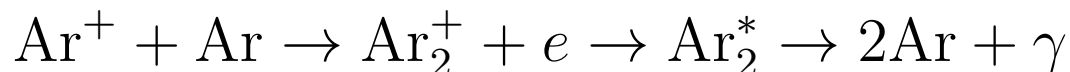# Photon Detection in Liquid Argon TPCs

Stuart Mufson

Large Area Cost Effective Detector Technologies Workshop

Fermilab

June 18, 2012

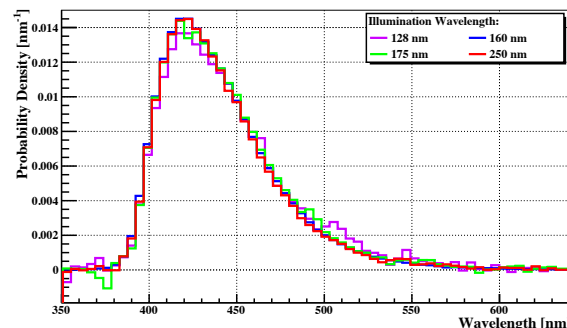# Photon Detection Overview

2 processes production scintillation light in LAr

$$\mathrm{Ar}^* + \mathrm{Ar} \rightarrow \mathrm{Ar}_2^* \rightarrow 2\mathrm{Ar} + \gamma$$

$$\mathrm{Ar}^+ + \mathrm{Ar} \rightarrow \mathrm{Ar}_2^+ + e \rightarrow \mathrm{Ar}_2^* \rightarrow$$

prompt light at 6 ns (23%) and late li
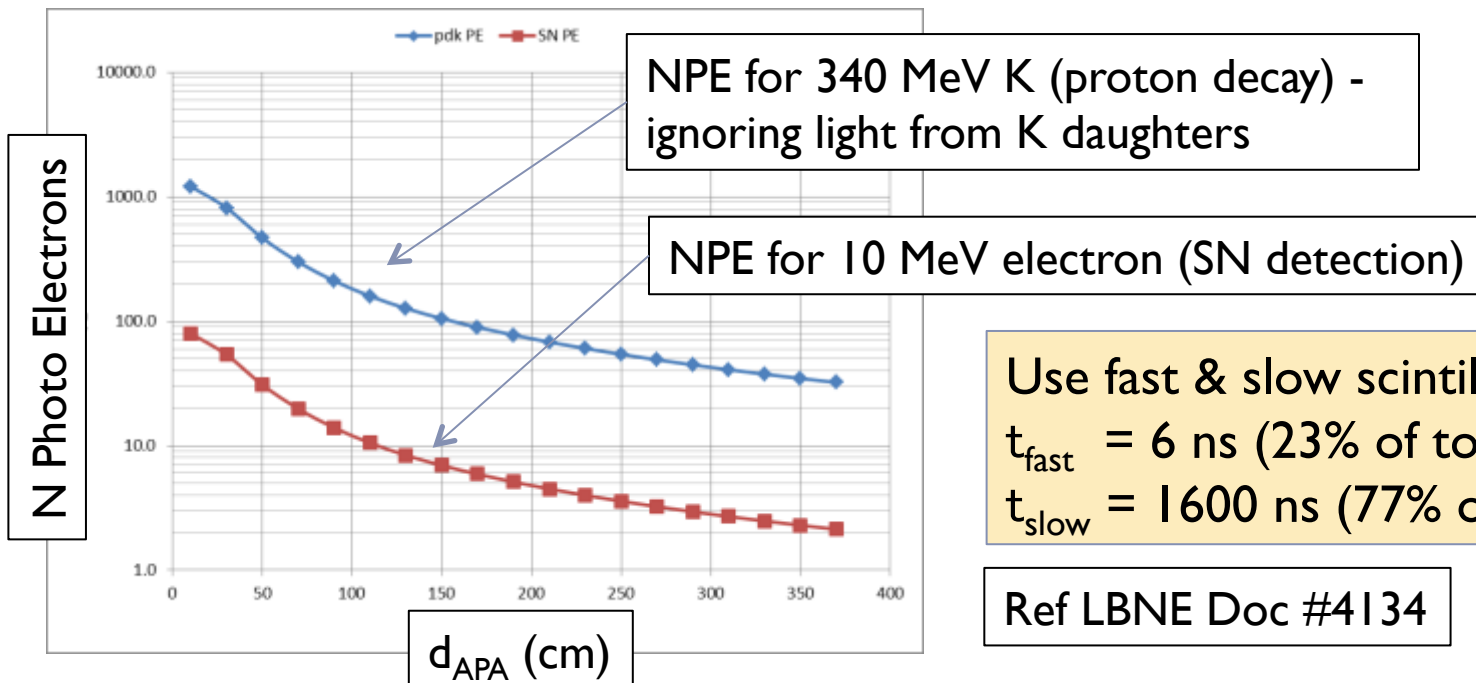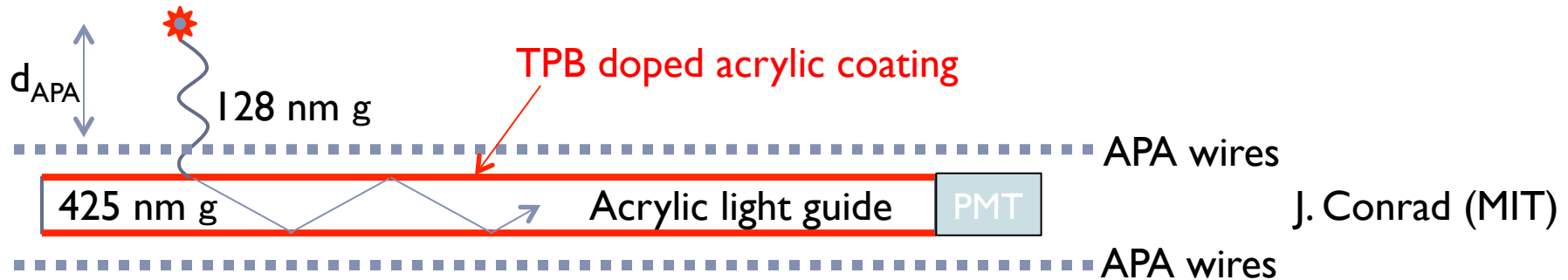

photons emitted in VUV at 128 nm where detection is difficult

- solution: TPB waveshifter
  to absorb UV photons and
  re-emit in the optical

TPB emission spectrum

Photon Detection
Stuart Mufson

d_{APA}

128 nm g

TPB doped acrylic coating

APA wires

425 nm g   Acrylic light guide   PMT   J. Conrad (MIT)

APA wires

N Photo Electrons

— pdk PE   — SN PE

NPE for 340 MeV K (proton decay) - ignoring light from K daughters

NPE for 10 MeV electron (SN detection)

d_{APA} (cm)

Use fast & slow scintillation light
t_{fast} = 6 ns (23% of total)
t_{slow} = 1600 ns (77% of total)

Ref LBNE Doc #4134

The Plan

The primary goals of this project are to investigate the additional science scope that a photon detection system would enable for (underground) liquid argon detectors, to establish the science-driven performance requirements, and to build and test a prototype that meets these requirements.

Three components to the Program:

1. Development of a prototype system for tests in the 35-ton cryostat
2. Simulations of photon detection in LAr TPCs
3. Develop photon detector designs for the next generation of LArTPC detectors

Science Drivers: Underground

There are significant "non-accelerator" science objectives that large, deep LArTPC detectors can explore.

1. Proton Decay

- critical issue is to achieve extremely high rejection of backgrounds, less than one event per 100 kt-yrs, that could masquerade as the very rare signal.
    – "golden" proton-decay channel in LAr (p -> $K^+\nu$) mimiced when a K^+ outside the exterior cathode planes enters the fiducial volume
    – photon detection unambiguously determines the position of the event in the detector

2. Supernova Neutrino Bursts

- detailed timing information from a photon system greatly enhances the understanding of the evolution of catastrophic stellar core collapse processes

Science Drivers: Underground

3. Atmospheric Neutrinos

- unique among sources used to study oscillations since the oscillated flux contains neutrinos and anti-neutrinos of all flavors, thereby enabling sensitive searches for new physics signatures
- the photon detection system improves the energy resolution, reducing systematic errors in the analyses, enabling more accurate searches

4. Mitigation of Spallation Backgrounds

- muons and muon-induced fast neutrons entering the detector from the surrounding rock
- backgrounds are important for neutrino detection in the range of a few to a few tens of MeV

Science Drivers: Surface Detector at Homestake

Photon detection is a valuable tool in a large surface LAr detector for mitigating backgrounds from CRs

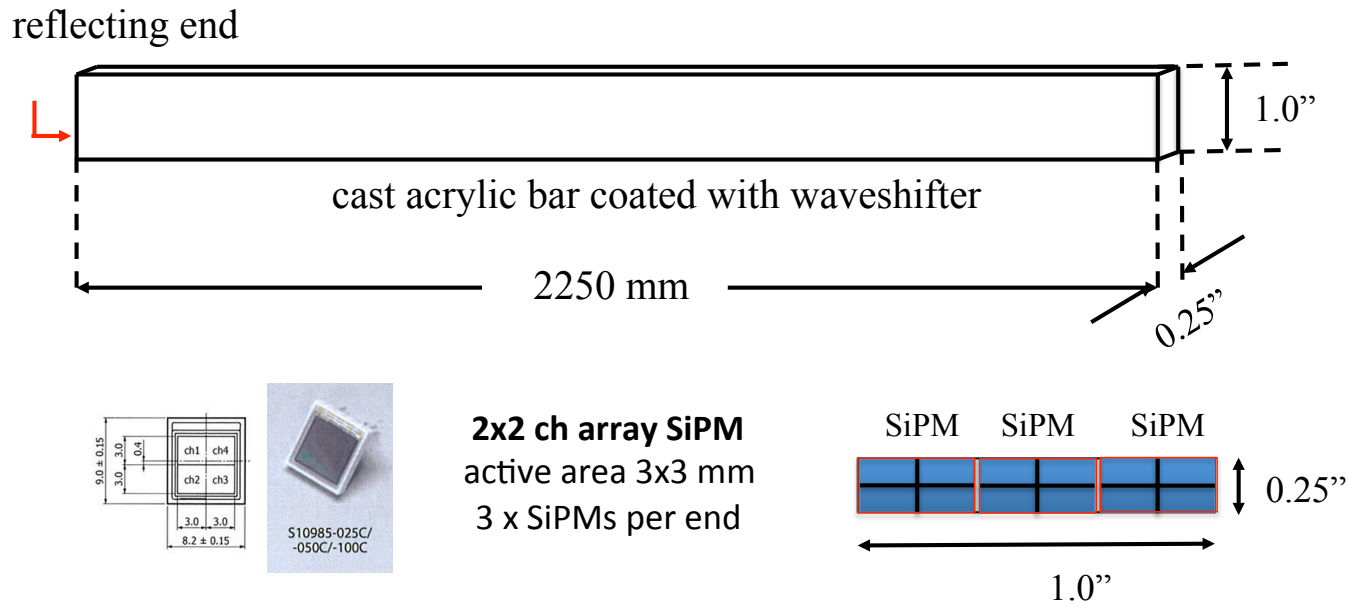- beam spills ~ few μsec, drift times ~ few msec
- the CR background rate ~ 10 kHz
- in a few msec, a handful of CR muons will fall within the drift time window
- with accurate t_0 from the photon detection system, events outside the beam spill window can be accurately identified; with dE/dx corrected with t_0, particle ID will further improve background rejection
- in conjunction with tracking that point events back to Fermilab, photon detection improves beam neutrino detection

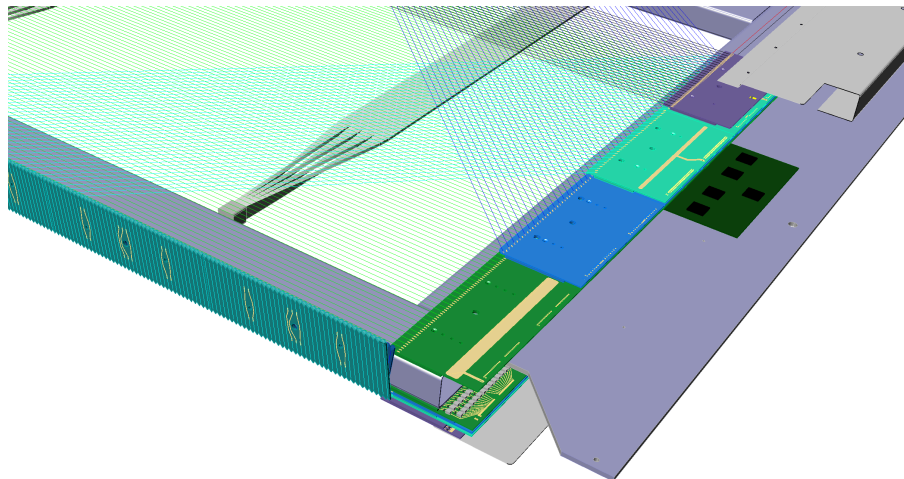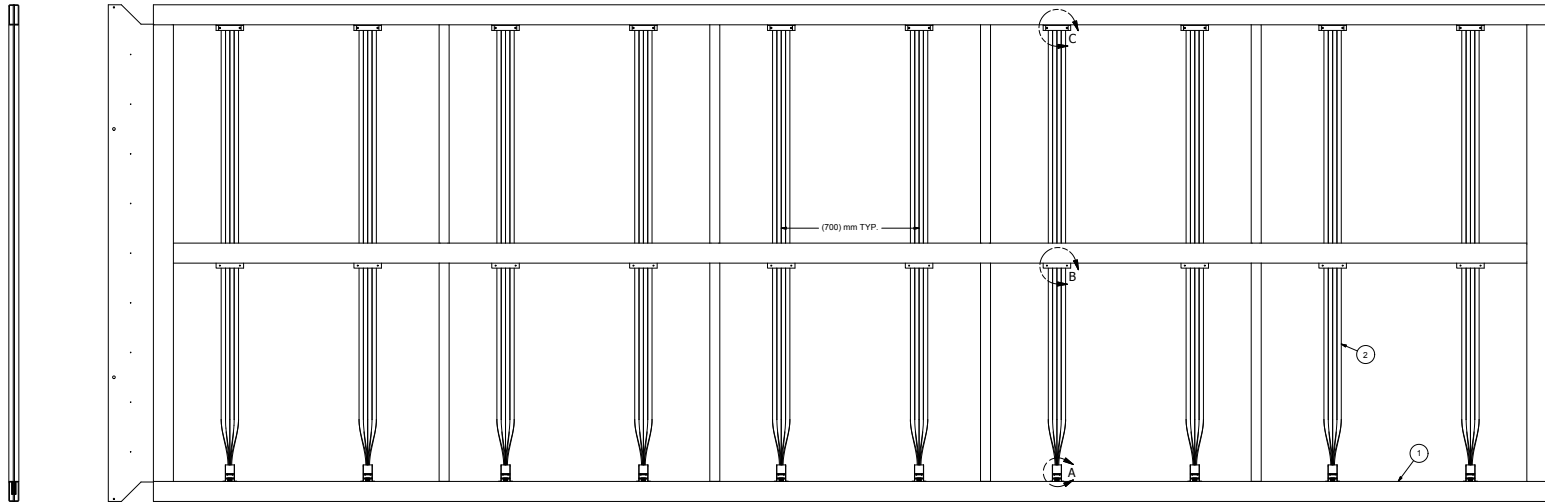# Research Program: Light Guides

1. Prototyping Conceptual Design

    Conceptual light guide design as described in CDR
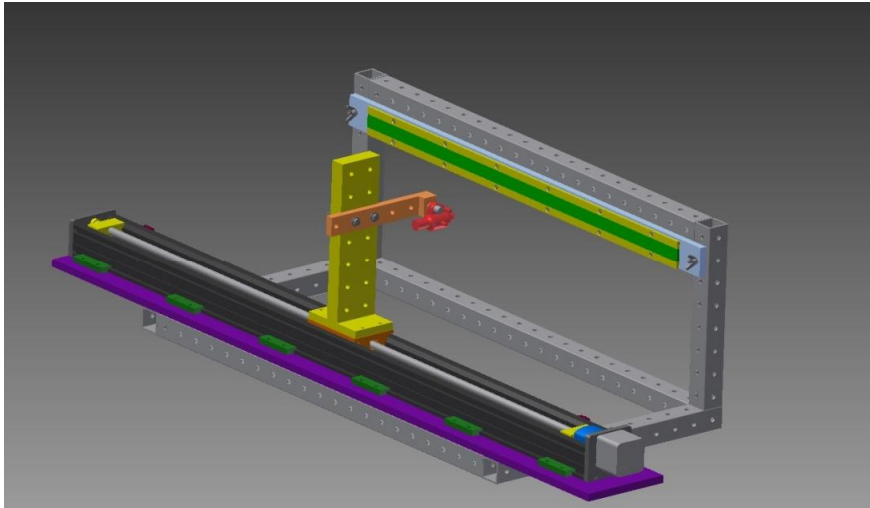
    light guide concept:

reflecting end

cast acrylic bar coated with waveshifter

2250 mm

1.0"

0.25"

S10985-025C/ -050C/-100C

ch1 ch4
ch2 ch3

9.0 ± 0.15
3.0 3.0 0.4
3.0 3.0
8.2 ± 0.15

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

SiPM   SiPM   SiPM

0.25"

1.0"

Research Program: Light Guide Mounting

Figure 2: Examples of waveforms after cuts described in Sec 3.1. The first pulse is early light which produces the trigger. The trigger level is set at a 15 ADC counts, which corresponds to just below 3 PE, as determined in Sec 3. The early pulses (with time constant of ~ 6 ns) are produced by multiple UV photons impinging on the bar. Thus the early pulses vary in pulseheight. Single-PE late light pulses can be also be seen in these events.

Lig
fror

VUV photons
on −

• c

ditional mode with record headers enabled. The channel is configured to have
an input range of +200 mV. A trigger is produced by a negative pulse with an

test setup at IU

We use both early and late pulses to convert pulseheight information in the
waveforms to the number of PE in the event.

3.1. Analysis Cuts for the Calibration Samples

In order to perform the calibration, "clean pulses," such as those shown in
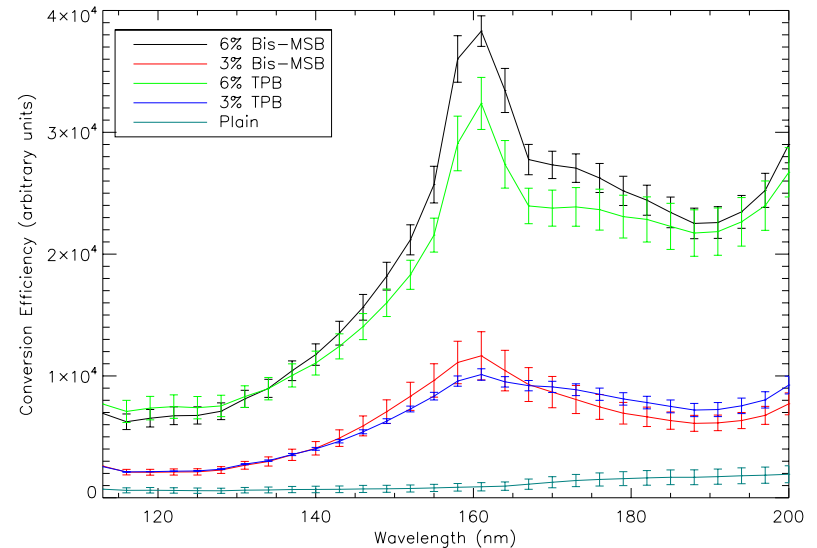
Research Program: Value Engineering

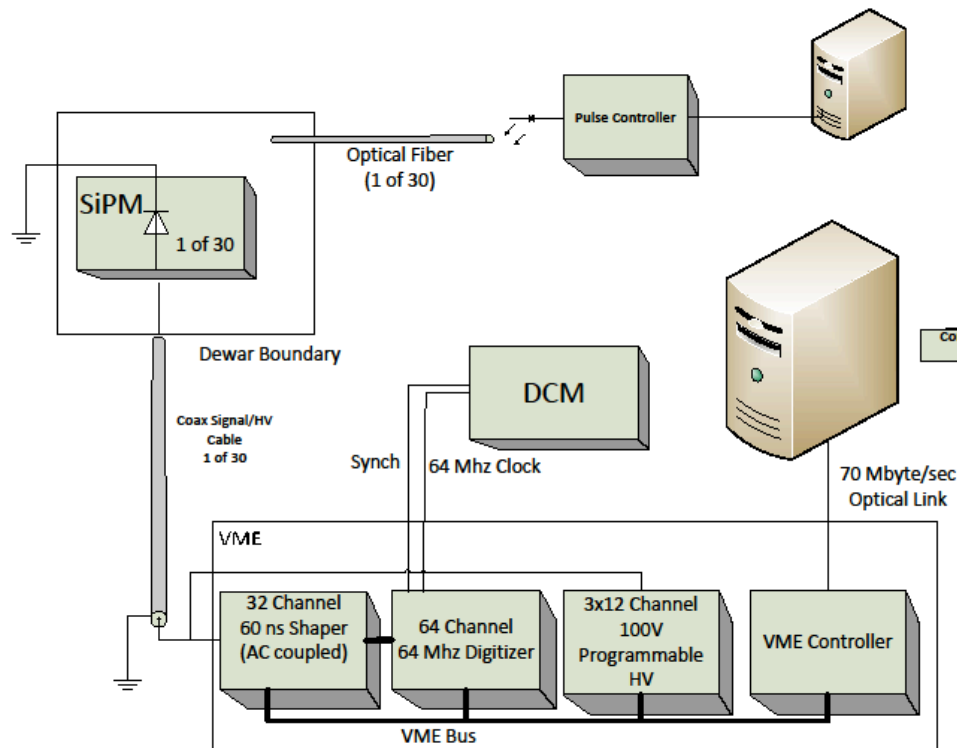## Look for plastic with long attenuation length –
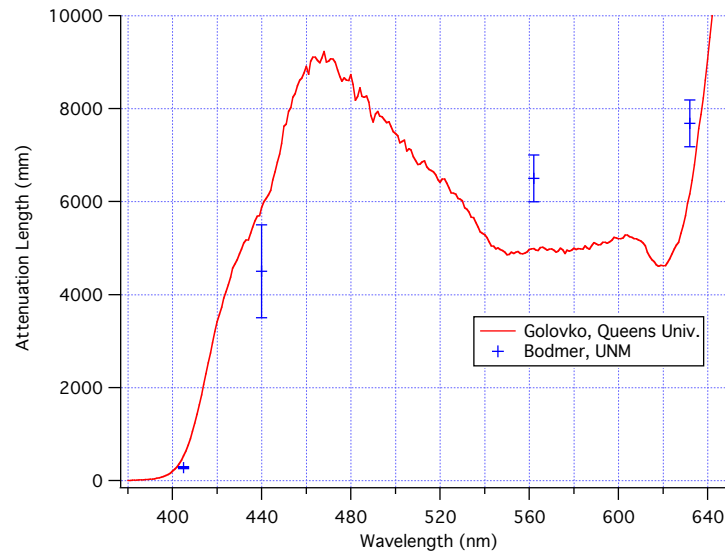
Investigate alternative waveshifters –

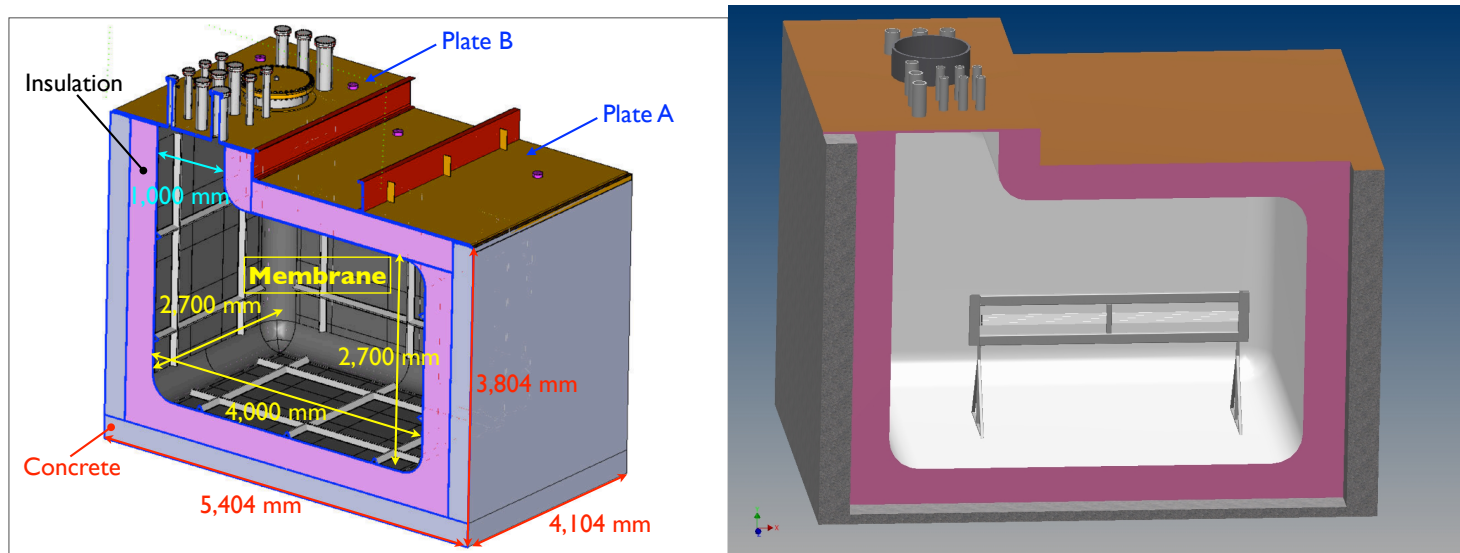# Research Program: DAQ Readout

Flexible electronics design as described in CDR –
warm and based on commercial off-the-shelf (COTS) hardware
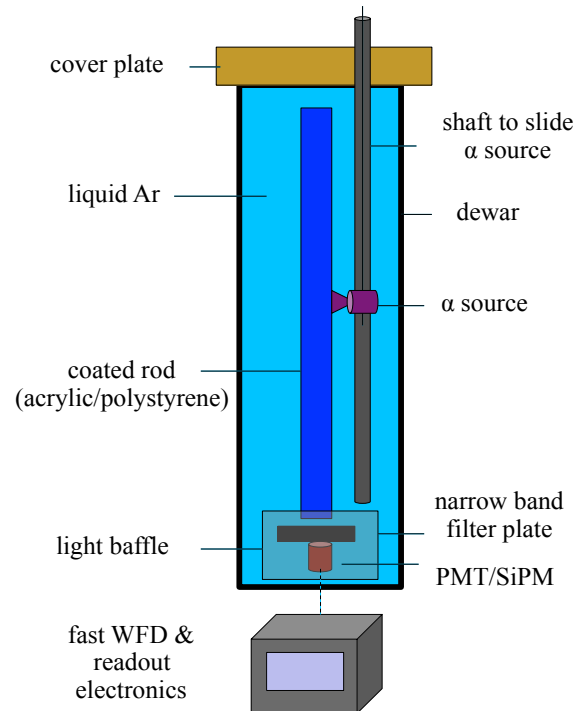

Figure xxxx

Test prototype photon detector system in LBNE 35-ton prototype membrane cryostat

Insulation

Plate B

Plate A

1,000 mm

Membrane

2,700 mm

2,700 mm

3,804 mm

4,000 mm

Concrete

5,404 mm

4,104 mm

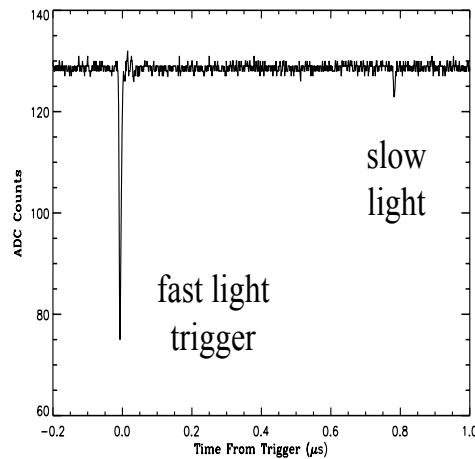project has agreed to fund a LAr fill for these tests
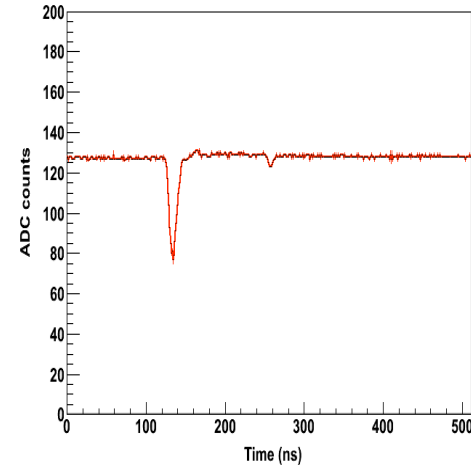
LAr Test Facility at IU

LAr test facility at Indiana:

LAr Test Facility: Results

Fast scintillation light signals have been observed whose topologies match those in Bugel *et al. Nucl.Inst.Meth. A* **640**, 69 (2011) – MIT group

IU   MIT

Research Program

2. Simulations

- Simulation, reconstruction and analysis code for LArTPCs exist as LArSoft
    - improve & expand code to answer basic physics questions
- Overall goal is to evaluate LArTPC physics sensitivity as a function of photon collection ability in general, and for the specific configurations in particular
    - Building on basic photon simulation code that already exists in LArSoft, we will develop code enabling simulation of different photon collection design configurations in a flexible way
    - develop reconstruction code optimized for low energy (up to a few tens of MeV) events
    - study how well cosmogenic low-energy (e.g. spallation) events be rejected using vertex information enabled by photon collection
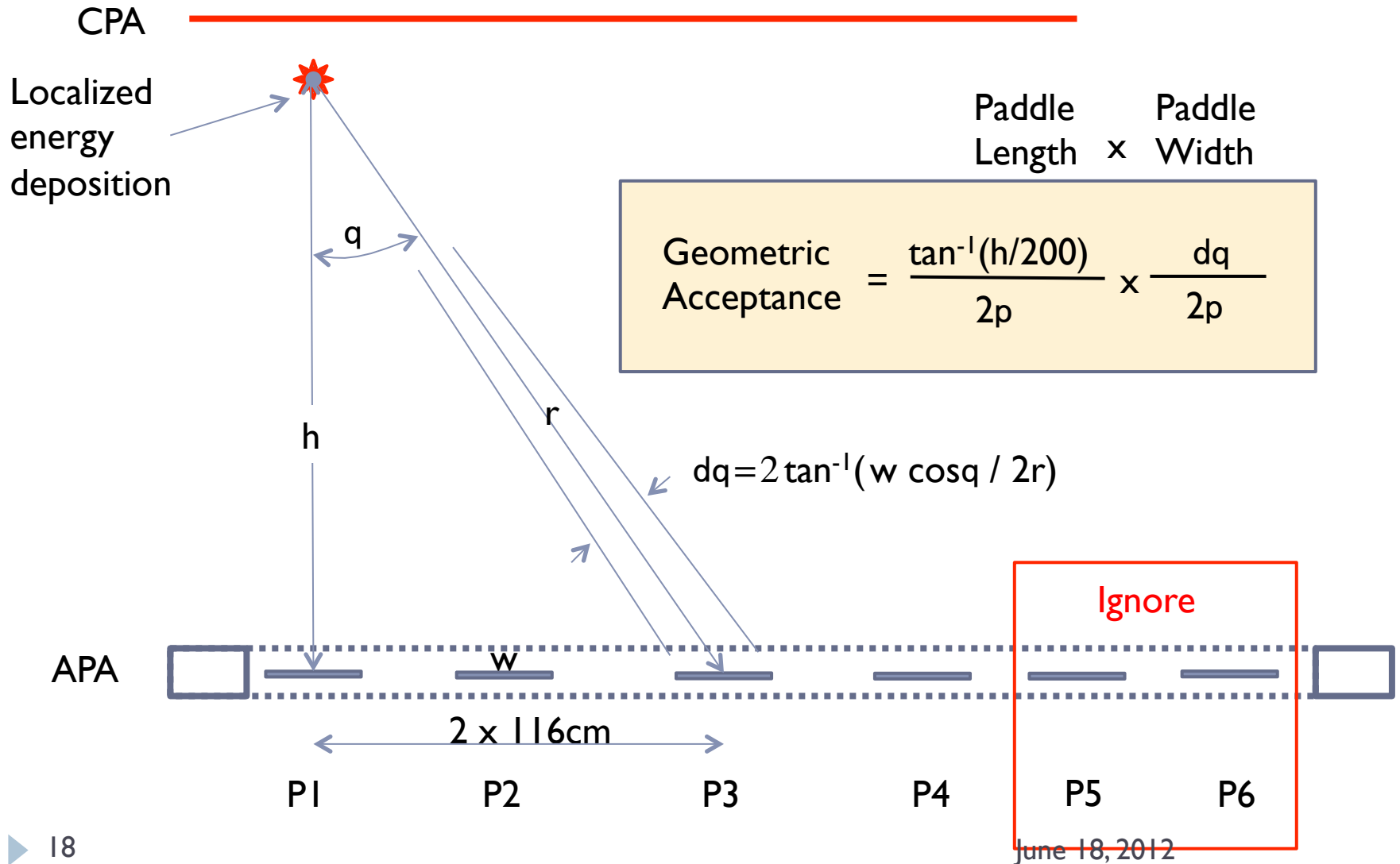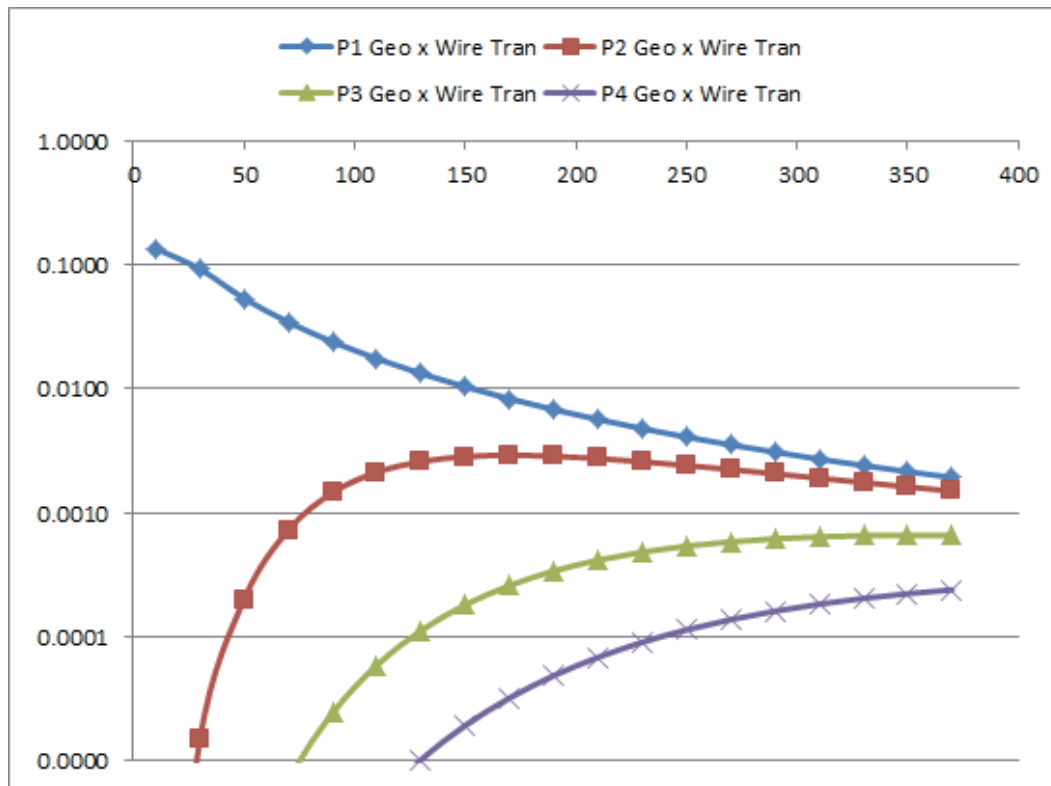
backup

Paddle Geometric Acceptance – Bruce Baller
Side View of Drift Cell

CPA

Localized energy deposition

q

h

r

$$dq = 2\tan^{-1}(w\cos q \, / \, 2r)$$

Paddle Length $\times$ Paddle Width

$$\text{Geometric Acceptance} = \frac{\tan^{-1}(h/200)}{2p} \times \frac{dq}{2p}$$

Ignore

APA

w

2 x 116cm

P1   P2   P3   P4   P5   P6

- (Geometric Acceptance) x (Wire Plane Transmission) for 4 adjacent paddles (P1 - P4) for light emitted a distance h (0 - 370 cm) directly above paddle P1.

- At a distance of 2.3 m the product < 1% for P1 and P2 (60 cm away).
- Paddles P3 (120 cm away) and P4 (180 cm away) down by an order of magnitude.
- <u>Conclusion</u>: light produced +/-2.5 m away from any paddle transverse to the drift direction will not hit the paddle.