Straw-Tubes for Pion-Electron-Separation at Low Momenta Using Measurements of dE/dx

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Abstract

For the planned ATLAS experiment it will be important to distinguish between electrons and pions at low energies to examine decay-channels of B-mesons.

It is a well established technique to separate electrons and pions by measuring their energy-loss per distance in several layers. In this paper the possibility of using a detector made of packed straw-tubes for dE/dx-measurements to separate pions and electrons at low energies is examined.

Results of simulations show that good electron-pion-separation seems achievable up to energies of about 7 GeV.

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1 Introduction

This paper presents a Monte-Carlo-study of a detector consisting of packed straw-tubes to measure dE/dx and space points for charged particles. The straw-tubes used are identical with the straws proposed for the TRT by the RD6-collaboration [1]. Information about dE/dx is useful for electron-pion-separation at low energies [2, 3].

The main motivation to separate electrons and pions at low energies comes from B-physics. Electrons of the decay

$$B_d^0 \longrightarrow J/\Psi \, K_S^0 \longrightarrow e^+ e^- \pi^+ \pi^-$$

have energies mainly lower than 5 GeV. In order to observe this decay it will be necessary to separate electrons from pions at these energies. As the calorimeters will not be able to identify particles at such low energies [4], making multiple measurements of dE/dx can be a possibility to do this separation [2].

Besides the capability to distinguish between electrons and pions, a detector made of many straw-tubes will give space-points with an accuracy of the about 140 μm using drift-time information [5]. A 20 cm thick detector made of straws with 4 mm diameter will give about 60 points for almost straight tracks. This feature will make such a detector very attractive for pattern-recognition.

A strong argument to use a detector without TRD-foam is the reduction of material in front of the calorimeters. The energy-resolution and particle-separation capabilities of the calorimeters depend heavily on the amount of material in front of them [4, 6].

In addition, a detector consisting only of straw-tubes is less space-consuming than a TRT. Thus it is possible to place the components of the inner detector further away from the interaction point. This has two important advantages. Firstly, the calorimeters become more efficient for particle-separation because conversions are less a problem. Secondly, due to the space gained radiation-sensitive components, e.g. the silicon-trackers, can be placed in radiation-safer areas further away from the beam pipe, adding to the robustness of the inner tracker.

2 Detector Configuration and Simulation

For the simulations performed up to now, a slightly simplified model of the detector was used. The barrel-form was not considered yet; so the detector consisted of several planar layers of straws. The detector is sketched in figure 1. For the simulation presented here sixty-one layers were used. With a diameter of 4 mm for each straw this gives a total thickness of 21.1 cm for the detector. As material for the straw-walls mylar of 50 μm thickness was used. The active gas inside the straws was a mixture of 70 % Xenon, 20 % CF_4 and 10 % CO_2. These straws are identical with the straws proposed for the TRT by the RD6-collaboration. Details about their properties can be found in reference [1].

The simulation of the detector was done by GEANT. A magnetic field of 2 Tesla was applied parallel to the straws, as it is planned for ATLAS. Material definitions were the same as in DICE. For simulating dE/dx, straw-response and electronic noise the routine TRDSIG by P. Nevski was used.

Electrons and pions of various momenta ranging from 700 MeV to 20 GeV were generated 80 cm away from the detector described above perpendicular to it. Electron-pion separation was analyzed for momenta 700 MeV, 1 GeV, 3 GeV, 5 GeV and 7 GeV. Pions with a momentum of 20 GeV were generated to verify the tracking-capability of the detector. In order to avoid any bias because of the vertex-position the vertex was spread by the straw-diameter of 4 mm.

momentum [GeV]	pion-efficiency
0.7	< 1 %
1.0	< 1 %
3.0	2.1 %
5.0	8.3 %
7.0	19.1 %

Table 1: Pion-efficiencies for 90 % electron-efficiency at various momenta

3   Analysis Procedure

During the simulation described in the previous section the center-coordinates of each straw which had been hit, the drift-time and the energy lost by the particle inside it were stored.

Firstly, the drift-time was converted to drift-distance. Then an initial decision on which side of the straw-center the particle passed was made by fitting a straight line to the possible points in five consecutive layers and keeping the points for which the fit gives the lowest chisquare. With these points and additional vertex-information a circle-fit was done using the *conformal mapping* method [7]. After this fit had been done, possible points were recalculated using the information from the circle-fit. Additionally, new decisions on which side of the straw-center the particle passed were made. Points that were more than 500 μm away from the calculated track were discarded. Then another circle-fit was done with the remaining points. An example of a reconstructed track can be found in figure 2.

After the track-reconstruction had been done, a mean value for dE/dx was calculated. The values for the energy lost in each straw were digitized simulating 4-bit FADCs. Then the mean dE/dx was calculated according to

$$\frac{dE}{dx} = \frac{\sum_{straws} \text{energy deposited in straw}}{\sum_{straws} \text{distance particle traveled in straw}}$$

The sums were performed using 60 % of the straws hit. The straws with the lowest values of energy deposited divided by distance traveled by particle were used. The distance was calculated by determining the points of intersection of the reconstructed track and the walls of the straw.

4   Results

The reconstructed momentum for pions with 20 GeV momentum is shown in figure 3. The resolution was found to be

$$\frac{\Delta p}{p} = 2.8\,\%$$

It has to be mentioned that the code used for the reconstruction was very preliminary, so it is likely that with an optimized code better results could be achieved. Figure 4 shows the quotient of the reconstructed length particles traveled through the straws divided by the actual length taken from GEANT while doing the simulation.

The results of the dE/dx-simulation are shown in figure 5. In the table 1 the pion-efficiencies for 90 % electron-efficiency can be found. The same data is represented graphically in figure 6.

5 Conclusions

These simulations show that pion-electron-separation can be achieved up to energies of about 5 to 7 GeV by measuring dE/dx in the detector described above. For a momentum of 5 GeV the rejection factor is about 10. For higher energies the calorimeters are expected to give additional rejection, so more studies have to be done what the combined performance of the calorimeters and the straw-detector would be. Additionally, other gas-mixtures which are optimized for measuring dE/dx have to be simulated.

At the present stage of the analysis no conclusion about the tracking-performance can be done as the simulations are too preliminary. In any case a straw-tracker will be able to supply about 60 space-points with a good accuracy of about 140 μm as measured by the RD6-collaboration.

Aspects like mechanical or electronical feasibility of the proposed detector are beyond the scope of this work and have to be analyzed in different studies.

6 Acknoledgements

References

[1] RD6-collaboration, *ATLAS Internal Note* **INDET-No-18** (1993).

[2] E. O'Brien et al., *IEEE Trans. Nucl. Sci.* **Vol. 40, No. 2** (1993) 153.

[3] H. Aihara et al., *IEEE Trans. Nucl. Sci.* **NS-30** (1983) 63.

[4] K. Jakobs, *ATLAS Internal Note* **CAL-No-19** (1993) [**TGT-Note 025**].

[5] I. Gavrilenko, *ATLAS Internal Note* **INDET-No-16** (1992).

[6] M. Seman et al., *ATLAS Internal Note* **CAL-No-038** (1994).

[7] M. Hansroul et al., *Nucl. Instr. Methods* **A270** (1988) 498.

61 layers of straws = 21.1cm

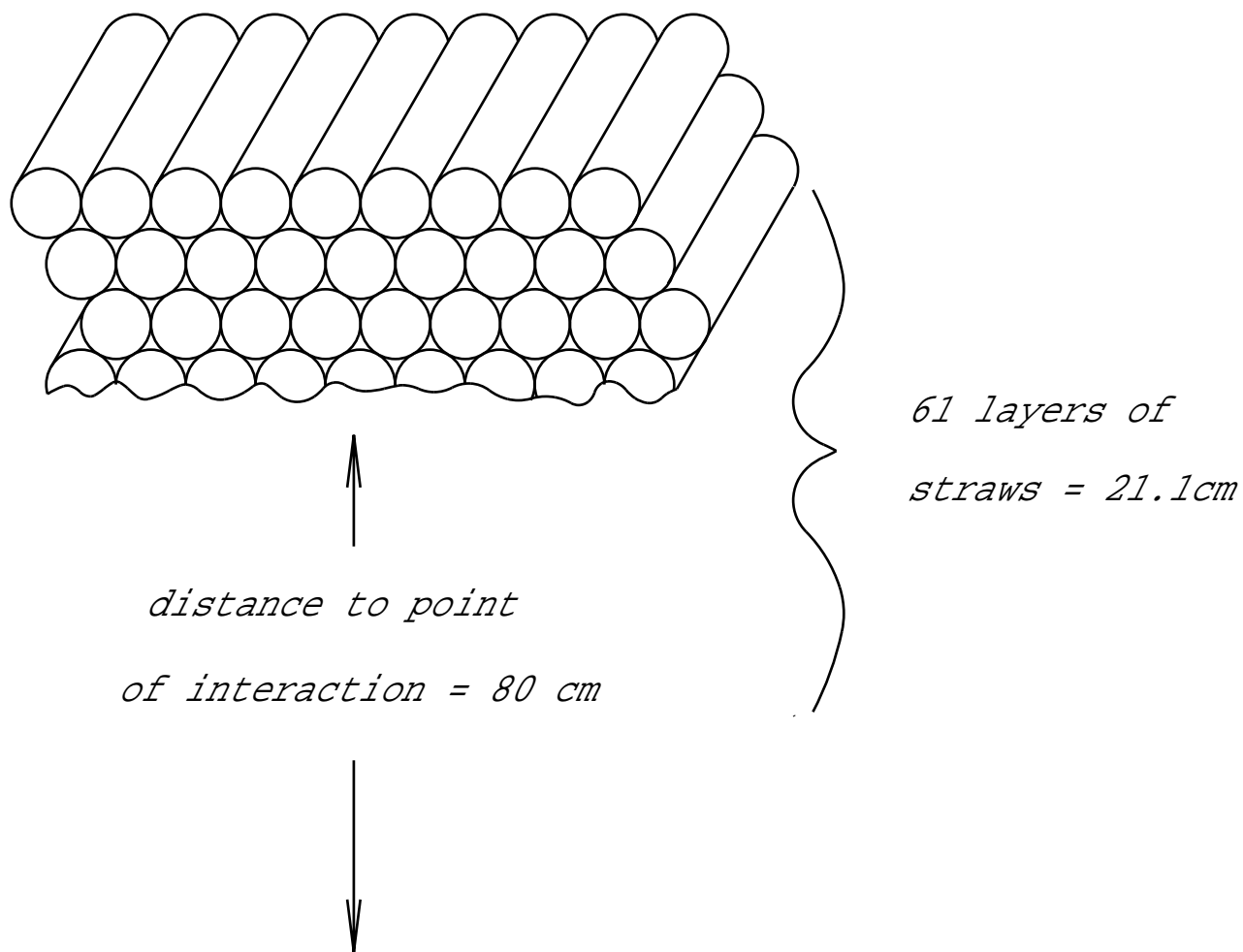*distance to point of interaction = 80 cm*

Figure 1: Layout of the detector used for the analysis
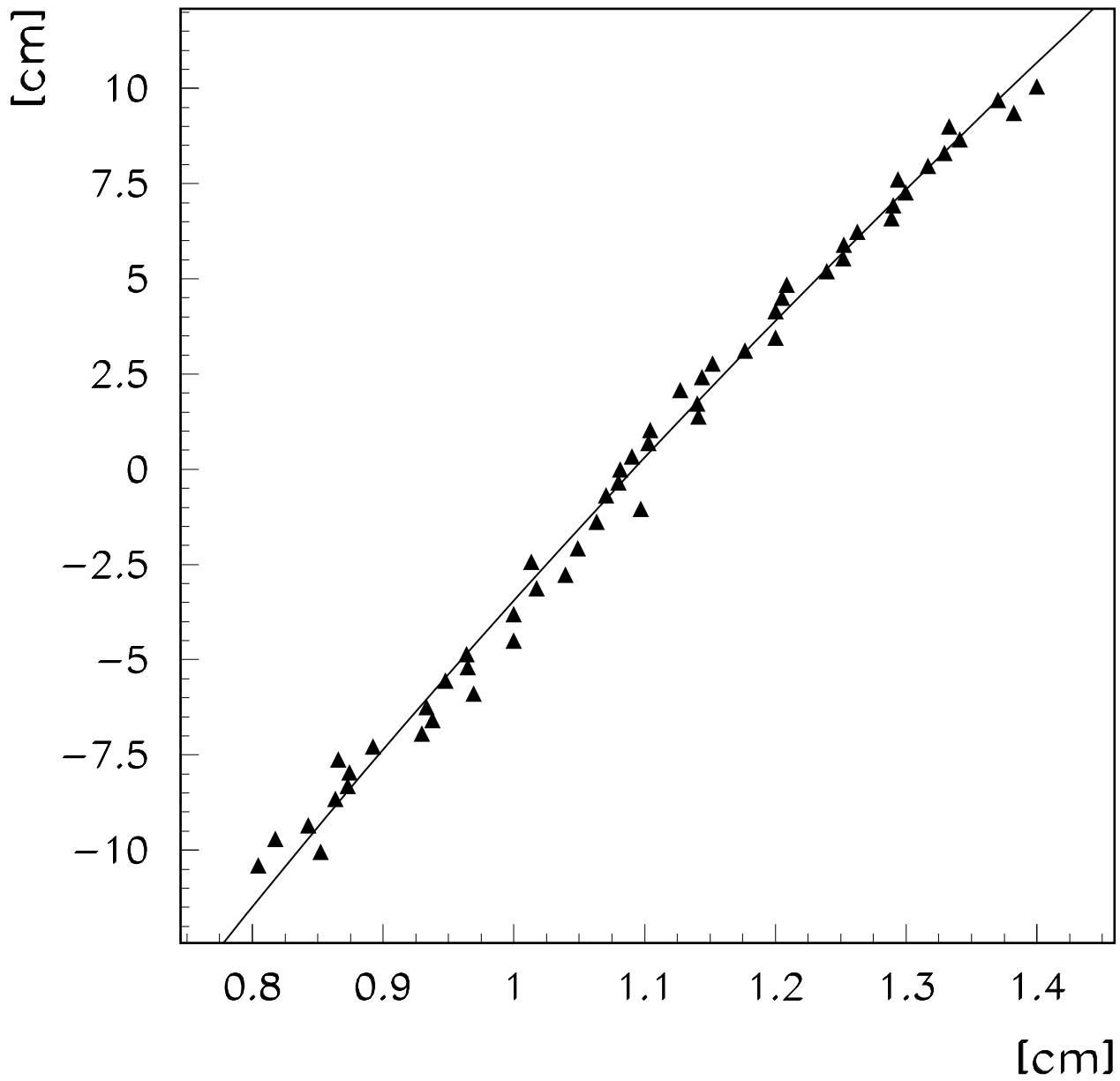
Figure 2: Example of a reconstructed track for a pion generated with 20 GeV momentum (The pion had been generated at [0,-90] and was deflected 8 mm to the right by the B-field before entering the detector)
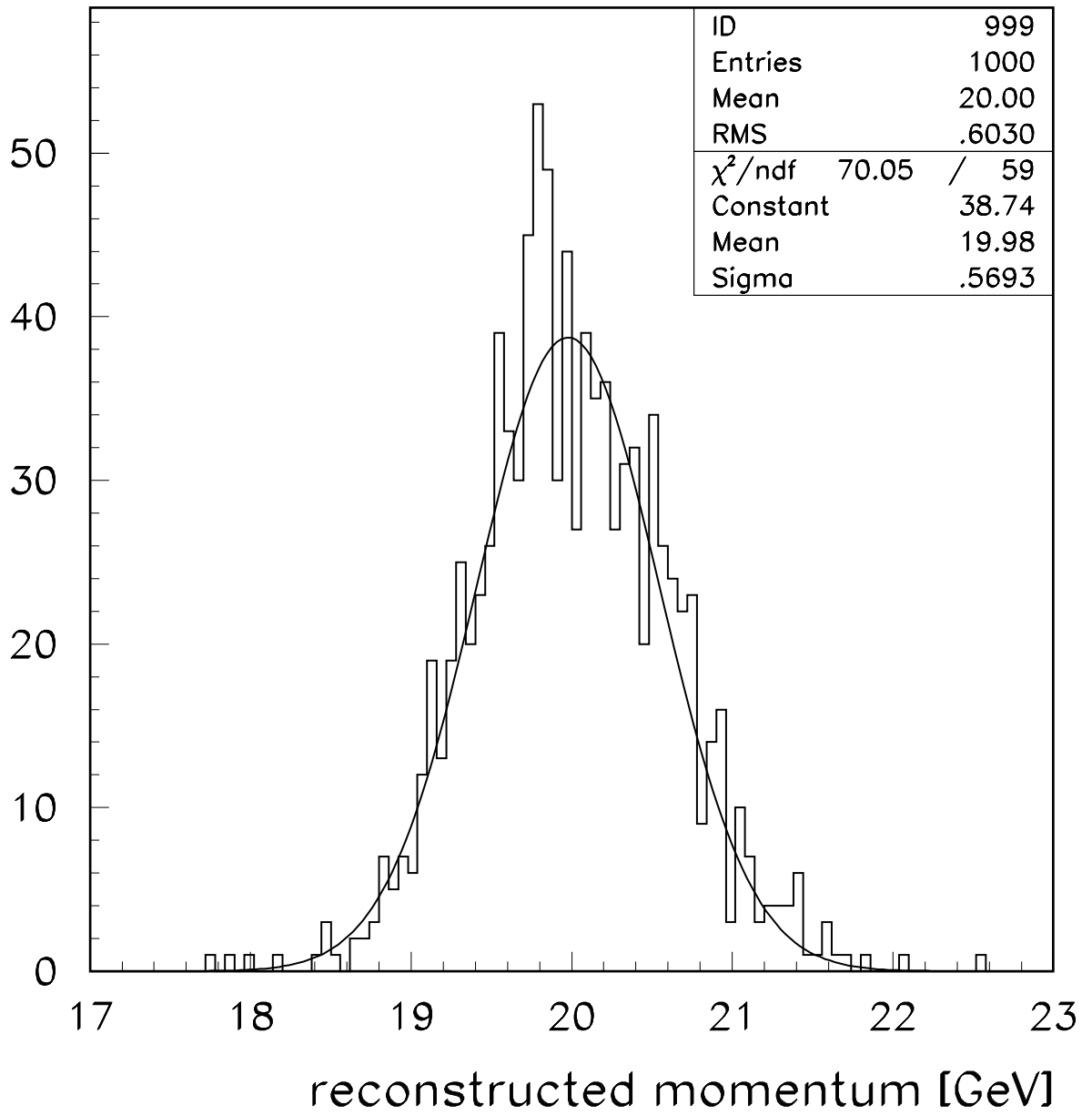
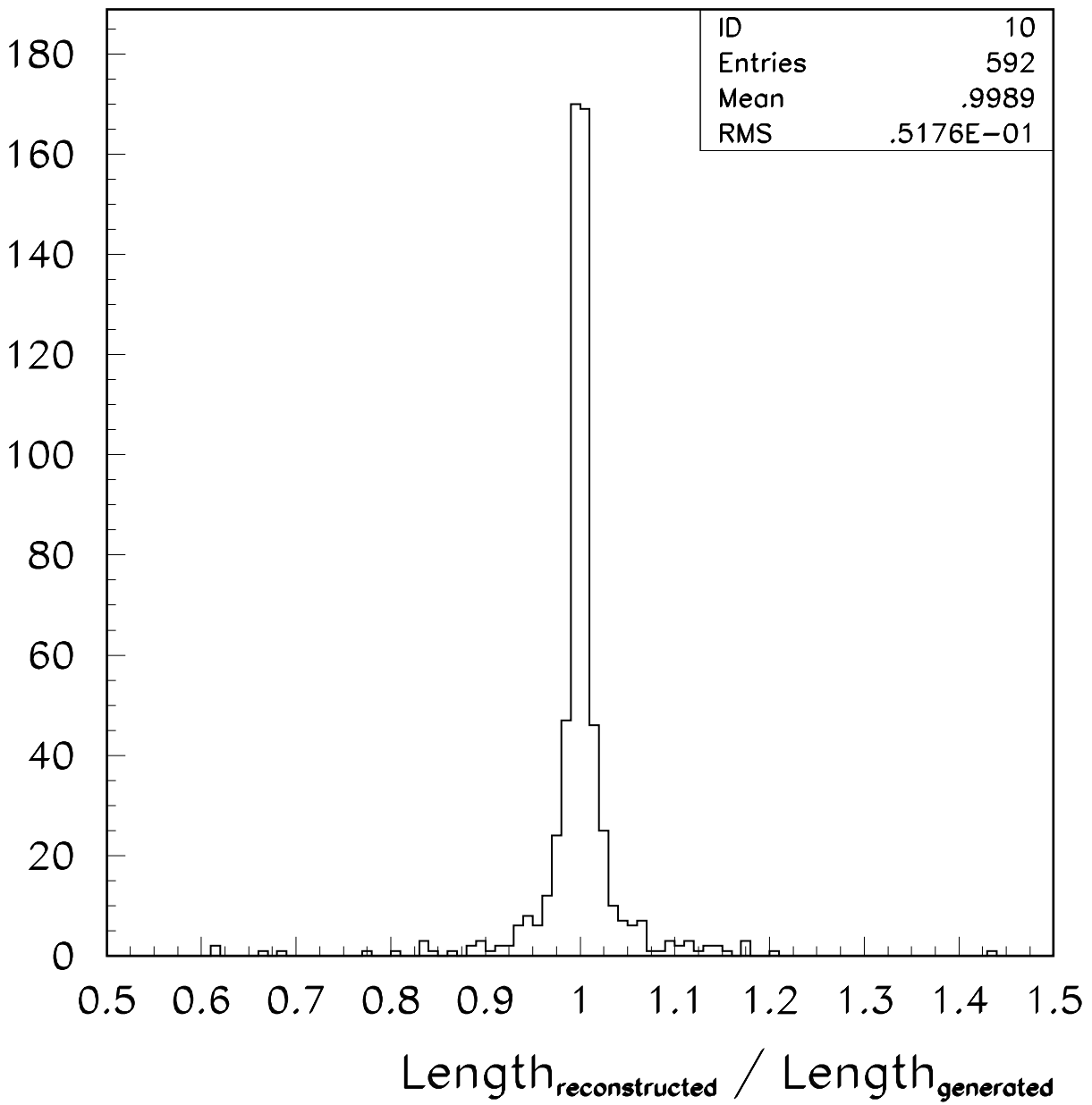Figure 3: Reconstructed momentum for pions generated with 20 GeV momentum

Figure 4: Reconstructed length particles passed through the straws divided by the generated length for 20 GeV pions
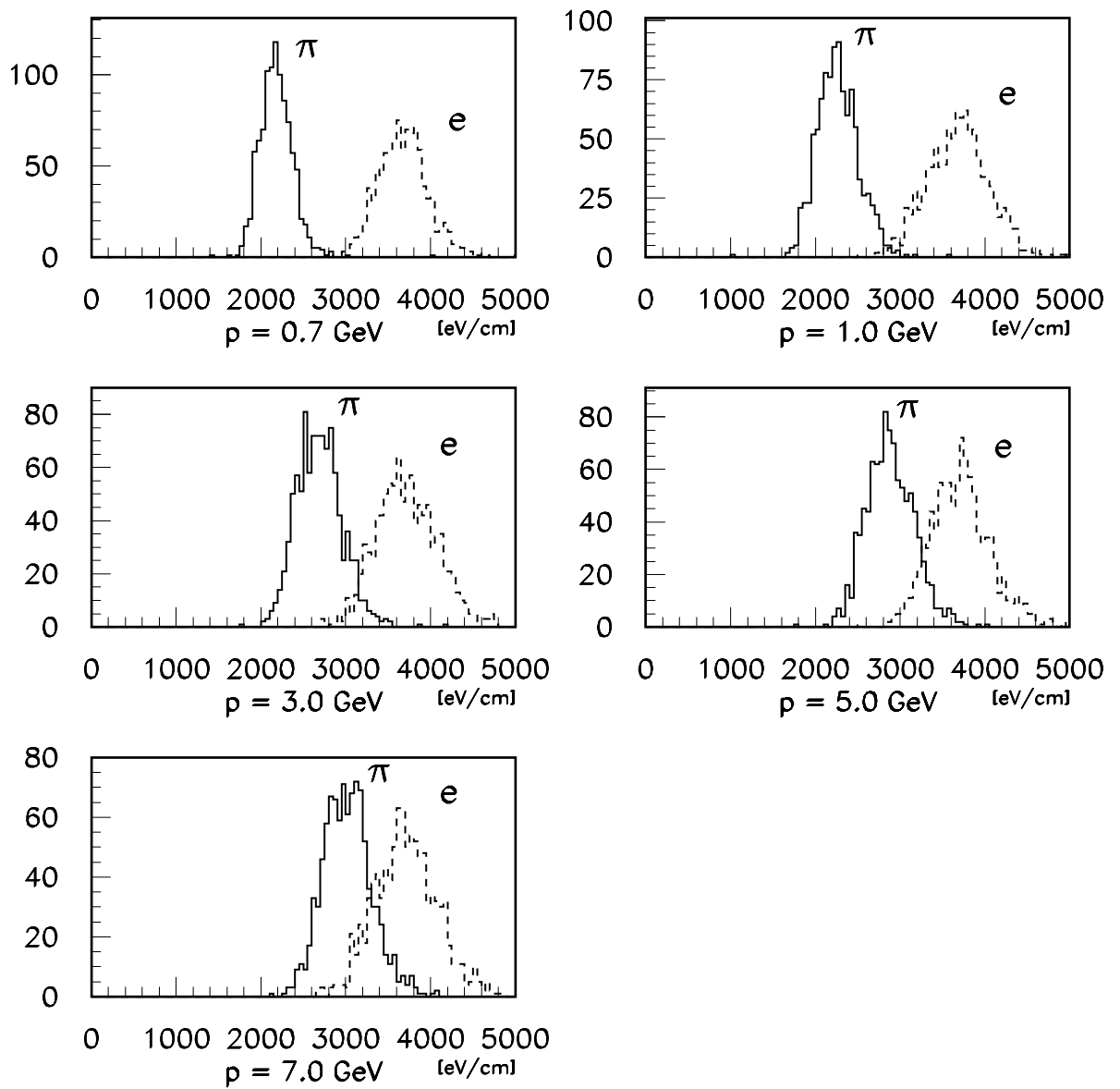
Figure 5: Simulated values of dE/dx for various momenta from 700 MeV to 7 GeV for electrons and pions
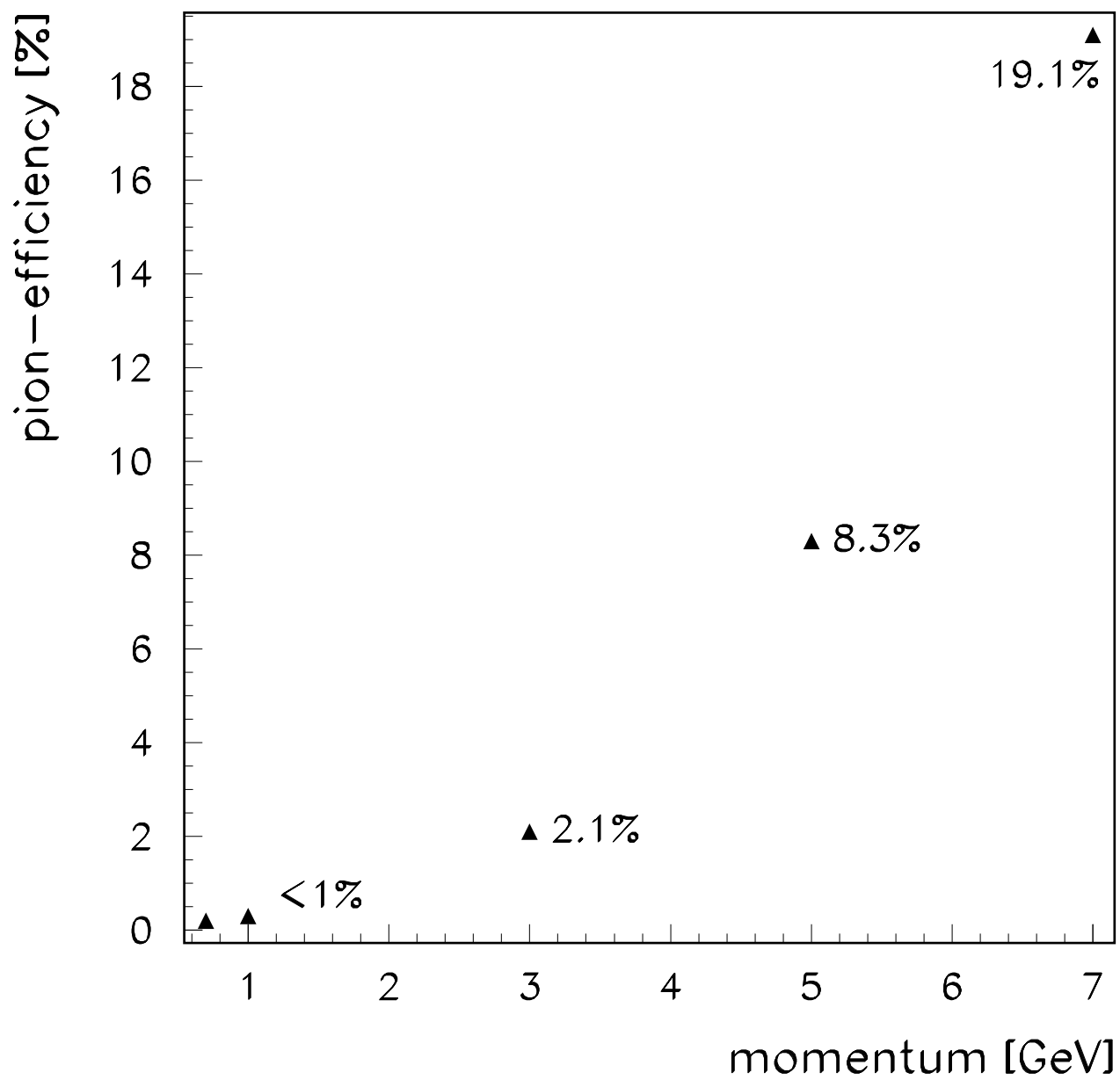
Figure 6: Pion-efficiency for 90 % electron-efficiency versus momentum