First Results from T3B

Tungsten Timing

T3B

TestBeam

CALICE ANALYSIS PHONE MEETING – FEBRUARY 2011

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CALICE
Calorimeter for ILC

TUM LMU
Excellence Cluster
Universe

Outline

- Introduction
- The T3B Setup (Tungsten Timing Test Beam)
- Data Analysis
- First Simulation Studies
- Results
- Summary

INTRODUCTION

Introduction

Calorimetry at CLIC is challenging:

1. A CLIC HCAL requires a very dense absorber to contain highly energetic jets and still fit into the magnet:

   → The solution (?): **Tungsten**

2. CLIC Bunch Separation: 0.5ns

   # BX/Bunch Train: 312 (in 156ns)

   → need event time stamping to reject background from $\gamma\gamma$-Interactions

   → Is Tungsten suitable for that?

The Problem:

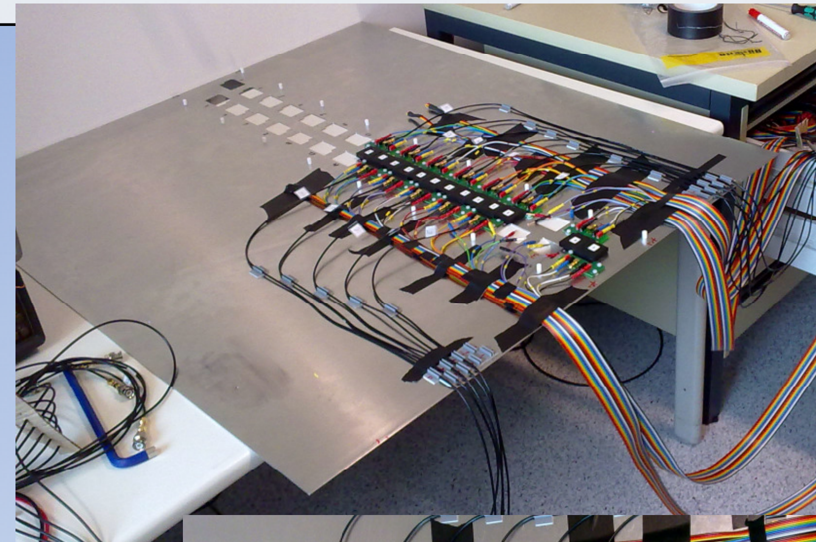
1. Timing precision of detector technology
2. Showers are not instantaneous (e.g. slow neutron component)

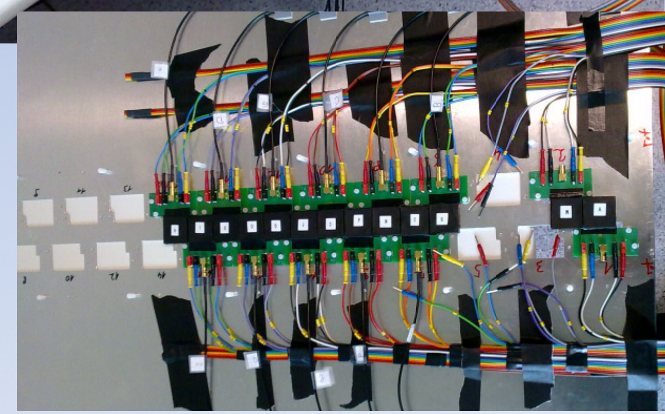
T3B: Investigate the time structure of hadronic showers in a WHCAL and check its reproducibility with GEANT4

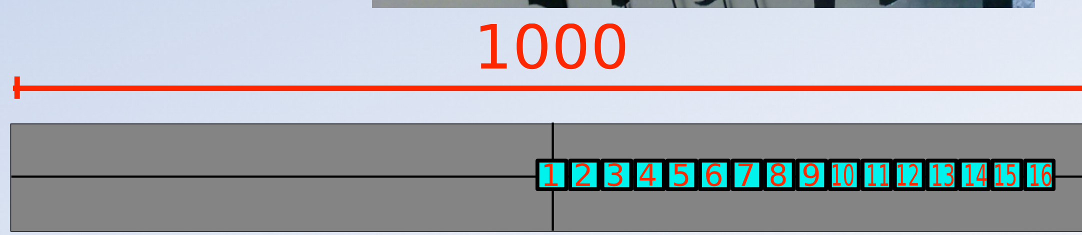
THE T3B SETUP
(TUNGSTEN TIMING TEST BEAM)

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)

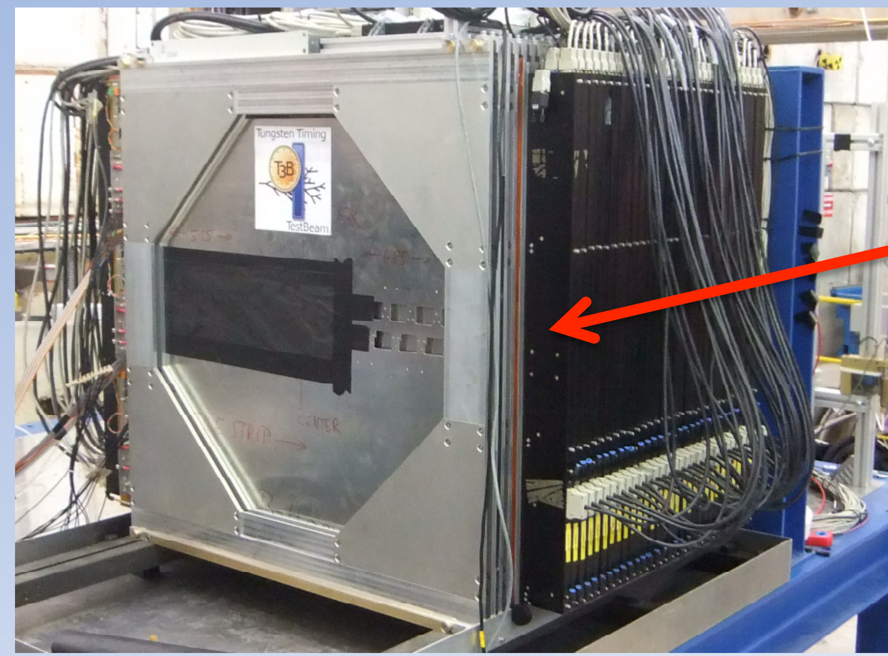


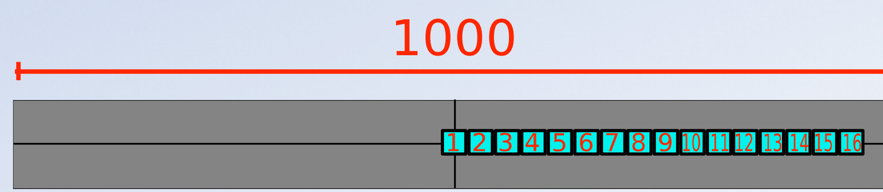




The T3B Experiment in CALICE

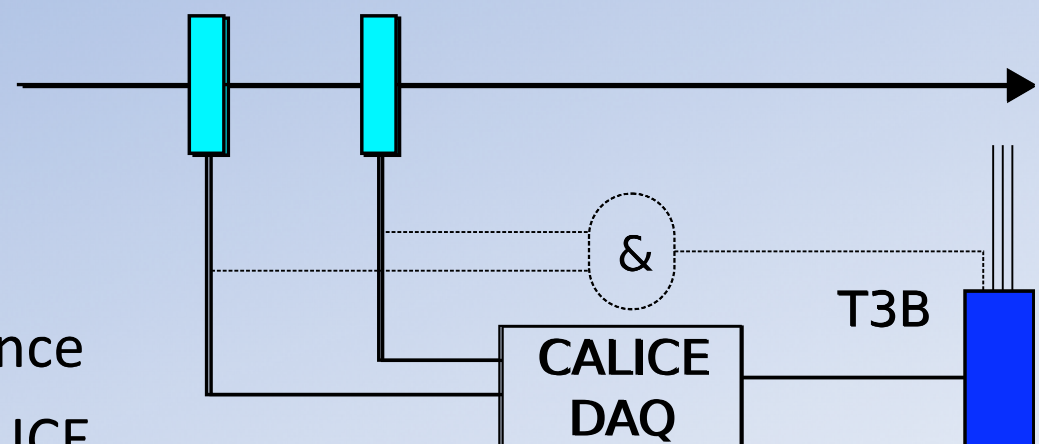
- T3B Layer positioned behind the CALICE W-HCAL
- Testbeam in Nov 2010 @ CERN PS
- Particle composition: Hadron mix (e,mu,pi,K,p)
- Energy range: 2-10GeV





CALICE <-> T3B: Synchronisation

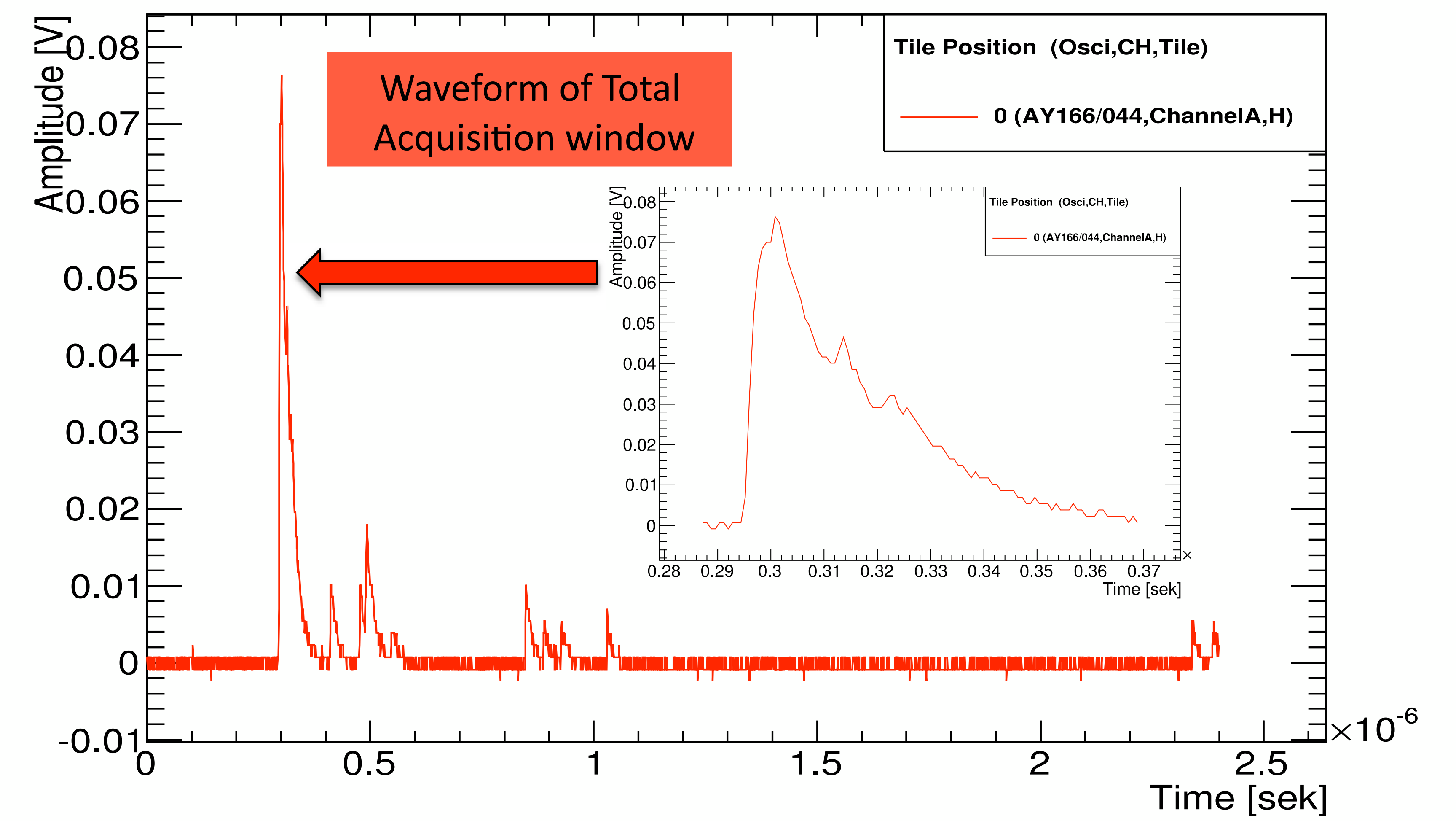
- Goal: Use CALICE HCAL to determine shower start information
  - T3B events need to be in sync with CALICE



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

DATA ANALYSIS

Data Analysis



T3B Waveforms:

Appearance of a typical event a one T3B channel

High short energy deposition, followed by potential late edeps

Data Analysis

Data Processing Steps (always on a cell by cell level):

- Pedestal Substraction

- Filtering: Reject processing of Waveforms with a Total Wfm Integral < 0.3MIP

  → Speed up data processing

- Averaging 1p.e. Waveforms (corresponding to 1 fired SiPM pixel)

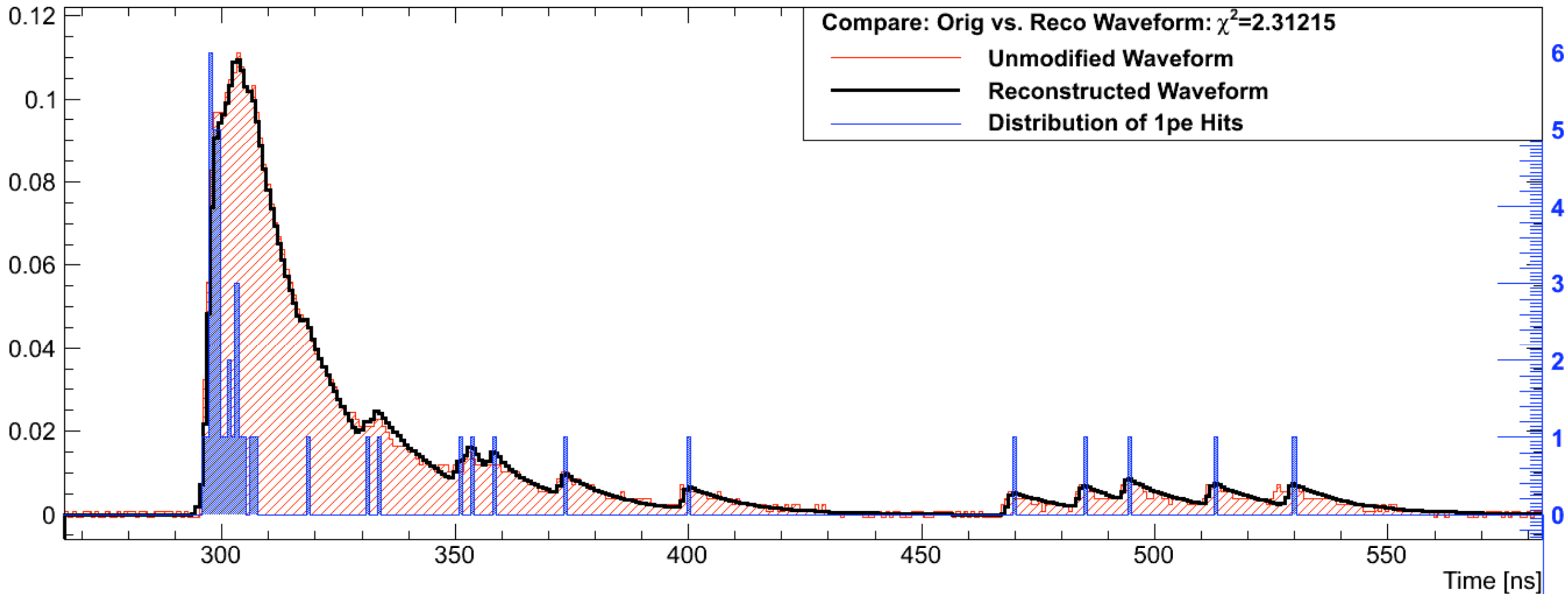
- Waveform decomposition: Substract 1p.e. Wfms consecutively from local maxima of the waveform until no maximum above 0.5p.e. can be found

Note: This is not meant as a full calibration (still in progress…)

→ We focus on Time Of First Hit (TofH) in this analysis

(Full calibration will only contribute higher order corrections to the TofH analysis)

Data Analysis: Waveform Decomposition



Verify the success of the procedure:

Build up the original waveform from the 1p.e. hit histogram → good agreement

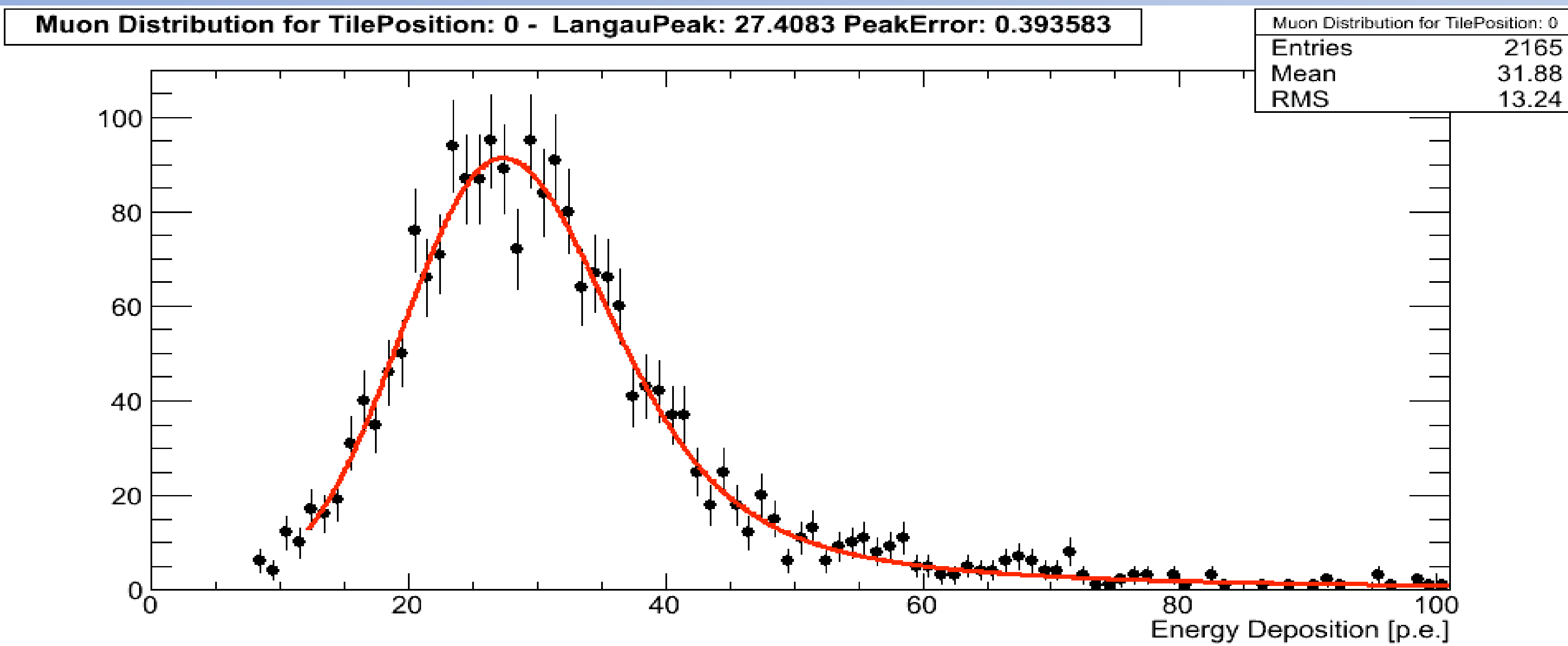
→ Obtain precise information of the arrival time of photons on the light sensor

→ The following analysis is performed on the 1p.e. hit histogram

Data Analysis: Waveform Decomposition

Check the data processing with muon runs:

Consider a hit if > 8p.e. are deposited within 9.6ns (or 96ns)



→ Obtain a reduced MIP amplitude of 20p.e. (27.4p.e. for 96ns)

→ A large fraction of SiPM afterpulses are excluded

→ Reduction of the muon peak width as fluctuations from afterpulsing are minimized

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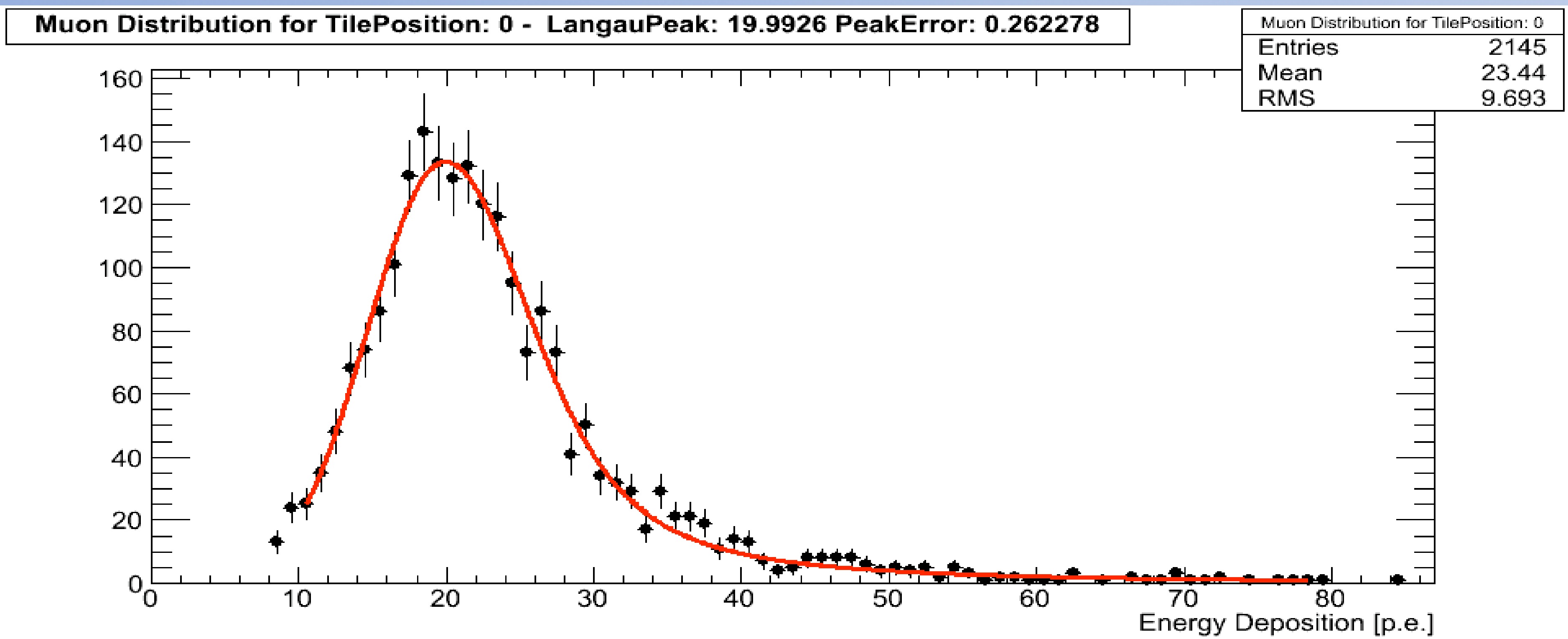

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Data Analysis: Time of first Hit (TofH)

Analysis of the time of the first hit of hadronic showers on the T3B tiles:

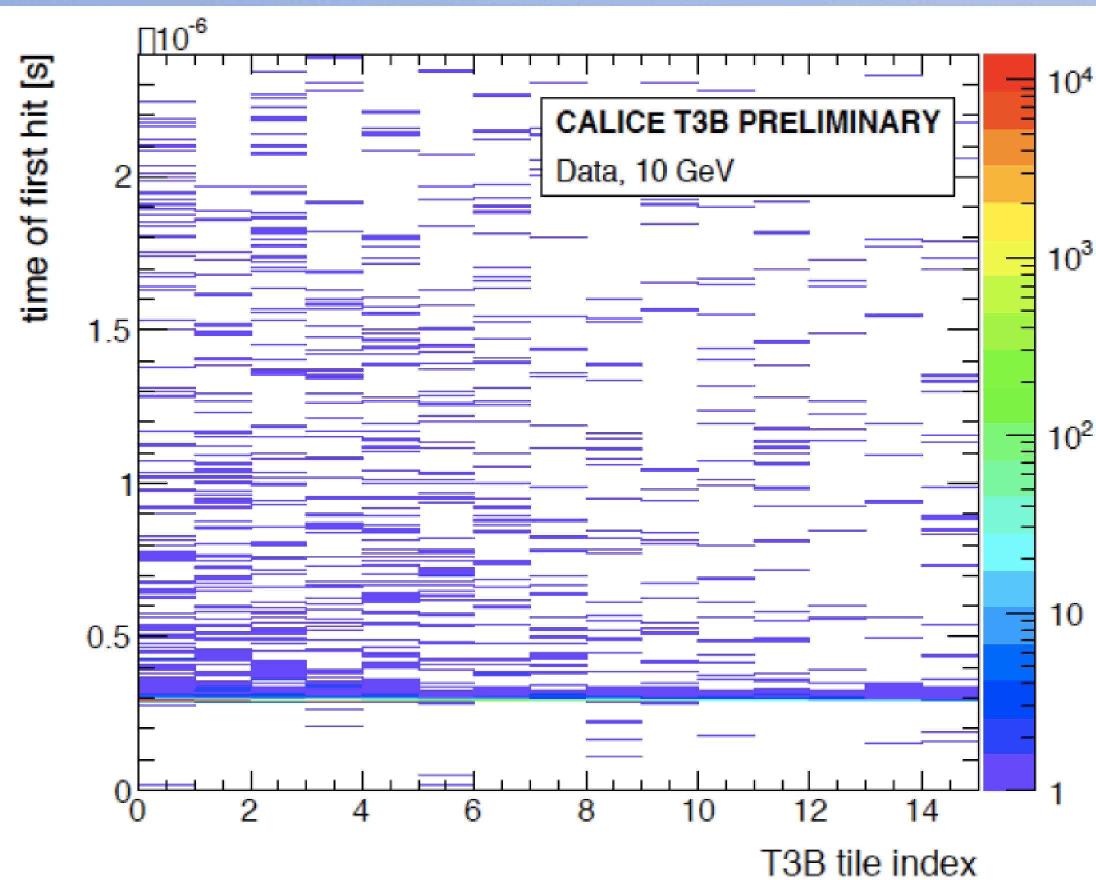
→ Classify the TofH as the time of the first 1p.e. hit of the first time > 8p.e. were deposited within 9.6ns

Configuration: T3B Standalone Analysis
Energy: 10GeV (best hit probability for T3B)
Statistics: 720.000 Events (650.000 accepted)
Particles: Pi- (to avoid beam contamination with protons, Cerenkov selection in future)

Note: At present no cell-to-cell MIP calibration

(only higher order corrections for TofH analysis)

Data Analysis: Time of first Hit (TofH)



Distribution of the time of first hit as a function of the radial position:

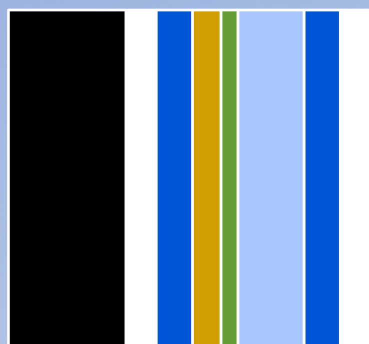
→ Cluster of events at early times in coincidence with beam particle

→ Considerable late activity in the shower

FIRST SIMULATION STUDIES

GEANT4 Simulation

- Simulated a reasonable approximation of the W HCAL:
  - 31 layer calorimeter (T3B approximated as the 31st Calice layer)



Layers modeled after CALICE Geometry description, omitting 3M foil layer

Tungsten: 94% W, 4% Ni, 2% Cu, density 17.6 g/cm^3

Total layer thickness: 24.5 mm

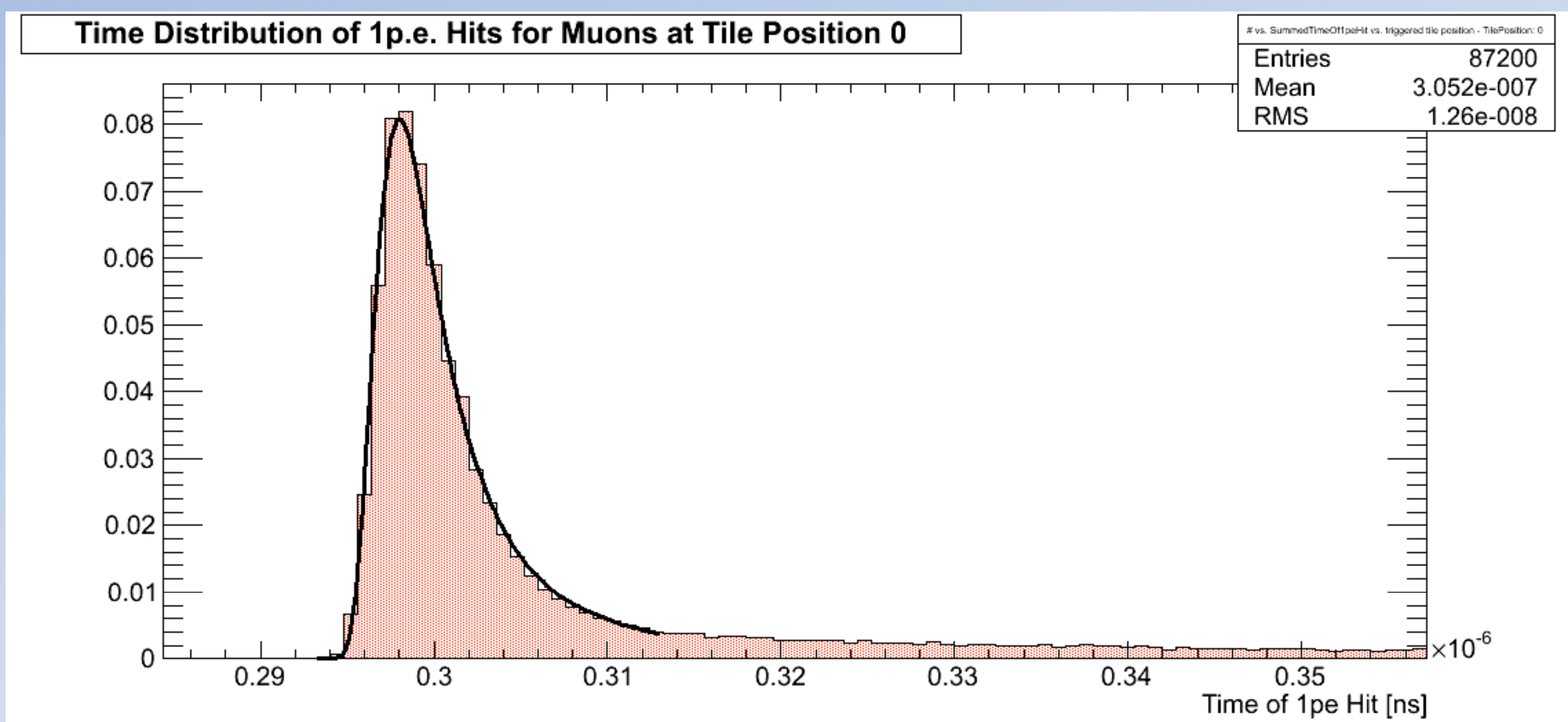
- Simulations:
  - Geant4.9.3 , Physics List QGSP_BERT and QGSP_BERT_HP (high prec. neutron tracking)
  - 800k π^- events at 10 GeV
  - Beam profile: Gaussian smearing of primary particle pos. (according to tracking system)
  - MIP conversion factor: 815 keV/MIP (determined from simulated muons)

Simulation: Data Processing

Simulation processing very close to data processing procedure:

- Subdivide the GEANT4 energy depositions in 0.8ns time bins
- Time smearing: Include the time structure of the response of the T3B system to instantaneous edeps (scintillator const, SiPM response, photon travel time)

  → approximate the 1p.e. hit distribution of muons (data) and smear each time bin (Sim)
- Demand > 0.4MIP within 9.6ns and accept the first time bin as the TofH

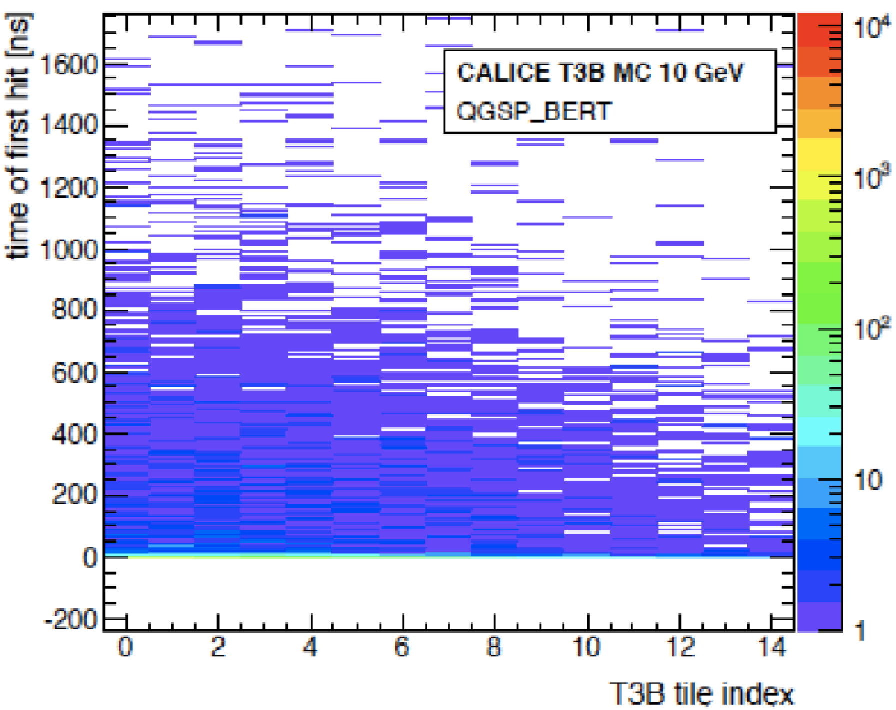


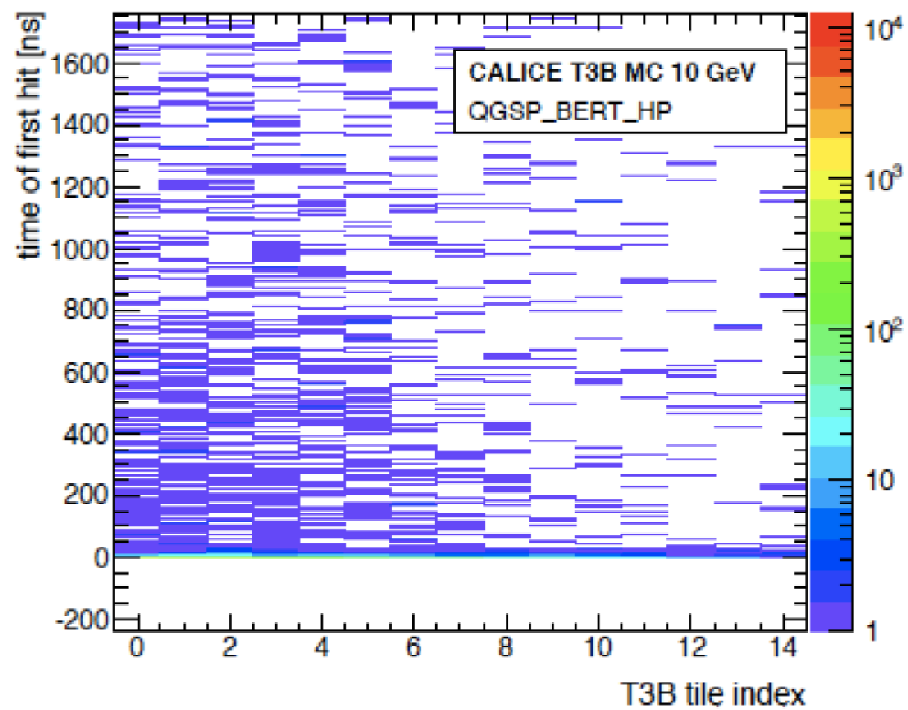
Simulation: Time of first Hit (TofH)

Comparison of the time of first hit distribution: QGSP_BERT vs. QGSP_BERT_HP

- Striking difference in the late shower evolution

  → delayed energy depositions considerably reduced in HP





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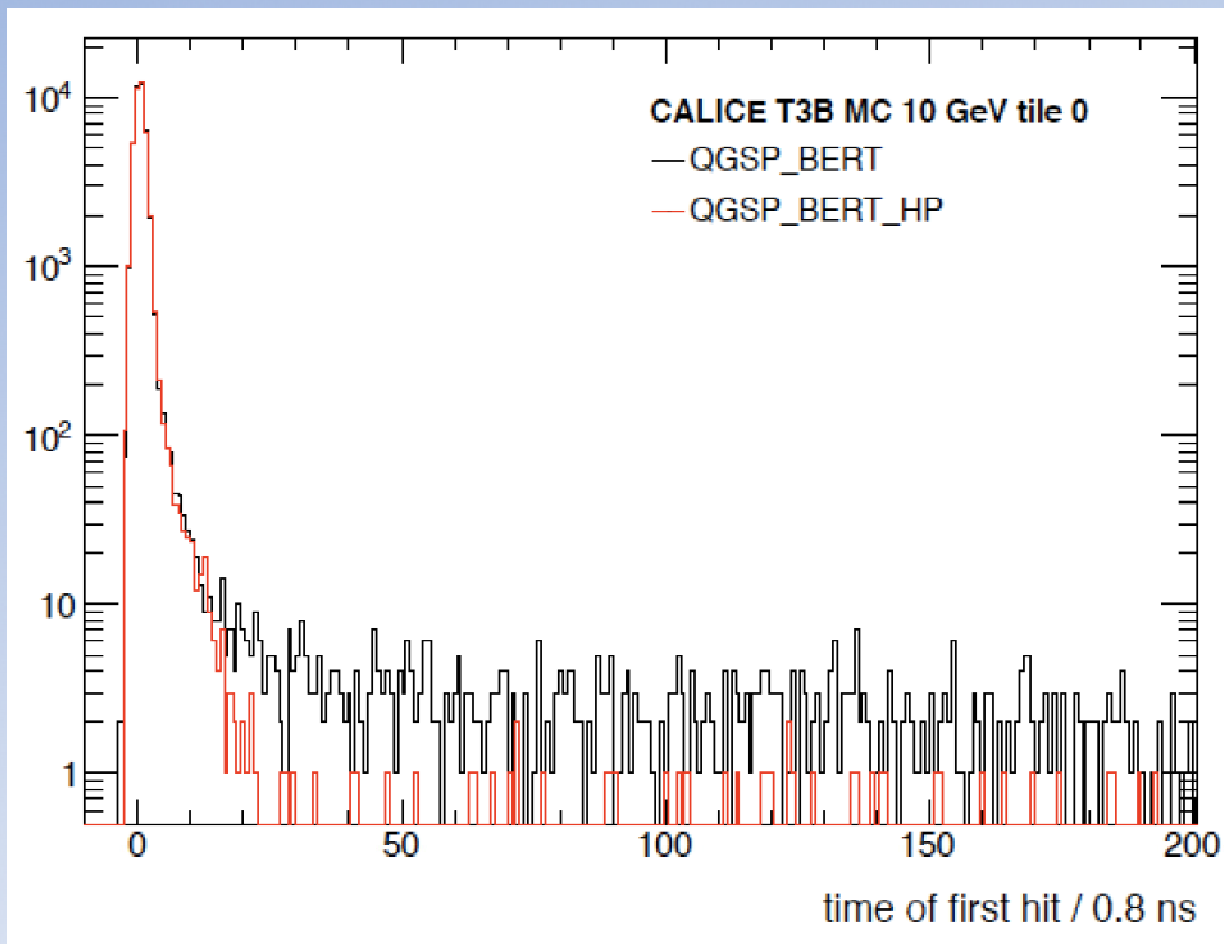


RESULTS

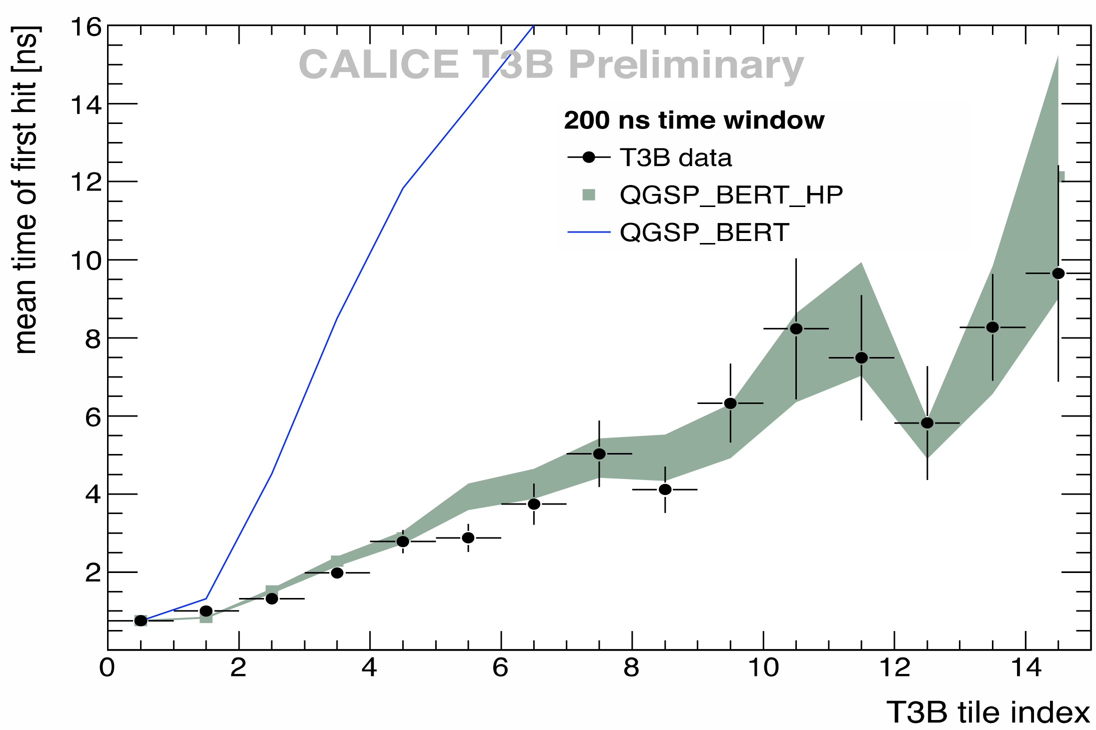
Results: Data vs. MC

The time of first hit is a good measure for the intrinsic time stamping possibilities in the calorimeter

Robust Comparison of Data vs. MC: Determine the mean time of first hit cell by cell

→ Investigate a time window of 200ns (-10ns to +190ns)

Remember: Bunch train length 156ns, shaping time of calice FE 180ns



Note:

- Beam axis through T3B tile 0
- Tile 10 is 30cm from beam axis

→ Data very well reproduced with QGSP_BERT_HP

→ QGSP_BERT overestimates late contributions at large radii

SUMMARY

Summary

We presented preliminary results on the time structure of hadronic showers

Setup: Investigated π^- events at 10 GeV in the CALICE WHCAL at 3 lambda depth using the T3B Timing Layer

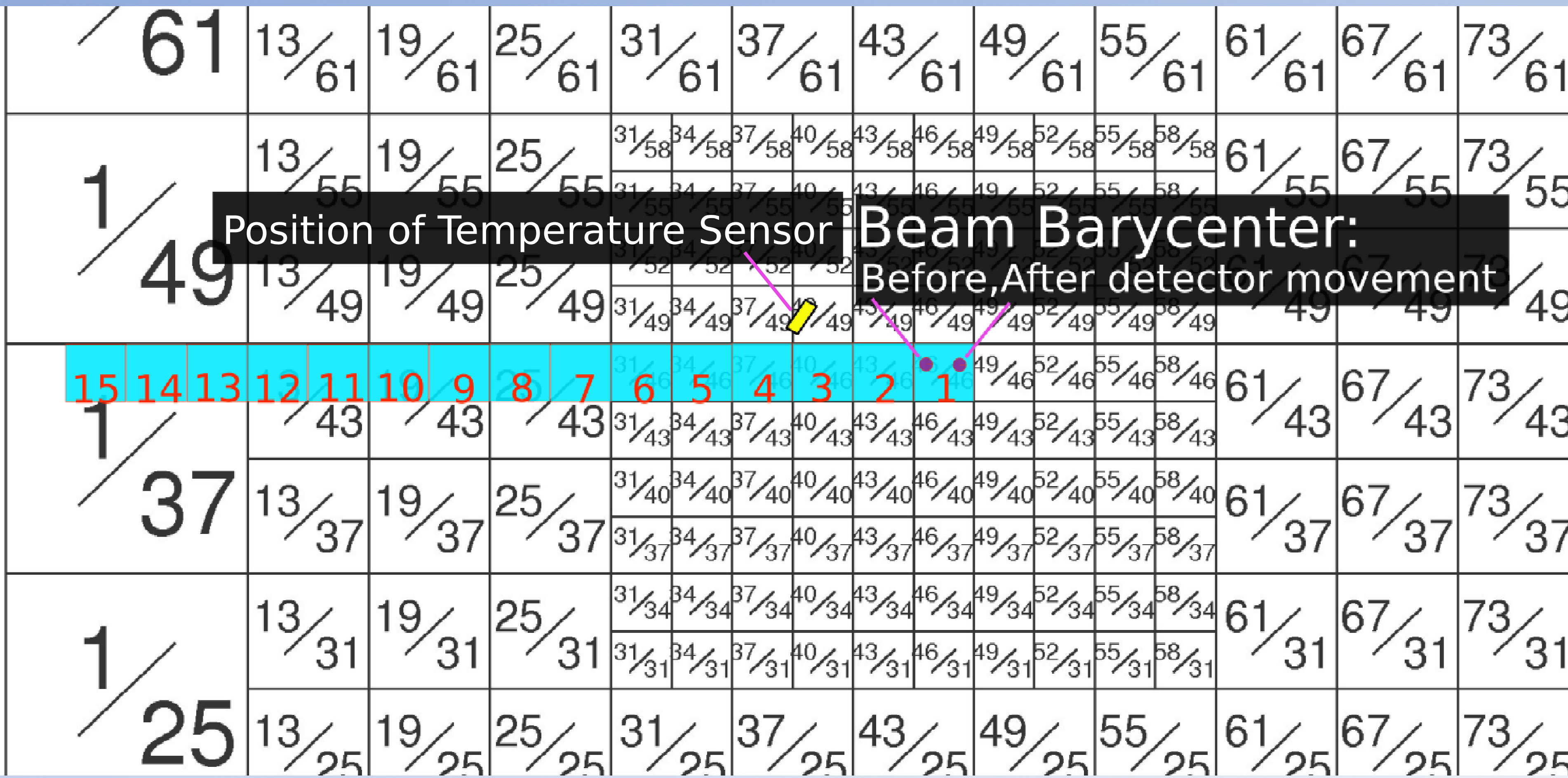
In the presented analysis we used the time of first hit as key parameter for the time structure of hadronic showers

Data vs. MC comparison shows excellent agreement for QGSP_BERT_HP and large discrepancies for QGSP_BERT

More timing analyses from the T3B group will follow…

BACKUP

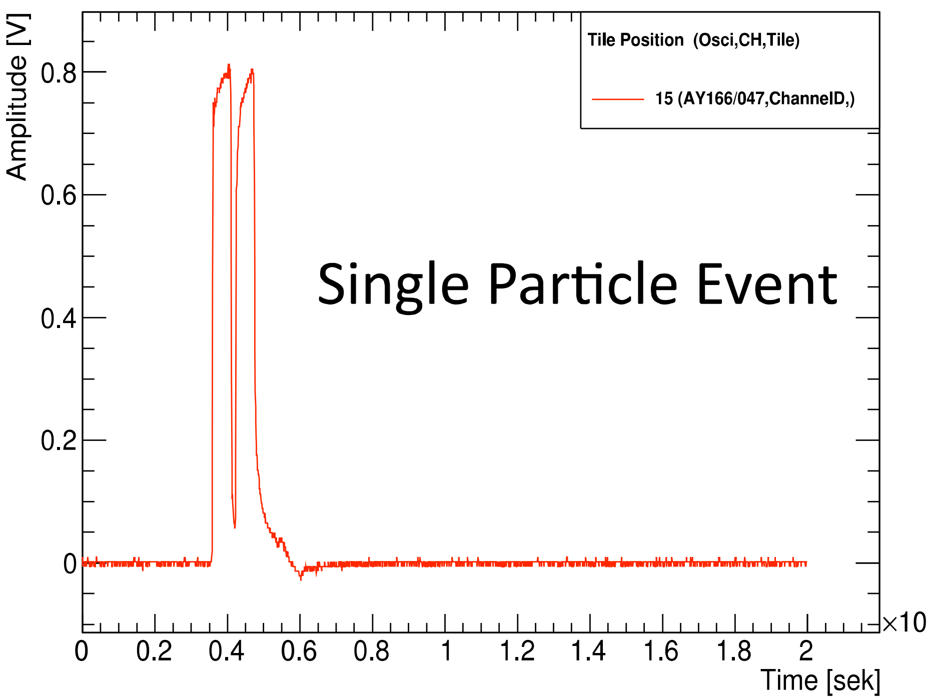
T3B Strip Position

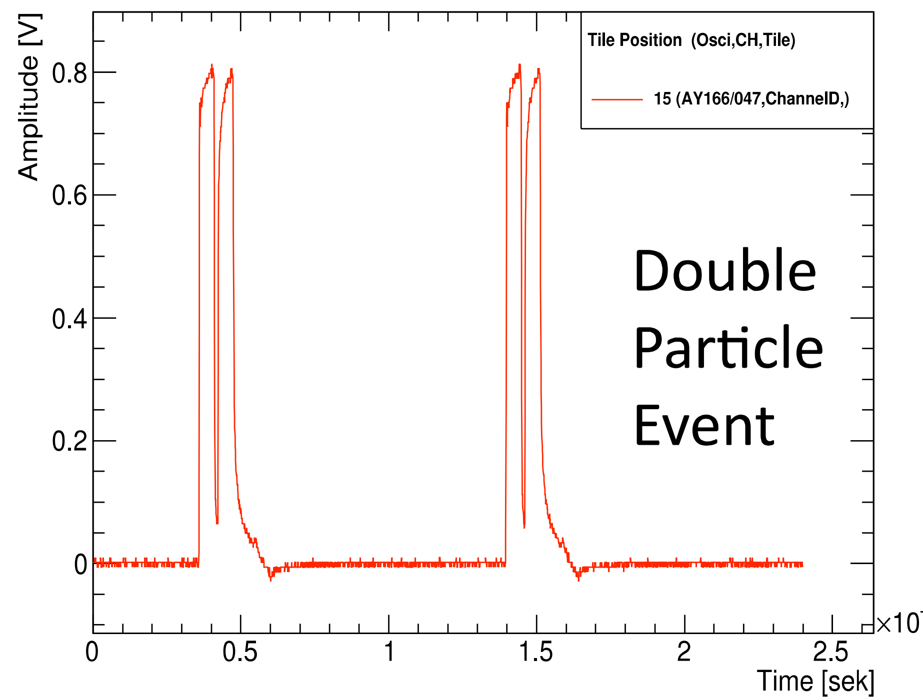


T3B Framework: Filter

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: Calibration

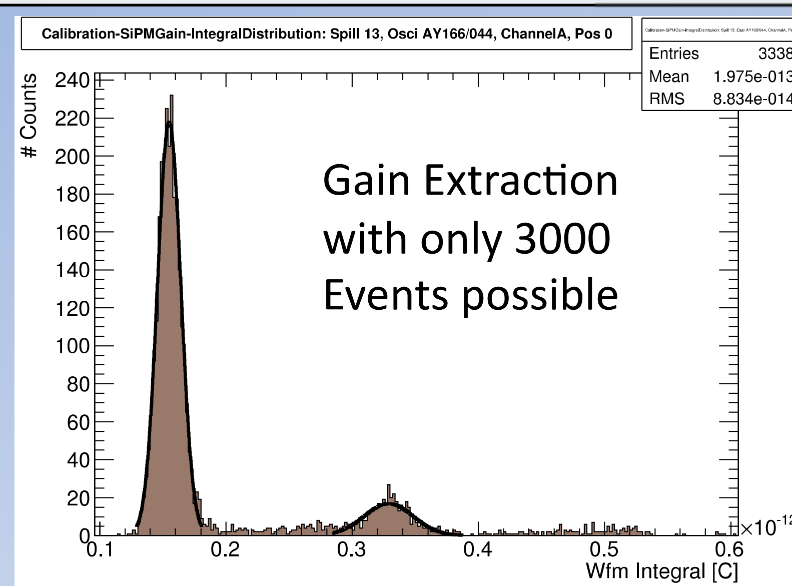
Calibration Mode: SiPM Gain

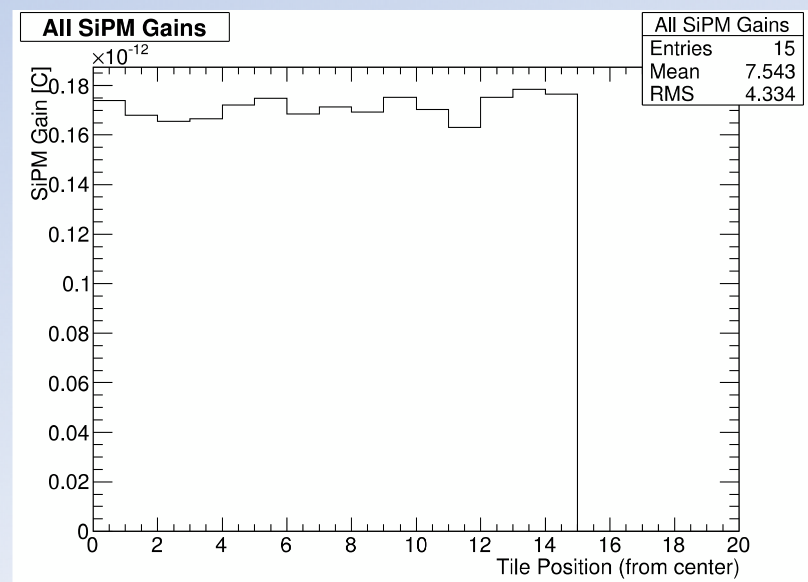
- We have ~125 Darkrate Events per Channel after each spill processing

- ~3000-4000 Events suffice for SiPM Gain extraction

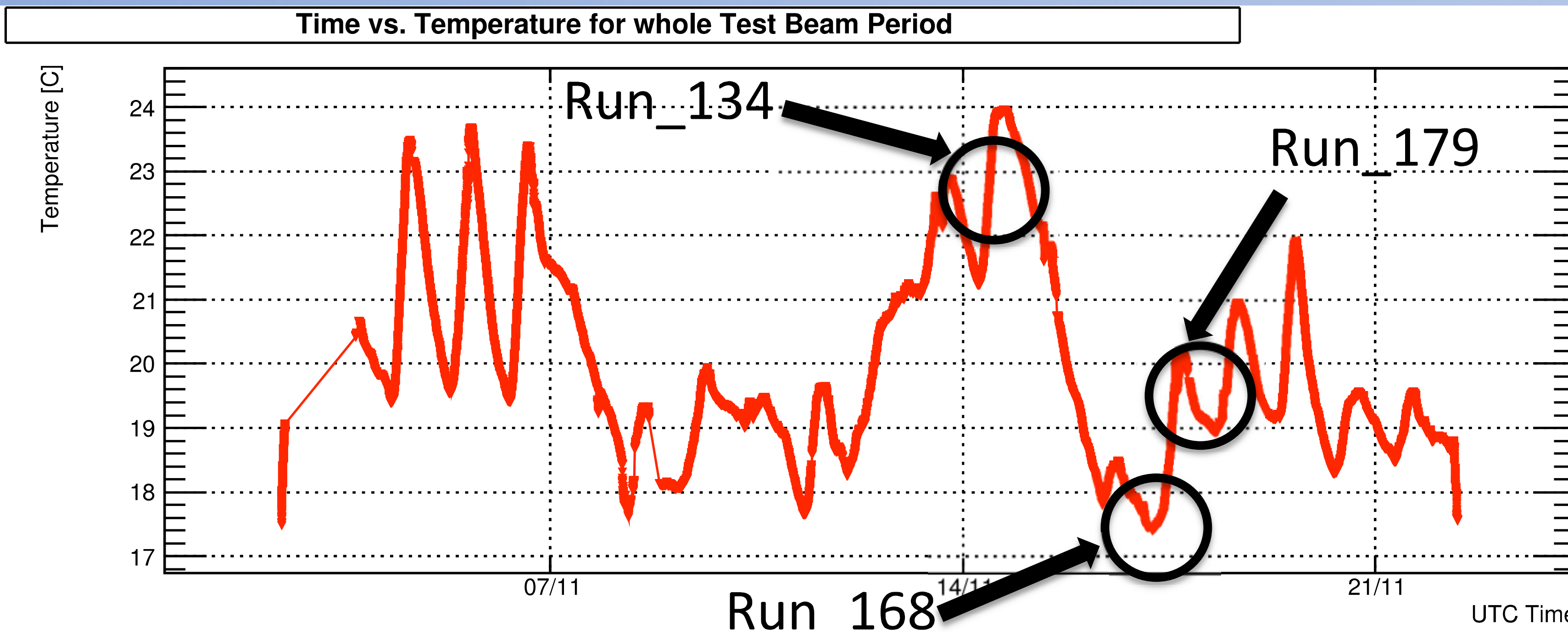
- choose 31 Spills
  → one independent gain calib value every ≈ 12minutes (assuming on average 2 Spills per supercycle)

Very high gain extraction efficiency (≈100%)





T3B Framework: Calibration



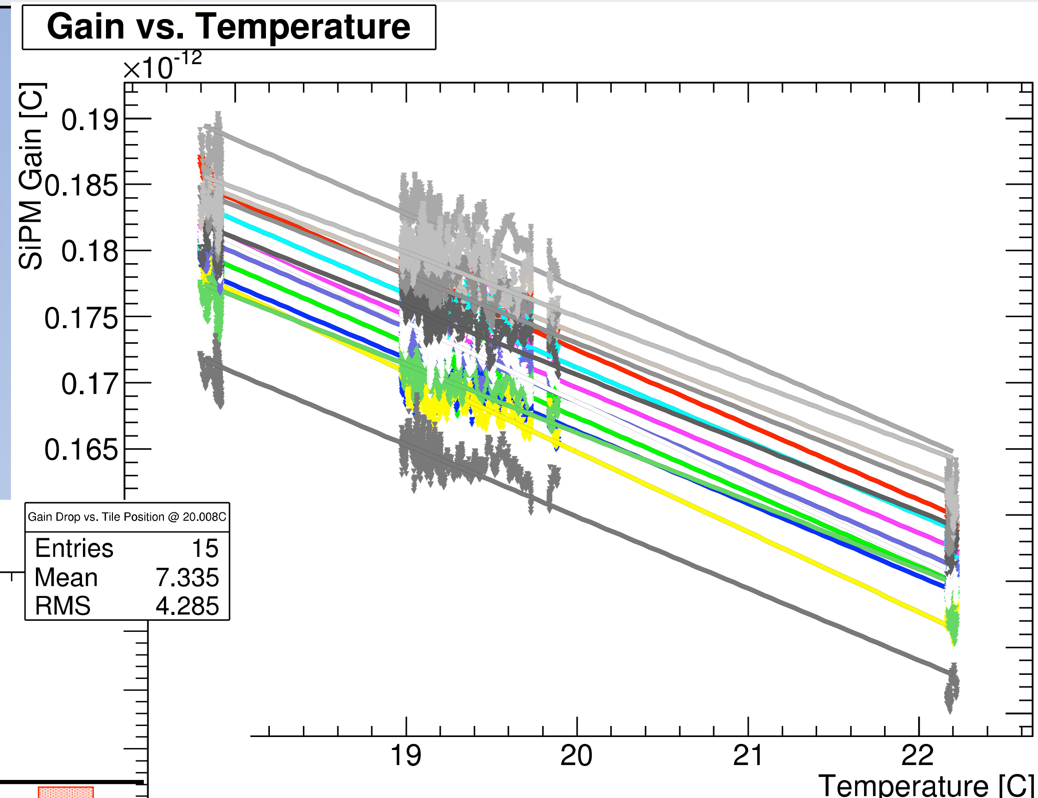
Wide Temperature Range of 17.5C-24C during TB Phase

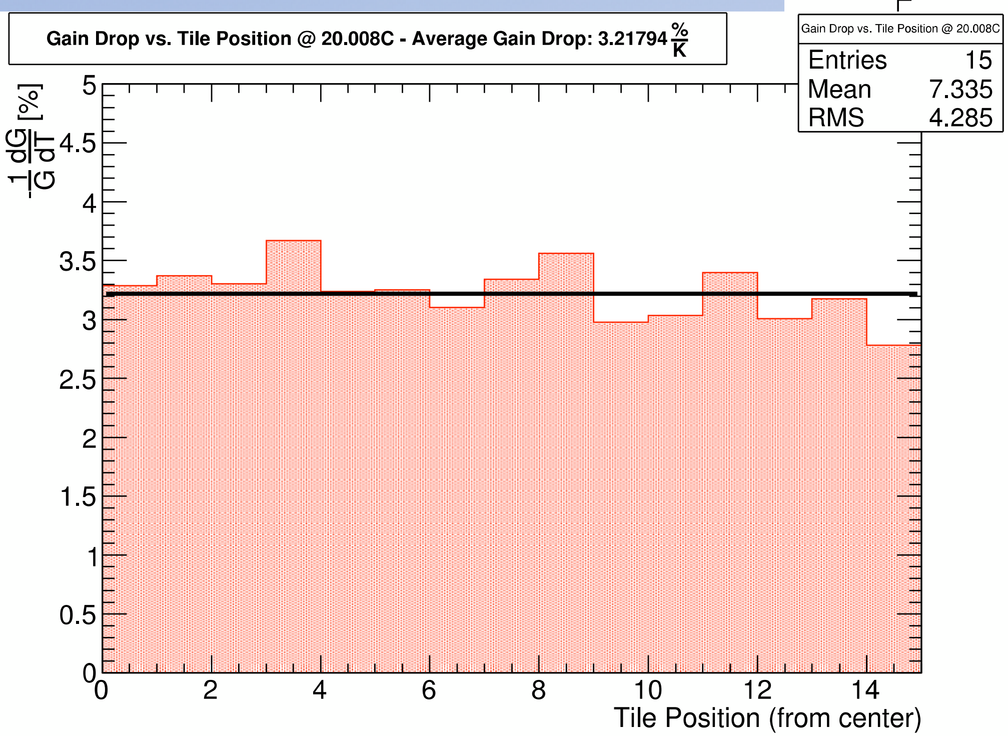
→ Choosing 3 good Runs with extreme temperatures

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:

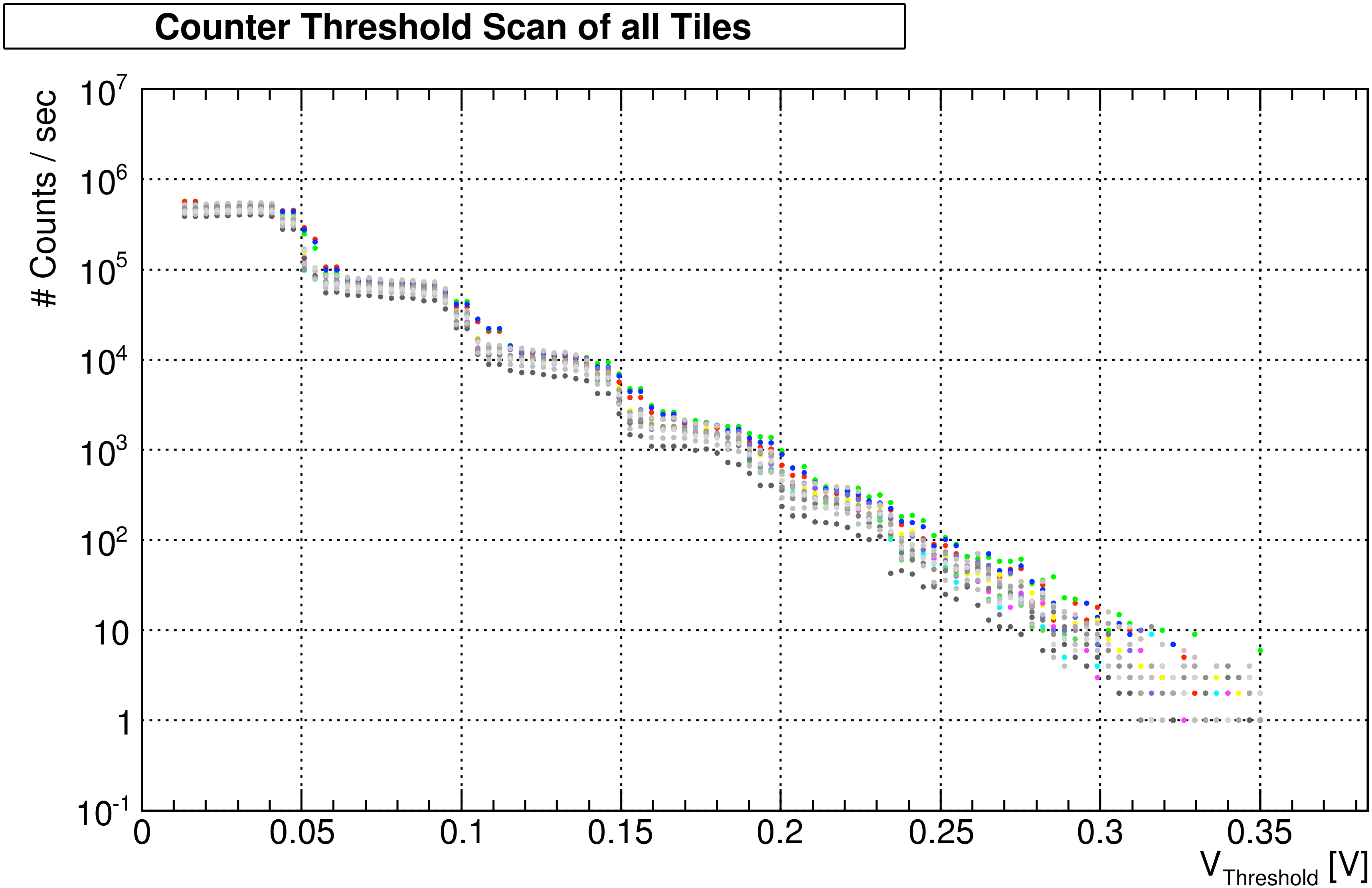
  → Record cosmics and rare very high darkpulses
  → Average all waveforms in a certain pulse height range
  → Substract the extracted AC from the average energy deposition at a certain time

  Challenge:

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

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]

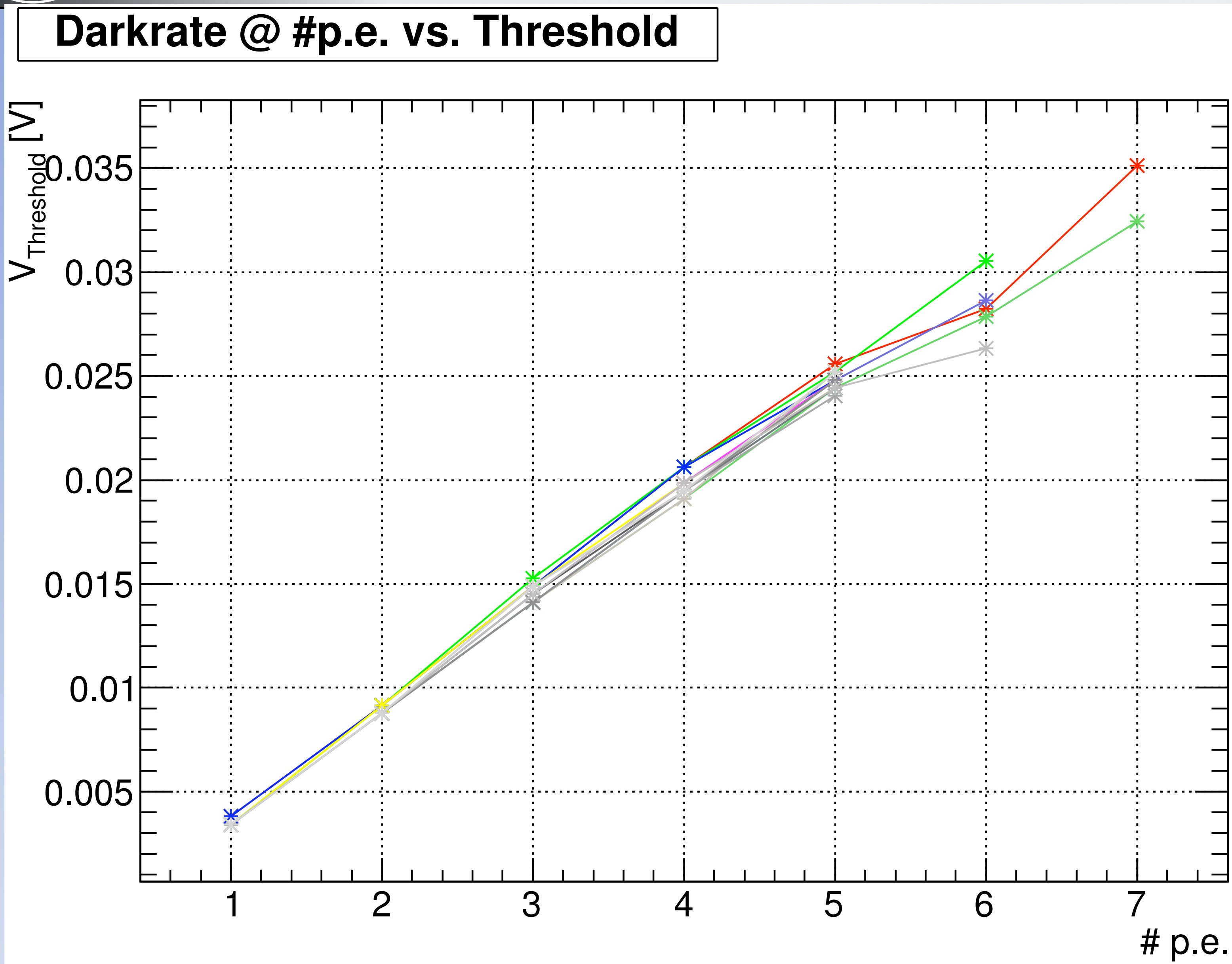
Backup: CTS

Counter Threshold Scan of all Tiles

Tile, Rate@#p.e.

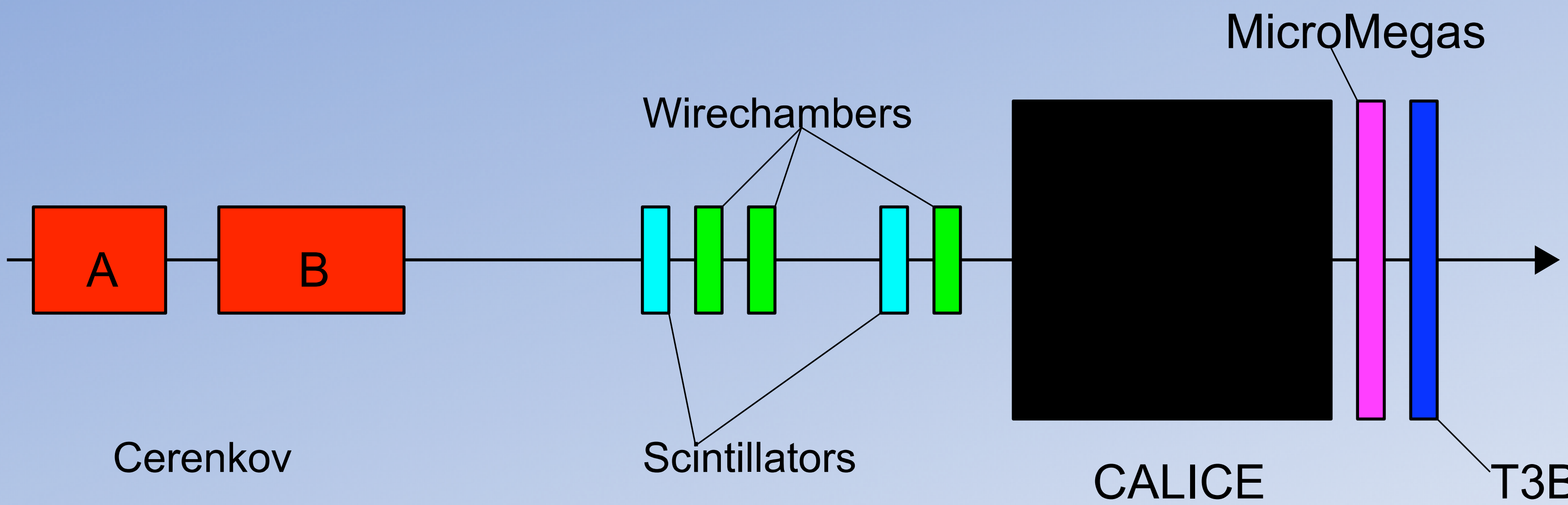
- H, 1: 497308, 2: 67922, 3: 10848, 4: 1735, 5: 290, 6: 93, 7: 10,
- D, 1: 485237, 2: 71970, 3: 11040, 4: 1927, 5: 372, 6: 60,
- G, 1: 495108, 2: 70095, 3: 11346, 4: 1826, 5: 353,
- C, 1: 462947, 2: 63806, 3: 9840, 4: 1616, 5: 303,
- N, 1: 452474, 2: 62205, 3: 9557, 4: 1463, 5: 246,
- B, 1: 478922, 2: 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.

Testbeam Setup November 2010



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