First beam test with a real size, six layer, series production detector stack for the ALICE TRD

ALICE TRD Collaboration

The Transition Radiation Detector (TRD) of the ALICE experiment at LHC is designed to provide electron/pion identification and tracking of all charged particles [1]. The TRD will supplement the TPC electron/pion identification by a pion rejection factor of the order of 100 at momenta in excess of 1 GeV/c, allowing precision measurements of quarkonia. Sophisticated on-detector electronics [2] will allow to trigger on high-momentum electrons and on jets. The project has completed a successful period of design and prototype tests [1, 3] and is now in the production stage.

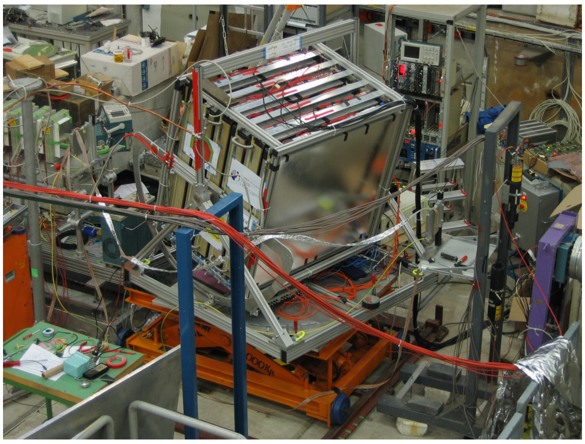

Figure 1: The TRD stack at the T9 beamline at CERN PS. The chambers are mounted in a frame allowing rotations of the detector with respect to the beam. The frame itself is installed on a lifting device.

A first beam test of a full size six-chamber detector stack of TRD was performed for two weeks at the CERN PS accelerator in October 2004. Measurements were carried out in an electron/pion beam with momenta of 1 to 10 GeV/c with the first chambers of the TRD series production. Fig. 1 shows a picture of the setup in the beam. Besides the TRD chambers, the setup was comprising of: beam trigger scintillators, a Pb-glass calorimeter and a Cherenkov detector for e/π identification and two Si-strip detectors for position reference.

Due to limited availability of readout board (ROB) prototypes, only one ROB was used for each detector layer. The detector signals from 288 detector pads are fed via flat cables into the 16 Multi Chip Modules (MCMs) on each ROB [4]. Each MCM consists of a Preamplifier/Shaper (PASA) and a digital Tracklet Preprocessor (TRAP) chip. The TRAP chip performs signal digitization (10-bit, 10 MHz sampling frequency), baseline subtraction, tail cancellation and tracklet fitting. For initialisation of the MCM chips and control of detector and electronics parameters, each ROB is equipped with a Detector Control System (DCS) mezzanine board. The DCS boards are compact standalone computing nodes running a Linux operating system, including Ethernet interface. Using the DIM protocol [5] for communication, the DCS boards are also delivering clock and trigger signals. For TRAP processor initialisation a broadcast is issued to all DCS boards which in turn send the binary operation code to all 68 CPUs on a readout board (four MIMD CPUs per TRAP chip) via a Slow Control Serial Network (SCSN) ring.

Once the data has been processed locally, it is sent through a 3-layer readout tree of MCMs, arriving via an ACEX card [6] in a readout computer. Here the data is converted into ALICE detector data link (DDL) format and travels via optical fiber into the DAQ system. The Data Acquisition (DAQ) system is based on ALICE DATE v4 [7]. We use two Local Data Concentrators (LDCs), one to readout the TRD stack, the second for the monitoring detectors. Event building is done on the Global Data Collector (GDC) and the data is then stored on a RAID disk server. The DAQ system is running at an average rate of 25 Hz at an event size of roughly 100 kBytes, limited only by the bandwidth of the ACEX card. More than 15 hosts were required during data taking to control and monitor the whole system. In order to facilitate the network configuration and for security reasons, the setup was operated in a private standalone Ethernet network. An on-line event display of a track in the TRD is shown in Fig. 2.

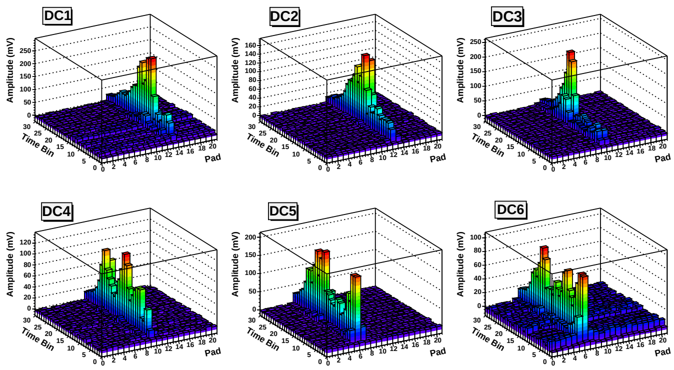

Figure 2: Event display of a track in the six chambers of the TRD.

In Fig. 3 we present the measured average signals as a function of drift time for pions and electrons, for the momentum of 4 GeV/c. The detector signal is spread over about 2 μs (the time zero is arbitrarily shifted). The peak at small drift times originates form the amplification region, while the plateau is from the drift region. For the electrons, the contribution of TR, which is preferentially absorbed at the entrance of the detector (corresponding to large drift times), is evident.

The distributions of measured integrated energy deposit in one layer of the detector are shown in Fig. 4 for pions and electrons of 2 and 6 GeV/c. The measured data are compared to calculations, which include ionization energy and, in case of electrons, transition radiation (TR).

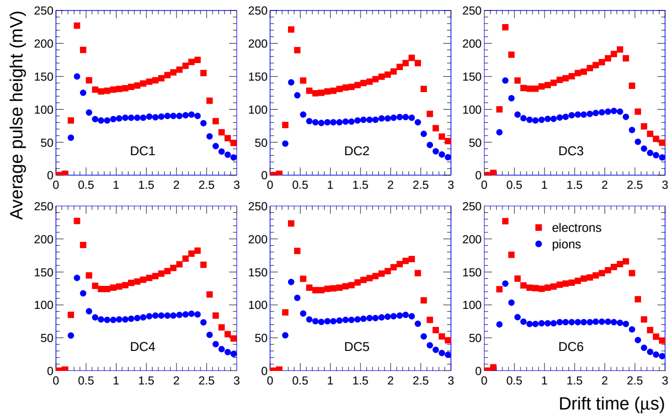

Figure 3: Average pulse heights for the 6 layers, for electrons and pions of 4 GeV/c.

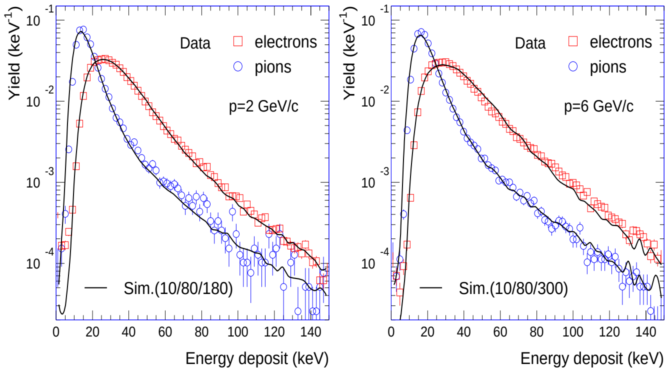

Figure 4: Integrated energy deposit spectra for one detector layer, for electrons and pions of 2 and 4 GeV/c. The lines are simulations.

The simulations were tuned to describe earlier measurements performed with prototypes [3] and describe well the present measurements.

In Fig. 5 we present the measured pion rejection (pion efficiency at 90% electron efficiency) as a function of momentum, using a simple likelihood method on total charge per layer (Fig. 4). The data obtained with the real size detectors is compared to data of smaller prototypes [3] measured in the same experiment. Compared to these reference detectors, the big chambers show a slightly worse pion rejection, which can be attributed to a smaller signal-to-noise value at which they were operated. In addition, the cross bar reinforcement of the radiators, used for the big chambers butnot for the small ones, may play a role too. The target pion rejection value is reached with this simple likelihood. Further improvements, using more sophisticated methods [3, 9], will provide a safety margin for the performance in the high-multiplicity events at LHC.

One of the special features of the readout pads geometry of the TRD chambers [1] is the alternating tilt of the pads relative to the beam axis (z). This improves the resolution in z direction, initially given only by the size of the long side of the pad (around 9 cm). For tracking within a single chamber (using the algorithm developed for the on-line straight-track reconstruction), this correlation is reduced to knowing the θ angle (along pads) of the track at the TRD entrance. In Fig. 6 we present the reconstructed angle for each layer, without and with the correction for the tilted pads, proving that the angle reconstruction method

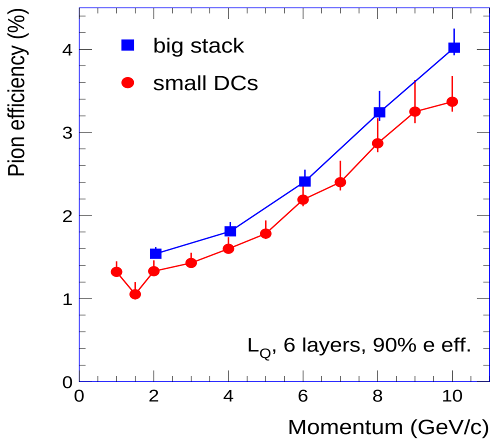

Figure 5: Momentum dependence of the pion efficiency.

works well. The difference between the reconstructed angle and the orientation of the stack (in ϕ-direction, i.e. across pads) is due to initial misalignment, and can be used as a reference for a further correction. Also shown in Fig. 6 is the distribution of the reconstructed angles, where it is demonstrated that resolutions below 0.5° are achieved. The analysis of the complete set of measurements, performed for a large range of angles (θ=0–25°, ϕ=0–20°), will validate the reconstruction algorithms and will allow detailed studies of position resolution performance [8].

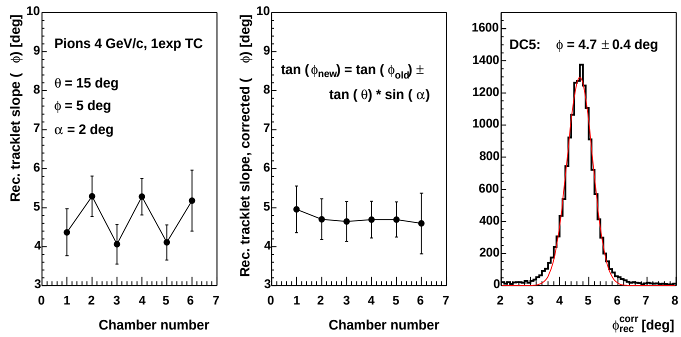

Figure 6: Layer dependence of the reconstructed angle, before and after correcting for the pad tilt, α.

In summary, the beam tests of real size detectors and final front-end electronics demonstrate that the envisaged design performance of the TRD can be achieved. Further analysis of the collected data will provide valuable inputs towards the preparation and final performance of the system in the ALICE setup.

References

[1] ALICE TRD Technical Design Report, CERN/LHCC 2001-021 (2001), `http://www-alice.gsi.de/trd`

[2] V. Lindenstruth, L. Musa, NIM A 522 (2004) 33.

[3] A. Andronic et al., NIM A 522 (2004) 40.

[4] I. Rusanov, J. Stachel, this Report.

[5] `http://dim.web.cern.ch/dim/`

[6] `http://www.kip.uni-heidelberg.de/ti/ACEXBoard/`

[7] `http://aldwww.cern.ch/`

[8] C. Adler et al., NIM A 540 (2005) 140.

[9] C. Baumann et al, GSI Sci. Rep. 2003, p. 66.