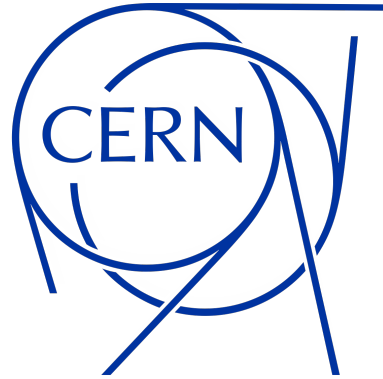


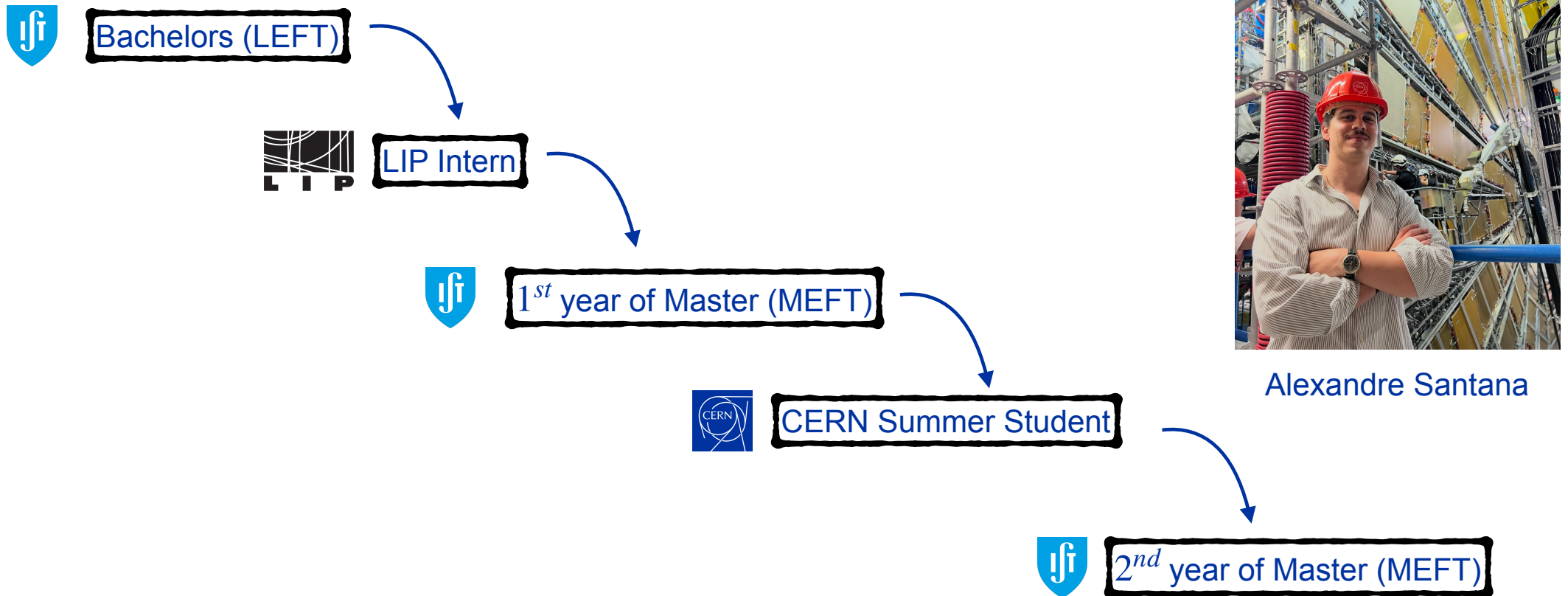


Long-term performance monitoring of the ATLAS New Small Wheel sTGC system

Alexandre Santana (CERN) - Summer Student

September 3, 2026

Who am I?

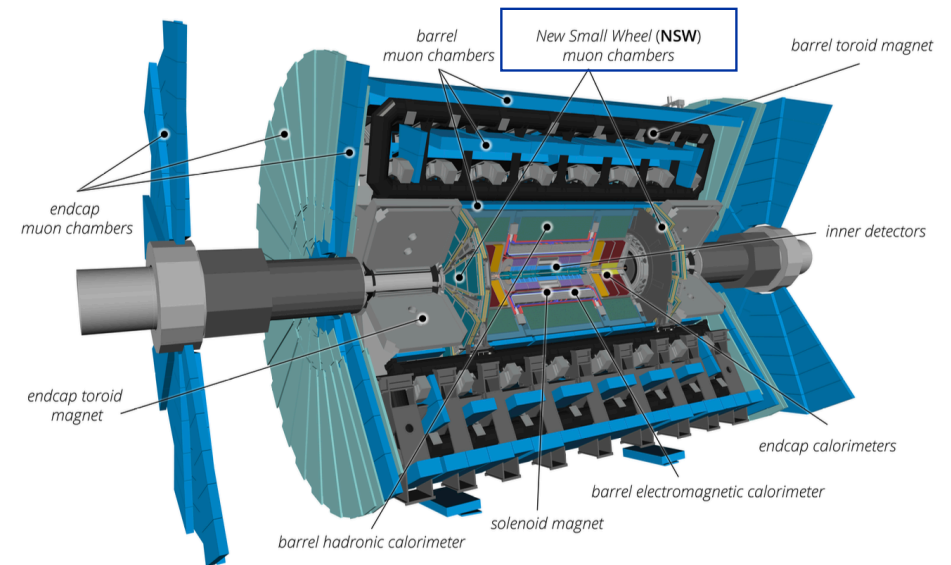


Alexandre Santana

Summer Student Project

Long Term Monitoring of the ATLAS NSW sTGC system - my project

- Study the behavior of the sTGC
- Monitor the performance to the HV layers overtime
- Identify degradation and failure patterns
- Help ensure long term reliability of the NSW during the High-Luminosity LHC period

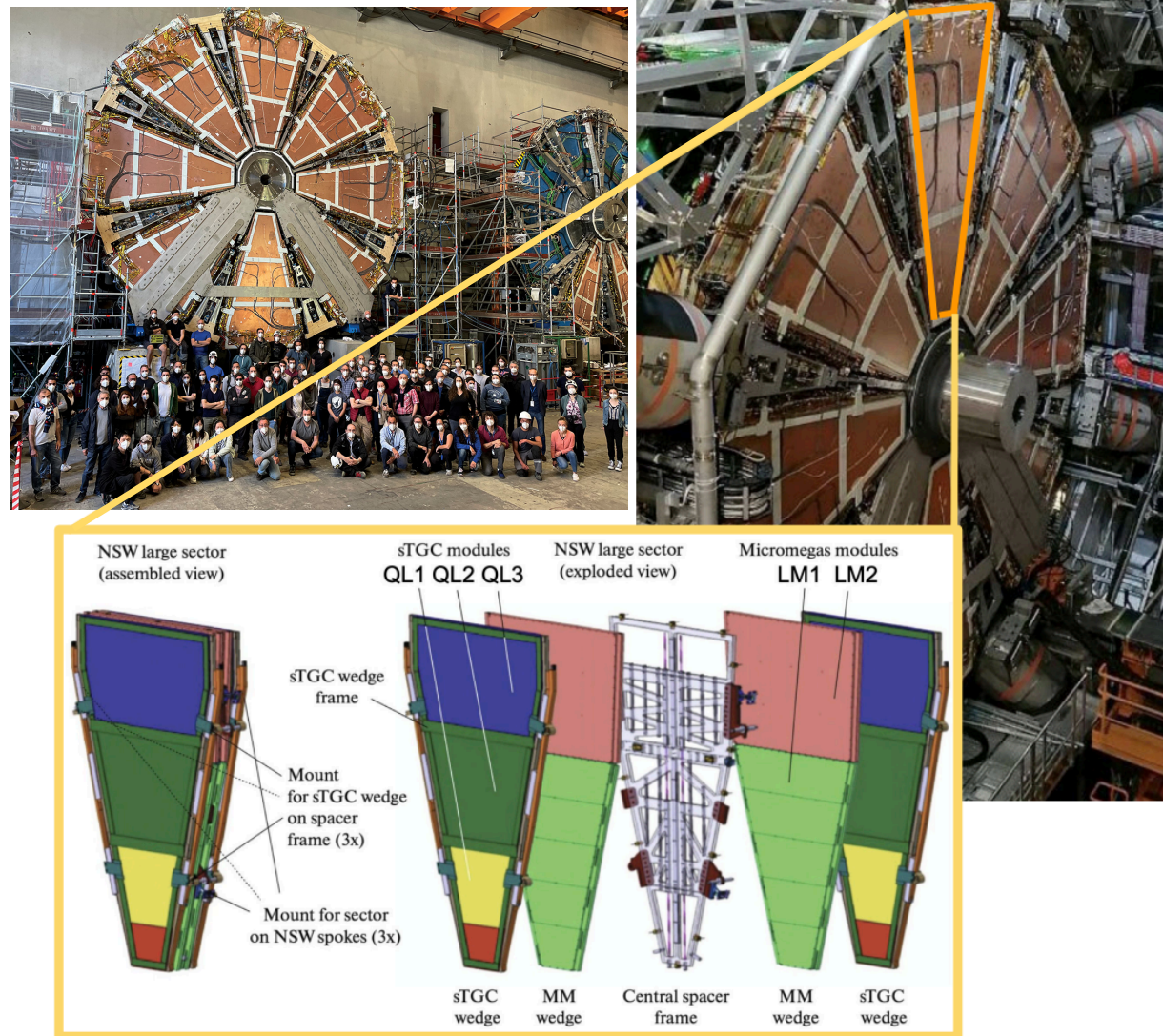


Cut-away view of the Run 3 configuration of the ATLAS detector indicating the locations of the larger detector sub-systems. Adapted from <https://arxiv.org/pdf/2305.16623>

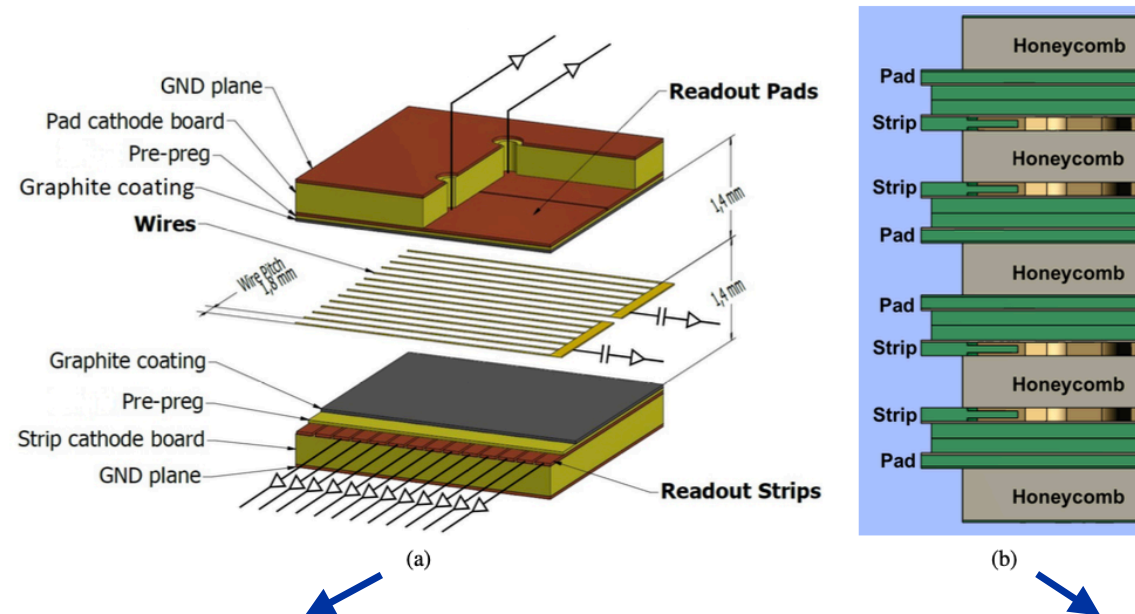
sTGC - NSW

Two sides A and B, each with 16 sectors

- **Large** sectors (odd number), **Small** sectors (Even number)
- 1 sector = 2 sTGC wedges (Inner and Outer)
- 1 wedge = 3 quadruplet (Q1, Q2 and Q3)
 - Each quad has 4 HV layers/gas gaps
 - Q1 chambers are divided into 2 HV channels
 - Innermost ($2.4 < |\eta| < 2.7$): R1
 - Outermost (R2)
 - Q2 (R3) and Q3 (R4) outermost quadruplets



sTGC Technology



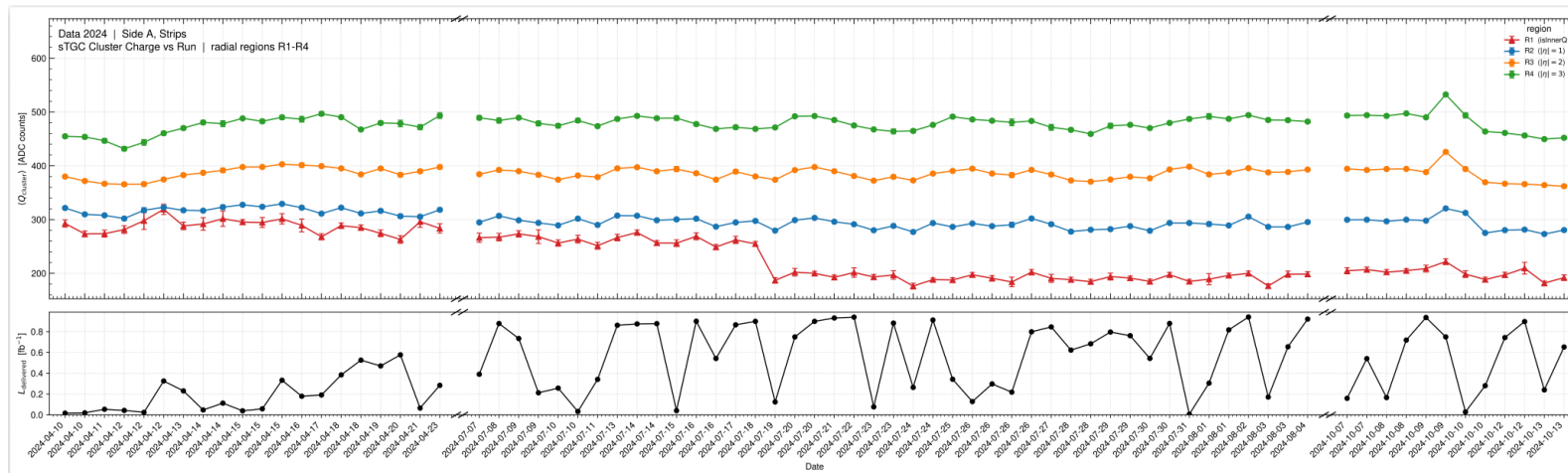
- **sTGC**: small-strip Thin Gap Chamber
- Gas gap structure: plane of anode wires at HV between two cathode boards (pads to trigger and strips to precise η coordinate)

- The quadruplet delivers 4 measurement layers: 4 gas gaps stacked, separated by a honeycomb
- 1 sector = 2 wedges = 8 layers
- Numbering in the analysis:
 - 1 $\rightarrow$ 4 for inner layers
 - 5 $\rightarrow$ 8 for outer layers

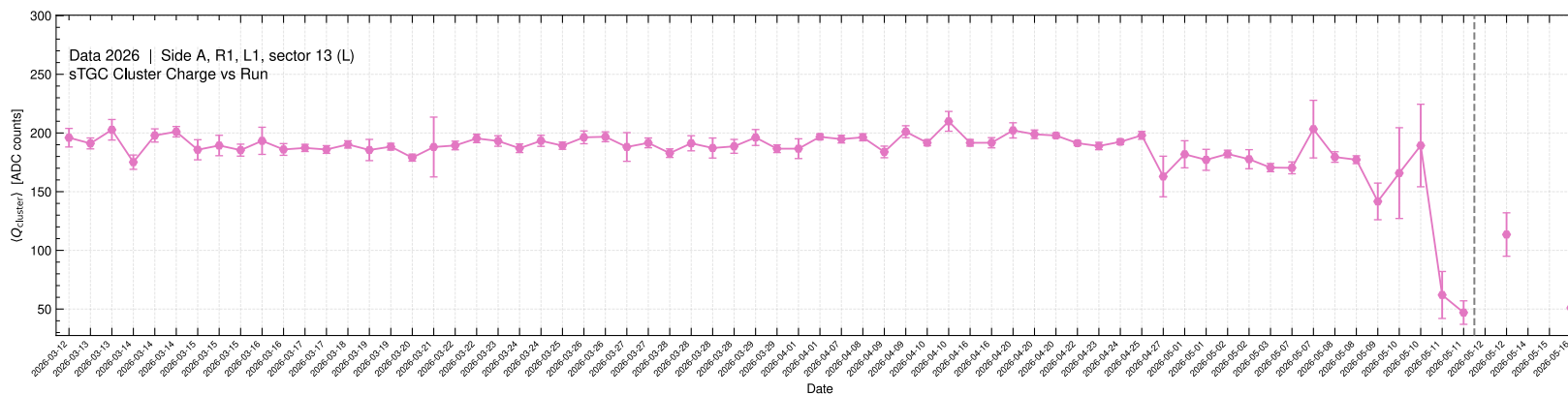
Cluster Charge Studies

First Studies

Average Cluster Charge ($\langle Q \rangle$) studies:



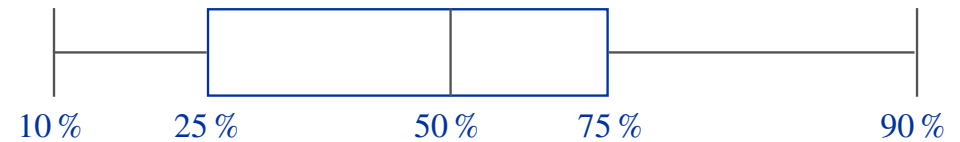
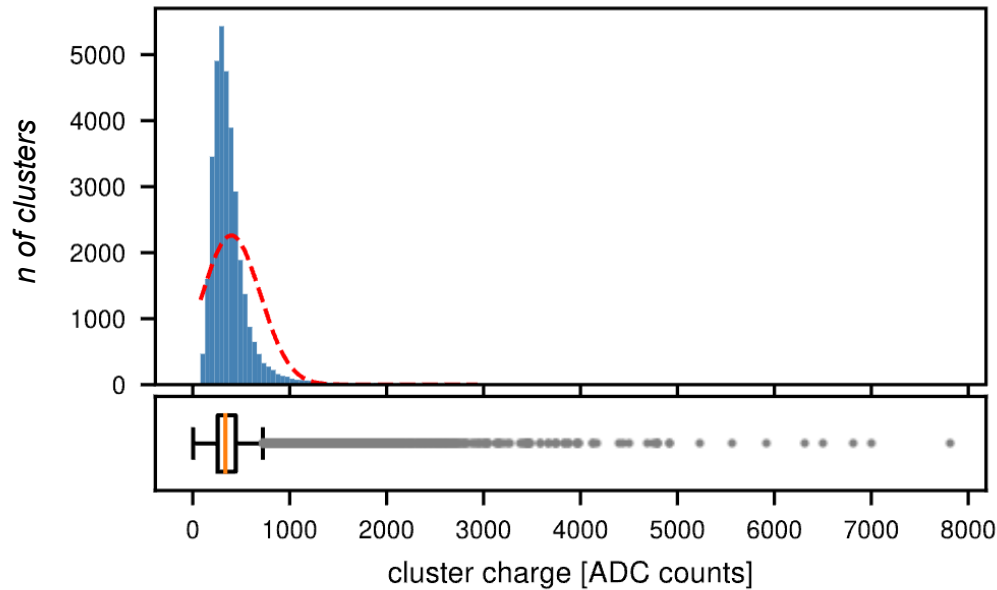
Average cluster charge vs run number in different HV channels integrated over the hole wheel



Average cluster charge against run for an HV region that stopped delivering data during 2026, side A, R1, layer 1, sector 13. Dashed vertical line marks the last interruption of the data taking before the channel was switched off.

Concept of box-and-whiskers

run 456314 2023-07-11 (n=34,948)



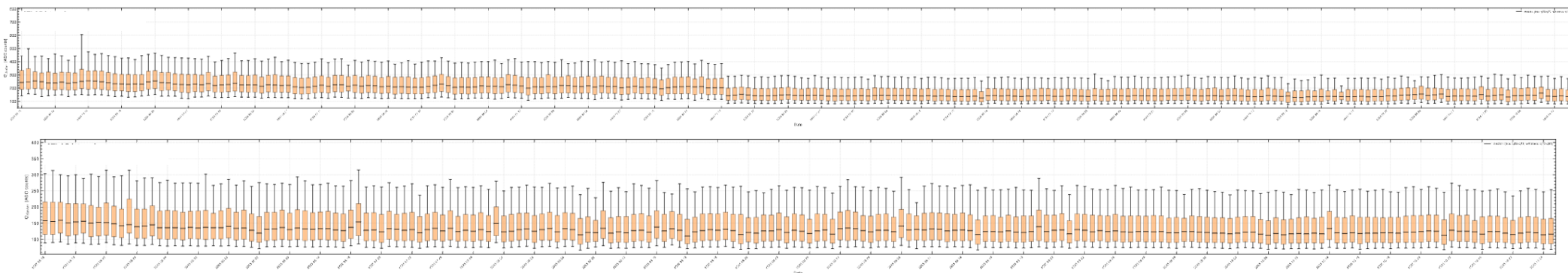
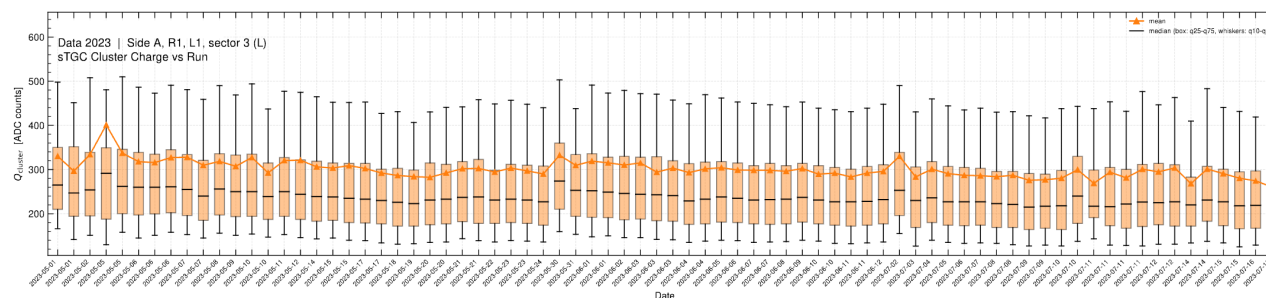
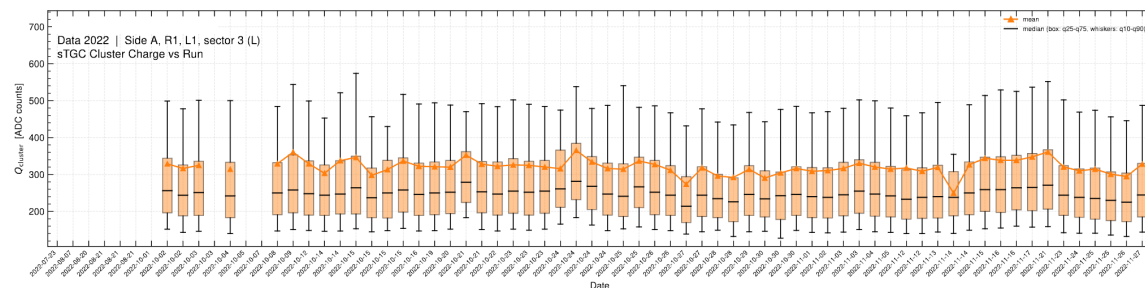
Limits of the box:

- Q1 (25%)
- Q2 (50% = median)
- Q3 (75%)

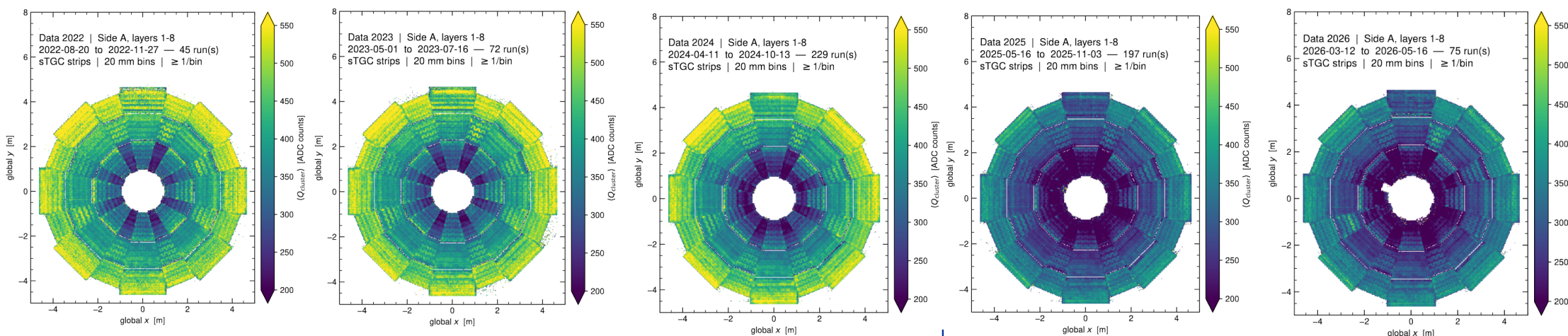
Limits of the whiskers:

- Left side 10%-25%
- Right side 75%-90%

Cluster Charge - Box and Whiskers



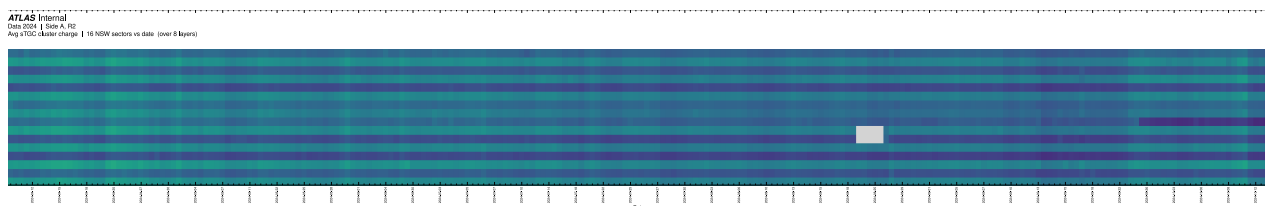
Cluster Charge across the NSW (Run 3 evolution)



2022

HV Reduction

2026



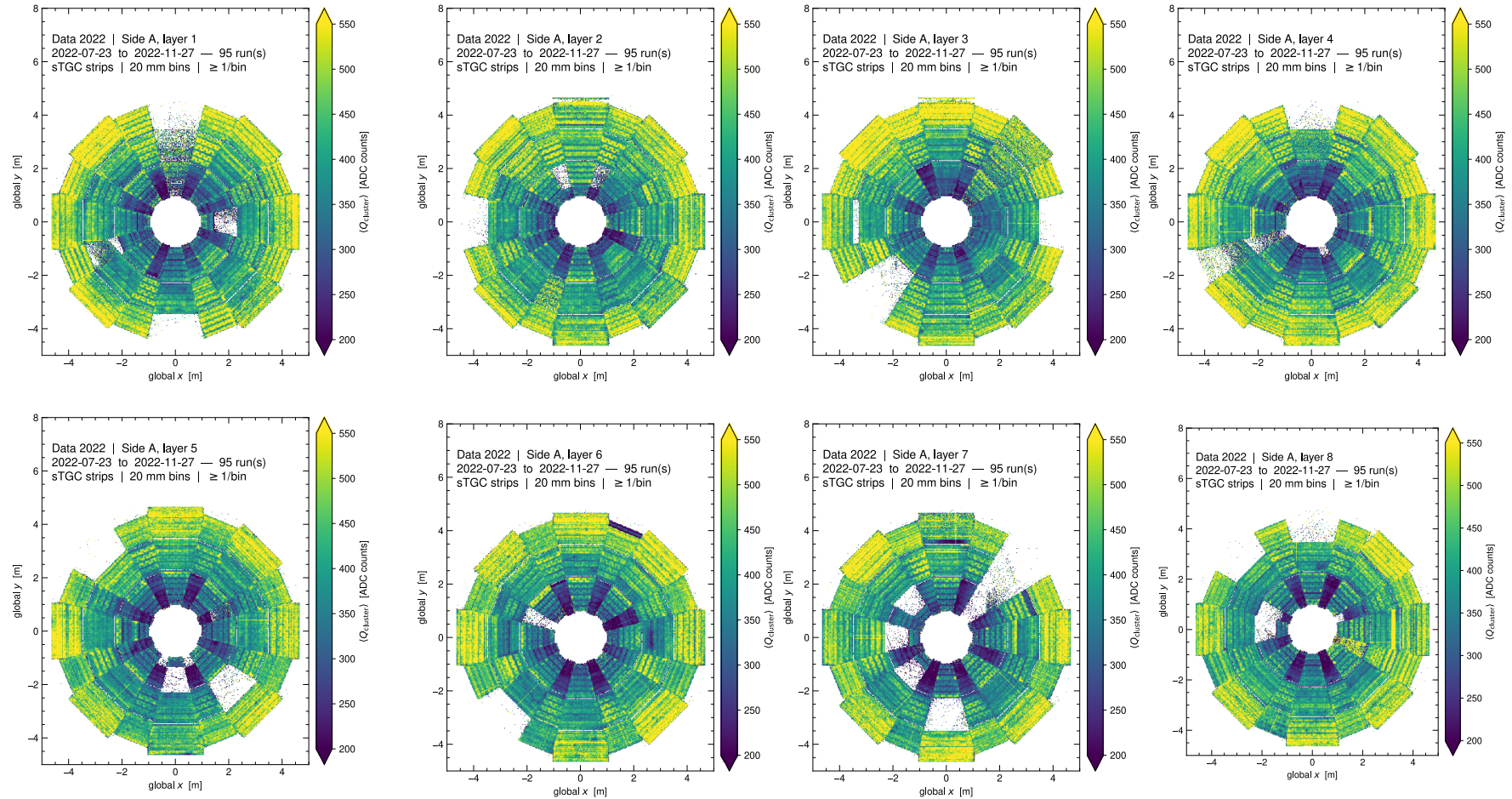
Average cluster charge of the sixteen sectors of side A, R2, against date over the 2024 data taking, with the eight layers averaged together. Odd numbered sectors are large and even numbered ones are small.

Cluster Charge Maps

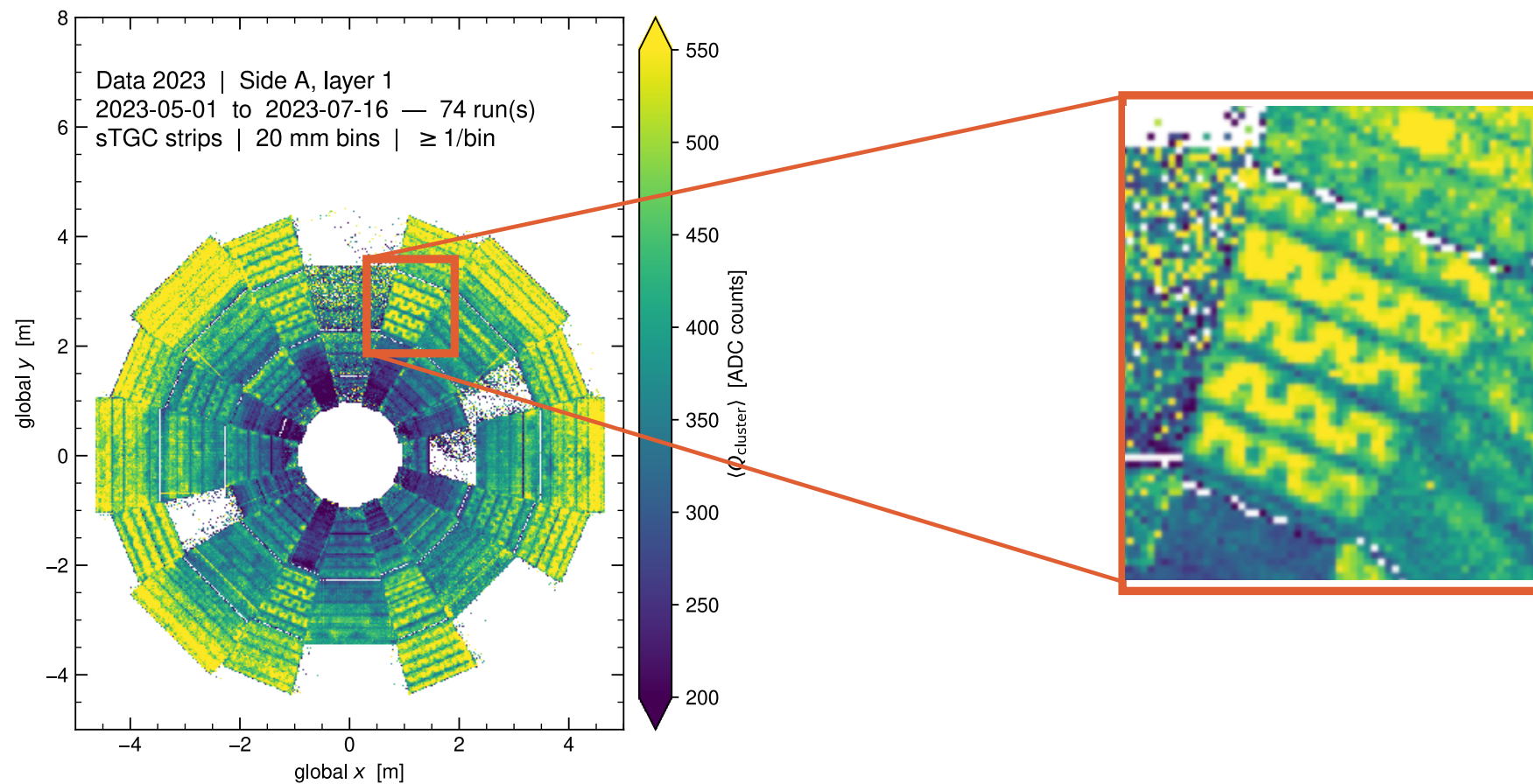
- **Produced the cluster charge maps for all the layers**
 - Side A and Side C
 - For each Run in each year (2022-2026)
 - Integrated maps per layer for each year (next slides)
- **All the maps show the pattern discussed last meeting**
- **Specifications:**
 - Bin size: 2 cm
 - Min n° of clusters per bin: 1
 - Branches used: `stgcOnTrackCharge`, `stgcClusterOnTrackGlobalPos_x/y`

(See Backup Slides)

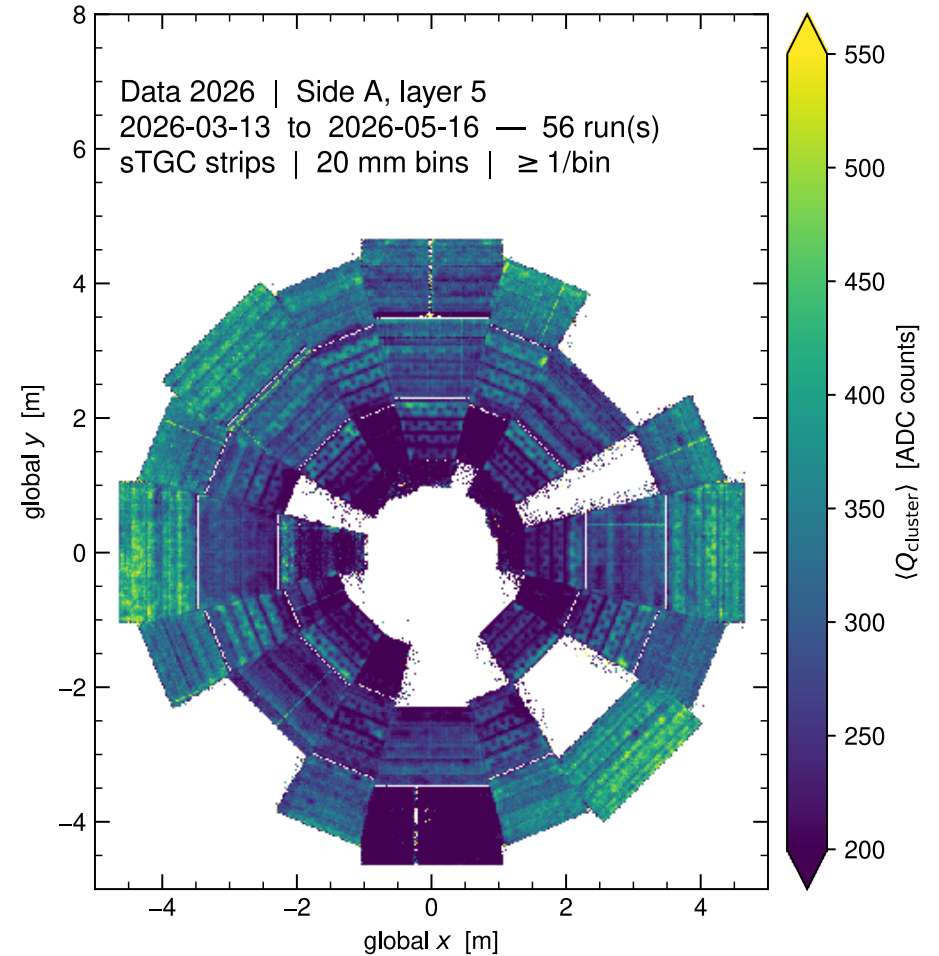
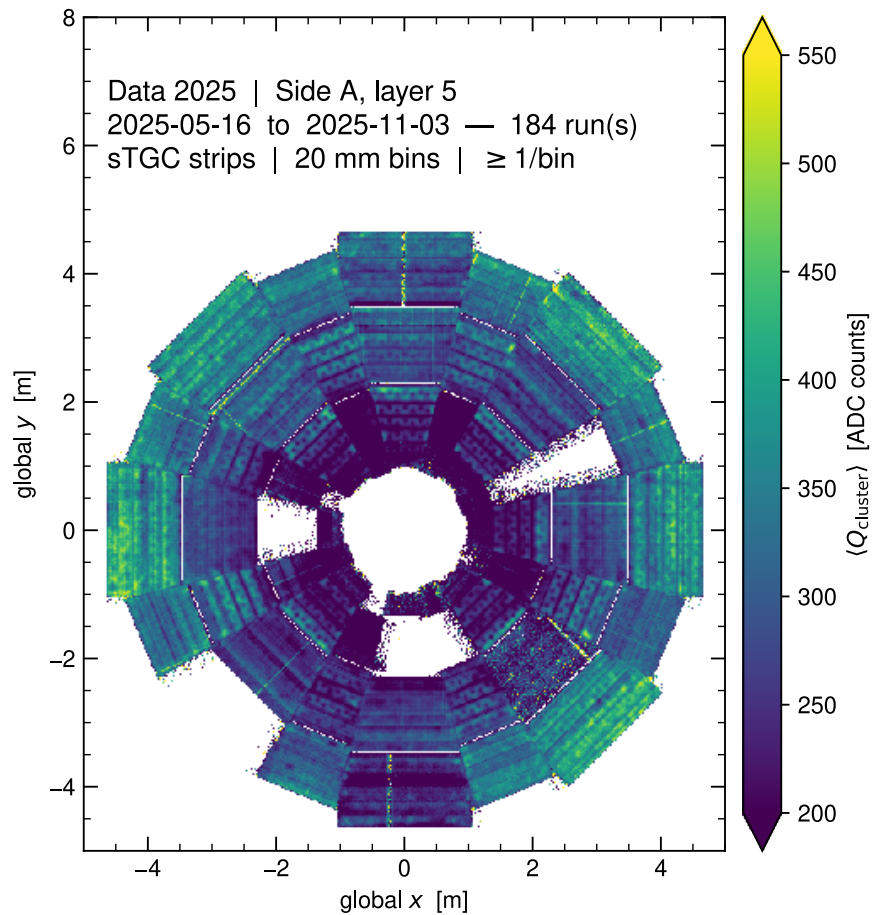
Cluster Charge maps 2022 - side A



Pattern evaluation



Cluster Charge maps 2025/2026 - side A



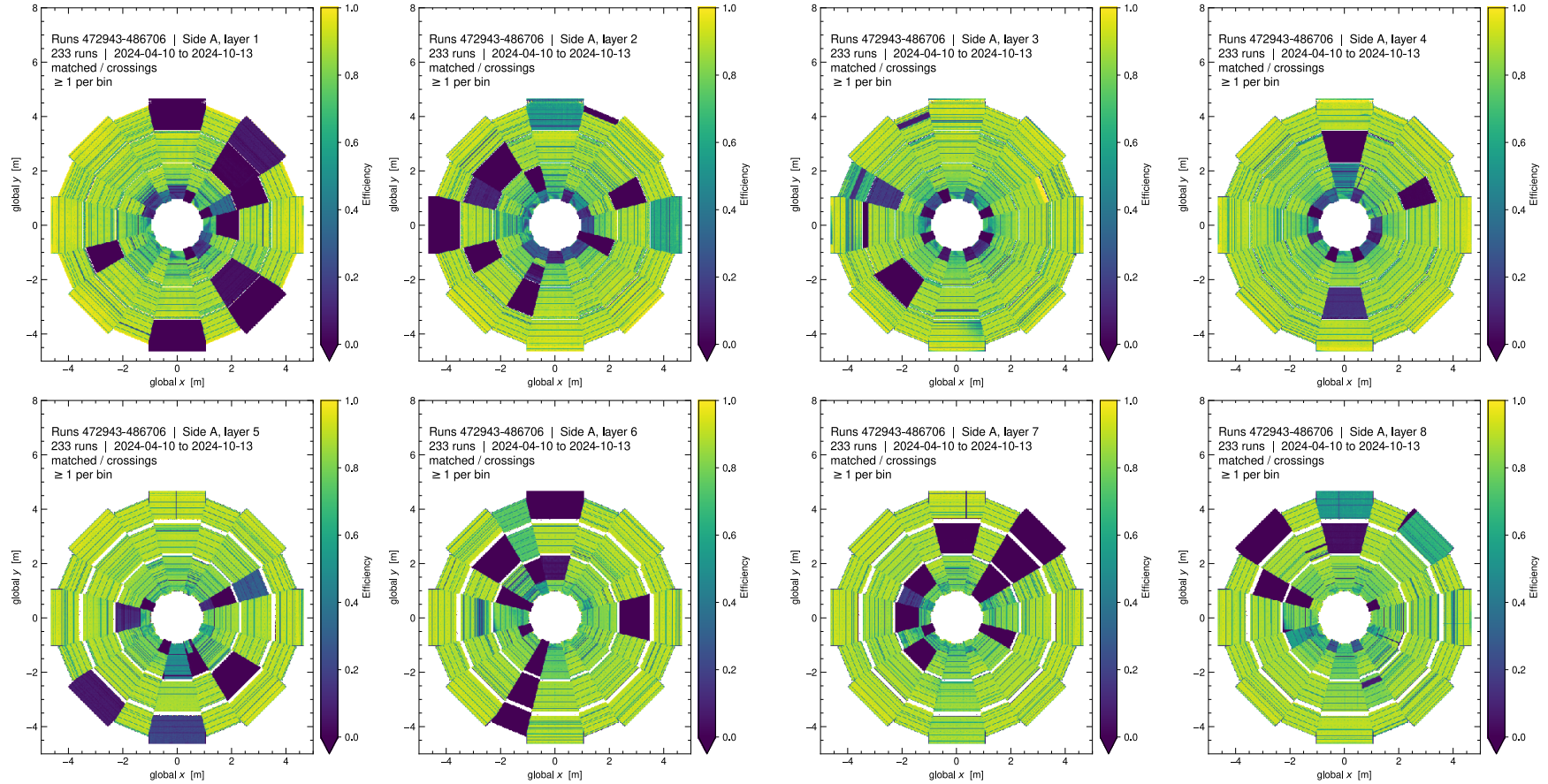
Efficiency and Rate Studies

Efficiency calculation

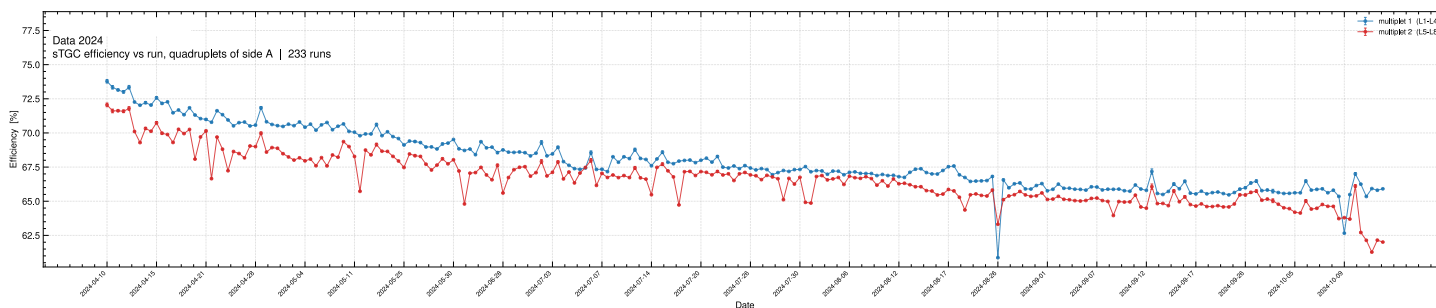
$$\varepsilon = \frac{\sum \text{crossings with link}}{\sum \text{crossings}} \Bigg\} p/\text{bin}$$

- **Crossing:** is an entry of `stgcTrackState`, measured by the inner detectors and the other muon spectrometers
- **Crossing with link:** the reconstruction matches a cluster to that crossing through `stgcTrackState_ClusterOnTrackLink`
- **Position:** the crossings are counted in each bin using `stgcTrackStateGlobalPos`
- **Both counts come from the same collection**

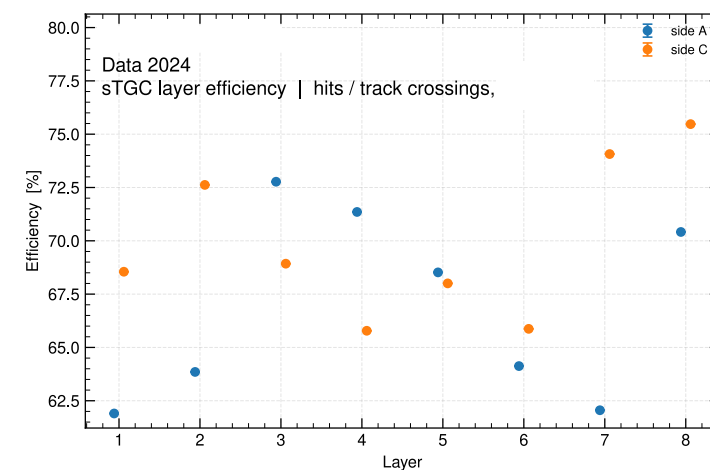
Efficiencies: $\varepsilon = \frac{\text{crossings with link}}{\text{total crossings}} \left. \vphantom{\frac{\text{crossings with link}}{\text{total crossings}}} \right\} \text{p/bin (Using TrackState branches only)}$



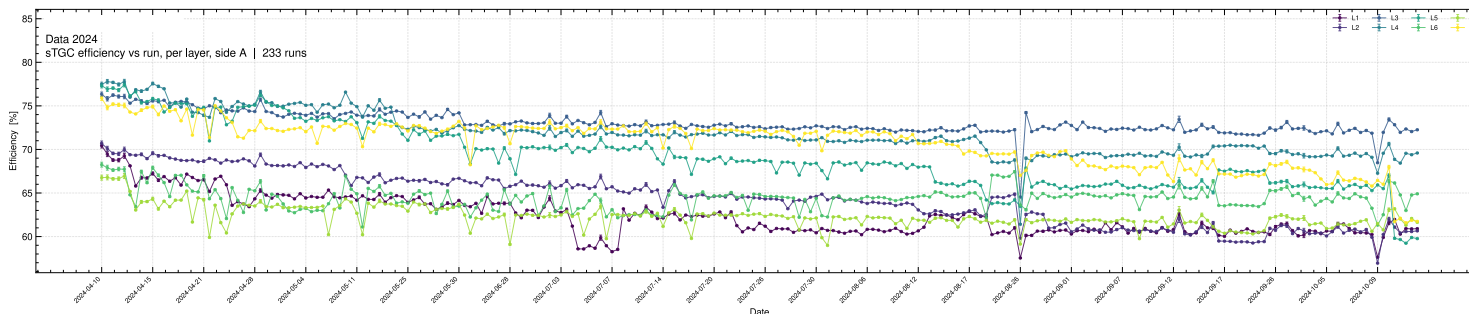
Efficiency evolution - 2024



Evolution of efficiency in 2024 integrated by inner and outer layers across all sectors in side A



Efficiency by layer over 2024



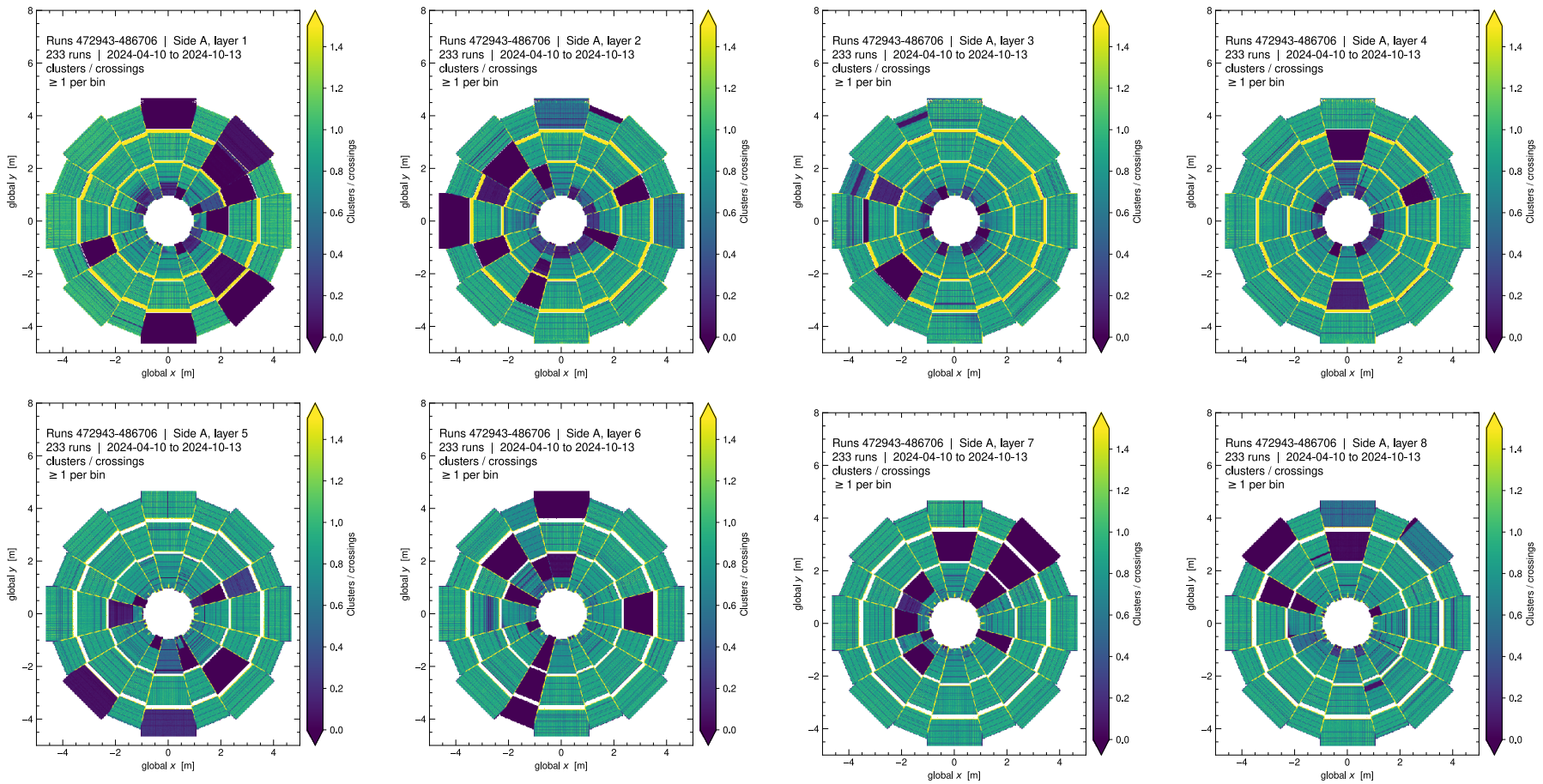
Evolution of efficiency in 2024 integrated by the 8 layers across all sectors in side A

Cluster/Crossing rate calculation

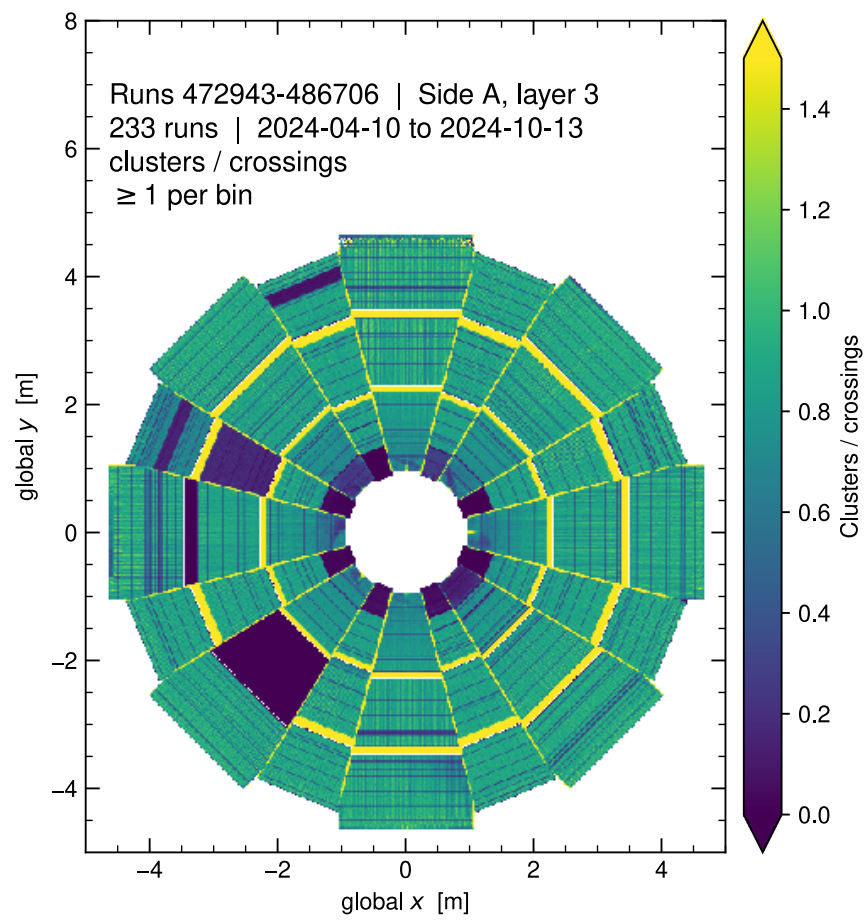
$$R = \frac{\sum \text{clusters}}{\sum \text{crossings}} \Bigg\} \text{ p/bin}$$

- **Clusters:** is an entry of `stgcClusterOnTrackGlobalPos`
- **Crossing:** is an entry of `stgcTrackState` with `stgcTrackStateGlobalPos` matching `stgcClusterOnTrackGlobalPos`

Rate: $R = \frac{\text{n}^\circ \text{ of clusters (OnTrack counts bined by global position)}}{\text{total crossings}} \left. \vphantom{\frac{\text{n}^\circ \text{ of clusters (OnTrack counts bined by global position)}}{\text{total crossings}}} \right\} \text{p/bin (Using OnTrack and TrackState branches)}$

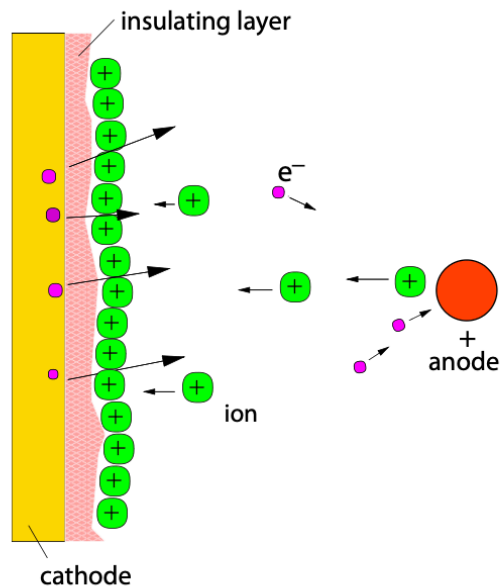


Rate: $R = \frac{\text{n}^\circ \text{ of clusters (OnTrack counts bined by global position)}}{\text{total crossings}} \left. \vphantom{\frac{\text{n}^\circ \text{ of clusters (OnTrack counts bined by global position)}}{\text{total crossings}}} \right\} \text{p/bin (Using OnTrack and TrackState branches)}$

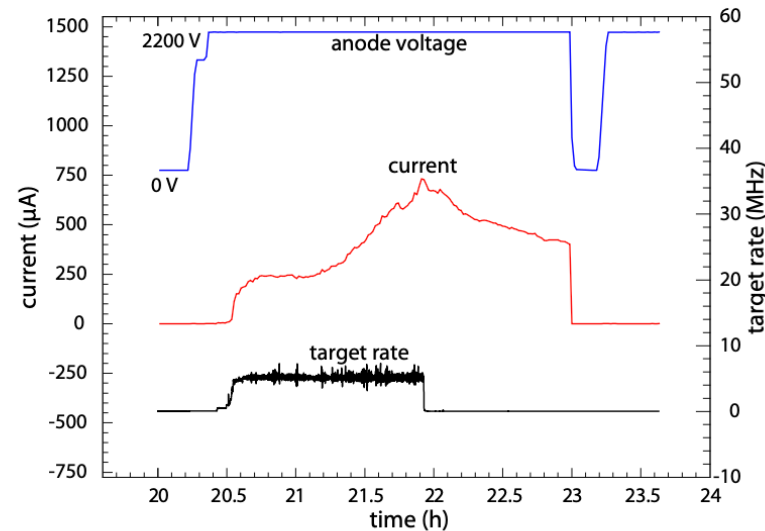


Position Studies and Malter Effect

Malter Effect - Cathodes



(a) Malter effect.

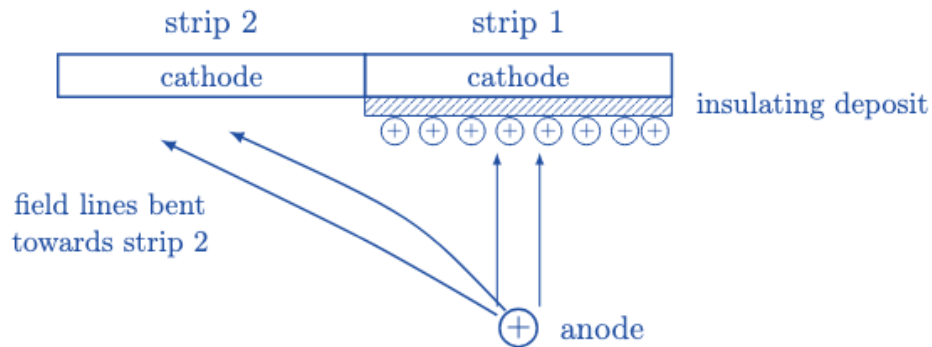


(b) Malter current.

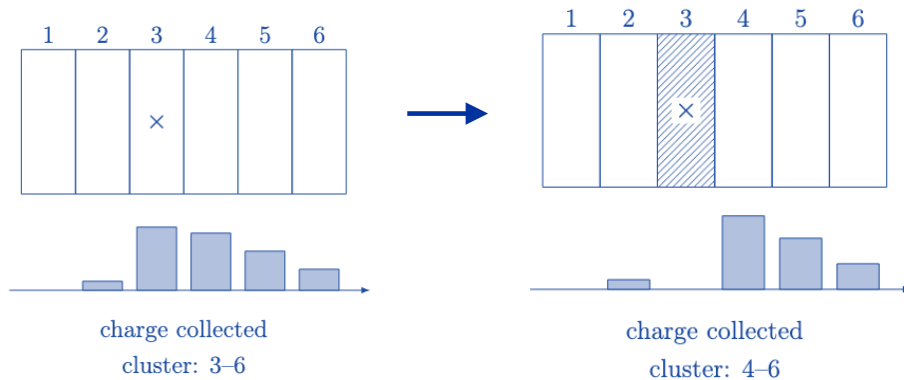
- Insulating deposits on the cathode lead to accretion of ions on this layer and hence the generation of a field between this charge layer and the cathode.
- Because of the very small distance of the charge to the cathode the field can become so strong that electrons are emitted from the cathode.
- The electrons drift towards the anode and generate yet more ions through gas amplification and thus a continuous current, the Malter current.

Malter Effect: My idea

n – pentane (45 %)+ CO₂ (55 %)



- The insulating deposit on the cathode bends the field lines away from the strip it covers
- They end on the neighbouring strip instead.
- The charges drawn on the outer surface of the deposit are the ions that accumulate there because they cannot be neutralised at the cathode underneath.



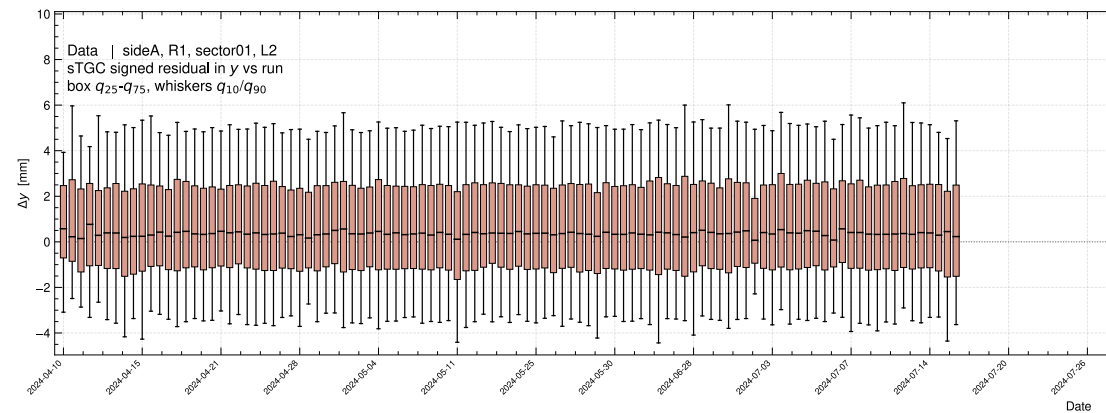
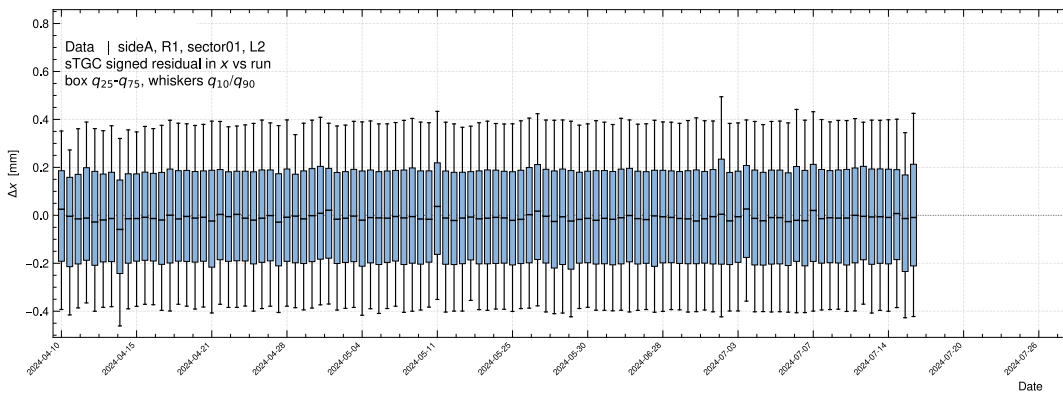
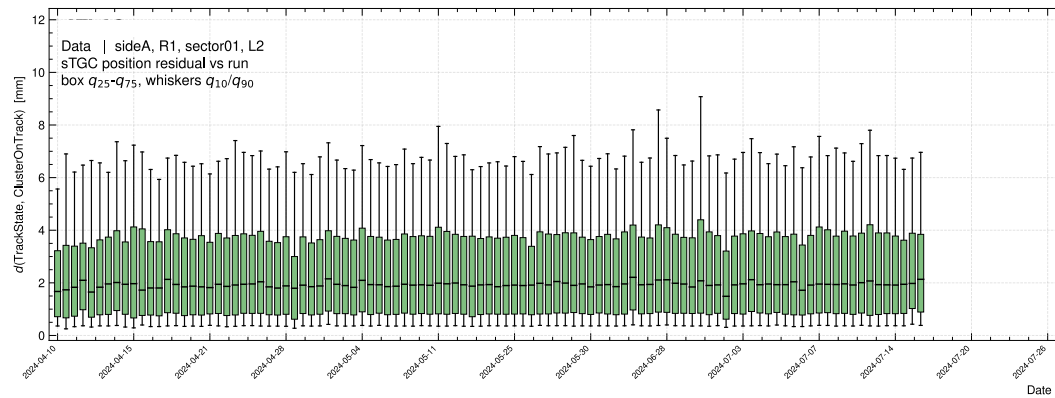
a)

b)

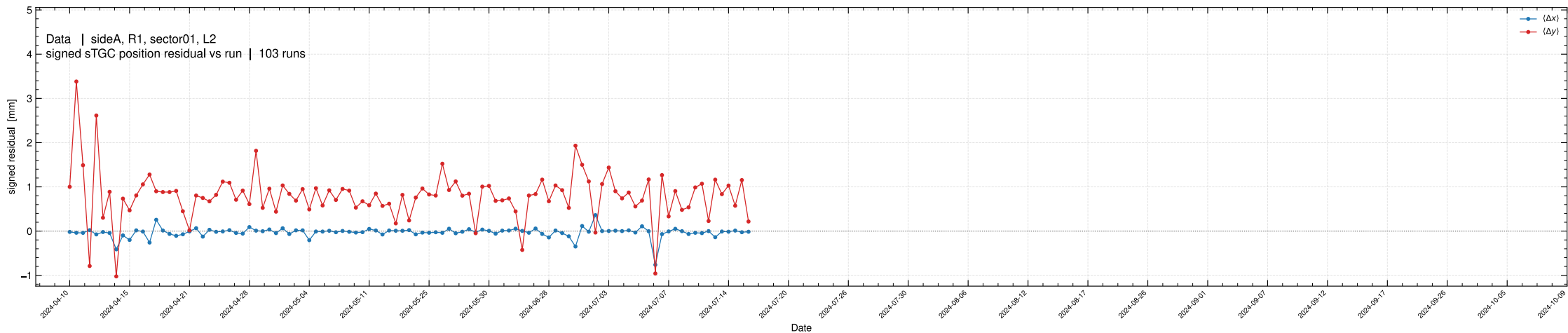
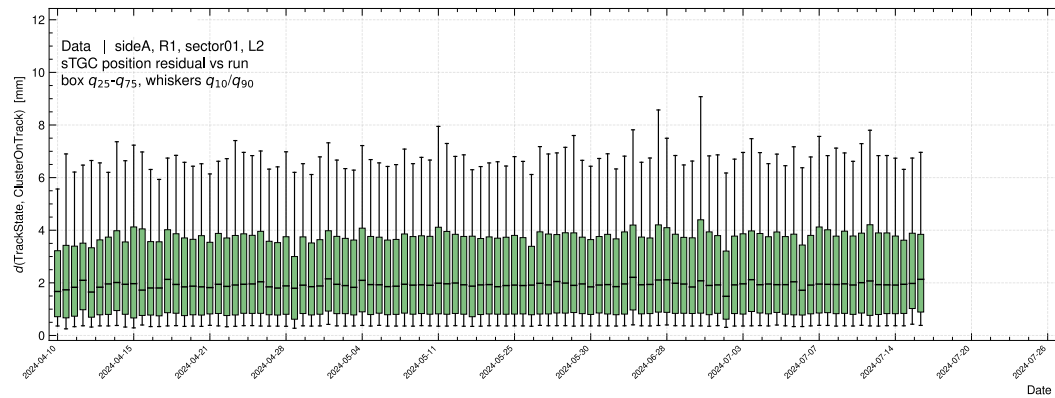
a) No deposit. The particle crosses at strip 3 and the charge is shared over strips 3 to 6.

b) Strip 3 carries the deposit. It contributes nothing and the cluster is formed from strips 4 to 6.

Malter effect studies: position reconstruction studies (box-and-whiskers)

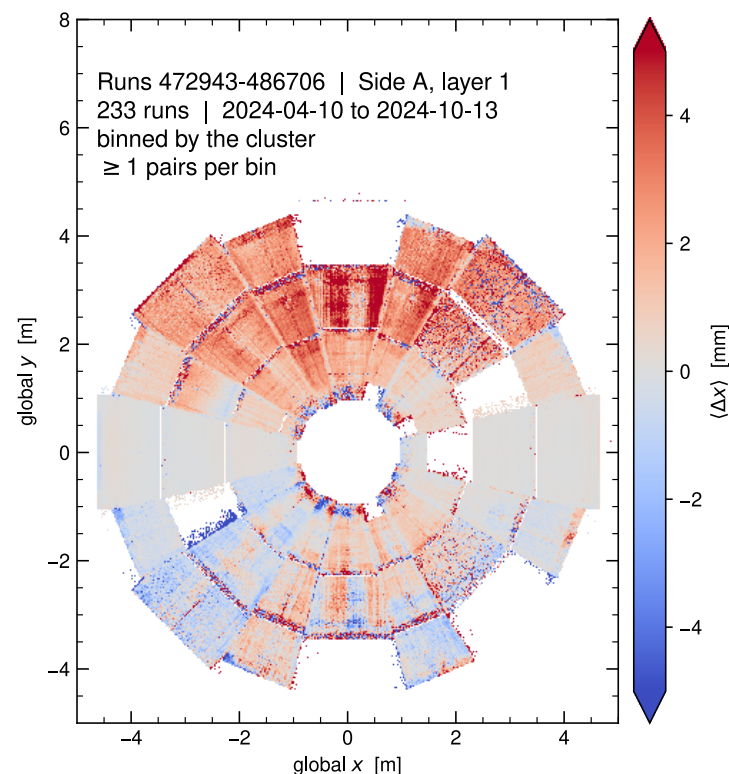
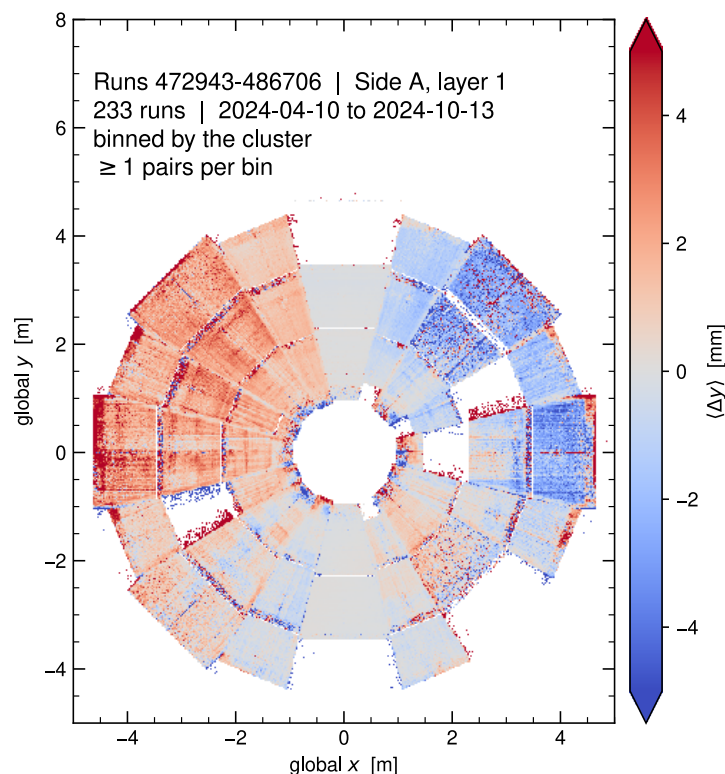


Malter effect studies: position reconstruction studies (box-and-whiskers)



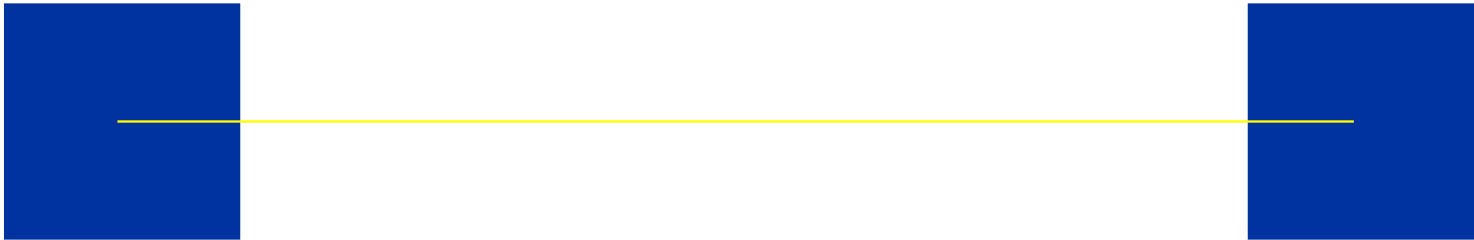
Malter effect studies: position reconstruction studies (most affected zones in Δx and Δy)

- When a sector is parallel to an axis (x or y), the deviations in that axis coordinates almost vanish



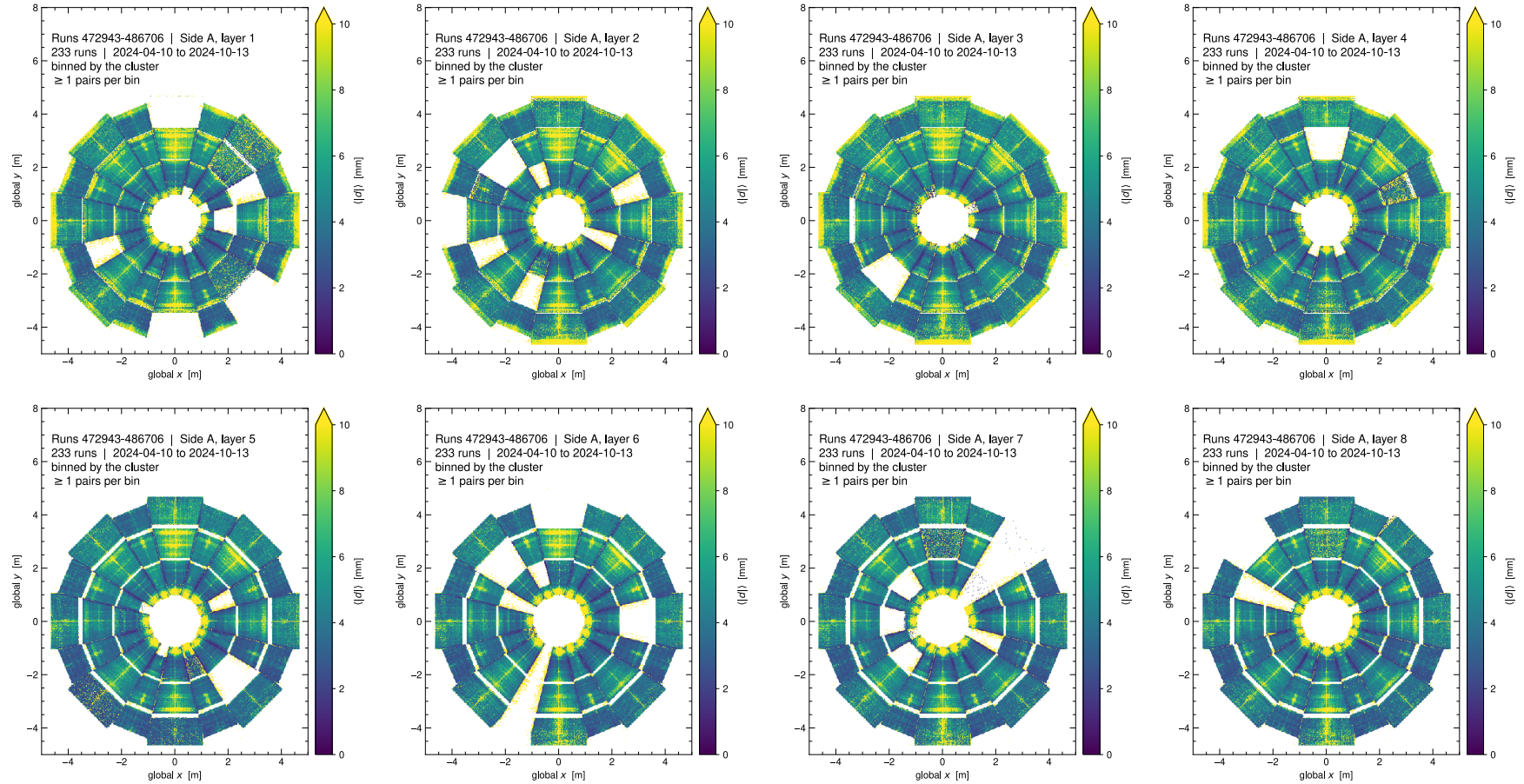
Malter Effect: mean crossing-to-cluster per bin

$$d = \sqrt{(x_{\text{cluster}} - x_{\text{crossing}})^2 + (y_{\text{cluster}} - y_{\text{crossing}})^2}$$

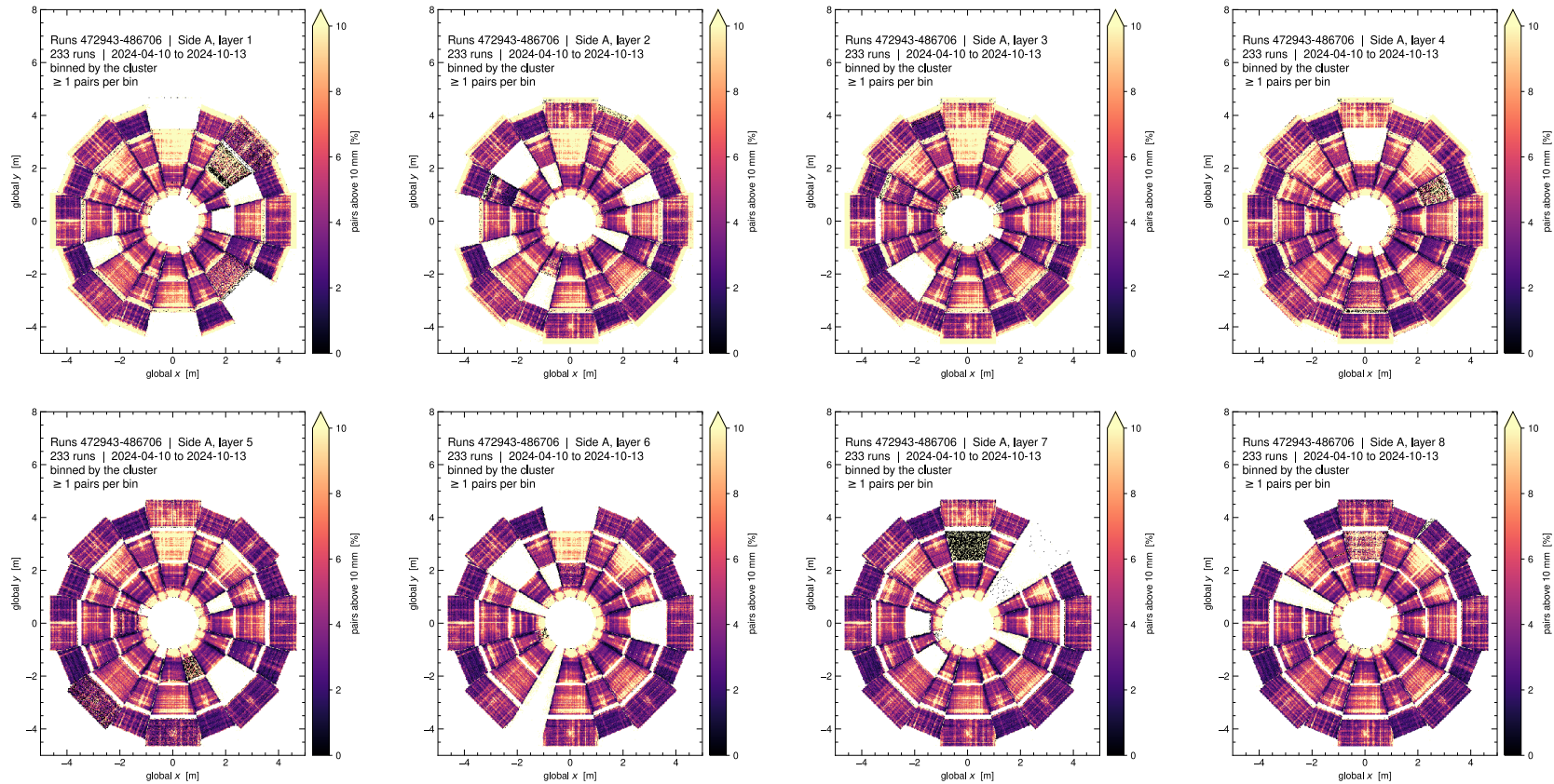


- The pair is formed on the chamber key, via `muonLink`
- The bin is chosen based on the position of the cluster
- The color scale of the distance between cluster and crossing is drawn in the `stgcClusterOnTrackGlobalPos` bin

Malter effect studies: position reconstruction studies (2D maps for 2024)



Malter effect studies: position reconstruction studies (2D maps for 2024 pairs with $|d| \geq 10mm$)



Malter Effect: binning comparison

- The same pairs are counted twice. Once in the bin chosen by the crossing's position, once in the bin chosen by the cluster's.

- The maps show the difference:

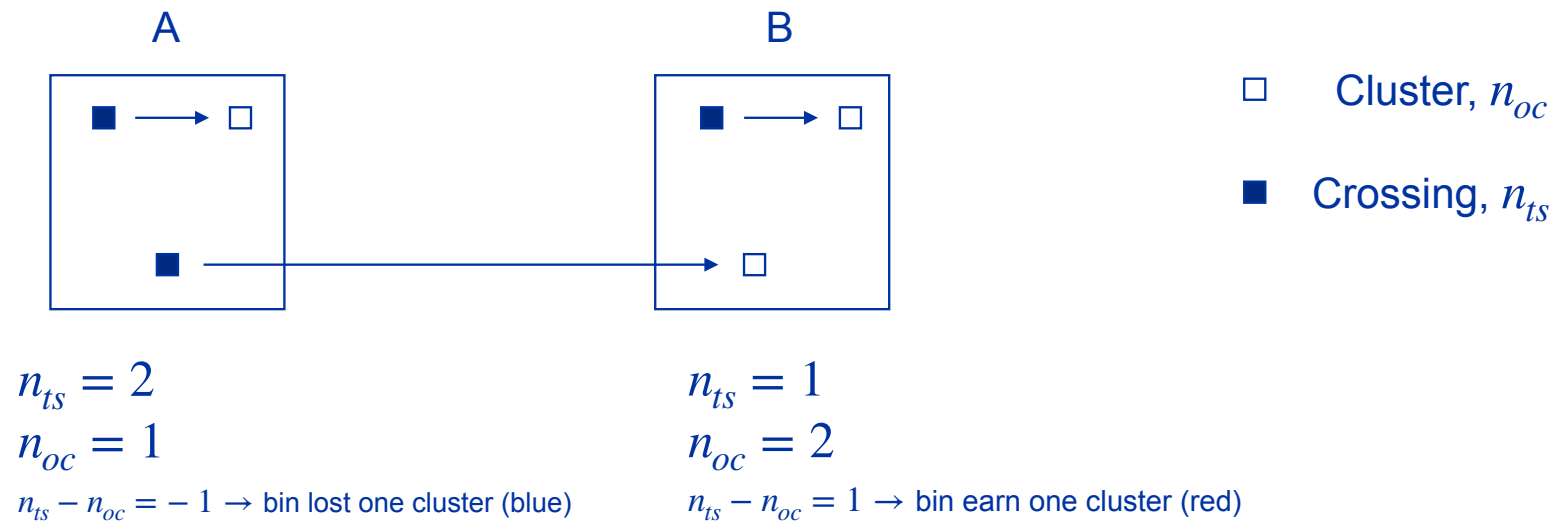
$$\text{compare} = 100 \times \frac{n_{oc} - n_{ts}}{n_{oc} + n_{ts}} \quad [\%]$$

- A pair whose two ends fall in the same 2 cm bin contributes to both counts and cancels → **white**.

- A pair whose ends fall in different bins does not → **red** where the cluster landed, **blue** where its track passed.

- If we have red and blue dot next to each other reveals the mismatch in position we are trying to find that might be the matter effect

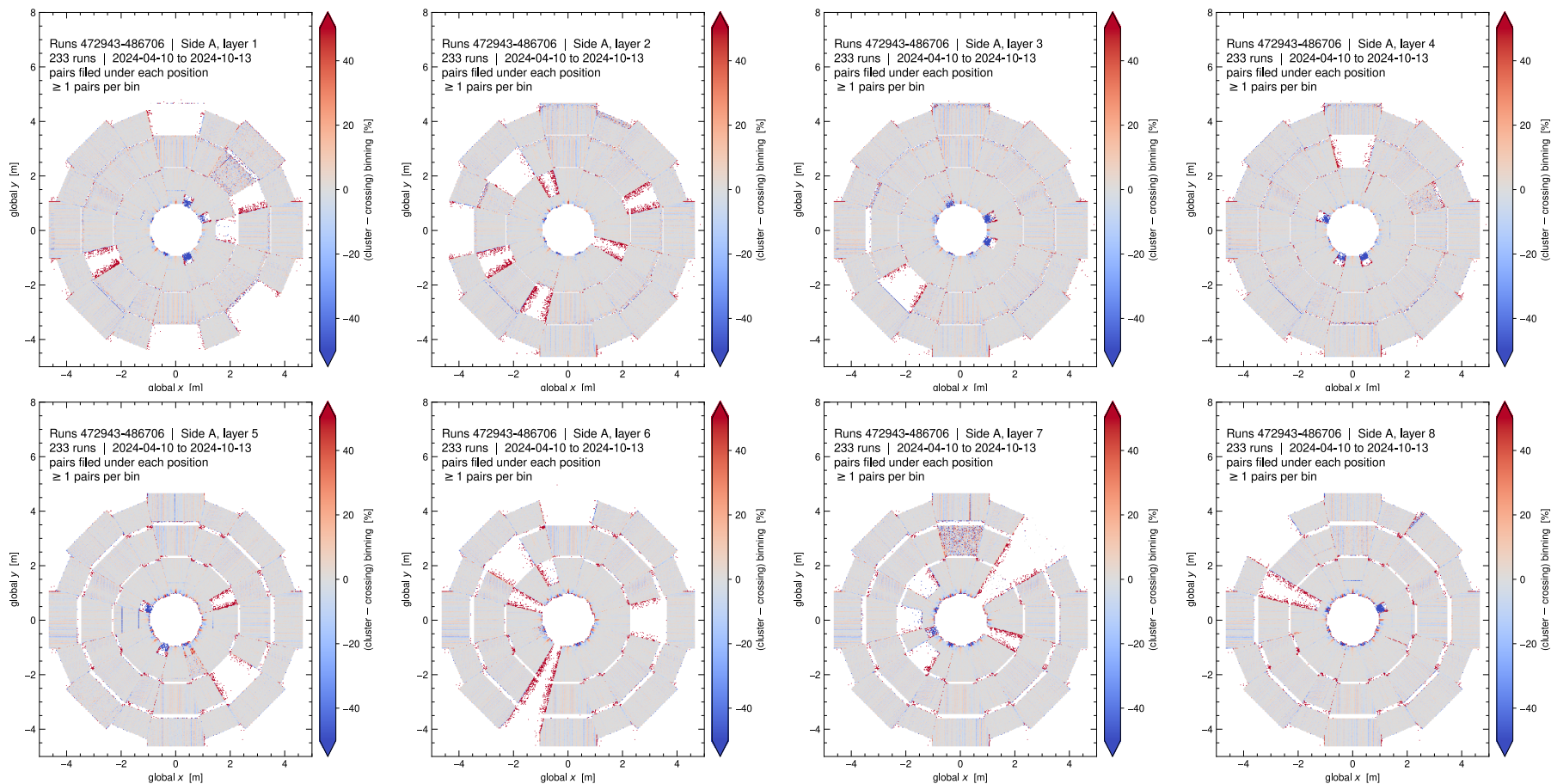
Malter Effect: binning comparison (illustration)



$$\text{compare} = 100 \times \frac{n_{oc} - n_{ts}}{n_{oc} + n_{ts}} \quad [\%]$$

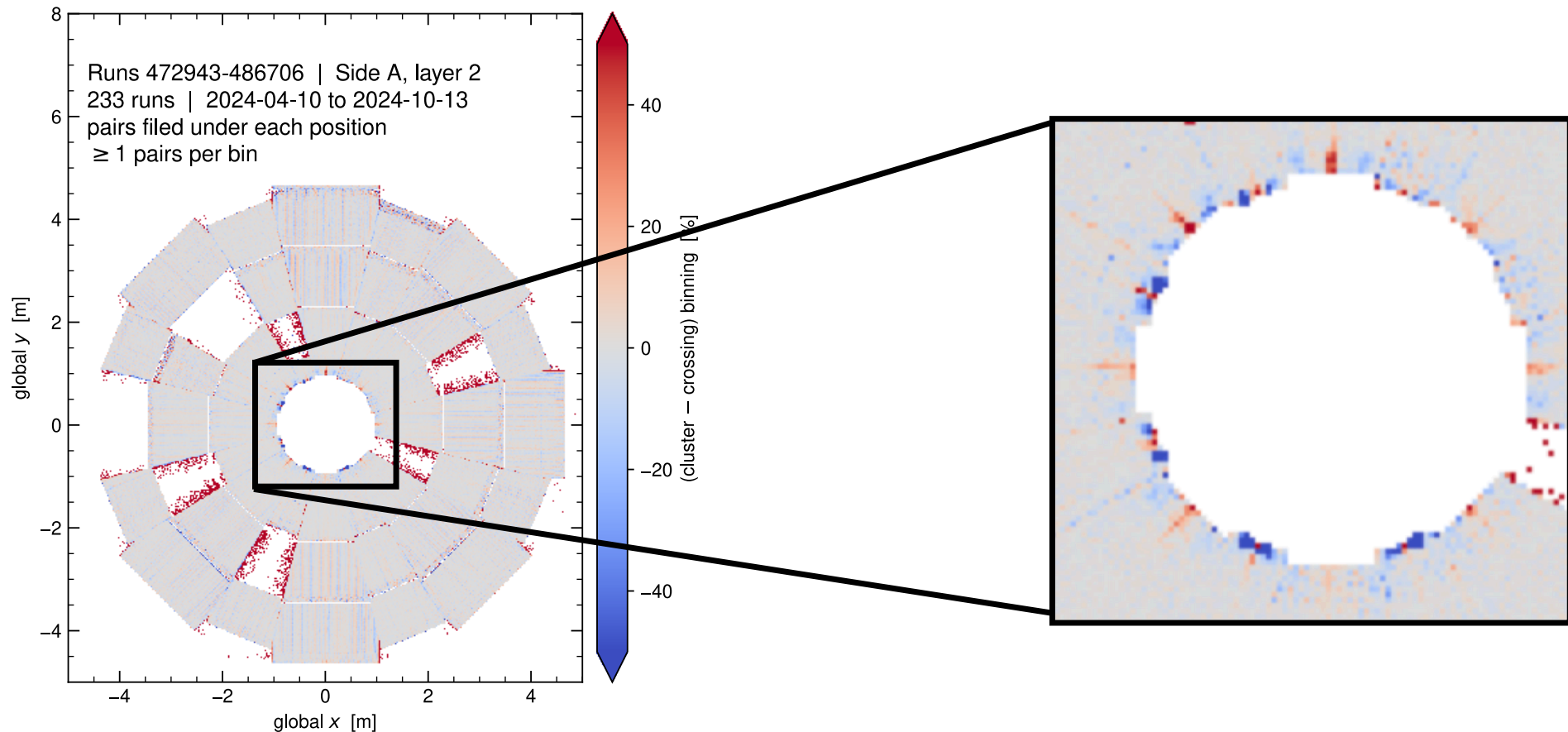
Malter effect studies: position reconstruction studies

(Binning comparison between OnTrack and TrackState pairs: 2D maps for 2024)



Malter effect studies: position reconstruction studies

(Binning comparison between OnTrack and TrackState pairs: 2D maps for 2024)



Conclusions

- The cluster charge increases from R1-R4 generally
- The cluster charge decreases over time during Run 3
- The efficiency maps are similar with the cluster charge distribution maps
- The position mismatches increase a little before the layer is called dead as well as the cluster charge
- We see mismatch in position between the clusters and the crossings which might indicate that the clusters are being reconstructed not in the position they were supposed to
- We can't say that this mismatch is due to the Malter effect although we have the tools to keep studying it
- The combination of bad efficiency, low cluster charge and position mismatch in R1's tells us that they are under some influence that prevents them from behaving properly

Thank you for your attention

(See the full report [here](#))



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