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Analysis of the electron/pion separation capability with real size ALICE TRD prototypes using a neural network algorithm

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Abstract

In 2004 a complete stack of ALICE TRD final chambers has been tested at CERN. Here, we report on first results of its capability for separating electrons and pions using a neural network algorithm in comparison to a likelihood method on total charge. Measurements for particle momenta from 2 to 10 GeV/c were carried out. As shown for small prototype chambers during a test beam in 2002, an improvement of the pion rejection was also obtained for the entire stack.

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Keywords: Drift chamber; Transition radiation detector; Particle identification; Electron/pion separation; Neural networks

1. Introduction

One of the main goals of the ALICE Transition Radiation Detector (TRD) is to provide good electron identification capability [1,2]. The design goal is to attain a pion rejection factor of 100 at an electron efficiency of 90%. This has been achieved in measurements with small prototypes [3]. Further improvement of the rejection factor has been obtained using a neural network algorithm (NN) [4].

In 2004 a complete stack of six TRD chambers with its final electronics has been tested for the first time. Measurements for particle momenta from 2 to 10 GeV/c were carried out. The pion rejection capabilities using a NN are reported.

2. Experimental setup

For the test measurements a stack of six series production ALICE TRD chambers were used. The stack consisted of two different types of chambers: L1C0 and L2C0. These will be used in the second and third layers of the final ALICE TRD [1], counted from the interaction point. In the testbeam stack the three chambers of type L1C0 were used as layers 0, 2 and 4 and the three type L2C0 chambers as layers 1, 3 and 5. The chambers were equipped with final electronics and were arranged corresponding to the final configuration of the ALICE TRD chambers.

The measurements were carried out at momenta of 2, 4, 6, 8 and 10 GeV/c at the T9 secondary beam line of the CERN PS [5]. The beam contained a mixture of electrons and negative pions. The stack was oriented such that the angles of incidence of the beam were $\theta = 15^\circ$ and $\phi = 5^\circ$[1] with respect to normal incidence. In addition to the stack beam trigger scintillators, two Si-strip detectors, a Cherenkov detector and a Pb-glass calorimeter were included in the beam line. The Cherenkov detector and the Pb-glass calorimeter provided an independent separation of electrons and pions while the Si-strip detectors were used to measure the position and angle of incidence for each beam particle.

In Fig. 1 the average pulse heights of the individual chambers are shown for electrons and pions. At short drift

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[1] In comparison to the final experiment θ corresponds to the polar angle and ϕ to the azimuthal angle with respect to the beam axis.

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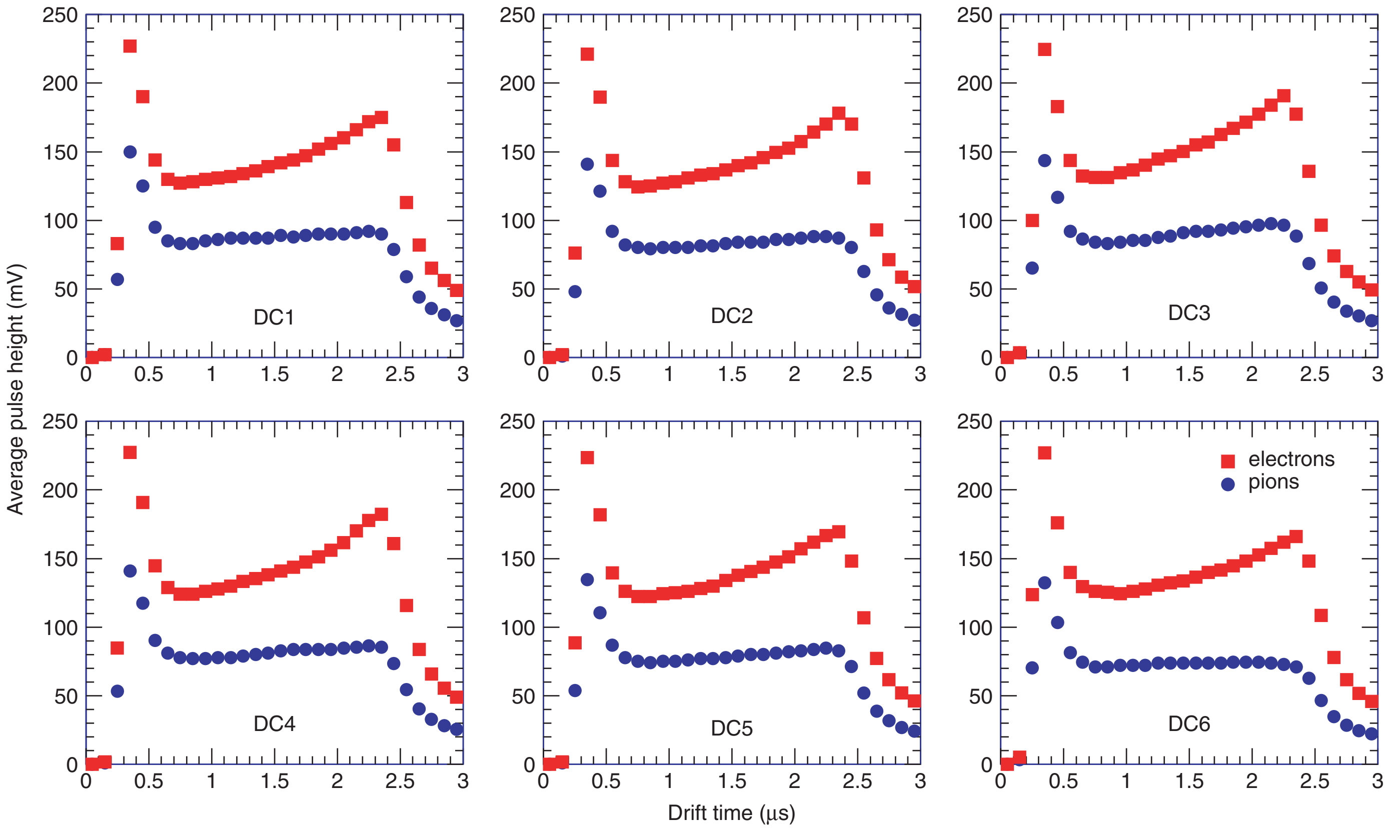

Fig. 1. Average pulse heights as a function of drift time for electrons and pions for the six chambers at a momentum of 4 GeV/c.

times as well as for the electron as for the pion spectra, the typical peak which originates from the amplification region can be seen. The electron spectra comprise an additional peak at large drift times generated by transition radiation photons originating from the radiator.

3. Results

A simple and effective method for electron/pion separation in TRDs is the likelihood on total deposited charge, LQ [6]. The spectra of charge integrated over drift time for pions and electrons at 2 and 4 GeV/c are shown in Fig. 2. To improve statistics, we add the signals in the six layers for these distributions. Based on these average spectra, we calculate the likelihood as follows:

$$L = \frac{P_e}{P_e + P_\pi} \tag{1}$$

with

$$P_e = \prod_{i=1}^{N} P(E_i|e), \quad P_\pi = \prod_{i=1}^{N} P(E_i|\pi) \tag{2}$$

where the products run over the number of detector layers N. The resulting pion efficiencies for six layers are presented as a function of momentum in Fig. 3.

A further improvement of the pion rejection capability can be reached by using NNs. The NNs employed in this analysis consisted of an input layer, two hidden layers and one output layer with two neurons, one for the electron probability and the other for the pion probability. The learning method was using the backpropagation algorithm. The training data for each momentum consisted of an electron and pion mixture of 10,000 events and the test data of another 5000–10,000 events. Due to the limited statistics the number of training epochs was increased to 20,000 to provide comparable learning capacity. Further details of the used NN can be found in Ref. [4].

The pion efficiency reached with the NN method also makes use of the likelihood method shown above. In case of the NN the deposited charge E_i in Eq. (2) is replaced by the excitations of the NN output neurons O_i. The distributions of the NN can be seen in Fig. 4. The result of this analysis is shown in Fig. 3. Evidently, NN are able to improve the pion rejection by about a factor of 2.5.

4. Conclusion

The pion efficiency of a complete stack of ALICE TRD chambers has been estimated using NNs. In this analysis, owing to poor statistics, an event-by-event analysis of the pion rejection was not possible. Nevertheless, the similarity between the average pion efficiency calculation with NNs

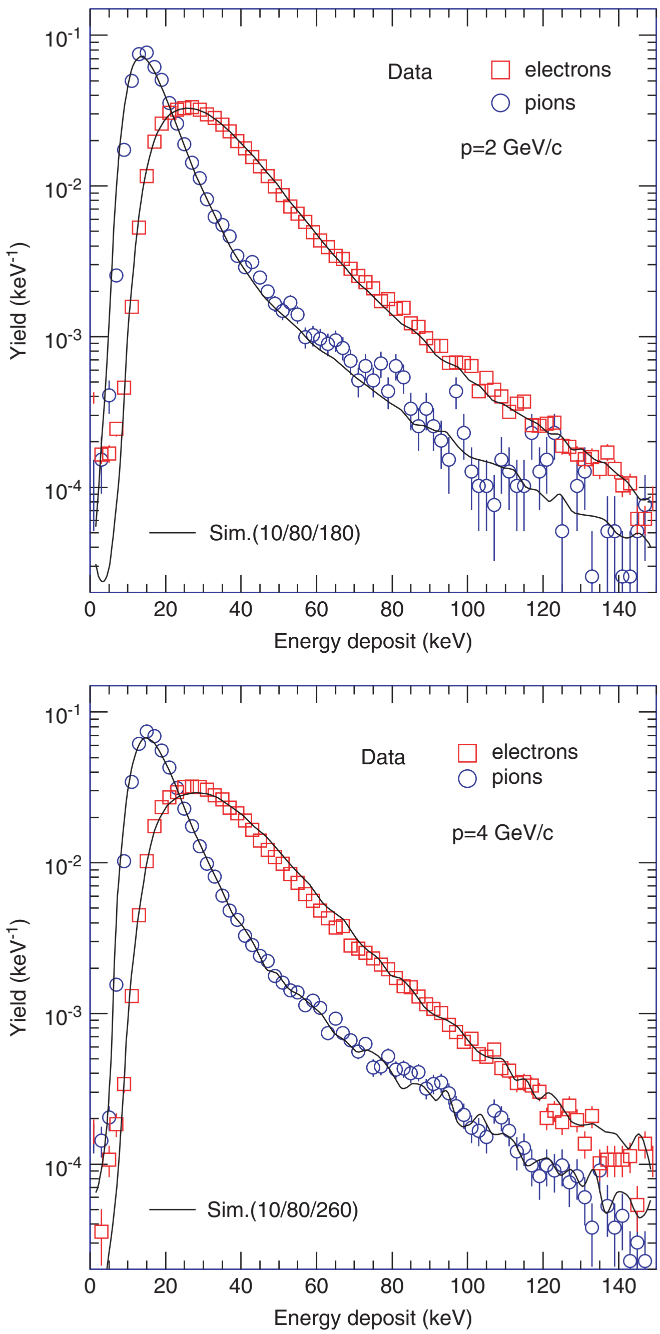

Fig. 2. The deposited charge spectra for electrons and pions in one detector layer. The spectra for 2 and 4 GeV/c are shown.

and the LQ method shows that the NNs have a larger pion rejection capability, as expected from previous results [4]. The calculations confirm the advantage of the NNs compared to the methods based on integrated charge.

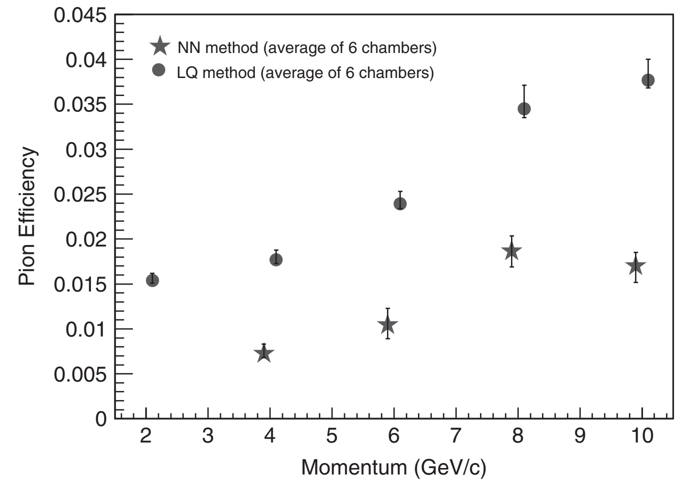

Fig. 3. Pion efficiency for different momenta. The pion efficiencies for the LQ method and the NNs are shown. For details see text.

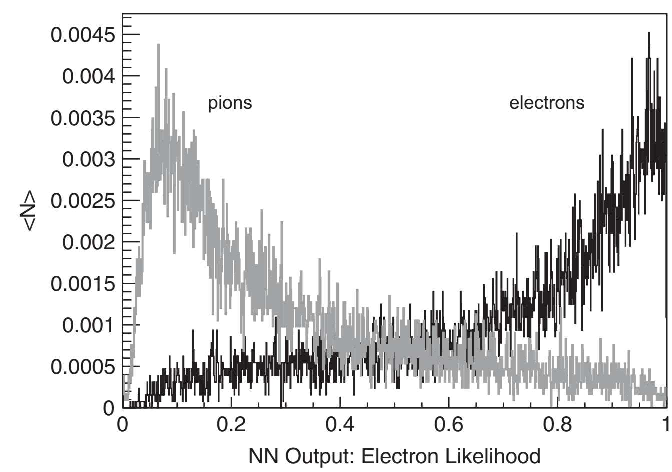

Fig. 4. The output of the NNs for electrons and pions. Shown are the distributions for a momentum of 6 GeV/c.

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