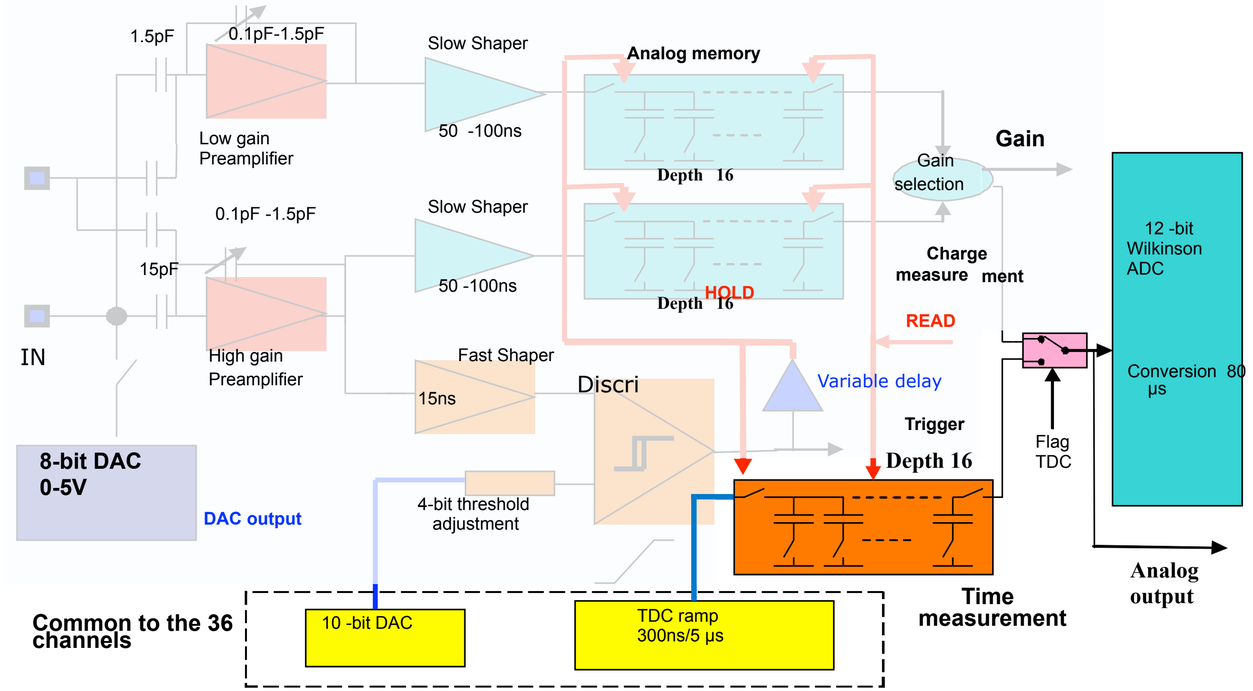
Timing in the AHCAL: SPIROC2E

SPIROC2E provides:

- Ramp TDC for single channel timing
- 16 switched capacitor memory cells per channel
- Clock speed of 250kHz (test beam mode) and 5MHz(ILC mode)



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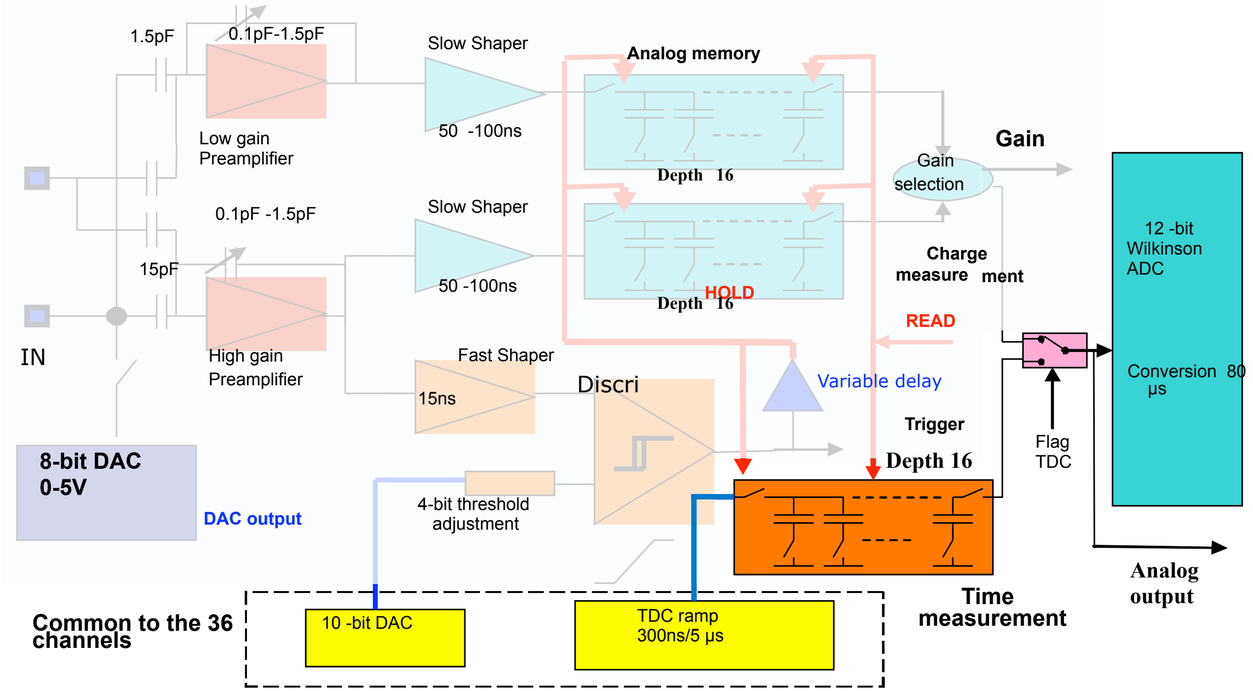

Time resolution of the electronics:

- 204.3ps (ILC mode)
- 2.7ns (test beam mode)

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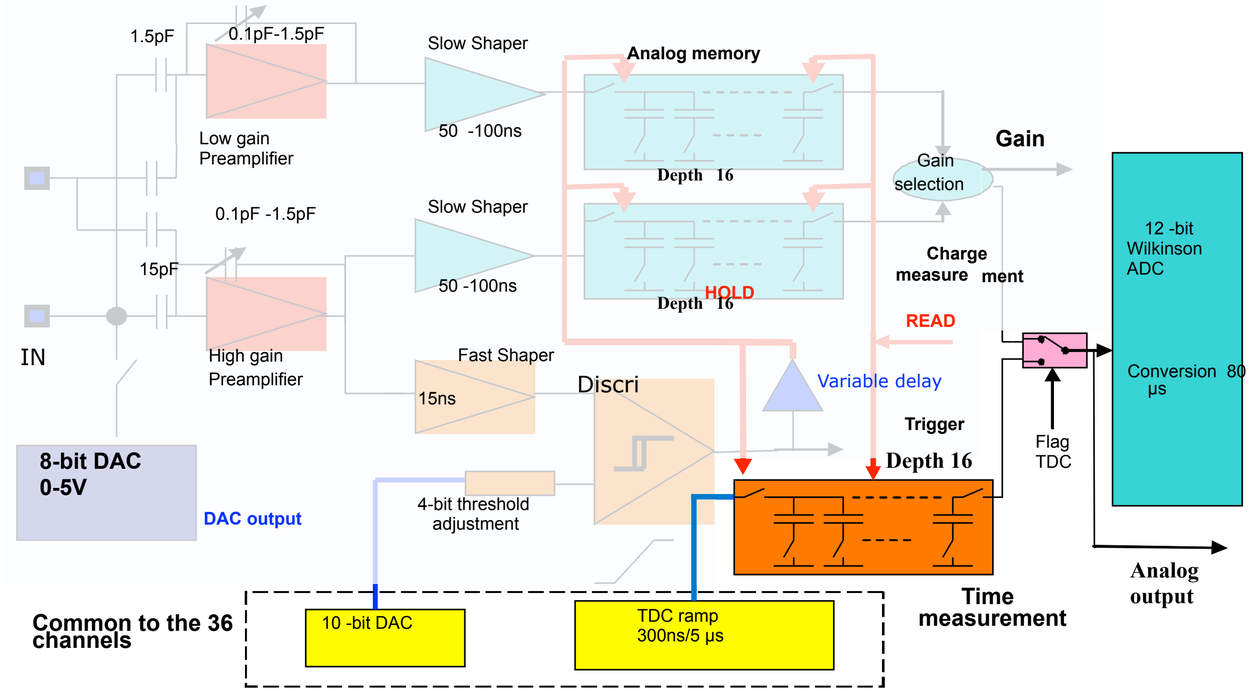


Time resolution of the electronics:

- 204.3ps (ILC mode)
- 2.7ns (test beam mode)

TDC Slope:

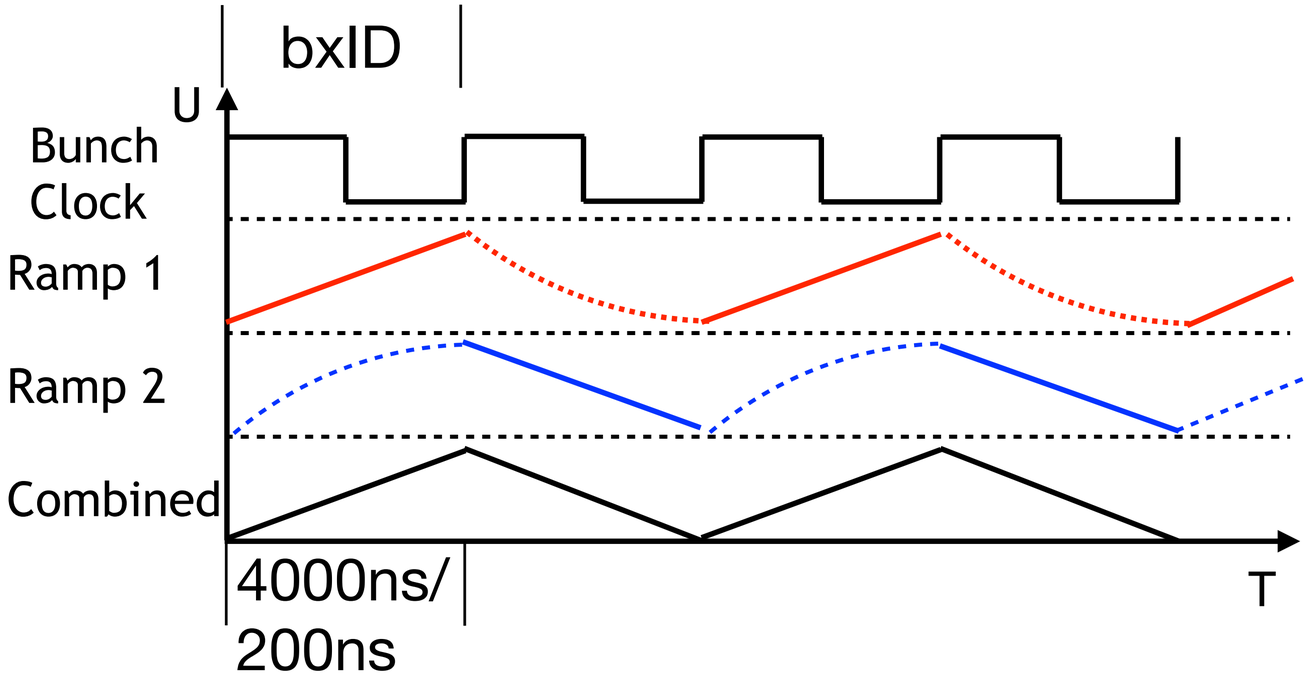
- ~ 80 ps / TDC bin (ILC mode)
- ~1.6 ns / TDC bin (test beam mode)

Time Calibration

Time Calibration

Time measurement with SPIROC2E:

1. External trigger with ~1ns resolution
2. Ramp up voltage during one bunch crossing ID



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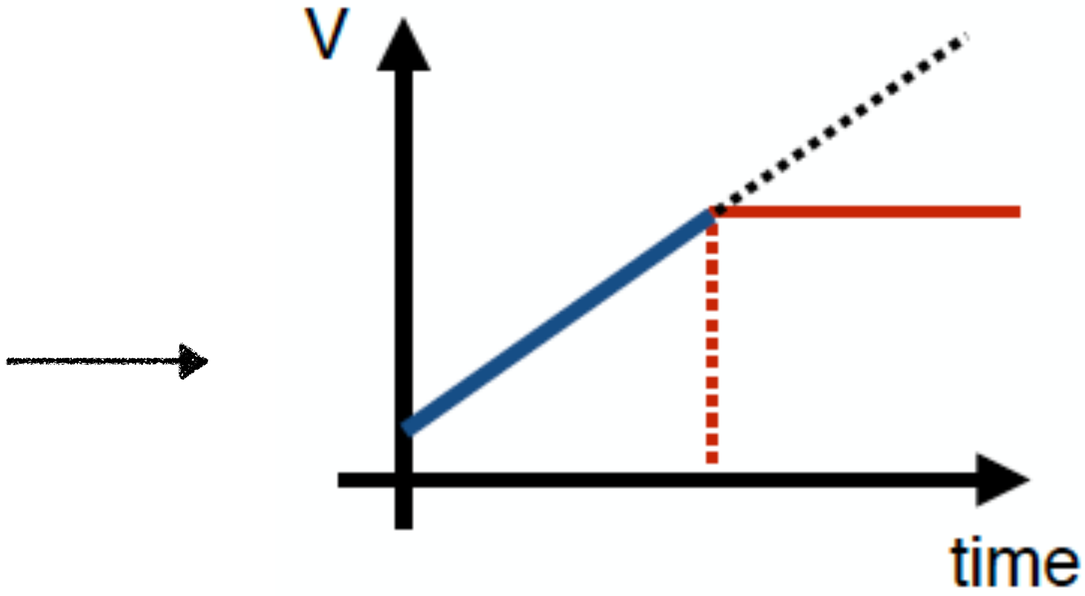

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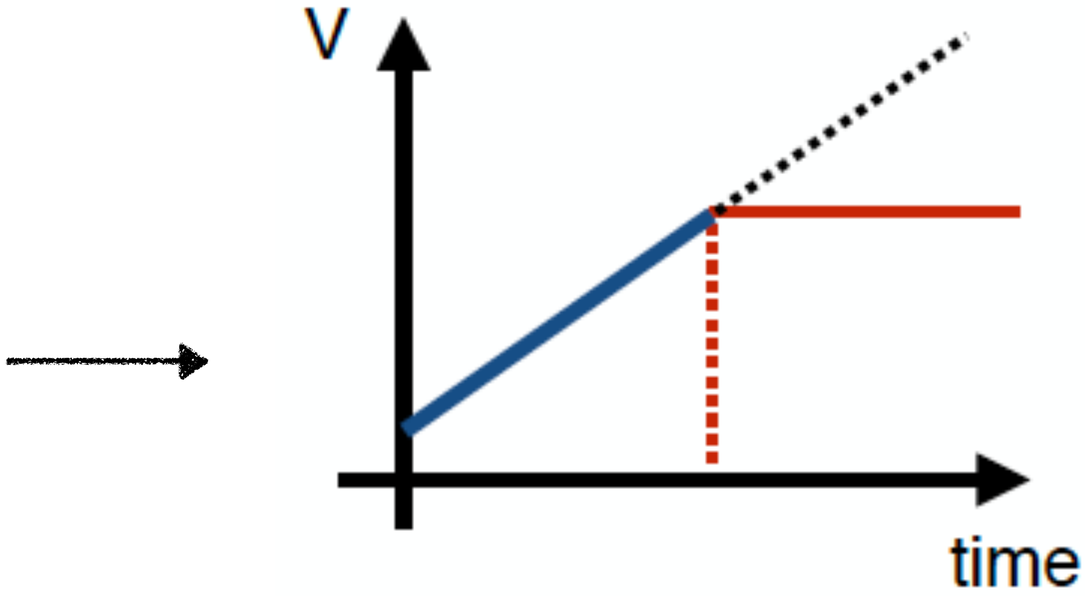

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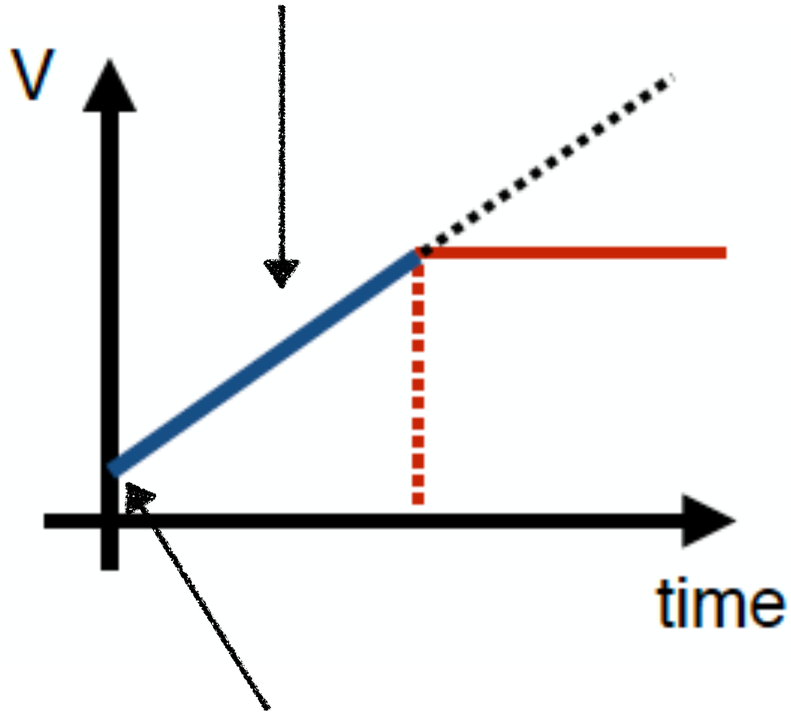
Slope is common to all channels on a chip



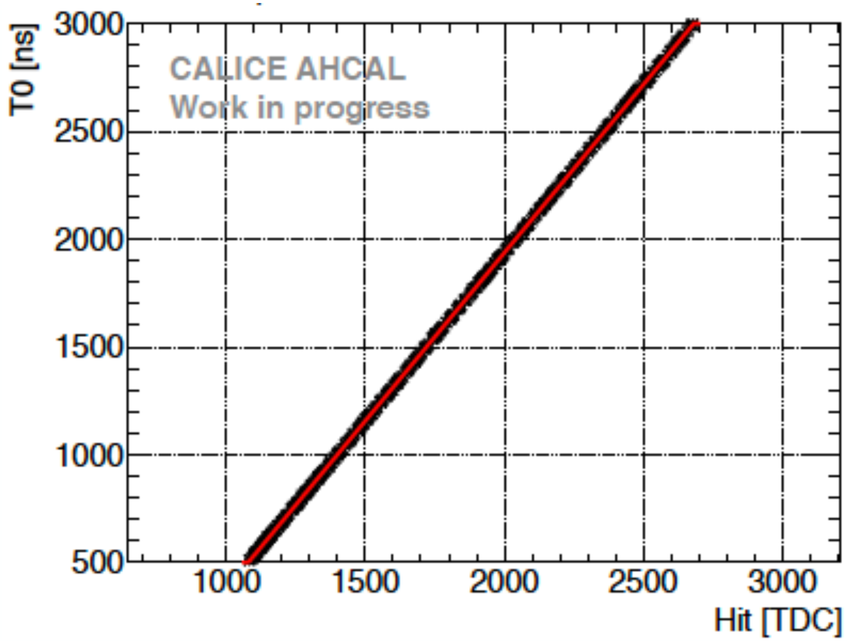
Offset is extracted for every memory cell

AHCAL Timing Performance

AHCAL Timing Performance

1. Extract slope by plotting trigger time against TDC readings

2. Fit with linear function



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3. Calculate hit time by

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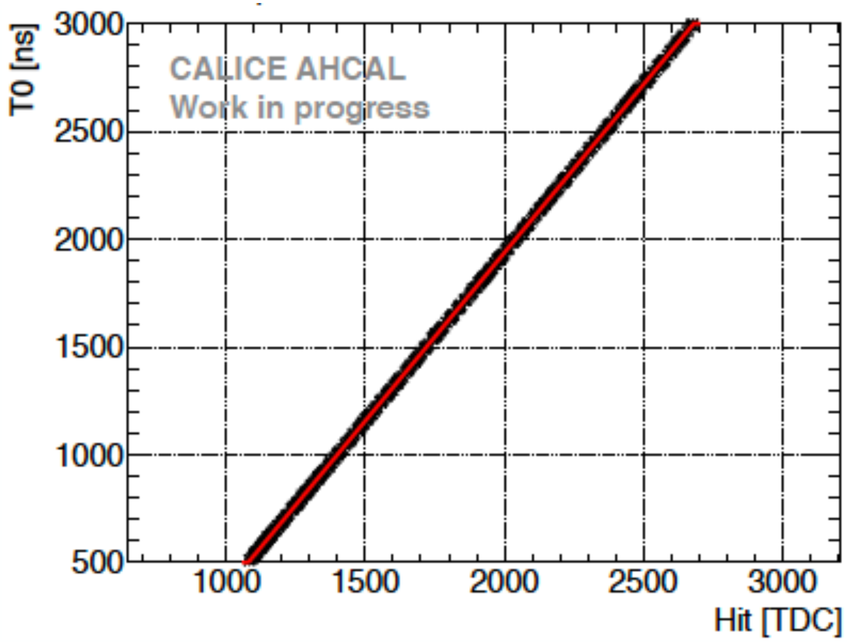

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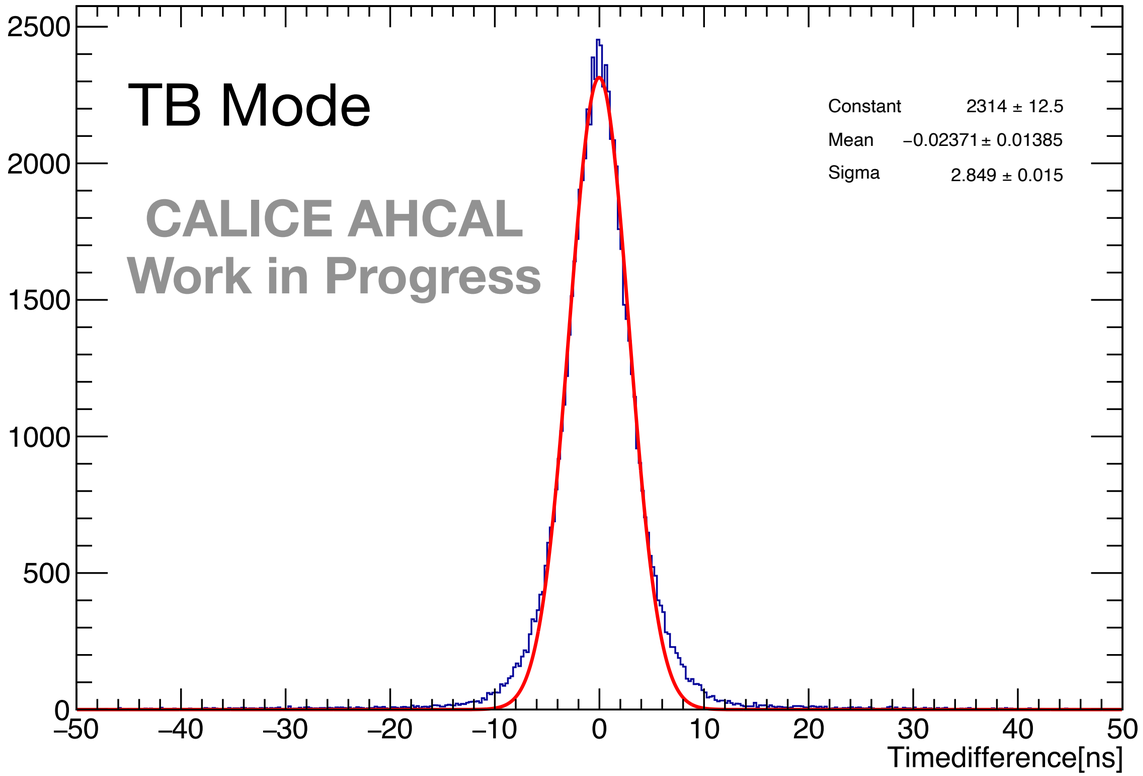

Single channel resolution: 2.859/√2 = 2.014ns

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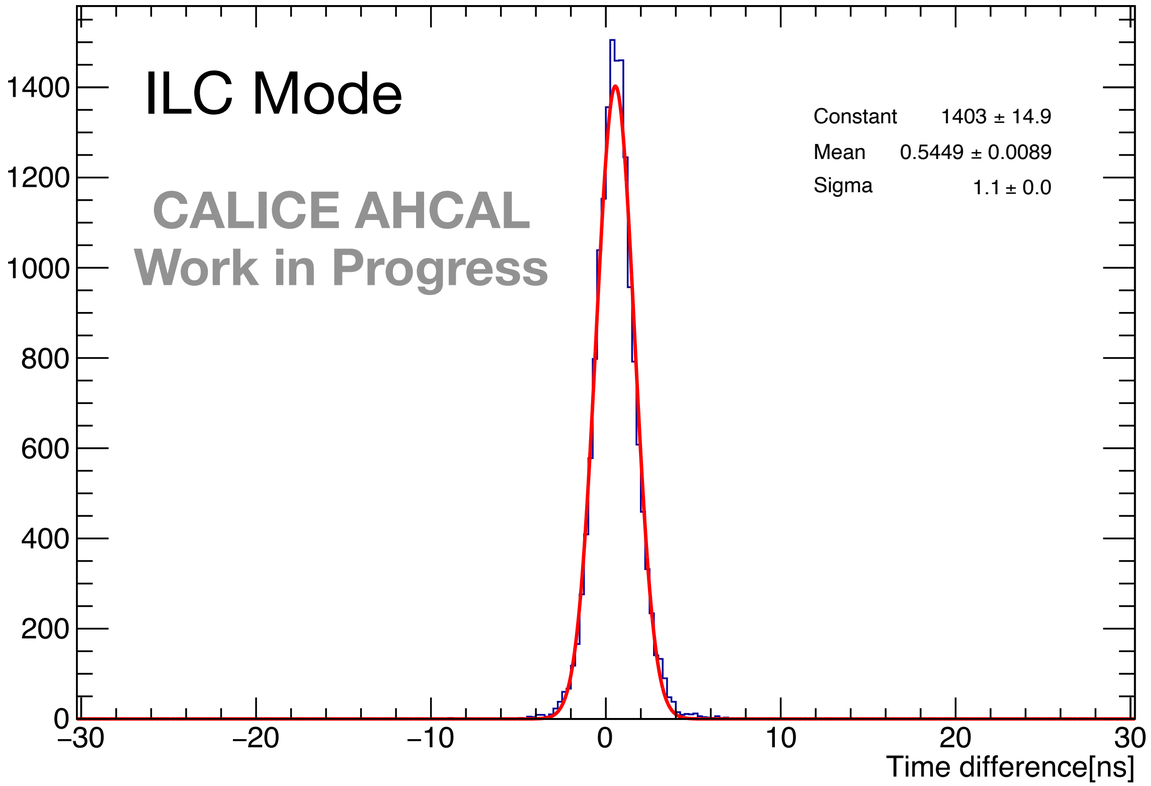

Single channel resolution: 1.1/√2 = 0.78ns

Scintillator Timing Setup

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Goal 1: Measure the time resolution of the SiPM-on-Tile technology:

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- Independent of the AHCAL electronics and DAQ
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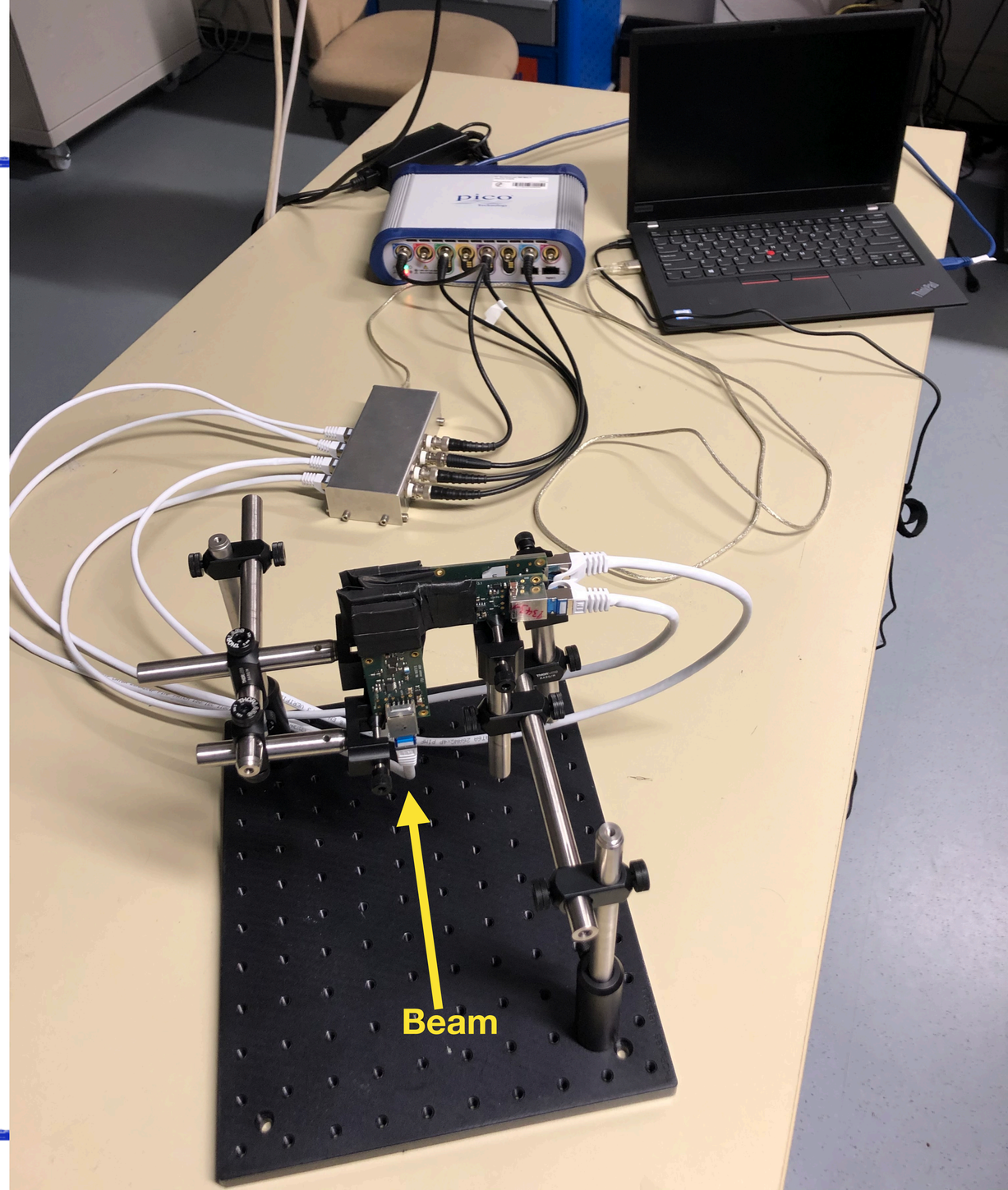
Goal2: Identification of limiting factors of the time resolution of the AHCAL

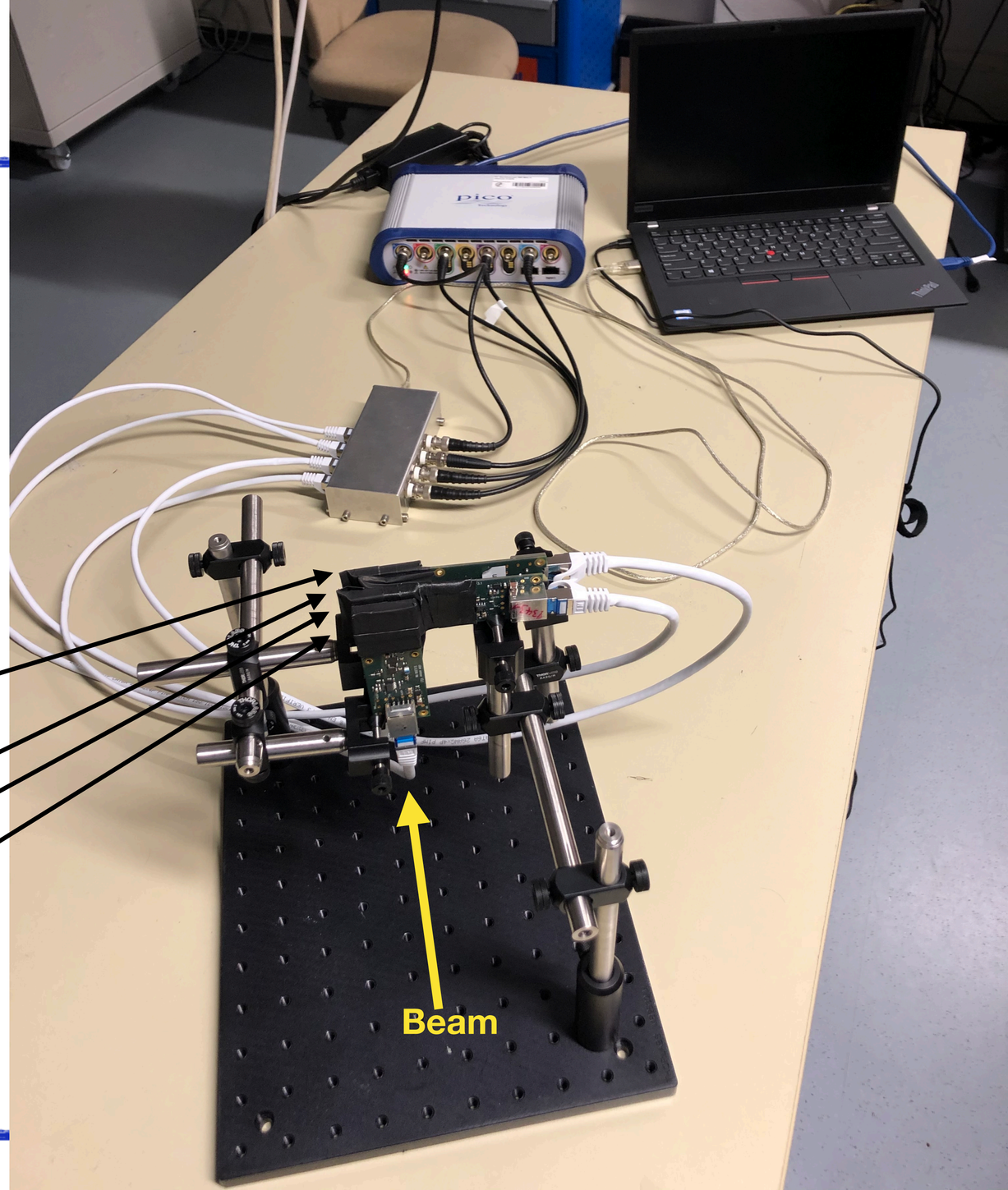
Setup



Setup

Stack of 4 Tiles:

- BC408 or Polystyrene (AHCAL)
- Hamamatsu S13360-1325PE



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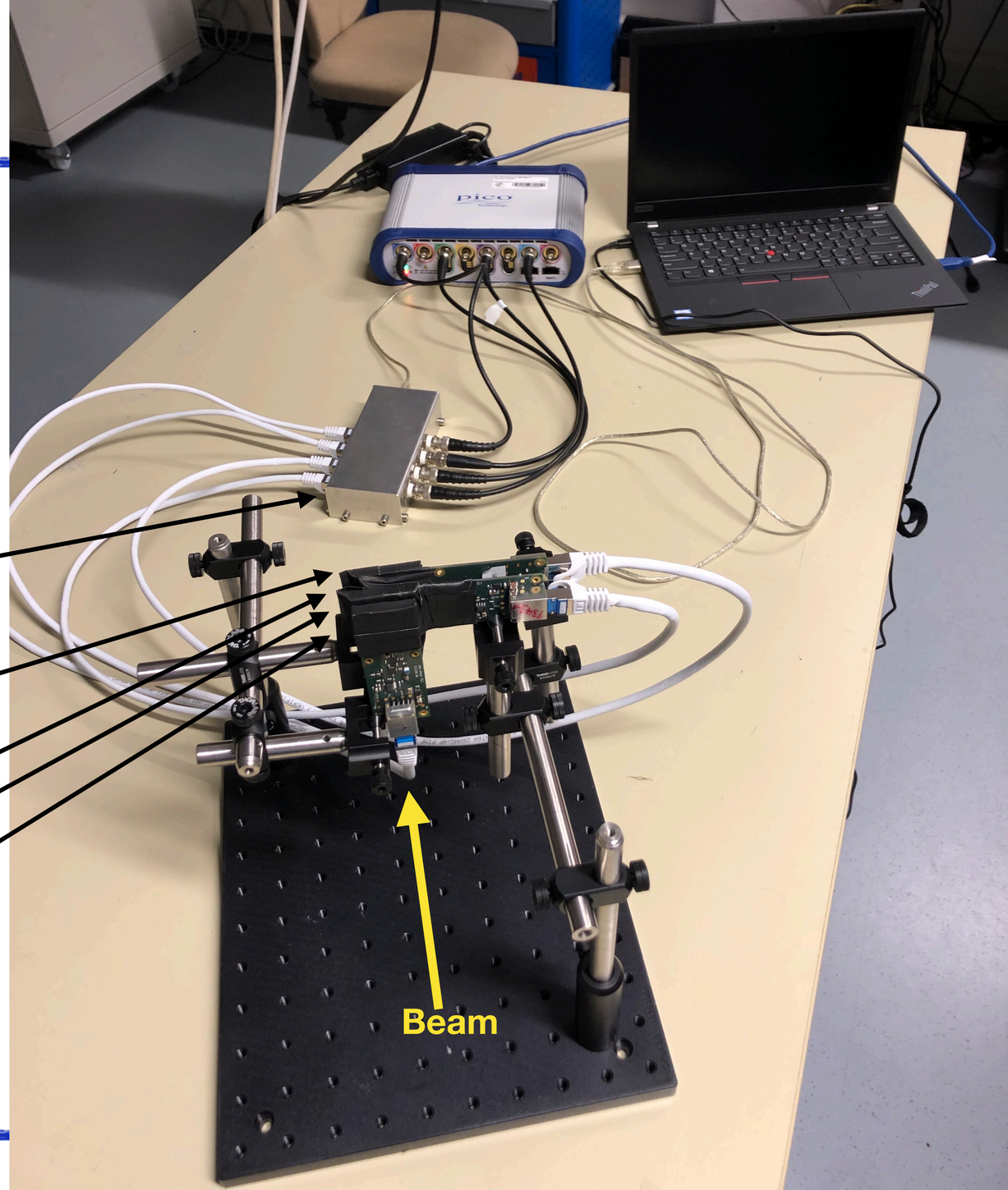
Ethernet Cat 7

Receiver Box:

- USB controlled power supply
- Split signal and power lines



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↓ **Ethernet Cat 7**

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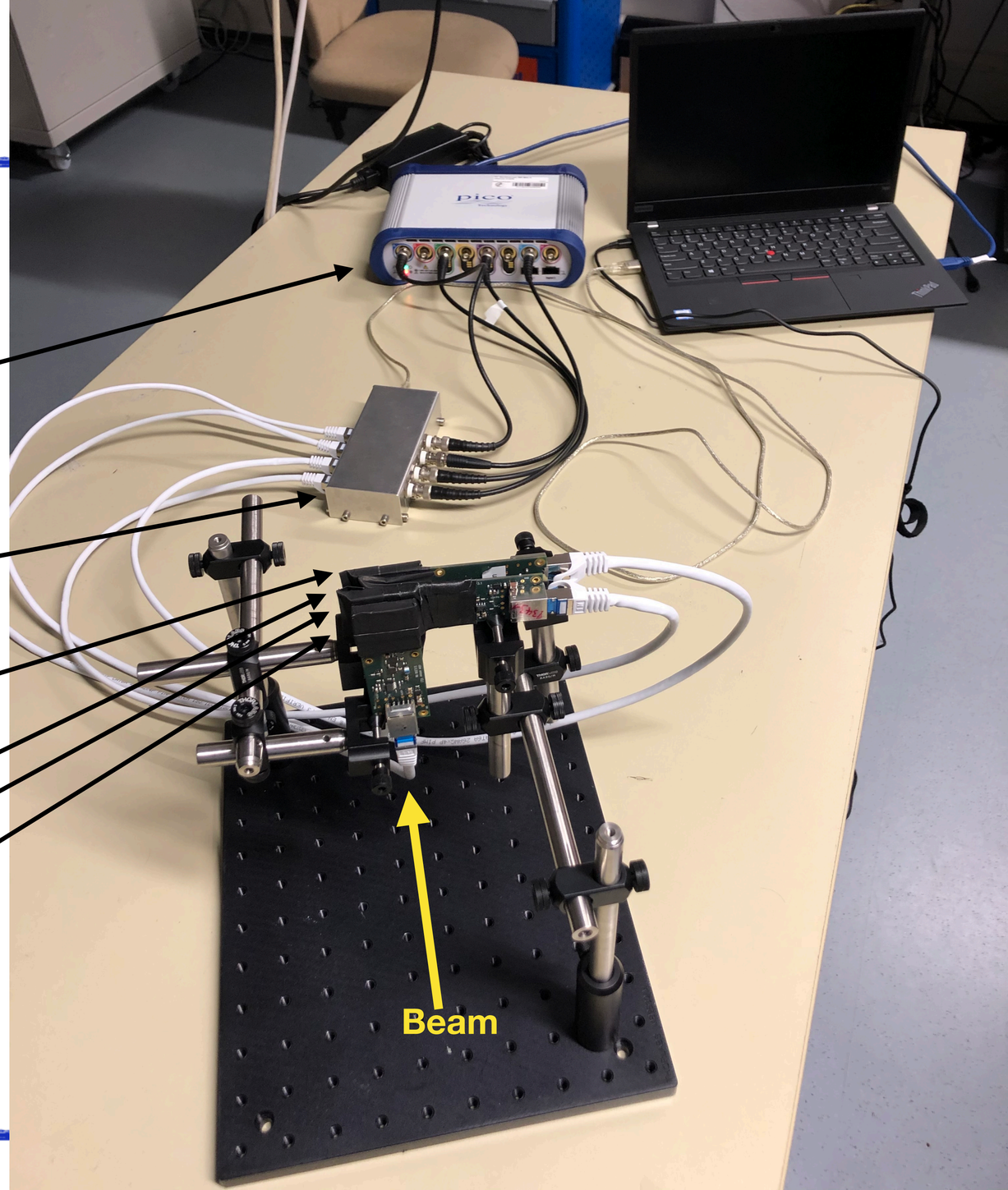
↓ **BNC**

Picoscope:

- Up to 2.5GHz sampling rate on 4 channels
- 300kHz peak trigger rate
- Save complete analog waveform



Data Taking at the DESY Testbeam

MIP spectrum for amplitude resolved time resolution measurement:

- Polystyrene scintillator and BC408 scintillator for higher light yield
- 2.5GHz and 1.25GHz sampling rate
- Tile size of $3\times3cm^2$ and $2\times2cm^2$

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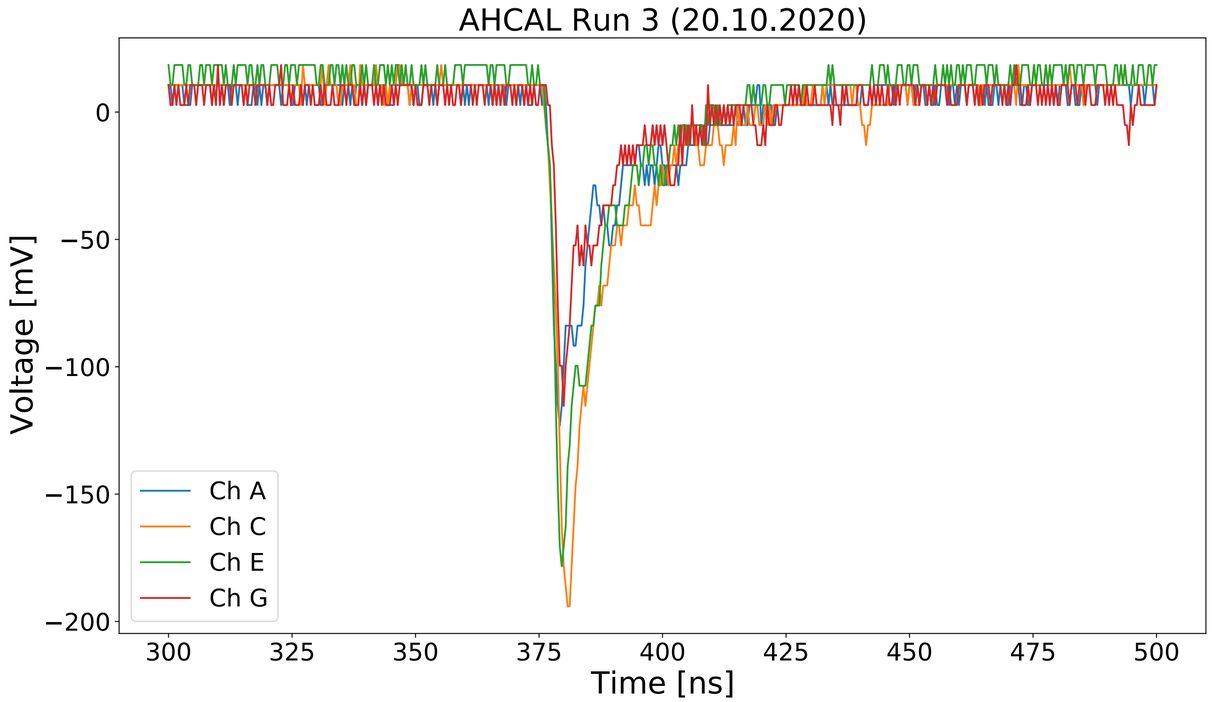

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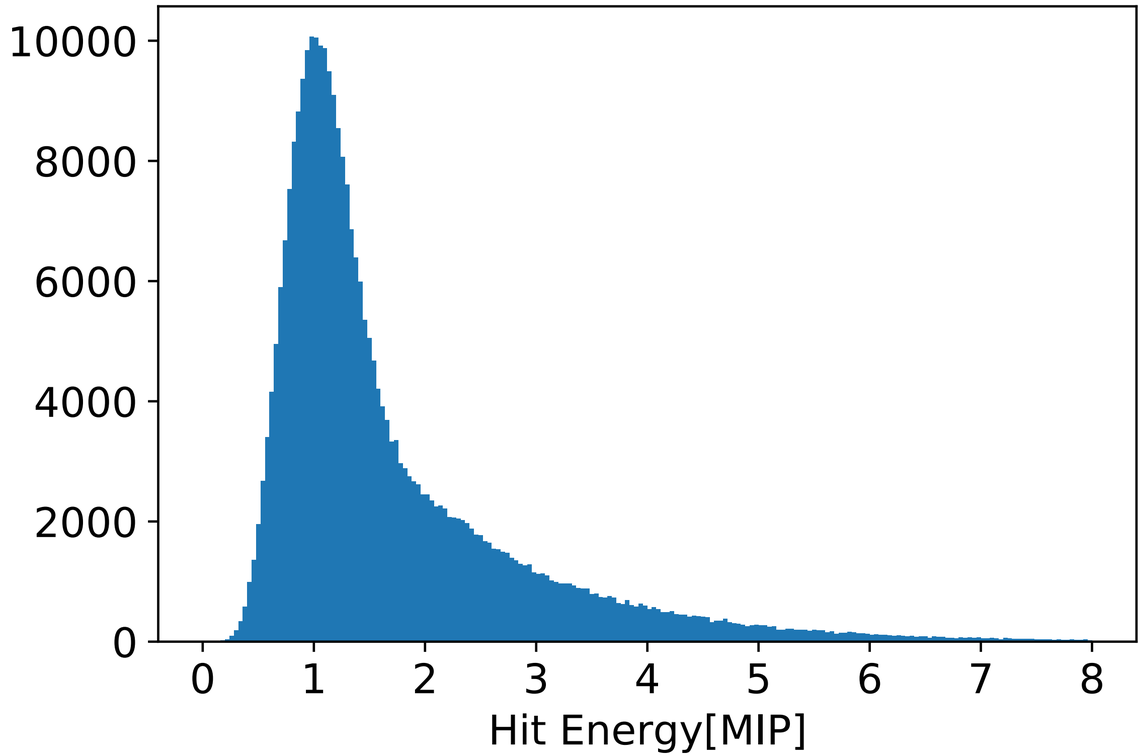

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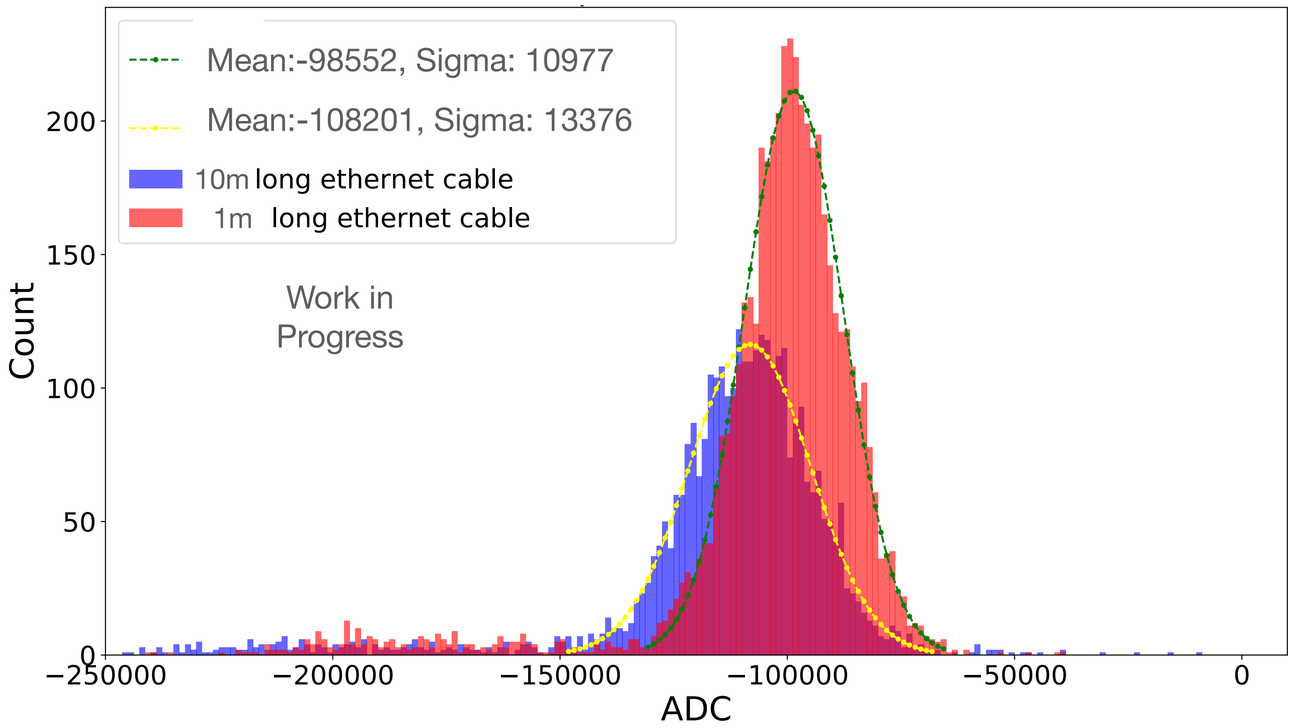
MIP spectrum with different cable length:

- Study impact on energy measurement
- Study impact on time measurement

Integral of 1pe signal



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Energy spectrum of EM showers by placing tungsten absorber plates:

- Increase statistics of high energy hits
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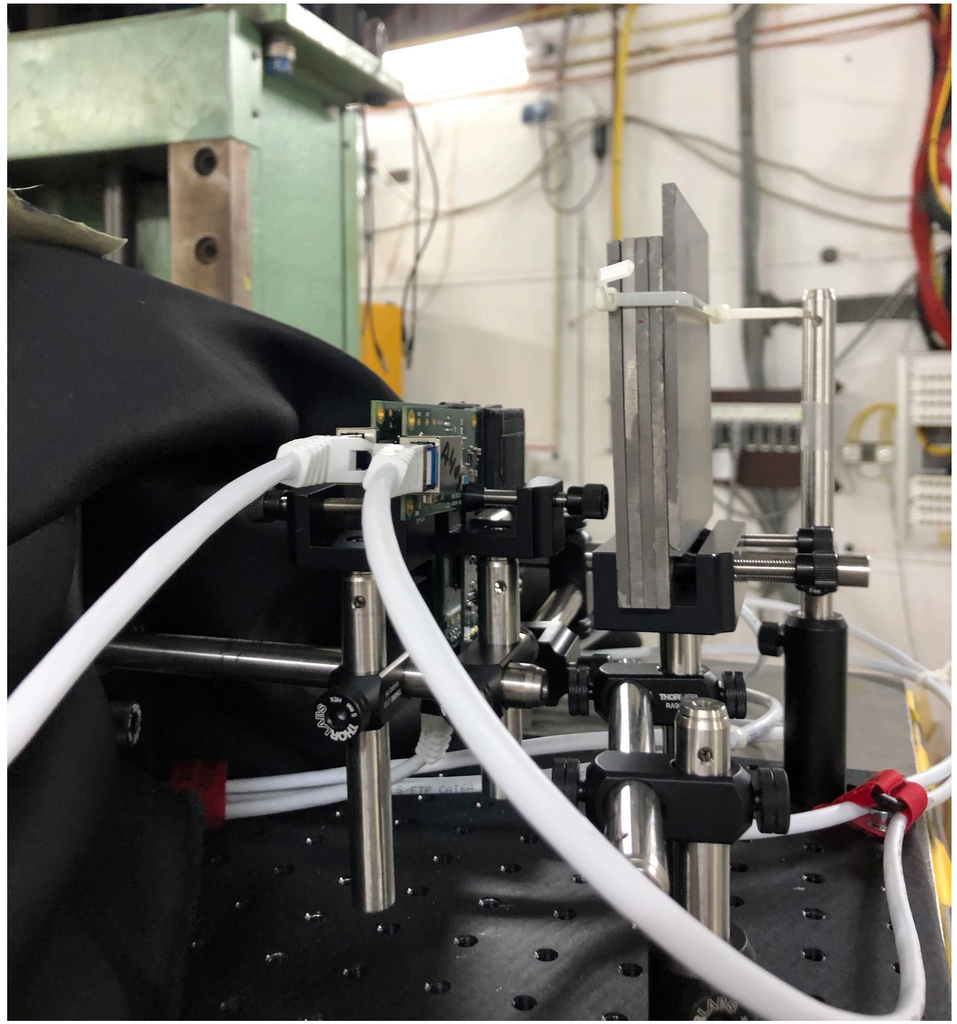

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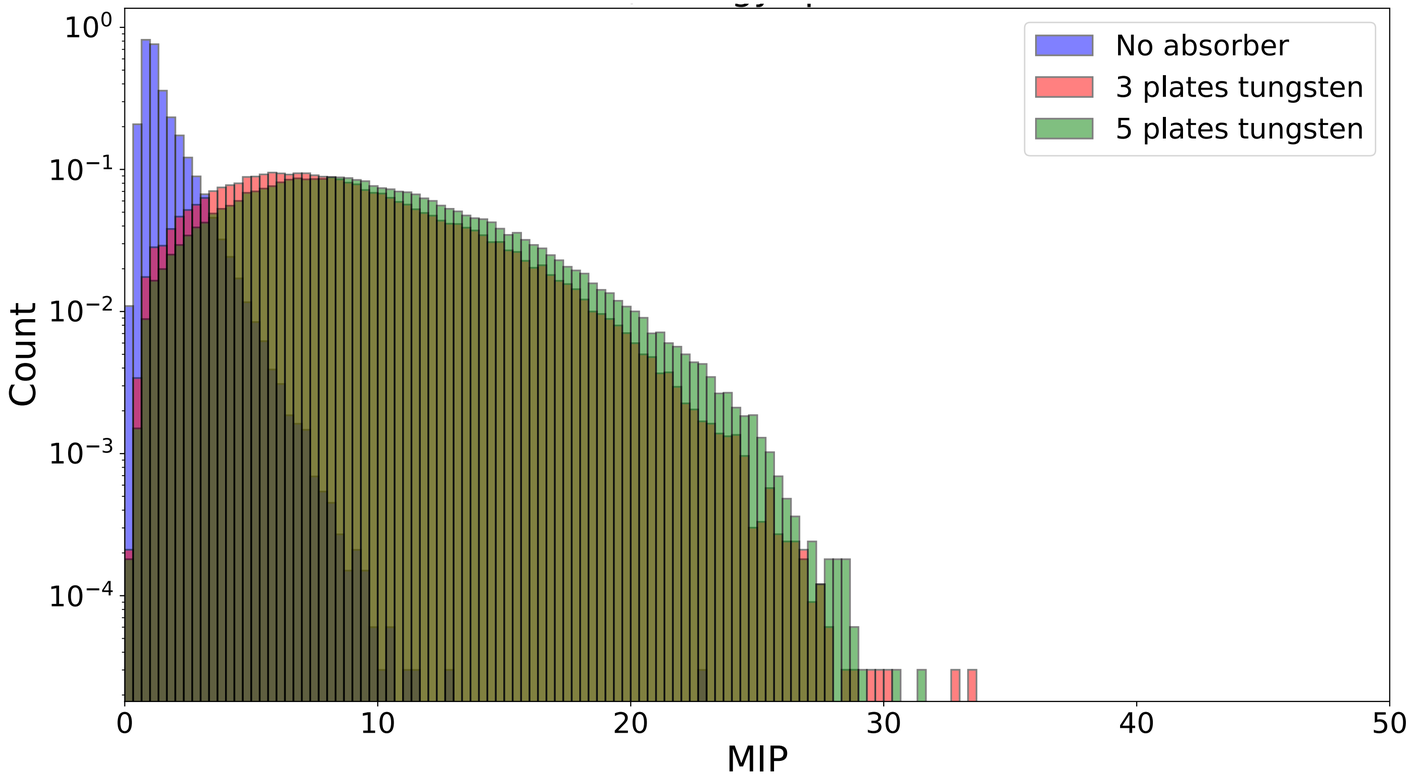

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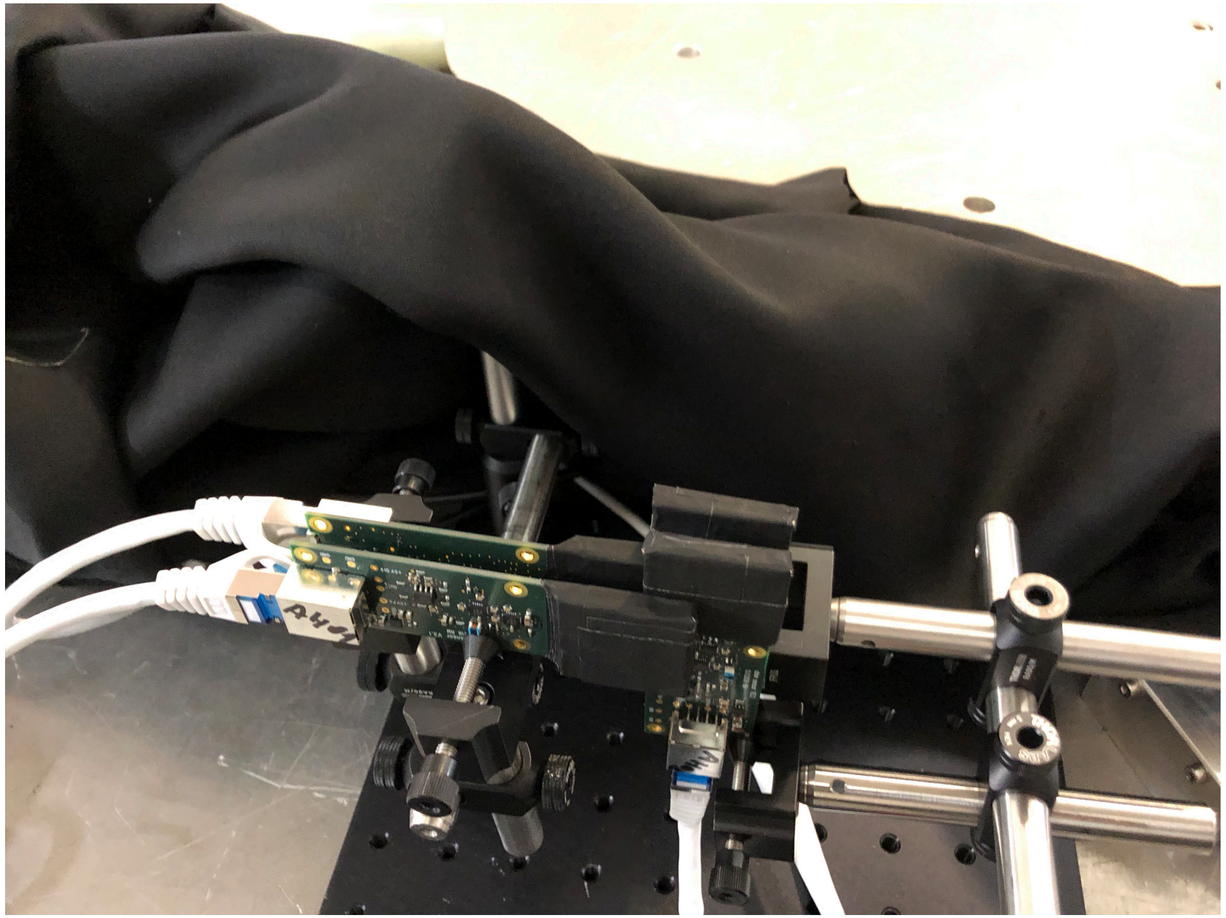
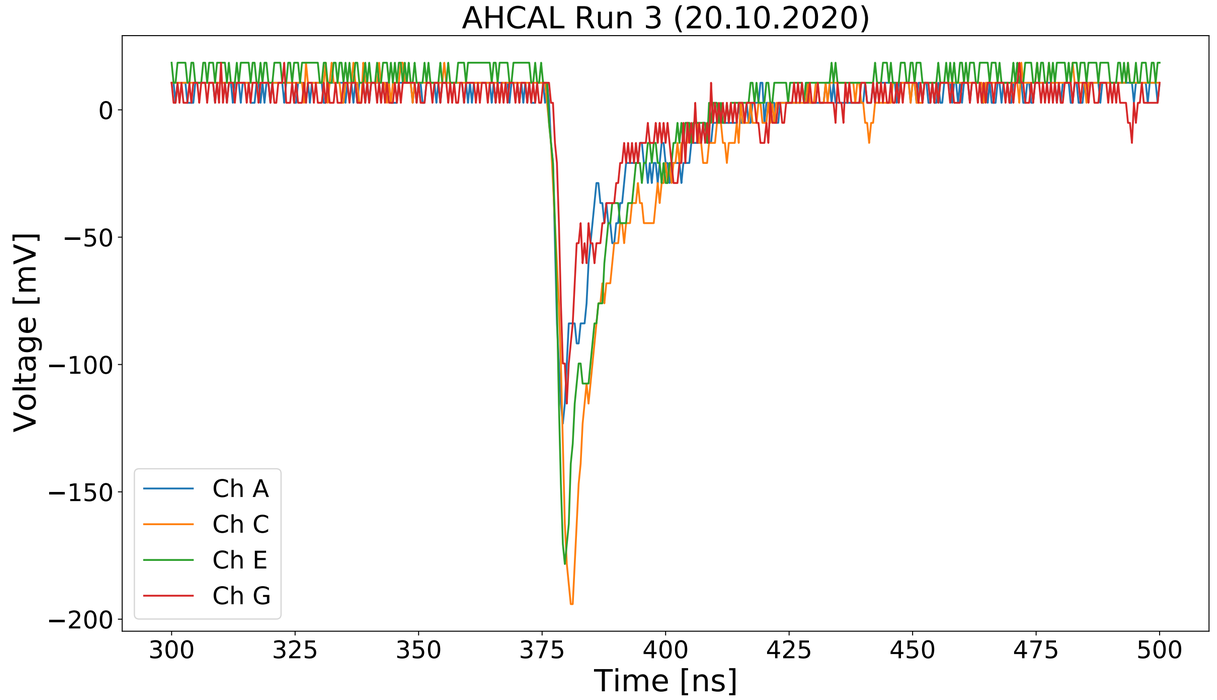


Displaced scintillators:

- Position dependent dataset
- Impact on energy response
- Impact on time resolution

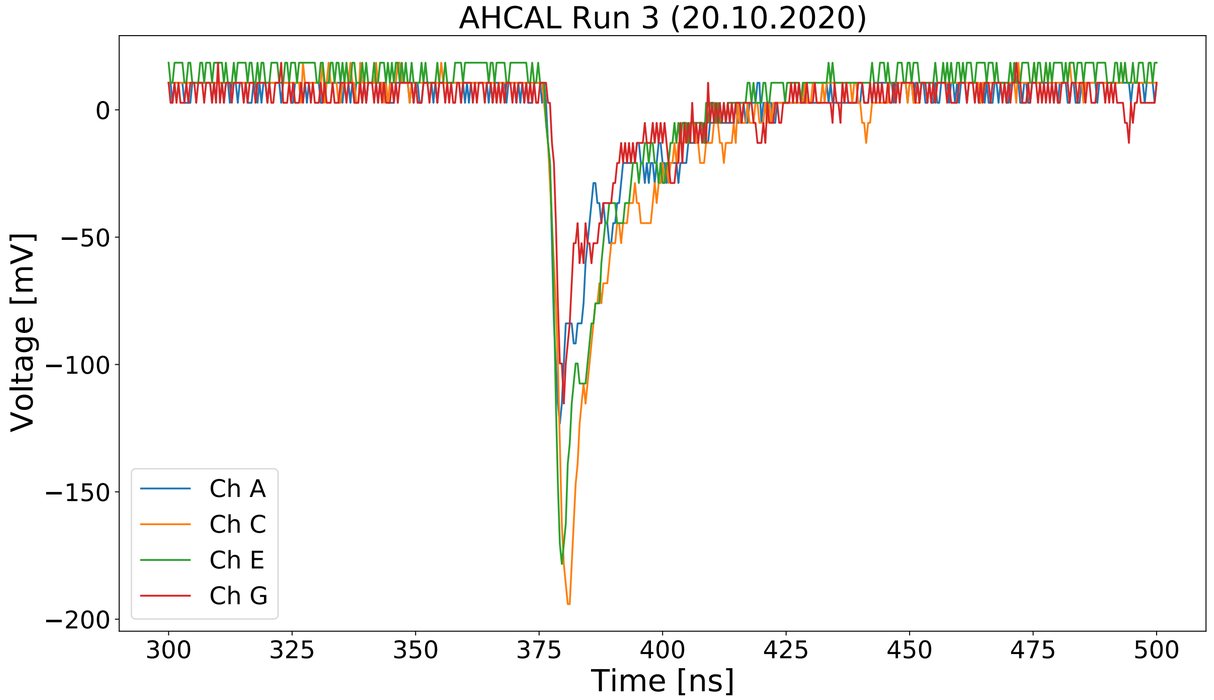
Event Reconstruction



Event Reconstruction

Per event:

1. Search for maximum amplitude in each waveform



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Per event:

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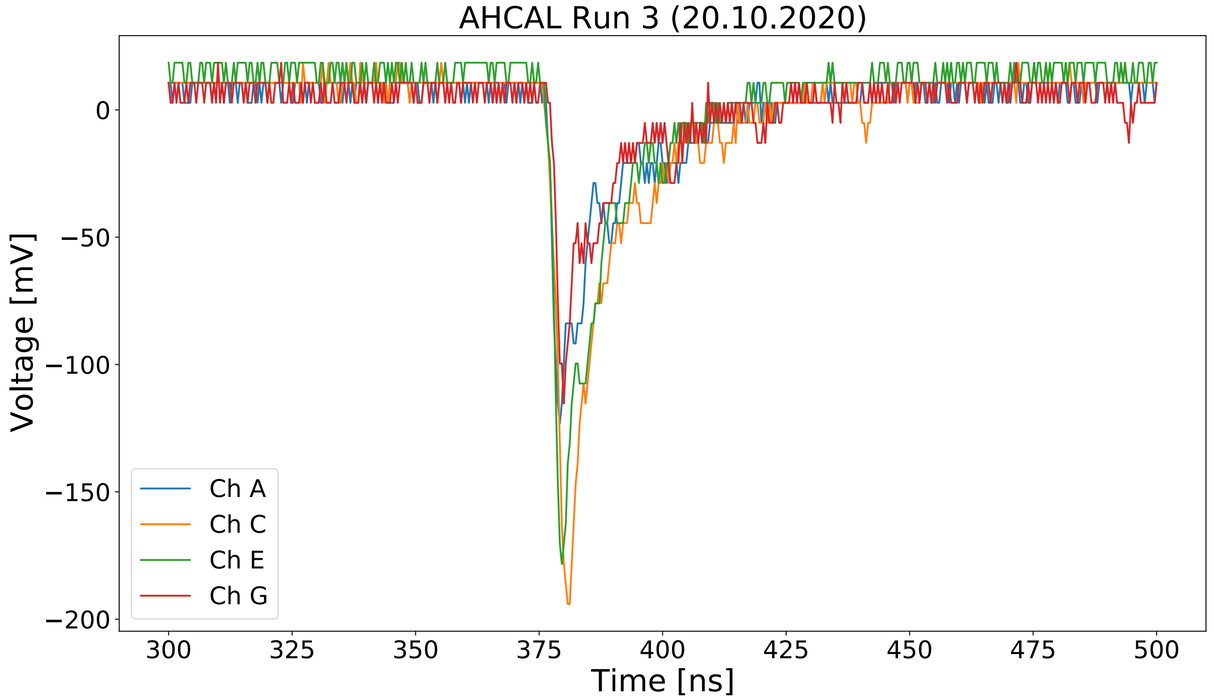

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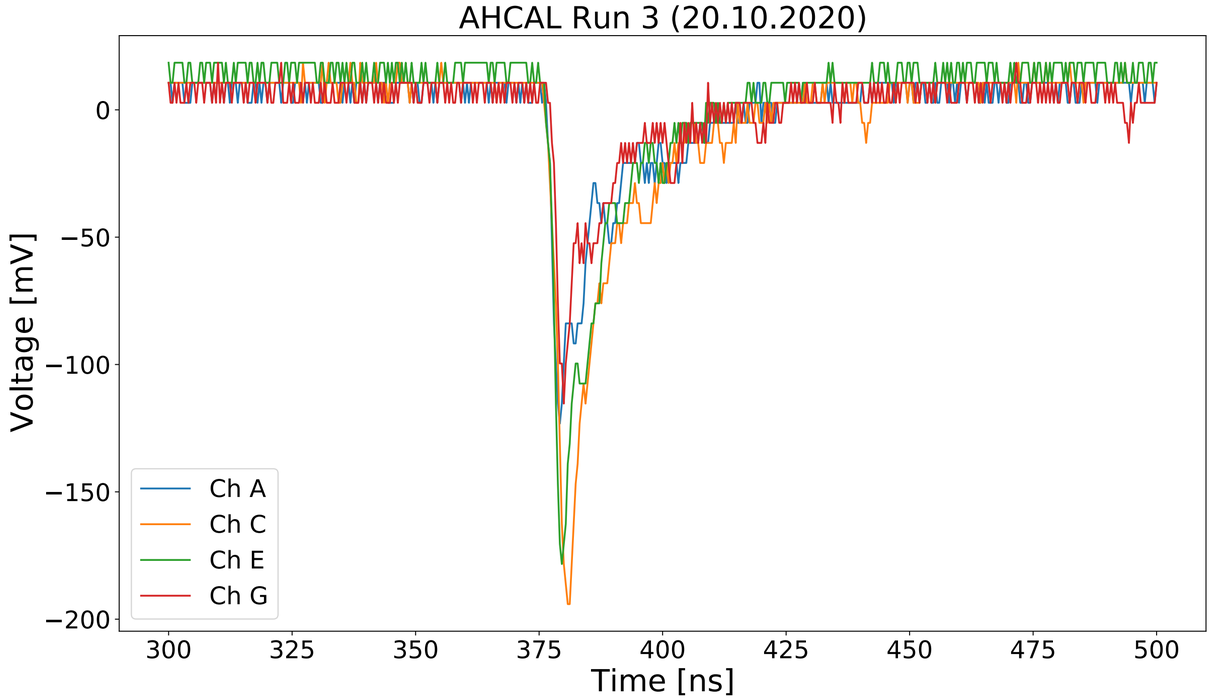

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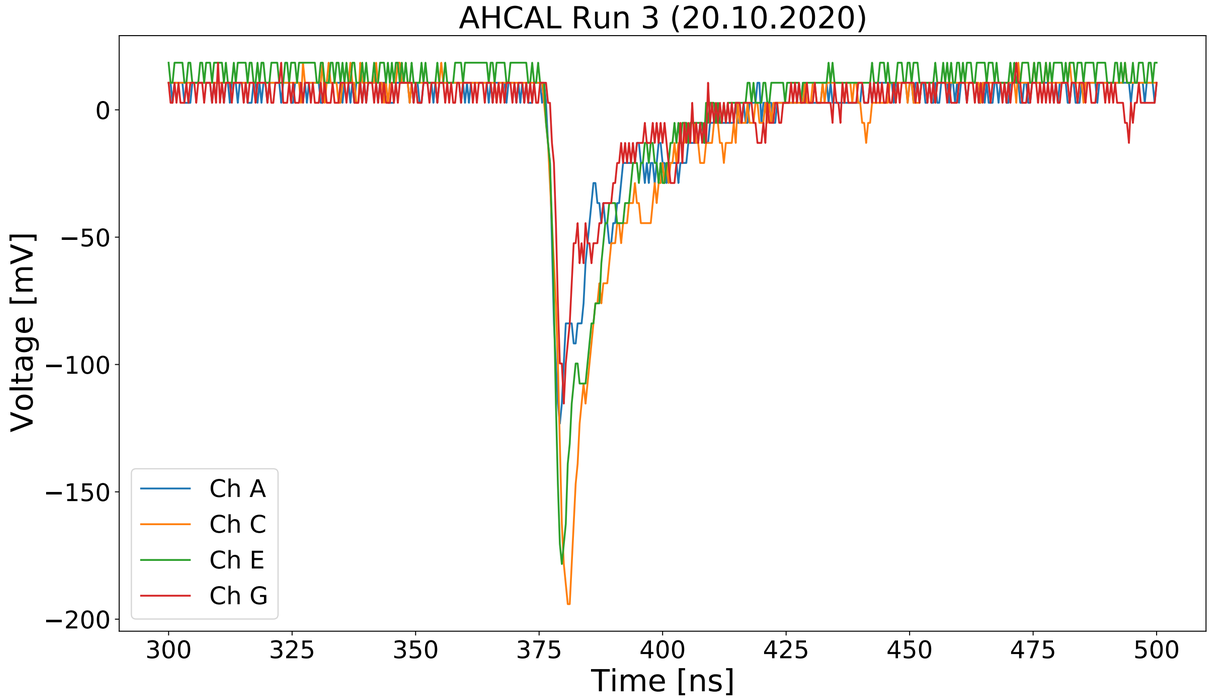

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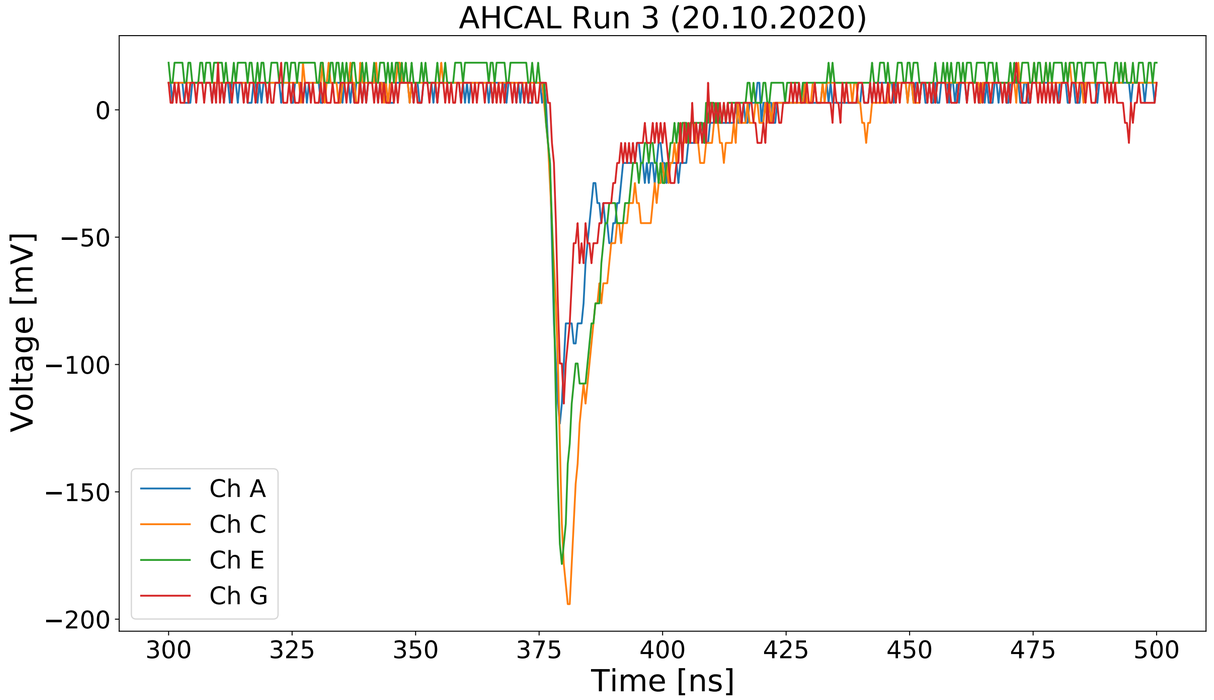

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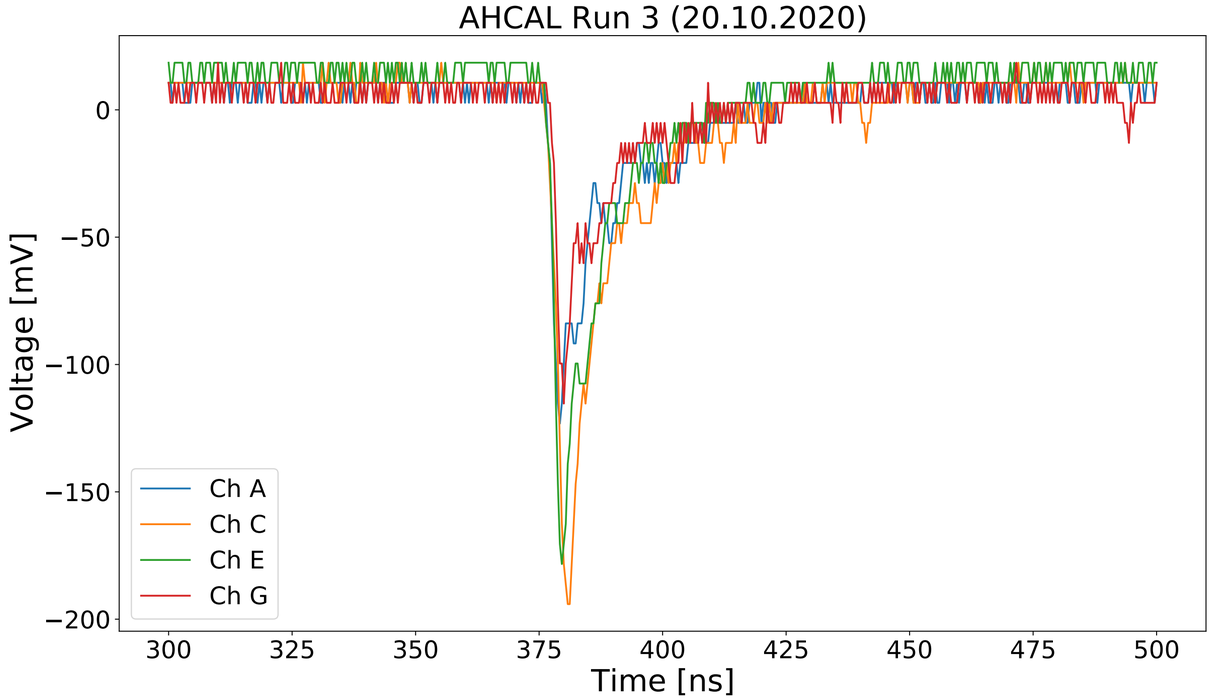
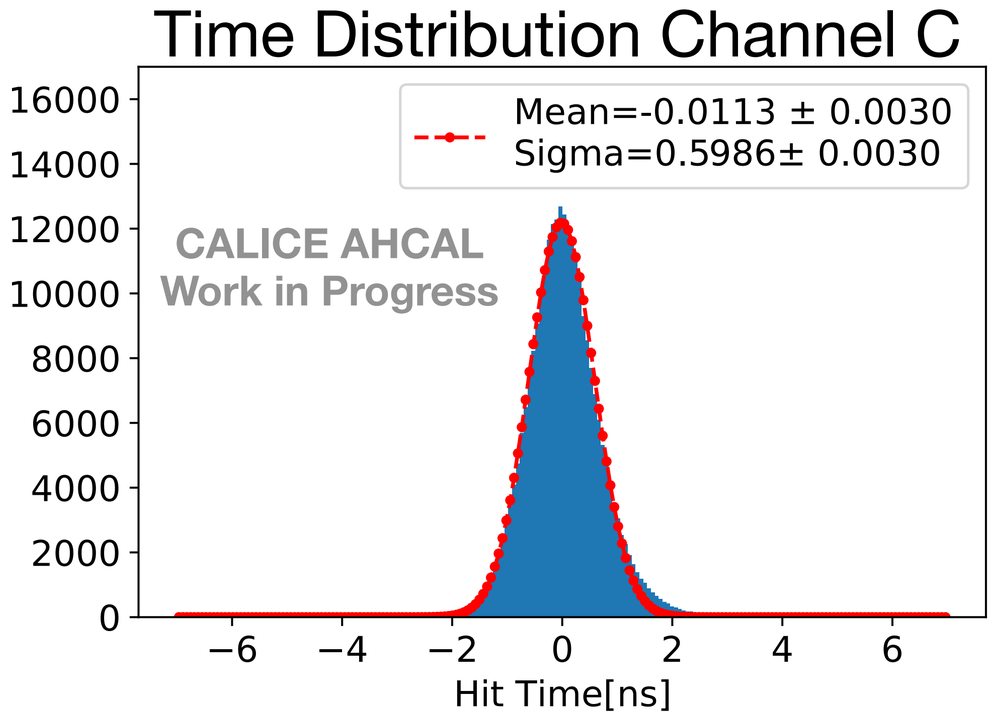
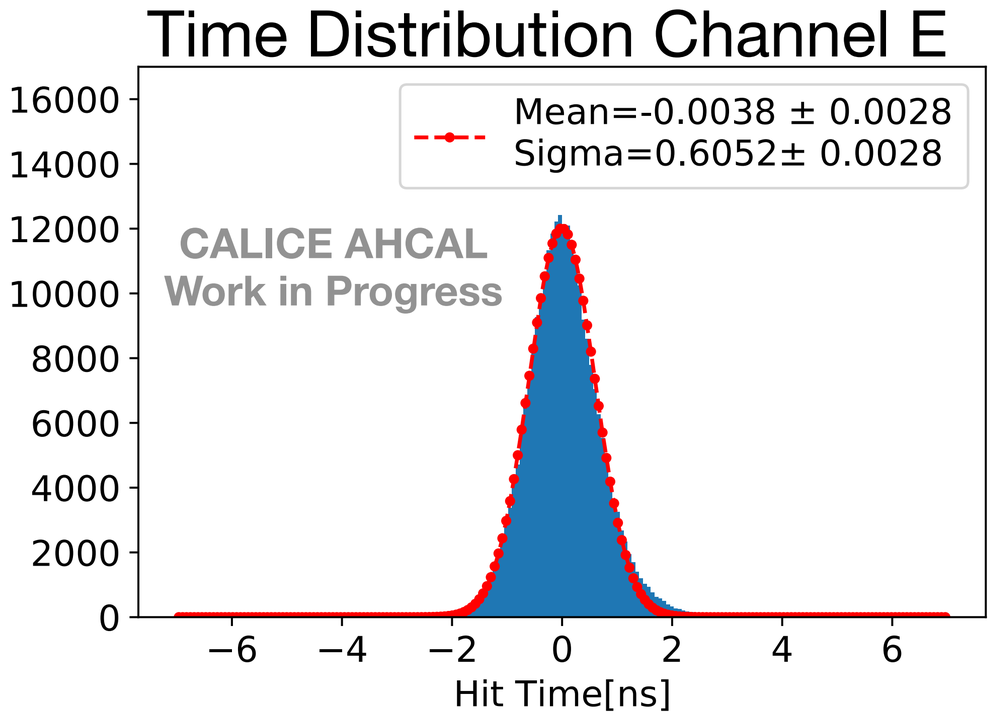


5. Calculate event time from average of trigger times
6. Calculate relative hit times by: event time - hit time

Time Resolution - Polystyrene Scintillator





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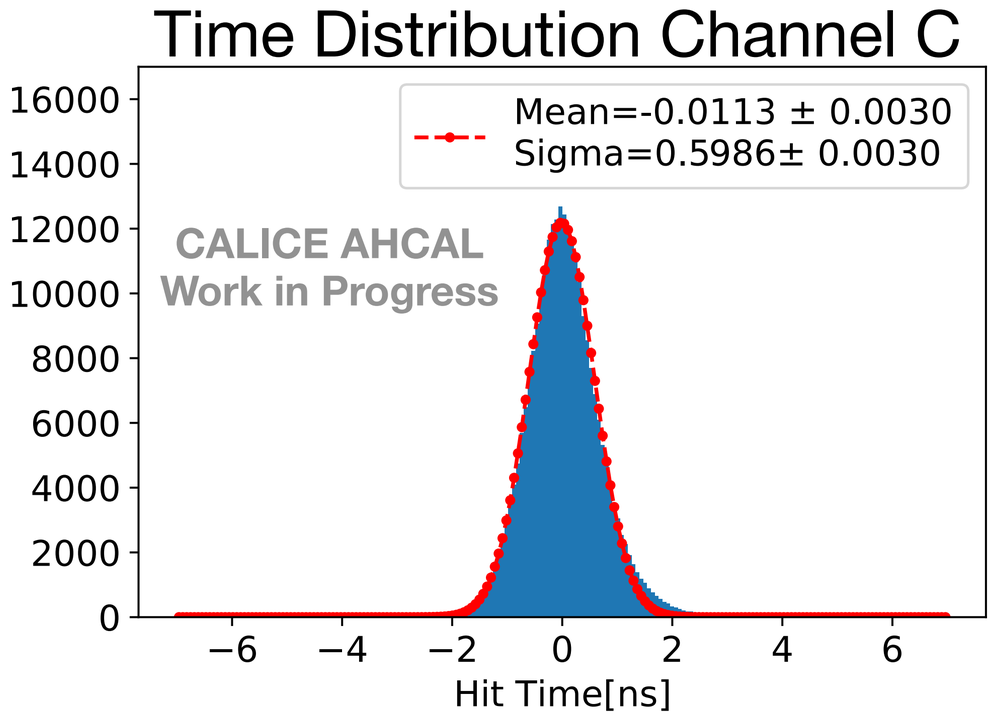
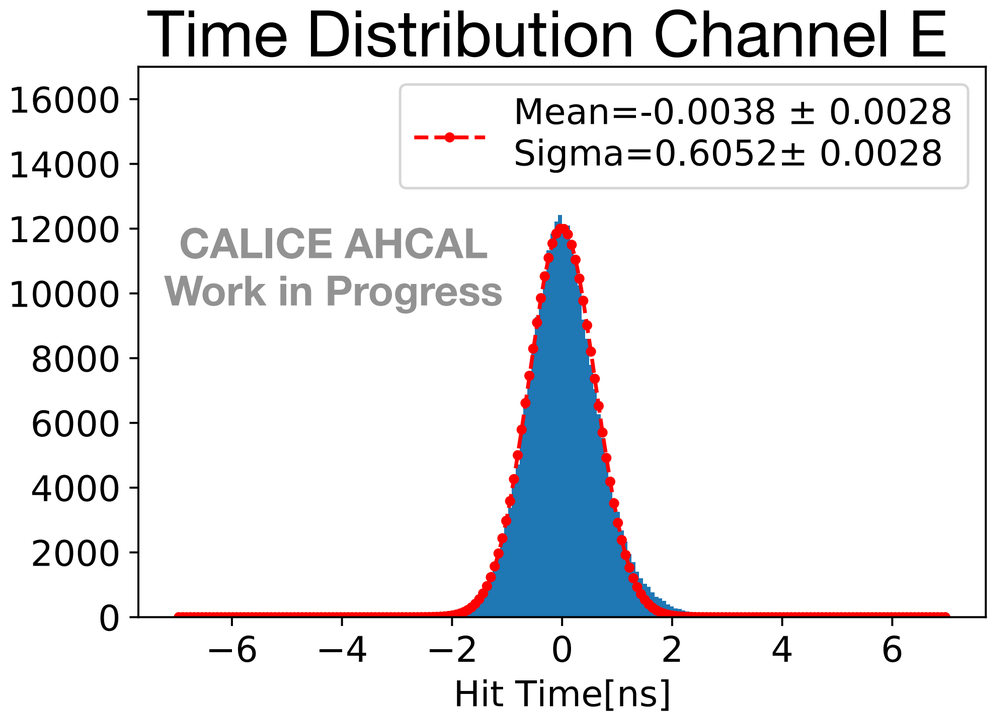
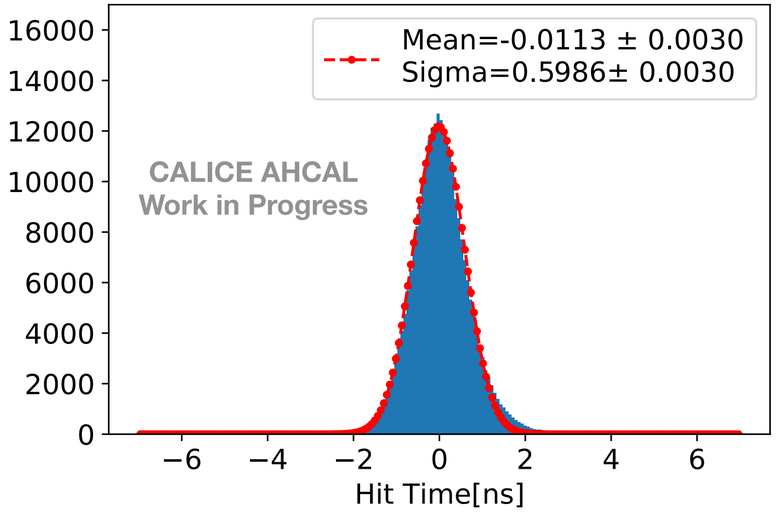
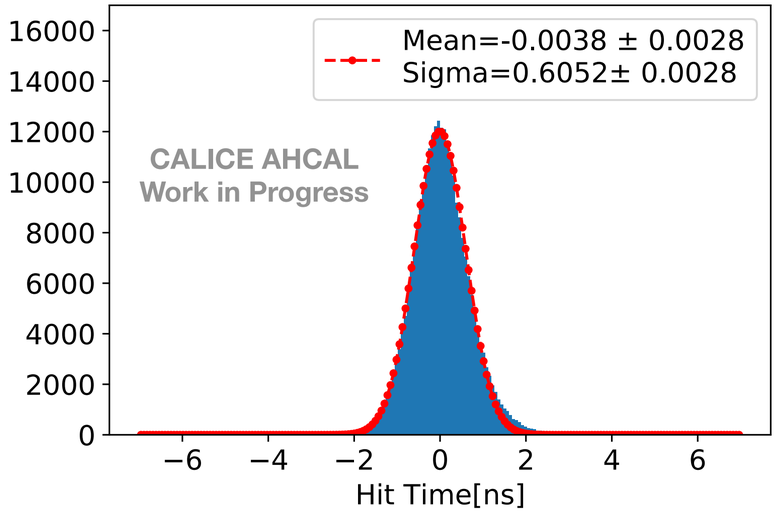


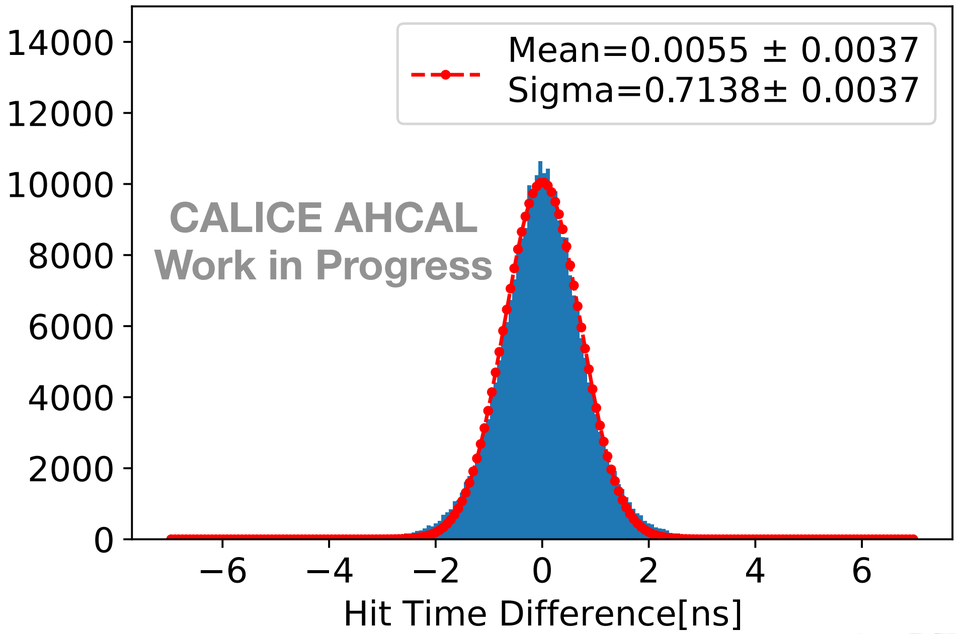


Obtain time difference of hits in channel C and channel E to calculate the resolution

Time Resolution - Polystyrene Scintillator







Time resolution=0.718/sqrt(2)=0.507ns

- Interpret as Intrinsic time resolution of SiPM-on-Tile

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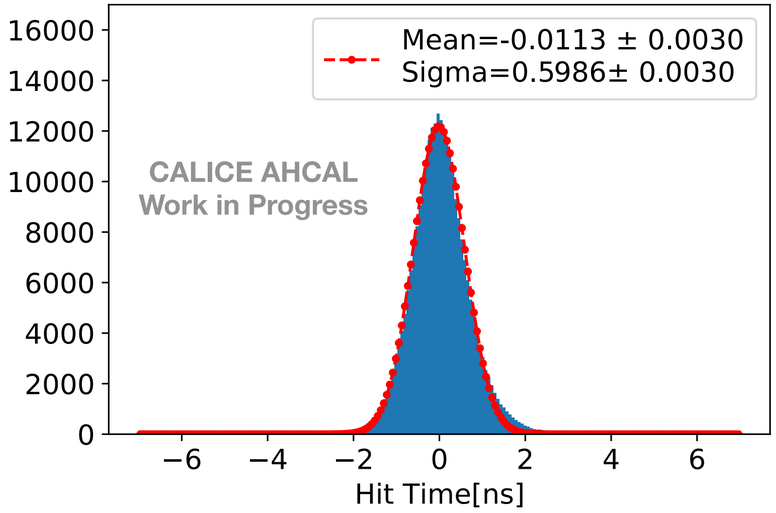
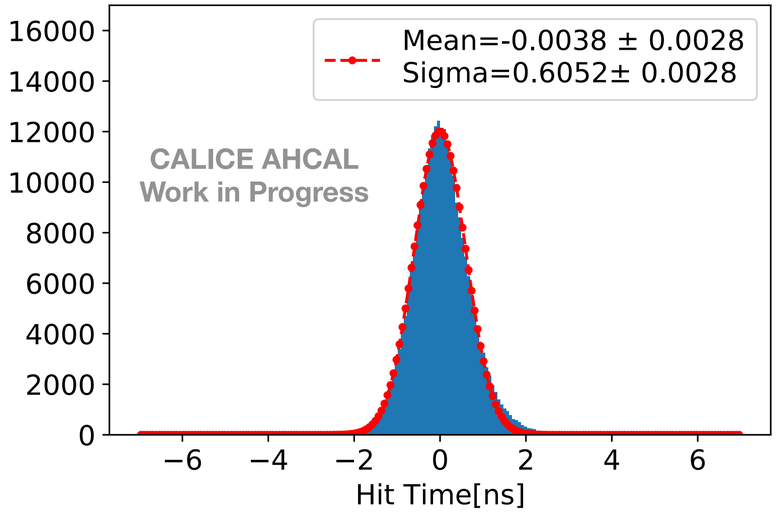
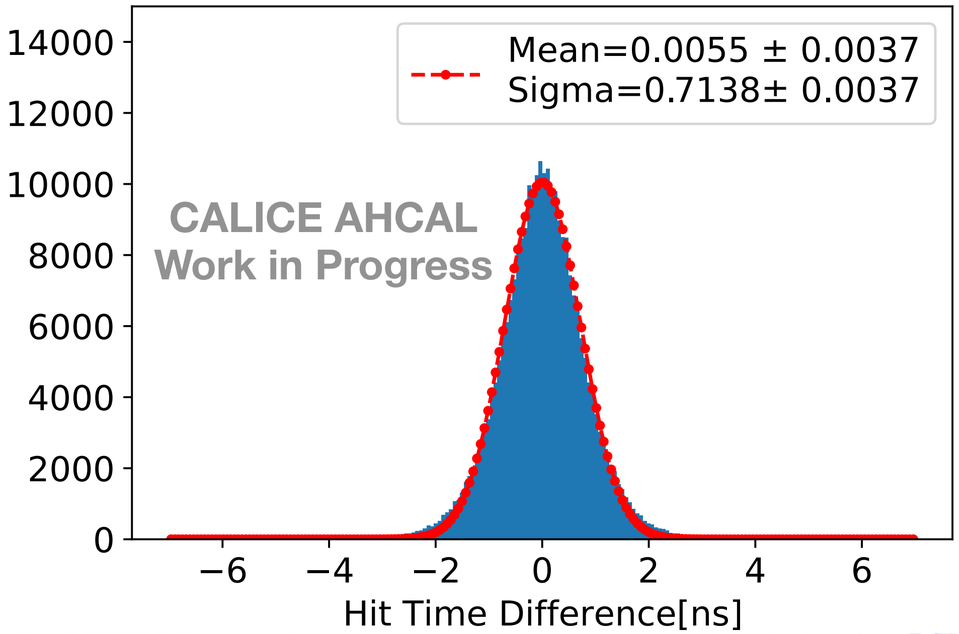






Time resolution=0.718/sqrt(2)=0.507ns

- Interpret as Intrinsic time resolution of SiPM-on-Tile

Compared to 0.780ns of the AHCAL:

- AHCAL front-end contributes ~0.6ns

Conclusion and Outlook

Successful implementation of modular tile test setup:

- Tested at DESY in October 2020
- Simple setup allows for various configurations and short access times

Conclusion and Outlook

Time resolution of SiPM-on-Tile configuration with polystyrene scintillator at 0.507ns

AHCAL prototype time resolution at 0.780ns:

- Front-end contributes ~0.6ns
- Improve front-end and SiPM-on-Tile configuration, to significantly improve the AHCAL time resolution

Conclusion and Outlook

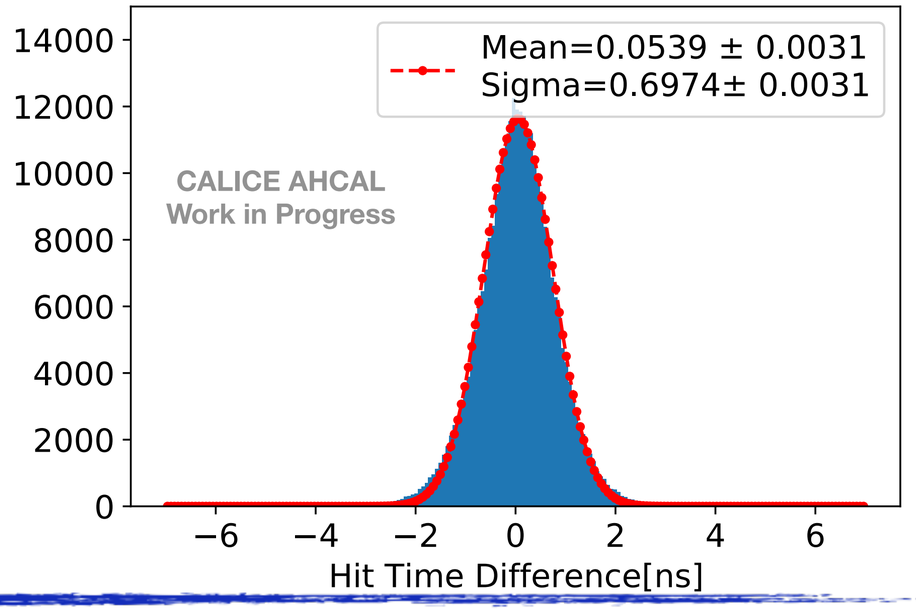
Time resolution of SiPM-on-Tile configuration with polystyrene scintillator at 0.507ns

AHCAL prototype time resolution at 0.780ns:

- Front-end contributes ~0.6ns
- Improve front-end and SiPM-on-Tile configuration, to significantly improve the AHCAL time resolution

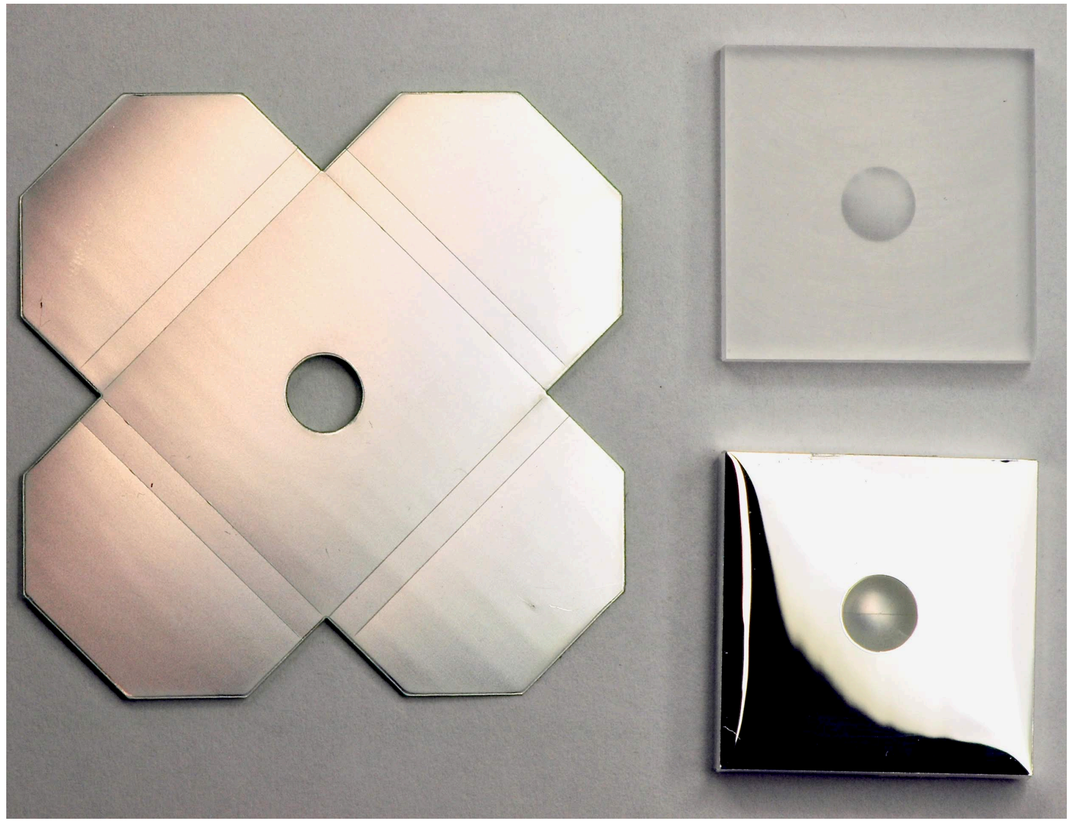
Analysis of full dataset ongoing:

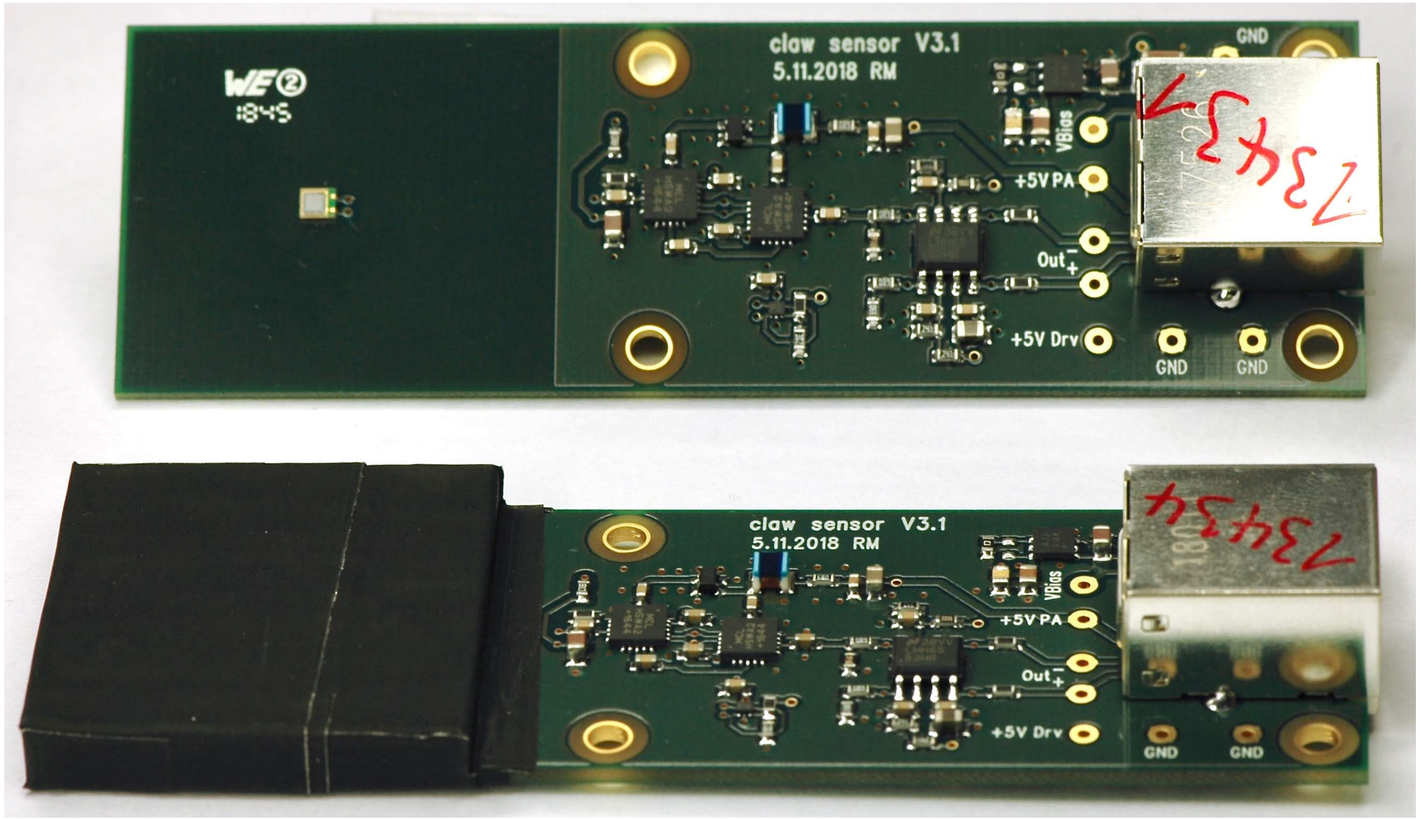
- Preliminary analysis of SiPM-on-Tile configuration with BC408 scintillator yields a time resolution of 0.697ns/sqrt(2)=0.490ns



Backup

Sensors



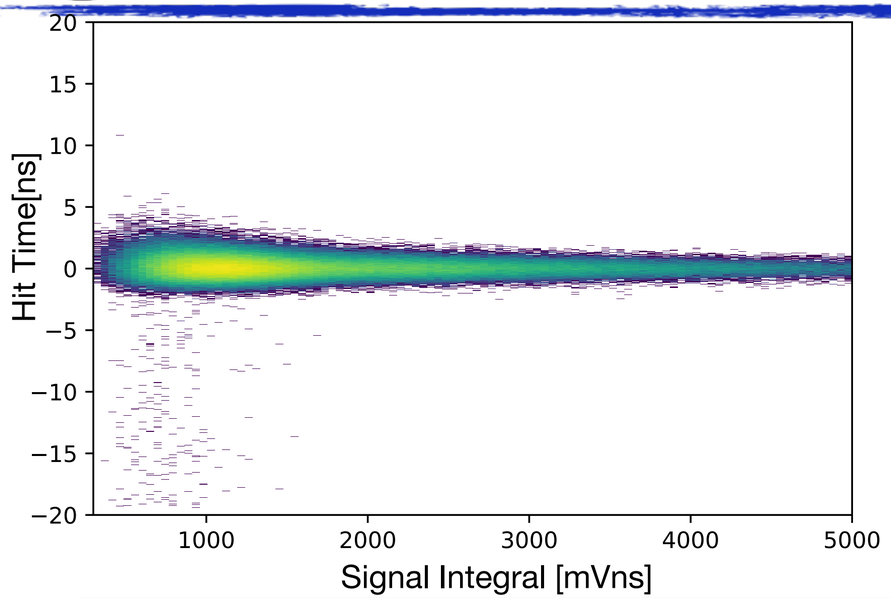

claw sensor V3.1
5.11.2018 RM
GND
VBias
+5V PA
Out
+5V Drv
GND
GND
claw sensor V3.1
5.11.2018 RM
VBias
+5V PA
Out
+5V Drv
GND
GND

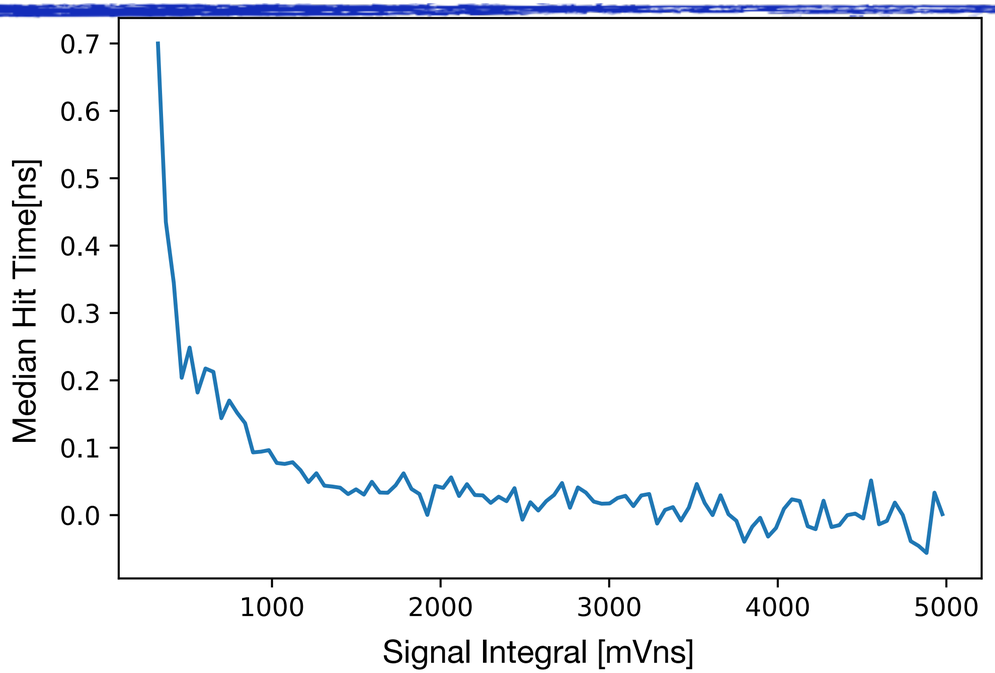
SiPM

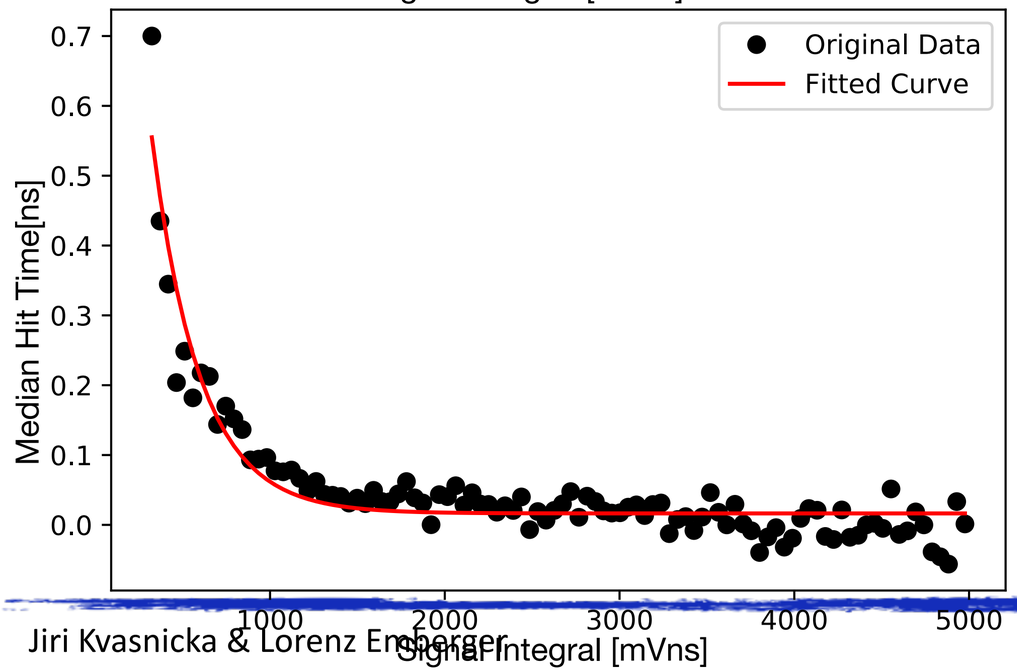
Number of channels	1 ch
Effective photosensitive area / ch	1.3 × 1.3 mm
Number of pixels /ch	2668
Pixel size	25 µm
Spectral response range	320 to 900 nm
Gain (typ.)	7.0×10^5

Information taken from: https://www.hamamatsu.com/eu/en/product/type/S13360-1325PE/index.html

Time Walk Channel E

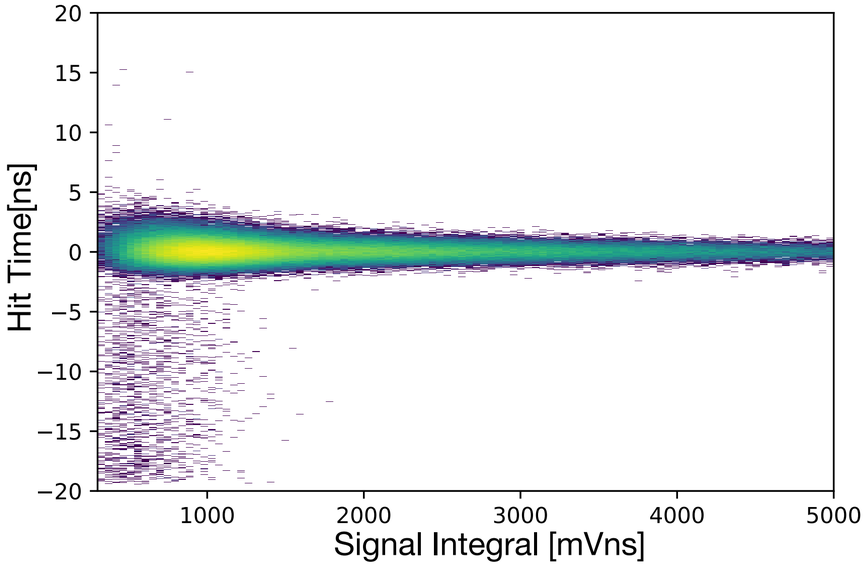




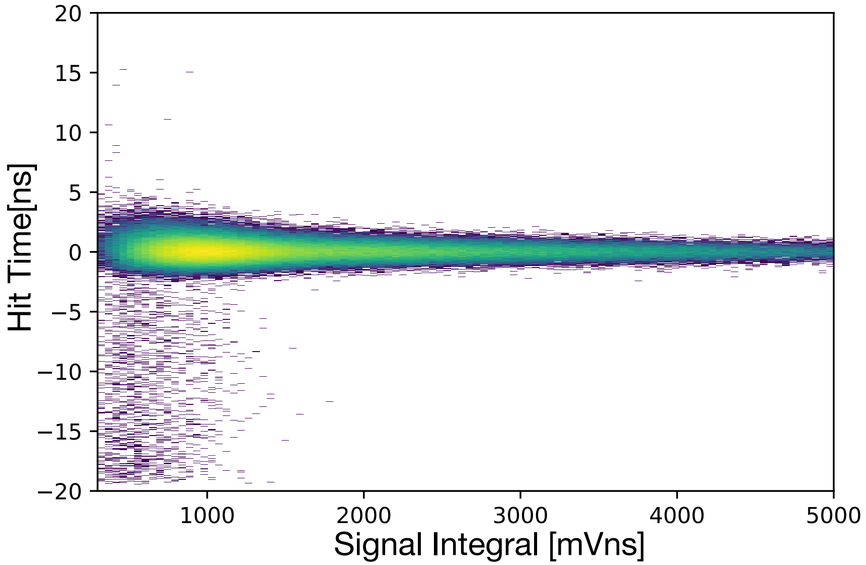


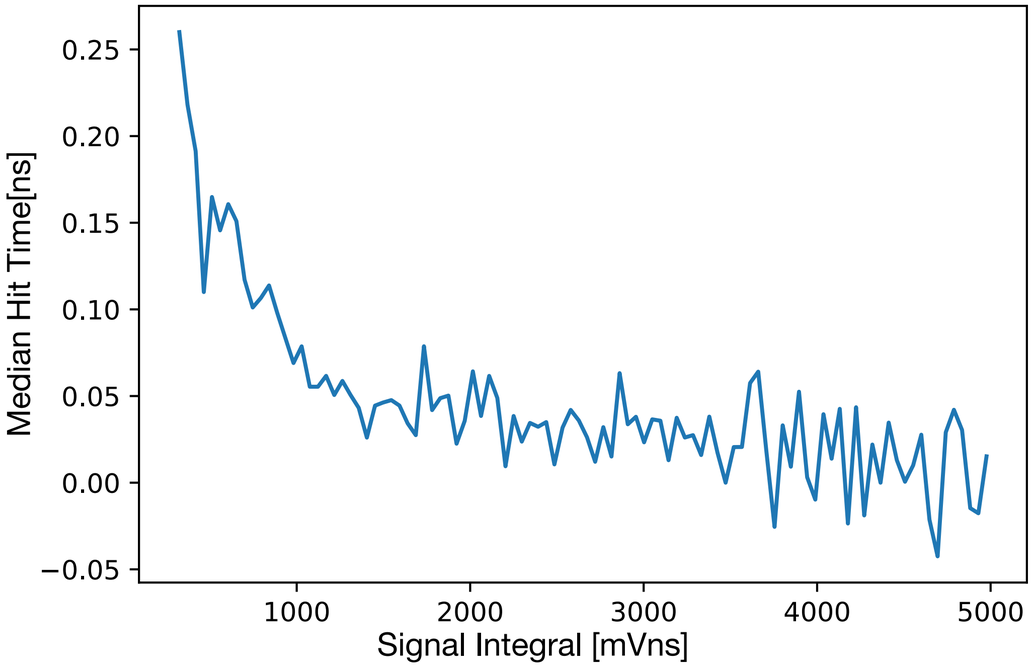
Correction = 1.7578*exp(-0.0037*x) + 0.0164

Time Walk Channel C

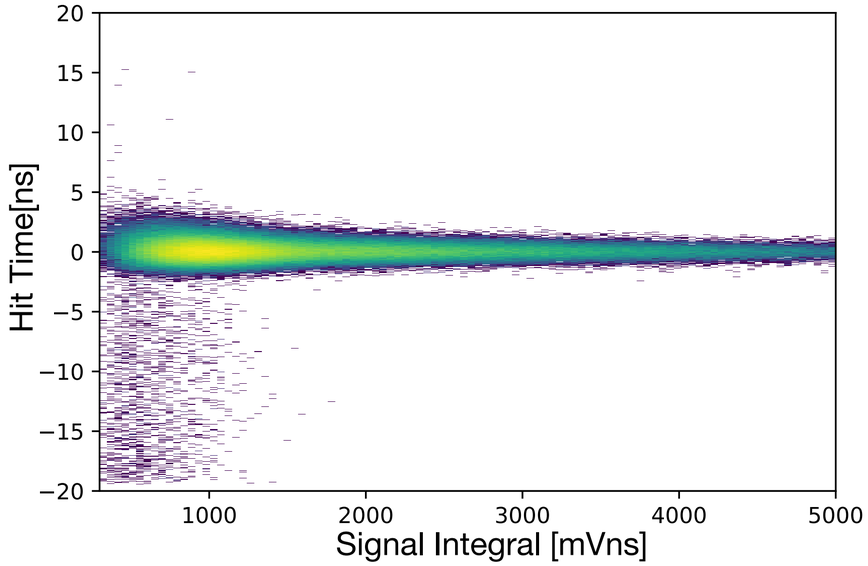


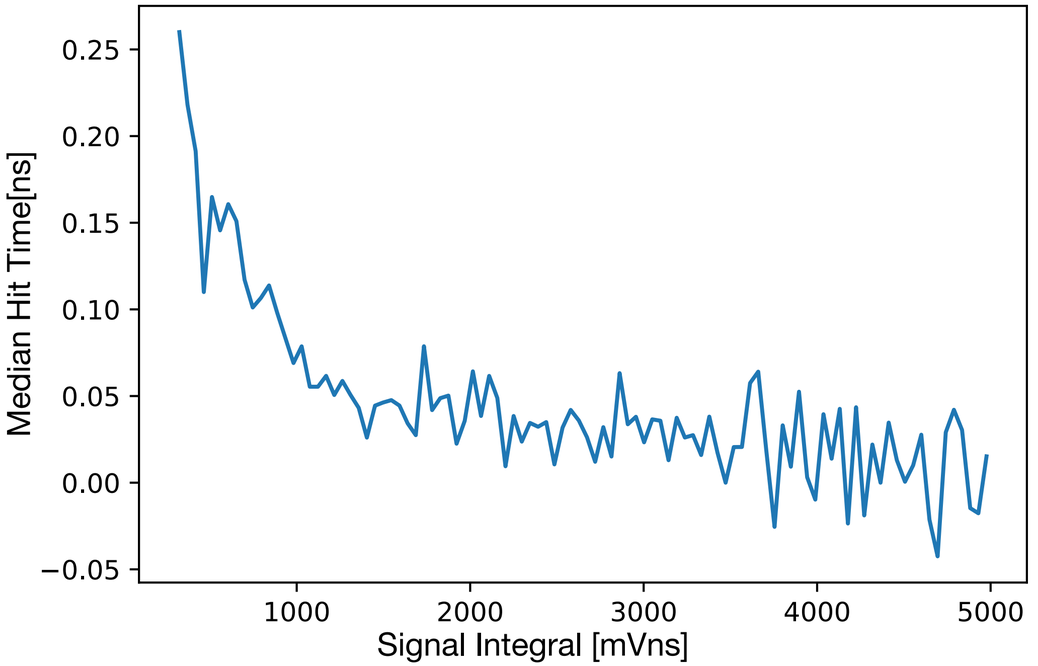
Time Walk Channel C

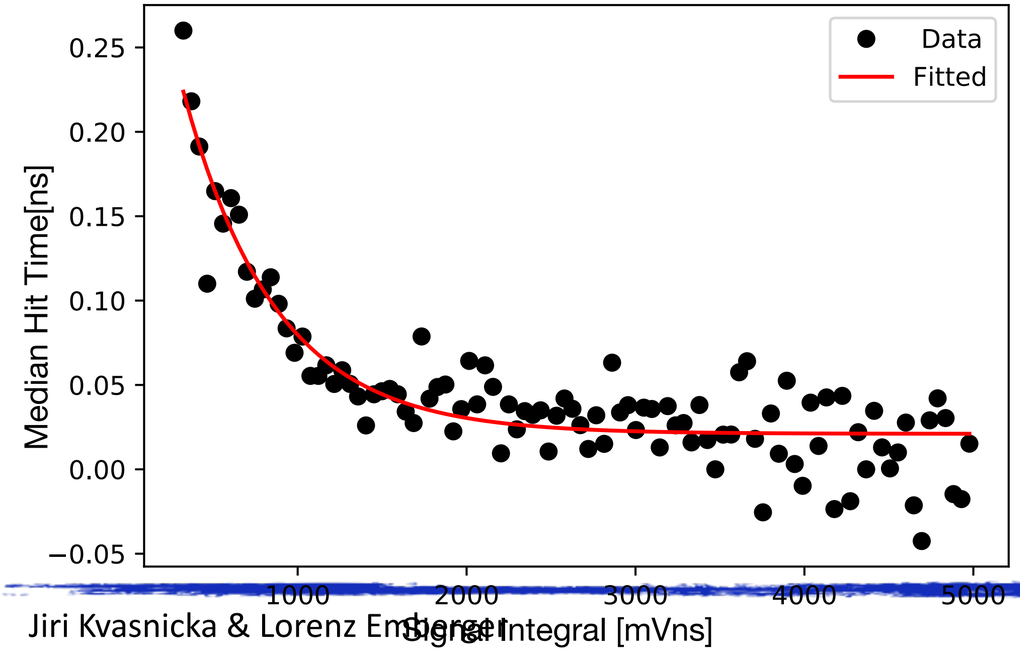




Time Walk Channel C







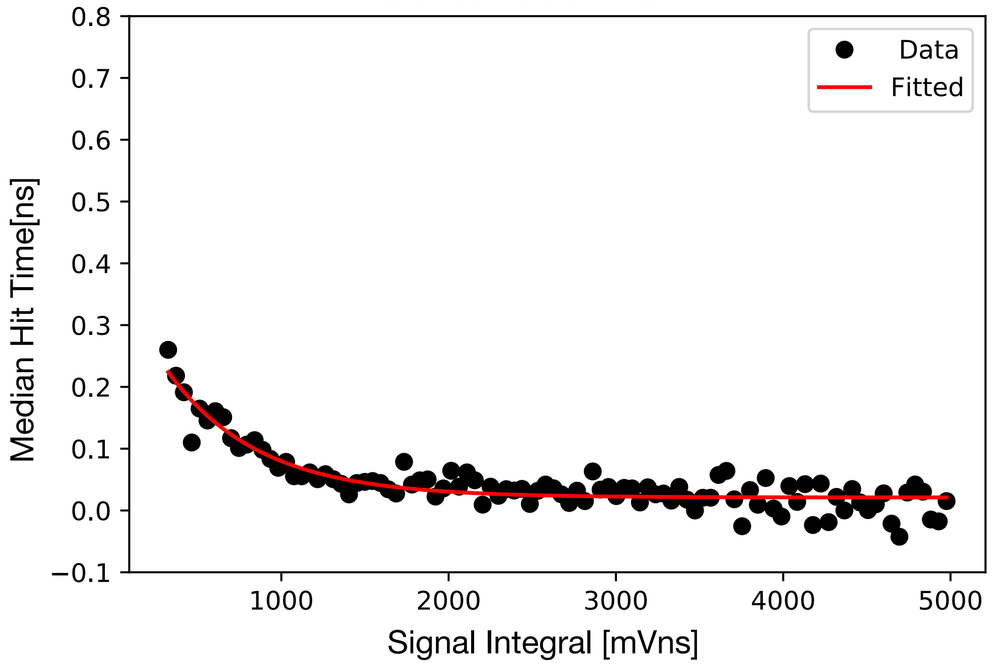
Correction = 0.3663*exp(-0.0018*x) + 0.02103

Same procedure done for channel E

Comparison of TW Behavior

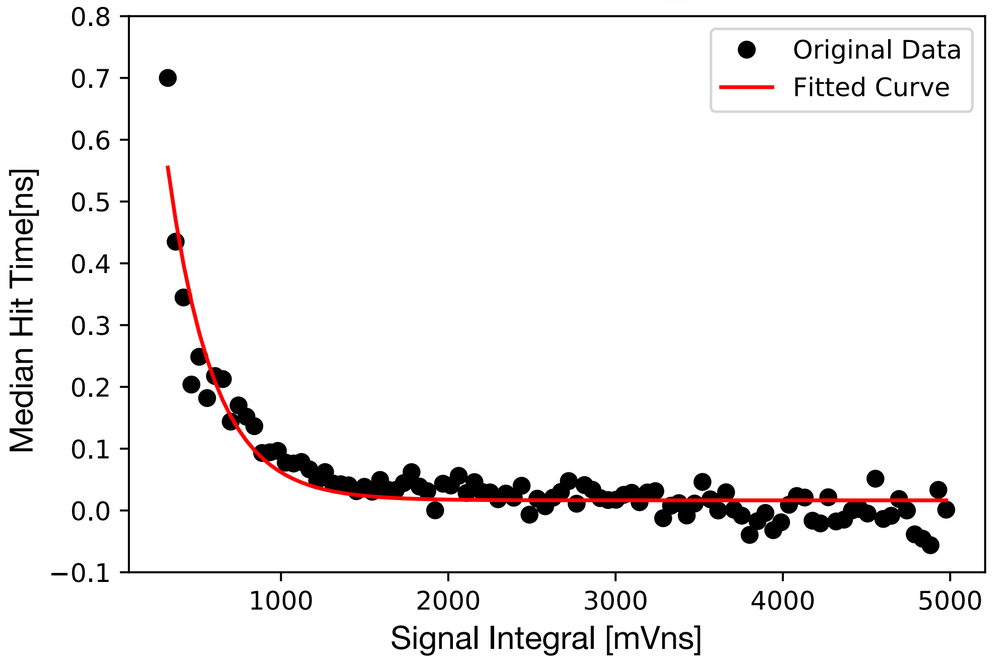
Very low statistics under ~500mVns

Channel C



Corr = 0.3663*exp(-0.0018*x) + 0.02103

Channel E

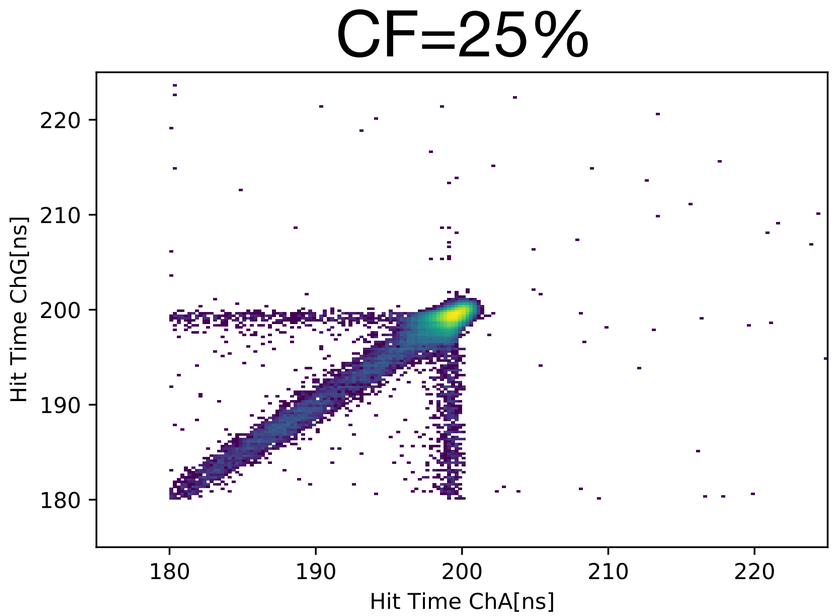


Corr = 1.7578*exp(-0.0037*x) + 0.0164

Trigger Channel A vs.Trigger Channel G

Pre-trigger time: 500samples * 0.4ns/sample=200 ns

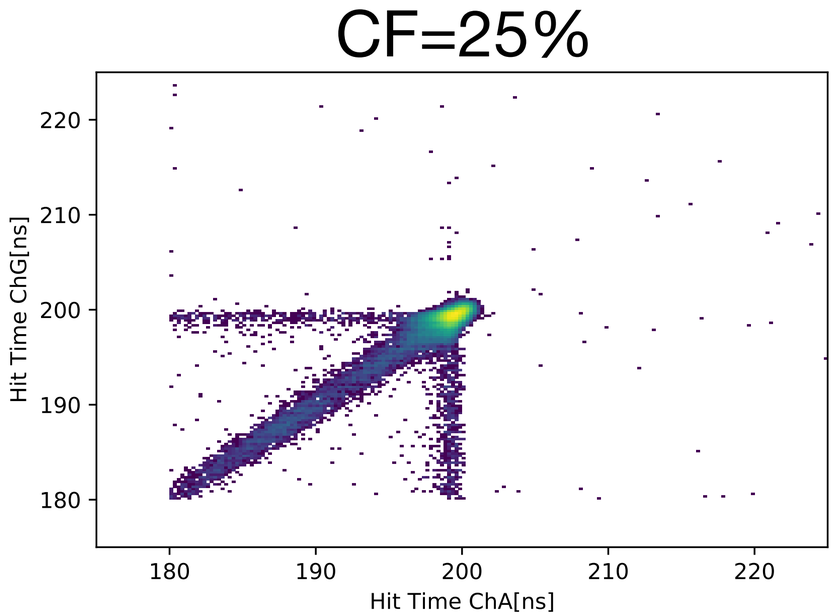
Earlier trigger times from noise or additional particle arriving earlier



Trigger Channel A vs.Trigger Channel G

Pre-trigger time: 500samples * 0.4ns/sample=200 ns

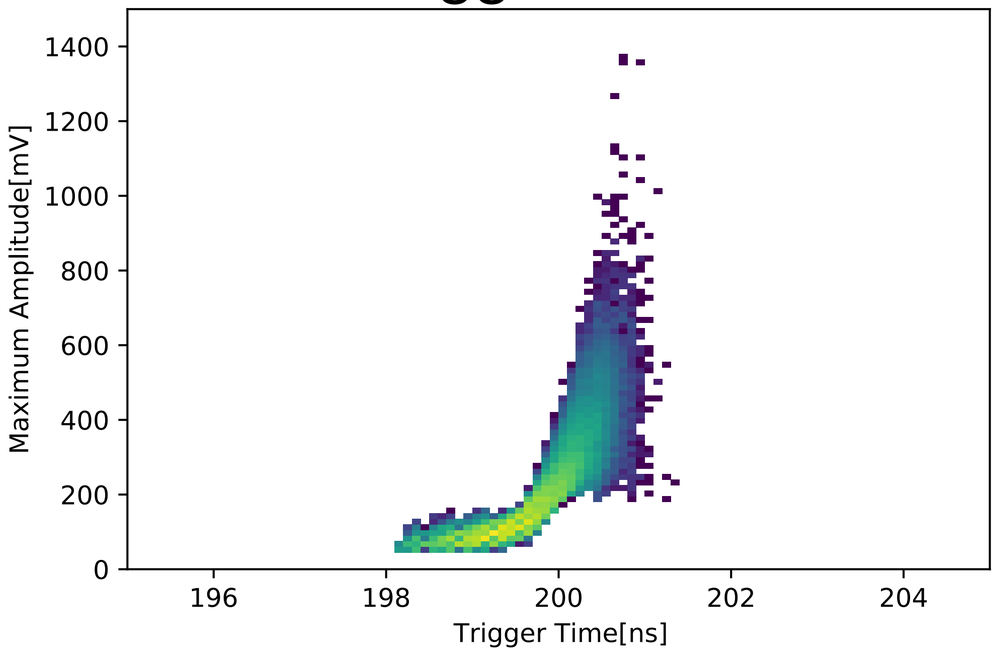
Earlier trigger times from noise or additional particle arriving earlier



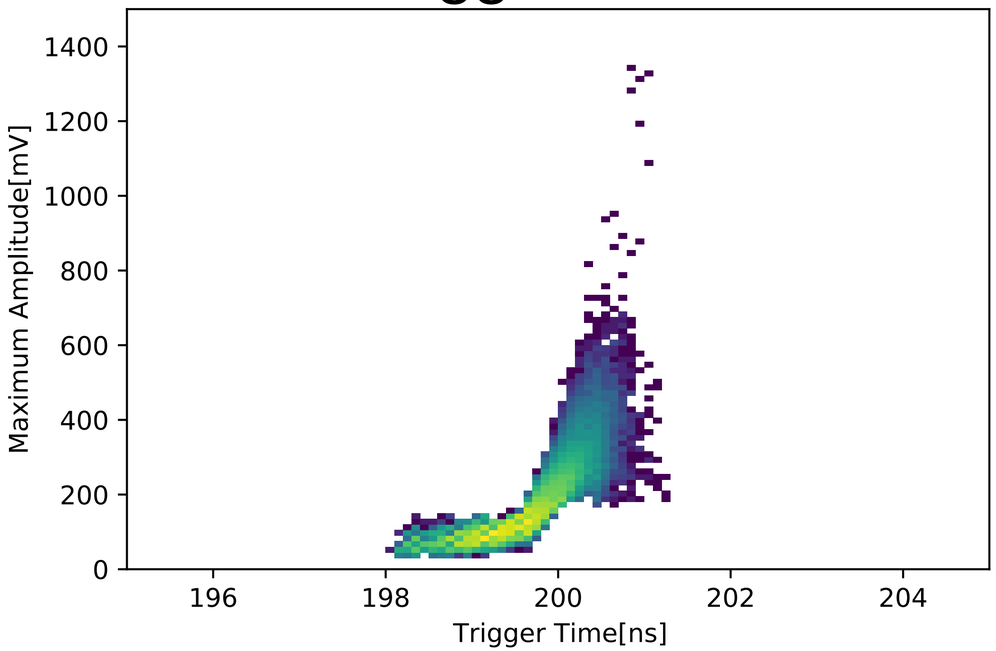
Only take triggers in between 198ns and 202ns

Trigger Time VS Amplitude

Trigger Channel A



Trigger Channel G

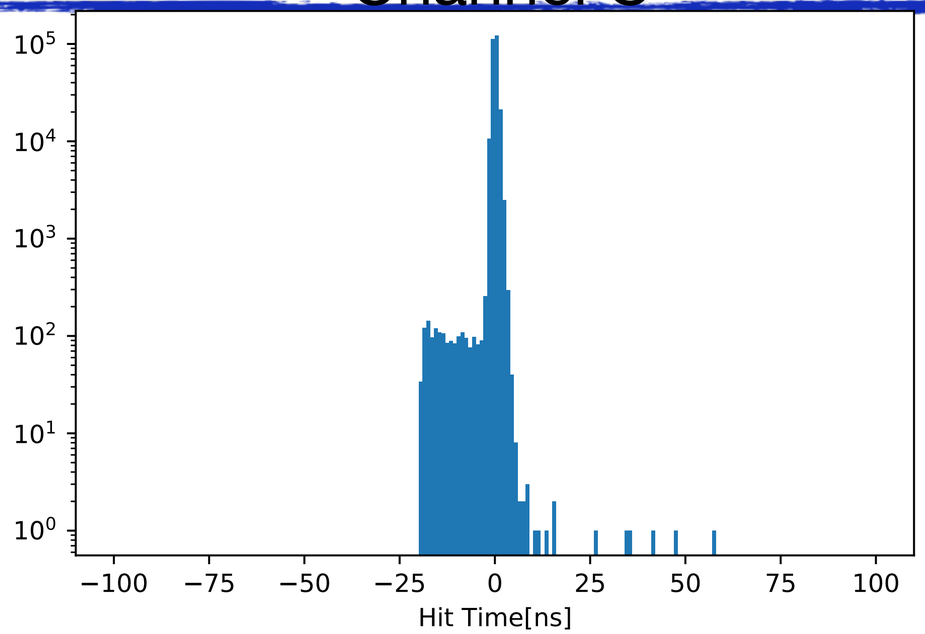


(TriggerA+TriggerG)/2 = reference time

Relative hit time = hit time - reference time

Relative Hit Time in Signal Channels

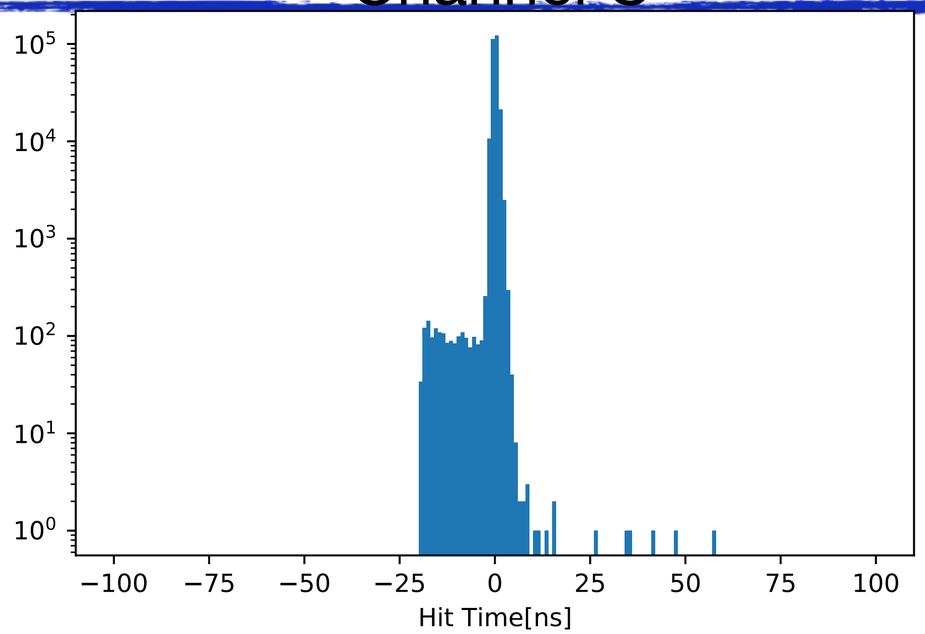
Channel C



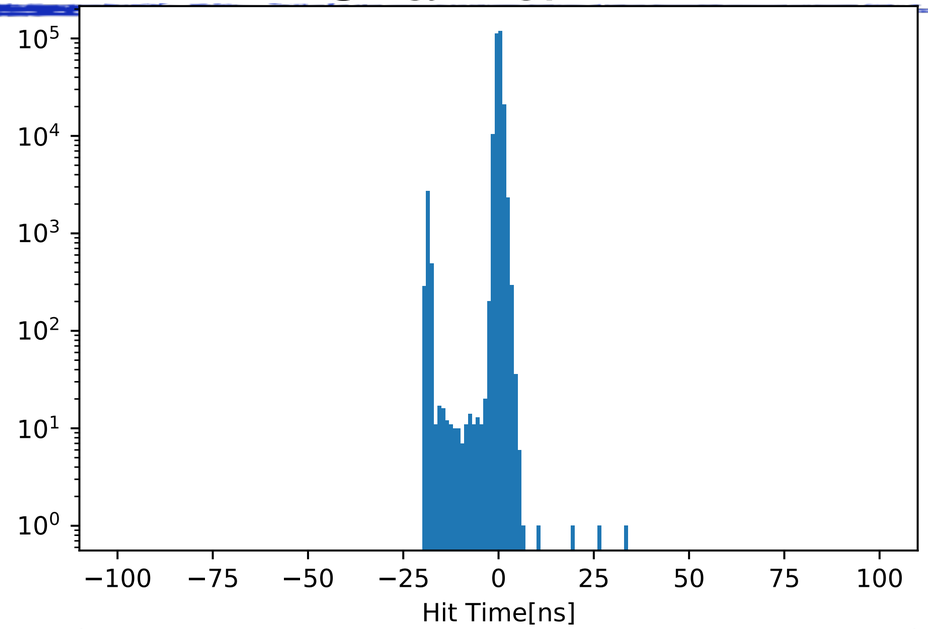
Tail to early times from noise or additional particle

Relative Hit Time in Signal Channels

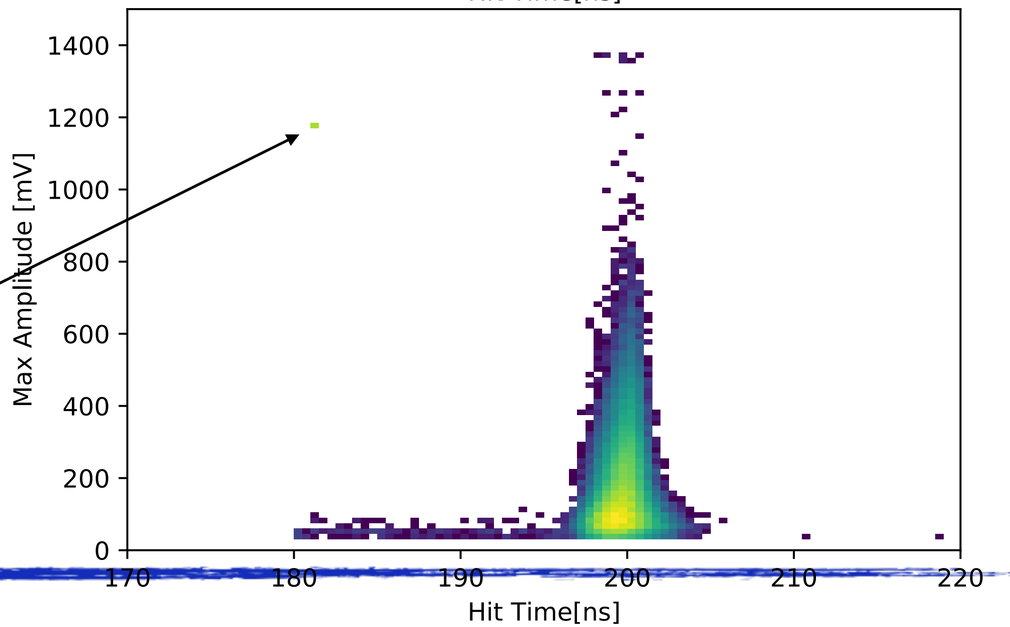
Channel C



Channel E



Tail to early times from noise or additional particle

Contribution in Channel E at 1180mV

Not yet understood, rejected