Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Nuclear Instruments and Methods in Physics Research A 563 (2006) 310–313
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH
Section A
www.elsevier.com/locate/nima

New test beam results with prototypes of the ALICE TRD

R. Bailhache*, C. Lippmann

GSI Darmstadt, Germany

for the ALICE TRD Collaboration

Available online 13 March 2006

Abstract

We present measurements of ionization energy deposit in $Xe, CO_2(15\%)$ and of transition radiation in an irregular radiator. The measurements are performed with prototypes of the ALICE Transition Radiation Detector (TRD) with a beam of electrons and pions of 1–10 GeV/c. We also present resulting electron–pion separation performances for the prototype chambers as well as for final, full-size TRD chambers.

PACS: 29.40.Cs

Keywords: Transition radiation detector; Drift chamber; Ionization energy loss; Electron–pion identification

1. Introduction

The ALICE Transition Radiation Detector (TRD) will provide electron–pion separation for momenta above 1 GeV/c and particle tracking in the high-multiplicity heavy-ion collisions at the LHC accelerator at CERN [1,2]. The electron identification is performed using a likelihood method [3], which requires as input the knowledge of the spectra of total energy deposit in the momentum range of interest. For pions (the dominating background) these spectra are determined by the ionization energy loss (dE/dx), while for electrons the additional contribution of transition radiation (TR) is superimposed. A realistic implementation of the TRD in the ALICE simulations (*AliRoot* [4]) requires measurements of pure TR spectra. We present recent measurements and simulations on dE/dx and TR performed with ALICE TRD prototypes. The resulting electron–pion separation performances of the ALICE TRD prototypes and final chambers will also be presented.

*Corresponding author.
E-mail address: bailhar4@hotmail.com (R. Bailhache).

2. Experimental setup

The measurements were carried out in autumn 2004 at the CERN PS accelerator using a mixture of electrons and negative pions with momenta from 1 to 10 GeV/c. The results are obtained using prototype drift chambers (DC) similar to the final ALICE TRD chambers, but with a smaller active area ($25 \times 32\,cm^2$). They are filled with Xe, CO_2 (15%). The first half of the test beam was devoted to measurements of energy loss and TR spectra. The method is similar to the one in Ref. [5] and a sketch is shown in Fig. 1. Clean samples of pions and electrons are selected using coincident thresholds on a Cherenkov detector (Ch) and a lead-glass calorimeter (Pbgl). Three scintillator detectors (S1–S3) are used for triggering and four Silicon detectors (SD1–SD4) as position reference. Three drift chambers (DC2–DC4) provide measurements of energy deposit with or without radiator in front of them and are used for electron/pion identification analysis. The TR photons produced in the radiator in front of the dipole magnet are detected separated from the beam in DC1. The absorption of the photons is minimized by using a He-pipe. The length of the magnet is approximately 0.5 m and the bending radius of the beam is kept approximately constant in the experiment by varying the strength of the magnetic field up to about 1 T. We investigated several different

0168-9002/$ - see front matter
doi:10.1016/j.nima.2006.02.157

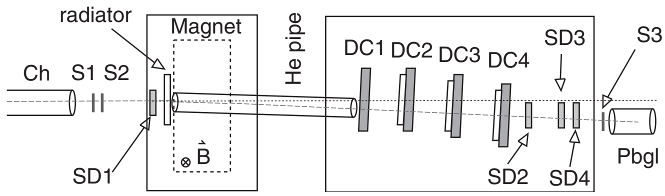

Fig. 1. Sketch of the beam setup. In a second part of the measurements the magnet and helium pipe were replaced by a stack of six final, real-size TRD chambers.

radiator configurations but in this publication we focus on the standard ALICE TRD radiator (a sandwich of fibers and foam with 4.8 cm thickness [1]).

In the second part of the test beam the dipole magnet and helium pipe were replaced by a stack of six final, full-size TRD chambers.

3. Ionization energy loss

The measurements of energy deposit by ionization are performed with the three prototype drift chambers DC2-4. In the Fig. 2, we present the dE/dx spectra averaged over the three chambers for a beam momentum of 6 GeV/c. The energy calibration has been performed using the most probable value (MPV) of the pion spectra. The spectra are compared to simulations with GEANT 4 [6].

In Fig. 3 we present the dE/dx MPV normalized to a minimum ionizing particle (MIP, $\gamma \approx 4$) as a function of the Lorentz factor γ. We extract the MPV of the spectra from fits with a sum of a Landau function and a Gaussian. Our data are compared to results of a previous test beam in the year 2002 with the same prototype DCs. Other measurements and calculations are also shown. For our momentum values the pions are in the regime of the relativistic rise of the energy loss, while the electrons are already at the Fermi plateau. The agreement with the different measurements is very good and the new data confirms the Fermi plateau found in 2002 [7], which is slightly larger than the calculations with GEANT 3 [8]. The calculations show also a more pronounced relativistic rise than the measurements. The data calculated with GEANT 4 reproduces all measurements very well.

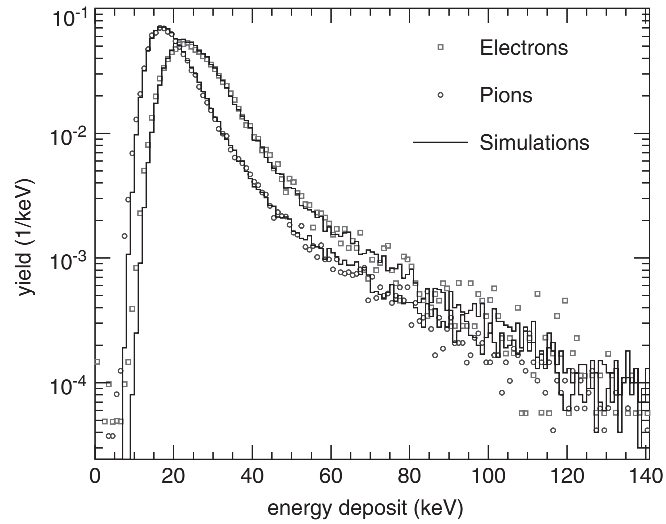

Fig. 2. Spectra of the ionization energy loss for pions and electrons at 6 GeV/c. The symbols represent the measurements. The lines are GEANT 4 simulations.

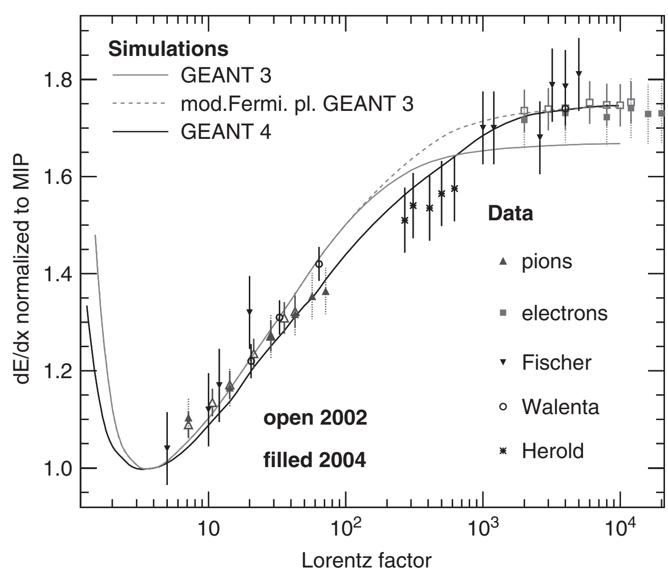

Fig. 3. MPV of the ionization energy loss as a function of the Lorentz factor γ. Our values (open symbols) are compared to previous results of a test beam in 2002 and to the measurements of Fischer [9], Walenta [10], and Herold [11]. The continuous lines are the simulations; the dashed line is obtained with an increased Fermi plateau for the GEANT 3 data [7,8]. This modification was introduced to reproduce the data.

4. TR spectra

An extensive measurement of pure TR spectra and the momentum dependent TR yield was carried out using different radiator configurations. For space reasons in this publication we will focus on the standard ALICE TRD sandwich radiators. All other results will be presented in an separate paper in preparation.

For each event in DC1 a TR cluster search is performed. Due to the magnetic field we are able to provide a separation from the beam of more than three pads for all momenta, which avoids a contamination of the measured TR energy with ionization energy. A radiation background at higher momenta is present also without any radiator. It can be attributed to synchrotron radiation from the magnet and is subtracted based on measurements without radiator. A limitation imposed by the method of measurement is connected with the limited space point resolution in drift direction which is directly related to the drift velocity and the sampling frequency of the employed ADC system [2], resulting in a limited separation efficiency for close TR clusters. Measured and simulated TR spectra for the ALICE TRD sandwich radiator at 2 GeV/c are shown in

Fig. 4. In the simulation we use the theory described in Ref. [5]. Three parameters are needed, which correspond to the number of foils N_f, the foil thickness d_1 and the foil separation d_2 for a regular foil structure. Since the TRD radiator is not a regular foil structure, the parameters can only reflect typical dimensions of the radiator materials, but are not unambiguously determined. Our set of parameters was chosen to best reproduce our measurements, taking into account also the correction for the limited cluster separation efficiency: $N_f = 120$, $d_1 = 15\,\mu m$ and $d_2 = 400\,\mu m$. Fig. 5 shows the momentum dependence of the mean number of detected TR photons.

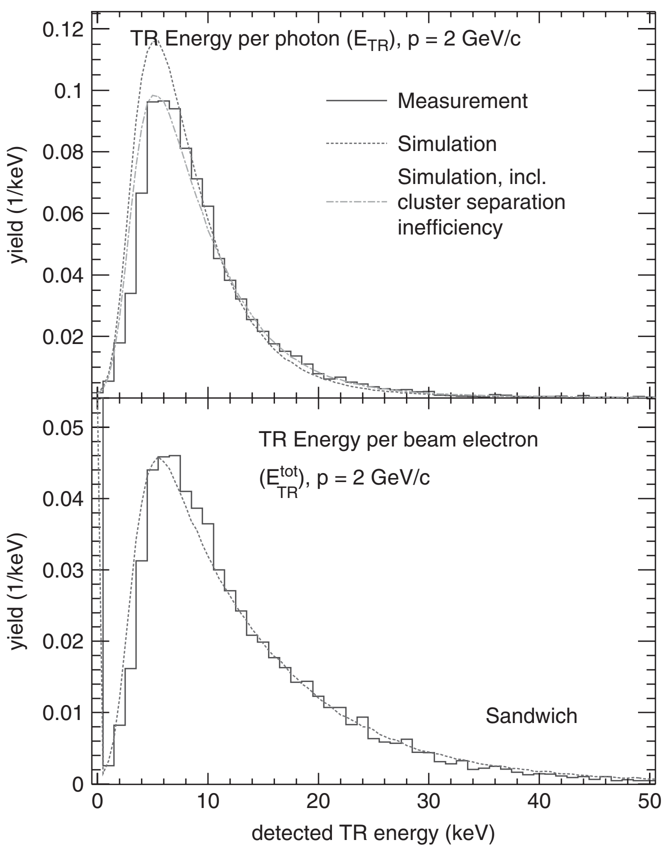

Fig. 4. Measured and simulated TR spectra at $2\,GeV/c$ for the ALICE TRD sandwich radiator. The upper panel shows the distribution of the energy of single TR photons (E_{TR}). The lower panel shows the distribution of the total TR energy (E_{TR}^{tot}). The simulations include the limited separation efficiency for very close TR photons.

5. Electron identification performance

Due to the dE/dx relativistic rise the separation between the pions and the electrons based only on dE/dx would be reduced as function of momentum (Fig. 3). That is the reason why we use also the fact that the electrons produce TR in this momentum range. The resulting pion efficiencies can be calculated using a likelihood on the total integrated energy loss (LQ). In addition, the exponential probability for the absorption of TR photons in the gas mixture can be exploited in a bidimensional likelihood (LQX). Here, the distribution of the time bin with the maximum measured amplitude is used together with the total integrated charge. In Fig. 6 we present a comparison of the two methods for 90% electron efficiency. The measurements are averaged over the three prototypes and the performance is extrapolated for the final configuration with 6 layers. The pion efficiency achieved is about 1% in the momentum range 1–2 GeV/c, with the expected degradation for higher momenta, resulting from the saturation of the TR yield (Fig. 5). There is a sizeable improvement, up to a factor of 1.5, with the bidimensional likelihood. It has been shown that further improvement can be achieved with a neural network method [13].

In Fig. 7 we compare the pion efficiency of the full-size detectors and the prototypes. They are calculated with the

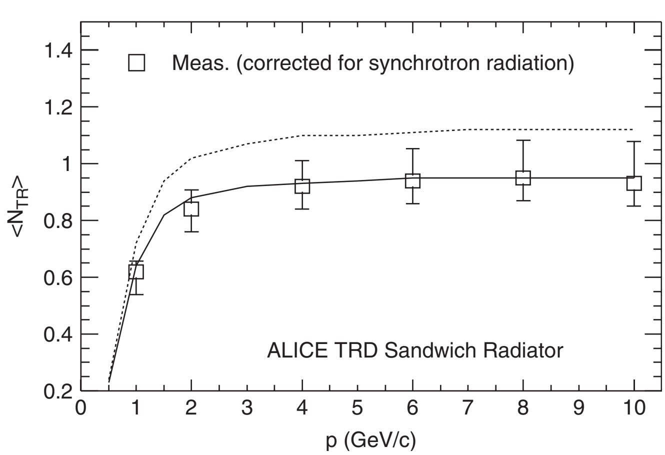

Fig. 5. Measured and simulated dependence of the mean number of detected TR photons $\langle N_{TR} \rangle$ on momentum. The simulated data shows the deposited mean number of TR photons (dotted line) and the mean number of photons detected by the TR cluster search algorithm (continuous line).

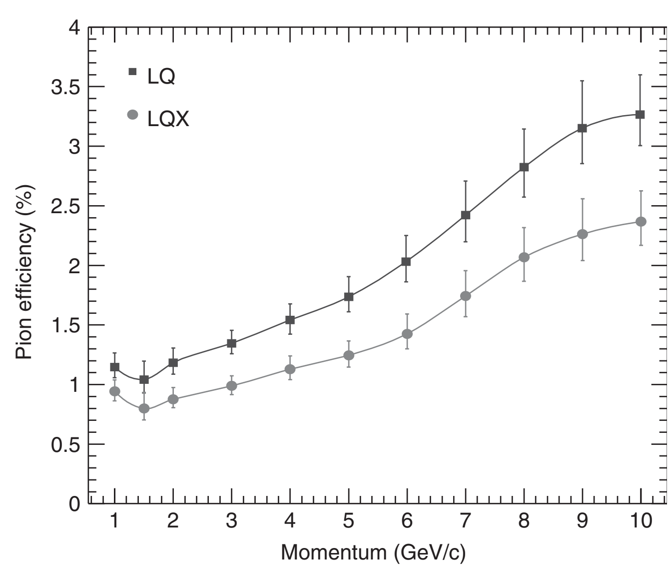

Fig. 6. Momentum dependence of the pion efficiency for 90% electron efficiency extrapolated to 6 layers.

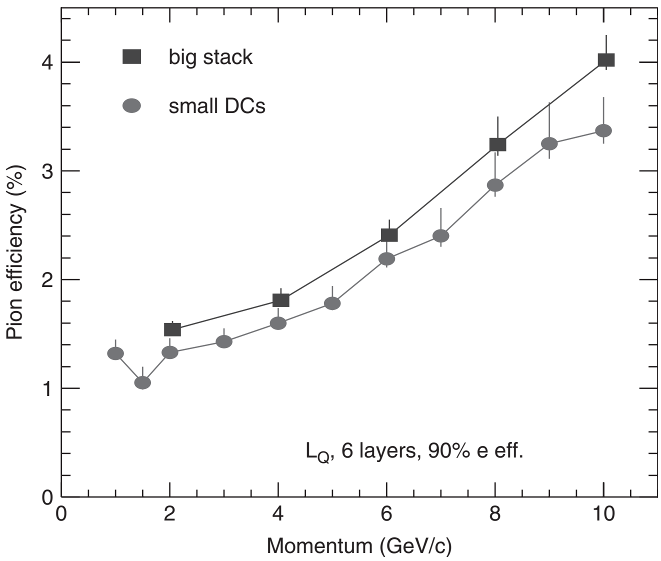

Fig. 7. Comparison of the pion efficiency for 90% electron efficiency for the prototype detectors with the full-size chambers for six layers. We use the LQ method. [12]

LQ method, for 90% electron efficiency and for six layers as a function of momentum. The data are obtained with charge spectra averaged over the detectors. The slight deterioration of the performance of the big chambers with respect to the prototype chambers may be explained by a worse signal-to-noise ratio for the real-size chambers.

6. Summary and conclusions

In the ALICE TRD the ionization energy loss and energy deposited by transition radiation (TR) is used to identify electrons. Ionization energy loss spectra of electrons and pions from 1 to $10\,\mathrm{GeV}/c$ in $Xe, CO_2(15\%)$ were measured and compared to simulations. GEANT 4 very nicely reproduces the measured momentum dependence and the spectral shapes. Pure transition radiation spectra of electrons in the same momentum range were measured and also show a good agreement with theory.

The pion efficiency achieved with likelihood methods is about 1% for 90%-electron efficiency and the final configuration with six layers.

References

[1] ALICE Transition radiation detector technical design Report, ALICE TDR 9, CERN/LHCC 2001-021.
[2] C. Adler, et al., Nucl. Instr. and Meth. A 540 (2005) 140.
[3] A. Andronic, et al., Nucl. Instr. and Meth. A 522 (2004) 40.
[4] R. Brun, et al., Nucl. Instr. and Meth. A 502 (2003) 339.
[5] C.W. Fabjan, et al., Phys. Lett. B 57 (1975) 483.
[6] S. Agostinelli, et al., Nucl. Instr. and Meth. A 506 (2003) 250.
[7] A. Andronic, et al., Nucl. Instr. and Meth. A 519 (2004) 508.
[8] R. Brun, et al., GEANT 3 User Guide, CERN, 1985.
[9] J. Fischer, et al., Nucl. Instr. and Meth. 127 (1975) 525.
[10] A.H. Walenta, et al., Nucl. Instr. and Meth. 161 (1979) 45.
[11] W.D. Herold, et al., Nucl. Instr. and Meth. 217 (1983) 277.
[12] ALICE TRD Collaboration, GSI Scientific Report (2004) 355.
[13] C. Adler, et al., Nucl. Instr. and Meth. A 552 (2005) 364.