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Status of the ALICE Experiment

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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 detector has been in the making for almost 20 years and it is now ready to exploit the rich discovery potential of the LHC. This report describes the main features of ALICE, the present status of the detector and some commissioning results.

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1. Introduction

The ALICE collaboration has presented a technical proposal in 1996 and the experiment was approved in 1997. The collaboration currently consists of around 1000 members from about100 institutes spread over 30 countries. ALICE is a dedicated heavy-ion detector built to exploit the unique physics potential of nucleus-nucleus interactions at LHC energies. The aim is to study the physics of strongly interacting matter at extreme energy densities, where the formation of a new phase of matter, the quark-gluon plasma, is expected [1] [2]. ALICE is also studying proton-proton collisions both as a comparison with heavy-ion collisions and in physics areas where ALICE is competitive with other LHC experiments. Because of the excellent tracking capabilities down to momenta 100 MeV/c and the powerful particle identification capabilities, ALICE has a unique physics potential with proton collisions.

The LHC will collide lead ions at 5.5 TeV/nucleon pair, corresponding to around 30 times the energy of RHIC. During 2010, LHC should collect a sizeable data sample with collisions at 7 TeV/proton pair, which is close to eventual energy of 5.5 TeV/nucleon pair for lead collisions, of which ALICE therefore must make very good use. The current 2010 LHC plan includes a first heavy-ion run at the end of the year.

On Monday November 23rd 2009, only 4 days after the presentation of this paper, ALICE and the other LHC experiments recorded the first proton collisions at the LHC injection energy of 450 GeV/beam. In the following weeks, around 500k p-p collisions at 450 GeV and 30k p-p collisions at 2.36 TeV were collected and the first results on charged particle pseudo-rapidity distributions were published by the ALICE collaboration [3].

2. Detector Design Considerations

The ALICE detector, shown in Figure 1, is described in detail in [4]. The principle design considerations of ALICE are: tracking and identification of particles down to very low momenta of about 100 MeV/c and up to a few hundred GeV/c; reconstruction of short-lived particles such as Hyperons, D and B Mesons; performance of these tasks in an environment with large charged-particle multiplicities, up to 8000 charged particles per rapidity unit at mid-rapidity.

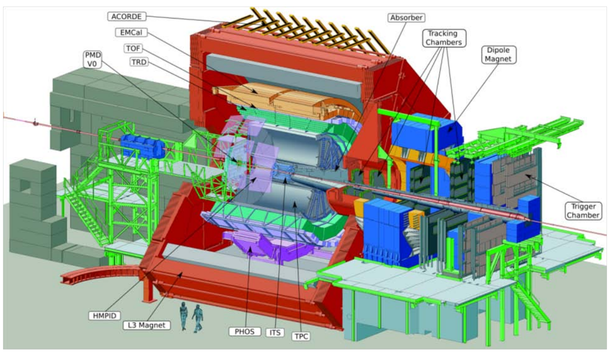

Figure 1: Layout of the ALICE detector.

Hadrons, electrons and photons are detected and identified in the central rapidity region (-0.9 $< \eta <$ 0.9) by a complex system of detectors immersed in a moderate (0.5 T) magnetic field. Tracking is performed with six layers of silicon detectors (ITS), a large-volume Time-Projection Chamber (TPC) and a high-granularity Transition-Radiation Detector (TRD). Particle identification in the central region is performed by measuring energy loss in the tracking detectors, transition radiation in the TRD, Time Of Flight (TOF) with a high-resolution array, Cherenkov radiation with a High-Momentum Particle Identification Detector (HMPID), and photons with a crystal PHOton Spectrometer (PHOS). A lead-scintillator EMCALorimter covers the outer perimeter of the central region. The TRD and EMCAL projects were only recently added to the ALICE experiment, so it was always the plan to complete these systems in future LHC shutdown periods.

The detection and identification of muons is performed with a dedicated spectrometer, including a large warm dipole magnet of 0.7 T maximum field and covering a domain of large rapidities (-4.0 $< \eta <$ -2.4). Additional detectors located at large rapidities complete the central detection system to characterize the event and to provide the interaction trigger. They cover: a wide acceptance (-3.4 $< \eta <$ 5.1) for the measurement of charged particles and triggering (Forward Multiplicity Detector - FMD, V0 and T0 detectors); and a narrow domain at large rapidities (2.3 $< \eta <$ 3.5) for photon multiplicity measurement (Photon Multiplicity Detector - PMD; beams' rapidity to measure spectator nucleons in heavy-ion collisions (Zero-Degree Calorimeters - ZDC).

3. Detector Installation Status

ALICE is situated at LHC Point2 and is housed in the cavern of the former LEP experiment L3. After removal of the L3 detector, the adaption of the L3 solenoid magnet for the ALICE experiment started in 2003. Preparation of the experimental area and support structures continued in 2004, the dipole magnet was installed and commissioned in 2005. The year 2006 saw the installation of the absorbers for the muon system, the central ALICE support structure (Spaceframe) and the arrival of the HMPID detector and first TOF and TRD modules. The major cavern activities were carried out in 2007, with installation of the tracking systems TPC and ITS, the installation of most of the services, and the installation of more TOF and TRD modules. The year concluded with a first cosmic commissioning run. Further commissioning runs in 2008 prepared the detector for the LHC start in September of the same year, where ALICE recorded first interactions of single circulating beams. After the LHC incident on September 19th 2008, the ALICE detector was again opened, installation of TRD modules continued and the first EMCAL modules were inserted in ALICE. Improvements of services, and further cosmic commissioning runs brought the ALICE detector into excellent shape for first LHC collisions and physics exploitation in November 2009.

The detectors that remain to be installed in the next LHC shutdowns are 11 TRD modules (7 installed), 6 EMCAL modules (4 installed) and 2 PHOS modules (3 installed). An extension of the EMCAL system by another 6 modules that will allow to recording of back to back jets is under consideration.

4. Global Commissioning Status

ALICE has been in continuous cosmic run operation starting from August 15th 2009 until

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the first LHC collisions end of November 2009. The DAQ has recorded cosmic data during 70% of this period, where the remaining 30% were partly used for calibration and stand-alone tests of the sub-detectors. The fraction of time lost due to starting of runs or abnormal behavior of the system was reasonably small. About 110 TByte of data were recorded during this cosmic run period. The ALICE DAQ can sustain a very high bandwidth tailored for the high multiplicity heavy ion collisions. A 7 day test of data migration at 1.275GB/s to the computing center without data recording and a 4 day test with 0.95GB/s with recording to tape qualified the specified DAQ performance. For proton proton collisions the current ALICE configuration results in an event size of around 300 kByte. The maximum event rate is at this moment limited by the ALICE detector to around 1 kHz.

ALICE uses a High Level Trigger (HLT) processor farm of which currently 60% is installed. With this setup the HLT is able to accept the full 1 kHz readout rate for proton proton collisions and to perform full reconstruction of the events. For Pb-Pb collisions the full HLT will be able to accept and reconstruct 200 Hz of central collisions and reduce the recording rate to a level that can be handled by the data storage.

The ALICE computing grid comprises 15k CPUs and around 5PB of disk and tape storage distributed in over 90 computing centers around the world. An average of about 6000 simultaneous jobs have been running at any time during the year 2009.

Several million cosmic events were recorded with different magnetic field configurations for system commissioning and detector calibration and alignment prior to the first LHC collisions.

5. Subdetector Commissioning and Calibration

In the following, a few of the main commissioning result are described.

5.1 Inner Tracking System (ITS)

The ALICE inner tracking system comprises 10 million silicon pixels (SPD) arranged in two radial layers, 133k channels of a silicon drift detector (SDD) arranged in two layers and 2.6 million channels of a double sided silicon strip detector (SSD), also arranged in two layers (Figure 2).

The first pixel layer is positioned at a distance of only 5 mm from the beampipe for good impact parameter resolution. A unique feature of the SPD is a fast OR signal from all chips that allows Level0 triggering on interactions with programmable topologies. This was used to efficiently select tracks that pass the TPC an all ITS detectors. The calibration of the silicon drift detector (SDD) is a major issue since the drift speed varies strongly with temperature. For this purpose 33x3 charge injectors are implemented in known positions for each half module. During a three month period in 2009 the drift speed of around 6.5 μm/ns varied only within 0.2%, which is close to the specified value. The double sided silicon strip detector (SSD) uses the matching of the signals on p and n side to reduce noise and ghost clusters, which is therefore also an item for precise calibration.

Overall the silicon detector is in very good shape. Between 10 and 15% of the SPD are currently off due to problems with the evaporative cooling of the detector. About 5% of the SDD detector are currently off due to a variety of issues not related to cooling. The SSD system has around 10% of channels off due to issues of connectivity and high leakage currents.

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Besides calibration of the individual ITS detectors the relative alignment of the detector modules was performed with COSMIC tracks. Using the SPD trigger, a trigger rate of 0.2Hz was achieved and 10^5 events were collected already in the year 2008. The alignment results are reported in [5]. For the SPD, the results indicate an effective space point resolution of about14 μm in the most precise direction, only 25% worse than the resolution of about 11 μm extracted from the Monte Carlo simulation without misalignments. For the SSD the results indicate that the residual misalignment for modules on ladders, after correction with measurements of module positions at the time of construction, is less than 5μm, i.e. negligible with respect to the intrinsic resolution of this detector in the most precise direction. The residual misalignment spread for the ladders with respect to the support cones amounts to about 20 μm.

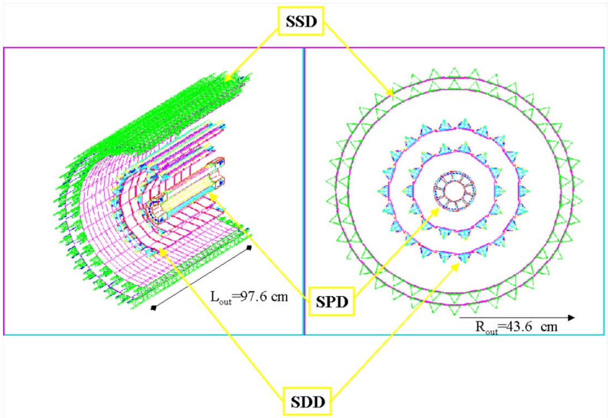

Figure 2: Geometry of the ALICE Inner Tracing System.

5.1.1 Time Projection Chamber

The ALICE TPC is described in detail in [6]. With it's length and diameter of 5 m×5 m, half a million of readout pads and 1000 samples in the time direction, it comprises 0.5×10^9 'readout channels'. Figure 3 shows a cosmic shower event in the TPC reconstructed by the HLT. The fact that the TPC is operated with a non saturated gas mixture poses the requirement of a temperature variation of <0.1 K across the entire drift volume, which was achieved by a long procedure of tuning the active cooling of the readout chamber bodies and the heat screens around the barrel of the TPC. The achieved noise figure of 700 electrons is even smaller than the specified 1000 electrons. By separately reconstructing bent muon tracks in the upper and lower half of the TPC, the momentum resolution can be determined, which is presented in Figure 4. A resolution of 6.5% at 10 GeV is achieved. Injecting Kr83 in the TPC gas allowed pad by pad gain calibration and a preliminary dE/dx resolution of 5.5% was achieved. In conclusion, the ALICE TPC is in excellent shape.

5.2 Time of Flight Detector

The ALICE Time of Flight (TOF) detector uses the novel Resistive Plate Chamber (RPC) technology, it is situated at a radial distance of 385 cm from the beamline and uses about 157k

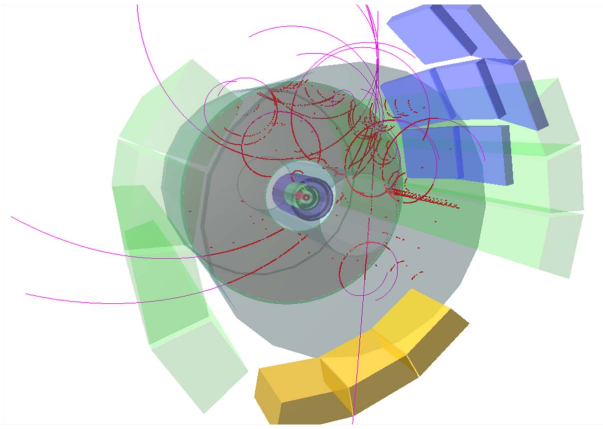

Figure 3: Event display of a cosmic shower in the ALICE TPC.

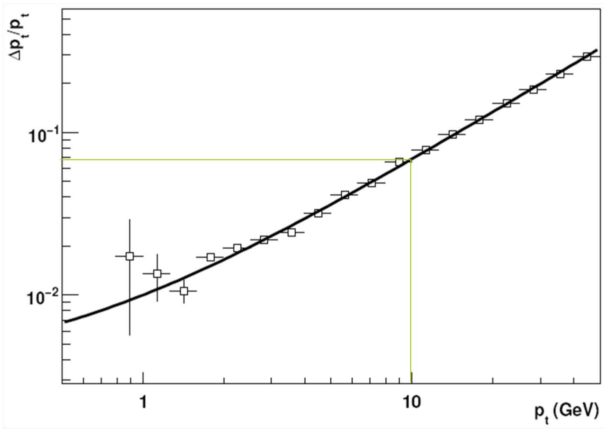

Figure 4: Preliminary TPC momentum resolution derived from cosmic data.

channels. The goal is a system time resolution of 80 ps, that should be achieved by calibration with proton collisions. Using cosmic muons, a preliminary resolution of 111 ps is achieved, which allows already a 3σ separation of Kaons and Pions up to at least 1.8 GeV/c and Kaons and Protons up to at least 3 GeV/c.

5.3 Transition Radiation Detector

The 7 (out of a total 18) installed TRD modules performed successful data taking with cosmic rays and Kr83 decays. The internal detector alignment is well advanced, and the Global Tracking Unit (GTU) selects good cosmic events with around 99% purity of good tracks in the TRD. After initial operation with and Ar/CO_2 gas mixture the final Xe/CO_2 gas is in use since November 2009 and particle tracks have been recorded. The TRD system will be completed in the next LHC shutdown periods.

5.4 Muon Spectrometer

The ALICE muon spectrometer is placed in the forward region and consists of a muon filter, a dipole magnet, 5 stations of tacking wire chambers with a total of 1.1 million readout pads and two stations of trigger RPCs with about 20 k channels. During the 2009 cosmic run, the muon trigger was fully operational about 96% of the tracking detector were read out. A few 100k of horizontal muons were collected with several magnetic field setting for validation of the system.

6. Conclusion

ALICE performed an extended cosmic commissioning run in 2008 and between August and November 2009 for calibration and verification the the experiment. This period was followed by a very successful data taking period during first LHC operation in November and December 2009, and first physics result were already reported.

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