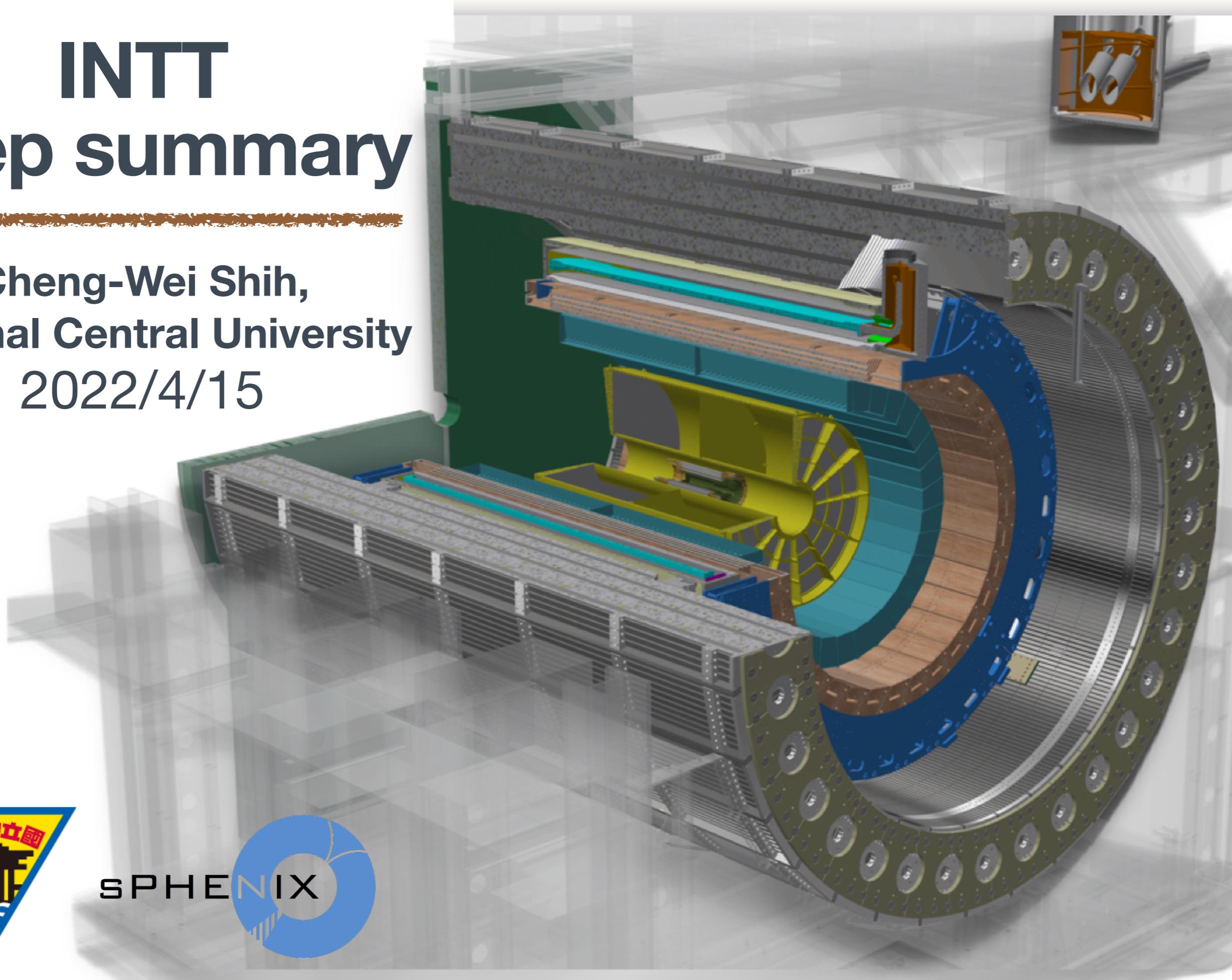


INTT edep summary

Cheng-Wei Shih,
National Central University
2022/4/15



// DAC scan

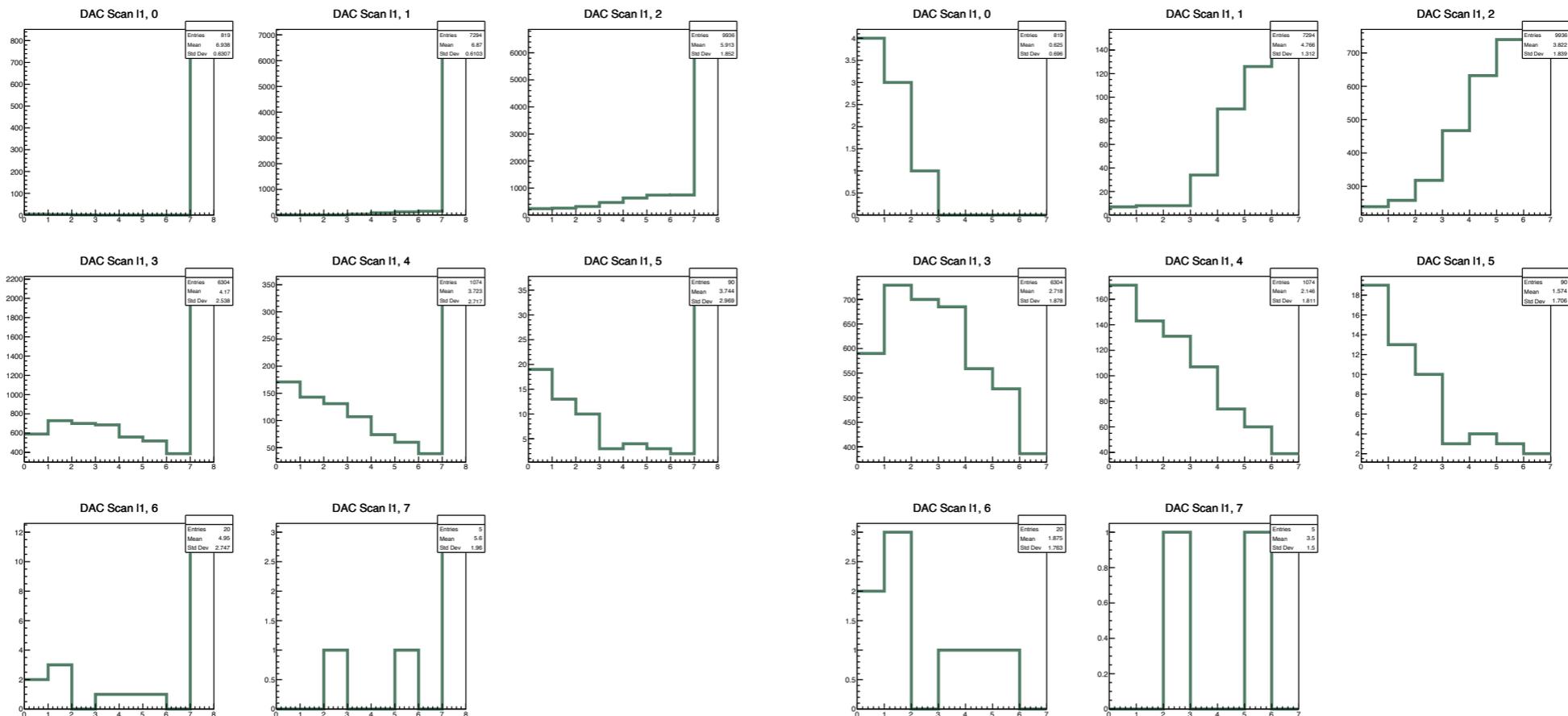
- Event profile has to be 111
- single hit for each layer only
- Clone groups in one INTT trigger event are deleted

- Algorithm is same as Testbeam2019 :
 - 6th, 7th bins : histogram **matching**
 - 8th bin : overflow, neglect
- Criteria :
 - Event profile has to be 111
 - single hit for each layer only

run1	run2	run3	run4	run5	run6	run7	run8
8	28	48	68	88	108	128	148
12	32	52	72	92	112	132	152
16	36	56	76	96	116	136	156
20	40	60	80	100	120	140	160
24	44	64	84	104	124	144	164
28	48	68	88	108	128	148	168
32	52	72	92	112	132	152	172
36	56	76	96	116	136	156	176
40	60	80	100	120	140	160	180

With 8th bin, L0

Without 8th bin, L0

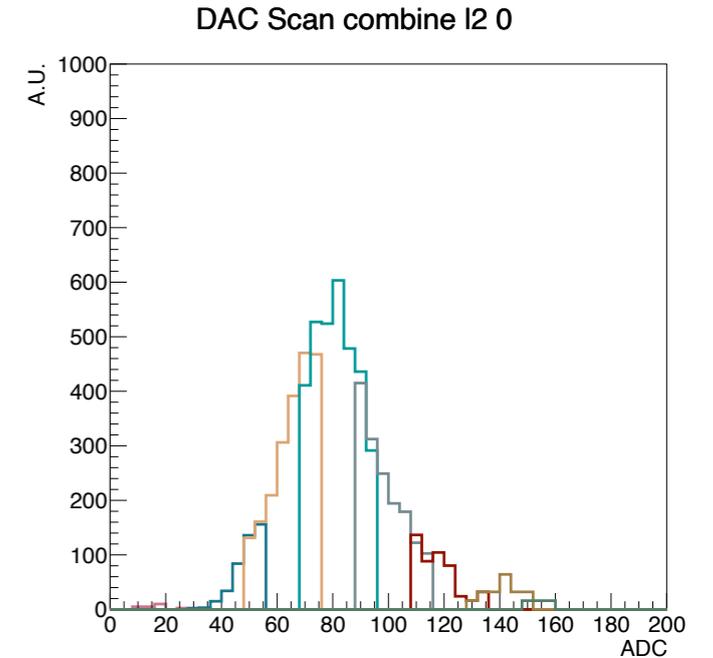
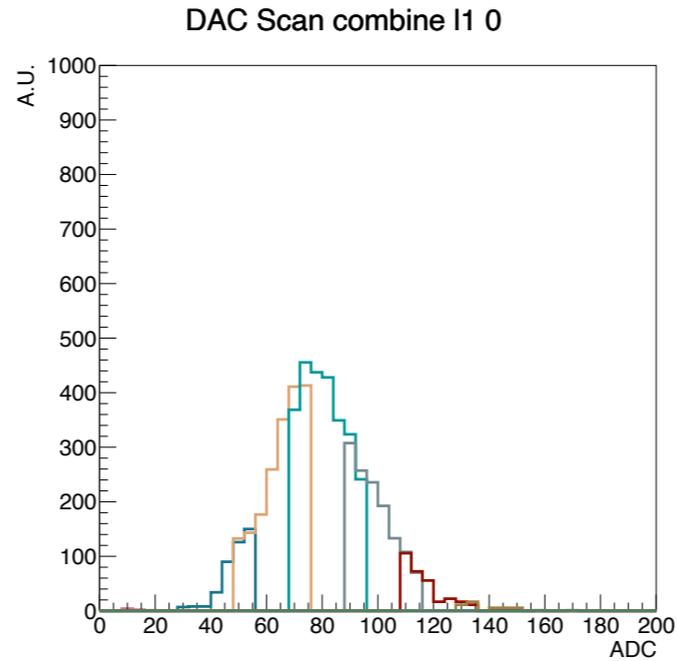
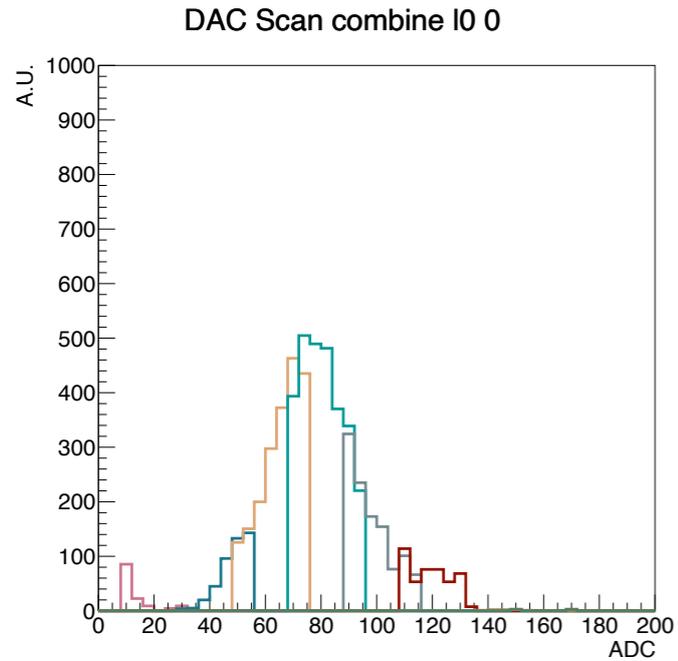


Testbeam2021, bias voltage 50 V

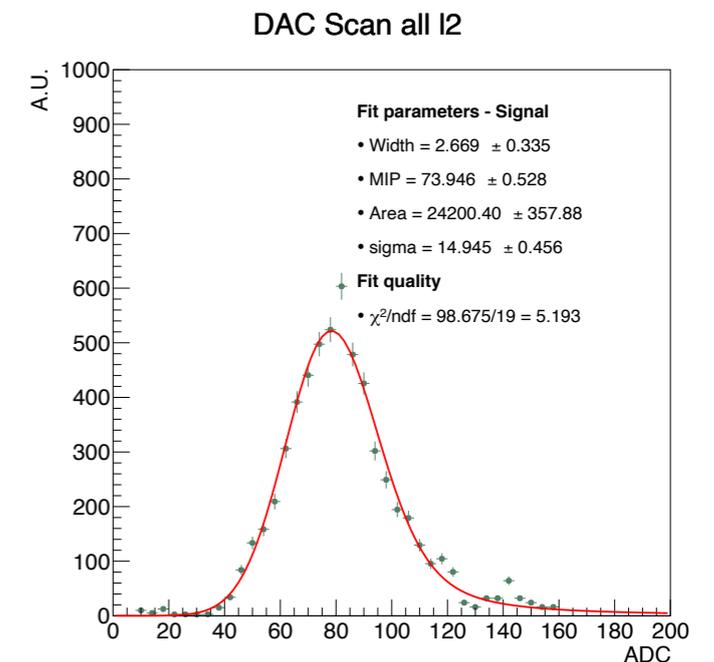
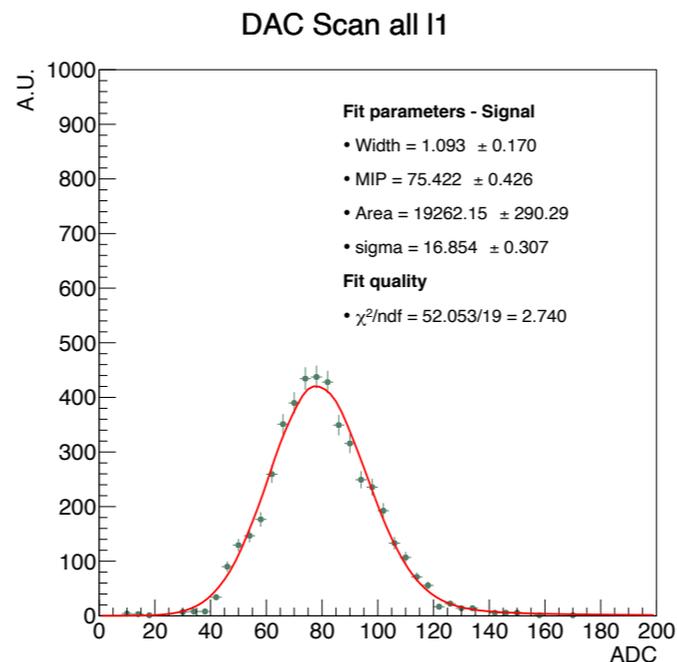
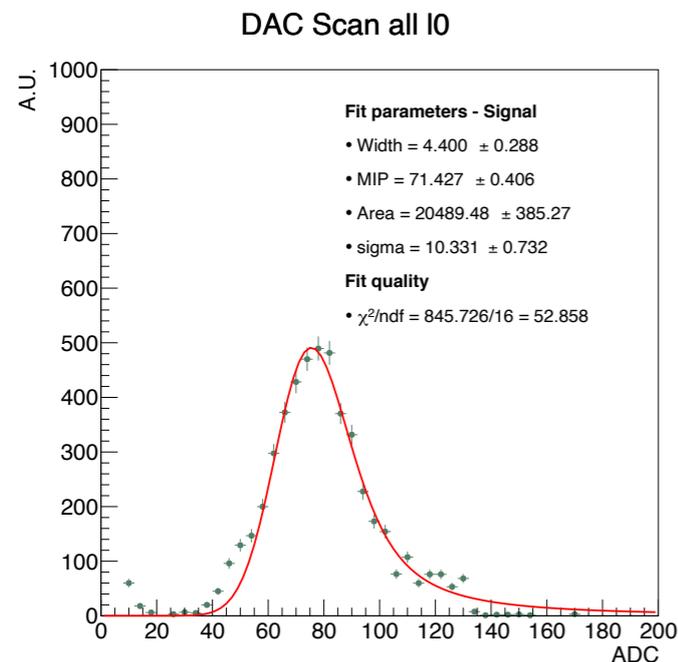
// DAC scan

- Event profile has to be 111
- single hit for each layer only
- Clone groups in one INTT trigger event are deleted

Histogram matching



Fitting function : Landau convolute with Gaussian

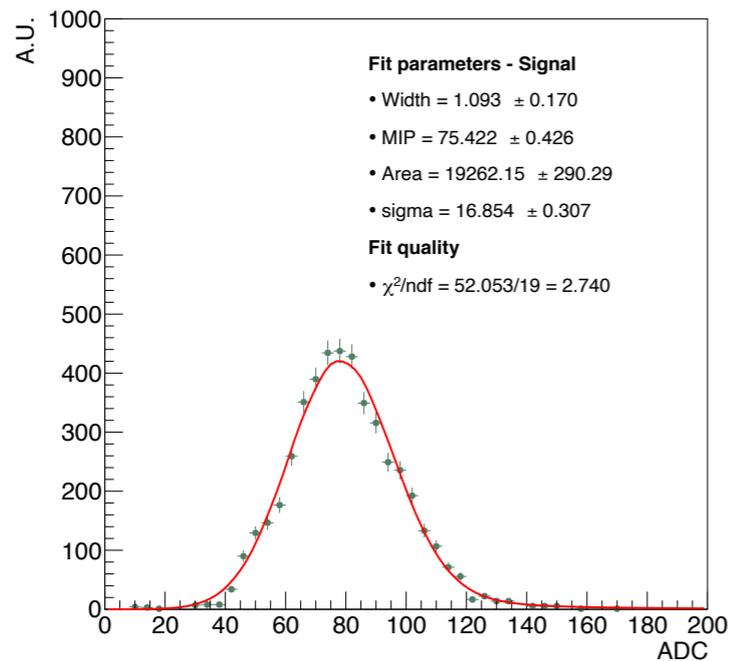


Testbeam2021, bias voltage 50 V

// DAC scan comparison

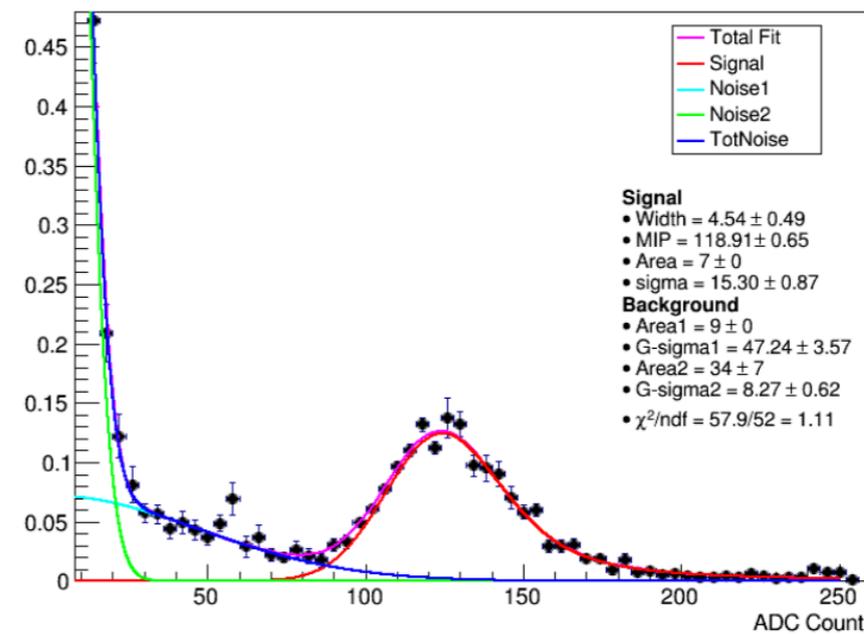
Testbeam2021, 50 V
Positron beam, 1 GeV

DAC Scan all I1



Testbeam2019, 100 V
Proton beam, 120 GeV

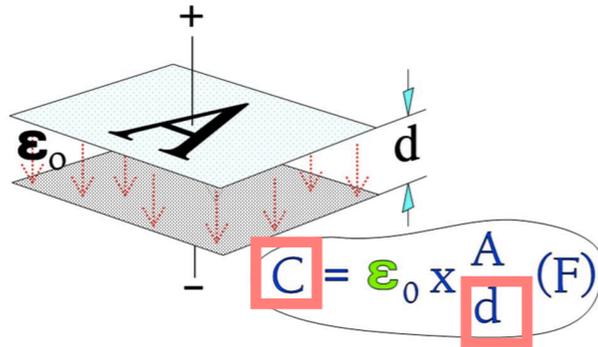
ifem=1 chip=45



The peak is different
Original though : because of the difference of the supplied voltage

// DAC scan comparison

Based on the materials I found



Based on the theory :

$$C \propto \frac{1}{d} \propto \frac{1}{\sqrt{V}} \propto \frac{1}{\text{signal}}$$

$$W_d = \sqrt{2\epsilon(V + V_{bi})/Ne} = \sqrt{2\rho\mu\epsilon(V + V_{bi})}$$

$$C = \sqrt{\frac{\epsilon_0 \epsilon_r}{2\mu\rho|V|}} \cdot A$$

C : capacitance
 d : the distance of the depletion region
 V : supply bias voltage
 signal : edep

$$\frac{dE/dx \cdot d}{I_0} = \frac{3.87 \cdot 10^6 \text{ eV/cm} \cdot 0.03 \text{ cm}}{3.62 \text{ eV}} \approx 3.2 \cdot 10^4 \text{ e}^- \text{h}^+ \text{-pairs}$$

Signal

// DAC scan comparison

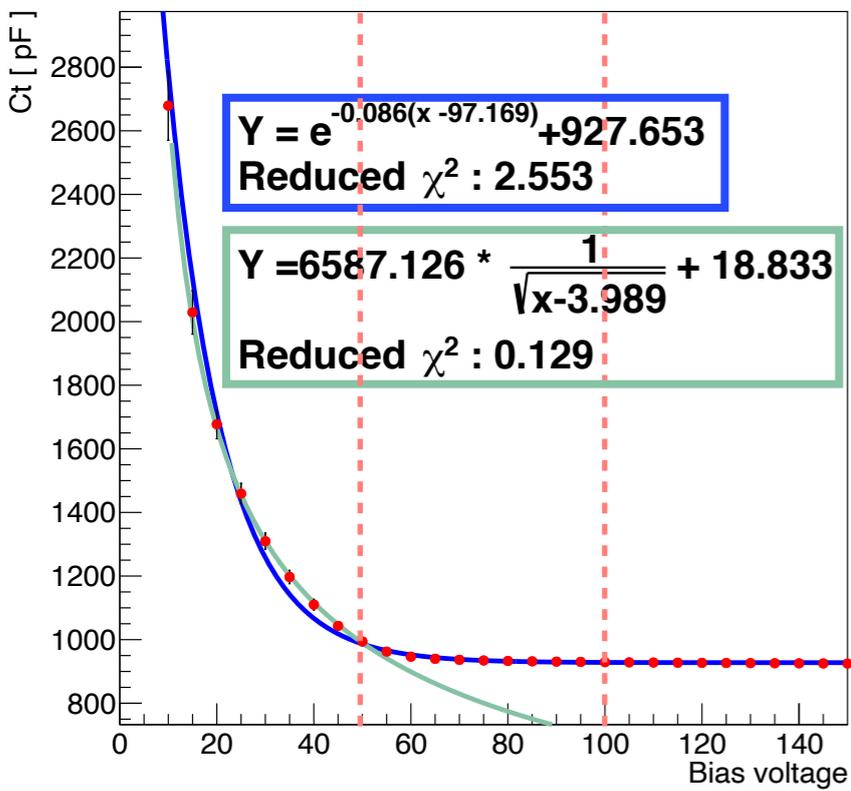
Based on the theory :

$$C \propto \frac{1}{d} \propto \frac{1}{\sqrt{V}} \propto \frac{1}{\text{signal}}$$

C : capacitance
 d : the distance of the depletion region
 V : supply bias voltage
 signal : edep

Verify **capacitance vs voltage**

INTT Type-A sensor, CV curve



	@24.35 V	@ 50 V	@ 100 V
Type A, Ct [pF]	1465.42	994.149	929.325

$$\frac{1}{\sqrt{50}} / \frac{1}{\sqrt{24.35}} = \boxed{0.697}$$

$$\frac{C@50V}{C@25.34V} = \frac{994.149}{1465.42} = \boxed{0.678} \quad \checkmark$$

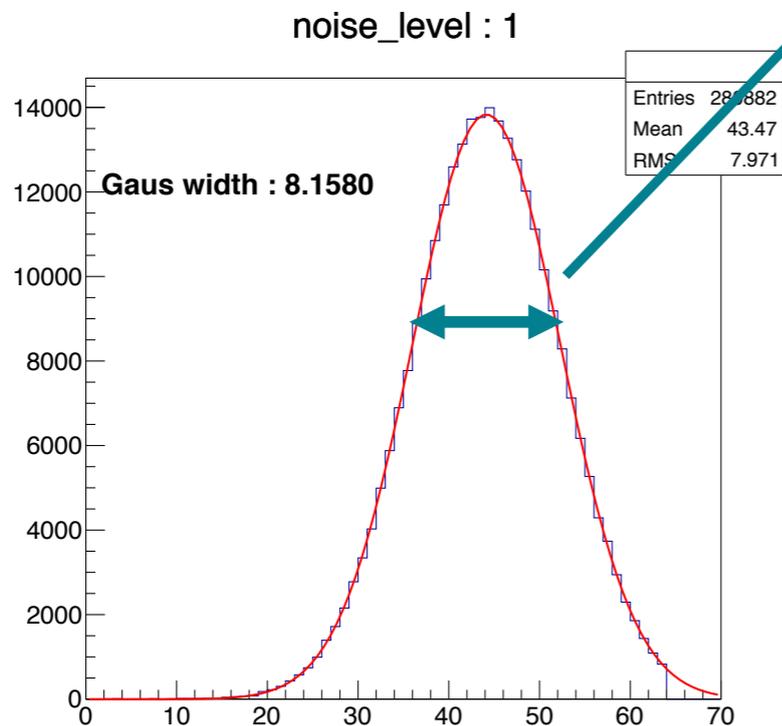
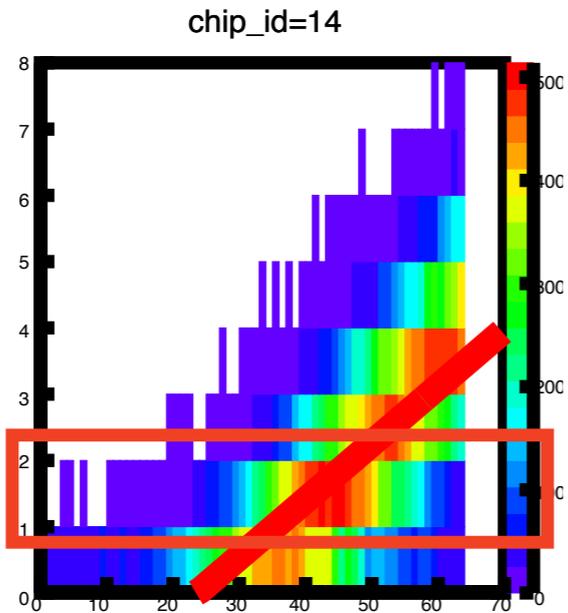
$$\frac{1}{\sqrt{100}} / \frac{1}{\sqrt{50}} = \boxed{0.707}$$

$$\frac{C@100V}{C@50V} = \frac{929.325}{994.149} = \boxed{0.934} \quad \times$$

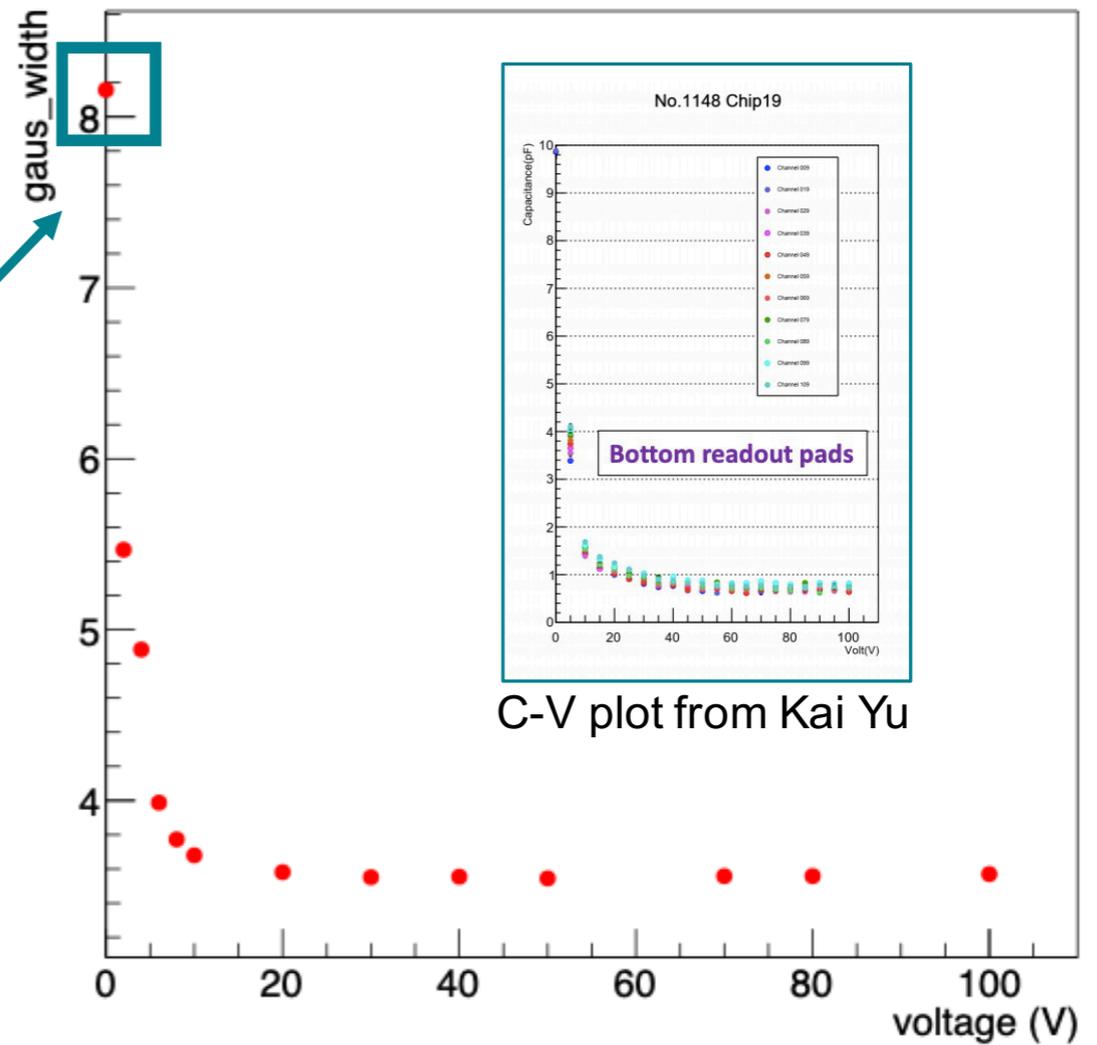
For the case of INTT, $C \propto \frac{1}{\sqrt{V}}$ seems to be suitable to describe the data only for the **range 0 V to 50 V**

// Supply voltage vs noise level

Previous results, 2020/06/19



pre-Production-002, gaus_width to V



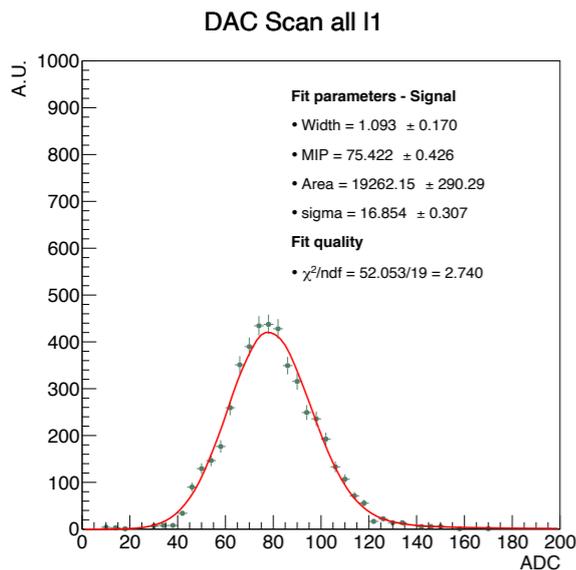
// DAC scan comparison

Based on the theory :

$$C \propto \frac{1}{d} \propto \frac{1}{\sqrt{V}} \propto \frac{1}{\text{signal}}$$

C : capacitance
 d : the distance of the depletion region
 V : supply bias voltage
 signal : edep

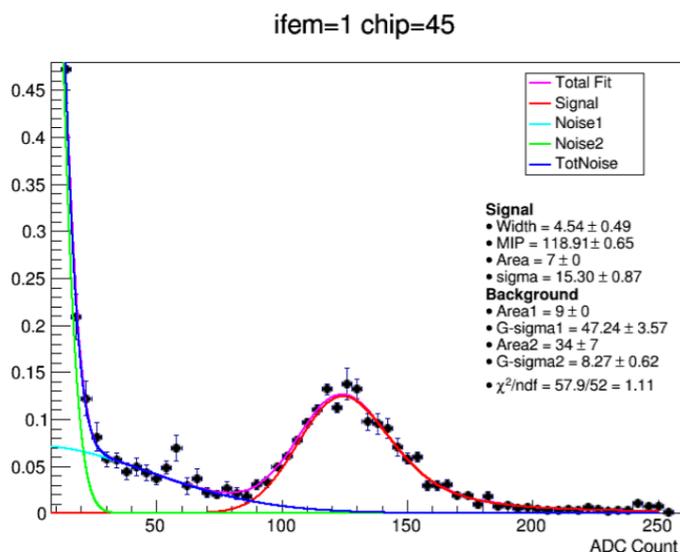
Verify edep vs voltage (V) and capacitance (C)



Compare $\frac{1}{\sqrt{V}}$ and $\frac{1}{\text{signal}}$ →

$$\frac{\frac{1}{\sqrt{100}}}{\frac{1}{\sqrt{50}}} = 0.707$$

$$\frac{\left(\frac{1}{\text{edep@100}}\right)}{\left(\frac{1}{\text{edep@50}}\right)} = 0.634$$

Compare "C" and $\frac{1}{\text{signal}}$ →

$$\frac{C@100V}{C@50V} = \frac{929.325}{994.149} = 0.934$$

$$\frac{\left(\frac{1}{\text{edep@100}}\right)}{\left(\frac{1}{\text{edep@50}}\right)} = 0.634$$


Conclusion : we should not use the voltage for the comparison, we should use capacitance.

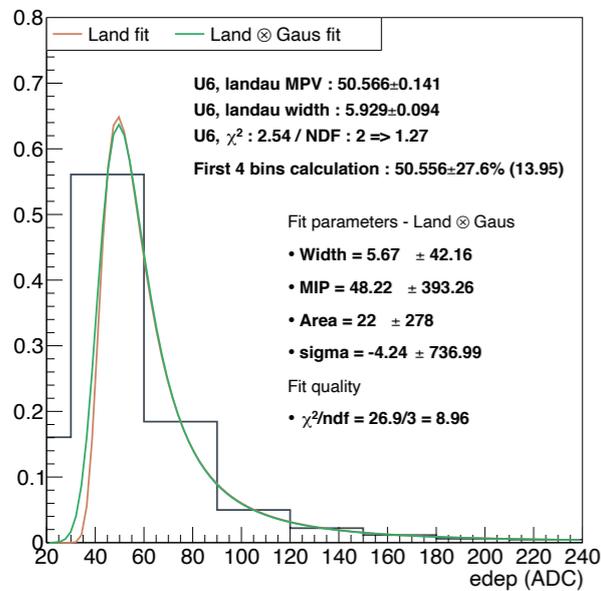
But the capacitance ratio doesn't match to the edep ratio

// Source test, different supply voltage

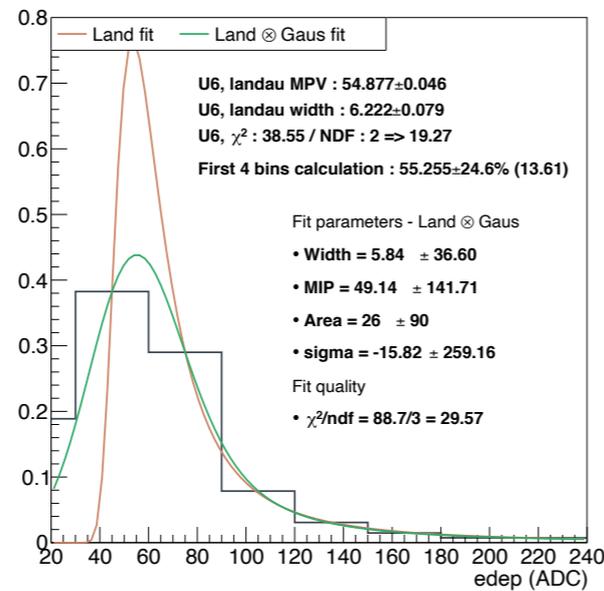
A further approach, the source test with different supply voltage. From 25 V to 100 V

Sr-90, self-trigger, threshold 20 ADC

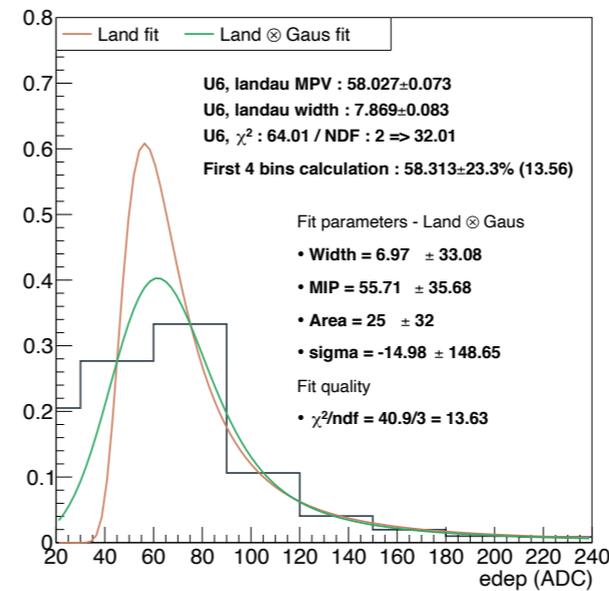
chip id : 6, voltage : 25



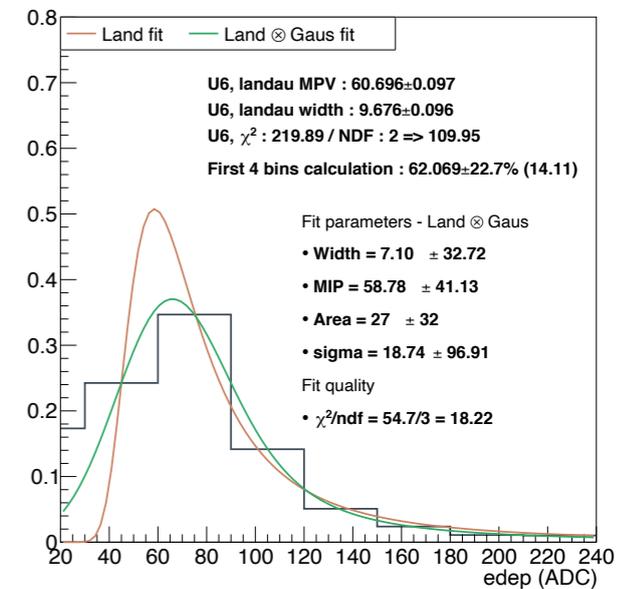
chip id : 6, voltage : 35



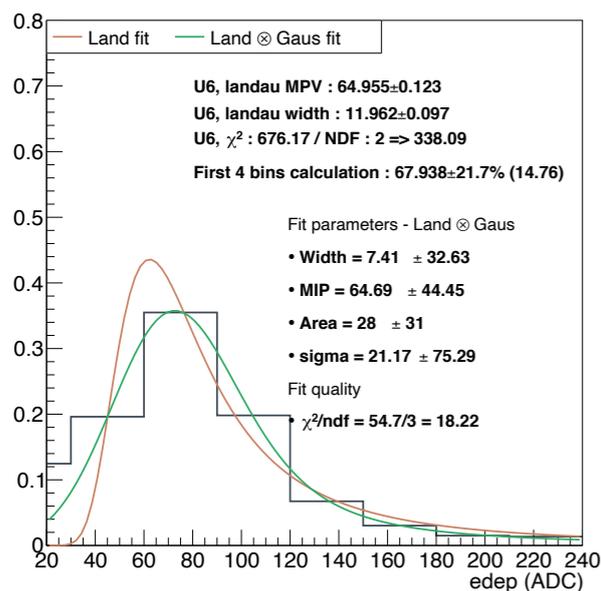
chip id : 6, voltage : 43



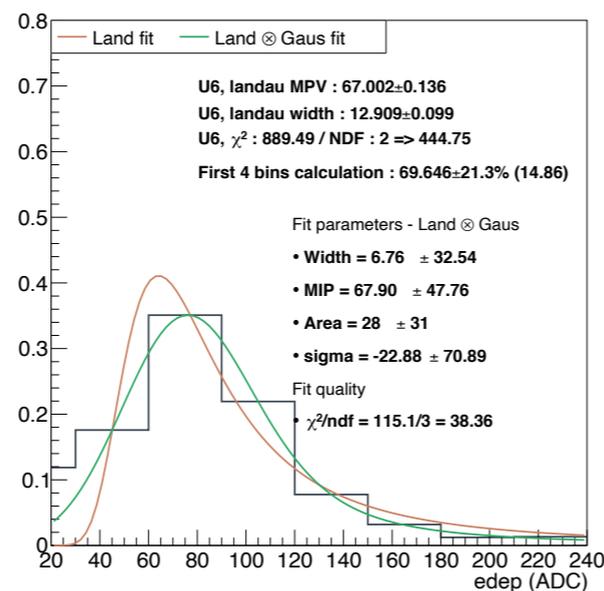
chip id : 6, voltage : 50



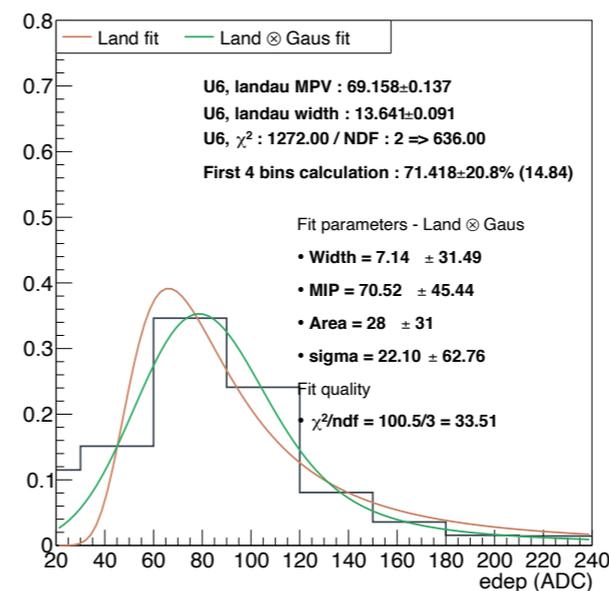
chip id : 6, voltage : 60



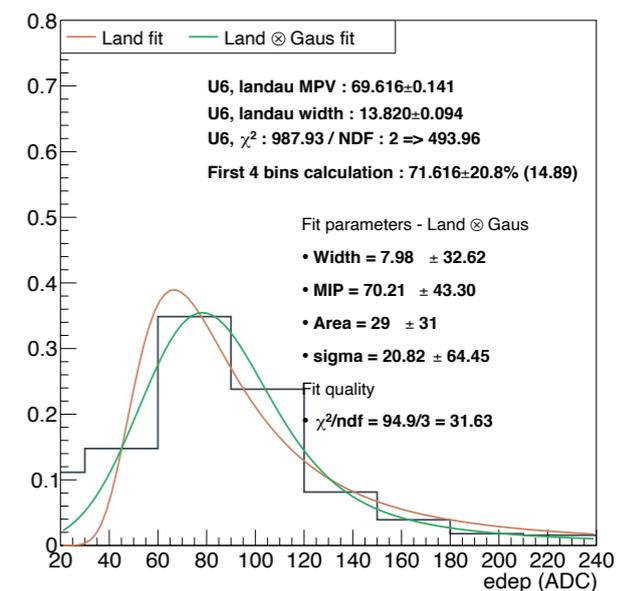
chip id : 6, voltage : 70



chip id : 6, voltage : 85



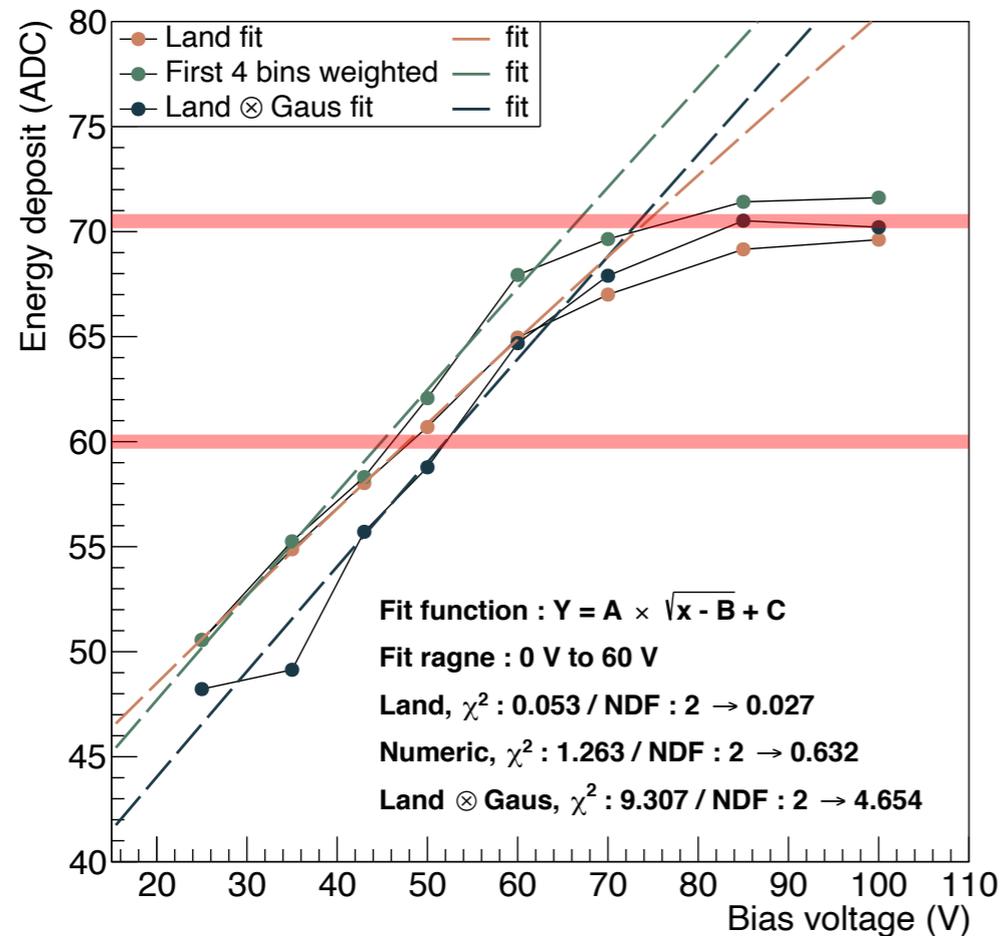
chip id : 6, voltage : 100



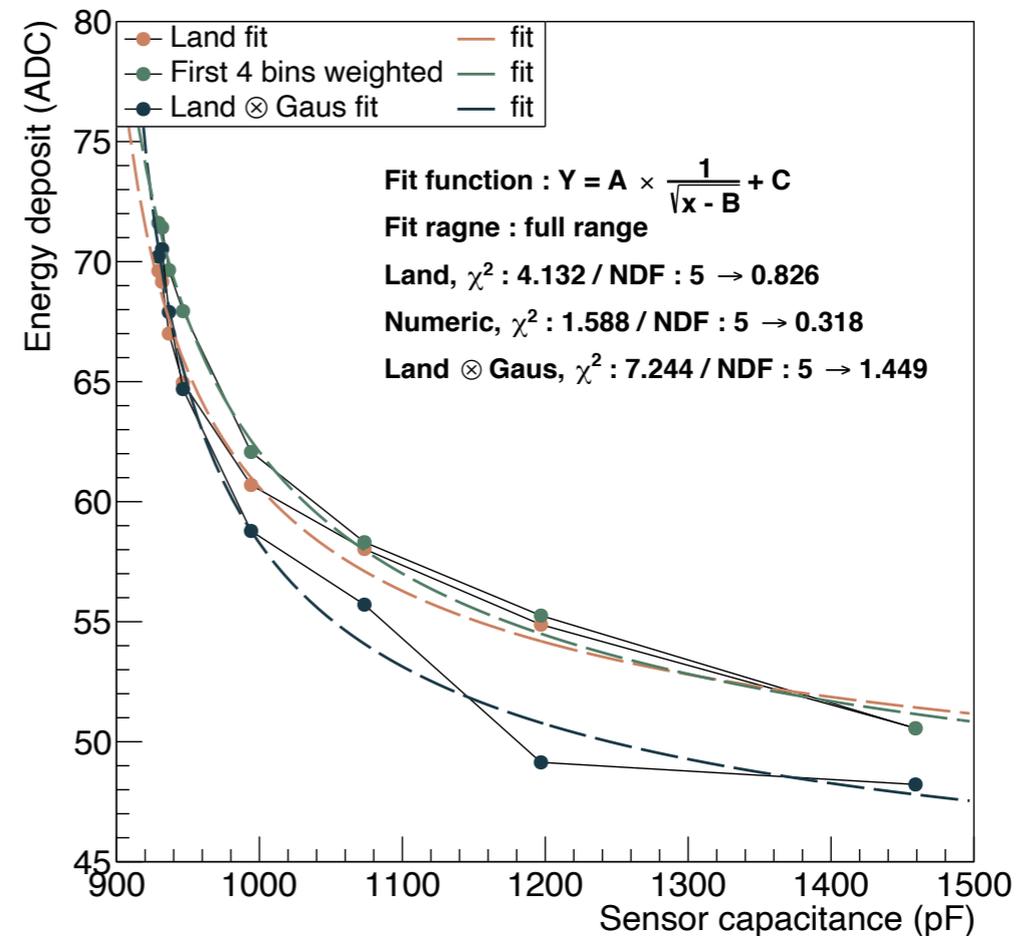
// Source test, different supply voltage

Because the resolution of the energy is poor, 3 approaches to obtain the peak position : pure land, land \otimes gauss and a numeric weighted method calculation with first 4 bins

Energy deposit v.s. Bias voltage



Energy deposit v.s. Sensor capacitance



The result fits to our expectation, the discrepancy increases as the bias voltage increases. Because the it gradually reaches to the limit of the depletion region

For the case of capacitance, it is reasonable as well. The full range is considered for the fitting.

// edep summary table

Item	Peak position Land x Gaus	Peak position pure land	setting	note
Testbeam2021, I0	71.427		DAC scan	50 V
Testbeam2021, I1	75.422		DAC scan	50 V
Testbeam2021, I2	73.946		DAC scan	50 V
Testbeam2019	118.91		DAC scan	100 V
Source test	58.78	60.696	8 bins, threshold 20 adc	50 V
Source test	70.21	69.616	8 bins, threshold 20 adc	100 V
Source test		77.987	8 bins, threshold 40 adc	100 V
Cosmic test	81.82	73.52	8 bins, threshold 15 adc	100V, 2 scis

// Another approach - G4 test

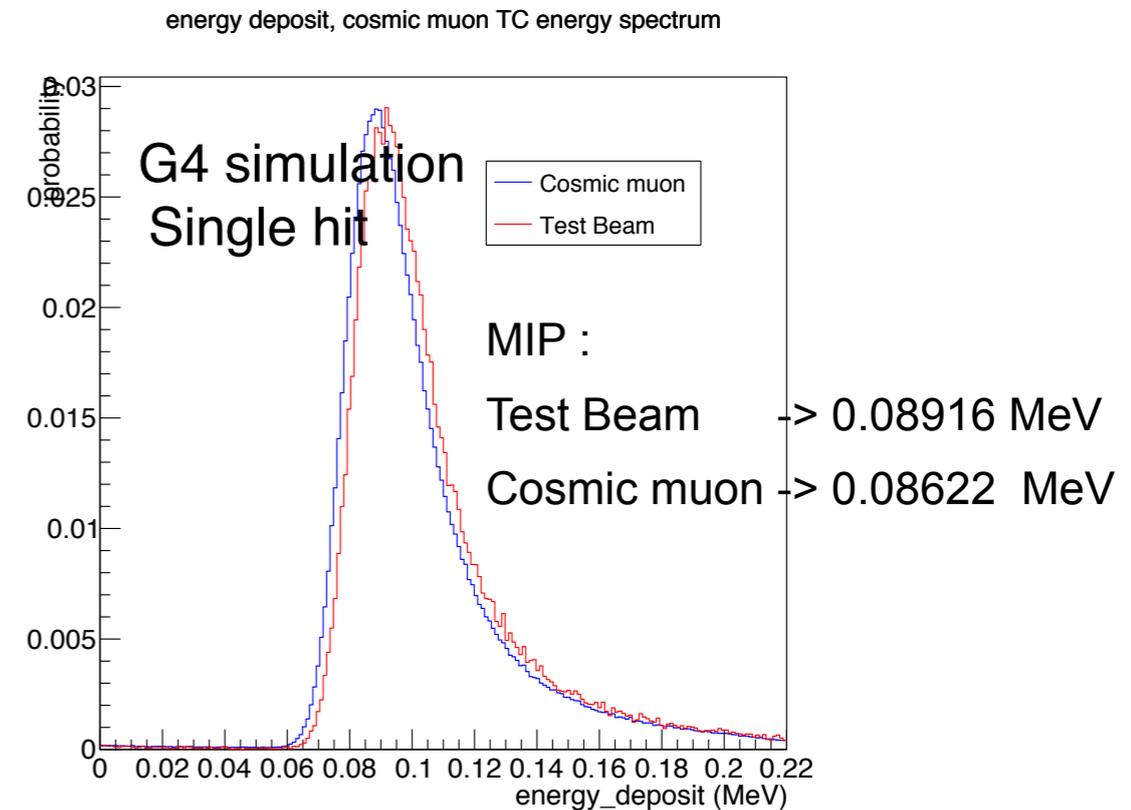
Conversion function :

$$mV = DAC * 4 + 210$$

$$mV = \frac{Edep * 10^6[eV] * 1.6 * 10^{-4}[fC] * G}{3.6eV} + O$$

G : 100 [mV/fC], O : 280 [mV]

Based on NWU's sophisticated study, the offset should be 200



$$\frac{0.089 \text{ MeV} * 10^6 * 1.6 * 10^{-4} * (Gain : 100)}{3.68 \text{ eV}} + (Offset : 200) = 586.956$$

$$(586.956 - 210) / 4. = 94.239 \text{ ADC}$$

// Summary

- Testbeam2021 vs source test
 - Testbeam (DAC scan, 50 V) : 73.598 adc
 - Source test (8 bins, 50 V) : 60.696 adc
 - Discrepancy : 17.5 % → reasonable
 - The supply voltage in Testbeam2021 seems to be confirmed to be 50 V.
- Source test vs cosmic test (100 V)
 - Source test (8 bins, threshold 20 adc) : 69.616
 - Cosmic test (8 bins, threshold 15 adc) : 73.52
 - Discrepancy : 5.3 % → reasonable
- Another approach, G4 : 94.239 ADC → contradicts with the Testbeam2019
- Based on the plots on slide 10, the edep @ 100 V should be ~ 80 adc → contradicts with the Testbeam2019.
 - Reason : Different readout system ? Gain ?

Back up

// 1 GeV positron beam vs 120 GeV proton beam

- Could the discrepancy is caused by some different physical process, because of different used beam ?
 - Seems to be NO. The paper : <https://iopscience.iop.org/article/10.1088/1748-0221/6/06/P06013/pdf>
- The paper used 100 MeV electron and 12 GeV proton

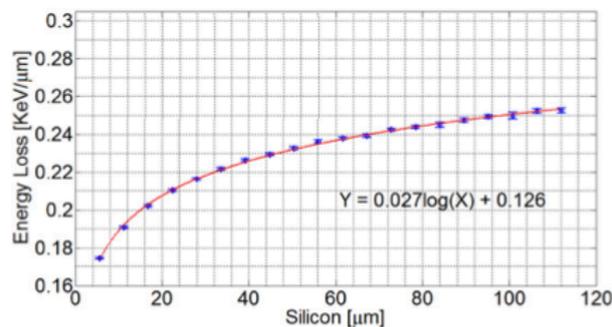


Figure 11. Energy loss for 12GeV protons passing through several silicon thickness.

The energy loss is similar

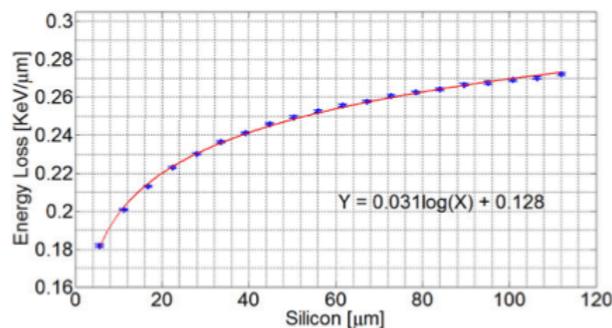
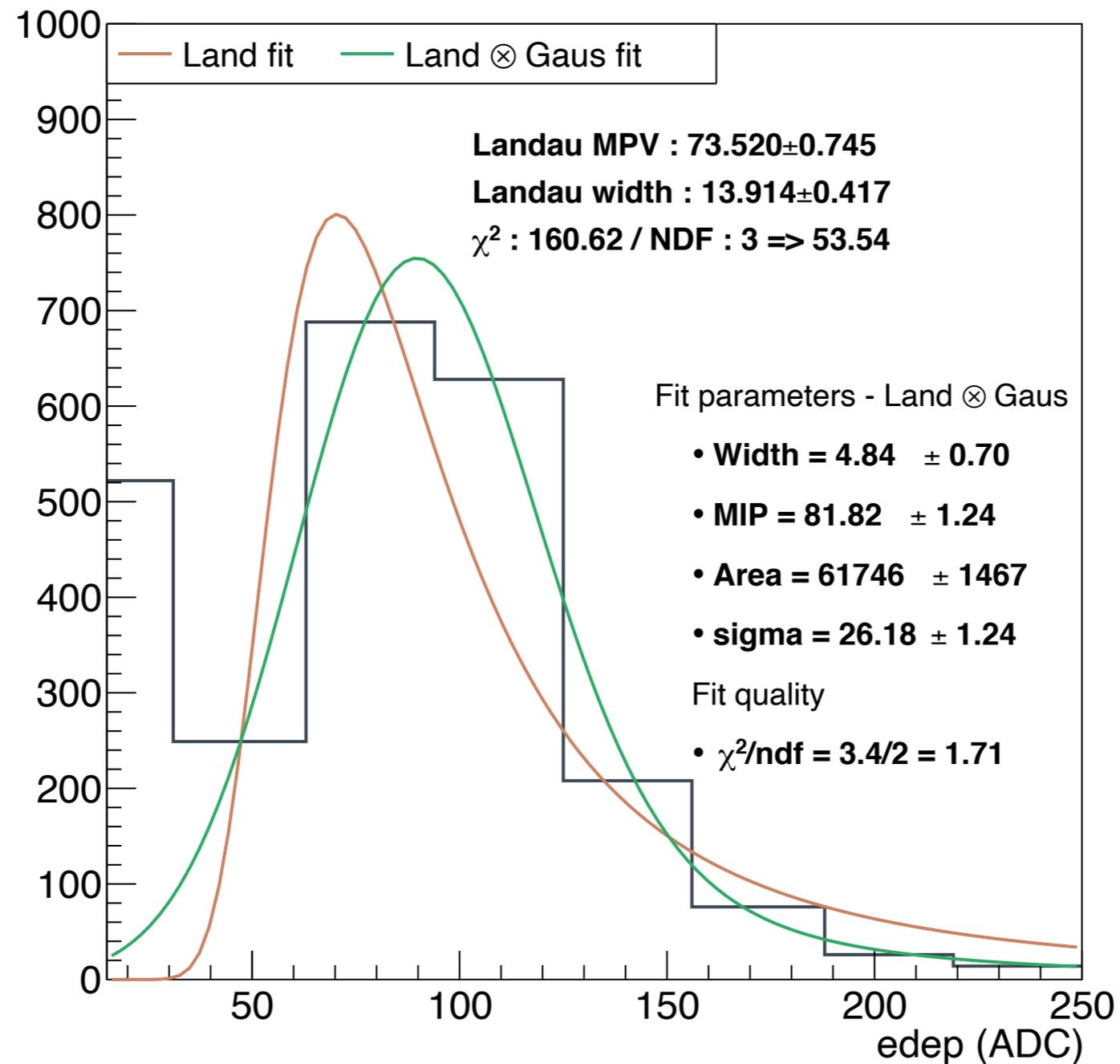


Figure 12. Energy loss for 100MeV electrons passing through several silicon thickness.

// Cosmic results

Cosmic ray, 2 scintillators & CC, 100 V



// conversion function

Conversion function :

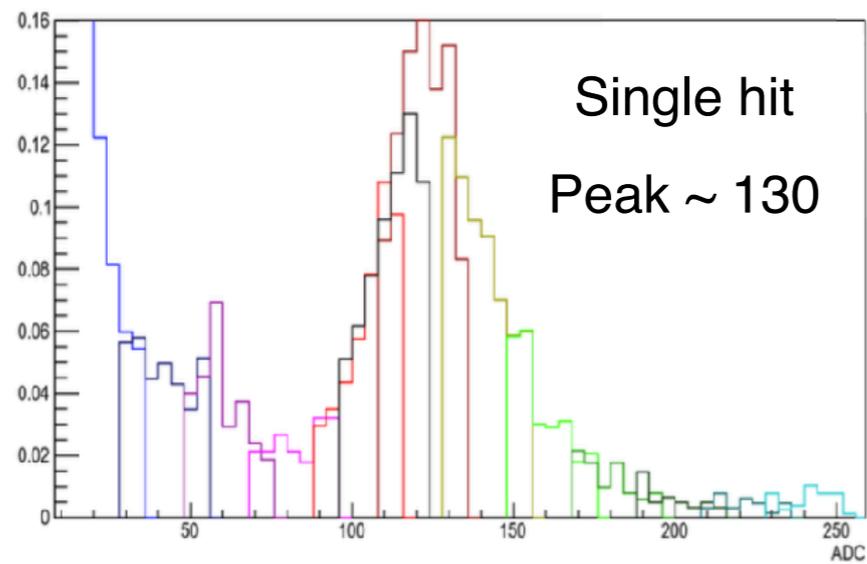
$$\text{mV} = \text{DAC} * 4 + 210$$

$$\text{mV} = \frac{E_{\text{dep}} * 10^6[\text{eV}] * 1.6 * 10^{-4}[\text{fC}] * G}{3.6\text{eV}} + O$$

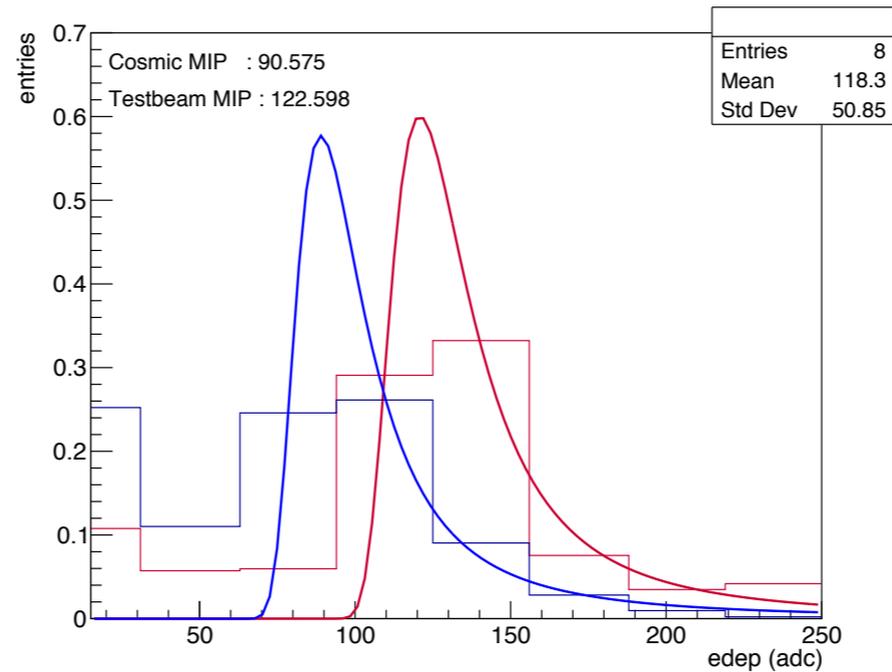
G : 100 [mV/fC], O : 280 [mV]

// DAC scan - comparison

TestBeam2019

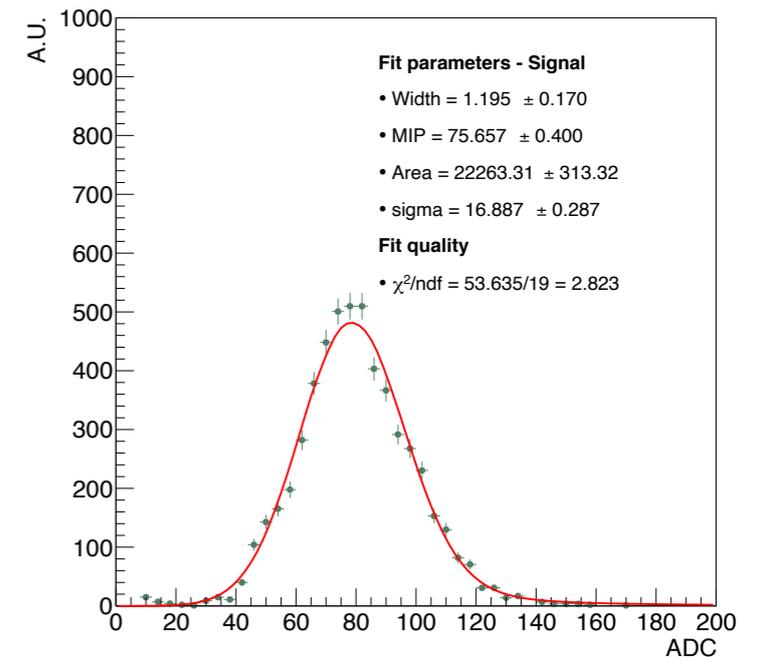


— Cosmic
— Testbeam2019



Cosmic MPV : 90.58
Testbeam : 122.598

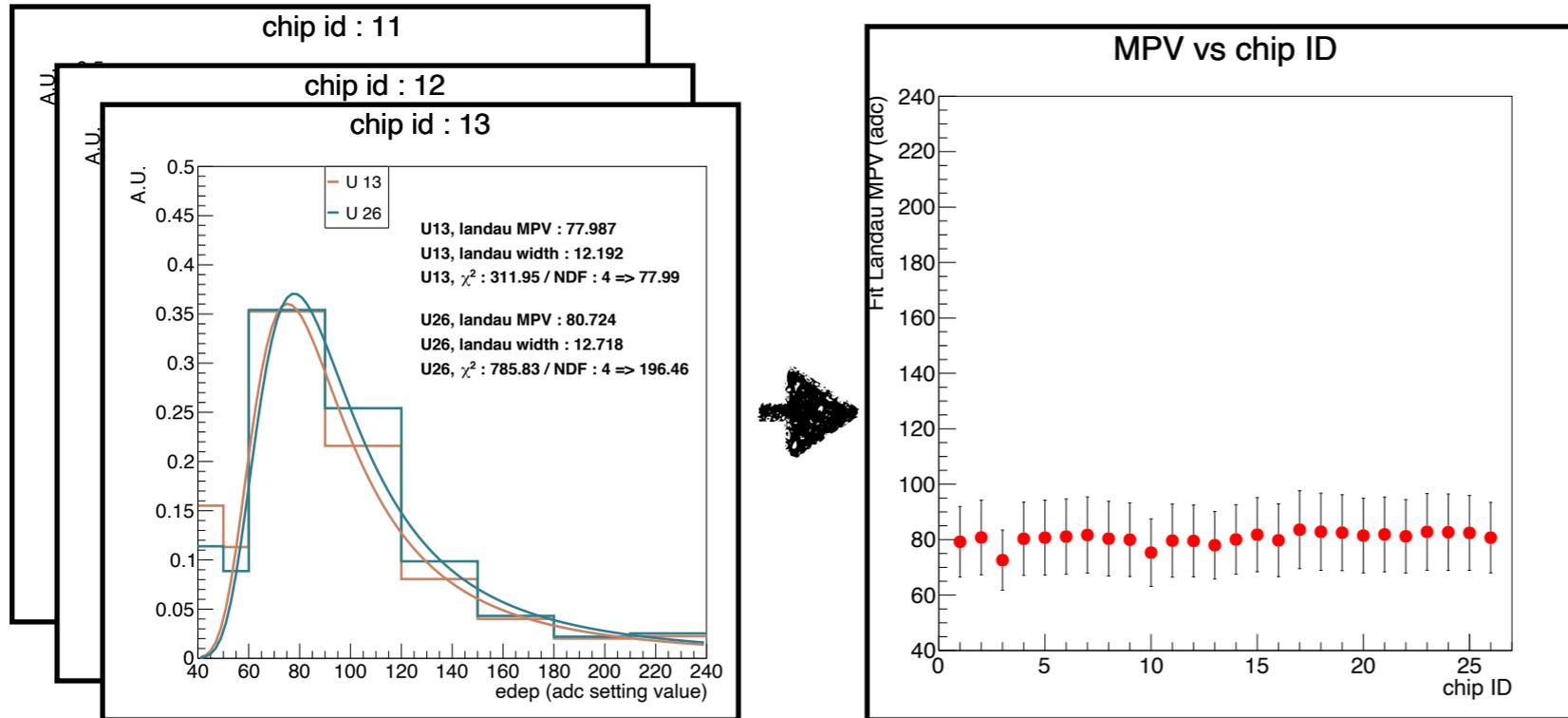
DAC Scan all I1



Bias voltage : 50V
MPV : 75.7

// Source test results, threshold 40 adc

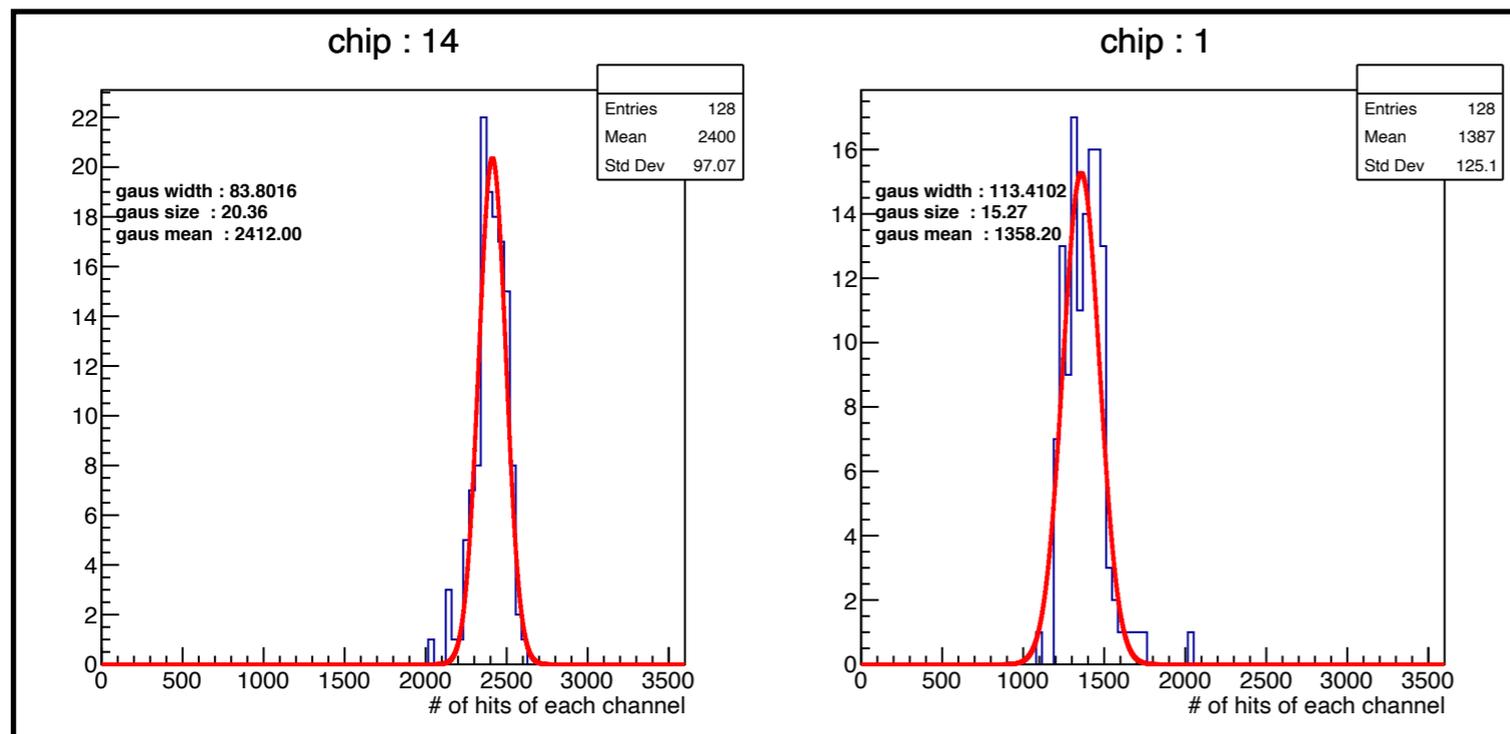
- 5 ladders were tested with the source



- Criteria 1 : entry < 5 sigma of the distribution
- Criteria 2 : entry < 5 sigma of the distribution and entry < 900

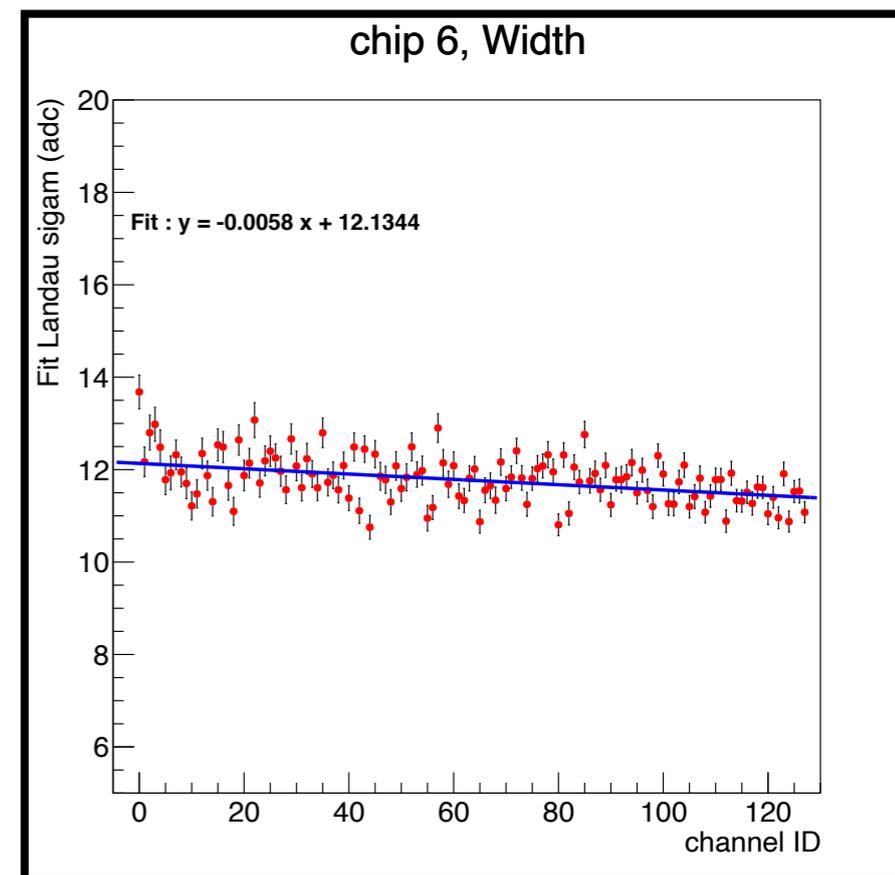
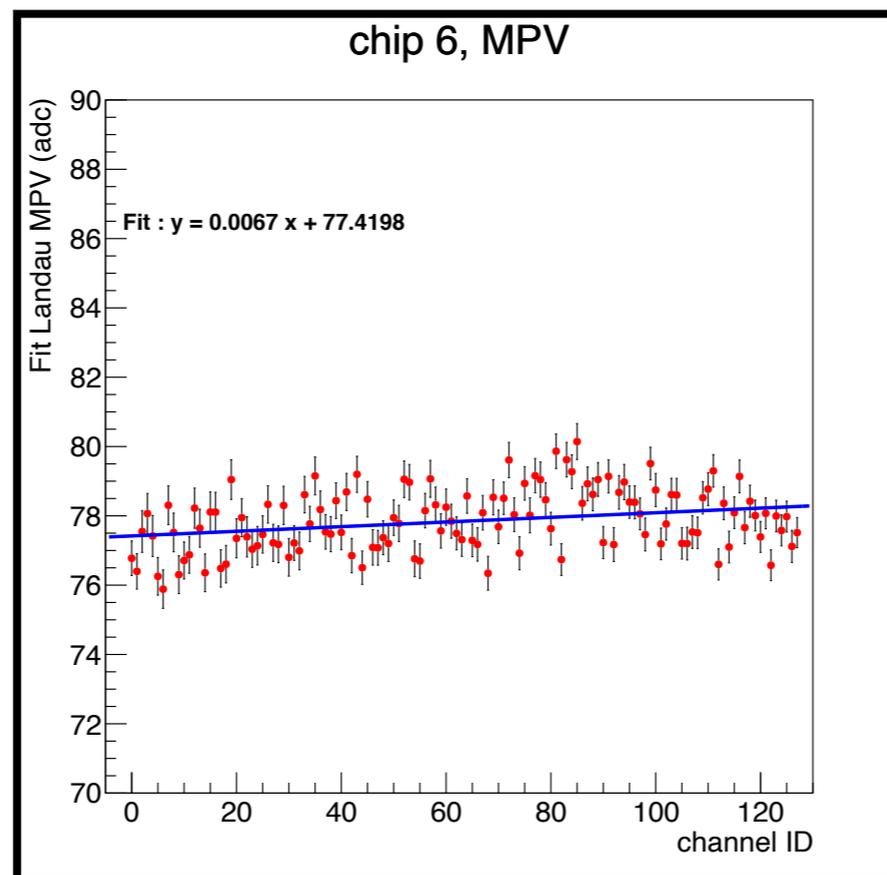
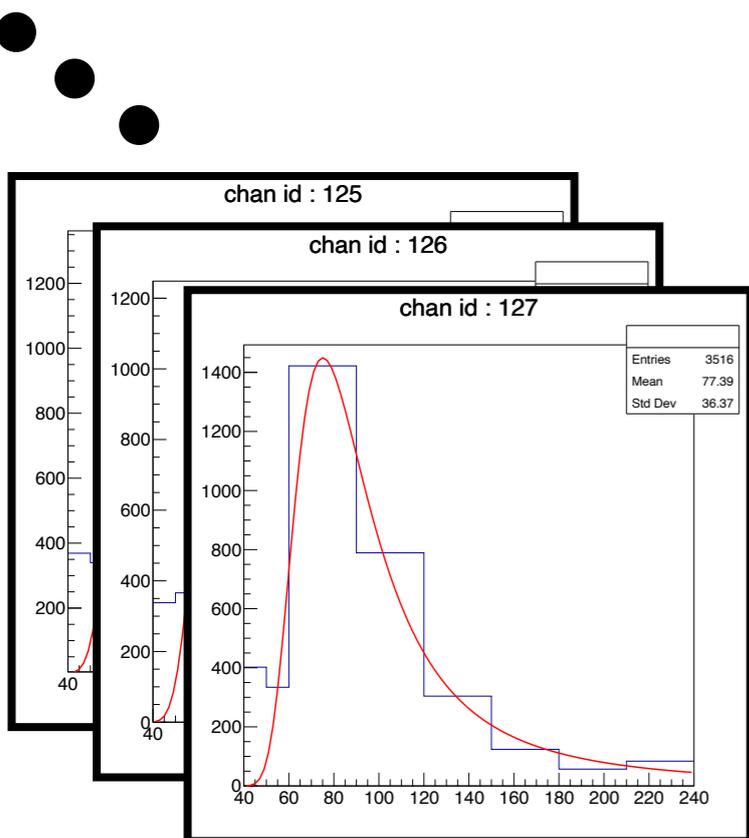
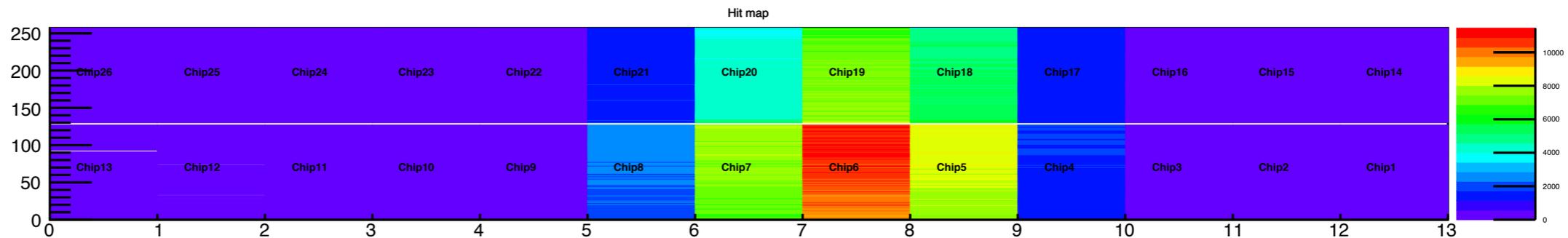
of bad channel

	Criteria 1	Criteria 2
02-0077	7	0
02-0046	2	1
02-0013	3	0
02-0016	5	1
02-0028	19	2



// Source test, channel consistency, threshold 40 adc

- Self-trigger mode
- Threshold : 40
- With Sr-90
- Fixed at U6
- 30 mins run



// Source test, system noise

Self-trigger, no source

Threshold (adc)	Operation time (min)	total event	rate (per min per channel)
15	15.5	20873	0.404 ± 0.0028
40	1282	926089	0.217 ± 0.00022

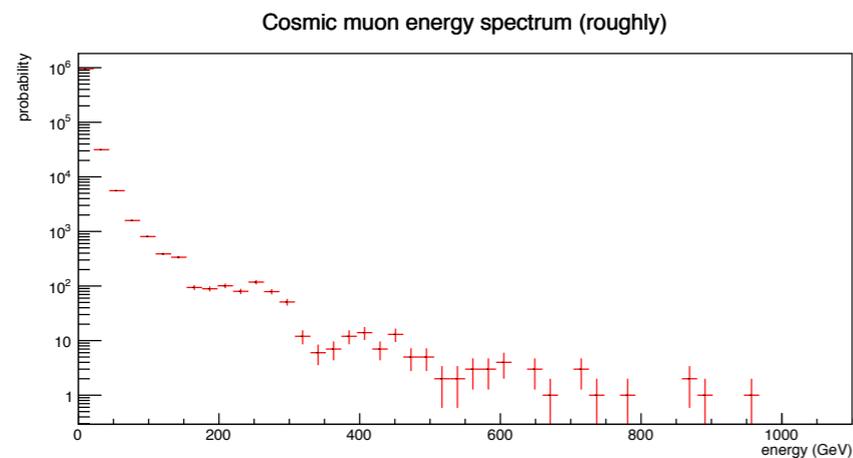
Cosmic test, comparison



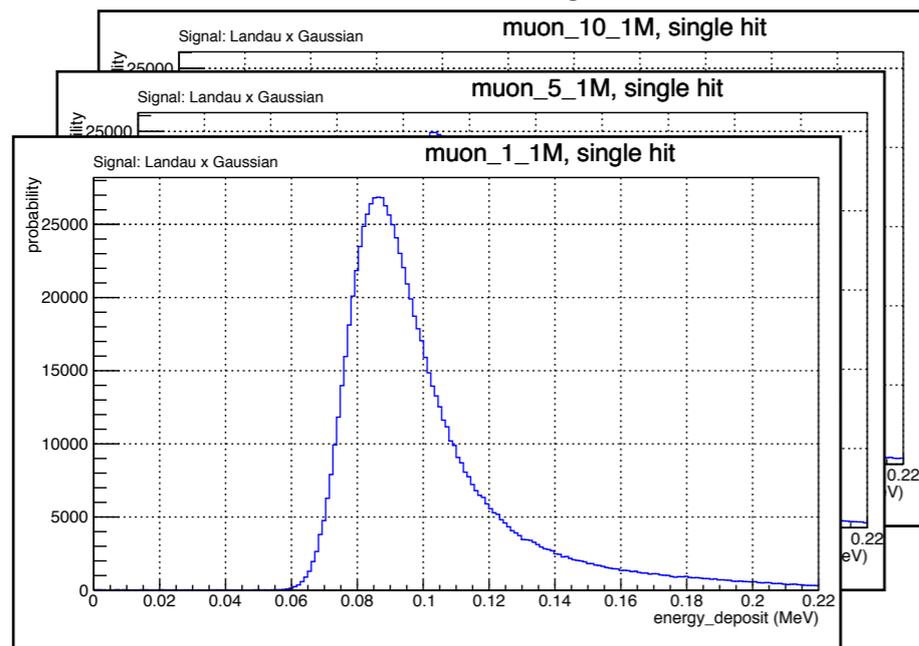
Beam information :

Test Beam : 120 GeV proton

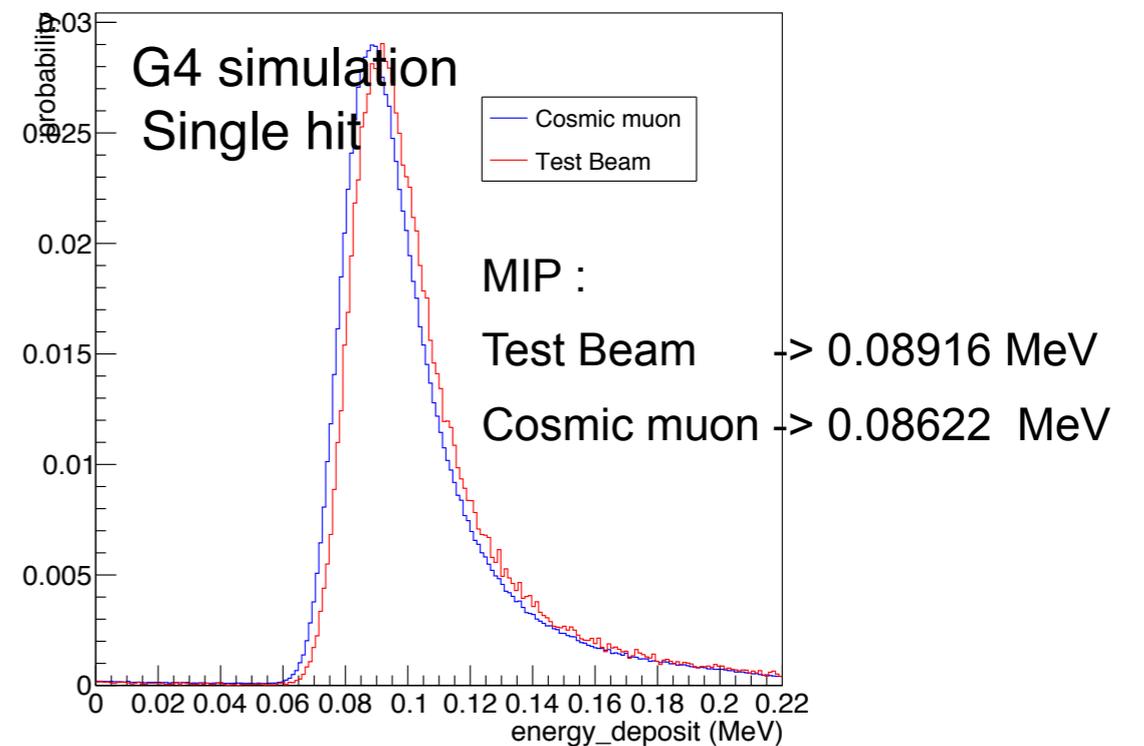
cosmic muon : roughly energy spectrum



•
• 1 to 130 GeV
•



energy deposit, cosmic muon TC energy spectrum



Muon edep scan, 1 GeV to 130 GeV

