The Transition Radiation Detector for ALICE at LHC

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Abstract

The Transition Radiation Detector (TRD) for the ALICE experiment at the Large Hadron Collider (LHC) identifies electrons and performs online tracking in the challenging high multiplicity environment of heavy-ion collisions within 6 microsecond after the interaction and thus requires excellent position resolution and pion rejection capability. The TRD consists of 540 Xe gas-filled pad readout drift chambers with radiators arranged in 18 super-modules in barrel geometry in the central part of the ALICE detector. The large active area of roughly 700 m^2 is covered by almost 1.2 million readout channels. Presently, three of in total 18 TRD super-modules are installed in the ALICE central barrel and commissioning of the detector using tracks from cosmic radiation coacting with other ALICE sub-detectors was successfully performed. For a period of six months, four installed super-modules of the detector were commissioned with cosmic radiation including a cosmic trigger generated by the TRD at level 1. We will report on the performance and current understanding of the detector based on these data.

This proceeding focuses XXX.

1. Introduction

ALICE (A Large Ion Collider Experiment) 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[1]. It studies medium property with the collision products such as heavy quarkonia, open charm and beauty, light vector meson, direct-γ, jets and high-p_T hadrons. One of the most powerful probe of the created QCD medium is heavy quarkonia and the suppression or enhancement[2] of it will tell us the role of screening of color charge and statistical recombination. Thus measurements of electrons are indispensable.

An important task of the Transition Radiation Detector (TRD) for the ALICE experiment is to supplement the Time Projection Chamber (TPC) electron/pion identification by a pion rejection factor of the order of 100 at momenta in axcess of 1 GeV/c. In addition, by measuremet of energy loss, the TRD improves the identification of other charged particle[1].

The TRD also contributes global central barrel tracking together with the Inner Tracking System (ITS) and TPC. It improves overall momentum resolution, especially at higher momenta. The resolution is as good as 3.5% at 100 GeV[1].

Additionally, TRD provides a fast trigger for single/pairs of electrons and cluster of high-p_T tracks, thus it allows us to study rare probes such as high-p_T J/ψ, Υ and high-E_T jets.

2. Working Principle of the TRD

The aimed pion rejection by a factor 100 at high-p_T is obtained by production of transition radiation which is unique for electrons within the relevant momentum range. The relativistic electron ($\gamma \geq 1000$) radiate photons in the X-ray range when it tranverse a boundary between media of different diffractive indices. This transition radiation (TR) photons (< 30 keV) are absorbed by high-Z gas mixture(Xe,CO_2) of high photoabsorption cross section. The recognition of this TR by characteristic peak at large drift time allows us to separate electron from pions.

The TRD surrounds the TPC in the central barrel($|\eta < 0.9|$) of ALICE with 540 chambers. The chambers are arranged in 18 super modules containing 5 stacks along the longitudinal and 6 layers along the radial direction. It has 694 m^2 active area and 28 m^2 gas volume of Xe/CO_2. The total radiation length is $\sim$ 24% and the weight is $\sim$ 30 tons.

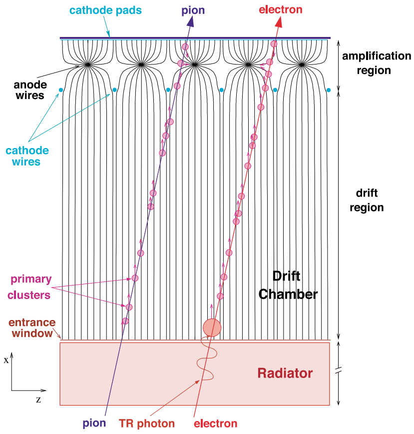
Each chamber consists of a carbon fibre laminated Rohacell/polypropylene fibre sandwich radiator(48 mm), drift(30 mm) and multi-wire proportional(7 mm) section with cathode readout pad. While very thin in radiation lengths to reduce Bremsstrahlung, the panel and the radiator provide enough mechanical rigidity of the chamber to keep gain uniformity better than 20%. Cross-sectional views of one TRD chamber together with average signals are shown in Fig. .

The TRD front-end electronics (FEE) is directly mounted on the back panel of the chamber. Groups of 18 pads are connected by short cables to a Multi-Chip Module (MCM) which comprises the Pre-Amplifier and Shaper Amplifier (PASA) and the Tracklet Processor (TRAP). The PASA has a 120 ns shaping time, a gain of 12.4 mV/pC, and a equivalent noise charge of 850 electrons at 25 pC of input capacitance. The TRAP chip comprises 21 channels 10 MHz 10 bits ADCs, four stages of digital filters, event buffers, readout interface and local tracking unit (Preprocessor and four 120 MHz CPUs) which allow to calculate the inclination of a track in the bending direction as well as the total charge deposited along the track. One Read-Out Board (ROB) consists of 17 or 18 MCMs and 6 or 8 ROBs are mounted on one chamber. Each chamber has one Linux based Detector Control System (DCS) board and two optical readout interface modules (ORI) for data shipping.

The local track segments (tracklets) and the raw data acquired by TRAP are sent to the global tracking unit (GTU) via 2.5 Gbps ORI. Based on the tracklets merged, GTU performs transverse momentum reconstruction and electron identification. After finding high-p_T tracks and identifying electrons, various trigger schemes are applied for di-electron decays and jets. Then this trigger contribution is sent to the ALICE central trigger processor (CTP) within 6.1 μs to drive the Level-1 trigger decision. Such a fast processing is done thanks to the massively parallel hardware architecture of the GTU whose core is FPGA-based. It is capable of processing up to 20k tracklets within 2 μs. GTU also forward raw data to DAQ when Level-2 accepted.

3. Integration, Installation and Commissioning

The assembly of a supermodule starts with the assembly of the supermodule hull including distribution of low voltage and cooling water. Afterwards, the readout chambers are installed layer by layer. Each layer undergoes tests of electronics, gas tightness, high-voltage distribution and cooling. The integration of a supermodule is concluded by several days of cosmics data taking to produce a calibration data set. Then the completed supermodules are transported to CERN for their final installation. Before its insertion in the ALICE setup, extensive testing is done on the surface to ensure that the detector is working.



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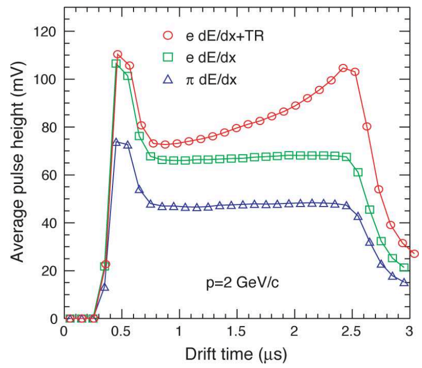

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After installation, noise level was checked. We archived average 1.1 ADC noise level which is close to design goal and dead channles are less than 0.1%.

Four supermodules were installed in the ALICE in 2008 and participated in the cosmic-ray data taking together with other detectors. Besides the proof of combined operation, these runs are used to gather reference data for alignment and calibration from tranversing cosmic particles. The cosmic trigger decision was based on coincident hits in the Time Of Flight (TOF) detector and GTU Level-1 trigger. It was first time to use the full chain of trigger sequence for TRD within ALICE setup and the GTU Level-1 trigger was the first running Level-1 trigger in ALICE. Level-1 rejection from Level-0 was by a factor 20 and Level-1 rate was ~0.05 Hz with the purity of larger than 85%. Total 55k tracks were recorded in the TRD under difficult constraints for cosmic-ray which should require tracks close to horizontal at 60 m below the surface. A display of a cosmic-ray event is shown in Fig. .

The TRD Detector Control System (DCS) which ensures safe and stable operation and monitoring of the detector has been also commissioned during this runs within the ALICE experiment.

Before the LHC injection test in 2008, we has progressed towards readiness for data taking.

The signal as a function of time averaged over all detectors is showing inf Fig. .

The tracking and PID algorithms of the TRD rely on the knowledge of several calibration constant depending on temperature and pressure, the gas composition and the chamber geometry. These are the drift velocity of the electrons, the time-offset of the signal, the gas gain and the width of the Pad Response Function. They will be calibrated using the raw signal of the detector or the signal from reconstructed tracks in p+p and Pb+Pb collisions. During the data taking, a first calibration is performed on the online systems, the Data Acquisition (DAQ) and High Level Trigger (HLT) and later also done in offline. With the assumption that the cosmic rays are uniformly distributed over the detector, a gas gain variation of about 16% was found over the chambers. Fig. shows the gain factors as function of the detector number for the four supermodules operated in ALICE in 2008.

The drift velocity and time offset are determined with the average signal as function of time shown in Fig. . The results obtained onlie were consistent with those obtained offline after the tracking in a second pass calibration. The extracted drift velocity values had a variation of 3.3%

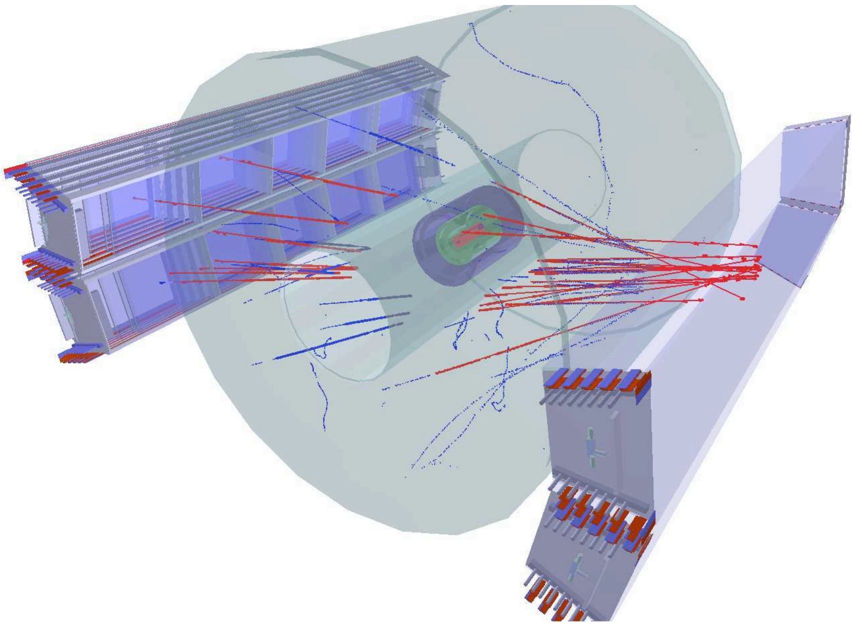


Figure 3: Cosmic-ray event display triggered with TRD Level-1

over the chambers.

The result for the spatial resolution obtained are summarized in Fig. .

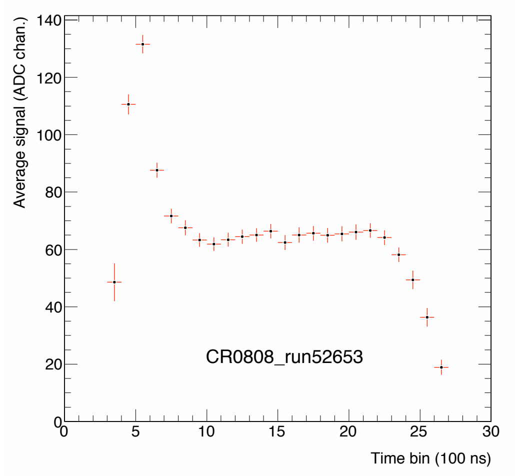
As a part of commissioning, at 2004 and 2007 there were test beam measurement at CERN PS with electron and pion beam. The likelihood distributions for six layers, based on the total energy deposit in one layer are shown in Fig. for the momentum of 2 GeV/c. Cuts of given electron efficiency are imposed on the likelihood value and the pion efficiency, π_{eff}, is calculated. The momentum dependance of pion efficiency calculated with different likelihood method is shown in Fig. . It demonstrate that we exceed design goal of factor 100 pion rejection for isolated tracks.

The resulting pion rejection capability was determined as a function of particle momentum.

Eight out of the total 18 supermodules of the TRD will be ready in the ALICE setup when cosmic-ray data taking resumes July 2009 and will contribute to physics results with beams expected to start in fall 2009. The TRD will be completed during the next shutdown period.

Acknowledgments

This is where one places acknowledgments for funding bodies etc., if needed. For the large collaborations, this is listed once and for all, together with the author lists etc. in the proceedings back-material.



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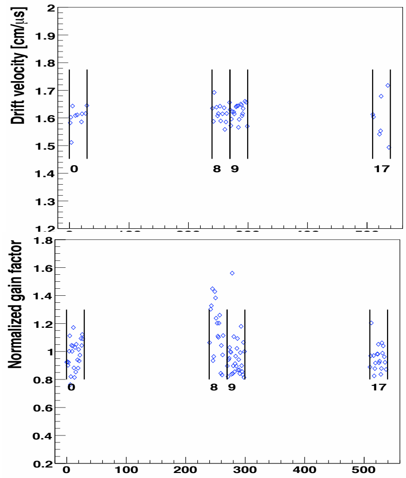

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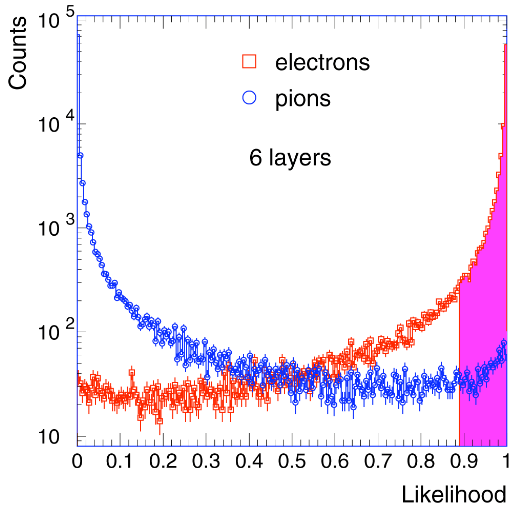

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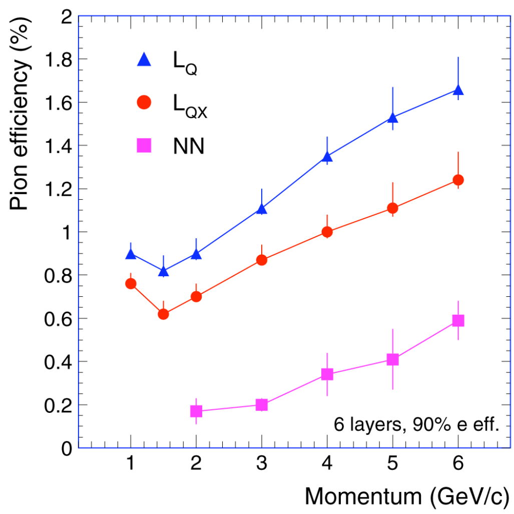

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