APAs at CERN

Wire tension measurements

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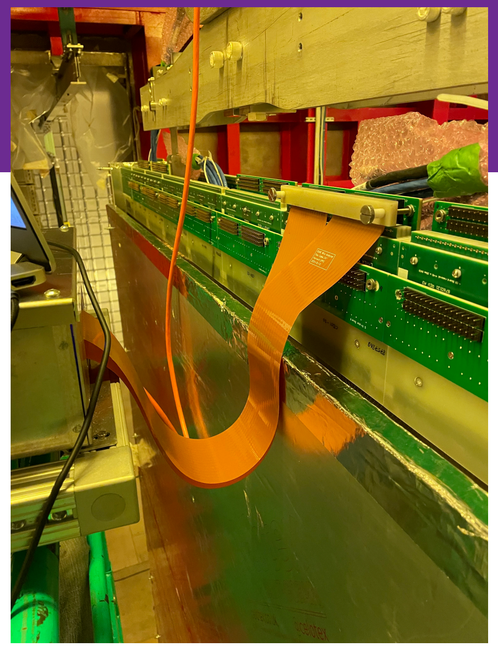
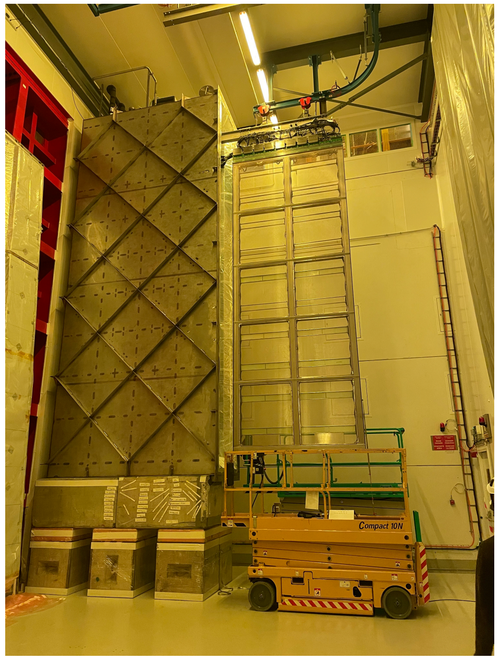
LBNF/DUNE UK Project Meeting - 5th July 2022

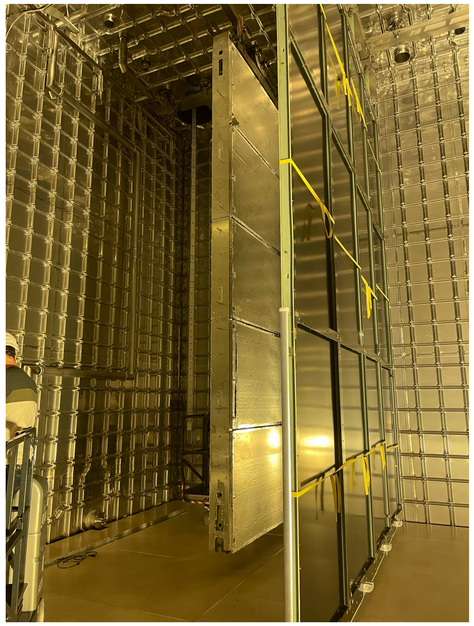
Proto-DUNE installation

An APA's journey at CERN

1. Arrives at the Neutrino Platform
2. Is taken out of the shipping and moved to the clean room
3. Wire tensions are measured with the DWA (more on that later)
4. Sub-systems are installed
5. Assembled APA is cold tested
6. Tested APA is installed into the cryostat







Current status

- UK APA 1 is in the cryostat (cold box test done)
- UK APA 2 is in the cold box (cold box test done but might need another)
- US APA 4 is in the clean room
- UK APA 3 is in its shipping frame

Next few weeks

- Cold test APA 4
- Move APA 3 to the clean room
- DWA test APA 3
- Assemble APA 3
- Cold test APA 3

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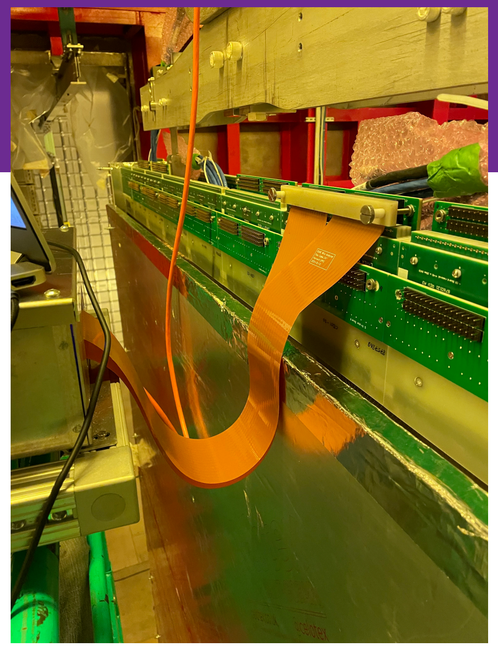
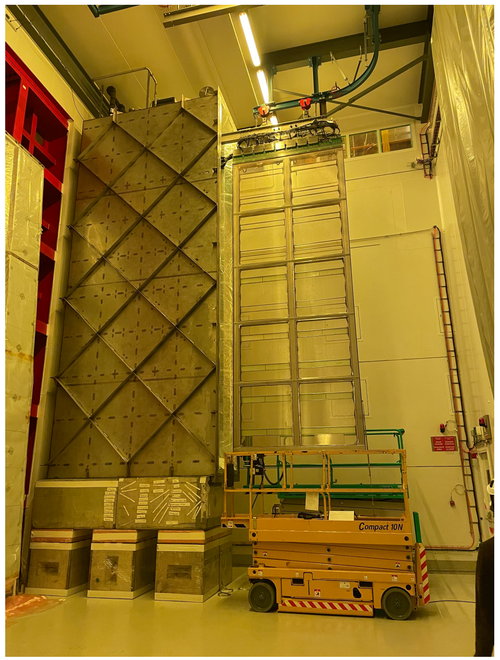
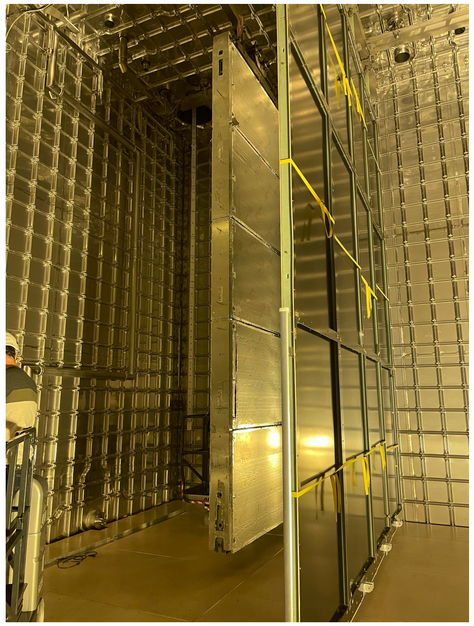


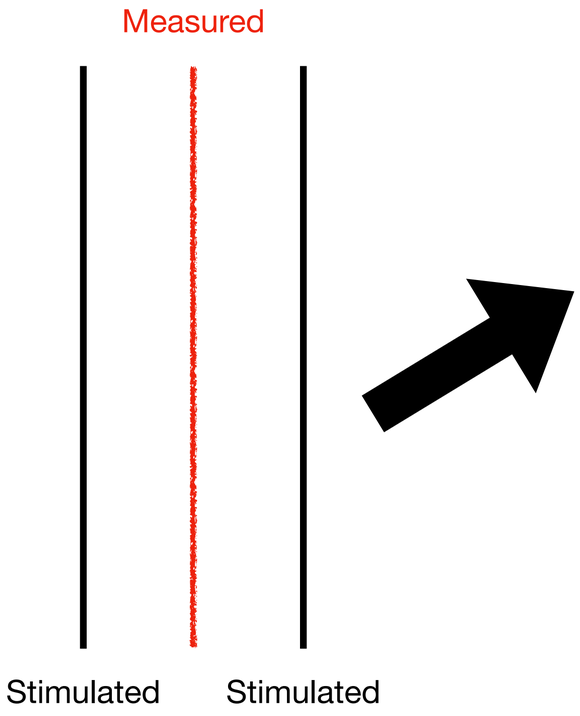


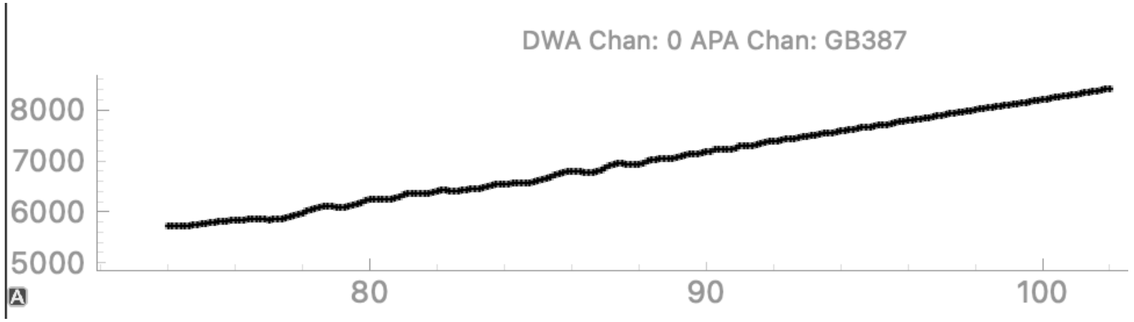


The Digital Wire Analyser

How to measure a tension?

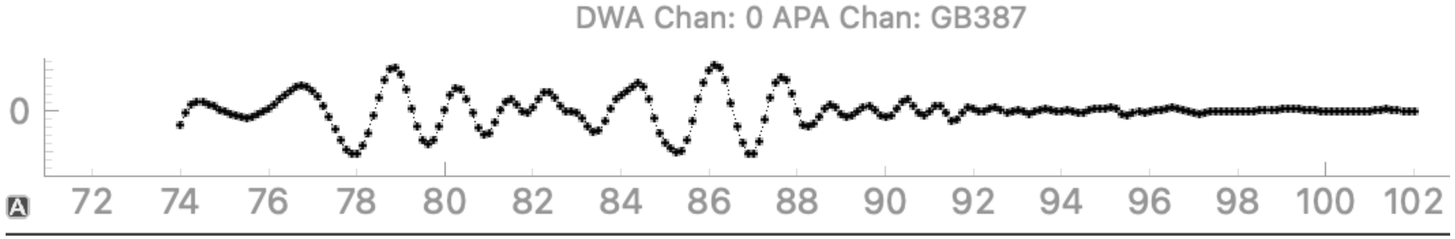
Tension is extracted by measuring the fundamental frequency of the wire





2. Read out middle wire while sweeping frequency of AC current

3. Smooth and subtract the baseline

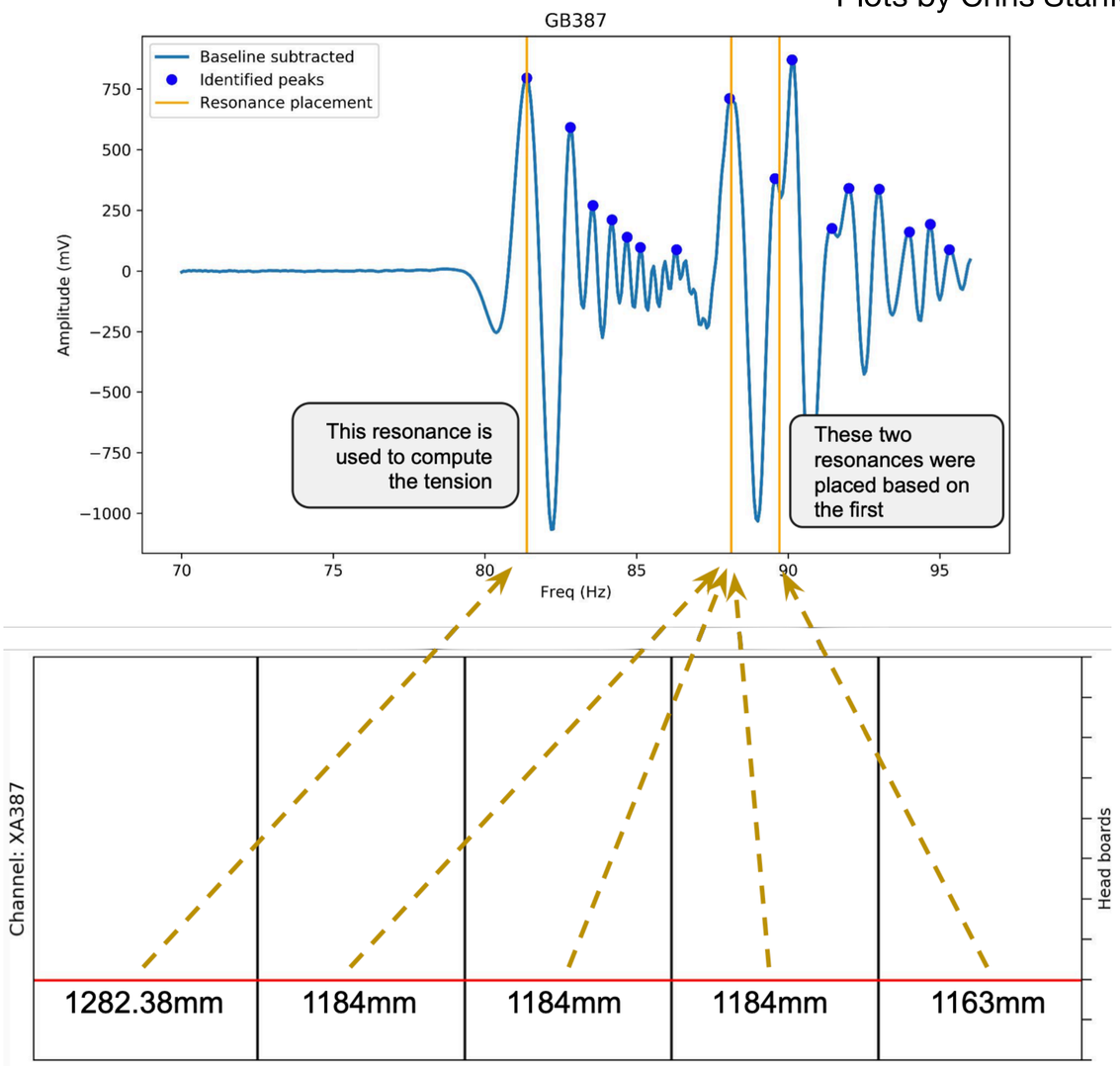


1. The two neighbouring wires are stimulated with a mix of AC and DC current.

Extracting the tension

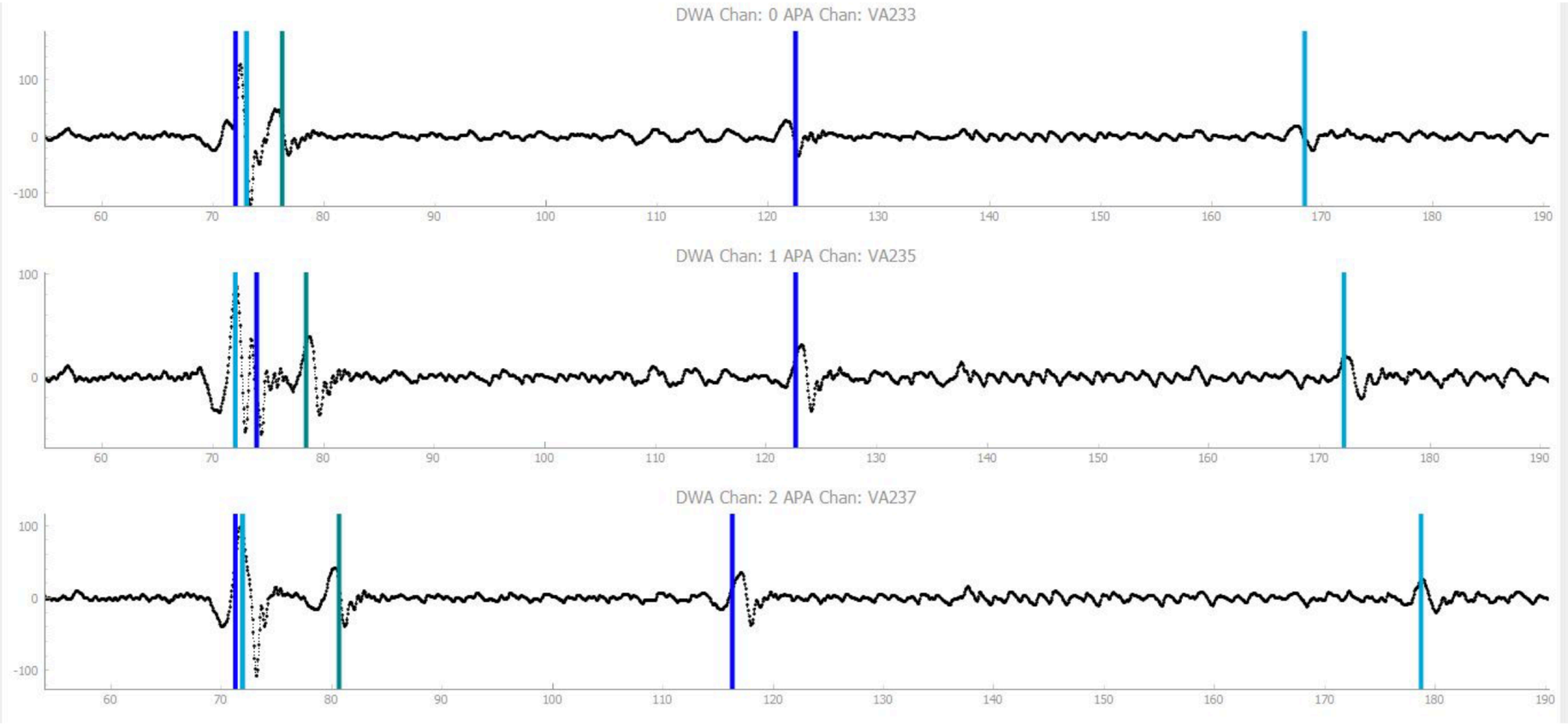
Plots by Chris Stanford

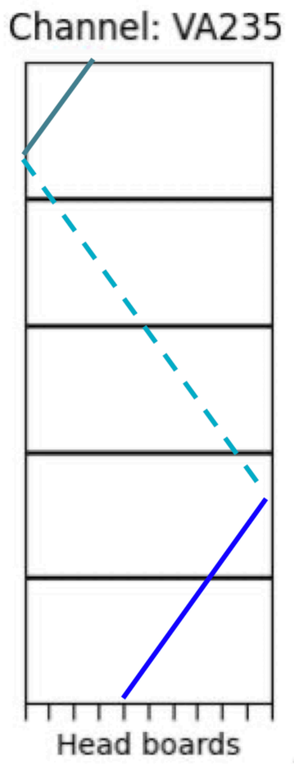
- Algorithm looks for resonance peaks in the baseline subtracted scan
- First peak is used to compute the tension
- Different peaks for different wire segments
    - Peak position depends on wire segment length



Mapping the wires

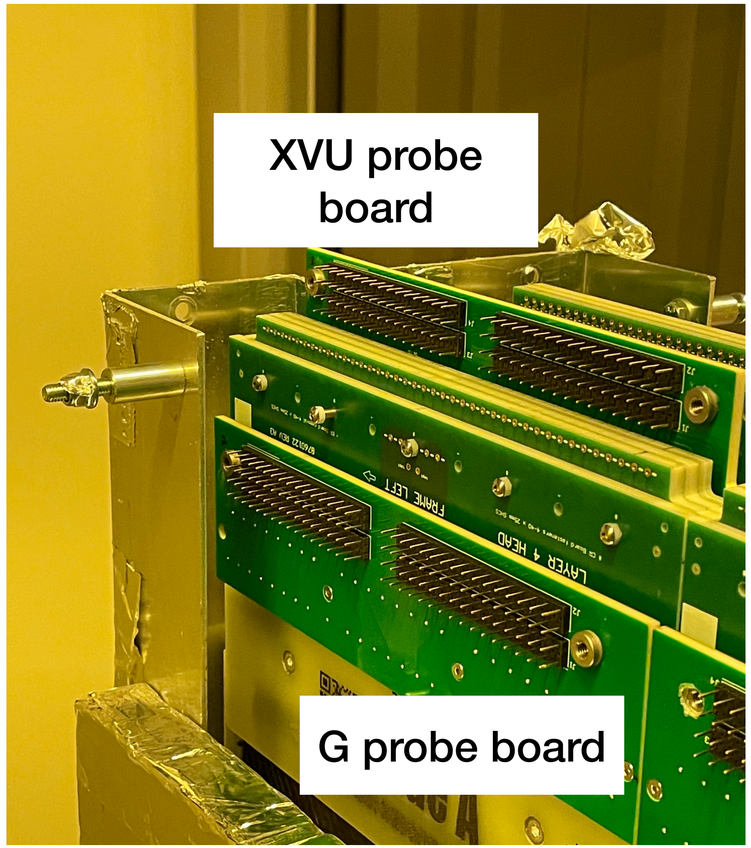
The DWA uses an algorithm to identify resonances and assign them to different wire segments





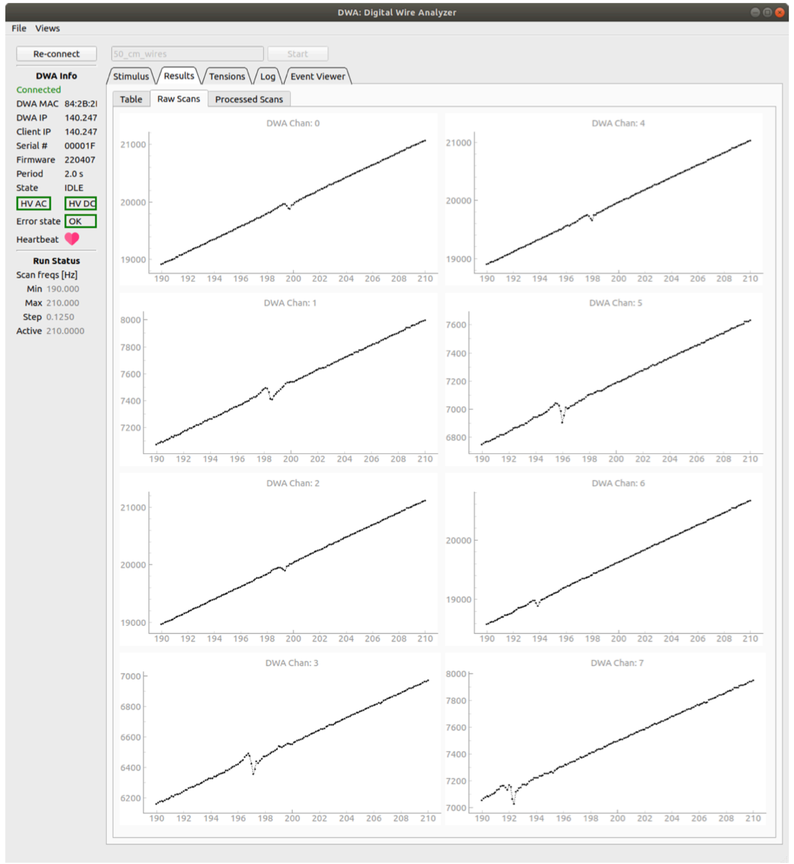
Slide by Chris Stanford

DWA usage



Attach DWA probe boards to the APA headboards

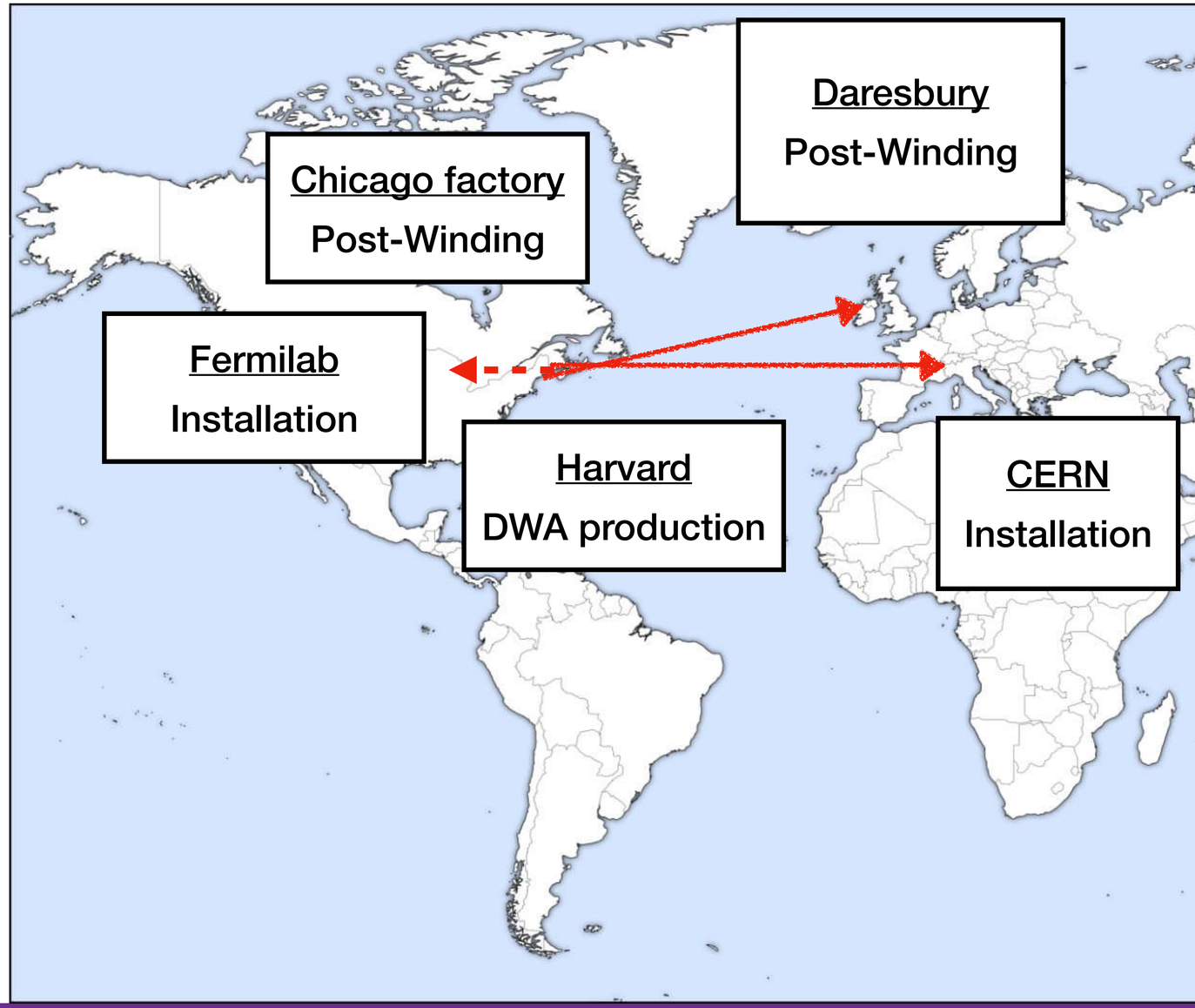
Connect DWA



Scan frequencies (8 wires at a time)

DWAs around the world

- DWAs in different locations to measure tensions at different stages
- DWA + probe boards produced at Harvard
- CERN and Daresbury DWAs already there
  - CERN measurements in this talk
- Fermilab and Chicago in production
  - Fall 2022 and beyond

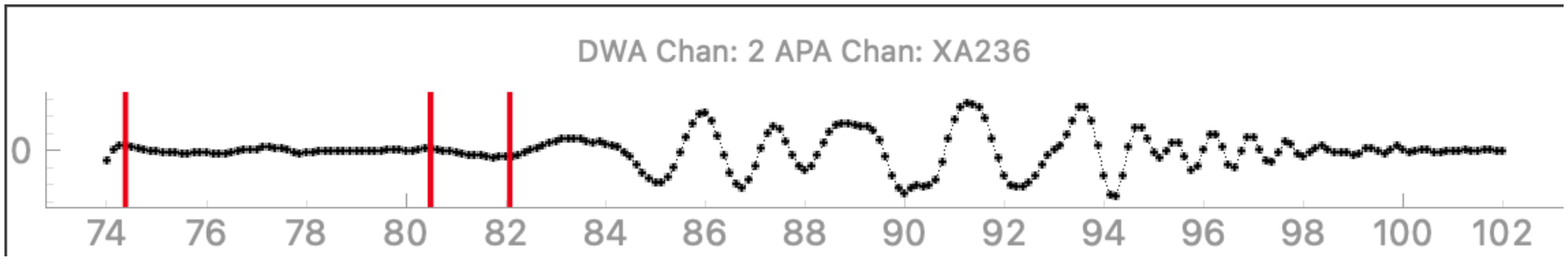


Known software glitches

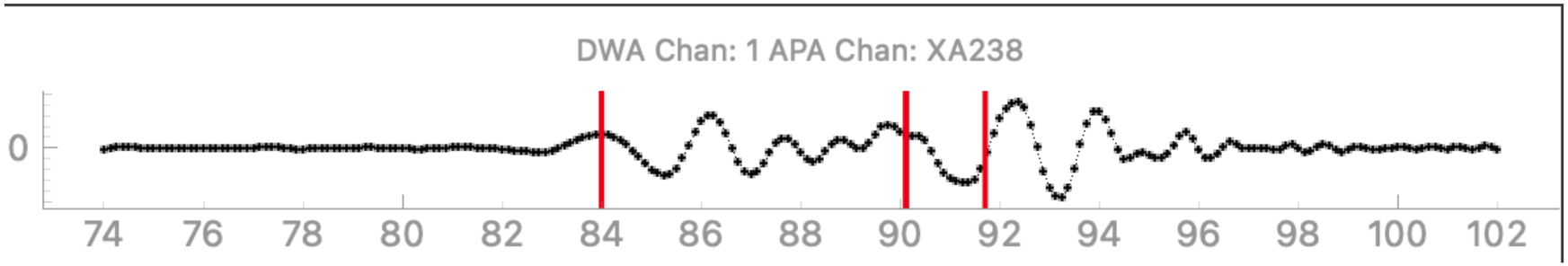
Wire tensions around 5 N

Happens for a significant fraction of wires in layer G and X.

Error due to the wrong placement of the peaks



Slight bump at the beginning is interpreted as the first peak.

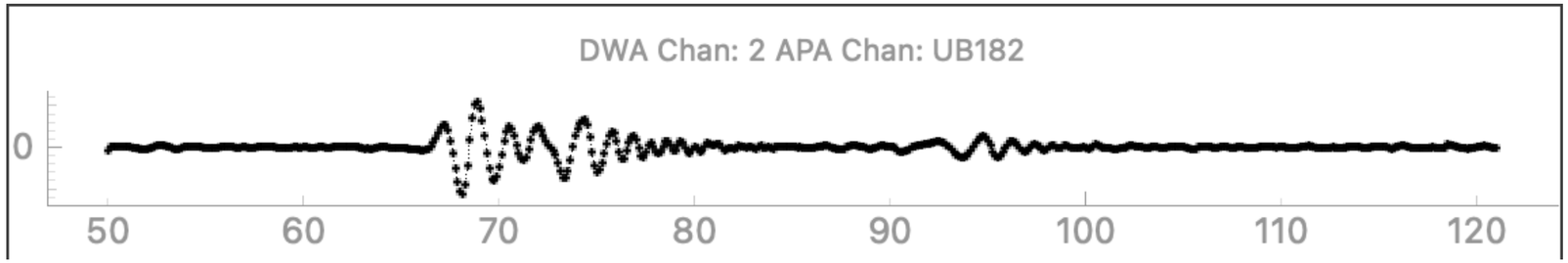


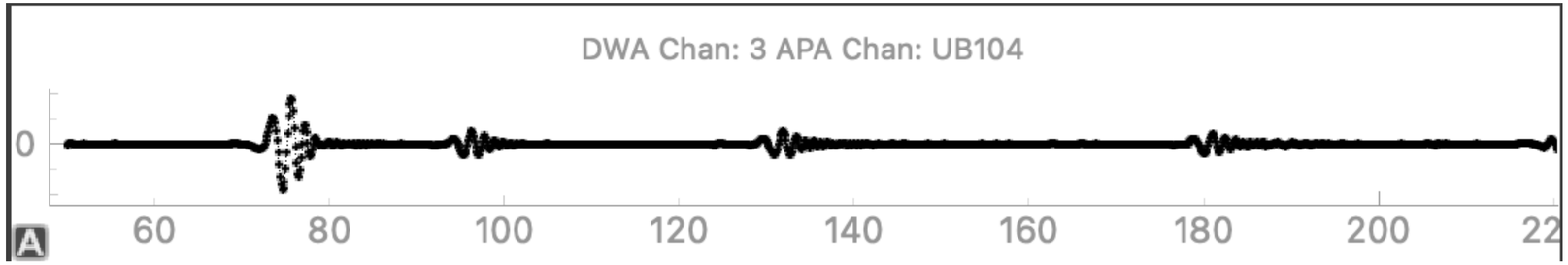
Correct peak positions

New version of the software greatly improved this issue.

Wires without tension

- For most of the wires without extracted tension, resonance scan looks perfectly fine but no peak found

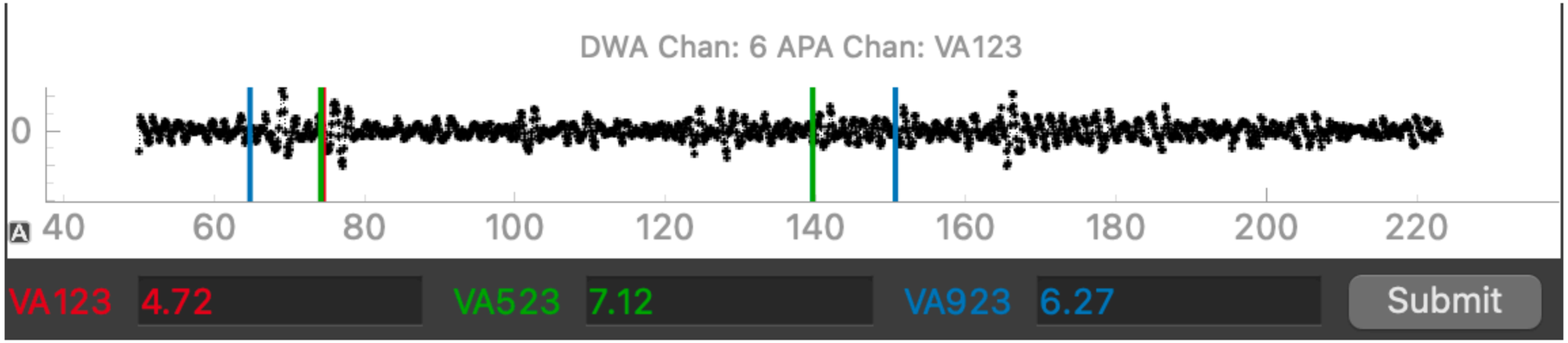




Also improved with new software version.

Tensions extracted without clear resonances

Some wires have tensions extracted but no clear resonance



Complicates missing wires checks

Measurements at CERN

APA 1

- All wires measured in vertical position except two (due to DWA misconfiguration)
- Comparison to previous CERN vertical measurement

APA 2

- 25% of wires measured in horizontal position
- All wires measured in vertical position
- Compare vertical and horizontal tensions

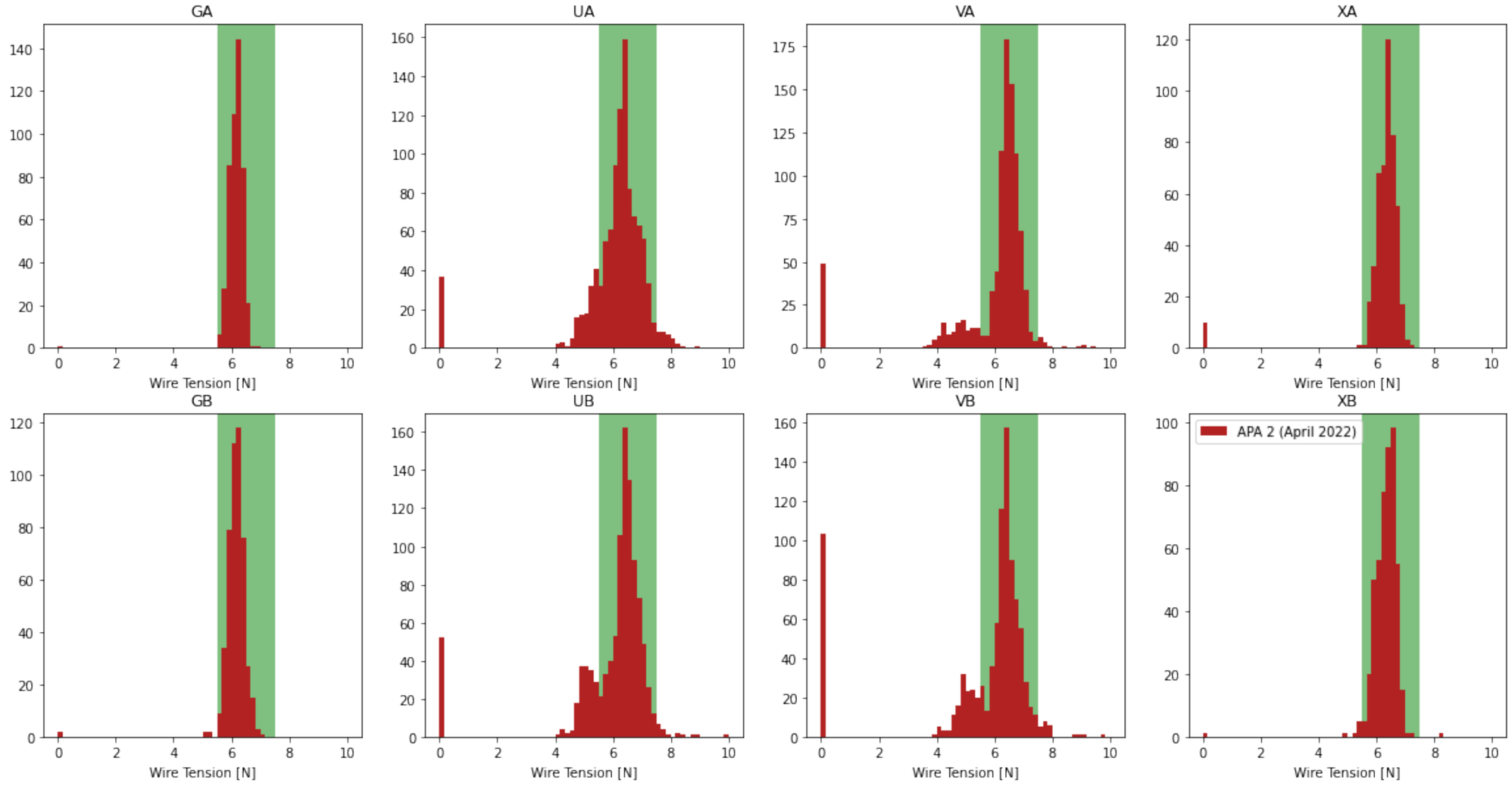
APA 4

- All wires measured in horizontal position
- Check for signs of missing wires
- All wires measured in vertical position

Many thanks to all the people from UK and US who helped getting these measurements done!

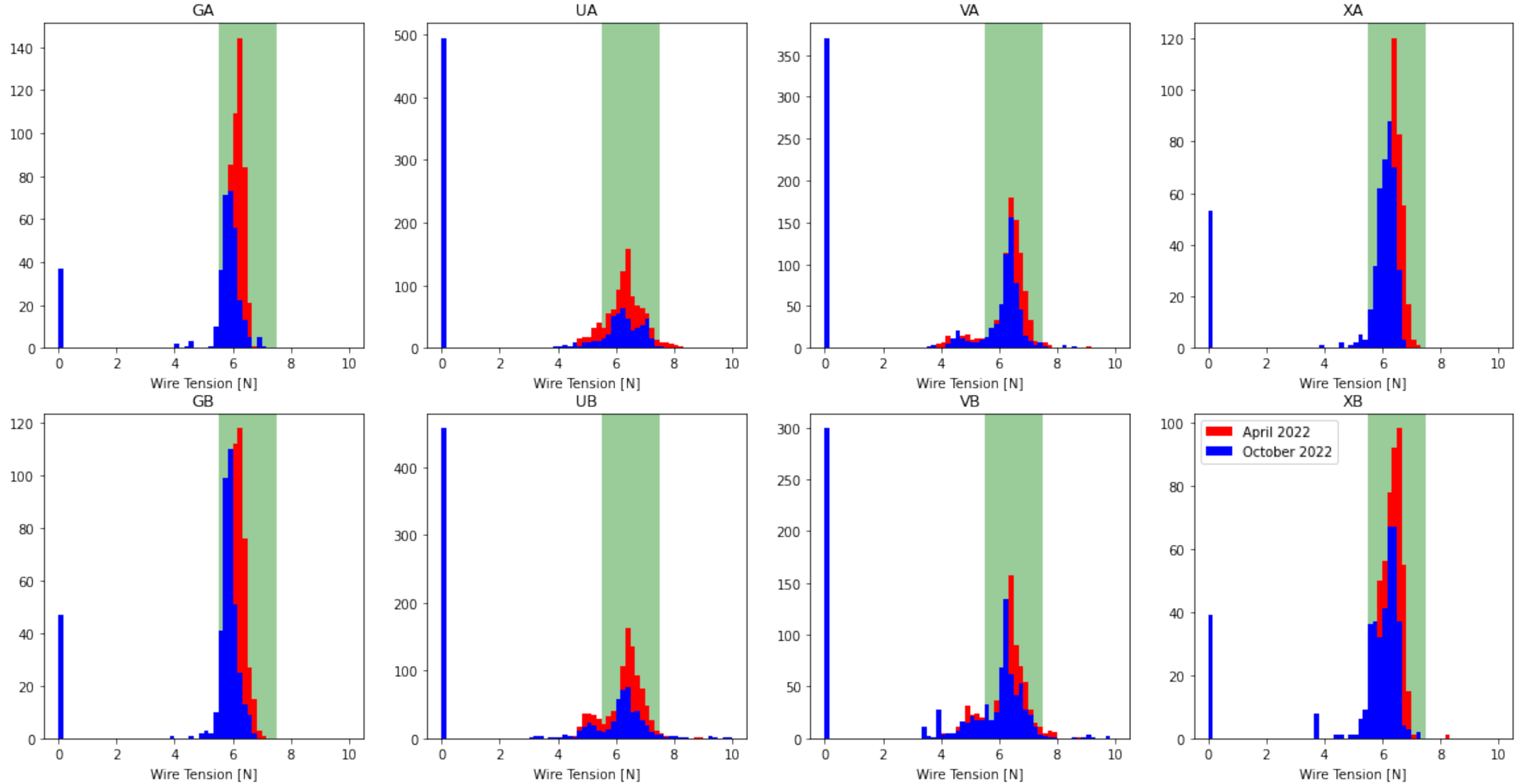
APA 1

Extracted tensions (April 2022)



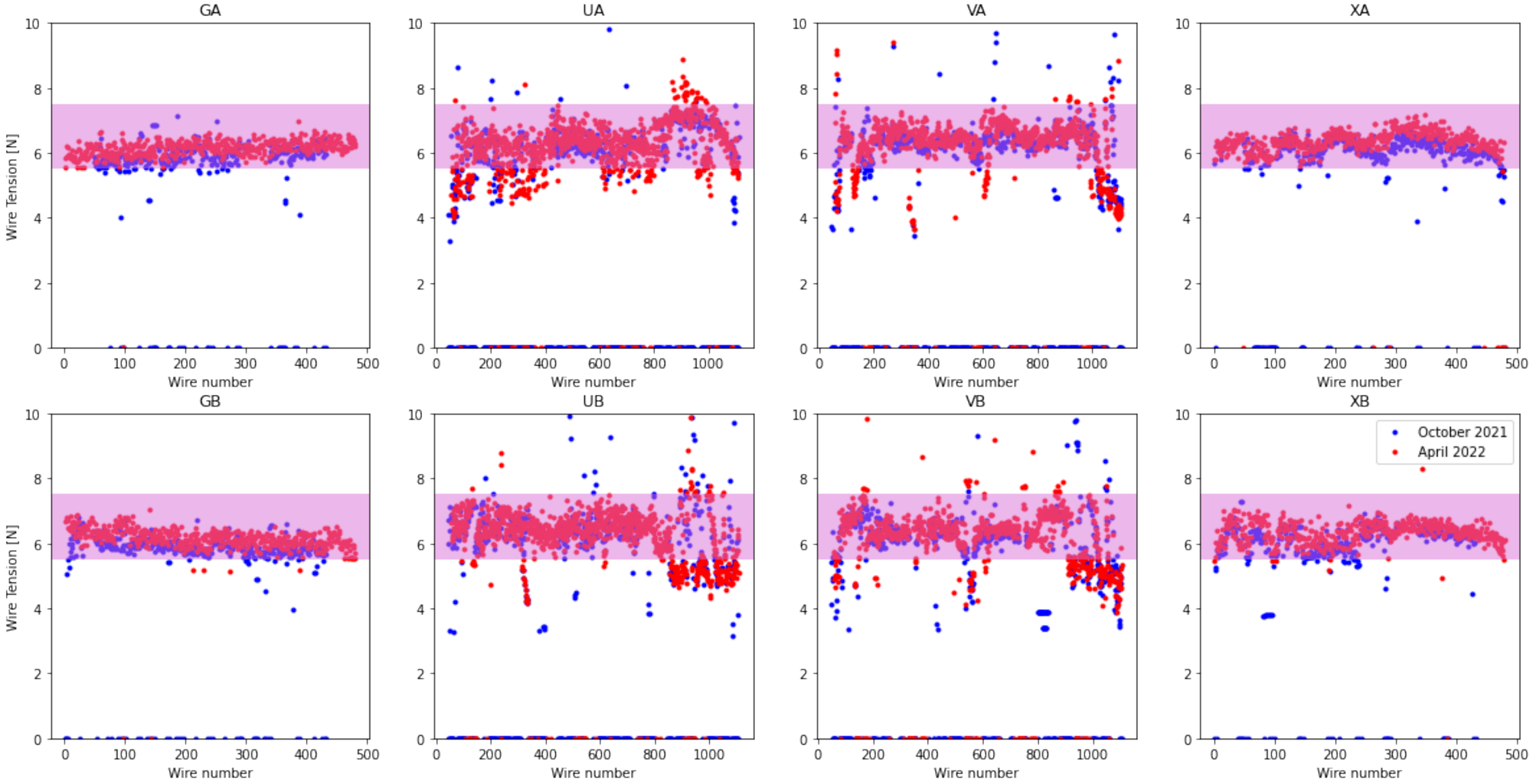
- Tensions mostly within tolerance
- Null tensions due to junk scans

Comparison with previous measurement

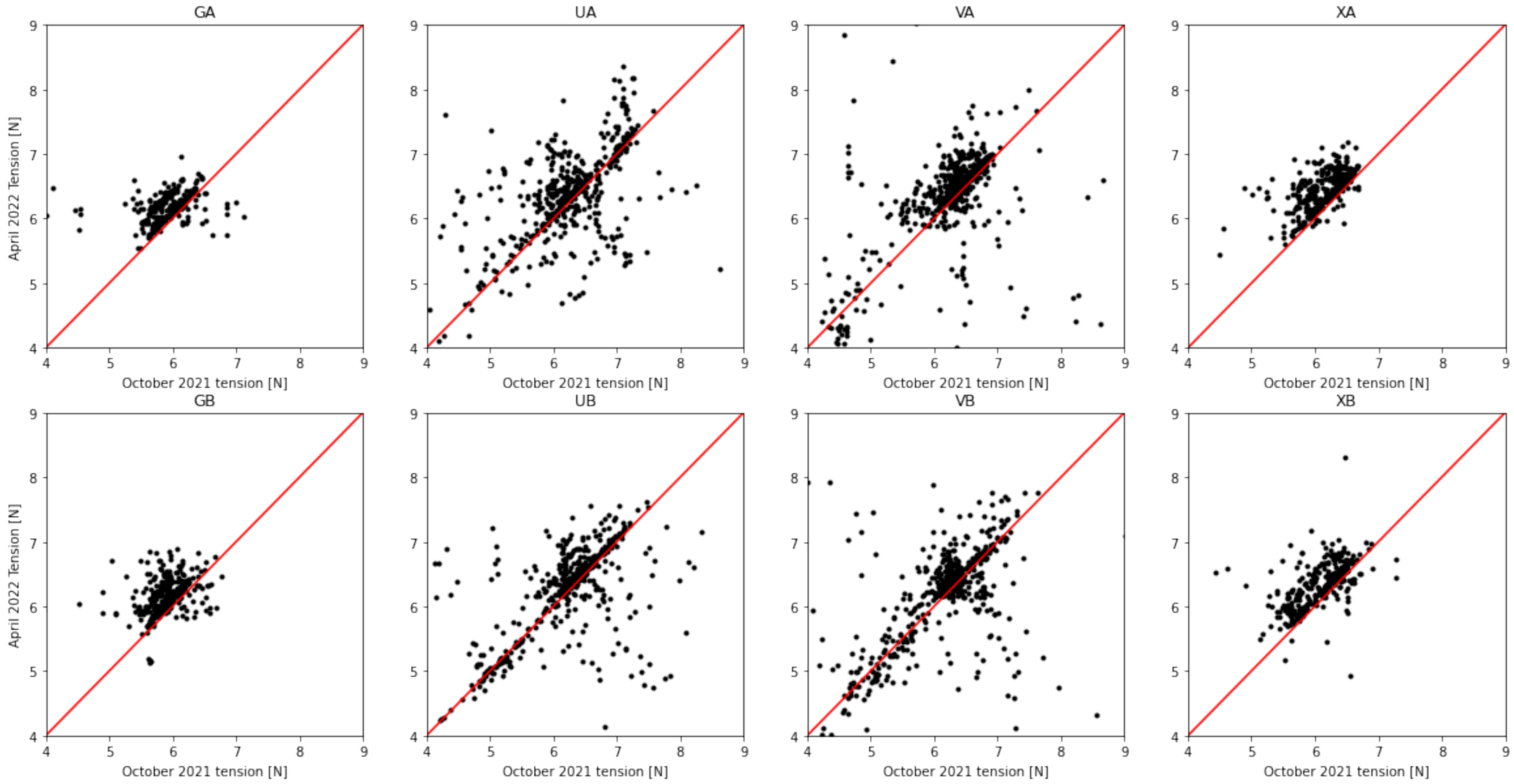


- Compared tensions with October 2021 measurement
- April tensions slightly higher
  - ➡ Due to correction in the density of wires

Comparison with previous measurement

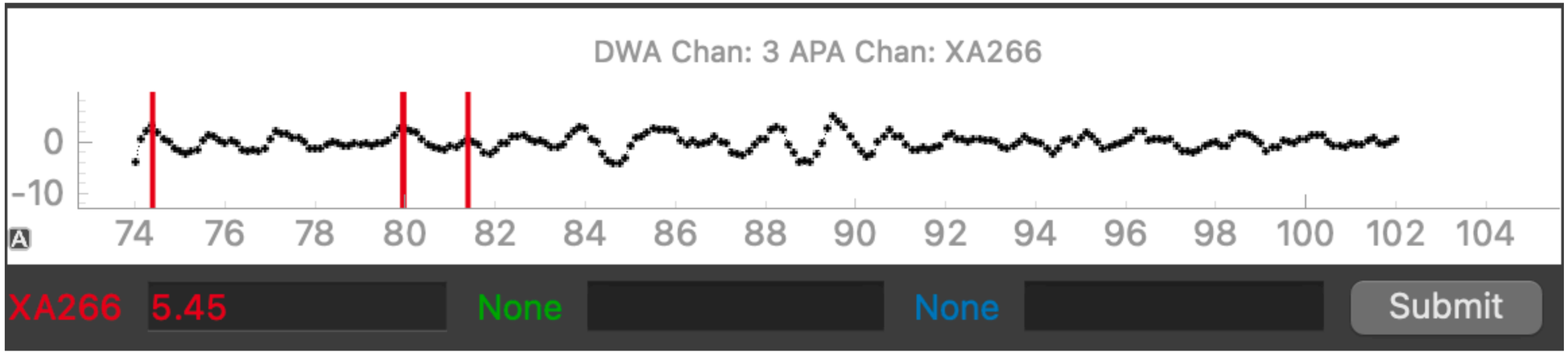


Comparison with previous measurement



Missing wire?

“Flat” scan for wire segment 266, side A, layer X, headboard 6 in April data



Had to be told to look for it as it shows a tension of 5.45 N

APA 2

APA 2 partial measurements

Horizontal (partial)

- Measured 25% of wires (5 headboards) in horizontal position
- All seemed fine except one:
  - Layer G, side A, wire segment 412
  - Tried measuring with a different probe board but same result.

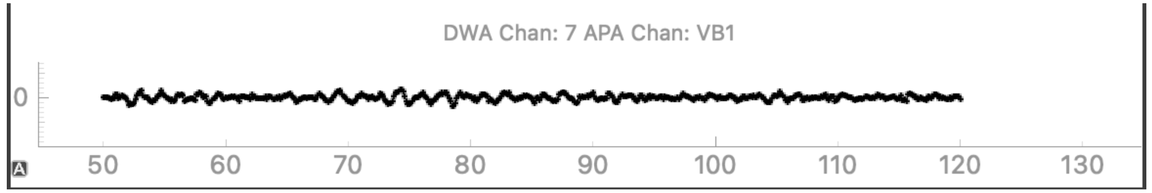
Vertical (full)

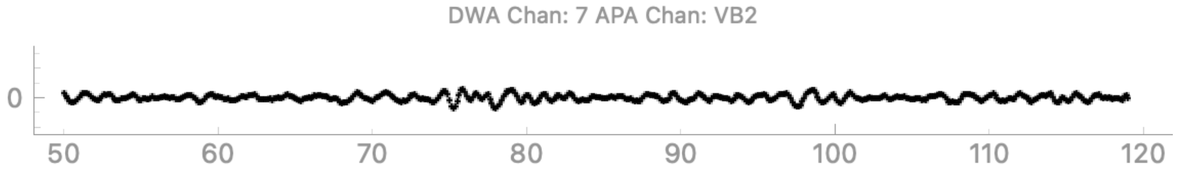
- Measured all wires in vertical position
- Faulty wires:
  - Layer V, side A, wire segment 401
  - Layer V, side A, wire segment 402

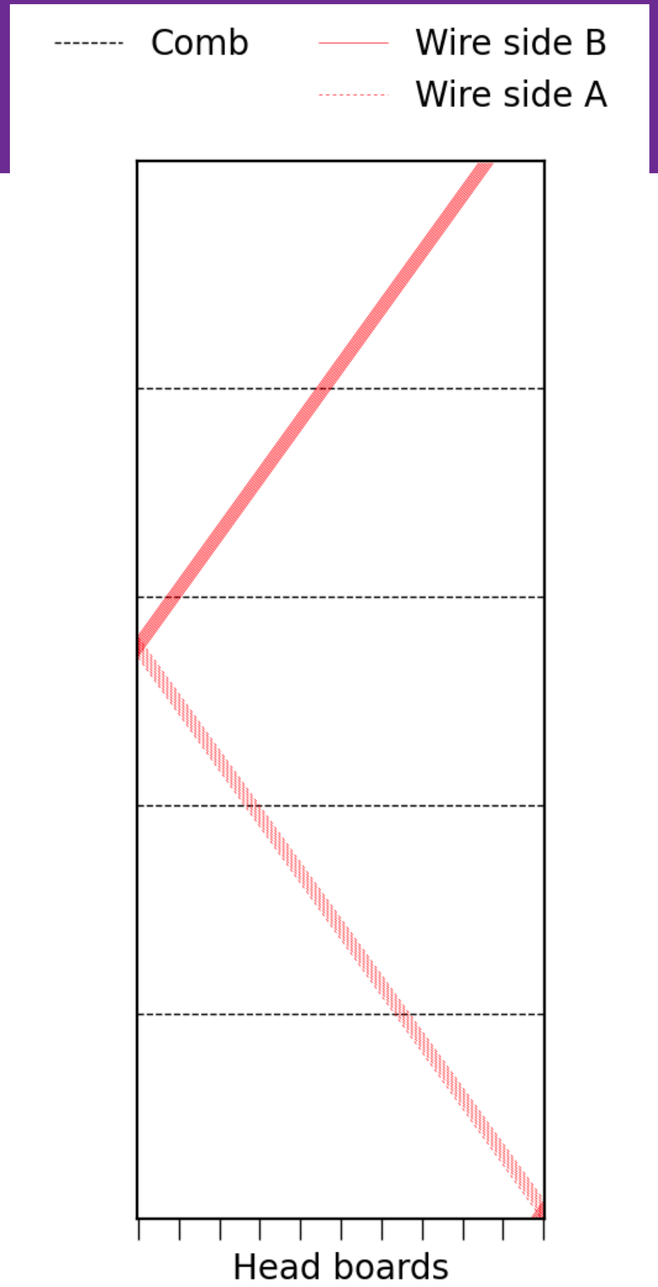
According to non-conformance report, 2 wires missing on V-layer on side A

Broken wires

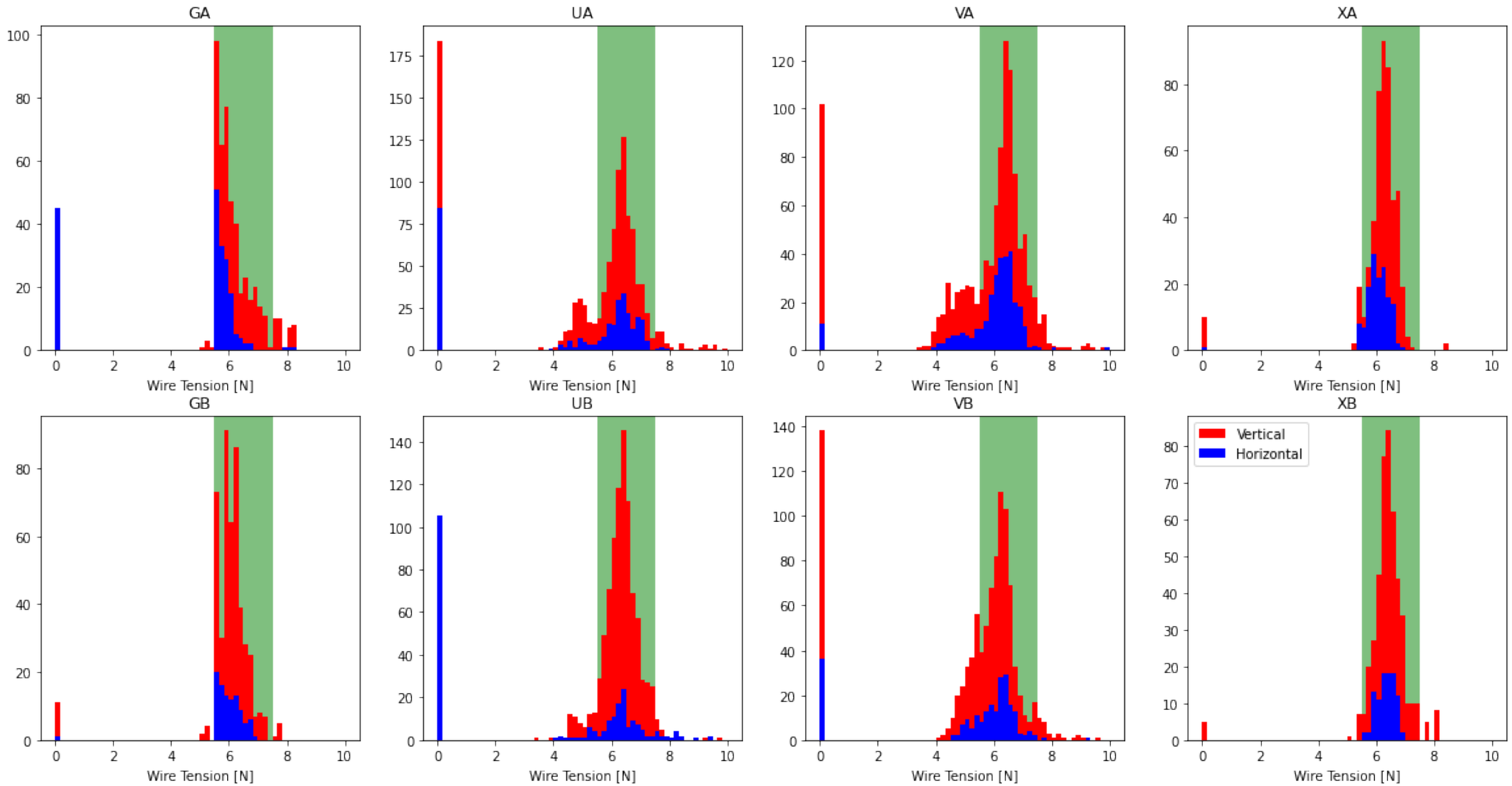
- Layer V, side A, wire segment 401
- Layer V, side A, wire segment 402



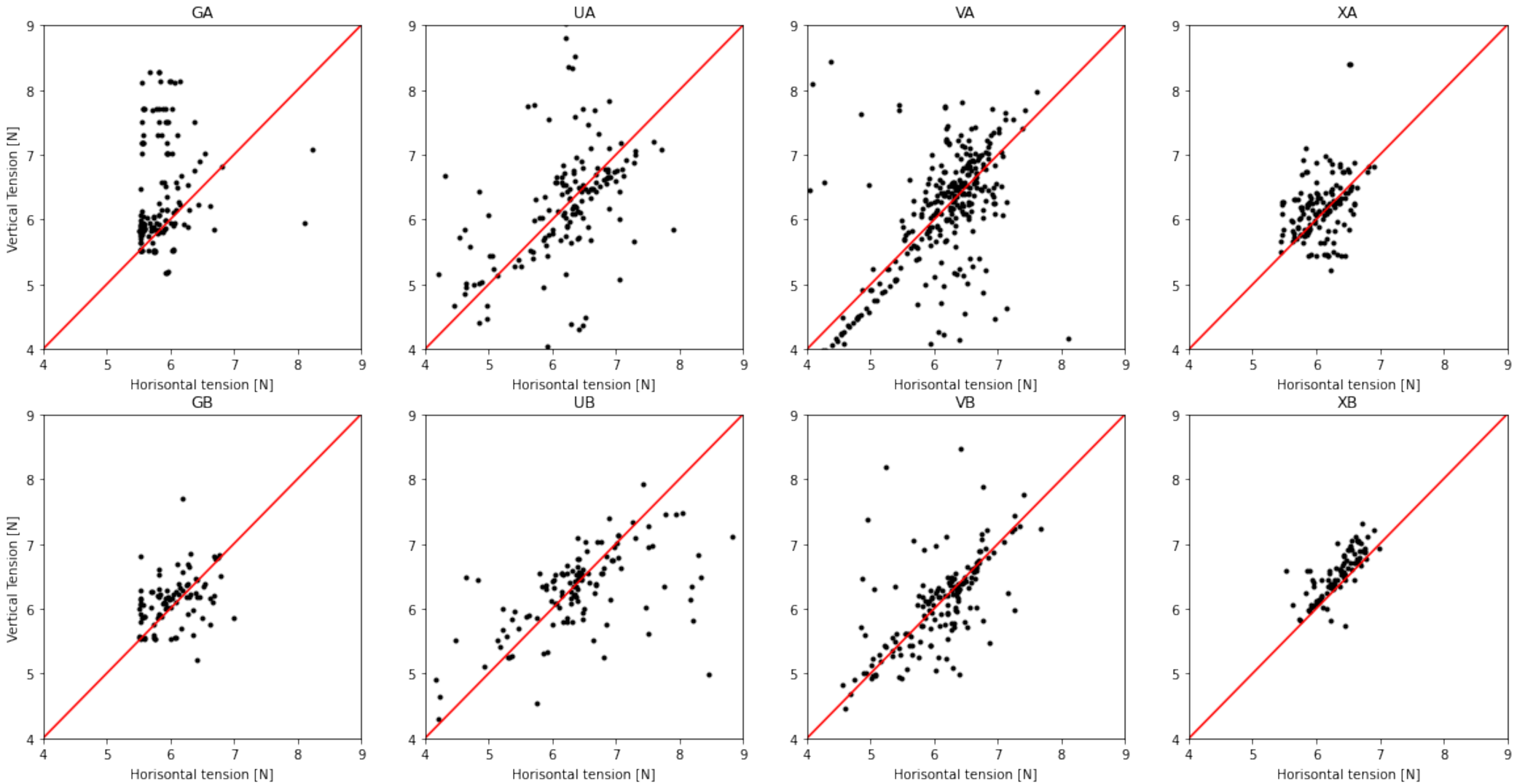




Vertical vs. Horizontal



Vertical vs. Horizontal



APA 4

APA 4 measurements

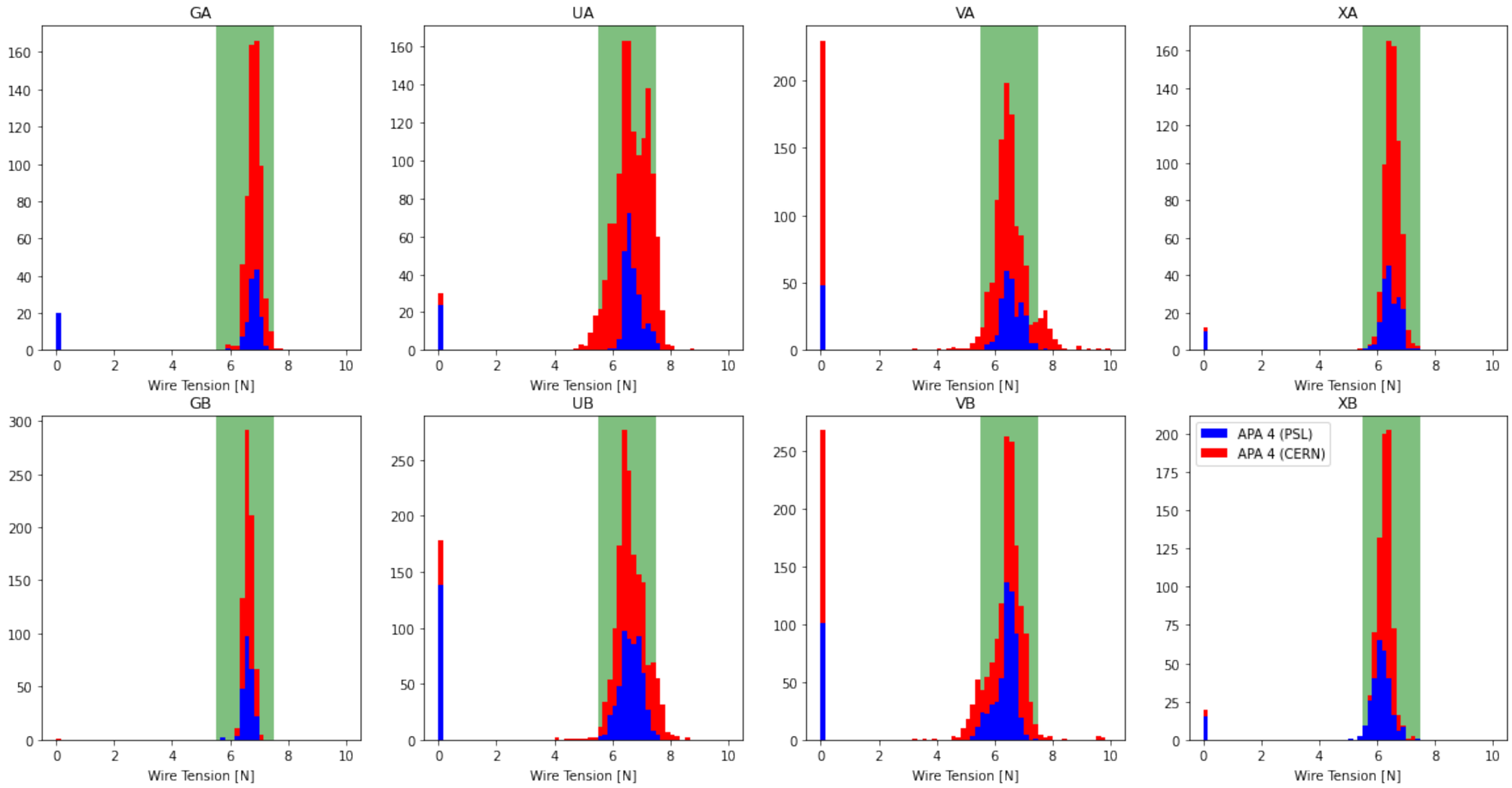
PSL (partial)

- Measured subset of wires in horizontal position while the APA was on the winder

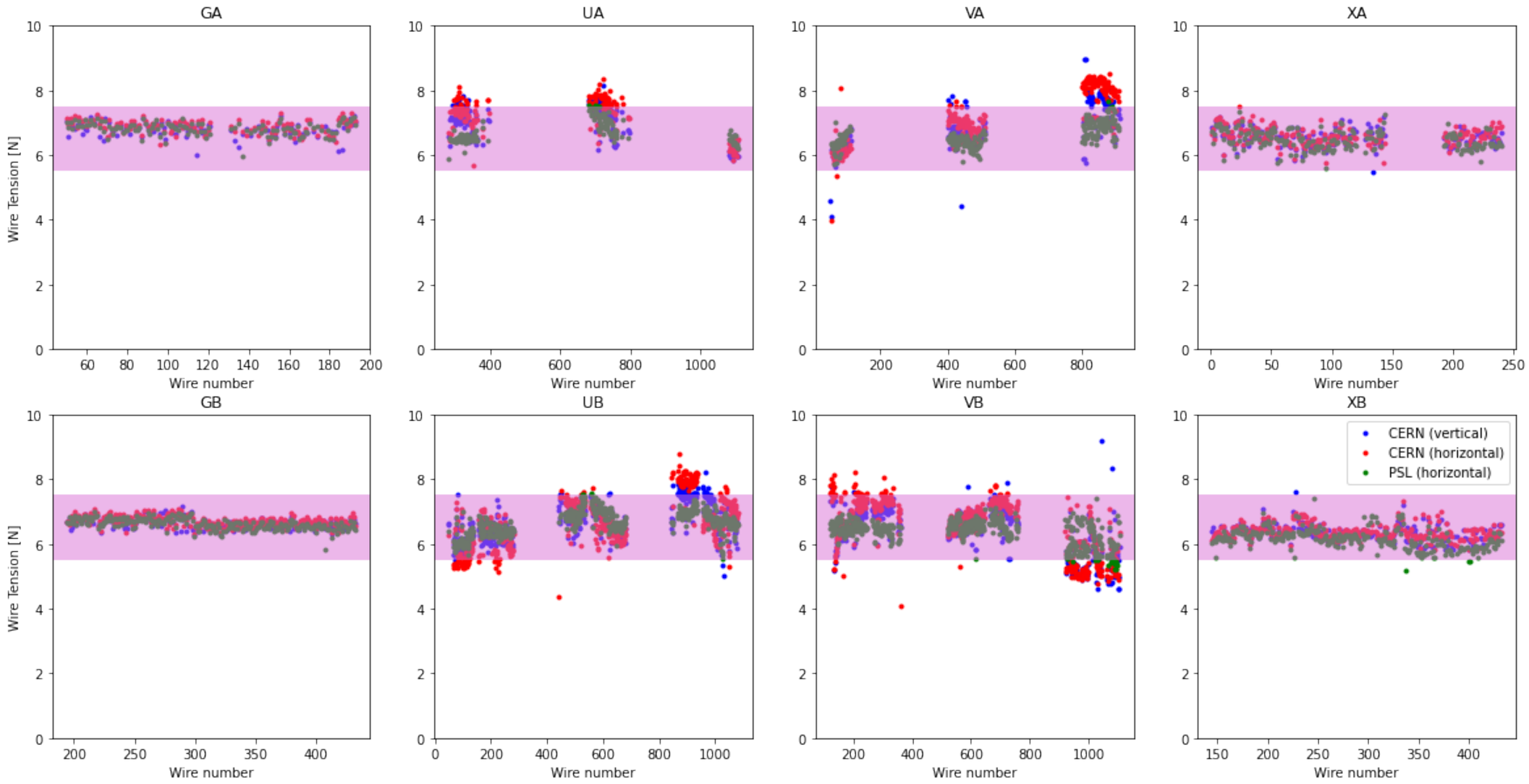
CERN (full)

- Measured all wires in horizontal position after arrival at CERN
- Check for issues after rough transport
- Re-measured all wires in vertical position
- Missing wires checks ongoing

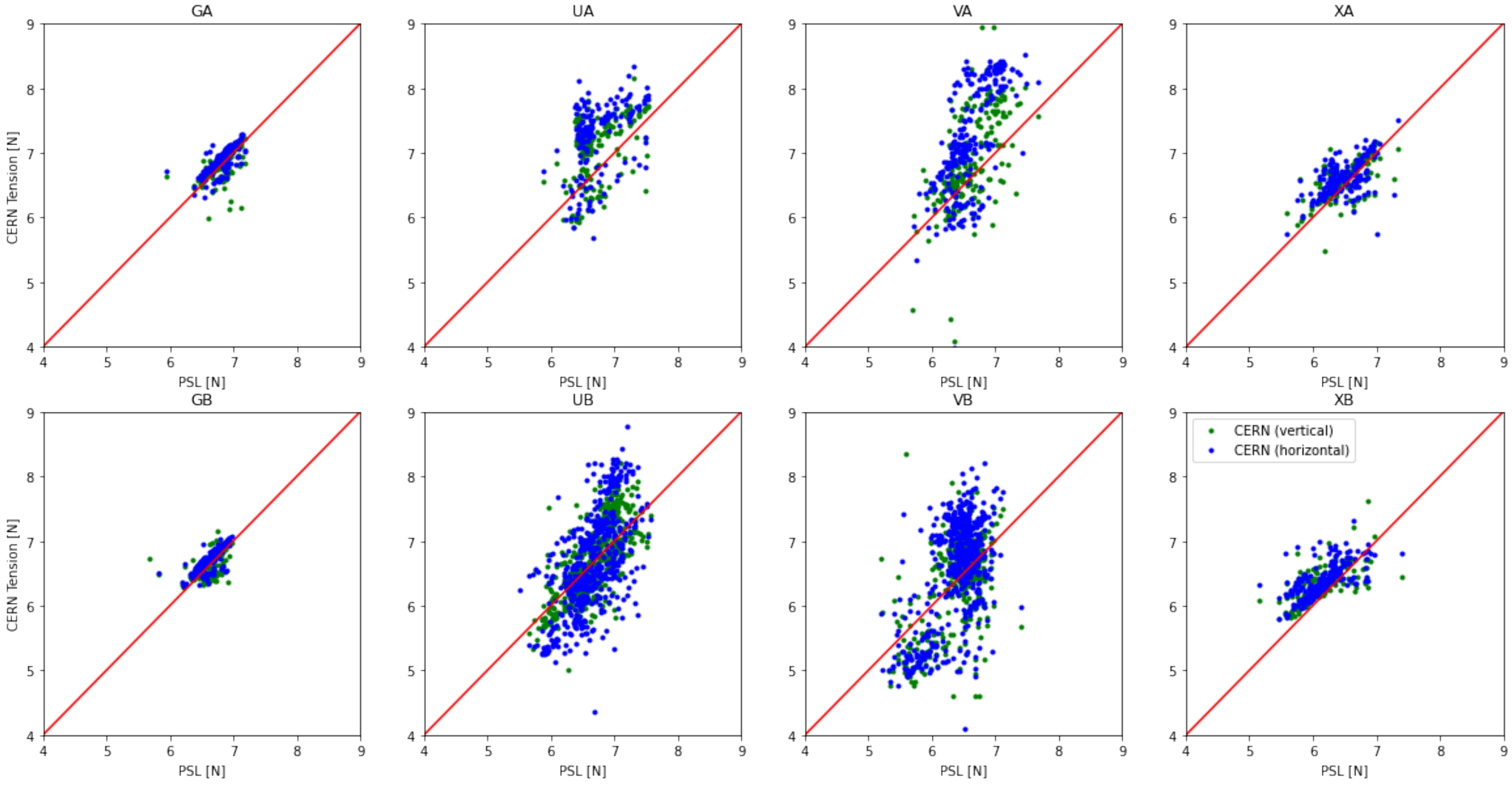
PSL vs. CERN



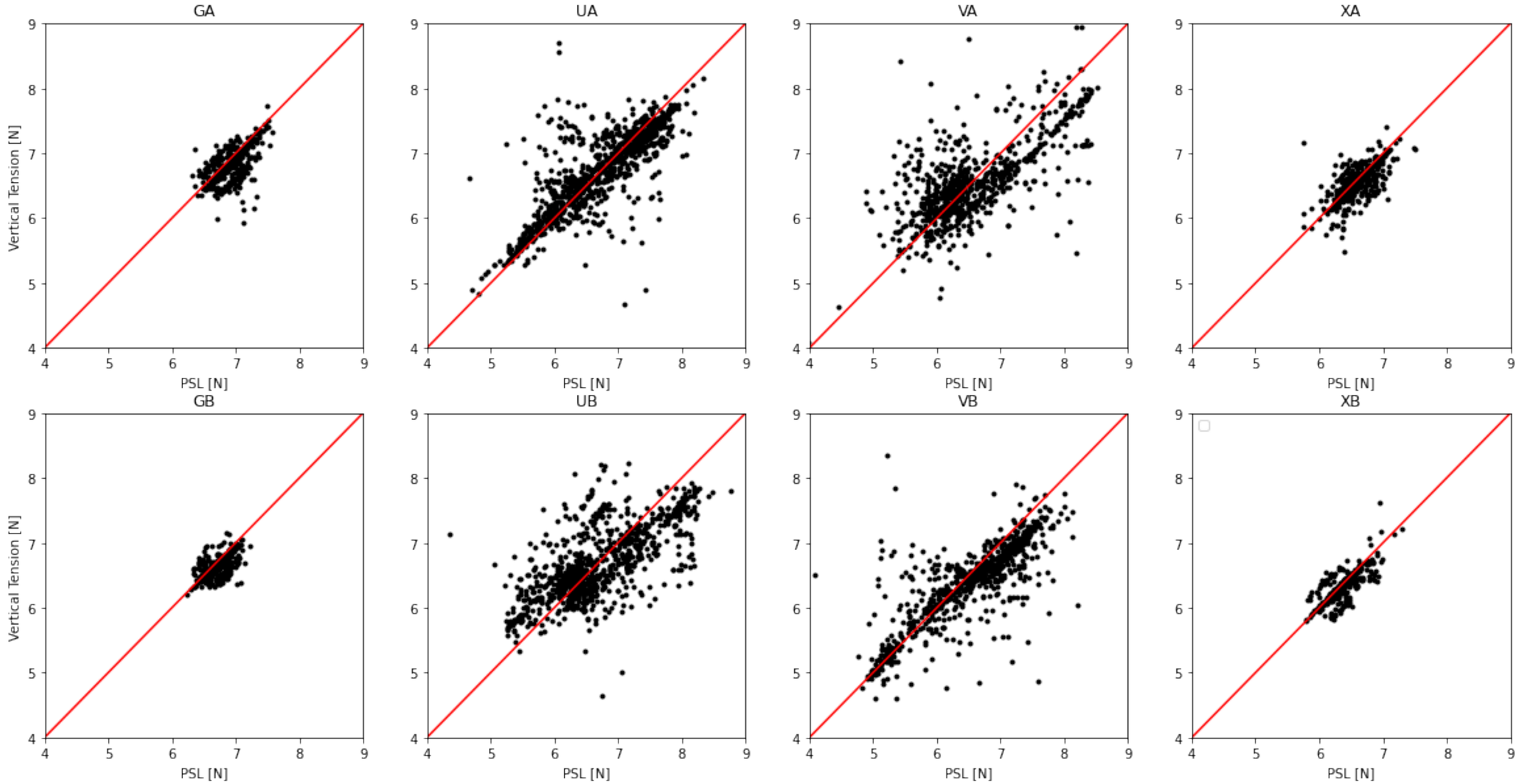
PSL vs. CERN vs. CERN



PSL vs. CERN vs. CERN



Horizontal vs Vertical



Summary

APA 1

- Measured all wires
- Compared with CERN partial measurement in October 2021
- DWA software changed, complicating the comparison
- Found one wire without tension

APA 2

- Measured 25% of wires in horizontal position
- Measured 80% of wires in vertical position
- Compared horizontal and vertical tensions
- Found two wires without tensions, in agreement with the NCR

APA 4

- Measured all wires in horizontal position
- Compared tensions to post-winding data taken at PSL
- Full measurement in vertical position
- Comparison of vertical and horizontal tensions

Software is still being continuously improved.