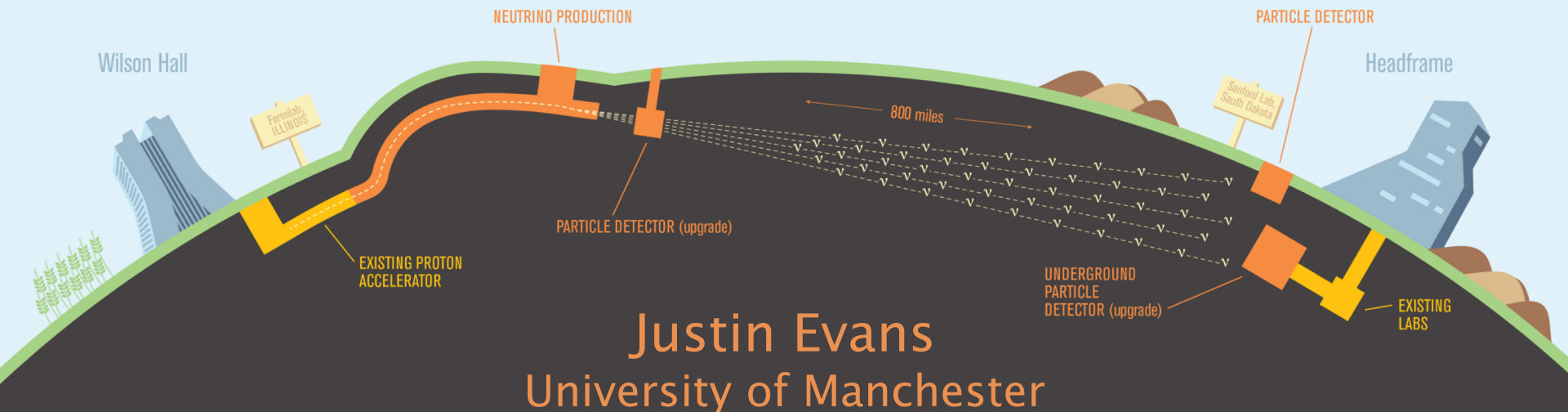


Lessons learnt from ProtoDUNE APA production



Justin Evans
University of Manchester

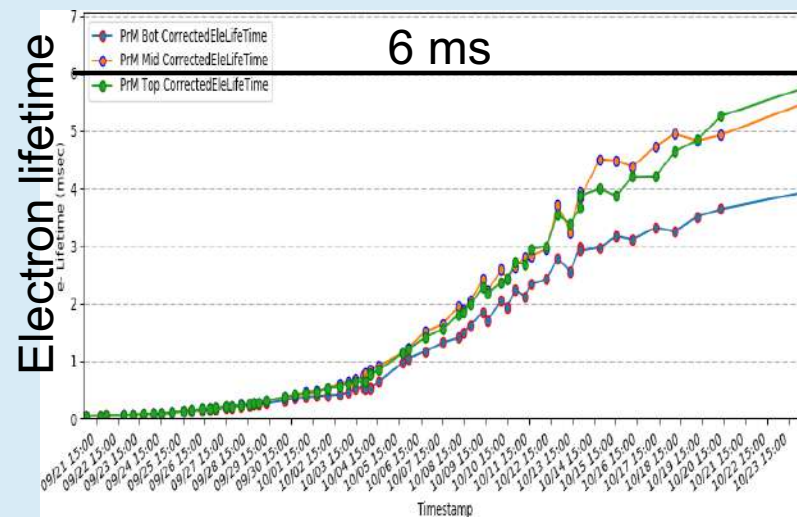
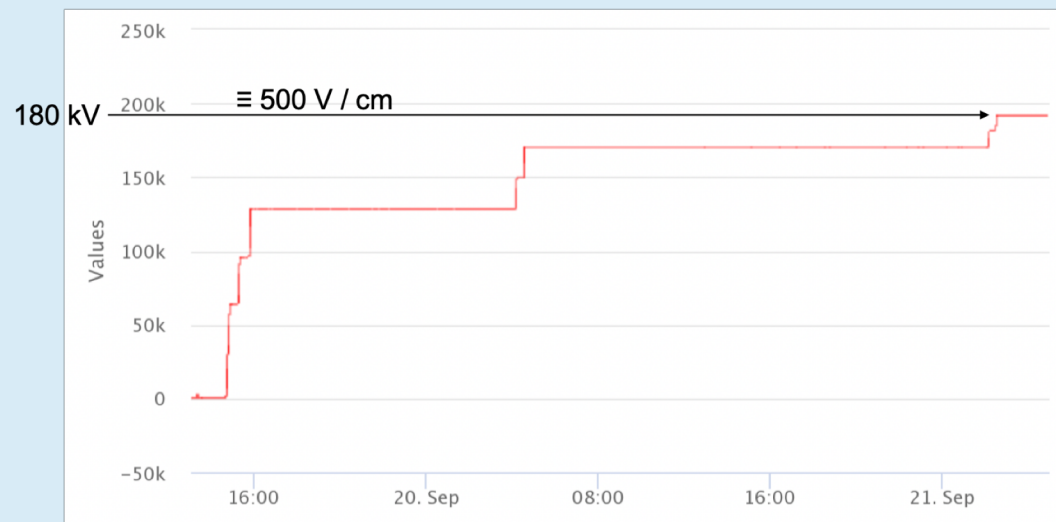
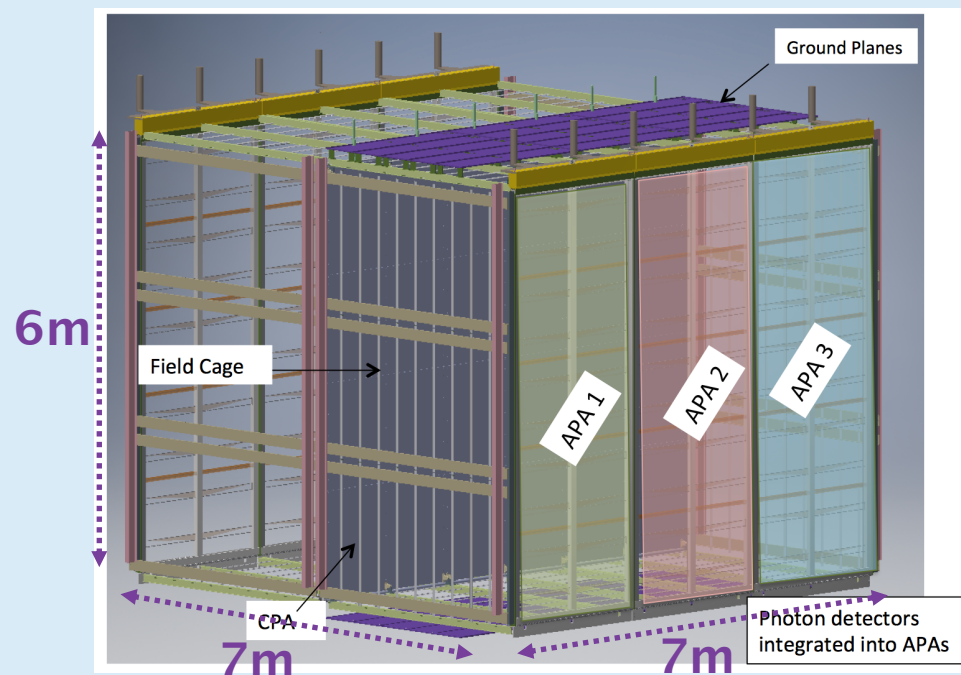
ProtoDUNE

A full test of the DUNE single-phase detector design

- Two drift volumes, 6 APAs

Shows that our baseline design can achieve our physics goals

- 6 ms electron lifetime
- Noise at the 550–650 e⁻/channel level (requirement <1000 e⁻/channel)



ProtoDUNE APAs



4 ProtoDUNE APAs produced at PSL

2 ProtoDUNE APAs produced at Daresbury

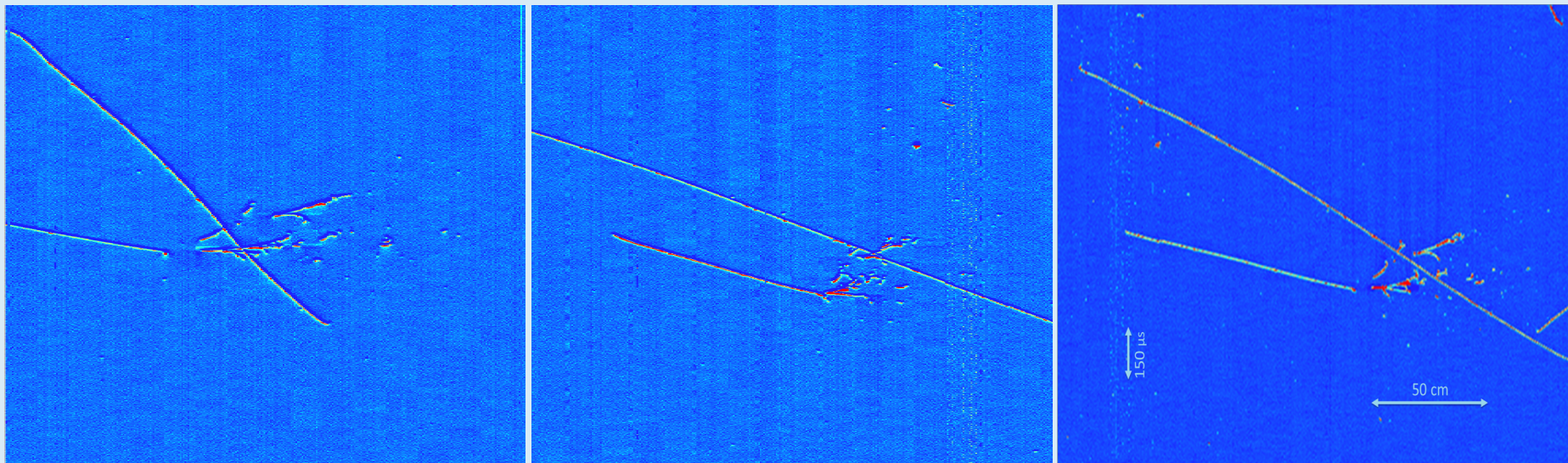
ProtoDUNE APA 7 produced at Daresbury

- Used to test the resolutions of some of our lessons

ProtoDUNE APAs used the 3x4" steel section

- Will be 4x4" for DUNE

ProtoDUNE works!



U plane

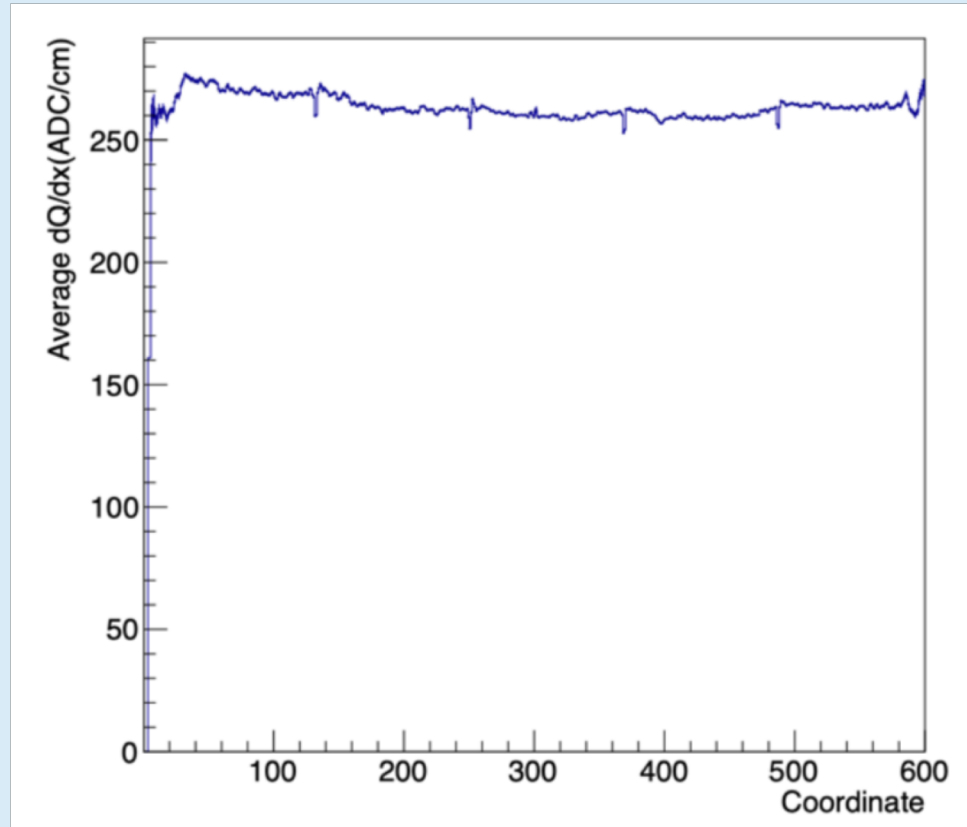
V plane

X plane

Run 5235 Ev. 10190, 1 GeV/c beam event

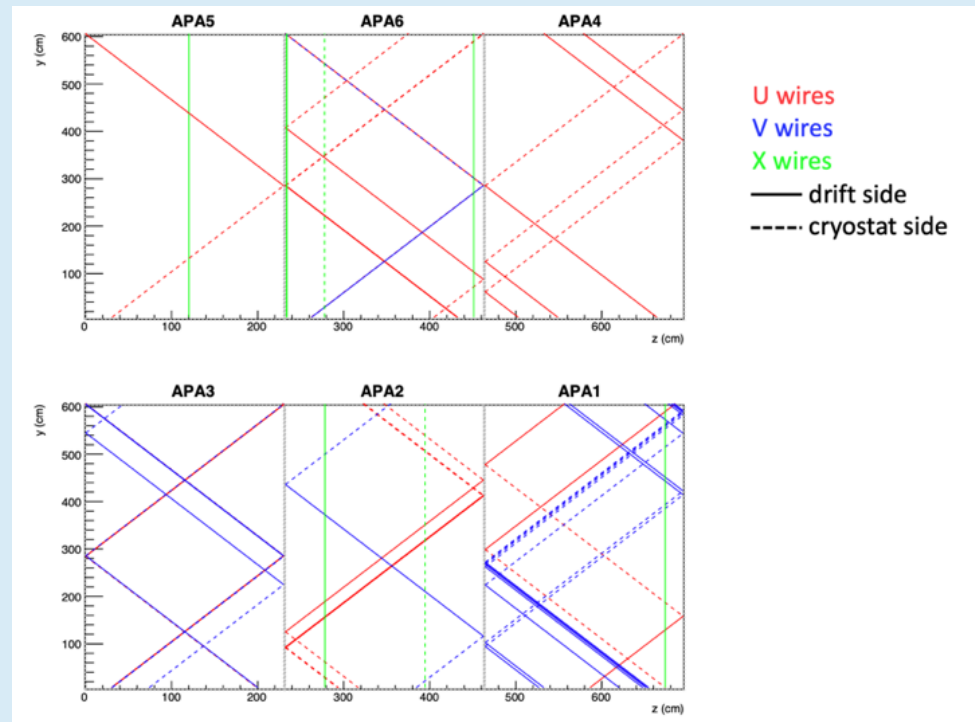
- Strong validation of the APA design with ProtoDUNE
- Images with details and resolution as needed for the physics analysis

We can even see the combs



➤ Shows just how sensitive our APAs are

Negligible disconnected channels



From Tingjun Yang

Only 38 out of 15,360 ProtoDUNE channels (0.2%) do not work in the LAr

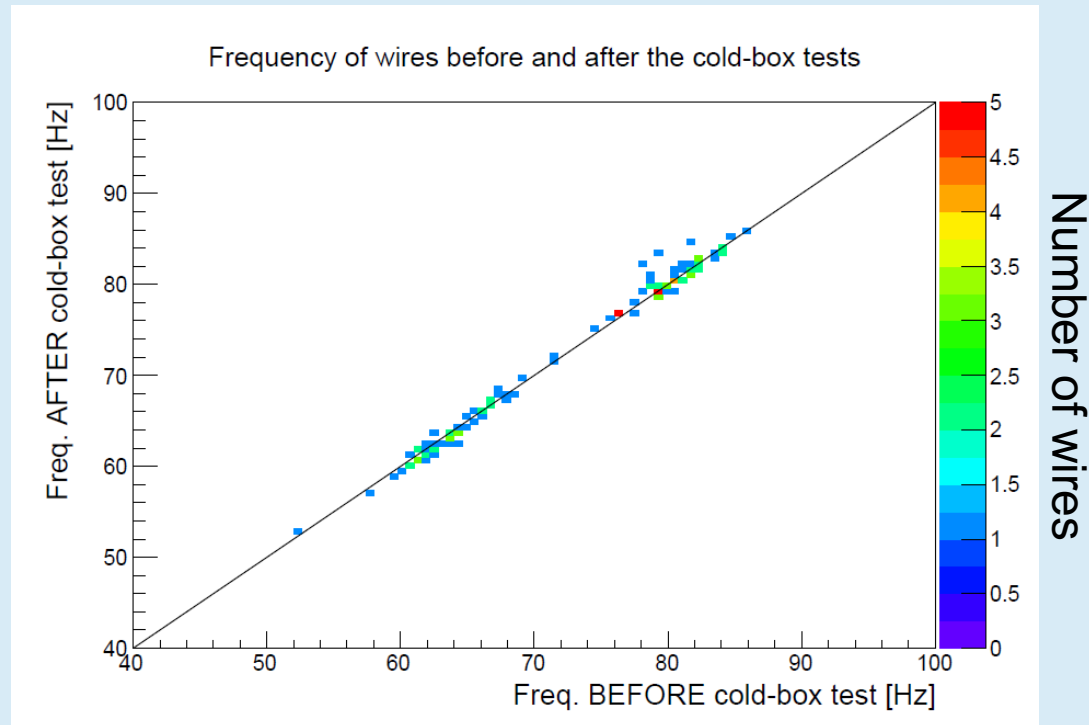
- DUNE requires <1.0% dead channels

For many of these we don't know the cause

Some worked in the cold box, but not in the LAr

Will continue to monitor ProtoDUNE to ensure the number of bad channels doesn't increase

ProtoDUNE APA QC

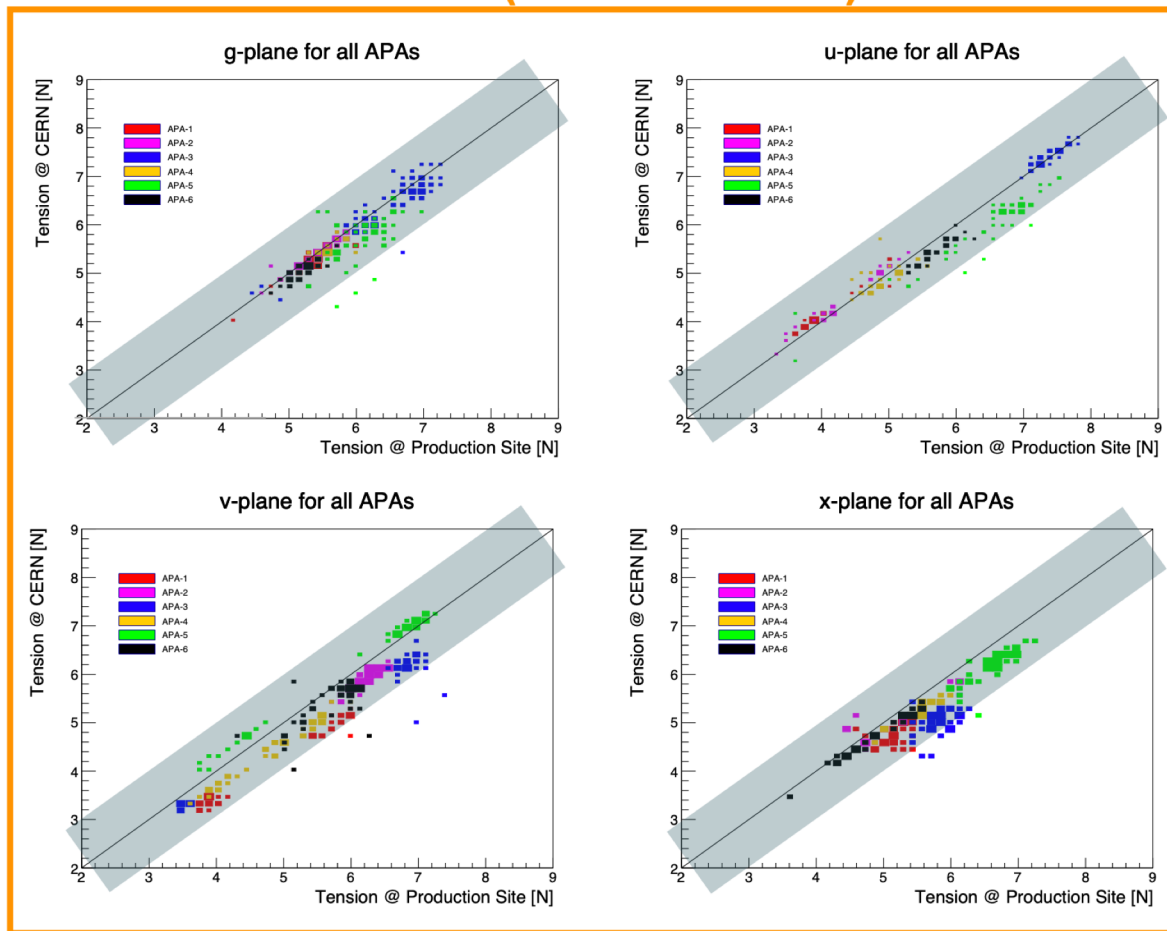


- No significant change in the resonant frequency of the wires before and after the cold box tests at CERN

Wire tensions

Wire tension (on ~10% of wires)

$\pm 1N$

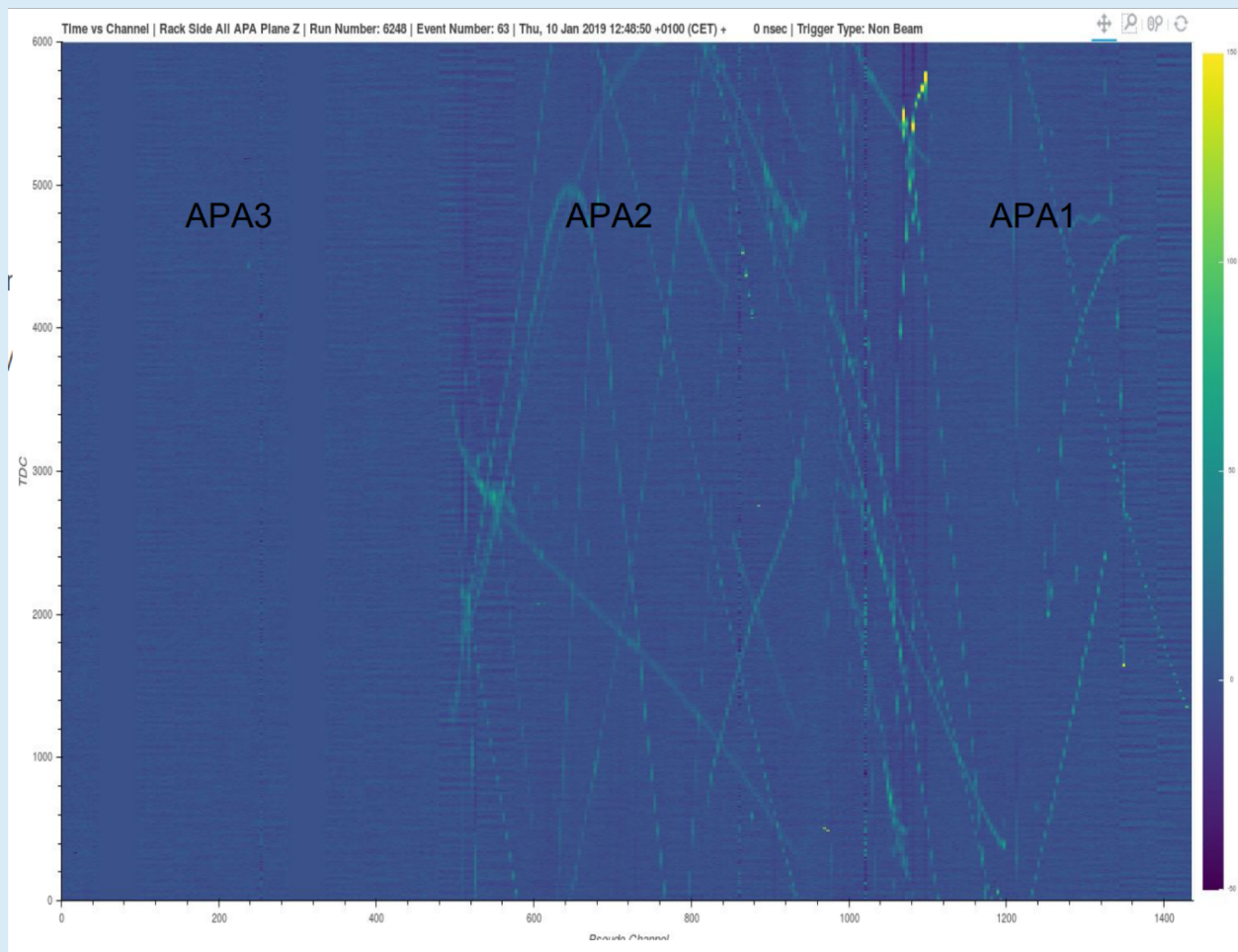


At production = Horizontal APA

At CERN = Vertical APA

- Some (minor) variation in tension between factories and CERN measurements

Disconnected g-layer

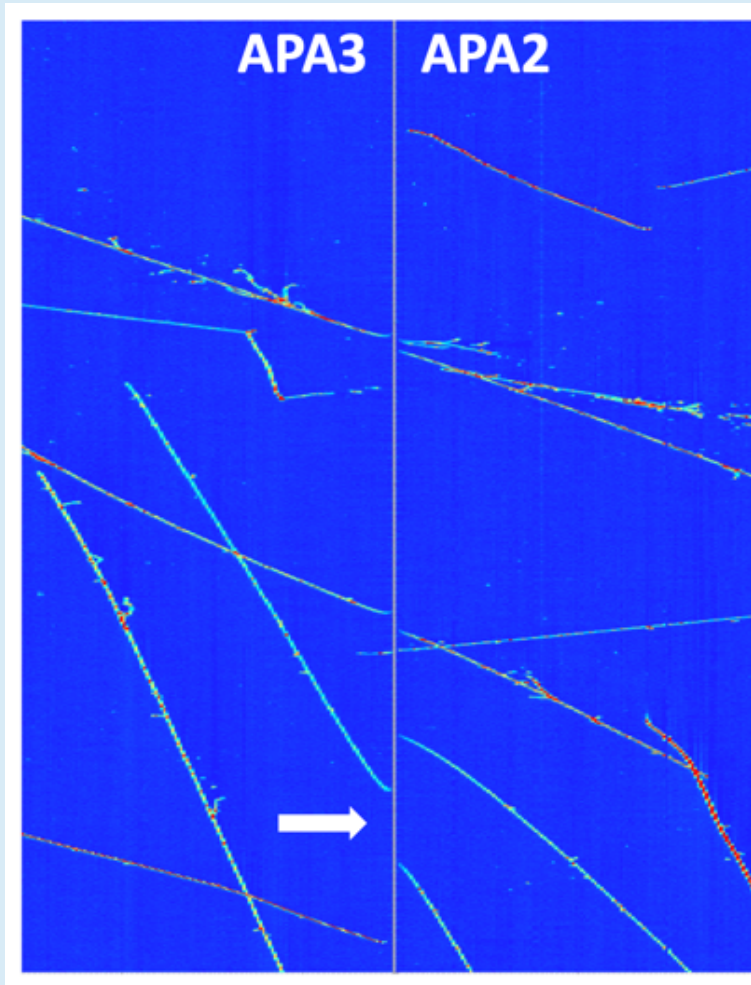


The g-plane on ProtoDUNE APA 3 was disconnected

- Once the plane charged itself up again, all was well

We don't know the reason, but are looking at ways of making the SHV connections easier to install

Electron diverters



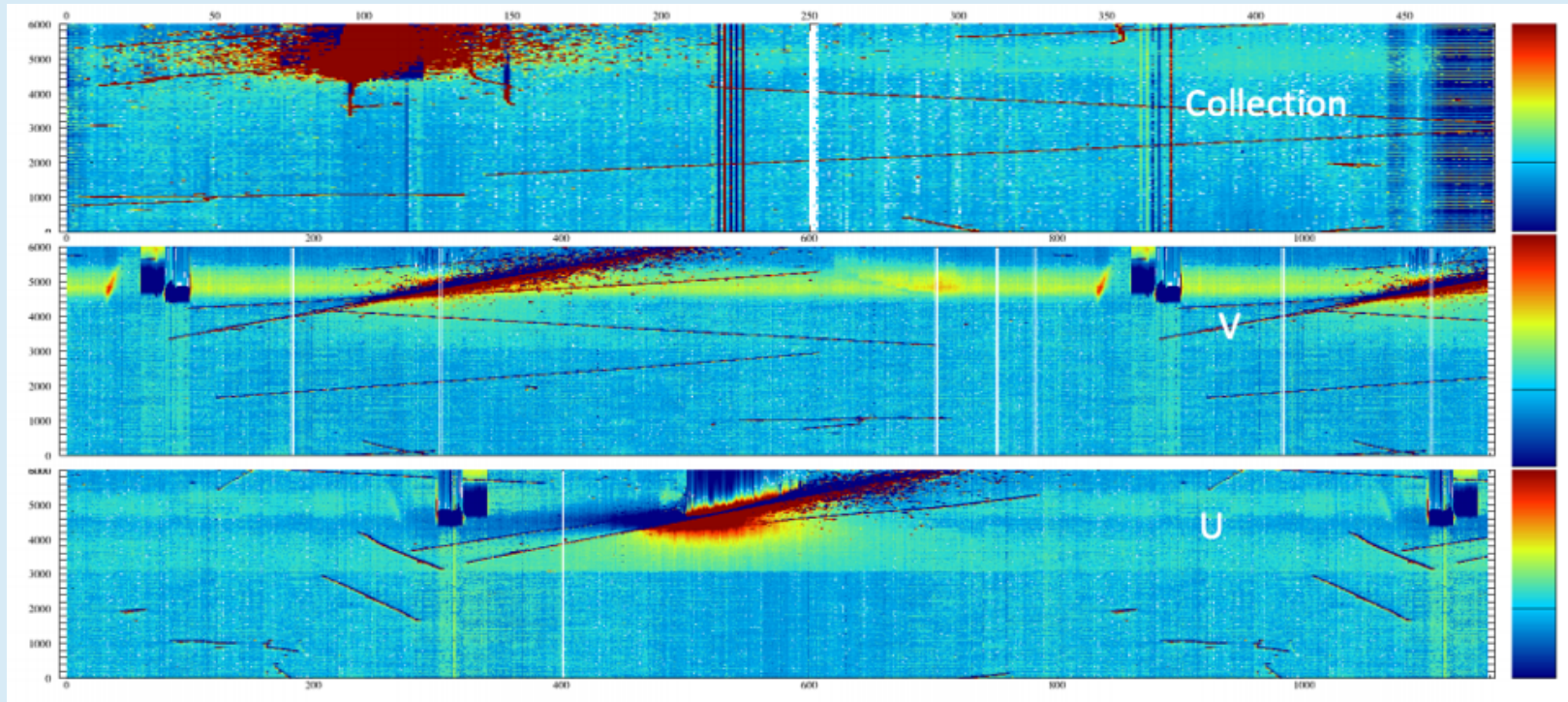
One of the electron diverters drew current, so we ran without voltage on them

- Effectively grounding them, so they modified the drift field

Effects seen on tracks near APA boundaries

- A task force is investigating the merits of using electron diverters (or not) in DUNE

g-layer shielding



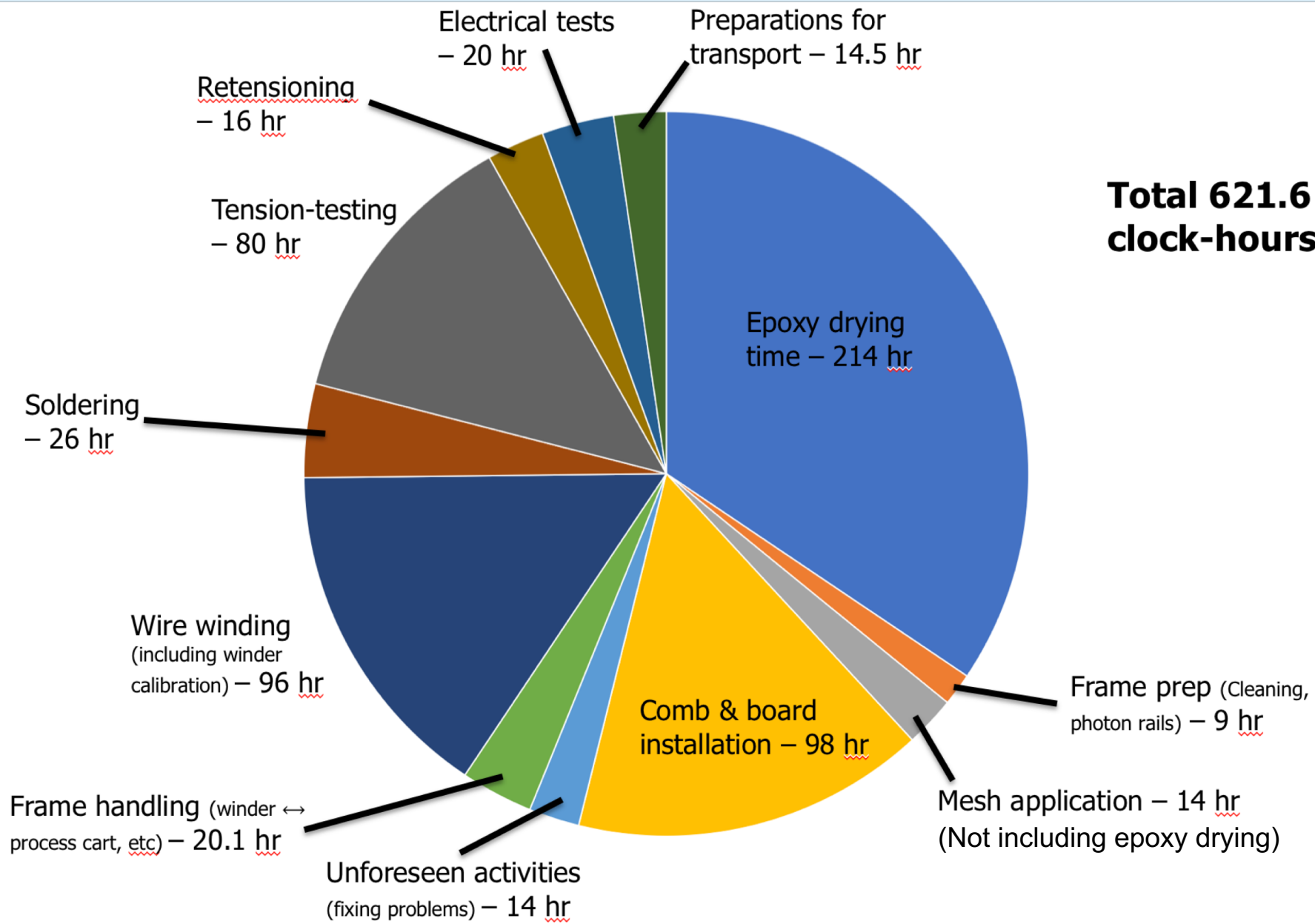
g-layer is to shield active layers from long-range induction effect

- But long-range effects are seen in big showers

Suggests more capacitance is needed

- g-bias boards have been redesigned to have one capacitor per wire

ProtoDUNE APA production



Grounding mesh application

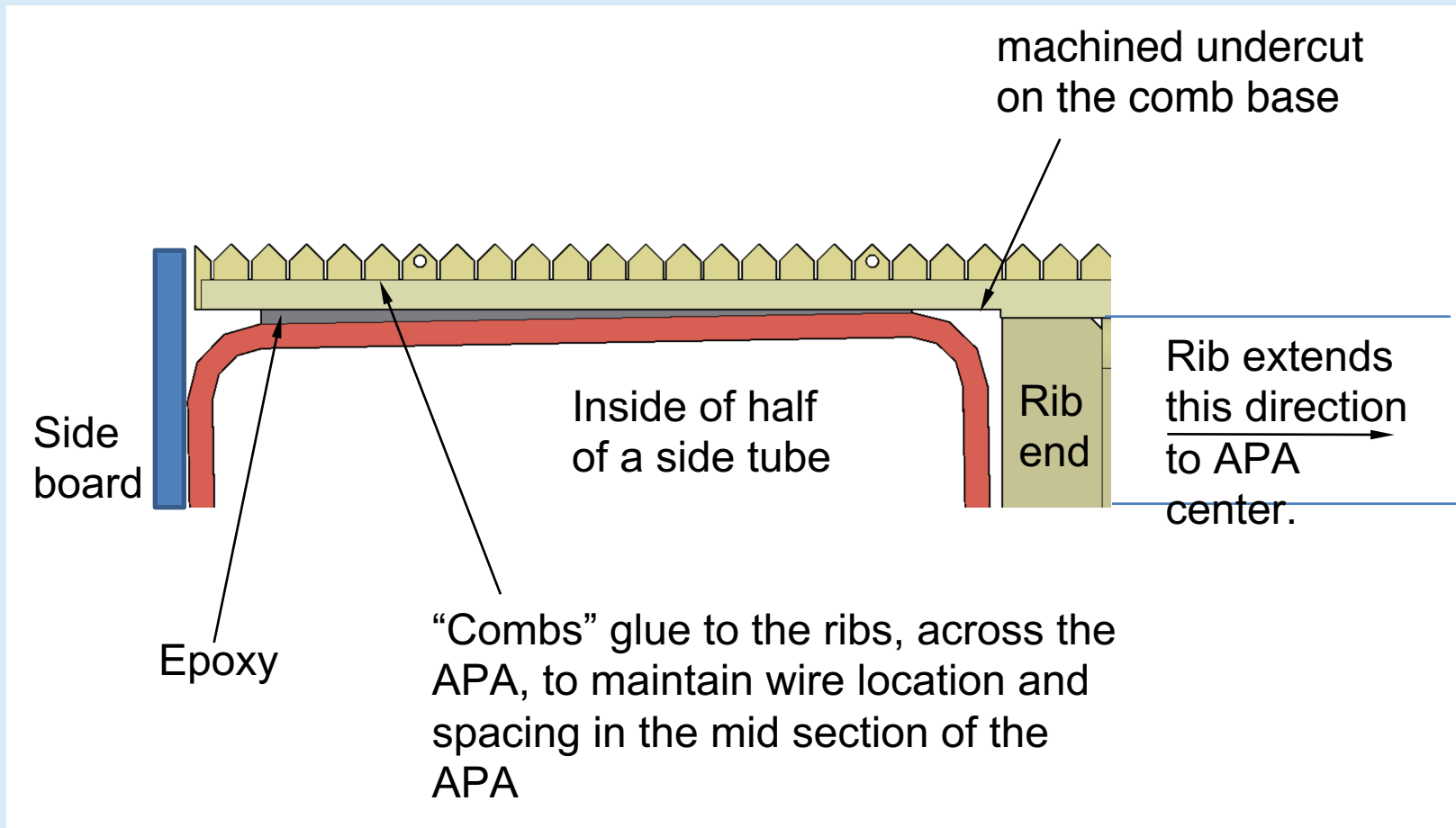


New proposal
Fast, easy and consistent
Tried on ProtoDUNE APA 7



Old procedure
Time consuming and difficult

Step in comb bases



- Minor issues with comb planarity at the junctions of APA frame components

Tension measurement



Measurement of wire tensions is hugely time-consuming

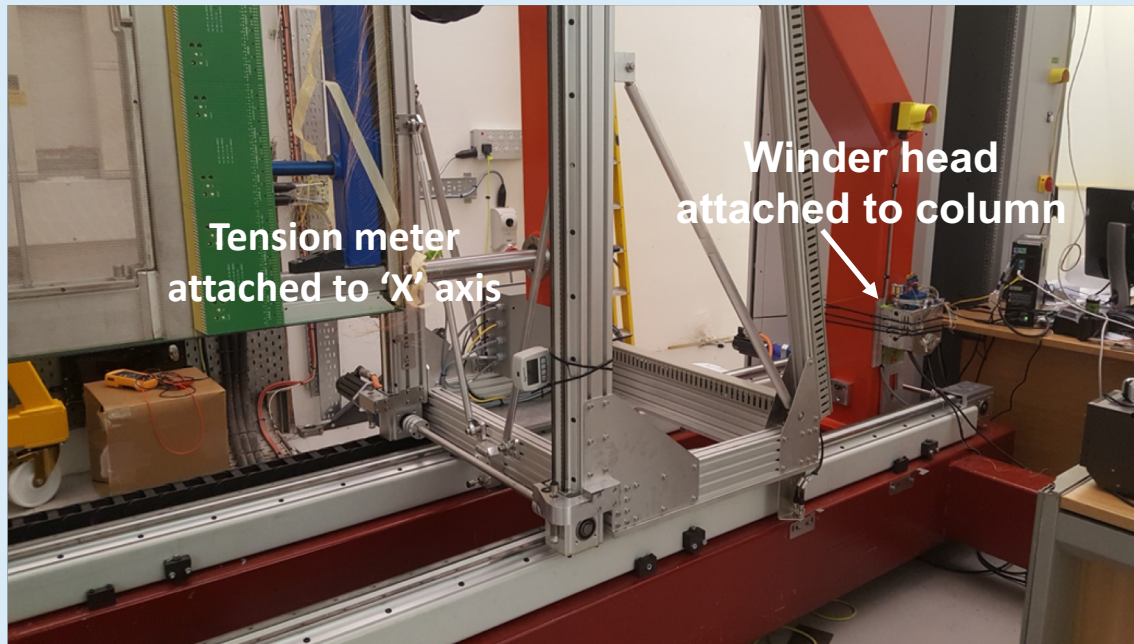
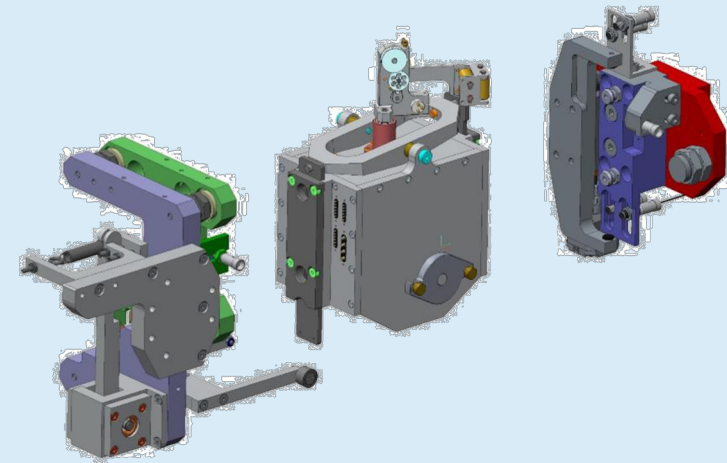
- ~80 hr / APA

Tension task force

- Electrical methods? New winding head – laser but just sample-test?

New winding head with active tension control

- Better tension uniformity
- Automatic capture of individual wire tension
- Possible time & cost savings for tension measurement



- Winder head operation in closed loop, wire strung to the tension meter
- Readout from load cell and tension meter within 0.2N

Upgraded winding machine



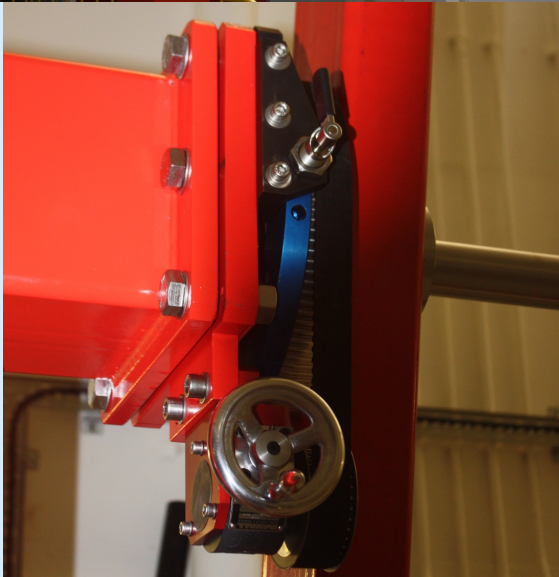
ProtoDUNE winding machine

- APAs were moved in and out of the winding machine at least twice per wire layer
- Time consuming

New machine

- Retractable arms to allow winding head to pass
- Geared rotation mechanism to allow access for installing geometry boards, combs, etc

APA stays in the winder throughout the winding process

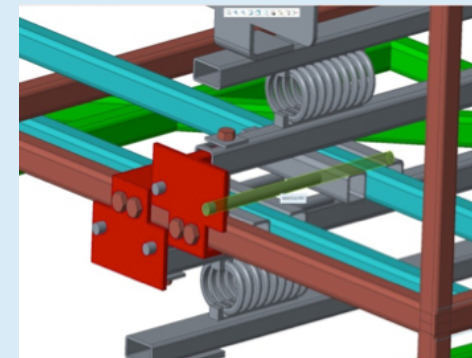
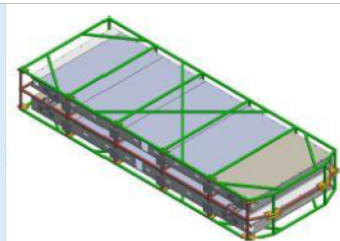


APA transportation

Some hardware came loose during ProtoDUNE shipping

We want to ship two APAs at once (cost reduction)

- New transport frame and box design to ship two APAs side-by-side on a MAFI trailer in ship hold and by road
- Used to ship from production sites to ITF, and then underground
- Working on procedure to lower down the shaft at SURF



Spring system for vibration damping

Conclusions

The ProtoDUNE experience was invaluable in demonstrating our APA design and in developing procedures

- The APAs worked spectacularly well
- We learnt which parts of the production procedure were difficult and time-consuming

We are developing new, improved procedures

- Minor design changes, upgrading the winder and process cart

A more complete set of lessons learnt are being tracked, as described in the accompanying report in EDMS

- EDMS → LBNF/DUNE → DUNE → SP APA Consortium → Engineering Notes → DUNE APA Lessons Learnt
- <https://edms.cern.ch/ui/#!master/navigator/project?P:100233194:100321633:subDocs>