Study of the ATLAS Hadronic Tile Calorimeter non-compensation sensitivity

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Abstract

A study of sensitivity of the e/h ratio of the ATLAS Hadronic Tile Calorimeter to the proton contamination in the positive pion beams has been performed. It turned out that the joint application of the proton contamination correction and the correction on the event selection criteria to the e/π ratios leads to unchanged value of the e/h ratio: $e/h = 1.36 \pm 0.01$.

1 Introduction

The value of e/h ratio for the ATLAS Hadronic Tile Calorimeter was determined on basis of the July 1999 test beam data. The analysis carried out in the work [1] led to the value $e/h = 1.36 \pm 0.01$. In the mentioned test beam the setup (Fig. 1) was exposed to the electrons and pion beams with energies 10, 20, 50, 80, 100, 150, 180, 300 GeV at different pseudorapidities: η = -0.15, -0.25, -0.35, -0.45, -0.55.

A drawback of that setup was that its structure did not guarantee full containment of hadronic shower, what was critical especially for high energies. Therefore, we were forced to reject the events with a longitudinal energy leakage by applying some selection criteria: the relative energy deposition in the first depth sampling was required to be $S_1 > 15\%$ of the total and the relative energy deposition in the first two depth samplings needed to be: $S_2 > 50\%$ of the total [1].

Fig. 2 shows the experimental e/h ratio corrected for the longitudinal energy leakage (black boxes) and the uncorrected one (open boxes) as a function of η [1]. It can be seen that the corrections lead to the smaller values of the e/h ratio that does not exhibit any η – dependence.

It should be noted that at energies 50 – 180 GeV the beam of positive pions was used. Later the works of S.Dita et al. [2, 3] appeared in which an impact of the proton contamination to the positive pion beams on the e/h ratio has been estimated. We have exploited some results of these works to obtain the corresponding corrections.

2 Proton contamination correction

Using the results of the analysis carried out by S.Dita et al. [2, 3] we have obtained the following corrections for the proton contamination of the pion beams used in the e/h analysis:

$$\left(\frac{e}{\pi}\right)_{exp} = \frac{R_e}{f_\pi \cdot R_\pi + f_p \cdot R_p} = \left(\frac{R_e}{R_\pi}\right) \cdot \frac{1}{f_\pi + f_p \cdot \left(\frac{R_p}{R_\pi}\right)} , \qquad (1)$$

$$\left(\frac{e}{\pi}\right)_{cor} = \left(\frac{e}{\pi}\right)_{exp} \cdot K_p , \qquad (2)$$

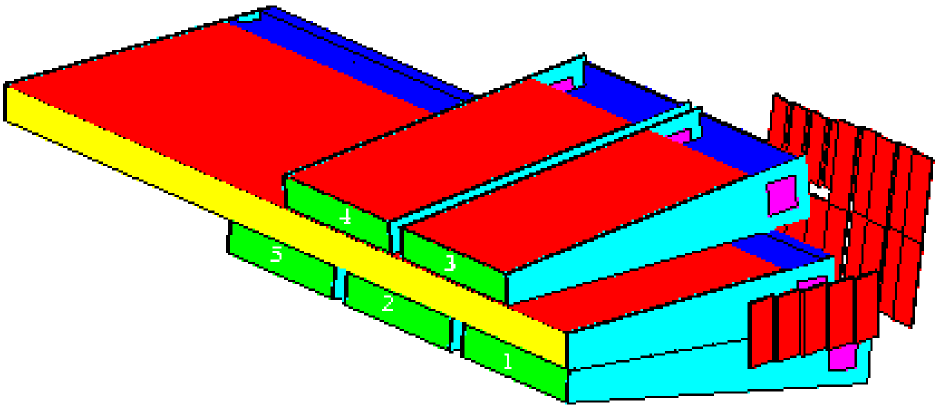

Figure 1: Sketch of the test beam setup.

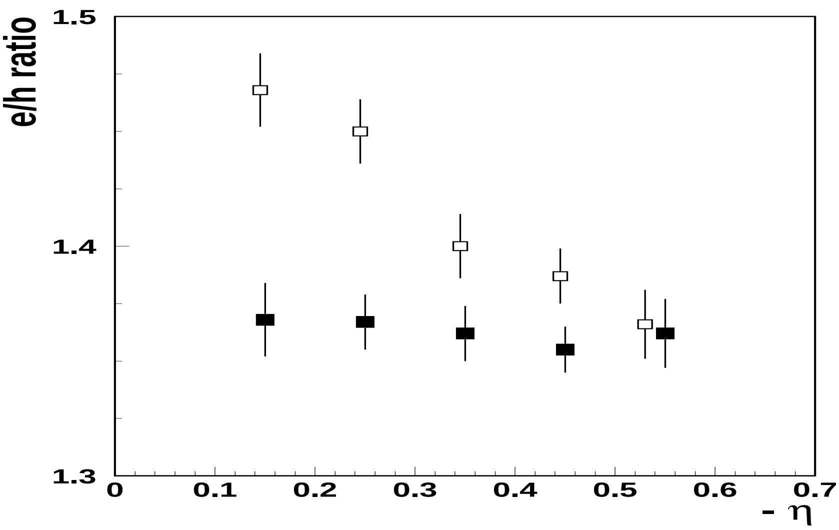

Figure 2: The e/h ratio corrected to the energy leakage (black boxes) and the uncorrected one (open boxes) as a function of η [1].

$$K_p = f_\pi + f_p \cdot \left(\frac{R_p}{R_\pi}\right) , \tag{3}$$

where R_e is the electron response, f_π (f_p) is the pion (proton) fraction in the beam and R_p/R_π is the proton/pion response ratio.

A dependence of the pion and proton fraction as a function of energy is shown in Fig. 3 and the same dependence for the proton/pion response ratio is depicted in Fig. 4. From that we see that the mean pion response is greater than the proton one. This fact can be attributed to the greater electromagnetic fraction (π^0's) in pion showers than in the proton ones — that is connected with the requirement of baryon number conservation in the shower development [5, 6].

The obtained corrections factors are given in Fig. 5 (black boxes).

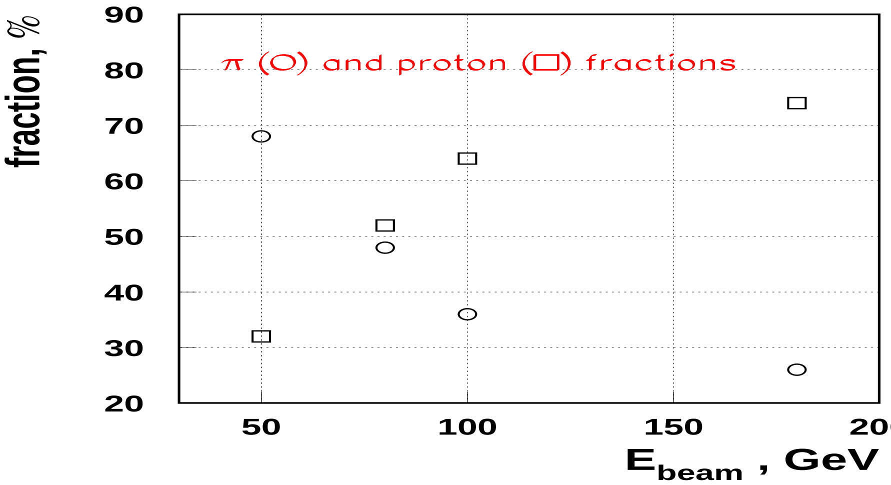

Figure 3: The π and proton fractions of the positive beams as a function of energy, from S.Dita et al. [2, 3].

3 Corrections for the selection criteria

Another type of corrections we need to cope with are those connected with the selection criteria applied at the level of the signal reconstruction.

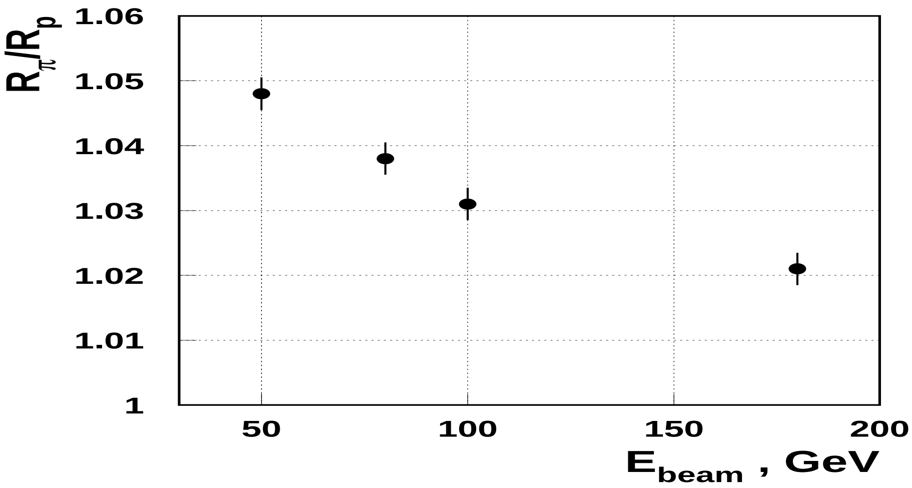

Figure 4: The pion/proton responses ratio as a function of energy, from S.Dita et al. [2, 3].

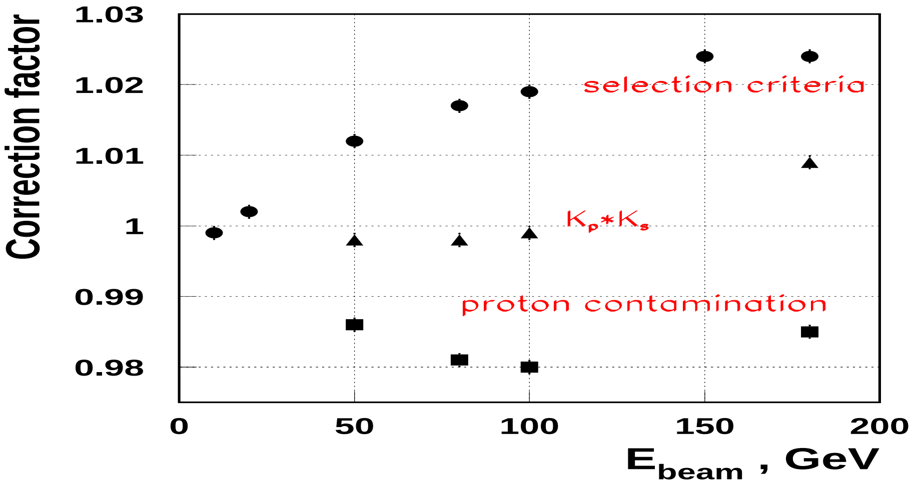

Figure 5: The correction factors for e/π ratios from the proton contamination (K_p), the selection criteria (K_s) and their product ($K_p \cdot K_s$)

These corrections we characterize with a correction factor, K_s, that can be expressed as $K_s = \frac{E_{15\%}}{E_{0\%}}$, where $E_{0\%}$ ($E_{15\%}$) are the mean reconstructed energies at given S_1-cut = 0% (15%). Application of the S_1-cut means that we take into account only the events in which the share of the signal in the first sampling is higher than the value of the applied S_1-cut. Dependencies of the mean responses as a function of S_1-cut for various beam energies can be found in the work [4] (see Table 3). In this work, using Monte Carlo simulation, an influence of the cuts used at the e/h ratio determination has been investigated. It has been shown that values of S_1-cut and S_2-cut used in the e/h extraction procedure have only a minor impact($\approx 1 \div 2\%$) on the e/h ratio value.

The obtained in [4] corrections factors are shown in Fig. 5 (circles) as a function energy. This figure gives also a product of the both correction factors ($K_p \cdot K_s$) which is in limits of 1 %.

4 The e/h ratio

The relation between e/π and the e/h ratio is as follows.

$$\frac{e}{\pi} = \frac{e/h}{1 + (e/h - 1) \cdot f_{\pi^0}} \ , \tag{4}$$

e/h is a factor characterizing an intrinsic non-compensation of calorimeter - it is a ratio of the calorimeter responses to the electromagnetic and non-electromagnetic (purely hadronic) components of hadronic showers, $f_{\pi^0} = E_e/E$ is a fraction of electromagnetic energy (E_e) in hadronic shower, which is parameterized as $f_{\pi^0} = 0.11 \cdot \ln E_{beam}$ [6].

We have used the relation 4 for extracting the e/h ratio. Fig. 6 demonstrates the e/π ratios as a function of incident energy with (black points) and without (open points) the correction on proton contamination. The correction leads to a decrease of the e/h ratio from 1.36 ± 0.01 to 1.32 ± 0.02.

Fig. 8 demonstrates the impact of the selection criteria on the e/h ratio which leads to an increase of the ratio to the value of 1.38 ± 0.01. The joint application of these two corrections leads to the value of e/h ratio (Fig. 7) that is fully compatible with the value reported previously [1], i.e. the corrected value is: $e/h = 1.36 \pm 0.01$.

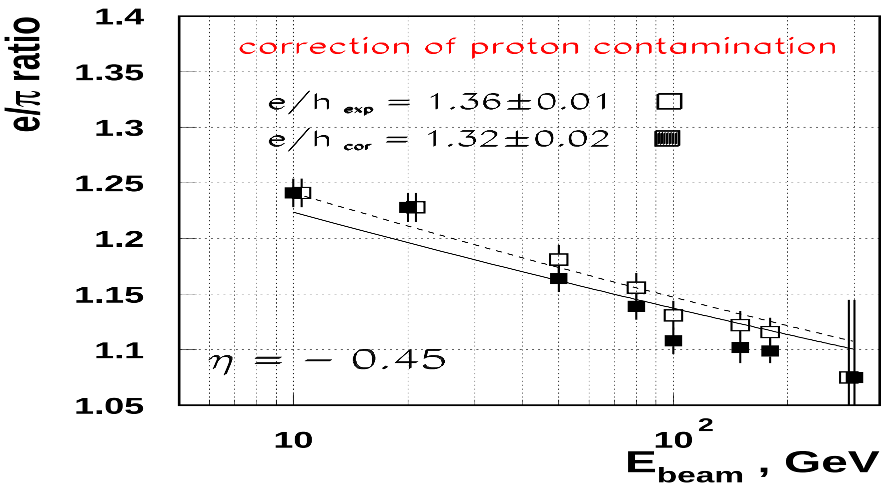

Figure 6: The e/π ratios as a function of energy with (black points) and without (open points) correction of proton contamination.

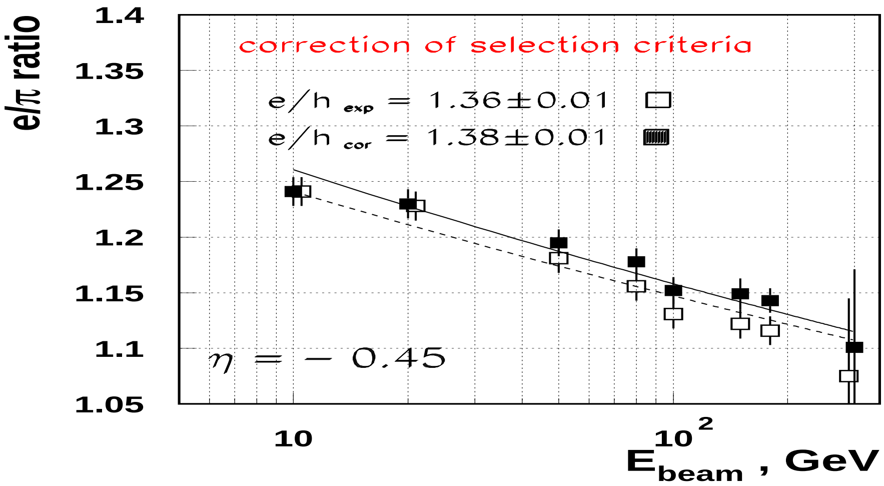

Figure 7: The e/π ratio as a function of energy with (black points) and without (open points) correction K_s of the selection criteria.

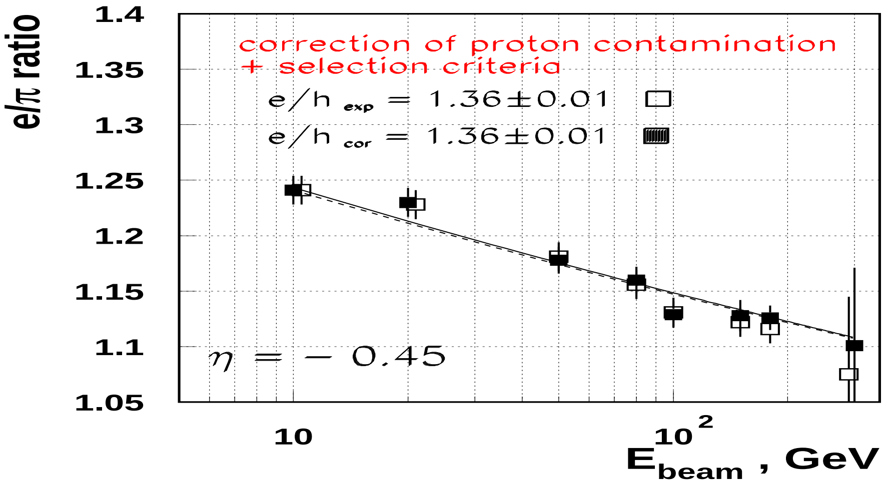

Figure 8: The e/π ratio as a function of energy with and without joint correction of the proton contamination and of the selection criteria.

5 Conclusions

A study of the impact of the proton contamination in the positive pion beams and the event selection criteria on determination of the e/h ratio from the test beam experimental data, has been performed. It turned out that the joint application of the corrections to the e/π ratio taking into account two effects leads to unchanged value of the e/h ratio: $e/h = 1.36 \pm 0.01$.

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