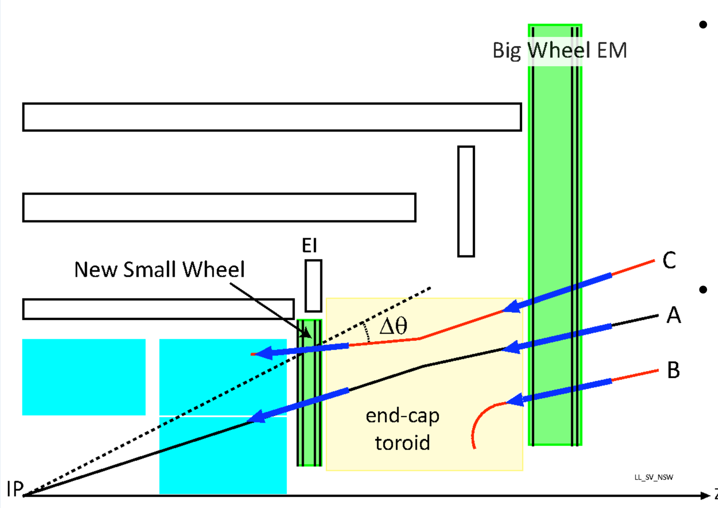
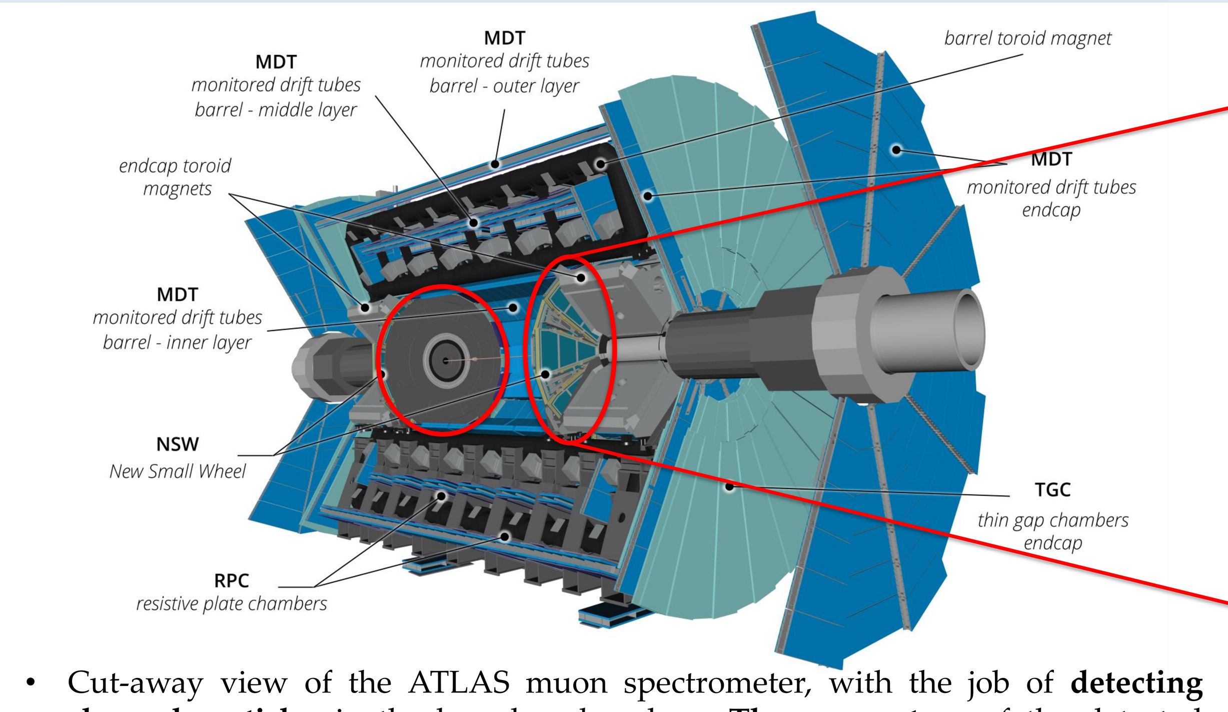
ATLAS New Small Wheel Trigger and Reconstruction Performance Studies with LHC Run-3 data

NSW motivation

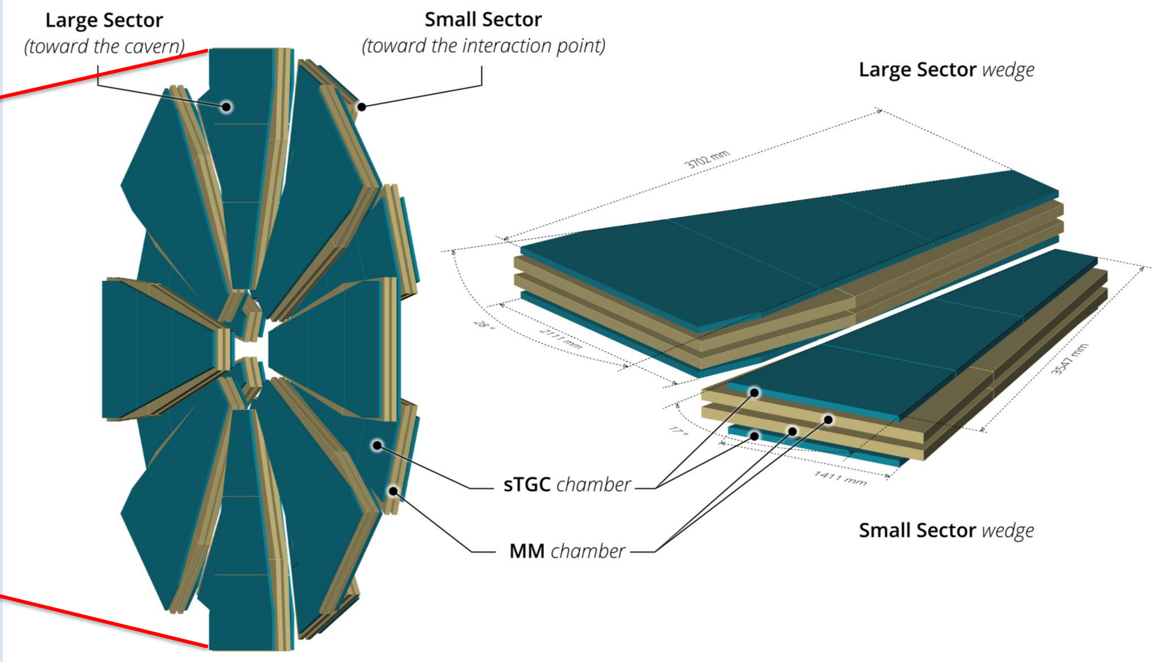


- The New Small Wheel (NSW) was designed to provide **fake trigger reduction** and to **improve muon tracking** in the pseudo-rapidity region of $1.3 < |\eta| < 2.4$ for triggering and $1.3 < |\eta| < 2.7$ for tracking.
- Those **fake muons** result mainly due to protons in the forward regions, that originate from nuclear reactions in front of the electro-magnetic calorimeter station.

The NSW in ATLAS



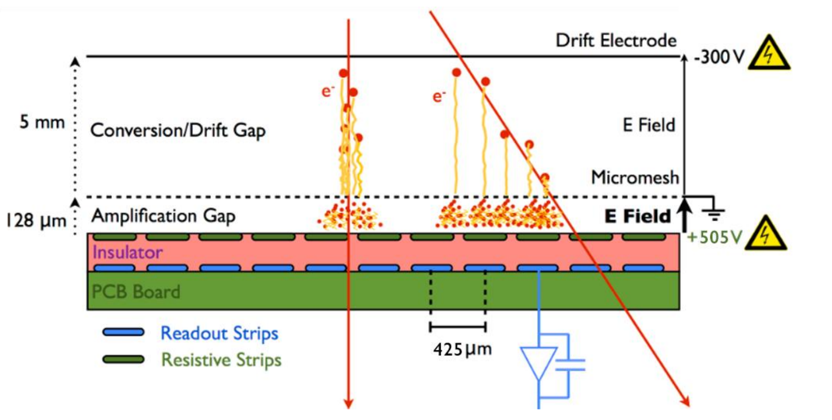
- Cut-away view of the ATLAS muon spectrometer, with the job of **detecting charged particles** in the barrel and endcap. **The momentum** of the detected particles **is measured up to** pseudo-rapidity **range of $|\eta| < 2.7$**.
- The main detector components (**NSW**) **upgraded for Run 3** are highlighted in **red circles**.



- **Structure of the NSW's 16 sectors**; their **staggered arrangement** ensured full coverage and **eliminates any gaps between adjacent areas.**
- Each sector consists of two wedges of sTGC (blue). The sTGC wedges sandwich the two MM (brown) wedges.
- Each of the sector contains **16 active layer: 8 of MM** and **8 of sTGC.**

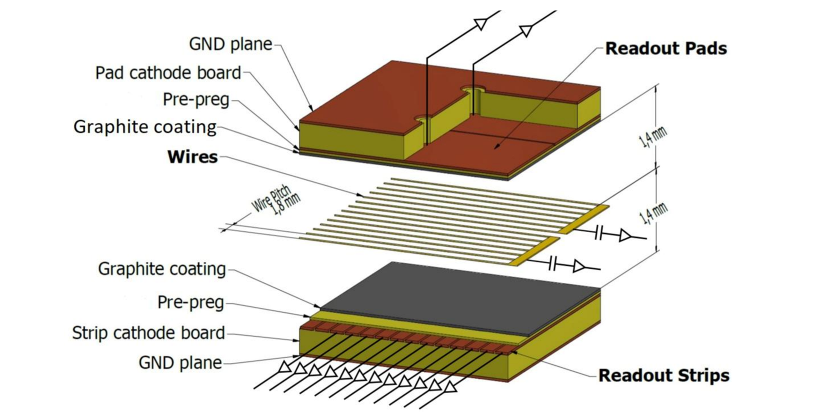
The NSW detector technologies

MicroMegas



- The MicroMegas (MM) detector operating principle (left) and arrangement of gas gaps (right) to form a quadruplet.
- The **active gas volume** is **separated into two regions** by means of a stainless-steel mesh, dividing it into a **drift and amplification gaps**.
- A ~ 120 µm thick amplification gap was chosen for **high-rate capability**, with **narrow readout strips** to **optimize noise and spatial resolution**.
- A **resistive layer** is used for **spark protection**.
- The used gas mixture is Ar:CO_2:i-C_4H_{10} (93:5:2).

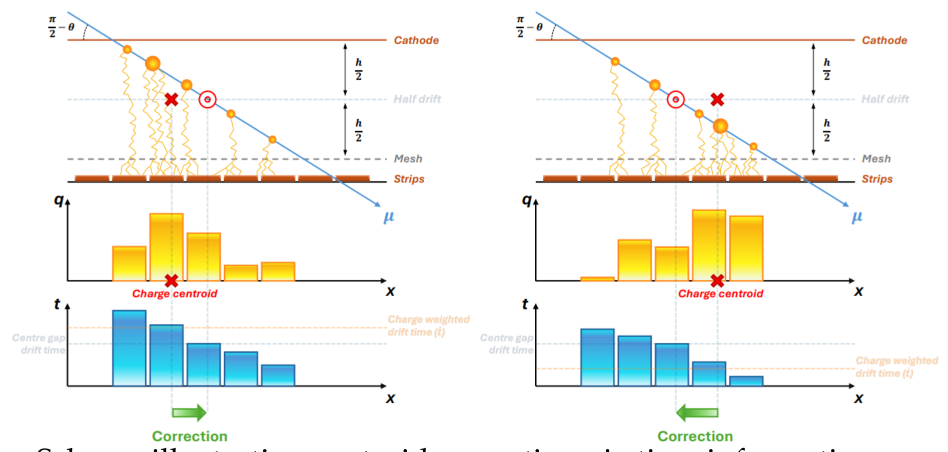
Small-Strip Thin Gap Chamber



- The small-strip Thin Gap Chamber sTGC detector operating principle (top) and arrangement of gas gaps (right) to form a quadruplet.
- **Narrow gas gap** is used to **increase time resolution**.
- The **pads** provide **coarse and fast** trigger and tracks position.
- The **wires**, arranged in groups of eight, provide the tracks **second coordinate**.
- The **strips** provide **fine** track **resolution** for trigger and reconstruction for the precision coordinate.
- The used gas mixture is CO_2:n-pentane (55:45).

Spatial resolutions

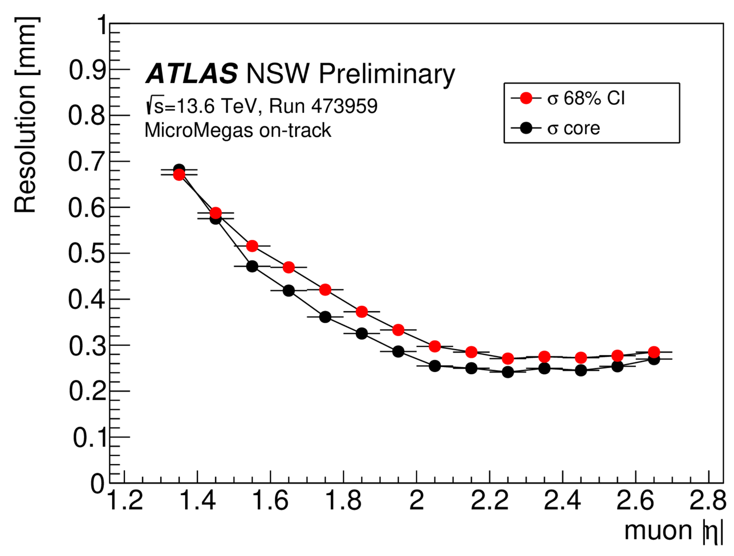
Time corrected centroid



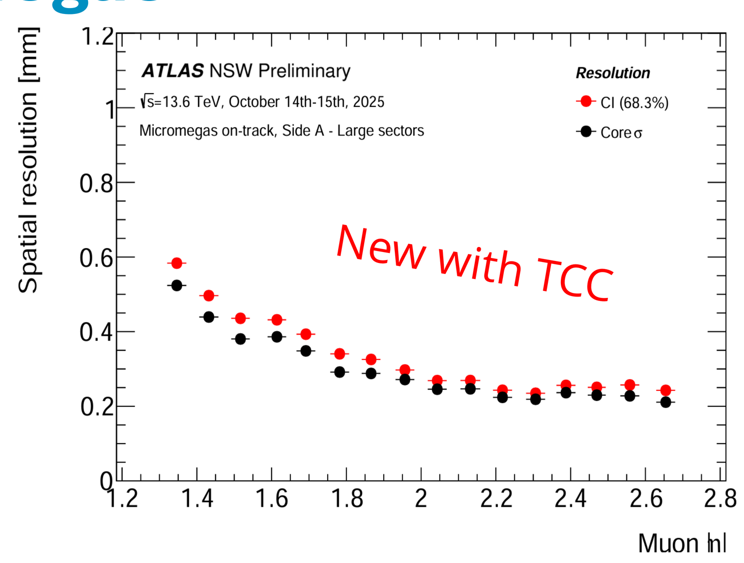
- Scheme illustrating centroid correction via time information.
- Since the ionization process is not uniform, this results in inhomogeneous charge distribution that skews the centroid position from the intended one.
- The Time Corrected Centroid (TCC) method corrects this shift using the electrons effective drift velocity and the muon polar angle obtained externally (e.g., the ATLAS Inner Detector (ID)):

$$\Delta x = \left(v_{drift}\,\bar{t}_{drift} - \frac{h}{2}\right)\tan(\theta)$$

MicroMegas

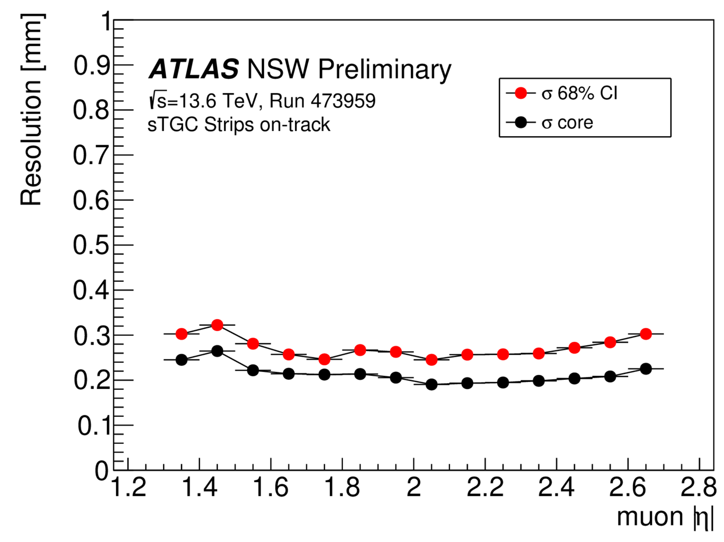


- **Spatial resolution** as a function of muon $|\eta|$ obtained by performing a double-gaussian fit to the residuals.
- The cluster are associated to a **combined muon track** (ID+MS) or **standalone** (MS) with $p_t > 15$ **MeV**.
- The resolution is defined as the σ corresponding to the **68% confidence interval of the fit function**, or the **σ associated to the narrowest Gaussian** (σ core).



- Spatial resolution as function of muon $|\eta|$, with resolution kinematic cuts and resolution definition as in the plot on the left.
- The **resolution improvement** obtained with the **TCC method** is shown for all layers of the Side-A large sector.

sTGC

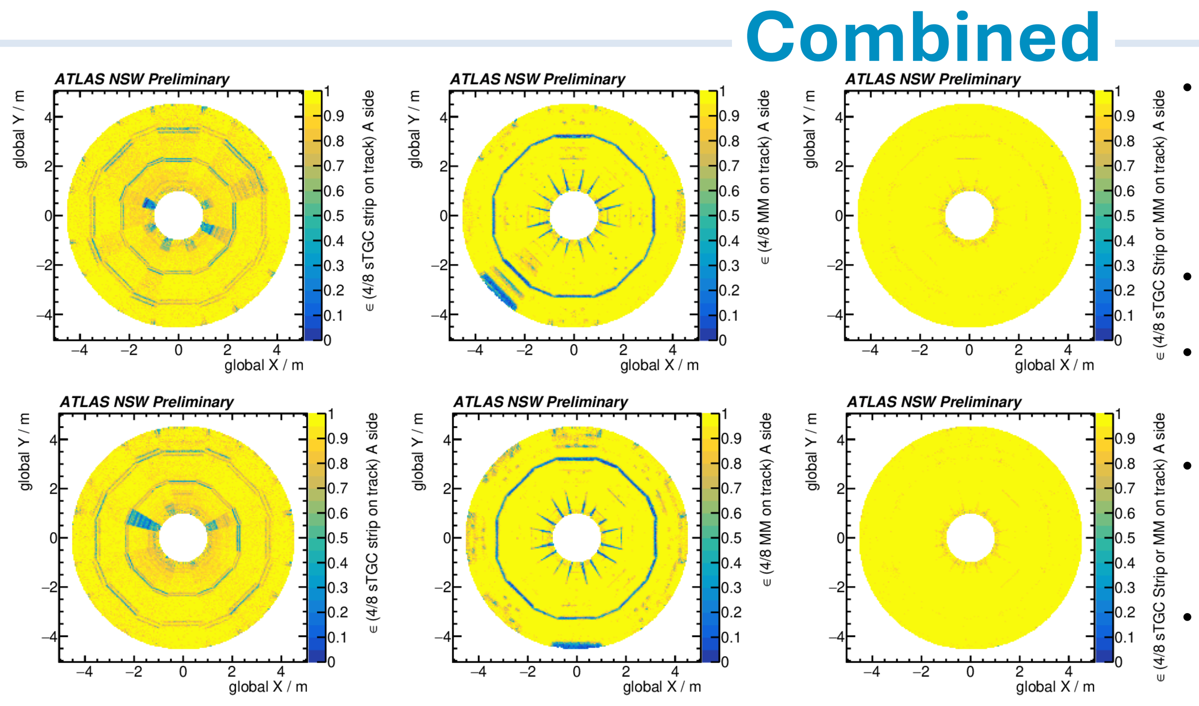


Spatial resolution as function of muon $|\eta|$, with resolution kinematic cuts and resolution definition as in the MM plots.

Work is ongoing to **improve the spatial resolutions for MM and sTGC** by **optimizing alignment, magnetic field corrections** and **cluster weighting algorithm**.

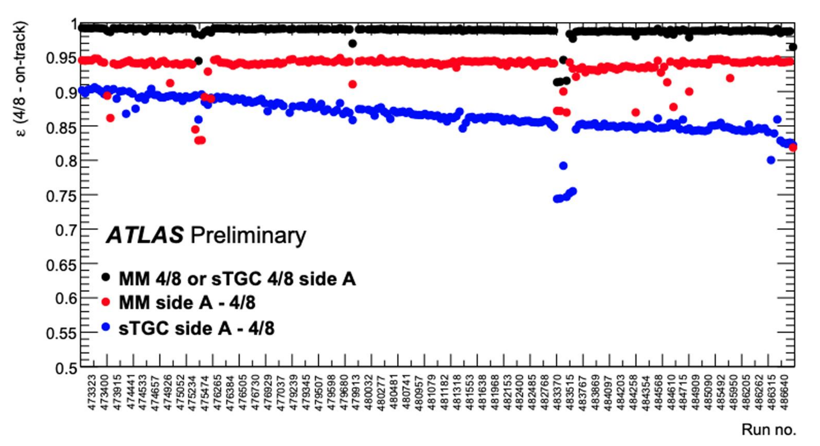
Efficiency

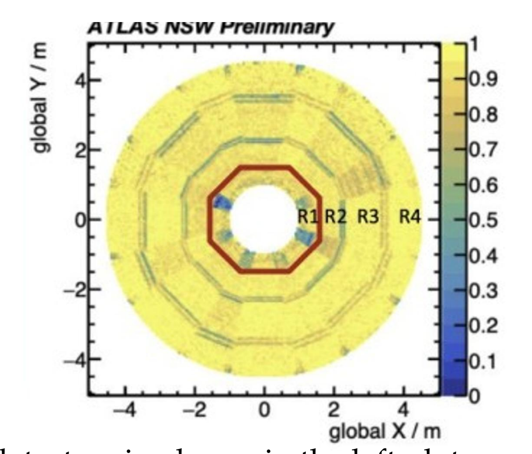
Combined



- Efficiency of having at least **4 out of 8** hit layers in **the sTGC** (**left column**), and in the **MM** (**central column**), and **efficiency for track reconstruction** (**right column**) for **side A** (top row) and **side C** (bottom row).
- **Efficiency for track reconstruction** is defined as 4 out of 8 MM **OR** 4 out of 8 sTGC.
- The right column shows the efficiency with which the NSW is contributing to the muon track reconstruction in the ATLAS end-caps.
- Even tough the single technologies present some inefficiencies area, **thanks to the designed redundancy**, the **NSW delivers excellent efficiency overall**.
- The **layer is considered efficient** if a **cluster** is found **within ± 5 mm** with respect to the extrapolated track position.

Performance over time

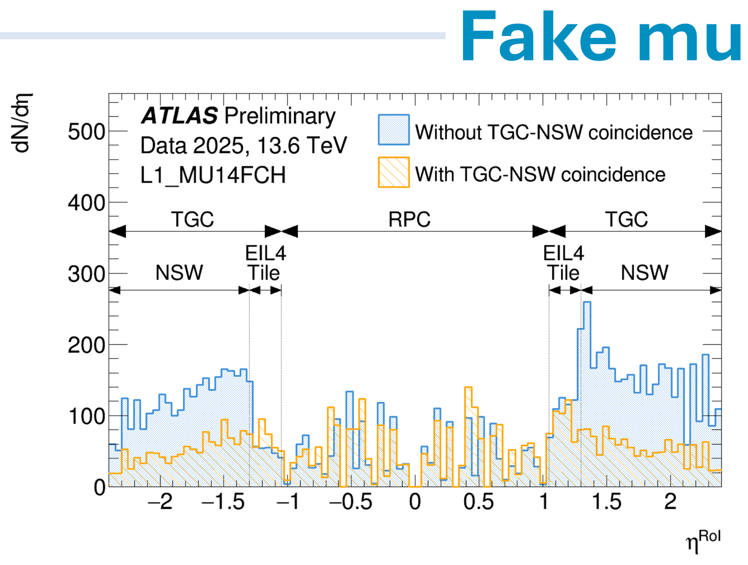




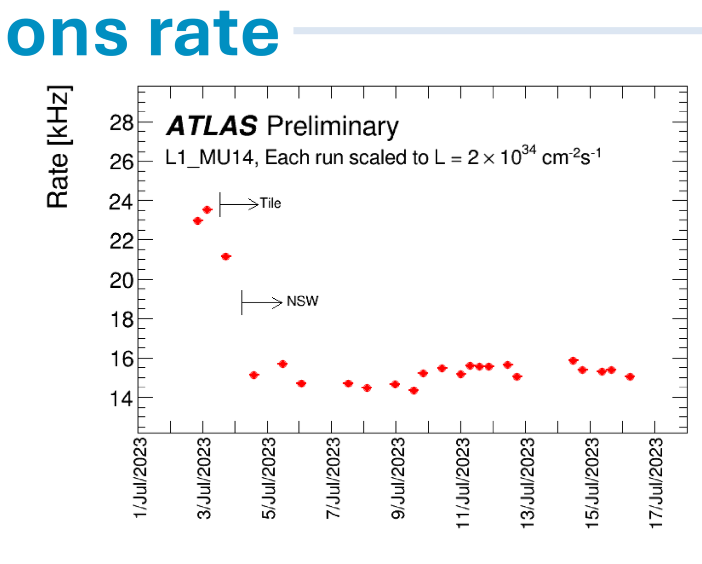
- The efficiency over time of the full NSW and its comprising detectors is shown in the left plot.
- At low angles (highlighted R1 ring of right plot) an inefficiency can be observed in the sTGC modules.
- **Those inefficiencies are under investigation** and will be **tackled during the LHC Long-Shutdown** period that will start in the summer of this year.
- Even though the efficiency of the sTGC detectors is decreasing the NSW **efficiency stays at ~ 100%**.

Trigger

Fake muons rate

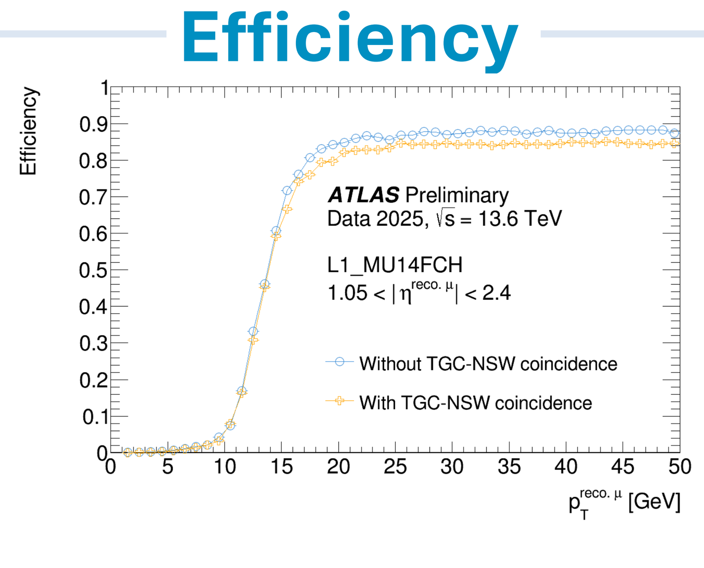


- Pseudo-rapidity distribution of the L1 muon trigger satisfying the 14 GeV threshold.
- **A rate decrease**, due to **better background rejection**, can be seen when comparing the data **with** and without the inclusion of **the NSW**.



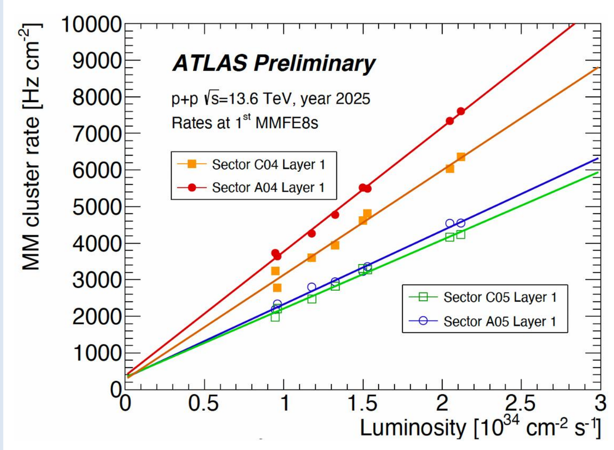
- Trigger rate of L1 muon trigger satisfying the 14 GeV threshold.
- After the **NSW coincidence** activation, a **significant decrease in rate** can be observed thanks to fake rejection.

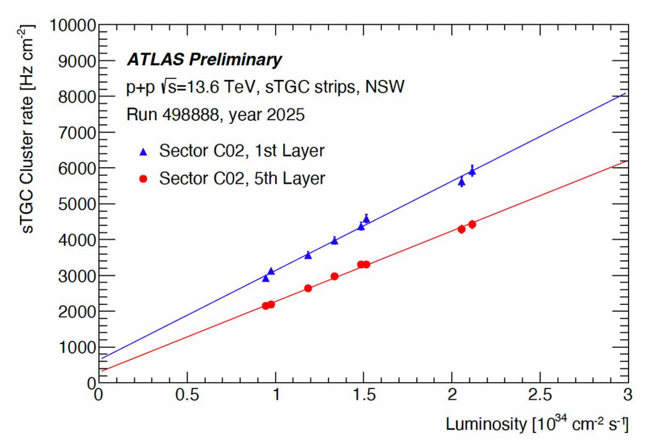
Efficiency



- Trigger rate of L1 muon trigger satisfying the 14 GeV threshold.
- The **coincidence** with the NSW has a **minor impact on the trigger efficiency.**

Background rates





- ATLAS NSW detectors were designed to withstand an estimated background radiation rate of about 20 kHz cm^{-2}.
- Background rate measurements for **MM (left)** and **sTGC (right)** under current operating conditions are shown. These values represent the **highest rates measured at maximum η** (closest to the beam line).
- The extrapolated rate at HL-LHC conditions ($\mathcal{L} = 5 \div 7 \times 10^{34}\ \mathrm{cm^{-2}s^{-1}}$) is of $18 \div 25$ kHz cm^{-2} for MM and $13 \div 18$ kHz cm^{-2} for sTGC.

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ATLAS EXPERIMENT