

Reflector-based light collection in LArTPC neutrino detectors

[DRAFT – 03 Jul 2014]

William Foreman

University of Chicago

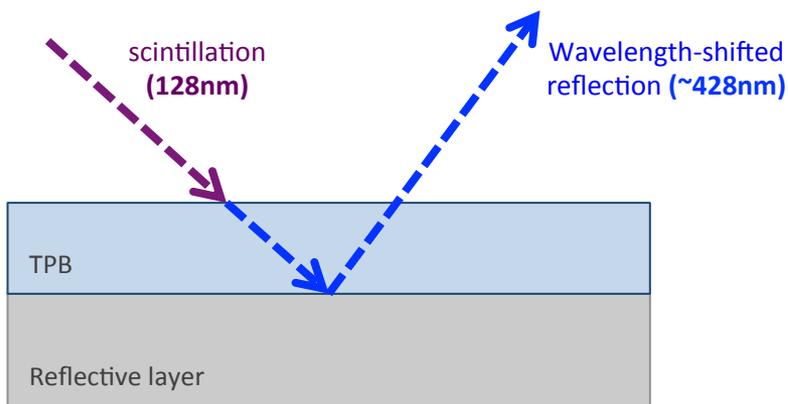
LArTPC R&D Workshop

8 July 2014 – FNAL

Outline

- Introduction and overview of technique
- Use in dark matter experiments
- The LArIAT Light Readout System
- Light yield simulations
- Light collection plans for LAr1-ND

Introduction

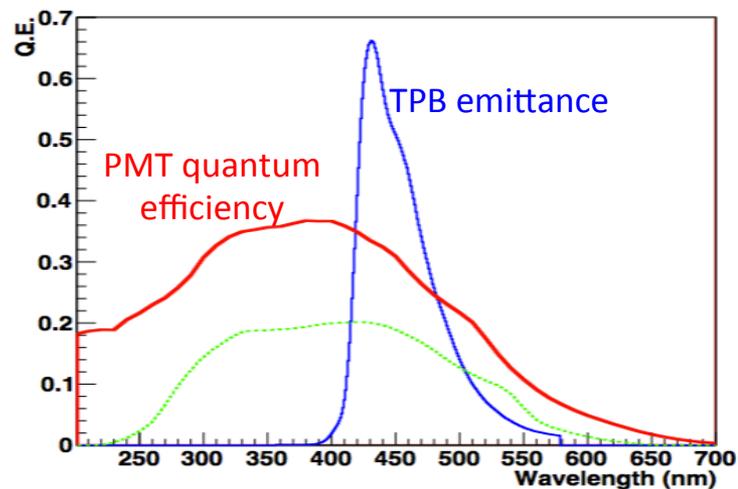
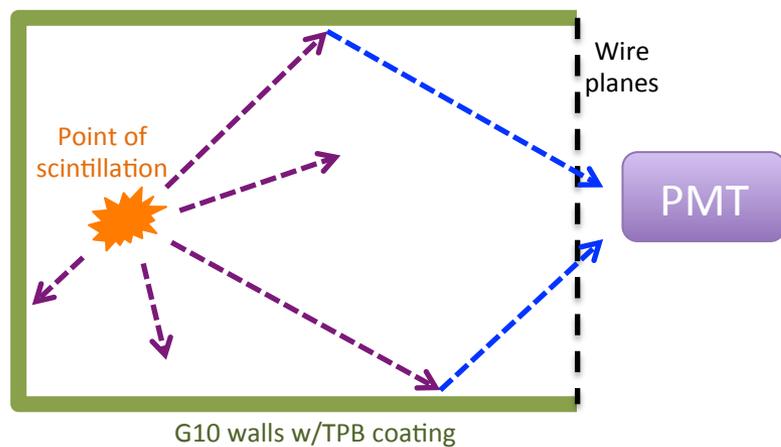


Wavelength-shifting tetraphenyl-butadiene film (TPB) evaporated onto a layer of reflector, which covers inner surfaces

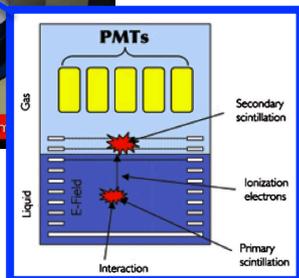
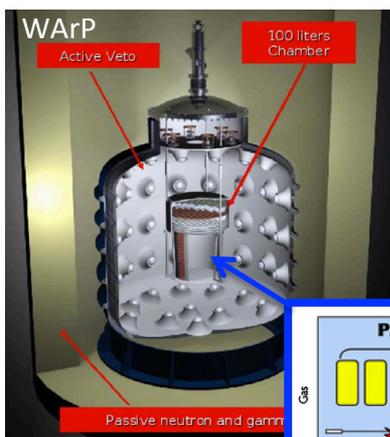
Blue light then collected at PMTs

Greater + more uniform light yield

- If PMTs coated with TPB, can differentiate direct/reflected light by arrival times



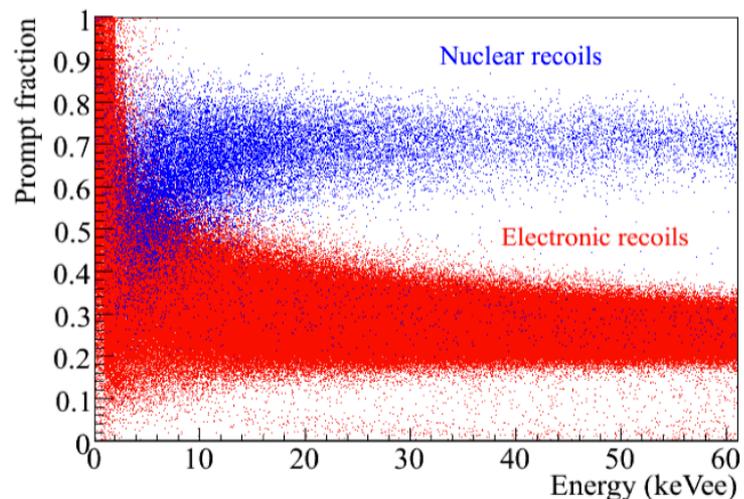
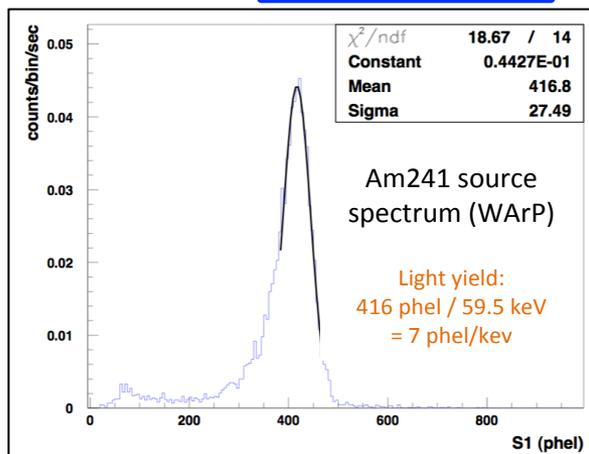
Use in dark matter searches



TPB reflector used in dark matter searches like WArP, ArDM, DarkSide

Pulse shape discrimination (PSD)

- Ratio fast-to-total light used to separate MIPs and genuine nuclear recoils
- In nuclear recoil energy range 50-100 KeV, 50% nuclear recoil acceptance with $\sim 10^{-6}$ electron recoil contamination (Lippincott et al, 2008)

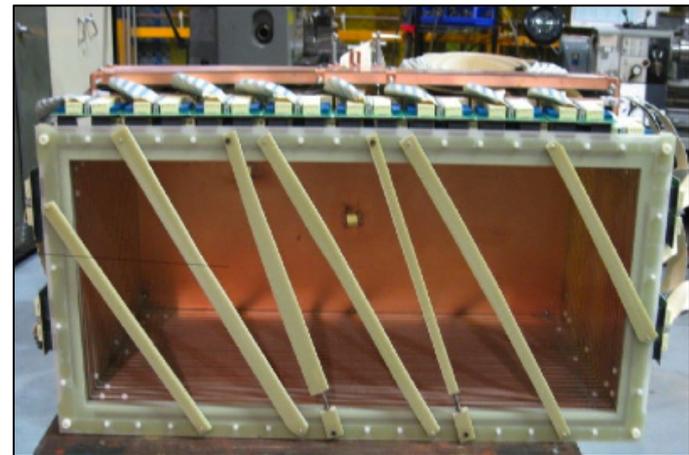
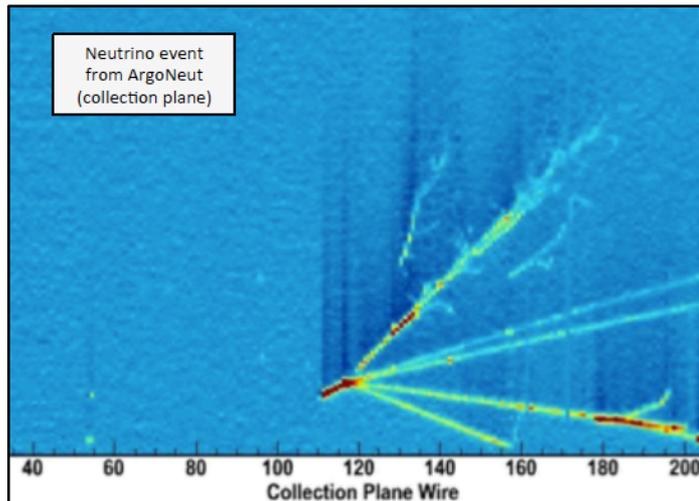
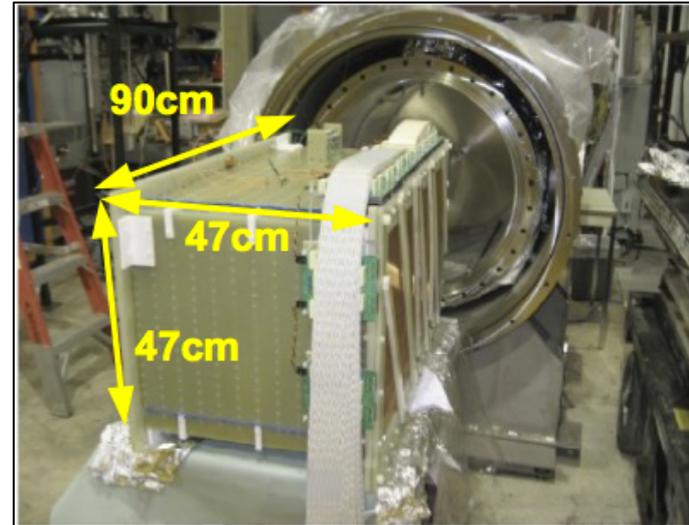


LArIAT: Liquid Argon in a Test Beam

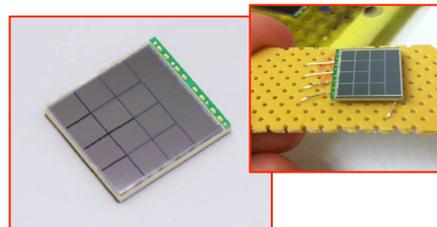
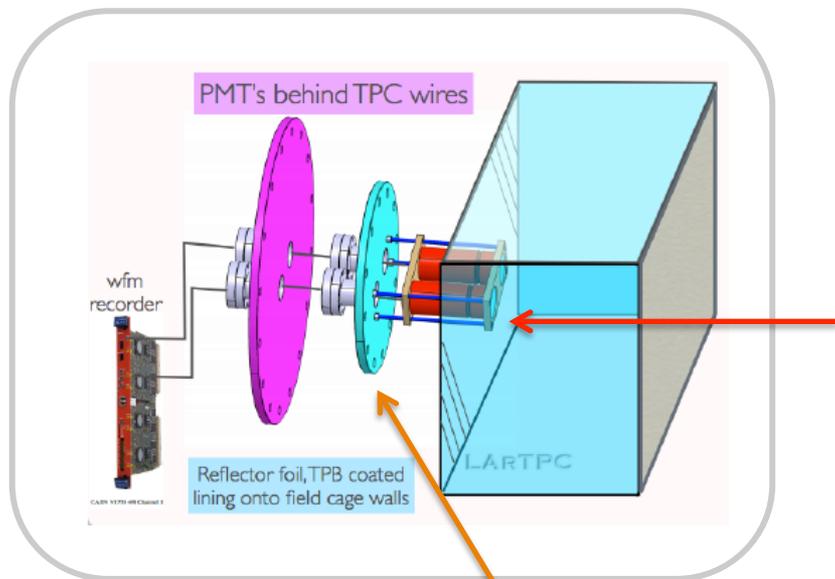
Program to create a permanent test facility to calibrate LArTPCs in a beam of charged particles (pions, protons, positrons...)

Phase I: Re-use ArgoNeuT detector in a test beam at Fermilab's M-Center starting later this year

- Adapt *reflector-based light collection system* for use in neutrino LArTPC experiments



LArIAT light readout system (1/2)



Two cryogenic PMTs

- 3" high QE (30%)
- 2" standard QE (20%)

Two SiPMs

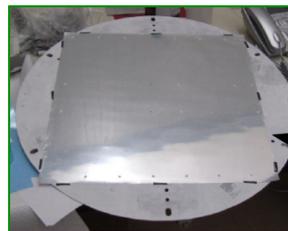
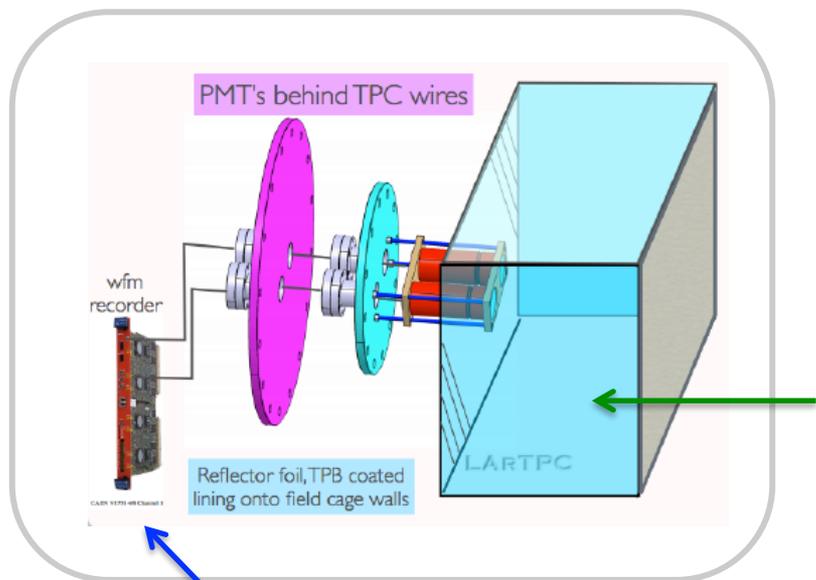
- 1.2x1.2 cm² each, QE 50% (arrays of 16 3x3mm channels)



Side port added to ArgoNeuT cryostat to accommodate PMTs and HV/readout



LArIAT light readout system (2/2)



Reflector foil before/after TPB evaporation

Inner walls of TPC lined with TPB reflector foil in order to maximize light collection compared to traditional LArTPCs



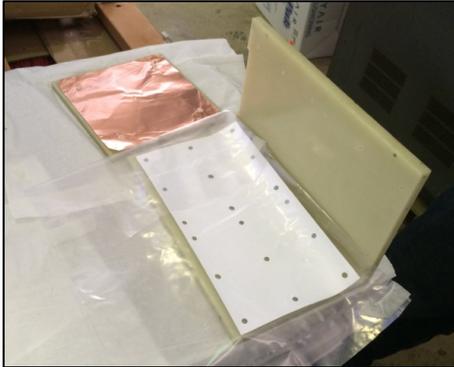
Test-mount of mock foil masks onto LArIAT TPC



Signals digitized by CAEN V1751 at 1GS/sec

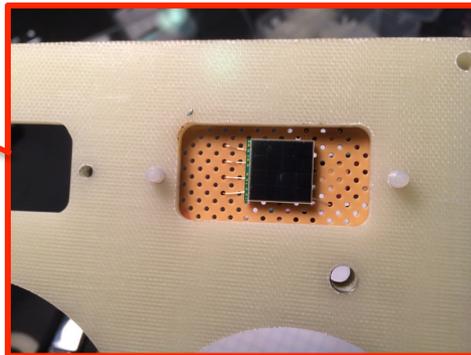
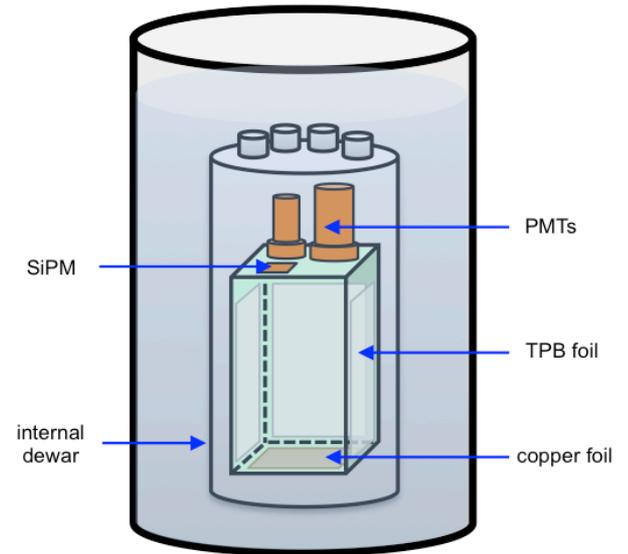
- Fast DAQ needed to differentiate fast & slow component ($\sim 1\text{ns}$ vs $\sim 1\mu\text{s}$)

Light readout test chamber (1/2)



To test components and DAQ in experimental conditions, test stand assembled at UChicago

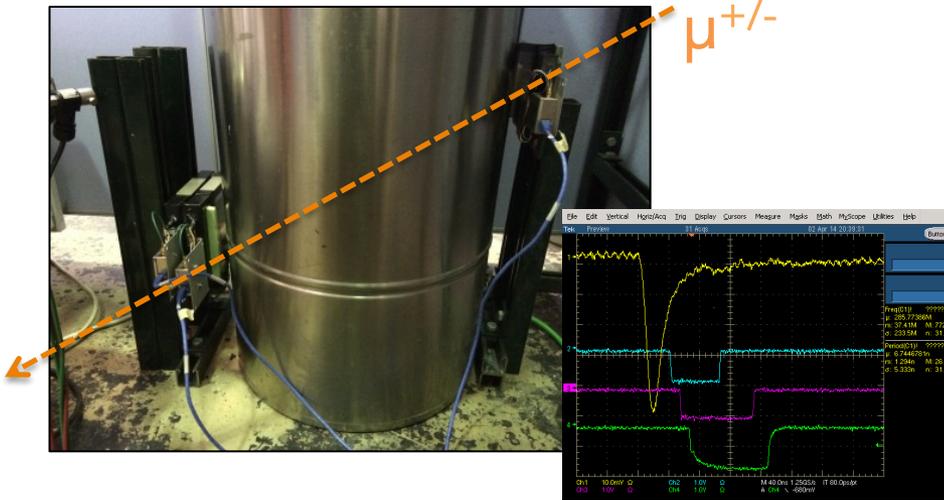
PMTs and SiPM mounted to top of mock-TPC (14x14x25cm) made of G10 (same material as LArIAT TPC) lined with TPB foil



SiPM peering into inner volume of mock-TPC



Light readout test chamber (2/2)

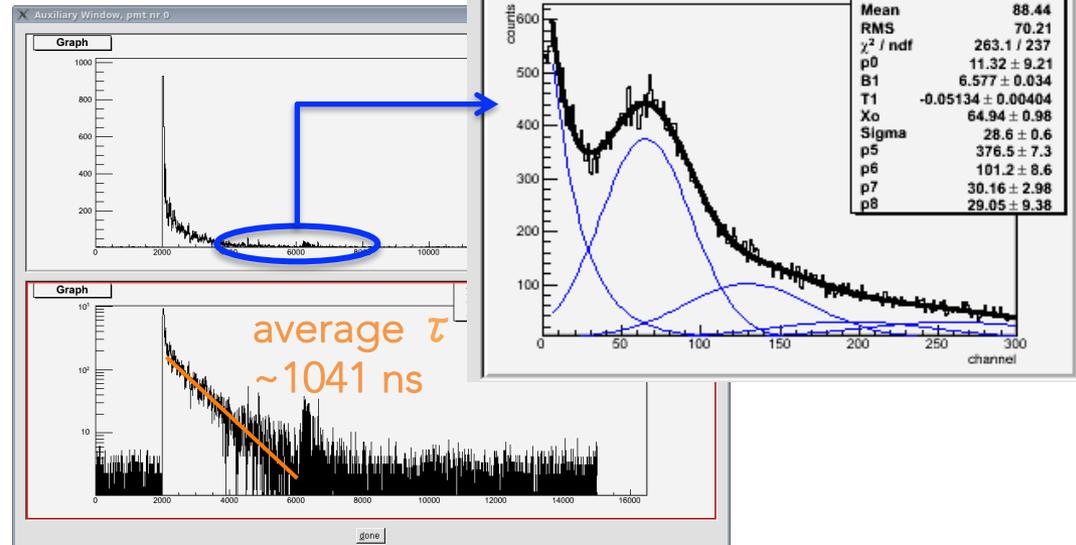


Observed LAr scintillation light in coincidence with cosmic rays

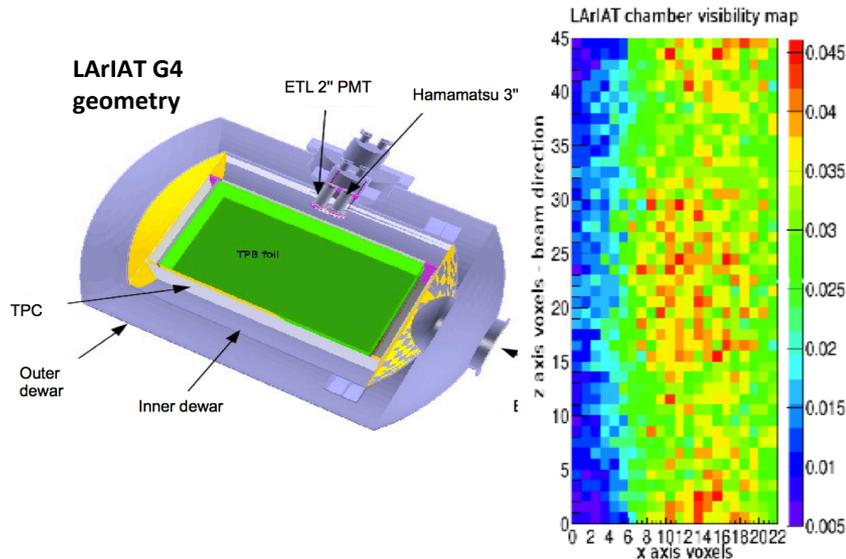
Scintillation from cobalt-60 gamma rays (1.1 MeV, 1.3 MeV)

Successful demonstration of DAQ chain through CAEN board

- Single photoelectron response (SER) measured from stray photons in tails
- Scintillation lifetime measured (purity estimation possible)



Light yield simulations



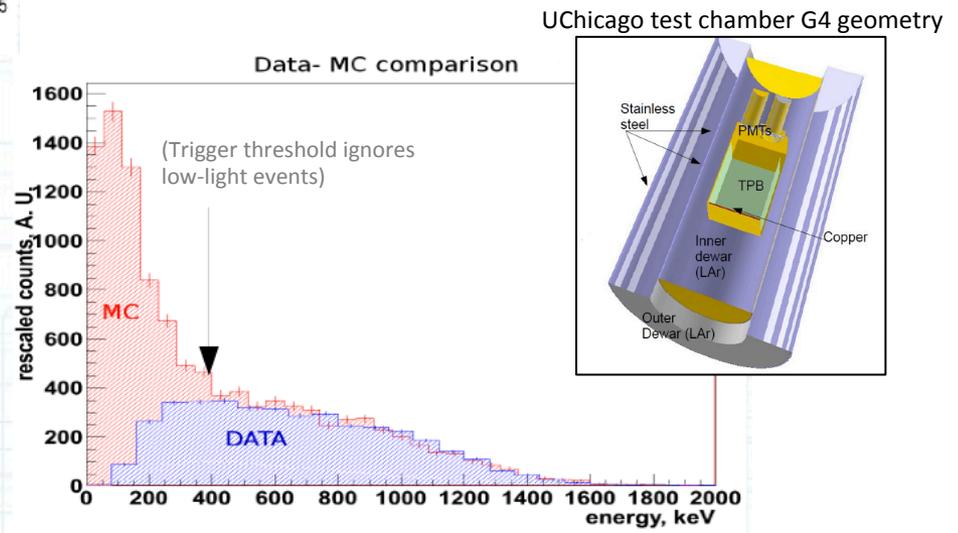
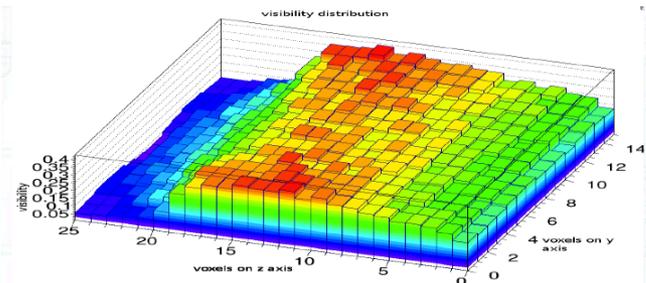
Fast optical simulation for LAr TPCs (B. Jones) more efficient than fully tracking millions of photons per event

- Volume divided into voxels, "visibility" of photons emitted from each voxel saved into library

Simulations modified by P. Kryczynski to account for wavelength-shifting reflectors

Results from UChicago test stand being used to optimize parameters

- Simulations tuned to reflect data

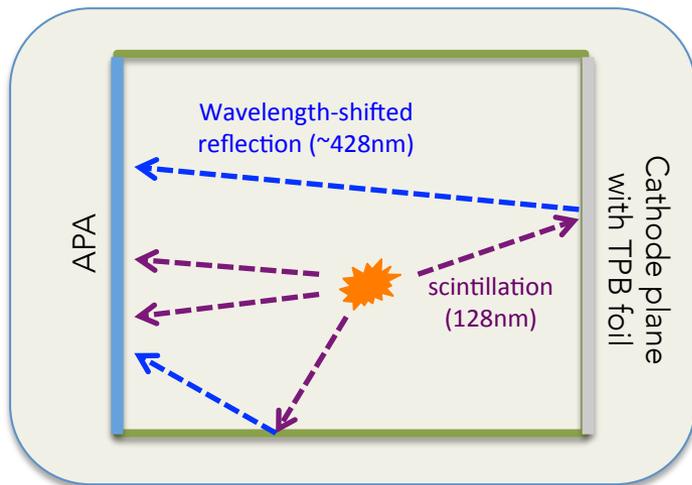


Light collection in LAr1-ND

Space along APAs can accommodate light collection system – aim to be compact as possible (SiPMs + light guides)

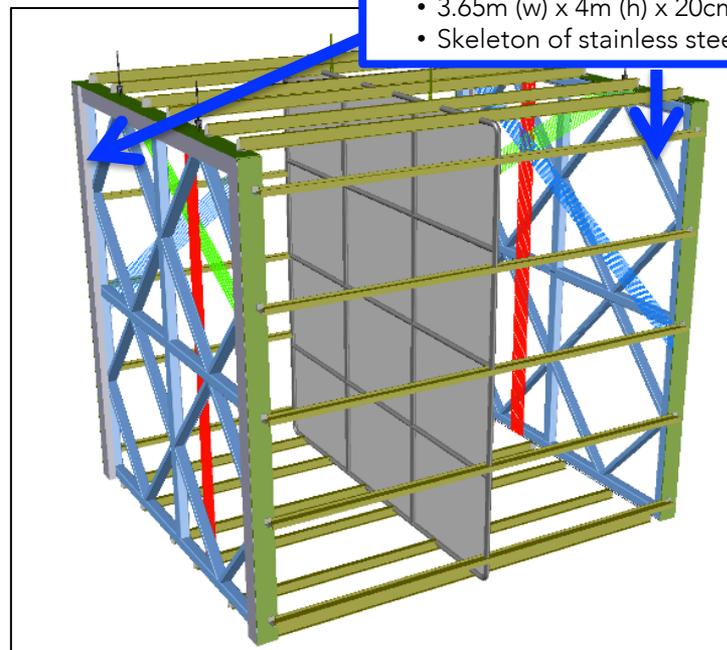
Acrylic TPB-coated light guides chosen for LBNF – will be put to test in LAr1-ND!

- Capacity for PSD needs to be tested
- Possibility for complementary use of TPB foil on cathode + walls



2 anode plane assemblies (APAs)

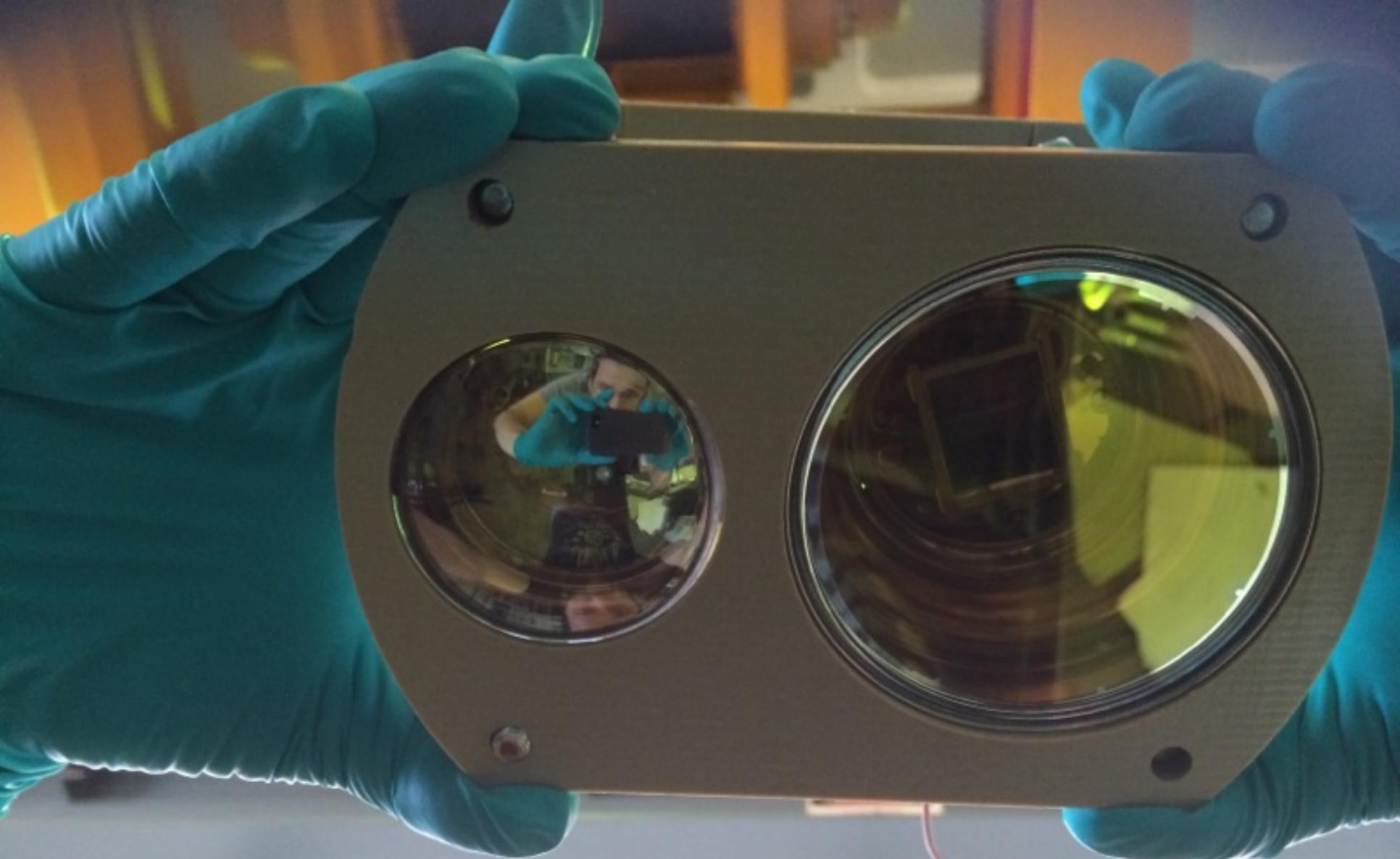
- 3.65m (w) x 4m (h) x 20cm (thick)
- Skeleton of stainless steel tubes



Studies underway to maximize physics + R&D potential of light collection system

In Summary

- ✧ Reflector-based light collection proven effective in nuclear recoil / MIP separation in LAr
 - Innovative (and, as of yet, **untested!**) approach to light collection in LArTPC neutrino experiments
- ✧ LArIAT light readout prototype operated successfully
 - Results being used to optimize light yield simulations
 - LArIAT will enable new studies on **PID, calorimetry, and muon sign-determination using scintillation light**
- ✧ LAr1-ND provides further opportunity to test reflector-based systems
 - Will help inform/optimize LBNF designs



Thank you