heavily affected by background from high vacuum pressure in the Long Straight Sections. The beam-gas collisions resulted in a background event rate which was typically a factor five larger than the p-p collision rate. Due to the 'particle load' on the detector we could turn on and start the data taking with all the detectors only 5-6 hours after declaration of stable beam.
This issue was addressed in conjunction with the machine coordinators and resulted in a change in the injection procedure that improved both the vacuum conditions and the background significantly. As a consequence we could start the data taking with all the detectors at a much earlier stage impacting on our overall efficiency.

In 2012 proton physics data taking until the last technical stop in September, ALICE collected approximately 200 million of good minimum bias events using a downscaled minimum bias trigger. For most of the running time, the trigger was configured for rare trigger running mode, keeping ~80% trigger live-time. The rare triggers consists of mainly jet triggers with EMCal and di-muon triggers, and the collected statistics are 0.6 pb^{-1} and 0.7 pb^{-1}, respectively.

Recently the TRD jet and electron triggers were successfully integrated and now stably accumulating data. With this new TRD trigger, we expect a J/ψ yield of more than $5x10^3$, which allows the study of J/ψ production in central rapidity.

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. Since the last Technical Stop in September the Machine now can deliver a peak luminosity of 15 to 18 Hz/μb corresponding to an average instantaneous luminosity of 7.0 Hz/μb for a fill.
With this significantly higher luminosity the di-muon triggers of 5 pb^{-1} could be achievable. With that statistics, we expect Y yield of $1.5x10^3$ and direct fit for three Y states becomes feasible.

If the main-satellite luminosity can be kept at this level and the background remains under control, some of the important goals for the 2012 proton physics program as e.g. the minimum bias reference sample as well as the mentioned di-muon triggers of 5 pb^{-1} will be met.

On 13^{th} September there was the first p-Pb pilot fill and for ALICE it was a very successful run. ALICE collected 1.8 milion minimum bias triggers at a rate of about 200 Hz. Subsequently, the LHC managed to displace the vertex collision by +/- 50cm to allow important cross-checks between the ITS and the FMD. This was successful and ALICE collected more than 260 thousand triggers for each displaced vertex.

<u>Physics & Analysis:</u>

In the last six months, the physics analysis activity concentrated on two fronts: the finalization into papers of the analyses presented at conferences in 2011 (16 papers have been submitted since the last RRB), and the analysis of the high statistics data samples collected in 2012. In particular, a large harvest of new results was released for the Hard Probes 2012 and Quark Matter 2012 conferences. Among these:

- A high statistics measurements of the nuclear modification factor and azimuthal asymmetry in the production of open charm (D mesons). The suppression of the production of D mesons at high transverse momenta is comparable to that of light flavoured particles, in spite of the c quarks being some two orders of magnitudes heavier than light quarks. Such strong coupling between c quarks and the medium should also be reflected in an azimuthal asymmetry of the production of D mesons with respect to the event reaction plane, for which there is indeed indication in the new high statistics data.
- A high statistics measurements of the nuclear modification factor and azimuthal asymmetry in the production of hidden charm (J/ψ). The new data confirm with higher statistics the observation already made on the 2010 sample of a J/ψ nuclear modification factor almost independent of centrality at low transverse momenta. Such a behaviour, very different from the strong centrality dependence observed at RHIC energies, or at high transverse momenta at the LHC, could be an indication of recombination at the hadronisation stage of pairs of charm quark and antiquark produced in different hard parton-parton collisions: a direct consequence of deconfinement. Such a scenario would also result in a finite azimuthal asymmetry of J/ψ production, for which there is indication in the new, high statistics sample
- The first measurement of the particle composition inside jets, which seems to be restored to values of species abundances similar to those found in pp, indicating vacuum-like fragmentation in spite of the strong quenching of the energy of the jets
- A measurement of longitudinal broadening of the near-side jet-like correlations, which might indicate an interplay between the jet components and the longitudinal flow of the QCD medium produced in the collision
- The first measurement of a thermal photon signal at the LHC. This is a very challenging measurement (which took some ten years for the RHIC experiments to perform). The signal reveals an intense electromagnetic radiation from the high density medium formed in the collision and confirms the energy density and temperature estimates extracted from the analysis of hadron production.

The data collected during a pilot LHC p-Pb run performed in September, in preparation for the long run scheduled for January 2013, were quickly analyzed , leading to two fast publications, one on the multiplicity distributions (somewhat disfavoring the predictions of parton saturation models) and one on the p-Pb nuclear modification factor. The latter is found to be consistent with one for transverse momenta of 2 GeV/c and above: a crucial control experiment, indicating that the strong suppression of hadron production at high transverse momenta observed in Pb-Pb collisions is practically entirely due to final state, medium effects.

During this period, the new physics organization has proven its effectiveness, with a substantial increase of both the number of analyses (as indicated by the increase in both the number of internal presentations and released preliminary results) and the number of papers (with a four-fold increase in the rate of paper production relative to the previous year).

Upgrades:

The long term goal of the ALICE experiment is to provide a precise characterization of the high-density, high-temperature phase of strongly interacting matter. To achieve this goal, high-statistics precision measurements are required, which necessitate to upgrade 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 2018 shutdown, the goals set up in our upgrade plans should be achieved collecting data until mid-2020's. In the Letter of Intent presented to LHCC at its September session we describe the main physics motivations for running the LHC with heavy ions at high luminosities and discuss 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 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 will now proceed to the preparation of Technical Design Reports for the various elements of the upgrades detector. The TDRs are expected to be submitted in about one year from now. The Upgrade program has the full commitment of the entire collaboration, and has in addition attracted new Institutions, motivated by both the excellence of the scientific program and the interest of the technological challenges involved. The possible addition of further specialized detectors to the ALICE upgrade (Muon Forward Tracker, Very High Momentum Particle Identification and Forward CALorimeter) is currently under study in the collaboration, which will decide on their pursuit in the coming months.