Update on TB Apr2023 at FNAL

Grace Cummings[1], Max Dubnowski[2], Christian Guinto-Brody[2],
Bob Hirosky[2], *Sasha Ledovskoy*[2], Christopher Martin[2]

[1] *Fermilab, USA*
[2] *University of Virginia, USA*

CalVision General Meeting
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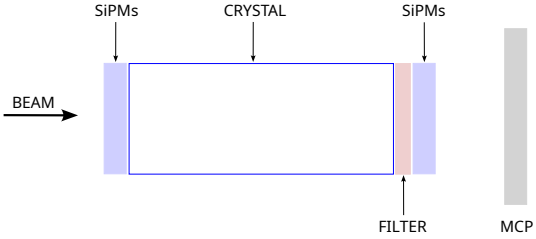
Reminder: TB Setup

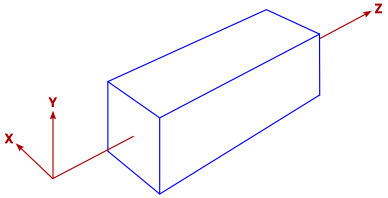
This is an update.
Previous presentation at CalVision General Meeting, Sep 14, 2023

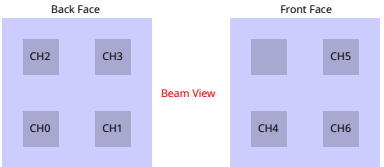
- Proton beam 120 GeV
- Crystal 25×25×60 mm^3
- Two arrays of 4 SiPMs, 6×6 mm^2
- Filter (optional)
- Coupling with optical grease
- MCP: Photek 240, 40 mm diameter
- Readout with scope: 7 SiPMs + MCP

Results for configurations:

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





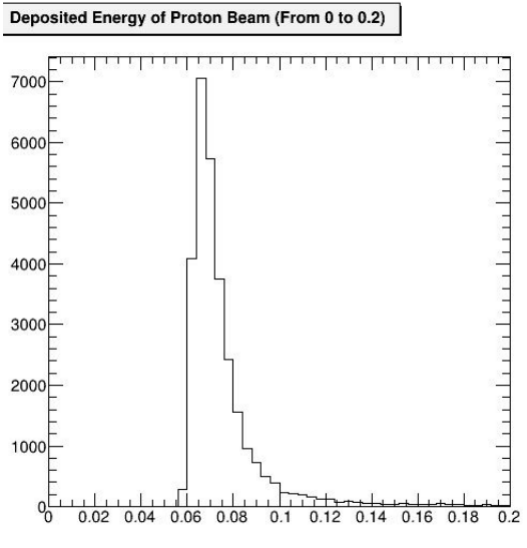


Simulations: Deposited energy in PbWO4 in GeV per event

(from Christian Guinto-Brody)

Most Probable Value (MPV) for energy deposition in $PbWO_4$ by 120 GeV protons is 66 MeV

There are many events with very large energy depositions (hadron showers)

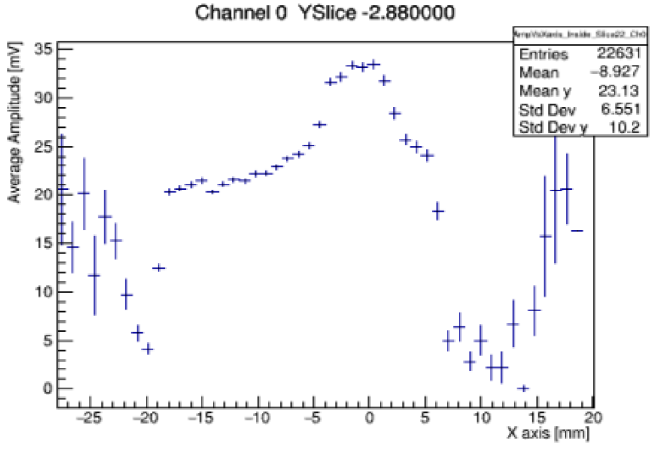


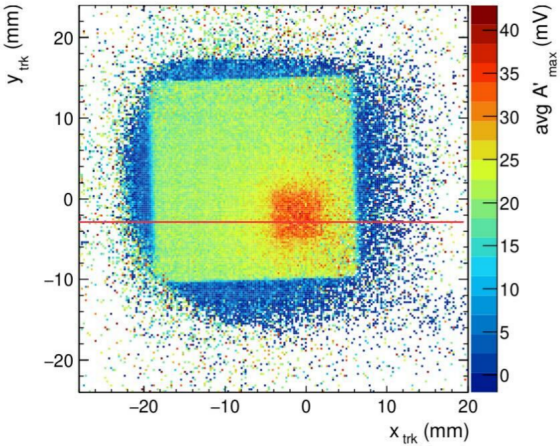
Data: Average SiPM amplitude vs beam position

(from Max Dubnowski)

Right plot: average SiPM amplitude for MIPs as a function of beam position
Left plot: Horizontal slice of 2D distribution at the center of SiPM

Increase in amplitude is $\sim \times 1.7$ at the center of SiPM

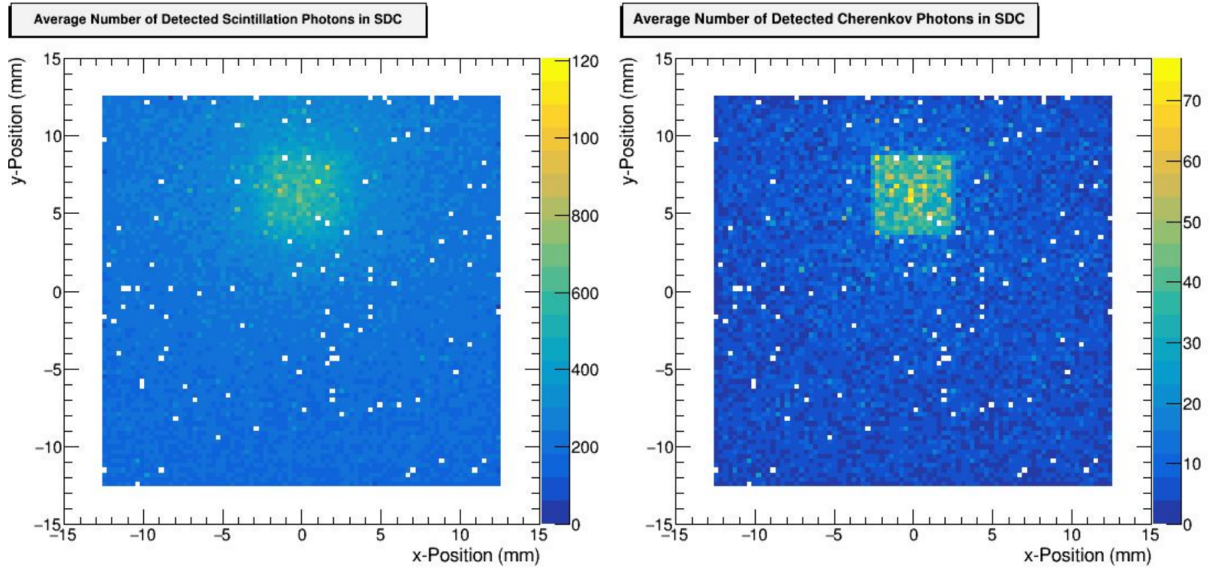




Simulations: Number of detected photons vs beam position

(from Christian Guinto-Brody)

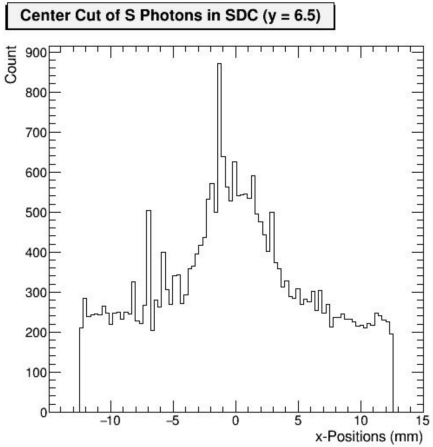
Simulations reproduce this behavior very well (SiPM location is different in MC)
Cerenkov photons give much sharper image of SiPM

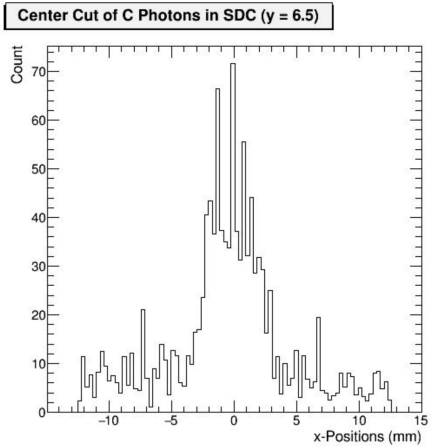


Simulations: Number of detected photons vs beam position (2)

(from Christian Guinto-Brody)

Horizontal slice of 2D distribution at the center of SiPM
Increase in amplitude is $\sim \times 2.2$ at the center of SiPM (to be compared with $\times 1.7$ for data)
MC needs some tuning



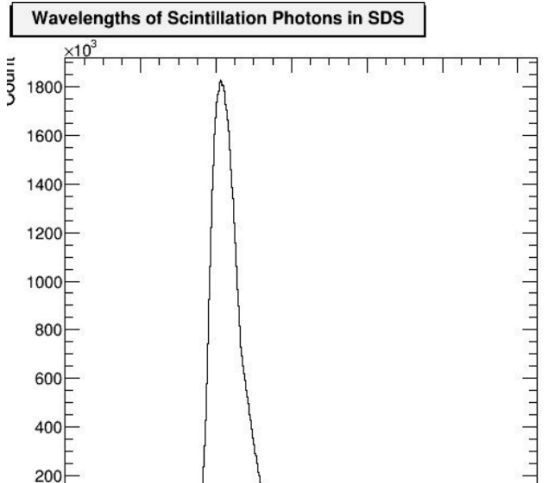


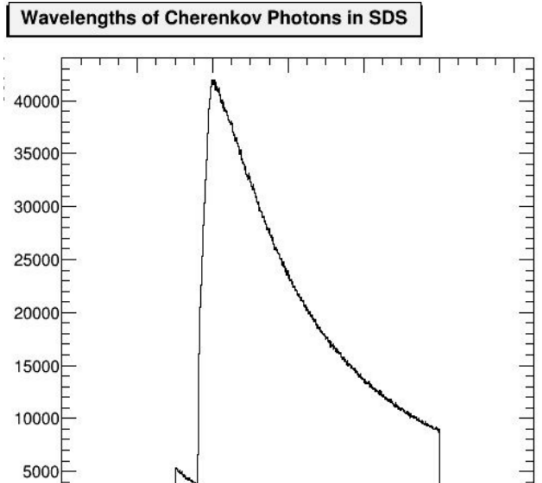
Simulations: Wavelength of detected photons

(from Christian Guinto-Brody)

Simulations have perfect detector

To compare with data and estimate Light Output: need to apply PDE and Filter response





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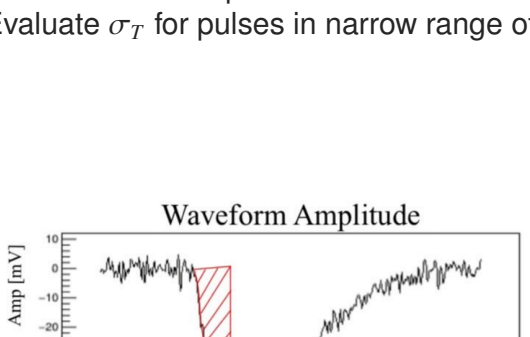
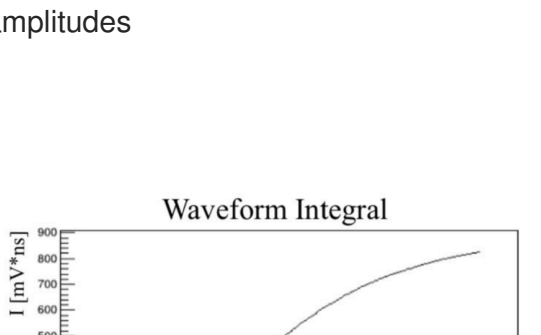
Timing resolution in PbWO4

Method I: Integrated pulse

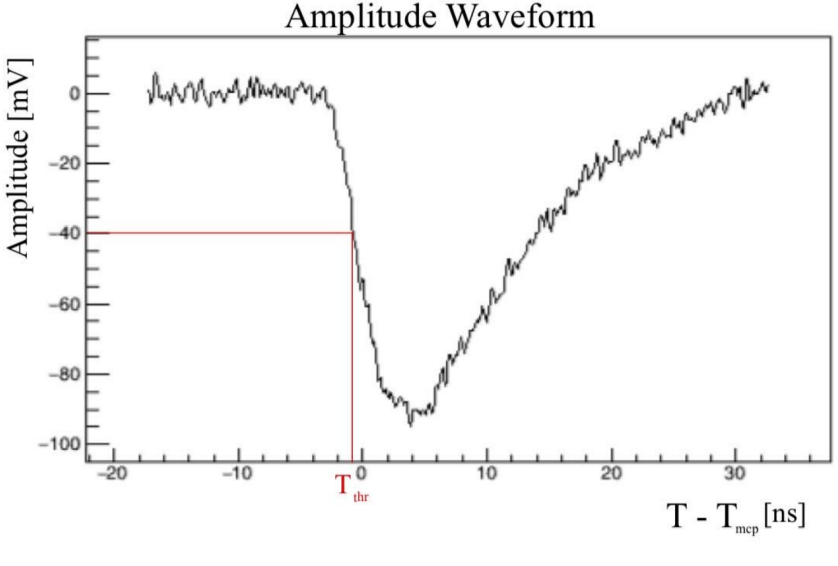
Pulse amplitude are low, suffer noise fluctuations
Construct integrated pulse
Apply threshold and evaluate its timestamp
Width of timestamp fluctuations at fixed threshold → time resolution
Evaluate σ_T for pulses in narrow range of amplitudes





Method II: Original pulse

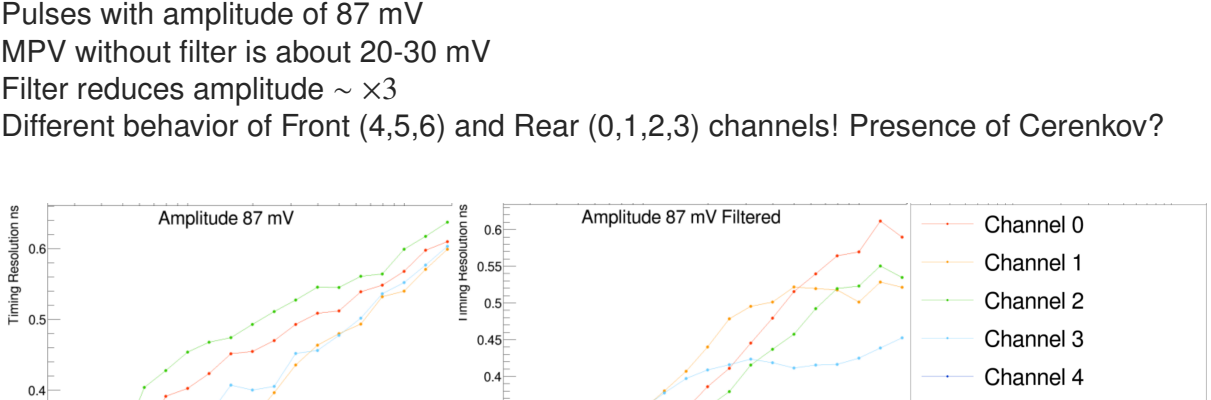
Works with large pulses (showers, not MIPs)
Apply threshold on rising edge and evaluate its timestamp, same as Method I



PbWO4 With and Without Filter. Integrated Pulse

(from Christopher Martin)

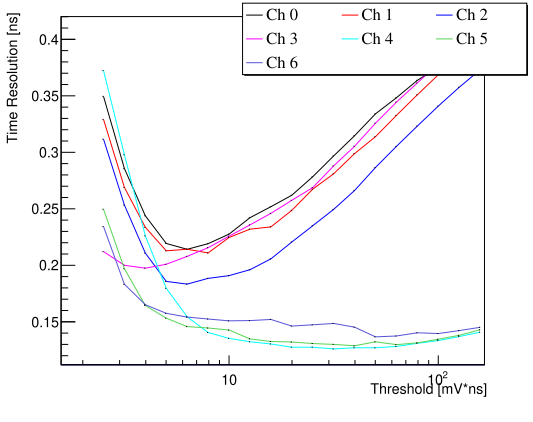
Time resolution vs threshold on integrated pulse
Pulses with amplitude of 87 mV
MPV without filter is about 20-30 mV
Filter reduces amplitude $\sim \times 3$
Different behavior of Front (4,5,6) and Rear (0,1,2,3) channels! Presence of Cerenkov?

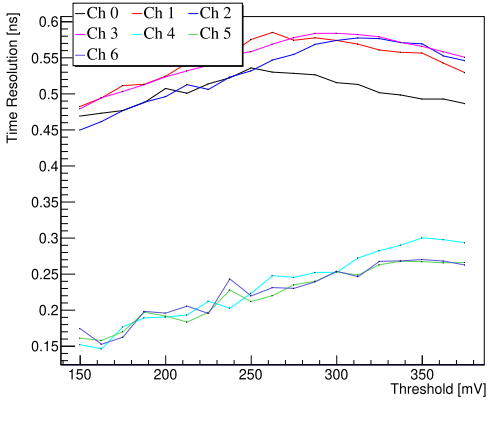


PbWO4 Without Filter. Integrated Pulse vs Original Pulse

(from Max Dubnowski)

Time resolution vs threshold
Showers. Amplitude of pulses is 500 mV, or $> 10 \times \mathrm{MPV}$
Need to investigate lower thresholds for original pulse
Again, different behavior of Front (4,5,6) and Rear (0,1,2,3) channels!
Presence of Cerenkov?





Summary

- Amplitude of MIPs varies a lot with beam position
  Simulations predict this behavior very well
- Time resolution results show very different behavior for Front and Rear channels in PbWO4 data with and without filter.

Next steps:

- Simulation studies to understand time resolution and Light Output