Progress in Photon Detection for LBNE

Stuart Mufson
Indiana University
Fermilab
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IU work is a group effort –

- Brice Adams
- Brian Baugh
- Tad Baptista
- Paul Smith
- Jon Urheim
- Denver Wittingham

Photon Detection Overview

2 processes production scintillation light in LAr

$$Ar^* + Ar \rightarrow Ar_2^* \rightarrow 2Ar + \gamma$$

$$Ar^+ + Ar \rightarrow Ar_2^+ + e \rightarrow Ar_2^* \rightarrow 2Ar + \gamma$$

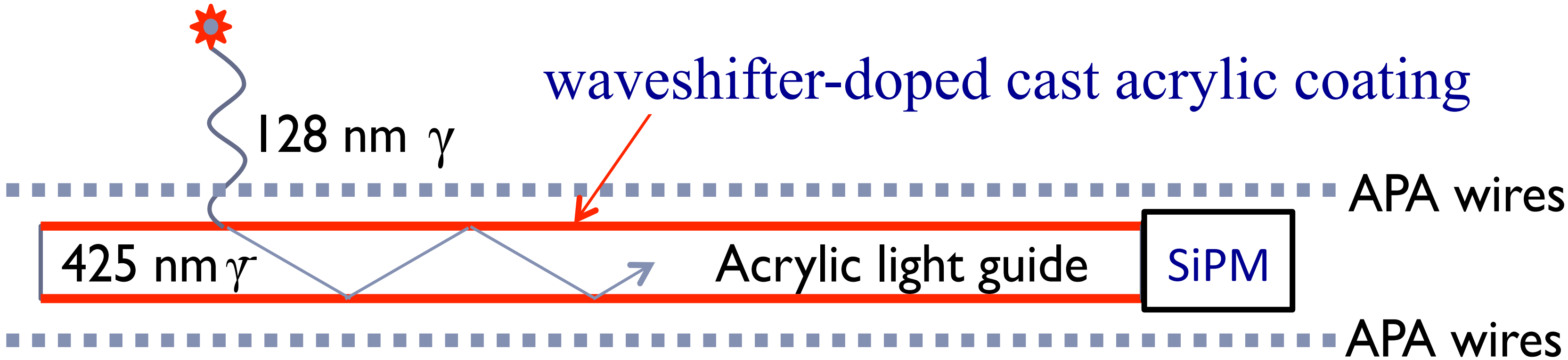
decay from singlet Ar_2^* state: prompt light at 6 ns (~25%)
decay from triplet Ar_2^* state: late light at 1.6 µs (~75%)

photons emitted in VUV at 128 nm, where

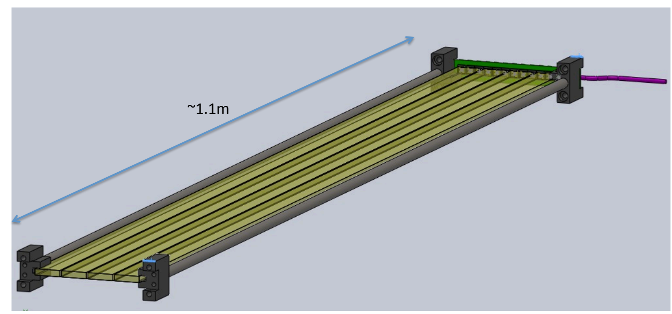
- photodectors are insensitive or expensive
- most materials are opaque
- solution: waveshifter (TPB/bis-MSB) to absorb UV photons and re-emit in the optical

Basic Element: Light Guide

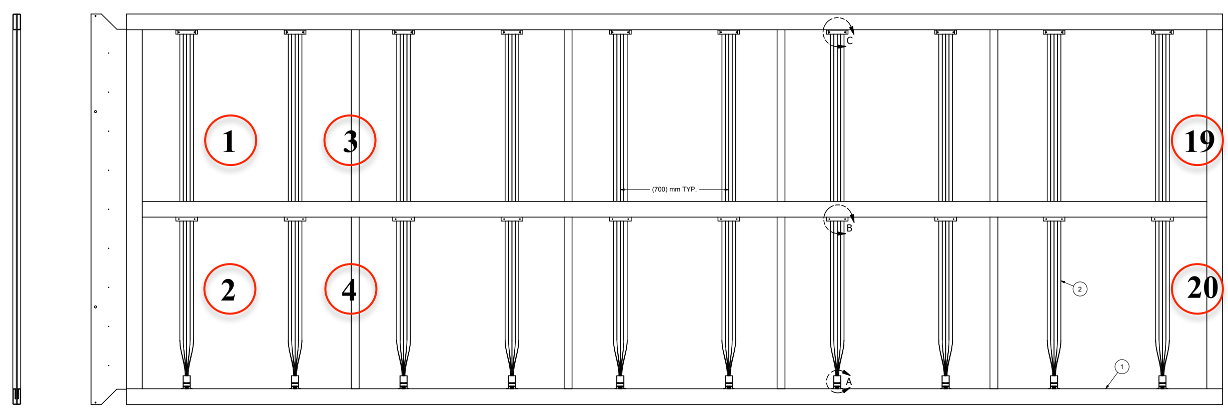
Design



4 light guides ganged into stainless steel Photon Detector Paddle (PDA)

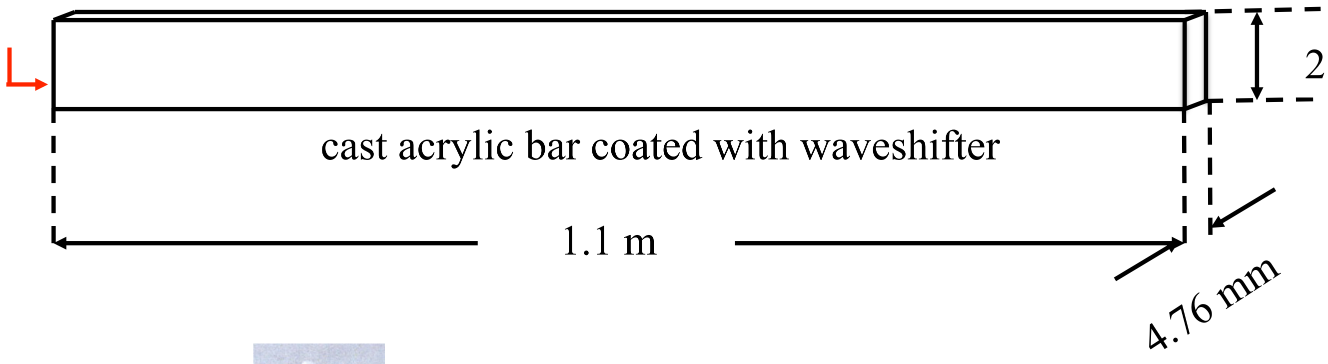


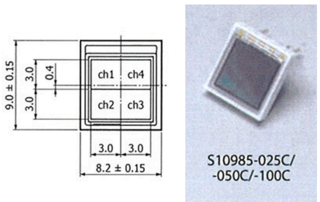
20 PDAs
per APA plane



Basic Element: Light Guide

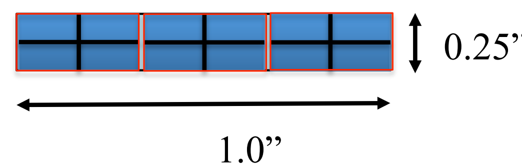
reflecting end



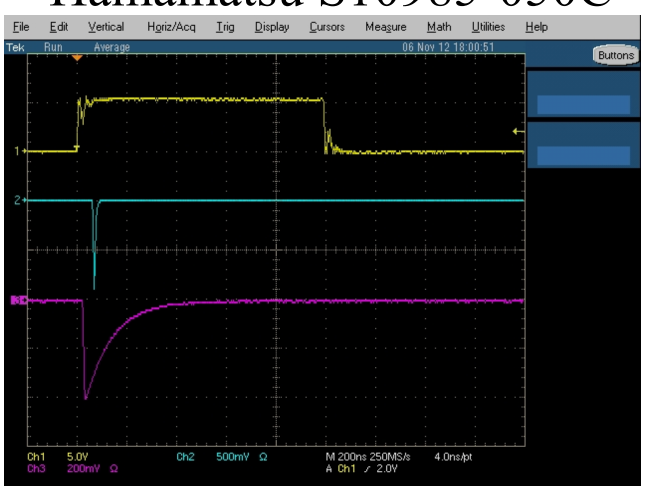


2x2 ch array SiPM
active area 3x3 mm
3 x SiPMs per end

SiPM SiPM SiPM



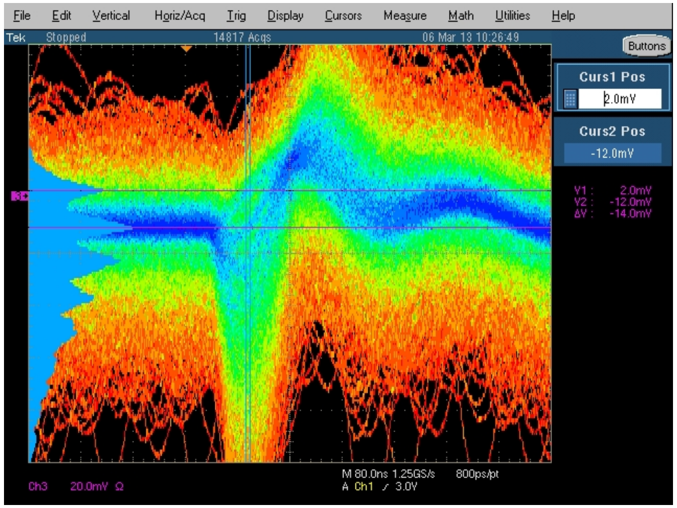
Hamamatsu S10985-050C



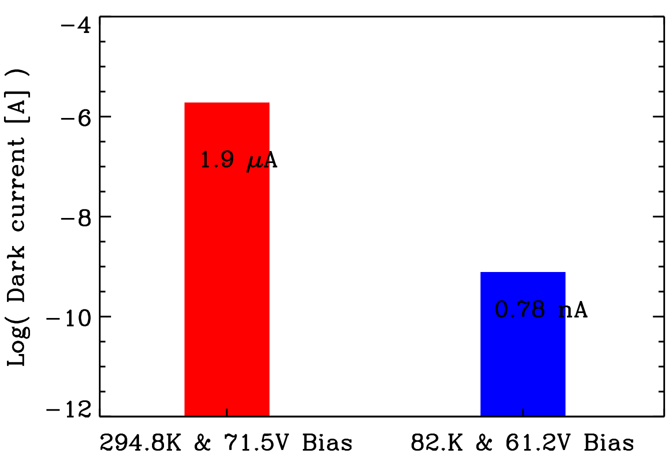
rise time ~ 20 ns; tail ~ 300 ns

LED trigger pulse (yellow)
PMT response (blue)
SiPM response (cyan)

Hamamatsu S10985-050C, biased at 72 V
4 quadrants connected in parallel
pulsed LED input signal

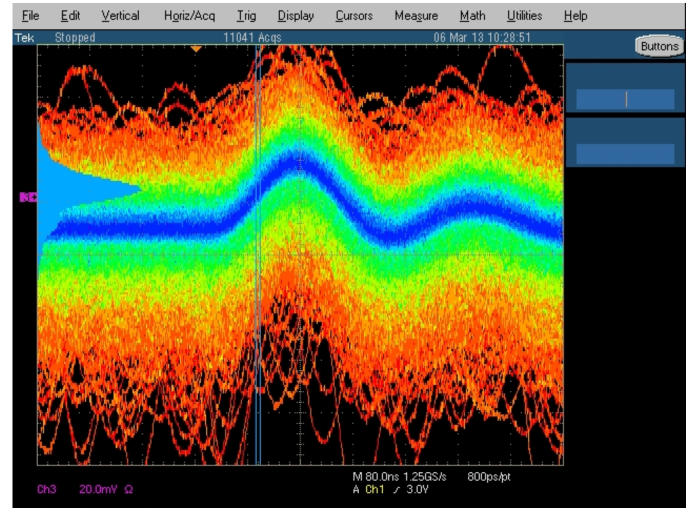


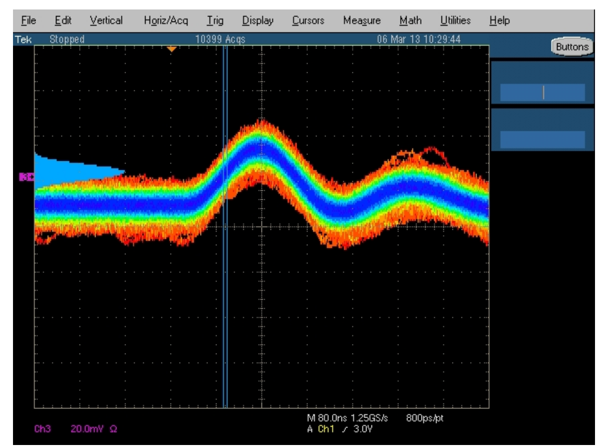
single PE signal amplitude after shaper = 14 mV; Gain = 200 → 70 μV out of SiPM



dark current: warm, cold

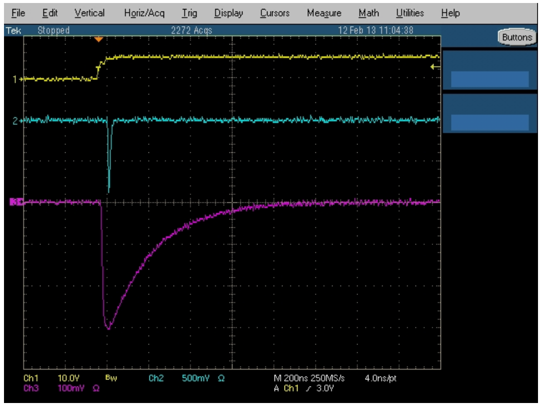
voltage to the LED off
electronics and SiPM noise



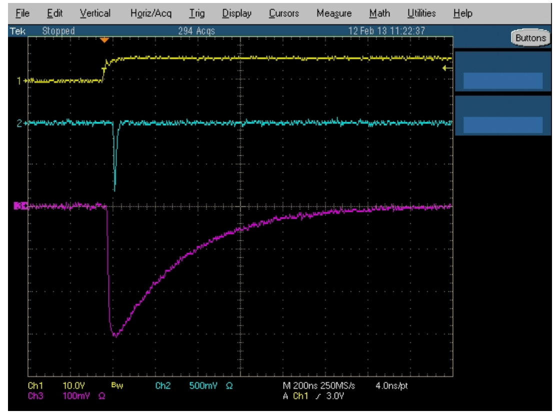


educed the SiPM bias to 70 volts, so this is the electronics noise

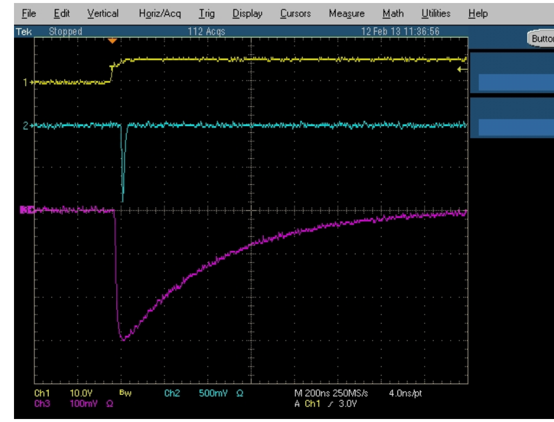
SensL (last release) SiPMs



1 SiPM
rt ~ 40 ns; tail ~ 220 ns

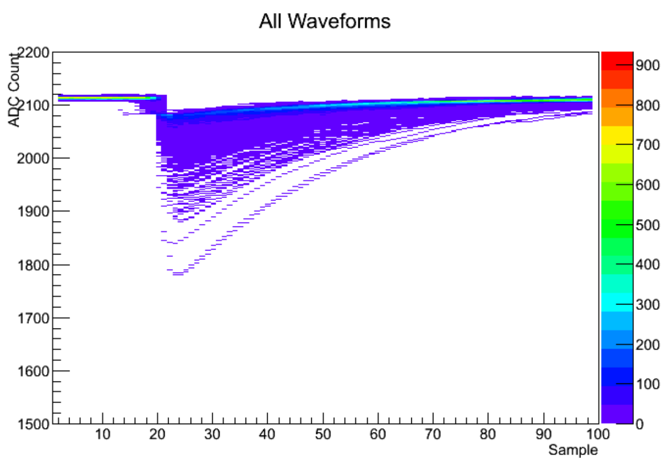


2 SiPMs
rt ~ 40 ns; tail ~ 400 ns

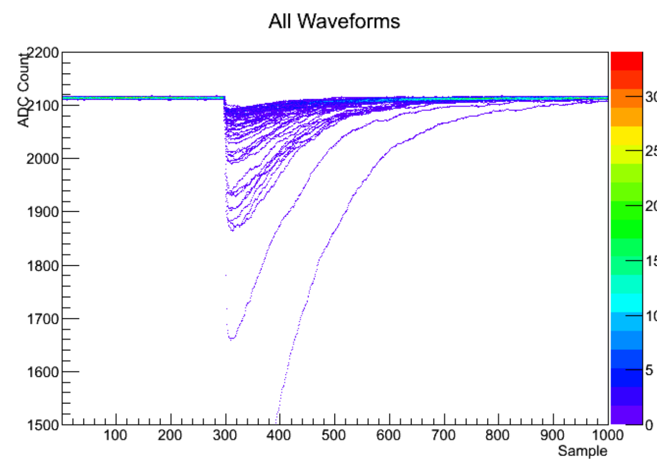


3 SiPMs
rt ~ 40 ns; tail ~ 500 ns

warm



16 ns/bin



16 ns/bin

cold

tails grow from room temperature to LAr temperature (87 K)

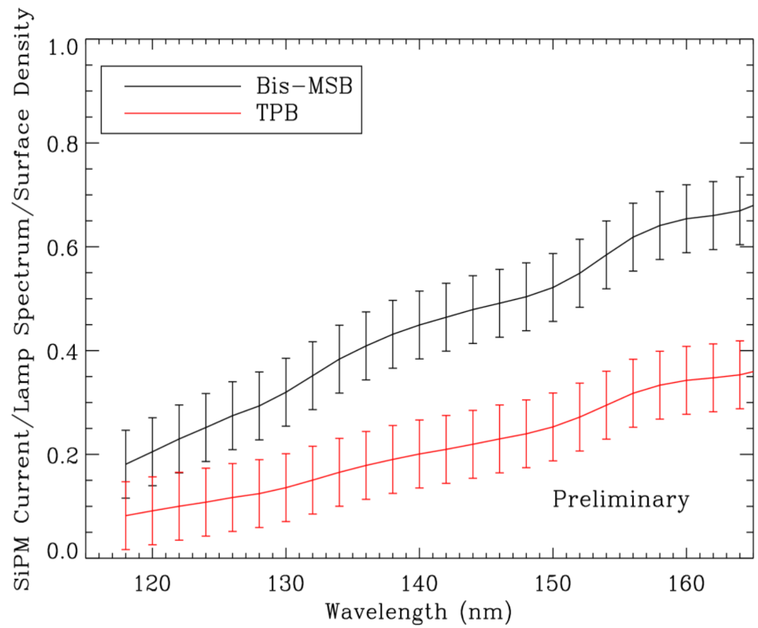
Cast acrylic waveshifter bars with an embedded surface layer of waveshifter

Table 1. Attenuation length of the tested acrylic

Manufacturer	Acrylic Type	Thickness (mm)	Wavelength (nm)	Attenuation Length (m)	Number of Meaurments
Lucite-UTRAN	Cast UVT	6.0	385	1.57 ± 0.03	3
Lucite-UTRAN	Cast UVT	6.0	420	2.60 ± 0.07	12
Lucite-UTRAN	Cast UVT	6.0	470	2.63 ± 0.07	3
ACRYLITE OP-4	Cast UVT	4.0	420	1.55 ± 0.02	3
Plexiglas Sunactive	Cast UVT	6.3	420	1.27 ± 0.03	3
Spartech-SUVT	Cast UVT	4.6	420	0.73 ± 0.04	9
McMaster-Carr	Extruded UVA	5.0	385	0.2317 ± 0.0003	3
McMaster-Carr	Extruded UVA	5.0	420	0.473 ± 0.006	4
McMaster-Carr	Extruded UVA	5.0	470	0.81 ± 0.04	3
Altec Plastics	Cast UVA	6.0	385	0.2301 ± 0.0008	3
Altec Plastics	Cast UVA	6.0	420	0.37 ± 0.01	4
Altec Plastics	Cast UVA	6.0	470	0.454 ± 0.006	3

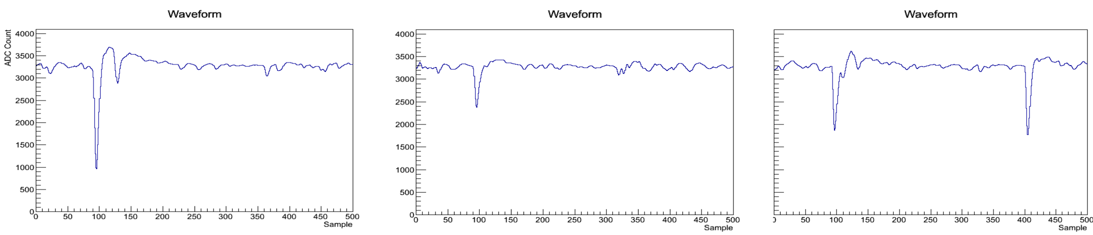
careful study of many types of cast acrylic found Lucite – UTRAN to have longest att'n length

VUV monochromator measurements continue to show that bis-MSB is as efficient as TPB in converting VUV photons into the optical – with a cost reduction of an order of magnitude

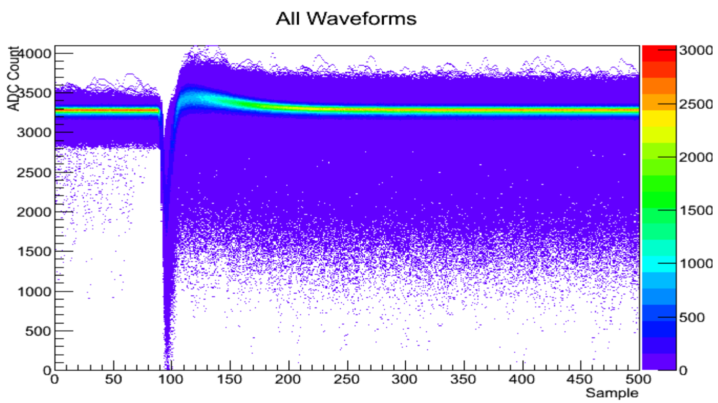


LAr tests with α source

Nevis shaper board, Gain = 200
CAEN DT5740 62.5 MHz digitizer



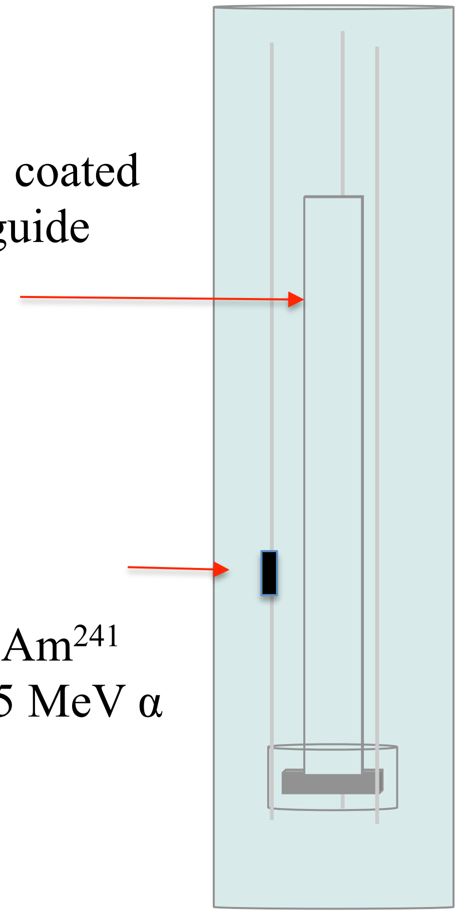
sample waveforms



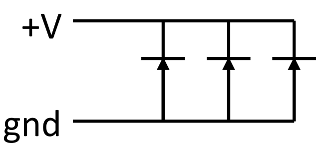
all waveforms

LAr dewar

bis-MSB coated
waveguide



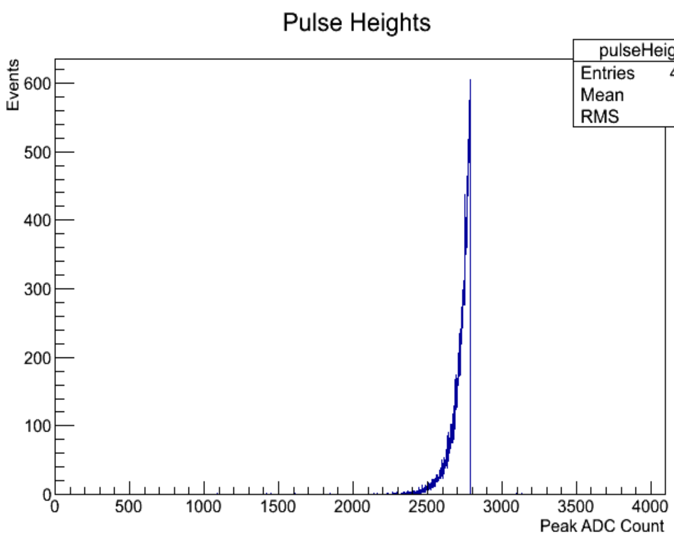
Am^{241}
5.5 MeV α



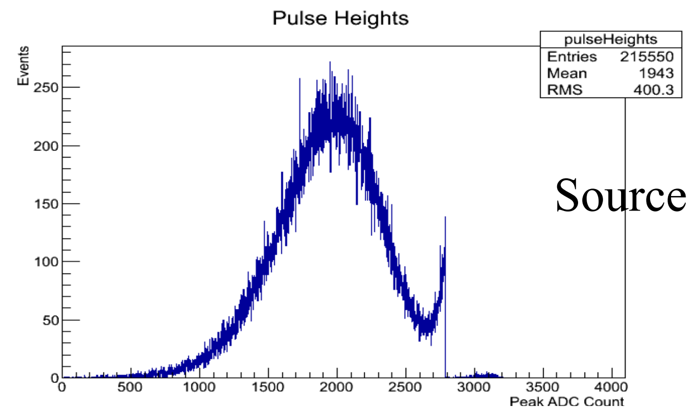
3 SensL SiPMs
Gain = 4 x 10^6

pulse height distribution

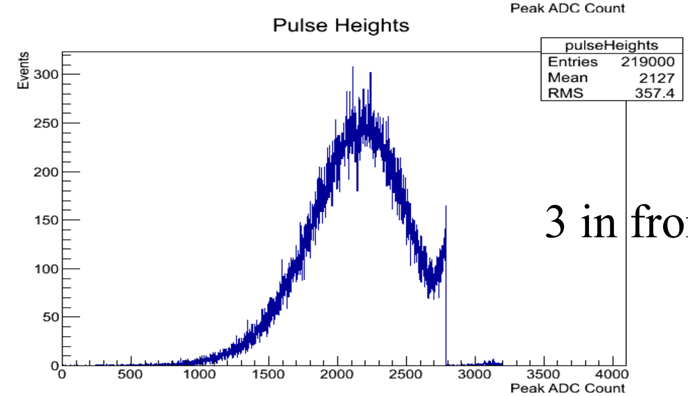
Am^{241} source
facing away



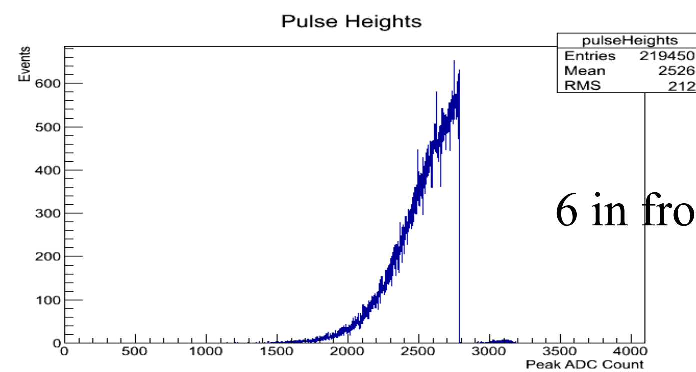
system noise



Source at bottom



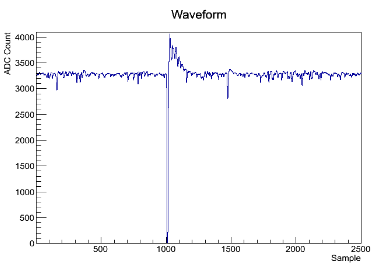
3 in from bottom



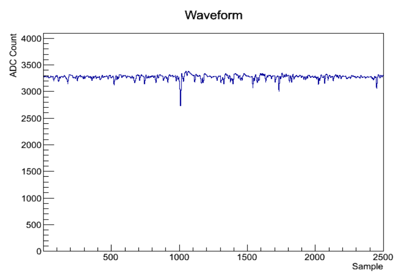
6 in from bottom

LAr tests with cosmics

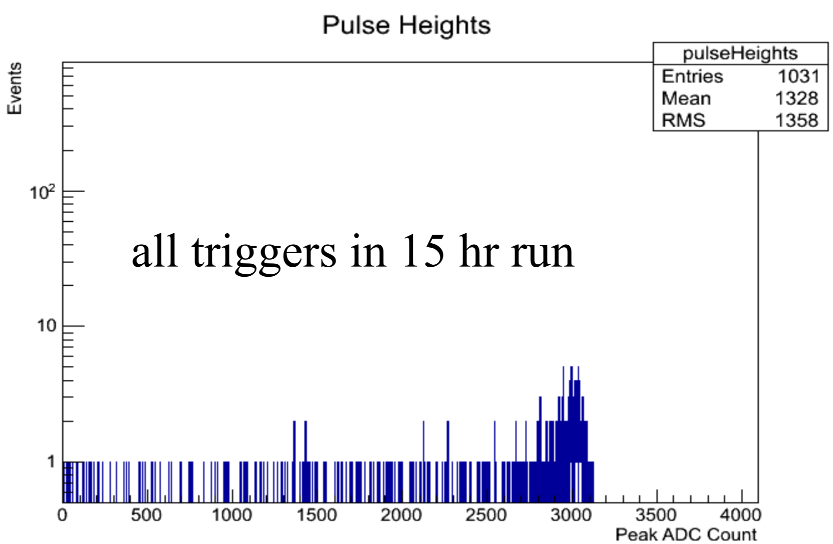
sample waveforms



MIP event



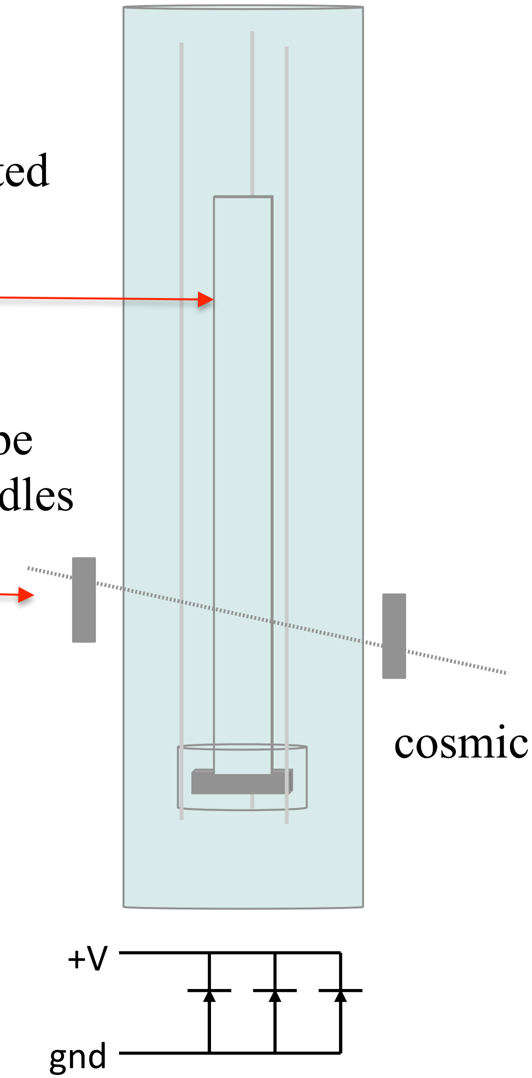
weak event



LAr dewar

bis-MSB coated waveguide

hodoscope trigger paddles



3 SensL SiPMs
Gain = 4 x 10^6

Summary

- We are making progress towards tests of prototype photon detector paddles in LAPD later this year
- We are continuing our tests of Hamamatsu and SensL SiPMs
- We continue to make progress in the manufacture of cast acrylic light guides
- We have triggered on and detected and Am^{241} and cosmic ray tracks in LAr