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Status of the ALICE Experiment

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Status of the ALICE experiment

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Abstract. ALICE (A Large Ion Collider Experiment), the dedicated detector designed to study nucleus–nucleus collisions at the LHC, is developing rapidly. While the experimental area is being cleared of the last elements of the L3 detector, who stopped data taking at the end of 2000, the ALICE collaboration is at work for the first steps of the installation of the detector, namely the refurbishing work on the L3 magnet and the adaptation of the infrastructure.

In the meantime, in the 77 laboratories of the Collaboration, the work of preparation of the detectors is changing gear: the R&D is completed on almost all elements, with some notable advances in innovative technologies, and the major detectors components have entered the production phase.

Moreover the TRD, a major new detector designed to expand the ALICE capability to identify electrons, has reached the Technical Design Report stage and is now being discussed by the LHCC.

The status of our understanding of the ALICE Physics potential is described in other papers in these proceedings[4, 5, 6], so I will concentrate here on a brief description of the ALICE detectors, with mention of the most recent results achieved.

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1 Introduction

At the LHC, it will be possible to explore a radically new regime of matter, increasing by a large factor in both volume and energy density from those achieved at the SpS and at RHIC. Thanks to the huge number of secondaries produced, it will be possible to measure many of the relevant variables on an event–by–event basis. The region of x_{Bj} explored will extend towards smaller-x values by two orders of magnitude, while particle production will be dominated by hard rather than soft processes. The LHC energy and luminosity will allow the full spectroscopy of the Y family and of D and B mesons, and will make accessible high-P_T probes of the early stages of the system evolution such as modifications in the fragmentation function of Jets. The higher initial temperatures will make the measurement of direct photons a potentially powerful tool. Last but not least, at the LHC the central region is expected to be essentially baryon-free, thus allowing a more direct comparison with lattice QCD calculations and with the conditions of the primordial Universe.

To exploit the extraordinary physics potential of nuclear collisions in the LHC, the ALICE Collaboration has designed a general purpose heavy ion detector, which will address most sensitive observables, detecting and identifying hadrons, leptons and photons over a wide range of momenta. The requirement of the combined capability to track and identify particles of very low up to fairly high P_T, and to reconstruct the decays of hyperons and D and B mesons in an environment with predicted multiplicities up to 8000/unit rapidity, has led to a unique design, with a very different optimization from the pp experiments at LHC. It relies on very high-granularity, yet relatively slow drift detectors, a weak, very-large volume magnetic field, and on specially developed detectors for particle identification.

The collaboration has grown steadily along the years to count now over 900 Physicists from 77 institutions in 27 countries. In addition, several new institutes from Europe, Latin America and South Africa are in the process of joining ALICE. Moreover, now that the experiments at the Relativistic Heavy Ion Collider at BNL are running and producing a wealth of physics results[7], a collaboration of about 50 researchers from several US institutions has submitted to DOE a proposal to join ALICE with a specific focus in the high-P_T observables which are of limited accessibility at RHIC. For the same reasons, several Japanese groups active in experiments at RHIC are now considering the possibility of joining ALICE as the natural continuation and complement to the Physics program they are pursuing at RHIC.

In addition to the running with Pb ions, ALICE will study collisions of ions of lower mass to vary the energy density, while running with proton beams (both pp and p-nucleus) will provide reference data. Thanks to the specificity of the ALICE detector, the pp reference data will allow a very rich program of pp physics[6], complementary to the ones carried by ATLAS, CMS and LHCB.

The general ALICE layout is shown in Fig.1 It consists of a central ($|\eta| \leq 0.9$) detector covering the full azimuth and a forward ($2.4 \leq \eta \leq 4$) muon arm, complemented by a forward photon counting detector and a multiplicity detector covering the forward rapidity region (up to $|\eta|$=5.1). A system of scintillators and quartz counters will provide fast trigger signals, and a zero degree calorimeter will measure the impact parameter. The central detector will be embedded in large magnet with a weak field of <0.5 T, and will consist of a high–resolution inner tracking system, a cylindrical time projection chamber, particle identification arrays (time of flight and ring imaging Cerenkov detectors), a transition radiation detector for electron identification and a single–arm high-resolution electromagnetic calorimeter[1, 2, 3].

2 Design Considerations

The LHC will run with Heavy Ions roughly 10% of its running time, and therefore we assume effectively 10^6 seconds of running time per year with Pb beams. The event rate for Pb–Pb collisions at the LHC, given the luminosity of 1.0 x 10^{27} $cm^{-2}s^{-1}$ and an inelastic cross– section of 8 b, will be 8000 minimum-bias collisions per second [14]. Of these events, some 5% correspond to the most central collisions. This low interaction rate has a crucial role in the design of the experiment, since it allows the use of slow but high–granularity detectors, like the time projection chamber (TPC) and the silicon drift detectors (SDD's). We expect to collect a few 10^7 central events/year. To increment the statistical significance of the high-P_T observables, especially the states of the Υ family, dedicated trigger systems will select candidate events in the muon spectrometer and in the TRD. A partial readout of the relevant detectors will be performed following these triggers.

The experiment is designed to cope with the highest anticipated multiplicities, which for central Pb–Pb collisions are 8000 charged particles per unit of rapidity. At the moment predictions range from 2000 to 8000 particles per unit η[11]. The rapidity acceptance has to be large enough to allow the study of particle ratios, p_t spectra and HBT (Hanbury-Brown-Twiss [13]) radii on an event-by-event basis, meaning several thousand reconstructed particles per event. Detecting the decay of particles at $p_\mathrm{t} < m$ requires about 2 units in rapidity (for masses above 1–2 GeV) and corresponding coverage in azimuth. A similar acceptance is necessary to collect a reasonable (few 10^3) sample of Υ in the dielectron channel, given the expected luminosity and running time. The rapidity coverage of the central detector ($|\eta| < 0.9$) has been chosen as a compromise between acceptance and cost. To be sensitive to the global event structure, $\mathrm{d}N_{ch}/\mathrm{d}\eta$ will be measured with multiplicity detectors in a large rapidity window ($-5.1 < \eta < 3.4$).

The design of the tracking system has primarily been driven by the requirement for safe and robust track finding. It uses mostly three-dimensional hit information and dense tracking with many points in a weak magnetic field. The field strength is a compromise between momentum resolution, low momentum acceptance, and tracking and trigger efficiency. The momentum cut-off should be as low as possible (< 100 MeV/c), in order to study collective effects associated with large length scales. A low-p_t cut-off is also mandatory to reject the soft conversion and Dalitz background in the lepton-pair spectrum. At high p_t the magnetic field determines the momentum resolution, which is essential for the study of jet quenching and high-p_t leptons. It also determines the effectiveness of the online selection of high-momentum electrons, which is performed in the TRD trigger processors by an online measurement of the sagitta. The ideal choice for hadronic physics, maximizing reconstruction efficiency, would be around 0.2T, while for the high-p_t observables a field of 0.4-0.5T would be the best choice. Since the high-p_t observables are the ones which are limited by statistics, ALICE will run mostly at the higher field.

The most stringent requirement on momentum resolution in the low-p_t region is posed by identical particle interferometry, owing to the large source radii and the correspondingly narrow momentum correlation enhancement. In the intermediate energy regime, the mass resolution should be of the order of the natural width of the ω and ϕ in order to maximize the signal-to-background ratio and, more importantly, to study mass and width of these mesons in the dense medium. At high momenta, the resolution has to be sufficient to measure the energy spectrum of jets via leading particles. The detection of hyperons, and even more of D and B mesons, requires in addition a high–resolution vertex detector close to the beam pipe.

The momentum range for particle identification can be restricted for the bulk of the hadronic signals to a few times the average p_t (>97% of all charged particles are below $p_\mathrm{t} = 2$ GeV/c). Good π/K/p separation (better than 3σ) is needed on a track-by-track basis for the abundant soft hadrons in order to study

HBT with identified particles, decays (hyperons, $\phi \rightarrow$K K and charmed mesons), and event-by-event particle ratios. A statistical analysis (separation better than 2σ) will be sufficient to measure inclusive particle ratios and p_t spectra in the mini-jet region. The e/π rejection has to be sufficient to reduce the additional combinatorial background due to misidentification to below the level remaining from unrejected Dalitz pairs, and extend to sufficiently high p_T to measure the decay of the Υ family in di-electrons.

The accuracy of the single inclusive photon spectra will be determined by systematic errors on photon-reconstruction efficiency and the knowledge of the decay background. An acceptable systematic error can be obtained only at low channel occupancy and therefore requires a calorimeter with small Molière radius at a large distance (≈ 5 m) from the vertex. The acceptance has been defined such as to keep the statistical errors below the expected systematic ones.

The muon spectrometer is designed to measure the production of the complete spectrum of heavy quark resonances, namely J/Ψ and Ψ',Υ, Υ' and Υ''. Given the production rates and decay geometry, full coverage in azimuth and a minimum acceptance of well over one unit is necessary. In the LHC environment, muons identification is possible only for momenta above about 4 GeV/c, so only in the forward regions, where they are Lorentz-boosted, the measurement of low-p_t charmonia is accessible. Moreover, by separating the rapidity regions of the muon spectrometer and the central detector allows an independent optimization of the two. The coverage ($2.4 \leq \eta \leq 4$) is again a compromise between these requirements and cost. The separation of the various states fixes on the other hand the required mass resolution to better than 100 MeV in the 10 GeV mass range. The very high multiplicity of PbPb collisions at the LHC imposes very tight constraints on the design of the muon spectrometer. In particular, to reduce the hit multiplicity in the tracking chambers to tolerable levels, the hadron absorber needs to efficiently absorb hadron within the spectrometer acceptance, while preserving the mass resolution, and shield the spectrometer from the particles at higher rapidities, in particular the ones emerging from the beam pipe. The absorber is located very close to the interaction vertex ($z = 90$ cm), and the material interposed is minimal. The readout rate allowed for the muon spectrometer is much higher than for the central detectors, and therefore for part of the muon triggers only some of the central detectors will be read out, namely the Photon Multiplcity Detector, the Pixel detectors, and the Forward detectors, still providing a rather detailed characterization of the events.

3 Detector layout and status

3.1 Magnet

The ideal choice for ALICE is a solenoid with a moderate field of $< 0.5T$, large enough to allow full tracking and particle identification inside the coil. In particular, because of the particle density, even using the highest density crystals available the Photon Spectrometer must be placed at about 5 m from the interaction vertex. The existing magnet of the L3 experiment is the only one to fulfill these requirements. The growing interest in high-p_t observables

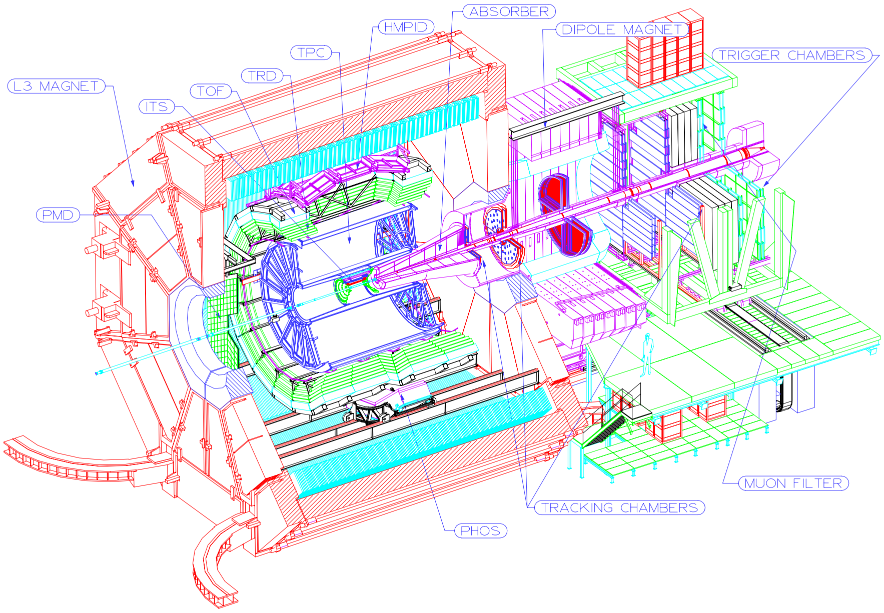

Fig. 1. Longitudinal view of the ALICE detector.

has led to the specific requirement of running the magnet up to its maximum nominal field of 0.5 T. To ensure that this feature is maintained for the long expected life of the experiment, ALICE is carrying out a major refurbishing of its cooling circuits. Moreover, studies have been performed that demonstrated that even in presence of a failure in one of the two circuits, a 0.4T field could still be reached by lowering the coolant temperature and increasing its speed. To improve the field homogeneity, an important ingredient for robust tracking in a high-multiplicity environment, ALICE will extend the iron magnet doors to a smaller radius. The two "door plugs", almost 50 Tons each, are being built in Russia, and will be installed in the course of 2002. The pit and the magnet will soon be ready to receive the first elements of the ALICE detector.

The ALICE central detectors will be held by a spaceframe structure sliding on rails, which optimizes both easy access to the detectors for installation and maintenance and the amount of material on the way of the particles to the outer detectors. The spaceframe design has therefore been carefully optimized so that the acceptance in particular of the TRD would not be significantly limited, while providing the necessary rigidity necessary to ensure the accurate and stress-free positioning of the TPC field cage. The design phase of the spaceframe is now completed, and the production is expected to be completed in 2002.

3.2 Inner Tracking System

The inner tracker provides secondary vertex reconstruction for hyperon and charmed meson decays, tracking and identification of low-p_{t} particles, and improved momentum resolution for the higher-p_{t} particles which also traverse the time projection chamber. The six cylindrical layers are located at r=4, 7, 15, 24, 39 and 44 cm, and cover $|\eta| < 0.9$ for all vertices located within the length of the interaction diamond ($\pm 1\sigma$), i.e. 10.6 cm along the beam direction (z). The first layer of pixel detectors has a more extended coverage ($|\eta| < 1.98$), to provide, together with the forward multiplicity detectors, a continuous coverage in rapidity for the measurement of charged multiplicity. Four layers will have analog readout to provide particle identification via $\mathrm{d}E/\mathrm{d}x$ in the $1/\beta^2$ region, which will give the ITS a stand-alone capability as low-p_{t} particle spectrometer. Because of the particle density and to achieve an impact parameter resolution below 100 μm, pixel detectors have been chosen for the innermost two layers, and silicon drift detectors for the following two. Double-sided silicon micro-strip detectors will equip the two outer layers. Minimization of the material thickness is an absolute priority, and the average thickness, all included, is kept below 1% of X_0 per layer. To keep material to a minimum, spaceframe carbon fiber structures are used to support the outer layers, weighing just 28 grams/meter each and yet providing a stiff support for the detectors and their electronics (the sagitta is below 100 μm over a meter). Over one half of these structures, result of a joint development with former Russian military industry, have already been produced.

The overall support structure and the installation procedure of the ITS are very complex, since access to the system is severely limited by the presence of the absorber for the muon arm, the need to limit showering into the TPC constrains the amount of material to be used, and the first pixel layer is positioned at just six millimeters from the beam pipe. Moreover, the about 10 kW of power dissipated by the over 12 million channels of electronics needs be removed maintaining on the outer surface of the ITS the thermal uniformity required by the TPC. A hybrid solution incorporating liquid cooling and a moderate air flow has been developed. This formidable set of system problems, of which the overall cabling in an extremely crowded space is not the least, has now found satisfactory solutions, which are being tested in several 1:1 scale mock-ups, which utilize mechanical structures produced with the same molds as the final ones, and thousands of connecting elements, heaters and cooling elements.

The heart of the Silicon Pixel Project is the front-end chip, a 13M transistors, 2cm^2 mixed-mode chip realized in radiation tolerant 0.25 μm CMOS technology. Each chip features over 8,000 independent, 50x425 μm^2 readout cells, with power consumption below 100 μW/channel. The detector has made remarkable progress in the last year. The functionality and radiation hardness of the prototype chip have been extensively tested in 2001, demonstrating that it does satisfy the ALICE specifications, and a first production batch has been produced and is now being tested. At the same time, bump-bonded assemblies have been realized with good yield with two producers, thus opening the way to the actual construction of the detector. Also the ancillary electronic chips are now in advance prototyping stage. The last challenge for the project is to reach the design material budget, which requires 150 μm-thick chips to be assembled with 200μm-thick sensors. Preliminary tests are very encouraging, and the yield will be assessed in the first half of 2002.

The design of the Silicon Drift Detectors[8], a very ambitious device of over

60 cm^2 of active area with integrated shaping of the drift and collection field and calibration devices, has been frozen. A pre-production sample of about 50 detectors has achieved the desired yield of about 70%. The mass production has already been tendered and will start mid-2002. The frontend chip, which includes a preamplifier, a 256-cells deep analog memory and a 10-bit ADC each for 64 channels, has been prototyped in radiation-tolerant, 0.25 μm CMOS technology, and satisfies the ALICE specifications. Also the digital chips which perform the digital buffering, the data compression and the controls have been successfully prototyped.

The double-sided silicon strip detectors which equip the two outer layers of the ITS are also in production, after the tender has been adjudicated to three producers. The frontend electronics is based on a readout chip which performs the preamplification, S/H, and serial analog output. The chip, after successful prototyping in standard CMOS, has been redesigned in the same technology used for the frontend of pixels and drift detectors. The new prototype, developed within one year, performs to specs and production is expected during 2002.

For the construction of the ≈2000 modules of silicon strip detectors and of the ≈300 modules of silicon drift detectors a similar approach has been chosen, which relies on the technology of flexible TAB-bondable Al microcables, which have been developed by an Ukrainian group in the collaboration. This technology allows a modular, robust assembly in which all elements and connections can be tested after each assembly step. Moreover, the use of Al conductor minimizes the material.

3.3 Time Projection Chamber

The TPC[9] is the main tracking detector in ALICE, and it plays a central role in the design of the experiment. It provides track finding, momentum measurement and particle identification via $\mathrm{d}E/\mathrm{d}x$. The TPC has an inner radius of 90 cm, given by the maximum acceptable hit density (0.1 cm^{-2}), and an outer radius of 250 cm, given by the length required for a $\mathrm{d}E/\mathrm{d}x$ resolution of $< 10\%$, necessary for particle identification. The design is optimized for good double-track resolution; in particular, the use of $\mathrm{Ne/CO_2}$ (90/10) minimizes electron diffusion and reduces the space charge. The 72 pad-readout chambers are arranged in two crowns of 18 azimuthal sectors at both ends of the TPC, and feature 570,000 channels. The chambers, after successful test of prototypes, are already advanced in construction, with the inner crown of one side completed, and the outer about to start.

The field cage must provide excellent mechanical precision (250 microns of accuracy in the planarity between the central electrode and the readout chambers) while keeping material to a minimum. Therefore it is realized in composite materials, and has been extensively prototyped. The field cage, with its 88m^3 is the largest such object ever built, is assembled close to the ALICE pit. To house it, the floor of the assembly hall had to be excavated two meters deep over an area of 240 square meters. The components are now being built, and the assembly is expected to be complete by the end of 2002.

The readout chain includes, for each channel, a preamp-shaper, a 10-bit ADC and a fairly complex digital circuit which performs tail cancellation, digital baseline restoration, data compression and multi-event buffering for event derandomization. In a quite unconventional approach, the custom digital design has been integrated in the same chip with a commercial ADC, thus reducing substantially the complexity of the assembly and the overall cost. The final prototypes of both the PASA and the ADC/digital chip have been submitted and will be tested at the beginning of 2002.

The overall performance of the ALICE tracking system has been simulated taking into account the details of the detector performance, and found to provide an efficiency in the TPC better than 90% practically independent of p_{t} down to about 100 MeV/c. The performance of the ALICE tracking, including the impact parameter resolution and the efficiency in the identification of secondary vertices, is described in detail in ref [4].

3.4 Particle Identification System

One of the distinctive features of ALICE is the particle identification capability, which is realized using a number of different techniques. This robust PID system will allow the identification of a large number of protons, pions and kaons in each Pb-Pb event, so that their transverse momentum spectra will be studied on an event-by-event basis. Coupled with the excellent vertexing capability of the ALICE tracking system, Hyperons (including the rare Ω) and the hadronic decays of charmed mesons will be measured. The performance of the ALICE PID system is discussed in detail in[4]. PID is provided over a large part of the phase space by the combination of $\mathrm{d}E/\mathrm{d}x$ measurement in the silicon and in the TPC with a barrel TOF at r=3.7 m, while a TRD allows electron identification above 1 Gev/c. A smaller-area Ring Imaging Cherenkov detector, covering about 15% of the acceptance of the ALICE central detectors, will allow the identification of hadrons up to higher momenta (π/K to 3 GeV/c and K/p to 5 GeV/c) .

3.4.1 The Time Of Flight Detector The TOF is a 140-m^2, 160,000 channel system, aiming at an overall time resolution of the order of 100 ps. This formidable technological problem has been solved by the development of simple, robust devices with high efficiency and excellent timing properties: the multigap resistive plate chambers (MRPC). The RPC is a gaseous detector with resistive electrodes, which quench the streamers so that they do not initiate a spark breakdown. Thus the RPC can be operated at much higher gains in avalanche mode. The multigap RPC is made of a series of gas gaps with a single set of read-out strips reading out all gas gaps in parallel. The intermediate plates take correct voltage due to electrostatics and are kept at correct voltage with flow of positive ions and electrons generated by the avalanche. The intermediate planes are “transparent” for avalanche signals, thus the induced signal on the external electrodes is the “analog sum” of the avalanches in all the gaps. The MRPC design has been improved during 2001, and has now reached its final form, consisting of a double stack with 2x5 gaps using low-cost glass and a simple technique using fishing wire to achieve uniform gaps. Test beam measurements have been performed with a full module and typical values of the resolution are in the 50-60 ps range, with efficiency above 99%. Also the lifetime and rate capability have been measured to be in excess of the ALICE requirements. Including the sources of timing errors, this system would guarantee the identifications of π, K and protons up to 2.5 GeV/c.

3.4.2 The High Momentum Particle Identification Detector For the high-momentum particle identification a RICH detector of the proximity focusing type is used, placed at a distance of $\approx$ 4.5m from the beam axis. The HMPID will consist of seven modules, each 1.5x1.5 m^2, for a total of over 160,000 readout channels. It will use a liquid C_6F_{14} radiator and a MWPC with pad readout as UV detector. The photo-cathode will be a thin layer of CsI evaporated onto the pad plane. The RICH will extend the 3 σ limit to $\approx$ 3 GeV/c for π/K identification and to $\approx$ 5 GeV/c for K/p. The HMPID is well into the construction phase, having defined and contracted all elements of the detector, and even already produced the chips for the frontend and readout electronics. The production of the first module is essentially complete, and will continue with the other seven for the coming years. To avoid aging of the photo-cathodes, they will be evaporated as late as possible, depending on the schedule of the LHC. A large prototype of the ALICE HMPID, corresponding to two-thirds of one of the seven modules, has been installed in the STAR experiment at RHIC, and is now operating and producing physics results. The ALICE HMPID is described in more detail in [10].

3.4.3 The Transition Radiation Detector Electron identification is achieved in ALICE by combining the particle identification capability of ITS, TPC and TOF and complementing it with a dedicated Transition Radiation Detector. The TRD will consist of six layers of radiator foil stacks followed by Time Expansion Chambers filled with Xenon/CO_2, providing an e/π rejection power of 100 in high multiplicity operation. The TRD fast tracking capability can also be used to trigger on high-p_t leptons, thus enriching their statistical sample, and hadrons, thus providing an essential trigger for jet leading particles. The primary purpose of the TRD is therefore to allow the measurement of D and B mesons in their semileptonic decays, and the Charmonium and Bottonomium families in their decay in electron pairs. The performance of ALICE in this essential physics channel is dicussed in[5]. The detector in its full configuration will cover the central barrel region of ALICE, and will consist of 540 modules organized in 36 azimuthal sectors, corresponding to the azimuthal segmentation of the TPC. The TRD will therefore need 800 m^2 of high-granularity readout chambers, equipped with over one million electronics channels. The elctronics will provide the time and analog information of the clusters, and proceed to a fast local reconstruction to produce a Level-1 trigger within 6 μs after the collision. With the currently available funding about half of the detector can be installed at LHC turn-on. The TRD technical design report has been submitted to the LHCC in October 2001, and is now being discussed. Different radiator configurations have been studied in beam tests, to verify that a structure fulfilling the detector mechanical requirements would nevertheless provide for a pion detection efficiency of less than 1% at 90% detection efficiency for electrons for momenta larger than 1 GeV/c. The front-end electronics design is advancing: the preamplifier has been successfully prototyped, and the digital chip, a very complex design that includes the ADC, the tracklet pre-processor, processor and merger and ancillary logic/interfaces, has been positively reviewed and the first prototype in now being produced.

3.5 Photon Spectrometer (PHOS)

Prompt photons, π^0's and η's will be measured in a single-arm, high-resolution electromagnetic calorimeter. Prompt photons are a small fraction of the meson decay photons, which must be accurately known before the former can be determined. This requires high granularity, and good energy and spatial resolution. The cell size must not exceed one Molière radius R_M and the occupancy 3%. The gamma reconstruction efficiency should be measurable to an accuracy of $\approx$ 4%. The PHOS will be located 5 m vertically beneath the interaction region and will be built from $\mathrm{PbWO_4}$, a material with small Molière radius and high light output. Crystal pre-production has started at the plant of North Crystals Co, Apatity, near Murmansk, Russia. By the end of 2001, 25 furnaces are in operation for the $\mathrm{PbWO_4}$ crystal growth, compared to only 4 one year ago. More than 1500 ingots have been grown. Some 600 shaped crystals of dimensions 22x22x180 mm^3 have already been accepted based on the results of laboratory tests. The 256 detector channels prototype electromagnetic calorimeter with 70 channels in operation was tested with high energy electrons in the energy range of 0.6-30 GeV. Hamamatsu APDs were used as photo detectors, since they allow to measure higher photon energies than PIN diodes, while providing similar performance at low energy. The system design is basically complete. The electronics will provide both energy and time information to reject antineutrons and a trigger for high-p_t photons and is in an advanced design stage.

3.6 Forward Detectors

Several smaller detector systems (ZDC, PMD, FMD, CASTOR, T0, V0) located at small angles will define and/or trigger on global event characteristics; in particular impact parameter, event reaction plane, multiplicity of charged secondaries and precise time of the event.

A set of four small and very dense calorimeters will be used to measure and trigger on the impact parameter of the collisions. Owing to their different Z/A values, it is possible to separate in space the neutron and proton spectators and the beam particles (Z/A $\simeq$ 0.4) by means of the first LHC dipole. Therefore, we will detect the neutron and proton spectators in two distinct calorimeters, made respectively of tantalum and brass with embedded quartz fibers, located on both sides of the interaction region $\approx$ 90 m downstream in the machine tunnel. Construction of the detector has started in 2001, while in parallel different photo detectors have been tested with the electromagnetic prototype. The amount of light from this prototype, when exposed to an electron beam of a few tens of GeV, is similar to that expected at LHC for a 2.7 TeV neutron in the hadronic calorimeter.

A similar calorimeter (CASTOR), located closer to the interaction region opposite to the muon arm, will measure electromagnetic and hadronic energy and the longitudinal evolution of showers in the baryon-rich, large rapidity region. A prototype comprising 3 reading units (October 2001.

The Photon Multiplicity Detector (PMD) will search for non statistical fluctuations in the ratio of photons to charged particles, measure collective flow and transverse energy of neutral particles, and in addition determine the reaction plane. It consists of a few m^2 pre-shower detector (a lead converter sandwiched between two planes of cellular honeycomb gas detectors) and is mounted behind the TPC opposite to the muon spectrometer. The location of the detecor has been moved closer to the interaction vertex (about z=-3.5 m) in order to minimize the material on front of the detector. Several prototypes were tested with both electron and pion beams and a similar device is being constructed by the same groups for the STAR experiment at RHIC.

The FMD detector (silicon pad detectors) will measure the pseudorapidity distribution of charged particles over a large fraction of phase space ($-5.1 < \eta < 1.7$ and $1.7 < \eta < 3.4$) and full azimuth. In this way, FMD and ITS together provide for all vertices in the interaction diamond continuous coverage for rapidity measurement over most of the phase space ($-5.1 < \eta < 3.4$). The FMD will be mosaics of silicon pad detectors organized in 5 disks, two on the muon arm side, where space is more limited, and three on the opposite one. The farthest disk will be mounted on a common assembly structure integrating also the PMD and one arm of the T0 and V0 detectors.

The T0 counters (24 Cherenkov radiaters with PMT R/O) will provide the event time with a precision of less than 50 ps. The V0 counters (scintillator paddles with PMT R/O) will be used as main interaction trigger and to locate the event vertex. By requiring the coincidence of both sides, the beam-gas interactions will be efficiently rejected, a measure particularly important for muon triggers.

The overall design of the forward detectors has been finalized in the course of 2001, and prototype developments are ongoing.

3.7 The Forward Muon Spectrometer

The forward muon spectrometer will allow the study of vector meson resonances via their $\mu^+\mu^-$ decay. The signals will appear on a continuum due to B and D meson decays and Drell-Yan processes. The spectrometer must have an efficiency for dimuons better than 90% and a mass resolution better than 100 MeV in the Y region and better than 70 MeV in the J/Ψ region. The momentum precision must be about 1%. The muon spectrometer consists of a composite absorber ($\approx 10\lambda_{INT}$) starting close to the interaction point(one meter) to reduce the μ background due to π and K decays. The absorber is carefully designed with layers of both high and low Z materials to reduce multiple scattering and particle leakage. A high-density small angle absorber with a central hole will shield the spectrometer form the particles emitted at angles from 0 to 2 degrees and allow LHC beams to traverse the spectrometer. A final muon identifier filter wall, consisting $\approx 10\lambda_{INT}$ of iron at the end of the spectrometer. The design of the absorber system is being finalized, with particular emphasis on cost effectiveness.

The spectrometer magnet is a large warm dipole magnet with a nominal field of 0.7 T, giving a 3 Tm field integral. The dipole will accept μ at angles smaller than 9 degrees. Both the coils and the yoke are under construction.

Ten planes, grouped in five "stations", of thin multiwire proportional chambers with cathode pad readout placed in front, inside and following the dipole will measure the muon trajectories. The design of the chambers for the first two stations has been improved considerably compared to the original concepts, both to be more robust in handling the high track density in the inner regions and to be essentially free of dead areas, thus maximizing acceptance. The design of these "frameless" chambers has been tested and construction of the first quadrant is starting. For the larger chambers of the following stations, which are organized in slats, prototypes have been successfully tested, and the tooling for the series production is being constructed. Also the development of the readout electronics is completed, and production of the frontend chips (MANAS) is starting in Indian industry.

Two single gap RPC planes will detect the particles emerging from the muon filter and trigger the spectrometer. The low resistivity chambers will be operated in streamer mode. Prototypes have been extensively tested the CERN GIF irradiation facility. It has been verified that indeed the required rate capability and time and space resolutions are achieved and maintained also after an irradiation equivalent to several years of ALICE running. The use of a new concept, dual-threshold frontend chip, especially designed for the streamer mode, has led to a significant improvement of the time resolution, to a sigma below one nanosecond.

3.8 Trigger and Data Acquisition

In the original ALICE design[1] the scope of the trigger system was very limited, essentially providing a gate to the TPC for central events and protecting against pileup. With increasing attention devoted to low-cross section, high-P_t observables, and the successive addition of the muon arm[2] and especially the TRD[3], the demands on the trigger system have increased dramatically. It now includes a pretrigger, three trigger levels (L0, L1 and L2) and a so-called High Level Trigger (HLT).

The pretrigger, essentially detecting an interaction using the small angle counters, provides in less than 100 ns a wake-up signal to the TRD frontend, thus allowing its digital electronics to be in a low-power mode most of the time. The L0 nd L1 triggers gate the fast detectors, while only after an L2 decision level has been reached, which includes an elaborate and flexible past-future protection scheme, the slow TPC is read out.

The HLT will implement features of online analysis of the full event during the data readout, by using both a dedicated computer farm and distributed intelligence in the data receivers and local data concentrators. The design of a first version of an appropriate FPGA Coprocessor PCI card, which also implements the receiver interface, has been started. A first version of a modular frame work, allowing very flexible low overhead orchestration of the HLT internal data flow was completed and optimized. This frame work is based on a publish/subscriber paradigm, allowing seamless integration of data flow and trigger monitoring.

HLT functions will include flexible trigger algorithms and data compression to advanced online tracking possibilities.

A general framework called the ALICE Data Acquisition Test Environment (DATE) system has been developed as a basis for the prototyping of the components of the DAQ and is currently used by the detector groups as DAQ for test beams. As for the ALICE-specific hardware, the prototype of the ALICE Detector Data Link or DDL (the optical link interfacing the DAQ and the detector electronics) has been tested extensively with fast data sources, and a DDL PCI 32 bit adapter card has been successfully developed.

In order to collect a sufficient number of events for physics analysis in the short heavy-ion running period, and given the large amount of information carried for each event (up to several 10 Mbytes) the DAQ system is designed to have a very large bandwidth of up to 1.25 Gbytes/s on mass storage. To reach this performance, ALICE has launched a series of so-called "Alice Data Challenges" which prototype each year both successive upgrades of the software and hardware implementations of increasing complexity and performance. In the third ADC, in 2001, event building has been performed at up to 550 MBytes/s and a total of more than 110 TBytes of data has been collected and archived with DATE at an average rate of 85 MByte/s during a whole week, formatted with the ROOT I/O package and stored in the CASTOR mass storage system. Following the experience gained during the Data Challenge, an integrated package for performance monitoring (AFFAIR) has been developed.

3.9 Offline

The strategy and status of the ALICE Offline is discussed elsewhere in these proceedings[4], yet it is worth mentioning here that the complete, ROOT-based, object oriented ALICE software framework has been finalized, including the whole chain from a detailed detector simulation, including accurate description of the response of the electronics, to the full reconstruction. While being the essential tool for the preparation of the Physics Performance Report in 2002, this framework has been a vital instrument for the final optimization of the detector parameters in 2001.

The ALICE offline project is now actively working on a Parallel ROOT Facility (PROOF) that will allow data processing and analysis to be done in parallel, transparent for the user, on distributed PC clusters. This system will make heavily use of the Grid services. A first test of the complete framework, from simulation to reconstruction and analysis has been completed during 5-week test in which 9 sites participated in production of 5800 events (corresponding to 5TB of data and requiring 10^5 CPU hours). This production was carried out entirely using AliEn - an implementation of Alice World Wide Computing Model developed by the Off-line Project.

4 Conclusion

ALICE is showing excellent health! While the collaboration keeps growing and gaining in momentum and cohesion, the Research and Development phase is essentially complete, with the various detector prototypes reaching and often surpassing design performance. The main detectors have entered the construction phase, and in particular the TPC, ALICE primary tracking device, is advancing very rapidly. At the same time, the Offline and Data Acquisition are getting ready to handle the ALICE formidable computing challenges. In summary, ALICE is on track to record the first pp collisions at the LHC in 2006.

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