Photon Detection System Preliminary QA/QC Plan

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on behalf of the
FD1-HD PDS QC/QA Working Group

Overview

Every subsystem group defined their specifications and requirements based on a diverse set of tests and characterization, emphasizing stress-tests and lifetime determination for the relevant components, as part of their QC planning. These were the base for the construction of their preliminary QA plans. The whole effort is registered in a master document (EDMS 2847126) organized per subsystem and covering the following topics:

- System requirements
- Manufacturing and procurement plans
- Fabrication, inspection and test procedures
- Further prototyping activities, when needed.

DUNE Photon Detection System Preliminary QAQC Plan

Contents

Supporting Documents and PDS-Consortia Interface

- All supporting documents are organized in a spreadsheet (EDMS 2812570) where EDMS links are listed.
- Interface documents between consortia containing drawings as well as procedures for testing, installation, safety and grounding, when those apply.

Consortium-Consortium	Document
APA	2088735
TPC-ELEC	2088720
JT-HV	2088721
JT-DAQ	2088726
JT-CALCI	2145137
JT-COMP	2145146

Consortium-Installation	2459137
Consortium-DSS	2852826

Relevant drawings include in each document

The PDS Subsystems on the QA/QC Document (chapters 2 to 7)

- Cold Electronics (CE)
- Warm Electronics (DAPHNE)
- Monitoring System
- Optical Modules (X-ARAPUCA)
- Cabling, Connections and Flanges ⬅️ cabling/connectors inside APA cleared preliminary design review
- SiPM ⬅️ already cleared their review

Pre-Installation QC (chapter 8)

QC during integration of the PD system into the APA, during cryostat installation, and in the period following installation until cryostat cooldown are detailed in the Detector Installation Plan (EDMS 2233449 and EDMS 2848034 for ProtoDUNE II). The details and exact quantities to be measured are currently under development within the consortium as our understanding of the quantities we can measure during this phase evolves, but the outline of a plan is in place and is detailed below.

- Incoming inspection: Upon receipt in the gray room in in front of the cryostat, a set of 10 modules is removed from their packing material and inspected for damage which may have occurred during shipping. Special attention will be paid to scratches to the dichroic filters, and the tightness of all accessible screws will be confirmed with appropriate torque screwdrivers

- Dimensional checks: All critical module dimensions will be checked with a set of go-nogo gauges similar to those used during fabrication to ensure that the module will fit inside the APA when installed. Module straightness will be checked at this time to ensure it is within tolerance. The module is installed in a test slot representing the tightest slot configuration with APA rail mounting tolerance.

Pre-Installation QC (chapter 8)

- Pre-insertion scan: Each module will be re-scanned using an LED scanner identical to those used during module fabrication and testing, and the results compared against previously recorded data.
- Pre-integration APA check: Each PD cable carrying signals out of the APA is connected to an automatic cable tester, which will allow simultaneous continuity checks for all cables during pre-testing and installation. A dummy module with dimensions representing the maximum allowed module size is inserted into each slot, testing module insertion and connectivity from the APA exit to each module position for all cable conductor pairs. The automatic cable tester is a bluetooth device, allowing automatic retrieval and storage of testing results. It is currently under development at Colorado State University.
- Pass-through cable check: For the upper APAs, which have extra cables passing through them to route signals from the lower APA, continuity checks and checks against accidental shorts to the APA frame are checked using the automatic cable tester.

APA Integration QC (chapter 8)

- Module continuity: As modules are inserted into the APA, the automatic cable tester will check continuity across all cable pairs and confirm there is no ground short from the APA to the module.

- APA stack assembly: As the passthrough cables in the upper APAs are connected to the signal cables in the lower APA (while an APA stack is being assembled), the automatic cable tester is used to confirm connectivity from the passthrough cable exit at the top of the upper APA to the appropriate lower APA PD module.

- Cold box testing: Following APA stack assembly and cold electronics mounting, the APA stack will be moved into a cold box immediately prior to installation in the cryostat. The APA stack will undergo a cold cycle in cold gaseous N2 similar to that performed prior to APA insertion into the ProtoDUNE2 cryostat. Checks will include (but not be limited to) measurement of dark count rate for each PD channel, detection of LED flasher signals with each channel, an a check for cross-talk to APA cold electronics.

Post-Installation QC (chapter 8)

- APA stack cabling in cryostat: As each APA stack is positioned in the cryostat and the cables are connected to the PD flange by the I&I installation team, PD cables will be connected to the DAPHNE modules for that APA stack which will be pre-installed before APA stack integration begins. An automatic script will check to ensure connectivity through all channels.

- Cryostat dark check: At the conclusion of installation each row of 3 APA stacks in the cryostat, and off-shift test of the PD modules in a darkened cryostat illuminated by the PD monitoring system LEDs read out through their warm electronics will be conducted to to ensure all channels are operational. As additional rows are installed, all PD modules currently installed in the cryostat will be re-checked to provide a temporal record of PD module performance and look for developing problems

- Pre-filling continuing checks: Following all APA installation and closure of the cryostat TCO, regular PD performance checks will continue through cooldown and filling with liquid argon to confirm continuing system stability until the final KPP is achieved and detector operating begins.

Lessons Learned from ProtoDUNE 2 (here in highlights, in full on chapter 9)

- Reception and material tracking: At all stages of assembly, the first action before assembling a component must be to check and write the pieces of each module. All groups should have access to this database, but we should grant writing permission only for the current action, process, etc. This procedure has been fully validated for the SiPM boards, which are in post-PRR stage.

- Mechanical assembly: Care must be taken with reception inspection of all components. During Module 0 assembly several pieces of (FR4, G10) were found during assembly to be not properly drilled and had to be drilled again so screws could pass by.

- Filter handling: Filter support structure should be modified to eliminate dual-purpose components used both for module structural integrity and to hold filters in place. Filters on both sides of the module can not share the same support structure.

- Feedthroughs and cable support: the protocol to lift the cables used in ProtoDUNE 2 is dangerous. Care must be taken to prevent requiring the scissor lift to remain in position for long periods of time, preventing emergency removal of personnel.

Fabrication, Inspection and Test Forms (chapter 10)

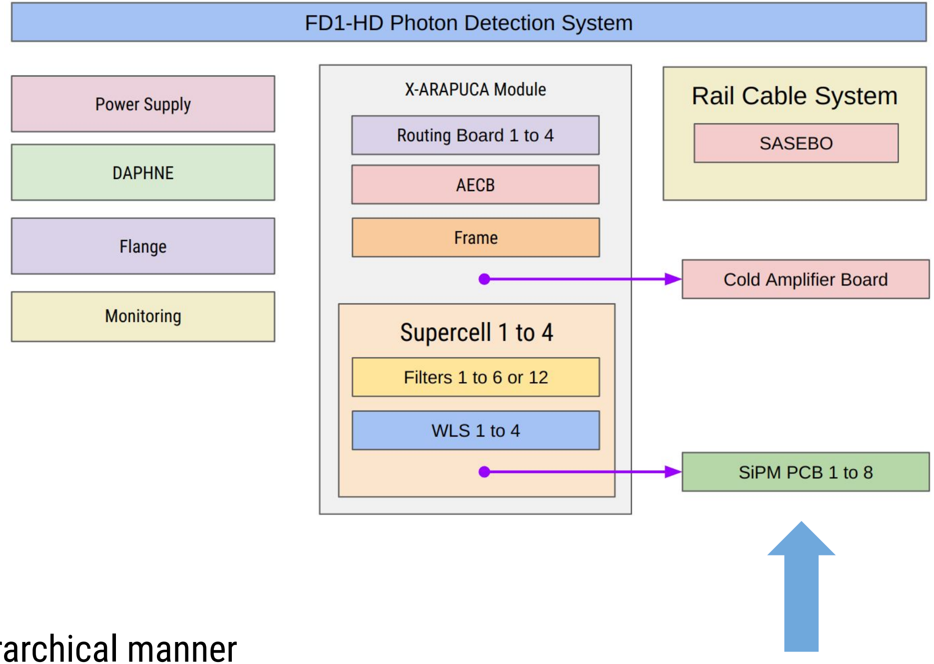
- All QC data (from assembly and pre- and post-installation into the APA) will be recorded on QC travelers and directly stored to the DUNE database for ready access of all QC data. Monthly summaries of key performance metrics (to be defined) will be generated and inspected to check for quality trends.
- Prior to shipping from assembly site:
  - dimensional checks of critical components and completed assemblies to insure satisfactory system interfaces;
  - post-assembly cryogenic checkouts of SiPM mounting PCBs (prior to assembly into PD modules;
  - module dimensional tolerances using go/no-go gauge set; and
  - warm scan of complete module using motor-driven LED scanner (or UV LED array).
- Following shipping to the U.S. reception and checkout facility but prior to storage at the South Dakota Storage Facility:
  - mechanical inspection;
  - warm scan (using identical scanner to initial scan); and
  - cryogenic testing of completed modules (in CSU CDDF).
- Following delivery to integration clean room underground, prior to and during integration and installation:
  - warm scan (using identical scanner to initial scan);
  - complete visual inspection of module against a standard set of inspection points, with photographic records kept for each module;
  - end-to-end cable continuity and short circuit tests of assembled cables; and
  - an Front End electronics functionality check

Fabrication, Inspection and Test Forms (chapter 10)

- Specific travellers for incoming material QC data , fabrication and inspection travelers, and inspection and test data.
- The information required for each from is listed in the QA/QC document. Here's a highlight:
- Incoming material QC data: Material receipt travelers will be generated by each detector sub-team to record data for each batch of incoming material.
- Fabrication and inspection travelers: Component fabrication travelers will be generated by each detector sub-team to record data for each sub-assembly process (example form at EDMS 2785928)
- Inspection and test data: Assembly test procedures will be generated by each detector sub-team to record data for each DUNE assembly QC test.

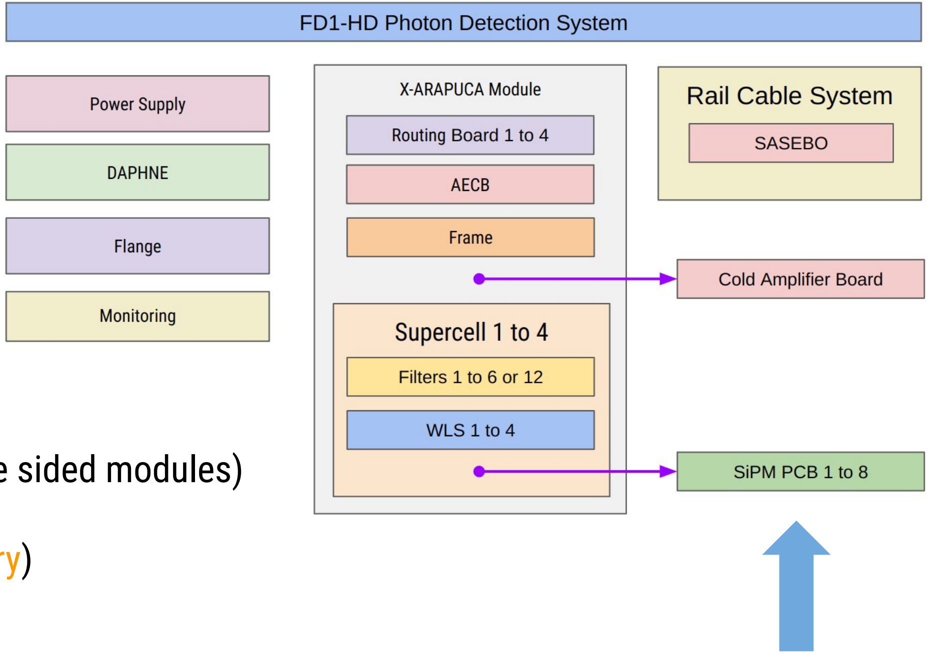
Hardware Database Implementation (chapter 11)

- Each subsystem is a component of the PDS
    - Power Supply
    - Flange
    - Warm Electronics (DAPHNE)
    - Monitoring System
    - Rail cable system
    - Optical Modules (X-ARAPUCA)
    - SiPM PCB
    - Cold Amplifier
- Unique PIDs are used in labels as QR or Barcodes
- Some components are related to each other in a hierarchical manner



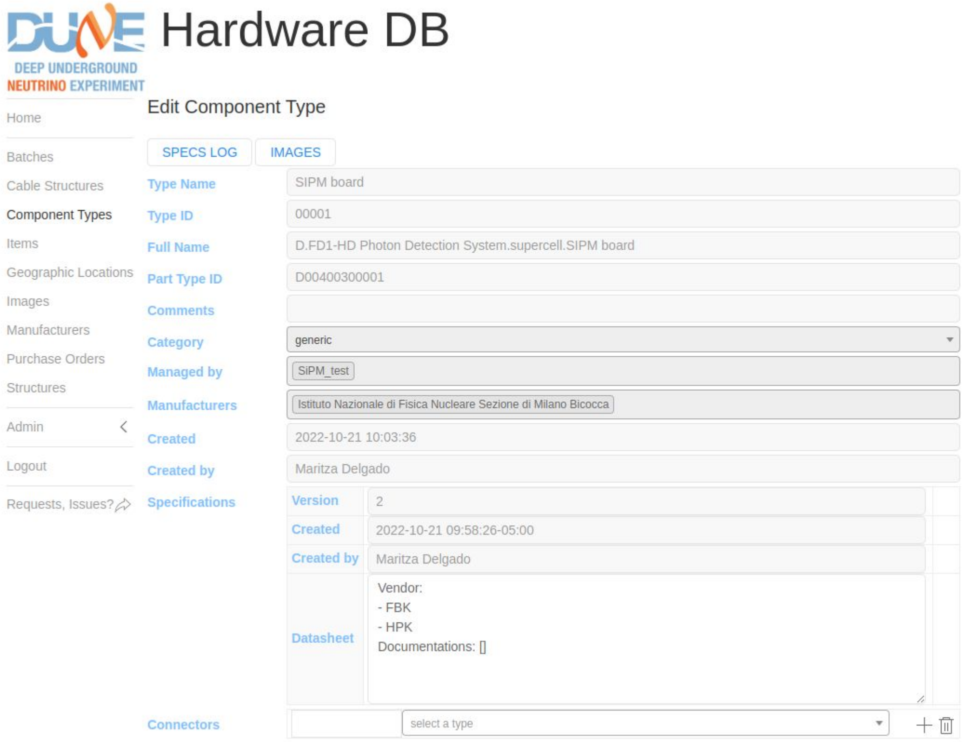
Hardware Database Implementation (chapter 11)

- Optical Modules (X-ARAPUCA)
  - 4 Routing Boards
  - 1 AECB
  - 1 Frame
  - 1 Cold Amplifier (linked from its own entry)
  - Supercells (one for each channel)
    - 6 or 12 Dichroic Filters (single or double sided modules)
    - Wavelength shifter light guides.
    - SiPM boards (linked from their own entry)



Hardware Database Implementation

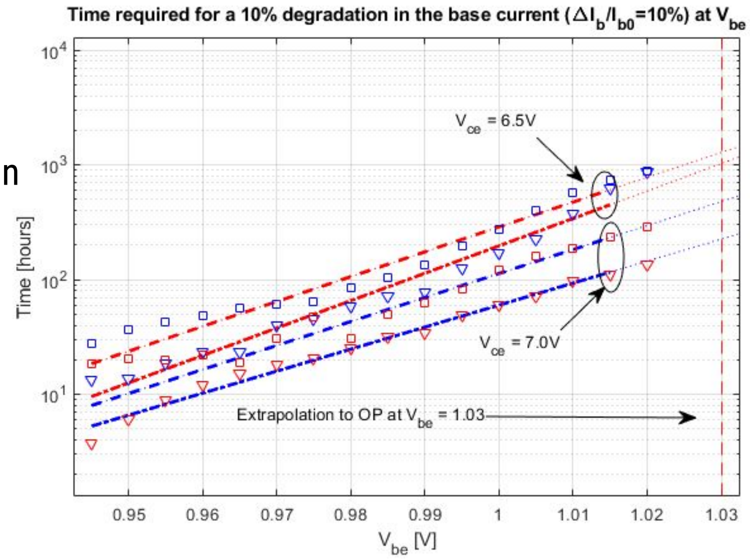
- Since the SiPM has already went through review, its HWDB branch is already in place.
- This doubles as learning experience for implementing the rest of the database.
- The database entries act as traveller form since it stores not only the location of a part but also the name, login, date and time of the person checking in and out.



BACKUP SLIDES

Cold Electronics

1. System Requirements
   - Using commercial off-the-shelf (COTS) parts
   - All parts characterized and stress-tested for degradation
   - Lifetime determined by extrapolation

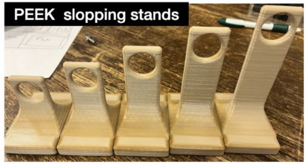


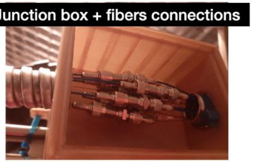
Monitoring System

3D printed light diffuser and assembly

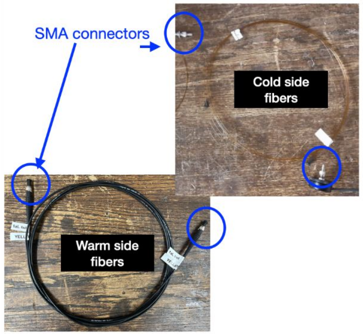
Testing of the 3D diffuser using a LED

Slopping stands and junction box

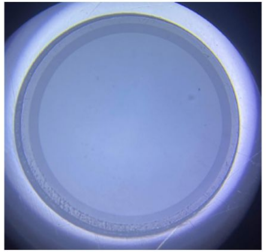




Optical Fiber Assembly

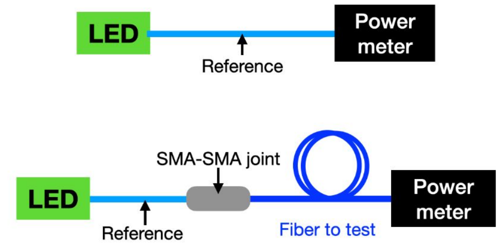


Visual inspection of fiber end



Light attenuation test

Estimation of the light loss between **reference fiber** and the **fiber to be tested**



X-ARAPUCA