# Precision survey of the readout strips of small-strip Thin Gap Chambers using X-rays

for the muon spectrometer upgrade of the ATLAS experiment

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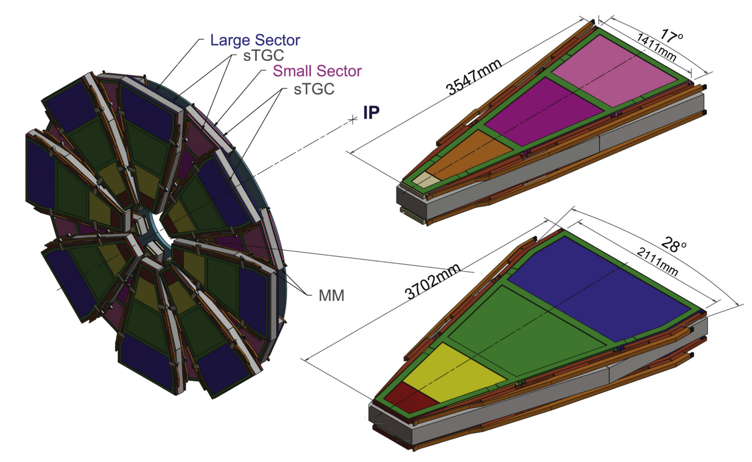
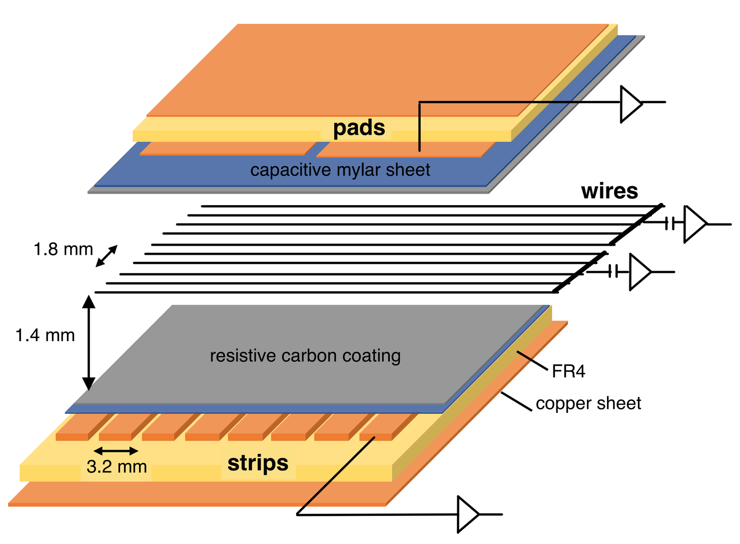
## small-strip Thin Gap Chambers (sTGC) for the New Small Wheel (NSW) upgrade

The first end-cap station of the ATLAS muon spectrometer will be replaced by the NSWs during the Large Hadron Collider (LHC) Long Shutdown of 2019-2020. The NSWs [1] will improve the online muon identification of ATLAS in anticipation of the planned increase of the LHC luminosity over the next decade.

Each NSW has 16 trapezoid **sectors** that combine the sTGC and Micromegas technologies. One sector has 2 sTGC **wedges** made up of 3 **modules**. Modules are multiplets with 4 layers of detection.

An sTGC is a thin multiwire chamber that operates with a mixture of n-pentane vapour and $CO_2$. Each side of the gas volume has a resistive cathode segmented in **pads** (triggering) or **strips** (precision tracking).



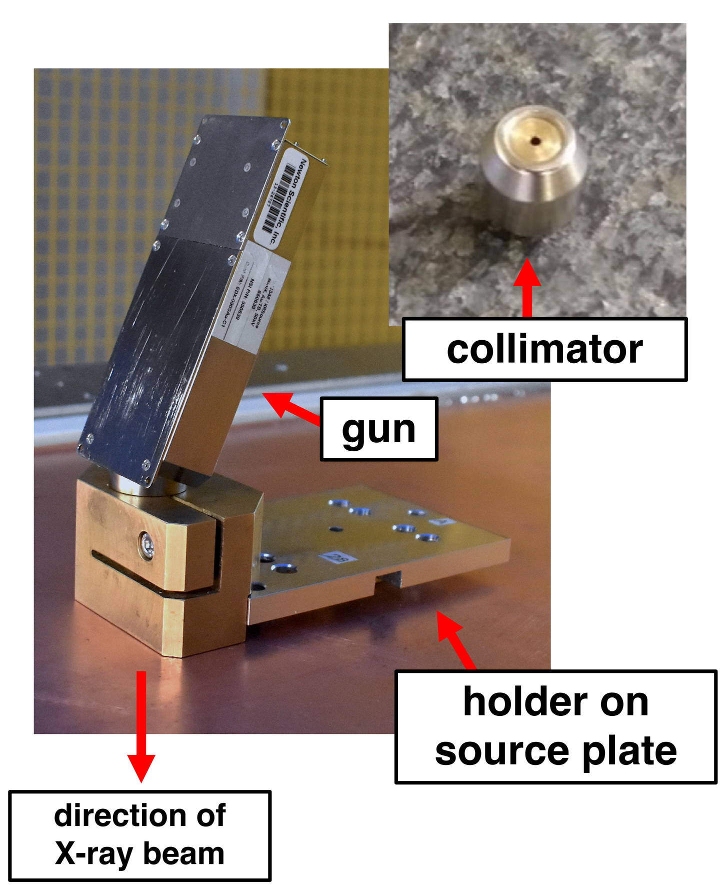

## X-ray survey

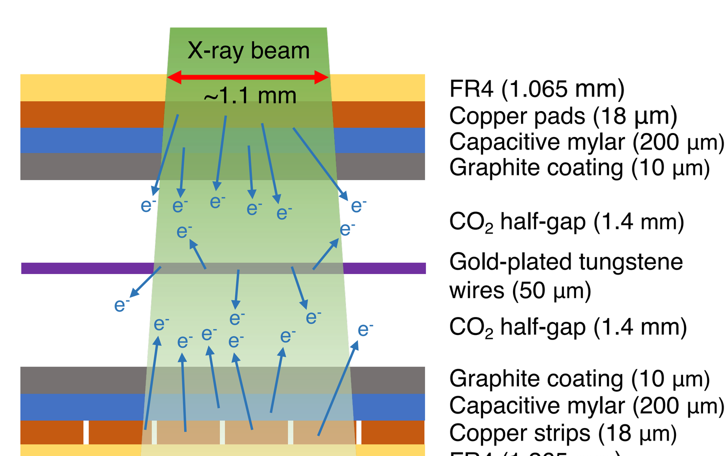
An X-ray survey of the cathode strips is carried out on all assembled wedges. The survey aims at measuring the **relative misalignments** between the strip cathode boards of the modules and of the source plates with respect to the module.

A gun[1] with a gold target is used to produce X-rays with energies of up to 40 keV with peaks in the 7-15 keV range. The gun is mounted on a **precision holder** with the tip perpendicular to the wedge surface. The holder is installed on the source plates with its position constrained with a **3-ball alignment system**. A cylindrical **collimator** (⌀ = 1.1 mm) is inserted in the tip of the gun.

Detected photoelectrons are mainly produced from X-rays hitting the copper cladding and anode wires of the gas volumes. Most detected photoelectrons are stopped in the gas volumes and initiate Townsend avalanches picked up by the strips.

Between **10 and 20 points** are surveyed on each module. Each point is associated with one position measurement per gas volume.




**Cross-section of an sTGC gas volume**
(not to scale)

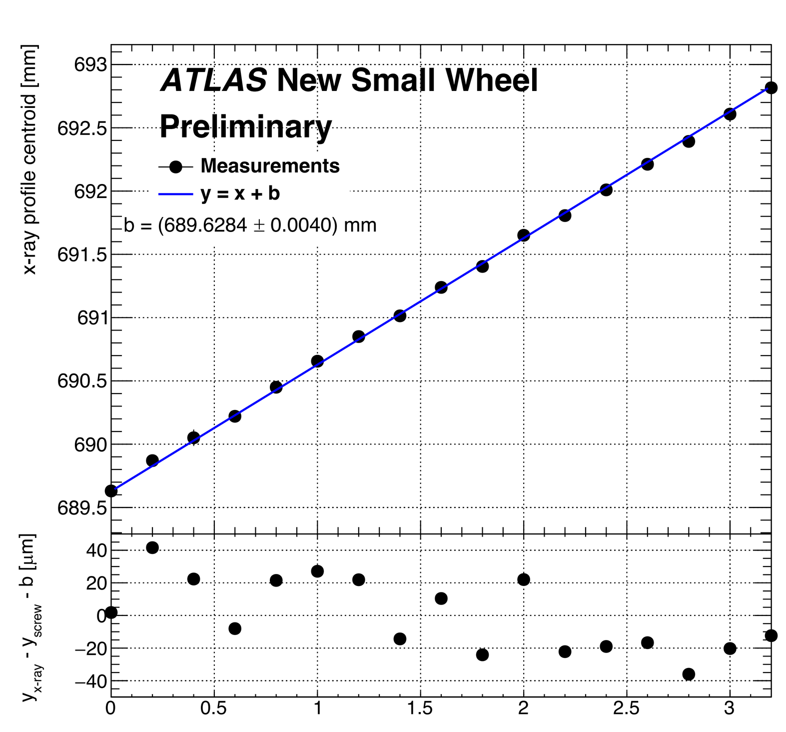
[1] Amptek Mini-X

## Spatial resolution

The spatial resolution is measured by comparing the centroid position of the X-ray irradiation profile to the setting of a **micrometric screw**.

The micrometric screw pushes the X-ray holder which is placed directly on the surface of a wedge. The movement of the holder is perpendicular to the strips and guided by a square angle.

The measurements are consistent with a spatial resolution better than **40 µm**.



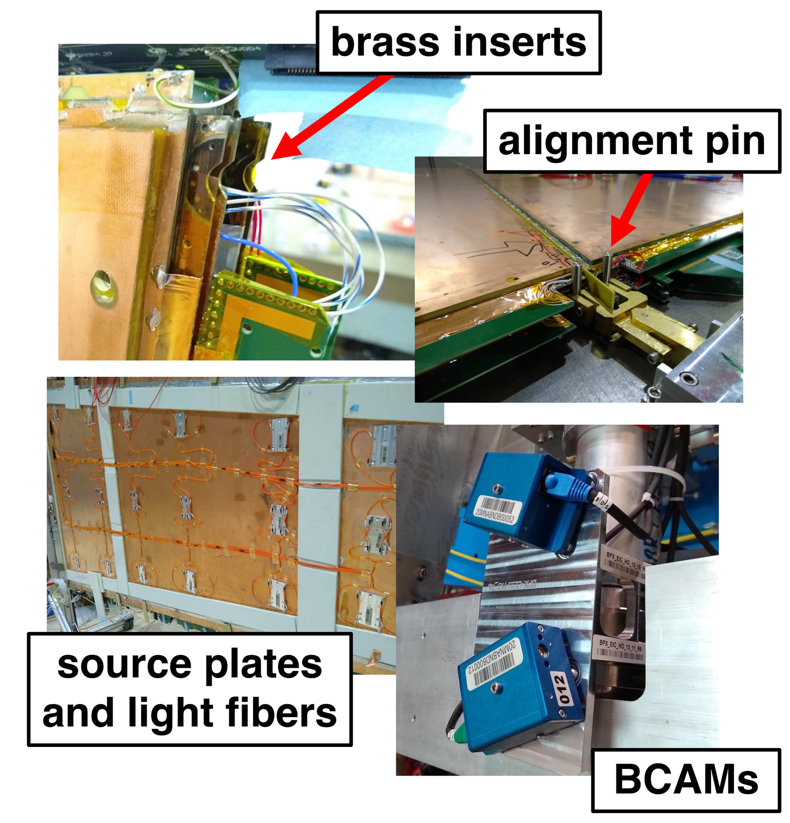

## Metrology and alignment of cathode strips

Non-conformities of the strip pattern on cathode boards are measured with **coordinate measuring machines** (CMM).

The strip cathode boards of a module are aligned using built-in **brass inserts** during construction. The modules of a wedge are also positioned using the brass inserts.

The NSW features an online optical alignment system which uses **BCAMs** (Brandeis CCD Angular Monitors) [2] to locate **source plates** installed using the brass inserts as reference for positioning.

**Deviations** of the strip pattern of up to **1 mm** with respect to the nominal position are observed.



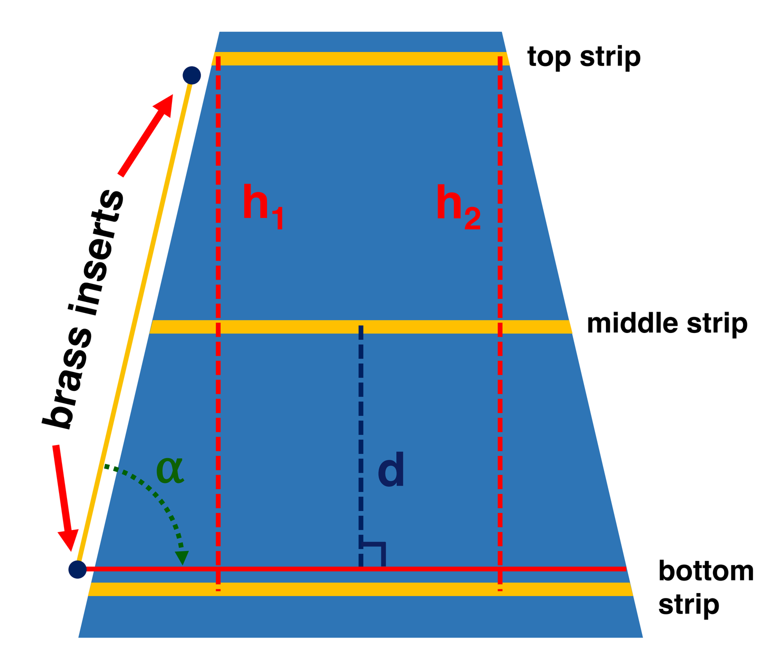

## Strip alignment model for the NSW

The local position of the strips with respect to the source plates on each individual strip boards is described by **4 parameters**:

- rotation (α-nominal)
- scale ($(h_1+h_2)/2$ – nominal)
- non-parallelism ($h_1$-$h_2$)
- offset (d-nominal)

CMM and X-ray survey results are combined in a **global alignment model**.

Aim to know the position of the strips within **100 µm** to achieve a transverse muon momentum resolution of **10% at $p_T$ = 1 TeV**.




## Data taking and analysis

The gas volumes of the surveyed wedge are flushed with **pure $CO_2$** and a bias voltage of 2.925 kV is applied to the anode wires. During X-ray irradiation, the strips are read out using the **VMM3** [3], an amplifier-shaper-discriminator ASIC, mounted on prototype front-end boards. The voltage thresholds of the electronic channels are tuned to equalize their hit efficiency. The data acquisition system uses **random triggers** to acquire strip hits. A data acquisition run of a few minutes is sufficient for one surveyed point.

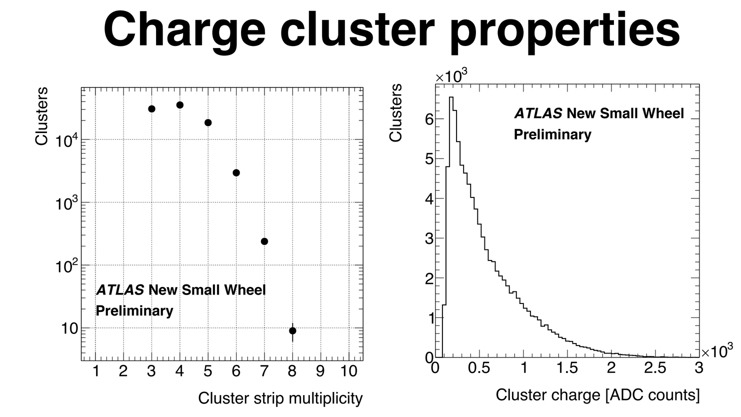
Contiguous strip hits within a time window of 75 ns make up **charge clusters**. The centroid position of the charge clusters is the mean parameter of a Gaussian function fitted to the pulse peak values of the hits. The measured position of individual X-rays is the centroid position of the clusters corrected for the **differential non-linearity** bias.

The X-ray beam position on each gas volume is corrected for

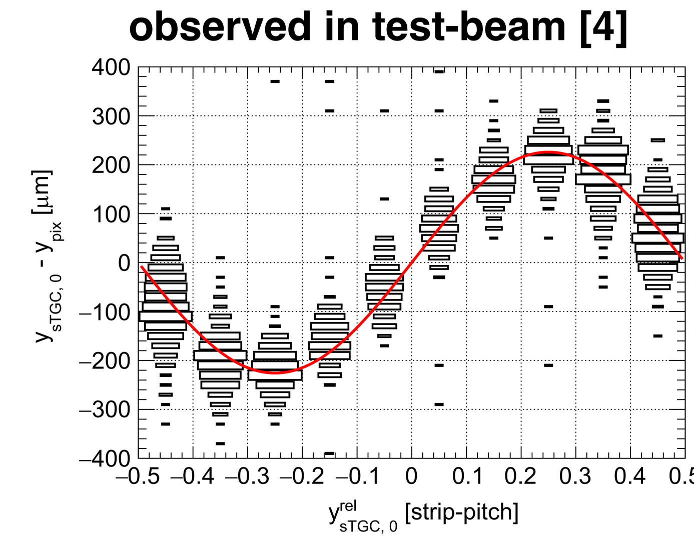
- the geometry of the machined holder,
- the positioning of the source plates,
- the angle of the collimator and,
- the angle of the source plate.

Deviations between the expected beam position and the centroid position of the X-ray irradiation profile correspond to the **local misalignments of the strip pattern.**

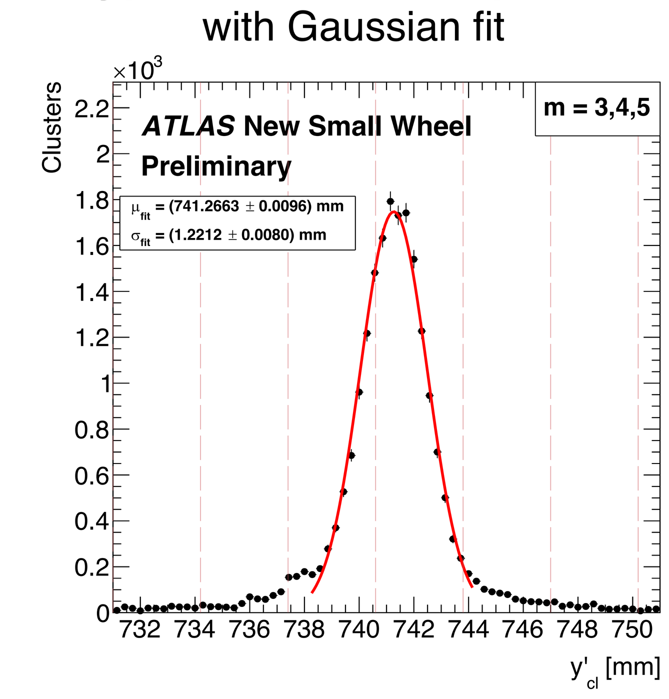
**Charge cluster properties**




**Effect of differential non-linearity observed in test-beam [4]**



**Typical irradiation profile**
with Gaussian fit




[1] CDS:CERN-LHCC-2013-006 [2] JINST 3 (2008) P11005 [3] CDS:ATL-MUON-PROC-2019-010 [4] NIM A 817 (2016) 85