Small-Strip Thin Gap Chambers for the Muon Spectrometer Upgrade of the ATLAS Experiment

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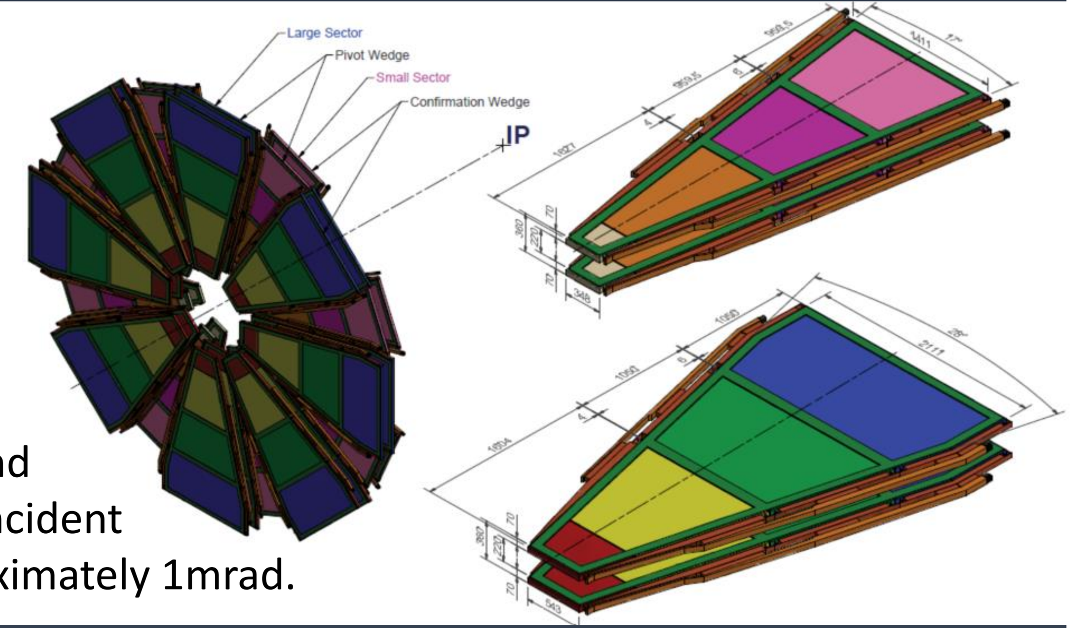
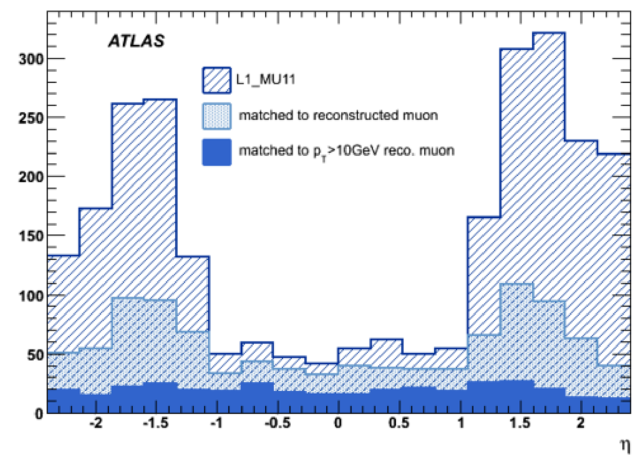
Introduction

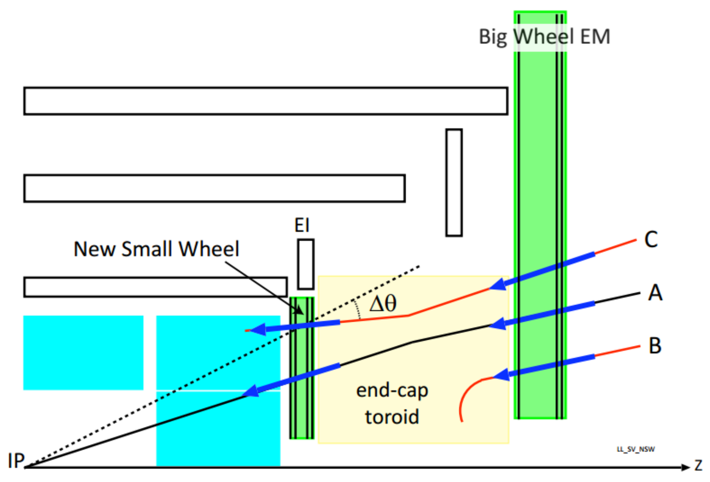
The instantaneous luminosity of the Large Hadron Collider at CERN will be increased by a factor of 5-7 with respect to the design value.
The largest phase-1 upgrade project for the ATLAS Muon System is the replacement of the present first station in the forward regions with the so-called New Small Wheels (NSWs) during the long-LHC shutdown in 2019/20.
Along with Micromegas, each side of the NSWs will be equipped with eight layers of small-strip thin gap chambers (sTGC) arranged in two quadruplets.
To reduce fake triggers, good precision tracking and trigger capabilities are required in the high background environment of LHC, each sTGC plane must achieve a **spatial resolution better than 100 µm** at normal incident angle to allow the Level-1 trigger track segments to be reconstructed with an angular resolution of approximately 1mrad.



Principal reasons to change the Small Wheel

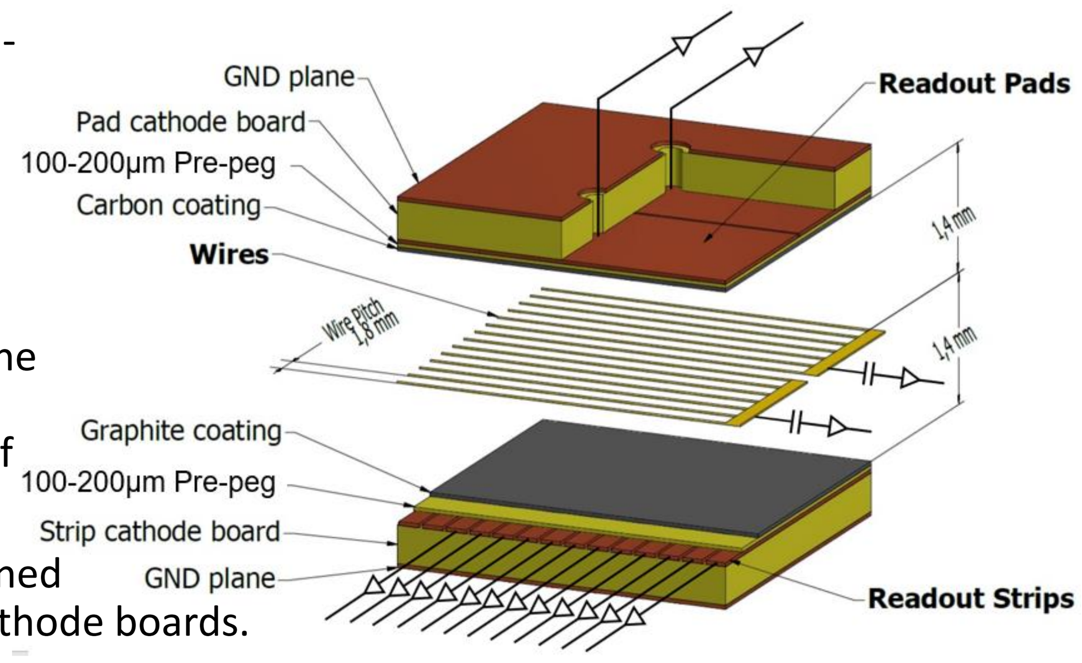
- Precise position measurement in front of the end-cap magnet is crucial for the momentum determination of the muon.
- Low energy particles produce fake triggers by hitting the end-cap trigger chambers at an angle similar to that of real high *p*T muons. An analysis of 2012 data demonstrates that **approximately 90% of the muon triggers in the end-caps are fake.**





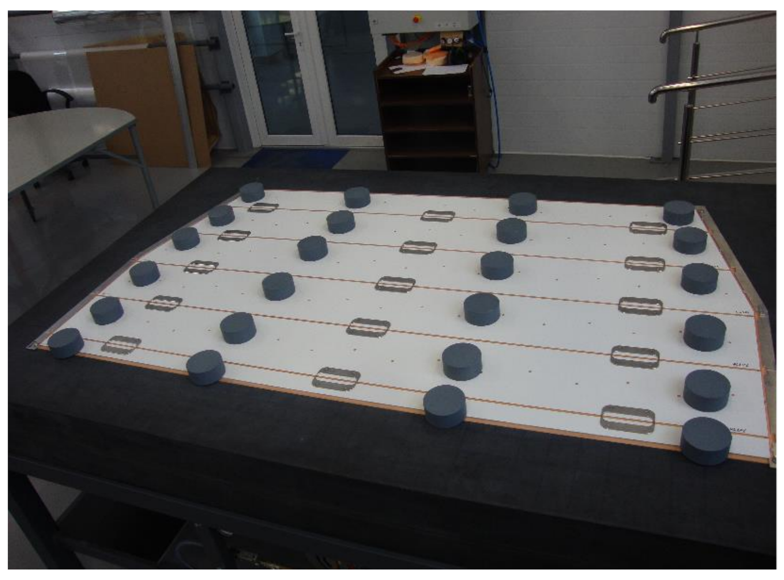
sTGC structure & features

- The basic sTGC structure consists of a grid of gold-plated tungsten wires sandwiched between two resistive cathode planes at a distance of 1.4mm from the wire plane.
- The precision cathode plane has strips with a 3.2mm pitch for precision readout relative to a precision brass insert outside the chamber, and the cathode plane on the other side has pads which determine the timing of the collision and group of strips to be used for trigger.
- The gap is provided using precision frames machined and sanded to 1.4mm ±20µm and glued to the cathode boards.
- The Muon trigger is performed with a precise angle measurement in the NSW and in coincidence with the outer detectors (Big Wheel)

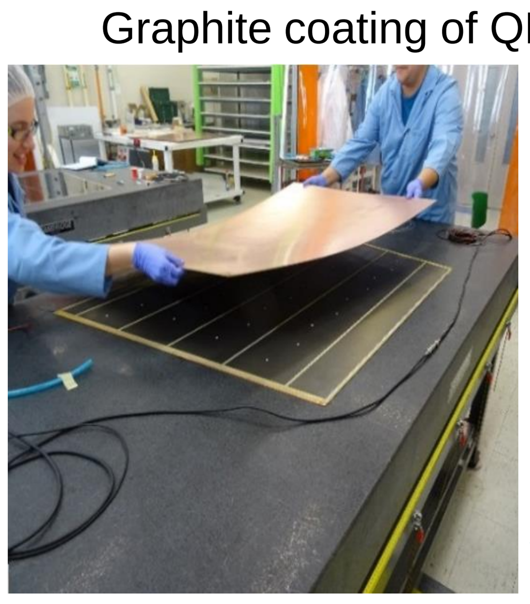


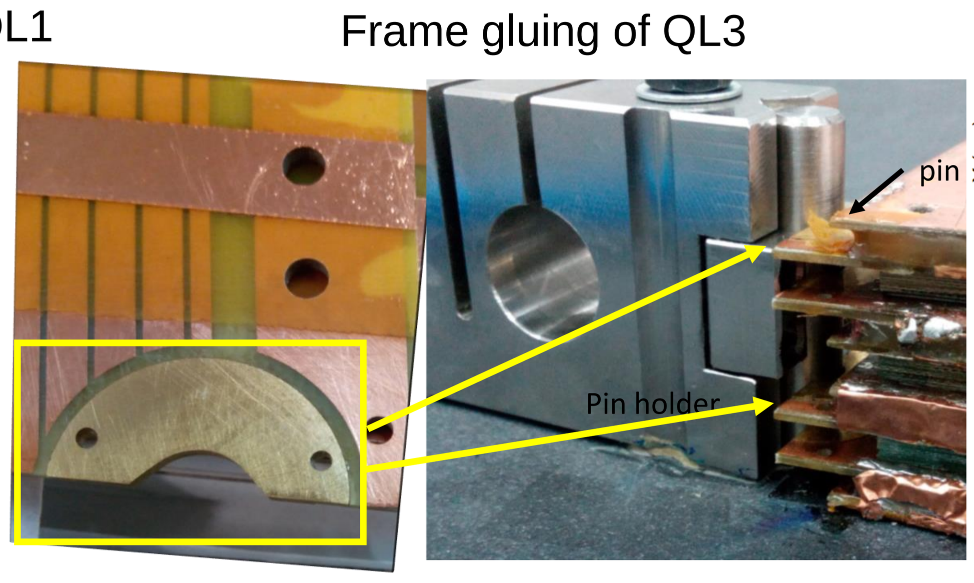
Construction steps


Graphite coating of QL1

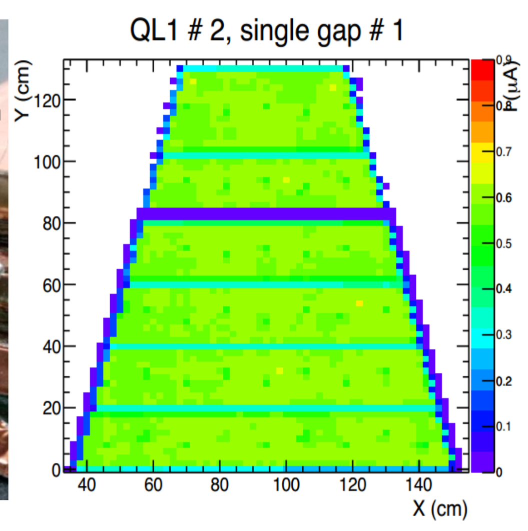

Frame gluing of QL3


Wire winding of QS2


Chamber closing of QS3



Precision quadruplet assembly of QS1

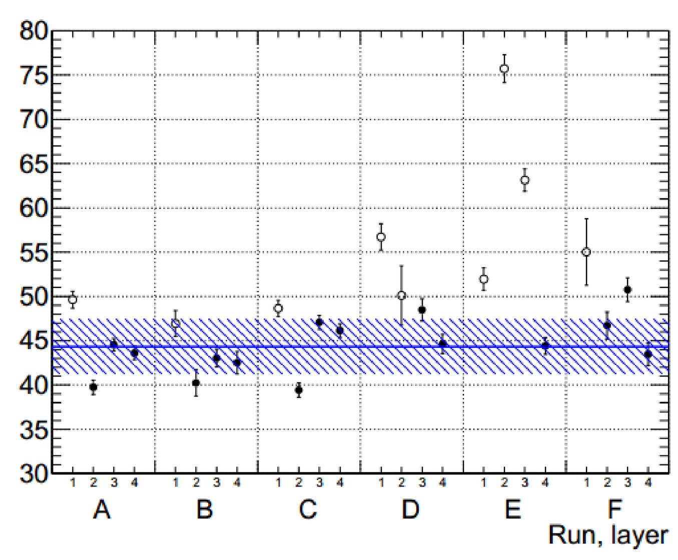


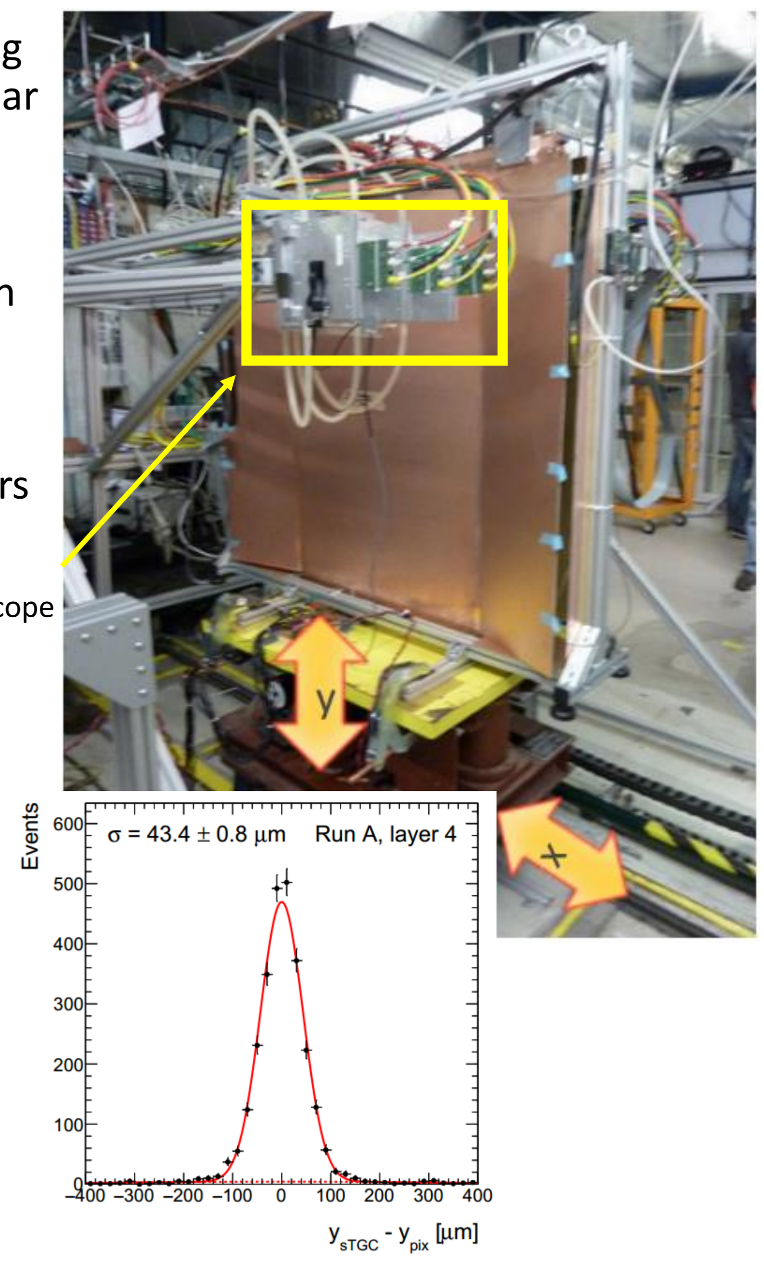
x-ray scan of QL1

Beam test results at FermiLab, position resolution

- Position resolution was measured using a 32GeV pion beam at Fermilab, Nuclear Instruments and Methods in Physics, 817, 85-92 (2016)
- The results shown a position resolution to be **better than 50µm** (bottom right plot) comparing to an external pixel telescope for different position scan in x-y (Runs: A,B,C,D,E,F) in different layers (layers: 1,2,3,4). see bottom left plot.

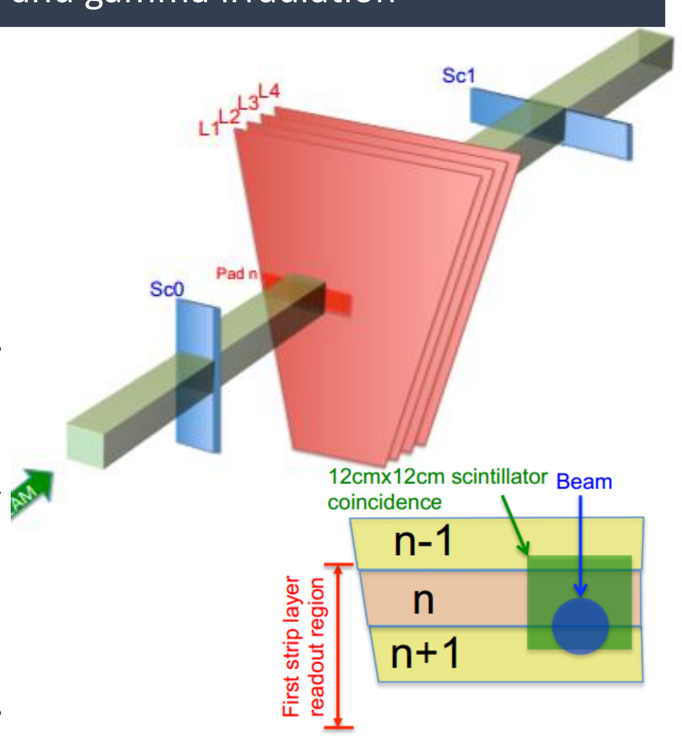
pixel telescope

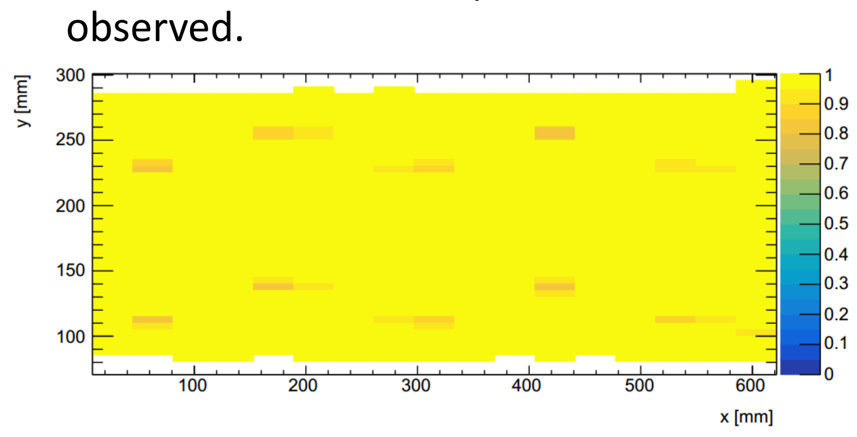




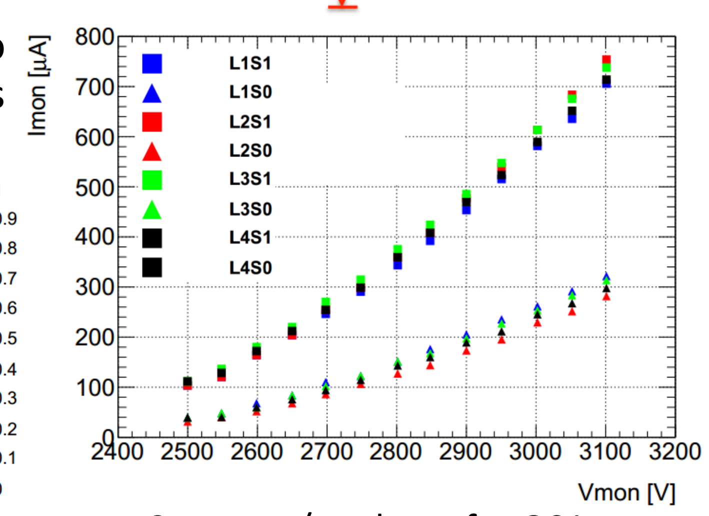
Efficiency tests at CERN & construction sites, and gamma irradiation

- Efficiency was measured at CERN using a 130GeV muon beam of about 4cm radius on a full size detector, Nuclear Instruments and Methods in Physics, 817, 85-92 (2016)
- It was determined that the detector efficiency is essentially 100% which was confirmed using cosmic muons at Canada, China and Israel, showing a efficiency >95% for the active area.
- Quadruplets were irradiated at GIF++ with Cs-137 at different voltages, with gamma rays at a rate of 30KHz/cm^2 the detector shows no saturation effect and no deterioration on performance was observed.





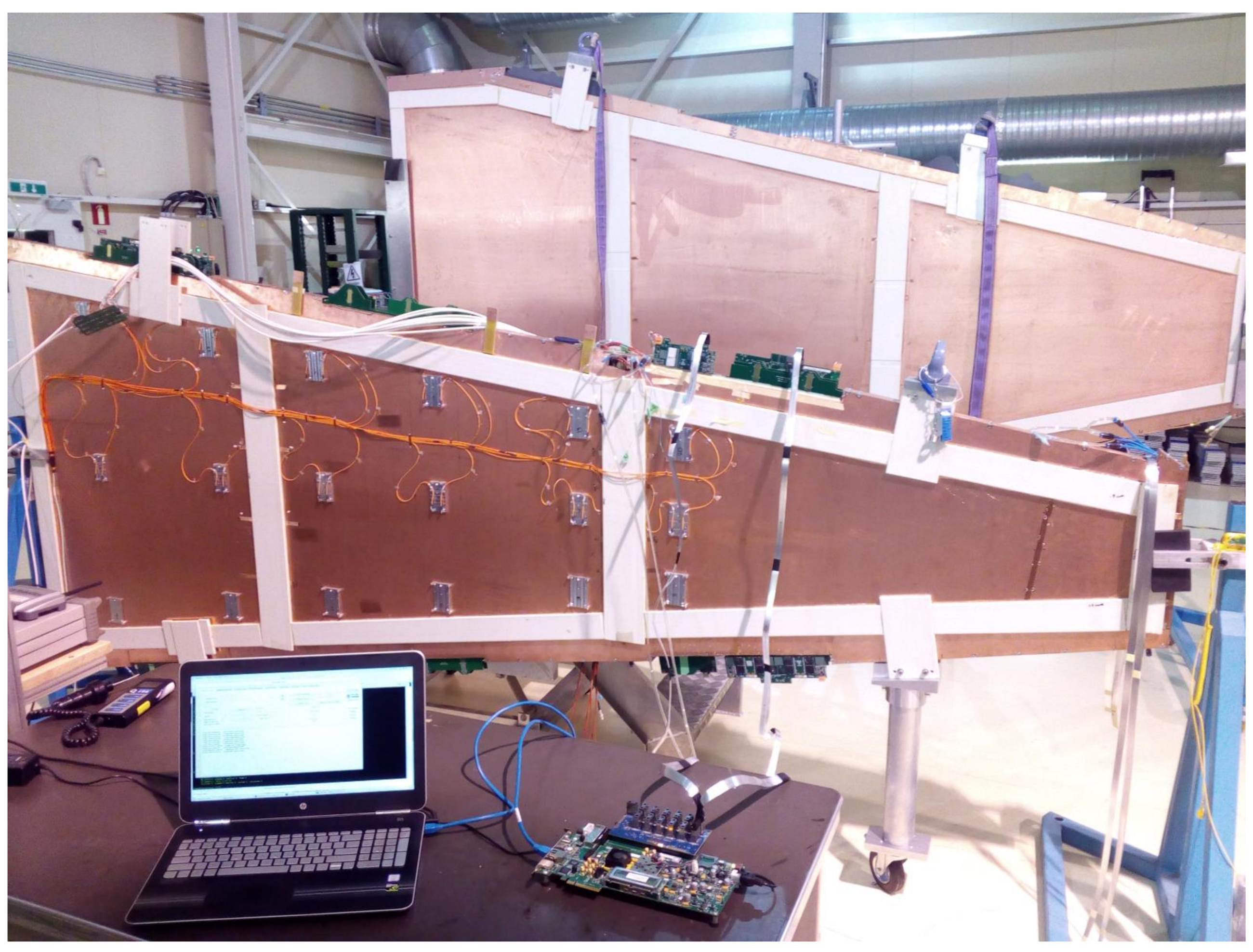
Strip efficiency map of prototype at McGill



Current v/s voltage for QS1 quadruplet (2 HV line per layer)

Current status and work

- **Quadruplet construction ramping up in all construction sites.**
- First small test wedge assembled with real quadruplets and fully instrumented.
- Used as test-bed for services installation and definition of wedge assembly protocol.
- Setbacks overcome include:
  - Winding wire breakages.
  - Cathode board production delays.
  - Front-end board (FEB) and adaptor board redesigns.


Small wedge chambers connected with the FEB to mini-DAQ

Acknowledgements

R. Rojas supported by Internal grant FI4061, UTFSM & Anillo grant ACT1406, Conicyt

ATLAS EXPERIMENT