Data analysis for the detection efficiency

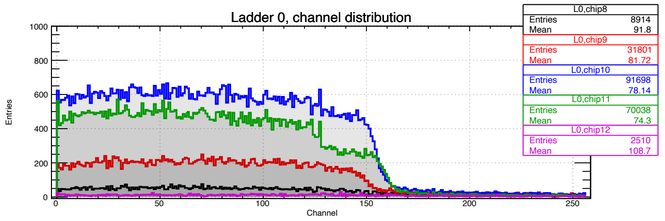
G. Nukazuka (RBRC)

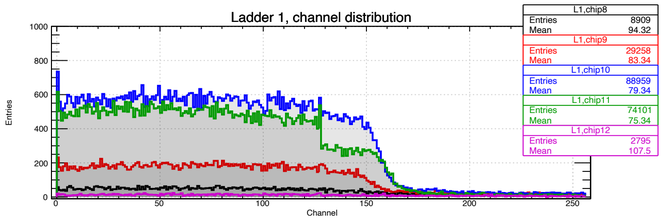
Past reports:

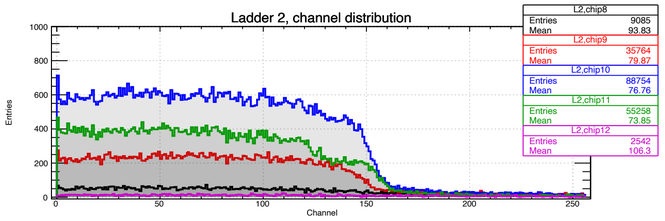
I. Jan/27/2022 (clone hits)
II. Feb/24/2022 (BCO grouping, clustering)

Homework

Run89, channel distributions,
chip8-12,
after clustering





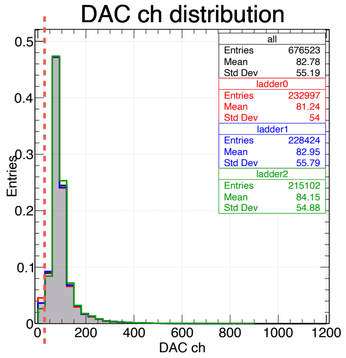


Last time, I report the jumps in the dist. for chip11. I got some homework.

① Removing hits with small ADC value

Takashi's config.

Run 89	ADC 0	ADC 1	ADC 2	ADC 3	ADC 4	ADC 5	ADC 6	ADC 7
DAC	15	30	60	90	120	150	180	210



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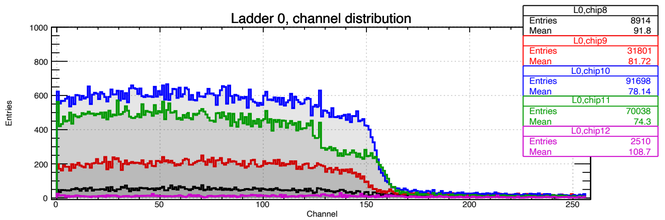

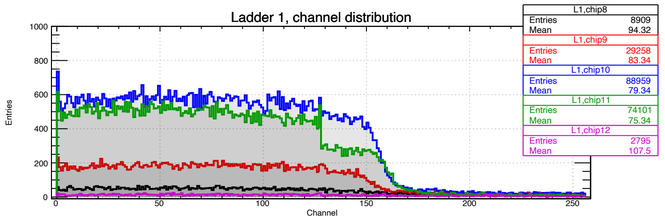

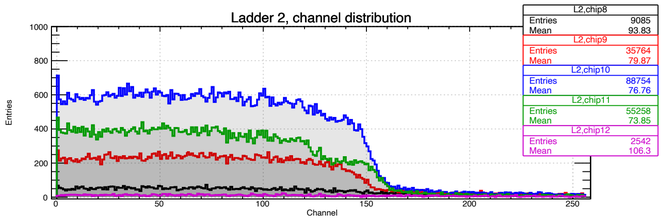

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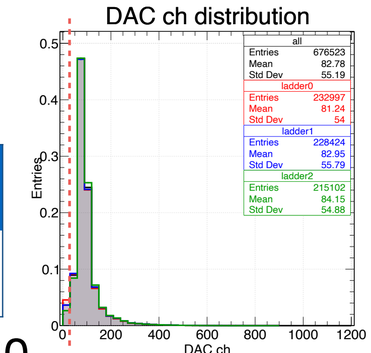
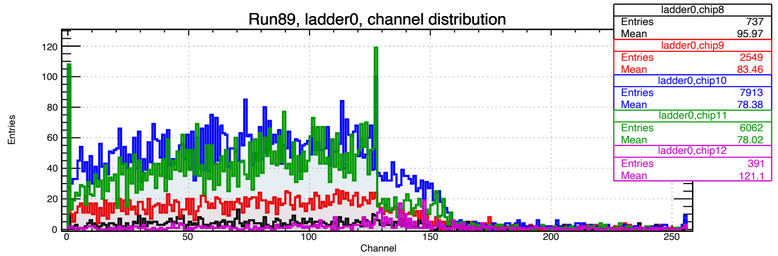
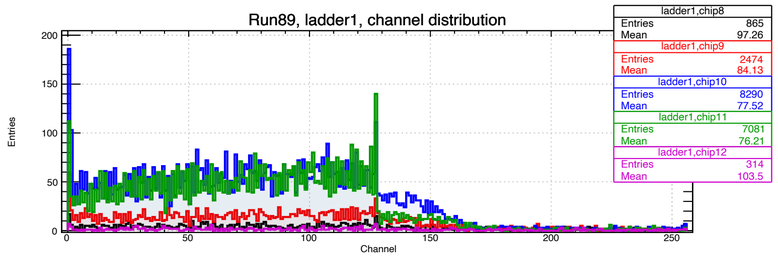
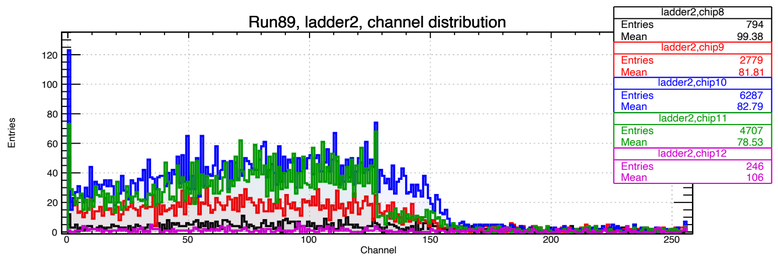


DAC ch ≦ 30







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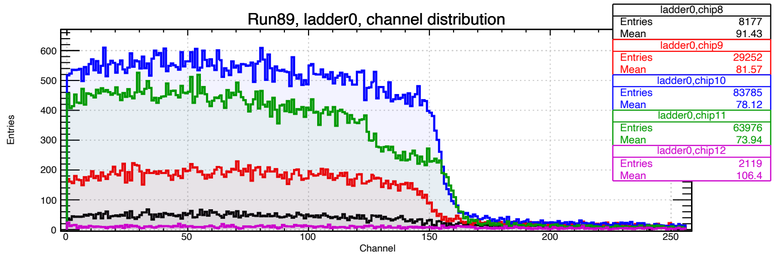
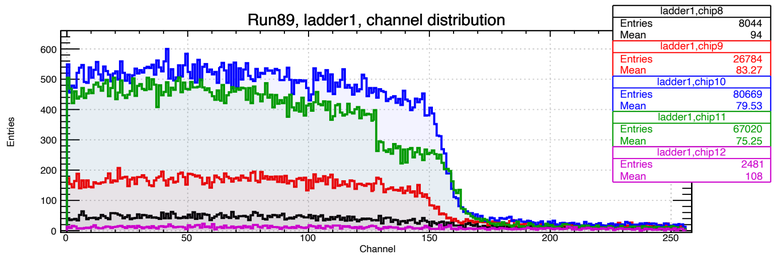
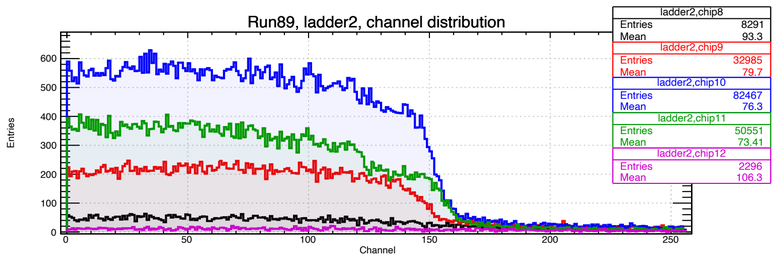


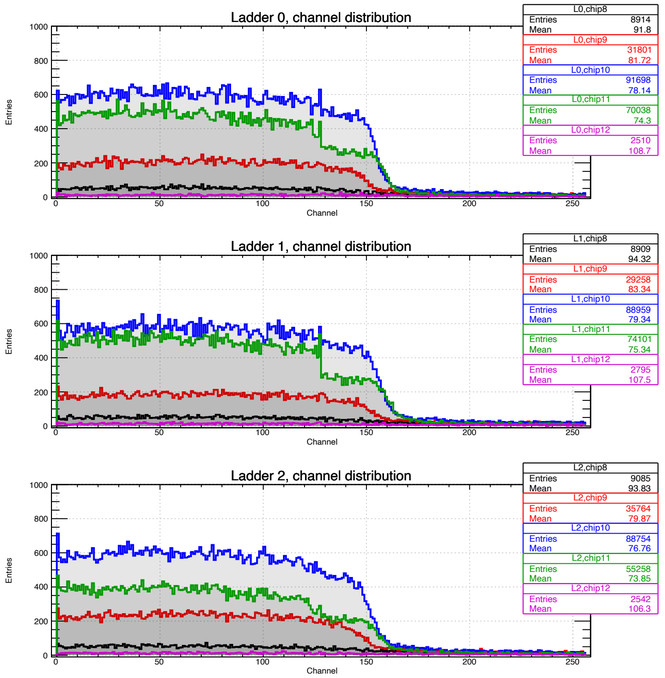




The DAC cut removes hits on ch 0 and 127, which probably have more noise hits, but the jump is still visible.

Homework

Run89, channel distributions,
chip8-12,
after clustering



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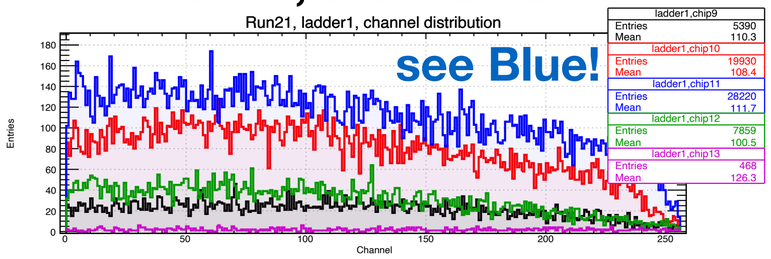

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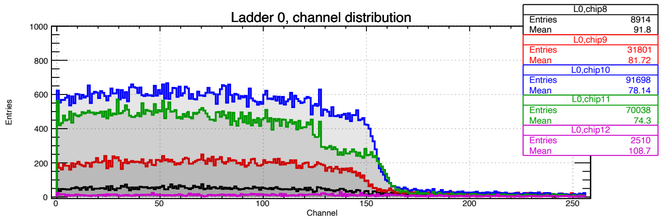

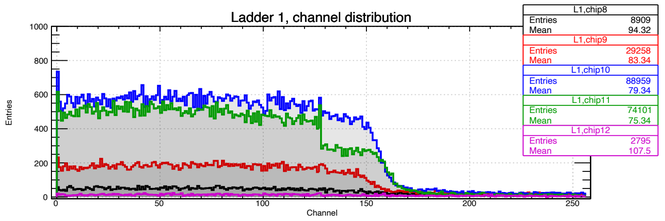

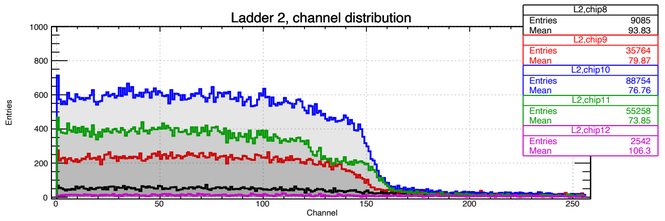

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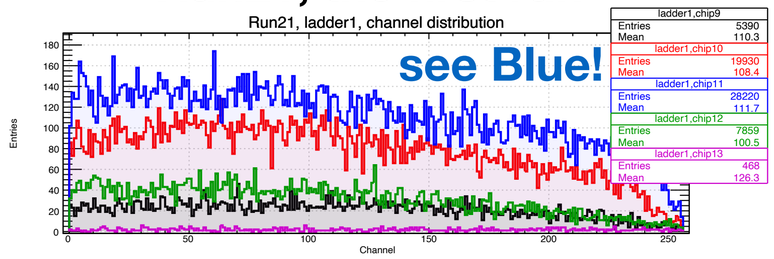
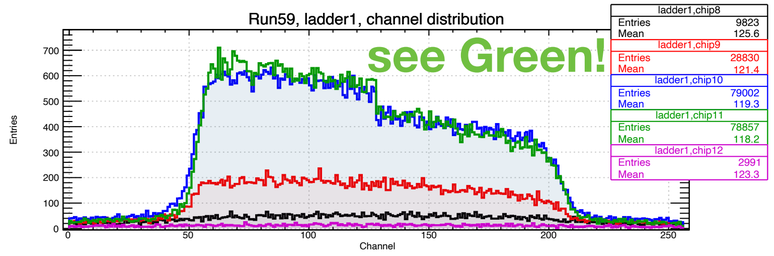


Run59, one of the mass production runs



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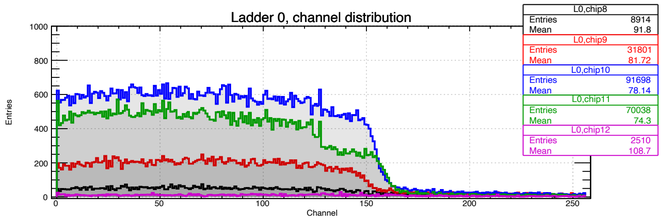

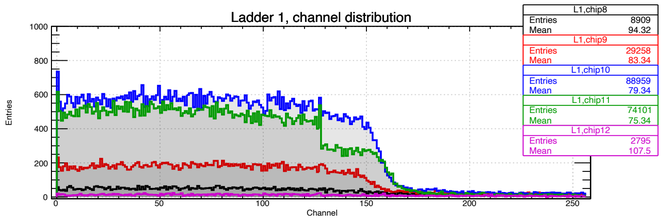

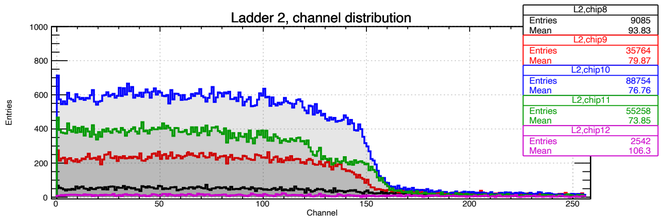

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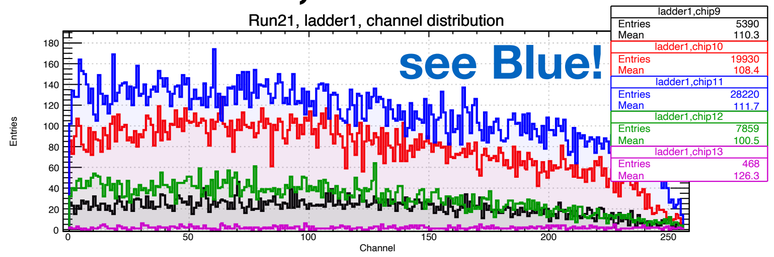

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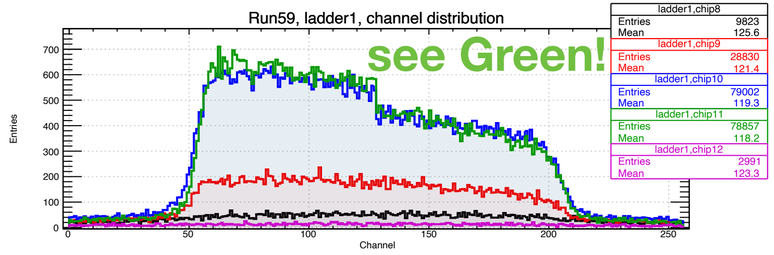
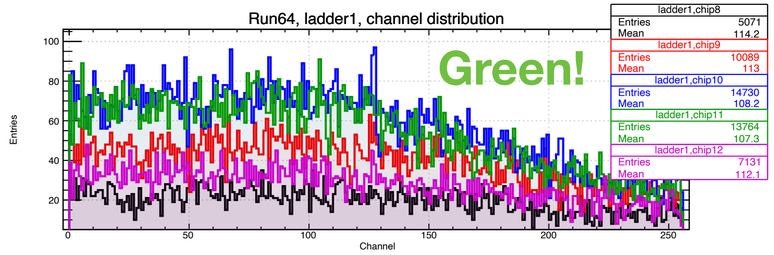


Run64, + Lead plates



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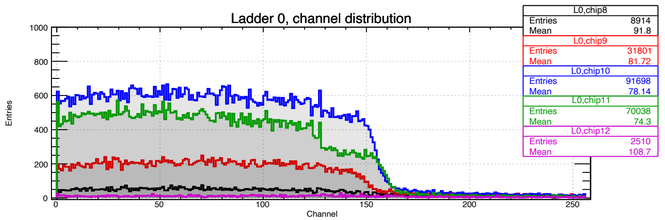

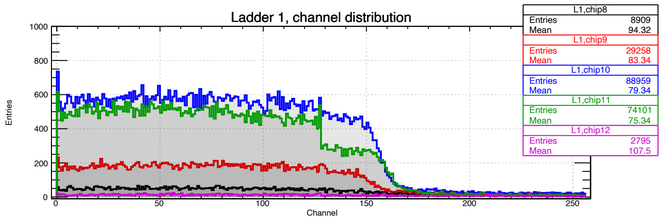

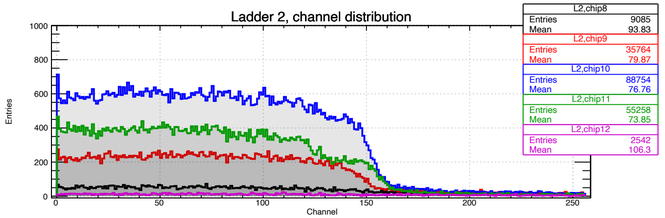

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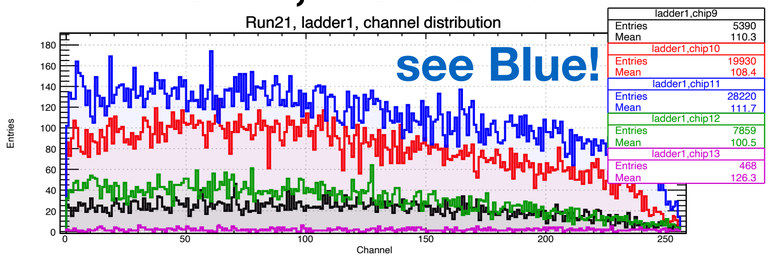

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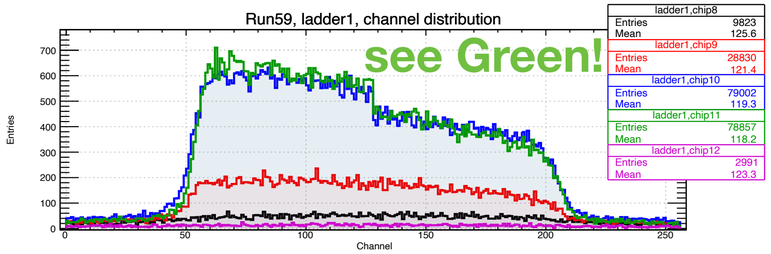

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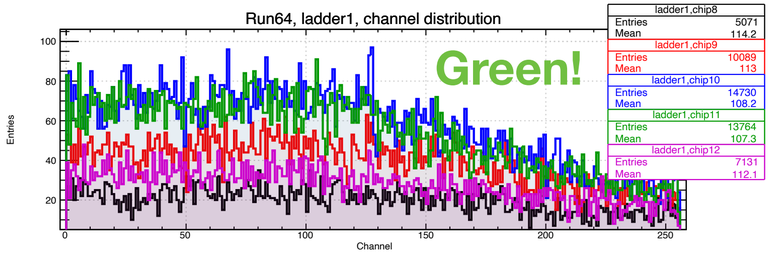
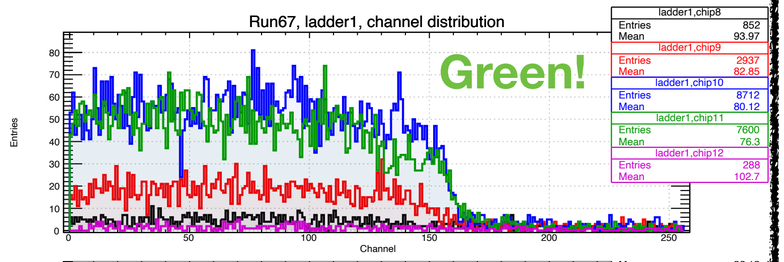
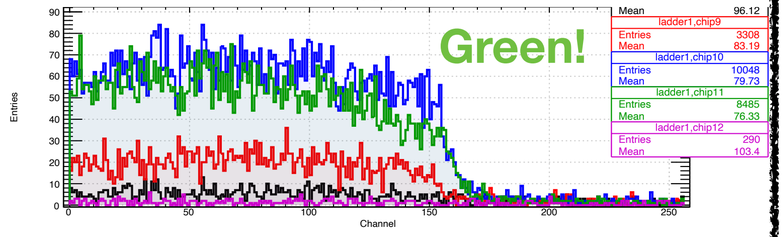
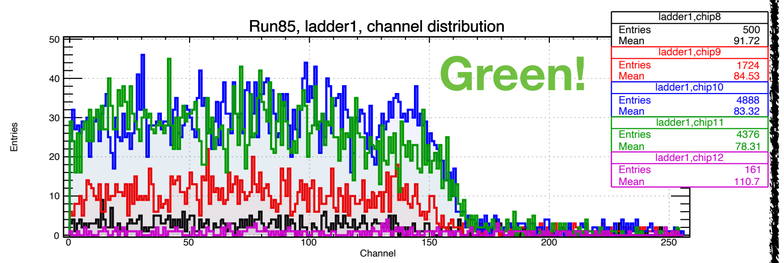


Run67, 77, 85, DAC scans







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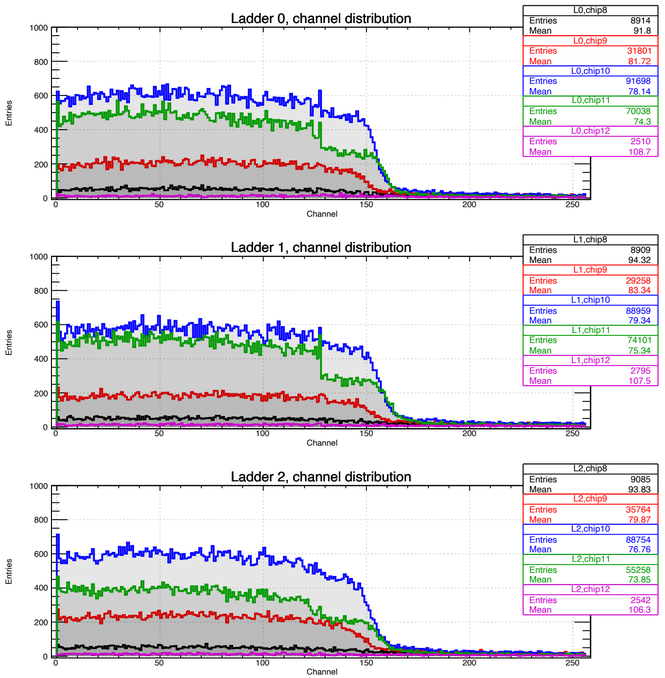

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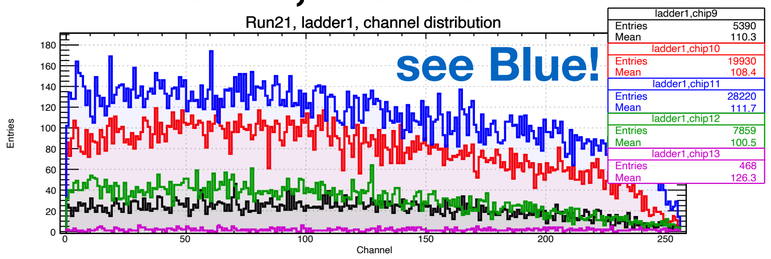

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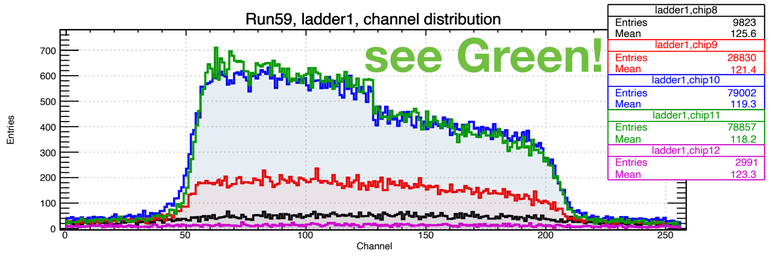

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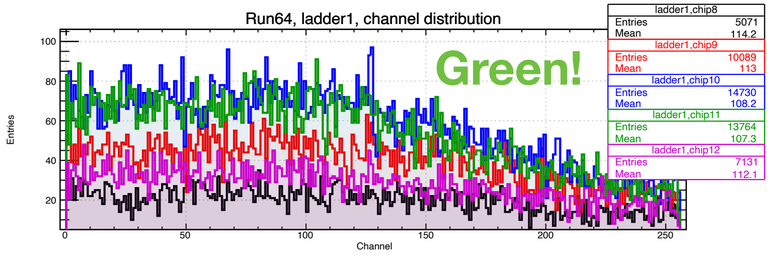

It's hard to find clear signal
to understand the jump.

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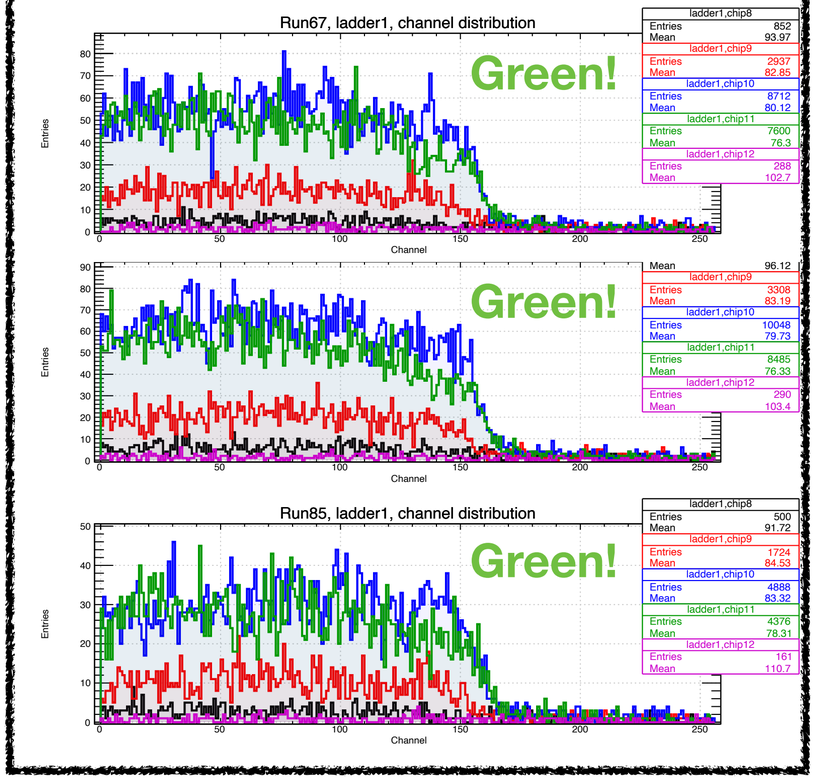
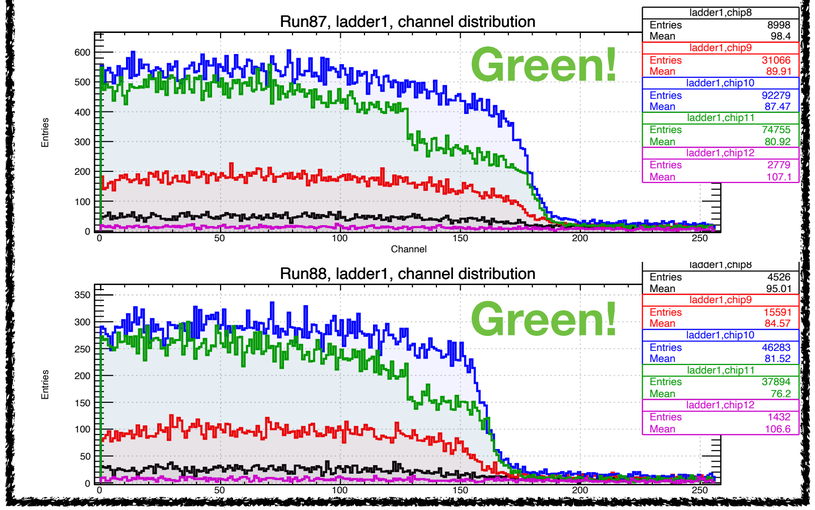


Run87, 88, The last runs



Plan to get the efficiency

Experiment data

MC data

✔ Data correction

(✔) Data generation

✔ Clone hits removal

(✔) Data format conversion

reported on Jan/27/2022

✔ Hits grouping with BCO

✔ Hits clustering → Check

reported on Feb/24/2022

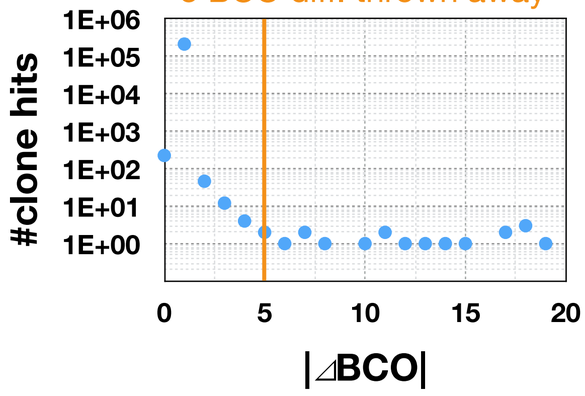
Tracking → Check

some iterations

Ladder alignment → Check

Efficiency calc. → Check

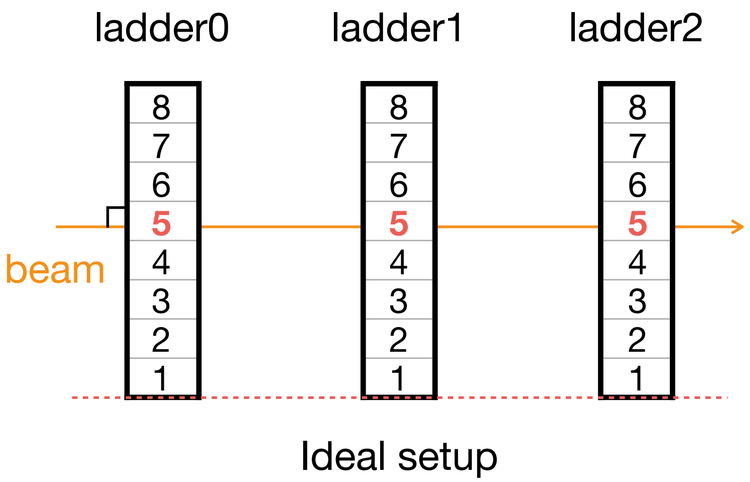
clones hits within
5 BCO diff. thrown away



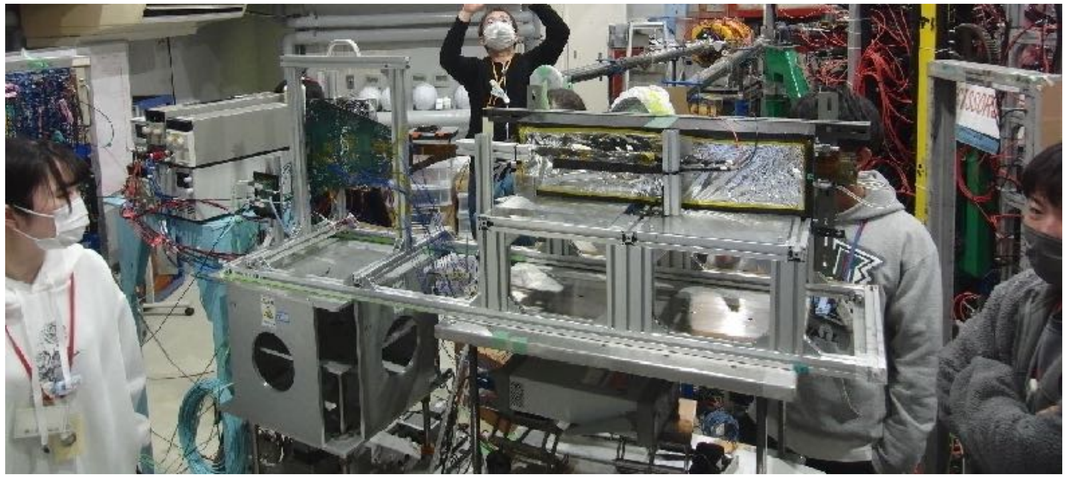
Eff. can be as a function of：

- run
- module
- chip
- ch
- BCO phase
- #BCO group
- RD or MC

Alignment

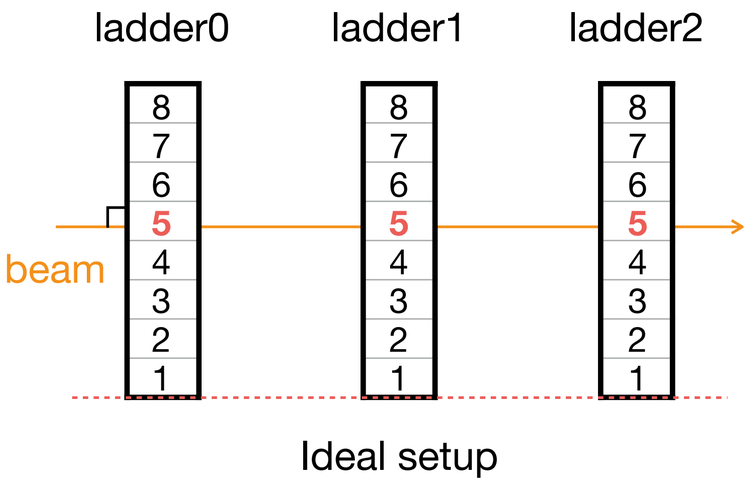


Ideal setup



We tried to set detectors to be aligned at same vertical/horizontal positions perpendicular to the beam.

Alignment



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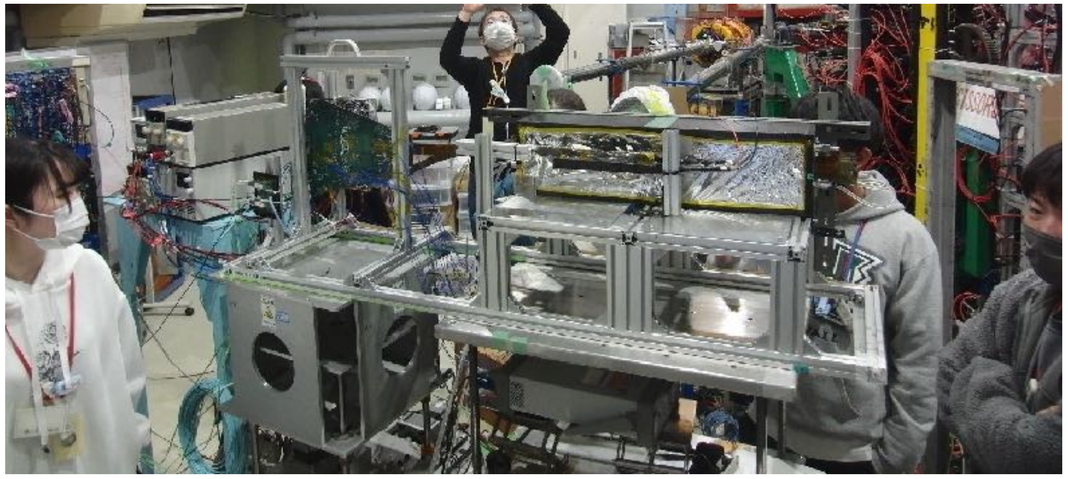

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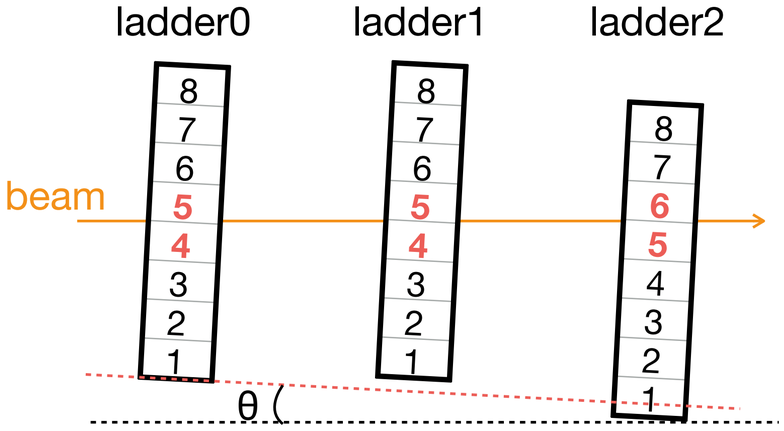


Setup in reality

Unfortunately, it's hard to achieve because

- the floor of the experimental area is not flat
- the stage for the setup is not flat
- the floor dark box is not flat
- the aluminum frame of the ladder is not straight
- precision of placement is limited
- etc.

These factors affect to the channel distribution directly (chip dist. too).
To predict a hit position from tracking, misalignment should be corrected as much as possible.

Residual distribution for alignment

Errors and residuals

From Wikipedia, the free encyclopedia

This article includes a list of general references, but **it lacks sufficient corre**
Please help to improve this article by introducing more precise citations. *(Sep*
when to remove this template message)

In statistics and optimization, **errors** and **residuals** are two closely related and easily confused measures of the deviation of an observed value of an element of a statistical sample from its "true value" (not necessarily observable). The **error** (or **disturbance**[*citation needed*]) of an observation is the deviation of the observed value from the true value of a quantity of interest (for example, a population mean). The **residual** is the difference between the observed value and the *estimated* value of the quantity of interest (for example, a sample mean). The distinction is most important in regression analysis, where the concepts are sometimes called the **regression errors** and **regression residuals** and where they lead to the concept of studentized residuals.

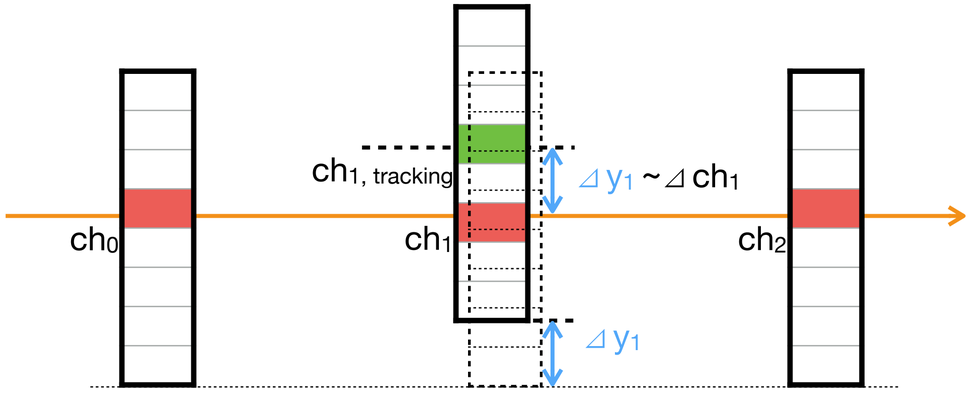
In our case, the residual in the channel distribution for ladder-*i* Δch_i is

$$\Delta ch_i = ch_i - ch_{i,\mathrm{tracking}}$$

To make the situation simple, if only vertical misalignment Δy is assumed,

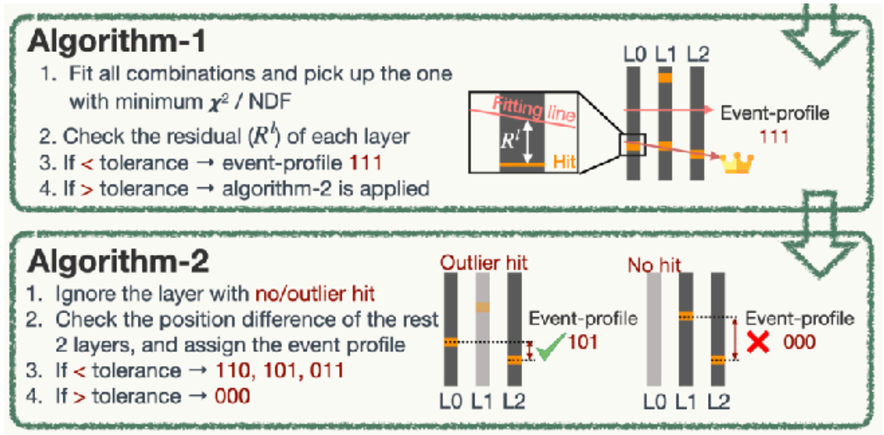
$$\Delta y_i = \Delta ch_i$$

Actually, Δch has uncertainties due to the position resolution and interaction of beam and ladders.



Misalignment affects to hit position prediction from tracking.

Cheng-Wei's way:



Cheng-Wei's poser shown at ELPH2022.

Miu's way:

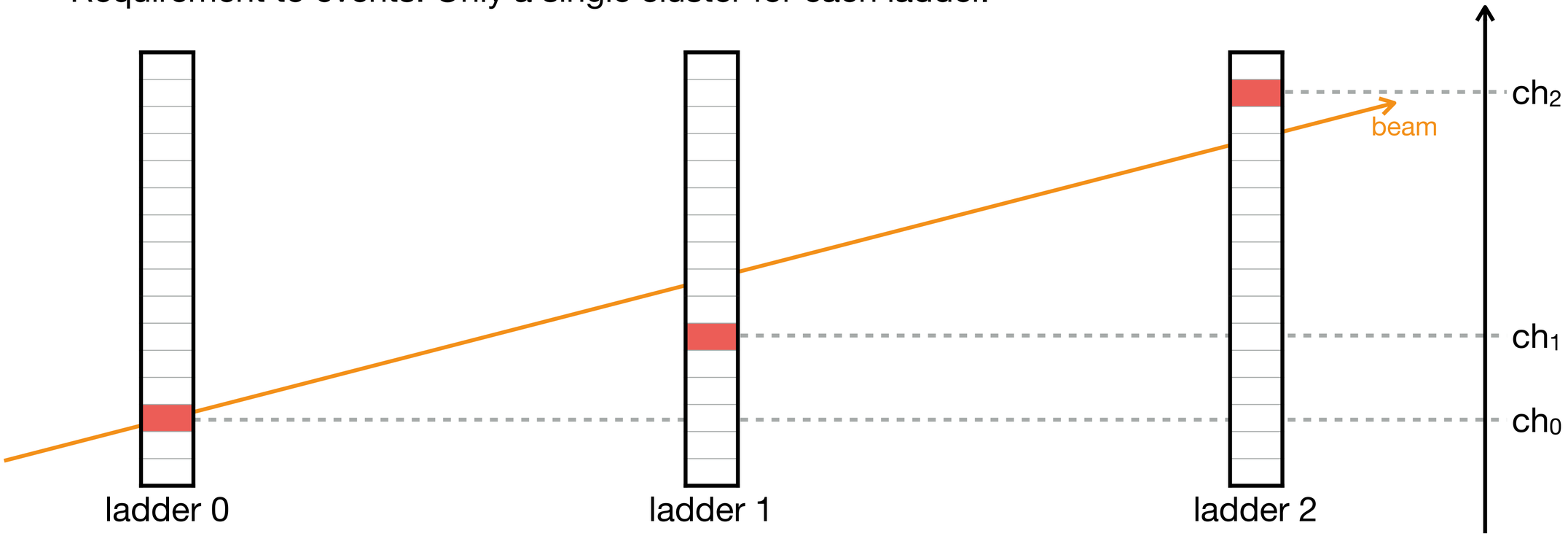
She will let me know the details.

Genki's way:

I like simpler way…

Residual, the simplest way

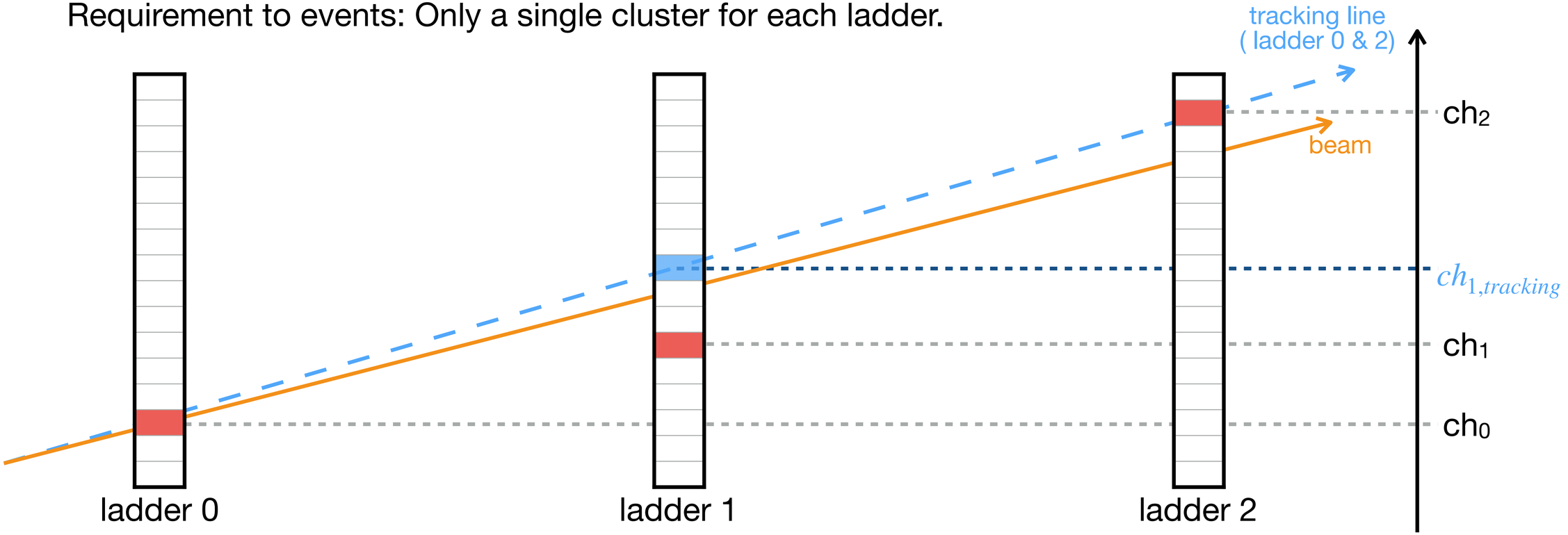
Assumption: Most of beams went through the ladders without scattered in large angle.
Requirement to events: Only a single cluster for each ladder.



Residual, the simplest way

Assumption: Most of beams went through the ladders without scattered in large angle, i.e. straight tracks.

Requirement to events: Only a single cluster for each ladder.



The tracking line can be determined uniquely because there are only 2 points for a line.

$$\Delta_1 = ch_1 - ch_{1,tracking}$$

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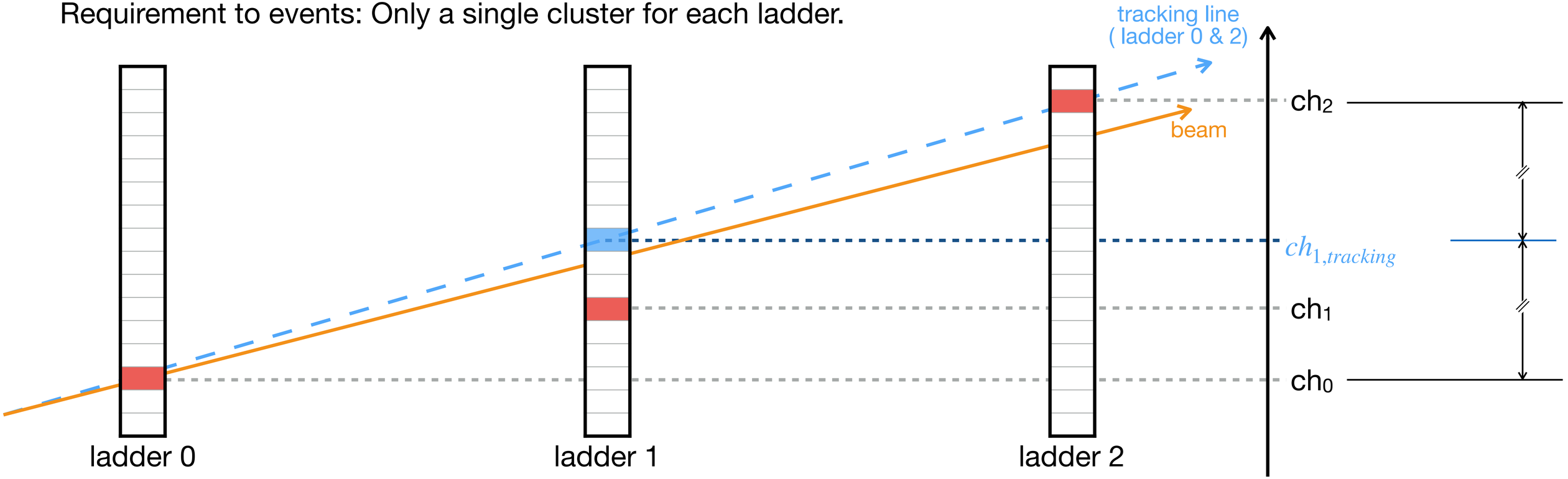

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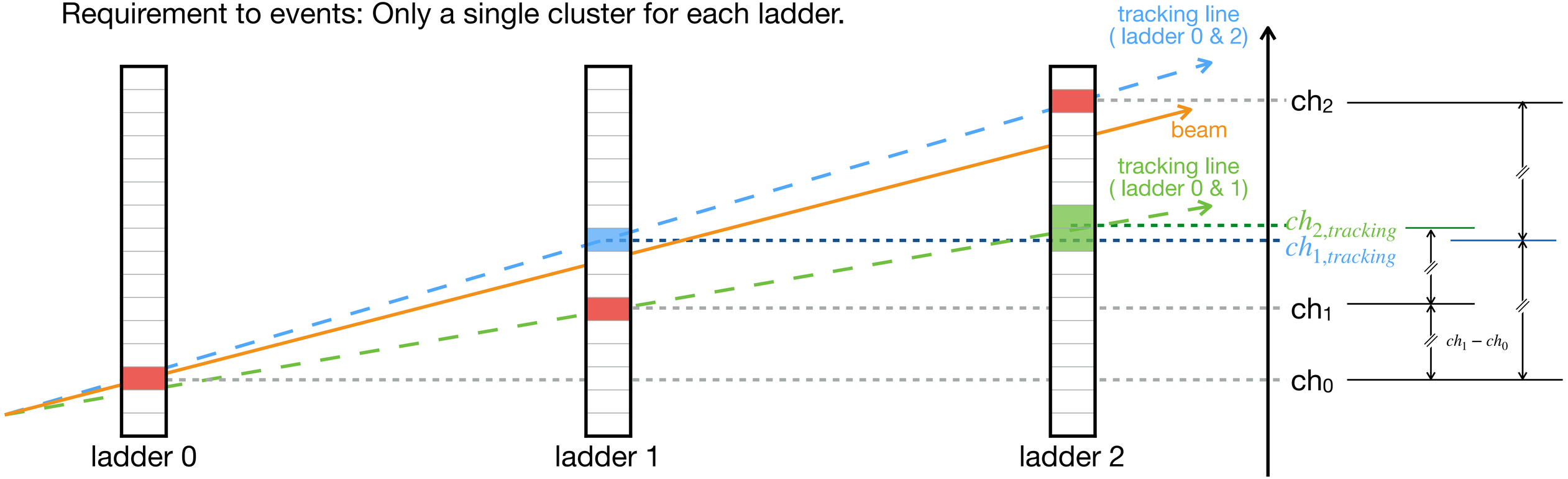

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$$\Delta_2 = ch_2 - ch_{2,tracking} = ch_2 - \{ch_1 + (ch_1 - ch_0)\} = ch_2 - 2ch_1 + ch_0 \ (= \Delta_0)$$

😄Good: Selection of the ideal cases,

😅Bad: Statistically limited(?), Impact of noise hits is big

Residual, the simplest way

$$\Delta_1 = ch_1 - ch_{1,tracking} = ch_1 - \frac{ch_0 + ch_2}{2}$$

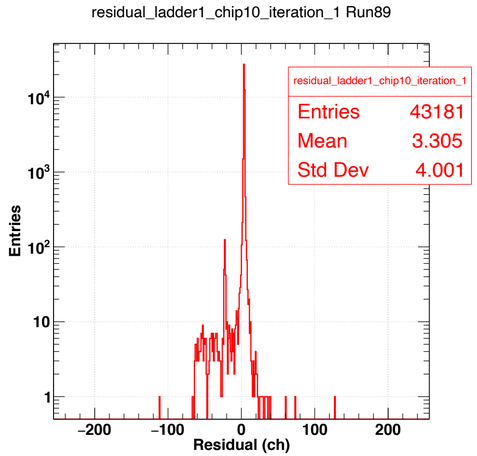
$$\Delta_2 = ch_2 - ch_{2,tracking} = ch_2 - \{ch_1 + (ch_1 - ch_0)\} = ch_2 - 2ch_1 + ch_0 \ (= \Delta_0)$$

run89, chip10

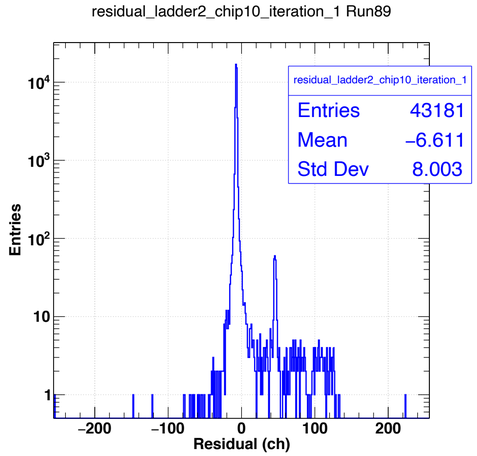
Hits with ampl != 0 are rejected.

no correction

$\Delta_1 = ch_1 - ch_{1,tracking}$



$\Delta_2 = ch_2 - ch_{2,tracking}$



Residual, the simplest way

$$\Delta_1 = ch_1 - ch_{1,tracking} = ch_1 - \frac{ch_0 + ch_2}{2}$$

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run89, chip10

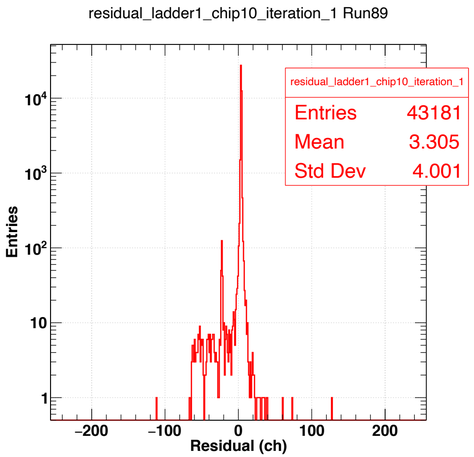
Hits with ampl != 0 are rejected.

no correction

with correction

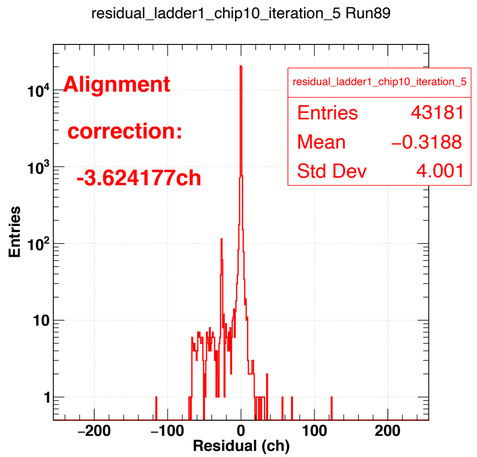
zoomed view

$\Delta_1 = ch_1 - ch_{1,tracking}$

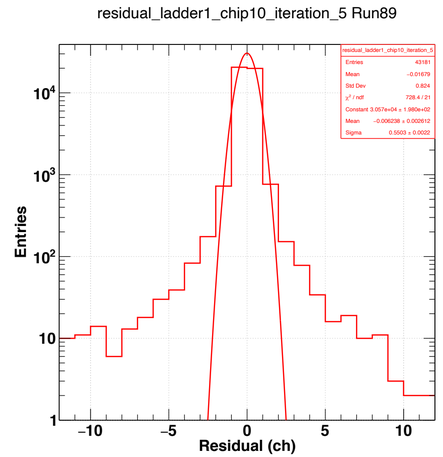


alignment correction

subtracting <⊿1>
estimated by
gaussian fitting

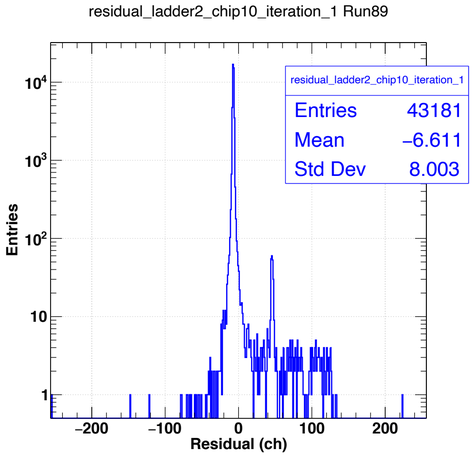


shifted by -3.62ch



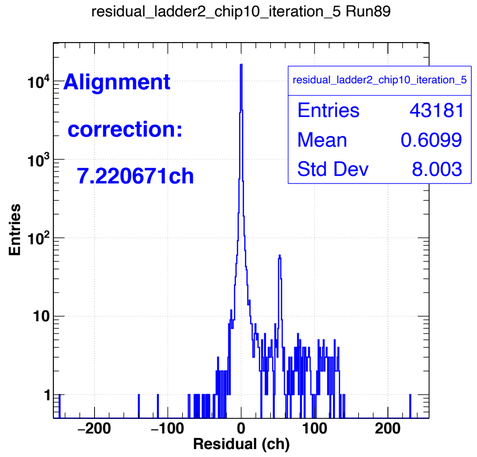
residual_ladder1_chip10_iteration_5	
Entries	43181
Mean	−0.01679
Std Dev	0.824
χ^2 / ndf	728.4 / 21
Constant	3.057e+04 ± 1.980e+02
Mean	−0.006238 ± 0.002612
Sigma	0.5503 ± 0.0022

$\Delta_2 = ch_2 - ch_{2,tracking}$

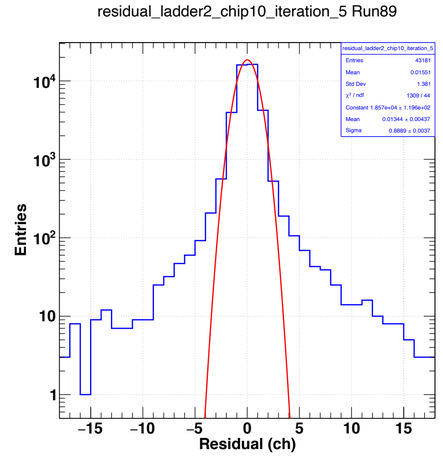


alignment correction

subtracting <⊿2>
estimated by
gaussian fitting



shifted by 7.22ch



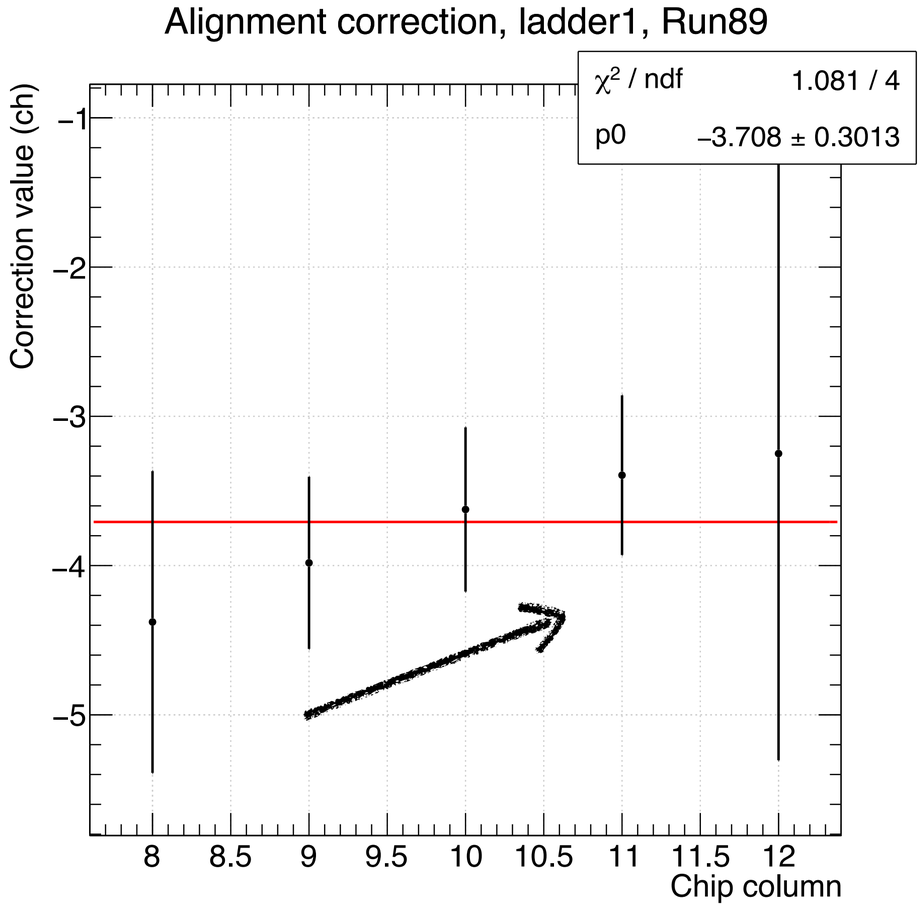
residual_ladder2_chip10_iteration_5	
Entries	43181
Mean	0.01551
Std Dev	1.381
χ^2 / ndf	1309 / 44
Constant	1.857e+04 ± 1.196e+02
Mean	0.01344 ± 0.00437
Sigma	0.8889 ± 0.0037

Residual, the simplest way

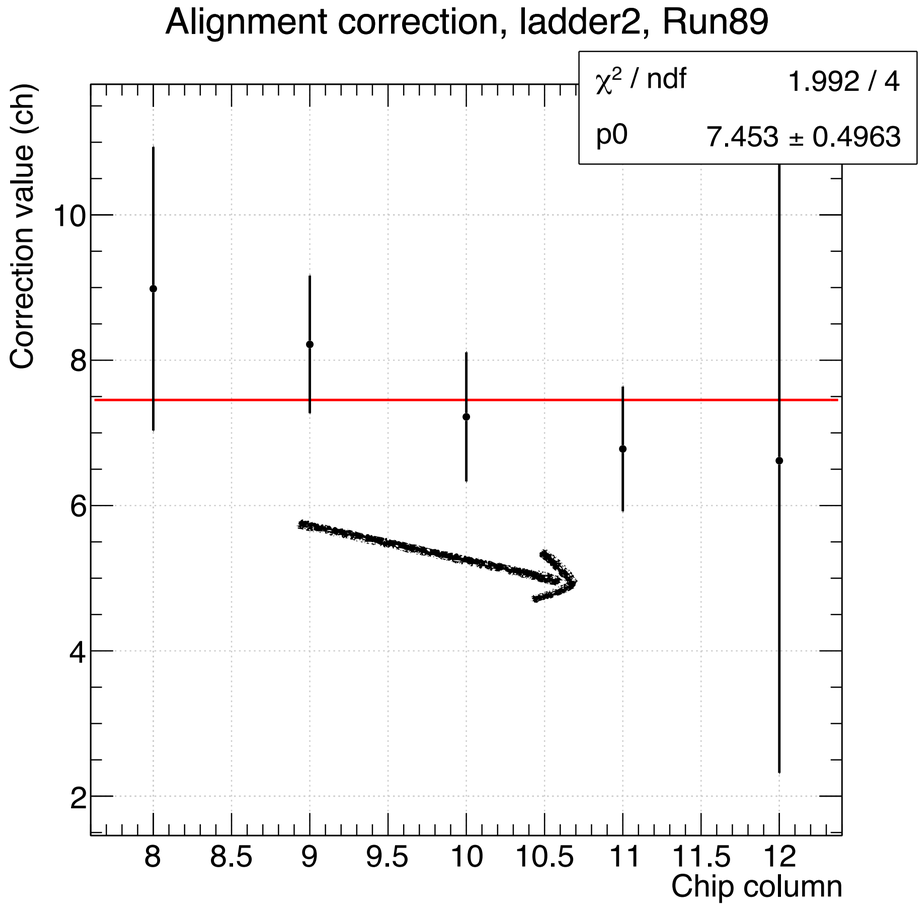
$$\Delta_1 = ch_1 - ch_{1,tracking} = ch_1 - \frac{ch_0 + ch_2}{2}$$
$$\Delta_2 = ch_2 - ch_{2,tracking} = ch_2 - \{ch_1 + (ch_1 - ch_0)\} = ch_2 - 2ch_1 + ch_0 \ (= \Delta_0)$$

Residual as a function of chip column
Run89

$$\Delta_1 = ch_1 - ch_{1,tracking}$$



$$\Delta_2 = ch_2 - ch_{2,tracking}$$



Residuals are consistent within uncertainty.
But there might be chip dependence.

Residual, the simplest way

$$\Delta_1 = ch_1 - ch_{1,tracking} = ch_1 - \frac{ch_0 + ch_2}{2}$$

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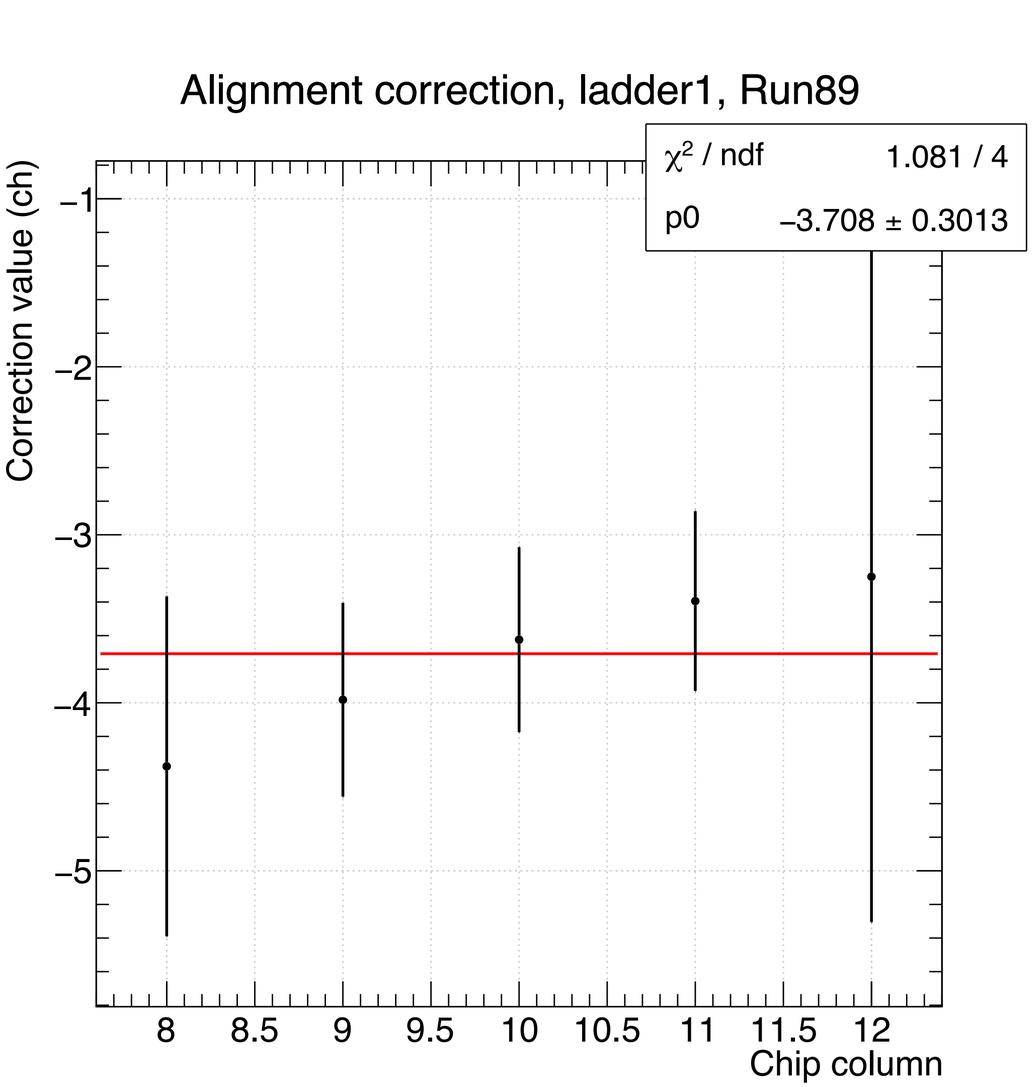
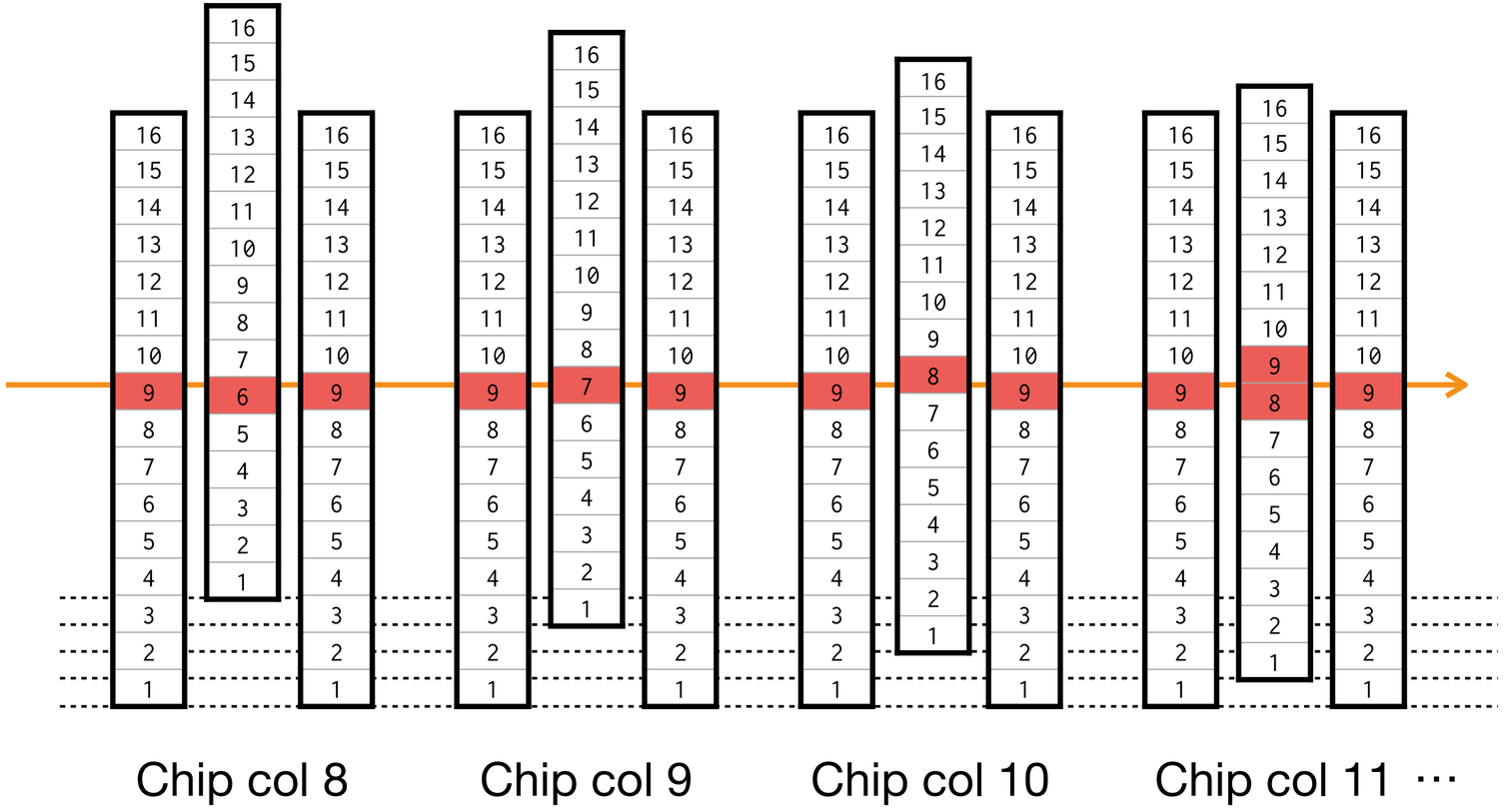
Interpretation of the residual trends





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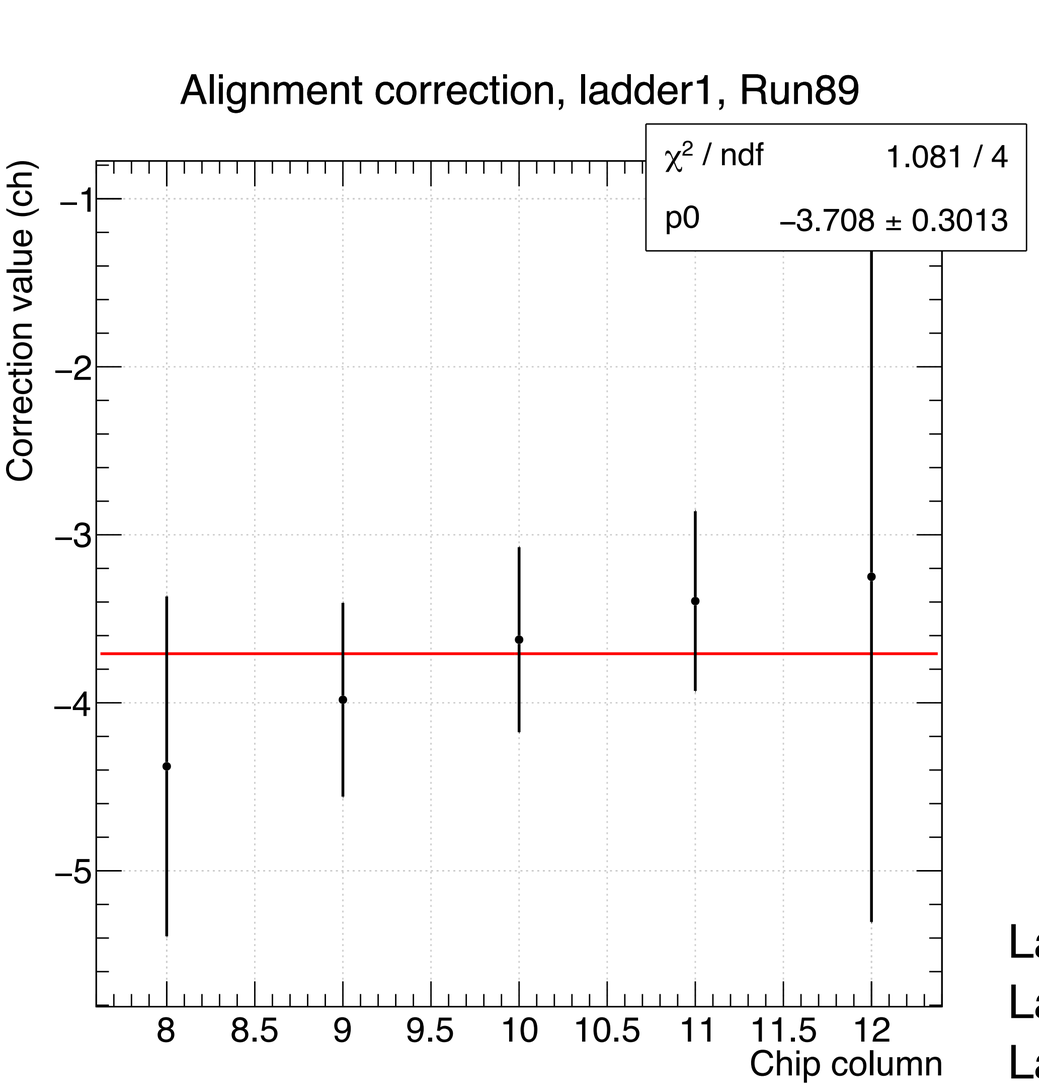

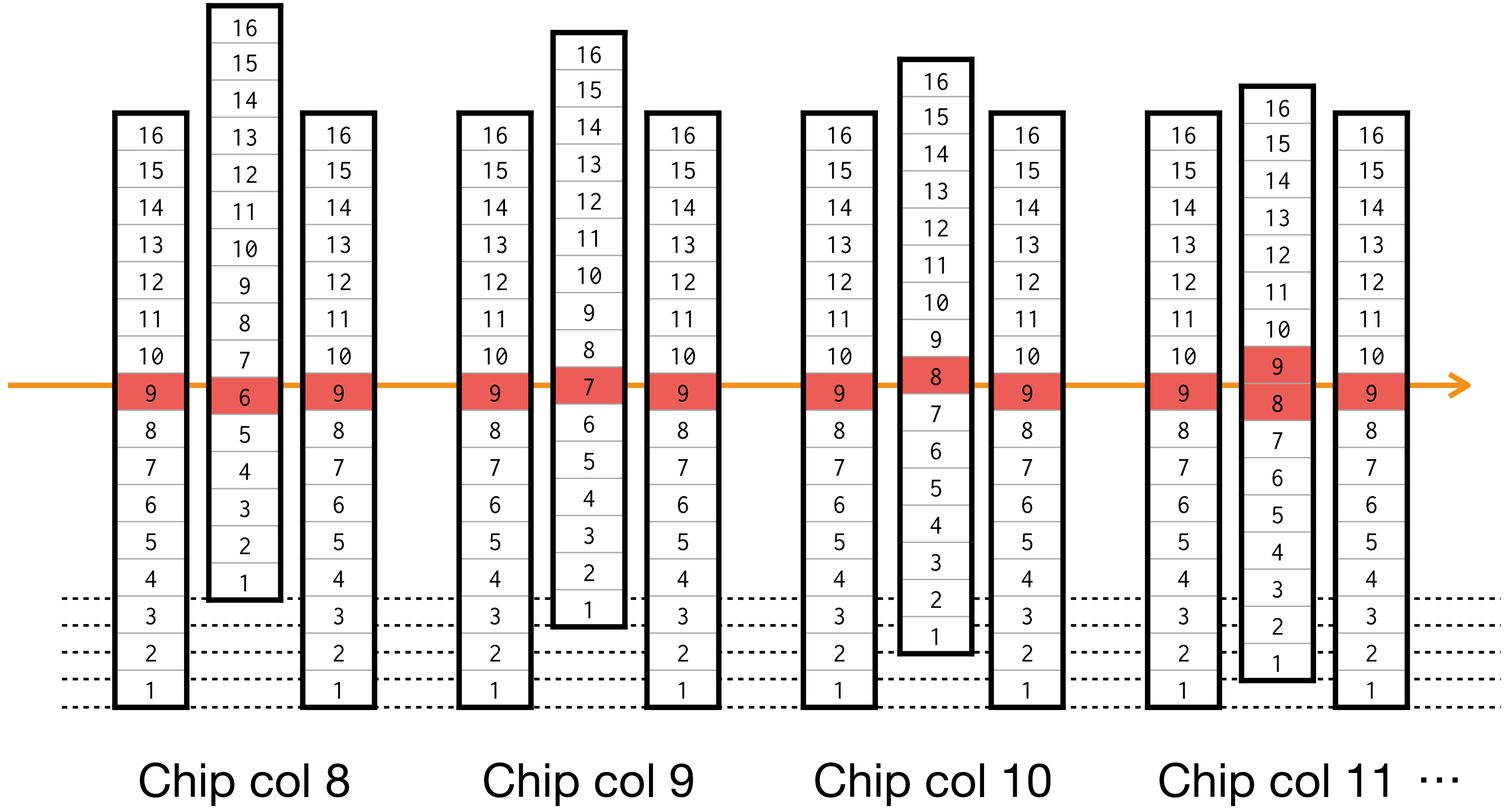

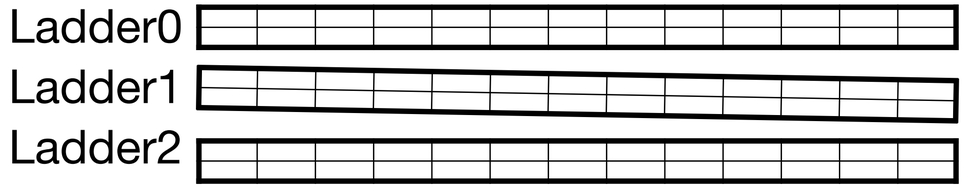

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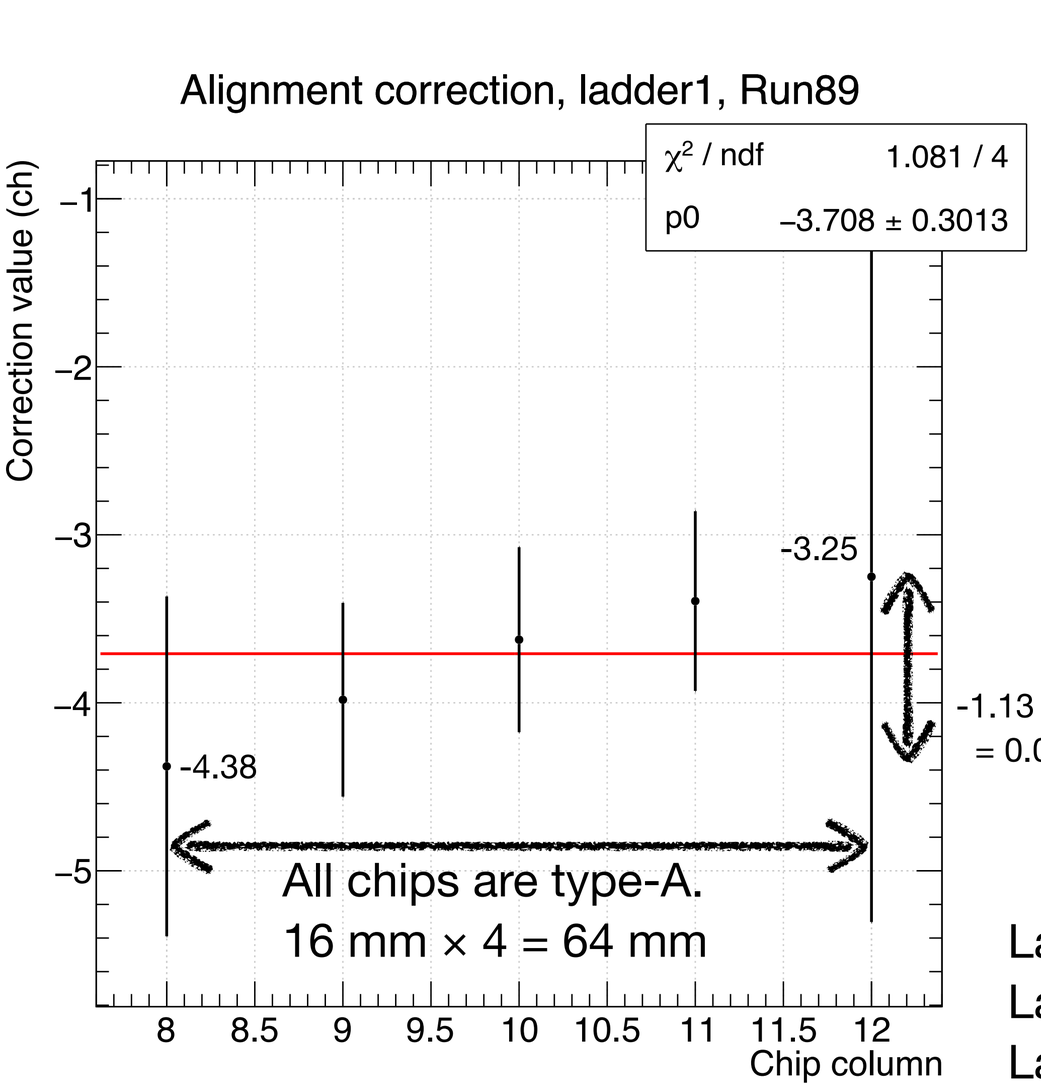

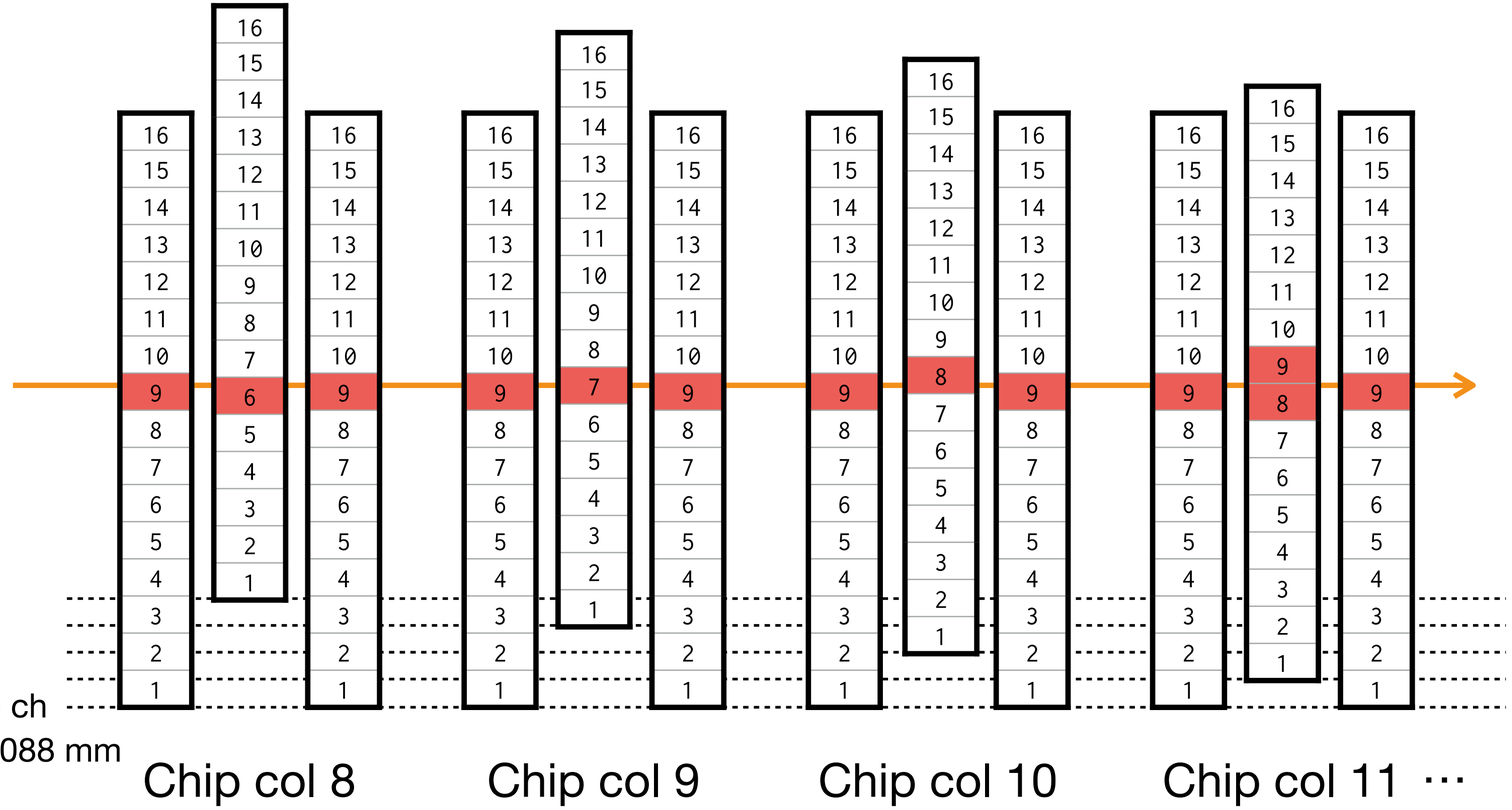

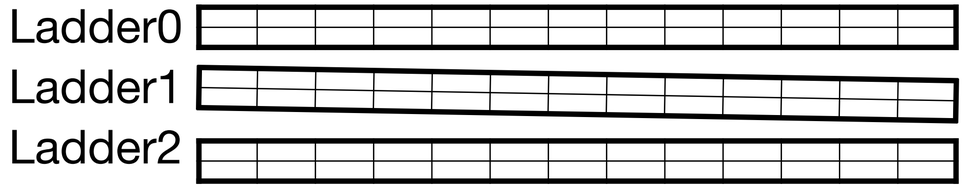

$$\theta = \arctan\left(\frac{0.088}{64}\right) = 0.1 \text{ mrad}$$

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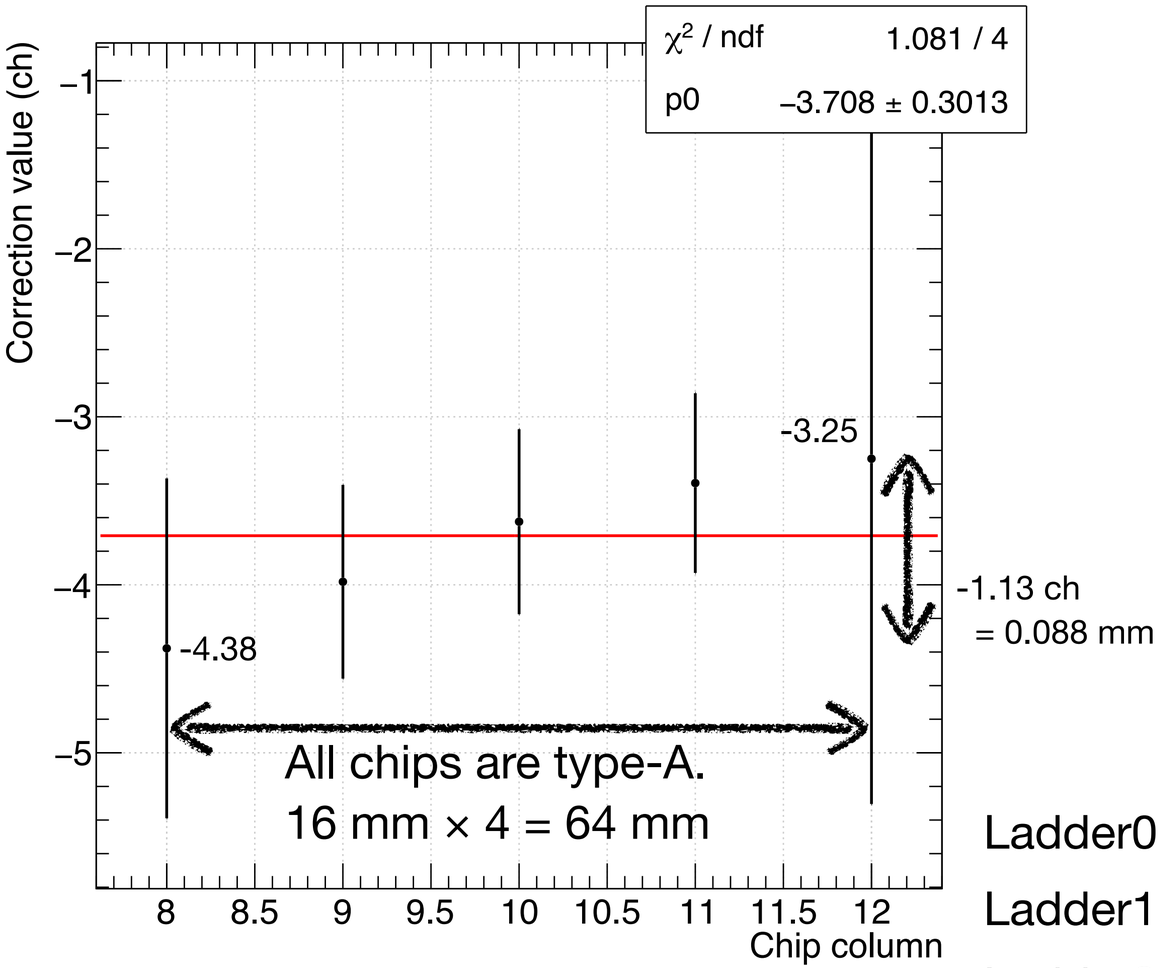
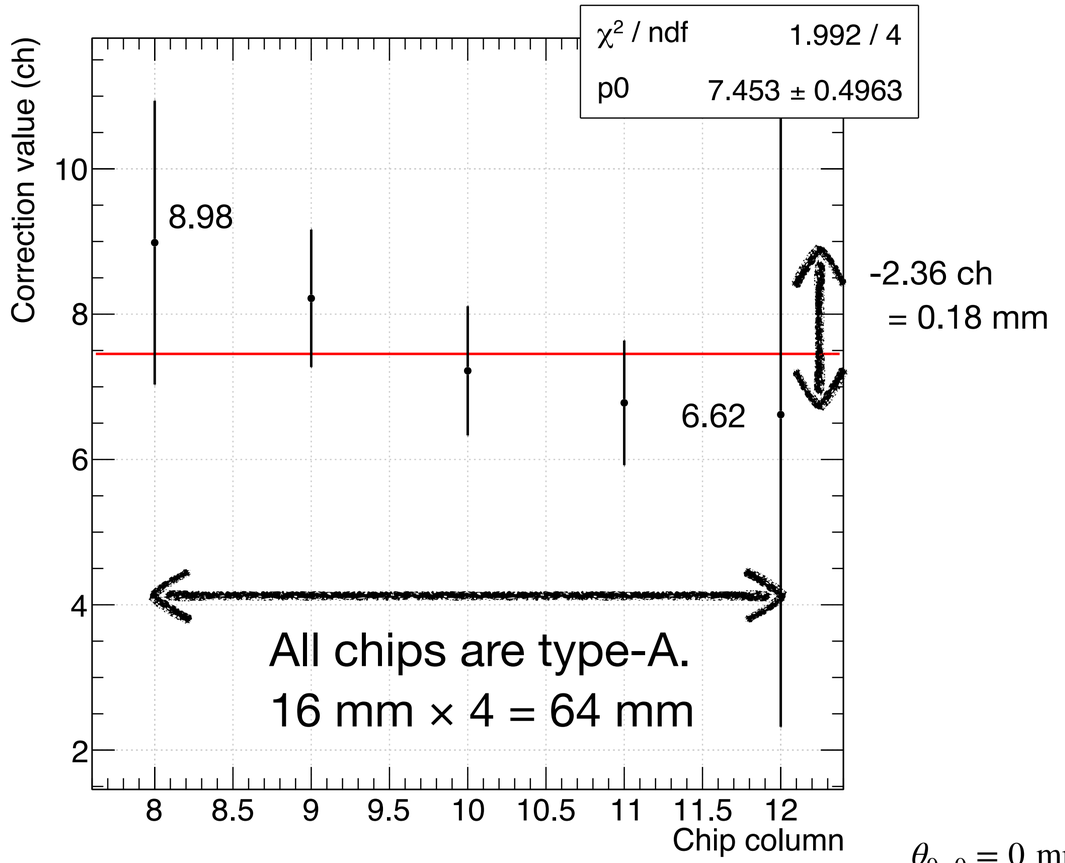
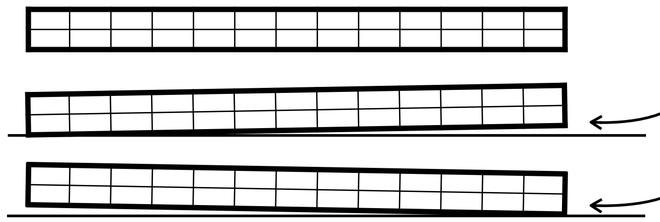
Interpretation of the residual trends

Alignment correction, ladder1, Run89



Alignment correction, ladder2, Run89





$\theta_{0-0} = 0$ mrad

$$\theta_{0-1} = \arctan\left(\frac{0.088}{64}\right) = 0.1 \text{ mrad}$$

$$\theta_{0-2} = \arctan\left(\frac{0.18}{64}\right) = 3 \text{ mrad}$$

It's possible to reproduce this tilt in MC. I'll try later.

Residual, the simplest way

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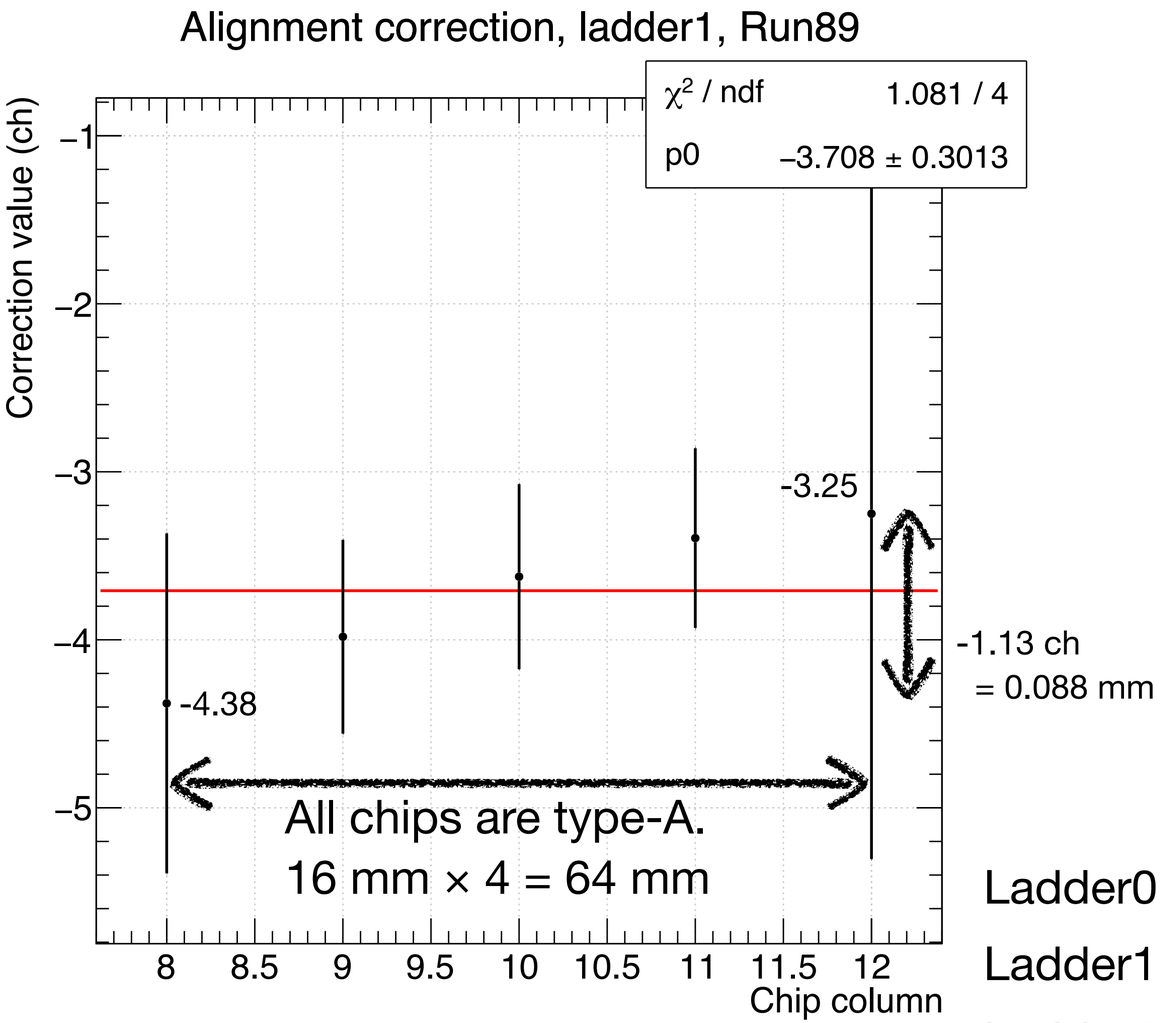
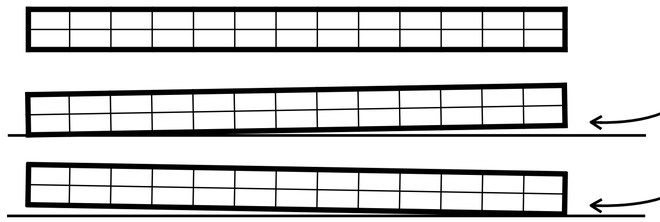
Interpretation of the residual trends



Analsis	Run	ε (%) Ladder 0	ε (%) Ladder 1	ε (%) Ladder 2
Cheng-Wei	89	$99.3^{+0.2}_{-0.2}$	$99.5^{+0.1}_{-0.2}$	$97.1^{+0.3}_{-0.4}$
Miu	87 88 89	99.53 ±0.02	99.39 ±0.03	99.56 ±0.02

Miu selected only chip column 10&11 while Cheng-Wei used all chip in detection efficiency analysis.

M. Morita, JPS annual meeting 2022.



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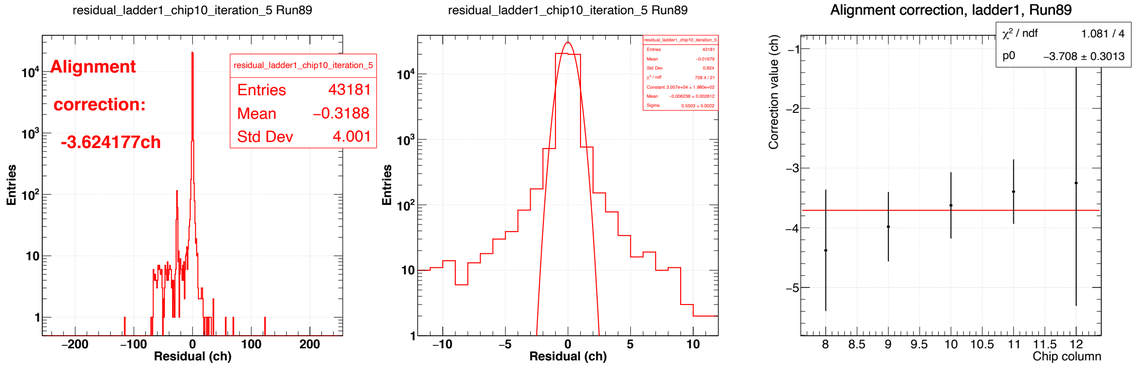
Is the residual trend in MC data?

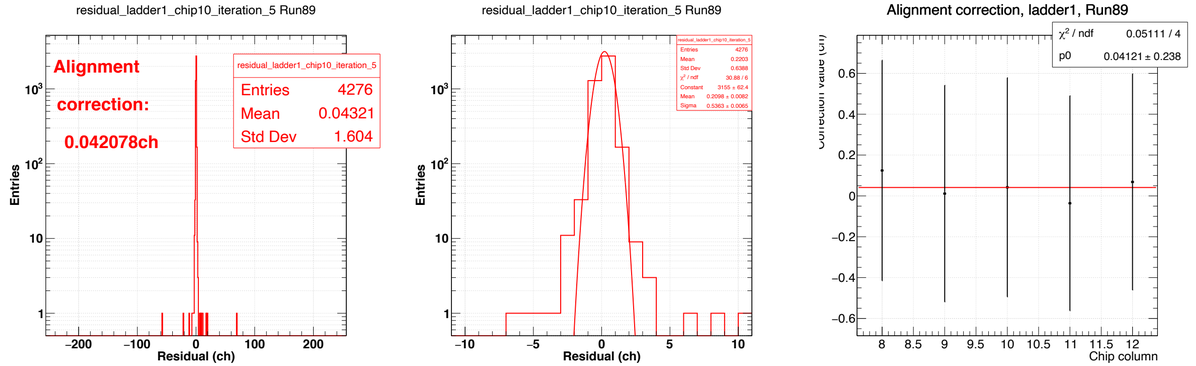
ELPH data

MC data

$\Delta_1 = ch_1 - ch_{1,tracking}$

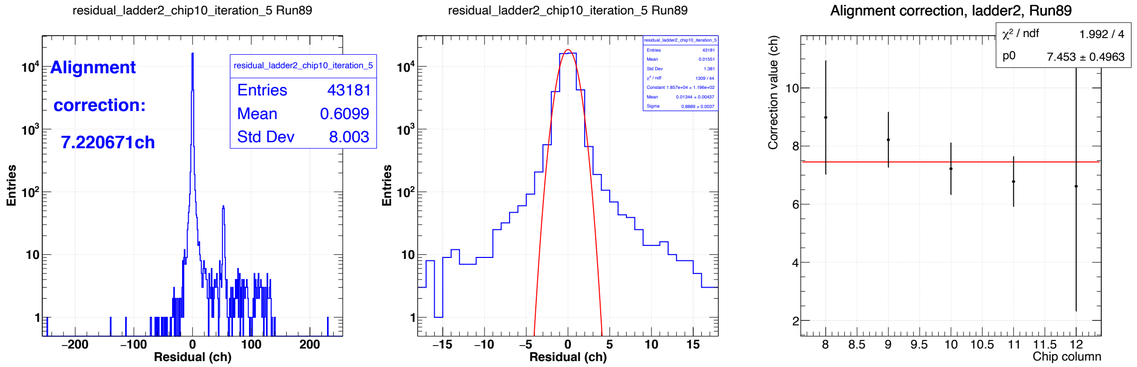


shifted by -3.62ch

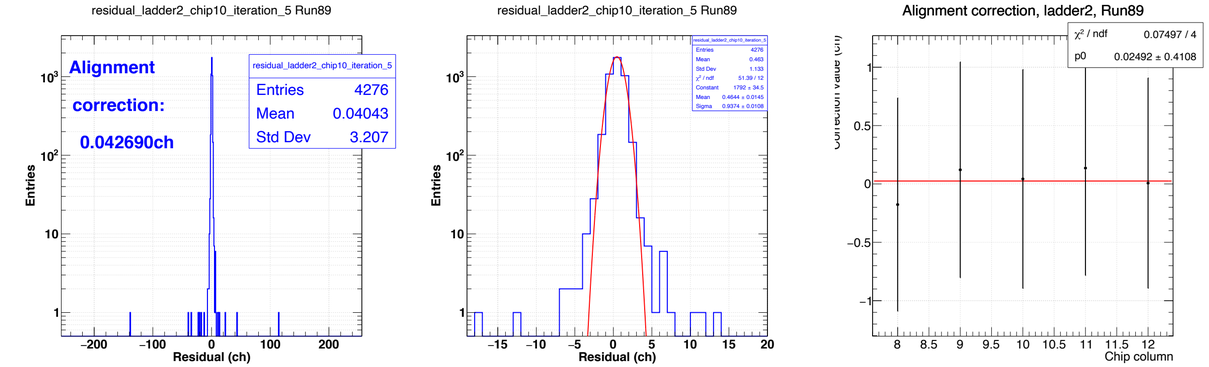


shifted by 0.04ch

$\Delta_2 = ch_2 - ch_{2,tracking}$



shifted by 7.22ch



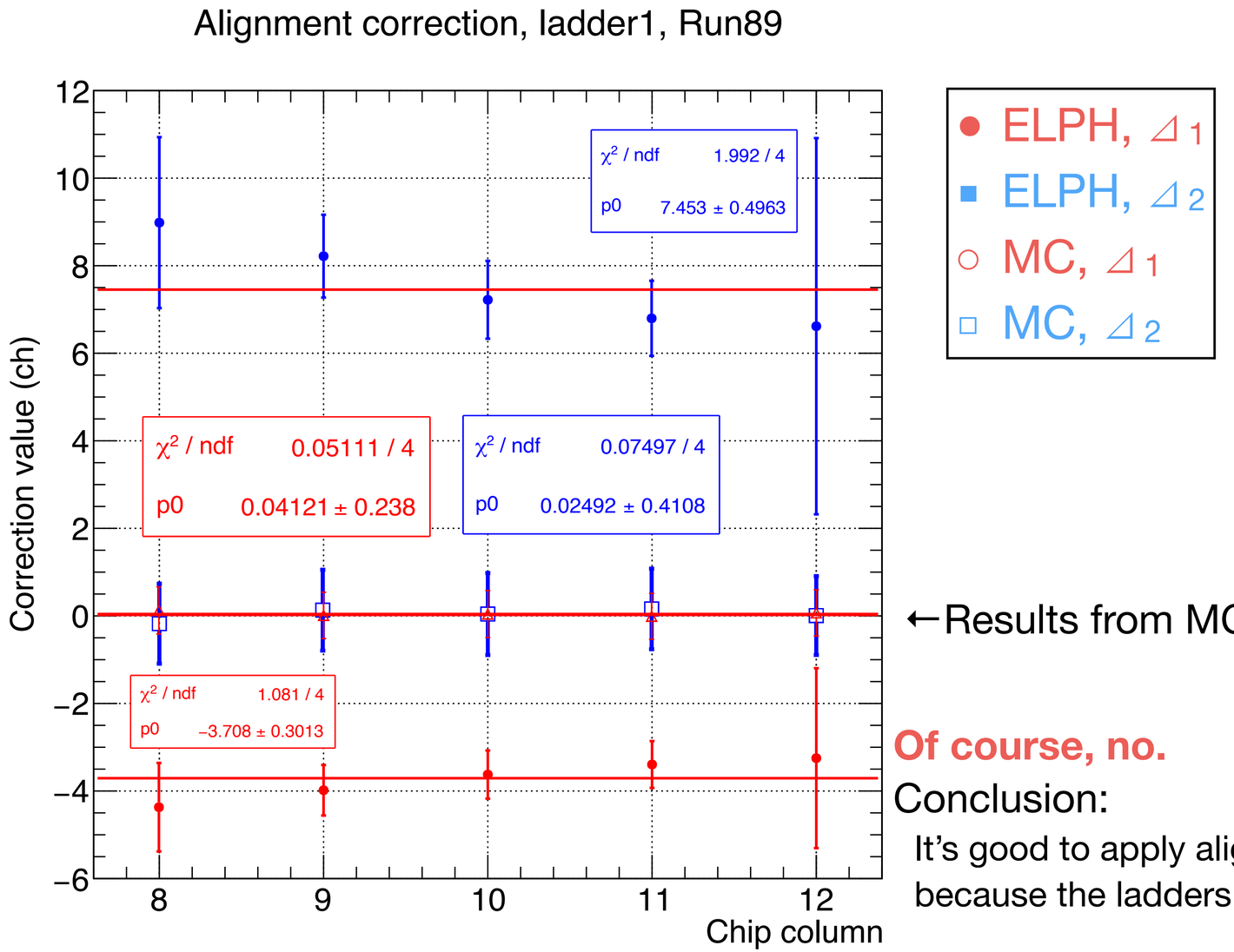
shifted by 0.04ch

note: Event matching of MC truth and INTT hit is not ready…
No time for that. Possible after QM22.

Residual, the simplest way

$$\Delta_1 = ch_1 - ch_{1,tracking} = ch_1 - \frac{ch_0 + ch_2}{2}$$
$$\Delta_2 = ch_2 - ch_{2,tracking} = ch_2 - \{ch_1 + (ch_1 - ch_0)\} = ch_2 - 2ch_1 + ch_0 \ (= \Delta_0)$$

Is the residual trend in MC data?



←Results from MC (overlapped)

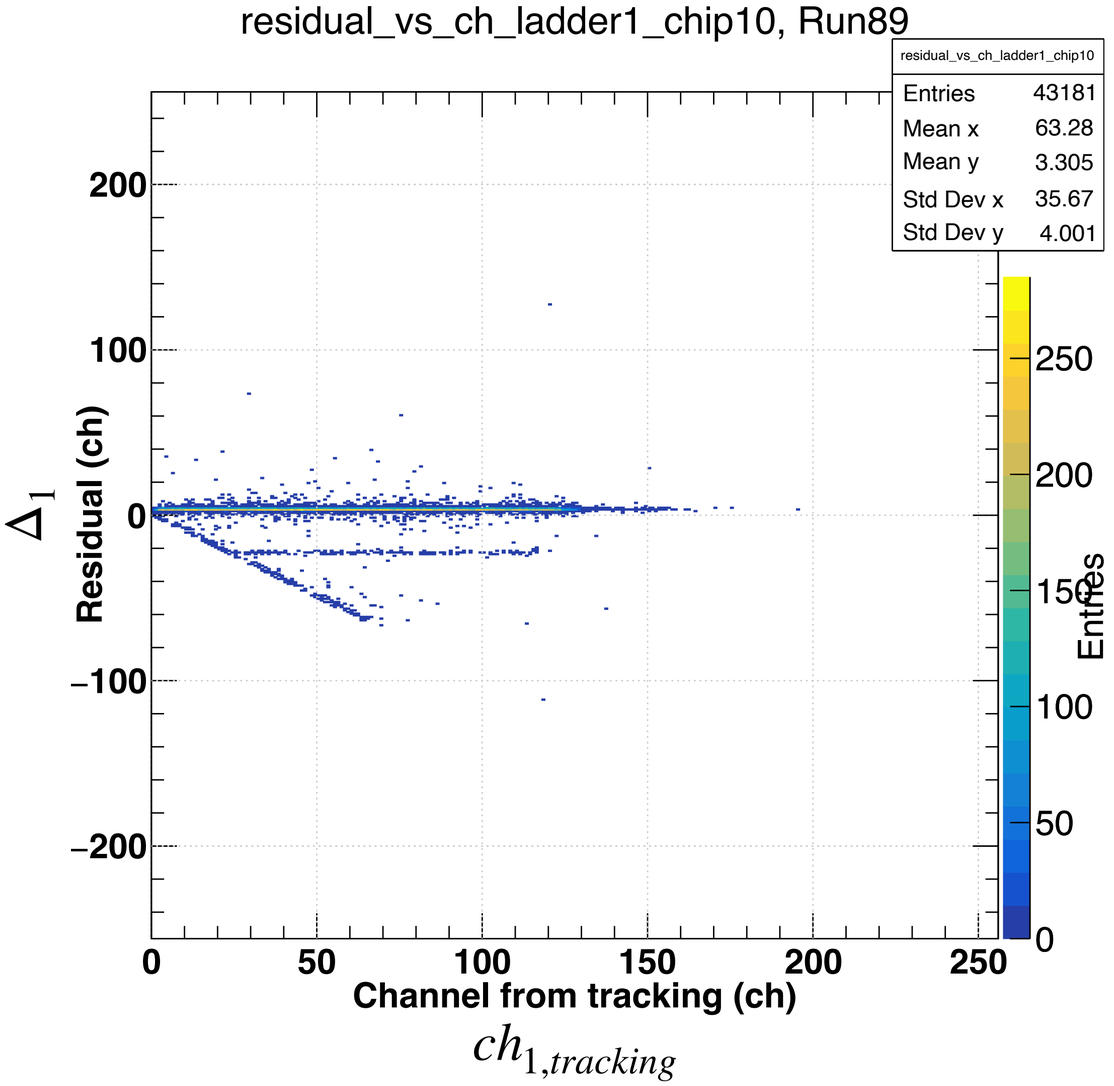
Of course, no.

Conclusion:

It's good to apply alignment correction chip by chip because the ladders are not aligned

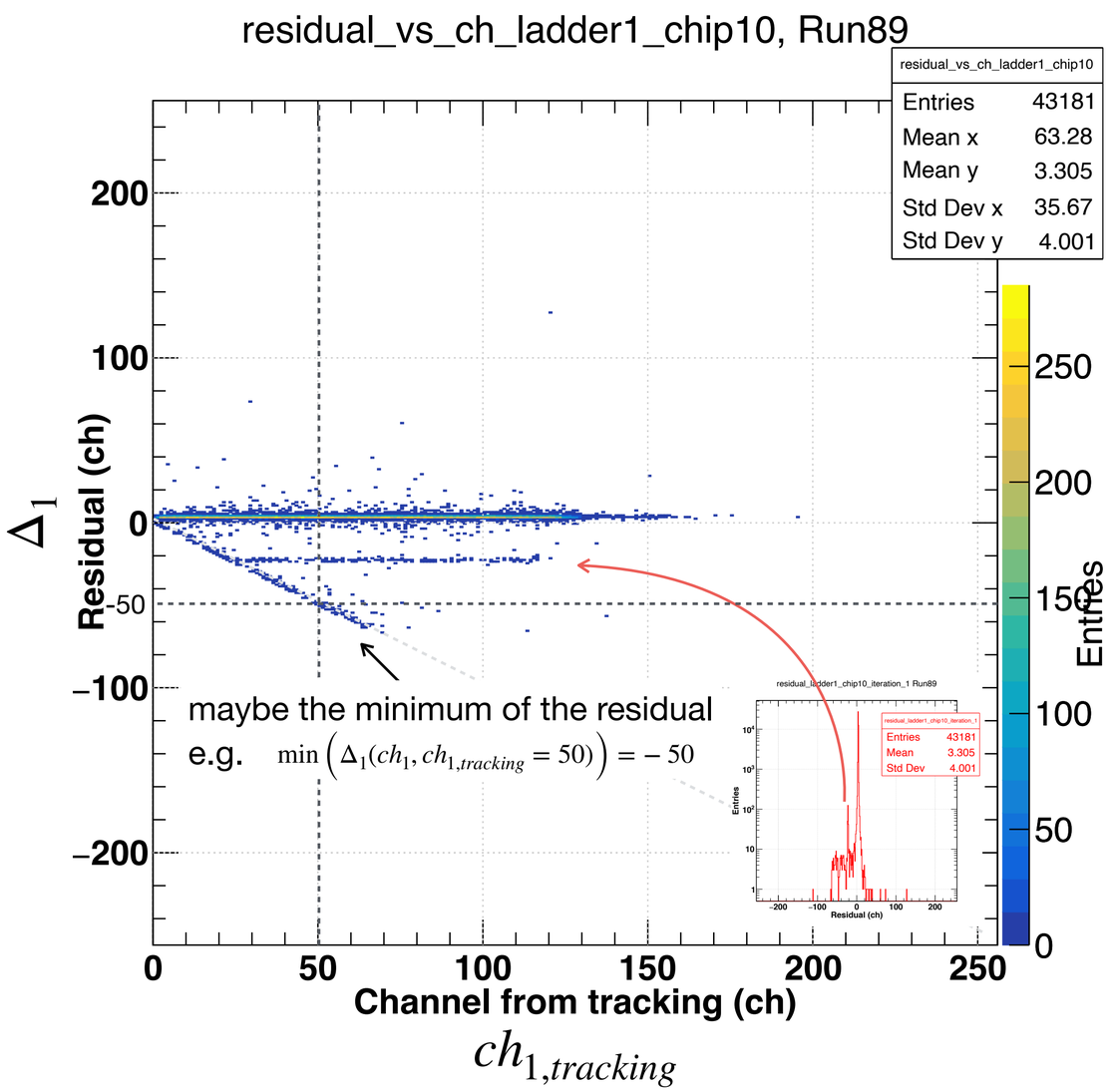
Residual, the simplest way, channel dependence

It’s possible to get the residual as a function of channel.
Run89, chip10, residual for ladder 1



Residual, the simplest way, channel dependence

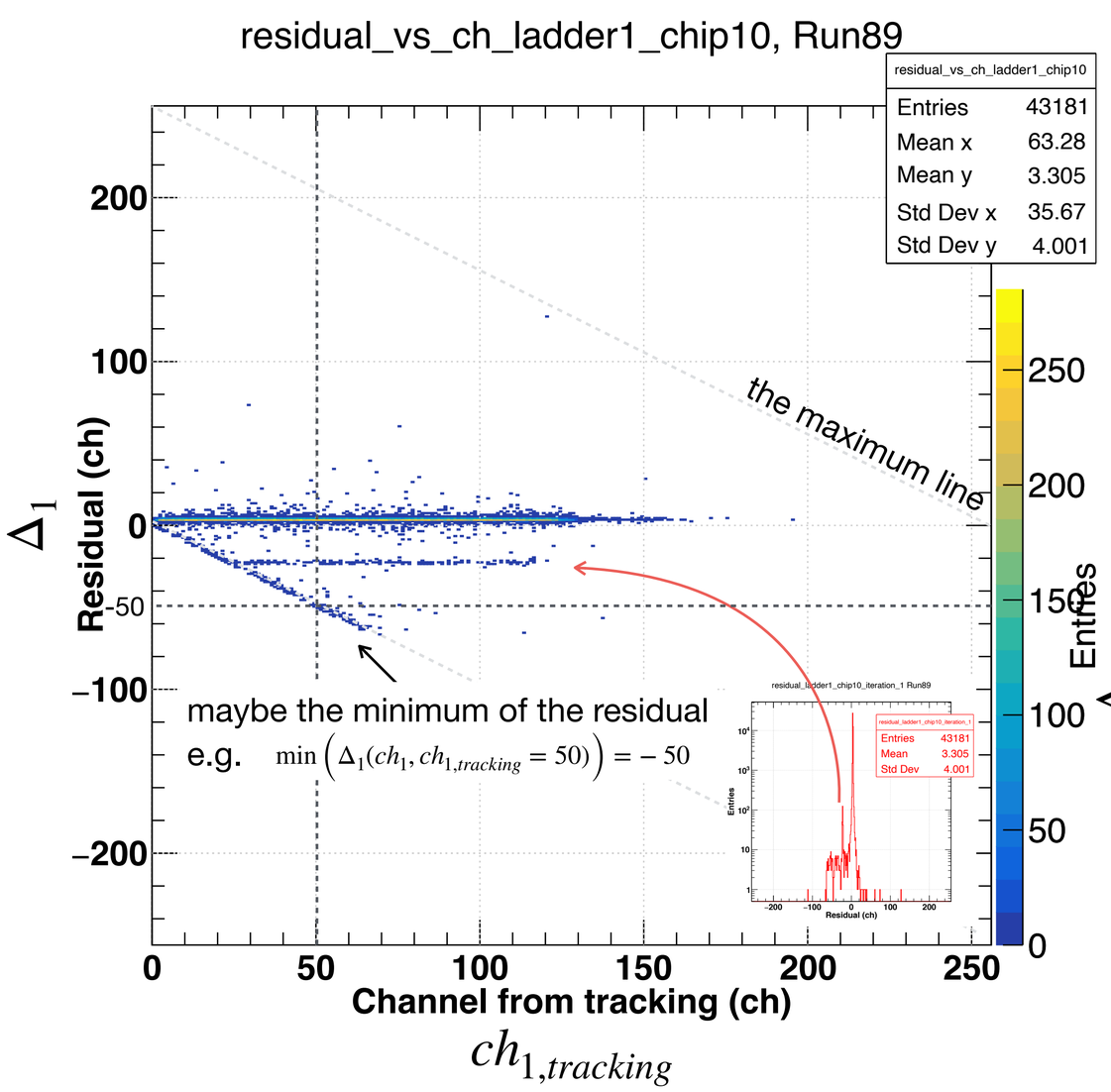
It’s possible to get the residual as a function of channel.
Run89, chip10, residual for ladder 1



The minimum line: $\Delta_i = 0 - ch_{i,\,tracking}$
→ Noise hit at ch = 0 of a chip in the lower row

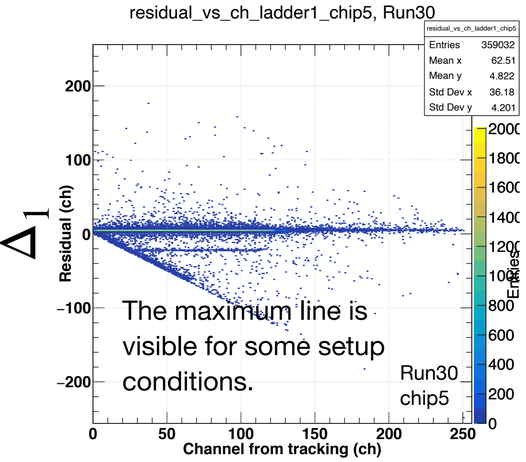
Residual, the simplest way, channel dependence

It’s possible to get the residual as a function of channel.
Run89, chip10, residual for ladder 1



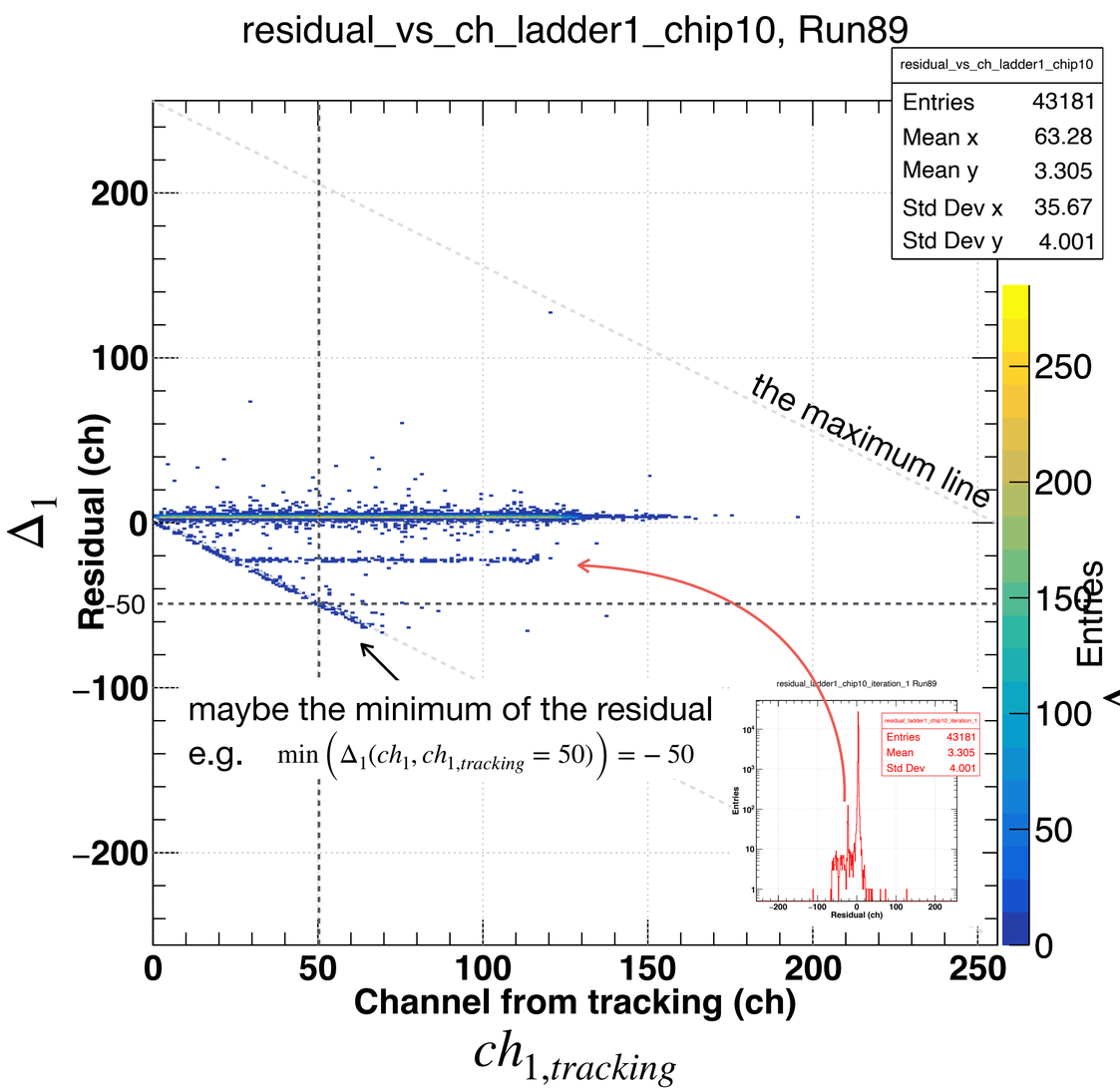
The minimum line: $\Delta_i = 0 - ch_{i,\,tracking}$
→ Noise hit at ch = 0 of a chip in the lower row

The maximum line: $\Delta_i = 255 - ch_{i,\,tracking}$
→ Noise hit at ch = 127 of a chip in the upper row



Residual, the simplest way, channel dependence

It's possible to get the residual as a function of channel.
Run89, chip10, residual for ladder 1



The minimum line: $\Delta_i = 0 - ch_{i,\,tracking}$
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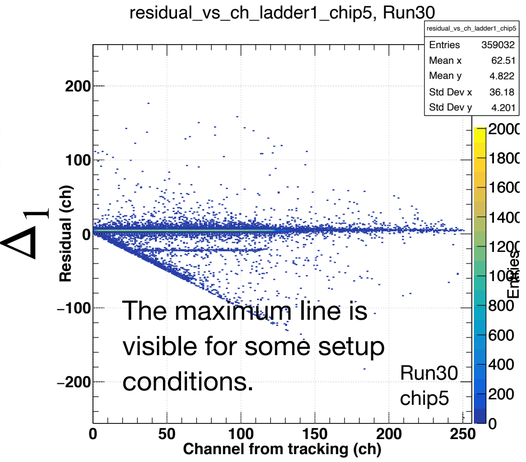
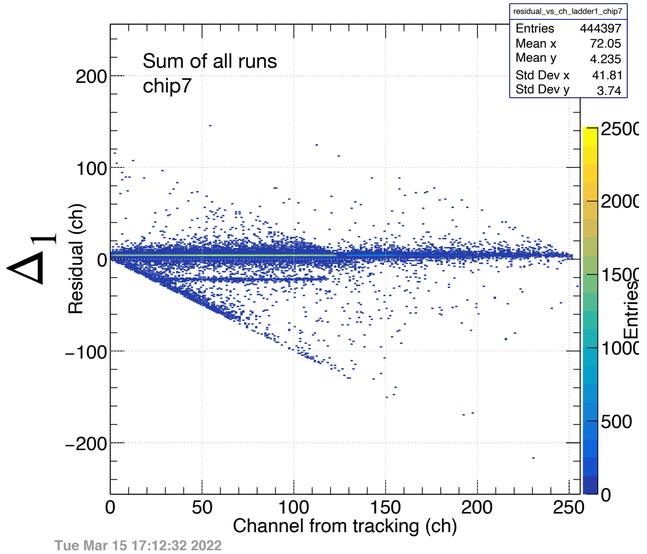
The maximum line: $\Delta_i = 255 - ch_{i,\,tracking}$
→ Noise hit at ch = 127 of a chip in the upper row

It means 2 more lines due to
noise at ch = 127 of a chip in the lower row → $\Delta_i = 127 - ch_{i,\,tracking}$
noise at ch = 0 of a chip in the upper row → $\Delta_i = 128 - ch_{i,\,tracking}$
should exist. 2 lines are probably degenerated.





Yes, another line(s) is visible.
It can be used to reject noise hits.

Residual, the simplest way, channel dependence

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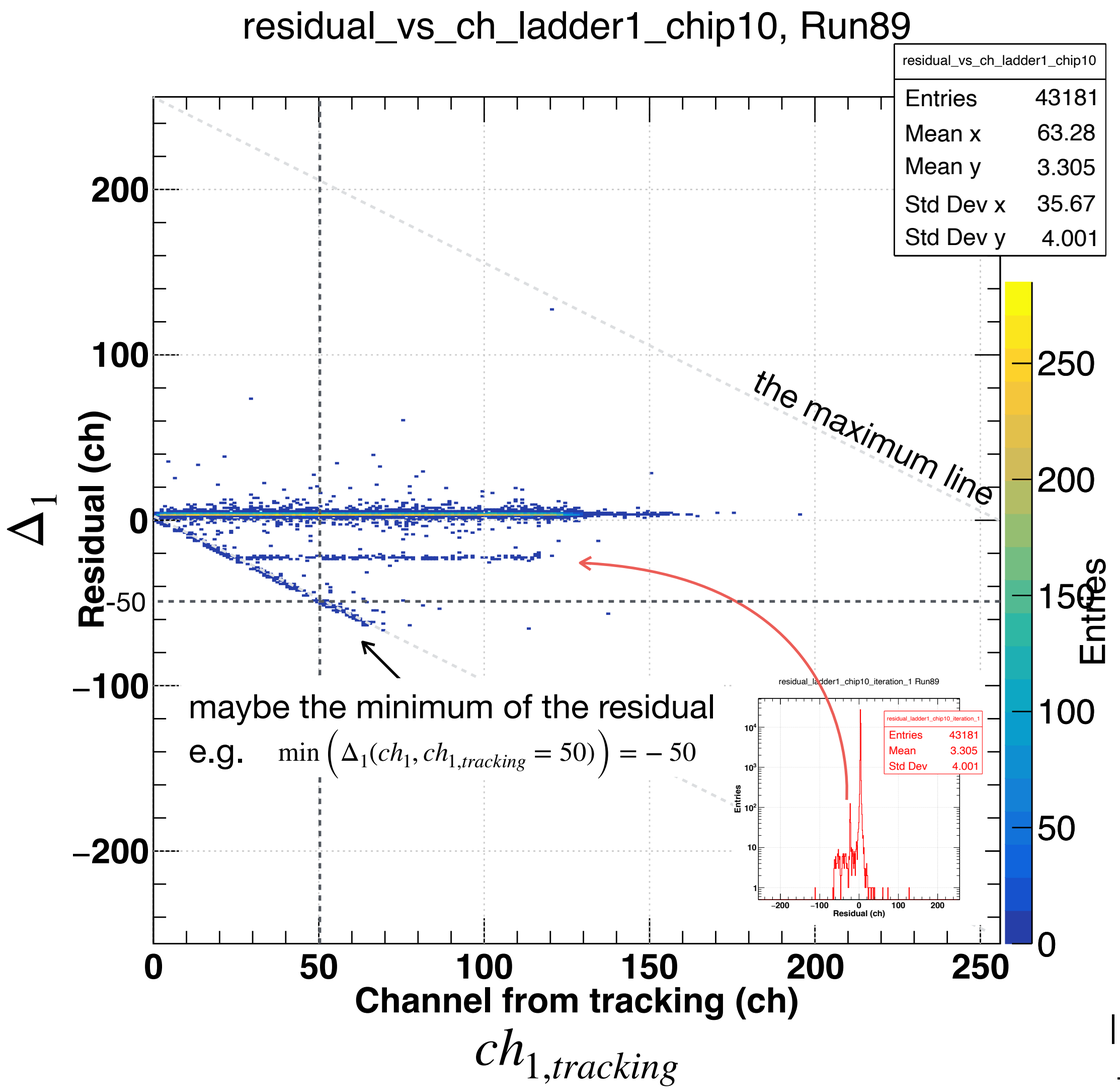
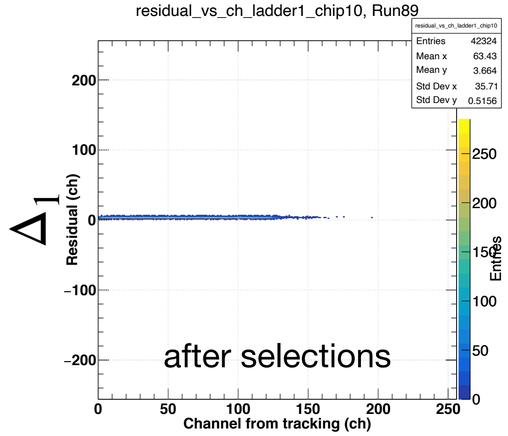
Run89, chip10, residual for ladder 1

$$\Delta_1 = ch_1 - ch_{1,tracking} = ch_1 - \frac{ch_0 + ch_2}{2}$$
$$\Delta_2 = ch_2 - ch_{2,tracking} = ch_2 - \{ch_1 + (ch_1 - ch_0)\} = ch_2 - 2ch_1 + ch_0 \ (= \Delta_0)$$





$$|\Delta_1| < 20$$
$$\rightarrow \ \langle ch_{1,tracking} \rangle - 3\sigma < ch_{1,tracking} < \langle ch_{1,tracking} \rangle + 3\sigma$$

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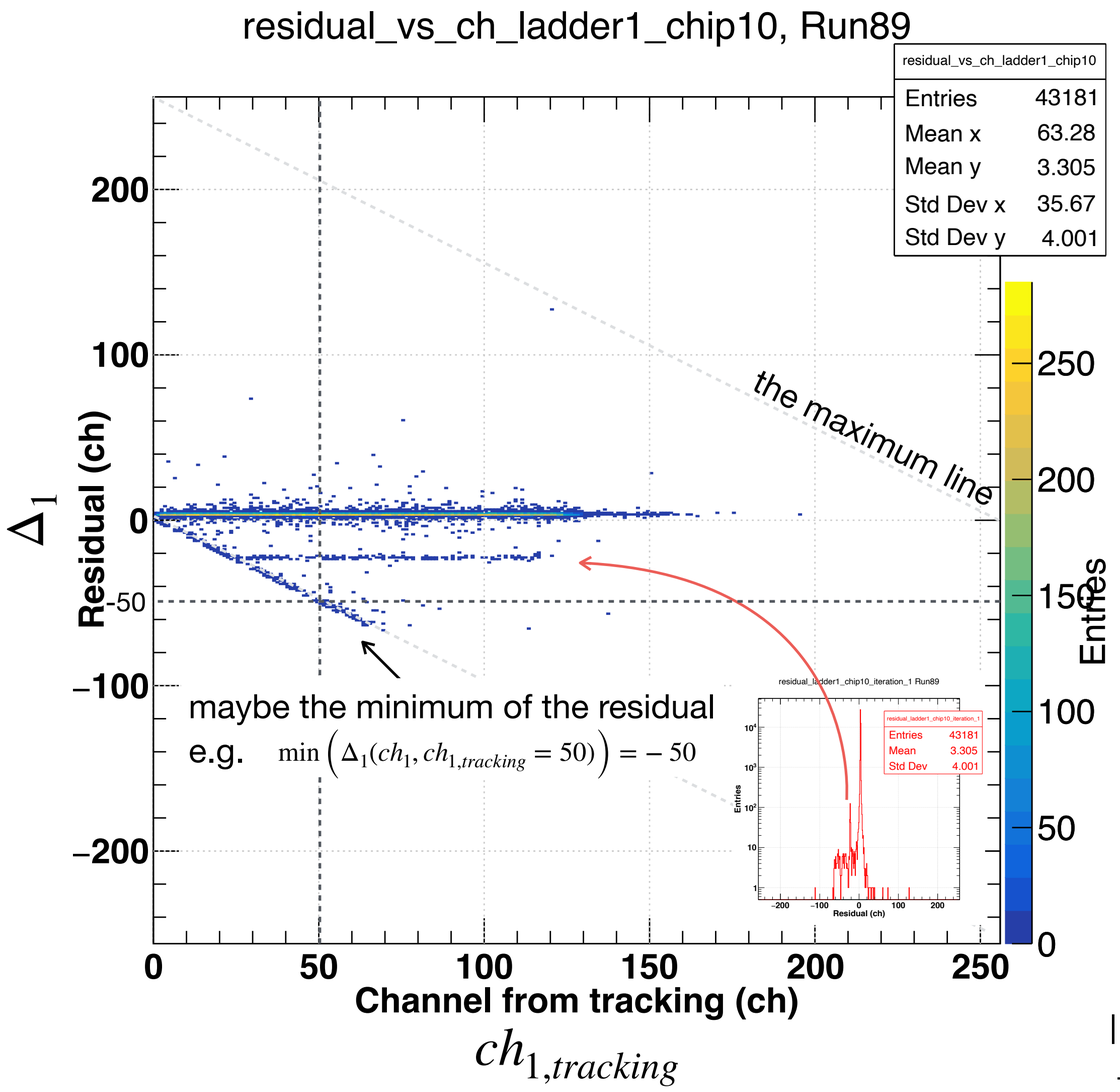
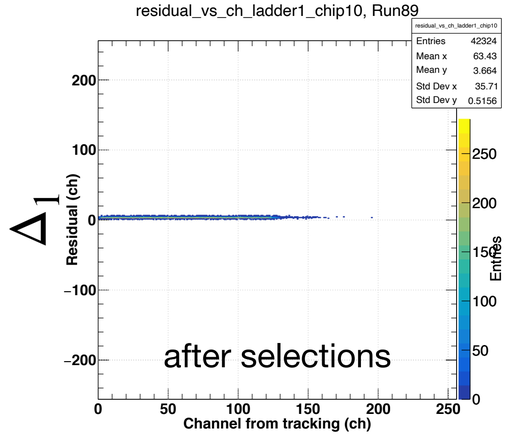
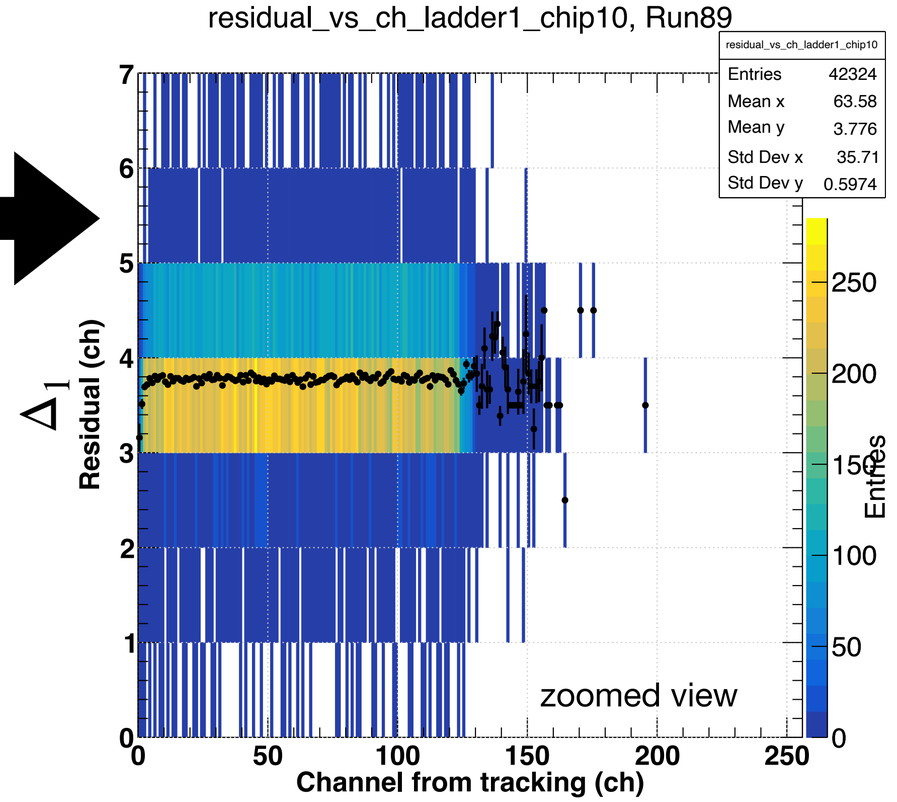


Event selections
around mean values





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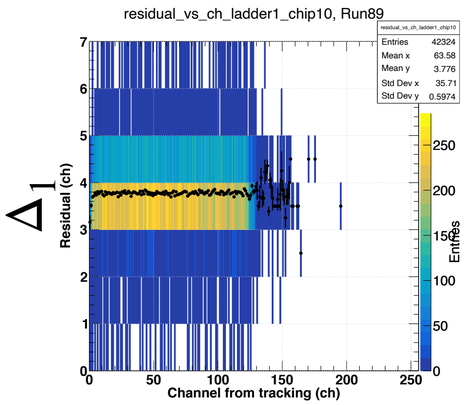
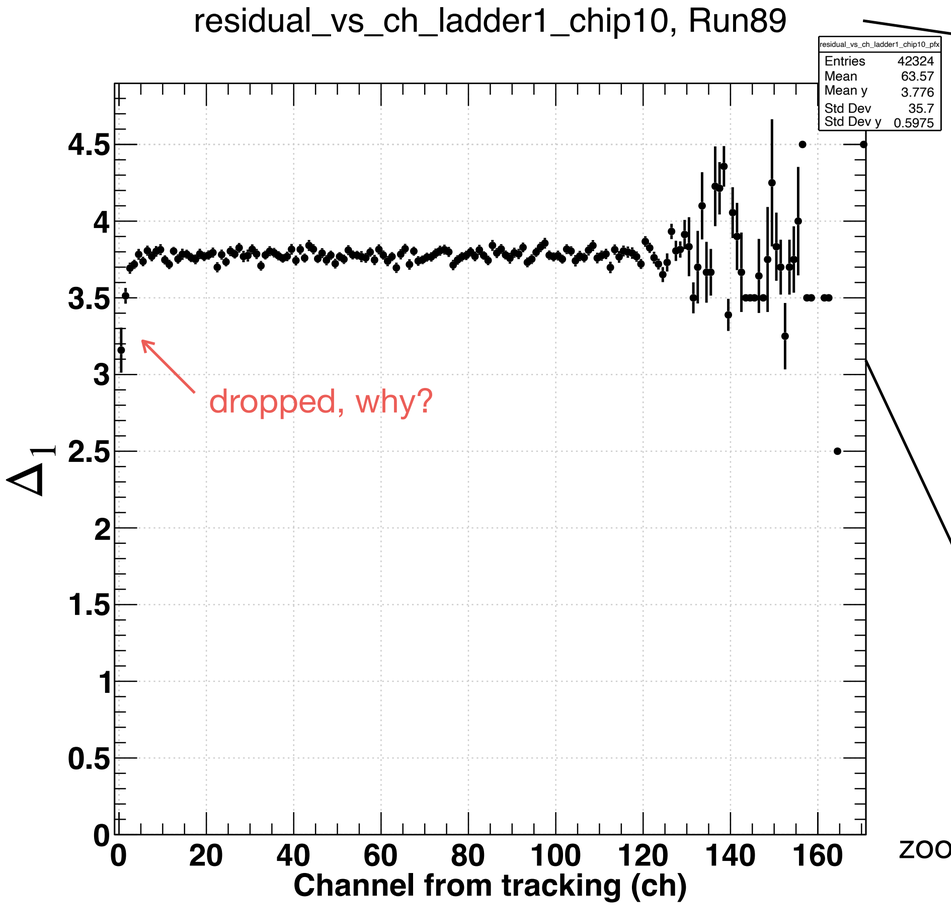
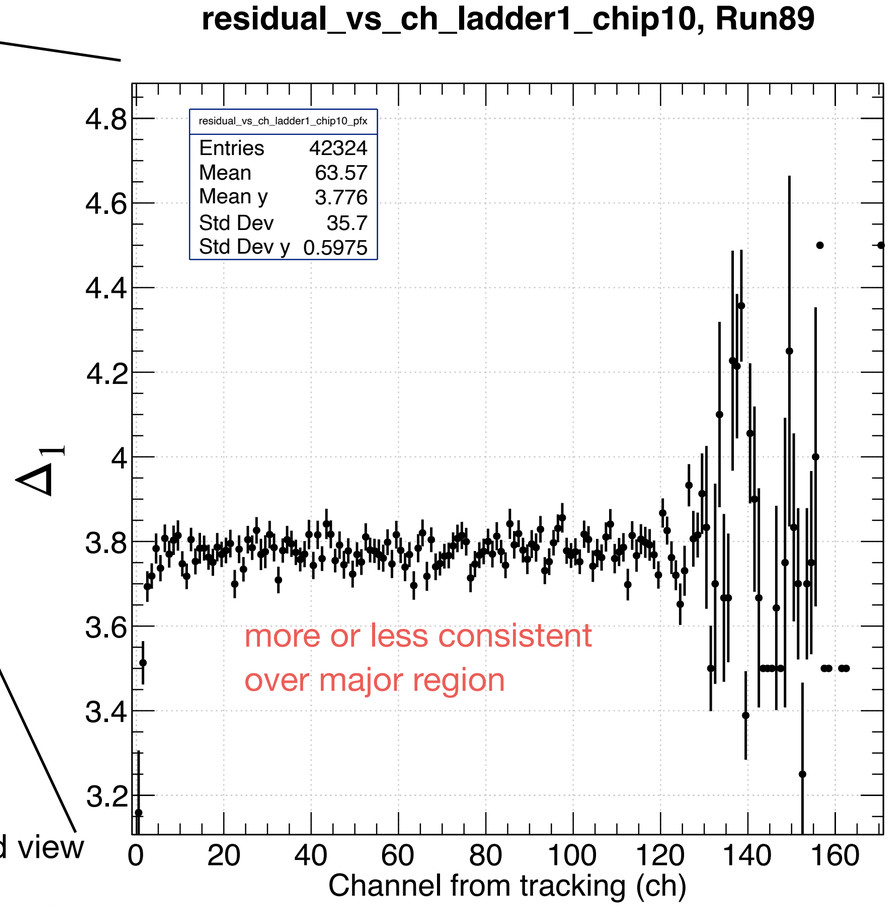




zoomed view



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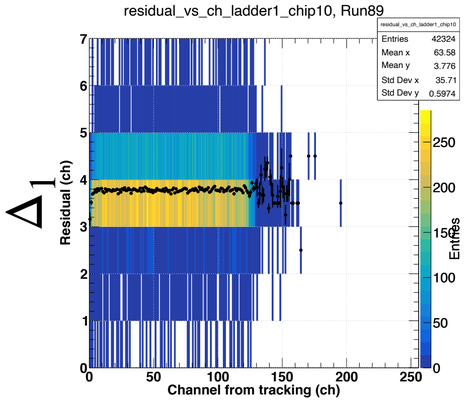
Residuals don’t depend on channel basically.

Residual, the simplest way, channel dependence

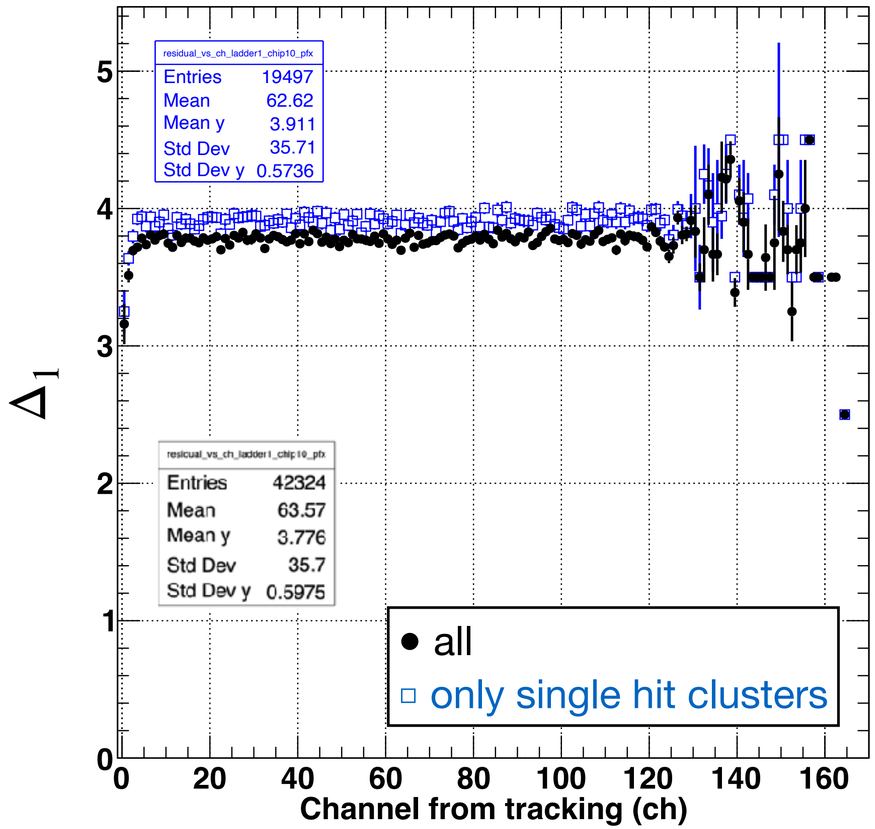
The residual distribution can be divided into bins of

- ADC (or DAC value)
- cluster size
- #ADC channel in a cluster (e.g. no ADC 0)
- ID of BCO group

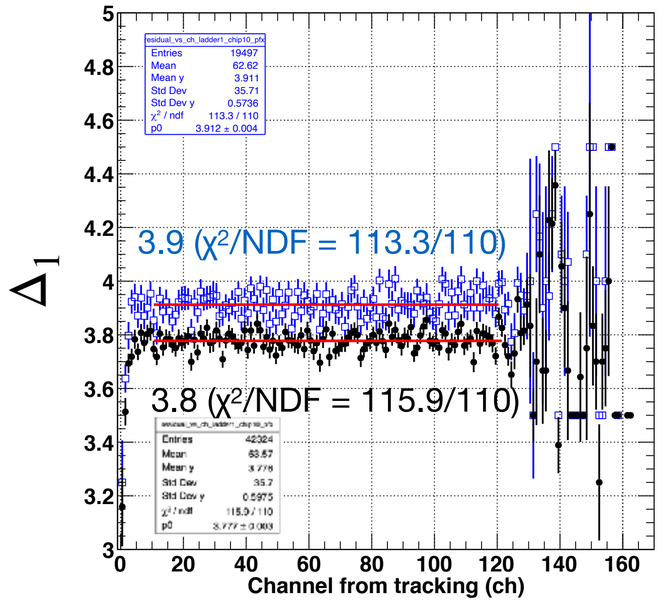
residual_vs_ch_ladder1_chip10, Run89



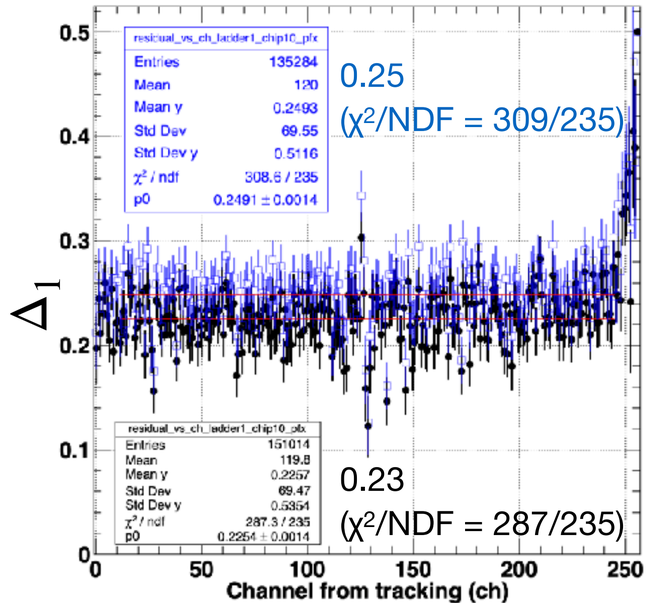
residual_vs_ch_ladder1_chip10, Run89



residual_vs_ch_ladder1_chip10, Run89



Run89



MC data
(different beam condition)

note: The ranges of y-axis are different.
← It means rapid increase of ch_1.

The same level of the difference was found in MC data as well.
It's due to my algorithm?
Anyway, the selection of single hit clusters are not affected by clustering algorithm.

Conclusion

The jump in the channel distributions

- Rejections of clusters with low DAC values tend to select noise hits, but the jumps are still remain.

Residual

- The simplest method was tested.
- Chip dependence was found.
  → Alignment correction depending on chip should be fine.
- No channel dependence was found.
  → Good.
- Hits on the tested ladder independent from expected hit position from tracking, mainly at ch 0 and 127, create flat residual distribution.
- Cluster size dependence was found.
  → The election of single hit clusters must be safe.
- Tests with MC data also performed. These are nice reference.