

sPHENIX INTT - Beam Test 2021

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2023/02/17 INTT meeting



Scattering and residual study

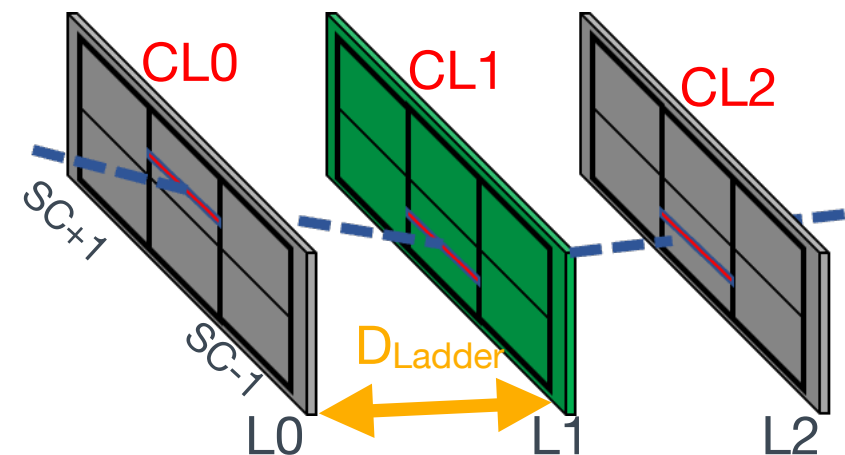
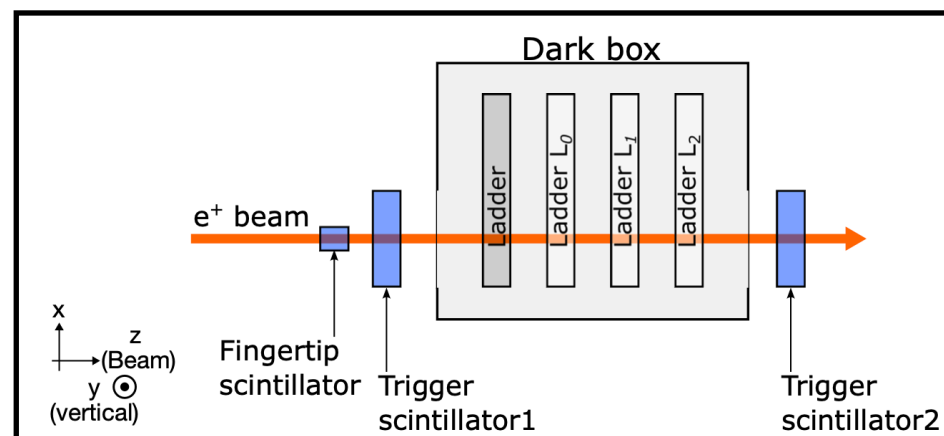
Distance between L0 and L1 (D_{Ladder}): 29.552 mm

Tracking	No double saving hits (no clone hits)
	Single Cluster in selected chip (SC) of L0 (SCL0), L1 (SCL1) and L2 (SCL2) required
	No cluster in adjacent chips (SC-1 & SC+1) required
	Cluster size == 1 for all clusters (to suppress the charge sharing effect)

Correction (data)

Alignment correction

Middle layer (L1), single chip



Calculation

Scattering	$[(CL2 - CL1)/D_{\text{Ladder}}] - [(CL1 - CL0)/D_{\text{Ladder}}]$
Residual	$[(CL2 + CL0)/2] - CL1$

Same data but different calculation

Scattering - MC comparison

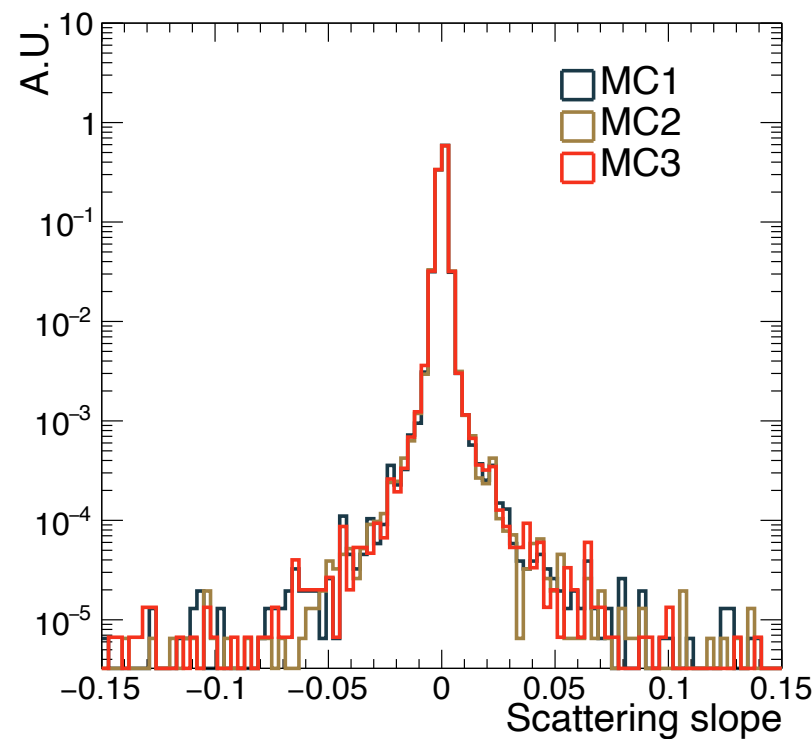
MC sampling (ELPH beam condition ON) :

1. Original set up + Sci. Al foil
 2. Original set up + Sci. Al foil + 10% HDI metal thickness increase
 3. Original set up + Sci. Al foil + 10% HDI metal thickness increase + precise physics list
 4. Original set up + Sci. Al foil + 10% HDI metal thickness increase + precise physics list + L1 Y-axis offset
 5. Original set up + Sci. Al foil + 10% HDI metal thickness increase + precise physics list + L1 Y-axis offset + INTT box vertical rotation
- 2 new MC samples

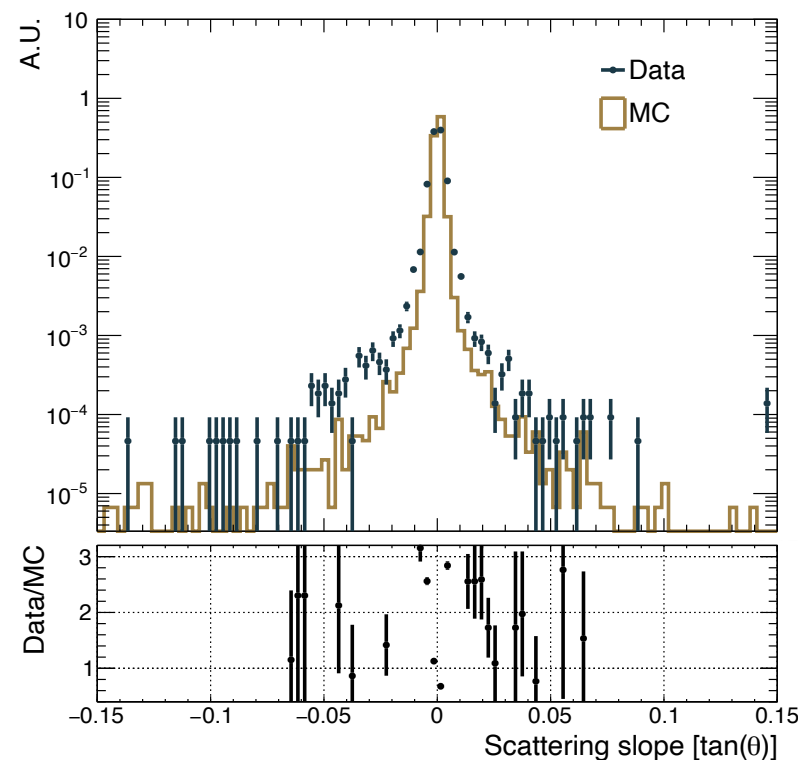
Recap

Data run52 U8 vs MC3

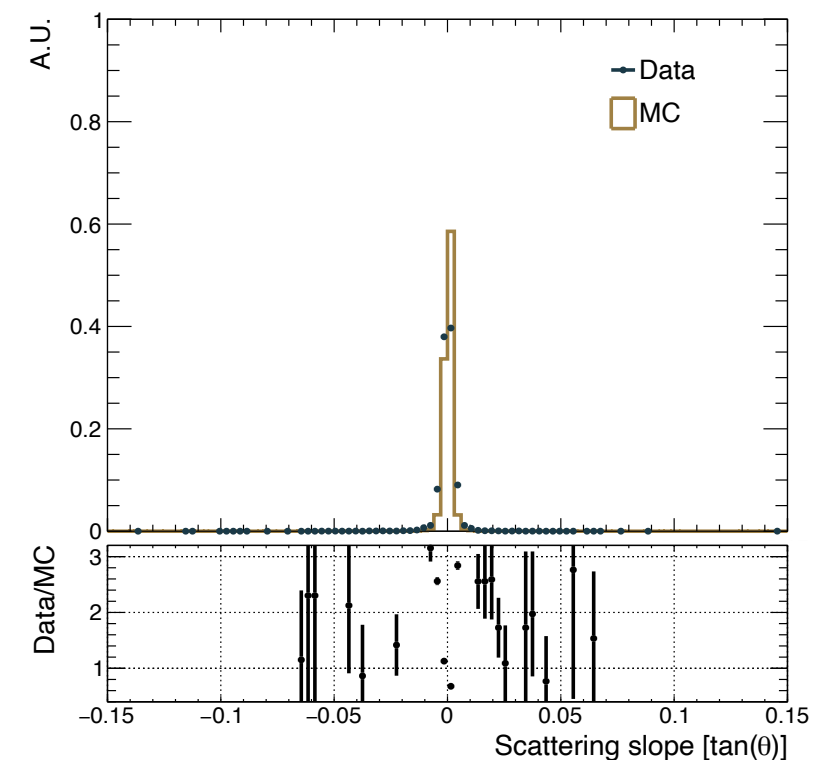
N of bins : 100
Bin width : 0.003



Almost no difference !

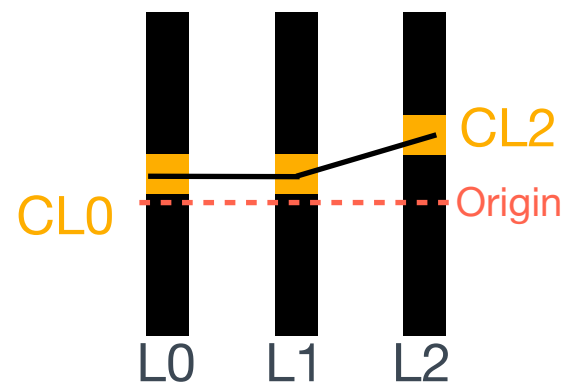


The discrepancy is quite huge between Data and MC



Scattering slope

CL0 : 0.039 mm (chan. 127)
CL1 : 0.039 mm (chan. 127)
CL2 : 0.117 mm (chan. 126)

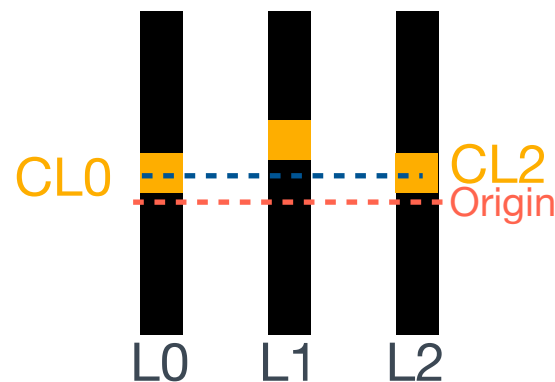


$$(0.117 - 0.039) / 29.552 - (0.039 - 0.039) / 29.552 = 0.002639$$

New beam width

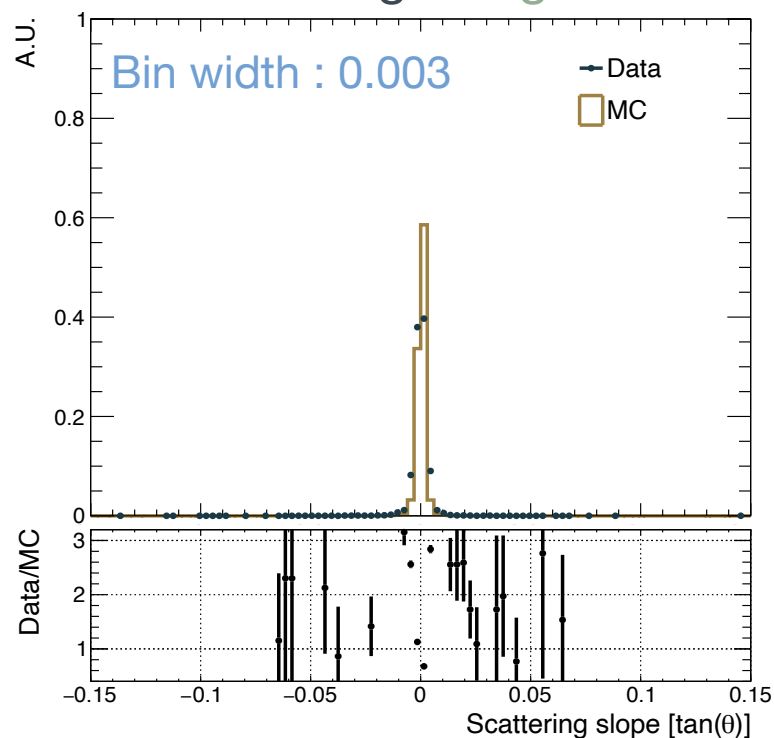
Residual

CL0 : 0.039 mm (chan. 127)
CL1 : 0.117 mm (chan. 126)
CL2 : 0.039 mm (chan. 127)

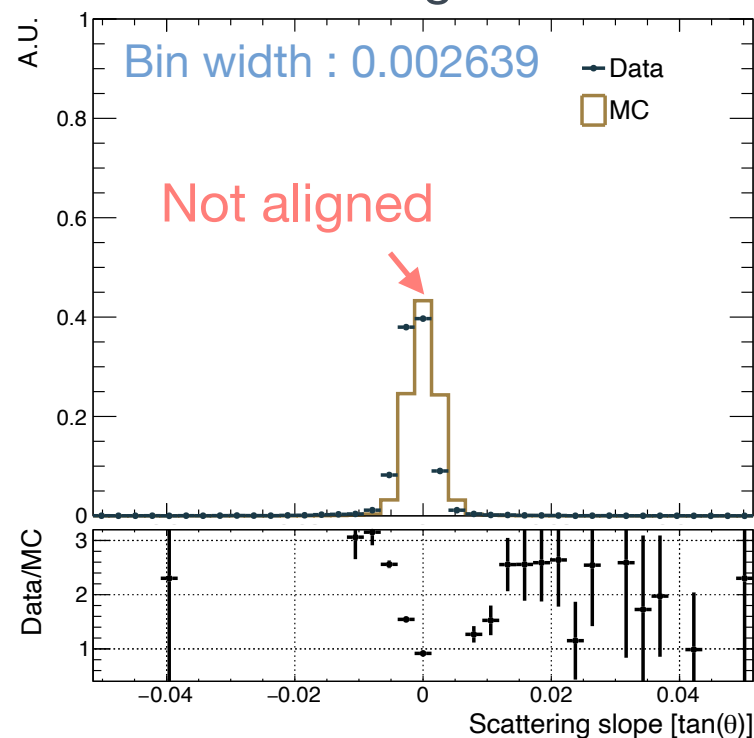


New beam width : 0.078 mm

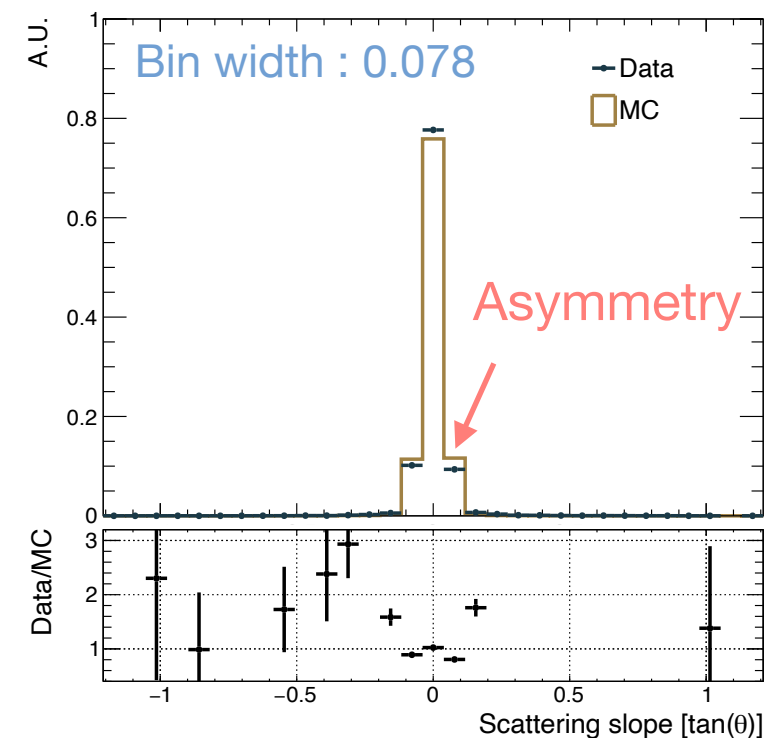
Scattering - original



Scattering - new

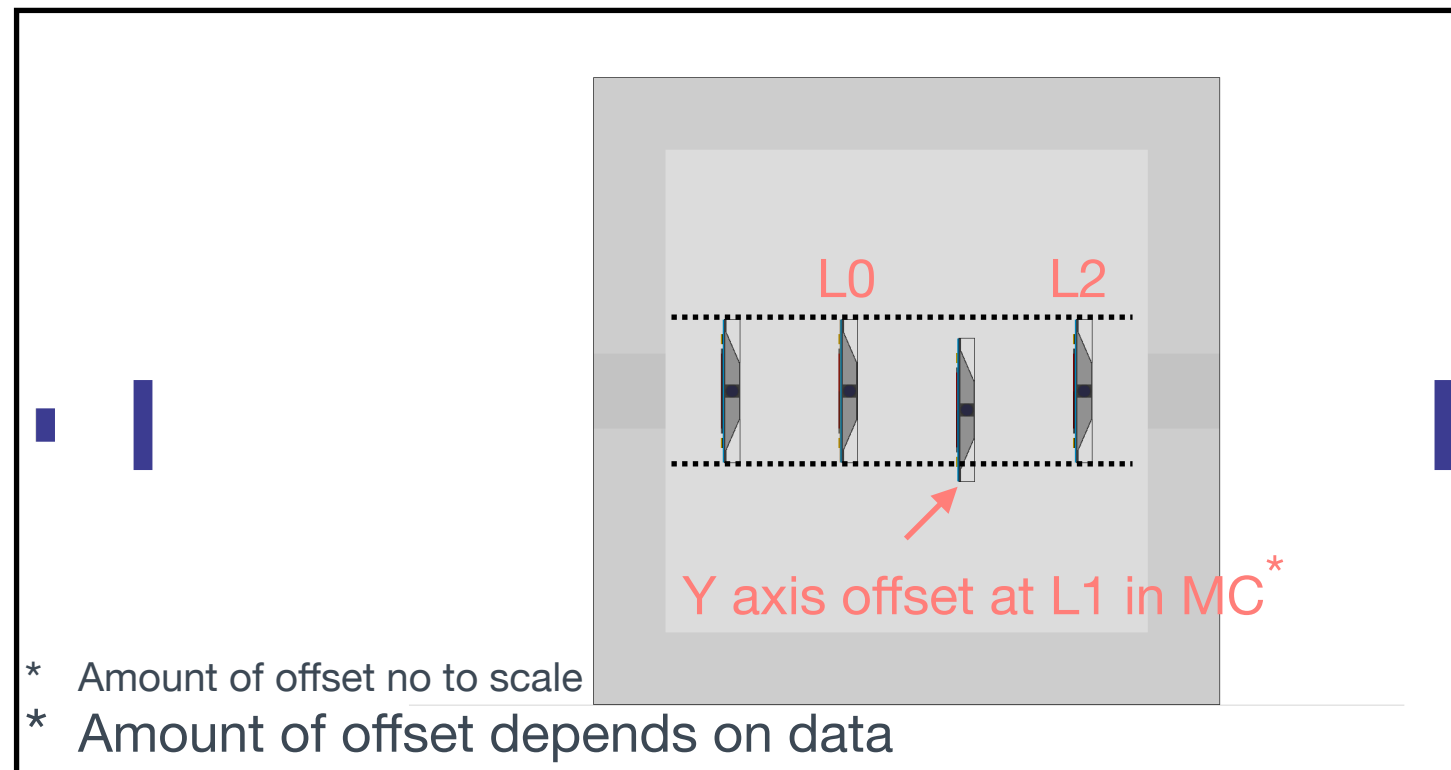


Residual - new



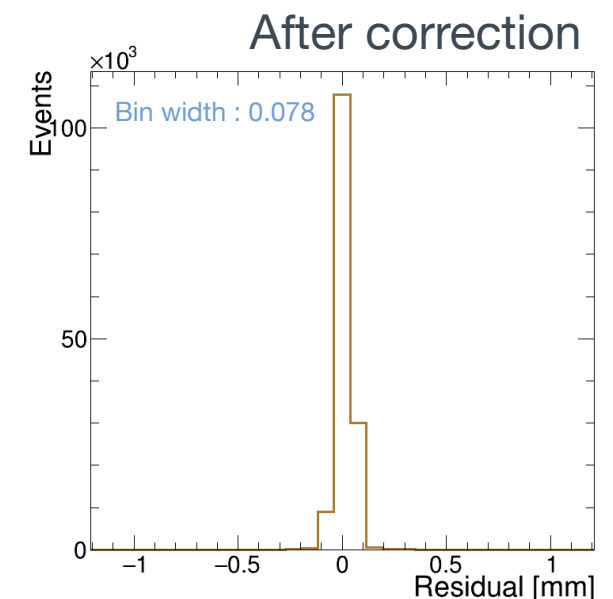
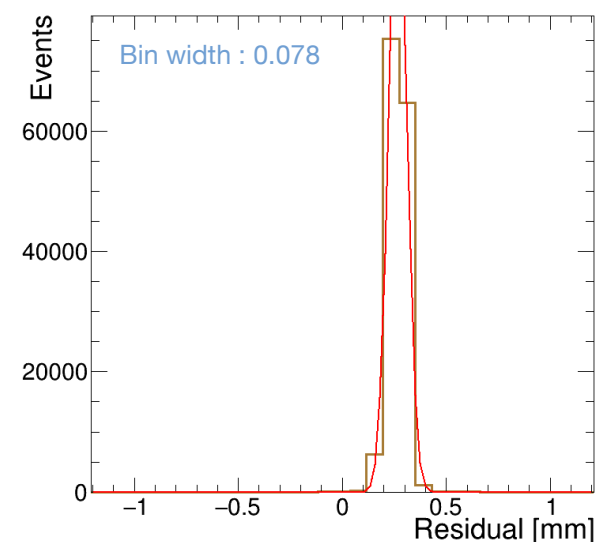
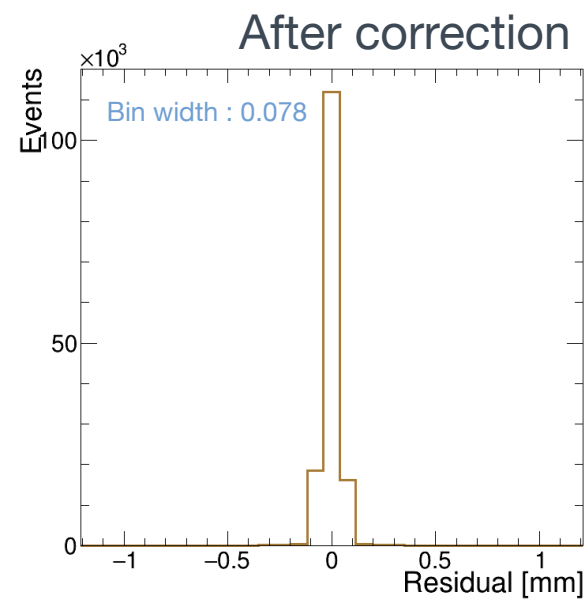
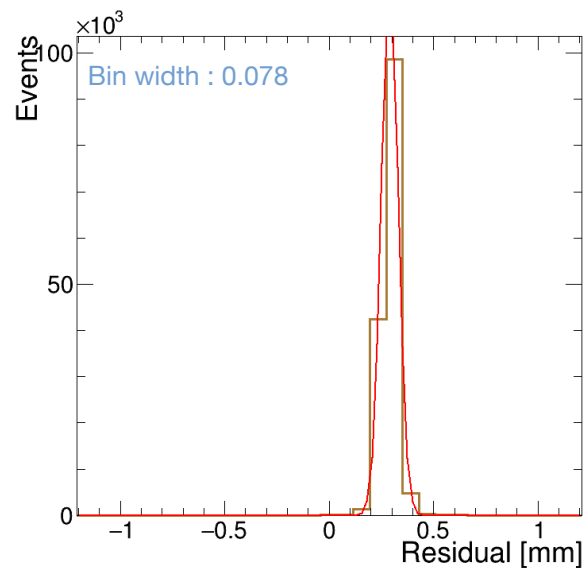
Introduction of misalignment in MC

With MC3 condition + L1 vertical misalignment = MC4



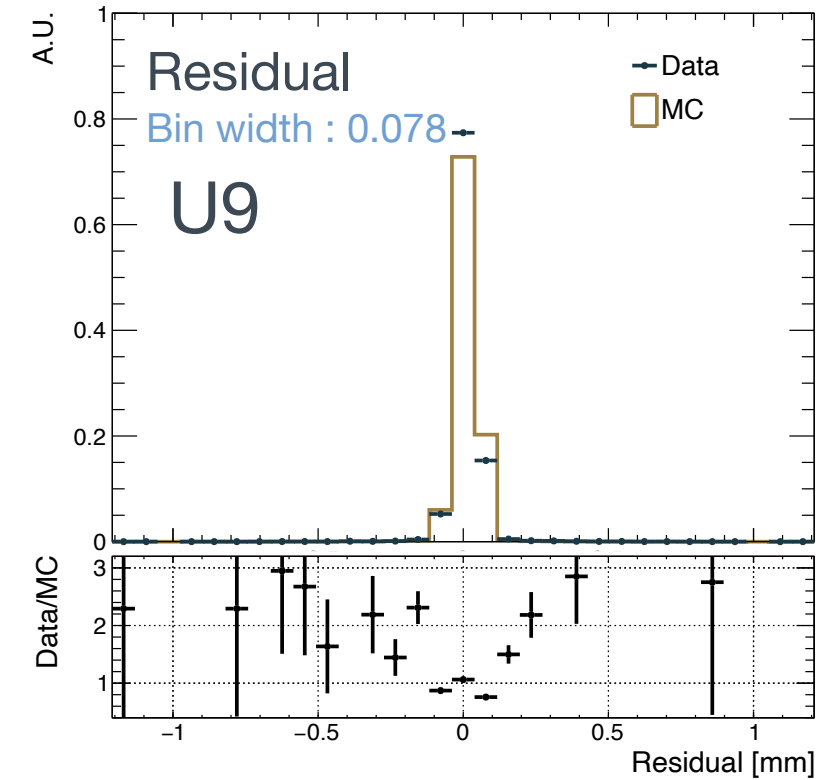
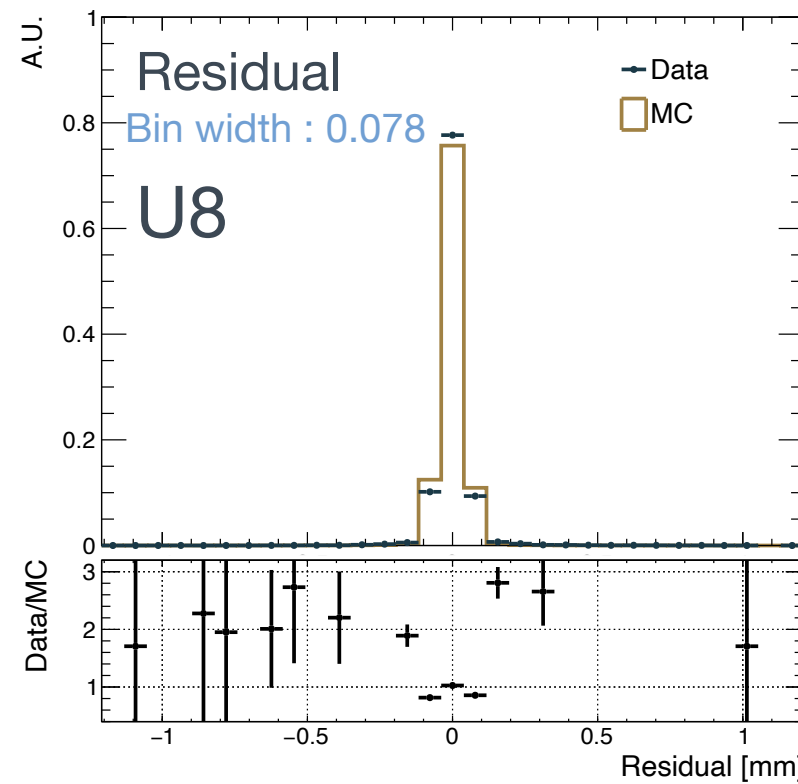
Amount of correction : 2.89928×10^{-1} mm
Based on run52 U8

Amount of correction : 2.66304×10^{-1} mm
Based on run52 U9

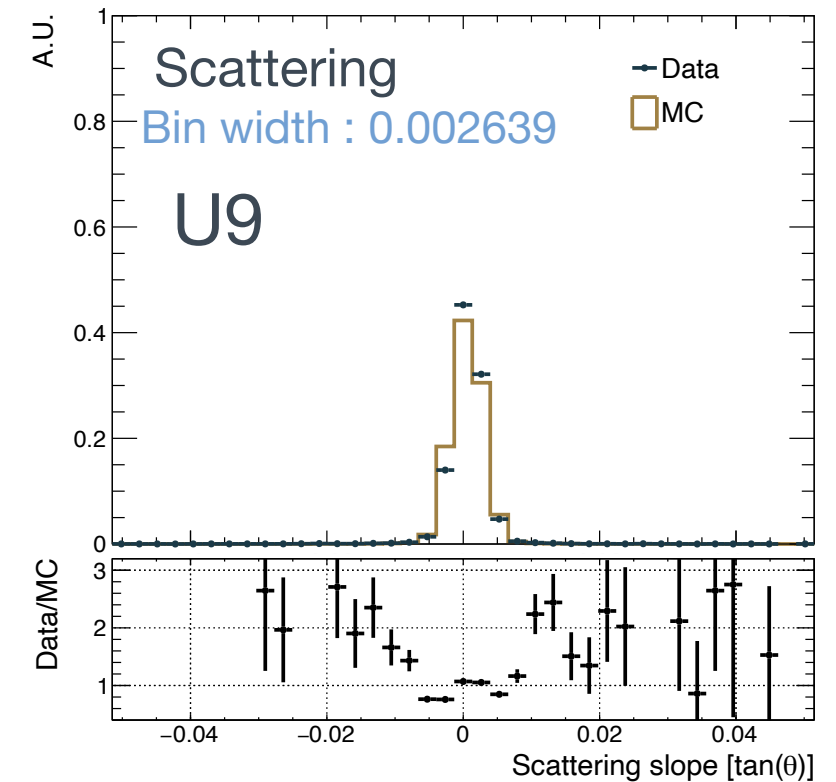
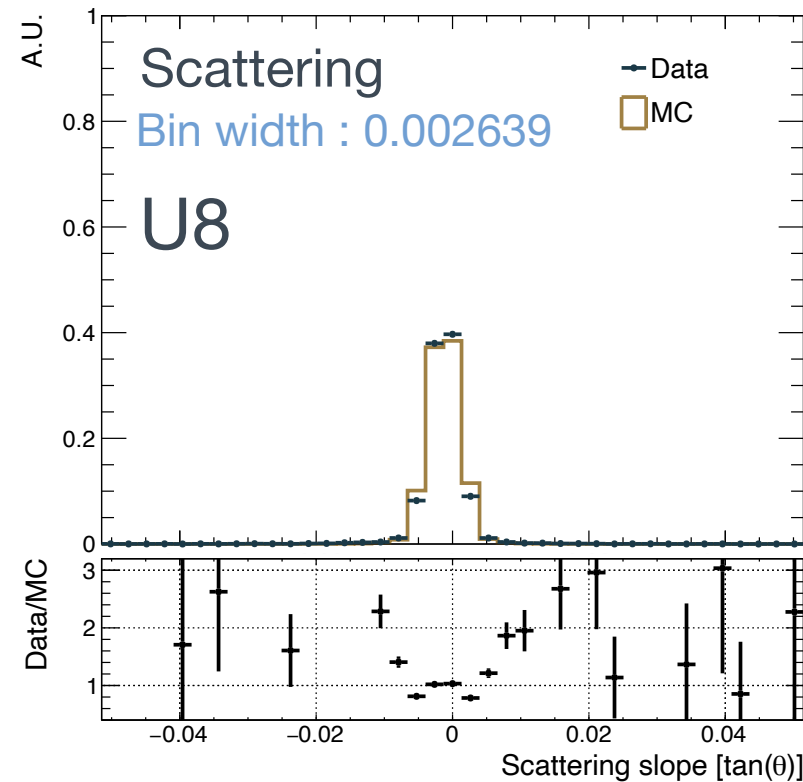
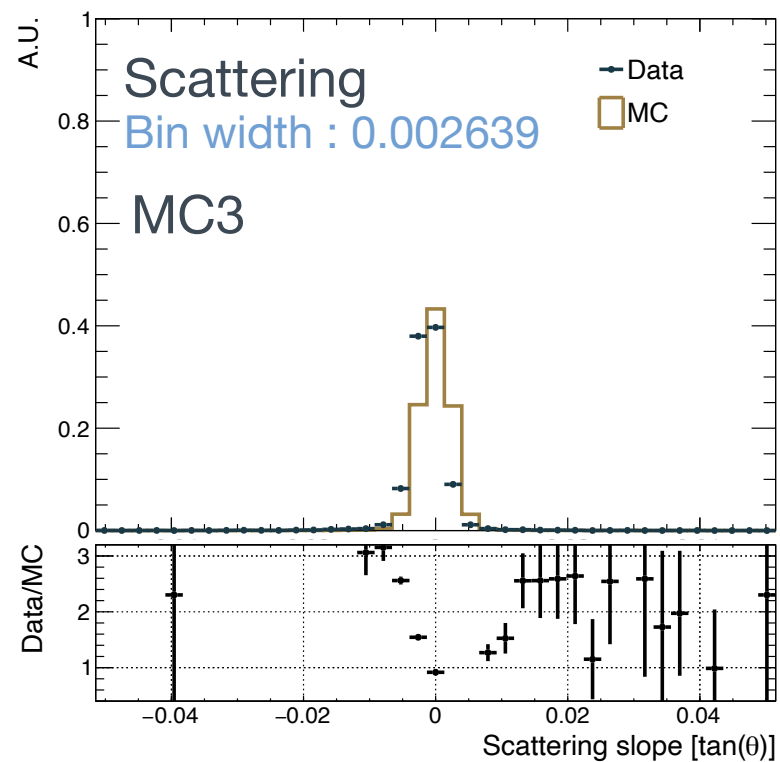


Introduction of misalignment in MC

Data : run52
MC : MC4

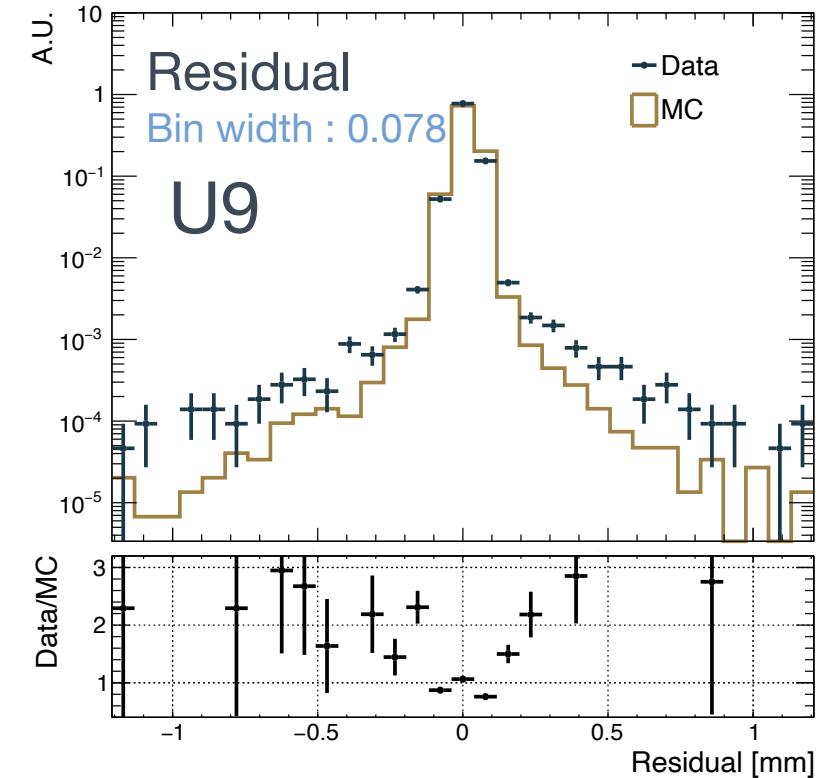
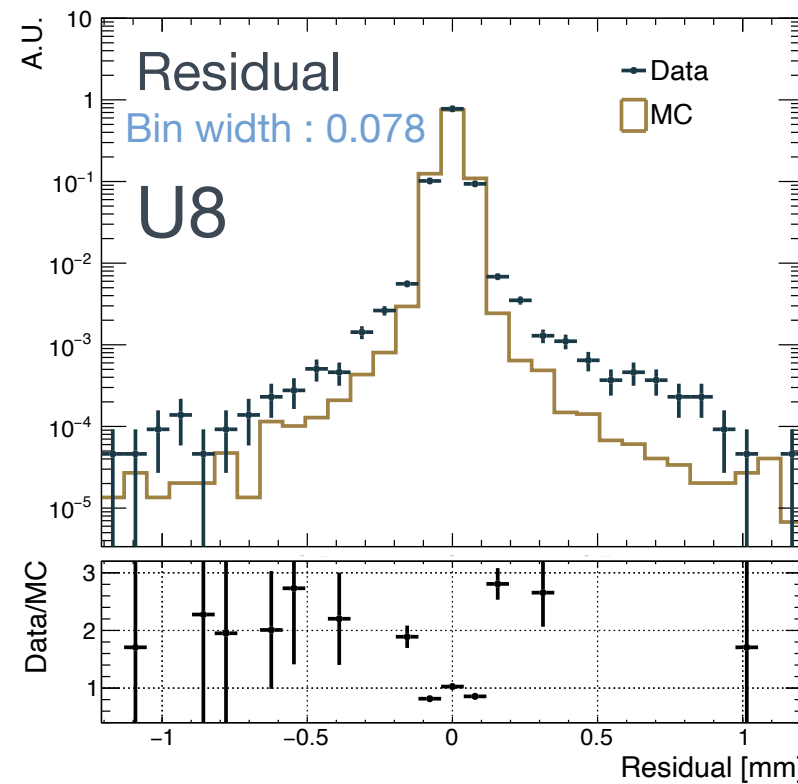


Previous result

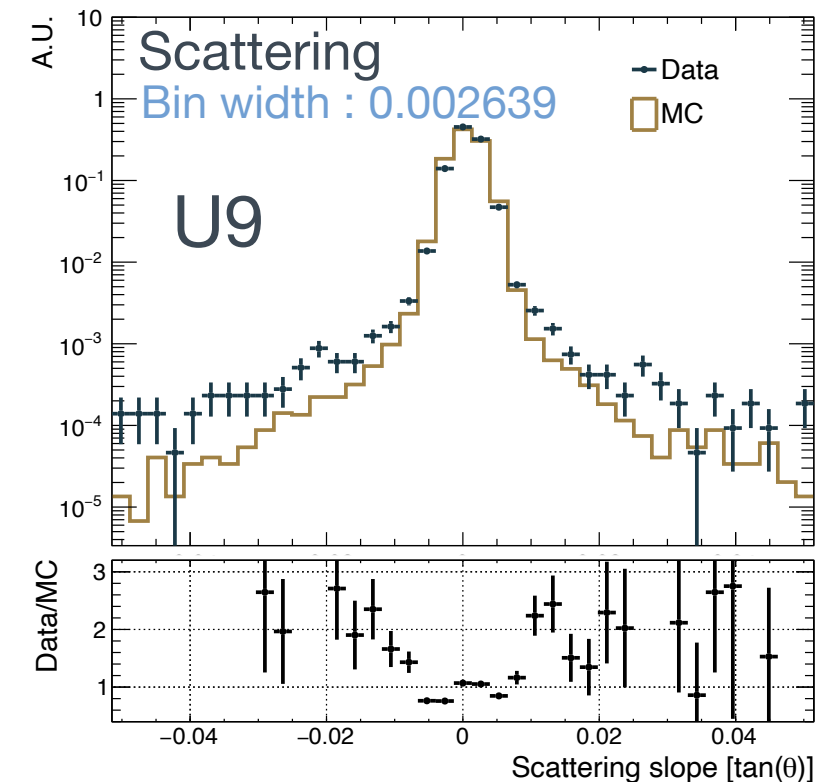
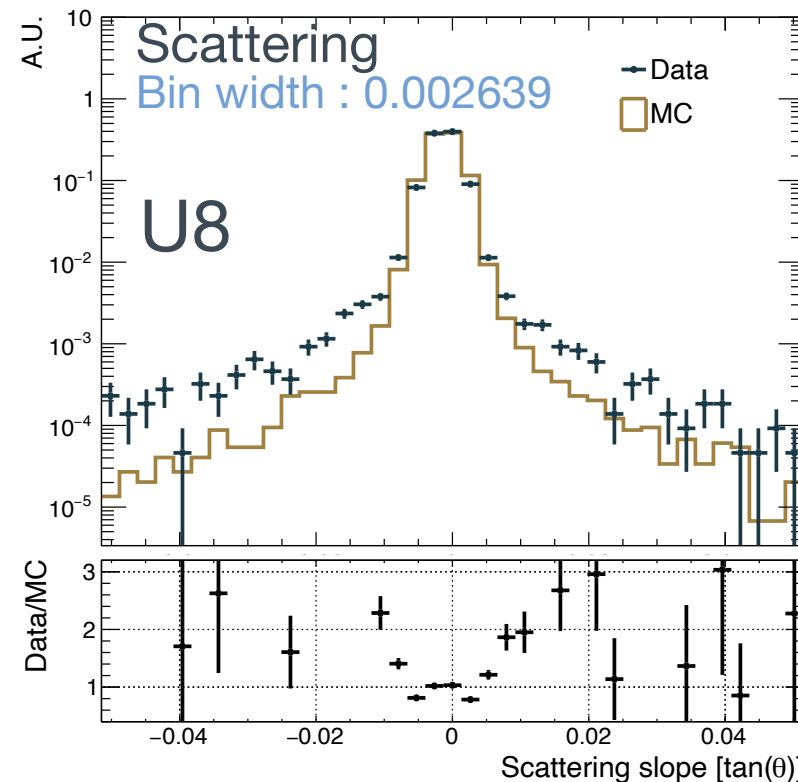
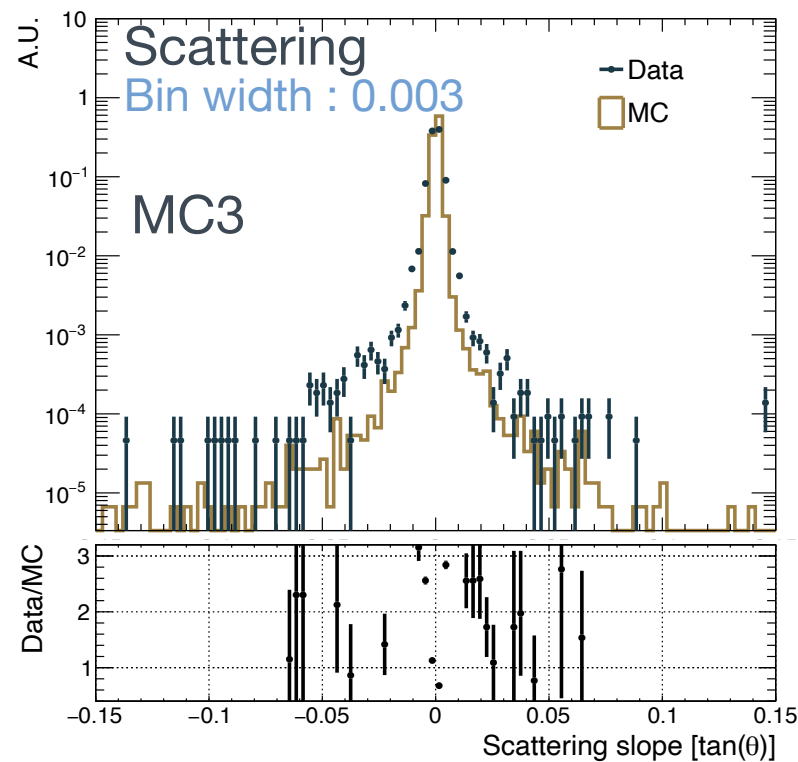


Introduction of misalignment in MC

Data : run52
MC : MC4



Previous result

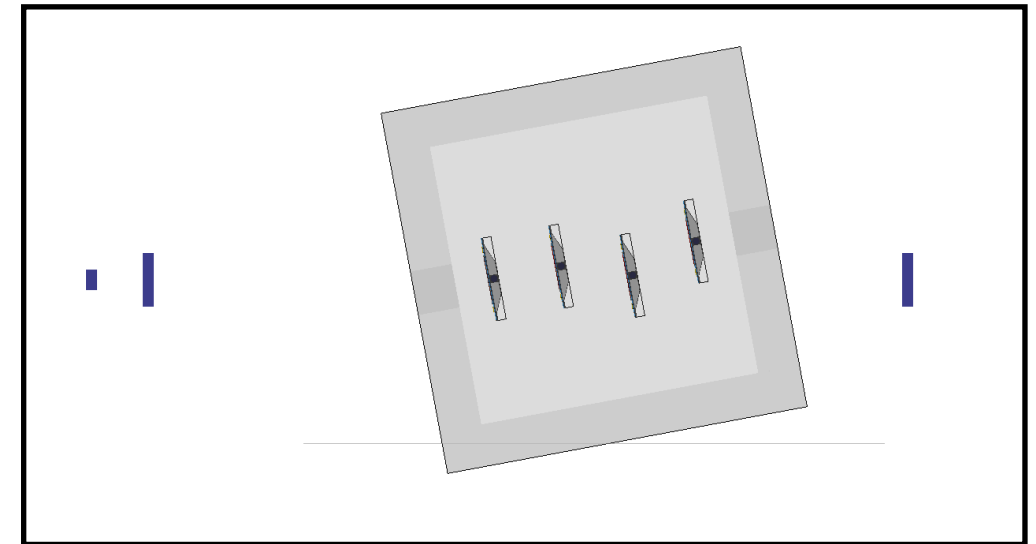
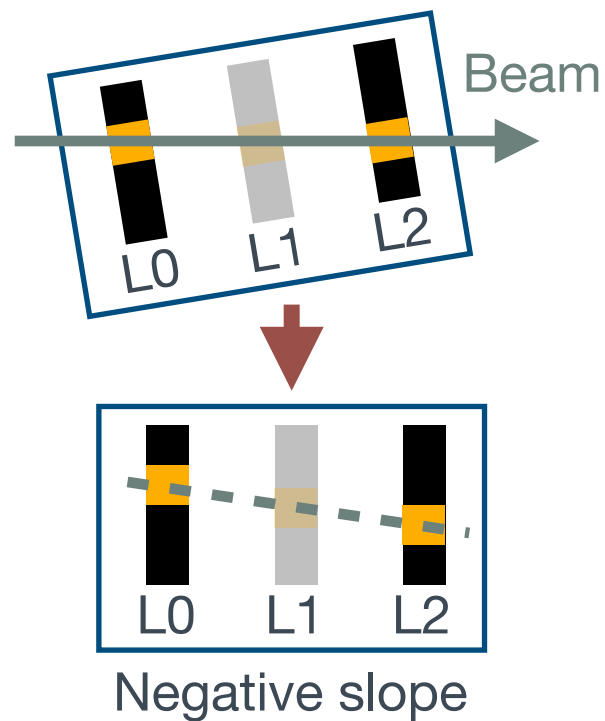
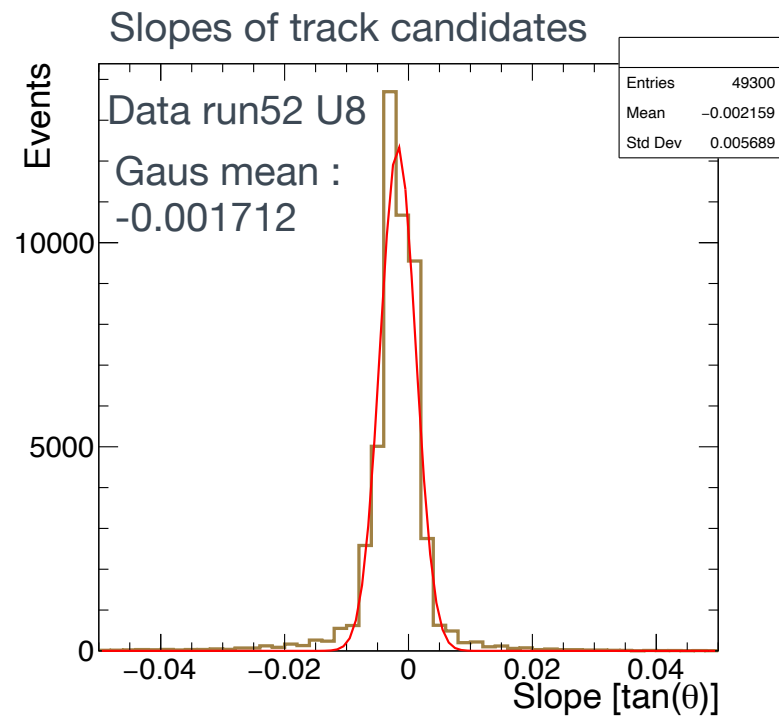


Introduction of the Dark box vertical rotation

With MC4 condition + vertical rotation = MC5

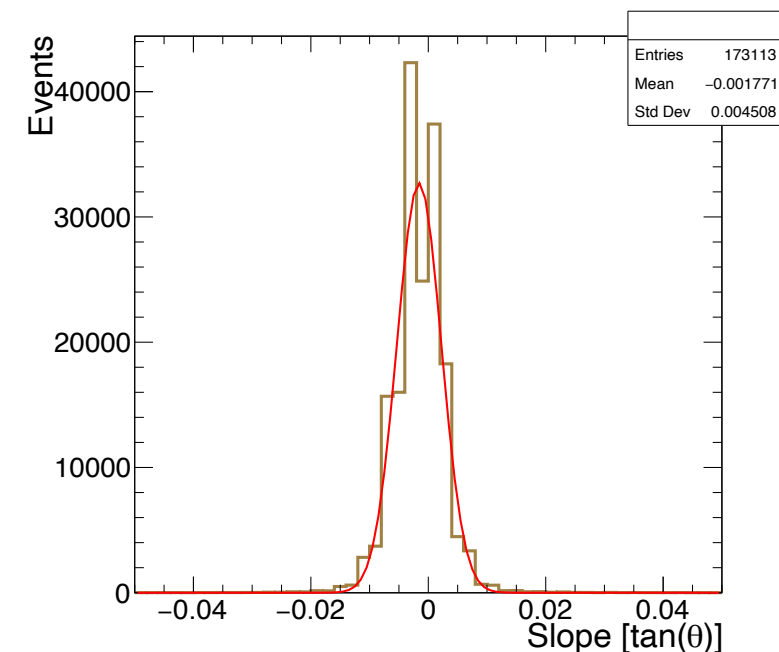
Recap

Track candidates	Single Cluster in selected chip (SC) of L0 (abbr. SCL0) and L2 (abbr. SCL2) required
	No cluster in adjacent chips (SC-1 & SC+1) required



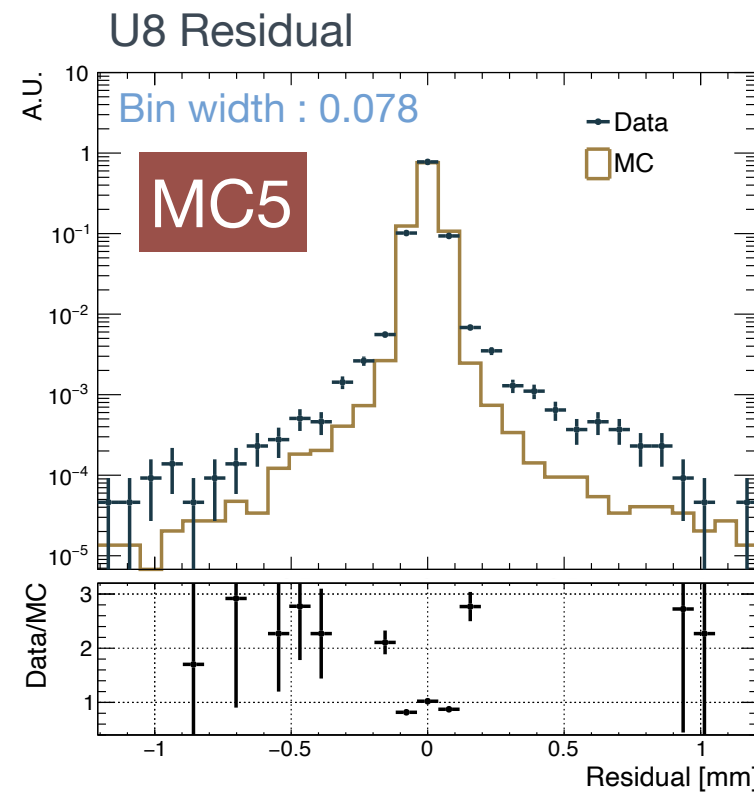
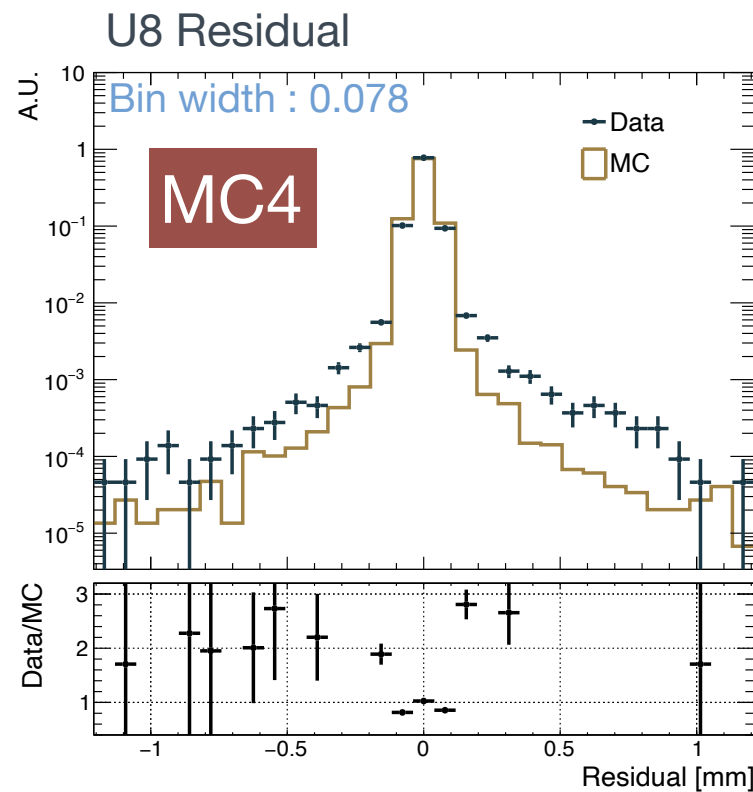
Amount of the applied vertical rotation is not to scale, based on data

- MC5 :
 - Set : -0.001712 (9.809e-02 degree)
 - Outcome : -0.00156313 (Gaus fit)

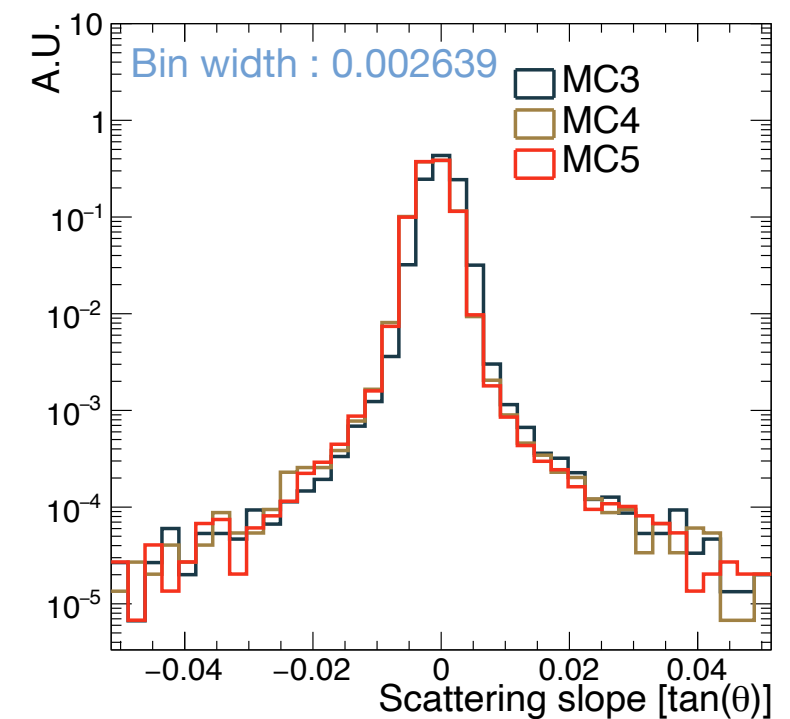


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5. Original set up + Sci. Al foil + 10% HDI metal thickness increase + precise physics list + L1 Y-axis offset + INTT box vertical rotation



very small improvement



Cluster size and cluster adc



Distance between L0 and L1: 29.552 mm

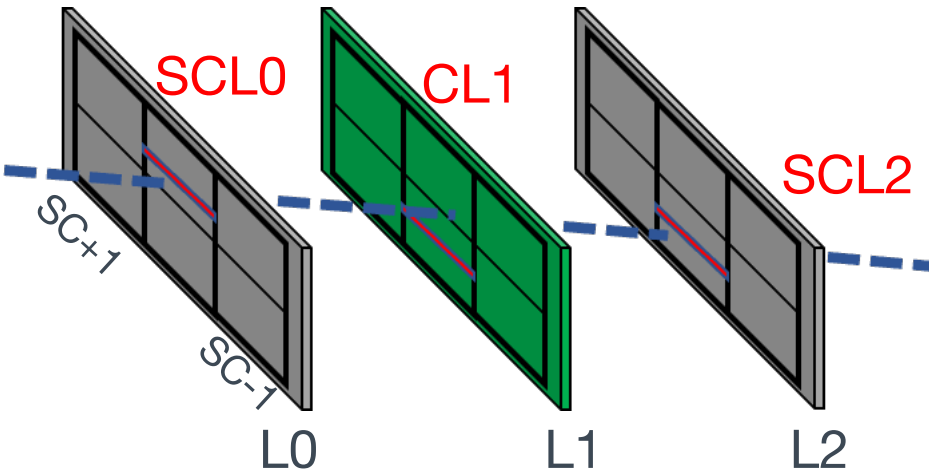
Tracking	No double saving hits (no clone hits)	
	Single Cluster	in selected chip (SC) of L0 (abbr. SCL0) and L2 (abbr. SCL2) required
	No cluster	in adjacent chips (SC-1 & SC+1) required

Event selection	Edge exclusion	(ladder bottom edge + 5 ch) < Y-pos of SCL0 and SCL2 < (ladder top edge - 5 ch)
	Cluster ADC	Sum of ADC of SCL0 > adc0 && Sum of ADC of SCL2 > adc0
	Slope cut	fabs(slope of SCL2 - SCL0) < 0.01

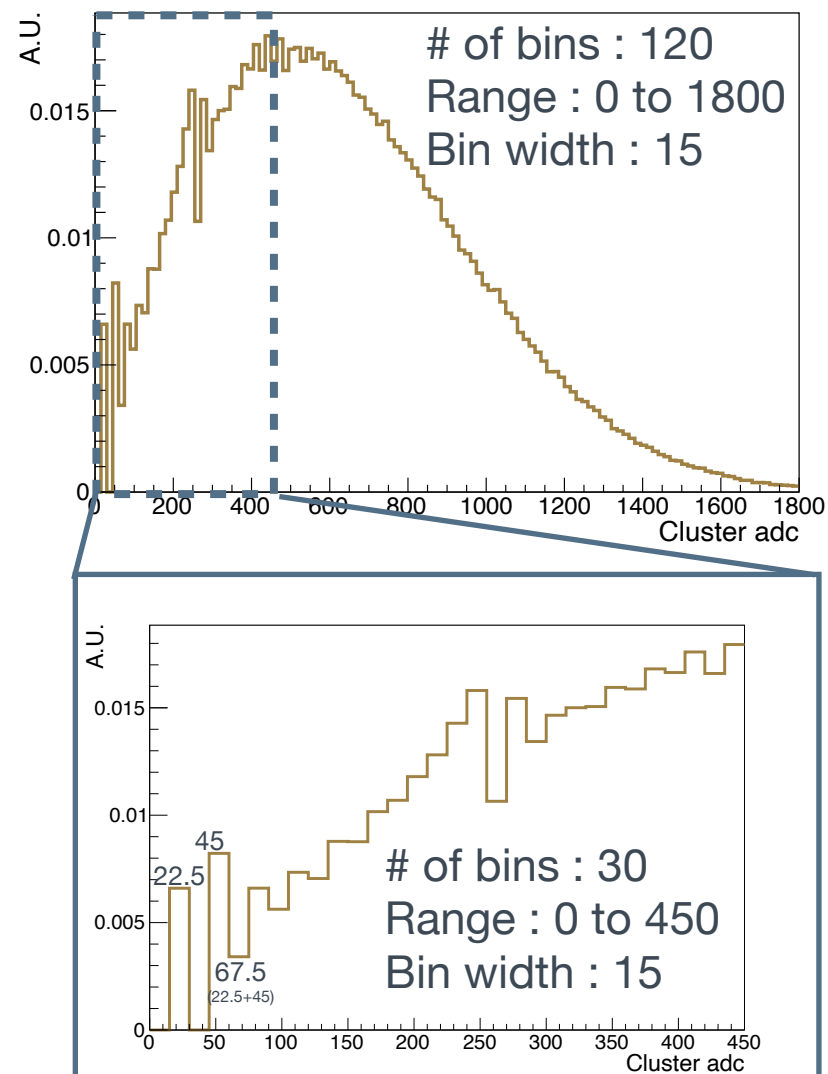
Good track classification	Residual	fabs(CL1 - the extrapolation position) < 3 strips (0.234 mm, currently used)
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Corrections

Alignment correction	Middle layer (L1), single chip
Slope correction	For the slope cut



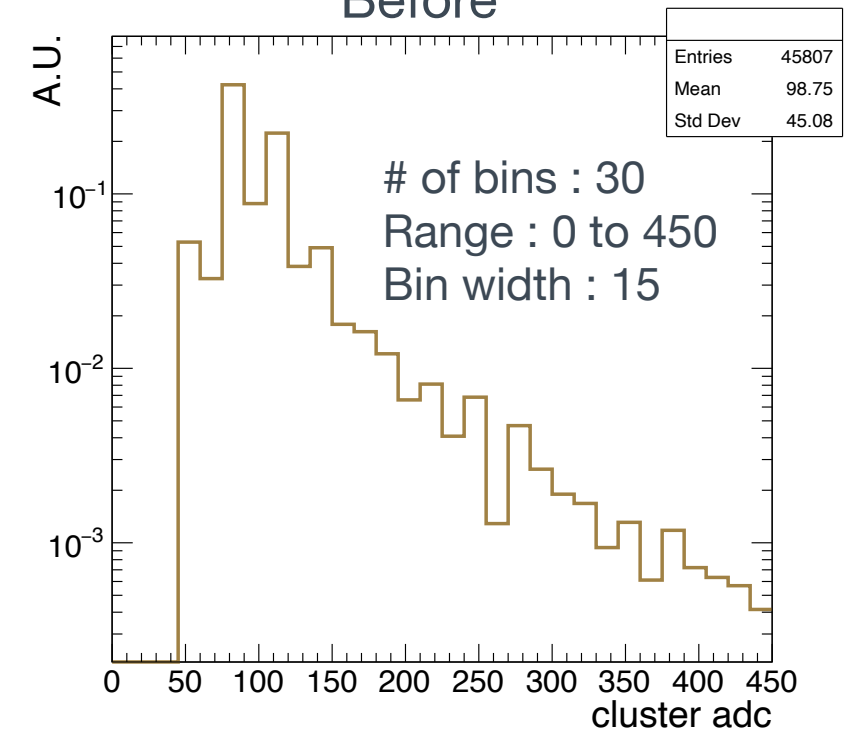
- DAC setting : 15, 30, 60, 90, 120, 150, 180, 210, 240
 - adc value : 22.5, 45, 75, 105, 135, 165, 195, 225
- Randomly determine the size of the cluster
 - Cluster size range : 1 to 19
 - Flat distribution
 - In the code : `int( TRandom3::Uniform(0, 20) )`
- Randomly determine the adc value of each hit in a cluster
 - Flat distribution with range 0 to 7
 - In the code : `int( TRandom3::Uniform(0, 8) )`



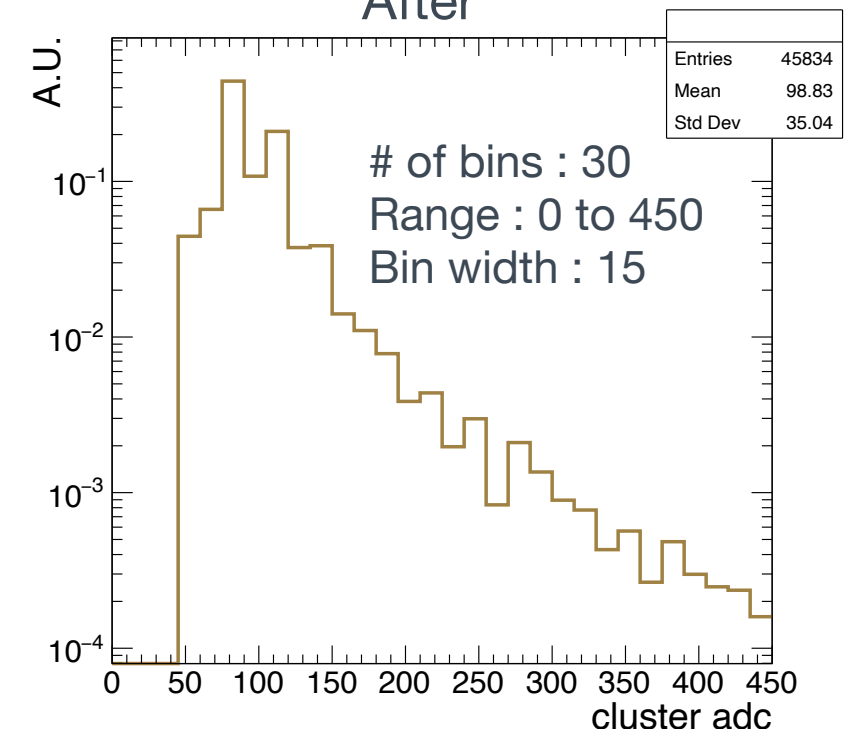
Consider this distribution as the bin calibration factor

Data run52 U8

Before

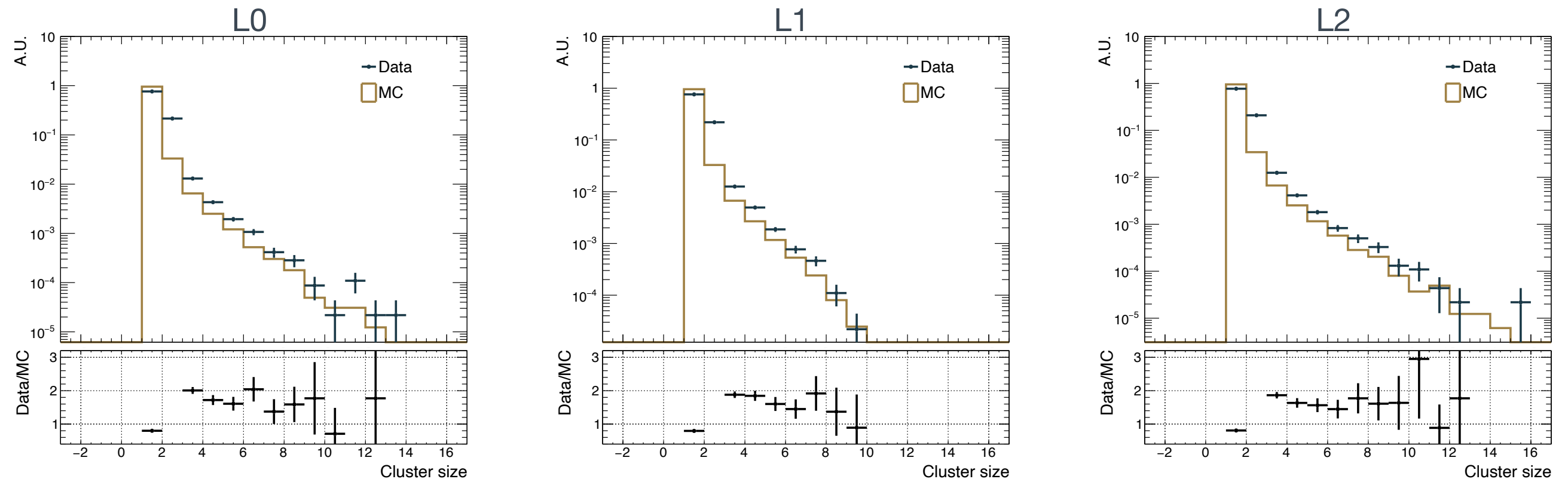


After

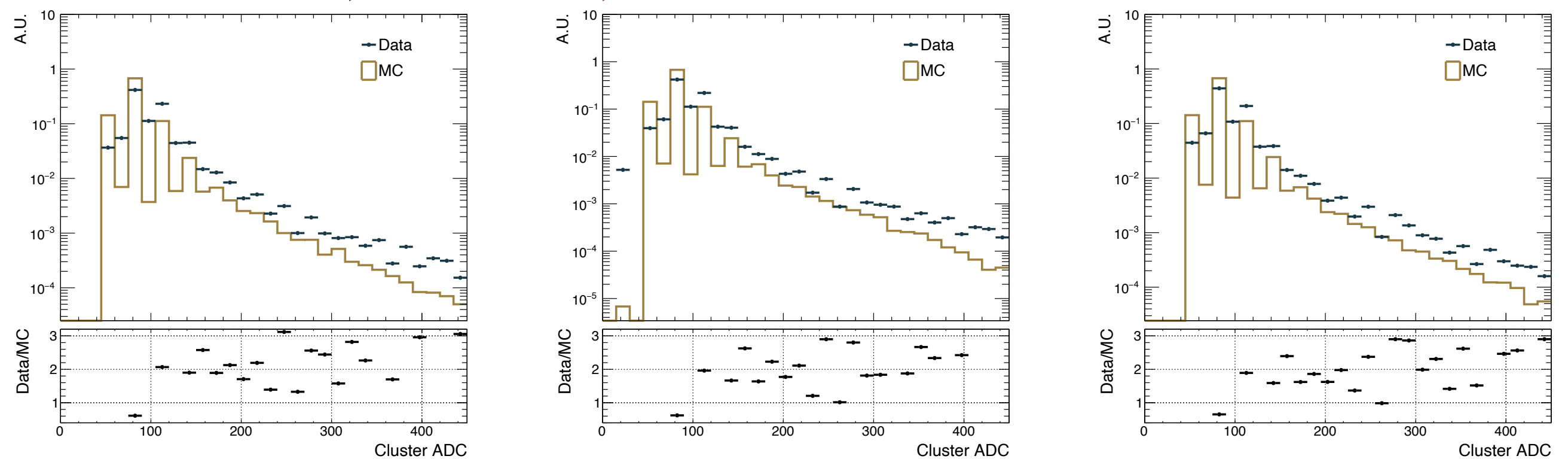


Cluster size and cluster adc - with selection

Cluster size distributions, Data : Run52 U8, MC : MC4 condition

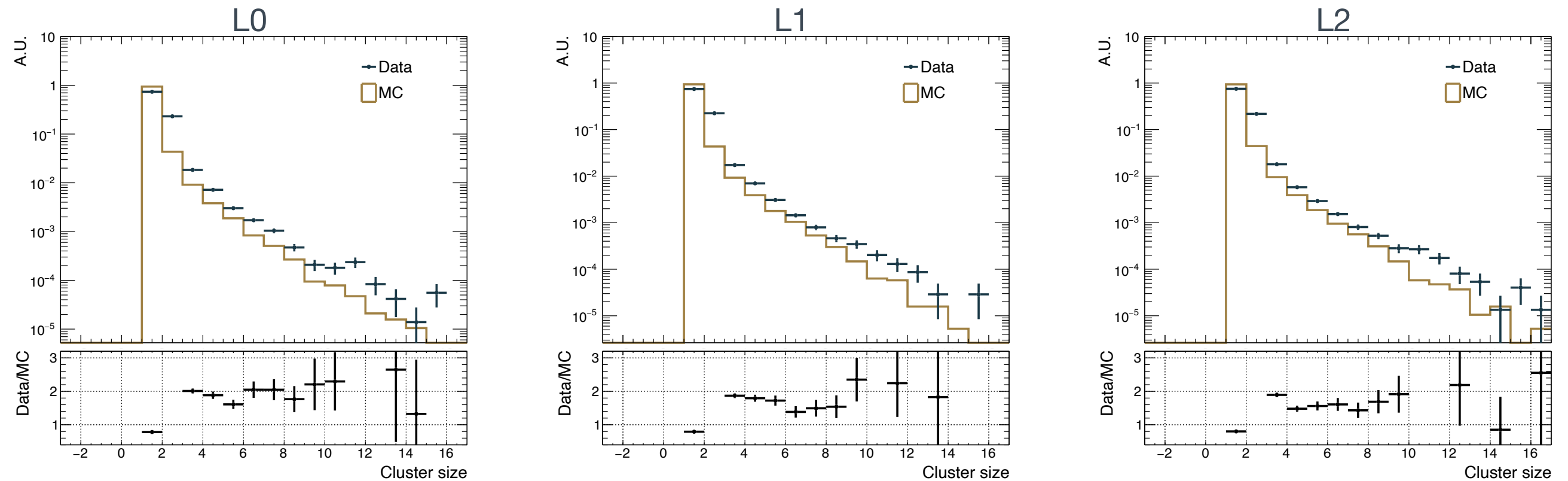


Cluster ADC distributions, Data : Run52 U8, MC : MC5 condition

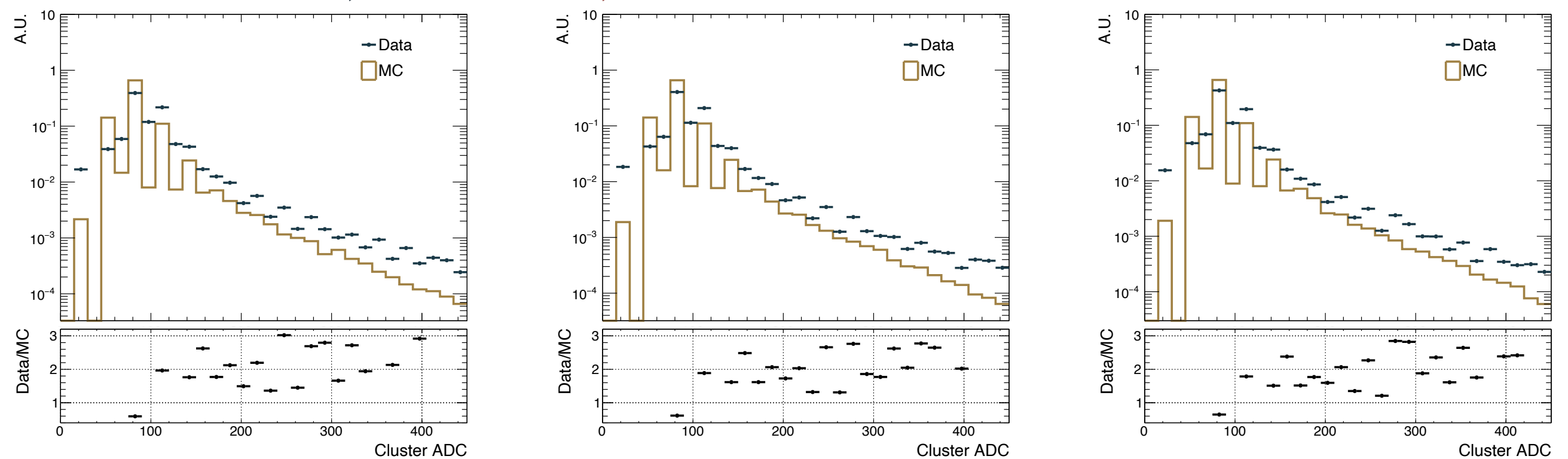


Cluster size and cluster adc - without selection

Cluster size distributions, Data : Run52 U8, MC : MC4 condition



Cluster ADC distributions, Data : Run52 U8, MC : MC5 condition



Deep study of the MC cluster adc distribution

- DAC setting : 15, 30, 60, 90, 120, 150, 180, 210, 240
 - adc value : 22.5, 45, 75, 105, 135, 165, 195, 225

- Possible cluster adc :

22.5

45

67.5

75

90

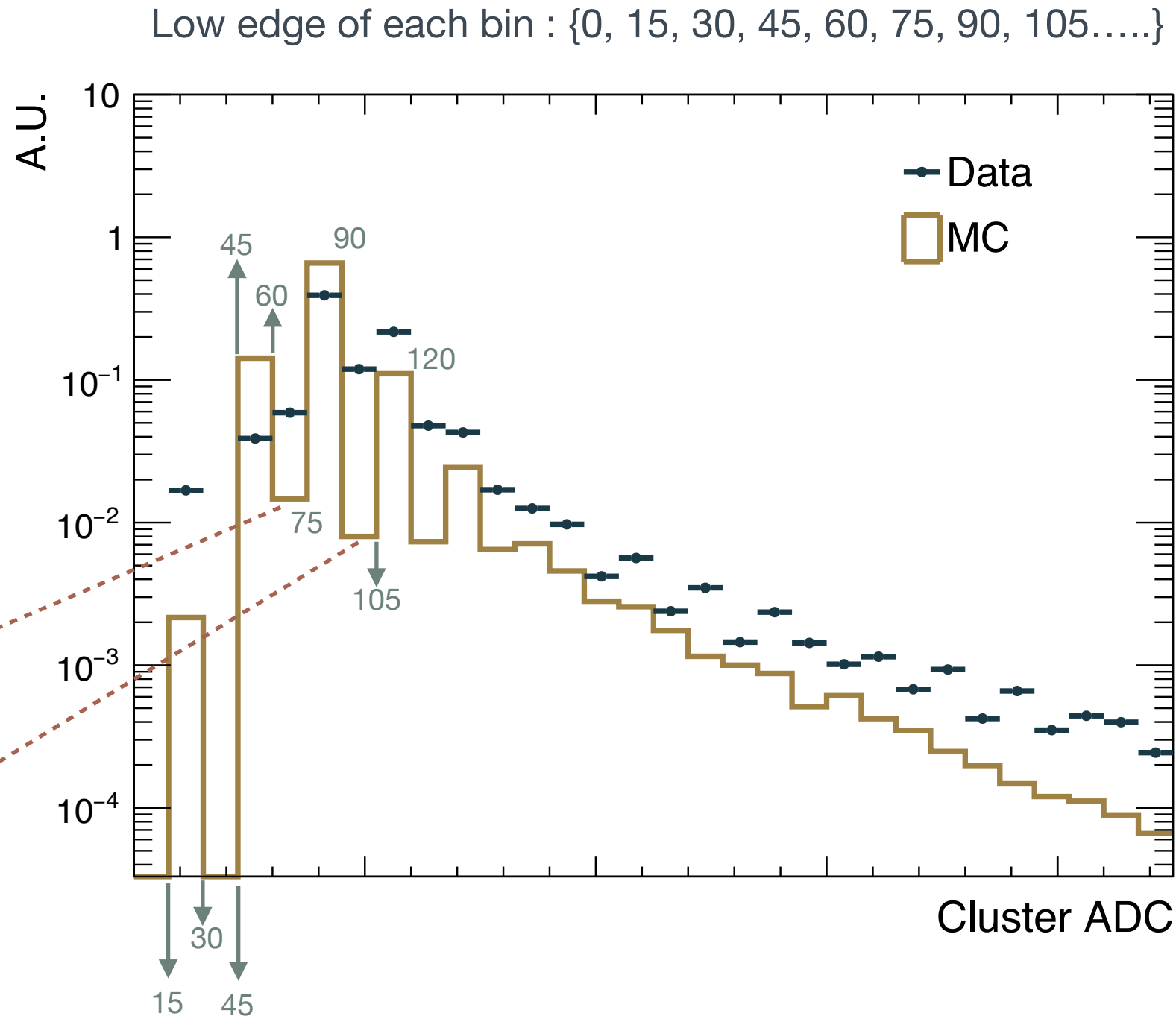
97.5

105

112.5...

Cluster size > 1

- Bin 15 ~ 30 : cluster ADC 22.5
- Bin 45 ~ 60 : cluster ADC 45
- Bin 60 ~ 75 : cluster ADC 67.5
- Bin 75 ~ 90 : cluster ADC 75
- Bin 90 ~ 105 : cluster ADC 90 & 97.5
- Bin 105 ~ 120 : cluster ADC 105 & 112.5



The bins with low entries can be filled only by multi-hits clusters.
In the MC, no charge sharing consideration

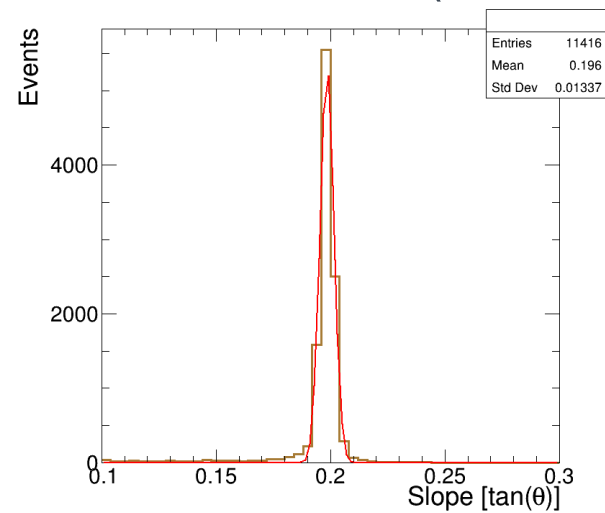
Cluster size - run61 (vertical rotation)

Based on note : vertical rotation : 13.7°

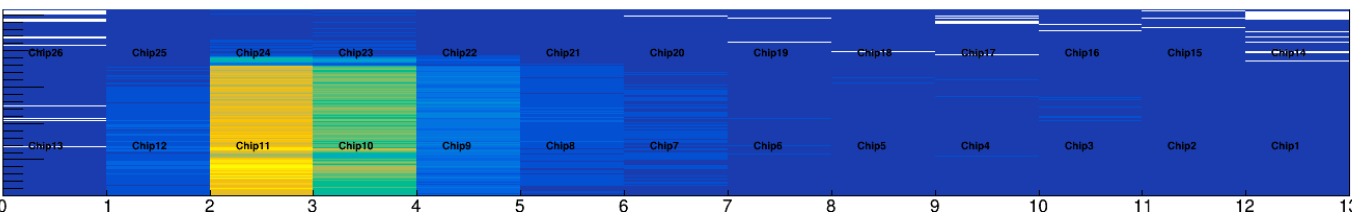
Data

U11 Track-candidate slope

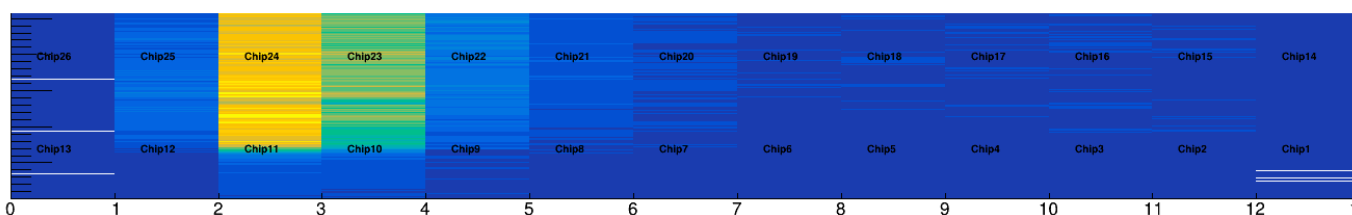
Fit mean : 1.98468e-01 (11.23 degree)



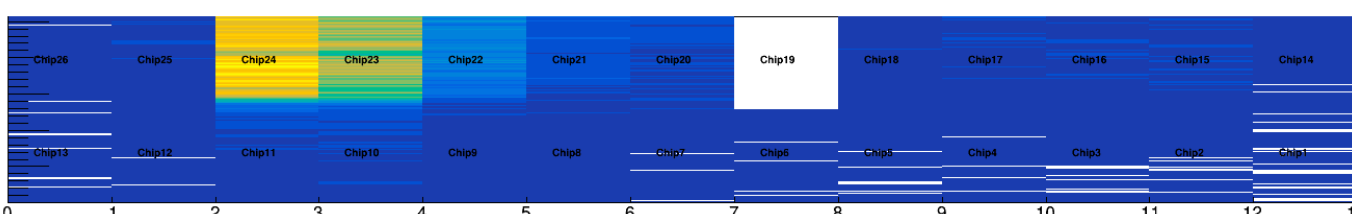
L0



L1



L2



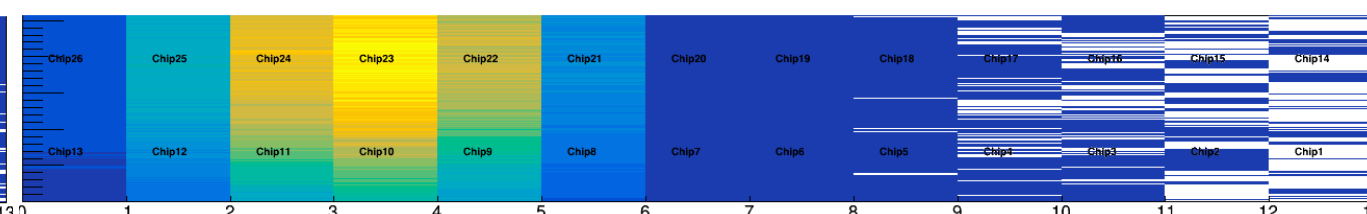
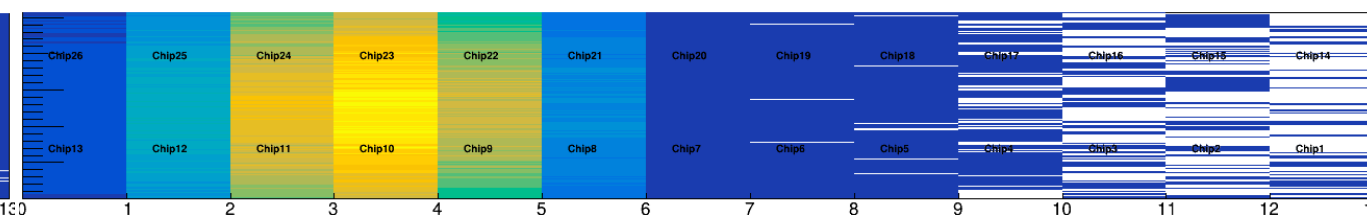
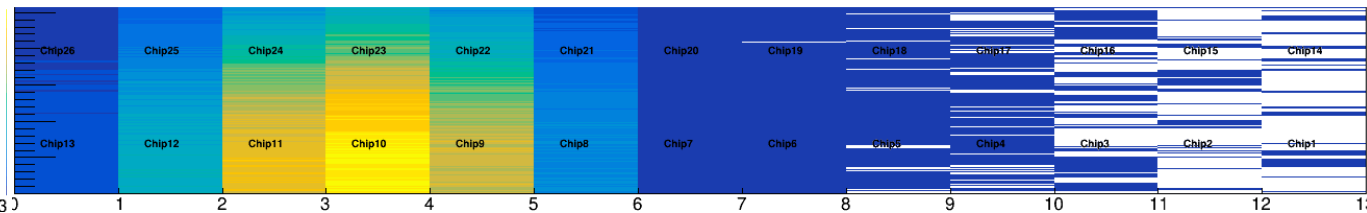
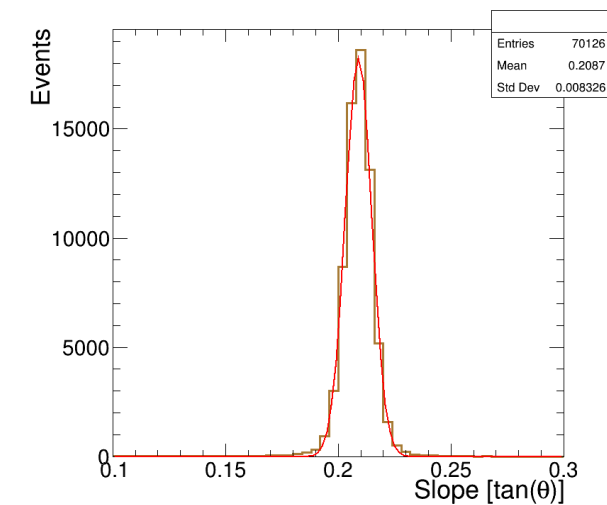
Chip19 is not drawn due to high entries

MC

U11 Track-candidate slope

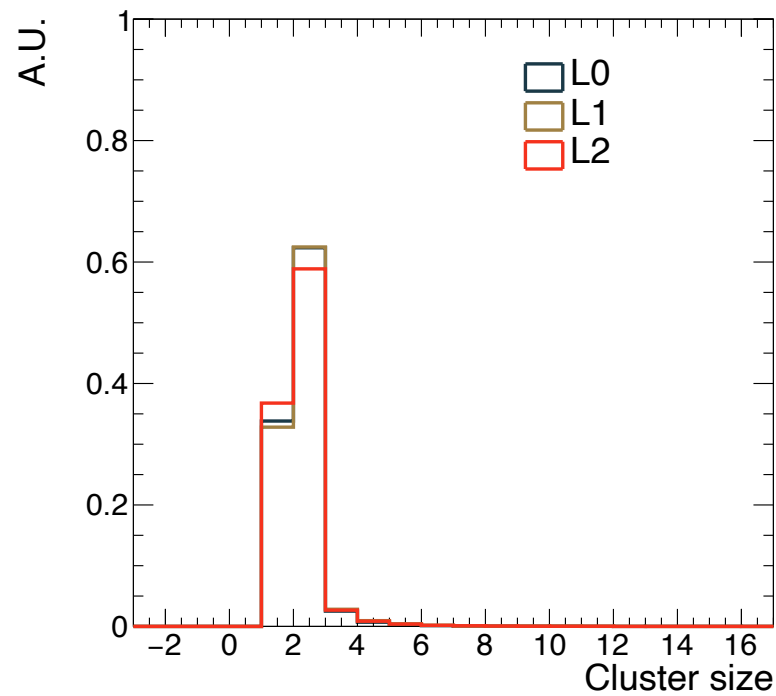
Set value : 11.23 degree

Fit mean : 2.09000e-01 (11.80 degree)

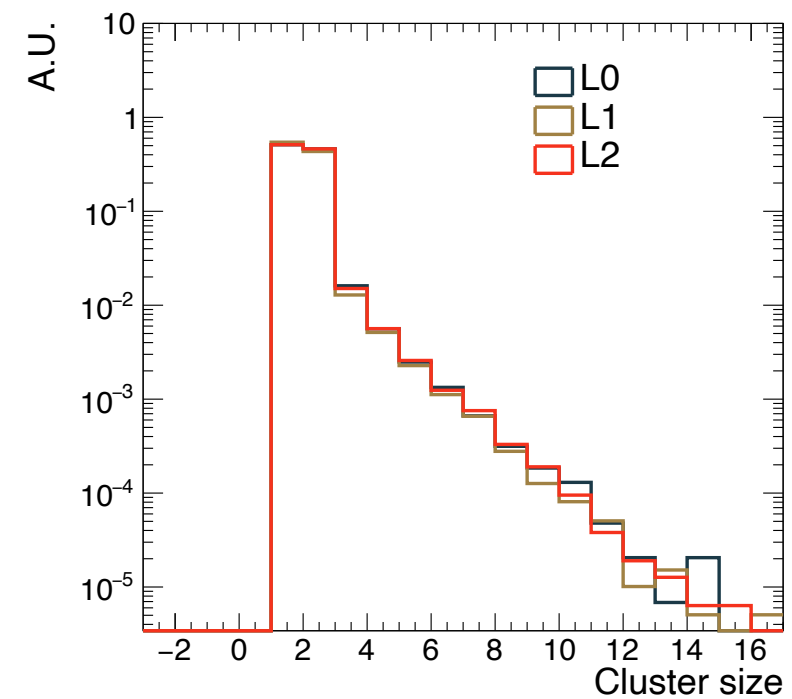
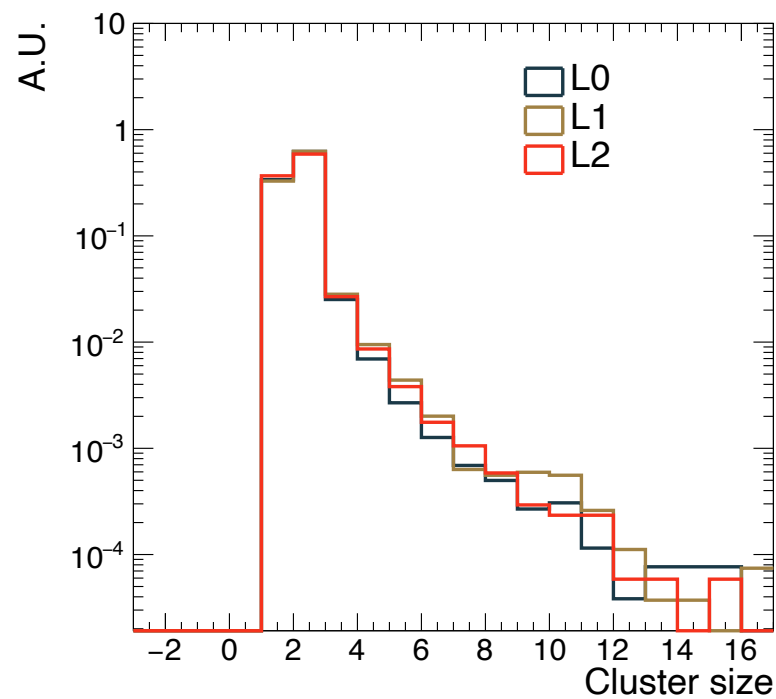
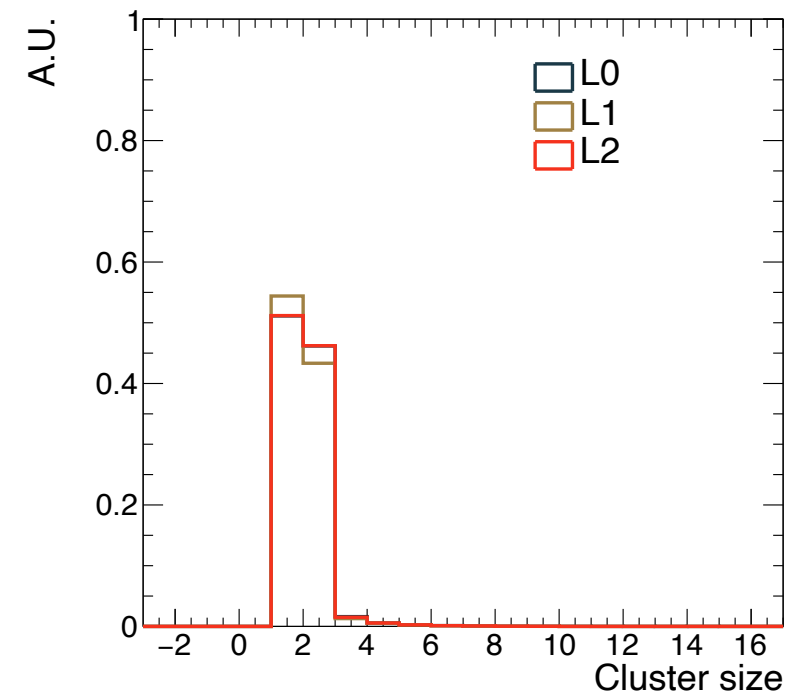


Cluster size - run61 (vertical rotation)

Data



MC

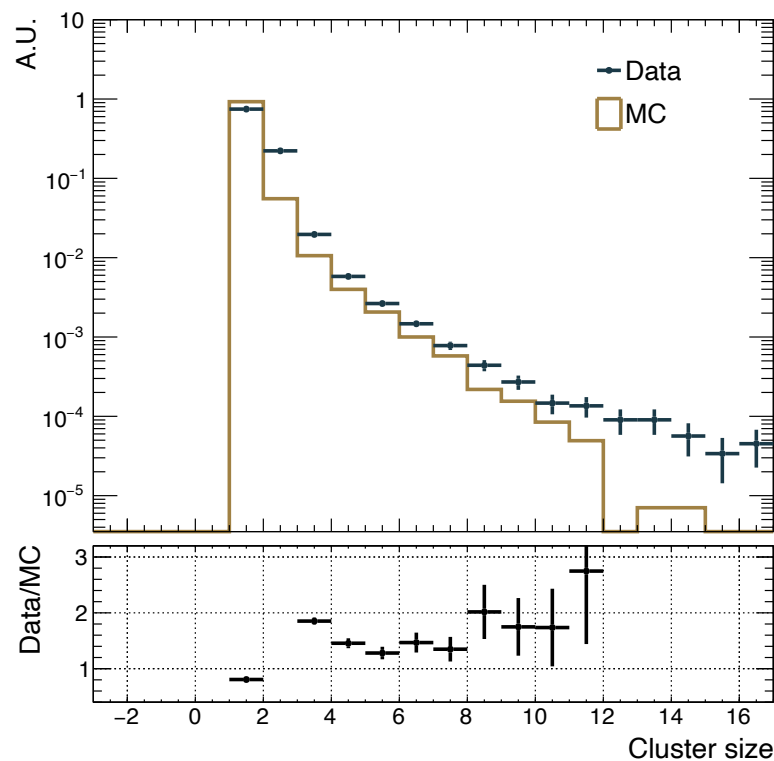


Cluster size - run61 (vertical rotation)

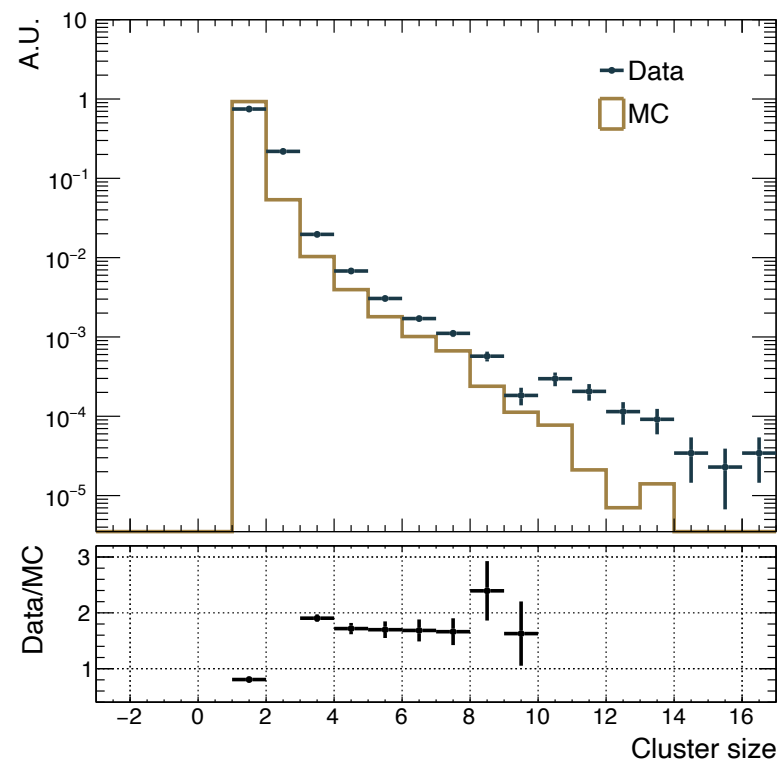
Data : Run89 U10, MC : Run89 MC5 condition

No selection

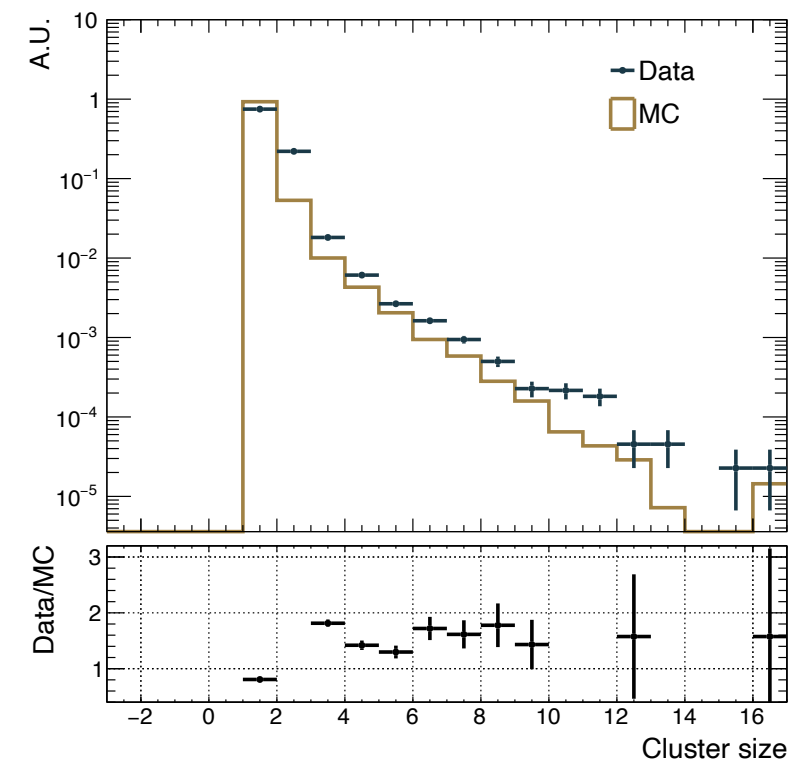
L0



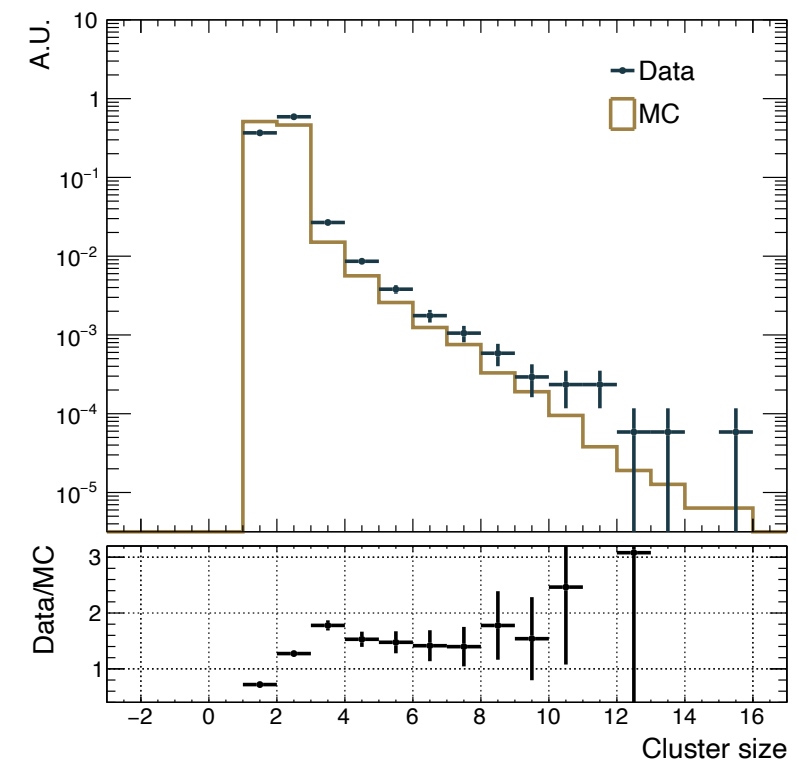
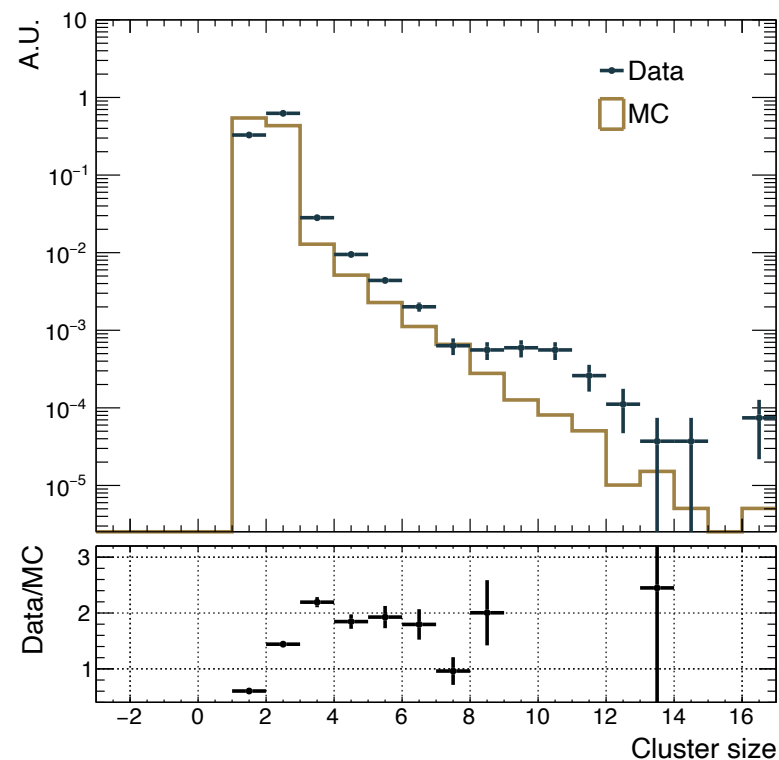
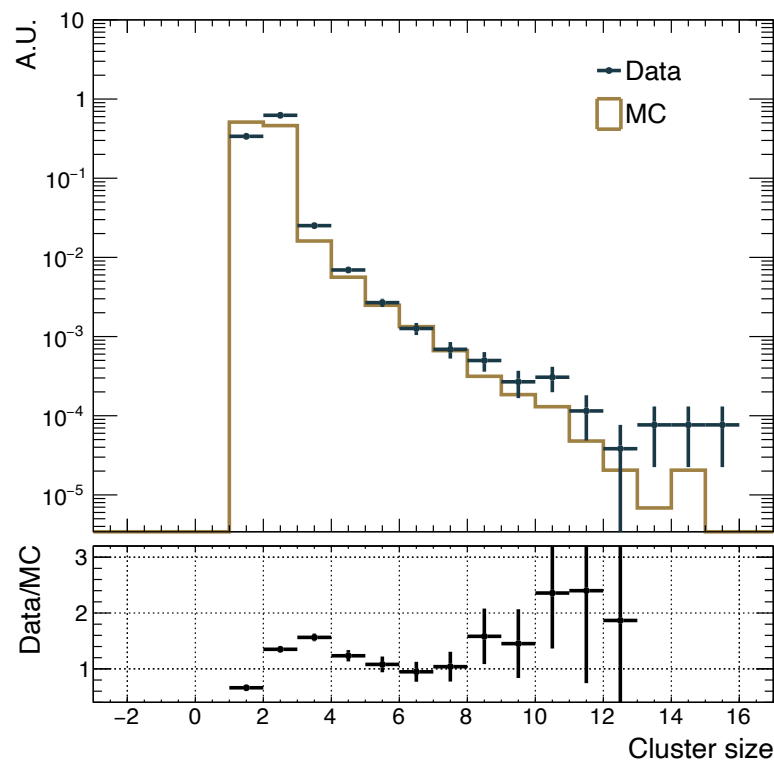
L1



L2

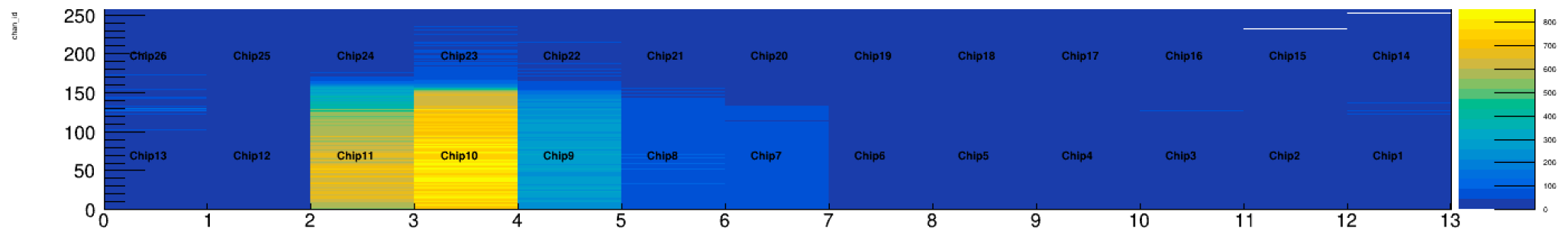


Data : Run61 U11, MC : Run61 MC4 condition

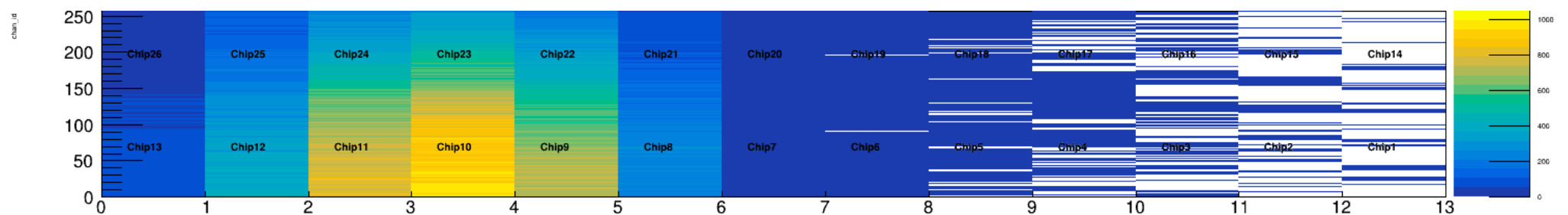


N track - run89 (= run64 W/O lead plate)

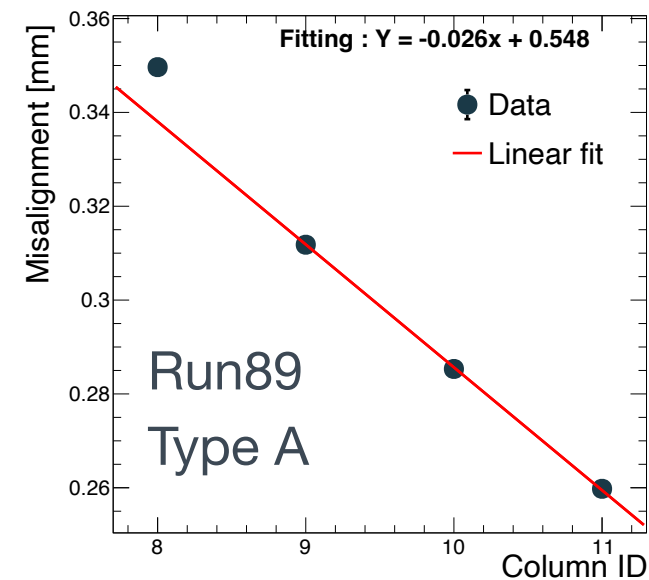
Data, run89 L0



MC5, run89 L0



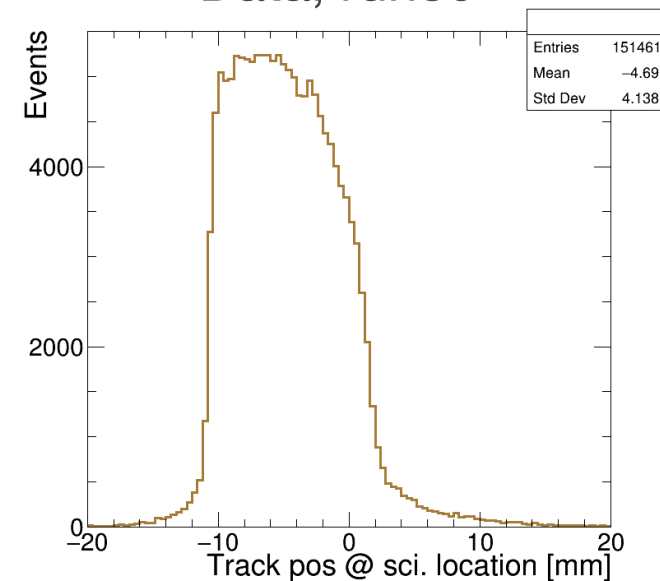
All columns are used in this study
Data L1 misalignment corrections : based on the fitting



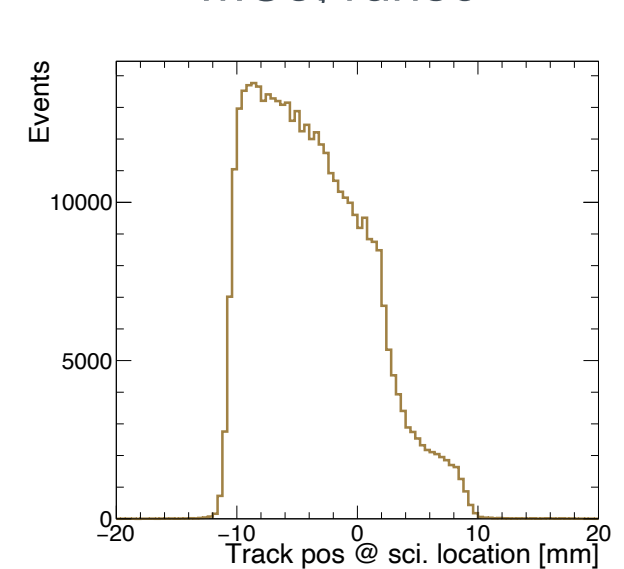
The correction of run89 type B is based on run33

Extrapolation pos. @ sci. location

Data, run89

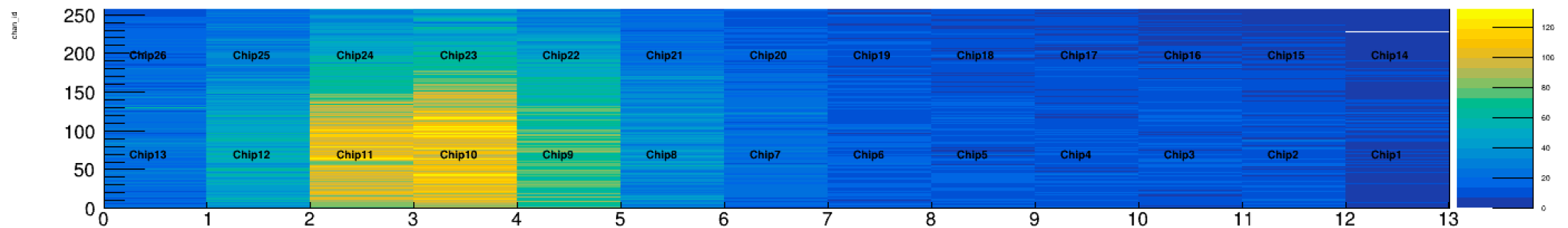


MC5, run89

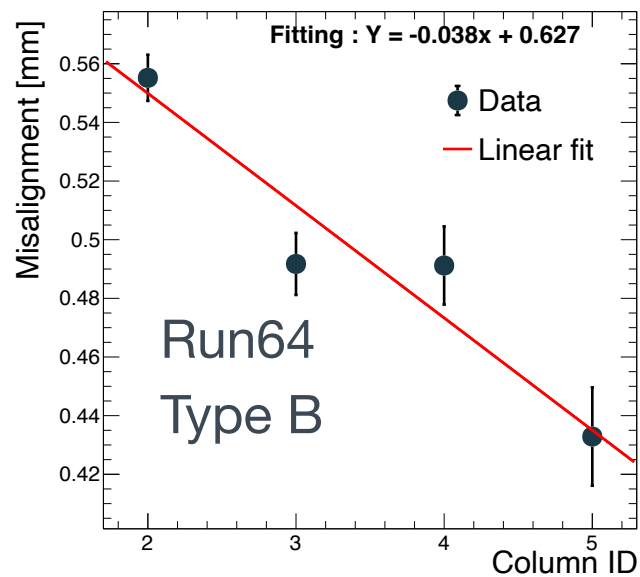
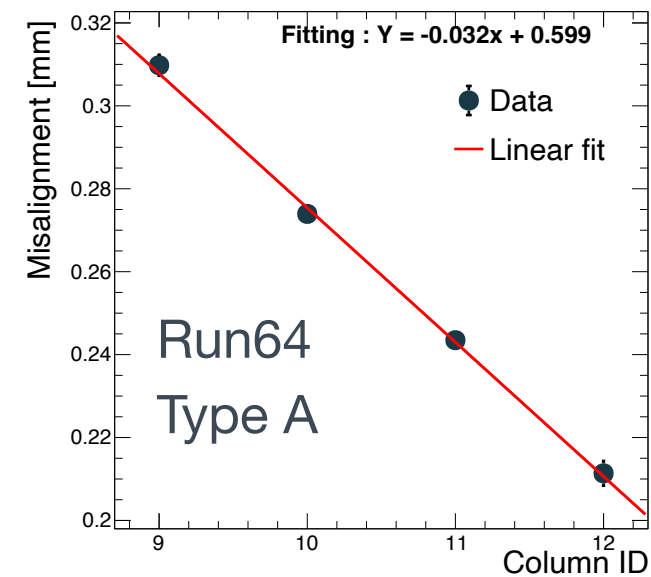


N track - run64 data (run 89 w/ lead plate)

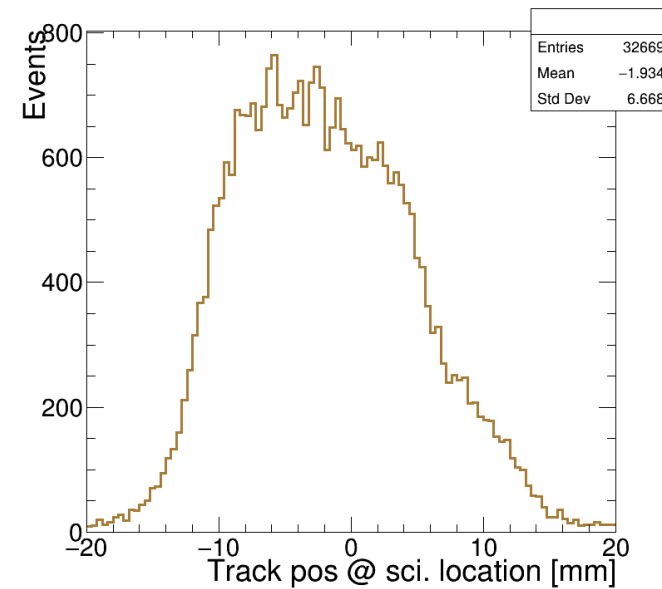
Data, run64 L0



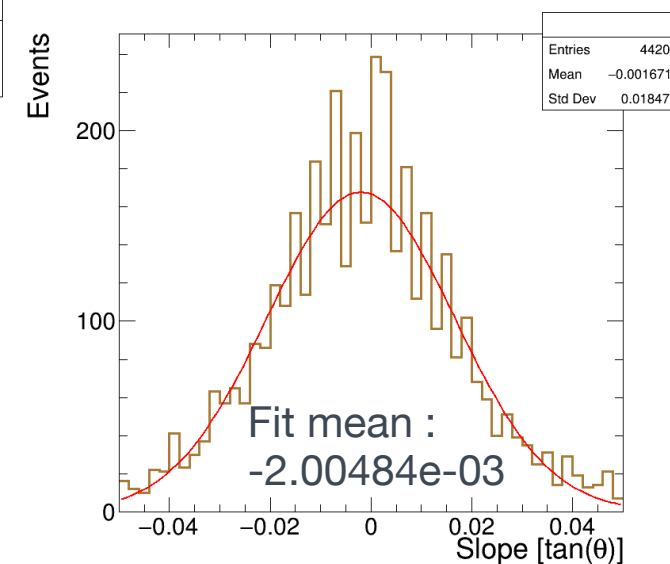
All columns are used in this study
Data L1 misalignment corrections : based on the fitting



Extrapolation pos.
@ sci. location



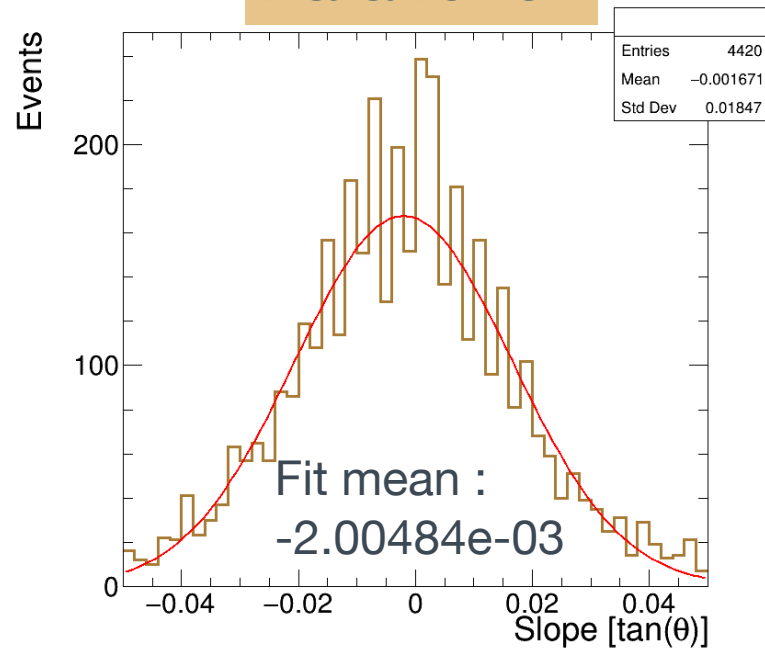
U10
track-candidate slope



N track - run64 MC (run 89 w/ lead plate)

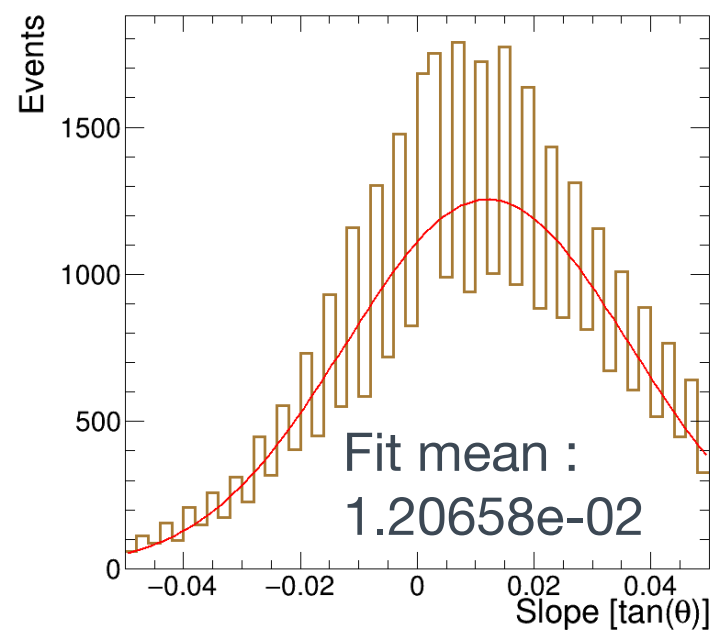
U10 track-candidate slope

Data run64



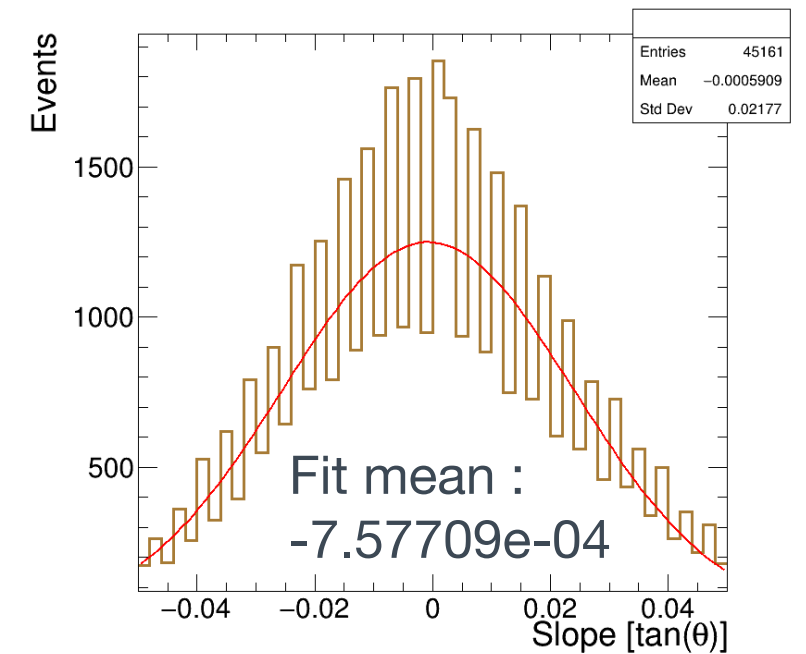
MCv1 of run64

MC4 (zero rotation)

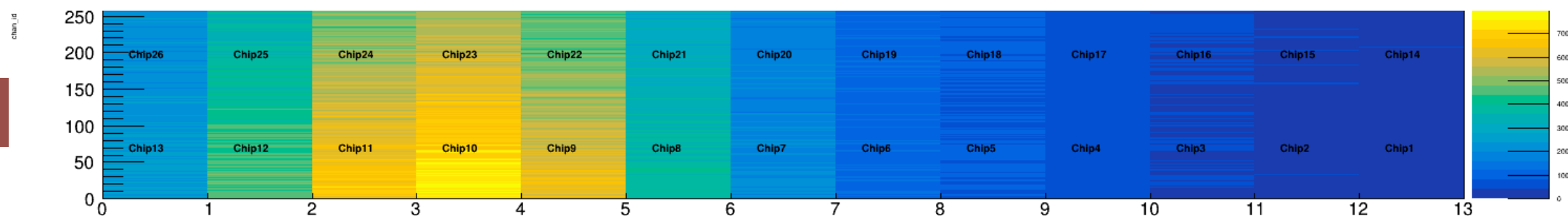


MCv2 of run64

MC5 ($2.00484e-03 + 1.20658e-02$)

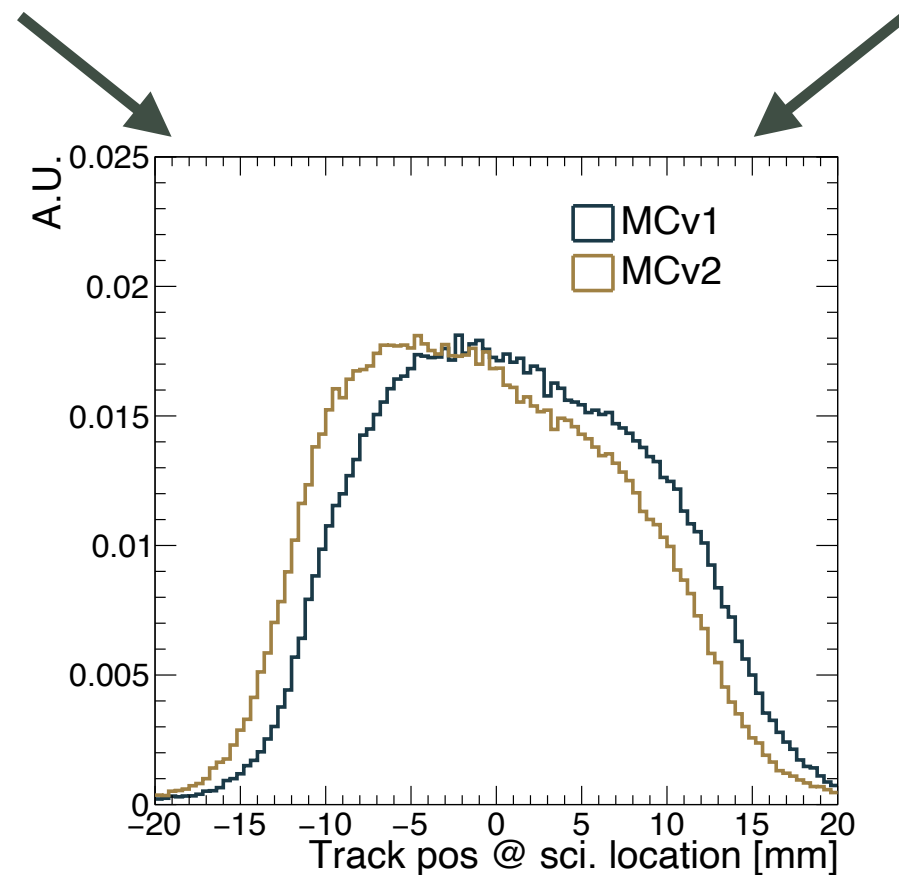
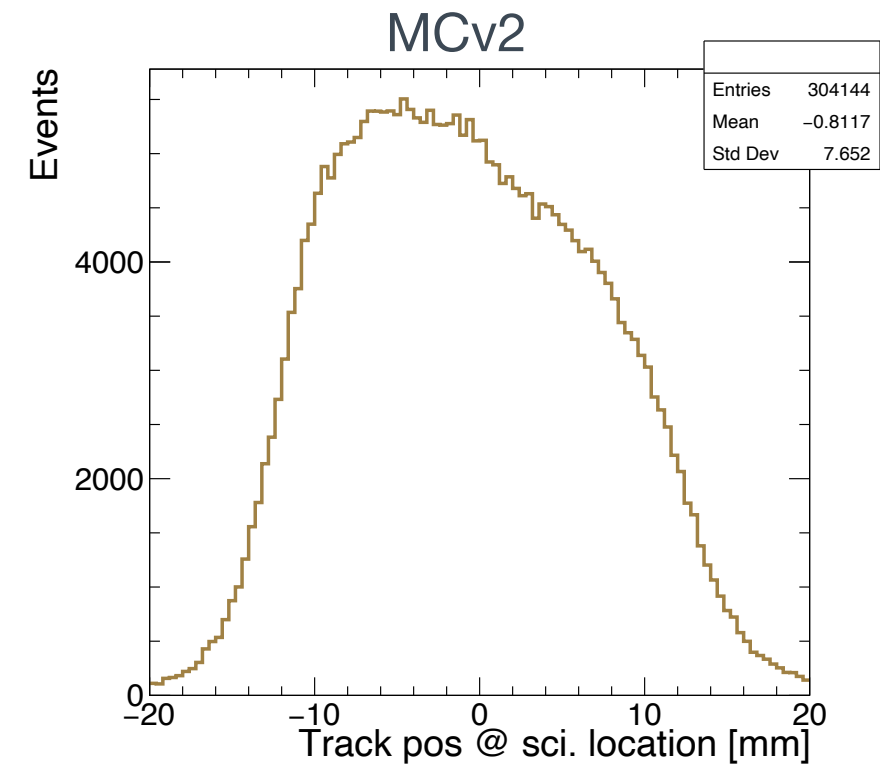
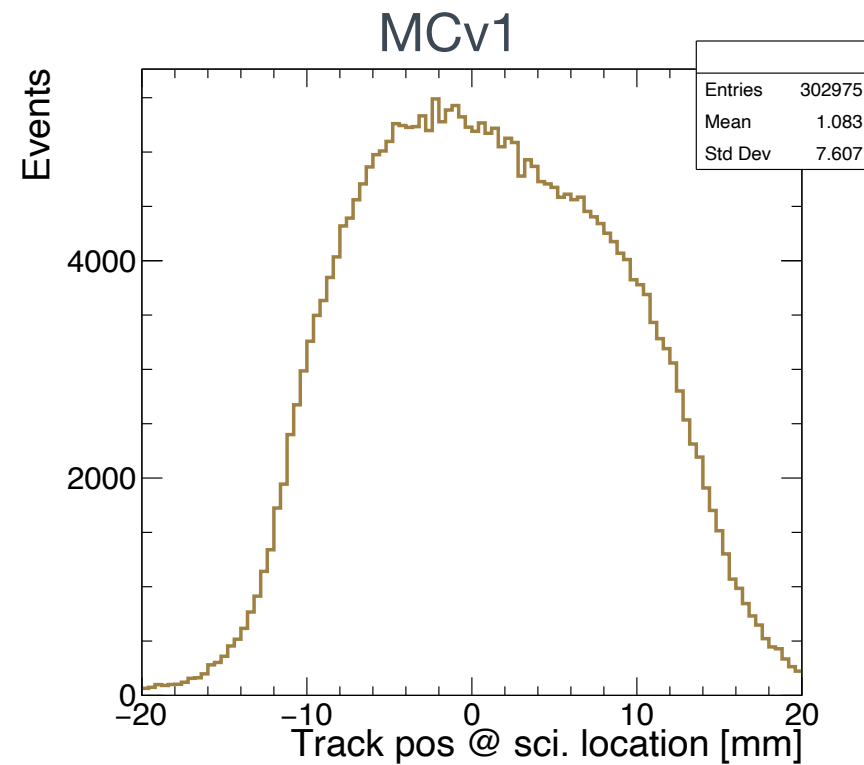
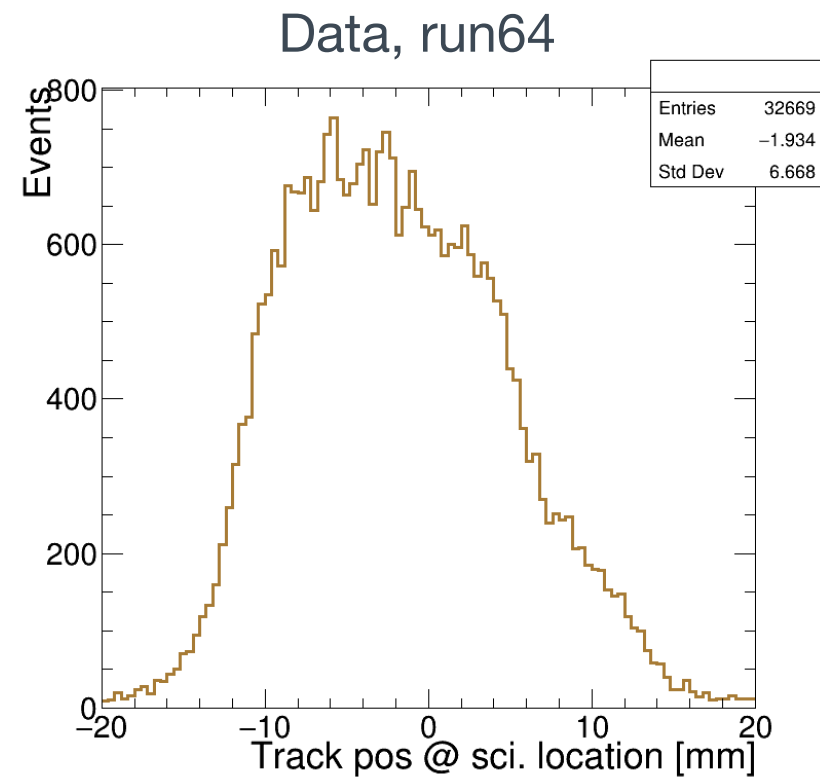


MC_v1 of run64 L0



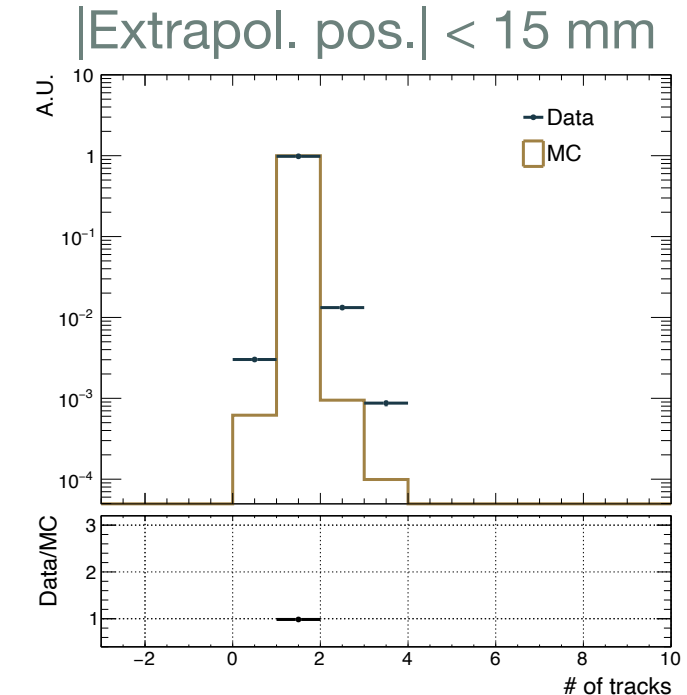
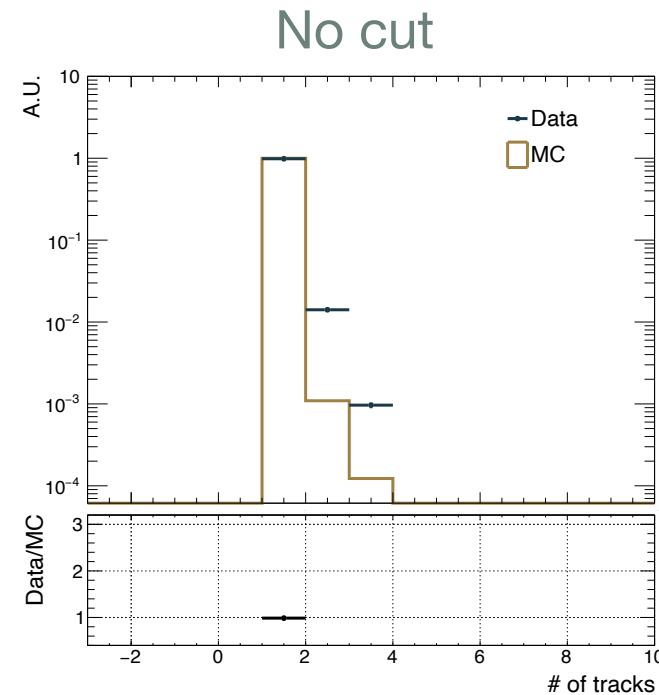
Leads to position mean of the track-candidate slope distribution

N track - extrapolation pos. @ sci. location

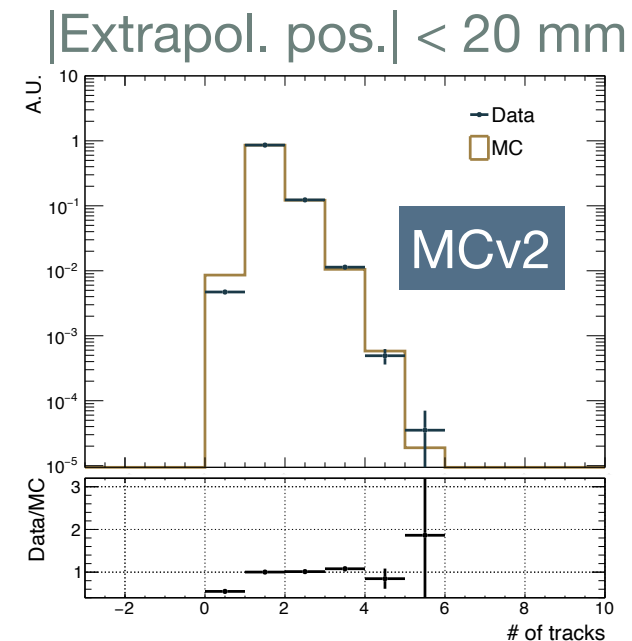
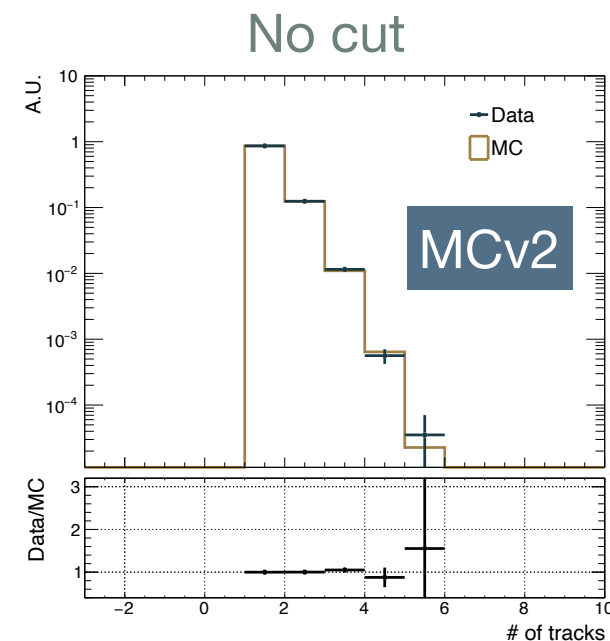
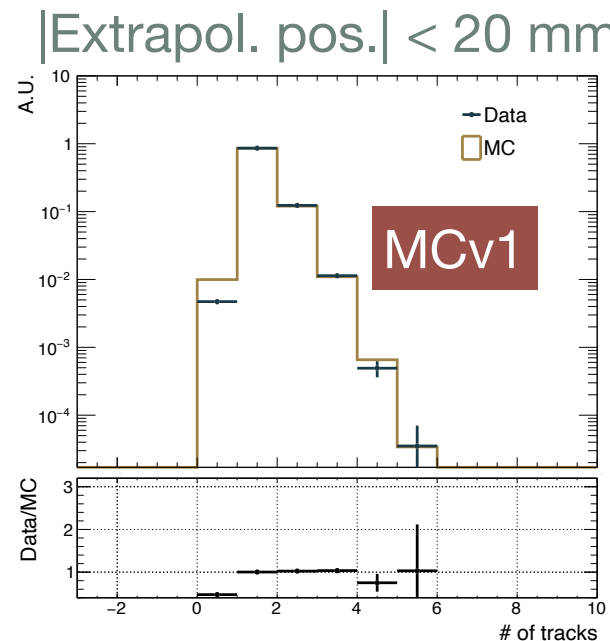
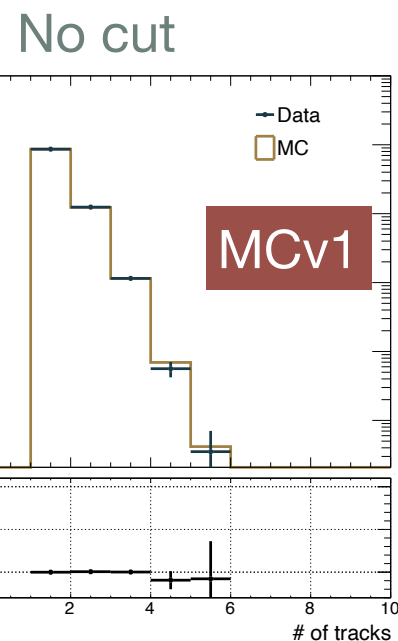


Run64 (with lead plate) - N track

Run 89
(= run64 W/O lead plate)



Run 64



Run89 : acceptable. It derives a question, what is the source of the multi-tracks ?

Run64 : excellent agreement $\rightarrow$ the evidence that the G4 simulation with the simple material in such energy range is correct

- The results shown above are based on the physics list “FTFP_BERT_EMZ”
 - “FTFP_BERT” : recommended by Geant4 developers for HEP applications
 - “_EMZ” : 4th option of the additional EM interaction package. In principle, is the most accurate one
 - Single coulomb scattering is not included

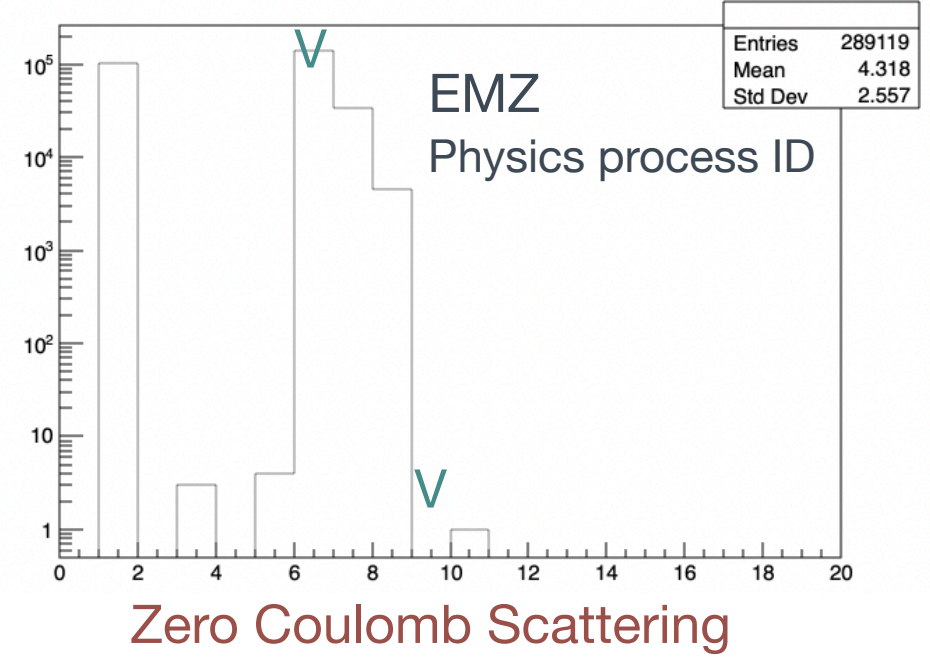
The active physics process of positron (same as electron)

In run.mac

```
/process/activate CoulombScat e+
/process/activate CoulombScat e-
```

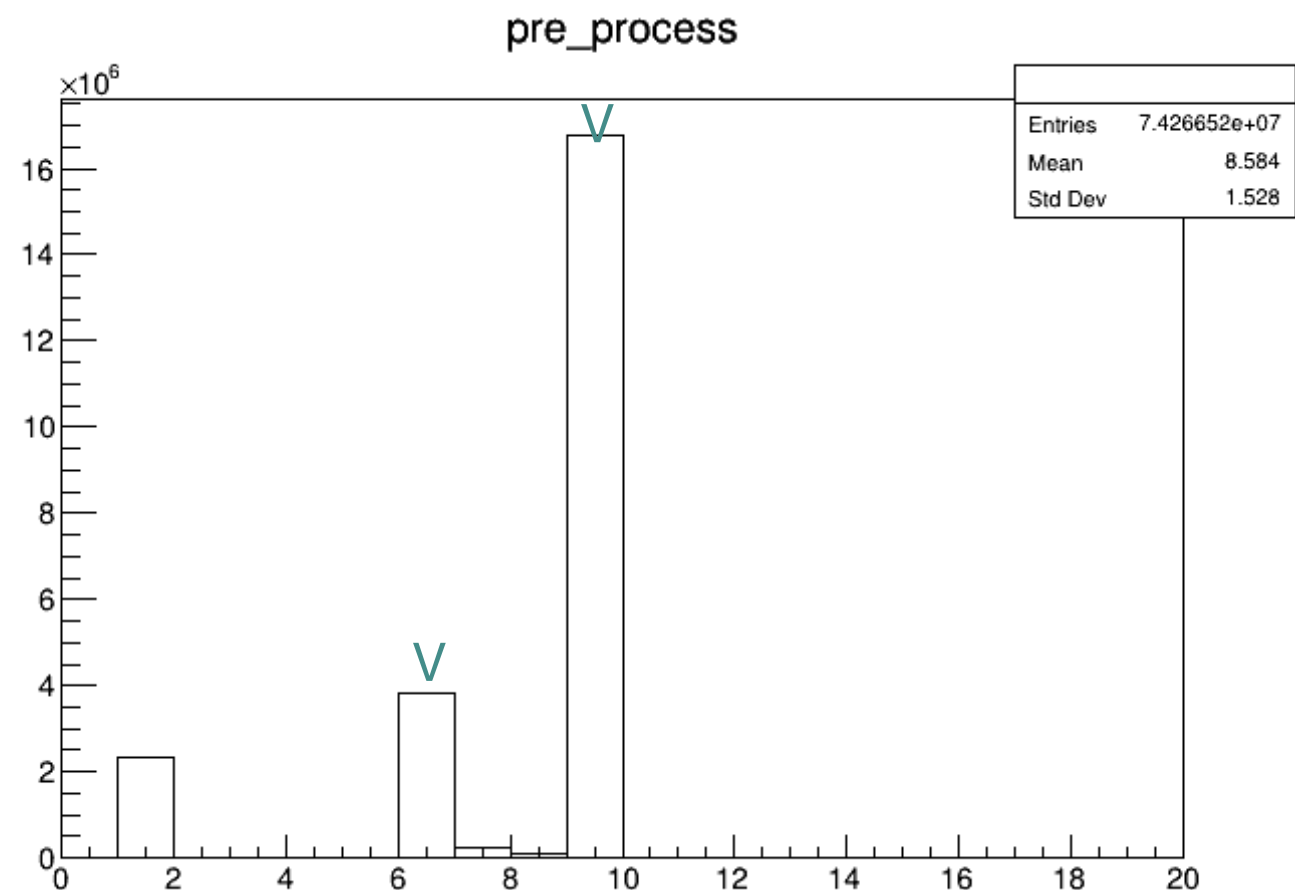
```
G4ProcessManager: particle[e+]
[0]=== process[Transportation :Transportation] Active
Ordering::      AtRest      AlongStep      PostStep
                GetPIL/    DoIt      GetPIL/    DoIt      GetPIL/    DoIt
Ordering::
index           -1:      -1:      2:      0:      6:      0:
parameter       -1:      -1:      0:      0:      0:      0:
[1]=== process[msc :Electromagnetic] Active
Ordering::      AtRest      AlongStep      PostStep
                GetPIL/    DoIt      GetPIL/    DoIt      GetPIL/    DoIt
Ordering::
index           -1:      -1:      1:      1:      -1:      -1:
parameter       -1:      -1:      1:      1:      -1:      -1:
[2]=== process[eIoni :Electromagnetic] Active
Ordering::      AtRest      AlongStep      PostStep
                GetPIL/    DoIt      GetPIL/    DoIt      GetPIL/    DoIt
Ordering::
index           -1:      -1:      0:      2:      5:      1:
parameter       -1:      -1:      2:      2:      2:      2:
[3]=== process[eBrem :Electromagnetic] Active
Ordering::      AtRest      AlongStep      PostStep
                GetPIL/    DoIt      GetPIL/    DoIt      GetPIL/    DoIt
Ordering::
index           -1:      -1:      -1:      -1:      4:      2:
parameter       -1:      -1:      -1:      -1:      3:      3:
[4]=== process[ePairProd :Electromagnetic] Active
Ordering::      AtRest      AlongStep      PostStep
                GetPIL/    DoIt      GetPIL/    DoIt      GetPIL/    DoIt
Ordering::
index           -1:      -1:      -1:      -1:      3:      3:
parameter       -1:      -1:      -1:      -1:      4:      4:
[5]=== process[annihil :Electromagnetic] Active
Ordering::      AtRest      AlongStep      PostStep
                GetPIL/    DoIt      GetPIL/    DoIt      GetPIL/    DoIt
Ordering::
index           0:      0:      -1:      -1:      2:      4:
parameter       5:      5:      -1:      -1:      5:      5:
[6]=== process[CoulombScat :Electromagnetic] Active
Ordering::      AtRest      AlongStep      PostStep
                GetPIL/    DoIt      GetPIL/    DoIt      GetPIL/    DoIt
Ordering::
index           -1:      -1:      -1:      -1:      1:      5:
parameter       -1:      -1:      -1:      -1:      1000: 1000:
```

1	Transportation
2	phot
3	compt
4	conv
5	Rayl
6	msc
7	eloni
8	eBrem
9	CoulombScat
10	annihil



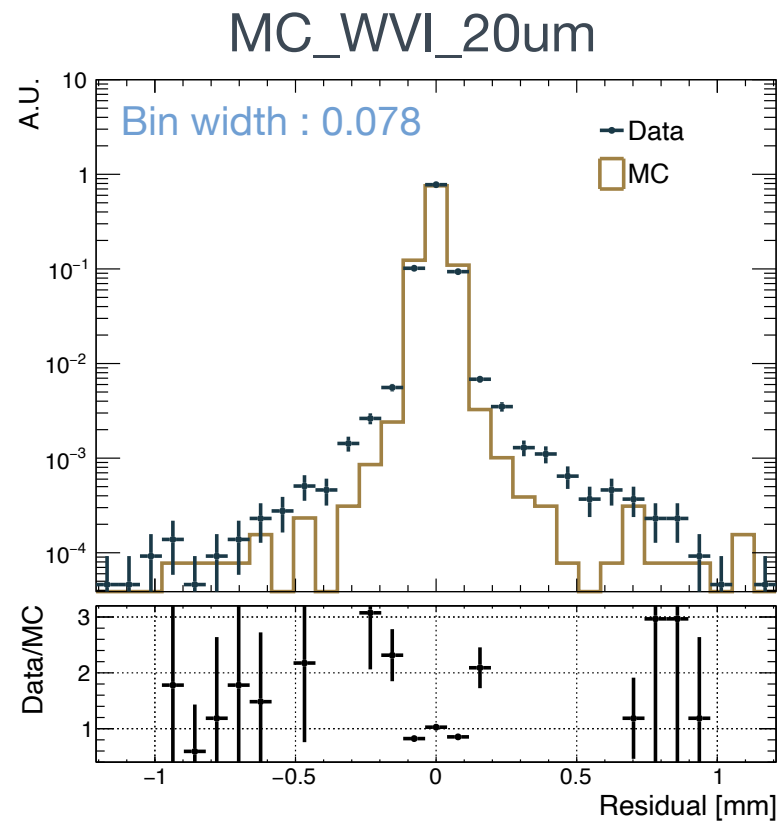
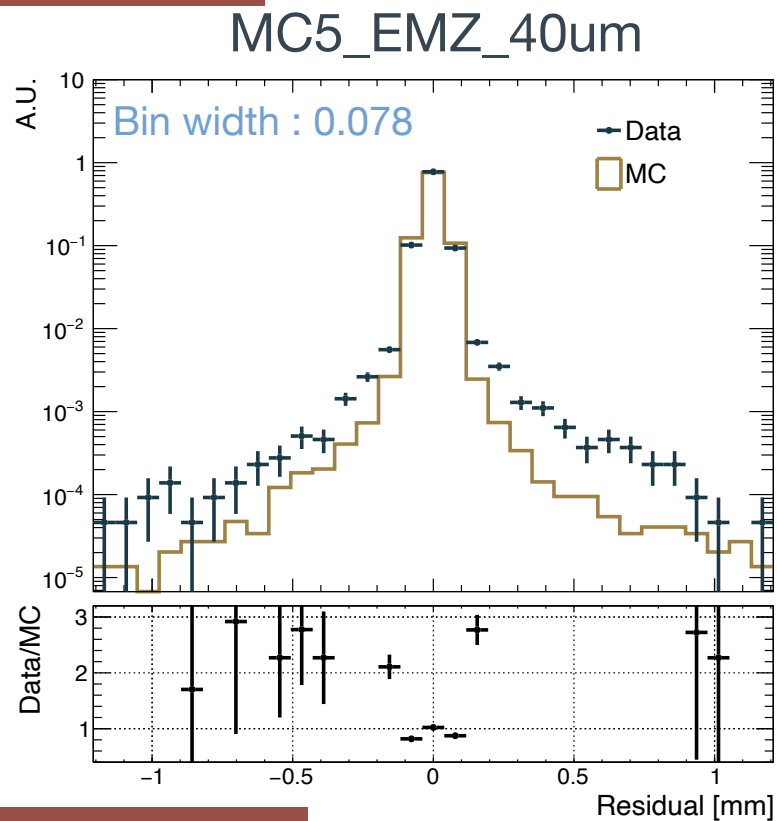
- The new test physics list “FTFP_BERT_WVI”
 - “FTFP_BERT” : recommended by Geant4 developers for HEP applications
 - “_WVI” : additional EM interaction package
 - the WentzelVI model is used for simulation of multiple scattering combined with single elastic at large angles

1	Transportation
2	phot
3	compt
4	conv
5	Rayl
6	msc
7	eloni
8	eBrem
9	CoulombScat
10	annihil



Comparison - residual & scattering distribution

U8 Residual

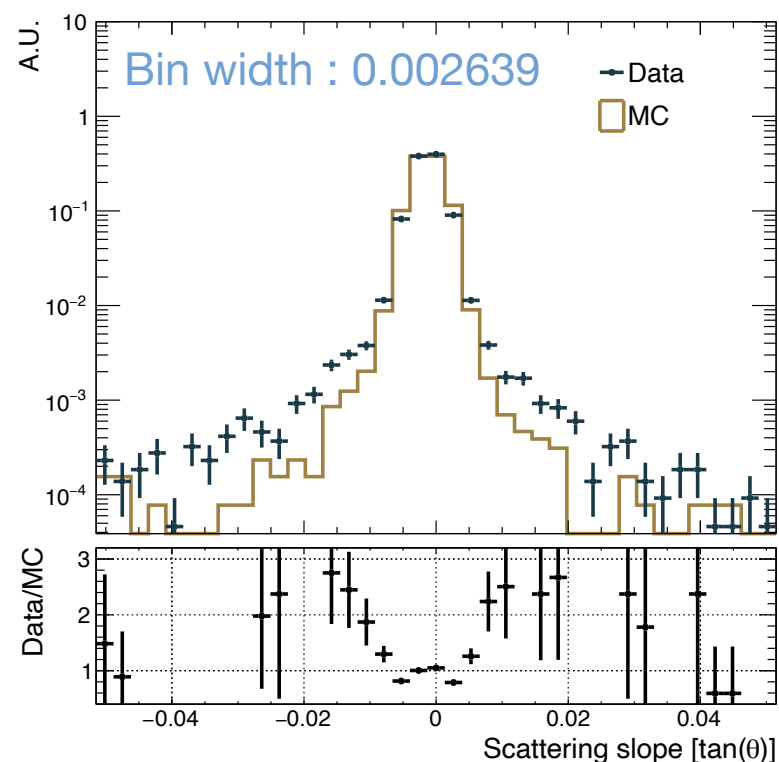
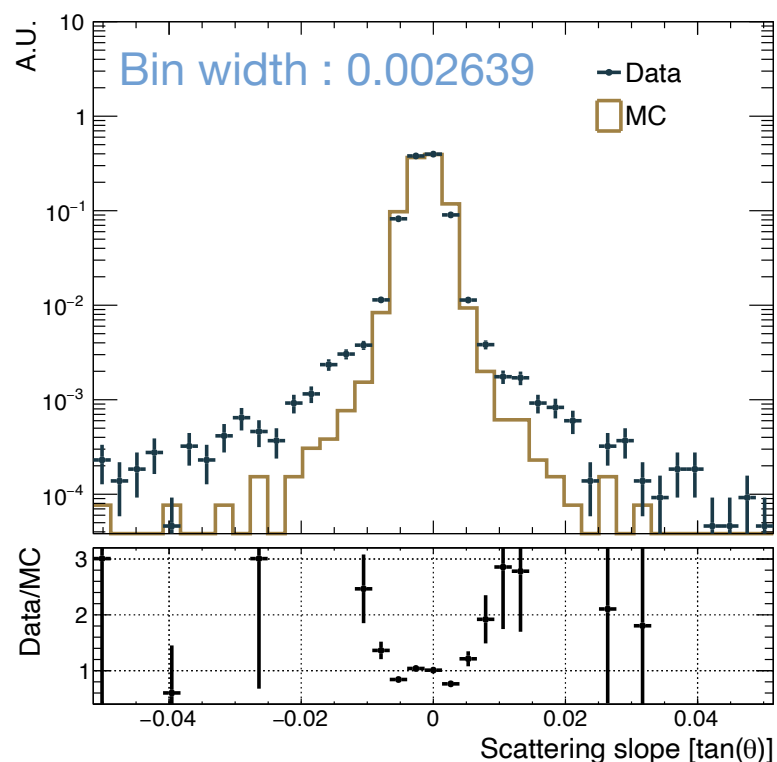


MC_SS_20um

Single coulomb scattering only
(no msc)

MC sample generating

U8 Scattering



MC sample generating

- The bin width is reconsidered, and the misalignment in MC is introduced
 - The agreement between data and MC becomes better, for both residual and scattering distribution. At least the tendency looks similar for the peak region
- The dark-box vertical rotation is also considered. The improvement is minor
- The cluster-size distribution of data is wider than the one of MC, which is as expected
 - Charge-sharing effect is not considered in MC, which is also the reason of the fish-bone like distribution in MC cluster ADC distribution

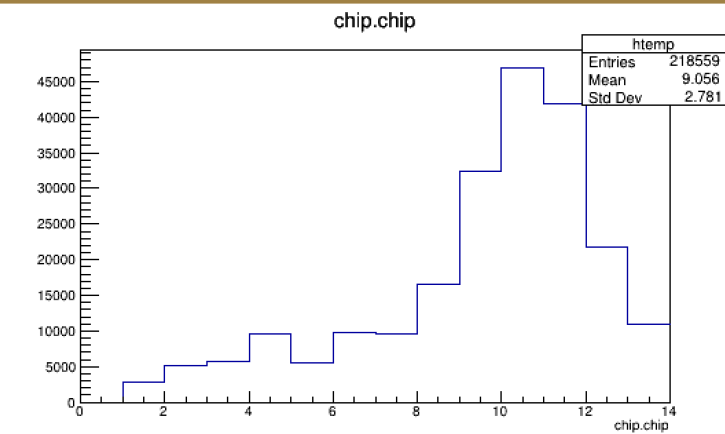
- The discrepancy of the cluster-size distribution between data and MC is kind of consistent for both rotated case and unrotated case
- In the run with lead plate, the excellent agreement gives the hint that the G4 simulation with the simple material in such energy range is correct
- The original physics list “FTFP_BERT_EMZ” I used doesn’t simulate the Coulomb scattering
- The new physics list “FTFP_BERT_WVI” considers the Coulomb scattering. The tail region improves

- Ladder geometry & material review
 - The thermal glue between HDI and stave is not included yet
 - Improvement is expected to be small
 - 10% more HDI metal has been considered, minor difference

Backup

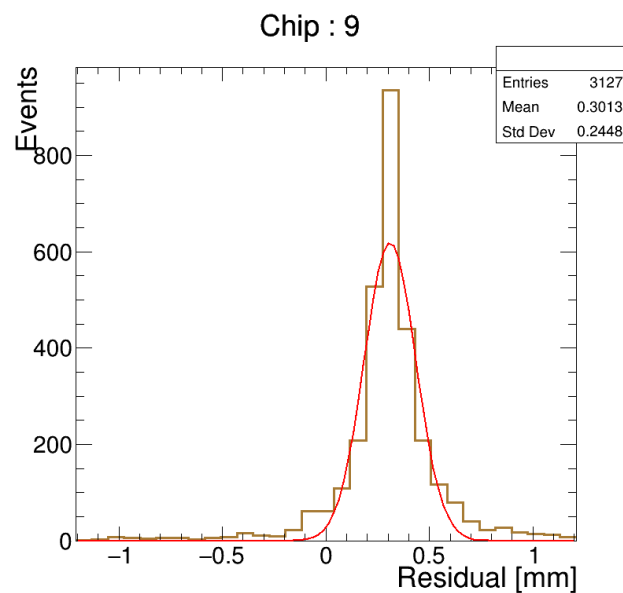
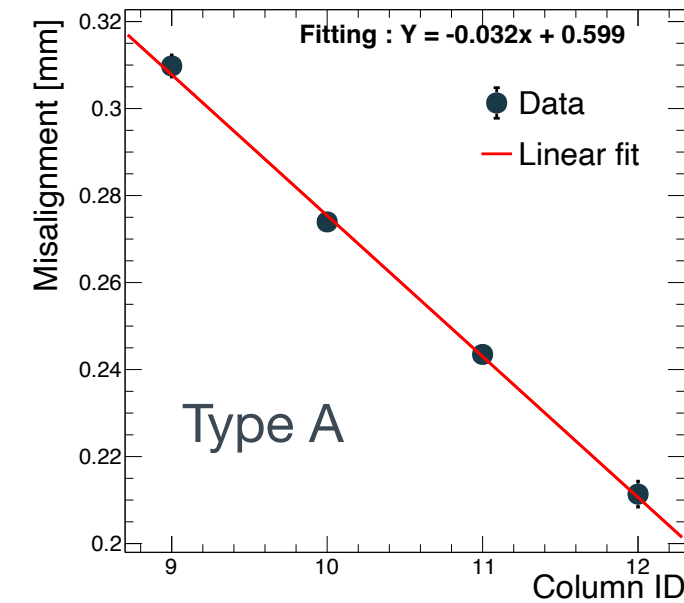
- 4 runs are used
 - Data run89
 - L1 offset correction : (all columns) based on fitting
 - Type A : from run 89 type A
 - Type B : from run 33 type B
 - vertical rotation correction : based on data run89 U10 : $-4.74917e-03$ [slope]
 - Data run64
 - L1 offset correction : (all columns) based on fitting
 - Type A : from run64 type A
 - Type B : from run64 type B
 - vertical rotation correction : based on data run64 U10 : $-2.00484e-03$ [slope]
- MC run89
 - **L1 offset input** : from U10 of data run89
 - L1 offset correction : (all columns) based on MC run89 U10
 - **vertical rotation input** : data run89 U10
 - vertical rotation correction : MC run89 U10
- MC run64
 - **L1 offset input** : from U10 of data run64
 - L1 offset correction : (all columns) based on MC run64 U10
 - **vertical rotation input** : data run64 U10
 - vertical rotation correction : MC run64 U10

Data Run64 (run 89 with lead plate) - chip residual

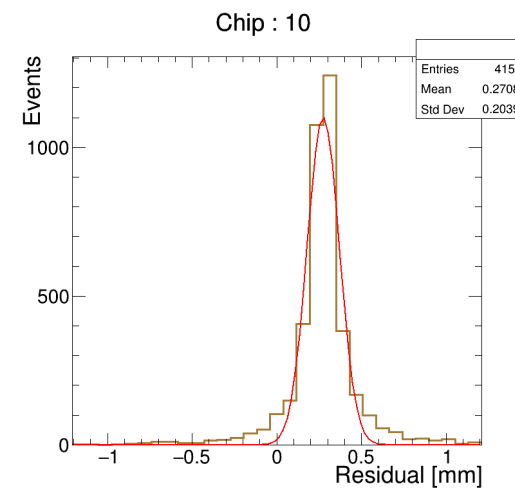


Type A

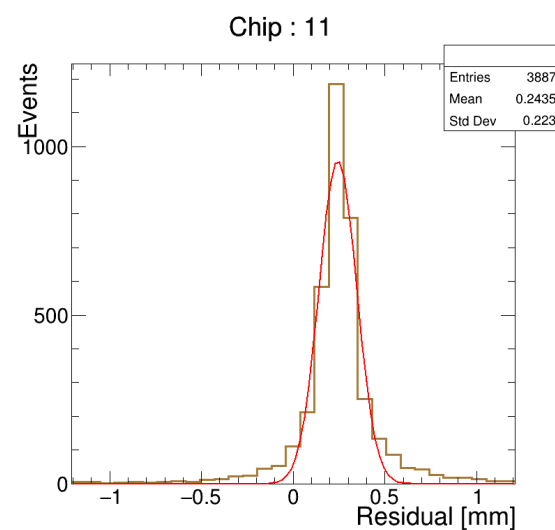
Parameter	Value	Uncertainty
$p0$	0.59931	± 0.0119656
$p1$	-0.0323918	± 0.00114698



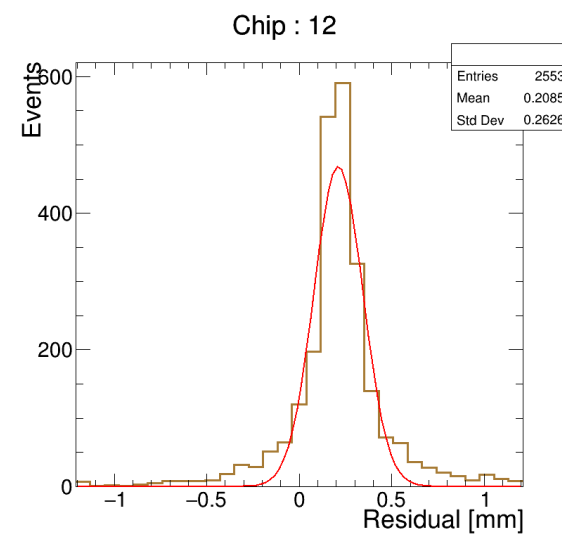
fit mean : $3.09796e-01$



fit mean : $2.73935e-01$

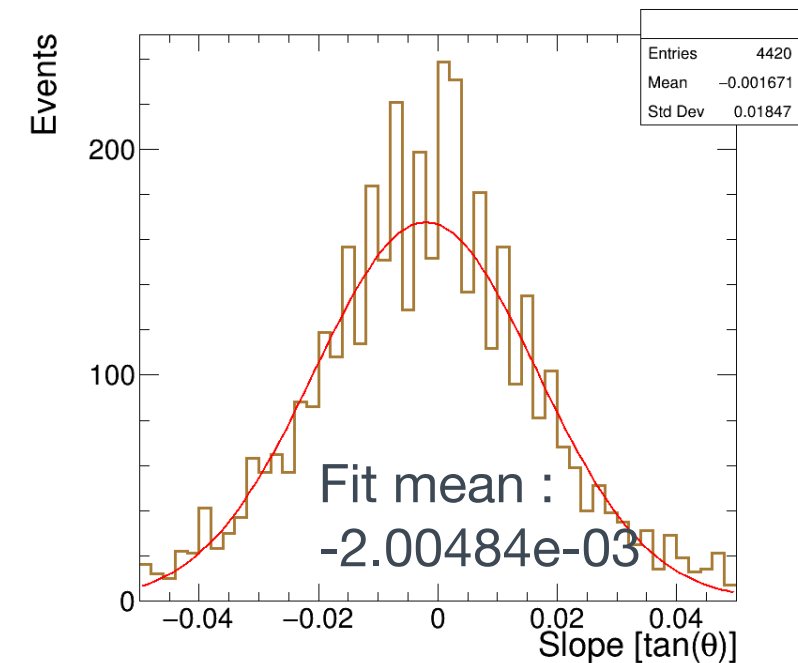


fit mean : $2.43477e-01$

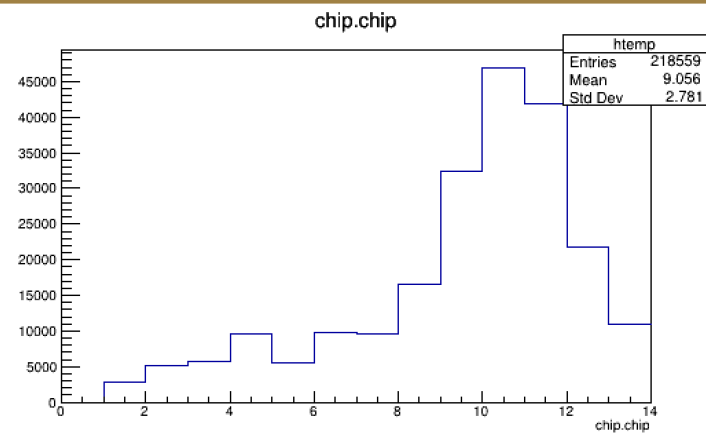


fit mean : $2.11363e-01$

U10 track-candidate slope

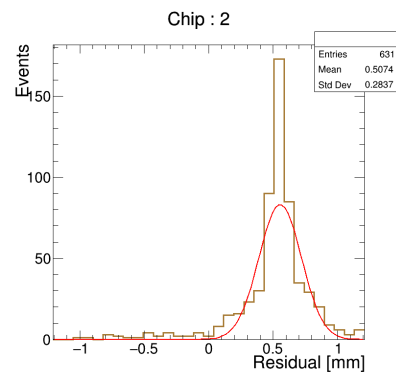


Data Run64 (run 89 with lead plate) - chip residual

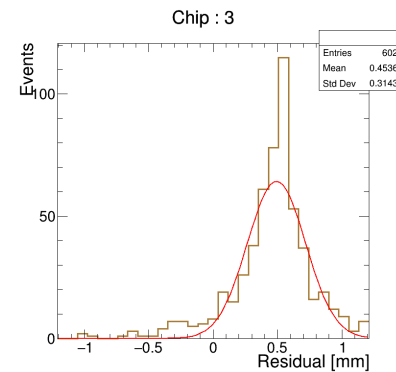


Type B
Data

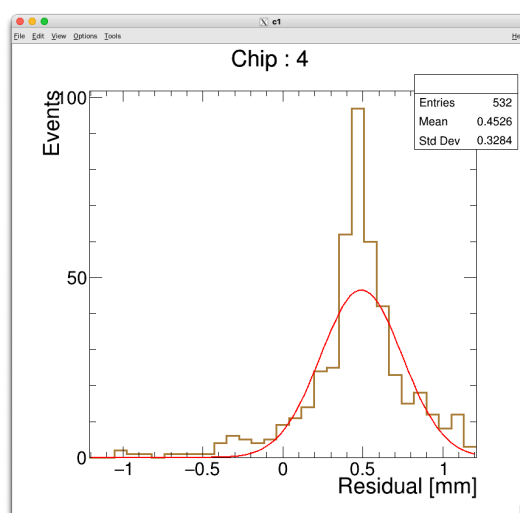
p0 root info. = 0.626502 +/- 0.0162958
p1 = -0.0382944 +/- 0.00529766



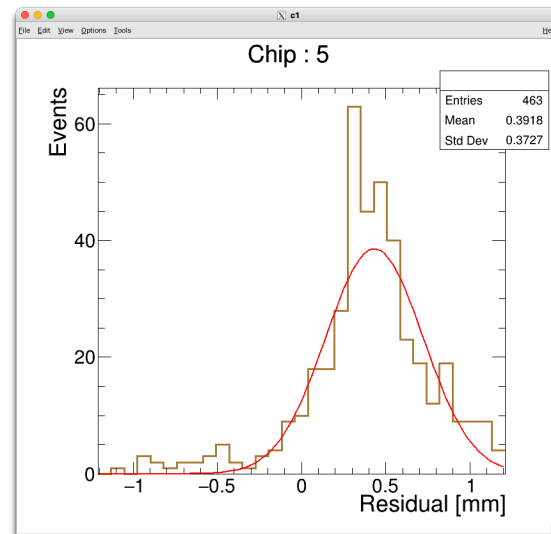
Fit mean :
5.55200e-01



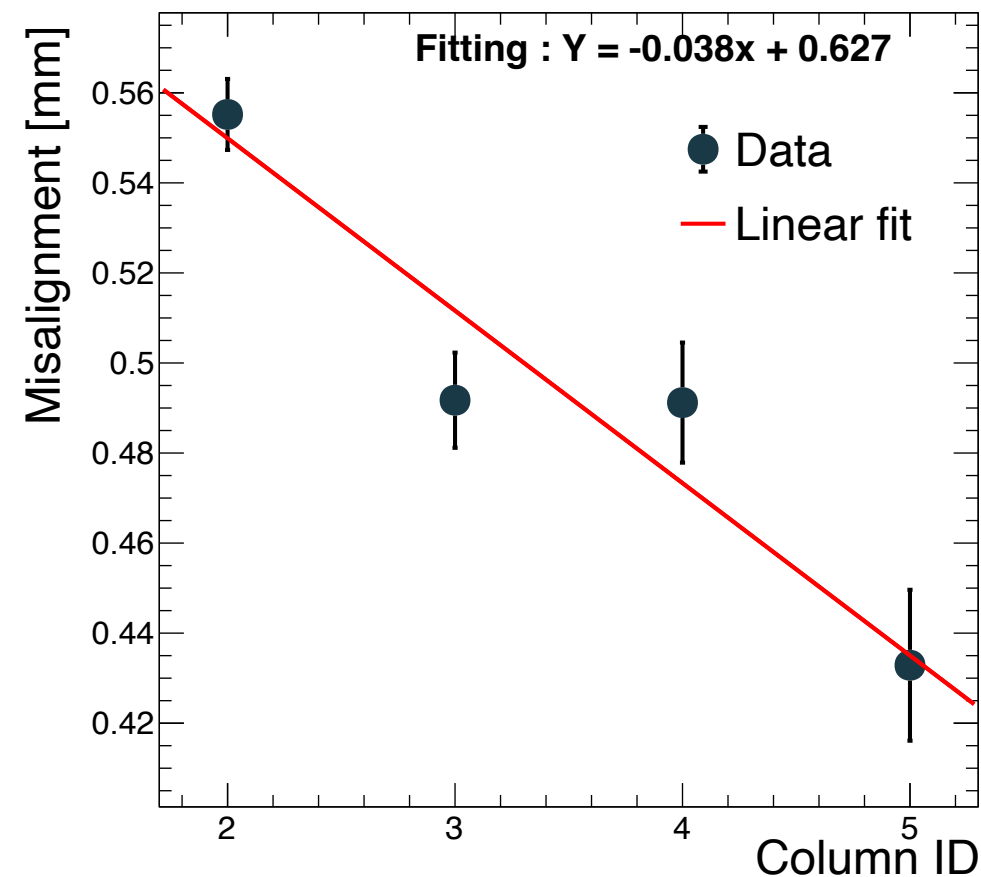
Fit mean :
4.91730e-01



Fit mean :
4.91200e-01



Fit mean :
4.32869e-01



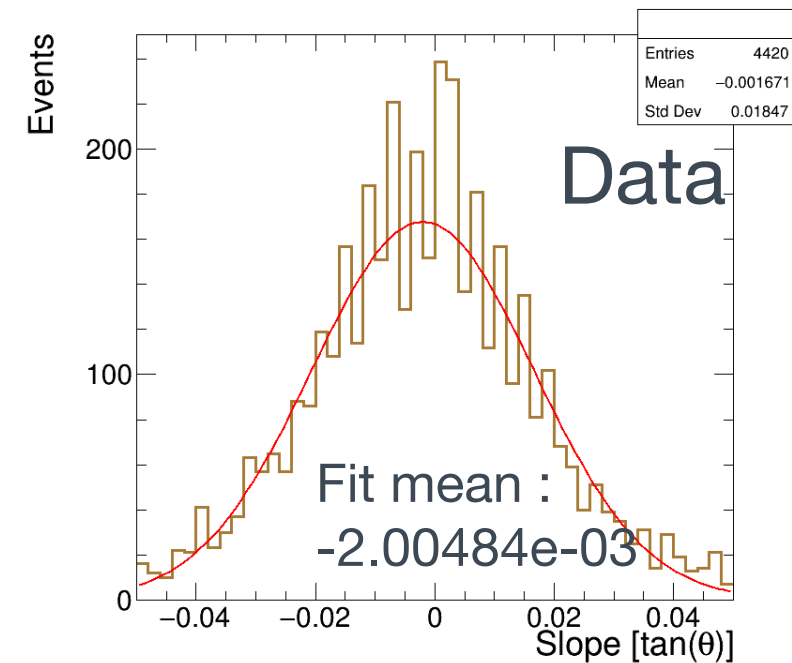
directory : /data4/chengwei/Geant4/INTT_simulation/G4/for_CW/Beamtest_data_Different_config/
MC_run64_with_lead_plate_with_run64_slope_and_offset

- G4 input L1 offset (from data run64 U10) : 2.73935e-01 mm
- G4 input vertical rotation (from data run64 U10) : 0.11486872 * deg

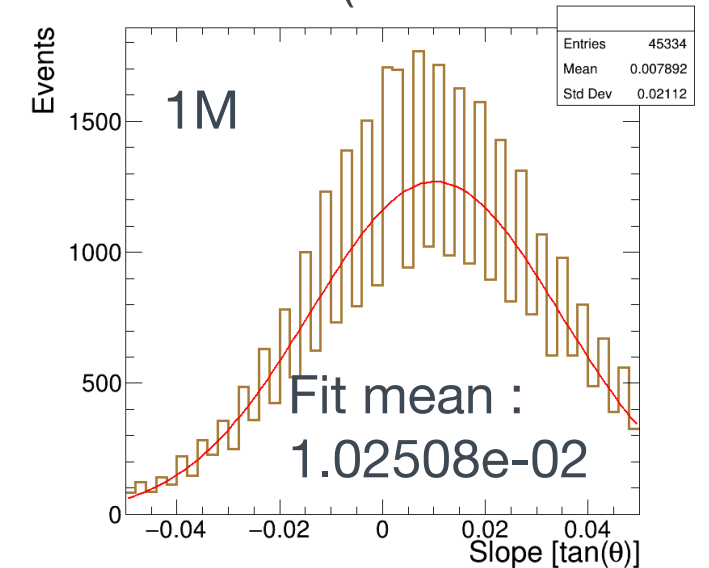
- G4 **Output** L1 offset (from MC run64 U10) : mm
- G4 **Output** vertical rotation (from MC run64 U10) :

N track - run64 (= run89 with lead plate)

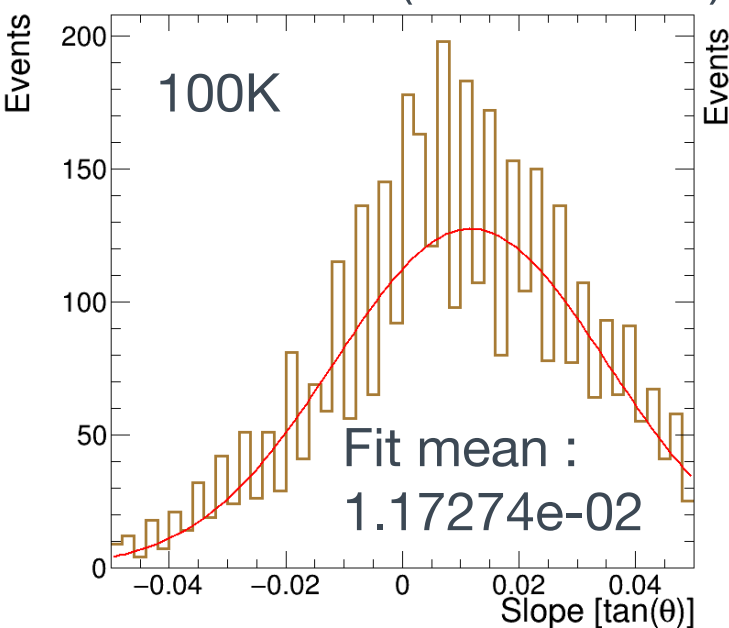
U10 track-candidate slope



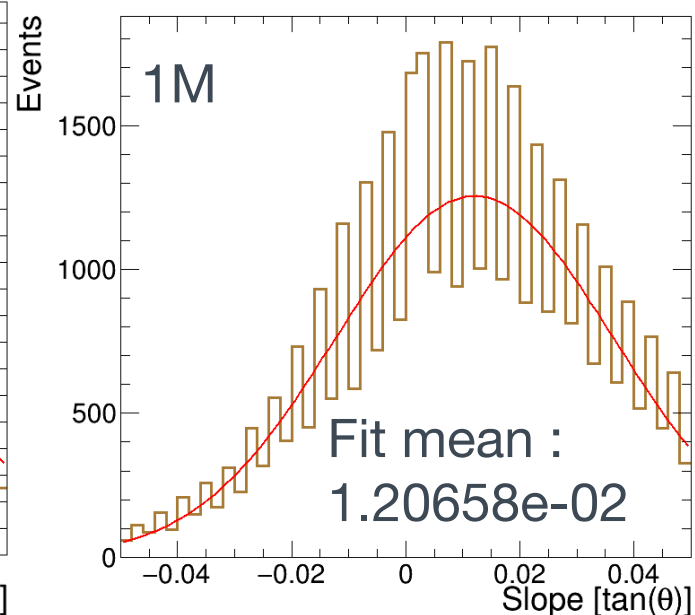
Track-candidate slope
MC5 run64, slope :
 $2.00484e-03$ (data run64 U10)



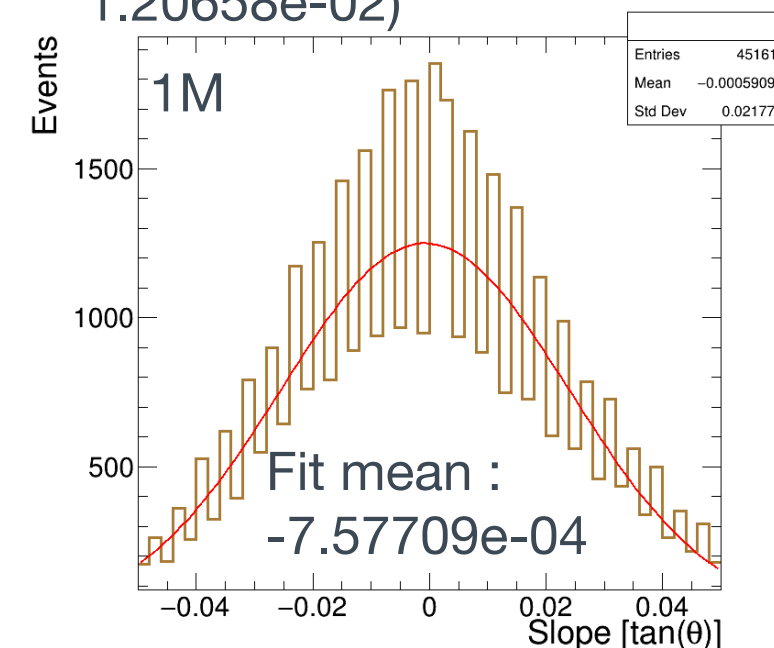
Track-candidate slope
MC4 run64 (zero rotation)



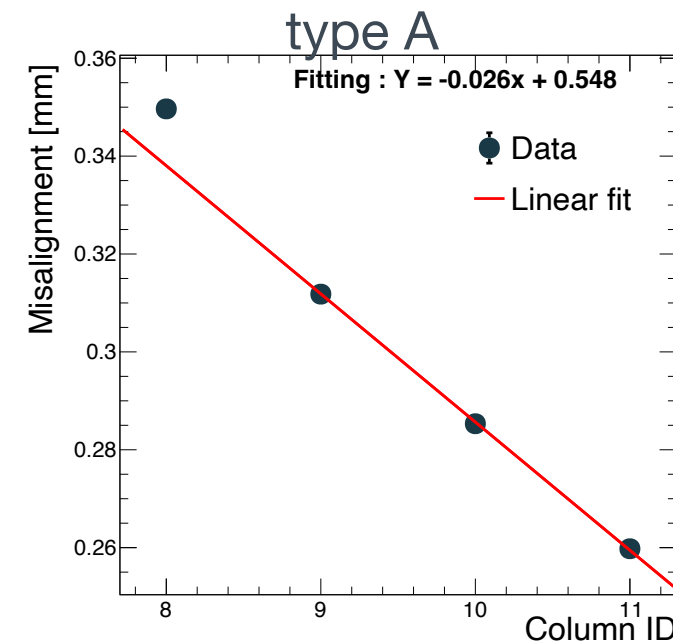
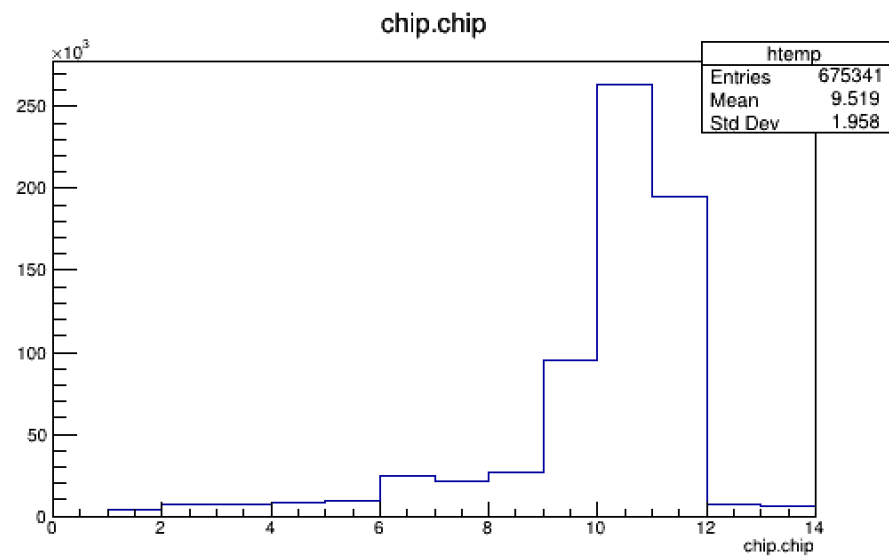
Track-candidate slope
MC4 run64 (zero rotation)



Track-candidate slope
MC5 run64 ($2.00484e-03 + 1.20658e-02$)

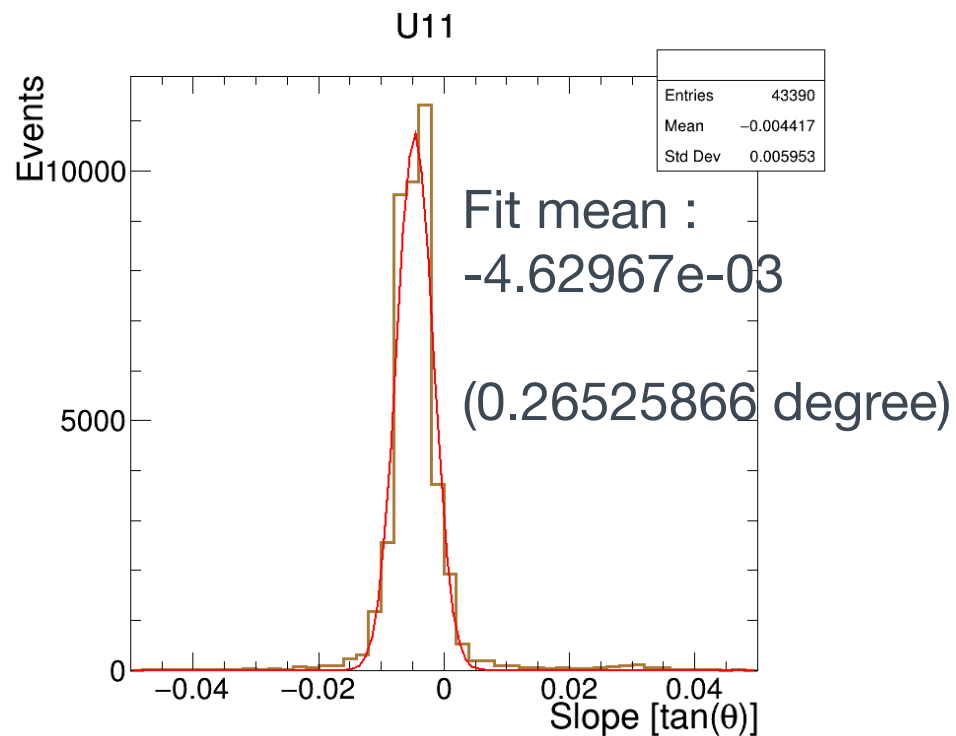


Data Run89 (reference data of run64)

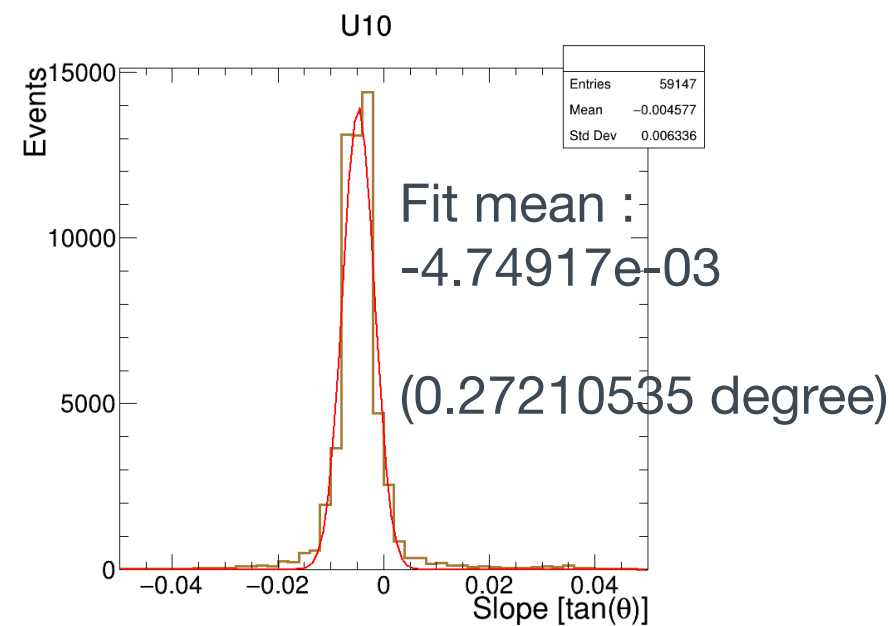


p0	=	0.547567	+/-	0.00188316
p1	=	-0.0261907	+/-	0.000183917

Data run89, track-candidate slope of U11



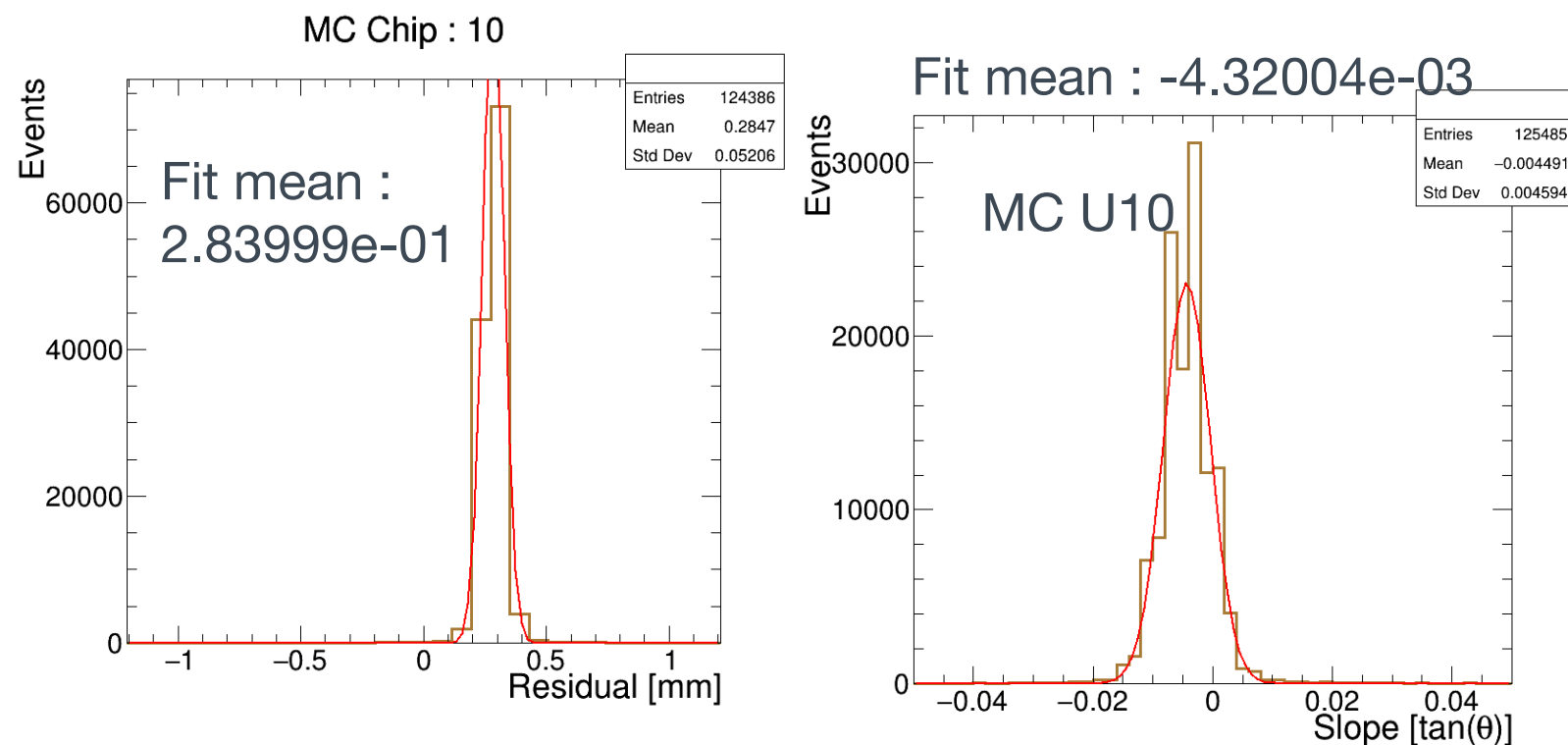
Data run89, track-candidate slope of U10



MC run89 (Run64 without lead plate)

location : /data4/chengwei/Geant4/INTT_simulation/G4/for_CW/Beamtest_data_Different_config/
MC_run64_without_lead_plate_equals_to_run89_with_run89_slope_and_offset

- G4 input L1 offset (from data run89 U10) : $2.85321\text{e-}01$ mm
- G4 input vertical rotation (from data run89 U10) : 0.27210535 * deg
- G4 **Output** L1 offset (from MC run89 U10) : $2.83999\text{e-}01$ mm
- G4 **Output** vertical rotation (from MC run89 U10) : $4.32004\text{e-}03$ (slope)

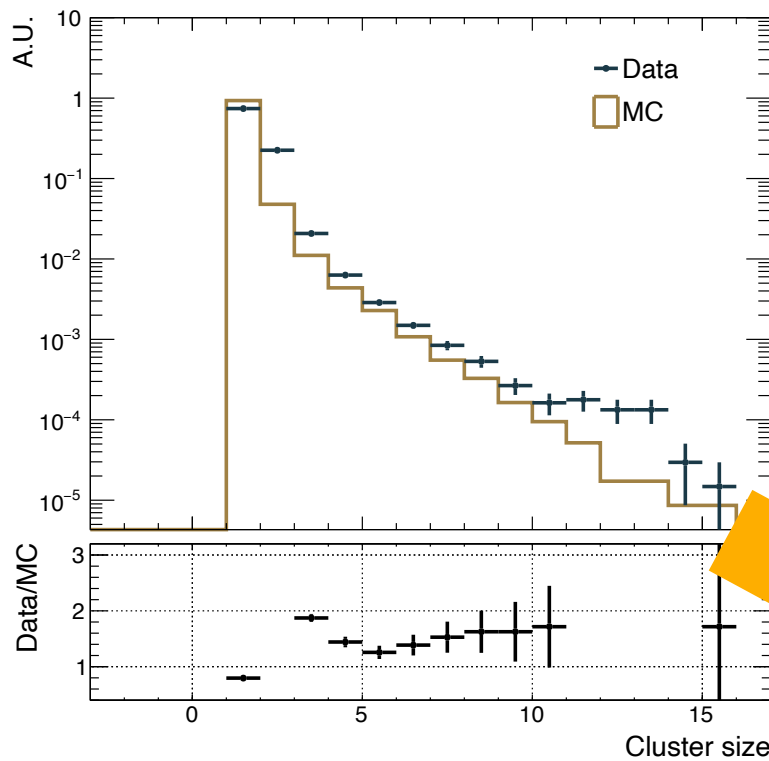


Cluster size - run61 (vertical rotation)

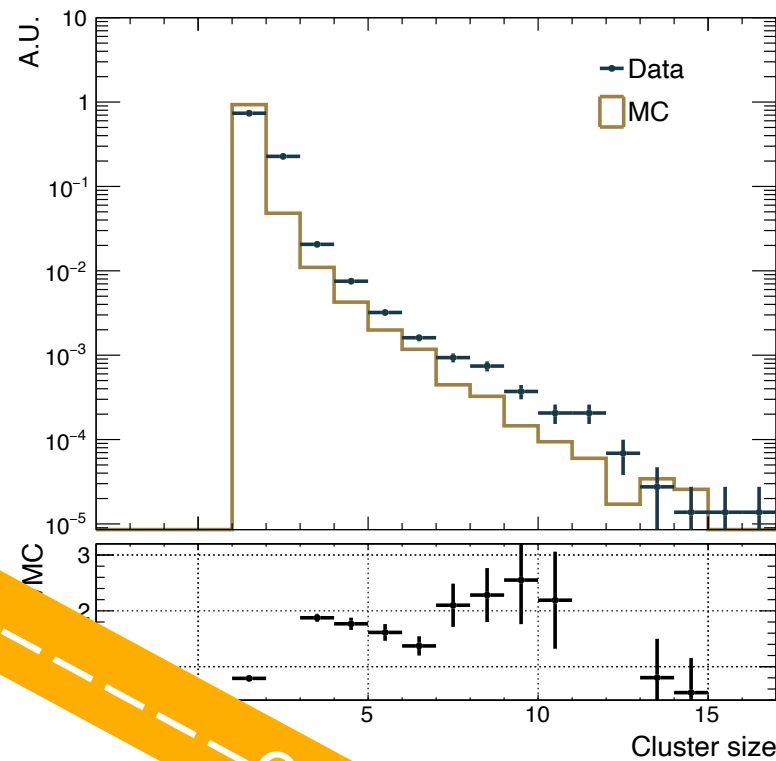
Data : Run89 (= run61 without vertical rotation) U11, MC : Run89 MC5 condition

No selection

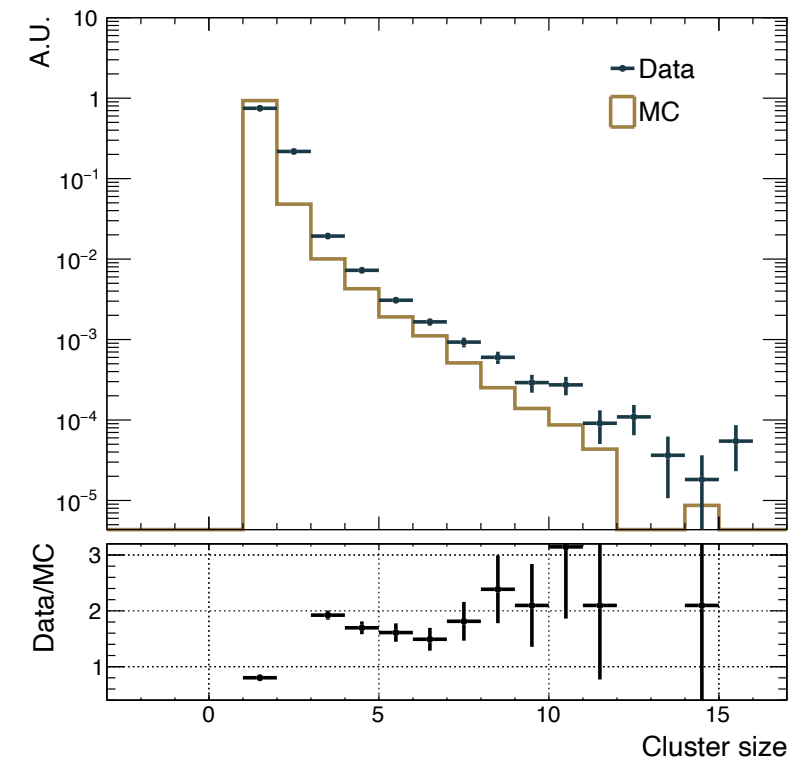
L0



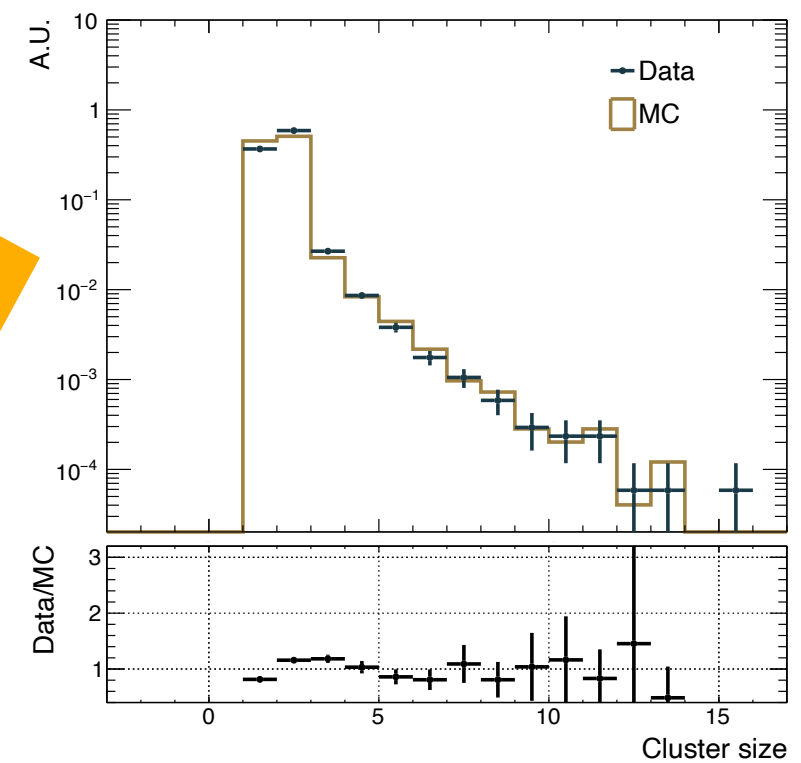
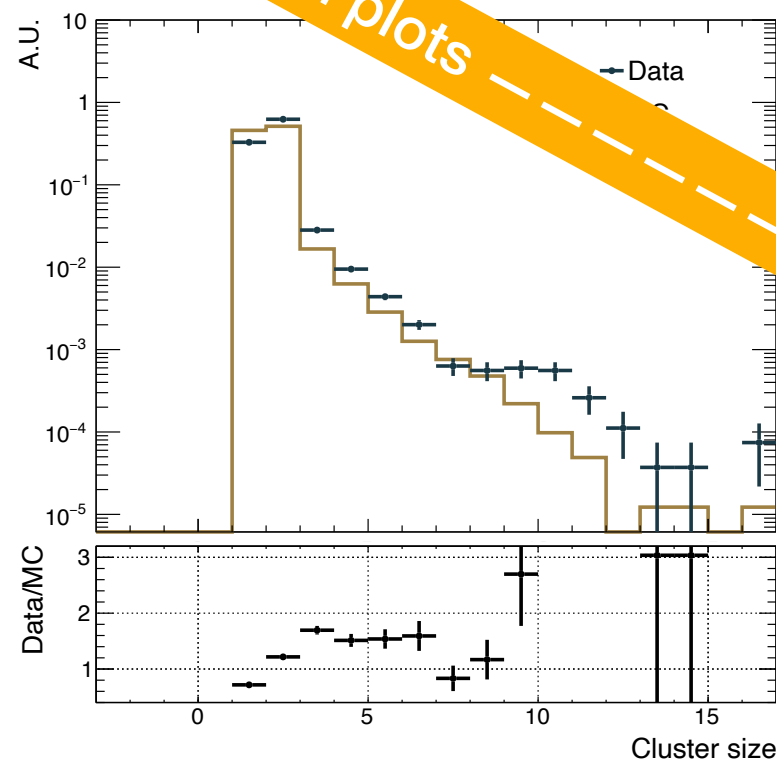
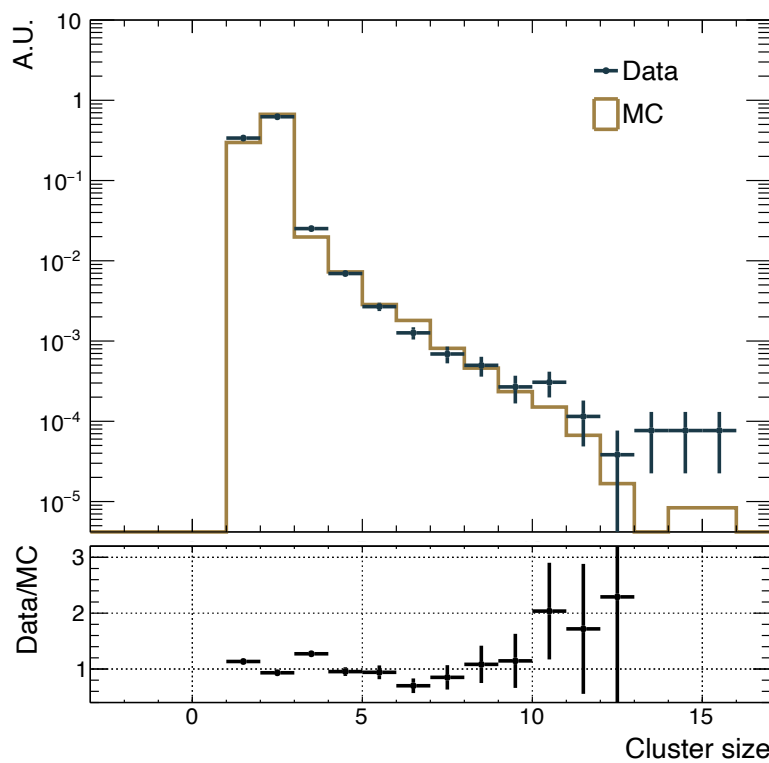
L1



L2



Data : Run61 U11, MC : Run61 MC4 condition



Data run61 (vertical rotation)

Beam spot : U11

