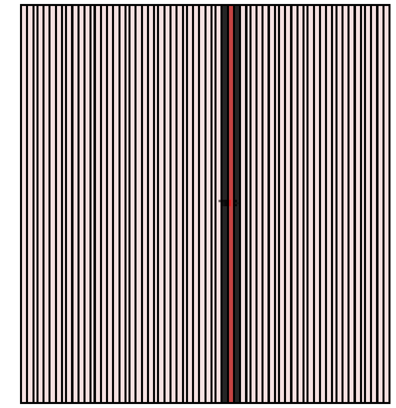
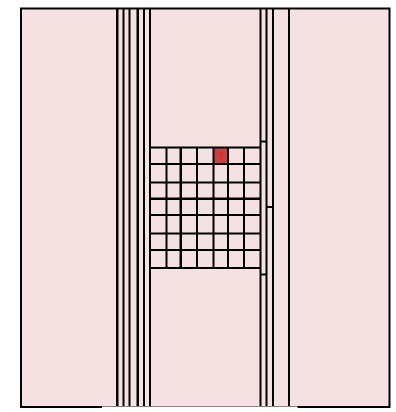
MuTom analysis

Summary of (some of) the knowledge acquired in the past months

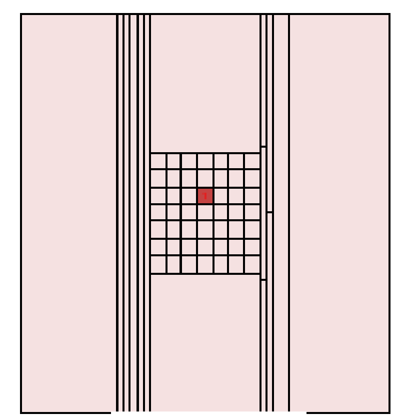
- From November 2020, the trigger was set to:
    - coincidence in two corepix planes: 1&2 | 2&3 | 1&3
    - only in the corepix area



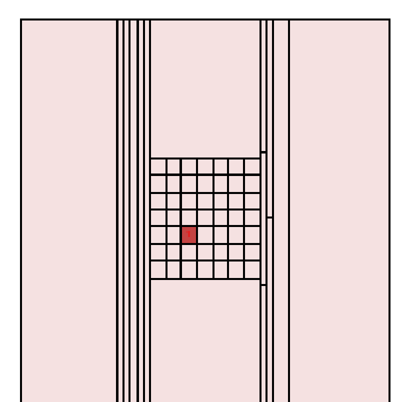
strips
#0 (#4)



corepix top
#1 (#3)

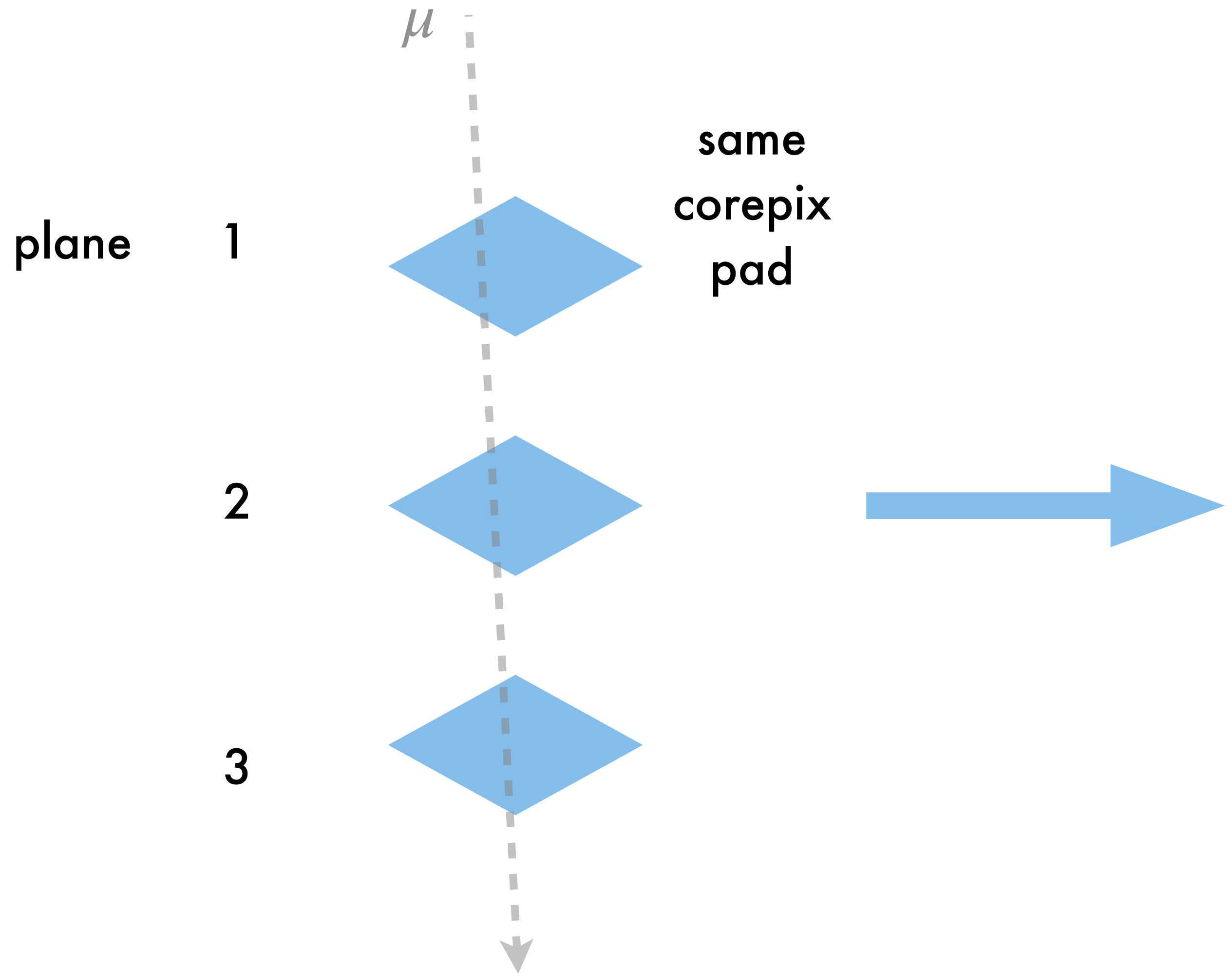


corepix middle
#2 (#2)



corepix bottom
#3 (#1)

Determination of each pad efficiency to vertical muons in each corepix

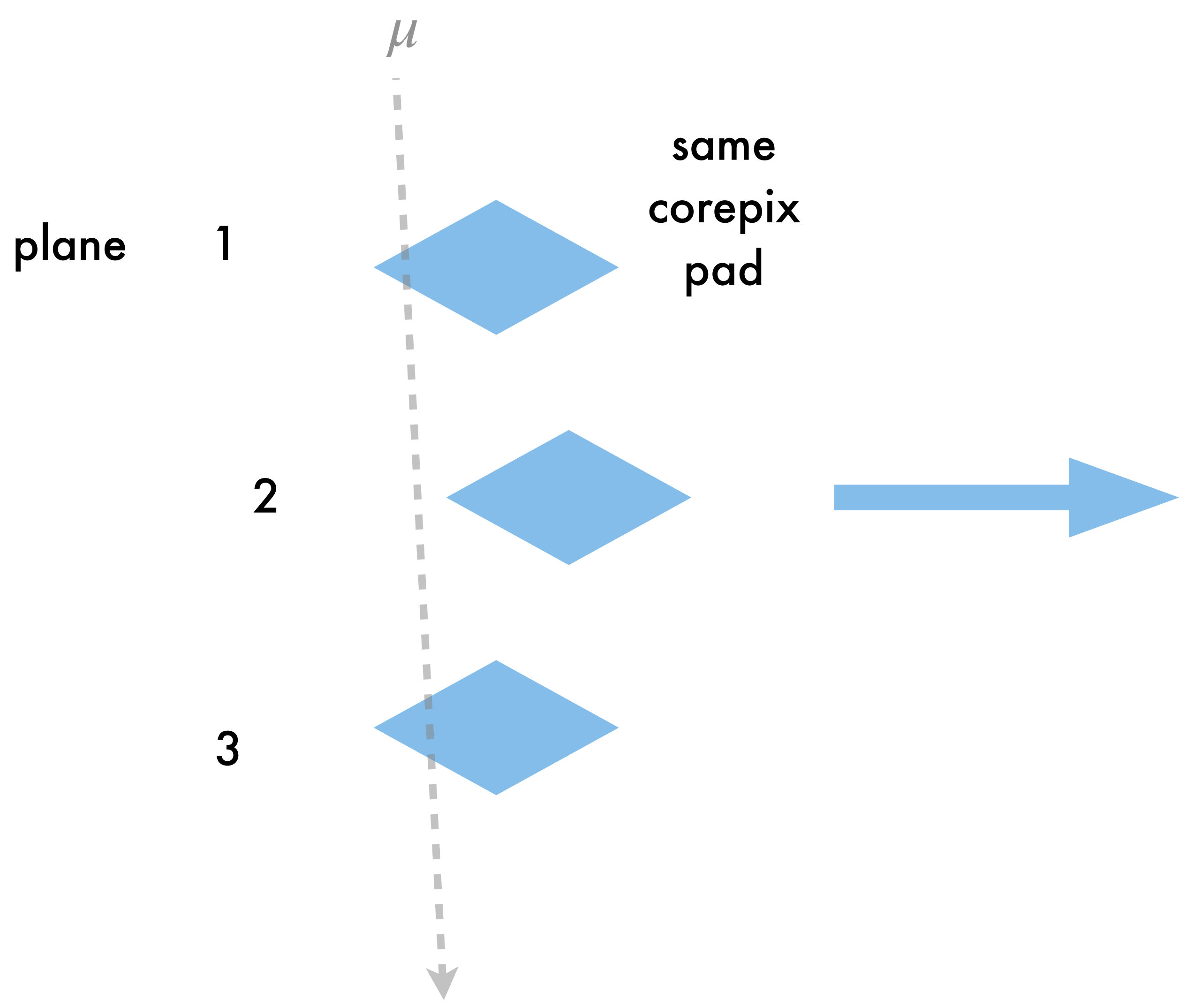


Efficiency in the pad of plane 2:

$$\epsilon_2 = \frac{N_{123}}{N_{13}}$$

N_{13}: number of events with the same pad in planes 1 and 3, irrespectively of what happens in plane 2

- Taking into account if there are misalignments



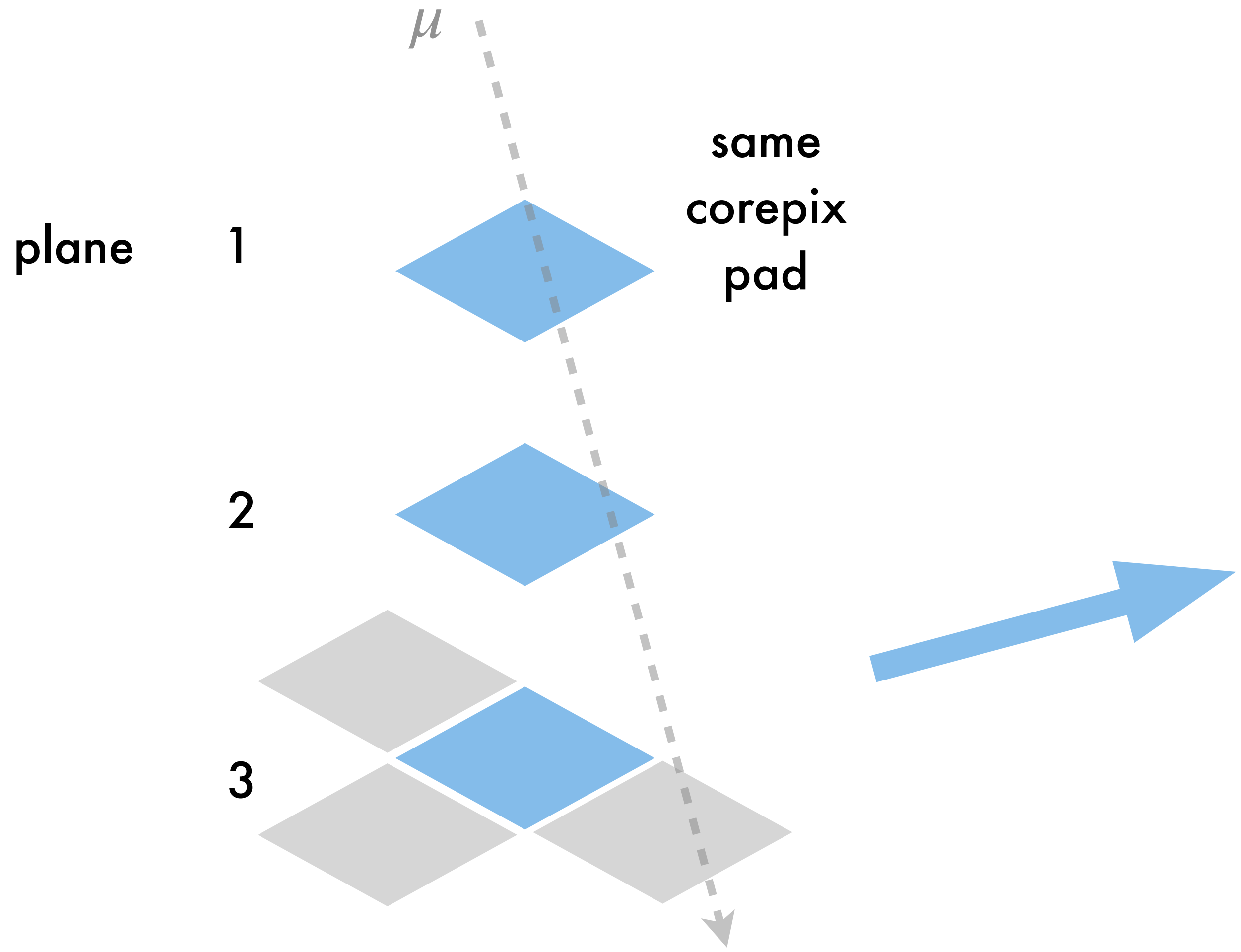
Efficiency in the pad of plane 2:

$$\epsilon_2 = \frac{N_{123}}{k_2 N_{13}}$$

Correction by a **geometrical factor**, computed from simulation:

$$k_2 = \frac{N_{123}^{sim}}{N_{13}^{sim}} \sim 1$$

- For planes 1 and 3, the correction from geometrical factors is bigger



Efficiency in the pad of plane 3:

$$\epsilon_3 = \frac{N_{123}}{k_3 N_{12}}$$

$$k_3 = \frac{N_{123}^{sim}}{N_{12}^{sim}} \sim 0.25$$

Efficiency determination is sensitive to small shifts in the planes

- In the analysis, the planes were first assumed to be aligned

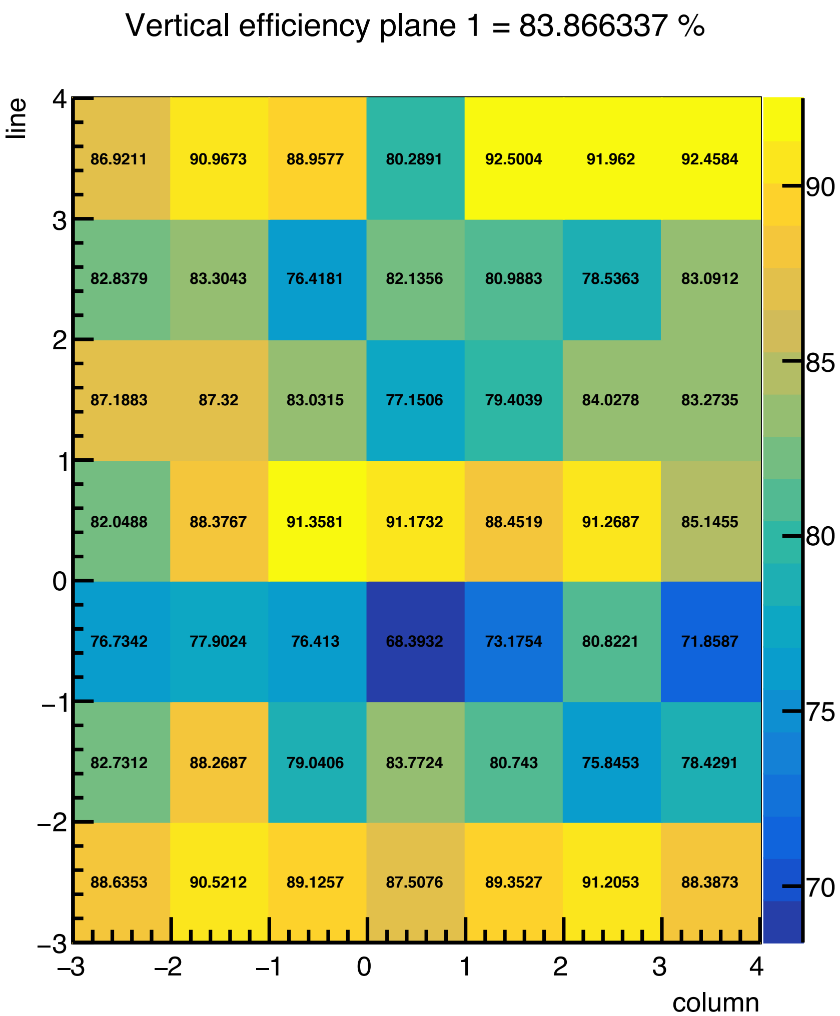
- Precise plane position measurements revealed small misalignments of up to 10 mm → all the estimated efficiencies increase up to 4% after updating the geometrical factor (computed from simulation)

- Status:
  - Aug 2020 - Mar 2021: precise planes position information
  - Apr 2021: planes were aligned

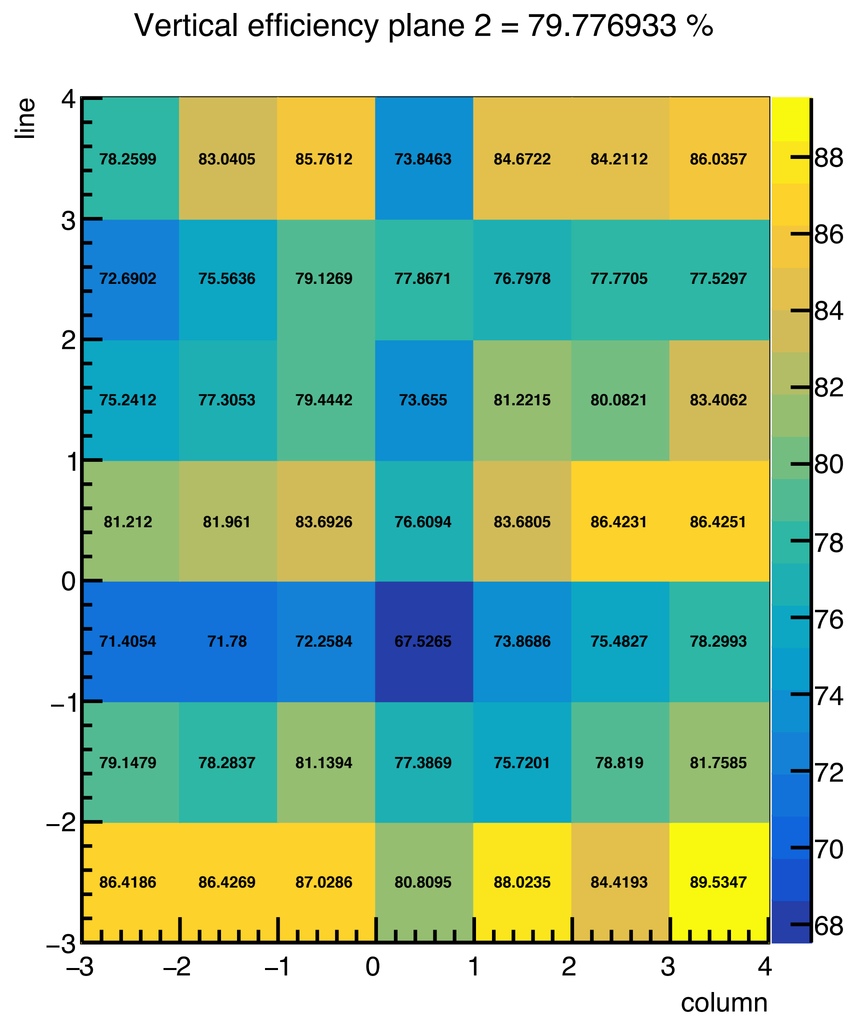
- To evaluate: systematic uncertainty on the efficiency given the uncertainty on the measured positions

Efficiency to vertical muons determined for every corepix pad

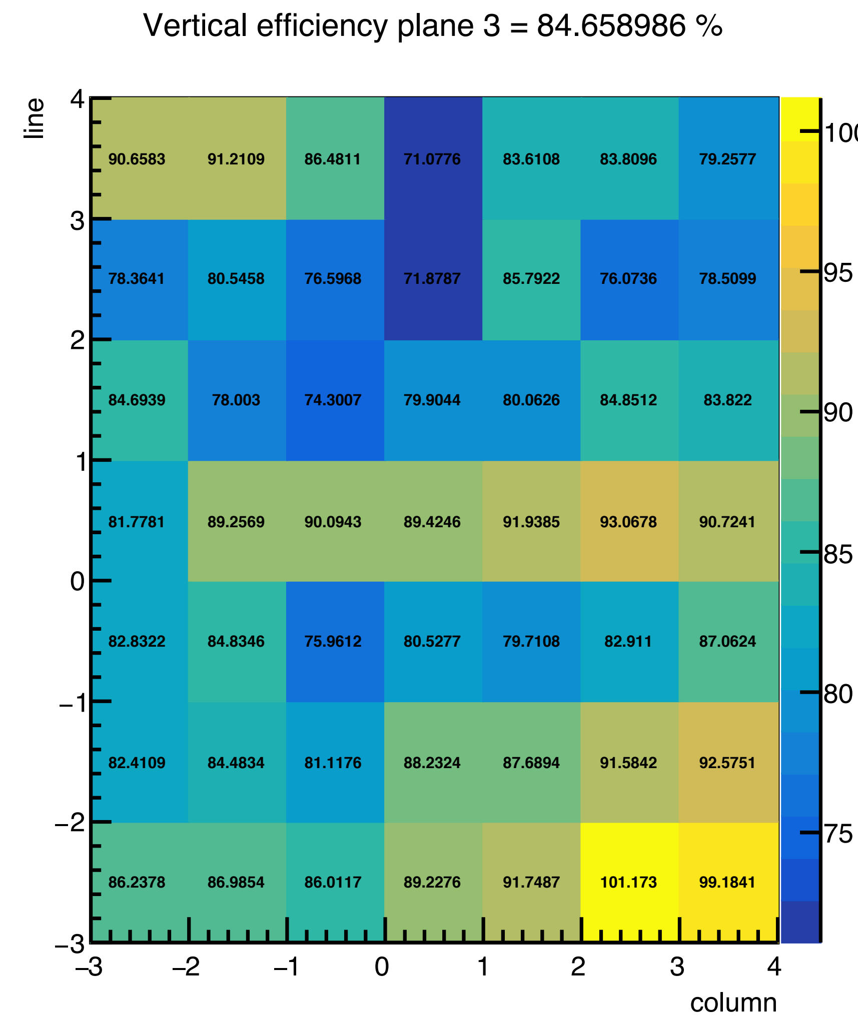
Plane 1



Plane 2



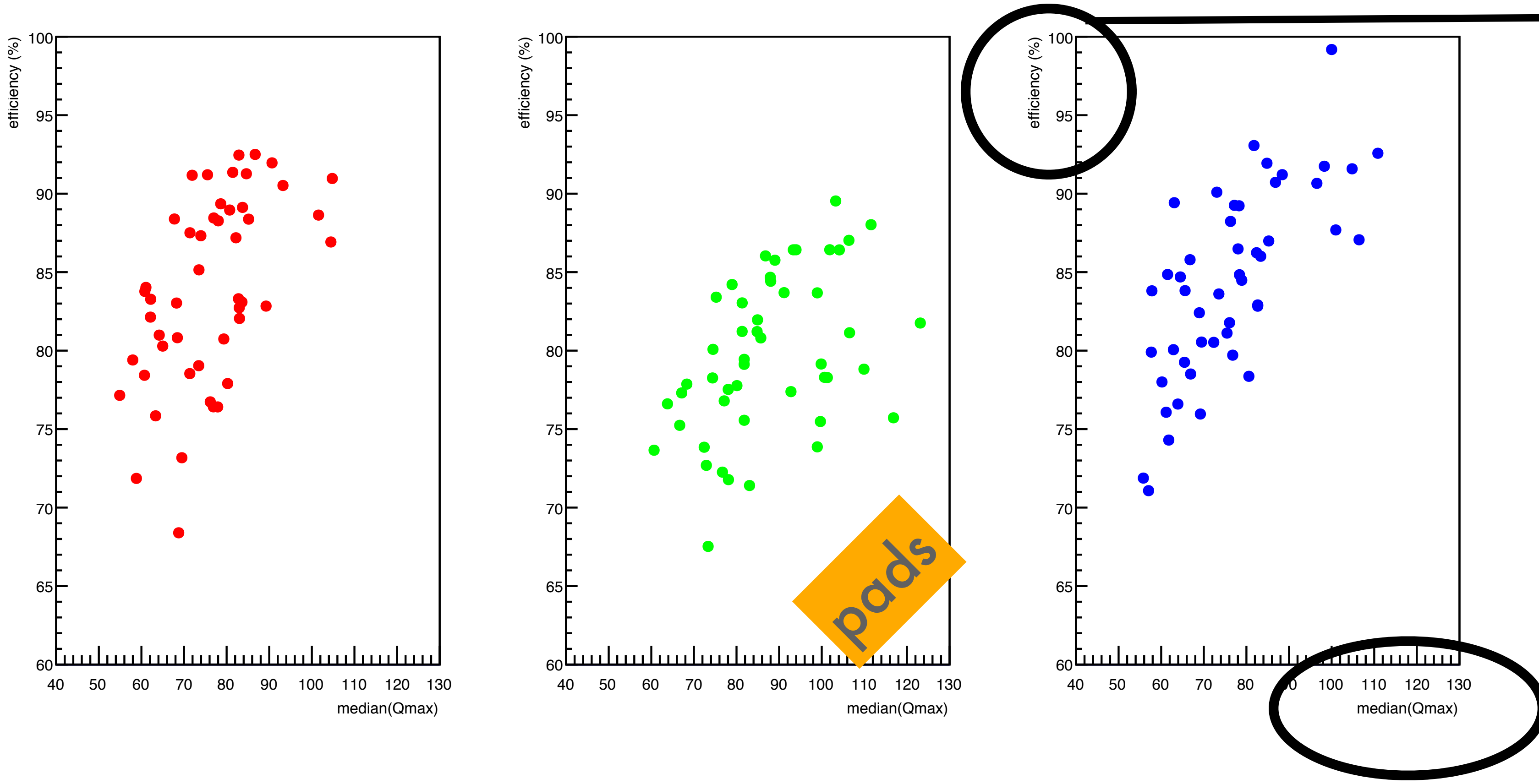
Plane 3



- Line patterns present in the three planes: <u>higher efficiency in the upper, central and lower lines</u>

- Central column in the three planes: smaller efficiency

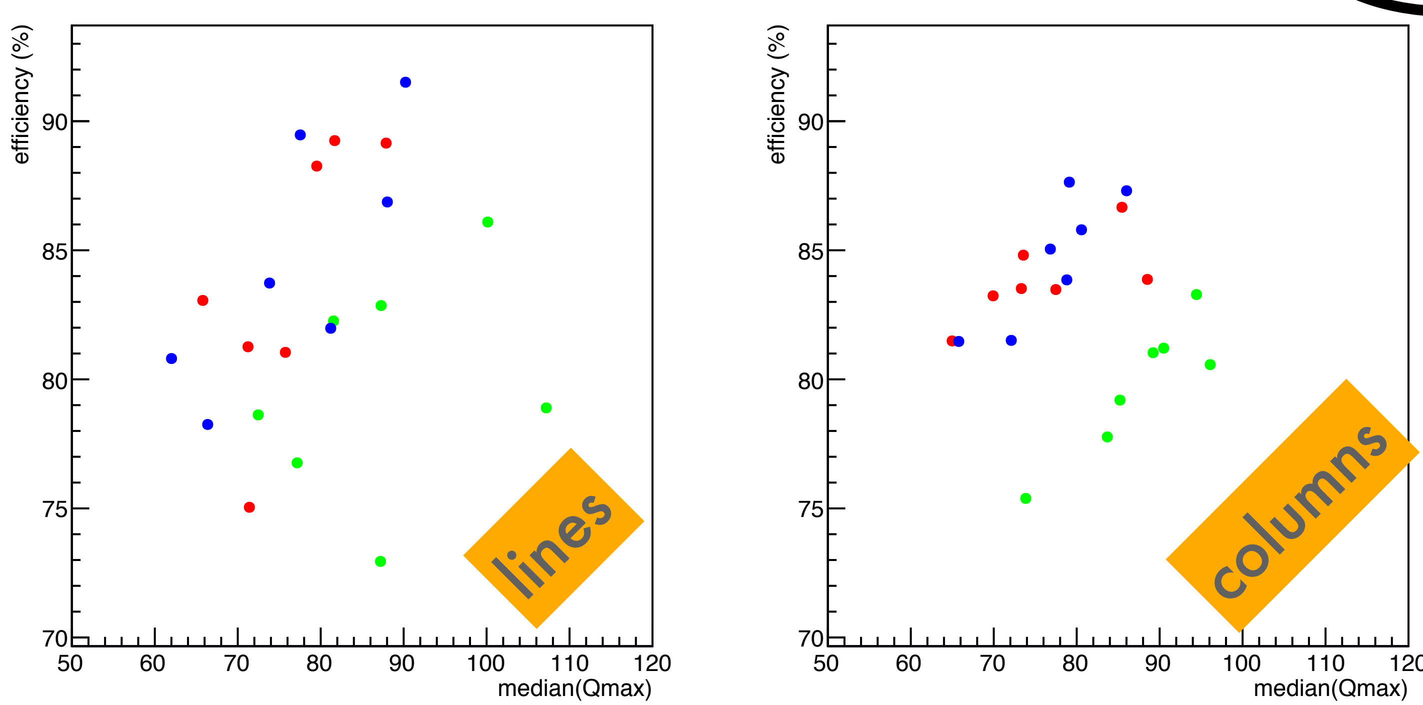
Correlation between the charge and the efficiency of a pad



efficiency

plane 1
plane 2
plane 3

median of the charge distribution



- Why do the charge distributions differ by pad?
  - Electronics effect: uncalibrated?
  - Detector effect: cross-talk from outer pads, cables or physical volume feature?

Approach: change the MAROC configurations:

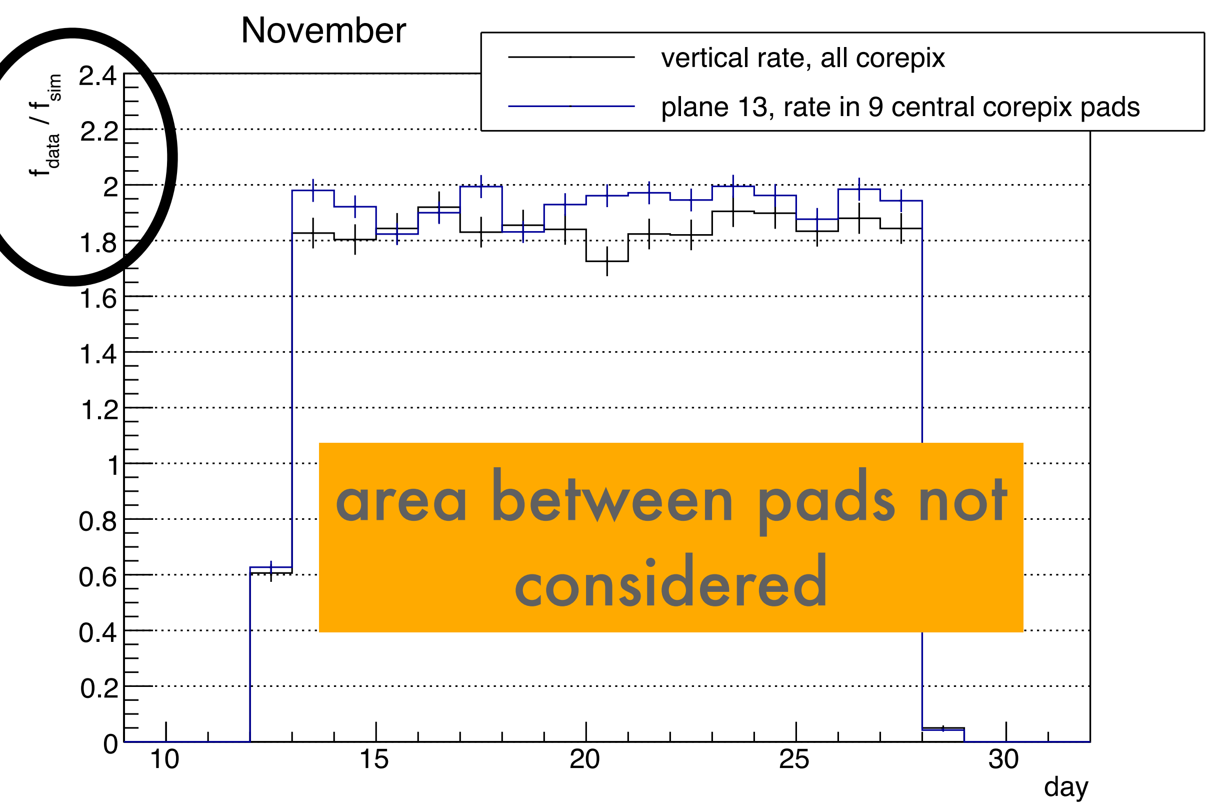
- adjust the pad gains → achieve uniform efficiencies?

Area between pads helps to understand the vertical rates

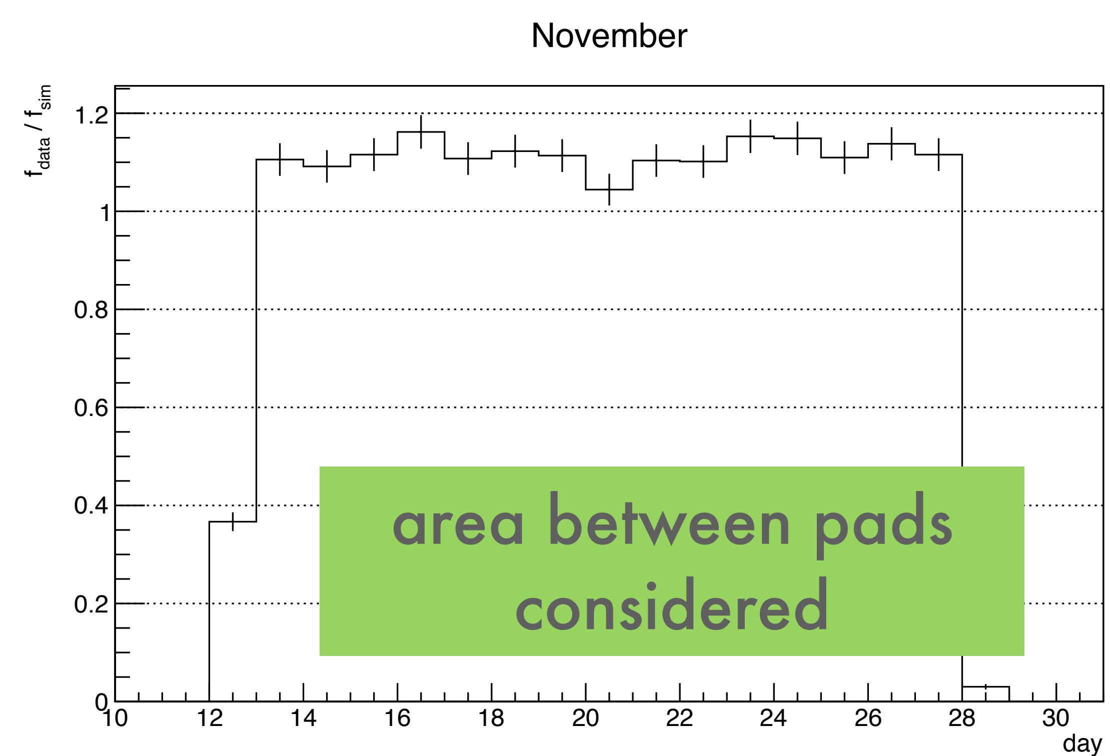
$$rate \propto \frac{N_{123}}{\epsilon_1 \epsilon_2 \epsilon_3}$$

$$\frac{\text{measured vert. rate}}{\text{expected vert. rate}}$$

simulation



- **80%** excess vertical events relative to expectation if area between the guard rings is not considered



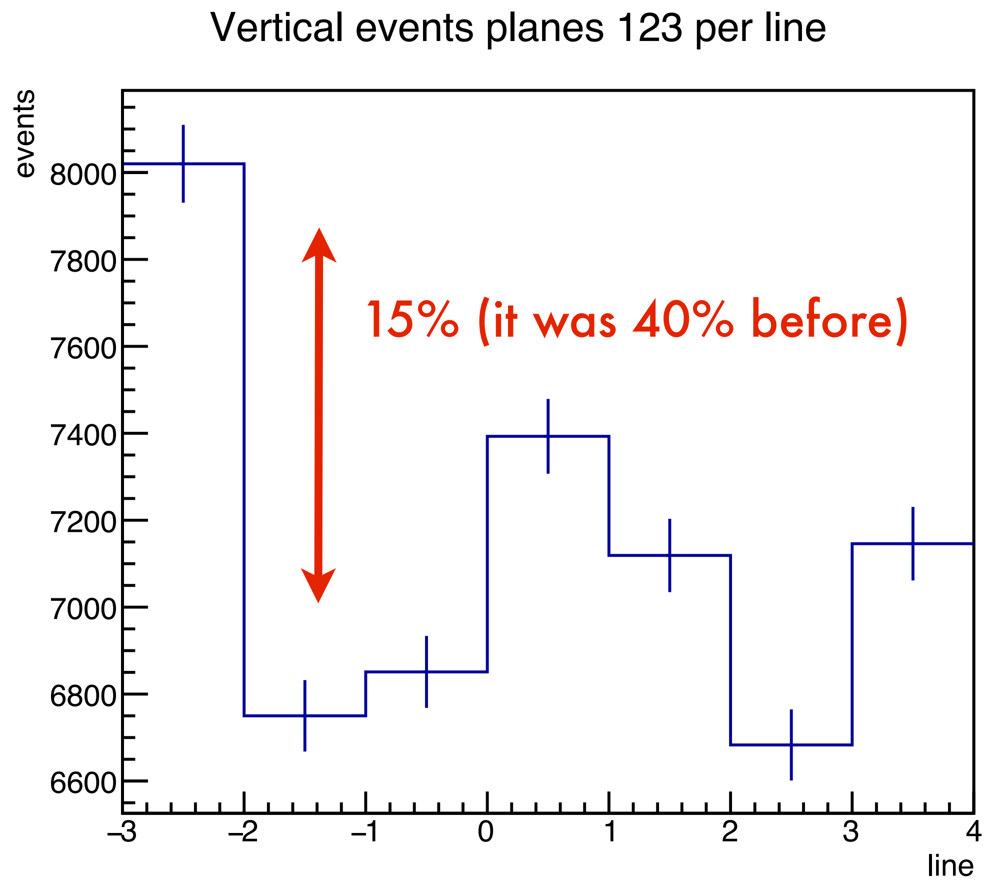
- When considering the dead area, effective pad area increases 30%, vertical pixel acceptance increases 65% → excess goes down to **15%**

- Jan-Mar 2021:
  - for each plane, find the pad with higher charge median
  - increase the gains of the remaining pads to the reference median

- As expected, efficiencies go up in the three planes: 2%, 1%, 4% respectively

- The uniformity improves, but the line patterns do not disappear

- Caveat: known bug and the applied gains not optimal



After adjusting the gains, the uniformity improves but the line patterns do not disappear

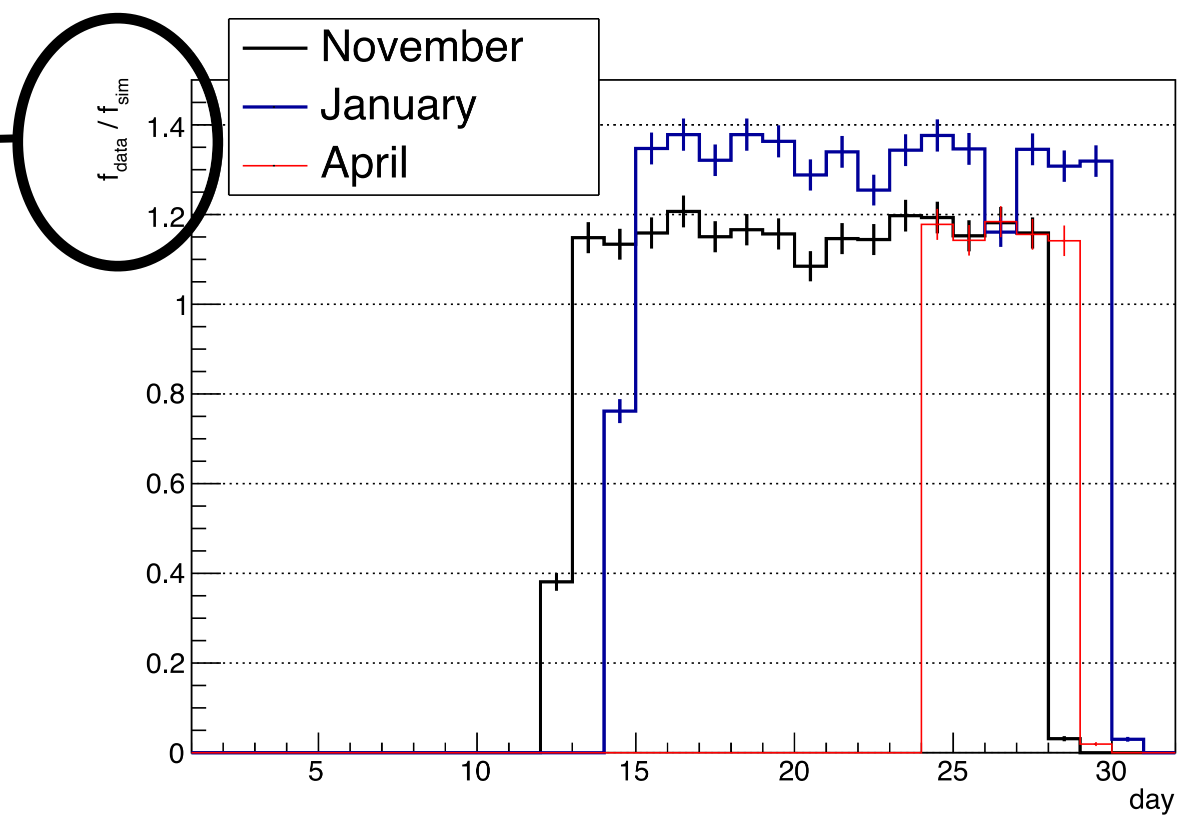
Jan-Mar 2021

- Number of events with <u>multiple hits increases significantly</u>

Interpretation: high gains lead to signal not contained in one pad, spreads to contiguous pads

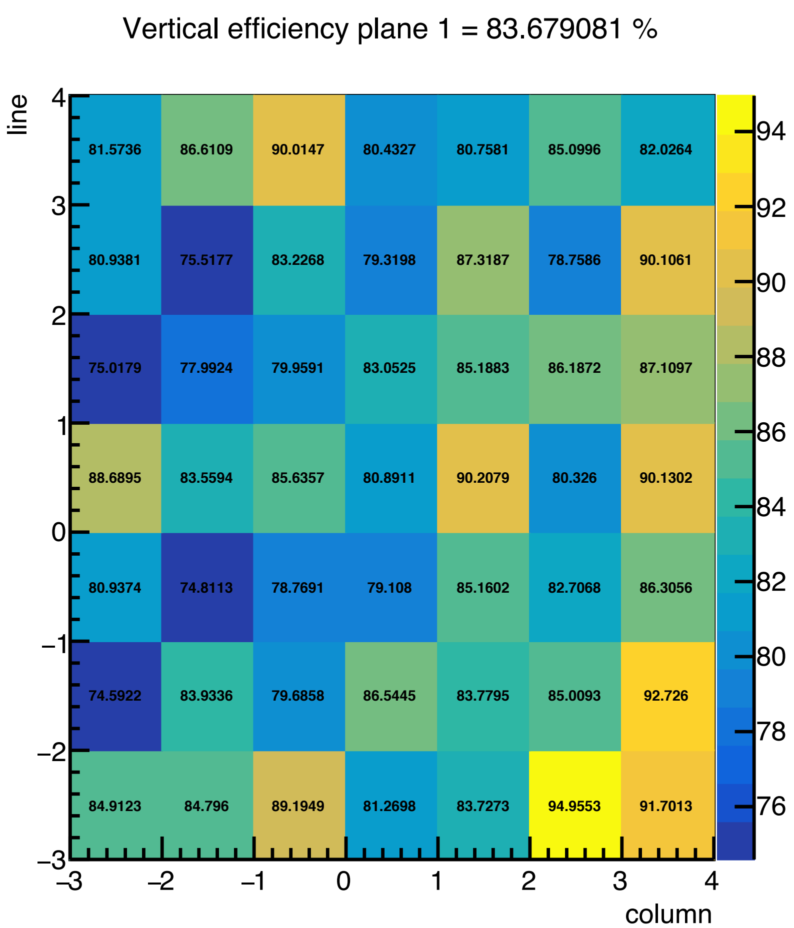
→ may happen that the muon goes through one pad but the pad with maximum charge is a different one (and we are selecting this)

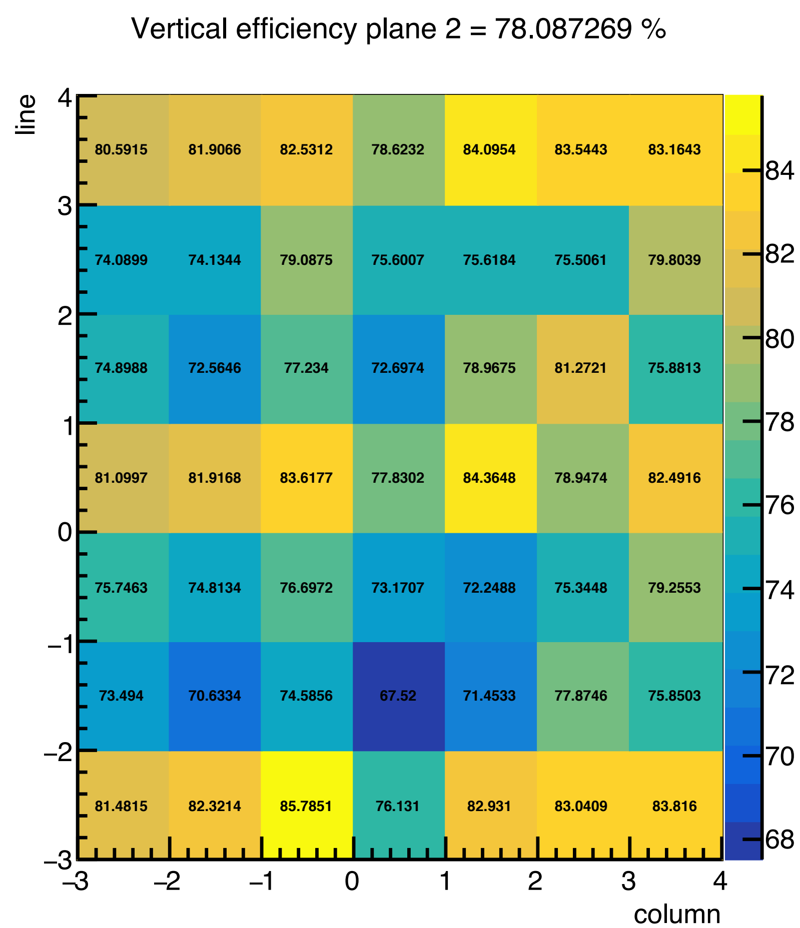
$$\frac{\text{measured vert. rate}}{\text{expected vert. rate}}$$

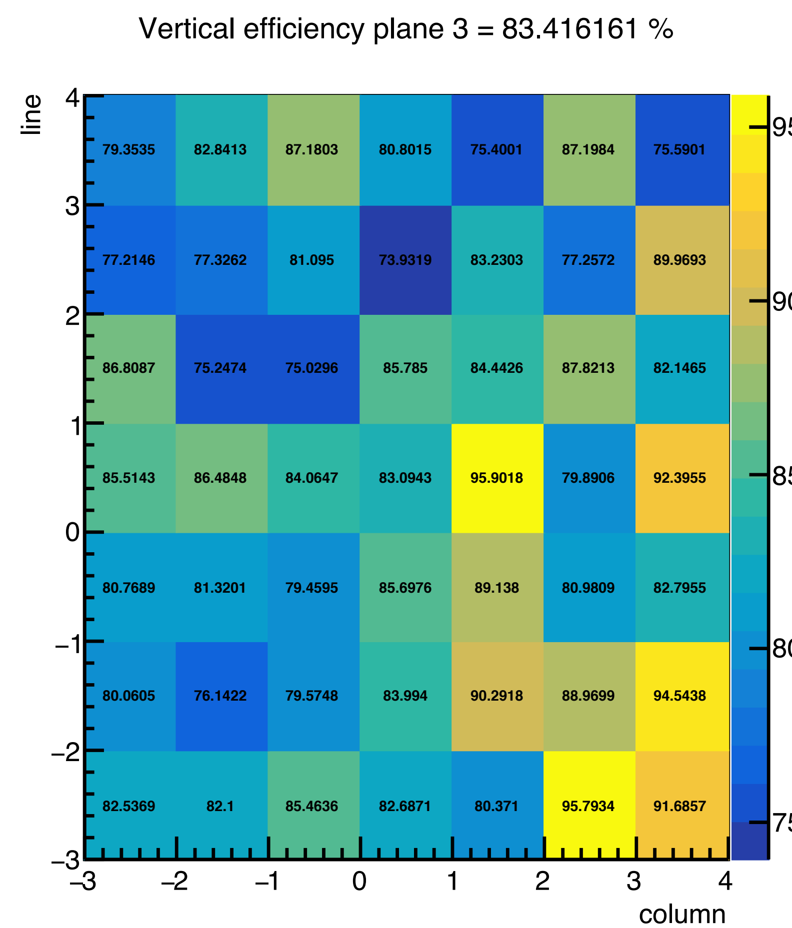


the discrepancy between measured and expected vertical rates goes up

- Apr-May, 2021:
  - try to achieve uniformity without previous effects of signal distribution by contiguous pads
  - adjust the gains to optimal "low" gains: find the average of the medians from November data







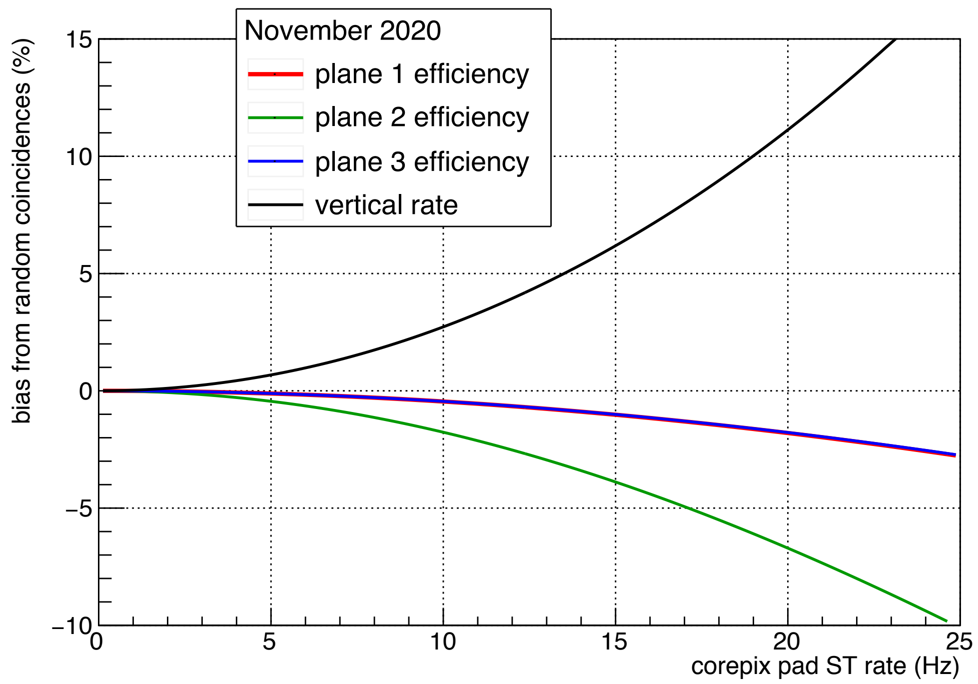
After adjusting the gains, the uniformity improves but the line patterns do not disappear

- 15-29 May, 2021:
  - set the gains outside the corepix to zero, to check if the big (and more noisy) pads are inducing signal in the corepix that creates the patterns
  - the line patterns do not disappear: the effect is not caused by electronics cross-talk from the outer pads

- Persistence of line patterns after adjusting gains points to something in the detector, instead of electronics?

- Moreover, features noticed:
  - $rate_{data} > rate_{sim}$
  - $\varepsilon_2 < \varepsilon_1, \varepsilon_3$

Can random coincidences help explain these?



$$\epsilon_2 = \frac{N_{123}}{k_2 N_{13}}$$

N_{123} → unaffected

$k_2 N_{13}$ → affected

$$\epsilon_3 = \frac{N_{123}}{k_3 N_{12}}$$

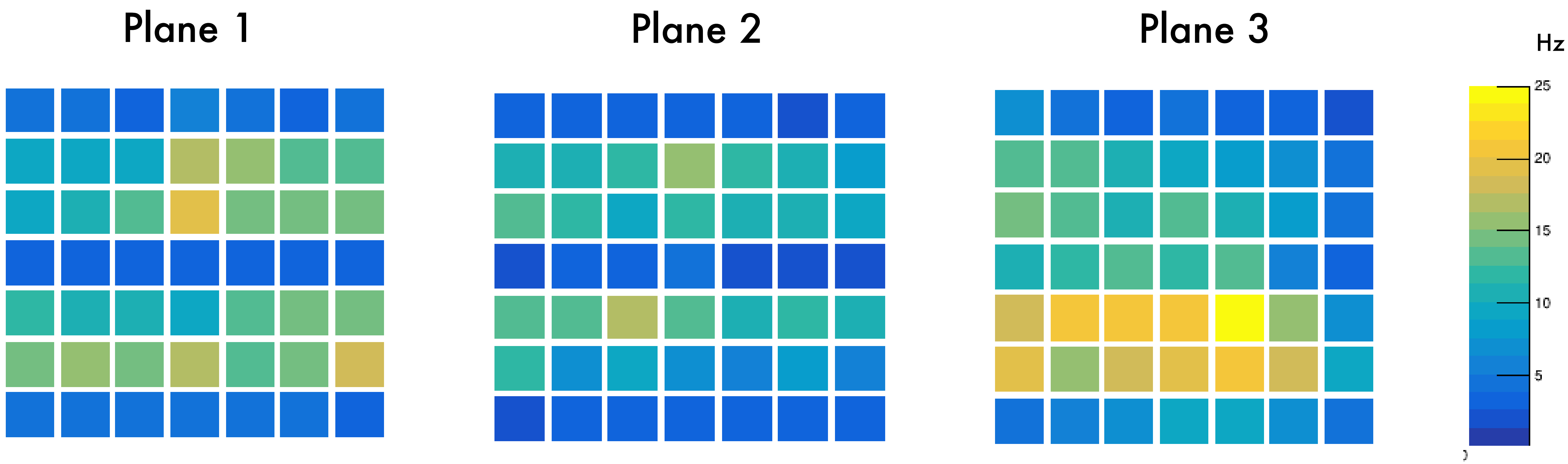
→ less affected: $k_2/k_3 = 4$

$$rate \propto \frac{N_{123}}{\epsilon_1 \epsilon_2 \epsilon_3}$$

- Approach: to estimate the random coincidences rates from the self-trigger data and use it to correct the efficiencies (ongoing)

- May - June, 2021:
  - self-trigger acquisition runs, that give information on the noise rates

Self trigger, May - June 2021



Assuming the applied gains are not causing the effect...

- Self-trigger rates show the same line patterns
  - rates dominated by background, not muons: the effect is not from the muon analysis

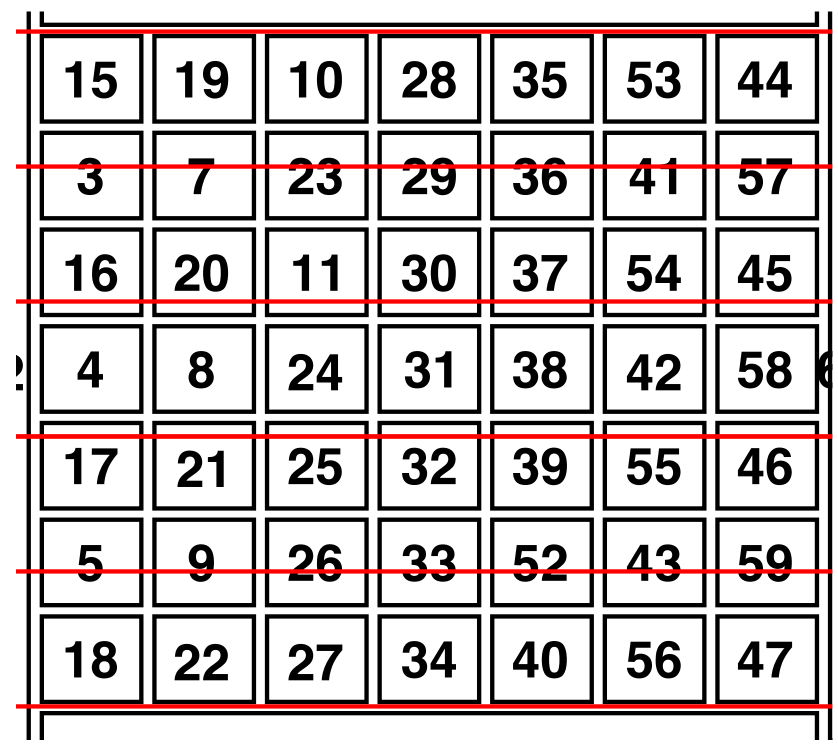
- Test with cables change
  - the pattern followed the cable/detector lines, not the MAROC lines: the effect is in the cable/detector, not in the electronics

Self trigger, May - June 2021

- The lines with higher background rates are the lines with lower efficiency

- Current working hypothesis: spacers are at the origin of the effect

- The position of the spacers is compatible with the position of the lines with lower efficiency



spacers in the gas volume

- The gas volume reduction due to the spacers dimensions (1 mm wide) implies a decrease of nearly 10% in the vertical muon rate

- Spacers are known to increase the self-trigger rate