Investigation of Detector Readout Systems

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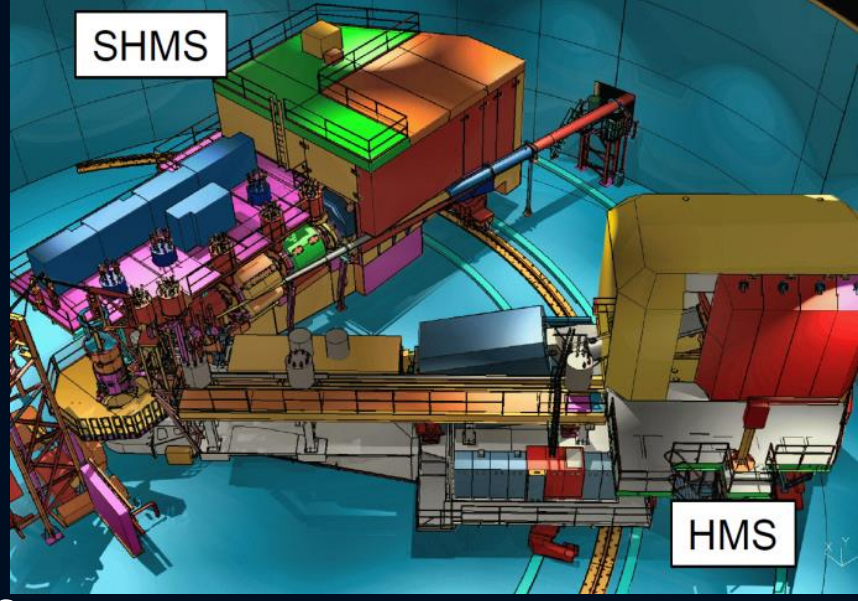
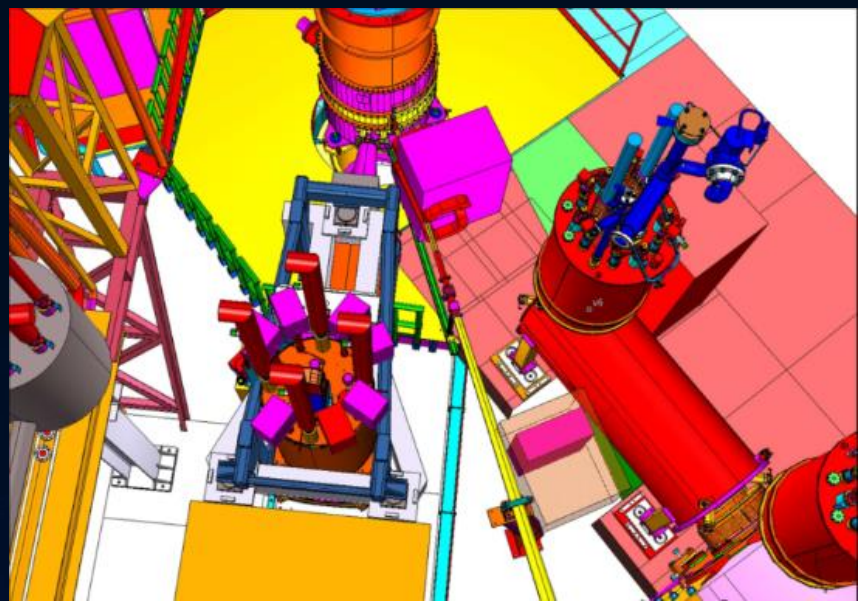
Background

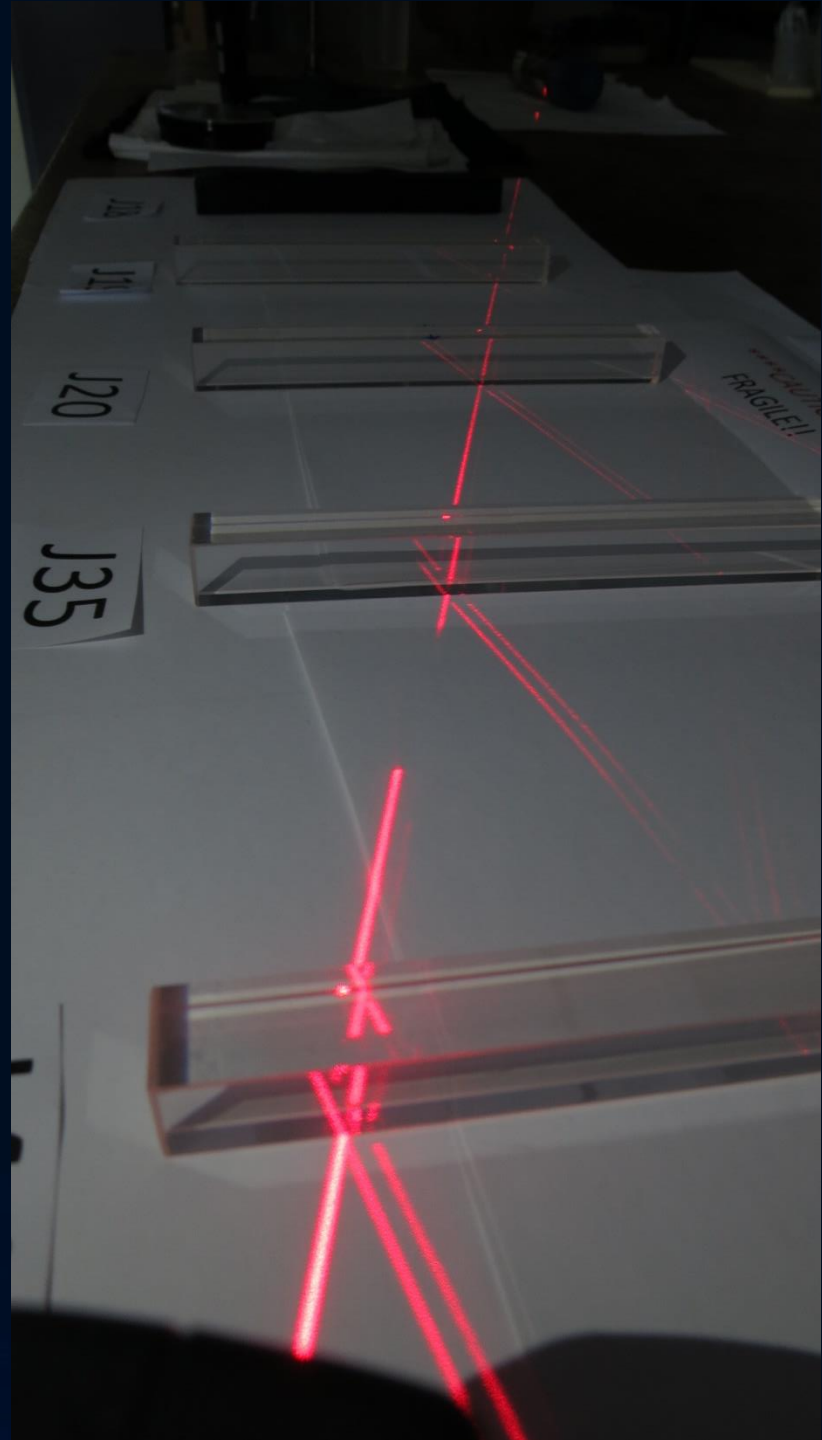
- High Momentum Spectrometer (HMS)
  - Designed to detect charged particles
  - Uses magnets to bend charged particles into the detectors
    - If one knows the mass of a particle, on can know how far it bends and place detectors accordingly
- Neutral Particle Spectrometer (NPS)
  - Designed to detect uncharged particles
    - As opposed to the HMS and the SHMS currently at JLAB
  - Uses a magnet to draw all charged particles away from the detectors
  - Mainly uses a calorimeter to detect particles





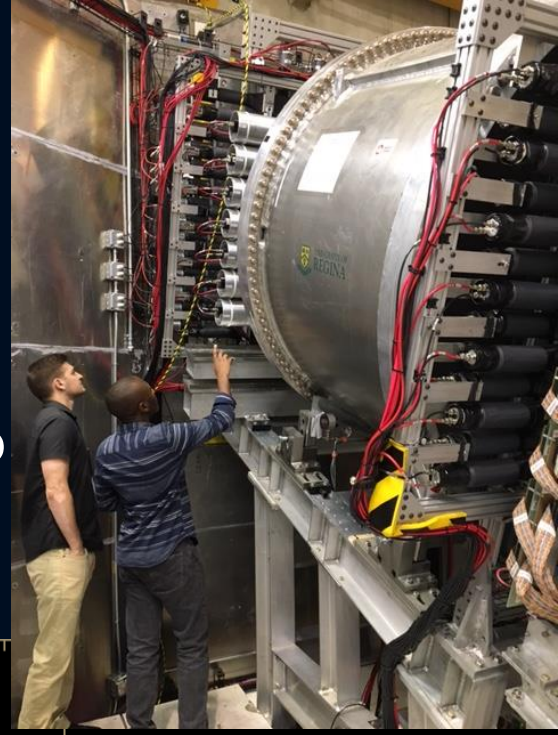
Calorimeters

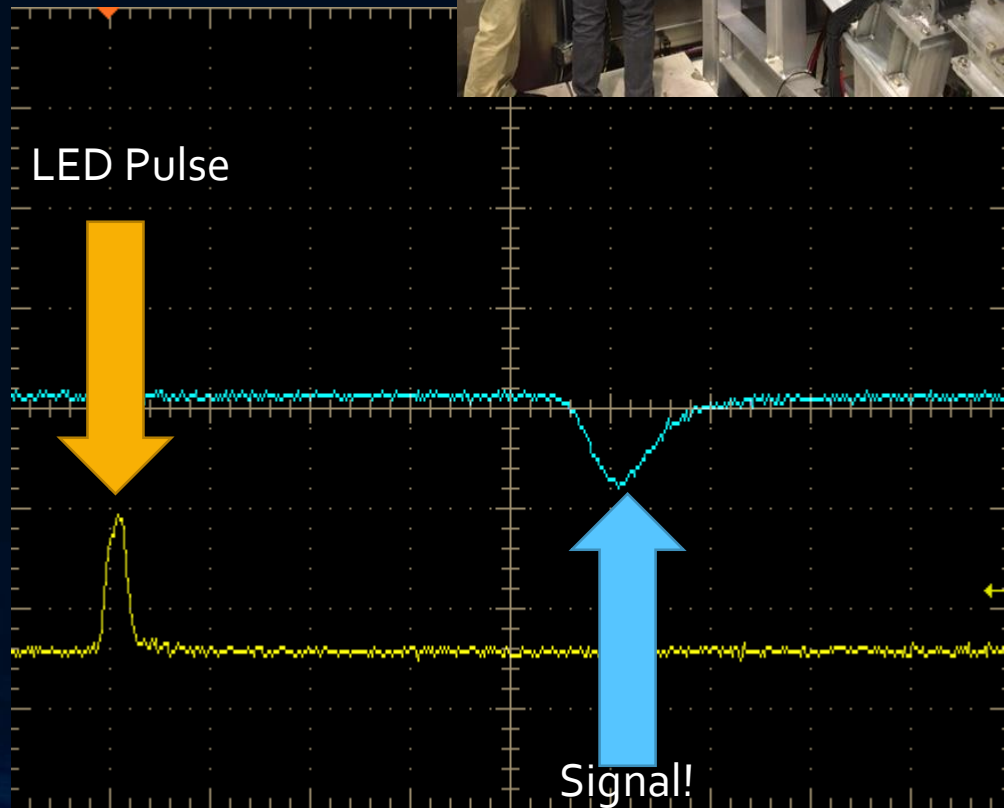
- Calorimeters are used to detect particles in both the NPS and HMS
- Calorimeters use specific materials (in this case $PbWO_4$ crystals) to detect minute particles
  - Materials need to be / have:
    - Dense and Radiation Hard
    - Low Molière Radius
    - High Light Yield (Transparent to Light)
- The amount of light created through scintillation is small
  - Humans cannot see it, therefore we need light collectors
    - PMTs
    - APDs



HMS Aerogel Cherenkov Detector

- The HMS Aerogel Cherenkov Detector was built ~11 years ago
- The 14 PMTs that were originally in the detector were tested and assumed dead
- I tested the PMTs and found a signal!

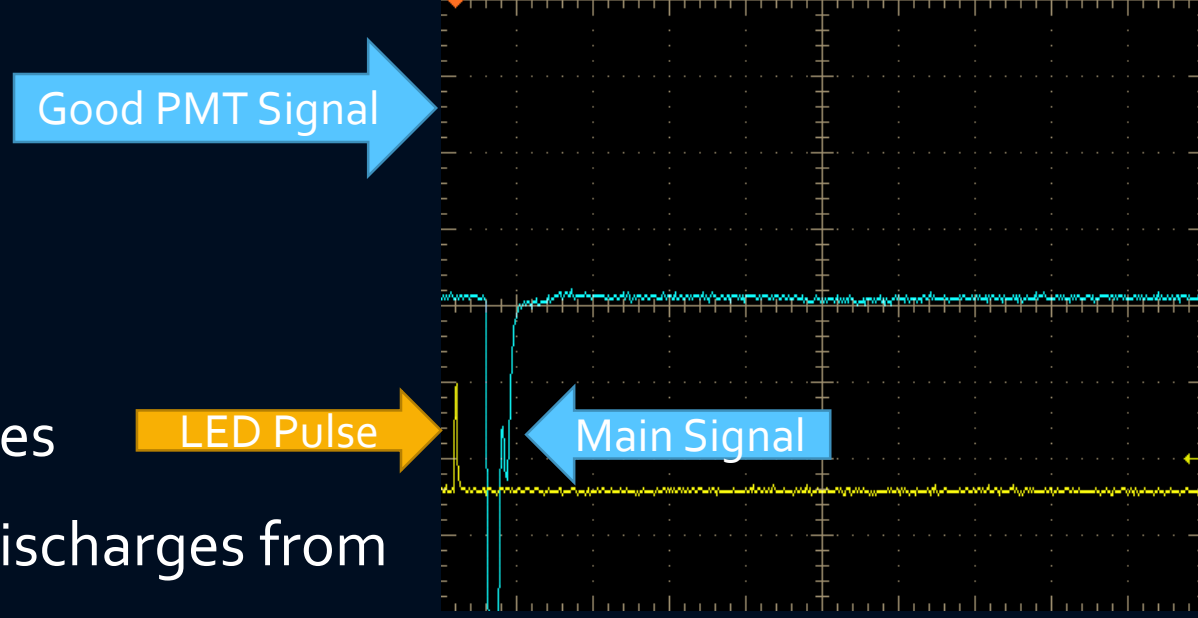


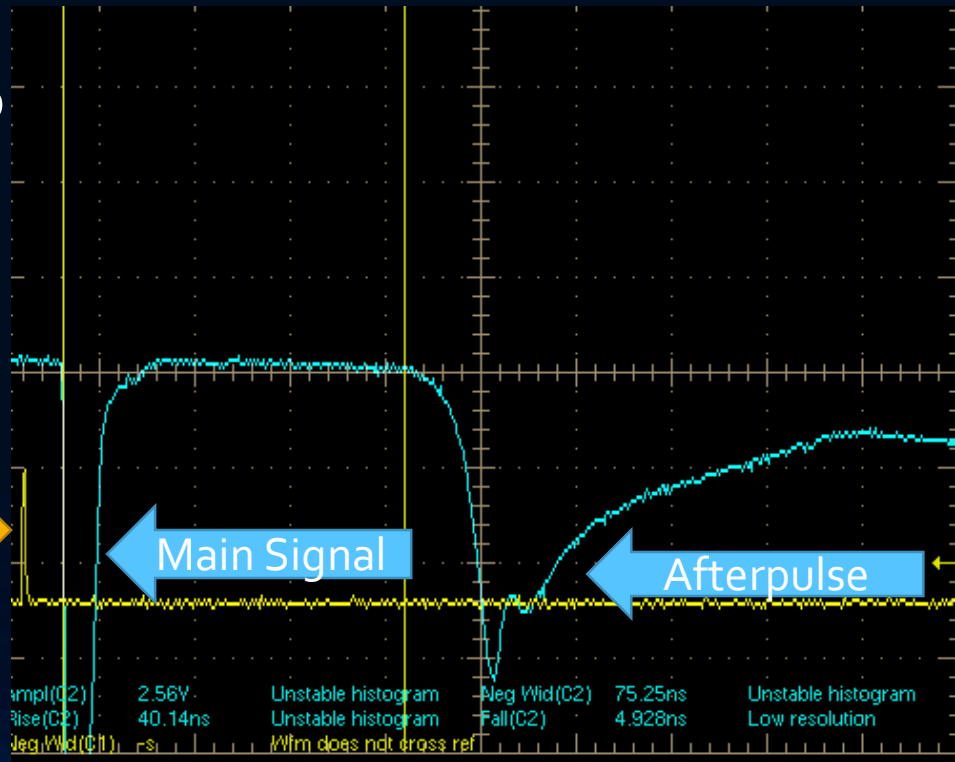


BUT..... ☹

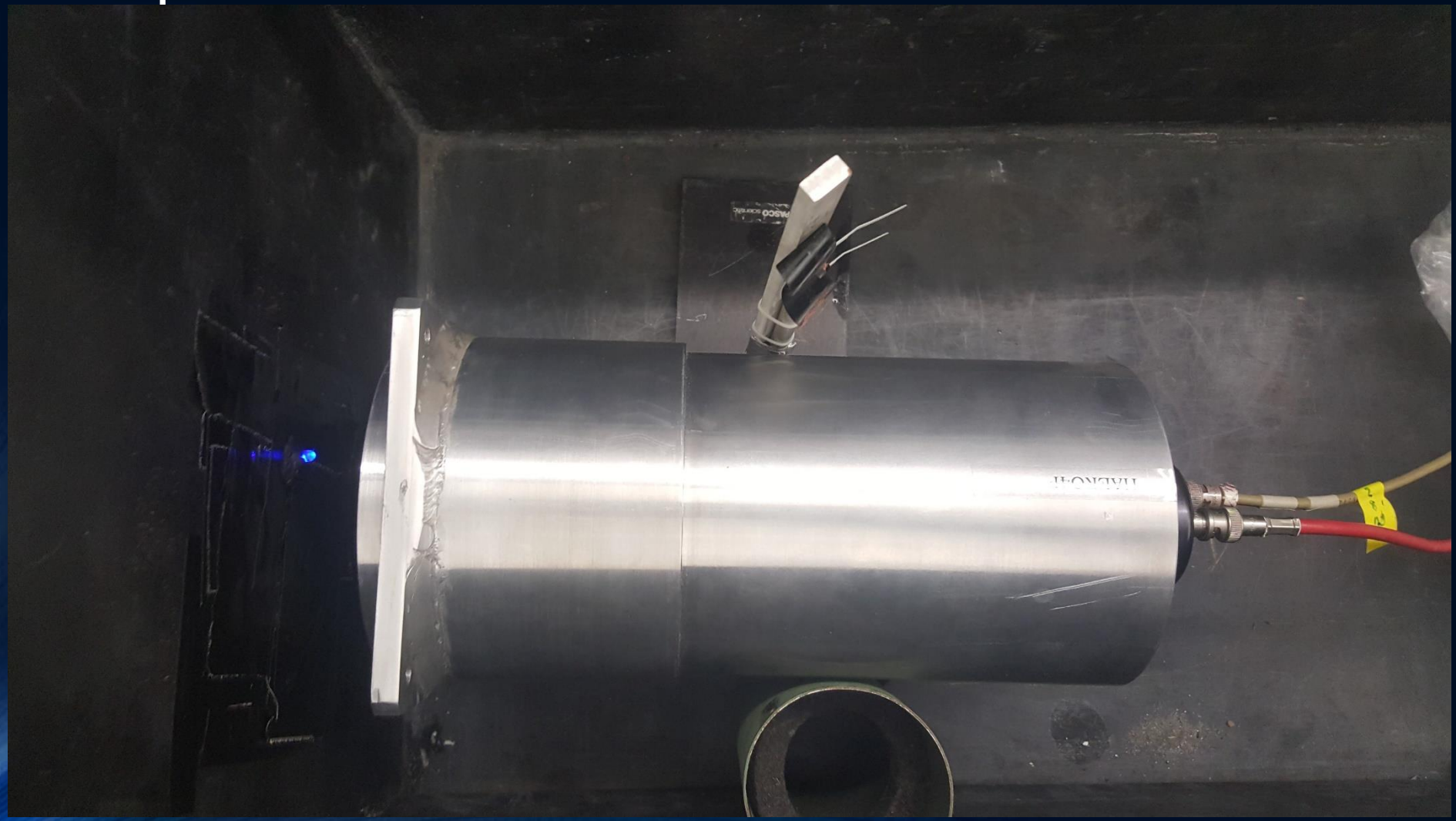
Afterpulses

- The signals that I found had afterpulses
- Afterpulses occur due to Townsend Discharges from the Helium inside of the PMT
- These afterpulses are evidence of Helium inside of the Vacuum of the PMT (According to a Research Paper by Incandela *et al.*)
- These afterpulses ruin the PMTs as their signals are now amplified by the afterpulse and any coincidence settings can pick up the afterpulse instead of the actual signal



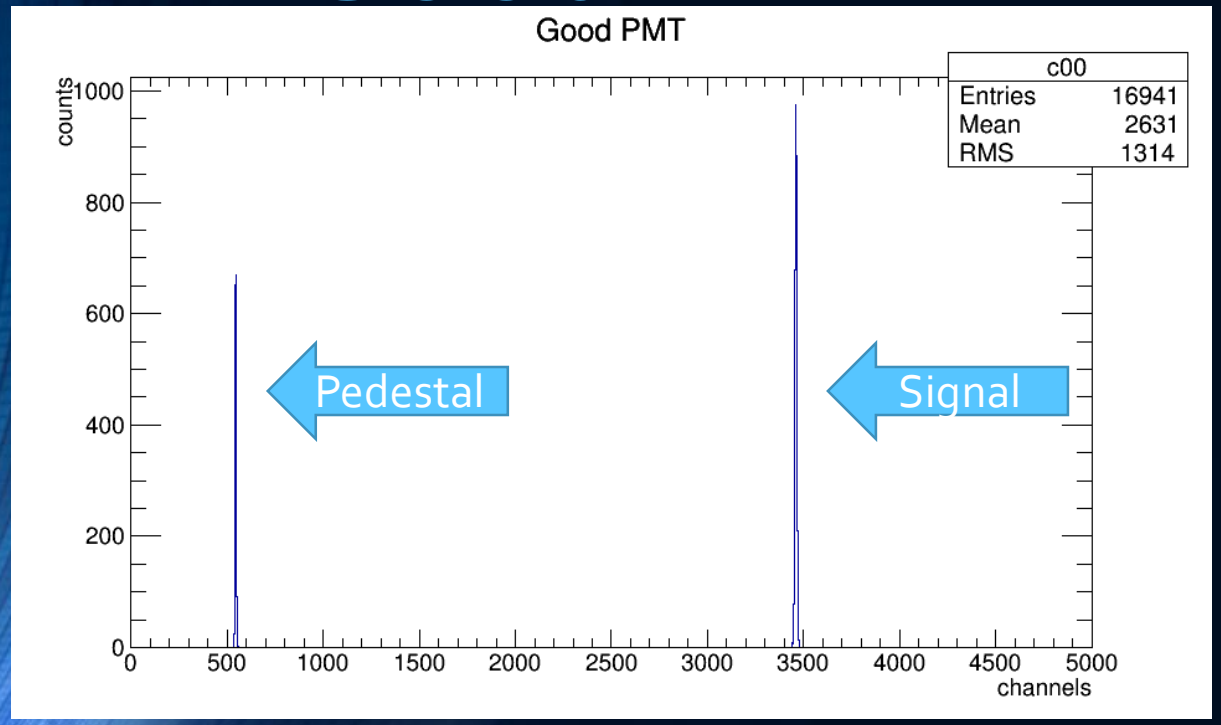


Setup

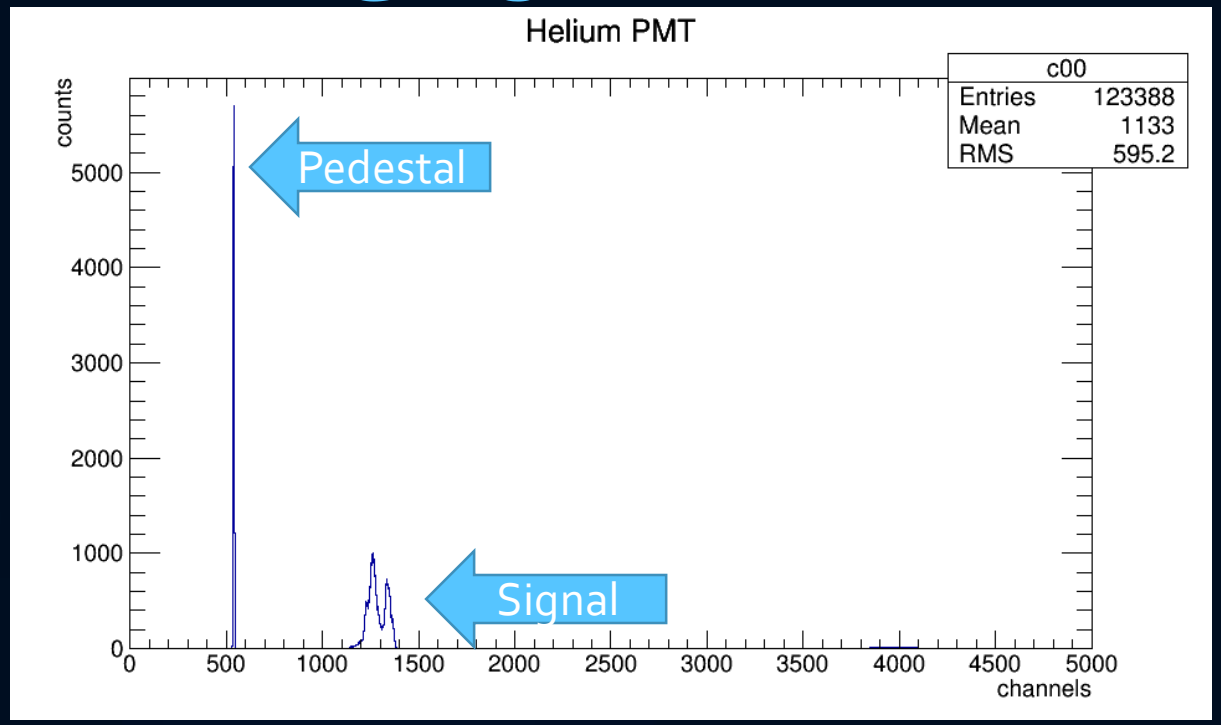


Signal Comparison

Good PMT



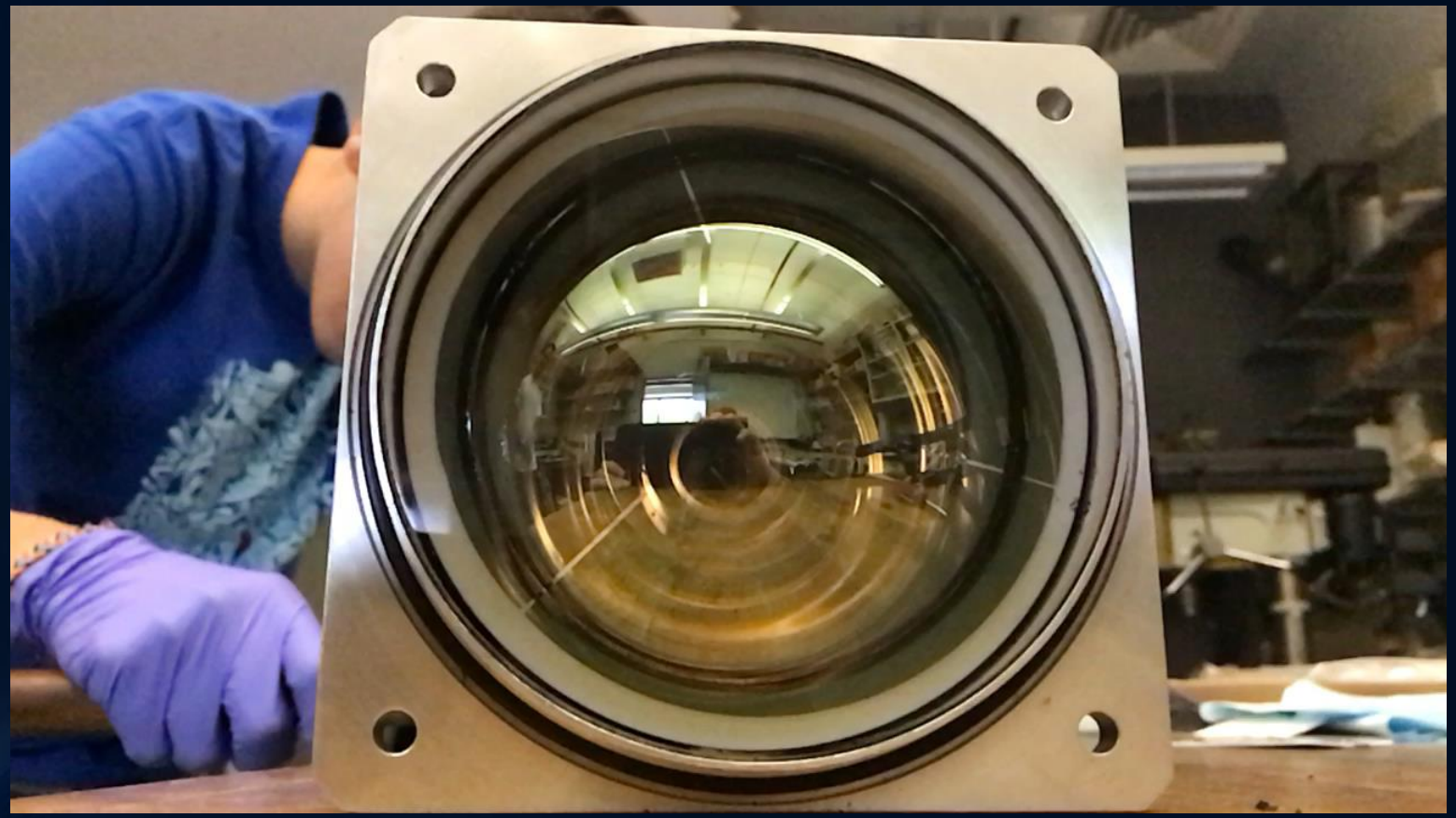
Helium PMT



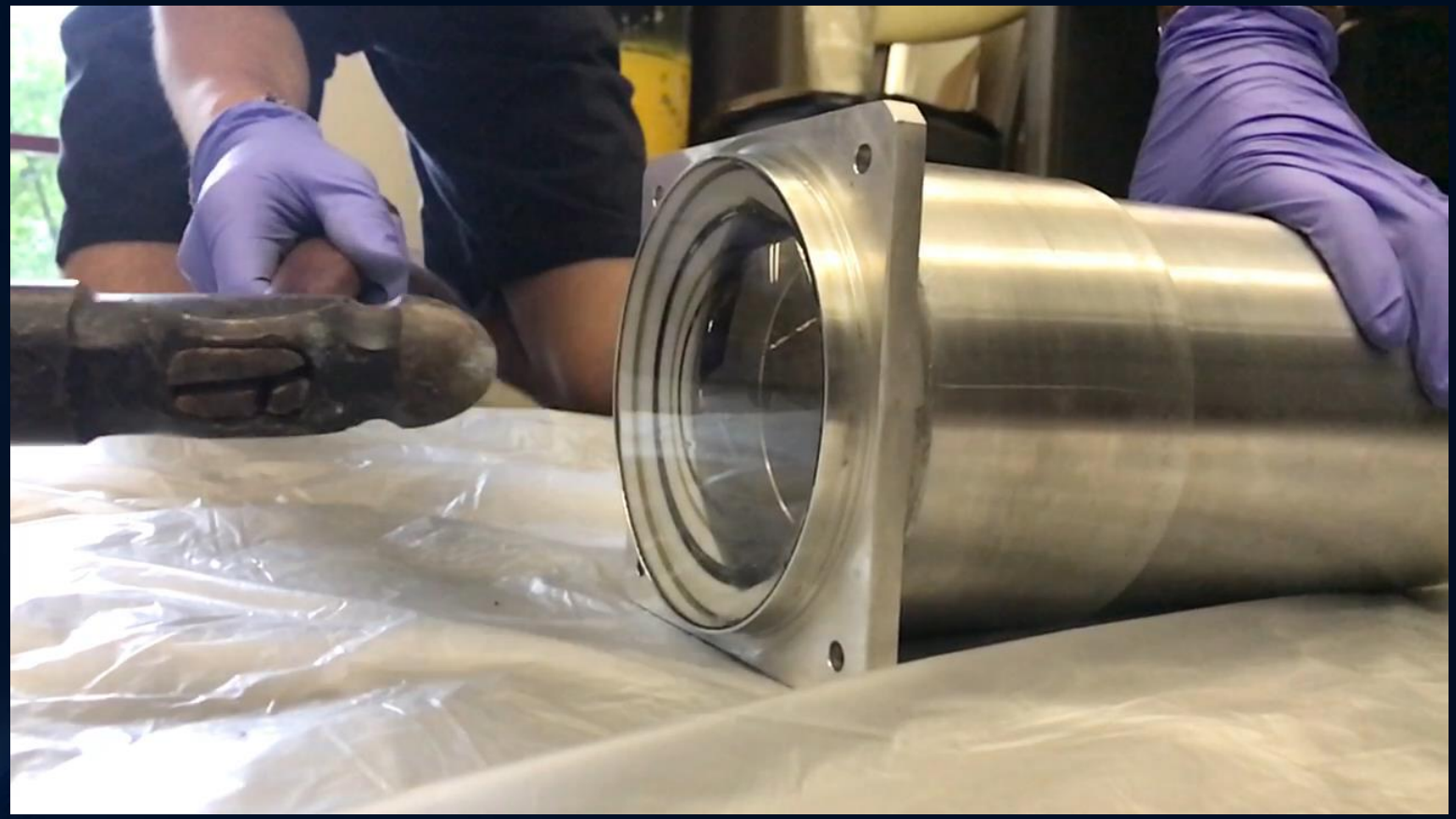
Removing PMTs

- Because of that, we had to remove PMTs from their cases
- To get rid of the Silicon, they were soaked in Xylene and then we could take out the PMTs

The Process



The Process – Part 2



Analyzing the Glass

- We then sent the glass of the PMT to be analyzed for its material components so we could determine its permeability to Helium
- A paper by Altemose provides a formula that relates the permeability constant of glass to molar masses of specific materials within it
- The full results will be available soon, but so far its seems as if the glass is permeable to helium in accordance with the PMT manuals and the research papers

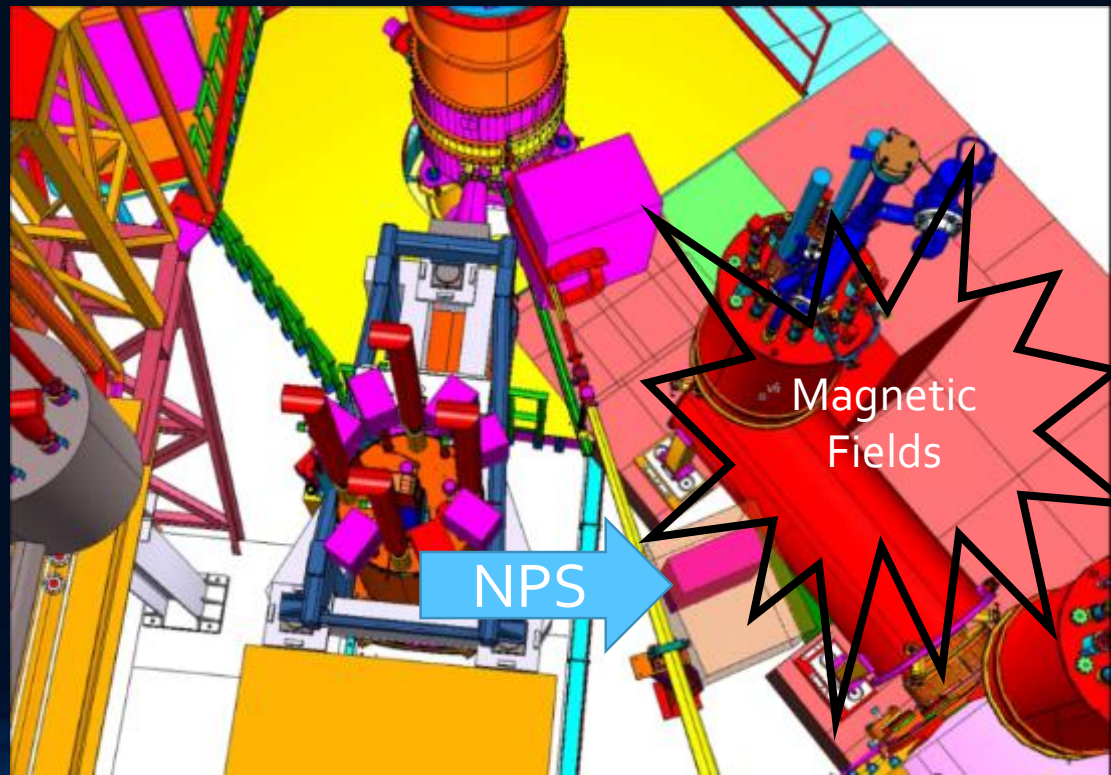
Quantification of sample PMT GLASS TOP CENTER

R.M.S.:	0.019
Result status:	NoC;
Sum before normalization:	81.3 %
Normalised to:	100.0 %
Sample type:	Loose powder
Correction applied for medium:	No
Correction applied for film:	No
Used Compound list:	OxidesVSL
Results database:	omnhefilm11min
Results database in:	c:\panalytical\superq\userdata

	Compound Name	Conc. (%)
1	Al2O3	4.664
2	As2O3	0.213
3	B2O3	! 0.000
4	BaO	0.054
5	CaO	0.027
6	CeO2	0.000
7	CuO	0.006
8	F	! 0.000
9	Fe2O3	0.020
10	Ga2O3	0.003
11	K2O	9.179
12	Li2O	! 0.000
13	Na2O	1.120
14	NiO	0.008
15	P2O5	0.007
16	PbO	0.014
17	Sb2O3	0.071
18	SiO2	84.571
19	SnO2	0.018
20	SrO	0.002
21	ZnO	0.013
22	ZrO2	0.010

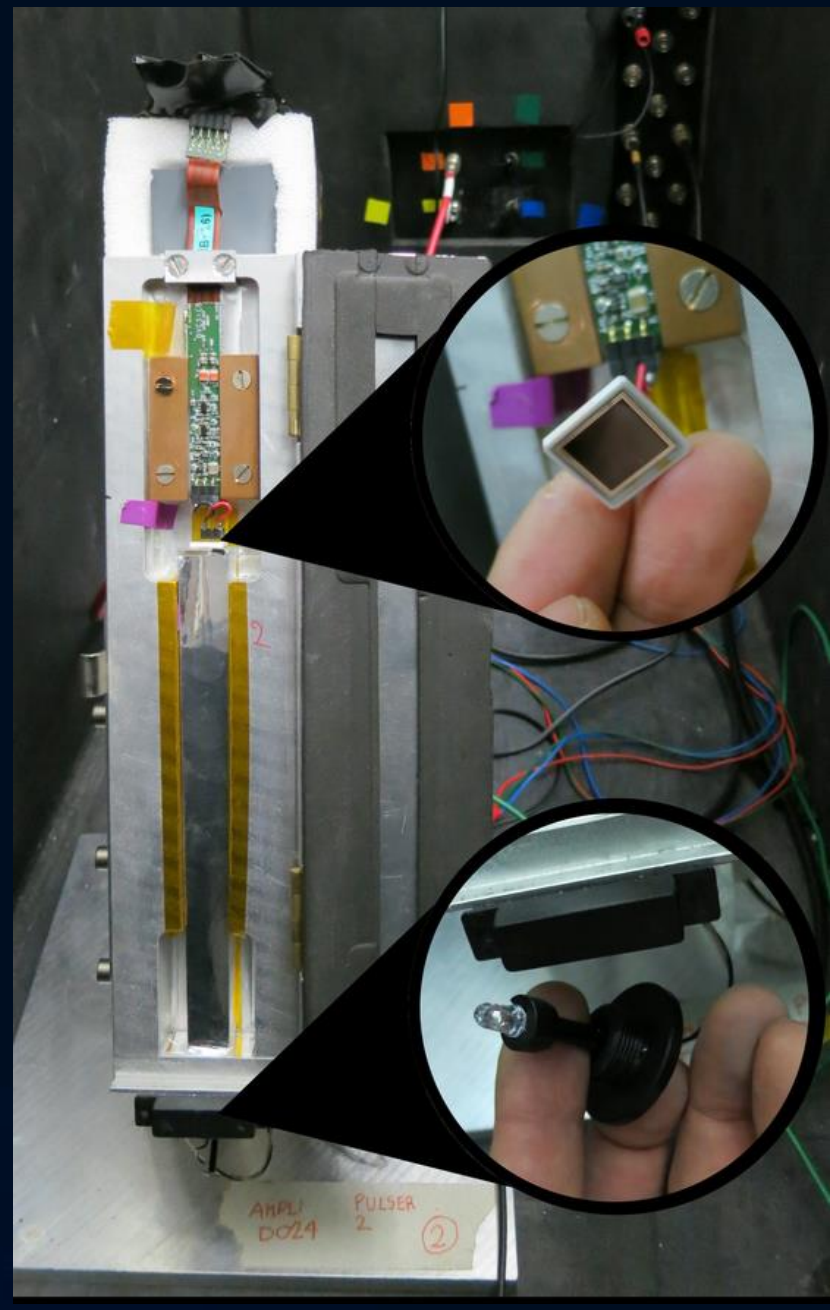
In Context of the NPS

- PMTs would be great in the NPS as they would give a high gain signal with relatively low noise, however, the must be shielded from:
  - Helium
  - Magnetic Fields
- Hence, Avalanche Photo-Diodes (APDs) presented themselves as viable alternatives in the NPS



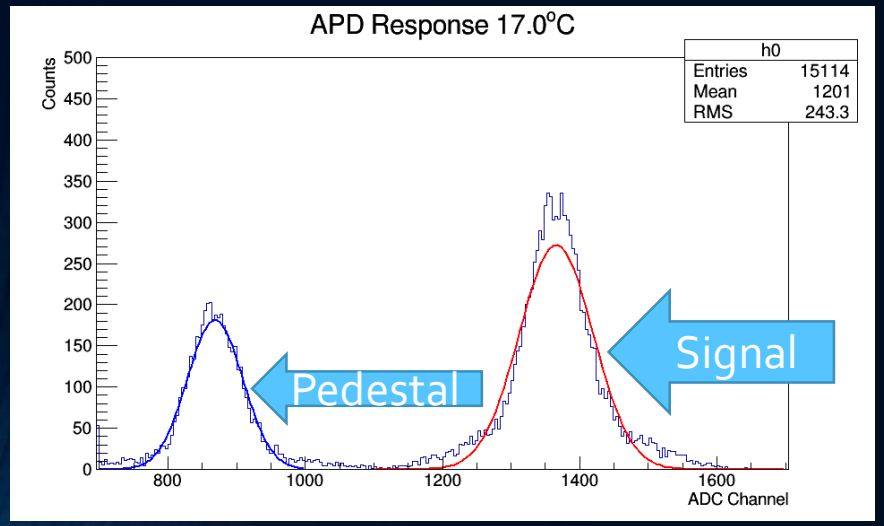
Avalanche Photo-Diodes (APDs)

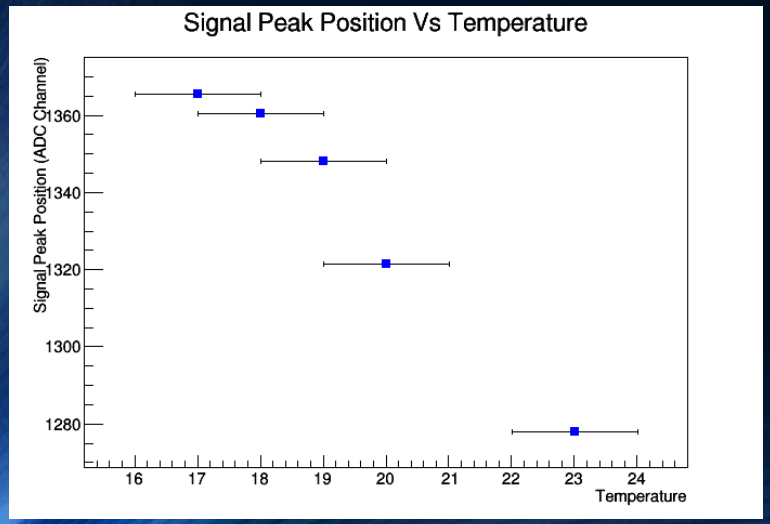
- You can think of APDs as reverse LEDs (or solar cells) that amplify incoming light into electrical current
- They use P-N junctions of Silicon
  - The incident photon excites an electron on the positive side through the photoelectric effect which then creates current

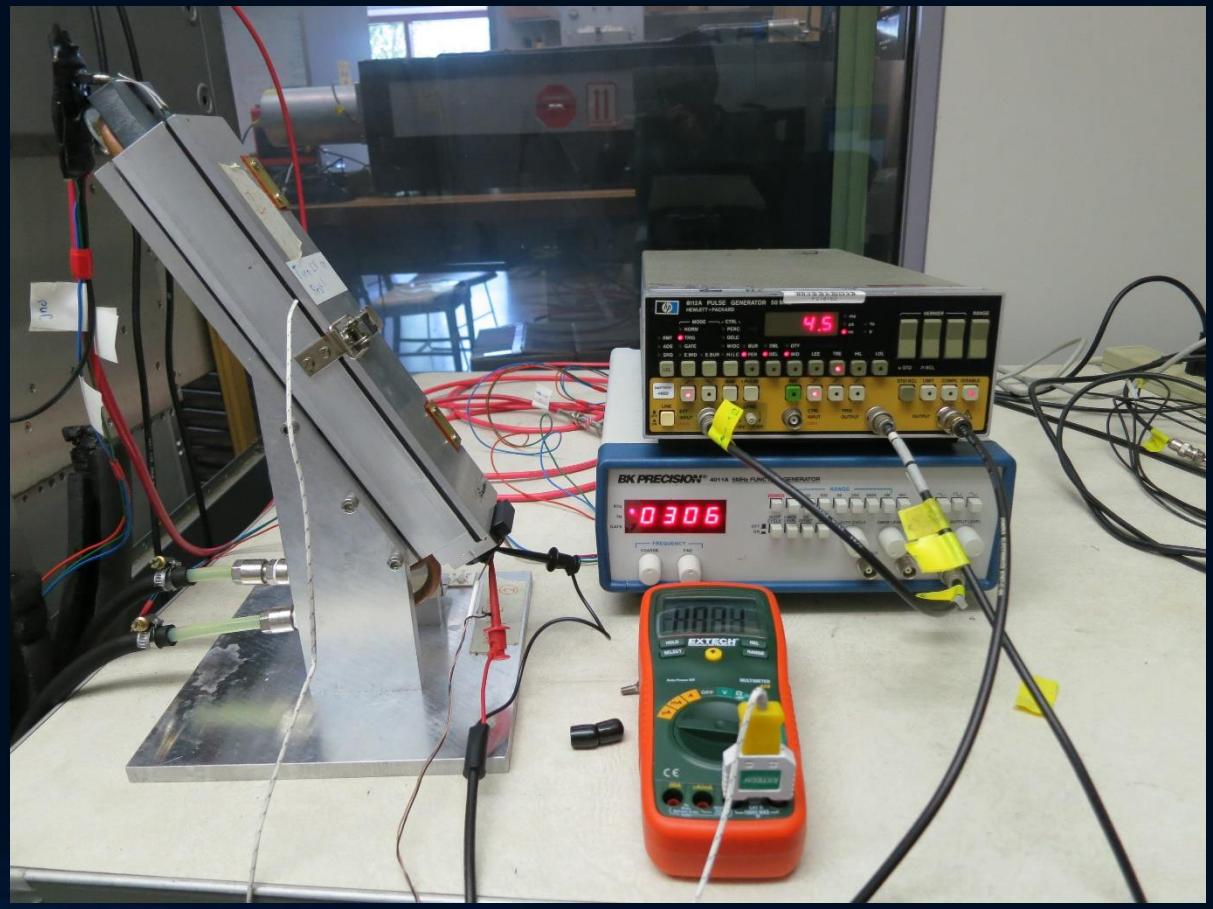


Aspect	PMTs	APDs
Main Mechanism	Photoelectric Effect	Photoelectric Effect
Size of the Detector	Large	Small
Size of the Sensor	Large	Small
Average Operating Voltage	1800 V	400 V
Signal Type	Analog	Analog
Magnetic Sensitivity	Extremely Sensitive	Not Sensitive
Vacuum Dependence	Must be a Vacuum	No Dependence
Temperature Dependence	No Dependence	Higher Temperatures cause noise
Radiation Dependence	No Dependence	Radiation Sensitive
Signal Strength	Strong	Not As Strong
Signal to Noise Ratio	Low	High

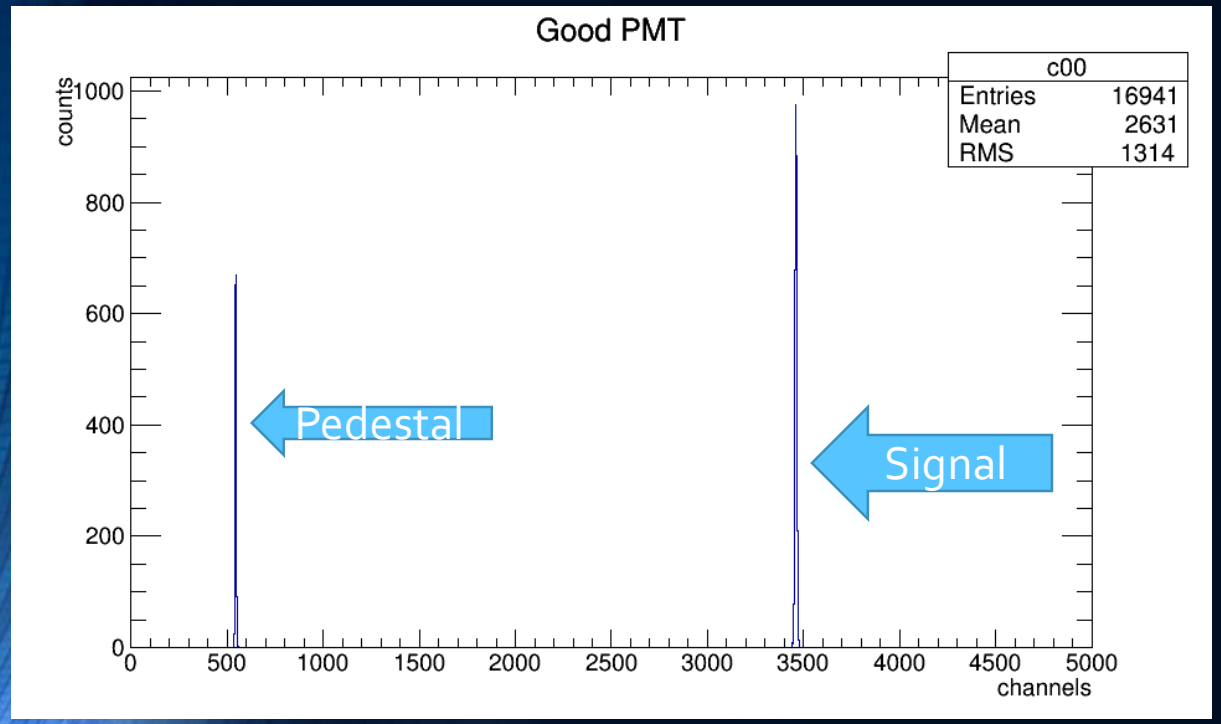
APD Temperature Dependency Examples

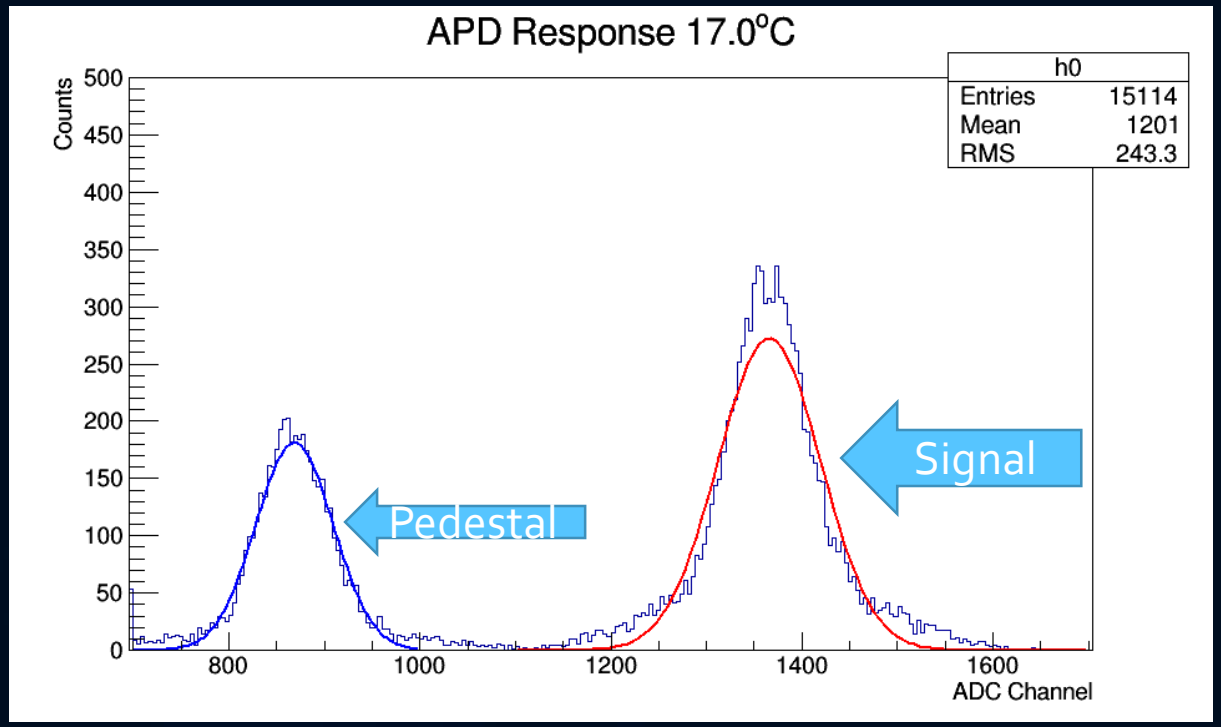






PMT Output v APD Output



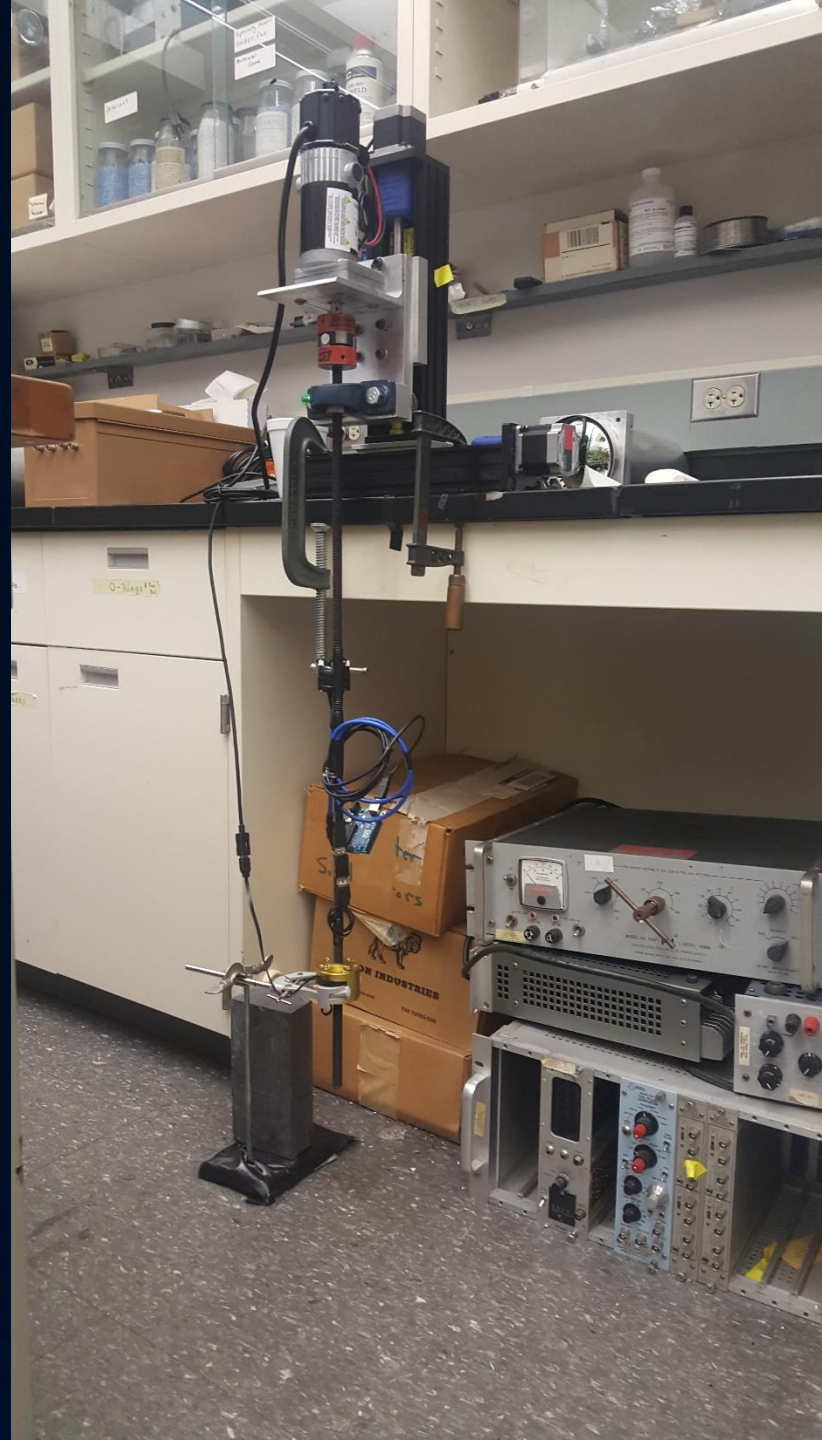


Comparison

- Each of the detectors has its advantages and disadvantages
- The NPS needs a detector for the calorimeter to amplify the light given off by the incoming particles
  - PMTs give a clearer signal but require magnetic shielding
  - APDs give a noisier signal but are more compact and do not require shielding
- Future comparison studies will determine whether or not money should be spent on shielding for the PMTs or APDs

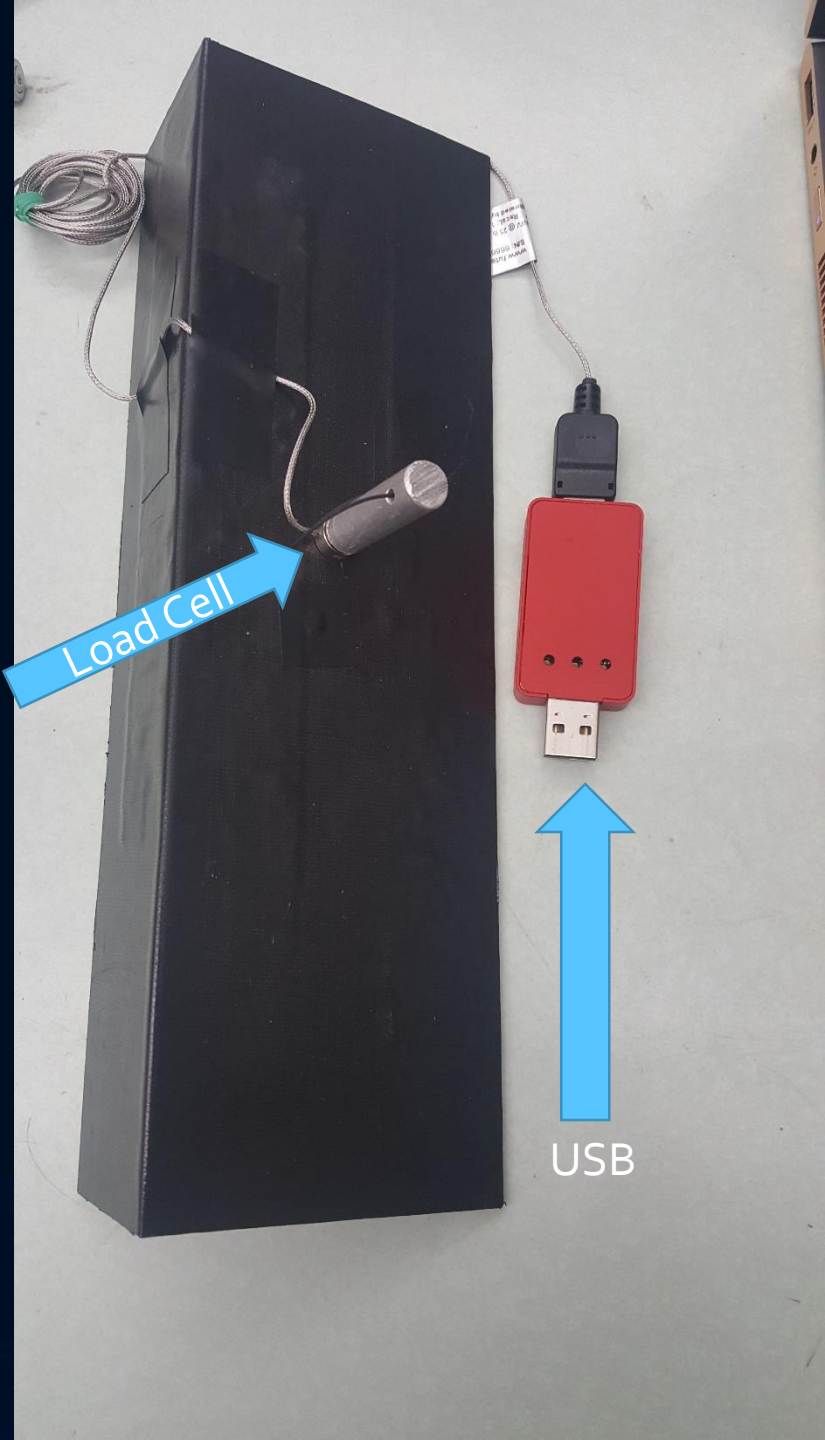
Data Acquisition Systems

- As many of you might have seen in Blessed's presentation, we have designed a crystal drawing system to grow our own crystals for the NPS
- Growing our own crystals provides certainty to the materials that are included within the crystals
- During my time here I worked on developing a data acquisition software to monitor the crystal weight using a load cell



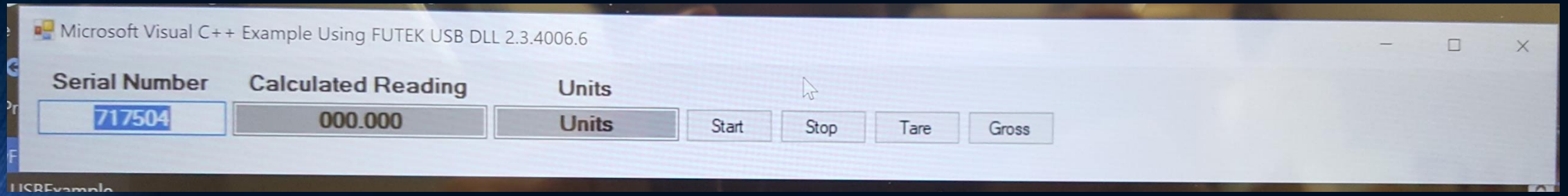
Purpose of the Readout Software

- To measure the crystal's growth in the oven, we need a load cell as we cannot peek into a 1200°C oven
- The USB sends a constant current into the load cell and measures the returning current
  - This returning current is given as a calculated reading



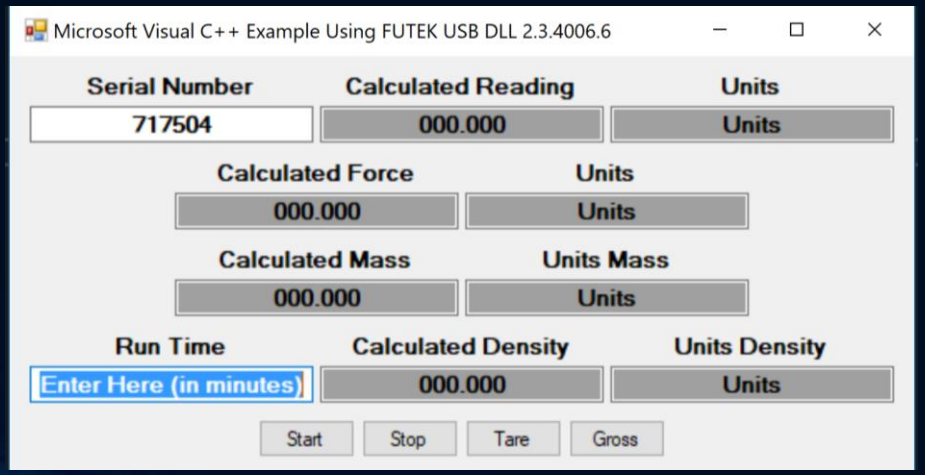
Starting Point

- It originally came with many bugs
- Once these bugs were fixed, the software looked like this:



The Final Product

- I altered the software to provide a readout in Newtons as it did not originally do so
  - To do so I used a fit that Blessed calculated to convert the calculated reading to Force in Newtons
- I also added Mass and Density as some of the readouts for the software to make it easy to understand the readout of the load cell
- I also enabled it to output a log file
- The final software looks like this:



Outlook

- Over the next couple of weeks, I will be working on the following:
  - Continue removing PMTs and installing new ones
  - Studying the temperature dependency of the APD
  - Getting the Load Cell Software to work on any Windows computer

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