Summer Research Troubleshooting ProtoDUNE

Luke M.

Standard Model (particle physics) and Neutrinos

Protons and Neutron are made up of smaller elementary particles known as Quarks and Leptons.

Leptons, unlike Quarks, can exist on their own without combing into larger particles.

Neutrinos are types of Leptons.

matter particles

	1st gen.	2nd gen.	3rd gen.
QUARK	u (up)	c (charm)	t (top)
	d (down)	s (strange)	b (bottom)
LEPTON	νe (e neutrino)	νμ (μ neutrino)	ντ (τ neutrino)
	e (electron)	μ (muon)	τ (tau)

Anti-quarks

$\bar{u}$ $\bar{d}$
$\bar{t}$ $\bar{b}$
$\bar{s}$ $\bar{c}$

Anti-leptons

e+ $\bar{\nu}_e$
$\bar{\mu}$ $\bar{\nu}_\mu$
$\bar{\tau}$ $\bar{\nu}_\tau$
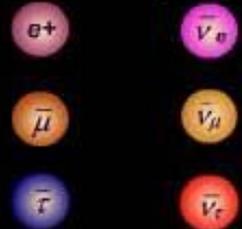
Neutrino's Unique properties

Neutrinos don't have any charge.

They will interact mainly using the weak force, but also the gravitational force.

Thus Neutrino can pass through entire planets of mass without interacting with a single particle.

Neutrinos have shown differences between matter and antimatter.

Sanford Underground Research Facility

800 miles (1300 kilometers)

Fermilab

NEUTRINO PRODUCTION

PARTICLE DETECTOR

PROTON ACCELERATOR

UNDERGROUND PARTICLE DETECTOR

EXISTING LABS
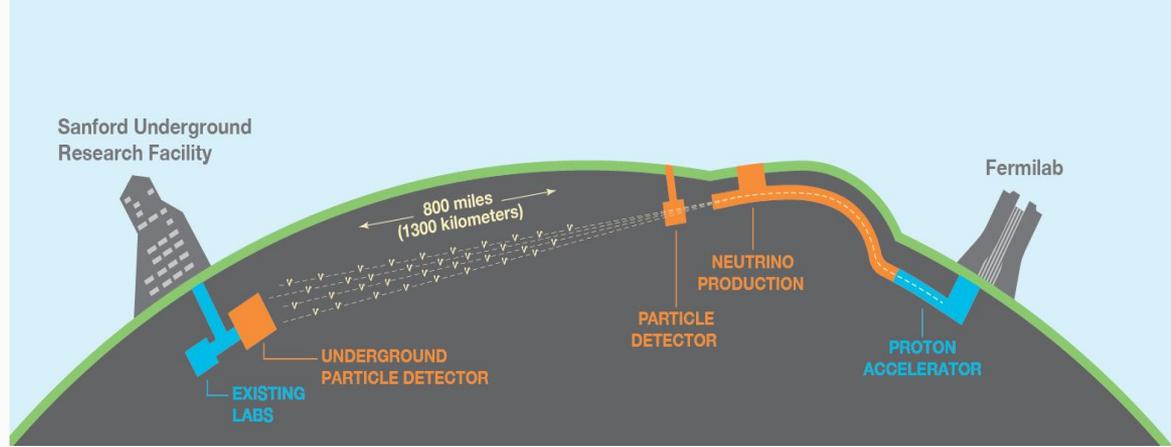
The Four Fundamental Forces of Nature
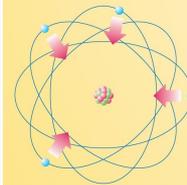
Electro-magnetism | Weak Interaction | Strong Interaction | Gravitation
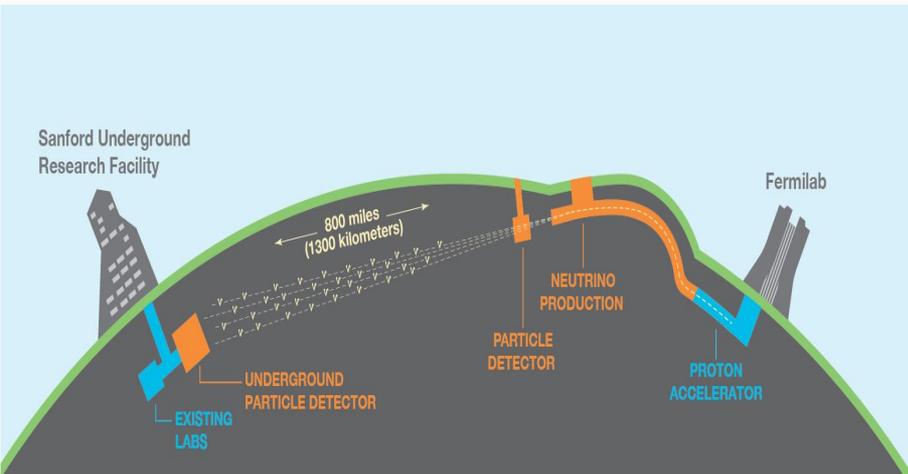
The DUNE project is trying to build DUNE Far detector inside the Sanford Underground Research Laboratory in Lead, SD.

The DUNE Far detector is a Liquid Argon Time Projection Chambers (LAr TPCs).

Hopefully this detector can be used to answer many different scientific inquiries by studying Neutrino collisions.

DUNE Far detector is planned to run five and ten years.

Our work in DUNE
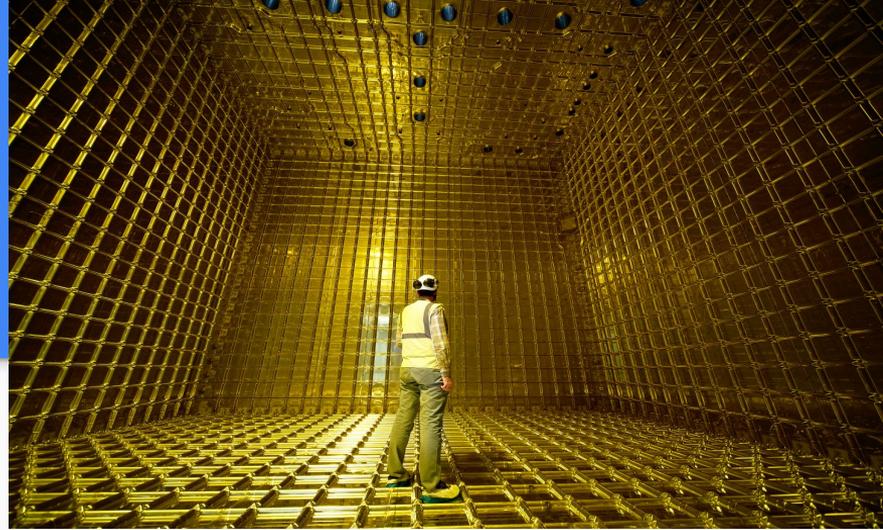
ProtoDUNE was a "small" prototype LAr TPC being studied in order to learn how to improve the long term viability of future Lar TPCs detectors.

One problem that appeared in ProtoDUNE was with its channels having difficulties detecting electrons.

I and my partner examined the protoDUNE detector's bad channels to categorize them, and then make programs that could automatically do this process for us.

Design of the Detector
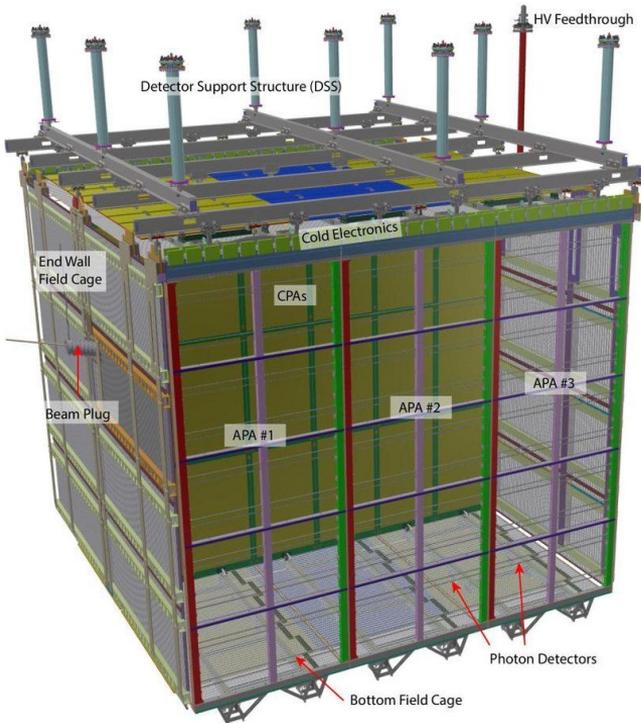
The general design of a LAr TPC detector is essentially a large tank of Liquid Argon with detectors for photons and electrons on the sides of the tank with a uniform electric field throughout the whole tank.

In the APAs are composed of individual channels that collect electrons.

The are two types of channels Collectors and Inductors.

The Data from the Detector

The detector collects data for at least an hour, which is called a run.

Each run is broken up into multiple events (6000 μs).

Originally, we were given only one recent run to look at along with a few programs and data used to make two different graphs.

Waveform Graphs

Waveform Graphs:

A waveform graph is a voltage (ADC) vs time (μs) plot.

Pedestal: The voltage the waveform centers around.

Hit: A large spike in the waveform, indicating a detection of a pulse of electrons.

Noise: The voltage spread of the pedestal.

The waveform graph shows a single event from a run.

Run 11621 Channel 11454

Run 11621 Channel 12797
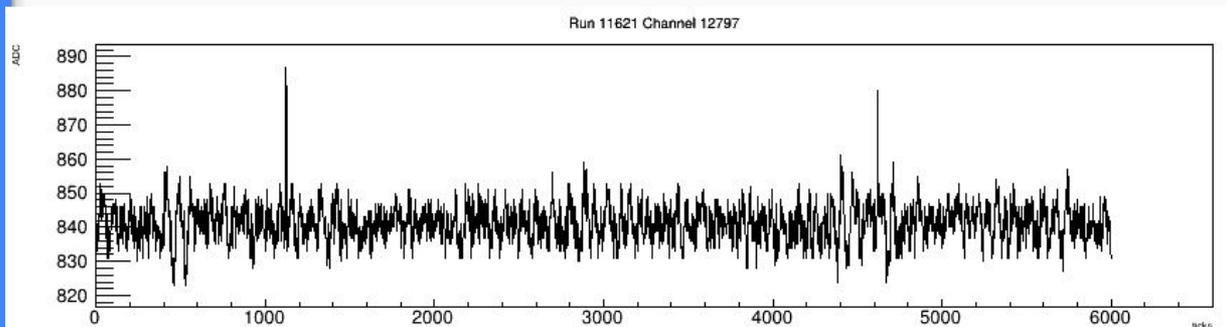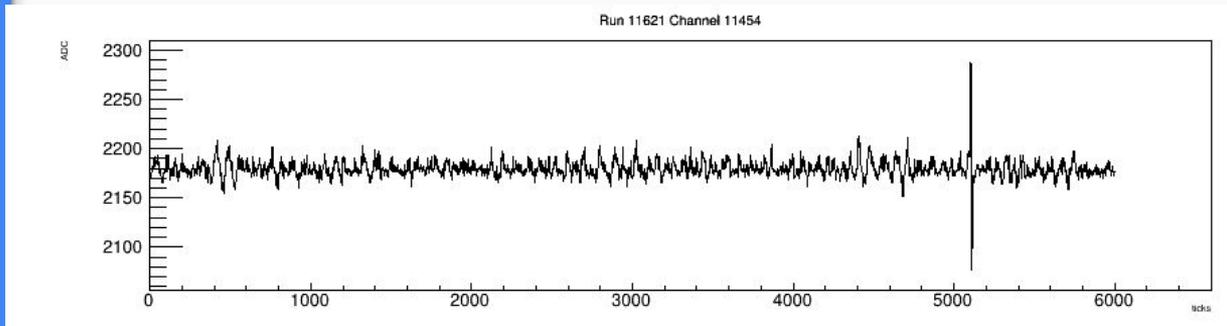
Waveform Graphs

Reco Hit Tagging:

A program that examines channel's data, and can be used to count the number of detections.

This program is used to create History Graphs (More on that later).

Run 11621 Channel 11454

Run 11621 Channel 12797
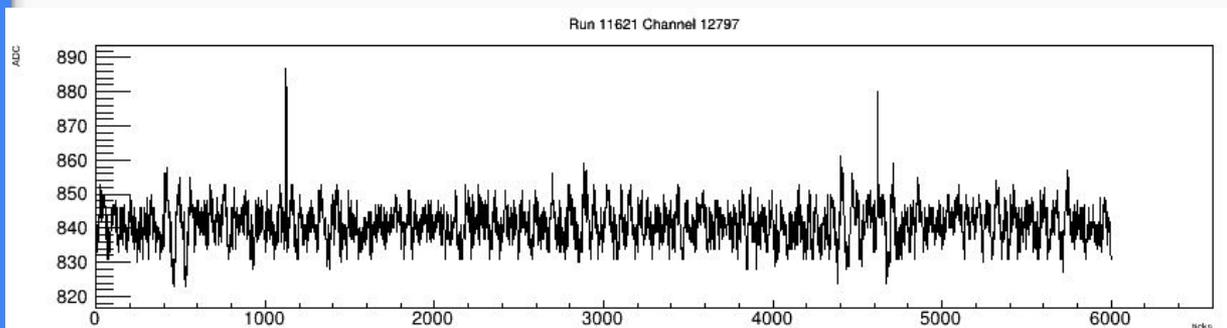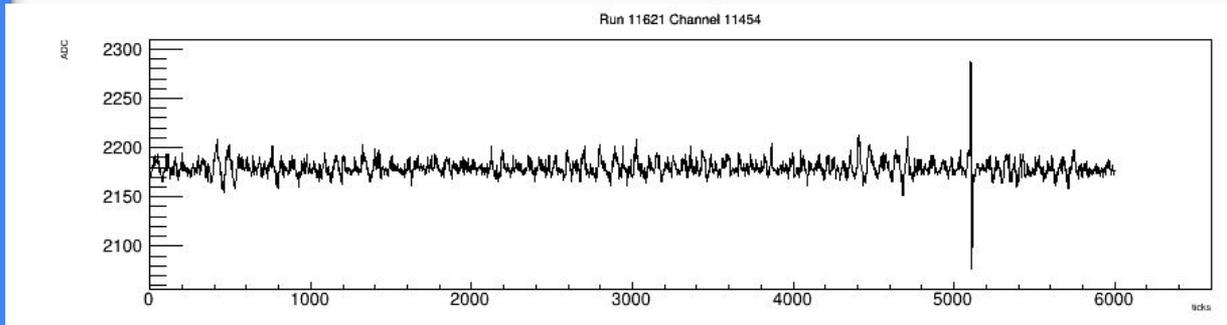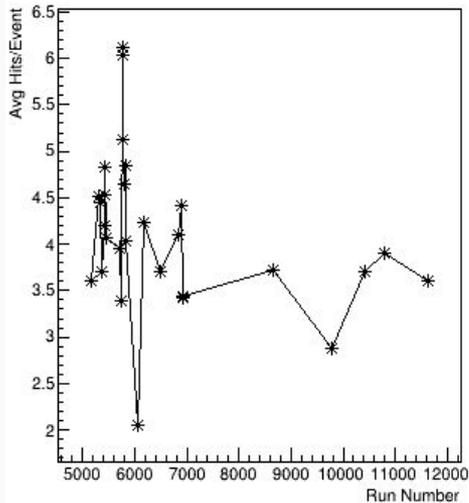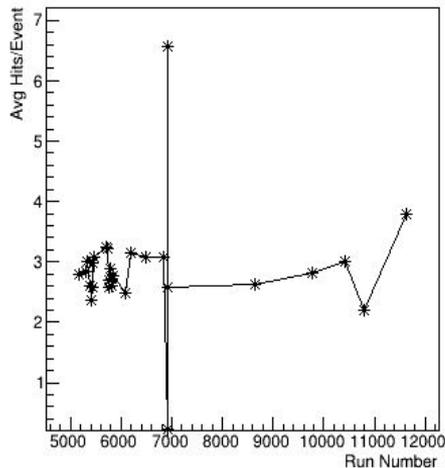
History Graph

History Graphs:

These graphs look at how well a channel has functioned over its history.

The y-axis is average Hits/Event (An event is 6 ms). The x-axis is the run number. A run is when the detector was collecting data.

A run with more than 14 or 0 average Hits/Event is considered abnormal behavior.

History graphs were composed from an event from multiple runs of the detector.

Categorization of the different problems with the channels

We used these graphs to categorize the problems channels can have into distinct groups.

The two problems that occur most often were channels dying or having electronic issues.

The 'death' of a channel

Electronic Issues

History of Channel 11517

Run 10794 Channel 4385
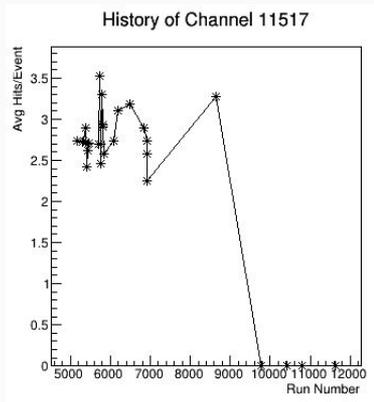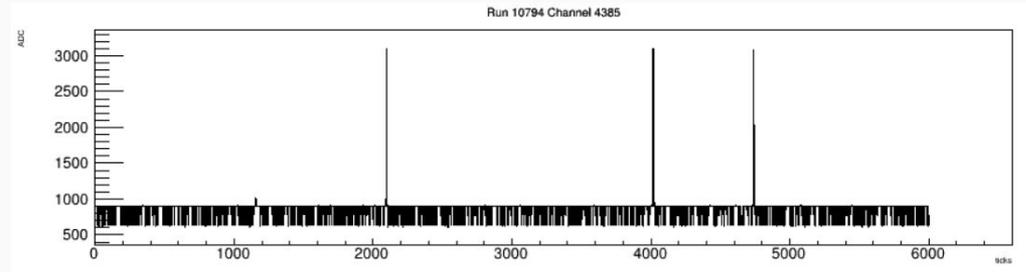
Problems with the History Graphs

Reco Hit Tagging Errors

We later found that for certain channels, the Reco Hit Tagging program wasn't recording hits when those channels had hits in their waveform.

Low Hits/Low Volts

This is a group of alive channels that due to a design flaw, could naturally get 0 Average Hits/Event for a run.

History of Channel 204
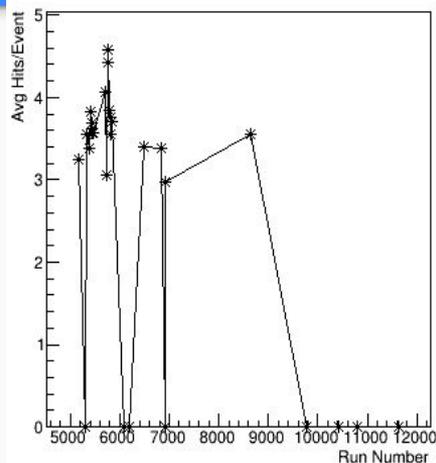
History of Channel 12799
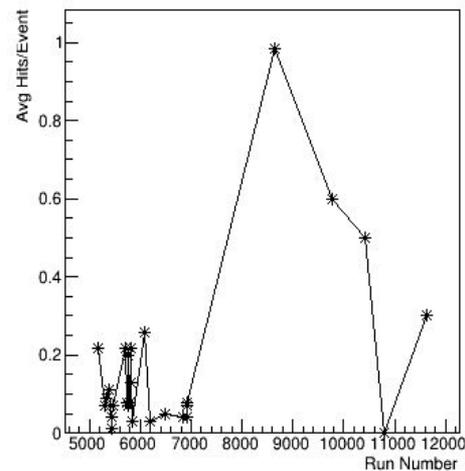
Run 11621 Channel 204

Problems with the History Graphs

Run 10794 Channel 1548
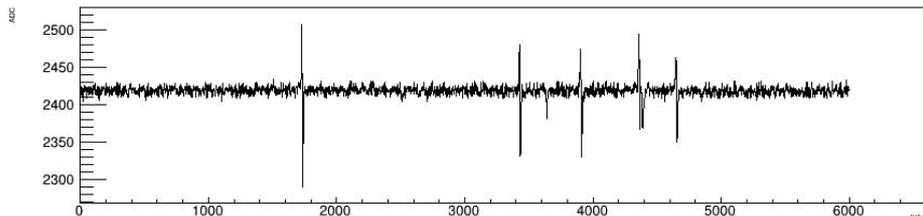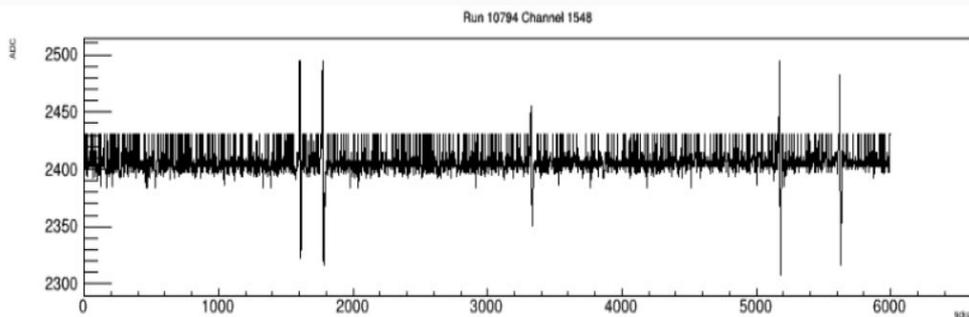
There were some Electronics Issues that couldn't be detected with the History Graphs.

The Electronic Problems couldn't be detected due to not being disruptive enough for it affect how Reco counts hits.

There were also a large group of channels that were disconnected, and thus didn't have a History Graph.

Solution to problems with History Graphs

Our solution was only using the Waveform Graphs, as they were more reliable.

By identifying unique traits to the different disruptions caused by each problem, we're able to make programs to identify each problem from the whole list of channels.

History of Channel 200
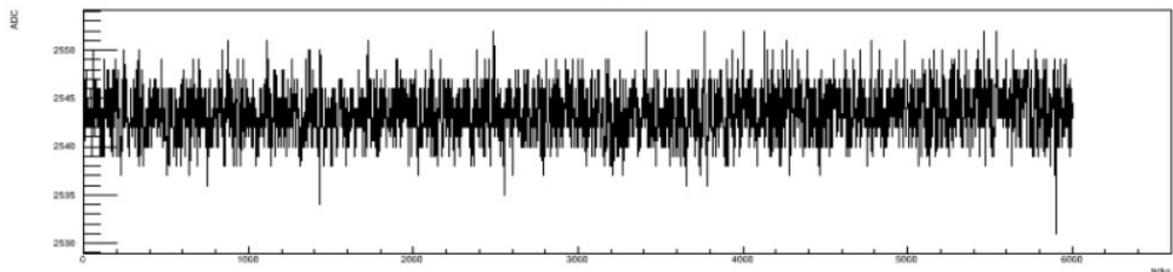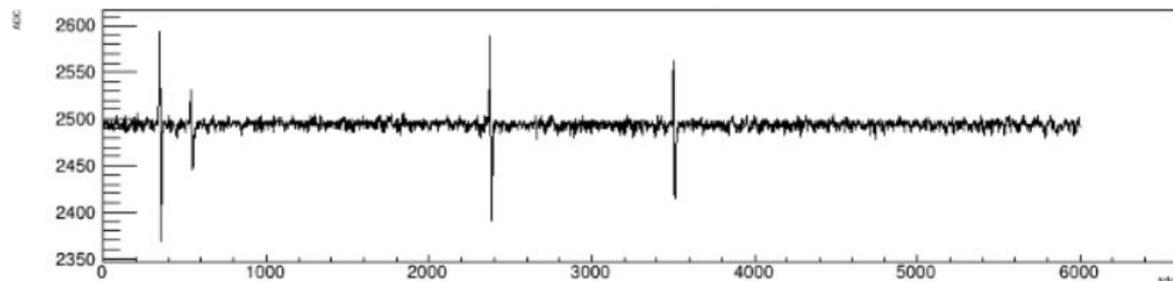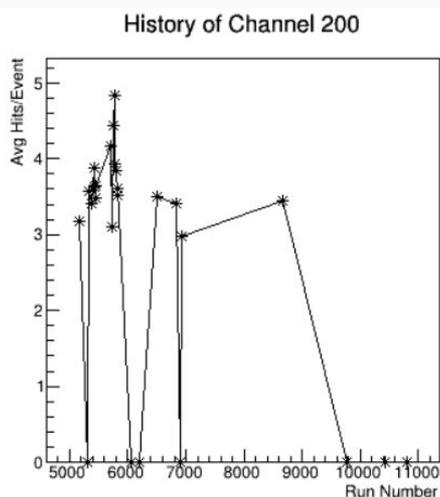
Dead Waveforms

The new way we identified whether a channel was dead was by checking if the channel had a run with a Dead Waveform.

A Dead Waveform has a different ratio between its range and standard deviation than a normal Waveform.
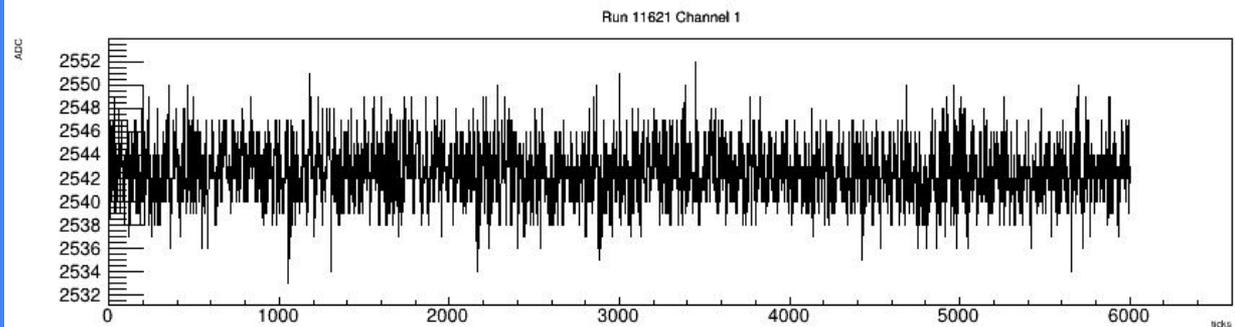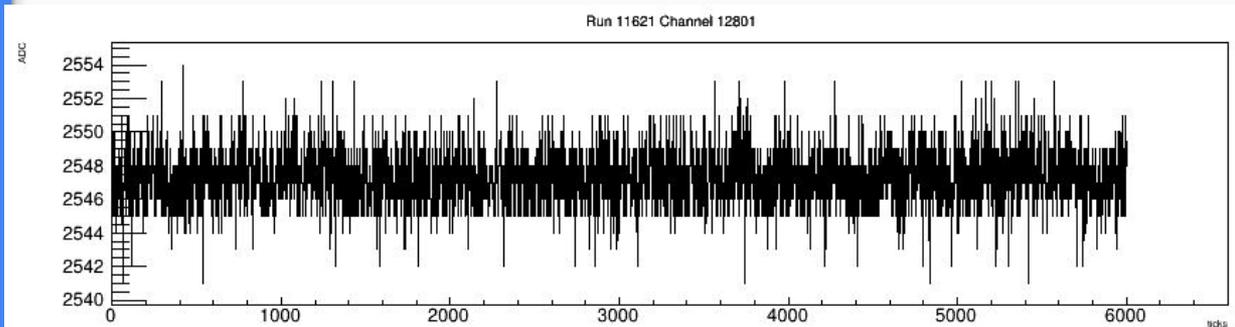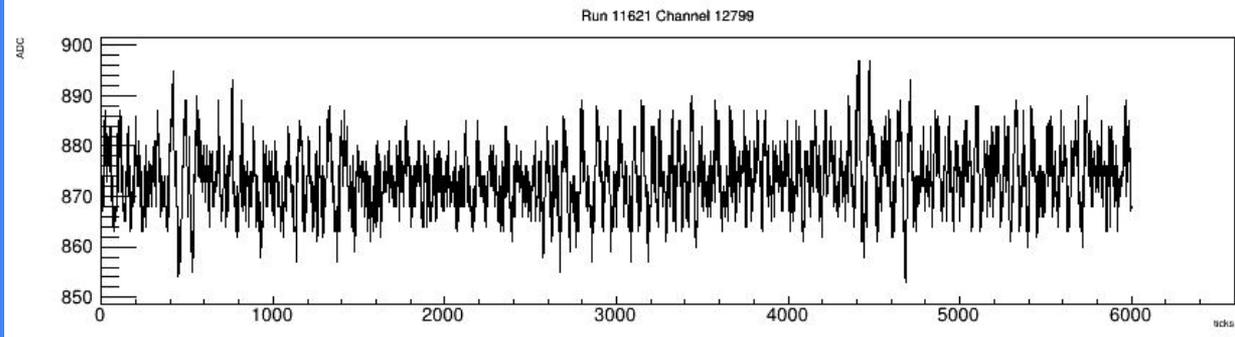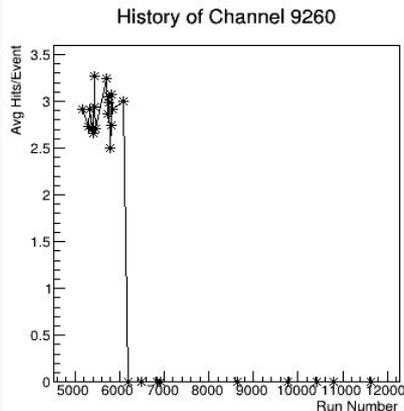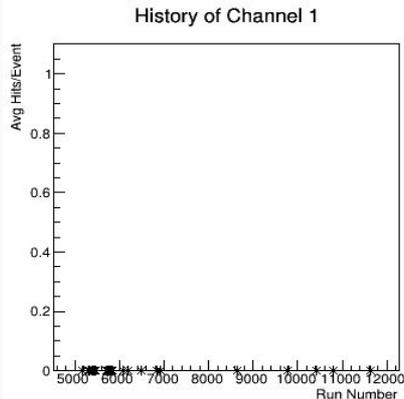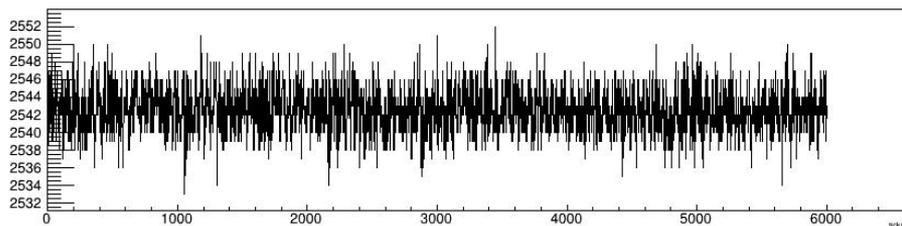
Hard Dead Channels

For a channel to die, it must no longer record any hits in its waveform.

It must also never at any point go back to normal activity.

Channels can die at any point.

Intermittent Channels

Intermittent: Channels that have died at least once and revived.

These channels can come in groups or alone.

It is possible for a channel to die and revive during a run.
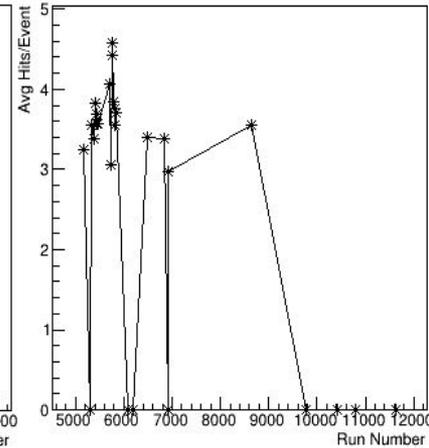
Electronic Issues

Noisy: A hitless waveform that looks normal, but its noise spans 100 ADC.

Oscillators: A waveform that oscillates between different values.

False Hits: Waveforms that jumps to high or low values.

Streak: A waveform that gets stuck on a single value.
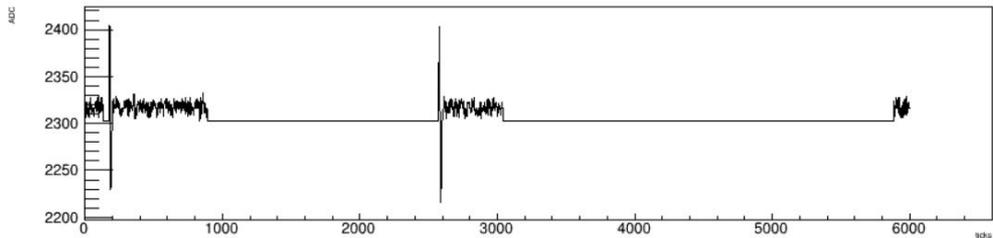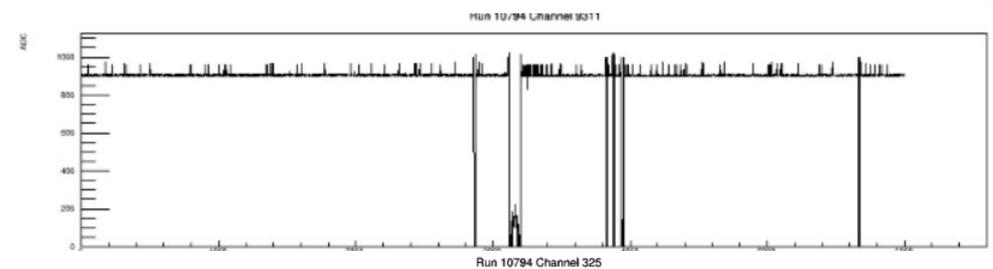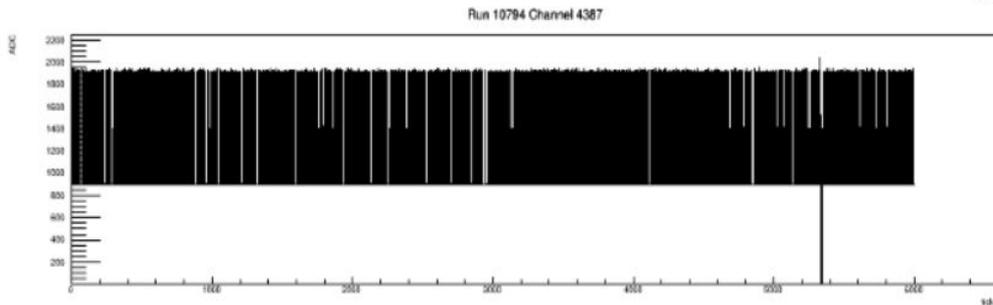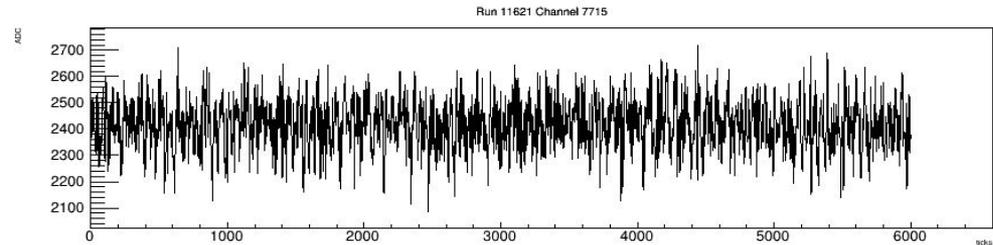
Electronic Issues Methods
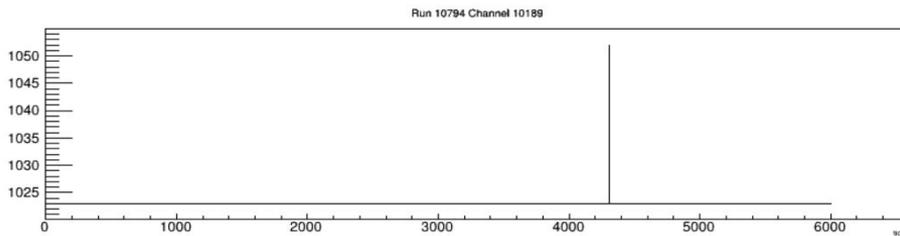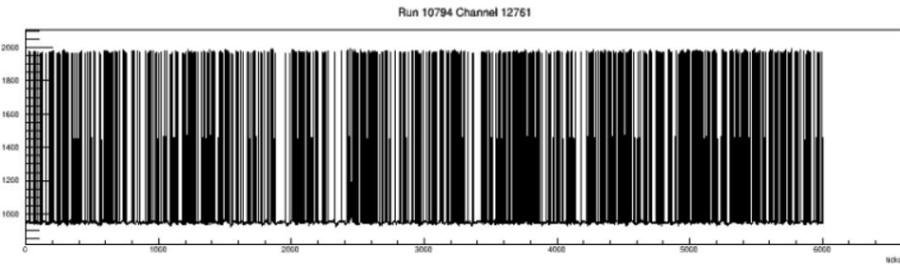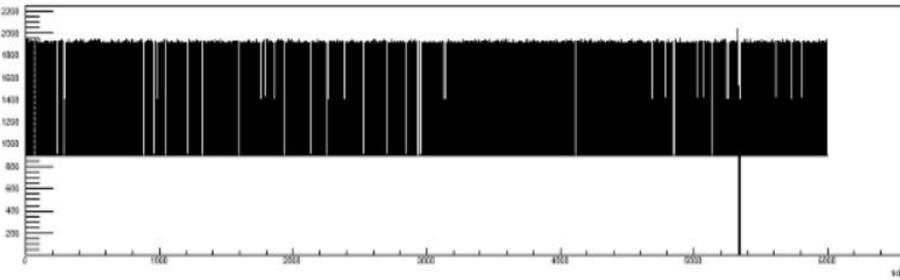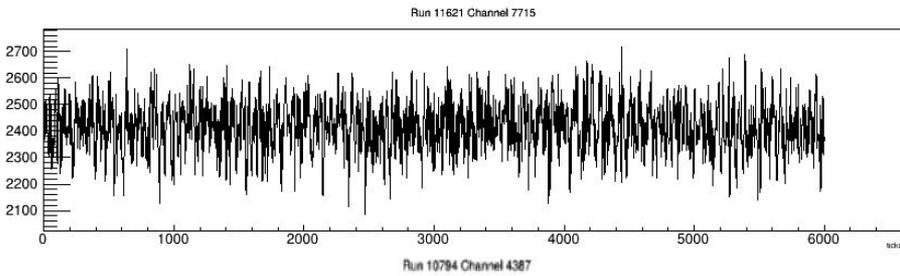
Noisy: Identified by looking at the number of times all the different values in the Waveform repeat.

Oscillators: Identified by seeing how many times one or two values in the Waveform is repeated compared to nearby values.

False Hits: Identified by seeing the standard deviation of potential 'hits' in the Waveform graph.

Streaks: Identified by examining how long a channel's Waveform graph stays on one value.

Predicting Bad Channels

It does not appear that we can use our data to predict when a channel goes bad.

The change between an alive channel into a dead channel is practically instantaneous.

While Electronic Issues appear to be more gradual, they still occur over a fraction of a second.

How some channel go bad or transition is still unknown.
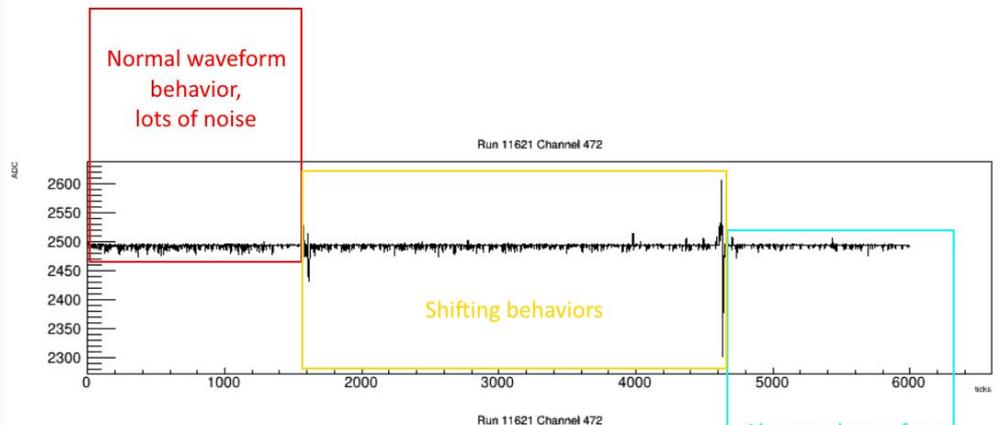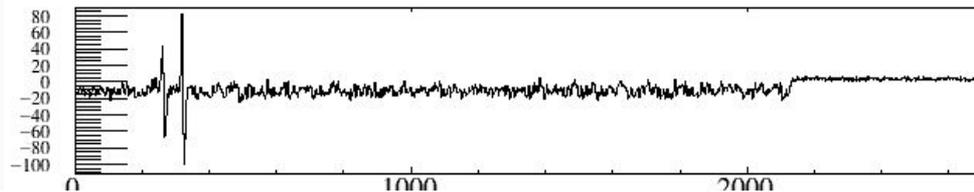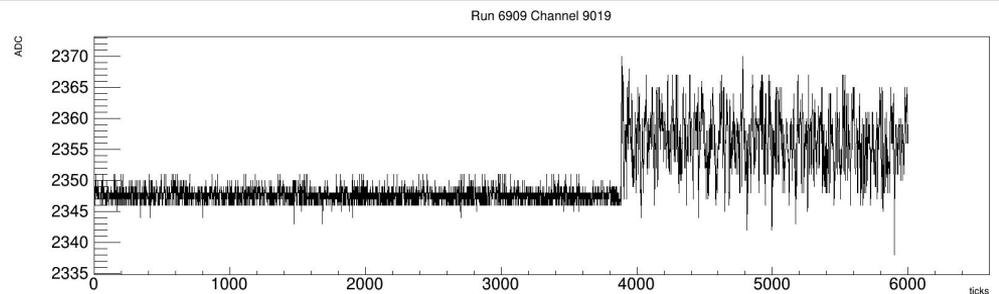
Summary

During our research, we discovered there have been 368 total channels that have gone bad over the two years protoDUNE has been active.

Since there are 15360 channels in the detector, this mean about 2.4% channels in the detector have ever been bad at one point or another over the past two years.

Of those 368 bad channels, 219 channels are currently bad, or about 59.5%.

Overall, these number actually show that protoDUNE's channels had been functioning very well, with very few of them actually becoming bad channels.

Our research itself has produced programs for identifying every known problem a channel in protoDUNE, although we couldn't find any methods for predicting bad channels.

Acknowledgements

Dr. Andrew Alton

David Wells

Thomas Junk

Augustana University

Augustana Physics Department

National Science Foundation REU program Black Hills State University

Fermilab

CERN

Sanford Underground Research Project

Thanks for watching