Installation and Upgrades for the Front End Electronics of the ATLAS New Small Wheel

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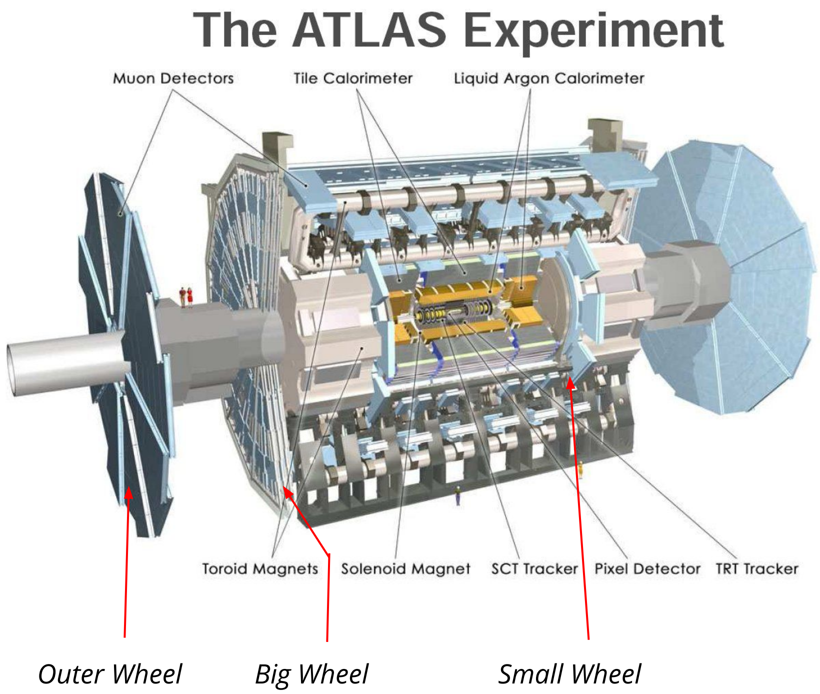
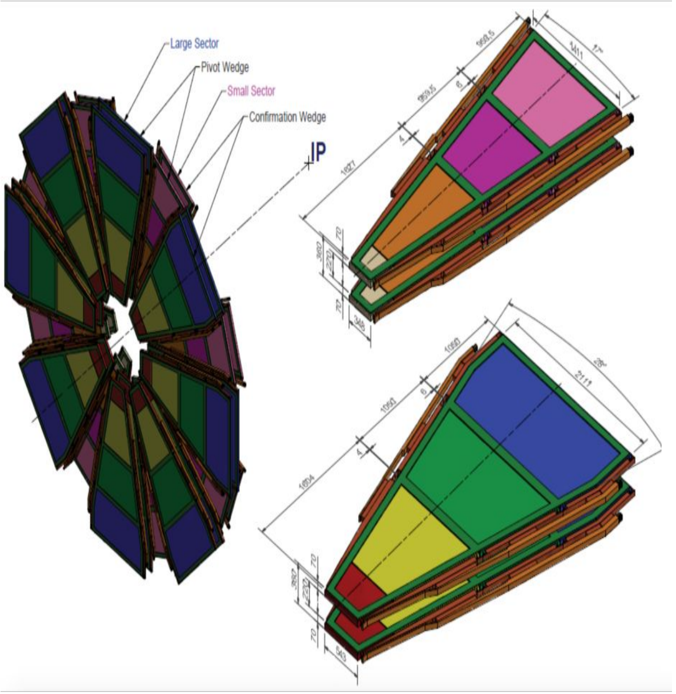
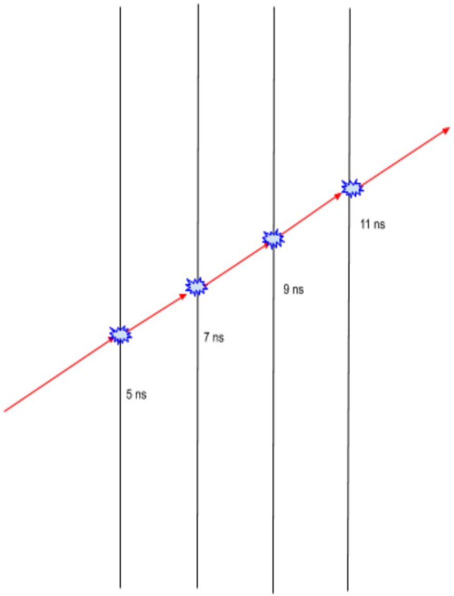
Experiment: ATLAS

- The ATLAS experiment is a general-purpose particle physics experiment which seeks to search for new physics and test the predictions of the Standard Model.
- The detector is currently undergoing upgrades and renovations during the second long shutdown



Project: Time Delay Measurements

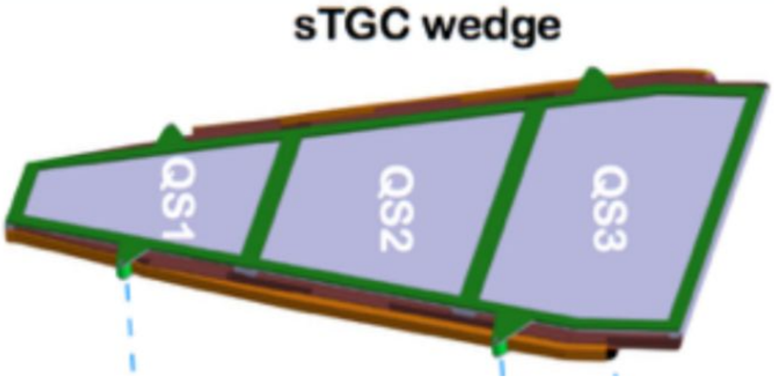


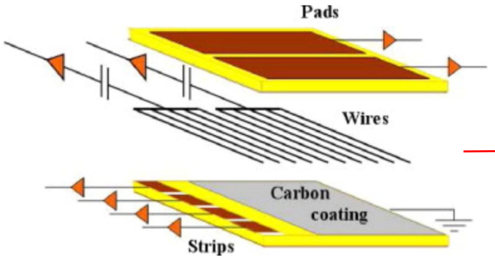


- The New Small Wheel is made up of sTGC and MicroMega detectors.
- Each detector component in the has a different cable length, meaning that we need a way to effectively predict the time delay without doing individual measurements.

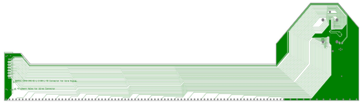
sTGC Wedge Background

- Each sTGC wedge is made of 3 quadruplates, each of which have 4 layers.
- On each of the four layers, there are a combination of strips, pads, and wires, which work together detect passing muons
- Each of these components has a readout channel, which will connect to an adapter board that provides and intermediate step between the front end boards and the detector





Detector Components

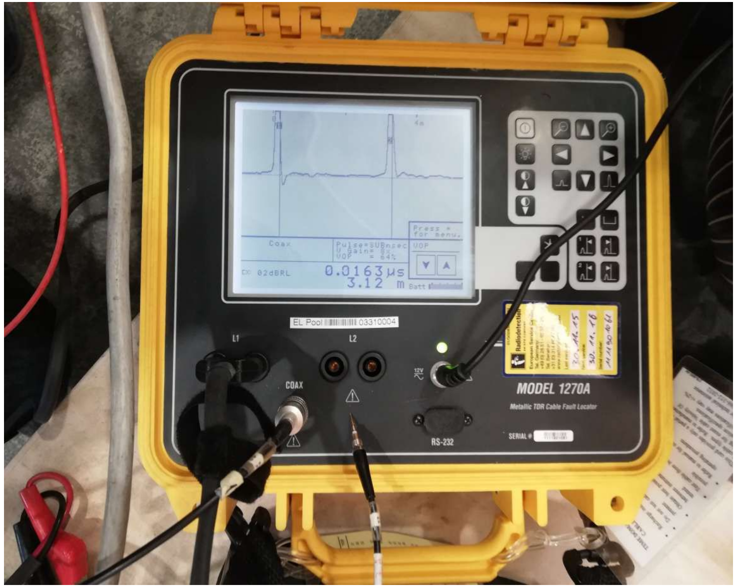


Adapter Board

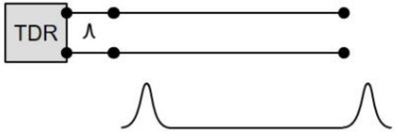
Front End Electronics

Experimental Setup

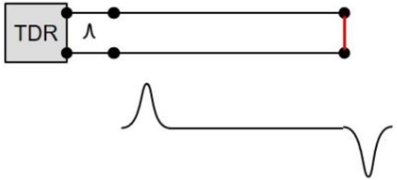
- The Time Domain Reflectometer (TDR) sends and electric pulse down the wire. Whenever there is a point in the wire that changes from one impedance to another, a part of the pulse is reflected
- Going from low to high impedance causes a positive reflection and going from high to low will cause a negative reflection.
- Open ended circuits will result in a positive reflection.
- Shorts will result in a negative reflection.

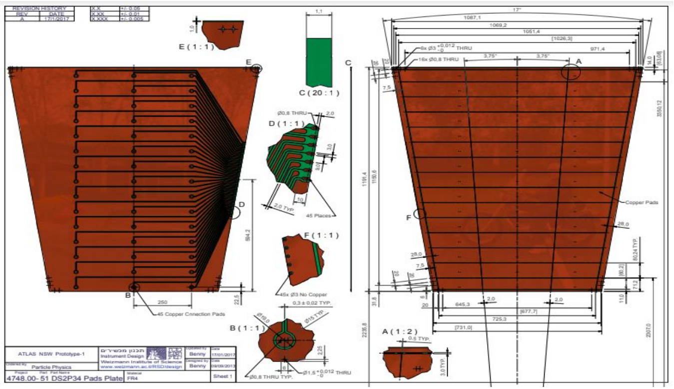


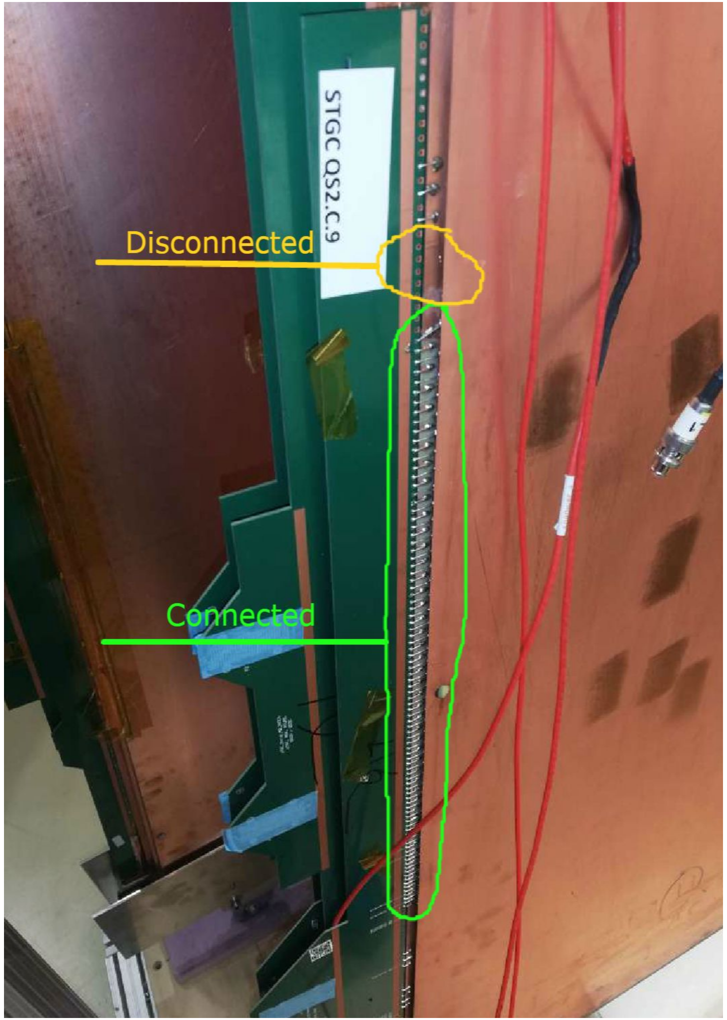
Open End



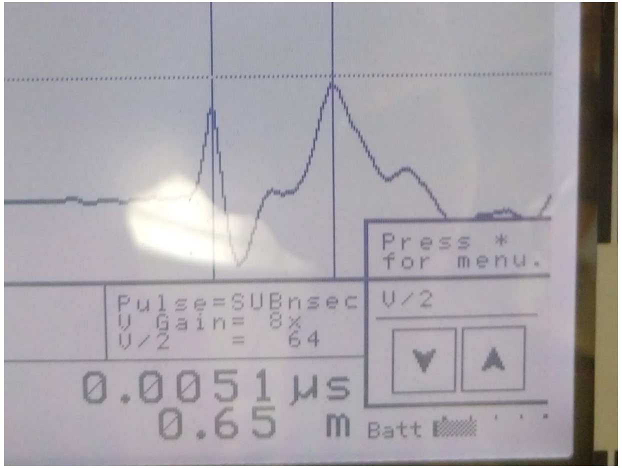
Short at Cable End



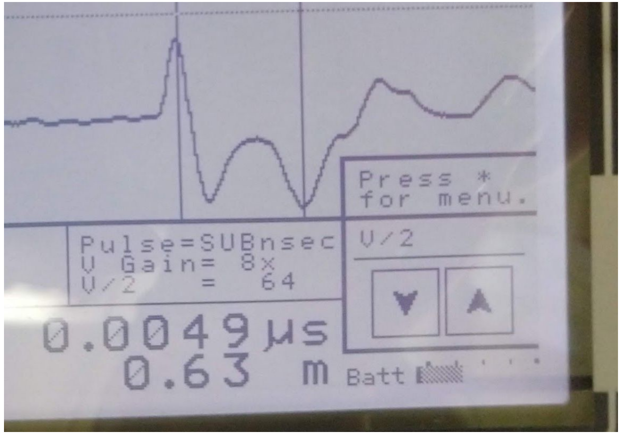




Disconnected Adapter Board Channel

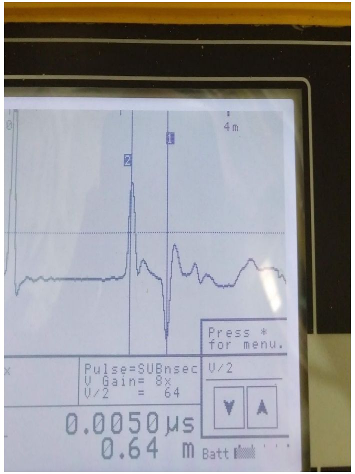


Connected Adapter Board Channel



Experimental Setup: Baseline Measurement

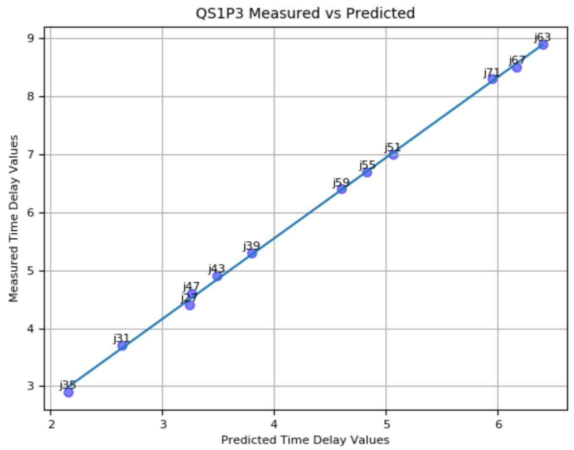
- We used a coaxial wire with a 16 ns delay to calibrate the velocity of propagation through the wire (approximately 1.95 *10^8 m/s) as our baseline for predicting the time delay in the detector.
- The actual material and environment inside of the detector is not accurately simulated by the coaxial cable, but it gives us a reasonable guess to compare our results against.

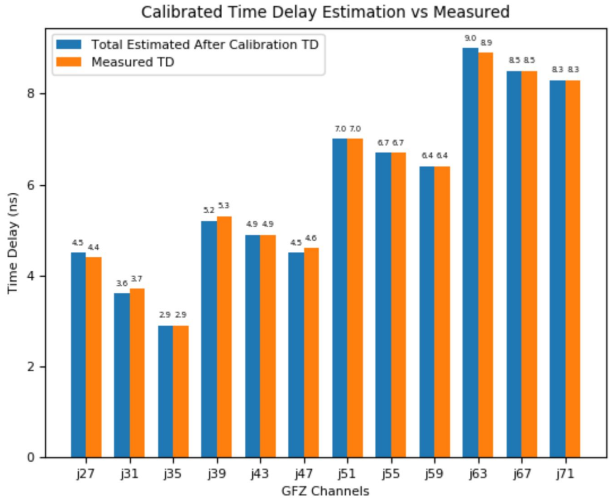


$$\frac{Length\ of\ Wire}{Time\ Delay} = Velocity\ of\ Propagation$$

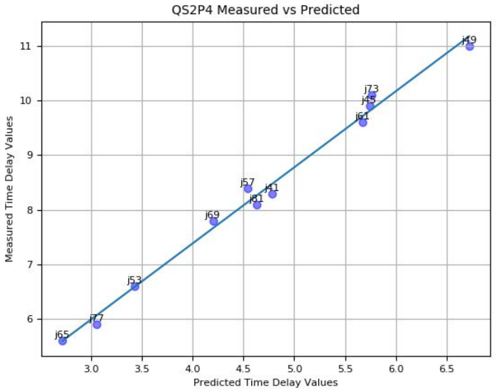
Initial Results

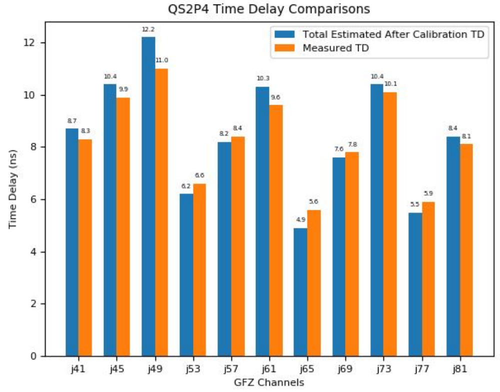
- We found a negligible difference between the velocity of propagation in the adapter boards and in the detector.
- As expected, the velocity of propagation was different from in the coaxial cable. We found that we could multiply the predicted time delay by a constant value, specific to each layer and quadruplate, to scale up to the measured values

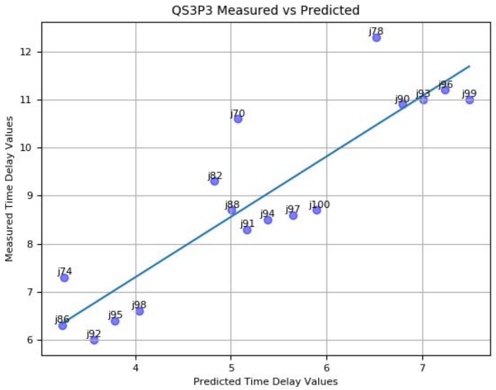


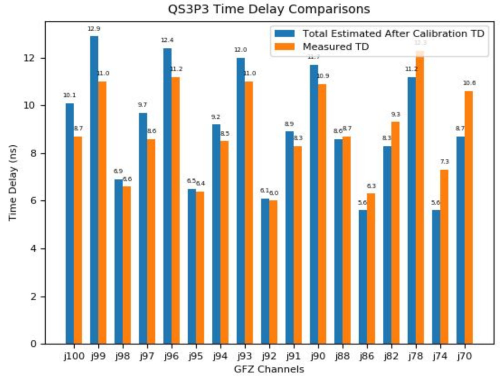


Results After Further Testing



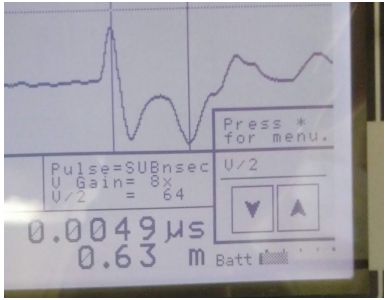




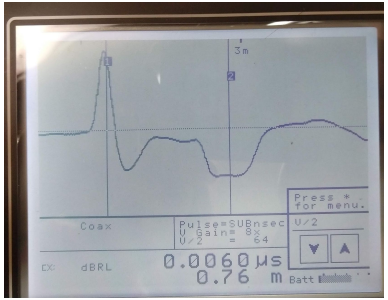


- For quadruplates QS1 and QS2 we found a linear relationship between the predicted time delay values and the measured time delay values, which means we only needed to scale by a single factor to correct our estimates
- The QS3 quadruplate showed a semi-linear relationship, but with much more variance in the data. Also, the data appears to be grouped more into certain sections.

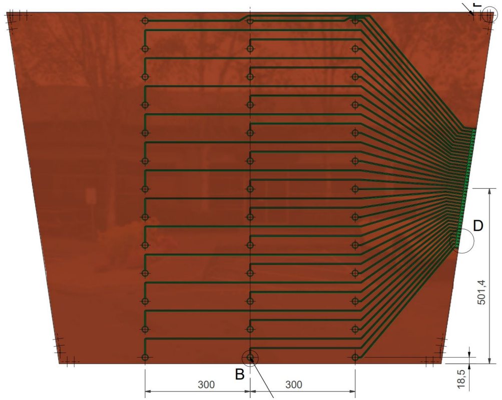
- The reason for this bizarre pattern that we find on all QS3 layers comes from a mistake in the initial assumption from the use of the TDR.
- The TDR is designed for measuring transmission lines, meaning that we must approximate the pads as points that cause the reflection at the end of the wire.
- This approximation becomes less accurate the larger the pads are, with the largest pads actually producing a superimposed image of multiple reflection from different points within its area, creating the wide, flat signal we see.
- We found that the width of this reflection decreased according with pad area, until it began to resemble the standard reflection.
- This means that on larger pads, we actually can have a variable trace length (and therefore variable time delay) based on where the particle hits within a given pad's area, creating an inherent, systematic uncertainty proportional to the pad's area

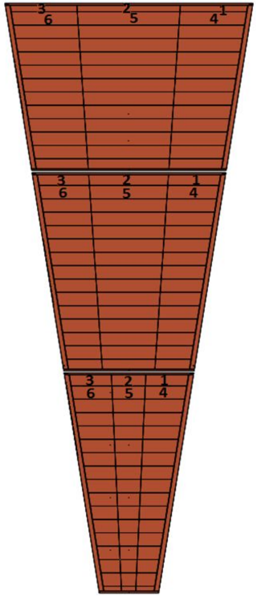


Standard Reflection



QS3 Large Pad Reflection



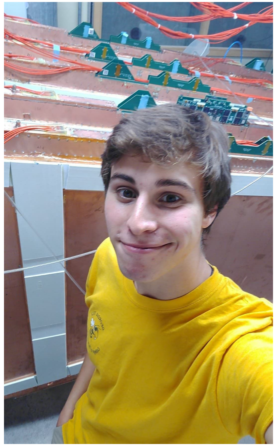


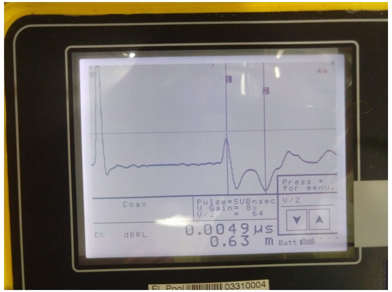
Key Conclusions and Future Work

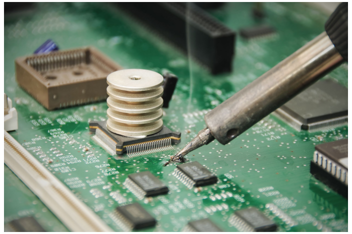
- The scaling ratio appears to be unique depending on the quadruplate and layer within the detector. This makes sense given that parasitic capacitance and other factors may affect the time delay, especially between different quadruplates and layers.
- We can predict the unique scaling factor for each quadruplate-layer combination with about 8 to 10 initial measurements, which on average gets our predicted values to within 1ns of the measured values.
- The VMM chips on the front end boards have a maximum resolution of about 3 nanoseconds, so our goal is only to get our predicted values accurate to within this window.
- More investigation will need to be done for the QS3 quadruplate to find the relationship between the systematic uncertainty and the pad area.

What I’ve learned

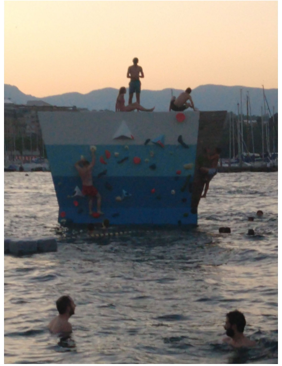
- How to use a TDR
- ROOT/C++
- Detectors are complicated
- How to manipulate lots of excel files
- Linux
- Soldering
- The proper way to address people over email (“Dear Colleagues”)

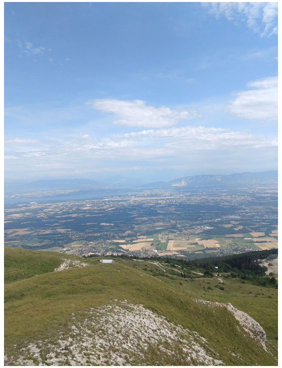


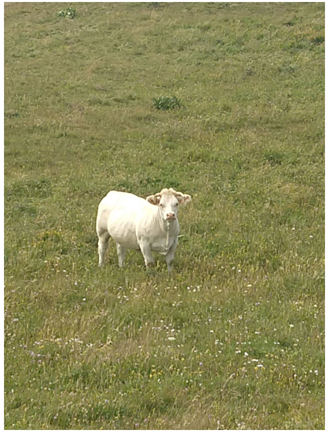




Cultural Experiences







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