Report – DWA measurements at CERN

Measurements on APAs 14 and 15
September 30th to October 4th, 2024
Pre-Cold Test

Matthew Wright
UNIVERSITY OF MANCHESTER

Pip Hamilton
IMPERIAL

Report – DWA measurements at CERN

Introduction

This report details the work necessary to complete DWA tension measurements on APAs 14 and 15 at CERN (ENH1, B 887), prior to cold testing. The APAs were shipped to CERN from the manufacturing site (Daresbury) in the APA Shipping Frame (ASF).

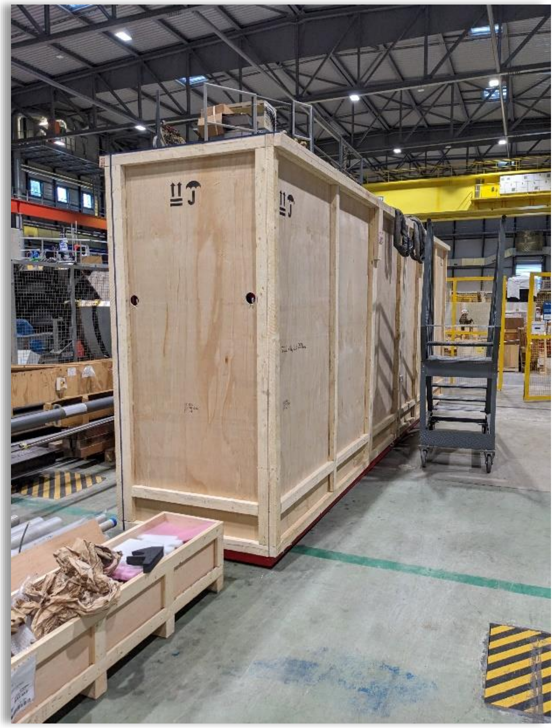
Along with details of the work necessary to perform these measurements, the lessons learned from this work and subsequent recommendations are also discussed.

Delivery

APAs 14 and 15 were delivered to Building 887 on Friday 27th September.

Support Rail for DWA, plus a tool set and various required mounting bolts and screws, were delivered with ASF to Building 887 on Friday 27th September.

DWA trolly shipped to CERN on Monday 30th September.



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Stage 1: Moving of ASF to measurement area and removal of shipping crate

ASF was lifted and moved into measuring area using 2x eyelet bolts located on top centre of ASF.

The ASF was covered by a 'Top Hat' crate which needed to be removed. This required the location of an additional 2x eyelet bolts attached to top of ASF hidden under a top panel of the crate.

Once ASF was in position, all eyelet bolts were removed and fitted to 4x Eyelet bolt receptacles located on crate (two on either side), thus allowing removal of crate from ASF.

All of the above had to be quickly organised on Mon 30th September. Fortunately, the riggers were available to perform this work.

Recommendations:

ASF must be delivered well in advance of any DWA operations. Arrangements for moving of ASF and removal of crate must be made in advance to ensure APAs are accessible for measurements when DWA operators arrive at CERN.

Any separate deliveries intended for B 887 may instead be delivered to Prévessin site reception building!

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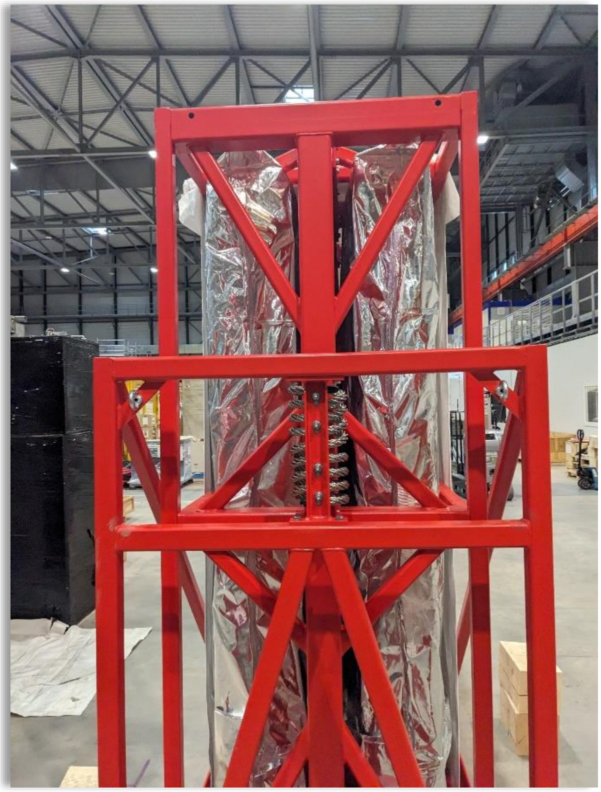
Stage 2 – Opening of tarp

ASF covered by a Velcro sealed tarp. Opening of end sections of the Velcro seals was required, the end sections being rolled up and placed on top of the ASF. The side sections were taped back to the main part of the tarp structure. This allowed full access to the head ends of the APAs.



Note: The APAs are loaded side by side into the ASFs in a head-to-foot sense; the head end of one APA being adjacent to the foot end of the other. Hence both ends of the tarp need to be opened to allow measurement access to both APAs.

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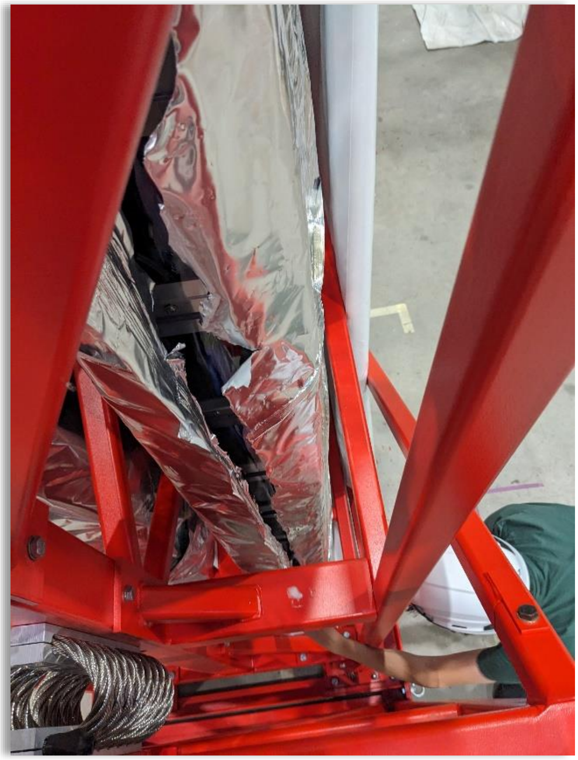
Stage 3 – Cutting of the APA environmental covers

APAs are covered by a heat-sealed wrapping cover to add additional environmental protection.

The head end of each of the APAs must be identified before these covers are opened. The headguards of the APAs can be located by feeling the structure underneath this cover. The headguards are significantly deeper than the footguards and can therefore be quickly identified.

A box-cutter knife was used to pierce the covers at the head ends of the APAs. The first cut made was down the centre line of the APA from top to bottom, along the side of a heat-seal seam.

Two additional cuts were made at the top and bottom of the APA. These ran along the foam protection strips located underneath the top and bottom sections of the cover



These cuts created 4 flaps that could be pulled back to reveal the head end of the APA and fully expose the headguard. The use of masking tape helped to keep the flaps pinned back, where necessary.

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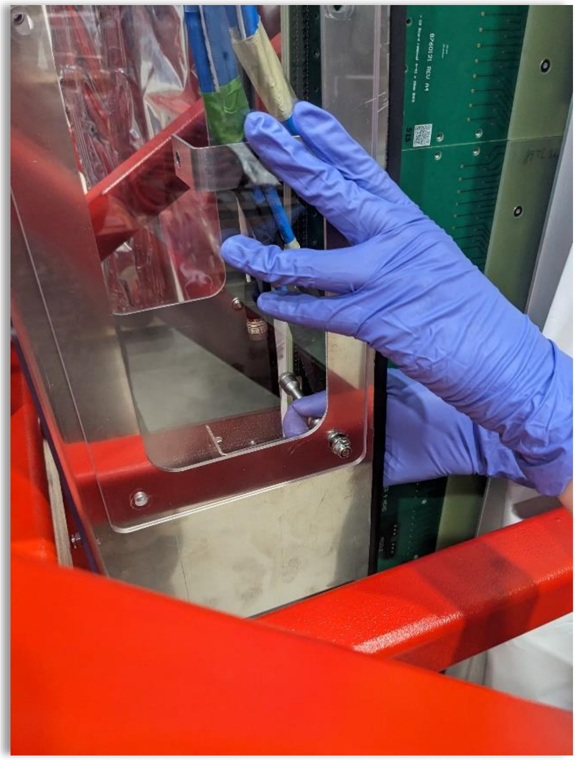
Stage 4 – Removal of Headguard

This first task requires the unbolting of the head guard from the brackets that connect it to the APA frame. This is a two-person job requiring support of the guard as it is detached.

Once removed, the headguard can be pulled back from the APA and rested on the ASF frame. The use of tape to secure its position is recommended. Operators must ensure that the headguard does not come in contact, at any point, with the Headboards.

Once free, the headguard can be removed. To do this, it must be lifted vertically up out of the ASF. In this instance this was not possible due to the interference with the ASF structure of the nuts used to fix the Perspex windows onto the Headguard. We therefore needed to remove these nuts before being able to extract it. This would have been avoided if the nuts had been located on the inside of the headguard and the low-profile button screw to which they are connected, located on the outside. After consulting with Rob Chapple (designer) at Manchester, it seems that the screws were indeed assembled the wrong way around. This must be communicated to the Daresbury technicians before future shipments are made.



Recommendations:

Nuts retaining Perspex windows on Headguard should be assembled on the inside with the connecting button screws on the outside. This will allow Headguard to clear ASF structures when being removed from APA/ASF.

Temporary suction handles could be attached to Perspex windows of headguard to aid its manipulation and removal/re-attachment.

Stage 4 – Assembly of X and G Probe boards onto Headboard stacks

Assembly of X and G probe boards onto outer headboards was relatively trivial. Use of nylon thumb screws for X probe board attachment proved very successful, negating the use of tools and reducing any risks associate with the dropping materials.

Initially (for APA 15), the G boards were attached using 4x M3 screws, in the manner of the original design method. For the outer face of the APA, this was relatively trivial but still a little tricky and with the inherent risks discussed above.

Furthermore, only a limited number of probe boards were available at CERN: 7x G Probe Boards, 13x X Probe Boards. This allowed one full side of an APA to be populated with X boards (x10), but 3x G probe boards needed to be removed and reattached to complete measurements on the G layer.

G Probe Board fixing holes were counterbore instead of countersink. This is not consistent with the design drawings of these boards, and made tightening of the attachment screws a little more difficult than usual. This was due to excessive friction between the flat underside of the screw heads and the counterbore profile.

Another problem encountered was the occasional decoupling of the broach nuts from the Probe Boards. The broach nuts allow the flex cable connector to be easily attached and disconnected from the Probe Board using the captive thumb screws on the flex cable head. A number of these broaching nuts were pulled out of their sockets as the flex cable head was unscrewed and detached from the probe boards.

Attaching of X probe boards to inner face of APA proved relatively simple, but attaching G Probe Boards using the traditional screws was extremely difficult due to access and line of sight issues.

When tackling the second APA to be measured (APA 14), we cut a number of the nylon thumb screws to the correct fitting length (different to the X Probe Boards) and used these instead to attach the boards. This was a significant improvement and reduced the time and effort required to attach these boards, particularly to the inner face of the APA.

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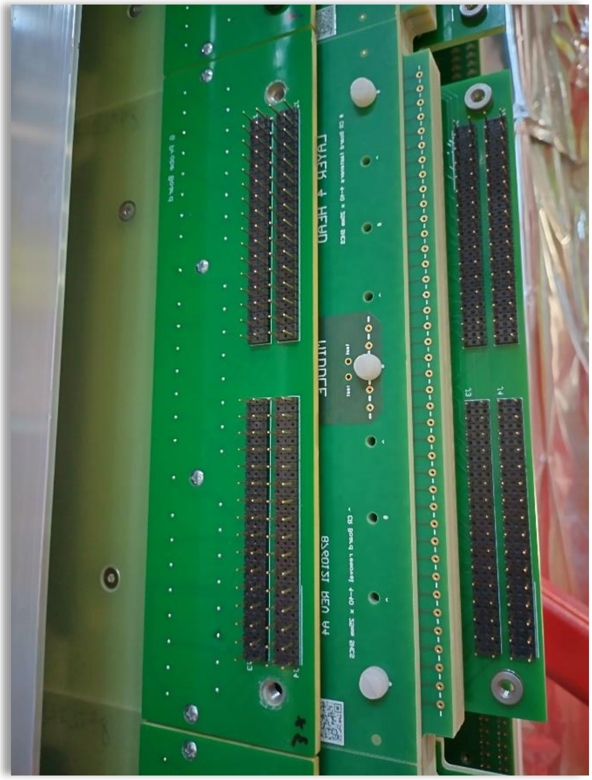

Recommendations:

Need to replace the G boards completely and supply additional X and G Probe Boards (minimum of 20 of each flavour required).

Easily portable steps/platform (1m high) would be useful when attempting to reach the high points of the APAs. The heavy-duty platform used on site was overkill for this work.

Need dedicated nylon screws for G Probe Board attachment.

The press-fit Broach nuts on Probe Boards need the addition of an appropriate epoxy to increase the binding strength to the FR4.

Need replacement Pogo Pins available at CERN in case of damage.

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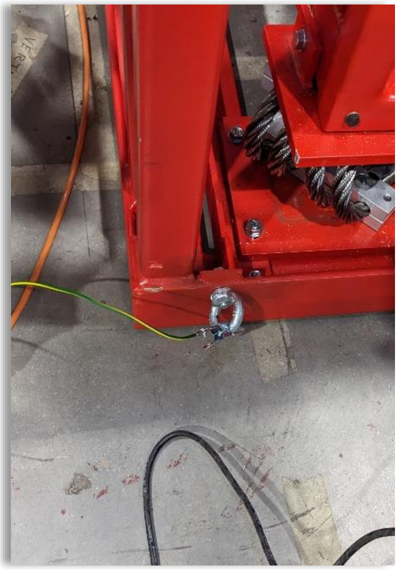
Stage 5 – Measurement

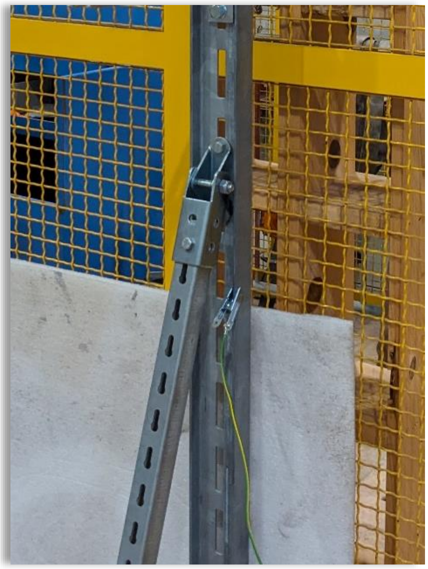
The DWA and Power Distribution Box were attached to the DWA plate which was then attached to the Support Rail Car on the trolly. The trolly worked extremely well and was easily manoeuvred and fixed into its final measurement position using the wheel locks.

The ASF was grounded to a building ground located on a cable tray approximately 10m from it. The DWA Trolly was then grounded to the ASF. In both cases a cable was used with crocodile clip connection made to the respective grounding points.

A grounding check was made using a borrowed multimeter.

An extension lead was used to bring power to the DWA and the DWA Laptop, and the DWA laptop was located on the trolly platform.

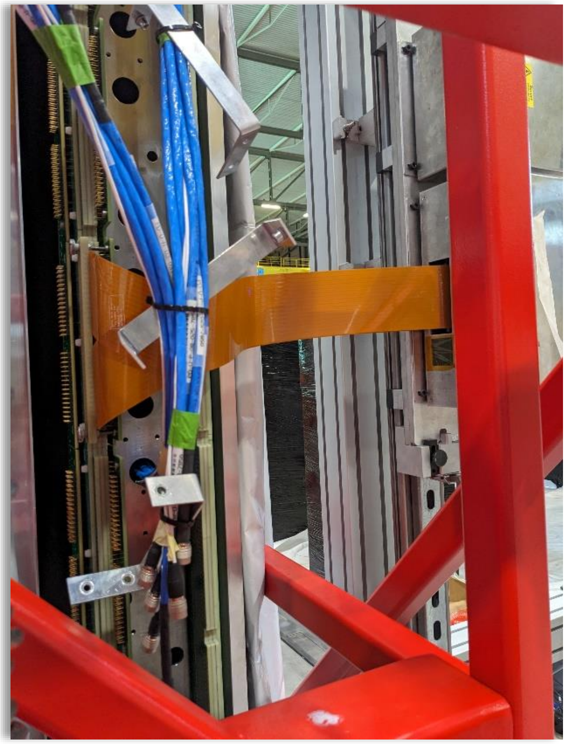




The flex cable was long enough to reach the probe boards on both the outer and inner faces of the APA. However, only a small amount of play was available when attached to the inner Head Boards.

Once some initial connection issues were resolved, measurement proved relatively straightforward.

A loss of communication between the analogue board and one of the relay boards did halt proceedings for approximately an hour during measurements on Side B of APA 14. This recovered and measurements were completed, but this highlights the fragility and temperamental nature of the DWA systems. Efforts to establish the cause of this and other related issues have now been given priority.



Recommendations:

Easily portable steps/platform (1m high) would be useful when attempting to reach the high points of the APAs. The heavy-duty platform used was inappropriate for this work.

Need a dedicated power extension lead.

Need a dedicated multimeter for continuity checks (grounding).

Need braided grounding straps with bolted connections to grounding points.

Longer flex cable (additional 10-20cm) might be useful.

Need a dedicated and stable DWA unit for CERN activities (applicable to all sites).

At least 2 flex cables should be available (1 spare).

Spare fuses for PDB AC input required.

Spare surface mount fuses required for regulators in PDB.

Access to soldering equipment may be required.

Step 6 – Completion and repackaging of APAs

Once measurements were completed, the DWA Trolly and associated cabling and equipment were removed from the ASF. The X and G probe boards were then removed and stored.

The Headguard brackets were then reattached to the APA frame and the ASF environmental protection cover was then re-sealed using masking tape.

Before re-inserting the headguards, the nut/screws binding the Perspex windows to the headguard frame were removed and replaced in the correct configuration (button screws inserted on the outside of the windows and bolted from the inside). The Headguards could then be replaced without conflict with any part of the ASF structure. Once again, this process requires two operators to ensure a steady and controlled reattachment process.

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Recommendations from DWA Safety Inspection at CERN

- Kapton tape to secure the chassis ground wires
- Board fuses to be covered in Kapton tape to prevent arcing
- Star washers on the chassis grounds (star washer under screw head)
- Mark voltage and current rating on the PDB
- Heat-shrink on wires to umbilical cord connector, if practical
- Ensure AC fuse housing on PDB is secure and does not rotate when fuse is extracted
- Ensure kettle lead connector on PDB is secure
- Shards of aluminium need to be removed from the boxes
- Ensure there is consistency between AC fuse rating on wiring diagram and actual fuse used.
- Establish that the ACL traces on the PDB board can handle 3.15A max input. Need trace width analysis.
- Cover needs to put on the random holes in the DWA boxes

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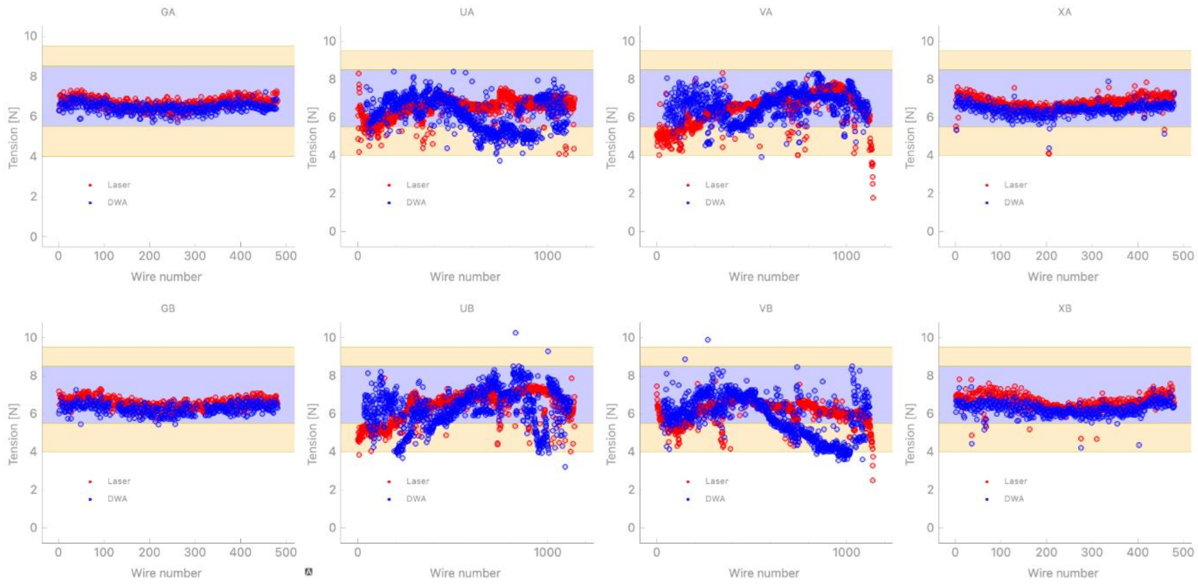
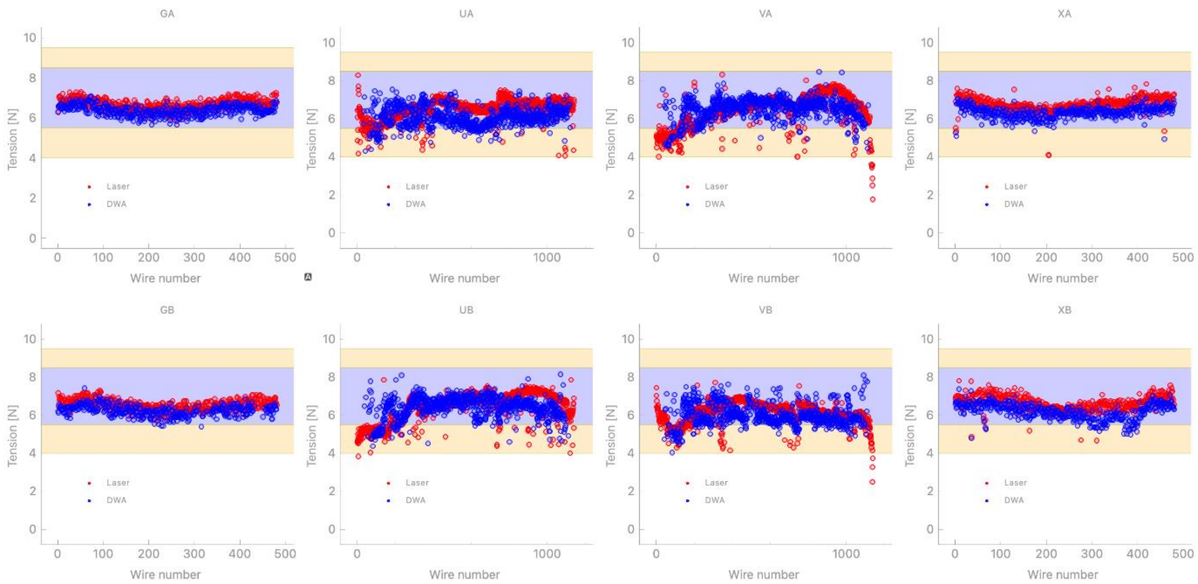
DWA Tension Data – APA 14

Pre-shipping data (Process Cart, Daresbury))



Post-shipping data (ASF, CERN)



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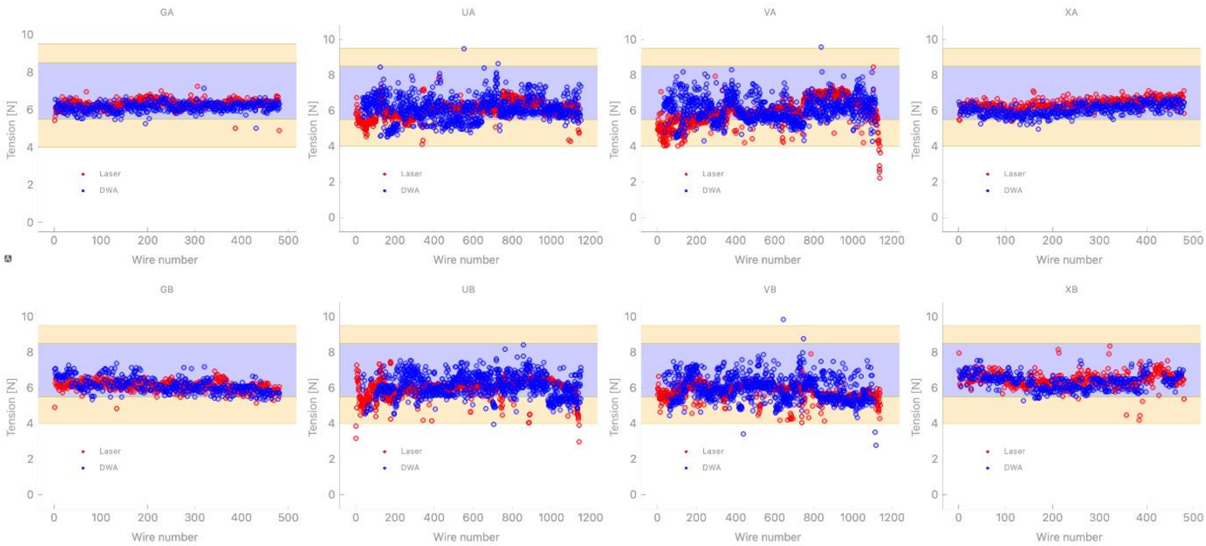
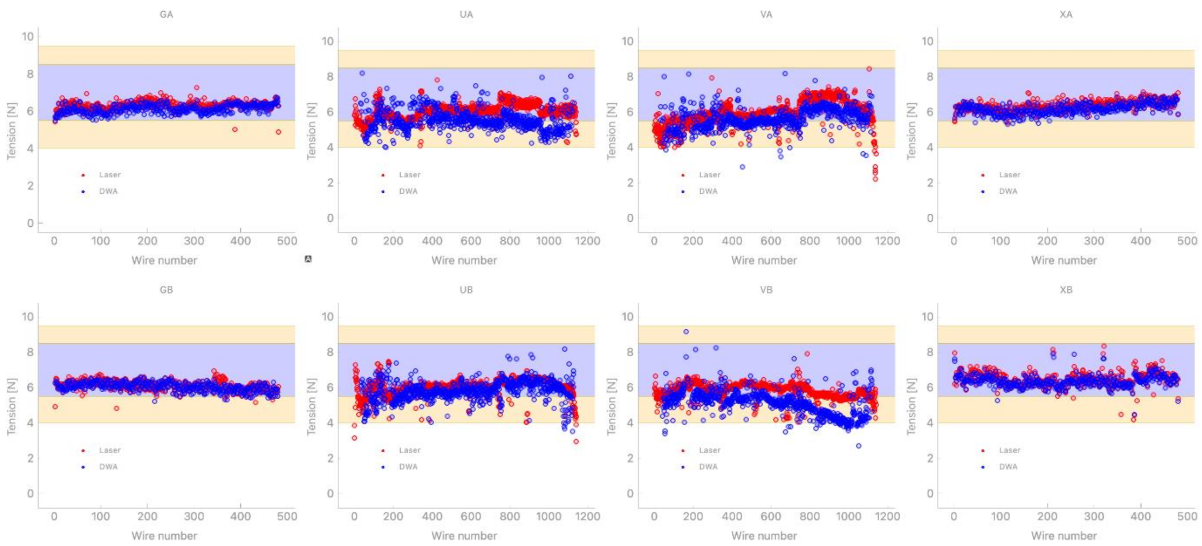
DWA Tension Data – APA 14

Pre-shipping data (Process Cart, Daresbury))

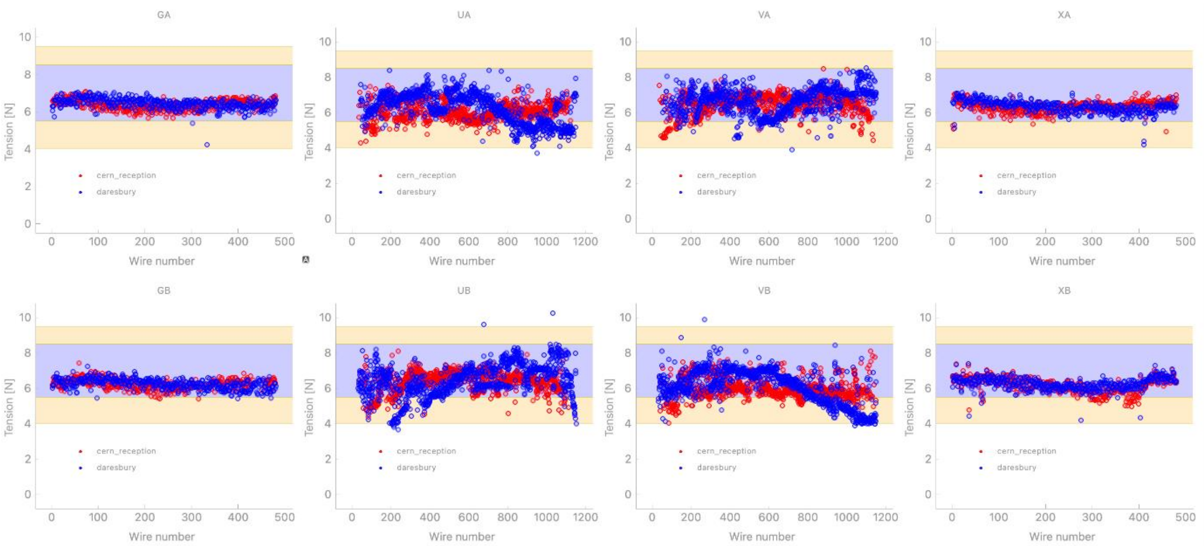


Post-shipping data (ASF, CERN)

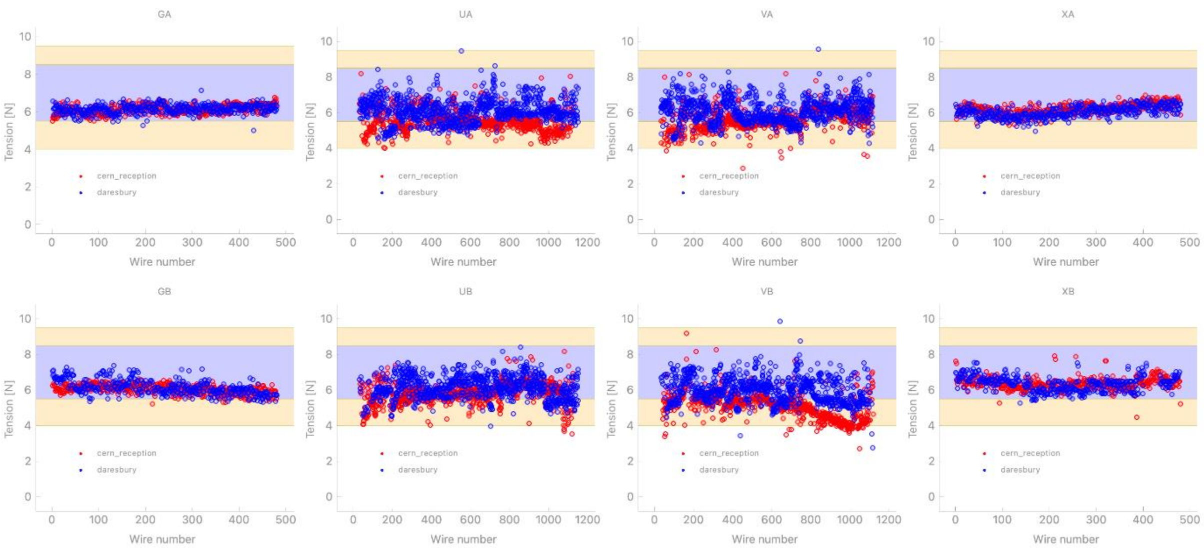


Pre- and Post-shipping Data Compared

APA 14



APA 15



APA 14

G and X layer tension data well matched to across the two measurements.

Sinusoidal-like variation observed in UA layer and VB layer tension data seen in pre-shipping data appears to have been suppressed in the post-shipping data. This may suggest the different mechanism of APA support in the ASF has altered the wire tensions in these layers (APA 'straightened out'??)

APA 15

G and X layer tension data well matched to across the two measurements.

There appears to be a drop in tension on U and V layers, most notably in UA and VB layers. Again, this could be indicative of the differences between the APA support mechanisms pre-and post-shipping. This is not necessarily suggestive of a change associated with transportation.

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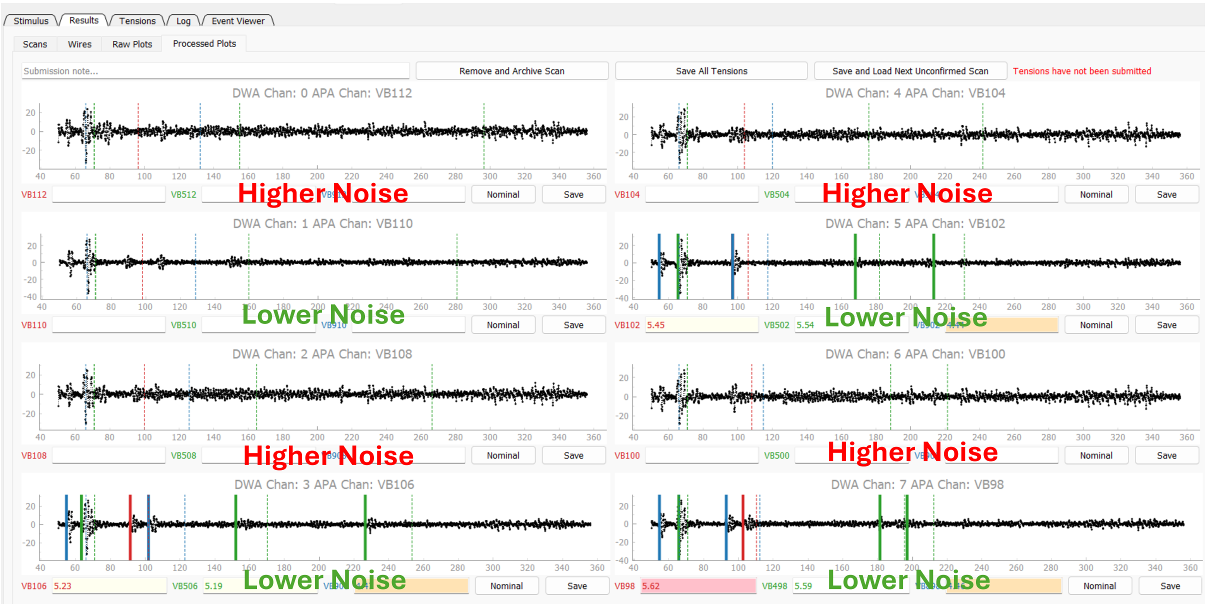
A Word About Noise

Examining data from measurements at CERN revealed a repeated pattern of noise in certain datasets. This noise dramatically impacts the resolution of sense current resonances in these data.

Data from APA 15 (CERN)



This pattern is repeated regardless of layer, Headboard or scan groups. Its source is therefore associated with the DWA and, more particularly, with the Analogue board (independent of which Relay Board is being activated for the scan).

The magnitude of the raw signal was noted to be significantly higher for traces showing the higher noise levels.

Further investigations made using Test Stand.

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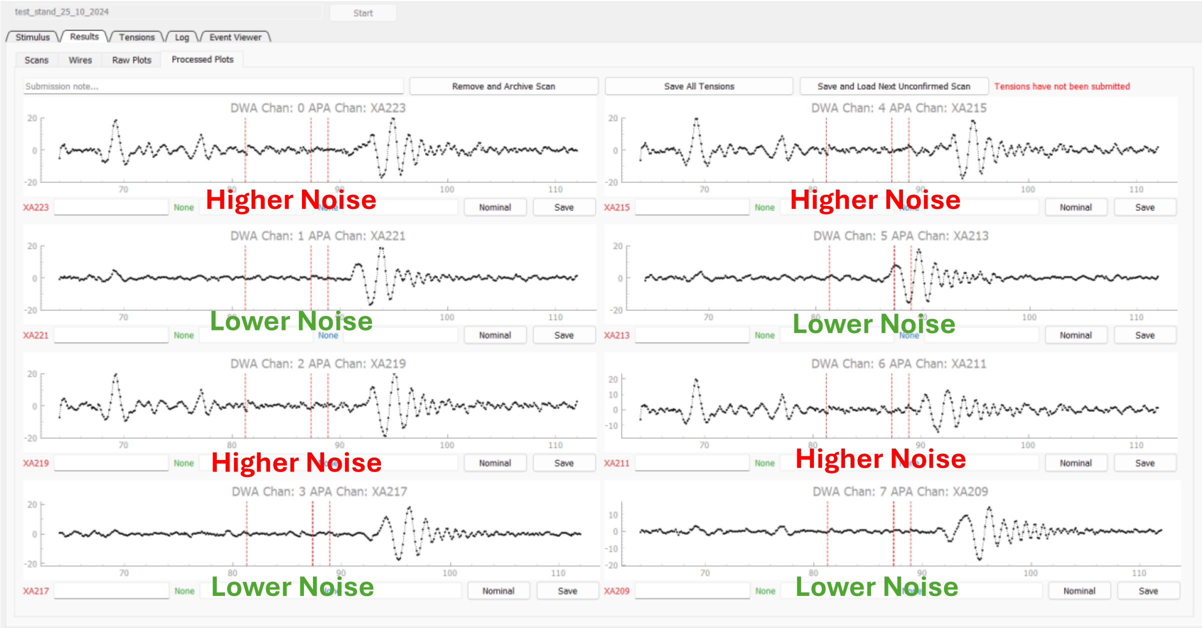
Data from Test Stand



Data taken when DWA disconnected from Test Stand

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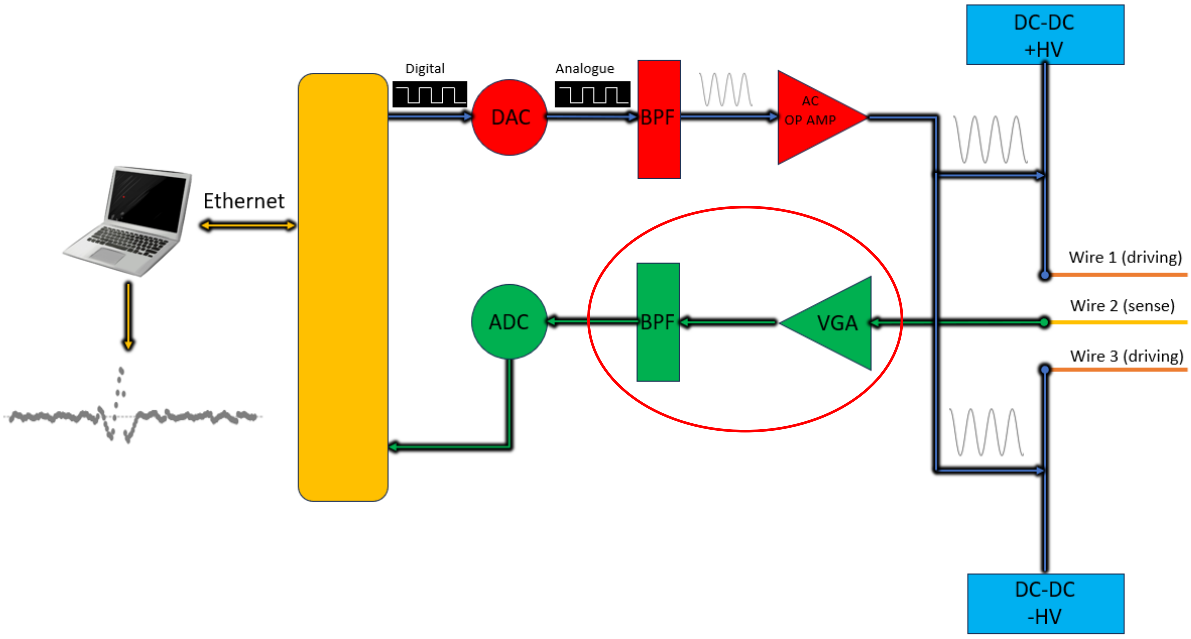
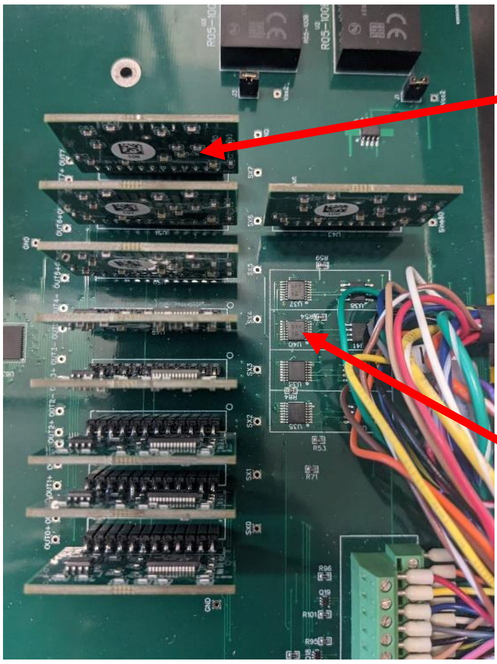
Causes?

Signal from each wire pass through a VGA and then onto a Band Pass Filter before being digitised and returned to the FPGA.





Band Pass Filter

Variable Gain Amplifier

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Test 1

BPFs were swapped over to see if this affected the signal noise patterns in the measured scans.

No effect seen.

Test 2

Outputs of the VGAs were sampled. These showed significantly higher gain for channels showing the higher noise.

Channel	Gain	Signal Noise
0	Higher	Higher
1	Lower	Lower
2	Higher	Higher
3	Lower	Lower
4	Higher	Higher
5	Lower	Lower
6	Higher	Higher
7	Lower	Lower

These VGAs are programmable digital gain amplifiers. It is likely that the gain is controlled by the FPGA and is set in the uploaded firmware.

To understand the reasons for the differences in the gains of these amplifiers, or to establish if these have been modified at some point, we are sending a report to Nathan Felt and John Oliver. It will likely be necessary that we modify the firmware by adjusting the pre-amp gains and study their influence on the signal-noise ratio.

Going Forward

To be sure of consistency between pre- and post-shipping measurements, all future DWA tests should be performed while APAs in ASFs.

Technical review of DWA boards to ensure any potential sources of noise are minimised. Already underway and to be supported by Electronics Engineers at RAL.

In-parallel DWA and Laser Tension measurements of U and V layers to establish consistency between the two techniques.

Longer-term, the removal of subjective element of data analysis (manual analysis) via modification of current executable or development of separate script to automatically and reliably identify signal resonances. This would benefit from the minimisation of signal noise.