First Results from T3B

Calice AHCAL Meeting – Desy, January 2011

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Max-Planck-Institute for Physics

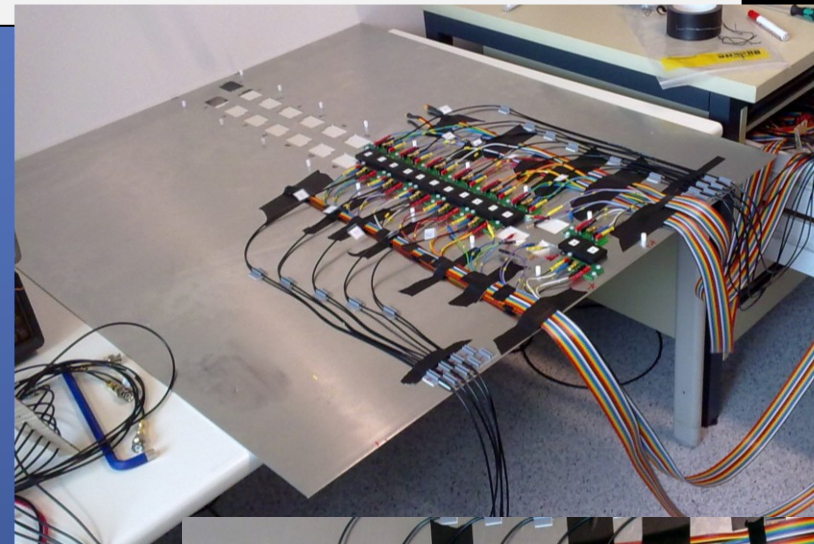
Outline

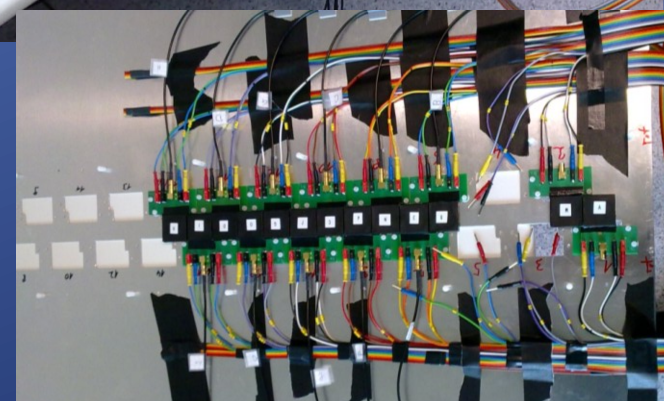
- Overview of T3B (Tungsten Timing Test Beam)
- Creation of an Analysis Framework
- Software Triggering
- Waveform Rejection: Filters
- First Steps Towards Calibration
- Where we want to go: Timing Analysis
- Summary

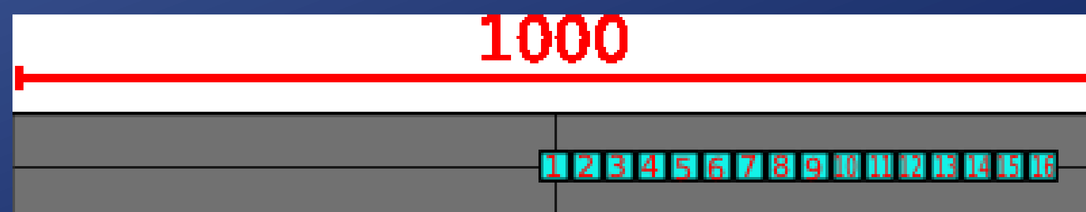
OVERVIEW OF T3B

The Test Beam Setup of T3B

- One layer = row of 15 scintillator tiles
- Tile size: 3 x 3 x 0.5 cm^3
- SiPM: Hamamatsu MPPC-50C
- Readout: 4 x PicoScope 6403
    - Fast Digitizer (1.25GSa/s on 4CH)
    - Deep memory (1GSa)
    - Fast data capturing (up to 1MHz)

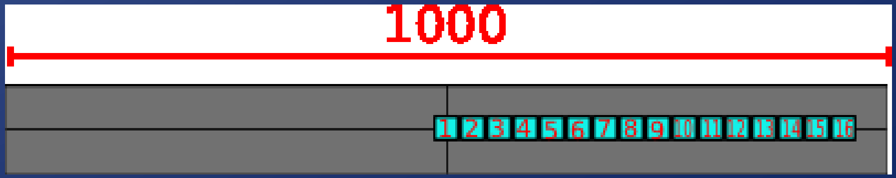


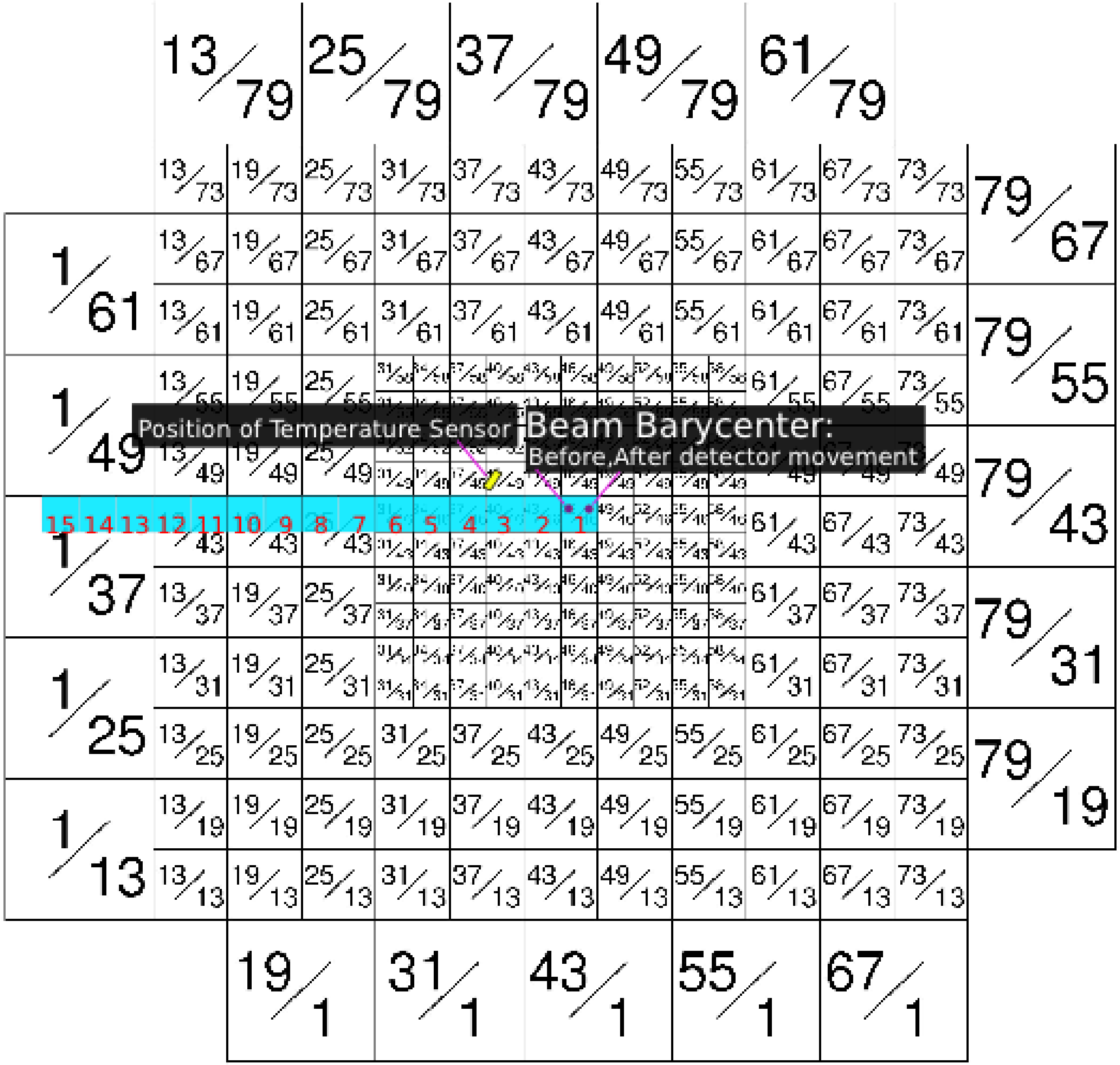




T3B as parasitic experiment in CALICE

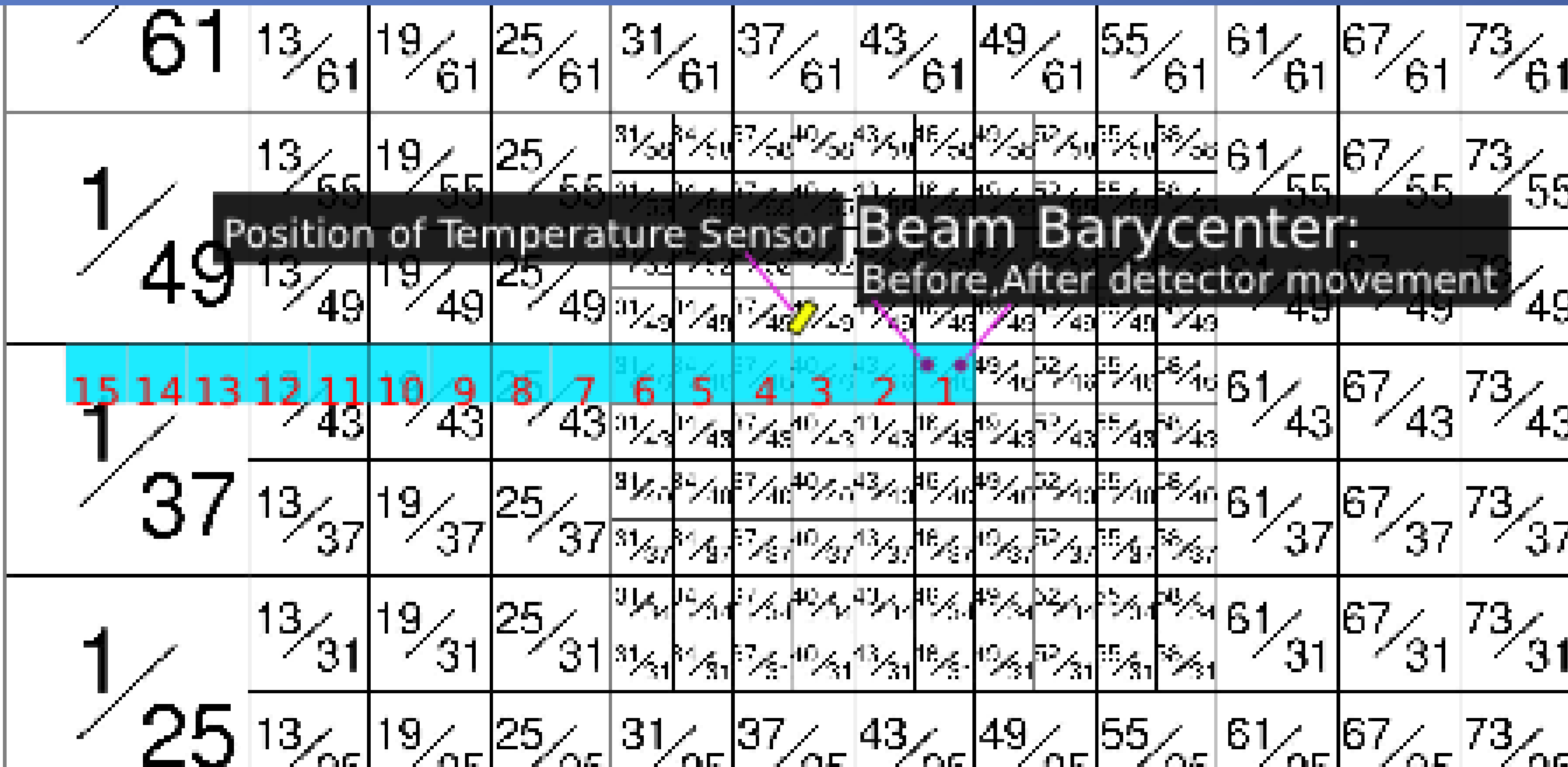
- T3B Layer positioned behind the CALICE W-HCAL
- Testbeam in Nov 2010 @ CERN PS
- Particle composition: Hadron mix (e,mu,pi,K,p)
- Energy range: 2-10GeV





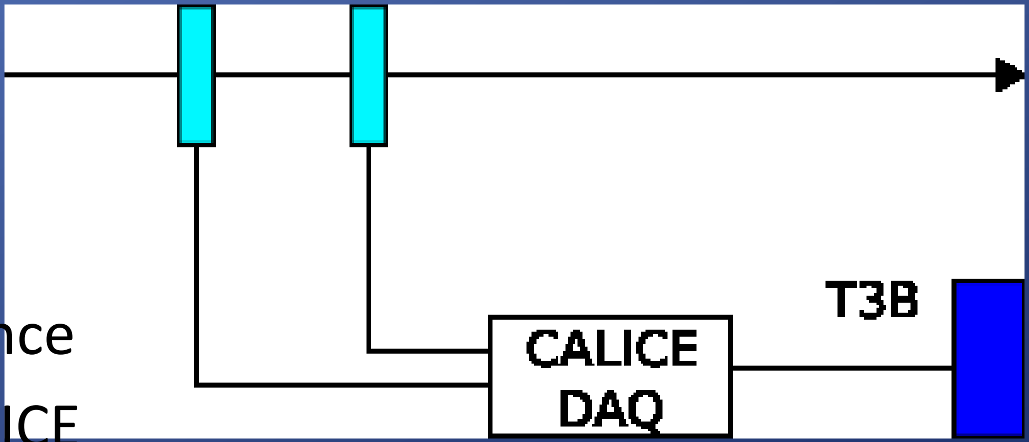
Position of Temperature Sensor
Beam Barycenter:
Before,After detector movement
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

T3B Strip Position



CALICE <-> T3B: Synchronisation

- Goal: Use CALICE HCAL to determine shower start information
  - T3B events need to be in sync with CALICE



- Trigger Setup:
  - CALICE Trigger on Scintilltor Concidence
  - T3B Trigger on CALICE
  - T3B monitors Scintillator Coincidence on one channel

CREATION OF AN ANALYSIS FRAMEWORK

The T3B Analysis Framework

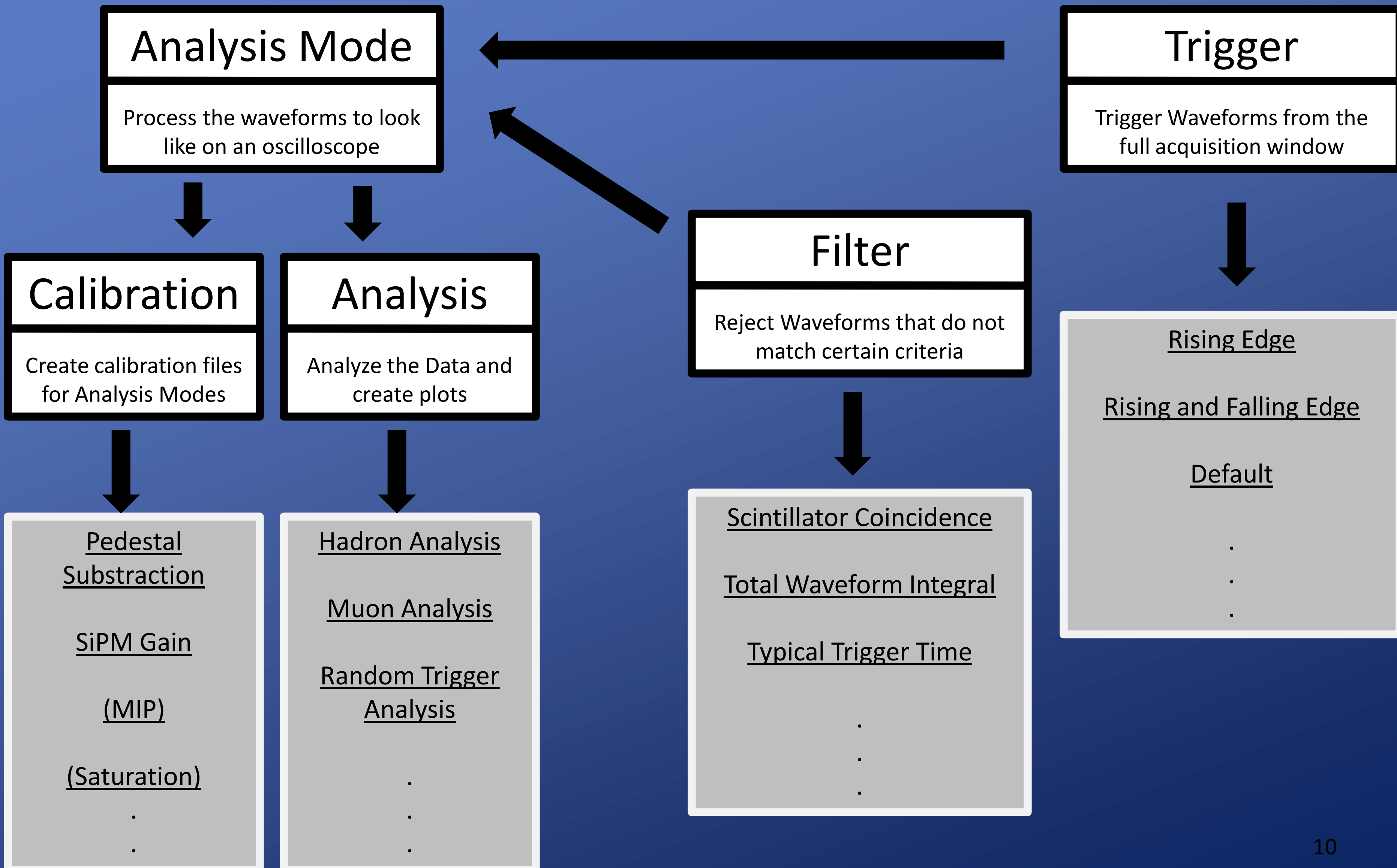
The T3B Analysis Framework is written in object-oriented C++ using the STL, ROOT and QT Core libraries

Main Tasks (so far stand-alone T3B):

- Easy and efficient access of the data taken during the TB period
- Calibrate the raw Waveforms (from ADC bits)
- Cycle through the Waveforms and extract the Info of interest
- Analyze the Waveforms and Create Plots
- Designed to be modular and easily extendable (work in progress…)

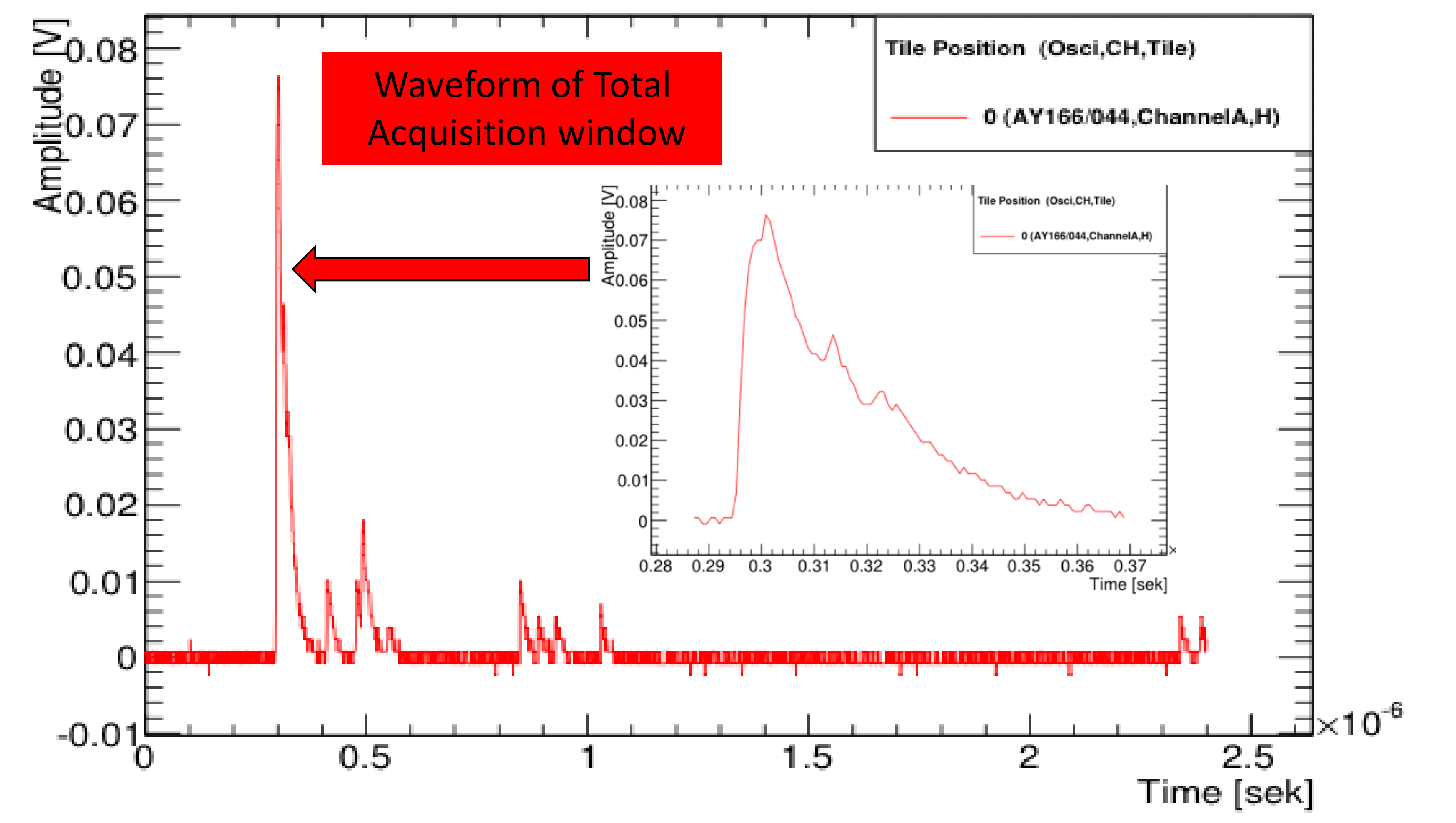
Provide a set of Analysis Modes, Software Triggers, Filters and Access Classes (e.g. for the Temperature Information, Pedestal Substraction…)

The Analysis Framework: Overview



SOFTWARE TRIGGERING

T3B Framework: Trigger



Software Trigger: Rising and falling edge

- Extract acquisition window if sample above and later below threshold
- Time resolved triggering of individual energy depositions

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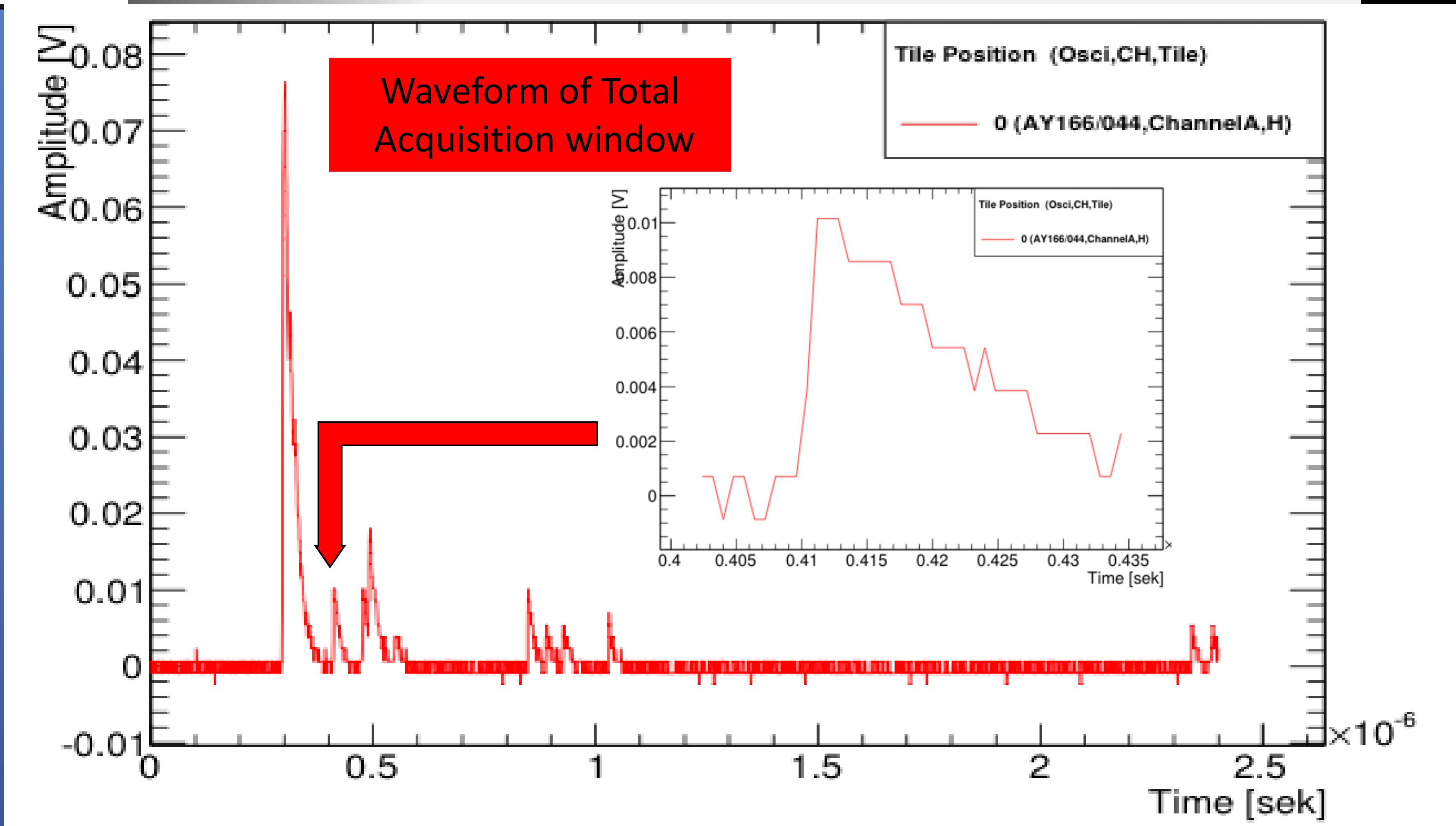

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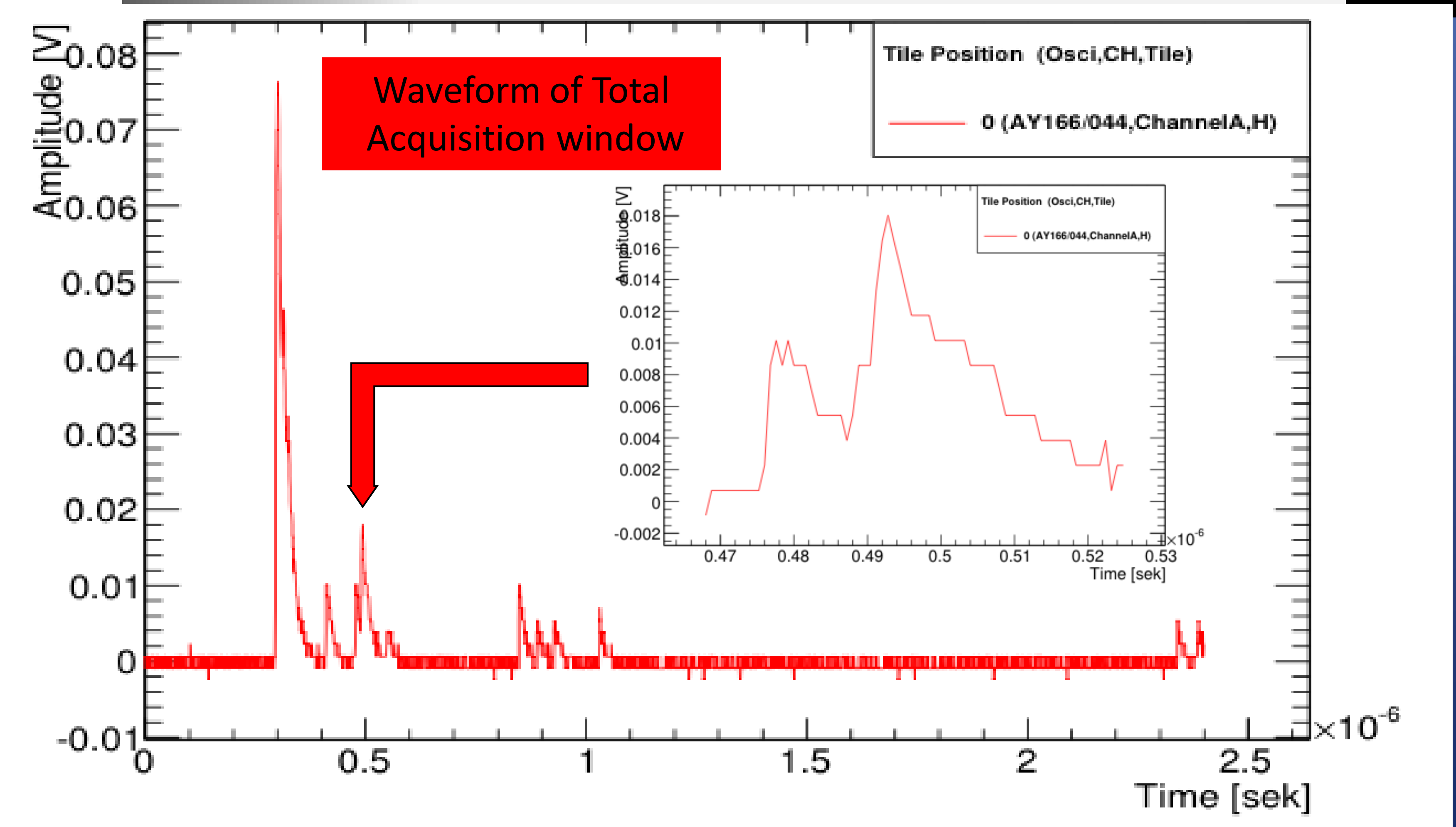

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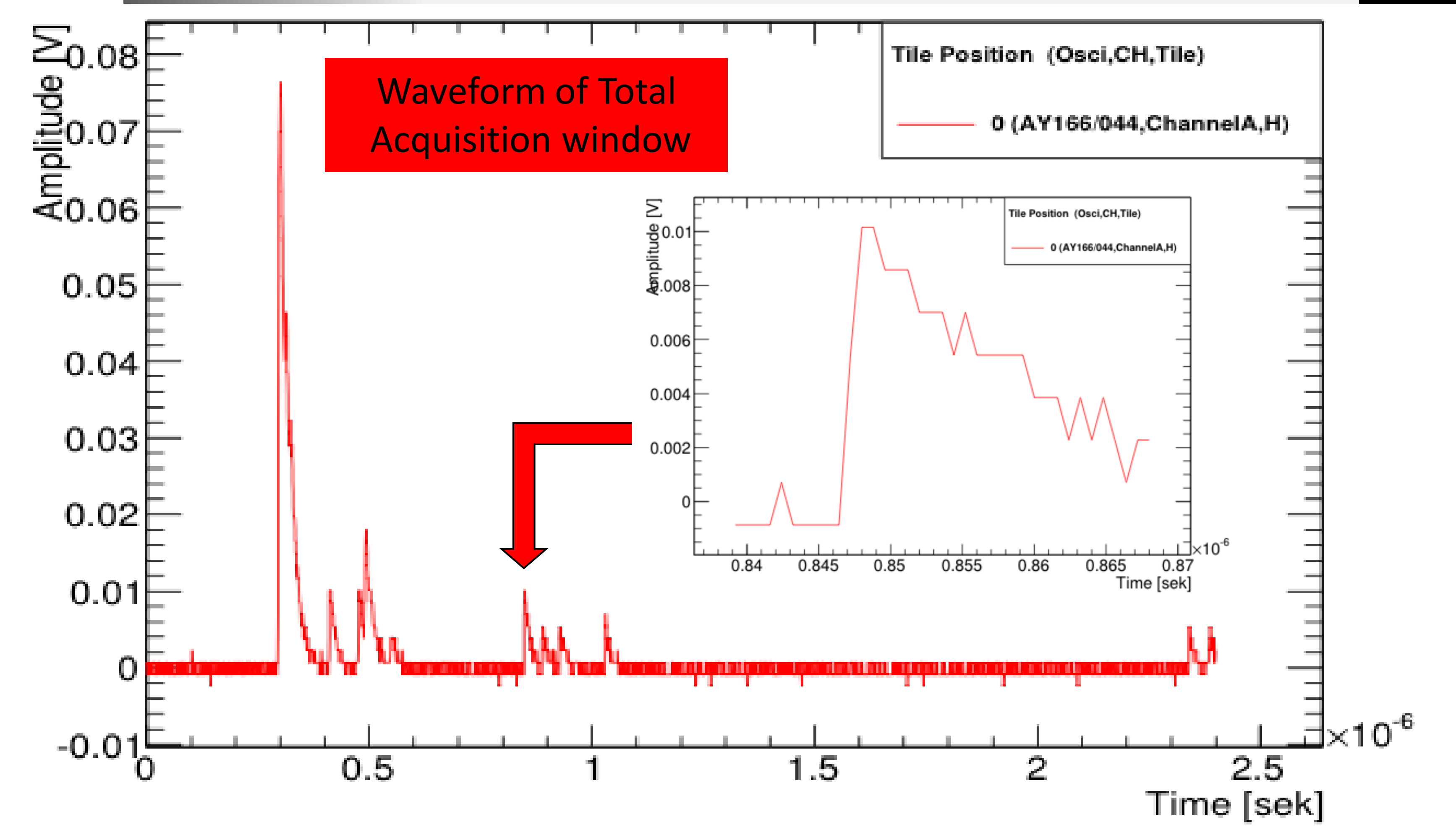

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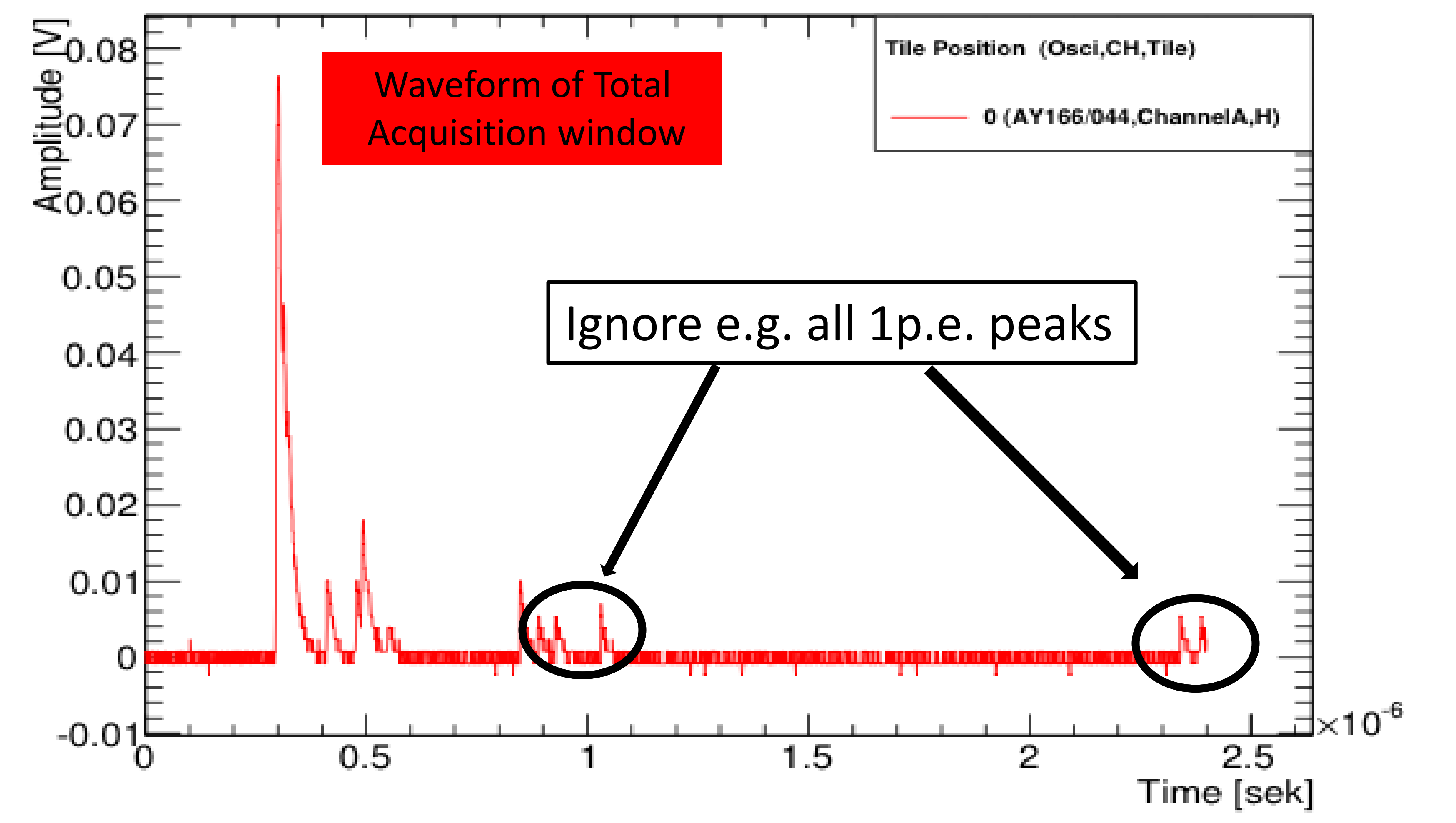


Software Trigger: Rising and falling edge

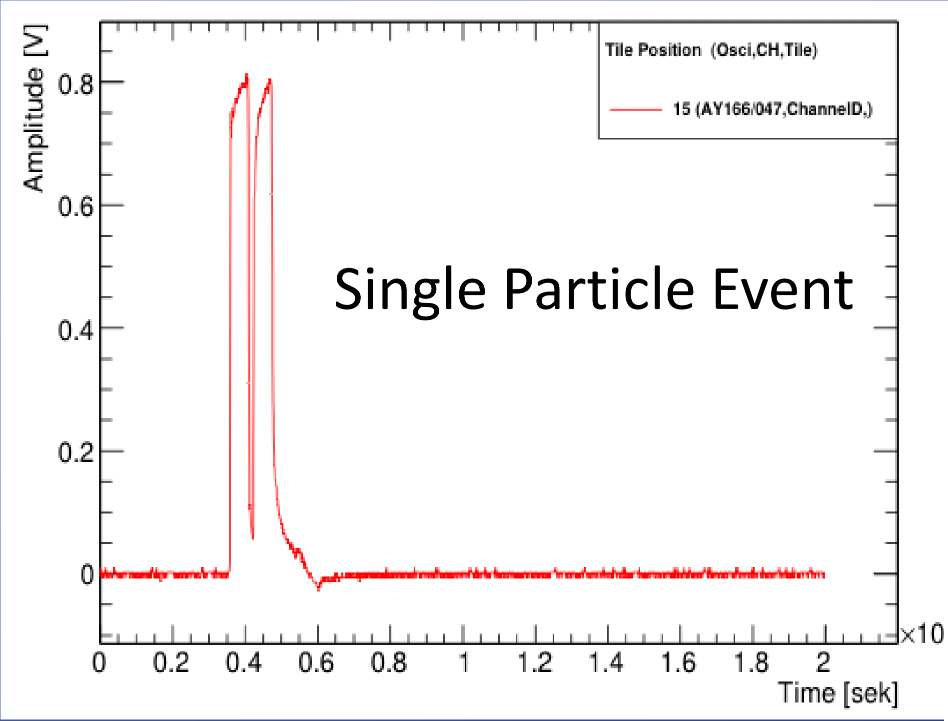
- Extract acquisition window if sample above and later below threshold
- Time resolved triggering of individual energy depositions

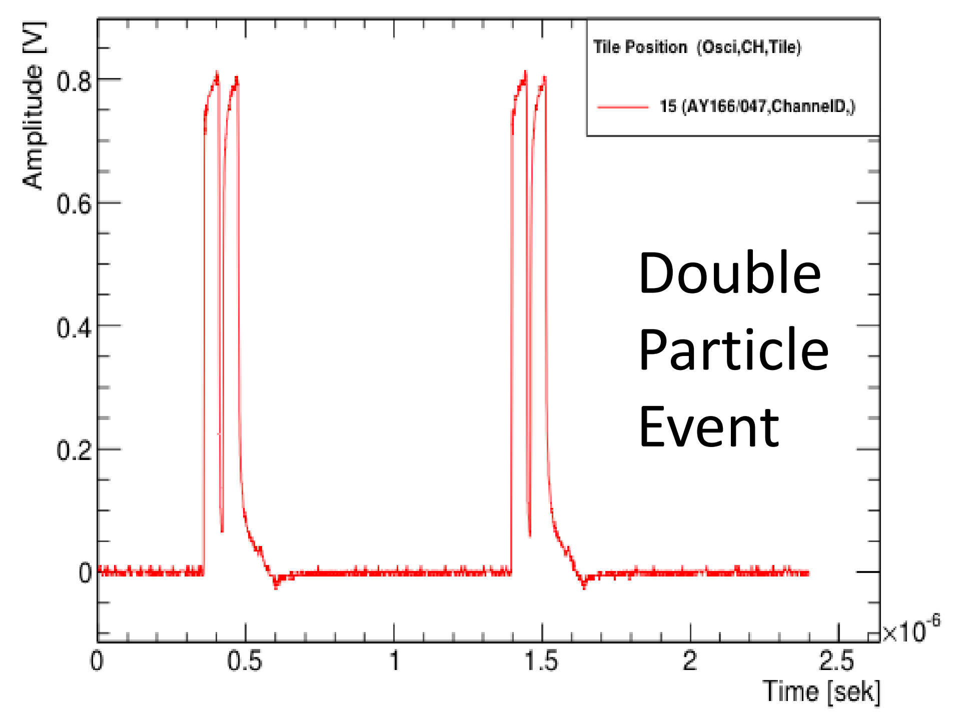
WAVEFORM REJECTION: FILTERS

T3B Framework: Filter

The 16th T3B Channel was connected to the scintillator coincidence signal in front of CALICE

Unfortunately, we had a cable reflection in the NIM Signal → Double Signal = 1 particle



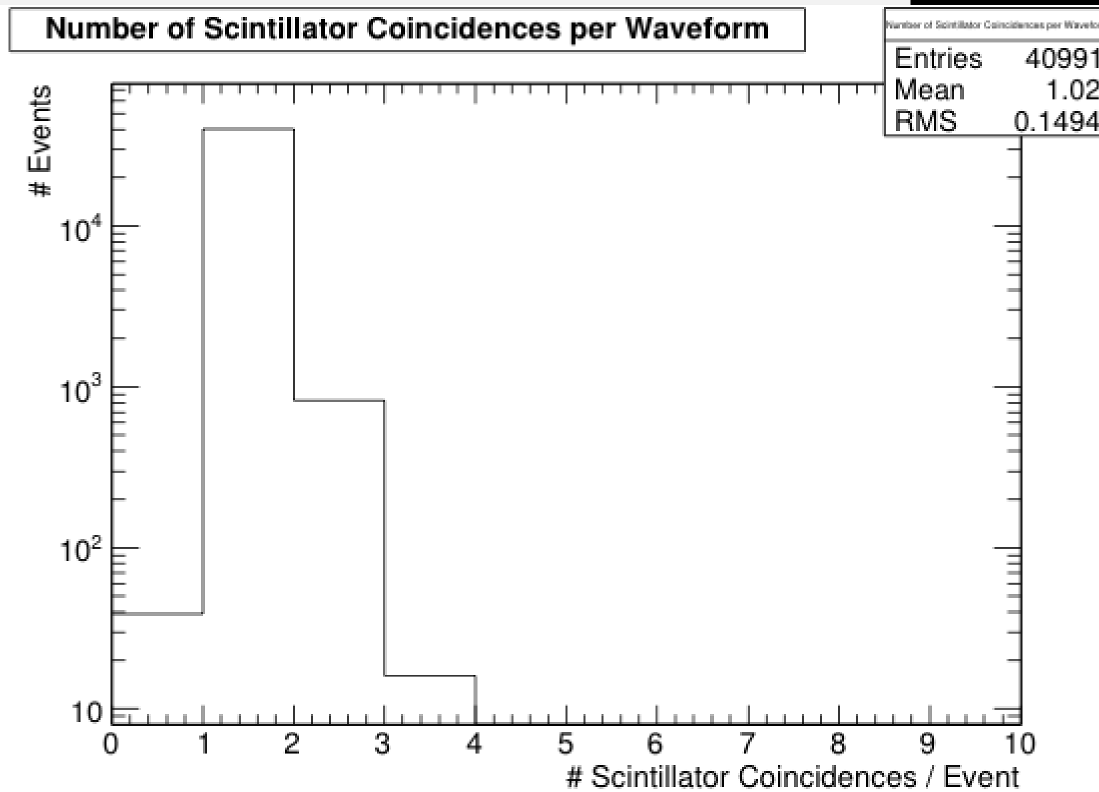


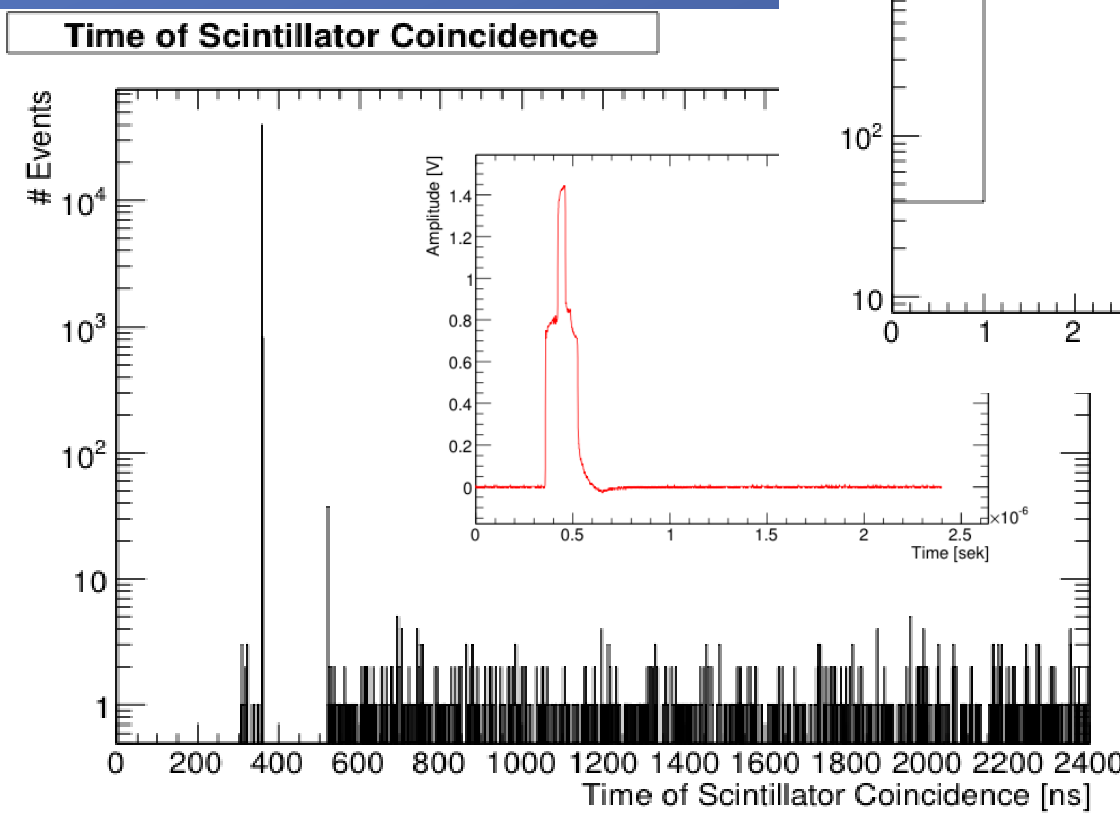
Scintillator Coincidence Filter:

- All Events which contain a number of coincidences != 1 are rejected
- Protection from multiple hits in one event
- Additional noise rejection

T3B Framework: Filter

1 Particle Ev: 97.85%
2 Particle Ev: 2.02%
3 Particle Ev: 0.04%
0 Particle Ev: 0.09%

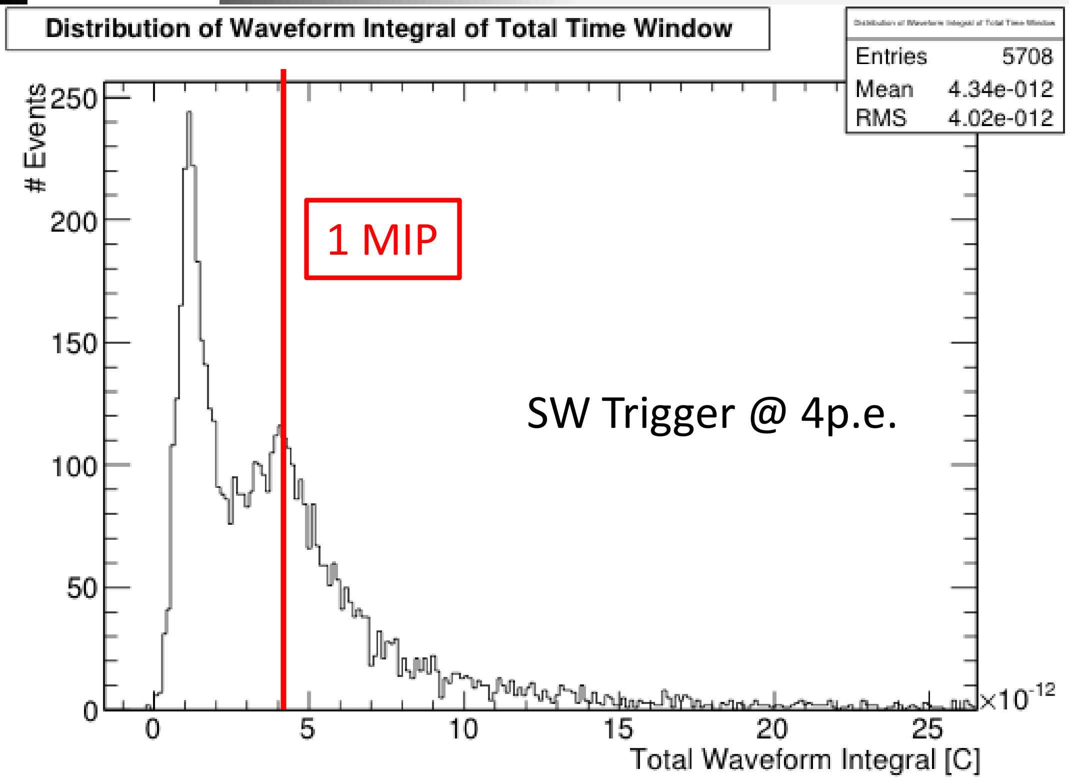


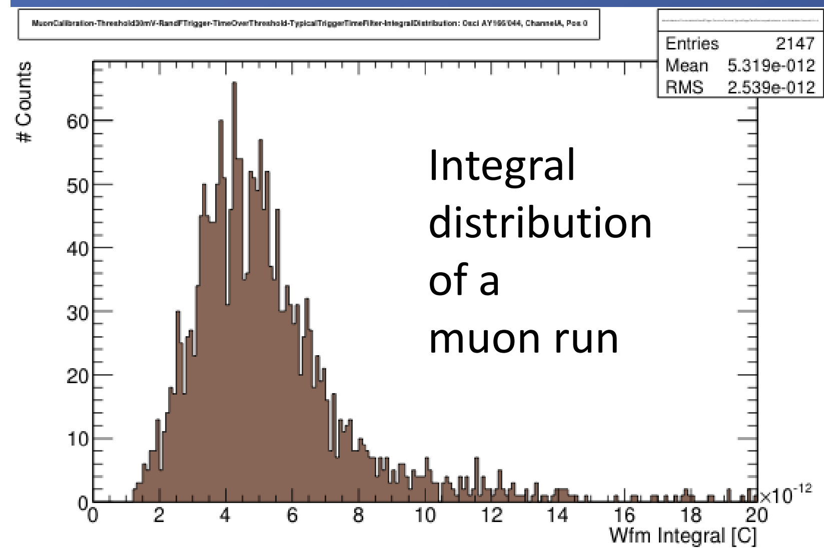


Multi-particle hits equally distributed over time

Gap due to hold-off time
Can be avoided in next step
… to be continued

T3B Framework: Filter





Total Waveform Integral Filter:

- All Waveforms with a total Waveform Integral (in full acquisition window) below the minimum of the distribution (at 0.6MIP) are rejected
- Efficient way to reject noise events
- Only possible with a dedicated pedestal substraction (see later)

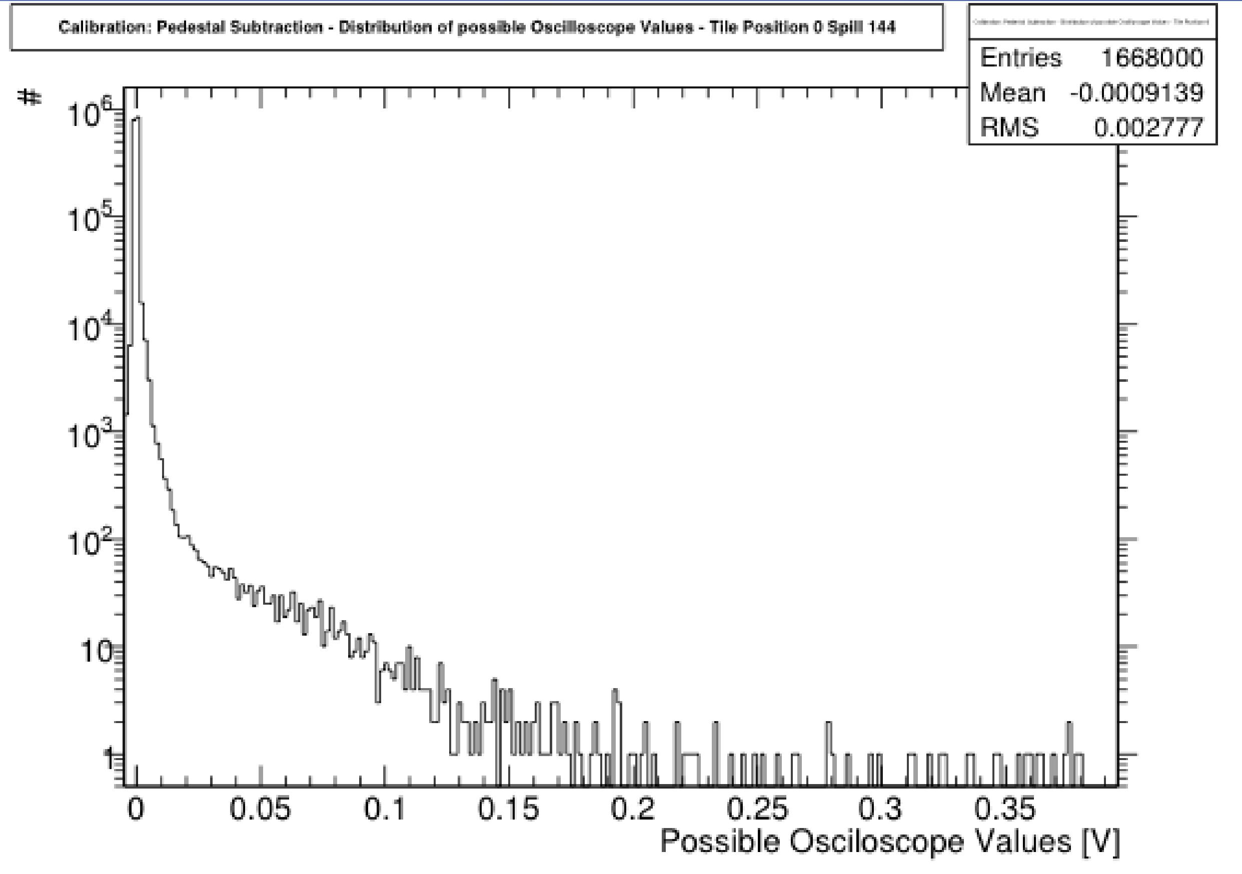
so far just coarse estimation → requires fits (Langau)   work in progress…

FIRST STEPS TOWARDS CALIBRATION

T3B Framework: Calibration

Calibration Mode: Pedestal Substraction

The disadvantage of recording so many “zeros” is an advantage for this calibration mode



Procedure:

Determine the distribution of all possible oscilloscope values

→Extract the bins which contain more than 5% of all histogram entries (mostly 2-3 bins)

→The mean equals the pedestal

→Pedestal value is determined on a spill by spill basis for each channel

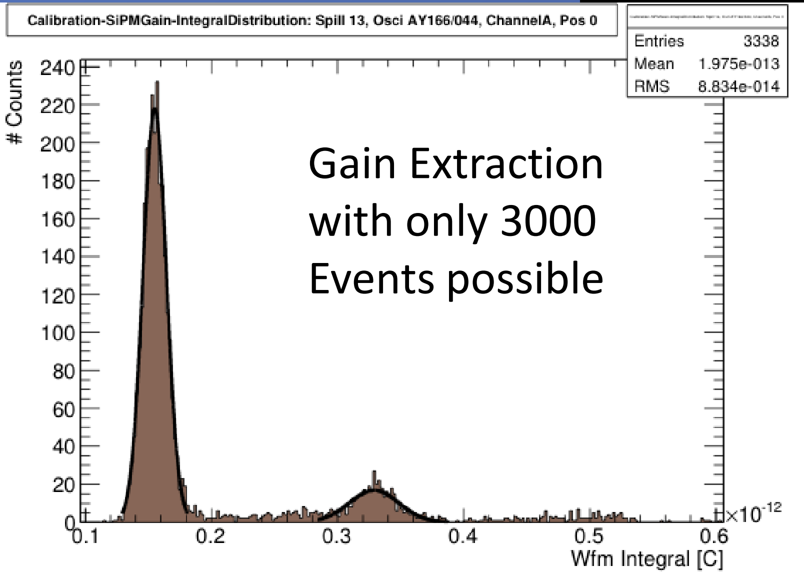
Procedure proved to be very stable

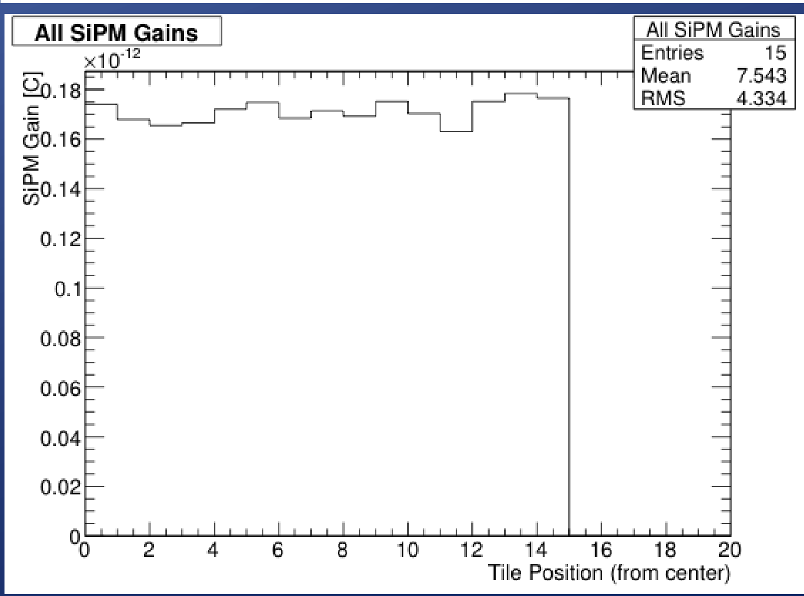
T3B Framework: Calibration

Calibration Mode: SiPM Gain

- We have ~125 Darkrate Events per Channel after each spill processing
- ~3000-4000 Events suffice for SiPM Gain extraction
- choose 31 Spills
  → one independent gain calib value every ≈ 12minutes (assuming on average 2 Spills per supercycle)

Very high gain extraction efficiency (≈100%)



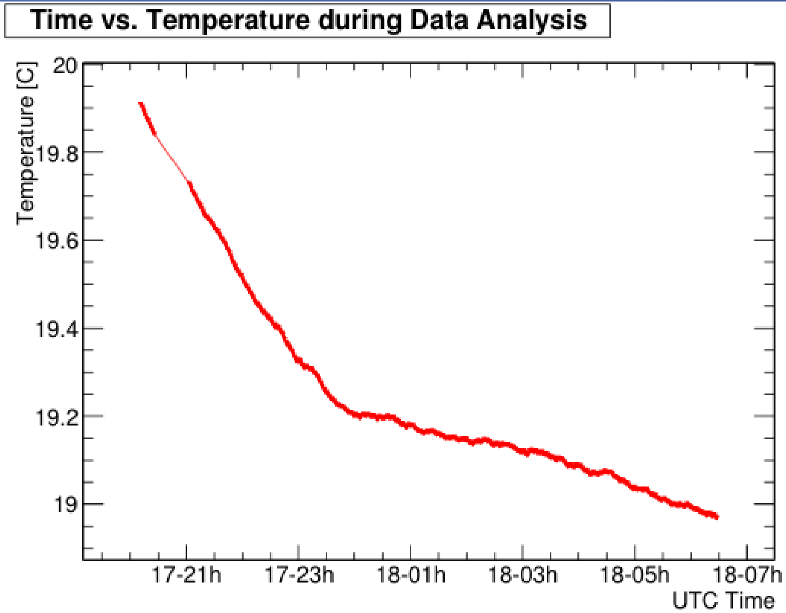


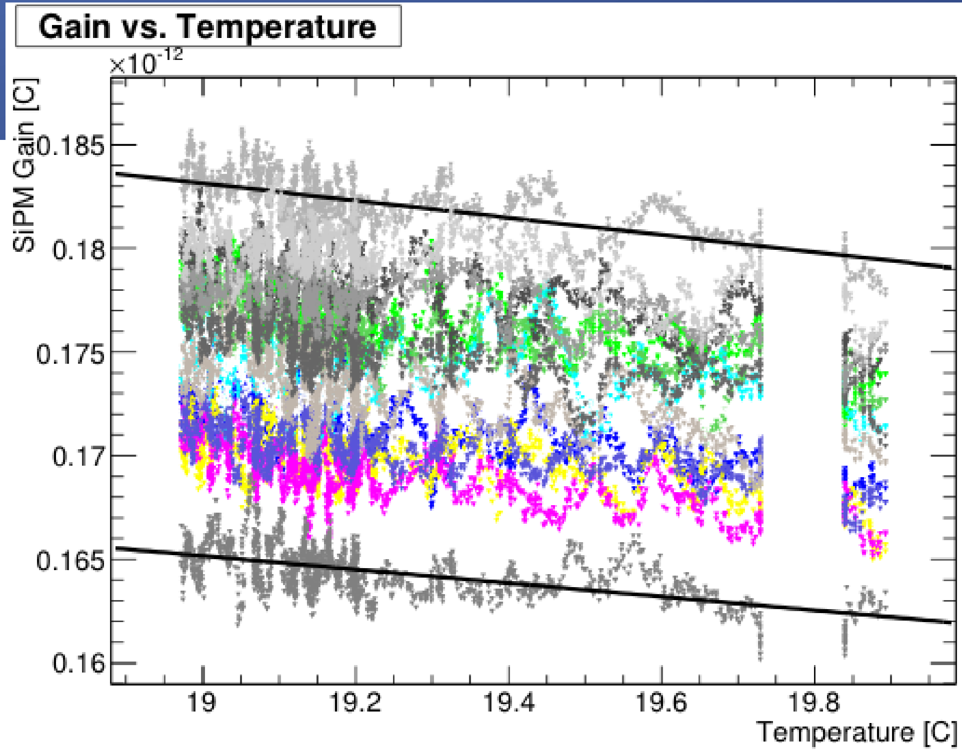
T3B Framework: Calibration

Long Term Stability of Gain Extraction:

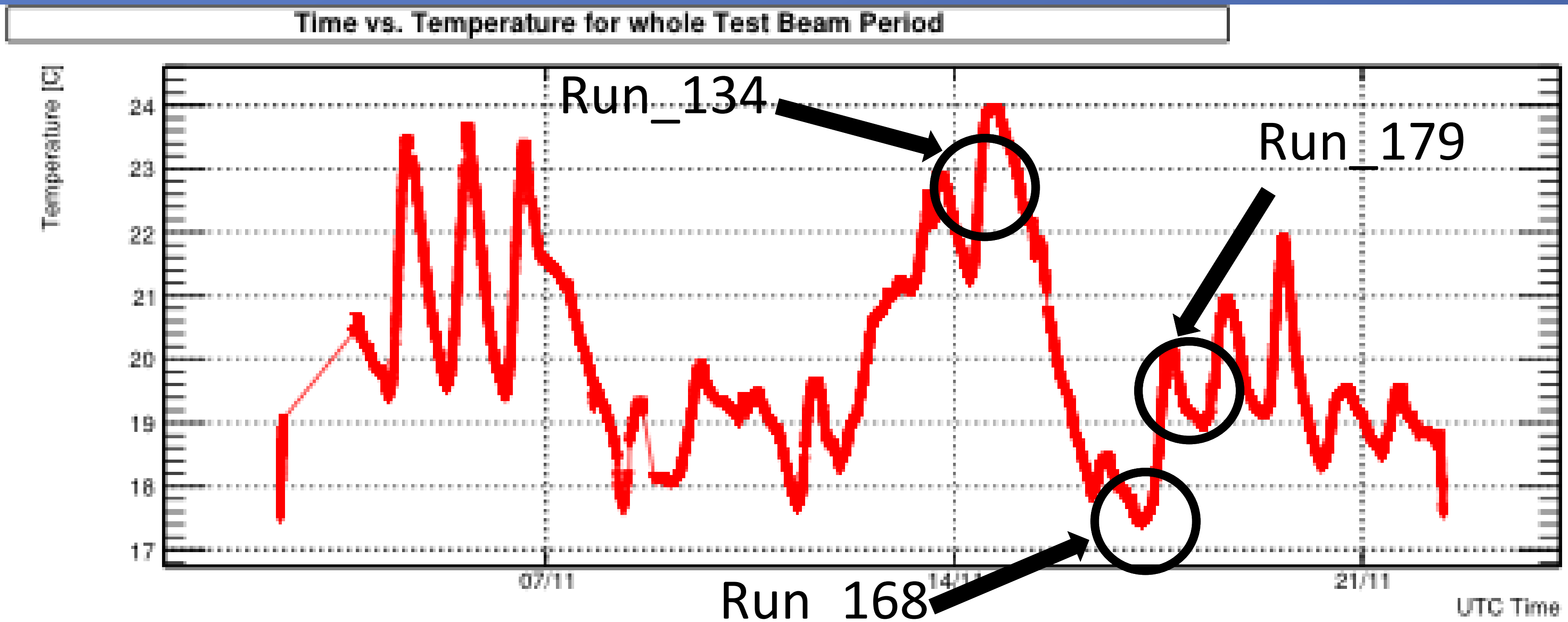
• Choosing Run_179 with 2100 Spills

• Correct tendency of the gain-temperature can be seen at only 0.8C Temperature difference





T3B Framework: Calibration



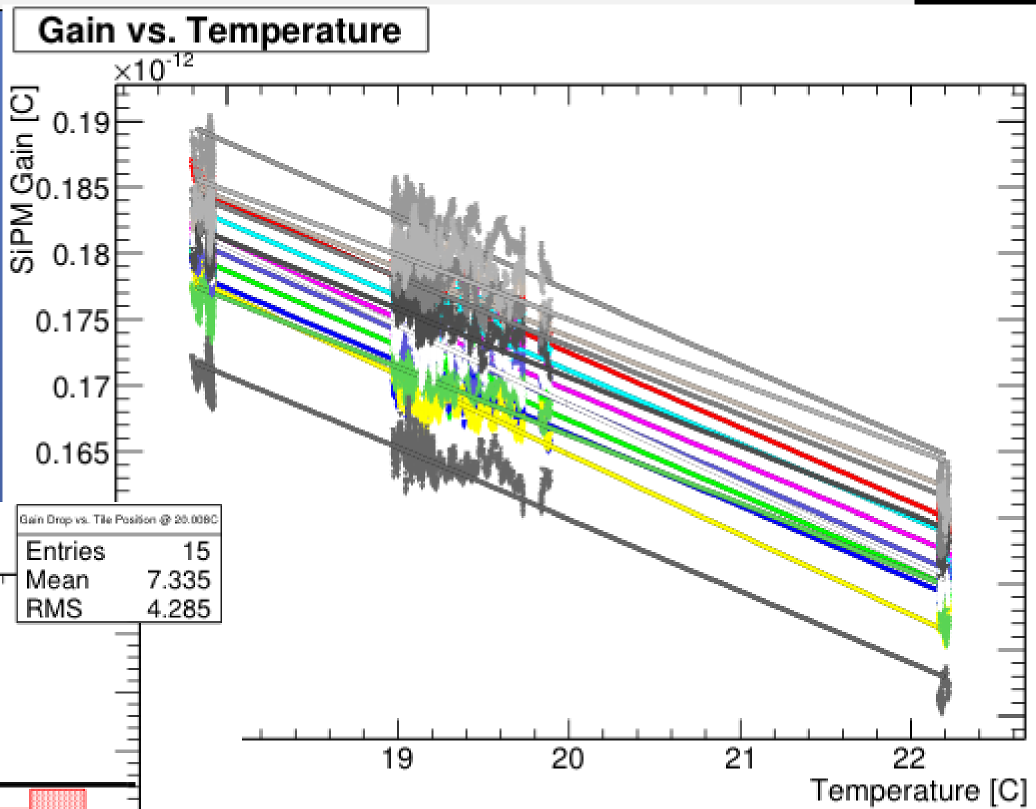
Wide Temperature Range of 17.5C-24C during TB Phase

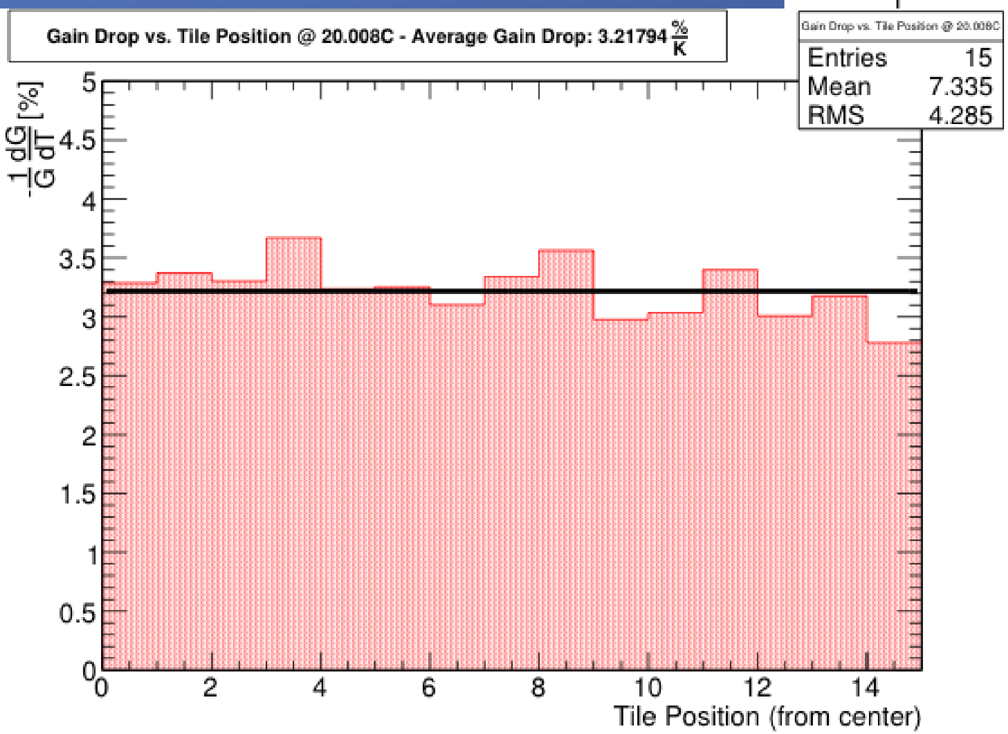
→ Choosing 3 good Runs with extreme temperatures

T3B Framework: Calibration

Gain Temperature Dependence for all channels

→Extracting the gain drop 1/G dG/dT from Fits





Average Gain drop of:

$$\frac{1}{G}\frac{dG}{dT} = 3.2\frac{\%}{K}$$

T3B Framework: Calibration

Next Steps:

- Gain extraction fit has still room for improvement → reduce fluctuations
- get SiPM Gain values for all runs

But:

- Gain Calibration is not the end of the story → Need MIP Calibration

- Test Bench: Gain-Amplitude Correlation

→ Measure #p.e./MIP with Sr90
(note: e- ≠ MIP but correlation identical)

→ Steer through different Bias Voltages and Temperatures and create dictionary

→ Obtain: $A(T,U_{Bias}) = c(T,U_{Bias}) \bullet G(T,U_{Bias})$

→ Check consistency for different cells

Perform a MIP Calibration using SiPM Gain Data

T3B Framework: Calibration

Further Challenges:

- **SiPM Saturation correction:**

  → Requires another Test Bench Setup, a calibrated low-intensity blue emitting LED, an efficient method to couple the light into the tile, and quite some time…

- **Correction for Afterpulsing:**

  → Need a dictionary: which pulse height causes on average which afterpulse contribution at a certain time after the initial pulse?

  Procedure:

  → Record cosmics and rare very high darkpulses
  → Average all waveforms in a certain pulse height range
  → Substract the extracted AC from the average energy deposition at a certain time

  Challenge:

  → Aquiring enough statistics requires a long term measurement
  → This was already done over the Christmas Holidays
  → Analysis is still to be done …

WHERE WE WANT TO GO: TIMING ANALYSIS

T3B Framework: Analysis

Long-term Goal: Measure the time resolved development of hadronic showers in a WHCAL

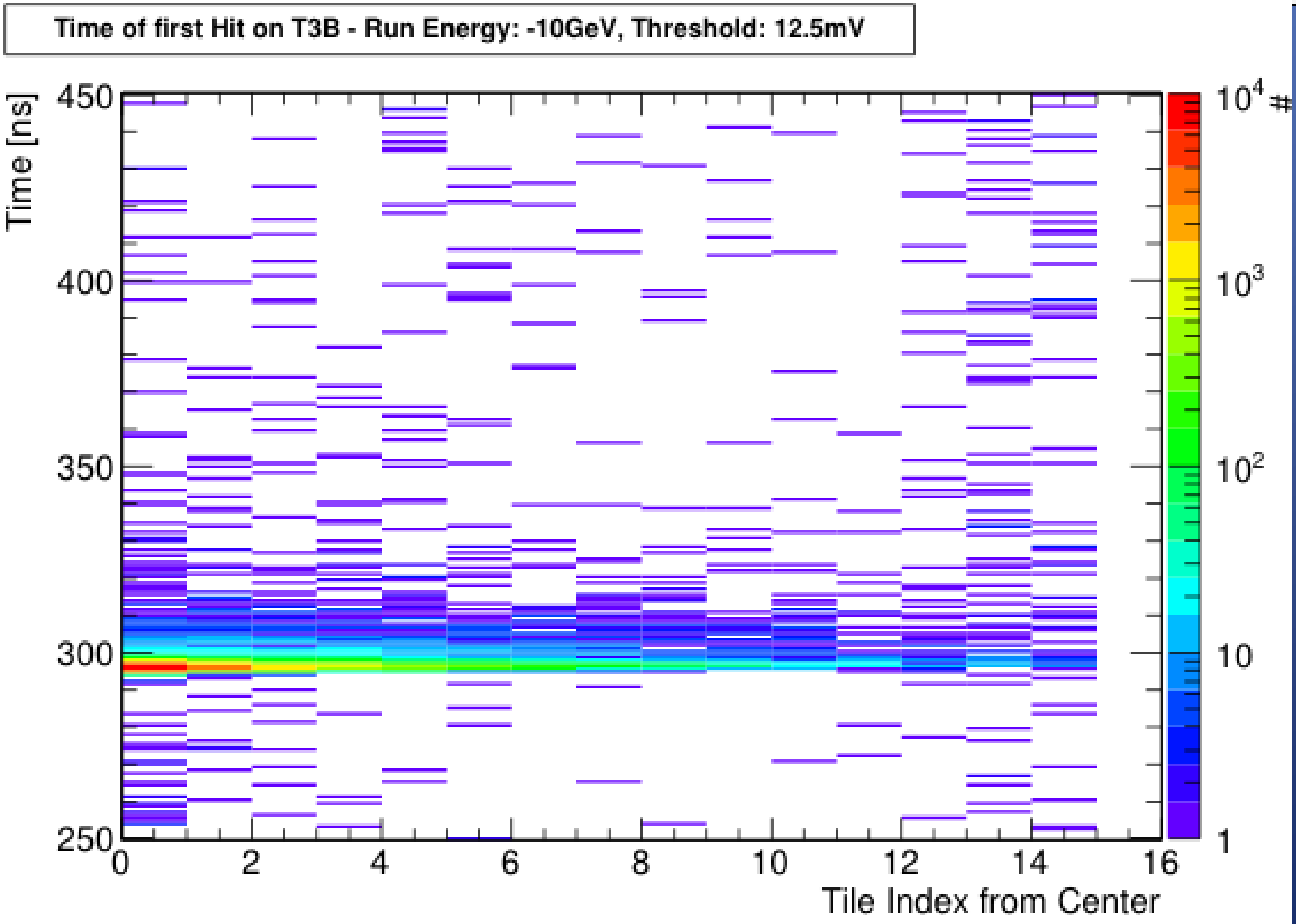
Important key parameters at CLIC:
Mean Time of First Hit, Mean Time of Hit, Energy Deposition vs. Time

The developed framework is capable of producing those plots, but a lot more work is to be done till they are perfectly reliable

Regard them as a first glimpse towards what's to come

Configuration: T3B Standalone Analysis
Particles: Hadron-Lepton Mix Energy: -10GeV
Statistics: 450.000 Events
Framework: Trigger: RisingAndFalling Thresholds: r: 2.5p.e. , f:0.5p.e.
Filter: Scintillator Coincidence, Total Waveform Integral (0.6MIP)
applied Calibration: Pedestal Substraction

T3B Framework: Analysis



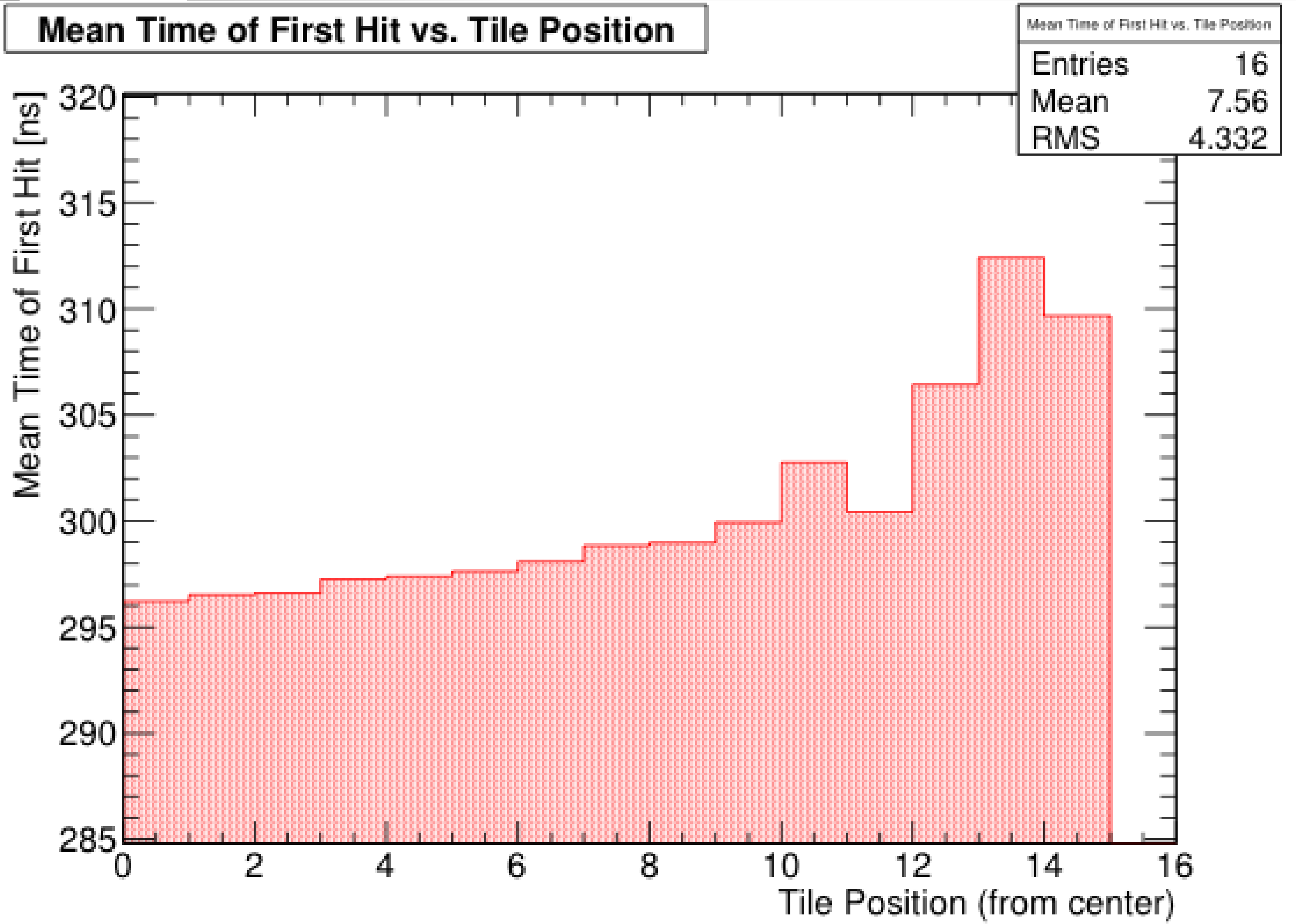
Time of First Hit:

Least biased by the incomplete calibration

Entries accumulate in a narrow region around the typical trigger time

Mean time of first hit increasing with distance from shower core

T3B Framework: Analysis



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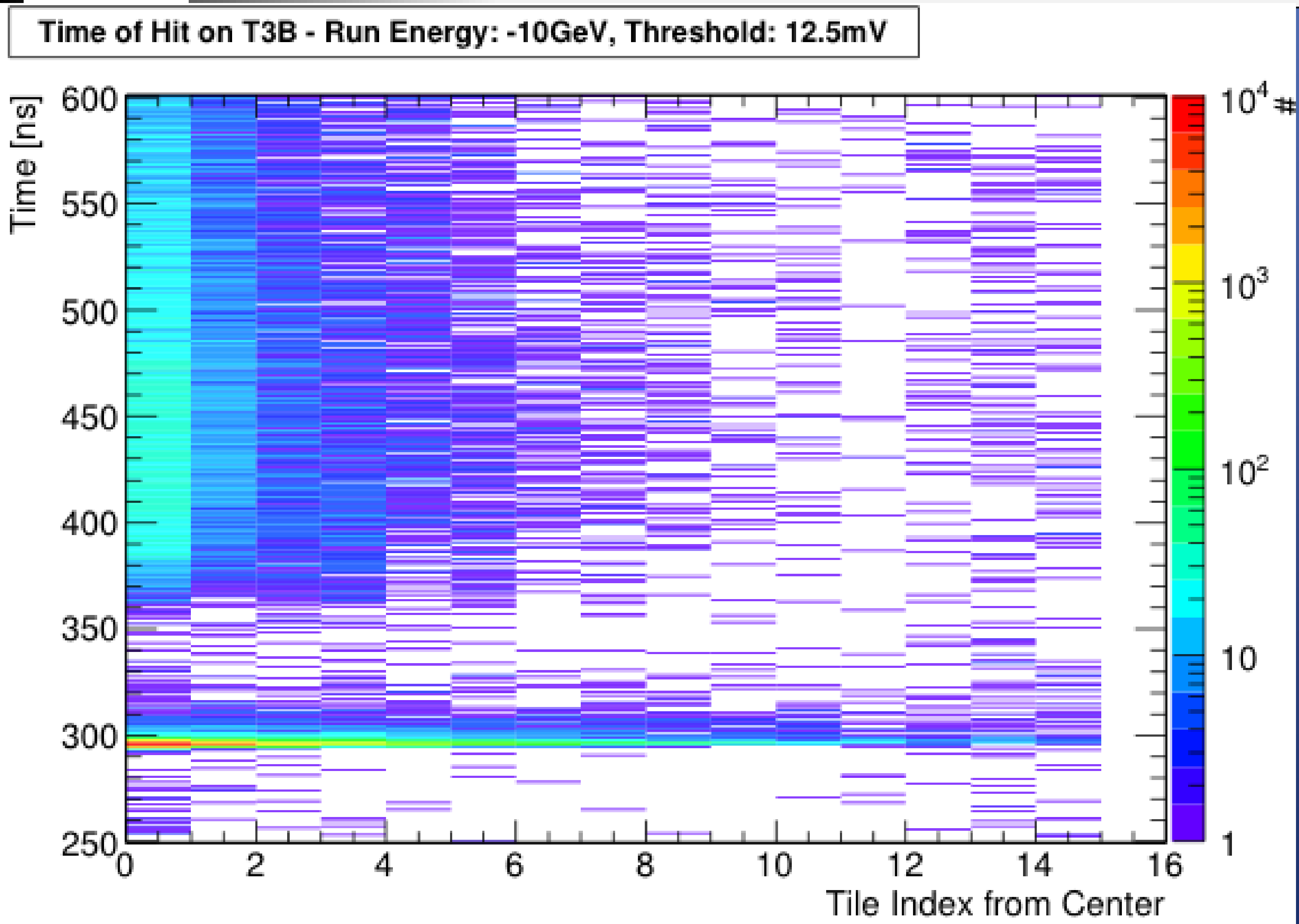

Time of Hit:

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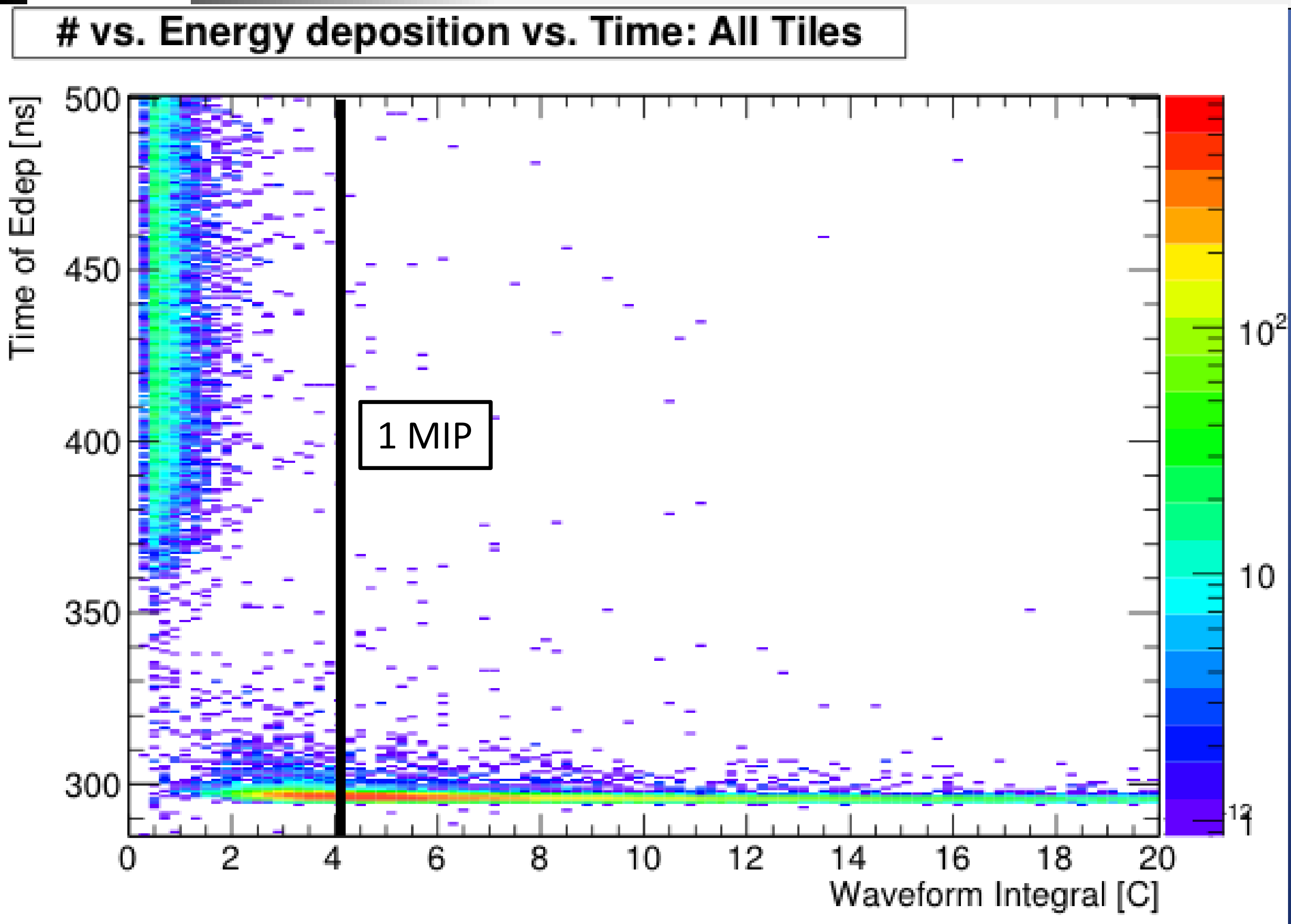
Afterpulsing contribution not yet accounted for

Time Gap:
Typical Signal Width
Software trigger waits for falling threshold

T3B Framework: Analysis



EDep vs. Time

High energy depositions are mostly within first 10-20ns

Few late Edeps above 1MIP, mostly below 0.5MIP

Afterpulsing and Saturation correction will have influence

SUMMARY

Summary

Achieved so far:

- Started development of an Analysis Framework for T3B (so far standalone)
- SiPM properties require dedicated analysis methods (Dakrate, Afterpulsing, T-dependence…)
- First set of Software Triggers, Waveform Filters and Data Access classes available
- Pedestal Substraction and SiPM Gain Calibration (through DR) works and seems stable

  → Both values available for each spill and each channel

There is still a lot of work to do:

- Complete the missing calibration steps (MIP, Saturation, Afterpulsing)
- Continue working on synchronization with CALICE

  → Needed for shower start and particle ID
- Simulate T3B events and develop a digitization procedure
- Compare simulation and data

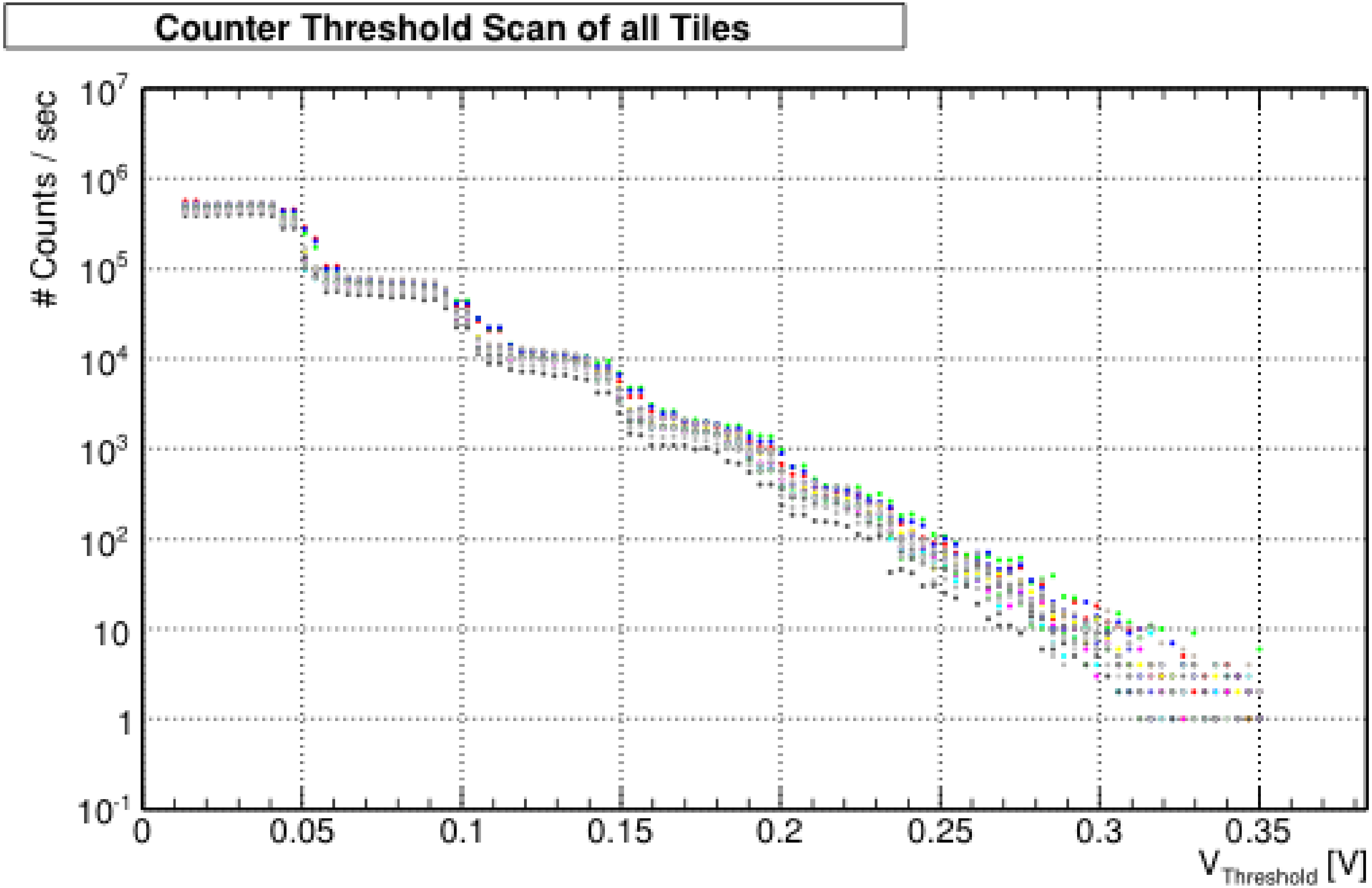
Special Thanks to:

- Frank Simon and Lars Weuste, whose commitment at CERN Commissioning and at Data Analysis
- The CALICE AHCAL Group, whose permanent support

Make this experiment possible!

BACKUP

Backup: CTS



Counter Threshold Scan of all Tiles
Counts / sec
10^7
10^6
10^5
10^4
10^3
10^2
10
1
10^{-1}
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
$V_{Threshold}$ [V]

Backup: CTS

Counter Threshold Scan of all Tiles

Tile, Rate@#p.e.

H, 1: 497308, 2: 67922, 3: 10848, 4: 1735, 5: 290, 6: 93, 7: 10,

D, 1: 485237, 2: 71970, 3: 11040, 4: 1927, 5: 372, 6: 60,

G, 1: 495108, 2: 70095, 3: 11346, 4: 1826, 5: 353,

C, 1: 462947, 2: 63806, 3: 9840, 4: 1616, 5: 303,

N, 1: 452474, 2: 62205, 3: 9557, 4: 1463, 5: 246,

B, 1: 478922, 2: 65735, 3: 10118, 4: 1615, 5: 277,

R, 1: 503667, 2: 68143, 3: 10271, 4: 1674, 5: 264, 6: 64, 7: 9,

L, 1: 531862, 2: 76155, 3: 12196, 4: 2029, 5: 325, 6: 65,

Q, 1: 542689, 2: 77169, 3: 12610, 4: 2121, 5: 370,

A, 1: 397765, 2: 49708, 3: 6973, 4: 1038, 5: 148,

E, 1: 483323, 2: 65765, 3: 10003, 4: 1584, 5: 245,

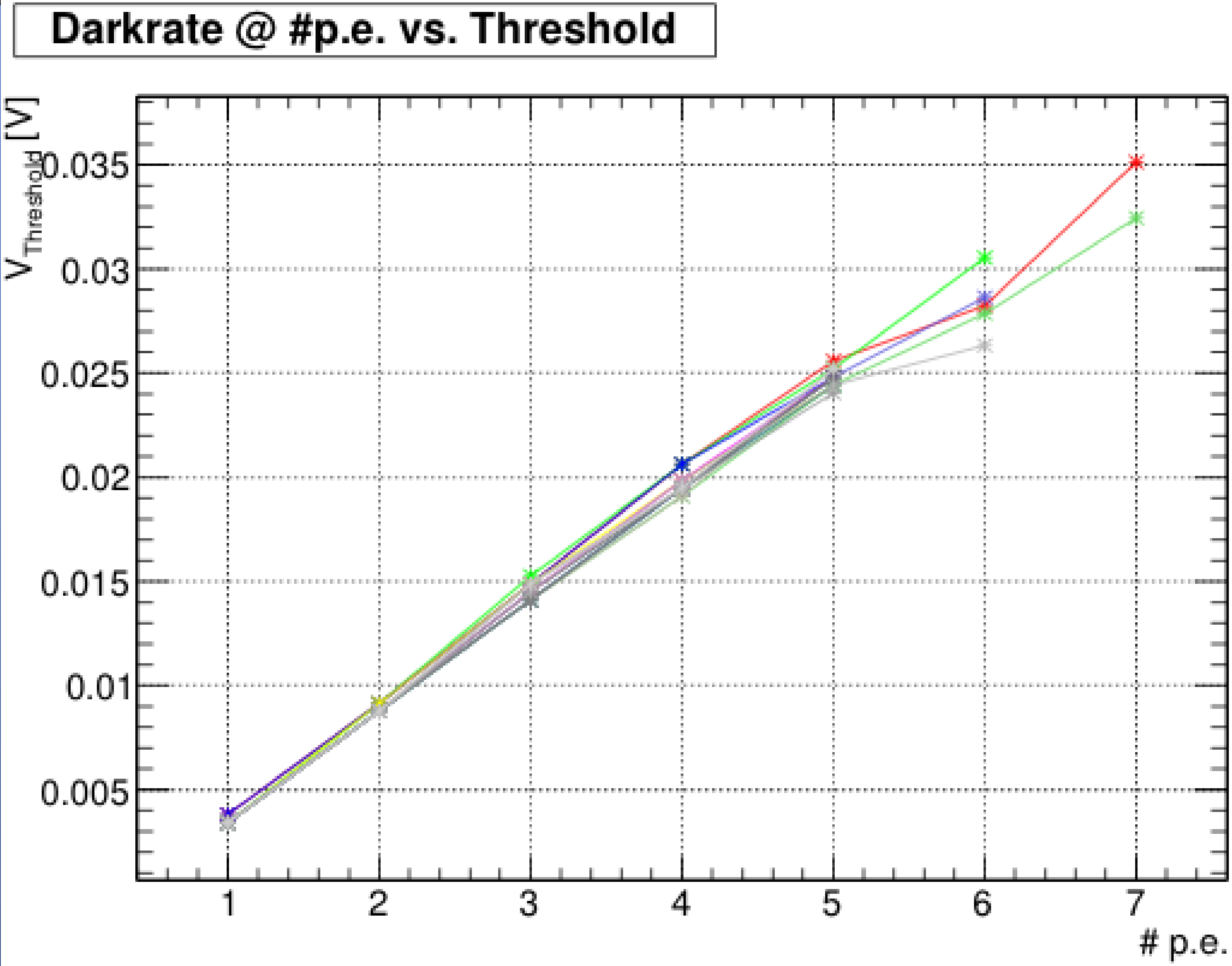
P, 1: 496048, 2: 68351, 3: 10486, 4: 1693, 5: 271,

J, 1: 467084, 2: 64208, 3: 9573, 4: 1632, 5: 298,

O, 1: 426415, 2: 55881, 3: 8281, 4: 1210, 5: 216, 6: 131,

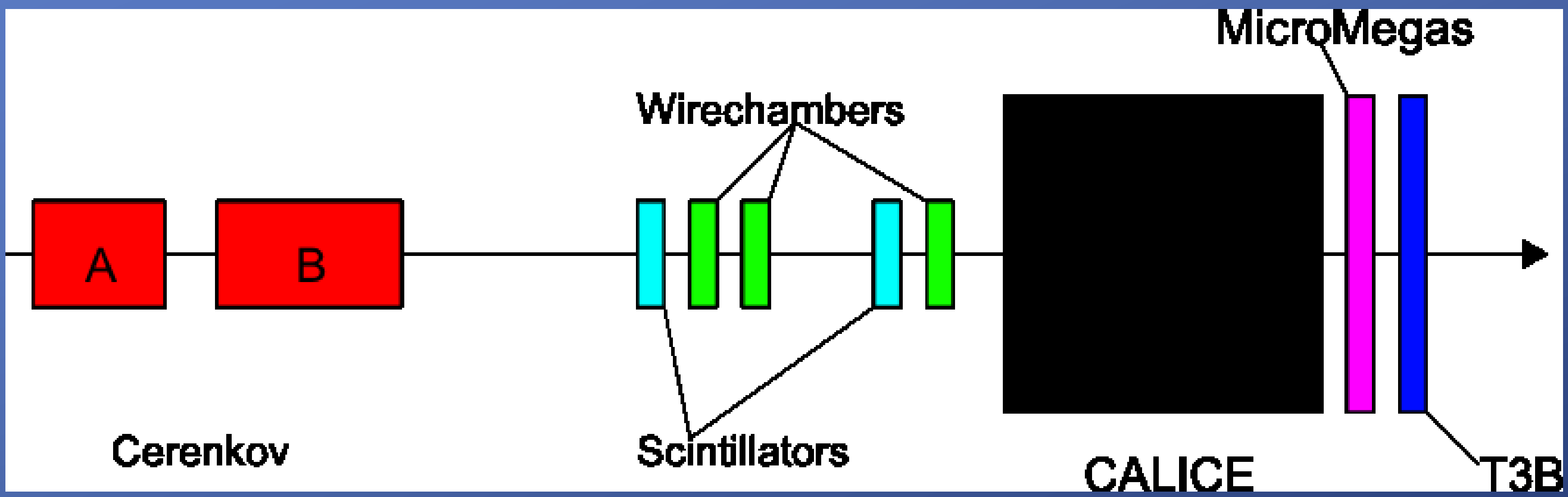
I, 1: 453875, 2: 61432, 3: 9000, 4: 1510, 5: 234,

Backup: CTS


Darkrate @ #p.e. vs. Threshold
V_Threshold [V]
0.035
0.03
0.025
0.02
0.015
0.01
0.005
1
2
3
4
5
6
7
p.e.

OLD BACKUP

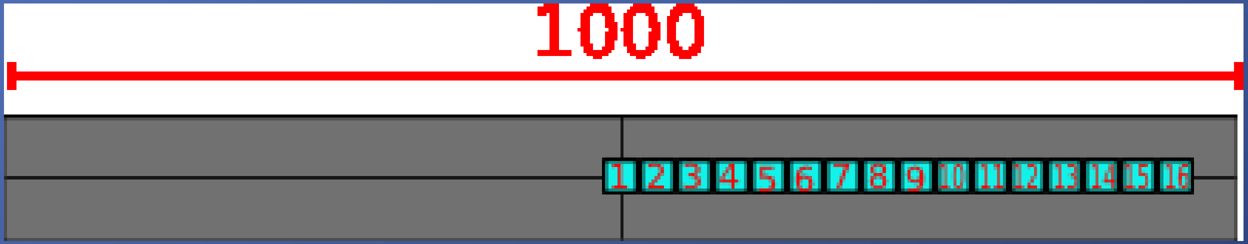
Testbeam Setup November 2010



- Cerenkov used for particle ID
- MicroMegas in front of T3B

Recap: Aims of the T3B Experiment

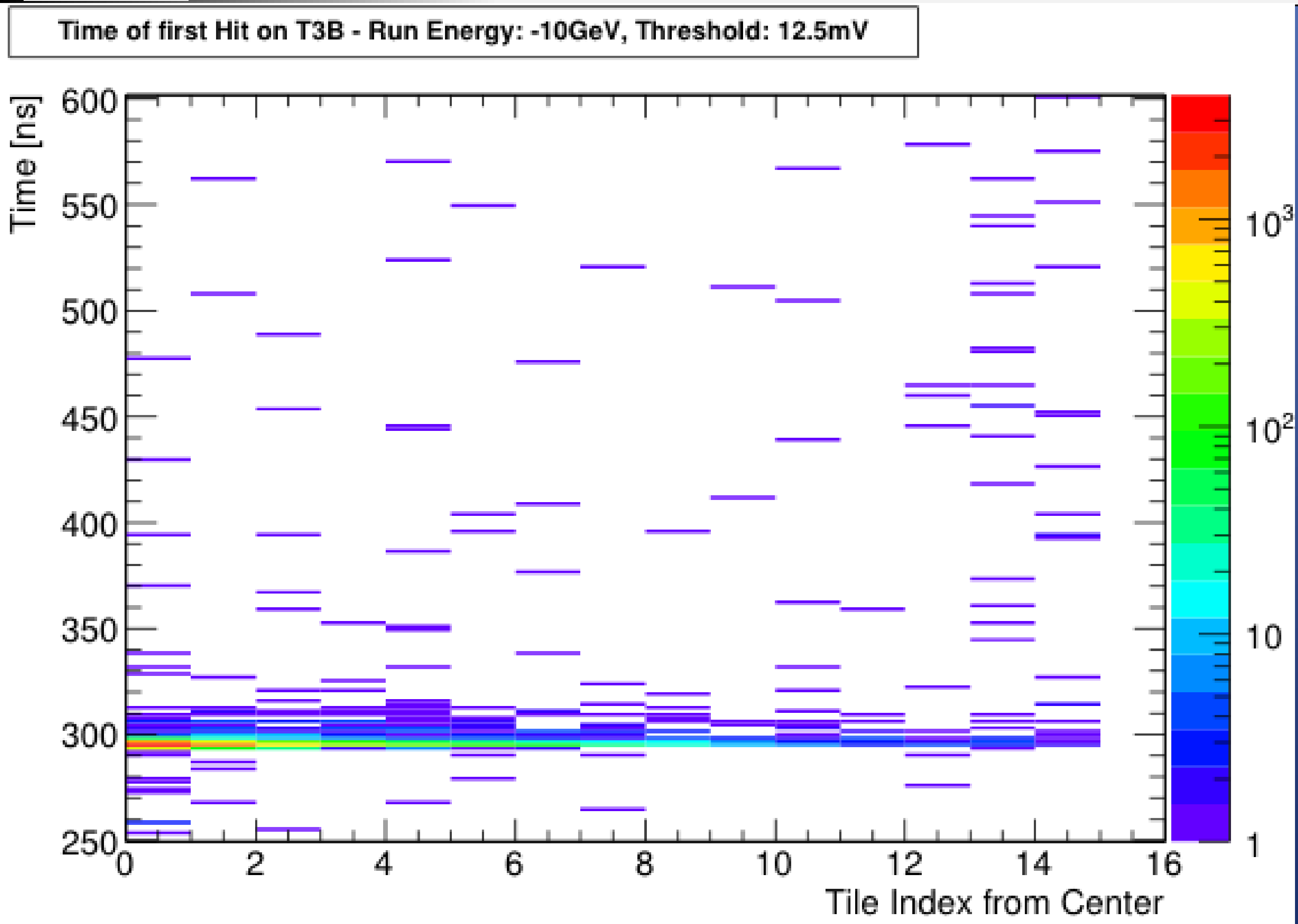
- Information about the time structure of hadronic showers in Tungsten is crucial for the development of a CLIC HCAL
  - The observed Time Structure depends on the active medium (sensitivity to neutrons) → Need scintillators to evaluate an analog HCAL
  - Directly coupled scintillator tiles, read out with fast digitizers can be used for detailed measurements of the time structure of the shower



  - Construct one timing layer = one strip of tiles
  - Run together with the CALICE AHCAL at CERN PS in November
  - Match T3B Events to CALICE Events to obtain the shower start

Obtain first information on the timing of the lateral and longitudinal shower profile

T3B Framework: Analysis



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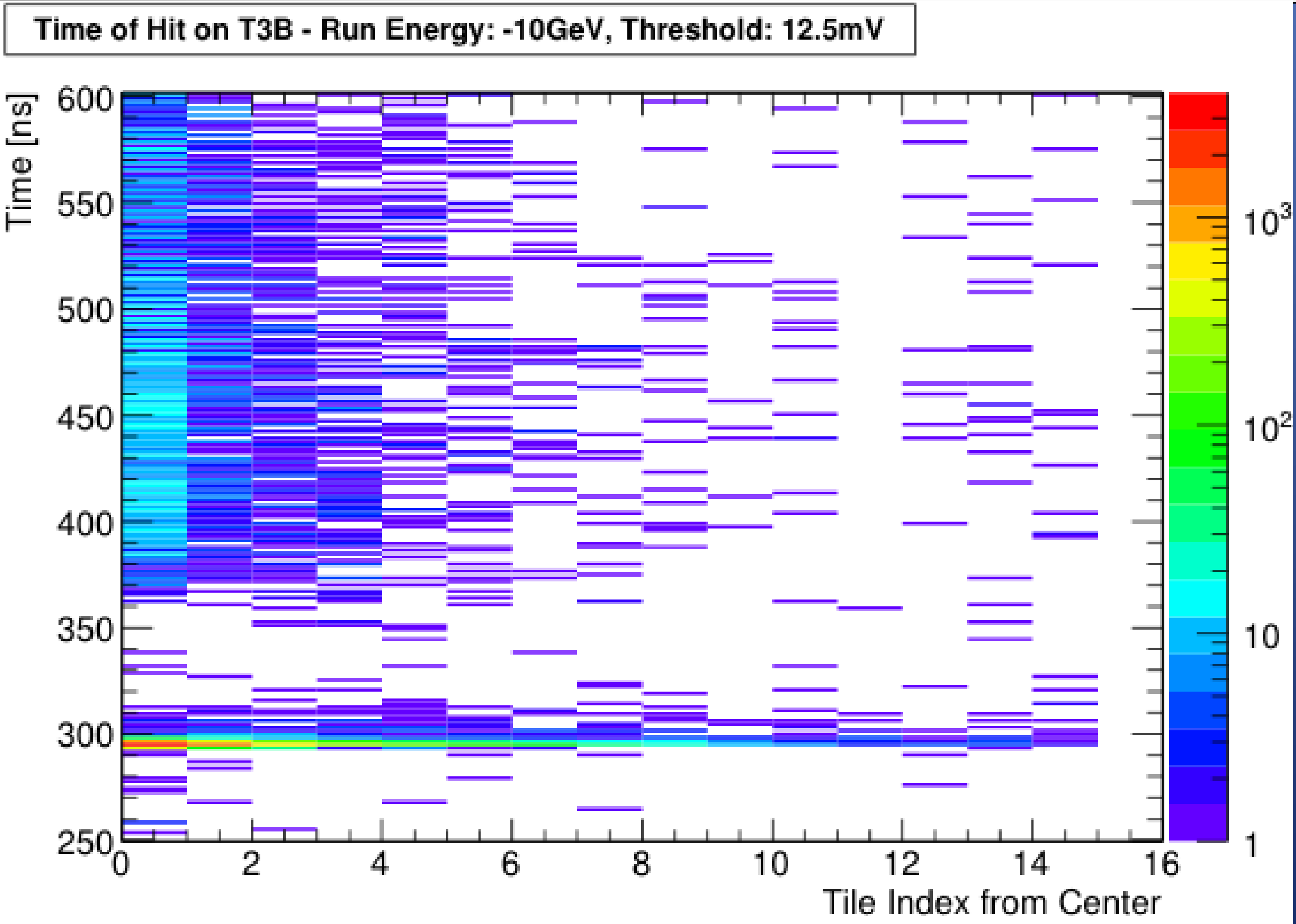

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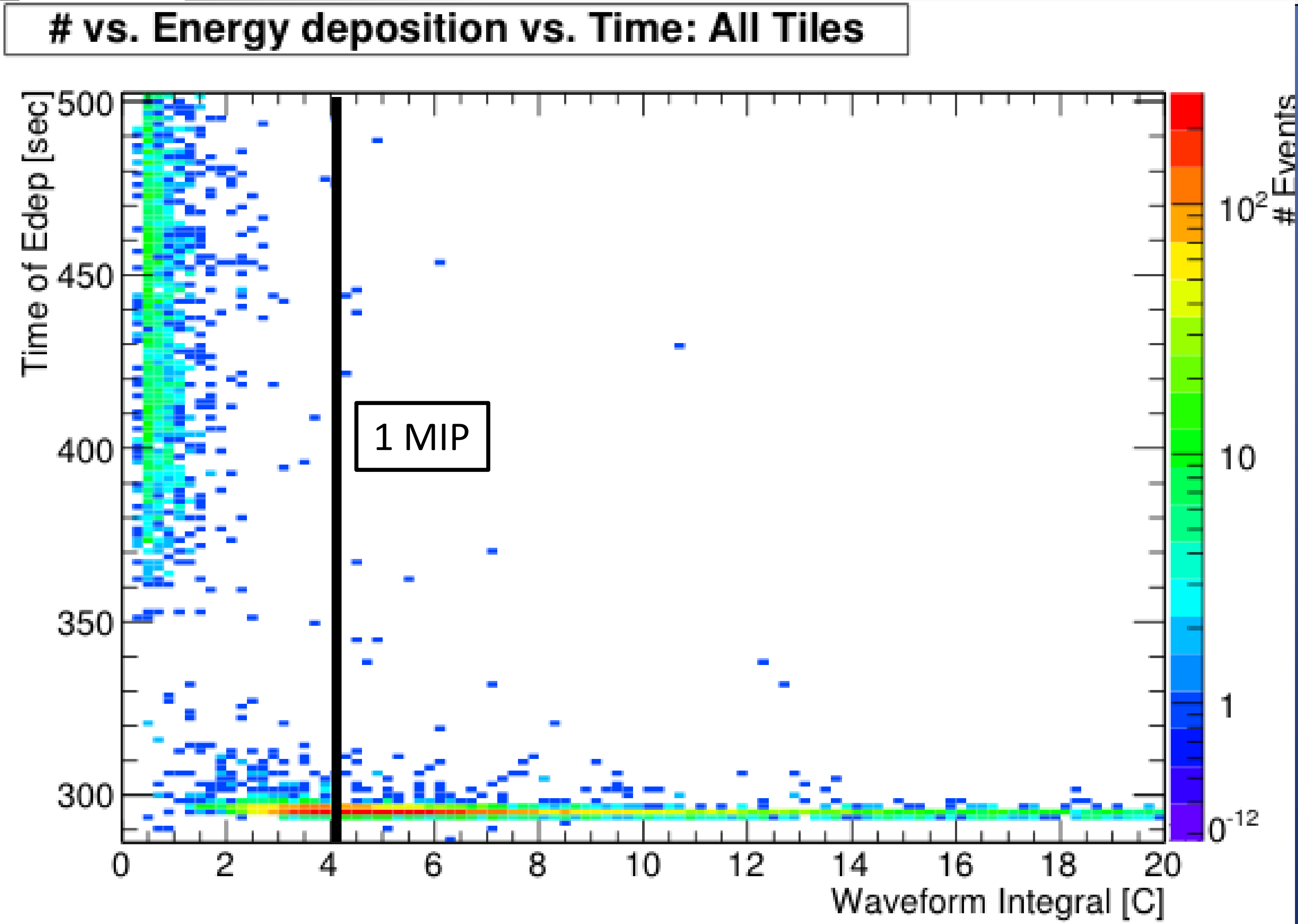

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