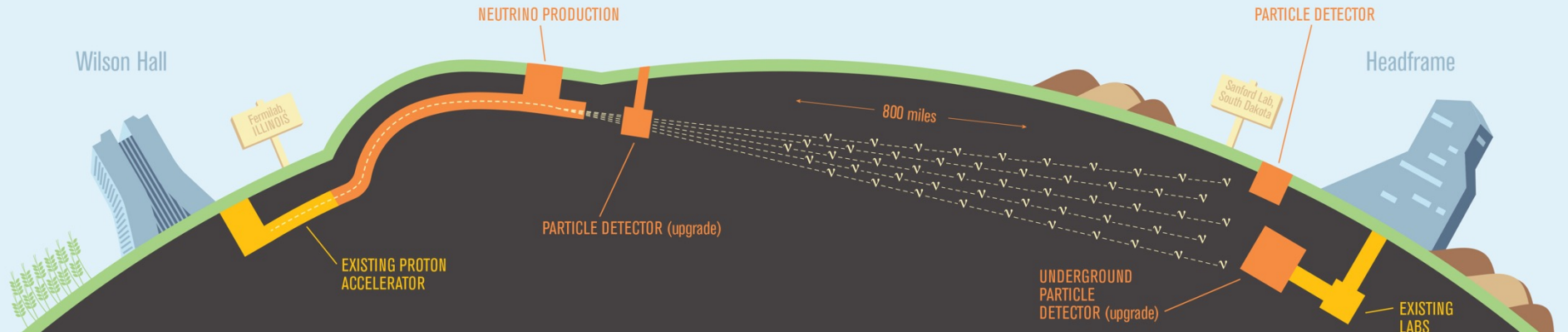
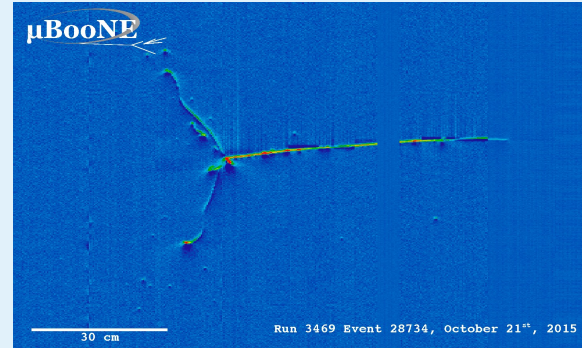
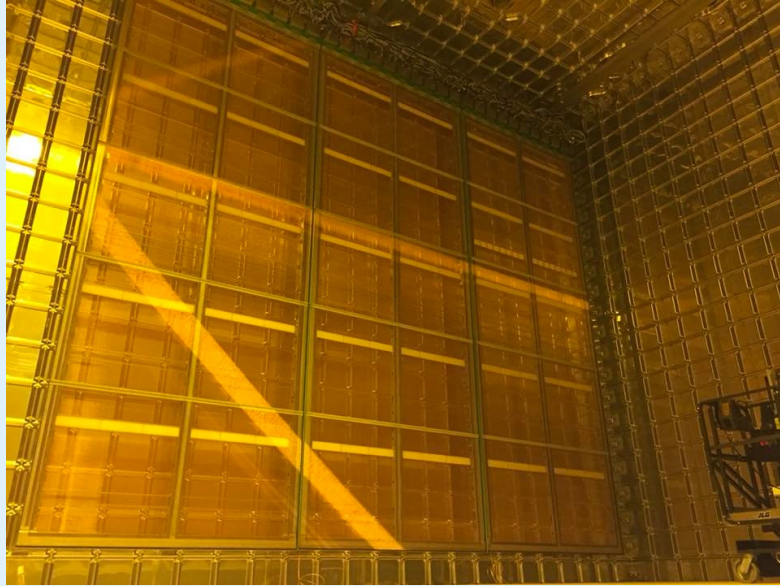


# APA construction

Justin Evans

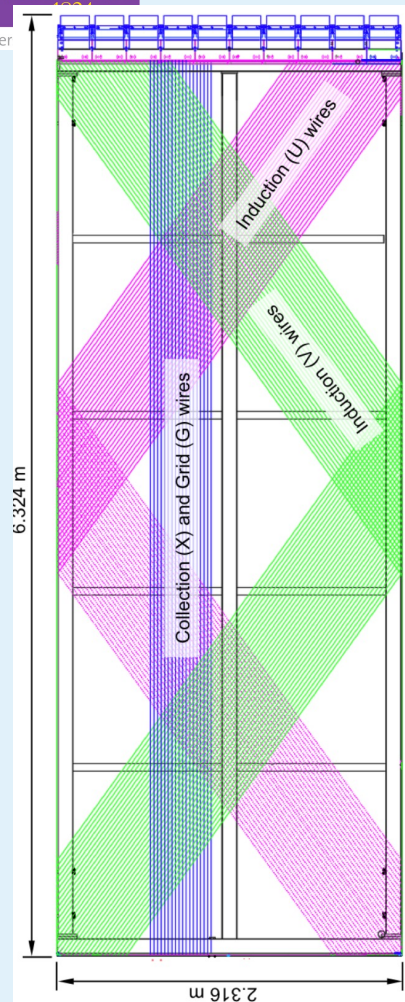


# Anode Plane Assemblies



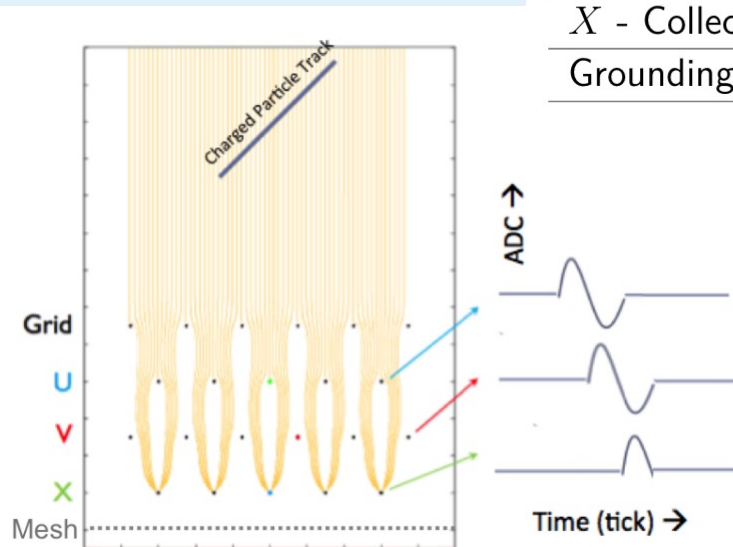
- Four wire planes: X, U, V, G
- 6 x 2.3 m
- 5.5k wires on each APA
- 35.7° winding angle on U and V layers
- ~5 mm wire pitch

# Anode plane assemblies

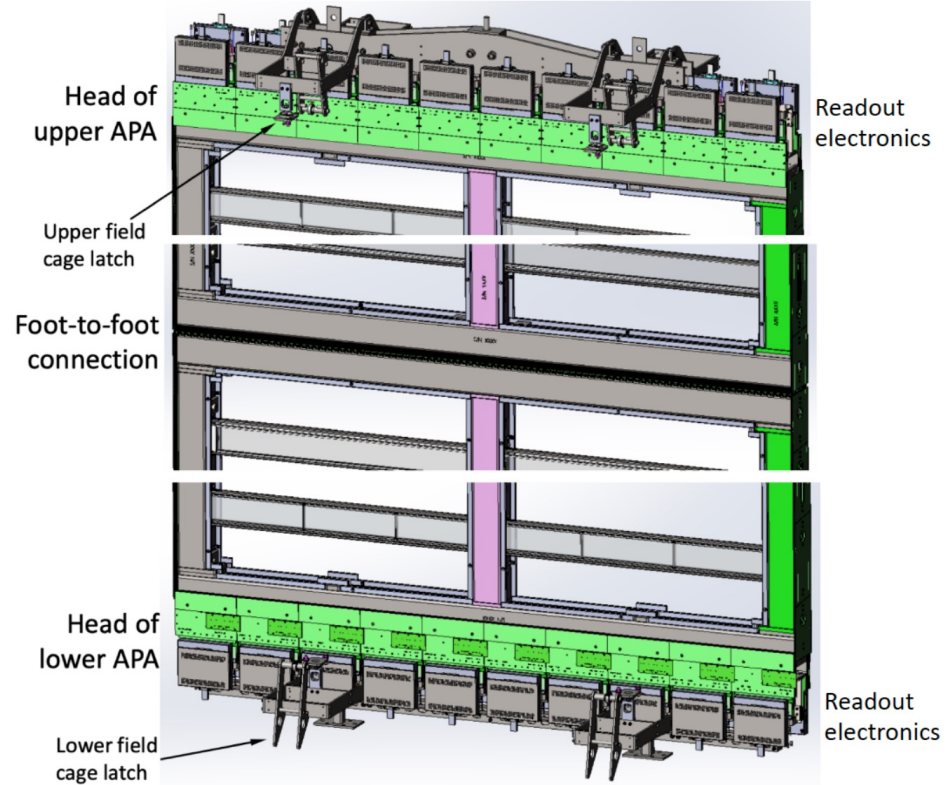
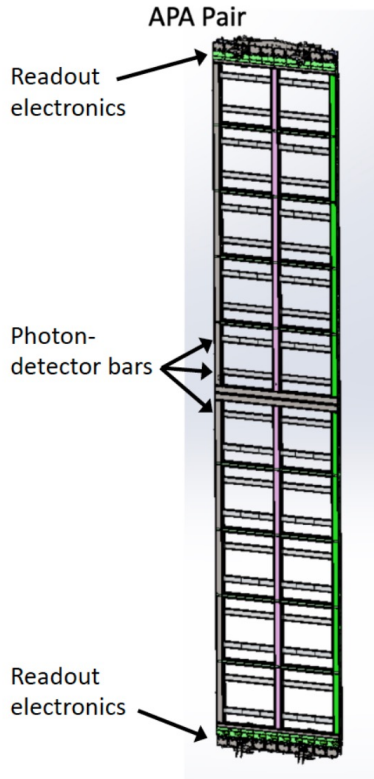


Read out at one end

Anode Plane	Bias Voltage
<i>G</i> - Grid	−665 V
<i>U</i> - Induction	−370 V
<i>V</i> - Induction	0 V
<i>X</i> - Collection	820 V
Grounding Mesh	0 V

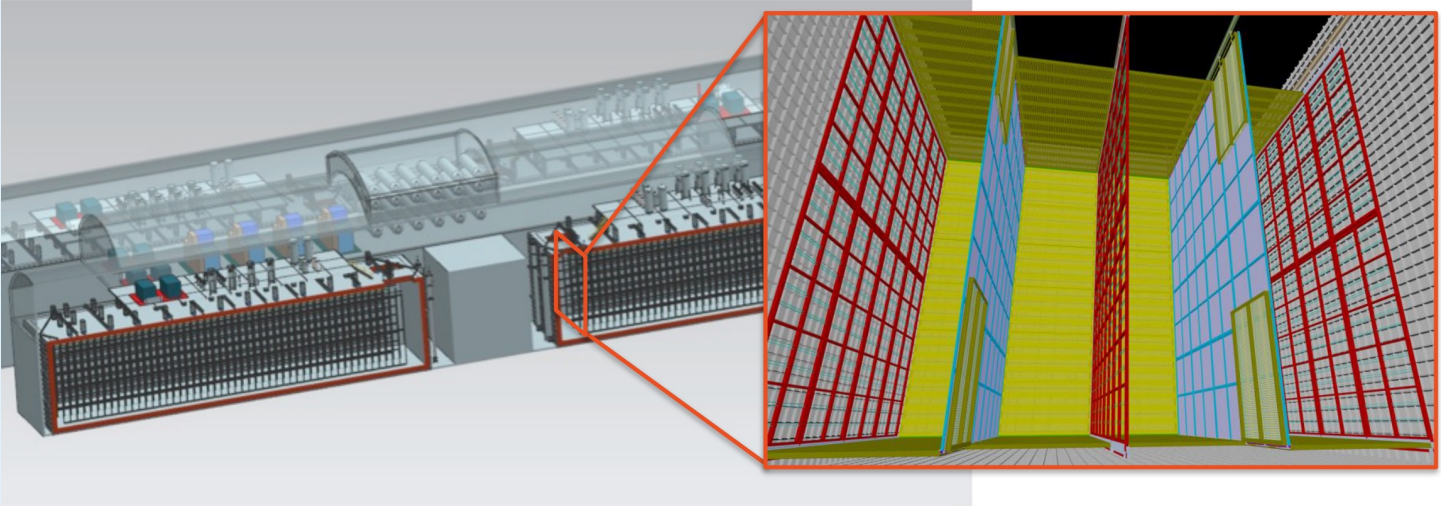


# Anode plane assemblies





# The Far Detector



Each 10 kt single-phase module requires 150 APAs

Our task is to build 130 APAs for the first module

- The US are making the remaining 20

A change in scope of our original proposal to make 150 APAs (half of the APAs for two 10 kt modules)

# The UK project

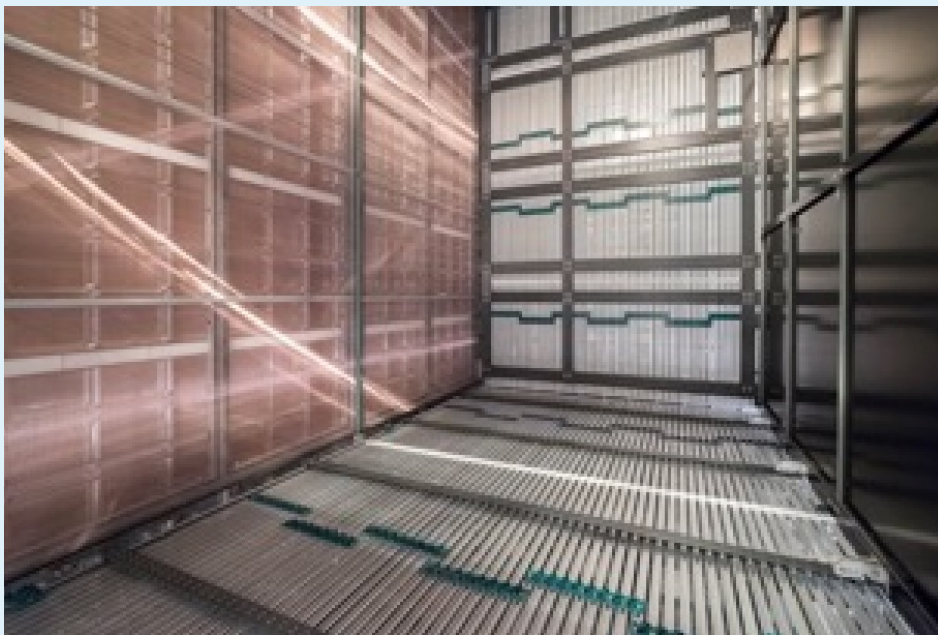
This is a huge project: very high-profile for the UK

- Producing a major subsystem for a flagship experiment
- Money provided direct from BEIS
- A £20M project

We are the first DUNE partner to move into the construction phase

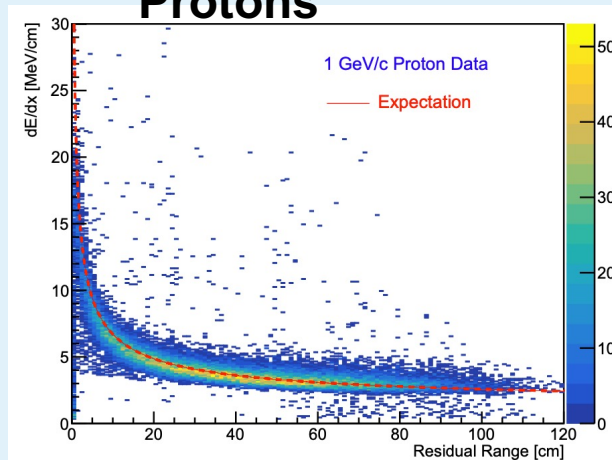


# ProtoDUNE-1

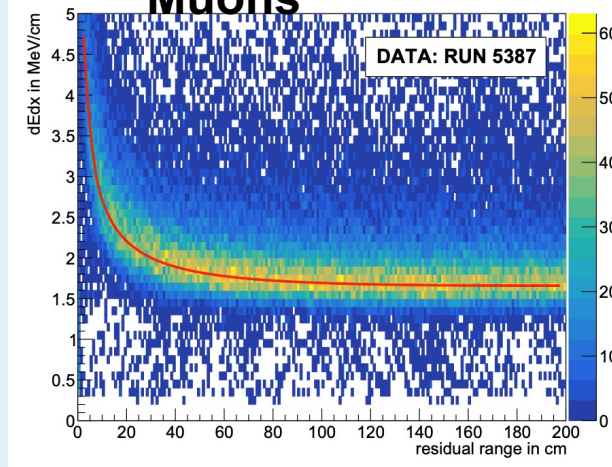


Two UK APAs; demonstrated excellent performance

## Protons



## Muons





# ProtoDUNE-1 broken wires

3 broken wires found during decommissioning

- 2 V-layer (APA 3) and 1 X-layer (APA 2)

Wires came loose during warm-up

- No shorting during data-taking

But the V-layer wires were dead throughout





# ProtoDUNE-1 broken wires

3 broken wires found during decommissioning

- 2 V-layer (APA 3) and 1 X-layer (APA 2)

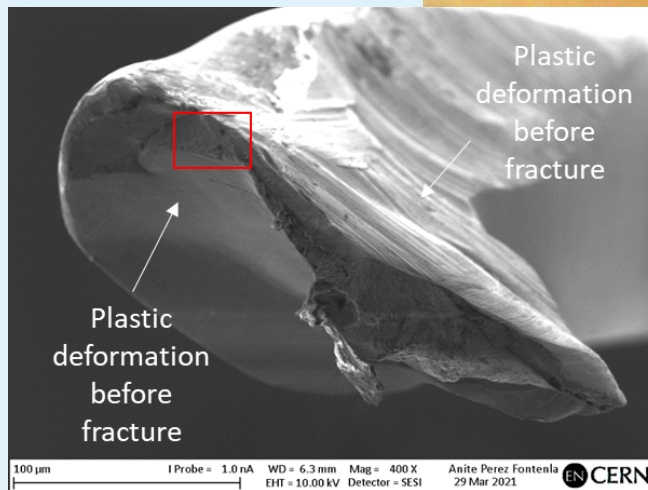
Wires came loose during warm-up

- No shorting during data-taking

But the V-layer wires were dead throughout

Extensive studies including electron microscopy and boroscope inspections

Causes of all broken wires understood and addressed in the design and procedures



# Broken X-layer wire

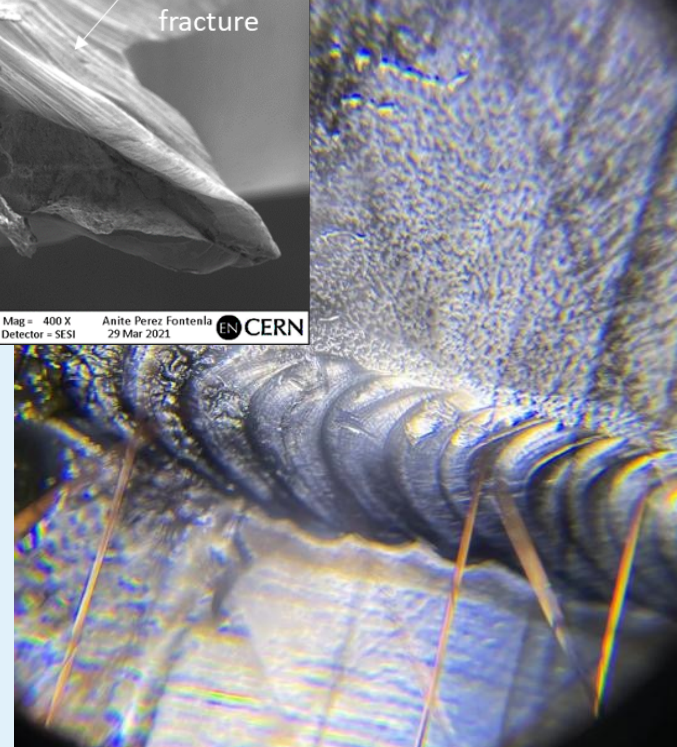
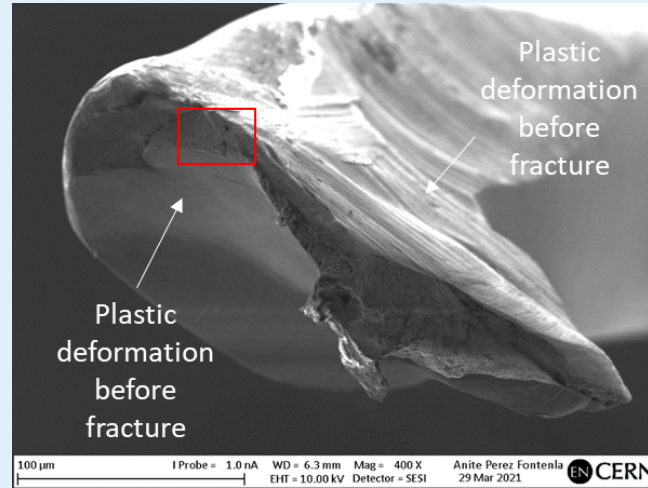
Broken end of wire shows pre-existing damage under electron microscope

Scratch visible on frame immediately below break point

Consistent with a tool hitting the wire and frame during construction

Procedures strengthened

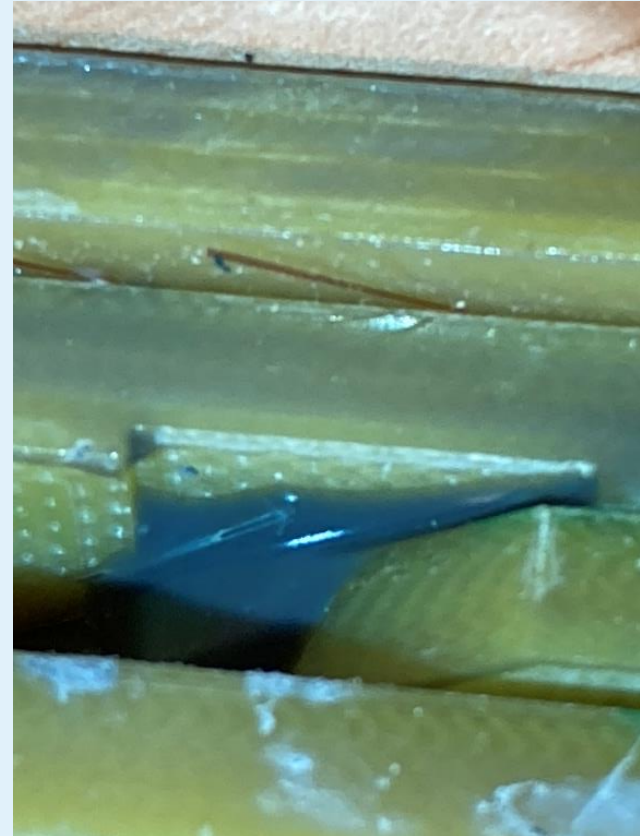
- If there is any suspicion that a wire might be damaged, that wire is to be removed



# Broken V-layer wires

Epoxy leaked into the gaps between head boards

- Unintentionally bonding the wire between two adjacent boards



# Broken V-layer wires

Epoxy leaked into the gaps between head boards

- Unintentionally bonding the wire between two adjacent boards

Short wire lengths between boards are prone to high stresses

- Also impacts other short corner wires





# Broken V-layer wires

Epoxy leaked into the gaps between head boards

- Unintentionally bonding the wire between two adjacent boards

Short wire lengths between boards are prone to high stresses

- Also impacts other short corner wires

Additional wire relief designed into the corner head boards

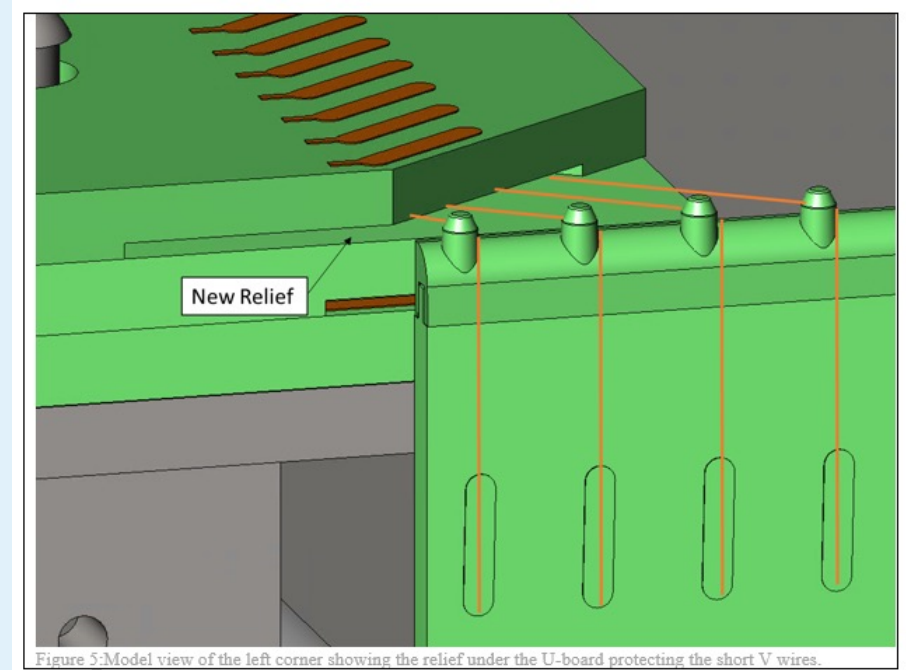


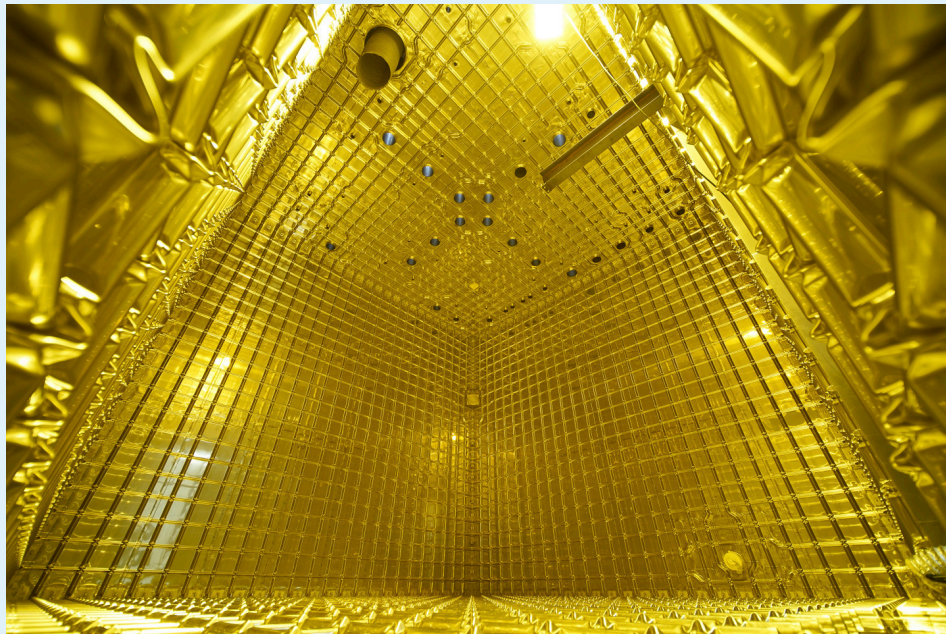
Figure 5: Model view of the left corner showing the relief under the U-board protecting the short V wires.

# ProtoDUNE-2

This will be a full system test of 'module 0' parts

- The final design of all DUNE FD parts
- APAs, PDs, electronics, field cage, HV, etc

We will provide three APAs, the US one



# ProtoDUNE-2

APA 1 built and sent to CERN in November

Cold test showed some problems with the readout boards (CR boards)

- Not UK parts
- See Christos's talk

The UK APA itself looks to be performing well



# Final Design Review

The APA Consortium went through a Final Design Review in September

This confirmed that the APA design is final and satisfies our requirements

- Gave us the go-ahead to begin big procurements.

Our next review milestone is the Production Readiness Review

- Likely 1–2 March, at Daresbury
- This is a review of specifically the UK's readiness for production
- This is our final review and will confirm that we are ready to commence mass-production of APAs



# APA frames

The underlying steel structure of the APA

Flatness is key

£2.5M contract just placed with Durham Sheet Metal (Sunderland) to produce 128

- They made our ProtoDUNE-2 frames



# Geometry boards

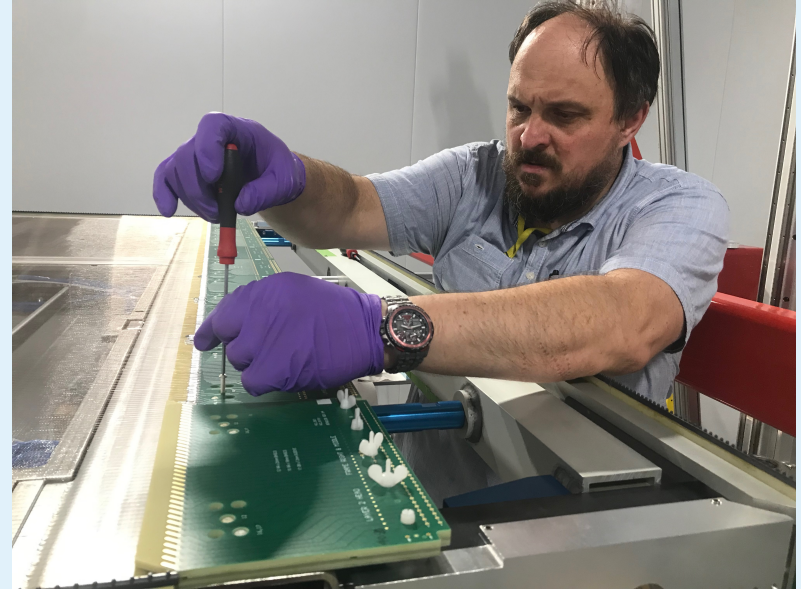
These set the alignment of all the wires

- Layer spacing and wire spacing

Almost 40,000 boards to be procured

~£1M tender has completed, with contract to be signed soon

Anthony and Nicola will explain the extensive QC and assembly these boards undergo



# Grounding mesh panels

- Attach straight to the APA frame to prevent charge from 'within' the APA being collected
- Another large tender soon to go live



# Transport frames

Yellow frame holds two APAs

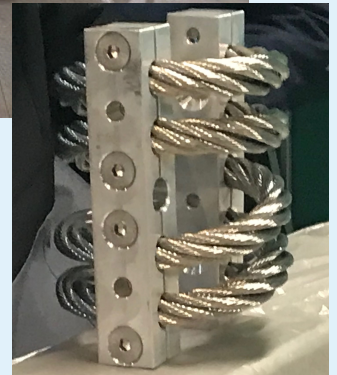
Attached to the red cradle via suspension springs

Extensive analysis

- Vibrational modes
- Impact analysis
- Finite element analysis
- Envelope studies

Comparison to data from a lorry trip around CERN

Still work to do to fully understand the suspension-spring response





# Upcoming milestones

Next cold test of APA 1 at CERN

- **Need UK people at CERN, likely from 21<sup>st</sup> March – please volunteer!**
- And we'll need people right through ProtoDUNE-2 installation and operations

APAs 2 and 3 need to go to CERN in April

Start of APA production

- In March, as soon as the first APA frame gets delivered

Production then continues until end of 2026

- Averaging 2 APAs per month

This will be a mammoth effort, bringing new technicians up to speed, and keeping the momentum up on APA production for the next 4.5 years

- Getting us this far has been a huge amount of work for the UK APA groups, prototyping, developing QC techniques, trialing vendors, writing tender packages, etc, etc