Performance of the first Canadian-made muon chamber prototype for the ATLAS experiment upgrade

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McGill

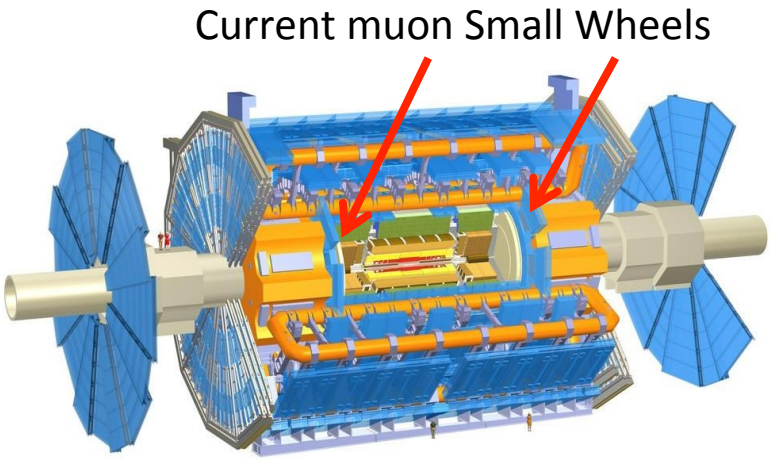
ATLAS EXPERIMENT

Outline

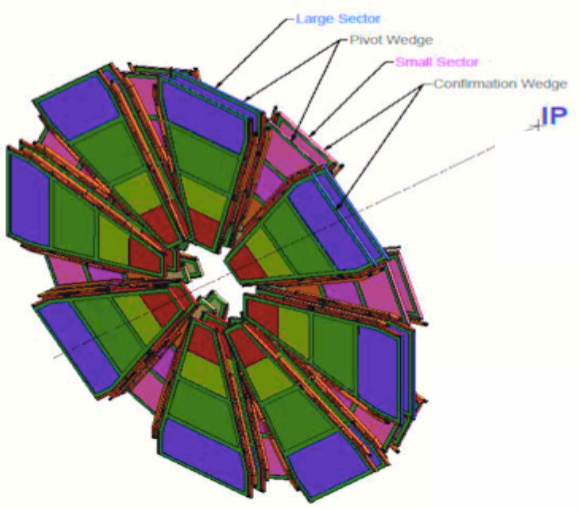
- The ATLAS New Small Wheel project
- The McGill Detector Testing Facility
- Preliminary results
  - Hit efficiency
  - Spatial resolution

ATLAS New Small Wheel (NSW) project

- The LHC will undergo a major upgrade in 2018 resulting in a doubling of its luminosity (up to $2x10^{34}$ $cm^{-2}s^{-1}$).
- The ATLAS detector will be upgraded during this period to take advantage of the increased luminosity.
- Parts of the current ATLAS muon spectrometer will be replaced by the NSWs to provide
  - a factor of ~7 reduction in fake muon trigger rate
  - improved precision muon tracking
- Parts of the NSW will be made of **small Thin Gap Chambers** (sTGC).
  - Approximately one third of sTGC detectors constructed and tested in Canada.



ATLAS detector



The ATLAS NSW

sTGC production in Canada

TRIUMF – Preparation of cathode planes.

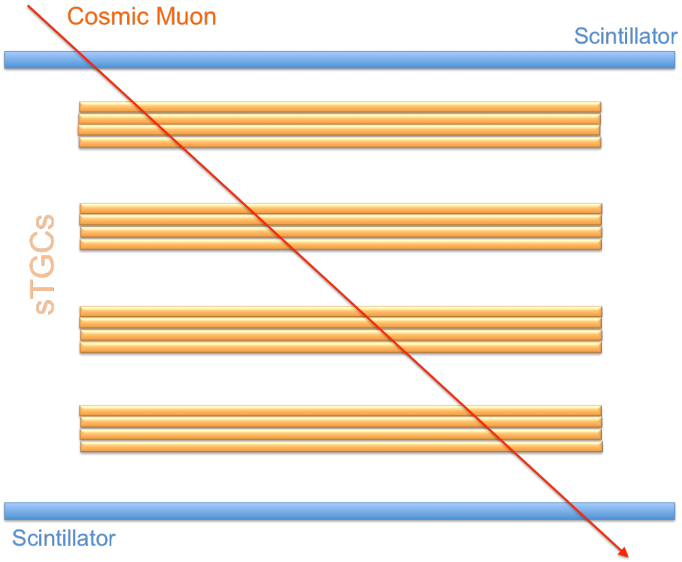
Carleton – Assembly of the sTGC quadruplets (4 gas gaps) modules.

McGill – Detector characterization, quality control and acceptance.

ATLAS (CERN) – Assembly and commissioning into the NSW.

The McGill sTGC Testing Facility

- McGill sTGC testing facility is ready to characterize Canadian-made sTGC quadruplets.
- Main elements of the sTGC qualification procedure:
  - Gas integrity test
  - High voltage test
  - Hit efficiency measurement (strips, pads, wires)
  - Spatial resolution (strips, wires)
- sTGC quadruplets are tested using a cosmic ray hodoscope which features:
  - an extruded aluminum structure allowing 4 quadruplets to be tested simultaneously,
  - 2 planes of plastic scintillator detectors to trigger the DAQ system (requires a top AND bottom coincidence).

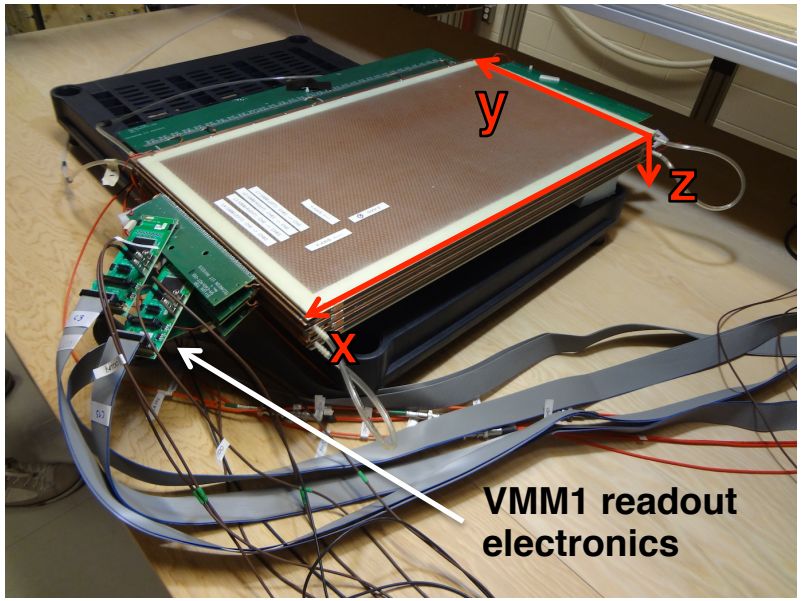


Concept of the sTGC test bench

Current state of the sTGC test bench

Experimental setup

- A prototype sTGC quadruplet of 40x60 cm^2 was tested at McGill using the cosmic ray test bench.
- Experimental setup:
  - Detector readout using first version of ASIC prototype (VMM1) designed for NSW.
  - 4 layers of strips instrumented providing up to 4 space points for track reconstruction.



Prototype sTGC quadruplet

Assembled by Canadians during a visit at the Weizmann Institute sTGC construction center (Israel) in 2014.

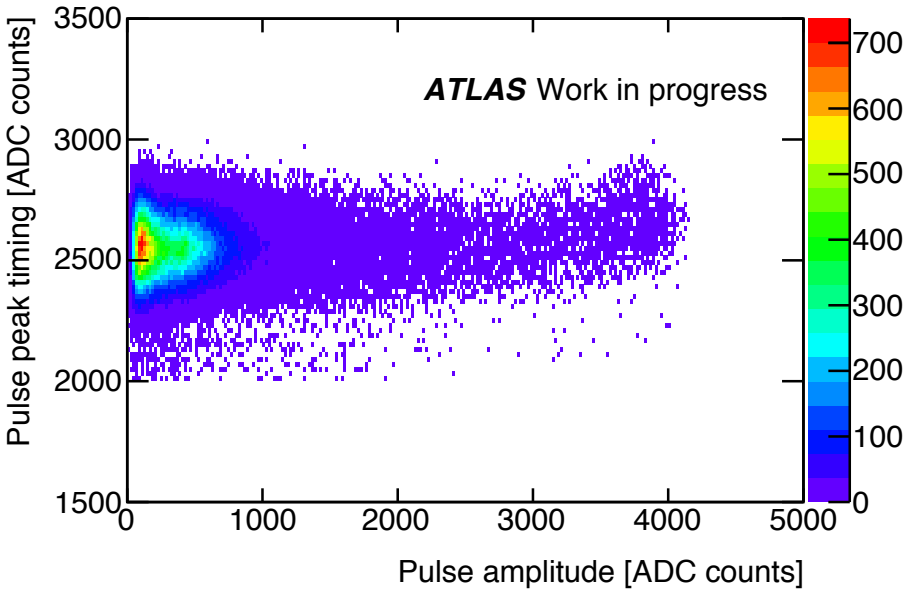
Event selection

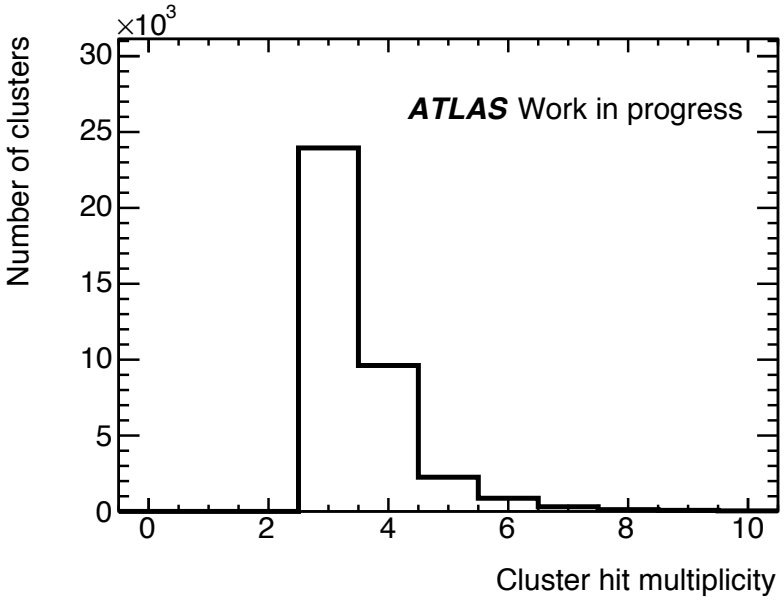
Cut	Number of events	Total efficiency [%]
All events	95548	100
Data quality	95545	100
Analog pulse timing	95111	100
Hit on a bad channel	57468	60
At least one good cluster on a layer	53442	56
At most one cluster per layer	53312	56
No hit on the side channels	49971	52
No non-hit channel next to maximum channel of the cluster	49559	52
≥ 2 layers hit	38366	40
≥ 3 layers hit	22748	24

Applied to all events

3 layers hit	15259	16
4 layers hit	7489	8

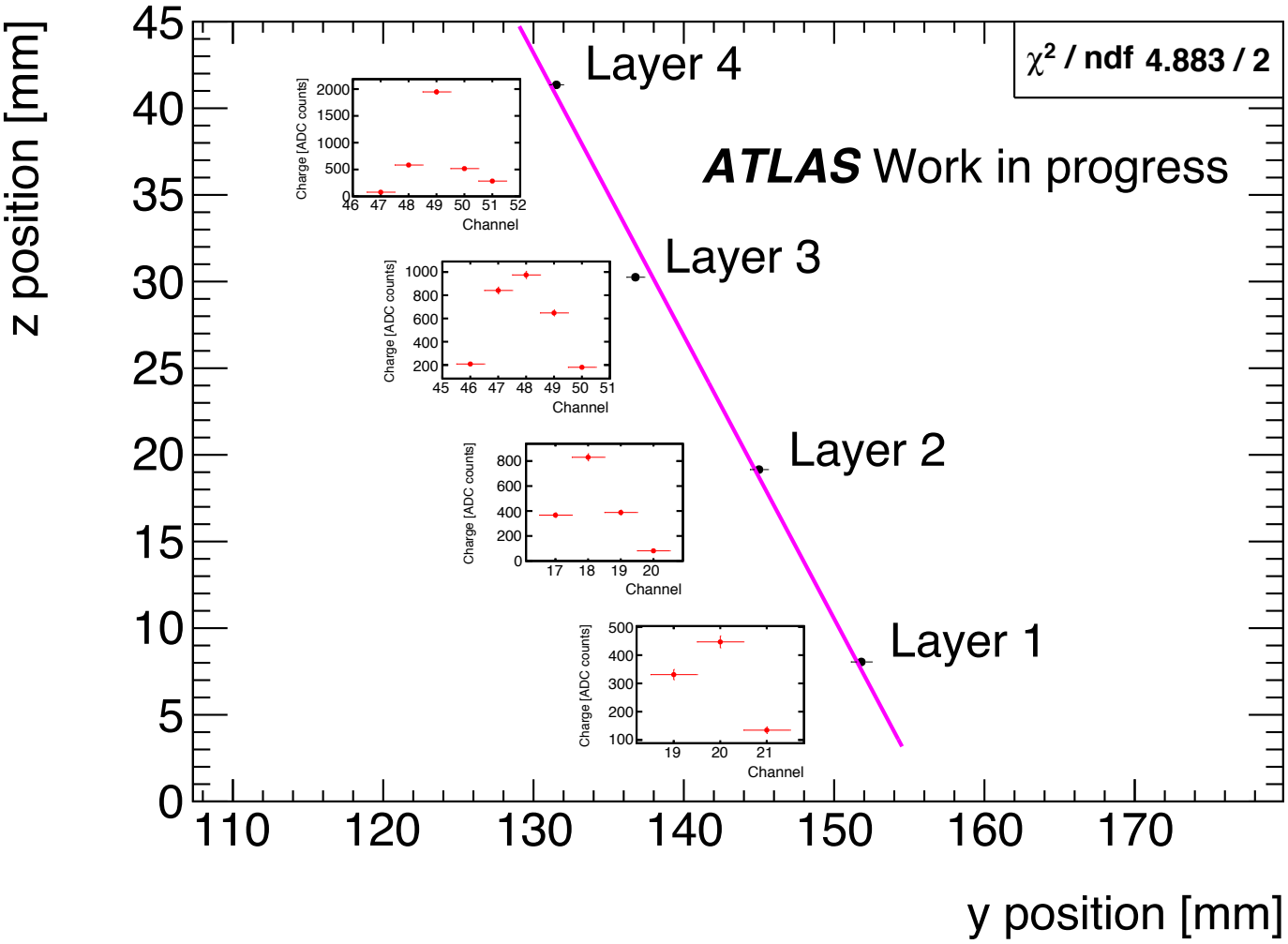
sTGC data acquisition





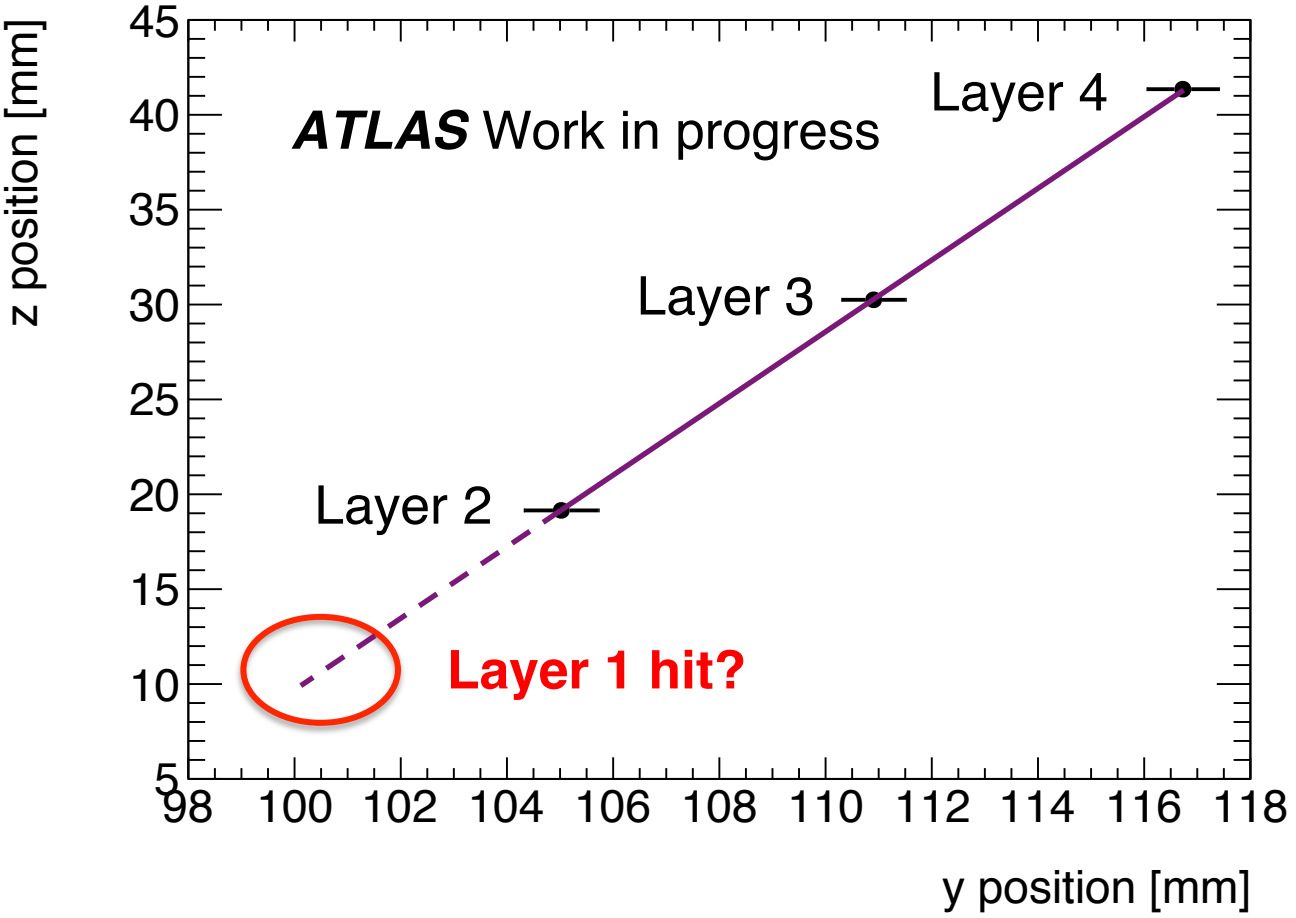
- The readout electronics provide pulse amplitude and timing information of analog signals.
- Ionization charge signal typically spreads over 3 to 5 strips.

Clustering and tracking



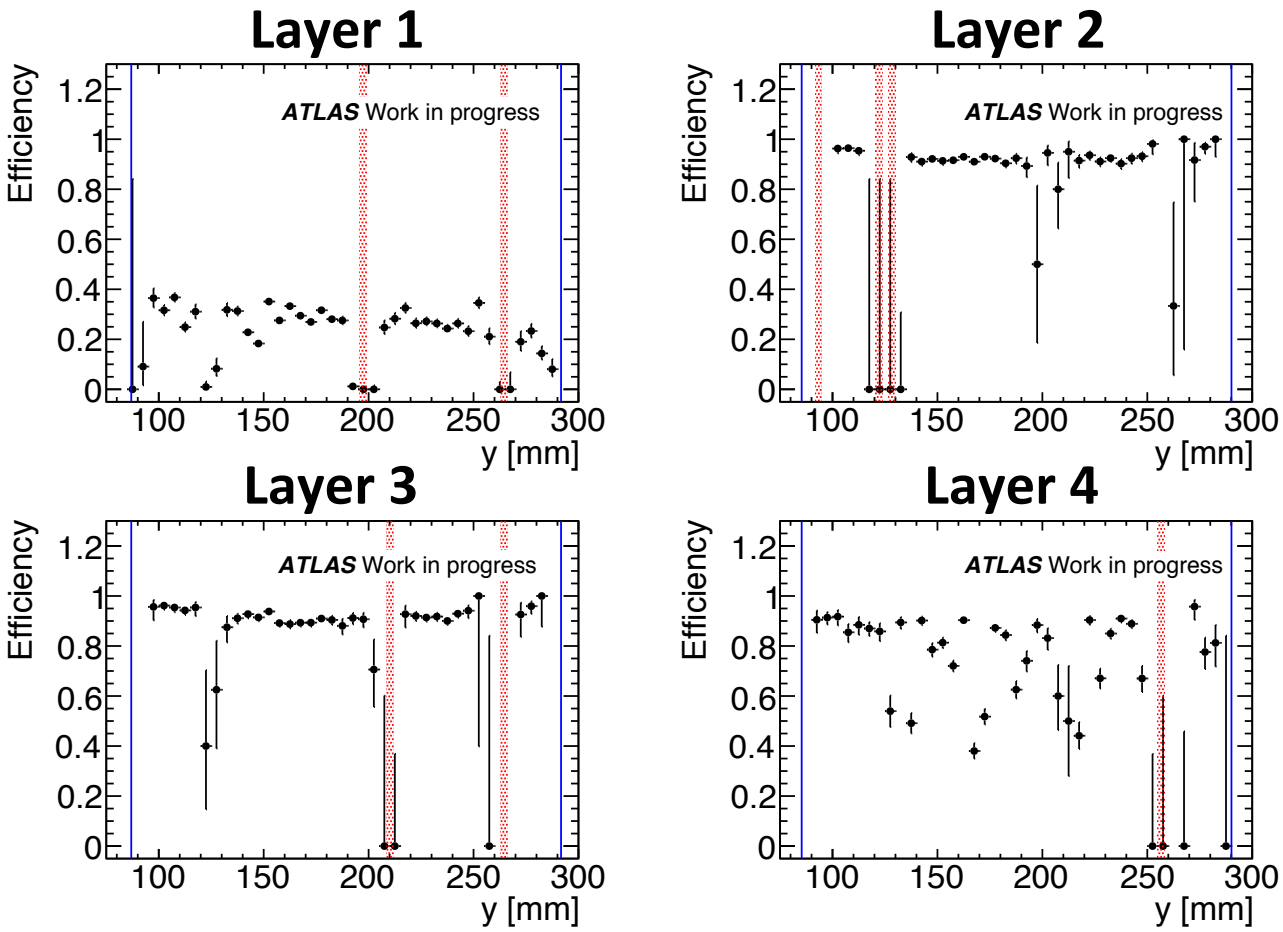
- Center of charge deposition clusters in each layer found using a weighted average.
- 2-D track reconstruction performed.

Hit efficiency – Calculation



$$\text{Efficiency} = \frac{\text{Number of reconstructed tracks with matching hit in layer of interest (within } \mathbf{3.2\,mm} \text{ of track)}}{\text{Number of reconstructed tracks}}$$

Hit efficiency - Results



- The **blue** lines highlight the limits of the instrumented area of the sTGC.
- The **red** areas highlight the position of bad channels.
- Lower efficiency on layer 1 not due to readout electronics.

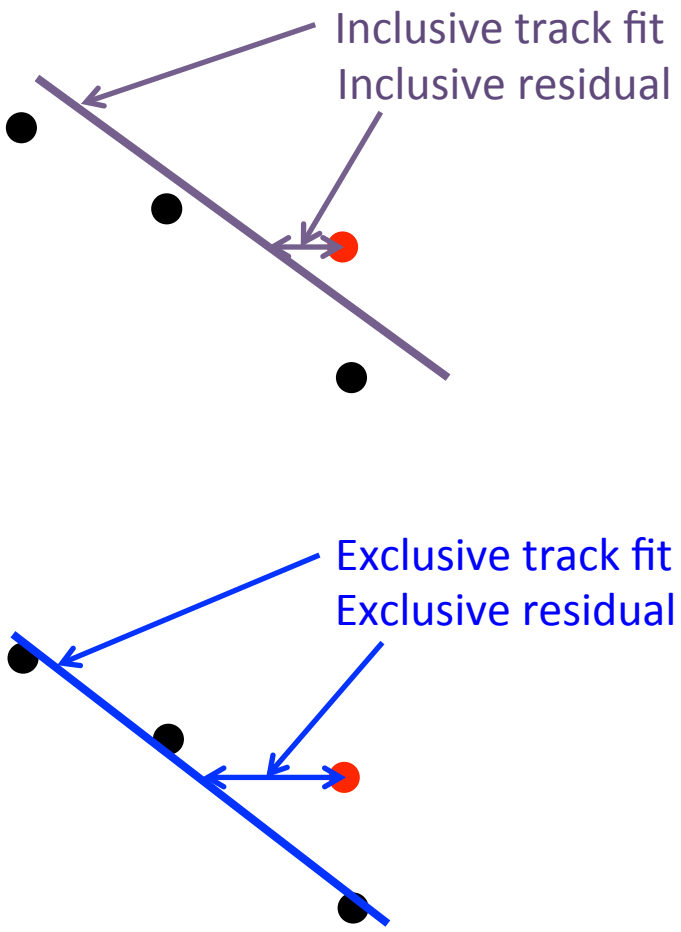
Track residuals

The track residuals are required to calculate the sTGC spatial resolution.

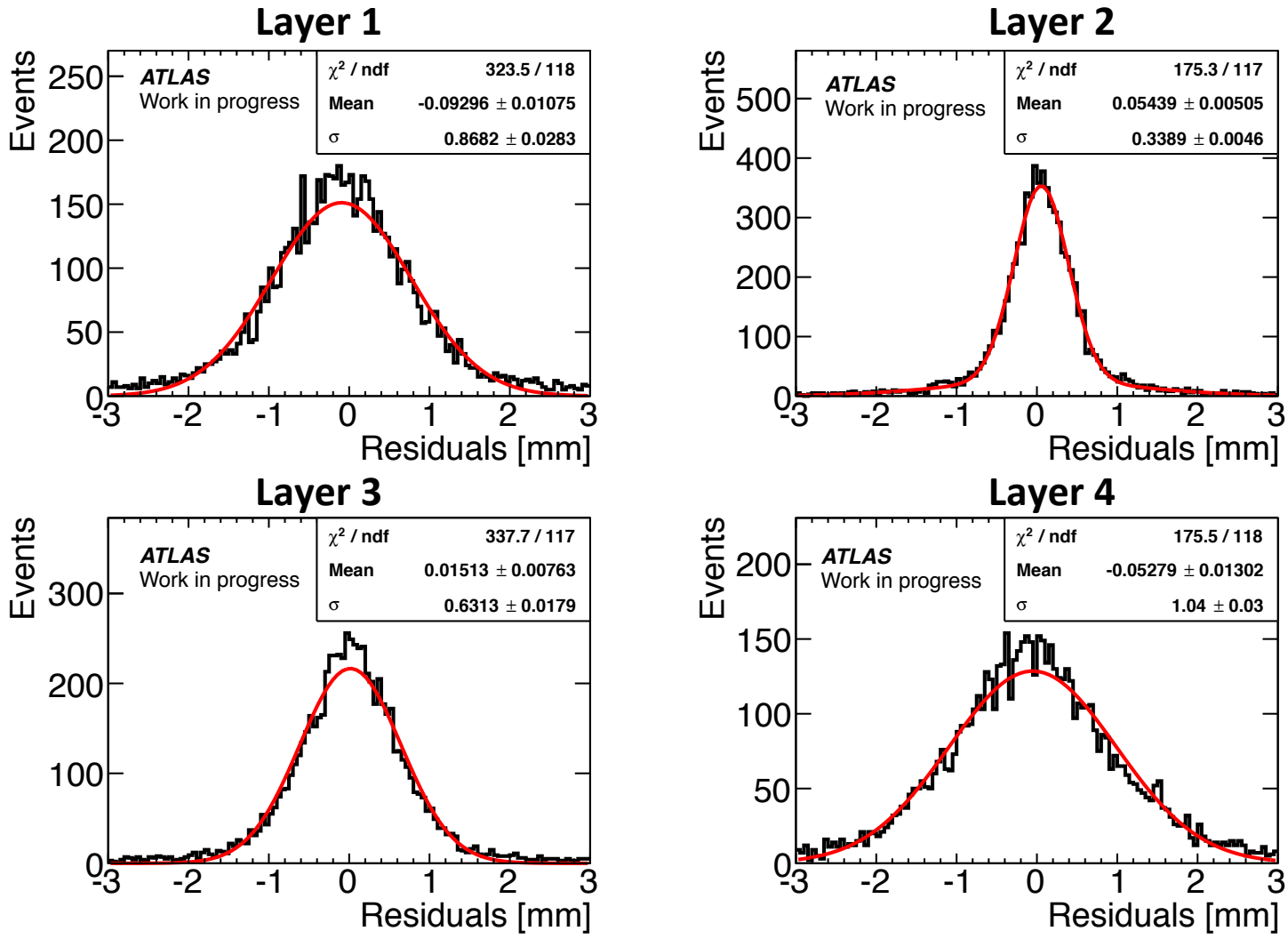
Residual: Distance (along the gas plane) between the fitted track and the hit in the layer of interest.

Inclusive residual: The track fit **includes** the layer of interest.

Exclusive residual: The track fit **excludes** the layer of interest.

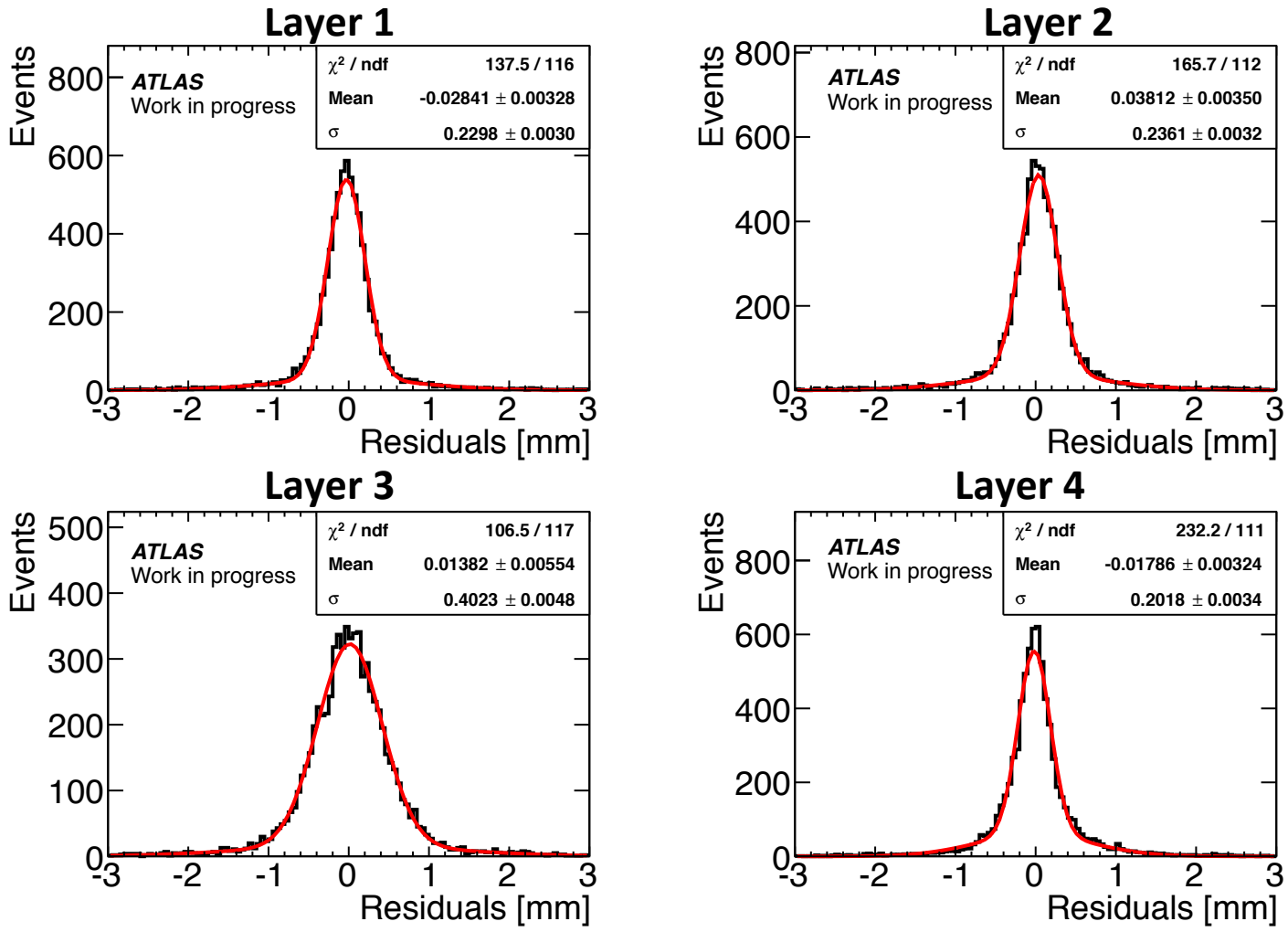


Exclusive residuals



- The distributions of layers 1 and 4 are wider because a track extrapolation is made (as opposed to track interpolation on layers 2 and 3).
- Without any layer alignment correction, spatial resolution of the order of 500 µm observed.

Inclusive residuals



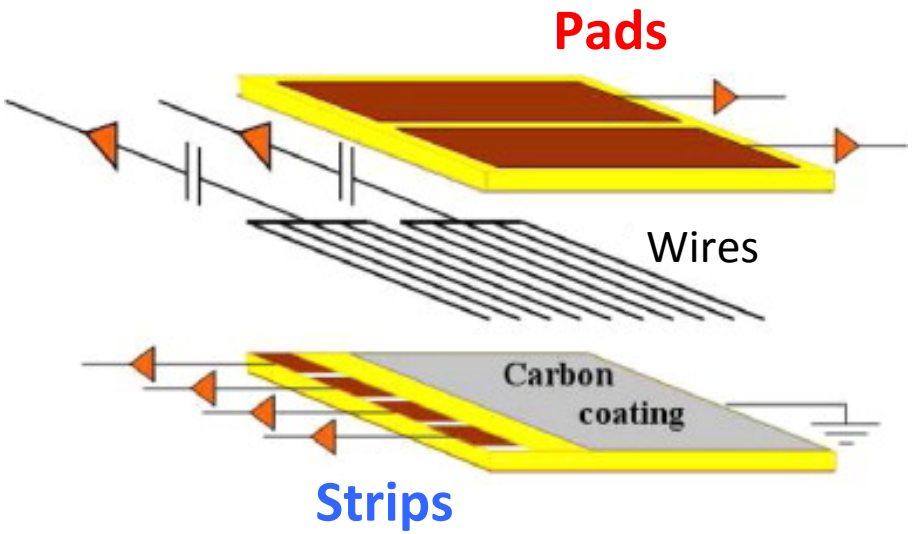
- Hints of possible mis-alignment of layer 3 from the discrepancy of the σ parameter of the gaussian fit with respect to the other layers.
- The inclusive residual distribution is narrower because the track fit includes the layer of interest.

Summary

- The McGill sTGC testing facility is ready to operate and already tested a prototype quadruplet.
- Algorithms for efficiency measurement are under development and the preliminary efficiency and residual distribution of the prototype quadruplet was calculated.
- Alignment algorithms are under development to precisely measure eventual layer mis-alignments.
- The Canadian-made sTGC module-0 (first full-sized sTGC that could be installed in the NSW) is scheduled to be built by the end of 2015 and tested at the McGill facility

Back-up slides

sTGC technology



sTGC internal structure

- Multiwire gas detector with anode-to-cathode distance (1.4 mm) smaller than anode-to-anode distance (1.8 mm).
- Operates with a gas mixture of CO2/n-pentane (55%/45%)
- 2 cathode planes covered with resistive graphite coating
- **Readout copper strips** and anode wires are used for **track reconstruction**
- **Readout copper pads** with large area used for **triggering** purposes
- **Signals from pads** and **strips** induced from the same gas gap.

The McGill sTGC Testing Facility

- **Gas system**
  - feeds the quadruplets with a n-pentane/ CO_2 mixture
  - allows for an independent control of the gas conditions (gas flow and presence of n-pentane) on each tray of the test bench
- **Slow control system**
  - monitors the gas conditions and the high voltage supply of the quadruplets
  - enforces a safe and stable operation of the testing facility throughout the whole duration of the sTGC modules qualification

The sTGC test bench gas system