2008 SiW ECAL MIP Calibration

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- Muon Selection
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Introductory Remarks

MIP Calibration of SiW ECAL:

Assign a **standard energy scale** to the electronic readout from the silicon active medium **of each pad**.

The Standard Energy Scale:

Energy deposition of **minimal ionizing muons**, defined as a **MIP**. A constant for a given thickness of the material.

Calibration Constants:

1 MIP= ? ADC counts, for each pad.

Extract by a fit using a convolution of Landau with Gaussian, where the Landau MPV gives the calibration constant.

Following previous works done by:

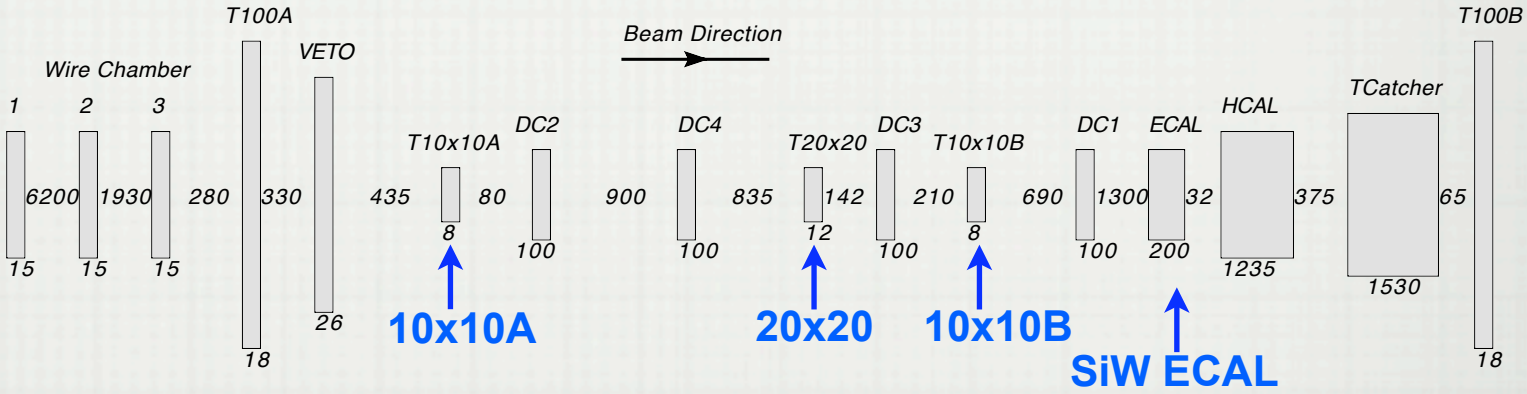
Goetz Gaycken, Marcel Reinhard

Experimental Conditions

FNAL Beam Line Configuration:

in Unit of mm

A Cerenkov in the upstream



Triggers:

1) 20x20 : For muon calibration runs, and electron runs
2) 10x10&Cerenkov : For low energy pion runs,
   a) large fraction of electrons in low energy beams
   b) Cerenkov for e/pi discrimination
   c) Cerenkov signal is slow, since it is far upstream

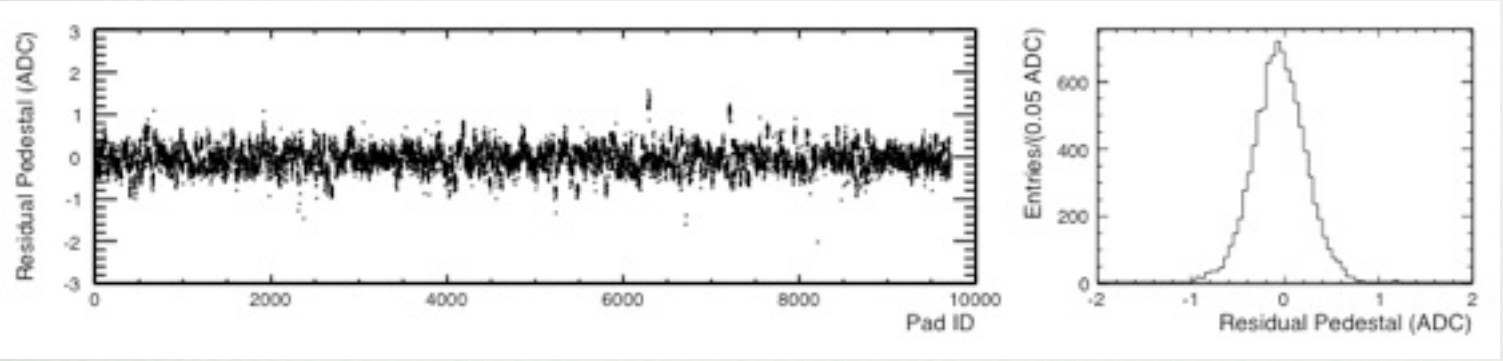
Data Samples:

Muon data triggered with 20x20 scintillator counter, July 2008 FNAL
About 520k events after reconstruction.

Stability of Residual Pedestal

After Pedestal Subtraction, the **Stabilities of Residual Pedestals and Noise** are checked:

- Take the noise signals recorded by each pad.
- Fit with a Gaussian function for each pad : fitting range [-5σ, +σ]
  - mean of the Gaussian: the **Residual Pedestal**
  - sigma of the Gaussian: the **Noise**



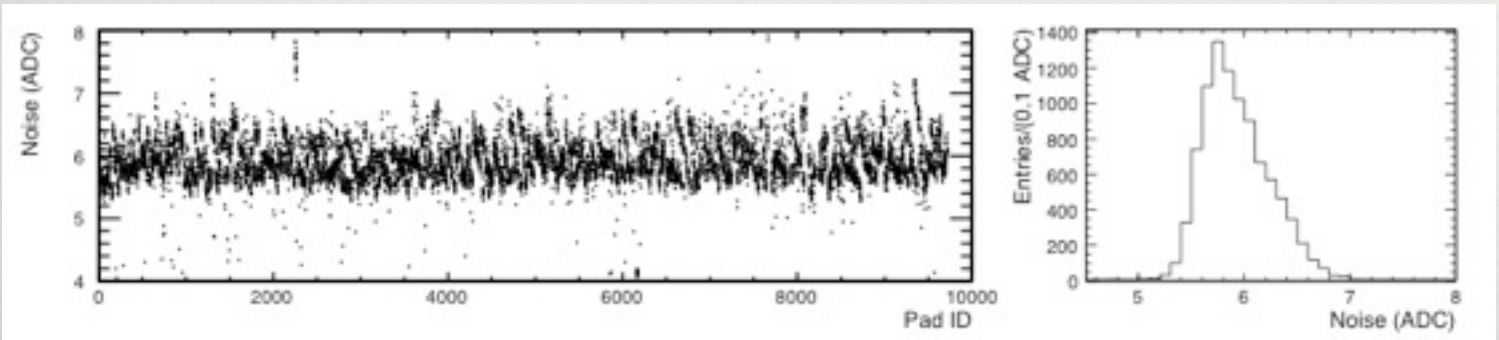
Residual Pedestals

mean:

-0.058±0.003 ADC

RMS:

0.281±0.002 ADC



Noise

mean:

5.930±0.003 ADC

RMS:

0.330±0.002 ADC

$$Pad\ ID = 9 \times 36 \times K + 36 \times (3 \times W_x + W_y) + (6 \times P_x + P_y)$$

Muon Selection

Muon Selection:

1) A signal hit: Response > 25 ADC counts

2) Fit to the hits as a straight line

3) Number of hits in the straight line must be greater than 10

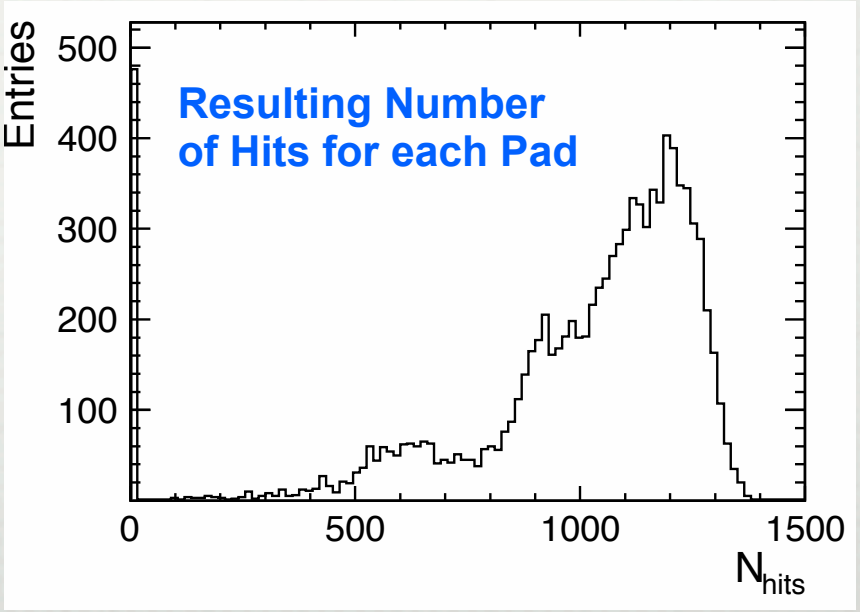
4) Distance between two hits in consecutive layers must be less than 2 cm

Statistics

Dead Pads: 476 (4.9%)

N hits less than 800: 1250 (12.9%)

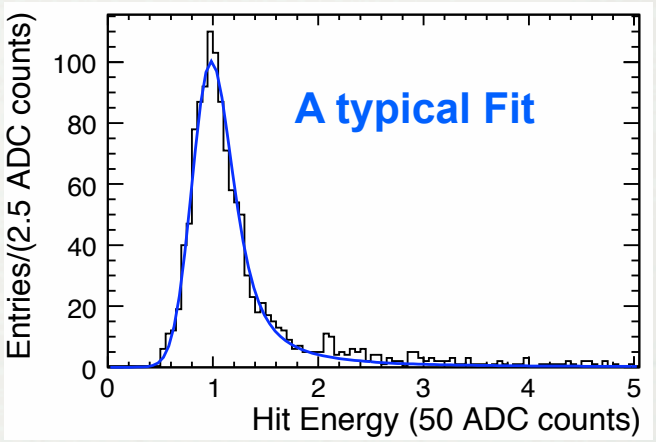
N hits greater than 800: 7992 (82.2%)

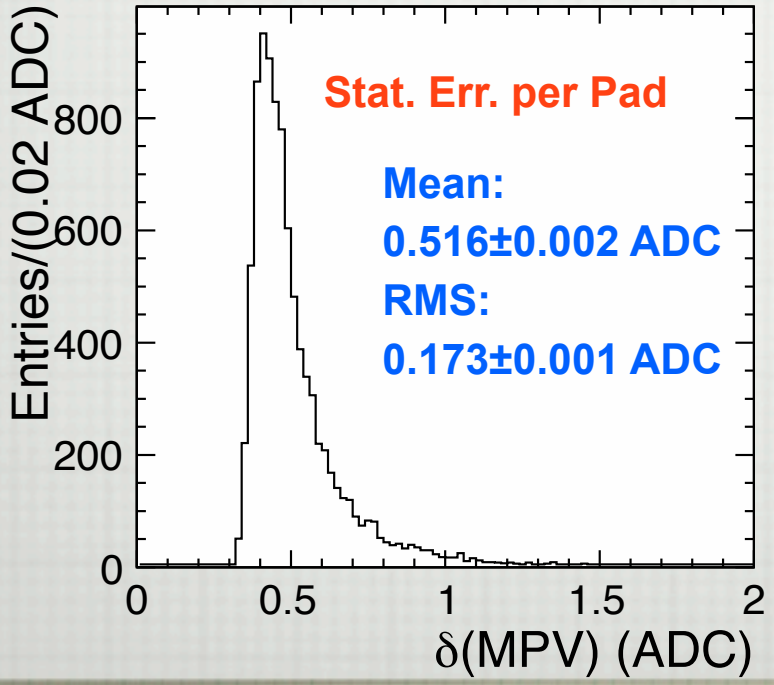


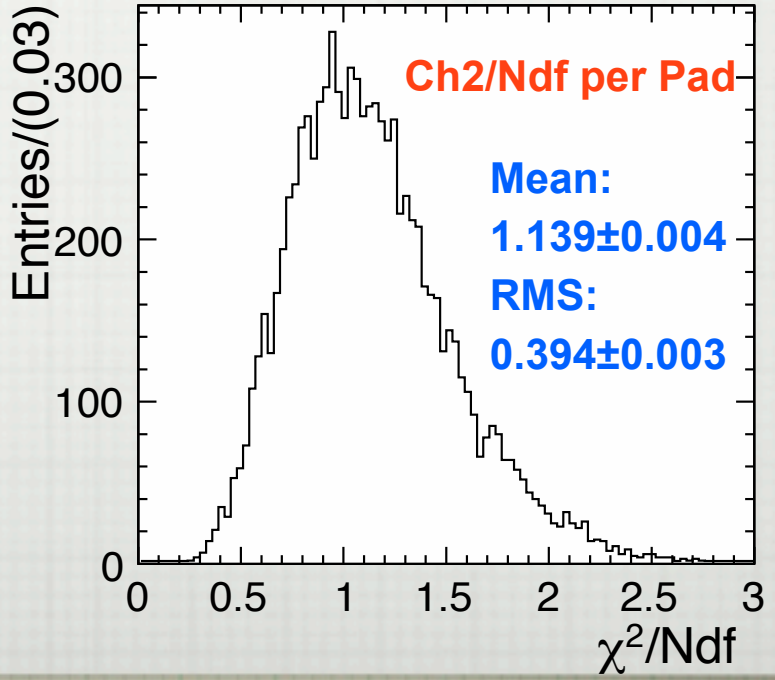
Fits

Fit for each pad with a Convolution of Landau with Gaussian:

- Landau MPV: the calibration constant
- Gaussian Sigma: the Noise (signal induced)
- Fitting Range: 25 to 78.5 ADC







Corrections for Dead Pads and Fit Failures

Number of Dead Pads: 476

Number of Fit Failures: 47

A fit failure, if any one of the following criteria is not satisfied:

1) MPV within (37.5, 53.5) ADC
2) Stat. Err. less than 2 ADC
3) Noise within (2, 14) ADC
4) Chi2/ndf within (0.5, 3)

Reason/Corrections for fit failures:

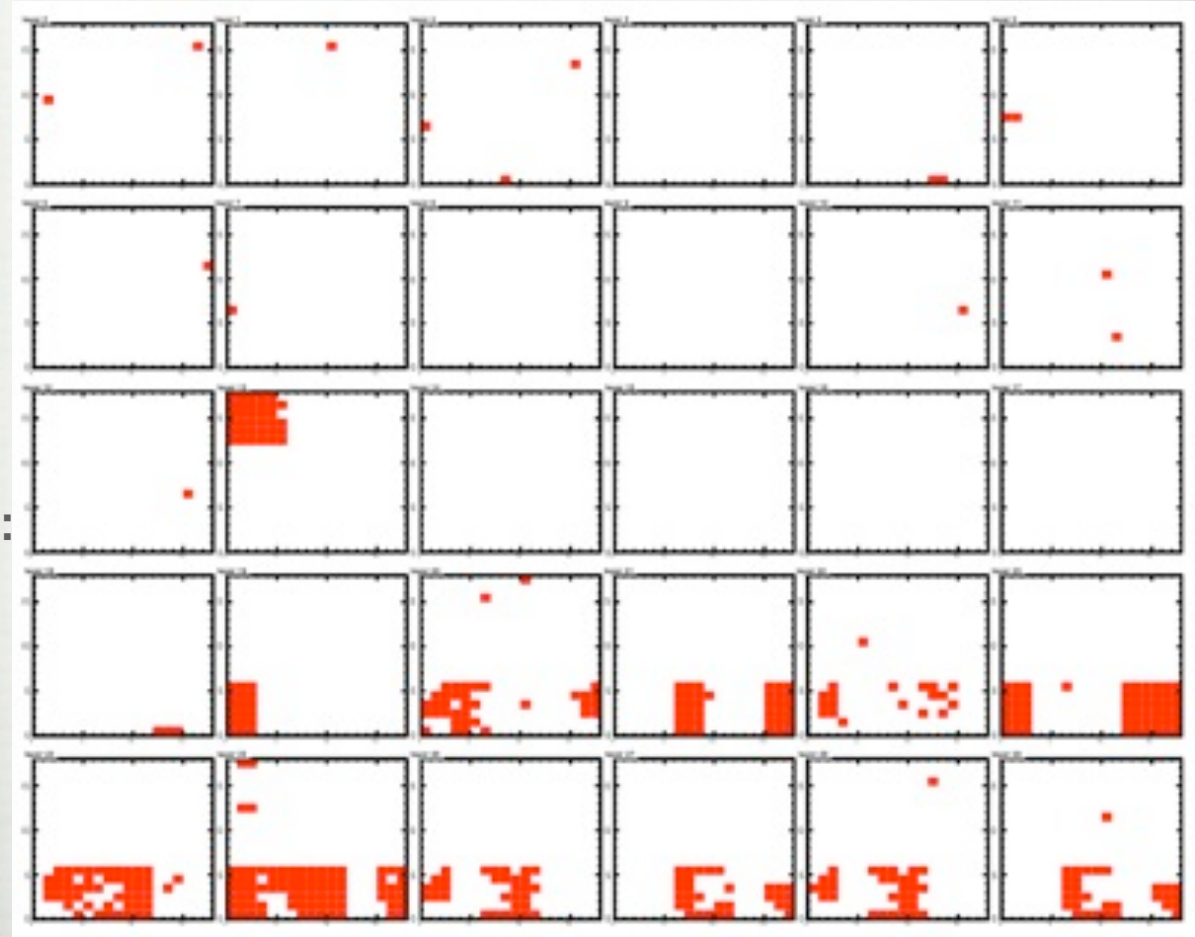
1) Due to abnormal residual pedestal:

- Refit together with another Gaussian to account for the residual pedestals
- 14 pads are recovered.

2) Short in statistics:

- 33 pads, treat as dead pads

Map of Dead Pads, for all 30 layers



Corrections for Dead Pads and Fitting Failures

Corrections for Dead Pads:

1) If it is found randomly:

- calibration constant: replaced by the mean of the same chip.
- error on calibration constant: the corresponding RMS. (on average for all chips: 1.31±0.03 ADC)

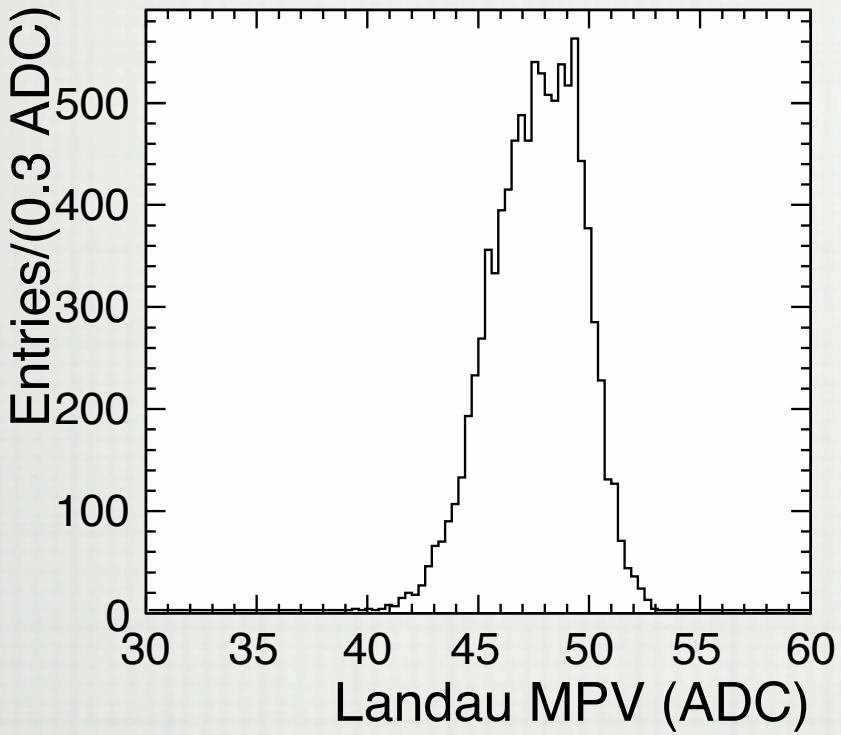
2) For a whole dead chip:

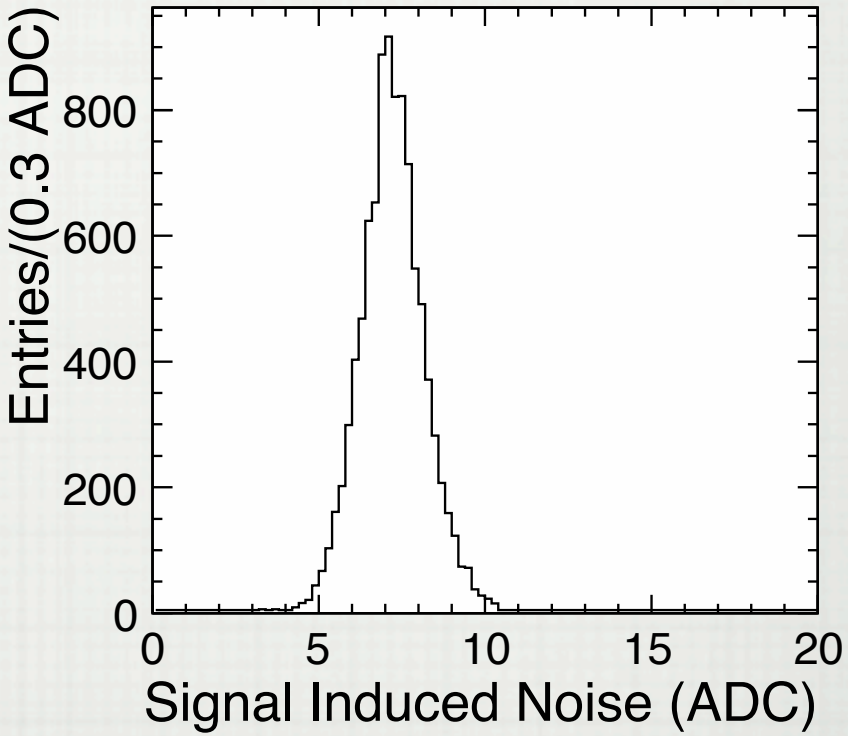
- calibration constant: replaced by the mean of the same PCB
- error on calibration constant: the corresponding RMS. (on average for all PCBs: 1.57±0.03 ADC)

3) In case more than half the pads in a PCB are dead:

- calibration constant: replaced by the mean of the other PCB in the same slab.
- error on calibration constant: The RMS of the difference between the mean of one PCB and each pad of the other PCB in the same slab. This RMS is 1.81±0.01 ADC, measured using all slabs.

Resulting Calibration Constants and Noise





Calibration Constants:

Mean:

47.61±0.02 ADC

RMS:

2.06±0.01 ADC

Signal Induced Noise:

Mean:

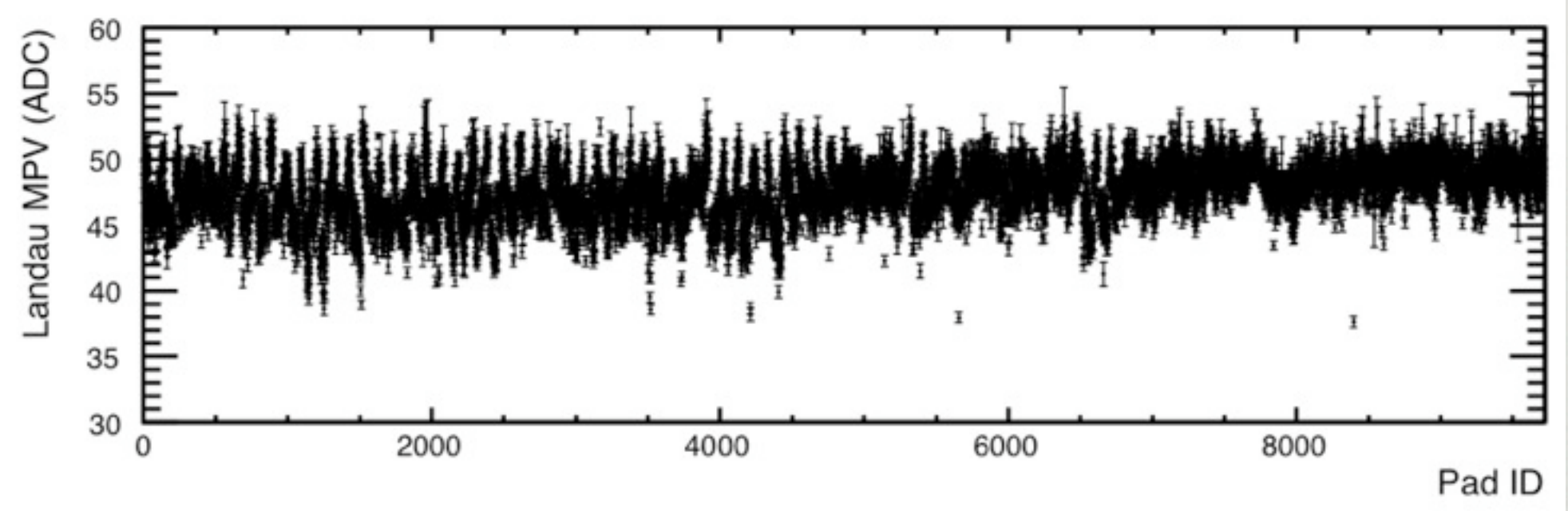
7.22±0.01 ADC

RMS:

1.00±0.01 ADC

Uniformity

Uniformity: Calibration Constants as a function of Pad Index, with error bar.



$$Pad\ ID = 9 \times 36 \times K + 36 \times (3 \times W_x + W_y) + (6 \times P_x + P_y)$$

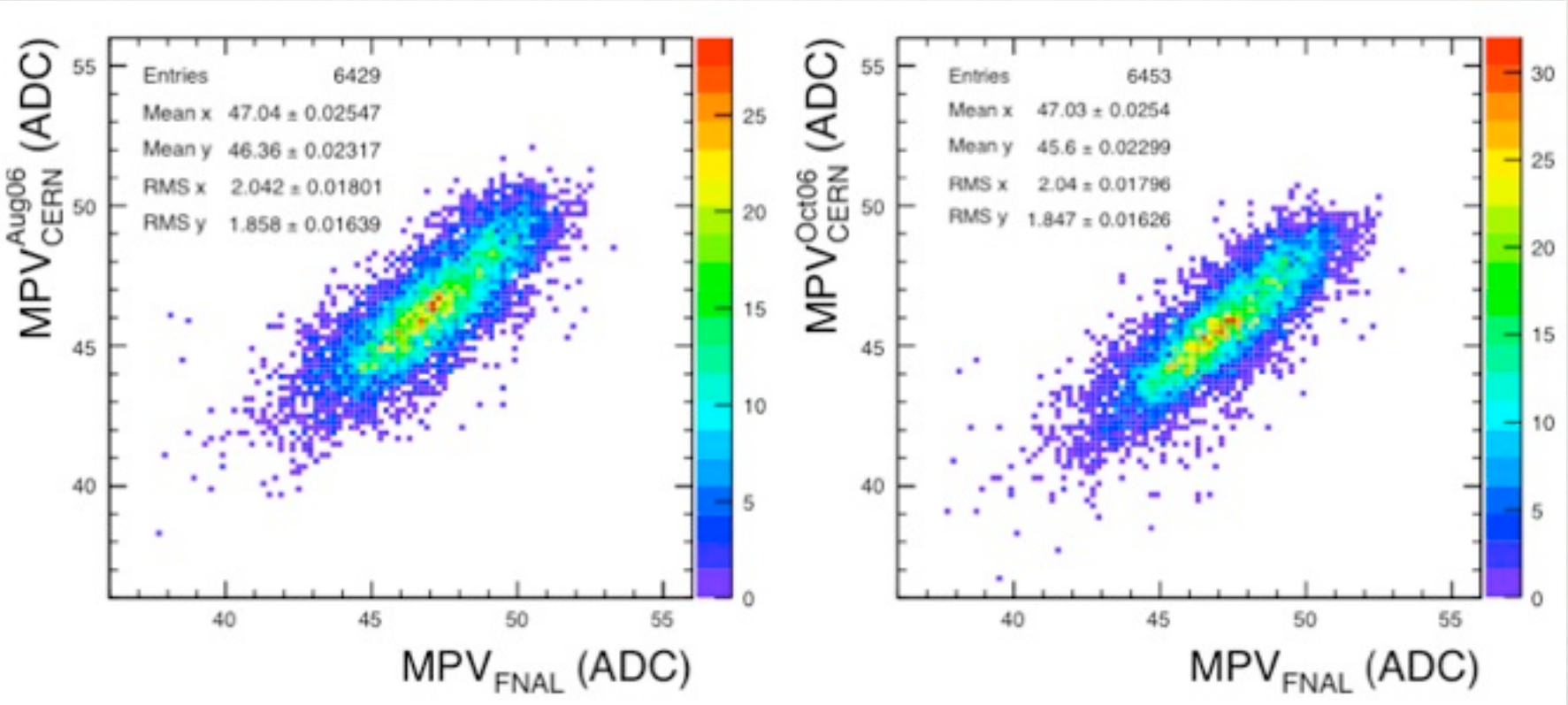
Calibration Constants:

Mean: 47.61±0.02 ADC

RMS: 2.06±0.01 ADC

Stability

Stability is checked by comparing with 2006 CERN Aug. and Oct. ones.



Correlation with Aug. 2006 CERN
Correlation Coefficient: 80.30%

Correlation with Oct. 2006 CERN
Correlation Coefficient: 83.76%

Stability

Difference of the calibration constants compared with 2006 CERN Aug. and Oct. ones.

$$Pad\ ID = 6 \times 36 \times K + 36 \times (2 \times W_x + W_y - 1) + (6 \times P_x + P_y)$$

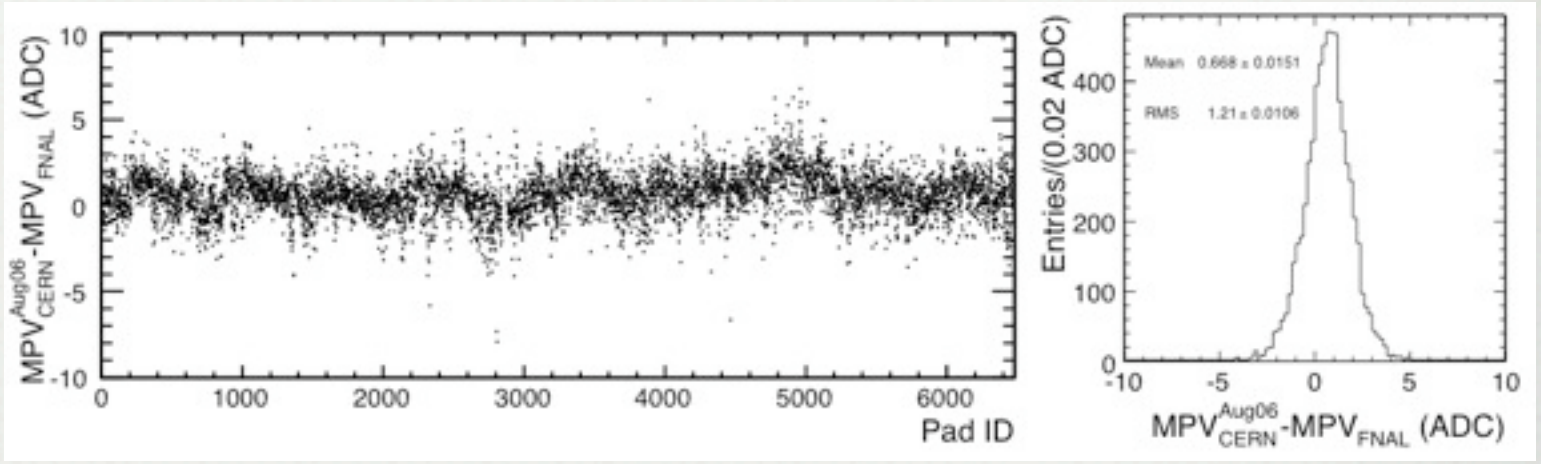
Difference with Aug. 2006 CERN

Mean Difference:

0.67±0.01 ADC

RMS:

1.21±0.01 ADC



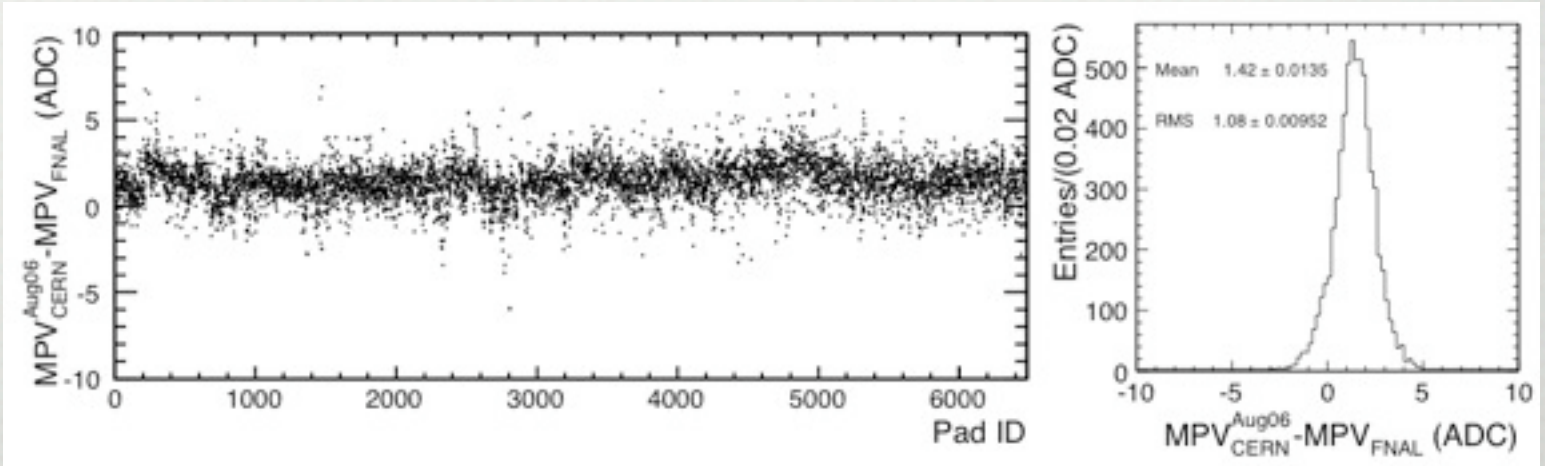
Difference with Oct. 2006 CERN

Mean Difference:

1.42±0.01 ADC

RMS:

1.08±0.01 ADC



Reason for the difference: Timing offset between different triggers

Systematic Errors

When apply the calibration constants to the electron runs, with the same 20x20 trigger:

1) Due to Residual Pedestals:

- mean of residual pedestals over all pads:

  -0.058±0.003 ADC Counts (0.12% of a MIP)

2) Due to Different Fitting Ranges:

- Comparing the results with that using the entire range.
- difference for each pad: mean: 0.258±0.004 ADC

  RMS : 0.366±0.003 ADC Counts (0.77% of a MIP)

  (systematic error)

In total a systematic error of :

0.37 ADC Counts (0.78% of a MIP)

for the electron runs

Systematic Errors

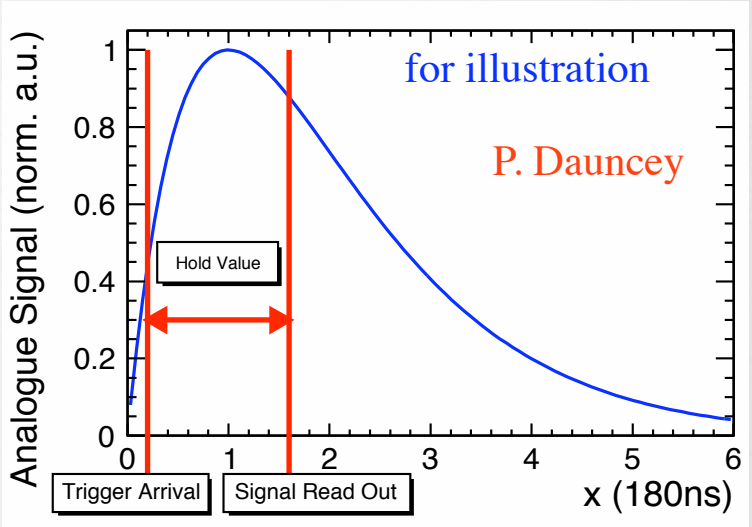
When apply the calibration constants to the pion runs with the 10x10&Cerenkov trigger:

Additional Systematic Error Due to the Timing Offset between Different Triggers:

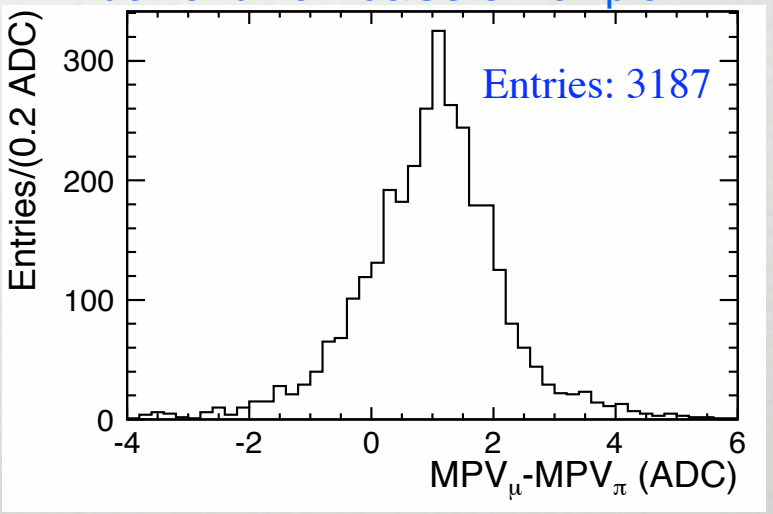
- Reason:
  - Difference in Trigger Arrival time
  - Difference in Hold Value

- Examine using minimal ionizing pions triggered with 10x10&Cerenkov:
  - Difference:
    Mean: 0.97±0.02 ADC
    RMS : 1.19±0.02 ADC
  - Take the mean as the systematic error.

In total a systematic error of :
1.04 ADC Counts (2.2% of a MIP)
for the pion runs.



MPV difference between 20x20 muon and 10x10&Cerenkov pion



Summary

- MIP Calibration for 2008 FNAL beam test is finished.
- Calibration Constants on average: 47.61 ±0.52(stat.) ±0.37(sys.) ADC
  - if apply on pion runs with 10x10&Cerenkov, a total systematic error : ±1.04(sys.) ADC
- Good Stability in Time Obtained
  - Compared with those of 2006 CERN,
    - reminding: after two years of operations, shipments all over the world
  - Correlation Coefficient is found greater than 80%
  - A Mean Difference of the order of 1 ADC Count
    - can be understood in terms of trigger timing offset
- It is an evidence that the calibration constants can be well controlled for a full SiW ECAL in a detector at ILC