Purity monitoring for ProtoDUNE

Richie Diurba (University of Minnesota) for the DUNE Collaboration

ICHEP 2020
Liquid Argon Purity Monitoring

- Liquid argon time-projection-chambers (LAr TPCs) use the measurement of drift electrons on an anode plane for calorimetry and tracking.
- Detector technology for neutrino experiments like DUNE, ICARUS, and MicroBooNE. Even used for dark matter experiments like DarkSide.
- Electronegative impurities, like water and O₂, in 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 quantify the LAr purity by measuring the lifetime of drift electrons [1].
- Uses a drift chamber that drifts electrons between a cathode and an anode and measures the ratio between the two.
- Stainless steel shaping rings ensure the electrons travel from cathode to anode.

**Schematic of a Purity Monitor**

- A flash from the Xe lamp leads to photoelectrons on the cathode that drift in a 20 cm drift chamber with a high voltage typically between 250-500 V [1].
- Two Frisch grids right next to the anode and cathode shorten the time it takes to make a reading.

**Obtaining a Drift Electron Lifetime**

- Measure Qₐ/Qₑ, the ratio of charge measured at the anode compared to the charge measured at the cathode.
  - Qₐ/Qₑ = e⁻ᵗ/τ
- This is converted to a drift electron lifetime using the Green’s function of the signal from the anode and cathode. In the limit that t₂ is much larger than the drift time it takes to go from the Frisch grids to the cathode and anode (t₁, t₃), then:
  - τ = \frac{1}{\log(\frac{Qₐ}{Qₑ})} (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-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.
- One 20 cm long purity monitor sits 2.5 m from the floor and the other sits near the floor of the cryostat.
- Started operation in August of 2019. Currently taking cosmic data.
Performance of Purity Monitors

- The DUNE Far Detector has a technical requirement that $\tau=3 \text{ ms}$ and a technical specification that $\tau>10 \text{ ms}$ for both detector technologies.

**ProtoDUNE-SP**


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, thereby altering the drift electron lifetime measured. 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. ProtoDUNE-DP also included a purity monitor with a much longer drift length, referred to as the Long Purity Monitor.

Measurement of the drift electron lifetime using cosmic muons agrees well with the purity monitors in ProtoDUNE-DP.

**Conclusion**

- Purity monitors make necessary measurements on the drift electron lifetime of liquid argon for calibration purposes.
- 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.