A study of clone hit II

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Analysis steps

Data

- Run 26960 (the latest cosmic run), merged event-base TTree

Steps

1. Finding noisy channels and removing them
   - Noisy channel analysis was not the main topic of this study. I did it quickly.
   - About 4% of all hits, including the clones, were removed. ← **Here was a bug!**
2. Making a hit-base TTree from the merged event-base TTree
   - I think a hit-base TTree is better for this analysis. To add some additional information and not to affected by the bugs in the decoder, I made it.
3. Looping over all hits in the hit-base TTree (hit_{ref}), and

   (a) if a clone candidate is found, information of hit_{ref} is saved into another TTree.

   (b) Looping over hits (hit_{can}) later than hit_{ref}, and

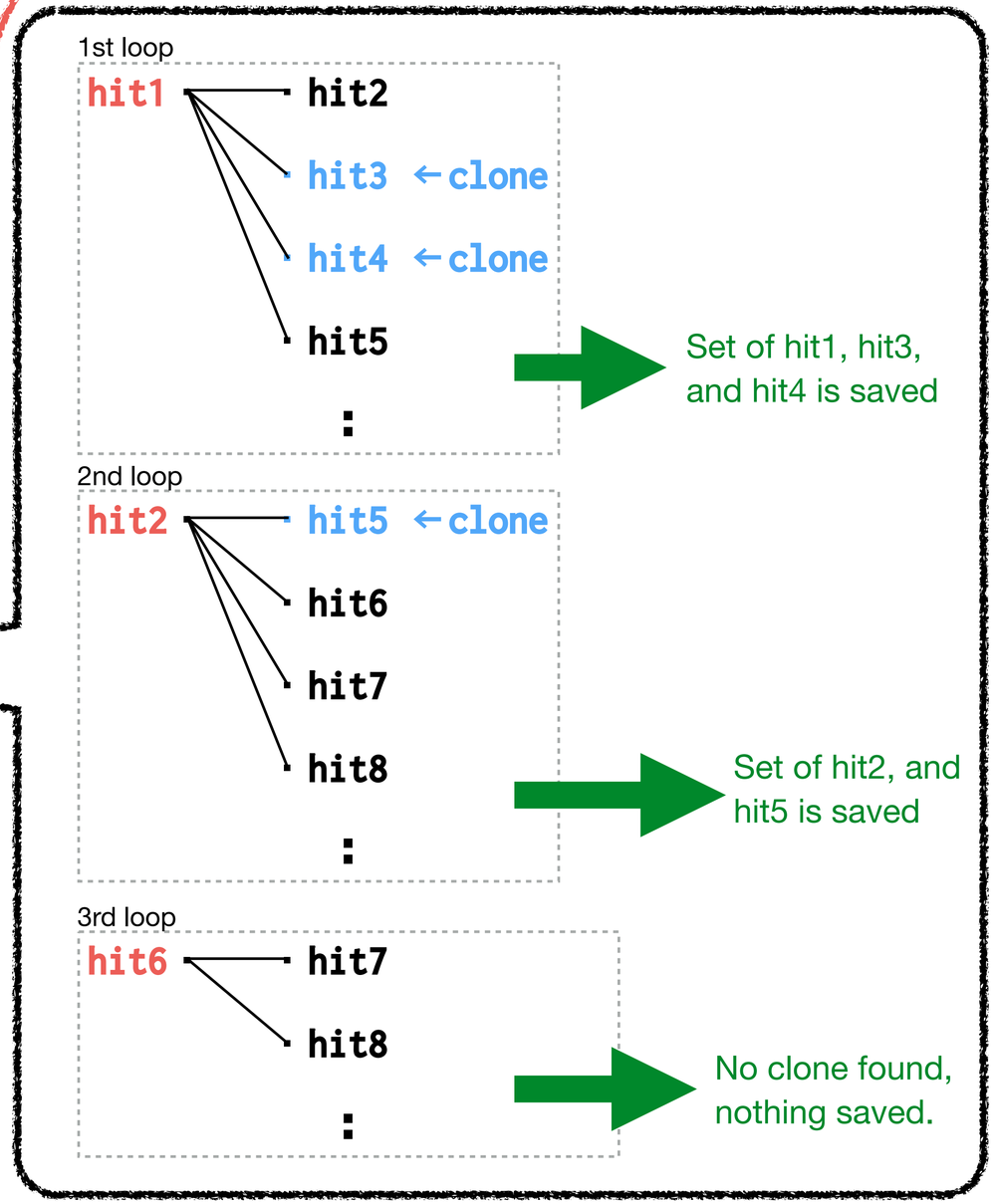
   (i) If $\Delta BCO\ full \equiv BCO\ full_{can} - BCO_{ref} > 1000 = 106$ μs, ignore it,

   (ii) Check whether hit_{can} is a clone candidate of hit_{ref} (pid, module, chip_id, chan_id)

   (iii) If hit_{can} is a clone candidate, attach the info to hit_{ref} *, and save them*

The flag history of the previous event was not cleared.

Idea of the step 3



Analysis steps

Data

- Run 26960 (the latest cosmic run), merged event-base TTree

Step

3. Analyzing the TTree produced in step 2.
   (a) Checking #hit_{can} ($ADC_{can} = ADC_{ref}$) / #hit_{ref}
   (b) Checking #hit_{can} ($ADC_{can} = ADC_{ref}$) / #hit_{ref} as a function of $\Delta BCO\ full \equiv BCO\ full_{can} - BCO_{ref}$
   (c) Checking #hit_{can} ($ADC_{can} \neq ADC_{ref}$) / #hit_{ref}
   (d) Checking #hit_{can} ($ADC_{can} \neq ADC_{ref}$) / #hit_{ref} as a function of $\Delta BCO\ full \equiv BCO\ full_{can} - BCO_{ref}$
   (e) etc.

Analysis, Clone hits with the same ADC as the reference

Data

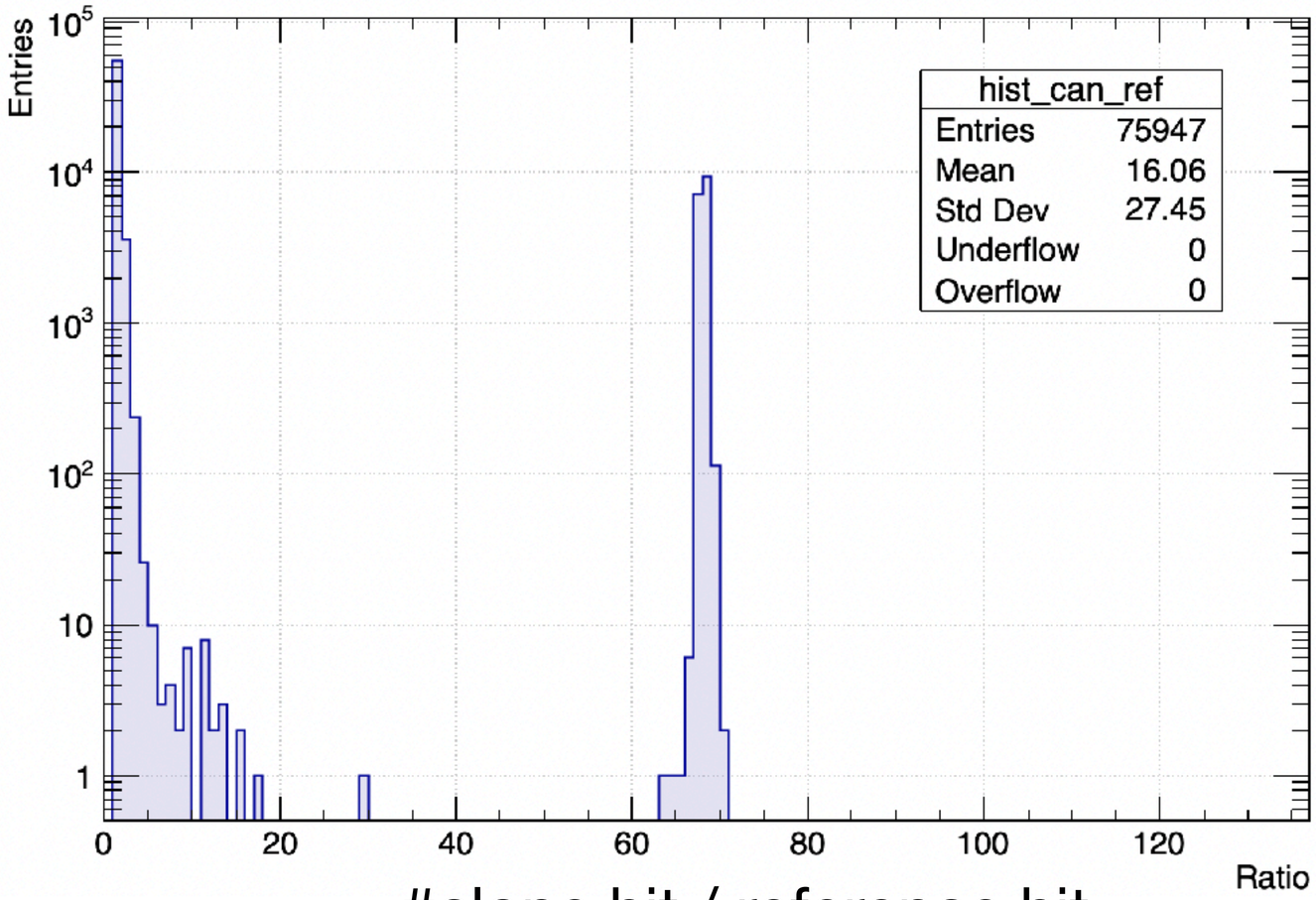
- Run 26960 (the latest cosmic run), merged event-base TTree

Step

3. Analyzing the TTree produced in step 2.
   (a) Checking #hit_{can} (ADC_{can} = ADC_{ref}) / #hit_{ref}

In the merged TTree		
#events	:	237408
#events with hit(s)	:	197526
#hits	:	6158266
After noisy channel rejection		
#hits	:	~~5930658~~ → 5530085
#removed hits	:	~~227608~~ → 628181
#hits / event	:	~~30.0~~ → 28.0
After step2 (ΔBCO cut)		
#reference hits	:	~~3705~~ → 77455
#clone hits	:	~~13183~~ → 1184450
with the same ADC	:	~~13175~~ → 1181926
with different ADC	:	~~9~~ → 2524

#clone hits was changed to a more reasonable value.
99.8% of clone hits have the same ADC as the reference.



#clone hit / reference hit

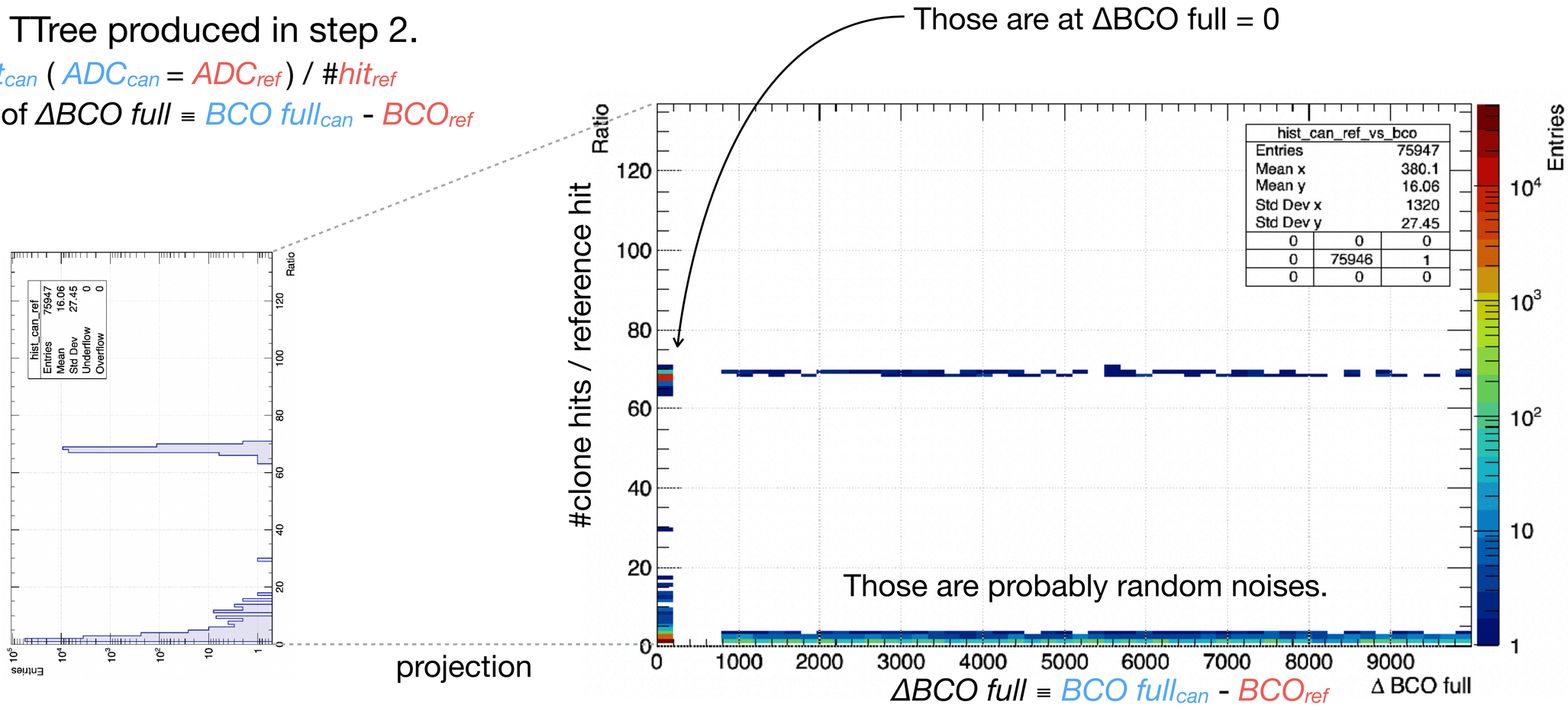
Analysis, Clone hits with the same ADC as the reference

Data

- Run 26960 (the latest cosmic run), merged event-base TTree

Step

3. Analyzing the TTree produced in step 2.
   (b) Checking #hit_{can} (ADC_{can} = ADC_{ref}) / #hit_{ref}
   as a function of $\Delta BCO\ full \equiv BCO\ full_{can} - BCO_{ref}$



The clone hits with the same ADC as the reference hits' have the same BCO full, i.e., in the same event. (This conclusion is not changed.)

Analysis, Clone hits with the same ADC as the reference

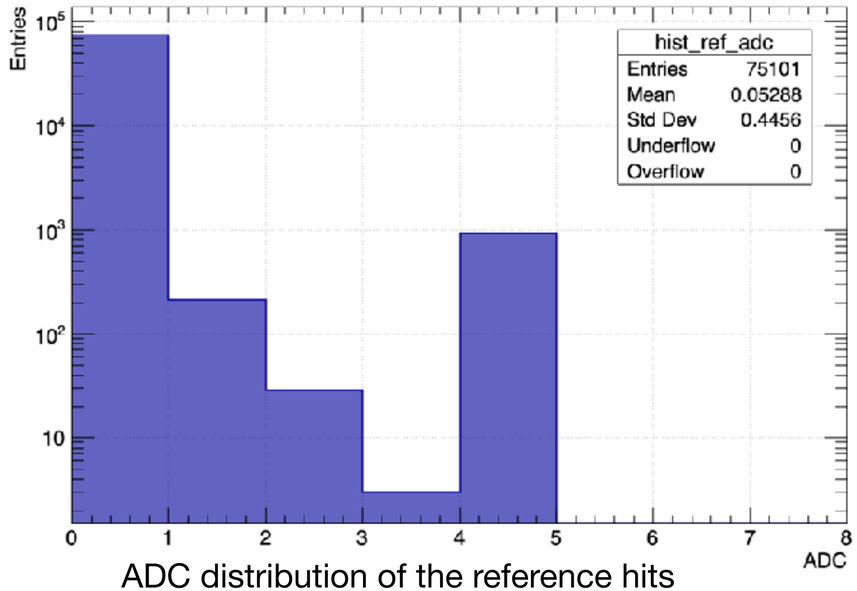
Data

- Run 26960 (the latest cosmic run), merged event-base TTree

Step

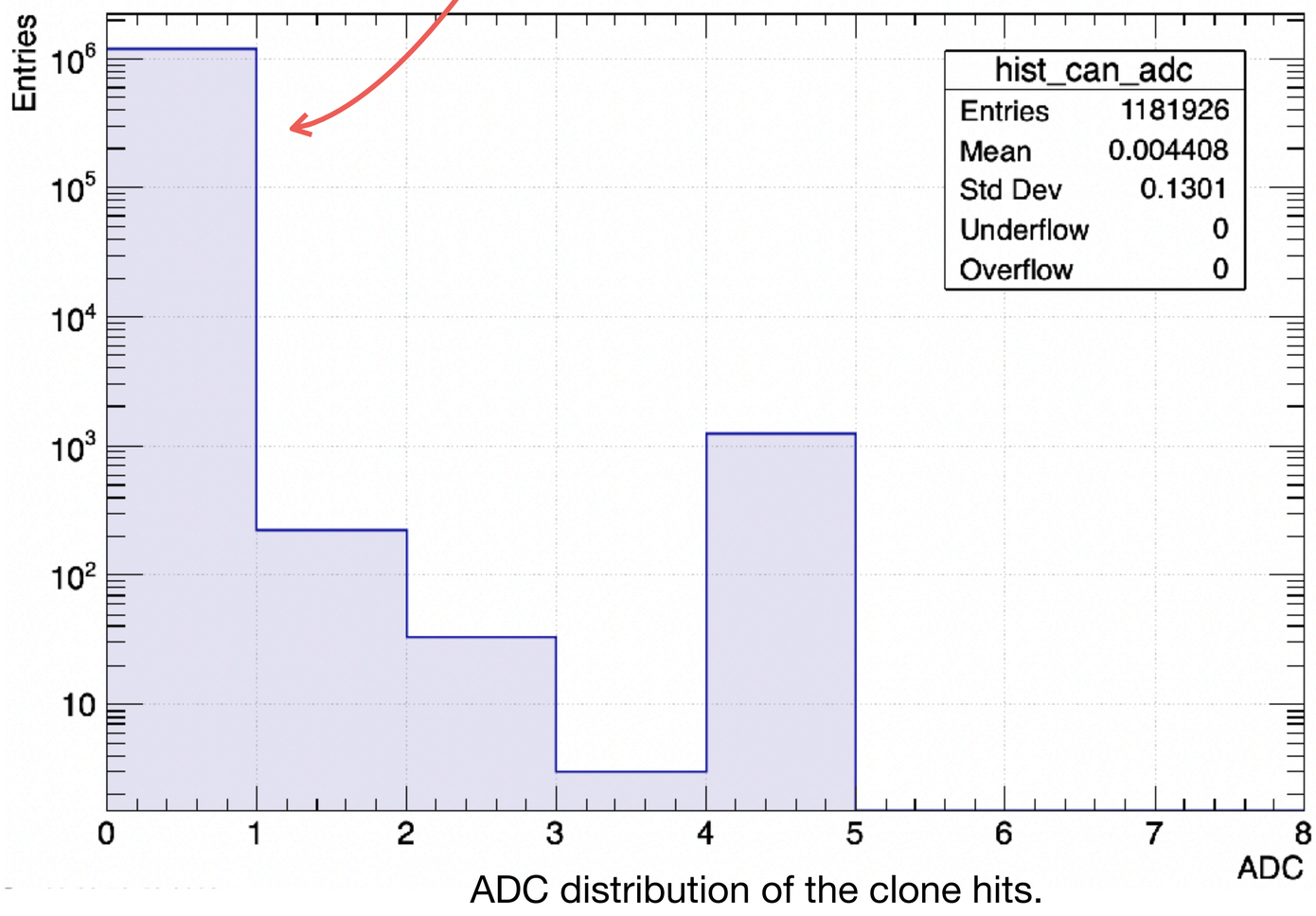
3. Analyzing the TTree produced in step 2.
   (b) Checking #hit_{can} ($ADC_{can} = ADC_{ref}$) / #hit_{ref}
   as a function of $\Delta BCO\ full \equiv BCO\ full_{can} - BCO_{ref}$

   (b') Checking ADC of #hit_{can} ($ADC_{can} = ADC_{ref}$)



ADC distribution of the reference hits

99.9% of all



ADC distribution of the clone hits.

Note. ADC of all clone hits are drawn.

Almost ADC = 0

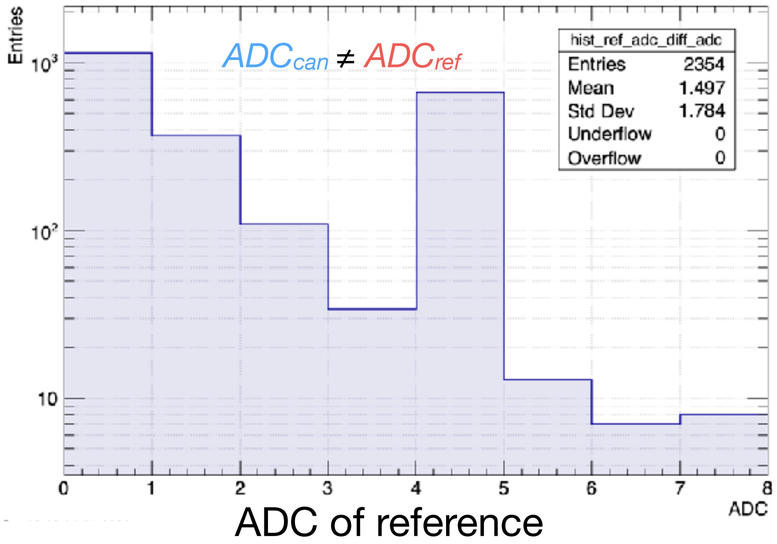
Analysis, Clone hits with different ADC from the reference

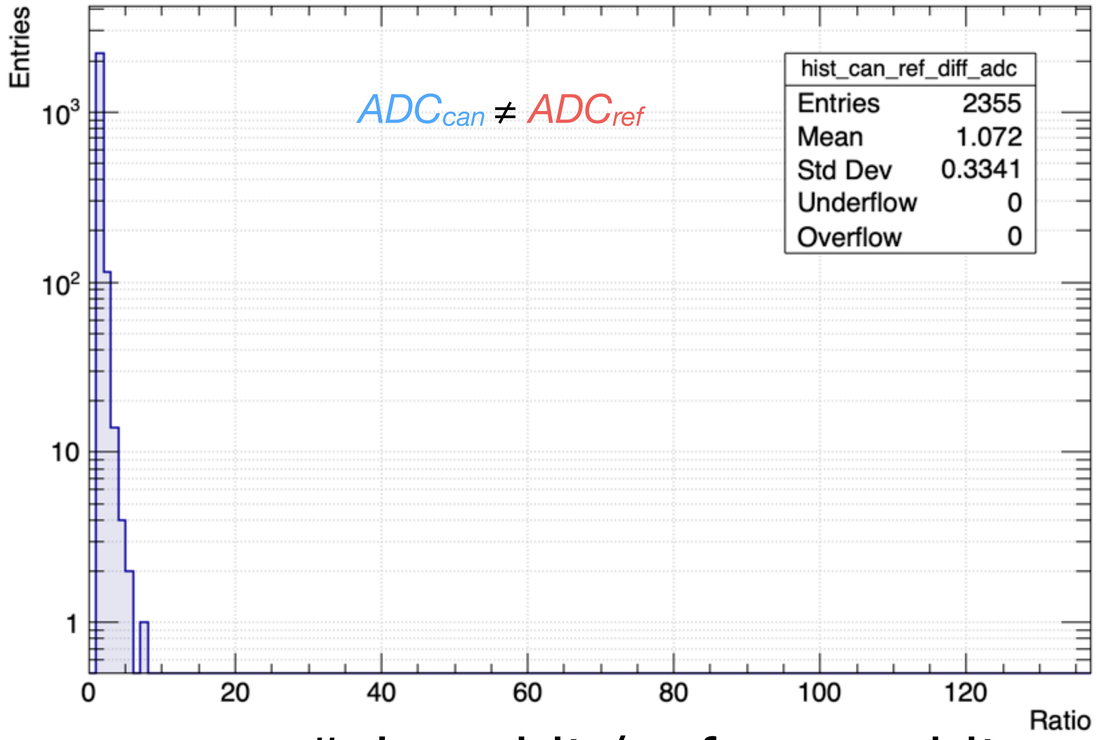
Data

- Run 26960 (the latest cosmic run), merged event-base TTree

Step

3. Analyzing the TTree produced in step 2.
   (c) Checking #hit_{can} ($ADC_{can} \neq ADC_{ref}$) / #hit_{ref}





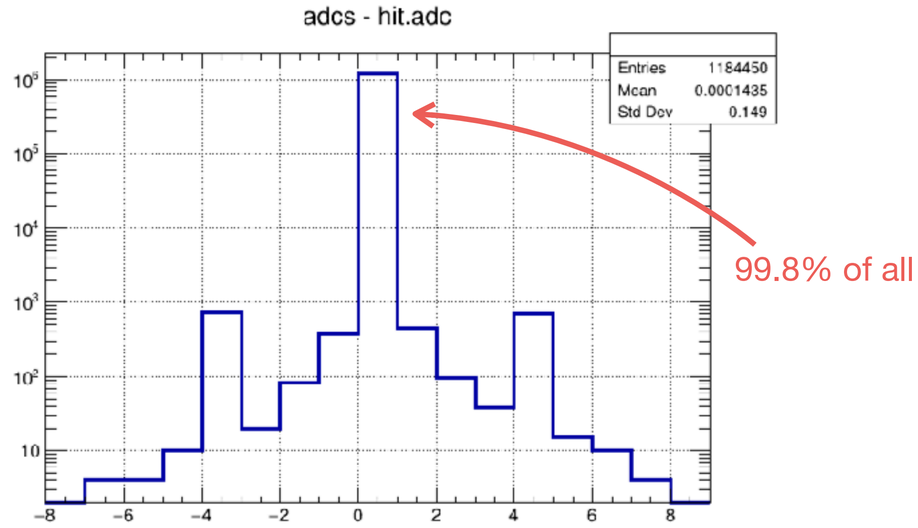
Analysis, Clone hits with different ADC from the reference

Data

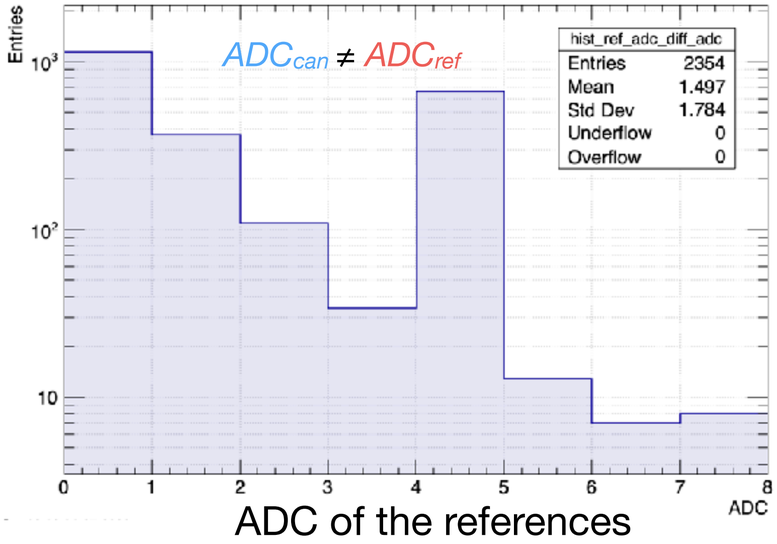
- Run 26960 (the latest cosmic run), merged event-base TTree

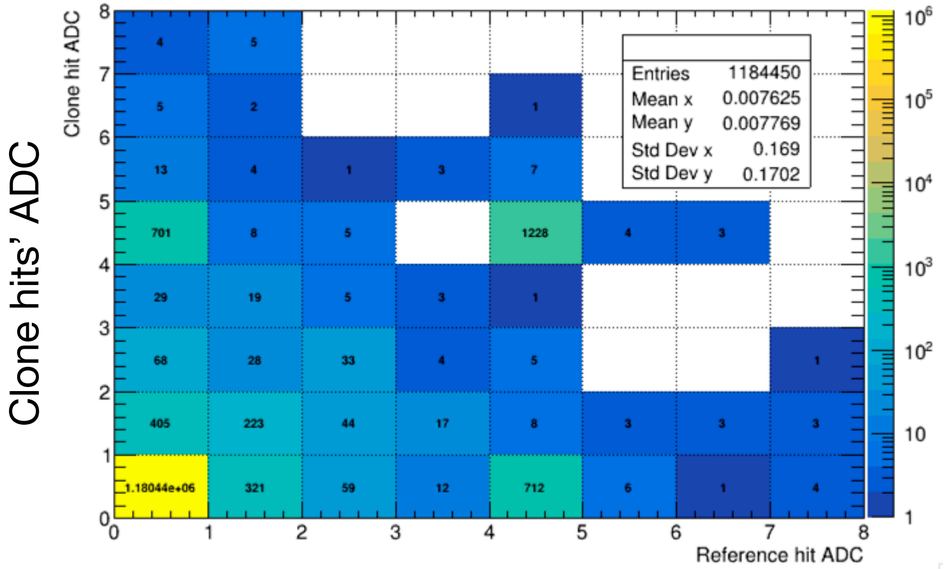
Step

3. Analyzing the TTree produced in step 2.
   (c) Checking #hit_{can} ($ADC_{can} \neq ADC_{ref}$) / #hit_{ref}



ΔADC = ADC_{can} - ADC_{ref}





Summary

Data

- Run 26960 (the latest cosmic run), merged event-base TTree

Step

3. Analyzing the TTree produced in step 2.
   (a) Checking #hit_{can} ($ADC_{can} = ADC_{ref}$) / #hit_{ref}
   (b) Checking #hit_{can} ($ADC_{can} = ADC_{ref}$) / #hit_{ref} as a function of $\Delta BCO\ full \equiv BCO\ full_{can} - BCO_{ref}$
   (c) Checking #hit_{can} ($ADC_{can} \neq ADC_{ref}$) / #hit_{ref}
   (d) Checking #hit_{can} ($ADC_{can} \neq ADC_{ref}$) / #hit_{ref} as a function of $\Delta BCO\ full \equiv BCO\ full_{can} - BCO_{ref}$
   (e) etc.

From the latest cosmic run 26960,

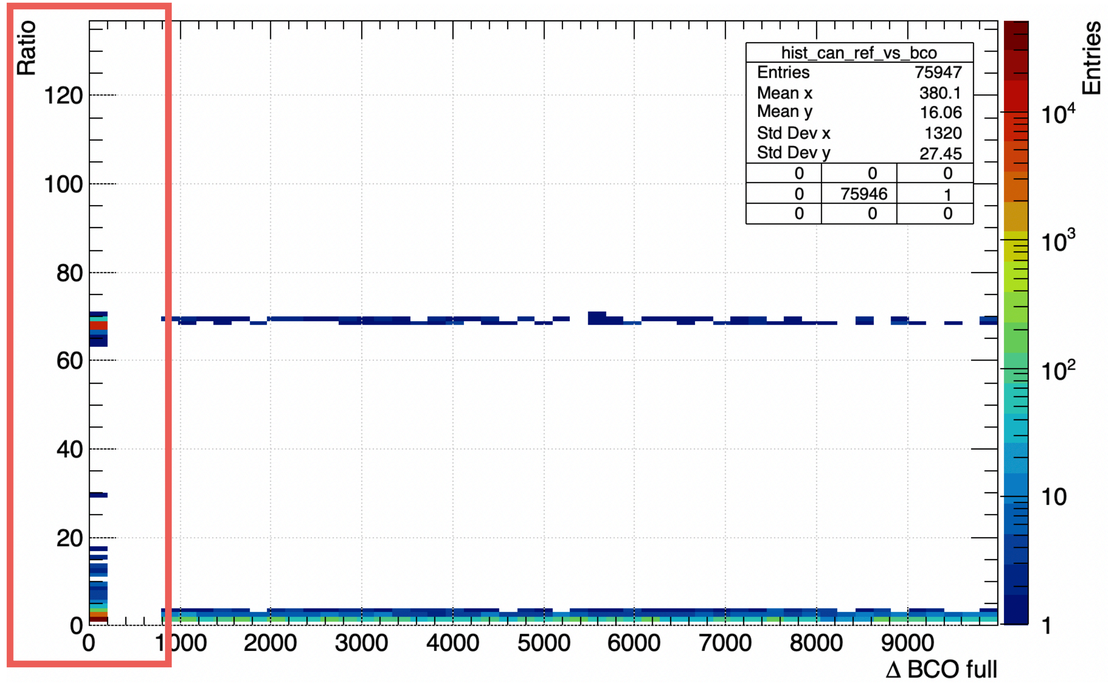
- **Clone hits with the same ADC as the reference hit have the same BCO full. (same conclusion)**
- **IN MOST CASES, the ADC value of clone hits with the same ADC as the reference hit is 0. (same conclusion)**
- **A very tiny amount of clone hits with different ADC from the reference hit were found. (same conclusion)**

Let’s check other cosmic runs. It’s easier than beam data.

Analysis, Other runs

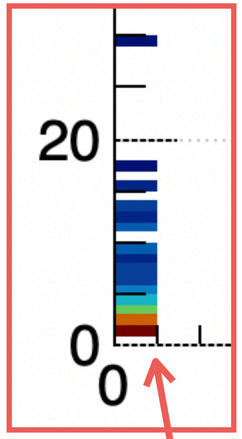
Data

- Run 26960 (the latest cosmic run), merged event-base TTree
  → Let's check other cosmic runs!




```
In the merged TTree
  #events                 :  237408
  #events with hit(s)     :  197526
  #hits                   : 6158266
-------------------------------------
After noisy channel rejection
  #hits                   : 5930658→5530085
  #removed hits           :  227608→ 628181
  #hits / event           :    30.0→   28.0
-------------------------------------
After step2 (ΔBCO cut)
  #reference hits         :    3705→  77455
  #clone hits             :   13183→1184450
    with the same ADC     :   13175→1181926
    with different ADC    :       9→   2524
```

The ratio of these values are checked.



Run	$\#hit_{can}\ (ADC_{can} \neq ADC_{ref})$	$\#hit_{can}\ (ADC_{can} = ADC_{ref})$	Ratio
26960	2457	1171349	0.002

Clone hits with the same BCO full as the reference are counted.

Analysis, Other runs

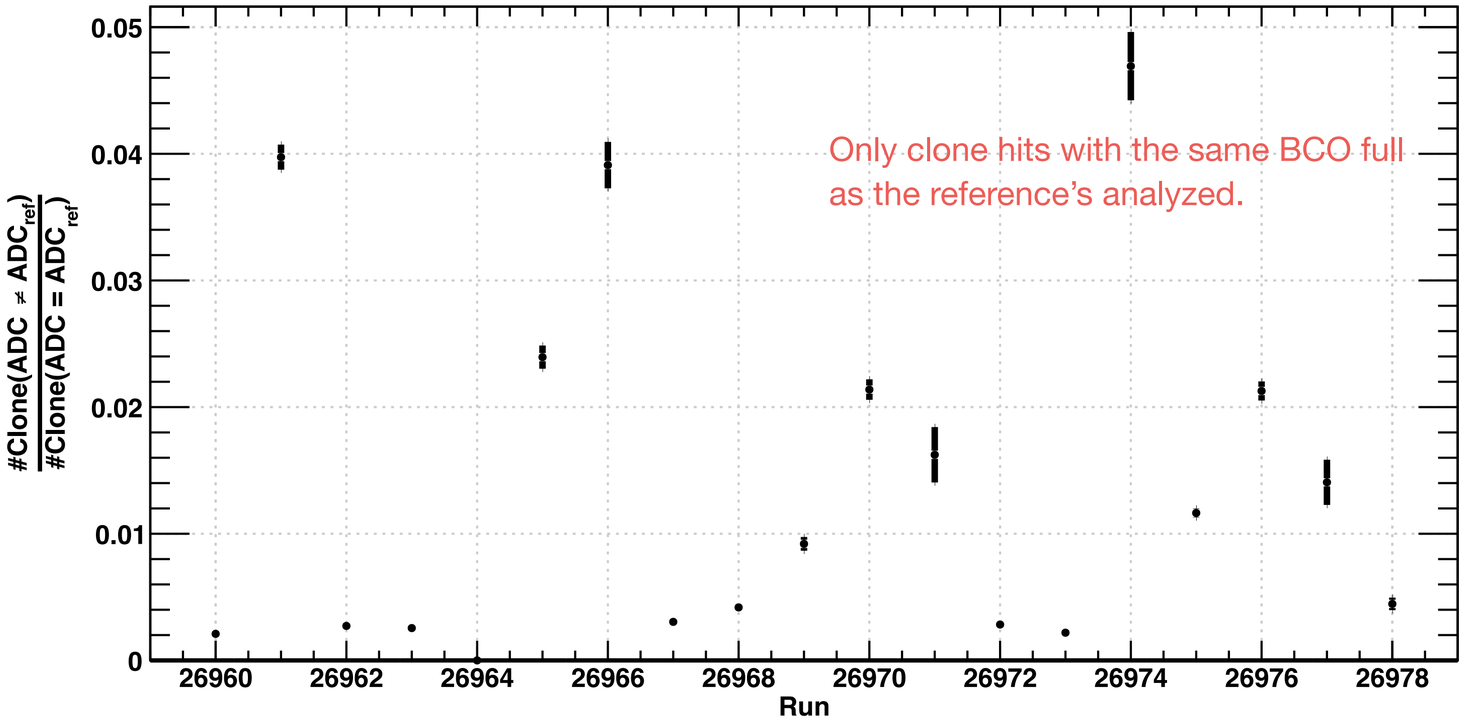
The error of the ratio:
The error propagation used.
√N is hired as the error of #hit.

$$\delta y = \sqrt{\left(\frac{\sqrt{x}}{y}\right)^2 + \left(\frac{x\sqrt{y}}{y^2}\right)^2}$$

Data

- Run 26960 (the latest cosmic run), merged event-base TTree
  → Let's check other cosmic runs!

Ratio of clone hits with different ADC to with same ADC



Amount of clone hits with different ADC from the reference might be less than 5% of those with the same ADC…?

Run	$\#hit_{can}$ ($ADC_{can} \neq ADC_{ref}$)	$\#hit_{can}$ ($ADC_{can} = ADC_{ref}$)	Ratio
26960	2457	1171349	0.002
26961	1672	42078	0.040
26962	913	335389	0.003
26963	959	375580	0.003
26964	0	3	0.000
26965	699	29192	0.024
26966	473	12095	0.039
26967	1005	330192	0.003
26968	1235	295093	0.004
26969	289	31403	0.009
26970	715	33437	0.021
26971	56	3449	0.016
26972	407	143595	0.003
26973	872	398489	0.002
26974	317	6756	0.047
26975	1088	93467	0.012
26976	812	38169	0.021
26977	63	4480	0.014
26978	81	18152	0.004

Analysis, Other runs

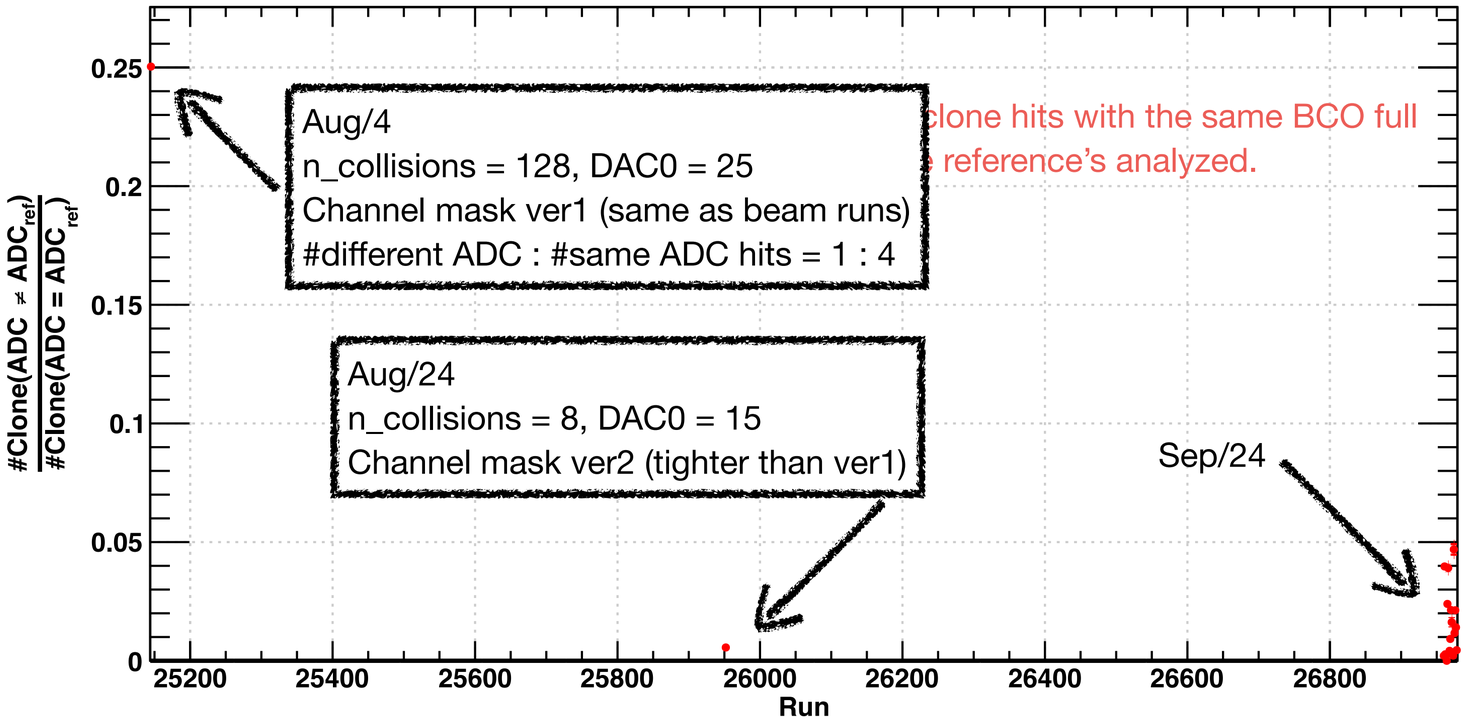
The error of the ratio:
The error propagation used.
√N is hired as the error of #hit.

$$\delta y = \sqrt{\left(\frac{\sqrt{x}}{y}\right)^2 + \left(\frac{x\sqrt{y}}{y^2}\right)^2}$$

Data

- Run 26960 (the latest cosmic run), merged event-base TTree
  → Let's check other cosmic runs!
- I also checked Run 25145 (Aug/4) and 25952 (Aug/24).

Ratio of clone hits with different ADC to with same ADC



Amount of clone hits with different ADC from the reference might be less than 5% of those with the same ADC…?

Run	$\#hit_{can}$ ($ADC_{can} \neq ADC_{ref}$)	$\#hit_{can}$ ($ADC_{can} = ADC_{ref}$)	Ratio
25145	52529	209805	0.250
25952	2538	453463	0.006
26960	2457	1171349	0.002
26961	1672	42078	0.040
26962	913	335389	0.003
26963	959	375580	0.003
26964	0	3	0.000
26965	699	29192	0.024
26966	473	12095	0.039
26967	1005	330192	0.003
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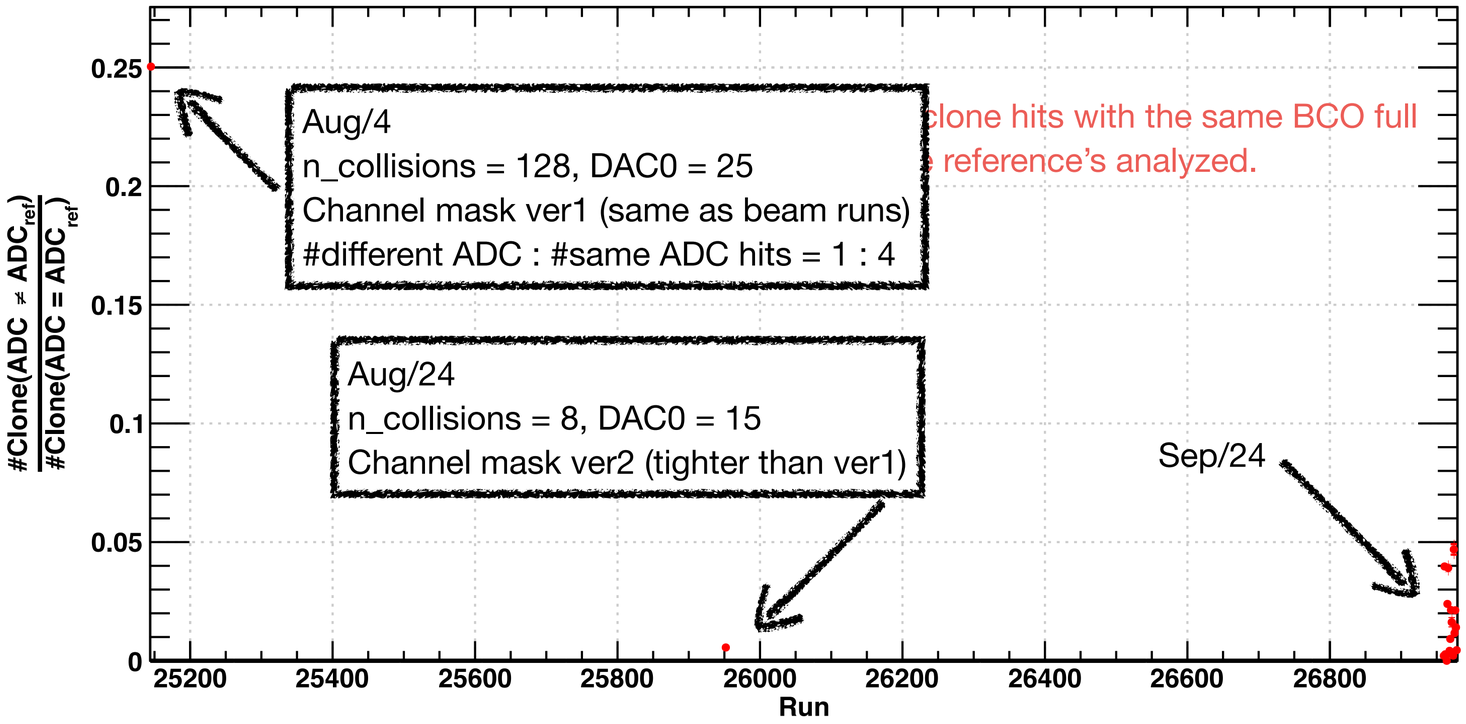
26975	1088	93467	0.012
26976	812	38169	0.021
26977	63	4480	0.014
26978	81	18152	0.004

Analysis, Run 25145

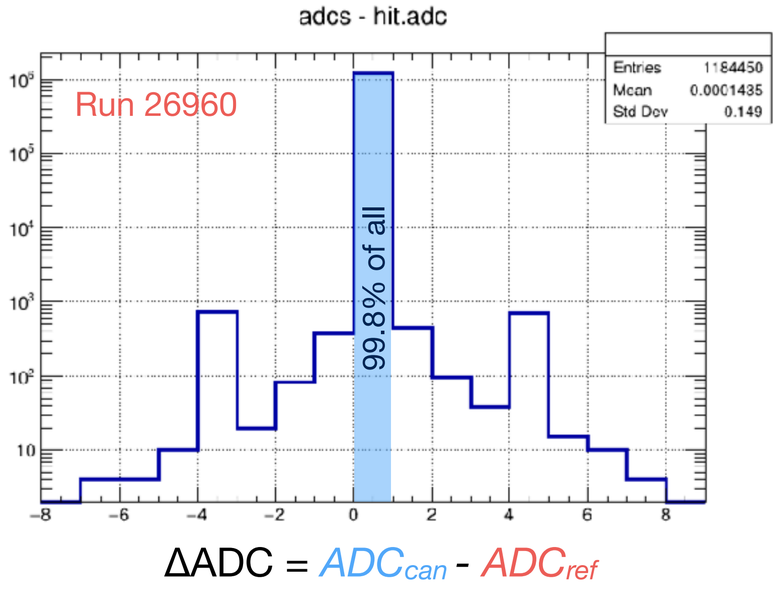
Data

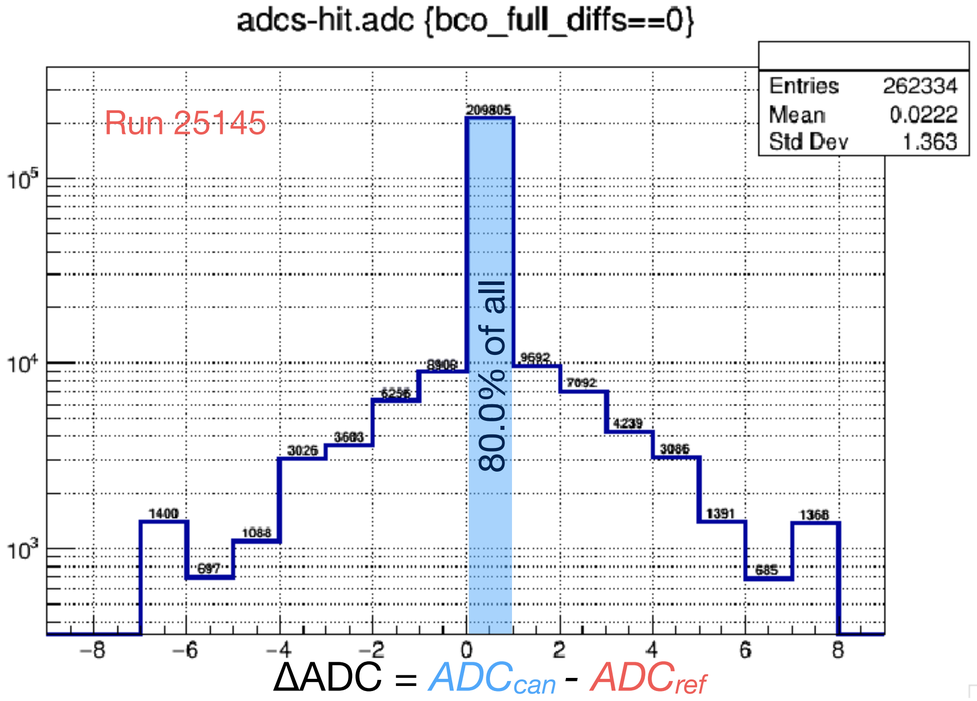
- Run 26960 (the latest cosmic run), merged event-base TTree
  → Let's check other cosmic runs!
- I also checked Run 25145 (Aug/4) and 25952 (Aug/24).

Ratio of clone hits with different ADC to with same ADC



Ratio of the clone hits with different/same ADC depends on the run.





Next steps

- The same analysis but including the noisy channels. ← Postponed
- Analyzing the beam data.
- Analyzing other cosmic data.

Beam Data Analysis, Clone hits with the same ADC as the reference

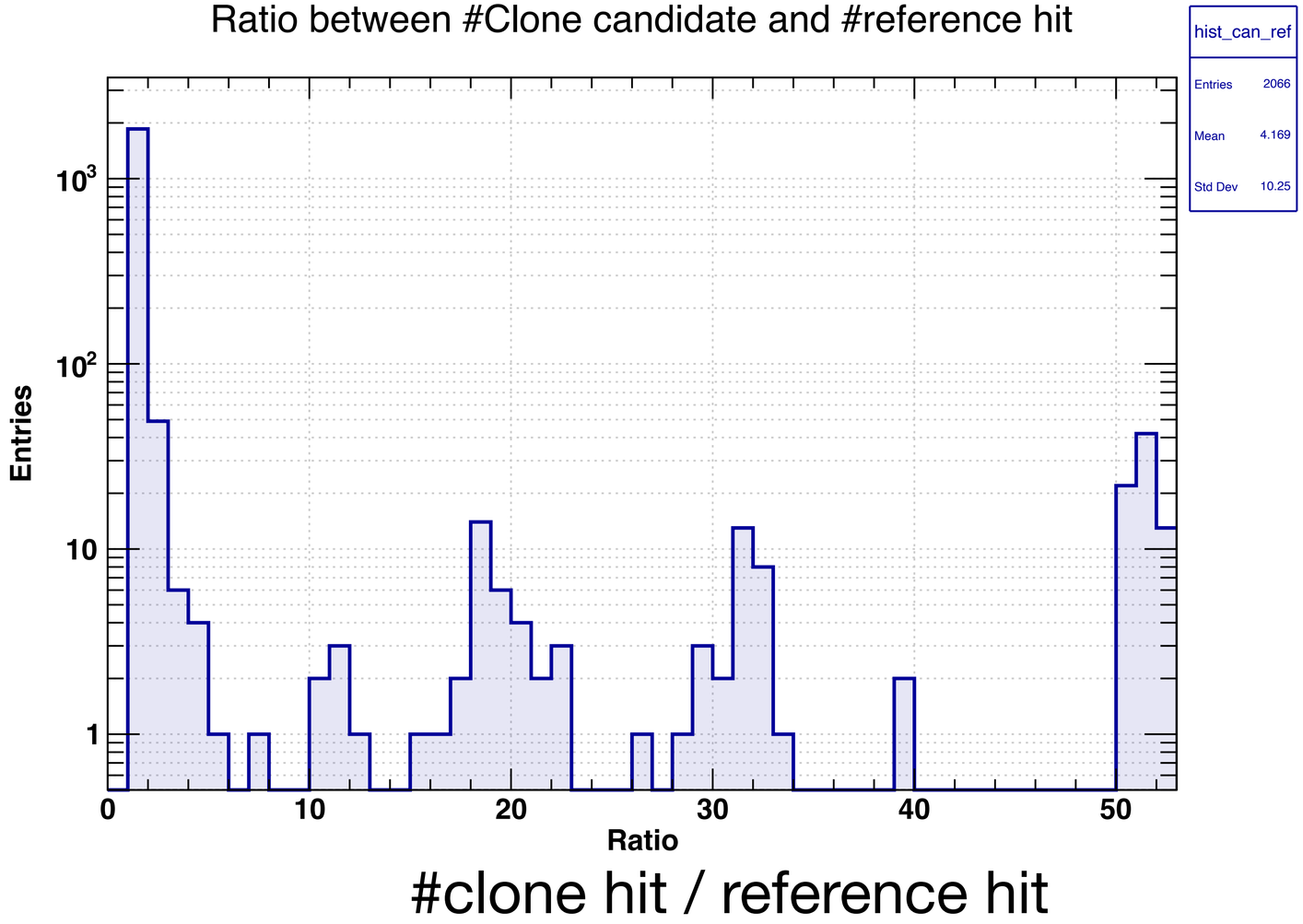
Data

- Run 26960 (the latest cosmic run), merged event-base TTree

Step

3. Analyzing the TTree produced in step 2.
   (a) Checking #hit_{can} ($ADC_{can} = ADC_{ref}$) / #hit_{ref}

In the merged TTree	
#events	: not
#events with hit(s)	:
#hits	: checked
After noisy channel rejection	
#hits	: not
#removed hits	:
#hits / event	: checked
After step2 (ΔBCO cut)	
#reference hits	:
#clone hits	: not
with the same ADC	: checked
with different ADC	:



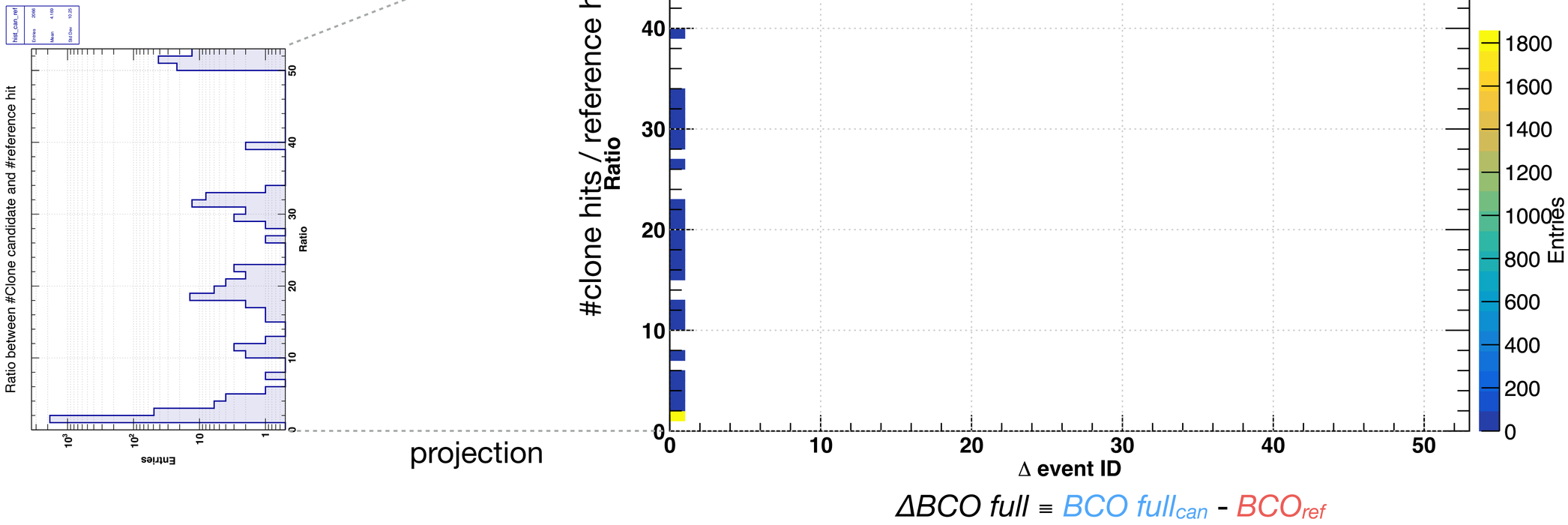
Beam Data Analysis, Clone hits with the same ADC as the reference

Data

- Run 26960 (the latest cosmic run), merged event-base TTree

Step

3. Analyzing the TTree produced in step 2.
   (b) Checking #hit_{can} (ADC_{can} = ADC_{ref}) / #hit_{ref}
   as a function of $\Delta BCO\ full \equiv BCO\ full_{can} - BCO_{ref}$



Beam Data Analysis, Clone hits with the same ADC as the reference

Data

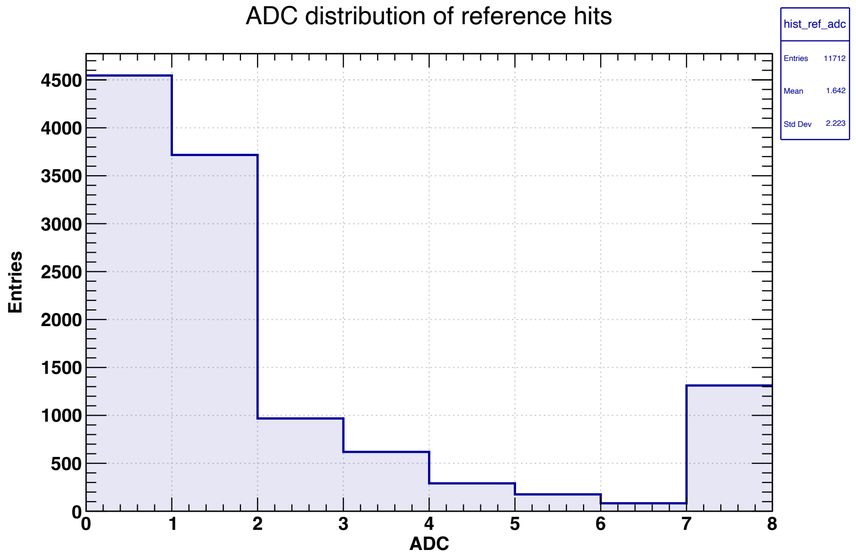
- Run 26960 (the latest cosmic run), merged event-base TTree

Step

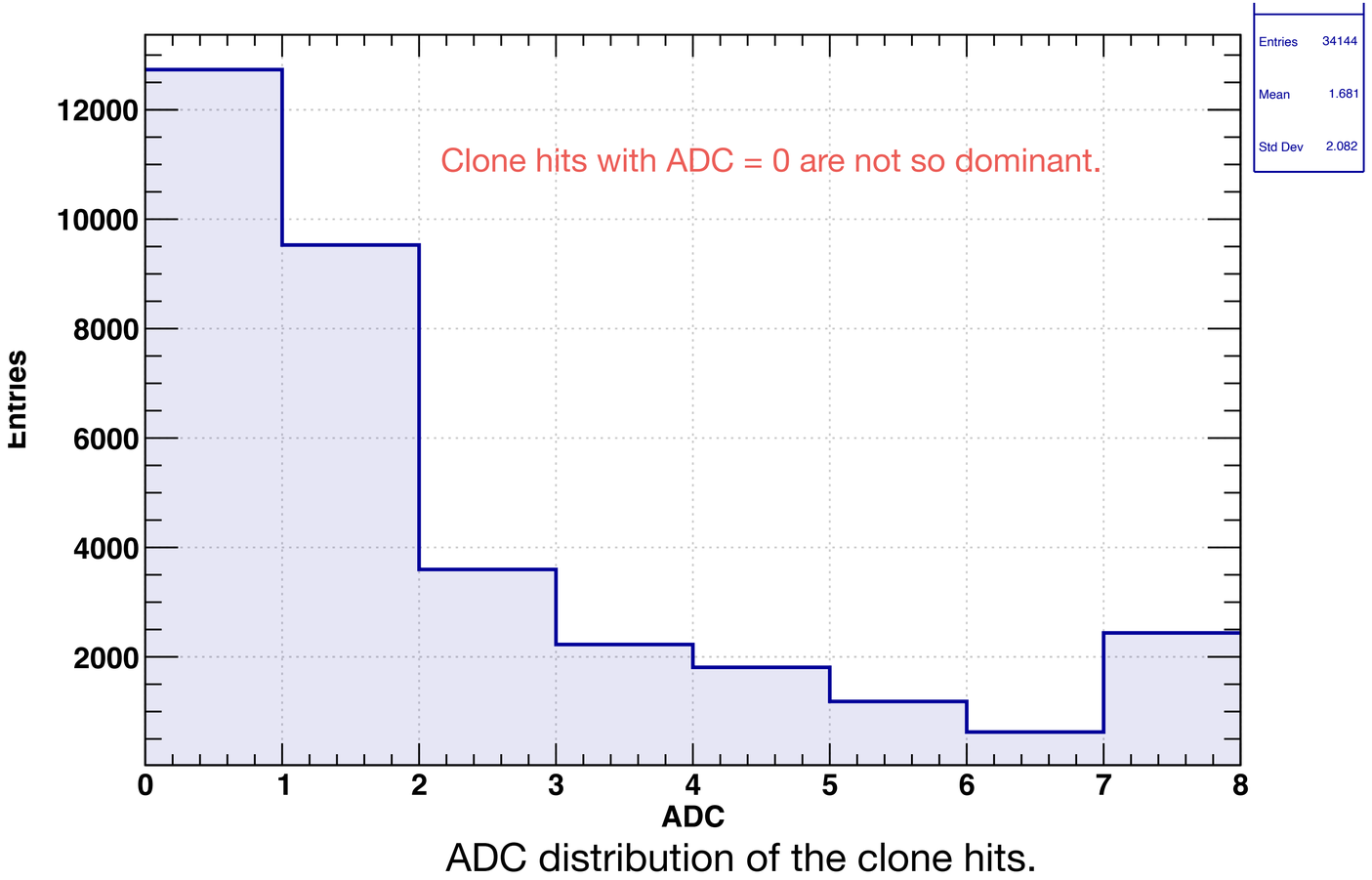
3. Analyzing the TTree produced in step 2.

   (b) Checking #hit_{can} (ADC_{can} = ADC_{ref}) / #hit_{ref}
   as a function of $\Delta BCO\ full \equiv BCO\ full_{can} - BCO_{ref}$

   (b') Checking ADC of #hit_{can} (ADC_{can} = ADC_{ref})



ADC distribution of the reference hits



ADC distribution of the clone hits.

Note. ADC of all clone hits are drawn.

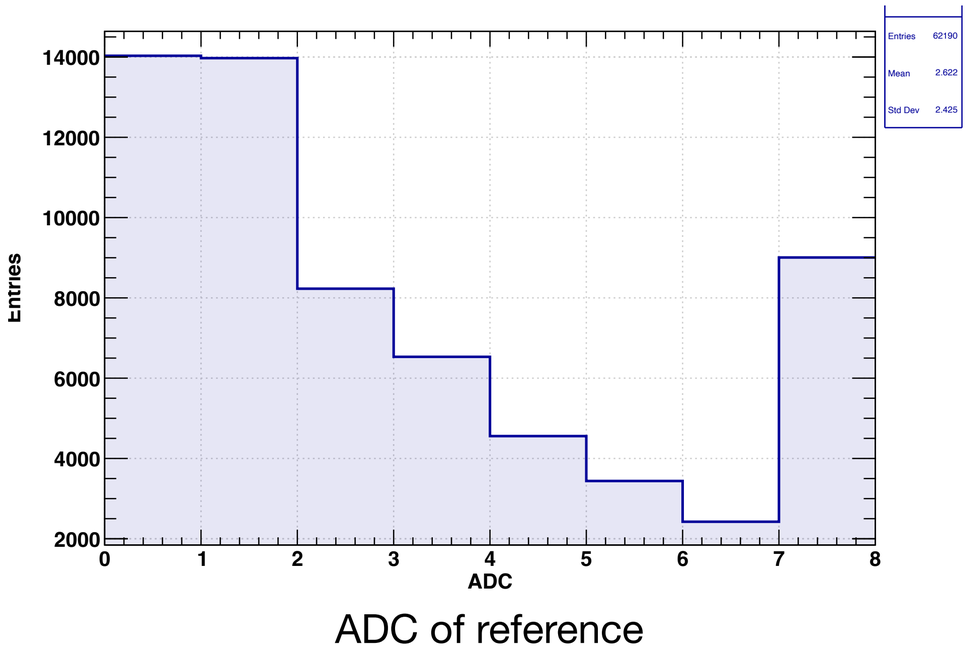
Beam Data Analysis, Clone hits with different ADC from the reference

Data

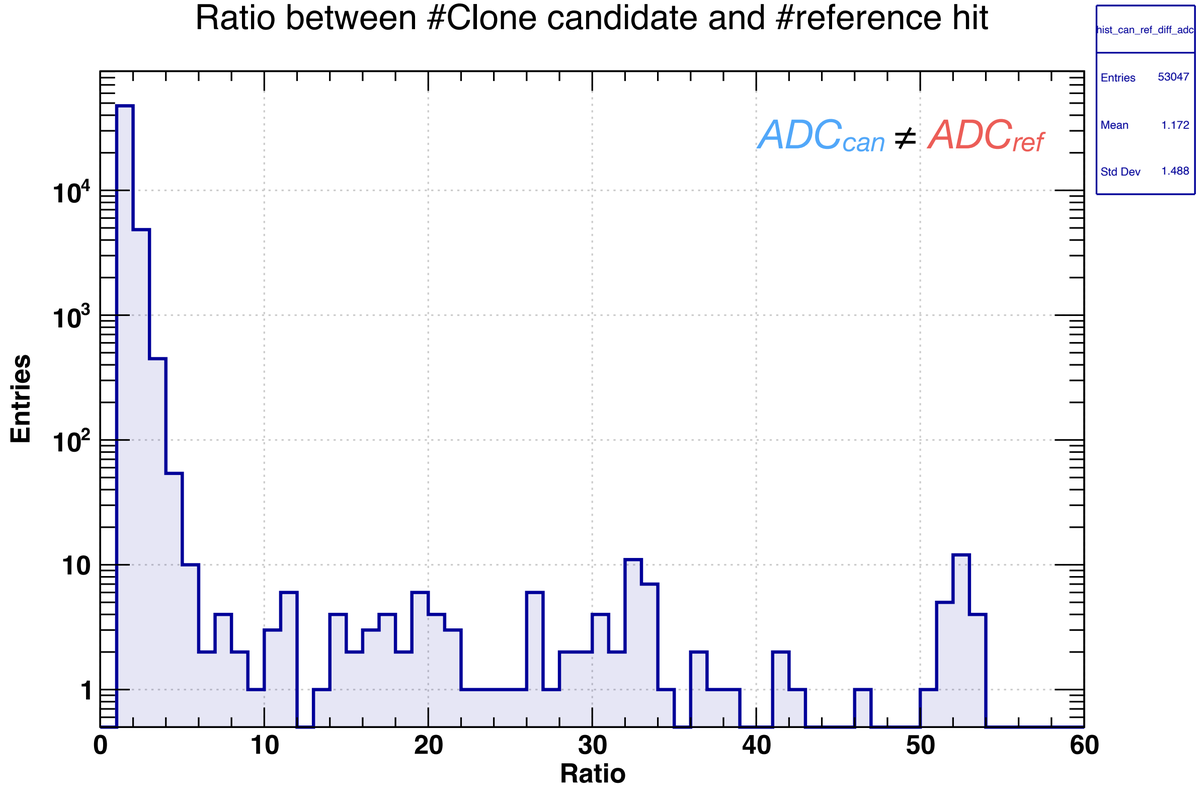
- Run 26960 (the latest cosmic run), merged event-base TTree

Step

3. Analyzing the TTree produced in step 2.
   (c) Checking #hit_{can} ($ADC_{can} \neq ADC_{ref}$) / #hit_{ref}



ADC of reference



#clone hit / reference hit

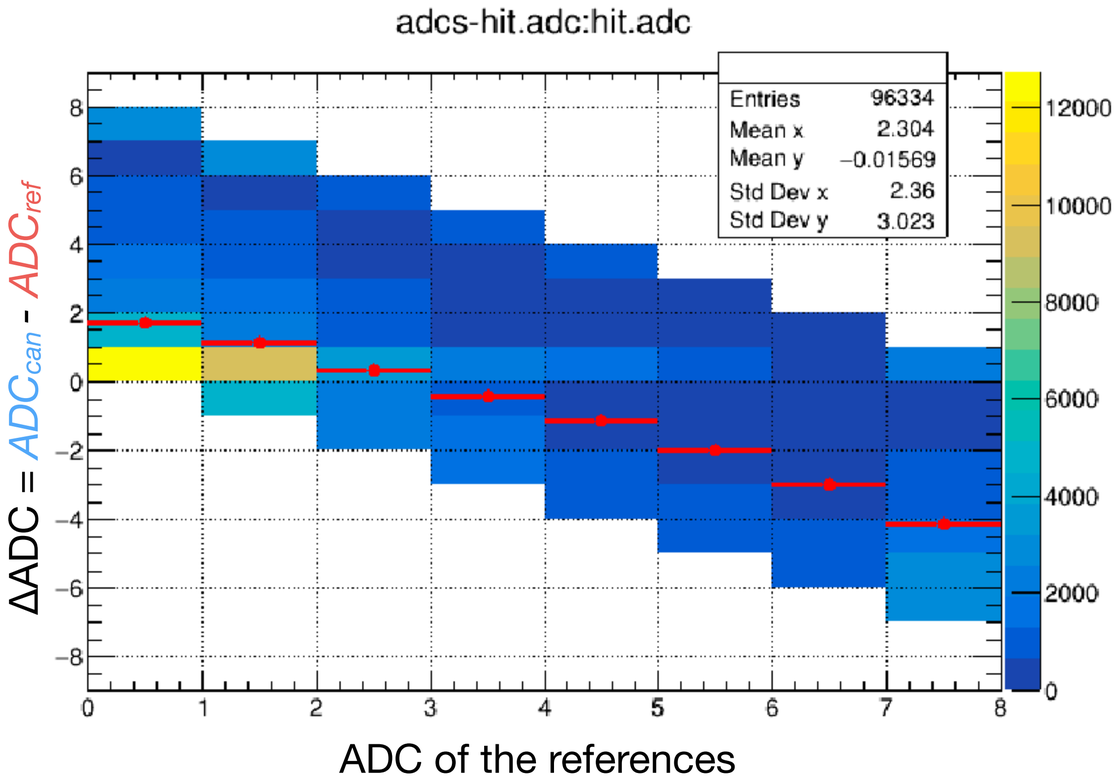
Analysis, Clone hits with same/different ADC from the reference

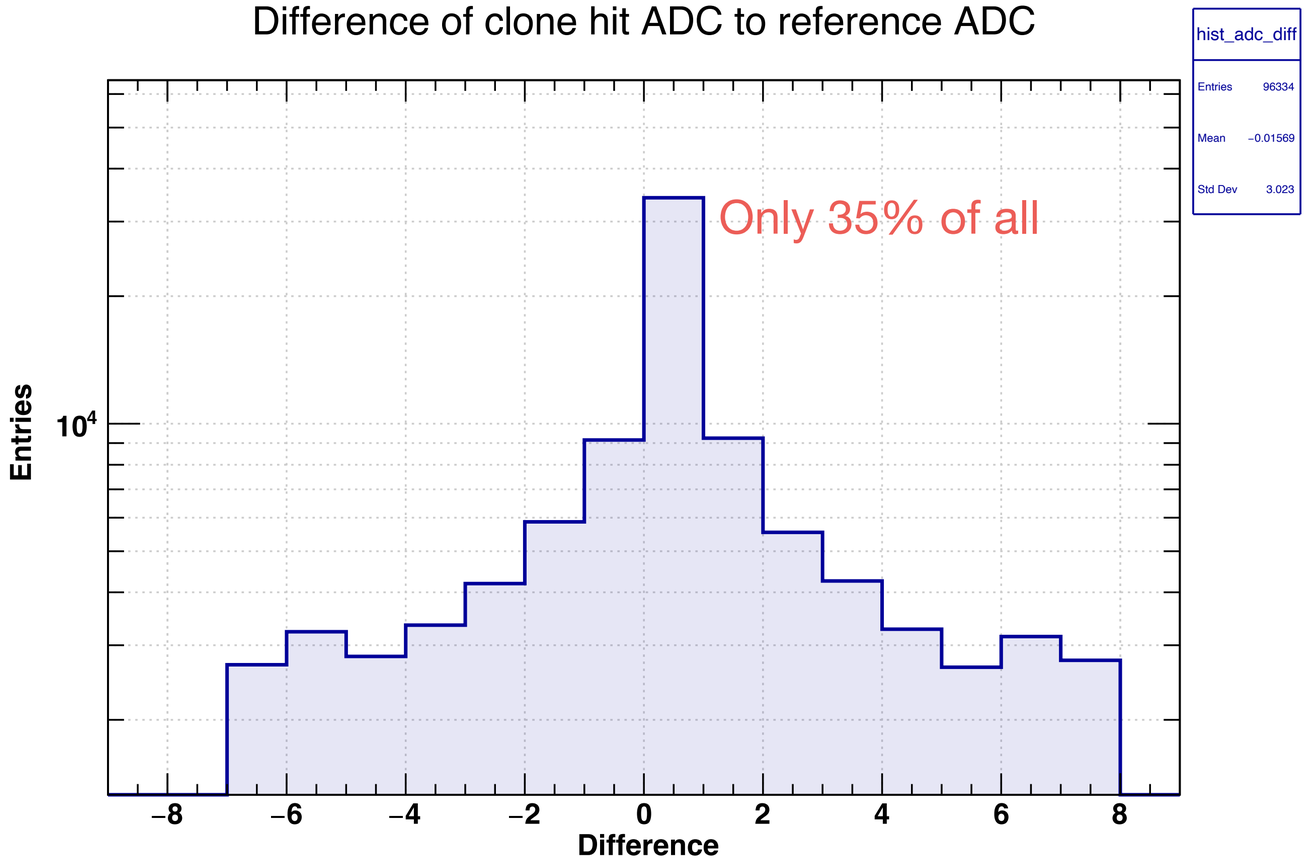
Data

- Run 26960 (the latest cosmic run), merged event-base TTree

Step

3. Analyzing the TTree produced in step 2.
   (c) Checking #hit_{can} ($ADC_{can} \neq ADC_{ref}$) / #hit_{ref}

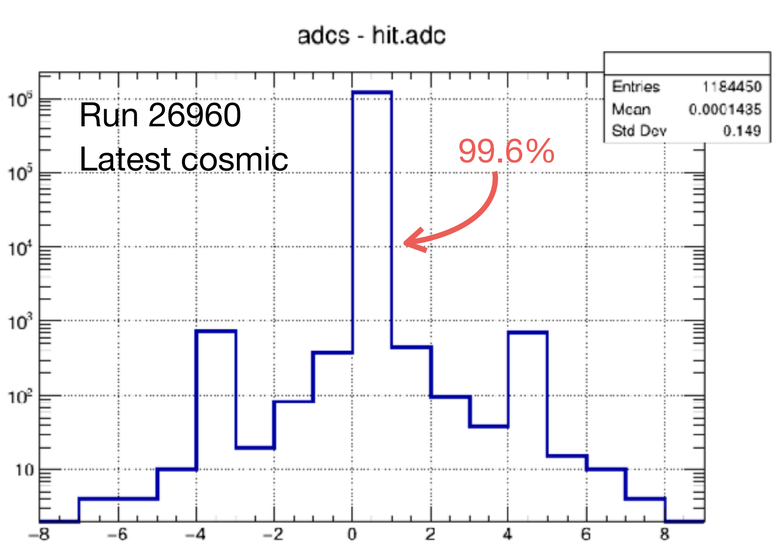


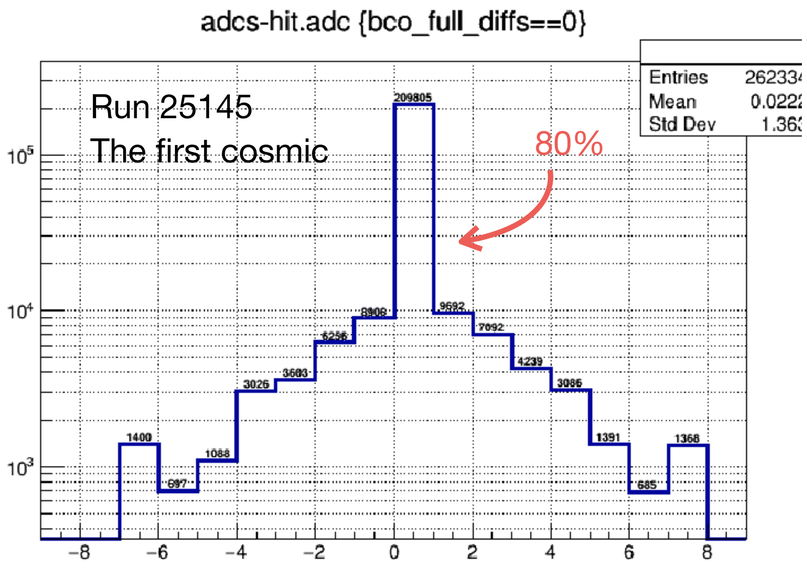


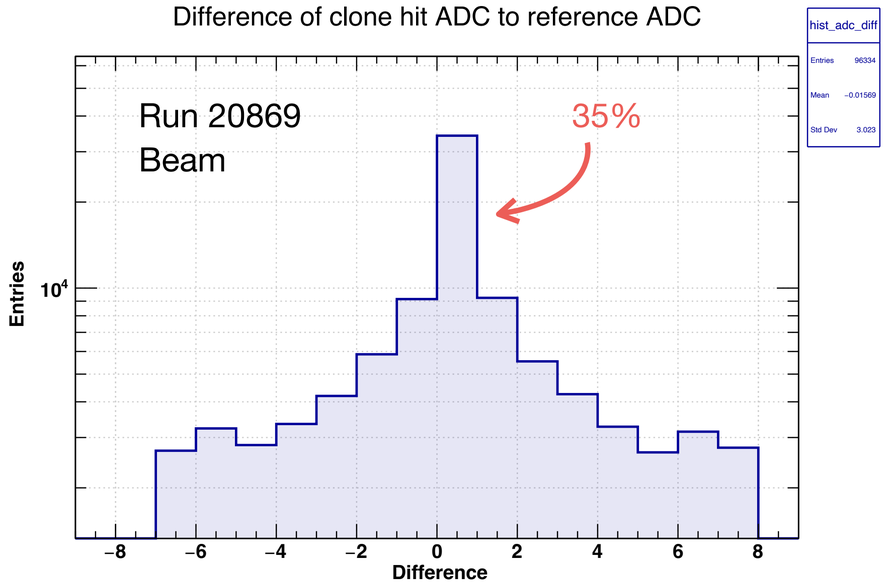
ΔADC = ADC_{can} - ADC_{ref}

Summary

The ratio of the clone hits with different/same ADC depends on the run.
We have to be careful of treating the clone hits with different ADC from the reference…
A cross-check may be needed.







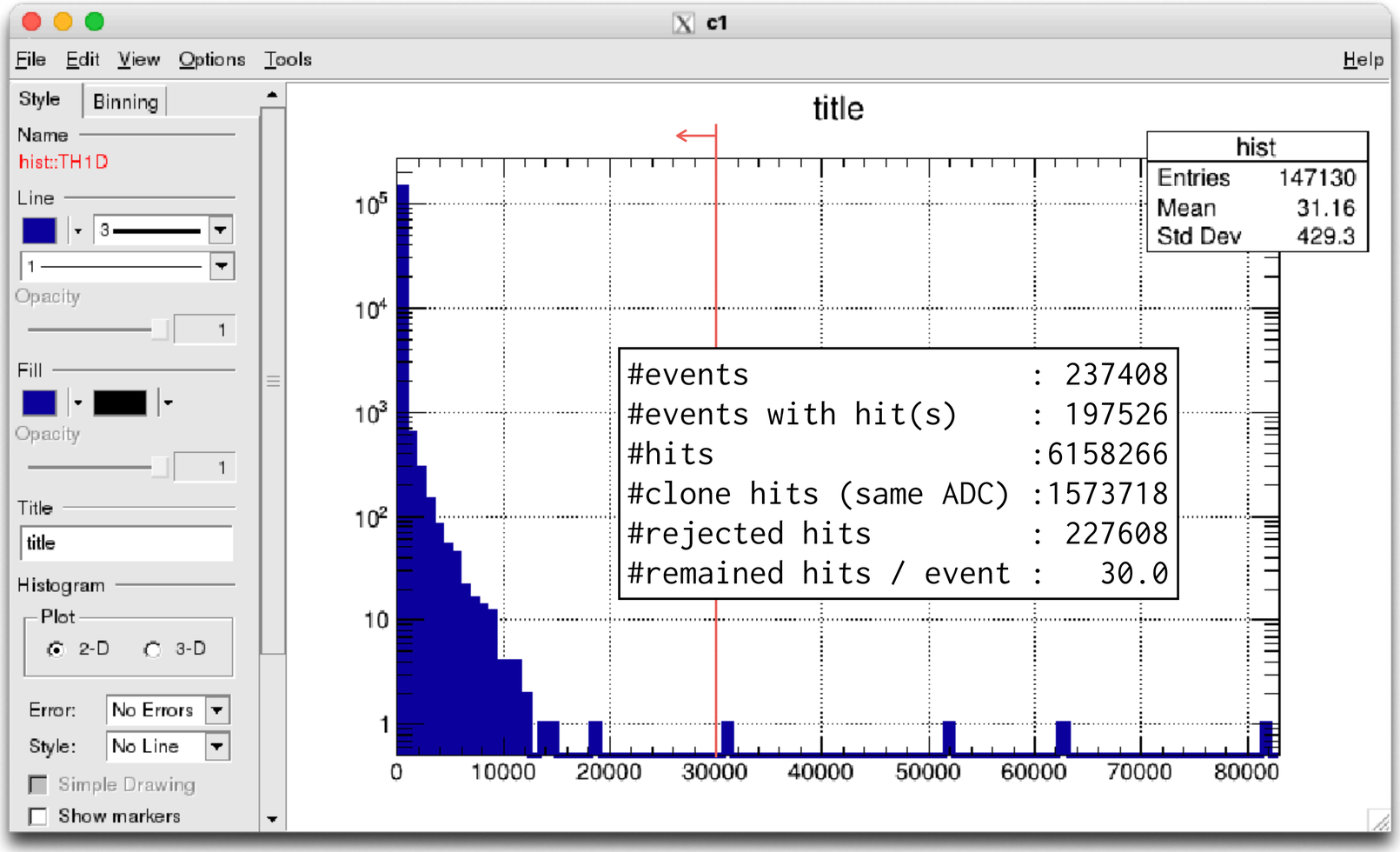
$$\Delta ADC = ADC_{can} - ADC_{ref}$$

Backup

Noisy channel analysis

Noisy channel analysis

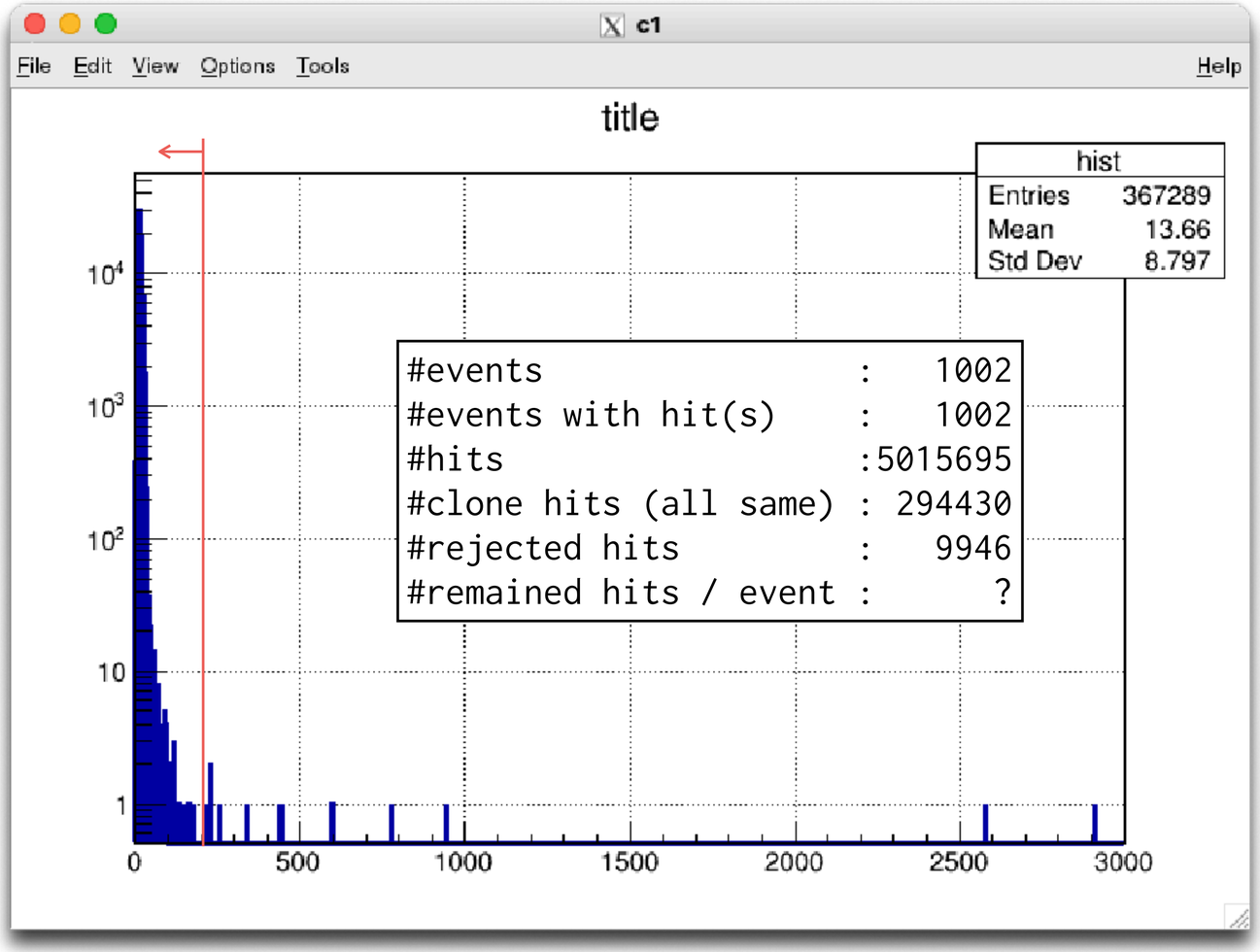
The top 4 channels with the most hits were rejected.
The threshold 4 can be optimized more.
Run26960



#pid	module	chip	ch	#hit	Ratio
3007	1	11	0	82049	1.3%
3007	1	12	0	62391	1.0%
3003	1	8	0	52110	0.8%
3007	12	19	0	31058	0.5%
Sum				227608	3.7%

Noisy channel analysis

The top N channels with the most hits were rejected.
The threshold N can be optimized more.
Run20869



Slides from the last report

Clone hit issue

Hits with the same parameters as a hit are found more or less often.

Parameters:

- module
- chip_id
- chan_id
- adc
- ampl
- fpga_id
- fem_id
- bco
- bco_full

They must be checked to judge whether this hit is a clone.

Clone-like hits, which have the same parameters but adc, have been reported.

It shouldn't matter except for calibration runs.

They were checked in the FEM era. They must be obsolete.

Whether they are checked or not depends on the analysis.

Those parameters were checked in analyzing data from the 3rd test beam experiment.
If all of them are the same, such hits were judged as clone hits and removed from the analysis.

The study in the past

A dedicated study was performed in the analysis of the 3rd test beam experiment by Genki.
At that time,

- Hits from 3 half-ladders were stored in a hit-base TTree.
- If all parameters of hits except BCO full are the same as a reference hit, they were tagged as clone candidates.
- If the difference of BCO full of hits is less than the threshold, they were judged as clone hits and removed from the analysis.

```
TTree
 ├─── trigger_1
 │     ├─── INTT_hit_1
 │     ├─── INTT_hit_2
 │     └─── INTT_hit_3
 ├─── trigger_2
 │     ├─── INTT_hit_1
 │     ├─── INTT_hit_2
 │     ├─── INTT_hit_3
 │     ├─── INTT_hit_4
 │     └─── INTT_hit_5
 └─── trigger_3
       ├─── INTT_hit_1
       ├─── INTT_hit_2
       ├─── INTT_hit_3
       └─── INTT_hit_4
```

The clone hits (aka. double saving)

Definition: Hits on INTT that
- belong to the same trigger event
- have the following parameters are the same as the other hit:
  - adc
  - ampl
  - chip_id
  - fpga_id
  - module
  - chan_id
  - fem_id

but BCO (full) is slightly different (± ?)

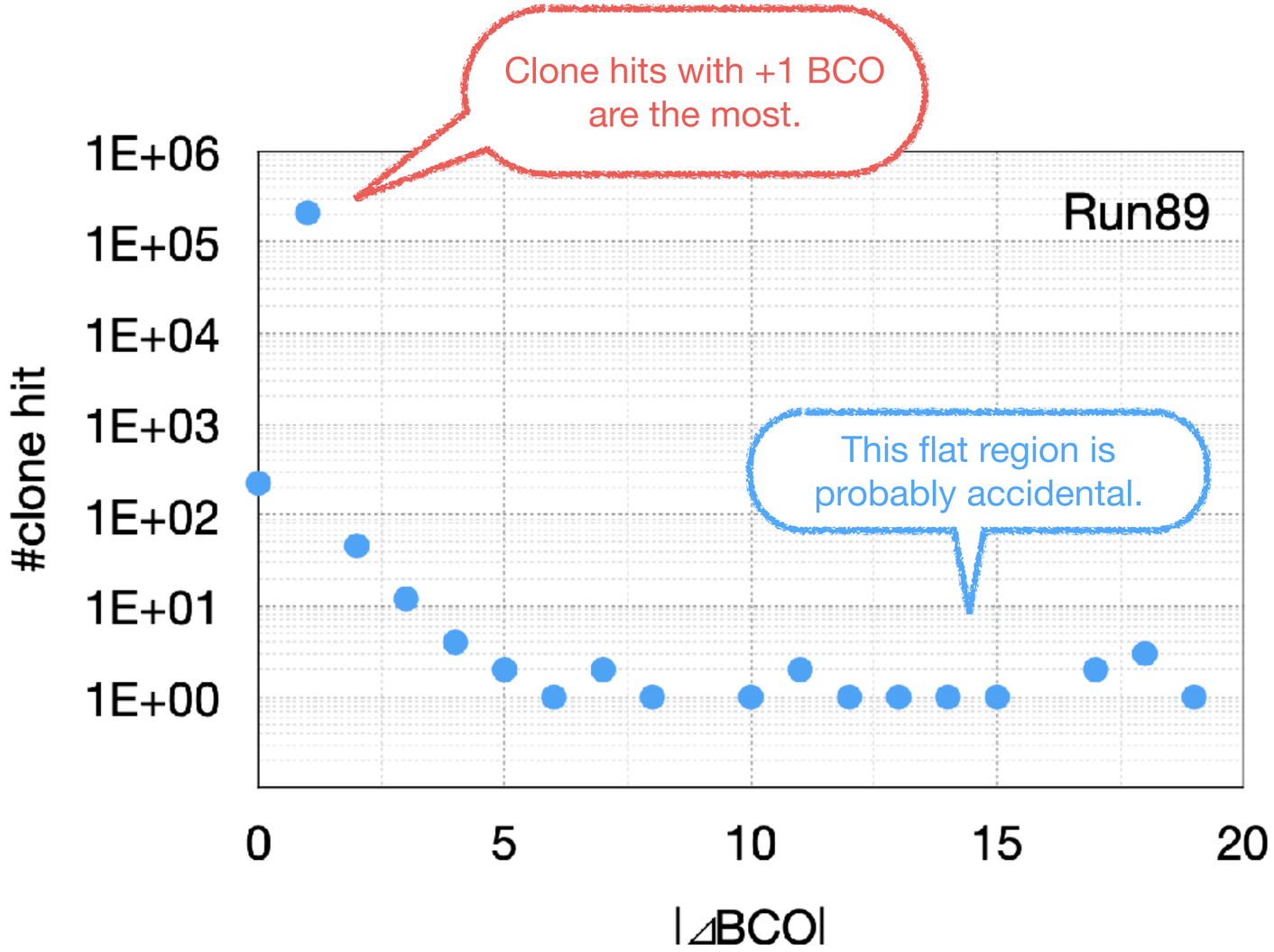
```
// loop over all hits
for( int i=0; i<adc->size(); i++ )
  {
    bool flag_clone_found = false;

    // loop over other hits to compare hit-i and hit-j
    for( int j=i+1; j<adc->size(); j++ )
      {
        int bco_diff = (*bco_full)[i] - (*bco_full)[j];

        // search range is here
        // if BCOs are different a lot, skip this
        if( abs(bco_diff) >= thre )
          continue;

        // check whether this hit (j) has the same parameters as the hit (i)
        if( (*adc)[i] != (*adc)[j] )
          continue;

        if( (*ampl)[i] != (*ampl)[j] )
          continue;

        if( (*chip_id)[i] != (*chip_id)[j] )
          continue;

        if( (*fpga_id)[i] != (*fpga_id)[j] )
          continue;

        if( (*module)[i] != (*module)[j] )
          continue;

        if( (*chan_id)[i] != (*chan_id)[j] )
          continue;

        if( (*fem_id)[i] != (*fem_id)[j] )
          continue;
```

Quite simple codes to judge whether this hit is clone or not

INTT meeting, 2022/01/27

The study in the past

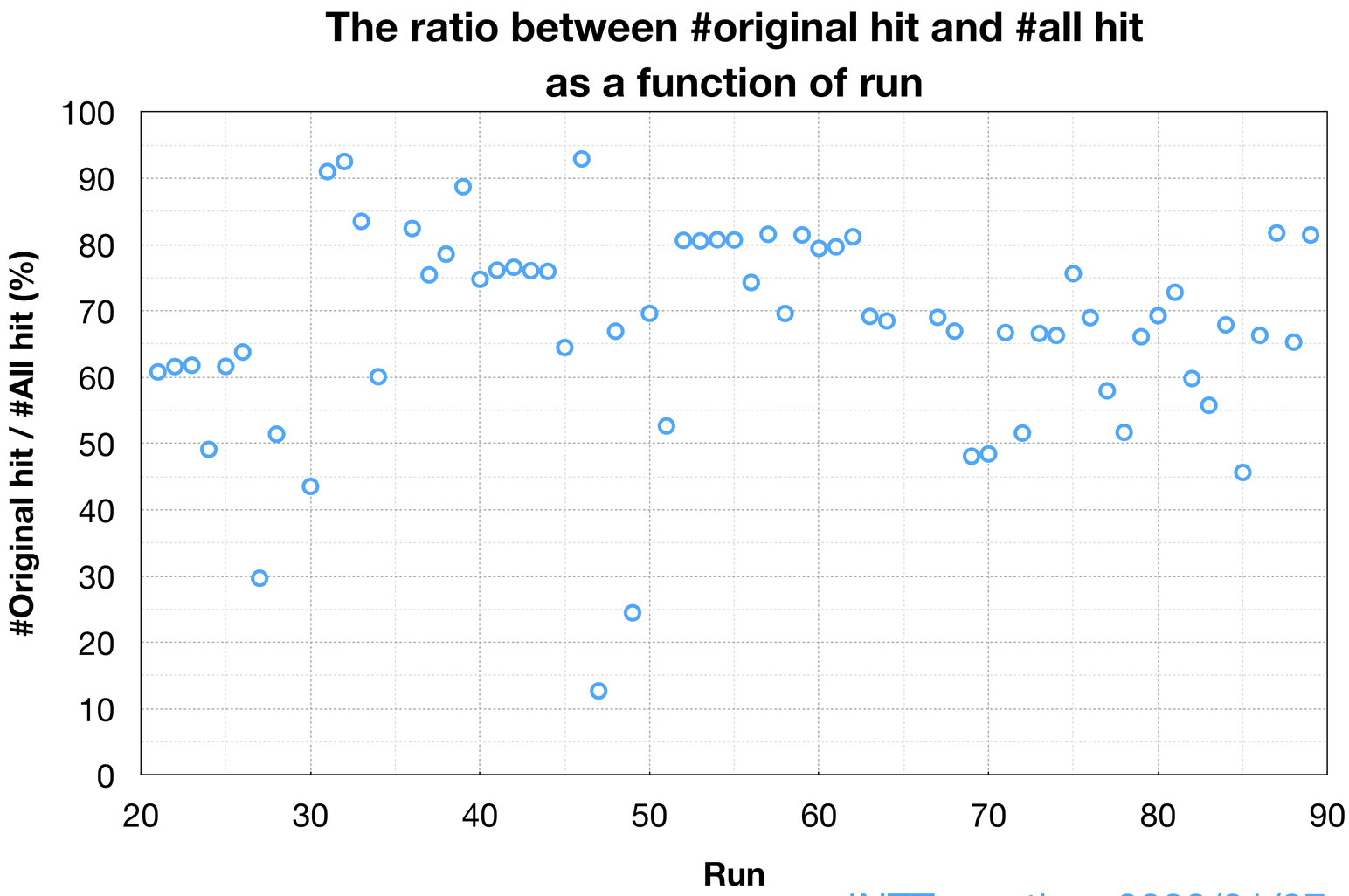
The number of hits which have the same parameters except BCO were counted. The number of clone hits is shown as a function of the BCO difference between the hits and the reference hit.



INTT meeting, 2022/01/27

The study in the past

The clone hits with a BCO difference of up to 5 were removed from the analysis.
The amount of clone hits strongly depends on the run; no clear tendency was found.



INTT meeting, 2022/01/27

Current status, the goal of this study, and things to be done

Current status

- Clone hits have been found with INTT barrel + FELIX.
  - We observed the clone hit issue with the FEM and the FELIX system FEM. The cause of the issue may be more detector side than FEM/FELIX, i.e., ROC or FPHX chip.
- The existence of clone-like hits, which have the same parameters except ADC, has been mentioned.

Goal

- Concluding how to treat clone hits.

Things to be done

- Confirmation of the status of FVTX.
  - Information from the FVTX group (communication b/w Itaru and Jin →)
  - Measurements at a test bench with the FVTX ladder.
- Understanding the issue by analyzing our data.
  - How often does it happen
  - Decomposing observables with FELIX, ladder, chip, or channel.
  - Observables as a function of the BCO (full) difference
  - Finding the clone-like hits

On 2023/10/07 10:38, Huang, Jin wrote:
> Hi Itaru
>
> I do not think we saw this: this would lead to calibration hit count higher than the input pulses count, which we never saw. In beam condition though, we never checked for this.
>
> There is some tricky delay configured individually for each of the ROC data FPGA which was trying to avoid hits arrival on the edge of clock. I would expect it would be different for INTT than FVTX as your cable length changed. This could be related.
>
> Cheers
>
> Jin

My naive question?

- How can we identify clone this from noise from hot channels?