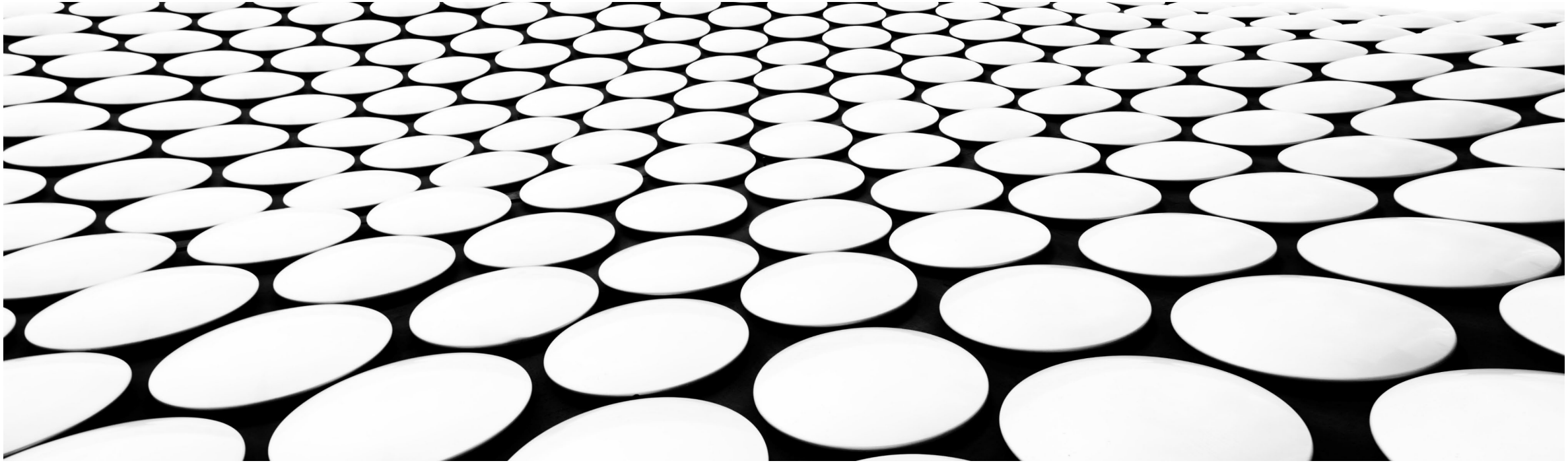
CLUSTERING METHODS FOR HIGH-LUMINOSITY

ANDREJ SARNATSKIY



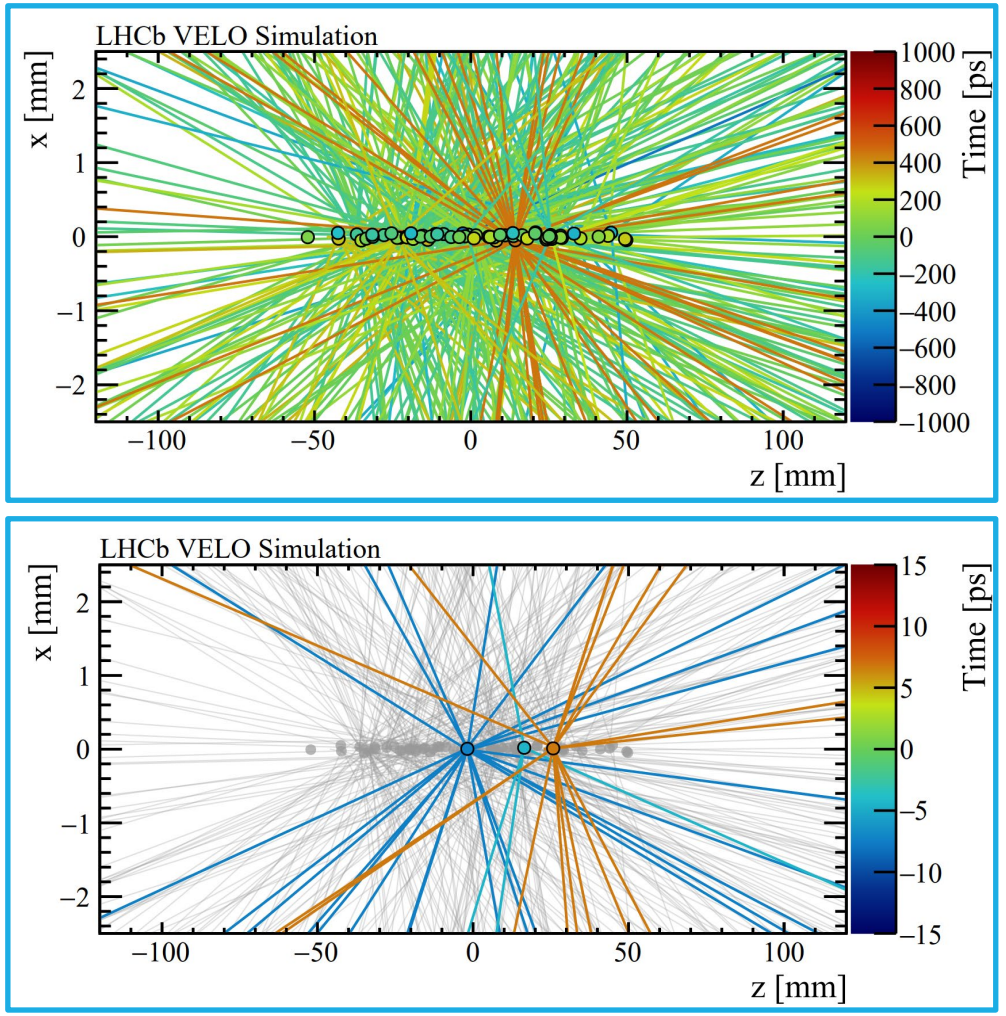
FASTER meeting

MOTIVATION

- Challenges to get data from chips to trigger farm
  - Decrease data rate (compression) ~ 1.6 Tbps
  - Distinguish PV events during high pile-up (timing) ~ 5 – 40 collisions
  - Apply corrections as soon as possible for improved reconstruction
- What corrections can be applied and where ?

  e.g. timewalk correction or hit interpolation
- Being part of both R&D and LHCb, analysis is done both on

  LHCb simulation of run5 and the current hardware.

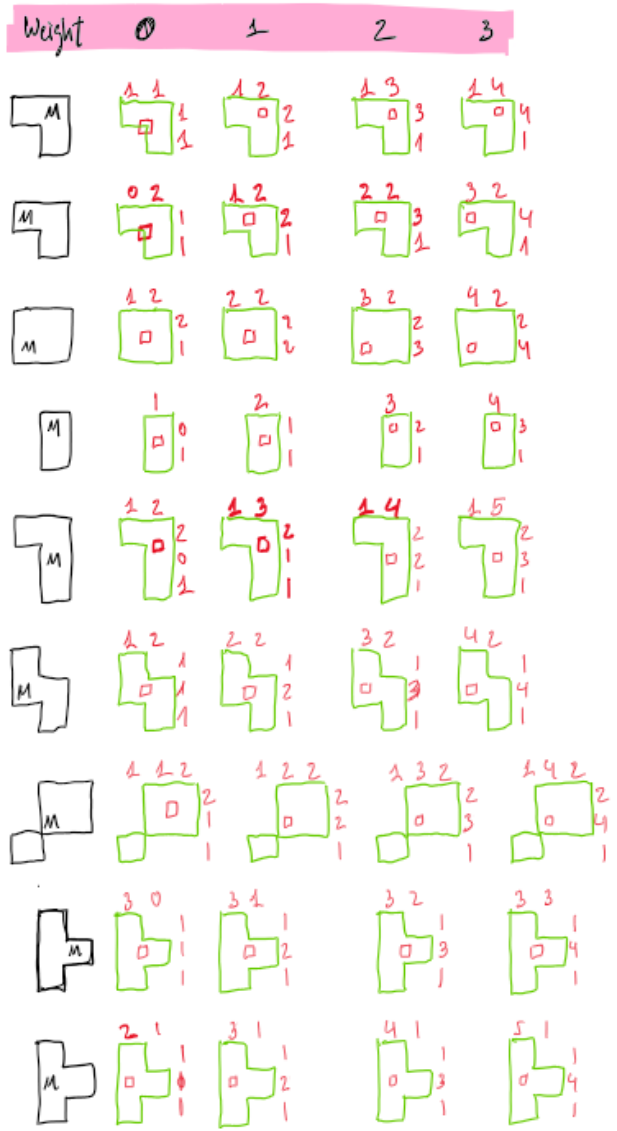


Courtesy: R. E. Geertsema

DATA PROCESSING

- Attempt to reduce data rate by rejection in the ASICs
  - Uncertainty of hits, e.g. multiple particles mimicking a cluster
  - No possibility of correcting data afterwards
  - Is the system reliable for the lifetime of U2?
  - Current bit structure of TimePix4 still available

- The alternative is to apply corrections down the road @ FPGA
  - Possibility of combining and correcting pixel hit to clusters
  - Firmware is adjustable

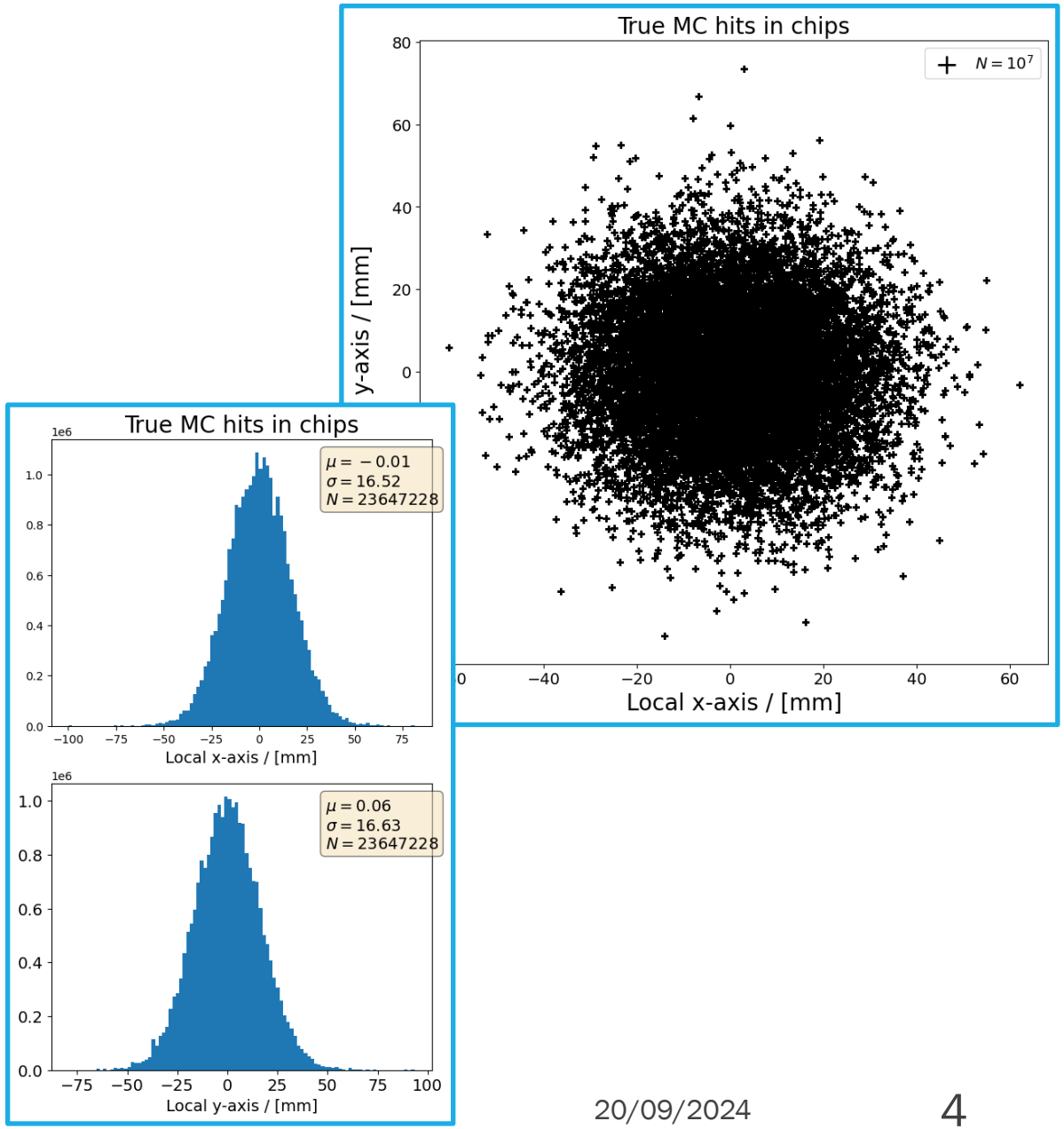


Reference to Xavi Llopart's presentation: https://indico.cern.ch/event/1381444/

Interesting methodology exists already: https://doi.org/10.1016/j.nima.2016.05.077

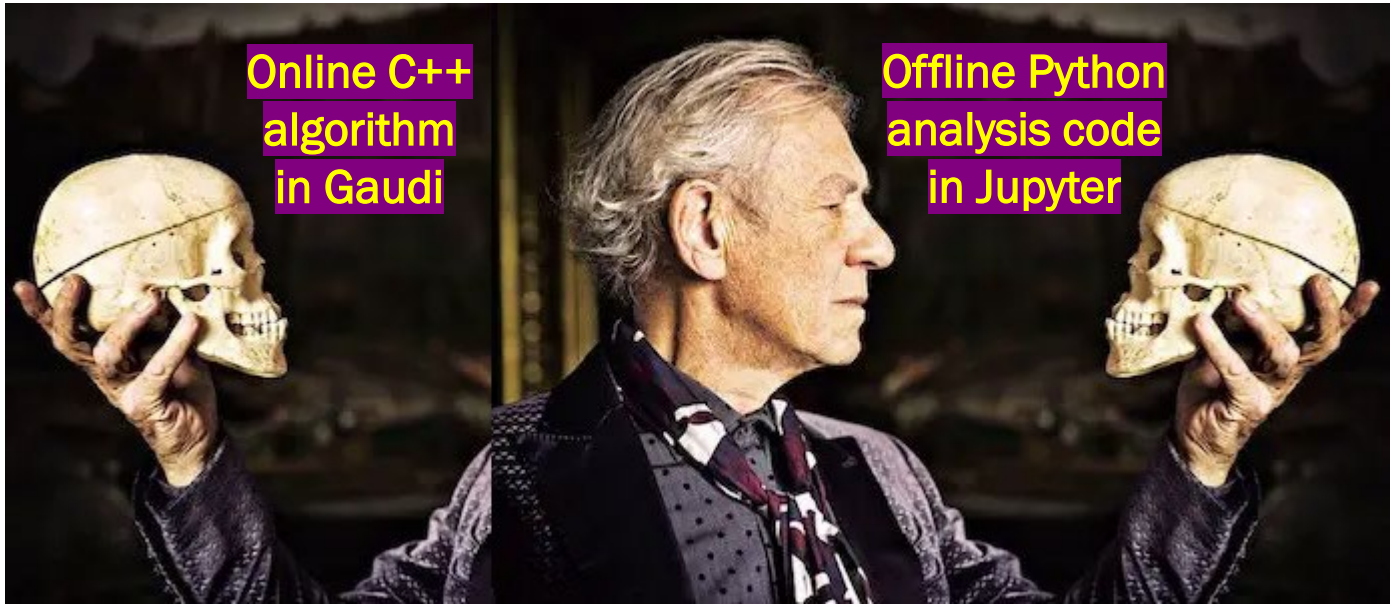
LHCB UPGRADE 2 SIMULATION

- Using LHCb simulation to analyse impact of algorithms
- Local (chip) coordinates needed
- Failed to use existing functions within LHCb software
- No geometry information found



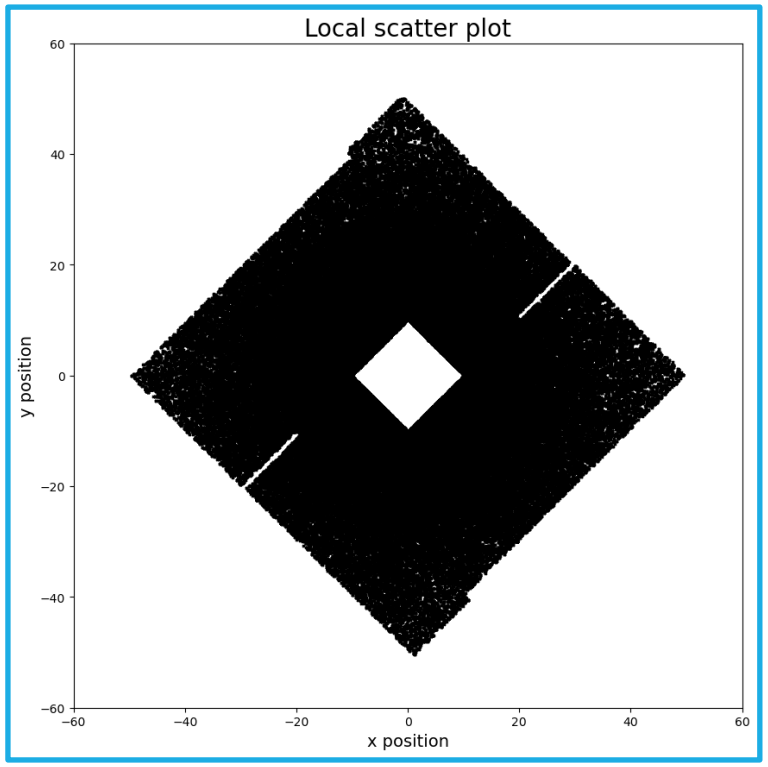
STRUGGLE OF DUALITY

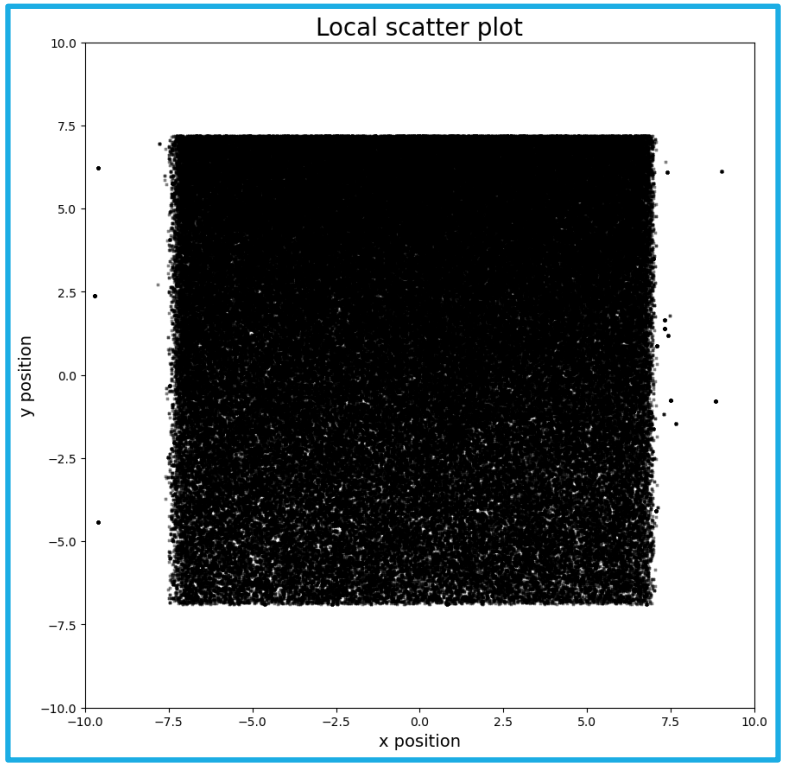
- Either run the LHCb simulation ones, then do analysis/transformations later
- Or implement additional code in the simulation



OFFLINE ANALYSIS

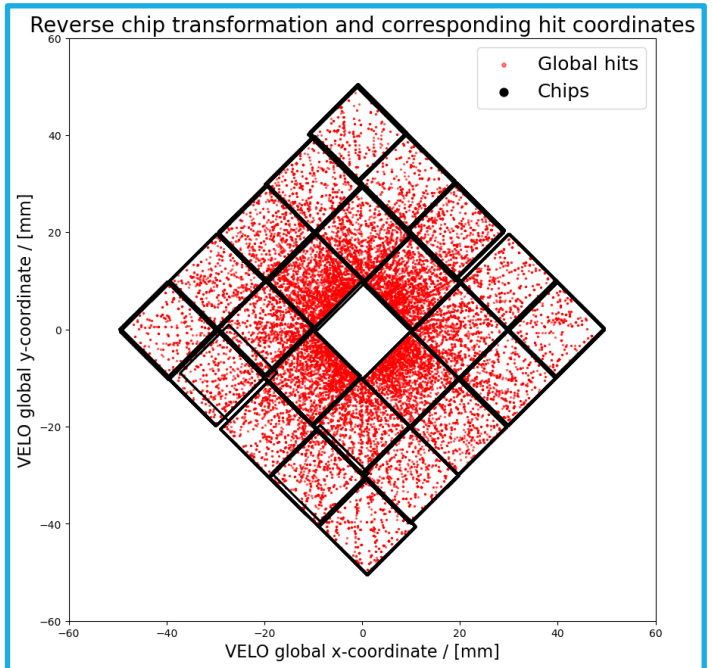
- Global to local mapping
- Columns and rows aligned, reflected if needed
- Additional micro alignment applied
- Source for systematic uncertainty

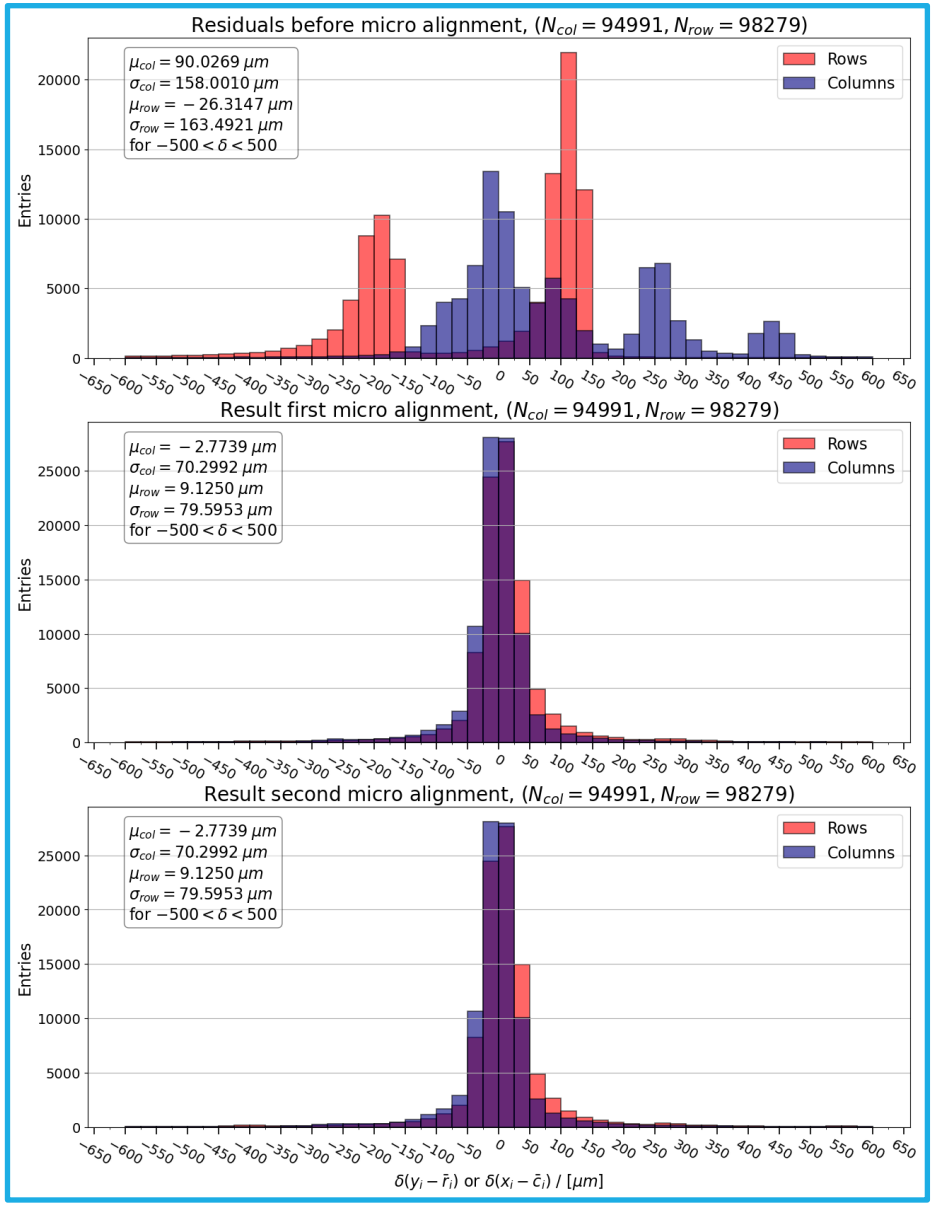




MICROALIGNMENT

- The error is plotted between the centre of the column/row x_i, y_i and the average of hits in that column/row $\bar{c}_i$, $\bar{r}_i$





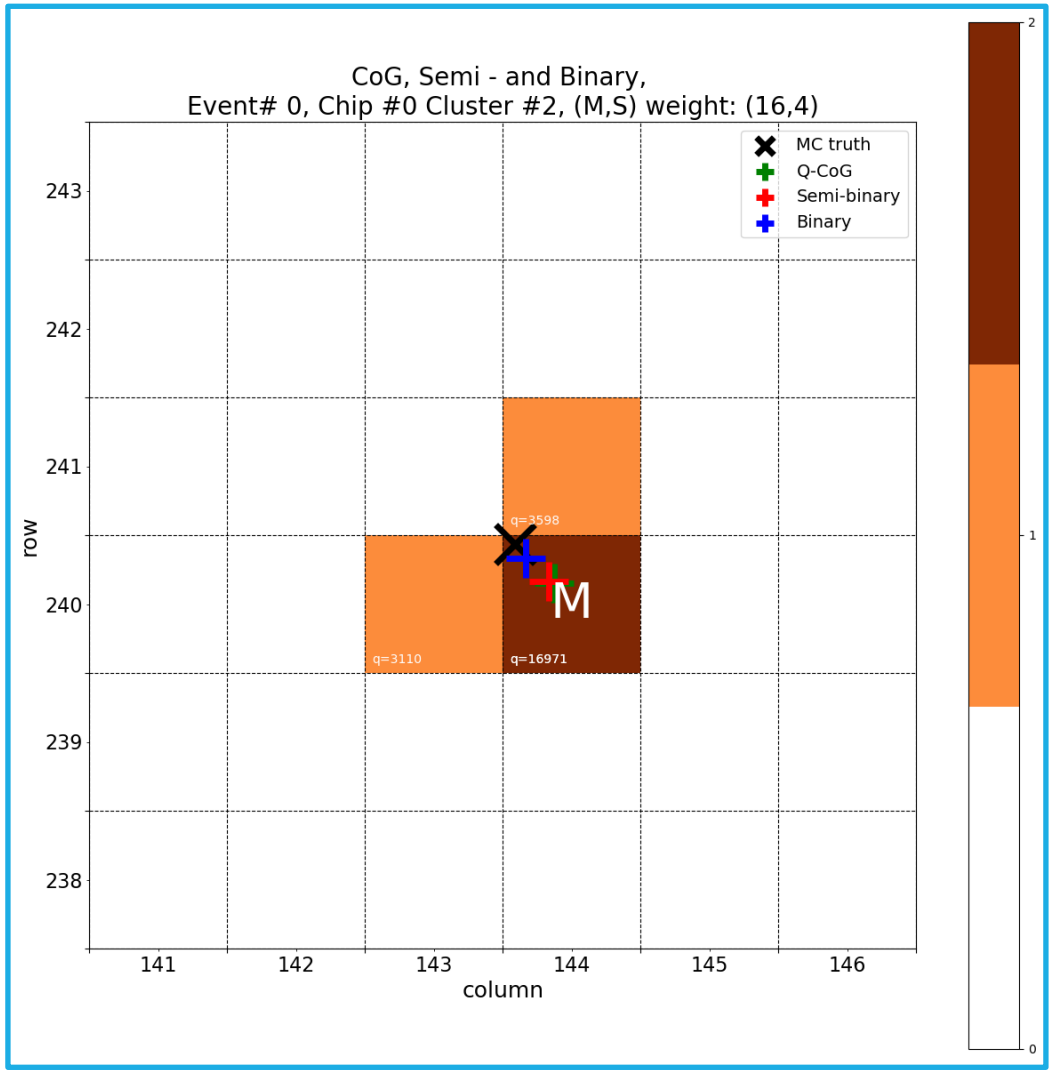
CLUSTERING INTERPOLATION

- Three methods tested:
  - Charge weighted center of gravity (CoG)
  - Binary

    Every pixel in cluster has equal weight
  - Semi-binary

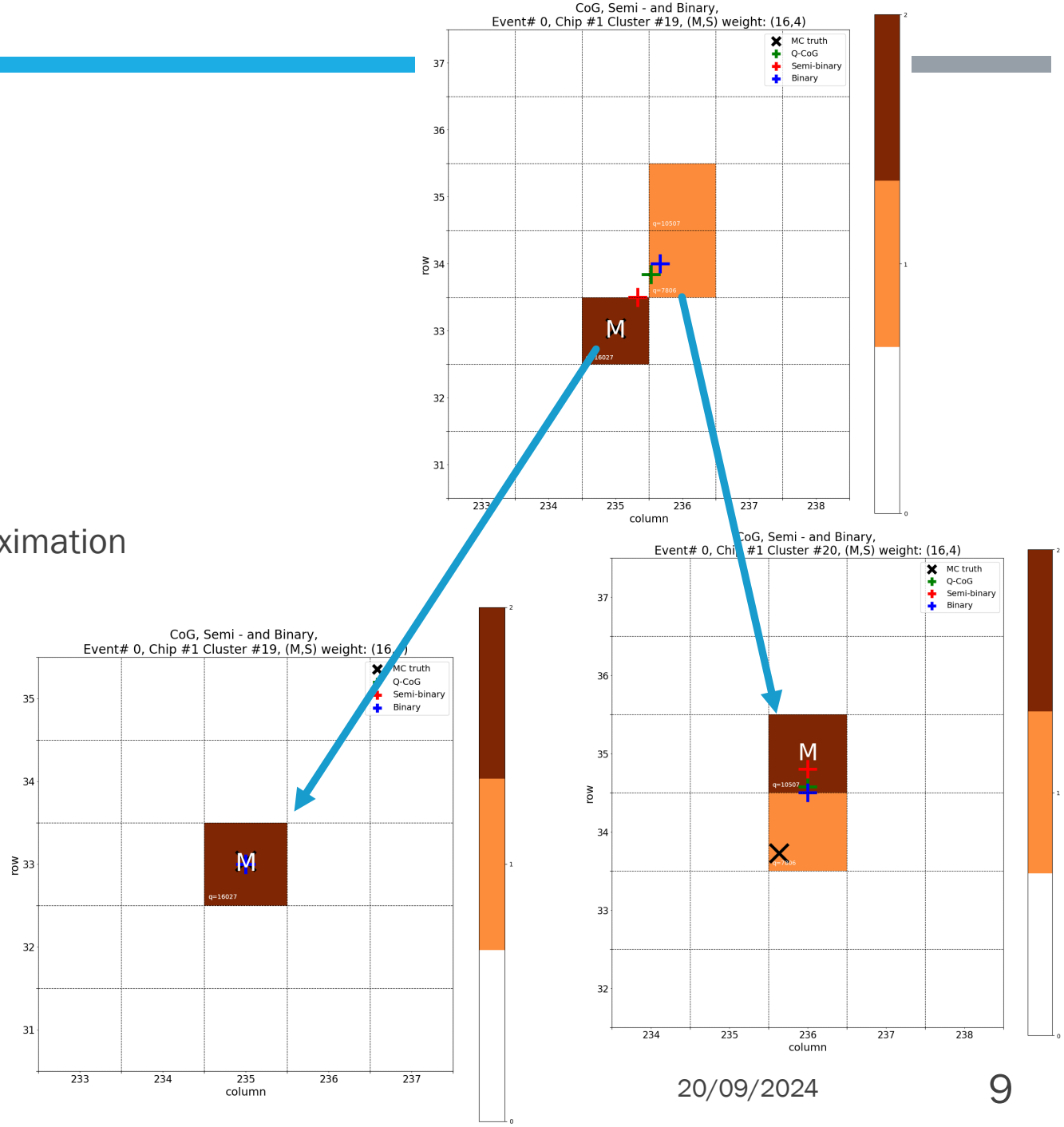
    Pixel with highest collected charge is Main pixel (M),

    others are Spectators (S). Different ratio's (M/S) tested.



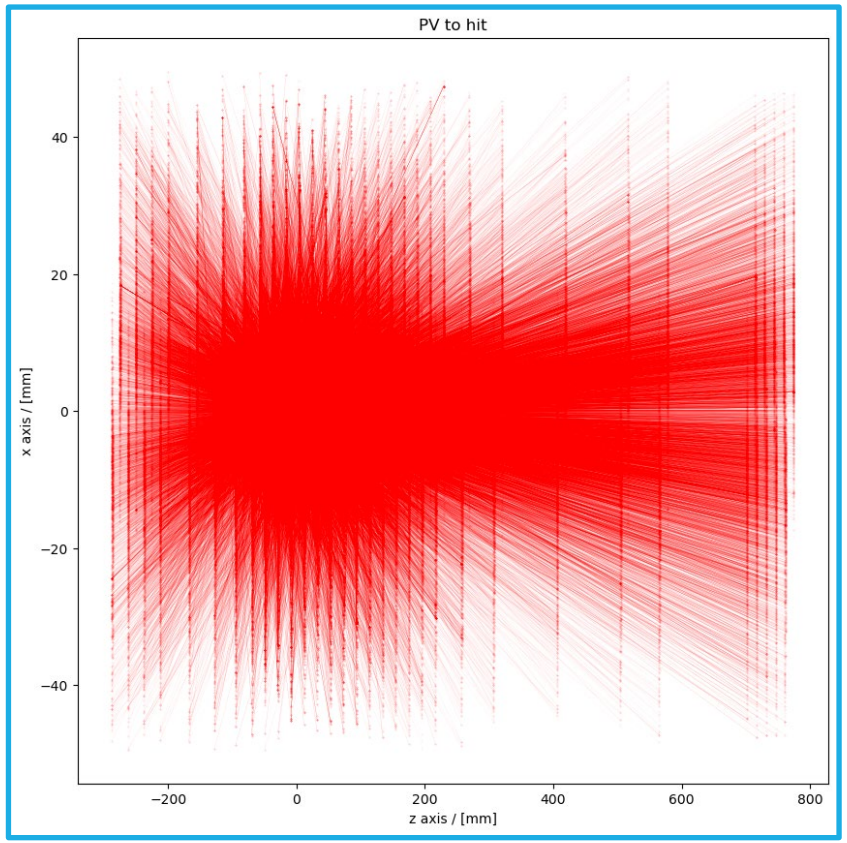
CLUSTERING INTERPOLATION

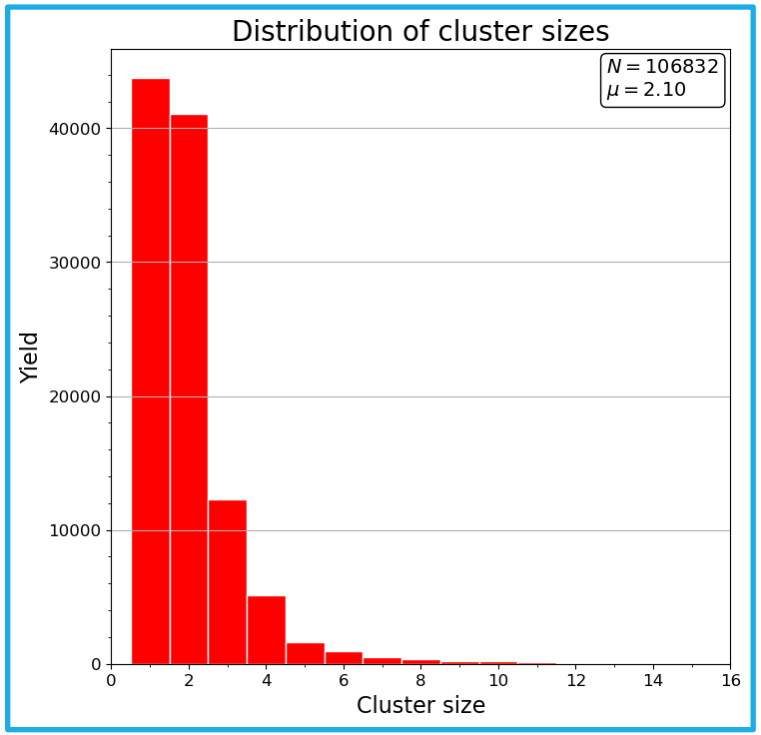
- Low statistic: 10 PV events, $\mathcal{O}$(200,000) hits
- First pixels are clustered by neighbourhood approximation
- Later simulation truth information used

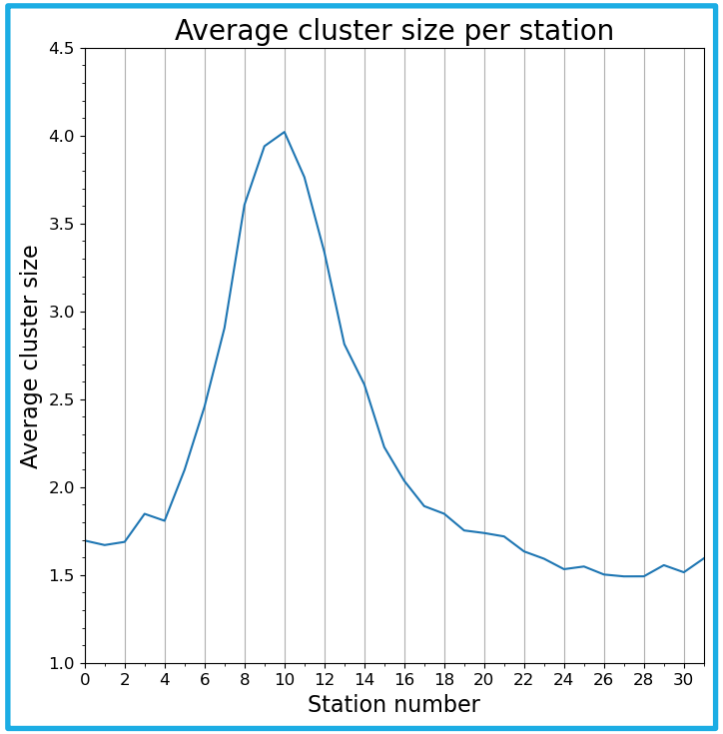


RESULTS

- All results are work in progress. Additional checks are still being made.





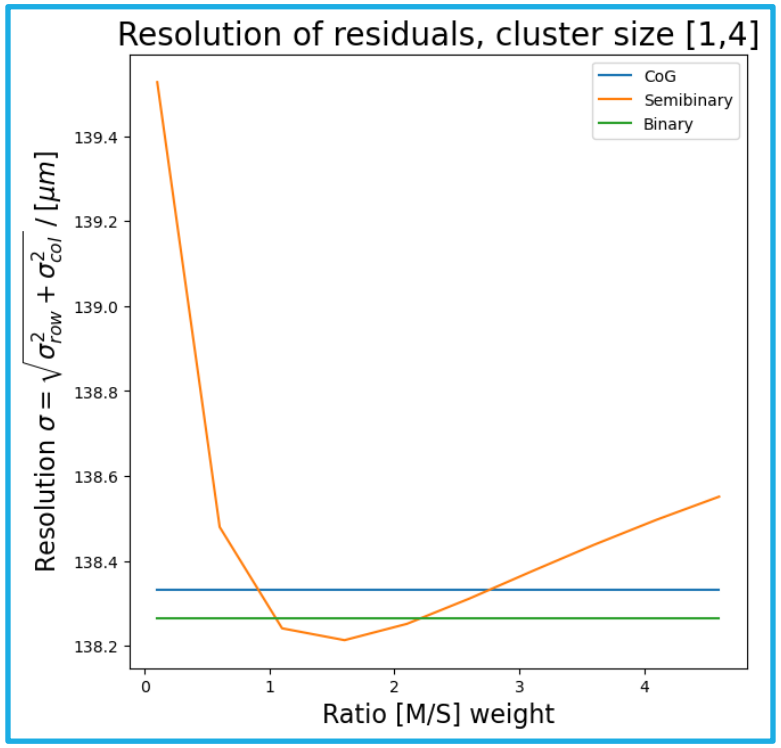


RESULTS

Some residuals are of order ~ 2000um

Caused either by the alignment or huge clusters

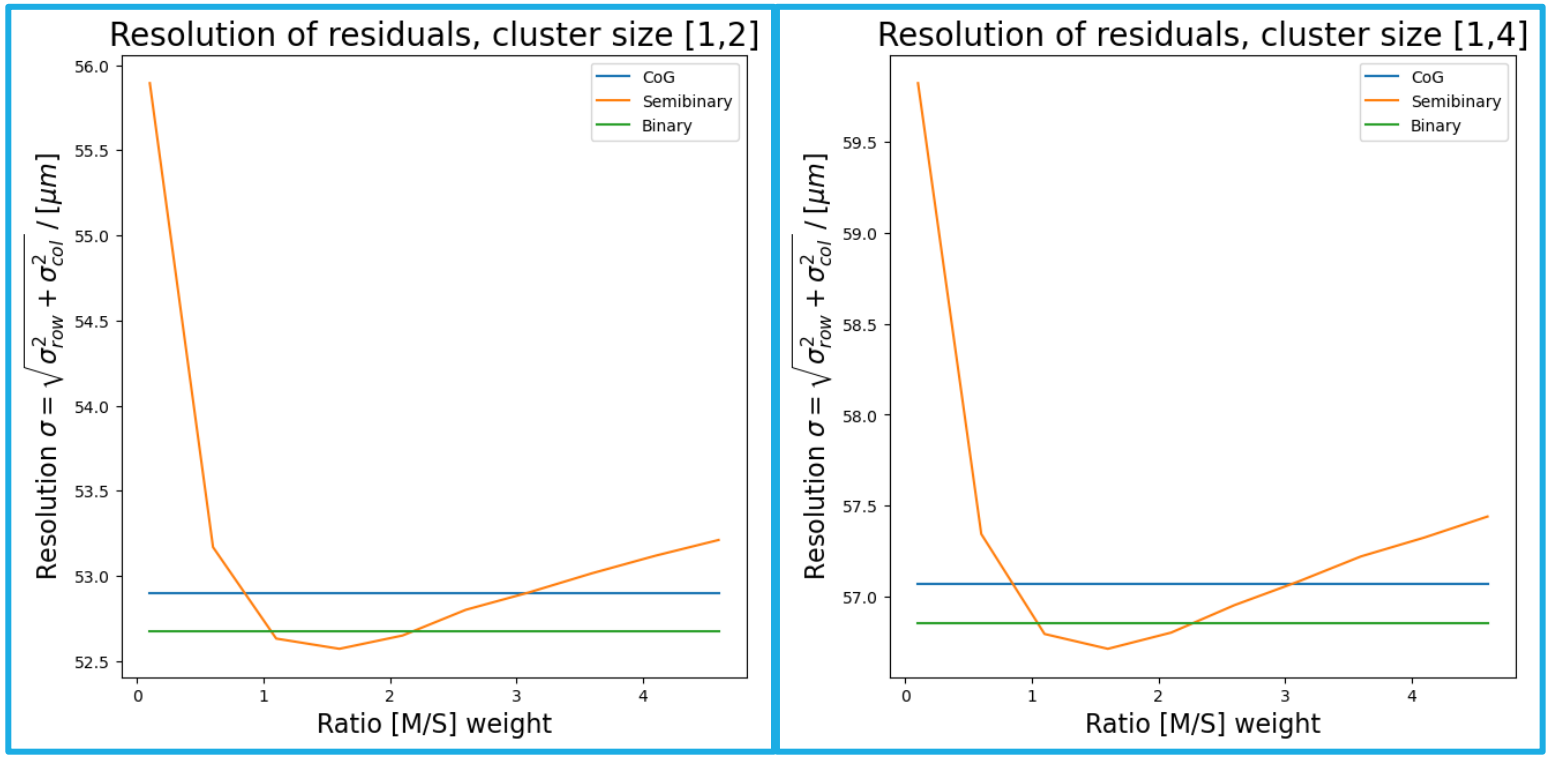
- Different (M/S) ratio's tested:
  - For different cluster size's



RESULTS

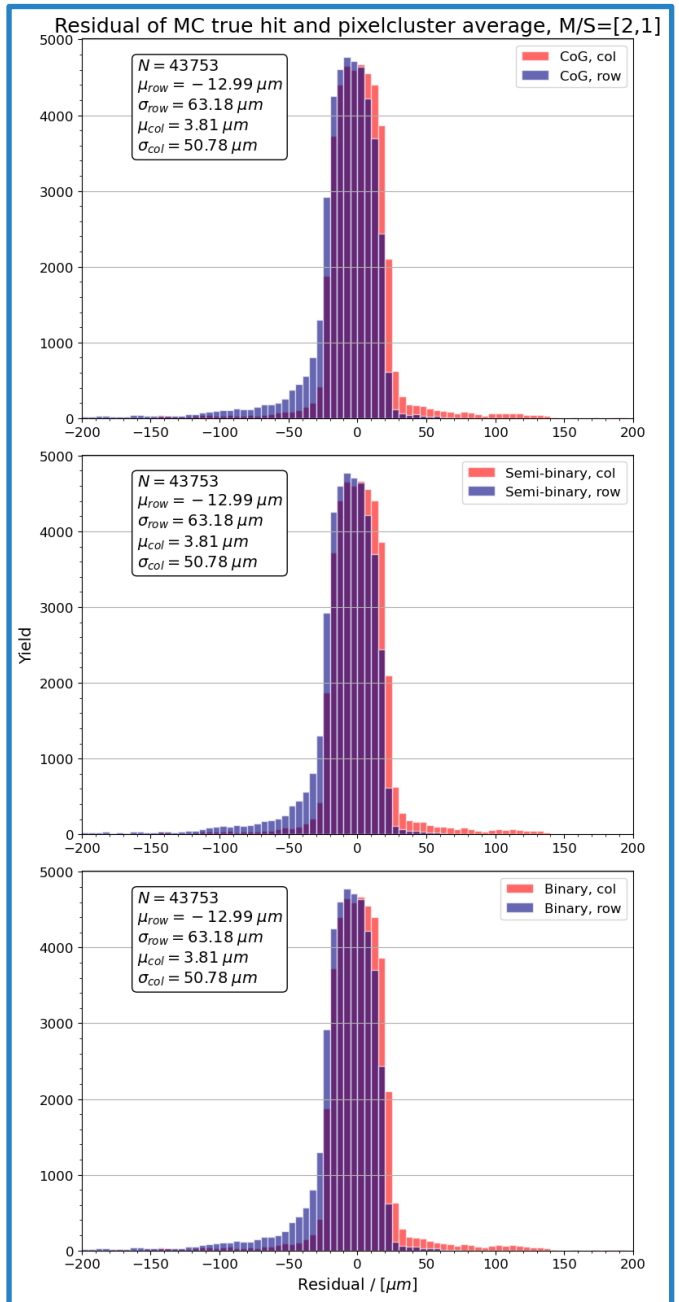
- Filtering out unphysical results shows better resolution

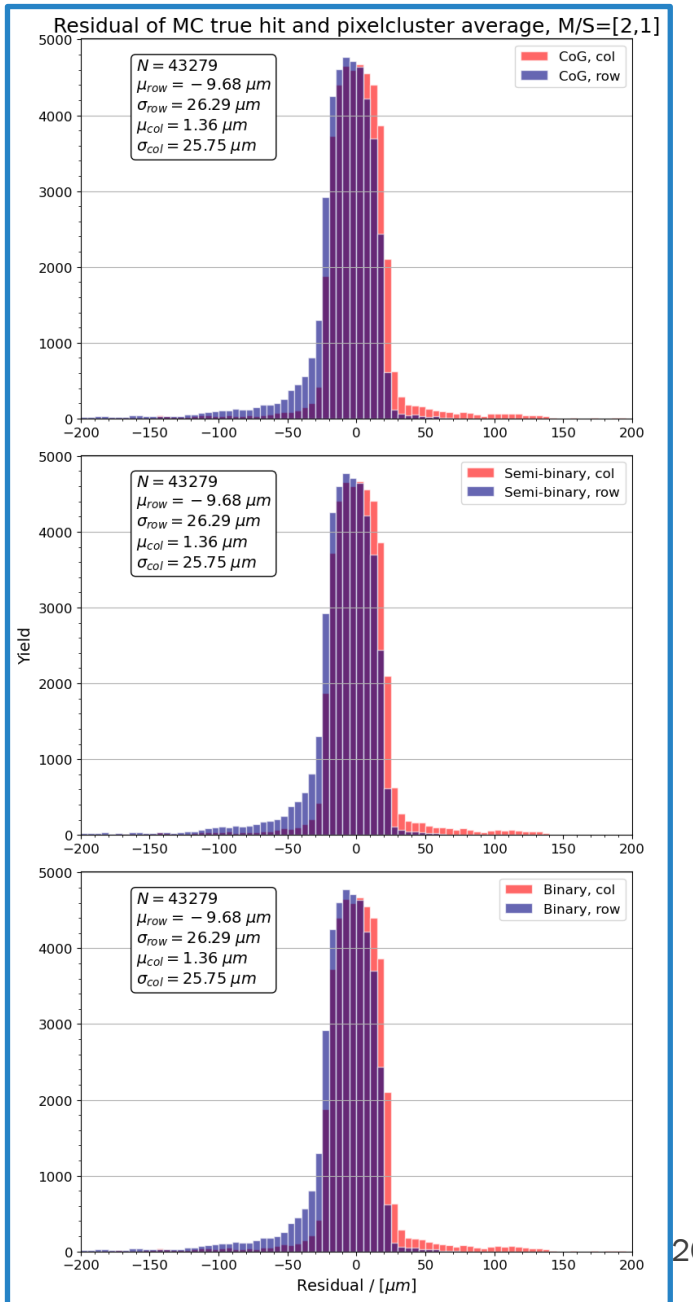
If |residuals| > 300 um filtered out:



RESULTS

- Sanity check
- Local residuals, <u>single</u> pixel clusters unfiltered

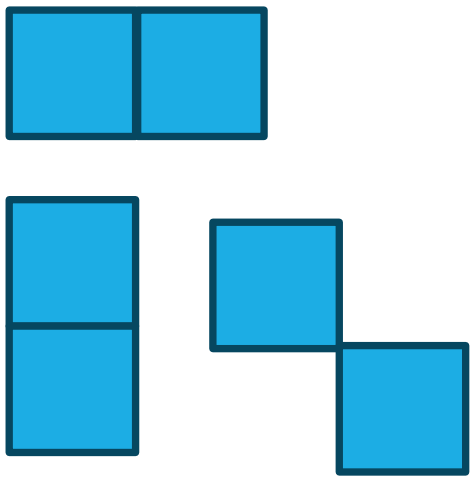


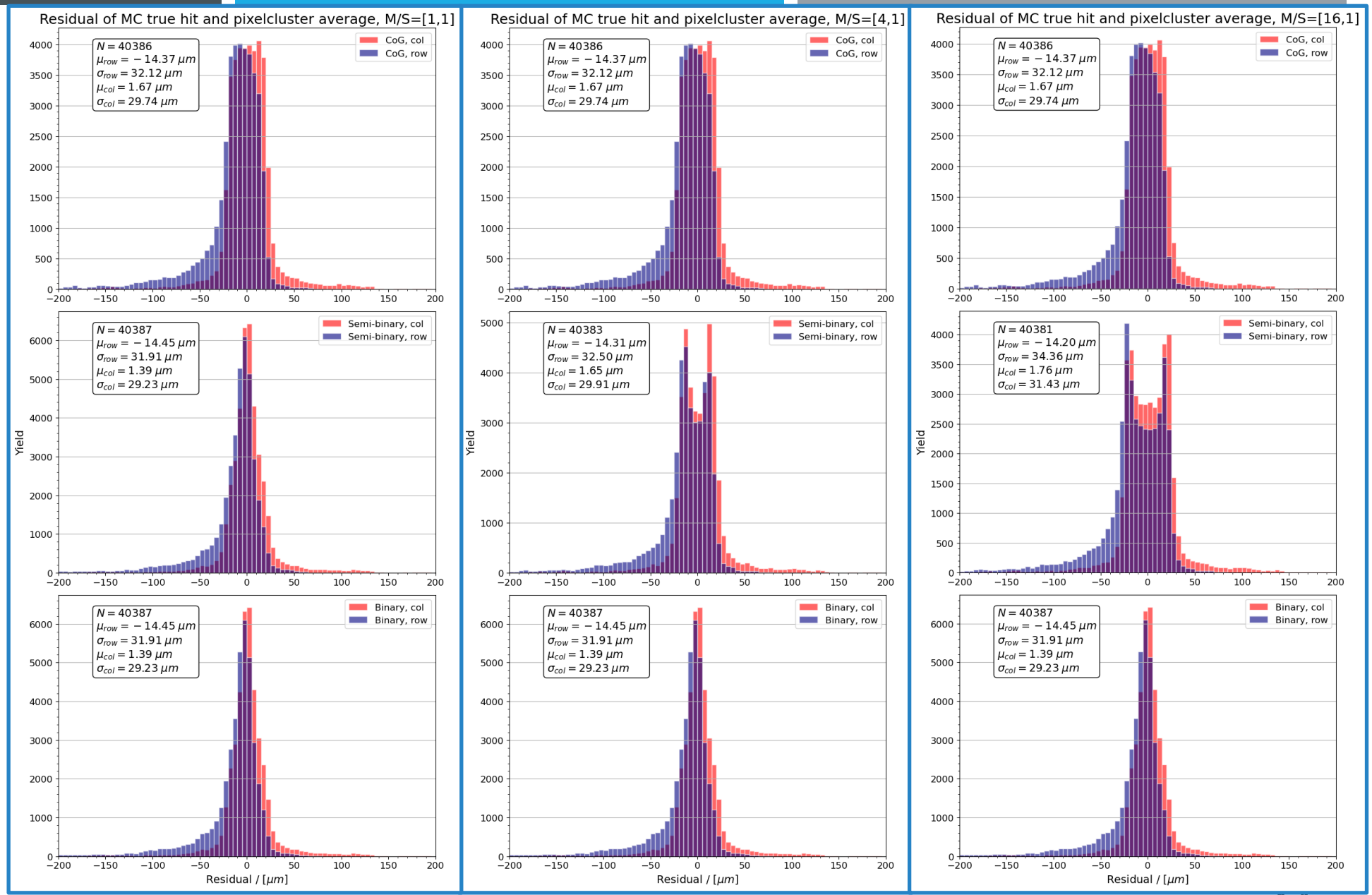


|res|>200um filtered

RESULTS

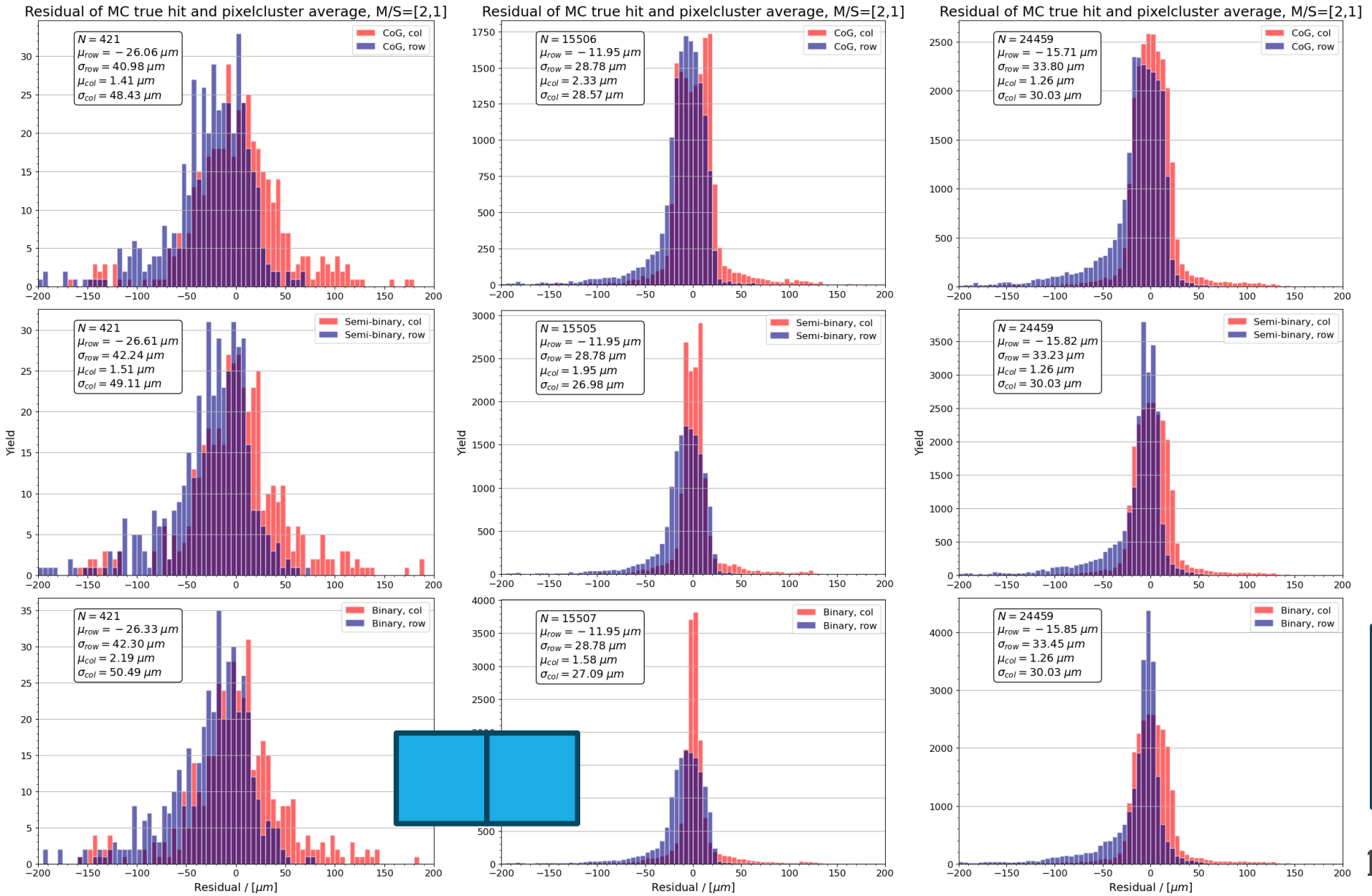
- Local residuals, double pixel clusters
  |res|>200um filtered





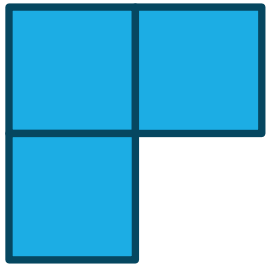
RESULTS

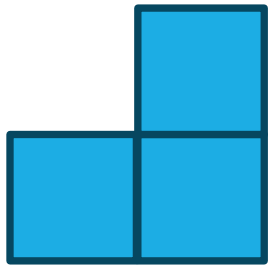
- Local residuals, two pixel clusters

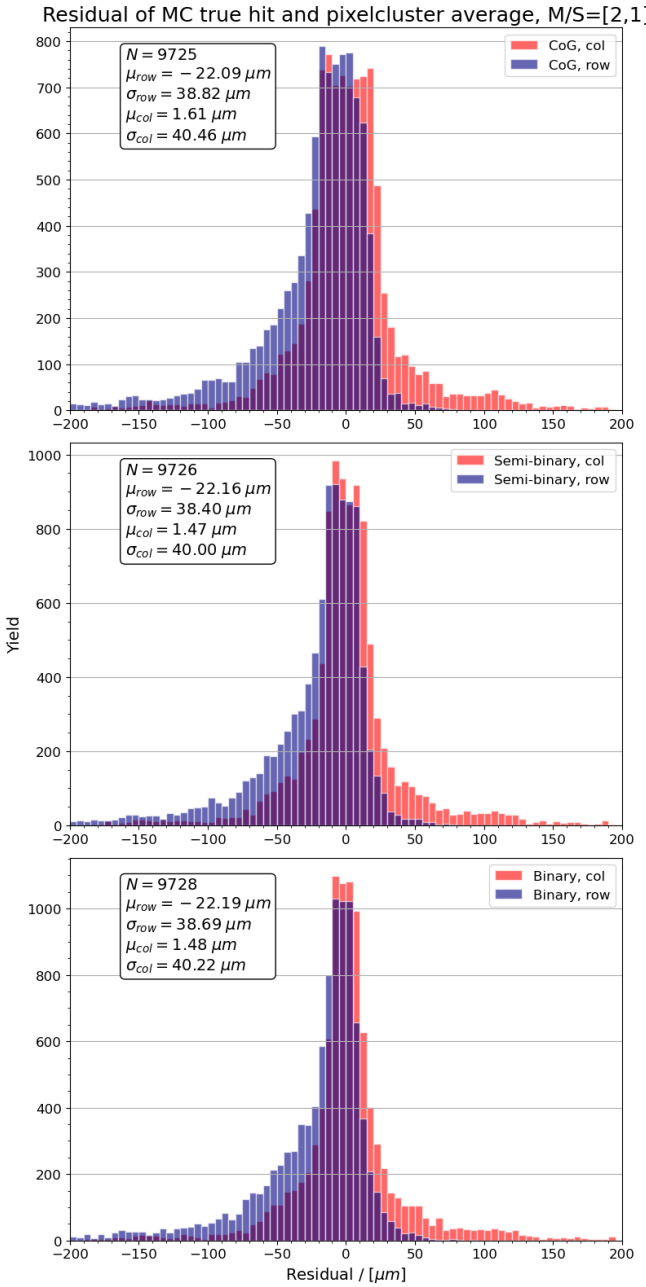


RESULTS

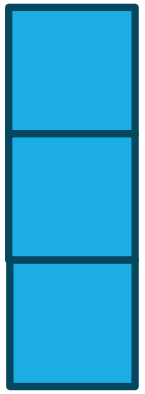
- Local residuals,
  3 pixel hits,
  within 2x2

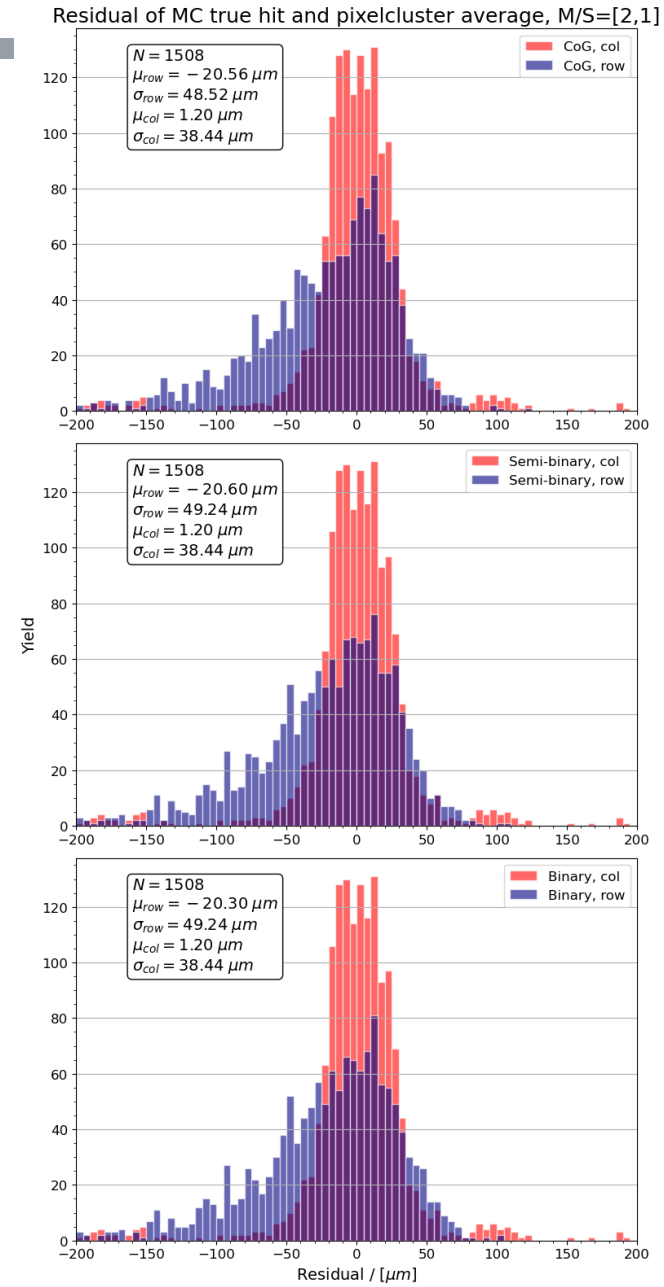






3 pixel hits,
within 1x3

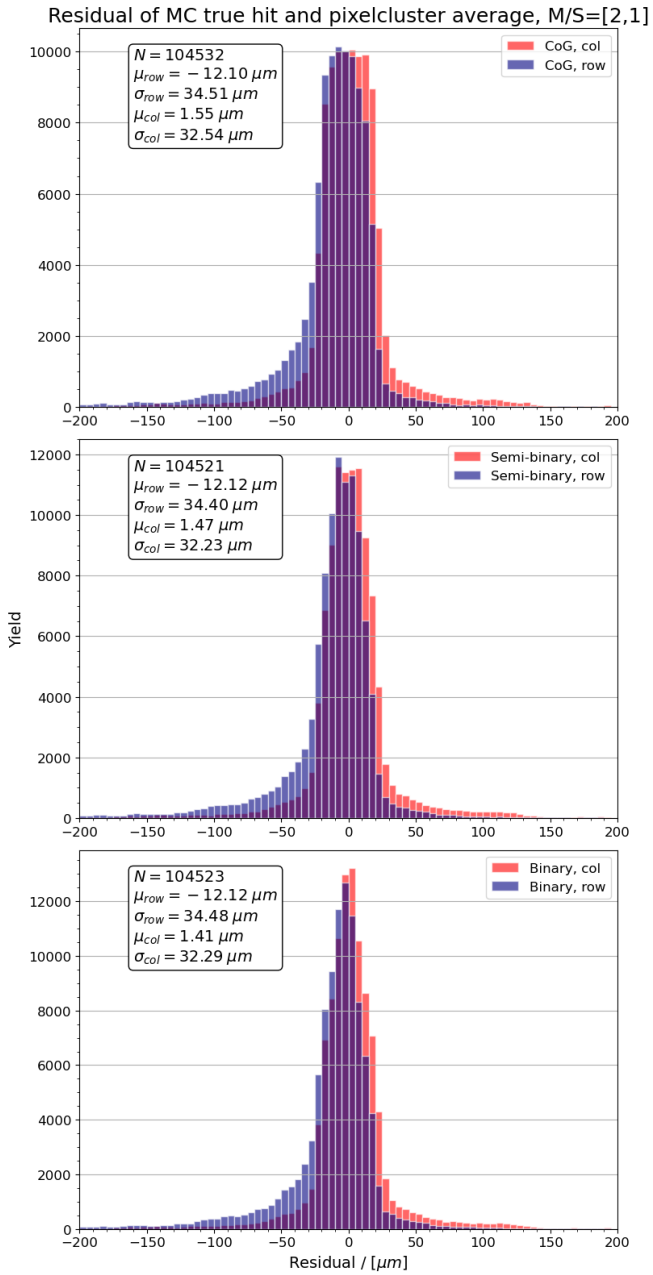




RESULTS

- Local residuals, all clusters

|residual| > 200 um filtered out

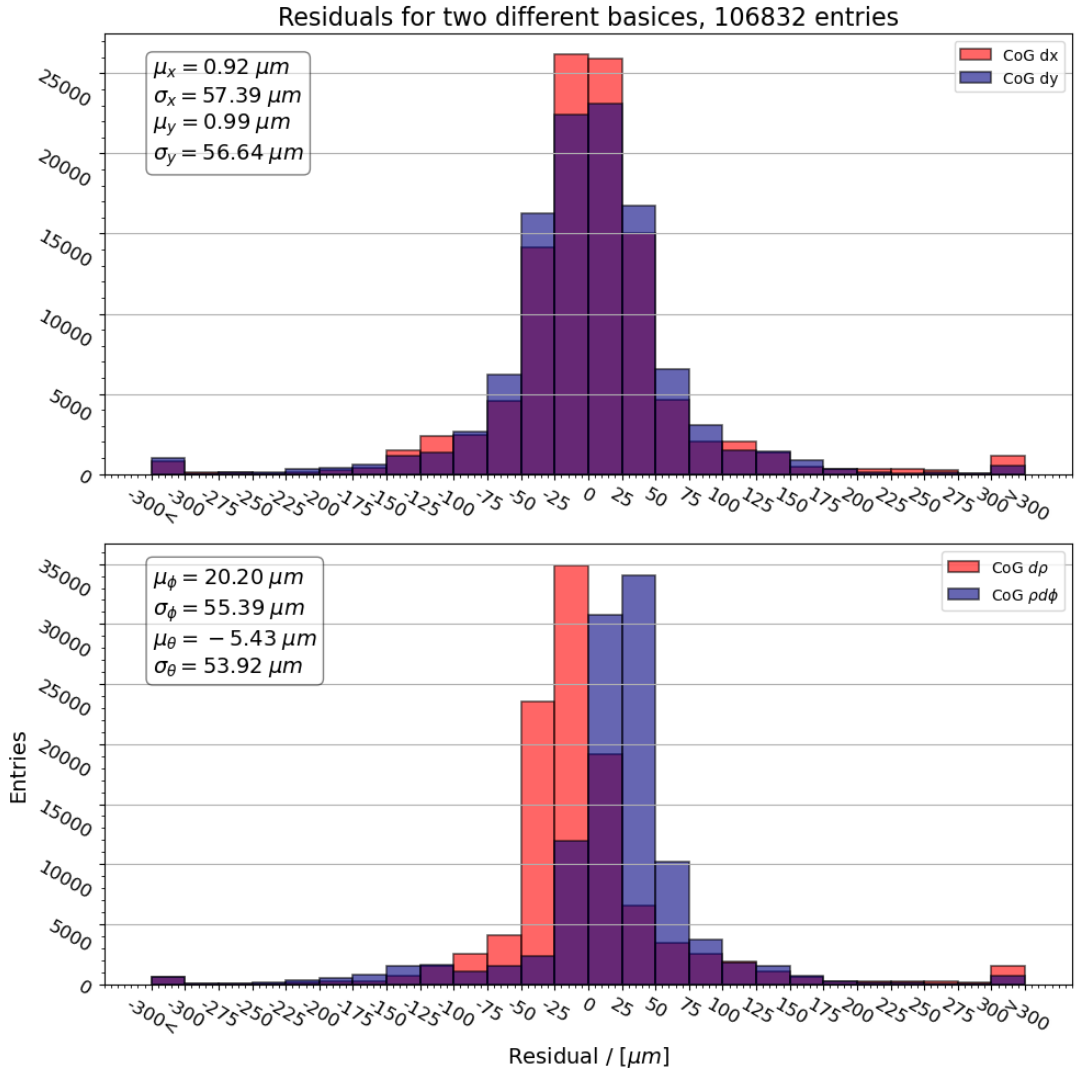


RESULTS

- Also angular residuals are considered: $(rd\theta, rd\phi)$
  - Residuals calculated as projections on the chip:
    - $rd\theta$ is approximated as $d\rho$
    - $rd\phi$ is approximated as $\rho d\phi$

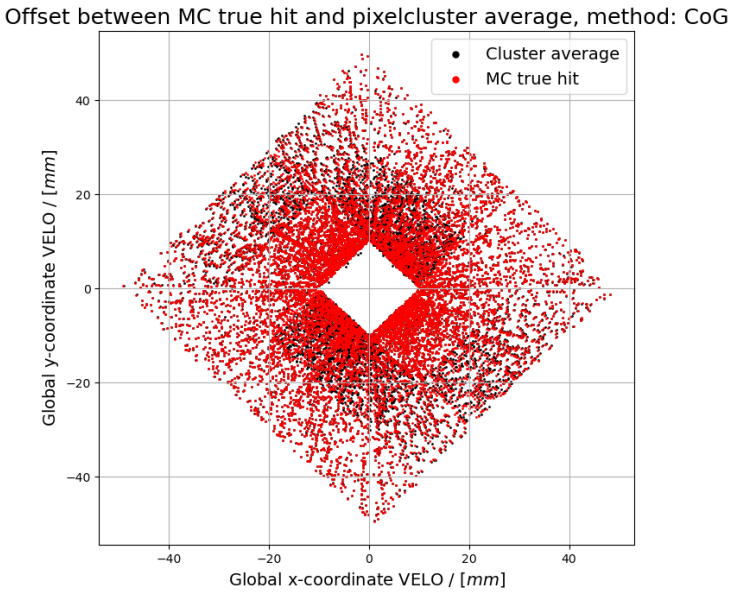
    where r is the global radius and ρ is the radius in XY-plane

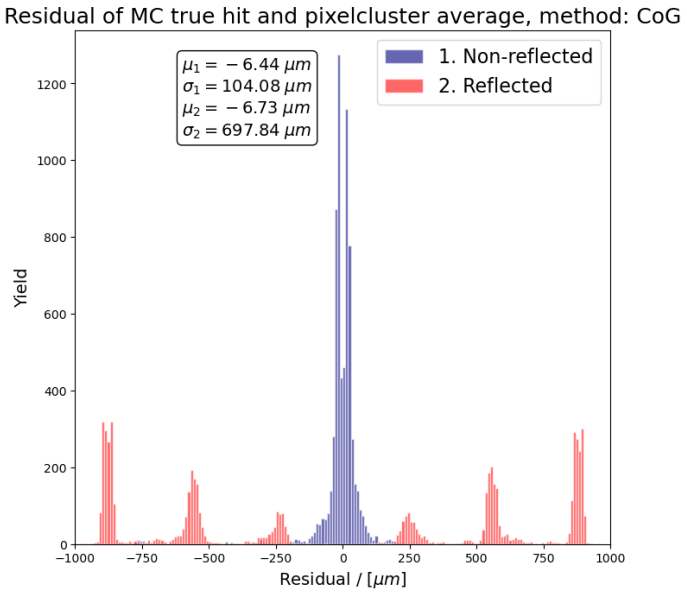
However the global coordinates are used for these residuals, see slide 9.



CAVEATS

- Apart from the micro alignment, additional systematic deviation found in simulation. Cause unknown.





Chip 0 (mod24): [dx,dy] = [+0.1, 0]
Chip 1 (mod24): [dx,dy] = [+0.25, 0]
Chip 2 (mod24): [dx,dy] = [+0.40, 0]
Chip 11 (mod24): [dx,dy] = [0, -0.27]
Chip 12 (mod24): [dx,dy] = [-0.1, 0]
Chip 13 (mod24): [dx,dy] = [-0.25, 0]
Chip 14 (mod24): [dx,dy] = [-0.40, 0]
Chip 23 (mod24): [dx,dy] = [0, +0.27]

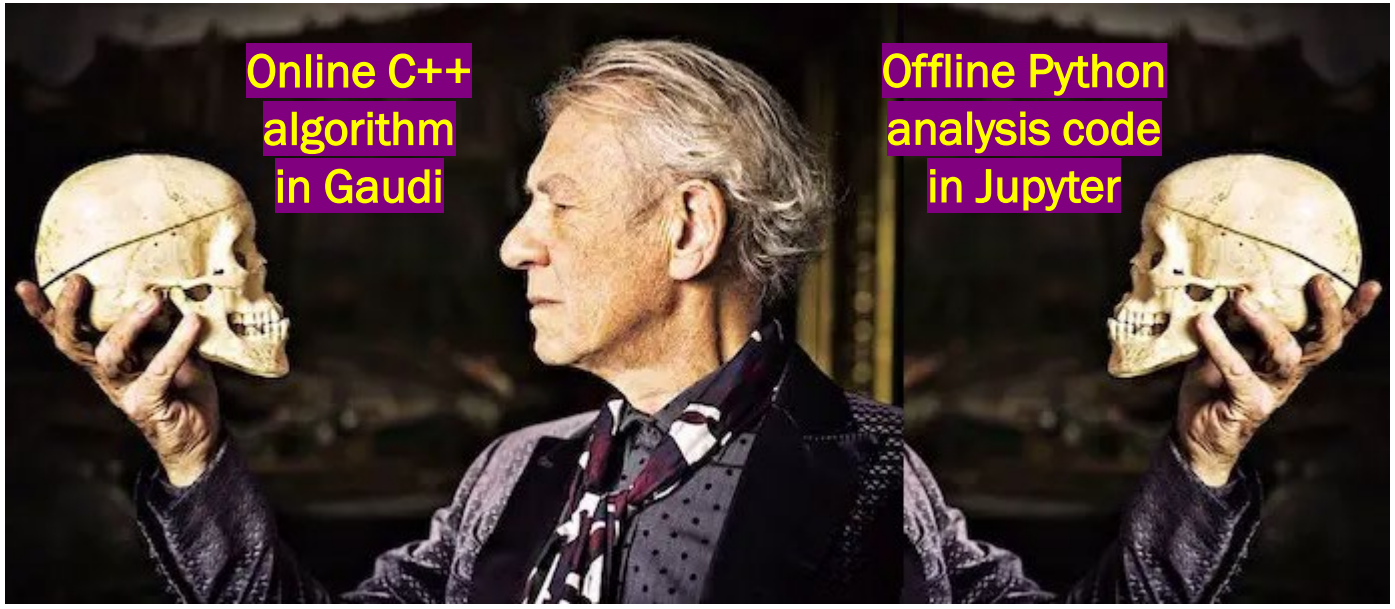
CAVEATS

- Apart from the micro alignment, additional systematic deviation found in simulation. Cause unknown.

- These results depend on the way pixel hits are and charge sharing is simulated.

CAVEATS

- Apart from the micro alignment, additional systematic deviation found in simulation. Cause unknown.
- These results depend on the way pixel hits and charge sharing are/is simulated.
- Clear indication that some code needs to run online



OUTLOOK

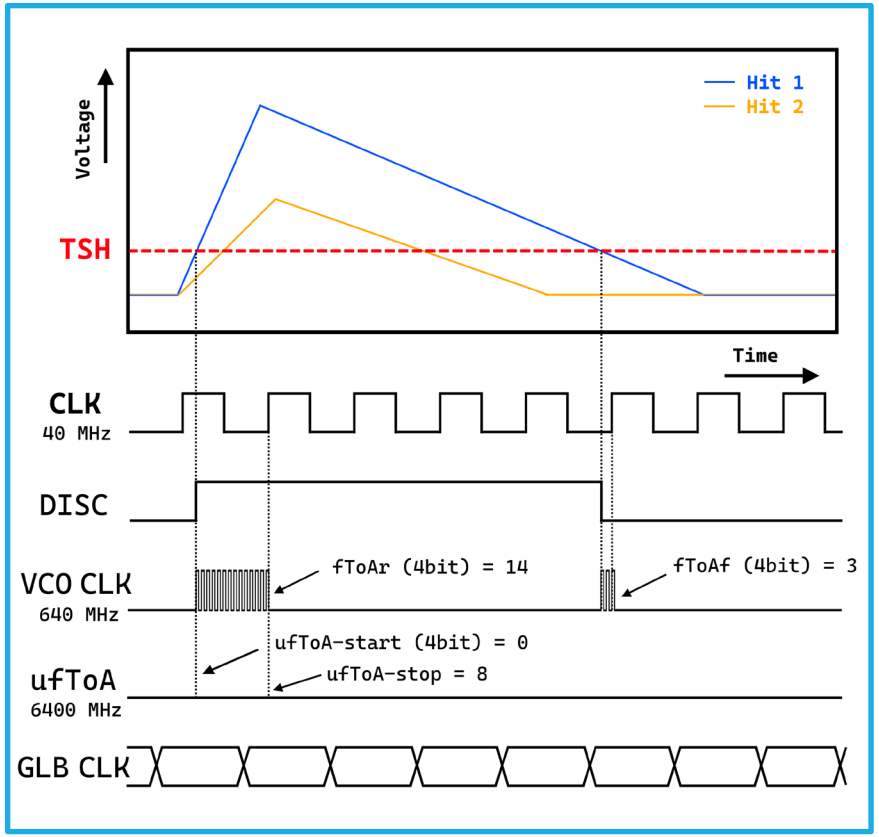
- Implement detailed timing in simulation

  → time-weighted clustering

- Investigating impact of digitization (bit allocation),

  e.g. in LHCb simulation and/or Allpix2

- Can timing information improve spatial resolution, or vice versa?



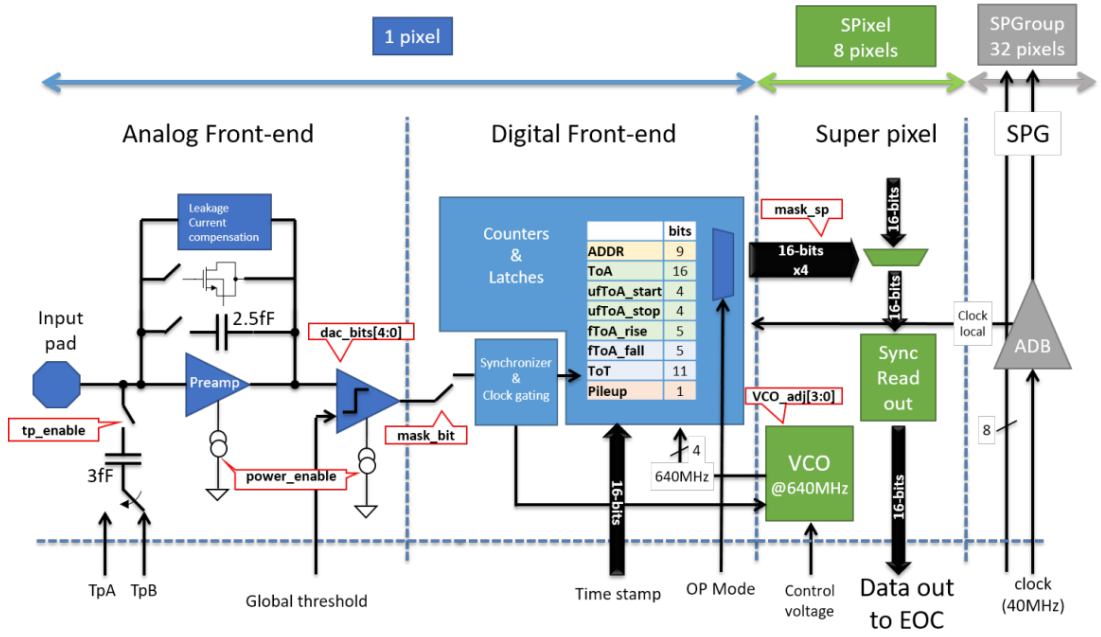
OUTLOOK

- Track reconstruction information can be fed back to cluster calculation to improve resolution
- Develop firmware to test algorithms during test beam

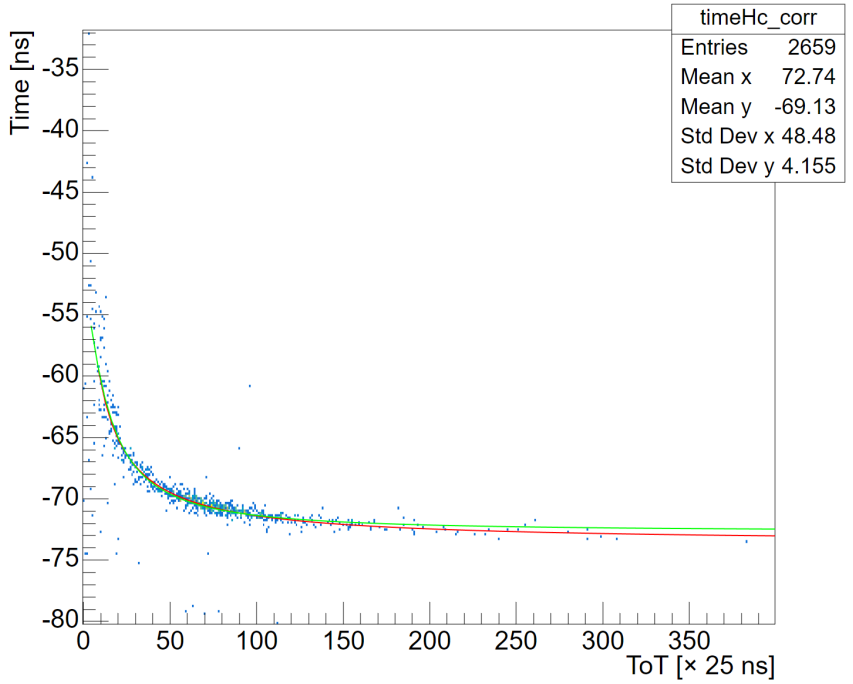
THANK YOU
FOR YOUR TIME AND ATTENTION

BACK UP

TIMING AND TIMEPIX



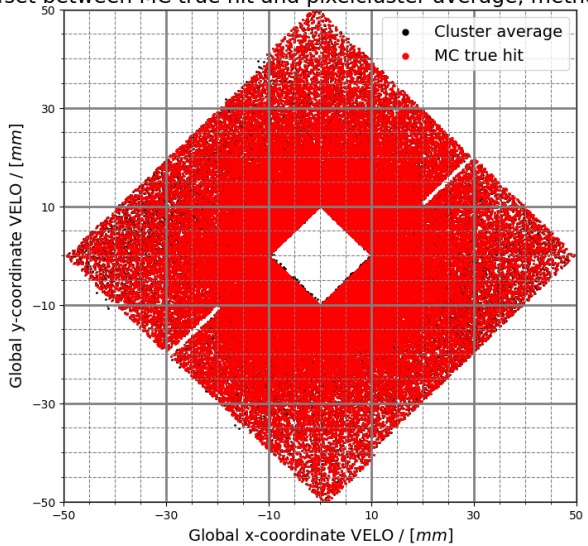
$$\Delta t_{tw} = \frac{b}{(\Delta T_{ToT} + c)^d} + a$$



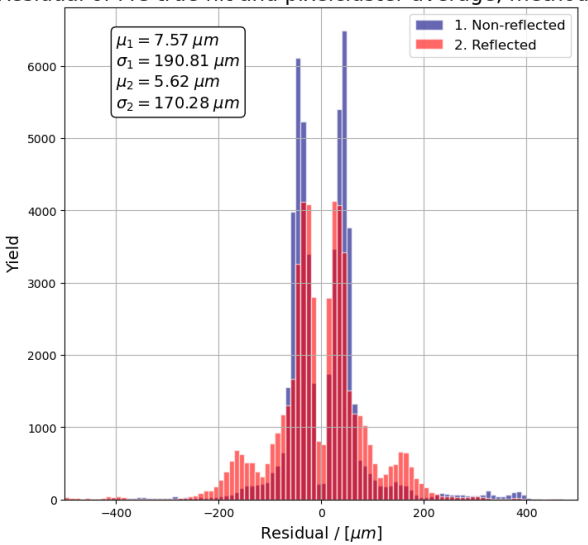
Courtesy: E. Rodríguez[2]

GLOBAL COORDINATES

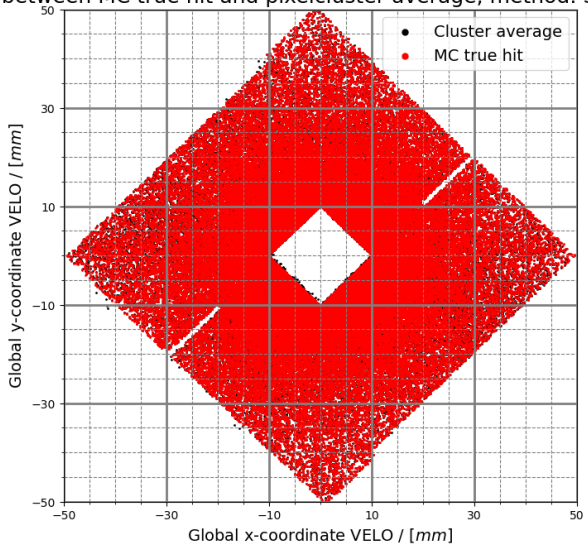
Offset between MC true hit and pixelcluster average, method: CoG



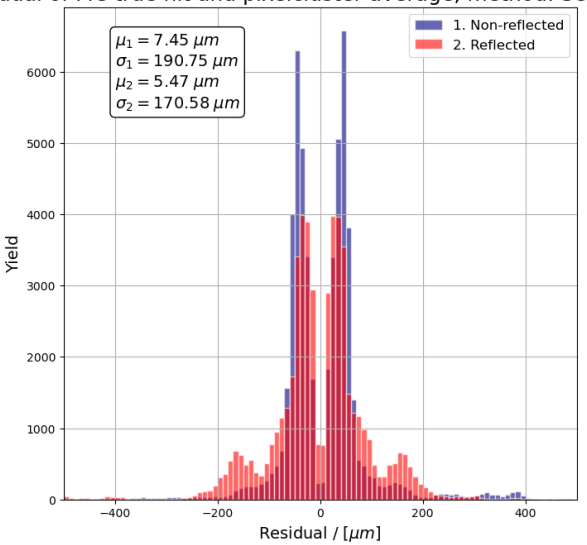
Residual of MC true hit and pixelcluster average, method: CoG



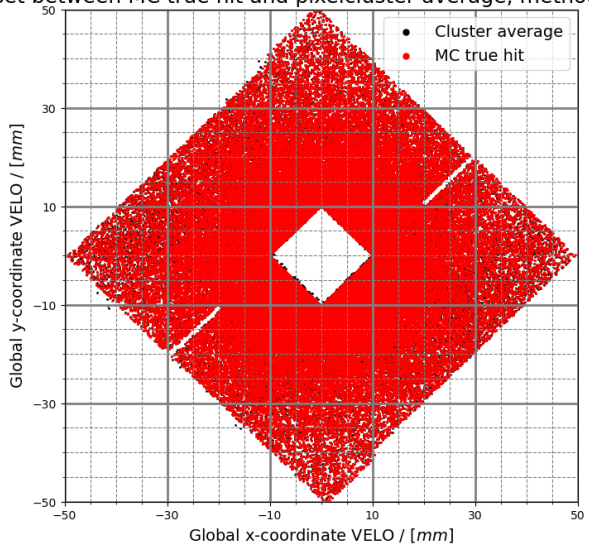
Offset between MC true hit and pixelcluster average, method: Semi-binary



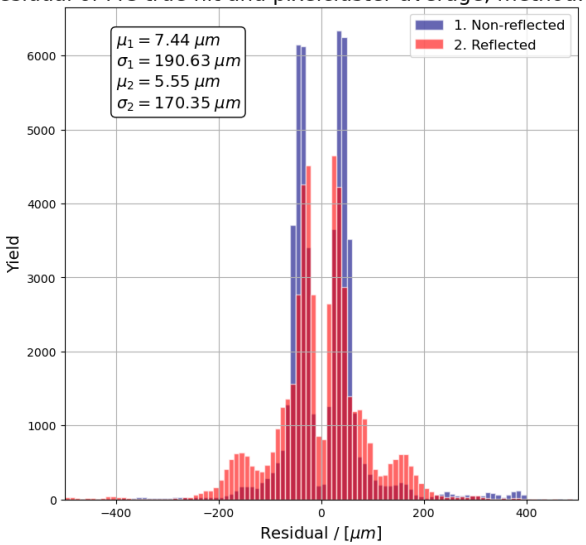
Residual of MC true hit and pixelcluster average, method: Semi-binary



Offset between MC true hit and pixelcluster average, method: Binary



Residual of MC true hit and pixelcluster average, method: Binary

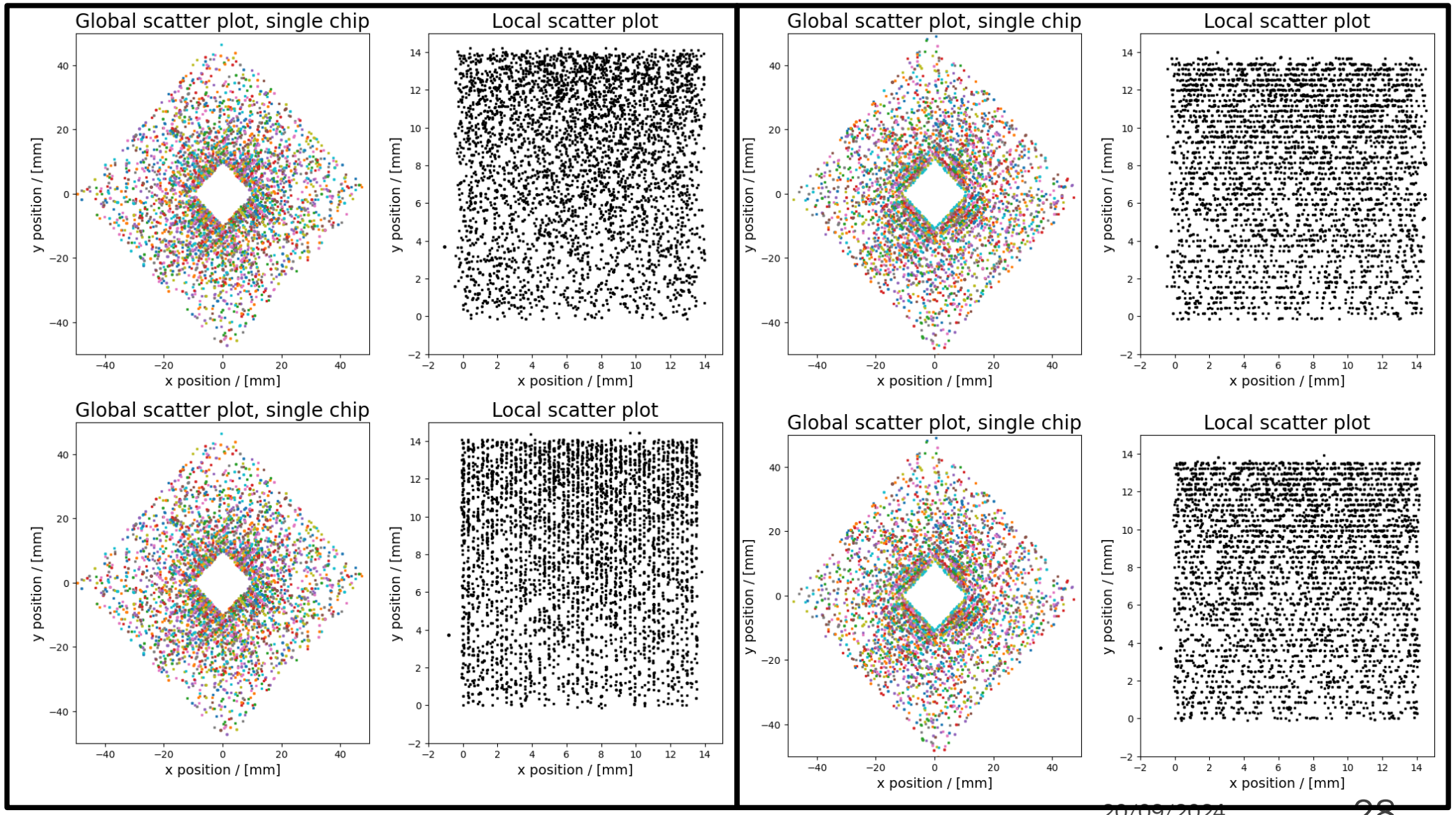


MICRO ALIGNMENT

every 5th row/column plotted

Before

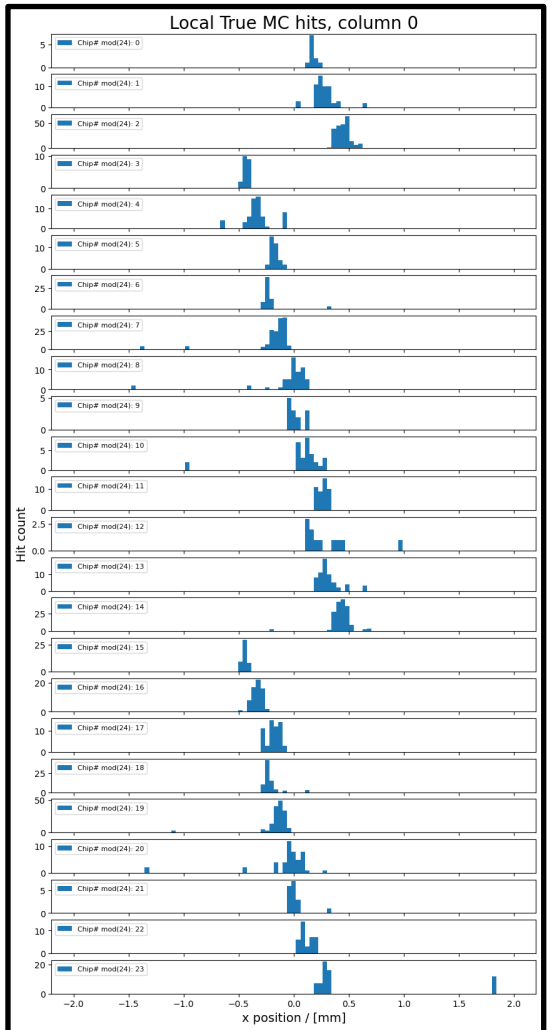
After

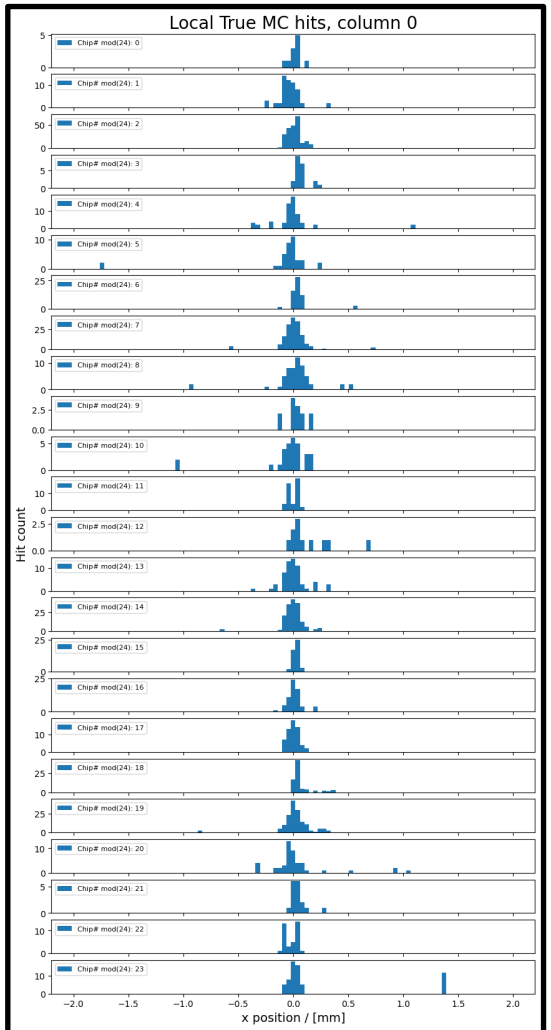


MICRO ALIGNMENT

Before

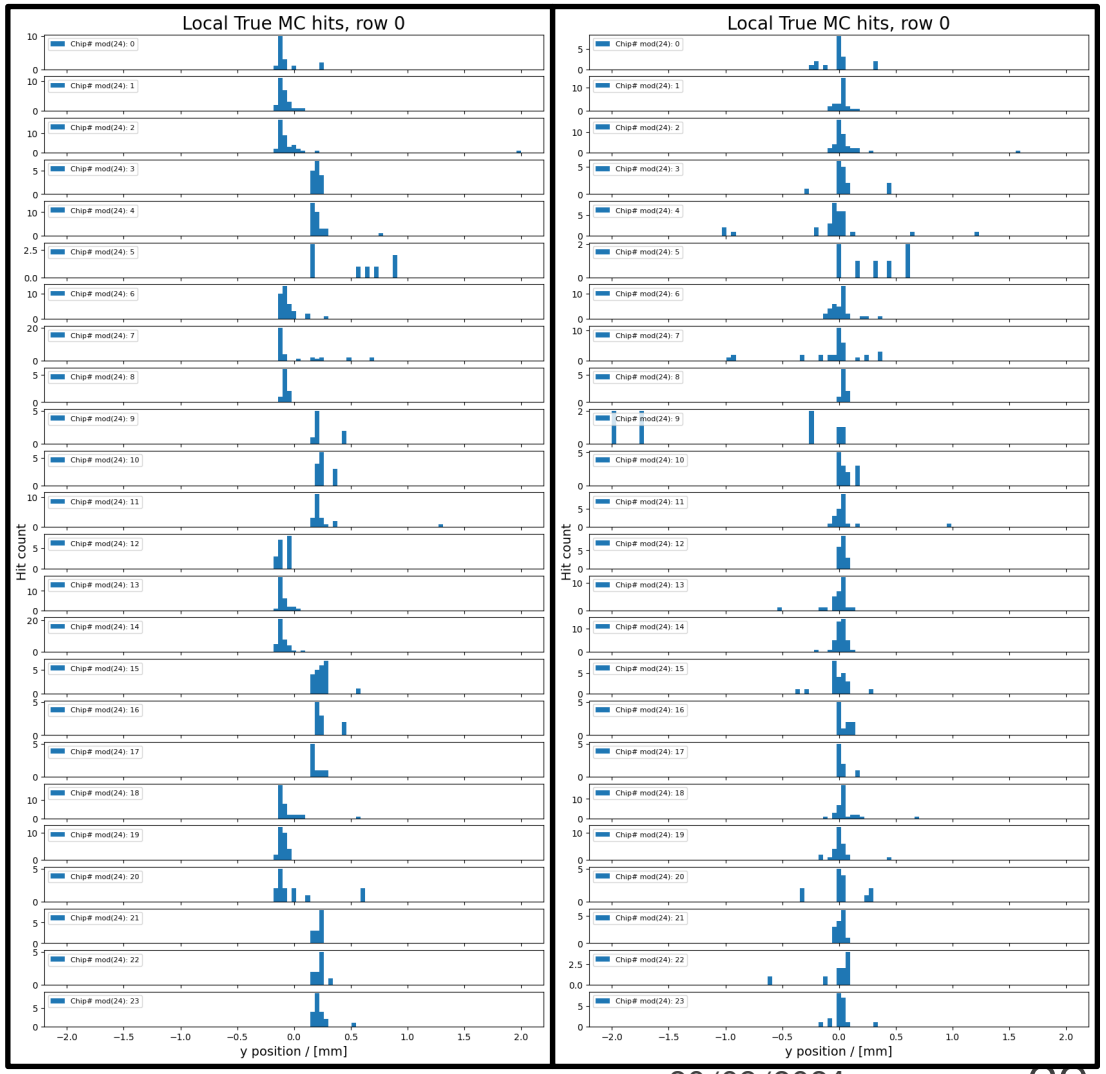
After





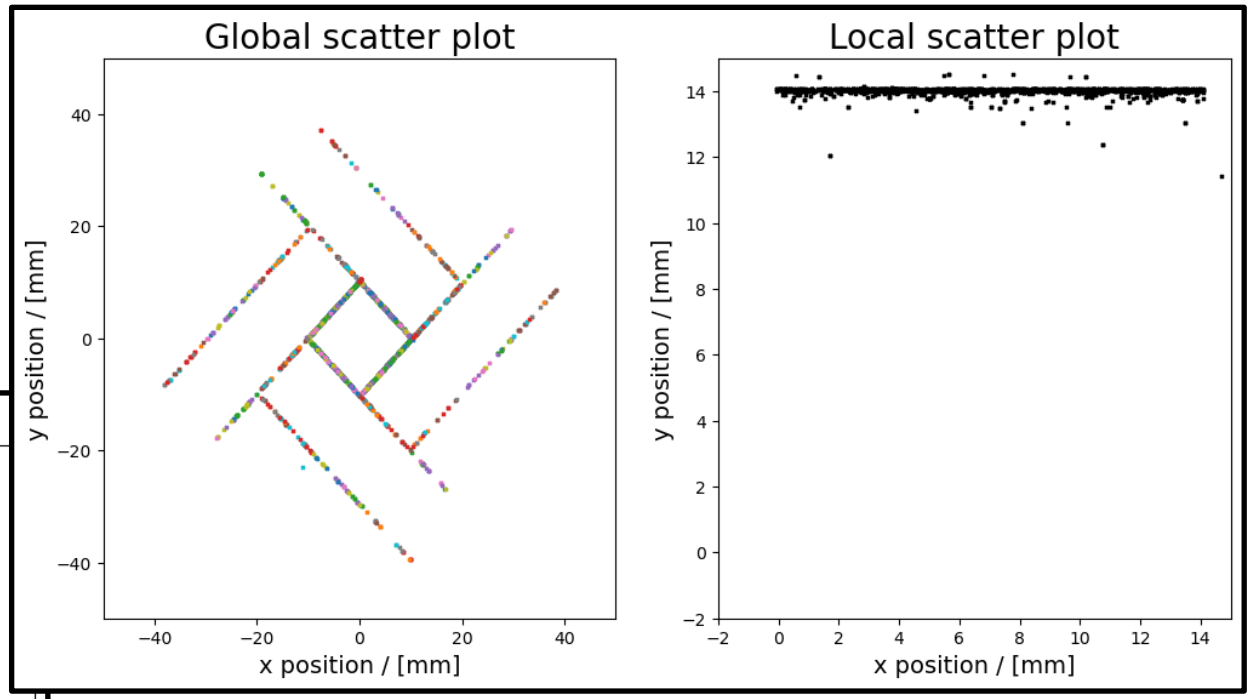
Before

After



MICRO ALIGNMENT

255th row



0th column