Purity monitoring for ProtoDUNE

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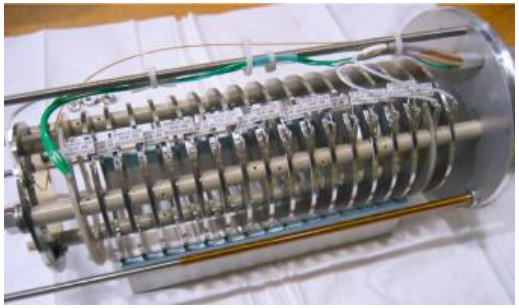
Liquid Argon Purity Monitoring

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

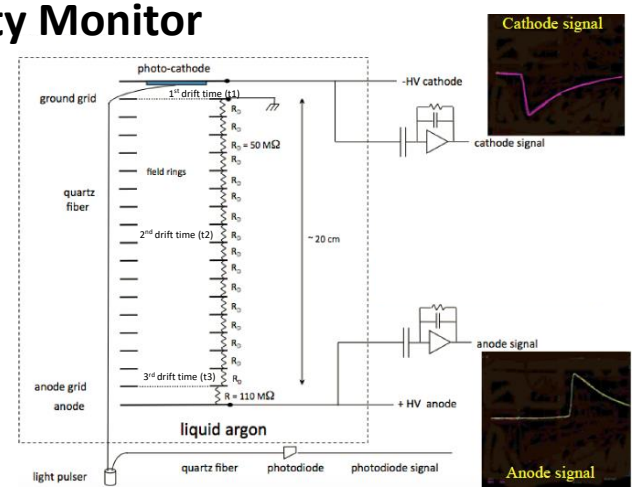
Basics



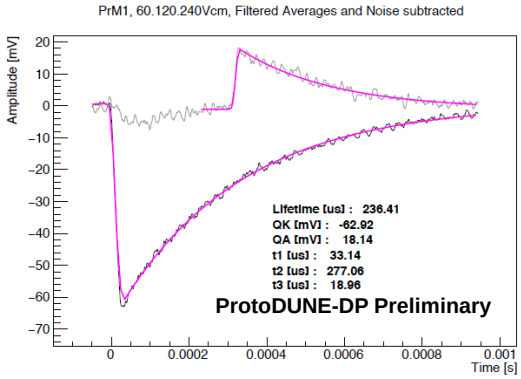
- ProtoDUNE utilizes purity monitors, the same design used for ICARUS, to measure the free lifetime of drift electrons before being captured.
- Drift electrons pass through stainless steel shaping rings as they travel.
- Small drift chamber covered in a Faraday cage. Operates at a different drift electric field than the TPC

Schematic of a Purity Monitor

- A flash from the Xe lap leads to electrons on the cathode that drift in 20 cm drift length in an electric field in order of 10^1 V/cm.
- Two Frisch grids right next to the anode and cathode shorten the time it takes to drift from anode to cathode.



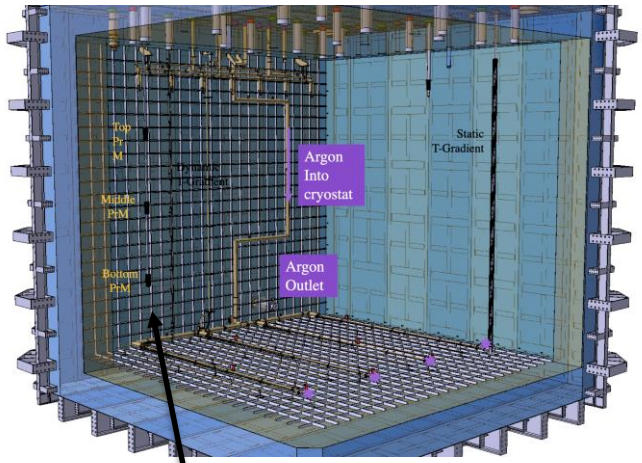
"Electron lifetime detector for liquid argon" Carugno, G. et al. Nucl.Instrum.Meth. A292 (1990) 80-584



Obtaining a Drift Electron Lifetime

- Measure Q_a/Q_c, the ratio of charge measured at the anode compared to the charge measured at the cathode.
  - $Q_a/Q_c=e^{-t/\tau}$
- This is converted to a drift electron lifetime using the Green's function of reading from the anode and cathode. In the limit that t2 is much larger than the other drift times, then:
  - $\tau = \frac{1}{\log\left(\frac{Qa}{Qc}\right)}(t2 + 0.5 * (t1 + t3))$

Installation and Placement

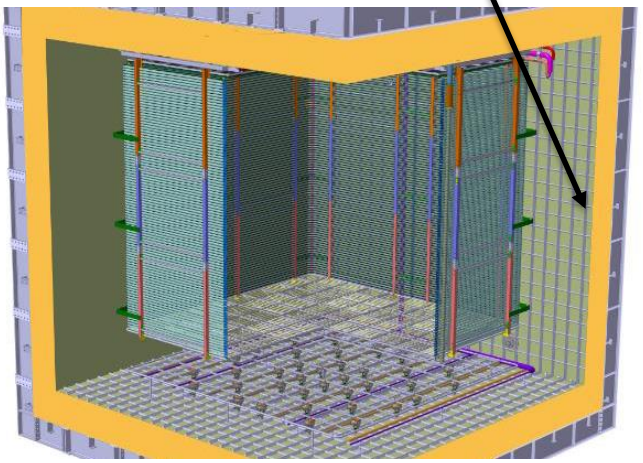


ProtoDUNE-SP

- Three purity monitors lie outside the TPC.
- The top purity monitor sits around 5 m from the bottom of the cryostat. The distance between purity monitors is 1.5 m.
- 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.
- The middle purity monitor sits 2.5 m from the floor.
- The bottom purity monitor sits near the floor of the cryostat.
- Started operation in September 2019. Currently taking cosmic data.

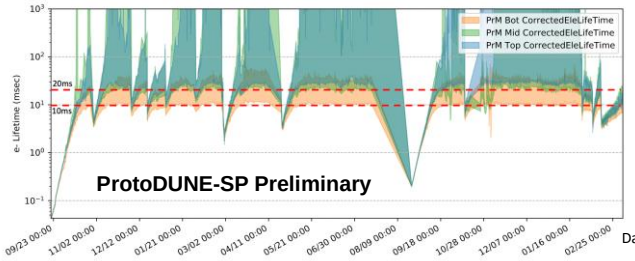


Performance of Purity Monitors

- **DUNE has the technical requirement that τ=3 ms and a technical specification that τ>10 ms for both detector technologies.**

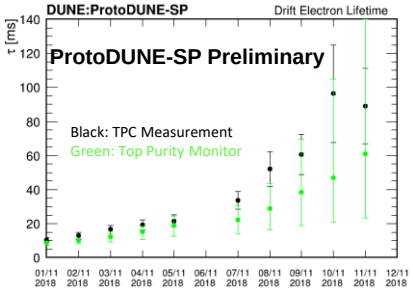
ProtoDUNE-SP

High drift electron lifetime throughout beam data-taking in Sept-Nov. 2018. Fluctuations due to pump turn-on and turn-off.



Dates start in 2018 and end in 2020

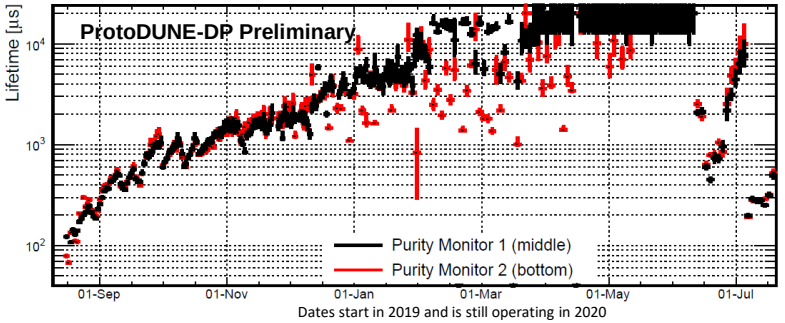
Measurements were made to compare the drift electron lifetime read by the purity monitors to that measured by the TPC using cosmic muons.



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

ProtoDUNE-DP

Purity has increased over the last year of operation. It has met the technical requirements.



Dates start in 2019 and is still operating in 2020

The decrease in purity over the past month occurred due to cryostat being opened to work on the high voltage extender.

Conclusion

- Purity monitors make necessary measurements on the drift electron lifetime of liquid argon that can be used to evaluate the charge loss between the cathode and anode in the TPC.
- Both ProtoDUNE detectors have reached the technical requirements for the DUNE Far Detectors.
- Purity monitor data is being utilized to calibrate datasets for precision dE/dx measurements for the various analyses of both detectors.