TILECAL-NO-99
6 December 1996
DRAFT 1

Energy Leakage Measurement in TILECAL using the Scintillating Detectors MuWalls

T. Davídek, R. Leitner
Nuclear Centre of the Faculty of Mathematics and Physics,
Charles University, Prague

S. Němeček
Institute of Physics of ASCR, Praha, Czech Republic

Abstract

The energy leakage from the prototype modules of the TILECAL hadronic calorimeter has been studied for various pion energies (80, 100, 150, 180 and 300 GeV). Two methods were developed to correct the energy deposited by the punchthrough events in the Tile calorimeter on the event-to-event basis. Both methods (NHit and Total signal) are based on the correlation between the response of the Muon walls counters and the total energy deposited in TILECAL. The NHit method takes into account the number of Muon wall counters with at least one charge particle hit, whereas the second one handles with the total signal in both Muon walls.

Both methods decrease the low energy tail and for energies above 100 GeV they improve the energy resolution.

1 Beam Test Setup

The experimental setup in the April 1996 beam test period was very close to that of the first combined test in September 1994 (see [1]), therefore only some important items are listed below :

- Two calorimeter prototypes were exposed by the beam : the LAr barrel e.m. calorimeter prototype and the Tile calorimeter prototype modules.

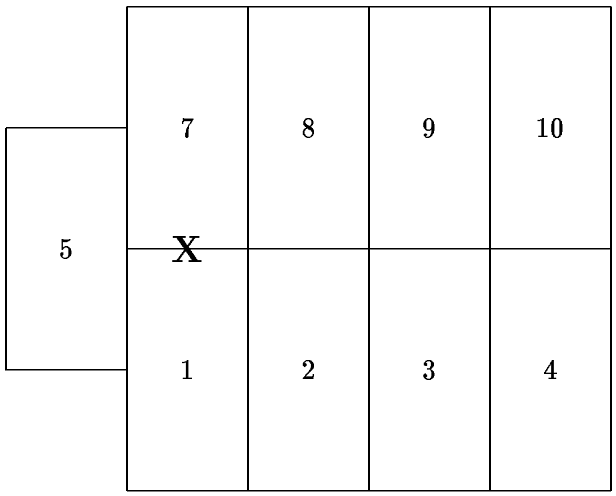

Figure 1: The scheme of the Back Muon wall as seen by the beam. The beam position is marked by X. The logical counter numbers are also displayed.

- The beam entered the detectors at the angle 11 degrees, but the impact point in the Tile calorimeter was shifted by 8 cm from the centre to the left to reduce the lateral leakage.
- The TILECAL consisted of five prototype modules, each being 180 cm long with the front face 100×20 cm^2. The modules are radially segmented into 4 depth segments, which corresponds to 9 λ_{int} in total.
- Two Muon walls [2] were installed to investigate the energy leakage. The back wall (consisted of 9 large scintillators – see Fig. 1) was placed behind the Tile calorimeter, whereas the side wall (the same configuration as in the May 95 standalone beam test – see Ref. [2]) was fixed to the central TILECAL module.
- Additional layer of scintillators (so called Midsamplers) was installed between the face of the Tile calorimeter and the cryostat to investigate the energy losses in the cryostat's depth material.

2 The Event Selection

First, the information from the beam detectors in front of the cryostat is used to impose cuts on the beam :

- The response from the beam scintillators is required to be compatible with that of one minimum ionizing particle (mip).
- The information from the x-y beam chambers is used to remove tracks with large angle with respect to the beam axis.

The punchthrough events are mainly those starting their hadronic showers in deeper radial segments, therefore only the events starting to develop the cascades in TILECAL have been selected. To select them, the signal from the LAr calorimeter should be compatible with that of a mip. Moreover, to remove events with hadronic interactions in the cryostat, cuts on the signal from the Midsamplers has been applied. The muon contamination was removed using the TbeamS3 scintillator counter behind the whole detection system.

3 Leaking Energy Measurement

The missing energy measurement suffers from the energy leakage from the calorimeter. Using the information from the Muon walls, one can estimate the leaking energy amount and thus correct the total energy E_{Htot} deposited in the hadronic calorimeter with respect to this effect.

Two such methods were examined. The first method (called NHit method) is based on the correlation between E_{Htot} and the number of Muon wall counters with at least one charge particle hit. The second method (called Total signal method) is similar to the first one, but takes into account the total signal in both Muon walls instead of the number of counters hit by charged particles.

3.1 NHit Method

First, we define the counter was hit by a charge particle when the signal is greater than the "minimum" between the low-signal region and the mip peak. Now let us investigate the dependence of E_{Htot} versus the number of Muon wall counters with charge particle hits (N_{hit}). It turns out that this dependence (see Fig. 2) obeys the function

$$E_{\mathrm{Htot}} = E^{0}_{\mathrm{Htot}} + P1 \times N_{\mathrm{hit}} + P2 \times N^{2}_{\mathrm{hit}} \tag{1}$$

where E^{0}_{Htot} is the peak value of the non-leaking events distribution. According to this relation one can determine the values of the parameters $P1$, $P2$ for each pion beam energy separately. Thus the average energy leakage for a given value N_{hit} is described by the relation

$$E_{\mathrm{leak}} = -P1 \times N_{\mathrm{hit}} - P2 \times N^{2}_{\mathrm{hit}} \tag{2}$$

Taking into account the obtained parameters $P1$ and $P2$, one can correct the energy $E^{\mathrm{corr}}_{\mathrm{Htot}}$ according to the formula

$$E^{\mathrm{corr}}_{\mathrm{Htot}} = E_{\mathrm{Htot}} - P1 \times N_{\mathrm{hit}} - P2 \times N^{2}_{\mathrm{hit}} \tag{3}$$

on the event-to-event basis. The procedure was carried out separately with each of the pion energy data. The results for the 300 GeV pions are shown in Fig. 2, the complete results for all studied pion beam energies are given in Tab. 3.

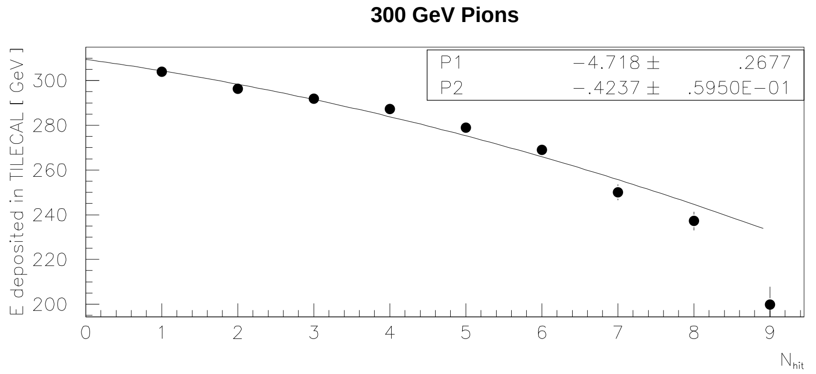

Figure 2: The dependence of the total energy deposited in TILECAL on the number of Muon wall counters with charged particles hits. The function (1) was fitted on the data.

3.2 Total Signal Method

This method aims to correct the hadronic energy according to the dependence $E_{\mathbf{Htot}}$ versus the total signal[1] from both Muon walls $S_{\mathbf{tot}}$. The mentioned dependence fulfils the relation

$$E_{\mathbf{Htot}} = E^{0}_{\mathbf{Htot}} + P1 \times S_{\mathbf{tot}} \tag{4}$$

so the corrected energy reads

$$E^{\mathbf{corr}}_{\mathbf{Htot}} = E_{\mathbf{Htot}} - P1 \times S_{\mathbf{tot}} \tag{5}$$

The procedure (same as in the case of the NHit method) was carried out to obtain the value $P1$ and to calculate the corrected energy. The result for the 300 GeV pions is depicted in Fig. 3, the parameter values are listed in Tab. 3.

3.3 Conclusion

Both methods decrease the low energy tail in the pion $E_{\mathbf{Htot}}$ distribution. This causes two effects :

- The energy resolution improvement.
- The Gaussian mean of the energy distribution shifts to that of the non-leaking events.

The NHit method works slightly better than the second one for the higher energies. Whereas the NHit method application on the 300 GeV pion data results in the approximately same low and high energy tails (events with $E^{\mathbf{corr}}_{\mathbf{Htot}} <$

---

[1] The signals normalized to one mip are summed. Therefore $S_{\mathbf{tot}}$ is expressed in units of mip.

mean$-3\,\sigma$, resp. $E^{\rm corr}_{\rm Htot} > mean{+}3\,\sigma$), the Total signal method over-compensates more events. This causes the low energy tail to be smaller than that of the NHit method, but the high energy tail increases substantially (see Fig. 4 and Tab. 1). Nevertheless, both methods provide the same energy resolution over the whole beam energy range studied (see Tab. 2).

Beam energy	Low energy tail [%]		
[GeV]	Uncorrected	NHit method	Total signal method
80	1.3	0.9	0.8
100	2.3	1.4	1.2
150	3.2	1.8	1.6
180	2.7	1.4	1.1
300	4.2	1.7	0.9

Table 1: The percentage of the low energy tail (events with $E_{\rm Htot} < mean - 3\,\sigma$, where *mean* and σ are the Gaussian parameters of the respective peak) for various beam energy and correction methods.

Beam energy	Energy resolution σ/E [%]		
[GeV]	Uncorrected	NHit method	Total signal method
80	8.4 ± 0.4	8.0 ± 0.4	8.1 ± 0.4
100	7.2 ± 0.2	7.0 ± 0.2	7.2 ± 0.2
150	6.2 ± 0.2	5.7 ± 0.2	5.8 ± 0.2
180	7.1 ± 0.2	6.4 ± 0.2	6.5 ± 0.2
300	6.0 ± 0.1	5.1 ± 0.1	5.1 ± 0.1

Table 2: The comparison of the energy resolution for various energies and correction method.

The parameter values $P1$, $P2$ are listed in Tab. 3. Whereas the absolute values of $P1$ slightly increases with the increasing beam energy (the results for 80 GeV pions suffer from the large errors due to the lower statistics) for both method, the parameter $P2$ is more-less constant over the whole studied range of beam energies.

Beam energy [GeV]	NHit method		Total signal method
	$P1$ [GeV]	$P2$ [GeV]	$P1$ [GeV/mip]
80	-4.90 ± 0.64	$+0.38 \pm 0.23$	-1.83 ± 0.22
100	-2.63 ± 0.28	-0.296 ± 0.077	-1.428 ± 0.074
150	-2.68 ± 0.31	-0.487 ± 0.079	-1.735 ± 0.070
180	-3.53 ± 0.34	-0.330 ± 0.083	-1.743 ± 0.066
300	-4.72 ± 0.28	-0.424 ± 0.044	-2.422 ± 0.044

Table 3: Average values of the energy correction parameters obtained from the fitted function (1), resp. (4). The listed statistical errors are those from the respective fit.

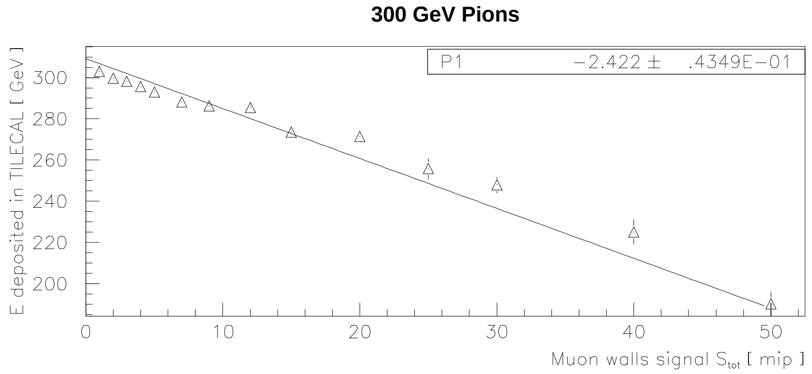

Figure 3: The total energy deposited in TILECAL versus the total signal in the Muon walls. The fitted function (4) is displayed as well.

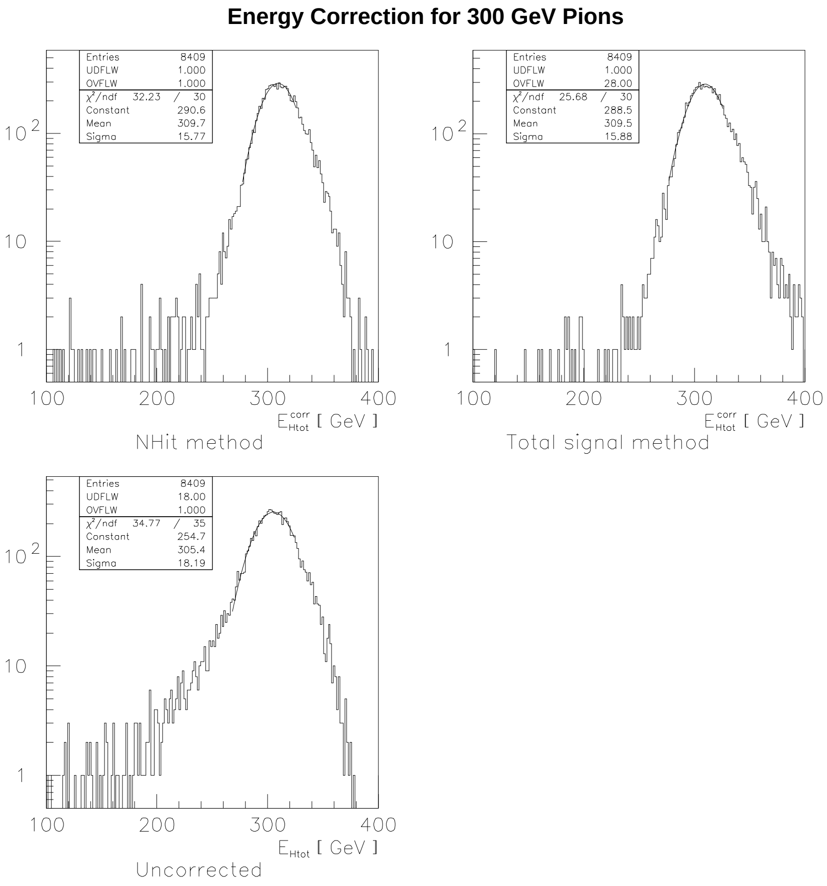
Energy Correction for 300 GeV Pions

Figure 4: Energy correction with respect to the leaking energy.

4 Acknowledgements

Financial support of the project by the grants GAUK-141 from the Grant Agency of Charles University and GACR/202/95/1623 from the Grant Agency of the Czech Republic is acknowledged.

References

[1] M. Cobal et al.: *Analysis results of the first combined test of the LArgon and TILECAL barrel calorimeter prototypes,* TILECAL-NO-67, CERN, 1995

[2] M. Lokajíček et al.: *Scintillating detector "Mu-wall" for measurement of charged particles leakage from the TILECAL prototype,* TILECAL-NO-63, CERN 1995