THE ALICE TRANSITION RADIATION DETECTOR*

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In this talk an overview of the ALICE transition radiation detector (TRD) is presented. In its final form the detector will consist of 540 individual detector modules with nearly 1.2 million readout channels. The TRD is part of the central barrel of ALICE and provides efficient electron identification for momenta above 1 GeV/c. In addition, it provides a fast trigger for charged particles with large transverse momentum. It is designed to operate in the very high multiplicity environment expected for heavy ion collisions at LHC.

1. The TRD within ALICE

ALICE (A Large Collider Experiment) [1] is the only dedicated heavy ion experiment at the CERN Large Hadron Collider (LHC) where Pb-nuclei will be accelerated up to $\sqrt{s} = 5.5$ TeV per nucleon pair. One important aspect in the study of these collisions is the detection of quarkonia such as J/ψ, ψ', and members of the Υ-family. Their production cross-section and transverse momentum spectra are tell-tale signatures for the characterization of the hottest and densest phase of a heavy ion collision, where the *quark-gluon-plasma* is formed. Quarkonia and mesons containing heavy quarks as measured by their (semi-)leptonic decays are especially well suited since they are not subject to the strong nuclear force. However, owing to their small production cross-section and their small branching into these decay channels, they require dedicated triggers. Identification of electrons with momenta above 1 GeV/c will be provided by the TRD [2,3]. Each of the individual readout modules of the TRD consists of a radiator followed by a short drift chamber. In the following we will outline the performance of

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the ALICE TRD and show how it will be able to provide an online trigger on electrons with large transverse momentum. The measurement of the specific ionization along with the transition radiation will allow to discern electrons from the large background of pions. On top of that, the online reconstruction of the track inclination will provide a direct measurement of the momentum.

2. The TRD in Numbers

The ALICE TRD will cover the pseudorapidity range $|\eta| < 0.9$. The 540 individual modules are arranged in six layers and cover a total area of 736 m^2. The layers are subdivided into 18 azimuthal and 5 longitudinal sections. Each detector consists of a sandwich radiator, a combination of ROHACELL and polypropylene fiber mats, of 48 mm thickness. It is followed by a drift chamber with a 30 mm drift gap and a 7 mm amplification gap read out via a segmented cathode pad plane glued to a multi-layer carbon fiber honeycomb backing. The chambers are operated with a Xe/CO_2 (85:15) [4] mixture (total volume about 28 m^3) in order to achieve a high conversion probability for transition radiation. The readout electronics of the 1.2 million individual pads (typical size: 7×88 mm^2) is mounted directly on the back of the detectors. The anticipated total radiation thickness of all six layers of the detectors is approximately 15%.

In the nominal magnetic field inside the ALICE magnet (B=0.4 T) the position resolution in $r\phi$-direction of 400(600) μm respectively for low(high) multiplicity[a] will yield a momentum resolution of $\delta p/p = 2.5\% \oplus 0.5\%(0.8\%)/\mathrm{GeV/c}$. The pion suppression at 90% electron efficiency for $p_t > 3$ GeV/c will be better than 100.

3. Position and Angular Resolution

The drift section is sampled in 20 time bins. Measurement of the charge sharing of adjacent pads allows for the reconstruction of the track within the drift volume. The position resolution is calculated as the standard deviation of the residuals of the individual measurements with respect to the reconstructed track. For measurements without magnetic field, the chambers were inclined with respect to the beam, with magnetic field, the measurements were carried out at nearly normal incidence; the measured angle corresponds to the Lorentz angle. A tail cancellation was applied to

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[a] corresponding to $\mathrm{d}N_{ch}/\mathrm{d}\eta = 2000$ ($\mathrm{d}N_{ch}/\mathrm{d}\eta = 8000$)

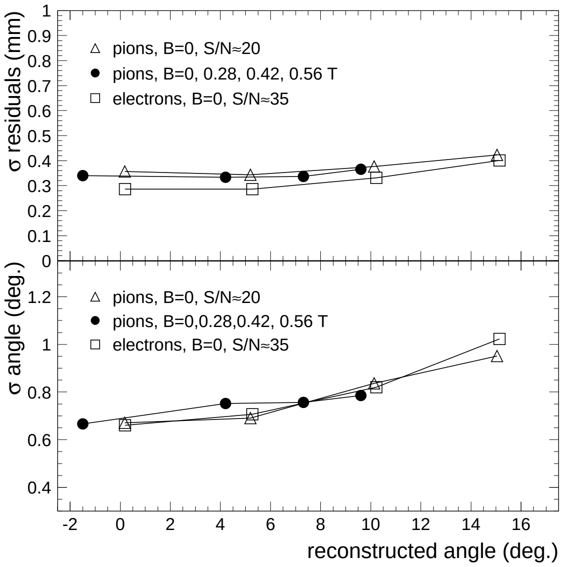

Figure 1. Point (top) and angular (bottom) resolution as function of reconstructed track angle measured with a prototype detector in a mixed beam of electrons and pions at 3 GeV/c (B=0) and 6 GeV/c (B≠0). Also quoted is the signal-to-noise ratio for electrons and pions.

compensate for the long tails of the shaper stage and the ion drift. The measured resolutions, presented in Fig. 1 are independent of an external magnetic field. A slight deterioration of the resolution for the largest incident angles can be seen due to imperfections in the tail cancellation. The achieved resolutions are within the specifications.

4. Electron/Pion Separation

Two effects lead to differences in the deposited energy of electrons and pions by which they can be distinguished from one another. For momenta of a few GeV/c the specific energy loss of electrons is larger than that of pions, because of the relativistic rise in the Bethe-Bloch formula. On top of that, about 0.7 TR photons with a mean energy of 10 keV are detected in the drift chamber [6]. The measured total energy deposit in the detectors is shown in Fig. 2 for pions and electrons of 2 GeV/c. The measurements were obtained by placing four identical chambers behind each other (DC1-DC4). Along with it, the solid line shows a simulation that includes a description of the specific energy loss as well as a suitable parameterization

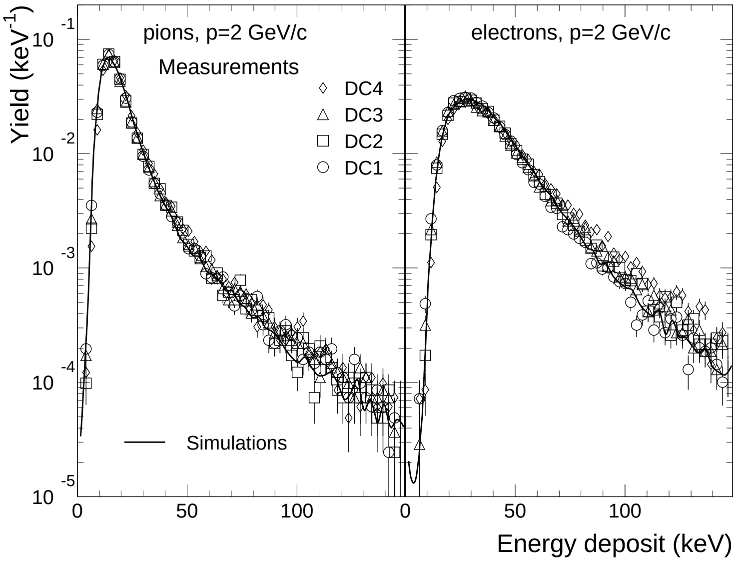

Figure 2. Total energy deposit in 4 consecutive detectors (DC1-DC4) for 2 GeV/c electrons and pions along with simulations including contributions from ionization and TR.

of the production and absorption of TR in the sandwich radiator.

As can be seen from Fig. 3, the probability of finding the largest individual energy deposit in a given time bin (Time max bin) is constant for pions (not considering the amplification region at small times), whereas for electrons it rises strongly towards long drift times corresponding to the entrance of the drift chamber. This is due to the large absorption cross-section for TR in the Xe-based gas mixture. In order to evaluate the electron/pion separation it is customary to quote the pion efficiency at 90% electron efficiency. This is obtained from a likelihood analysis of the normalized charge distributions extrapolated from the measured four layers to the six layers that will be used in ALICE. The pion efficiency is shown in Fig. 4 as a function of momentum. The likelihood on total charge method (L_Q) is based on the integrated total energy deposit along the particle track. Using this method the pion efficiency depends on momentum, because for large momenta the relativistic rise in the specifig energy loss for pions starts compensating the effect of TR for electrons. The discrimination power of the TRD can be further improved by a likelihood analysis based on total charge

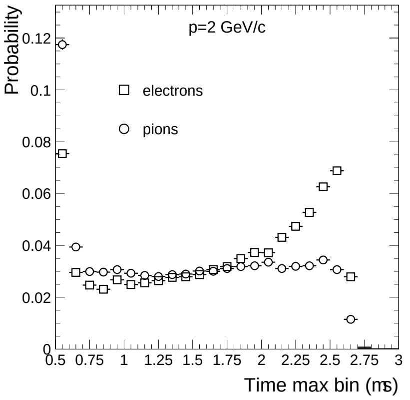

Figure 3. Probability for largest energy deposit in one time bin of electrons and pions as function of drift time

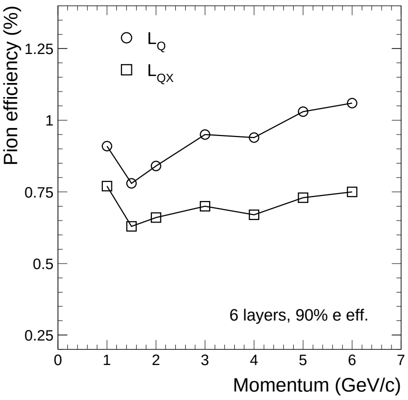

Figure 4. Pion efficiency as function of momentum (extrapolated to six layers) from a simple likelihood on total charge (L_Q) and a likelihood on total charge correlated with the drift time for which the largest pulse height is recorded (L_{QX}).

and position (L_{QX}). This method exploits the fact that TR accompanying an electron track is preferentially converted at the entrance of the chamber, i.e. at large drift times. With this method it is possible to achieve an almost constant pion efficiency significantly smaller than 1% over a large range of momenta corresponding to a pion rejection factor of larger than 100 in the electron sample.

5. Readout Electronics

A block diagram displaying the main elements of the readout electronics of the TRD is shown in Fig. 5. All components apart from the Global Tracking Unit (GTU) are implemented in two custom ASICs and are directly mounted on the detector in order to optimize power consumption and latency for the trigger decision. The analog ASIC contains the pre-amplifier, shaper, and output driver. The other ASIC is a mixed analog/digital design containing the ADC, tracklet pre-processor, event buffer, and tracklet processor. Both chips are mounted on a so-called multi-chip module (MCM) serving 18 pads. The pre-amplifier and shaper circuit has a conversion gain of 12 mV/fC, a shaping time of 120 ns, an input dynamic range of 164 fC, and provides a maximum differential output of 1 V. The anticipated maximum equivalent input noise is 1,000 e in-system. The power consumption

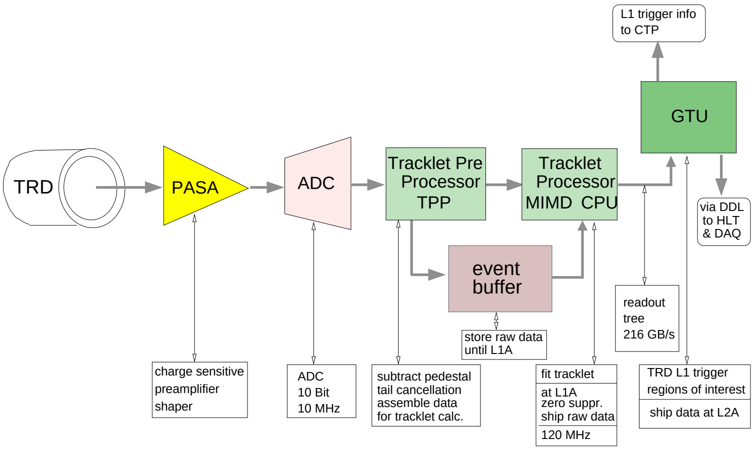

Figure 5. Block Diagram of the TRD front-end electronics.

per channel is about 12 mW.

The ADC is a full custom 0.18 μm design of a 10-bit 10-MHz differential ADC with a power consumption of about 5 mW. It is followed by a digital filter in order to compensate tails of the pulses due to slow ion drift and tails from the electronics, i.e. the time response function. Without such a filter, significant distortions in the position measurement would be incurred depending on the history of pulse heights. These position measurements are used to reconstruct the track segments (tracklets) inside the drift region of the individual chambers.

The output of the digital filters is directly fed into the tracklet preprocessor. Here, all relevant sums are calculated which are subsequently used by the tracklet processor in order to calculate the position and inclination of tracklets. Up to four candidate tracklets per MCM are shipped to the GTU, where tracklets from the individual layers are combined and matching cuts as well as momentum cuts and more involved cuts (such as cuts on the invariant mass of pairs) can be applied. The GTU will be implemented in FPGAs close to the Central Trigger Processor (CTP). All computations are finished and the trigger decision of the TRD is sent to the CTP 6 μs after the interaction.

6. Conclusion

The ALICE TRD is well suited to study quarkonia production in the high multiplicity environment of Pb+Pb collisions at the LHC. Test measurements have shown that the anticipated space point resolution as well as a good electron/pion discrimination can be achieved. The electronics will be capable of providing a fast trigger for high momentum electrons facilitating a measurement of Υ-mesons in heavy ion collisions. In conjunction with the other tracking detectors of the ALICE central barrel, it will be possible to measure Υ-mesons with a mass resolution of 1%. Currently, it is foreseen to install about 58% of the detector in time for the first heavy ion collisions at the LHC in 2007.

ALICE TRD collaboration

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References

1. ALICE, Technical Proposal, CERN/LHCC 95-71, LHCC/P3 (1995).
2. ALICE Collaboration, Addendum to ALICE Proposal, CERN/LHCC 99-13, LHCC/P3-Addendum 2 (1999).
3. ALICE TRD, Technical Design Report, CERN/LHCC 2001-021 (2001); *http://www.gsi.de/alice/trdtdr*
4. A. Andronic *et al.*, ALICE TRD Collaboration, Nucl. Inst. Meth. **A 498**(2003), 143.
5. A. Andronic *et al.*, ALICE TRD Collaboration, submitted to Nucl. Inst. Meth..
6. O. Busch *et al.*, ALICE TRD Collaboration, to be submitted.