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# Studies of the Turn-On Behaviour of the EMCal/RICH Trigger

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**Abstract**

This writeup presents a summary of several studies performed in 2003 to get a better understanding of the turn-on behaviour of the EMCal part of the EMCal-RICH-Trigger. Goal of these studies is to find a procedure to sharpen up the turn-on-curves of the EMCal triggers. Several different approaches have been made. Pedestals for all individual trigger tiles have been determined and used to modify the thresholds. The results of this pedestal scan were used in the pp-run to increase the rejection power of the EMCal triggers. The laser/LED calibration and monitoring system of the PHENIX detector was used, to study the turn-on behaviour of single trigger tiles. Another approach was the usage of an internal pulser in the FEMs of the EMCal.

# Contents

# 1 Introduction

The front end electronics of the electromagnetic calorimeter is capable of detecting electrons and photons above three different programmable thresholds in overlapping trigger tiles and above one programmable threshold in non overlapping tiles. Each front end module (FEM) processes the signals from 144 (12x12) photomultipliers. The board carries six daughter cards (ASIC cards) which hold 6 so called MONDO chips, each processing the signals from a block of 2x2 EMCal towers. The signals from the photomultipliers (PMT) are passed through variable gain amplifiers (VGA).
The MONDO chips perform energy sums for the connected 2x2 PMTs and for 4x4 overlapping tiles formed using information received from the neighbour above and the upper-left and left neighbours (as seen standing behind the EMCal, looking into the interaction region). The 36 2x2 sums are compared to one and the 36 4x4 sums to three programmable thresholds. The resulting 36 + 108 bits are sent to a Trigger Card. In total there are 172 FEMs and an equal number of trigger cards.

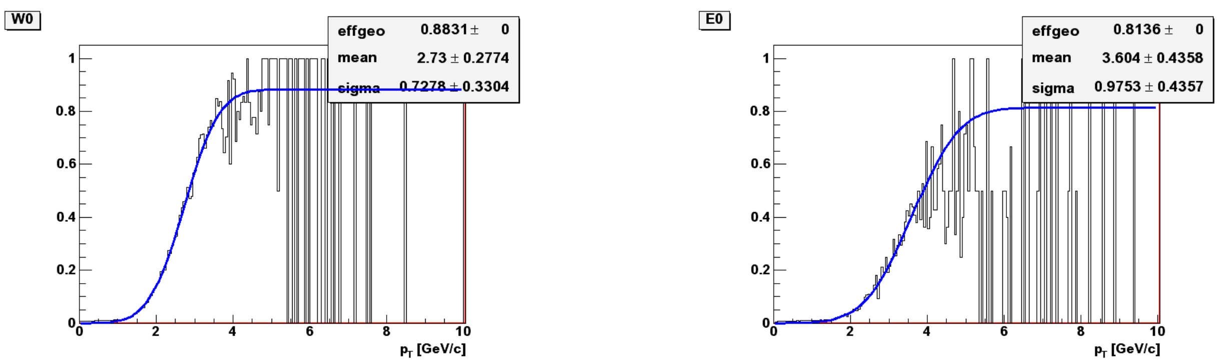


**Figure 1:** *The gamma-efficiency of the 4x4a trigger (DAC value 31) as a function of* $\mathrm{p_T}$ *for sector W0 (right) and E0 (left) from the dAu data in Run3.*

The turn-on curves of the EMCal are broader than expected (see Fig. 1 from the 2003 dAu run), resulting in lower rejection factors. One question is, whether this behaviour is caused by broad turn-on curves of the individual trigger tiles or whether the tiles themselves have a rather narrow turn-on curve and the broad overall turn-on curve is an effect of not well aligned turn-on curves for the single tiles.
During Run3 several attempts were made to get a better understanding of the turn-on behaviour of the EMCal trigger, which should finally result in a method to sharpen turn-on curves. Upon these studies were a pedestal scan, a laser/LED scan, a CALDAC scan and a HV scan.

- The pedestal scan is used to determine the pedestal for every trigger tile separately and will be discussed in section 2.

- The laser/LED scan (described in section 3) was done by varying the laser/LED intensity of the EMCal laser monitoring/calibration system, measuring turn-on curves for each trigger tile separately .
- The LED scan showed some problems in case of the PbGl part of the EMCal. For this reason, the intensity of the LED was constant while the HV of the photomultipliers was changed, to change the gain of the photomultiplier. Details can be found in section 4.
- An internal pulser (CALDAC) can be used, to produce signals with different intensities to study the turn-on behaviour of single tiles (see section 5).
- In section 6 the time dependence of thresholds is investigated.
- The last section gives a short summary and an outlook to the possibility of further improvements.

## 2 Pedestal Scan

### 2.1 What has been done ?

The pedestal scan was performed in the following way: For every trigger tile 1000 events in forced accept mode were taken. The threshold values (DAC settings) were varied in the range from 17 to 33 in case of the 4x4 triggers and from 7 to 23 in case of the 2x2 trigger. To obtain the pedestal position for a single trigger tile, all other tiles were masked off and additionally the threshold was set to the highest DAC-value (63).
For each supermodule this scan was performed in parallel. The scan for one trigger tile takes about 20 min. In this case, configuration files for the four EMCal granules East-Top, East-Bottom, West-Top and West-Bottom are sent in parallel. The trigger related .hex file `tr.hex` is sent via broadcast.

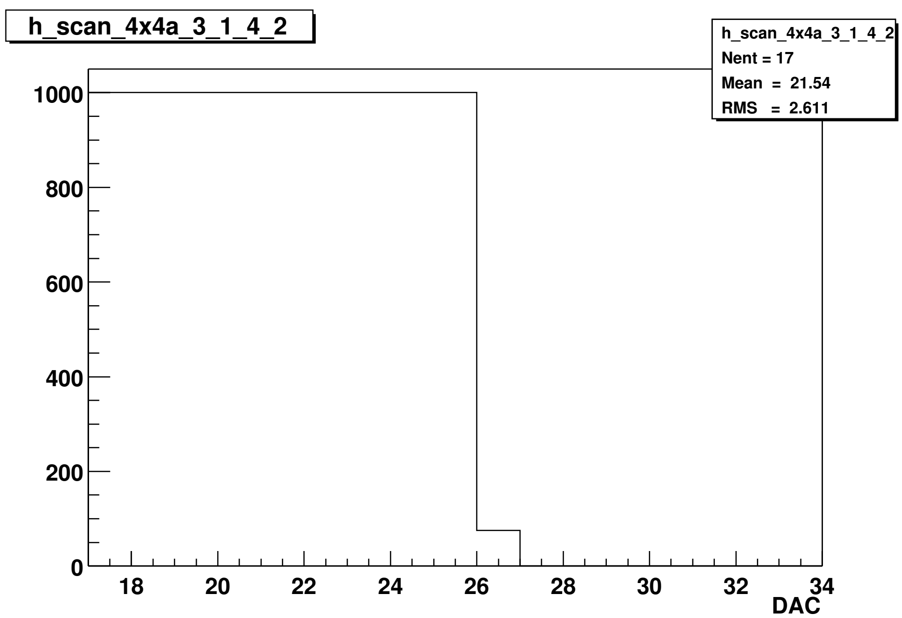


**Figure 2:** *Typical turn-on curve for a pedestal scan.*

Fig. 2 shows a typical turn-on curve of this pedestal scan for one trigger tile. For low DAC-values, i.e. low threshold values the number of entries corresponds to the maximum number of forced accepted events of 1000. At some point the threshold setting is high enough, so less events are accepted by the trigger. Finally, at even higher DAC settings, no events are accepted anymore.
The lowest DAC-value that still contains 0 events is used in the following analysis as the turn-on point. This point is easy to find and allows therefore an easy alignment of all the trigger tiles.

## 2.2 HV-dependence

Two scans for one trigger tile were performed with different HV settings. During one pedestal scan the HV of the calorimeter was turned off. In the second case, the HV was turned on. No significant differences between these two measurements can be found (see fig. 3).

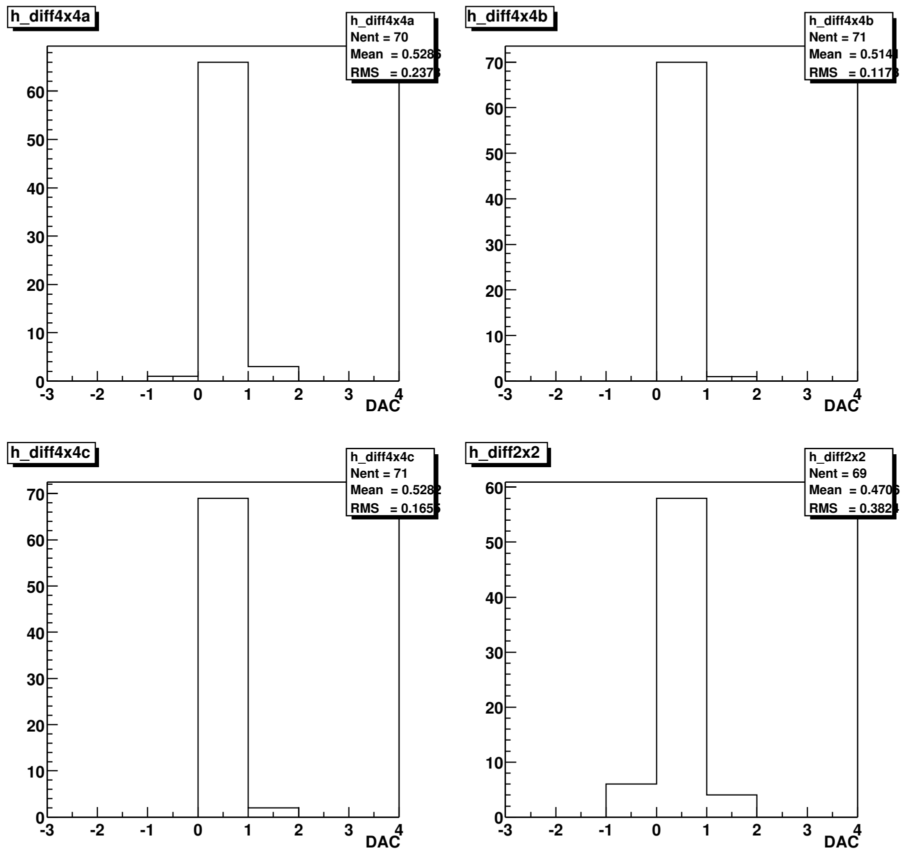


**Figure 3:** *Difference of the pedestals for measurements with and without HV.*

## 2.3 Mean-Values and width of the pedestal distributions

In Fig. 4 the distribution of the pedestal positions for the four different triggers (4x4a, 4x4b, 4x4c and 2x2) are shown. Entries at the DAC value 34 are due to noisy[1] or dead[2]

[1]This means, the number of entries for this trigger tile is 1000 for all DAC values in the range 17-32 for the 4x4 and 7-22 for 2x2.

[2]This means, the number of entries for this trigger tile is 0 for all DAC values in the range 17-32 for the 4x4 and 7-22 for 2x2; Some tiles were tested at even lower DAC settings of 2 and no signal was found.

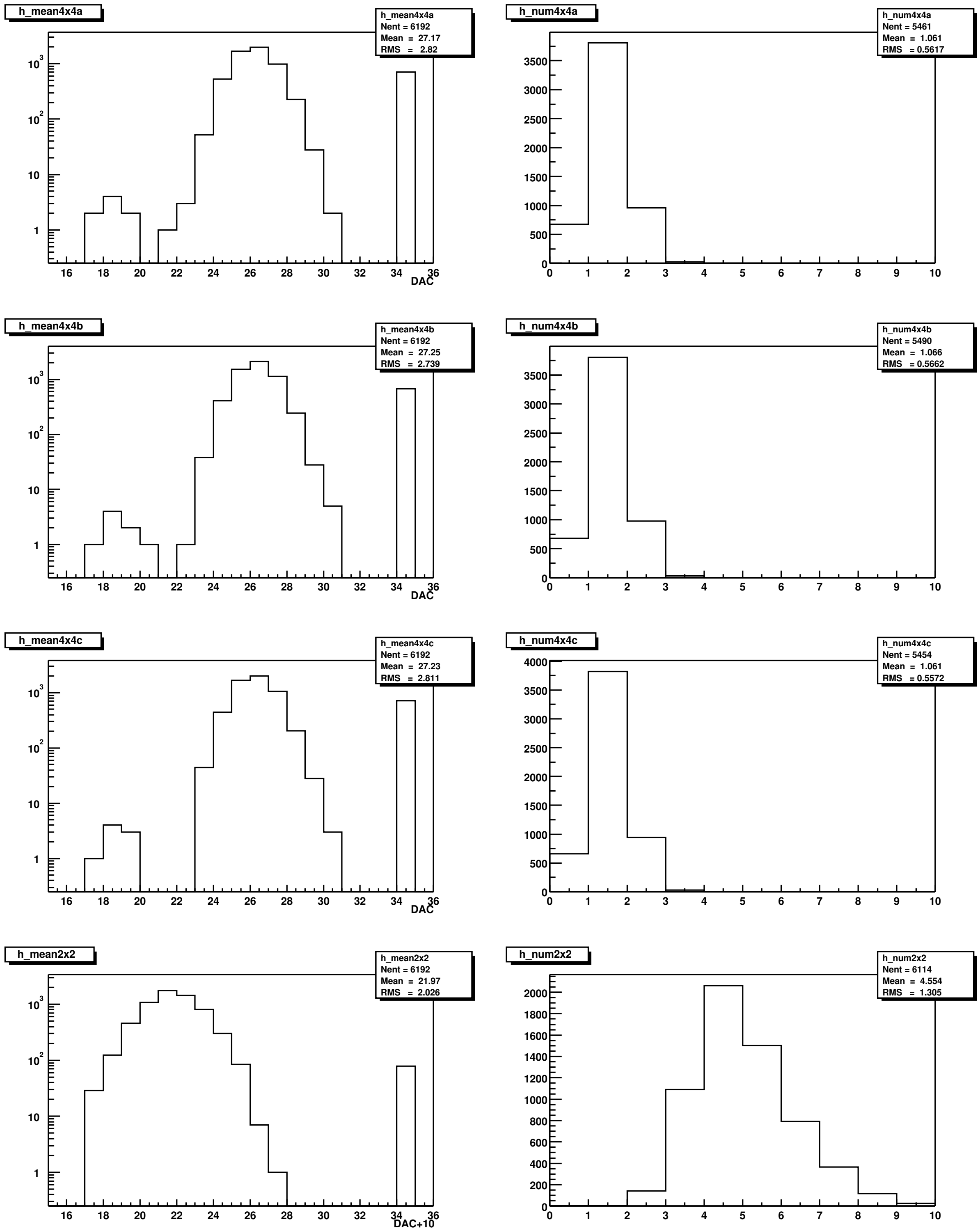


**Figure 4:** *Left: Distribution of the pedestal position. Right: Width of the pedestal turn-on-curve*

trigger tiles.
The distribution for the 2x2 trigger is a little broader (In DAC values, not in energy) than for the 4x4 triggers. The width of the turn-on curve was determined by counting the number of DAC values where the number of entries is smaller than 1000 and larger than 0.
Remarkable for the three 4x4 triggers are the 8 entries at very low DAC values (between 17 and 20). These entries are from the supermodules in the upper right corners of the eight sectors with the combination ASIC 5 / MONDO 5, i. e. in the upper right corner of the supermodules.
The width of the turn-on curve is in case of the 4x4 trigger in most cases 1, e.g. there is one DAC value with entries between 0 and 1000.
The maximum of the width distribution for the 2x2 is at 4. But there is a rather long tail and turn-on curves with a width of 9 and more exist (see fig. 5). This width seems to be in agreement with the pre-amplified 2x2 signal compared to the 4x4.

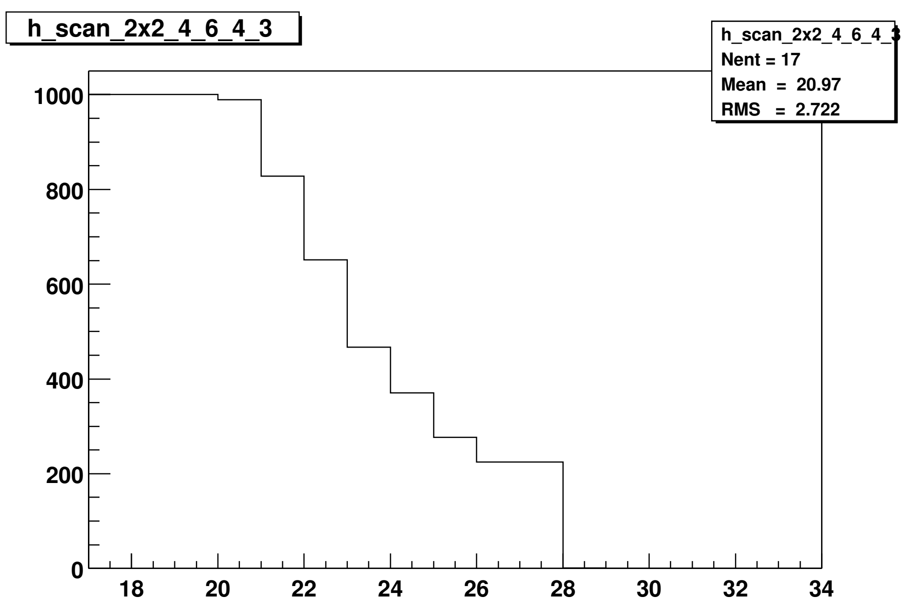


**Figure 5:** *Example of a broad turn-on curve for the 2x2 trigger.*

The individual pedestals are shown in Fig. 43 to 46 in Appendix B. Tiles, with no entries appear white. Tiles that are noisy (that is they have a signal for all measured DAC settings) are marked red.
One can see, that partly the supermodule as a whole is noisy. Single noisy channels can be masked of by raising the threshold to 63. If the whole FEM is noisy, raising the threshold to 63 does not help and the whole supermodule has to be masked of additionally in the ROCs.

Some ASIC boards seem to be dead. Also remarkable are the left and upper edges in case of the 4x4 triggers. They seem to be dead (was confirmed with the laser scan) except for the upper right corner (ASIC 5/MONDO 5) which has exceptionally low pedestals.

## 2.4 Pedestal correlation

The pedestals of the 3 different 4x4 triggers show a correlation (see Fig. 6).

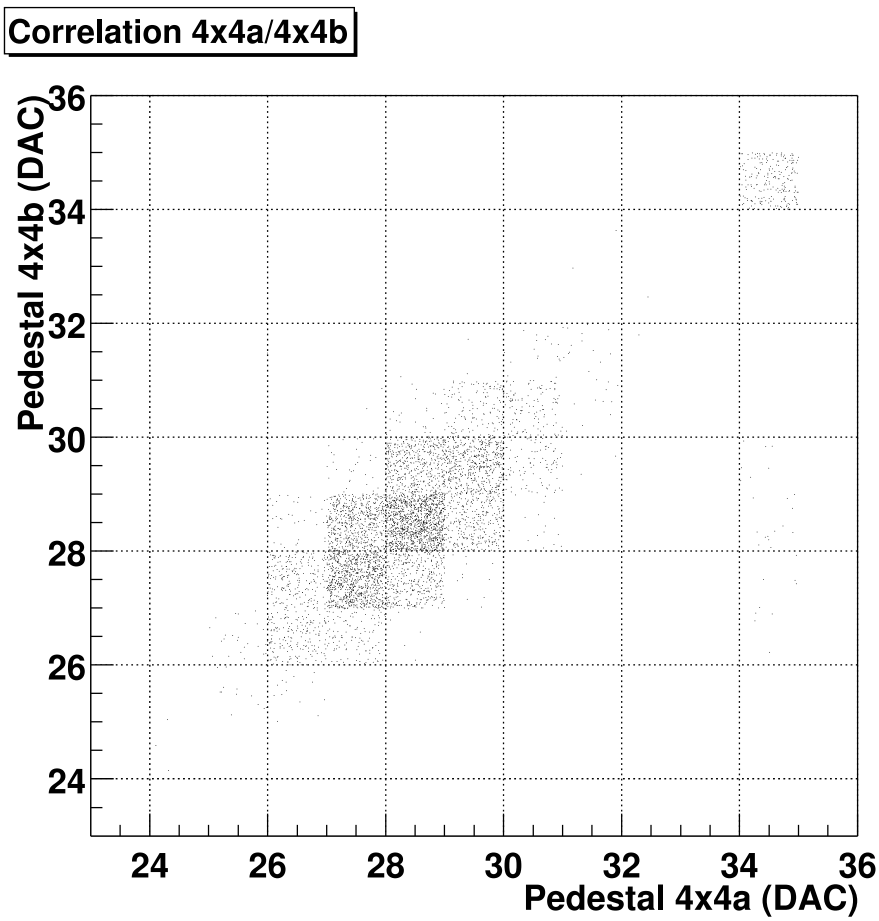


**Figure 6:** *Correlation between the 4x4a and 4x4b pedestals. The DAC value 34 corresponds to a noisy or dead channel.*

## 2.5 Using modified threshold settings

The results of the pedestal scan can be used to improve the EMCal trigger and modified thresholds were used during the pp run.

To verify that the pedestal-scan helps to sharpen up the turn-on-curves, the laser scan can be used. In fig. 7 the distributions for the thresholds determined with the laser scan before and after optimization with the pedestal scan are shown. While the average value of the threshold is mainly unchanged, the width of the distribution is reduced by a factor of approx. 2 to 3.

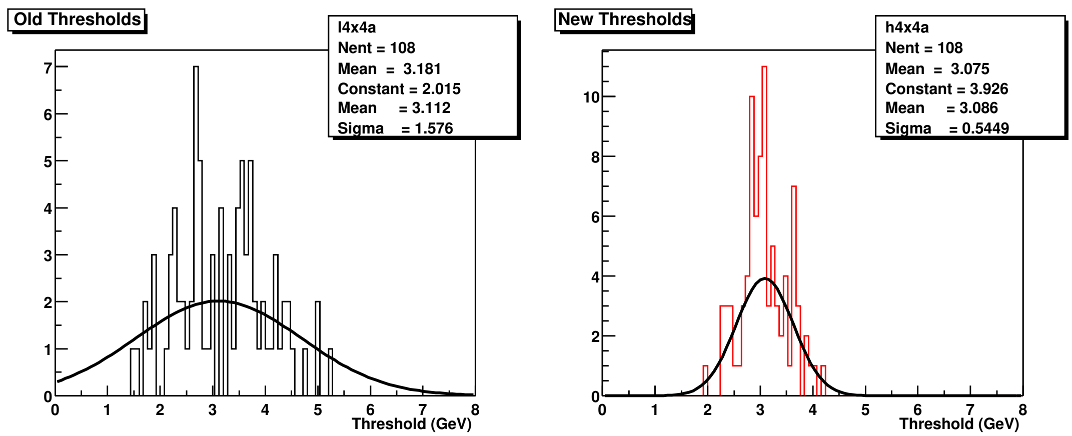


**Figure 7:** *Comparison of the Turn-On-Point distributions of the laser scan before (left, Run 82746) and after (right, Run 84499) adjusting the thresholds with the pedestal scan. Shown are results for the 4x4a. The distributions with the new thresholds are narrower, the mean value stays approx. the same.*

### Improved rejection factors

The narrower distributions of the thresholds of the individual tiles results in improved rejection factors:

| Trigger | Old RF | New RF |
|---|---|---|
| 2x2 (800 MeV) | 29.5 | 35 |
| 4x4a (2.8 GeV) | 863 | 1989 |
| 4x4b (3.5 GeV) | 3762 | 5197 |
| 4x4c (2.1 GeV) | 190 | 606 |
| e (2x2$\otimes$RICH) | 977 | 1077 |

**Table 1:** *Rejection factors with old and new threshold settings.*

These rejection factors were determined at the beginning of the pp run in Run 3.

Another useful result of the pedestal scan is the possibility to mask of single noisy tiles. The number of masked supermodules can be reduced considerably by raising the threshold of single tiles to the maximum value of 63.

# 3 Laser Scan

The Laser/LED Scan was done by taking data with the big partition. Laser and LED intensities were varied during data taking. Thresholds for the four EMCal triggers were set to fixed values. Again all but one tile per supermodule was masked off during this laser scan by raising the thresholds of the other tiles to 63 and additionally using the on/off option[3] in the configuration files.

## 3.1 Some results for the PbSc

Runs of about 1hr duration have been taken (see Tab. 8 for details). From these runs, the turn on curves for the individual trigger tiles in the PbSc can be determined (see fig. 8). The turn on curves themselves are rather sharp. Within approx. 0.1 GeV the efficiency

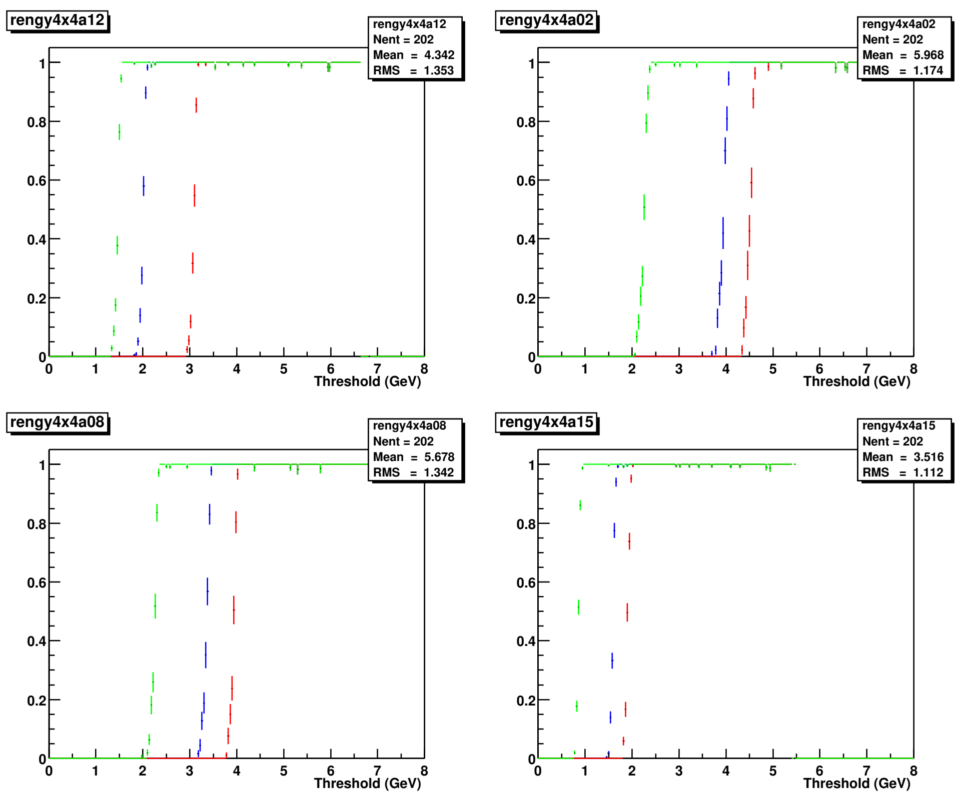


**Figure 8:** *Comparison of different turn on curves for the ASIC/MONDO combination 3/4 for different supermodules in sector W0. Shown are the turn on curves for the 4x4a (blue at DAC 31), the 4x4b (red, DAC 32) and the 4x4c trigger (green, DAC 30).*

[3]This option enables trigger tiles for the summation

of one trigger tile rises to 1. The variation of the threshold value as a function of trigger tile is large. The difference between the three 4x4 trigger thresholds (set at 31,32 and 30 respectively) is not constant.

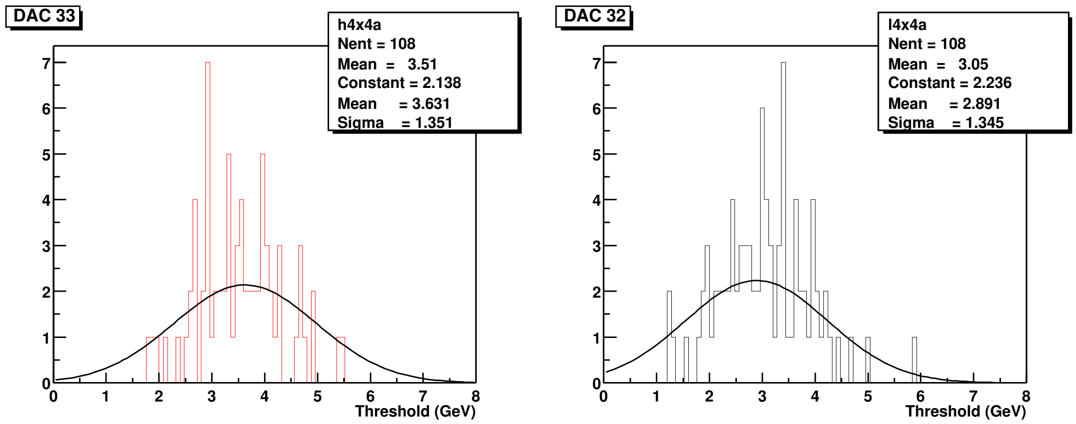


**Figure 9:** *Distributions of the Turn-On-Points for the ASIC/MONDO combination 3/4 for the 4x4a trigger and a threshold setting of 33 (left) and 32 (right).*

In Figure 9 the distribution of the Turn-On-Points for two different threshold settings (DAC setting 33 and 32) are shown. The distributions are broad. The mean values differ by about 0.7 GeV.
In Fig. 10 the differences between the turn-on-points for the two threshold settings are shown. This distribution has a mean value of 0.6 GeV with a sigma of 0.08 GeV. From the

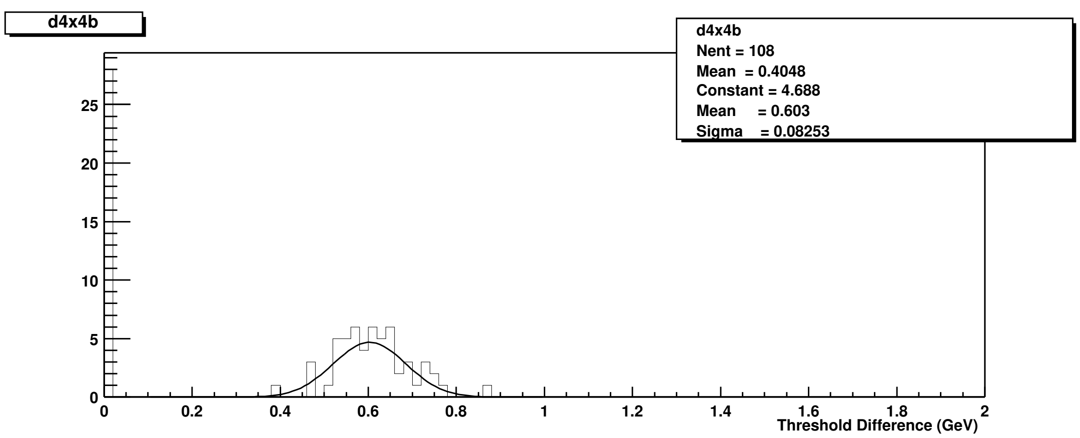


**Figure 10:** *The differences between the turn-on-points for the two threshold settings.*

laser scan the following mean thresholds can be deduced: A DAC-value of 30 corresponds to a mean threshold of approx. 2.5 GeV, DAC value 31 is about 3.0 GeV and a DAC setting of 32 results in a threshold of about 3.5 GeV (more statistics is needed).

## 3.2 Correlation of thresholds

The threshold settings for the 4x4a, 4x4b and 4x4c trigger are correlated. Fig. 11 shows the correlation of the 4x4a and 4x4b thresholds for the tiles with the ASIC/MONDO combination 3/4.

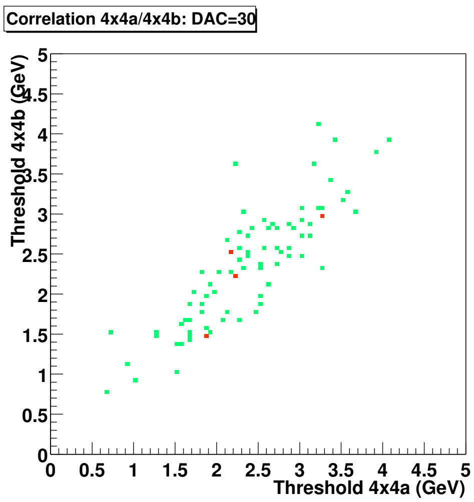


**Figure 11:** *Correlation of the 4x4a and 4x4b thresholds for the ASIC/MONDO combination 3/4 and the DAC setting of 30.*

Fig. 12 shows the difference of the thresholds for the 4x4a and 4x4b trigger for the same trigger tile at a DAC setting of 30.

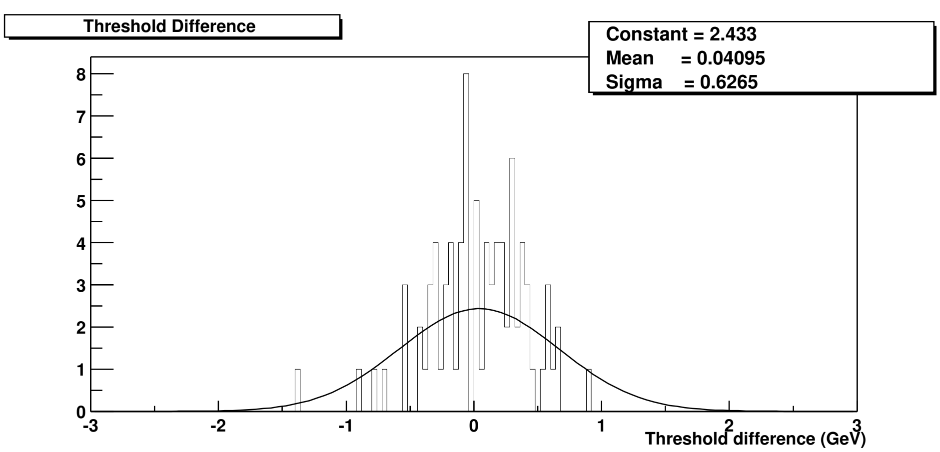


**Figure 12:** *Difference of the 4x4a and 4x4b thresholds for a DAC setting of 30.*

## 3.3 Linearity of the threshold settings

To test the linearity of the threshold settings three measurements for the ASIC/MONDO combination 3/4 were performed with different DAC settings:

| Run | 4x4a | 4x4b | 4x4c | 2x2 |
|---|---|---|---|---|
| 82746 | 31 | 32 | 30 | 34 |
| 83275 | 32 | 33 | 34 | 24 |
| 84505 | 30 | 31 | 32 | 38 |
| 84506 | 32 | 30 | 31 | 40 |

**Table 2:** *The different threshold settings for ASIC 3/MONDO 4 used to test the linearity of the DAC settings.*

Run 82746 was taken about one week before the other two runs. From these Runs the thresholds were determined. The dependence of the threshold from the DAC value should be linear. This can be tested by fitting a linear function. Fig. 13 shows the $\chi^2$-distribution of the linear fit as well as the distributions of the two fit parameters p0 and p1.

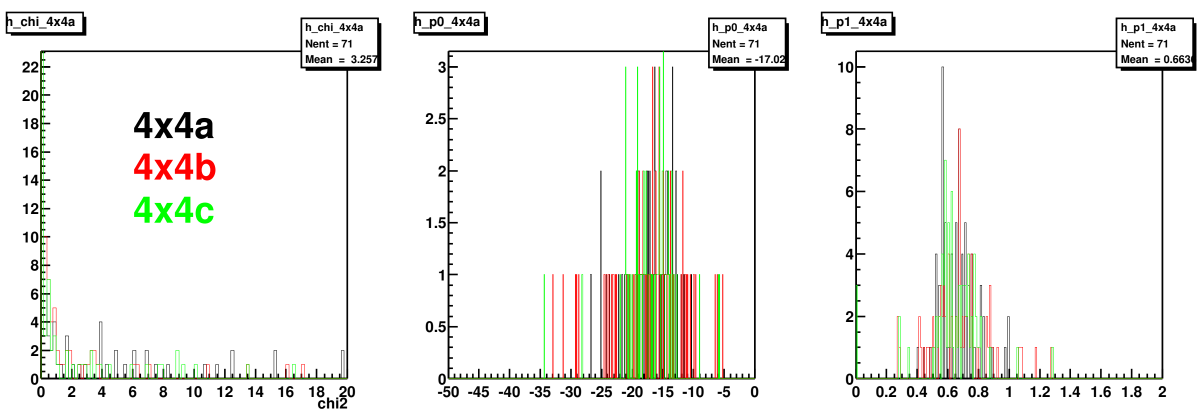


**Figure 13:** *Distribution of the fit parameters of a linear fit to the three threshold settings. The $\chi^2$-Distribution is shown on the left, parameter p0 in the center and p1 at the right side.*

From these fits one can see, that the average DAC width corresponds to about 0.6 to 0.7 GeV. A lot of trigger tiles have a large $\chi^2$. If we define tiles with a $\chi^2 > 3$ as bad tiles, then there are approx. 40% bad tiles in the 4x4a and 20% in each the 4x4b and 4x4c resp. In fig. 14 a selection of fits is shown. For some trigger tiles the behavior is linear . On the other hand, a lot of tiles don't show a linear behavior and some tiles even show lower thresholds when the DAC value is raised.

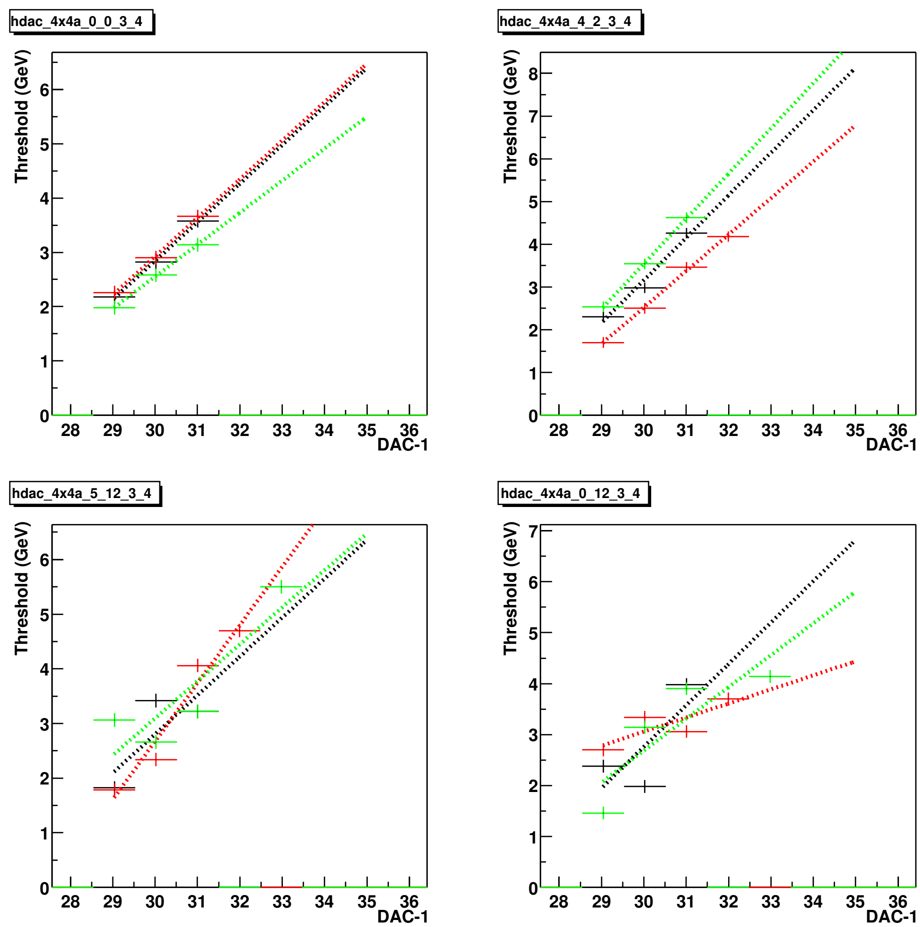


**Figure 14:** *Some examples for the linear fit to the DAC settings. Shown are results for the 4x4a (black), 4x4b(red) and 4x4c(green). In the upper two plots, the linearity of the response to different DAC settings is very good, while for the two lower plots large deviations form a linear behavior can be seen.*

There are two possible explanations for this behavior:

- MONDO chips are faulty and show this strange behavior.
- Thresholds are not stable. Some measurements were performed with several days delay.

## 3.4 Thresholds for the 2x2 trigger

Thresholds for the 2x2 trigger seem to be also slightly higher than the expected thresholds. The distributions seem to have tails to higher energies, which are caused by the different

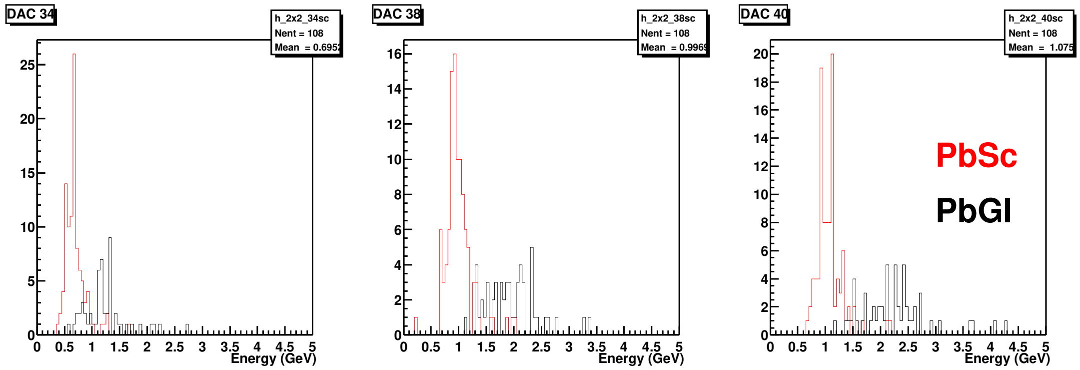


**Figure 15:** *Distribution of 2x2-thresholds for DAC values 34 (left), 38 (center) and 40 (right) for PbSc (red) and PbGl (black).*

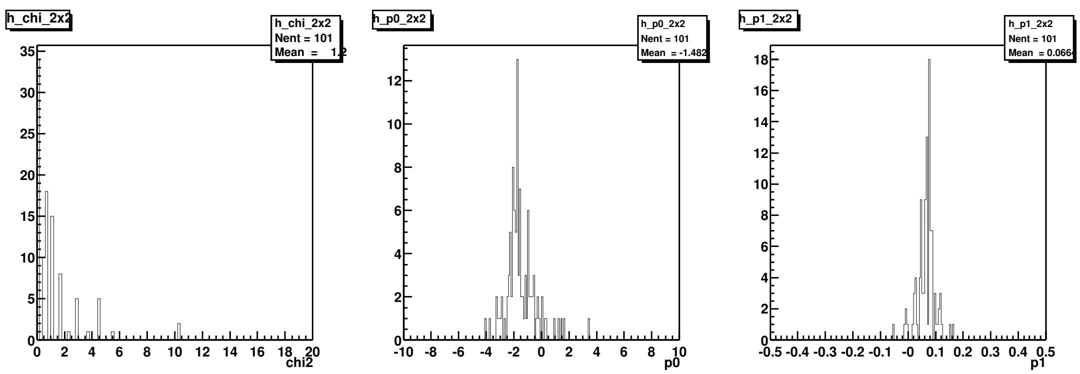


**Figure 16:** *Distributions of the $\chi^2$(left) and the parameters p0 (center) and p1 (right) from the fit of 2x2-threshold.*

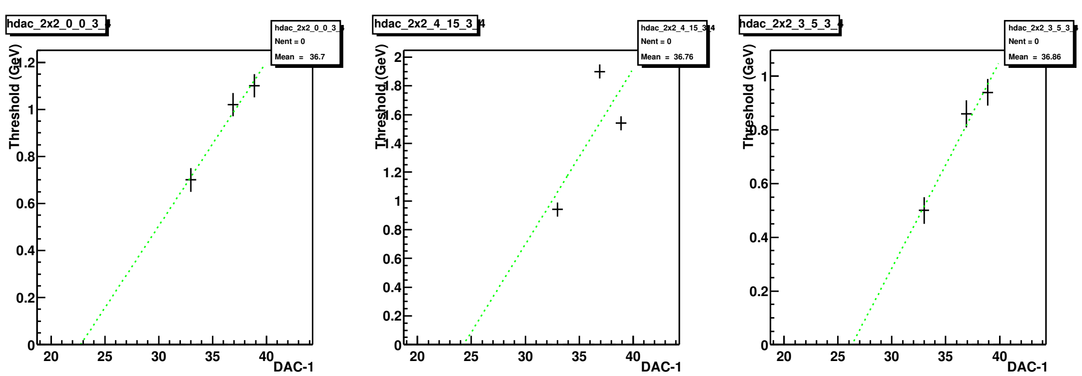


**Figure 17:** *Examples for the linear fit to the 2x2 threshold.for different trigger tiles. The width of the turn-on curve was estimated as 0.05 GeV.*

behavior of the PbGl.
These results were obtained at thresholds, that are higher than the usual threshold settings. The laser intensity is to high to use lower thresholds. This might have an effect on the results. For example, the mean value of the pedestal of the 2x2 trigger is at a DAC value of 14 to 15. From these linear fits, a zero value for the energy would be expected at DAC values in the order of 20-25. This might be an indication, that the linearity is not given at low DAC settings used during a physics run.

## 3.5 Comparison of the pedestal and the laser scan

A first test of the usefulness of the pedestal scan is to check whether the results of the laser scan are related to the thresholds from the laser scan. This is done in fig. 19. One can see, that the results are correlated. But the pedestal scan is not sufficient to establish an adjustment of the turn-on points within one DAC setting (approx. 0.6 GeV).
Fig. 18 shows the correlation between the pedestal from the pedestal scan and the zero crossing of the linear fit to the series of measurements for different threshold settings (see Tab. 2).

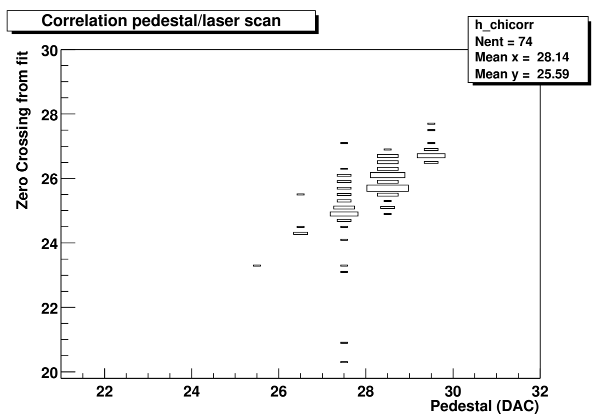


**Figure 18:** *Correlation between the pedestal and the zero crossing obtained from the linear fit to several laser scans at different thresholds for the ASIC/MONDO combination 3/4.*

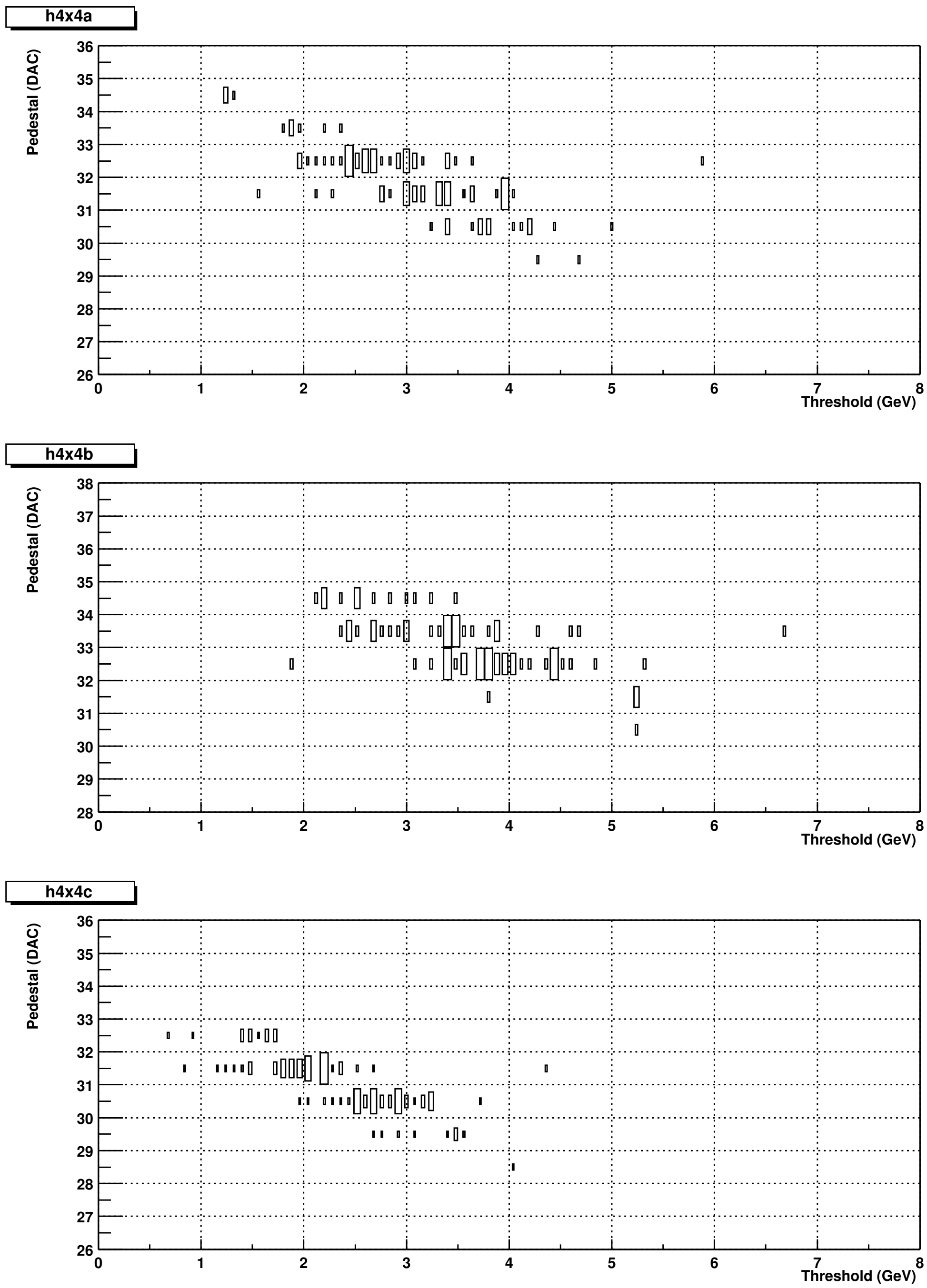


**Figure 19:** *Correlation between the pedestal and the turn-on-point from the laser scan for the ASIC/MONDO combination 3/4. Shown are the correlations for the 4x4a (top), 4x4b (center) and 4x4c (bottom).*

## 3.6 Special Runs

Some special laser scan runs were taken to investigate the 4x4 summation. During these runs, tiles were turned on by the on/off switch which had the highest possible threshold, while tiles that were disabled by this on/off-switch had a regular threshold setting.

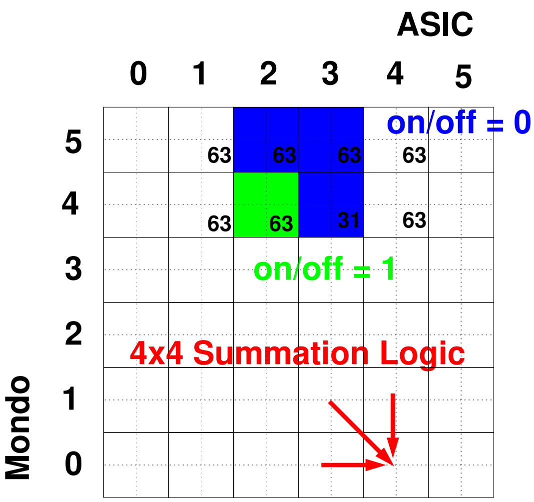


**Figure 20:** *Illustration of the special runs. All tiles but one were disabled using the on/off-feature, which disables the tower connection. The thresholds off all tiles but one were set to 63. The tile that was enabled does not coincide with the tile with the lower threshold.*

Two tiles were tested to check the 4x4 summation. The runs involved are:

1. readout = ASIC3/MONDO4

| | |
|---|---|
| input=A3/M4 : | Run 92580 (30,30,30= 4x4a,b,c) for c |
| | Run 92585 (31,31,31) for a |
| | Run 92589 (32,32,32) for b |
| input=A2/M4 : | Run 92600 (31,32,30) |
| input=A2/M5 : | Run 92603 (31,32,30) |
| input=A3/M5 : | Run 92606 (31,32,30) |

   A3/M4 is taken as a reference in the figures.

2. readout = ASIC3/MONDO2

| | |
|---|---|
| input=A2/M2 : | Run 92611(31,32,30) |
| input=A2/M3 : | Run 92615(31,32,30) |
| input=A3/M3 : | Run 92614(31,32,30) |

   A2/M2 is taken as a reference in the figures.

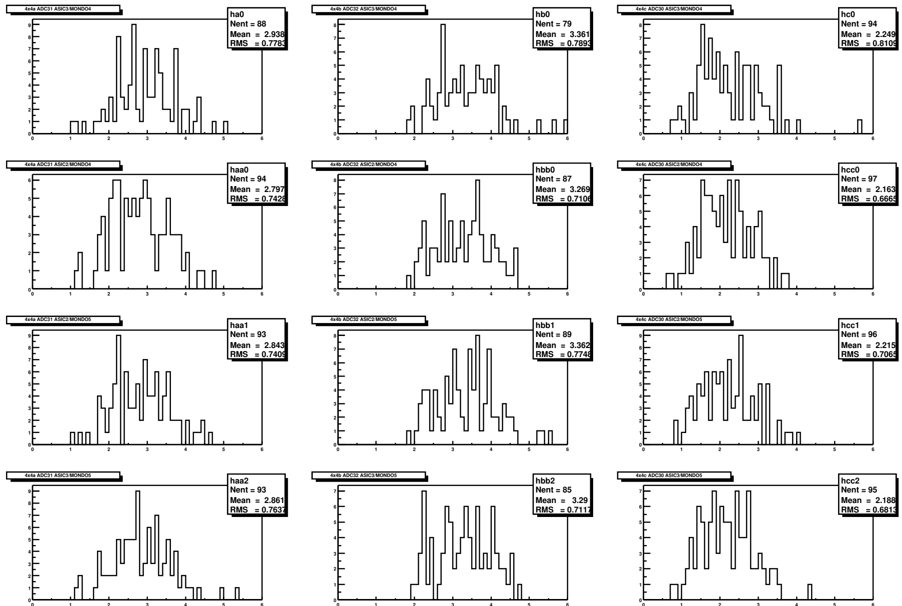

**Figure 21:** *All thresholds of A3/M4 set.*

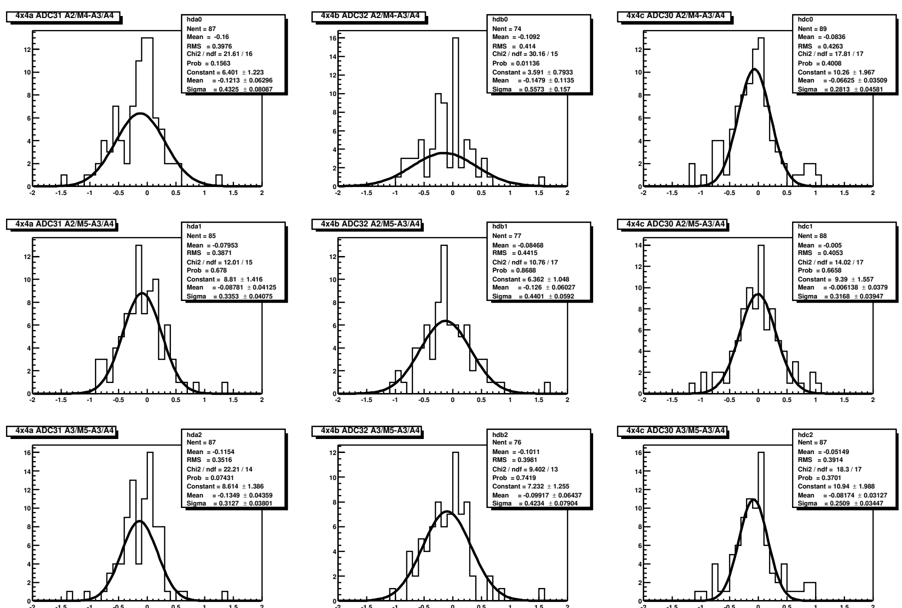

**Figure 22:** *Distribution of differences thresholds of A3/M4 set.*

The results for the combination A3/M4[4] are shown in fig. 21 to 23. The results from both sets have the same tendency. The difference for different inputs is between 300 and 400 MeV for different inputs. It seems slightly larger for higher threshold. The average is zero. There are correlations in the different 4x4 modes.
The behavior looks very similar to the time variation (see section 6). How can we exclude the possibility of short time (approx. 10 min.) variation?

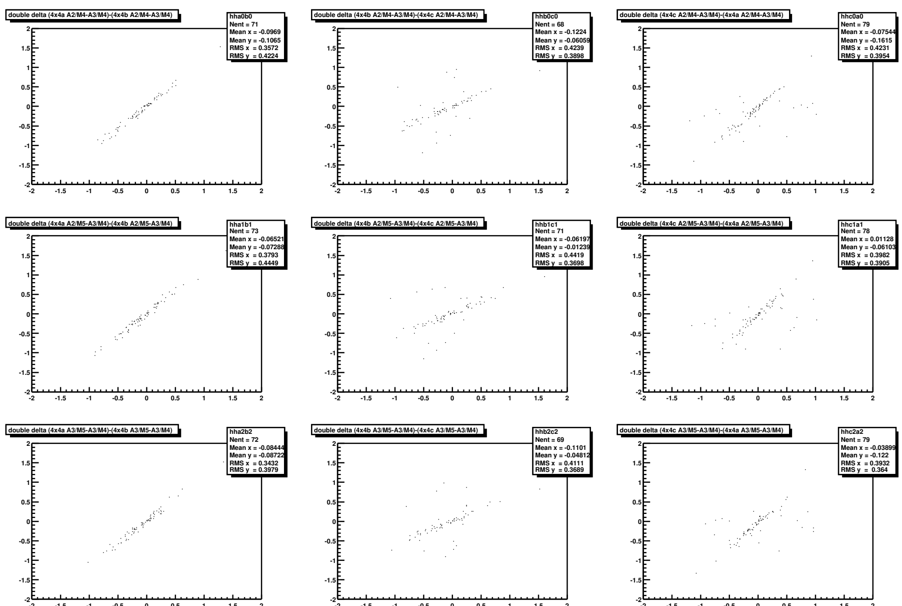

**Figure 23:** *Difference of difference between 4x4 modes.*

[4]Plots for A3/M2 can be found in appendix D

# 4 Results for PbGl

The PbGl part of the EMCal is not connected to the laser system. For calibration and monitoring purposes a LED system is used. This LED system contains two yellow LEDs, a so called avalanche yellow and a variable yellow. The intensity of the avalanche yellow LEDs is fixed. The intensity of the variable yellow LEDs can be changed by varying the voltage of the power supply for these LEDs.

## 4.1 LED scan

In parallel to the laser scan, the intensity of the LED signal of the variable yellow LED was changed continuously to obtain a turn-on curve for the PbGl part of the EMCal. All tiles but one per supermodule were masked.

The LED signal is not a good simulation of a real physics signal, the duration of the LED pulse is too long. Because of these problems, the thresholds determined with the LED pulses are very different from the physics thresholds and have values in the 4-12 GeV range (see fig. 24).

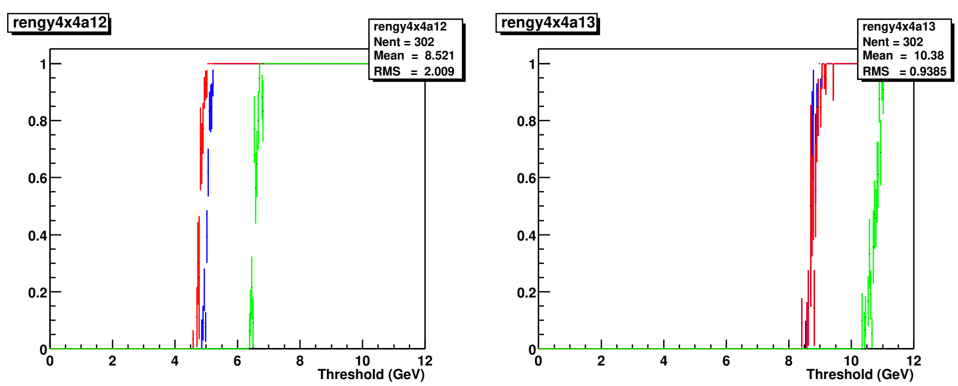


**Figure 24:** *Comparison of different turn on curves for the ASIC/MONDO combination 3/4 for different supermodules in sector E1. Shown are the turn on curves for the 4x4a (blue at DAC 30), the 4x4b (red, DAC 31) and the 4x4c trigger (green, DAC 32).*

Whether these scans can be used to sharpen up the turn-on curves is not clear yet. It is possible, that relative variations of the thresholds can still be adjusted with the LED scan.

The trigger is optimized for signals from PbSc. Signals from the PbGl are broader and not so high. This may be the reason for higher thresholds in the PbGl while using the same DAC values for PbSc and PbGl - also in real physics data.

## 4.2 HV scan

Because the signals of the variable yellow LED are to broad to simulate real physics signals, another approach has been tried to obtain turn-on curves for the PbGl. In this case, the so called avalanche yellow LED was used. This LED produces a shorter pulse than the variable yellow but with a fixed intensity. To obtain a turn-on curve, the gains of the photomultipliers were changed by varying the HV.
A HV-change of $\Delta V$ will result in a change of the gain $G$ of:

$$\frac{\Delta G}{G} = n \frac{\Delta V}{V} \tag{1}$$

$n$ is the number of Dynodes, in this case $n = 8$.

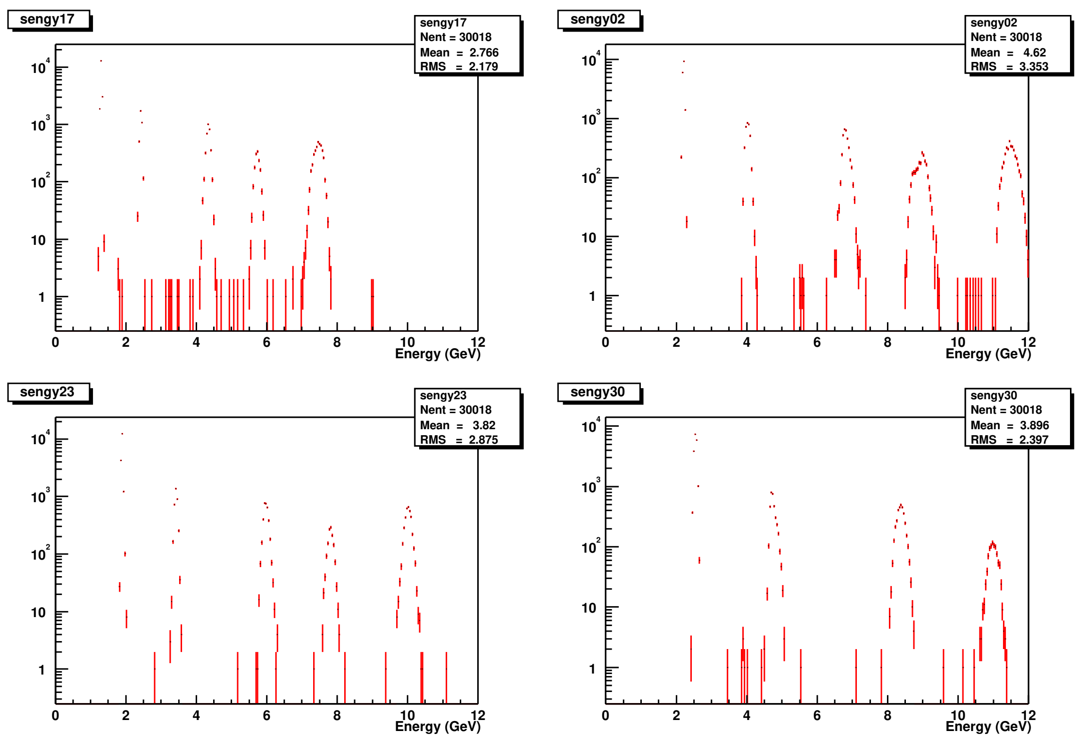


**Figure 25:** *Results from the HV scan. Shown are the energy spectra for four supermodules using the avalanche yellow LED while the HV of the PbGl was varied.*

During Run 92687 the HV of the PbGl part of the EMCal was changed. The standard values of the HV were modified according to table 3.
During the next 30 min. the HV was changed by $-100$ V, $-50$ V, $+0$ V , $+50$ V, $+100$ V, $+150$ V and $+200$ V. The threshold settings were 39 for the 2x2 and 29, 30, 28 for the 4x4a, 4x4b and 4x4c. In figure 25 some results of this measurement are shown. One can see,

| $HV_{old}$ | | | $HV_{new}$ |
|---|---|---|---|
| | V | < 1450 V | V = 1050 V |
| 1450 V < | V | < 1550 V | V = 1125 V |
| 1150 V < | V | < 1650 V | V = 1200 V |
| 1650 V < | V | < 1750 V | V = 1275 V |
| 1750 V < | V | < 1850 V | V = 1350 V |
| 1850 V < | V | < 1950 V | V = 1425 V |
| 1950 V < | V | | V = 1500 V |

**Table 3:** *Variation of HV settings.*

that the steps of the HV changes were too big. It is not possible to obtain turn-on-curves for all supermodules with these settings.
For very few supermodules, the turn-on point lies within a covered range of the HV scan and it is possible to estimate the turn-on point from the HV-scan. Examples of these turn-on curves can be seen in fig. 26. A HV-scan might be useful to examine the turn-on curves for the PbGl. But it would be necessary to change the HV in smaller steps.

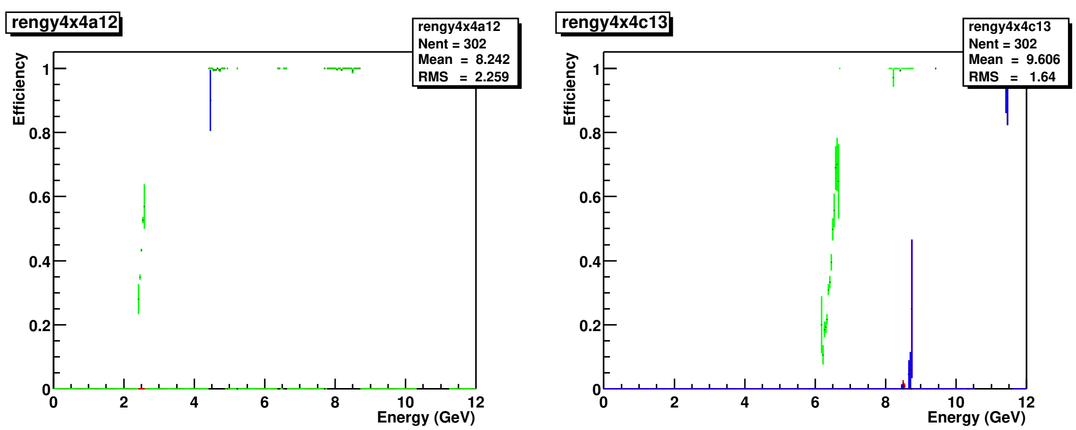


**Figure 26:** *Turn-on Curves for the ASIC/MONDO combination 3/4 in the sector E1 from the HV-scan. Shown are the turn on curves for the 4x4a (blue at DAC 29), the 4x4b (red, DAC 30) and the 4x4c trigger (green, DAC 28).*

## 4.3 Comparison LED- and HV-Scan

In Fig. 27 the results for the turn-on curves from the LED- and the HV-Scan are shown. This was one of the very few supermodules, that showed a turn-on curve in case of the HV- and LED-scan. So it is questionable, whether the behaviour of this supermodule is

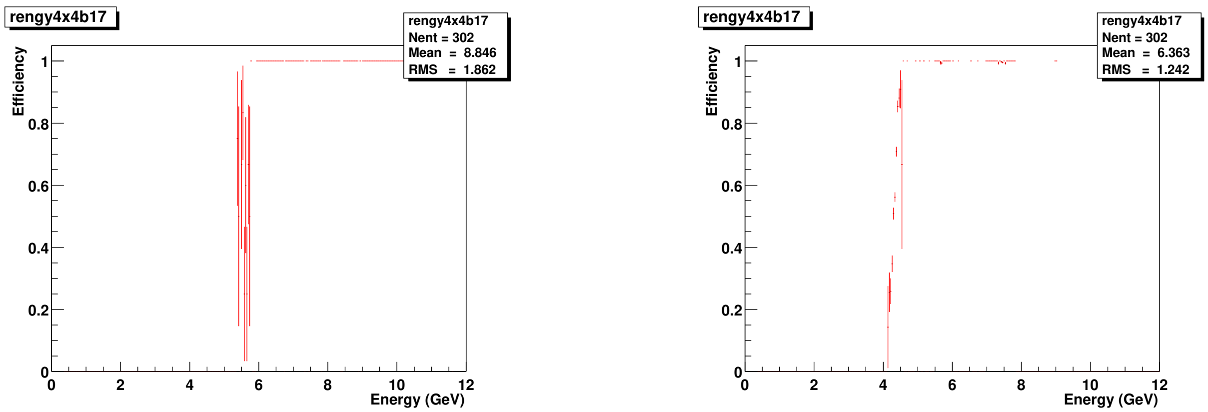


**Figure 27:** *Turn-On-Curves for the LED scan (left) and HV scan (right) for the ASIC/MONDO combination 3/4 and the supermodule 17 in sector E0. Both curves are obtained with DAC values of 30 and the trigger 4x4b.*

typical. In case of this supermodule, the turn-on point for the DAC value of 30 is around 5.5 GeV in case of the LED-scan and around 4.5 GeV in case of the HV scan. During the Run 3 pp-run a DAC value of 29 was used for a threshold of approx. 2.8 GeV (as obtained from the pedestal scan).
This threshold of the HV-scan seems to be more realistic. But it remains unclear, whether this is the same threshold as for real physics data. From the pedestal scan a threshold of approx. 3.5 GeV would be expected, but it is hard to make any conclusions based only on one supermodule.

# 5 Tests with the internal pulser

Each element of the front end electronics of the EMCal contains an internal pulser (CALDAC). This internal pulser consists basically of a capacity, that can be charged via a DAC. Possible values range from 0 to 63. The values of the CALDAC setting can be set via serial download of the EMCal asic.hex files for each trigger tile. Charging and firing of the internal pulser are done via the GTM.

| CALDAC | Run |
|---|---|
| 30 | 92681 |
| 23 | 92677 |
| 21 | 92668 |
| 19 | 92669 |
| 18 | 92676 |
| 17 | 92678 |
| 16 | 92679 |
| 10 | 92682 |

**Table 4:** *Overview of runs taken with different caldac settings.*

At the end of Run3 some short test measurements (see Tab. 4) have been performed to investigate the possibilities of this internal pulser to improve EMCal threshold settings. For these test a small partition consisting of the EMCal and the ERT was used.

## 5.1 EMCal response

Figure 28 shows the response of one tower to this internal pulser for the different CALDAC settings used. The width ($1\sigma$ from a Gaussian fit) of the distributions is peaks at around 5 ADC channels (with a very long tail to higher values up to 30 channels in ADC values). Some towers/internal pulsers show a dependence of the width from the CALDAC value (see Fig. 29).
The peak position is not linear dependent of the CALDAC value. The best fit is a polynomial of degree 2: $p_0 + p_1 x + p_2 x^2$. Fig. 30 shows some examples of fits to the peak position as a function of CALDAC setting. The curves look different. In figure 31 is the distribution of the three parameters $p_0$, $p_1$ and $p_2$ for the different EMCal towers shown. One can see that the variation is pretty large, which means, that the EMCal response of every trigger tile has to be measured, in case the CALDAC scan should be used to sharpen up turn-on curves.
The $\chi^2$-distribution is shown in figure 32. The distribution shows a broad peak from 0 to 3. To test, whether it is enough to make just three measurements to obtain a good fit, the following test was made: The polynomial function was only fitted to three CALDAC

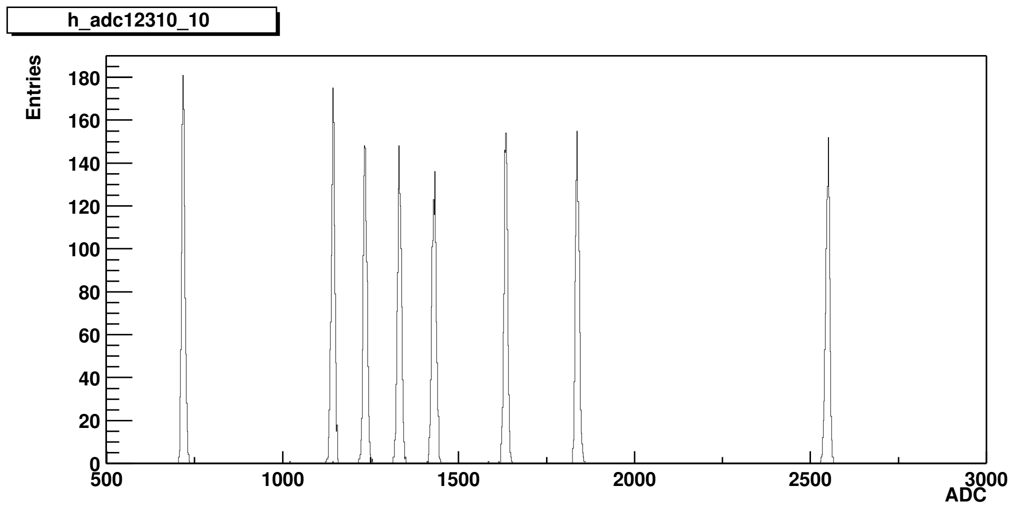


**Figure 28:** *Response of the EMCal tower 12310 to a series of CALDAC settings. Every peak consists of approx. 1000 events taken for the CALDAC values 10, 16, 17, 18, 19, 21, 23 and 30.*

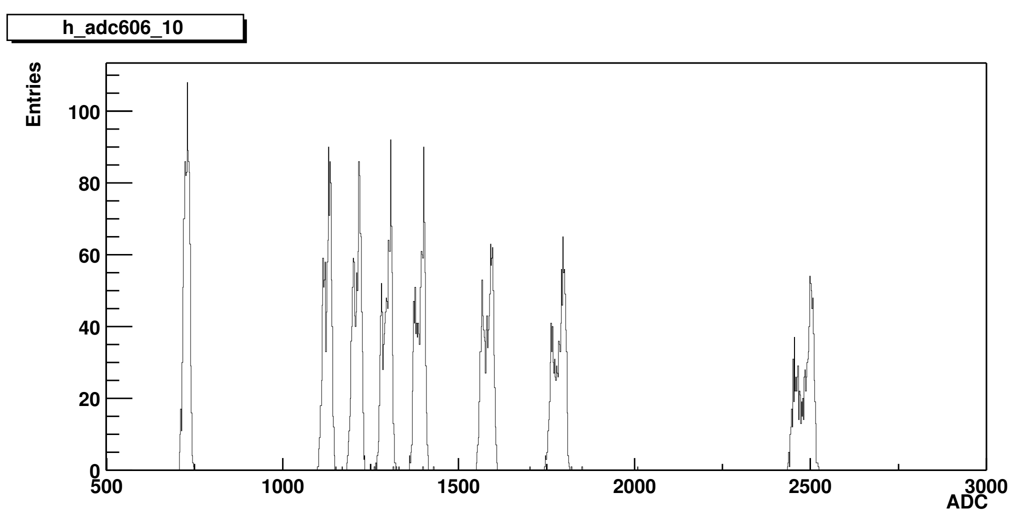


**Figure 29:** *Response of the EMCal tower 606 to a series of CALDAC settings. Every peak consists of approx. 1000 events taken for the CALDAC values 10, 16, 17, 18, 19, 21, 23 and 30. The distributions have a width of approx. 30 channels in ADC and are much wider for higher CALDAC settings.*

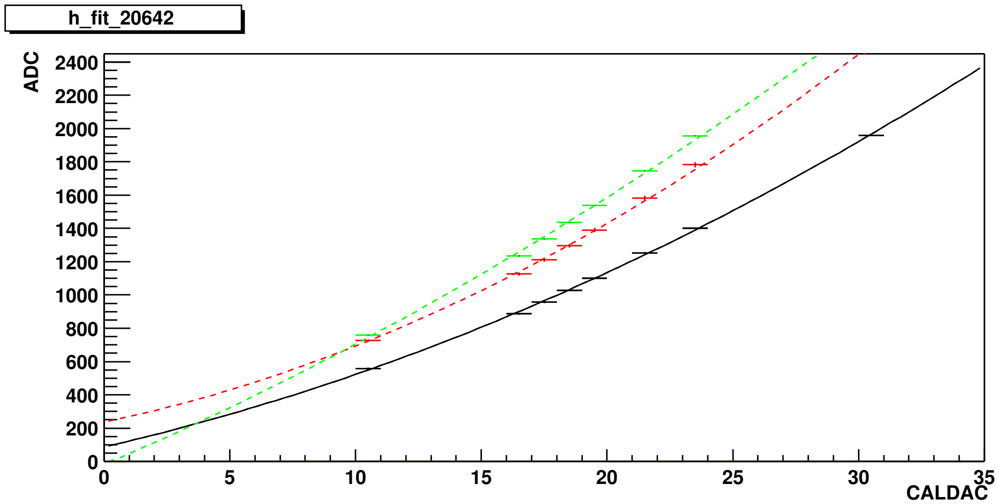


**Figure 30:** *Shown are the peak positions in ADC values (found by a Gaussian fit to the peaks; the error bars correspond to 1σ values of these fits.) as a function of CALDAC settings for three different EMCal towers. Also shown are some fits* $p_0 + p_1x + p_2x^2$ *to the peak positions.*

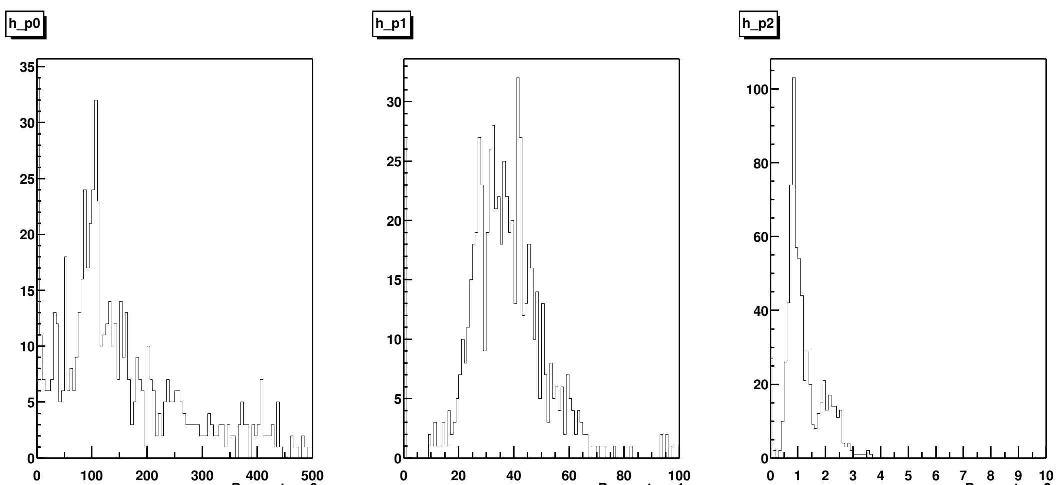


**Figure 31:** *Shown are the distributions of the three parameters* $p_0$*,* $p_1$ *and* $p_2$ *from the fit* $p_0 + p_1x + p_2x^2$*. to all towers used during the CALDAC scan.*

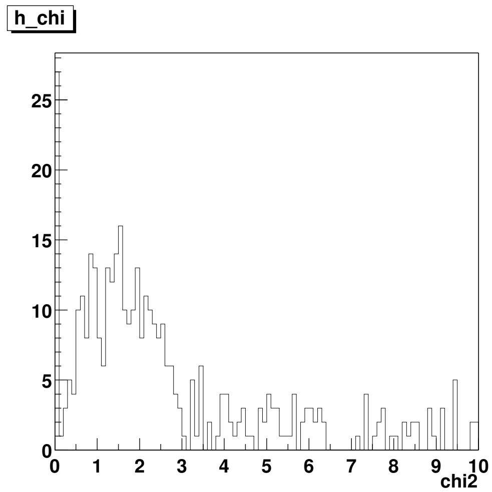


**Figure 32:** $\chi^2$*-distribution of the polynomial fits.*

values at 10, 19 and 30. Then the difference from this fitted function at CALDAC 16 from the measured ADC value at the CALDAC value of 16 was taken. The distribution of this difference is shown in Fig. 33. The difference seems to be small compared to the coarse adjustments possible in the ERT, i.e. 600-700 MeV steps for one DAC tic.

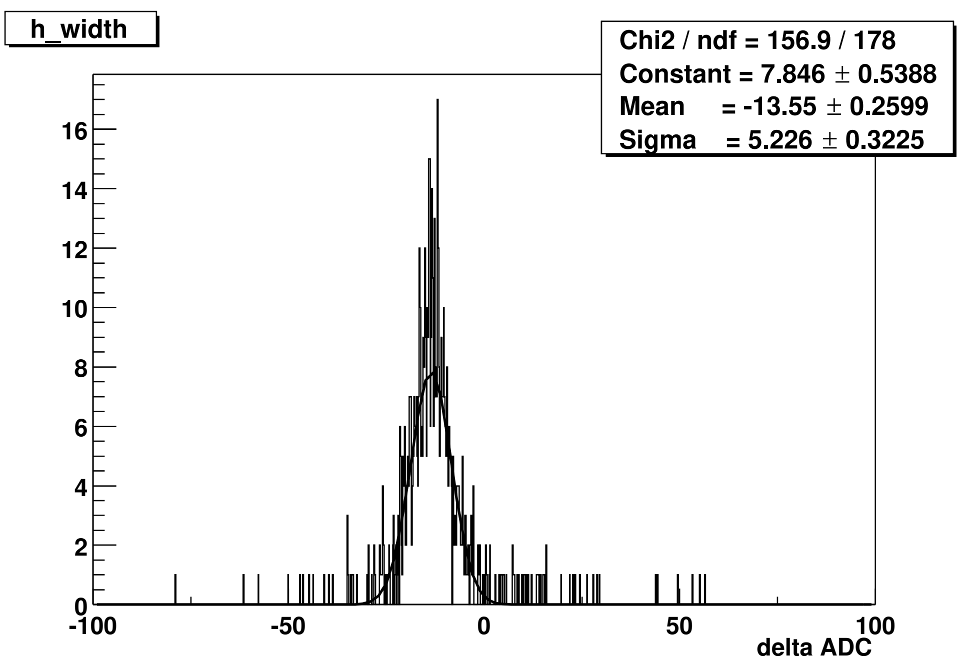


**Figure 33:** *A polynomial function was fitted to three CALDAC values at 10, 19 and 30. This plot shows the difference (in ADC channels) of the value of this fitted function at CALDAC 16 from the measured value at the CALDAC value 16.*

## 5.2 ERT response

During the CALDAC scan the following thresholds were used: 2x2(39), 4x4a(29), 4x4b(30) and 4x4c(28). In Fig. 34 some results of these tests are shown.
From these measurements it can be seen, that the step size for different CALDAC settings would be small enough, to adjust thresholds within 600-700 MeV.

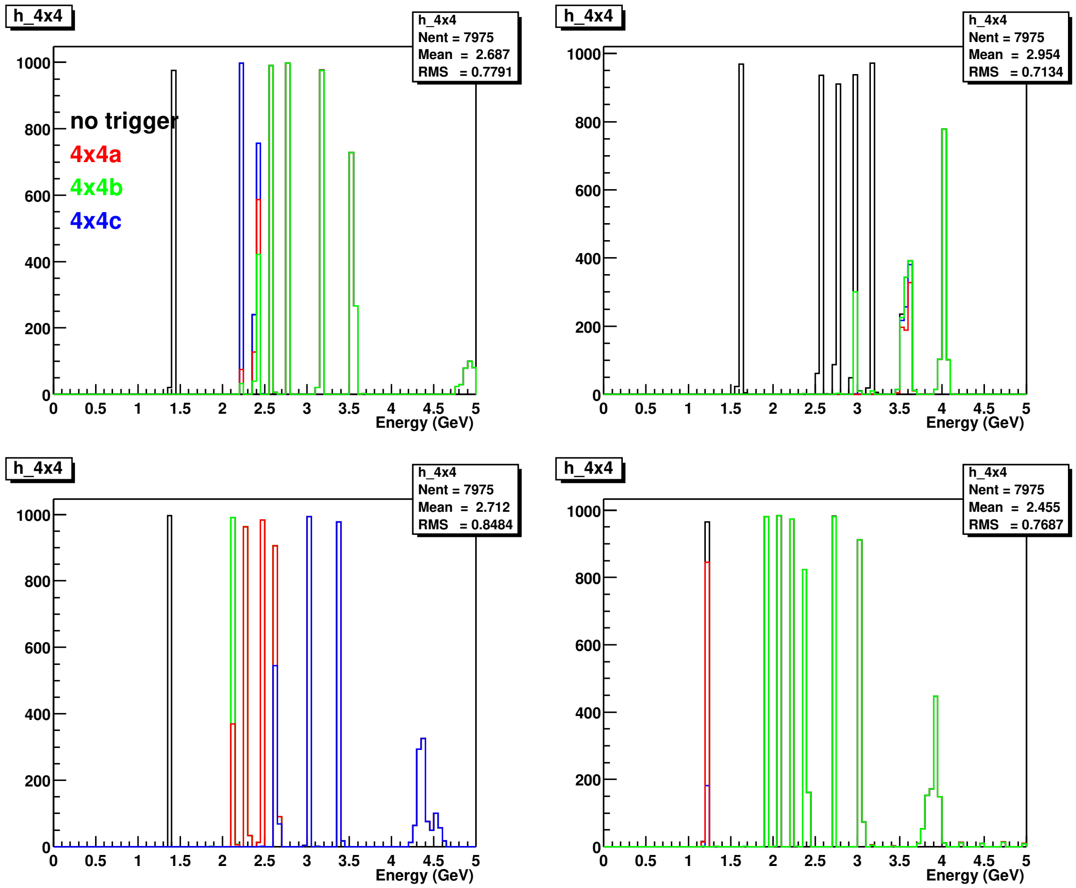


**Figure 34:** *Examples for the ERT response to the CALDAC scan. Shown are turn-on curves for the different 4x4 triggers. The black histograms show the EMCal response without trigger condition.*

# 6 Time stability

Sharpening up turn-on curves does only make sense, if the adjusted thresholds are stable over a long period of time, especially if the procedure to adjust the thresholds is time consuming.

## 6.1 Pedestal Scan

A second pedestal scan was performed about six weeks after the first pedestal scan. Some tiles (about 15%) show a small change in pedestals (of about 1 DAC setting). The mean values of the pedestals do not change. Fig. 35 shows the distributions of the differences of the pedestals for these two measurements.

In appendix C the difference of the pedestals for the individual tiles is shown. There is no systematic shift visible. From these results it is hard to understand, why additional hot channels appeared during the pp run and supermodules had to be masked of - especially in case of the higher threshold triggers like 4x4b with a mean DAC setting of 31, i.e. 3-4 DAC settings above the pedestal.

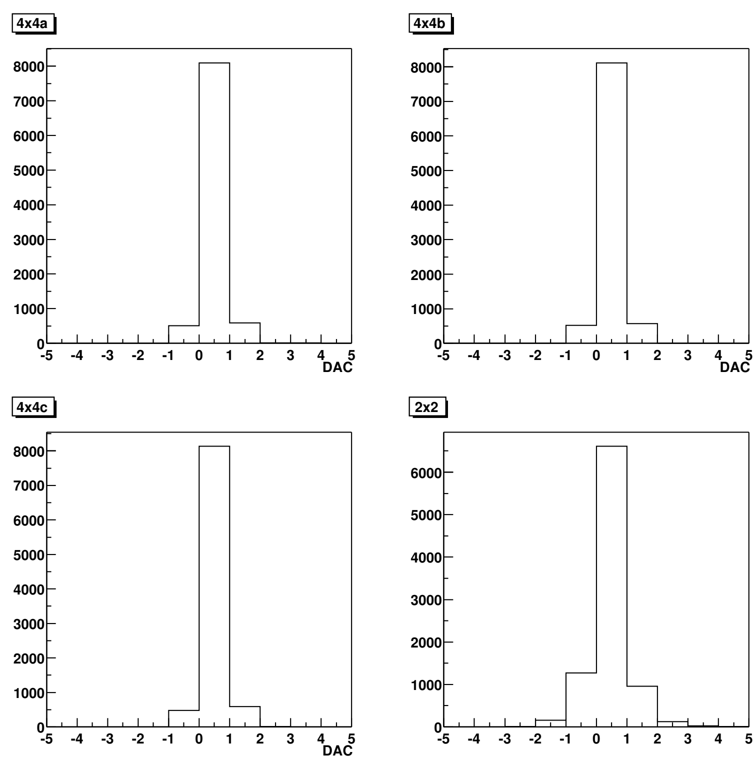


**Figure 35:** *Difference of the pedestals for measurements after a nine week period.*

## 6.2 Laser Scan

To study the time dependence of the thresholds, two laser scans were performed. The first scan (**old**) was performed at the end of March 2003 (Runs 84505 (30,31,32=4x4a,b,c), 84506 (32,30,31) and 84507 (31,32,30)). Another laser scan (**new**) was done at the beginning of June 2003 (Run 92580 (30,30,30), 92585 (31,31,31) and 92589 (32,32,32)). The EMCal gain coefficients were taken from the DB. It includes time variation correction. For the first part, it was taken from the date of Run 85302, because there were obvious miscalibrations for that shutdown period.

| Run | Trigger | total | dead | hot | wide |
|---|---|---|---|---|---|
| 84505 | a | 30 | 16 | 3 | 9 |
| | b | 31 | 15 | 0 | 3 |
| | c | 32 | 18 | 0 | 25 |
| 84506 | a | 32 | 16 | 0 | 23 |
| | b | 30 | 15 | 0 | 9 |
| | c | 31 | 17 | 0 | 9 |
| 84507 | a | 31 | 75 | 2 | 2 |
| | b | 32 | 89 | 0 | 2 |
| | c | 30 | 51 | 1 | 5 |

**Table 5:** *Overview of the first laser scan.*

A threshold search algorithm was applied. The request was

$$2\mathsf{bin} < (\mathsf{xhigh}(> 95\%) - \mathsf{xlow}(< 5\%)) < 10\mathsf{bin}(@40\mathsf{MeV/bin}) \qquad (2)$$

for the turn-on curve. All PbSc (=108 SMs) was categorized to four groups, which are

| Run | Trigger | total | dead | hot | wide |
|---|---|---|---|---|---|
| 92580 | a | 30 | 3 | 5 | 8 |
| | b | 30 | 3 | 3 | 8 |
| | c | 30 | 3 | 4 | 7 |
| 92585 | a | 31 | 7 | 5 | 8 |
| | b | 31 | 8 | 4 | 11 |
| | c | 31 | 8 | 4 | 7 |
| 92589 | a | 32 | 11 | 5 | 18 |
| | b | 32 | 10 | 4 | 15 |
| | c | 32 | 9 | 6 | 19 |

**Table 6:** *Overview of the second laser scan.*

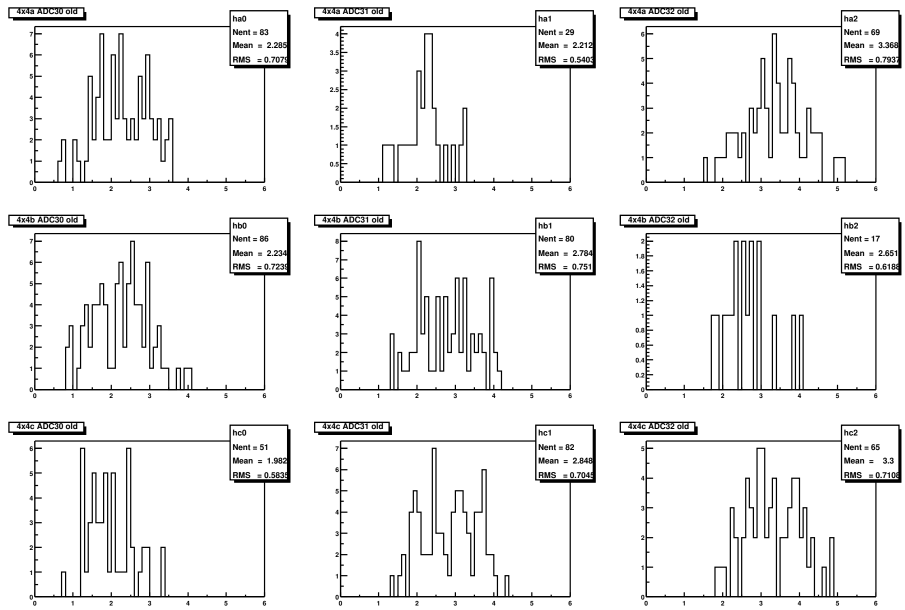

**Figure 36:** *Distribution of thresholds for the 4x4 triggers as obtained at the end of March 03.*

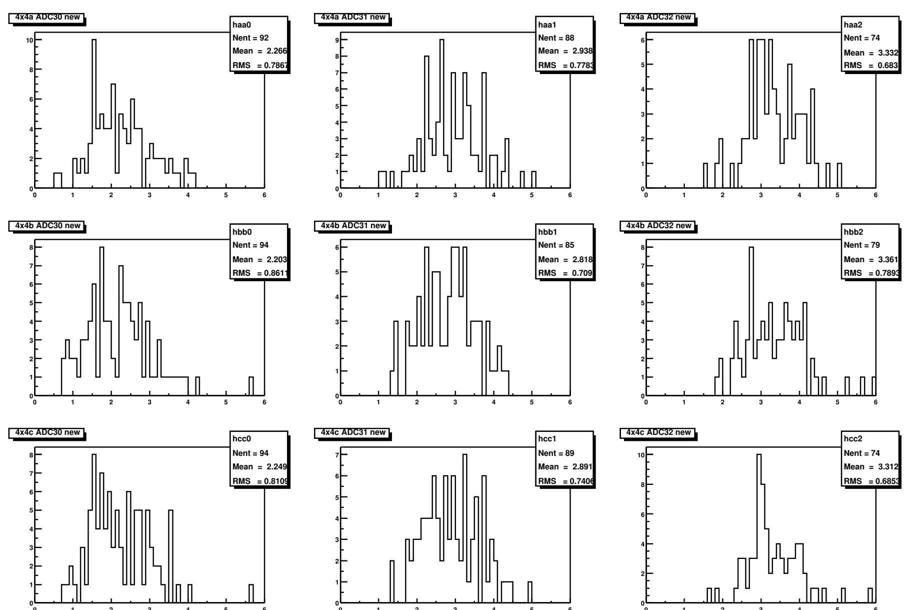

**Figure 37:** *Distribution of thresholds for the 4x4 triggers as obtained at the beginning of June 03.*

"good", "dead", "hot" and "wide". Tables 5 and 6 give an overview of the results of these two laser scans.
Run 84507 is too short. Not the whole energy range is covered in this run, resulting in the huge number of dead tiles. Note that the dead tiles of Run 92585 and 92589 are due to a laser problem. No signals came out from a part of W3 sector. In Fig. 36 and 37 the distributions of the thresholds for the old and the new laser scan are shown.
The difference of the thresholds for individual tiles between the old and the new laser scan are shown in Fig. 38. The thresholds kept the mean value, but each tile moved in the order of 400 MeV (1σ) which is much larger than the single turn-on width (The individual tile turn-on width (1σ) is roughly 100 MeV ). From this we can deduce, that the thresholds of the individual tiles are time dependent. The gain varies and is time dependent. The gain variation of individual tiles can be in the order of ±5% (measured in Run3 dAu), which seems a little to small to explain the large changes in the threshold.
The threshold changes are correlated in 4x4a,b,c. This can be seen in Fig. 39 to 42 on the following pages.

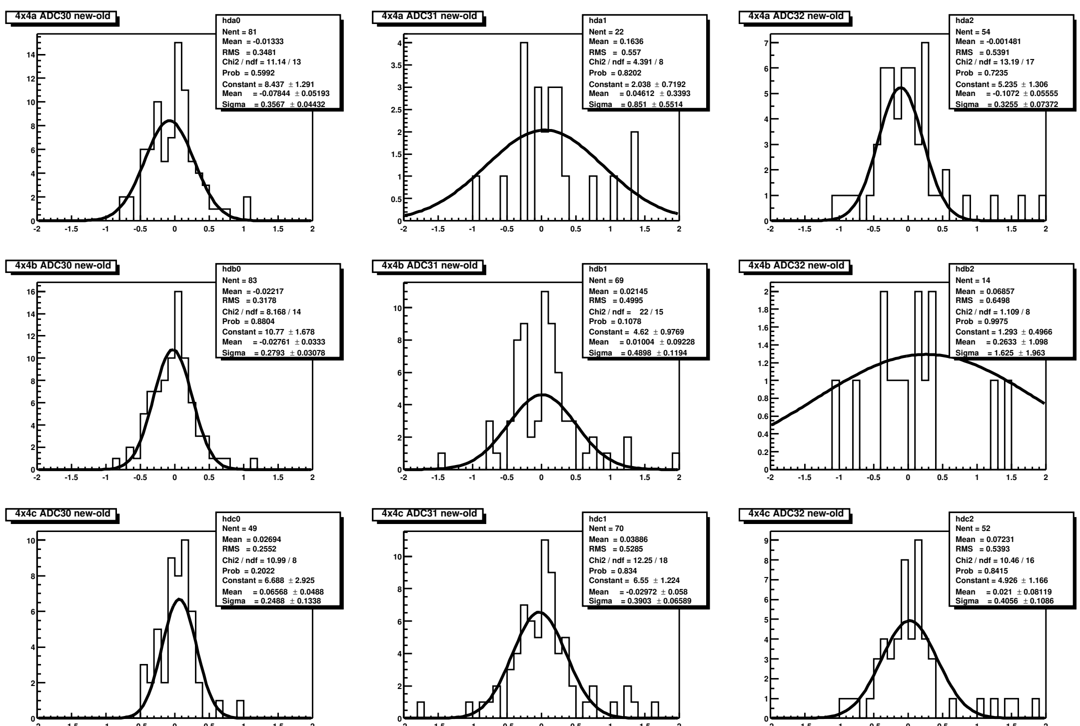


**Figure 38:** *Distribution of the difference of the thresholds for the individual tiles from the old and the new laser scan.*

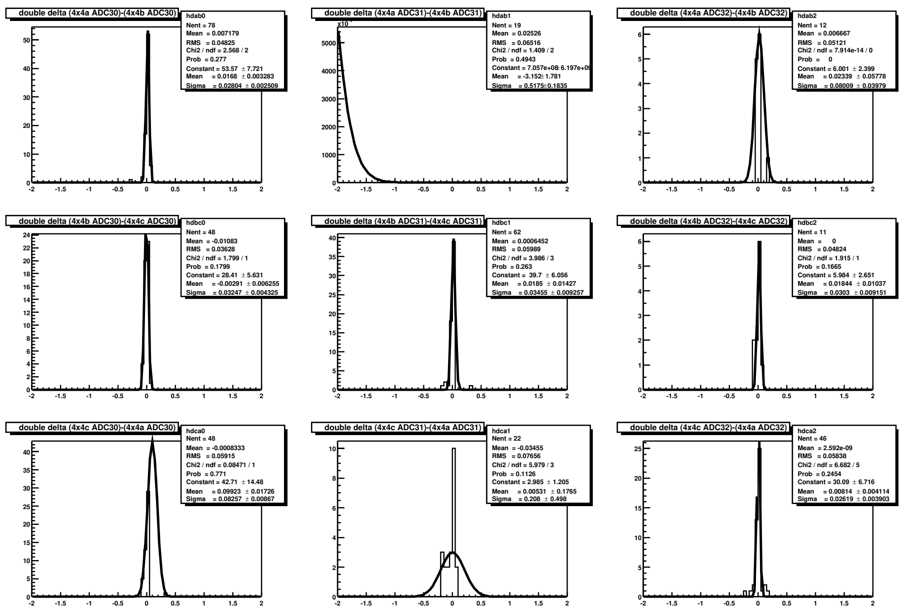

**Figure 39:** *Comparison of the threshold difference in the same tile.*

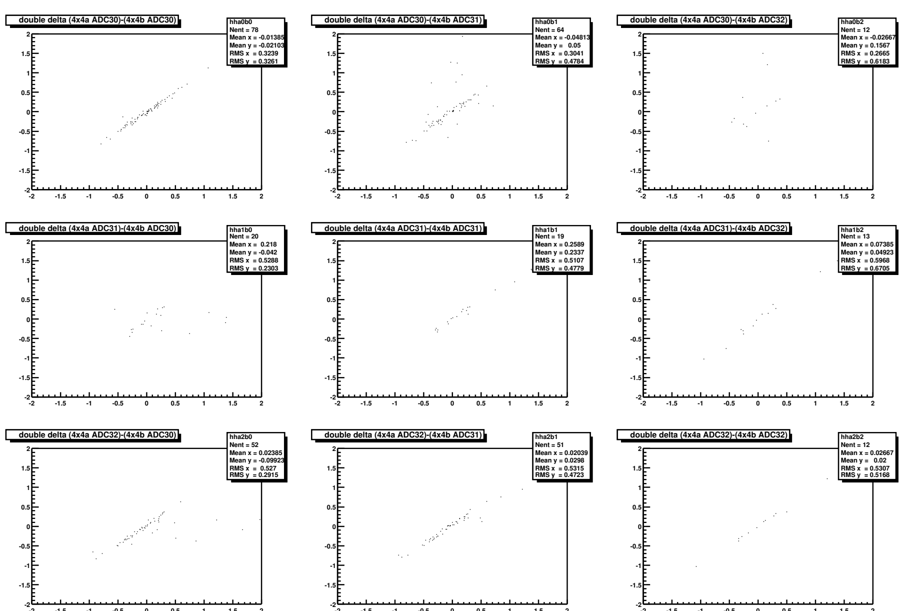

**Figure 40:** *Correlations between the differences of the old and new scan for the a and b triggers .*

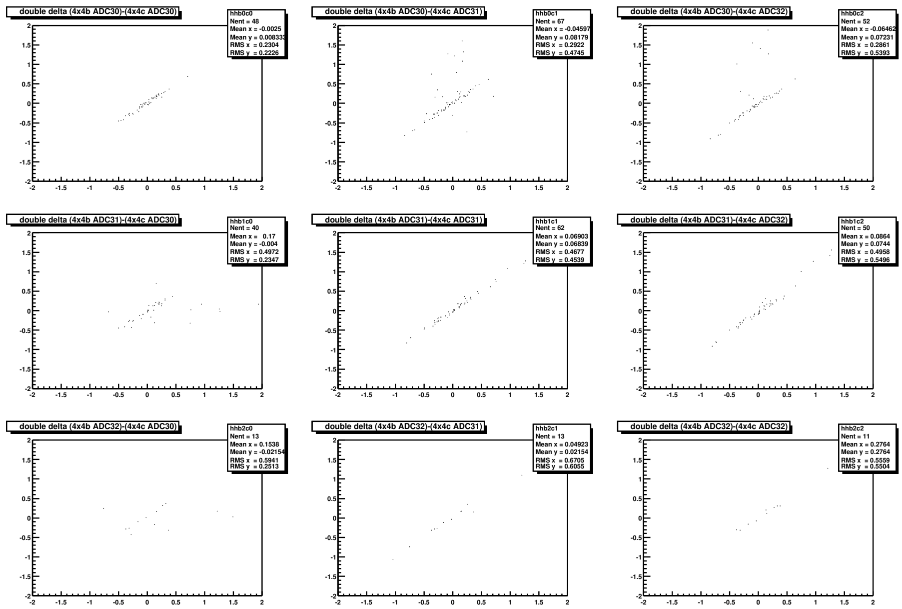


**Figure 41:** *Distribution of thresholds for the 4x4 triggers as obtained at the beginning of June 03.*

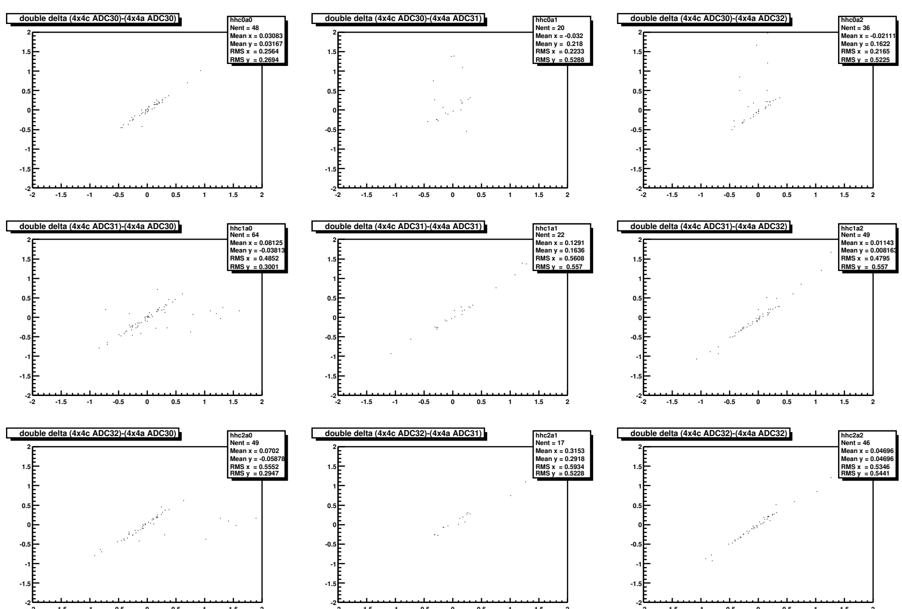


**Figure 42:** *Distribution of thresholds for the 4x4 triggers as obtained at the beginning of June 03.*

# 7 Summary

## Pedestal Scan

The pedestal scan is easy and fast done (approx. 8–12h) in an automated way for the PbGl and PbSc in the same way. The pedestal scan can be used to increase the rejection factor of the EMCal 4x4-triggers. The pedestal scan is not capable of aligning the individual turn-on points within one DAC tic. Some hot tiles can be found and masked off by setting the threshold to 63. It is possible to detect noisy FEMs.

## Laser/LED Scan

The laser/LED scan showed, that the turn on curves for the individual tiles are rather sharp (100 MeV), but that these are not well aligned. Furthermore some tiles show a strange behaviour, where raising the DAC-value leads to a lower threshold. This behaviour is consistent with variations of the thresholds with time.

Adjusting the thresholds of all tiles is very time consuming. The scan of one tile with one threshold takes about 1h. This means one complete laser scan takes about 36h. The data volume is very large, so the data analysis itself is also time consuming and complicated (The laser scan for one tile can be analyzed in about 30min, if the job is distributed to a couple of workstations).It remains unclear, how many iterations of this laser scan are necessary to align all tile thresholds. Another drawback of this method is, that it is not possible to use the variable yellow LED. This means a LED scan is not usable to improve turn-on curves. PbGl and PbSc have to be treated in different ways.

## HV Scan

Statistics for a clear statement is insufficient. The signal of the avalanche yellow LED seems to be closer to the physics signal than the variable gain yellow. But a laser-timing-scan showed, that even the signal of the avalanche yellow is twice as long as the laser signal.

## CALDAC Scan

The EMCal response to the internal pulser is different for the different towers. Therefore this response has to be measured prior to – or at the same time as trying to – determine the turn-on curves. The step size of the CALDAC settings should be small enough to use this method to align the thresholds of the different tiles. The duration of this measurement will be slightly longer than the pedestal scan (more subsystems have to be read out in serial). The data volume should be much smaller than for the laser scan, because it will be enough to record a couple (approx. 1000) events per setting.

Advantage: It might be possible to do CALDAC scans in stand-alone mode, using scripts. PbGl and PbSc are treated in the same way.

## Are improvements possible ?

I assume, that one DAC tic corresponds to 700 MeV. From the laser-scan with the modified thresholds (according to the pedestal scan) we obtain a Gaussian distribution of the thresholds with a sigma of 550 MeV (see Fig. 7. The fit is not very good. The real distribution is probably narrower, so this will be a kind of upper limit). This means in a $\pm 350$ MeV range are about 45% of all the tiles.
The question is, whether this situation can be significantly improved by using thresholds which have been aligned according to a laser or CALDAC scan. Let's assume, that we are able to align all thresholds within one DAC tic. Because the thresholds are not stable and will change with time, this situation will also change and the turn-on curves will broaden. To get an estimation about the influence of these threshold changes, I generated 172 random numbers equally distributed between 1.4 and 2.1 GeV. Every number is the threshold for one tile. For every of these numbers, I generated another random number, now a Gaussian distribution around the threshold with $\sigma = 350$ MeV. Adding all 172 Gaussian distributions, I obtain: Approx. 110 tiles are still between 1.4 and 2.1 GeV. This is more like an upper limit and should be compared to the lower limit of 77 tiles that are in the same range after the pedestal scan.

| | Pedestal Scan | Laser/CALDAC |
|---|---|---|
| 1 DAC tic | 77 | 110 |
| 3 DAC tics | 132 | 170 |
| 5 DAC tics | 162 | 172 |

**Table 7:** *Distribution of trigger tile thresholds after optimization.*

Using a simulation with all 6192 tiles of one trigger type, one obtains that 60% of the tiles are still within one DAC tic, 98% are within 3 DAC tics [5].

[5] These numbers decrease to 55% and 97% resp., in case the width of the Gaussian distribution is set to 400 MeV

# A Runs for laser scan

| RUN | ASIC | MONDO | 4x4a | 4x4b | 4x4c | 2x2 | remarks |
|---|---|---|---|---|---|---|---|
| 82400 | 0 | 3 | 31 | 32 | 30 | 34 | |
| 82412 | 1 | 3 | 31 | 32 | 30 | 34 | |
| 82413 | 2 | 3 | 31 | 32 | 30 | 34 | ? |
| 82415 | 2 | 3 | 31 | 32 | 30 | 34 | |
| 82416 | 3 | 3 | 31 | 32 | 30 | 34 | |
| 82417 | 4 | 3 | 31 | 32 | 30 | 34 | |
| 82418 | 5 | 3 | 31 | 32 | 30 | 34 | 18min |
| 82577 | 5 | 3 | 31 | 32 | 30 | 34 | 20min cosmic trigger? |
| 82195 | 1 | 2 | 31 | 32 | 30 | 34 | |
| 82261 | 5 | 1 | 31 | 32 | 30 | 34 | |
| 82262 | 2 | 2 | 31 | 32 | 30 | 34 | 24min |
| 82354 | 2 | 2 | 31 | 32 | 30 | 34 | 36min no trigger? |
| 82357 | 3 | 2 | 31 | 32 | 30 | 34 | |
| 82372 | 4 | 2 | 31 | 32 | 30 | 34 | |
| 82398 | 5 | 2 | 31 | 32 | 30 | 34 | |
| 82578 | 5 | 3 | 31 | 32 | 30 | 34 | 12min cosmic trigger? |
| 82580 | 5 | 3 | 31 | 32 | 30 | 34 | New flow-control, no clock triggers |
| 82581 | 0 | 4 | 31 | 32 | 30 | 34 | |
| 82590 | 1 | 4 | 31 | 32 | 30 | 34 | |
| 82591 | 0 | 0 | 31 | 32 | 30 | 34 | |
| 82592 | 1 | 0 | 31 | 32 | 30 | 34 | |
| 82593 | 2 | 0 | 31 | 32 | 30 | 34 | |
| 82606 | 3 | 0 | 31 | 32 | 30 | 34 | |
| 82607 | 4 | 0 | 31 | 32 | 30 | 34 | |
| 82612 | 5 | 0 | 31 | 32 | 30 | 34 | |
| 82656 | 0 | 1 | 31 | 32 | 30 | 34 | |
| 82668 | 1 | 1 | 31 | 32 | 30 | 34 | |
| 82673 | 2 | 1 | 31 | 32 | 30 | 34 | |
| 82674 | 3 | 1 | 31 | 32 | 30 | 34 | |
| 82675 | 4 | 1 | 31 | 32 | 30 | 34 | |
| 82744 | 0 | 2 | 31 | 32 | 30 | 34 | |
| 82745 | 2 | 4 | 31 | 32 | 30 | 34 | |
| 82746 | 3 | 4 | 31 | 32 | 30 | 34 | |
| 82747 | 4 | 4 | 31 | 32 | 30 | 34 | |
| 82777 | 5 | 4 | 31 | 32 | 30 | 34 | |
| 82785 | 0 | 5 | 31 | 32 | 30 | 34 | |

| RUN | ASIC | MONDO | 4x4a | 4x4b | 4x4c | 2x2 | remarks |
|---|---|---|---|---|---|---|---|
| 82786 | 1 | 5 | 31 | 32 | 30 | 34 | |
| 82787 | 2 | 5 | 31 | 32 | 30 | 34 | |
| 82788 | 3 | 5 | 31 | 32 | 30 | 34 | |
| 82789 | 4 | 5 | 31 | 32 | 30 | 34 | |
| 82791 | 5 | 5 | 31 | 32 | 30 | 34 | |
| 83275 | 3 | 4 | 32 | 33 | 34 | 24 | |
| 83276 | 3 | 4 | 31 | 34 | 35 | 34 | wrong ? looks like:32 33 34 24 |
| 82933 | 2 | 3 | 32 | 33 | 34 | 24 | |
| 82937 | 2 | 3 | 31 | 34 | 35 | 34 | |
| 84499 | 2 | 3 | 31 | 32 | 30 | 34 | new threshold |
| 84505 | 3 | 4 | 30 | 31 | 32 | 38 | |
| 84506 | 3 | 4 | 32 | 30 | 31 | 40 | |
| 84507 | 3 | 4 | 31 | 32 | 30 | 42 | |

Table 8: Runs taken for the laser scan

| RUN | ASIC | MONDO | 4x4a | 4x4b | 4x4c | 2x2 | remarks |
|---|---|---|---|---|---|---|---|
| 92580 | 3 | 4 | 30 | 30 | 30 | 34 | |
| 92585 | 3 | 4 | 31 | 31 | 31 | 38 | |
| 92589 | 3 | 4 | 32 | 32 | 32 | 42 | |
| 92593 | 3 | 4 | 33 | 33 | 33 | 46 | |
| 92596 | 3 | 4 | 34 | 34 | 34 | 50 | |
| 92600 | 2 | 4 | 63 | 63 | 63 | 63 | 3/4 with thresh. 31,32,30,40 |
| 92603 | 2 | 5 | 63 | 63 | 63 | 63 | 3/4 with thresh. 31,32,30,40 |
| 92606 | 2 | 4 | 63 | 63 | 63 | 63 | 3/4 with thresh. 31,32,30,40 |
| 92611 | 2 | 2 | 63 | 63 | 63 | 63 | 3/2 with thresh. 31,32,30,40 |
| 92614 | 3 | 3 | 63 | 63 | 63 | 63 | 3/2 with thresh. 31,32,30,40 |
| 92615 | 2 | 3 | 63 | 63 | 63 | 63 | 3/2 with thresh. 31,32,30,40 |
| 92617 | 1 | 2 | 32 | 32 | 32 | 36 | |
| 92618 | 1 | 2 | 34 | 34 | 34 | 38 | |
| 92619 | 1 | 2 | 36 | 36 | 36 | 40 | |
| 92620 | 1 | 2 | 38 | 38 | 38 | 42 | |
| 92621 | 1 | 2 | 40 | 40 | 40 | 44 | |
| 92622 | 1 | 2 | 42 | 42 | 42 | 46 | |
| 92623 | 1 | 2 | 44 | 44 | 44 | 48 | |
| 92624 | 1 | 2 | 46 | 46 | 46 | 50 | |

Table 9: Runs taken for the laser scan

# B Pedestals

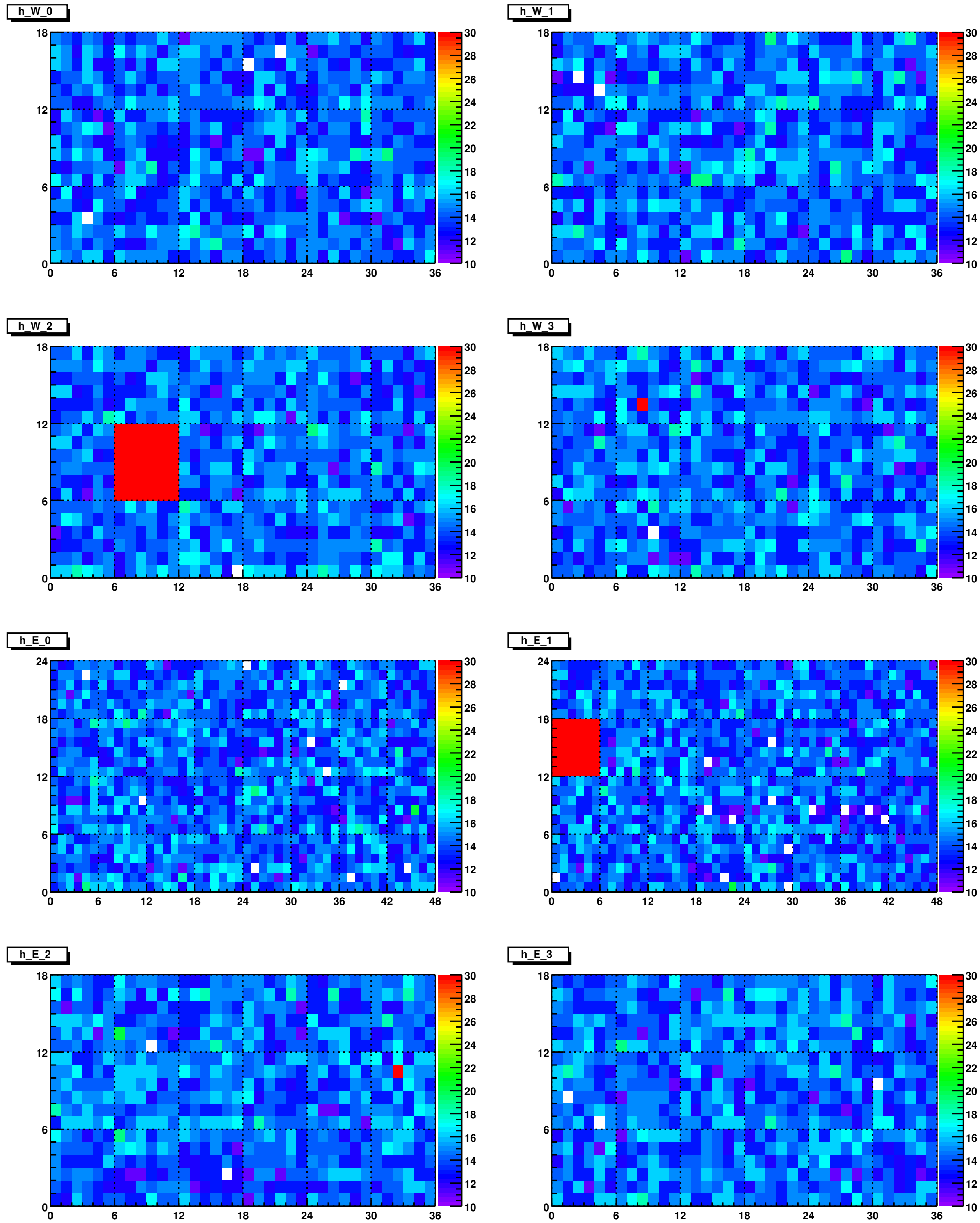


**Figure 43:** *Pedestals for the 2x2.*

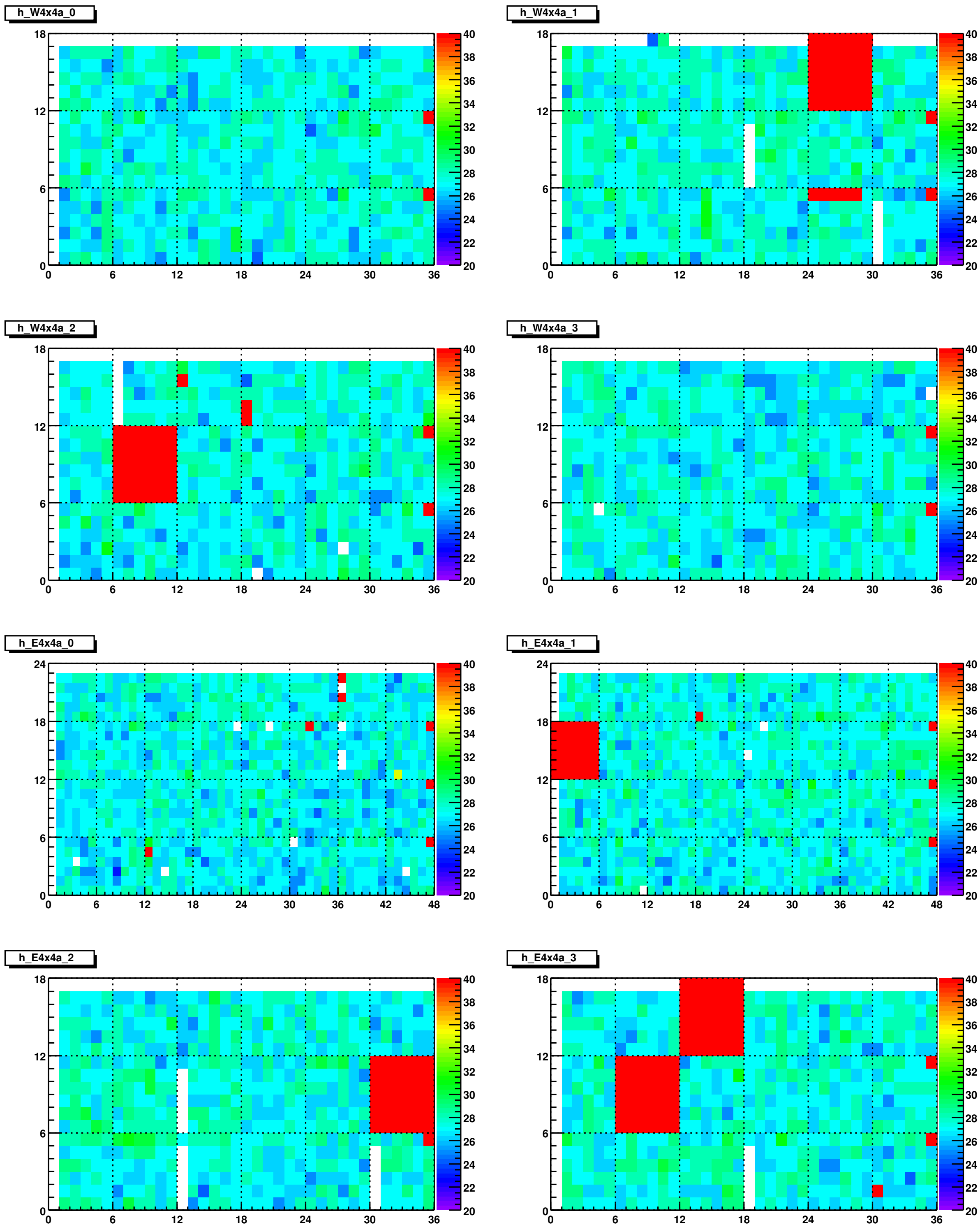


**Figure 44:** *Pedestals for the 4x4a.*

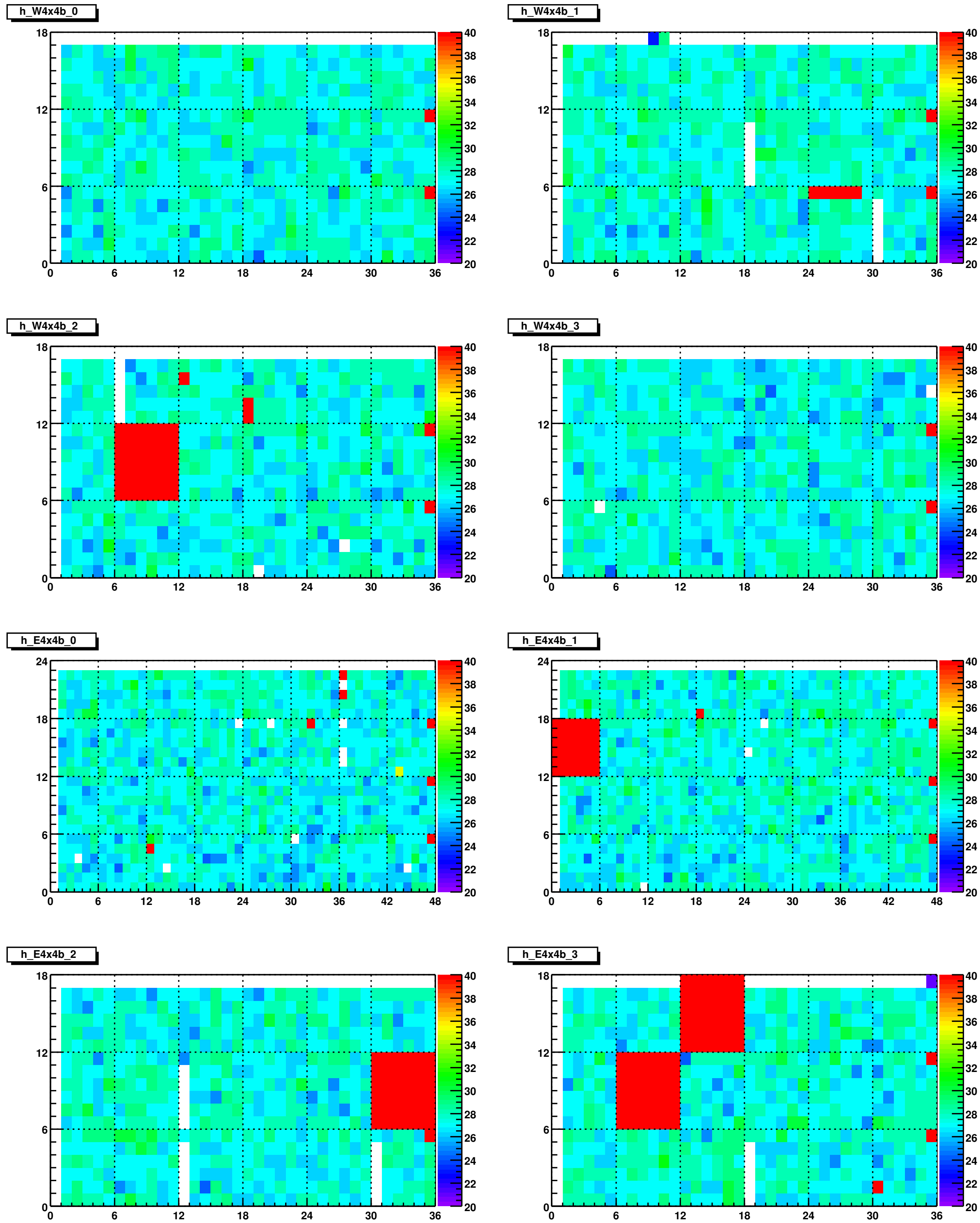


**Figure 45:** *Pedestals for the 4x4b.*

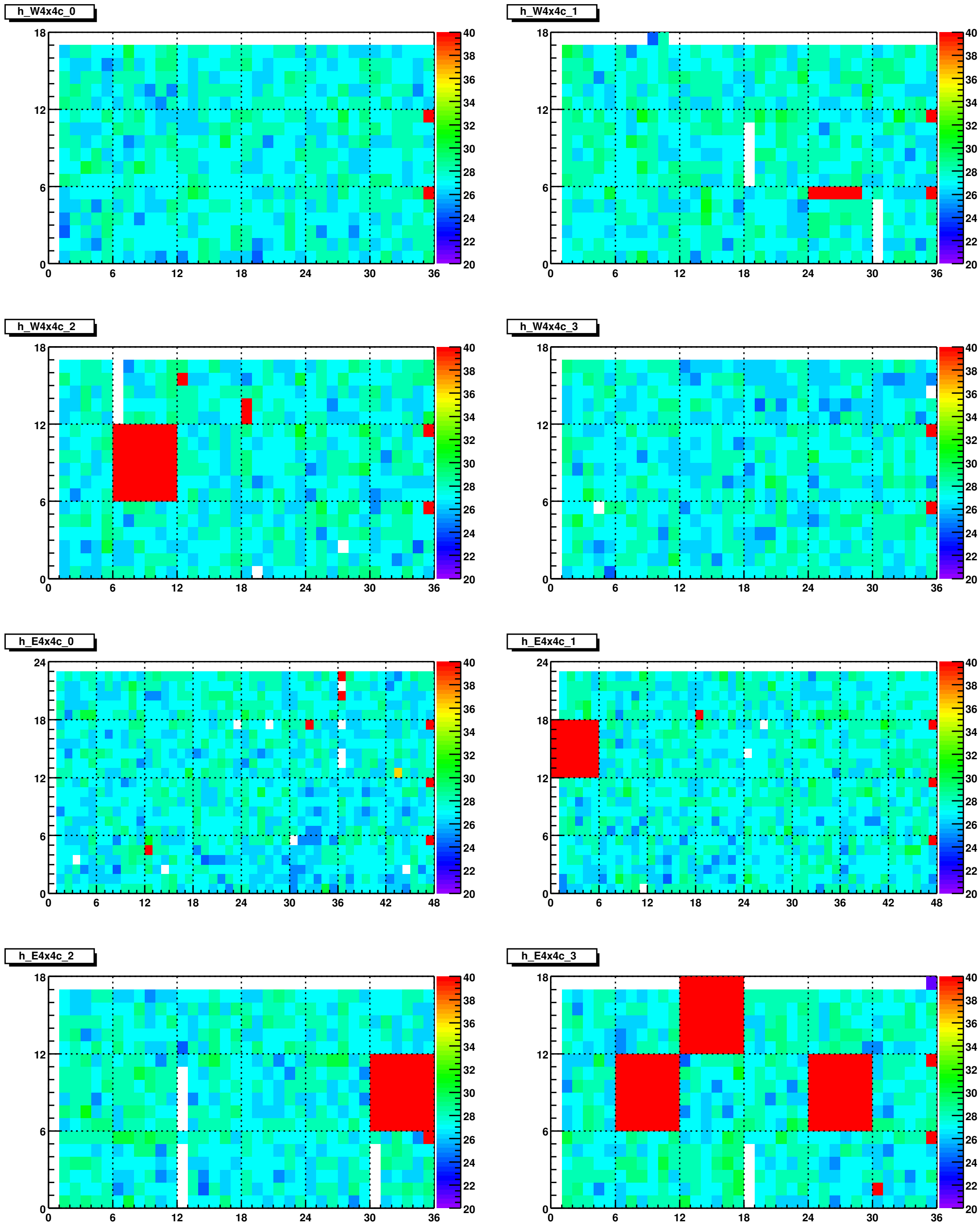


**Figure 46:** *Pedestals for the 4x4c.*

# C Time stability of pedestals

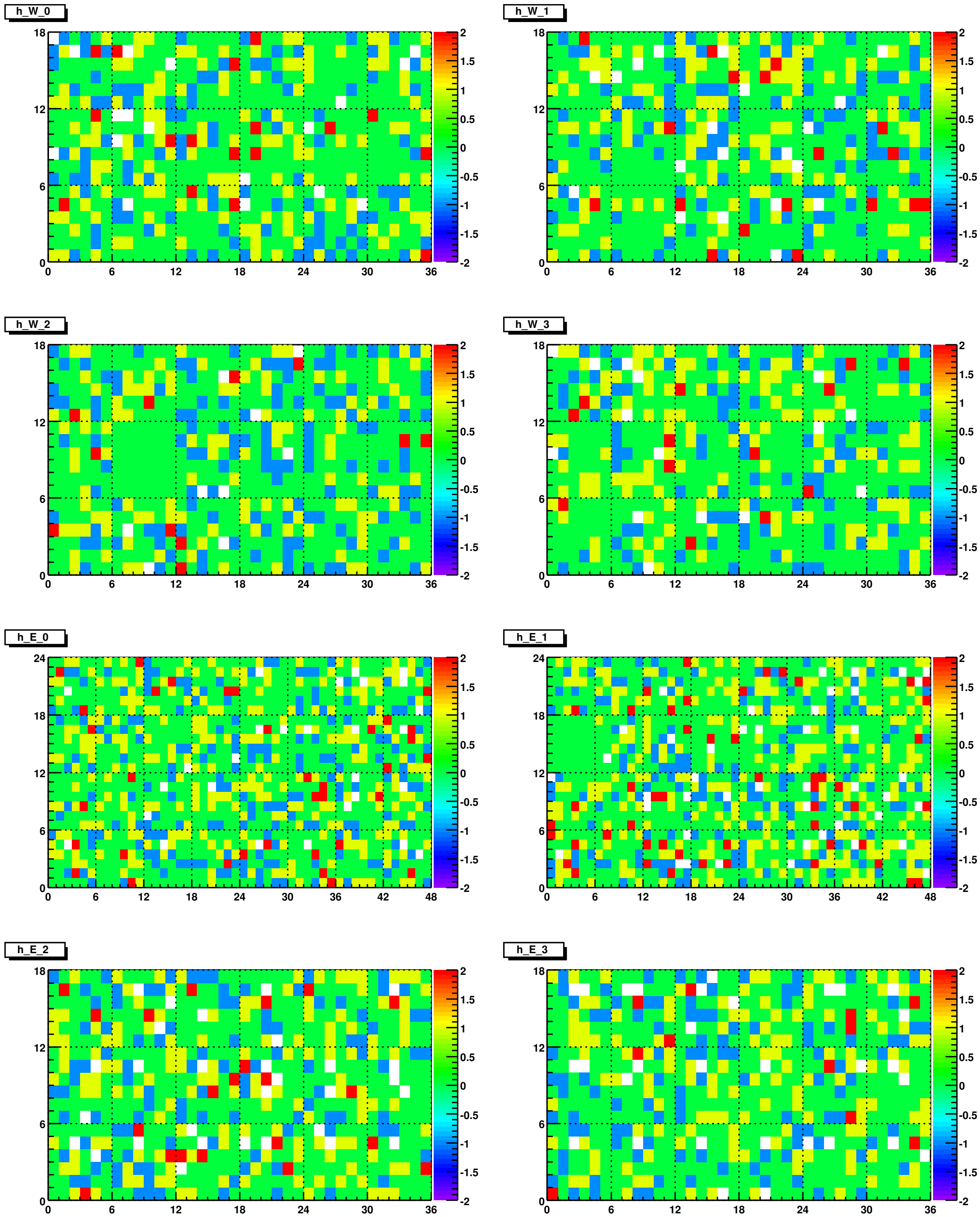


**Figure 47:** *Deviation of the two pedestal measurements for the 2x2.*

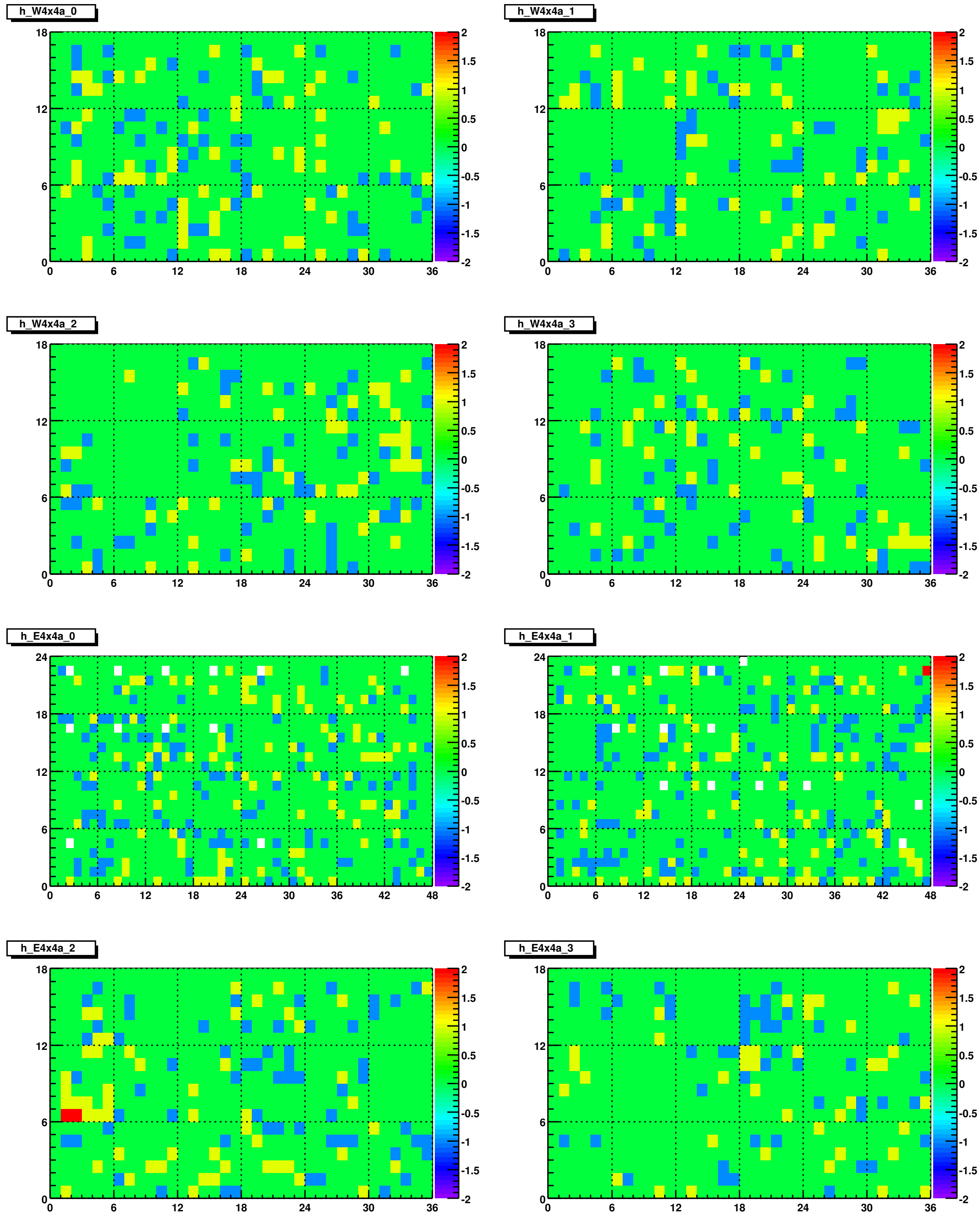


**Figure 48:** *Difference between the two pedestal measurements for the 4x4a.*

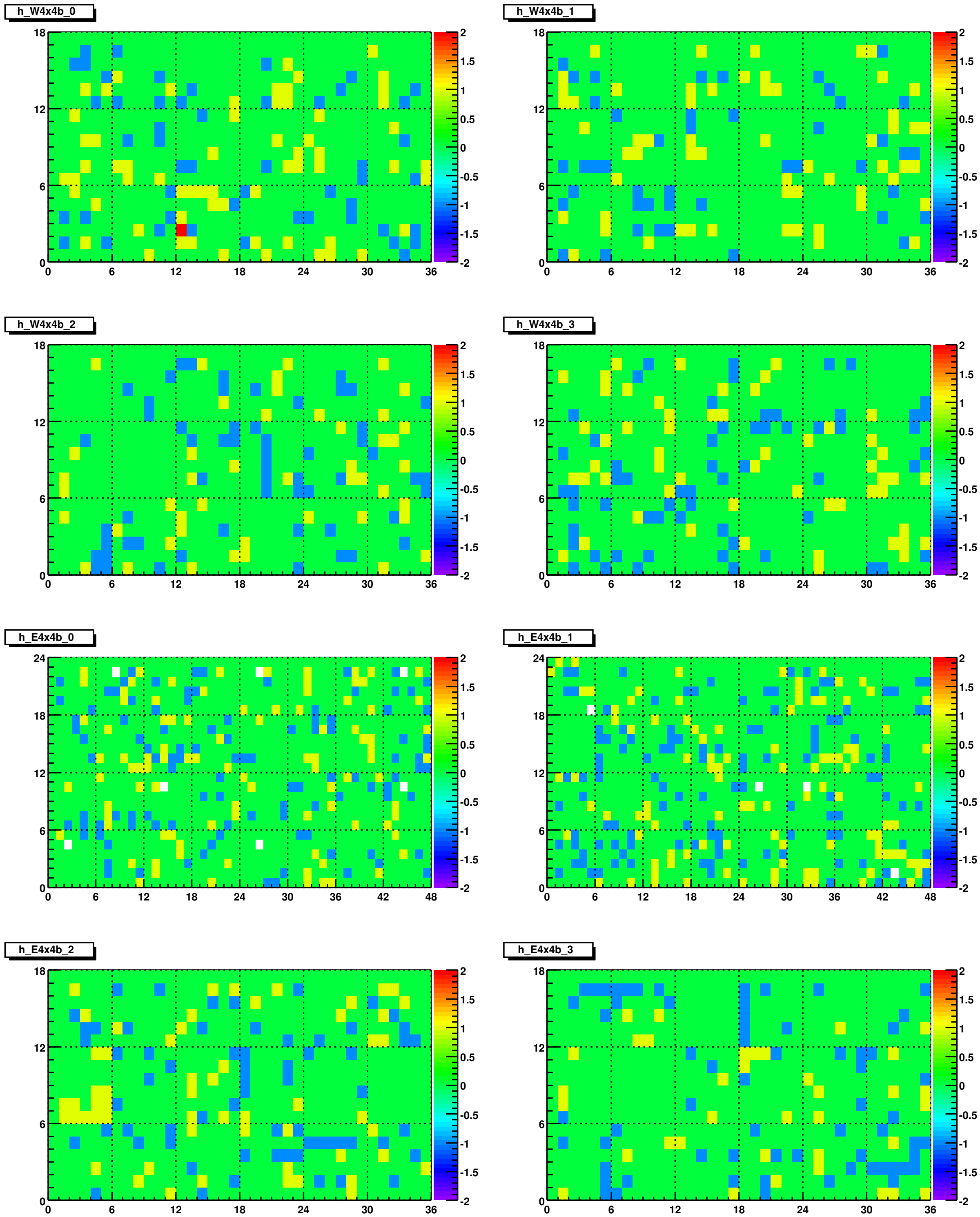


**Figure 49:** *Difference between the two pedestal measurements for the 4x4b.*

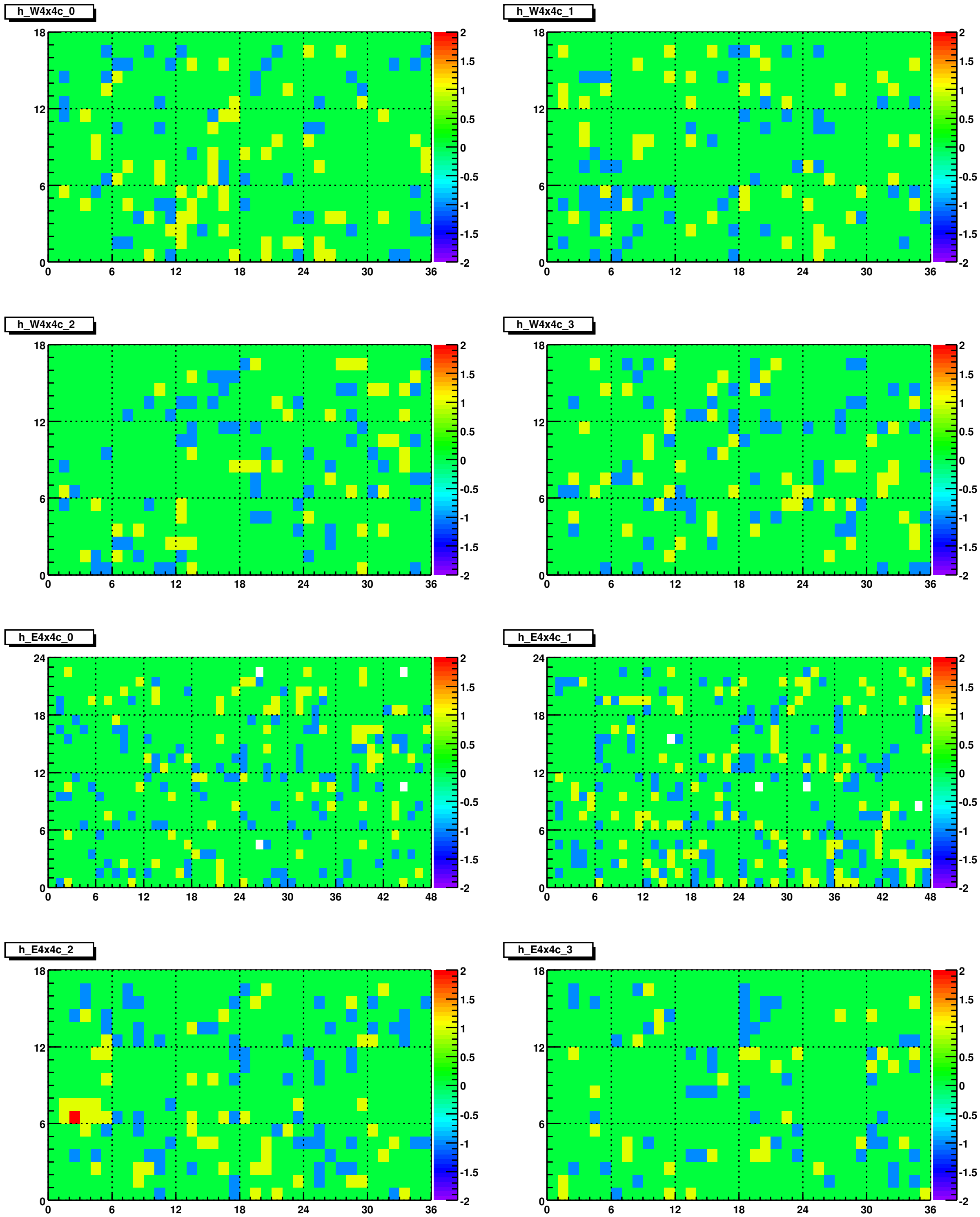


**Figure 50:** *Difference between the two pedestal measurements for the 4x4c.*

# D Special Runs

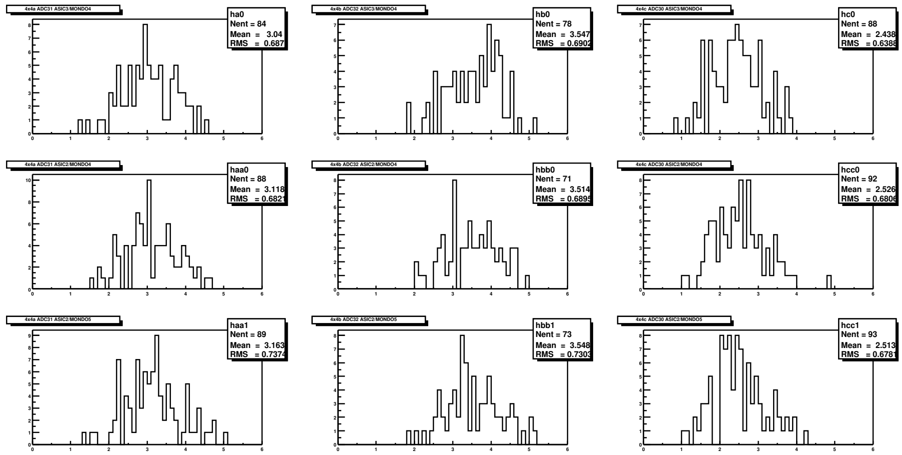


**Figure 51:** *All thresholds of A3/M2 set.*

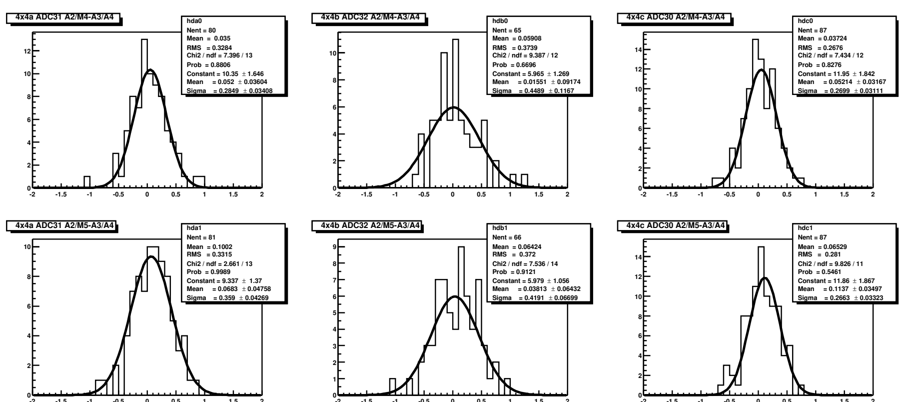


**Figure 52:** *Distribution of differences thresholds of A3/M2 set.*

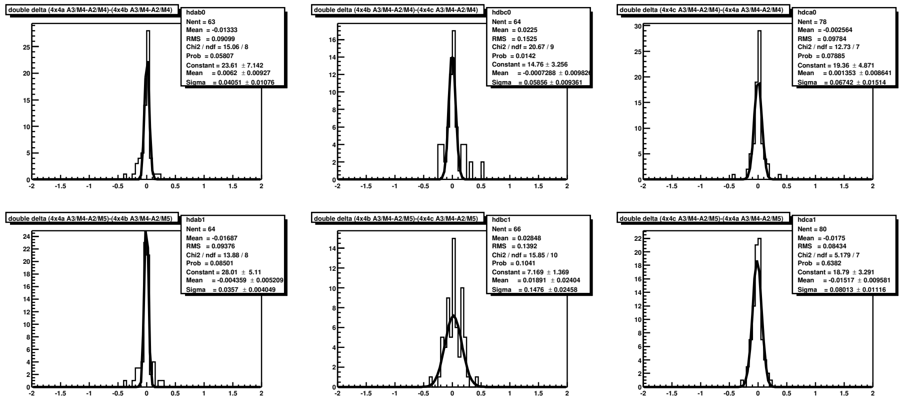

**Figure 53:** *Difference of difference between 4x4 modes for A3/M2.*

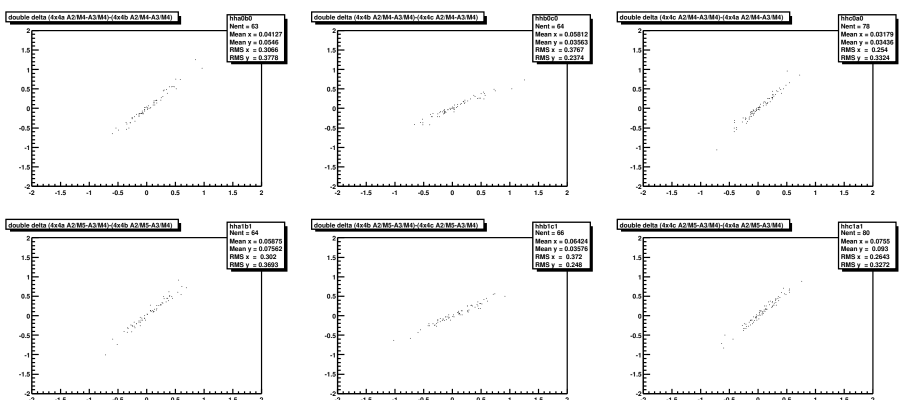

**Figure 54:** *Difference of difference between 4x4 modes for A3/M2.*