university of groningen

# Digitization for the Forward Endcap Calorimeter

Viktor Rodin

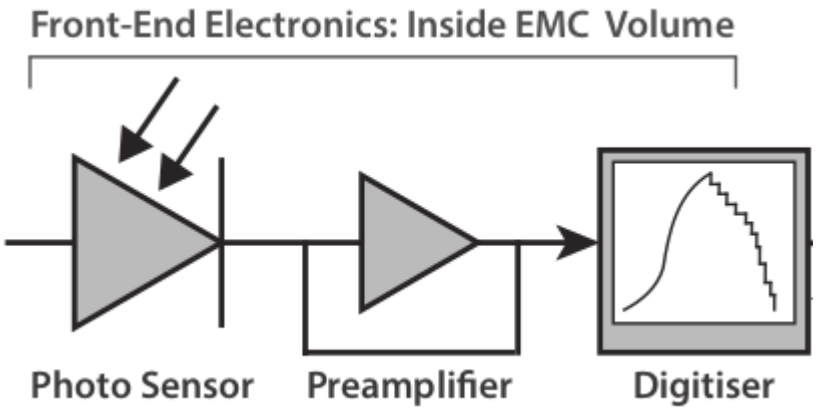
Myroslav Kavatsyuk

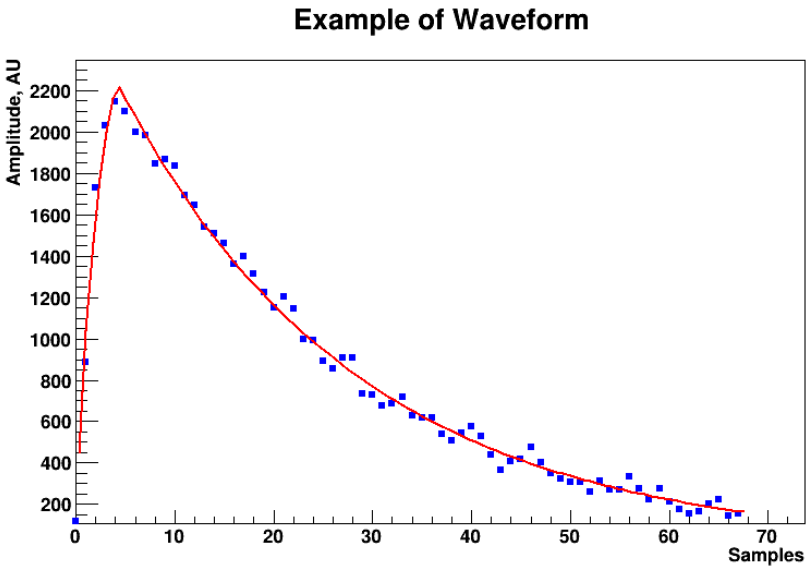
# Main goals

- **Implement the digitization procedure, used in EMC digitizers, into the Pandaroot**

- **Cross-checking of the simulation perfomance with realisitic digitization.**

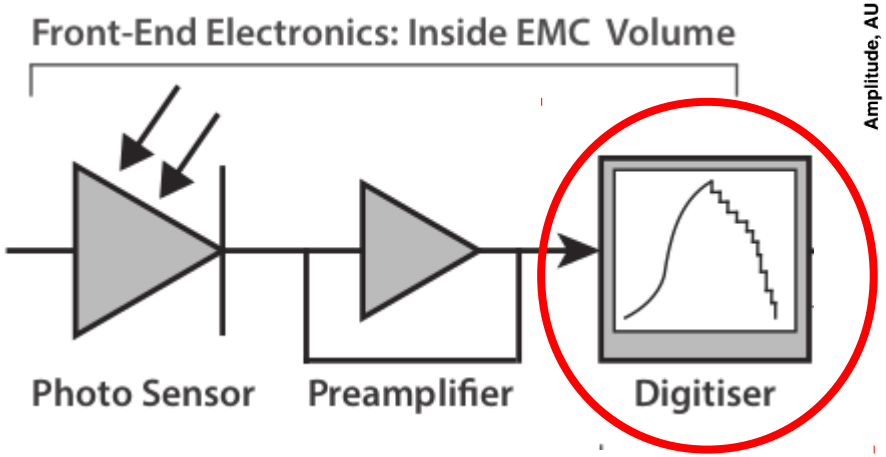
# Introduction

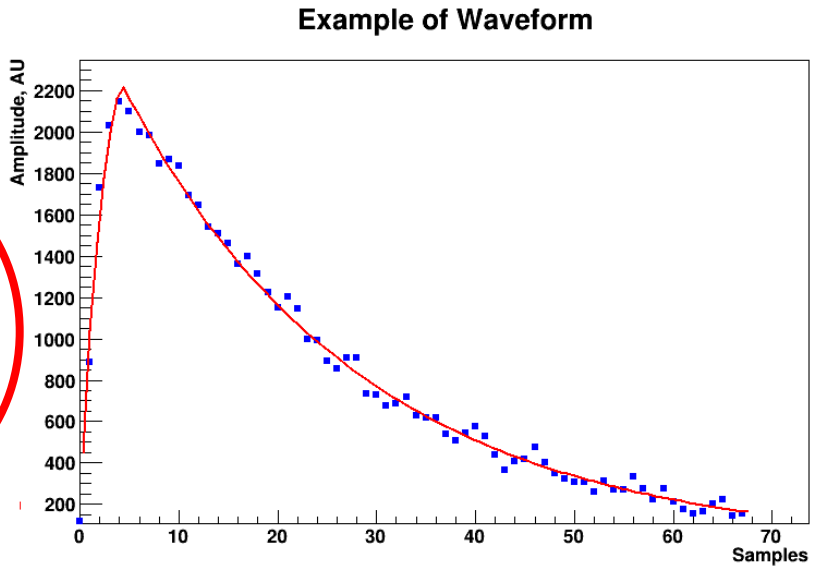



FEE Output

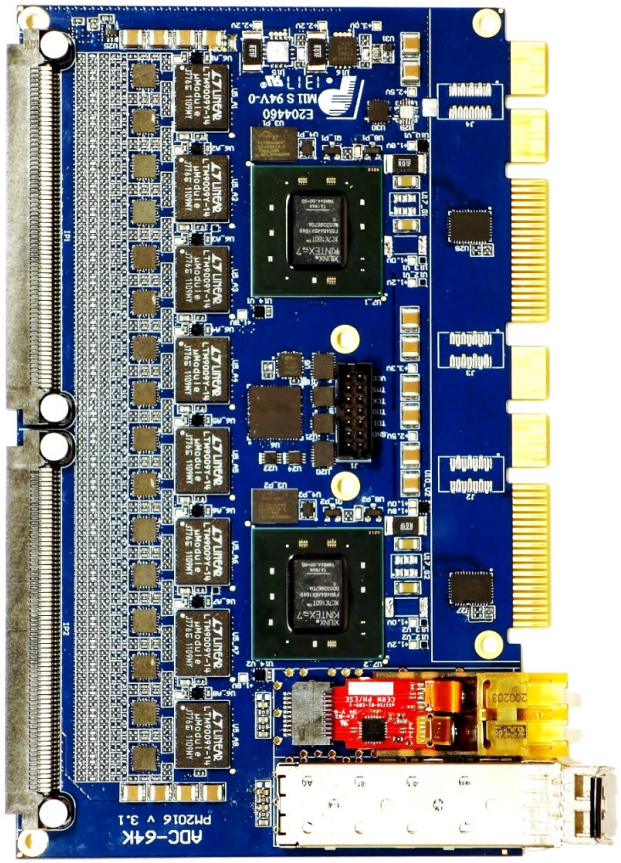
# Introduction




FEE Output

# Digitizer



Sampling ADC board

Sampling – 80 MS/s

Resolution – 14 bit

Input channels – 32

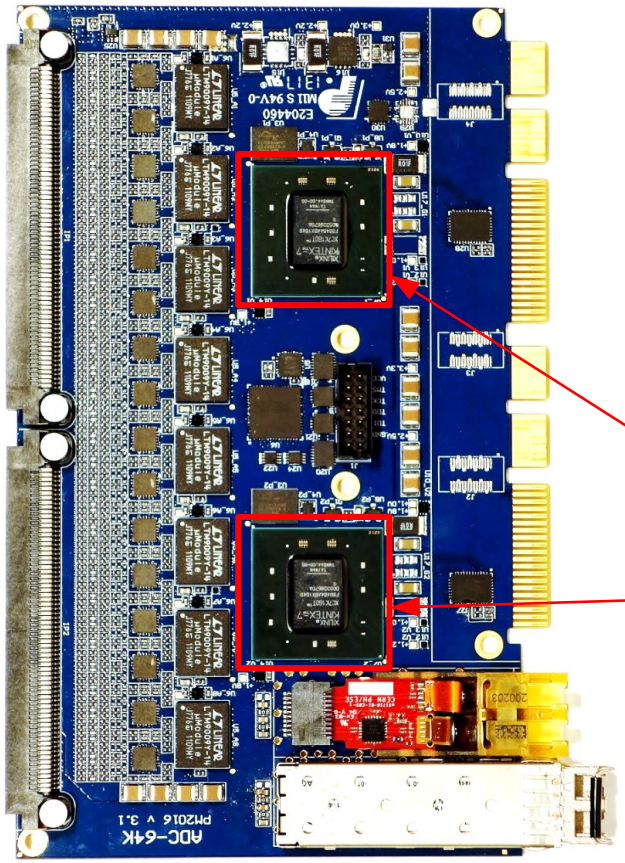
High/low gain splitting

2 Kintex-7 FPGAs

Online feature extraction

Interface – Optical, SFP, LC-type

# Digitizer



Sampling ADC board

Sampling – 80 MS/s

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Input channels – 32

High/low gain splitting

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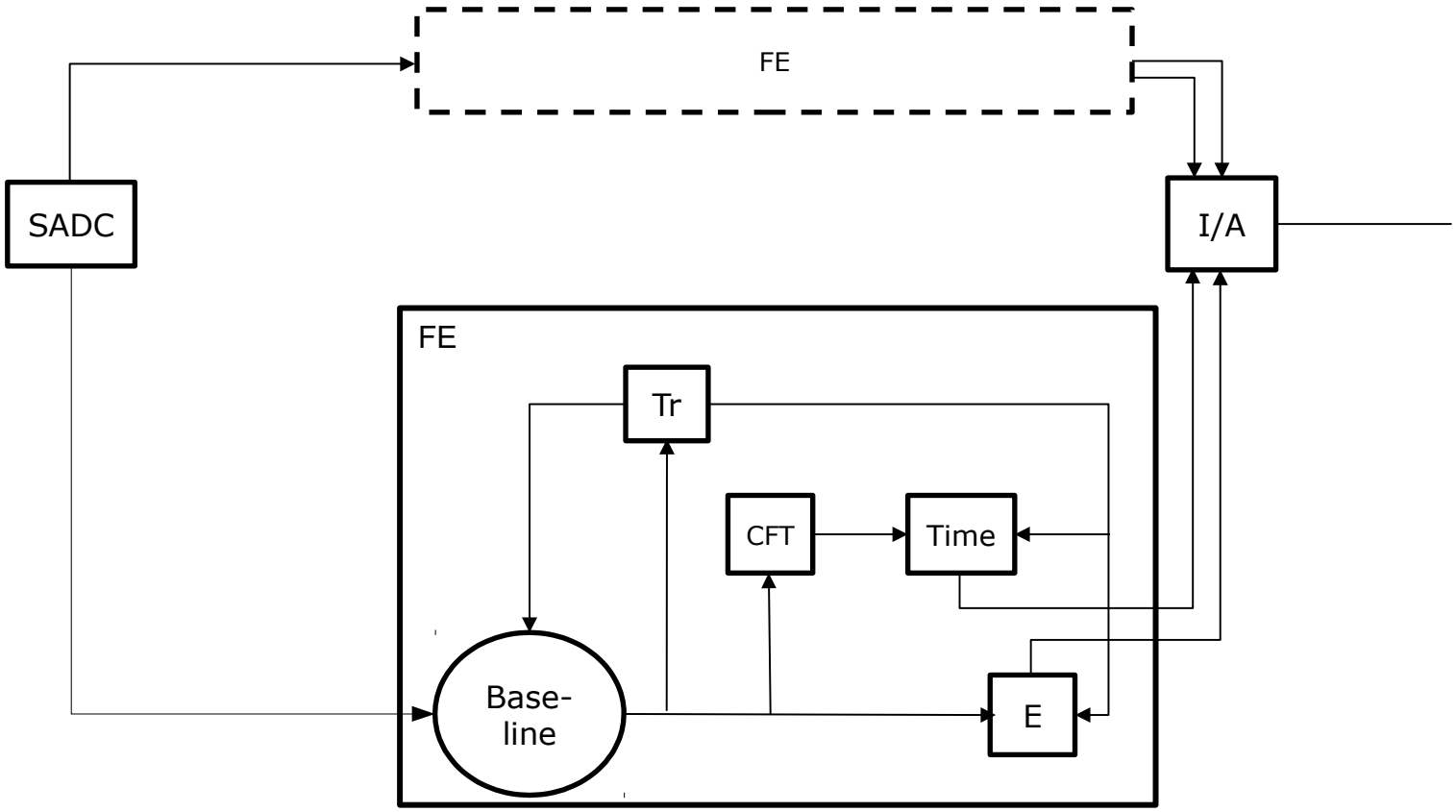
Online feature extraction

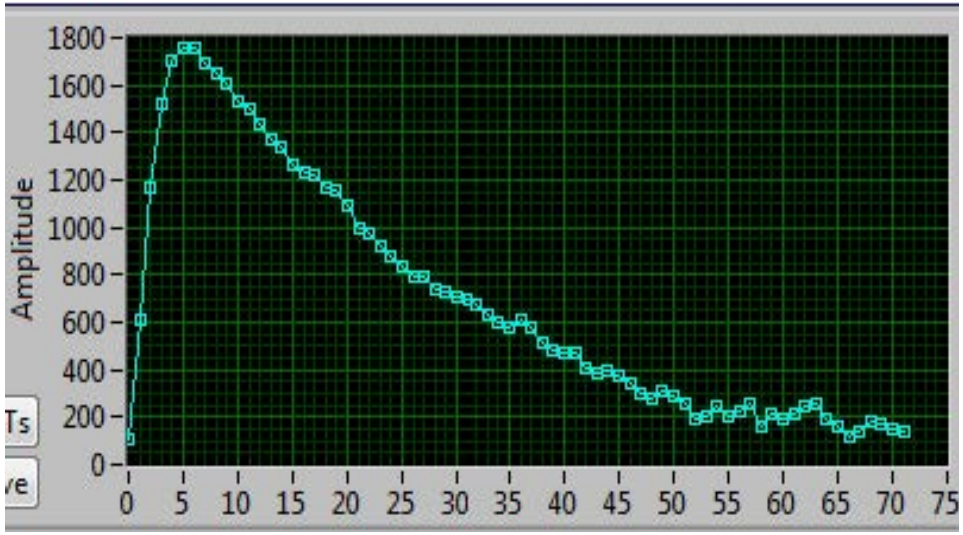
Interface – Optical, SFP, LC-type

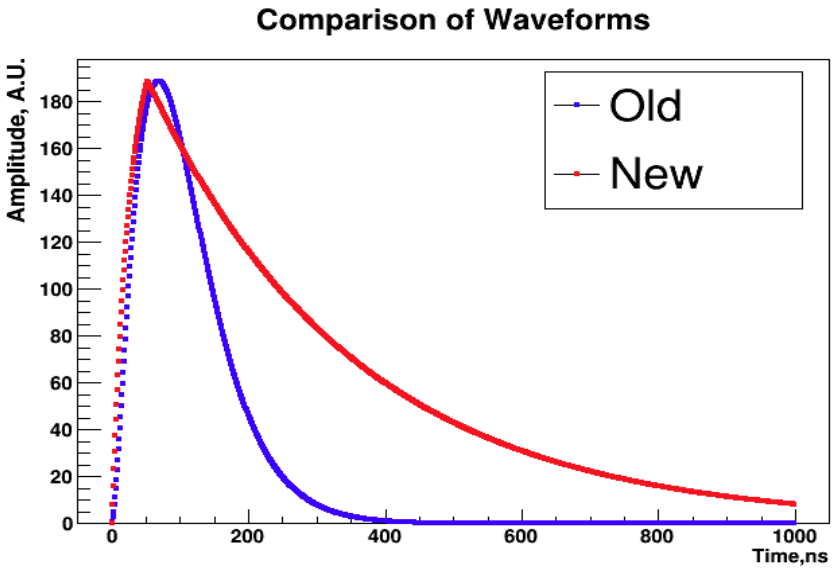
# Feature extraction



# Waveform shape

The shape of waveform  from the FEE



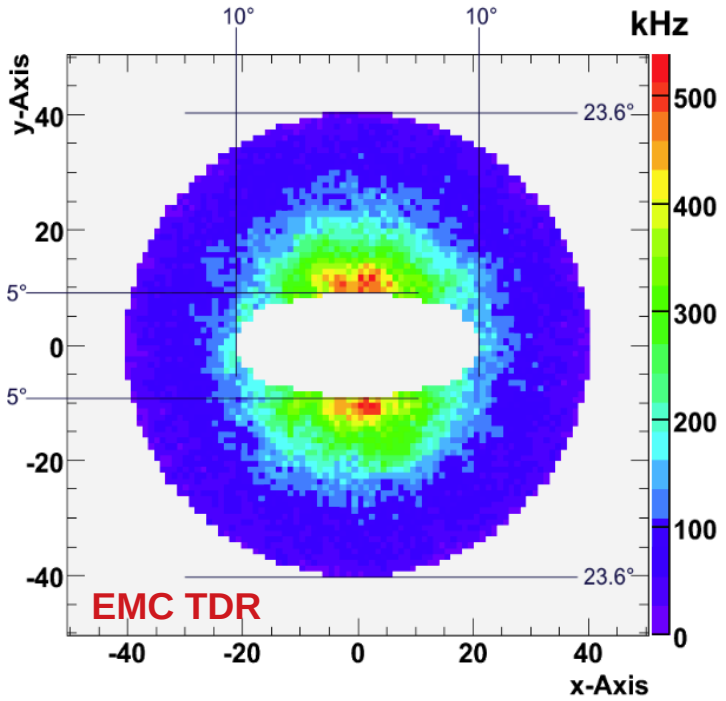




Old – shape of waveform which used in Pandaroot now.

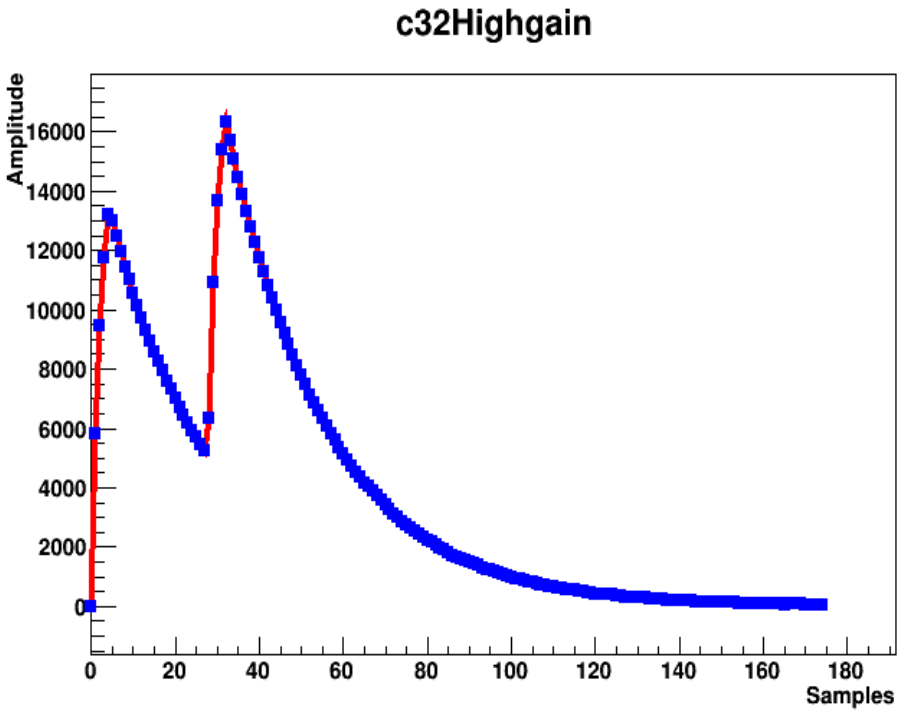
New – shape of waveform from the final FEE version

New shape is not yet  in Pandaroot repository.

# Pile-up case

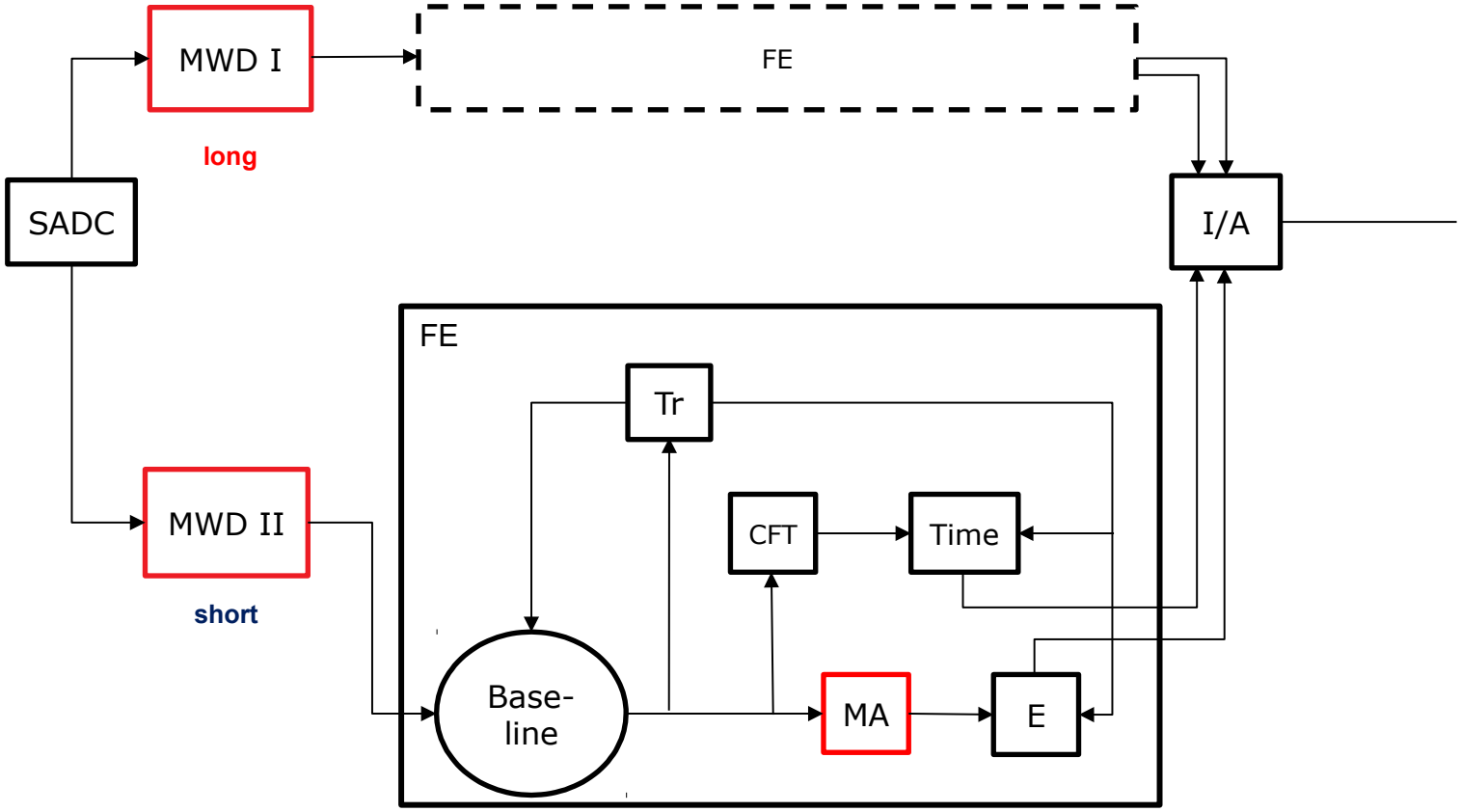



The expected hit rate in the Forward Endcap EMC




Example of the pile-up case

# Feature extraction with filters

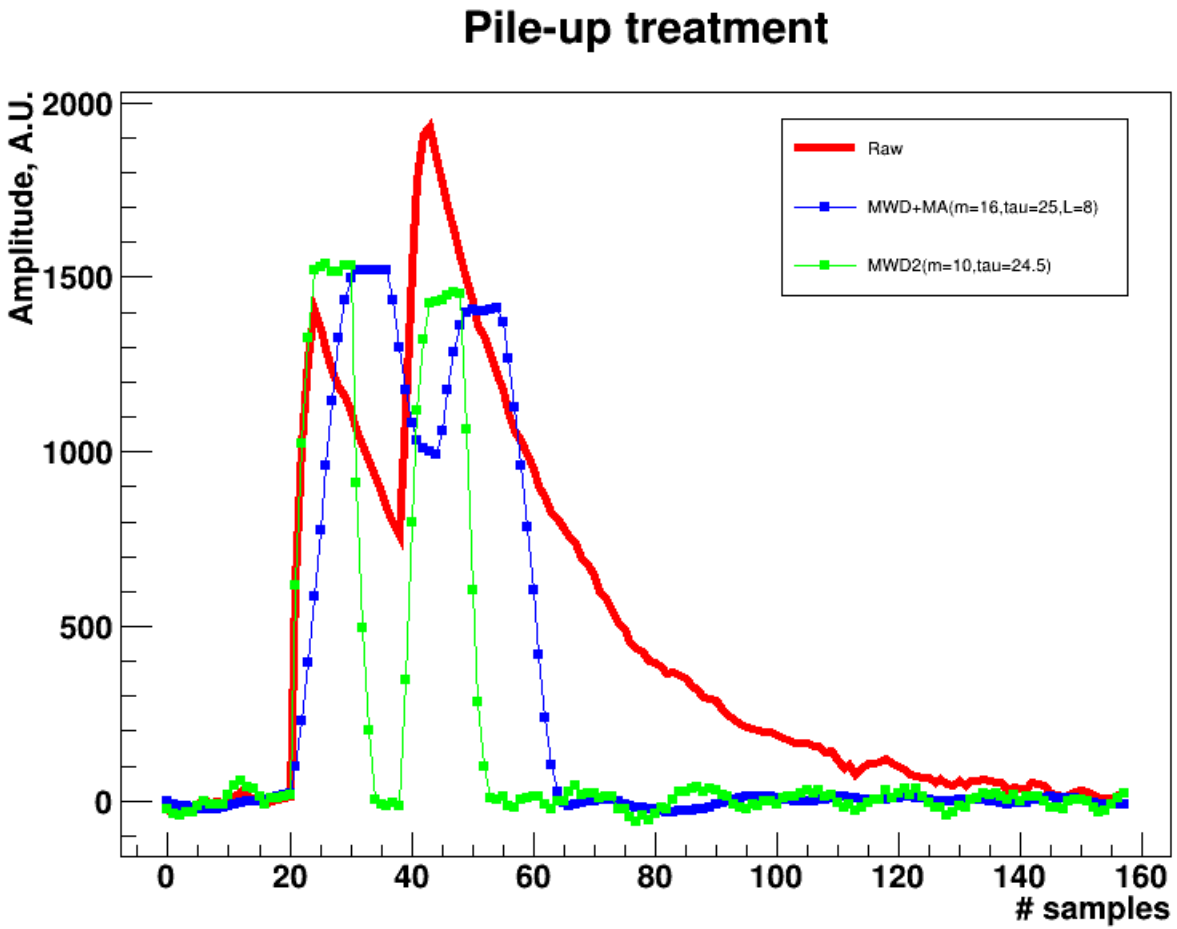


# Pile-up recovery algorithm

Moving Window Deconvolution filter (MWD) reduces the length of pulse, and therefore minimizes the overlap between pulses.

Moving Average filter suppress the noise, hence increases the accuracy of the feature extraction procedure.

Both filters are used in the pile-up recovery algorithm.



# MWD and MA filters

$$MWD_m[n] = x[n] - x[n-m] + \frac{1}{\tau} \sum_{i=n-m}^{i-1} x(i)$$

*x(i)* – value of sample,
m – length of window in samples,
$\tau$ – inverted index of exponential tail of the pulse.

$$MA[n] = \frac{1}{L} \sum_{j=0}^{L-1} A(n+j)$$

L – number of samples for averaging.
(Usually it is half of MWD length)

# Main issues

- **What is realistic noise?**
- **Which values of parameters are optimal for the MWD and MA filters ?**
- **What resolution will be after the feature extraction considering the previous point?**

# Waveforms from Bochum

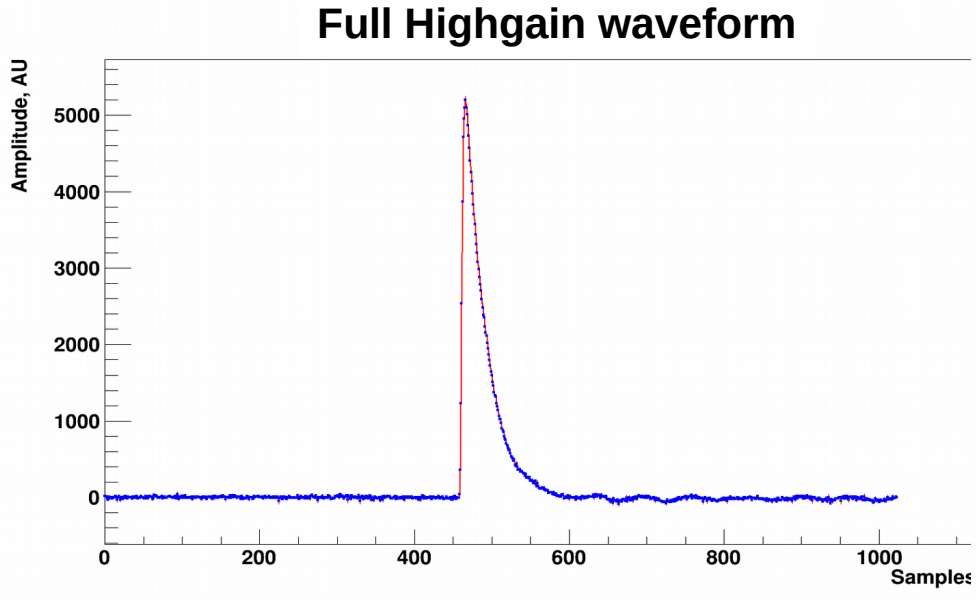
Waveforms provided by the Bochum group:

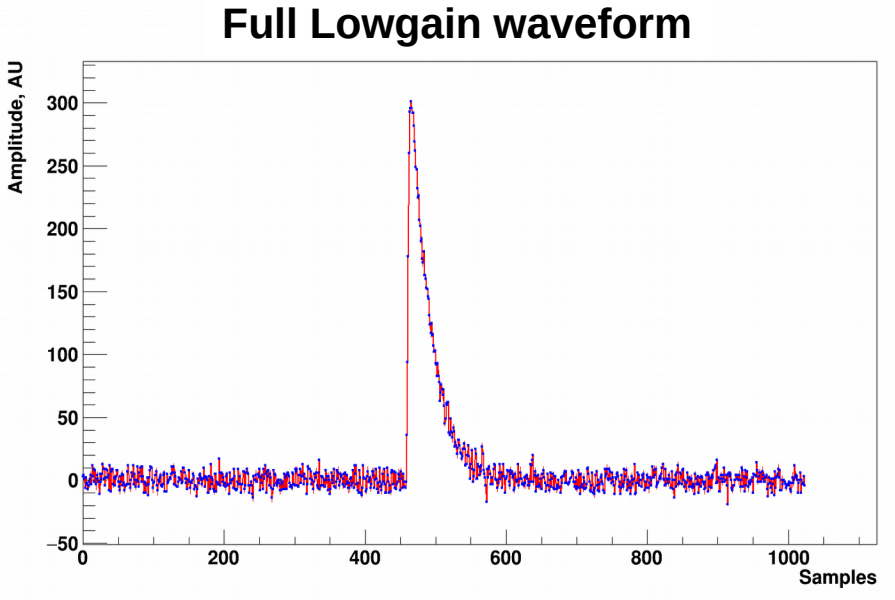
- Measurement with light pulser in the range of 10 MeV to 12 GeV;
- final version of ADC;
- production Fw Endcap subunit.

Used to determine noise parameters and resolution.

# Resolution studies

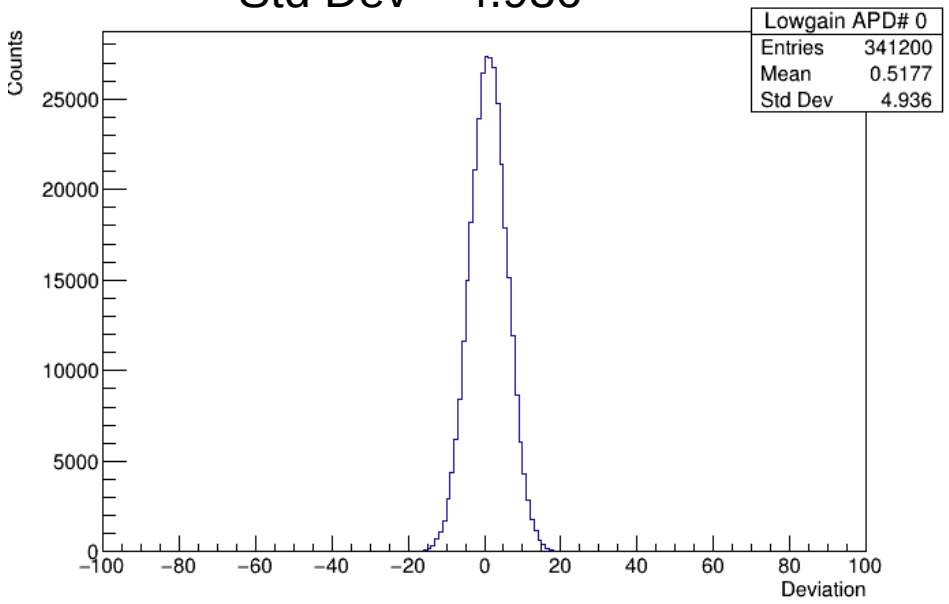
Waveform data, 262 MeV



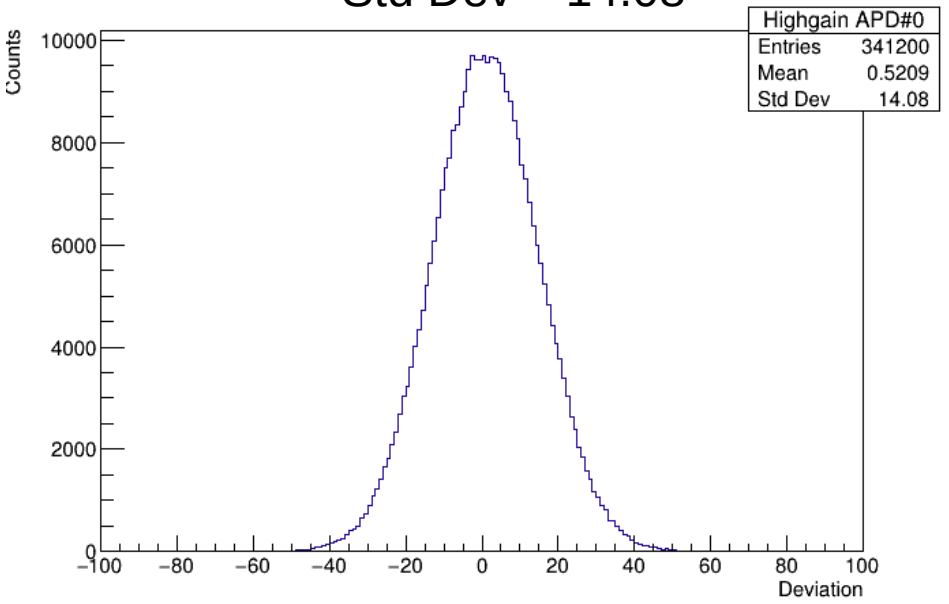



# Noise measurement, experiment

Lowgain
Mean – 0.5177
Std Dev – 4.936




Highgain
Mean – 0.5209
Std Dev – 14.08



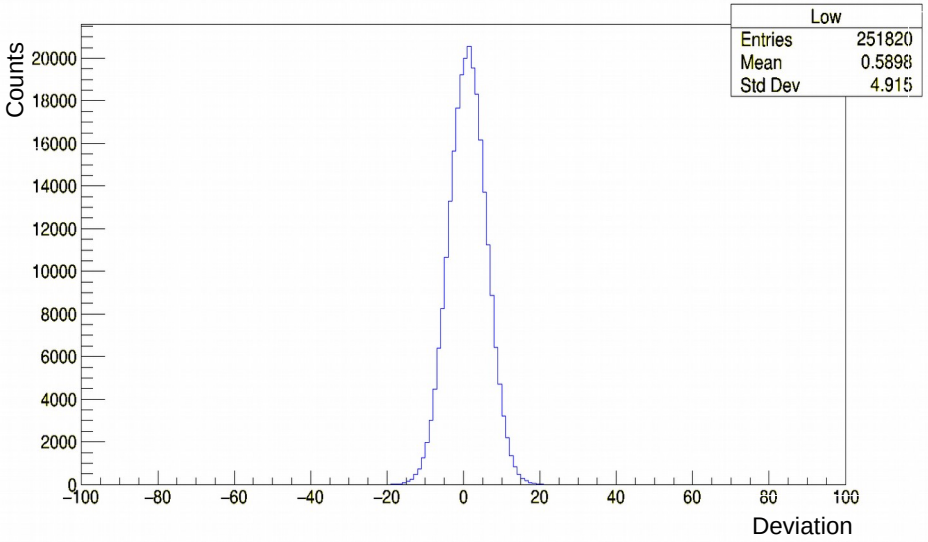

400 first samples from each waveform after baseline substraction.

# Noise measurement, simulations

Lowgain

Mean – 0.5898

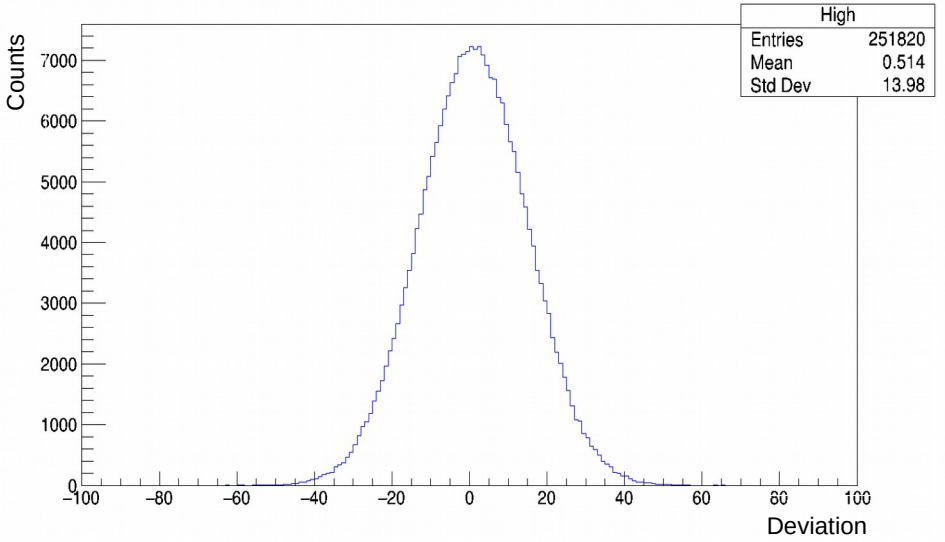
Std Dev – 4.915




Highgain

Mean – 0.514

Std Dev – 13.98



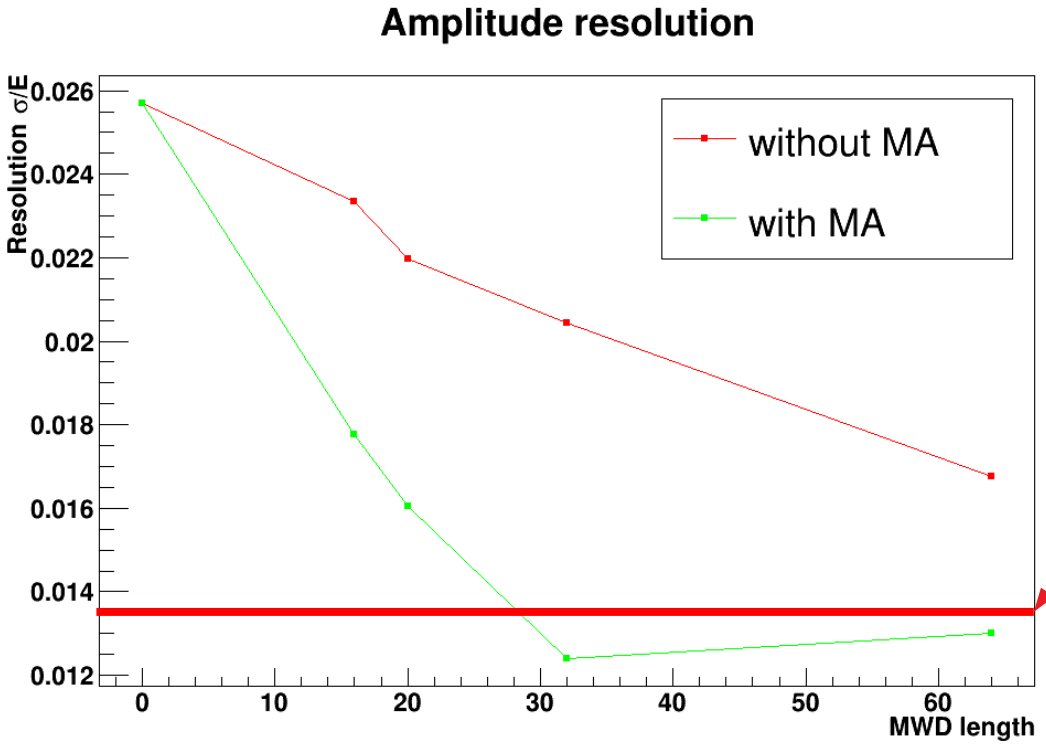

Noise level in Pandaroot has been adjusted to the experimental results.

# Analysis of waveforms

Integral and amplitude resolution have been evaluated.

Two modes were tested – dynamic and fixed window. In the first case, integration continues if the value is above a certain threshold. In the second case, the integration is limited by sampling range.

# Experimental results

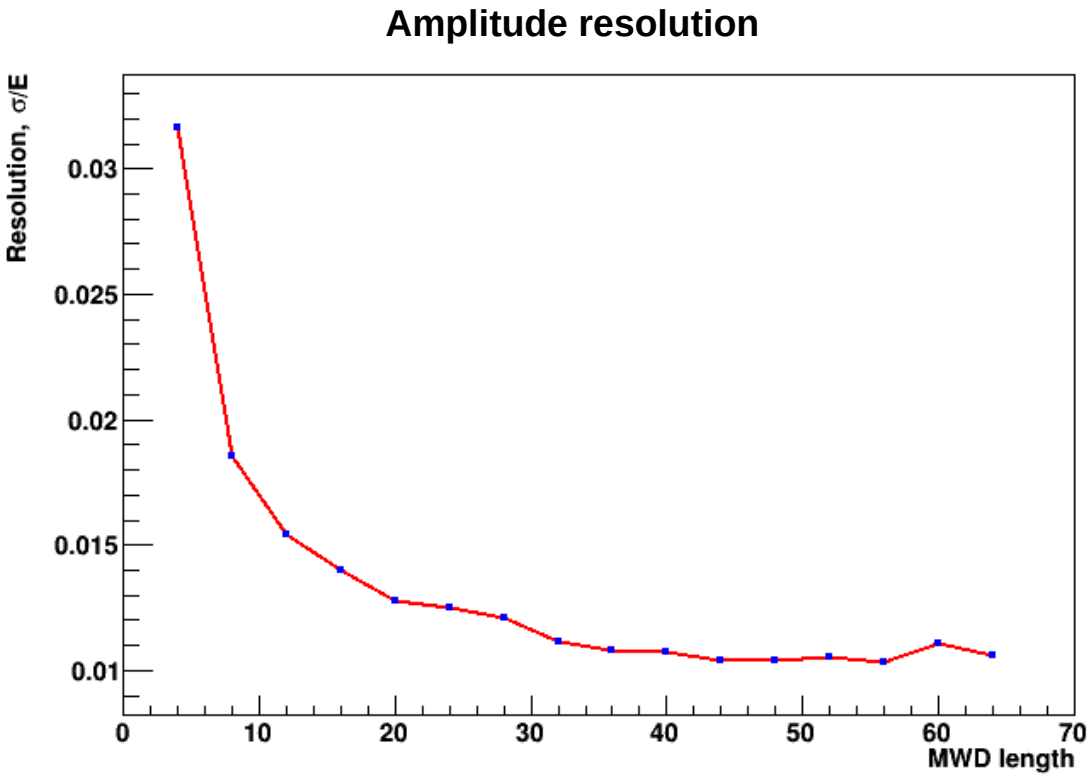



best resolution value in case of integration

Using of longer MA and MWD filters is better for the energy determination?

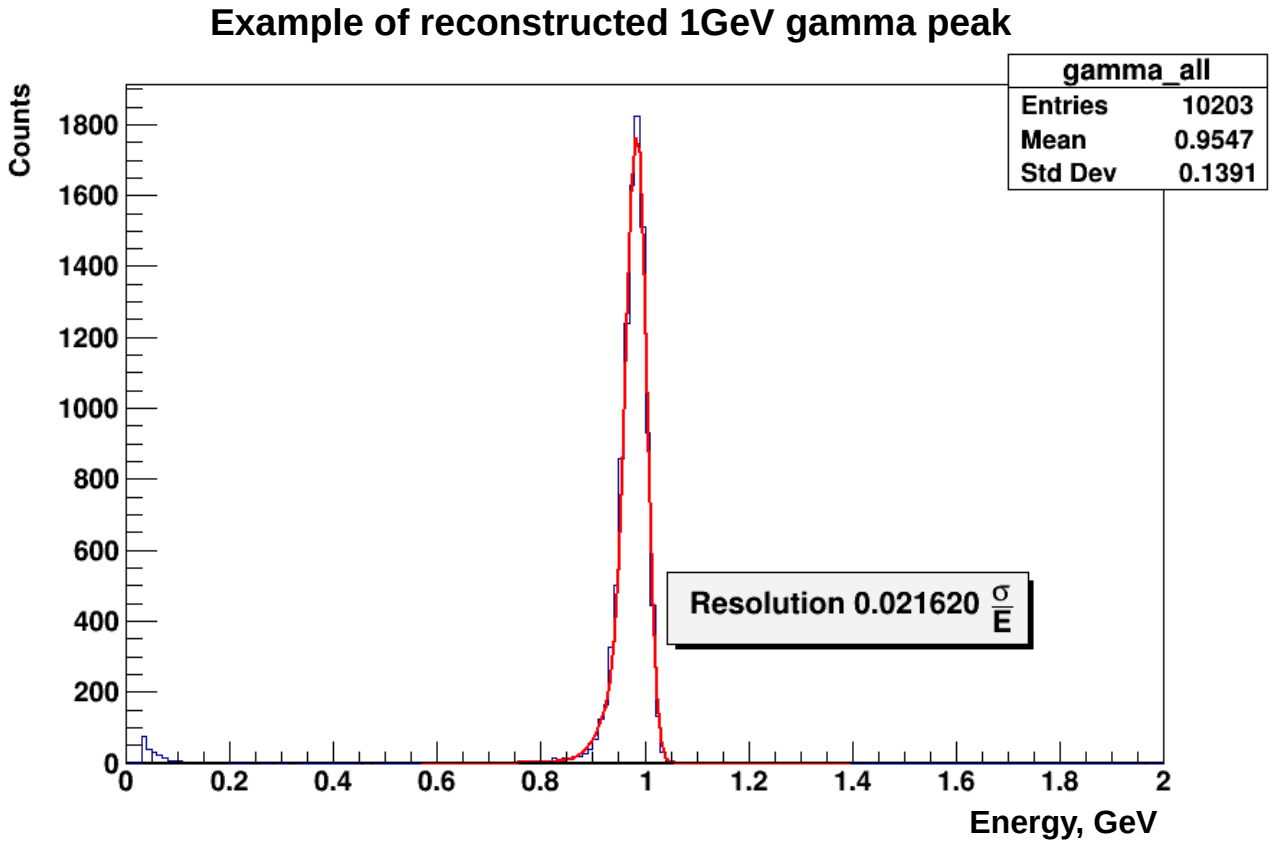
# Pandaroot simulation

Light pulser simulation in Pandaroot with energy 0.262 GeV




Same behaviour as in the case of measurements.

# Pandaroot simulation




Gabler Fit was used to study single crystal and cluster resolutions.

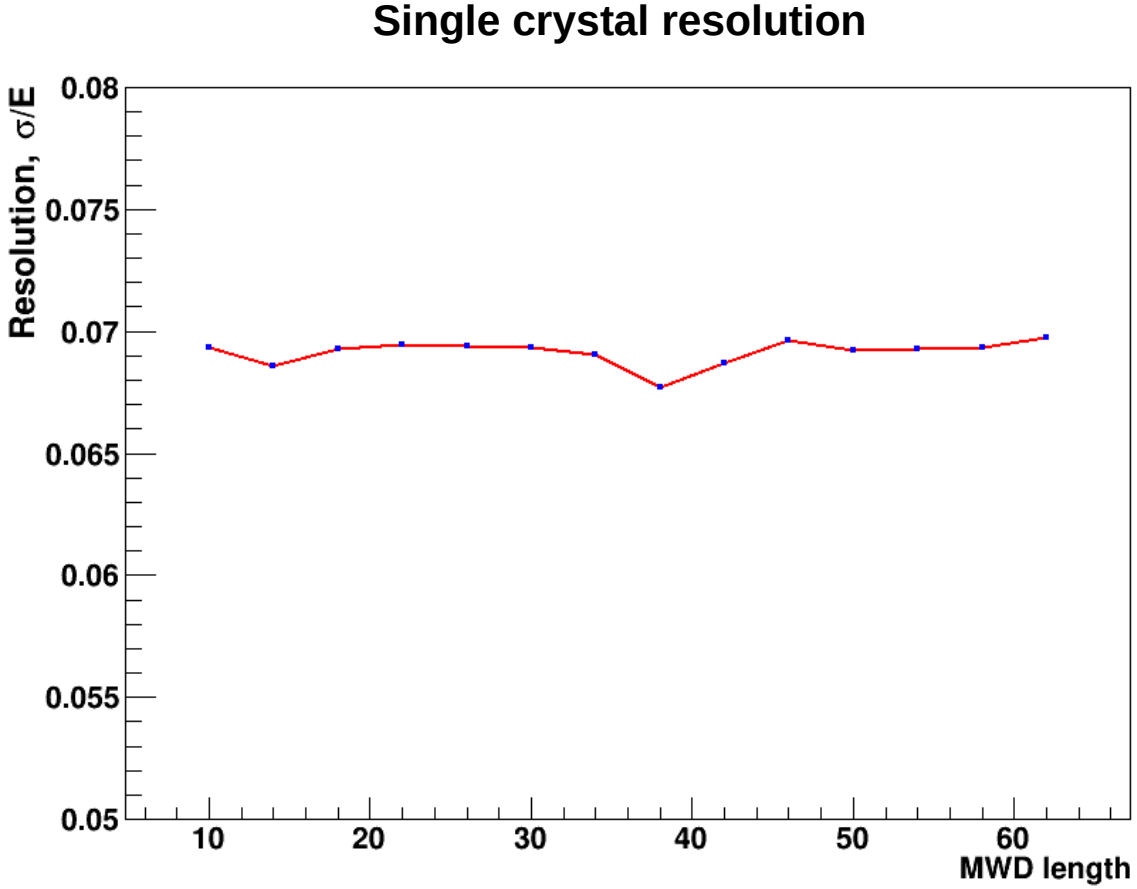
# Pandaroot simulation

10000 gammas with energy 0.262 GeV
shot to a single point at the hit rate 1kHz.

Resolution does not improve with increasing MWD length.

Without MA and MWD
Resolution – 0.06955

Shower effect yields bigger effect than smoothing of noise

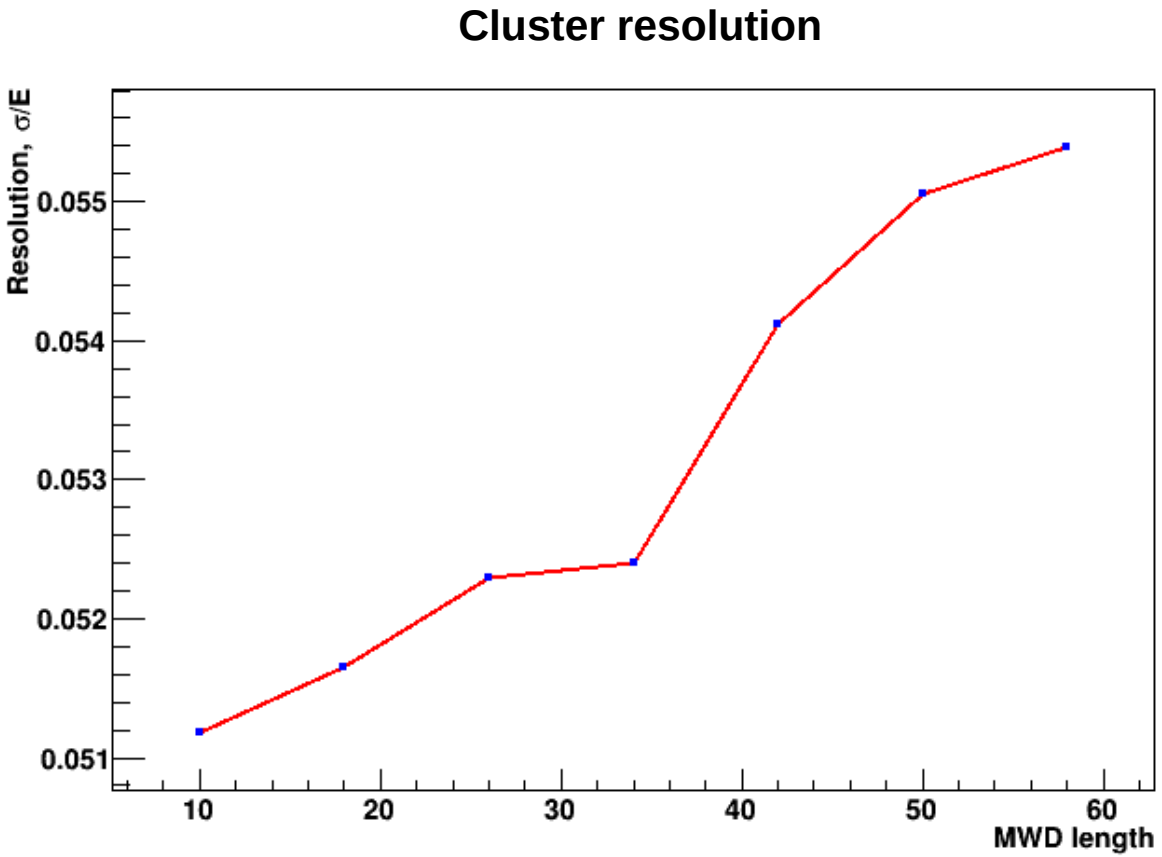


# Pandaroot simulation

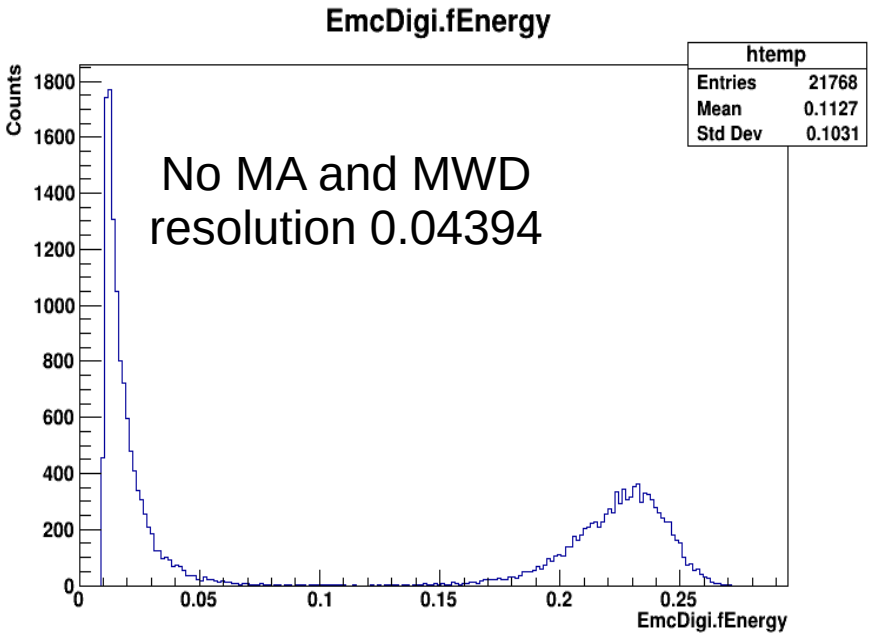
10000 gammas with energy 0.262 GeV shot to a single point at the hit rate 1kHz.

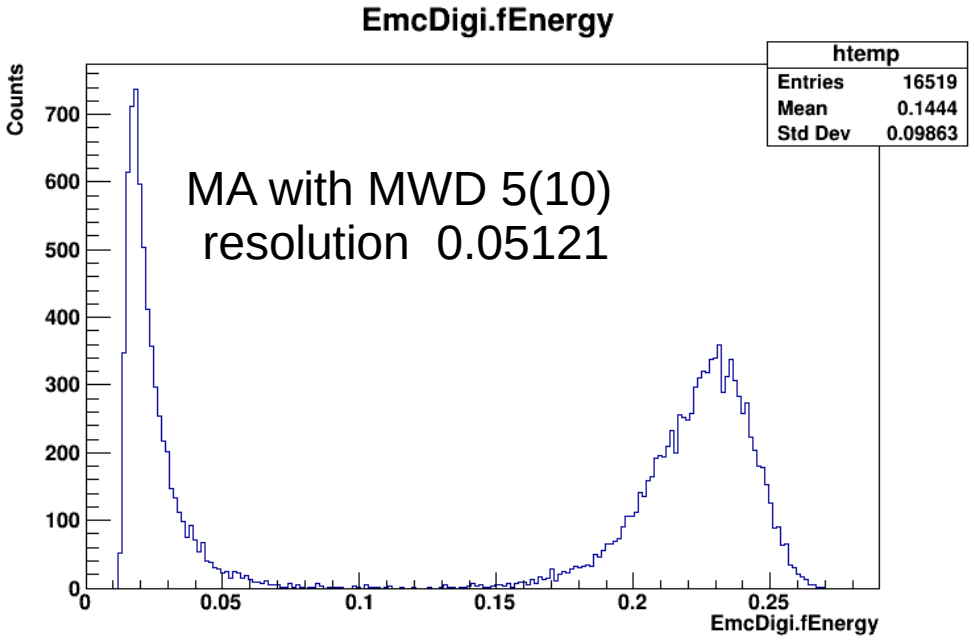
Resolution without MA and MWD - 0.04394

Smoothing makes resolution worse if filters are longer. Why?



# Pandaroot simulation



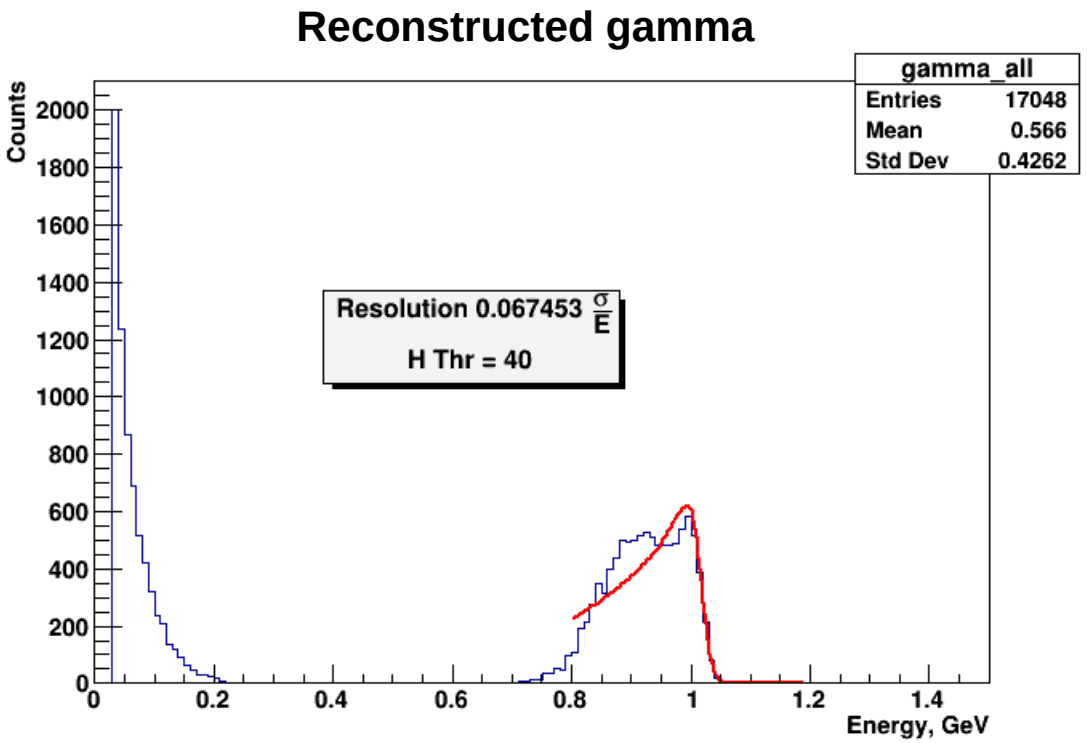

- Cluster resolution depends on the number of digis.
  - MA smoothes rising edge of pulse, thus time determination for low energy hits becomes worse and some of them cannot be detected.

Solution: Change thresholds

# Pandaroot simulation

A resolution in case if there are no filters, Highgain Threshold =40 A.U.

10000 gammas with energy 1 GeV shot to a single point at the hit rate 1kHz.

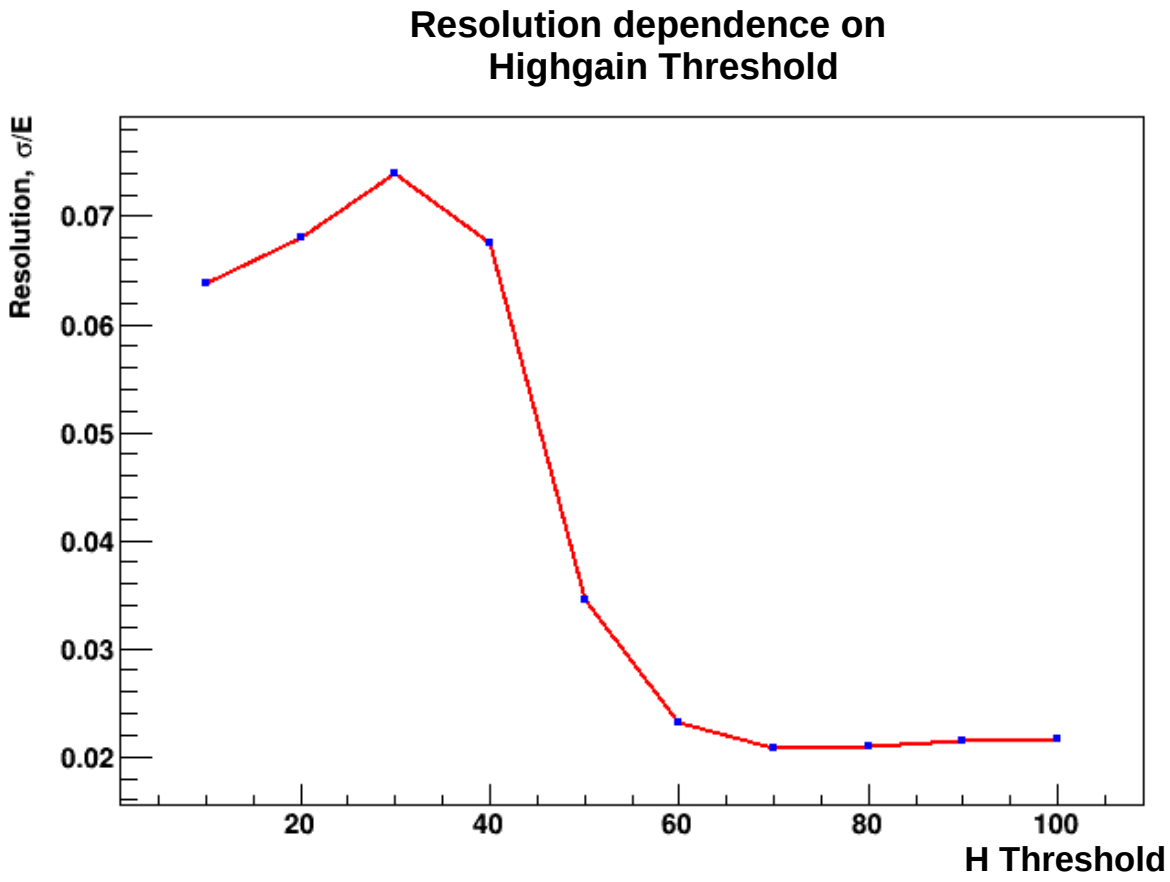



Unsatisfactory perfomance. Why?

# Pandaroot simulation

Lower threshold – more digis are reconstructed.

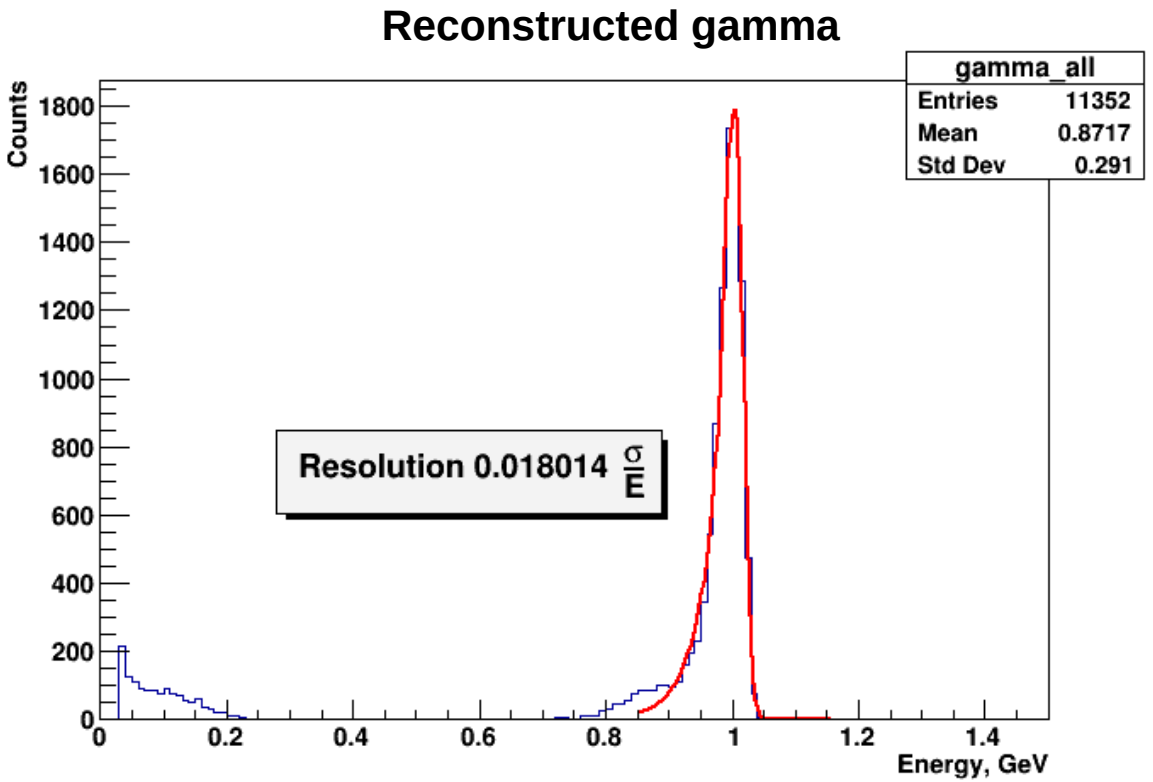
But at some level, one can detect more noise and less the real signals.



# Pandaroot simulation

MWD and MA
Highgain Threshold =20 A.U.

TDR requirement
0.03

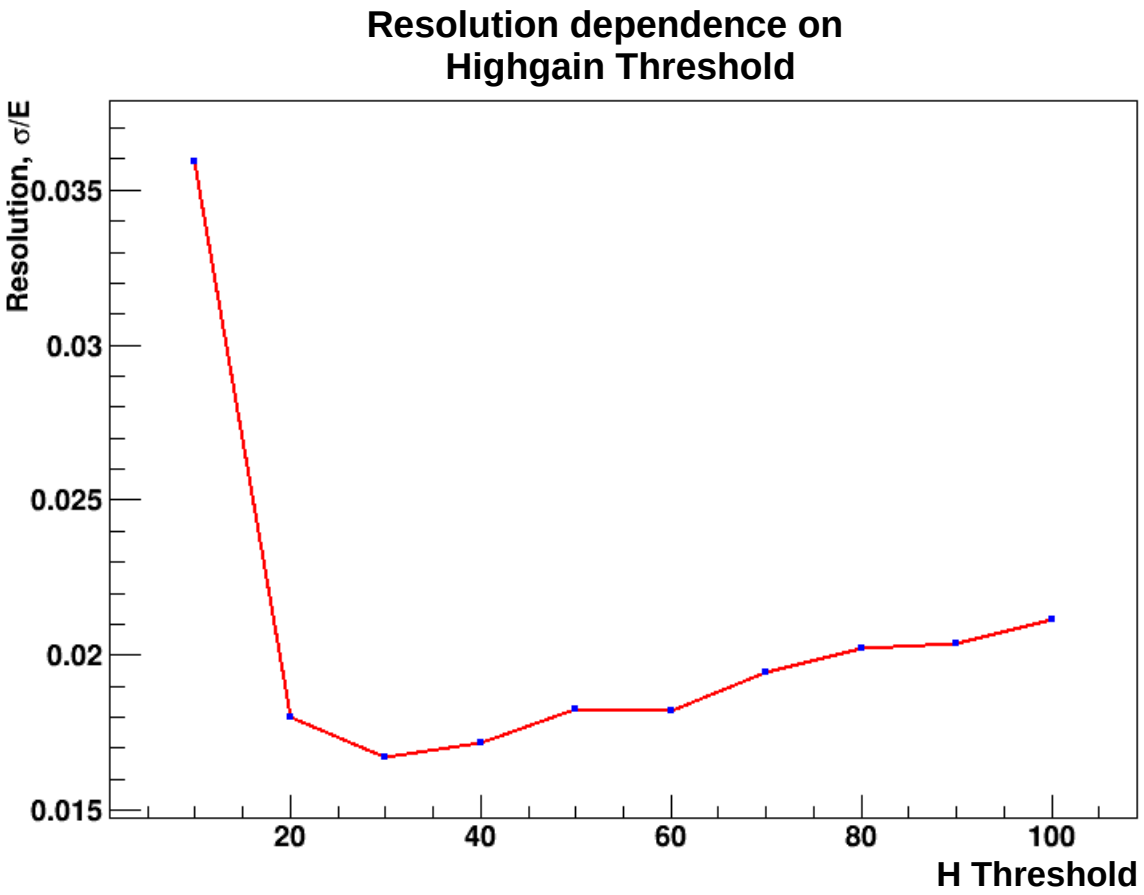


# Pandaroot simulation

Length of MWD(MA) 20(10)

Due to the MA, it is possible to apply lower threshold level.

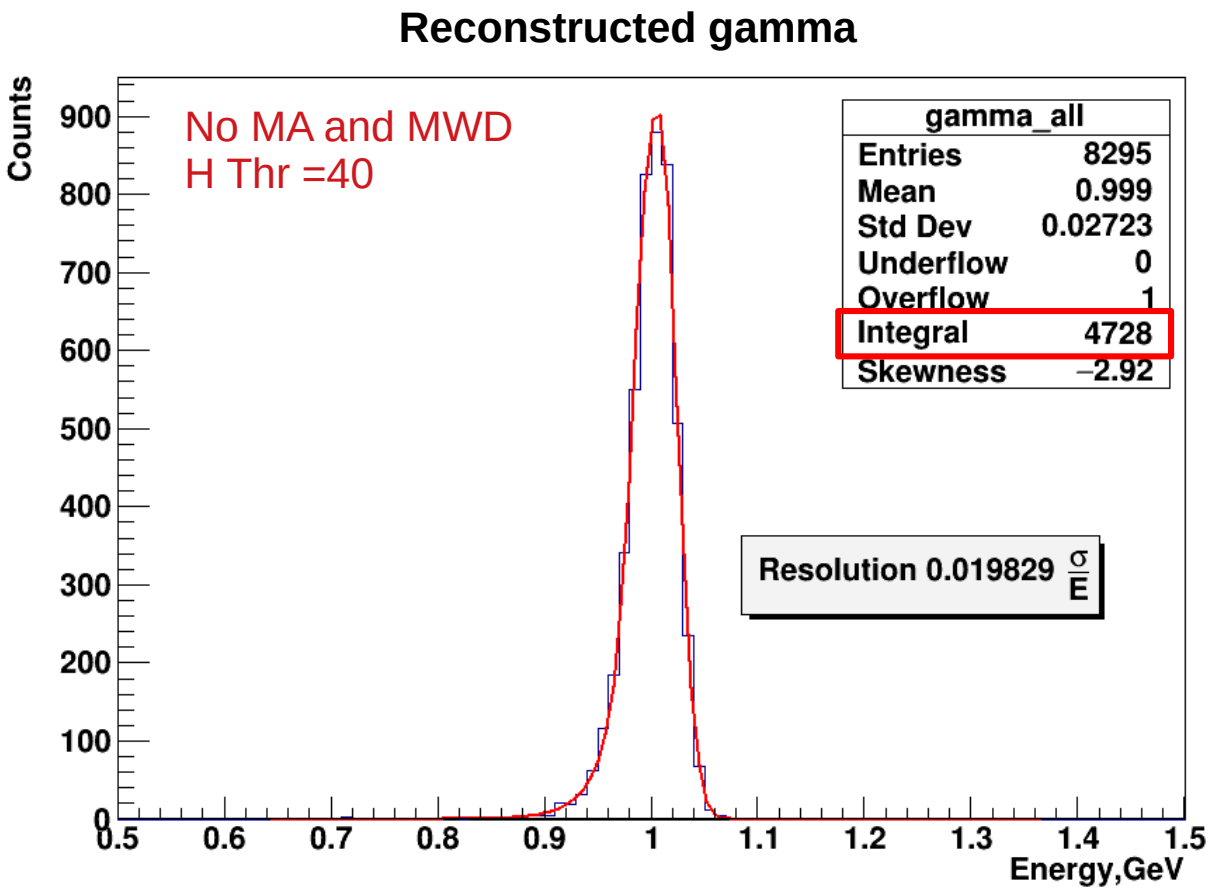
Short pulse but resolution is better!



# Pandaroot simulation

## Pile-up case

10000 gammas with energy 1 GeV shot to a single point at the hit rate 500kHz.



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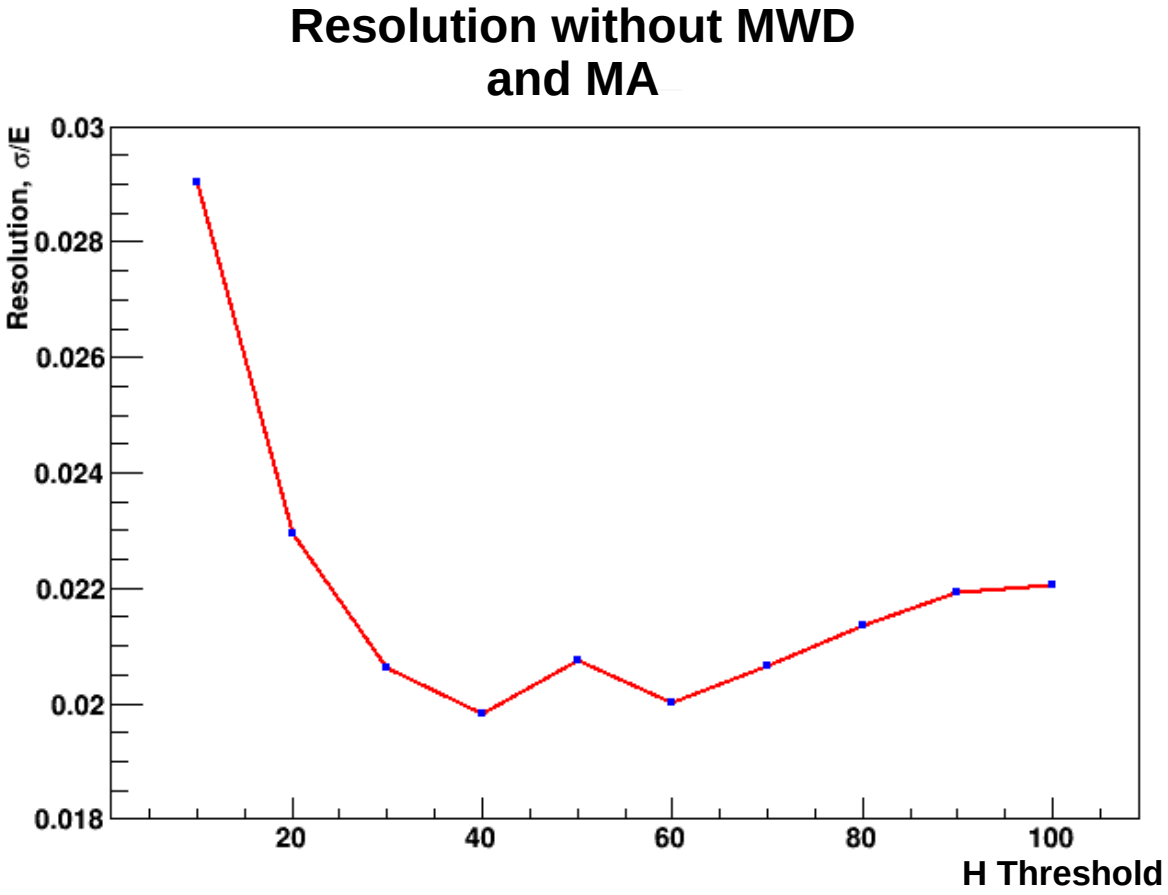

# Pandaroot simulation

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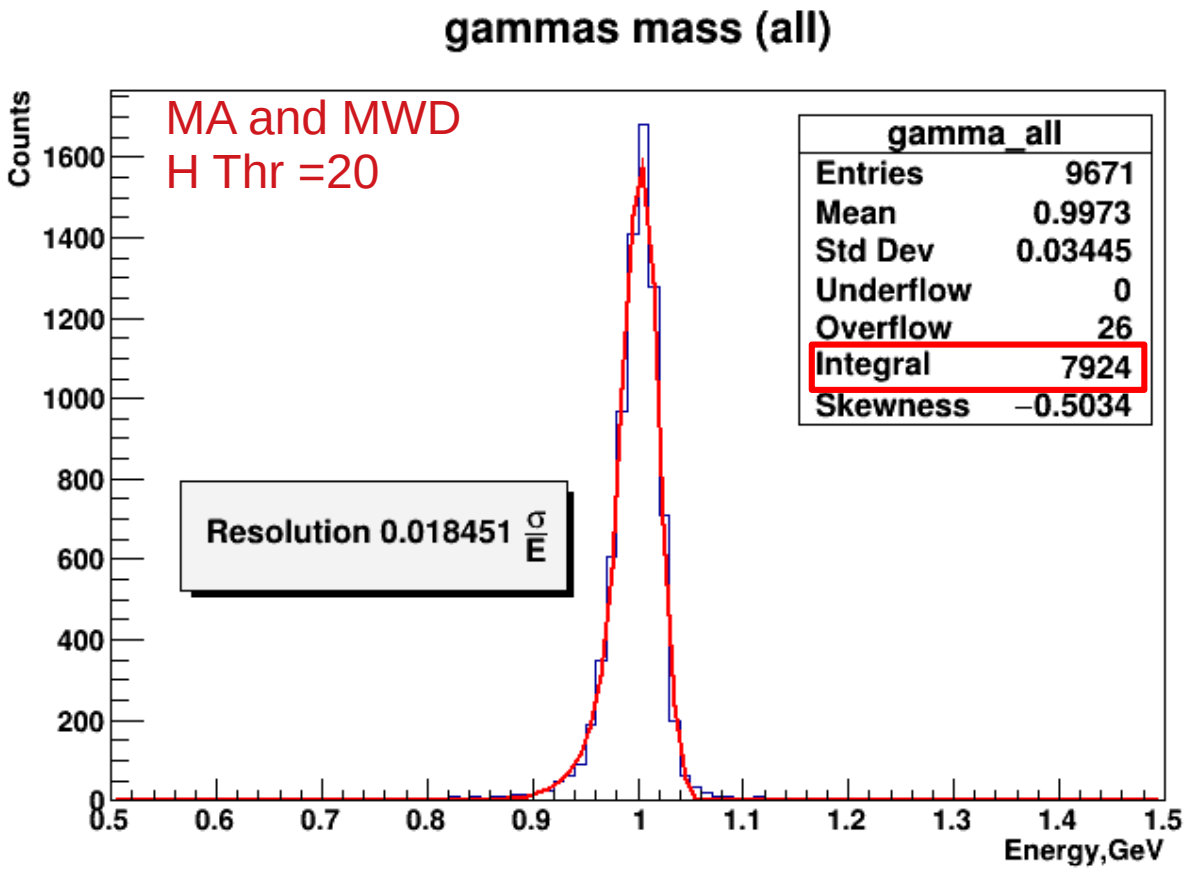
10000 gammas with energy 1 GeV shot to a single point at the hit rate 500kHz.

TDR requirement 0.03



# Pandaroot simulation

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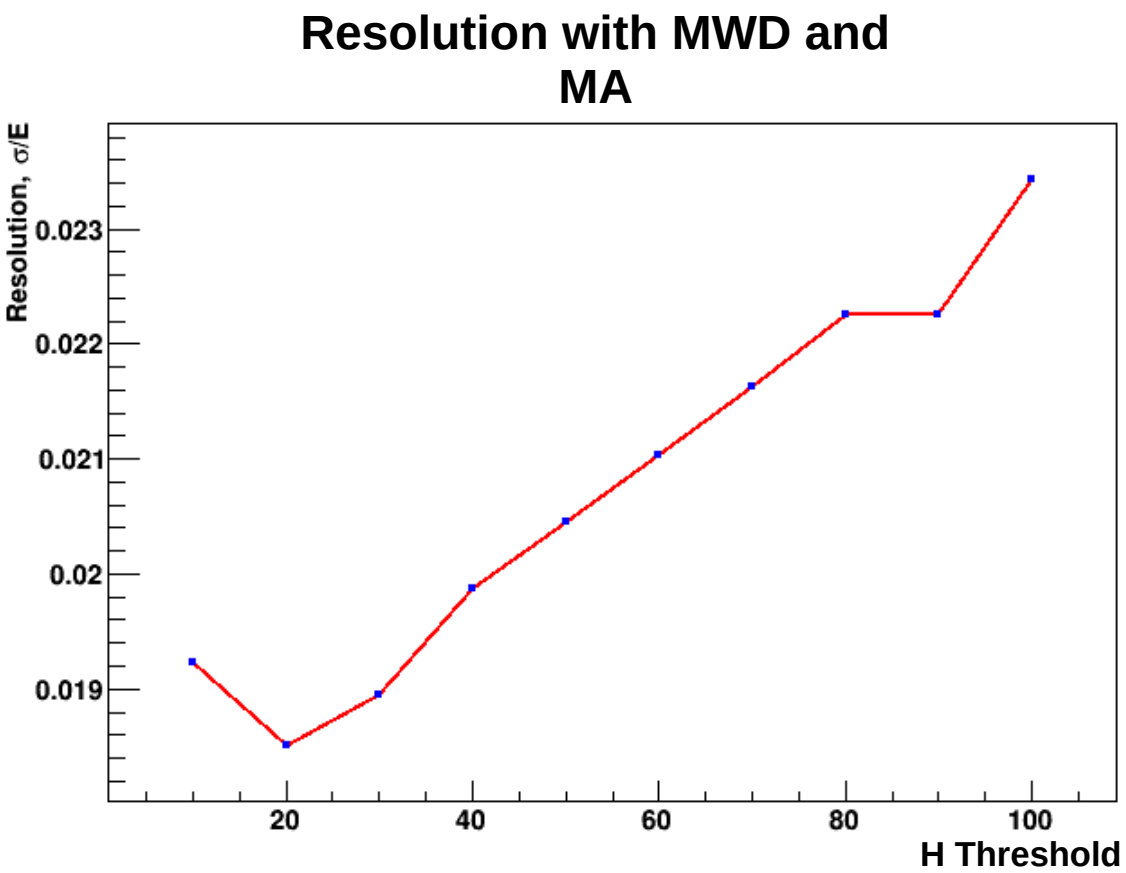


# Summary

- The noise features are investigated
- The optimal parameters for the pile-up recovery algorithm are found
- Pile-up recovery algorithm is imlemented in Pandaroot and it improves the resolution

# Thanks for attention!

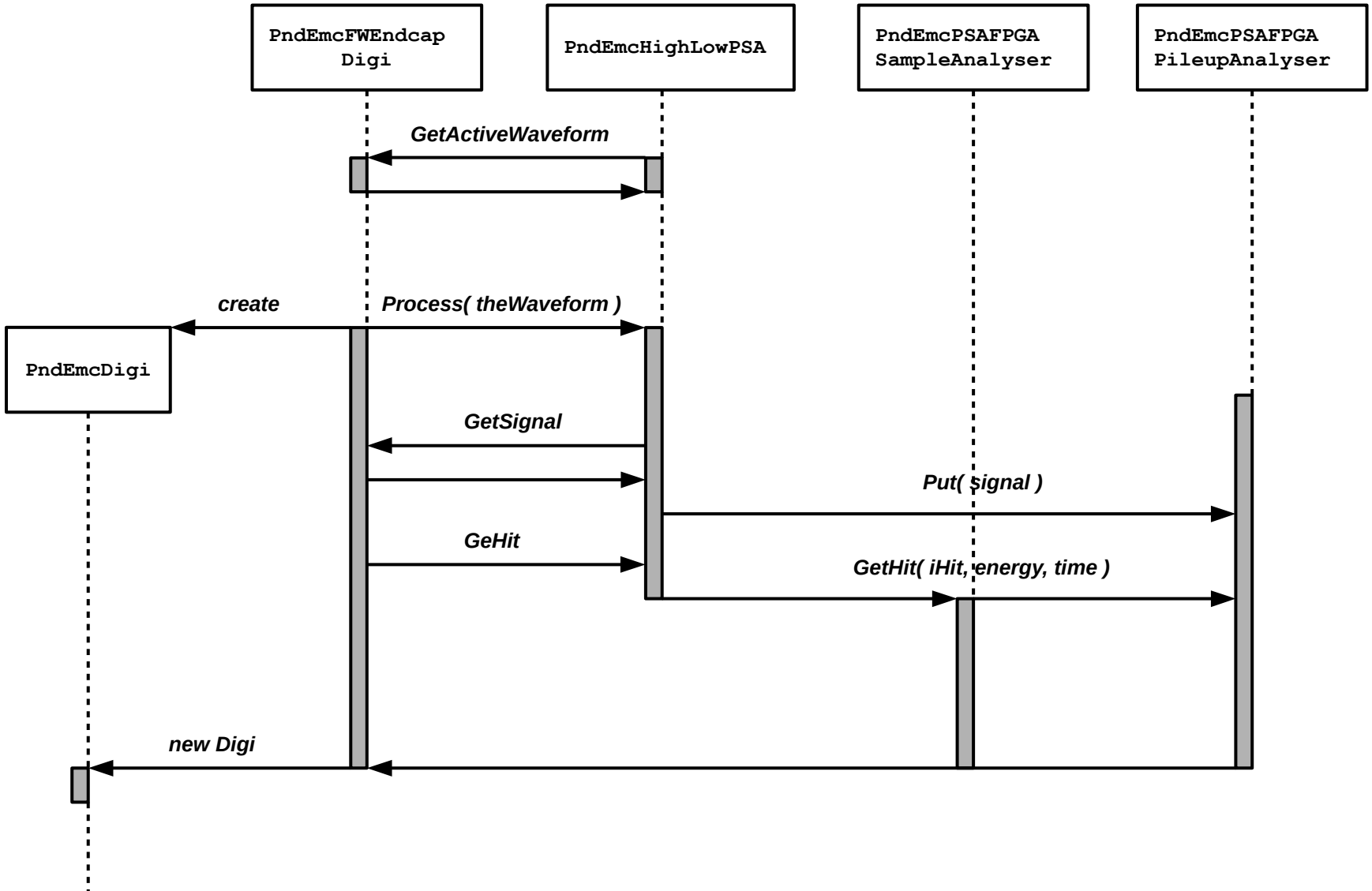
# Backup slides

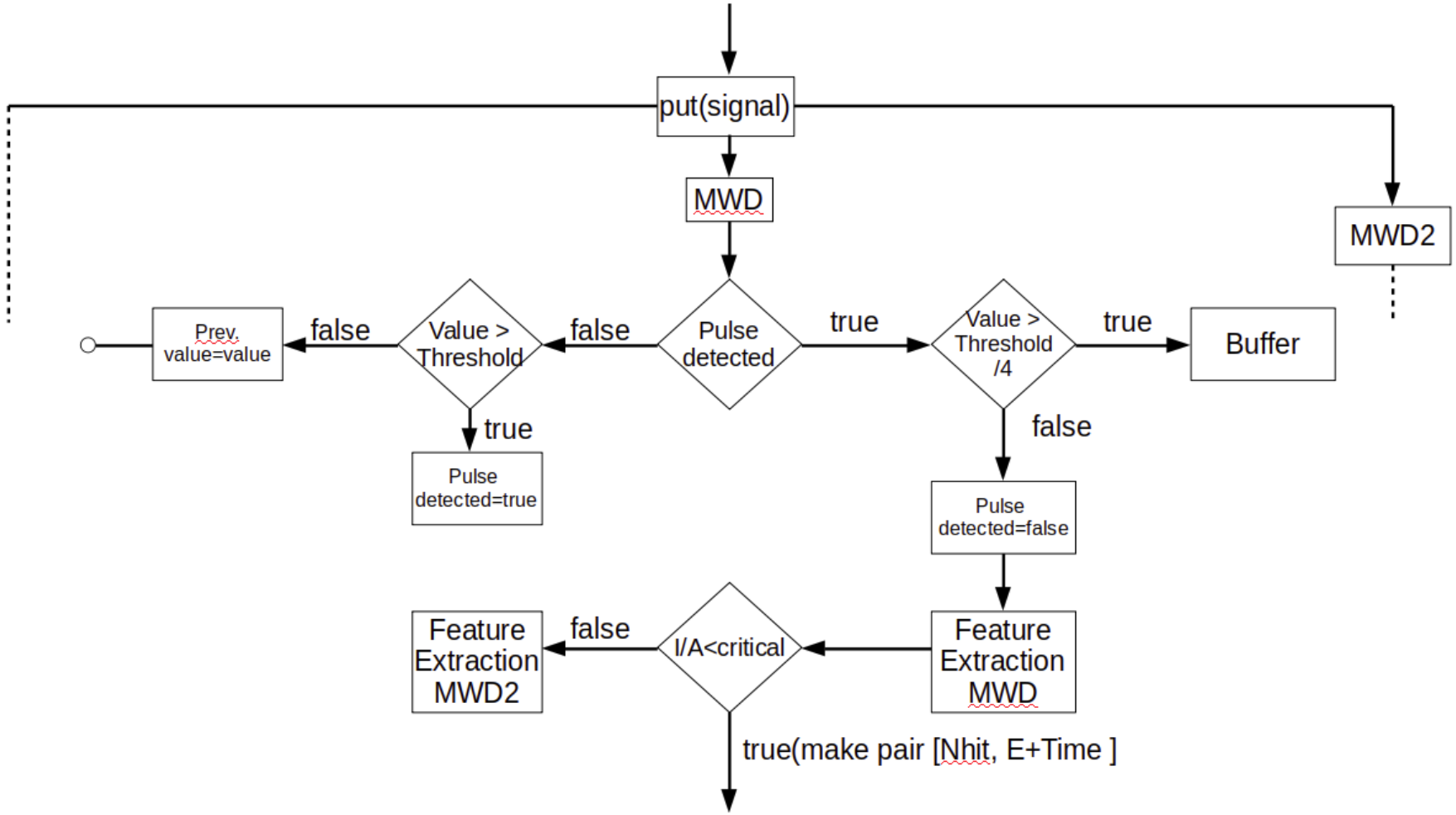
# Waveforms from Bochum

The Bochum group produces the final version of FwE EMC subunits.

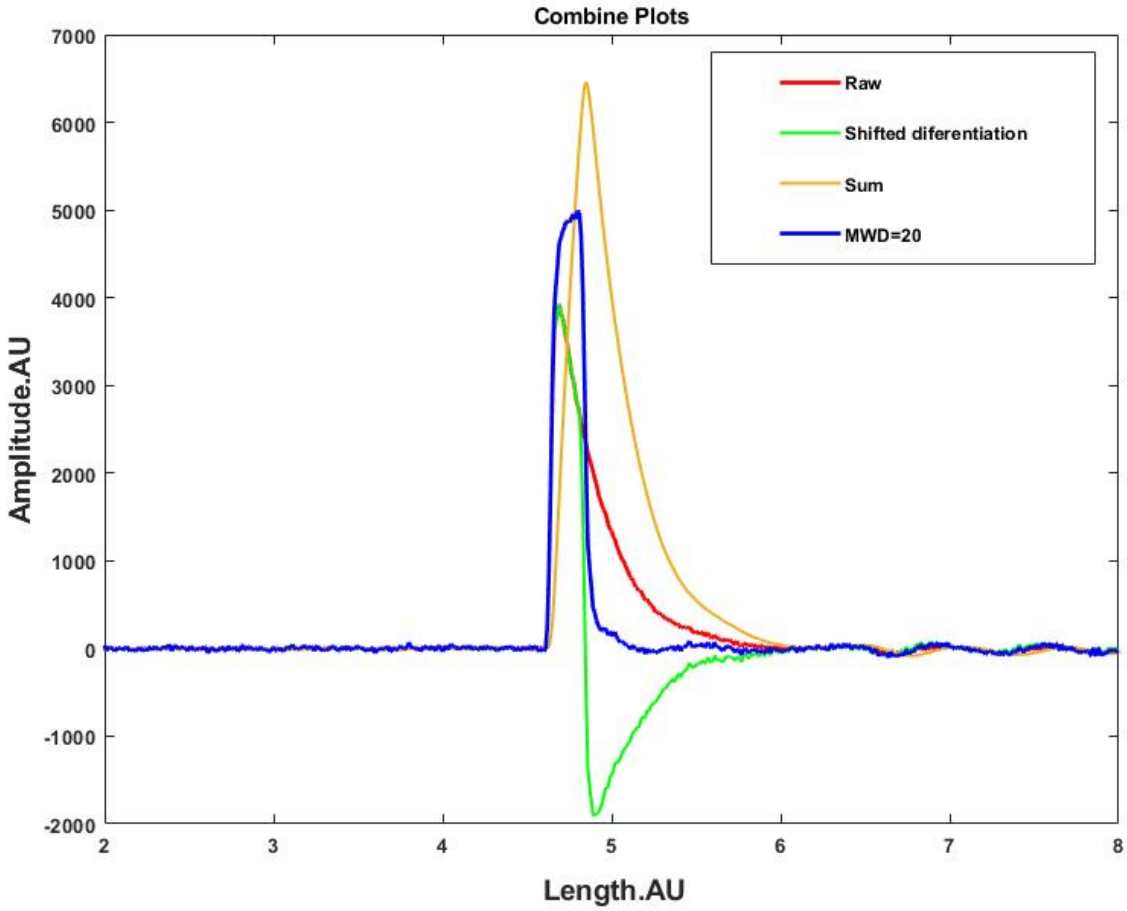
4 data files with waveform events corresponding different energy (10 MeV – 12 GeV) have been sent to us from their side.

Each data file contains more than 700 events. Each event represents the output from 32 APDs with Highgain and Lowgain channels – in total 64 waveforms per event.


PndEmcFWEndcap Digi
PndEmcHighLowPSA
PndEmcPSAFPGA SampleAnalyser
PndEmcPSAFPGA PileupAnalyser
GetActiveWaveform
create
Process( theWaveform )
PndEmcDigi
GetSignal
Put( signal )
GeHit
GetHit( iHit, energy, time )
new Digi


put(signal)
MWD
MWD2
Prev. value=value
false
Value > Threshold
false
Pulse detected
true
Value > Threshold /4
true
Buffer
true
Pulse detected=true
false
Pulse detected=false
Feature Extraction MWD2
false
I/A<critical
Feature Extraction MWD
true(make pair [Nhit, E+Time ]

# MWD and MA filters




Shifted differentiation

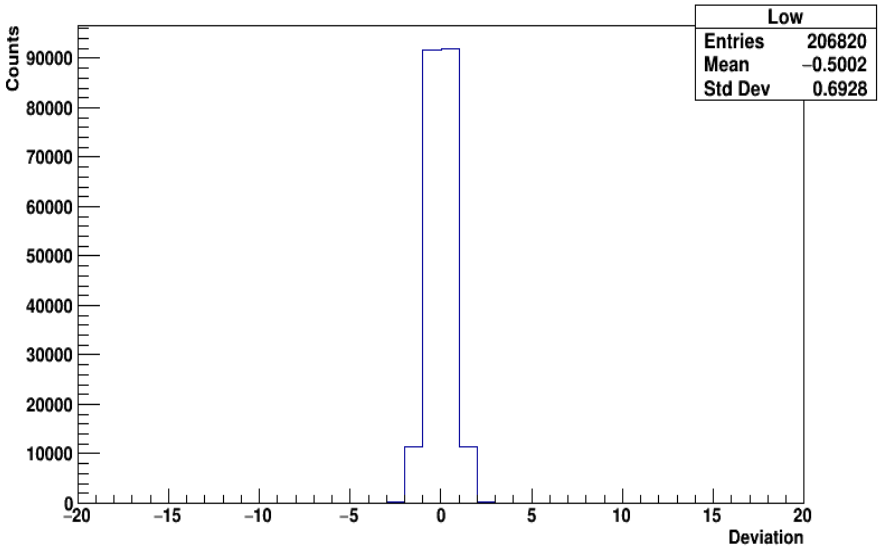
$$x[n] - x[n-m]$$

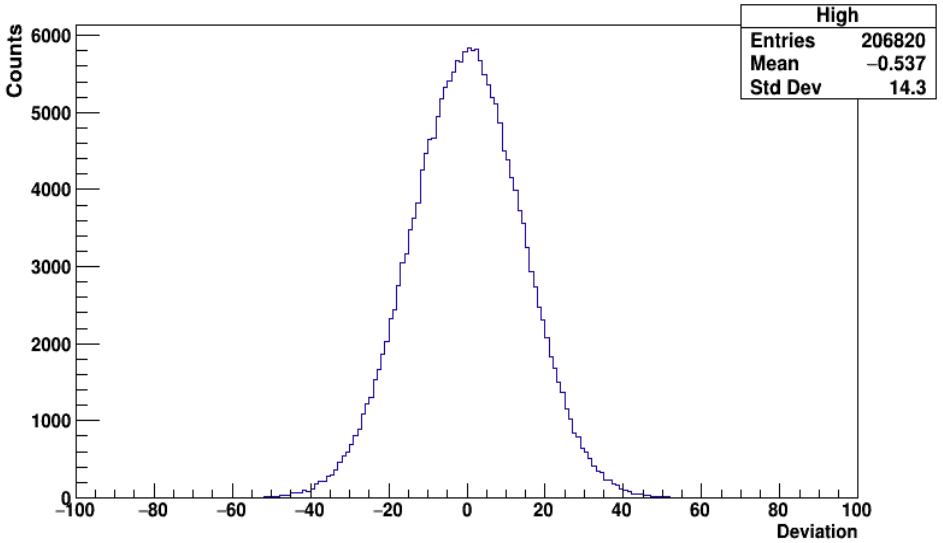
Sum

$$\frac{1}{\tau}\sum_{i=n-m}^{i-1} x(i)$$

# Noise measurement

Similar procedure has been done in Pandaroot to study the noise level. Discrepancy was observed.




## Lowgain

Mean -0.5002
Std Dev 0.6928

## Highgain

Mean -0.537
Std Dev 14.3