

Purity monitoring for ProtoDUNE

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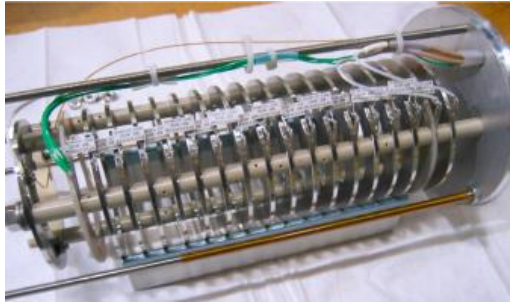
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Liquid Argon Purity Monitoring

- Liquid argon time-projection-chambers (LAr TPCs) use drifted ionized electrons for calorimetry and tracking.
- Detector technology for neutrino experiments like DUNE and ICARUS. Even used for dark matter experiments like DarkSide.
- Electronegative impurities, like water and O_2 , can capture ionized electrons and reduce the size of signals on the readout.
- ProtoDUNE operates a single-phase and dual-phase detector to prototype the eventual DUNE Far Detector modules.

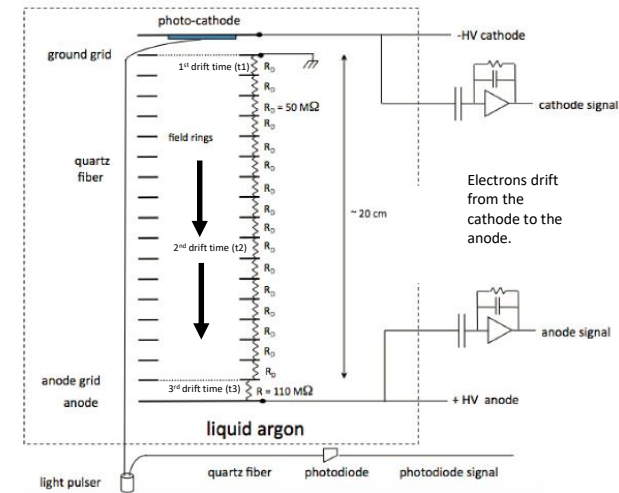
Basics



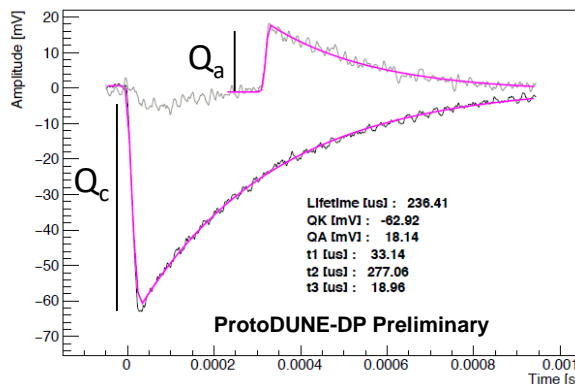
- ProtoDUNE utilizes purity monitors, the same design used for ICARUS, to quantify the LAr purity by measuring the lifetime of drift electrons [1].
- Uses a drift chamber that drifts electrons from a cathode to an anode.
- Stainless steel shaping rings guide the electrons.

Schematic of a Purity Monitor

- A flash from the Xe lamp leads to photoelectrons on the cathode.
- Electrons then drift in a 20 cm drift chamber in a high voltage typically between 250-500 V [1].
- Two Frisch grids in front of the anode and cathode sharpen the signal and shorten the signal's duration.



PrM1, 60.120.240Vcm, Filtered Averages and Noise subtracted



Obtaining a Drift Electron Lifetime

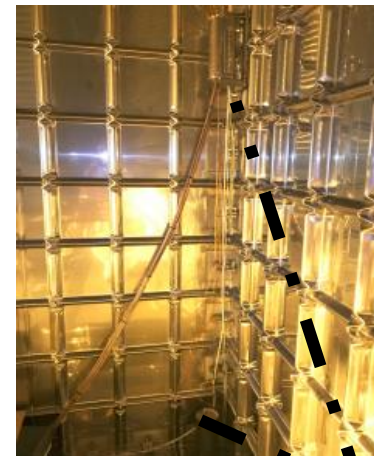
- Measure Q_a/Q_c , charge between cathode and anode.
 - $Q_a/Q_c = e^{-t/\tau}$
- Convert the ratio into a τ .
 - $\tau = \frac{1}{\log(Q_a/Q_c)} (t_{drift})$
- For Dual-Phase: $t_{drift} = t_2 + 0.5(t_1 + t_3)$

[1] S. Amerio, S. Amoroso, M. Antonello, P. Aprili, M. Armenante, F. Arneodo et al., Design, Construction and Tests of the ICARUS T600 Detector, Nuclear Inst. Methd Section A 527(2004) 329–410.

Installation and Placement

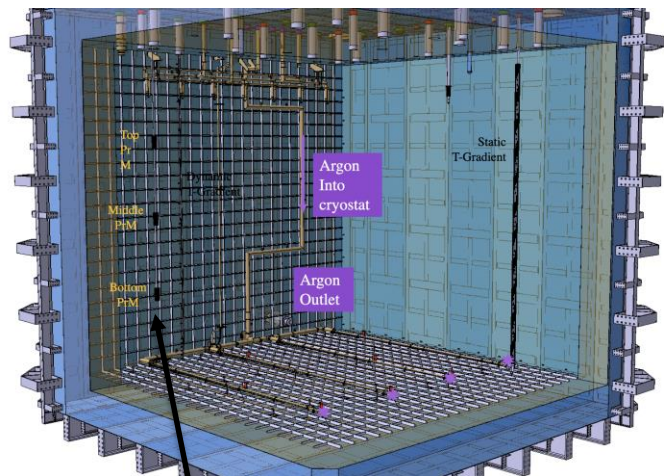
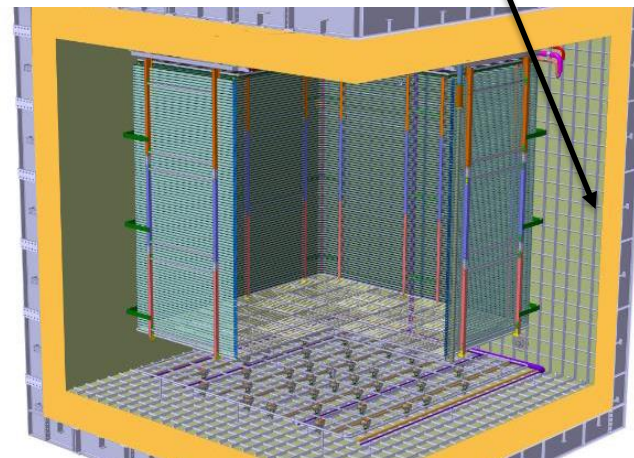
ProtoDUNE-SP

- Three purity monitors lie outside the TPC.
- ProtoDUNE-SP started operation in September 2018. Ceased operations on July 20th, 2020.



ProtoDUNE-DP

- Two short purity monitors of drift length around 20 cm sit up against a corner of the cryostat.
- One purity monitor of much longer drift length (not pictured) was also installed.
- Started operation in August of 2019. Currently taking cosmic data.

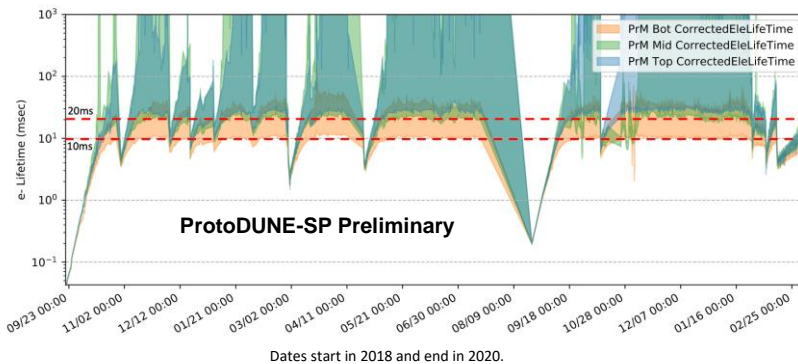


Performance of Purity Monitors

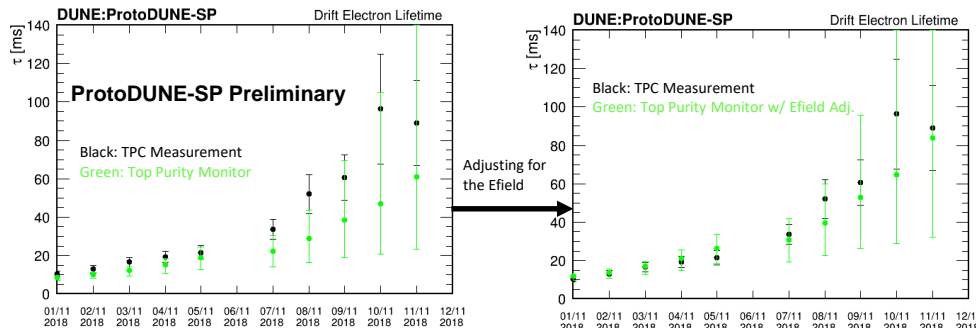
- The DUNE Far Detector has a tech. req. that $\tau=3$ ms and a tech. spec. that $\tau>10$ ms for both detector technologies.

ProtoDUNE-SP

Measured high purity throughout operations except for an incident in summer of 2019.



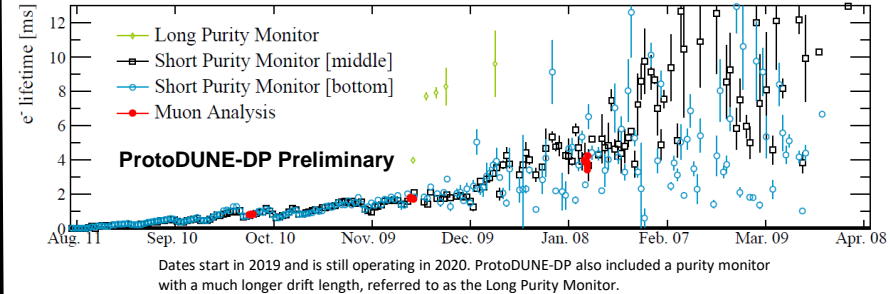
The TPC drift electron lifetime was measured directly using cosmic muons to validate purity monitor measurements.



Attachment rates for impurities differ based on the electric field of the drift volume. The purity monitors operate at around 25 V/cm, while the TPC operates at 500 V/cm.

ProtoDUNE-DP

Purity has increased over the last year of operations and met DUNE Far Detector specifications.



Cosmic muon measurements of the drift electron lifetime agree with the purity monitors in ProtoDUNE-DP.

Conclusion

- ProtoDUNE uses the same design of purity monitors as the DUNE Far Detector will and its lessons will inform the operation at the Far Detector modules [2].
- Both prototype modules measured a drift electron lifetime that met DUNE Far Detector specifications.
- Purity monitor data is being utilized to calibrate datasets for precision dE/dx measurements for both detectors.

[2] B. Abi, A. A. Abud, R. Acciarri, M. Acero, G. Adamov, M. Adamowski et al., *First Results on ProtoDUNE-SP Liquid Argon Time Projection Chamber Performance from a Beam Test at the CERN Neutrino Platform*, arXiv preprint arXiv:2007.06722(2020).