SiPM Gain calibration & Cooling Test

260922

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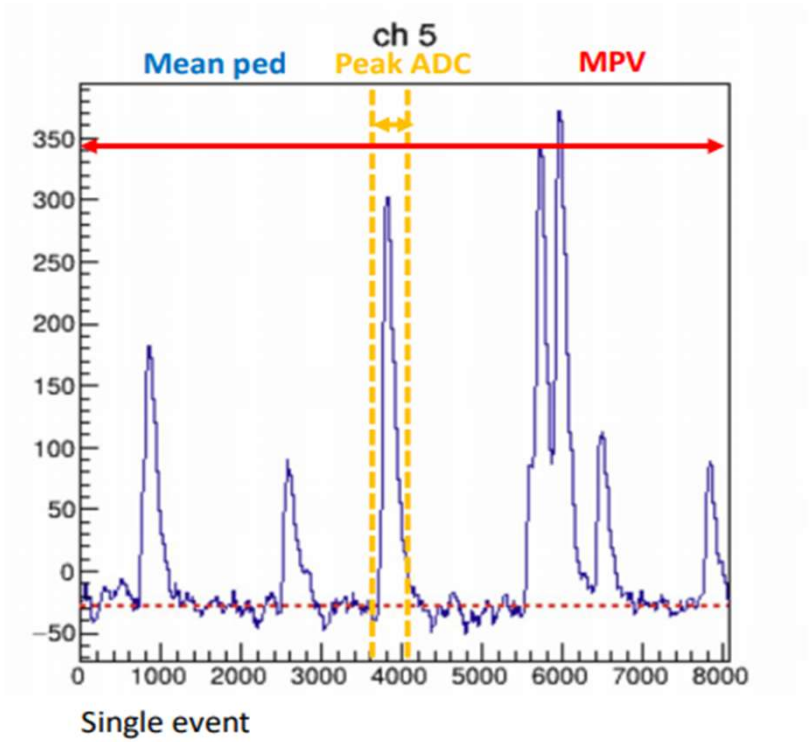
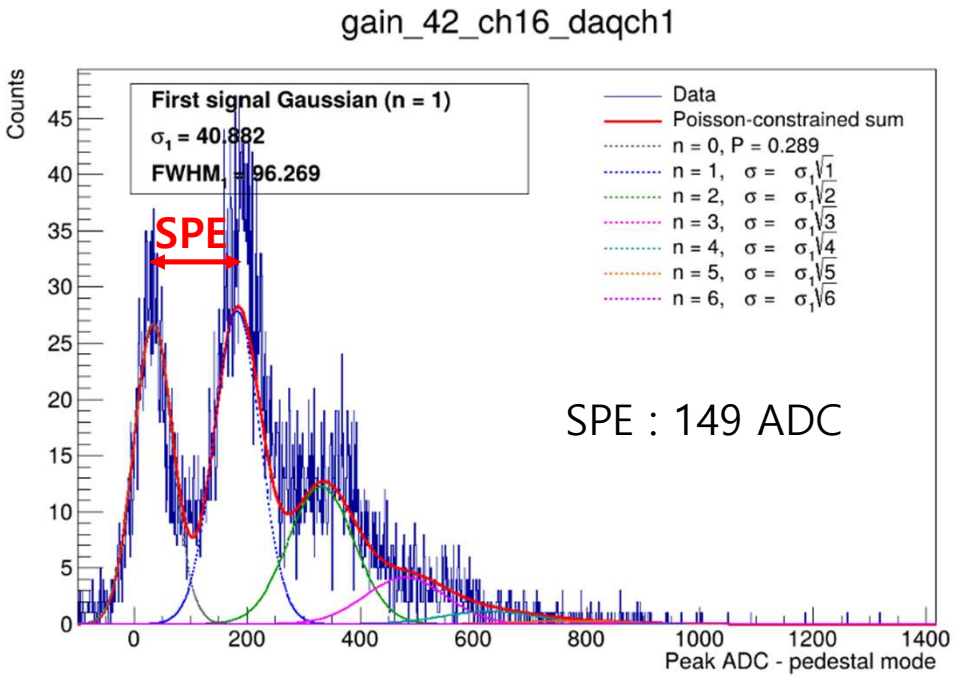
1. Gain calibration

Gain calibration for 26CERNTB



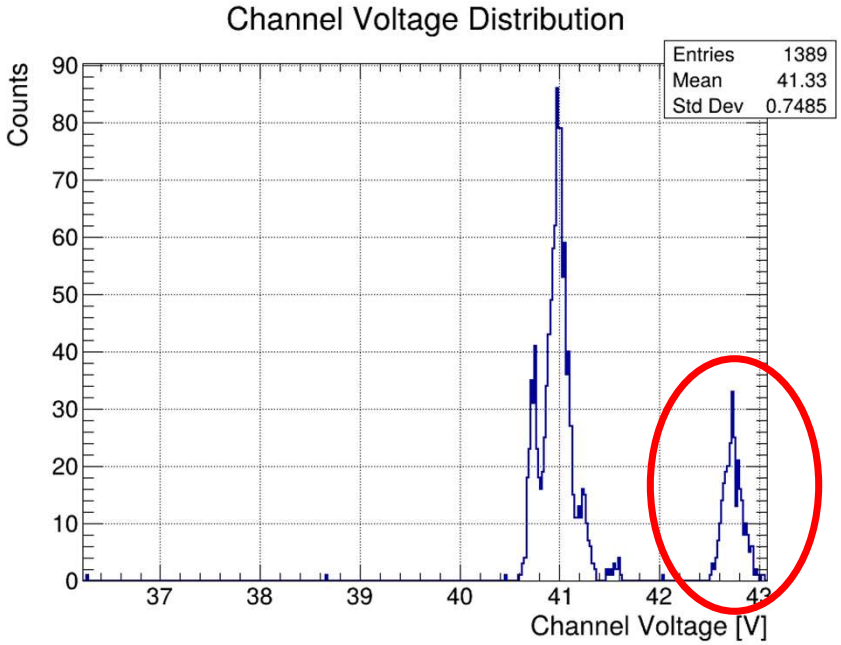
Single event with DC setup



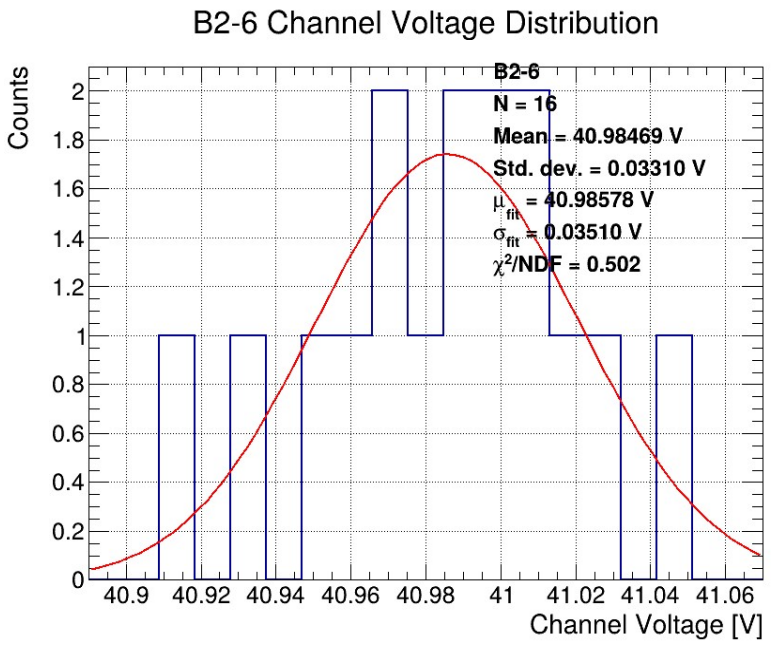
Peak ADC with DC setup

- Calibration with dark current for 26CERN
- Peak size = Peak – baseline
- SPE = 2 p.e. – 1 p.e.

Gain calibration for 26CERN TB



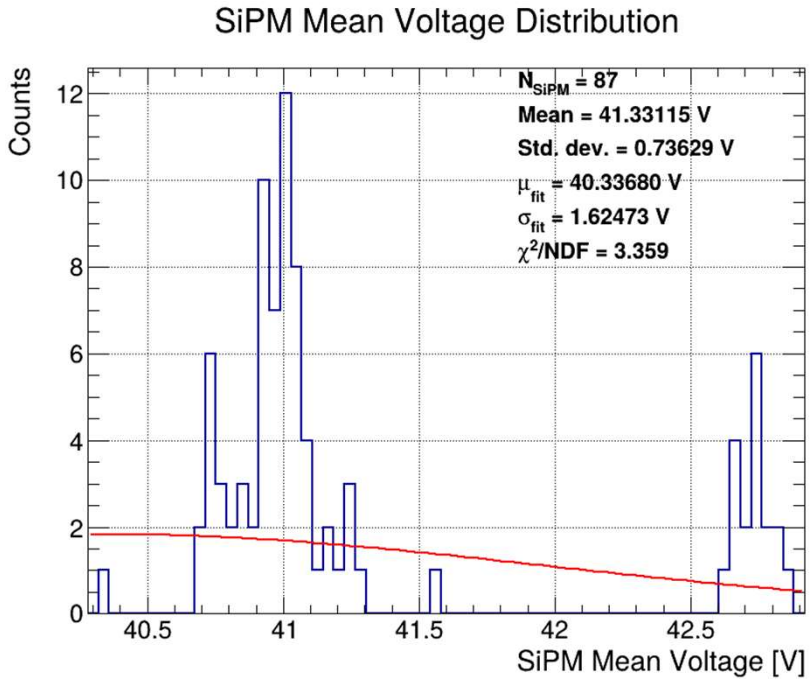
Total calibrated gain distribution

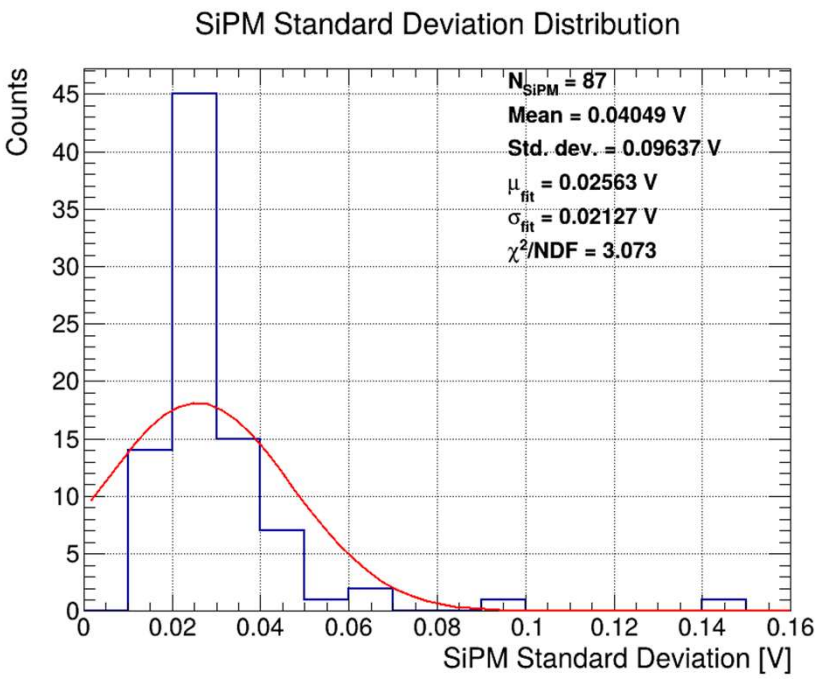


16 ch calibrated gain per same SiPM array

- 87 SiPMs (1389 channels) used (3 channels are disabled)
- 2 peaks exist => Should find single events
- Voltage distribution at SiPM 1 array (16 channels)

Gain distribution – N=87 arrays





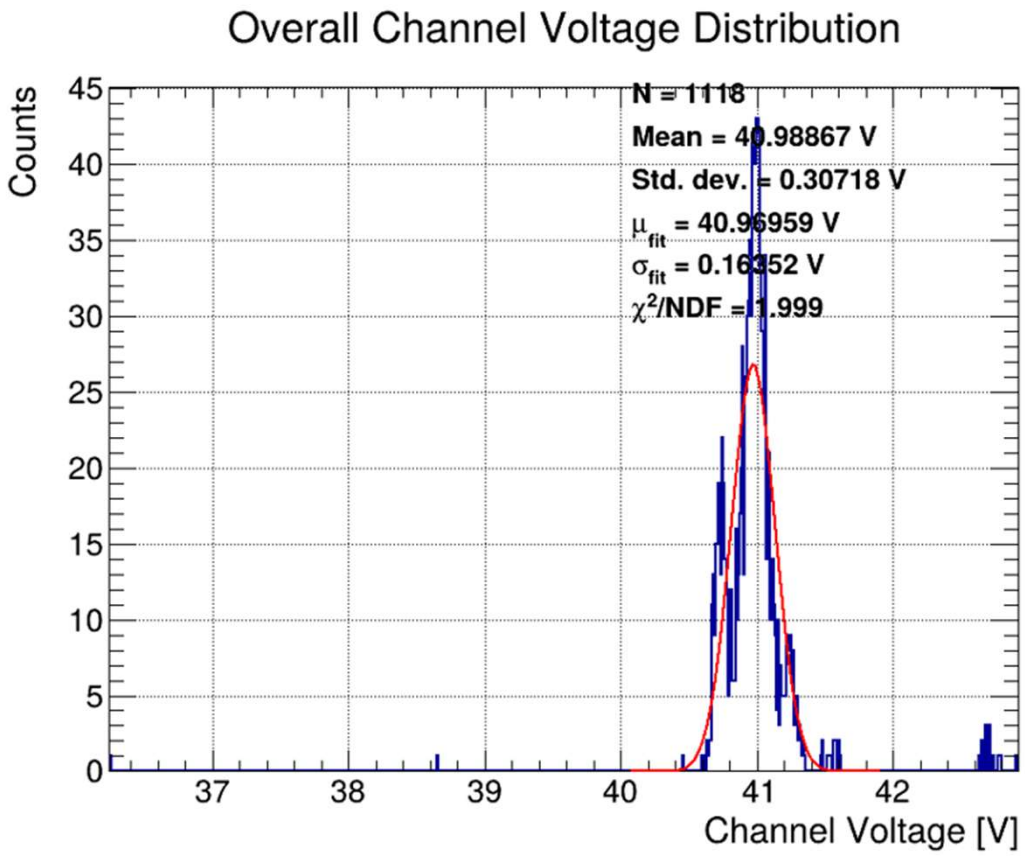
SiPM Mean Voltage Distribution

- Cannot Fit well

SiPM Standard Deviation Distribution

- Std of fitting function : 0.0213 V
- Mean of fitting function : 0.0256 V

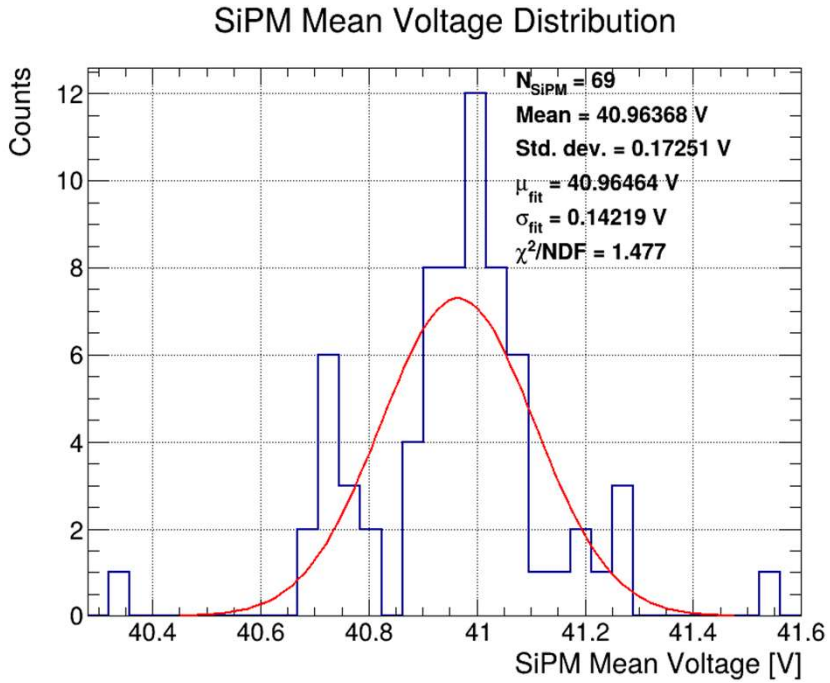
Gain calibration for 26CERN TB

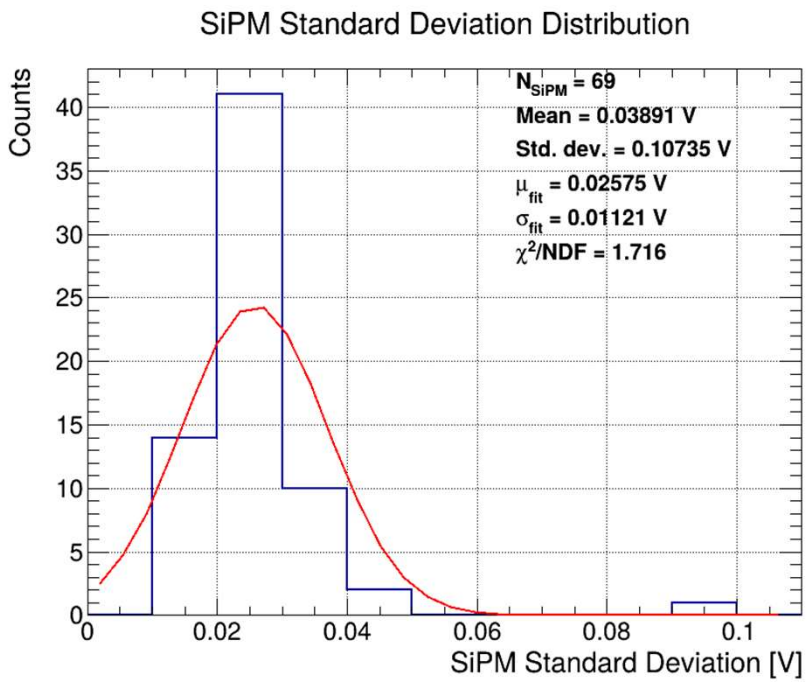


Total calibrated gain distribution

- 69 SiPM arrays (1118 channels)
- Std of fitting function : 0.16352
- Mean of fitting function : 40.97 V

Gain distribution – SiPM mean





SiPM Mean Voltage Distribution

- Std of fitting function : 0.142 V
- Mean of fitting function : 40.964 V

SiPM Standard Deviation Distribution

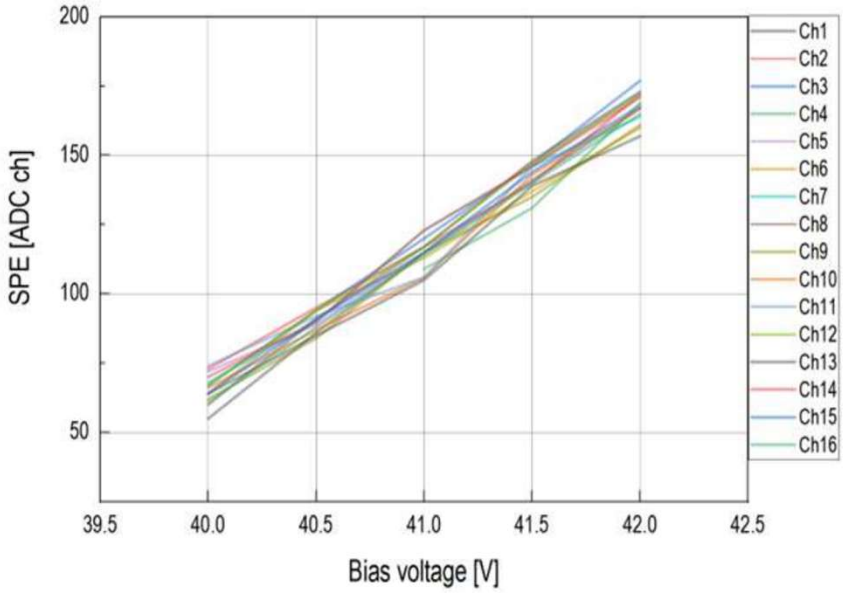
- Std of fitting function : 0.0112 V
- Mean of fitting function : 0.0258 V

To do - Gain calibration

- Wrong gain SiPM debugging
- Resolution data at 26CERNTB (Common 41 V VS Calibrated voltage) analysis

2. Cooling

Temperature test – Gain difference



SiPM Bias voltage – SPE grape
at 1 SiPM 16 channels array

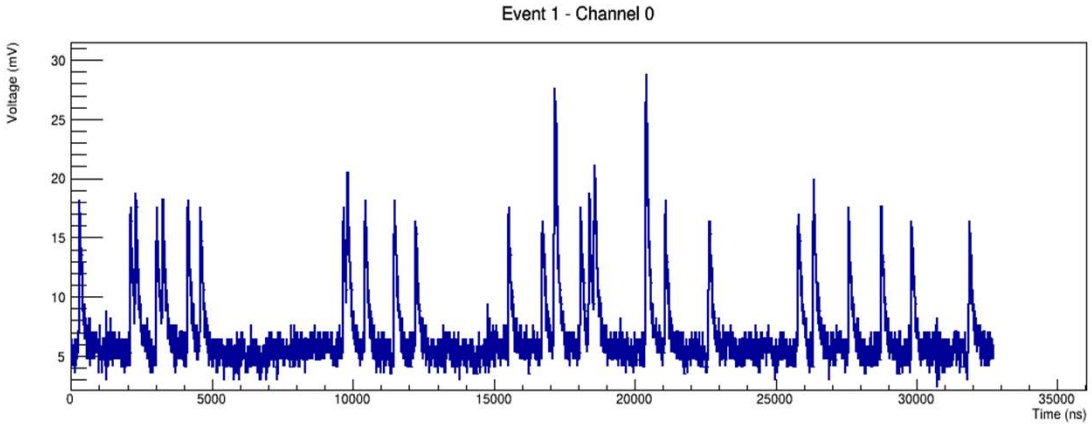
Electrical and optical characteristics (Typ. Ta=25 °C, Vover=2.7 V, unless otherwise noted)

Parameter		Symbol	S14160/S14161 -3050HS-04, -08	S14160/S14161 -4050HS-06	S14160/S14161 -6050HS-04	unit
Spectral response range		λ	270 to 900			nm
Peak sensitivity wavelength		λp	450			nm
Photon detection efficiency at λp*3		PDE	50			%
Breakdown voltage		VBR	38			V
Recommended operating voltage*4		Vop	VBR + 2.7			V
Vop variation between channels in one product*5	Typ.	-	0.1			V
	Max.		0.2			
Dark current	Typ.	ID	0.6	1.1	2.5	μA
	Max.		1.8	3.3	7.5	
Crosstalk probability		-	7			%
Terminal capacitance		Ct	500	900	2000	pF
Gain		M	2.5 × 10^6			-
Temperature coefficient of recommended reverse voltage		ΔTVop	34			mV/°C

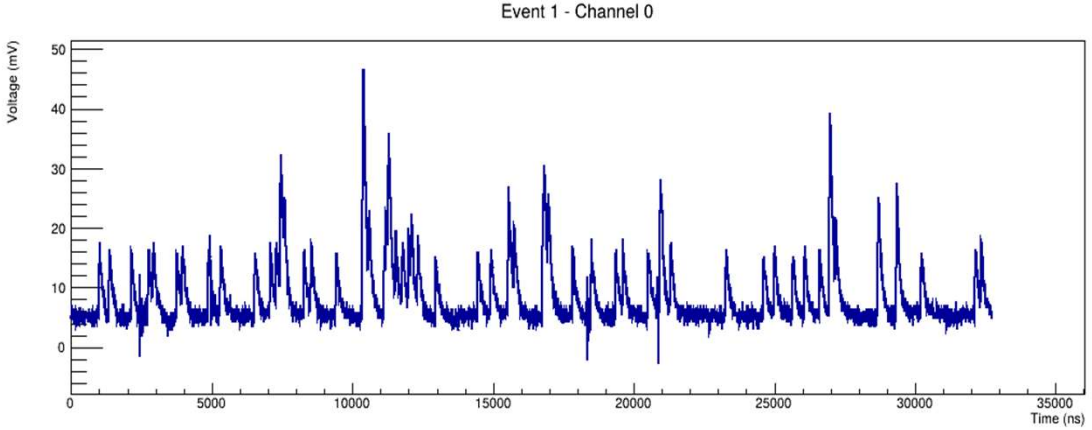
Chiller at KNU

- 90 SiPMs were calibrated at KNU
- Vbr difference by temperature (34 mV per 1 °C)
- Gain difference at different temperature is essential

Temperature test – Dark Current Rate



1 channel single event at 14 ℃

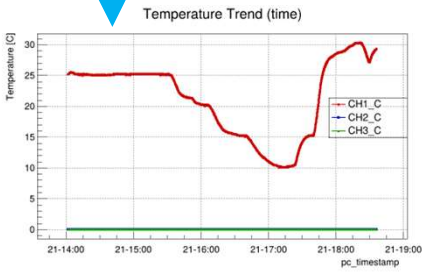


1 channel single event at 25 ℃

- DCR for 1 event
- Depends on temperature (# of DC at 25 ℃ > # of DC at 14 ℃)

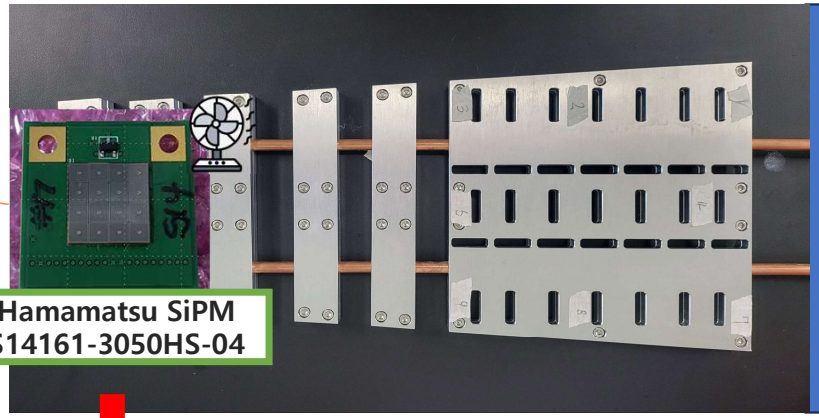
Temperature test setup

Data logger
(GRAPHTEC GL260)

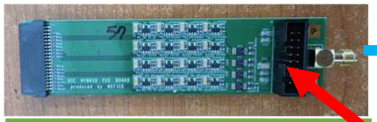


Temperature
Online monitoring

Thermocouple
(T-type)



Hamamatsu SiPM
S14161-3050HS-04



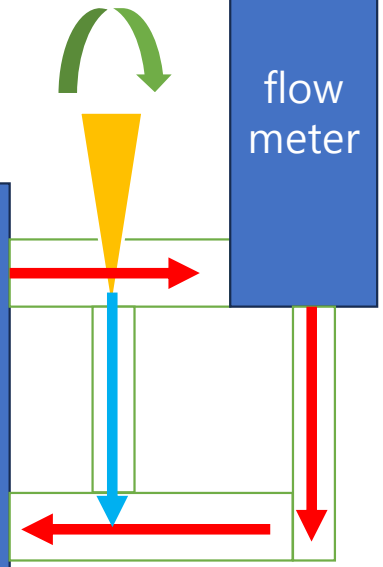
SiPM AMP board
By NOTICE Korea

DAQ

Power
Module

chiller

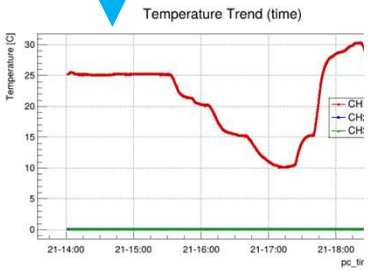
flow
meter



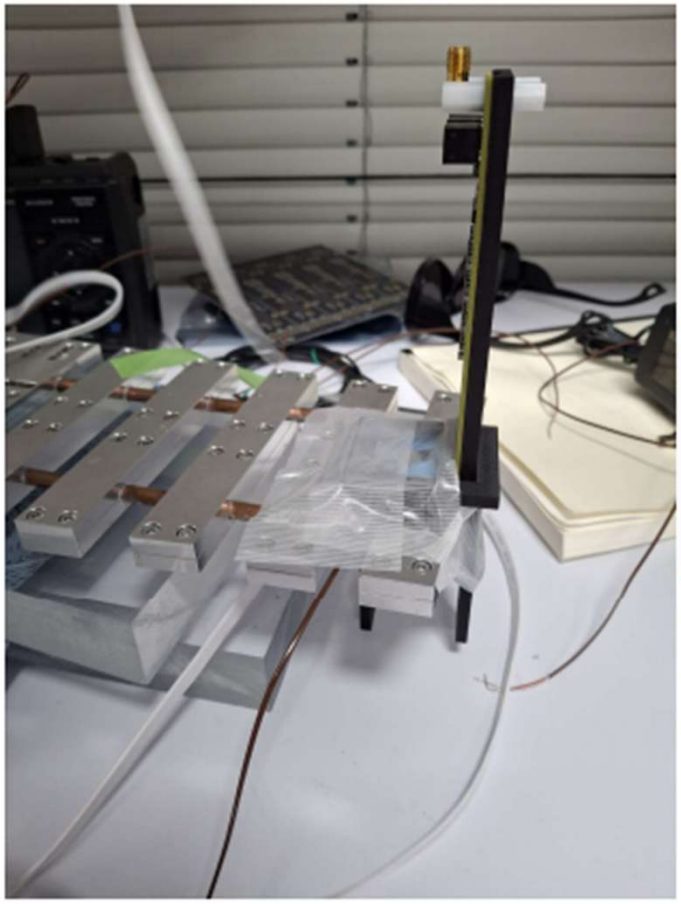
Bypass System

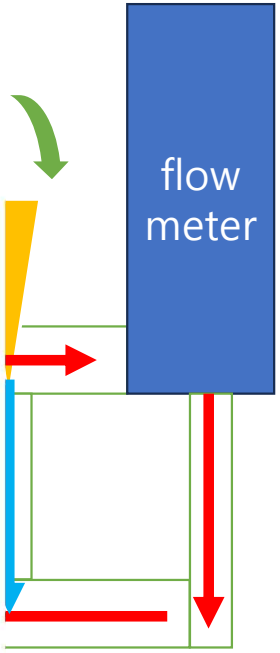
Temperature test setup

Data logger
(GRAPHTEC GL260)



Temperature
Online monitoring

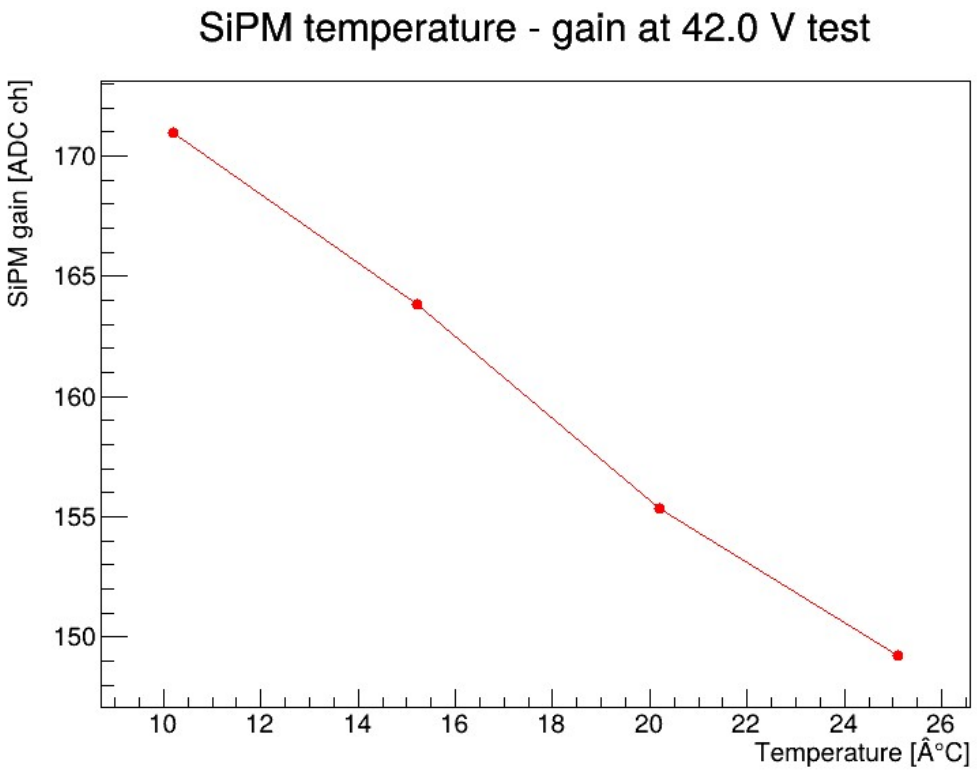




/pass System

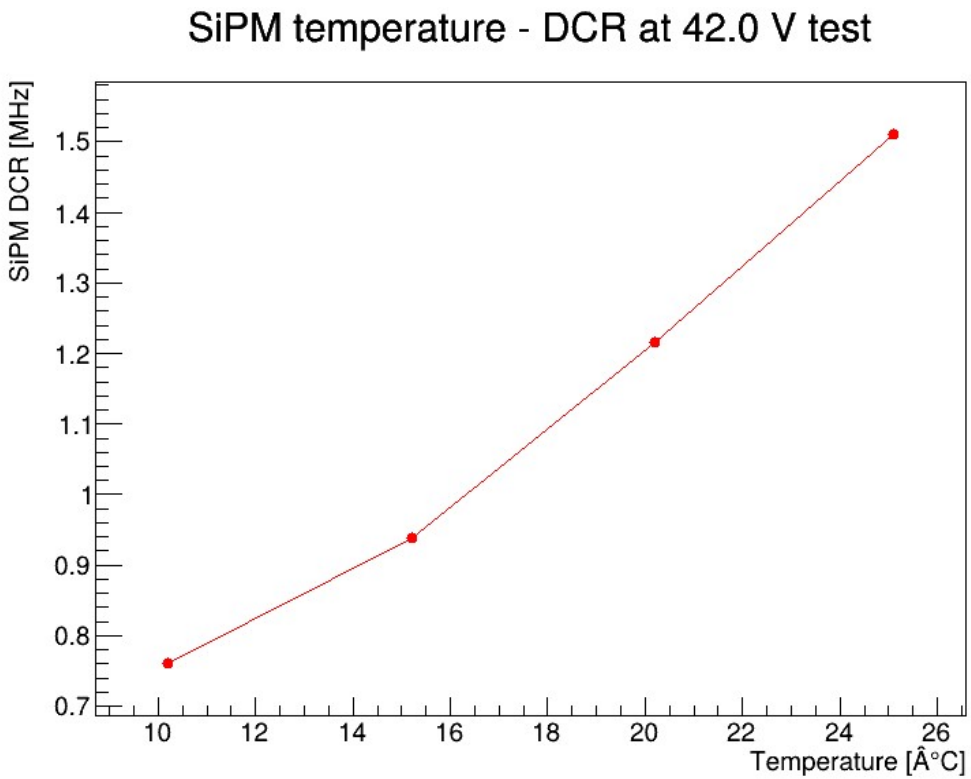
Module

Temperature test – Gain



- 4 temperature points (10 ℃ ~ 25 ℃, 5 ℃ stamps)
- Gain calibration with same algorithm (previous led test)
- Gain calibration for each temperature – Seung Won YEO
- Gain decreases linearly as temperature increases.

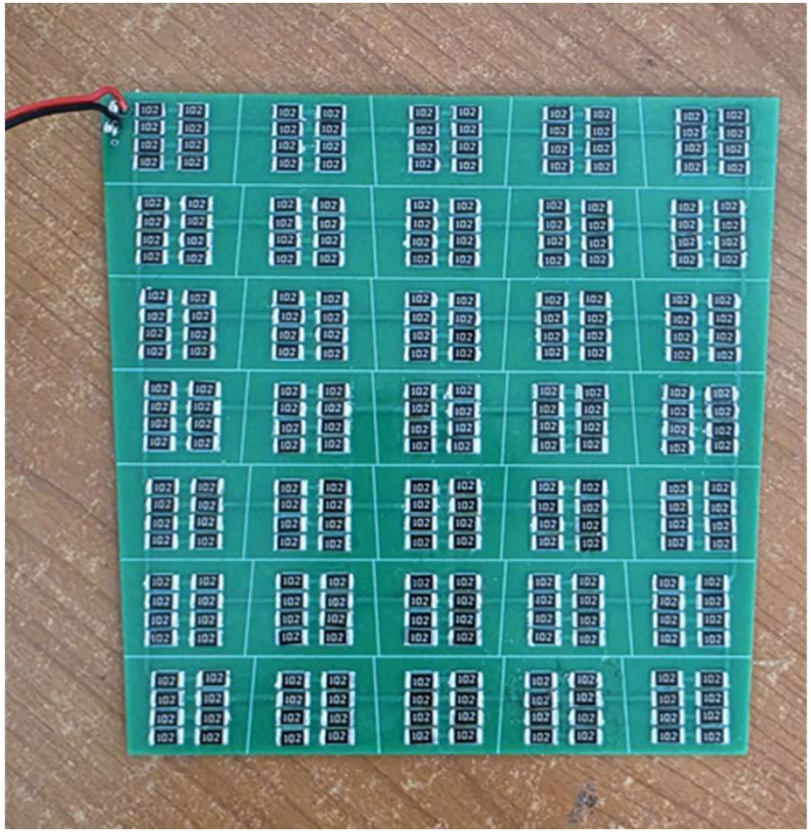
Temperature test – Dark Current Rate



- 4 temperature points (10 ℃ ~ 25 ℃, 5 ℃ stamps)
- DCR fitting logic – Geon Woo SONG
- DCR increases linearly as temperature increases.

To do - Cooling

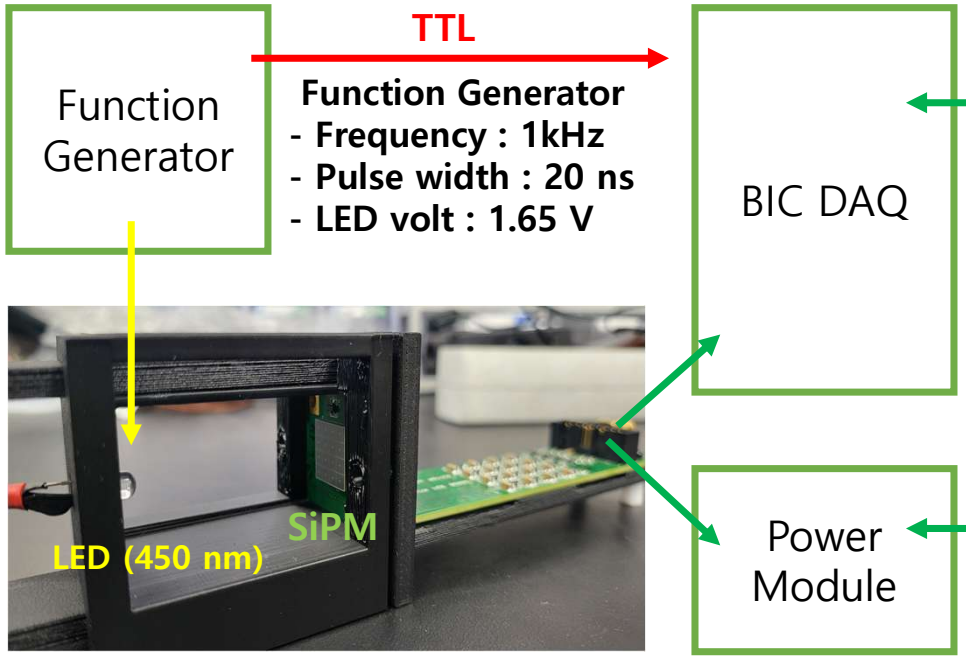
- DCR test (SiPM bias voltage – DCR)
- DCR function debugging
- Cooling test with bulk dummy board (separate test)



Bulk dummy board

Backup

SiPM Gain Calibration – LED Setup



- Single photoelectron (SPE) measurement with LED setup
- Each channel was operated individually
- SPE scan was performed at different SiPM bias voltage for each channel.

- BIC DAQ
  - 62.5 MHz (16 ns) FADC
  - 14 bit ADC with voltage range 0~2 V

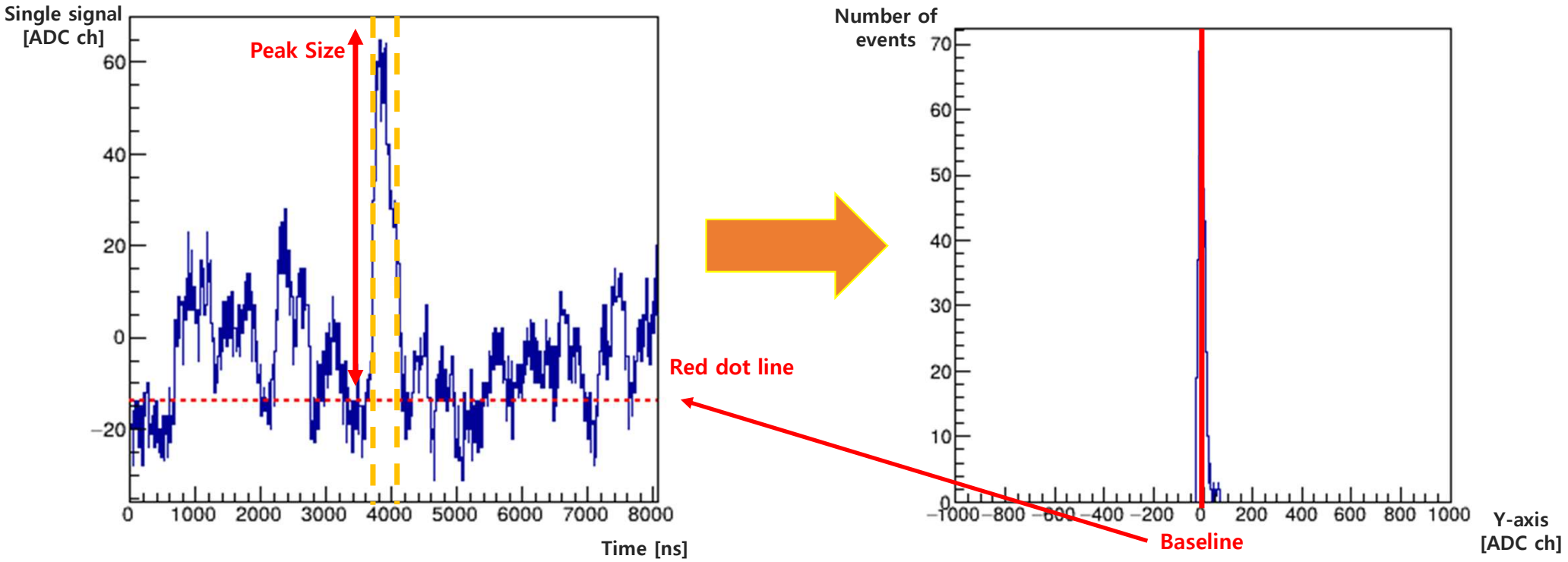
- BIC Power module
  - Give individual voltage for each SiPM channels
  - 12 bit DAC with voltage range 0~10 V
  - Get temperature data with SiPM temperature sensor

DAQ Setup

- NKFADC500
  - 500 MHz (2 ns) FADC
  - 12 bit ADC with voltage range 0~2 V

- BIC DAQ
  - 62.5 MHz (16 ns) FADC
  - 14 bit ADC with voltage range 0~2 V

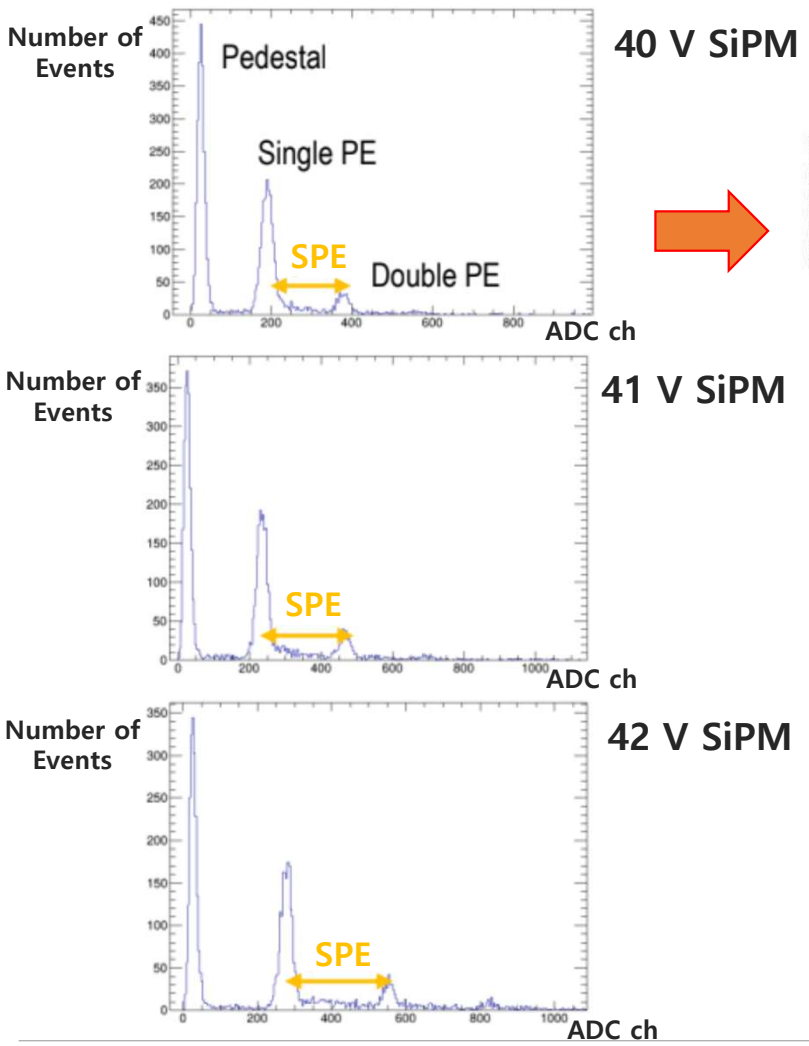
SiPM Gain Calibration – LED Logic

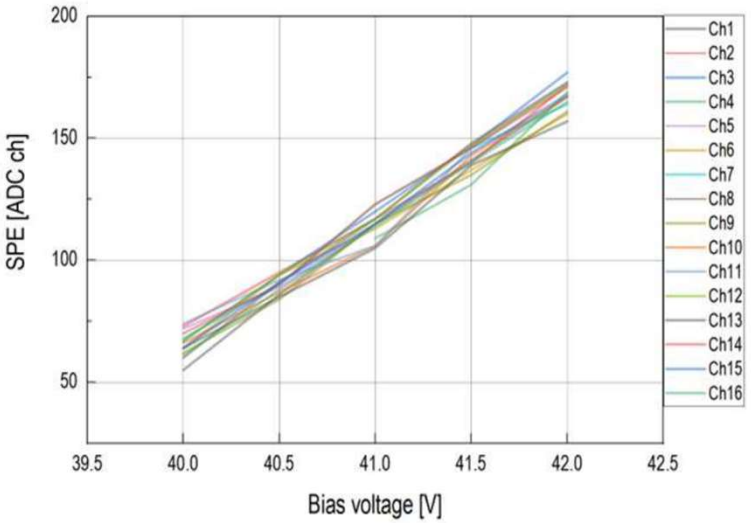


- Single event of SiPM each channel per each bias voltage
- To measure single photoelectron (SPE), Low intensity of LED was needed

- Baseline determined from y-axis projection of ADC values outside of the LED windows
  (High dark current rates)
- Red dot line (Peak position used as baseline))

SiPM Gain Calibration – Peak ADC Distribution

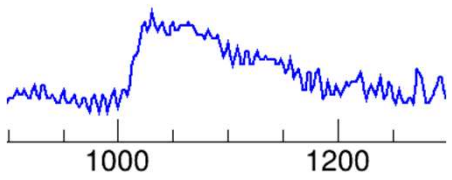


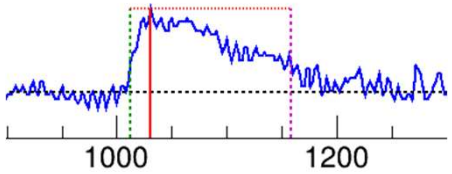


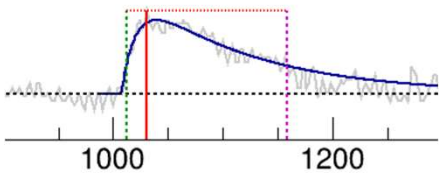
- SiPM Peak ADC Distribution with using LED Logic (Peak Size)
- Gain calibration already done

DCR Fitting Overview

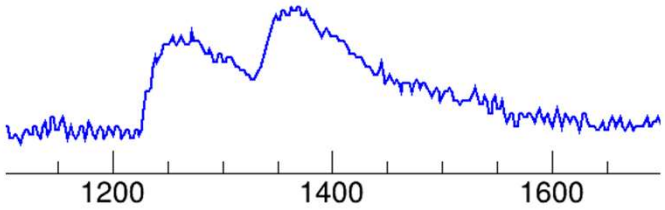
Single Pulse

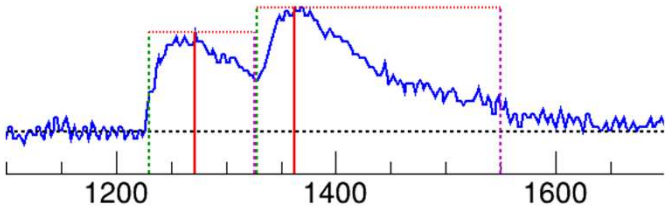


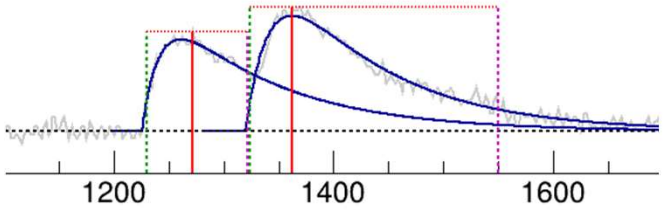




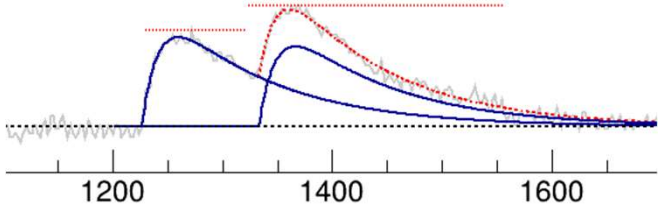
Cluster



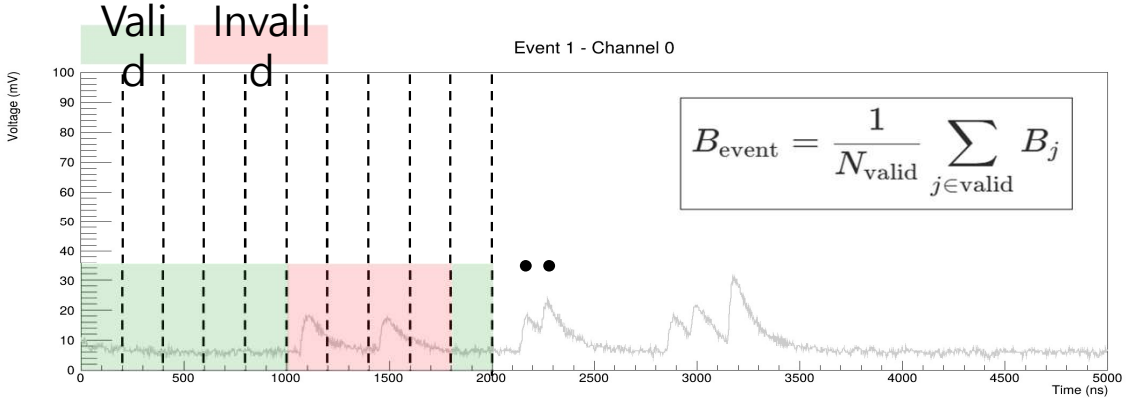




Final Form

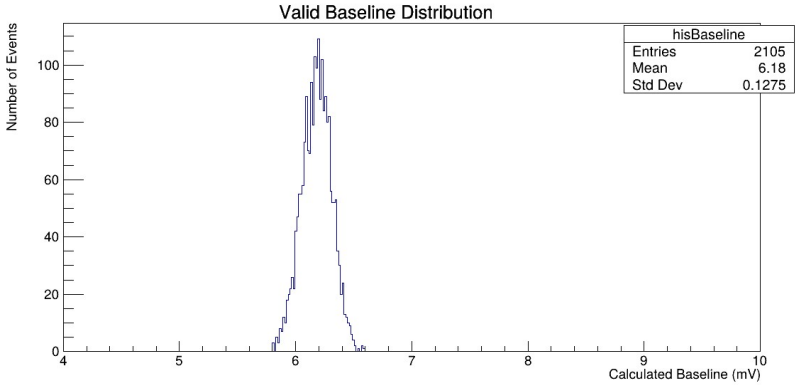


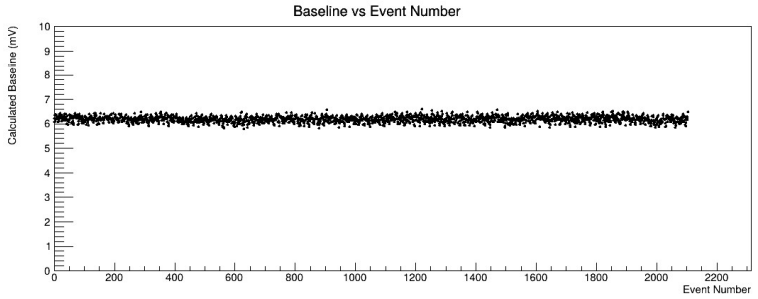
1. Baseline Correction



Valid Event : 2105 event

Baseline RMS: 0.128 mV





- Divide the entire waveform into 100-sample (200 ns) intervals.
- Select the valid intervals and calculate their average.

Mean : 6.180225 mV

Mean error : 0.002779 mV

RMS : 0.127510 mV

2. Pulse Model

Single Pulse Model

$$f_1(t) = \begin{cases} B, & t < t_0 \\ B + AN(e^{-\frac{dt}{\tau_d}} - e^{-\frac{dt}{\tau_r}}), & t \geq t_0 \end{cases}$$

- τ_d : Decay Time
- τ_r : Rise Time
- B : Baseline

} 한 Cluster 내 Parameter 공유

- A : Pulse Height
- t_0 : start Time

} 각 펄스당 할당

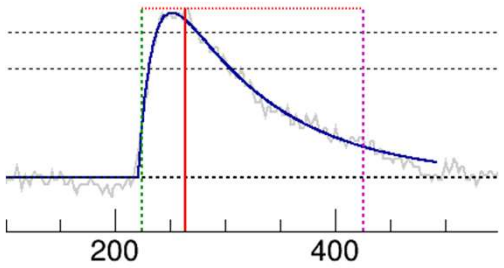
n-Pulse Model

$$f_n(t) = \begin{cases} B, & t < t_0 \\ B + \sum_{i=1}^{n} A_i\, N(e^{-\frac{dt}{\tau_d}} - e^{-\frac{dt}{\tau_r}}), & t \geq t_0 \end{cases}$$

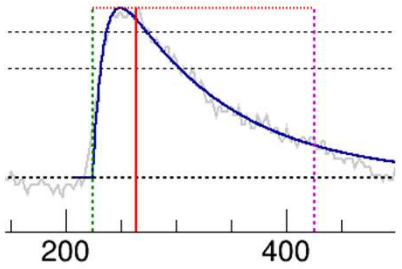
2. Pulse Shape Model

Parameter Set/Fix

SET t_0
SET τ_d
SET τ_r
FIX B
SET A



FIX t_0
SET τ_d
SET τ_r
FIX B
SET A



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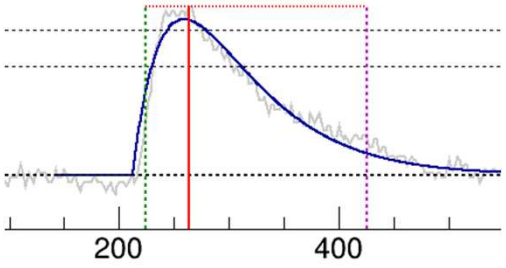

FIX t_0
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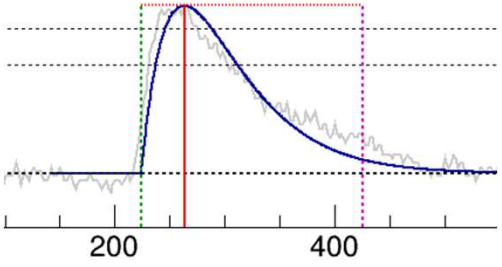
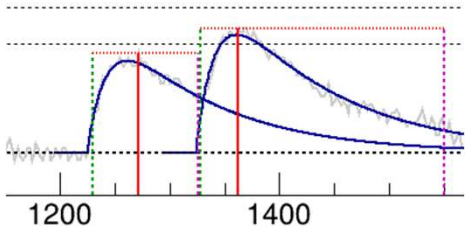


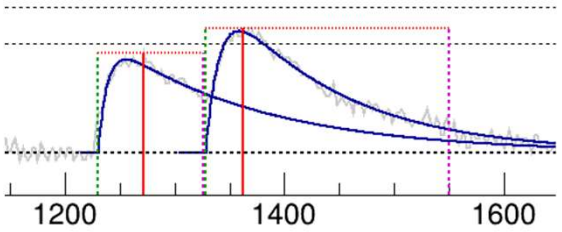
2. Pulse Shape Model

Parameter Set/Fix

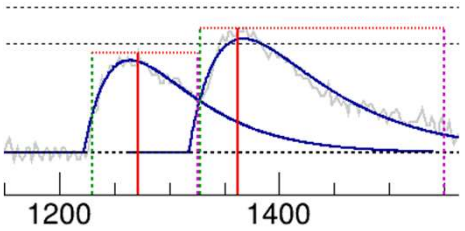
SET t_0
SET τ_d
SET τ_r
FIX B
SET A



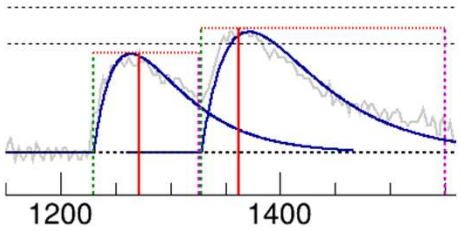
FIX t_0
SET τ_d
SET τ_r
FIX B
SET A



SET t_0
SET τ_d
FIX τ_r
FIX B
SET A

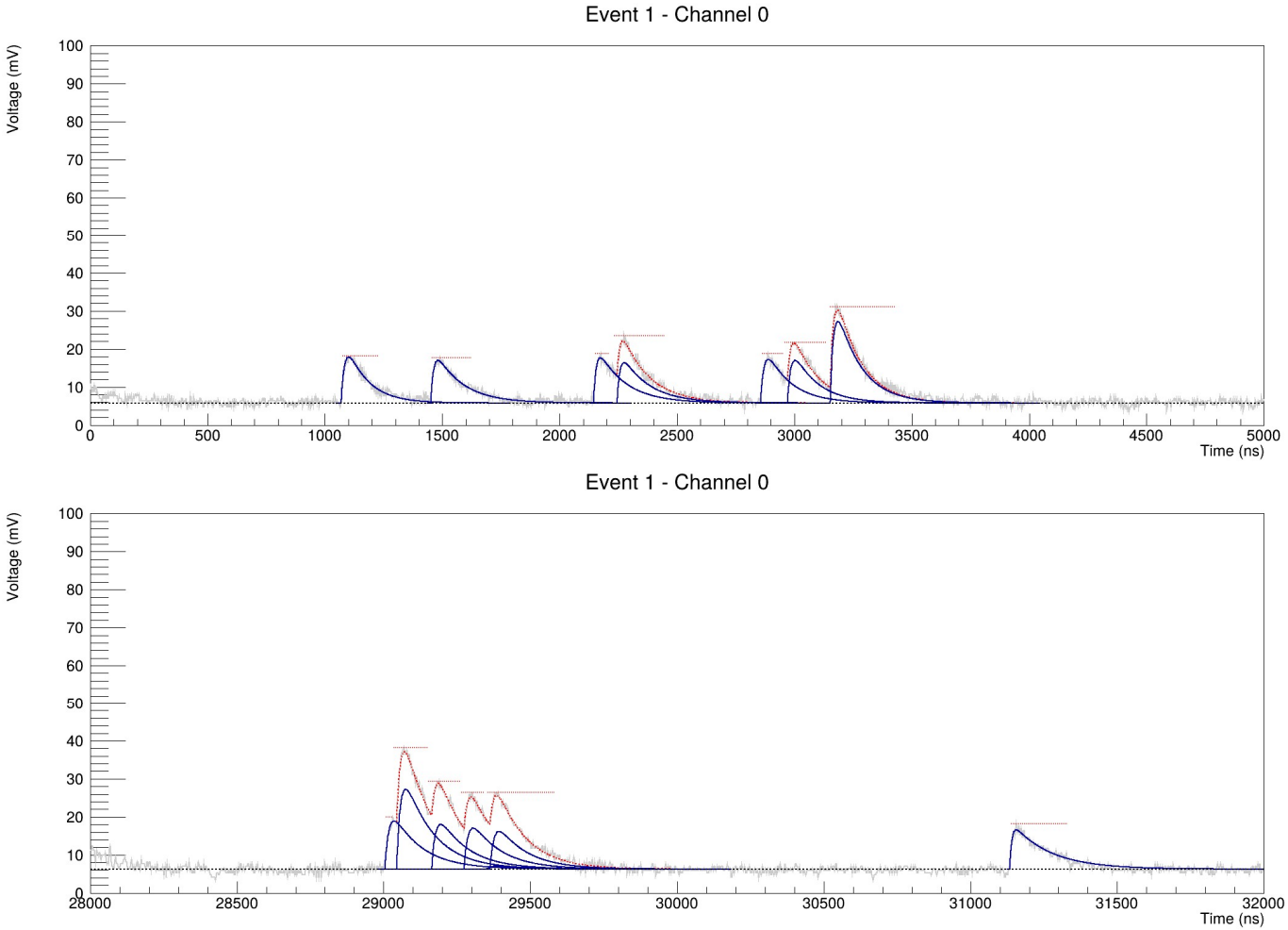


FIX t_0
SET τ_d
FIX τ_r
FIX B
SET A



→ Free Parameter is Best! (Except Baseline)

2. Pulse Model



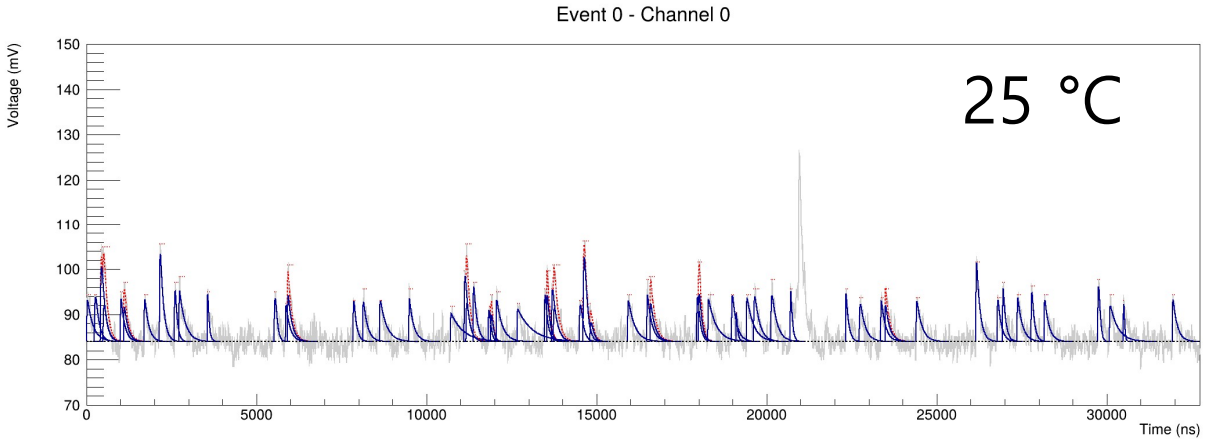
Raw Data

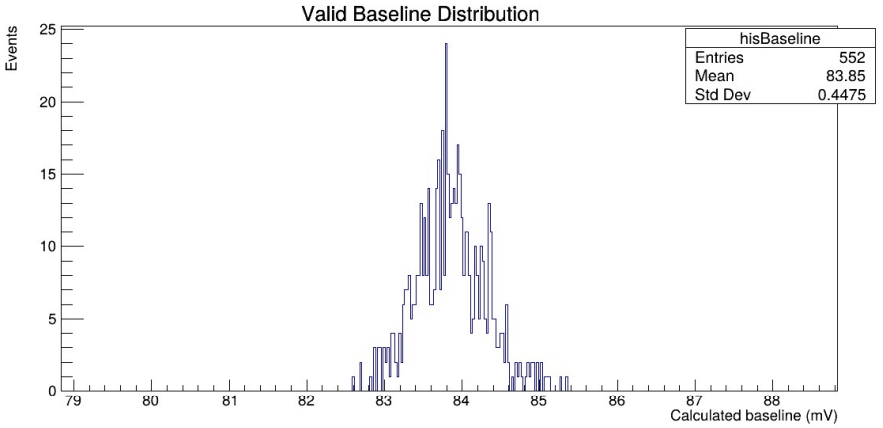
Total Fitted Model

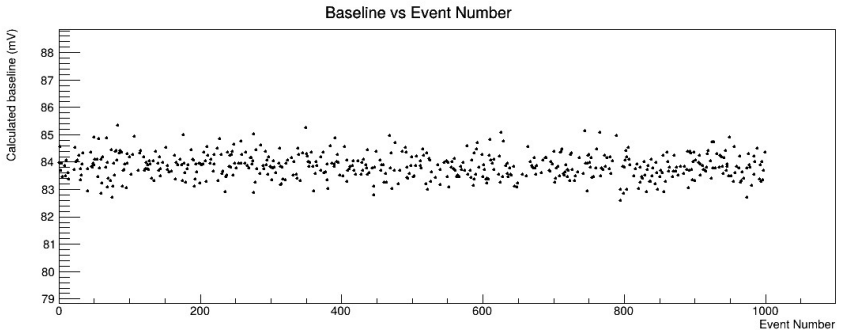
Pulse Component

Temperature VS DCR

Measurement condition
NKFADC500
1 ADC = 0.66 mV





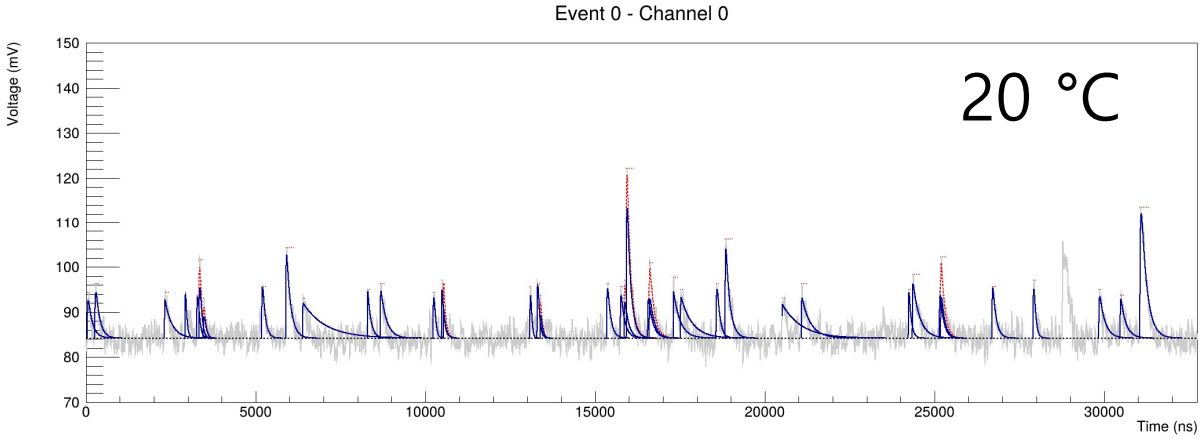


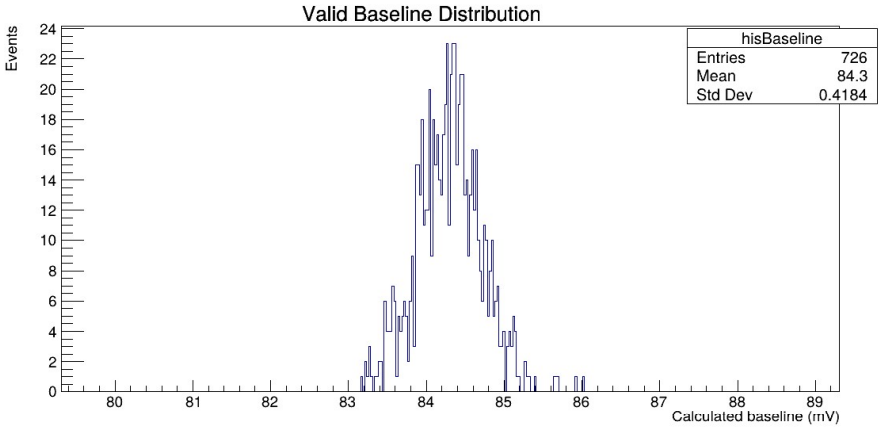

```
Fit usability
Single fits             : 16787 / 18277 usable (91.8477%)
Cluster final fits      : 3661 / 4234 usable (86.4667%)
Total pulse fits        : 24748 / 28799 usable (85.9335%)
```

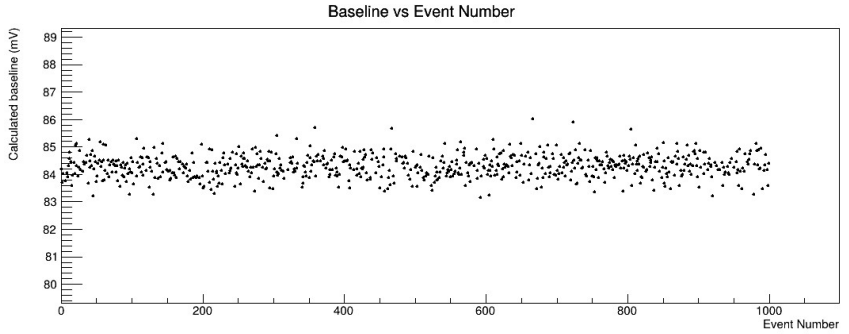
Baseline
Success: 552 / 1000
Mean: 83.85 mV
RMS: 0.447 mV

Temperature VS DCR

Measurement condition
NKFADC500
1 ADC = 0.66 mV





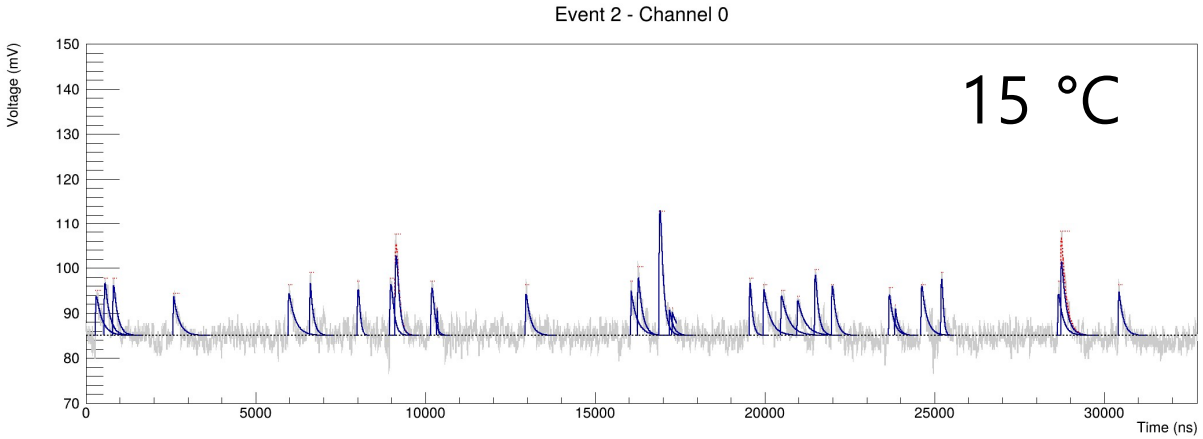


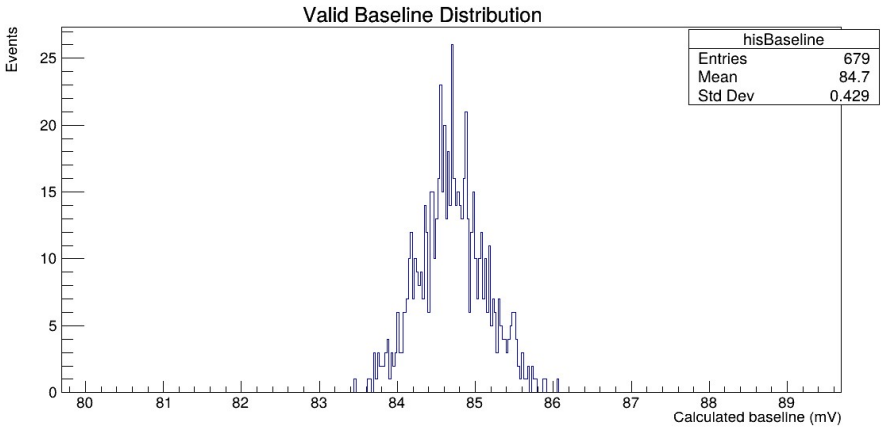

```
Fit usability
Single fits             : 13929 / 15160 usable (91.8799%)
Cluster final fits      : 2850 / 3226 usable (88.3447%)
Total pulse fits        : 19860 / 22996 usable (86.3628%)
```

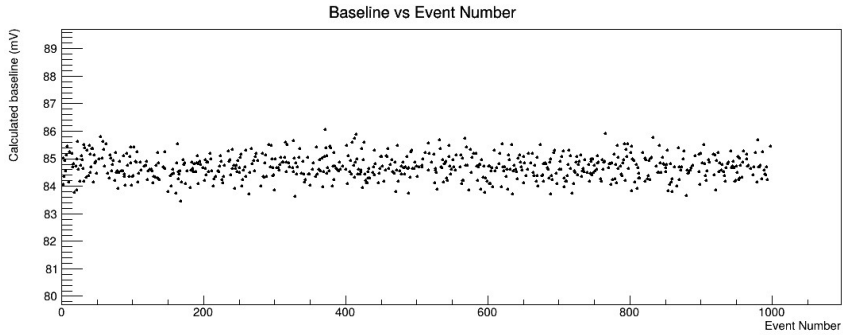
Baseline
Success: 726 / 1000
Mean: 84.29 mV
RMS: 0.428 mV

Temperature VS DCR

Measurement condition
NKFADC500
1 ADC = 0.66 mV





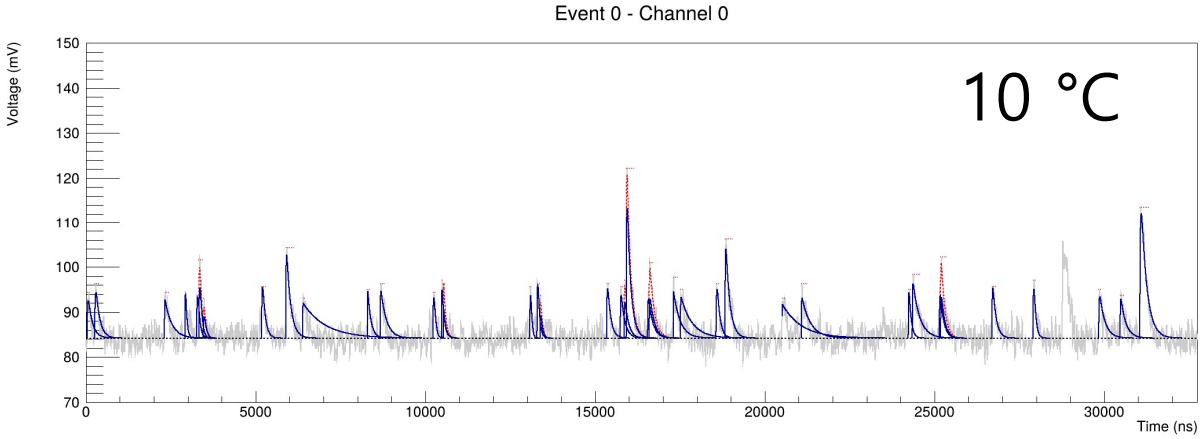


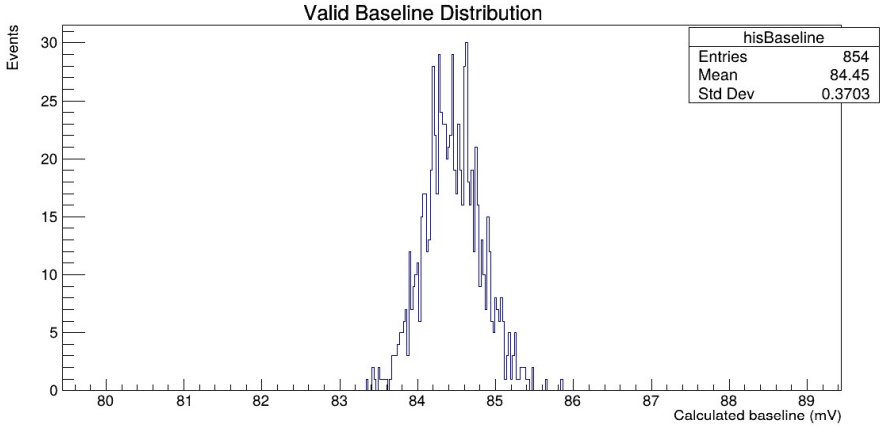

```
Fit usability
Single fits          : 11199 / 12048 usable (92.9532%)
Cluster final fits   : 1975 / 2239 usable (88.2090%)
Total pulse fits     : 15161 / 17356 usable (87.3531%)
```

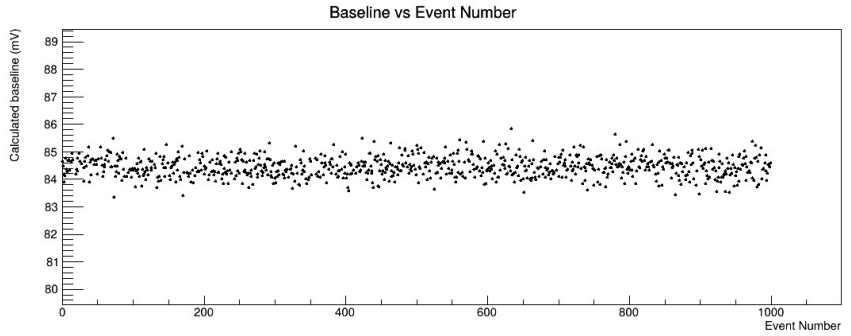
Baseline
Success: 679 / 1000
Mean: 84.69 mV
RMS: 0.428 mV

Temperature VS DCR

Measurement condition
NKFADC500
1 ADC = 0.66 mV



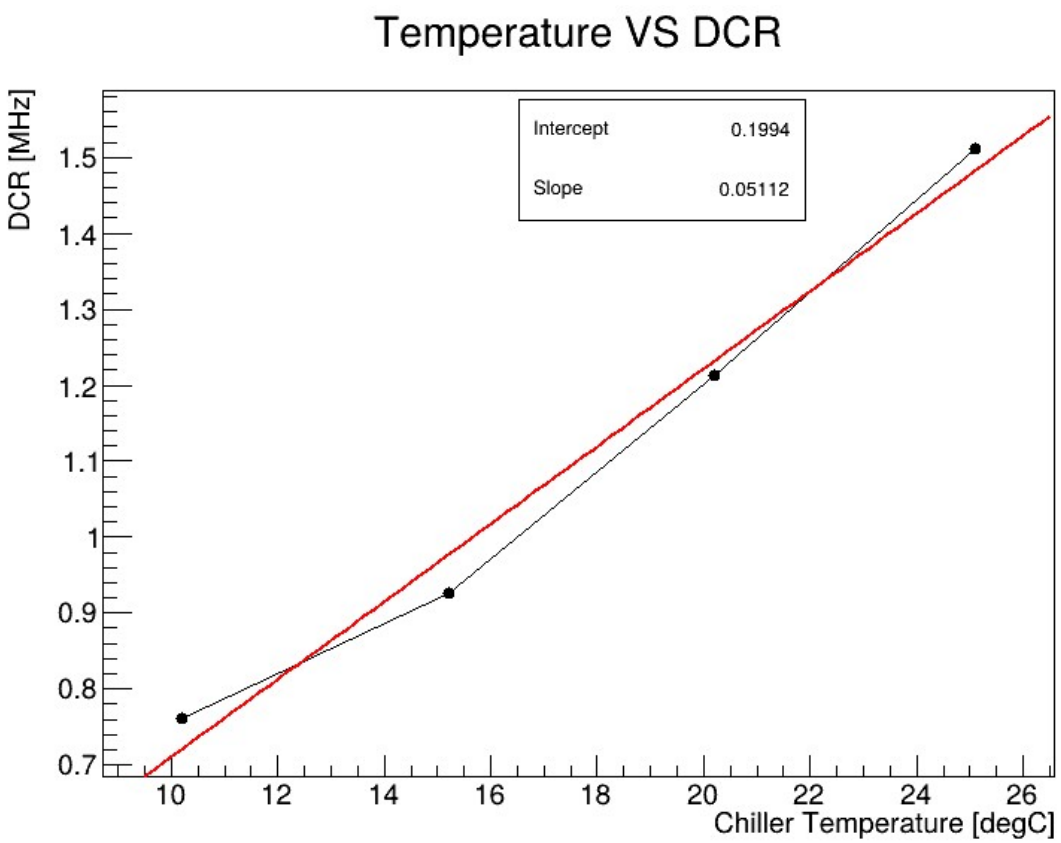





```
Fit usability
Single fits             : 9558 / 10227 usable (93.4585%)
Cluster final fits      : 1461 / 1629 usable (89.6869%)
Total pulse fits        : 12446 / 14015 usable (88.8049%)
```

Baseline
Success: 854 / 1000
Mean: 84.44 mV
RMS: 0.370 mV

5. Temperature VS DCR Linearity



Temp [deg C]	DCR [MHz]
10.2	0.760386
15.2	0.926259
20.2	1.21334
25.1	1.51197

- 500 event
- Sampling time : 16386 μs

5. Temperature VS DCR Hist