Reflector-based light collection in LArTPC neutrino detectors

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LArTPC R&D Workshop
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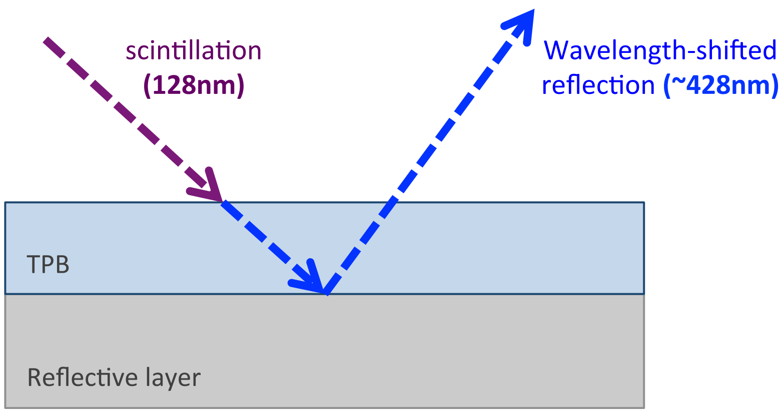
Outline

- Introduction and overview of the reflective technique
- Use in dark matter searches and possible advantages for neutrino experiments
- The LArIAT light readout system
- Test stand and light yield simulations
- Possibilities for future neutrino detectors

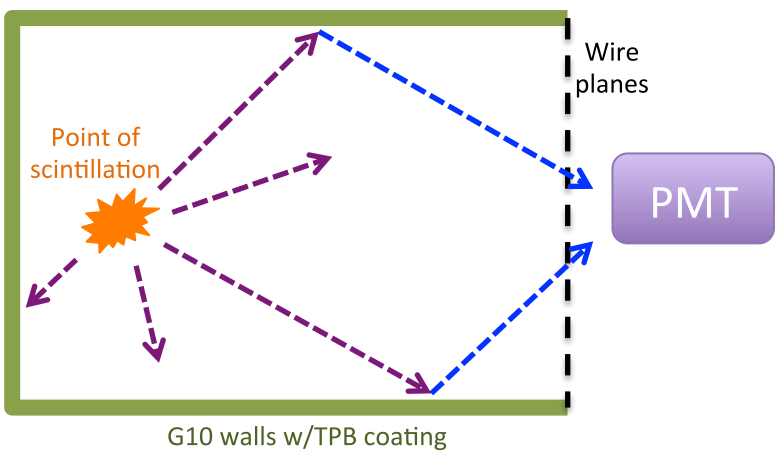
Reflector-based approach to light collection

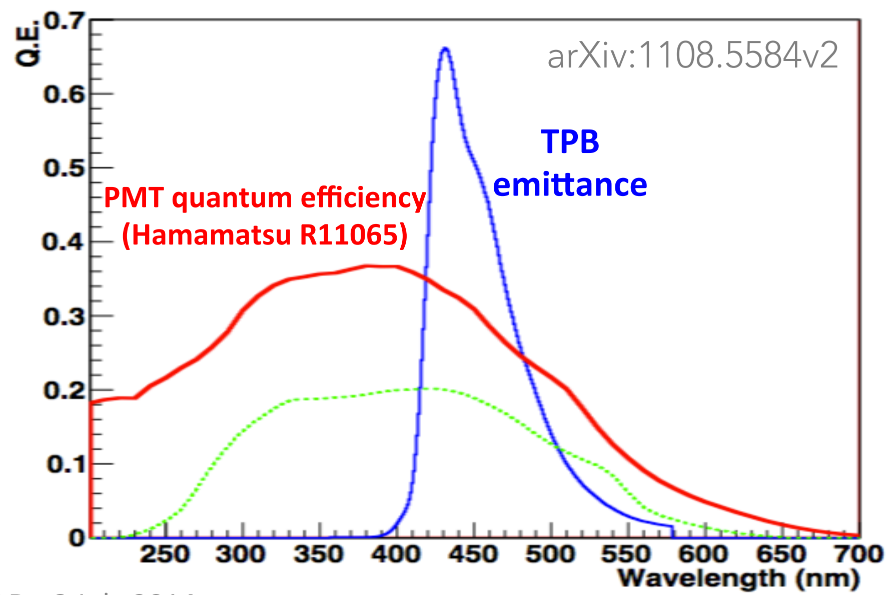


Wavelength-shifting tetraphenyl-butadiene film (TPB) evaporated onto a layer of reflecting foil covering inner surfaces. Blue light then detected by PMTs.

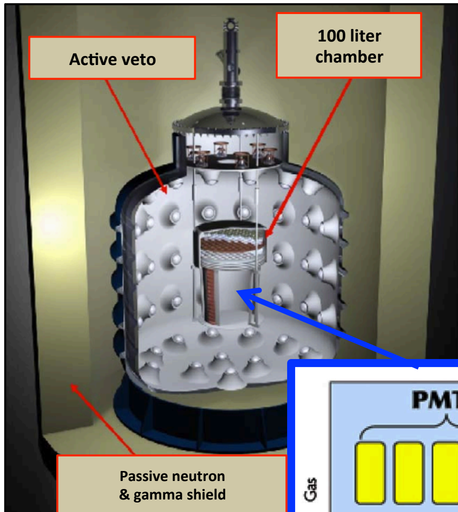
Greater + more uniform light yield

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

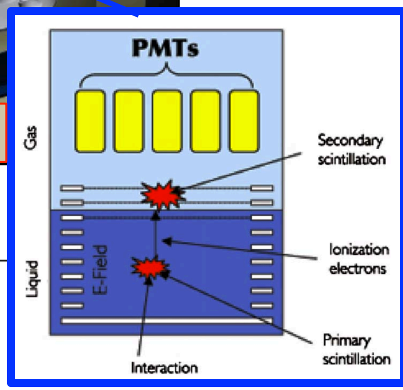


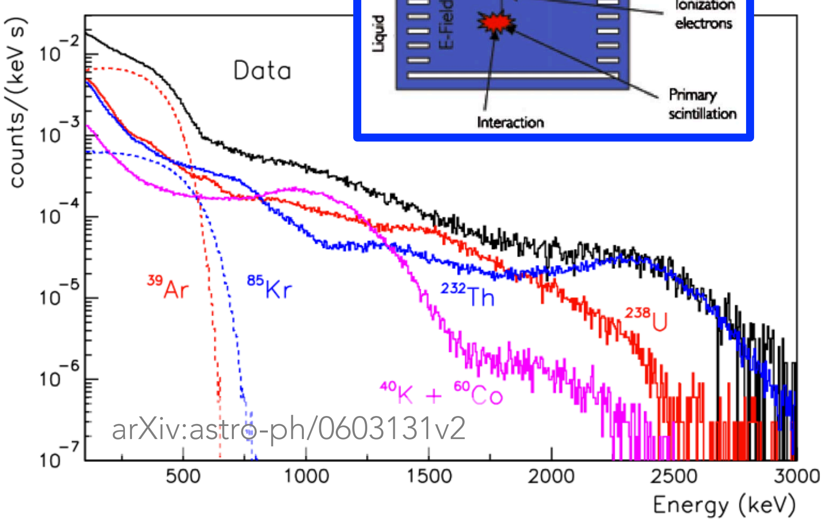


Use in dark matter searches



WArP 100 Detector



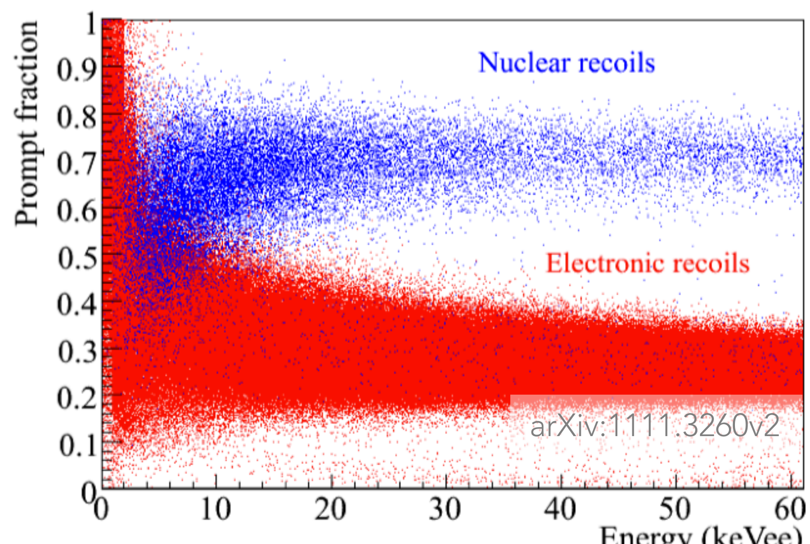


TPB reflector used in dark matter searches like WArP, ArDM, DarkSide

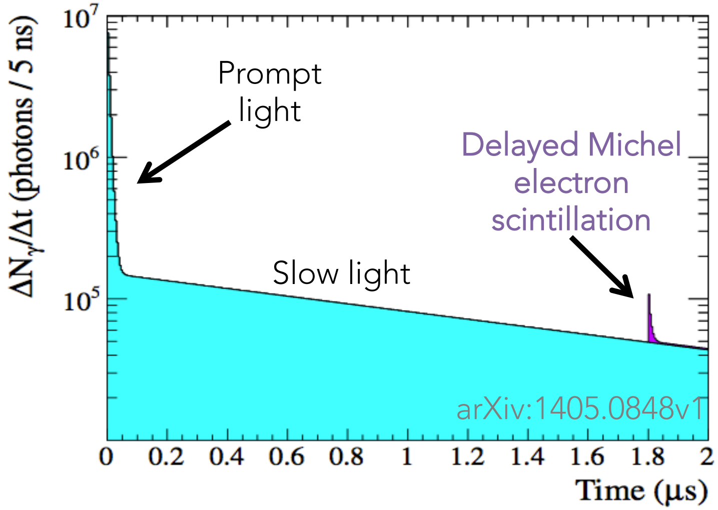
- High light yield efficiency (~10%)

Pulse shape discrimination (PSD)

- Fast-to-total light ratio used to separate MIPs and genuine nuclear recoils
- For recoil E range 50-100 KeV, 50% nuclear recoil acceptance, ~10^{-6} electron recoil contamination (Lippincott *et al*, 2008)

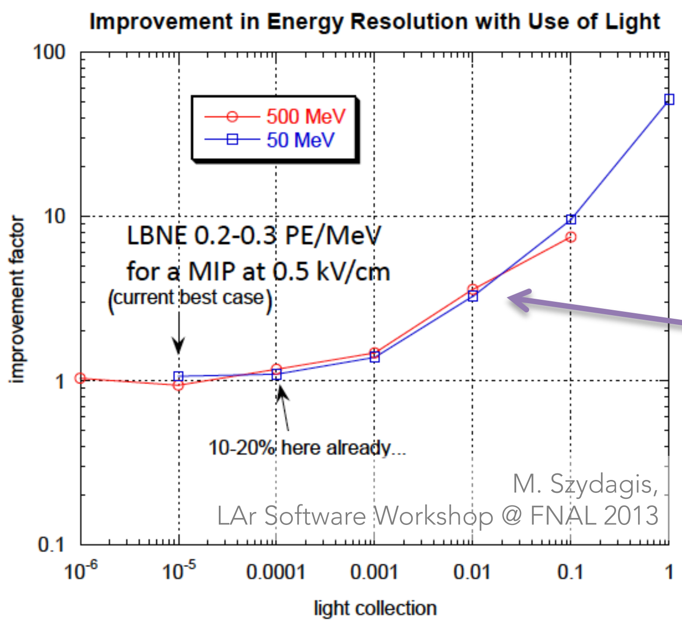


Advantages for neutrino detection



PID, calorimetry and muon sign determination in neutrino interactions in LAr could benefit from higher light yield

- Photon yield complements charge collection and helps compensate for ion recombination (better energy resolution)
- Delayed Michel electrons from μ^- capture can tag pure sample of neutrino events



For appreciable contribution from scintillation, need light collection efficiency 0.1% or greater *(M. Sorel, 2014)*

Factor x3 improvement in E resolution at 1% (*M. Szydagis, 2013*)

Can use reflecting foil technology to enhance light collection!

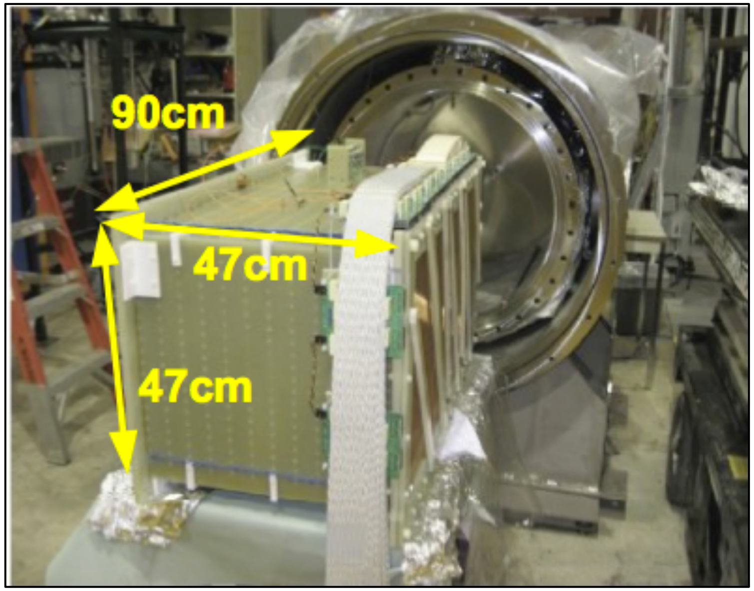
LArIAT: Liquid Argon in a Test Beam

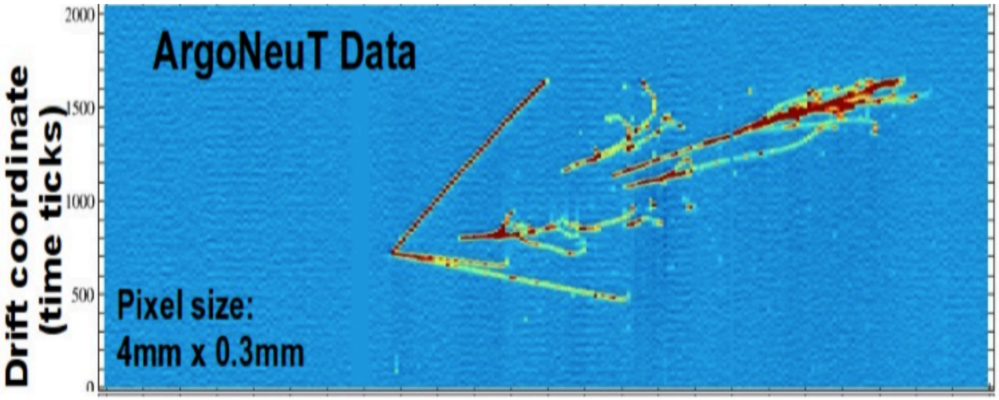
Program to create a long-term test facility to calibrate LArTPCs in a beam of charged particles

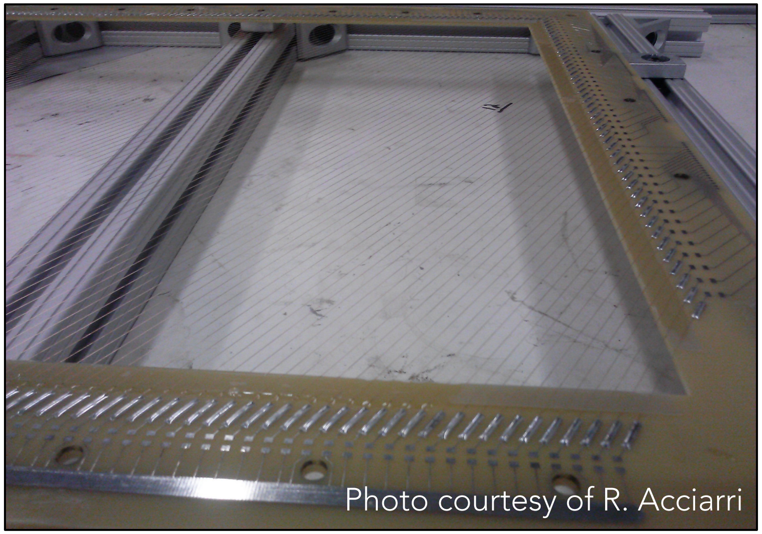
- See talk by **Roberto Acciarri** tomorrow for more information

Phase I: Re-use ArgoNeuT detector in a test beam at MCenter at the Fermilab Test Beam Facility starting later this year

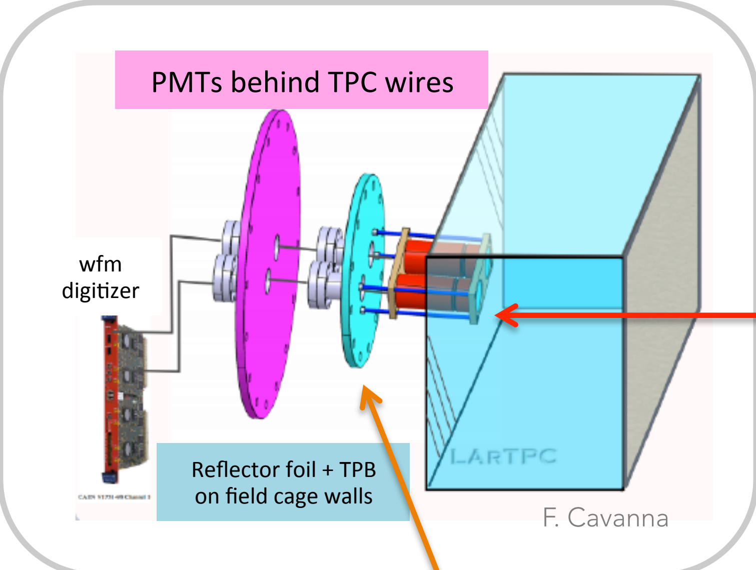
- Adapt *reflector-based light collection system*
- Expected light collection efficiency **~ 3%** (factor ~10^2 greater than in MicroBooNE or ICARUS)

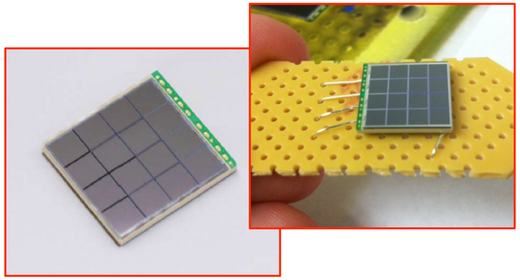


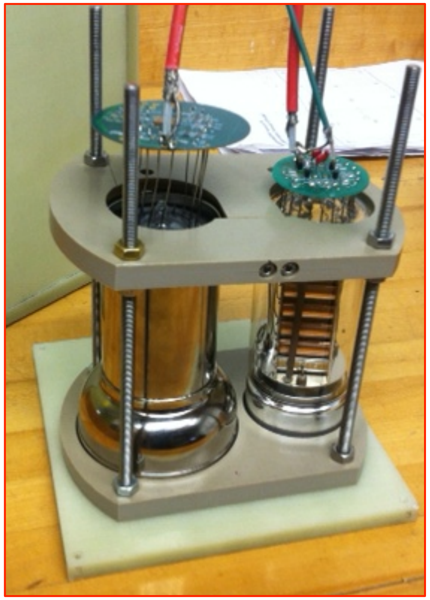




LArIAT light readout system (1/2)





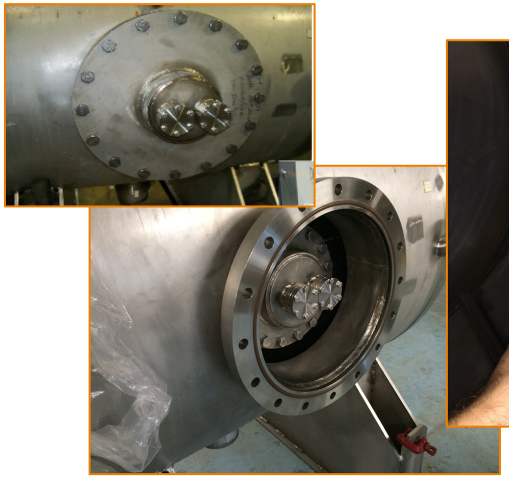


Two cryogenic PMTs

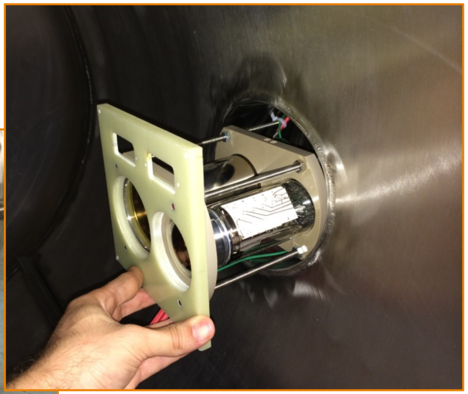
- 3" high QE (30%)
- 2" standard QE (20%)

Two SiPMs

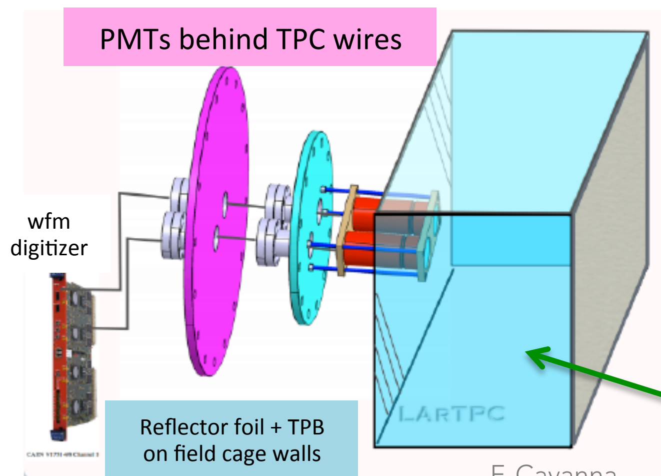
- 1.2x1.2 cm^2 each, QE 50% (arrays of 16 3x3mm channels)

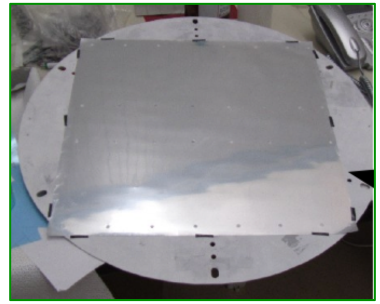


Side port added to ArgoNeuT cryostat to accommodate PMTs and HV/readout



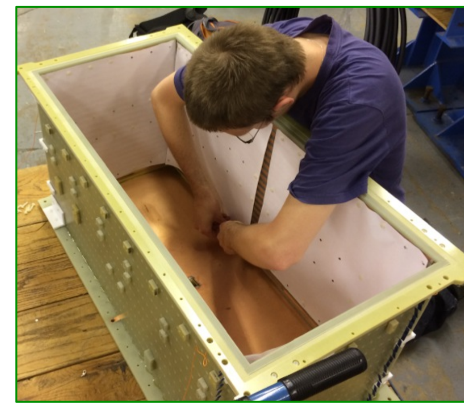
LArIAT light readout system (2/2)





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

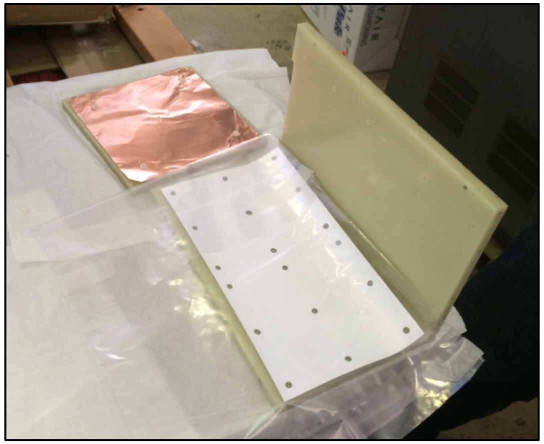


Test-mount of mock foil masks onto LArIAT TPC

Signals digitized by
CAEN V1751 at 1GS/sec

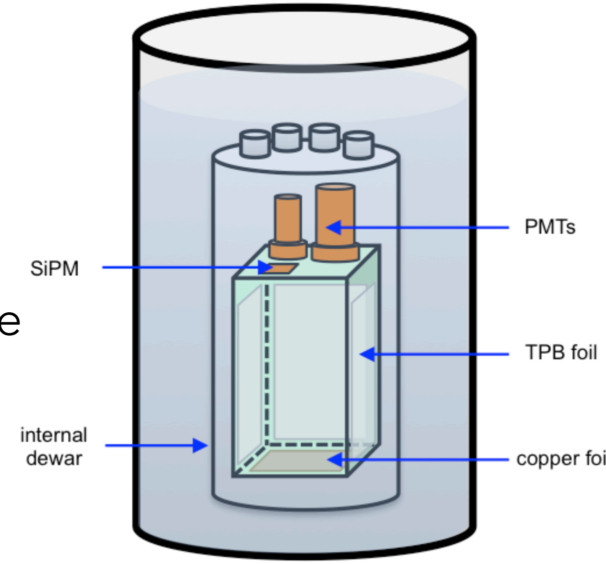
- Fast DAQ to optimize differentiation of fast & slow component (~7ns vs ~1μs)

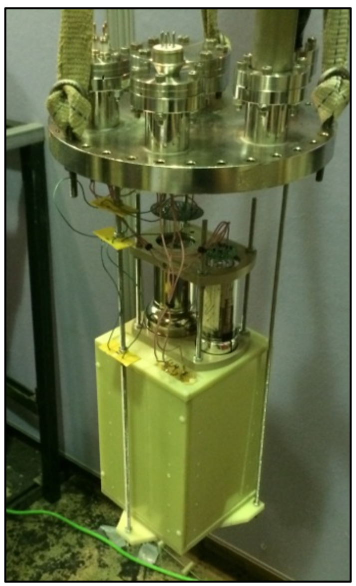
Light readout test chamber (1/2)

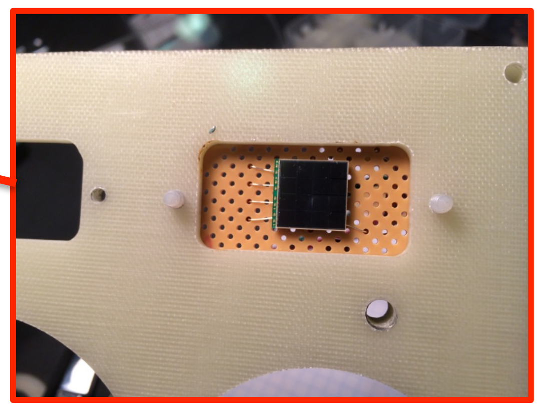


To test components and DAQ in experimental conditions, test stand assembled at UChicago

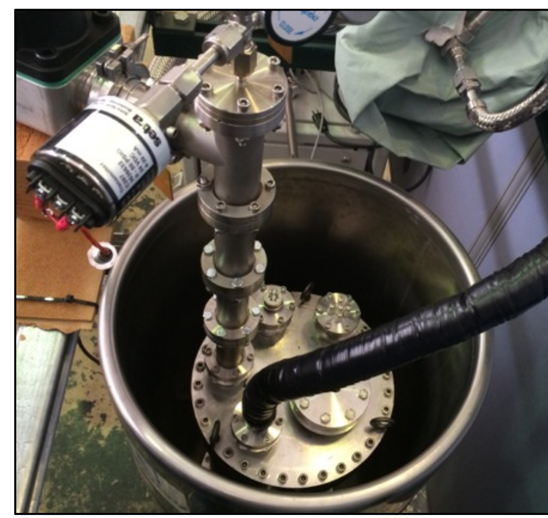
PMTs and SiPM mounted to top of mock-TPC (14x14x25cm) made of G10 (same material as LArIAT TPC) lined with TPB foil



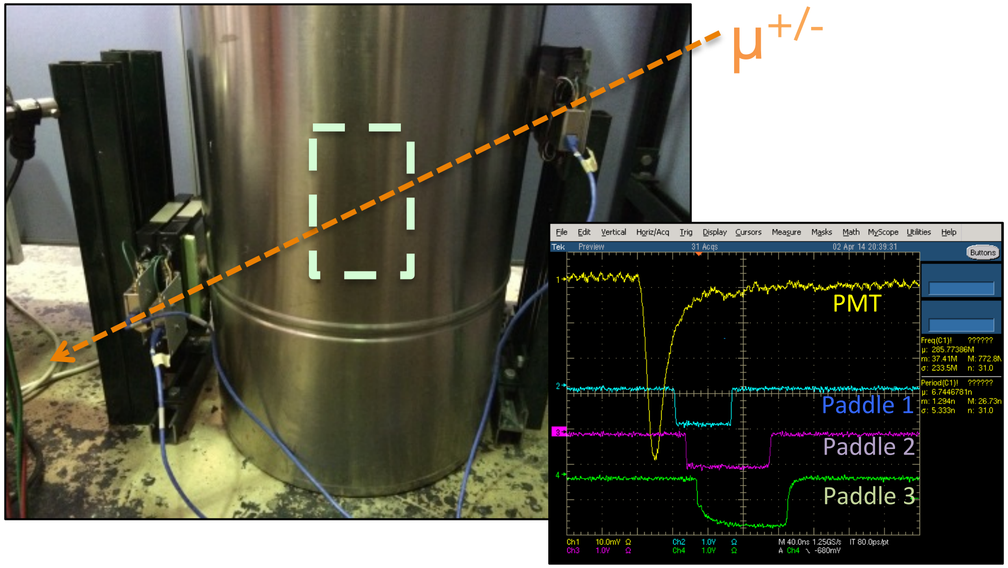




SiPM peering into inner volume of mock-TPC



Light readout test chamber (2/2)

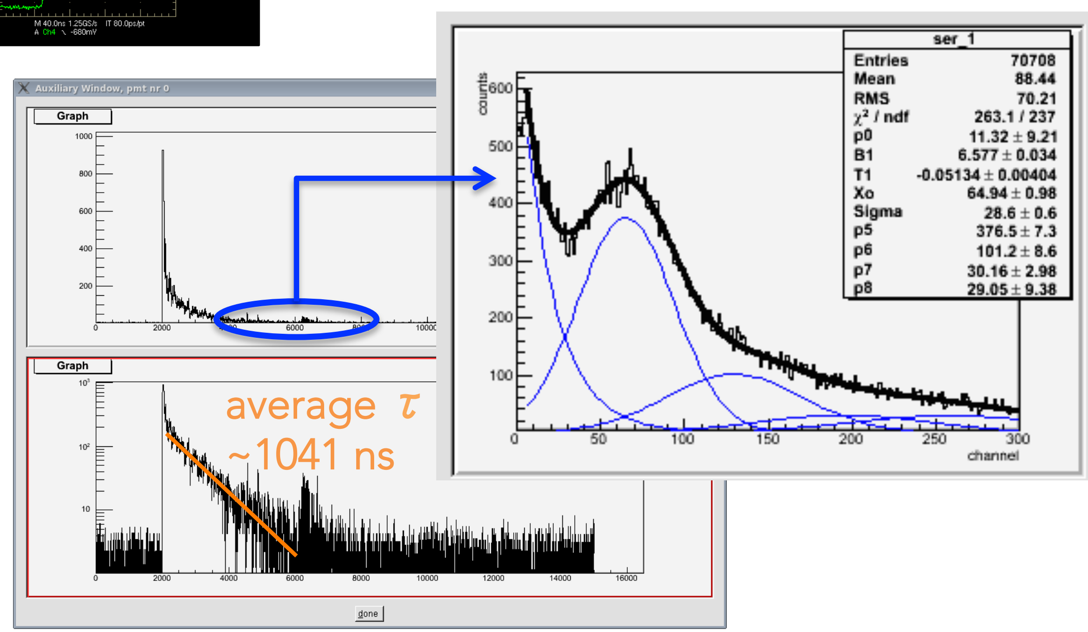


Observed LAr scintillation light in coincidence with cosmic rays

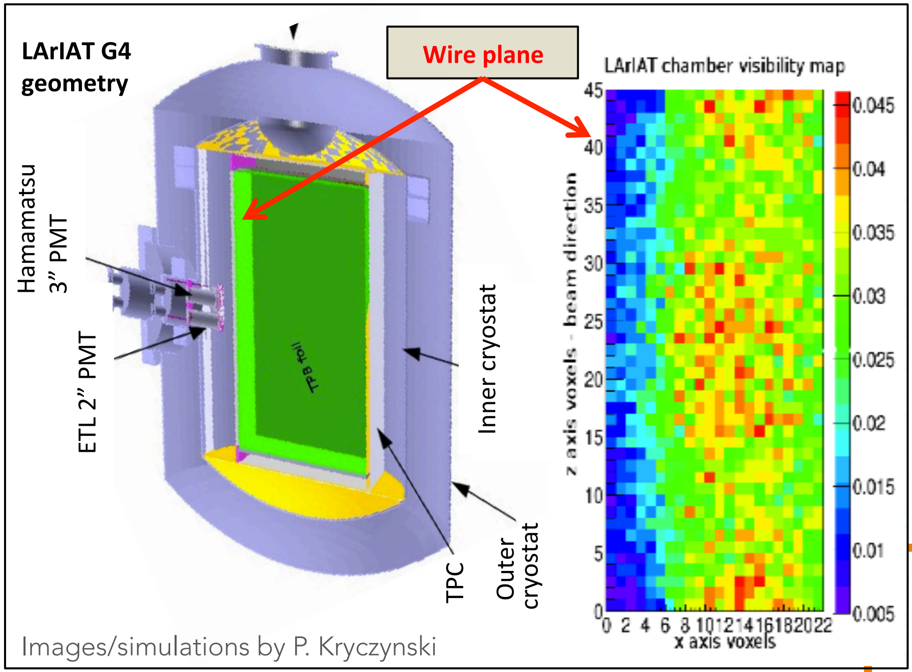
Scintillation from cobalt-60 gamma rays (1.1 MeV, 1.3 MeV) used for light yield measurement

Successful demonstration of DAQ chain through CAEN board

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



Light yield simulations



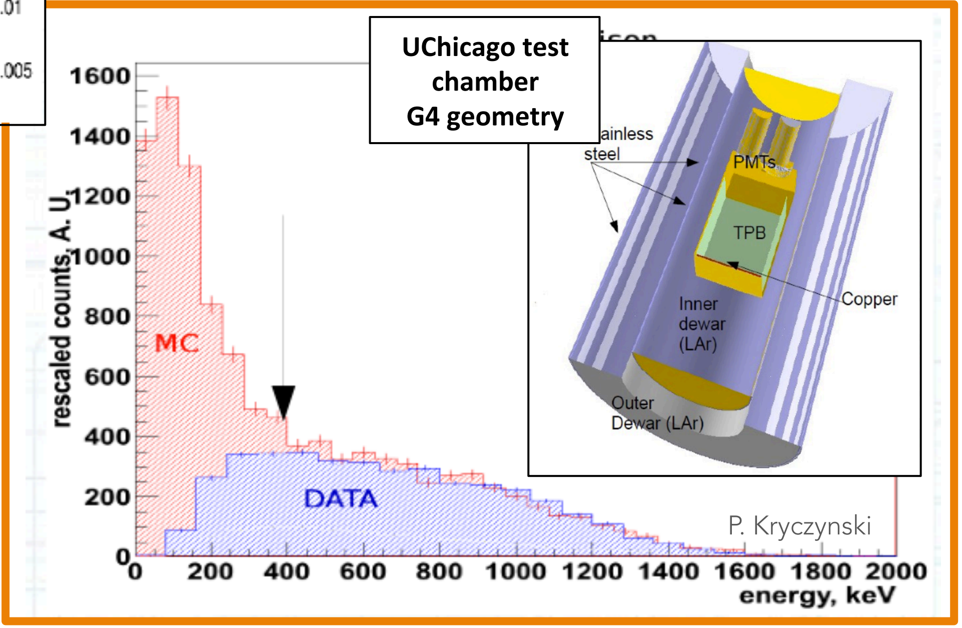
Fast optical simulation (B. Jones) more efficient than fully tracking millions of photons per event

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

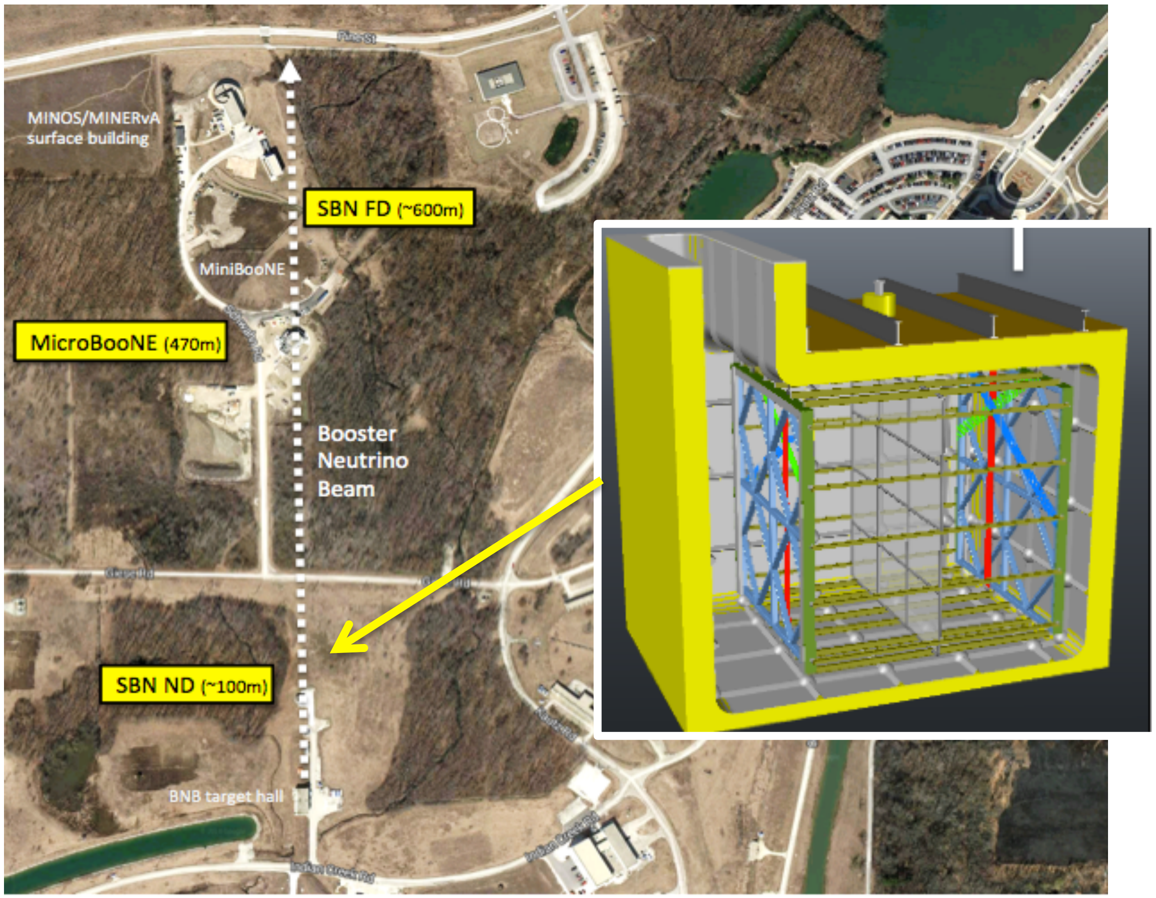
Simulations modified by P. Kryczynski to account for wavelength-shifting reflectors

Results from UChicago test stand being used to optimize parameters

- Simulations tuned to reflect data



LAr1-ND: a near detector on the BNB



82-ton (active volume) modular LArTPC to be located 100m down BNB

High-statistics measurements of `intrinsic' BNB content

- Reduce flux uncertainties for downstream detectors
- ~1M of ν_μ events/yr = precision ν-Ar x-secs
- Together with MicroBooNE + far detector, help characterize & definitively understand MiniBooNE low-E excess

See proposal:
LAr1-ND: Testing Neutrino Anomalies with Multiple LAr TPC Detectors at Fermilab (P-1053)

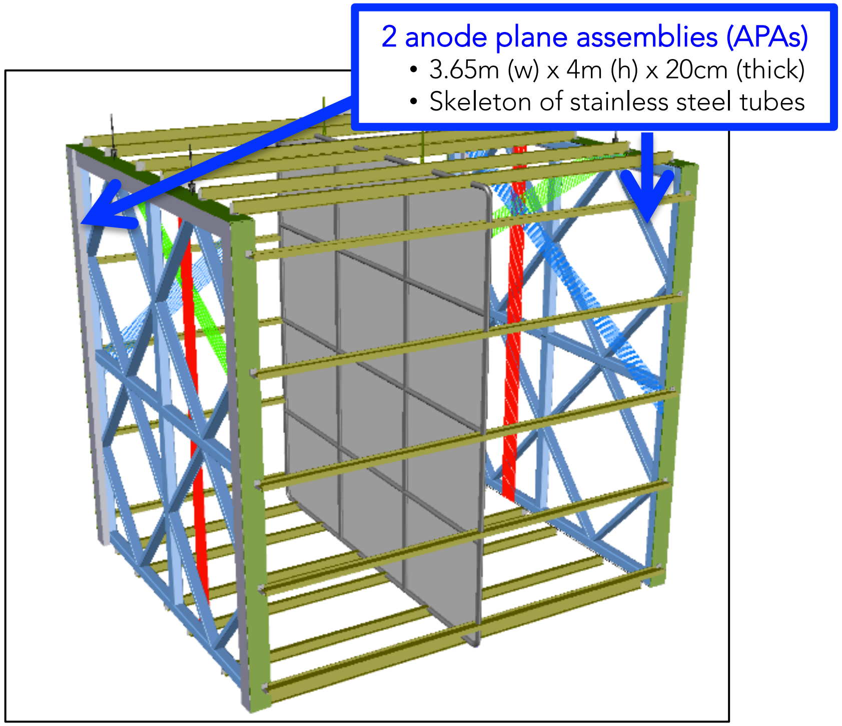
Light collection in LAr1-ND

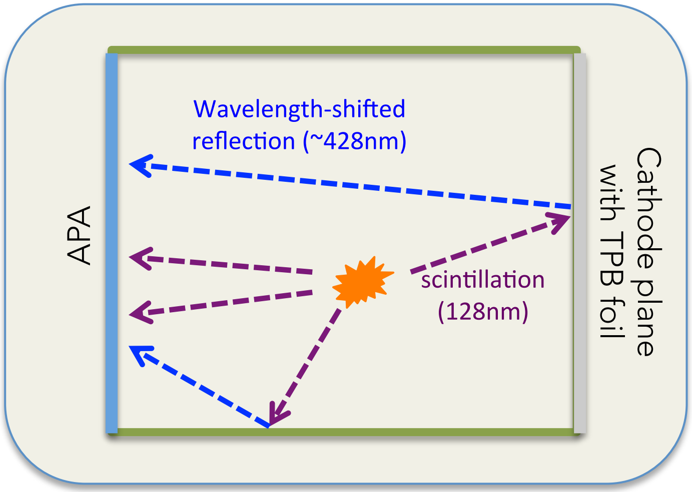
Space along APAs can accommodate light collection system

- Aim to be <u>compact</u> as possible

Opportunity to test new optical systems for use in future experiments (like LBNE)

- Acrylic TPB-coated light guides
- Possibility for complementary use of TPB foil on cathode + walls

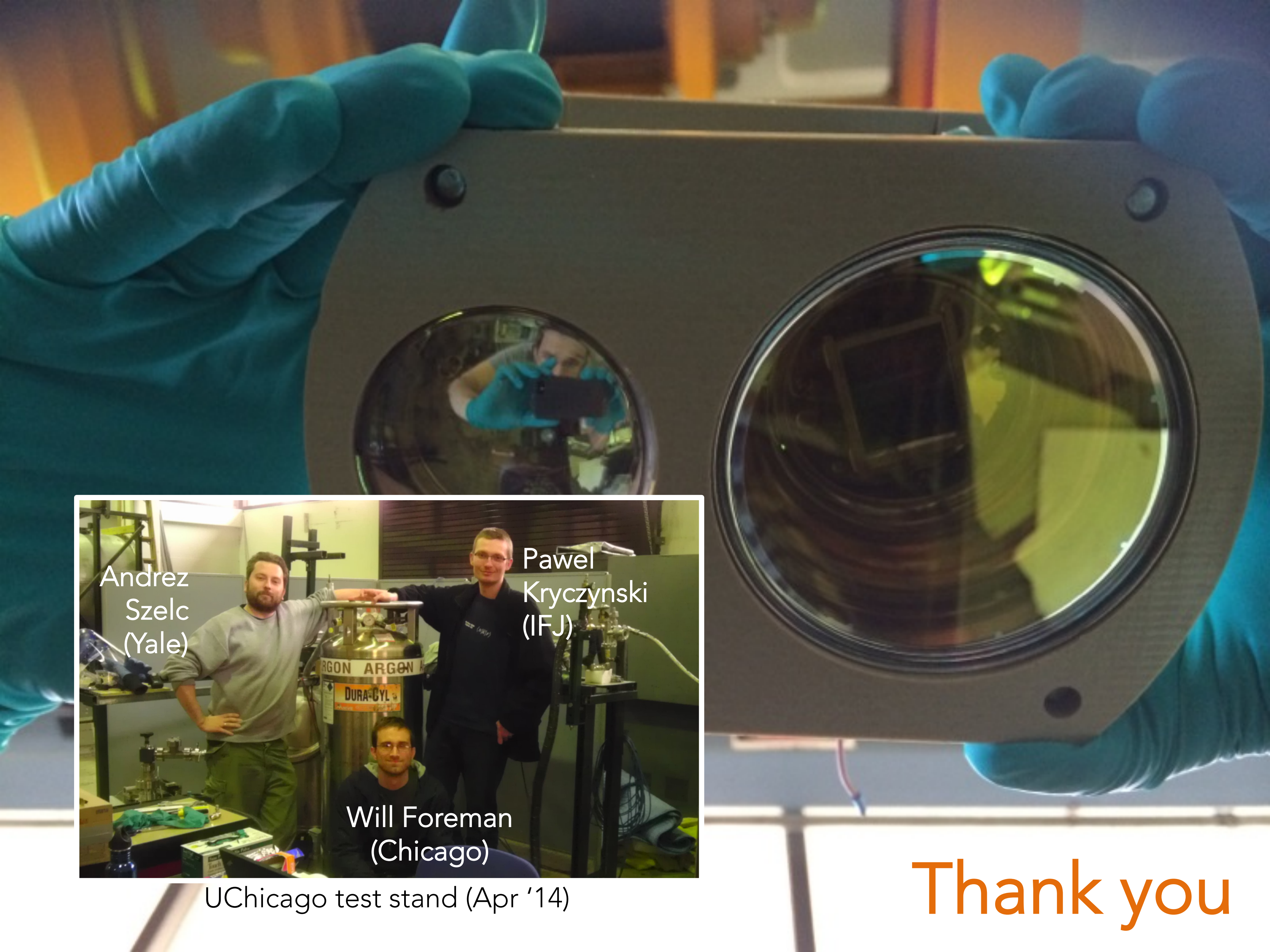




Studies underway to maximize physics + R&D potential of light collection system

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 will enable new studies on PID, calorimetry, and muon sign determination using scintillation light
- LAr1-ND provides further opportunity to test a next-generation light collection system for LArTPCs
  - Can help inform/optimize future long-baseline detectors



UChicago test stand (Apr '14)

Thank you