ATLAS New Small Wheel: sTGC testing and assembly

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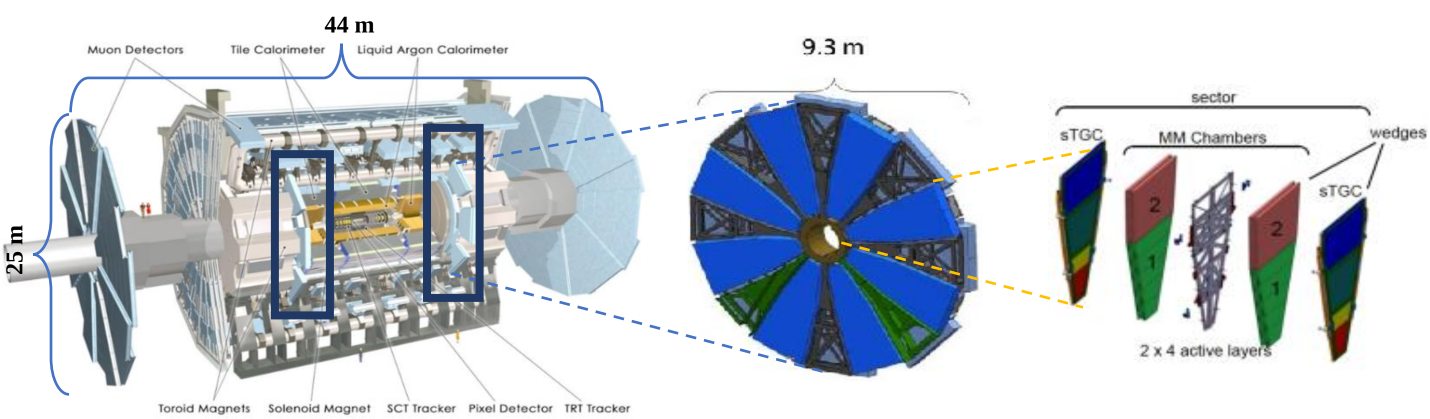
Abstract

The Large Hadron Collider (LHC) is under extensive upgrades to achieve a higher luminosity [1]. This will allow the LHC experiments to have a greater sensitivity to new physics at multi-TeV energies. In anticipation of the higher collision rate and background, the innermost endcap of the current ATLAS Muon System is being replaced with the New Small Wheel (NSW) during the second large shut down of the LHC (2018-2021). The NSW consists of two types of detectors using small-strip Thin Cap Chambers (sTGC) and MicroMegas (MM) technologies respectively. The sTGC detectors aim to provide fast trigger and high precision muon tracking under high luminosity conditions. The sTGC quadruplets are currently being constructed in five countries and shipped to CERN. At CERN, multiple tests are performed on the quadruplets before they are assembled into wedges. The wedge assembly process will be reviewed and the electrical connectivity test, also known as the “pulser test”, will be described in detail.

I. Introduction

The LHC is under a series of upgrades to achieve high luminosity of up to 5-7 times the design value, within the next decades. The increased luminosity will allow for greater sensitivity to new physics processes and more precise Standard Model measurements [2]. It will also result in greater background and particle fluences, which is a challenge when analyzing the data from ATLAS, one of the particle physics experiments of the LHC. To operate in high background rate (up to 15 kHz/cm^2) while maintaining high tracking precision and providing information for the Level-1 trigger, the ATLAS detector is being upgraded [3]. In particular the innermost end cap of the muon spectrometer, the Small Wheel (SW), is being replaced by the New Small Wheel (NSW), during the second Long Shutdown of the LHC (LS2). The NSW will be capable of simultaneously triggering and tracking with a spatial resolution of 100 μm and an angular resolution of 1mrad, thus reducing the false muon trigger rate which is would otherwise be about 90% [4].

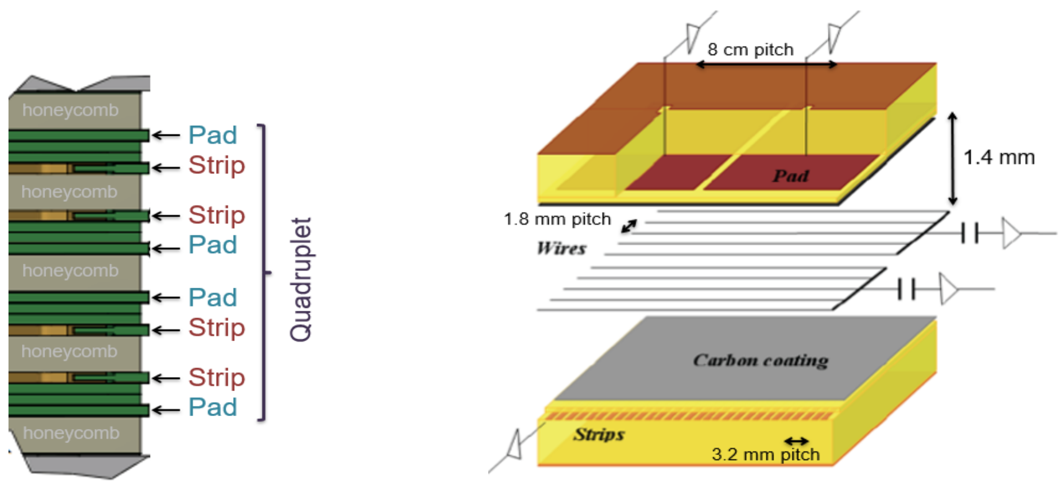


(a) (b) (c)

Figure 1: (a) The location of the NSW in the ATLAS detector, (b) a schematic of the overall structure of the NSW, 8 small sectors facing the interaction point and 8 large ones, (c)a breakdown of one sector, the sTGC composed of three trapezoidal quadruplet chambers and the MM composed of two quadruplet chambers with a support stand in the middle

The New Small Wheel, seen in Figure 1, consists of 8 large and 8 small sectors. Each sector is composed of two micromegas (MM) wedges between two small-strip Thin Gap Chambers (sTGC) wedges. The sTGC function primarily as the Level-1 trigger due to their 3-out-of-4 coincidence triggering capabilities. The MM function primarily trackers due to their small gap and strip pitch [4]. Both technologies independently are capable both of trigger and tracking with great precision.

The sTGC wedges are composed of three trapezoidal quadruplets which are constructed and tested in Canada, Chile, China, Israel and Russia. Each quadruplet is made of four layers of sTGC. The sTGC are multiwire, gaseous ionization chambers, the basic structure is seen in Figure 2.



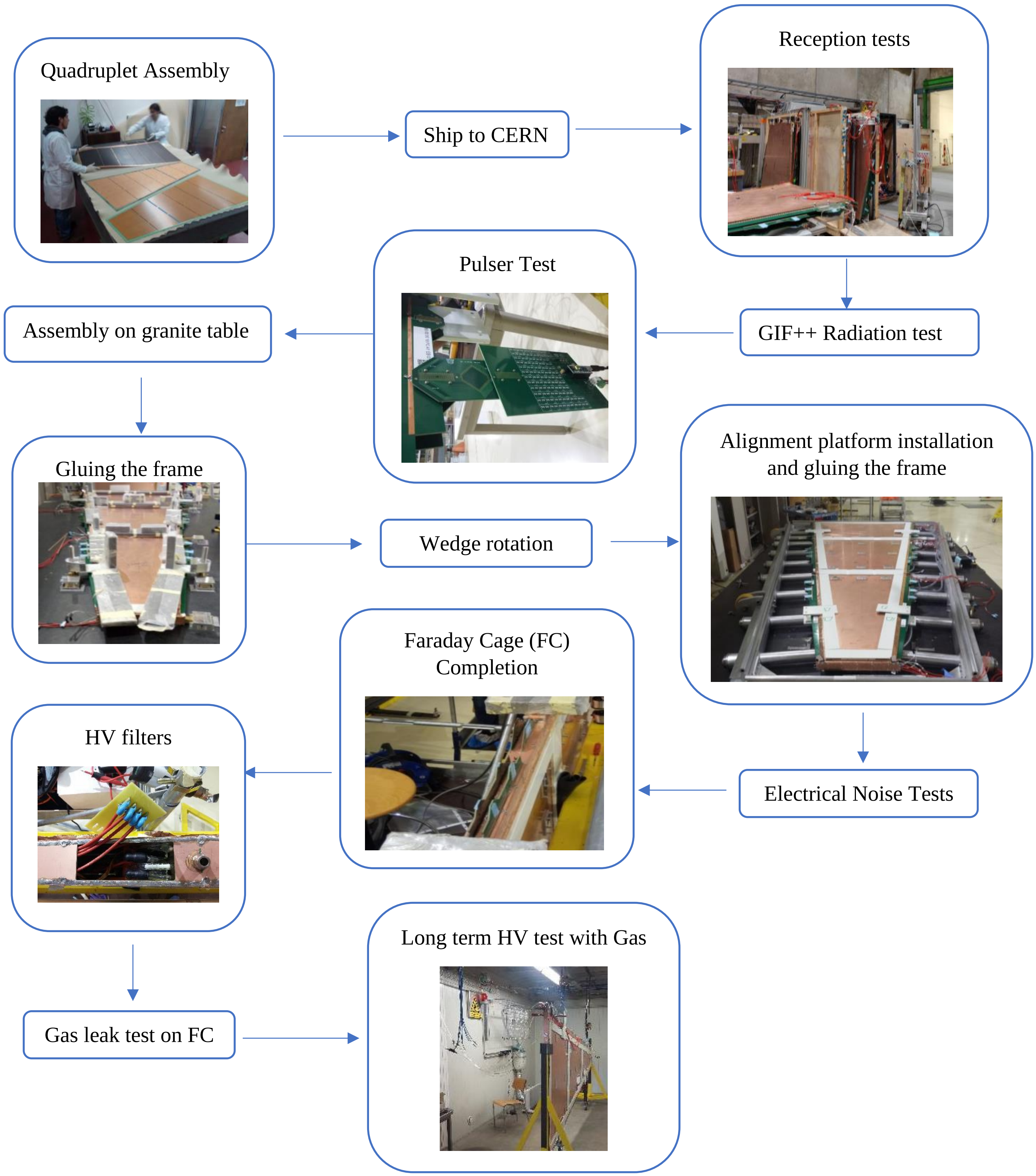
(a) (b)

Figure 2: (a) The cross section of a quadruplet, the 4 layers of sTGCs can be seen alternating with the honeycomb protection layer, (b) The schematic diagram of the sTGC structure [5]

Each chamber consists of gold-plated tungsten wires (50μm diameter) with a pitch of 1.8mm, that are held at a potential of 2.9kV. The wires produce a strong electric field and provide tracking information (in ϕ). The wires are in the centre of a 2.8mm gas gap, on either side of the gas gap there is a cathode board and an FR4 plane that is plated with a resistive graphite layer. One of the cathodes have copper pads and the other has copper strips that are perpendicular to the wires. The pads are used for 3-out-of-4 coincidence triggering, defining the region of interest, and to determine which strips are to be readout. The strips have a 3.2mm pitch and are used for precision tracking (in η), this pitch is much smaller i.e. the resolution is much greater, than the previous TGC technology in the SW. The operating gas is a mixture of 55% CO_2 and 45% n-pentane [5].

The physical assembly of the sTGC wedges was the focus of the summer project and thus an overview of the assembly process will be presented as well as a focus on the electrical connectivity test (pulser test) which was the main task performed.

II. sTGC Wedge Assembly



1. **Quadruplet Assembly**
   The sTGC wedges are composed of three small quadruplets (QS1, QS2, QS3) and three large quadruplets (QL1, QL2, QL3), which are being constructed in at five different constructions sites: Canada (QS3, QL2), Chile (QS1), China (QS2), Israel (QS3, QL1), Russia (QL3). Gas gaps are closed and subsequently glued into doublets then quadruplets. Functionality tests (high voltage tests, pulser test, cosmic test) are performed at the construction sites. After passing the tests the quads are shipped to CERN.

2. **Reception tests**
   Upon receiving the shipment, visual tests are performed to check for physical damage occurred during shipping. A high voltage (HV) test is performed on the wires and a gas leak test is preformed on the gas gaps to check that the chambers are still functional. [6]

3. **GIF ++ radiation test**
   The chambers are moved into the Gamma Irradiation Facility (GIF++) to be tested with a radiation source to ensure that they would maintain functionality under the background radiation expected during runs. [6]

4. **Pulser Test**
   The chambers are then shipped to a clean room environment in which the electrical connectivity of the pads, strips and wires, is checked. This process is explained in the next section.

5. **Assembly on the granite table**
   The quadruplets are then cleaned and aligned on a granite table using alignment pins that have a precision higher than 50µm.
   i. Copper tape is soldered around the outer perimeter of the wedge to make the connection between the wedge and the faraday cage.
   ii. The wedge is sanded, for better adherence, and a fibreglass frame is glued onto the wedge using Araldite 2011 epoxy.
   iii. When the glue is cured, a turning tool using a vacuum pump is placed on top of the wedge and the wedge is turned on the table.
   iv. An alignment team installs optic cable alignment platforms, their relative position is precisely measured using photogrammetry
   v. Steps i. and ii. are repeated on the second side of the wedge and a rotating support is installed on the wedge. The wedge is then placed upright on a rotating stand.

6. **Noise tests**
   An electronics team performs electronic noise tests. These test results are compared to the pulser test results to see if the same faulty channels are observed. If problematic channels are found, an attempt is made to fix the channels. A problem that the pulser test is not able to detect is the case of two strips being shorted to each other, this can be detected in the

noise test. In this case one of the channels is disconnected, to avoid damaging the electronics, and the change is documented.

7. **Assembly of the Faraday cage**
   Once the channels are fixed, high voltage (low pass) filters are installed on the high voltage cables. Then copper plated FR4 faraday cage pieces are glued and sealed around the adaptor boards. The faraday cage is then tested for leaks by flushing it with CO_2 and using a sniffer. As many leaks as possible are sealed with epoxy glue.

8. **Long term HV testing**
   The wedge is then moved to a gas room, the gas gaps are filled with the 55% CO_2 and 45% n-pentane mixture and a voltage of 2.8- 2.9kV is applied on the wires over a period of about 8 weeks. The current is measured on the wires to ensure that the wedges will be functional, i.e. no current will be seen, over that period.

III. The Pulser Test

The purpose of the pulser test is to check the electrical connectivity and the readout of the pads, strips and wires. The set up of the pulser test can be seen in Figure 3.

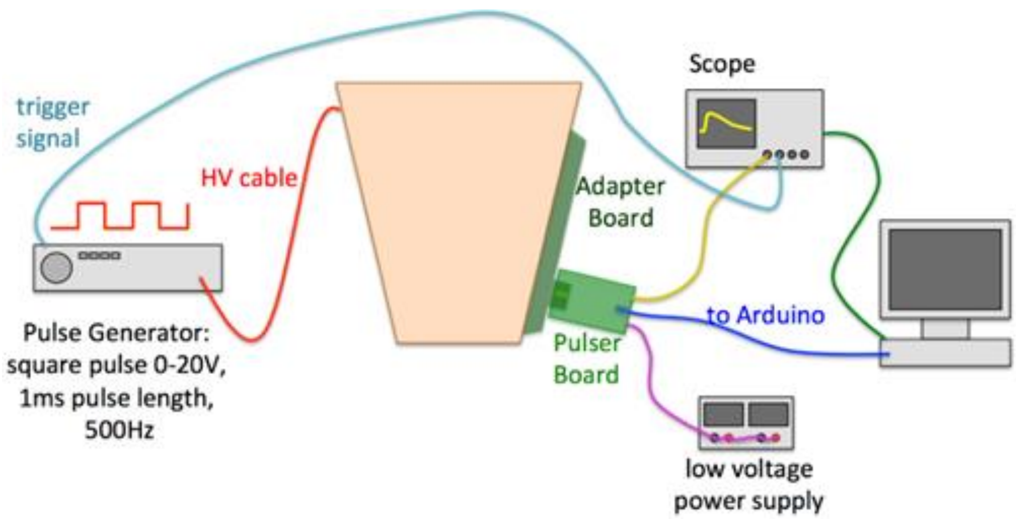


Figure 3: Schematic set up of the electrical connectivity test [7]

Procedure:

1. A square pulse is injected onto the wires through the High Voltage (HV) cable. A signal is induced on the strips and the pads through capacitive coupling. The signal from the strips, pads and wires is routed through the adapter board to the pulser board. The pulser board is a multiplexer board that selects the signal from one channel on the adaptor board at a time.

2. The signal from the selected channel is sent to the oscilloscope to be digitized and saved to the computer. The computer program works with the pulser board to obtain the signal, channel by channel, from every strip, pad and wire.
3. Amplitude, variance and mean of the signal is collected and the computer sorts/ classifies the results based on the expected peak-to-peak amplitude and waveform for that channel. A typical waveform for the signal obtained from the strips, pads and wires can be seen in Figure 4.

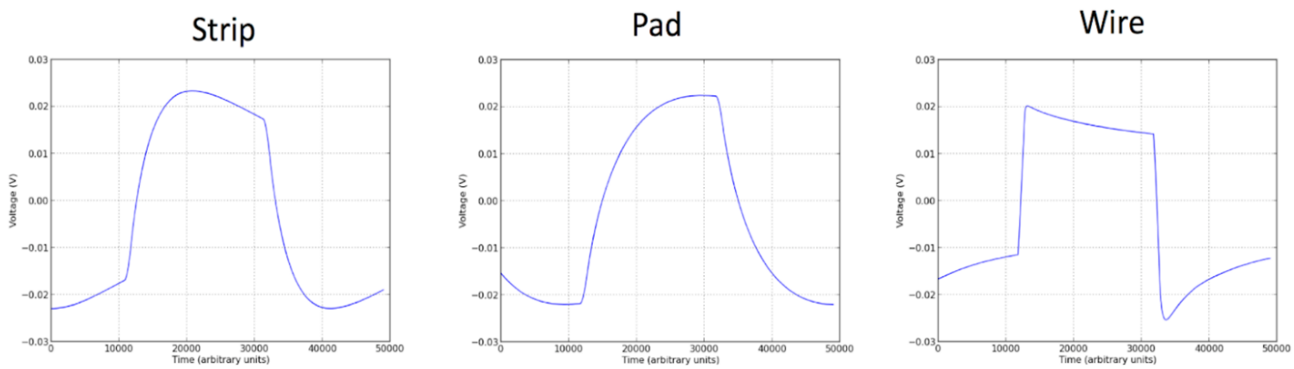
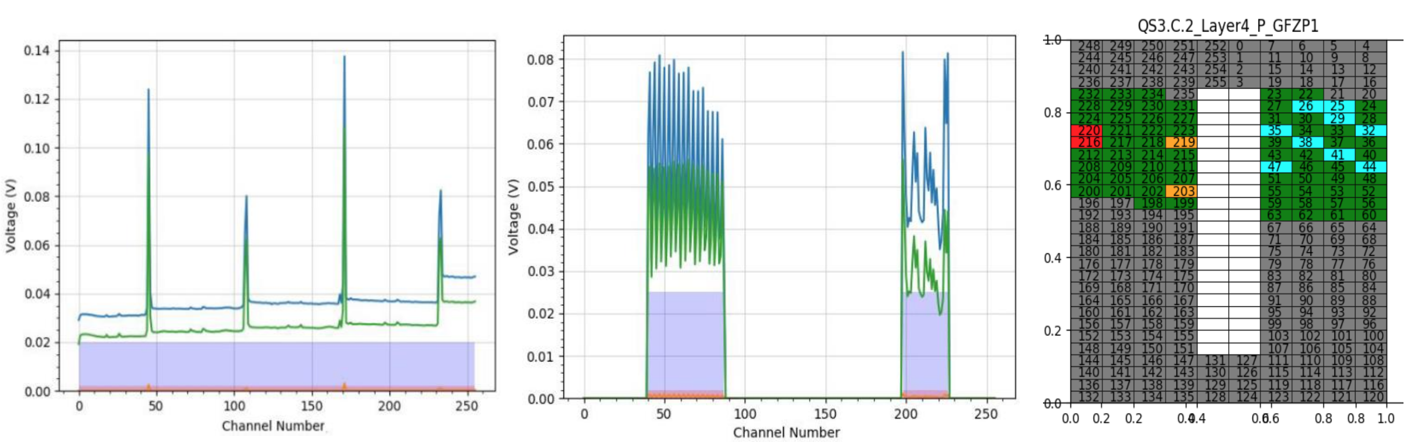


Figure 4: The signal waveform obtained from correctly functioning strips, pads and wires. [7]

4. The computer provides two ways of analyzing the data: a graph of the amplitude for all channels being tested in one run, and a visual representation of the classification of each channel on the connector. These two graphical results can be seen in Figure 5. Each pin on the connector corresponds to one channel and based on the number of the channel (as found on the connector graph) the exact position on the wedge of the strip/pad/wire is known, this is very helpful when having to fix a faulty channel. A green channel has the expected waveform and amplitude, blue has a higher than expected amplitude, an orange channel has lower amplitude than expected and a red channel has a low amplitude and a waveform that is not expected, a gray box represents that a channel is not expected to be connected.

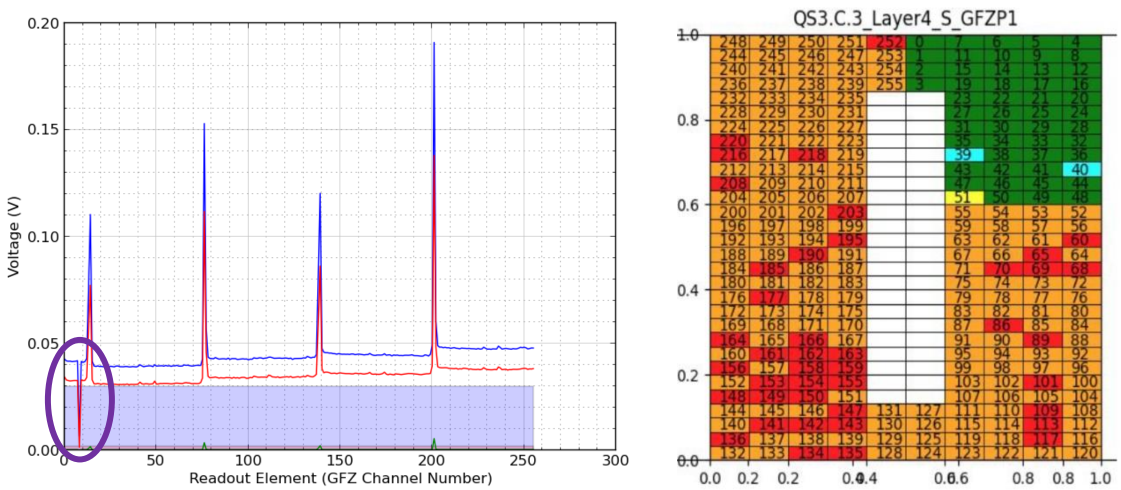


(a) (b) (c) (d)

Figure 5: The expected shape of an amplitude graph for all the (a) strips, (b) pads, (c) wires. The blue curve corresponds to the peak-to-peak amplitude, (d) the representation of the classification of the channels on the connector

Trouble Shooting

1. Grounded Channel
   Figure 6 shows an example of a test result that implies that a channel is shorted to ground- this is seen by the very low amplitude in that channel. To check if a channel is truly shorted to ground, a multimeter is used to test the exact channel based on the connector mapping. If the channel is grounded the exact location on the wedge is found and the cross-grounding (between the pad and strip cathodes) in that area is removed and cleaned and the channel is tested again. If the channel was fixed the test is rerun, if the channel was not fixed it is disconnected to avoid damaging the electronics.



(a) (b)

Figure 6: (a) In the circle a low amplitude spike can be seen that could indicate a grounded channel, (b) the classification map of a poor connection

2. Low signal
   When the amplitude graph looks like Figure 6 and it is not grounded, when checked with the multimeter, that implies that the channel could be faulty. In order to check that the channel is at fault and not the connection, the connector and pulser board are disconnected and a single pin is used to check the amplitude and shape of the channel. If the amplitude and shape are not as expected that channel is documented as faulty, it can not be used.

All of the pulser test results are documented in the ATLAS NSW twiki page [7]. So far nine small wedges are assembled, seven of which were completed during the summer period.

IV. Conclusion

The New Small Wheel is currently being assembled at CERN to prepare the muon spectrometer of ATLAS for higher luminosity. In total seven small sTGC wedges were tested and assembled at CERN during the summer period. All the wedges that were completed contained faulty channels (less than one per thousand channels), they were discovered by running the pulser test and the noise tests, many of those channels were able to be fixed, the rest were documented.

V. Acknowledgements

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