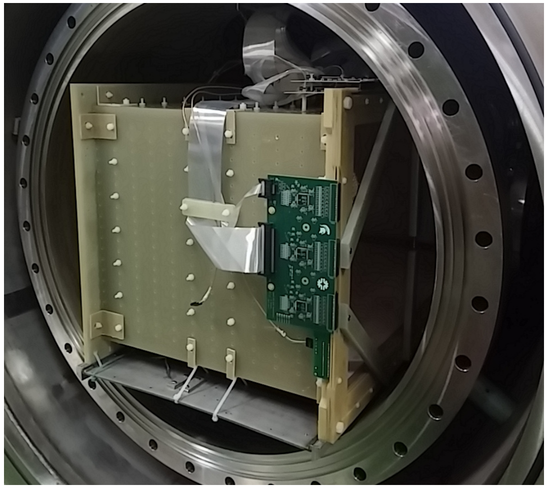
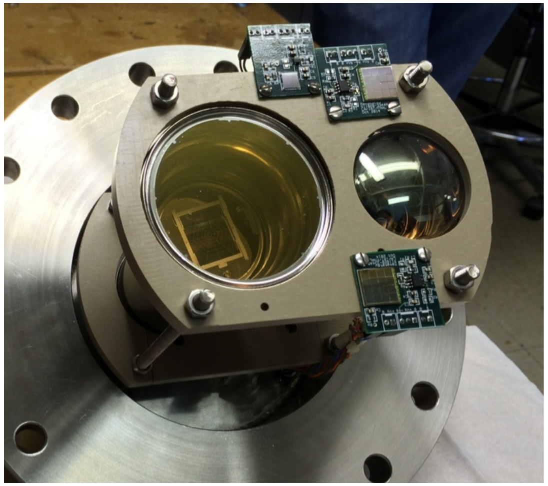




LArIAT TPC

&

Light Collection System

Roberto Acciarri – Fermilab

LArIAT Operation Readiness Review – 13-14 June 2015

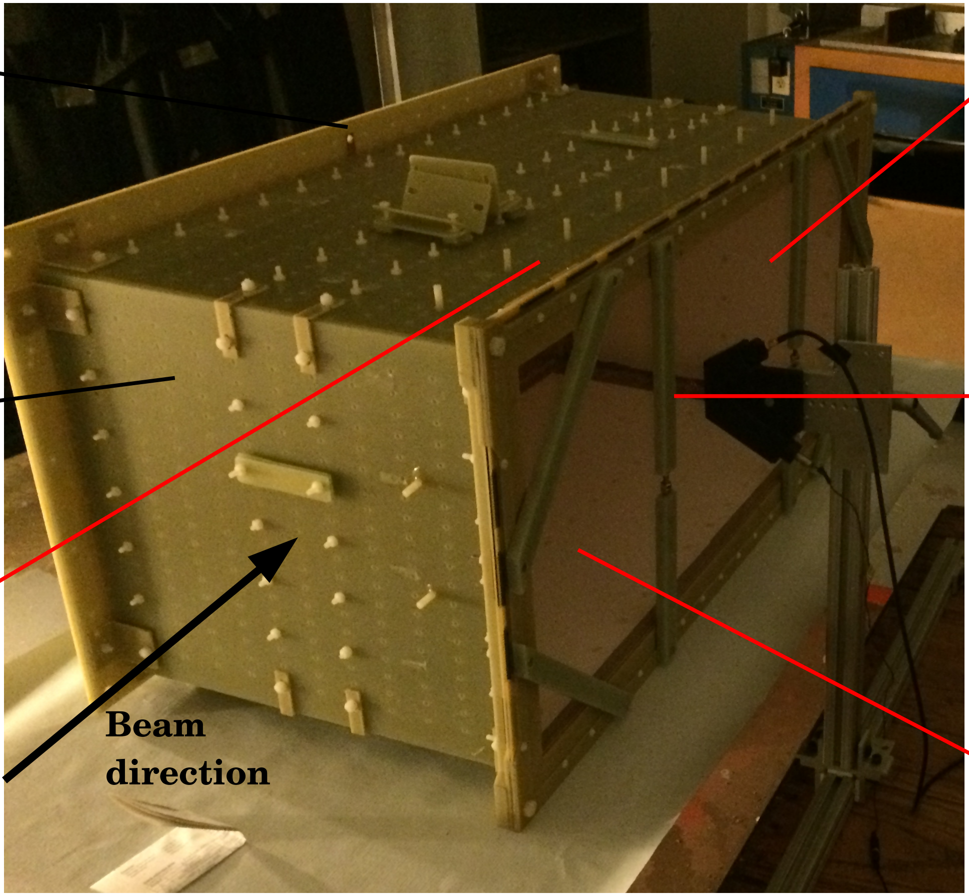
LArIAT TPC

Refurbished ArgoNeuT TPC: 47 w × 40 h × 90 l cm^3, ~ 170 lt LAr

New HV feedthrough

Same G10 support structure and field shaping rings. New resistors and surge protection devices

New cold electronics (not shown)



New wire planes

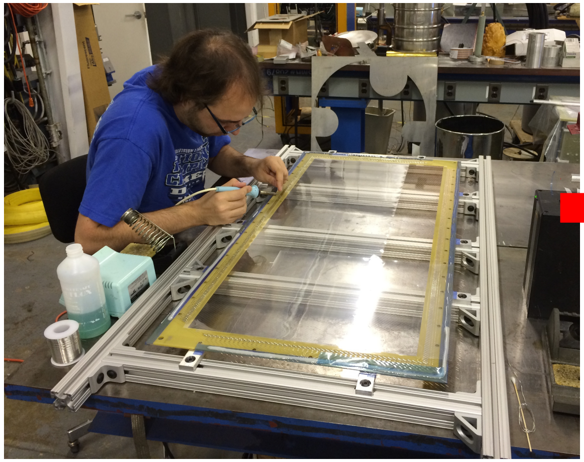
New tensioning bars

Interior walls covered with reflector + wavelength shifter for light collection

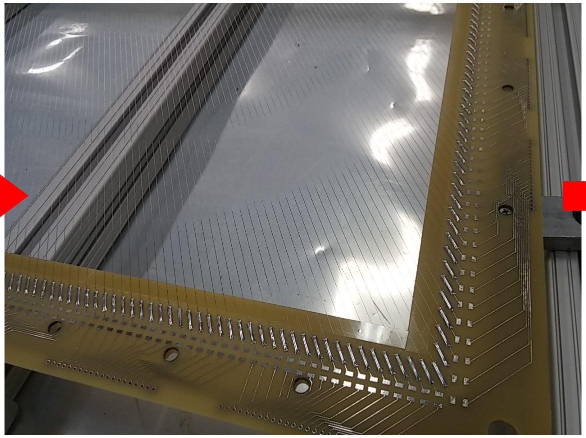
Wire Planes

- ✔ Three wire planes with interplane spacing of 4 mm
- ✔ Each plane composed by 4 mm spaced, parallel Beryllium-Copper wires (⊘=152 μm)
- ✔ 225 vertical wires for the Shield plane, 240 wires oriented at +60° (-60°) for Induction (Collection) plane
- ✔ Wire frames with newly designed wire-electronics connection delivered to Fermilab in Spring 2014
- ✔ Wire planes assembly (wire tensioning, soldering onto the frames, soldering and test of RC components) performed at Lab6 during Summer 2014

Greg soldering wires onto the frame



Nice job!

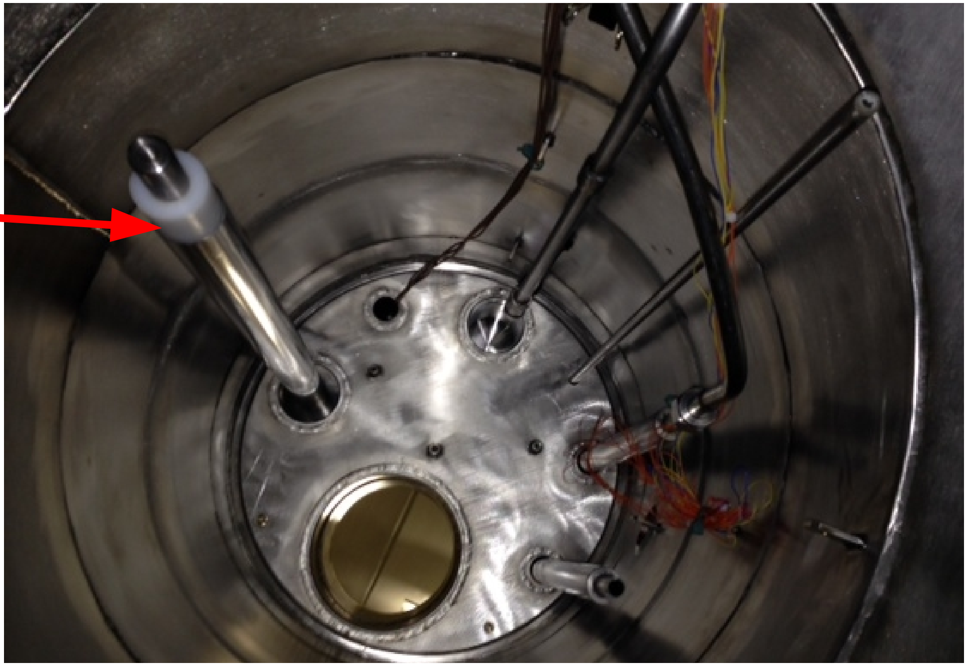


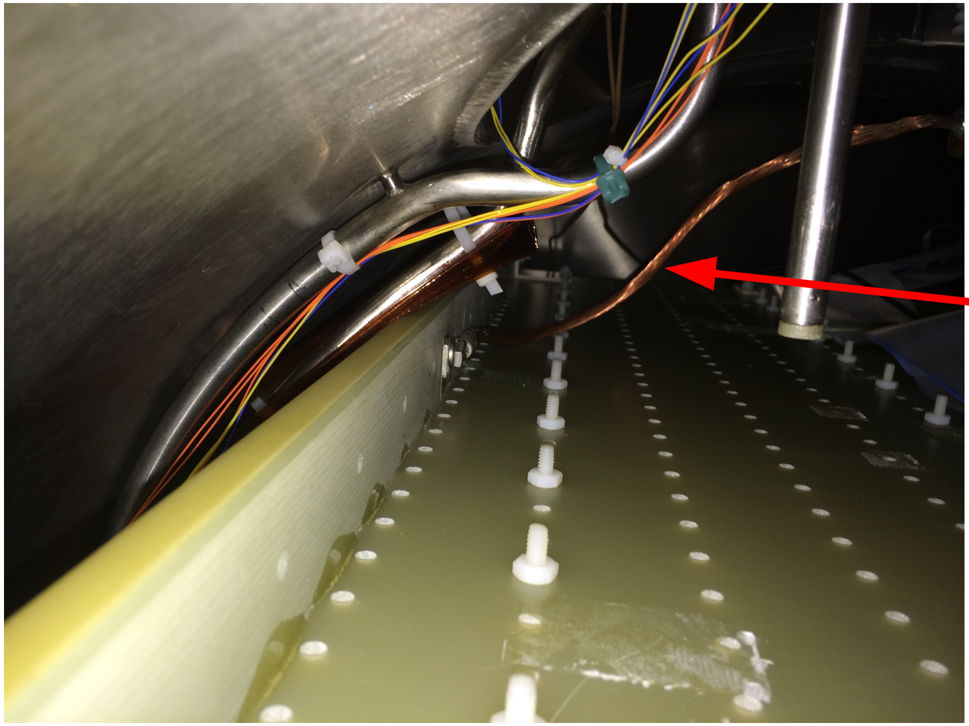
RC components directly soldered onto the frame

HV system

HV feedthrough (HV FT), cathode and field shaping rings are the main constituent of the HV system

- HV FT composed by an inner conductor rod, a high-density polyethylene tube and an outer stainless steel tube

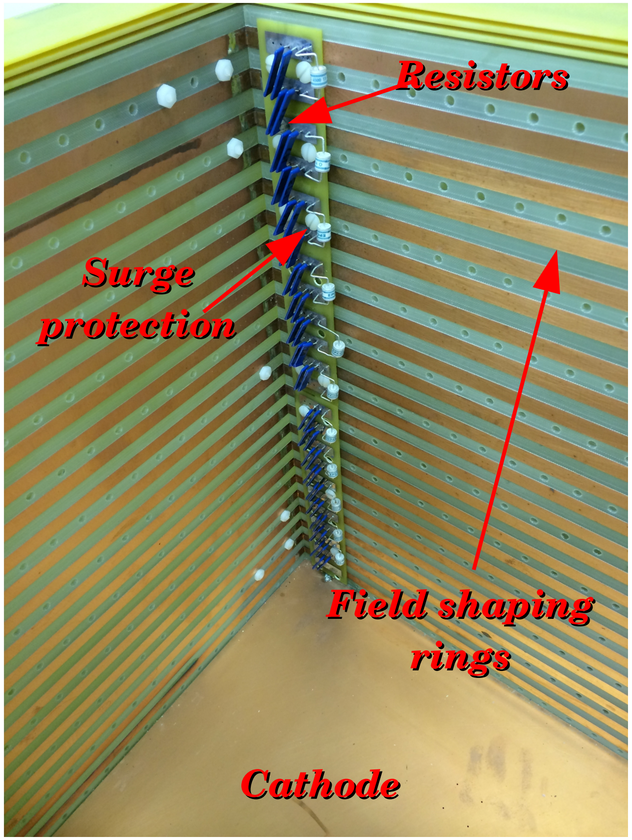




- Connection to the cathode by a flexible conductor rod bolted at both ends
- A “measured one, cut twice” problem found with first FT
- Smaller FT realized and cold tested up to -50kV

HV system

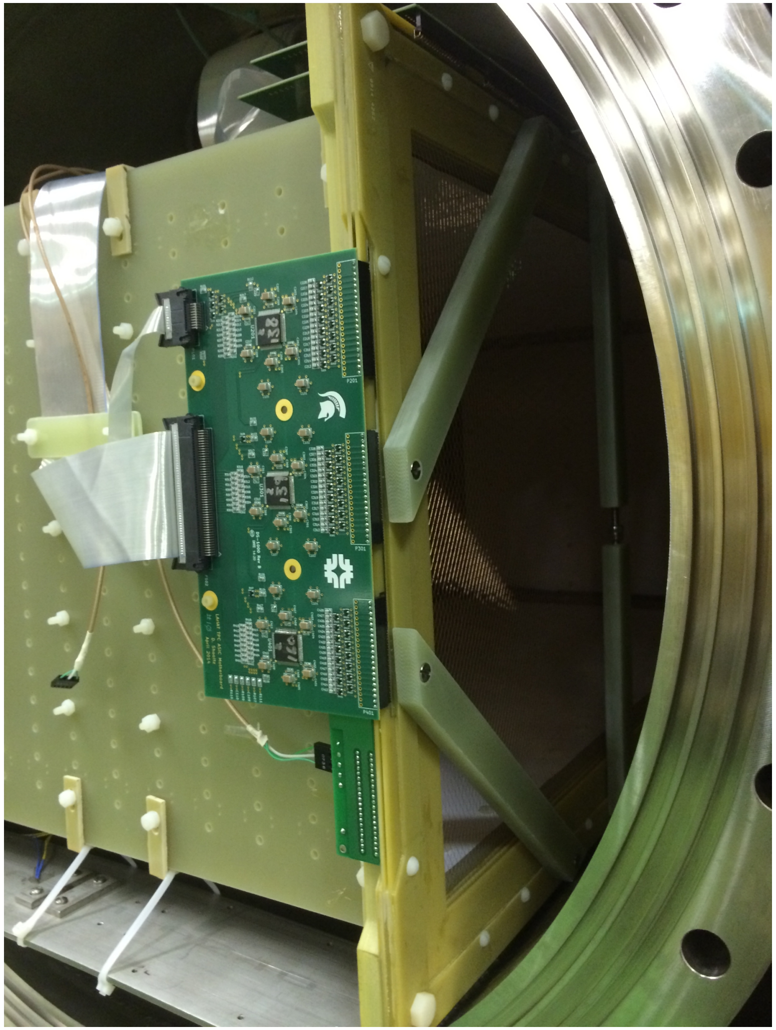
HV feedthrough (HV FT), cathode and field shaping rings are the main constituent of the HV system



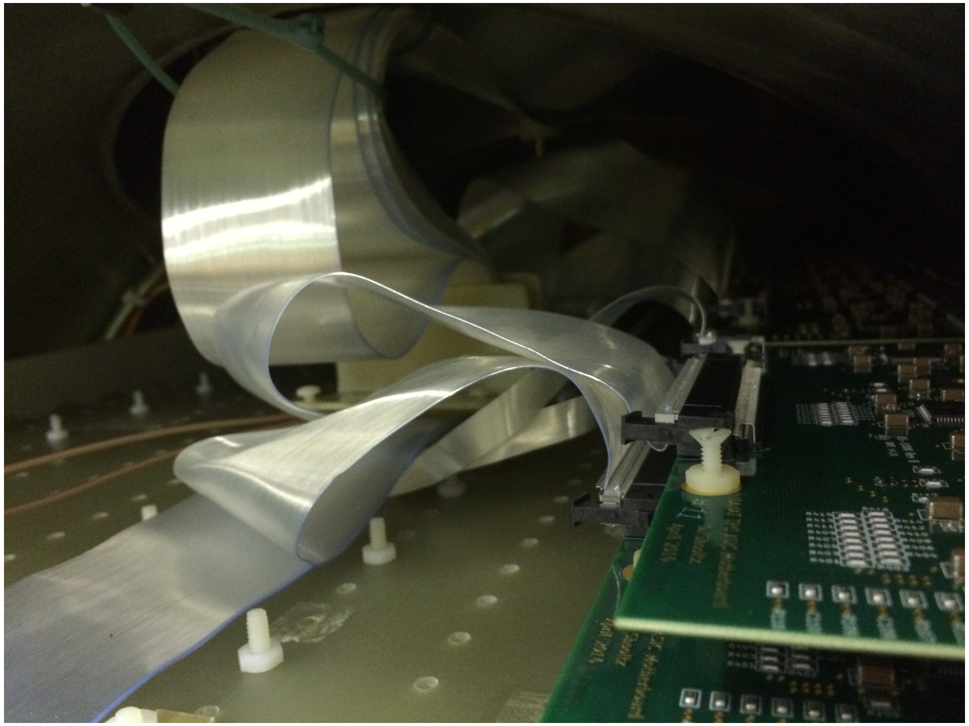
- The cathode, a G10 plain sheet with copper metalization on the inner surface, is biased @ -23.5 kV
- The field shaping system is composed by copper strips 1 cm wide spaced at 1 cm intervals, forming 23 rectangular rings all the way across the TPC
- Each ring is connected to the next by four 1 GΩ resistors in parallel and one surge protection device, ensuring a uniform E_{field} = 500 V/cm
- Warm and cold test and installation of resistor and surge protection devices performed at Lab6 during Summer 2014

- Shield, Induction and Collection planes are independently biased at -300 V, -18 V, +338 V respectively, to ensure the maximum transparency of Shield and Induction plane to drifting electrons

Cold Electronics

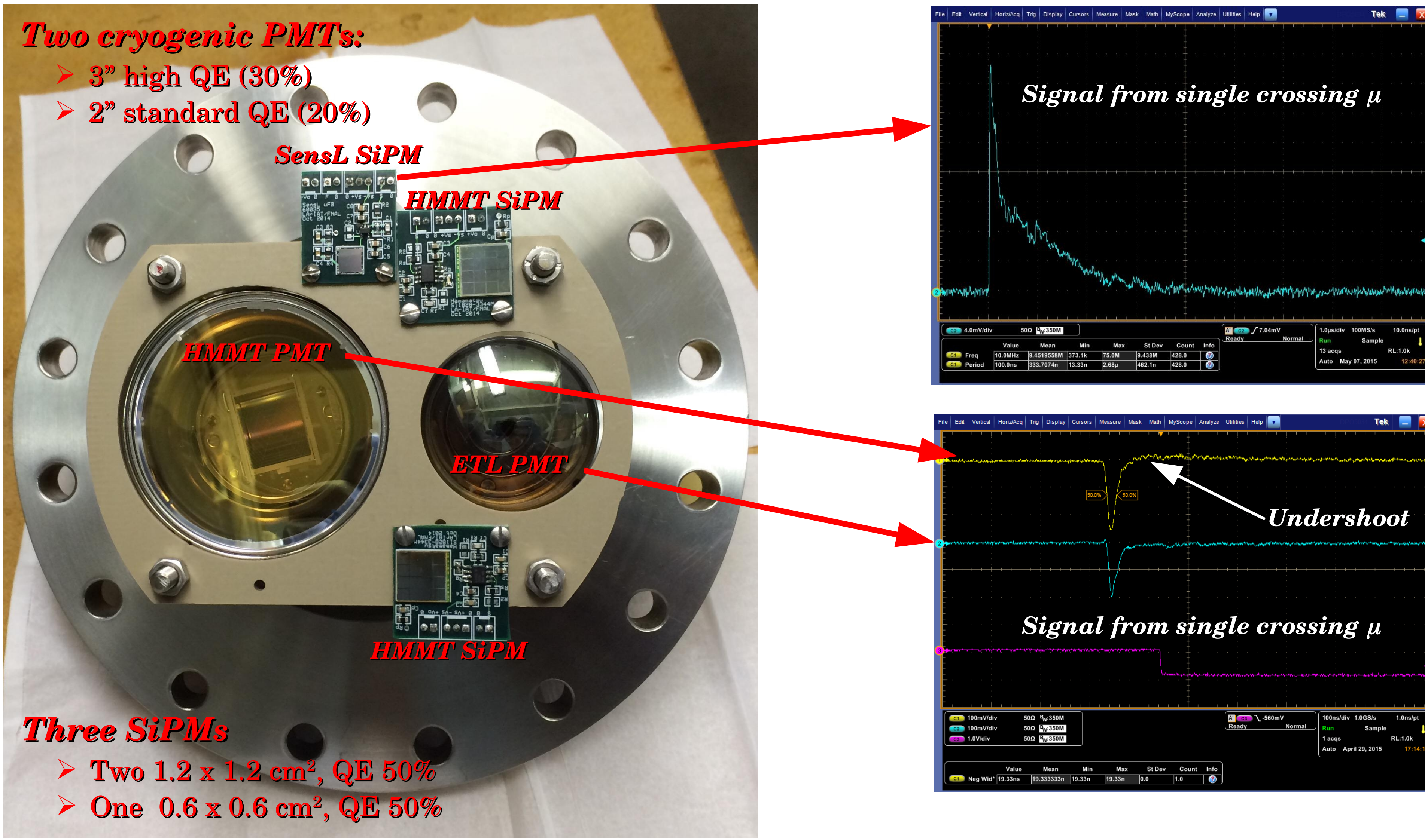


Small modifications to accommodate the new cold electronics and route the cables



Light Collection System

Realize a high efficiency light readout system derived from Dark Matter LAr detectors to extend the use of the scintillation light to calorimetric energy reconstruction and particle identification



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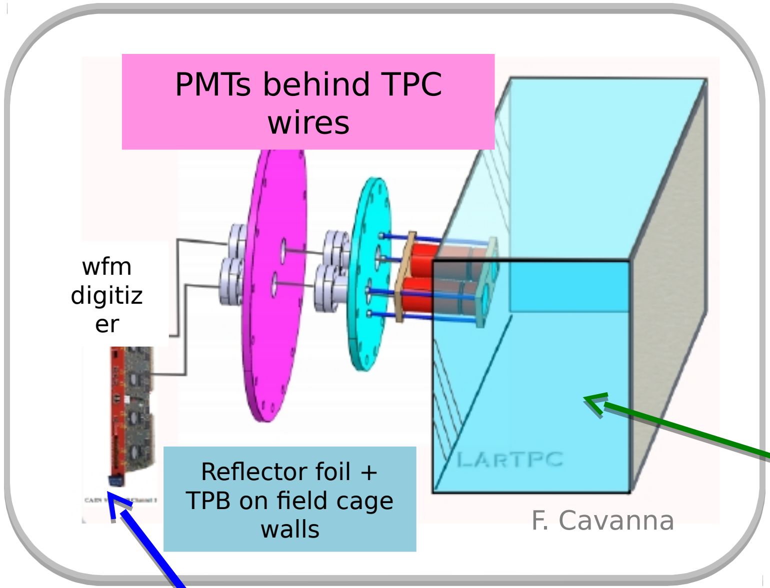
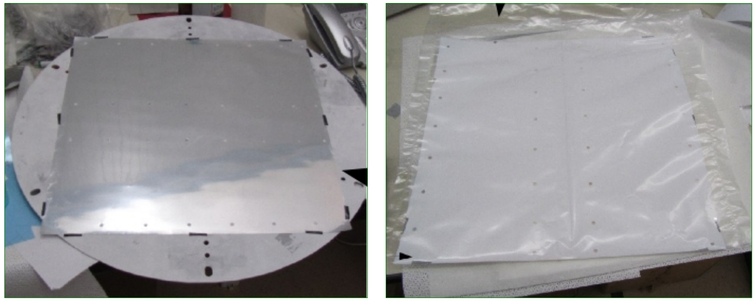
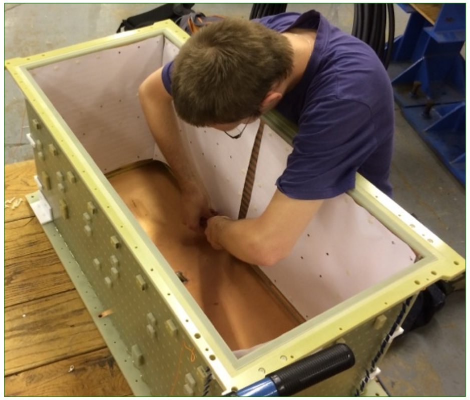




Reflector foil before/after TPB evaporation

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



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

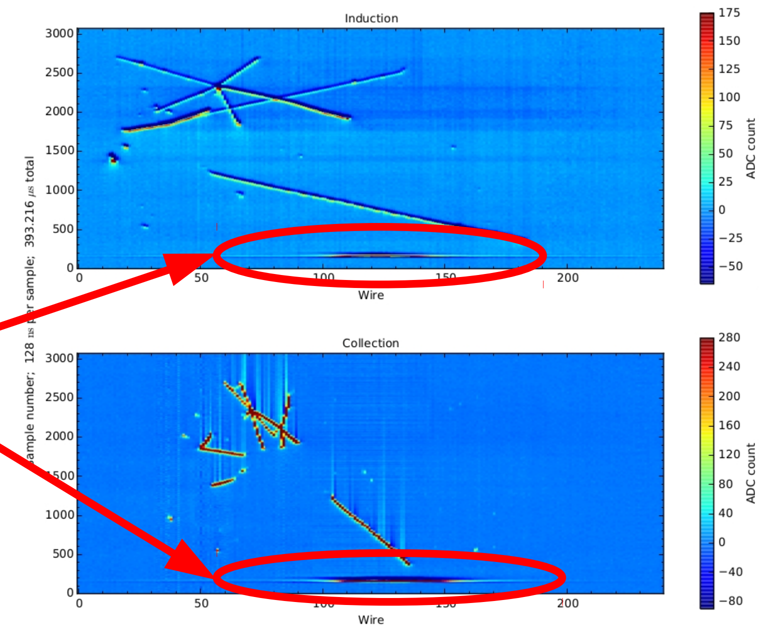
- Fast DAQ to optimize differentiation of fast & slow component (~7ns vs ~1µs)

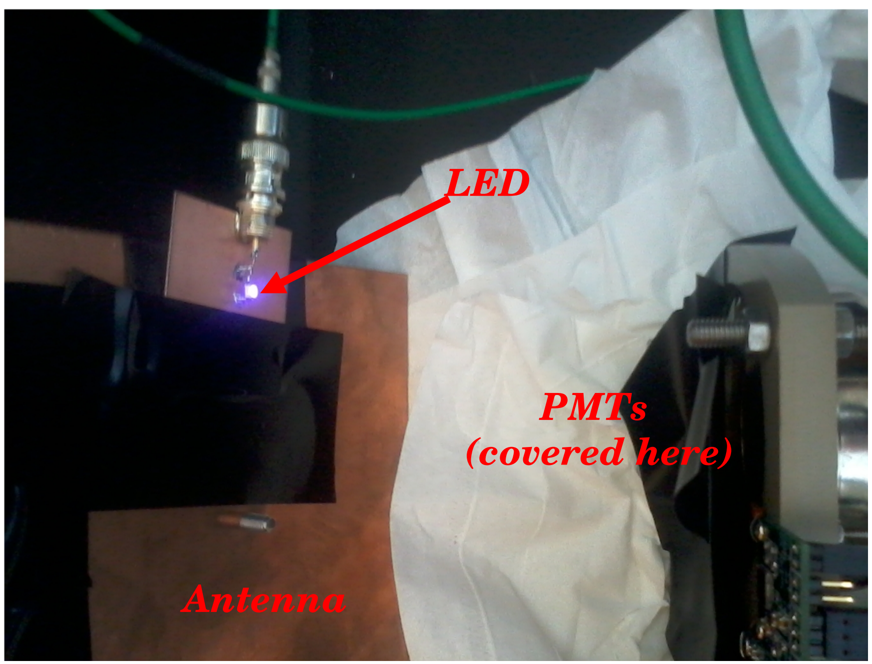
Test-mount of mock foil masks onto LArIAT TPC

HMMT problem

Broken capacitor on HMMT PMT base + PMT metal case connected to the photocatode + negatively polarized base (PMT case biased @ -1.3 kV, 2 cm away from +300 V collection plane) produced:

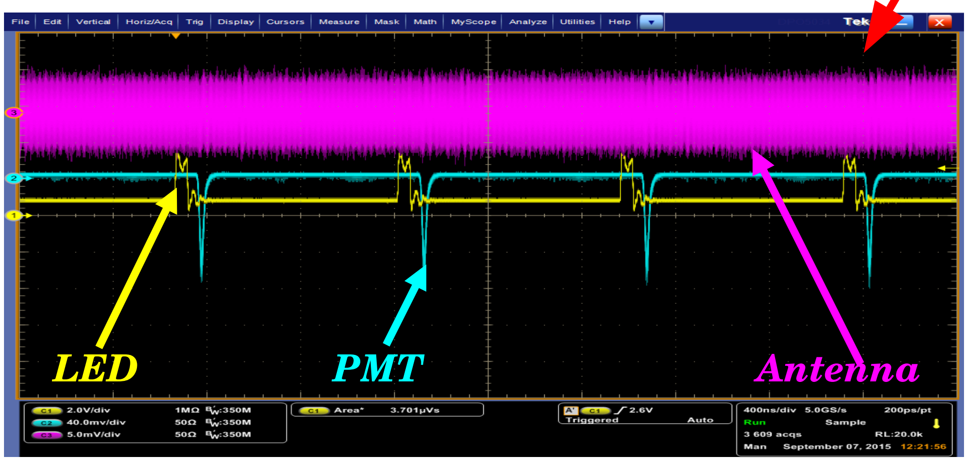
- ➢ Undershoot on HMMT PMT signal
- ➢ Induced noise on wire planes in time with light signal
- ➢ Noise on SiPMs signal





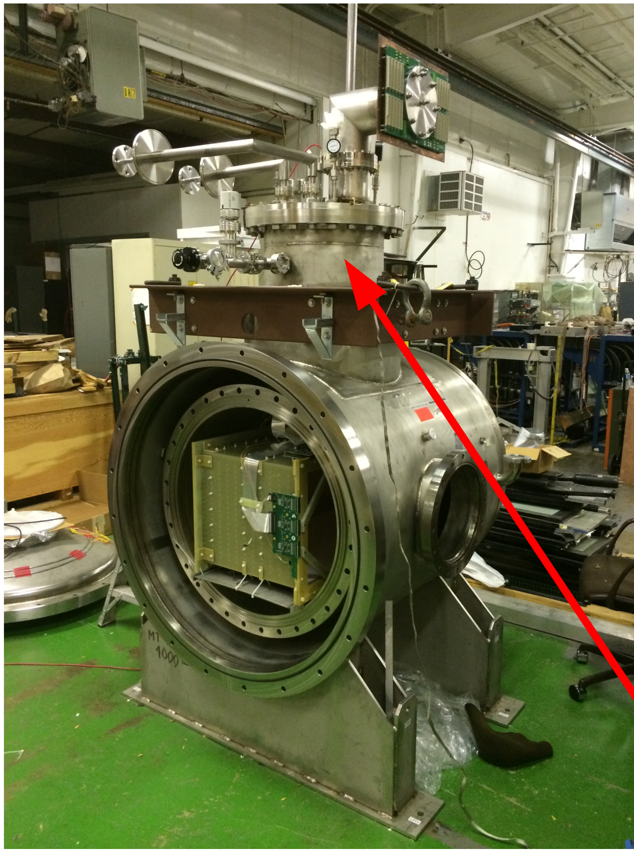
- ➢ HMMT PMT off for most of the data taking
- ➢ At the end of the run, warm test in a black box with LED light and a copper plate acting as antenna to study the problem and investigate the possibility of PMT-induced signal on wires

HMMT problem & solution

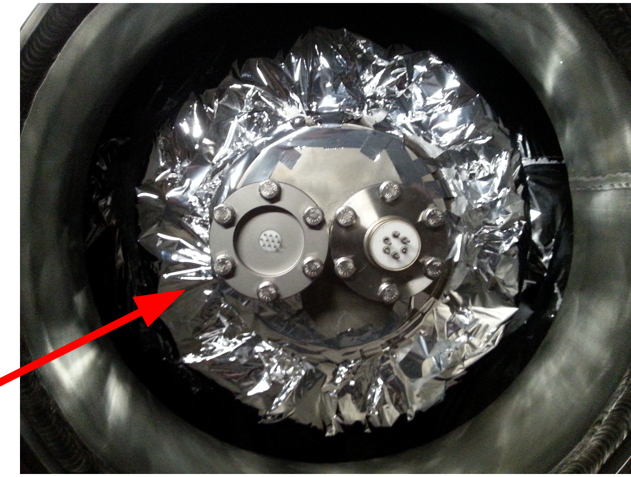


- Test with broken-capacitor, negatively biased PMT
- In correspondence to LED light pulse, undershoot (proportional to LED intensity) on PMT and induced signal on antenna observed
- Test with new HMMT PMT and new, positively biased base (metal case at ground)
- In correspondence to LED light pulse, no undershoot on PMT and no induced signal on antenna observed
- Plan to use the new PMT with positive base in the next run and install a small copper plate coupled to a SIPM in front of wire planes for antenna studies

Surrounding LAr detectors: the Cryostat

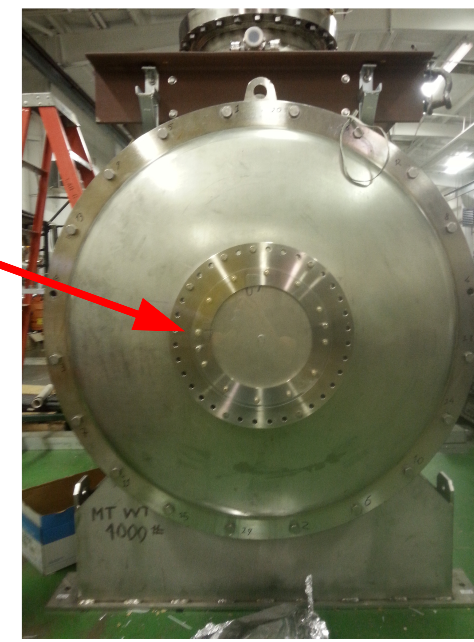


Stainless steel, vacuum-jacketed, super-insulated ArgoNeuT cryostat with small modifications:



- Side flange for light collection system

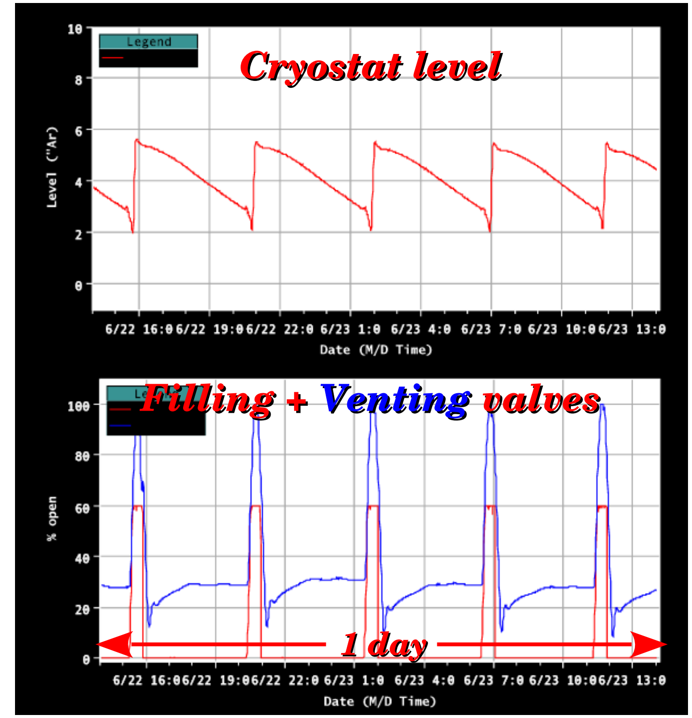
- Ti beam window on outer front flange and excluder on inner front flange for minimization of the material along the beam particles path

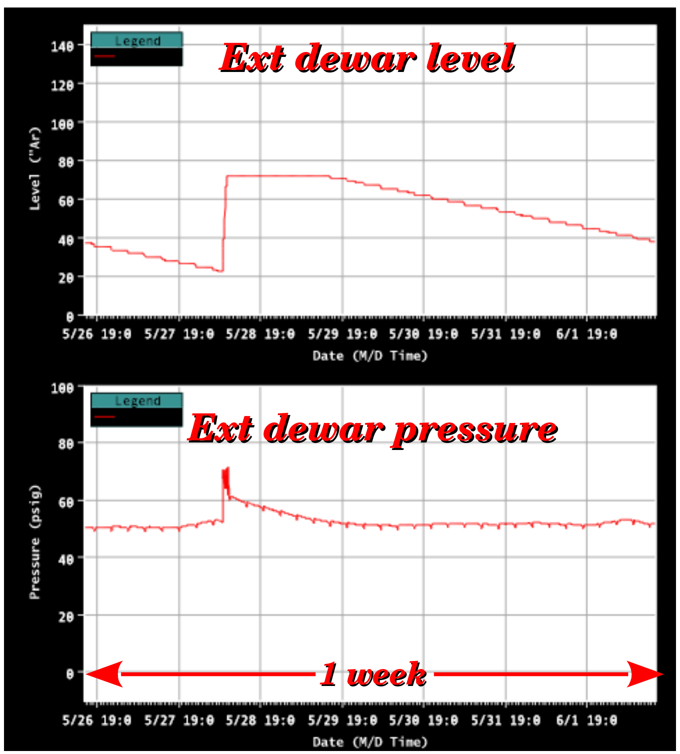


A wide chimney on the top of the cryostat allows an access path for HV FT, signal cables from the LArTPC and from temperature and level sensors, as well as for the filling and venting cryogenic pipes

From detectors to LAr detectors

- LAr supplied to the cryostat by an external dewar filled weekly
- A filter for H_2O and O_2 removal + a filter for dust removal along the filling line ensures delivery of high purity Ar to the cryostat





- LAr not recirculated – excess boil-off GAr vented out
- LAr level in the cryostat monitored through a level meter present in the cryostat chimney. An automatized filling system keeps LAr level at a safe height respect to the TPC

Monitoring LAr purity

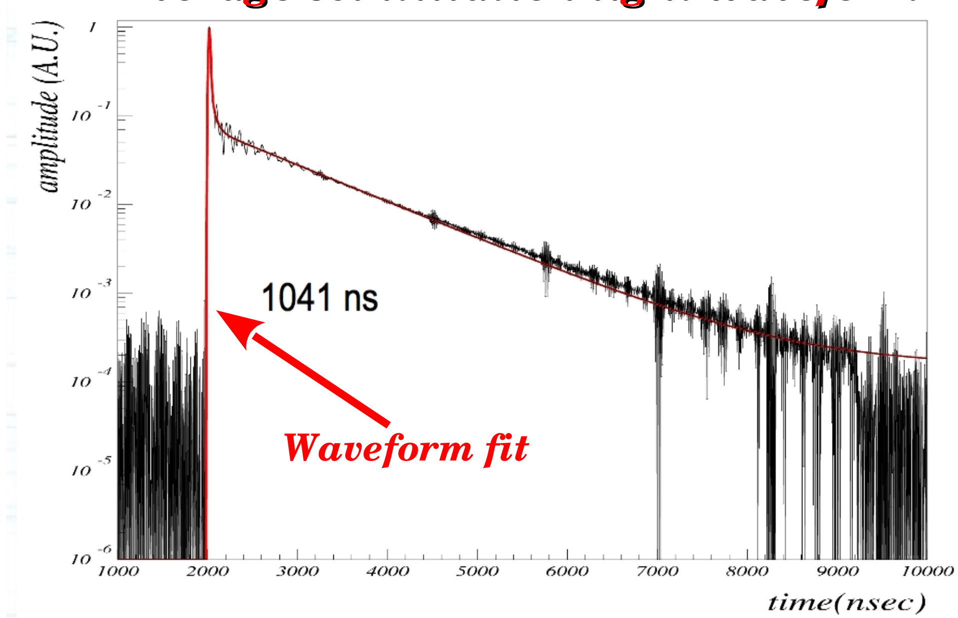
- Presence of electronegative contaminants (H_2O, O_2) in LAr decreases the number of e^- collected at wires → < 1 ppb of electronegative contaminants required

- Presence of N_2 in LAr mainly decreases the slow component of the scintillation light → ≤ 1 ppm of N_2 required

- Gas analyzers allow monitoring of O_2, H_2O and N_2 content throughout the cryo-system with sensitivity down to few ppbs (O_2, H_2O) and fractions of ppm (N_2)

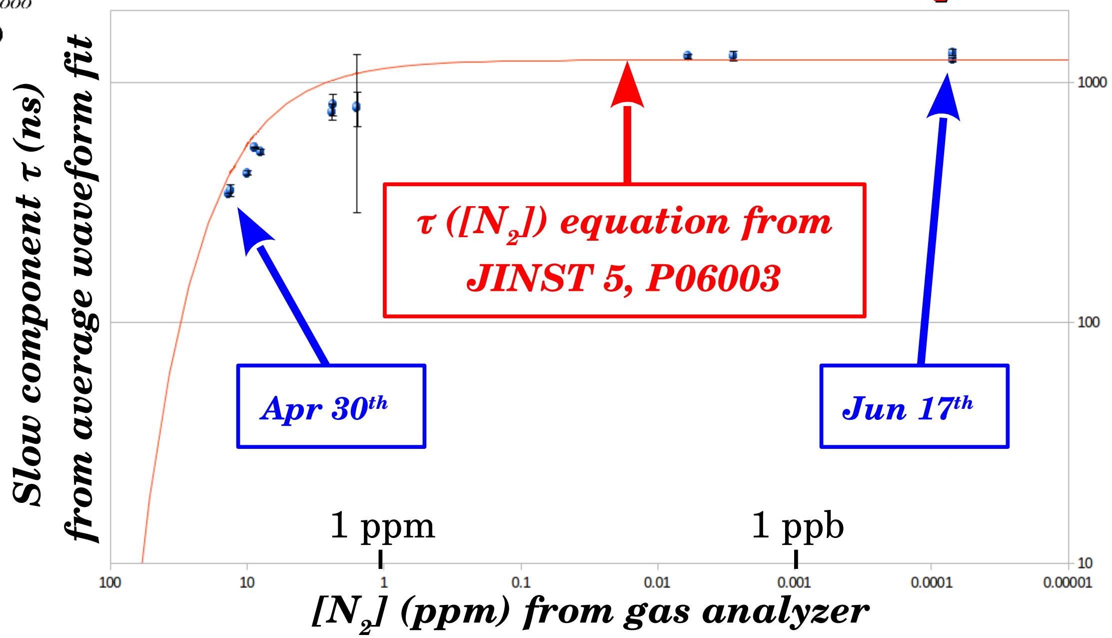
- To precisely measure the electronegative contaminant concentration in LAr we rely on the TPC itself!

Monitoring LAr purity: N_2 concentration



N_2 content in LAr can be extracted from the slow component time constant of the scintillation light collected by the PMTs

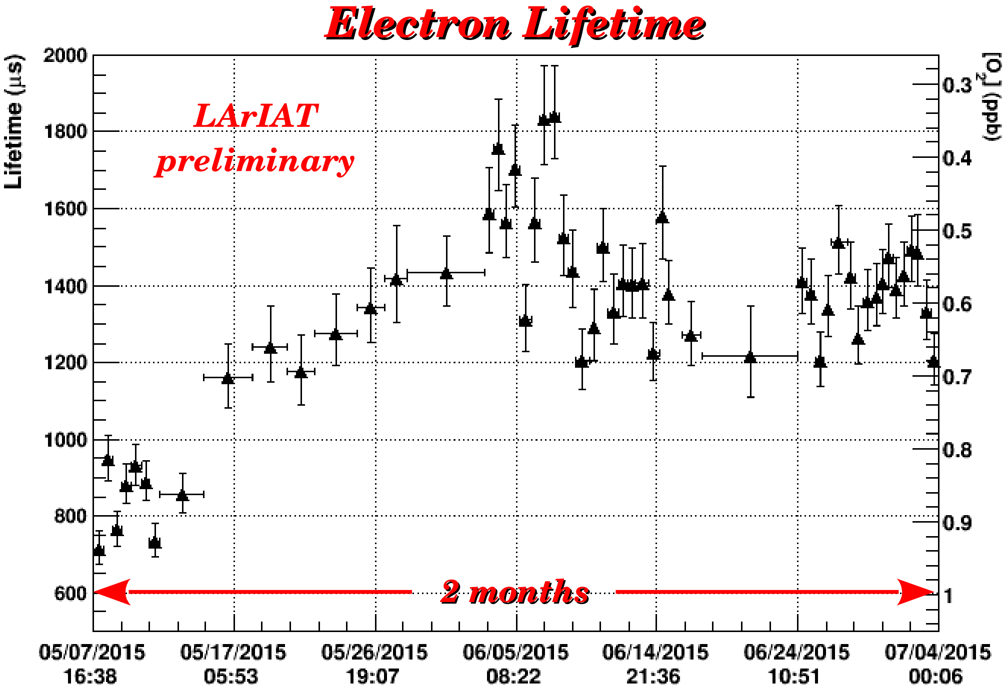
Values obtained using this technique well agrees with the measurement performed by the cryo-system gas analyzer

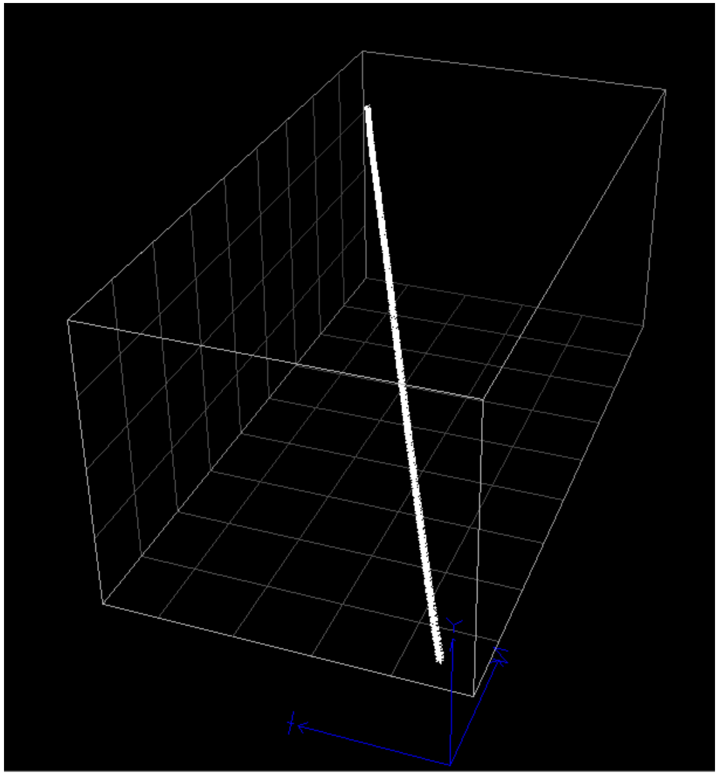


Monitoring LAr purity: O_2 concentration

- Cosmic tagger paddles allow to trigger on minimum ionizing muons crossing the full diagonal of the TPC in between beam spills

- A fit of the charge vs drift time allows to extract the electron lifetime and infer the O_2 concentration in LAr at levels below the sensitivity of the gas analyzers



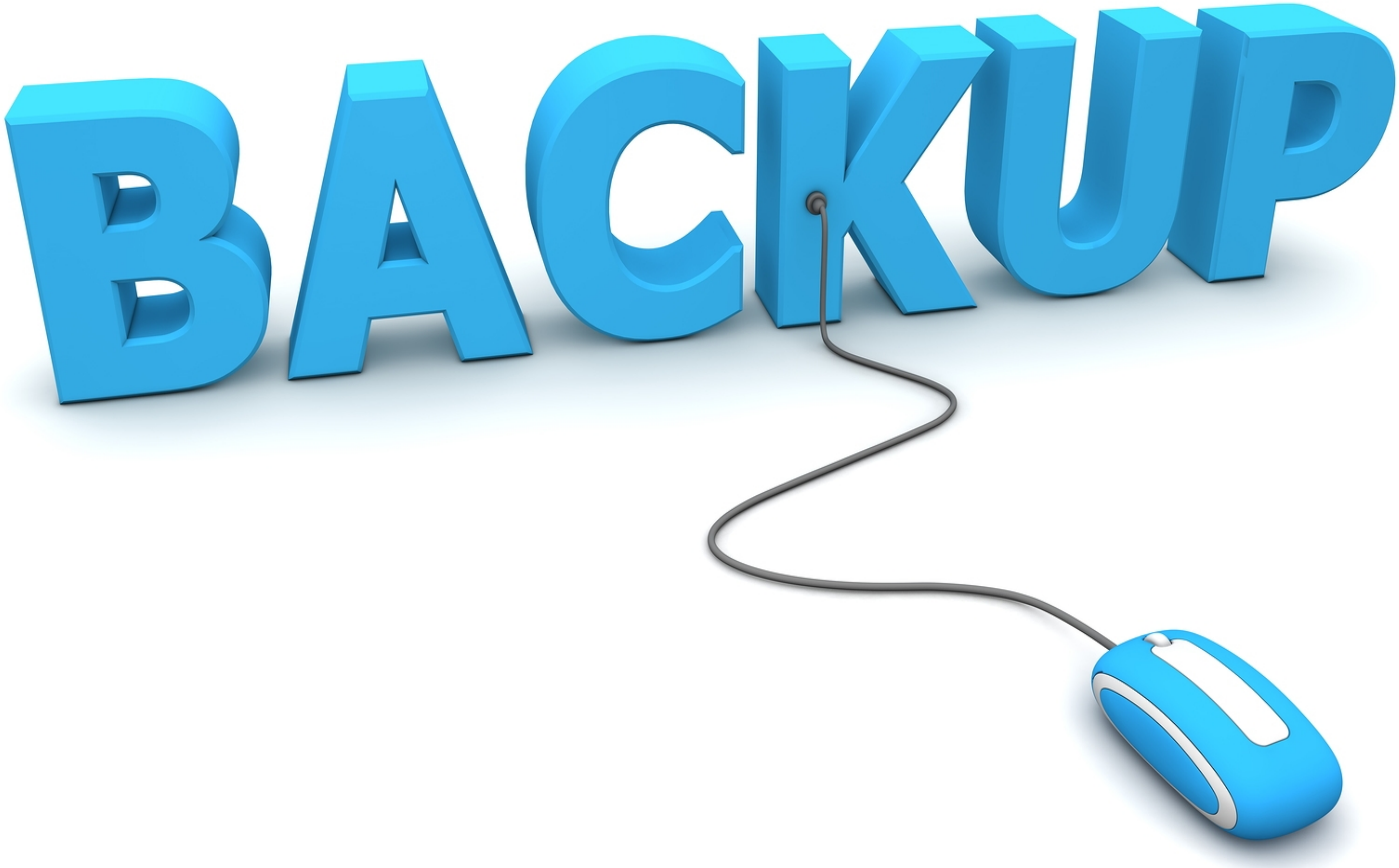


- Fully reconstructed and analyzed the ~2 months of data (only cosmics) available

- Achieved and maintained a LAr purity better than 1 ppb [O_2] throughout the whole run

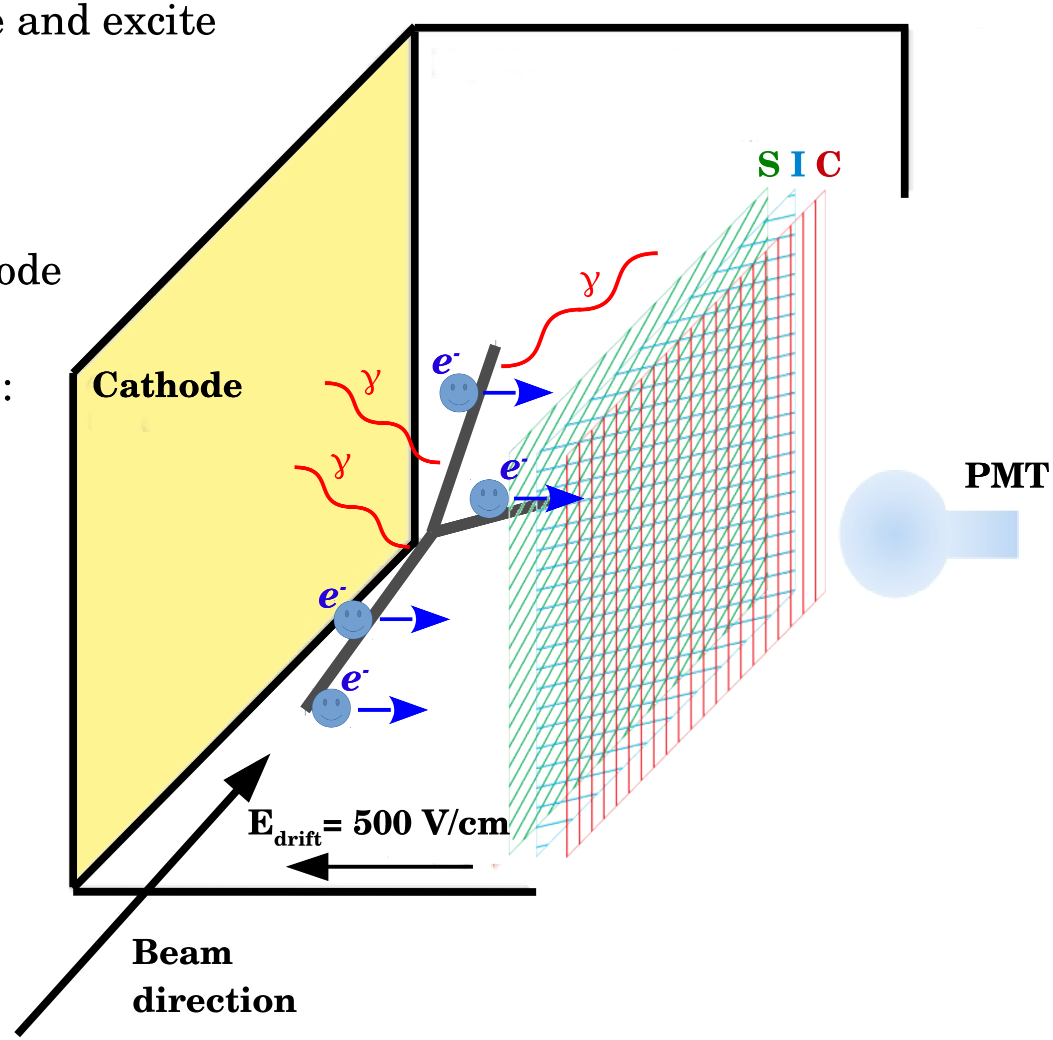
Conclusions

- All TPC and light collection system components carefully tested and assembled
- LAr detectors in place and ready to operate by early January 2015
- LArTPC run smoothly and without major issues
- Analysis of crossing cosmic muon showed we are able to achieve and maintain the necessary LAr purity level through the whole run


BACKUP

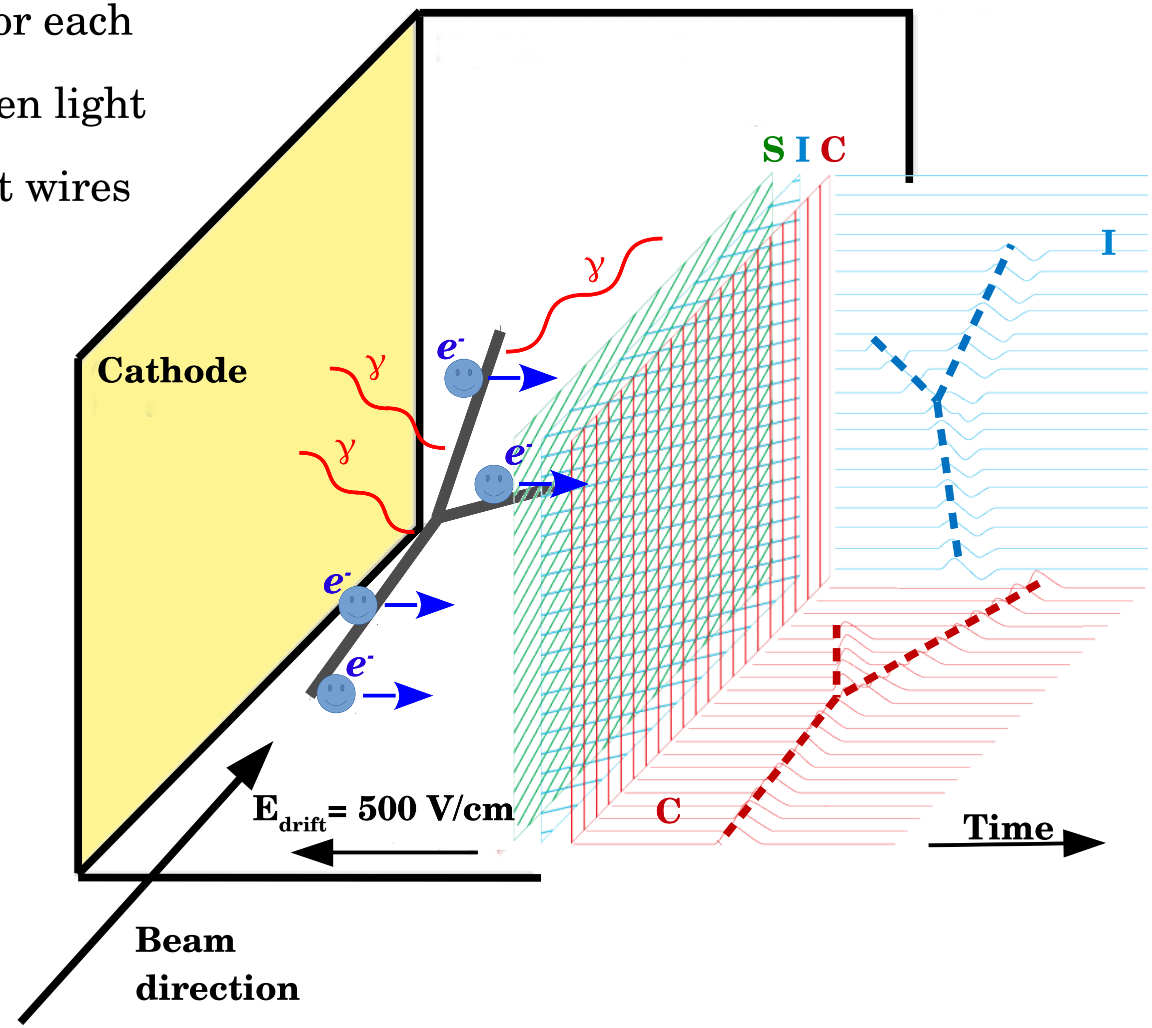
LArTPC: Principle of operation

- Particles entering the TPC volume ionize and excite the LAr:
  - γ from scintillation collected by PMTs
  - e^- drift at constant velocity towards anode
- Anode made by 3 planes of parallel wires:
  - Shield plane (not read out): shapes the E_{field} near the anode wires and shields the outer planes from positive drifting charge
  - Induction plane: signal induced by electrons passing by the wire
  - Collection plane: signal given by electrons collected on the wire



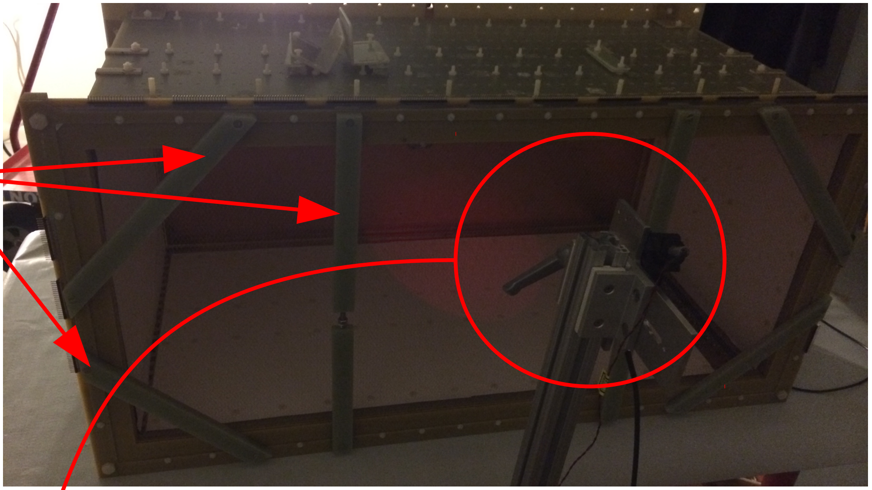
LArTPC: Principle of operation

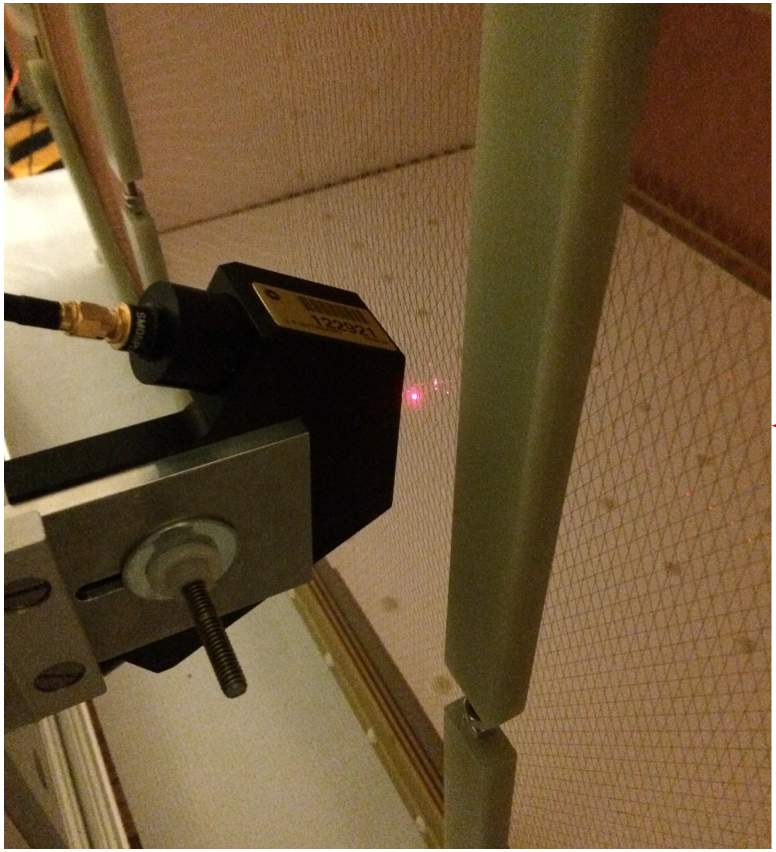
- X-coordinate (parallel to the drift field) for each plane given by the time difference between light collected at PMTs and charge collected at wires
- Y (vertical and perpendicular to the drift field) and Z-coordinate (horizontal and perpendicular to the drift field) given by combining wire information from both planes
- Charge collected on the last plane provides calorimetry information



Tensioning of the wire planes

Two sets of 2 fixed, diagonal G10 bars and 1 adjustable, vertical G10 bar to prevent wire frames from bending under wire tension and thermal stress. Middle of the plane kept undisturbed for the light collection system





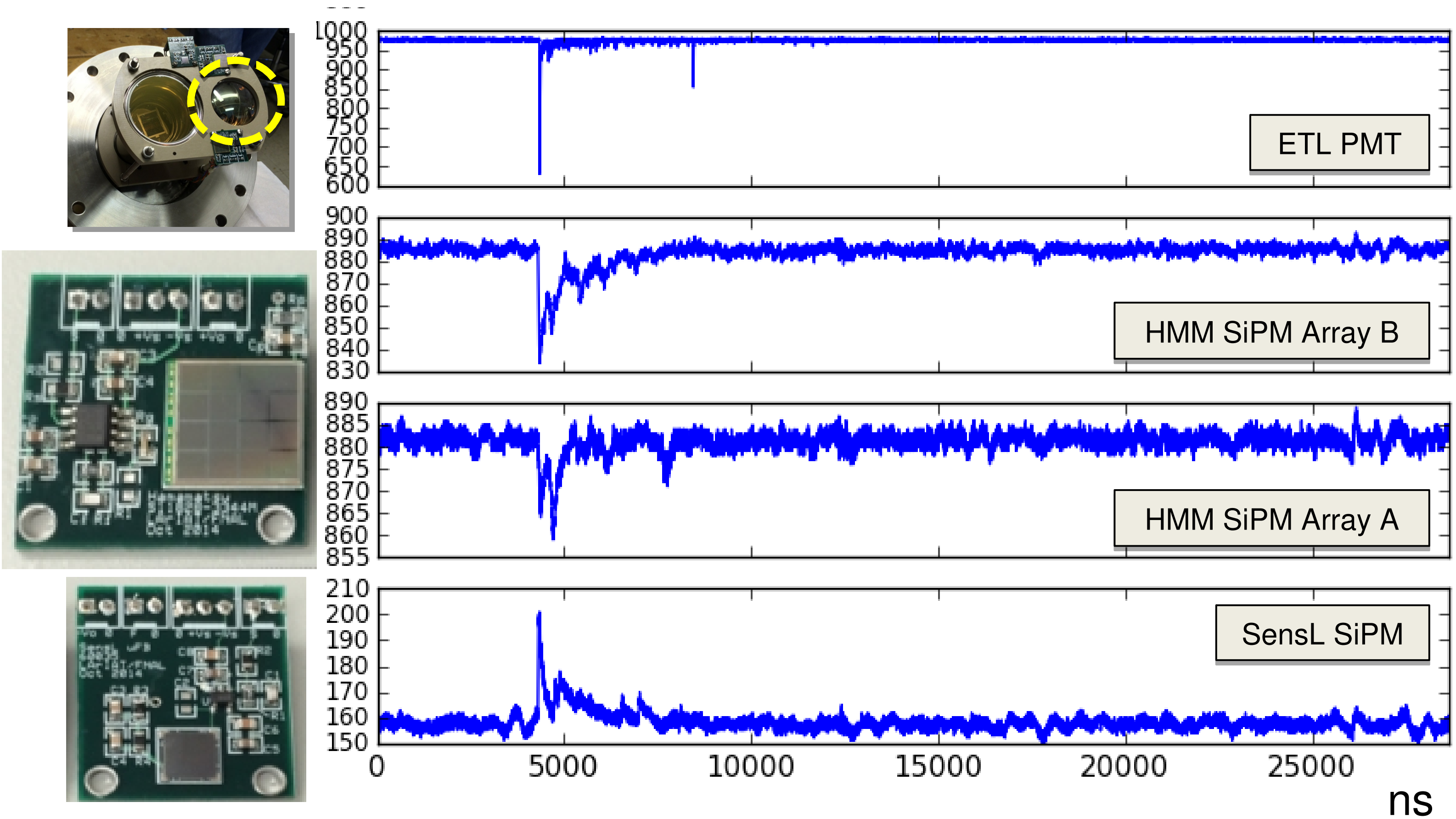
Laser system used to check wire tension by measuring the vibration frequency of samples of wires from all the three planes

PMTs and SiPM signals

Hamamatsu SiPM arrays differ by type of opamp, and by health of SiPM chip.

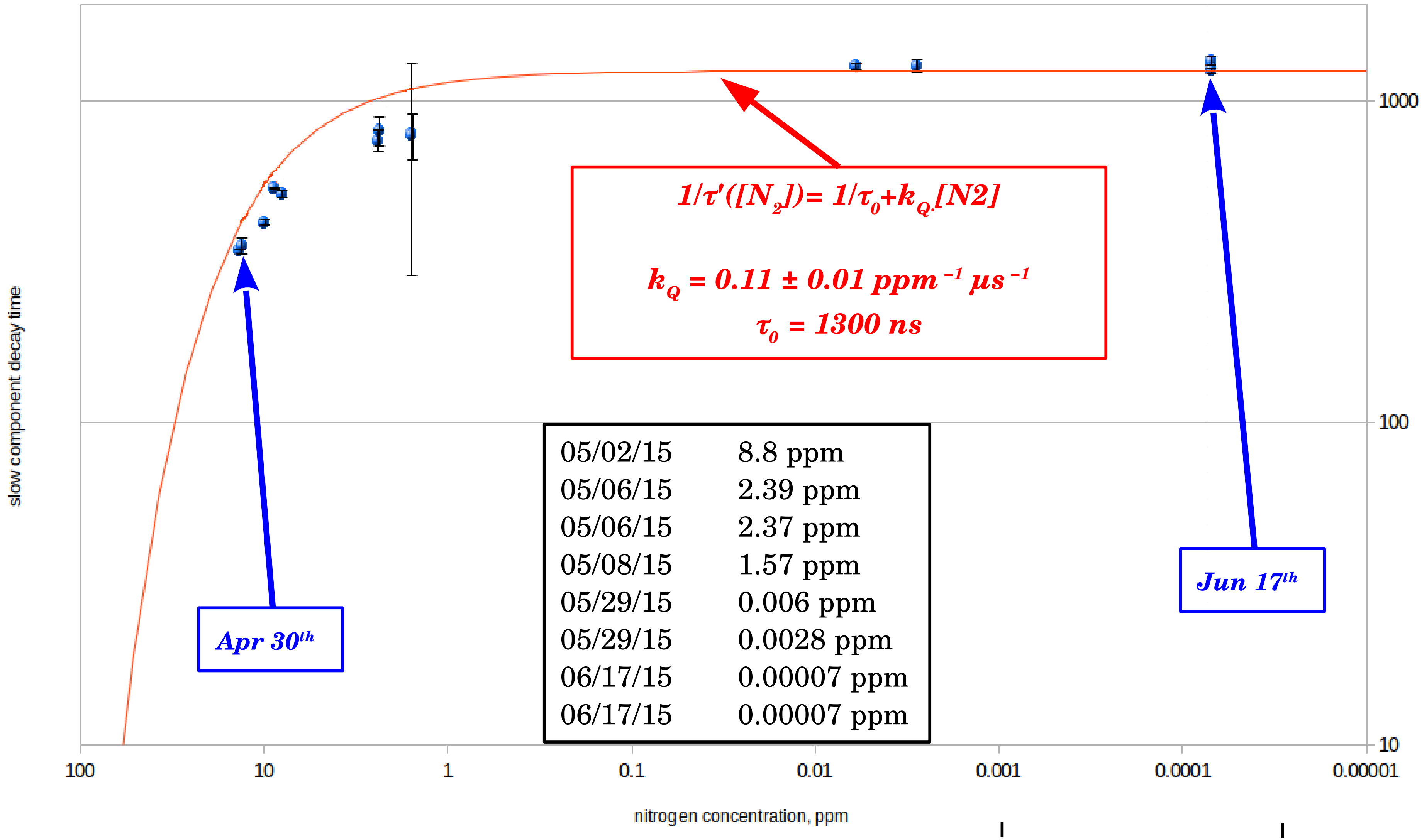
- A uses ADA-4891, B uses OPA-656
- B has fewer (11 out of 16) functional channels due to repeated reflow soldering during testing

Time resolution of SiPMs expected to improve with updated circuit designs.



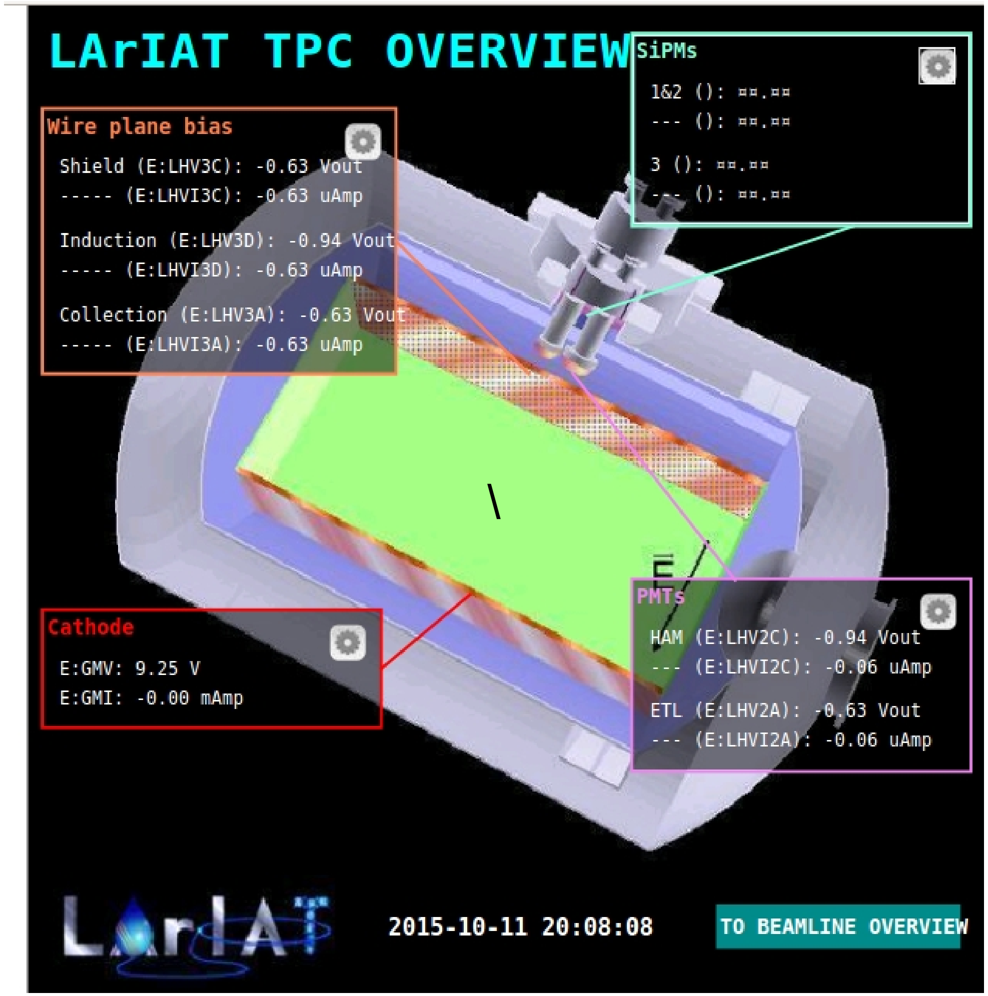
Monitoring LAr purity: N_2 concentration

Slow component decay time VS [N_2]



05/02/15	8.8 ppm
05/06/15	2.39 ppm
05/06/15	2.37 ppm
05/08/15	1.57 ppm
05/29/15	0.006 ppm
05/29/15	0.0028 ppm
06/17/15	0.00007 ppm
06/17/15	0.00007 ppm

Monitoring the TPC



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