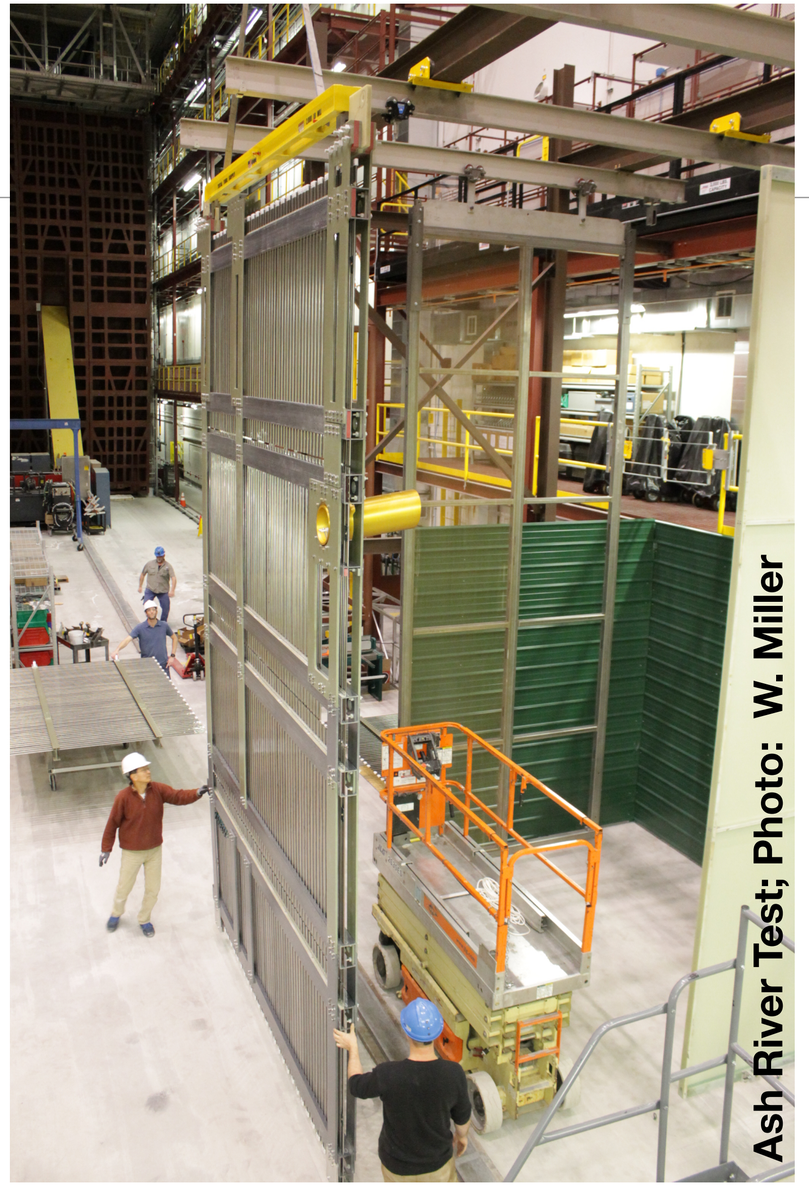
DUNE/SBN Meeting Lessons Learned: Detector Operations
HV System: Tests in the 35t Prototype

May 15, 2017

Motivation

- There have been two large tests of the ProtoDUNE-SP design
  - Ash River: A test assembly for mechanical issues in Minnesota. Used full-sized components.
  - HV Test at the 35t: Test of the design with regard to HV performance

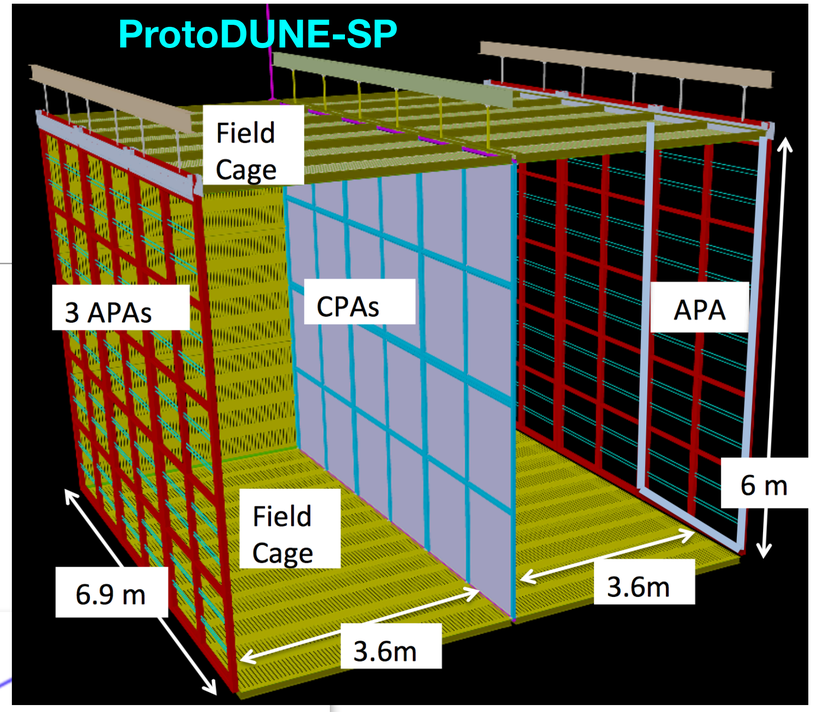


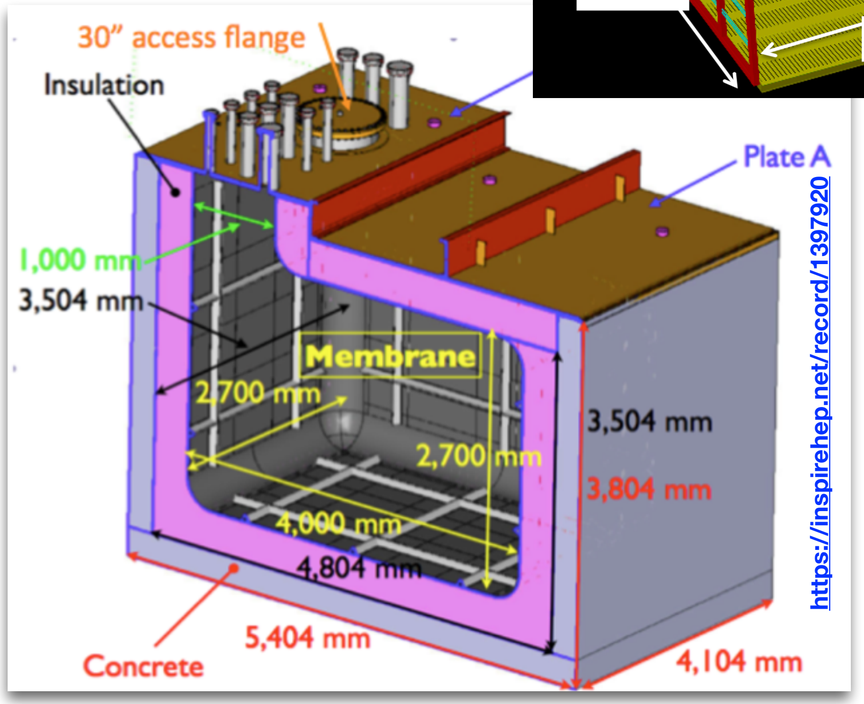
Where?

- The test was done in the 35t cryostat in PC-4
- At PC-4, we have access to a filtration system, gas analyzers, purity monitors, cooling, and LAPD can serve as a storage vessel for us

Where? 35t

- We were limited by size. ProtoDUNE-SP is 6 m tall x 6.9 m in beam direction with 2 3.6 m drift regions.
- The inner dimensions of the 35t are 4 m long x 2.7 m tall x 2.7 m wide
- We did a reduced field cage test.
  - Full-sized profiles, beams, etc. but only the first 10 profiles
  - Full dimensions were about 1.5 m x 1.5 m x 1.5 m
- Notable feature of the 35t: Everything must fit down a 30” manhole





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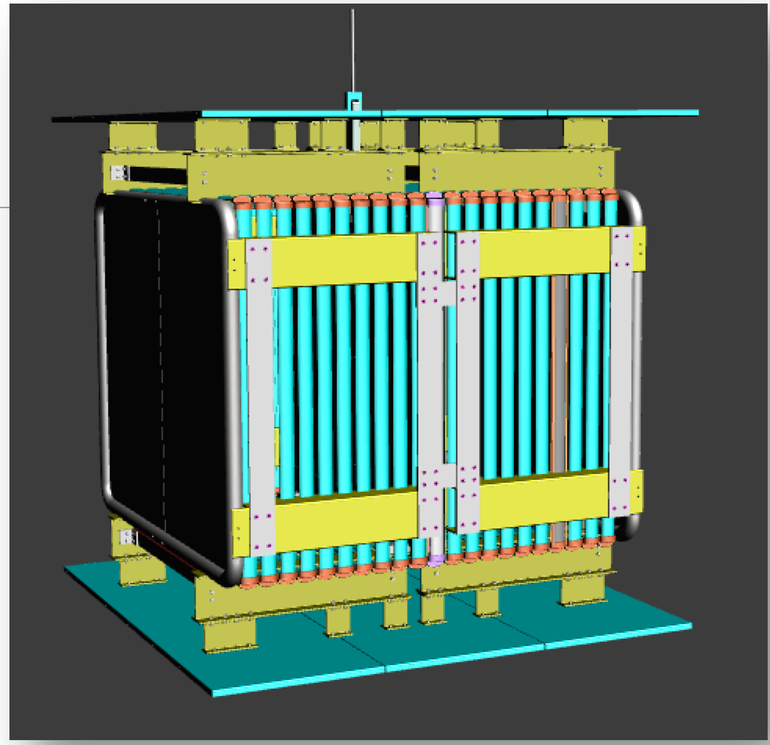
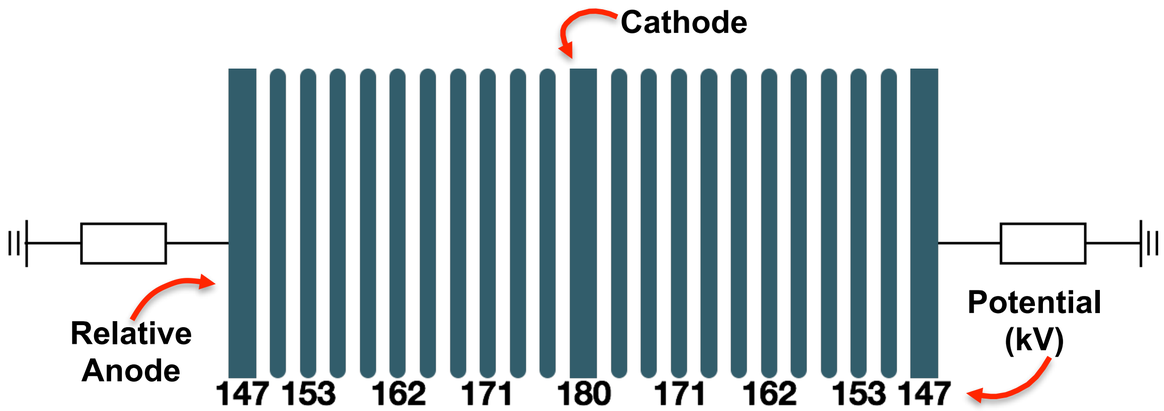
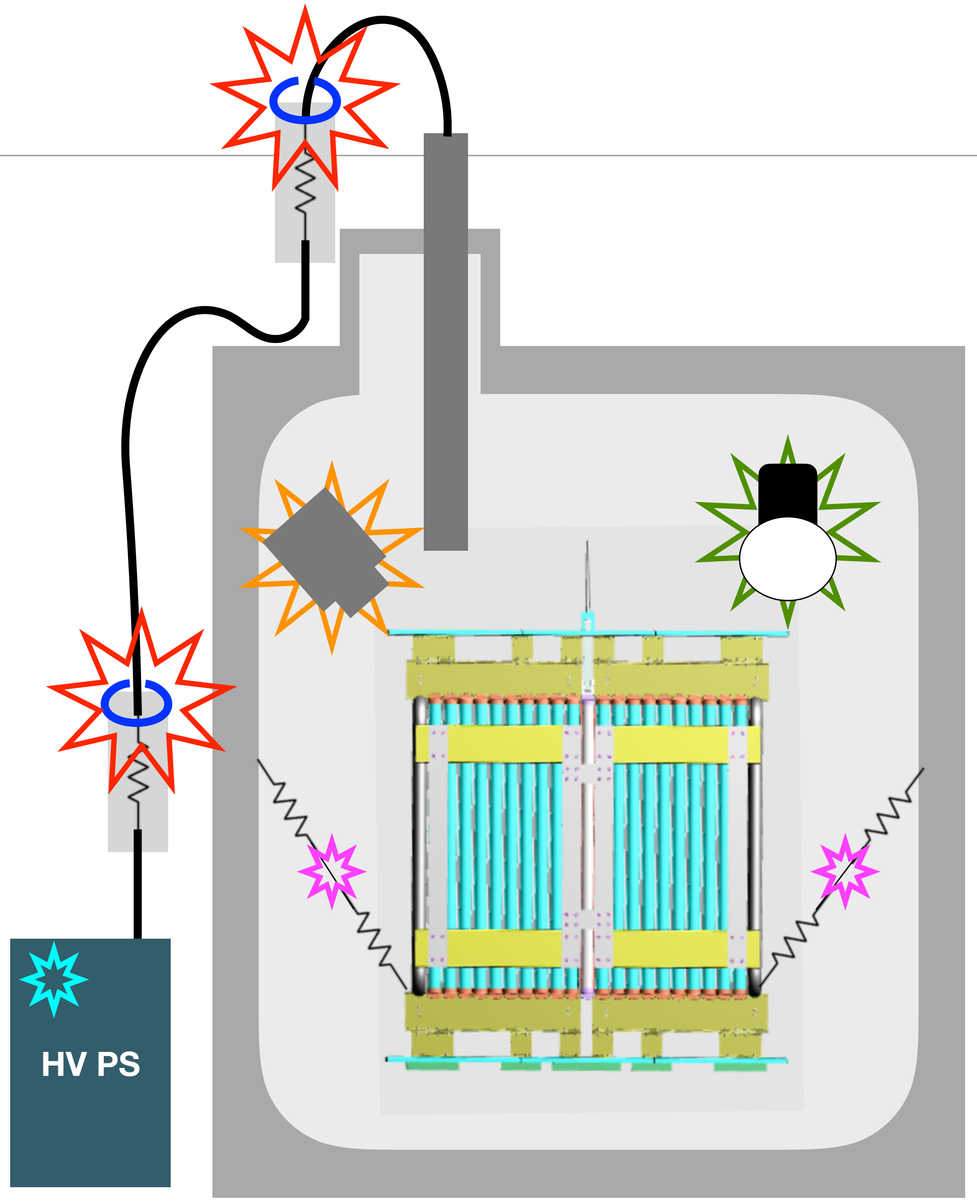




Overview of Diagnostics for the Test

- Power supply: voltage and current monitoring
- Two toroids on the HV cable
- Two pick-off points near the end of the resistor network
- Three PMTs. No wavelength shifter on them
- Cameras



Experiences Relating To Installation

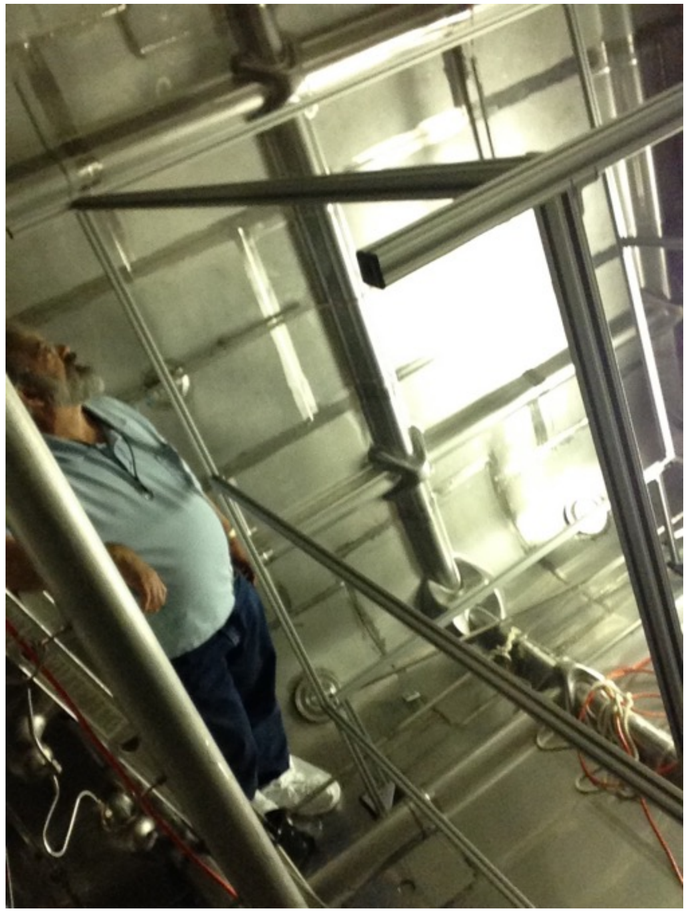
- The installation really began at W&M with Jeff Nelson and his team cleaning the parts, and test assembling what they could there
  - He gave a talk on his experience at the last collaboration meeting.
  - Besides pre-assembly, they machined a number of the parts, bagged and cleaned all the parts they were given, molykoted screws, organized things in a sane way (labeled bags attached to pieces with special tape). They led the assembly in the cryostat.
- Parts did arrive late to W&M — this caused our schedule to slip and installation did not begin until after New Years
  - Part of this was likely due to doing a test while the design was being refined, and people/shops were overloaded.

PC4 is….available

- PC4 is not a cleanroom.
- Bob K. cleaned out a space near the base to the cryostat stairs and had the floor prepped as a staging area
- We removed access to the outside from on top of the cryostat — everyone had to enter through a separate door, go downstairs, then up to the cryostat.
  - Goal was to reduce the amount of dust/dirt/whatever from entering the cryostat directly, or by making the platform dirty such that we could take it in with us
- Confined space required a fan at times. Fan was not HEPA filtered (just a particulate filter).
- Tip: Have copious amounts of booties & gloves on hand and in different sizes.

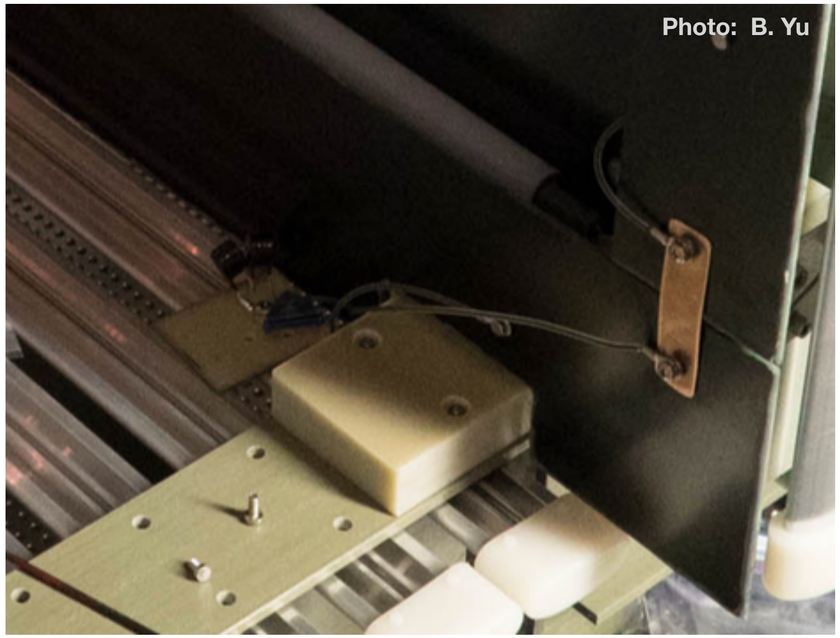
35t Cryostat

- The cryostat was wiped down with deionized water before installation began (cannot use alcohol) — decent way to start with a clean slate
- We made a mock-up of the field cage before it was delivered to get a sense for the scale and begin to come up with ways to mount the instrumentation
  - Perhaps not necessary but helped us understand what we would be dealing with — (also helped us design the supports)
- LAPD (essentially a storage vessel in this case) was filled with LAr in Nov. for our test.
  - This made the filling process much quicker (no need to wait for multiple trucks)



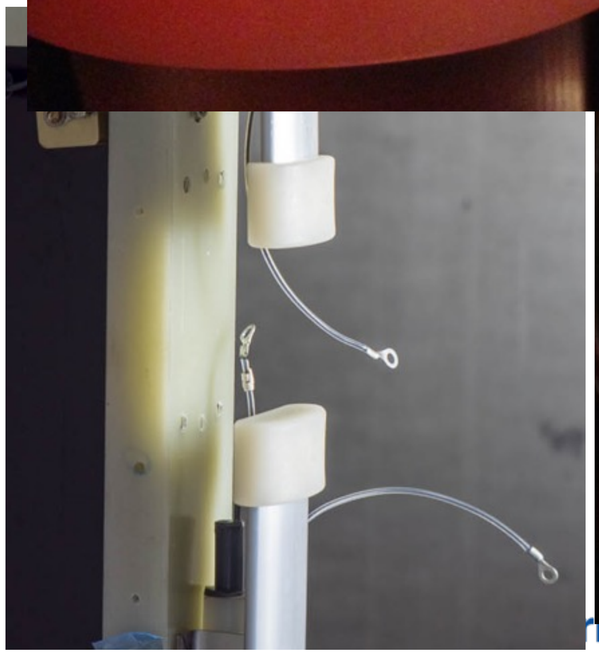
Installation: Notes/Thoughts/Lessons

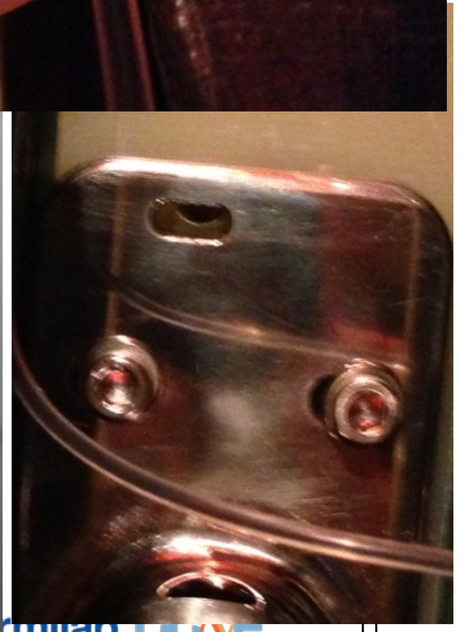
- We were trying to test the PD-SP design, but some parts and our installation order (as necessitated by the cryostat) were different. Caveat emptor.
- Installing the end walls was challenging. Somehow the hole did not line up correctly and we had to have the holes enlarged.
  - Mock-ups/test builds …. something to ensure this won't happen in your detector
- The electrical connections were very challenging.
  - Going from end wall to cathode frame required attaching the end wall on the bottom and leaning it out to make the connections inside. There was an added issue of having to capture a nut in a channel. We ended up having two people (one had to hold the end wall) — took a number of attempts — and had to jamb a glove in to capture the screw while reaching around inside to make the connection.
  - I believe this has been addressed in the PD-SP design
  - Extra thought on electrical connections: Don't forget the spring/split washers.
    - This wasn't specified. Really need clear instructions.



Installation: Notes/Thoughts/Lessons

- We had a difficult time attaching the HV receptacle cup.
- It required getting a number of ring lugs through a screw that would reach into a tapped hole to make the electrical connection.
- The screw wasn't there.
- We had to attempt finger contortions to adjust the profiles that eventually should shield the cup connection point on the cathode frame. Could not remove fully and could not attach with any screw driver
- A number of the wires with the ring lugs on them were too short.
- The wire + ring lugs were fragile and broke. Turning a screw with a ring lug on it turns it a bit…. sometimes it was a bit much for the wire. (This has been addressed; see this talk)
- The holes on the cup arm did not match the holes on the cathode.
- Tips: One should be careful with ring lugs — while turning a screw through them, you will twist them. A stud coming out of the cathode with a non-threaded section would have been easier to work with.
    - Stranded wire… strain relief has been added in the new connections
    - Electrical connections should be a part of any mockup





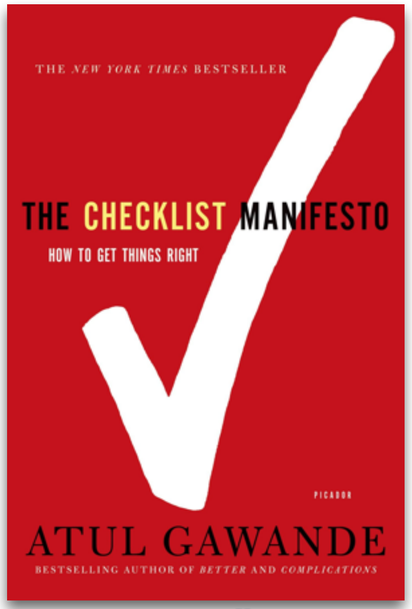
Installation: Notes/Thoughts/Lessons

- We checked the resistance regularly. First, just the field cage, then the field cage + anode to ground resistor chain.
- Before sealing the cryostat, we did an HV test in air (40 kV) to check the connections, our instrumentation, and our procedures.
  - Test inserted the HV feedthrough. ~200 lbs — not easy
    - Checked positioning with a warm camera
    - Technician gained experience and was able to improve the procedure in the future
  - PS issue — identified a problem where the HV PS current setting & read back were off by a factor of 10.
  - One of the pick-offs became disconnected.
    - Issue with solder on the board was fixed. No problem since.

Identifying these features while the stakes are lower is a plus

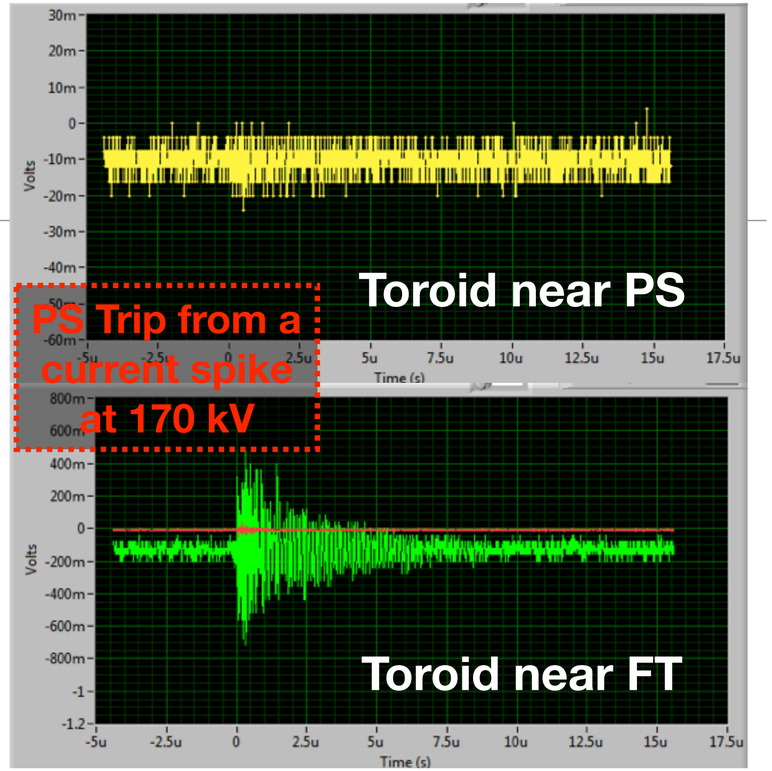
Installation: One last item…

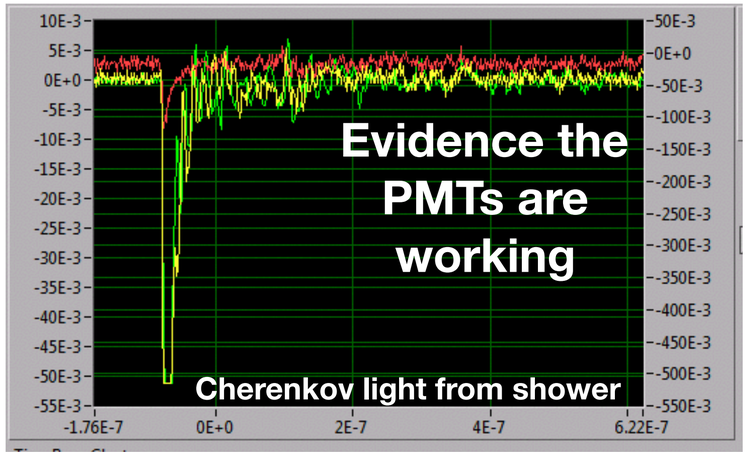
- After we were closed up the cryostat and were purging, we realized there was a leak in the heater system.
  - We had to seal off the heater cables making the heaters inoperable for this run
  - Tip: A global punch list at the end could have prevented this.



Thoughts on Diagnostics

- We used a -200 kV 1 mA Heinzinger supply (borrowed from UCLA).
  - We were able to get *up to* 20 nA resolution on the current
- The goal of the multiple toroids was to better determine the location of any current instability
- The pick-off points were some of our best diagnostics
  - With two drift regions sharing a common voltage source, one could, in principle, determine the location of any leakage current in the chain.
  - We had the pick-off points going to both a DVM and an oscilloscope
- PMTs worked, but we saw no light associated with HV events
  - See H.Y. Liao's work in our weekly meeting
- Cold cameras are challenging and will likely benefit from independent development
  - Low light situations are especially challenging. Depending on one's goals, installation of lights could be considered.





A Very Brief Summary of Operations and Testing

- Filling and purification went very well
  - A lifetime of 5-6 ms was attained (previously 35t had ~3 ms). See A. Hahn.
- We reached 190 kV (~180 kV on the cathode) within a day after filling up in ~7 ppb LAr
- Identified a purity effect:
  - We saw high current draws as we purified — “streamers”
  - We could get something that behaved like a breakdown in lower purity argon (<1ms)
- Observed evidence of charge up effects
- At 200 kV (max of supply), we provoked a major E&M event and identified a pump-“failure” mode:
  - Interlocks to pumps (and more) need to be carefully planned out. One would ideally not like a momentary low reading from a glitch to turn off a pump.
- Status: The bulk of the liquid was transferred to LAPD last week. We are boiling off the last inches now.
- More on this in the DUNE parallel session

Closing Thoughts

- Schedule:
  - Parts were late getting to W&M and this pushed our filling schedule back
  - Installation took twice as long as expected — field fits, things not fitting together, challenging connections
    - The electrical connections and some other pieces were not part of the test assembly at W&M
    - All of the pieces need to be included — the interfaces are what matter
- Cleanliness:
  - The 35t was not “clean-room like” as were were working.
    - This was compounded by a longer-than-expected installation
- General:
  - It’s good to have the people who designed the system present for installation — general lesson from other experiments.
  - We were somewhat hampered by PC-4 being a satellite building here.
    - It’s hard to forecast what’s needed, but assembling tools/hardware/equipment/supplies that the project owns (so that one doesn’t have to return it) is an obvious, good idea.
    - There’s not a real shop at PC4. If something in the cryostat needed to be machined, it became a real pain.
  - Photographer — it’s useful to have a dedicated photographer go in to take photos once or twice during the assembly. An earlier 35t run diagnosed a PMT issue from one of these photos.
  - Power outages — (At FNAL) we have planned power outages a few times a year. Asking to be notified of these well in advance helps with planning and one may be able to get it moved.

Closing Thoughts (continued)

- Instrumentation — Worked and provided useful information
  - It is useful to monitor the current draw/resistance of the field cage during the purge, cool down, and filling processes with a low voltage unit with a very good current resolution
  - Instrumenting the pick-off points to both a Keithley and scope provided useful diagnostics
  - Gas analyzers to show the quality of the gas and liquid improving
  - And purity monitors to show the progression to good liquid at all heights
  - The quality of the current readout from the Heinzinger (HV power supply)
  - The scope on the toroid
  - The ability to read these out remotely, log them, and also view IFIX for cryogenics data
  - People dedicated to these data