Small-strip Thin Gap Chambers(sTGC) for the Muon Spectrometer Upgrade of the ATLAS Experiment

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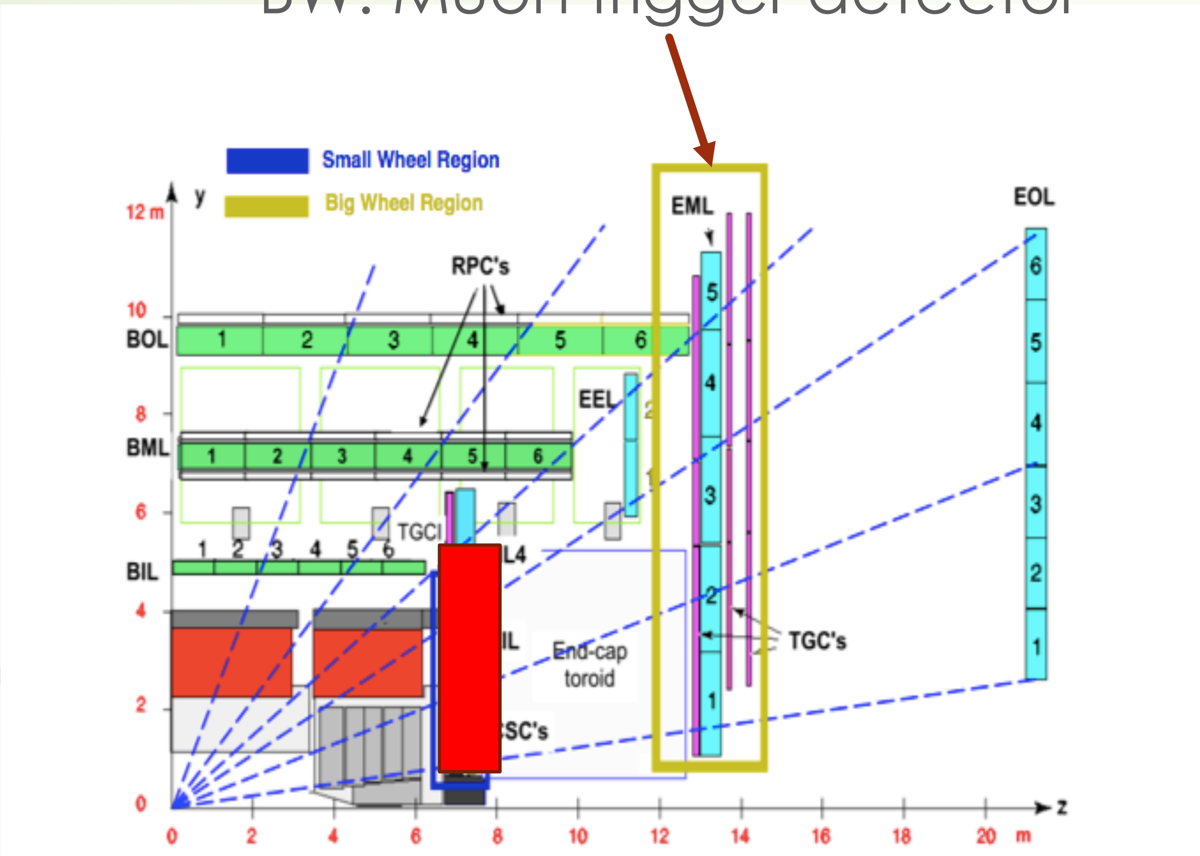
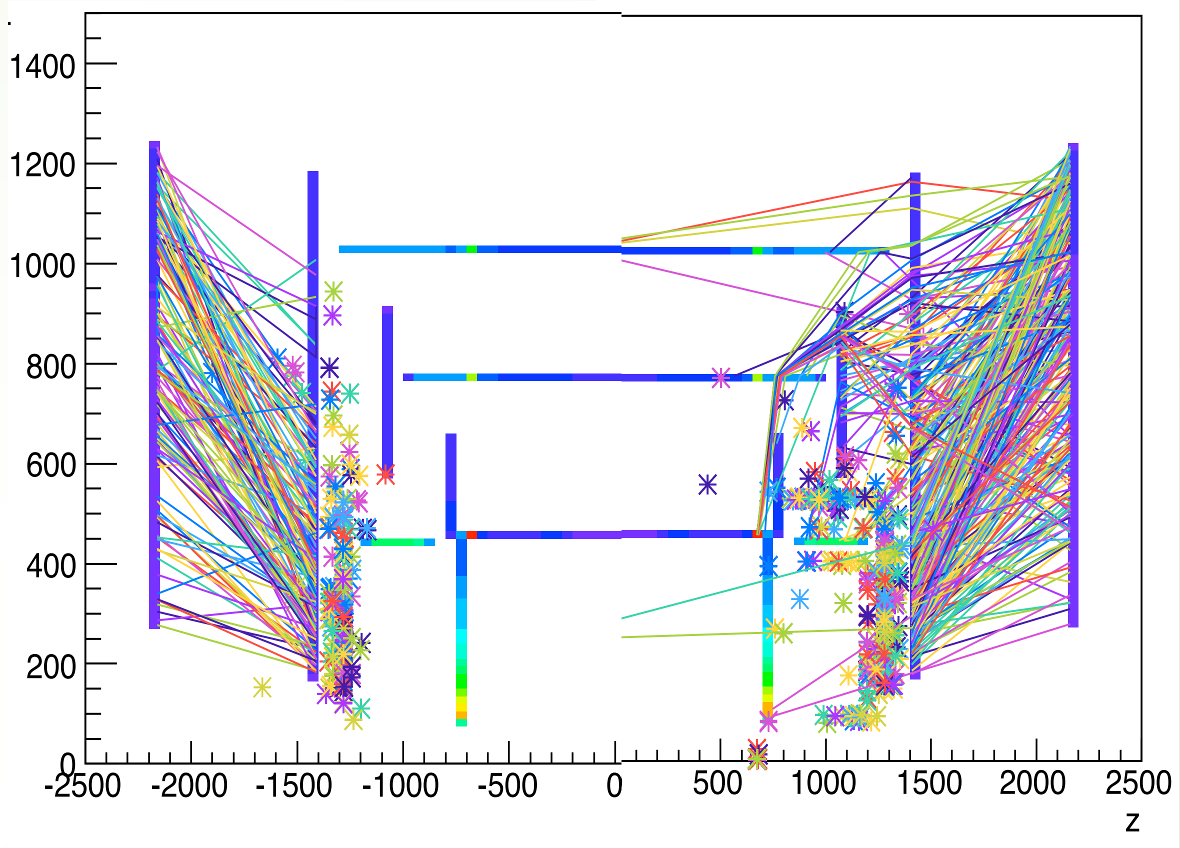
On behalf of ATLAS Muon Collaboration

LHC and ATLAS upgrade

BW: Muon trigger detector



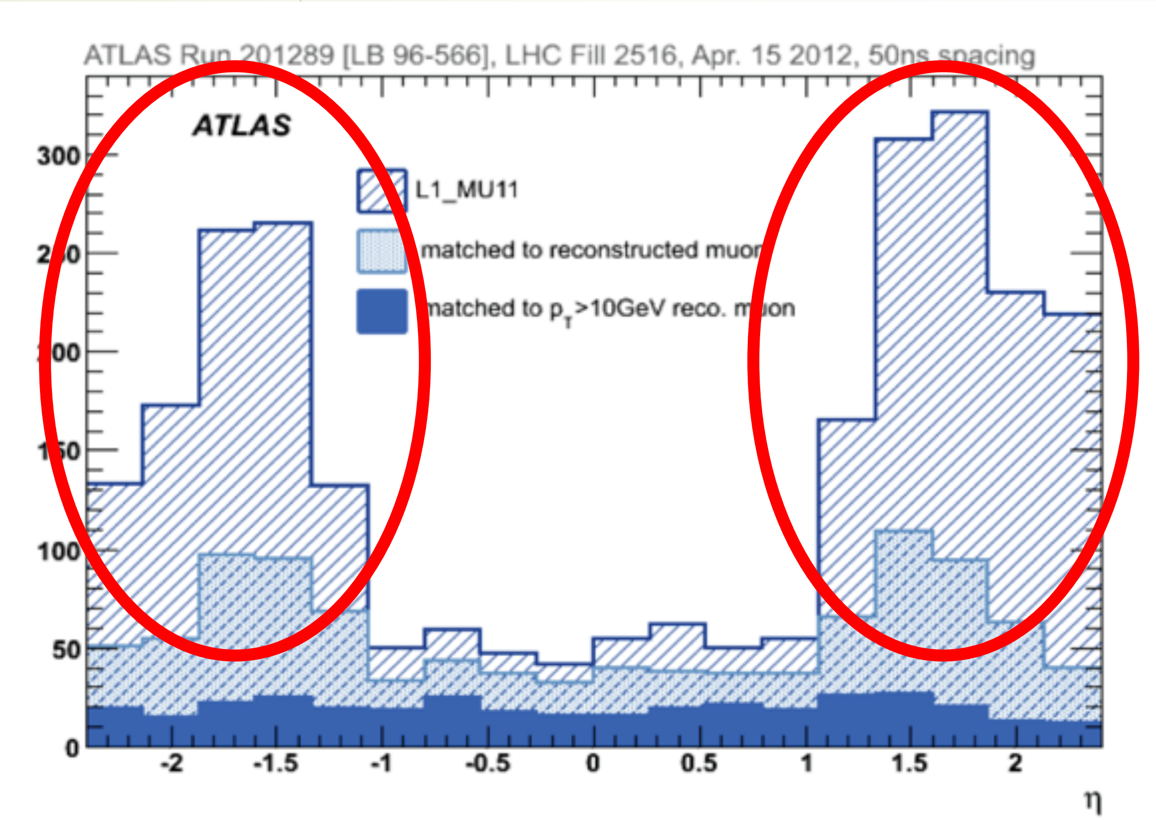


In the endcap region, the muon trigger is provided by the 3 stations of TGCs (Big Wheels) located outside of the endcap magnet. Many hits are not produced by muons from IP, many fake muon triggers are produced.

To work at high luminosity LHC, ATLAS has to be upgraded that, in the year of 2019-20, a NSW(New Small Wheel) will be built to reduce the fake muon trigger.

Muon trigger occupancy

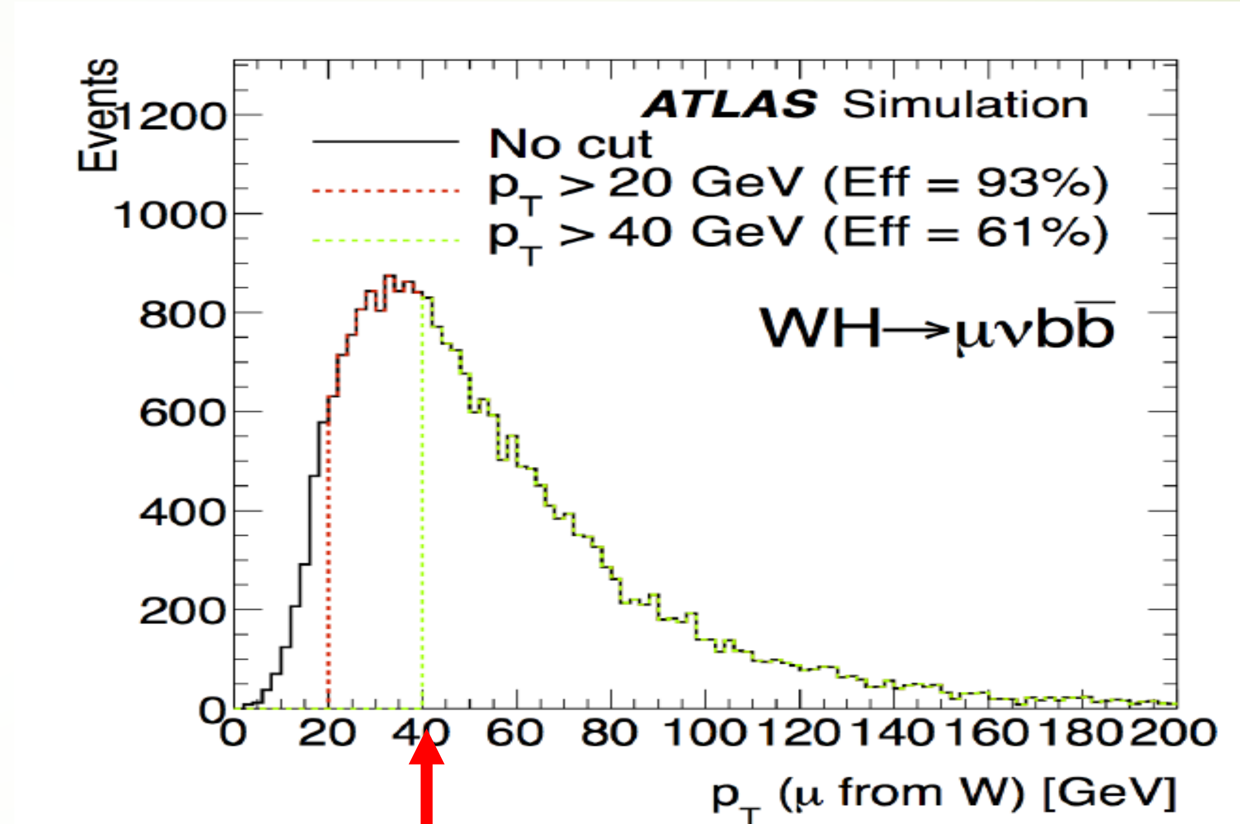
For HL-LHC,the allowed level-1 trigger will be **100kHz,**
And **20kHz** for muon



90% Forward Muon trigger are fake, waste the bandwidth of the DAQ

L1MU threshold (GeV)	Level-1 rate (kHz)
$p_T > 20$	60 ± 11
$p_T > 40$	29 ± 5
$p_T > 20$ barrel only	7 ± 1

3x10^{34}cm-^{2}s^{-1}



Increasing Pt cut lose lot of events

L1MU threshold (GeV)	$H \to b\bar{b}$ (%)	$H \to W^+W^-$ (%)
$p_T > 20$	93	94
$p_T > 40$	61	75
$p_T > 20$ barrel only	43	72

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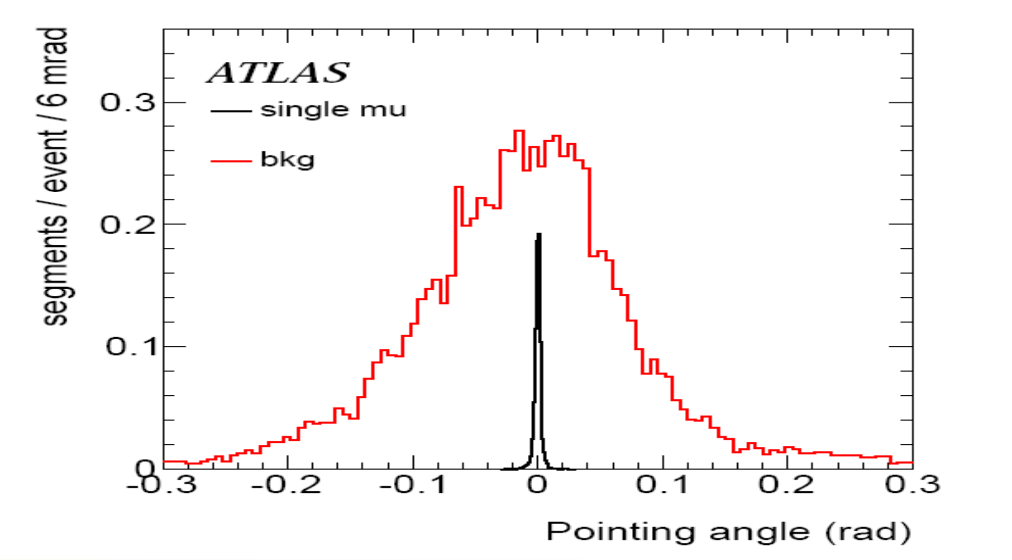
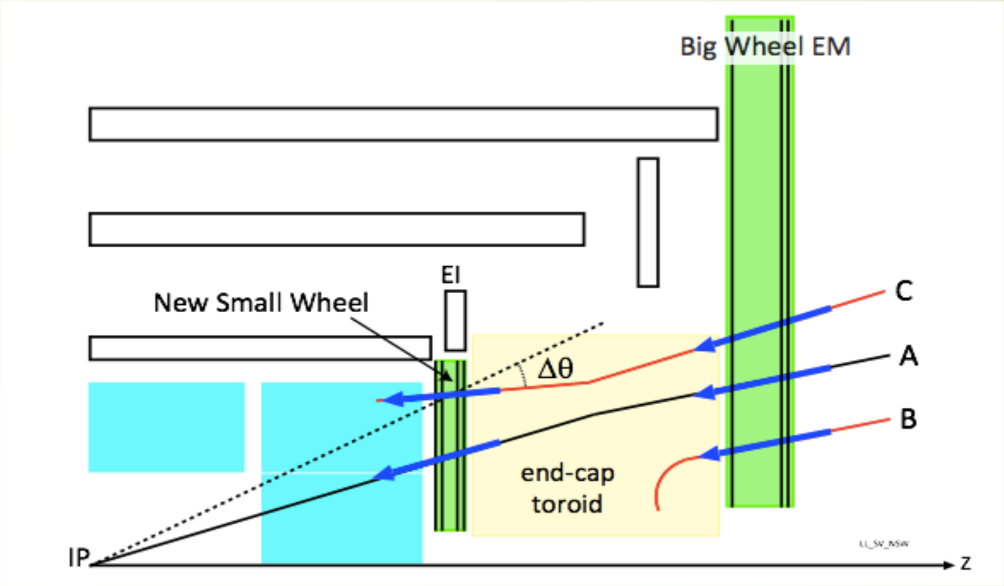
Muon trigger upgrade strategy



1. $\Delta\theta$ distribution of real muon and background
2. Cut at $\Delta\theta$<7.5mrad highly suppress the background.



NSW principle: Reject tracks not from the IP.

B: created within the toroid

C: from the interations in the magnet system.

L1MU threshold (GeV)	Level-1 rate (kHz)
$p_T > 20$	60 ± 11
$p_T > 40$	29 ± 5
$p_T > 20$ barrel only	7 ± 1
$p_T > 20$ with NSW	22 ± 3
$p_T > 20$ with NSW and EIL4	17 ± 2

The level-1 trigger can be reduced to under 20kHz

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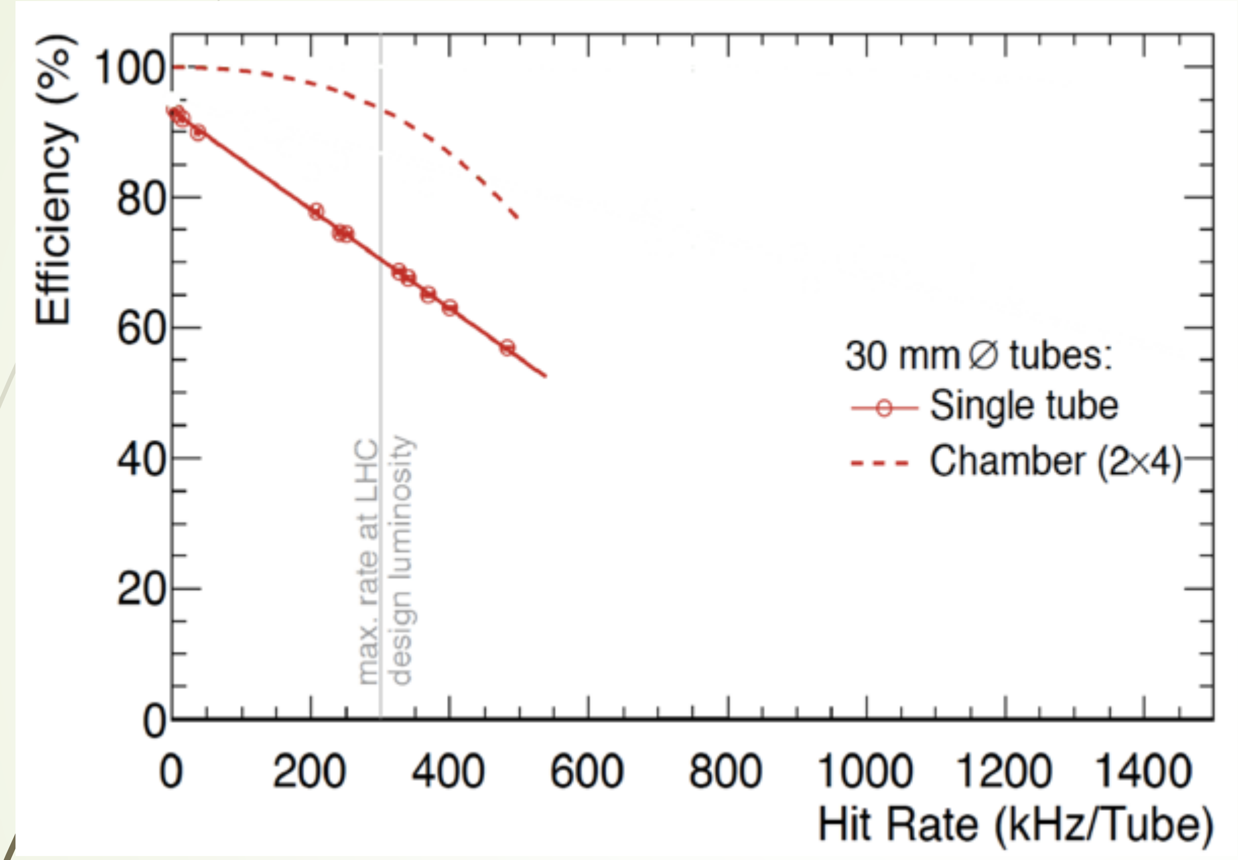
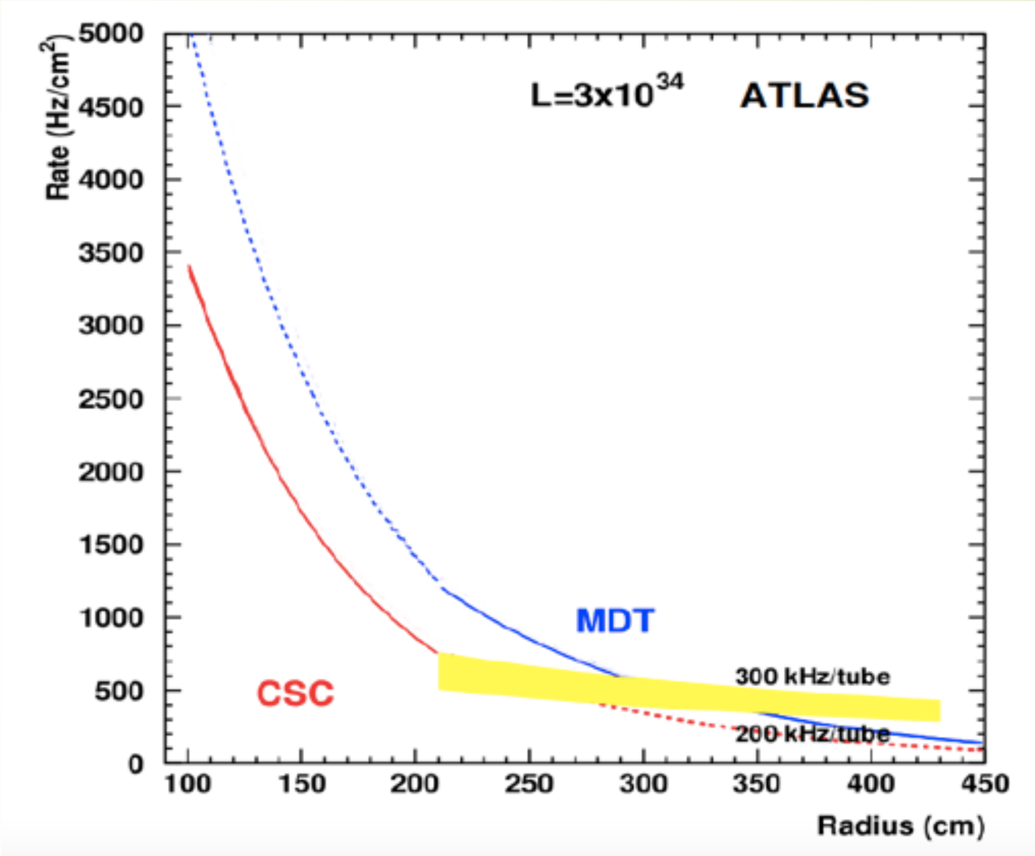
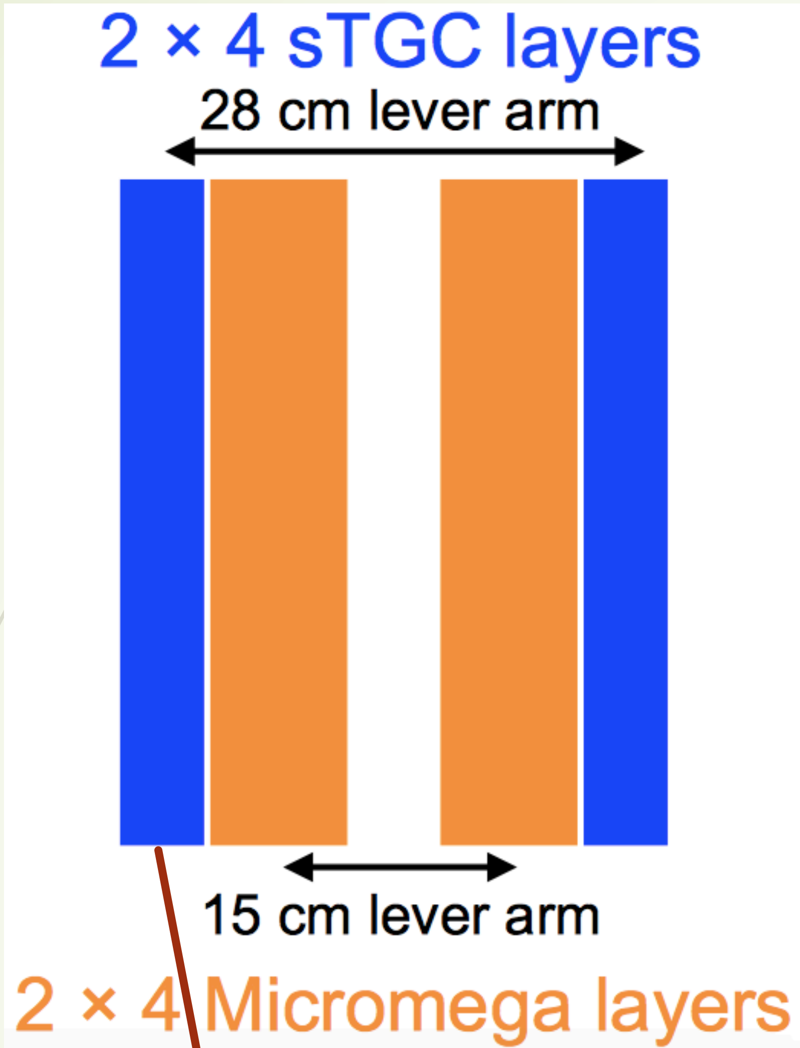
upgrade requirement on tracking

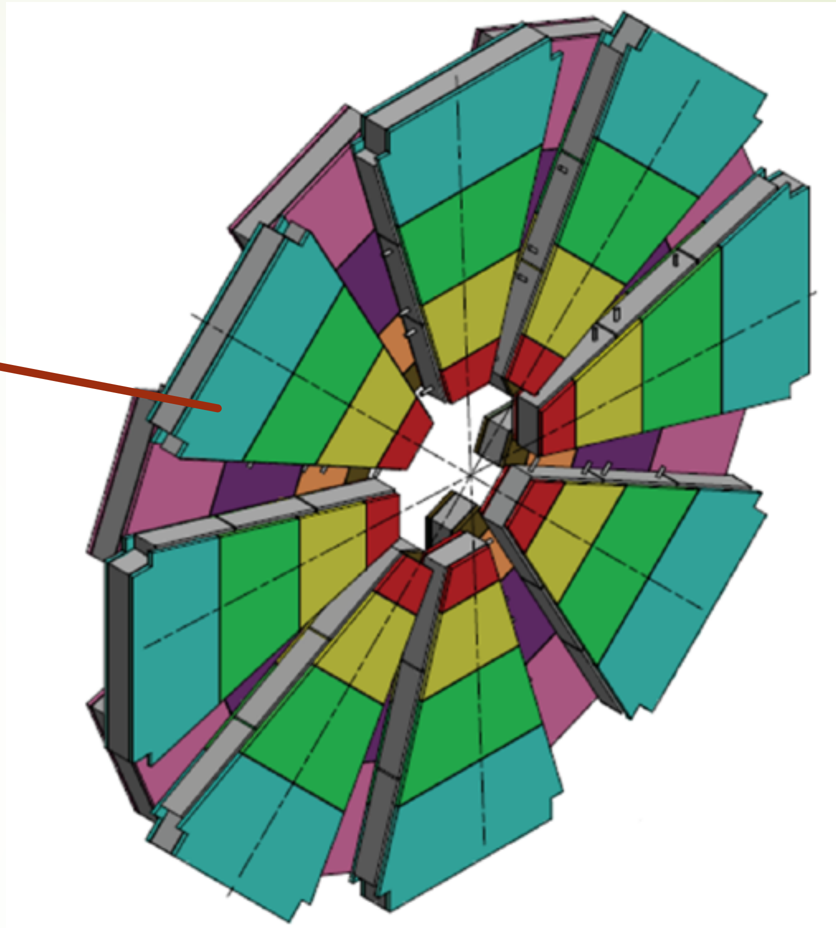


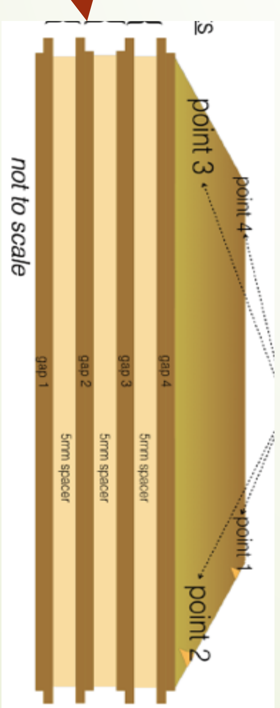


MDT at the SW lose its efficiency at higher radiation environment quickly.

New Small Wheel Layout







sTGC and MM(MicroMegas detector) are selected to compose the NSW

Both will be used for the online trigger and offline track-segment reconstruction

Requirements on NSW

1. Online angular resolution of 1 mrad for trigger (to match the 1mrad angular resolution of BW after phase 2 upgrade
2. Higher requirement on space resolution: offline tracking together with MM achieve 100μm
3. Fast response as or better than now TGC stations.
4. The NSW will be able to operate in radiation region of up to 15 kHz/cm^2

Need fast, precise, and high radiation resistant detectors

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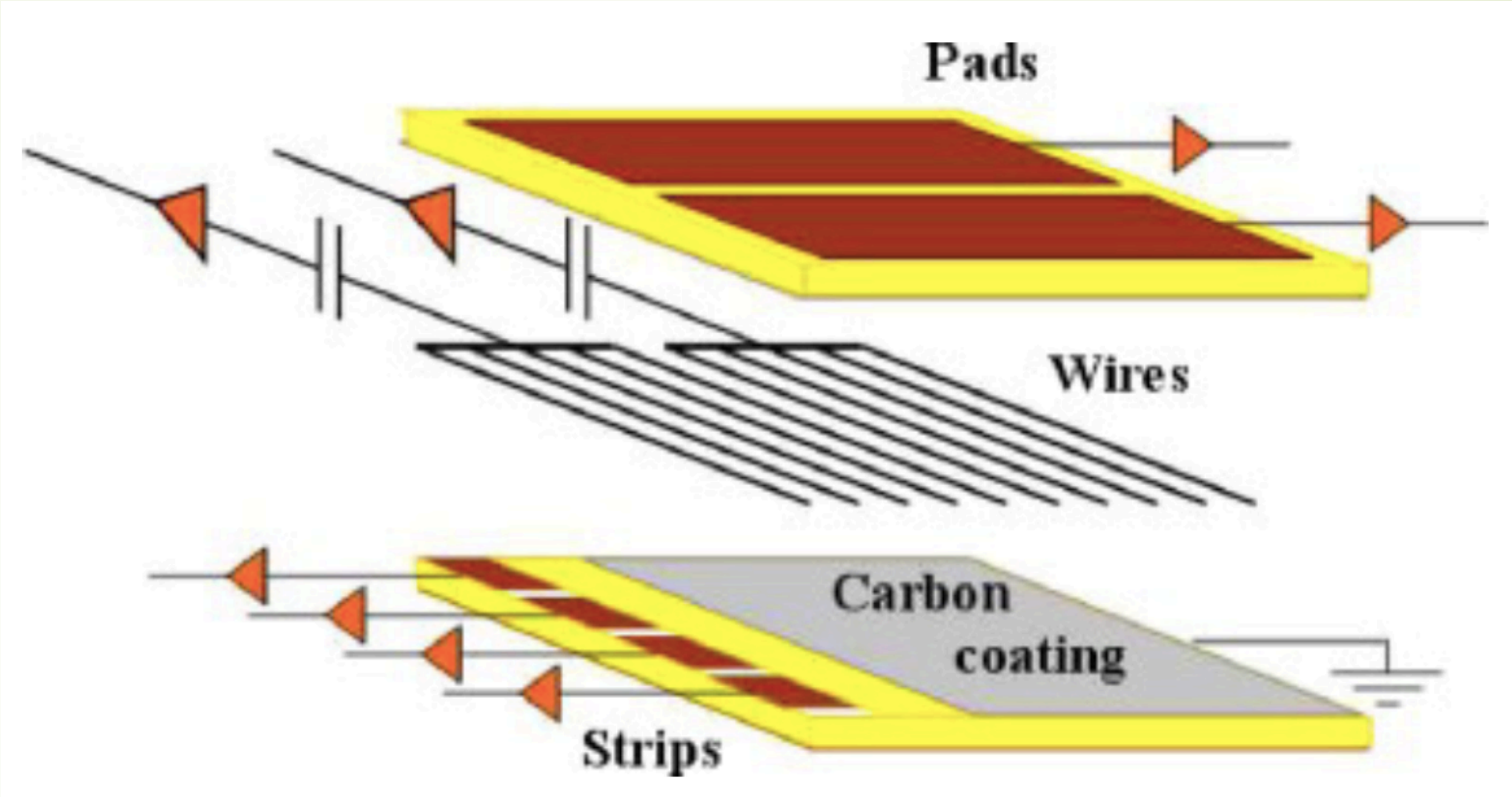
small-strip thin gap chamber



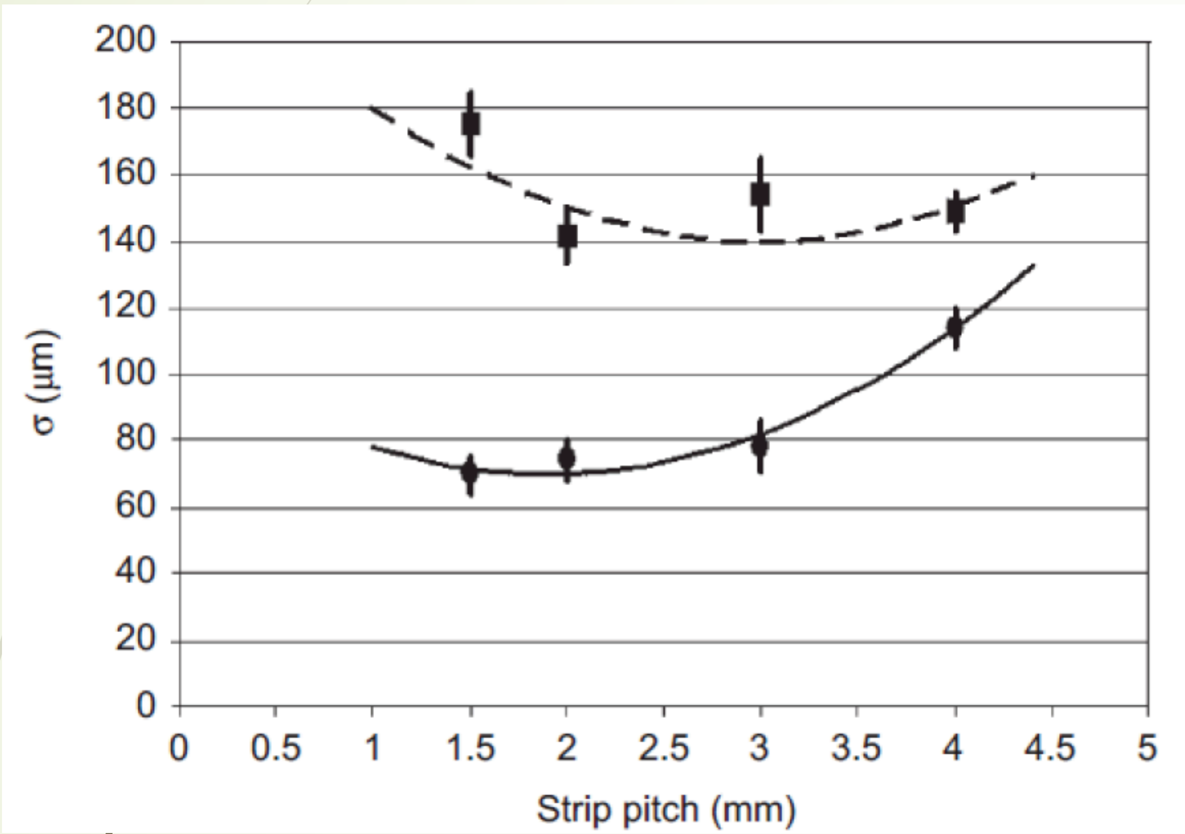
sTGC detector developed from ATLAS TGC detector with:

- Same electron avalanche structure, fast response as TGC
- Higher flux tolerance
- Higher space resolution

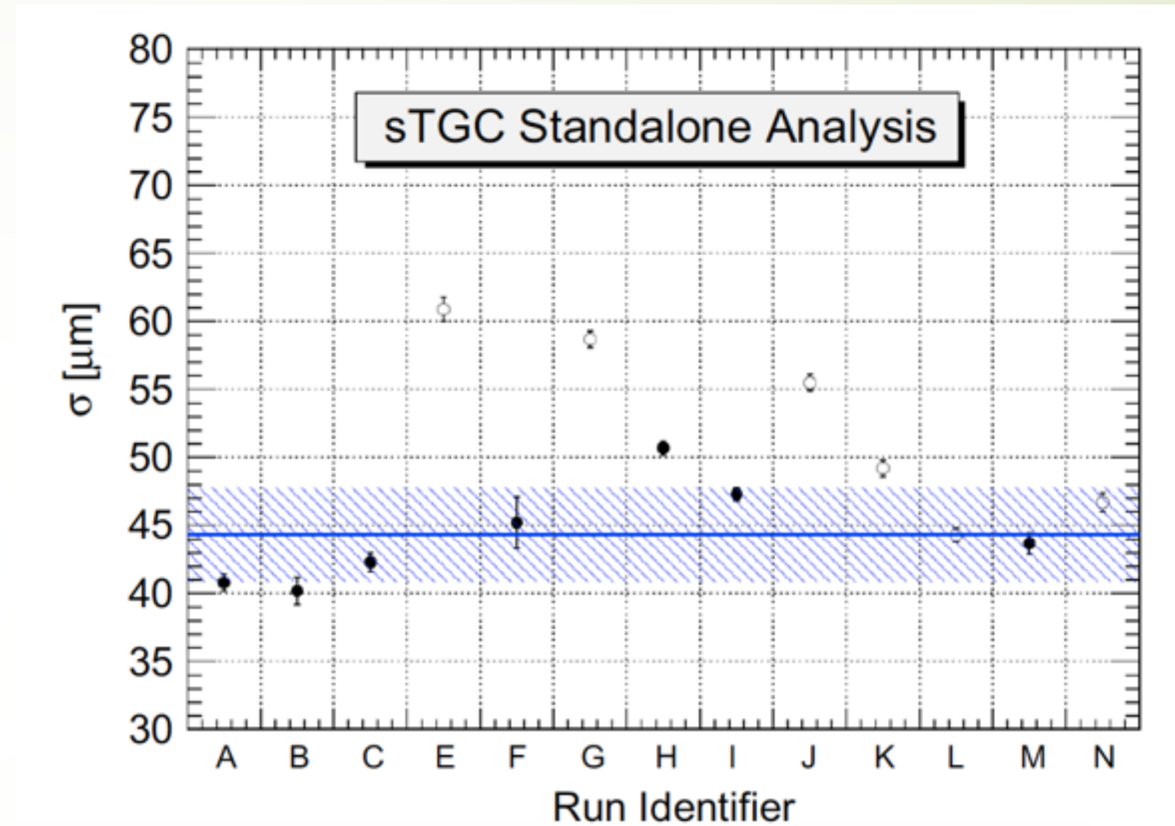
On NSW:

- Pads provide the level-0 trigger
- Strips data provide level-1 trigger
- Wires provide position in ϕ direction

Space resolution of sTGC



Space resolution at muon incident angle 0°-10°(solid line) and 20°-30° (dashed line), using TOT(time over threshold) of signals



Space resolution measured in beam test with incident angle 0 at several place of the first full size module

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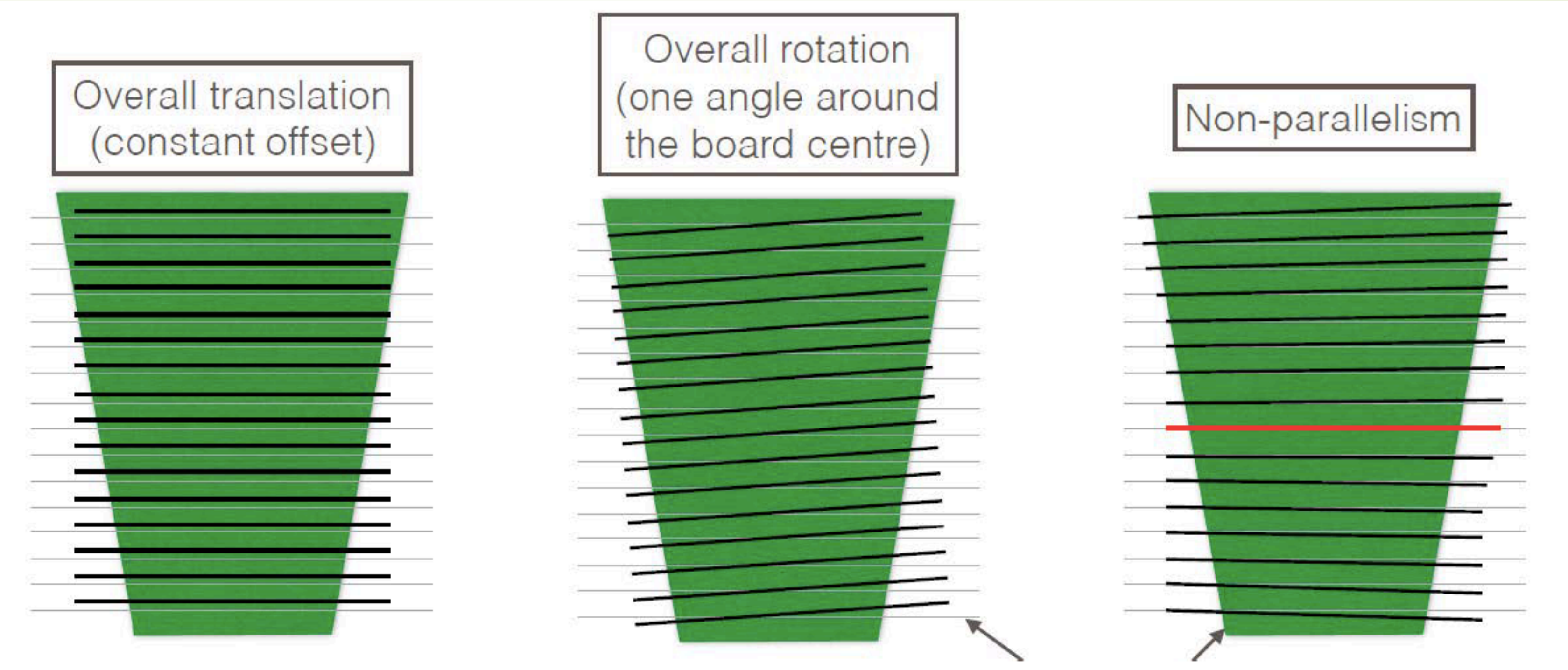
Space resolution degradation due to limitation of mechanical precision



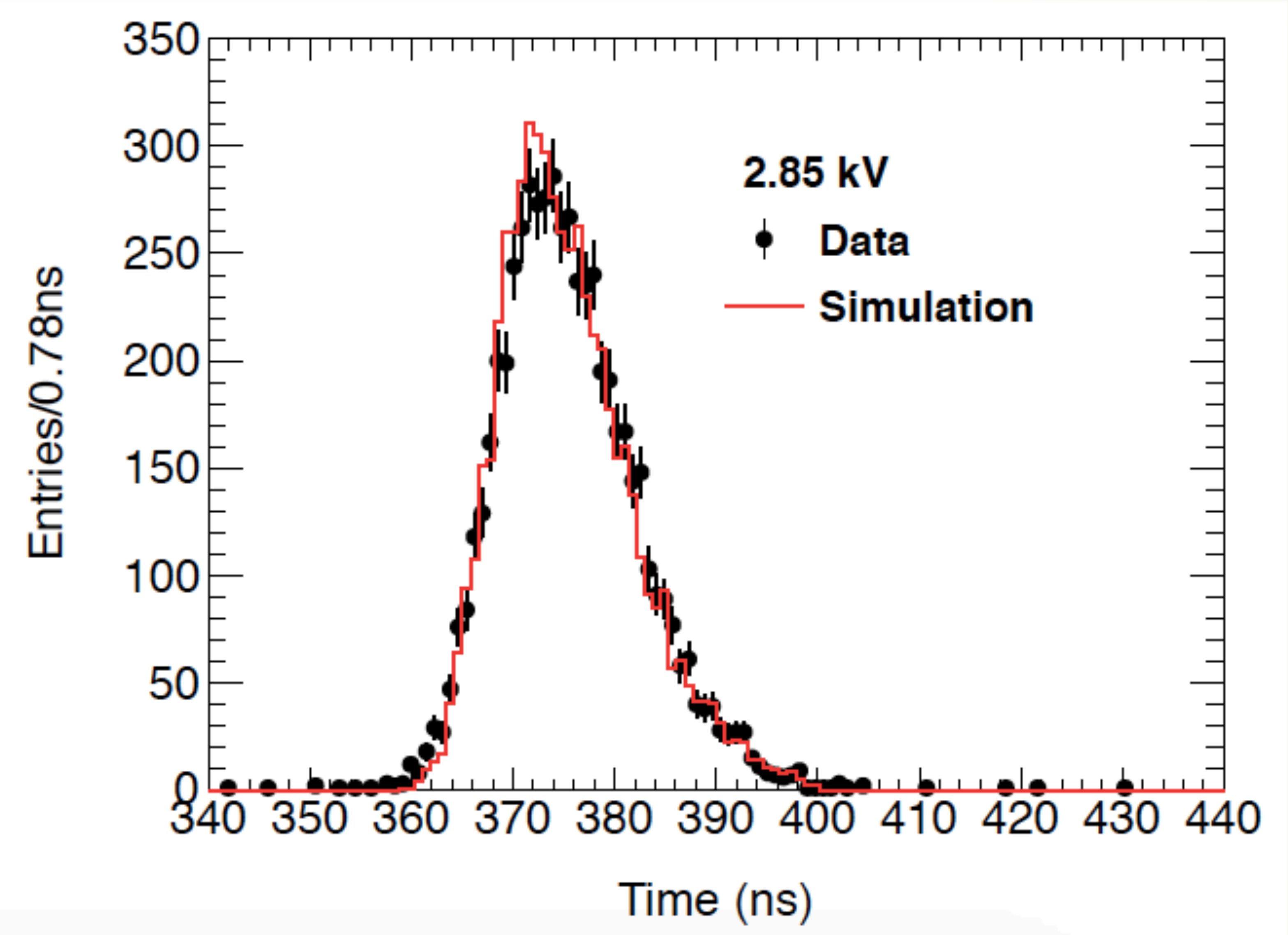
The global shift (tolerance $\pm 75\ \mu m$) and rotation(± 4 or 2mrad) can be corrected online,

Position scale and non-parallelism (tolerance $\pm 75\ \mu m$) degrade the space resolution.

It's a challenge for mechanical production of such large detector.

The resolution will be improved by total 16 layers of detectors, to compensate the degradation.

Fast response and good time resolution



95% of the total hits are contained within a 25 ns time window after proper adjustment of window offset.

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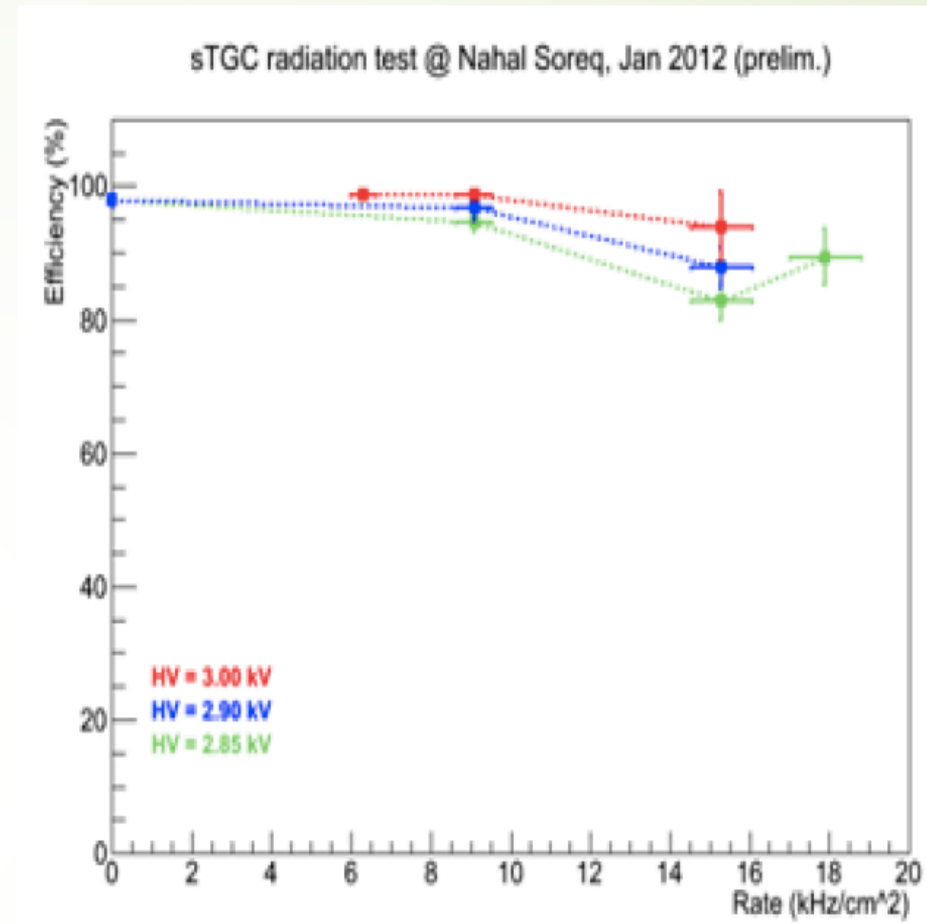
Flux tolerance



The ground use sprayed graphite (200/100kΩ/■),

The resistance is designed to be small enough to evacuate the avalanche charge quickly, but resistive to the fast signals through the CR network of detector and FEB, so that the charge can be picked up by the strip/pad outside of graphite

it can work in radiation environment up to 16 kHz/cm^2

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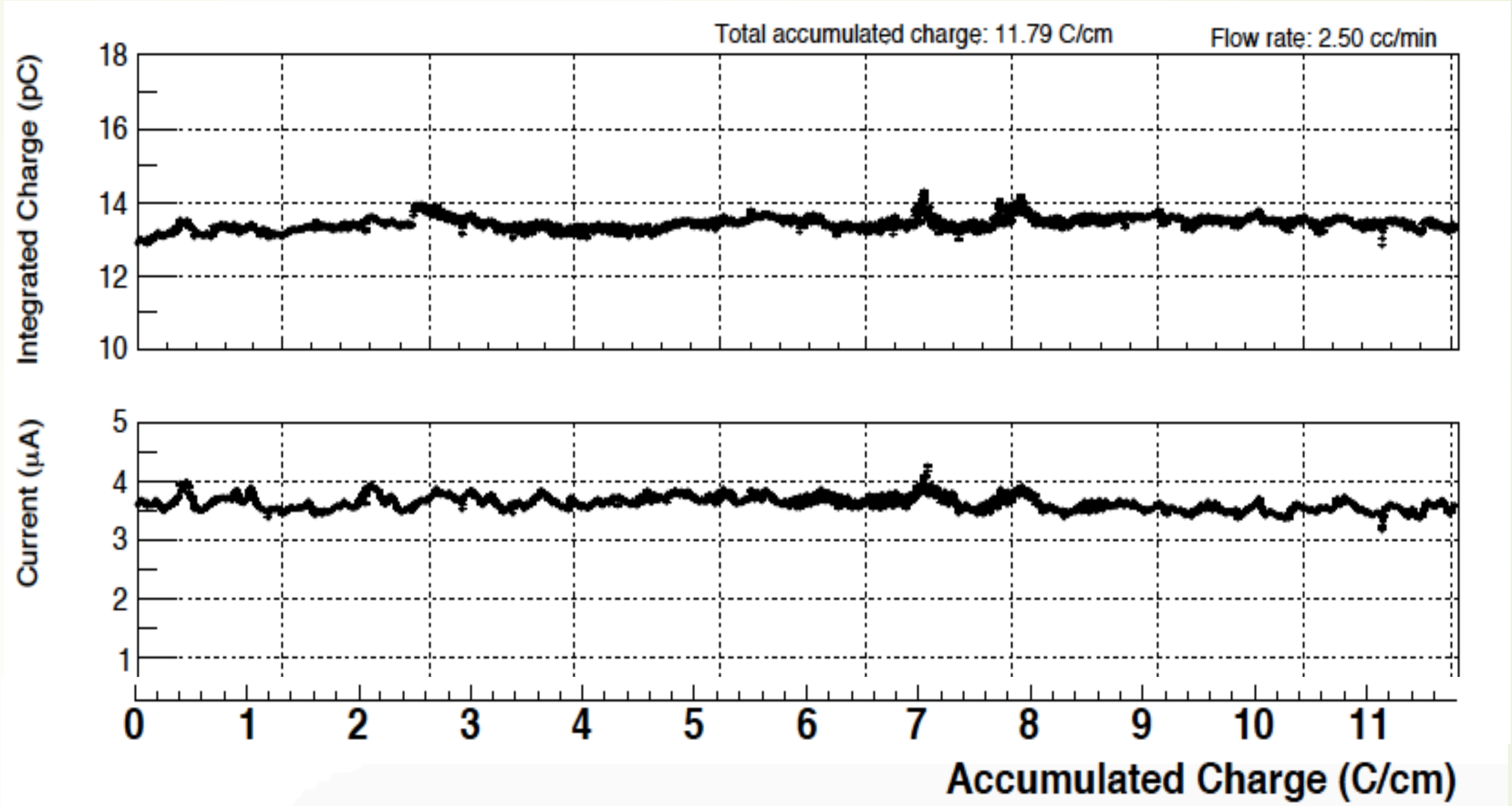
Integrated charge

current



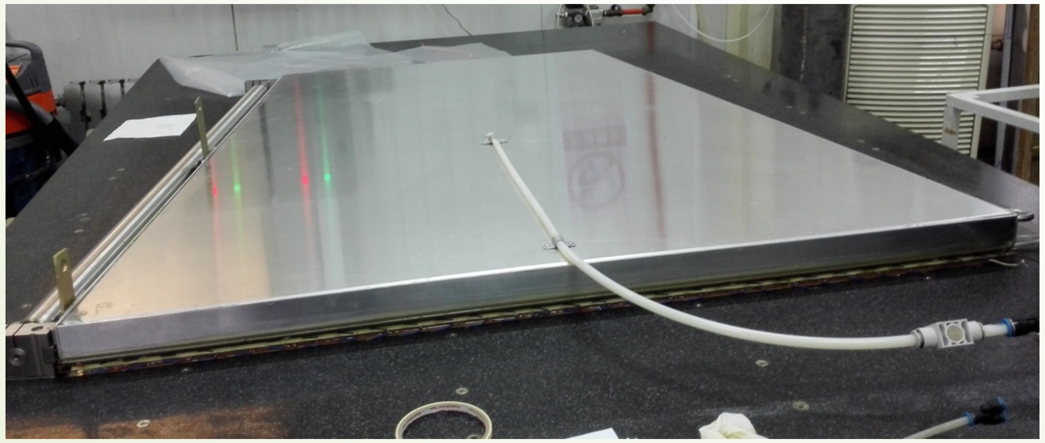
The ATLAS muon end-cap detectors are expected to be exposed to 1C/cm^2 of accumulated charge during the 15 years of operation in Run 3

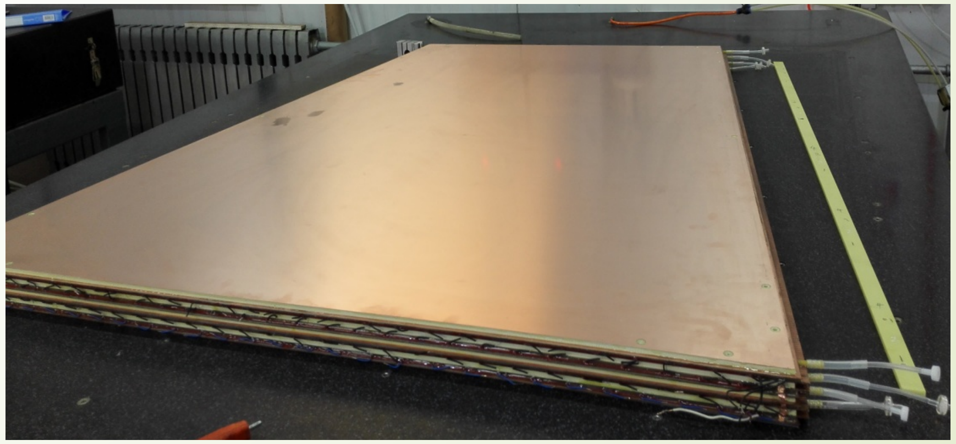
Integrated charge and current of detector was found to be constant as function of accumulated charge up to 12C/cm (corresponding to accumulated charge of 85C/cm^2)

ATL-MUON-SLIDE-2016-500

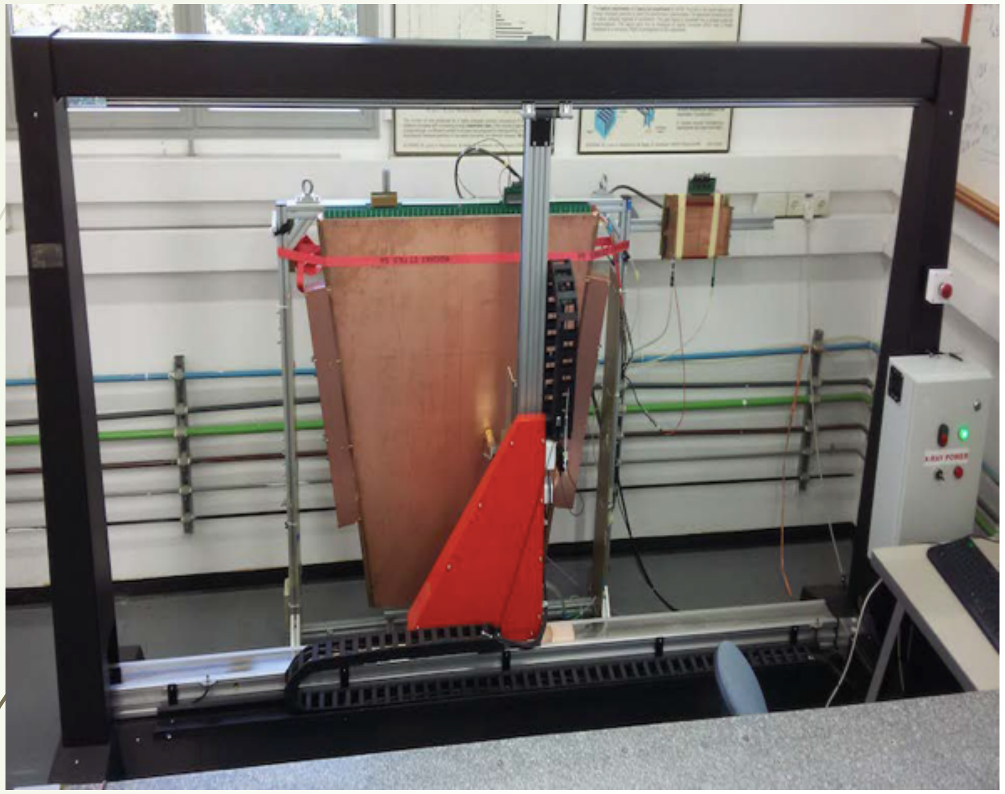
Construction challenges

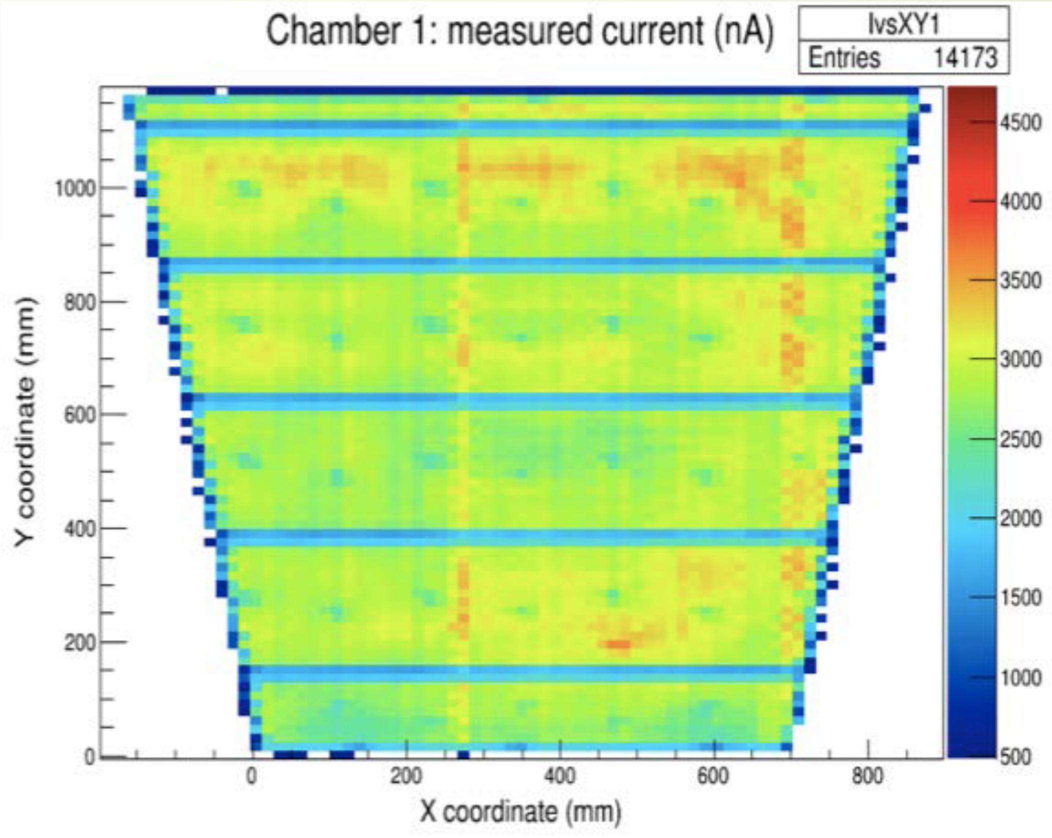
1. Strips position deviation relative to nominal tolerance<$\pm 75\mu m$
2. Uniformity of cathode board, tolerance $\pm 25\mu m$ on periphery, and $\pm 37.5\mu m$ at other area.
3. Mechanical parts tolerance < $20\mu m$ to keep constant anode-cathode distance.
4. Wire pitch tolerance 100 μm
5. Accumulated thickness/flatness tolerance for a module <$200\mu m$.





Gain uniformity measurement

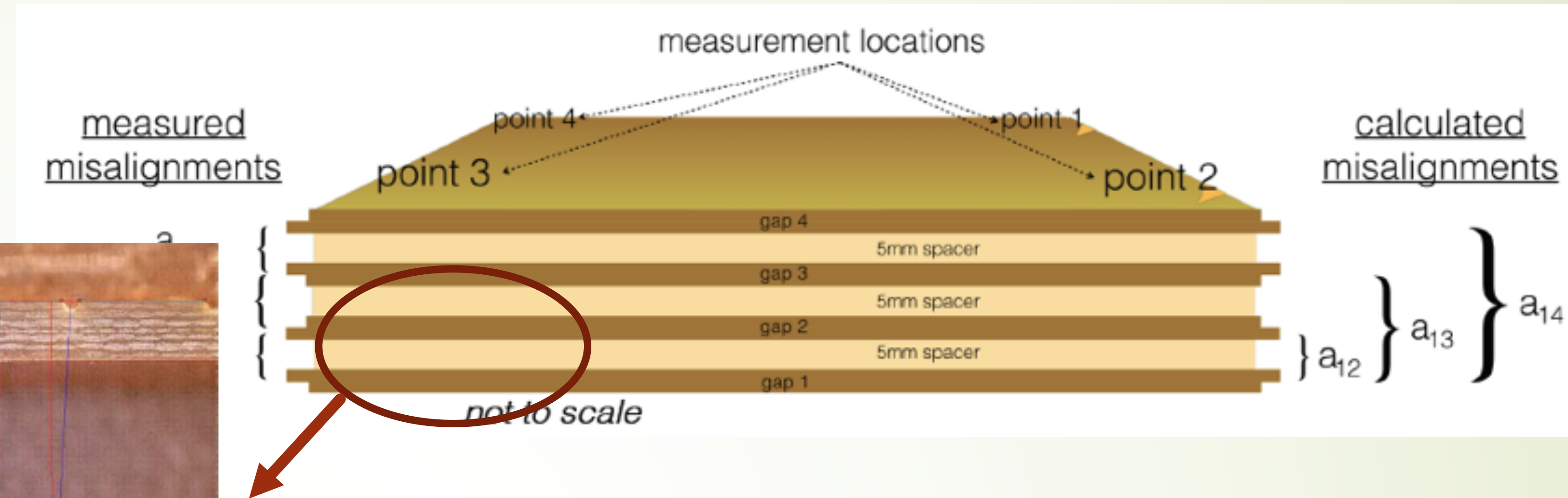


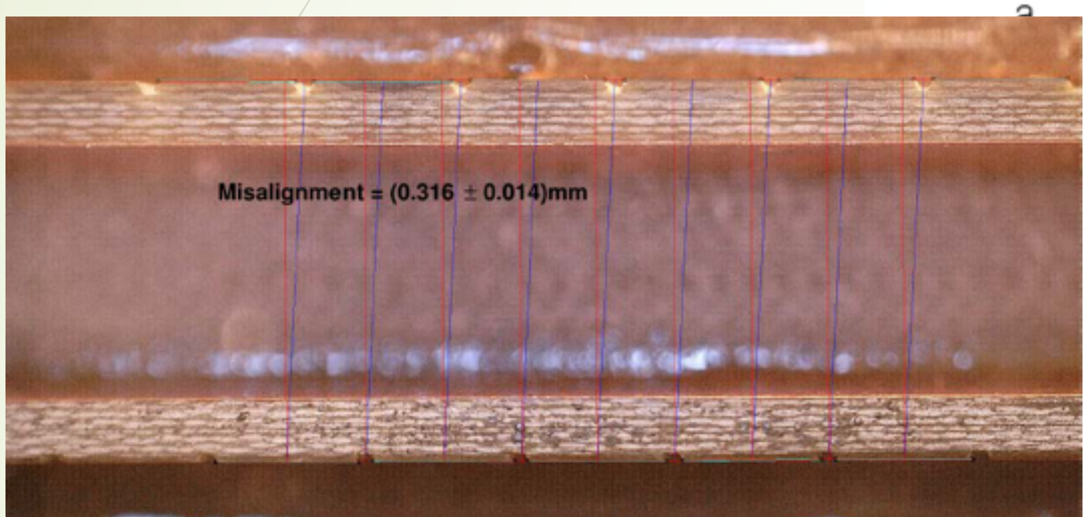


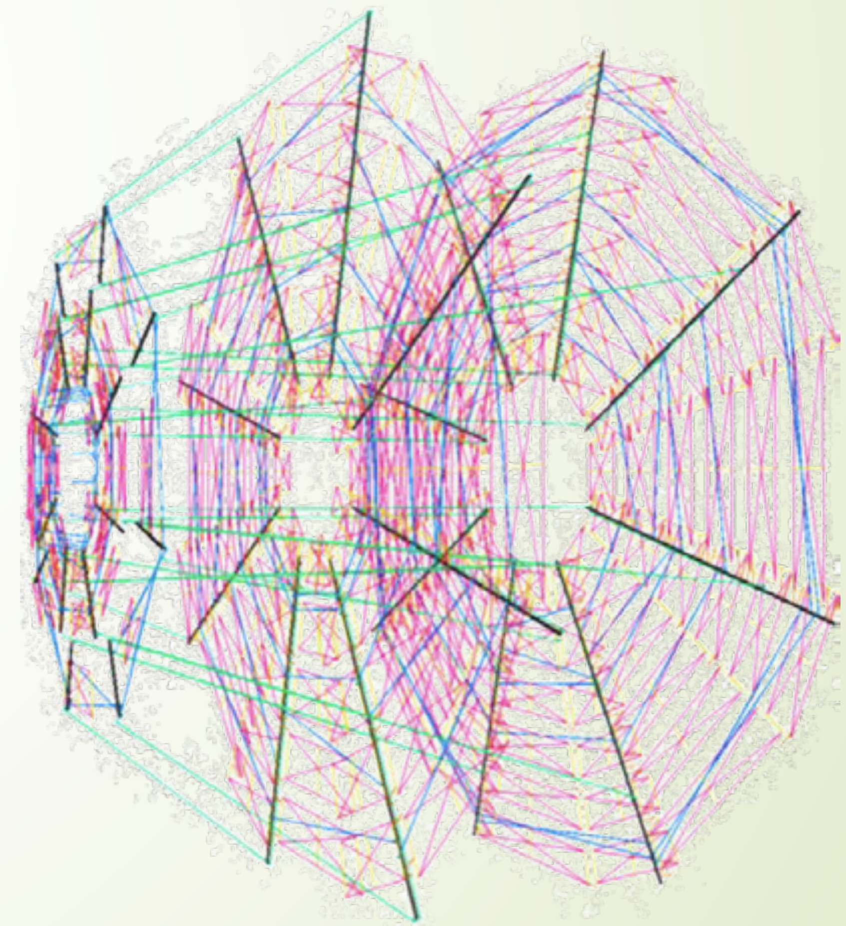
X-ray used to scan the sensitive plane of detector while the detector current is monitored.

The 2D drawing shows the current/gain at each point of the detector plan.

Problematic area are clearly spotted.







The relative shift measured with microscope with a precision of 20μm

The module is involved in the EC muon alignment system

cosmic test

With cosmic test:
1. The local space resolution is measured/scanned
2. Efficiency scan
3. the relative shift/rotation of strips pattern are measured
4. gain uniformity validated.

High radiation test at CERN before installation

sTGC module tested at area with gamma radiation > 20 kHz/cm^2, requiring:

1. No HV drop should be observed
2. Current restored after switching off the source

Summary

1. sTGC developed from ATLAS TGC with improved space resolution and flux ability
2. Comprehensive design, beam test, construction technique study were performed, proving it's feasibility as NSW detector
3. Prototypes of different types were produced and tested in beam, cosmic, x-ray etc.