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Concerns In The 2021 Beam Test Results And Cosmic Ray Measurement

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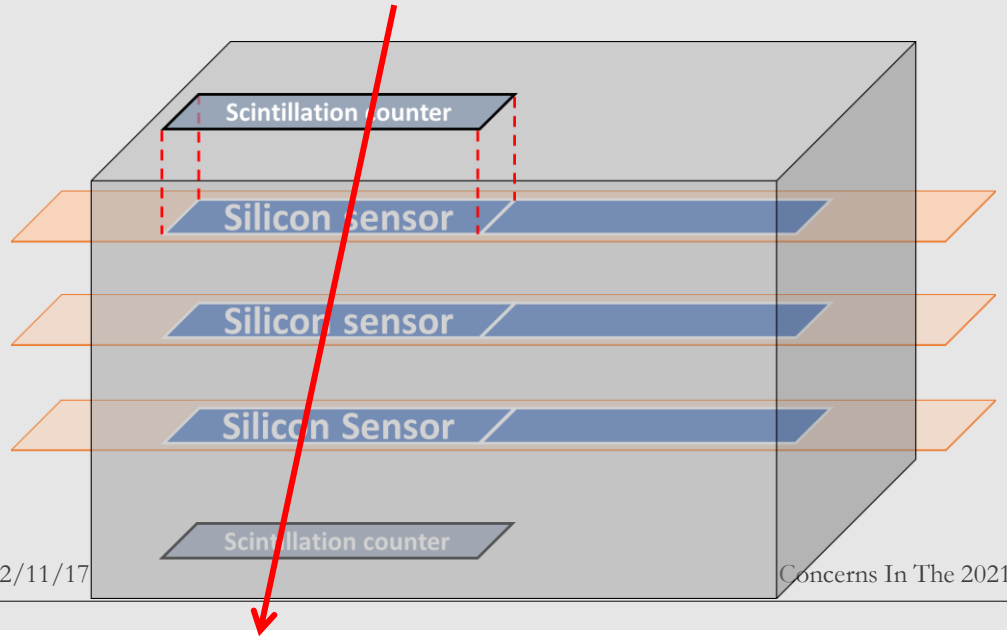
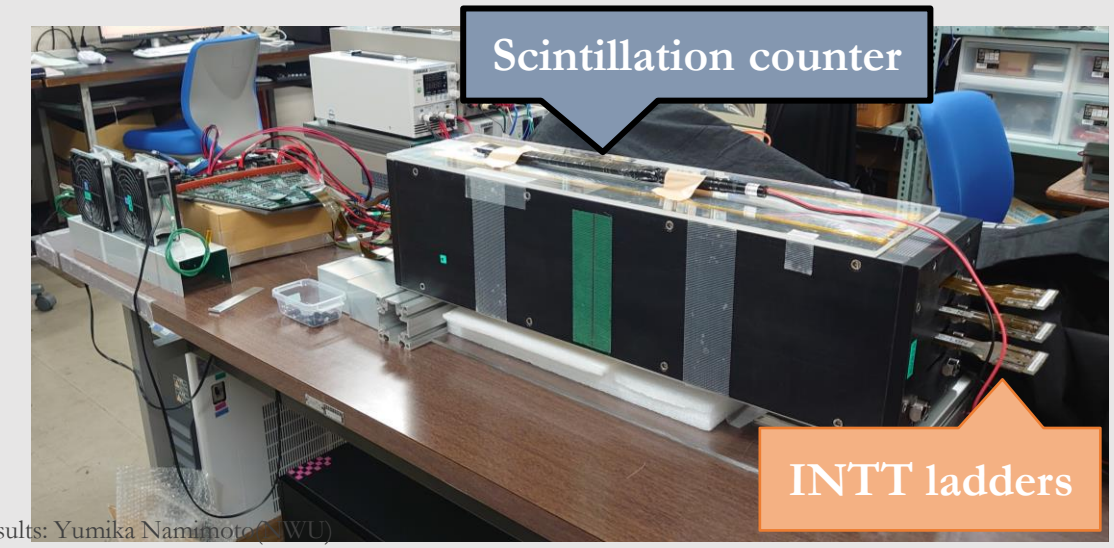
Introduction

- Last December, INTT JP team did the beam test at Tohoku univ. in Japan.
- Purpose: 1. Measure the INTT efficiency.
  2. Confirm the effects of BCO on efficiency.
- We got 99% detection efficiency, but we couldn't confirm that effects of BCO efficiency.
- Therefore we should do cosmic measurements to confirm the BCO effects.
- We calculate the efficiency by using cosmic data at present.

Setup in NWU

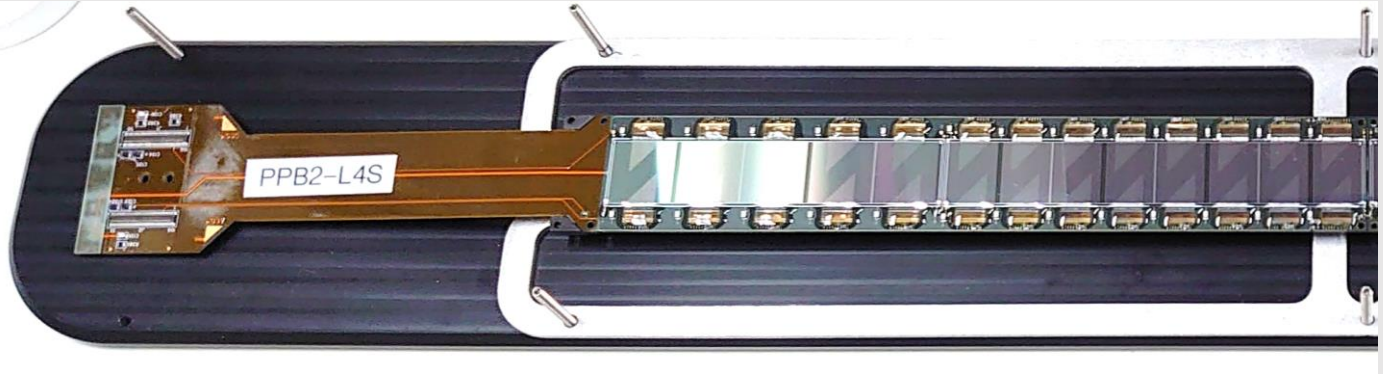
- We use 3 ladders for cosmic measurements. (Upper: Taiwan ladder HDI No.256, middle: PPB2-L5, lower: PPB2-L6)
  - Setup is same as beam test.
- Trigger: 2 scintillators

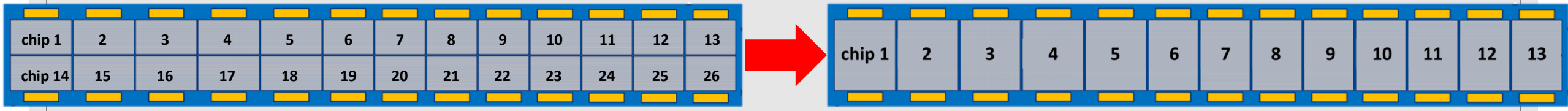




Numbering of chips and channels (in this analysis)

- Actually an INTT silicon sensor ladder consists of 2 half ladders.
- A half ladder has 26 readout chips therefore its sensors divide 26 areas, but in this analysis we group 2 arranged vertically areas into 1 area.

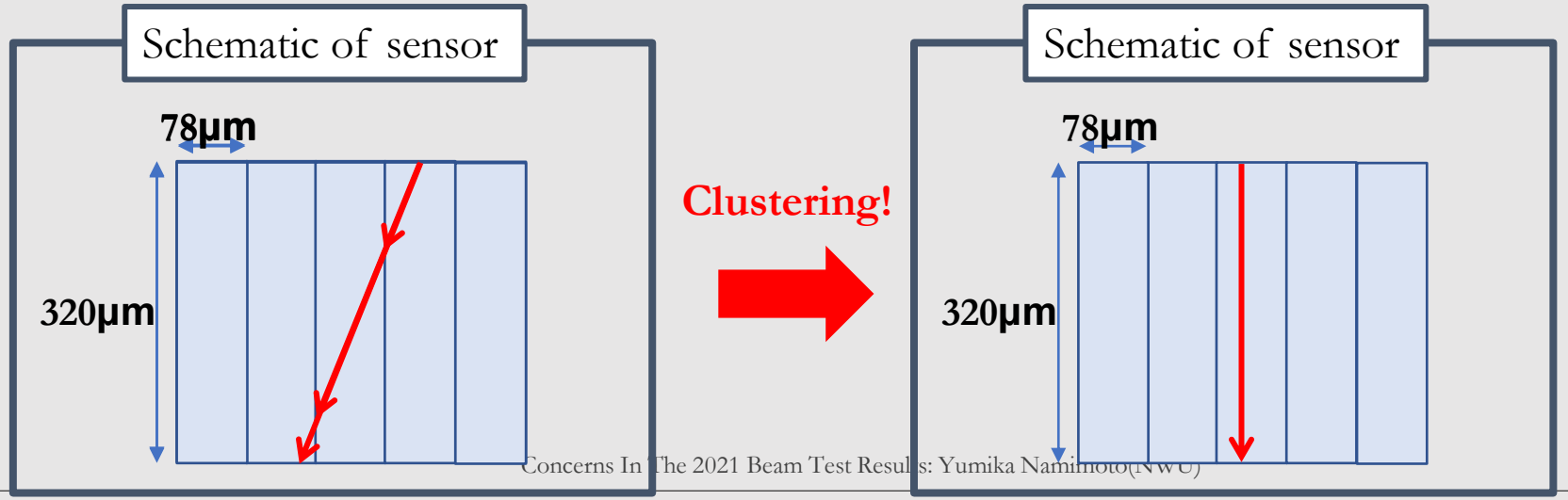




Clustering

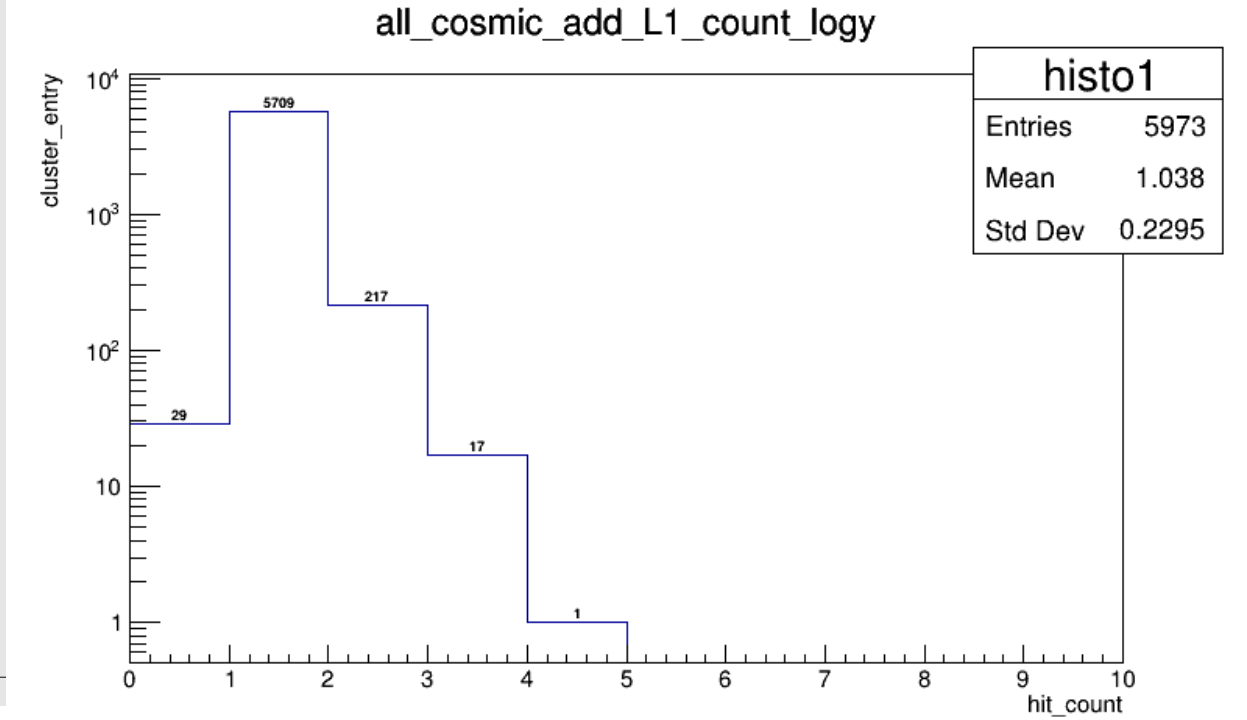
- Some cosmic rays go through multiple strips. Therefore we did clustering.
- Process:

1. Group cosmic rays hits if they come same timing.
2. Separate those hits every ladders, chips.
3. If those hits go through adjoining strips, calculate average strip position weighting by ADC value.



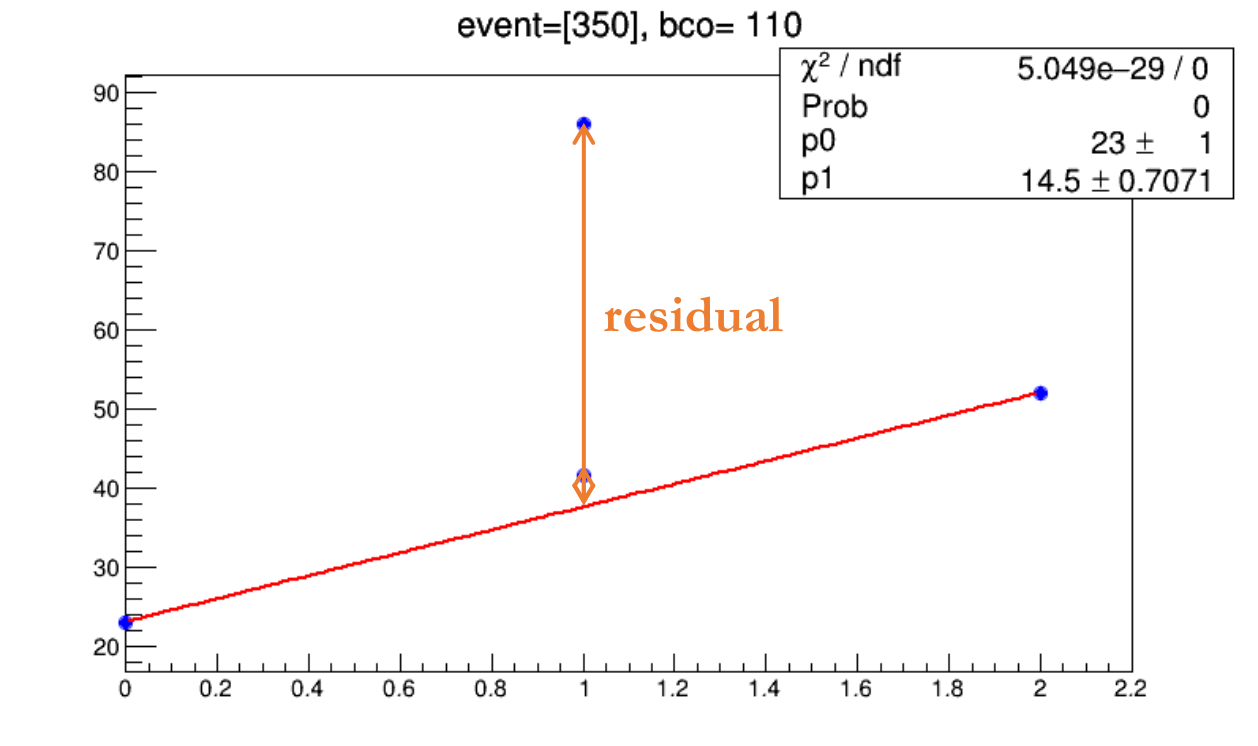
Number of clusters

- In middle ladder, almost of all cosmic ray hit consists of **1** cluster. But sometimes **2 or more** clusters are detected at same time.
- To confirm multiple clusters include cosmic ray or not, we compared the characteristic of multiple clusters.



Residual distribution

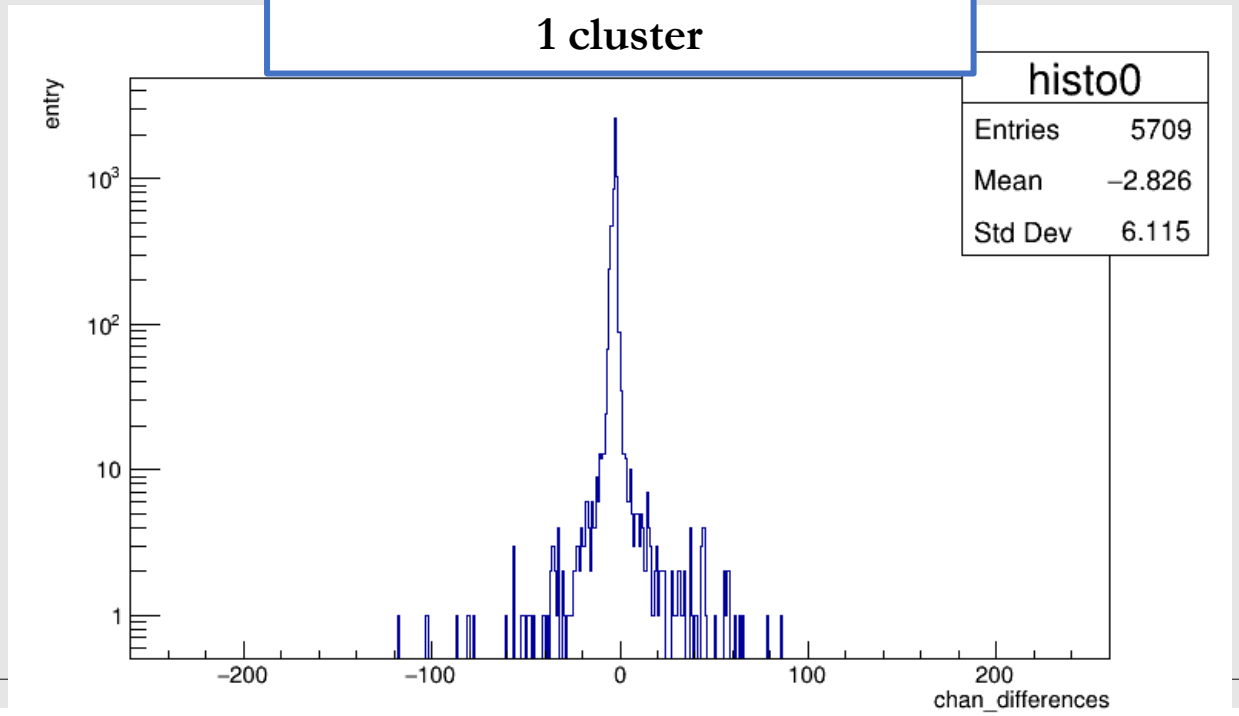
- We can estimate a ladder cluster position from the other 2 ladders tracking.
- Residual = (Expected position) – (Real position)



Residual distribution: middle ladder

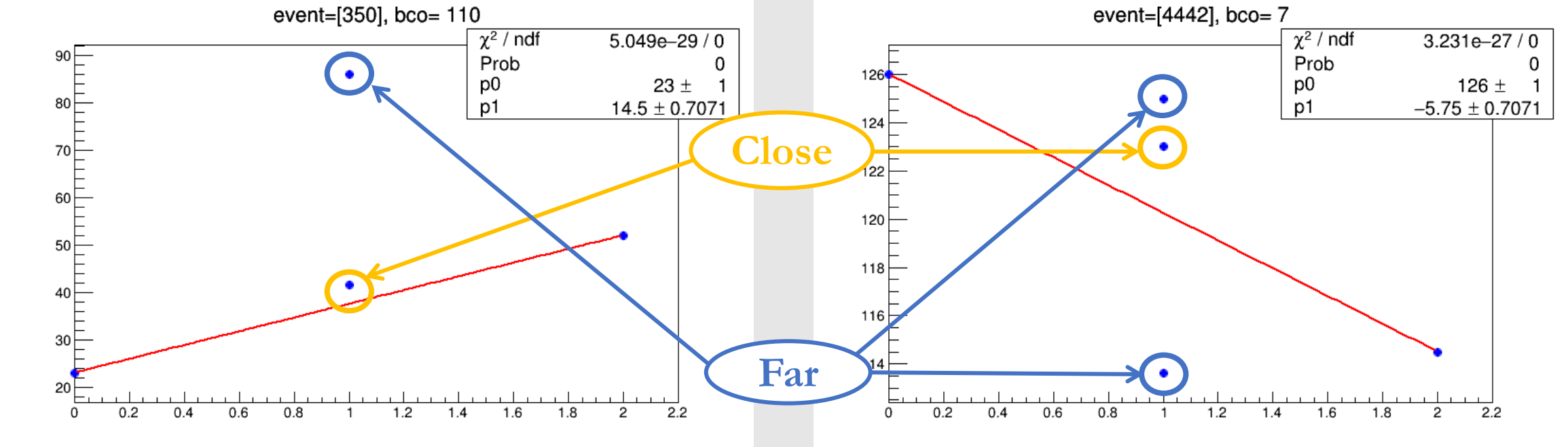
- We draw some residual distributions of middle ladder.
- If middle ladder detect **only 1** cluster, the residual distribution is below.

Middle ladder residual distribution:
1 cluster



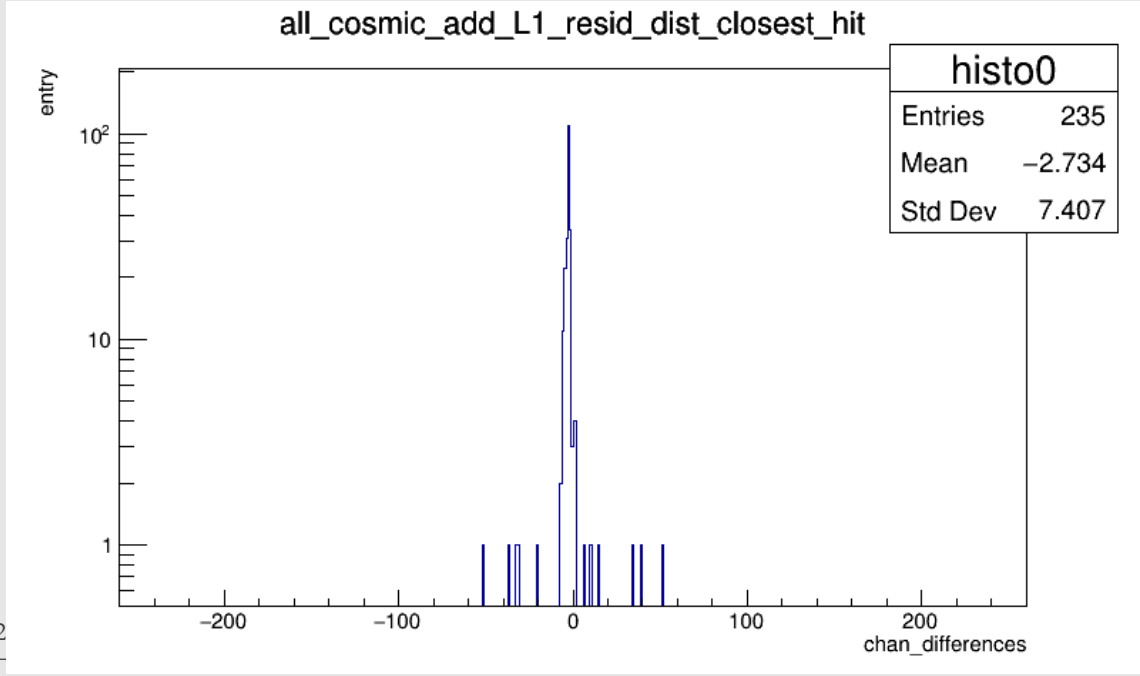
Residual distribution: middle ladder

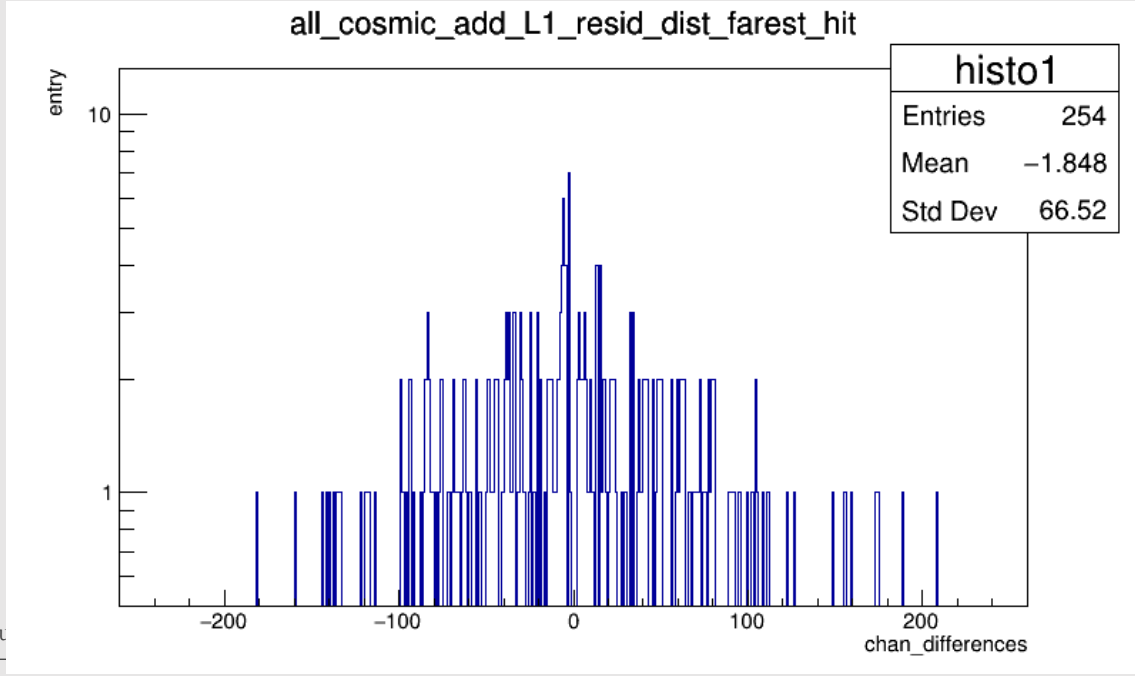
- If middle ladder detected multiple clusters, we separated clusters close to estimate position cluster and others.



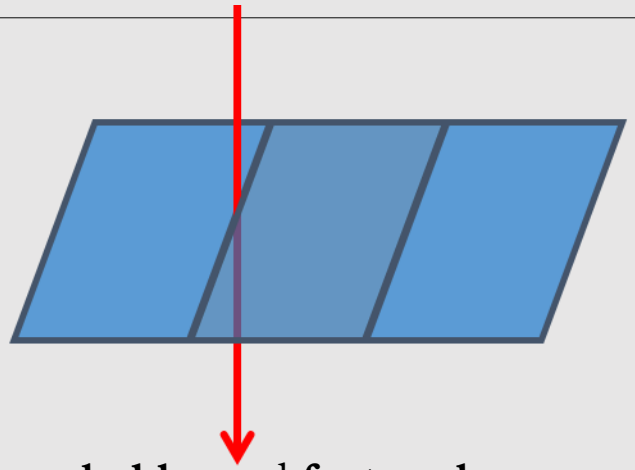
Residual distribution: middle ladder

- If middle ladder detected multiple clusters, we separated clusters close to estimate position cluster and others.
- Closest hit residual distribution is **left**, far hits residual distribution is **right**.
- Closest hit shows sharp peak and others show wide distribution.

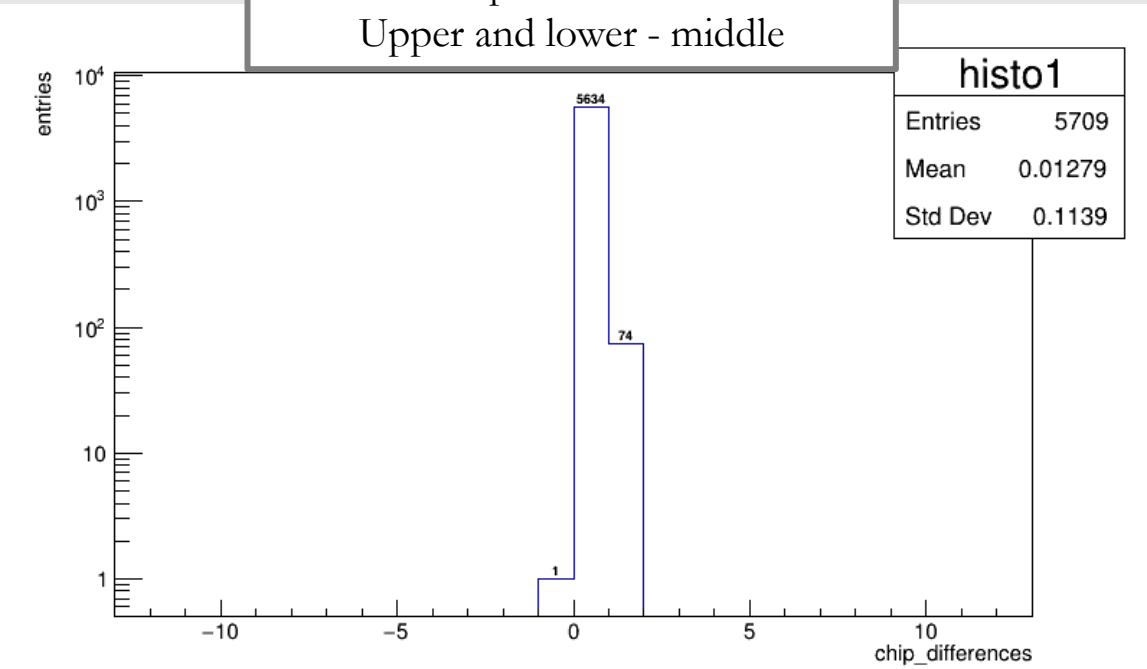




Chip differences

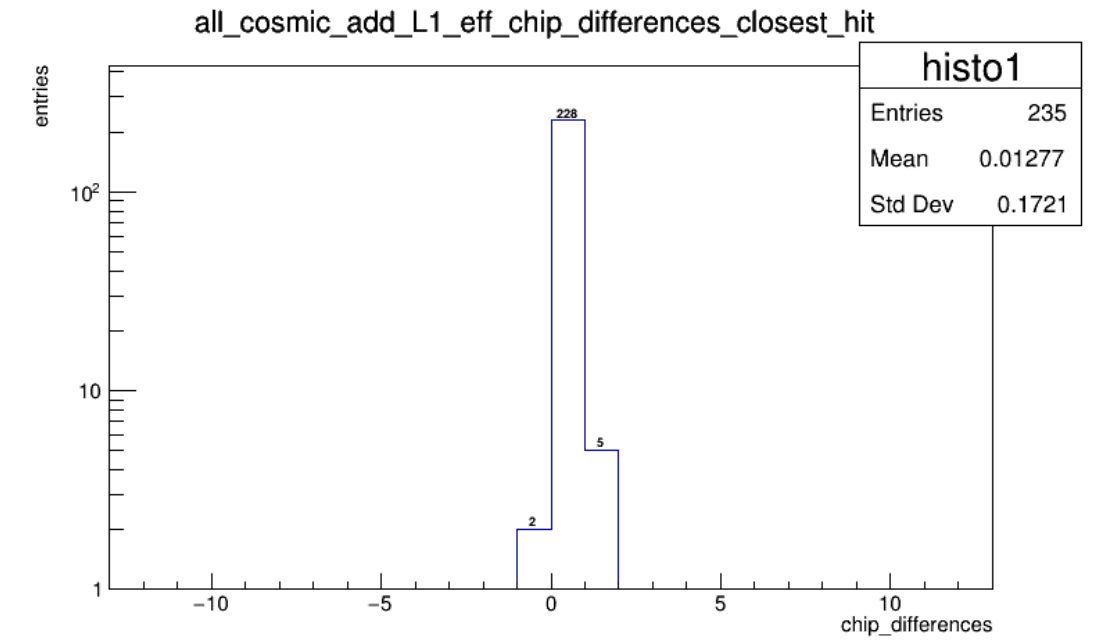


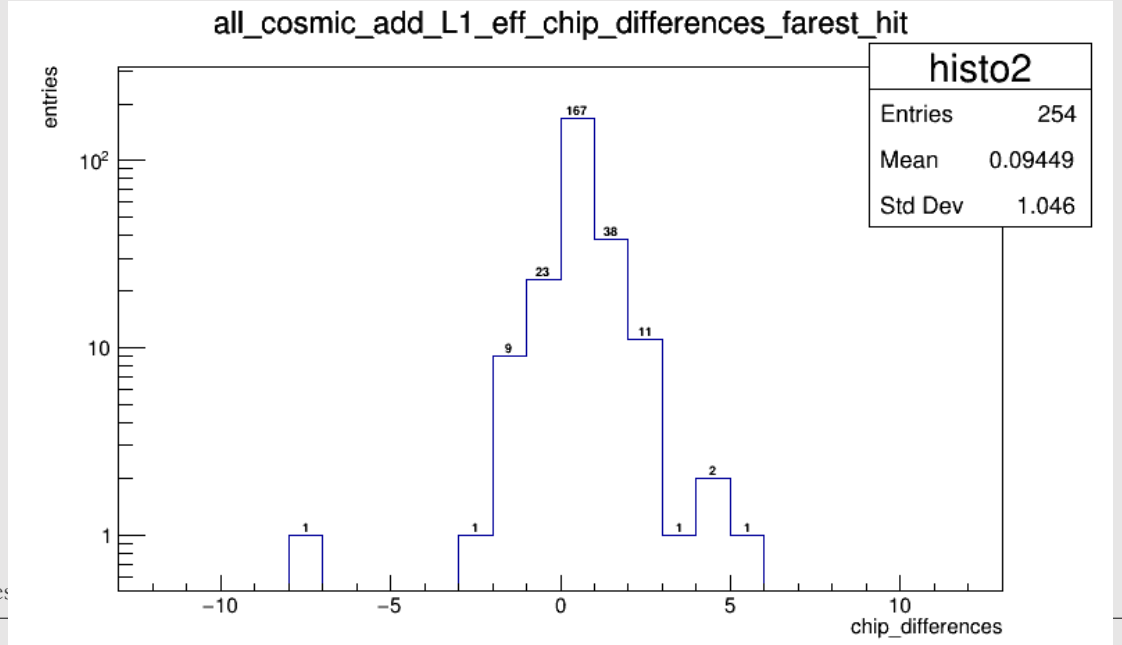
- If cosmic rays go through between chips, it is detected in 2 chips.
- When all ladders detected only **1** cluster each, chip number differences between **base ladder** and **featured ladder** show below.
- Only 1 cluster chip differences fit into ± 1 chips.



Chip differences: multiple clusters

- When middle ladder detected multiple clusters, we separated clusters close to estimate position cluster and others like residual distribution analysis.
- Left: closest clusters chip differences. Right: Other clusters chip differences.
- Closest clusters differences are fit into ± 1 chips, but other clusters show wide distribution.





ADC distribution

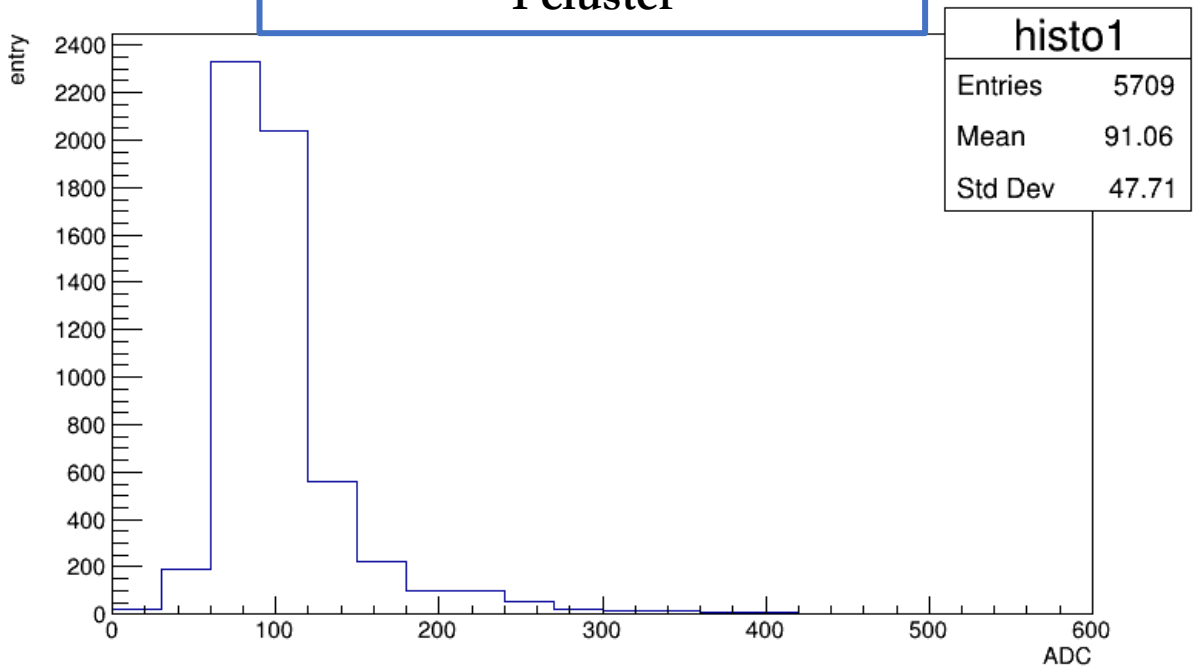
- We can set threshold by DAC value in GUI. The transformation formula is: $\mathrm{DAC} \times 4 + 210\ (\mathrm{mV})$
- In clustering process, we did adding up ADC value therefore it is possible clusters have over 210 ADC value.

	DAC setting	Voltage(mV)
DAC 0	15	270
DAC 1	30	330
DAC 2	60	450
DAC 3	90	570
DAC 4	120	690
DAC 5	150	810
DAC 6	180	930
DAC 7	210	1050

ADC distribution

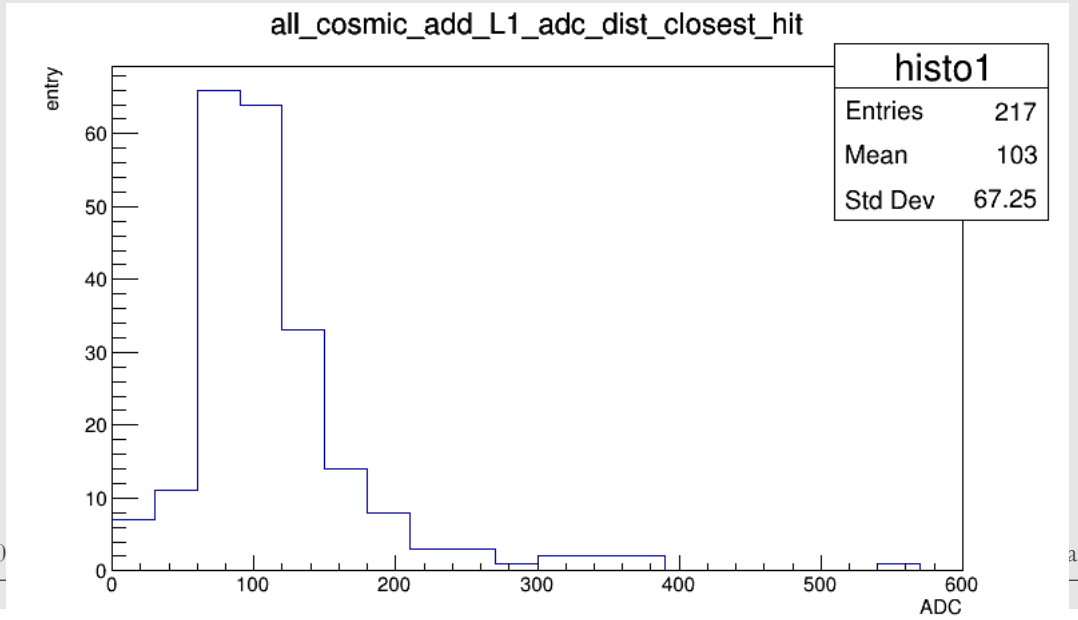
- Like residual distribution and chip differences, we analysis ADC distribution by only 1 cluster, multiple clusters closest one and others.
- In middle ladder detected only 1 cluster, the ADC distribution is below.
- We can find MIP peal in ADC 60 – 120 .

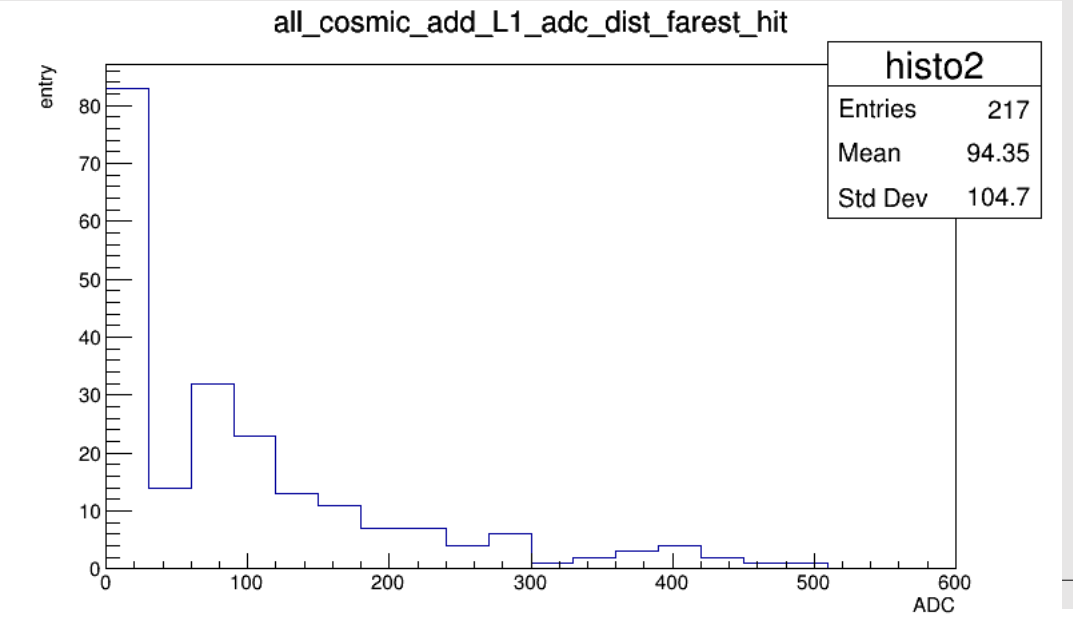
Middle ladder ADC distribution:
1 cluster



ADC distribution

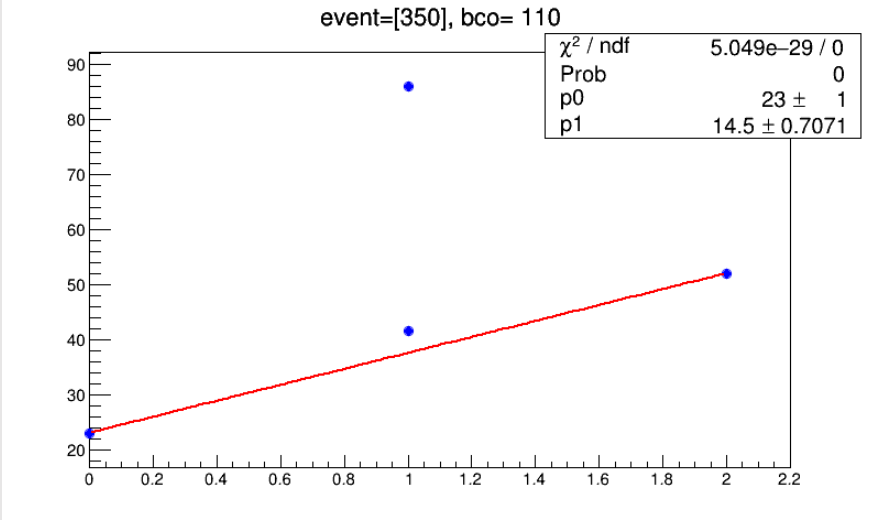
- Like residual distribution and chip differences, we analysis ADC distribution by only 1 cluster, multiple clusters closest one and others.
- Left: closest clusters ADC distribution. Right: other clusters ADC distribution.
- Left shows MIP peak in ADC 60-120 similarly to only 1 cluster but in right figure, lowest ADC value has most entries.





Clusters analysis: Result

- Because of residual distribution, chip differences and ADC distribution, multiple clusters include the true cosmic ray cluster.



- The characteristics of true cosmic ray cluster:
  - Sharp peak in residual distribution.
  - Fit chip differences in ± 1 chip.
  - MIP peak in ADC value 60-120.

- By these characteristics, we can develop some limitation to calculate the efficiency.

Definition of efficiency

- We call the ladder which calculate the efficiency **featured ladder**, and call other ladders **base ladders**.

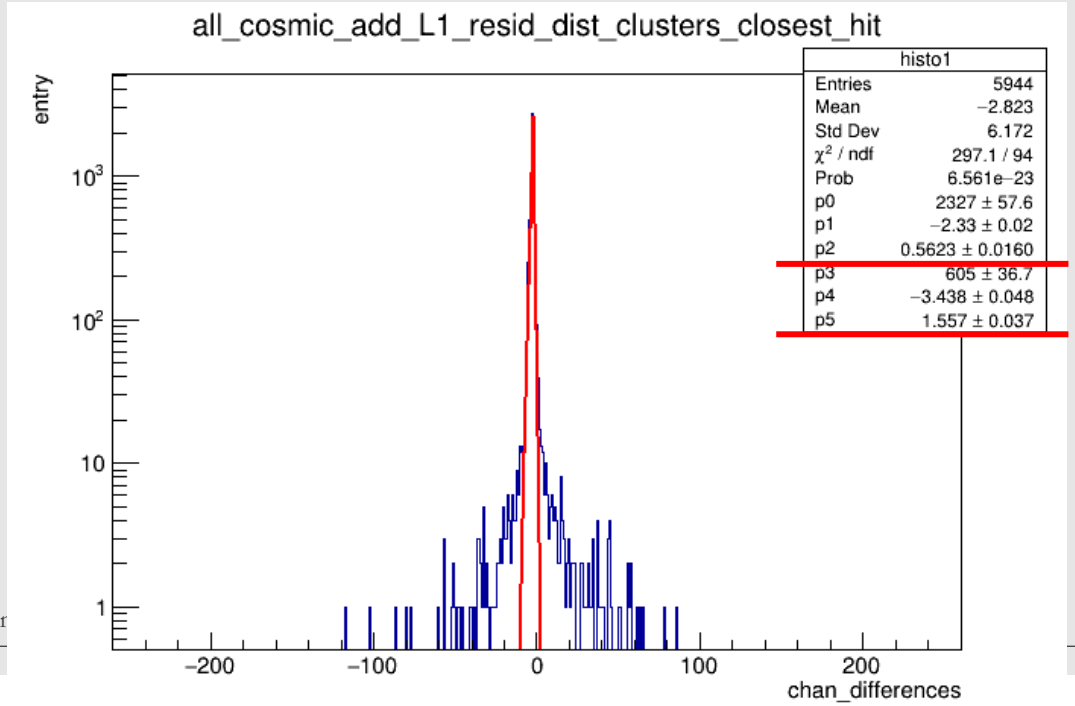
- Limit the number of clusters in base ladders to **1**.
- If featured ladder detects some clusters, it define "**detected**".
- If featured ladder **does not** detect cluster, it define "**undetected**".

$$\epsilon_{\text{Ladder 1}} = \frac{\text{N(Ladder 0 hit} \cap \text{Ladder 1 hit} \cap \text{Ladder 2 hit)}}{\text{N(Ladder 0 hit} \cap \text{Ladder 2 hit)}}$$

- Errors are calculated by the binomial distribution errors.
- **Without any limitation**, the efficiency is $\frac{5944}{5973} = 99.51 \pm 0.09\%$

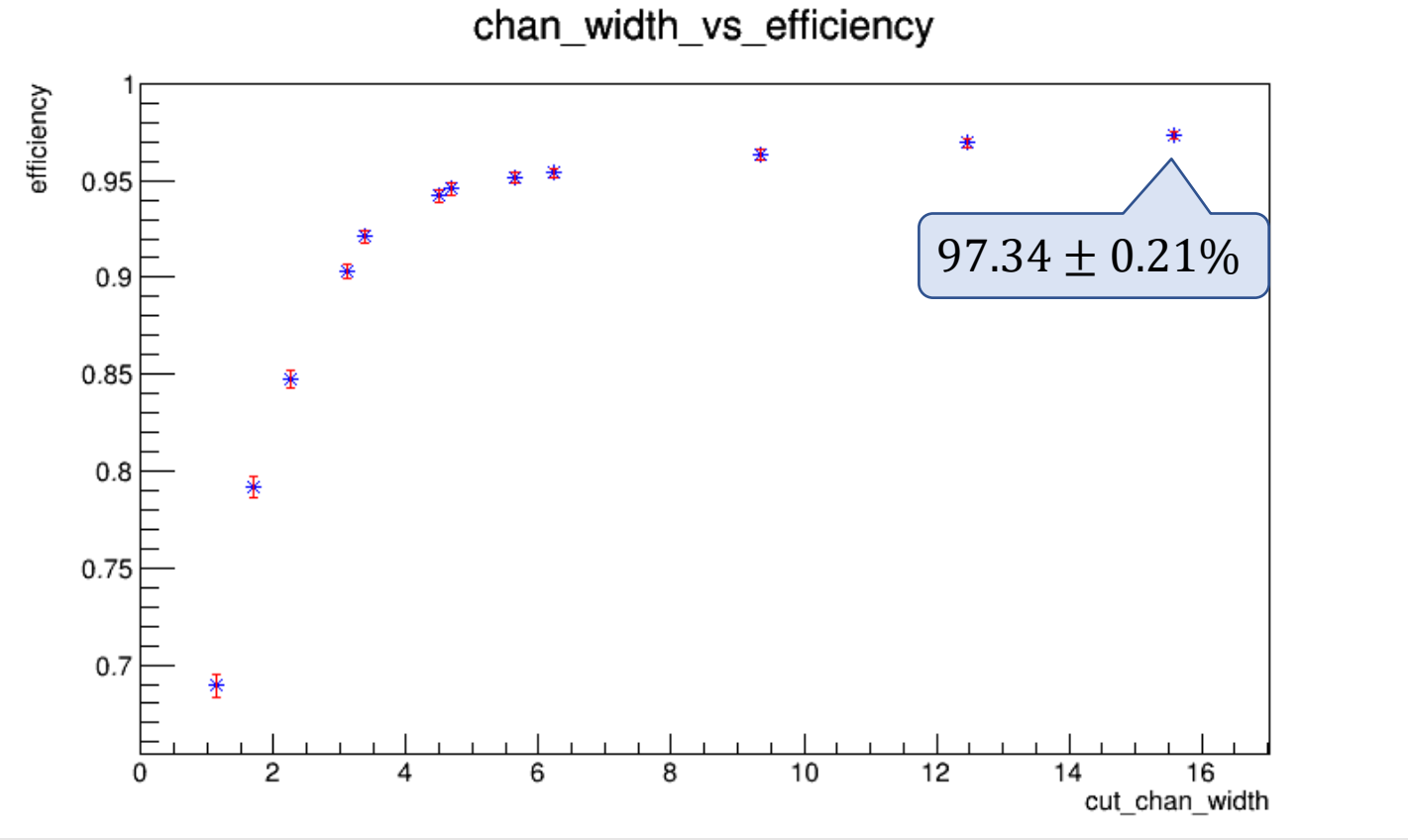
Efficiency: Residual distribution limitation

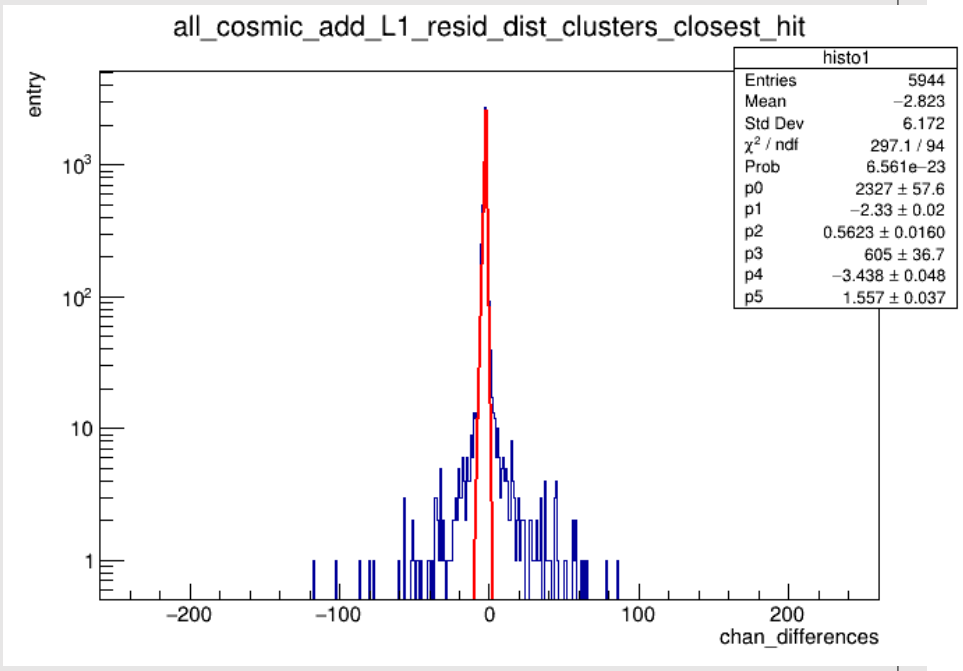
- We fit **double-gaussian** to the residual distribution, which include only 1 cluster and closest cluster in multiple clusters.
- Because of double-gaussian fit, we have 2 sigma, narrow and wide.
- We calculate some efficiencies in narrow 2 sigma, 3sigma, 4…10sigma and wide 2sigma, 3sigma, 4sigma… 10sigma around -2.33(narrow peak).



Efficiency: Residual distribution limitation

- We draw efficiency vs hit difference graph below.





Efficiency: chip differences limits

- We calculate the efficiency of middle ladder.

1, No limits(Upper and lower ladders have **1** cluster at **same chip** and middle ladder has some clusters in **anywhere**)

$$\text{Efficiency} = \frac{5944}{5973} = 99.51 \pm 0.09\%$$

2, All ladders have cluster(s) at same chip

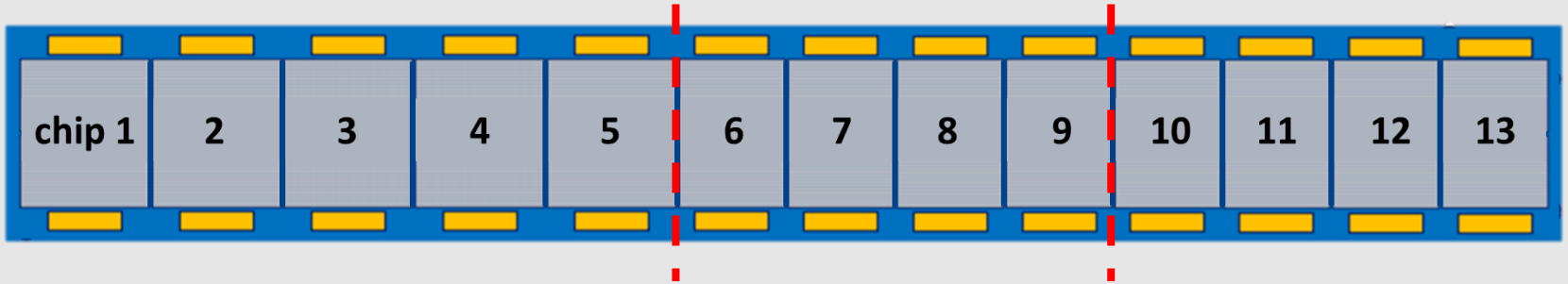
$$\text{Efficiency} = \frac{5864}{5973} = 98.18 \pm 0.17\%$$

3, $|(\text{Upper and lower ladder chip}) - (\text{Middle ladder chip})| \leq 1$

$$\text{Efficiency} = \frac{5934}{5944} = 99.81 \pm 0.06\%$$

Efficiency: Z-position dependence (chip direction)

- We divide INTT half ladder into 13 chips.
- Group 4 or 5 chips and calculate efficiencies in each group.



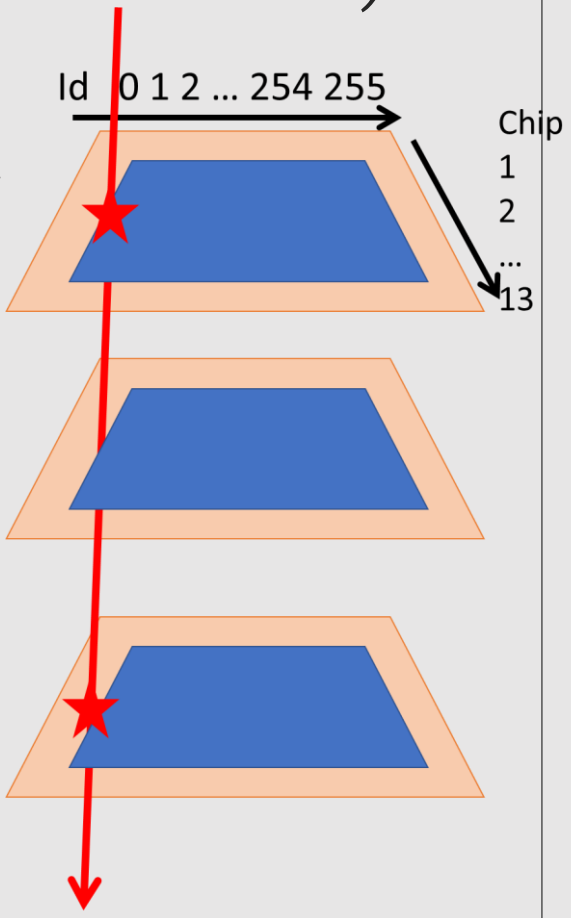
- Chip1-5: $\frac{2828}{2842} = 99.51 \pm 0.13\%$
- Chip6-9: $\frac{1750}{1762} = 99.32 \pm 0.20\%$
- Chip10-13: $\frac{1348}{1351} = 99.78 \pm 0.13\%$

Efficiency: X-position dependence (channel direction)

- If cosmic rays go through outside strips(ex: strip id 0, 255) it's difficult to detect.
- Therefore we should cut off outside strips signals.
- To develop how many outside strips should cut off, we confirm the efficiencies

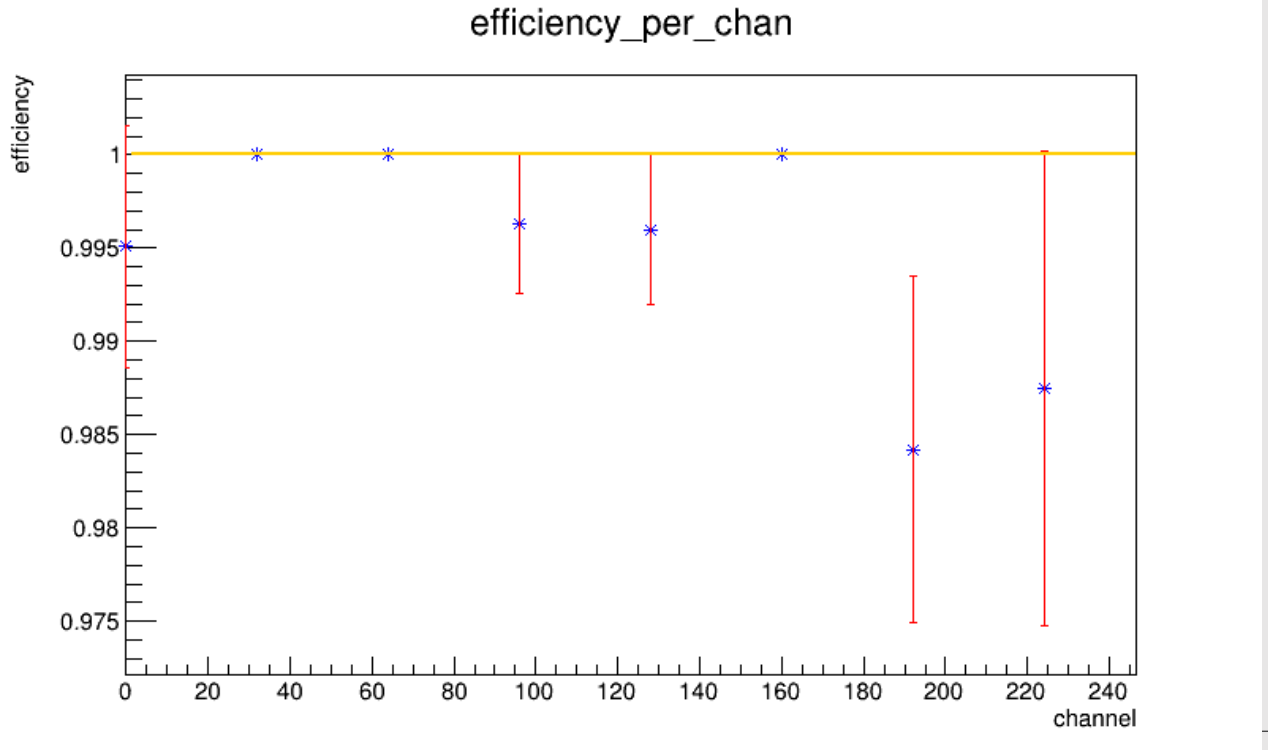
In each group of strips.

- INTT silicon sensor has 256 strips therefore we divide it into 8 group.



Efficiency: X-position dependence (channel direction)

- Group 1 include strip id 0-31, Group 2 is 32-63, Groupe 3 is 64-95…
- We plot the efficiencies in Y axis and X axis shows initial strip id in the group.



Summary

- From the analysis, we found some cosmic rays/ noises characteristics.
- At present we calculate the efficiencies in many limitation.

- What we do next;
- Combinate limitations and calculate the efficiency.
- Confirm BCO effects to the efficiency.