Pedestal study (continued)

Vladislav Balagura
LLR – Ecole polytechnique / IN2P3 / CNRS
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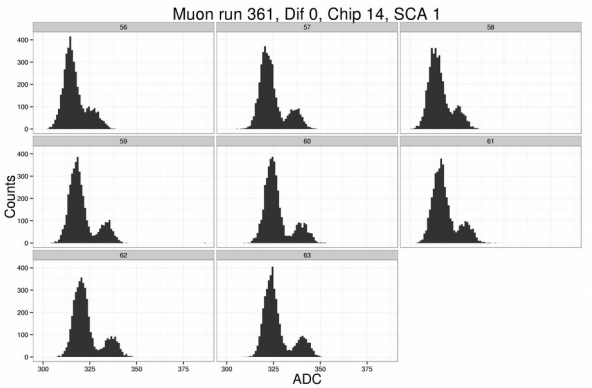
Reminder on a previous report on Dec 17:

Pedestals should be calculated
- per chip, channel and SCA.
In addition, in pedestal calculation I remove
- retriggers
(conservatively: BX+3 is removed even if fired in the other chip)
- and events with any negative triggers
(<0.75 * min_across_chips(median pedestal within chip)).

Still, there are double pedestal peaks in many channels, especially the last ones, in SCA 1, chip 14, dif 0 in a 2 hours muon run 361 taken as an example.



Which peak to take for pedestal subtraction to achieve the best accuracy in muon calibration?

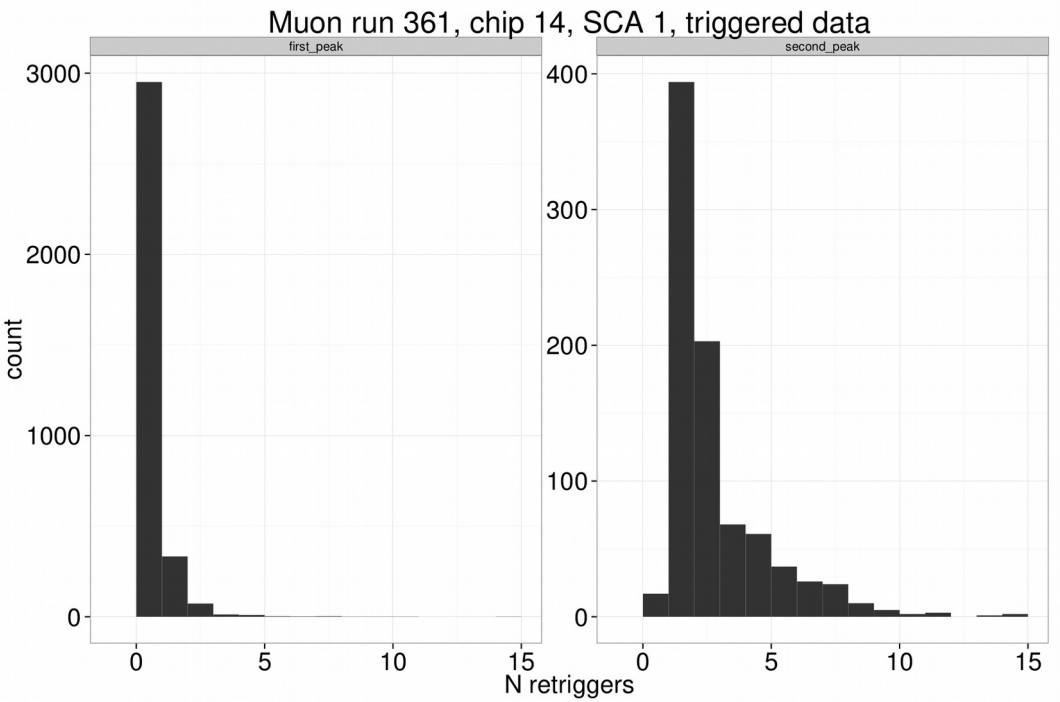
Reminder on previous report

Observations:

- peaks in different channels are 100% correlated
- they are correlated with retrigger pattern which follow in SCA2,3,…
- two peaks have approximately the same width

Possible interpretation: there are two states in the chip. They determine
- the pedestal positions (shifts)
- the retriggers

Number of retriggers for left and right pedestal peaks selected in chip 14, channel 60



Pedestal depends on retriggers!

Left pedestal peak corresponds

1) mainly to the case when there are no retriggers in the following BX's.

Due to a finite duration of OR64 trigger signal
(OR between triggers in any of 64 channels),
it may fire in BX and extend to BX+1. In this case, both BX and BX+1 are triggered (SKIROC triggering is determined by the level of OR64, not by its edge). Ie. this happens if trigger occurs close to the BX clock (rising edge).

In this case, typically, there should be no real triggers in BX+1 (only by rare coincidences), and nothing in the following BX+2,+3, ...
2) This kind of retriggers also belongs to the left pedestal peak.

In addition, in even smaller fraction of events with pedestals on the left,
3) such BX+1 without triggers is followed by (possibly many) triggers in BX+3,+4, …, but note, BX+2 is absent.

Pedestal correlation with retriggers

Another group (pedestals on the right) is formed by events with:
4) triggers in BX+1 (regardless of whether and what is present in BX+2,3,...)
5) no triggers in BX+1 (only pedestals), but BX+2 is present

Why this happens is not known. Only the first types of events 1) and 2) are expected.

This report: extend this study to other chips and layers. Whether there are common patterns across chips, layers?

In the future: to other SCAs and runs.

Pedestals in other chips

To study many chips and channels, one needs automatic tools and algorithms which take into account rare cases (outliers).

To be less biased by outliers, I prefer to use “robust statistics”:
Mean → median (50% of data on the left and 50% on the right)
RMS → mad = (median absolute deviation from the median) * 1.4826
1.4826 ensures that mad=RMS for a pure Gaussian.

Eg. in the pedestal spectra there may be
- a few high signals far on the right: kill them by upper limit median(adc)+50
- pedestal RMS may be far too high or too low:
consider abs(rms-median(rms))>3*mad(rms) as outliers and remove such channels

Separate measurement of two peaks

Select “clean” events for two groups:
- without any retriggers (→ left pedestal)
- with >=10 triggers in BX+1 (→right pedestal)

and measure two pedestal peaks separately.

Next slides:
- measurement of “clean” peaks
- various plots of pedestal centers / RMS's for two peaks, their separation distances for all 1024 x 3 channels

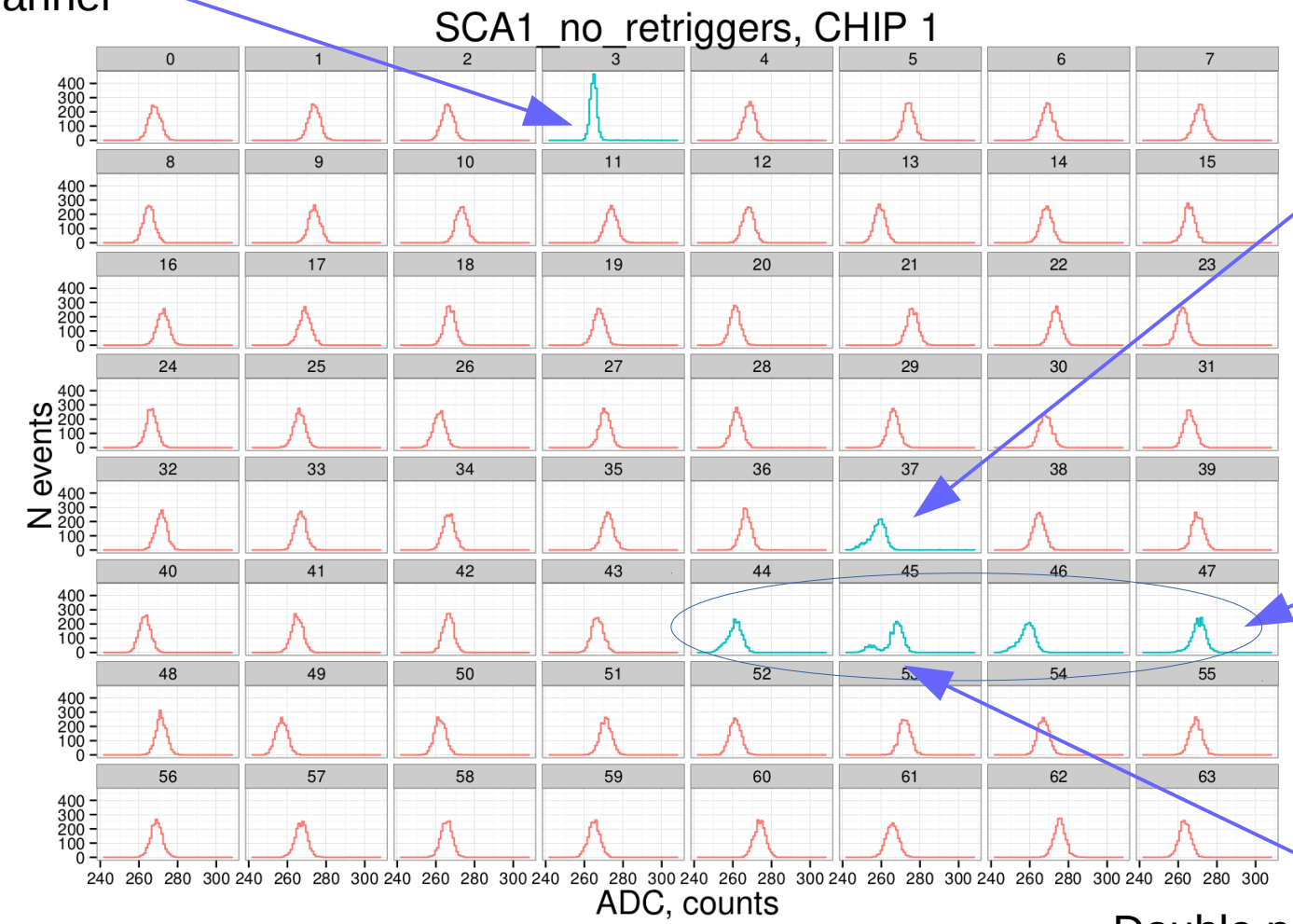
- If two pedestal positions are known, for a given event we may try to determine automatically to which pedestal group the event is closer (ie. in which of two states the chip is). Here, we use 100% correlation between the channels, all pedestals are either on the left or on the right. Combining all channels allows to improve precision and to understand better correlation with retriggers.

Pedestals without retrig's, single peaks

Example: chip 1, same DIF 0, no retriggers. RMS “outliers” are shown in blue.

Masked channel

Problematic (always masked) channel 37



Form same top-left pattern in upper and lower parts of FEV10 (chips 1 and 9 only). Much higher pedestal peaks in triggered data. Could be due to noise pick up in FEV10.

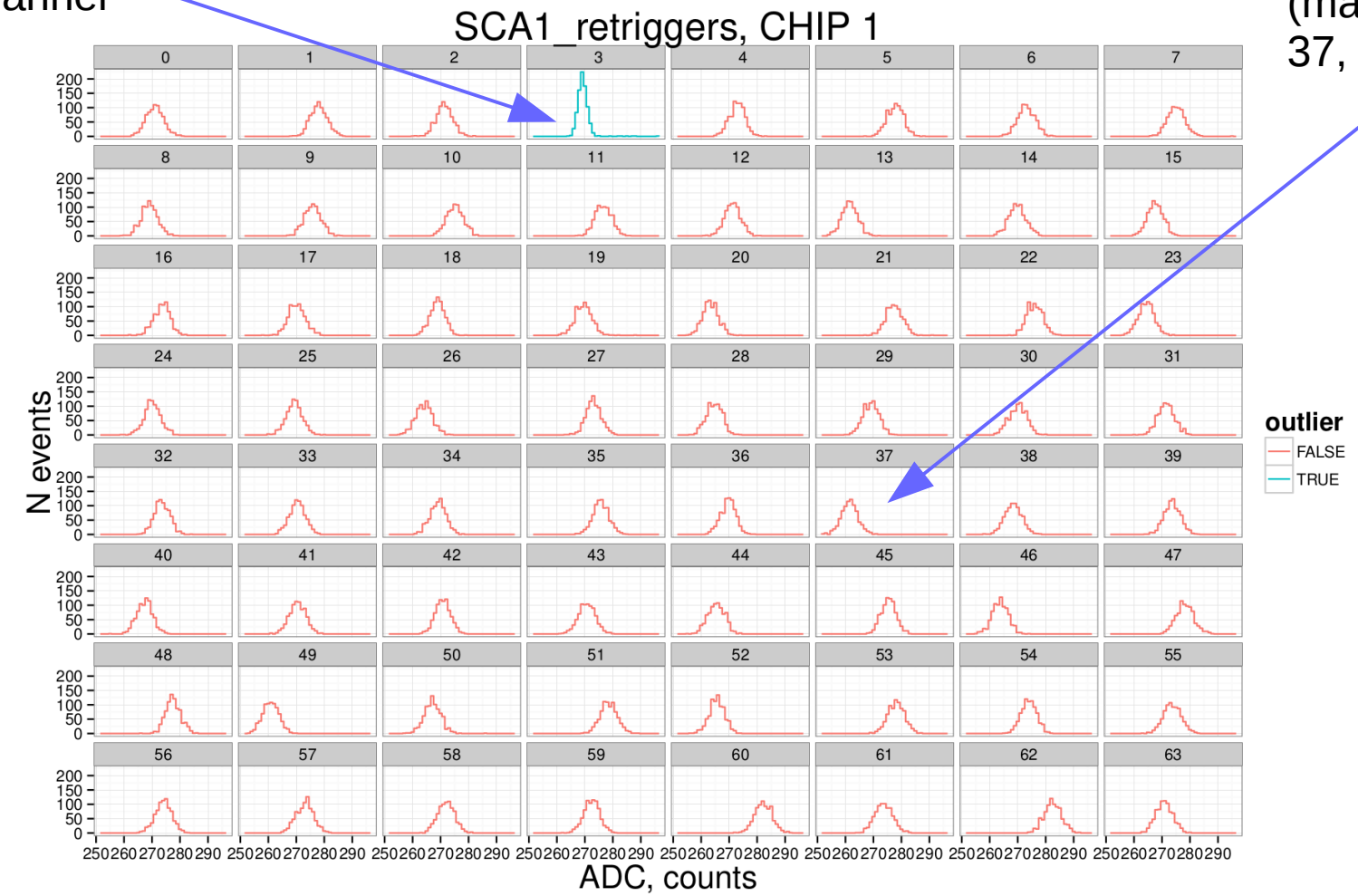
Double peaks, but only in these channels in chips 1 and 9.

Pedestals with many retriggers

Example: chip 1, same DIF 0, >=10 triggers in BX+1. Take median as center.

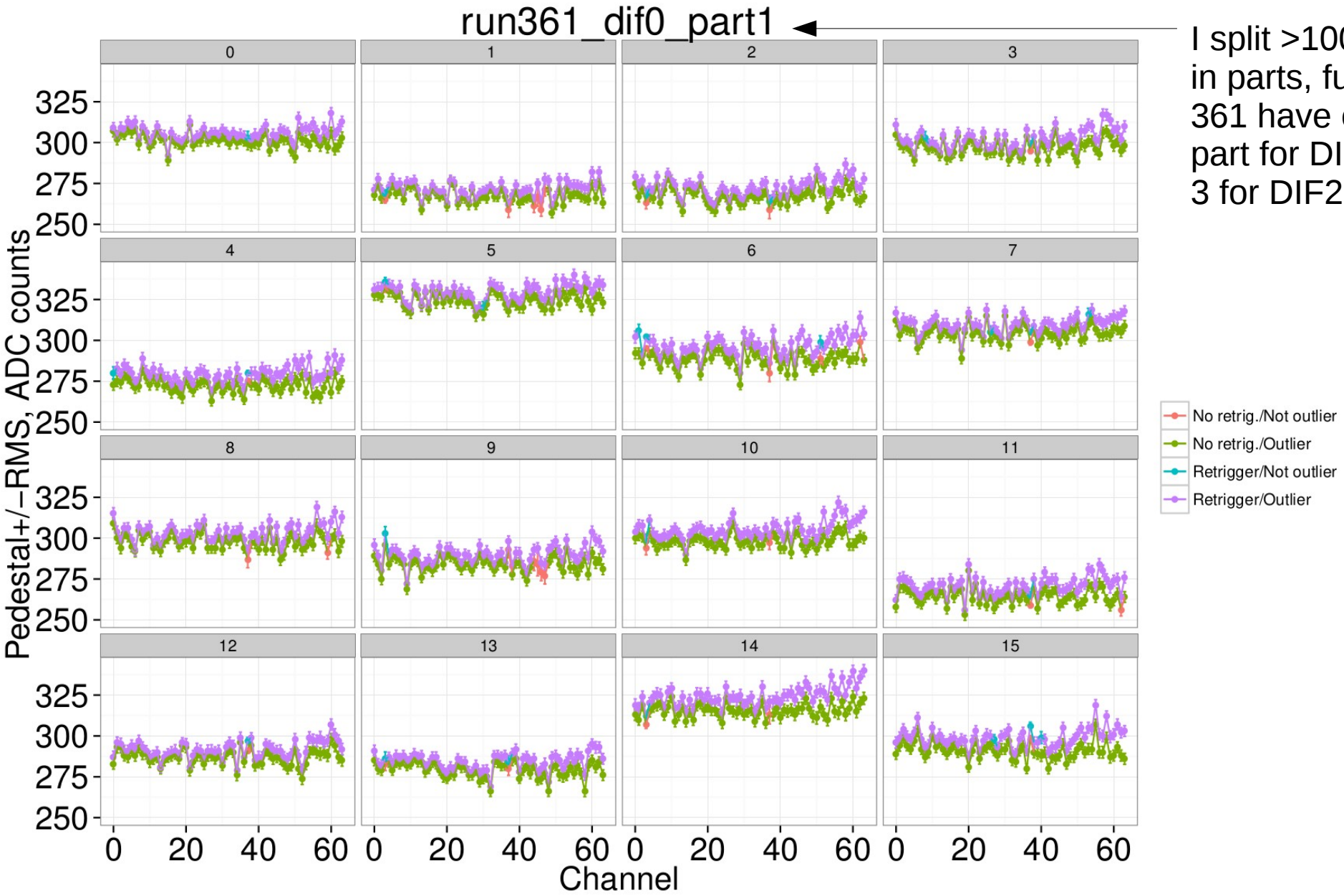
Masked channel

Problematic (masked) channel 37, good here



Pedestals in 16 chips

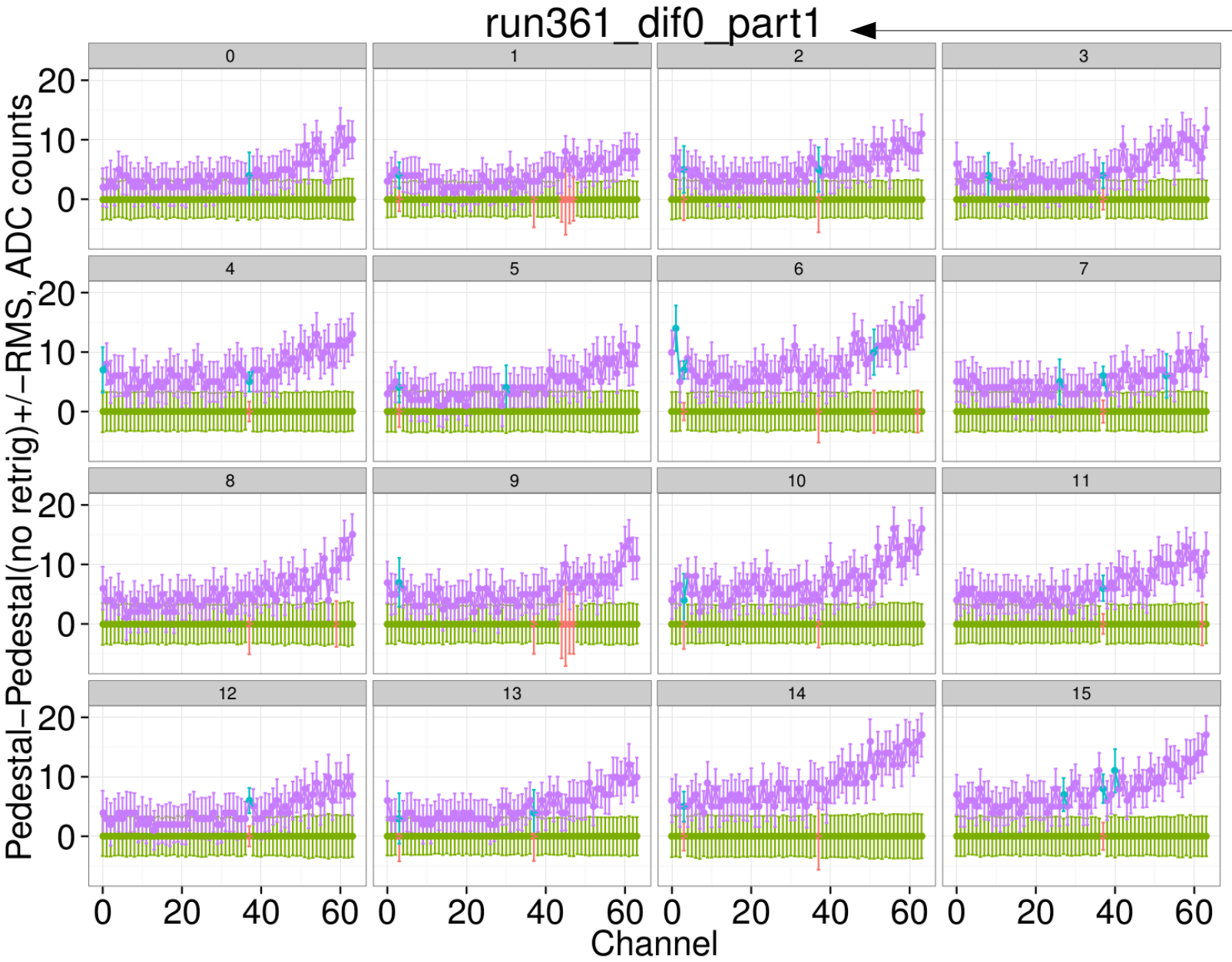
Left-right pedestal medians shown by colors, RMS - by error bars



I split >100 MB files in parts, full run 361 have only one part for DIF0,1 and 3 for DIF2 (noisier)

Pedestals – left peak position

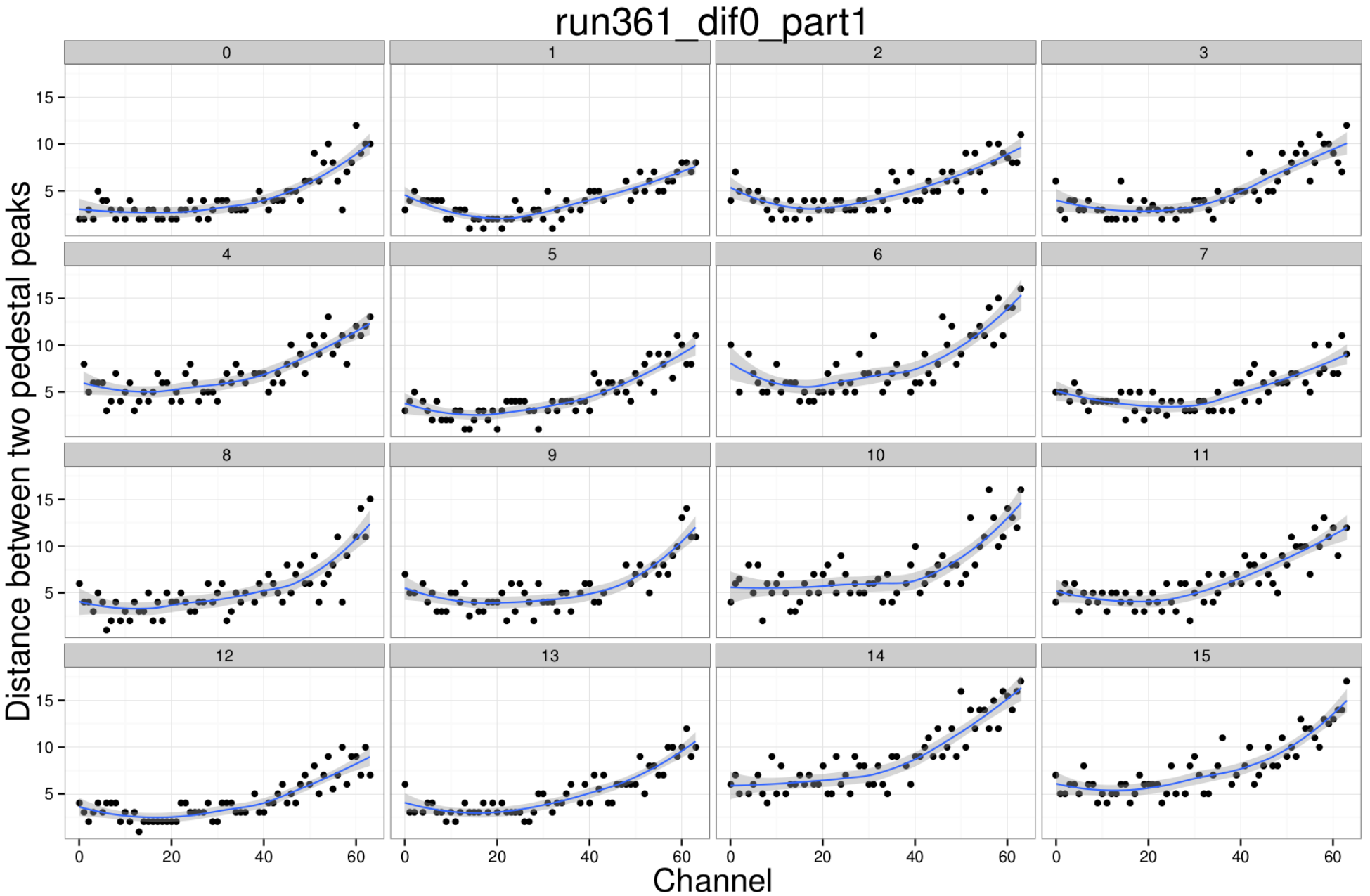
Same, but left pedestal is subtracted. Error bars again show RMS



I split >100 MB files in parts, but here for DIF0,1 _part1 means full run

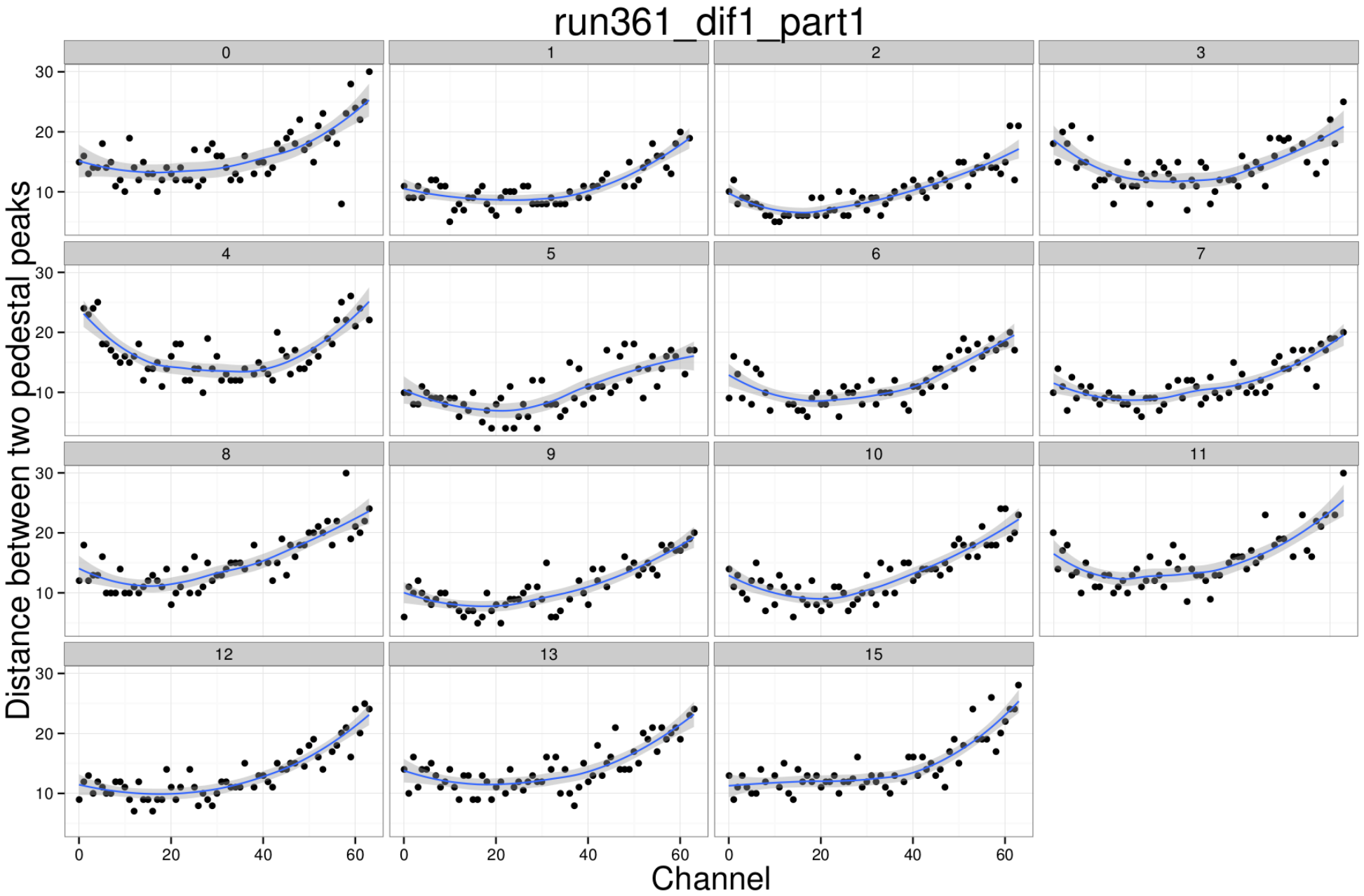
Distance between pedestals, DIF 0

Same separation. Always larger for upper channels (>40). Range: 2-10



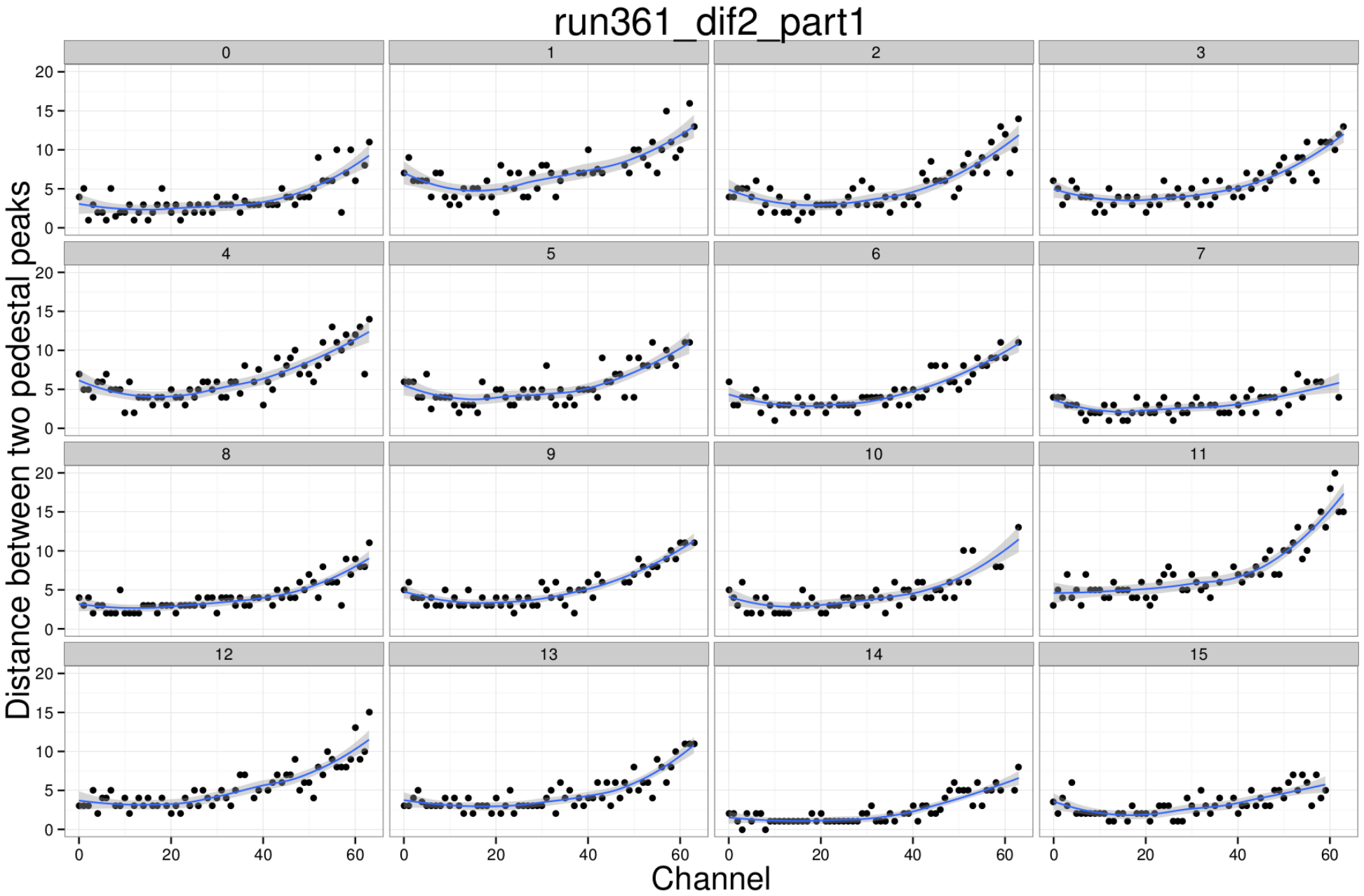
Distance between pedestals, DIF 1

Much higher separation in DIF1 (?!), range: 10-25



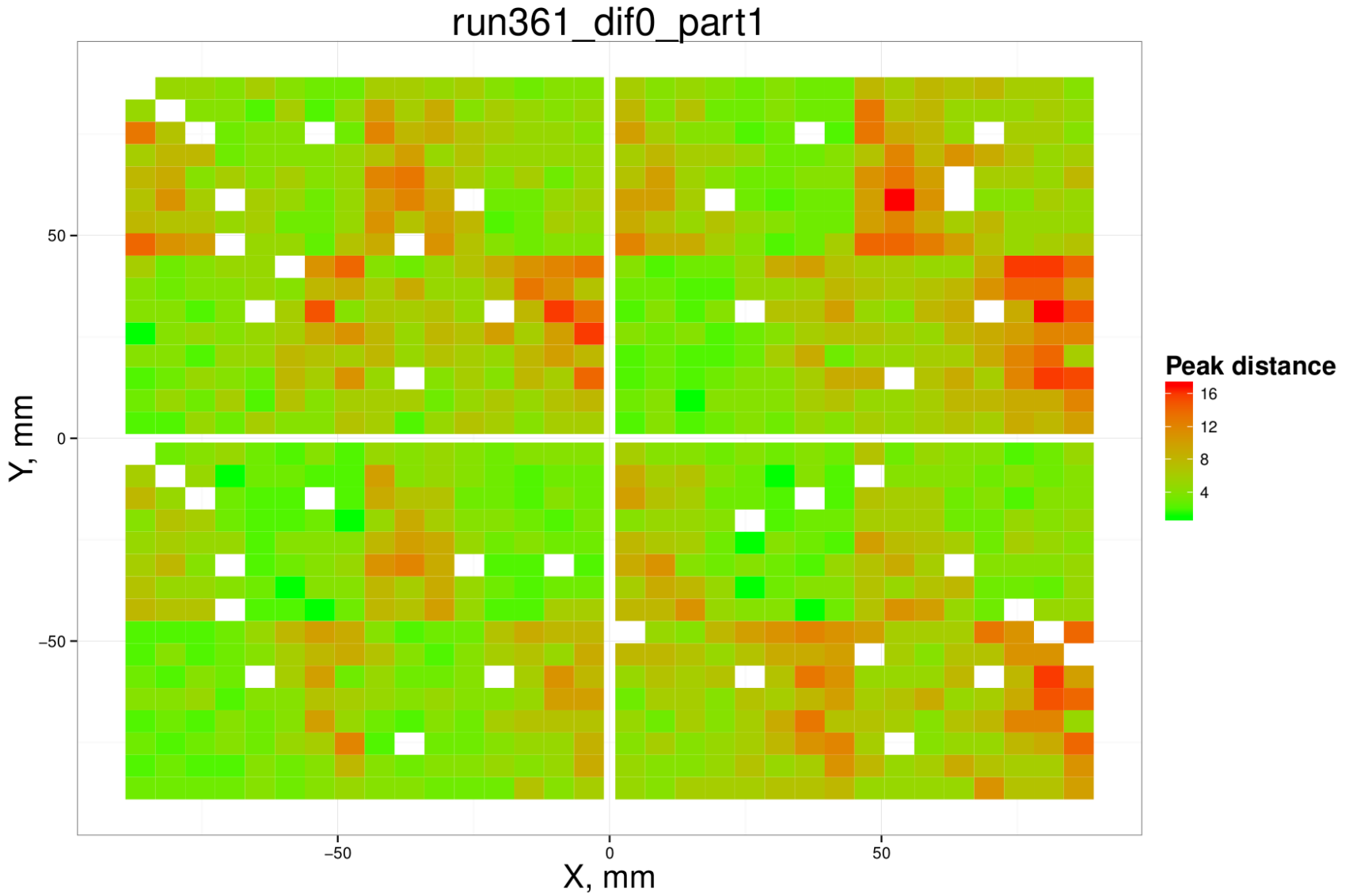
Distance between pedestals, DIF 2

About the same in DIF2 as in DIF0.



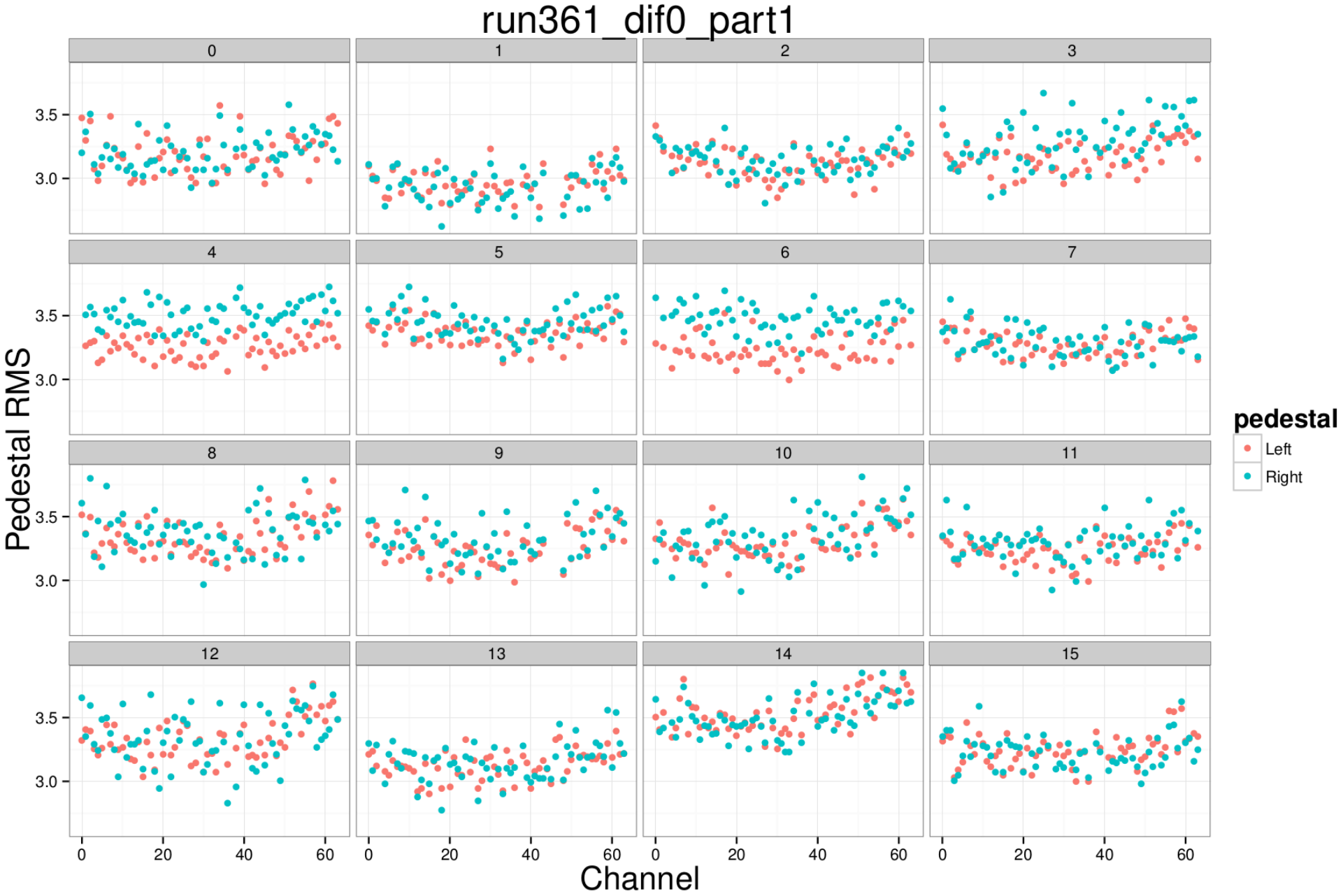
Distance between pedestals in X-Y

16 patterns probably due to channel mapping (same for different chips) and larger peak distance for upper channels (>40)



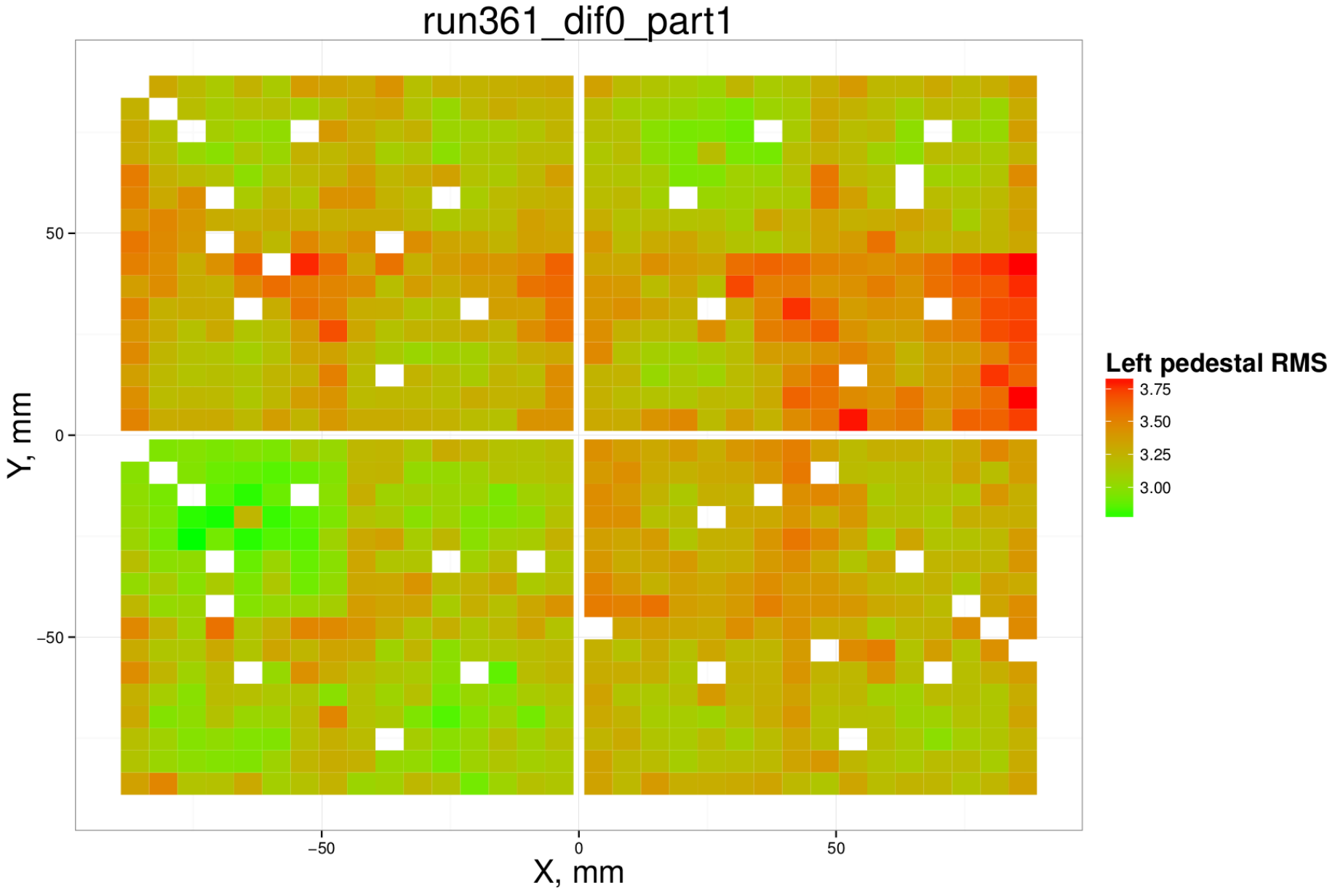
Pedestal RMS, wo outliers

Left – right have similar widths



Left pedestal RMS in X-Y

No pronounced patterns, same for right pedestal RMS



Conclusion on pedestal positions and widths

No pronounced patterns in XY (except a few channels in chips 1,9), and no visible similarities between 3 layers.
→ No correlation with the PCB properties observed
However, why in ALL DIF1 chips the splitting is significantly larger than in DIF0,2? Correlation with PCB?

- Double pedestals are present in all chips
- Pedestal peak splitting generally increases for upper channels.
- Splitting significantly varies from chip to chip

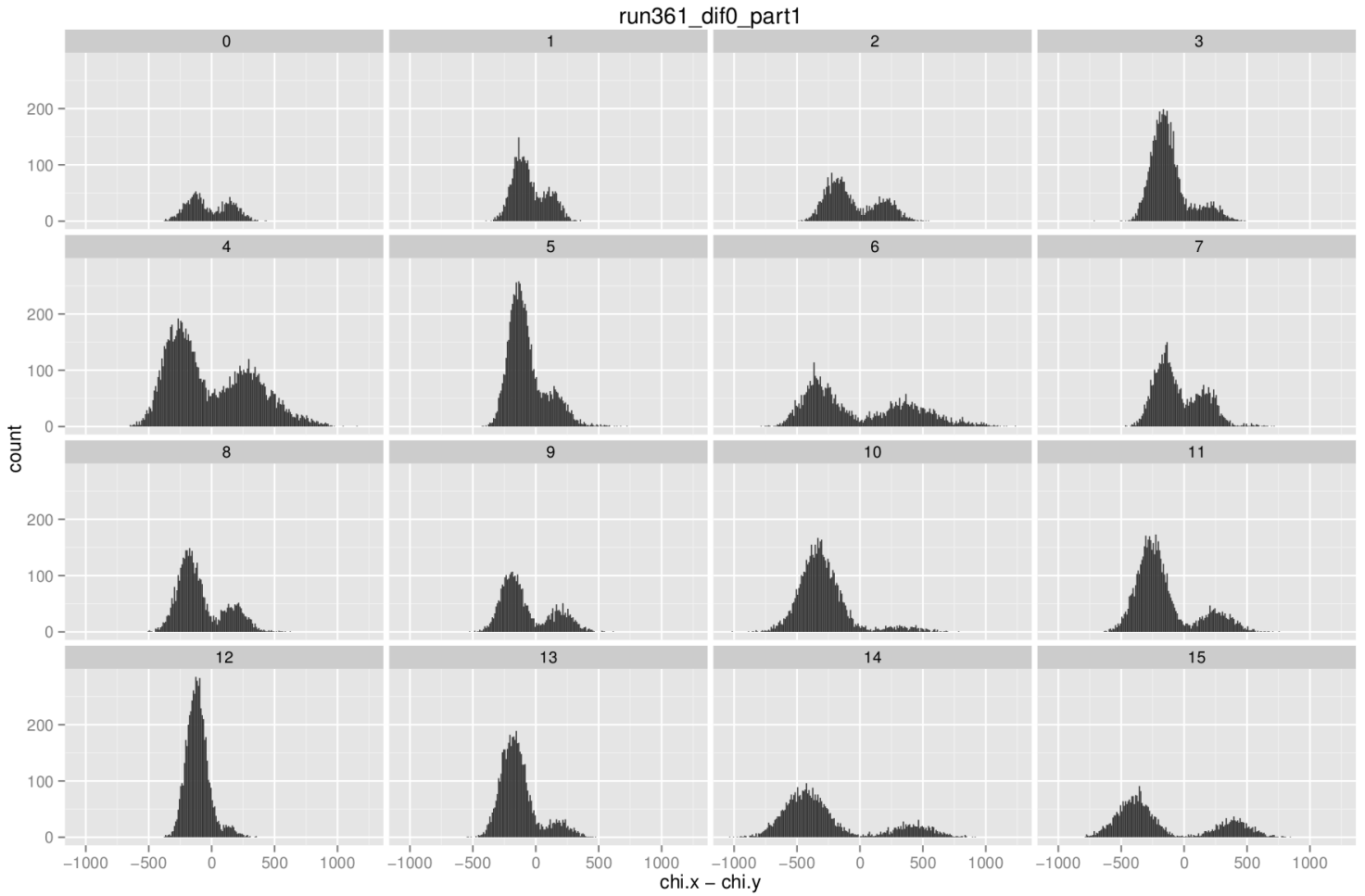
In DIF 0,2 the pedestals shift on the right by 2-10 ADC counts , while in DIF 1 by 10-25 (!) Why the effect is much higher in DIF 1?
For comparison: we used 1.2 pF gain, so MIP is at about 60.

RMS of both pedestal peaks are similar.

Now, in every event we may match the measured pedestals to expected left-right centers and find in which of the two states the chip is. Here, we use 100% correlation between the channels, all pedestals are either on the left or on the right. Combining all channels allows to improve

Classification left-right w/all channels

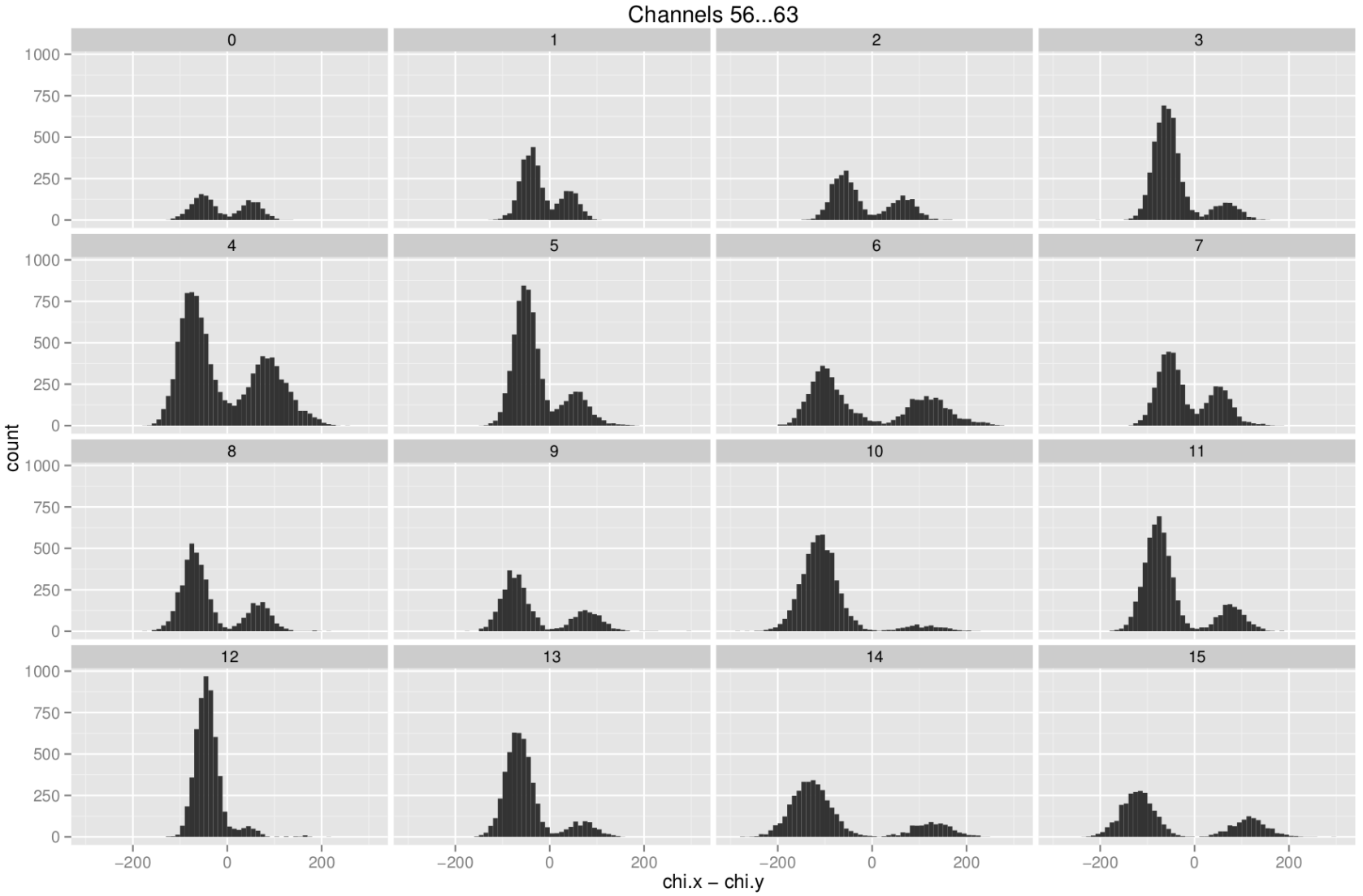
First attempt: form chi^2 as a sum over (ADC – pedestal)^2 / RMS^2 for all channels for the left and for the right pedestals. Then, compare chi^2_left and chi^2_right, eg. plot their difference:



Two peaks correspond to left-right classification, but they are not everywhere well separated

Chi2 classification w/8 upper channels

Channels with little separation add small power, but contribute to fluctuations. Chi^2 is not optimal for classification problem. Eg. usage of only upper 8 channels 56...63 improves classification quality:



Average all channels

Instead of chi^2, one may

- change ADC scale for each channel by
ADC → (ADC-left) / (right – left)

where left/right – pedestal peak positions. This sets peaks at 0 and 1

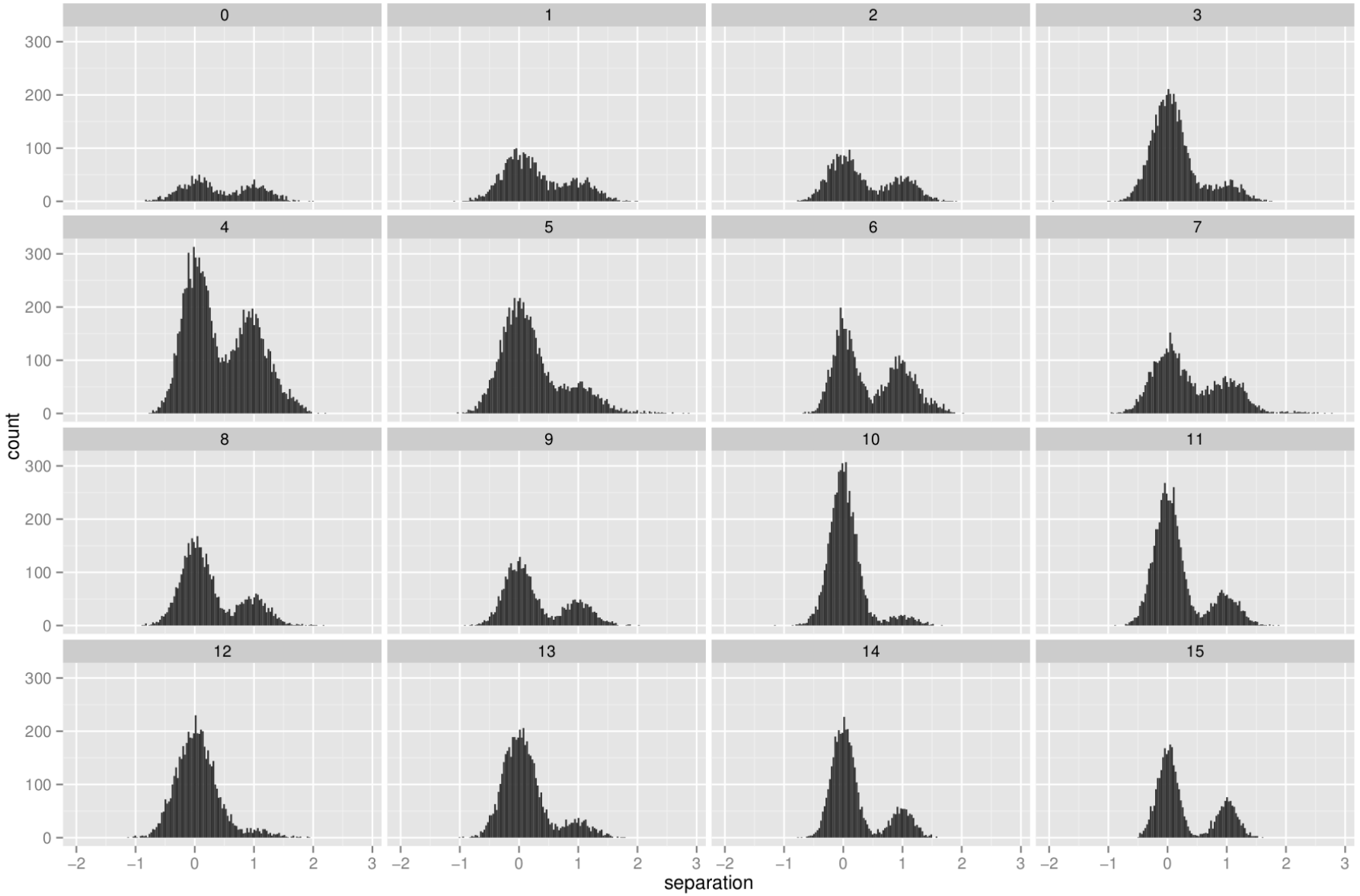
- consider different channels as different measurements of either 0 or 1. Since all channels are correlated, 0 and 1 are chosen synchronously by the chip in all channels. Assign errors RMS/(right-left) to every measurement. (For simplicity, I take RMS = (RMS.left + RMS.right)/2).

Average all such measurements to improve precision assuming normal independent distributions in not-triggered channels with pedestals:
<x> = sum((x.i-x.0)/sigma.i^2) / sigma(1/sigma.i^2)

This has a potential advantage that channels with small (right-left) have large errors RMS/(right-left) and in <x> their contribution and fluctuations are quadratically suppressed (compared to chi^2).

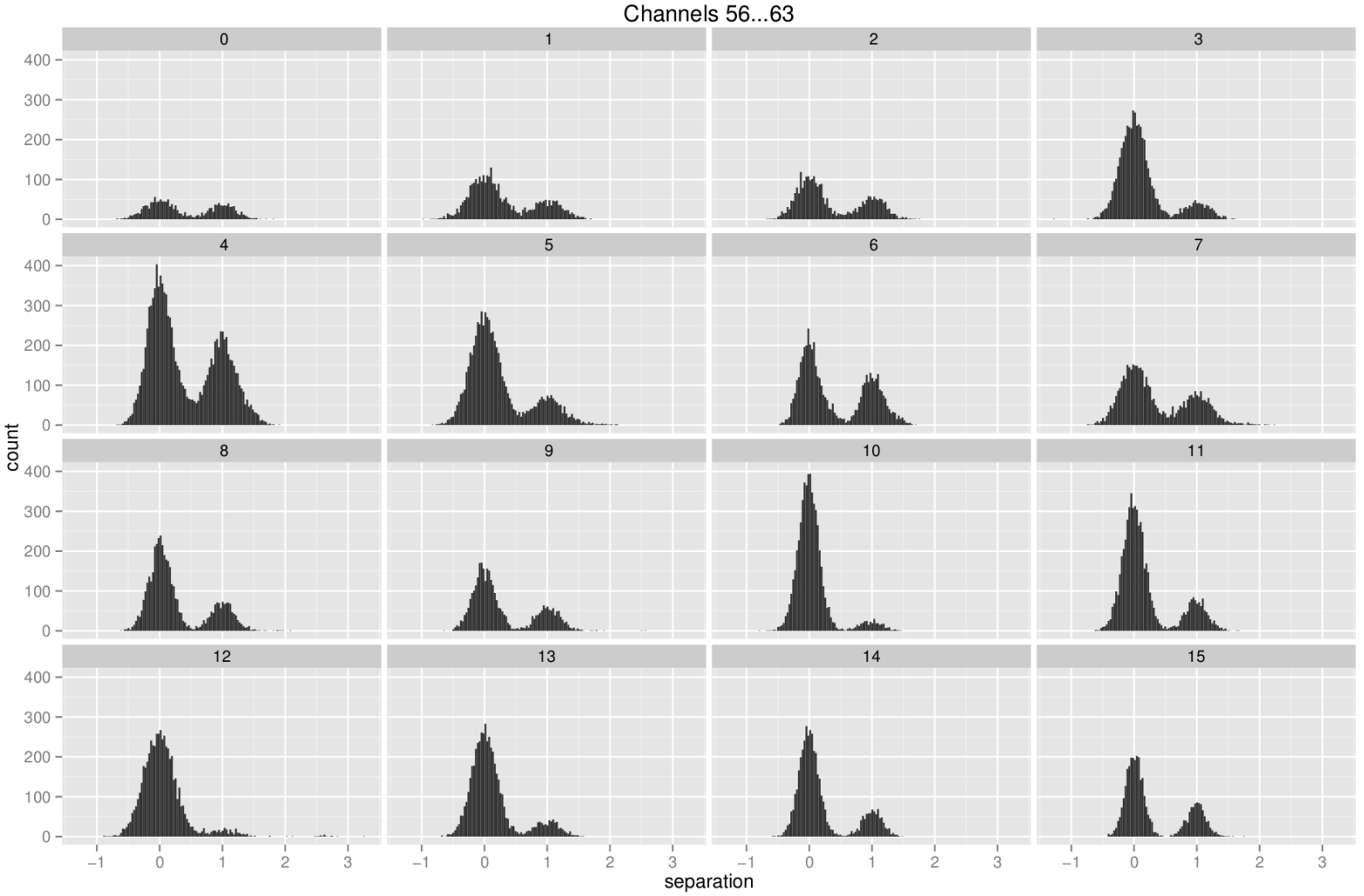
“Average” all channels

Still, not much better



“Average” 8 upper channels, DIF0

Usage of only upper 8 channels 56...63 still improves classification:



Consider this as the best solution for a moment. Point 0.5 separates left-right. Note, in some cases there is a sizable overlap.

Best classification method?

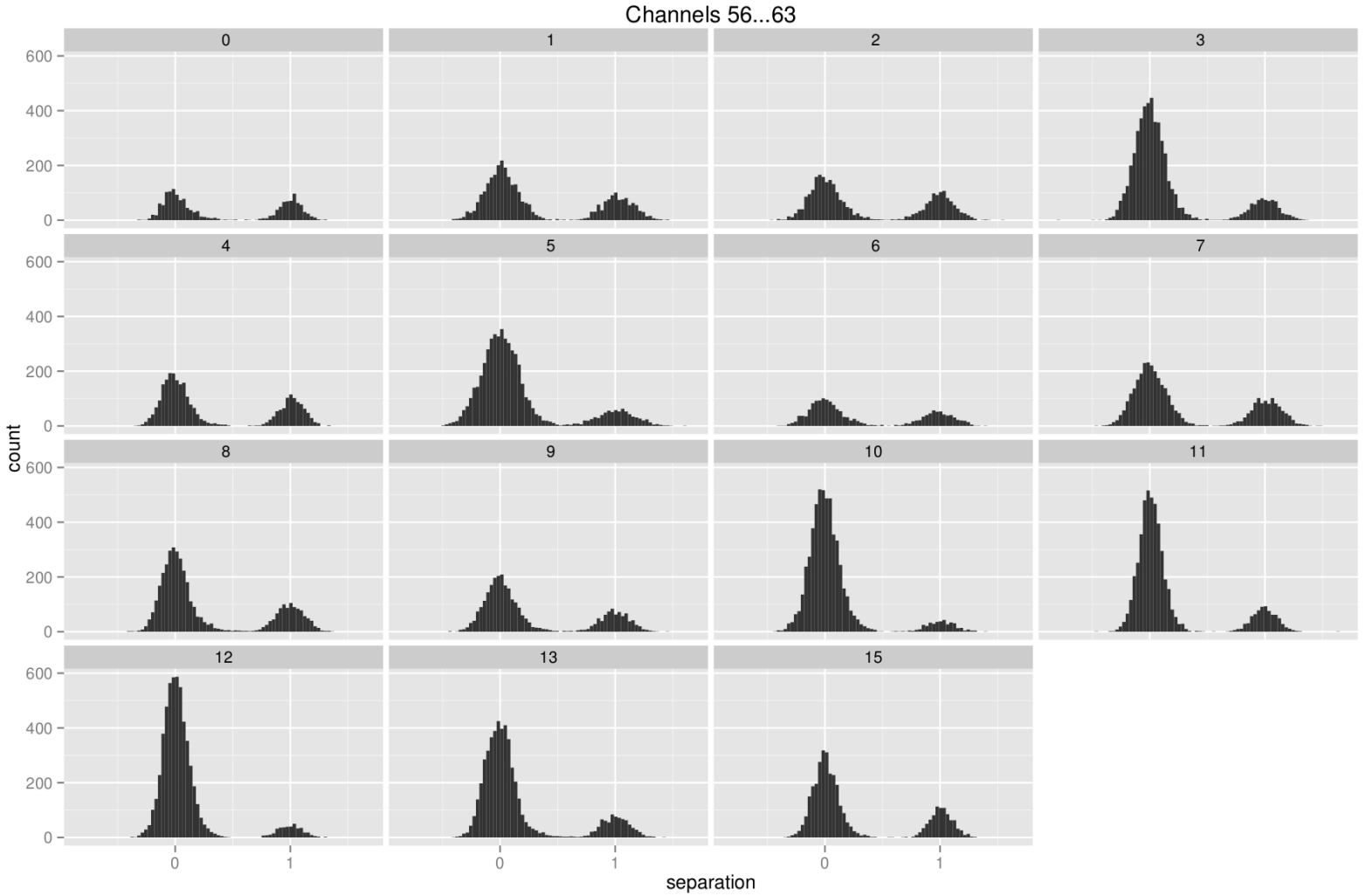
Method of “averaging” is not the best for **classification** problem, as it can be improved by *dropping* the information from channels with small separation power (right-left).

I do not know the best solution, **classification** is an interesting mathematical problem.

In averaging, a separation approximately equivalent to upper 8 channels may be achieved by chaning the “suppression” power from 2 to 8:
<x> = sum((x.i-x.0)/sigma.i^8) / sigma(1/sigma.i^8)
and by considering all channels.

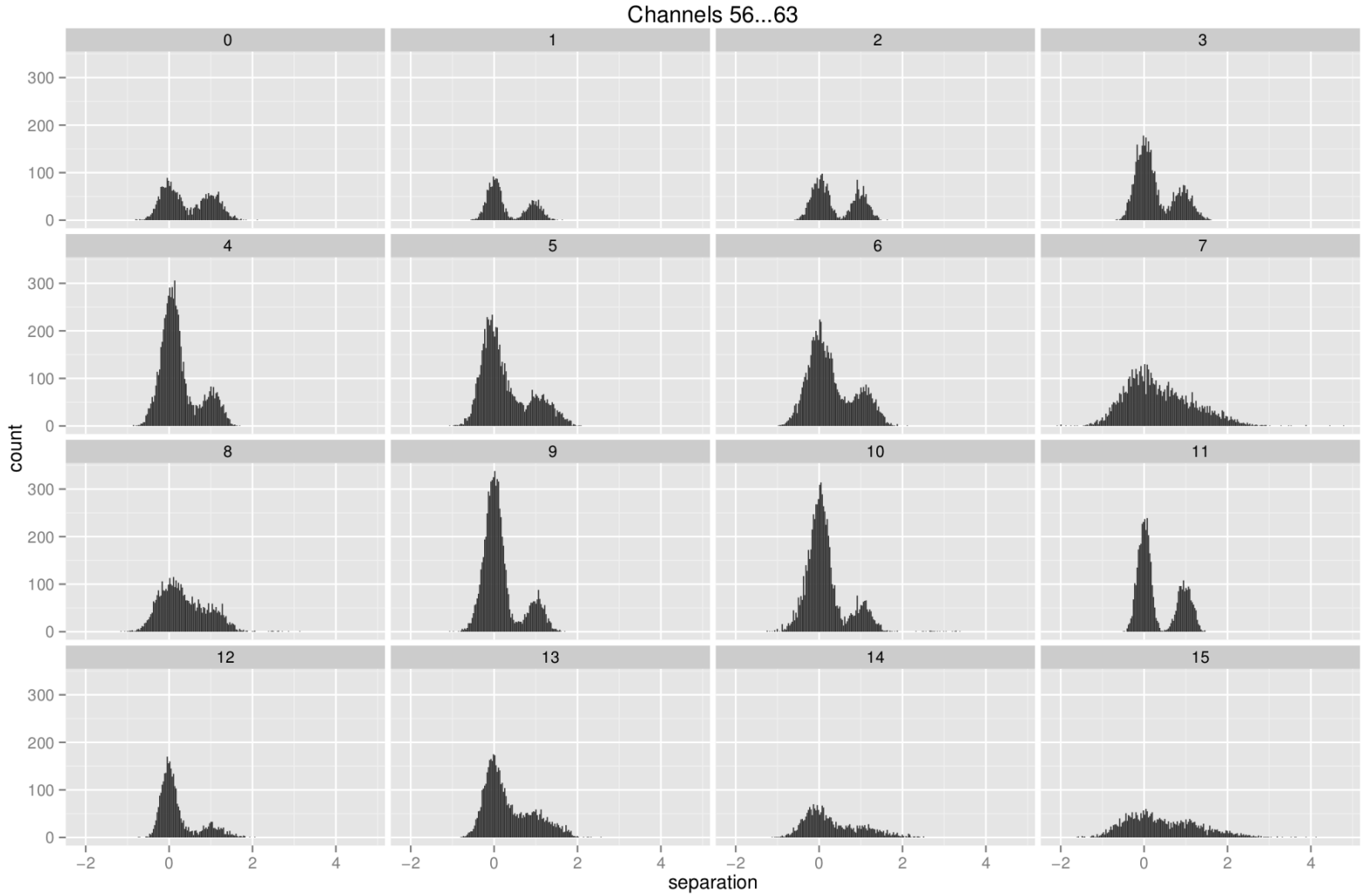
“Average” 8 upper channels, DIF1

DIF1 has much stronger left-right splitting, 10-25 ADC counts instead of 2-10. Therefore, the separation power is better.



“Average” 8 upper channels, DIF2

Note, in DIF0,1 muon rate >> noise rate, while in DIF2 it is the opposite: noises (triggered peak at zero after pedestal subtraction) >> muon rate



Correlate left-right with retriggers

Using developed automated technique, we may, finally, correlate left-right classification with retriggers for all chip, channels.

Retrigger classification

First case (normal):
1) No retriggers in BX+1,2,…
2+3) BX+1 is present, but contains no triggers, nothing in BX+2, while BX+3,4.. may be absent (2) or present with anything inside (3)

Second case (“strong” retrigger):
4) there are triggers in BX+1 (regardless of whether and what is present in BX+2,3,...)
5) no triggers in BX+1 (only pedestals), but BX+2 is present

This classification is “empirical”. In fact, it is “optimized” to have better correlation with left-right in DIF0. The best to my current knowledge but may potentially be improved. Case 3) has little statistics.

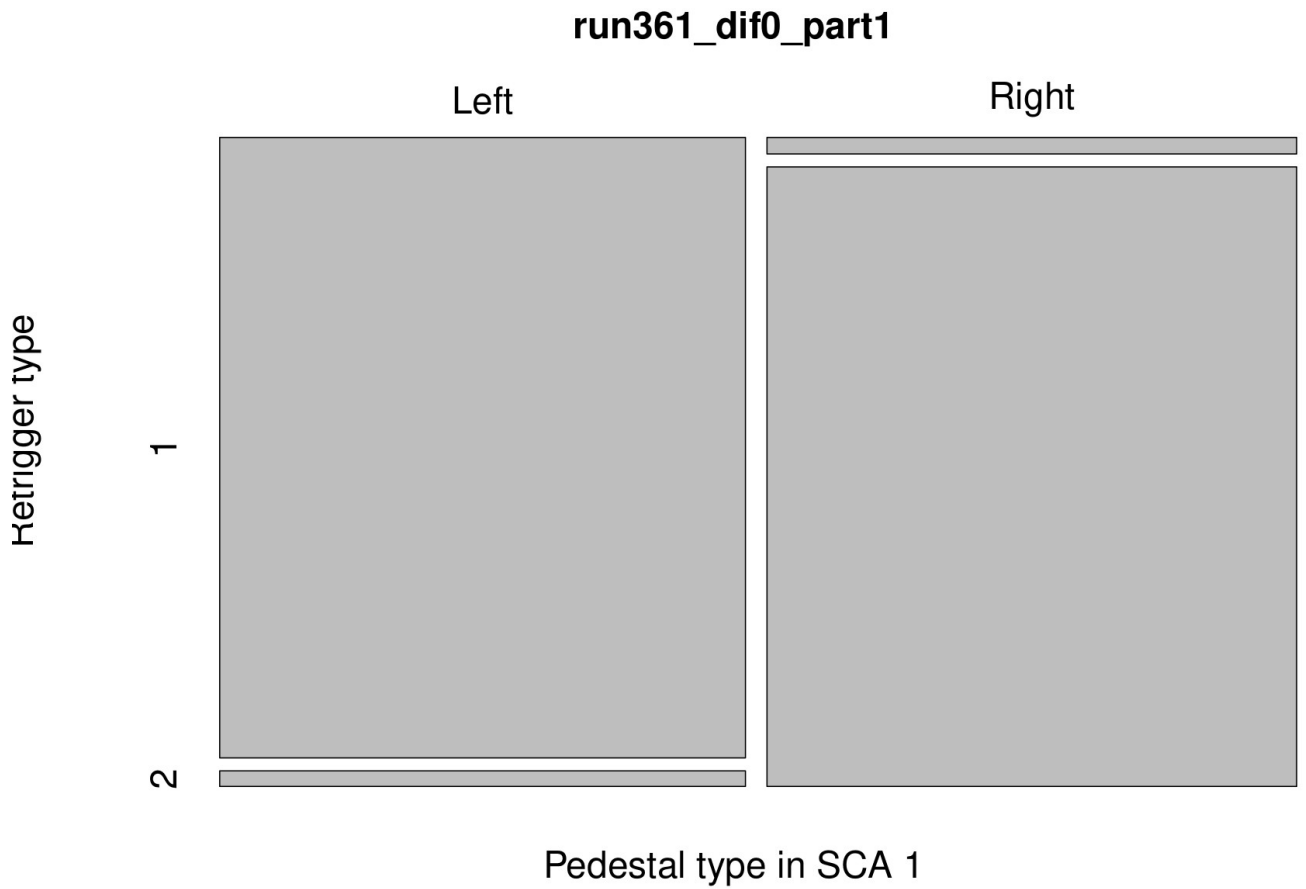
Correlation of pedestals with retriggers in 16 chips, all 1024 DIF0 channels

About 50-50 between left-right or normal-strong retrigger cases.

Almost 100% pedestal-retrigger correlation:

probability of mismatch, ie. left-strong retrigger (2) or right-normal (1) is only 2.5%

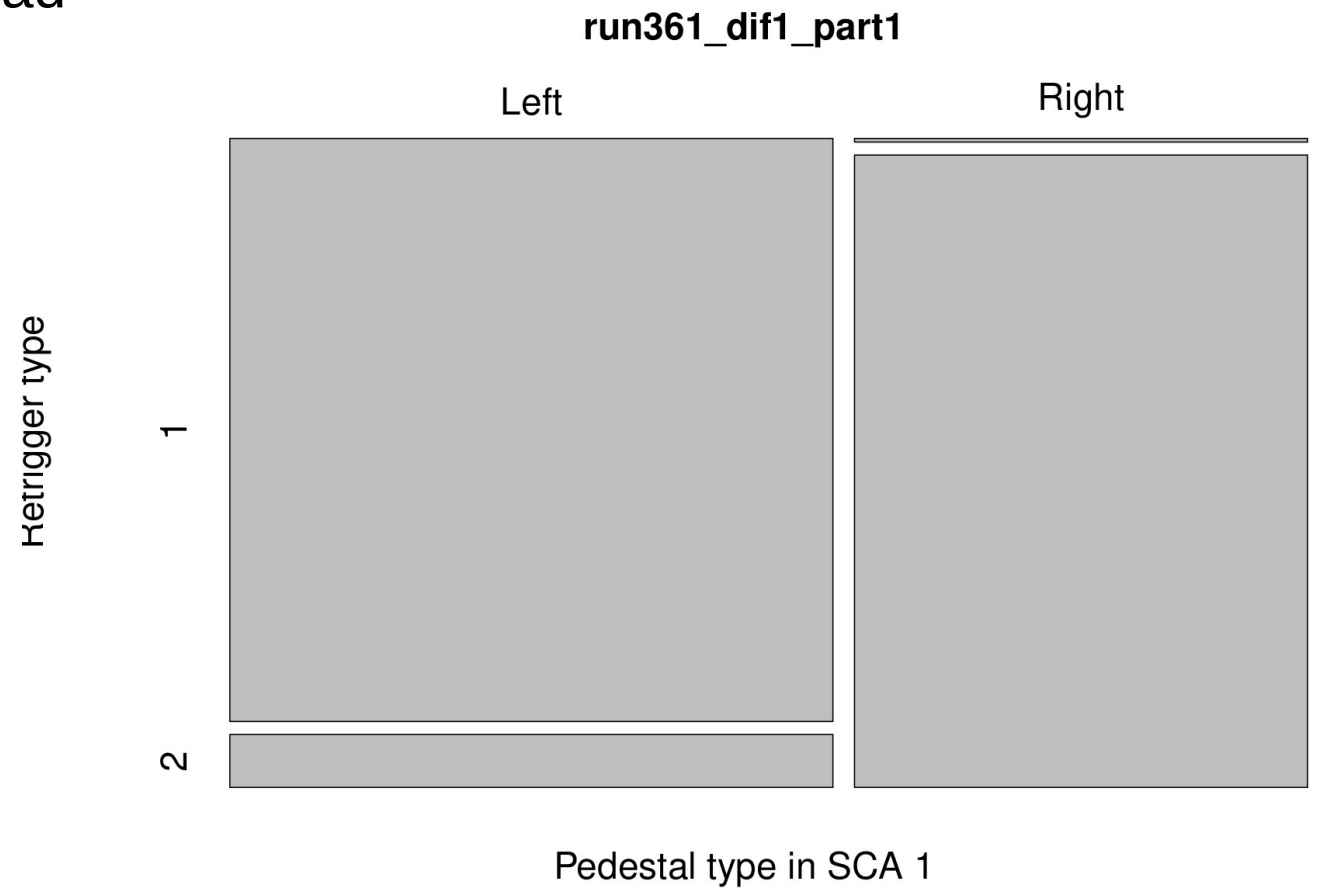
	Left	Right
1	0.486	0.013
2	0.012	0.489



Correlation of pedestals with retriggers in DIF1

5% mismatches (instead of 2.5% in DIF0):

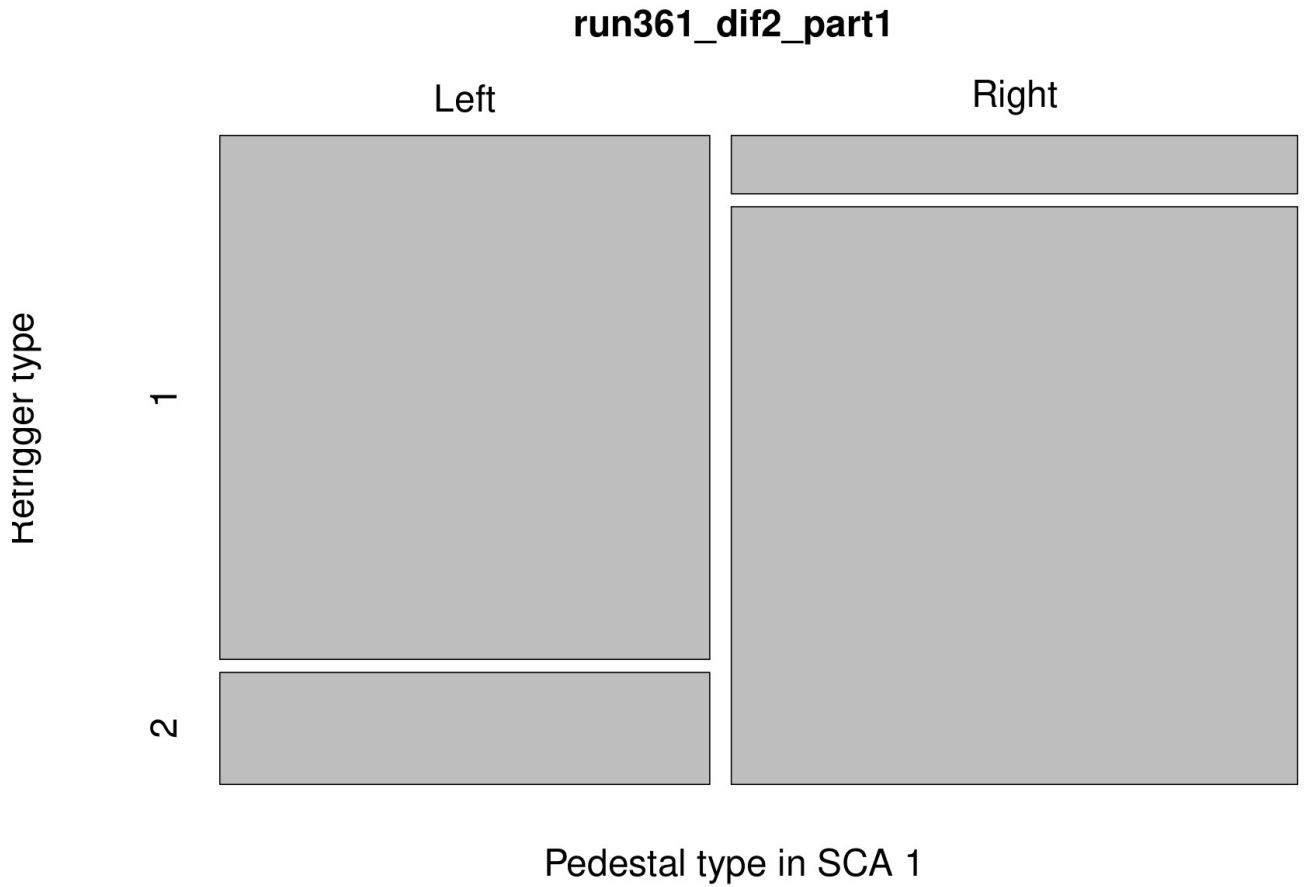
	Left	Right
1	0.5235	0.0024
2	0.0475	0.4266



Correlation of pedestals with retriggers in DIF2

13% mismatches, but note, this is a layer with (much) higher noise, this may complicate things

	Left	Right
1	0.382	0.049
2	0.082	0.487



Discussion on possible pedestal calculation

In the end, how to calculate and subtract pedestals?

One may distinguish left-right cases based on
- retriggers. Can be wrong in 13% in DIF2.
- available not-triggered channels (pedestals). Eg. “average” pedestals only for 8 upper channels. This may be ok for muon data with typically only one triggered channel, so at least 7 upper channels are available in “averaging” (ie. averaging to 0 or 1 for left-right).
- both retriggers and available pedestals, conservatively require that they are consistent. Sacrifice 13% of mismatches in DIF2.

There is a question about showers. All 8 upper channels may be triggered and do not provide pedestals.
- May be we are not so much interested in precision measurements with showers. Precision is needed for muon calibration only (?)
- For a moment, I do not know whether pedestals are not disturbed in shower data (busy events) by any extra effects.