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Results from prototype tests for the ALICE TRD

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Abstract

Electron ID and tracking in ALICE, in particular at the trigger level, require excellent TRD performance in terms of pion rejection and position resolution. We present results of prototype measurements in beams of 1–6 GeV/c. A position resolution down to 200 μm, angular resolution of 1° and pion rejection factors better than 100 are reached. Measurements of the ionization energy deposit and pure transition radiation spectrum are discussed.

Keywords: Drift chambers; Transition Radiation Detector; Position resolution; Transition radiation spectrum; Electron/pion identification

1. Introduction

A Large Ion Collider Experiment (ALICE) [1] is the only dedicated heavy ion experiment at CERN LHC. The study of heavy quark production in Pb–Pb collisions at $\sqrt{s} = 5.5$ TeV per nucleon pair is a central part of the ALICE physics program. The Transition Radiation Detector (TRD), in conjunction with other ALICE detectors, will allow to explore the production of quarkonia like J/Ψ, Ψ' and the members of the Υ family as well as open charm and open beauty. To study such rare probes via their (semi-) leptonic decays, dedicated triggers are mandatory to access the relevant signatures with sufficient statistics. The TRD trigger via online tracking and electron identification requires excellent pion rejection and position resolution: the detected transition radiation (TR) is used as a signature to discriminate incident electrons from the large pionic background; high momentum electrons are detected selecting stiff tracks in a magnetic field. The TRD consists of 540 drift chambers (DC) and mixed fiber/foam radiator, arranged in six radial layers.

2. Experimental setup

The measurements were carried out with prototype DC with a construction similar to that anticipated for the final ALICE TRD [2], but with a smaller active area (25×32 cm^2). The prototypes have a drift region of 30 mm and an amplification region of 7 mm equipped with anode wires (W–Au) of 20 μm with a pitch of 5 mm. The cathode wires (Cu–Be) have 75 μm diameter and a pitch of 2.5 mm. We read out the signal on a segmented cathode plane with

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† A list of the members of the ALICE TRD collaboration is given at the end of this paper.

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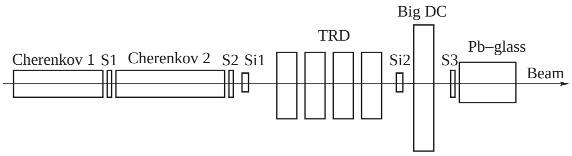

Fig. 1. Schematic view of the prototype test setup (not to scale).

rectangular pads of 8 cm length and 0.75 cm width. The entrance window (25 μm aluminized kapton) simultaneously serves as gas barrier and as drift electrode. We operate the DC with the standard gas mixture for the TRD, Xe,CO_2 (15%), at atmospheric pressure.

We use a prototype of an ASIC charge-sensitive preamplifier/shaper (PASA) specially designed and built for the TRD. The output of the PASA is processed by an 8-bit nonlinear Flash ADC (FADC) with 20 MHz sampling frequency. In the prototype tests, we read out a row of 8 adjacent pads.

The radiators are composed of 8 pure polypropylene fiber mats, corresponding to 4 cm total thickness, in a box of 6 mm carbon fiber-enforced Rohacell© HF71.

The measurements were carried out at the secondary pion beam facility with natural electron content at the CERN PS. The setup is depicted in Fig. 1. The coincidence of the scintillators S1, S2, S3 defines the beam trigger. Two threshold Cherenkov detectors and a Pb–glass calorimeter are used as reference for electron/pion identification. Dedicated triggers were used to enhance the electron content in the recorded data sample. In addition to the four small size DC, a real size prototype was operated in the beam; we focus here on the performance of the small size detectors.

3. Position resolution

Charge sharing between adjacent cathode pads allows reconstruction of the displacement along the pad row of the ionization electrons from an incident track. The angle of incidence with respect to the drift field is extracted from a straight line fit to the displacements as a function of drift time in the drift region. The width σ of the gaussian distribution of the residuals of the fit defines the point resolution, and the distribution of reconstructed angles the angular resolution. In Fig. 2, upper panel, we present the point resolution for pions measured at perpendicular beam incidence as a function of the signal-to-noise ratio (S/N). No magnetic field was applied for these measurements. An offline deconvolution is applied to the signal to optimize the time response. The measurements were carried out at beam momenta of 3 and 6 GeV/c. The momentum dependence of the position resolution is very small. The point resolution at $S/N \simeq 30$, the value anticipated for operation in ALICE, is better than 300 μm. This degrades to about 400 μm for non-normal incidence.

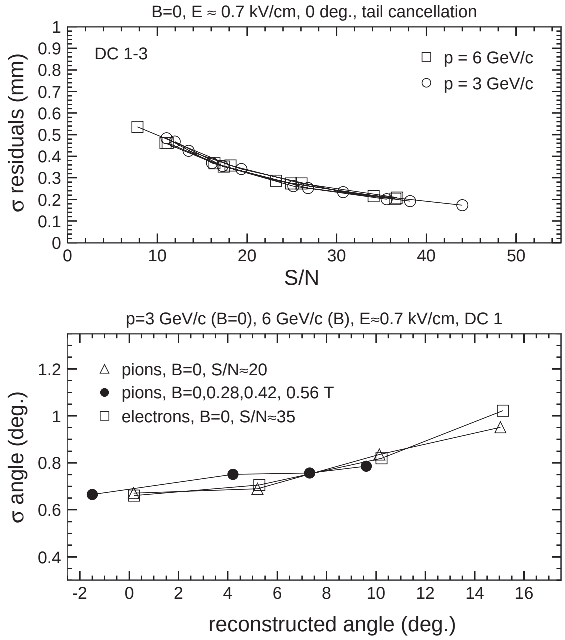

Fig. 2. Position resolution. Upper panel: point resolution as function of the S/N. Lower panel: angular resolution versus reconstructed angle.

In the lower panel we compare the angular resolution for pions and electrons and present the resolution obtained with magnetic field. For $B = 0$ the beam incident angle is reconstructed, which was varied by tilting the chamber. For runs with magnetic field the reconstructed angle corresponds to a convolution of the incident angle and the

Lorentz angle of the drifting electrons. All measurements were carried out at equal anode voltage resulting in a S/N of ~ 35 for electrons and ~ 20 for pions. In all cases an angular resolution better than 1° is reached.

4. TR spectroscopy

For the measurements of the pure TR spectrum we separated the radiator from the DC by a helium-filled pipe of 80 cm length. To deflect the beam, the assembly was placed in a dipole magnet, as shown in Fig. 3. Individual TR clusters are reconstructed requiring sufficient separation from the identified beam ionization clusters. We establish the relation between charge and energy by comparing the pion charge spectra measured in separate $B = 0$ runs to the calculated ionization energy deposit (see Section 5). The TR spectra of total and single photon energy for $2\,\mathrm{GeV}/c$ electron momentum are shown in the upper panel of Fig. 4. The data are compared to simulations of TR production from a regular radiator. The configuration (270 polypropylene foils of 10 μm thickness interspaced by air gaps of 80 μm) was tuned to reproduce the data; these parameters represent a reasonable description of the actual radiator material [2]. Photon absorption cross sections in the media and the detector gas are included. Measured and simulated spectra are independently normalized. The simulations reproduce well the spectrum of total TR energy. The measured single photon distribution has a higher tail than calculated, indicating unresolved overlapping clusters. In the lower panels we present the momentum dependence of the TR yield. The error bars represent the uncertainty of the cluster charge measurement, the error estimated for the energy calibration and, in case of the m.p.v., the error of

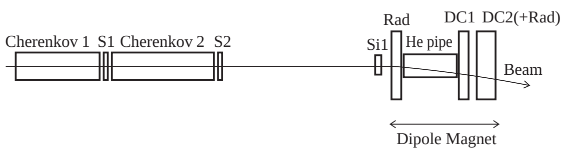

Fig. 3. Schematic view of the setup for pure TR measurements (not to scale).

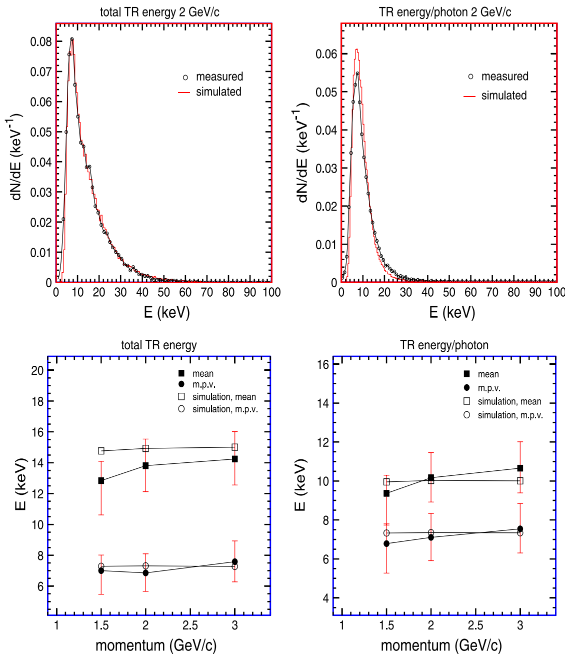

Fig. 4. Upper panel: spectra of total TR energy and single photon energy per incident electron of $2\,\mathrm{GeV}/c$, momentum. Lower panel: mean and most probable value (m.p.v.) of the spectra. The measurements are compared to calculations for a regular radiator.

the Gaussian fit to the maximum of the spectrum. Data and simulations agree within the measurements errors, but the measured TR yield seems to increase stronger with momentum than the calculated values.

5. Pion rejection

Fig. 5 shows the energy deposit measured for pions and electrons at $B = 0$ and 15° beam incident angle. The pion data are compared to a microscopic simulation of the ionization energy loss [3]. Width and shape of the measured distributions are well reproduced by the calculations. To simulate the energy deposit by electrons, we scale the pion spectrum to account for the relativistic rise of the ionization energy loss and add the TR contribution as presented in the previous section. The simulations are in good agreement with the measurements. We observe a

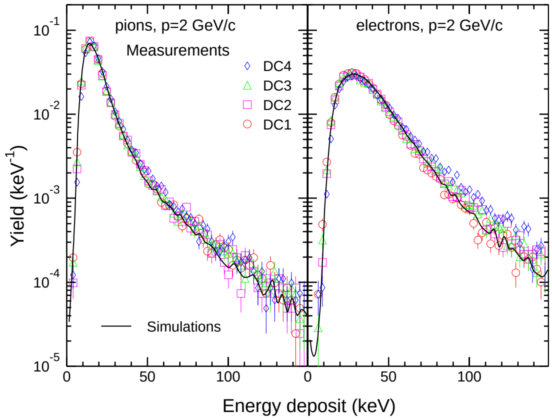

Fig. 5. Spectra of energy deposit for pions and electrons at $B = 0$. Data are compared to simulations of the pure ionization and TR contribution.

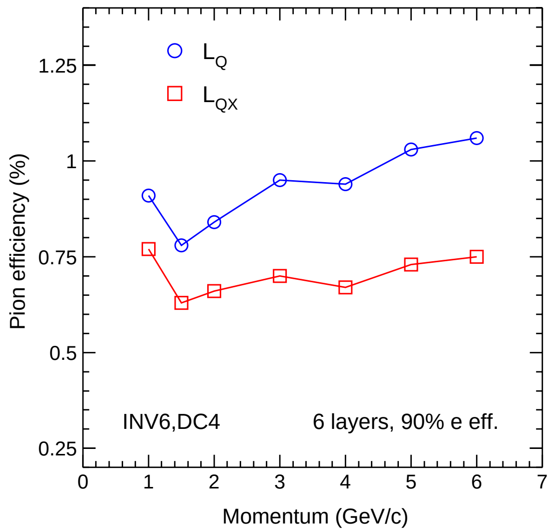

Fig. 6. Pion efficiency extrapolated to six layers, obtained with likelihood on total charge (L_Q) and likelihood on charge and drift time of the maximal pulse height (L_{QX}).

systematic increase of the high energy tail with the depth of the layer due to the feedthrough of TR produced upstream.

The capability of the TRD to discriminate between pions and electrons is estimated in a likelihood approach and measured in terms of pion efficiency at 90% electron efficiency. The normalized charge spectra measured for electrons and pions are interpreted as probability distributions of charge deposit for the two particle species. The resulting pion efficiency, extrapolated from 4 to 6 layers, is presented in Fig. 6. The strong improvement in performance from 1 to 1.5 GeV/c indicates an increase of the TR yield, the degradation at higher momenta is due to the relativistic rise of the pion ionization. Exploiting the time information of the pulse height distribution, the pion rejection can be further improved. Due to the high absorption cross sections of the detector gas, TR photons are preferentially deposited close to the entrance window, i.e. at late drift times. Using a likelihood on total charge and drift time position of the pulse height maximum, L_{QX}, pion efficiencies well below 1% are reached, corresponding to a rejection factor greater than 100.

6. Conclusions

We have demonstrated that position resolution and pion rejection of the DC prototypes meet the required performance of the ALICE TRD. The ionization energy deposit and relativistic rise in the detector gas are understood. We can reproduce the measured TR spectrum with simulations of a regular radiator.

ALICE TRD collaboration

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