Analysis of W-AHCAL data

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on behalf of W-AHCAL CERN group

Introduction

2010 data

- W-AHCAL: **30 layers**
- Energies: 1-10 GeV
- Dedicated muon runs in CERN T7
- Mixed runs (e, π, μ, p) in CERN T9

2011 data

- W-AHCAL: **38 layers**
- TCMT added
- Energies: 10-300 GeV
- Mixed runs (e, π, μ, p, K) in CERN PS and SPS
- Dedicated muon runs, detector scans

Analysis strategy

- Final goals:
  - Energy resolution
  - Shower shapes
  - Comparison with GEANT4 models
    $\Rightarrow$ analysis note/paper
- Combine 2010/2011 data
- Start with e^+/e^- (electromagnetic showers are theoretically simple, good tool for checking the calibration)
- Once calibration validated, continue with hadrons

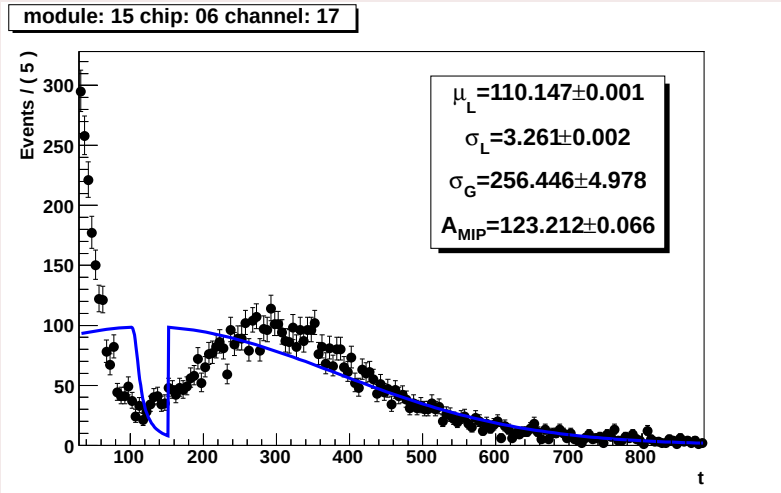
Mühsam ernährt sich das Eichhörnchen ...

MIP calibrations

- AHCAL response calibrated in terms of **muons as MIPs**
- Two calibration data sets: 2010 and 2011
  $\Rightarrow$ need to check:
  - quality of MIP determination
  - consistency between 2 calibration sets

Quality of MIP determination

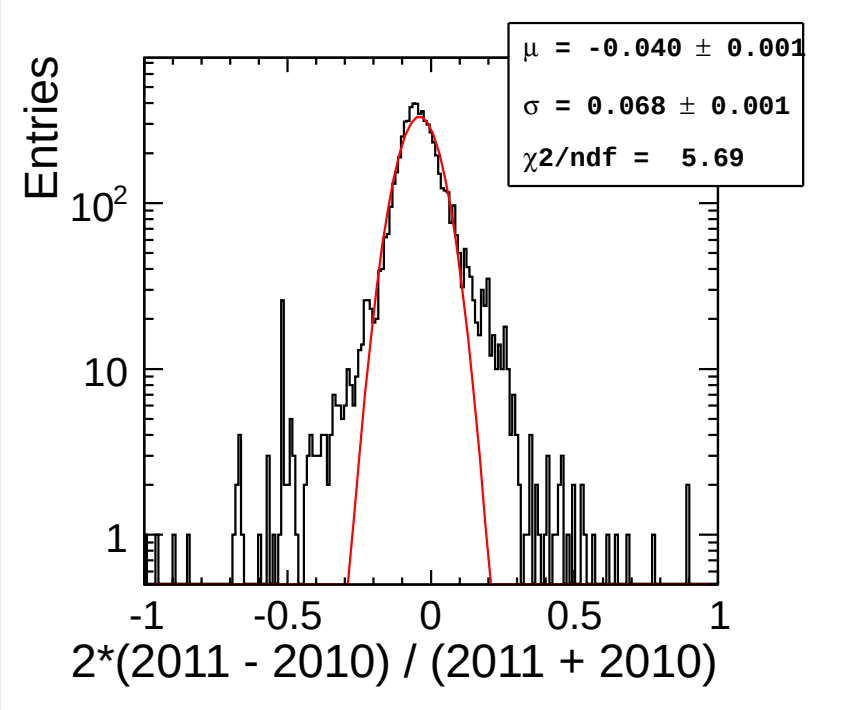
- Muon finder:
  - Extend existing version to find muons which traverse AHCAL at an angle
- Fit:
  - Use package developed for Fe-AHCAL (LanGaus fit)
  - Works mostly well, but a few problematic cases which cannot be detected automatically
  - See also example 1 and example 2



MIP calibrations: 2010 vs. 2011

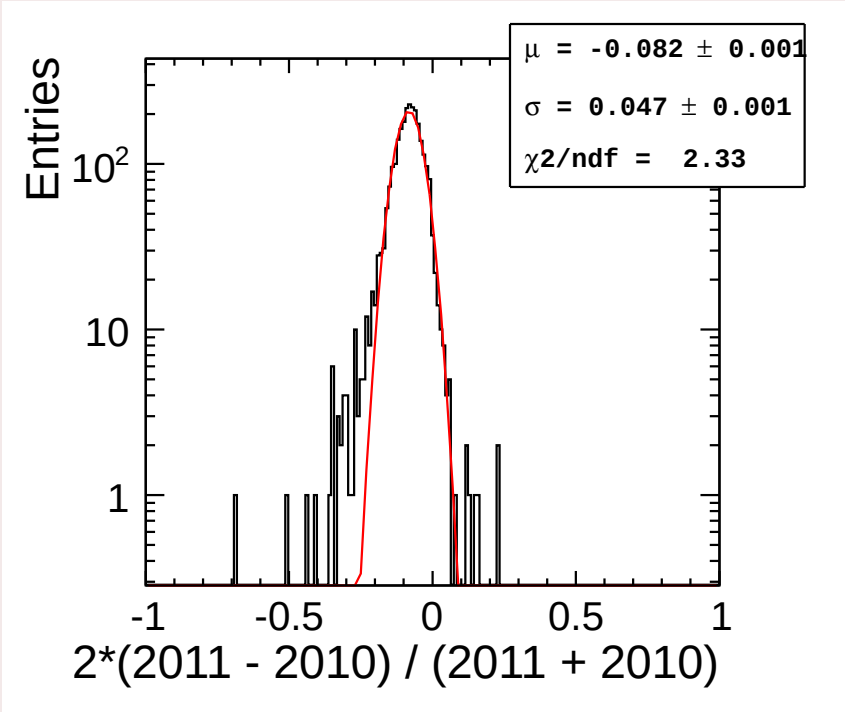
Before clean up

- Compare 2010 with 2011 calibrations by correcting them using a common reference temperature



After clean up

- After visual inspection of MIP fits and correction of problematic ones



⇒ Reduced tails, but ∼ 8% shift (maybe due to differences in hold values)

MIP calibrations

2010 data

- Muon triggers: $50 \times 50\ \mathrm{cm}^2$
- Small coverage

2011 data

- Muon triggers: $80 \times 80\ \mathrm{cm}^2$, dedicated scans with $30 \times 30\ \mathrm{cm}^2$
- Larger coverage

- For missing channels in one calibration set, decided to use scaled values from other set (scale factors obtained for each half-module)

Year	Total number of channels	Calibrated channels	Scaled channels
2010	6480	92%	25%
2011	7608	90%	6%

MIP calibration available for $\geq 90\%$ of the channels

- For the distribution of constants in a layer before and after scaling:

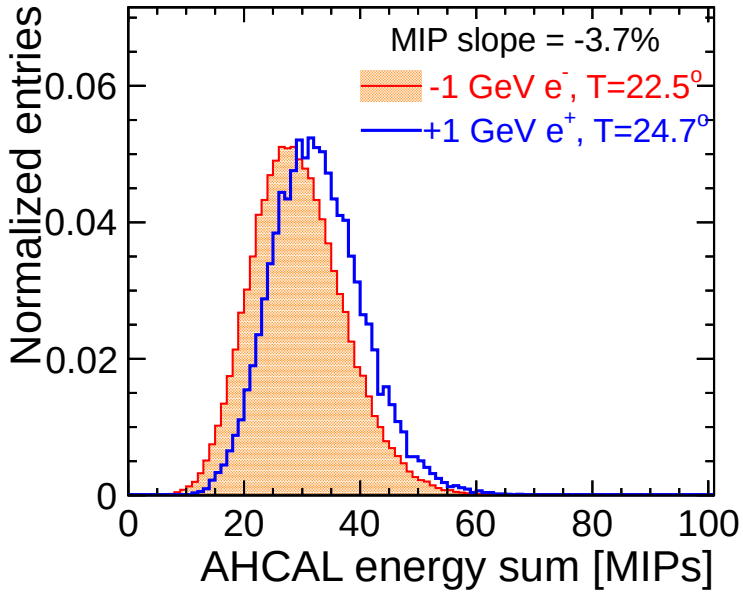
See backup slide

Improved situation (first nuts), let's go to the next issue

Temperature dependence

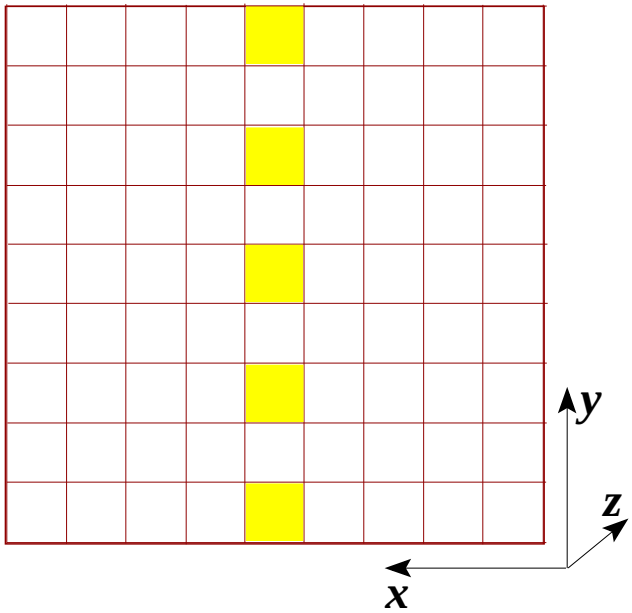
- SiPM response depends on temperature $\Rightarrow$ need to correct for it, as data is taken at varying temperatures
- Need to make sure that we have
  - Good temperature measurement
  - Temperature correction method is as good as possible

- Example of improper T correction:



Temperature measurement

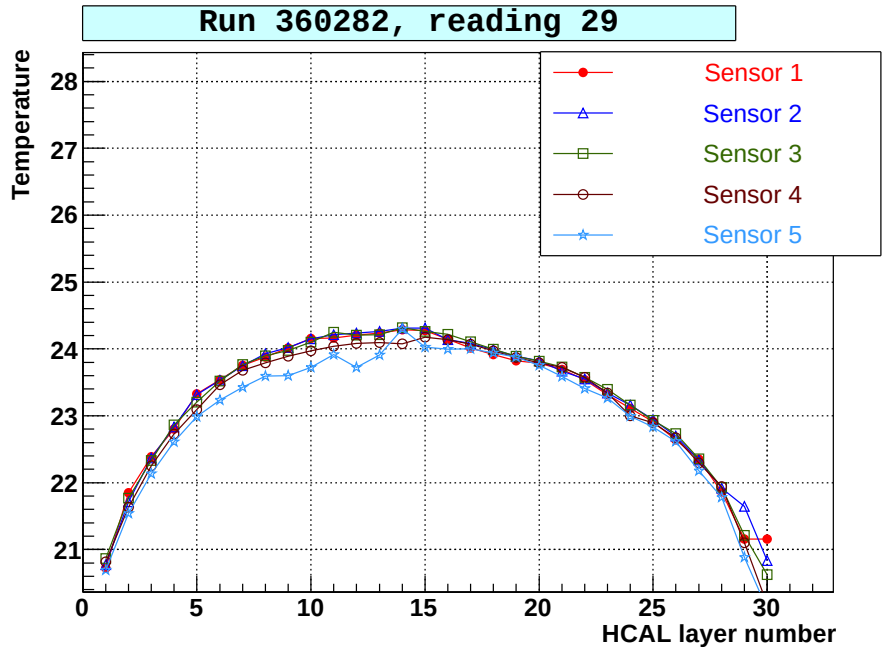
- Temperature in an AHCAL module measured with 5 sensors (every 10 minutes)



- For details about T measurement and applied corrections, see

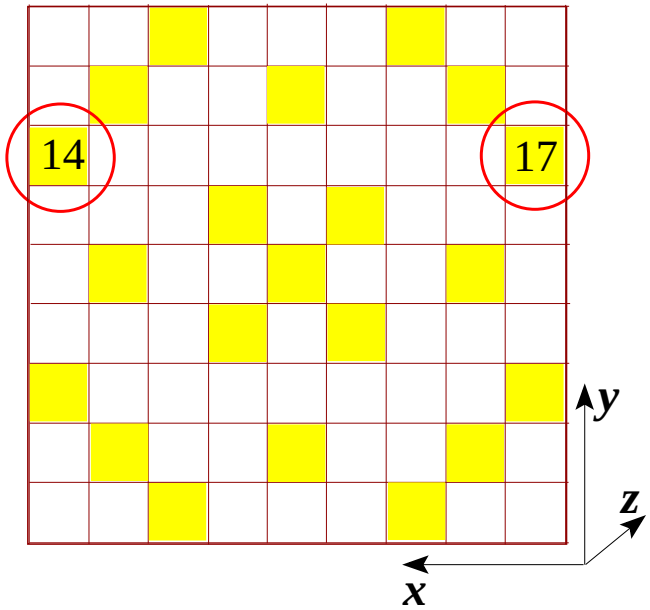
▸ AHCAL temperature note

- Temperature spread along y: typically 0.5 deg C.
- Spread along z: around 3-4 deg. C, or less (depending mostly on weather)

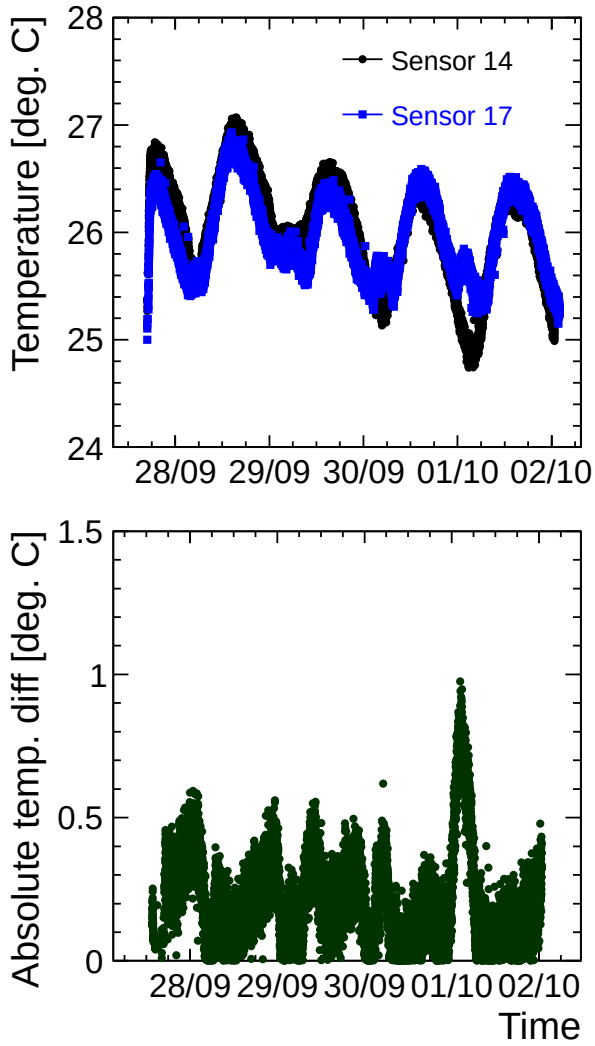


Temperature measurement

- September-October 2011: layer with 21 T3B temperature sensors



- For more details, see elog entries:
  - 29.09.2011 18:45
  - 01.10.2011 20:41
  - 03.10.2011 08:56
  - 13.10.2011 17:48
- See also profile 1 and profile 2



Local maximum of 1 deg. C difference along x, mostly < 0.5 deg. C

Temperature correction

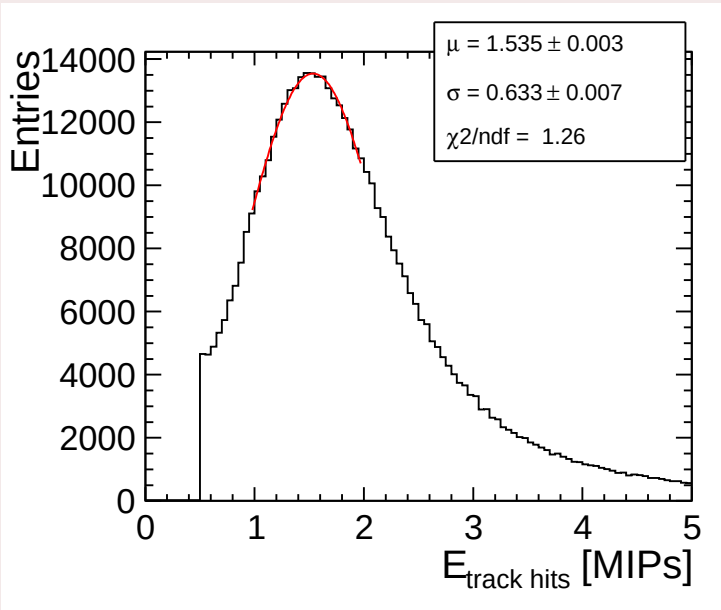
- How to correct for T?
  - SiPM response depends inversely linear with $T \Rightarrow$ measure slopes and use them for correction

How to measure MIP T slopes?

- Reconstruct data (without T correction)
- Find muons
- Look at the variation of the muon energy with T

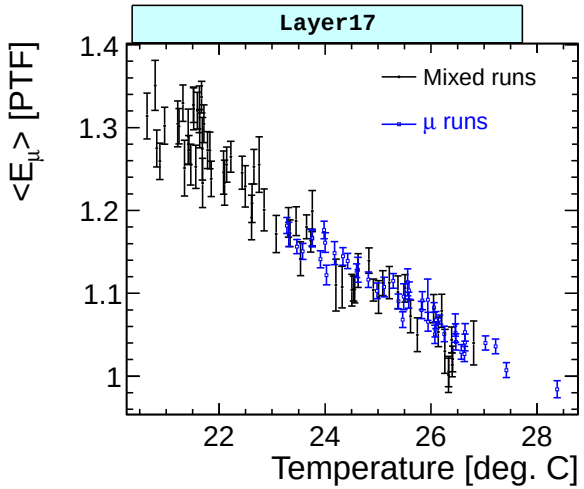
How to measure muon energy?

- Find muons hits with `PrimaryTrackFinder` (other methods tried, but results not so stable), with additional cuts see here
- Fit single hit energy spectra (Gaussian, limited range)

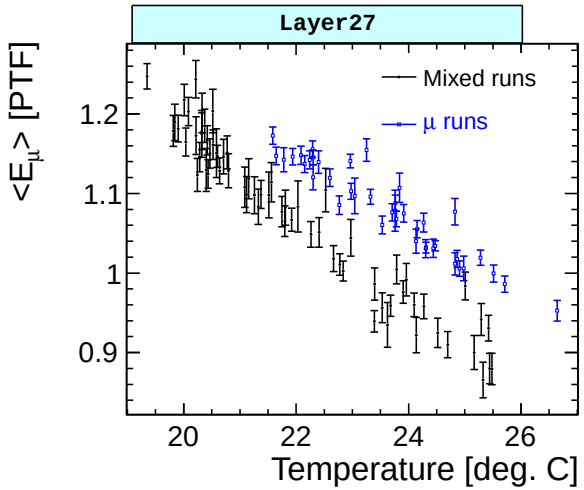


2010 MIP temperature slopes

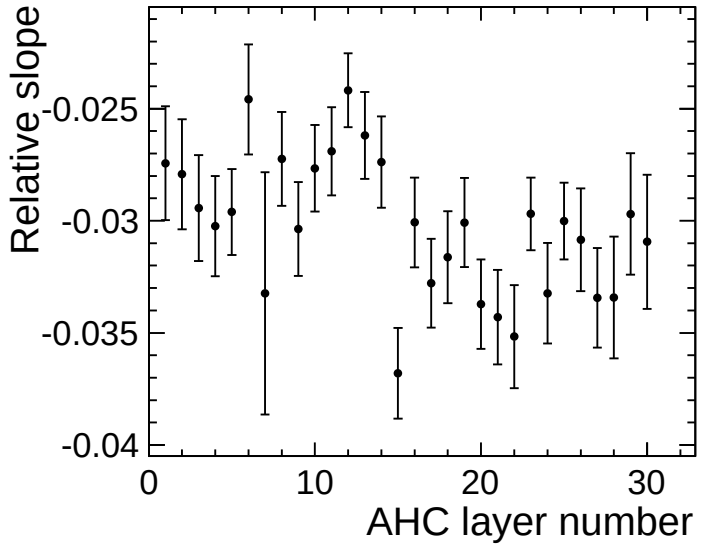
- Determine relative slopes per layer
- Most distributions look ok



- But around 1/5th of layers show double-band structure



- Distributions for all layers can be found here
- Relative slopes obtained using **only** pure muon runs:

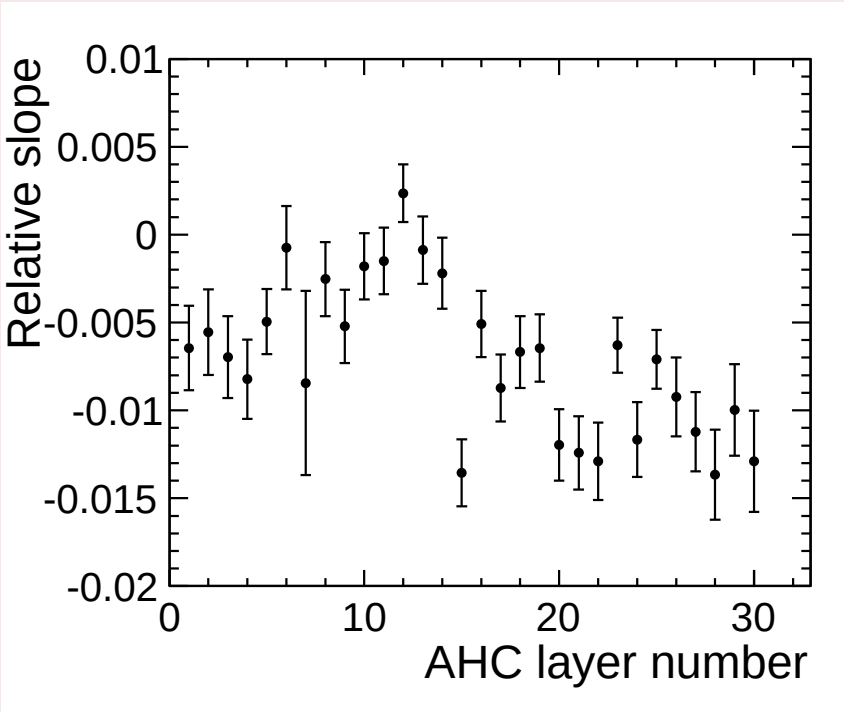


Average value: -3.0% (Fe-AHCAL CERN 2007 global slope: -3.7%)

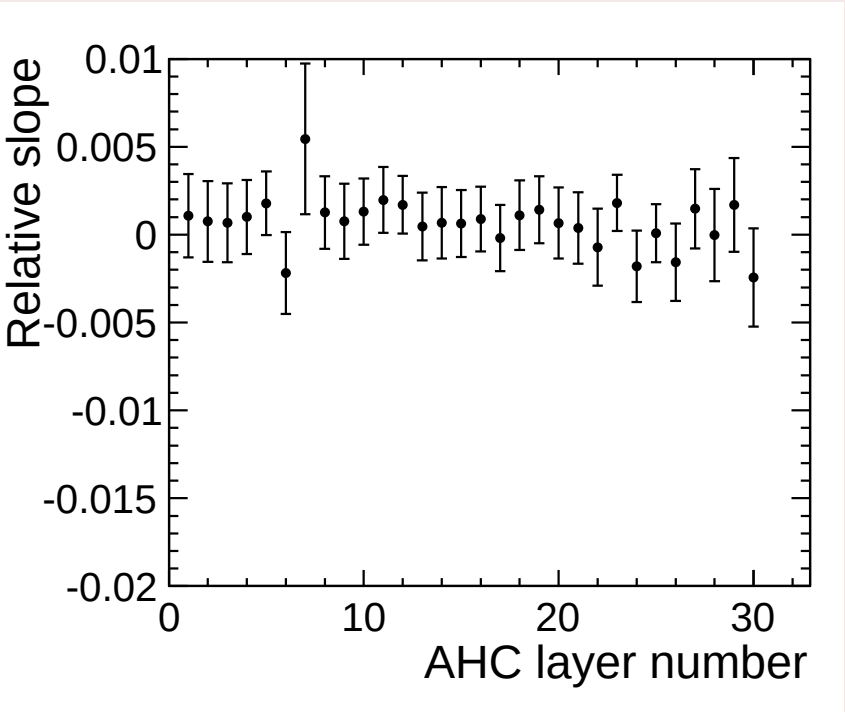
2010: Results of T correction

- Apply temperature correction and look at **pure muon runs only**

Slopes after T correction with a global slope of -3.0%



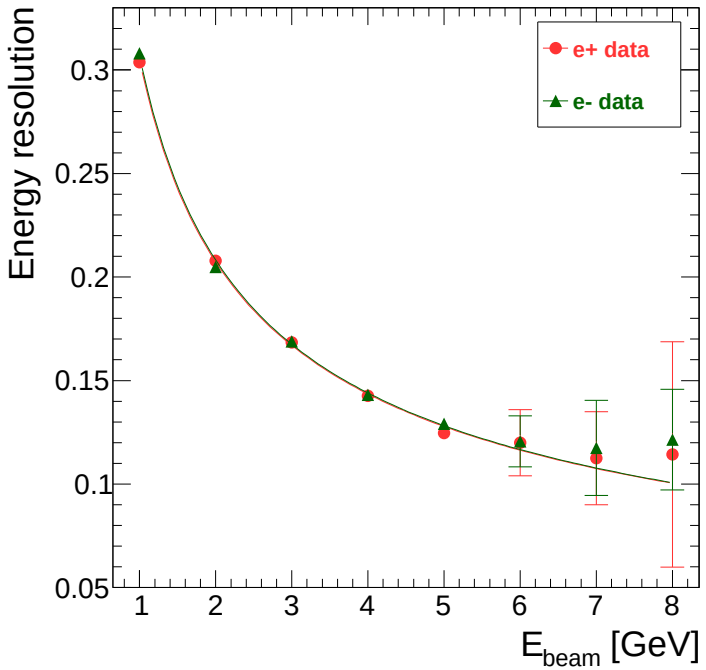
Slopes after T correction with relative slopes per layer

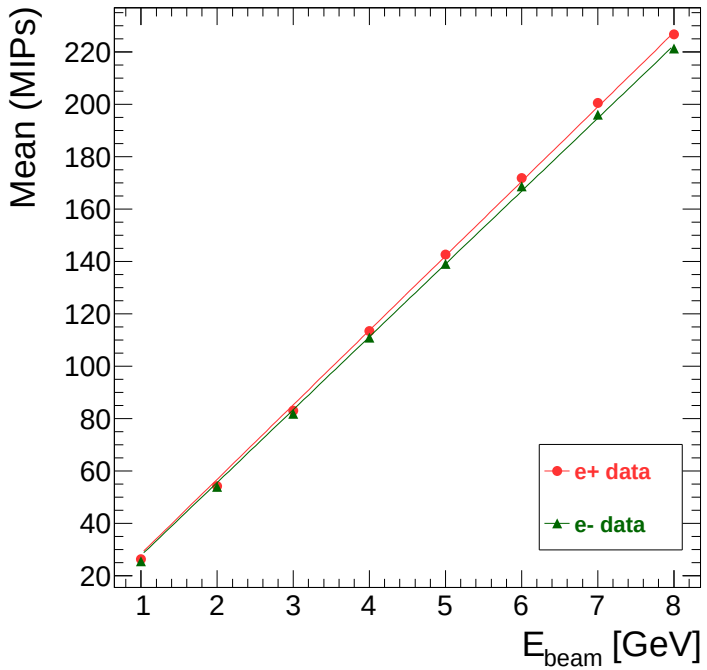


Using slopes per layer is better than just using one global slope

2010 analysis

- In parallel: develop analysis chain (using preliminary calibrations) of both EM and hadronic data (only a few EM results shown here)
- e^+/e^- data: low statistics for $E > 5$ GeV ▸ see example fits
- Error bars in the plot: first attempt for last 3 energy points to estimate systematics due to low statistics

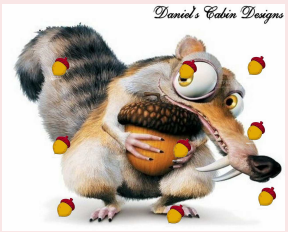




- MC generation ready, just waiting for another round of digitisation with new calibration constants ▸ see examples

Overview and conclusions

- Cleaning of MIP fits/constants done, improved muon selection
- Developed tools for measuring MIP slopes per layer
- 2010 relative MIP temperature slopes: few layers show separate bands for pure muon runs and mixed runs (under investigation)
- 2011 data: muon selection to be refined (E_{beam} from 10 GeV to 300 GeV, use TCMT)
- Analysis chain: ready
- Ongoing work on quality of energy resolution fits, using preliminary calibrations (fit bias, systematics due to low statistics)

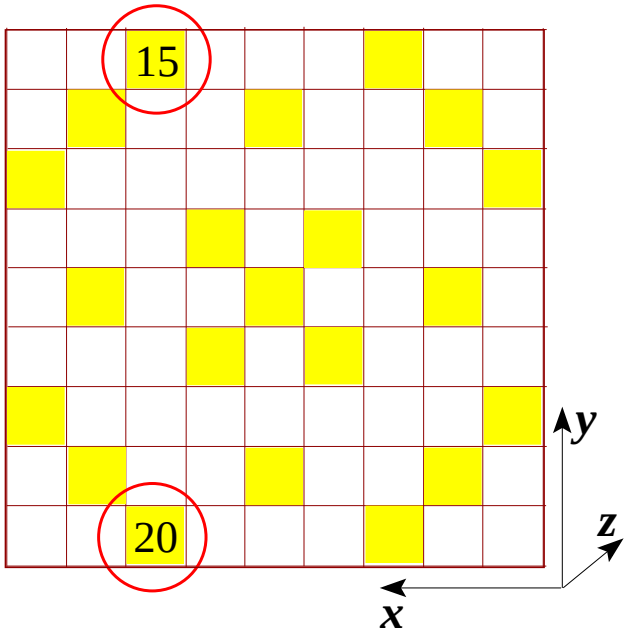


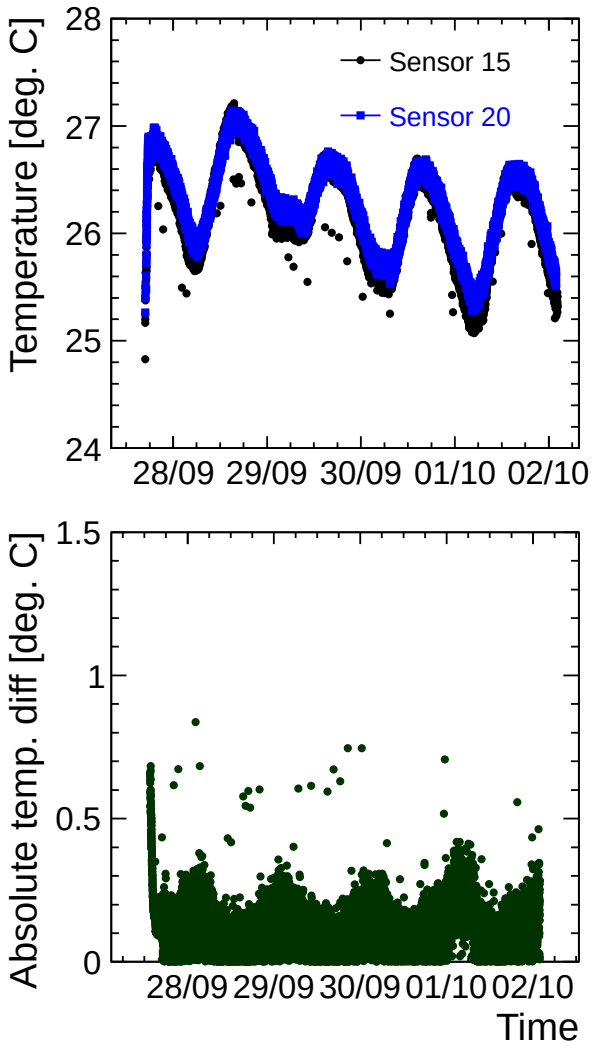
- Still many nuts to gather
- You are welcome to join the effort
- You can follow developments by looking at the W-AHCAL analysis meetings on the CERN indico page:
  - http://indico.cern.ch/categoryDisplay.py?categId=2533

Backup

Temperature measurement

- September-October 2011: layer with 21 T3B temperature sensors





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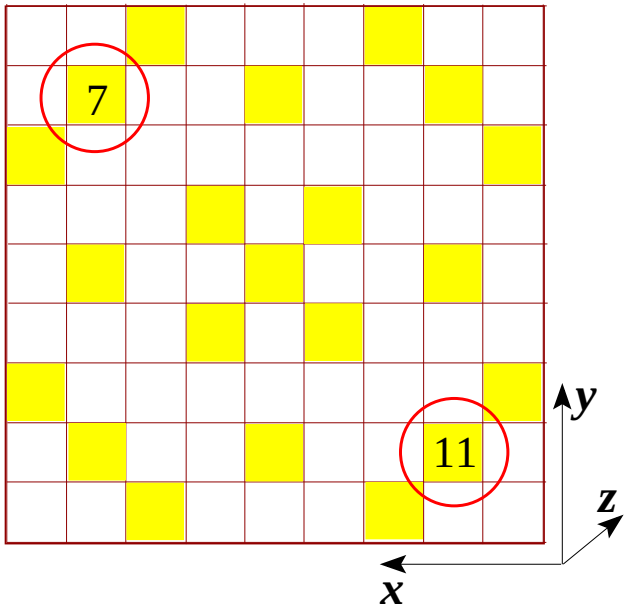
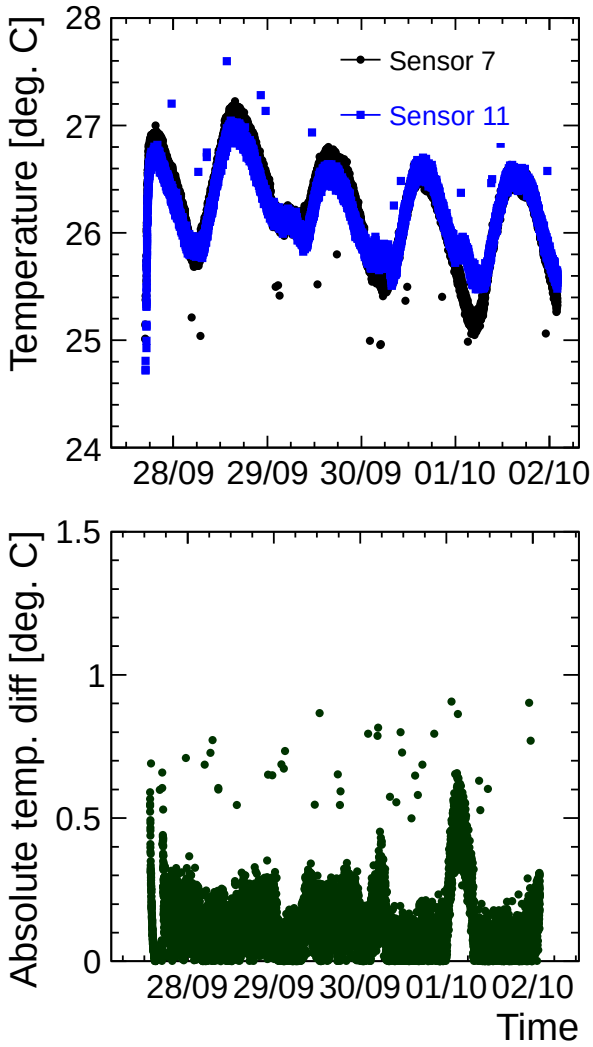
Local maxima of 0.7-0.8 deg. C
difference along y, mostly < 0.3 deg. C

Temperature measurement

- September-October 2011: layer with 21 T3B temperature sensors





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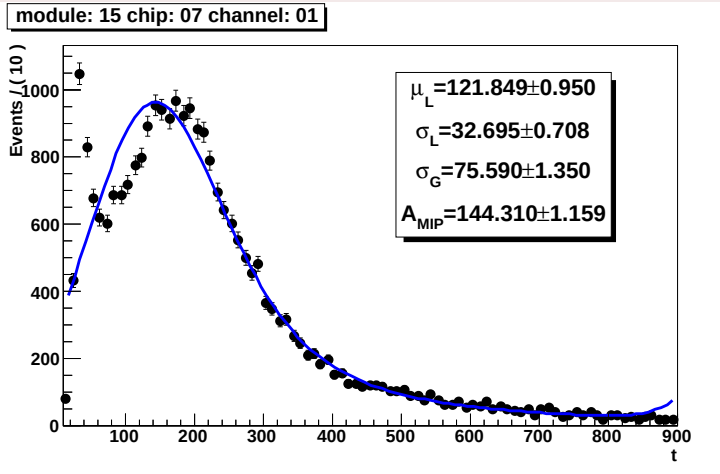
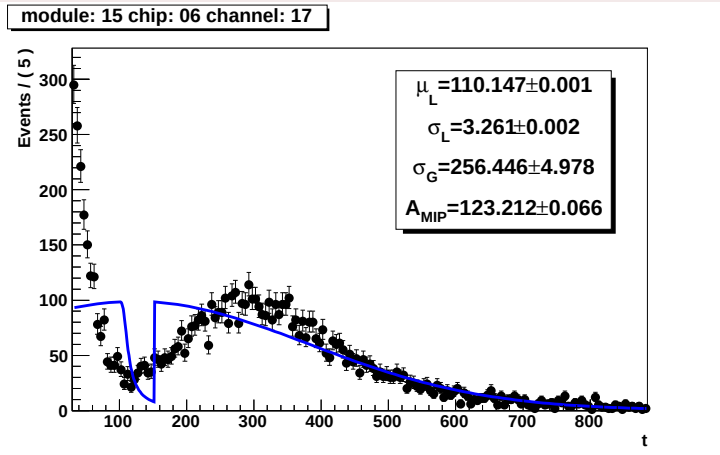
Local maxima of 0.8-0.9 deg. C difference in diagonal,
mostly < 0.3 deg. C

Checking of muon fits

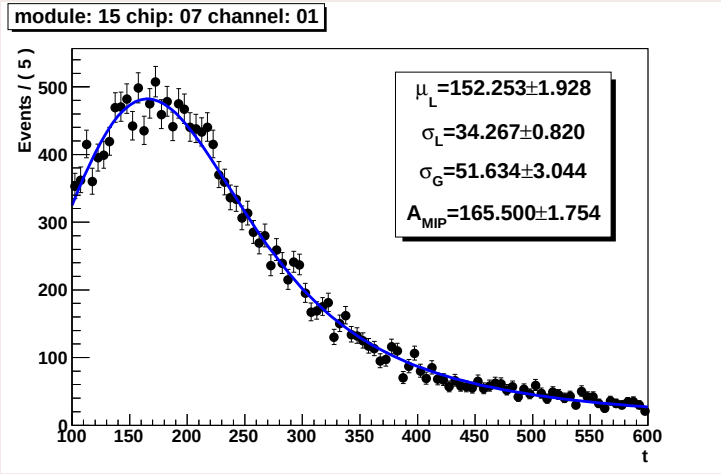
- A few examples of typical ill-behaving fits

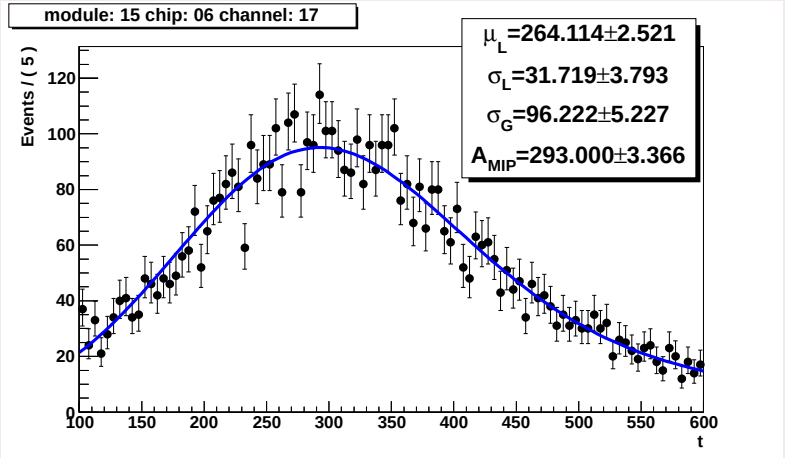
Original fits





New fits





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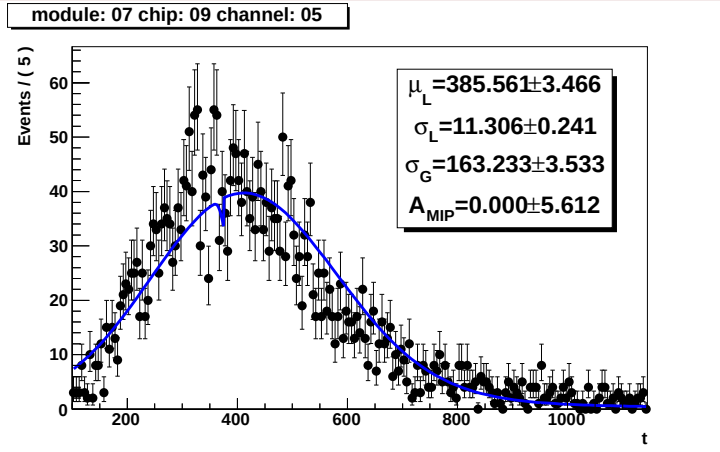
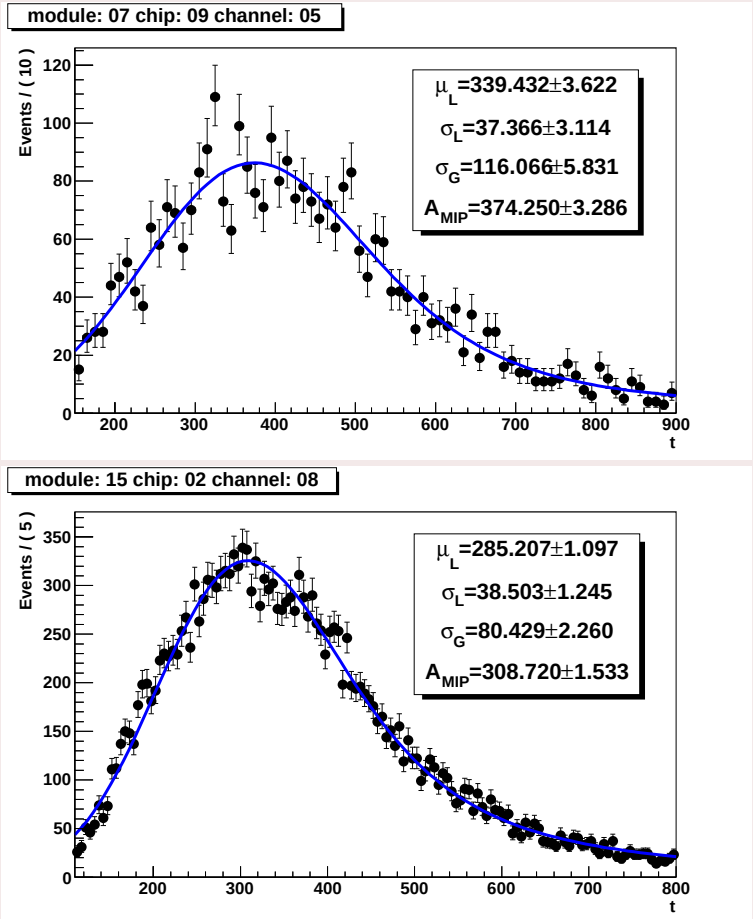
Checking of muon fits

Original fits



New fits



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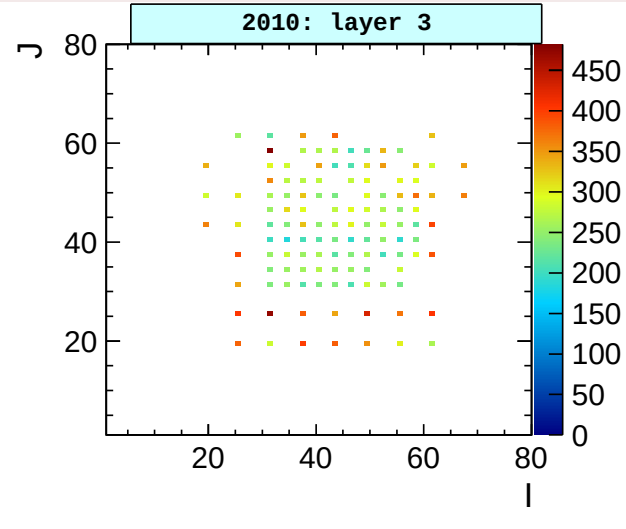
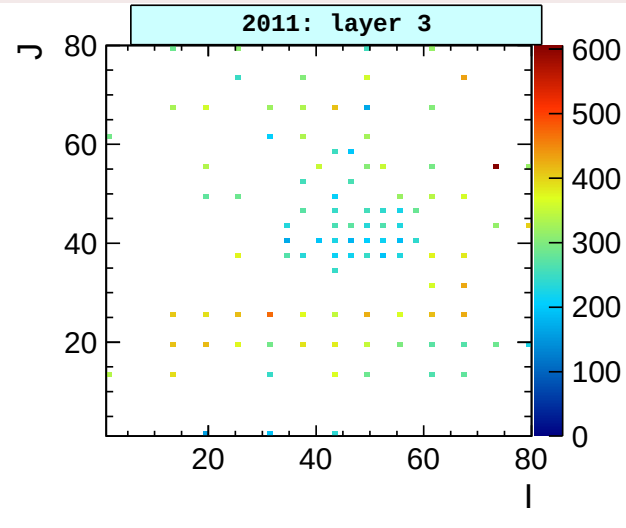
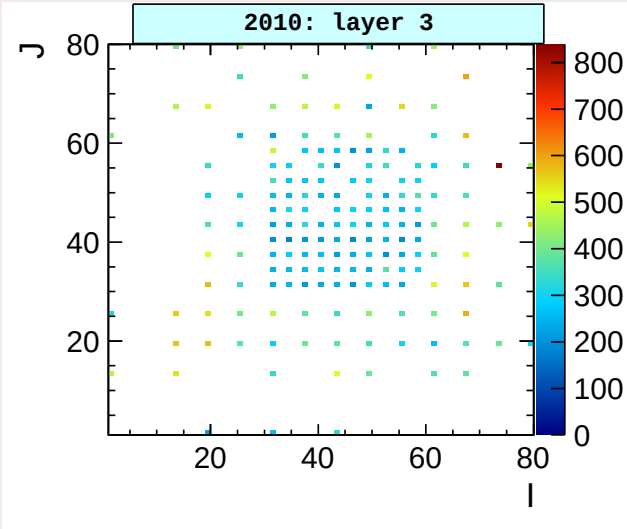
MIP calibration constants

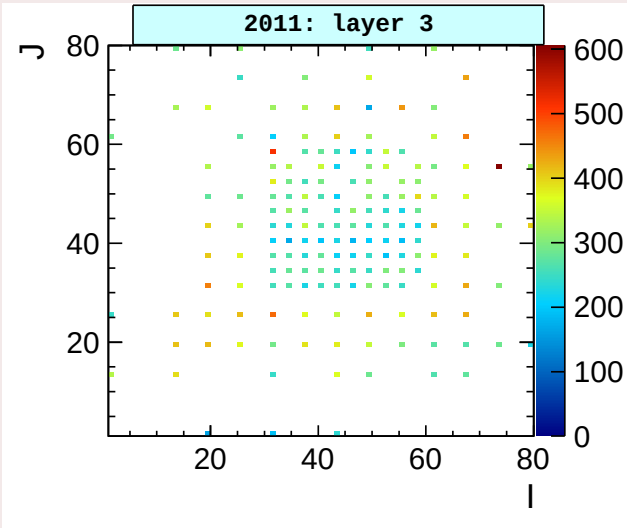
BEFORE scaling





AFTER scaling





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Muon selection improved

Improved muon selection with additional cuts (after `PrimaryTrackFinder`):

- Maximum 2 hits per layer
- At least 20 hits in an event
- At least 20 active layers
- Reject punch-through pions with: $energyPerLayer < 3 \cdot median$, where $median = TMath :: Median(30, energyPerLayerArray)$

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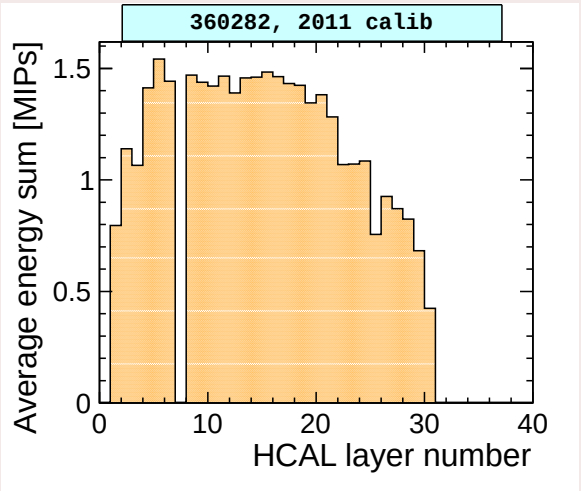
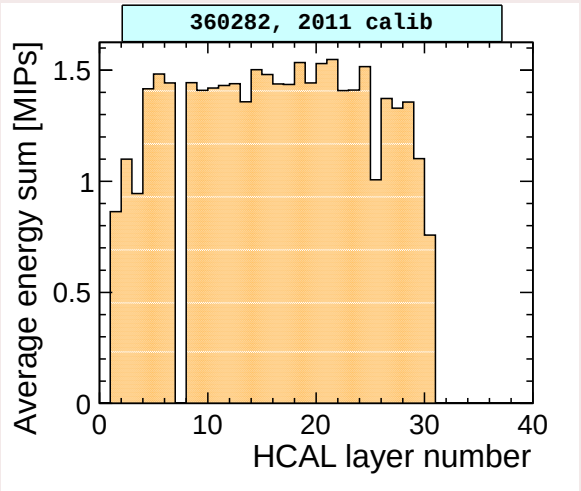
W/O cuts



With cuts

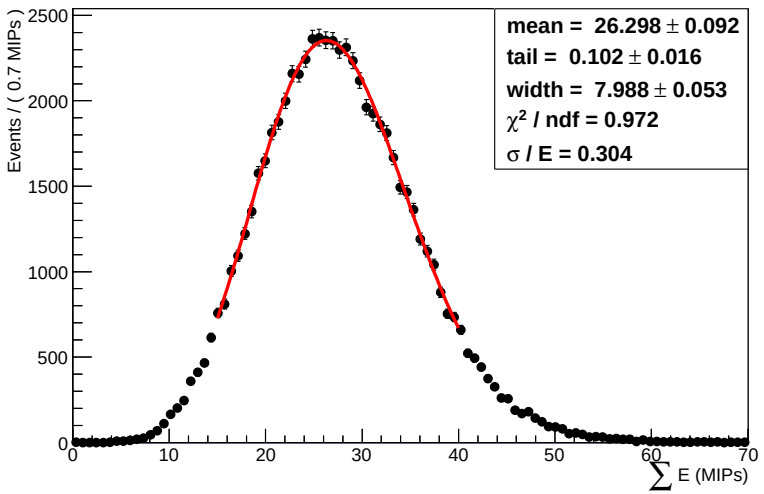


2010 e^+ data: Example fits

- Fit with Novosibirsk function

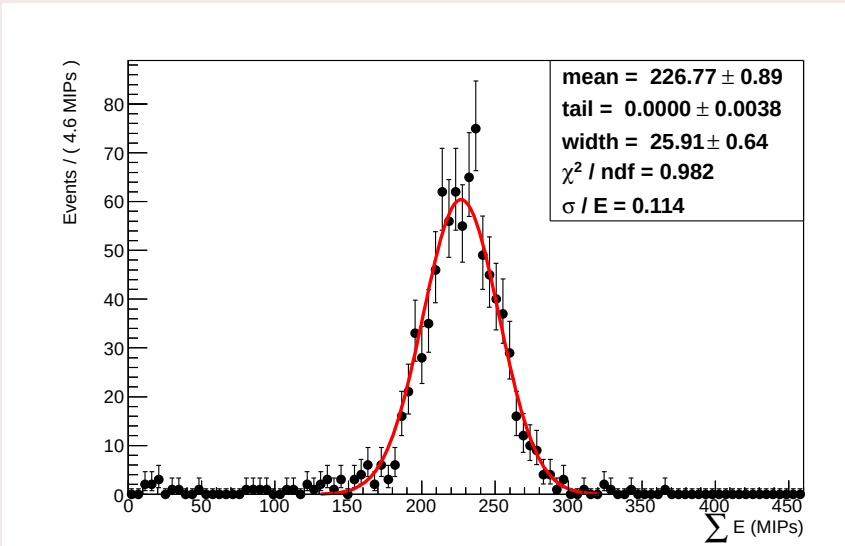
1 GeV e^+

- About 80k events (all available runs) $\Rightarrow$ stable fit



8 GeV e^+

- About 800 events (all available runs)$\Rightarrow$ need to check bias and stability of fit



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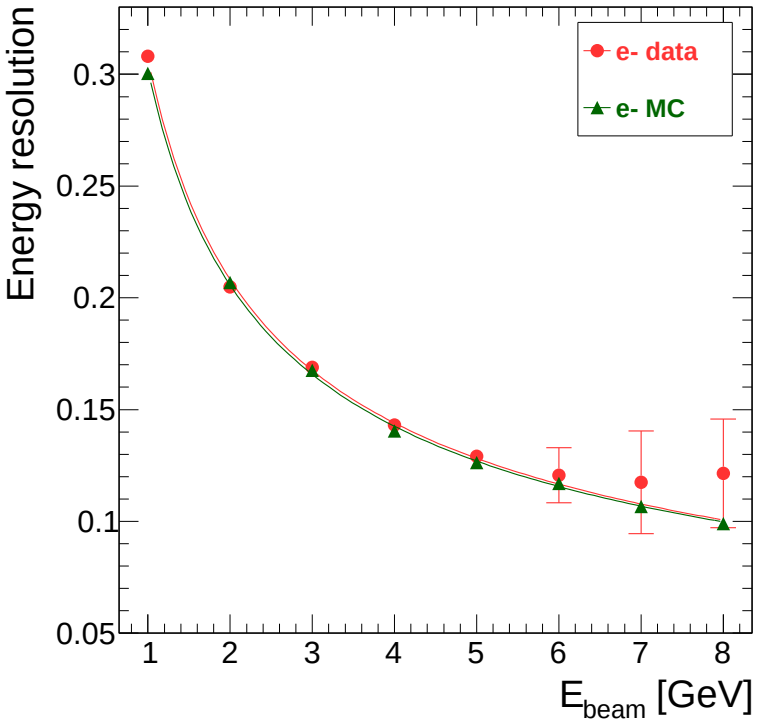
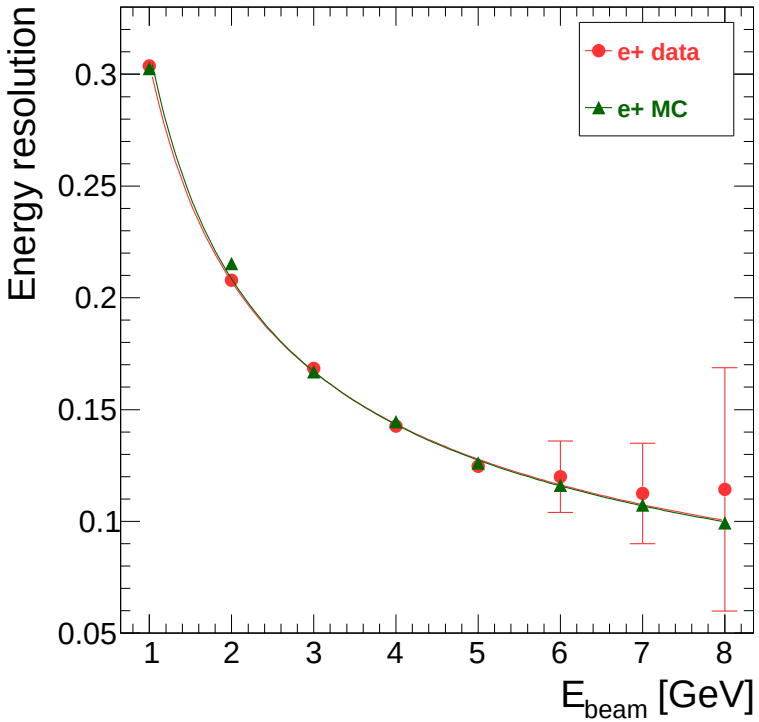
2010 e^+/e^-: Data vs. Monte Carlo





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