Data analysis for the V detection efficiency

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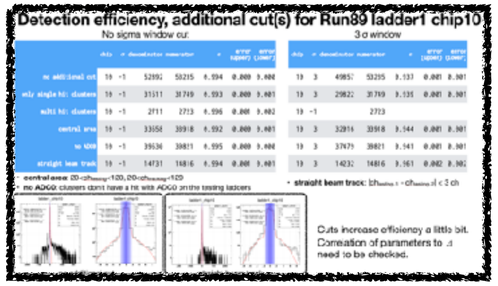
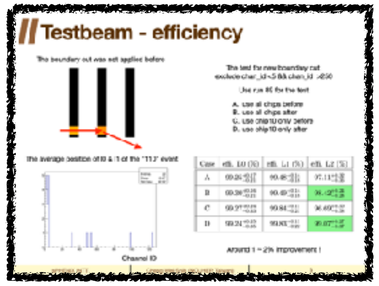
Past reports:

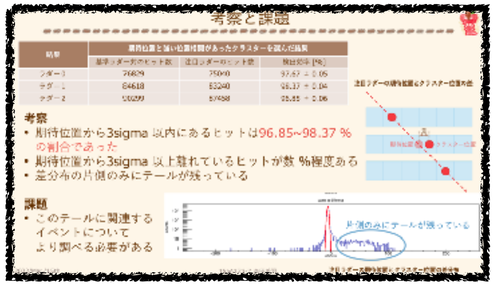
I. Jan/27/2022 (clone hits)
II. Feb/24/2022 (BCO grouping, clustering)
III. Mar/17/2022 (alignment)
IV. Mar/24/2022 (detection efficiency)

Issue: Analyzer dependence of the detection efficiency

Detection efficiency analysis of Run89 were done by Chen-Wei, Miu, and me.
The results without the sigma window cut to the residual distributions were consistent while with 3-sigma window cut look inconsistent.







No sigma window cut

	chip	σ	ε Ladder 0	ε Ladder 1	ε Ladder 2
Genki, no additional cut	10	-1	0.994	0.994	0.954
Genki, straight beam track	10	-1	0.981	0.994	0.963
Chen-Wei, ELPH poster					
Chen-Wei, new (3/24)					
Miu	10	-1	0.995	0.994	0.996

3 σ window

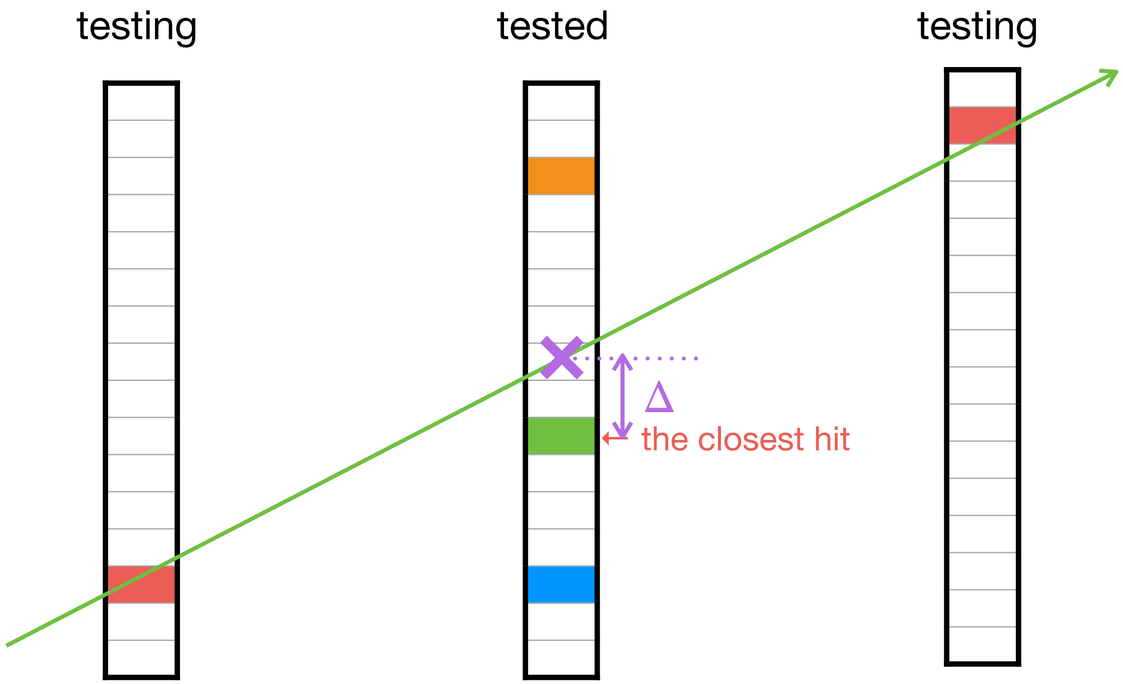
chip	σ	ε Ladder 0	ε Ladder 1	ε Ladder 2
10	3	0.940	0.937	0.894
10	3	0.883	0.961	0.921
all	3	0.993	0.995	0.971
10	3	0.992	0.998	0.991
10	3	0.977	0.984	0.969

The difference must be understood.

Issue: Analyzer dependence, tracking methods

From the conversation with Chen-Wei after the INTT meeting last week, I think got the point which made the difference.

Geometrical determination (Genki, Miu)

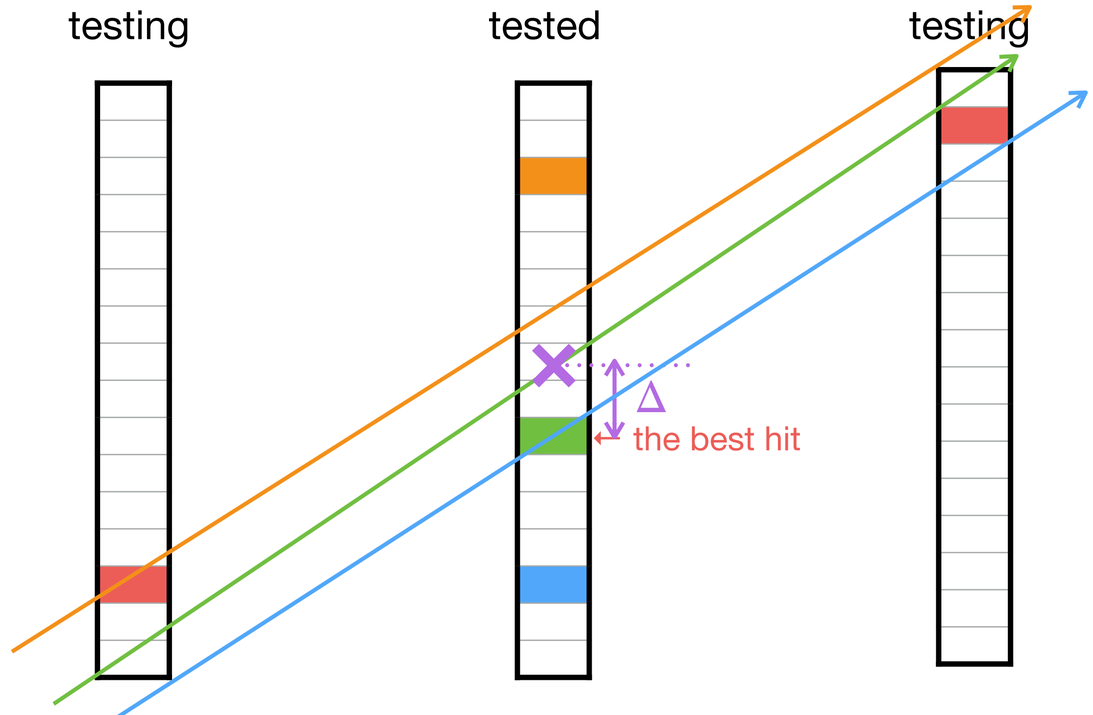


A cluster on each testing ladder are used for tracking.
The track can be determined uniquely:

$$y = ax + b \quad \text{and} \quad p_1 = (x_1, y_1)\ \&\ p_2 = (x_2, y_2)$$

The closest hit on the tested ladder to the predicted position by tracking is treated as a candidate.

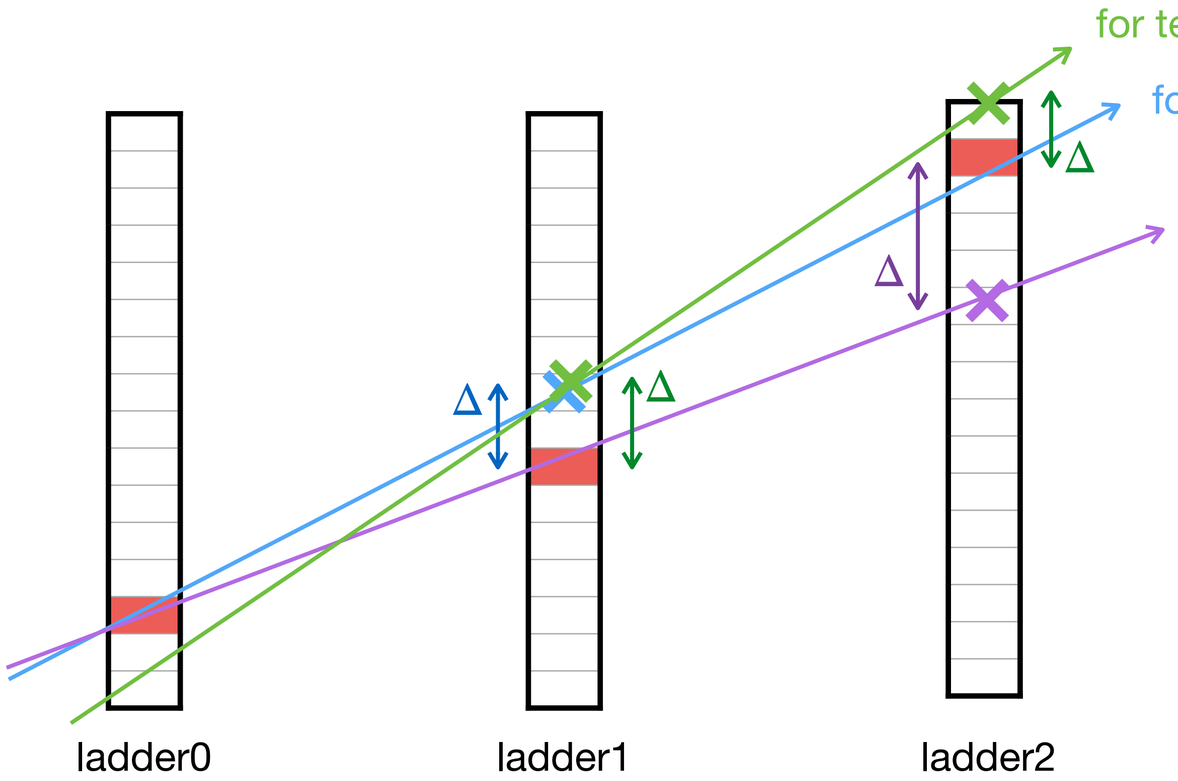
Determination by fitting (Cheng-Wei)

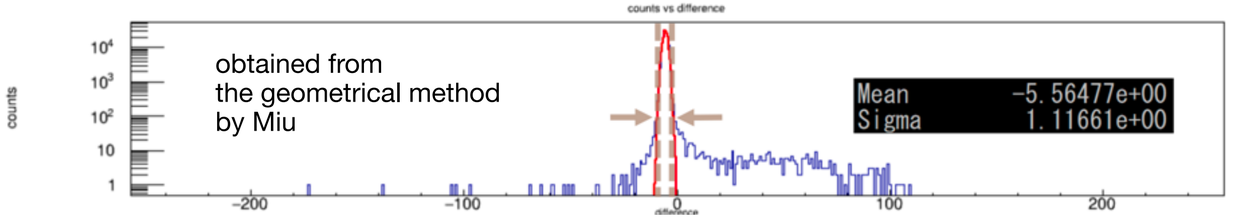


χ^2_{orange}: 17
χ^2_{green}: 3
χ^2_{blue}: 24

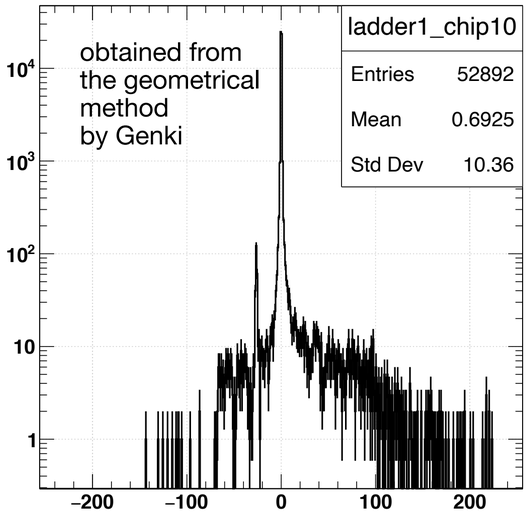
A cluster on each testing ladder and one of a cluster on the tested are used for tracking.
A track is made by fitting to the 3 points with a straight line. The track with the smallest χ^2 is hired.

Issue: Analyzer dependence, tracking methods

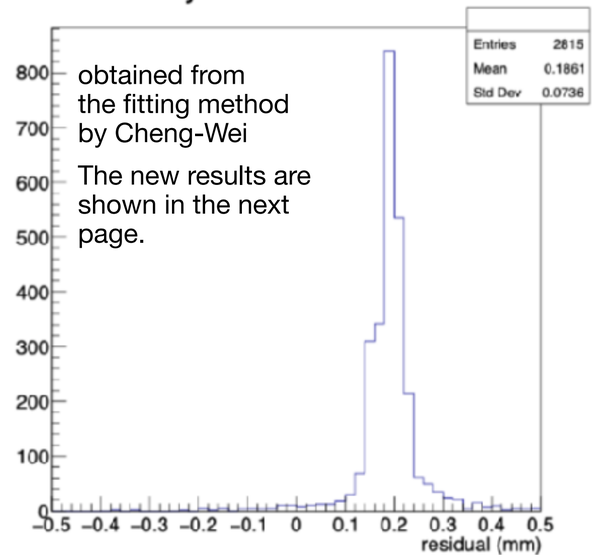




ladder1_chip10



layer1 Y axis residual



The fitting method always makes a moderate line to all hits.
The geometrical method never care the tested ladder
so sometimes overestimates the residual.
These tracking methods give different residual distributions. It means the detection efficiency without the sigma window cut is consistent but different with the sigma window.

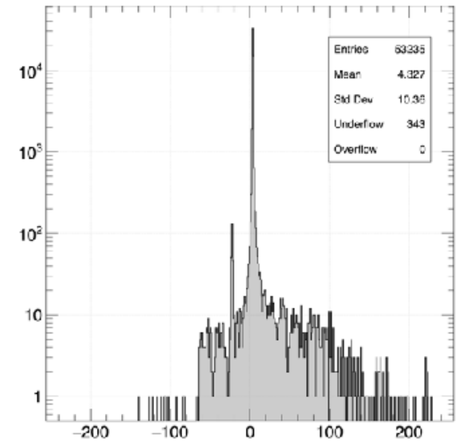
Issue: Analyzer dependence, trying the fitting method

Run89

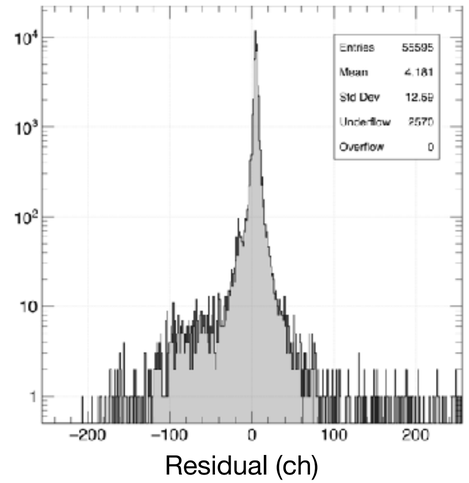
Geometrical method

Genki

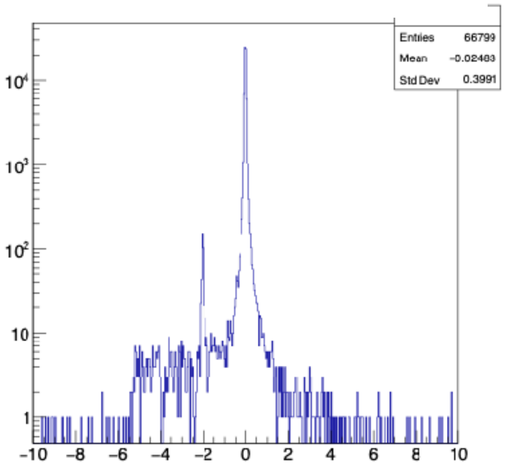
ladder1, chip10



ladder2, chip10



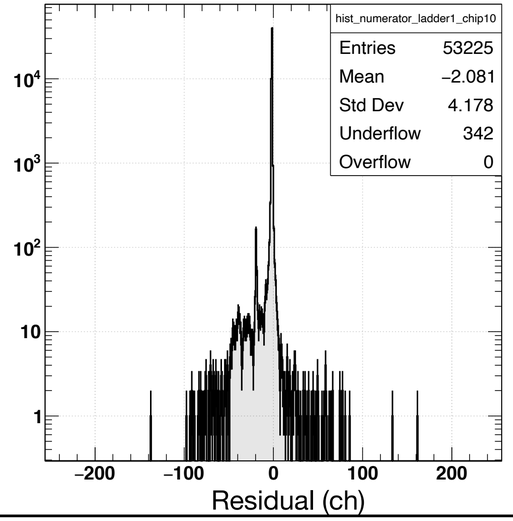
Chen-Wei

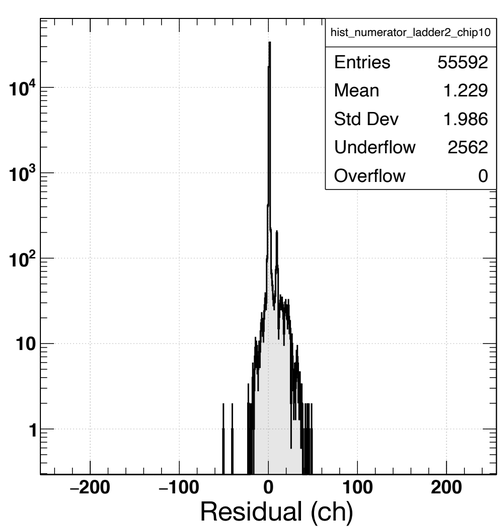


Note:
Genki → Cheng-wei: 256 ch ~ 20 mm
Cheng-Wei → Genki: 10 mm ~ 128 ch

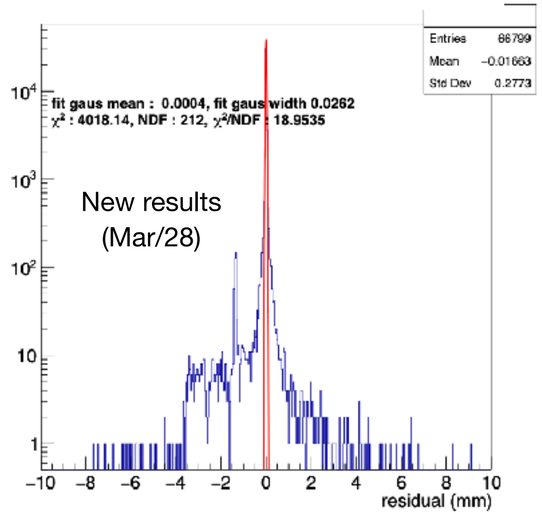
Fitting method

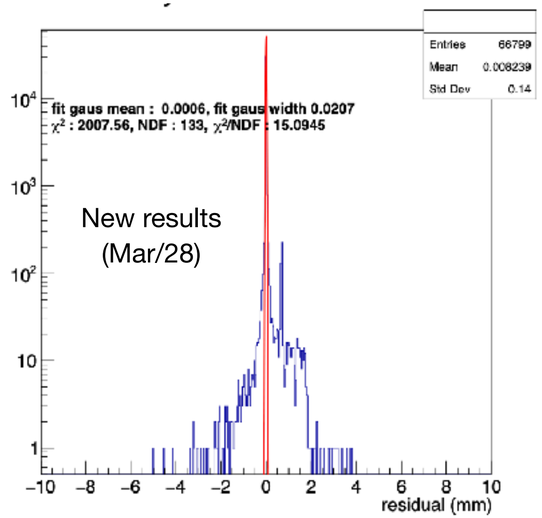
Genki





Chen-Wei





Note: My plots are updated from the ones sent to the INTT mailing list. There were bugs.

Issue: Analyzer dependence, trying the fitting method

Run89

Geometrical method

Fitting method

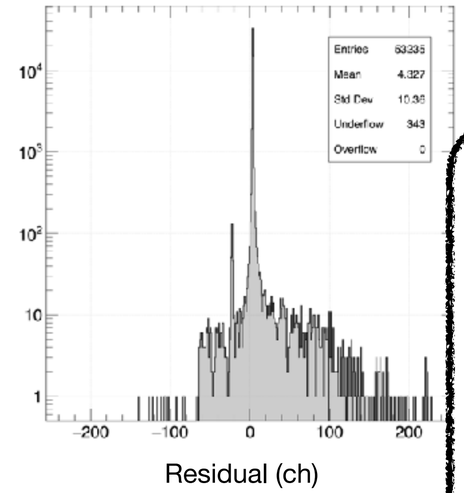
Genki

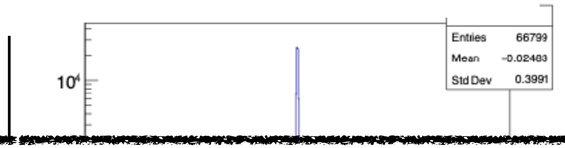
Chen-Wei

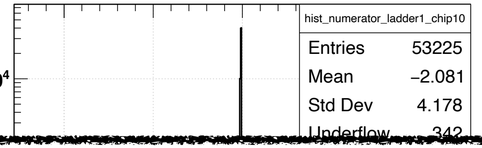
Genki

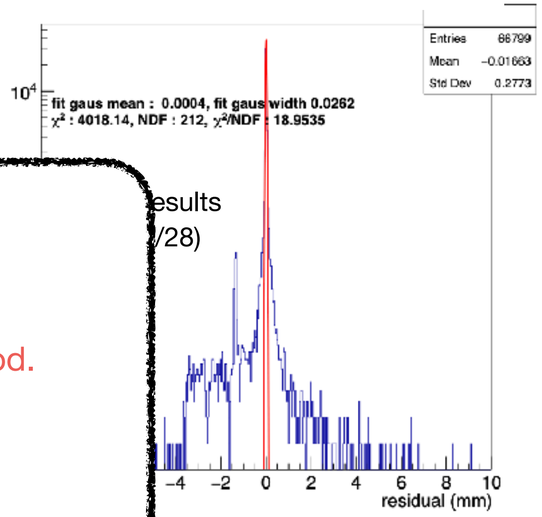
Chen-Wei

ladder1, chip10

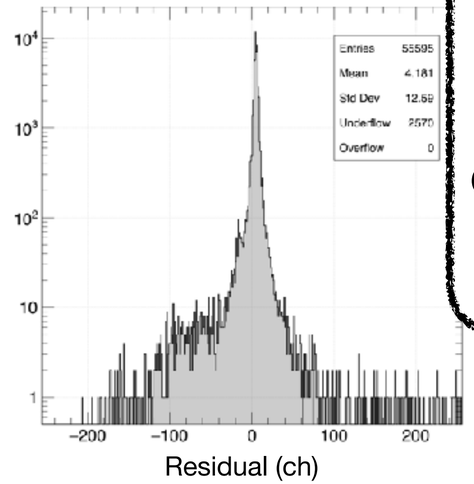


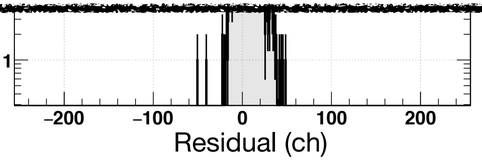


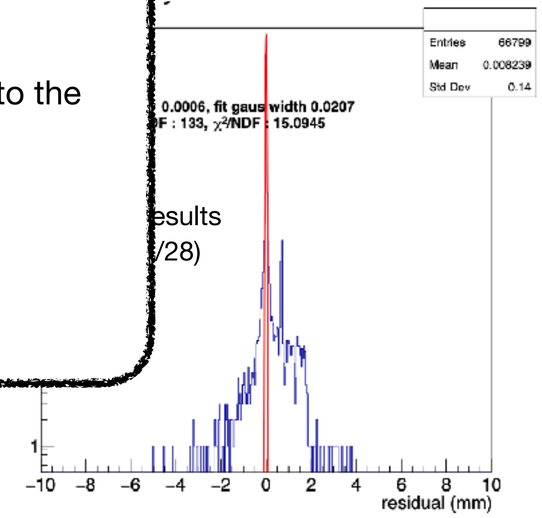




ladder2, chip10







Genki's results:

Residual distributions using the methods are different as expected.
The flat background seen in the geometrical method is quite small in the fitting method.
The positions of the satellite peak in ladder2 towards in opposite directions. I don't understand why…

Cheng-Wei's new results:

New results were obtained using Genki's data having no clone hits.
The fitting method creates narrower distribution than the geometrical method.
The satellite peak exists for all plots. They were not seen in the previous results (due to the scale of the y-axis?).

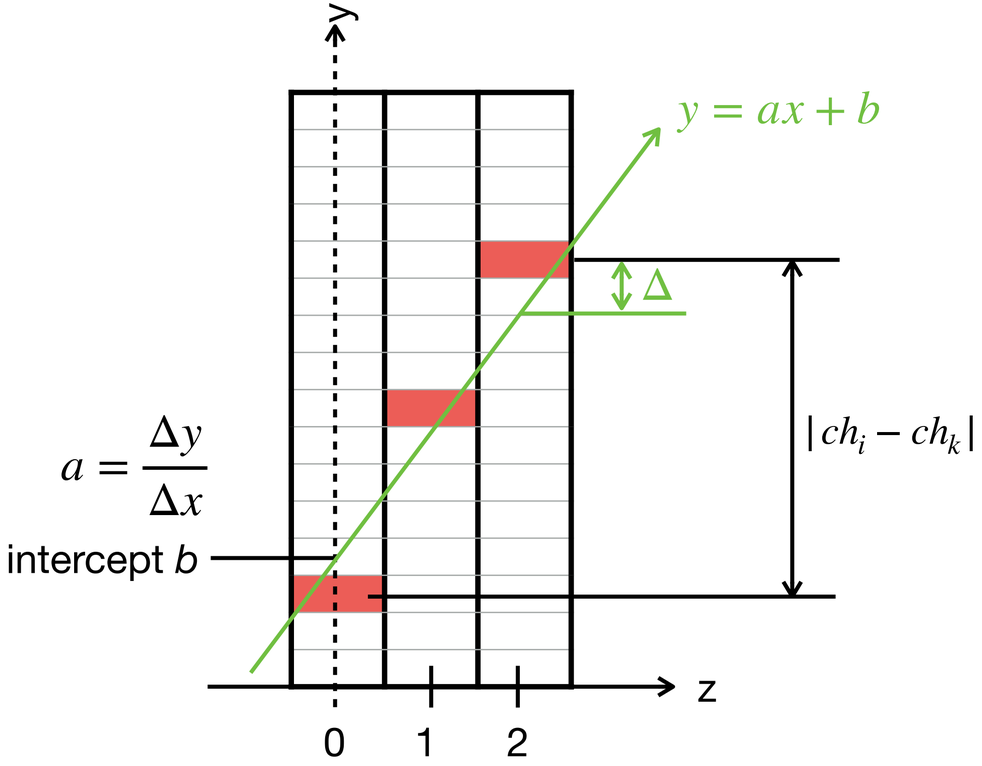
Genki's vs Cheng-Wei's

Results look consistent.

Genki → Cheng-wei: 256 ch ~ 20 mm
Cheng-Wei → Genki: 10 mm ~ 128 ch

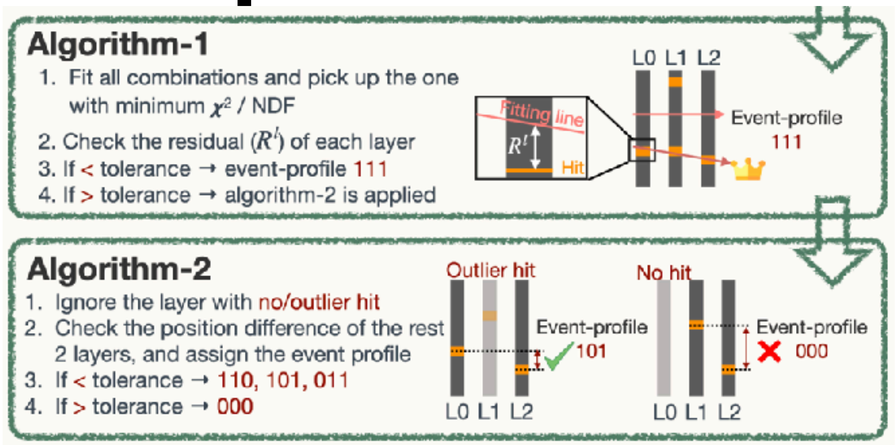
Issue: Analyzer dependence, track slope cut

As far as I understand, a requirement of small track slope is included in Chen-Wei's analysis. The largest value required to the slope is the same as the 3-σ window cut.



slope: channel difference when moving from a ladder to the next ladder

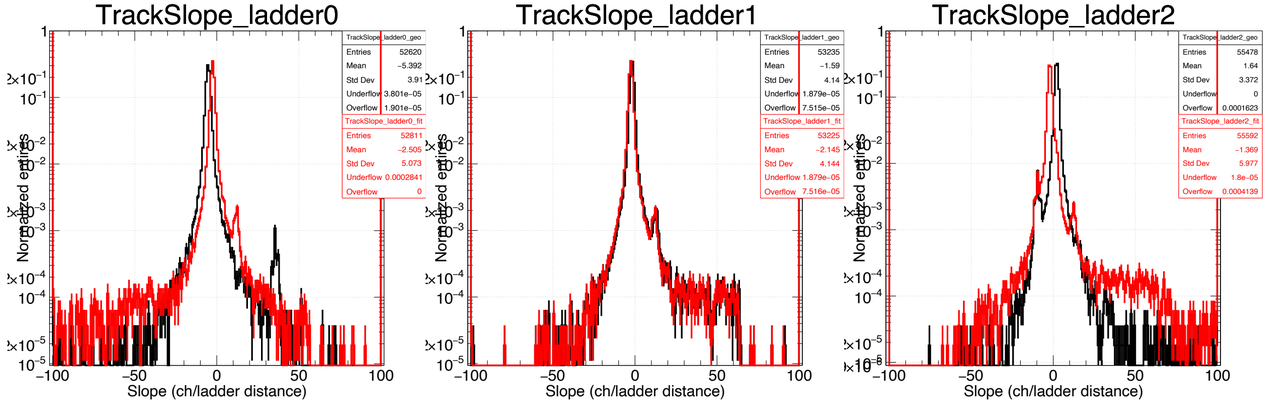
intercept: position at ladder0



Cheng-Wei, ELPH2022

- Geometrical method
- Fitting method

Run89, chip10



Track slope distributions

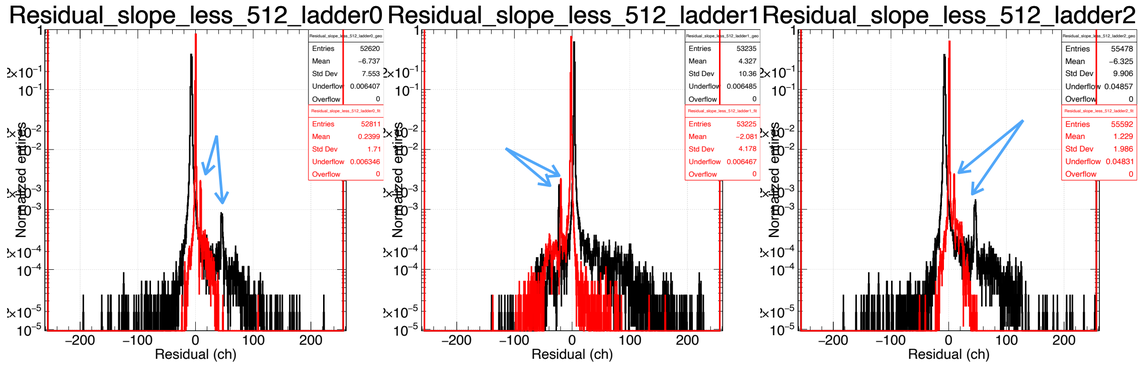
Again, there are some discrepancy between the 2 methods, and I need to take time to investigate it…

Issue: Analyzer dependence, track slope cut to the residual dists.

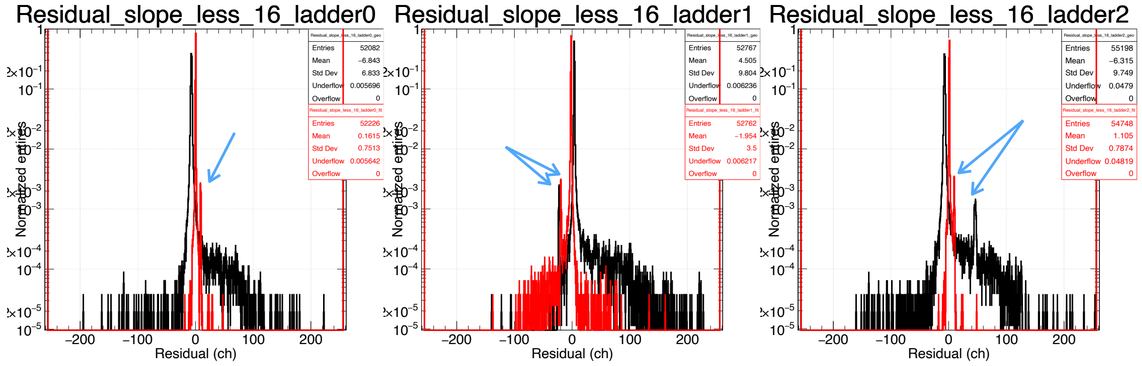
Run89, chip10

Ladder0 Ladder1 Ladder2

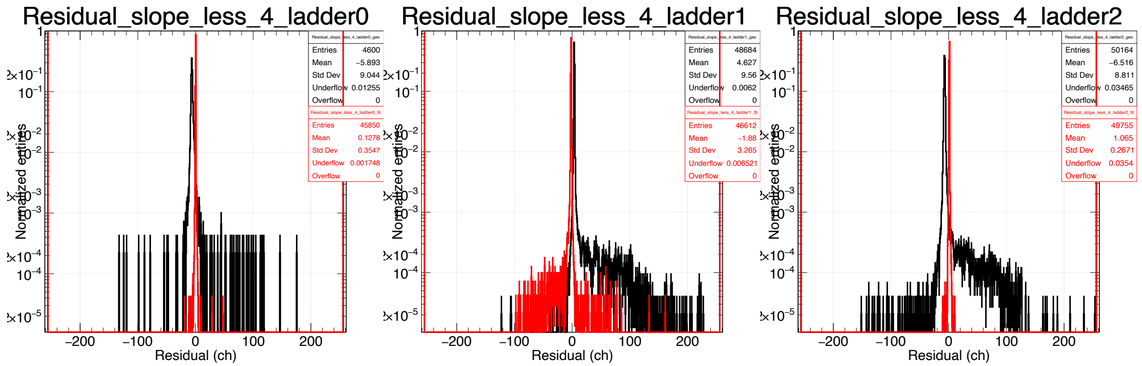
No slope cut



|slope| < 16



|slope| < 4

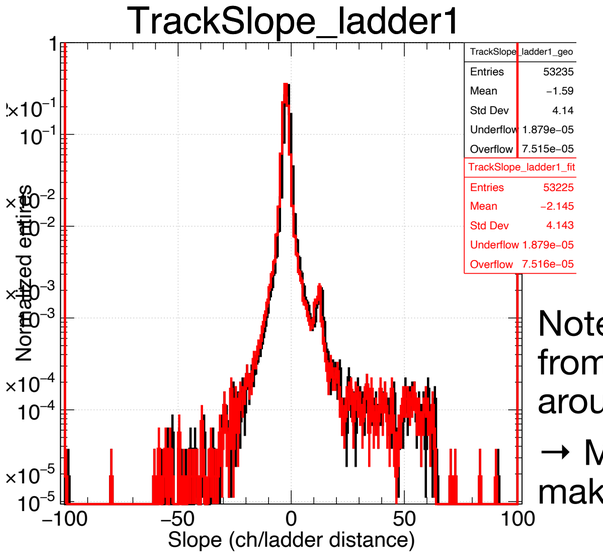


The satellite peaks are strongly suppressed by the slope cut.

The track slope cut |slope|<16 narrows the distributions.

The track slope cut |slope|<4 completely removes the satellite peak for all cases. It's not due to less statistics because the hight of the peak is not so affected.

Chen-Wei applied |slope| < 3 in my understanding. This cut doesn't improve my results somehow. Since the track slope distribution is not centered, I tried selecting events around the mean value (How large is fine?).

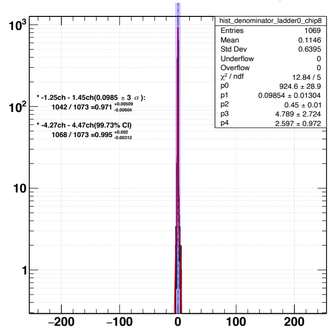


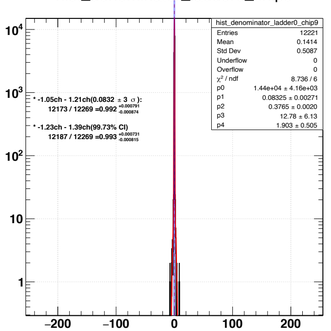
Note: Track slope distribution from MC data distributes around 0.

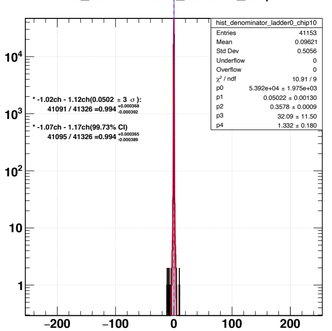
→ My analysis codes don't make a bias.

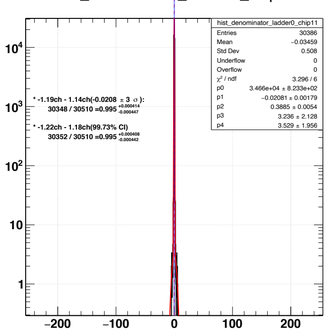
Residuals, Whole range

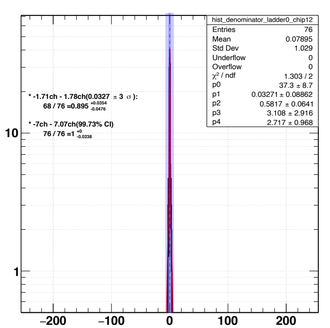
	chip8	chip9	chip10	chip11	chip12
ladder0	hist_denominator_ladder0_chip8	hist_denominator_ladder0_chip9	hist_denominator_ladder0_chip10	hist_denominator_ladder0_chip11	hist_denominator_ladder0_chip12
ladder1	hist_denominator_ladder1_chip8	hist_denominator_ladder1_chip9	hist_denominator_ladder1_chip10	hist_denominator_ladder1_chip11	hist_denominator_ladder1_chip12
ladder2	hist_denominator_ladder2_chip8	hist_denominator_ladder2_chip9	hist_denominator_ladder2_chip10	hist_denominator_ladder2_chip11	hist_denominator_ladder2_chip12

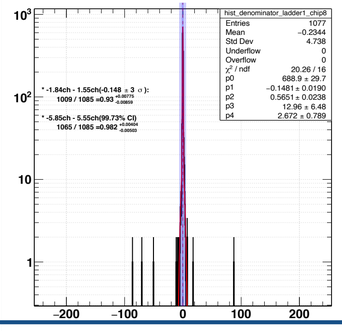


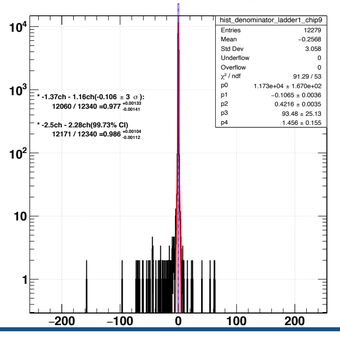


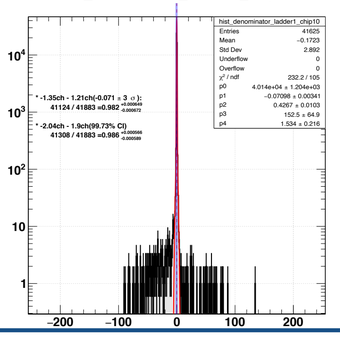


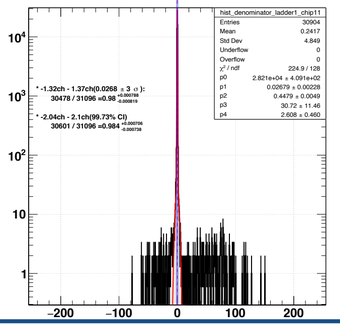


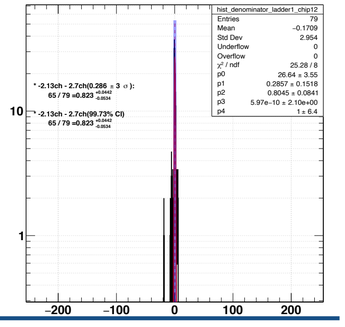


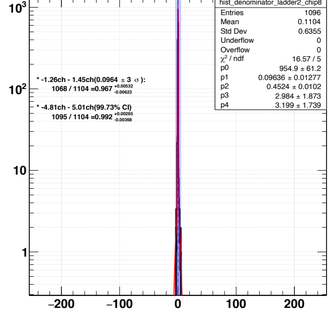


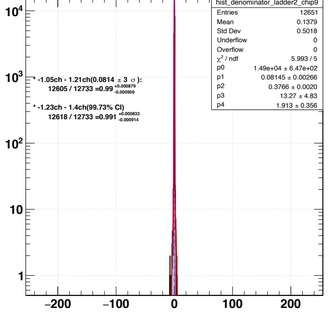


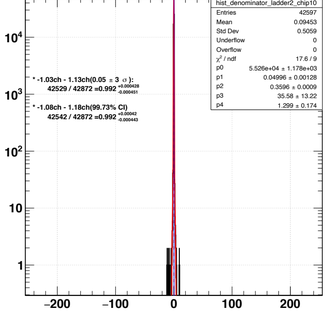


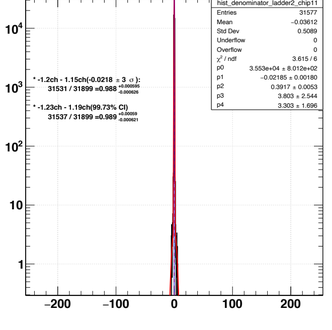


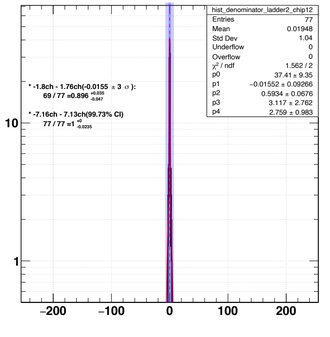






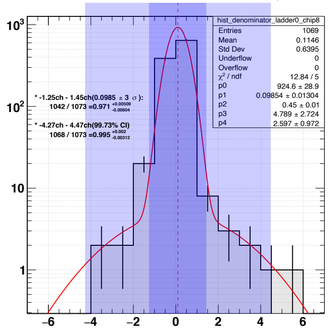


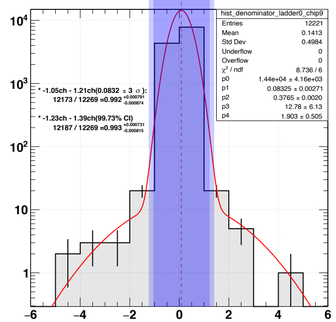


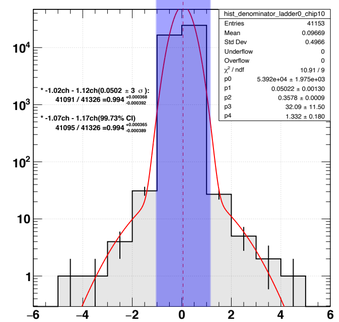


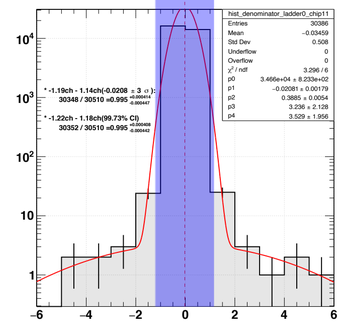
Residuals, Zoomed

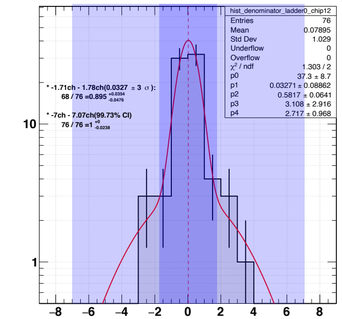
	chip8	chip9	chip10	chip11	chip12
ladder0	hist_denominator_ladder0_chip8	hist_denominator_ladder0_chip9	hist_denominator_ladder0_chip10	hist_denominator_ladder0_chip11	hist_denominator_ladder0_chip12
ladder1	hist_denominator_ladder1_chip8	hist_denominator_ladder1_chip9	hist_denominator_ladder1_chip10	hist_denominator_ladder1_chip11	hist_denominator_ladder1_chip12
ladder2	hist_denominator_ladder2_chip8	hist_denominator_ladder2_chip9	hist_denominator_ladder2_chip10	hist_denominator_ladder2_chip11	hist_denominator_ladder2_chip12

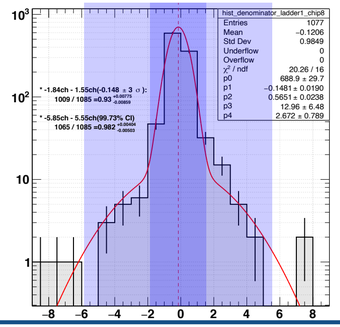


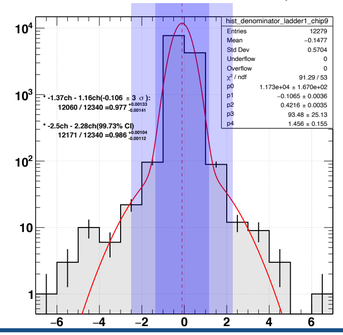


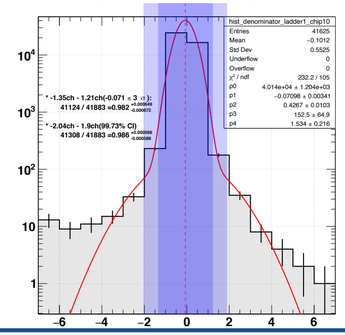


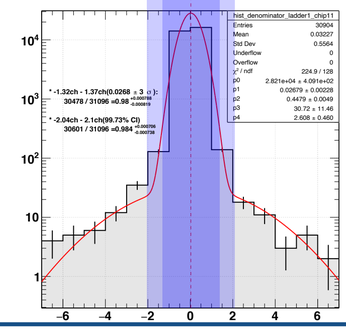


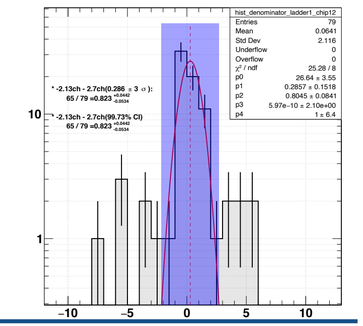


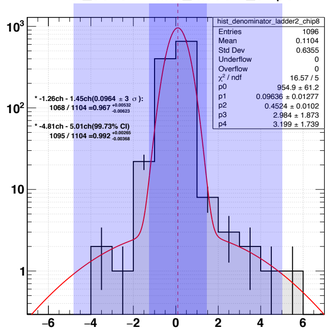


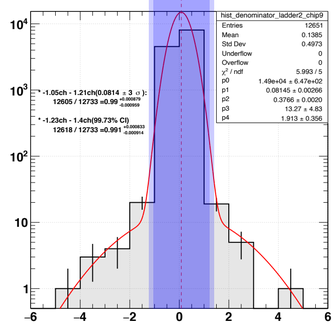


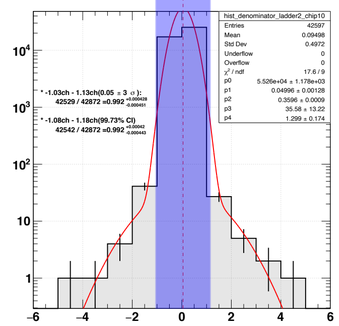


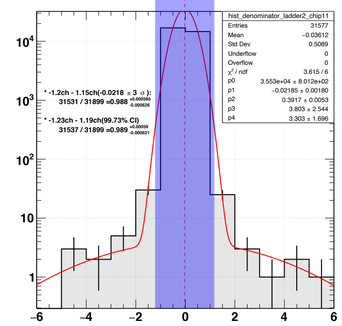


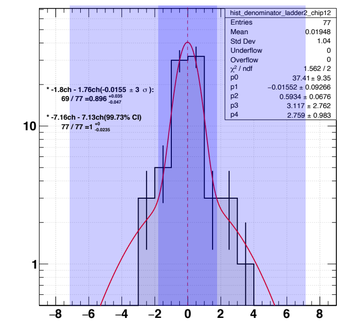




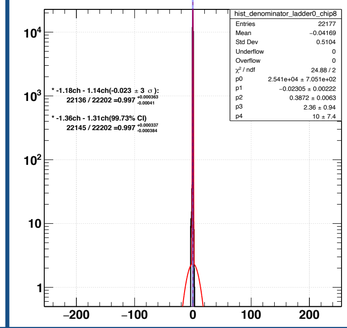
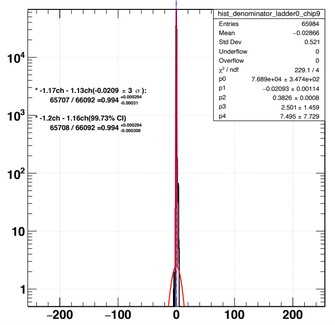
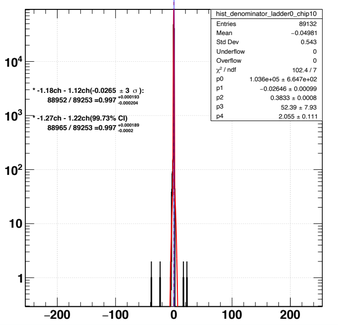
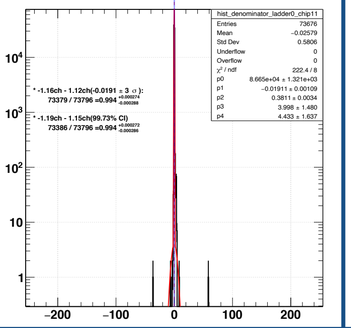
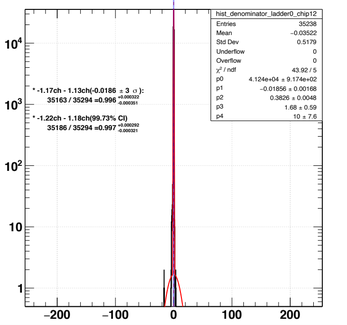
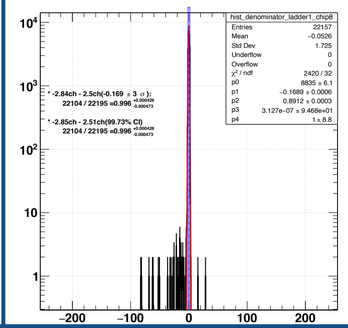
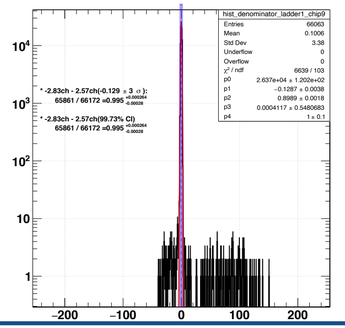
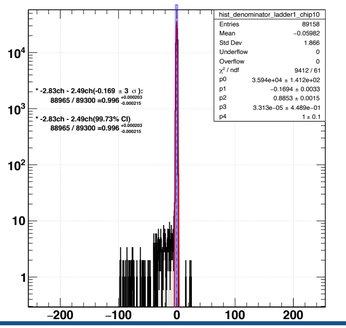
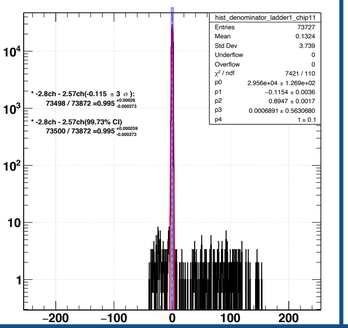
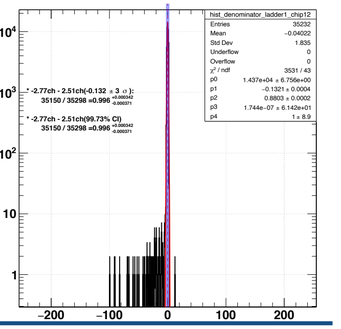
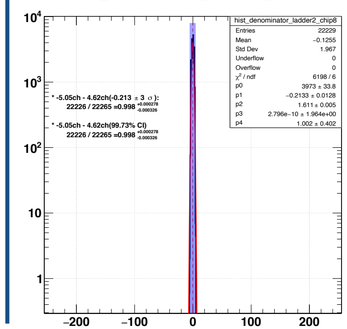
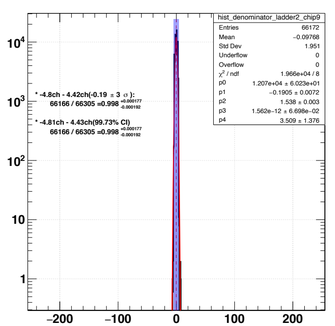
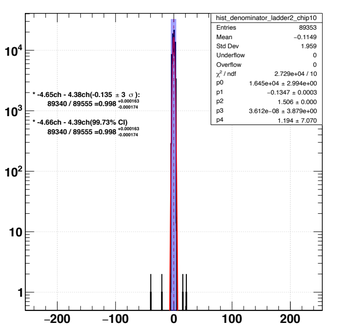
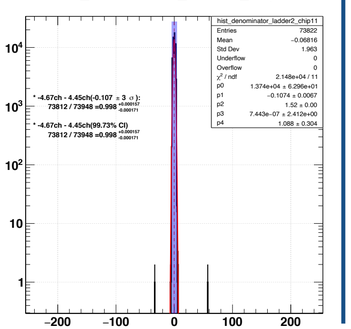
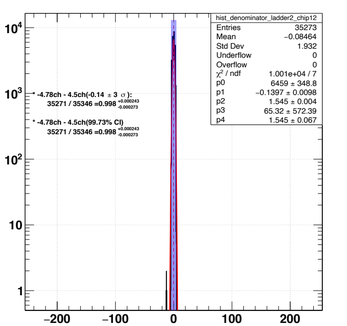






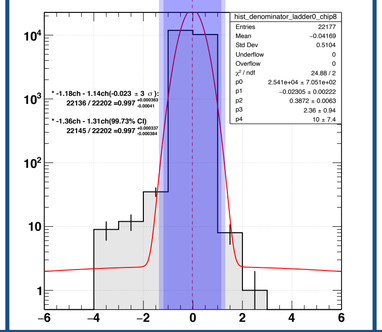


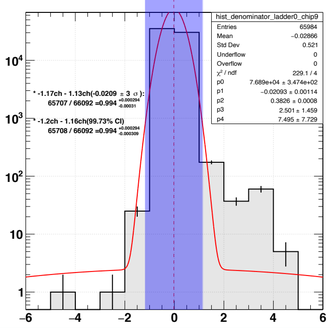
MC, Residuals, Whole range

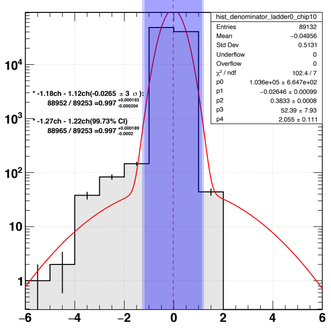
	chip8	chip9	chip10	chip11	chip12
ladder0	hist_denominator_ladder0_chip8 	hist_denominator_ladder0_chip9 	hist_denominator_ladder0_chip10 	hist_denominator_ladder0_chip11 	hist_denominator_ladder0_chip12 
ladder1	hist_denominator_ladder1_chip8 	hist_denominator_ladder1_chip9 	hist_denominator_ladder1_chip10 	hist_denominator_ladder1_chip11 	hist_denominator_ladder1_chip12 
ladder2	hist_denominator_ladder2_chip8 	hist_denominator_ladder2_chip9 	hist_denominator_ladder2_chip10 	hist_denominator_ladder2_chip11 	hist_denominator_ladder2_chip12 

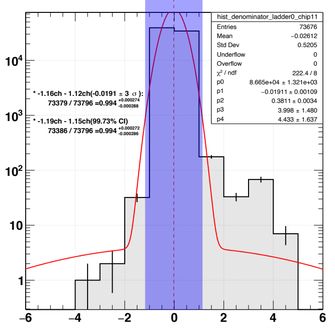
MC, Residuals, Zoomed

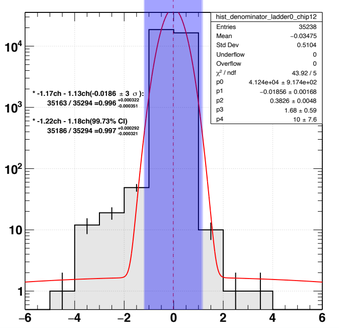
	chip8	chip9	chip10	chip11	chip12
ladder0	hist_denominator_ladder0_chip8	hist_denominator_ladder0_chip9	hist_denominator_ladder0_chip10	hist_denominator_ladder0_chip11	hist_denominator_ladder0_chip12
ladder1	hist_denominator_ladder1_chip8	hist_denominator_ladder1_chip9	hist_denominator_ladder1_chip10	hist_denominator_ladder1_chip11	hist_denominator_ladder1_chip12
ladder2	hist_denominator_ladder2_chip8	hist_denominator_ladder2_chip9	hist_denominator_ladder2_chip10	hist_denominator_ladder2_chip11	hist_denominator_ladder2_chip12

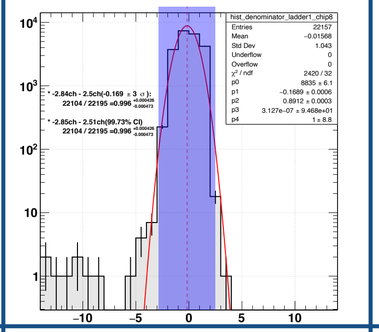


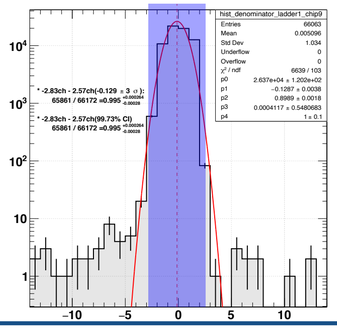


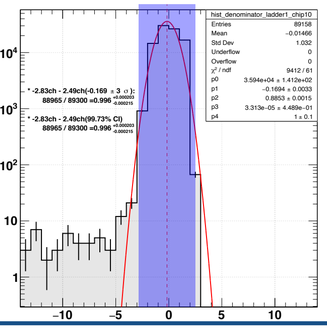


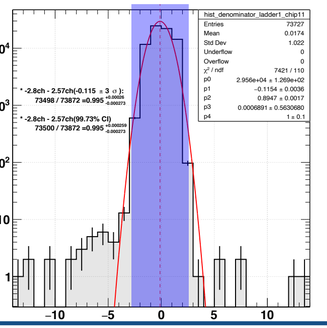


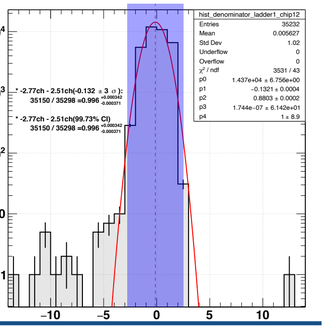


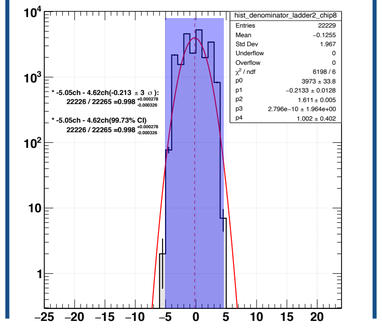


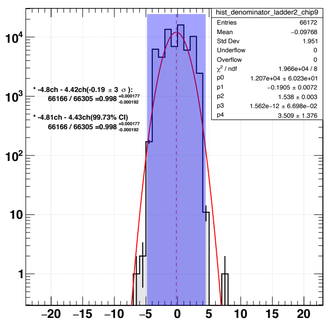


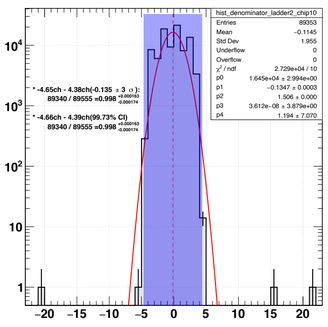


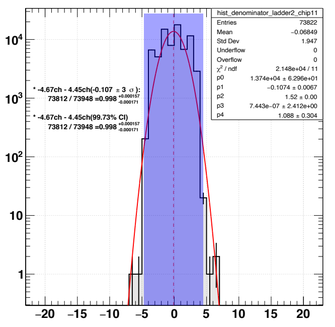


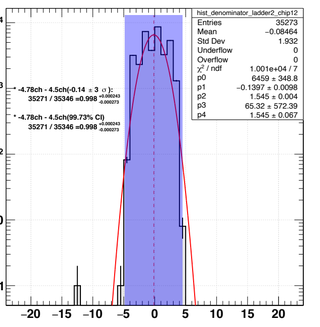












Issue: Analyzer dependence, Detection efficiency with Fitting method

Ladder0

Chip	σ	#hits found	#track	ε	Upper error	Lower error
8	-1	1069	1073	0.996	0.002	0.003
8	3	1042	1073	0.971	0.005	0.006
9	-1	12221	12269	0.996	0.001	0.001
9	3	12173	12269	0.992	0.001	0.001
10	-1	41153	41326	0.996	0.000	0.000
10	3	41091	41326	0.994	0.000	0.000
11	-1	30386	30510	0.996	0.000	0.000
11	3	30348	30510	0.995	0.000	0.000
12	-1	76	76	1.000	0.000	0.024
12	3	68	76	0.895	0.035	0.048
all	-1	84905	85254	0.996		
all	3	84722	85254	0.994		

Ladder1

Chip	σ	#hits found	#track	ε	Upper error	Lower error
8	-1	1077	1085	0.993	0.003	0.004
8	3	1009	1085	0.930	0.008	0.009
9	-1	12279	12340	0.995	0.001	0.001
9	3	12060	12340	0.977	0.001	0.001
10	-1	41625	41883	0.994	0.000	0.000
10	3	41124	41883	0.982	0.001	0.001
11	-1	30904	31096	0.994	0.000	0.000
11	3	30478	31096	0.980	0.001	0.001
12	-1	79	79	1.000	0.000	0.023
12	3	65	79	0.823	0.044	0.053
all	-1	85964	86483	0.994		
all	3	83727	85398	0.980		

Ladder2

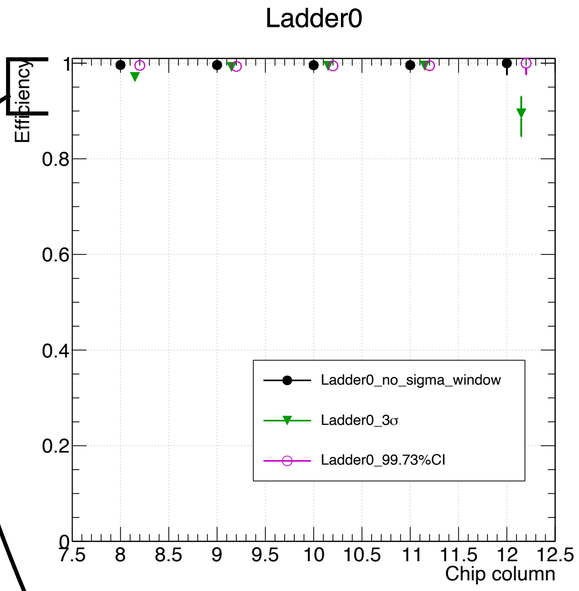
Chip	σ	#hits found	#track	ε	Upper error	Lower error
8	-1	1096	1104	0.993	0.002	0.004
8	3	1068	1104	0.967	0.005	0.006
9	-1	12651	12733	0.994	0.001	0.001
9	3	12605	12733	0.990	0.001	0.001
10	-1	42597	42872	0.994	0.000	0.000
10	3	42529	42872	0.992	0.000	0.000
11	-1	31577	31899	0.990	0.001	0.001
11	3	31531	31899	0.988	0.001	0.001
12	-1	77	77	1.000	0.000	0.024
12	3	69	77	0.896	0.035	0.047
all	-1	87998	88685	0.992		
all	3	87802	88685	0.990		

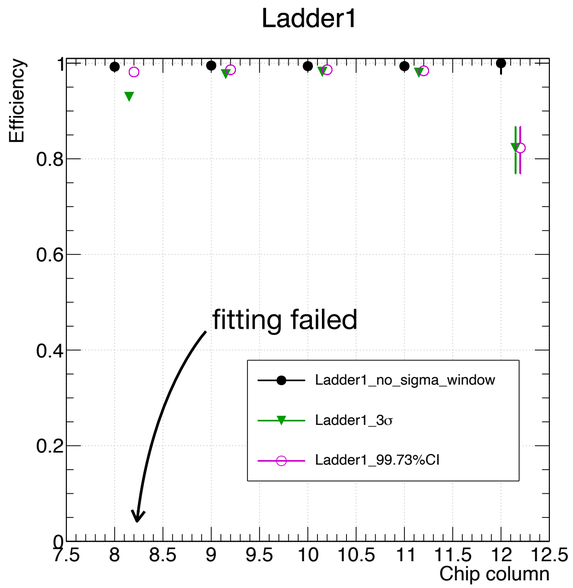
Note: $10<ch_{testing}$ is not used

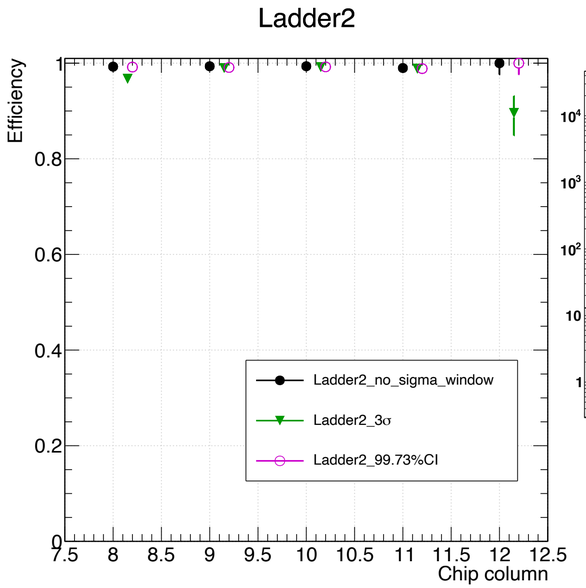
Note2: The results sent to the mailing list required “-3<slope<-1” while these are required “-4.3<slope<-0.3”

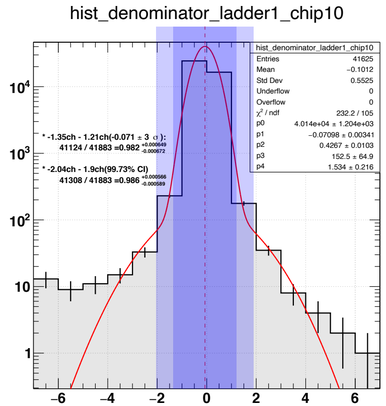
Issue: Analyzer dependence, Detection efficiency with Fitting method

Run89

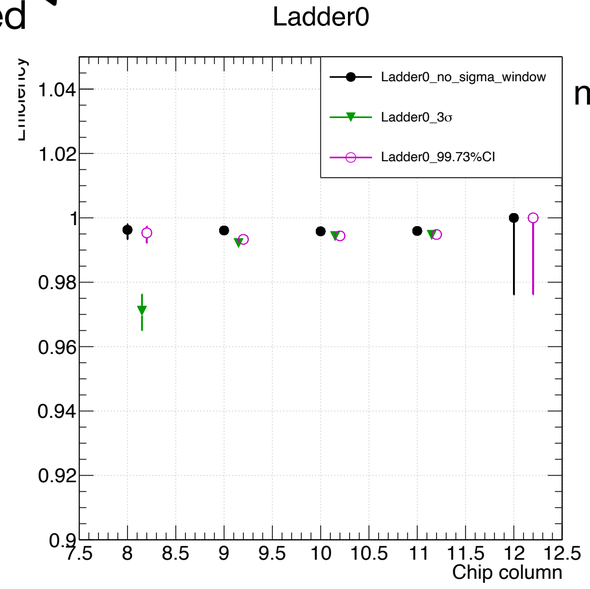




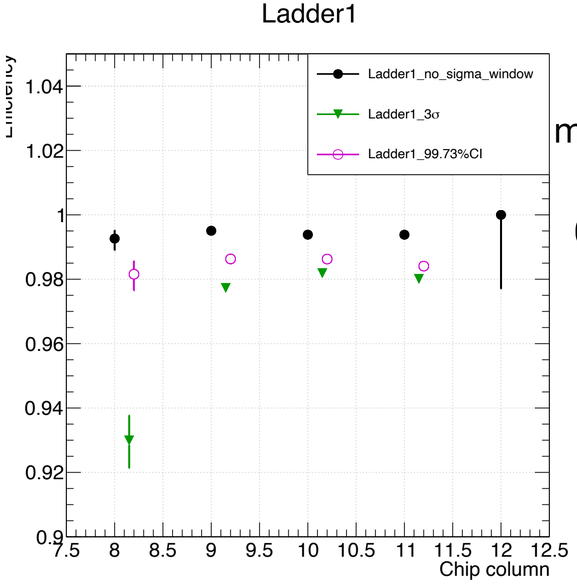




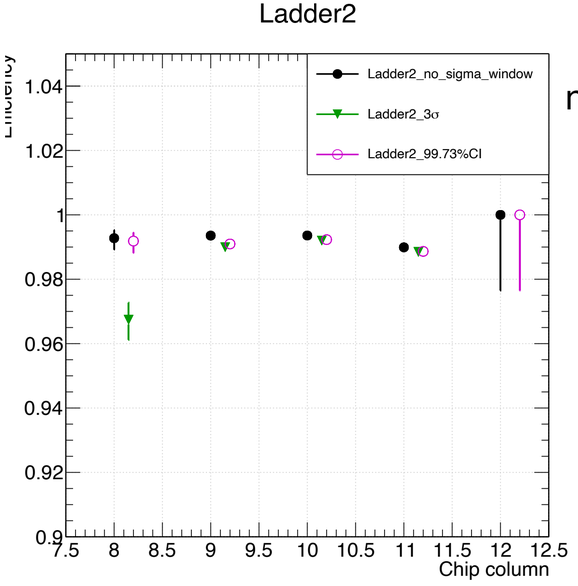
zoomed



mean of 3σ 0.994



mean of 3σ 0.980



mean of 3σ 0.990

Issue: Analyzer dependence, Detection efficiency, Comparison

Since the track slope distributions from the 2 methods are not the same, comparison of the detection efficiency with the track slope cut is not possible. Comparison with the cut is briefly shown.

Detection efficiency without the sigma window cut

Ladder0

	Chip	σ	ε Fitting	ε Geometrical	Fit. - Geom.
0	9	-1	99.6%	99.6%	0.04%
0	10	-1	99.6%	99.5%	0.03%
0	11	-1	99.6%	99.6%	0.00%

Ladder1

	Chip	σ	ε Fitting	ε Geometrical	Fit. - Geom.
1	9	-1	99.5%	99.5%	0.05%
1	10	-1	99.4%	99.4%	0.01%
1	11	-1	99.4%	99.4%	-0.02%

Ladder2

	Chip	σ	ε Fitting	ε Geometrical	Fit. - Geom.
2	9	-1	99.4%	99.5%	-0.10%
2	10	-1	99.4%	99.4%	-0.02%
2	11	-1	99.0%	99.0%	0.01%

→ No big difference between the 2 methods as expected

Detection efficiency with the 3-sigma window cut

	Chip	σ	ε Fitting	ε Geometrical	Fit. - Geom.
0	9	3	99.2%	96.3%	2.96%
0	10	3	99.4%	97.0%	2.43%
0	11	3	99.5%	96.7%	2.77%

	Chip	σ	ε Fitting	ε Geometrical	Fit. - Geom.
1	9	3	97.7%	96.1%	1.63%
1	10	3	98.2%	96.2%	2.02%
1	11	3	98.0%	95.5%	2.52%

	Chip	σ	ε Fitting	ε Geometrical	Fit. - Geom.
2	9	3	99.0%	95.2%	3.81%
2	10	3	99.2%	95.9%	3.29%
2	11	3	98.8%	95.2%	3.68%

→ Few % of difference!

Issue: Analyzer dependence, Conclusion

Genki tried the fitting method, which have beed hired by Cheng-Wei.

Residual distributions obtained from the fitting method are slightly sharper than ones from the the geometrical method. The track slope cuts suppress the satellite peak drastically, and remove the tail-like structure around the peak especially for the fitting method.

Since much sharper residual distributions are obtained thanks to the fitting method and the track slope cuts, more the 99% efficiency was achieved with the 3-sigma window cut. This is consistent with Chen-Wei's results.

For better results:

- [x] optimization of alignment correction depending on the chips
- [ ] consideration of the 3-sigma window cut
- [ ] optimization of the stack slope cut

No sigma window cut

	chip	σ	ε Ladder 0	ε Ladder 1	ε Ladder 2
Genki, no additional cut	10	-1	0.994	0.994	0.954
Genki, straight beam track	10	-1	0.981	0.994	0.963
Genki, Fitting method	**10**	**-1**	**0.996**	**0.994**	**0.994**
Chen-Wei, ELPH poster					
Chen-Wei, new (3/24)					
Miu	10	-1	0.995	0.994	0.996
Genki, Fitting method, MC	10	-1	0.999	0.998	0.998

3 σ window

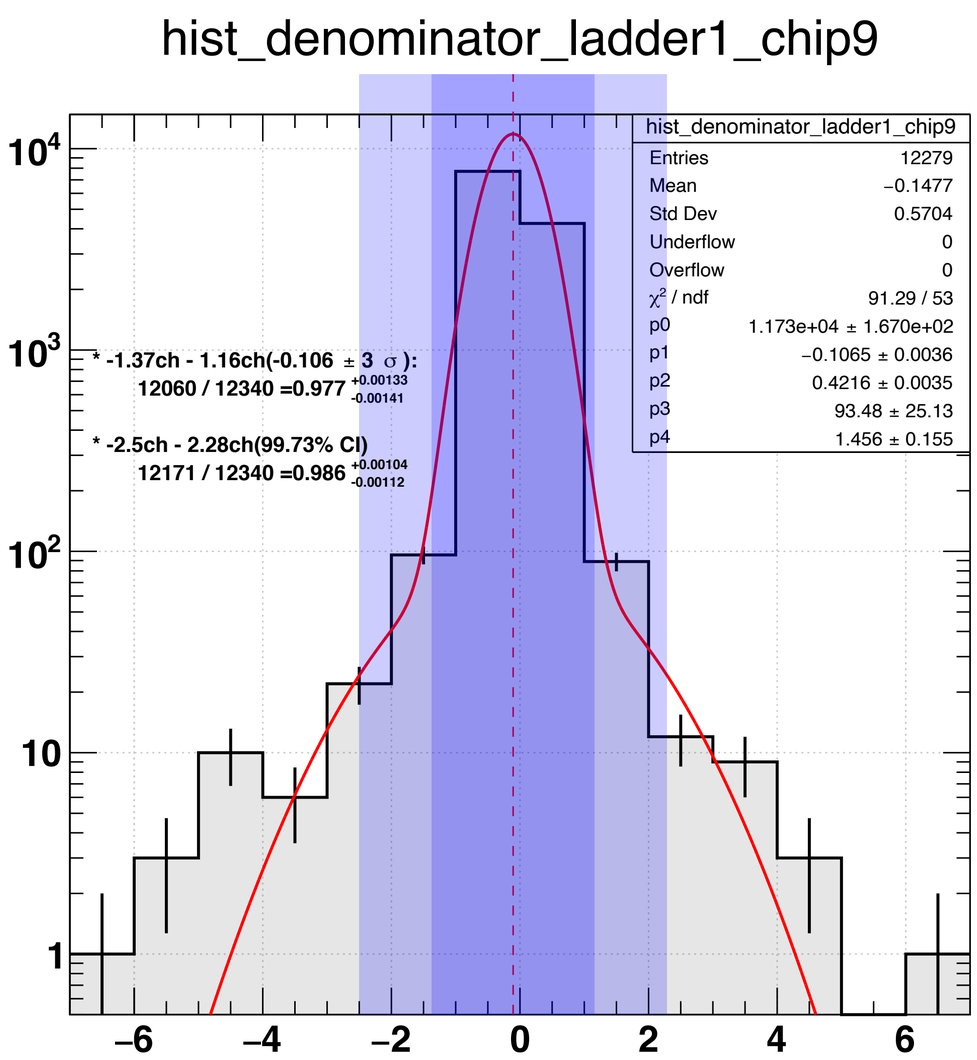
chip	σ	ε Ladder 0	ε Ladder 1	ε Ladder 2
10	3	0.940	0.937	0.894
10	3	0.883	0.961	0.921
10	**3**	**0.994**	**0.982**	**0.992**
?	3	0.993	0.995	0.971
10	3	0.992	0.998	0.991
10	3	0.977	0.984	0.969
10	3	0.997	0.996	0.998

The difference well was understood.

backup

Detection efficiency, to get better results…

Run89, chip10




```
bool Get3SigmaRange( TF1* f, double& lower, double& upper )
{
  double xmin = f->GetXmin();
  double xmax = f->GetXmax();

  //double mean = f->Mean( xmin, xmax ); // usuless, It's fine in CINT,
  double mean = f->GetParameter(1);
  double whole_area = f->Integral( xmin, xmax );

  double division = 1e5;
  double step = (xmax - xmin ) / division;

  for( int i=0; i<int(division); i++ )
    {
      double xmin_current = mean - i * step;
      double xmax_current = mean + i * step;

      double area = f->Integral( xmin_current, xmax_current );

      if( area / whole_area > 0.9973 )
        {
          lower = xmin_current;
          upper = xmax_current;
          return true;
        }
    }

  return false;
}
```

I calculated 99.73% of the all area of the fitting function:

$$\left(\int_{\mu-a}^{\mu+a} f(x)dx \right) / S = 0.9973$$

	min	max	denominator	numerator	ε
The leading gaussian	-1.37	1.16	12060	12340	0.977
Whole distribution	-2.5	2.28	12171	12340	0.986

Since the residual distributions are not reproduced by a single gaussian, acceptance range for detection efficiency calculation should be modified accordingly, otherwise we underestimate the efficiency.
This effort slightly increases the efficiency. For low statistic distributions, it increases the efficiency up to 0.1.