The LArIAT Light Collection System

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on behalf of the light collection team:
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David Schmitz, Andrzej Szelc

LArIAT Collaboration Meeting
11 July 2014 – FNAL

Outline

- The case for enhanced light collection
- The LArIAT light readout system
- The test chamber at UChicago
- Feedthrough tests & current status
- PMT tests with ACNET power supplies (ongoing)

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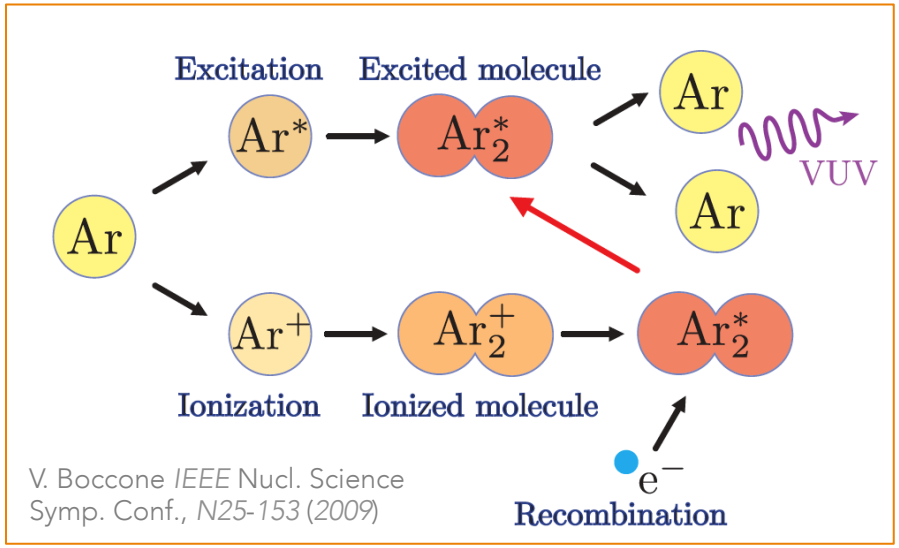
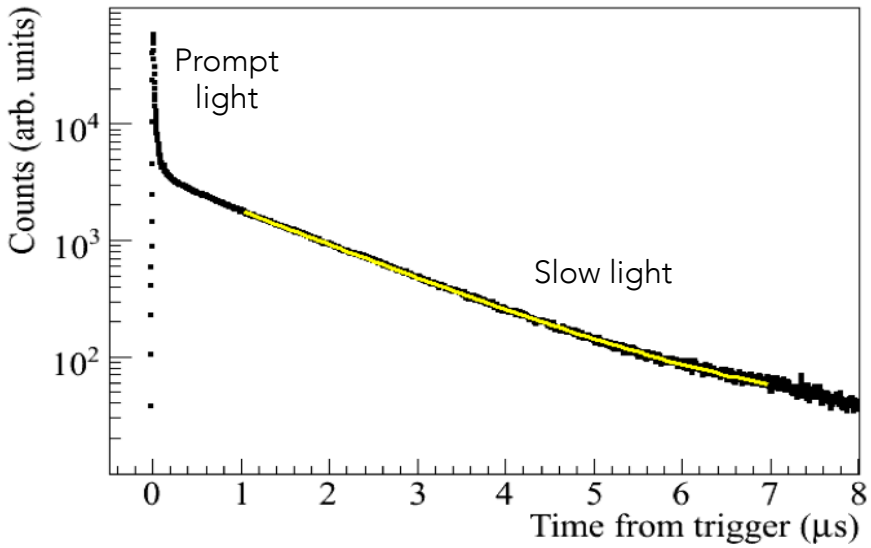
Scintillation in LAr

- Argon scintillates at 128 nm, with ~10k's γ/MeV in LAr
- Wavelength-shifting is needed before detection by PMTs
- Typically used for non-beam event triggers, cosmic ray veto

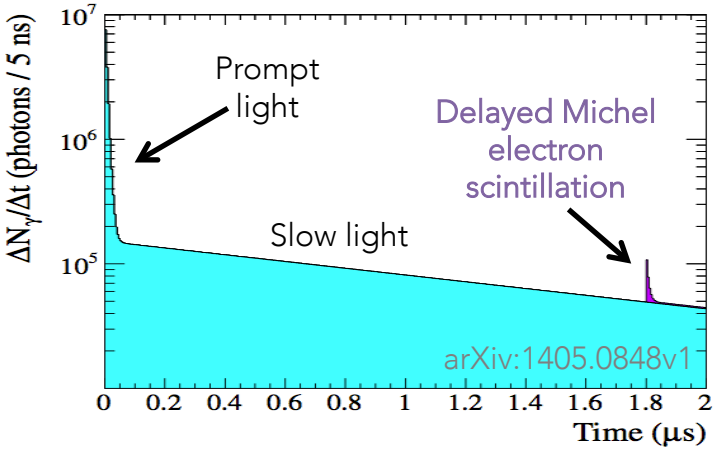


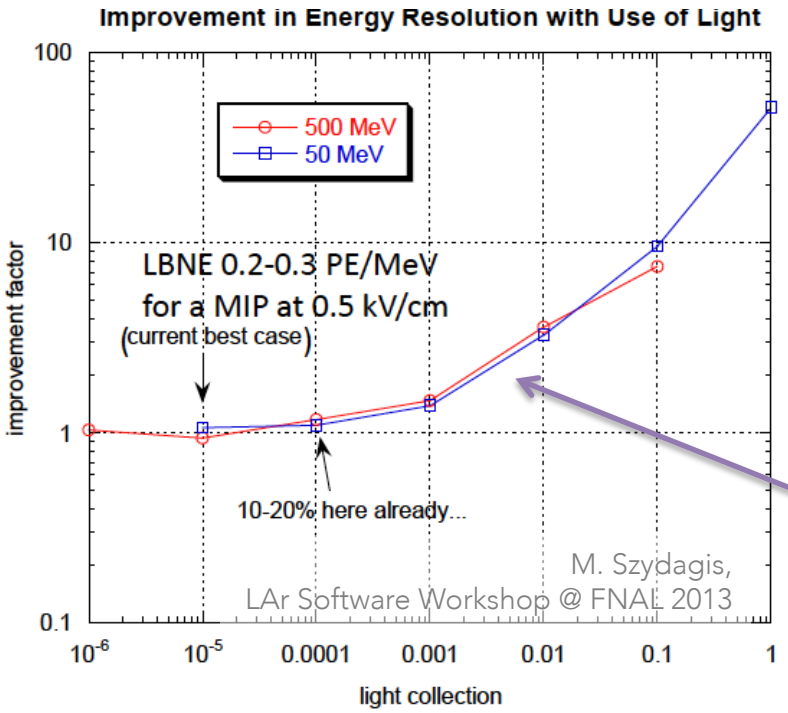
V. Boccone *IEEE* Nucl. Science Symp. Conf., *N25-153 (2009)*

- However, lots of information contained in this light!
  - Fast and slow components dependent on ionization density (background discrimination in dark matter searches)



Potential advantages for neutrino detection





- Photon yield complements charge yield to correct for ion recombination
  - ➢ better energy resolution!
- Delayed Michel electrons from μ^- capture can tag pure sample of neutrino events
  - ➢ non-magnetic sign determination!

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

Factor x2 improvement in E resolution at 0.5% (*M. Szydagis, 2013*)

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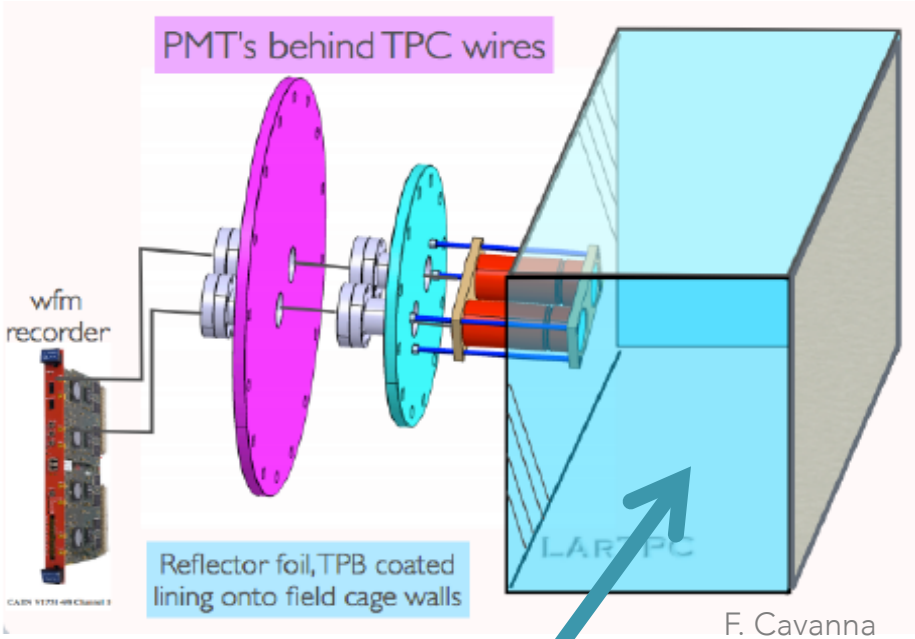
Enhancing light collection in LArIAT

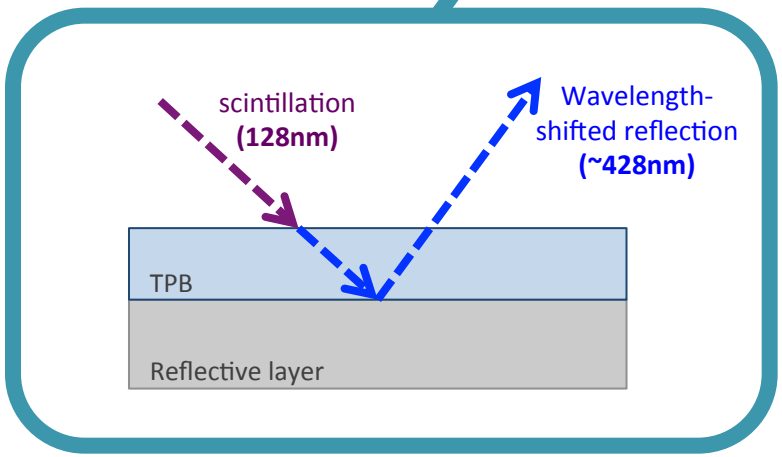
We want to collect much more light than traditional LArTPCs

TPB reflector-based light collection system used in dark matter searches (WArP, ArDM, DarkSide…)

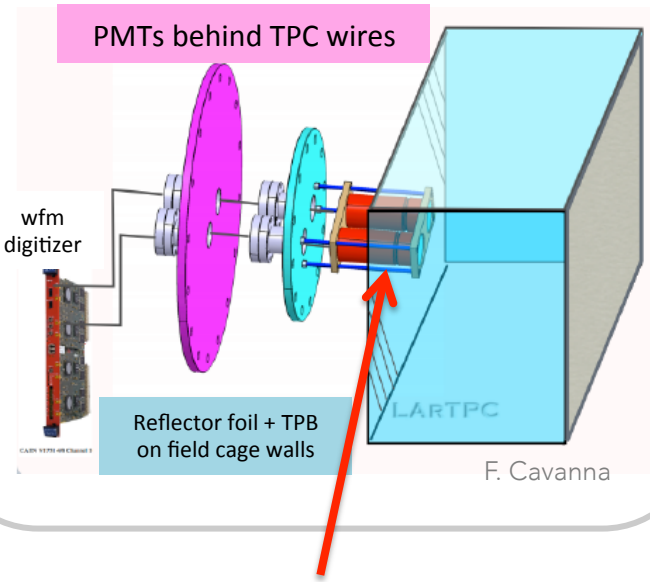
Expected light collection efficiency ~ 0.1%

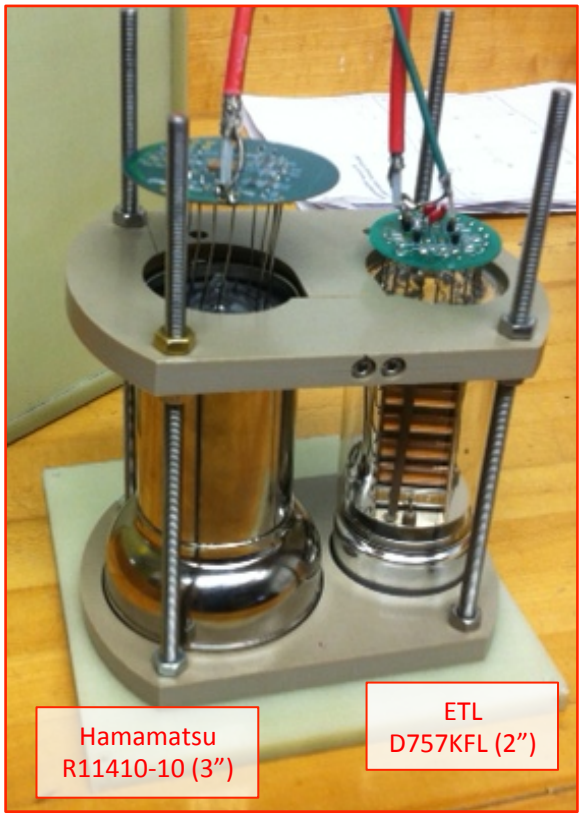
- at least ~10x greater than MicroBooNE or ICARUS

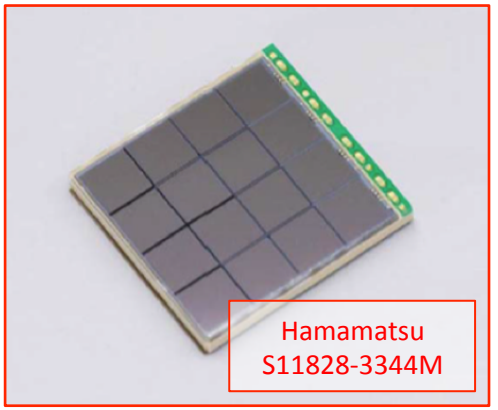


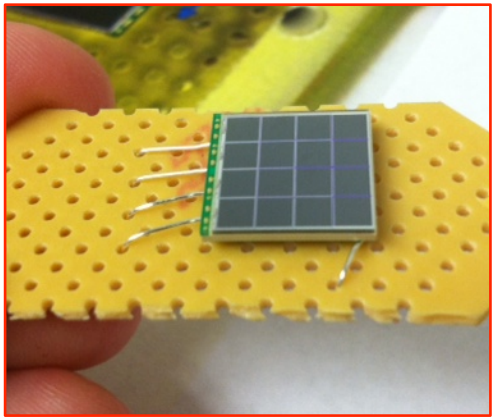


LArIAT light readout system (1/3)









The photodetectors:

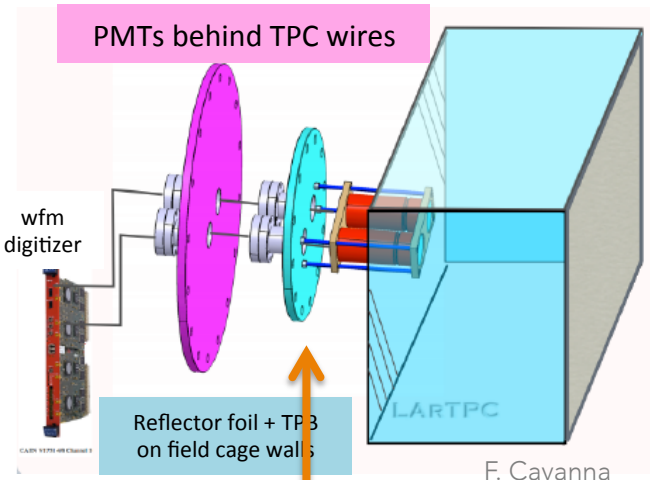
Two cryogenic PMTs

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

Two SiPMs

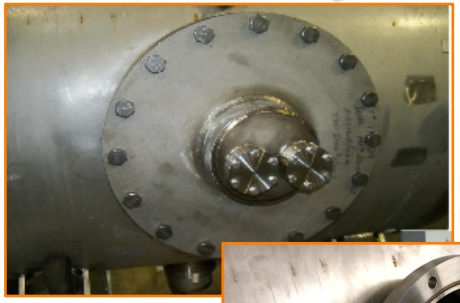
- 1.2x1.2 cm^2 each, QE 50%
  (arrays of 16 3x3mm channels)

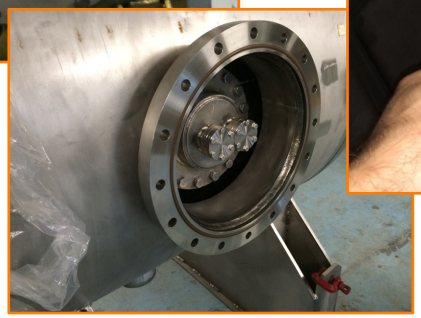
LArIAT light readout system (2/3)



Side port added to ArgoNeuT cryostat to accommodate PMTs

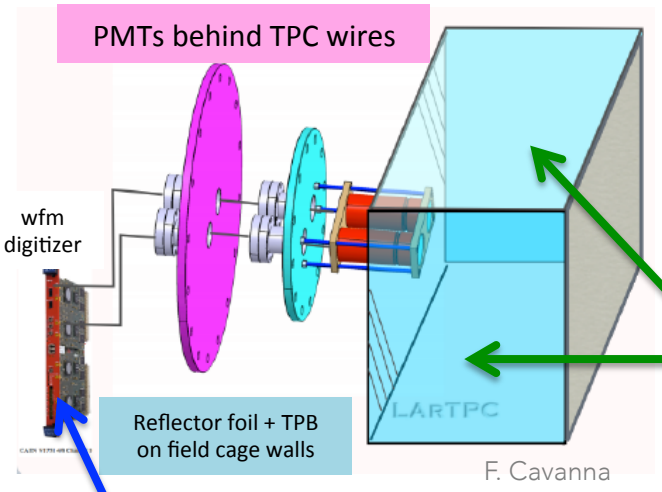
Planning best way to install and support PMT holder

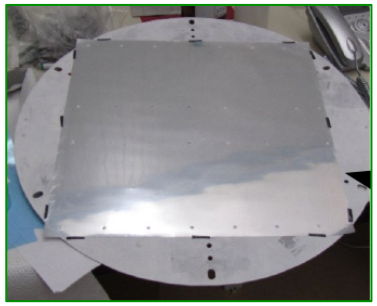




Test fit in Lab 6 (TPC + light system into cryostat) scheduled for Wed, Jul 16

LArIAT light readout system (3/3)





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

- Figured out optimal way to handle and attach
- Some holes in TPC need re-machining

Signals digitized by **CAEN V1751** at 1GS/sec

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

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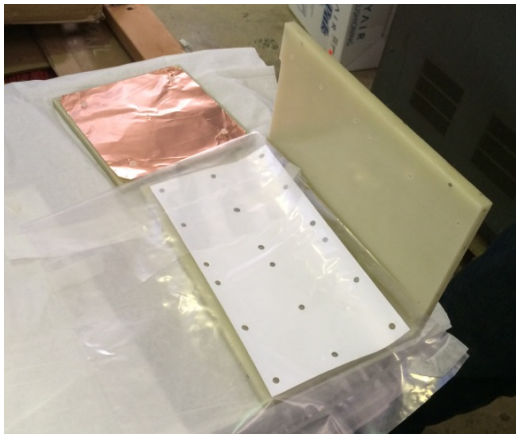
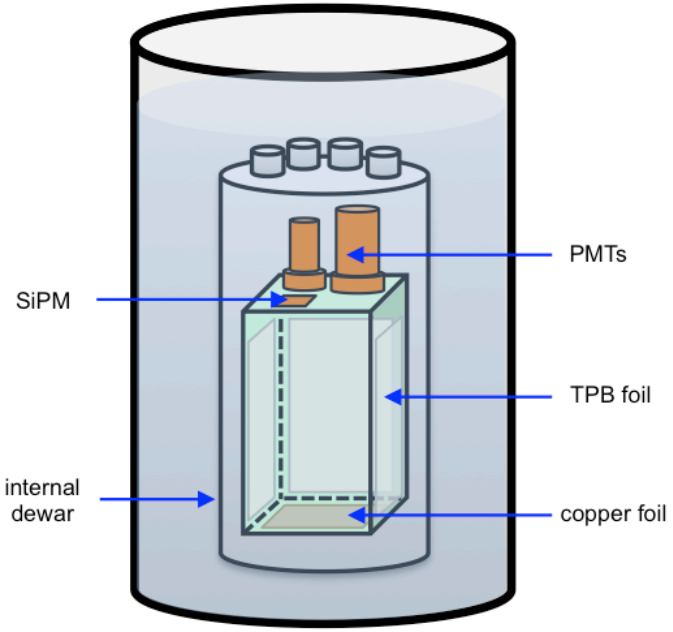
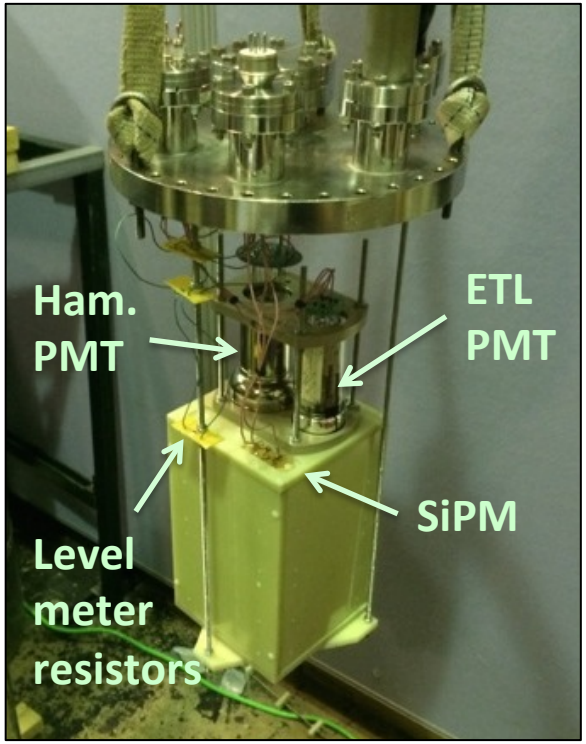
Light readout test chamber

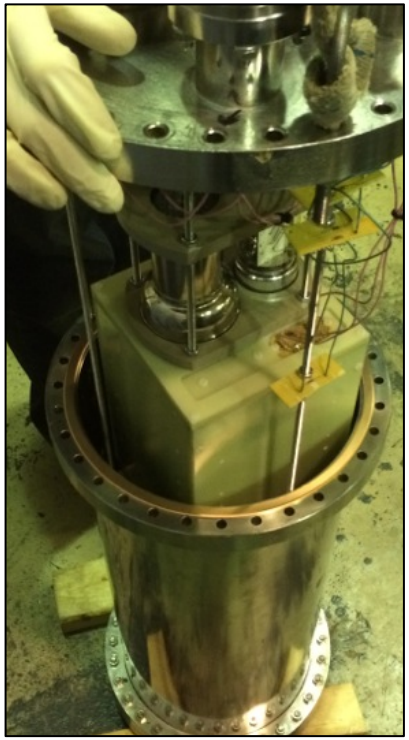


Test stand assembled at UChicago (Mar-Apr 2014)

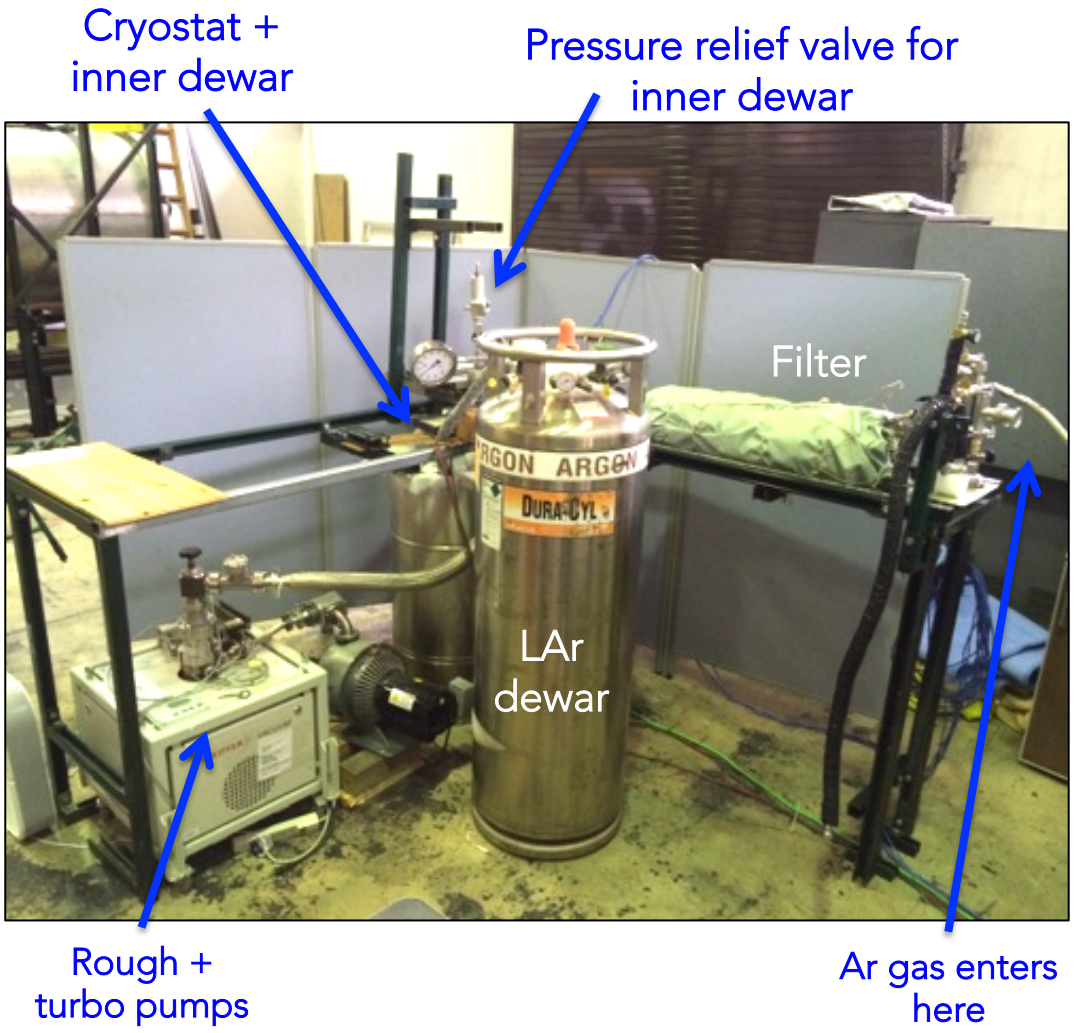
PMTs and SiPM mounted to top of mock-TPC (14x14x25cm) made of G10 lined with TPB foil







Test setup



Inner dewar evacuated for several days

Outer cryostat then filled with LAr (continue pumping on inner for ~day)

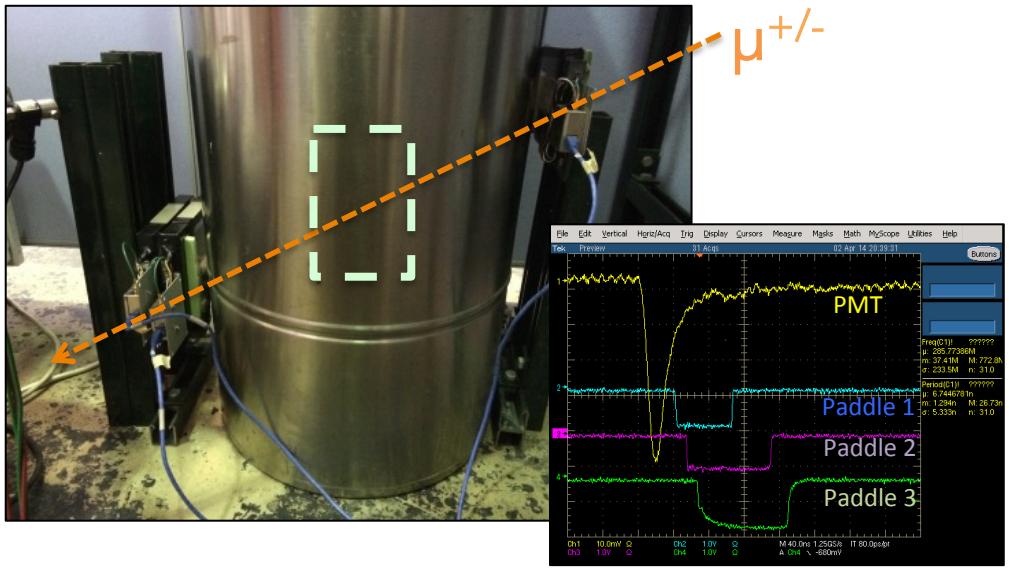
Filtered Ar gas flushed into inner dewar to condense into liquid

Liquid level read out using a series of carbon composite resistors in inner dewar

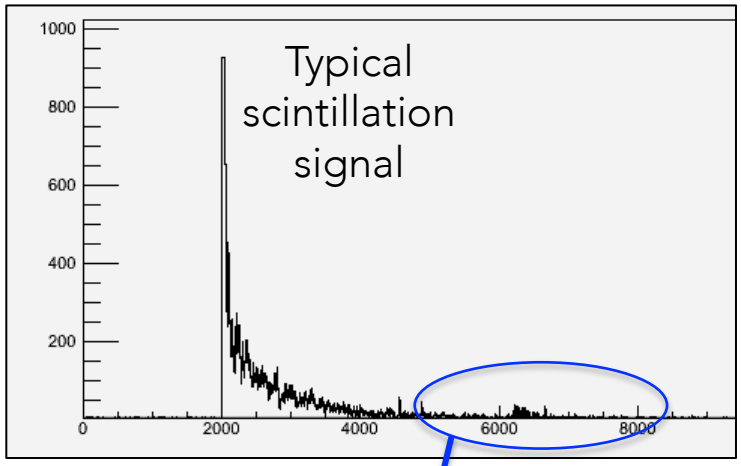
Primary data runs

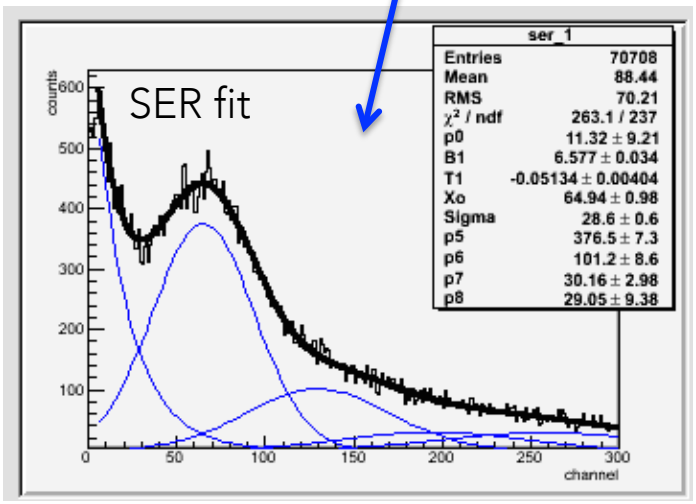
1. LAr scintillation light in coincidence with cosmic rays
   - Several different arrangement of counter paddles

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



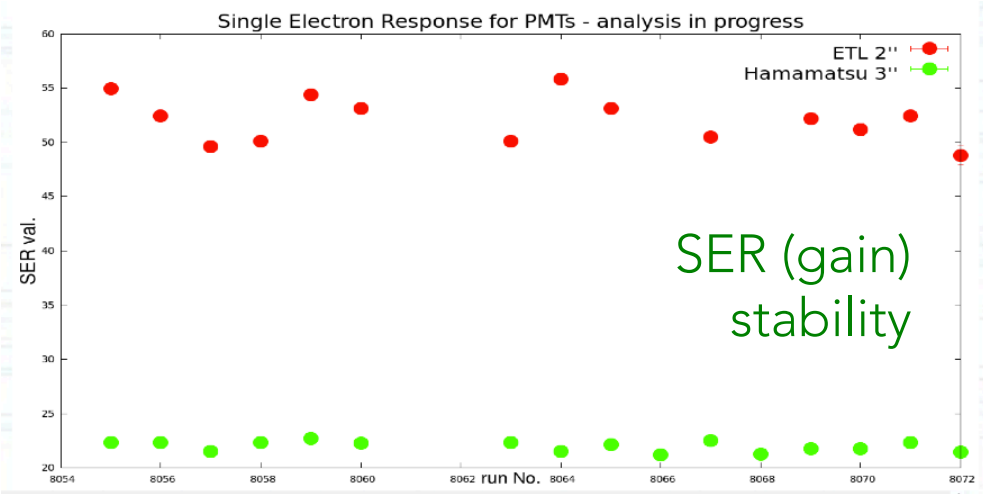
Single photoelectron calibration





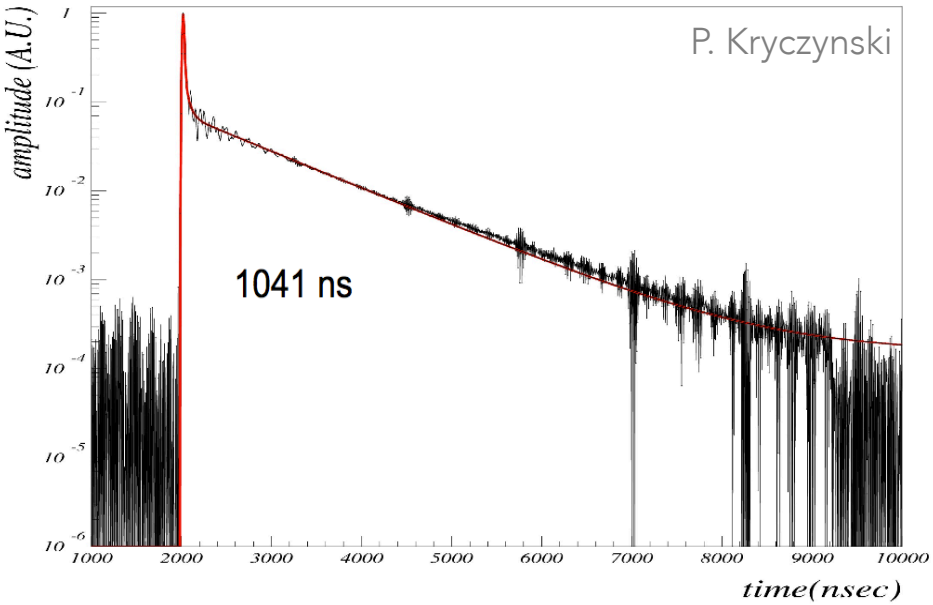
Single photo-electron response (SER) measurable for PMT gain measurement

- Single photoelectron signals (phe) selected from (slow-light) tails of signals
- Several per event are individually integrated & added to histogram
- Over 1000s of events, we get a distribution of 1phe, 2phe, etc…

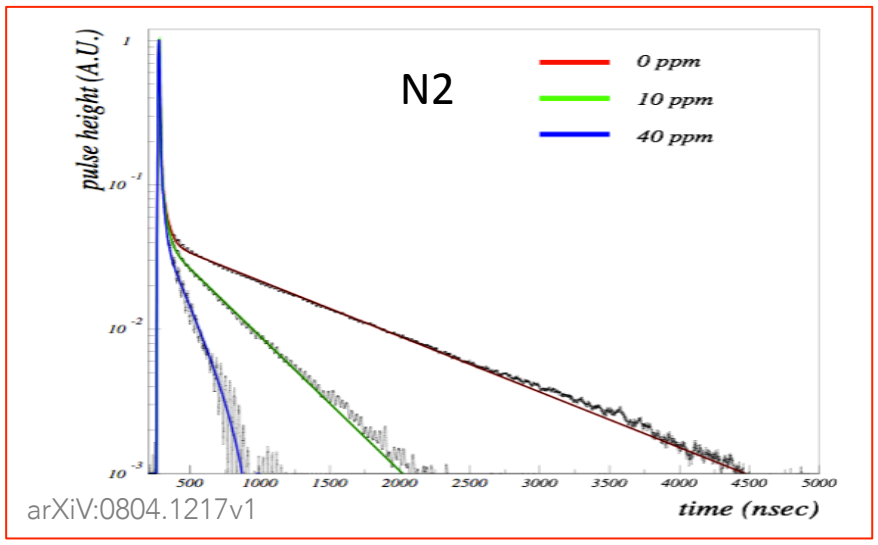


P. Kryczynski

Average scintillation lifetime



Slow component lifetime measured using fit to average waveform



Useful as potential cross-check on LAr purity

- N2 or O2 concentrations lead to quenching of slow light

Test chamber outcomes

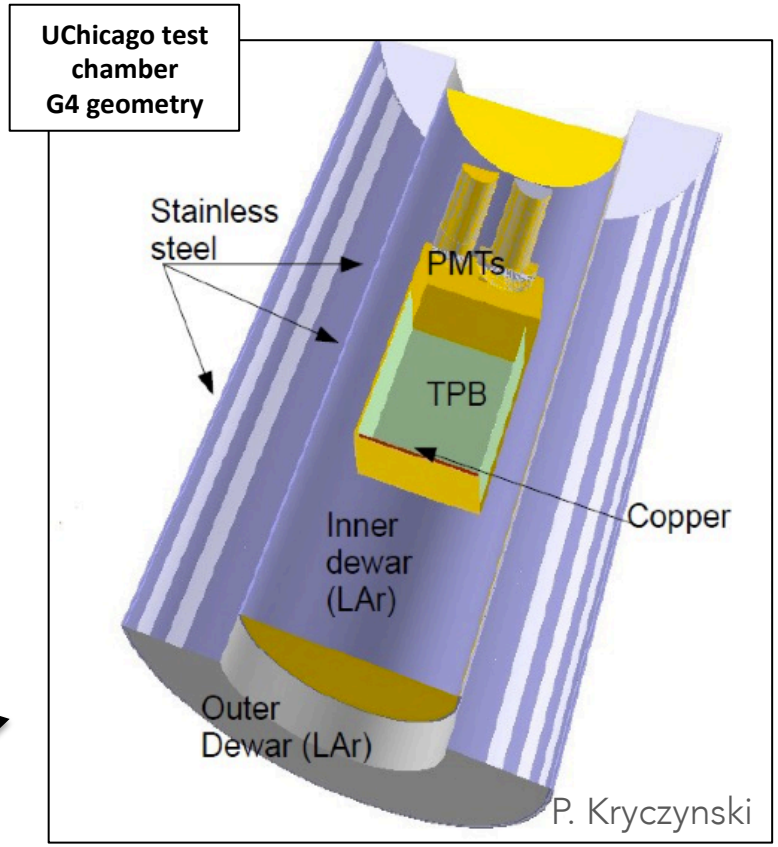
Successful demonstration of test-DAQ chain and use of the TPB foils in LAr

Later tests of PMTs in air revealed no loss of gain

Chance to refine techniques and catch problems before installation into LArIAT

- HV feedthrough failures in LAr (see following slides)
- No SiPM response

Light yield simulations using chamber geometry done by Pawel Kryczynski (see his talk later!)



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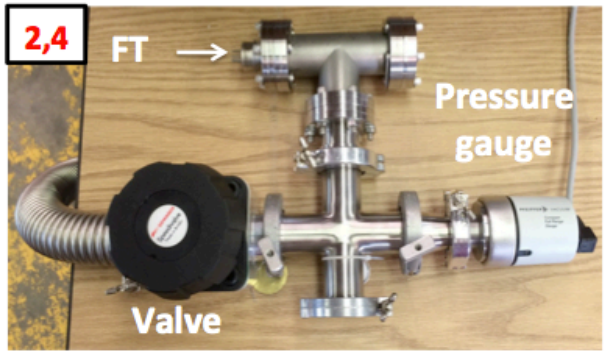
Feedthrough tests

Ceramic in a 5pin high voltage FT cracked in LAr tests at UC

We subjected the remaining FTs to stress tests

1. Cold shock dips in LN2
2. Vacuum chamber test
3. Side port test with LN2
4. Vacuum chamber re-test

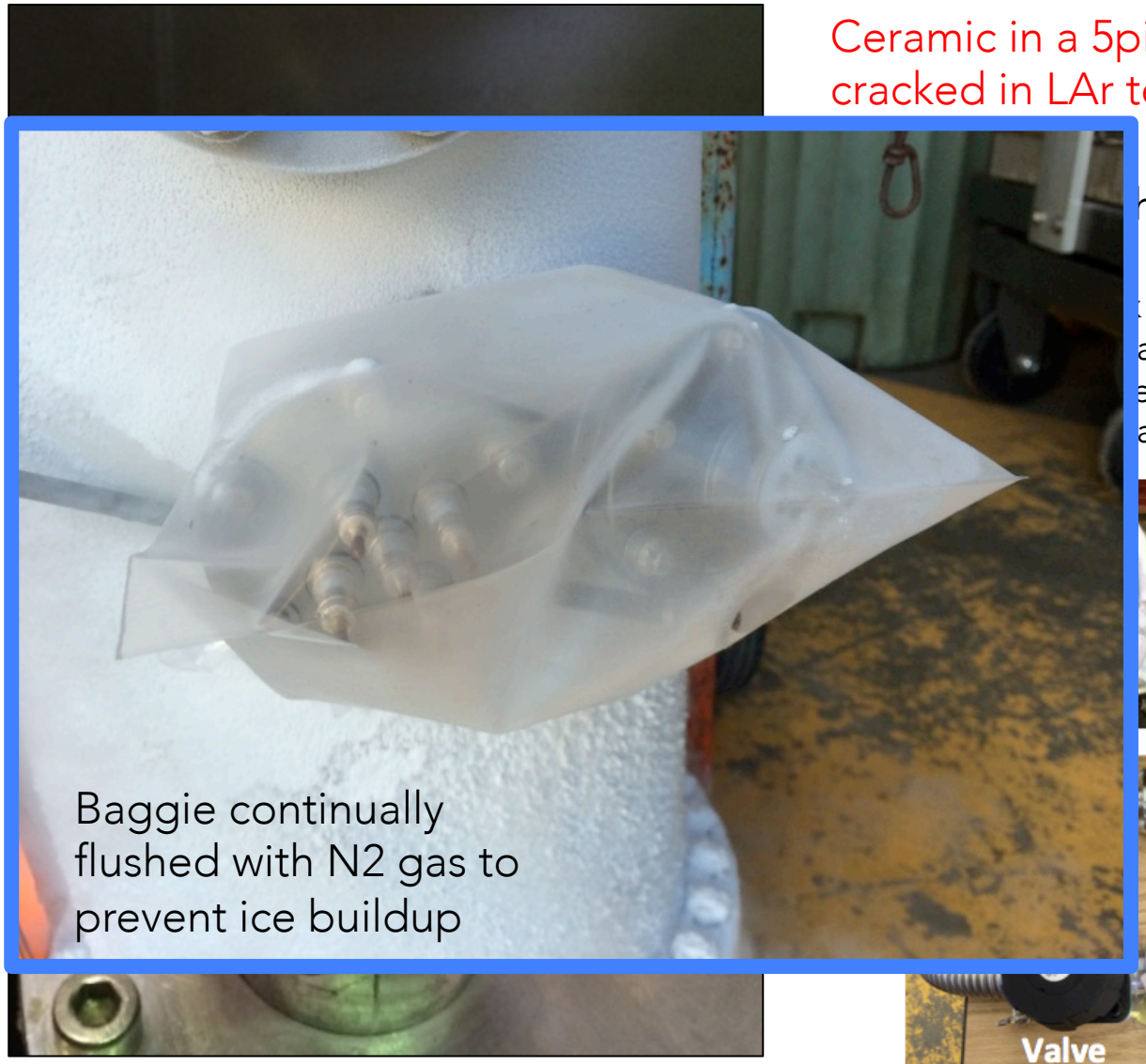


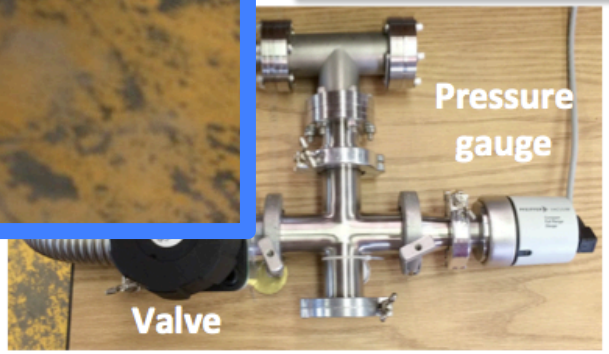
Feedthrough tests

Ceramic in a 5pin high voltage FT cracked in LAr tests at UC

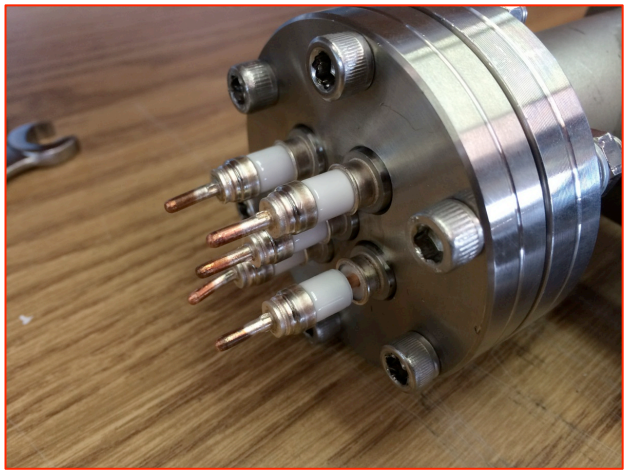
he remaining FTs

dips in LN2
amber test
est with LN2
amber re-test

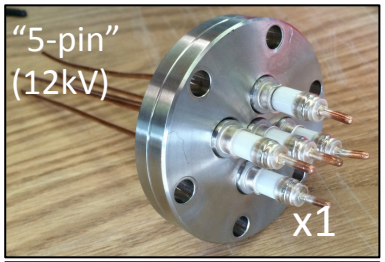


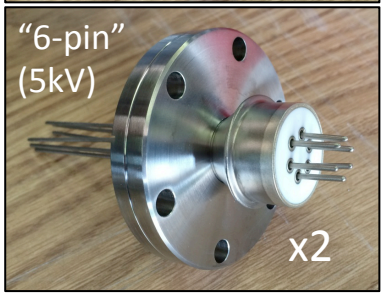


Feedthrough test results



One of the two remaining 5-pin FTs cracked after LN2 stress test dips

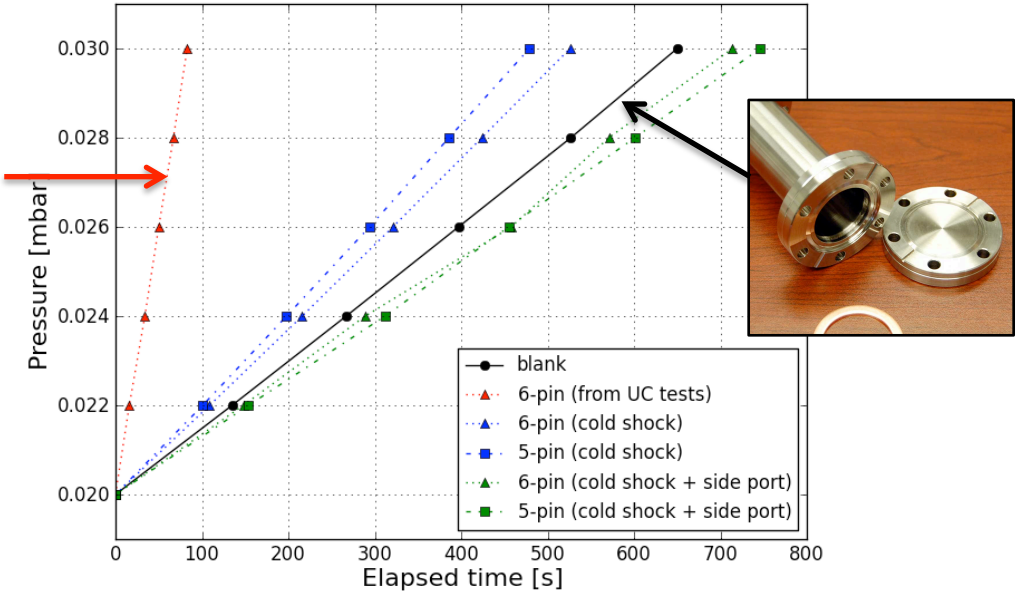




Survivors:
One 5-pin
Two 6-pins

6-pin from UChicago tests not holding vacuum well…

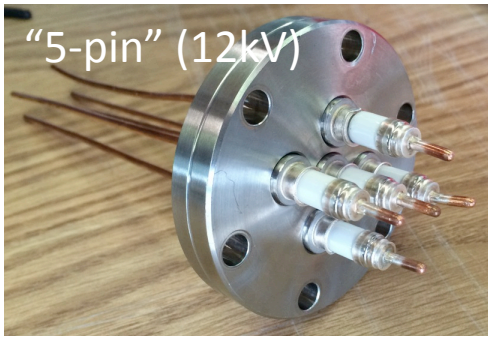
Remaining FTs after stress tests appear in good condition

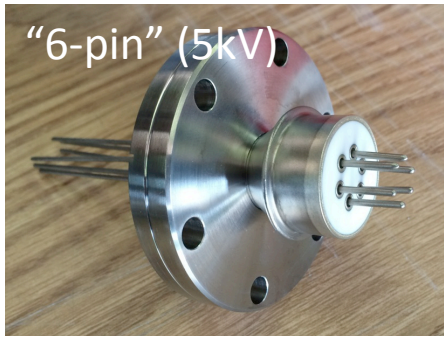


FT test outcomes and current status

- CeramTec has replaced both broken 5-pin FTs

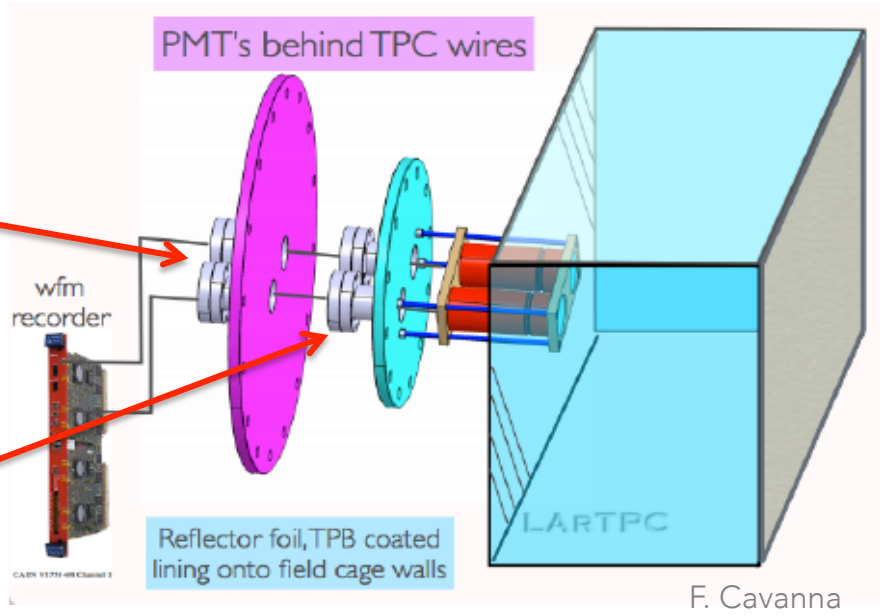
- In meantime, we have **two** FTs that appear resilient to LAr and can hold vacuum





Planning to test **new replacement** FTs on vacuum, and use these on outer ports (vacuum-air gradient)

Surviving FTs from tests on inner ports (LAr-vacuum gradient)



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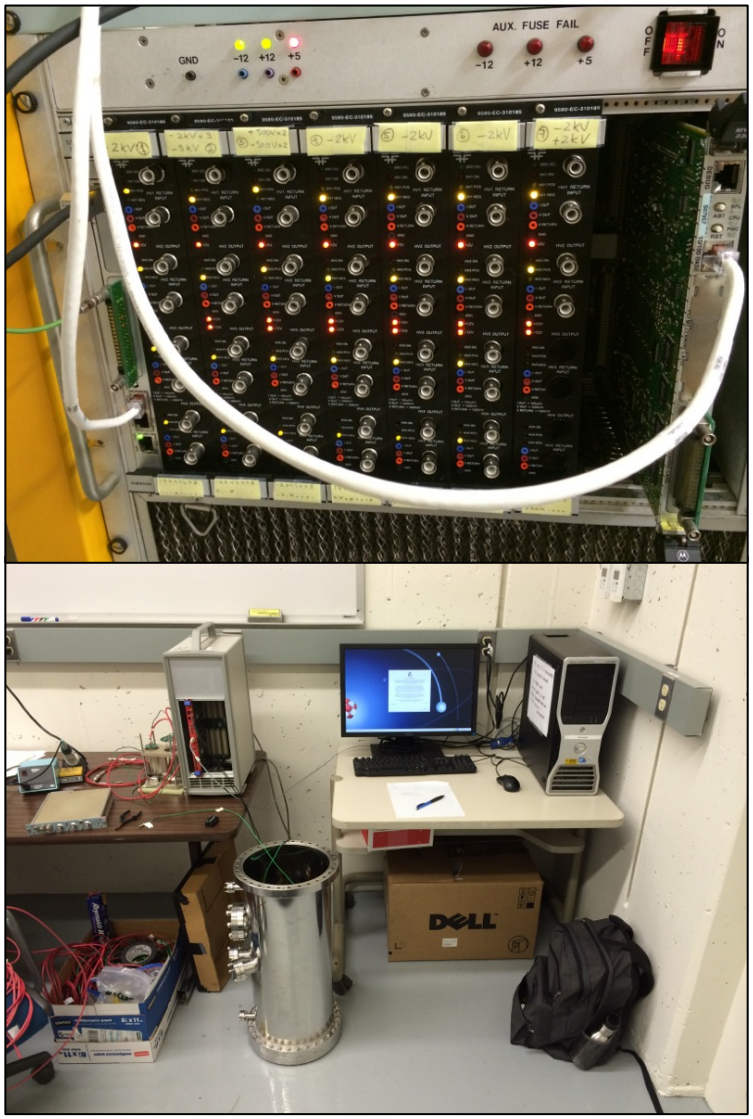
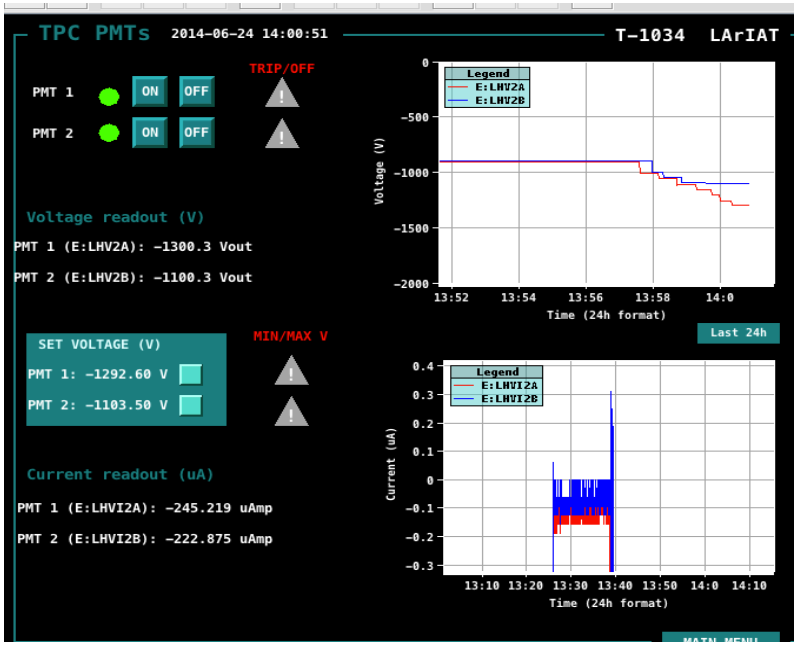
PMT tests with ACNET power supplies



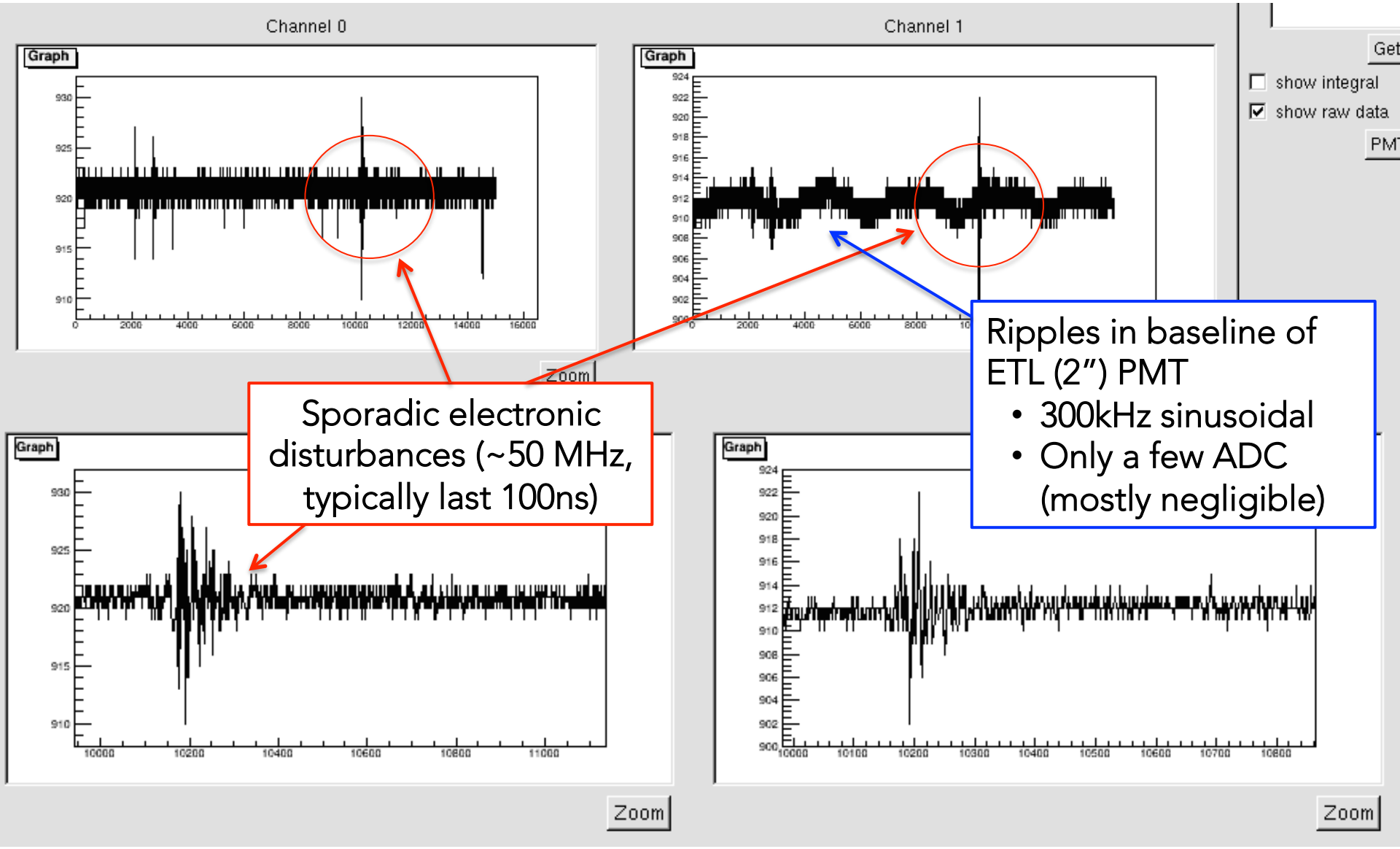
Testing ACNET power supplies at MCenter (see Flor's talk)

- Supplies controlled by synoptic interface
- Extra controls for ramping up HV implemented (thanks, Flor and Charlie!)

Have test DAQ chain working on lariat-test01



Current issues

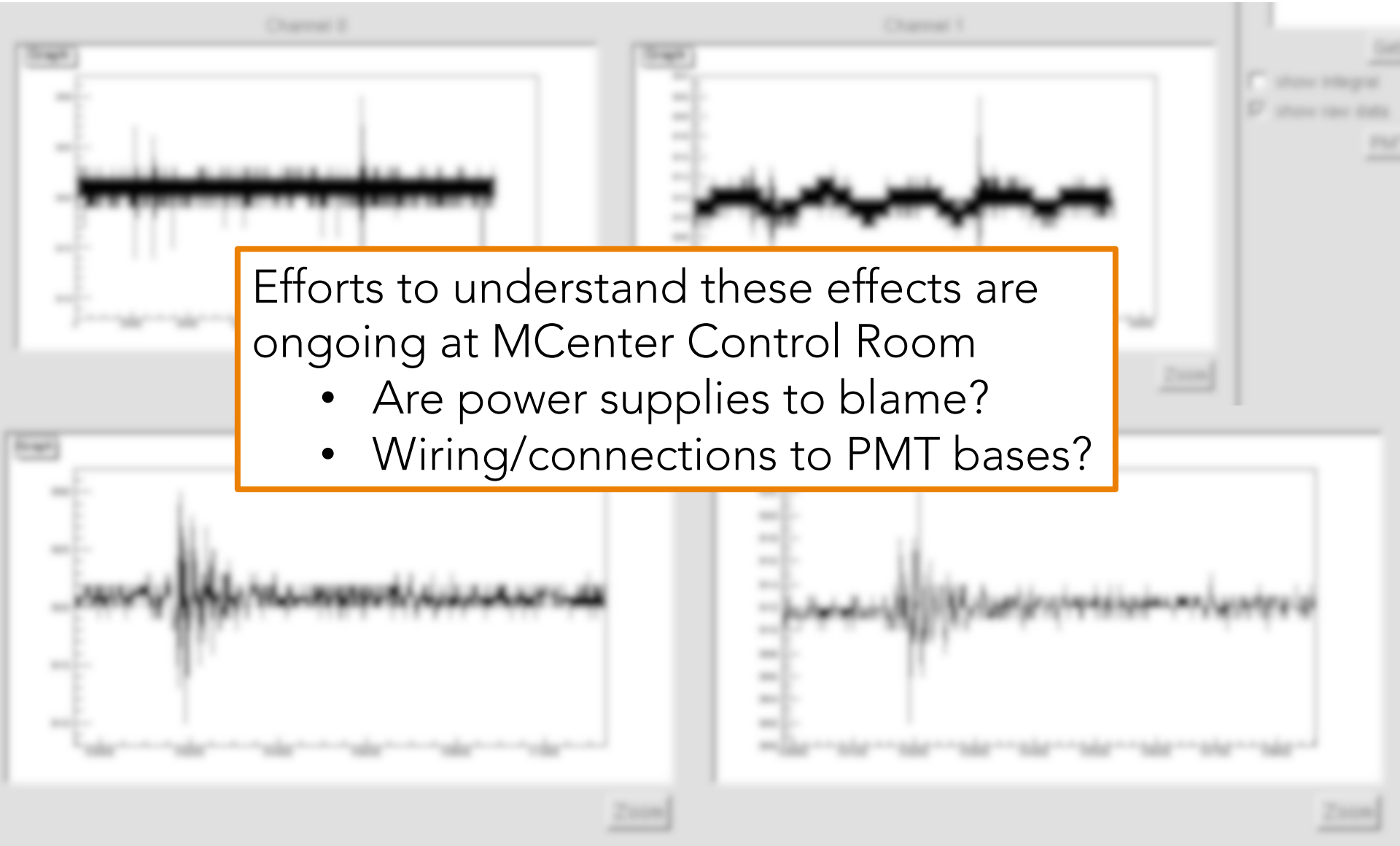


Sporadic electronic disturbances (~50 MHz, typically last 100ns)

Ripples in baseline of ETL (2") PMT

- 300kHz sinusoidal
- Only a few ADC (mostly negligible)

Current issues



Efforts to understand these effects are ongoing at MCenter Control Room

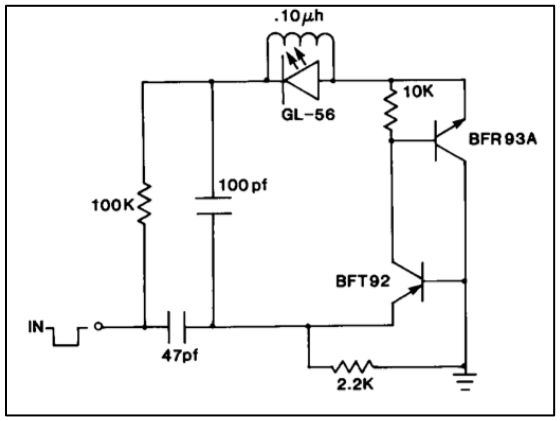
- Are power supplies to blame?
- Wiring/connections to PMT bases?

Summary

- LArIAT's light collection system is an innovative and untested approach in LArTPC neutrino experiments
  - Enable studies on PID, calorimetry, and muon sign determination using scintillation light
- Successful demonstration of DAQ in UChicago tests
  - Exposed vital problems in FTs
  - Tech note in progress
  - Results helping to refine fast optical simulations w/reflector
- Next steps:
  - Resolve PMT complications and complete final gain tests in air
  - Test installation into cryostat in Lab 6
  - Resolve SiPM readout problems

Backup slides

LED pulser for PMT tests in air



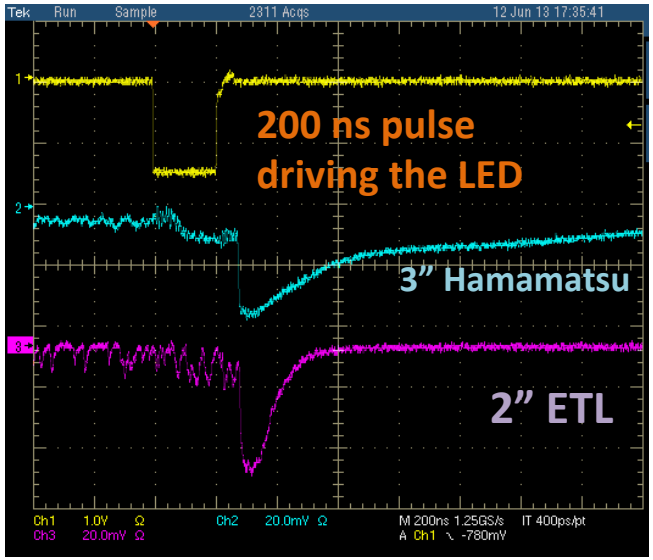
"A Fast Timing Light Pulser for Scintillation Detectors", 1985

In air, no scintillation! So we need an artificial light source…

LED flasher (Kapustinsky design) was assembled

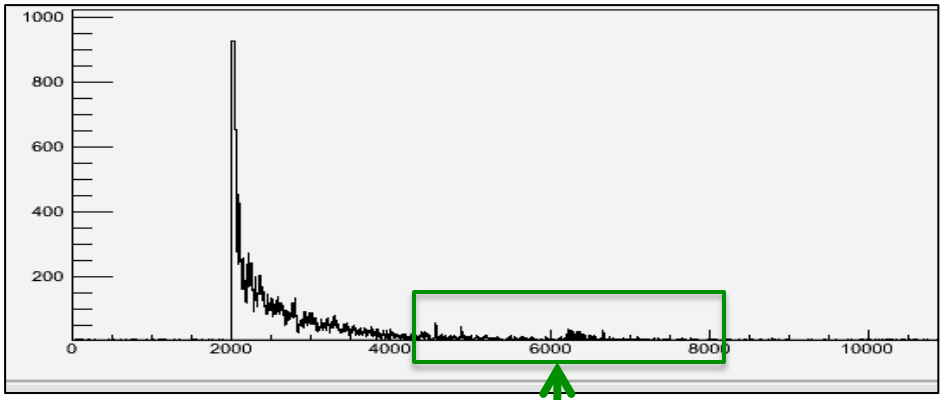
- LED: Nichia NSPB300A LED; 3mm, 470 nm

Produces either narrow (~10nm) pulse or wide (several-μs) pulse by swapping out 0.1uH inductor



Example of detected pulse shapes from flasher in "**wide pulse mode**"

Calibrating with single photoelectrons



Single photo-electron response (SER) measuring PMT gain

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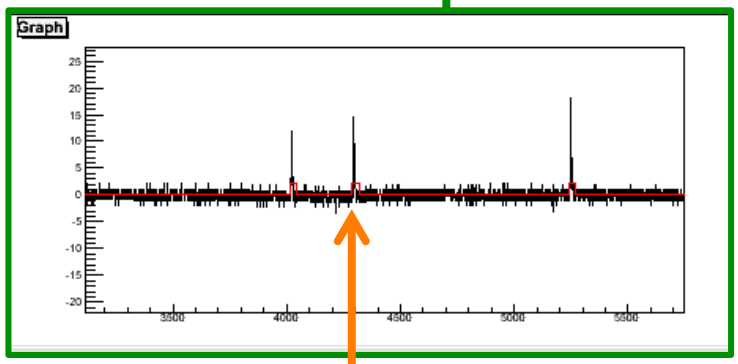
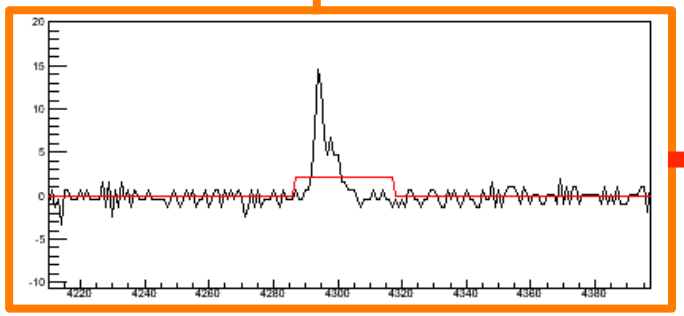
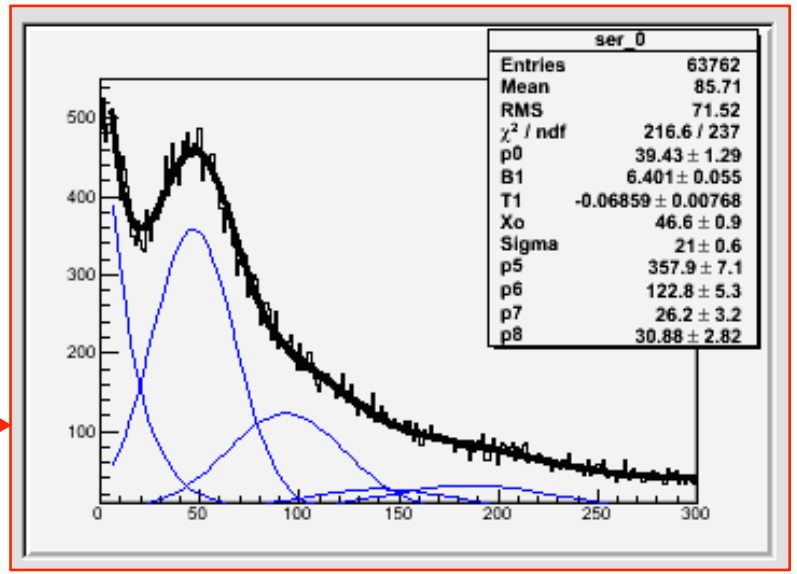
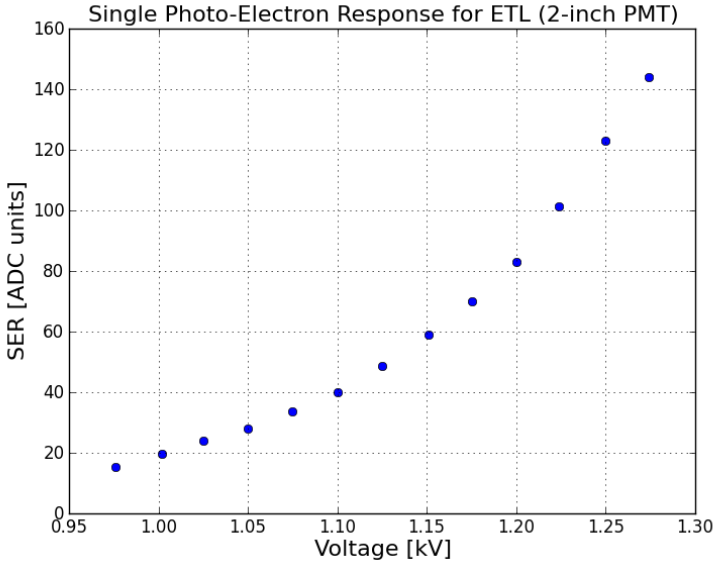
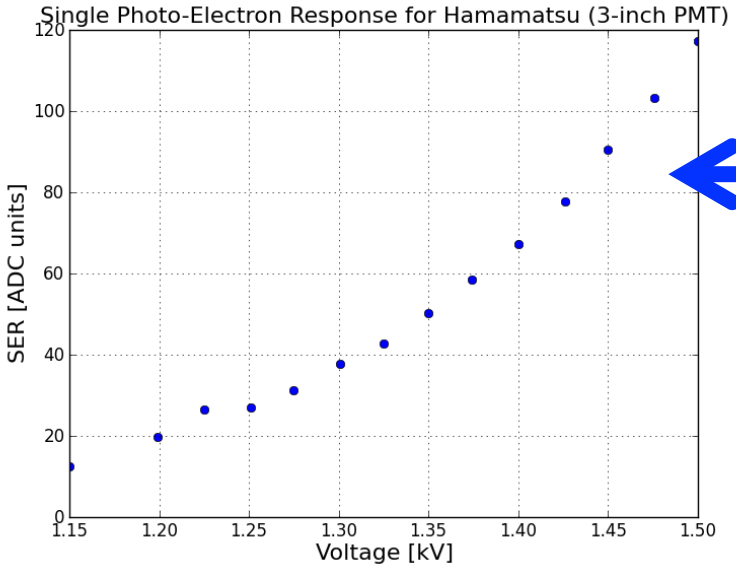




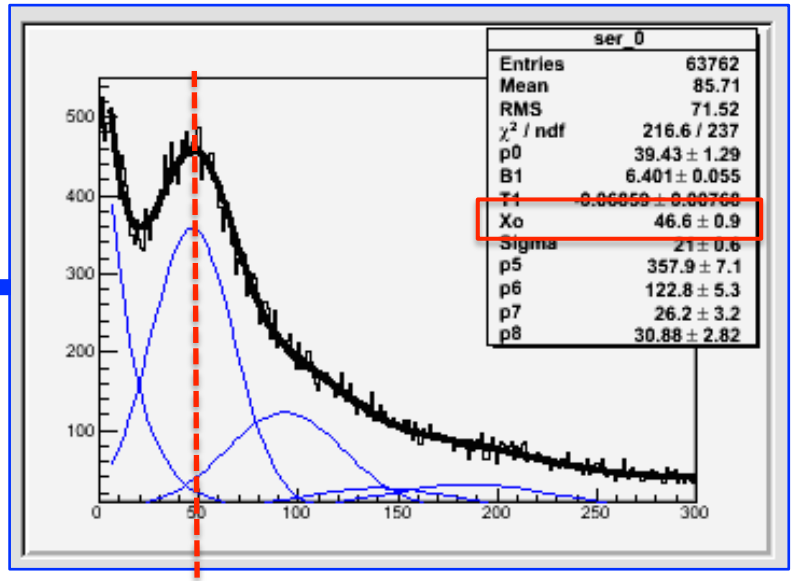


Calibrating with single photoelectrons



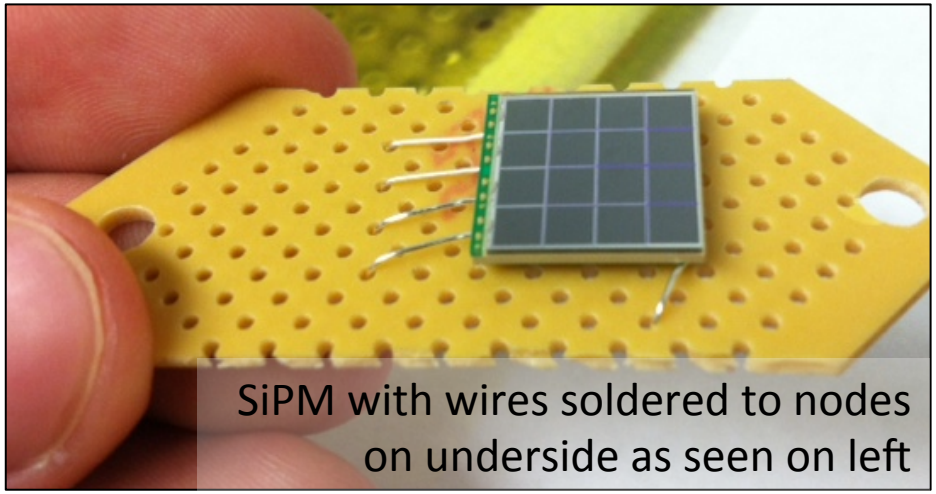


Position of 1phe position from fit to histogram (x_0) rises with HV as expected

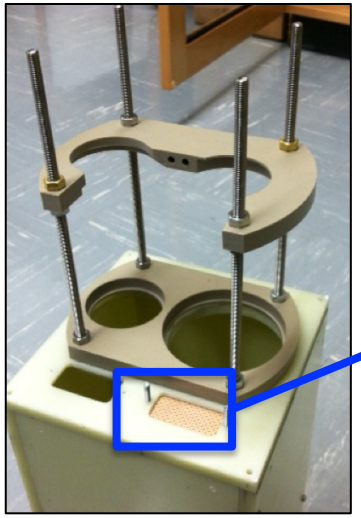


x_0

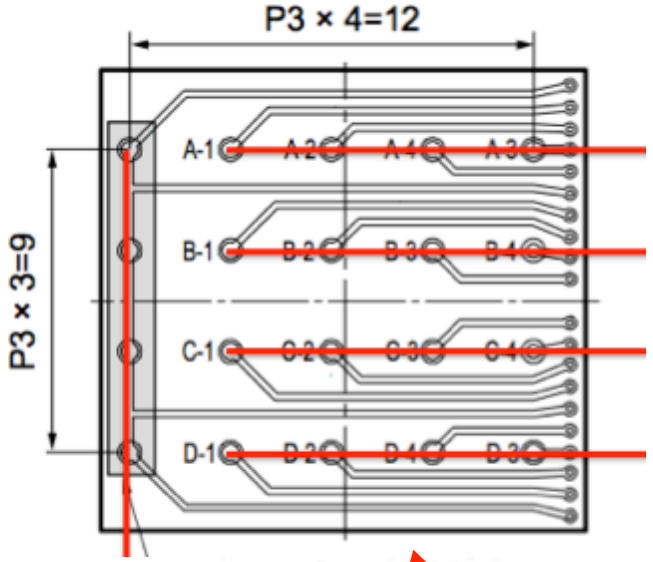
SiPM mounting and readout circuit

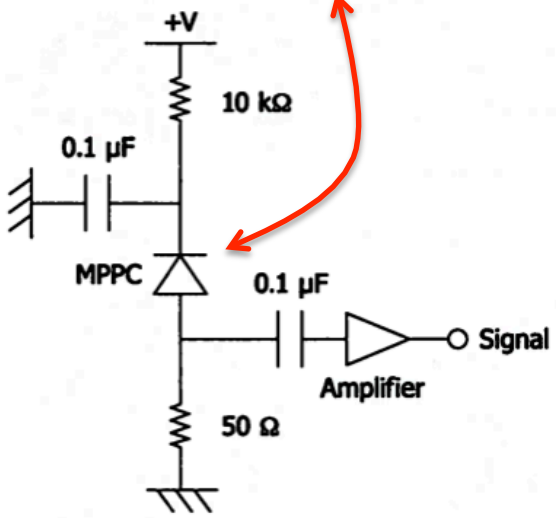


SiPM with wires soldered to nodes on underside as seen on left

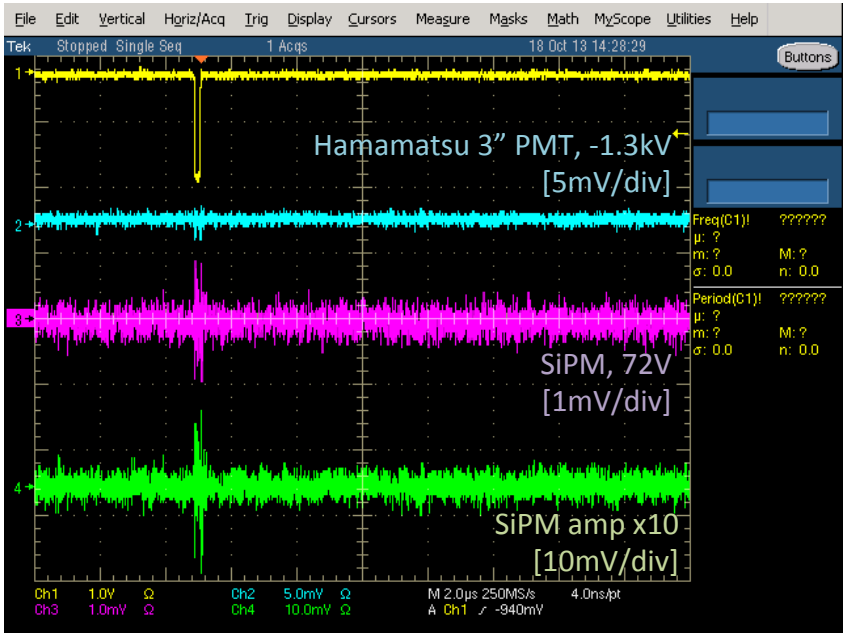


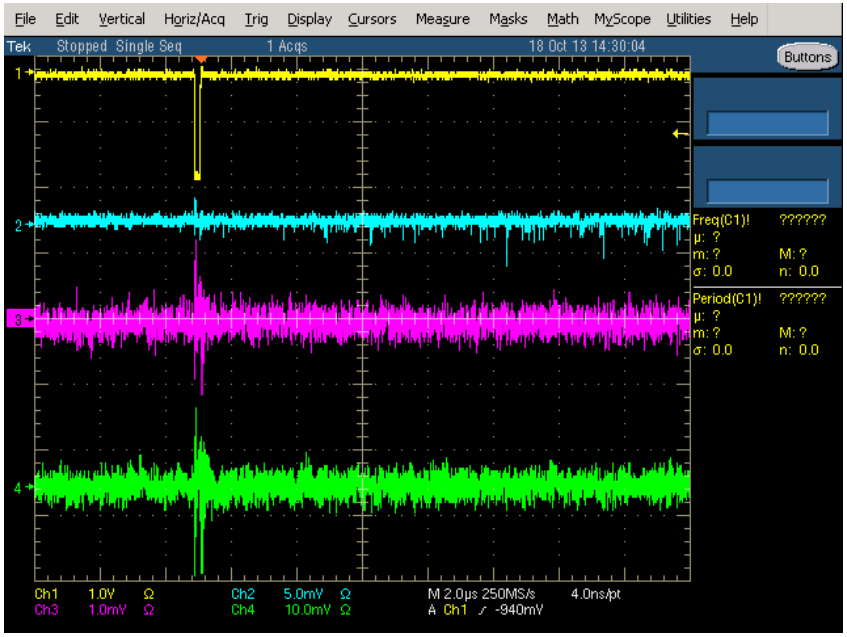
G10 box lid (SiPM and PMTs look down into the volume)





SiPM readout problems (1/2)



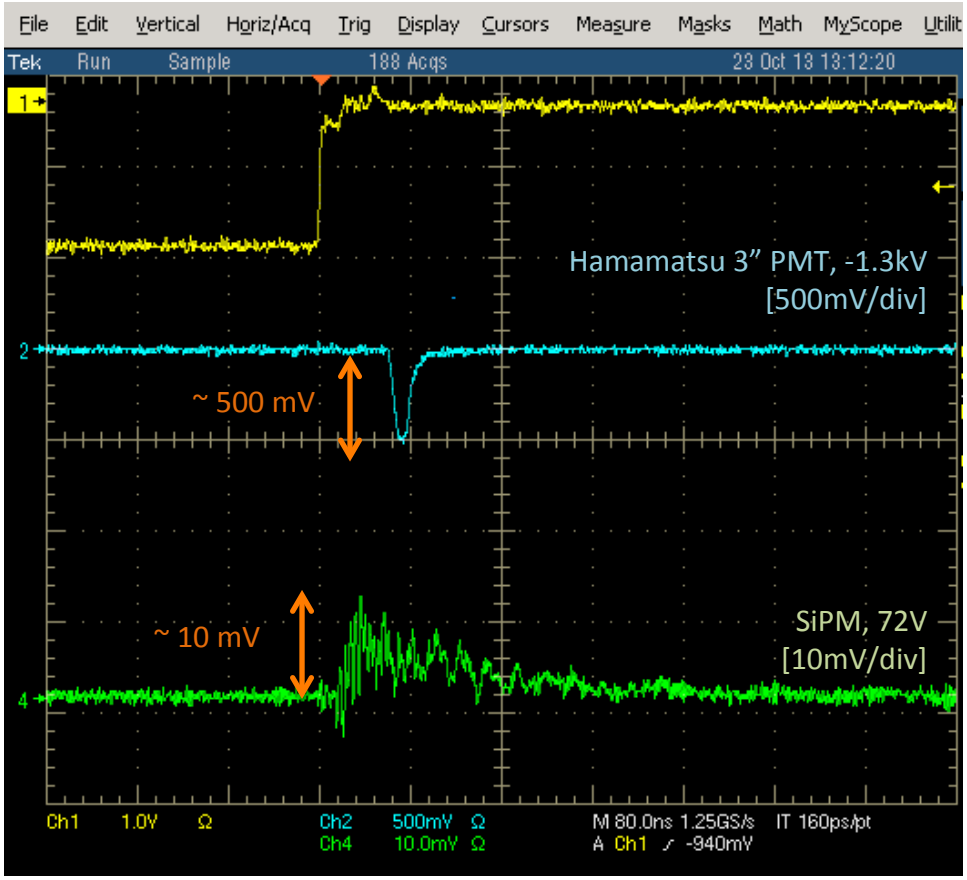


No light → Gradually turn up LED intensity

Cannot see photoelectron peaks in the SiPM like we can in the PMTs…

- Tried amplifying using NIM module for positive PMT amplification (Phillips 774)
  → amps noise as well as signal (d’oh!)

SiPM readout problems (2/2)



Bright and narrow LED flash…

- Seen by PMT as sharp 500mV pulse
- Seen by SiPM as unstable ~10mV pulse with bizarre ringing and long tail

Need better response in order to calibrate the SiPM and be sensitive to SER

- Parasitic capacitance of coupled readout circuit?
- Have tried many different circuit configurations with no success..