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APA assembly

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DUNE FDR: APA
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Talk Outline

- DUNE APA factories
- Overview of key equipment
- DUNE build sequence
- DUNE APA assembly process

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DUNE APA Factories - UK

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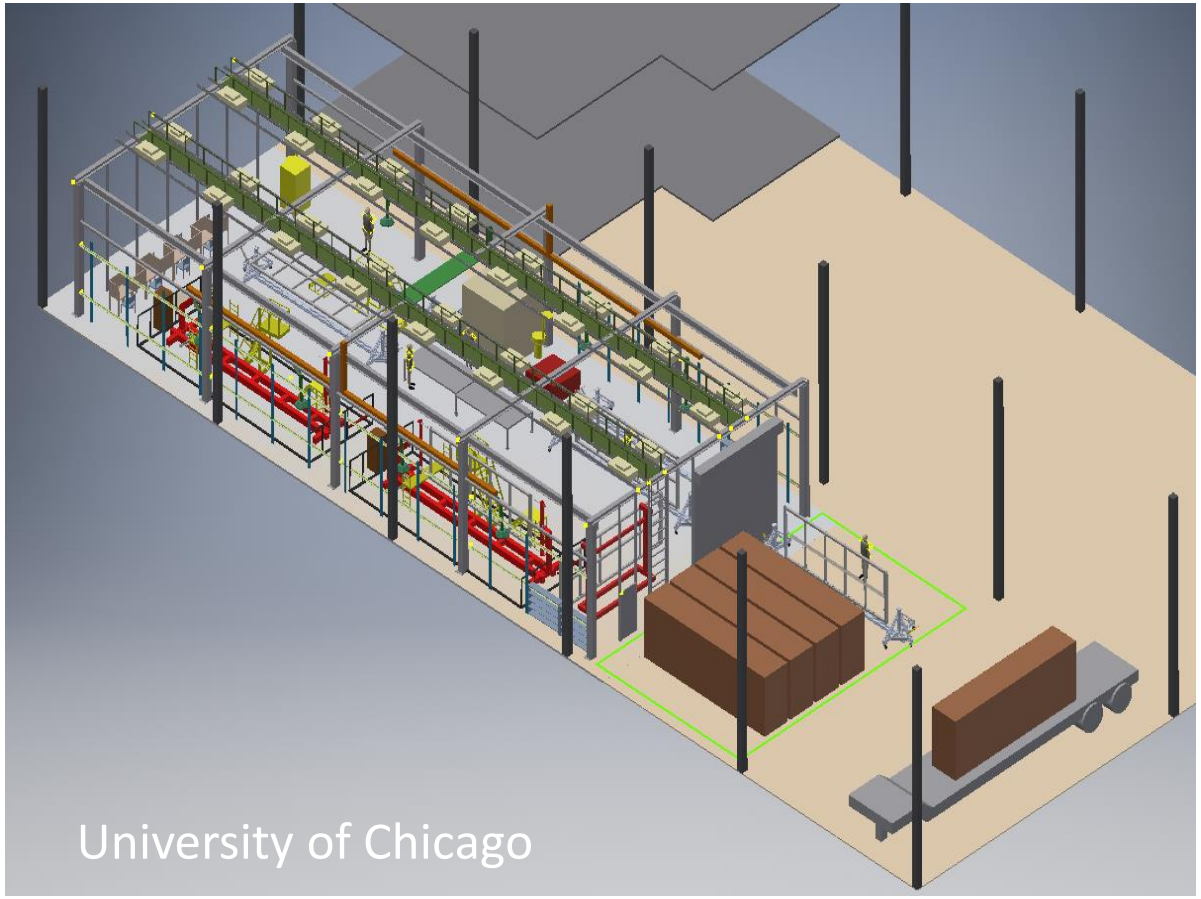
DUNE APA Factories - USA

PSL, University of Wisconsin



University of Chicago

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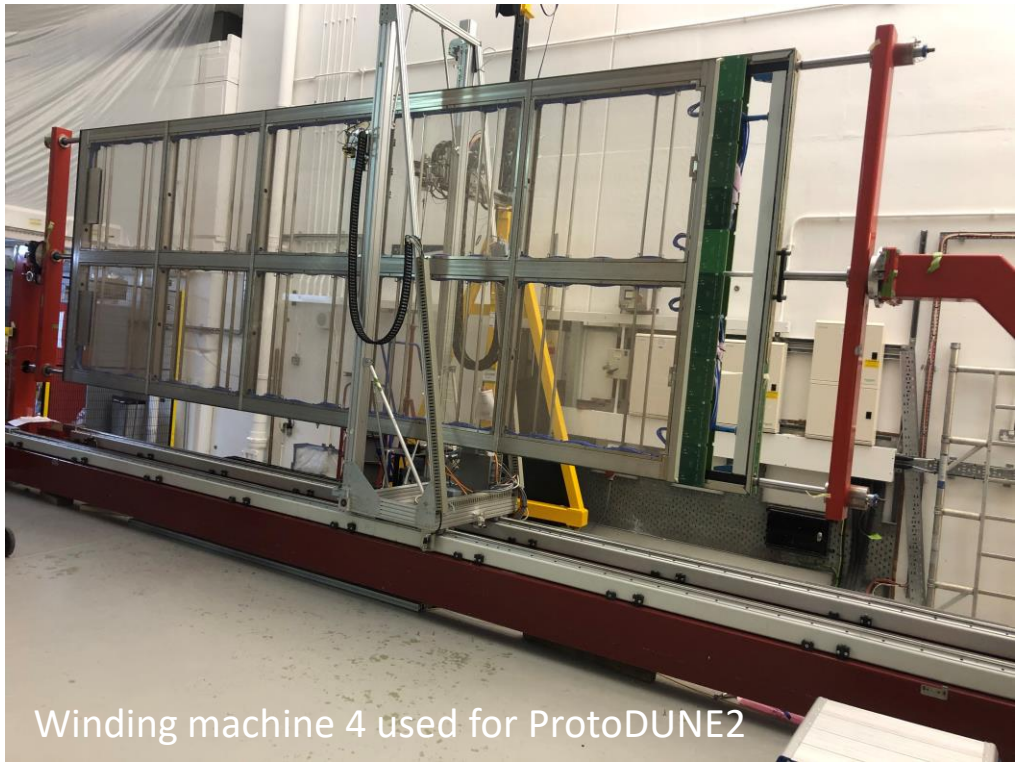
APA winding machines

Winding machine 1 in DL factory



Winding machine 4 used for ProtoDUNE2

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How we wind a diagonal plane

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DUNE Process cart

Process carts are used to prepare frames for the winding machines and to move APAs around factories

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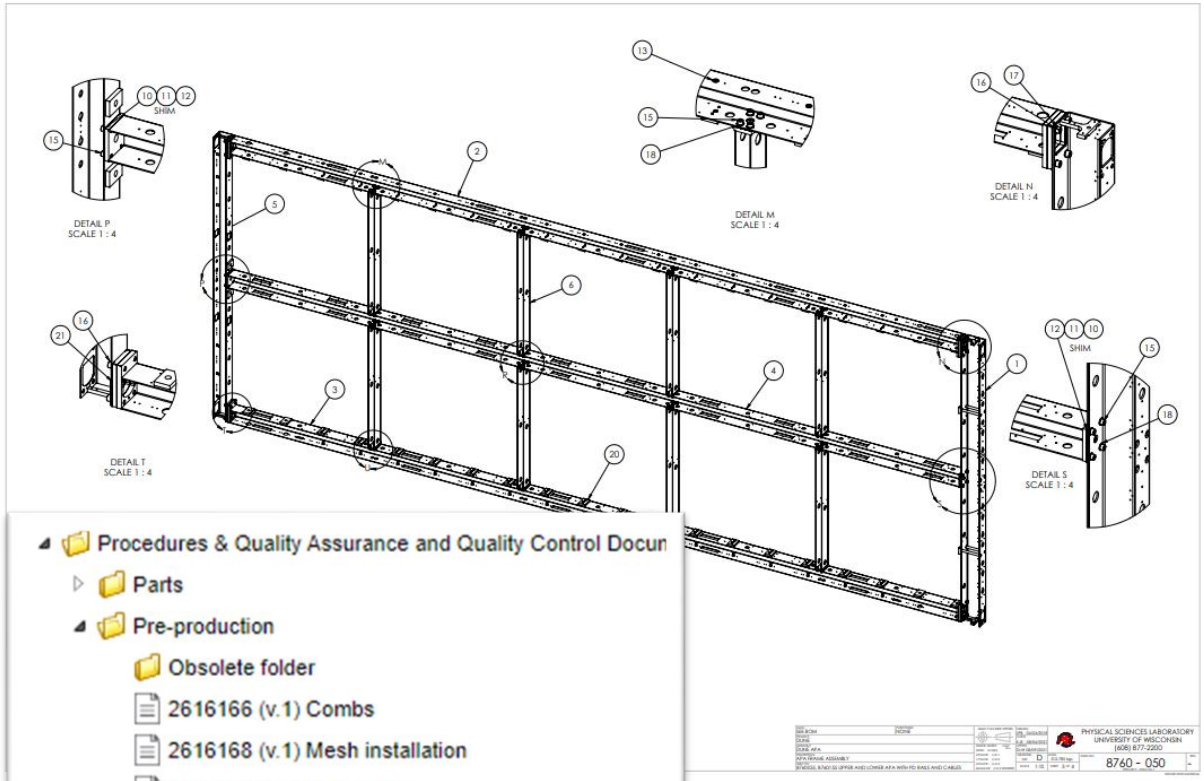
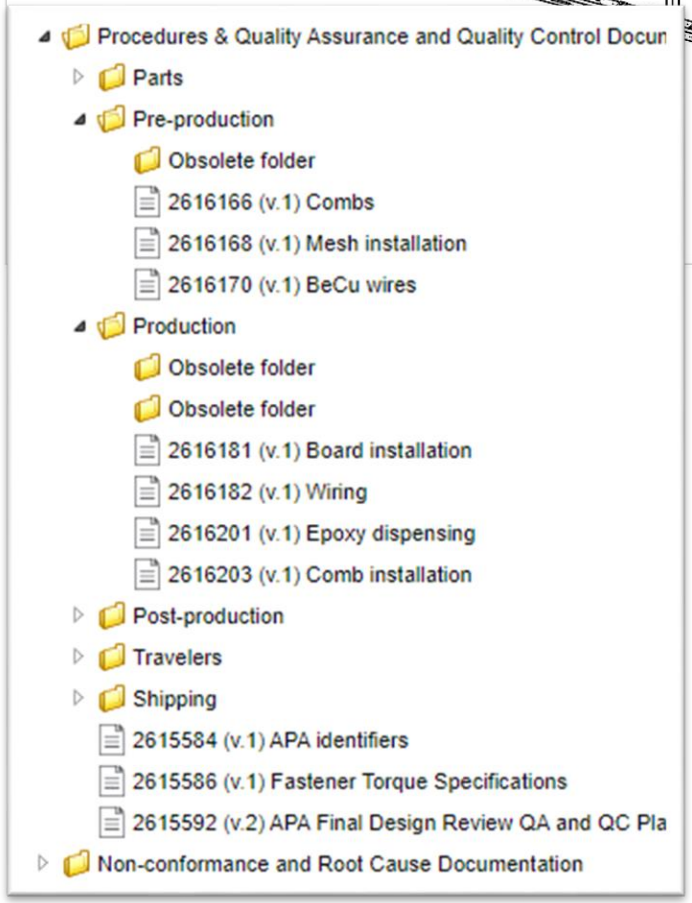
APA build sequence

- Bare APA frame in APA process cart
- Mount PD hardware and temperature sensors
- Mount mesh panels
- Move APA to winding machine
- Wind the 4 layers of the APA:
  - X-layer, v-layer (diagonal), u-layer (diagonal), g-layer
- Move to a process cart and pack up in protection panels
- Install protected APA in shipping frame
- Ready to ship





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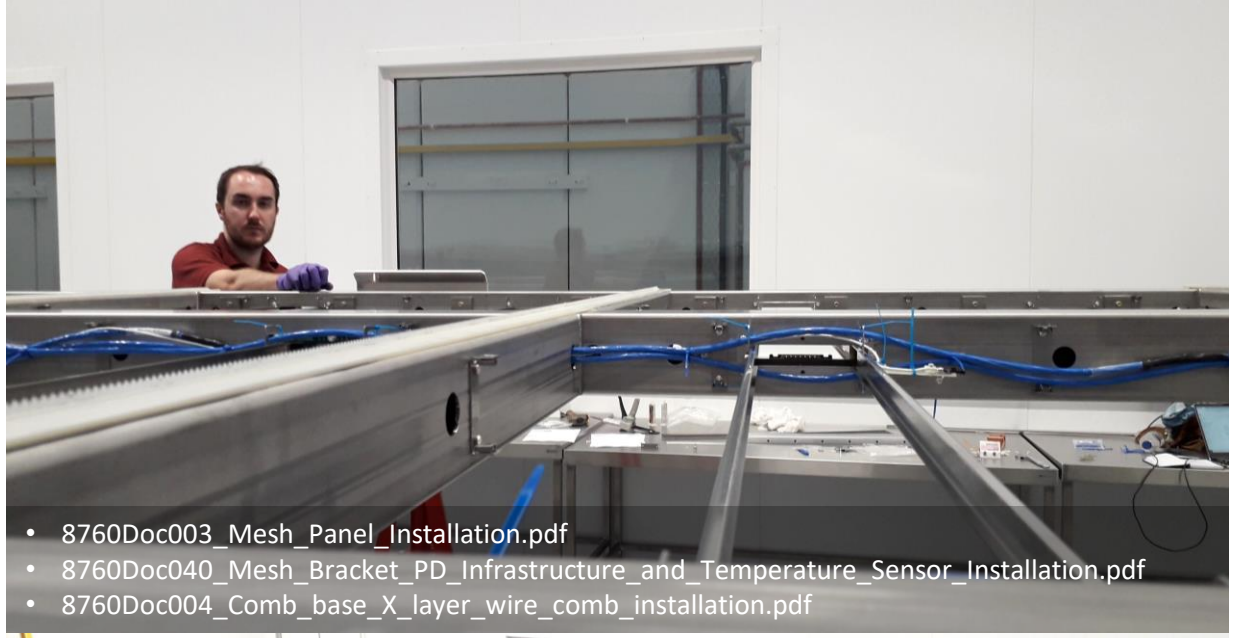
Frame prep

- Install photon detector (PD) rails and cables
  - Electrical test of PD assemblies (continuity and isolation against defined resistor values)
- Install liquid argon temperature sensors and cabling
  - Electrical test of resistance against defined values
- Install comb bases and combs
- Ready for mesh panels



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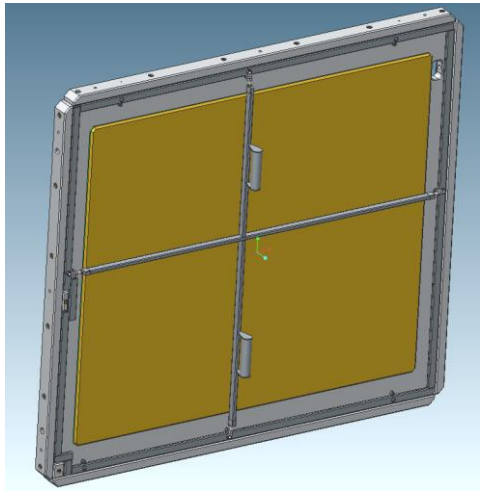
Mesh Panel install

- Inspected and QC checked mesh panels x 20 of 5 different types.
- Insert mesh panel into mesh panel checking fixture for that panel type and fit it's cross-frame to pre-tension the mesh panels
- Take mesh panel with fitted cross-frame and inserting into relevant section of the APA frame
- Fix to mesh panel brackets using lock-washers
- Repeat for remaining 19 mesh panels
- Visual inspection against photograph of correct install and check there are no pockets in the mesh.
- If pockets is found remove individual panel and re-process through inspection and QC steps.

Ready to install X-layer PCBs



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X-layer

- Fix x-layer boards to APA frame with bolts as described in procedures:
  - 8760Doc005_Head_Board_Installation.pdf
  - 8760Doc006_Foot_Board_Installation.pdf
  - 8760Doc008_Side_Board_Installation.pdf
- Transfer the APA frame to the winding machine
- In parallel with the x-layer board install on the APA frame, install x-layer transition boards on the support spine of the winding machine
- Using calibration camera calibrate pin positions of x-layer boards so the control system knows where the hardware is
- Use force gauge to check output tension from winding head is within spec
- Load x-layer winding “recipe” in control system and commence winding as per procedure 8760Doc009_Winding.pdf
- Sample tension check using laser method – typically ~5% wires on each side of the APA
- If sample tensions within spec then commence soldering each wire on each side of the APA as per procedure 8760Doc011_Tape_Solder_Trim.pdf
- Cut wires from transition boards and one end of the foot end so that tension is held between solder pads
- Tension test all wires

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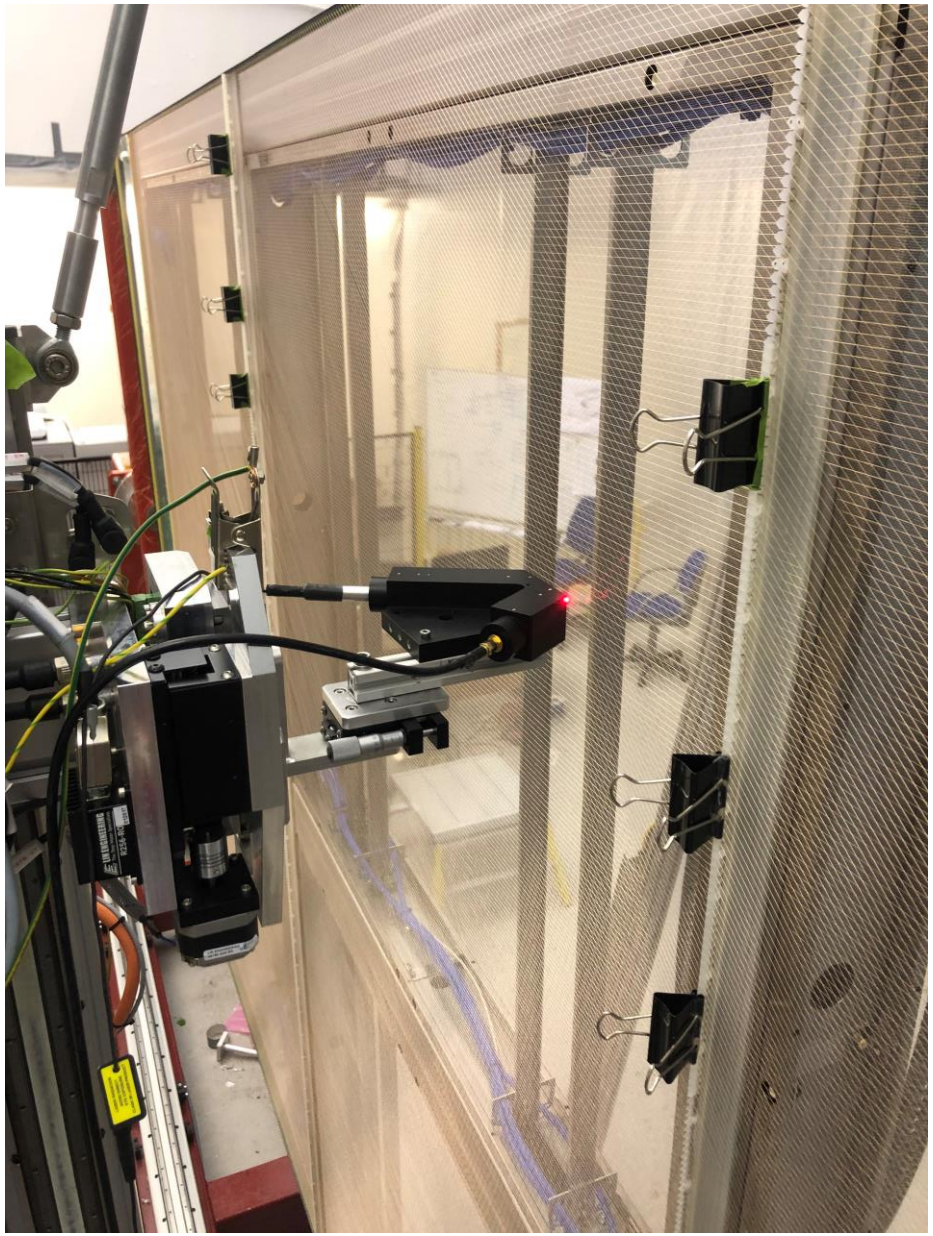
Laser tension method

- Load laser head onto the winding machine
- Isolate wires into “zone(s)” using a barrier on the combs. Zones are between the ribs of the APA.
- For x- and g-layers only isolate in one zone to better control accuracy
- For diagonal layers v- and u- layer 4 zones are isolated on each side of the APA which tests all the wires wound on these layers (because of how they wrap around the frame)
- The reading is in Hz which is converted to N
- The tension spec for the x- and g- layers is 6.5 N with a tolerance of +/-1N
- The tension for the diagonal layers is dependent on the wire length as the spec is as follows:
  - Long wires have length ≥ 500mm Tension set point 6.5 N
  - Short wires have length < 500mm and ≥50mm Tension set point 5N
  - Very short wires have length <50mm n/a



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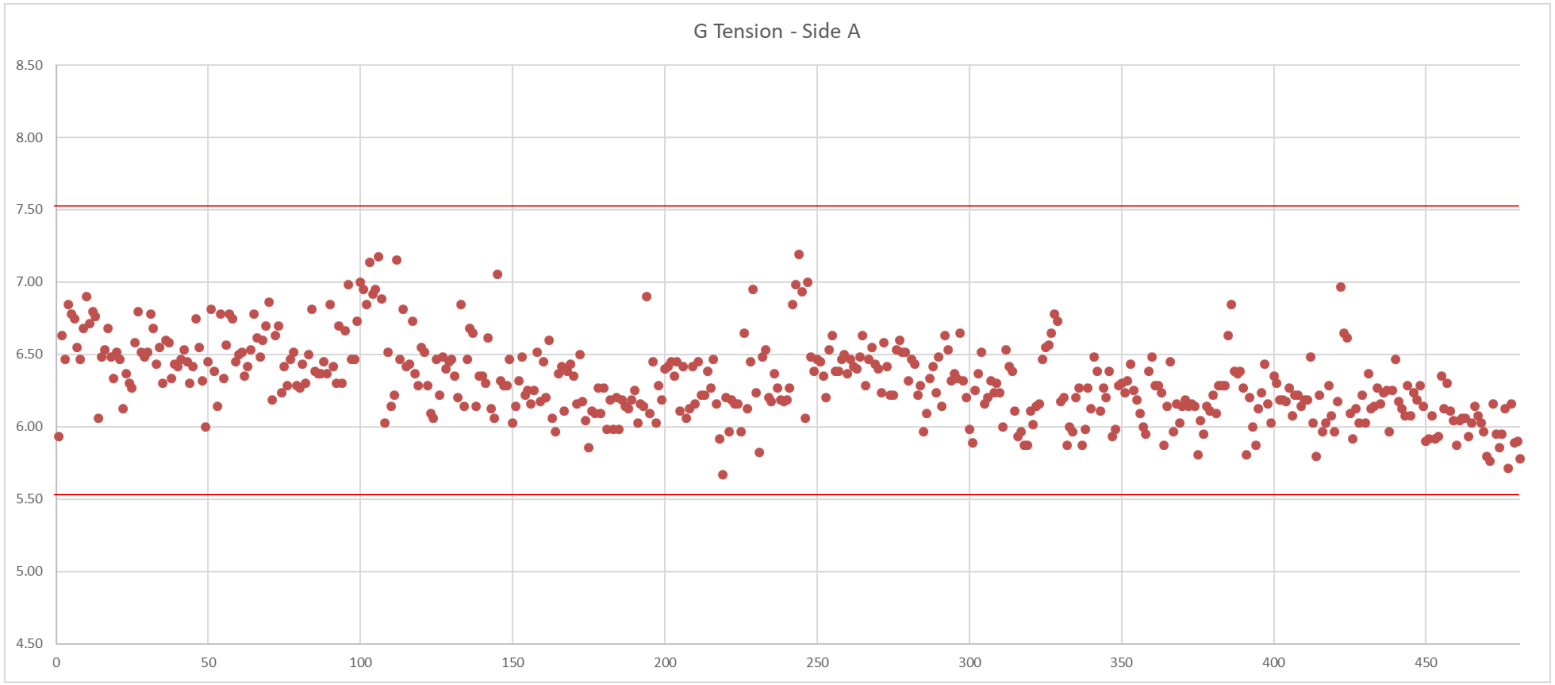
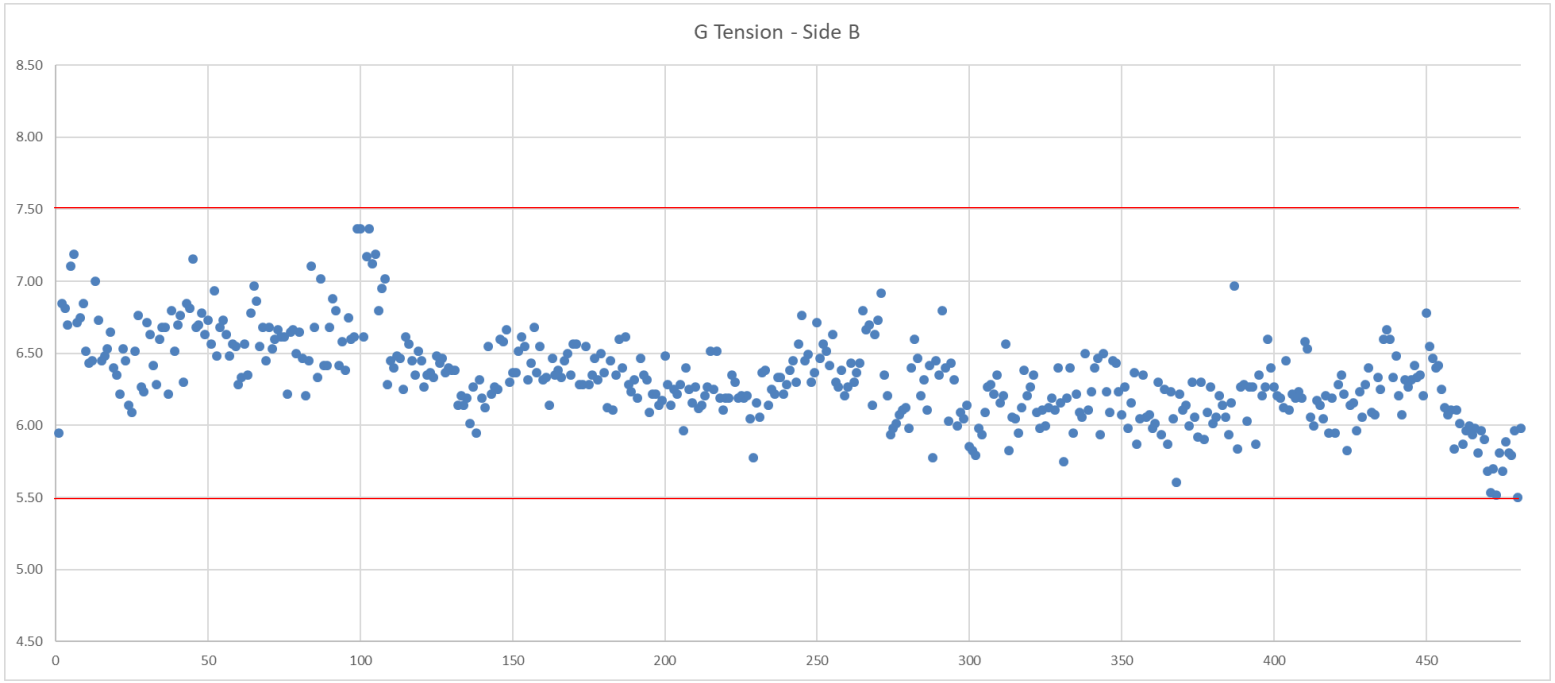
Example of tensions from g-layer of ProtoDUNE2 APA#1 obtained with laser method





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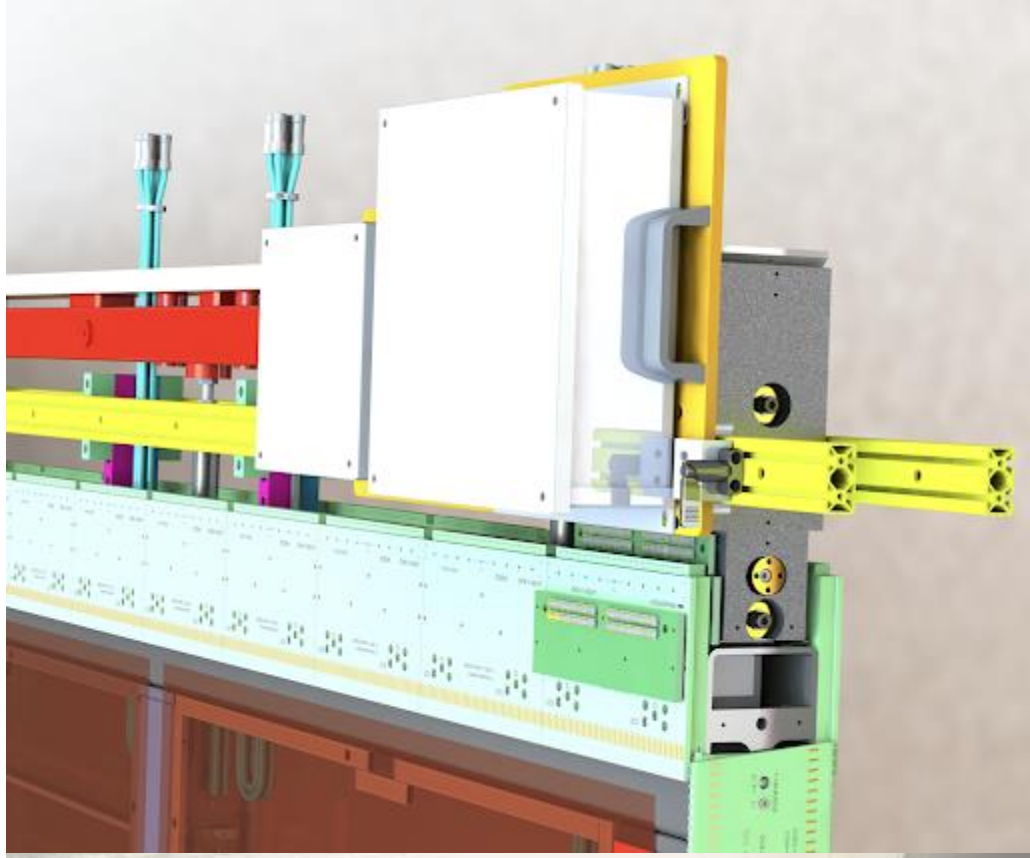
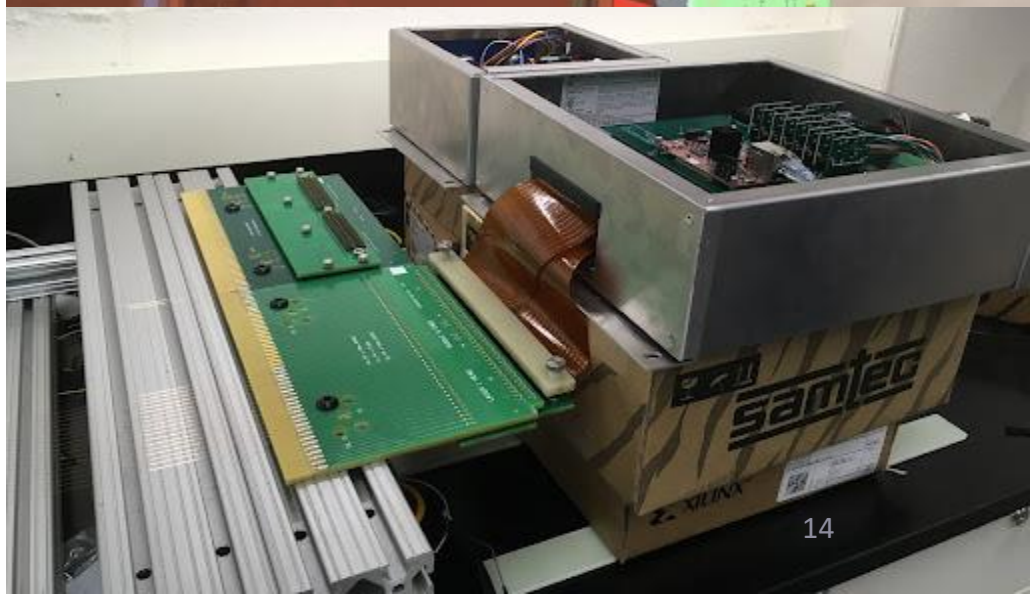
DWA (DUNE Wire Analyser) tension method

- Custom instrument measuring wire tension of eight wires at a time using an electrical method
  - Measures the tension of a wire by stimulating at high voltage its two neighbours in a wire plane
  - Accesses wires electrically by connecting to probe boards, which themselves connect to the head boards in a similar way to CR boards and G bias filter boards
  - Is supported in the winder by a rail spanning the APA width that makes use of the CE tees mounting points
  - Outputs tension values directly in Sietch via software
- In final stages of development
  - Production expected this fall
  - Possibility of testing electrical continuity of wires and measuring wire capacitance





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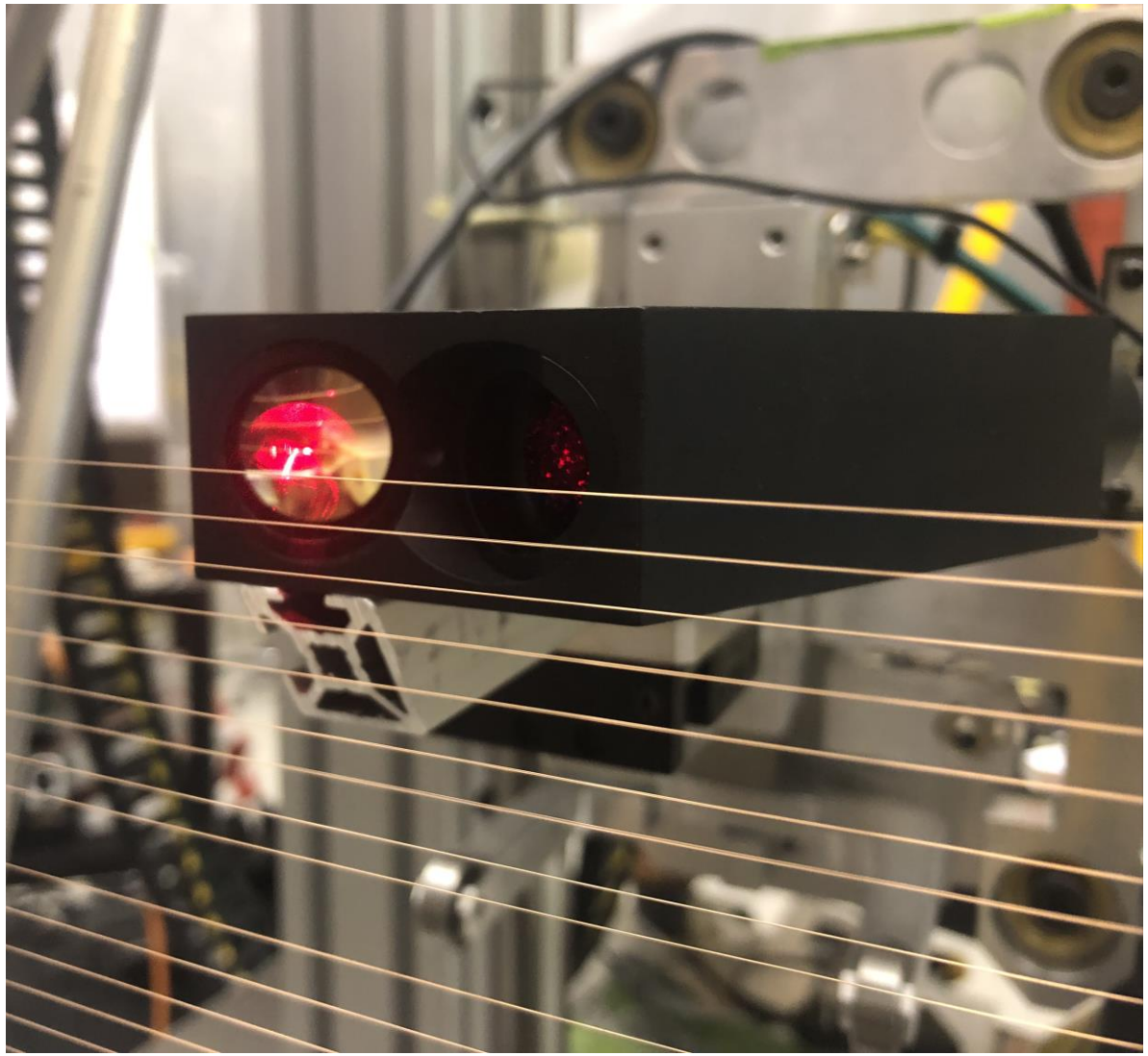
X-layer continued

- If tensions within spec then trim excess wire back to solder pad on all wires
- If any wire tensions are out of spec then replace these wire(s)
- Electrical testing of all wires- continuity and isolation against defined spec at known RH% as per procedure: 8760Doc012_Electrical_Testing.pdf
  - If any values out of spec investigate issue and potentially replace wire
- Proceed to v-layer



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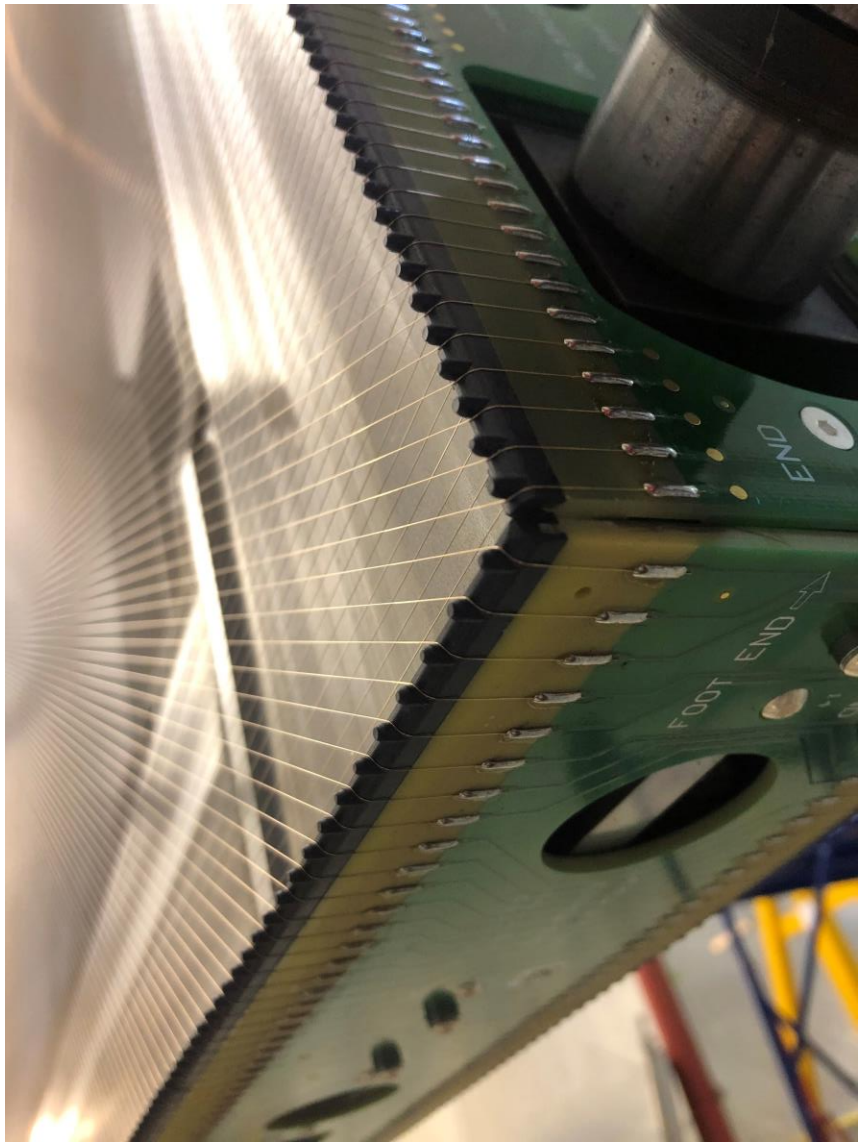
V-layer (diagonal layer)

- Fix v-layer boards to APA frame with bolts and epoxy using specified quantities of epoxy applied in a defined pattern using a Nordson epoxy machine
- Once boards are affixed in place wait 8 hours (epoxy cure time)
- In parallel with affixing boards, install combs and v-layer transition boards
- Using calibration camera calibrate pin positions of v-layer boards so the control system knows where the hardware is
- Use force gauge to check output tension from winding head is within spec
- Load v-layer winding “recipe” in control system and commence winding
- Sample tension check using laser method – typically ~5% wires on each side of the APA
- If sample tensions within spec then commence soldering each wire on each side of the APA
- Cut wires from transition boards and one end of the foot end so that tension is held between solder pads
- Tension test all wires



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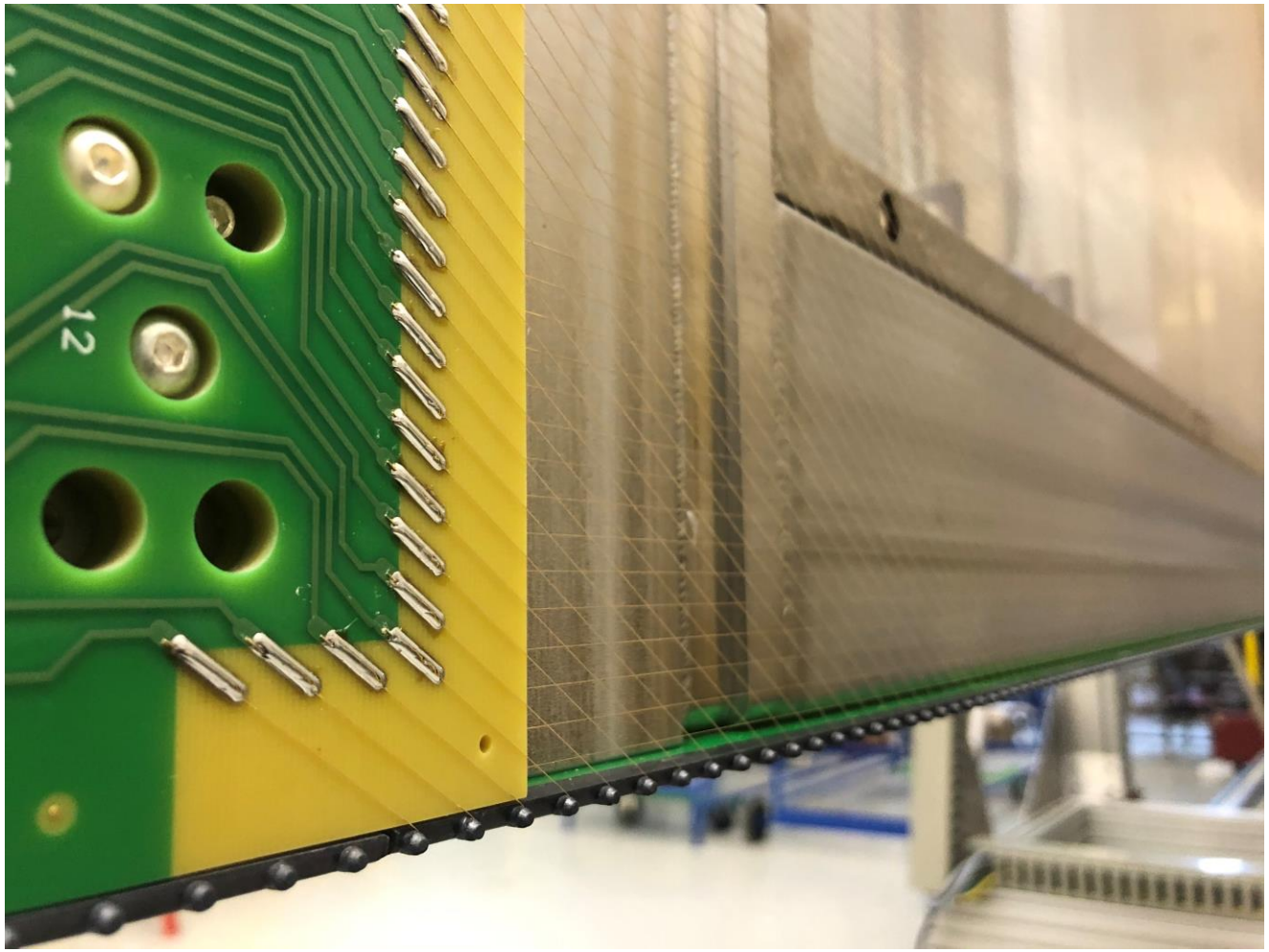
V-layer cont..

- If tensions within spec then trim excess wire back to solder pad on all wires
- If any wire tensions are out of spec then replace these wire(s)
- Electrical testing of all wires- continuity and isolation against defined spec at known RH%
- If any values out of spec investigate issue and potentially replace wire
- Proceed to u-layer



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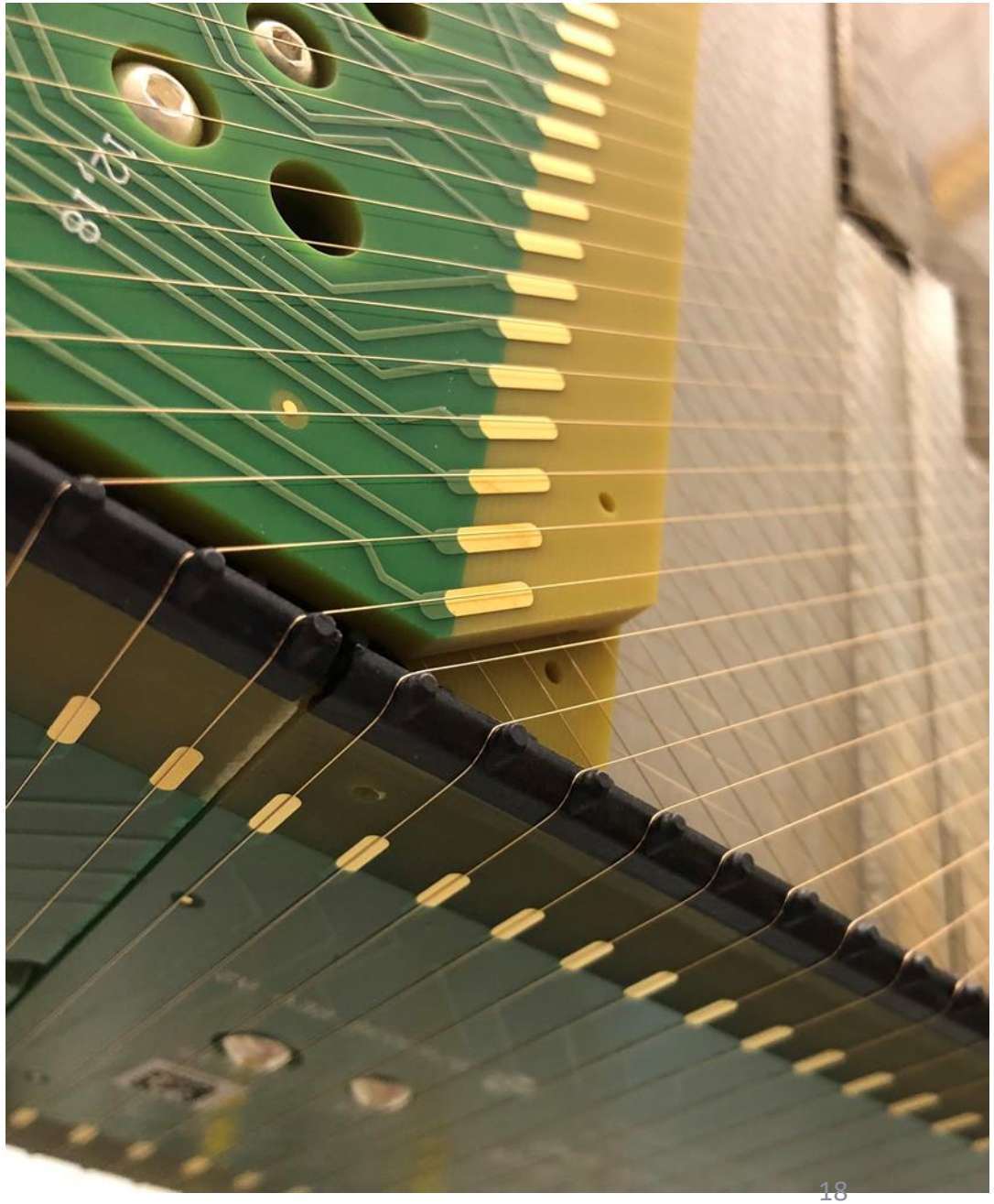
U-layer (diagonal layer)

- Fix u-layer boards to APA frame with bolts and epoxy using specified quantities of epoxy applied in a defined pattern using a Nordson epoxy machine
- Once boards are affixed in place wait 8 hours (epoxy cure time)
- In parallel with affixing boards, install combs and u-layer transition boards
- Using calibration camera calibrate pin positions of u-layer boards so the control system knows where the hardware is
- Use force gauge to check output tension from winding head is within spec
- Load u-layer winding “recipe” in control system and commence winding
- Sample tension check using laser method – typically ~5% wires on each side of the APA
- If sample tensions within spec then commence soldering each wire on each side of the APA
- Cut wires from transition boards and one end of the foot end so that tension is held between solder pads
- Tension test all wires



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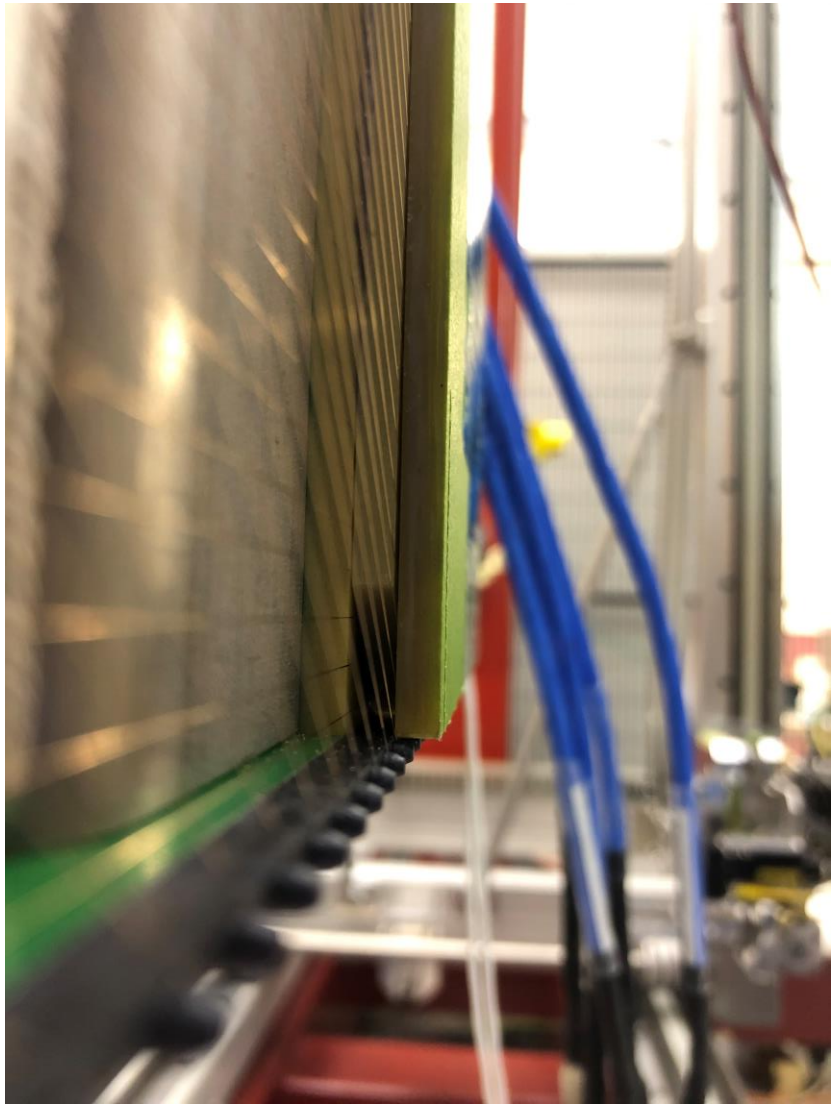
U-layer cont..

- If tensions within spec then trim excess wire back to solder pad on all wires
- If any wire tensions are out of spec then replace these wire(s)
- Electrical testing of all wires- continuity and isolation against defined spec at known RH%
- If any values out of spec investigate issue and potentially replace wire
- Proceed to g-layer



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G-layer

- Fix g-layer boards to APA frame with bolts and epoxy using specified quantities of epoxy applied in a defined pattern using a Nordson epoxy machine
- In parallel with the x-layer board install on the APA frame, install g-layer transition boards on the winding machine
- Using calibration camera calibrate pin positions of g-layer boards so the control system knows where the hardware is
- Use force gauge to check output tension from winding head is within spec
- Load g-layer winding “recipe” in control system and commence winding
- Sample tension check using laser method – typically ~5% wires on each side of the APA
- If sample tensions within spec then commence soldering each wire on each side of the APA
- Cut wires from transition boards and one end of the foot end so that tension is held between solder pads
- Tension test all wires

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G-layer cont..

- If tensions within spec then trim excess wire back to solder pad on all wires
- If any wire tensions are out of spec then replace these wire(s)
- Electrical testing of all wires- continuity and isolation against defined spec at known RH%
- If any values out of spec investigate issue and potentially replace wire

All planes wound

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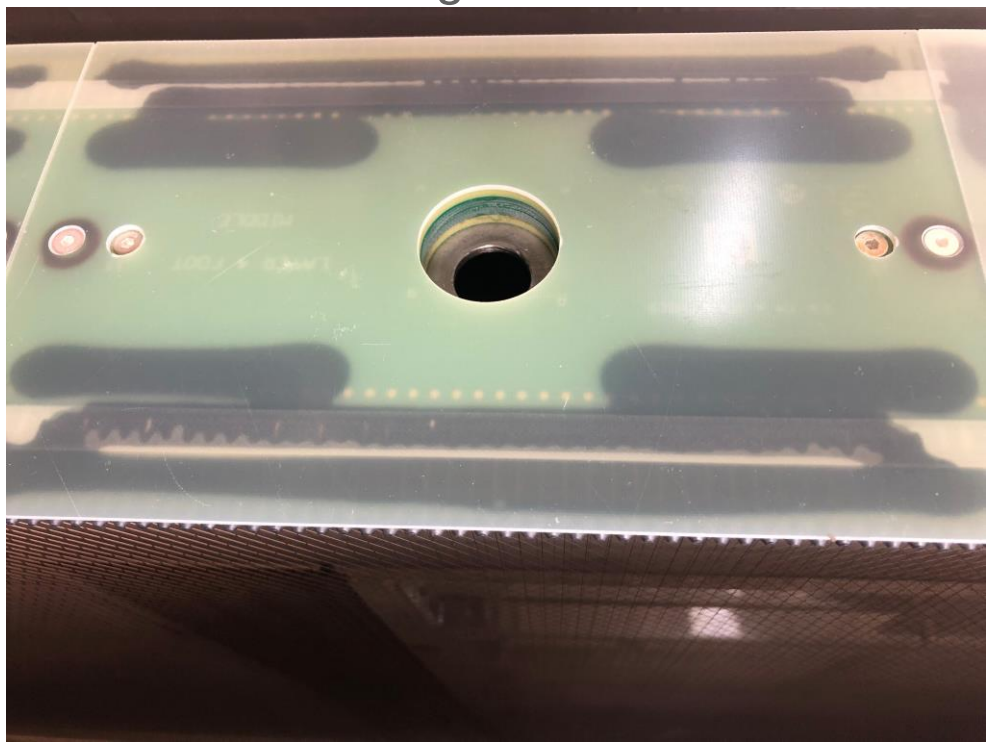
Cover boards & comb caps

- Fix cover boards to APA frame with bolts and epoxy using specified quantities of epoxy applied in a defined pattern using a Nordson epoxy machine
- Install comb caps onto combs
- Apply epoxy to side board screw fixings



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Protection panels

- Move built APA to a process cart
- Fit protection panels
  - The panels comprise aluminium u-section edge protection and foam composite side panels covering the faces of the APA

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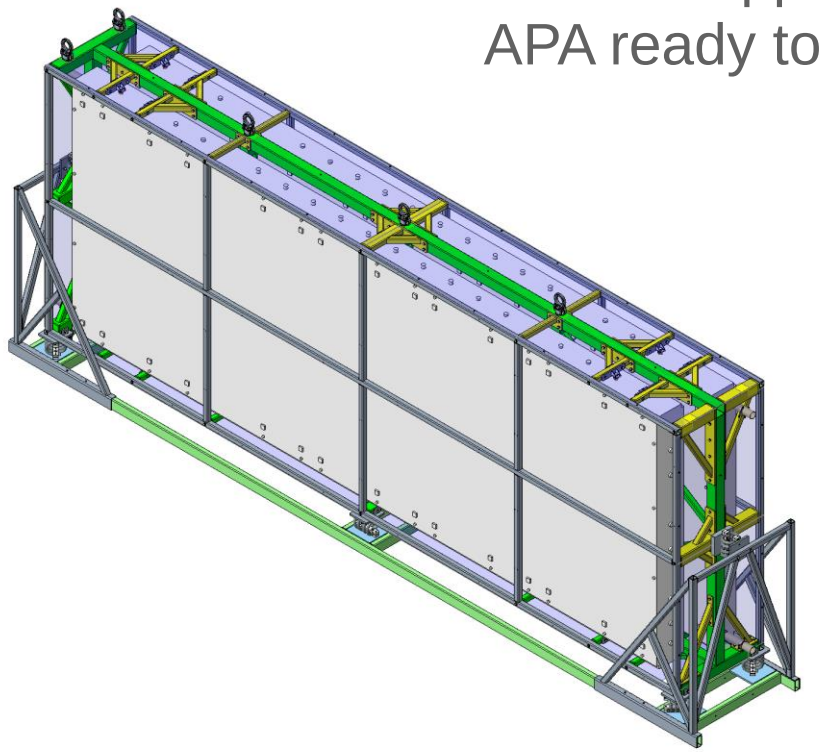
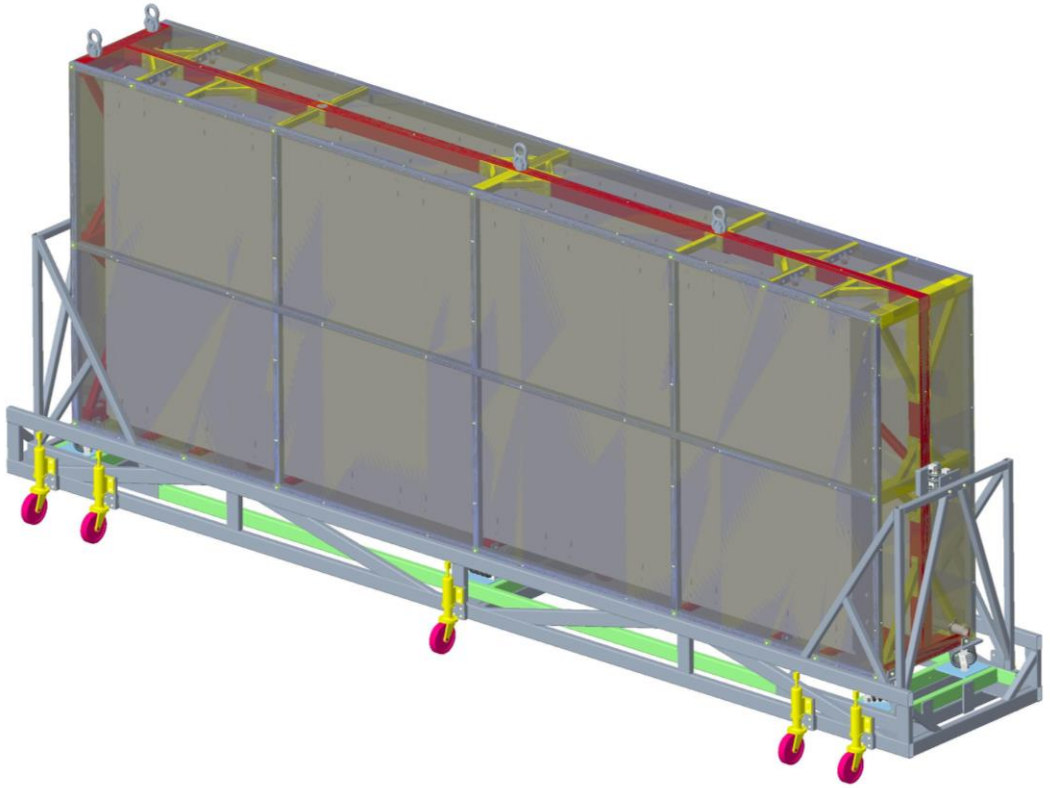
Prep for shipping

- APA fitted in shipping frame/box
- Conduit insertion
- Seal shipping frame

APA ready to ship





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Thank you

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