Update on analysis of TB Apr 2023

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CalVision General Meeting
Sep 14, 2023

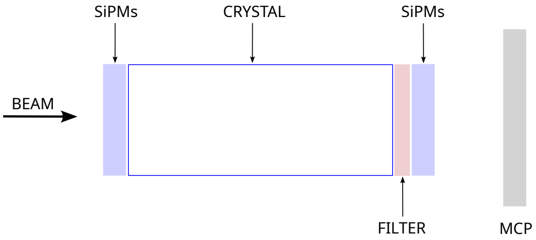
TB Setup

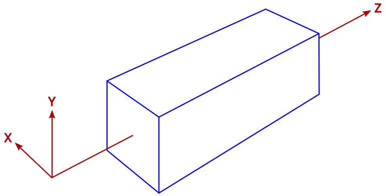
Described previously in presentation by Grace Cummings at CalVision General Meeting, May 11, 2023

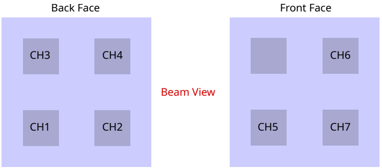
- Proton beam 120 GeV
- Crystal 25×25×60 mm^3
- Two arrays of 4 SiPMs, 6×6 mm^2
- Filter (optional)
- Coupling with optical grease
- MCP: Photek 240, 40 mm diameter
- Readout with scope: 7 SiPMs + MCP

Results for configurations:

- PWO_4 without filter
- PWO_4 with long pass R660 filter
- BGO with notch U330 filter

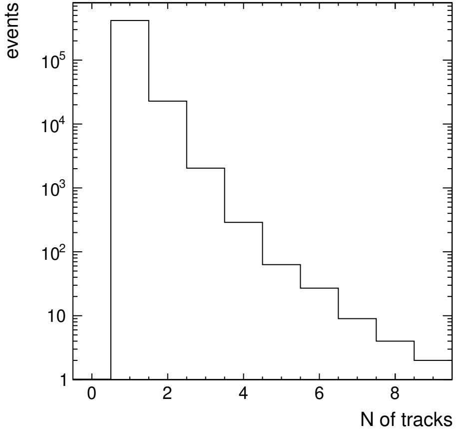


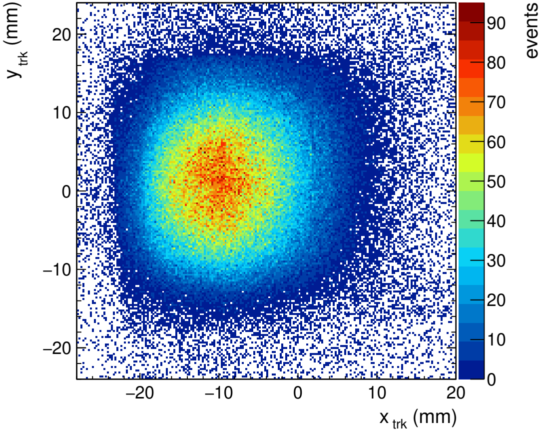




Beam tracks

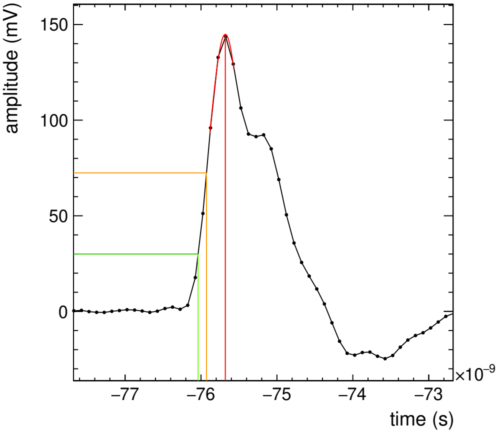
Reconstructed with silicon-pixel telescope
A single track, most of the time
Wide beam illuminates entire crystal
After all selection, ~10% of events have mis-measured track position

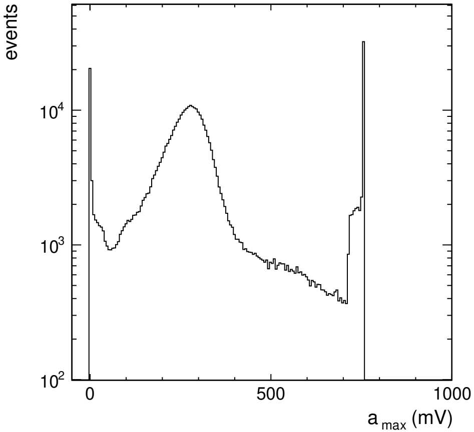




MCP amplitude and time reconstruction

Typical MCP waveform after baseline subtraction is show on the left
Distribution of amplitude of the sample at maximum is show on the right
Waveforms are clipped at about 700-800 mV
Events with zero MCP amplitude: beam is outside of MCP
Events with very large MCP amplitude: multiple tracks
Tip of the waveform is fitted with gaussian → amplitude and time of MCP



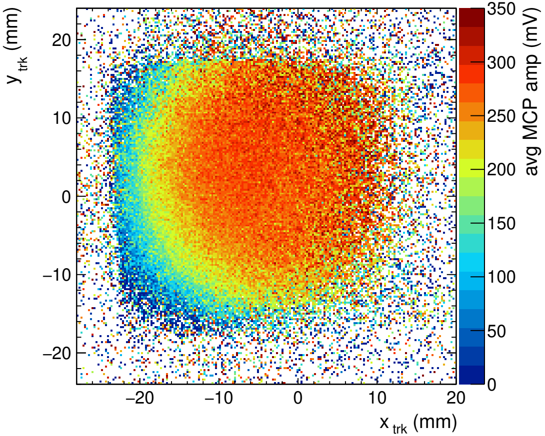


MCP position

Average MCP amplitude for non-showering event as a function of track position

MCP response drops to zero for tracks outside of MCP

MCP image is consistent with 40 mm diameter of sensitive region



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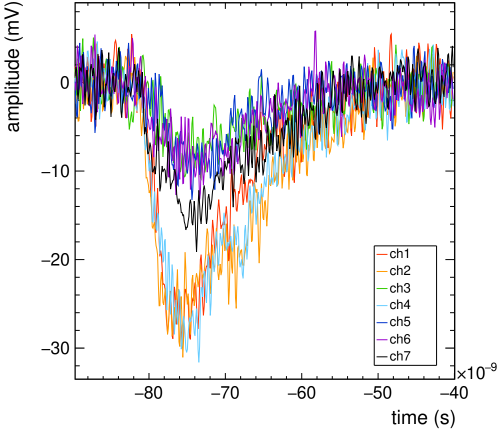
PWO without filter

Typical SiPM Waveforms

Example of one MIP event with amplitudes close to MPV

Challenge to measure amplitude and timing

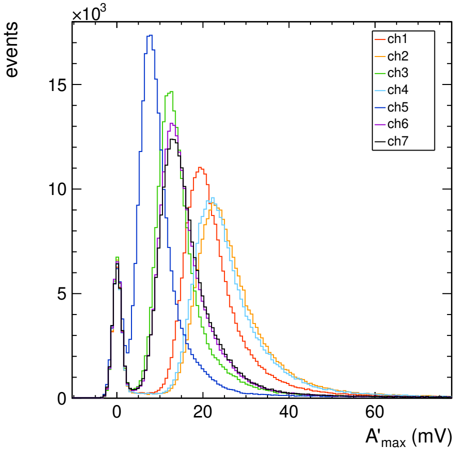
Amplitude is estimated using integral of the pulse



SiPM amplitude

All events with single track and good MCP amplitudes

Events with tracks outside of the crystal give noise peak at zero

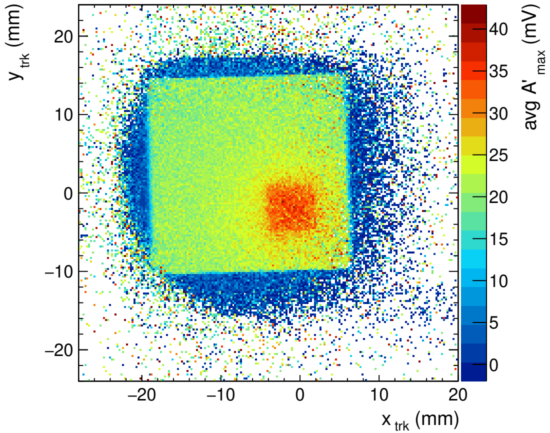


SiPM position

Average amplitude in CH1 as a function of track position

The closer track to SiPM, the larger the amplitude

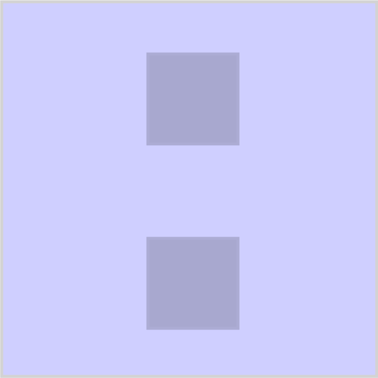
A clear image of each SiPM allow to identify its location

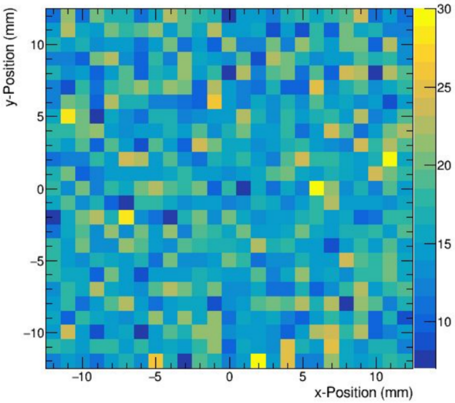


Simulations

(from Christian Guinto-Brody)

$25\times25\times60$ mm^3 PWO crystal
Two 6×6 mm^2 SiPMs at the Back face (differen location from TB)
Uniform beam of 120 GeV protons



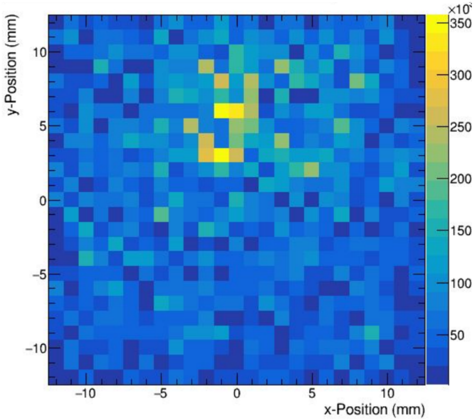


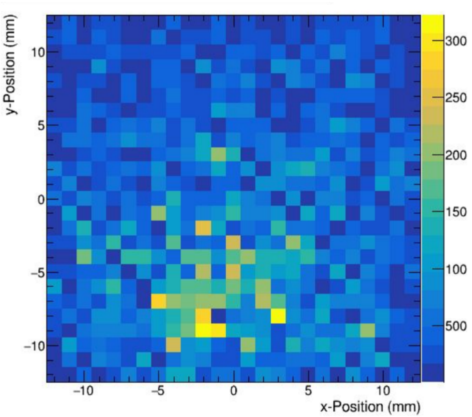
Simulations (2)

(from Christian Guinto-Brody)

Left: Number of Scintillation photons detected in SiPM1 vs beam position
Right: Number of Cerenkov photons detected in SiPM2 vs beam position

These are the early stages of simulation studies but it confirms position dependence of collected light





PWO without filter
vs
PWO with filter

Amplitude in each SiPM

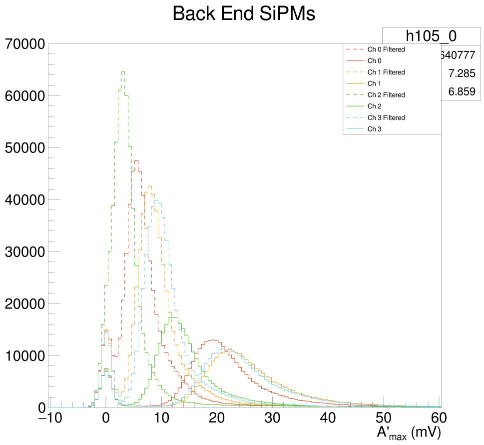
(from Chris Martin)

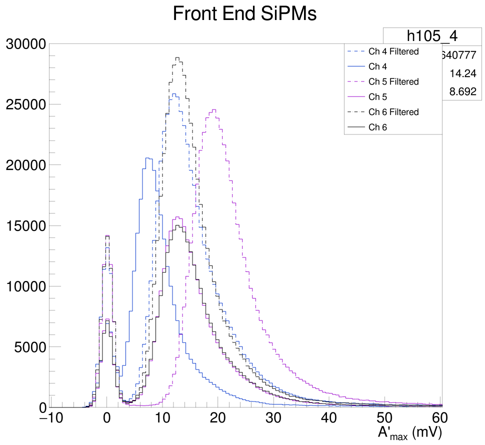
Roughly: filter kills $\lambda < 660$ nm

Two sets of runs: “with filter” and “without filter”. Filter is at the back SiPMs only

SiPMs with filter have much lower amplitude (left plot) as expected

SiPMs without filter should have the same distribution “with” and “without” (right plot)... ... it is NOT the case → installation of the filter changes the setup!



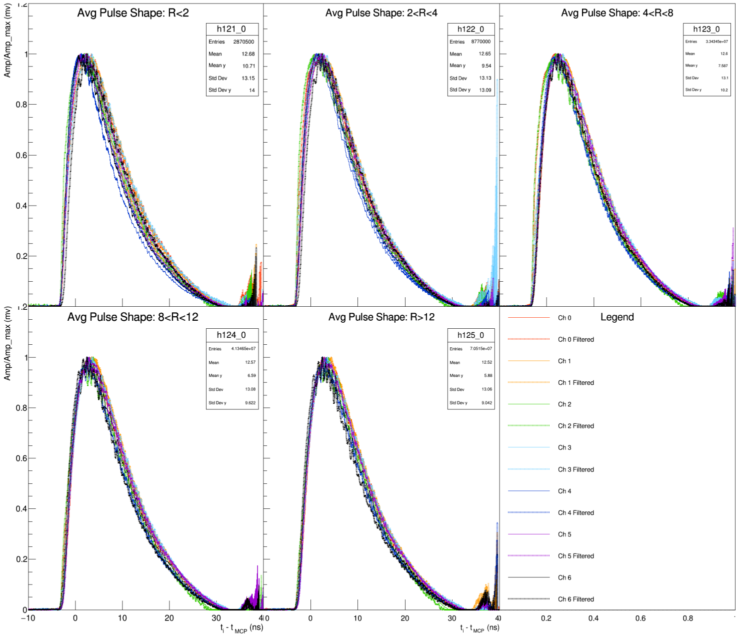


Average pulse shape vs distance between SiPM and the track

(from Chris Martin)

Busy plot, ignore details

Roughly, pulse shapes are the same but there are fine details to work out

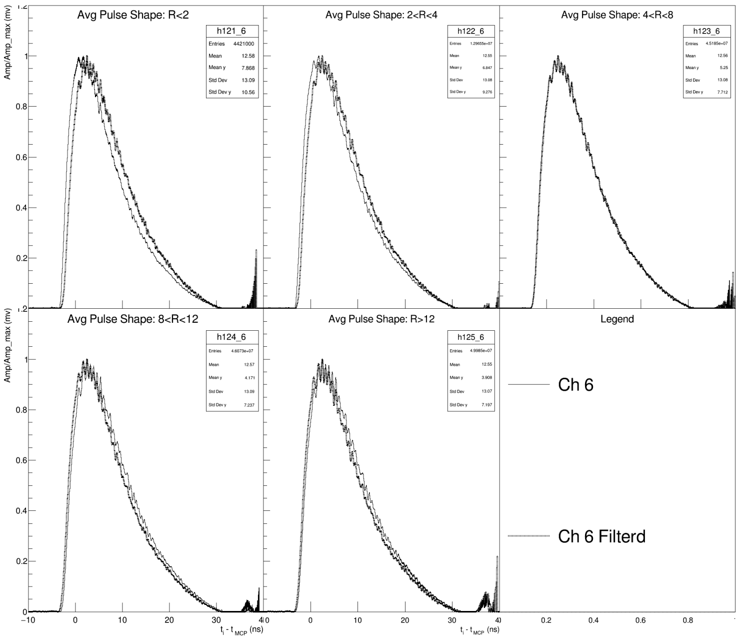


Alexander Ledovskoy UNIVERSITY of VIRGINIA 2023/09/14

A SiPM in Front

(from Chris Martin)

No change in pulse shape is expected, but it does!
Fine variations in shape → under investigation



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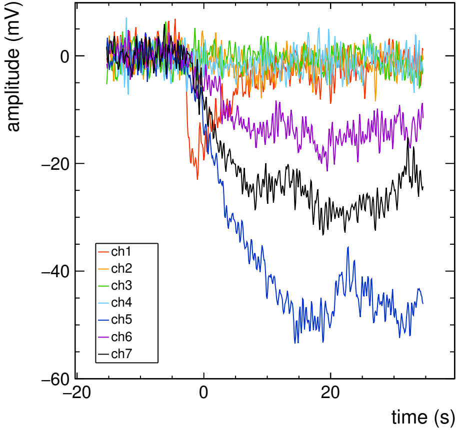
BGO with U330 filter at the Back

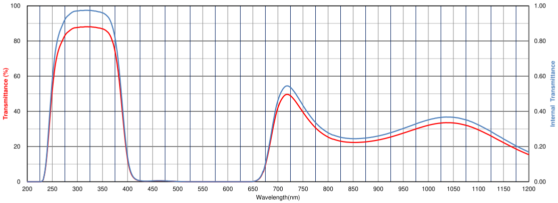
Typical Waveforms

Right plot shows an event for MIP with energy depositions close to MPV

A track is within 2 mm from the center of CH1. Amplitudes are very low.



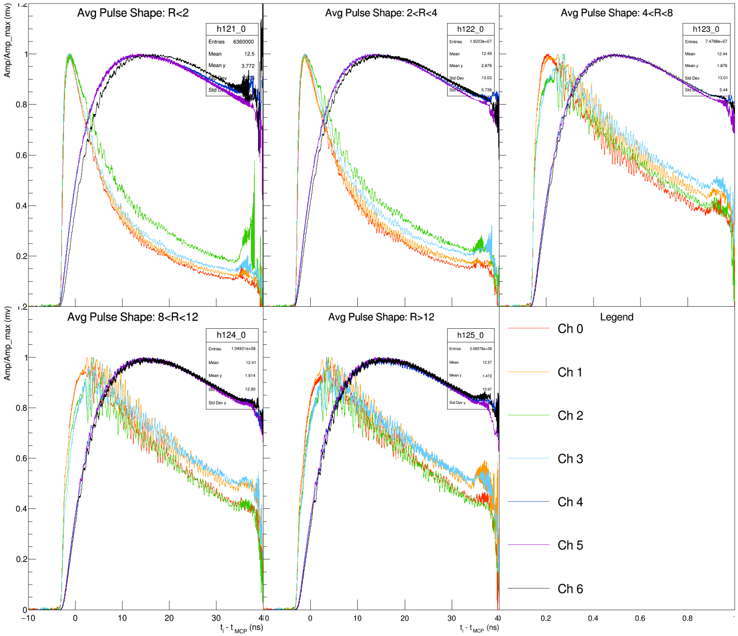
Filter is installed at Back face of the crystal



Average pulse shape vs distance between SiPM and the track

(from Chris Martin)

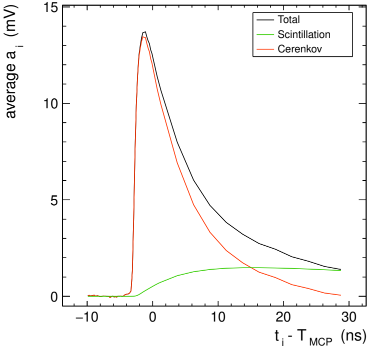
Dramatically different pulse shapes in SiPMs with filter

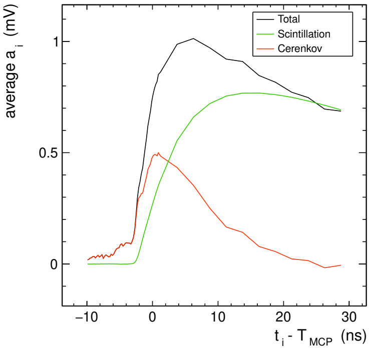


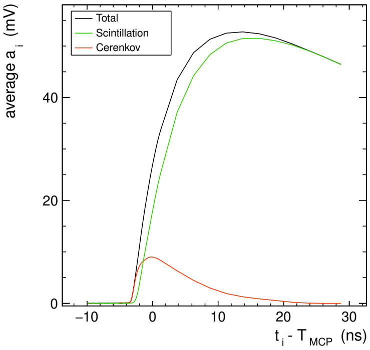
Separate Cerenkov from Scintillation. Very crude.

Build average pulse shapes for amplitudes in 0.5–2.0 MPV
Assume CH5, Ring=4 is a pure Scintillation, negligible Cerenkov
Assume there is no Cerenkov at t=30 ns → normalize Scintillation shape
Subtract Scint. shape from measured one → Cerenkov shape

Left : CH1, Ring0 (Back)
Middle : CH1, Ring4 (Back)
Right : CH5, Ring0 (Front)







Change in amplitude vs ring. Cerenkov and Scintillation

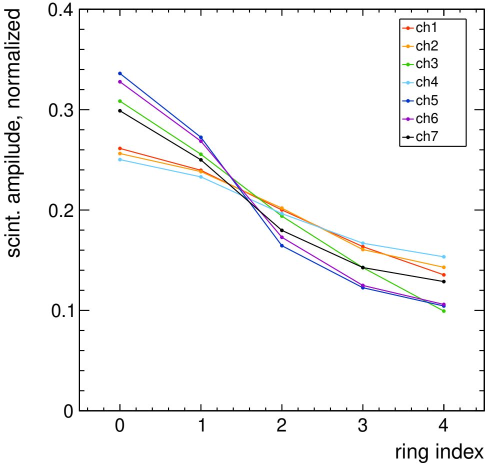
Average amplitude for MIP in mV

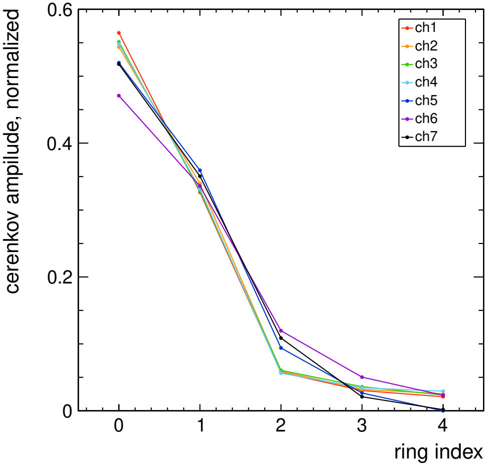
CH	Scint.	Cerenkov
1	1.48	13.4
2	1.85	13.6
3	1.38	6.48
4	2.16	13.9
5	51.5	9.01
6	49.7	9.00
7	69.0	9.31

Roughly, amplitude of Cerenkov contribution

$$A = N_{\mathrm{pe}} \cdot A_{1\mathrm{pe}}$$

If we know $A_{1\mathrm{pe}} \rightarrow$
we know Cerenkov yield





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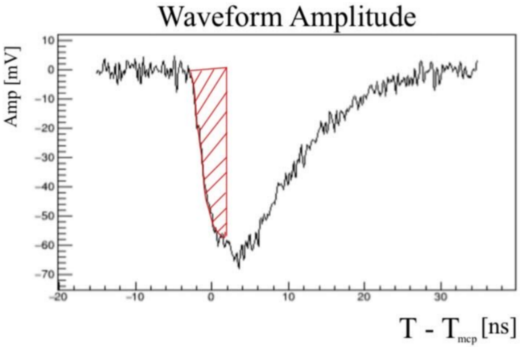
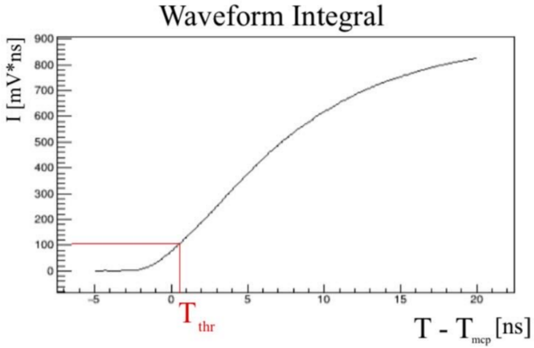
Timing resolution in PWO without filter

from Max Dubnowski

Method

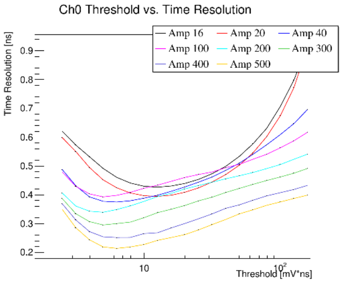
Pulse amplitude are low, suffer noise fluctuations
Construct integrated pulse
Apply threshold and evaluate its timestamp
Width of timestamp fluctuations at fixed threshold → time resolution
Evaluate σ_T for pulses in narrow range of amplitudes

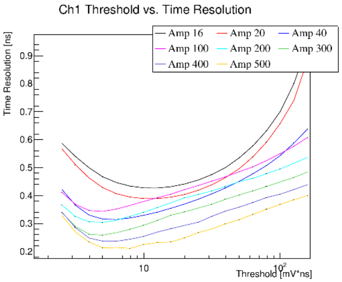


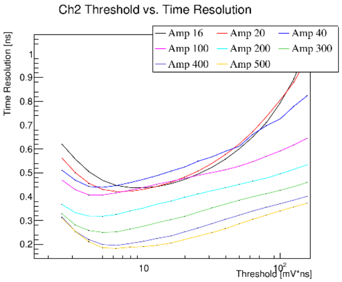


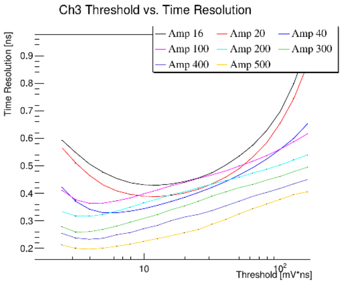
Time Resolution vs Threshold

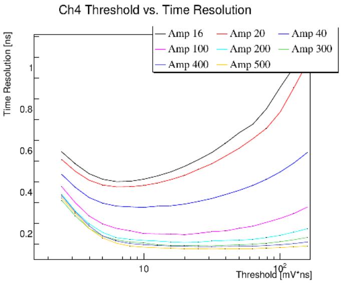
…for pulses with different amplitudes → resolution improves for larger amplitude
…for SiPMs in Front and Rear → Front SiPMs have better resolution (why?)

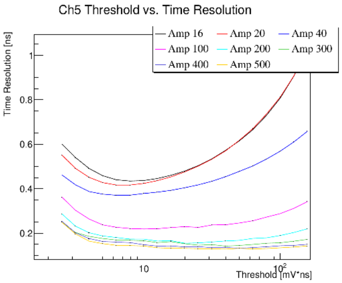












Summary

- A first glance at TB data
- Observed dependence of amplitude and pulse shape on track position
- A preliminary method to estimate Cerenkov yield is emerging
- Time resolution studies has started. First results look reasonable
- Simulation studies has started. First results confirm observations.
- Plan is to do in-depth investigation of observed effects