Studies of cosmic ray events in ATLAS sTGC muon chamber prototypes

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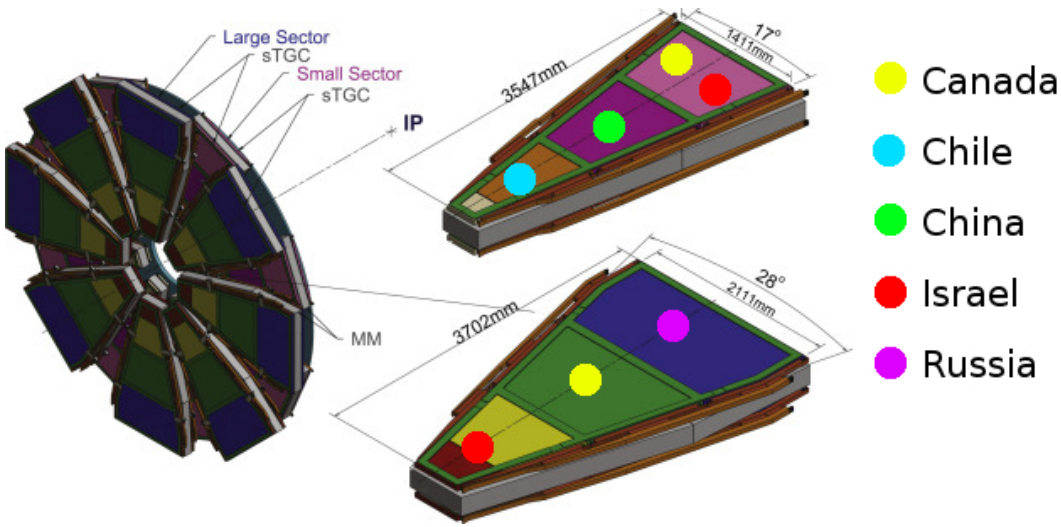
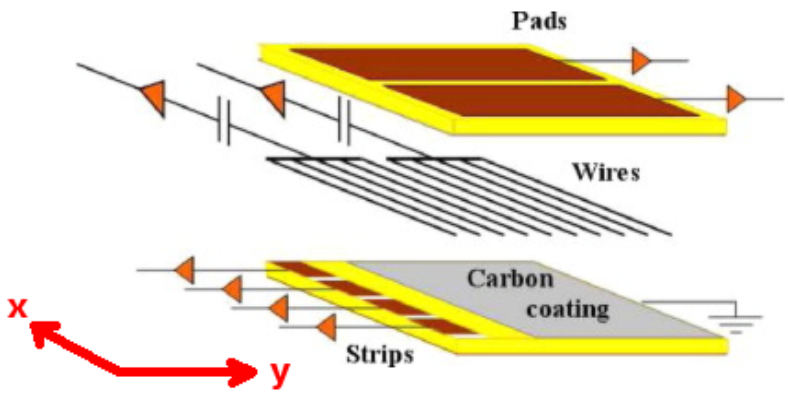
Outline

ATLAS New Small Wheel Upgrade Project

- Motivation: (Run-1) High μ fake rate in forward region of ATLAS $\Rightarrow$ New detector needed for triggering Run-3 (see I. Trigger's talk)
  - Current Small Wheel (SW) uses Thin Gap Chamber (TGC) detectors
  - Small-strip Thin Gap Chambers (sTGC) technology developed for New Small Wheel (NSW)
  - Canada involved in production of 1/4 of the sTGC

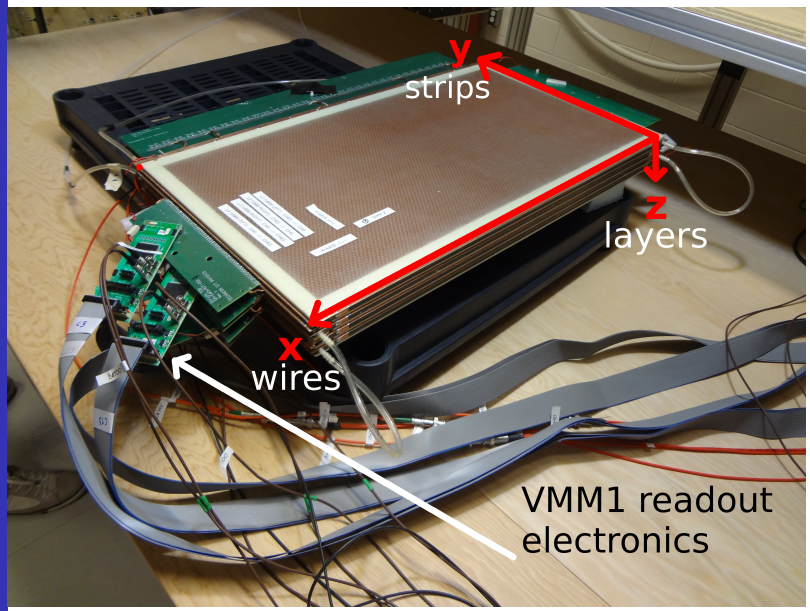


TGC Structure



- Wires [x axis]
  - Wire pitch: 1.8 mm
- Strips [y axis]
  - Strip pitch: 3.2 mm
- Pads [xy axis]
  - Laid in tiles
  - 28 channels on layers 1, 3
  - 40 channels on layers 2, 4
- Z axis: 4 layers (quadruplet)

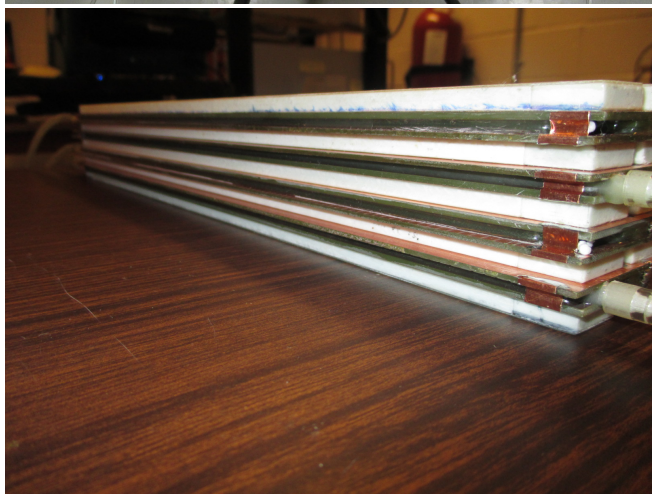
McGill sTGC Testbench



- 3D data available from detector, but my study only uses 2D information for tracking (strips, layers)

- McGill responsible for quality assurance / performance characterization of Canadian sTGC modules
- Goal: measure hit efficiency and spatial resolution of sTGC planes
- Relies heavily on track reconstruction: my project is to better understand the nature of Cosmic Ray events recorded by sTGC quadruplet through track reconstruction

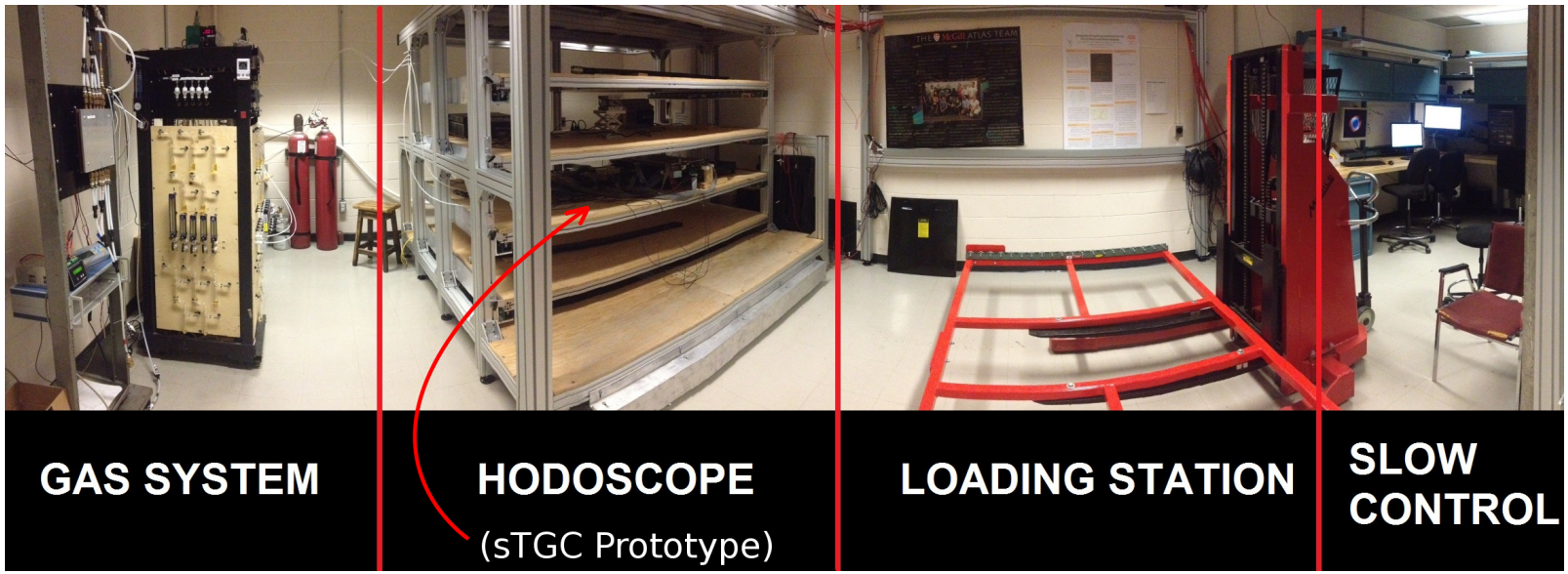
40x60 cm^2 sTGC Prototype



McGill currently uses an ATLAS sTGC prototype to validate quality control measurements

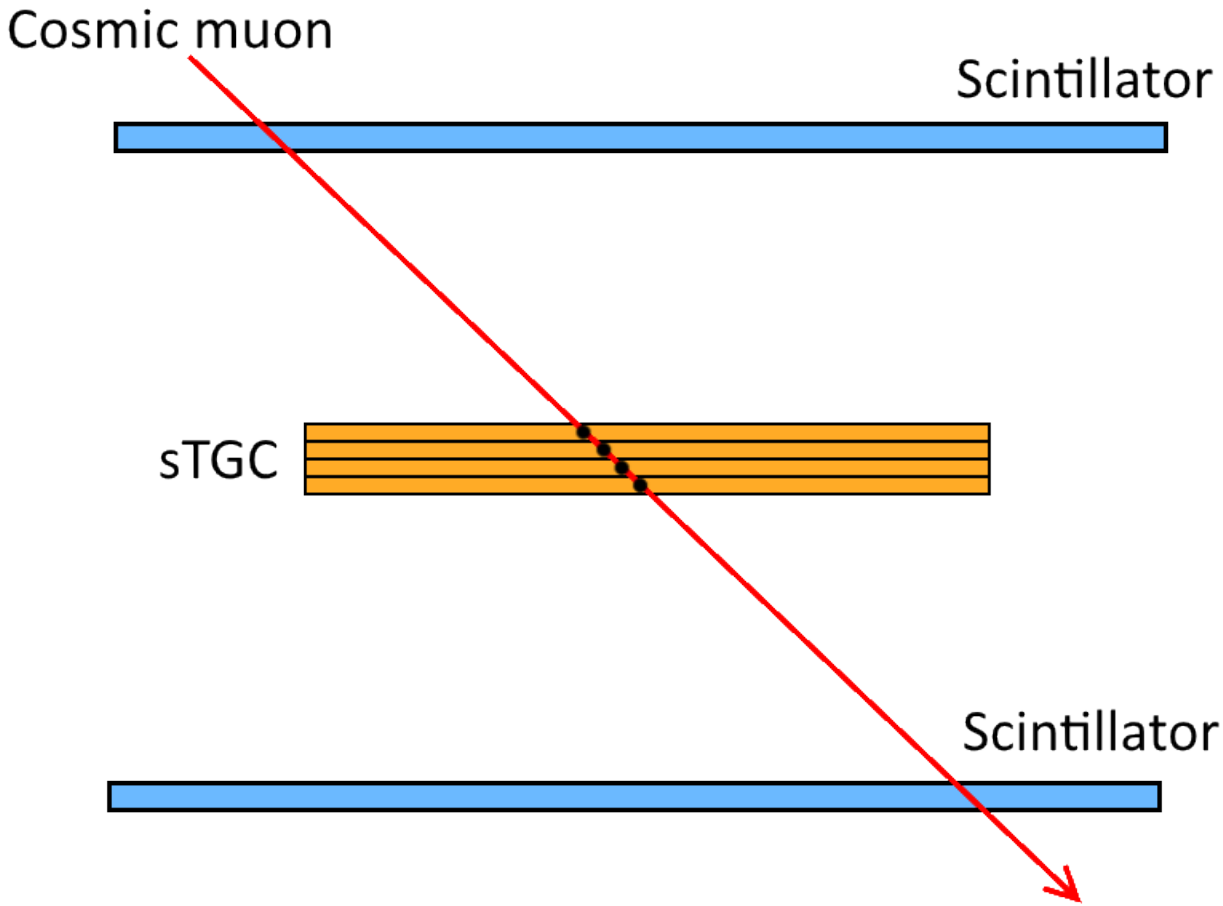
- Designed by Weizmann Institute Group
- Built by sTGC Canadian Group (TRIUMF & Carleton U) in Israel
- Tested at Fermilab
  - ▸ NIM A817 (2016) 85-92

McGill sTGC Testing Lab



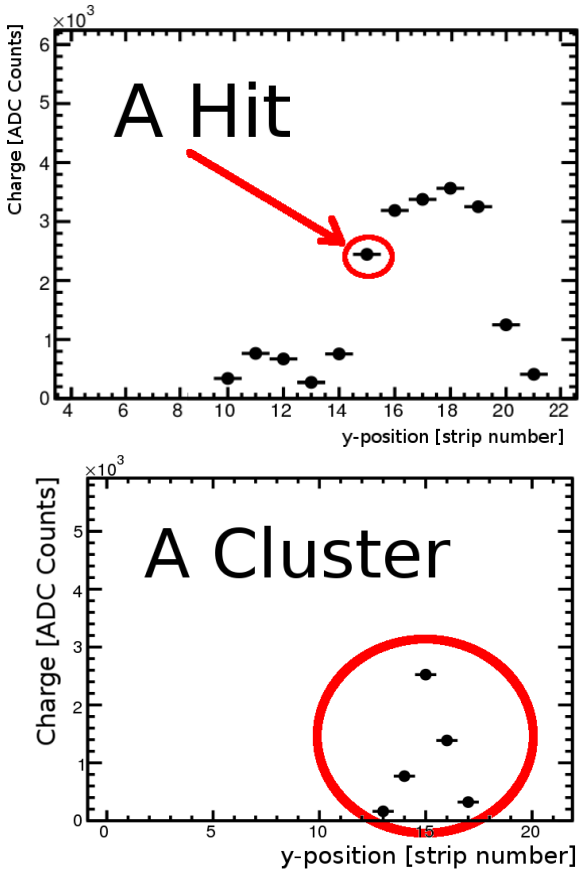
- Gas System provides n-pentane:CO_2 mixture of 45%:55% by volume
- Slow Control system in place to ensure lab safety
- McGill group published paper to JINST about development and characterization of these two components:
  - ▸ JINST 12(04):P04027, 2017

Cosmic Ray Detection

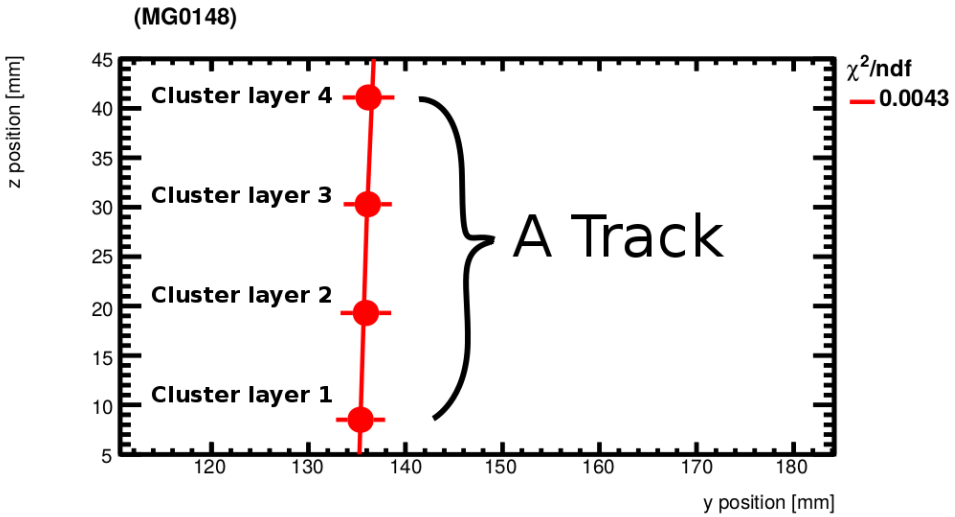


- Trigger on the scintillators.
- sTGC quadruplet has 4 layers.

Definitions for Multi-Cluster Track Analysis

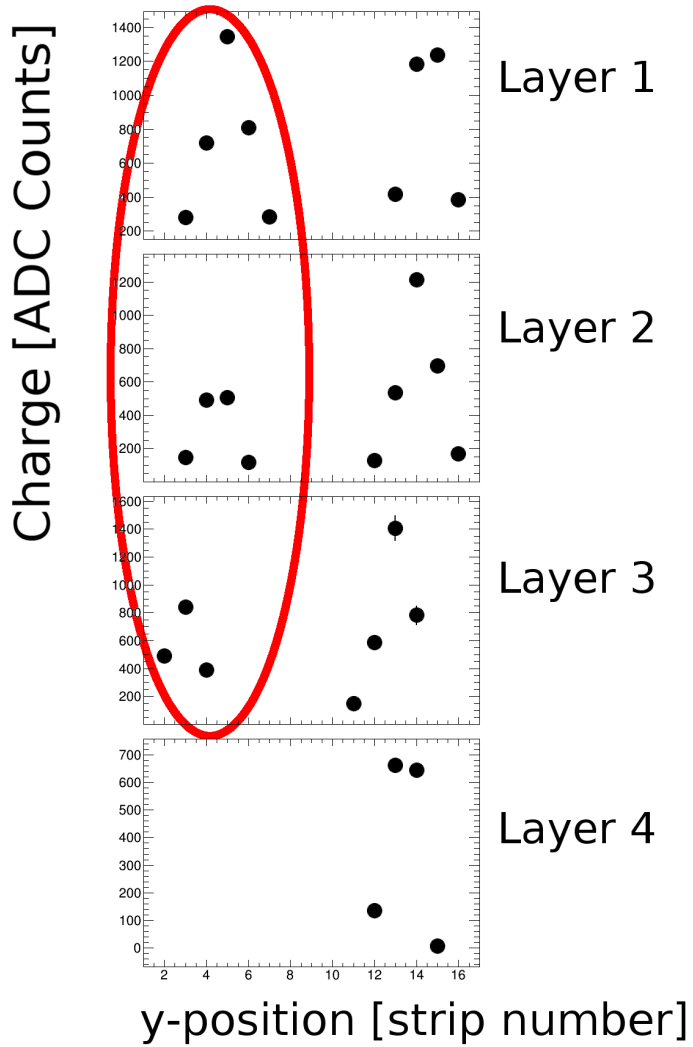


Contiguous hits form a cluster



Motivation for Multi-Cluster Event Analysis

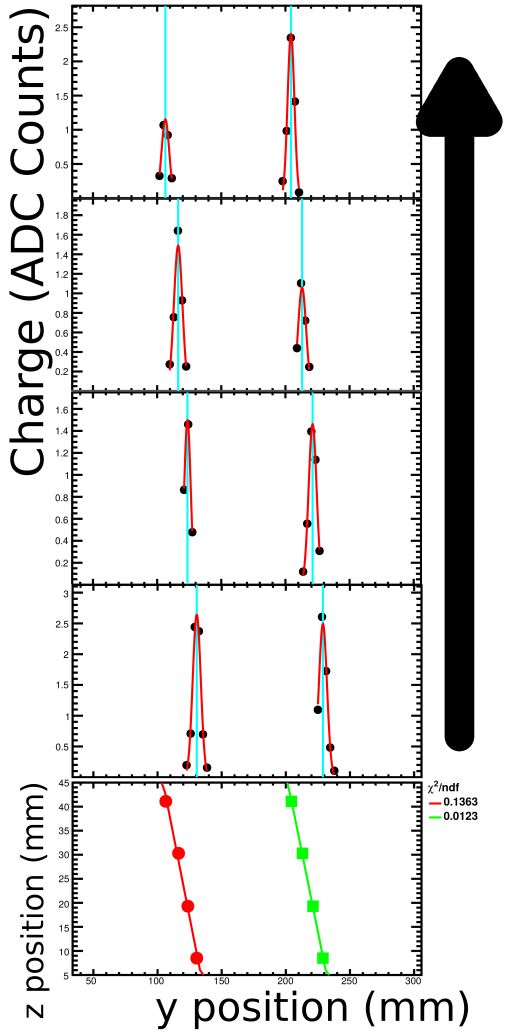
- Current sTGC analysis algorithm only does tracking using layers with at most one cluster
- We find that $\sim$ 4% cosmic muons produce $\geq$ 2 clusters in at least one of the layers
- Want to categorize multi-cluster events to know what we throw out of the analysis
  - $\geq$ 2 muons
  - delta-ray
  - spurious hits / false signals / other



Tracking Algorithm

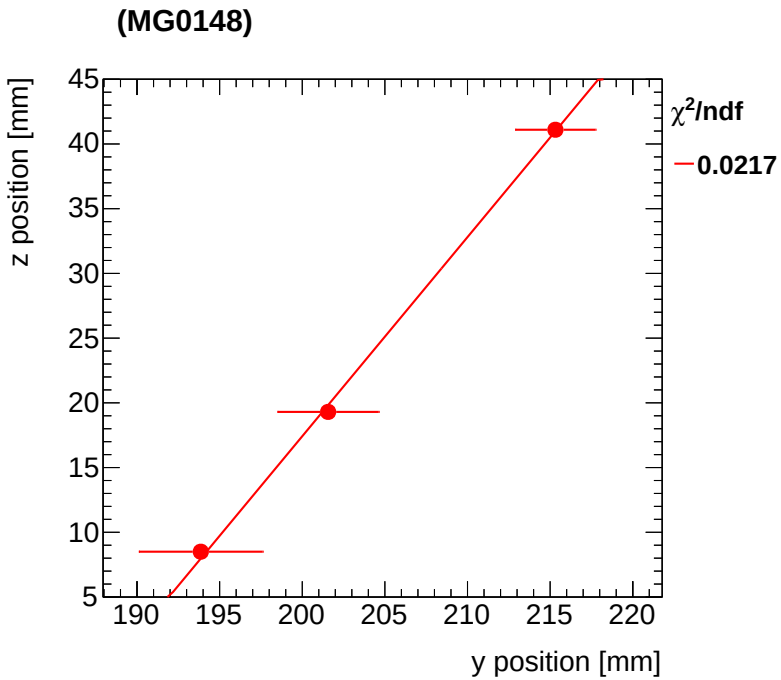
Félix Léger

- Current algorithm for multi-tracking is the following:
  - Separate clusters with 2 maxima into two individual clusters (if need be)
  - Try every possible combination of hits in an event to form a track containing a hit on every layer
  - Compare every track that contains 2 common hits and keep the track with smallest χ^2
  - For tracks with a common cluster, re-fit excluding this cluster.

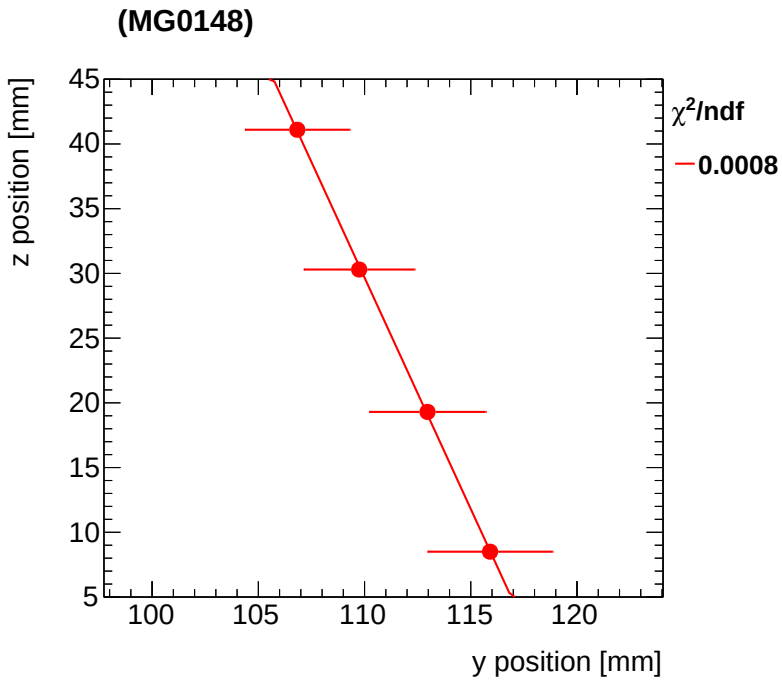


Different Event Categories (1/3)

Single track with 3 layers



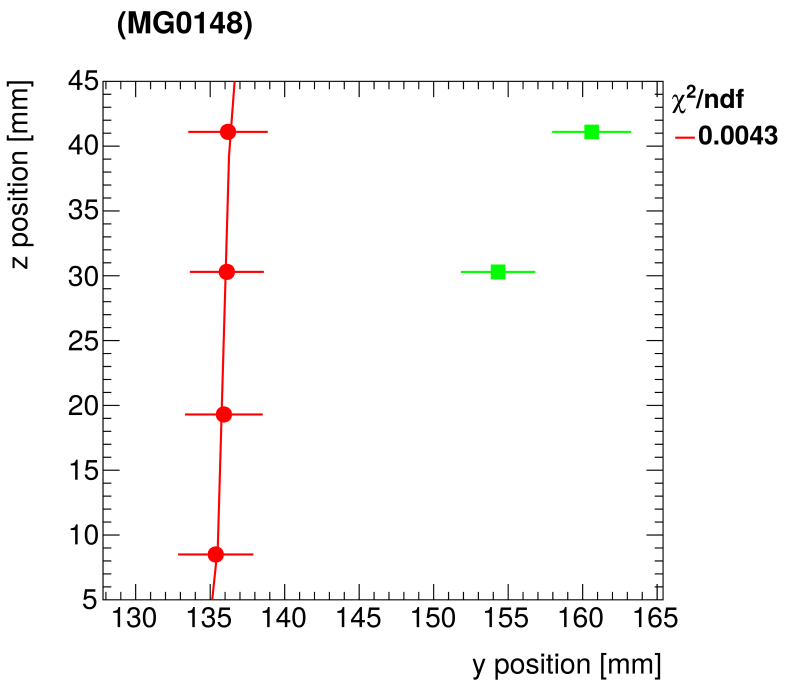
Single track with 4 layers



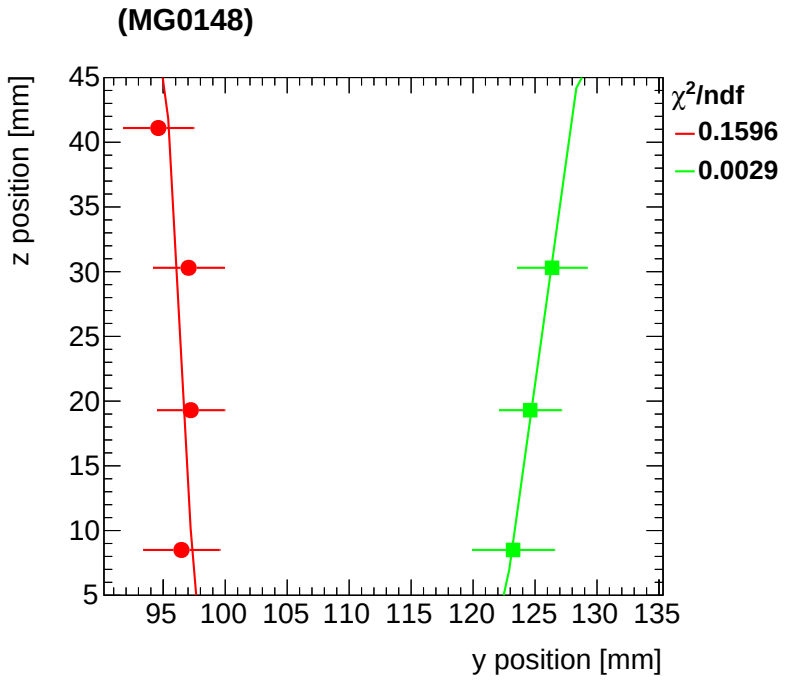
These events are used for efficiency and resolution measurements for the sTGC

Different Event Categories (2/3)

1 track, double cluster



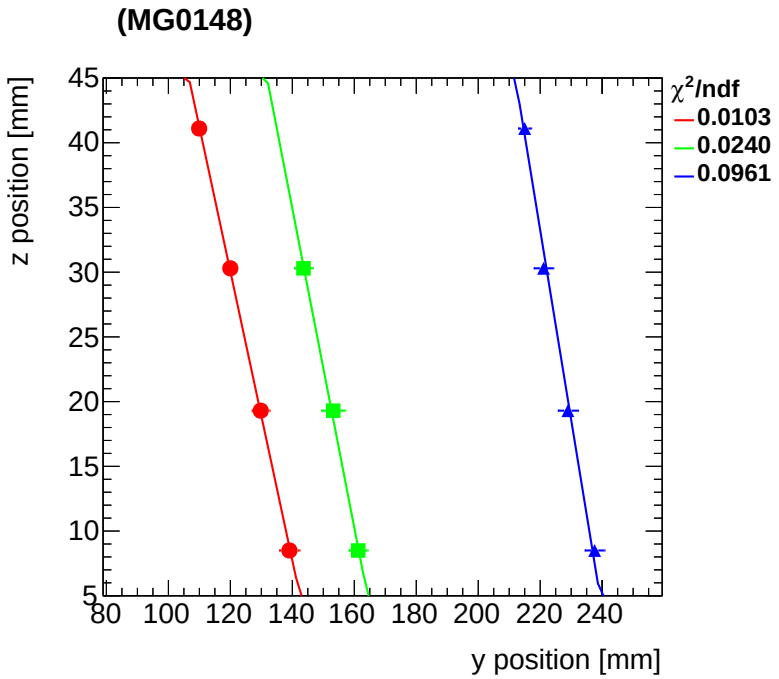
2 tracks



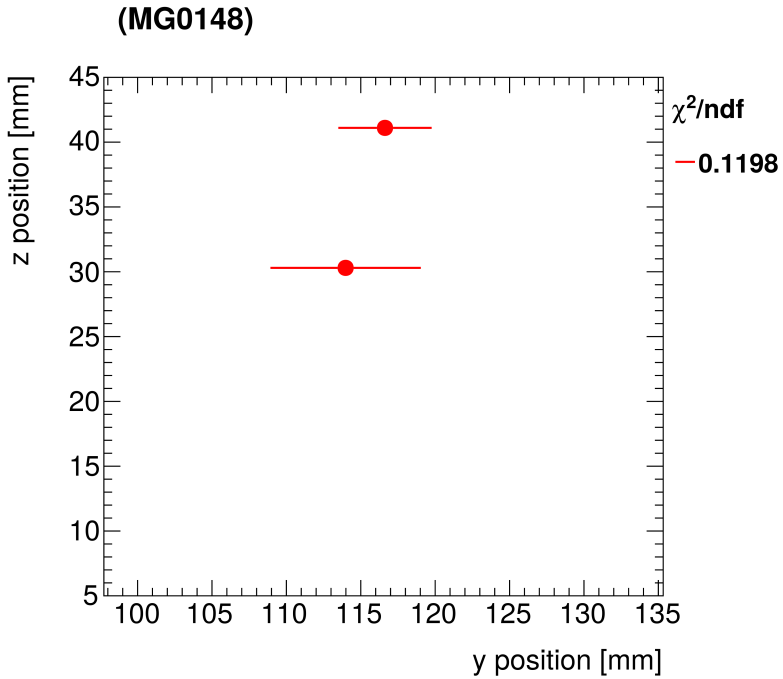
These events are not used for sTGC characterization

Different Event Categories (3/3)

3+ tracks

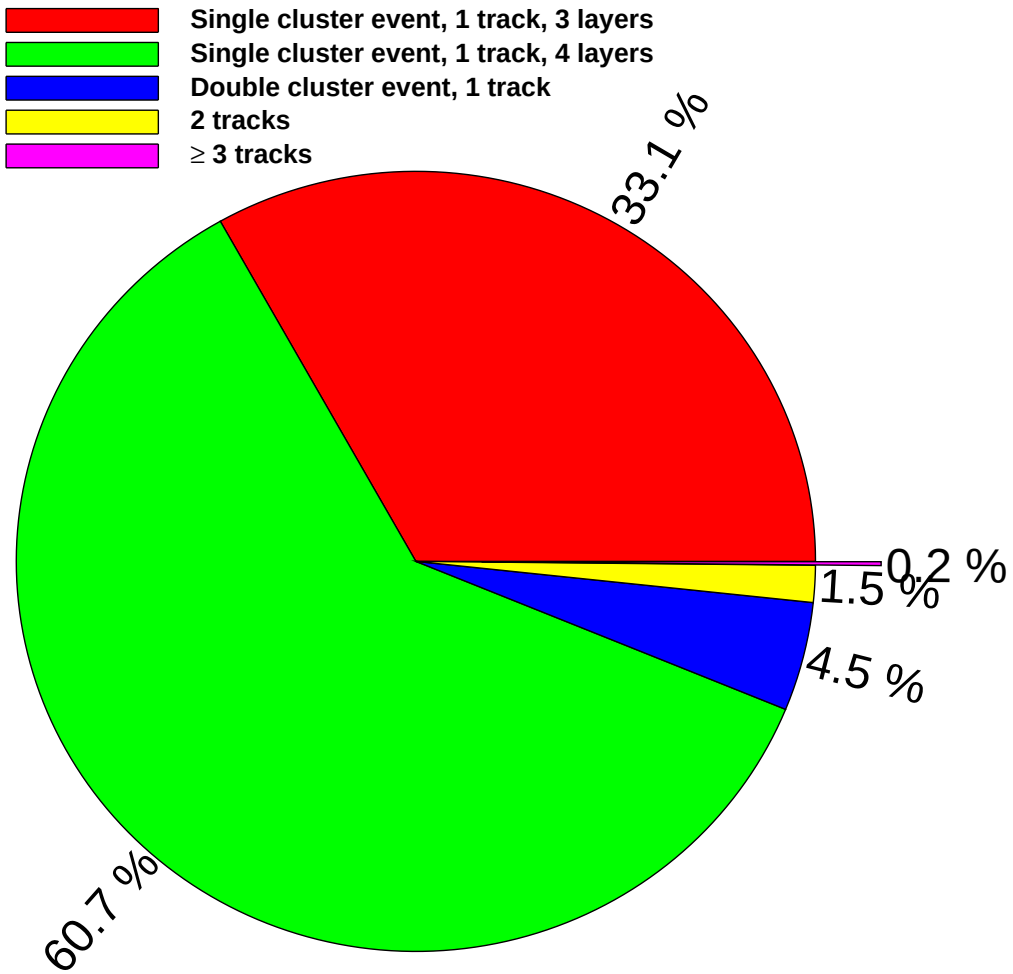


No tracks



These events are not used for sTGC characterization

Categorization of Cosmic Ray Events



$\sim$ 480000 events

- Categorizing events provides better understanding of data composition and event reconstruction

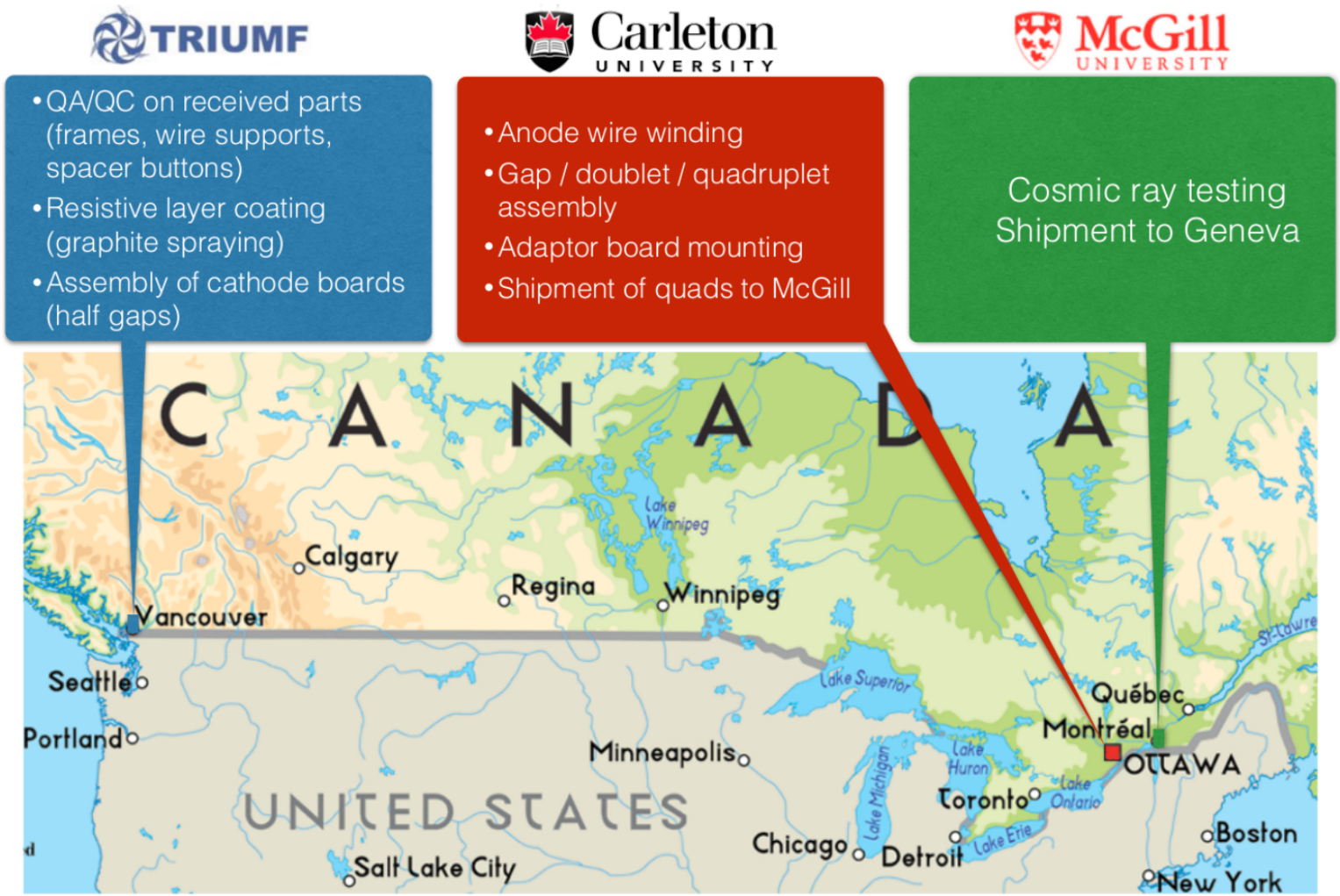
Summary and Outlook

- Testing facility physically located at McGill now fully operational, currently uses 40x60 cm^2 sTGC prototype
- The analysis of cosmic muon data is functional, extended the code to include multi-cluster tracking
- This process was useful to develop a better understanding of the sTGC data and to improve the track reconstruction
- First sTGC modules are expected to arrive at McGill during the summer

Thanks!

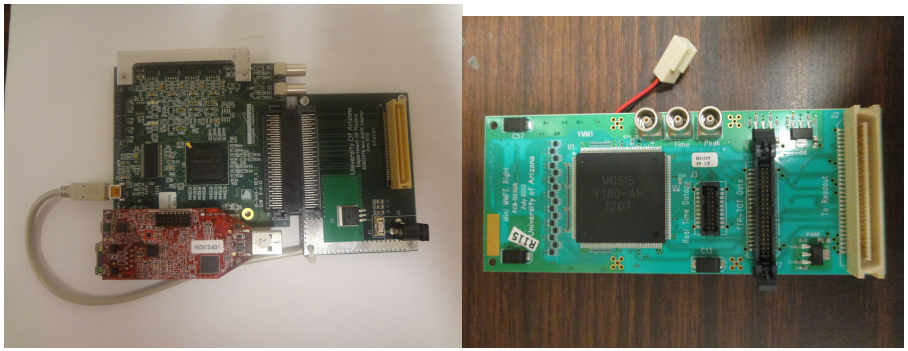
Backup slides

Canadian sTGC Production



sTGC Data Acquisition

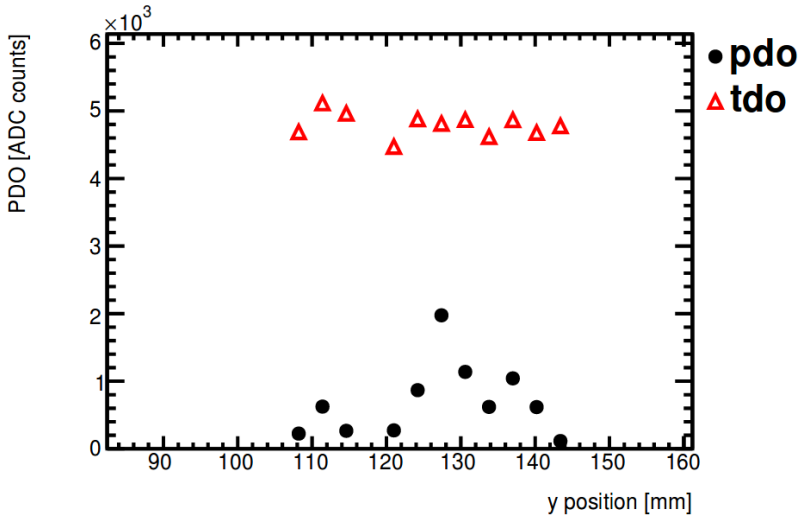
- Currently using first generation prototype of front end electronics (VMM1 ASIC)
  - 8 chips available (64 readout channels each) with associated interface cards for digitization and data formatting

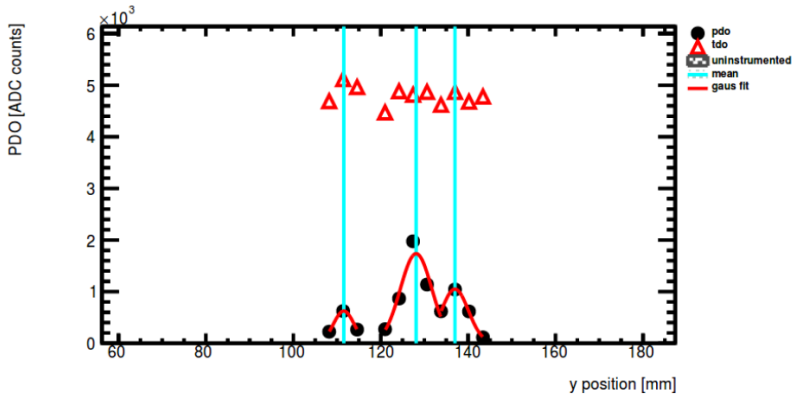


- Cosmic data processed for event building and data quality into ROOT trees
  - Same format as Fermilab testbeam 2014 (same electronics)
  - Main analysis package applies channel mapping and cuts, performs strip channels clustering and tracking, and finally computes various efficiencies and resolutions
  - Extensively used and tested, stable since May 2016
  - Will use VMM2 instead of VMM1 for testing at McGill

Cluster with 2 Maxima Separation Algorithm Demo

Before and after algorithm. Notice the cluster in the [120-140]mm range is continuous, but contains 2 bumps.





Cluster Cleaning Cuts

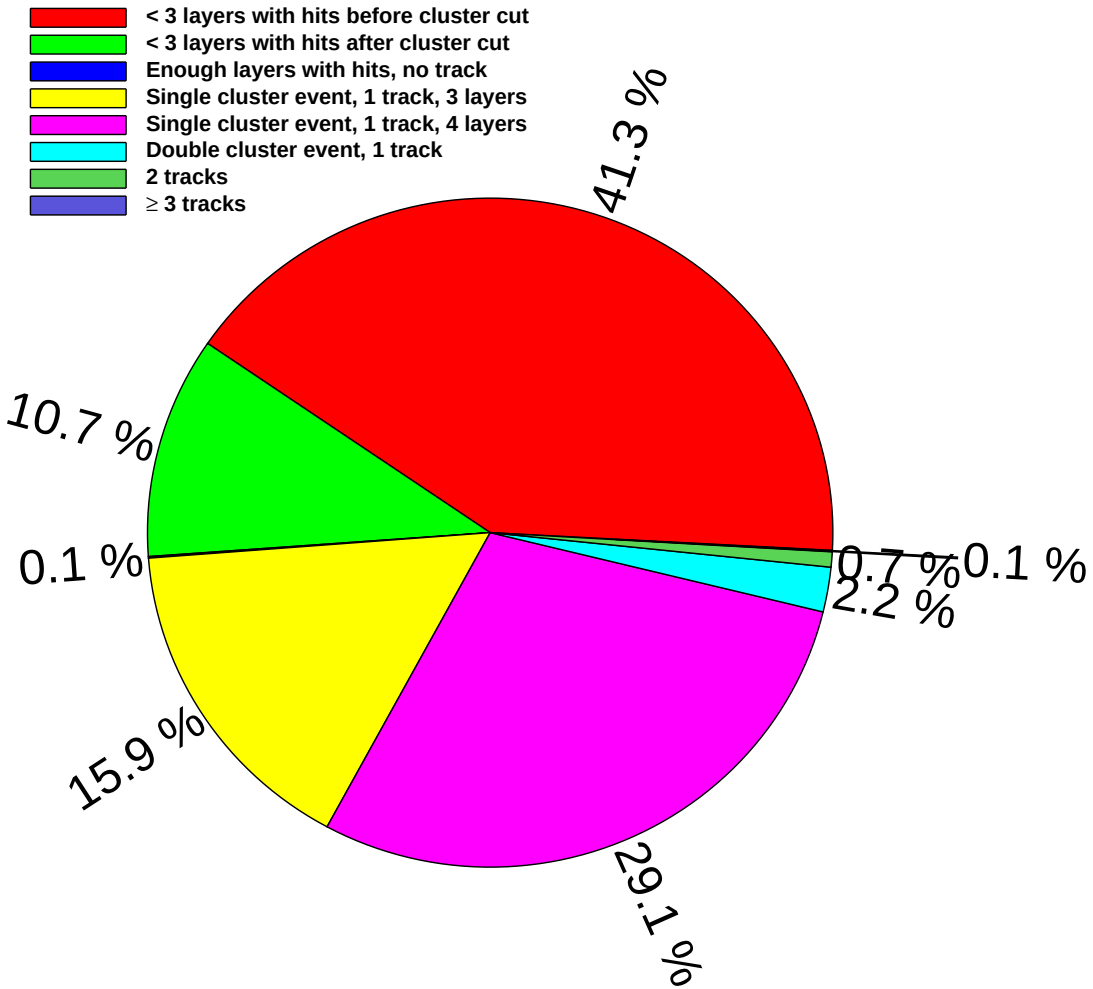
Before applying multi-tracking algorithm, these cuts are applied on clusters (strips, y-axis):

- Cluster must contain ≥ 3 strip hits
- Cluster cannot "touch" either extremity of the strips layer
- The leftmost and rightmost strip hits of a cluster cannot contain the peak

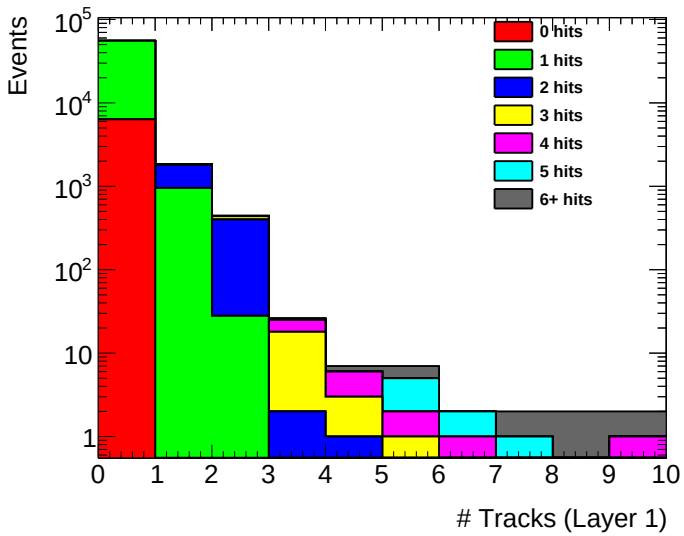
Categorization of Multi-Cluster Events

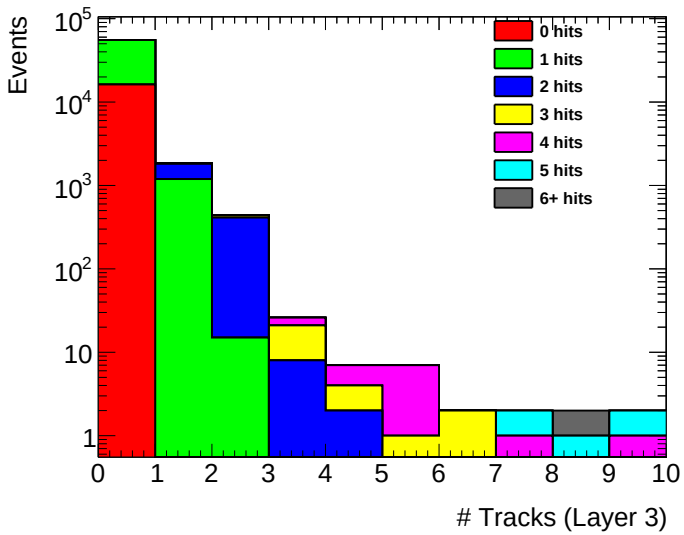
Same figure as previous pie chart, but includes events where tracking failed

10^6 events



Tracks VS # Clusters



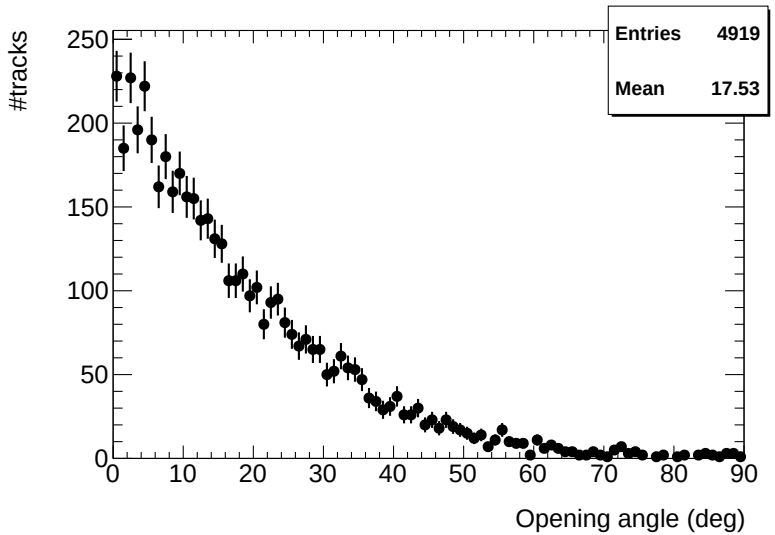


Relation between number of tracks and clusters for different layers

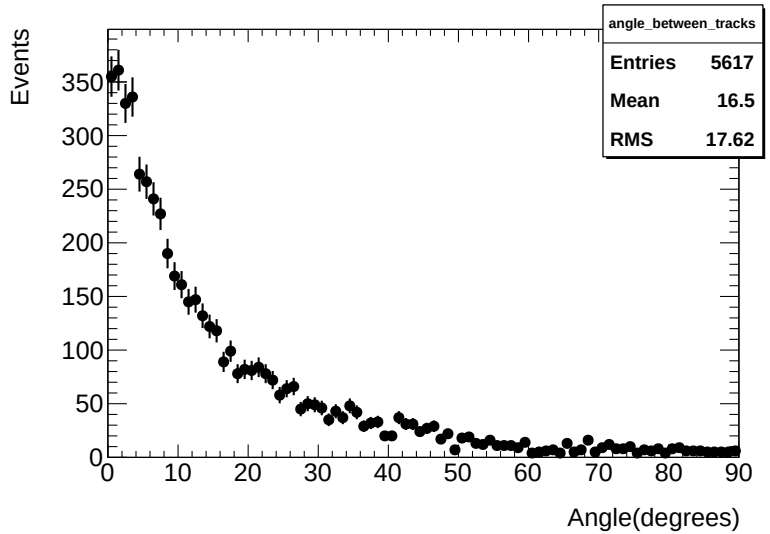
- The number of tracks roughly follows the number of hits on a layer
- Events with high number of tracks are rarer
- Statistics look similar on different layers
- $\Rightarrow$ follows expectations

Comparison with Simulation

Geant MC Simulation (cut for δ-ray)



Data from run MG0148



Very preliminary results, work in progress