APD Status

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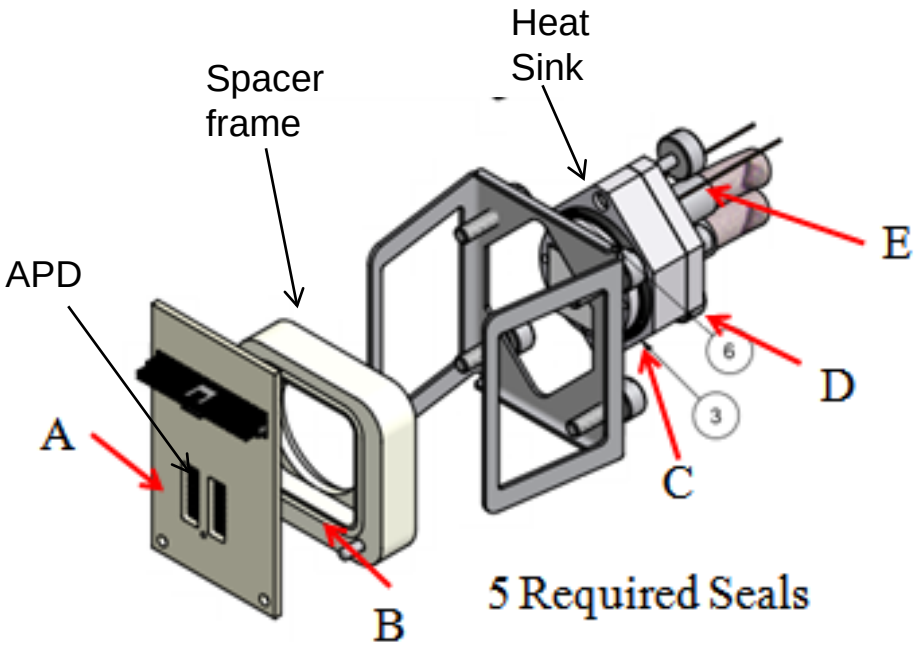
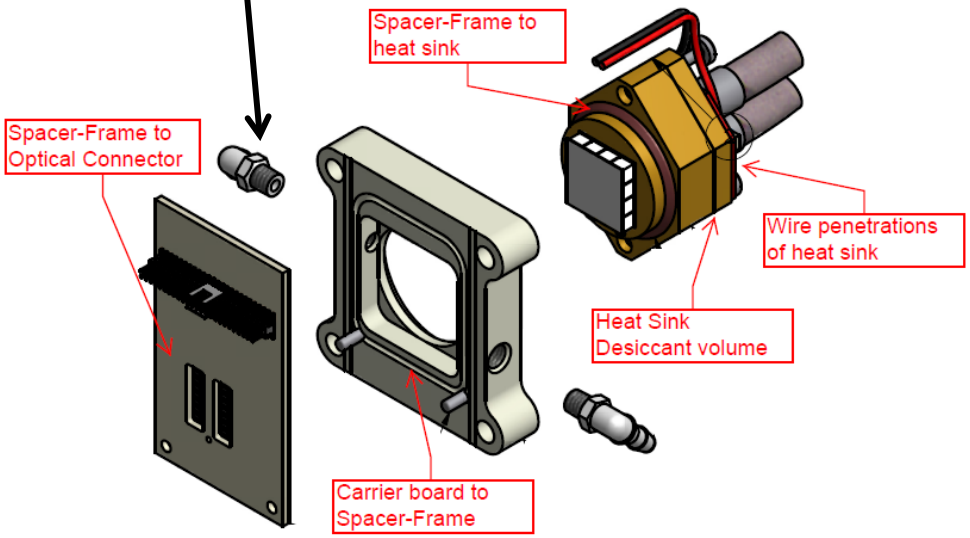
APD Seals

- Of the initial 315 successful installations on the prototype Near Detector, ultimately none survived
  - The more we looked at the installations, the more errors we found
    - The installation was quite difficult and 5 perfect seals were required to make sure no water vapor reached the cold APD surfaces. Then the small remaining volume was made dry via an internal desiccant.
  - Even 75 “golden installations” identified by the experts died at the rate of a few per week when cooled to -15^{o}C
- The 5 seals:
  - A: APD to Spacer frame
  - B: Spacer frame to APD
  - C: Spacer frame to Heat Sink
  - D: internal to heat sink
  - E: wire feed-throughs to heat sink
- We built vacuum test fixtures to check seals
  - Found E was a major problem
  - But after 3 iterations, still had leak**s**.



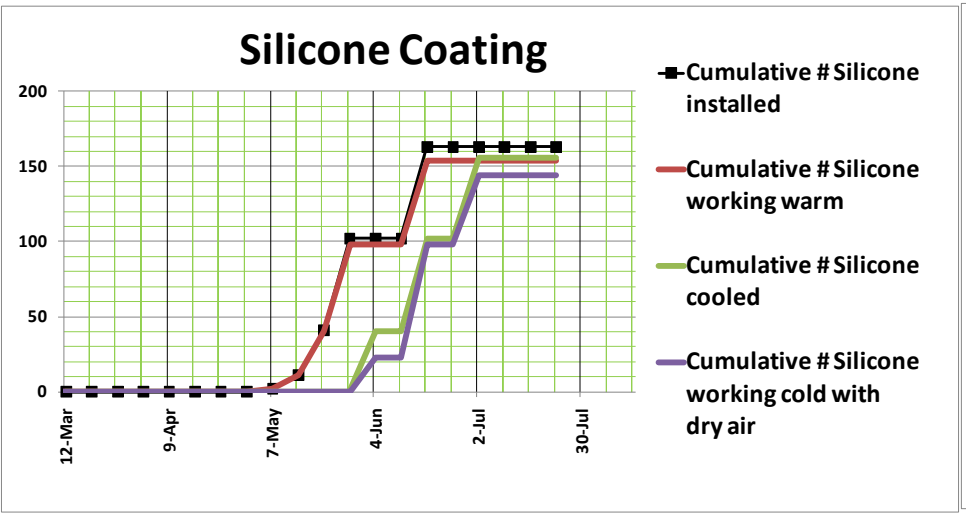
Switched to a dry air purge system

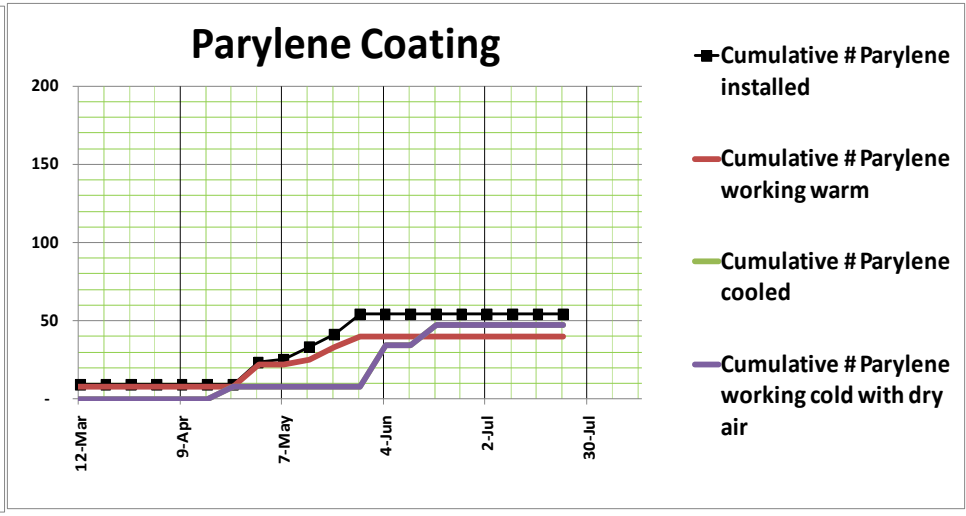
- 32 APDs in series with input and output ports on the spacer frame
- A knob to turn if problems are found:
  - Each set of 32 has its own flow control
    - 0.1 – 1.0 SCFH
    - Limit to <2 SCFH to limit the heat load on the thermoelectric cooler
- Instrumentation to know it is “dry”
  - Input & Output dewpoint measurement
    - Typically -53 ^{o}C input, -44 ^{o}C at end of string
    - - 25 ^{o}C is the spec
  - Broken hose is obvious
  - Noisy APD due to leaks is easy to find
- Other features
  - Air in system has ISO Class 5 cleanliness
  - Automatic backup is certified dry Nitrogen in bottles



APD status with Dry Air system

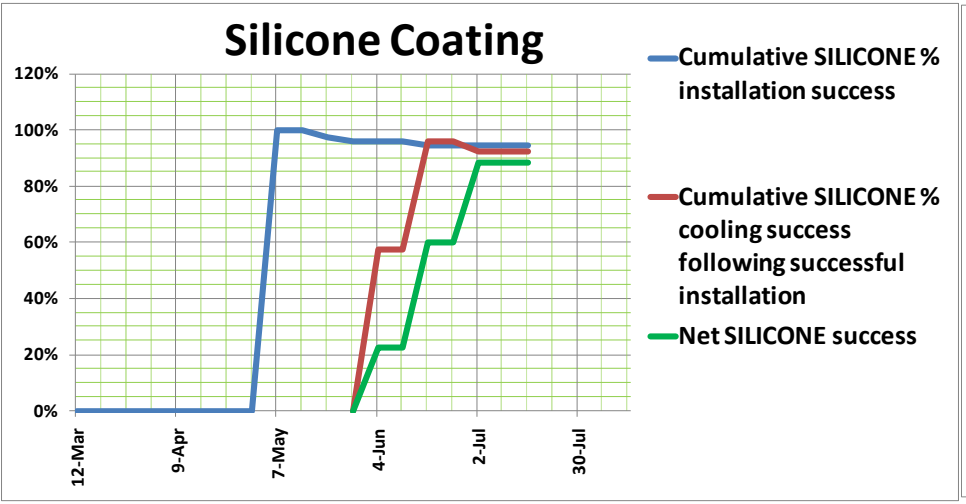
- We have installed 163 new APDs with Silicone coating
- We have installed 54 APDs with Parylene coating

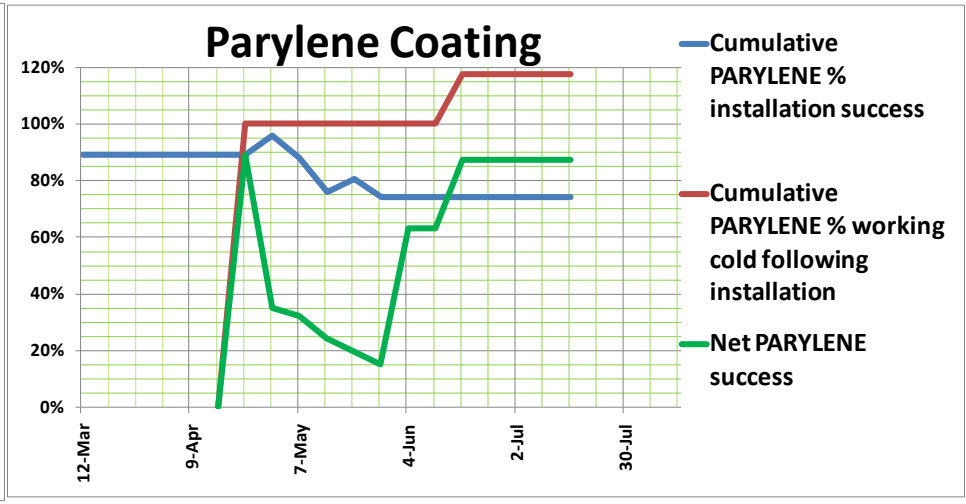




- Had planned to install ~50 additional Parylene coated APDs this week, but vendor managed to damage the thermistor on ~ 40 of them with his mask
  - Another thing we need to learn since Hamamatsu warranty will not apply if WE coat APDs
  - Parylene Vendor is looking at his procedure and will propose corrective actions to prevent more occurrences
  - We are having the thermistors repaired (done before), but no time estimate

APD % success by coating





- A small number of Parylene were cooled early on, then there was a gap before cooling more -- led to the green line going down on the right plot
- Bottom line: the two coatings have VERY similar success rates:
- Silicone 94% success on installation, then 92% when cooled.
  - **Silicone NET is 88%**
- Parylene 74% success on installation, but then 118% when cooled.
  - **Parylene NET is 87%.**
    - Some did not work warm but do work when cooled
- No tests done on any failures yet.

Performance while cooled

- Would like ~150 units working with each coating, then follow performance for some time
- Parylene performance so far:
  - 54 have been working for various times, 3 – 12 weeks, no failures.
  - 100% are still working cold
- Several Silicone coated APDs failed last week, more this week
  - July 16, 3 failed after 1 week cold
  - July 16, 1 failed after 3 weeks cold
  - July 23, 3 failed after 2 weeks cold
  - July 23, 4 failed after 4 weeks cold
  - **11 of 144 have failed**
  - **Down to 92% still working cold**
  - No autopsy or further tests done yet

APD Coatings

- The original APDs from Hamamatsu had passivation (~1 micron of SiO_2)
  - But the passivation was removed by Hamamatsu over the active pixel area since it acted as a transmission filter for 500 nm light
  - This meant the APDs were completely unprotected at the pixels.
  - This was a likely source of installation problems
    when we had dirty optical connectors or
    fibers touching the pixel surfaces or
    water condensation on the pixel surfaces.
- The 250 APDs delivered in March 2012 were different
  - Passivation left in place over pixels
  - TWO additional coatings tried
    - Silicone applied by Hamamatsu
    - Parylene applied by a US vendor through Caltech

APD Coatings

- **Silicone** coating properties
  - Max of ~ 1mil, but Fermilab measurements show variation over surface with some spots possibly not coated
    - Lump in center, may have meniscus on sides of pixel area compromising installation
  - Coats only the front pixel area of the APD

- **Parylene** coating properties
  - Vacuum deposition process, so well controlled at 0.5 mil with uniform coating over all surfaces
    - no lump, no meniscus
  - Coats pixel area and back of board where APD is bump-bonded

Other things we now know about the coatings

- Hamamatsu has done mechanical tests with both coatings
  - Cycle temperature from -20 ^{o}C to +80 ^{o}C many times
  - Silicone: No mechanical problems found
  - Parylene: No mechanical problems found
- We have set up an aging test of both coatings at Caltech
  - 6 APDs of each type of coating
  - Operate at 80 ^{o}C (max recommended by Hamamatsu), < 10% relative humidity.
  - Chemical aging processes typically go 2 times as fast for every 10^{o}C increase in temperature.
  - We have completed a 160 hour test
    - Relative to room temperature, this is approximately 14 months of storage
    - Relative to operating temperature of -15 oC, this is 13.2 years of operation
  - Test with 523 nm light, about the middle of our spectrum
    - Measure 2% RMS (advertised QE precision of 2-3%)
    - Average change was -0.5% = no change within error
  - Also no visible evidence of discoloration or yellowing seen
  - Test continues