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ALICE Status and Potential

Jurgen Schukraft
CERN
CH-1211 Geneva 23, Switzerland
E-mail: `Jurgen.Schukraft@cern.ch`

After more than 15 years of design, construction, and installation, ALICE, the experiment dedicated to heavy ion physics at the LHC, was commissioned during the first part of 2008 and ready for the LHC start-up in September 2009. This contribution describes the status and readiness of the various subsystems of ALICE; first results from cosmics and LHC injection tests on detector performance, calibration, alignment, and prospects for first physics are summarized elsewhere in these proceedings.

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1. Introduction

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 and proton-nucleus collisions at the LHC. Data taking during proton-proton runs will provide reference data for the heavy ion program and address a number of specific QCD topics for which the detector is complementary to the other LHC experiments. ALICE currently includes over 1000 members from around 100 institutions in some 30 countries.

ALICE (see Fig.1) 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 TPC, three particle identification arrays of Time-of-Flight (TOF), Cherenkov (HMPID) and Transition Radiation (TRD) counters and two single-arm electromagnetic calorimeters (high resolution PHOS and large acceptance EMCAL). 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 calibration trigger on cosmic rays (ACORDE) is installed on top of the L3 magnet. The detector as installed in 2008 is described in detail in Ref [1].

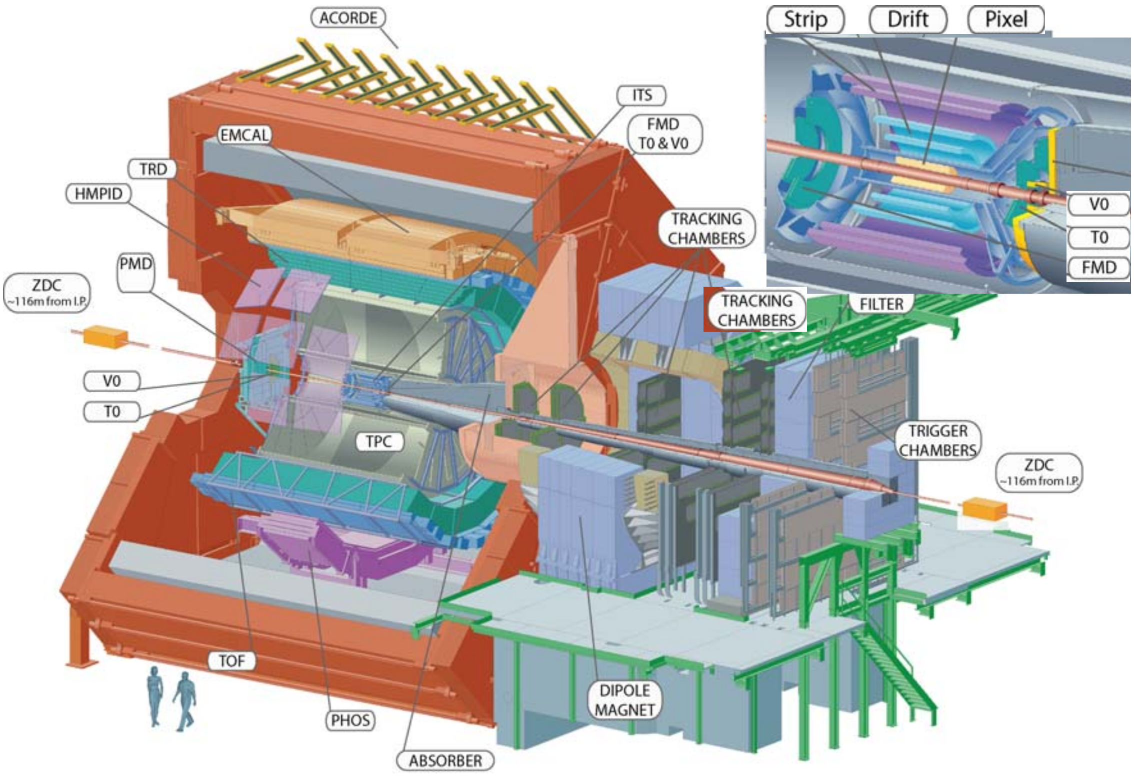

Figure 1: ALICE Setup. ALICE uses 18 different detector systems, indicated in the figure with their acronyms. The central detectors are located inside the L3 magnet (left side), the forward Muon arm spectrometer is located on the right and the insert top right is a blow-up of the interaction region showing the 6 layers of the ITS and the forward trigger and multiplicity detectors (T0, V0, FMD).

2. Detector Status

Installation activities finished by the end of spring 2008, with all detectors completely installed with the exception of TRD (4/18 modules installed), PHOS (1/5), and PMD (9/48). Construction is still ongoing for the TRD, which was fully approved and funded only in 2006, and PHOS, where currently sufficient $PbWO_4$ crystals have been produced for 3 out of the 5 modules. DAQ and HLT hardware were installed at 40% of capacity, corresponding to the luminosity requirements expected in 2008. The EMCAL jet calorimeter was added to ALICE only in 2007 and construction started early 2008; the first two modules (out of 11) are expected to be ready for installation in 2009. Fig 2 shows part of the ALICE Collaboration in front of the experiment, closed and ready for data taking, around mid 2008.

Figure 2: 'Family photo' of parts of the ALICE Collaboration, after completion of installation (July 2008)

Detector integration and commissioning was a main activity over the last year, with two shorter cosmic runs of several weeks late 2007 and early 2008. Since May 2008 and until mid October ALICE has been operated continuously (24/7) for about 6 months, taking cosmic and calibration triggers for global system commissioning, alignment, and calibration.

During LHC commissioning in September, only a subset of detectors was switched on because of the occasionally very high particle flux during beam tuning. Nevertheless, timing of most trigger detectors was verified and adjusted with beam. Details on the commissioning activities and first results on detector calibration and alignment with cosmics can be found in the contribution by S. Chapeland elsewhere in these proceedings.

2.1 Central Tracking Detectors

The vertex detector (ITS) consists of six cylindrical layers of coordinate-sensitive silicon detectors (approx 6.5 m^2 area, 13 million channels), covering the angular range 90 ± 45^0 at radii between 3.9 cm and 43 cm. The innermost cylinders consist of pixel and drift detectors (two layers each) whereas the outermost layers are made from double sided strip detectors. The main purpose of the ITS is the detection of secondary vertices (heavy quarks and hyperons) and the stand-alone track finding of low momentum charged particles.

Production of all ITS detectors and associated electronics was completed by early 2007 and the detectors were installed around the central Be beam pipe and connected during the course of that year. The detector and trigger commissioning has been completed and the final tuning of operational parameters is well advanced; some difficulties adjusting the cooling flow in a small number of pixel ladders have been encountered and will be addressed during the 2008/9 winter shutdown. The overall performance is very satisfactory, with noise levels at the design value. More than 100k single muon tracks traversing the full ITS have been collected and used for the preliminary alignment, starting with the pixel detector where the residual misalignment is comparable with the intrinsic detector position resolution (Fig. 3). The ITS was fully operational during the beam injection tests since June 2008 and provided information on the background levels in ALICE.

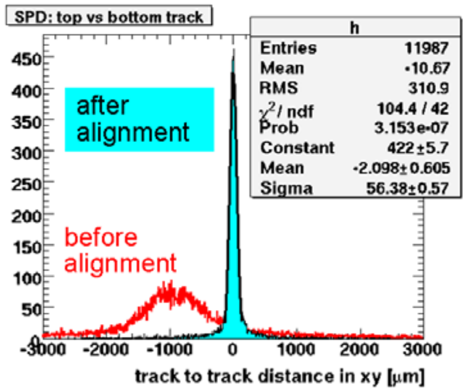

Figure 3:Mismatch between top and bottom half of single cosmic tracks before and after alignment of the pixel detector.

The TPC (5.5 m long, 5.2 m diameter, 90 m^3 drift volume, 500 k channels) is the main tracking detector of ALICE, used for track finding, momentum measurement and particle identification by dE/dx. It was lowered underground early 2007 and installed in its final position at the end of 2007. The chamber gain was calibrated using radioactive Krypton injected into the gas volume and with cosmics (Fig. 4). Laser calibration with and without magnetic field has been performed to characterize non-linearities and to calibrate the drift velocity. All active cooling circuits were turned on, and the temperature stability in the TPC after correction is less than 0.1K. Momentum and dE/dx resolutions have been determined from cosmic ray running. After identifying and removing several sources of electronic noise, all detector parameters are at or better than specifications. However, the access to the front-end electronics was found to be unsatisfactory (obstructed by services and cables) and will be improved during the next shutdown.

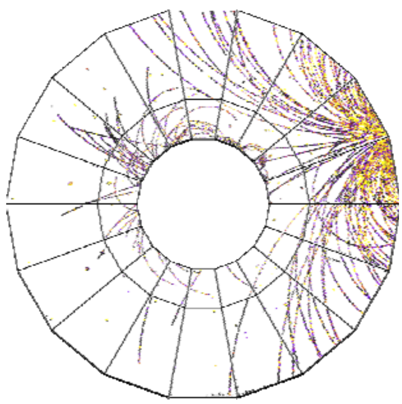

Figure 4: Cosmic ray induced shower in the TPC

2.2 Particle Identification Detectors and Calorimeters

The TOF detector (140 m^2 of Multigap Resistive Plate Chambers, 160k channels) will identify pions, kaons and protons produced in the central region with momentum below about 2.5 GeV/c for pions and kaons, up to 4 GeV/c for protons. The last super module was installed in April 2008 and 2/3 of the area was fully commissioned by early September. Data taken with the magnetic field on and off have allowed to reconstruct cosmic tracks in the TPC and to test the matching algorithms between TPC and TOF. The level 0 TOF trigger was fully functional with a dark counting rate twice better than expected from tests above ground. A first rough time calibration with cosmics was achieved, but much more statistics with interaction triggers will be needed to reach the specification of < 100 ps time resolution.

The HMPID is a proximity-focusing RICH using a liquid radiator, in conjunction with a reflective CsI photo-cathode, evaporated on the pad-segmented cathode of a multi-wire proportional chamber. The detector**,** together with its auxiliary systems, has been fully commissioned and successfully integrated in the experiment DAQ and DCS systems. Beam induced events have been recorded during the LHC commissioning as well as events with cosmic rays, exploiting the TOF trigger facility. Offline analysis shows the detector is qualitatively performing as expected although, due to the low statistics available, it is not possible to assess quantitatively its performance in terms of gas gain or photo-cathodes quantum efficiency. The study of the matching between tracks reconstructed in the TPC and entering the HMPID, for which a few hundred tracks are available, shows a distance between the extrapolated and impact points of less than 1 cm, without alignment corrections. The noise level is measured, as expected, less than 1000 electrons on average and HV stability has been recovered after tightening of the connectors.

The Transition Radiation Detector (TRD) will identify electrons with momenta above 1 GeV/c to study production rates of quarkonia and heavy quarks (charm, beauty) near midrapidity. It consists of 6 layers of Xenon/CO2-filled wire chambers preceded by a composite radiator (foam and fibres). Production and assembly of the TRD is still ongoing, but 4 super modules were successfully operated during the entire cosmic data taking period of ALICE. The Global Tracking Unit has been successfully commissioned and a special Level-1 trigger for cosmic rays has been shown to work.

The PHOS (Photon Spectrometer) detector is a single-arm high-resolution electromagnetic calorimeter (8m^2 area, 18 k channels) made with lead tungstate crystals ($PbWO_4$) designed to measure direct photons and π^0 / η spectra at high momentum. Because some retrofitting of the mechanics was found necessary to improve air tightness of the PHOS modules, only one of the three available units was installed and operated in 2008; all three units will be ready for beam in 2009.

The EMCAL (Electromagnetic Calorimeter), designed to measure and trigger on high energy jets, is a large electromagnetic Pb-scintillator sampling calorimeter covering ±0.7 units in pseudo-rapidity and 110^0 in azimuth with almost 13,000 readout-towers. Construction started in April 2008, but the heavy support structure and most of the services are already installed inside the central magnet.

2.3 Muon Arm

The forward muon arm is designed in order to cover the complete spectrum of quarkonium resonances, i.e J/Ψ, Ψ', Y, Y', Y''. It will measure the decay of these resonances into muons, both in proton-proton and in heavy-ion collisions, with a mass resolution sufficient to separate all states. The muon tracking system uses 10 planes of high granularity Cathode Pad and Cathode Strip chambers (90 m^2, 1.1M channels) whereas the muon trigger is based on 4 planes of single gap Resistive Plate Chambers (RPCs, 120 m^2, 20 k channels) made with low resistivity Bakelite plates.

A number of tracking chambers showed excessive noise pick-up from environmental sources in the cavers, which was eventually solved and about 2/3 of the chambers where fully commissioned. The full trigger system was active during the LHC injection tests and background particles, from interactions with beam screens, were detected.

2.4 Trigger and Forward Detectors

ALICE uses a number of smaller detector systems (ZDC, PMD, FMD, T0, V0) located at small angles to define and trigger on global event characteristics; in particular impact parameter and event reaction plane.

The Zero Degree Calorimeters (ZDC) consists of two sets of hadronic calorimeters located 116 m from the interaction point on both sides of the experiment and two small electromagnet calorimeters located on one side just outside the L3 magnet. The Photon Multiplicity Detector (PMD), consisting of a few m^2 of pre-shower detectors (a lead converter sandwiched between two planes of cellular honeycomb gas detectors), will search for non statistical fluctuations in the ratio of photons to charged particles and measure collective flow and transverse energy of neutral particles. The ACORDE scintillator detector is installed on top of the L3 magnet and regularly used during cosmic test runs. The FMD detector (silicon pad detectors) can measure charged particle multiplicity over a large fraction of phase space ($5.1<\eta < -3.4$); the T0 counters (24 Cherenkov radiators with PMT R/O) will provide the event vertex online and the event time with a precision of less than 50 ps; the V0 counters (2x32 scintillator paddles with PMT R/O) provide the main interaction trigger.

All these detector systems were fully installed and commissioned in 2008, with the exception of parts of the PMD, which requires additional external spark protection circuits to improve the robustness of the FEE. All systems were operated both as trigger detector and to monitor background rates during the first LHC injections and the trigger timing was measured and adjusted.

2.5 Online systems (Trigger, DAQ, HLT, DCS, ECS), Offline

All online systems were in continuous use (24x7) as from March '08. They provided to the 14 detectors installed the equivalent of 288 days of data taking in standalone mode (individual detectors) for a total of 8 x 10^9 events. This has resulted in 1.3 PBytes of data collected out of which 41 TBytes have been recorded. The equivalent of 139 days of global data taking (several detectors in common) have been performed for the physics partition used in cosmics and during the LHC start-up (7 x 10^9 events, 443 TBytes of data collected, 235 TBytes recorded). The full

High Level Trigger (HLT) data path was tested and in use, providing online reconstruction, event visualization, and data compression. The detectors and the online systems have been controlled by the ECS (Experiment Control System) for a total of 34900 standalone runs and 6600 global runs.

The ALICE offline software (AliRoot) was ready in time to process data from the first LHC beam. Cosmic data reconstruction was routinely performed with a special tuning of the reconstruction parameters. The analysis framework is production ready for Grid analysis and for prompt parallel analysis on PROOF clusters at CAF and GSI. Information needed for analysis was automatically extracted and stored continuously in the Condition Data Base.

3. Early Physics Prospects

The main use of pp data in ALICE is as a baseline comparison measurement for the heavy ion program, where many results are expressed as a ratio of (properly scaled) cross sections between nucleus-nucleus and proton-proton collisions. However, the specific capabilities of ALICE at midrapidity (good acceptance down to very low momenta and PID) allow a number of large cross section QCD measurements which are unique at LHC. These include a detailed survey and characterization of minimum bias pp collisions (multiplicity, p_t distributions, particle production, ...), which will allow a good tuning of event generators (which differ widely in their predictions for LHC) and a careful evaluation of the background caused by event pile-up at the nominal LHC luminosity. Specific measurements also include baryon production at midrapidity (to elucidate the mechanism of baryon number transport) and heavy quark production (charm/beauty) down to zero transverse momentum. The prospects for ‘first physics’ measurements, requiring only days to weeks of data taking, as well as some topics relevant for heavy ion beams are described elsewhere in these proceedings. The full menu of physics topics and the expected performance is summarized in the ALICE Physics Performance Reports [2, 3].

4. Summary

ALICE met its installations goals for the first year configuration by mid 2008. The detector is however not yet complete, as a number of additional systems have been added over the years (the latest being the EMCAL jet calorimeter in 2008). Commissioning and initial calibration/alignment during an extensive 6 month cosmic data taking period and the - unfortunately much shorter - LHC injection tests went rather smooth, without hitting major obstacles (of course a large number of minor/medium size problems where found and solved along the way). The detector performance, as far as could be verified without interactions, was found to be within or very close to specifications.

References

[1] The ALICE Collaboration, K Aamodt *et al.,* JINST **3** (2008) S08002.

[2] The ALICE Collaboration, F Carminati *et al.,* J. Phys. G **30** (2004) 1517.

[3] The ALICE Collaboration, B Alessandro *et al.,* J. Phys. G **32** (2006) 1295.