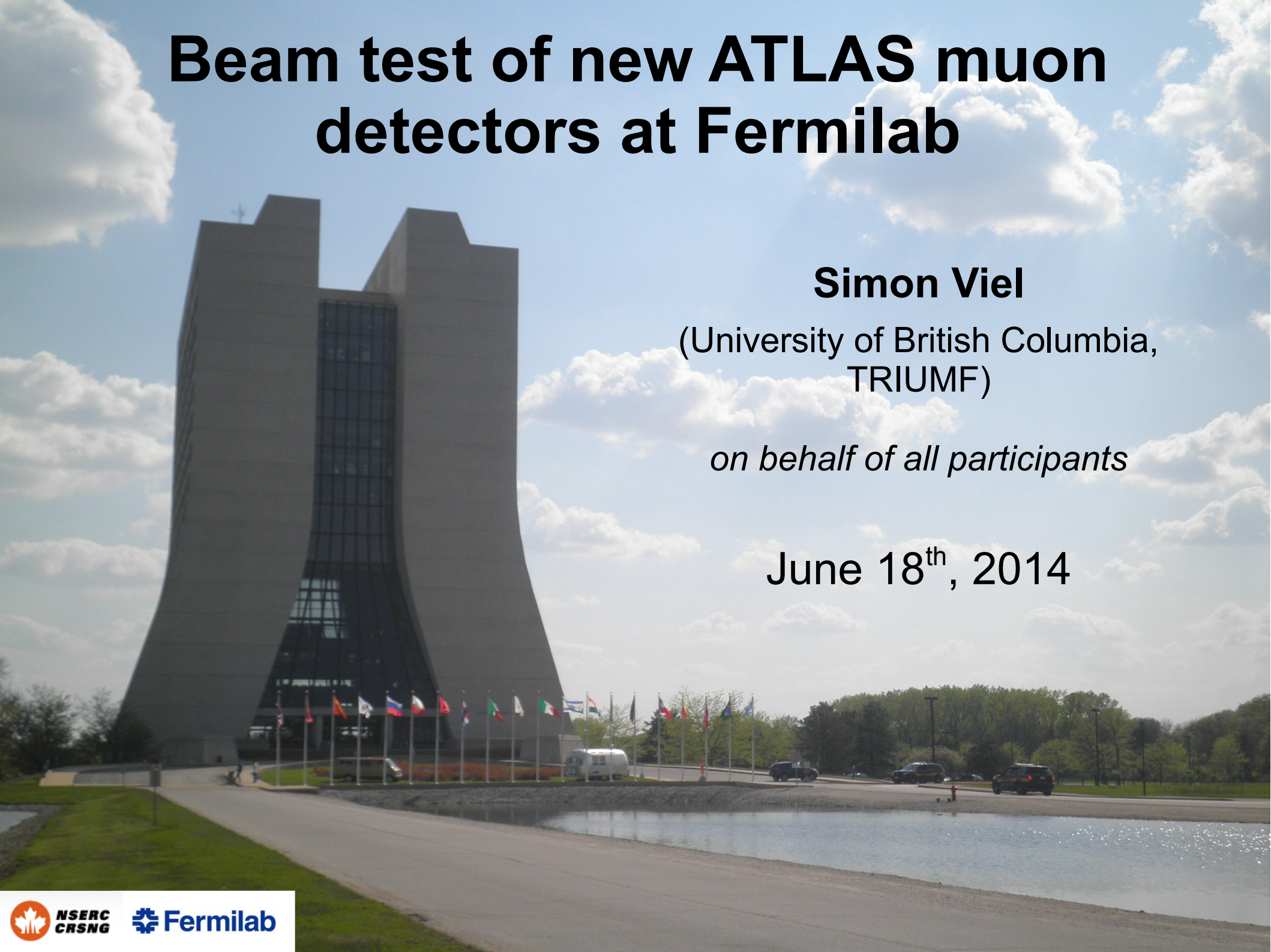
Beam test of new ATLAS muon detectors at Fermilab



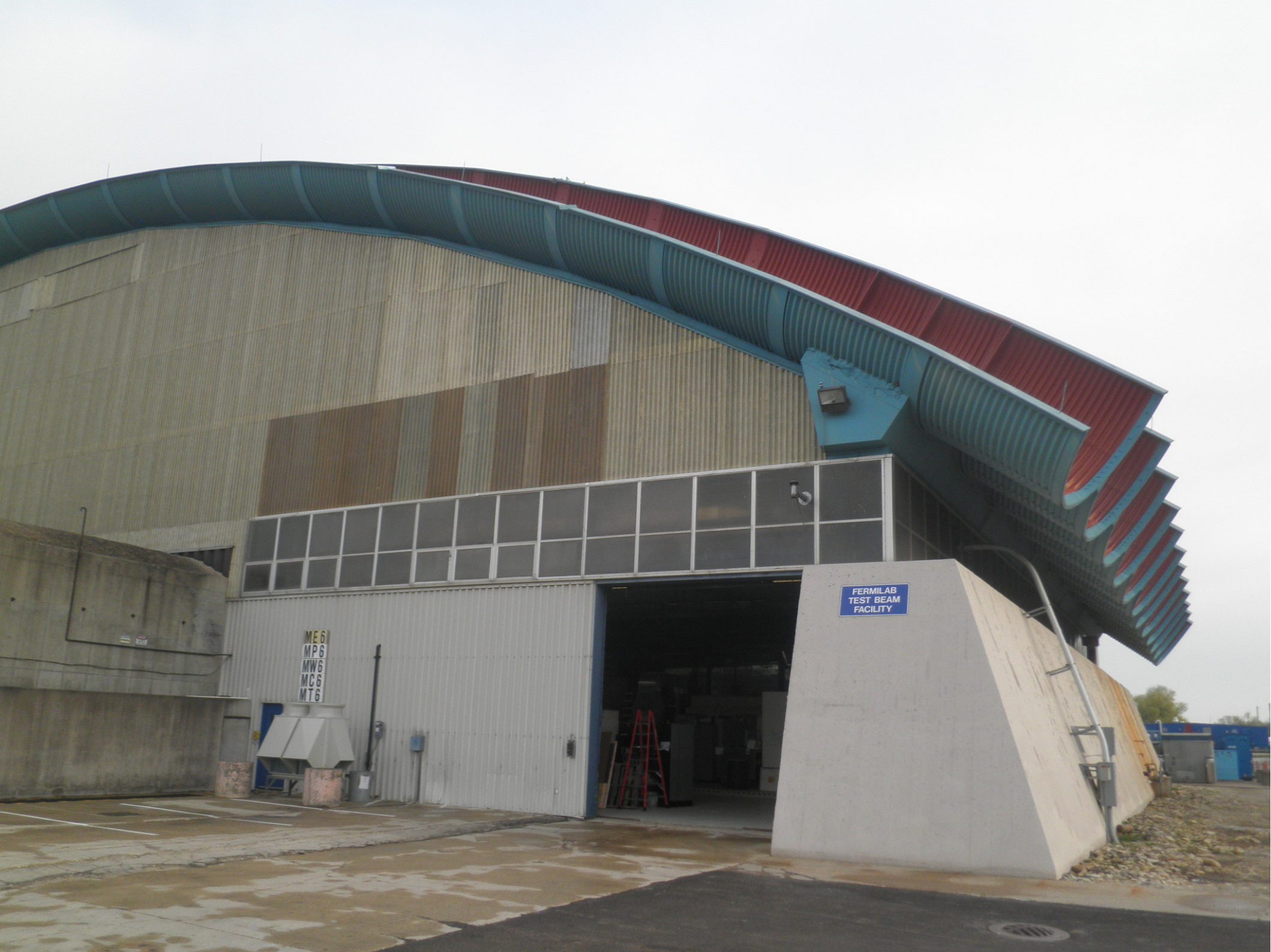
Simon Viel

(University of British Columbia, TRIUMF)

on behalf of all participants

June 18th, 2014

NSERC CRSNG Fermilab


FERMILAB
TEST BEAM
FACILITY
ME6
MP6
MW6
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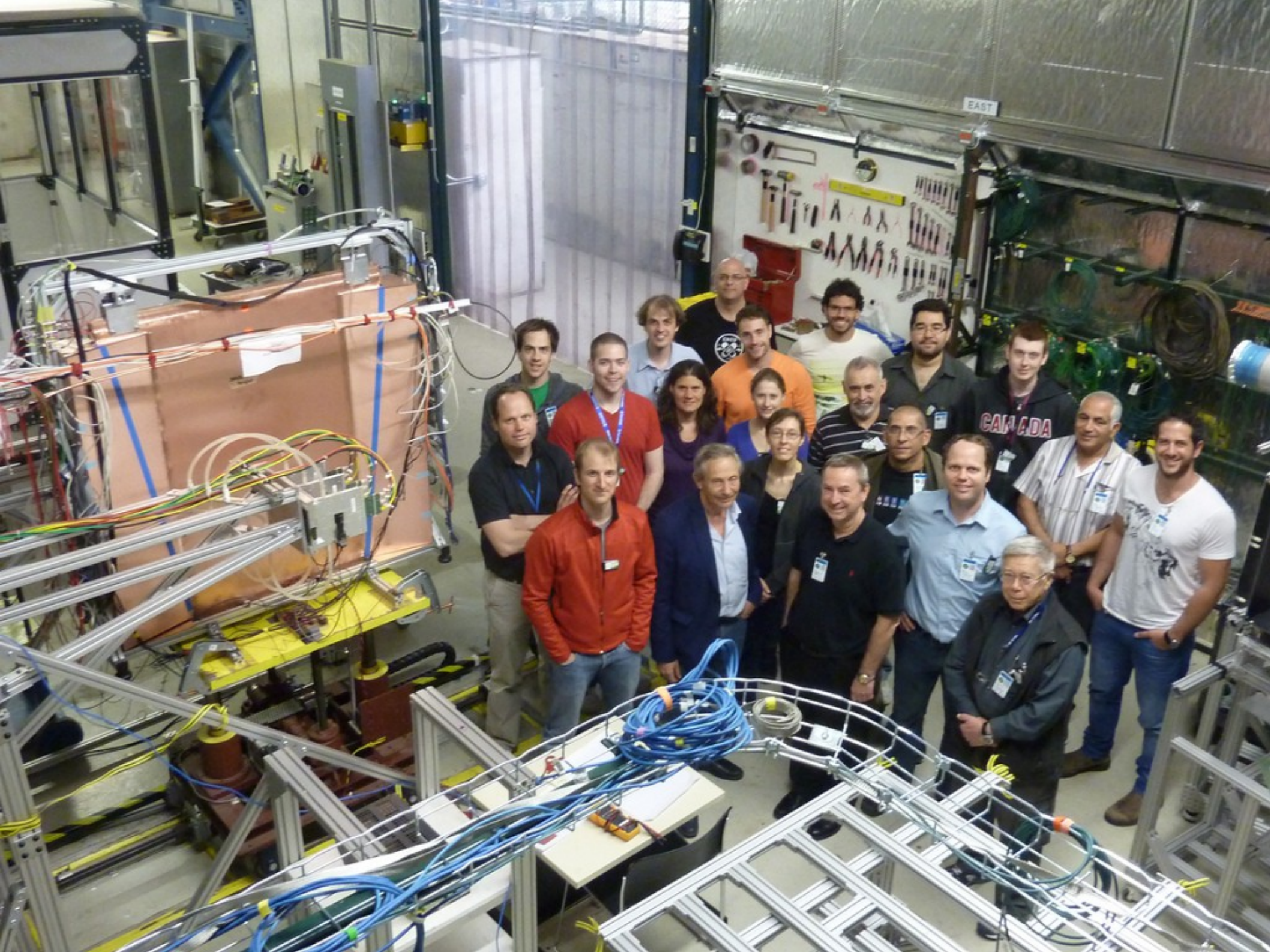
Fermilab Test Beam Facility
FERMILAB
TEST BEAM
FACILITY
AED
AED
AED
AED


EAST
CANADA

FTBF Experiment T-1049 – May 7-22, 2014

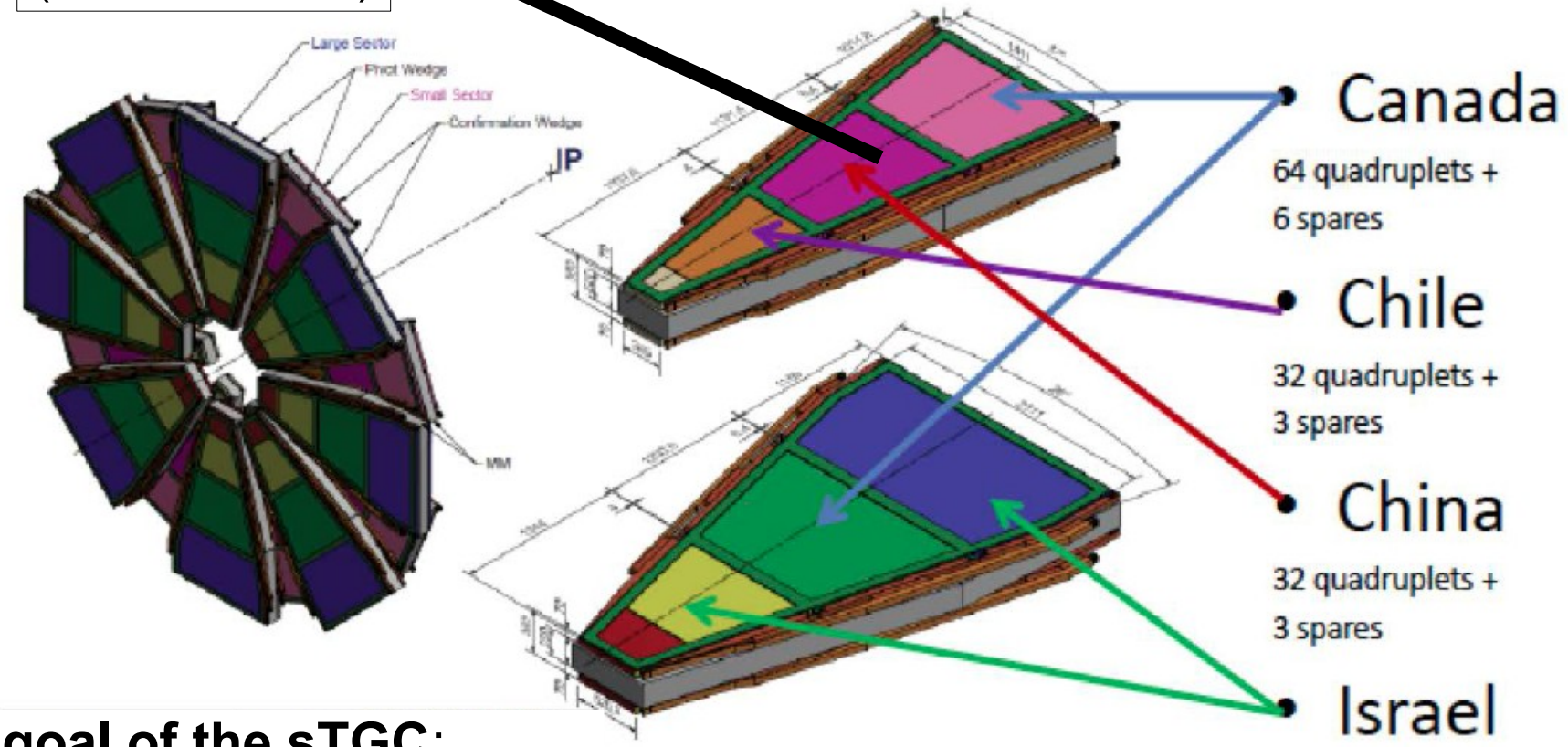
- **Israel**
  - Weizmann Institute (G. Mikenberg, M. Shoa, V. Smakhtin)
  - Tel Aviv University (Y. Benhammou, H. Cohen, M. Davies)
  - Technion - Israel Institute of Technology (N. Lupu, A. Vdovin)
- **Canada**
  - Carleton University (A. Bellerive, T. Koffas, J. Botte, S. Rettie, S. Weber, M. Batygov, P. Gravelle, M. Bowcock)
  - McGill University (B. Vachon, B. Lefebvre, C. Bélanger-Champagne, A. Robichaud-Véronneau)
  - Université de Montréal (L. Gauthier)
  - Simon Fraser University (B. Stelzer, H. Torres, D. Mori)
  - TRIUMF (O. Stelzer-Chilton, E. Perez Codina, S. Viel)
- Collaborators from **Chile** (Universidad Técnica Federico Santa Maria, Pontificia Universidad Católica de Chile) and **China** (Shandong University) could unfortunately not be present

small-strip Thin Gap Chamber prototypes

Module -1

(Made in Israel)

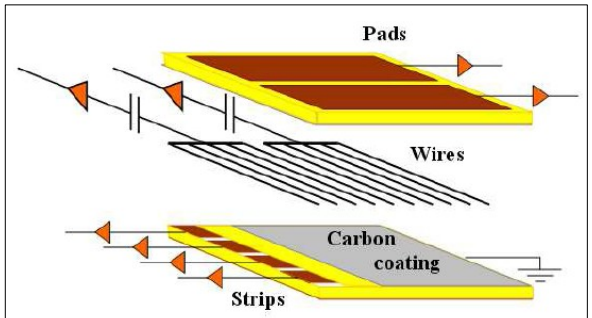
And a 40x60 cm^2 chamber



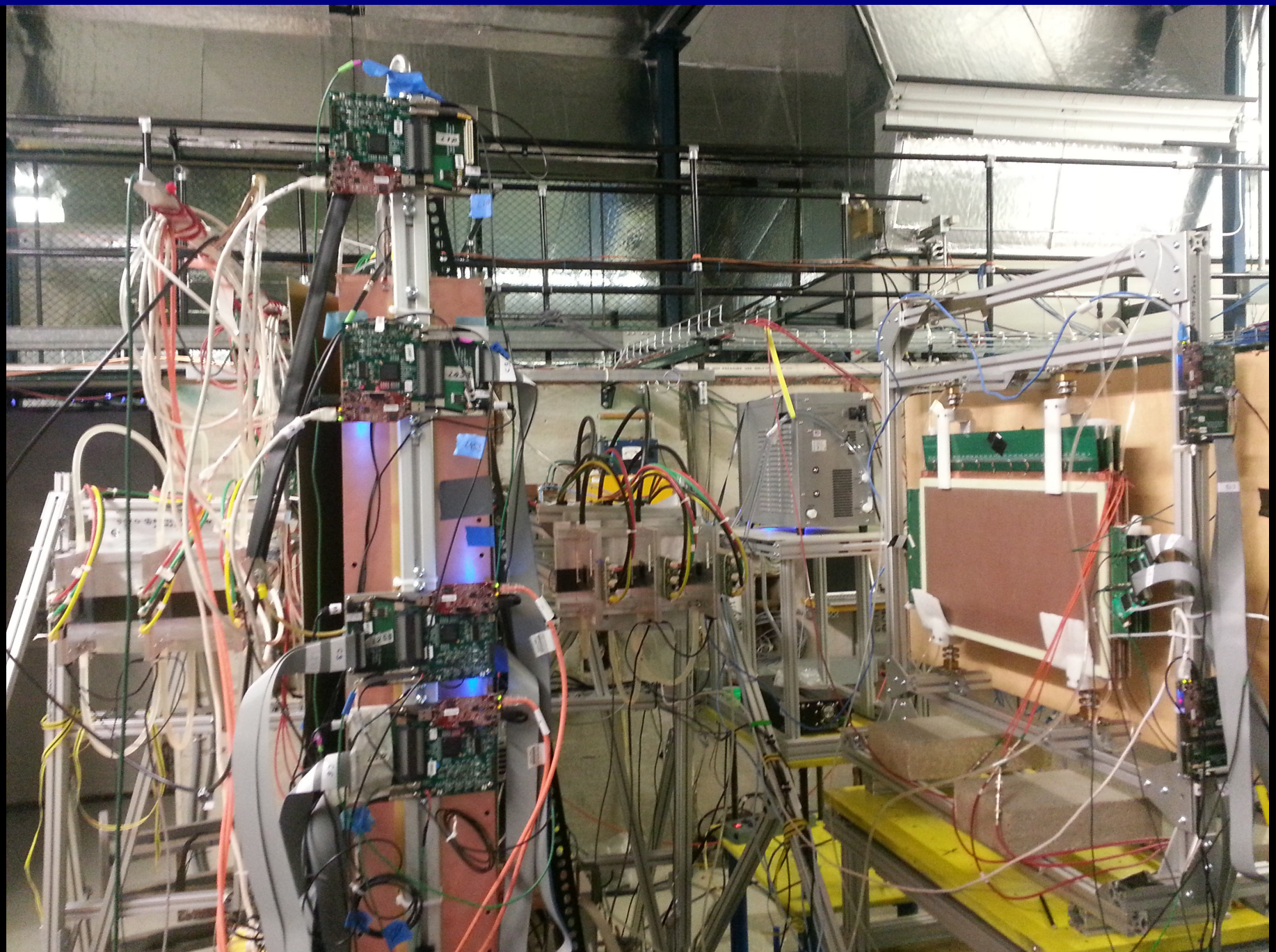
- **Canada**
  64 quadruplets +
  6 spares
- **Chile**
  32 quadruplets +
  3 spares
- **China**
  32 quadruplets +
  3 spares
- **Israel**
  64 quadruplets +
  6 spares

Main goal of the sTGC:

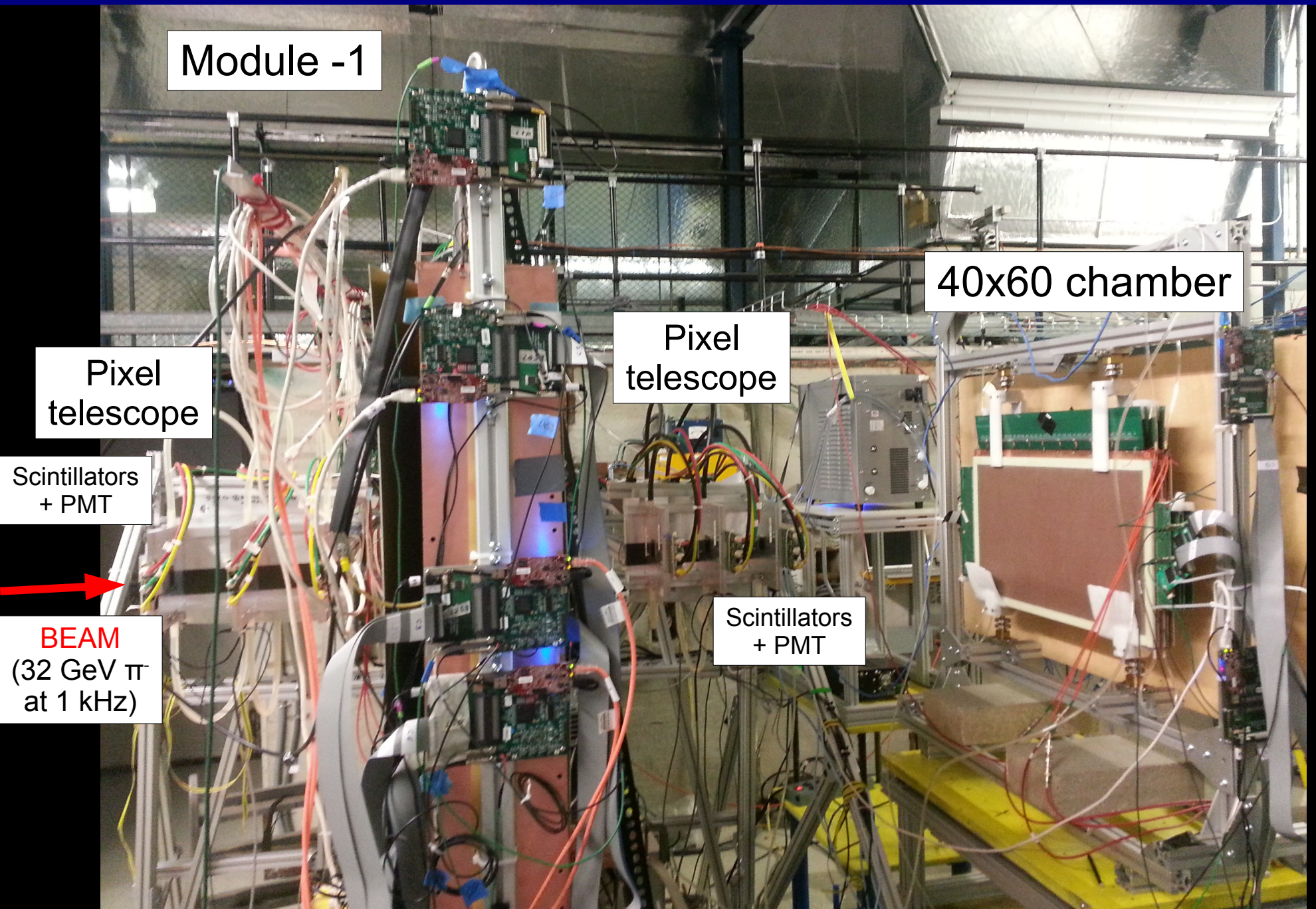
Enhance trigger capabilities in the ATLAS Muon Spectrometer for operation at the very high LHC collision rates after 2018



Experimental setup



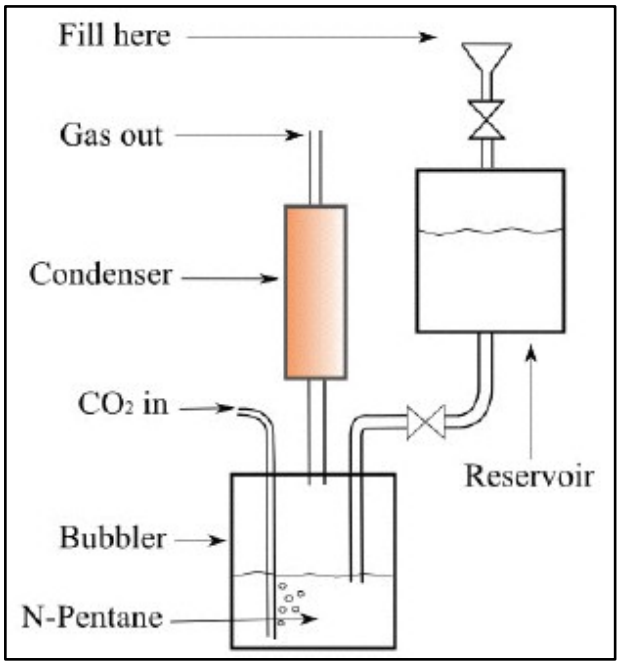
Experimental setup



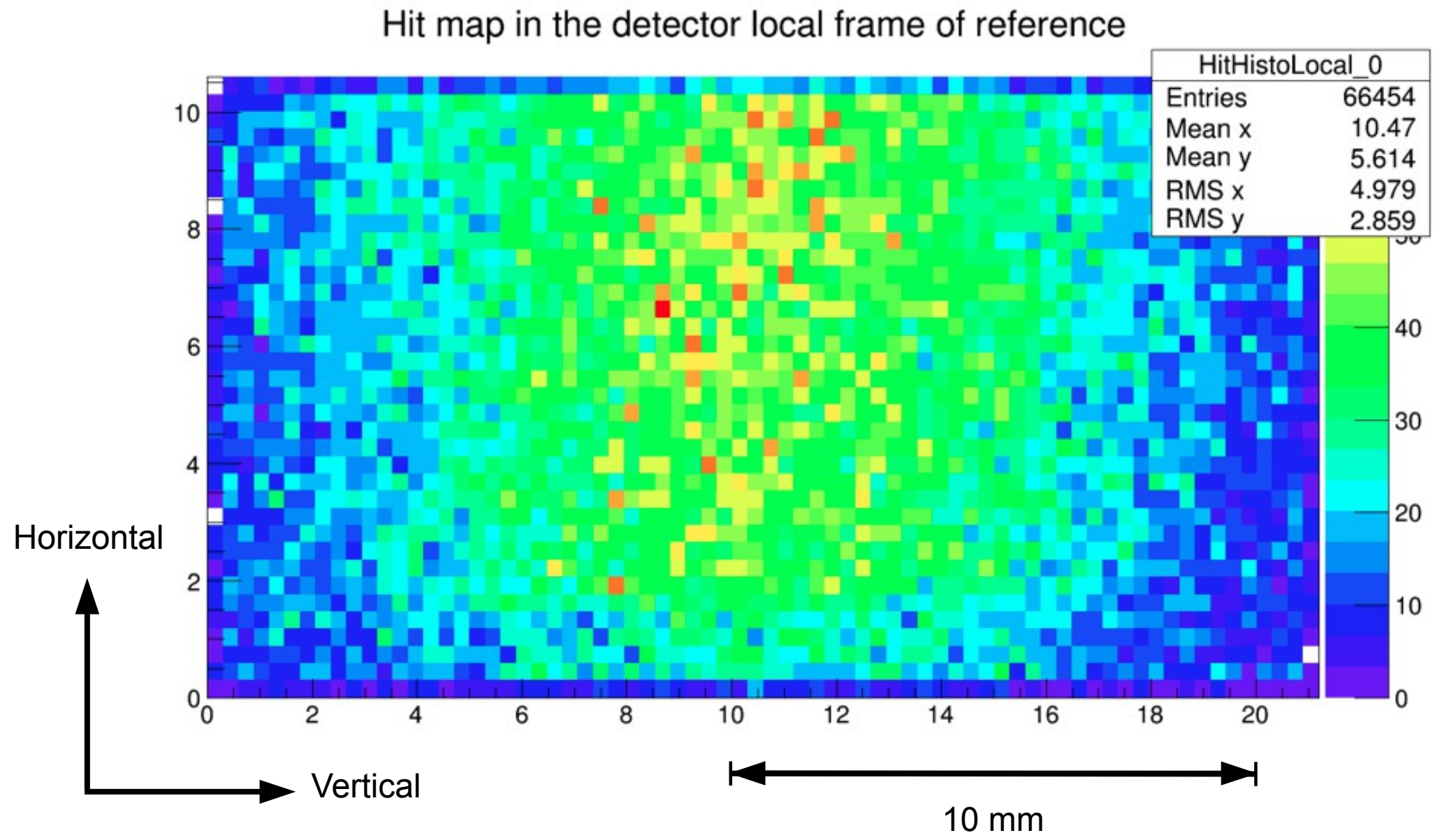
Experimental setup

- sTGC chambers filled with a mix of **55% CO_2** and **45% n-pentane**
- Result: a highly-quenching mixture in which electrons drift at high velocities, making possible the use of the sTGC as **trigger** chambers

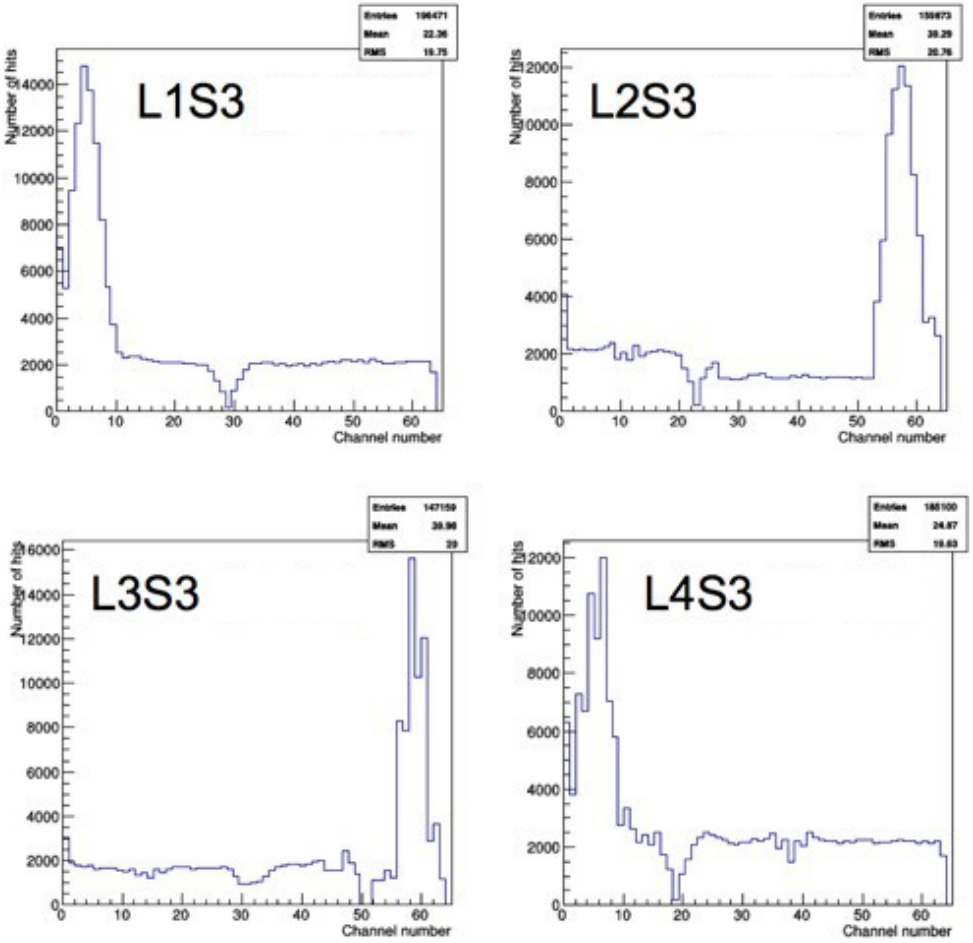
Gas system

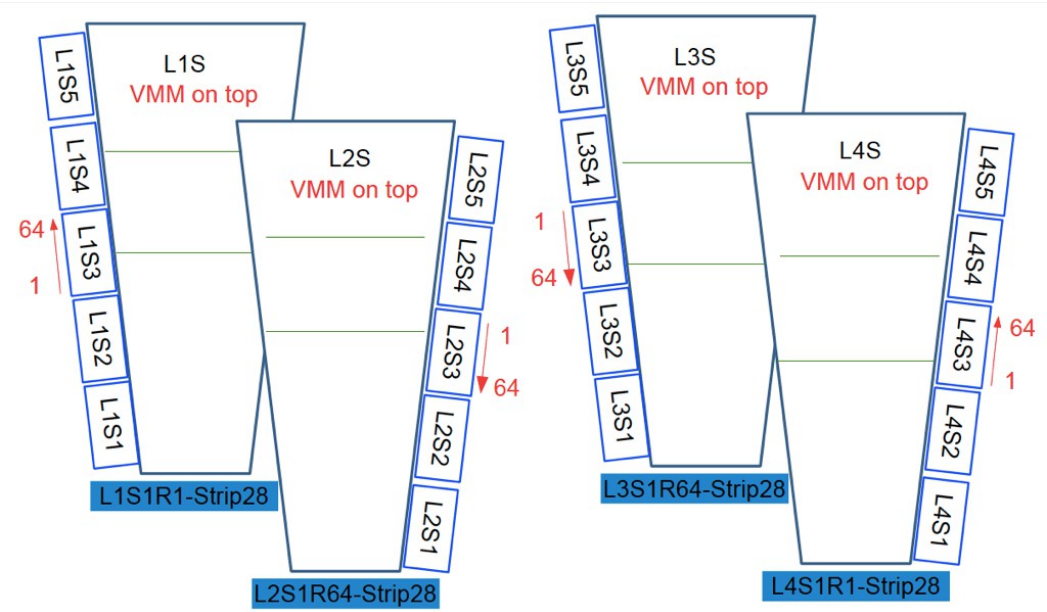


Pixel detector hit map with beam



First beam run (including cosmic rays)



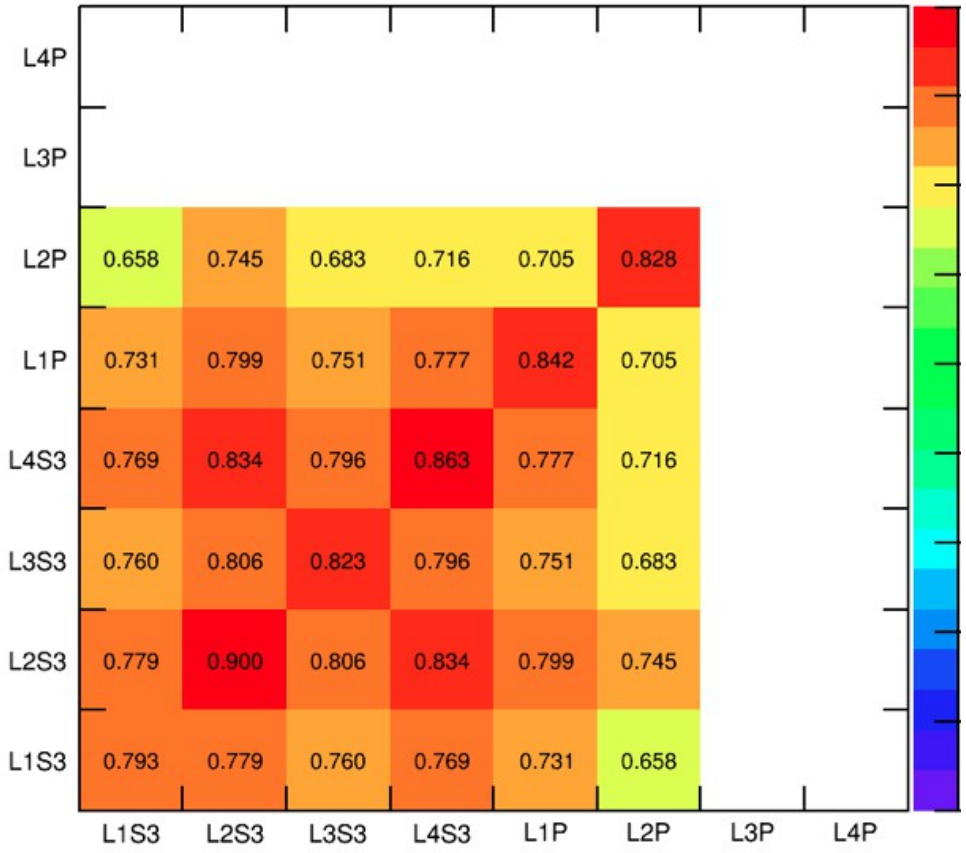


- The middle of the Module -1 (S3) is read out for all four layers
- The **support** structure can be seen

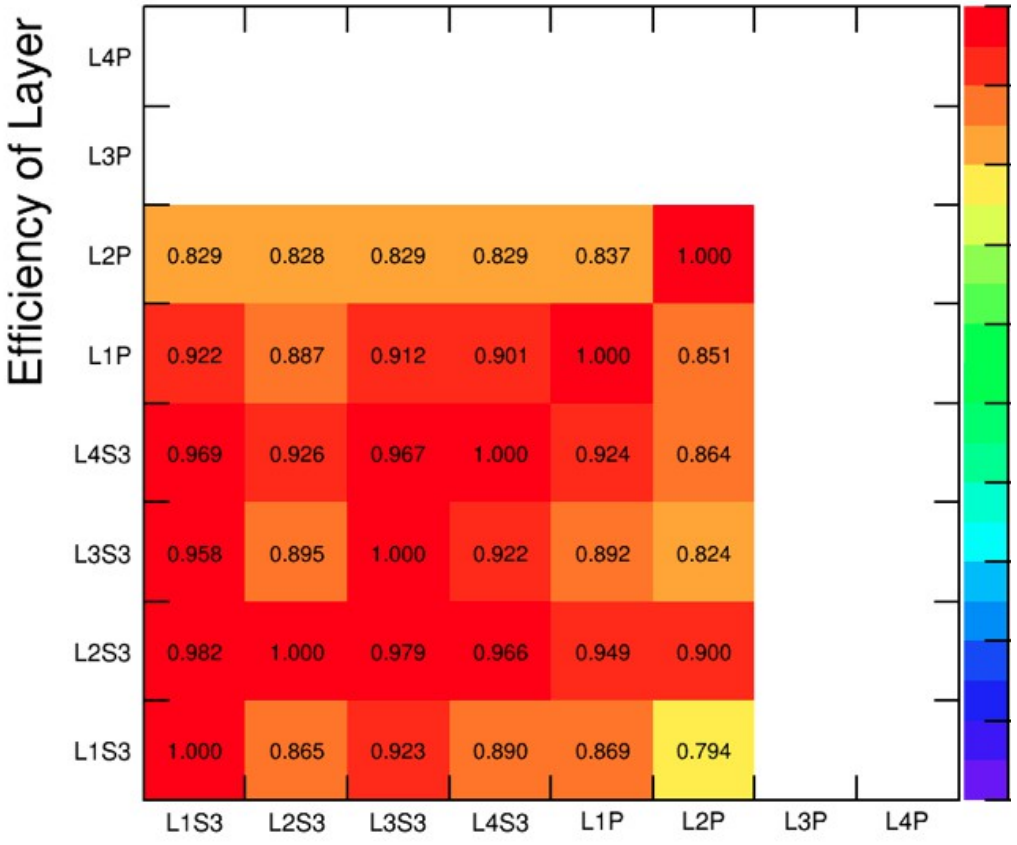
- **Online data quality monitoring** proves essential to detect synchronization problems, dead and noisy channels to avoid, and to tweak the chamber gain and threshold values

sTGC readout synchronization

- This and next slides: **Preliminary results for Module -1**
  - Observed synchronization between layers read out:
    - More work is necessary to fully understand the synchronization patterns

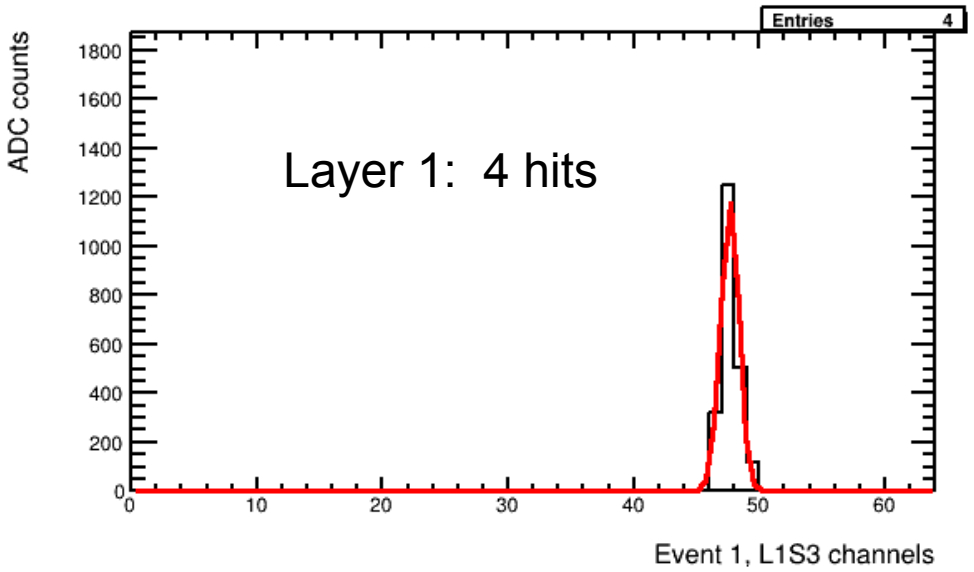


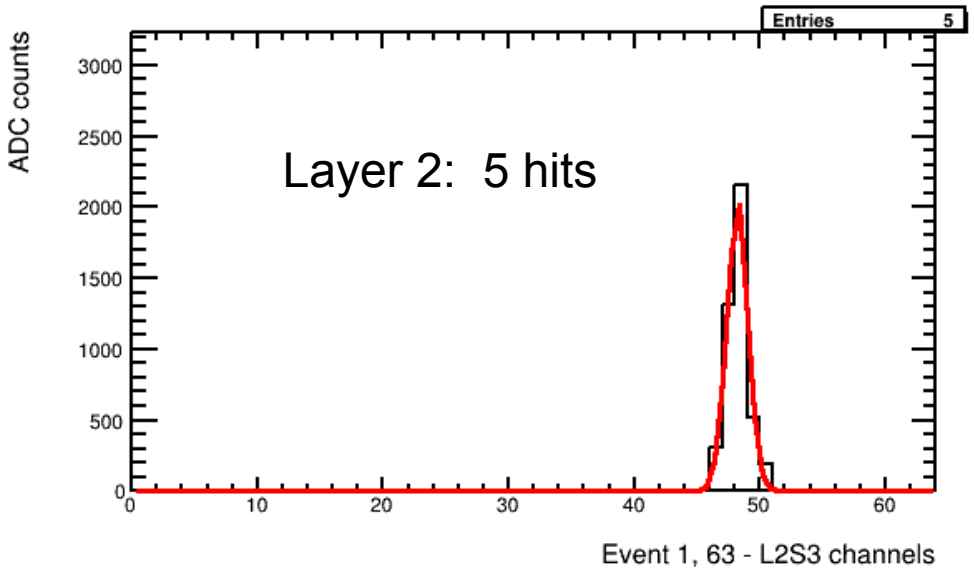
2D: Coincidence rates for clusters and pads

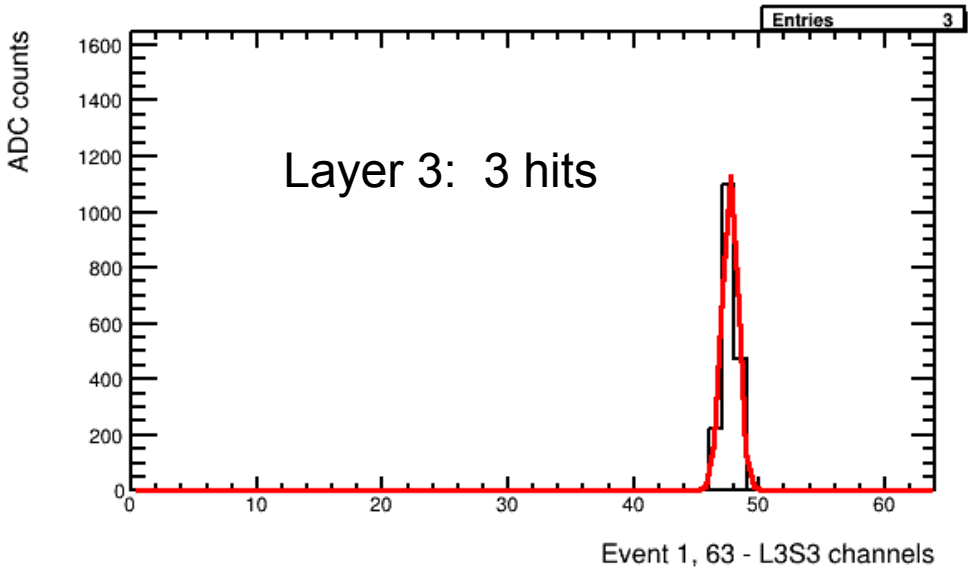


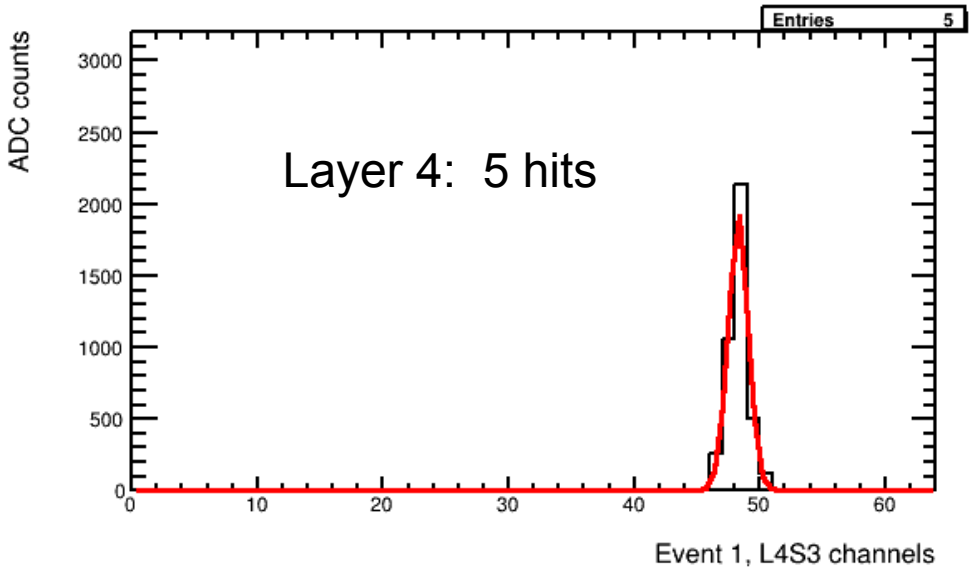
With Respect to Layer

Example selected event from Module -1

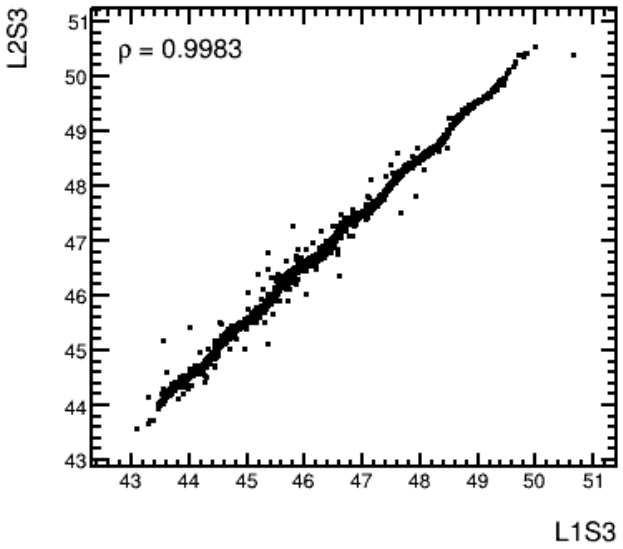


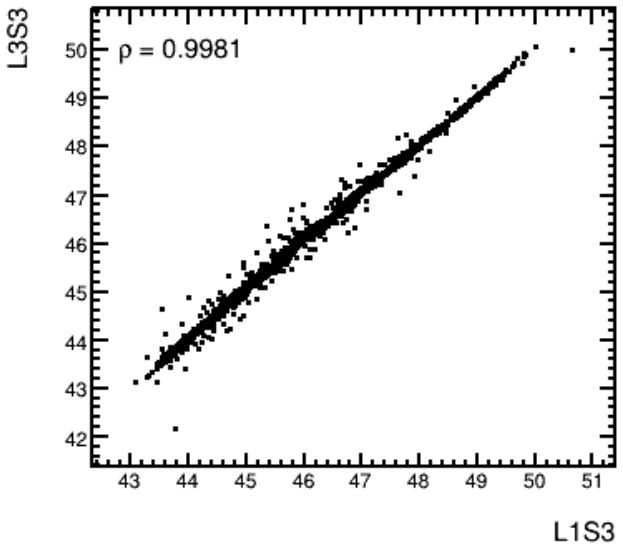


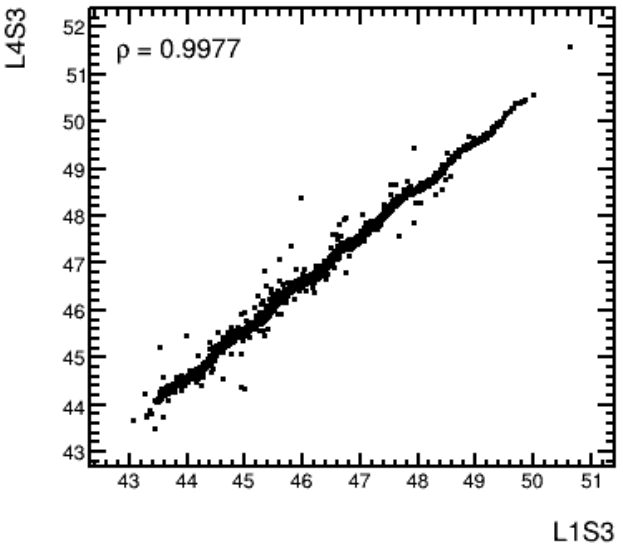


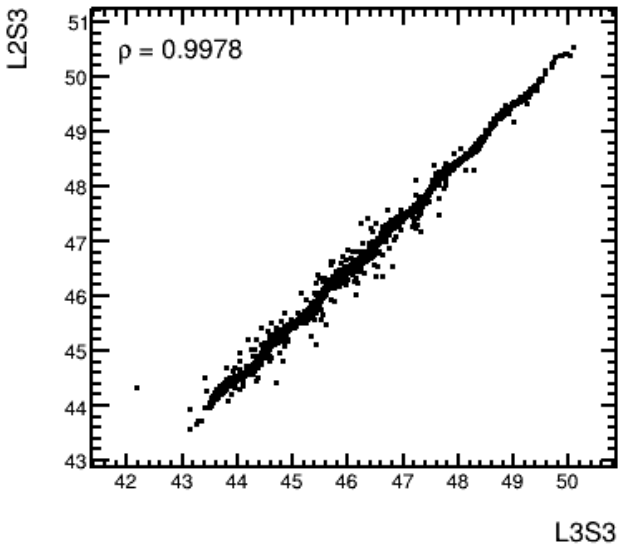


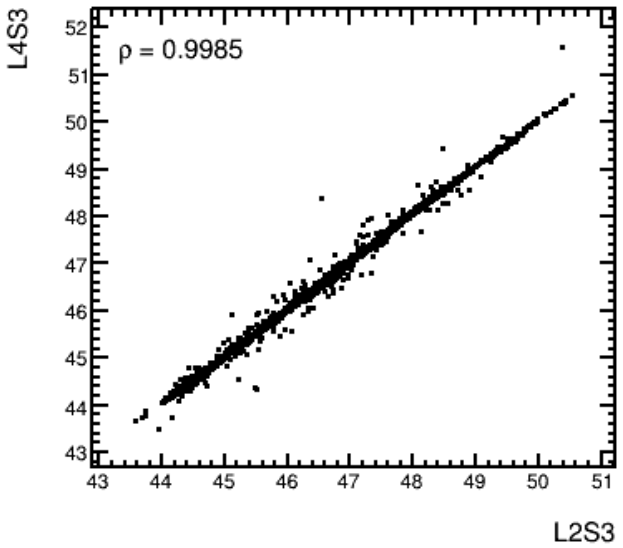
sTGC cluster centre correlations, uncorrected

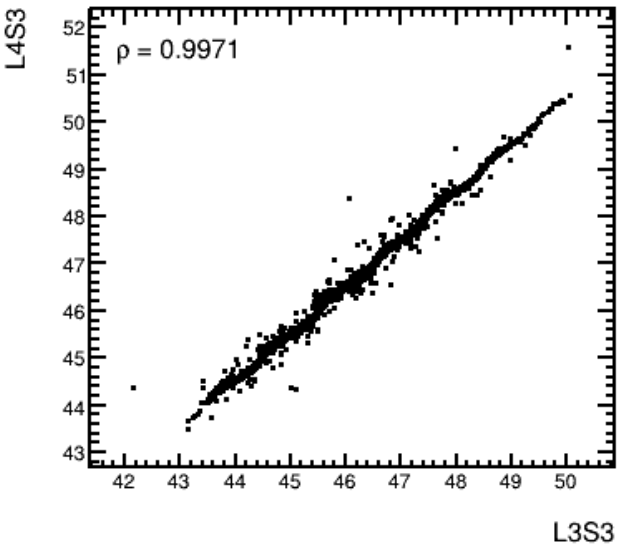




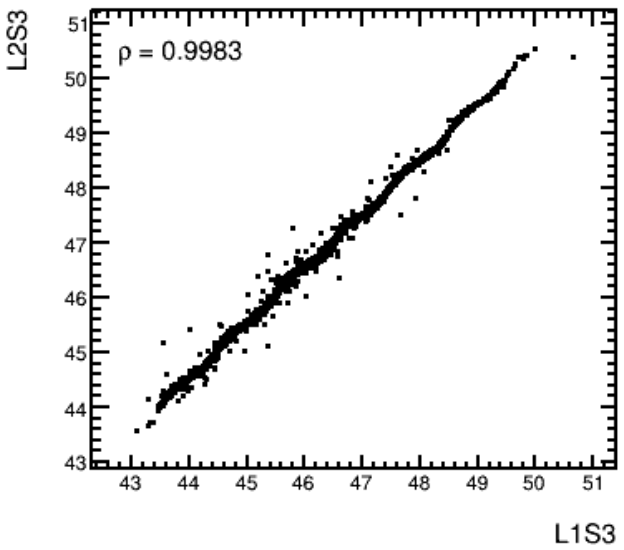


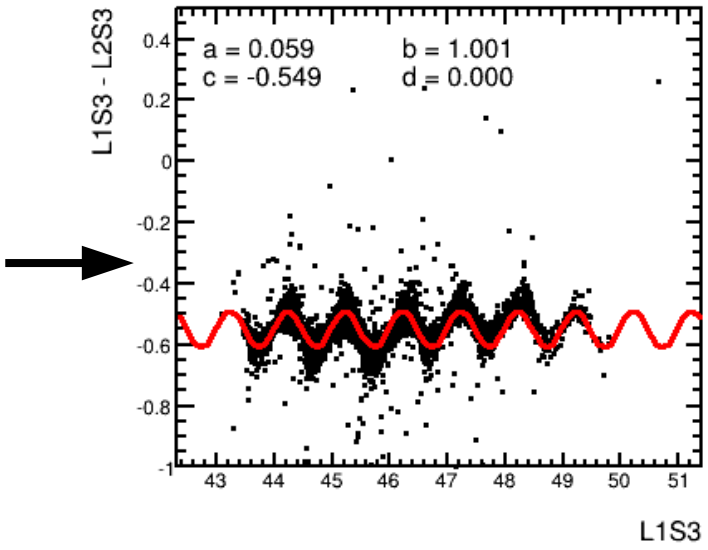


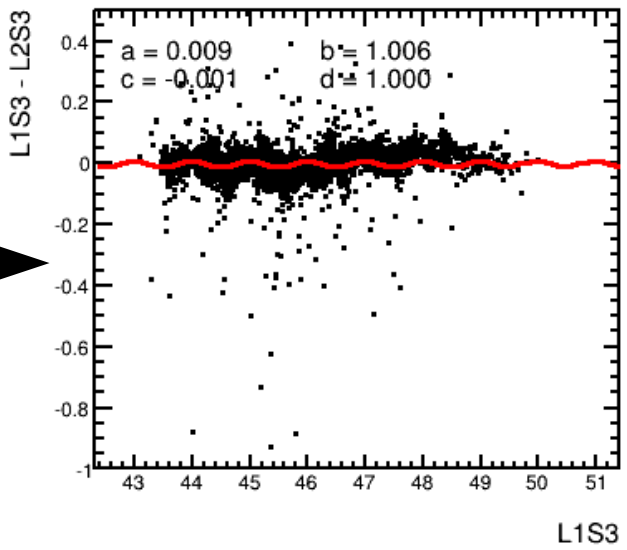




sTGC cluster centre corrections

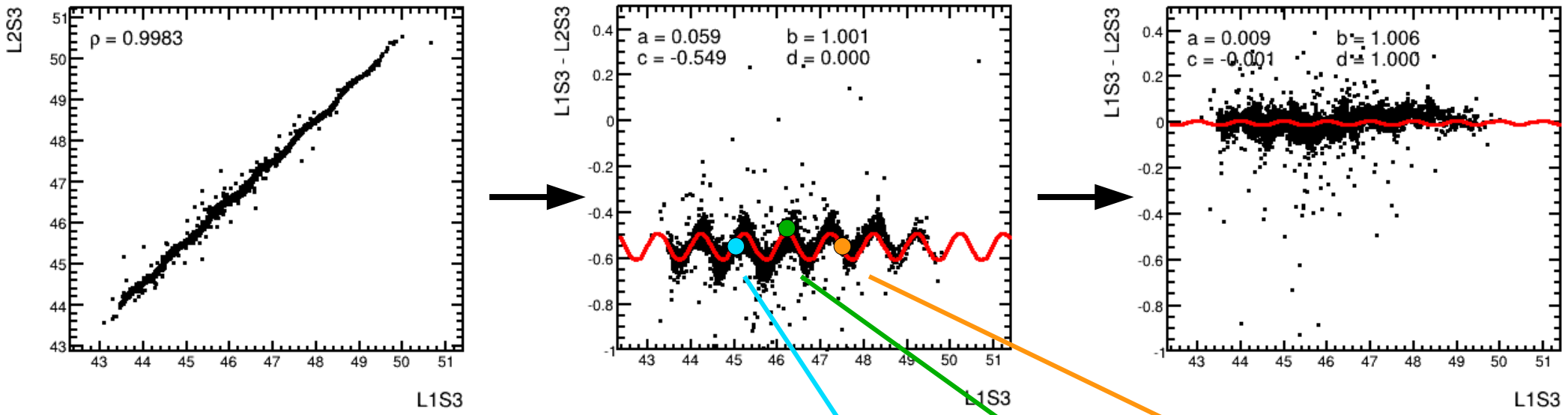




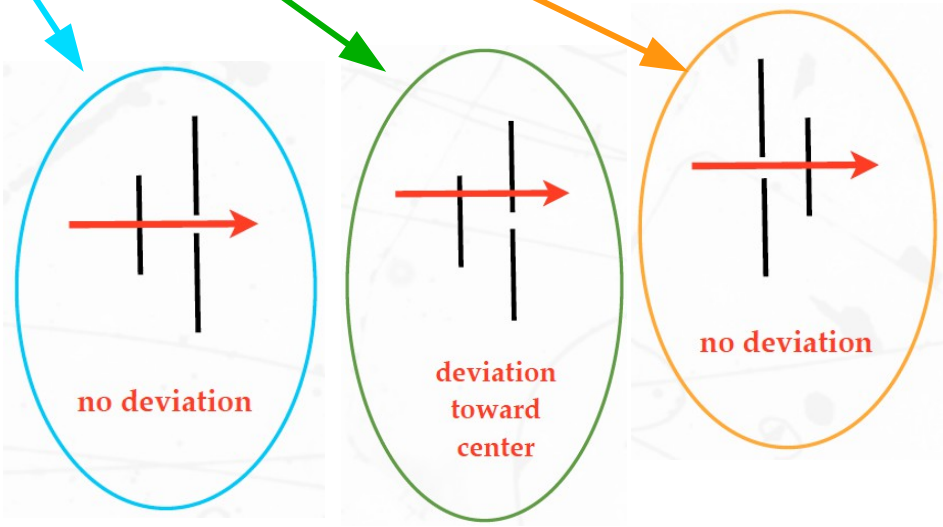


- **Rotate** and **zoom**
  - Sine wave structure clearly visible
- **Fit**: $f(y_1) = a \sin(2\pi (b\, y_1 + d)) + c$
- **Apply** correction

sTGC cluster centre corrections

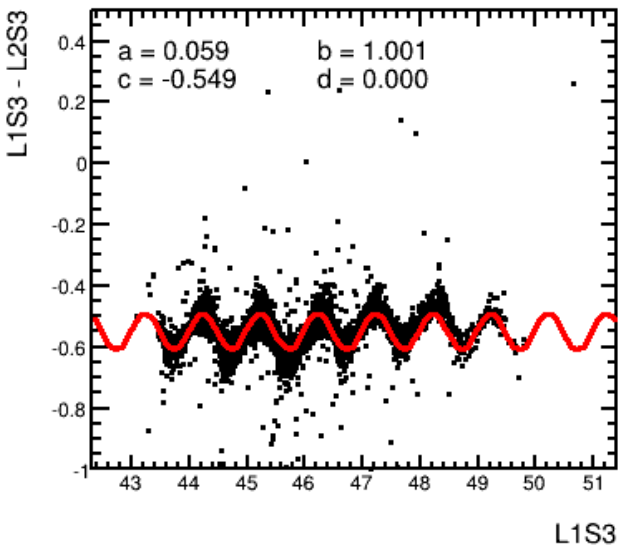


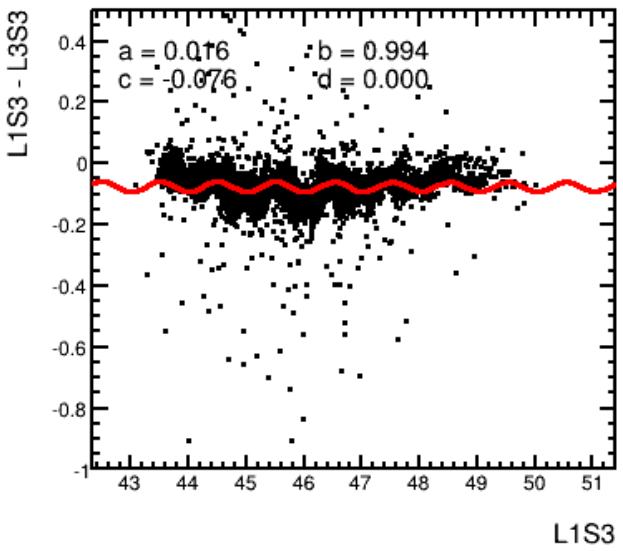
- **Rotate** and **zoom**
  - Sine wave structure clearly visible
- **Fit**: $f(y_1) = a \sin(2\pi (b\, y_1 + d)) + c$
- **Apply** correction

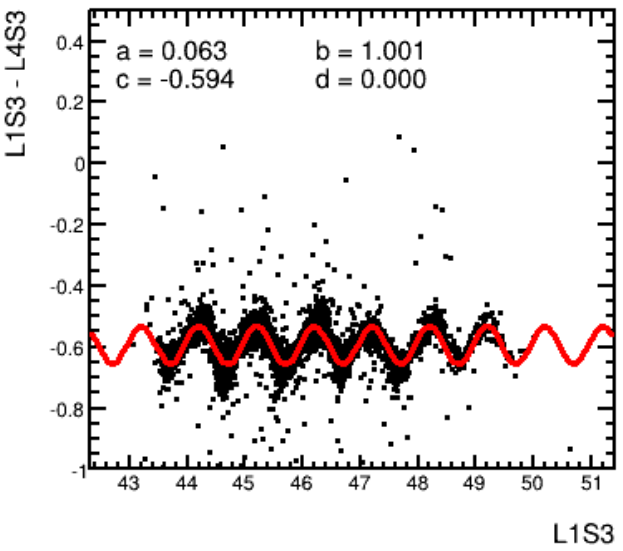


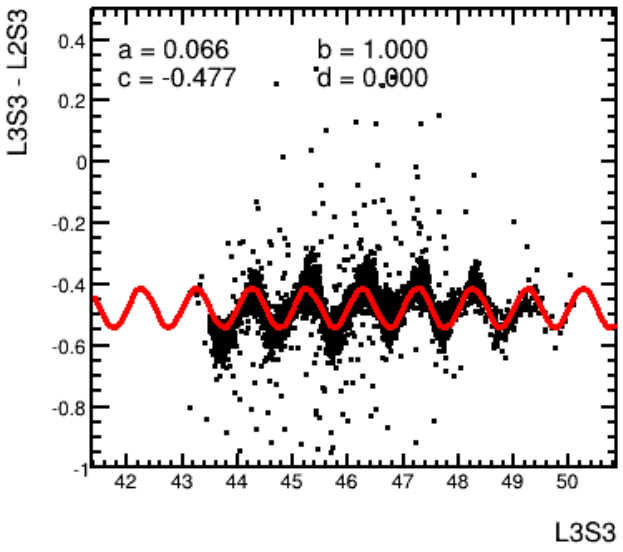
Reason for sine wave structure: cluster means are biased toward strip centres

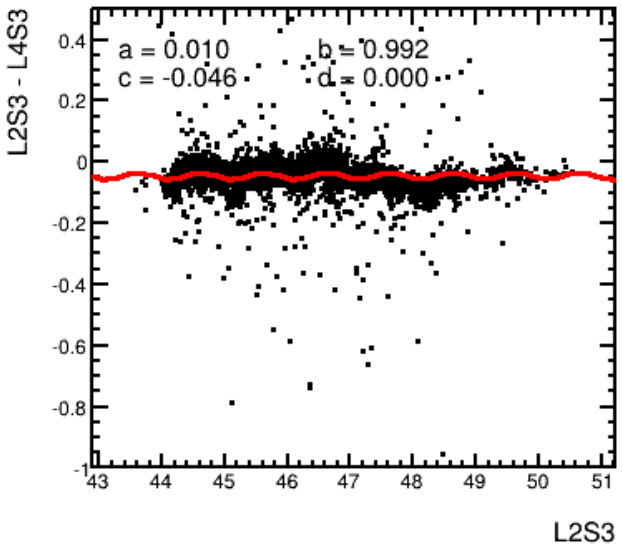
sTGC cluster centre correlations, uncorrected

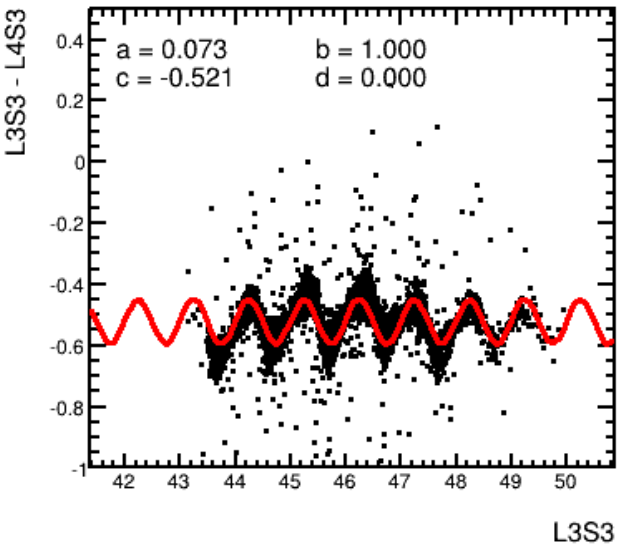




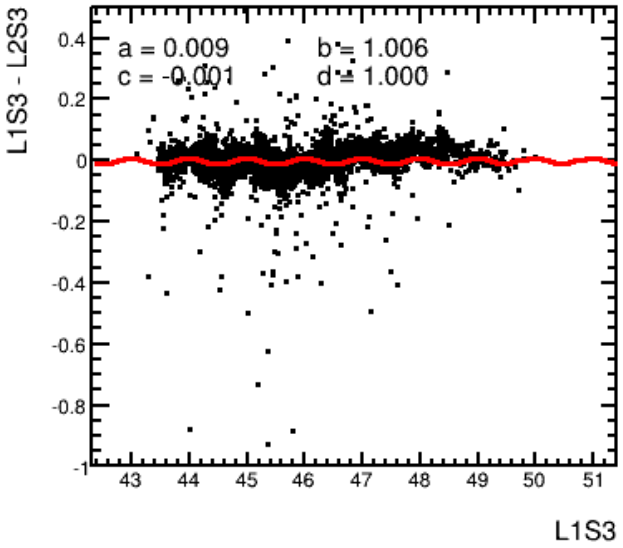


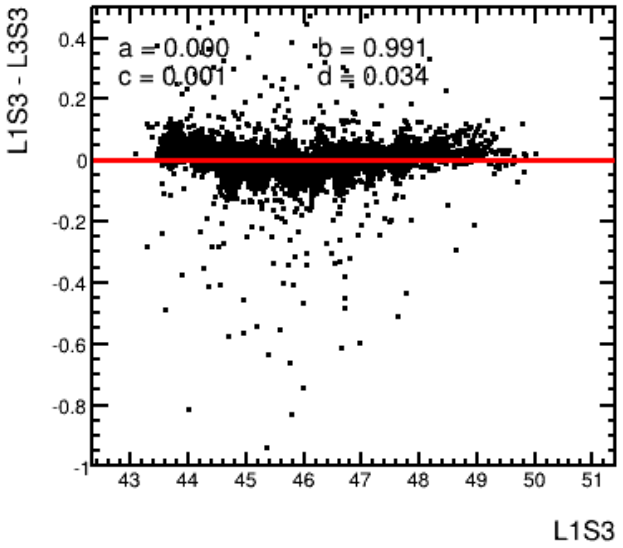


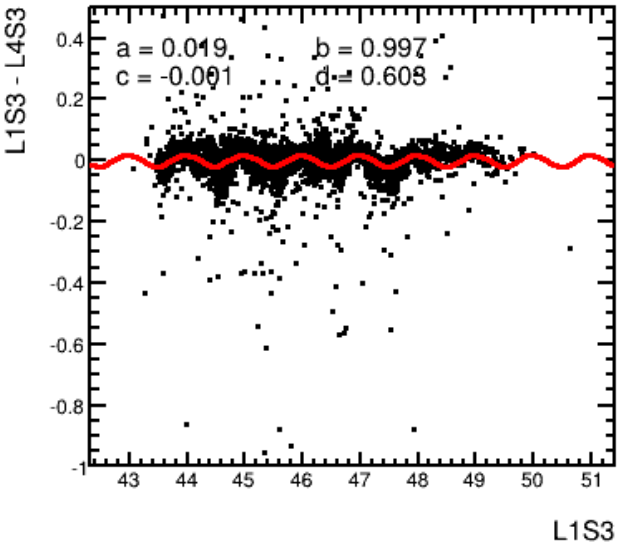


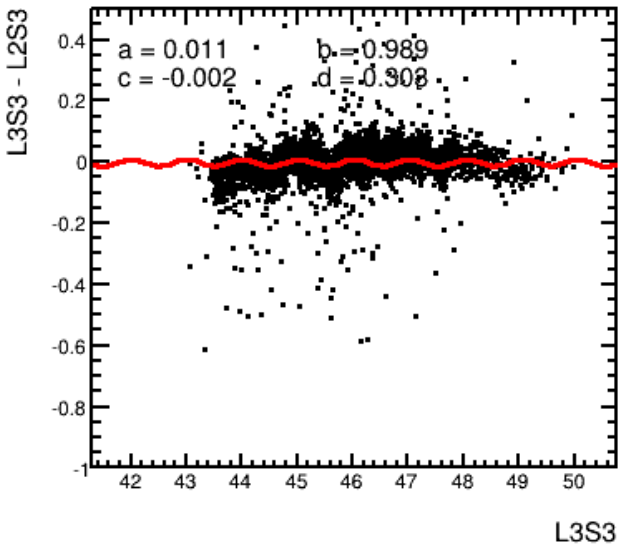


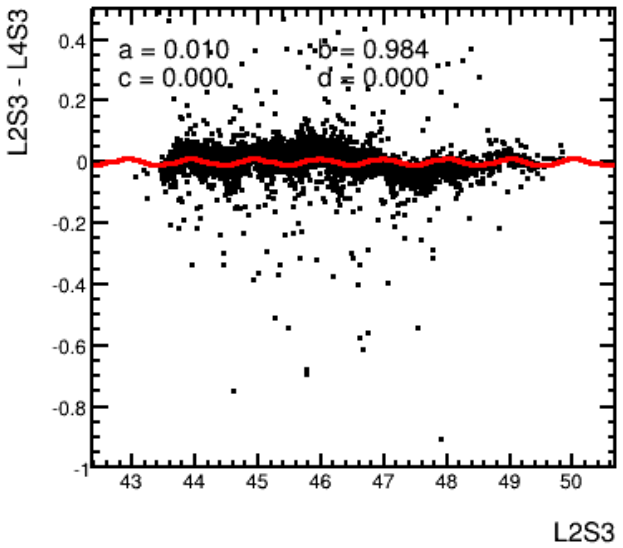
sTGC cluster centre correlations, corrected

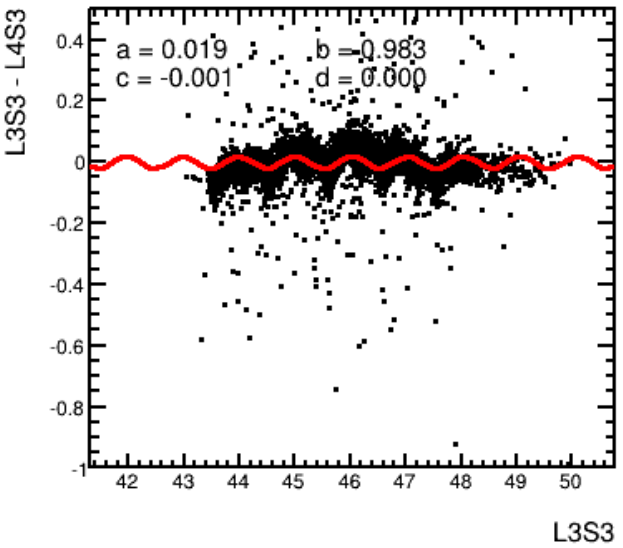




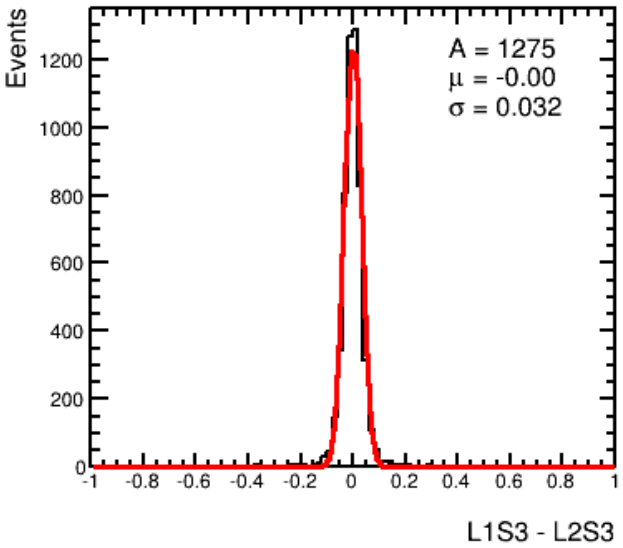


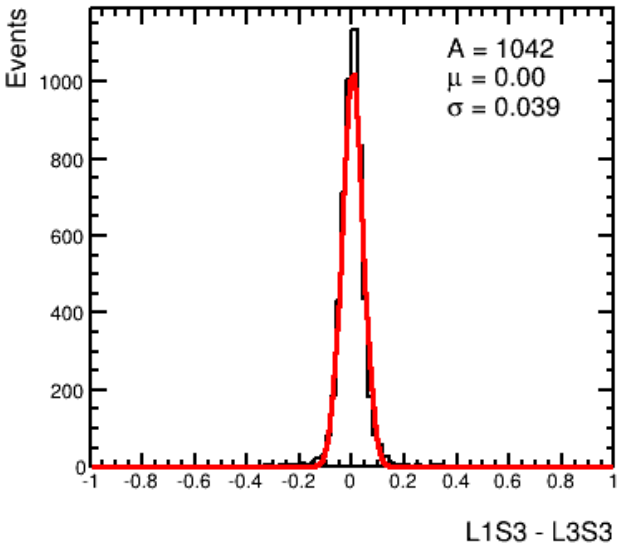


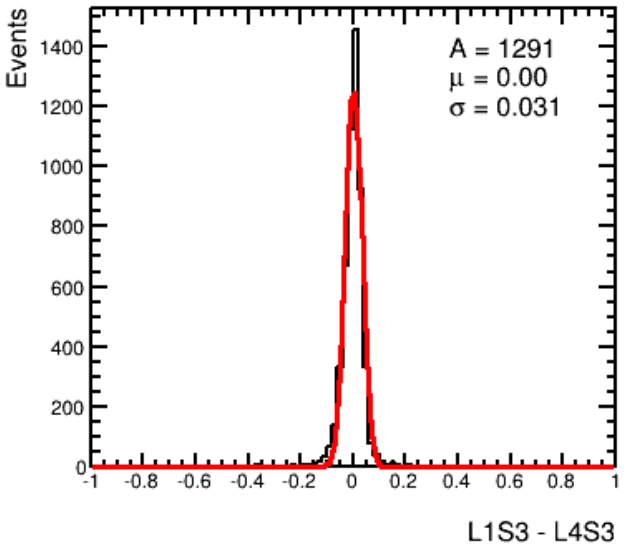


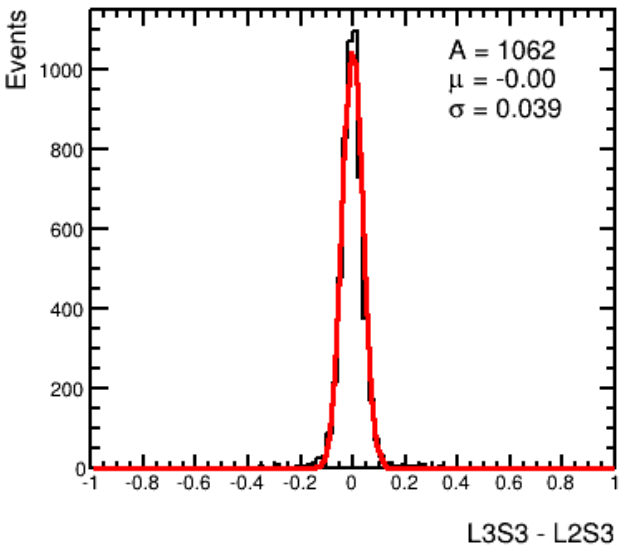


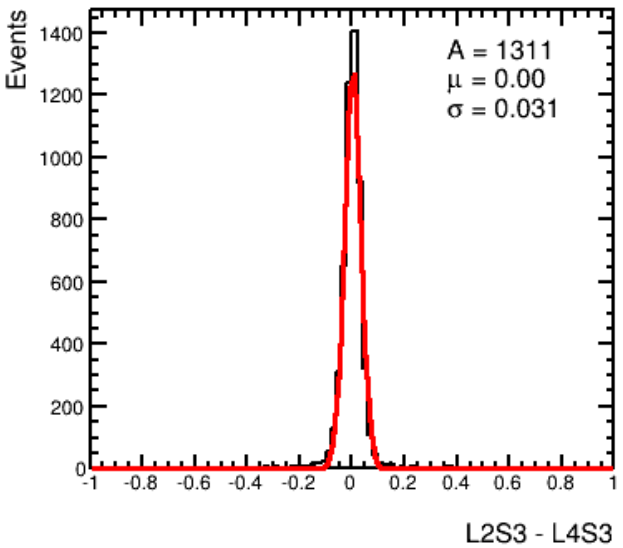
sTGC cluster centre correlation projections

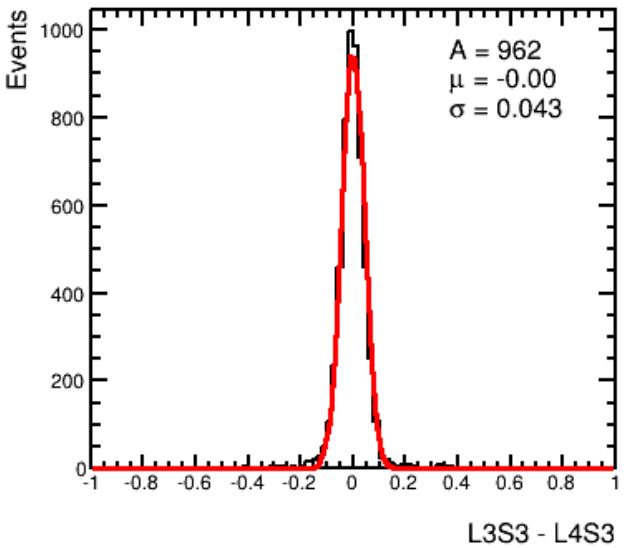




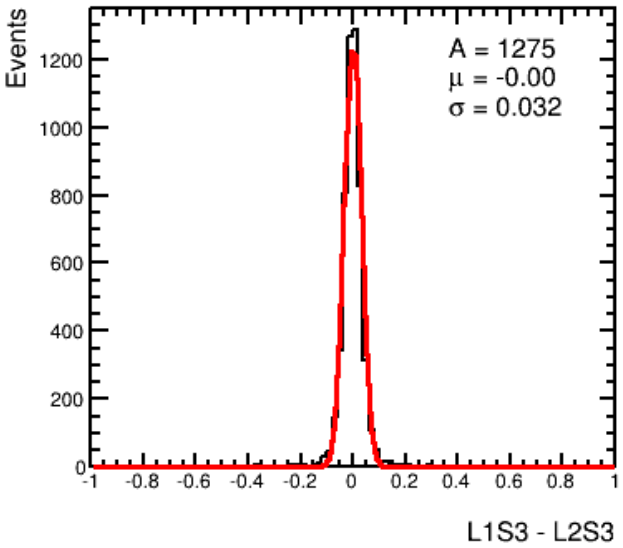


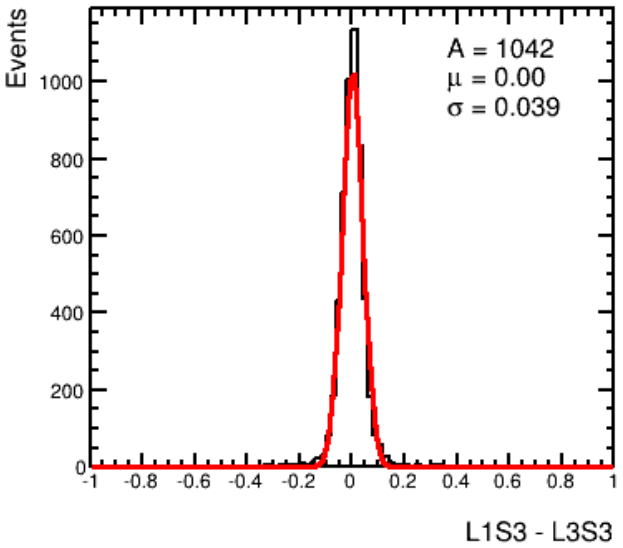


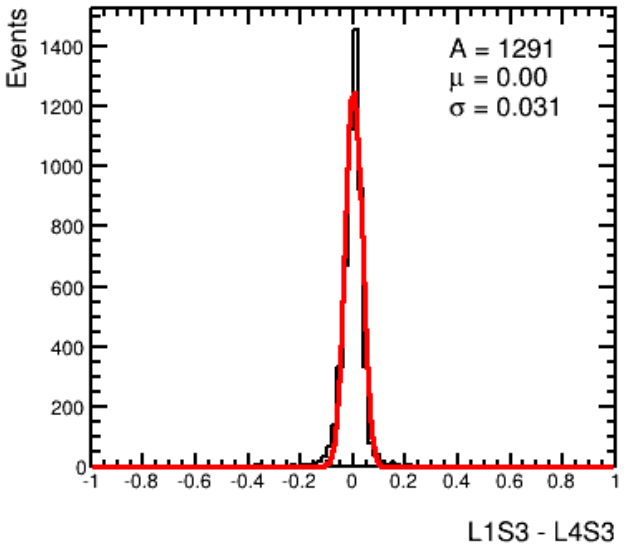




sTGC cluster centre correlation projections

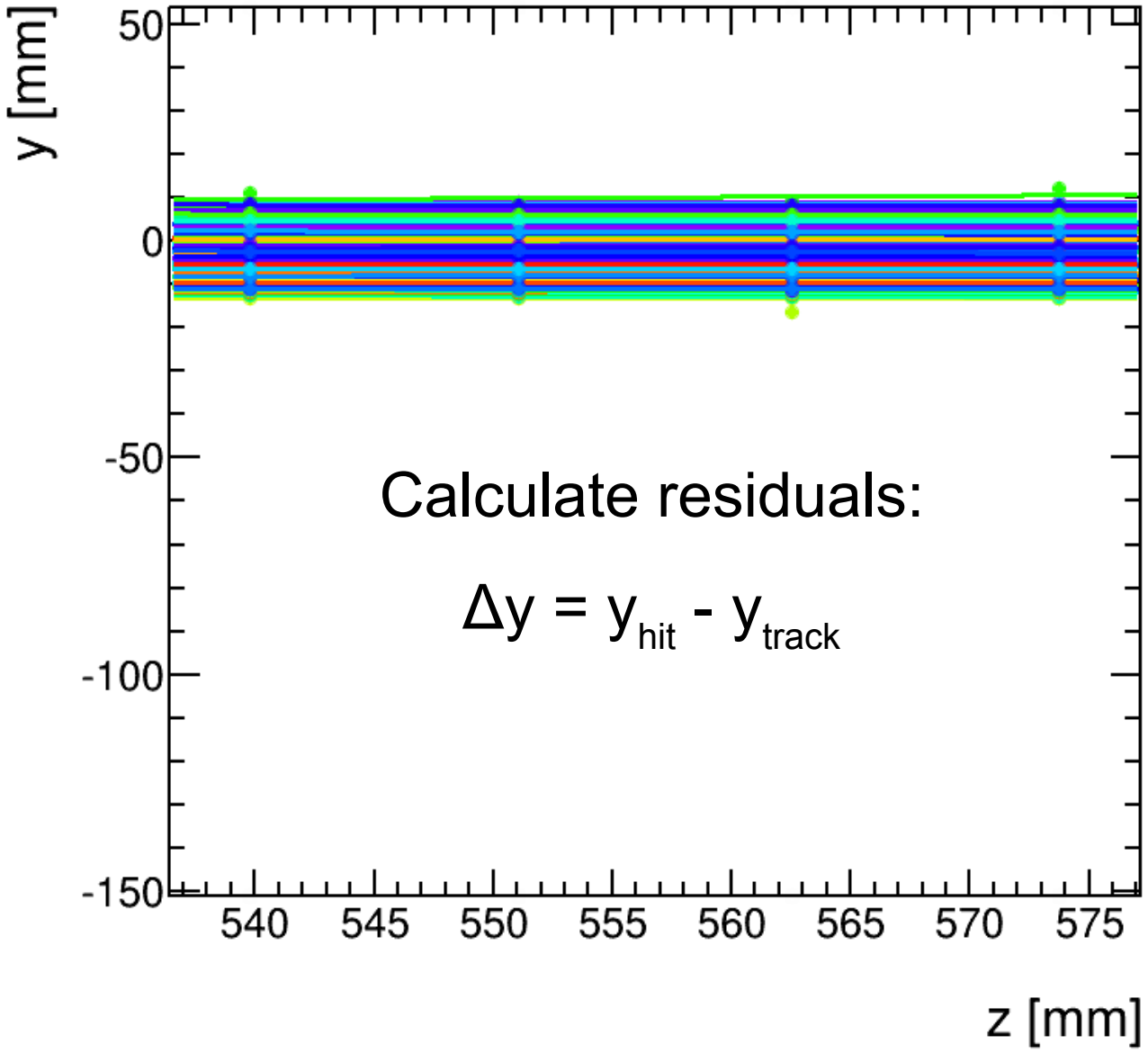




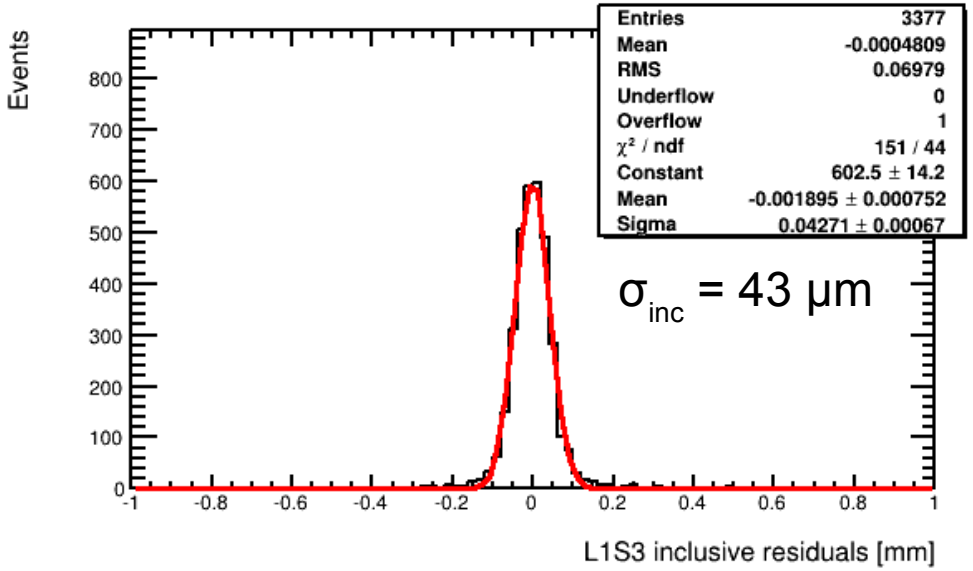


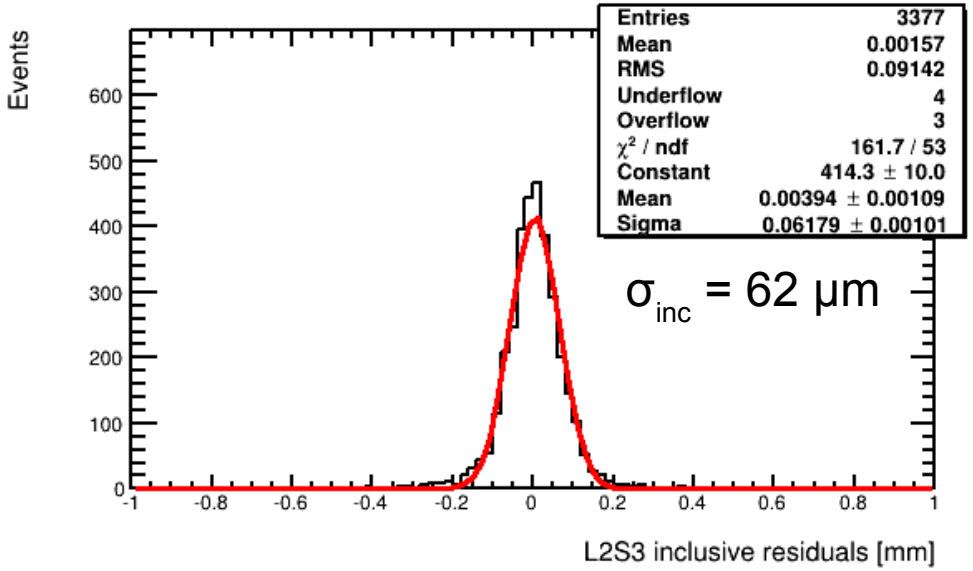
- First indication of the sTGC resolution: $\sigma_{L1 - LX} / \sqrt{2}$
  - Layer 1 vs. Layer 2: 0.032 strip * 3.2 mm/strip / $\sqrt{2}$ ~ **70 μm**
  - Layer 1 vs. Layer 3: 0.039 strip * 3.2 mm/strip / $\sqrt{2}$ ~ **90 μm**
  - Layer 1 vs. Layer 4: 0.031 strip * 3.2 mm/strip / $\sqrt{2}$ ~ **70 μm**
- The sine wave corrections are also applied in the following slides

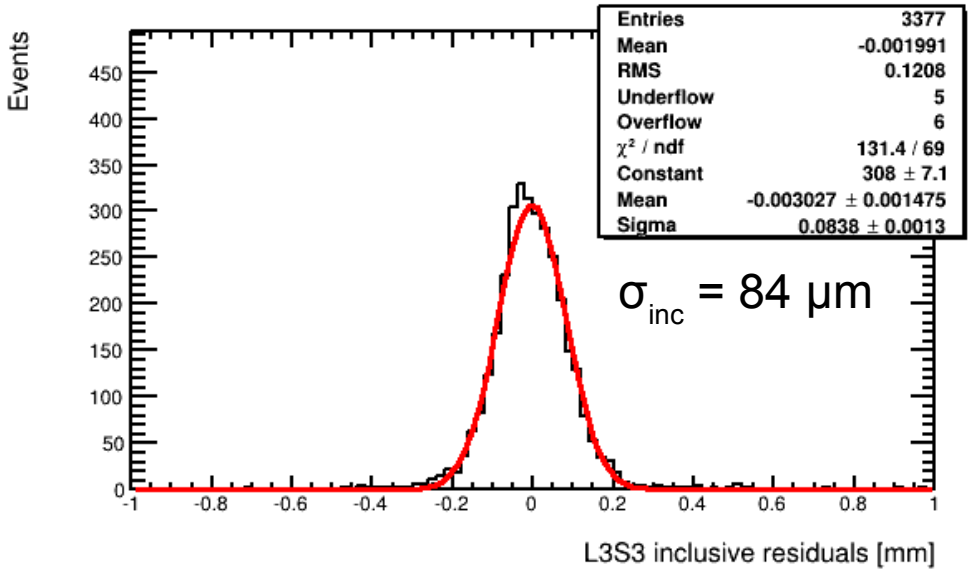
sTGC standalone tracks

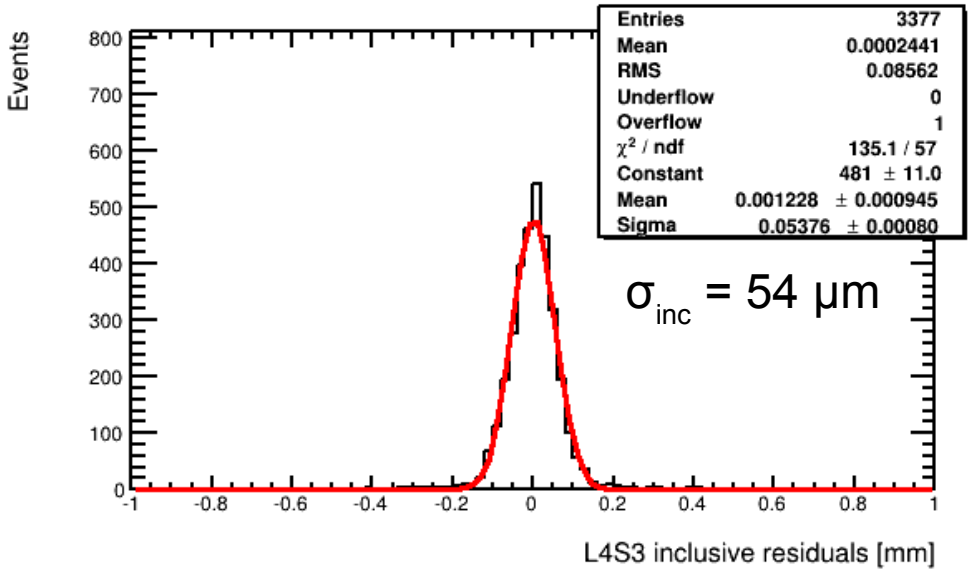


sTGC inclusive residuals

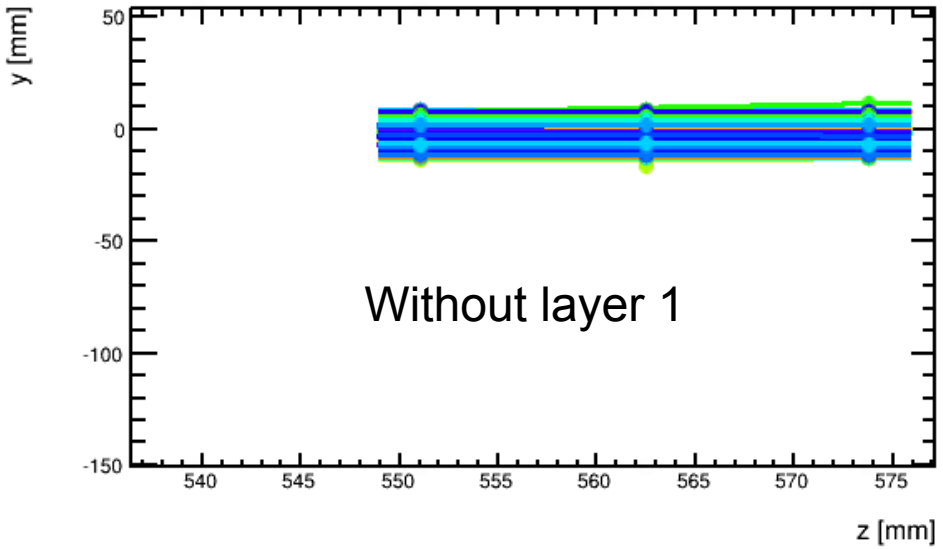


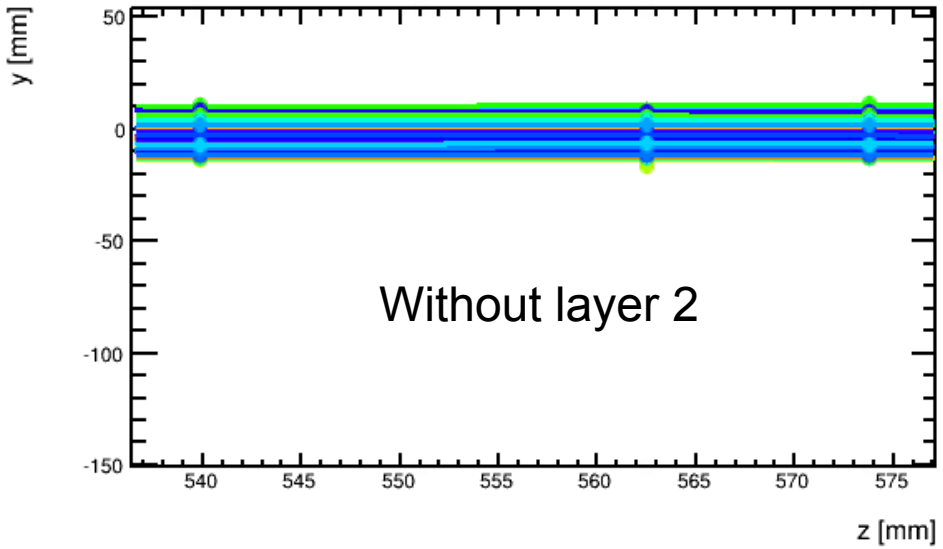


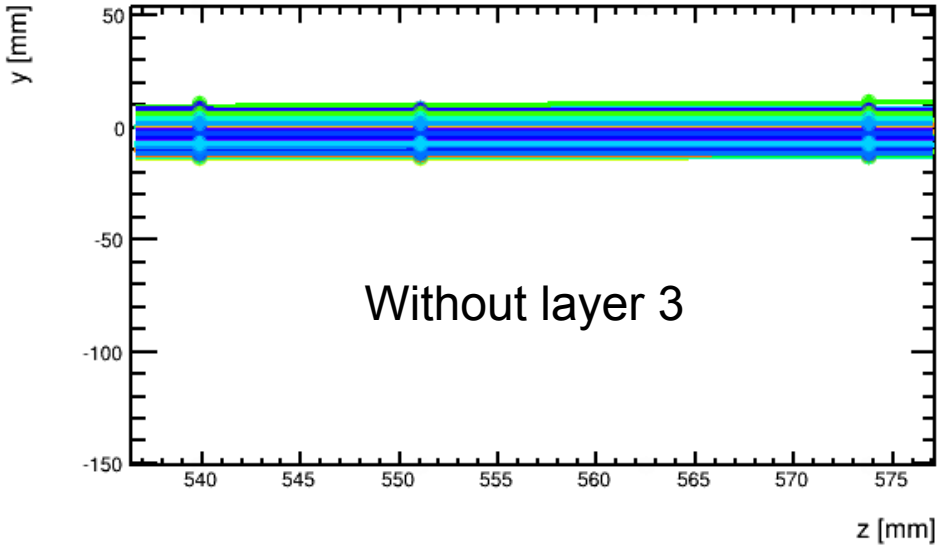


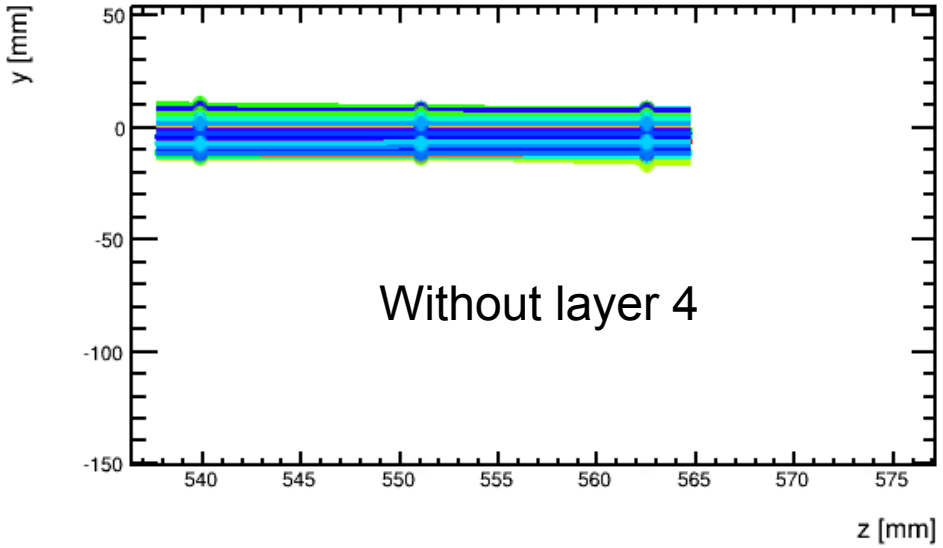


sTGC standalone tracks (3 out of 4)

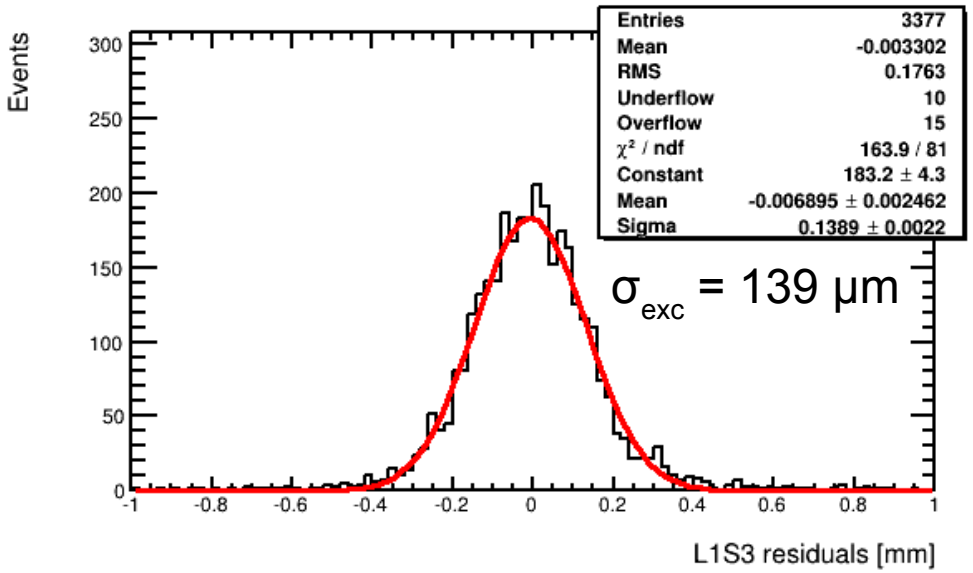


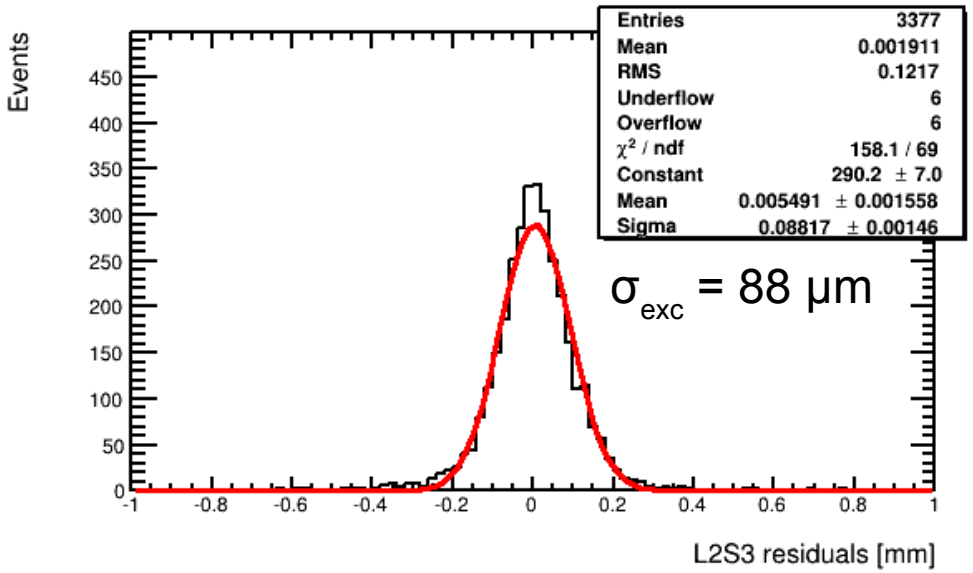


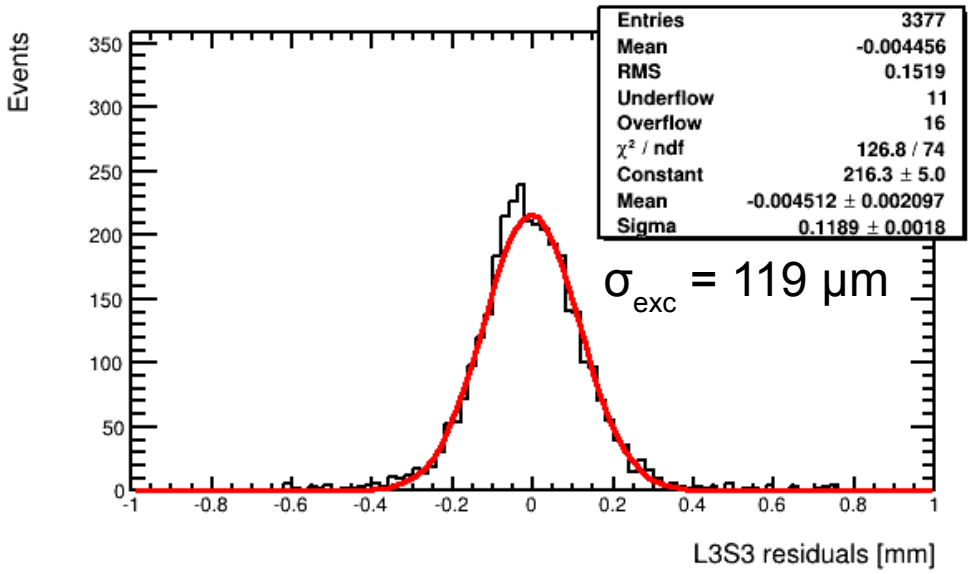


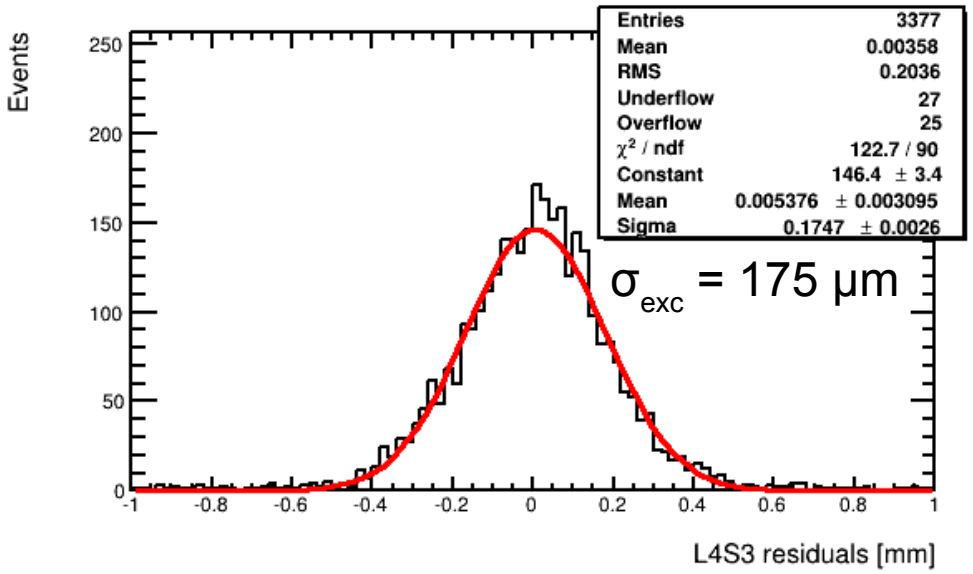


sTGC exclusive residuals









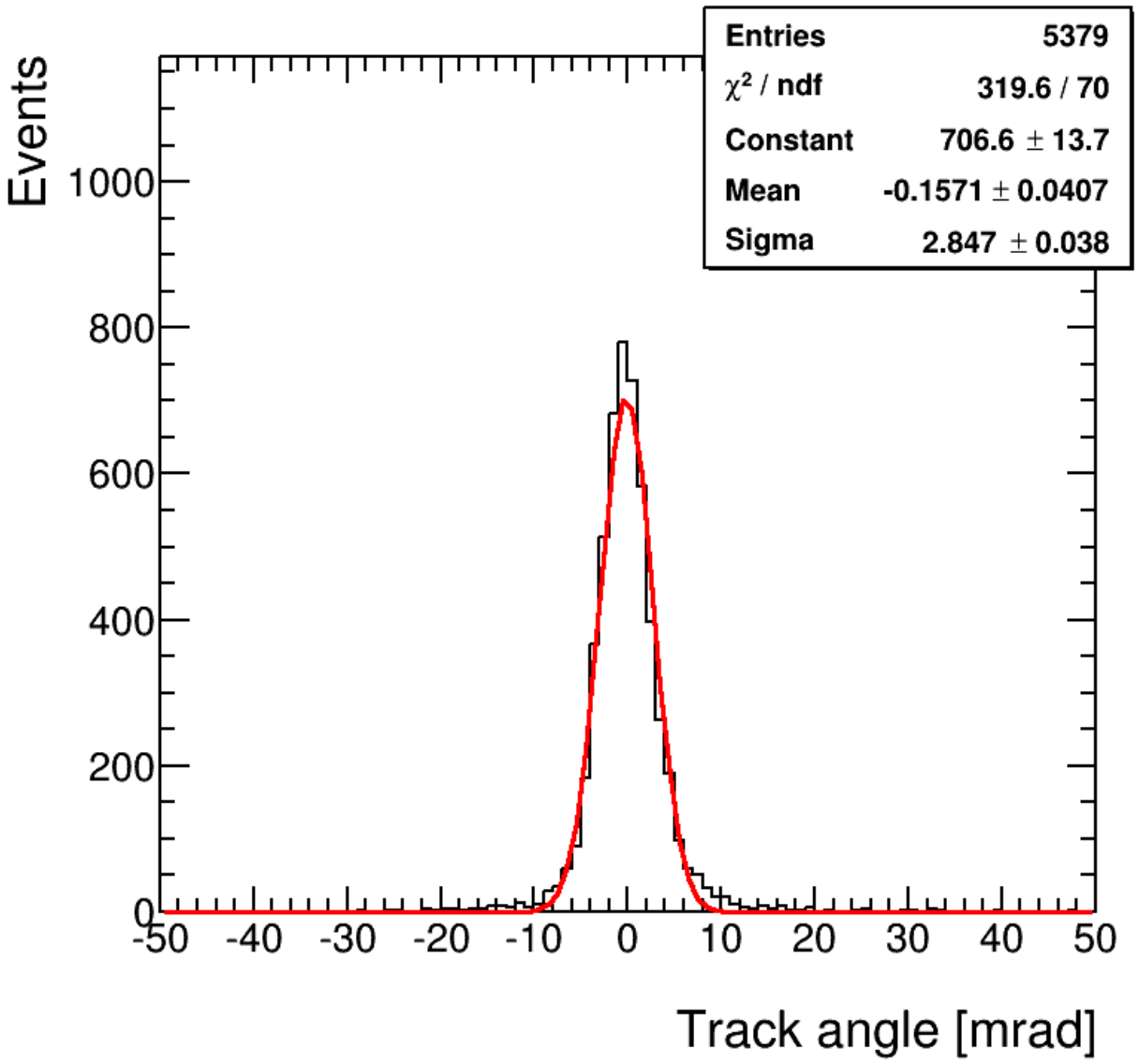
sTGC standalone resolution

Layer	L1S3	L2S3	L3S3	L4S3
Inclusive resolution	43 ± 1 μm	62 ± 1 μm	84 ± 1 μm	54 ± 1 μm
Exclusive resolution	139 ± 2 μm	88 ± 1 μm	119 ± 2 μm	175 ± 3 μm
Resolution	**~ 80 μm**	**~ 70 μm**	**~ 100 μm**	**~ 100 μm**

- The sTGC standalone resolution is given by $\sigma = \sqrt{\sigma_{inc} \times \sigma_{exc}}$
  - Uncertainties on the incl. and excl. resolution values are statistical only

Resolution calculation procedure reference:
DOI: 10.1016/j.nima.2004.08.132

sTGC angular resolution



- Angular resolution:

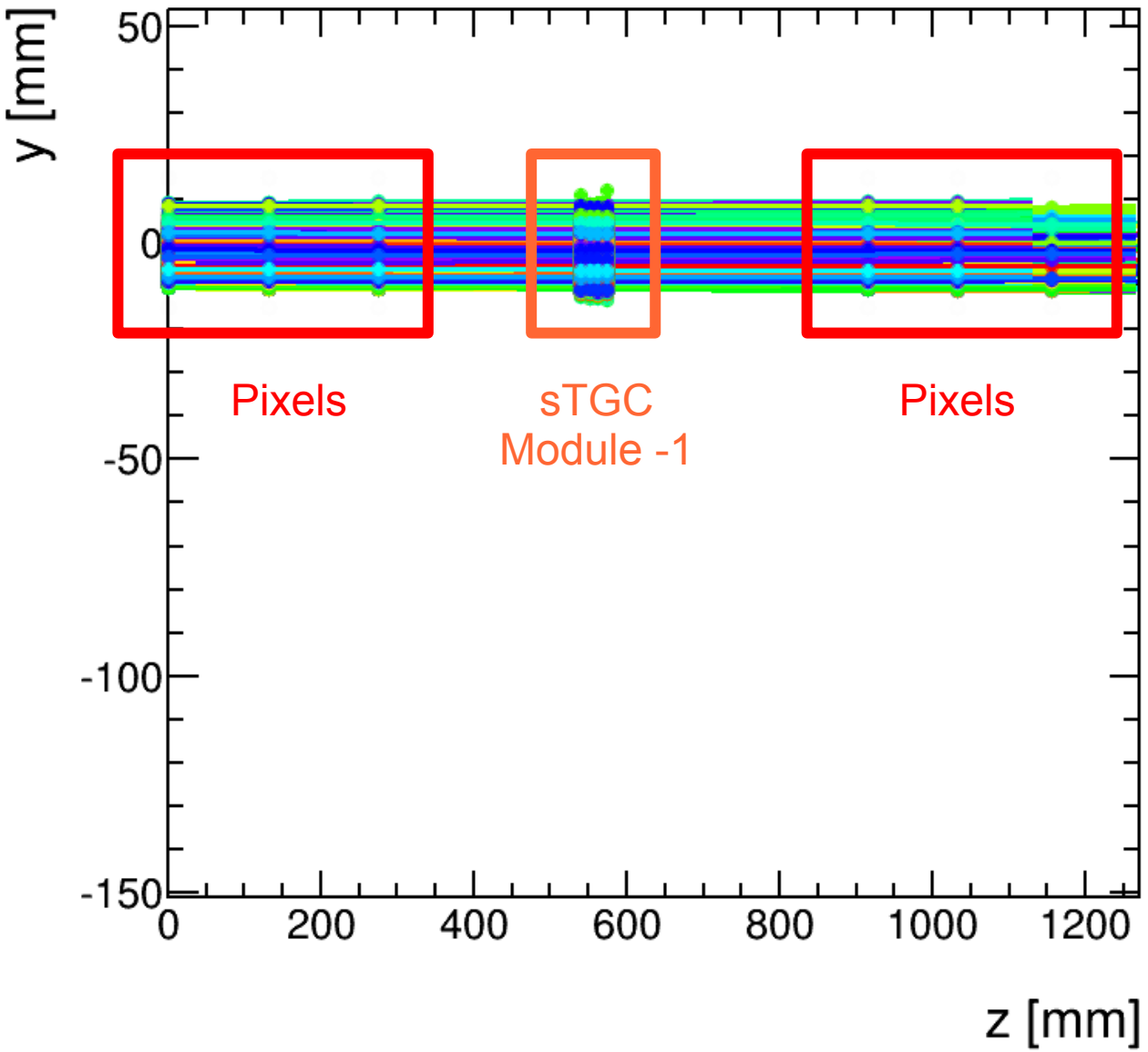
  σ_θ = 2.8 mrad

  $\sigma_y \sim \sigma_\theta$ * 34 mm

  ~ 100 μm

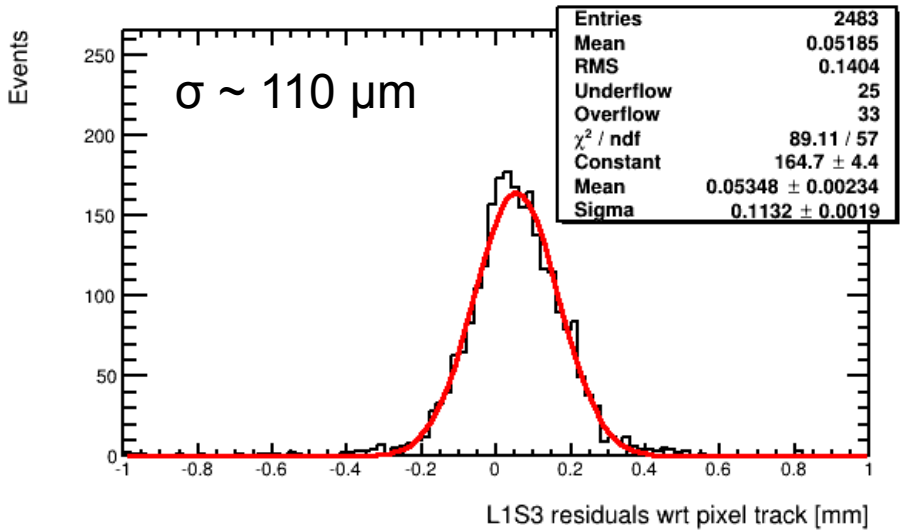
- All three methods yield **comparable results** for the sTGC standalone resolution

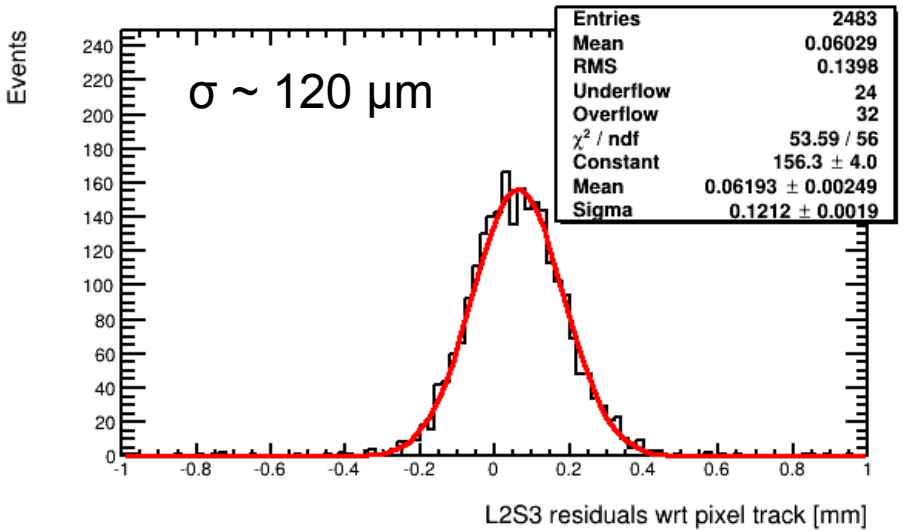
Combined pixel and sTGC tracks

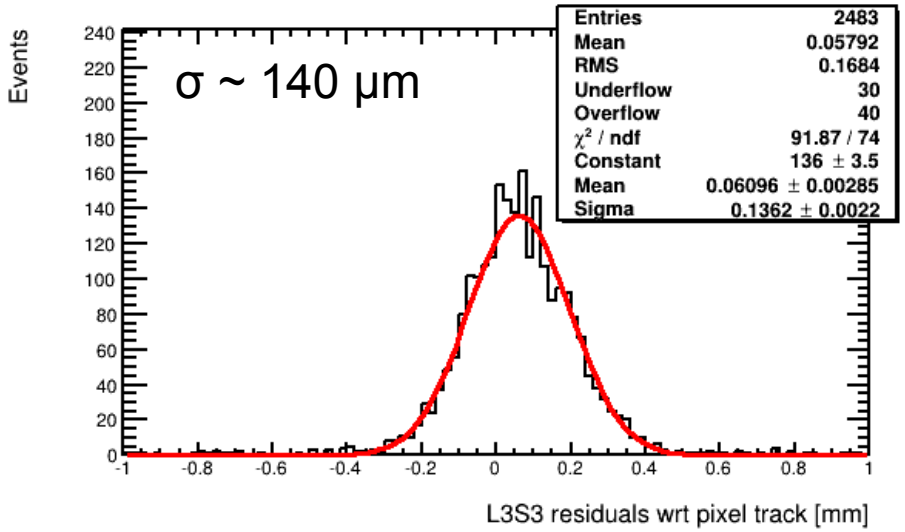


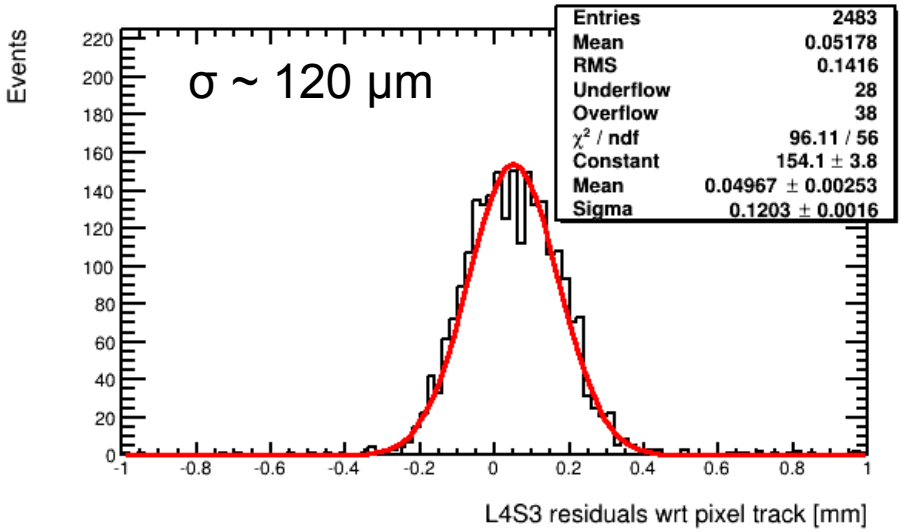
sTGC residuals wrt pixel track

Very preliminary: multiple-scattering effects and mis-alignment not corrected



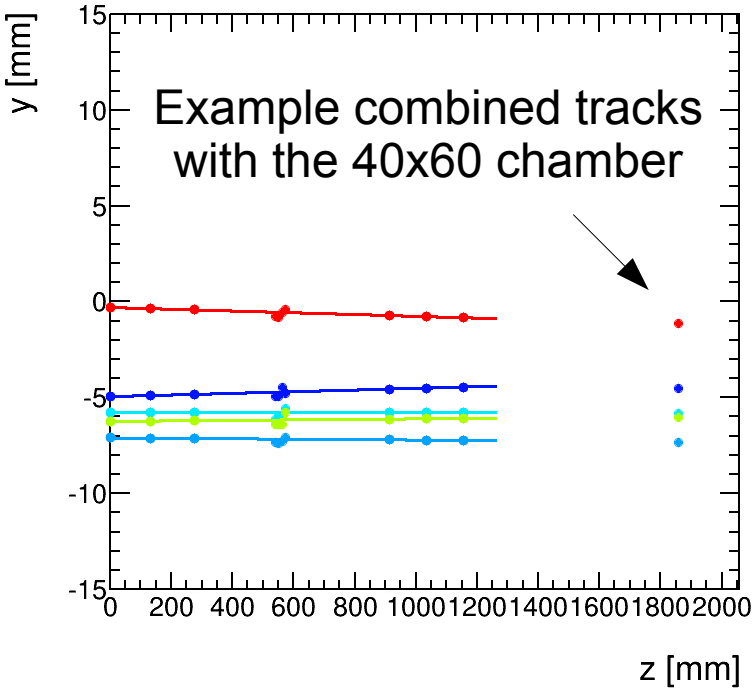






Conclusion

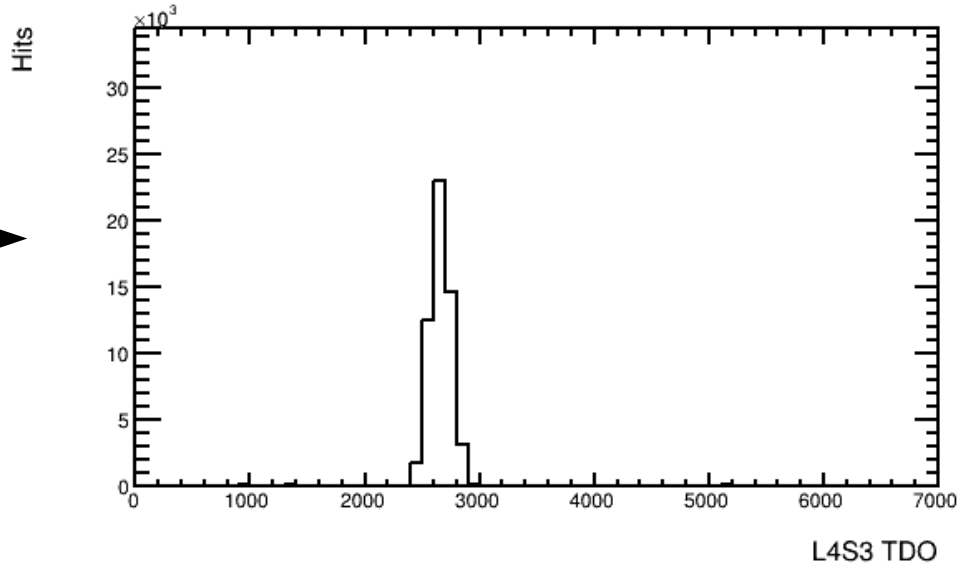
- The **ATLAS sTGC test beam** at Fermilab is a success !
  - Thanks to all who participated, and to the FTBF for their hospitality
- Preliminary results for the Module -1 **resolution**: σ ~ 70-100 μm
  - Coming up: detailed analysis of all runs, including data with the 40x60 chamber
    - Will require corrections for mis-alignment and multiple-scattering effects (using a 3+3 pixel fit, or better)
  - Quantify resolution and deformations using data taken at different points in the Module -1
- Measured good detector **efficiency**
  - Small inefficiencies observed for pads, to be investigated



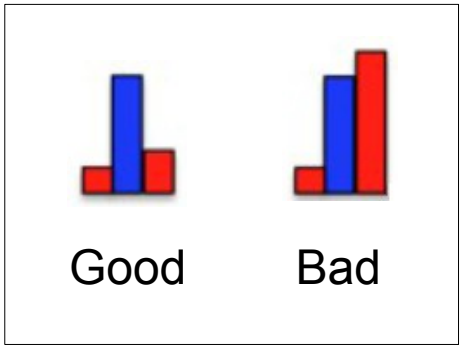
BONUS SLIDES

sTGC event selection

- Hit selection
  - Remove noisy channels
  - Time Digital Output window: 2300-3300



- Cluster selection
  - 3 to 5 hits per cluster
  - All cluster channels within 2 strips of mode
  - Channel mode of cluster not next to channel with zero amplitude



- Event selection
  - Four out of four layers
  - At most 2 clusters with only 3 channels

Event synchronization