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The ALICE TPC—An innovative device for heavy ion collisions at LHC

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Abstract

The ALICE Time-Projection Chamber is designed for operation in the extreme environment of heavy ion collisions up to Pb–Pb at LHC. The design is 'conventional' in overall structure but innovative in many details. Construction has been completed; at present the TPC is being commissioned above ground.

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1. Introduction

ALICE is the only experiment at the Large Hadron Collider dedicated to the investigation of heavy ion collisions. The ALICE Time-Projection Chamber (TPC) [1] is the main tracking detector in the ALICE central barrel, situated between a silicon vertex detector (ITS) [2] on the inside, a Transition-Radiation Detector and a Time-of-Flight array on the outside. It covers the pseudo-rapidity range $|\eta| < 0.9$.

The TPC has been designed for a maximum multiplicity $dN_{ch}/dy = 8000$, resulting in 20 000 charged primary and secondary tracks in the acceptance, an unprecedented track density for a TPC. Although this multiplicity might be higher by a factor of 4 than the extrapolation from RHIC data, this upper limit has been kept for the design and simulations. At the Pb–Pb design luminosity, a minimum-bias interaction rate of 8 kHz is expected of which about 10% are to be considered as central collisions. Extreme multiplicities and high rates set new demands on the design of a TPC. In the following, the design and innovative features of the ALICE TPC hardware will be briefly discussed, then the performance both from simulation and test results will be presented. These results would not have been possible without very significant advances in the tracking software. Finally the current status and first commissioning results are reported. For more details on specifications and performance of the various sub-detectors of ALICE and for the combined system, see the ALICE Physics Performance Reports [3].

2. The TPC design and specifications

The TPC is cylindrical in shape with an active radial range from about 85 to 250 cm, and an overall length along the beam direction of 500 cm, divided by the central HV electrode into two drift regions of 250 cm length. Multi-wire proportional chambers are mounted into 18 trapezoidal sectors in each end-plate.

The field cage is based on a design with a central high-voltage electrode and two opposite axial resistive potential dividers which create a highly uniform electrostatic field in the common gas volume. The central electrode is an aluminized, stretched Mylar foil. The potential of the drift region is defined by Mylar strips wound around 18 inner and outer support rods which contain the resistor chains, gas in- and outlet and a system for distribution of laser rays. Because of the drift gas used in the TPC, the field cage has to be operated at a rather high gradient of about 400 V/cm, with a high voltage of 100 kV at the central

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electrode which results in a maximum drift time of about 100 µs. The field cage is surrounded by double-shelled containment vessels with CO_2 as insulator. Composite materials were chosen for high mechanical stability at a low material budget (only 3.5% of a radiation length for tracks with normal incidence).

The readout chambers instrument the two end plates of the TPC cylinder with an overall active area of $32.5\,m^2$, with 18 sectors on either side. The chambers are multi-wire proportional chambers with cathode pad readout. The sectors are segmented radially into two chambers with varying pad sizes, optimized for the radial dependence of the track density.

There are about 560 000 pads, radially pointing, with 3 sizes: 4×7.5 for the inner chambers, 6×10 and $6 \times 15\,mm^2$ $(r \times \varphi)$ for the outer chambers, with 159 pad rows radially. The pad geometry results in a pad occupancy (fraction above threshold) at the maximum design multiplicity ranging from 40% to 15% from inner to outer radius of the TPC. It turns out that occupancy is mainly dictated by the width of the track image as collected at the readout chamber. It is dominated in radial and time direction by diffusion for large drift lengths and by track inclination at short drift length; in φ-direction the width is dominated by the width of the induced signal ('pad response function'). For the inner readout chamber, the anode–cathode gap was chosen to be only 2 mm , resulting in a pad response function with $\sigma = 2.0\,mm$.

The readout chambers are gated and only opened upon a first-level trigger for one drift-time interval ($\sim 100\,\mu s$), reducing the load on the chambers and the space charge in the drift region from positive ions drifting back from the multiplication region. This is particularly important in view of the high trigger rates of $> 200\,Hz$ anticipated for Pb–Pb running.

For a position resolution not limited by the signal-to-noise ratio, the gas gain has to be sufficiently large. For the chosen pad sizes and rather low dE/dx of the drift gas, inevitable in view of the desired low multiple scattering, a rather large gas gain of 2×10^4 is necessary at the design noise figure of 1000e (rms) for the electronics.

The original drift gas choice was Ne/CO_2 (90/10). The choice of Neon as the main component of the drift gas is mainly dictated by the requirements on momentum resolution and rate capability. Both multiple scattering and ion mobility are favorable for Neon compared to Argon; the ion mobility is higher by a factor of 4, important in view of space-charge limitations. The quencher was chosen based on ageing and safety considerations which rule out hydrocarbons in the ALICE environment. The drawback is that this mixture is a 'cold' gas, with a steep dependence of drift velocity on temperature, requiring a thermal stability of $\Delta T \leqslant 0.1\,K$ in the drift volume.

More recently it was decided to add 5% N_2 to the mixture [4], with two benefits: (i) the maximum stable gas gain is about a factor of 2 higher due to the added quencher, (ii) the fraction of N_2 and its influence on the gas gain can be better controlled (the original gas system does not remove N_2). The total drift time for 250 cm stays below 100 µs [5].

The goal of a temperature homogeneity of 0.1 K is rather ambitious. The TPC is shielded towards the other detectors by water-cooled thermal screens, except, for material budget reasons, in the central part of the inner cylinder where the adjacent ITS is required to match the TPC temperature. The heat sources of the TPC itself, i.e. the front-end electronics and even the resistive HV-divider, are all water-cooled. The thermal contact to the readout chambers is only via thin Kapton cables; the pad plane backings contain a water-cooled heat screen.

The pad signals are treated in a charge-sensitive amplifier and shaper in 0.35 µm CMOS technology with 16 channels per chip. One 10-bit ADC per channel samples the analog signal at a rate of 5 or 10 MHz (500 or 1000 samples). The following pipelined digital processor performs pedestal subtraction, tail cancellation, zero-suppression, baseline restoration, formatting and buffering. The ADC's and digital circuits of 16 channels are implemented in one chip (ALTRO) in a 0.25 µm CMOS process. The digital signal processing is essential for the performance at high occupancy and rate. An important feature is that processing parameters and algorithms can be reconfigured. The overall system noise value is about 600e rms for the typical pad capacitance of 12 pF.

The front-end electronics chain consists of a 128 channel front-end card (FEC) with only 40 mW/channel, a front-end bus for rows of up to 25 FEC's linked to one readout control unit (RCU), with 6 RCUs for each of the 36 readout sectors. Connection to the data acquisition system is via optical links (one per RCU). The data rate capabilities of the TPC readout are designed to allow transfer of 200 central Pb–Pb events/s for the extreme multiplicity case. At higher rates, distortions due to space-charge effects will limit the performance.

3. Performance and status

The position resolution of the TPC including all effects is expected to vary from 1100 to 800 µm in φ-direction and 1250 to 1100 µm in z-direction, depending on r and z. The dE/dx resolution in simulation for isolated tracks is 5.3%. Careful treatment of the amplitude splitting leads to an only moderately increased value of 6.5% at $dN/dy = 8000$.

Considerable effort has gone into the pattern recognition and tracking software, where now a track efficiency of about 97% (of geometrically accepted tracks) has been reached in simulation for the maximum multiplicity, a value we did not expect to be obtainable in the beginning. The momentum resolution for the TPC alone or combined with the other tracking devices, is shown in Fig. 1. For $dN/dy = 6000$ and a magnetic field of 0.5 T, the expected combined resolution is better than 4% at $100\,GeV/c$, implying excellent performance also for hard probes. To

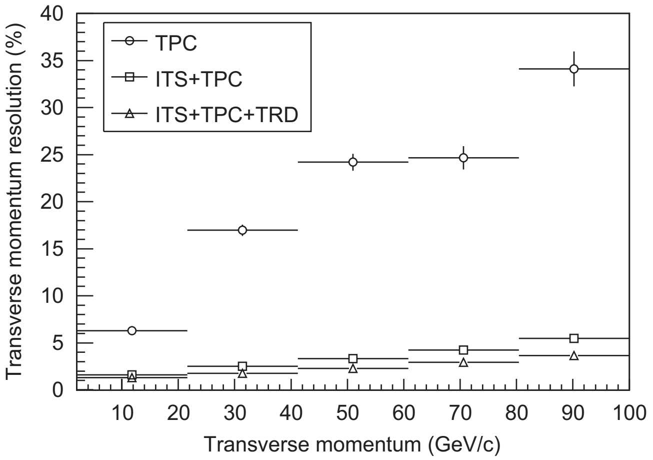

Fig. 1. Momentum resolution of the TPC, stand-alone or in combination with the silicon vertex detector (ITS) and TRD at $dN/dy = 6000$.

obtain this value in the final setup will require very accurate alignment of the detectors. The basic ingredients of the simulation, e.g. diffusion and pad response function, have already been verified in test measurements with cosmic rays and laser tracks.

The field cage and the series production of the readout chambers were completed in 2004. In 2005 the complicated sequence of operations in the space frame for the assembly of the ITS was exercised with the final components except for a dummy ITS. After this, the readout chambers were installed. This was a rather delicate operation as the geometry of the ROCs is such that they have to be mounted from the *inside* of the field cage. This geometry minimizes the dead area between chambers; it requires, however, a chamber mounting tool that allows to insert the ROCs on a long arm completely into the drift volume, turn them parallel to the end plate and then retract them to their mounting points from the inside. In the first quarter of 2006 the front-end cards were installed into the readout chambers, completing the installation phase.

Commissioning of the TPC is done above ground before the TPC goes into the cavern, foreseen in fall 2006. In April 2006, the gas system was started. After reaching the final gas mixture, the drift high voltage (100 kV) was applied, and readout and front-end electronics commissioning started. Each sector will be verified with cosmic rays triggered by ACORDE [6] and laser tracks.

4. Conclusion

In summary, the hardware of the ALICE TPC is fully assembled and currently being commissioned. The first results indicate a performance as anticipated in the simulations. Installation in the ALICE underground area will commence in fall 2006 and the detector should be ready for first collisions in 2007.

References

[1] ALICE TPC Technical Design Report, CERN/LHCC 2000-001, 2000.
[2] P. Riedler, ALICE Collaboration, these proceedings.
[3] ALICE Collaboration, Physics Performance Report, Volume I, J. Phys. G 30 (2004) 1517;
Physics Performance Report, Volume II, J. Phys. G 32 (2006) 1295.
[4] C. Garabatos, ALICE Collaboration, Proceedings of the 10th Vienna Conference on Instrumentation, 2004, Nucl. Instr. and Meth. A 535 (2004) 197.
[5] J. Wiechula, et al., Nucl. Instr. and Meth. A 548 (2005) 582.
[6] ACORDE, these proceedings.