SMD HBU performance in 2015 test beam

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Mainz SMD HBU performance in 2015 test beam

Outline:

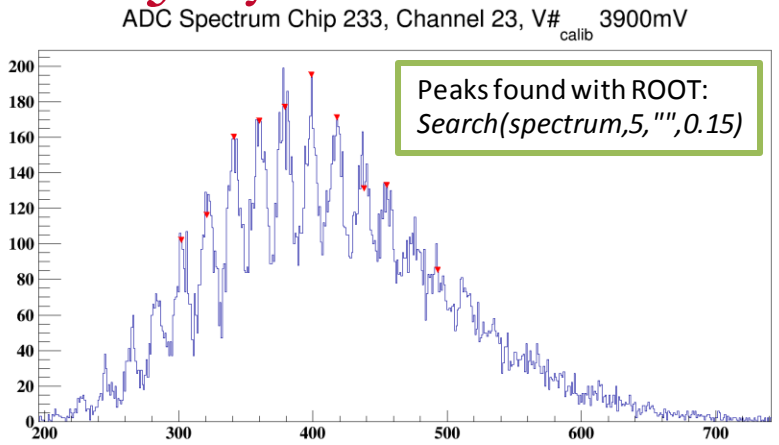
- Gain measurements in July test beam for Mainz SMD HBU
  - Motivation & steps used
  - Results and comparison
- MIP response analysis using July Muon data for Mainz SMD HBU
  - Analysis steps used
  - First preliminary results
  - Comparison and first selections
- Ongoing studies of energy distribution and shower shape
- Conclusion

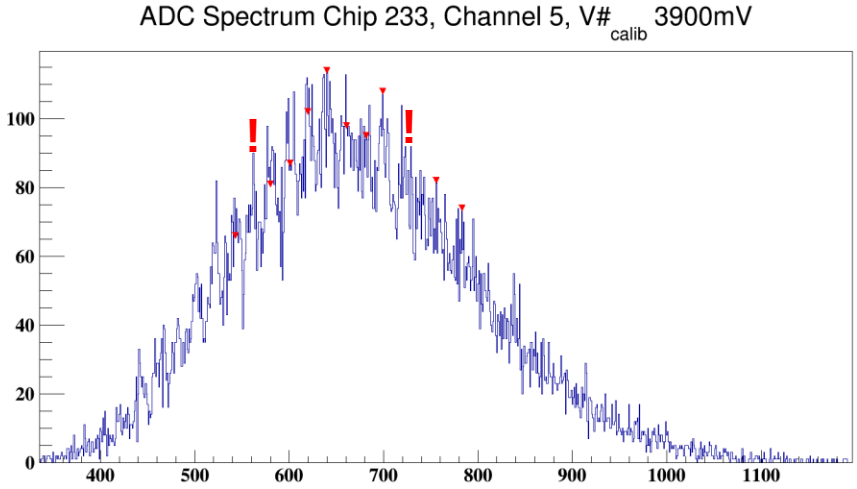
SMD HBU - Gain measurements in July test beam

Motivation

Not all gain measurements look as nice as this one, where:

- The light intensity is small enough
- Peaks are well separated
- Enough peaks are found with the script (red triangle)

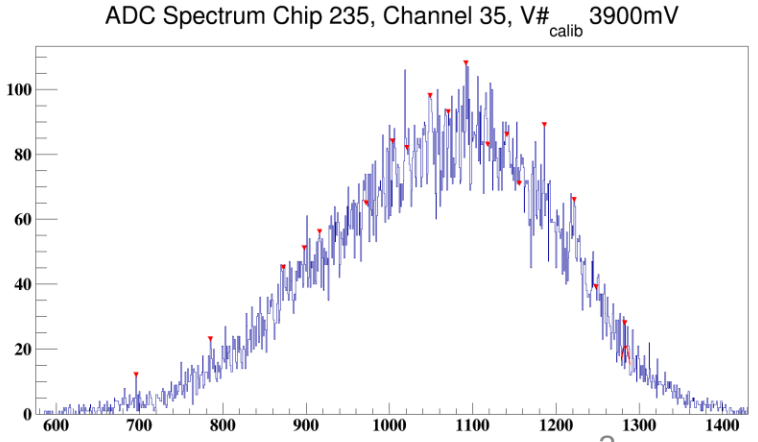




Many of them look like this one, where:

- The light intensity is higher
- Peaks are not well separated
- Some peaks are not found with the script (**!**), which leads to issues when using the standard gain script

And some are even worse..



➢ One reason for too much (or too less) light is, that during test beam, LED data was mostly taken in 100 mV steps.
50 mV steps would help finding ADC spectra with better light intensity.

SMD HBU - Gain measurements in July test beam

Gain analysis steps

- Gain equals the distance of two following peaks in a ADC spectrum.

- Use root Tspectrum Search() function to find peaks in ADC spectrum.
  settings used are very crucial and sensitive, have to be checked:
  "Search(spectrum,5,"",0.15);"

- Check, if distances between two following peaks are in a certain range, two possible methods:

- **Standard method**:
  - If the following condition is true, the gain value is accepted:
    $(diffX[i-1] - 2 * sigmaX[i-1]) < \boldsymbol{diffX}[\boldsymbol{i}] < (diffX[i-1] + 2 * sigmaX[i-1])$
  - Multi Gauss fit to accepted peaks.
  - Advantage: Can be used for every HBU.
  - Disadvantage: If the first gain is bad, a following good one will be rejected, too.

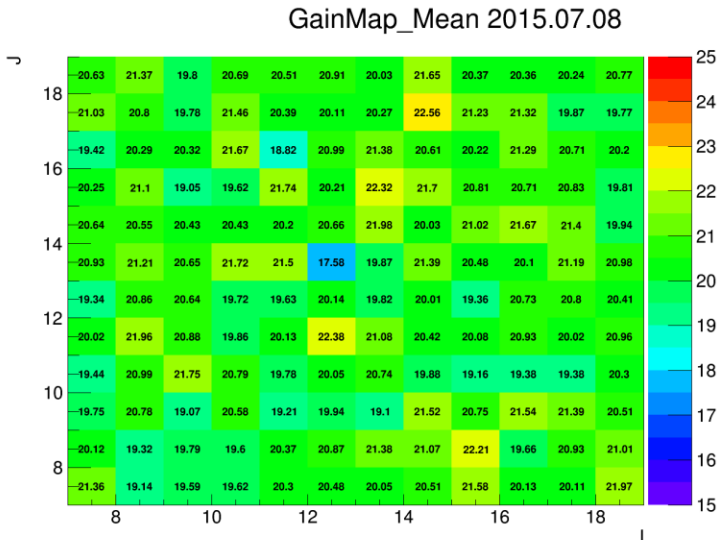
- **New simplified method** (* which can only be used for one specific board, not for all HBUs at once):
  - If the following condition is true, the gain value is accepted:
    $lowestGain < \boldsymbol{diffX}[\boldsymbol{i}] < highestGain$ (values used: 17 | 25).
  - Fit a single Gauss to every found peak.
  - Gain Value: Mean value of all accepted gains.

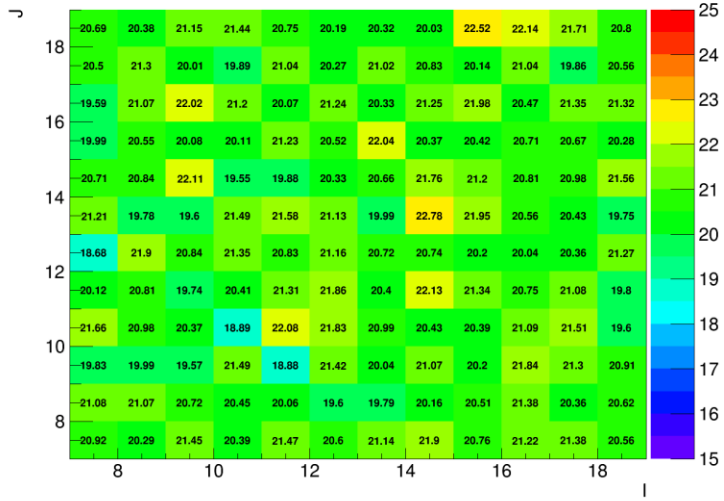
  - Advantage: All "good" gain values are taken into account, which allows to get more statistics for a noisy ADC spectrum.

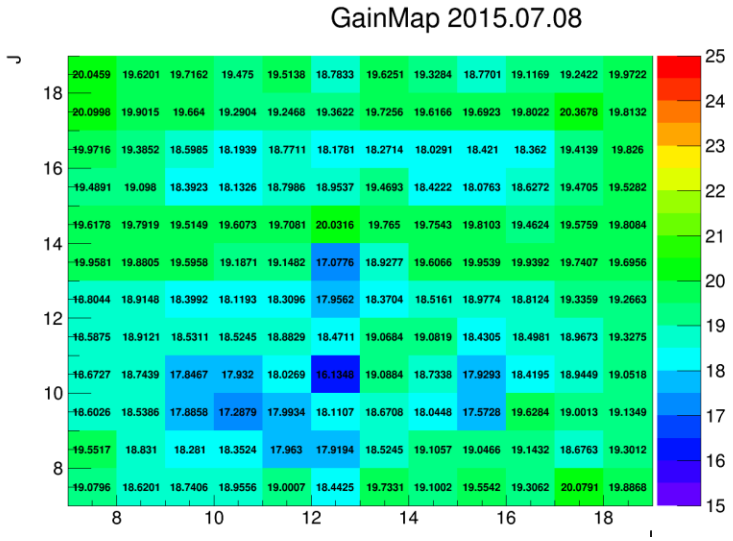
SMD HBU - Gain measurements in July test beam

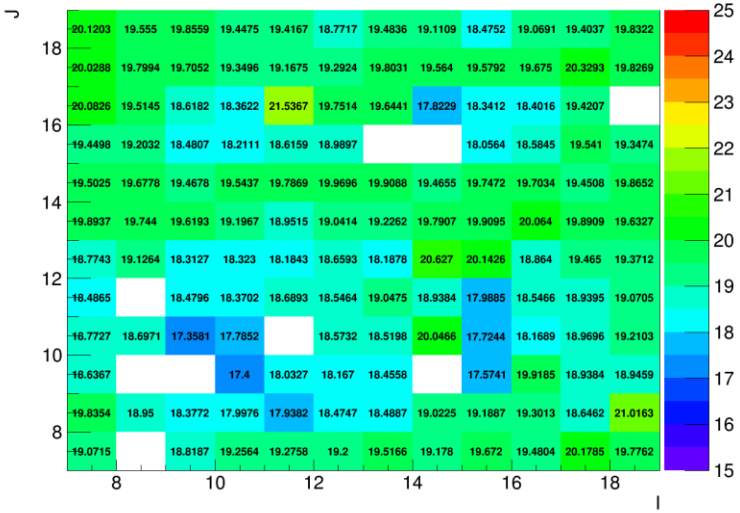
Gain results comparison

New method (left) and standard method (right)









- suggests good gain stability during test beam

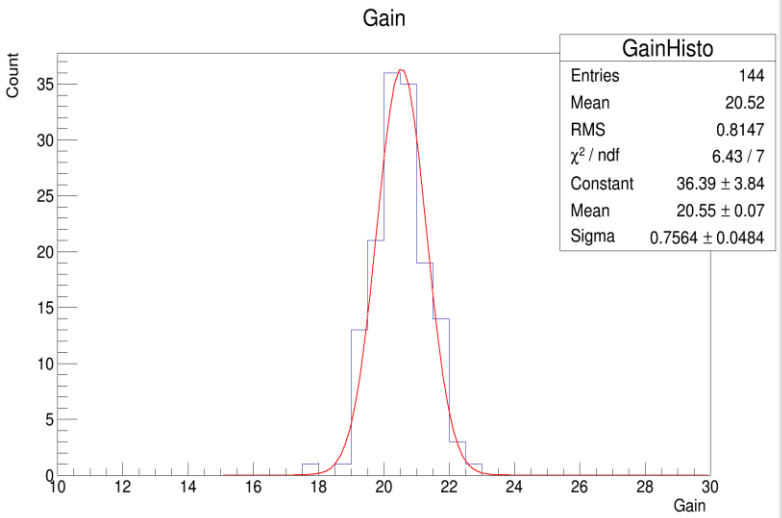
New method:
- Provides higher statistics.
- Allows results, where standard method fails.

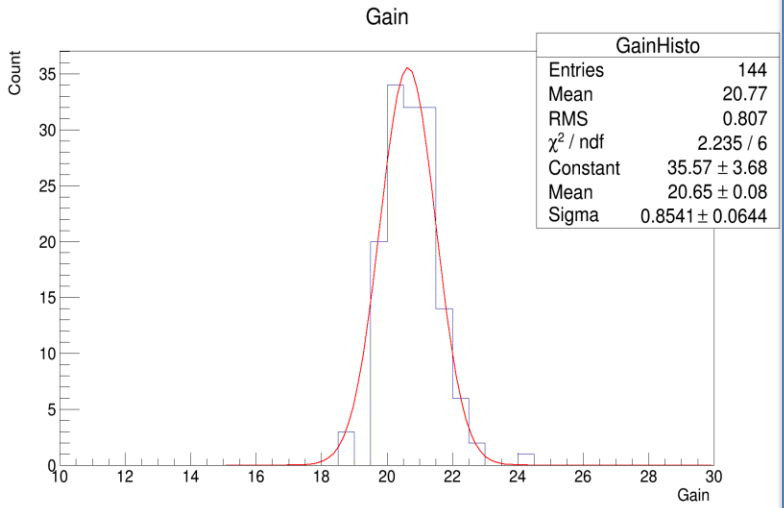
But remember:
This method is only usable for single HBUs, since the expected gain value has to be known. Not recommended for the complete detector gain analysis with different SiPMs and gains.

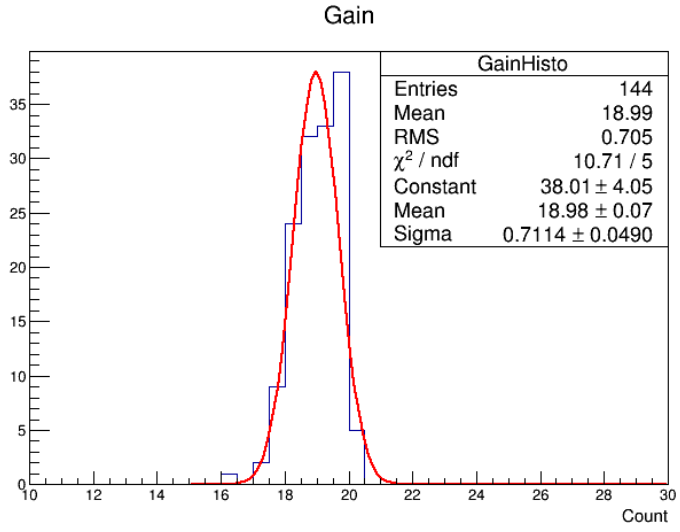
SMD HBU - Gain measurements in July test beam

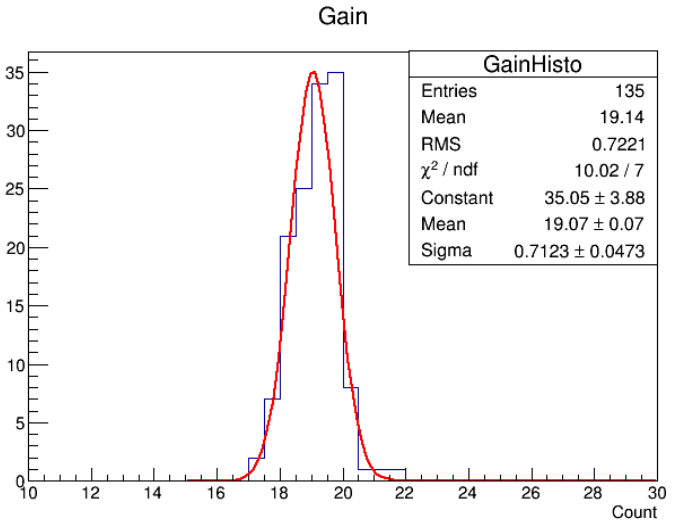
Gain results comparison

New method (left) and standard method (right)









- Sigma≈ 4% good enough?

New method:

- Provides higher statistics.
- Allows results, where standard method fails.
- Is shifted to higher values with respect to std. meth.
- Relative Sigma in both cases ≈ 4%.

Next step:

- Further investigation in temperature dependencies
- Understanding the shift

SMD HBU - MIP Response analysis in July TB using Muon data

MIP response analysis steps

1. Reconstruction from raw data to ROOT data using pedestal subtraction.

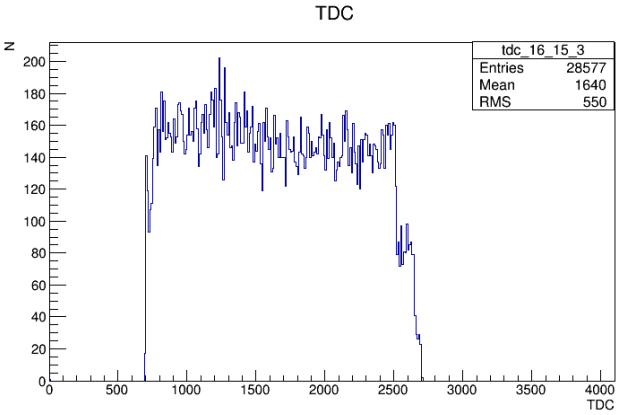
2. Requirement per event:
   - Total number of hits < 200.
   - At least 1 T0 hit.
   - Acceptable TDC value.

Not yet tuned!

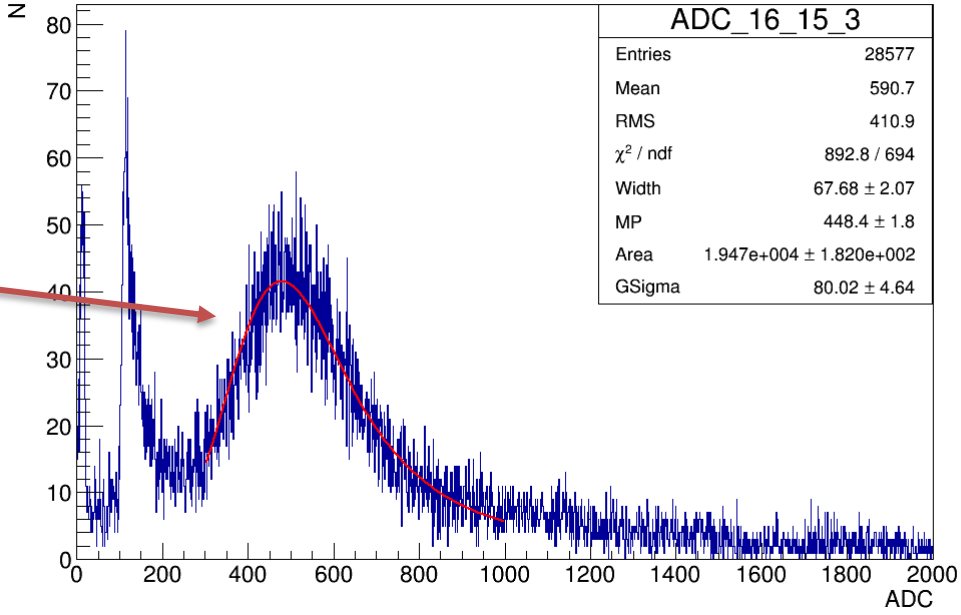
3. For *every* hit in an accepted event:
   - Add energy (ADC) to a histogram for the specific hit position.
   - Therefore, not only real MIP hits but also noise is added.

4. For every histogram/position:
   - Apply Landau-Gaussian fit
   - Convert from ADC to p.e. -> ADC/***gain***
   - At this point, the gain value gets crucial!

5. Plot results.



Example of ADC spectrum in position 16|15 at layer 3

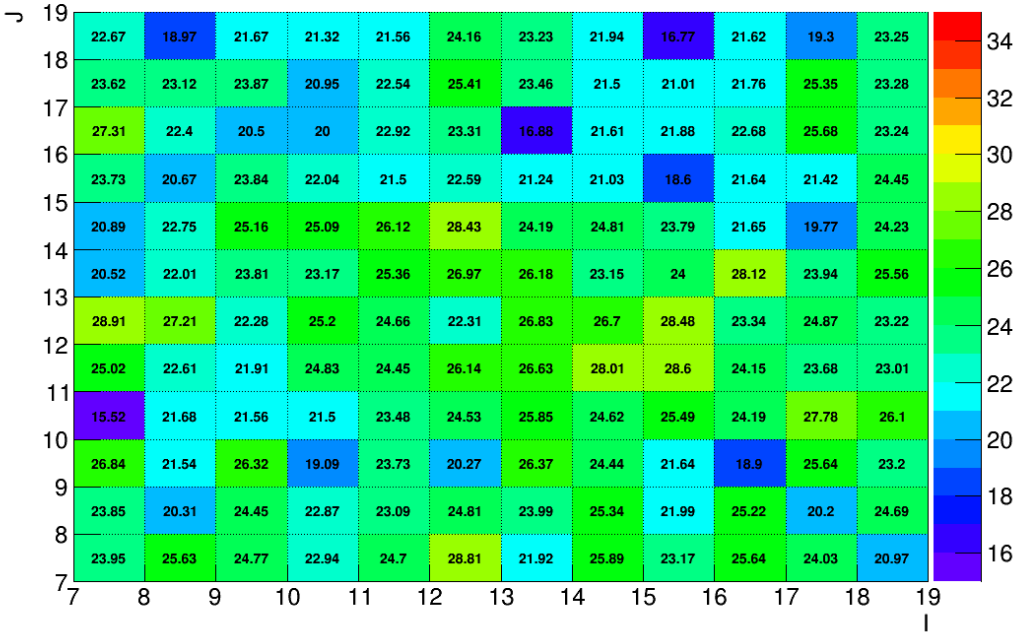


SMD HBU - MIP Response analysis in July TB using Muon data

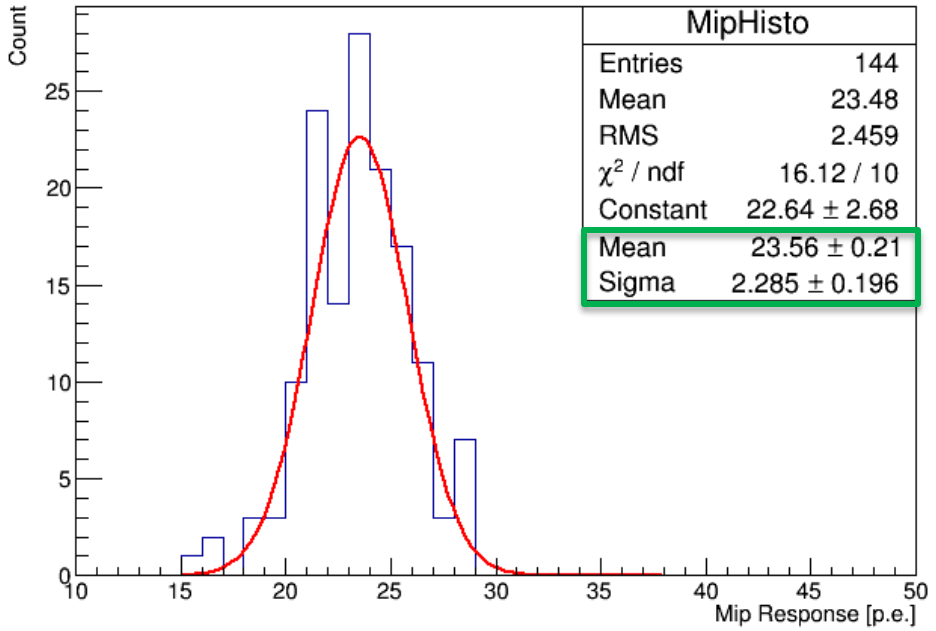
MIP response: First preliminary results

- Gain values from 2015.07.08 (new method) used, since they were taken at the first day of measurement.

MIP-Response (CERN July Testbeam)



MIP response spread

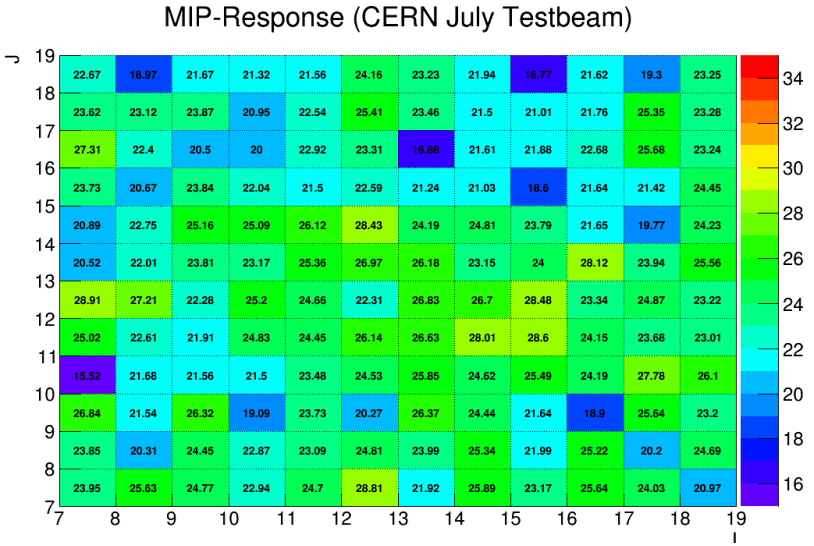


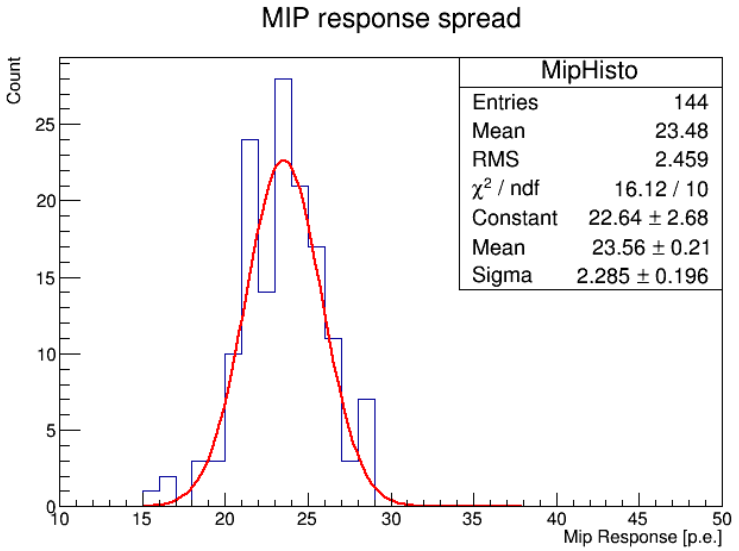
Sigma of ≈ 9.6% sufficient?
Remember:
- Gain ($\sigma \approx 4\%$)
- preliminary result.

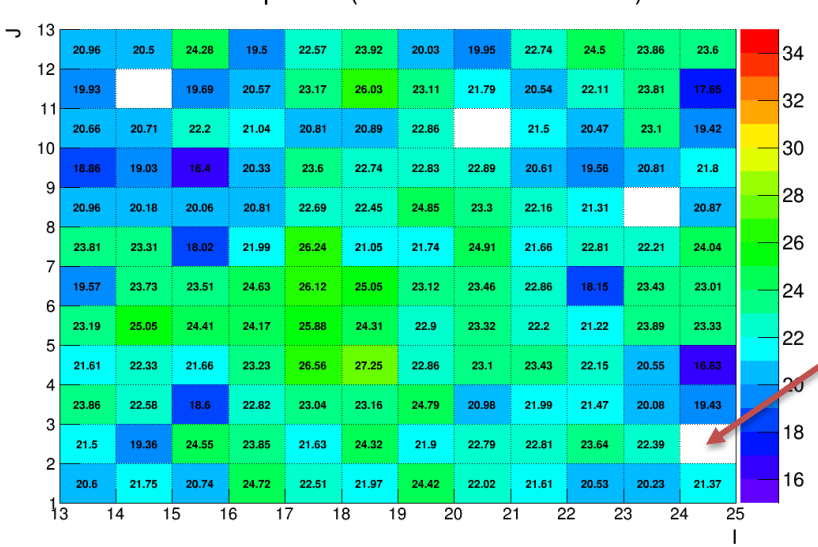
SMD HBU - MIP Response analysis in July TB using Muon data

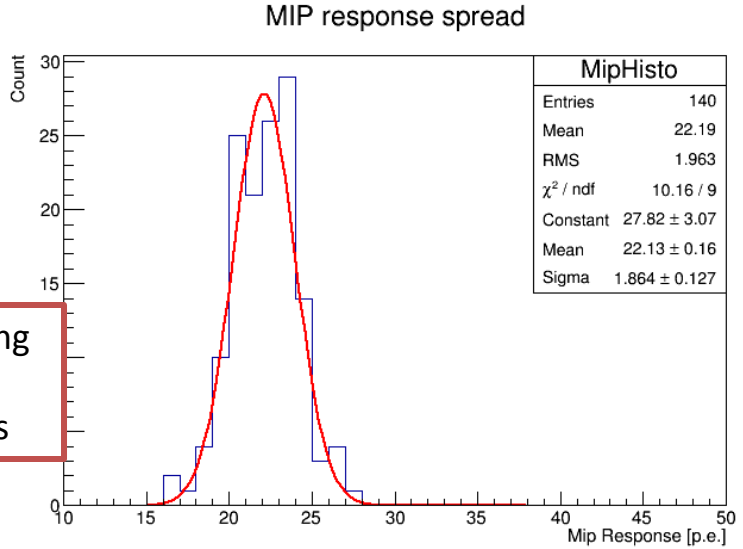
MIP response: First preliminary results and comparison

- Top: July CERN TB
- Bottom: February DESY TB









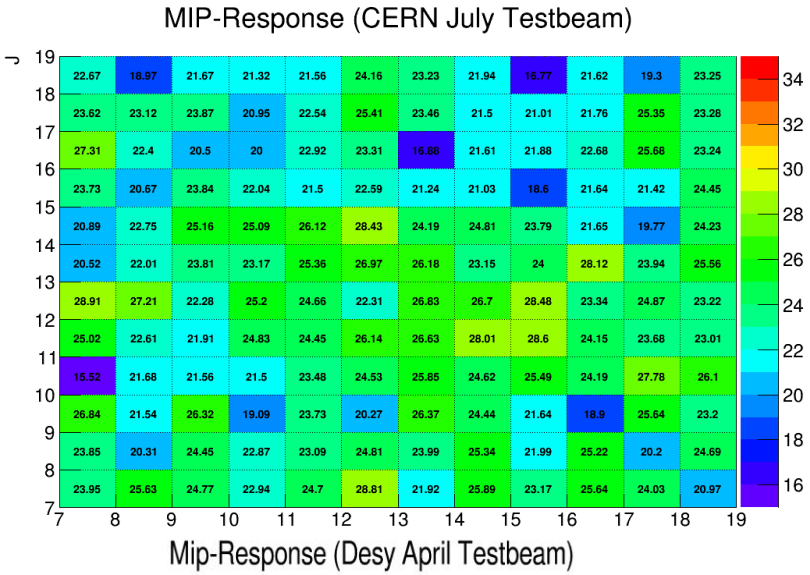
Missing gain values

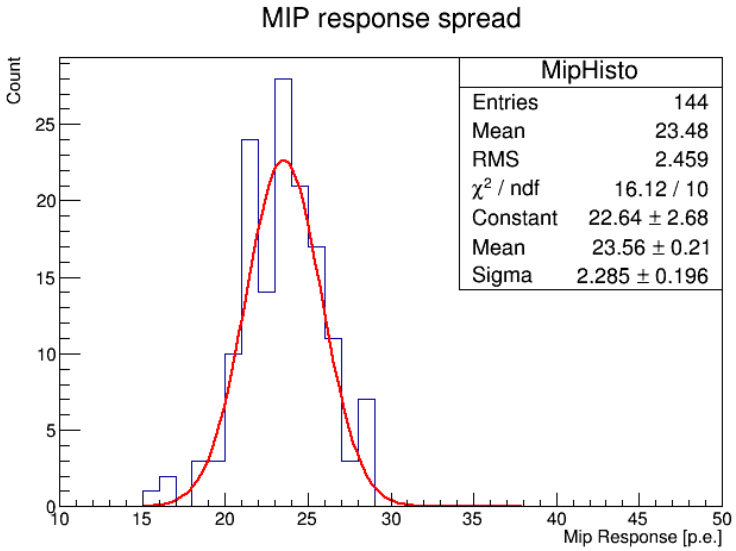
But:
Different bias and preamplifier settings!
Electron beam.

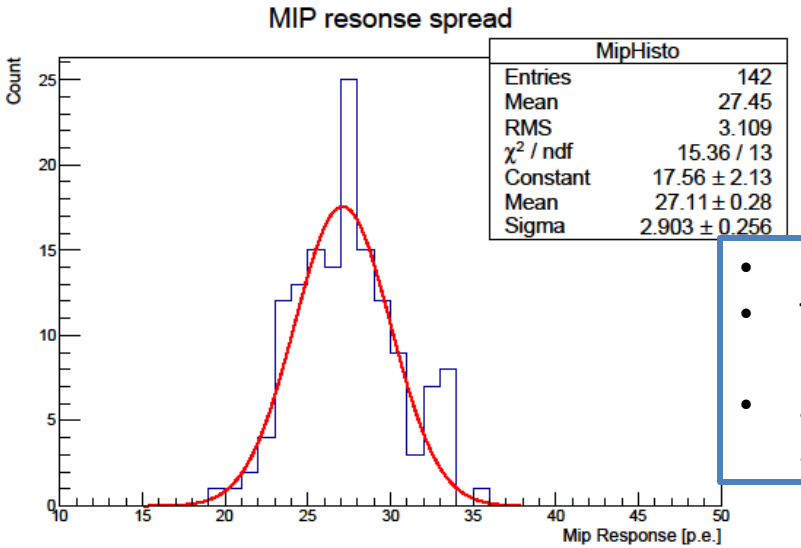
SMD HBU - MIP Response analysis in July TB using Muon data

MIP response: First preliminary results and comparison

- Top: July CERN TB
- Bottom: April DESY TB





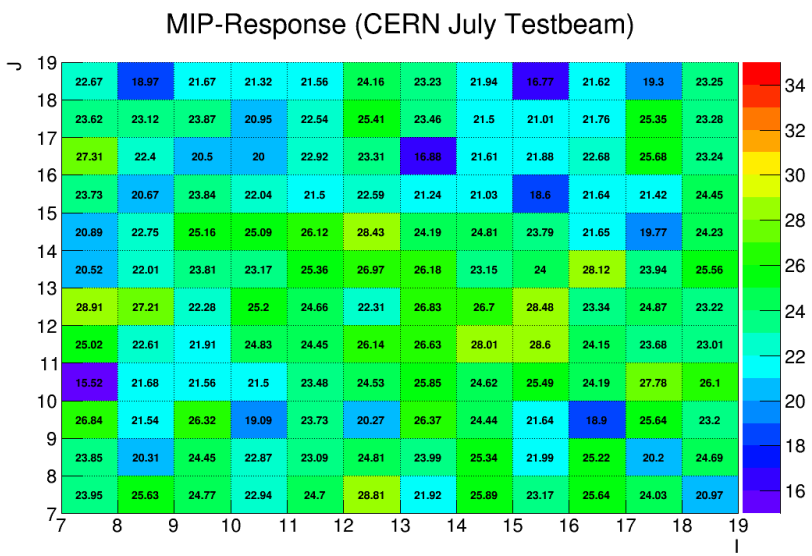


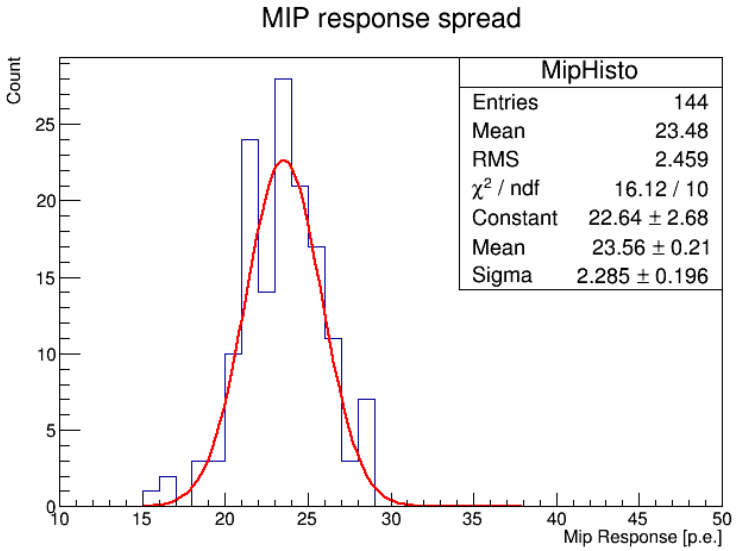
- Electron beam.
- Temperature unclear.
- Suffered from showers.

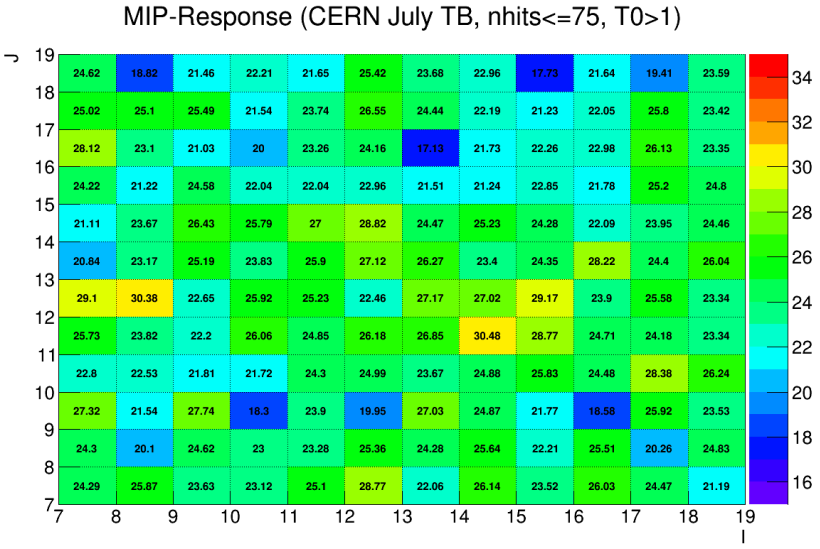
SMD HBU - MIP Response analysis in July TB using Muon data

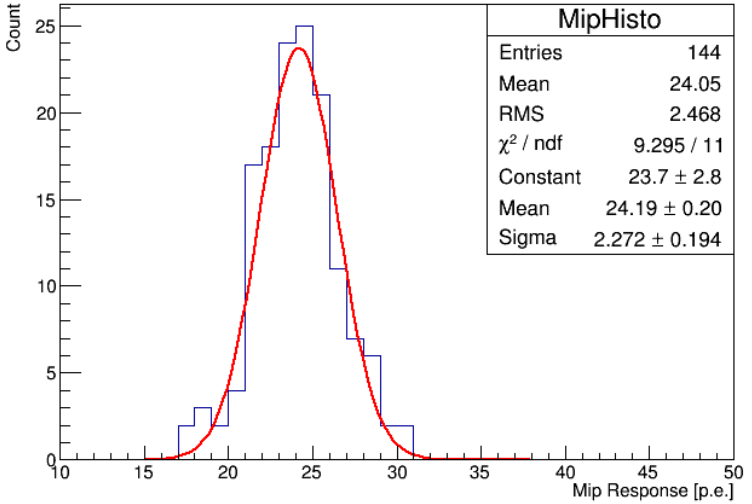
MIP response: First improvements

- Top: July CERN TB
- Bottom: First change: Total number of hits ≤ 75 & at least 2 T0 hits









- Slight increase of mean MIP value as expected.

More selections will follow soon..

Ongoing studies of energy distribution and shower shape

- Reminder: Results from FNAL (2008/2009) and CERN (2007):
  - Good results for linearity tests
  - Algorithm to find first layer of shower is working

- Strategy: making these tests work for new 2015 data from CERN, including:
  - Obtaining the first layer of shower with algorithm based on PrimaryTrackFinder Processor
  - Study of different variables (total energy, layer of maximum energy, first layer of shower,…) to understand and classify events

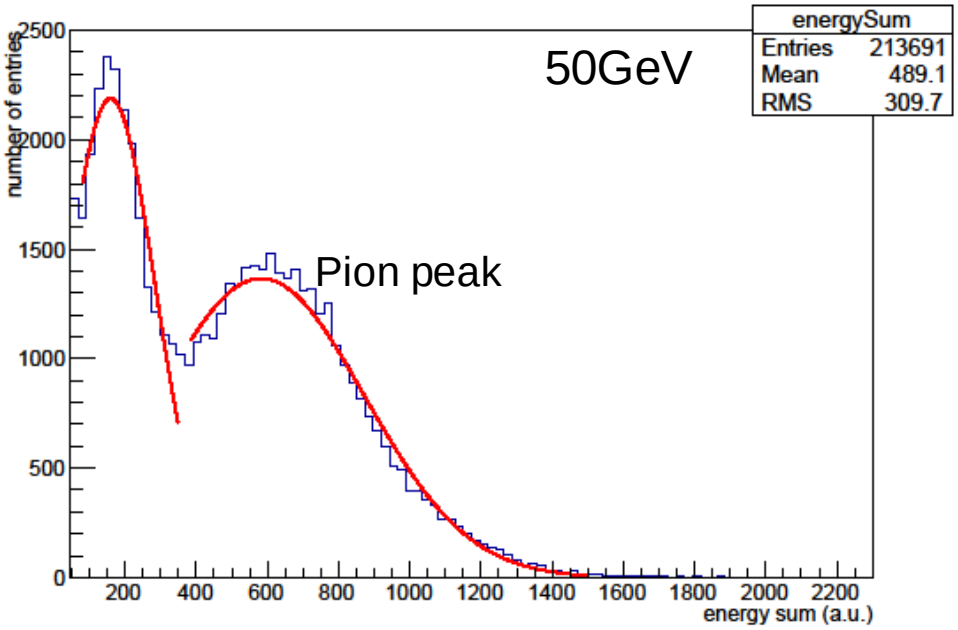
- Now:
  - Able to process the 2015 data.
    - technical difficulties with reconstruction software solved.
  - First result of linearity test.

- Future plans:
  - Results for remaining variables.

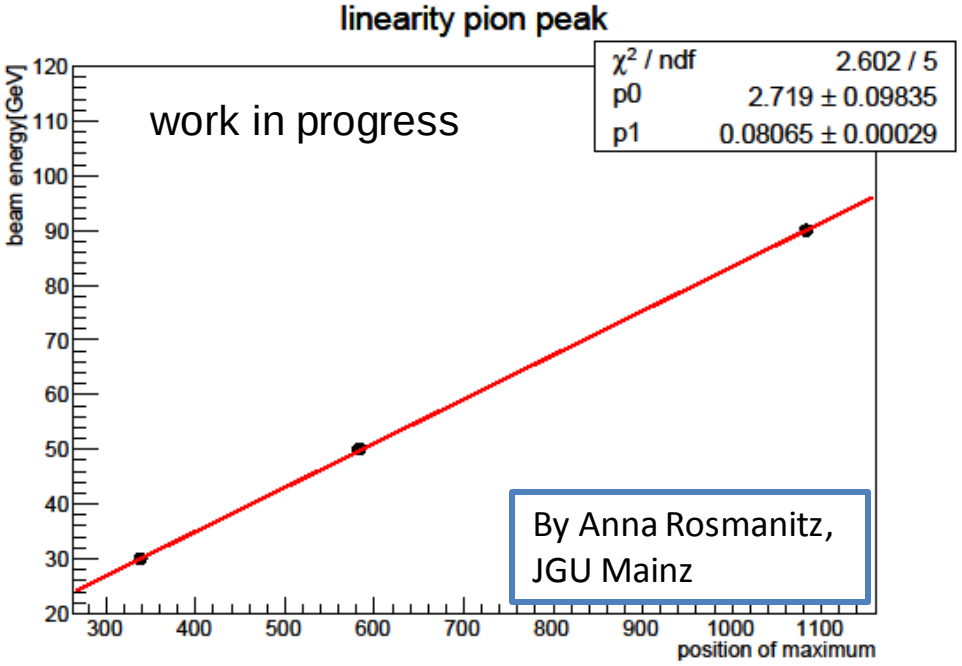
Ongoing studies of energy distribution and shower shape

First results for total energy:

Perform fits on total energy to select pion showers.



Linearity of the energy with respect to beam energy.



Mainz SMD HBU performance in 2015 test beam

Conclusion:

- Performed new gain analysis.
  - More statistics since more good gain values are accepted.
  - Allows to obtain gain values, where standard script fails.
  - Next step:
    - Check temperature dependencies.
    - Understand shift between both methods.

- Started MIP response analysis for July Muon Runs.
  - Promising results, work in progress.
  - Next steps:
    - Limitation of number of hits per event, to reject showers, multiple MIPs etc.
    - Increase number of needed T0 hits.
    - Add track finder (minimum number of hits in same XY-position).

- First results of energy linearity tests with Pion data.

Thank you!

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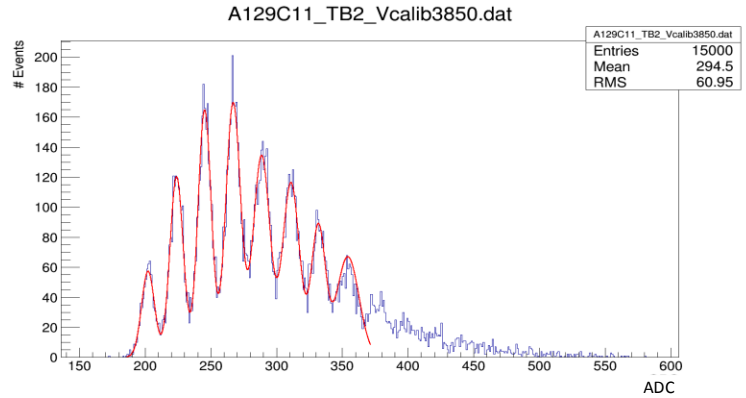
JG|U

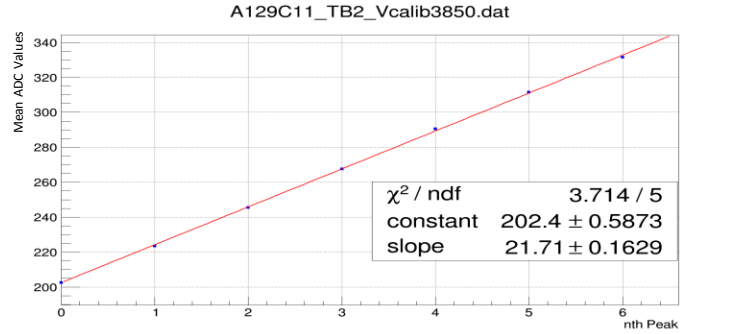
Backup

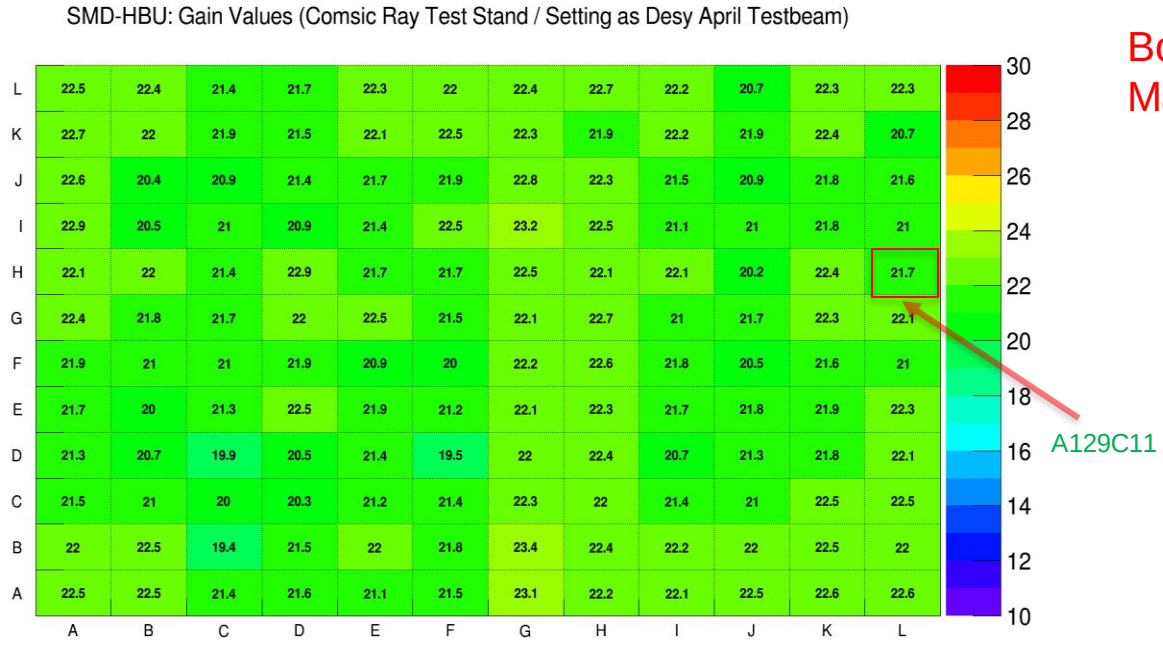
Obtaining Gain Values (Example: A129C11)

Procedure:

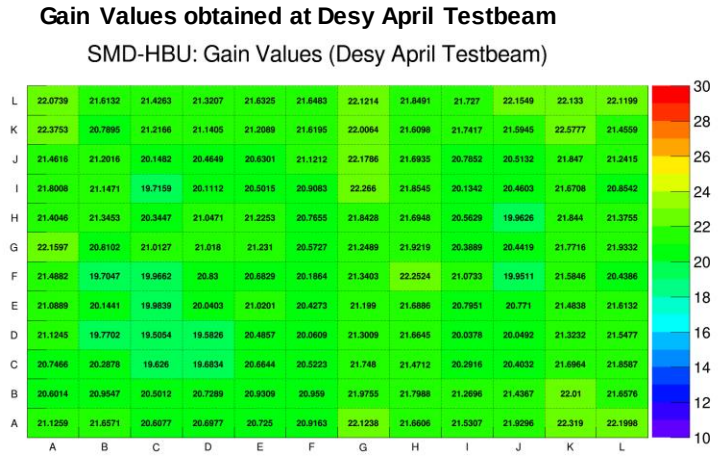
- Plot Single Photon Spectrum (SPS)
- Find peaks in spectrum and get distance between neighboring peaks. (ROOT Peakfinder)
- As long as Peak to Peak distance is within a certain range → Store Peak position
- Apply linear fit to stored Peak positions → Obtain Gain.
- Additional: Use information from ROOT Peakfinder to fit a sum of Gaussian Distributions to the spectrum.



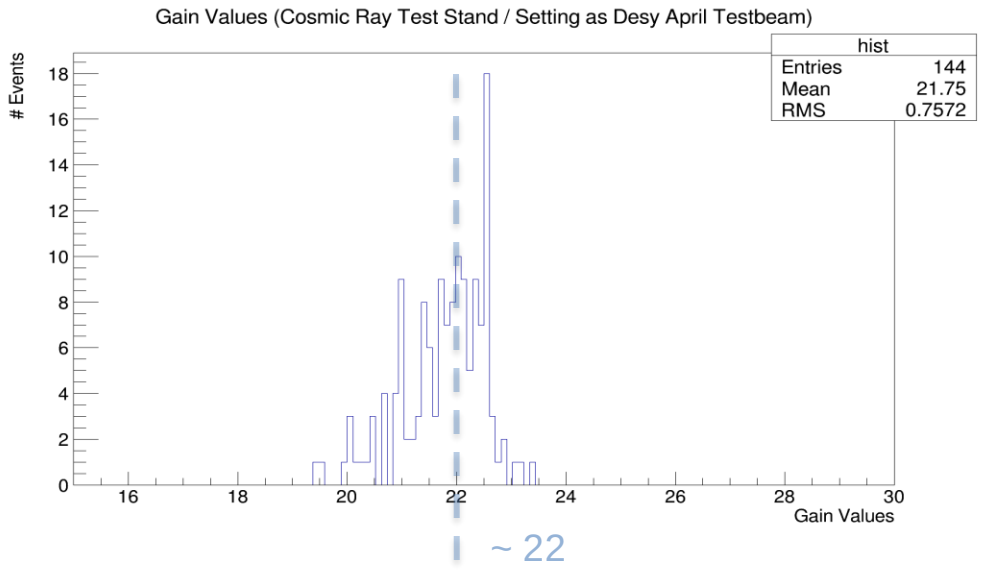




Both maps verify good uniformity of Mainz SMD-HBU



Compare Gain Values obtained at Cosmic Ray Test Stand & Desy April Testbeam



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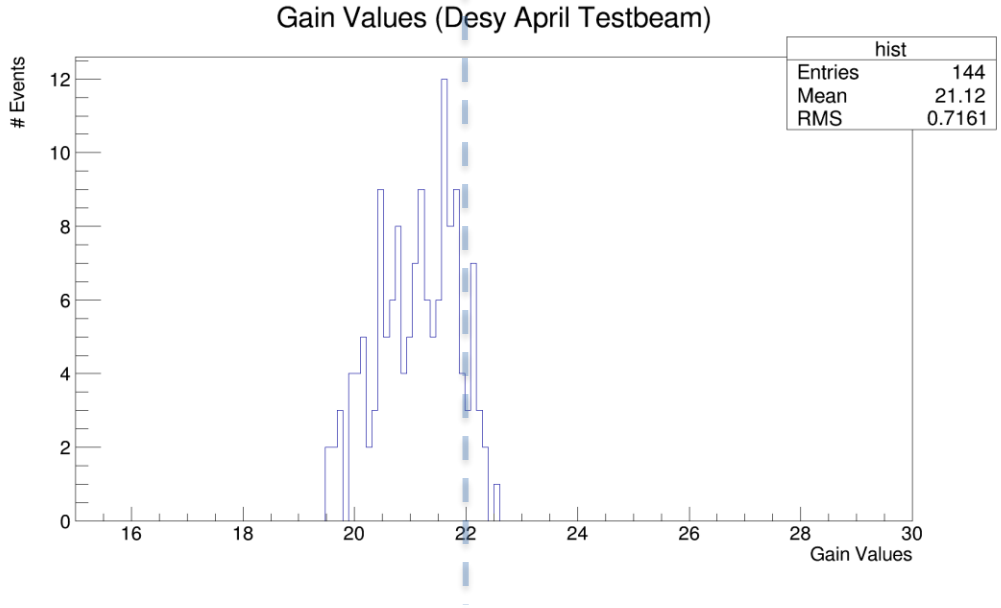


Gain Values obtained in Mainz are slightly higher than the ones obtained in the Desy April Testbeam.

A possible cause for this difference might be the different temperature present in the Cosmic Ray Test Stand and the Desy April Testbeam.

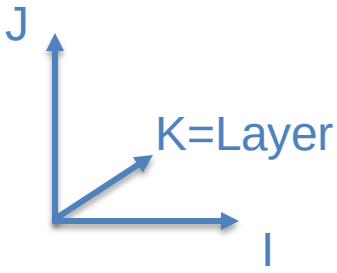
Cosmic Ray Test Stand

Sensor	Average Temp. [°C]
T1	26.95
T2	26.02
T3	25.48
T4	25.17
T5	25.30
T6	25.12

Temperature difference between Cosmic Ray Test Stand and Desy April Testbeam possible

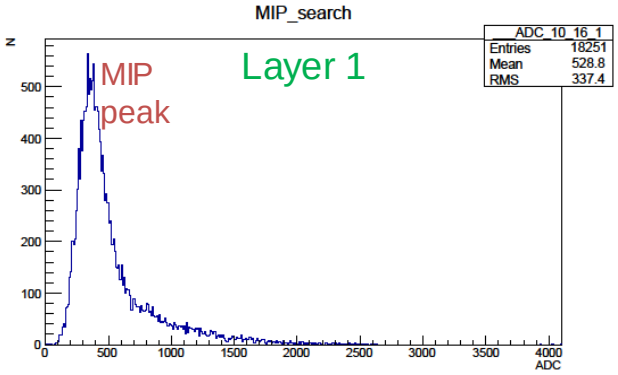
Measurement at DESY April Testbeam (Airstack)

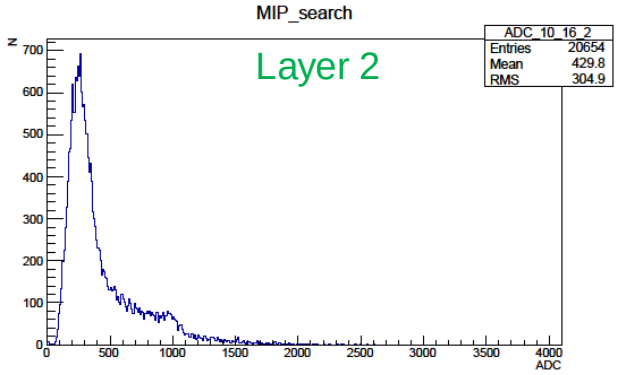
MIP response analysis steps

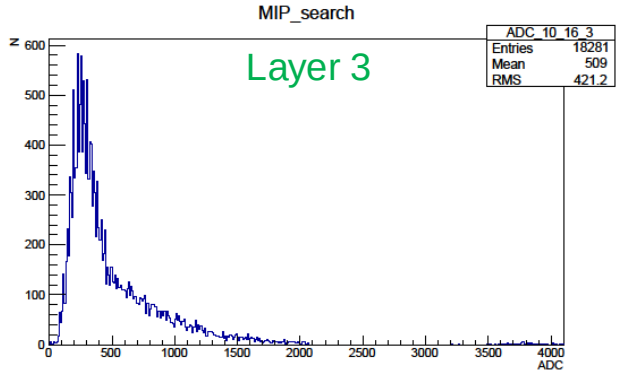


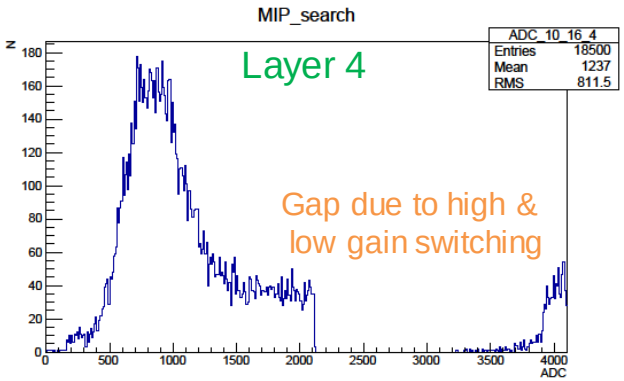
1. Reconstruction from raw data into ROOT data using pedestal subtraction
2. Find channel number of Beam Position (maximum energy deposited in one Run)
3. Add all energies in all cycles to histograms, where IJ(K) position = IJ of Beam
4. Convert from ADC to p.e. -> ADC/gain
5. Applying selections
6. Landau-Gaussian fit

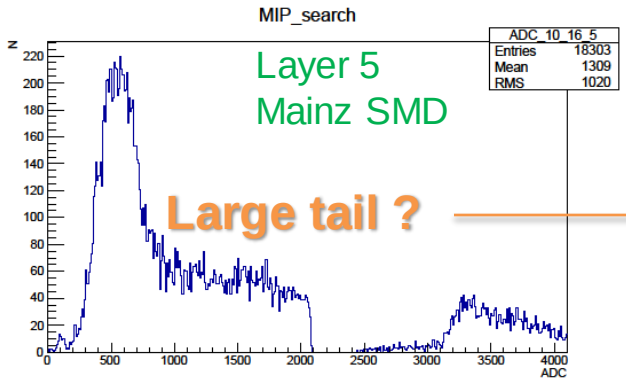
How it looks like after step 3:







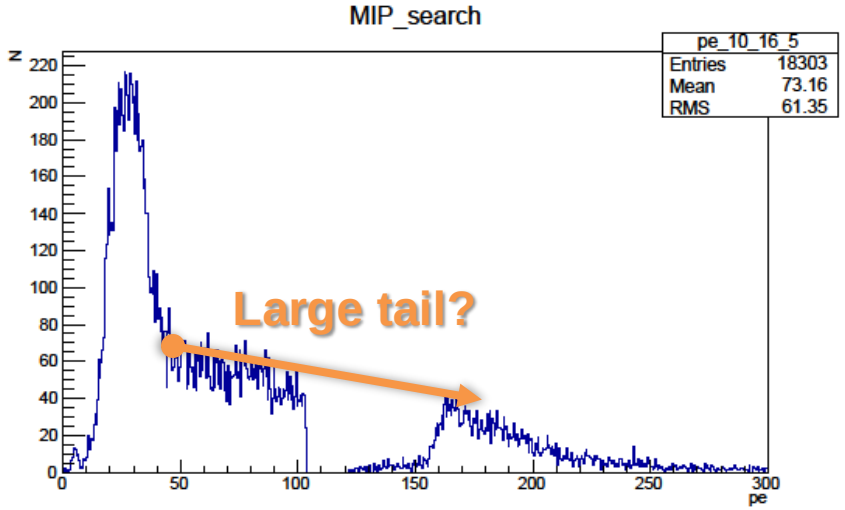




- DAQ
- Shower
- Multiple MIPs
- …?

Measurement at DESY Testbeam (April)

Applying Selections



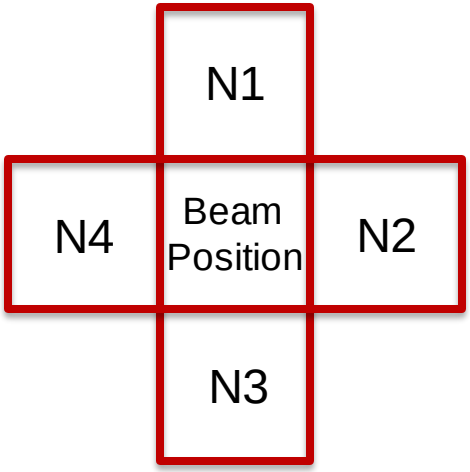
Large tail

Many entries for higher Energies than MIP-Energy in late layers (4 & 5), maybe due to shower production?

Need for explanation and correction/selection

First Step: Checking Neighbors

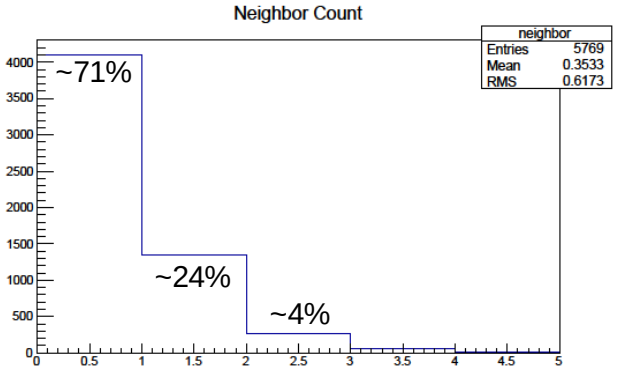
Neighbor definition:



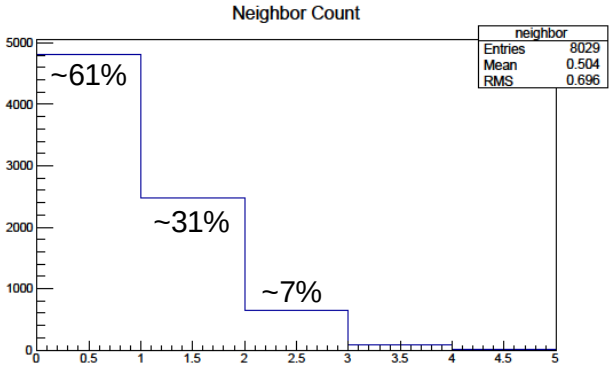
Measurement at DESY Testbeam (April)

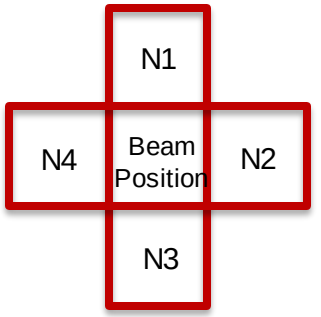
Checking Neighbors

Within MIP Peak: **20pe < E < 40pe**

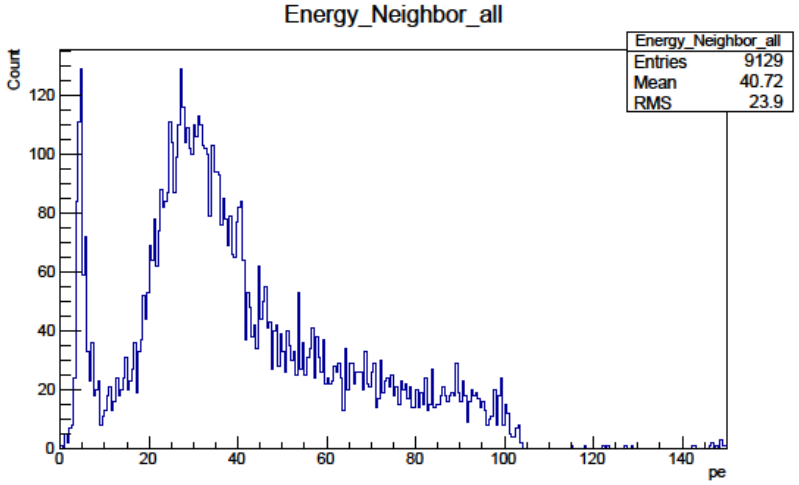


Higher than MIP: **40pe < E < 200pe**



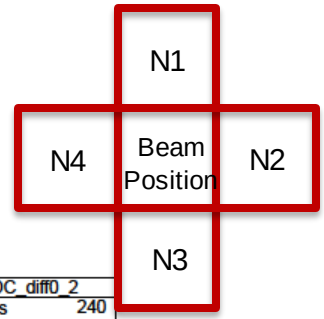


All neighbor energy hits, if there was a hit at beam position:



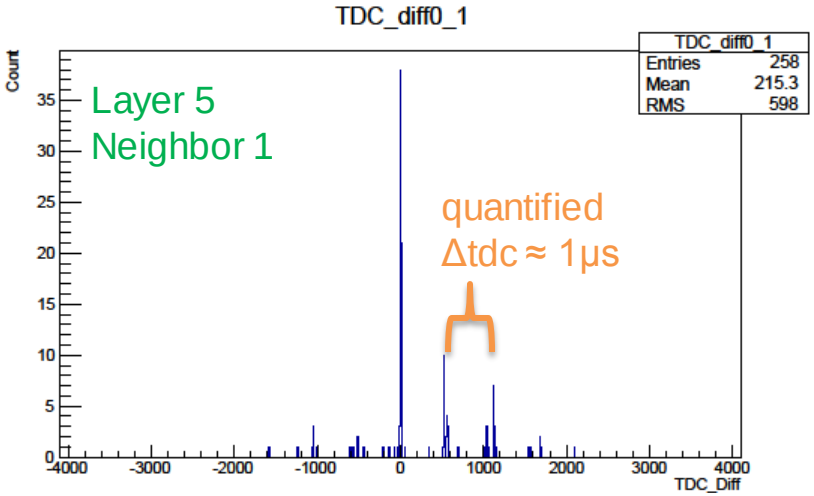
- Looks like there are events with more than one MIP
- **Next step: Check TDC differences**

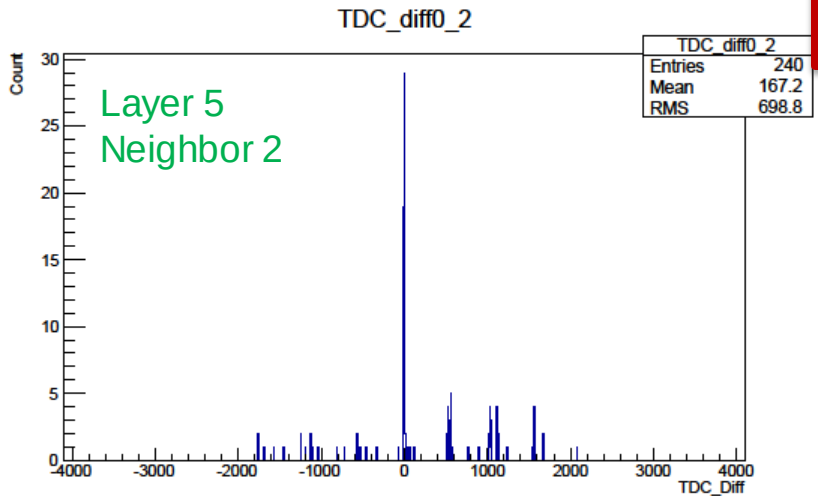
Measurement at DESY Testbeam (April)

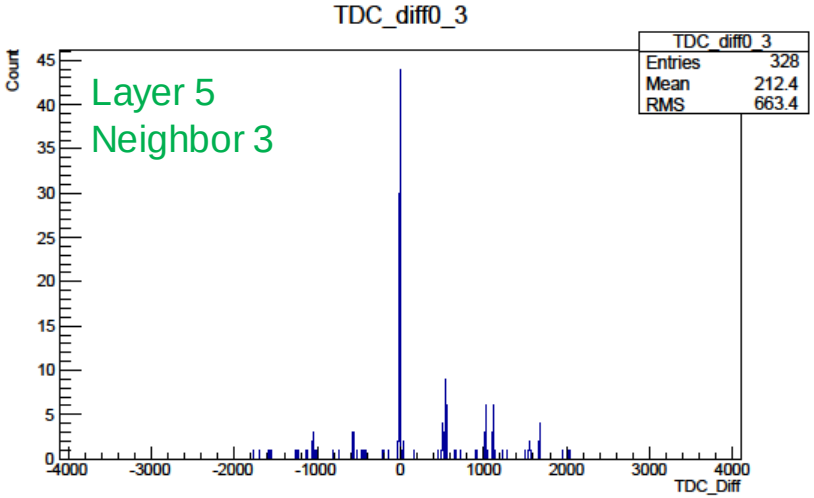


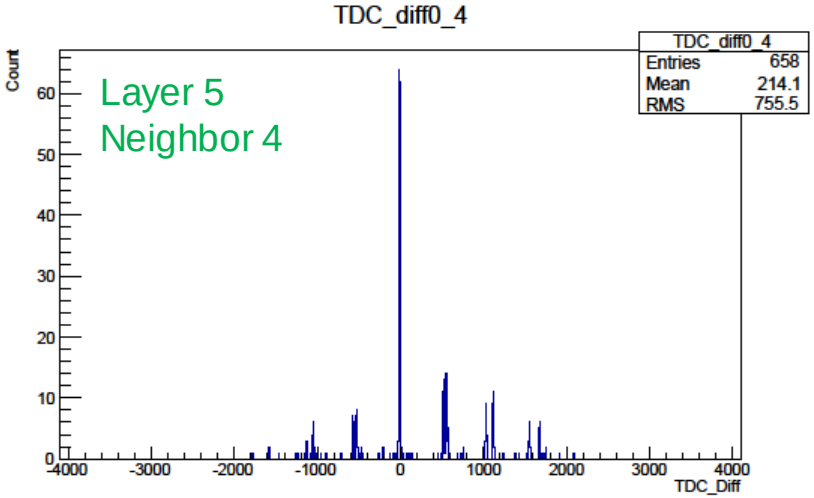
Checking Neighbors:

TDC Difference (tdc_n - tdc_mip) for neighbor n=1 to 4









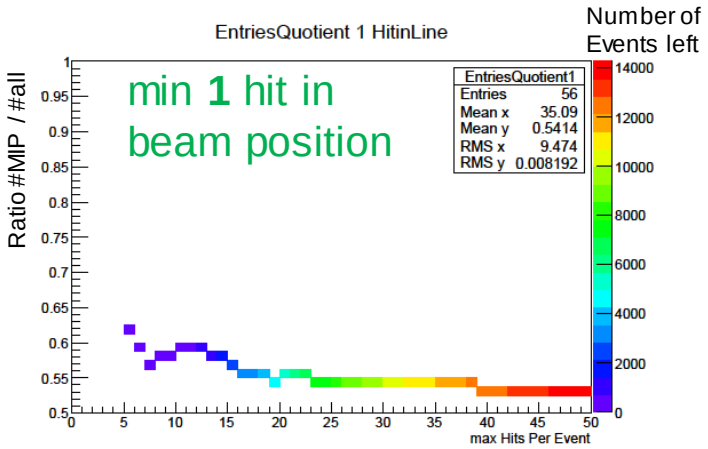
The time difference Δtdc equals the DESY II revolution frequency of 1 MHz

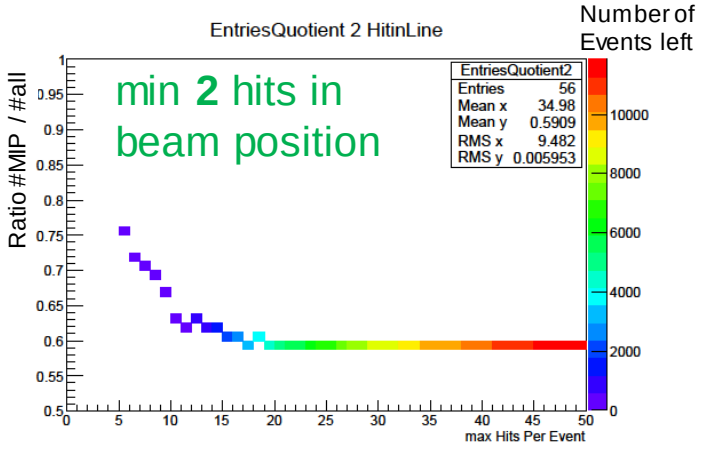
- Sometimes more than one electron is shot at the detector within the open time window

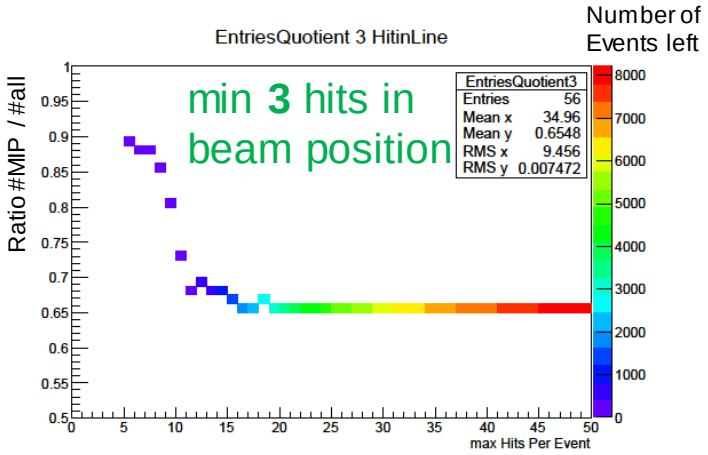
Measurement at DESY Testbeam (April)

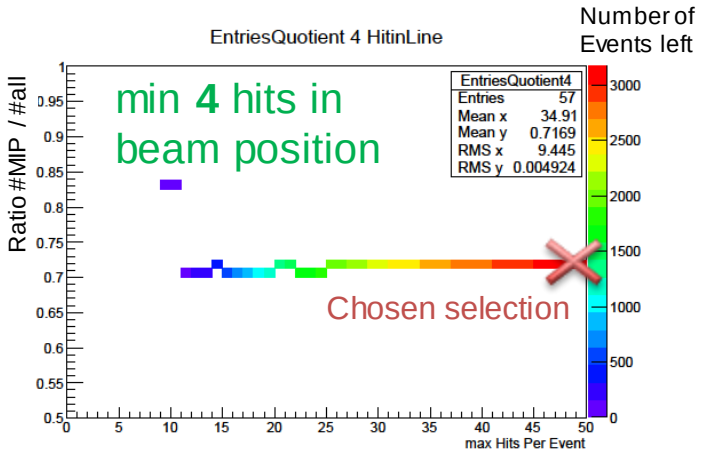
Selections to reduce shower / multiple events

- Track finder in all layers: min 1 .. 4 hits in line in beam position
- Reducing maximum allowed number of hits per event









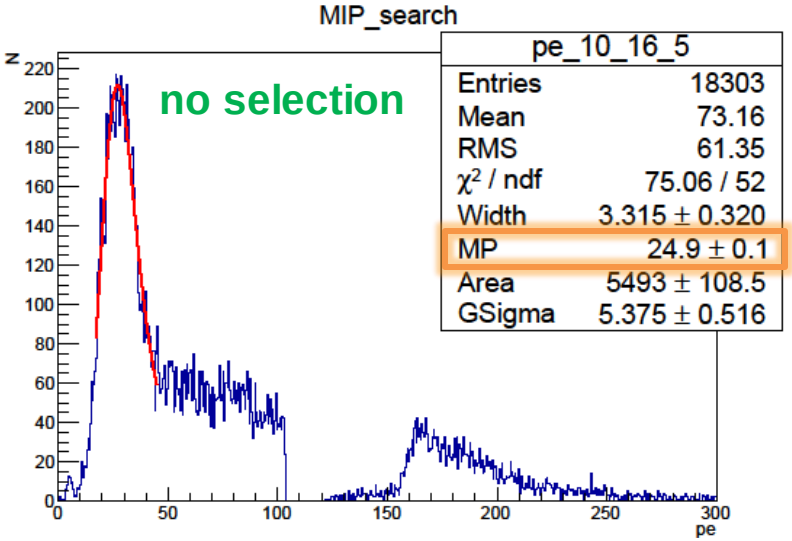
Results:

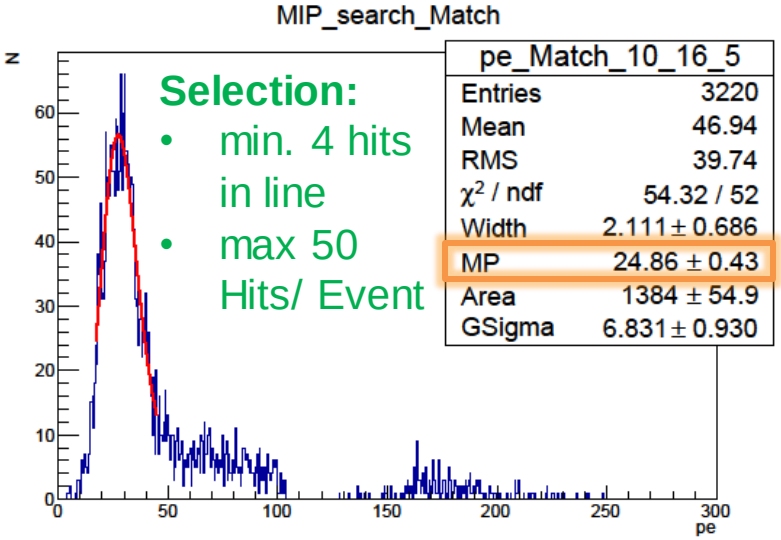
- **Without** selections, ratio between #MIP/#all is **≈ 48%**
- Including selections, the ratio can be increased up to 90% while statistics decrease
- Chosen selection:
  - min. 4 hits in line
  - ~71% #Mip/#all
  - acceptable statistics

Measurement at DESY Testbeam (April)

Selections to reduce shower / multiple events

- Track finder in all layers: min 1 .. 4 hits in line in beam position
- Reducing maximum allowed number of hits per event





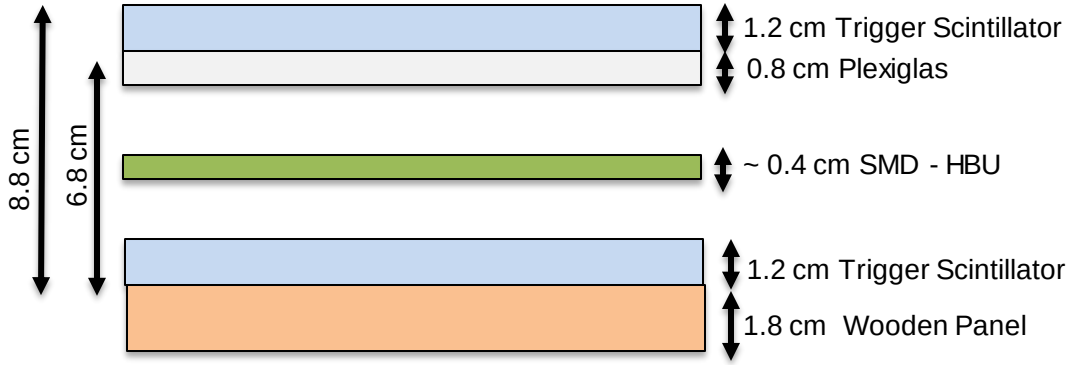
Results:

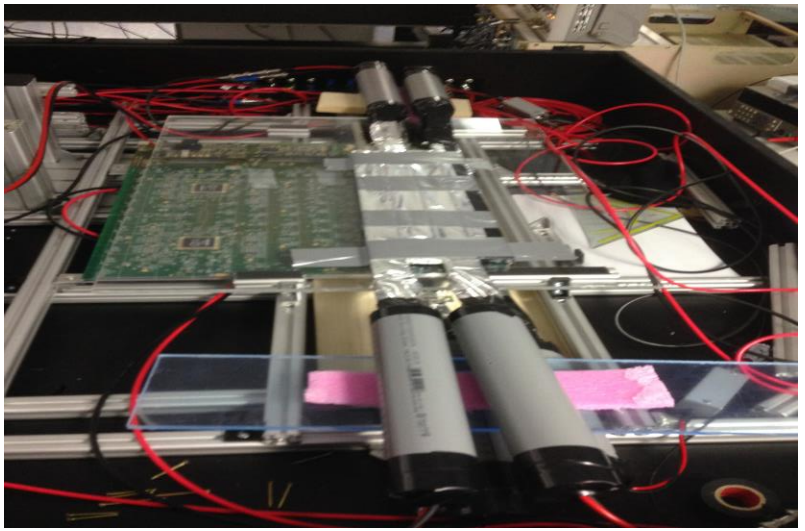
- Long tail can be significantly reduced by applying event selections
- Hint for shower generation

- Nearly no effect on most probable value of Landau-Gaussian (≈ MIP Response)

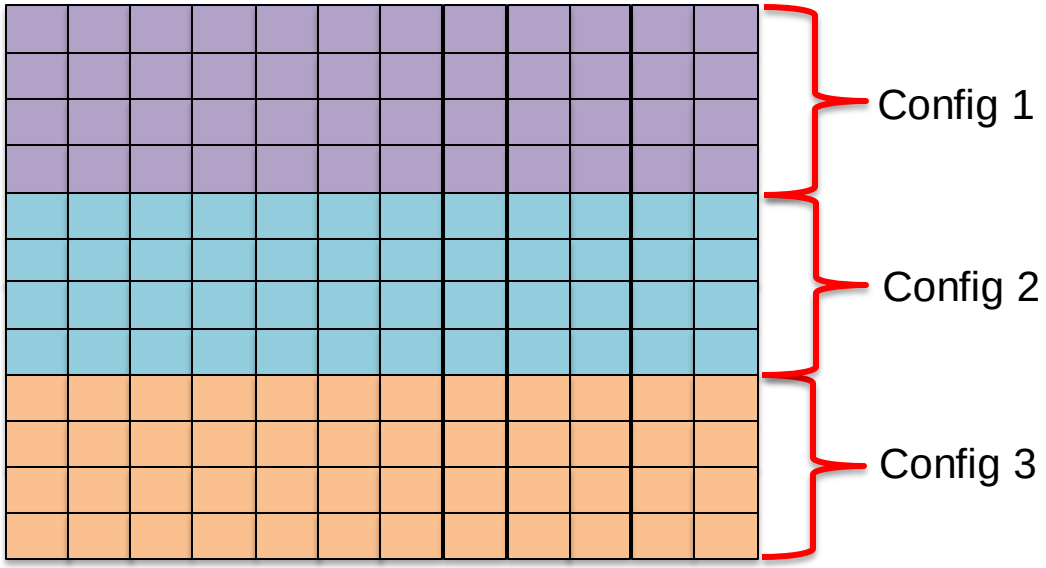
Measurement in Cosmic Ray Teststand

Experimental Setup:





SMD - HBU

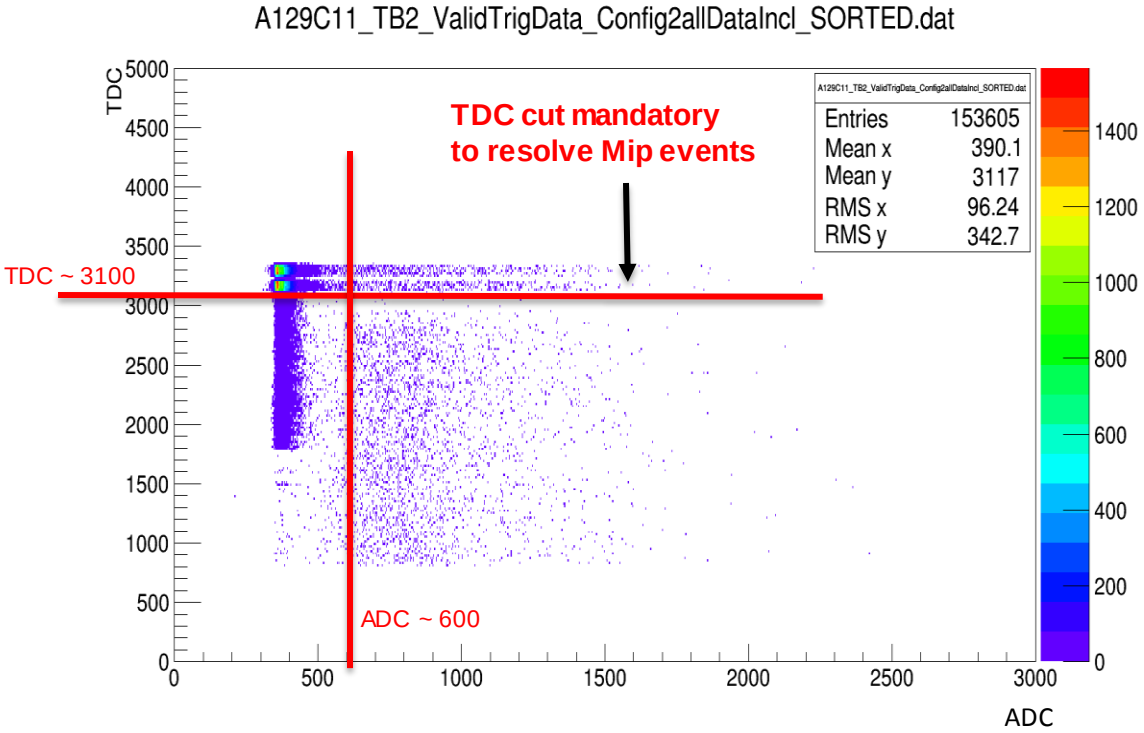


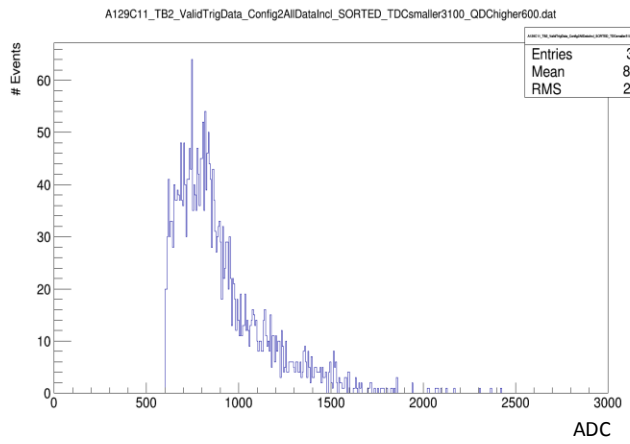
- For the measurement 4 trigger scintillator strips were used on top as well as on the bottom.
- 3 different configuration were needed to cover the whole SMD-HBU.
- Several data acquisition runs were performed for each configuration. Information was combined later on. In total we measured:

  Config 1 → 1.625.000 Cycles
  Config 2 → 1.310.000 Cycles
  Config 3 → 1.595.000 Cycles

Measurement in Cosmic Ray Teststand

Config 2 (A129C11 triggered)



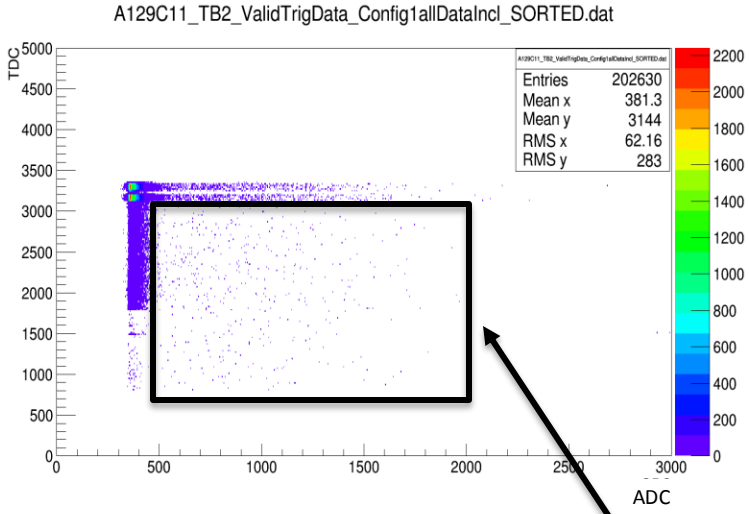


Histogram for channel **A129C11** with:

TDC < 3100
ADC > 600

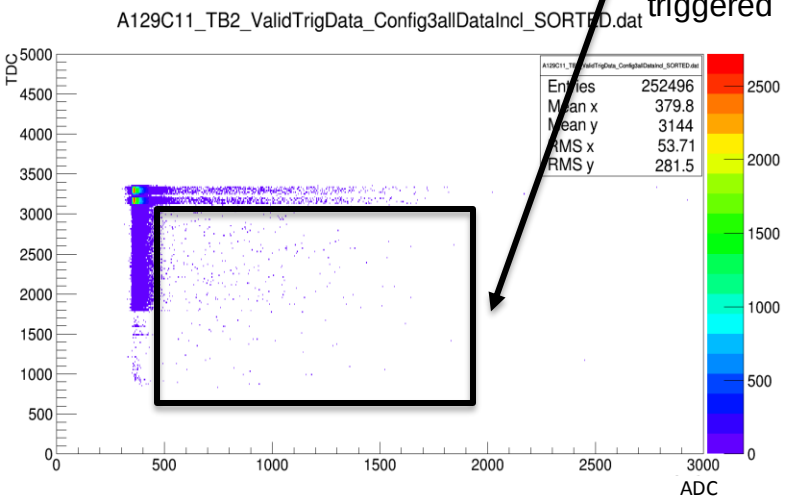
Note:
requiring ADC > 600 is enough to separate Mip-events from DCR events for **all channels.**

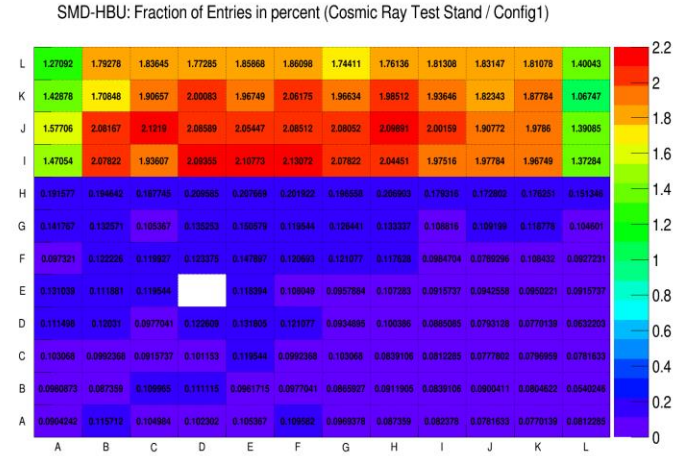
Config 1: A129C11 not triggered

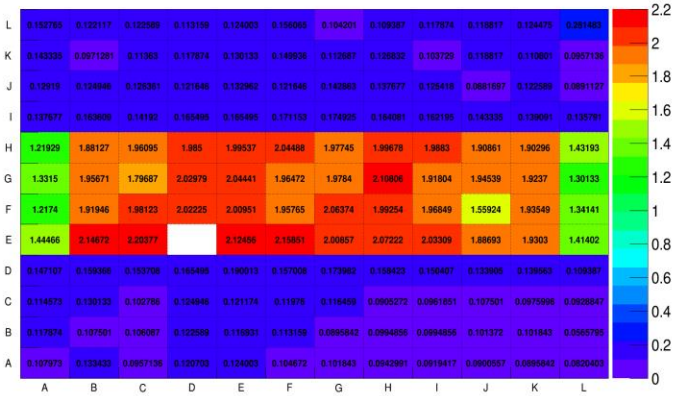


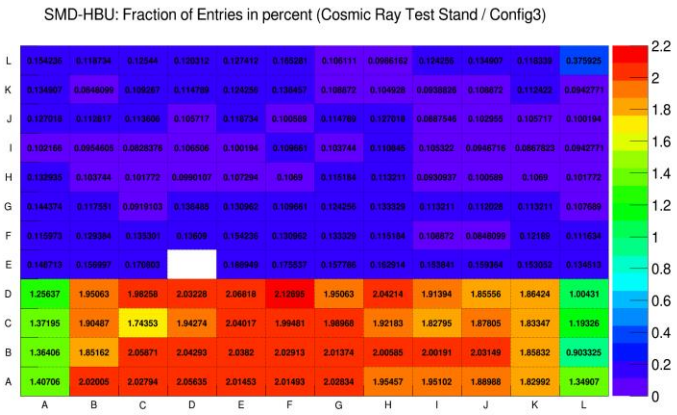
Mip-Entries expected, only if channel was triggered

Config 3: A129C11 not triggered









Measured MIP events in Cosmic Ray Teststand

To resolve the MIP events a cut with ADC > 600 and a ASIC dependend TDC cut was applied to the measured data.

Entries as fraction of the total entries in percent.

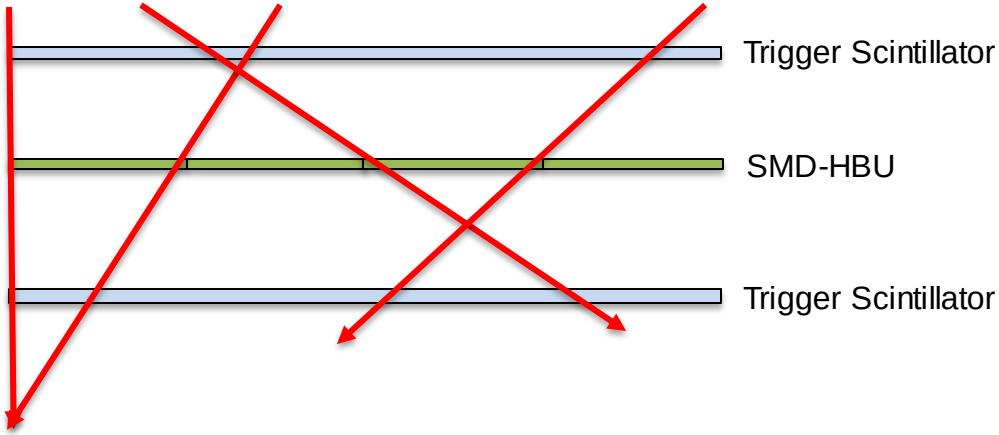
ASIC dependent TDC cut:
A129 → TDC < 3100
A130 → TDC < 3200
A131 → TDC < 2700
A132 → TDC < 3150

Total entries with ADC > 600 & TDC cut:
Config 1 → 260.992 entries on whole HBU
Config 2 → 212.091 entries on whole HBU
Config 3 → 253.508 entries on whole HBU

Note:

- **white spot** on map: A132C26 (broken channel)
- Less entries measured on the **left and right edge** of the SMD-HBU for each configuration due to the geometrical acceptance angle.

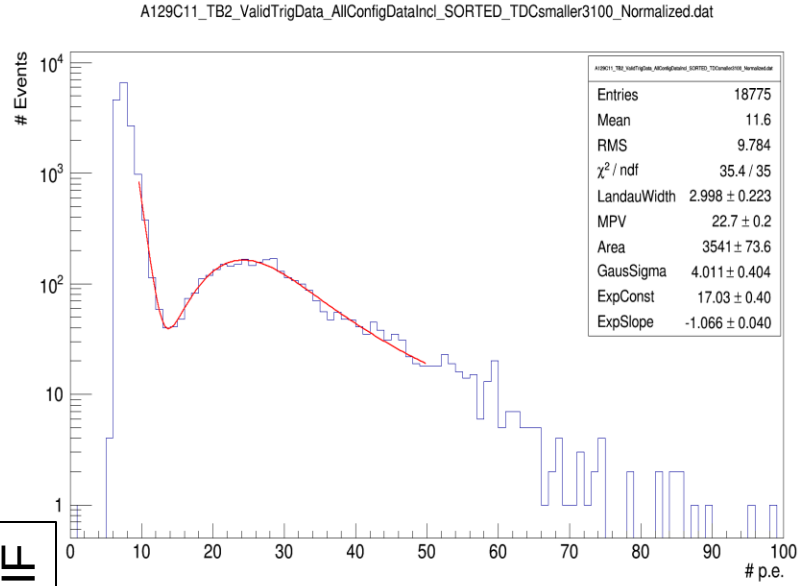
Geometrical Acceptance:

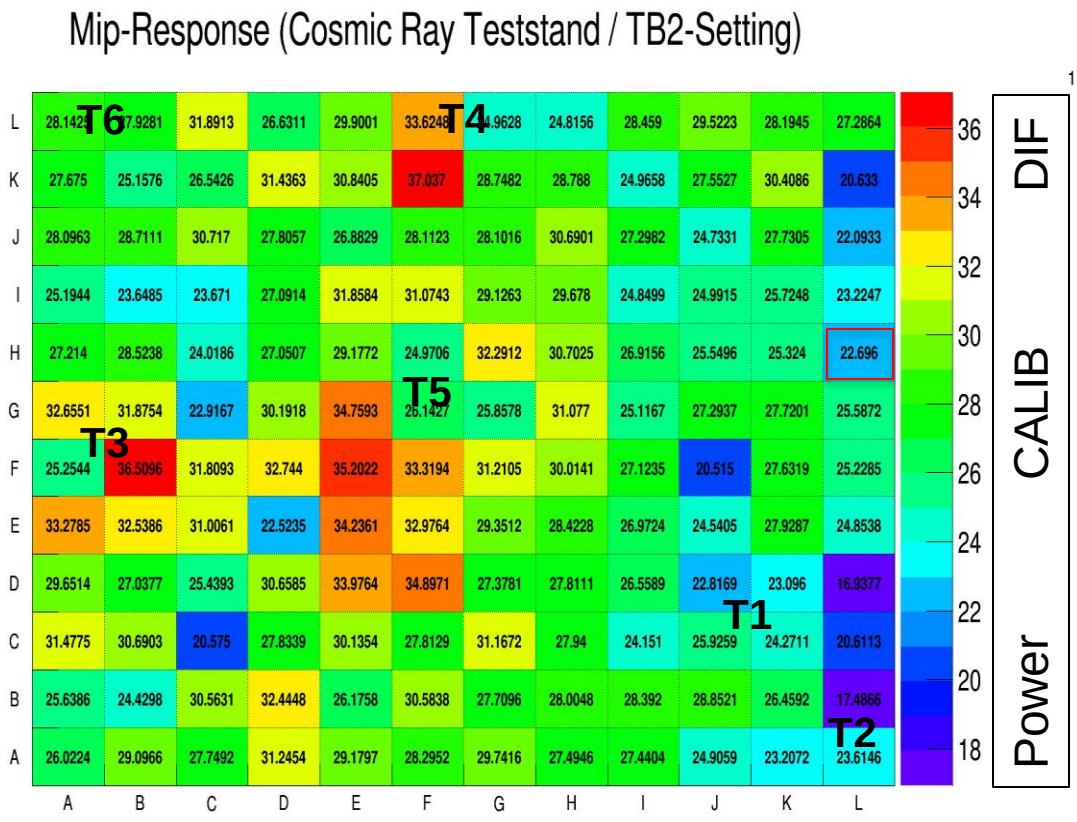


Determination of MIP response (Example A129C11)

Procedure:

- Data with (ASIC dependend) TDC cut is plotted
- Spectra is fitted with the sum of an exponential (two parameters) and a Landau-Gaussian convoluted function.
- MIP response equals the MPV of the Landau-Gaussian convoluted distribution





Possible reason for lower MIP response on the right edge of the map: **Temperature ?**

Sensor	Average Temp. [°C]
T1	30.44
T2	29.96
T3	27.70
T4	27.55
T5	27.87
T6	26.82