Electronics Production and APD Plans

Leon Mualem

FEB/TECC Status

- **FEBs Under assembly**
- >1100 FEBs have been received in 3 weeks
  - Jumper problem slowed delivery – assembler reworking
  - ramping to 1000/wk
- Testing of first 100 boards documented in nova-doc-6979
- Testing of new production still working out some bugs
  - Quality looks to be good, ~95% passing
  - Should begin production testing next week
- **TECC also in production and testing**
- Received 1500
- Receiving ~750/week
- 820 tested so far, >97% passed
- Both of these tasks sprinting toward the finish line
- Should arrive at finish line in July 2012!

Power Distribution

- Operational readiness manual completed and posted on docdb.
  - 194 pages of documentation
- As of 4/19 signed pORC for Power Distribution System
  - Excellent work
- Relay racks:
  - Rack protection system 90% done.
- LV test document completed and posted on docdb.
- PDB-FEB cables: First diblock completed.
- LVPS-PDB cables: First diblock completed.
- HVPS-PDB cables: First diblock completed.
- LVPS-DCM cables: Done.
- Cable trays: At Ash River.
- Cable tray/PDB supports: All parts received.
  - They are being assembled at fab shop.
- 12/90 PDB-DCM tables
- 518/720 cable tray supports

Power Distribution (Part II)

- PDB testing has resumed now.
- Current counts of parts: (at least this many)
- PDB mainframes: 30/ 74/ 198 tested/fabricated/total
- -> FEB cards: 480/1850/3168 "
- -> DCM cards: 38/ 204/ 204 "
- -> IND cards: 30/ 204/ 204 “
- -> Backplanes: 30/ 100/ 200 "
- Shipping:
- All LV power supplies shipped and installed
- Ash River HV mainframes and supplies shipped

DAQ HW

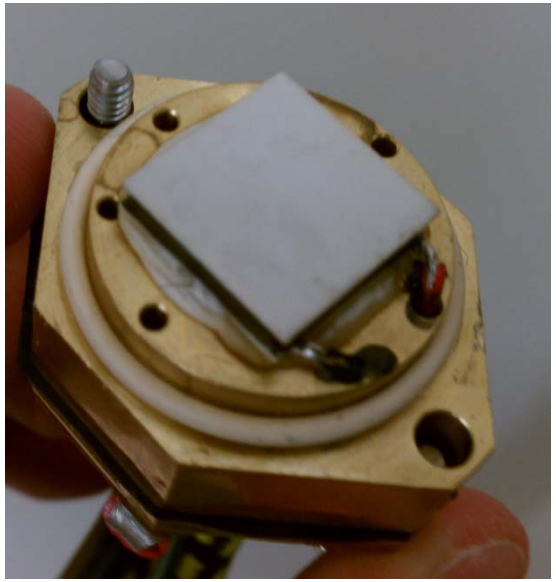
- See Next Talk
- It’s good to have a Deputy.

Cooling Problems (Aug)

- Cooled APDs that appeared to be properly installed (Golden installations) still failed
- What happened
  - Removed APDs returned to Caltech
  - Nothing particularly wrong with APD mounting, boards, ….
  - Returned another batch of 6 failed APDs with heat sinks attached.
    - Tested for leaks (pull vacuum on them)
    - THEY ALL LEAKED
    - All at heat sink wires
  - Returned another batch of 15 heatsinks
    - All leaked, 1 or 2 spacer frames poorly glued as well.

Developed Solution

- Lots of back and forth testing with IU to make vacuum testers and sealed heat sinks
- Finally settled on a solution
- Potted heatsink.
- 20 delivered, more in production



Coating/Installation tests (Oct)

- Recovery Status
- In October installed
  - 2 silicone coated
  - 9 uncoated recovered
  - 5 parylene coated (1 leaky, 4 sealed)
- Currently working
  - 1 recovered of 9 installed
  - Parylene coated: 4 Sealed of 4 installed
- Parylene looking better, still small numbers

APD additional installation (Dec)

- Attempted to install ~20 sealed APDs/heat sinks in Dec.
- Using new mounting scheme:
  - 6 Parylene, 10 new silicone coated
- Using old mounting scheme:
  - 5 uncoated/recovered APDs to test new seals
- New Mounting parts worked well ergonomically
- Had trouble getting parts to test sealed with test fixture
  - Still working on diagnosis, may be due to NDOS boss height
  - remove/replace some heat sinks this weekend to test further
  - Some heat sinks used in December leaks
  - Leaks in some cases may be due to lower (maybe 0) compression of o-ring with shims

Purge Decision

- Purging was always an option
- All initial prototypes included a purge of some type
- Desiccant option eliminated a plumbing system AND was shown to have lifetime of >40 years for *sealed* modules
- Several iterations were made over Oct-Jan
- Each found problems and improved greatly
- Still finding problems after these iterations
  - Time was too short to continue AND be ready to install at Ash River
- Dry purge was needed to compensate for remaining known and unknown seal problems

Further installations

- Planned to receive coated and uncoated APDs from Hamamatsu beginning at the end of January
- Actual delivery, end of March
- Substrate (carrier board) problems from Hamamatsu supplier caused the delay
- Delivered 185 in 2 weeks
  - production is getting faster, less worry about delivering 1000/month
- Uncoated received parylene coating in Rancho Cucamonga
- Meanwhile Stuart Mufson and Co. started manufacture of 500 new boxes (needed for installation with new clamping hardware)
  - The start of this was delayed until impact of gas purge on box was known
  - Expected to be last piece, but vendor shipping Early!
  - Tooling took about 1.5 weeks, production < 1 week.
  - Also good news for production, another sprint to the finish.
- Install/Test ASAP
- Would love to get out of the gate on this one, but can’t afford another tumble
- Will know much more in 3 weeks.

Further installations

- Pre-install FEBs in boxes when boxes arrive next week
- Remove boxes/FEBs from block 0
- Swap FEBs into new boxes and place on block 5 (almost empty)
- Work forward toward instrumented portion
- Week of 4/30
  - Begin Installing Coated arrays
  - ~160 silicone ~90 Parylene
  - Install gas purge on new strings
- APDs that are in the way of install, and on muon catcher can be removed and shipped to Caltech for parylene coating, testing and prep for reinstall

Conclusions

- Electronics and DAQ hardware production sprinting out of the gate
- Photodetector splinted and ready to trot
  - When proven raceworthy will finally begin to gallop
  - Won’t achieve electronics production rate, but should be able to keep in the race to the end.

Task Force and Expert Reviews

- Convened internal task force to identify and mitigate causes of difficulties
- Convened expert review panel to guide future steps

- Task Force Recommendations
  - ✓ APD (Mualem,Oliver,Tesarek)
    - Proceed with Silicone (more uniform) coating on APD surface
    - Meet with Hamamatsu Factory to establish communication and finalize specifications
  - ✓ Determine cause of failures under cooling
    - Test seal with low compression (Mualem/Trevor/Caltech)
    - Test heat sink seal after gasket trimming procedure (Mualem/Trevor/Caltech)
    - Carefully collect evidence from parts that failed to determine cause (Muether/FNAL)
  - ✓ Mounting (Fox/IUSEEM)
    - Redesign mounting clip to ease installation
    - Use current specifications of parts/procedures to optimize seal compression
  - ✓ Electronics Boxes(Fox/IUSEEM)
    - Modify overlap design to ease installation
    - Provide positive ground connection of the two pieces

- Expert Review Recommendations
  - ✓ Devise test plans that separately address:
    - The long-term reliability and susceptibilities of the APD array itself
    - The long-term reliability and susceptibilities of the packaged device from Hamamatsu
    - The long-term reliability and susceptibilities of the assemblies mounted on the detector.
  - ✓ Develop a production qualification plan
  - Fully qualify the installation procedure
  - ✓ Appoint a member of the collaboration with appropriate semiconductor detector experience to oversee the APD qualification and testing.
  - Perform a Production Readiness Review, before launching the production of the APDs.
  - Perform an Electronics Systems Readiness Review before installation of the APD assembles on the far detector.
  - ✓ Revise the installation schedule to accommodate the delays that will occur if these recommendations are followed.

Status of APD tests

- Test Plan:
  - Silicone Coated APDs:
    - One unit to be installed with a leak
    - no o-ring between HS and spacer frame
  - Silicone Coated APDs:
    - 10 coming from Hamamatsu at end of October.
    - These will get sealed & tested heat sinks
  - Parylene Coated APDs:
    - One unit in hand.
    - Will be mounted with a leaky heat sink. (VERY leaky, no o-ring between HS and spacer frame)
  - Parylene Coated APDs:
    - Getting 10 of our "recovered" APDs coated
    - These will get sealed & tested heat sinks

- Results so far:
  - 1 installed with leak, 1 with good seal
    - Leaky one too noisy to run (=dead)
    - Sealed one is still good cold
  - 10 arrived
    - Tested at Caltech, sent to Fermilab
    - Coating thickness measured at Fermilab
    - Back to Caltech for retest next (this week)
    - After retest, will install with new mounting scheme
  - 1 Parylene installed with leak
    - Still running cold
    - Slowly stopped working (assume ice), warmed up
    - Cooled again, **still works!**
  - 4 Parylene installed with good seals
    - All are still running cold
    - Only 90% of pixels work due to Parylene vendor
  - Now looking at a new vendor in L.A.
    - Easier to watch that they handle silicon properly
    - They note a slow deposition is clearer, so perhaps we can recover the 5% of light loss seen with vendor #1. Will do 5 recovered APDs
  - Conclusions?
    - Parylene does protect silicon from damage
    - Parylene worth continuing

MORE Status of APD tests

- Test Plan:
  - Uncoated APDs:
    - 10 **recovered** after cleaning and drying
    - These will get sealed & tested heat sinks
  - Uncoated NEVER USED APDs:
    - 10 never used yet
    - These will get sealed & tested heat sinks

- Results so far:
  - 9 uncoated installed with good seals
    - 8 are too noisy to run (=dead)
    - Only 1 is still running cold
  - Conclusion
    - “recovered” APDs aren’t recovered.
    - Stop trying to recover more
  - This test not started yet
    - waiting for complete set of parts for new mounting scheme

APD Expert Recommendations with DRAFT responses

- Devise test plans that separately address:
  - **1 a)** The long-term reliability and susceptibilities of the APD array itself. This could consist of testing bare die from Hamamatsu, mounted and wire-bonded onto a suitable test board.
  - **While these APDs required new masks, they are modifications to the structure of existing devices, S8550s, used extensively in medical imaging, and the whole class of single channel devices, such as those in use on CMS. The changes were considered low risk by Hamamatsu and others.**
  - **As such, these types of tests were not planned. They can be performed as a test that might be useful <u>if there are further problems</u> at some point down the line, and we will investigate involvement of other groups that might perform these tests.**
  - **We are exploring help from the Fermilab Particle Physics Division and from Czech NOvA collaborators.**

APD Expert Recommendations with DRAFT responses

- Devise test plans that separately address:
  - **1 b)** The long-term reliability and susceptibilities of the packaged device from Hamamatsu (i.e. APDs which have been bump-bonded on to a carrier)
  - **Leon Mualem (L2) will do this test on the new parts coming from Hamamatsu. An environmental chamber exists at Caltech for such "aging studies" with cycling between low and high temperatures.**

  - **1 c)** The long-term reliability and susceptibilities of the assemblies mounted on the detector.
  - **This was and still is the object of the prototype Near Detector. We intend to run the new Hamamatsu parts (and likely Parylene coated existing parts) on the prototype before giving the go-ahead to Hamamatsu for production of 12,000.**

APD Expert Recommendations
with DRAFT responses

- These (above) tests should be performed with a statistically significant number of devices (~ 20 or more) so that reliable predictive data may be obtained. The test should follow industry standards for qualification of sensitive electronics, including heat cycling, and for the assembled modules humidity testing. The environmental tests should continue after the detector installation is complete and operation has begun, in order to detect any early signs of failure.
  - **We will start with 10 for the first two tests**
  - **For tests on the Near Detector we will have ~200 Hamamatsu silicone-coated parts and would aim for ~ 150 Parylene-coated parts.**
- Document, with milestone dates, which tests must be passed by which date in order to demonstrate that the APD array, its packaging, and the installation process have demonstrated sufficient reliability for production.
  - **As indicated above, we inserted a 2 month test of Hamamatsu silicone coated (in parallel with Parylene coated) on the prototype Near Detector. We need to demonstrate a success rate of ~ 95% to have a viable plan for Ash River.**
  - **Need to set "passing mark" for the rapid aging tests at Caltech**

APD Expert Recommendations
with DRAFT responses

- **2)** Develop a production qualification plan. As the APDs are delivered lot samples should be tested to ensure continuity of production quality. Equally, lot samples of the space frame need to be tested to assure the continued quality of their production.
  - **The test plan already called for every APD to be tested on the APD test stand at room temperature and cooled to operating temperature of -15C. This is in addition to Hamamatsu factory qualification tests.**
  - **In addition, the components will all be tested for seal quality before being shipped, and before installation.**
  - **The tests and procedures developed in response to the rapid aging test at Caltech will also be used to sample test new lots of production of all components. Monitoring would use the same procedures developed for those tests.**

APD Expert Recommendations
with DRAFT responses

- **3)** Fully qualify the installation procedure, with the steps minimized and simplified and, if necessary, any special tooling produced; this could include a further optimization of the mechanics for ease of installation.
  - **An updated installation procedure exists based on the new mounting scheme.**
  - **The procedure was updated prior to the installation of the coated devices based on installation of the test devices.**
  - **In addition we intend to train the Ash River workforce in installation by having them here at Fermilab for the coated array installation work.**
- **4)** Appoint a member of the collaboration with appropriate semiconductor detector experience to oversee the APD qualification and testing.
  - **Leon Mualem (L2) is it.**
- **5)** Perform a Production Readiness Review, before launching the production of the APDs.
  - **We will hold such a review near the end of the 2 month test on the prototype Near Detector in late September, 2012.**

APD Expert Recommendations
with DRAFT responses

- **6)** Perform an Electronics Systems Readiness Review before installation of the APD assemblies on the far detector.
  - **This review has been incorporated in the project schedule.**
  - **The review of operation of the final FEBs on the prototype detector has been completed and includes a full noise analysis.**
  - **The final review will include information available from the prototype detector on the failure rate of TECs.**

- **7)** Revise the installation schedule to accommodate the delays that will occur if these recommendations are followed.
  - **All recommendations have been incorporated into the project schedule**
  - **Hamamatsu factory specified a 2 month delay from the final decision on coating to the start of delivery at the rate of 1000 parts/month**
  - **Demonstrated installation rate using older, more difficult, hardware on the prototype detector was 1.5x faster than required.**
    - **This has not been included in the schedule**

QA Audits

- UVA Power distribution system
  - NOvA-doc-6820
- Harvard Front-End Electronics
  - NOvA-doc-7190
- IU Heat Sink and TECC production
  - NOvA-doc-NYAV