APA Populated Board Production
PRR Kickoff Meeting

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November 26, 2024

Outline

- Scope, Cost and Schedule
- Design Status
- Work planning and control
- Production and Quality Assurance

Documentation For Review

Documentation Category	Document Description	EDMS Link
Systems Engineering	Subsystem Model	https://edms.cern.ch/project/CERN-0000196720
	Interface Documents	Consortia Interfaces APA Wire to CE Map
	Fabrication Drawings	https://edms.cern.ch/project/CERN-0000253396
	Part Identifiers	https://edms.cern.ch/document/2684658/LAST_RELEASED
	Database Entry	APA QA Database
	Installation Plan	https://edms.cern.ch/document/3086484/LAST_RELEASED
Electrical Engineering	Grounding and Shielding Plan	https://edms.cern.ch/document/2617017/LAST_RELEASED
	Wiring Diagrams	https://edms.cern.ch/project/CERN-0000253396
	Detailed Cable Drawings	Cable Harness Drawings (8765023, 8765024) SHV Assembly Drawing (8760959)
	PCB Documentation	https://edms.cern.ch/project/CERN-0000253396
	ESD Procedures	See Production Procedures for Each Assembly Type See Installation Procedures for Each Assembly Type
Compliance Office	Electrical and Mechanical Safety Reviews	https://edms.cern.ch/document/3070147/LAST_RELEASED
	Applicable Engineering Codes and Standards	https://edms.cern.ch/document/3070147/LAST_RELEASED
	Compliance Office Approvals	ESDA
	Procurement Plan	https://edms.cern.ch/document/3086484/LAST_RELEASED
	Vendor QC Documentation Plans	https://edms.cern.ch/document/3086484/LAST_RELEASED
	Handling of Critical Components	https://edms.cern.ch/document/3086484/LAST_RELEASED
	ECR/ECN Process	Engineering Change Request Engineering Change Notification
	Worker Training Requirements	https://edms.cern.ch/project/CERN-0000230863
Technical Coordination	Production Schedule	Production Status Google Sheet - Populated Boards Tab
	Shipping Plan and Schedule	https://edms.cern.ch/document/3086484/LAST_RELEASED
	Resources	Board production equipment includes: Keyance Metrology Pick and Place Machines Vapor Phase Reflow Selective Solder Machine Custom Automated Test Stands for CR,G-bias and CE Adapter boards Mill-Max pin insertion robot
	Production Risks and Mitigations	https://edms.cern.ch/document/3086484/LAST_RELEASED
	Sign-offs for transfer of Produced Items	https://edms.cern.ch/document/3086484/LAST_RELEASED

- The PRR documents are accessible from EDMS
- Links are organized according to category
- Some EDMS entries contain multiple documents; when that happens links are duplicated in the sheet

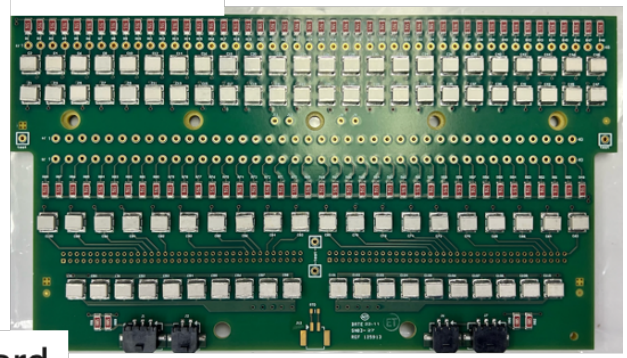
Review Office	Responses to Previous Reviews	https://edms.cern.ch/document/2604165/LAST_RELEASED
	Final Testing and Performance Results of Pre-Production Work	https://edms.cern.ch/document/3086484/LAST_RELEASED
	Design Changes since FDR	Use of hexagonal Mill-Max inserts and included specification of copper plating for Mill-Max holes in geometry and CR boards.
ES&H	Facility Safety Plans	https://edms.cern.ch/document/3070147/LAST_RELEASED
	Hazard Analysis for Production	https://edms.cern.ch/document/3070147/LAST_RELEASED
Quality Assurance	Manufacturing and Testing Procedures	https://edms.cern.ch/project/CERN-0000230863
	Shipping, Handling and Storage Specifications	https://edms.cern.ch/document/3086484/LAST_RELEASED
	QA/QC Plan	https://edms.cern.ch/document/3070145/LAST_RELEASED
	Traveler Documents	Auto-generated by APA QA database web-application
	Non-conformance Documents	Stored in APA QA database
	DB Plans	APA QA Database
	Assigned Sign-offs	https://edms.cern.ch/document/3086484/LAST_RELEASED
	Installation and Testing Procedures	https://edms.cern.ch/project/CERN-0000253415

Scope

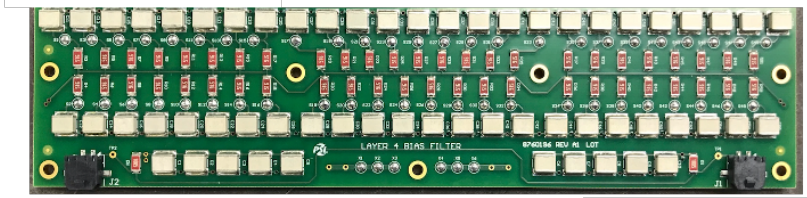
Charge Q1a

- CR boards - connected to signals from X,V, U layers
- G-bias boards - connected to G layer
- CE adapter board - interface between APA and cold electronics
- Bias voltage distribution harnesses
- SHV board - distributes bias voltage to wire layers through cable harness

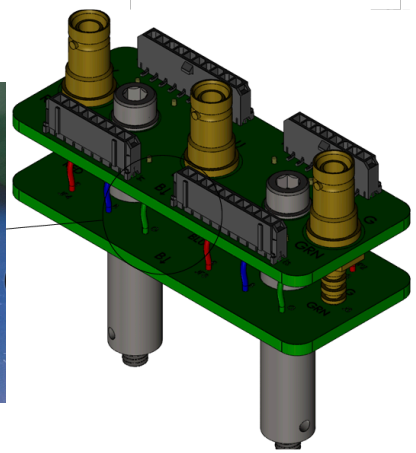
CR Board



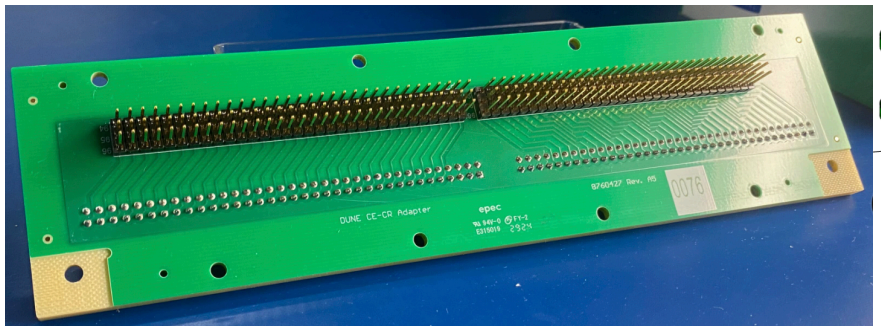
G-bias Board



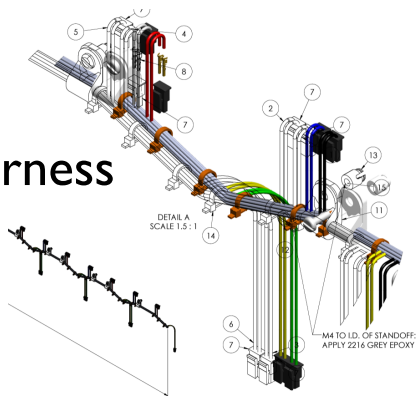
SHV Board



CE Adapter Board



Cable Harness

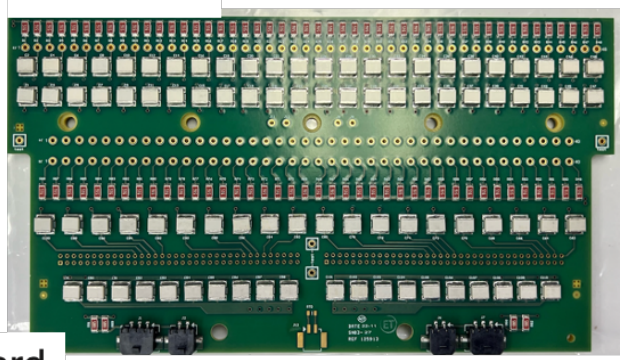


Scope

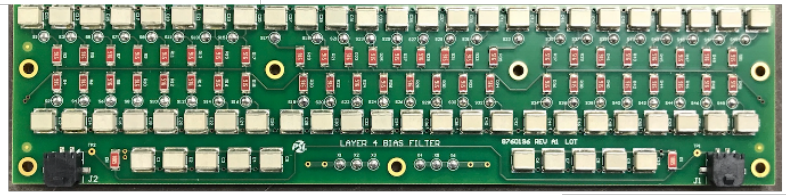
Charge Q1a

Assembly	Number Per APA	Total + Spares
CR	20	3000 + 200
G-bias	20	3000 + 200
CE Adapter	20	3000 + 200
Harness	2	300 + 20
SHV	1	150 + 10

CR Board

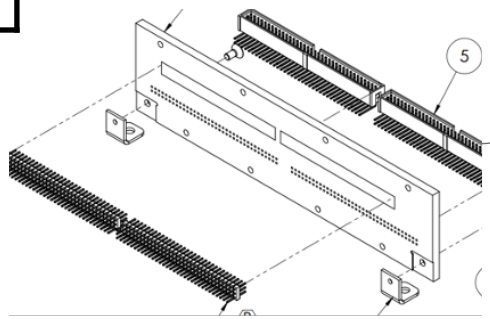


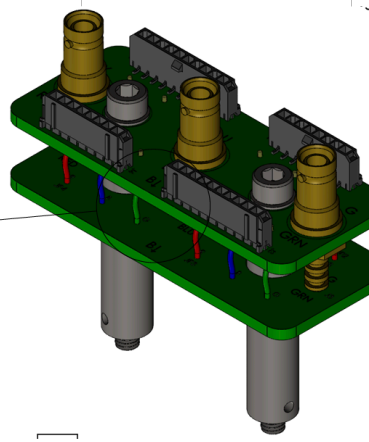
G-bias Board



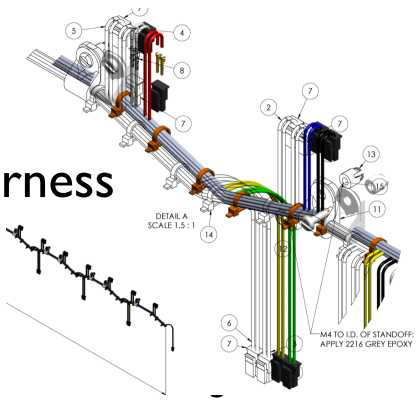
SHV Board

CE Adapter Board





Cable Harness



Costs

DEEP UNDERGROUND NEUTRINO EXPERIMENT

Charge Q1b

Assembly	PCBs	Electrical Components	Mechanical Components	Labor	Total Per APA
CR	1.34	0.48	0.23	9.64	11.69
G-bias	0.16	0.15	1.78	3.30	5.39
CE Adapter	0.16	0.39	0.18	3.30	4.03
Harness	NA	0.49	0.71	2.86	4.06
SHV	0.01	0.10	0.0	0.62	0.73
Capacitors	NA	4.59	NA	NA	4.59
Total	**1.67**	**6.20**	**2.90**	**19.72**	**30.49**

- Table shows costs in $k per APA
- Costs include assumption of 90% yield for components and an additional 10% inefficiency factor for labor
- Total cost including spares is $4,878k

Schedule

Charge Q1b

Assembly	Production Cadence	50% Complete Date	100% Complete Date	Installation Duration
CR	4 APAs/month	August 2026	April 2028	April 2028 - February 2029
G-bias	4 APAs/month	August 2026	April 2028	
Harness	8 APAs/month	October 2025	August 2026	
SHV	16 APAs/month	April 2025	October 2025	
CE Adapter	8 APAs/month	October 2025	August 2026	August 2025 - September 2027

- The above table assumes a start date of 1 December 2024
- CE adapter boards delivered to CE Consortium - 50% needed by Sep. 2026
- SHV production will likely start later, but we have plenty of time
- All assemblies completed well before their need-by date

Supply Chain

Charge Q1b/Q4b

- The CD3a/b scope provides funding for procurement of all PCBs and components needed: Procurement Plan is on EDMS
- Procuring all boards and components in batches to match the shelf-lives of the items: biggest risks are oxidation of copper pads and aging of pre-soldered surface mount components
  - Boards typically take 20 days from date of order, ordering in batches of approximately 1000 boards
  - Components depend on available stock, but typically 6 weeks or less for quantities required to assemble 1000 boards
  - Capacitors are long-lead time; first half of total needed ordered to be delivered in 4 equal batches, will do the same for the second half
- We have a Wisconsin Governor's Waiver that allows us to streamline procurement

Pre-Production QA

DEEP UNDERGROUND NEUTRINO EXPERIMENT

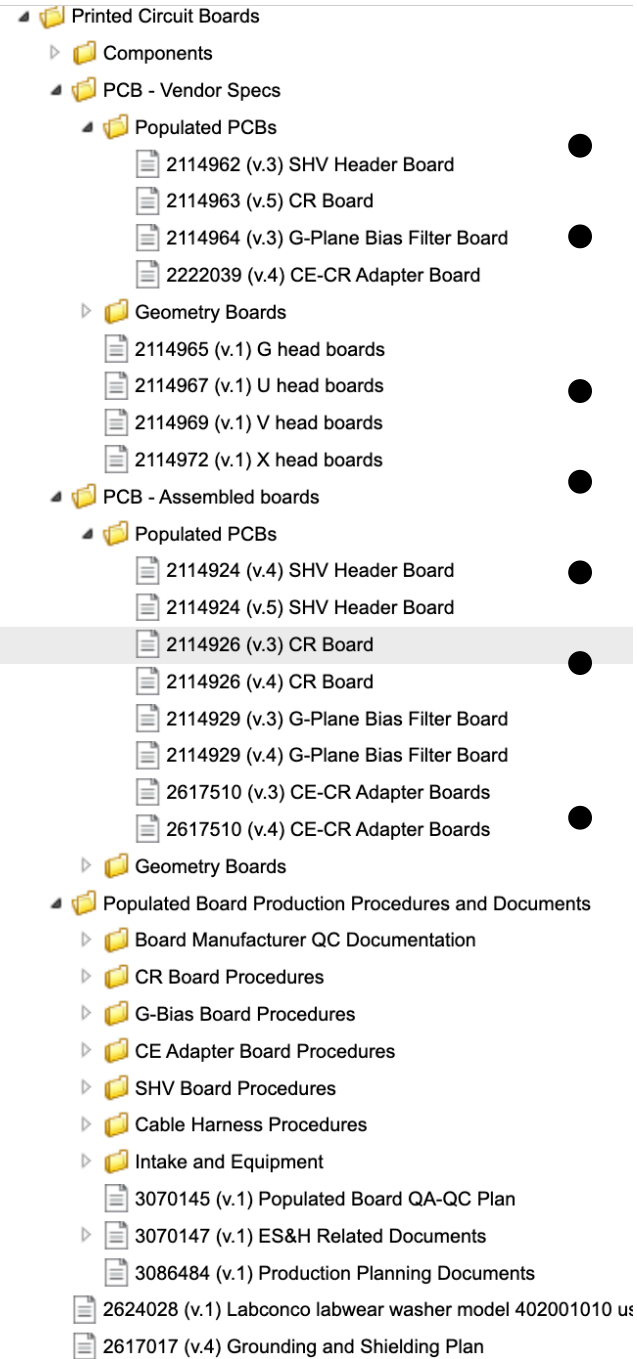
Charge Q1c

Board Type	Quantity Assembled	Quantity Passed (%Yield)
CE Adapter	44	44 (100%)
CR	40	40 (100%)
G-bias	44	43 (97.7%)
SHV	4	4 (100%)
Bias Voltage Distribution Harness Sets	2	2 (100%)

- QA results of pre-production assembly are in EDMS
- Our goal is for 90% yield of assemblies to be ready for use at SURF
- We are over-achieving the goal with at least 97% yield so far
- The yield of PCBs passing the Keyence metrology checks is similarly high - currently above 95%
- No assemblies will be sent to SURF unless they pass all acceptance tests

Design Status

Charge Q2a/b

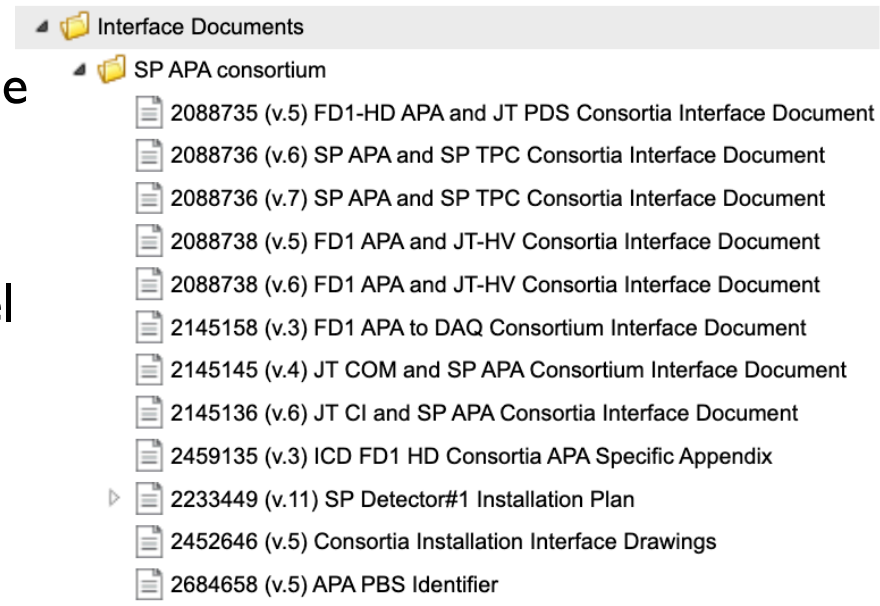


- APA requirements are in EDMS
- Board specifications and drawings are in EDMS, folder structure is shown at right
- Current versions of the boards were deployed in ProtoDUNE II
- Folders relevant for this review are labeled "Populated"
- "PCB - Vendor Specs" are files sent to PCB manufacturers
- "PCB - Assembled boards" are the mechanical assembly drawings for all boards
- Design changes since the FDR (August 2021) are:
  - Switch to hexagonal profile Mill-Max pins
  - Specified plating amount for Mill-Max pin holes
  - Changed to using 2 and 3 pin Molex connectors for G-bias and CR boards and cable harnesses to ensure proper cable attachments

Interfaces

Charge Q2a

- Interface documents are accessible from the APA EDMS area
- The only interfaces for this scope of this PRR are with the TPC consortium
- The CE adapter boards create the link between the CR boards and the FEMBs
- We developed the channel mapping with the CE group to go from APA wire segment to CE channel
- The SHV assemblies accept the bias voltage cables from the TPC consortium
- In both cases, the components on the APA assemblies were chosen in collaboration with the other consortium
- The other boards and harnesses connect to the APA frame or head board stack



Previous Recommendations

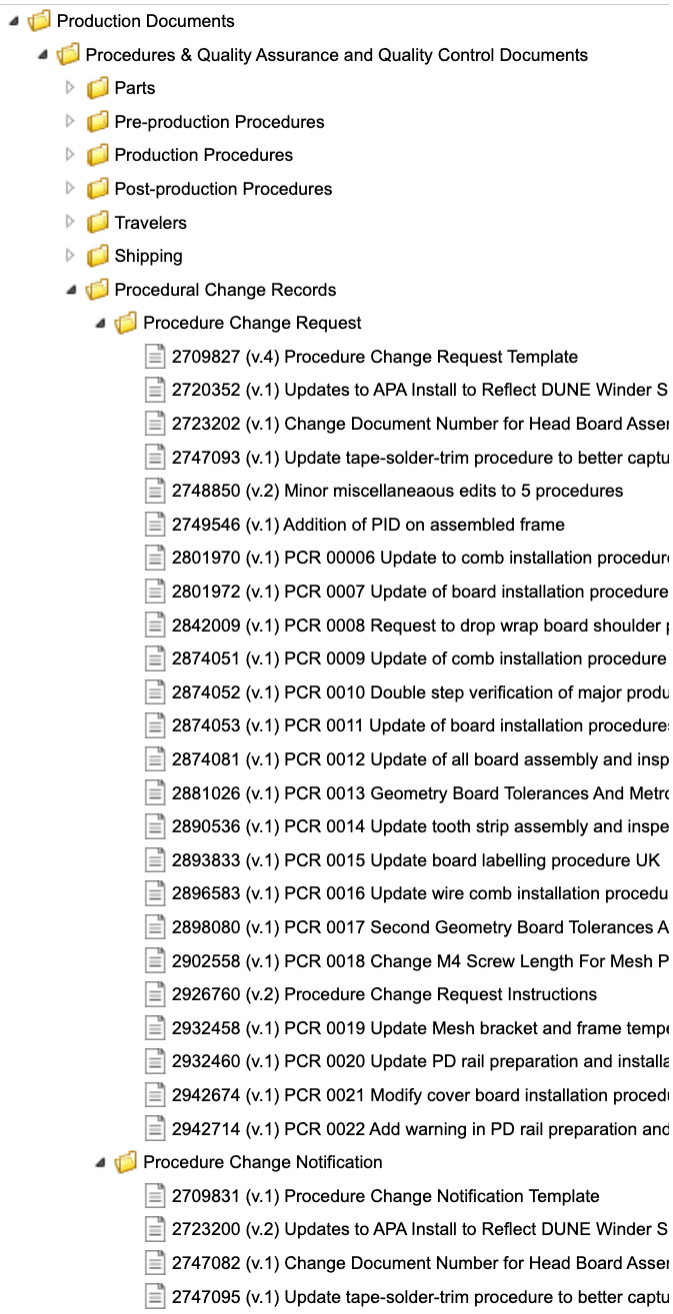
Charge Q2c

Review Type	Review Title	Rec. No.	Recommendation Text	Owner(s)	Owner Email	Response by Owner	Scheduled Cl	Actual Close	Status (Owner)	Status (RO)	Status (DPD o
FDR	FD1 APA FDR	1	The APA team should ensure that updated schematics and associated BOMs are present in EDMS to accurately reflect the connectors used on the production boards.	JE, BR, CT	justin.evans@manchester.ac.uk	All PCB drawing packages have been updated in EDMS.	2/4/22	2/4/22	**Completed**	Complete	**Closed**

- Recommendations from the FDR are on EDMS
- Only one was relevant to the scope of this PRR (see above)
- The recommendation was completed and closed in February 2022

Change Control

Charge Q2d



- The APA consortium has a process released on EDMS for approving both engineering and procedure change requests
- Change requests are posted and circulated to the relevant people for review through EDMS
- Once approved, updated procedures or drawings are approved and released
- Finally a change notification is processed through EDMS to ensure all relevant folks are informed

Production Team

Charge Q3a/b

- Pam Marr-Laundrie is leading the effort and it couldn't be in better hands
- Xu Zhai can provide some engineering support as needed
- Andy Arbuckle is the lead electrical tech - years of experience building components for DUNE and IceCube; will run the component assembly equipment
- Mary Severson, Christine Verdico, Phil Johnson and Soeun Ouk are other techs from PSL performing QA checks, washing boards and assembling harnesses
- Looking to supplement the core team by bringing under-utilized techs from other UW departments to PSL
- We have also identified a couple of undergrads, Krishna Lakkaraju and Maya Lee, to help with Keyence checks, laser marking of boards and running test stands
- P6 includes 0.45 FTE engineer and 4.55 FTE technician labor per year for this work

Setting up for Production

Charge Q3c

- Production will take place at UW PSL
- The production area has been set up over several months with a lot of equipment: pick and place machines, vapor phase reflow, board metrology, selective solder machine, pin insertion robot

Setting up for Production

DEEP UNDERGROUND NEUTRINO EXPERIMENT

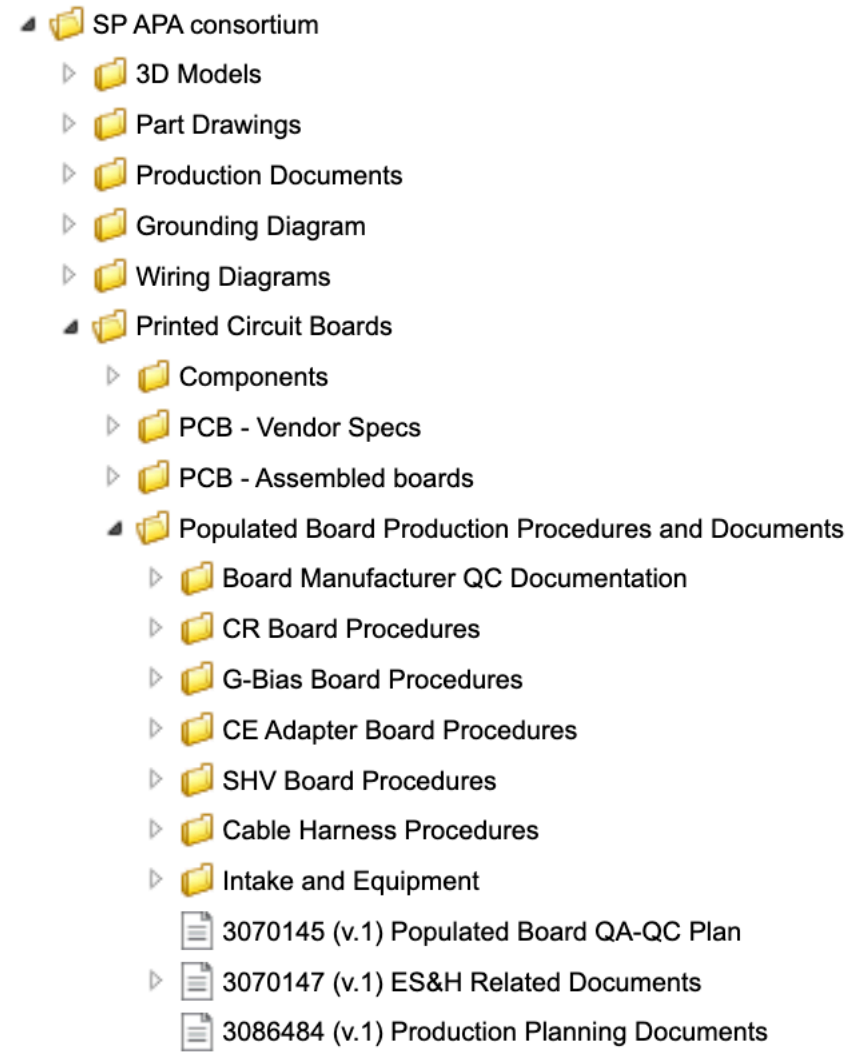
Charge Q3c

- Selective solder machine is my favorite
- Used for the connectors on the CR and CE adapter boards
- Provides a very uniform solder connection in a fraction of the time it took to make the ProtoDUNE I and II boards
- Several board washers for the different processes
- Automated test stands for CR and G-bias boards are ready for use

Setting up for Production

Charge Q3c/d

- Procedures and work instructions are released in EDMS
- Procedures for incoming inspection, assembly and testing of all assemblies are grouped by assembly type
- We also have procedures for material intake and equipment maintenance
- Pam engaged with UW ES&H to ensure safe working conditions during the assembly, documents are posted to EDMS
- The Electrical Safety Design Analysis was approved by the CO (Terri Shaw) and is also posted to EDMS



Risks and Mitigations

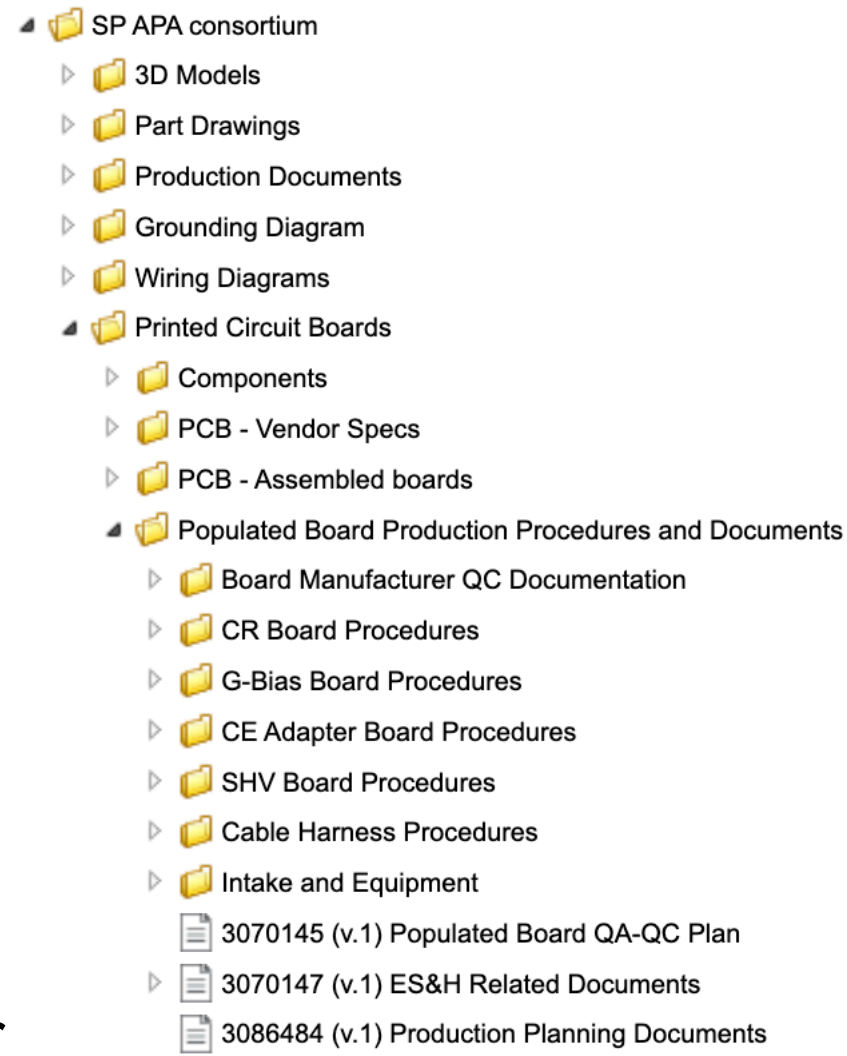
Charge Q4a

- Two primary risks for this production
  - Availability of capacitors - still to procure 289,168 of them
  - Availability of labor at UW PSL
  - See EDMS for more details
- Capacitor mitigation is to order the full amount from a supplier and have the capacitors delivered in several smaller batches over the course of several months
- Currently have enough capacitors on-hand for half the production
- We have identified a team of 5 PSL techs available for this production supplemented with undergraduates
- We are also working on a deal with other campus departments to bring in skilled electrical techs as needed when those departments have capacity to do so

Incoming Inspection

Charge Q4c

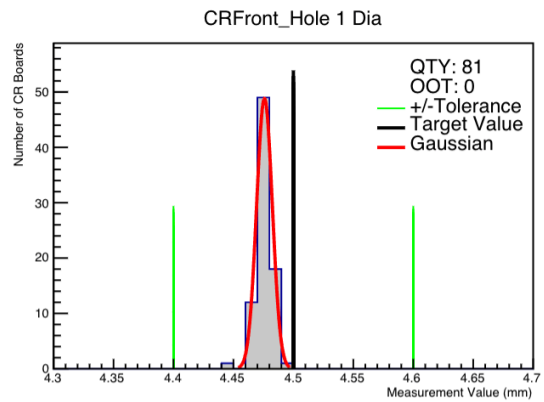
- Procedures for intake of PCBs and inspection are released in EDMS
- The process varies slightly from one board type to another; specific procedures are listed in subfolders for each board type
- There is no incoming inspection of bulk components such as resisters, capacitors, connectors, etc. as those components are assumed to have high yield from the manufacturer
- For both PCBs and components we have ordered sufficient quantities to allow up to 10% to fail
- If we have higher yields we will order fewer materials in the last batches

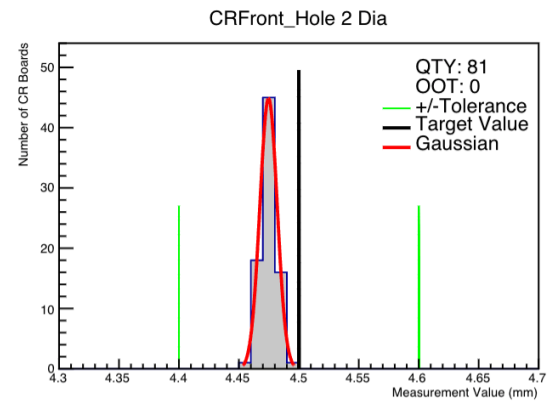


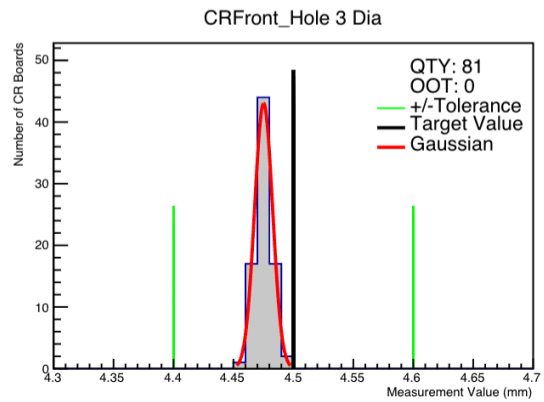
Incoming Inspection

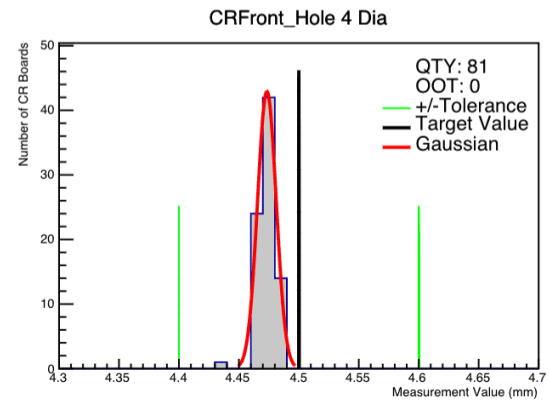
Charge Q4c/f

- We create distributions of all feature positions and compare them to the target values and tolerances
- The number of out-of-tolerance (OOT) boards are recorded and any OOT board is identified with the offending measurement(s)
- Metrology data are stored locally, but not deemed necessary to go into the database
- All boards are laser marked after metrology checks, even those that fail
- QA materials from vendors are stored on EDMS





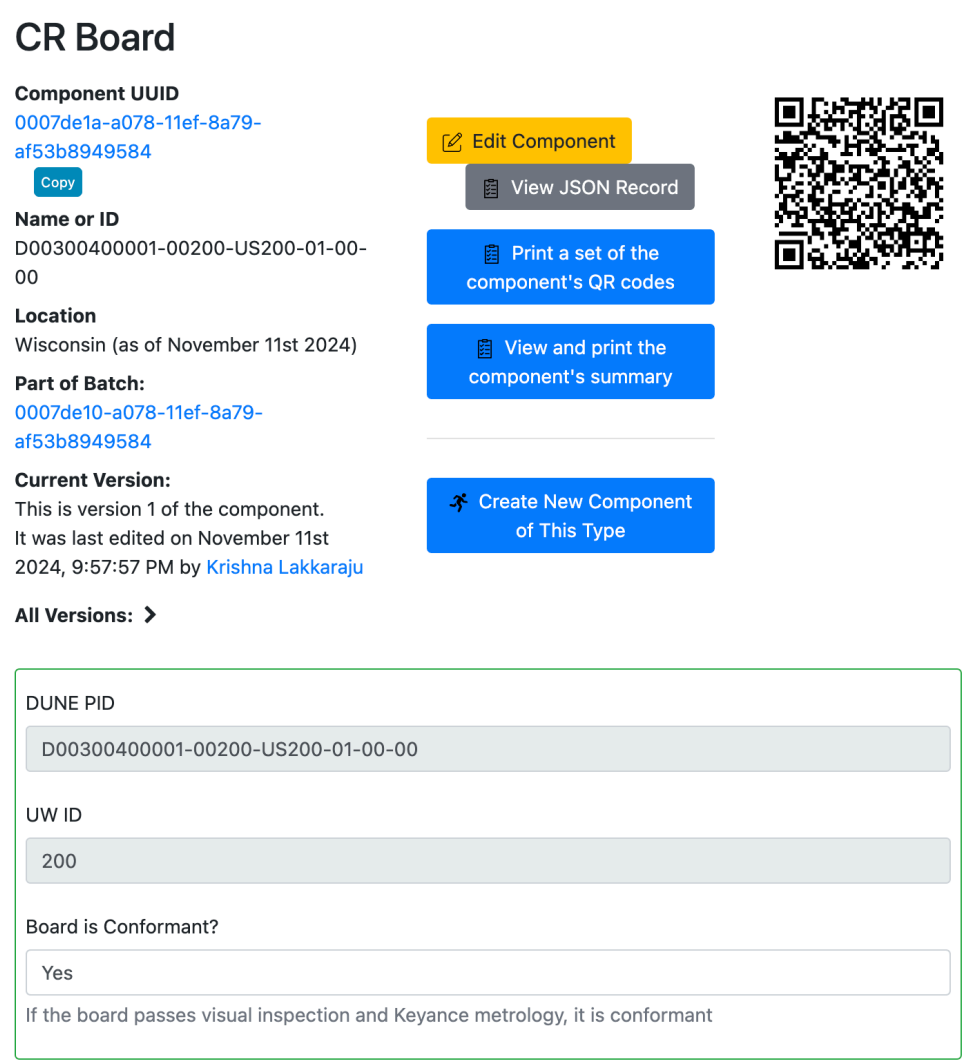




QA Data

Charge Q4d/e/f

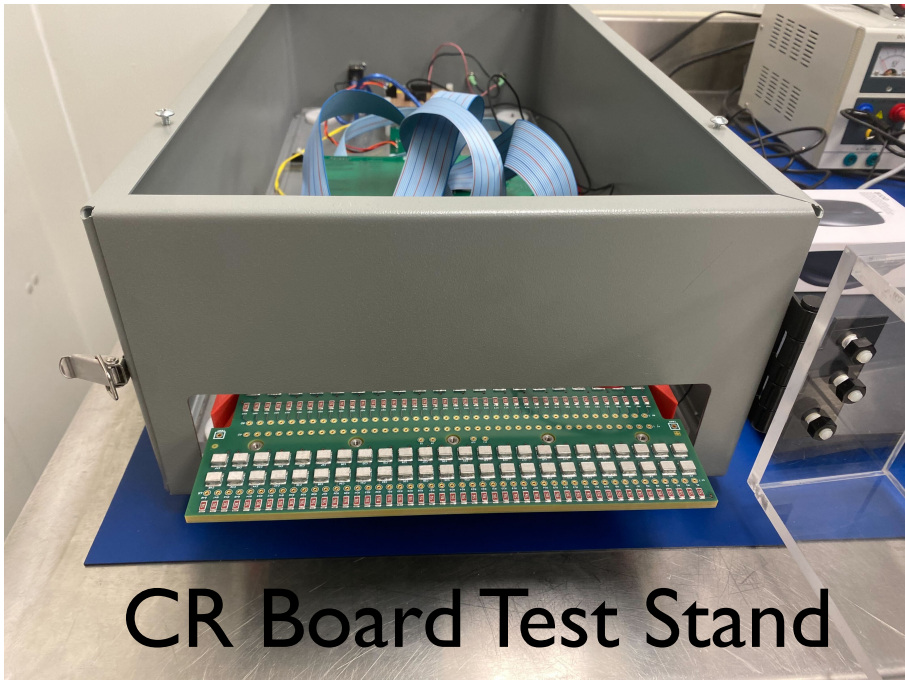
- The APA consortium developed a database for storing all QA data, including travelers
- Instructions are on EDMS
- The component page for a CR board is shown at right
- The database automatically populates the DUNE PID, local UW ID (marked on board) and a QR code for the board
- PCBs that fail incoming inspection are marked as non-conformant and put aside
- Travelers are auto-generated using the "Component Summary" button



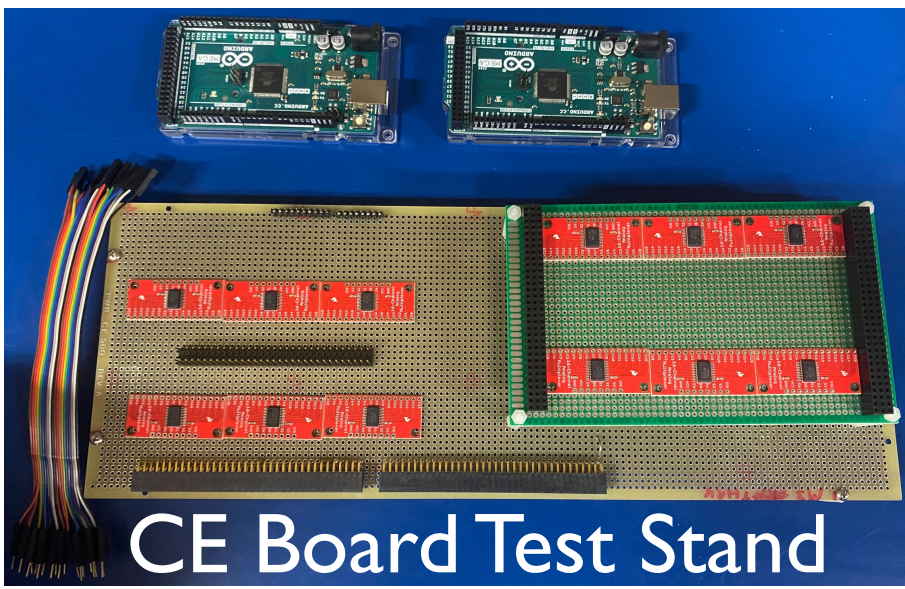
QA of the Assemblies

Charge Q4d/e/f

- Every assembly has a QA check performed after completion
- G-bias and CR boards are tested for the RC time constant and leakage current in the warm, cold-cycled and then tested again warm
- Developed bespoke test stands for these boards to ensure safe capacitor discharge and reliable operation
- CE adapter boards are checked for continuity and isolation between channels
- Harnesses are tested for continuity
- SHV assemblies will be tested for continuity



CR Board Test Stand



CE Board Test Stand

QA Data

Charge Q4d/e/f

- The test results are stored in the database and associated to each individual assembly in the database
- The form for the QA check is shown at right
- The cold cycle tests are recorded only for G-bias and CR boards
- Any assembly that fails QA testing is set aside and will not be shipped to SURF

Component Type *

Pick what type of component is being QC'ed

Pre-Cold Cycle Test

- Passed
- Failed

Post-Cold Cycle Test

- Passed
- Failed

QA Test Result

- Passed
- Failed

Comments

Any relevant comments, ie replaced capacitor number XX, etc

Storage and Shipping

Charge Q4g

- The storage and shipping plan is released on EDMS
- After testing is completed the boards are packaged in anti-static bags with desiccant
- CE adapter boards must be sent to the FEMB production sites so they are packaged and sent separately from the other assemblies
- Will package remaining assemblies as kits containing enough assemblies for a single APA and sent to SURF as needed for the installation
- There will be 10 total spare kits; the installation team can open a spare kit to get spare assemblies for multiple APAs
- The kits are recorded in the database and QR codes pointing to those entries will be included with the kits
- The database is able to track the inventory through these kit entries

Testing at SURF

Charge Q4g

- We anticipate a few tests at SURF
  - CR boards will be checked for leakage current, although it appears doing so is more a test of humidity in the environment than an issue with the boards
  - The combination of the SHV assemblies, G-bias, CR boards and harnesses will be checked for continuity along the full chain
  - Both tests currently require the assemblies to be installed on an APA
  - We may come up with a leakage current test that can be done before installation
- Installation procedures will be posted to EDMS, but are not finalized yet

Summary

- We are ready to start production