Light Monitoring System (LMS) & Cooling System in KNU

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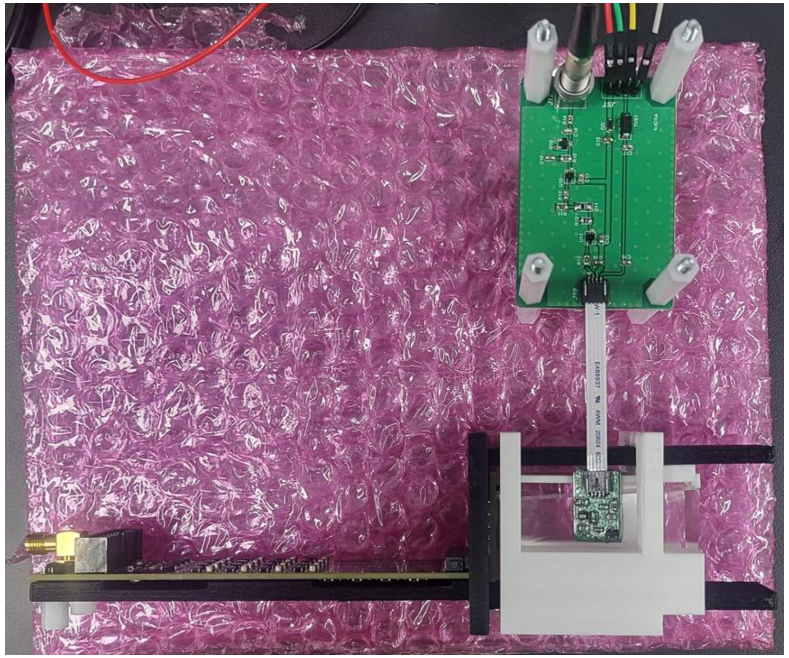
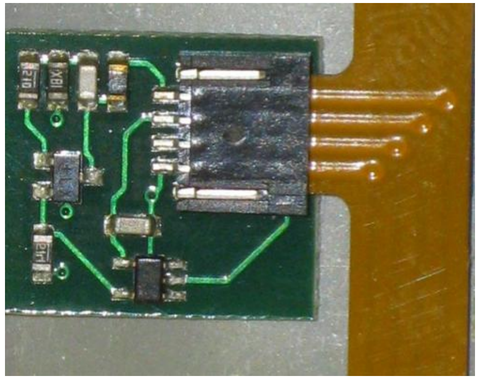
1. Light Monitoring System (LMS)

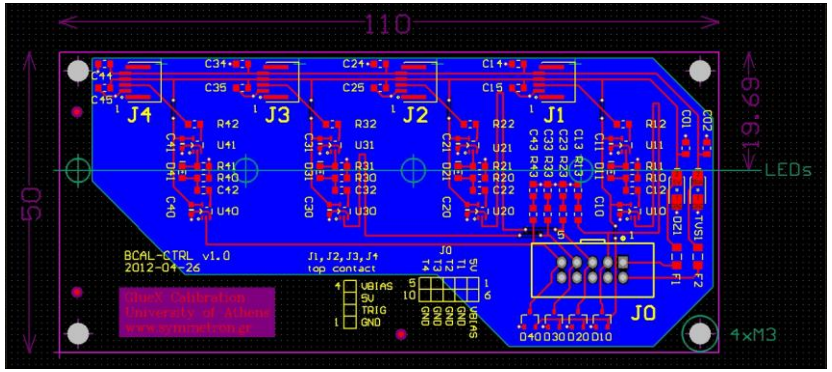


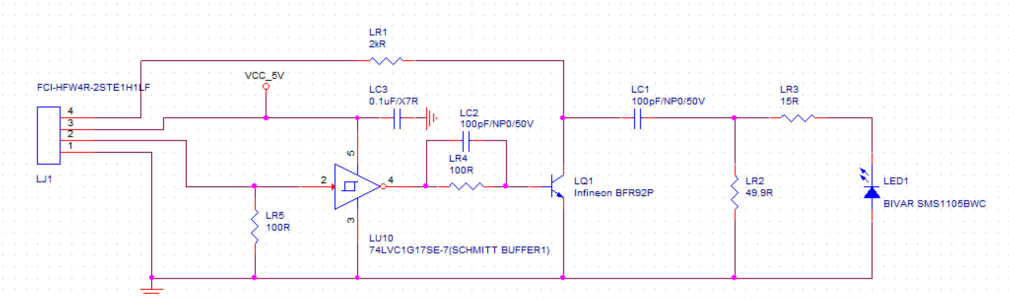
Overview of LMS



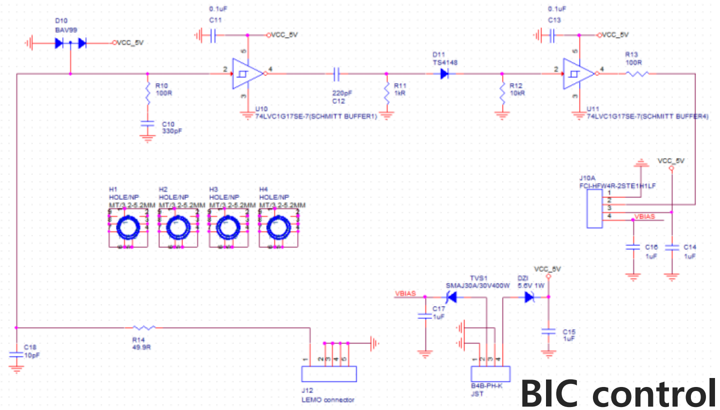
GlueX LED board circuit

GlueX controller board circuit





BIC LED board circuit

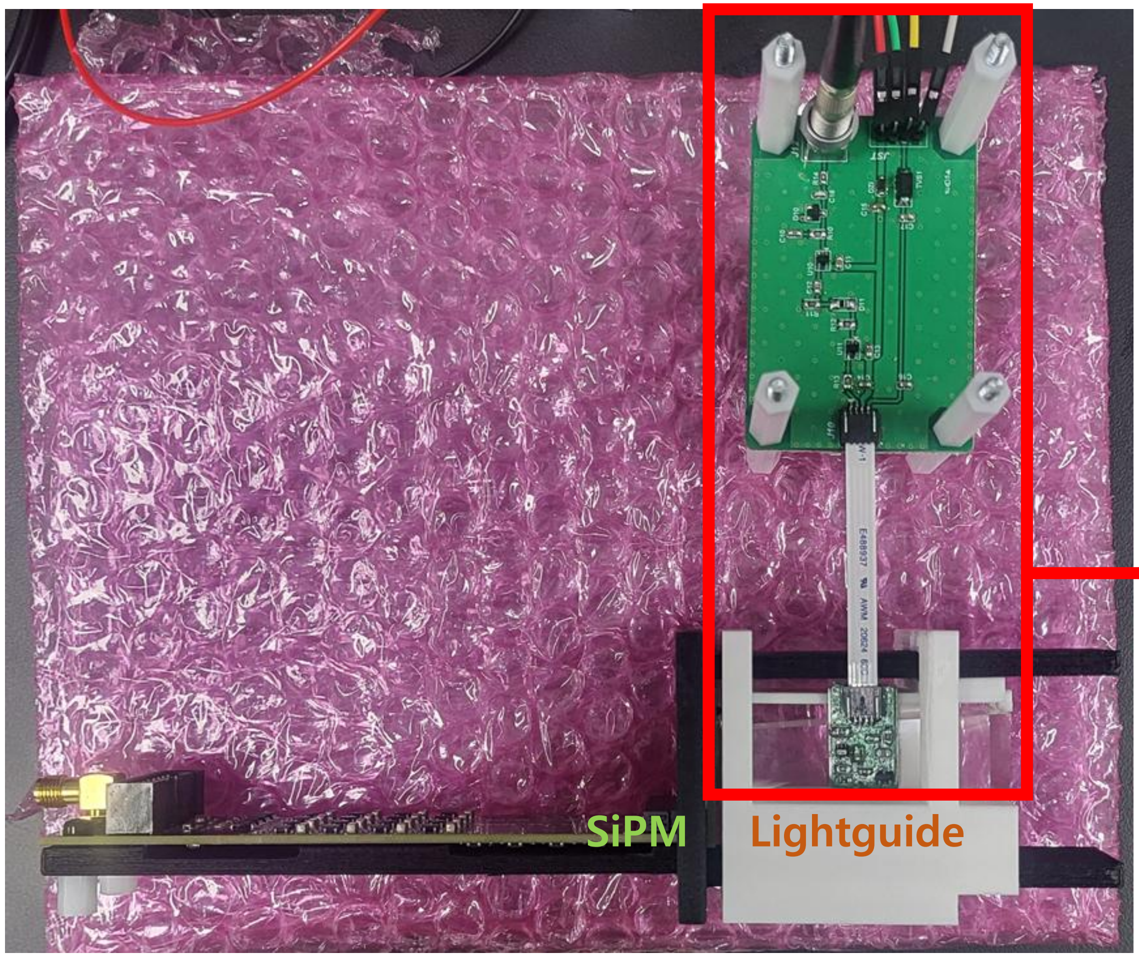


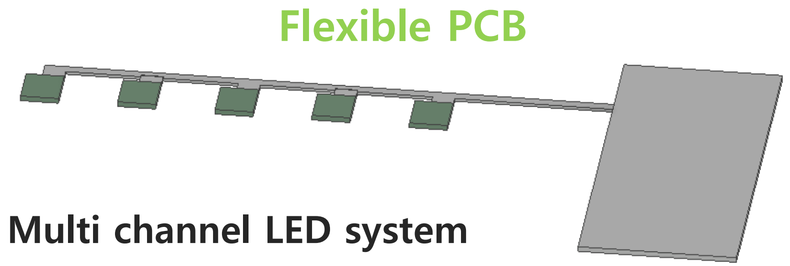
BIC controller board circuit

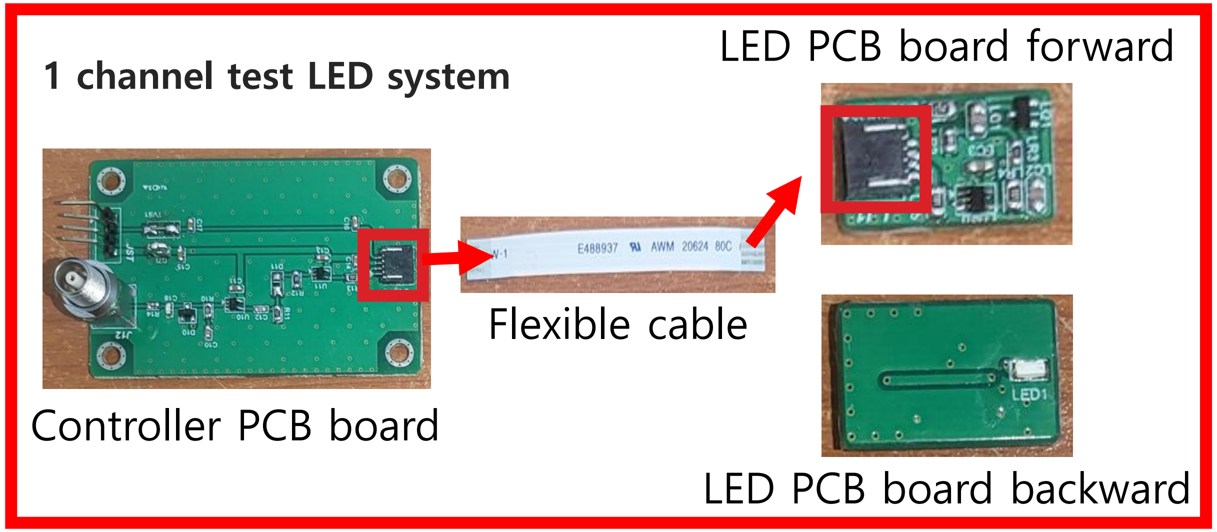
BIC LED & Controller board circuit
(By Dr. Efstratios Anassontzis)

- GlueX LMS System (by Dr. Efstratios Anassontzis & Prof. Zisis Papandreou)
- Use LED pulse method from GlueX LED circuit → Make BIC LED circuit
- Controller board for LED trigger signal

Overview – KNU LMS Board

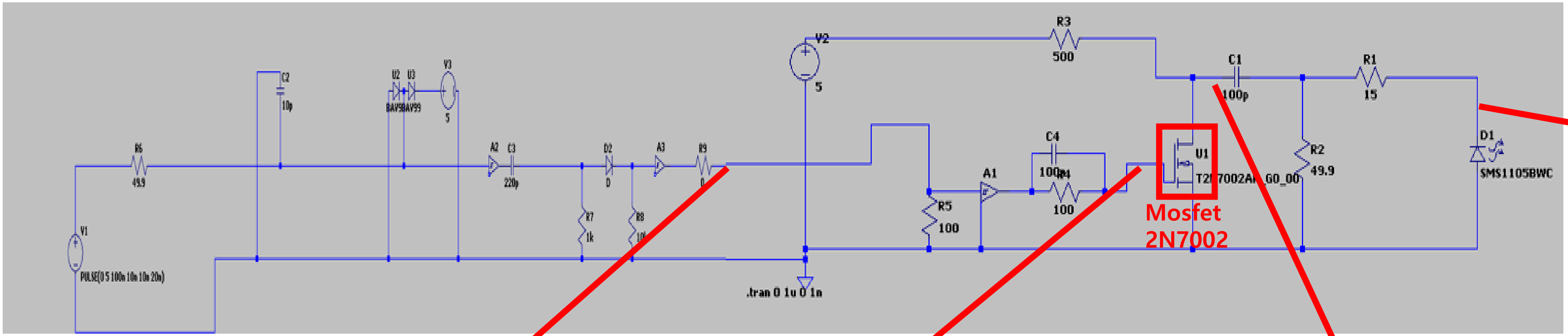


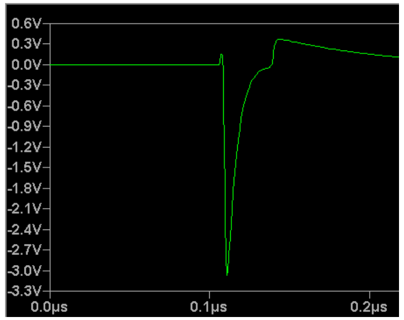




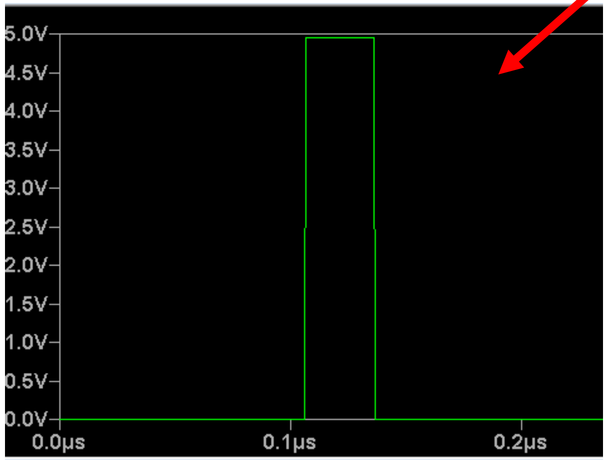
- LED board attached with lightguide (20 mm X 18 mm)
- Many channel LED board
- Full LED board operation using a flexible PCB
- 1 channel LED board for LED test

LMS – Simulation for KNU Board

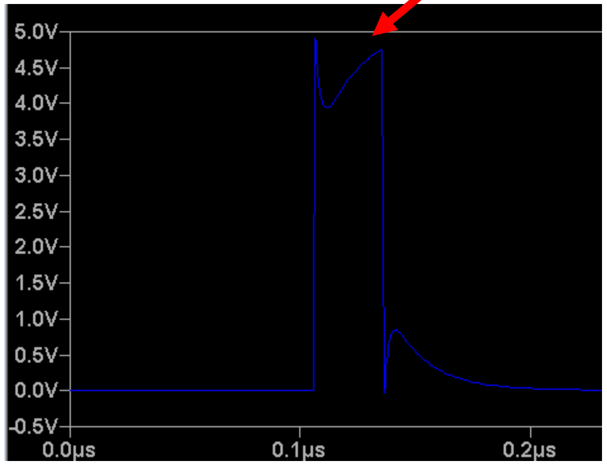




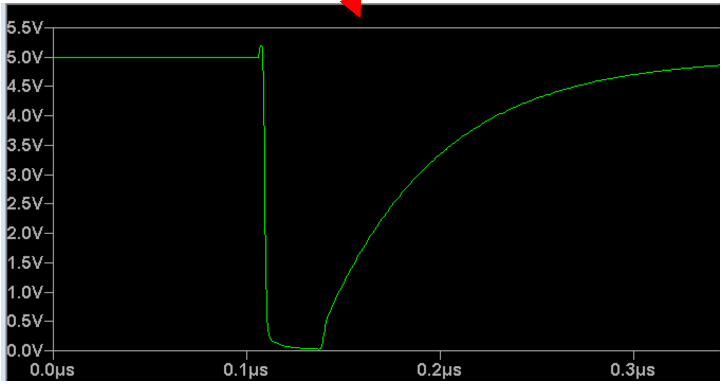
Voltage signal applied to the LED



Trigger signal for the applied voltage at the end of controller board

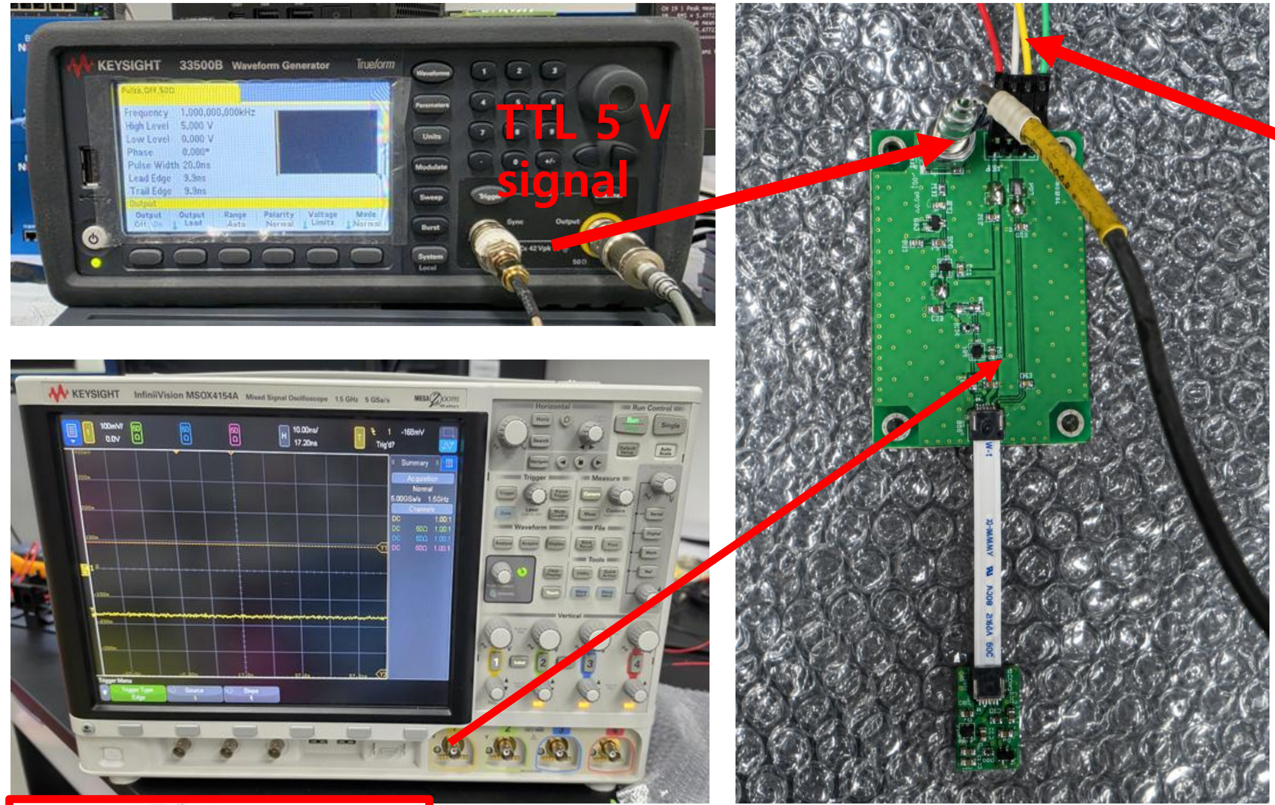


Trigger signal for the applied voltage before the mosfet



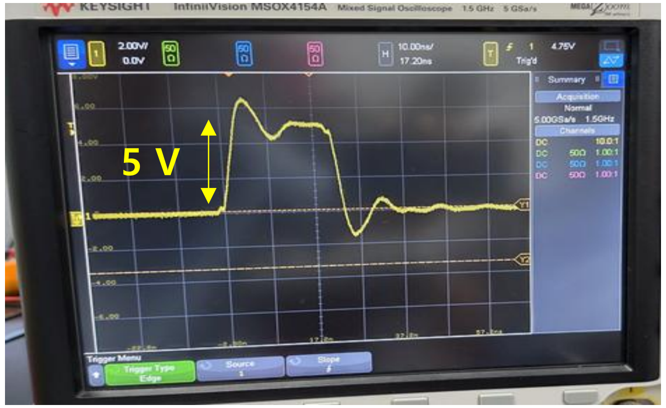
Recharging after the voltage charged (Discharged by the mosfet)

LMS – Oscilloscope signal

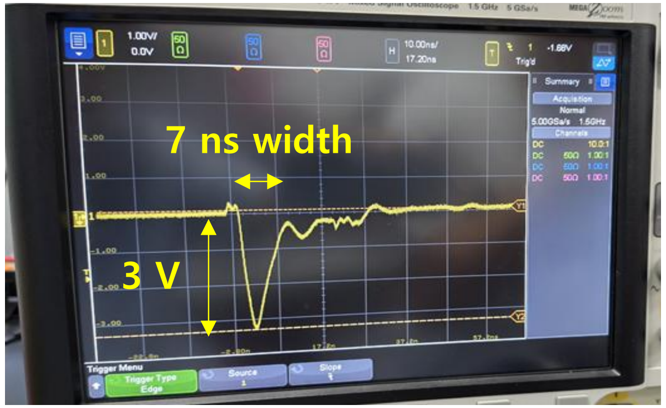


LED voltage 5 V

+5 V for buffer



Trigger signal before the mosfet

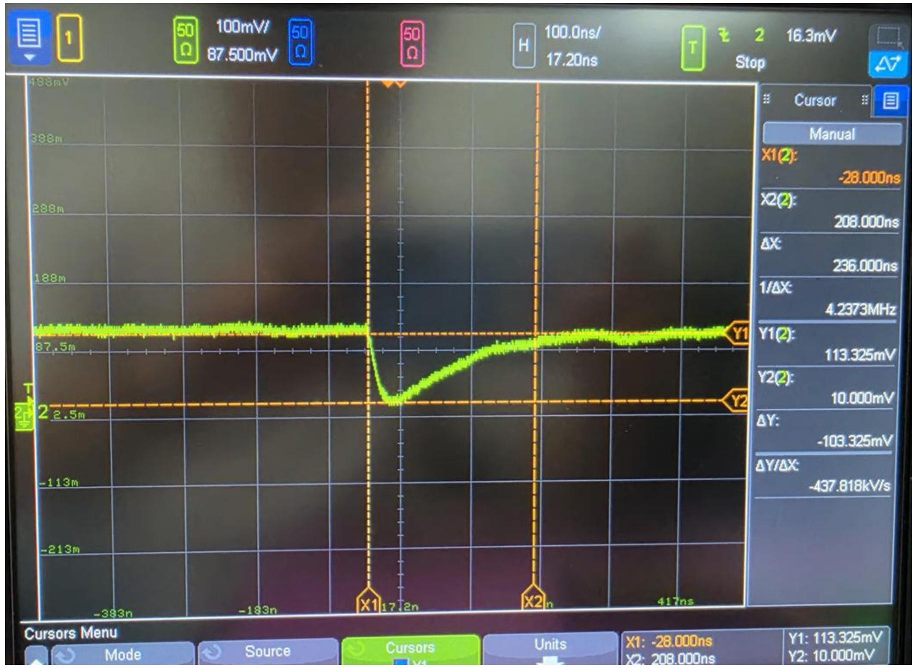


Voltage signal applied to the LED

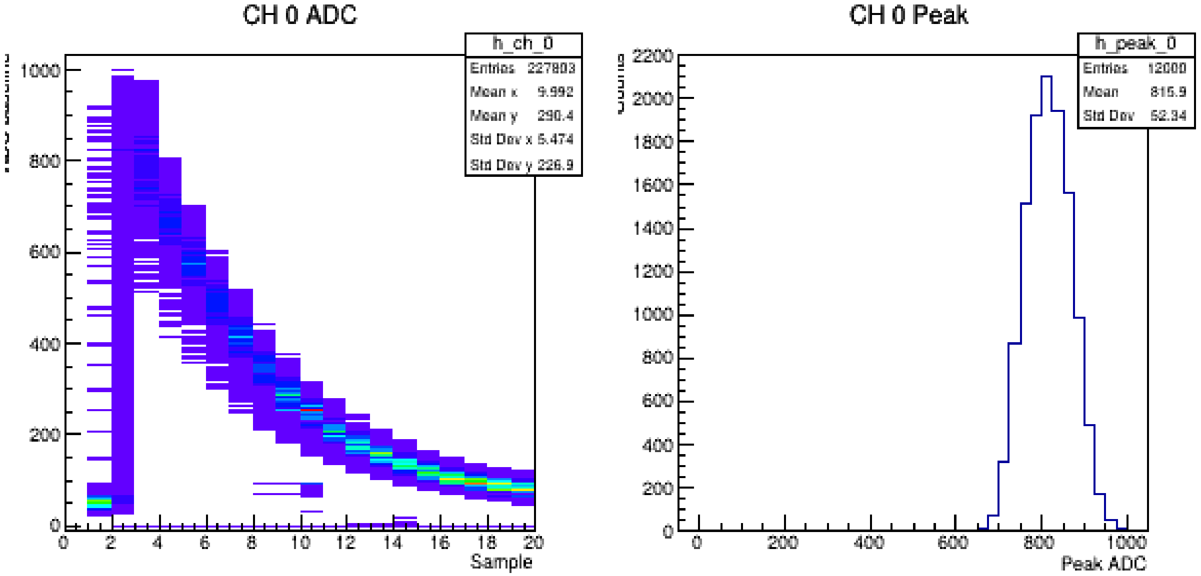
Signal with passive probe

- Signals are similar between simulation & oscilloscope

LMS – SiPM Signal with LED board



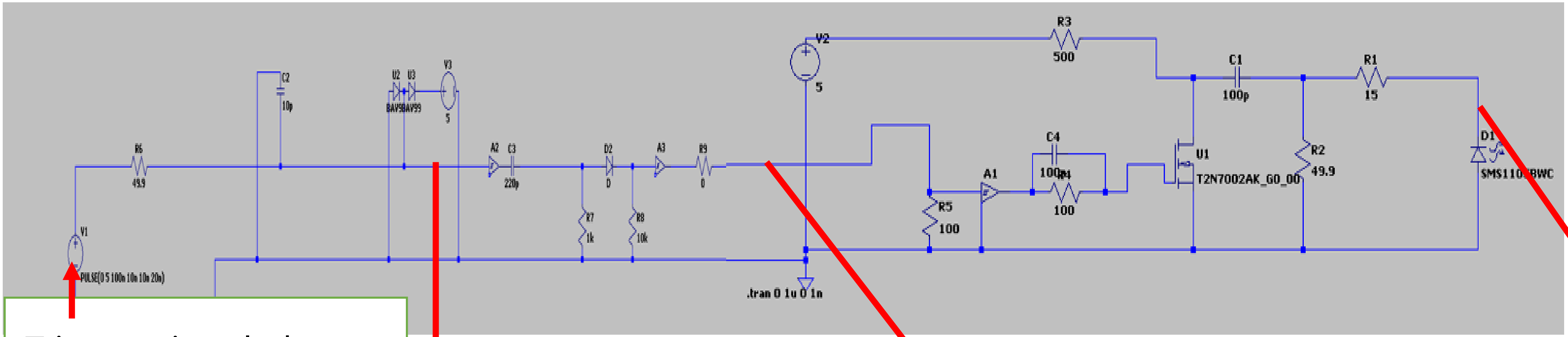
LED signal with oscilloscope



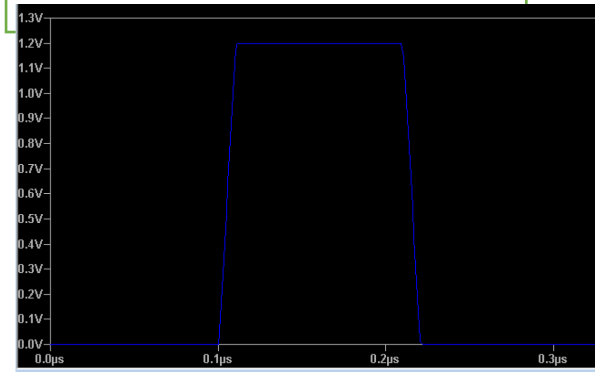
LED signal with H2GCROC

- LED voltage : 4.8 V
- LED trigger : 5.0 V TTL (For function generator)
- Signal exist (Both Oscilloscope & H2GCROC)

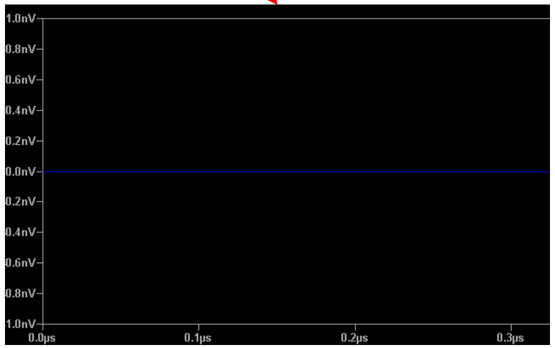
LMS – Additional simulation (Norbert's comment - 1)



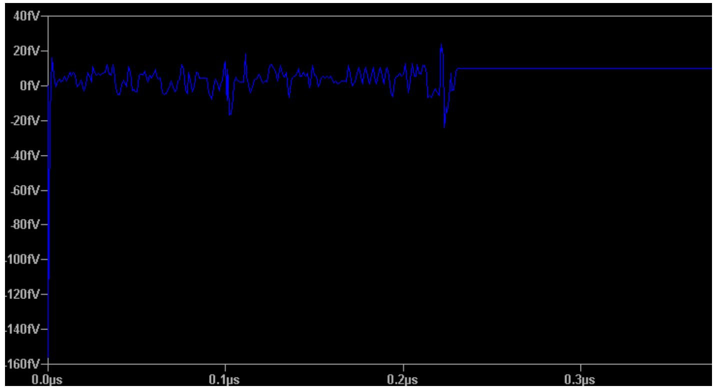
Trigger signal change
20 ns, 5 V TTL
To
100 ns, 1.2 V TTL



Trigger signal before the schmitt buffer

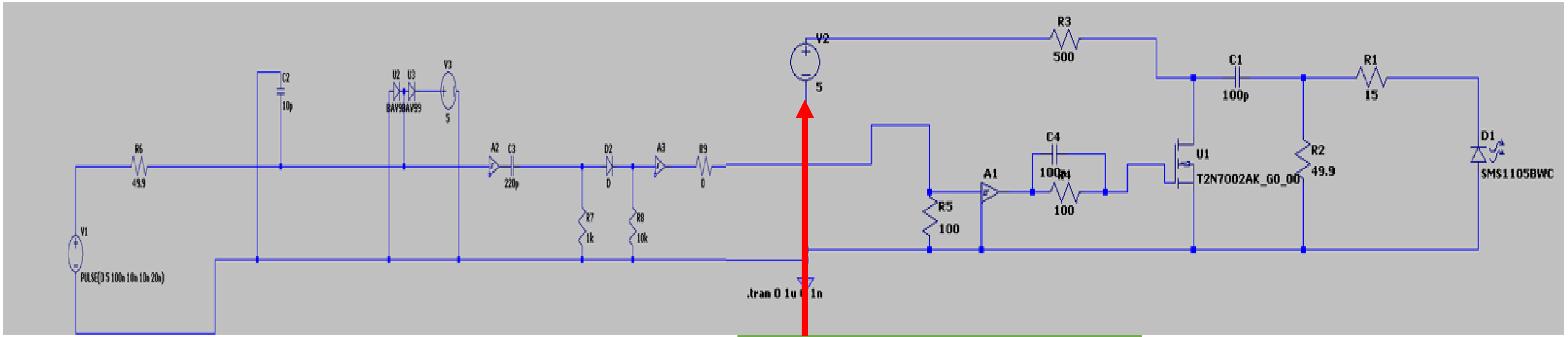


Trigger signal disappear
after the Schmitt buffer



No voltage signal to the LED
(femto volt scale signal)

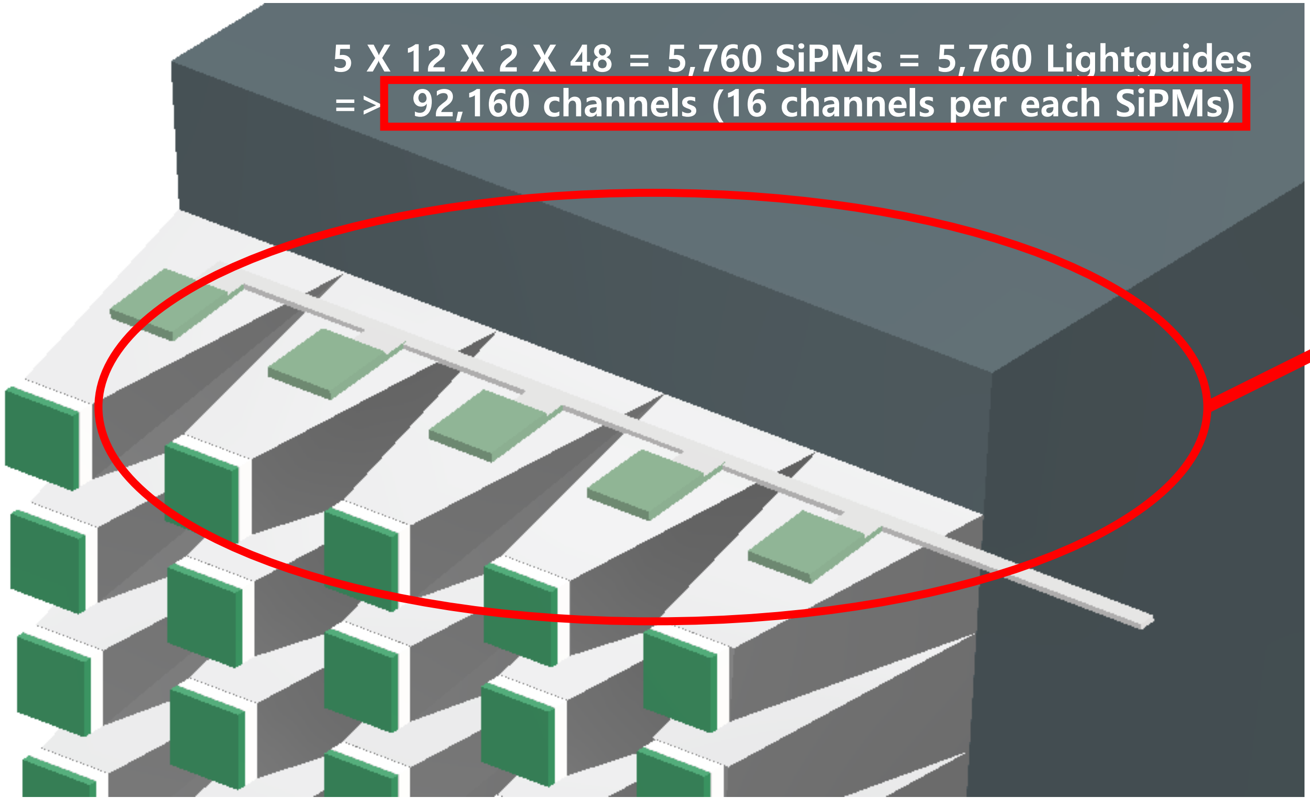
LMS – Additional simulation (Norbert's comment - 2)

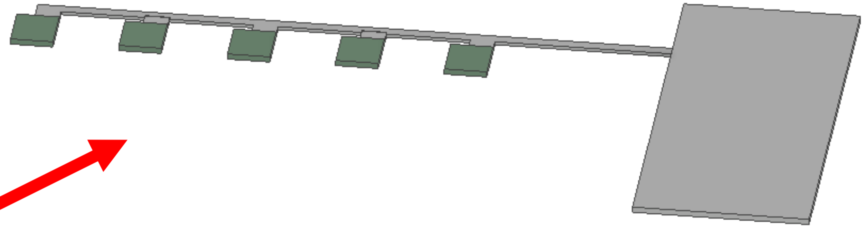


LED voltage change

- LED voltage change with 12-bit DAC on the LpGBT (Low-Power GigaBit Transceiver – ASIC)

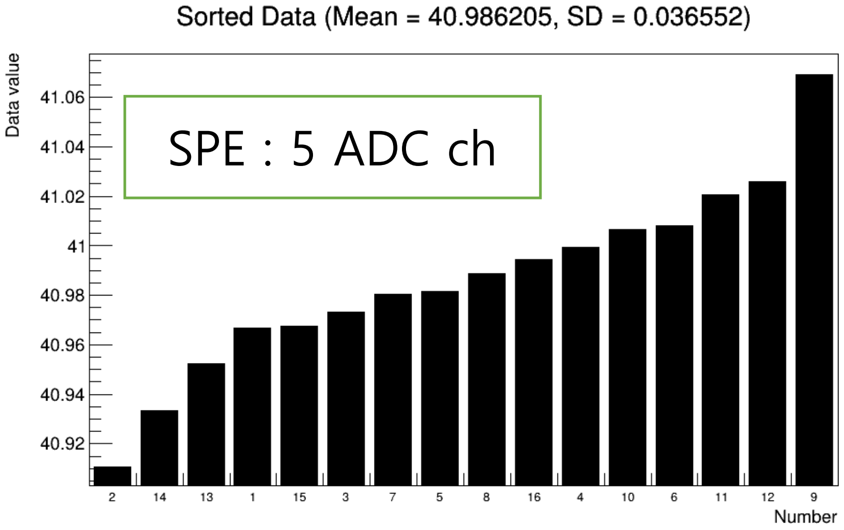
SiPM channels for LMS

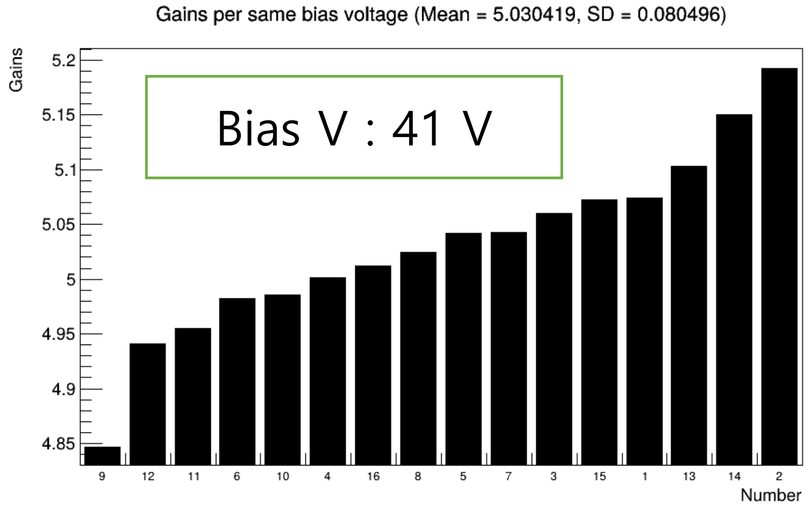


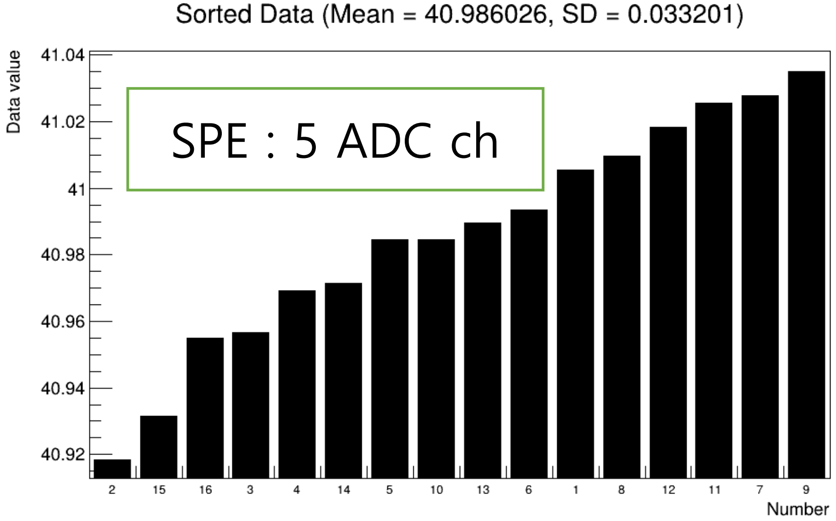


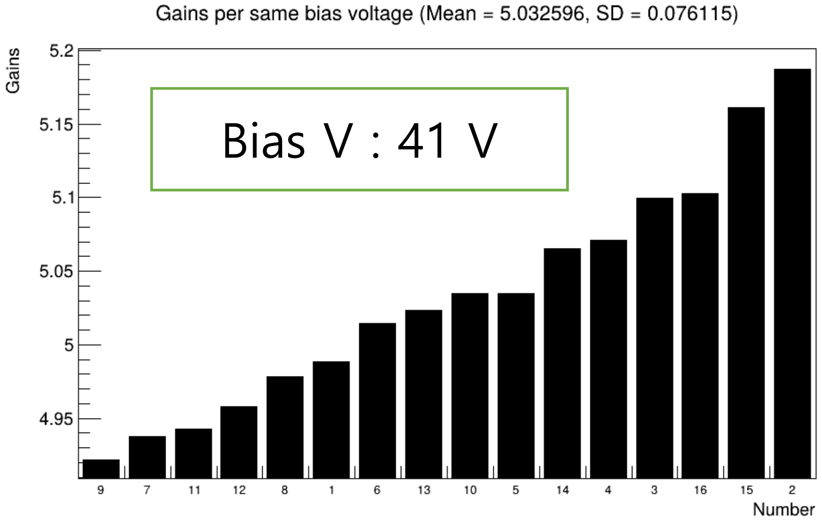
- About 92,000 channels for BIC
- Gain calibration is quite challengeable

Gain calibration results









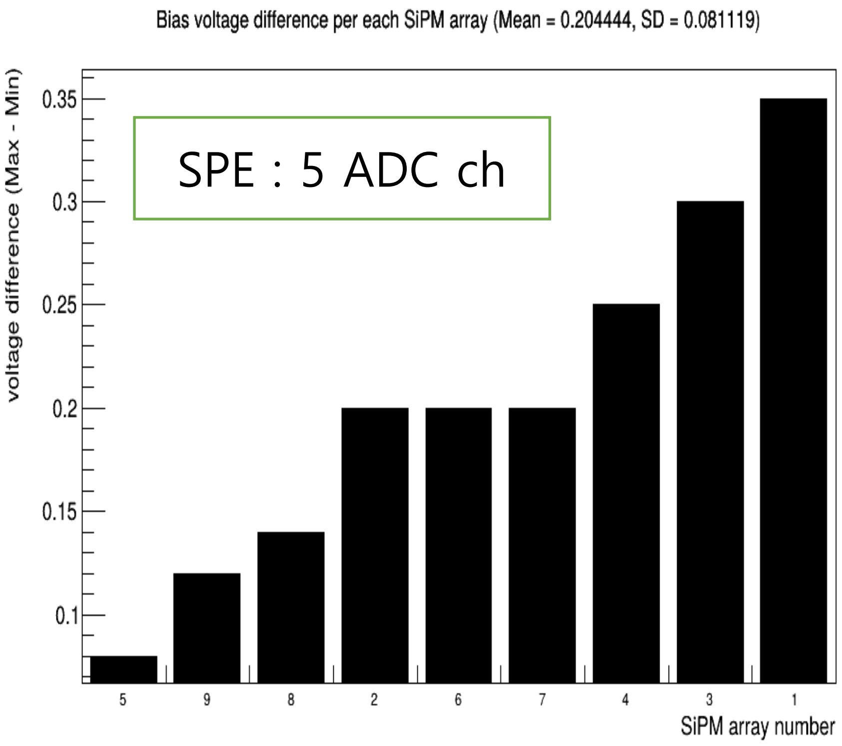
Bias voltage per each channel

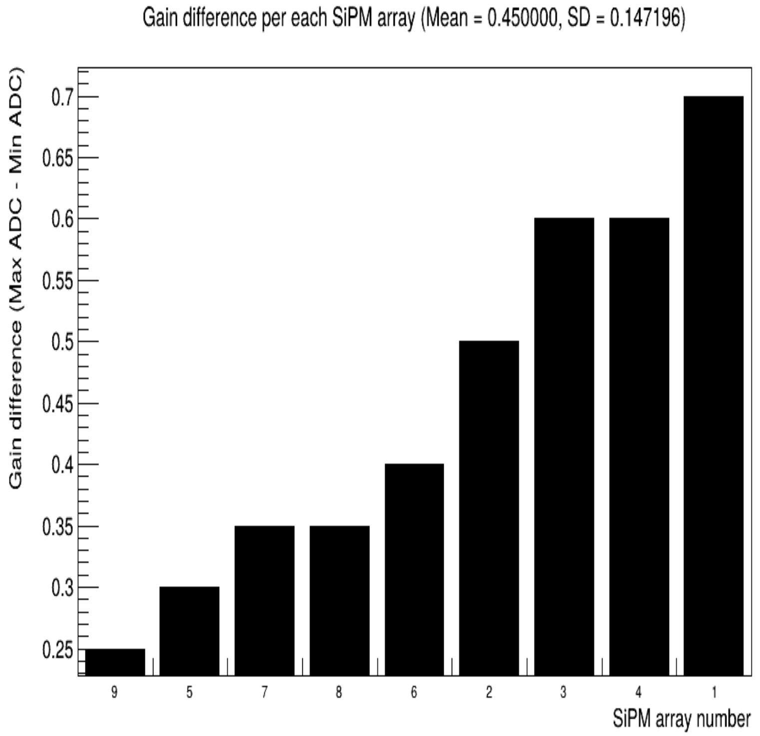
SPE (ADC) per each channel

- SiPM 16 channel array (Used at KEK beam test at May)
- Bias voltage difference => 0.2 V at same SPE (5 adc ch)
- SPE difference => 0.4 adc ch at same bias voltage (41 V)

Gain calibration results

Bias V : 41 V

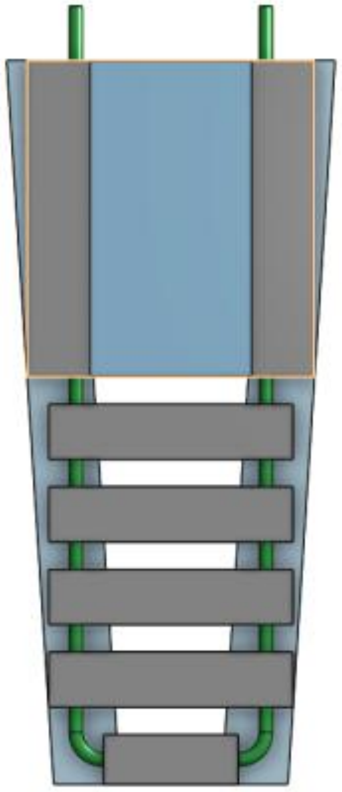




- 9-SiPM array
  (All gain calibrated boards)
- Bias voltage difference per each SiPM array
  => mean : 0.204, std : 0.081
- Gain difference per each SiPM array
  => mean : 0.45, std : 0.147

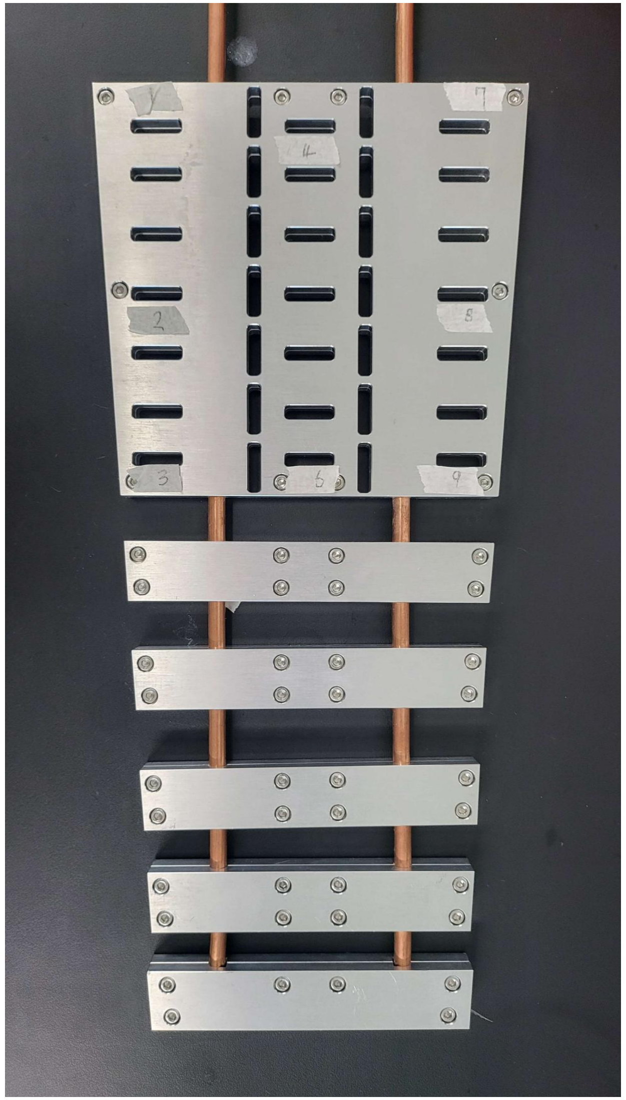
2. Cooling System

Cooling System at KNU



- Design by Manitoba University

- Cooling Simulation Condition
- Side 1 : ESB PCB with SiPMs
- Side 2 : CALOROC and AstroPix ETC
- Design Dimension
  - Cu cooling lines ¼″ OD
  - Aluminum cold plate thickness ½″
- Required temp. : 7°C ±1°C (based on GlueX experience)
- 7°C chilled water
- 0.3 gal/min (~1.1 L/min)



- KNU cold plate

Cooling System at KNU

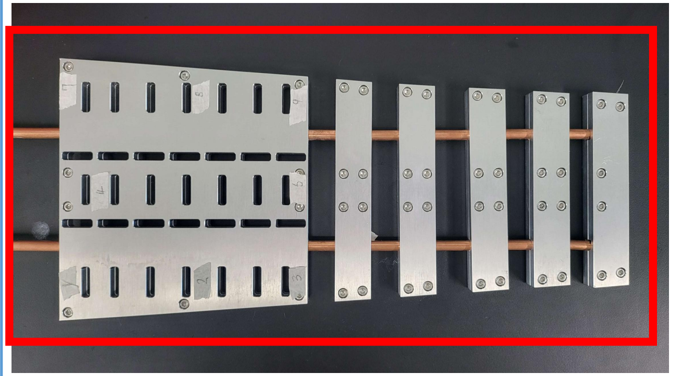
Additional
Pump
(flow rate : 1.16 L/min)

Chiller

Silicon Tube | Copper Tube

Water inlet
(5°C ±1°C)

Water outlet
(7°C ±1°C)



BIC Cooling Plate

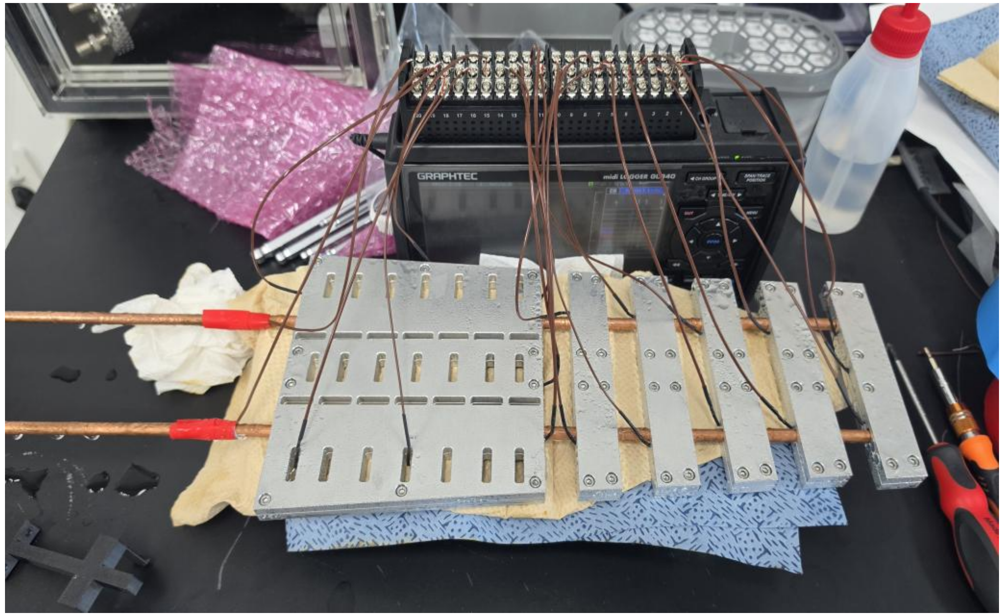
Data logger monitoring
(PC)

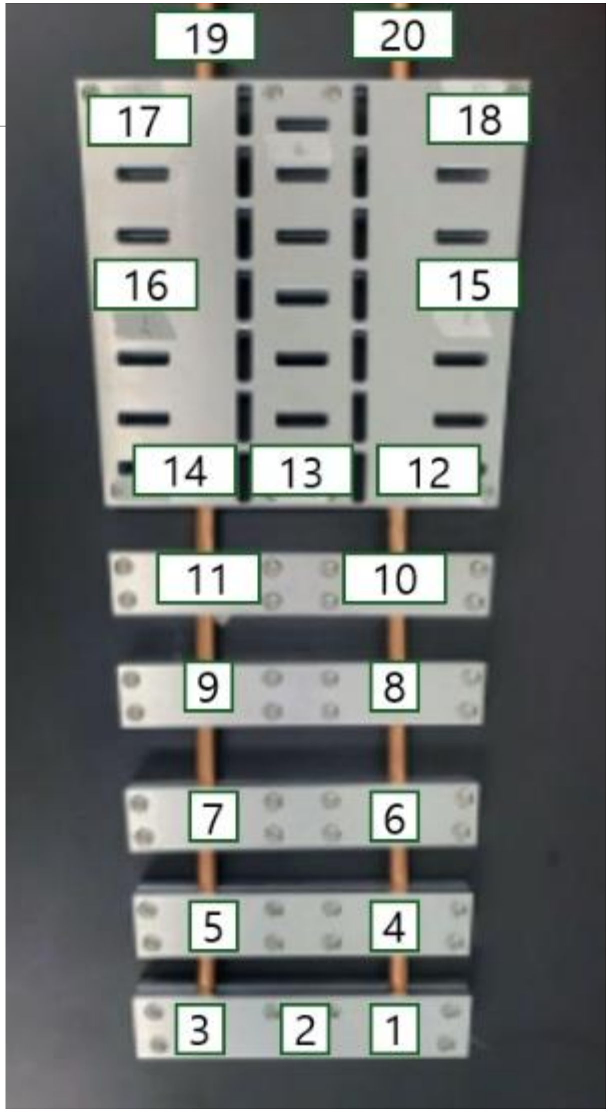
Data logger
(GRAPHTEC GL840)

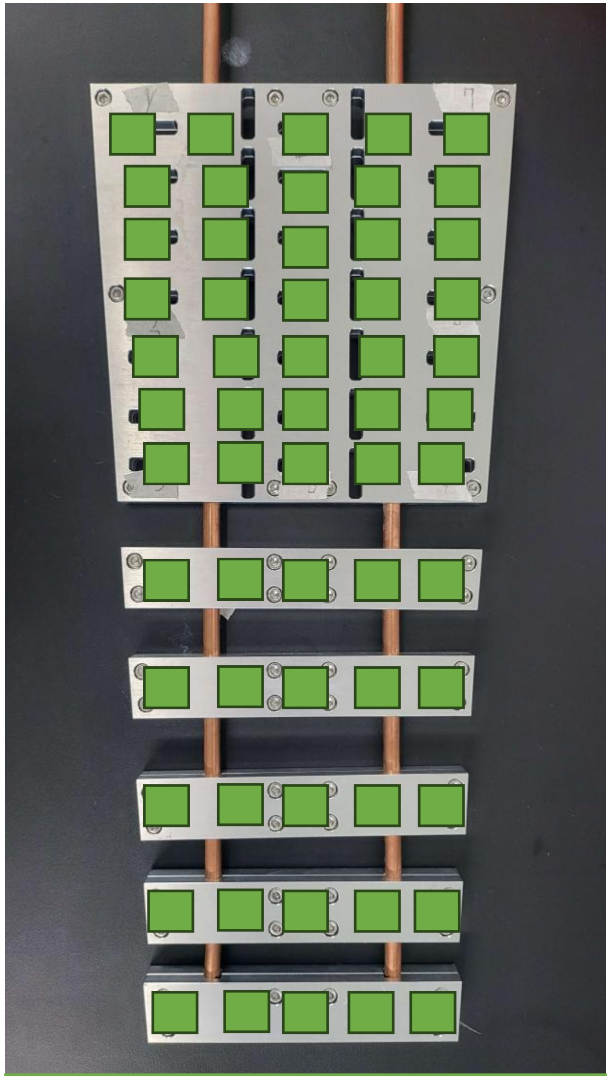
Thermocouple
(T-type)

- Cooling system with data logger & thermocouple.
- Plan to make a dummy board for cooling test

Cooling system

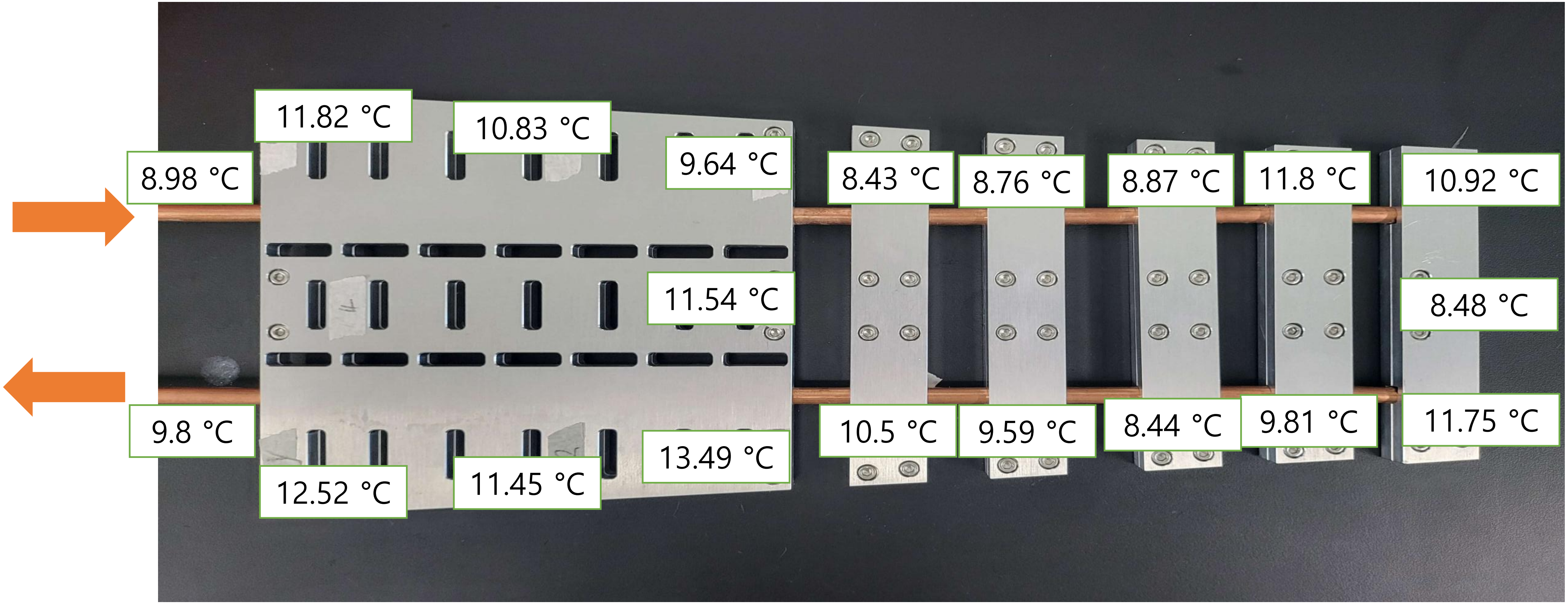





Expected SiPMs location

- 20 point on Al plate
- Same length of thermocouple
- Flow rate : 1.16L/min => 7 days
- Flow direction : 20 -> 18 -> 15 -> 12 -> 10 -> 8 -> 6 -> 4 -> 1 -> 2 -> 3 -> 5 -> 7 -> 9 -> 11 -> 14 -> 16 -> 17 -> 19
- SiPM (S14161-3050HS-04) temperature coefficient of recommended reverse voltage : 34 mV/°C

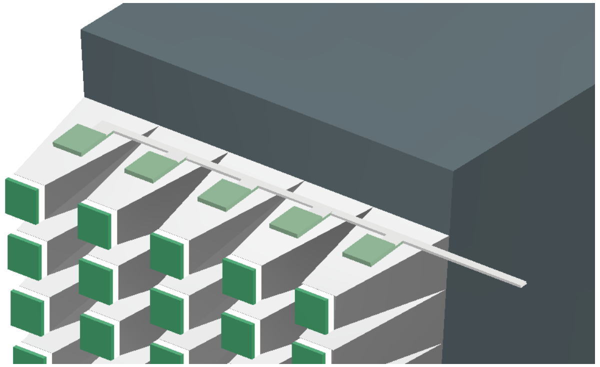
Average temp. at 20 points



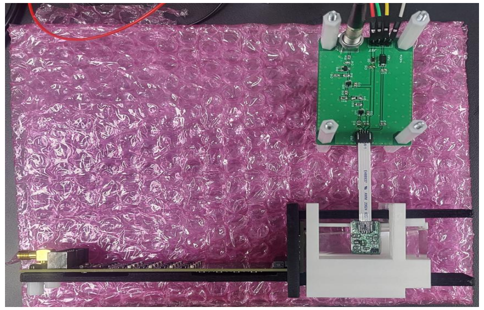
- Average temperature data received over 7 days
- Difference temperature at each point : about 1~2°C, max : 5°C

Summary

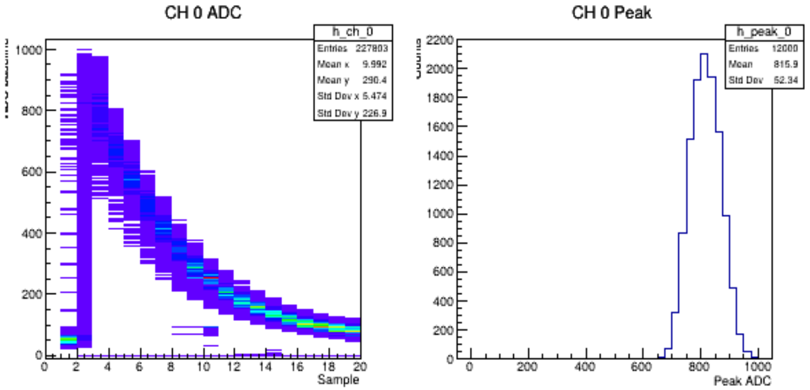
- LMS at KNU => LED signal exist with H2GCROC
- Too many channels (about 92,000)
  => Gain calibration is challengeable
- Gains per each 16 channels at same bias voltage
  => Gain difference : maximum 0.4 adc ch
- Cooling system at KNU
- Temperature data received over 7 days



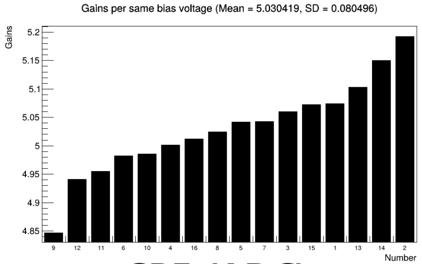
LMS system



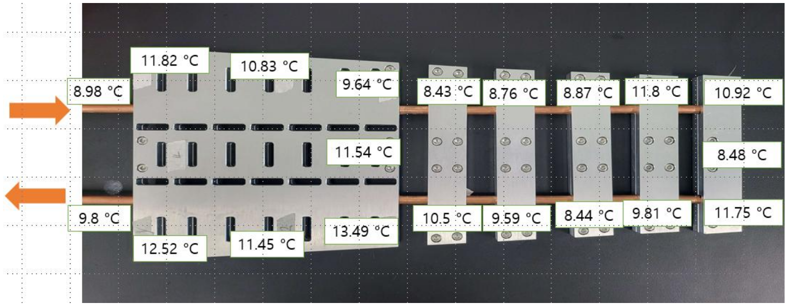
LED test board



LED signal



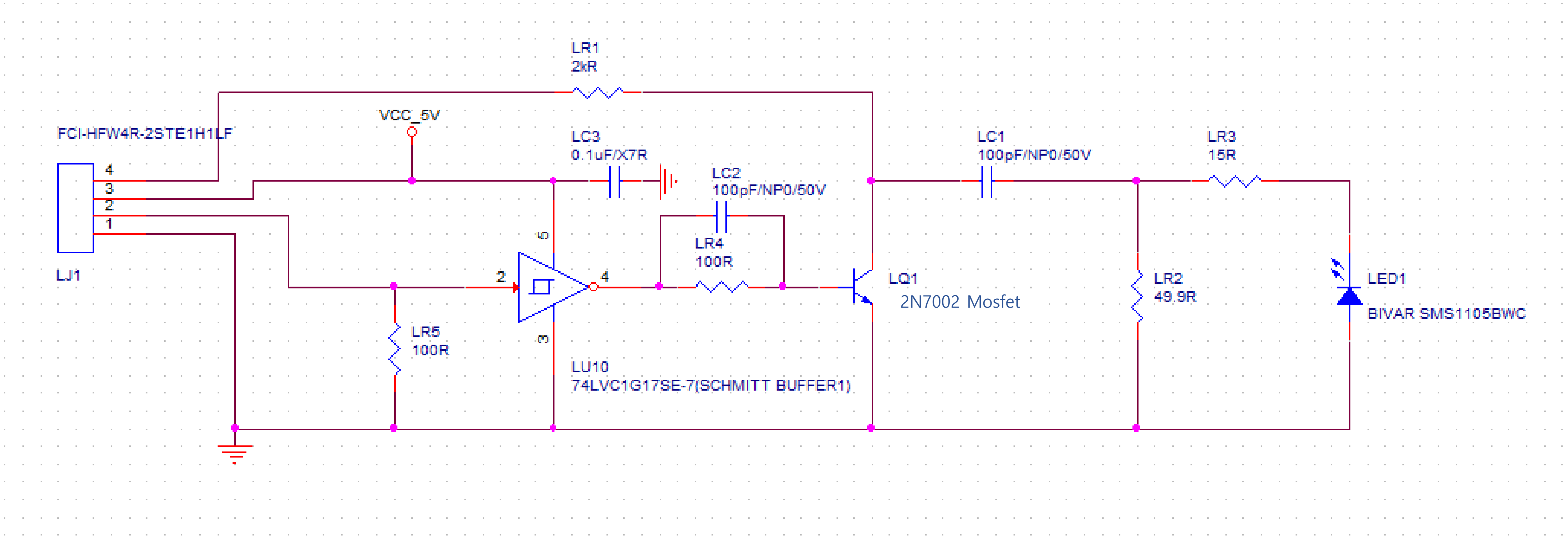
SPE (ADC)
per each channel



Average temp. at 20 points

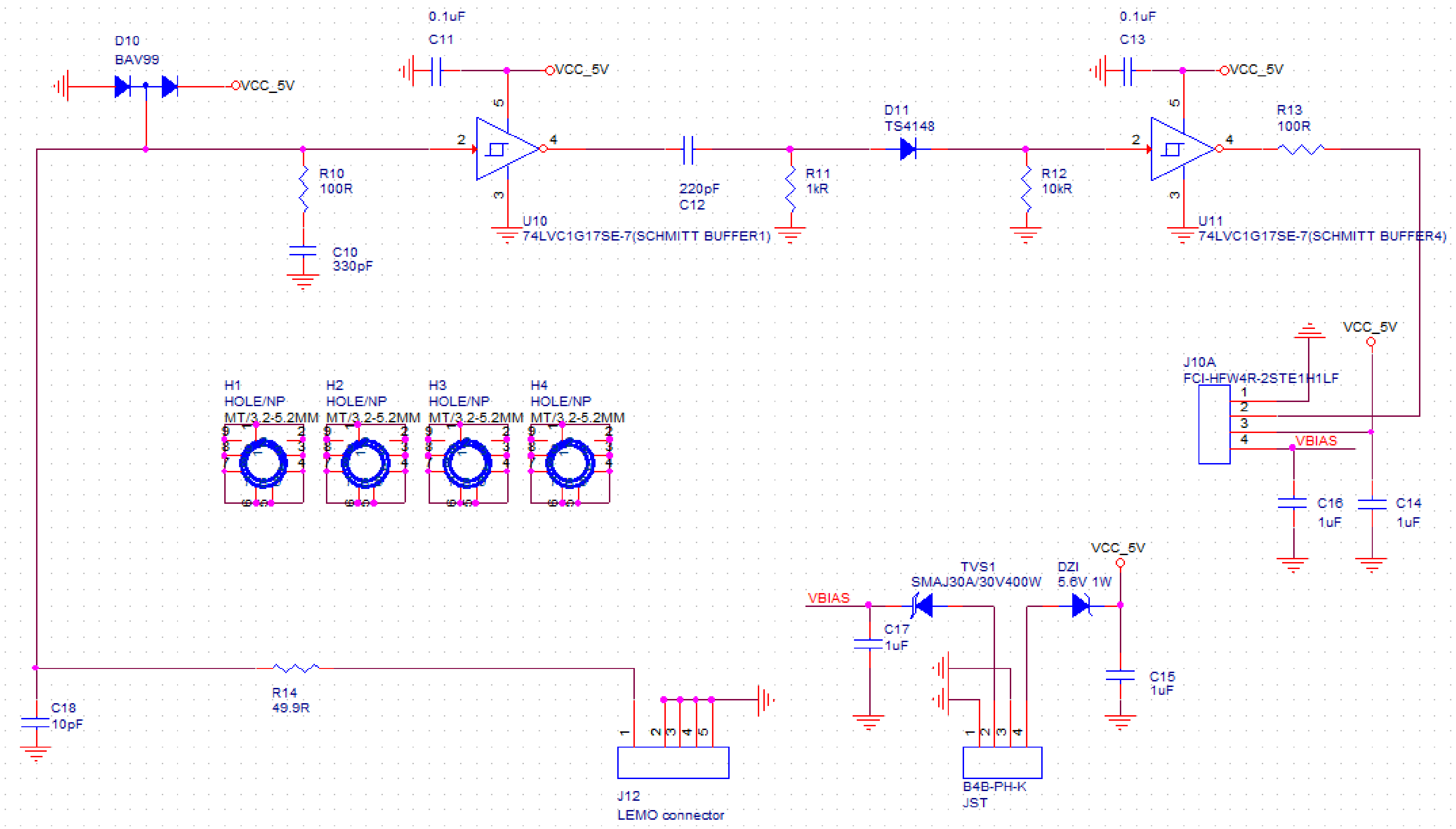
Backup

LED circuit



- KNU LED board circuit
- Schmitt Buffer for accurate trigger signal transmission
- Mosfet fot switch ➡ Discharge the capacitor (LC1) ➡ 7 ns, 3 V voltage pulse is applied to LED

LED circuit



- KNU Controller board circuit
- 1 channel for test circuit (Ultimately 7 channel for BIC bulk)

LED circuit

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Relative gain monitoring of the GlueX calorimeters ☆

CrossMark

E.G. Anassontzis [a], P. Ioannou [a], C. Kourkoumelis [a,*], G. Vasileiadis [a], G. Voulgaris [a], E. Kappos [b], T. Beattie [c], S. Krueger [c], G.J. Lolos [c], Z. Papandreou [c,**], A.Yu. Semenov [c], J. Frye [d], J. Leckey [d], M.R. Shepherd [d], T. Bogart [e,1], D. Lawrence [e], E.S. Smith [e]

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The GlueX Collaboration

A R T I C L E I N F O

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Lead glass calorimeter
Sampling calorimeter

A B S T R A C T

The relative gain of the photodetectors for the GlueX Barrel and Forward calorimeters will be monitored using modular LED driver systems. The BCAL system consists of a global controller that feeds power, bias voltage and trigger signals to 96 local controllers situated at the ends of the 48 BCAL modules, which drive 40 LEDs associated with the 40 light guides at the end of each module. The FCAL system consists also of a global controller, a local controller for each acrylic quadrant covering the face of the FCAL, and ten 4-LED pulser boards per local controller connected in a star configuration along the edges of the acrylic panes. The respective systems are currently being installed on the detectors and their tested performance is presented herein.

1. Project background

as a sampling calorimeter and will be deployed inside GlueX's superconducting solenoid

2.1. BCAL LED monitoring design

The monitoring system is designed to track the stability of the MPPC output signals about once per day between data runs and has the advantage that (together with selective HV settings) one can pulse individual MPPCs that are normally summed into an fADC input. Moreover, the observation of each LED by opposite MPPCs on the same readout cell provides a means of separating out temperature drifts as gradients on the upstream and downstream end in conjunction with the MPPC cooling plate temperature recordings.

To minimize cabling, simplify construction and reduce size and cost while maintaining a degree of flexibility in its pulsing options, a modular LED driver system has been designed in three levels. At the top level, a global controller feeds power, bias voltage and four trigger signals to 96 local controllers situated at the ends of the 48 BCAL modules, one controller per module per side. At the next level, each local controller (or BCAL controller) pulses the 40 LEDs associated with the 40 light guides at the end of a module as four independent trigger groups. Each group corresponds to one of the four columns of ten light guides shown in Fig. 1(d). LEDs in the same group are fired simultaneously by one of the four trigger signals, illuminating an entire column of light guides. At the third level, a miniature 1-LED pulser circuit board is attached directly onto each light guide, directing light towards the opposite end of the module. LED pulser boards in groups of ten are attached to a common bus cable connected to the controller board. The configuration of a BCAL controller with 40 LED pulser boards instrumenting one end of one module is shown in Fig. 2.

BCAL controllers buffer the four in-coming trigger signals and relay each one to one column of ten LEDs using a bespoke flat flexible cable to carry the common trigger along with the bias and supply voltages, as illustrated in the left panel of Fig. 3. Finally, each pulser board regenerates the in-coming trigger using a fast, high-current buffer to obtain a clean, fast-rising waveform which drives a high-speed MOSFET switch. This results in an ≈7 ns FWHM light pulse as a charged capacitor discharges through the LED. The actual circuit board is depicted in the right panel of Fig. 3.

The pulser circuit schematic is shown in Fig. 4. The energy

BCAL end view

single module end

Fig. 1. Sketch of Barrel Calorimeter readout. (a) A three-dimensional rendering of the BCAL; (b) top-half cutaway (partial side view) of a BCAL module showing its polar angle coverage and location with respect to the GlueX LH_2 target; (c) end view of the BCAL depicting all 48 azimuthal modules and (d) an end view of a single module showing the readout segmentation. More details can be found in the text.

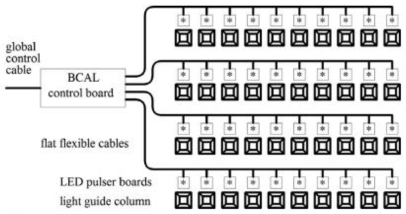


Fig. 2. Configuration of the BCAL LED monitoring system. The 335 mm bespoke flat flexible cable caters for the slightly varying pitch between light guides.

Fig. 3. Left panel: one end of a prototype BCAL module, showing two of its four columns of light guides. The LED pulsers are mounted on the side of the light guides attached to a common flexible cable. The free end of the flexible cable connects to the control board (not shown here). Right panel: BCAL LED pulser

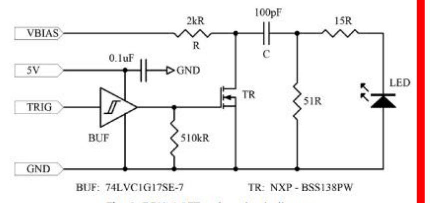


Fig. 4. BCAL 1-LED pulser circuit diagram.

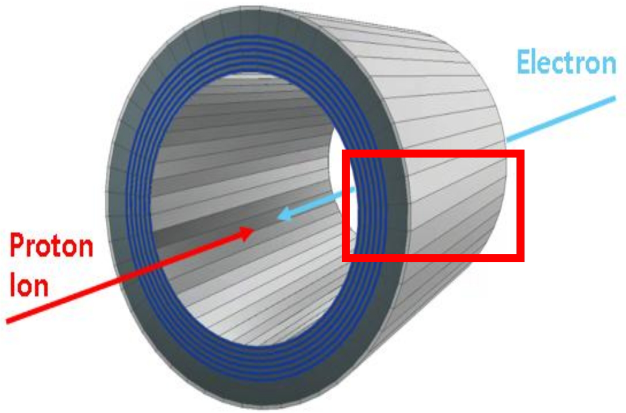
LED monitoring system is independent of the MPPC bias distribution system, thus allowing independent monitoring of individual MPPCs through each readout sum. In summary, the BCAL system employs a total of 3840 (48 × 2 × 40) LED pulser boards, 384 flat flexible cables, and 96 (48 × 2) controllers. Details of the BCAL monitoring system can be found elsewhere [10].

Major considerations in the design of the LED light pulser were (1) to minimize its physical size, due to the very limited space available between light guides as is evident from Fig. 3, (2) very low power dissipation, to minimize temperature variations that deteriorate the performance stability of the LEDs, (3) to achieve nanosecond performance with a wide variety of LED types and wavelengths, (4) to control the emitted pulse intensity, and (5) to minimize any electromagnetic interference that might affect the performance of MPPCs. On those grounds, and mainly (1), pulser designs based on monostable multivibrators, avalanche transistors

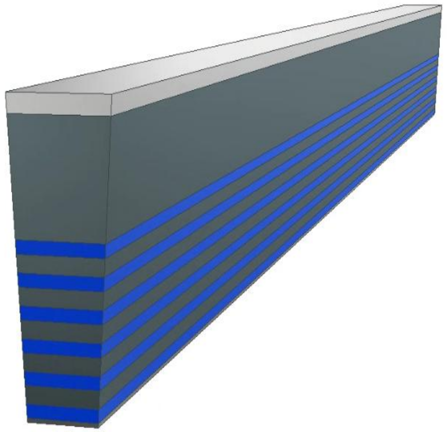
- Origin of the KNU LMS Design

  By Dr. Efstratios Anassontzis & Prof. Zisis Papandreou

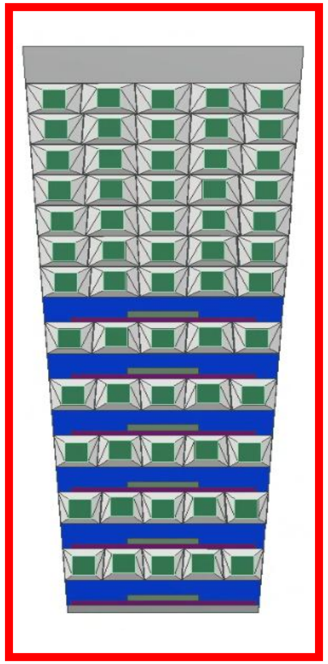
Overview of BIC



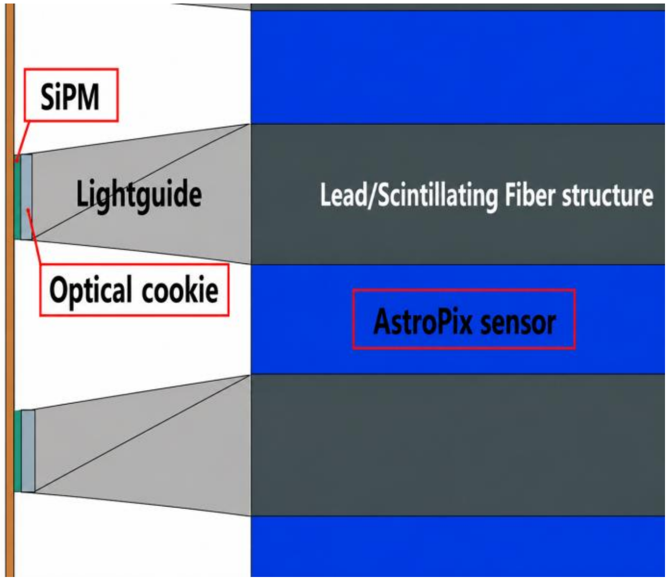
Barrel Imaging Calorimeter (BIC)
(48 sectors)



1 sector of BIC



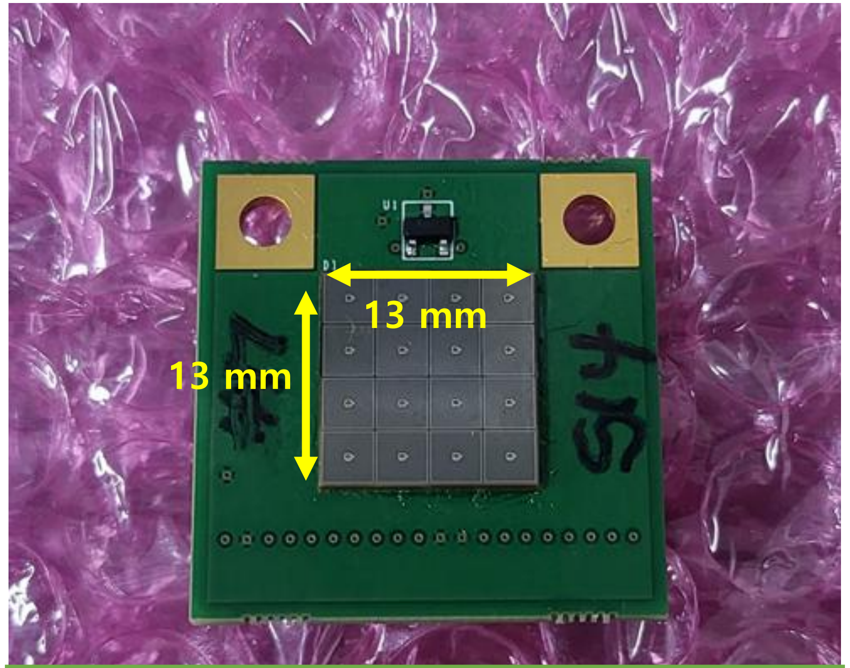
End of the sector
60 SiPMs + Lightguides



Side selectional details

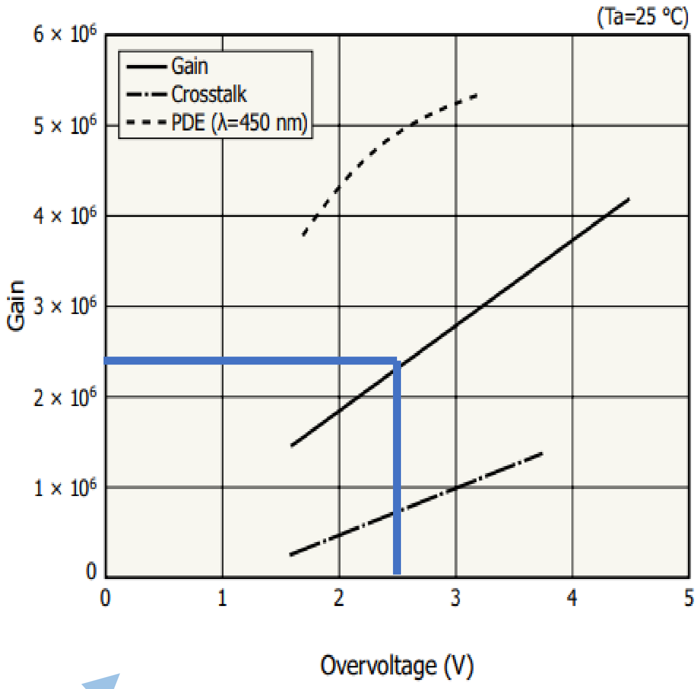
- Calorimeter readout Requirements
  - BIC energy resolution
  - Gain calibration mechanism
  - Light Monitoring System (LMS) structure

SiPM Gain Calibration



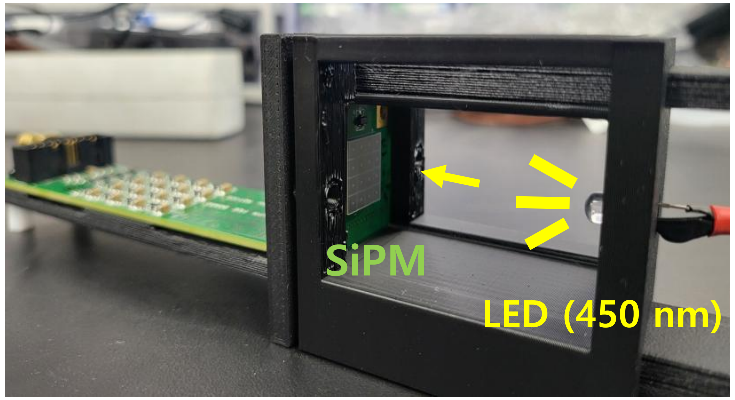
Hamamatsu SiPM
S14161-3050HS-04

- Photo Detection Efficiency : 50% (450 nm)
- operating voltage 38.5 V
- Gain : 2.5 × 10^6 at overvoltage 2.5 V
- 16 channel per 1 SiPM array
- 3531 pixels per 1 channel



SiPM gain curve
(Overvoltage – Gain)

- Each channel has different Vbr
- SiPM bias voltage ∝ SiPM gain
- Gain calibration of each channel is critical
- To draw gain curve…
  → LED setup !!



LED test setup

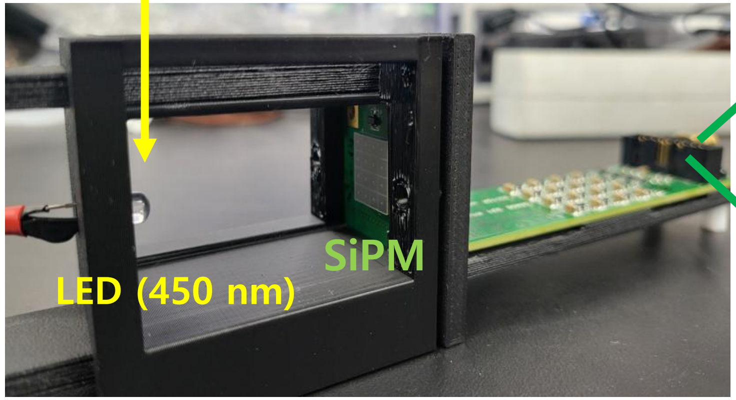
SiPM Gain Calibration – LED Setup

Function Generator

TTL

Function Generator
- Frequency : 1kHz
- Pulse width : 20 ns
- LED volt : 1.65 V

BIC DAQ



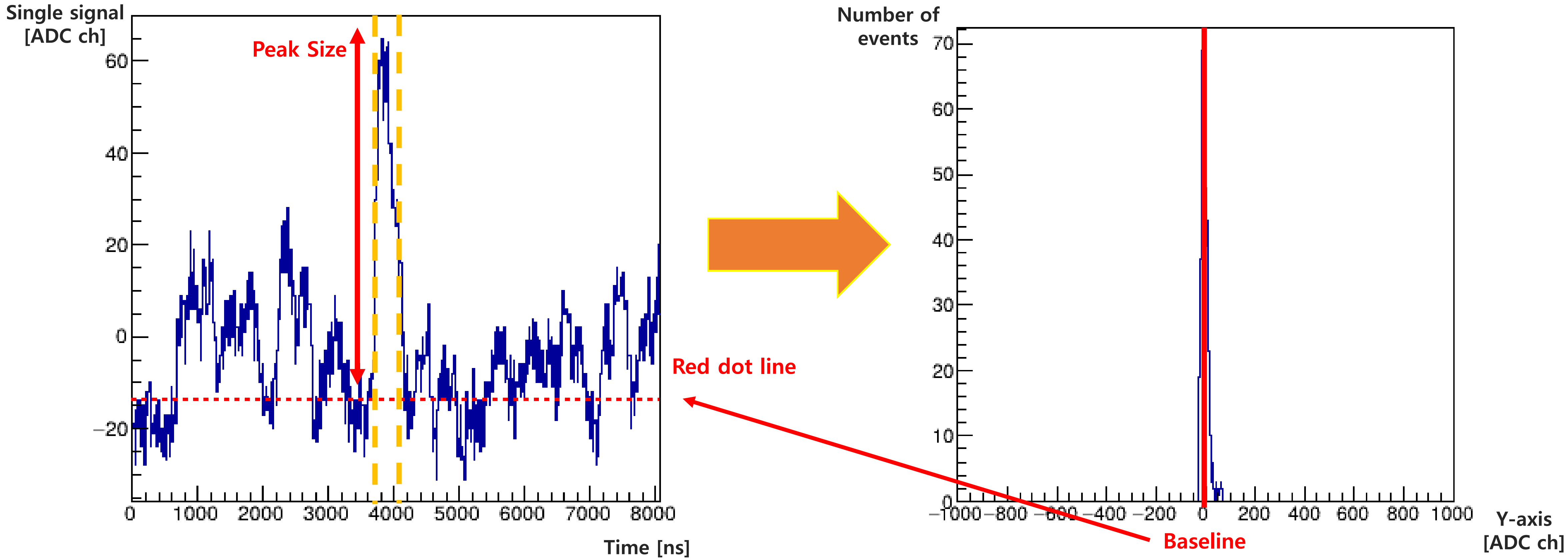
Power Module

- 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

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

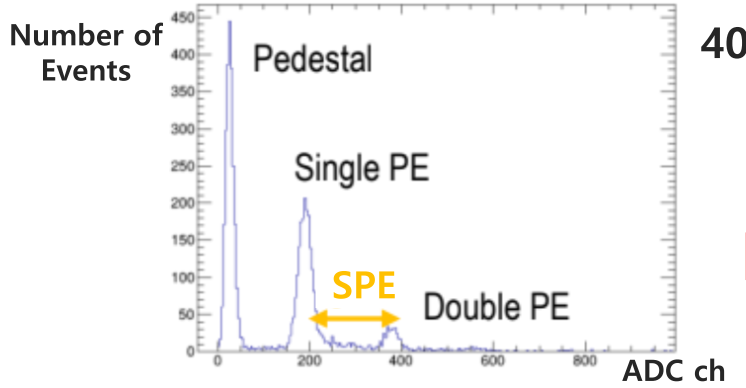
SiPM Gain Calibration – LED Logic



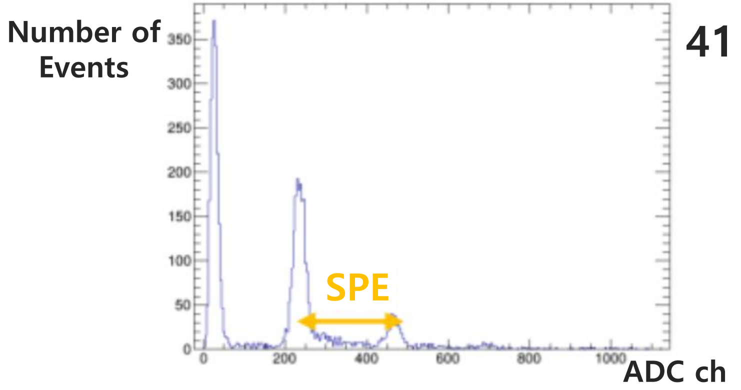
- Single event of SiPM each channel per each bias voltage
- To measure single photoelectron (SPE), Low intensity of LED was needed

- 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))

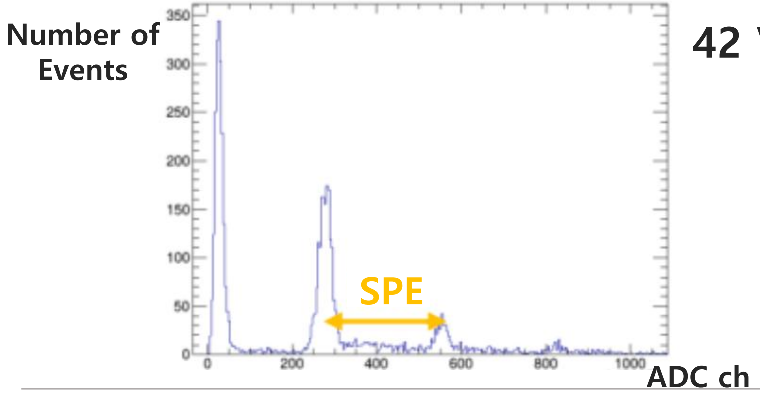
SiPM Gain Calibration – Peak ADC Distribution



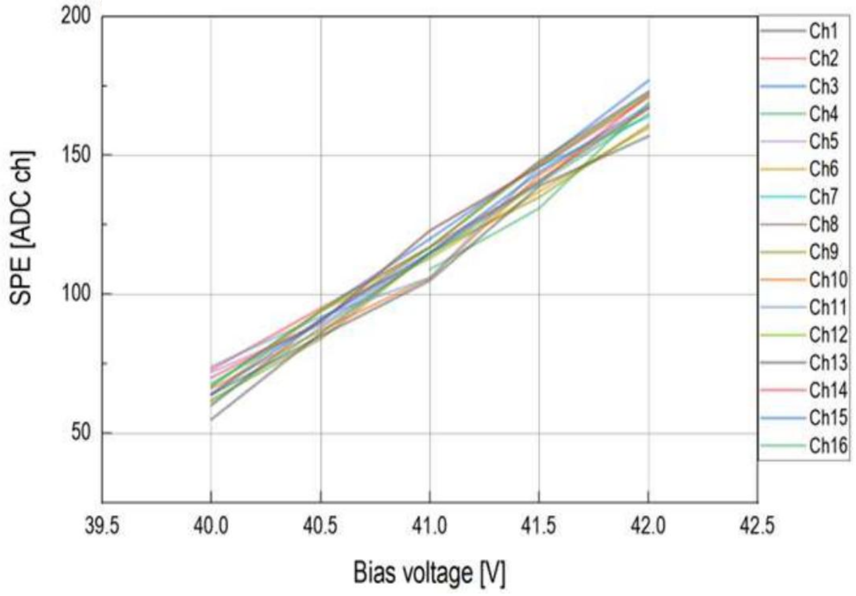
40 V SiPM



41 V SiPM

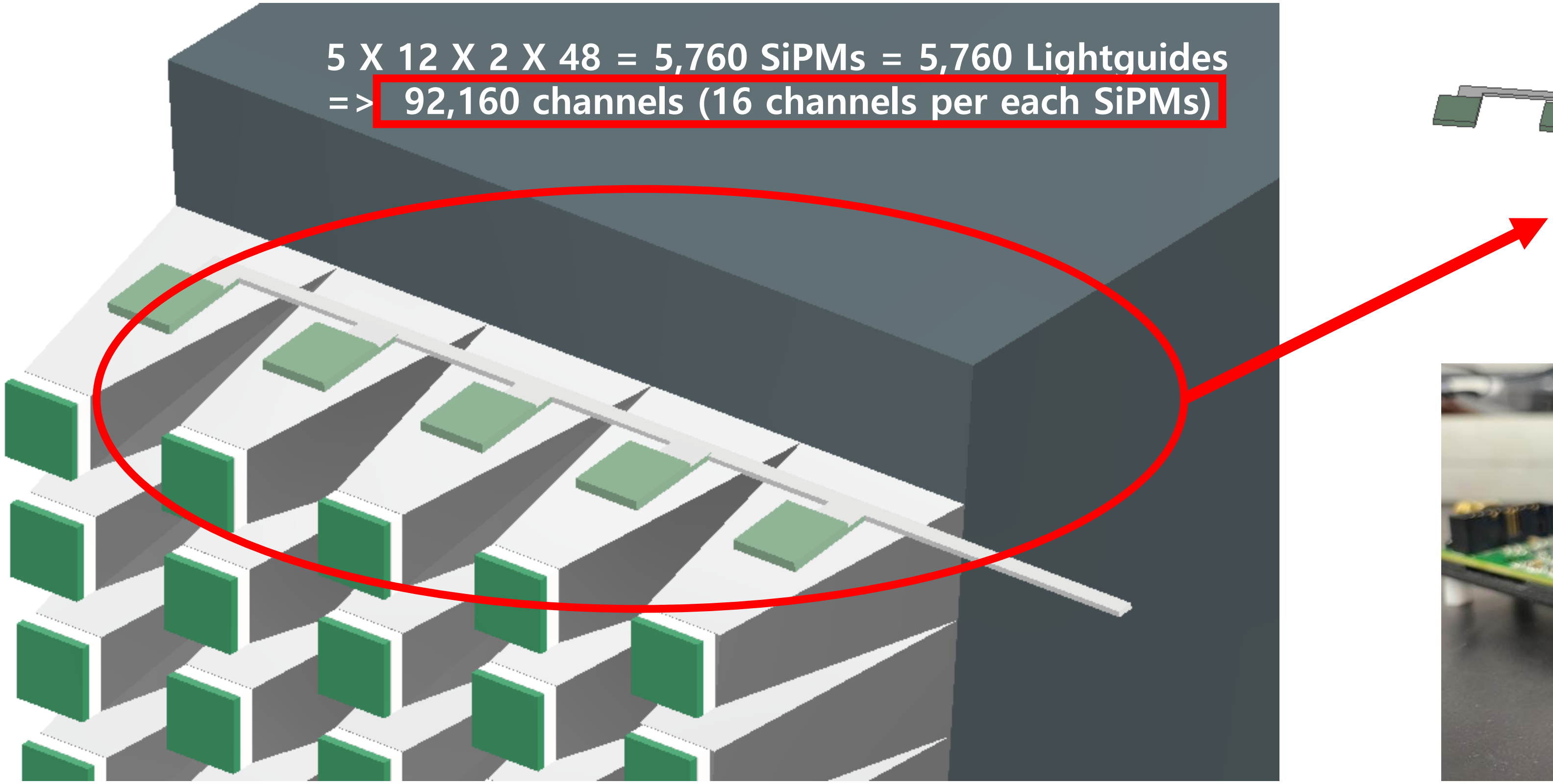


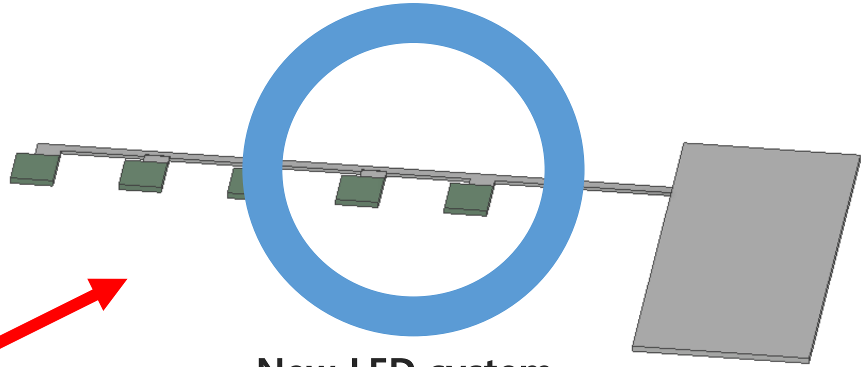
42 V SiPM



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

Light Monitoring System (LMS) - Overview



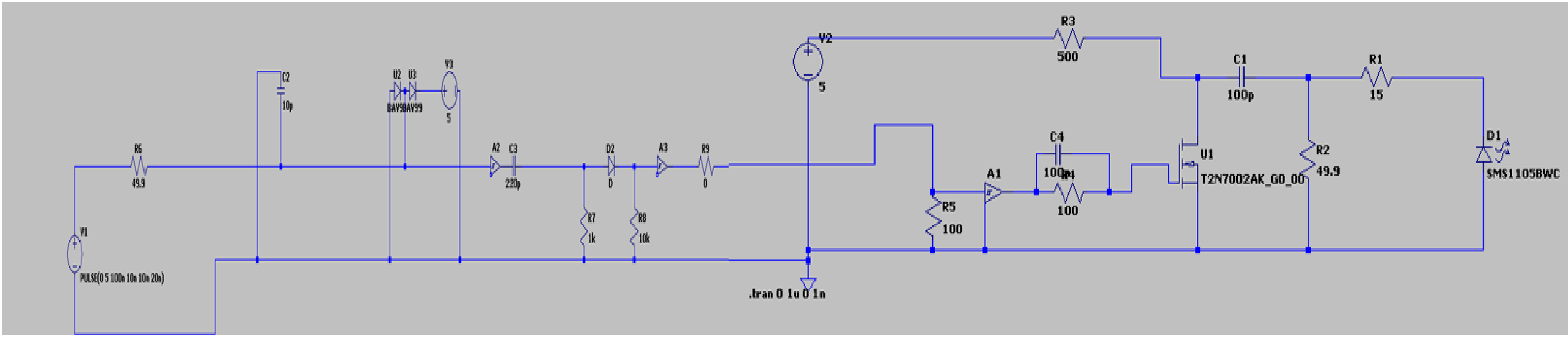


New LED system

Previous LED setup

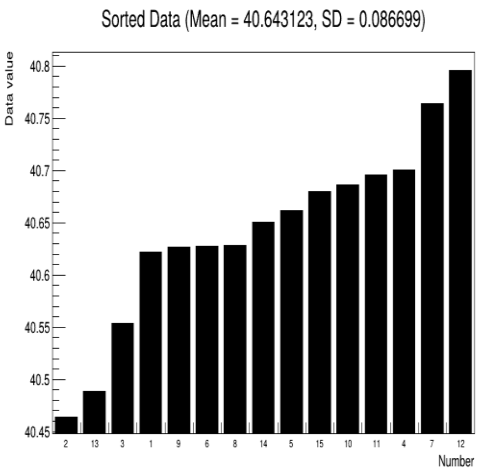
- Gain calibration should be needed while BIC running ⇨ LED setup must be installed together with the BIC
- Previous SiPM LED Setup cannot be fit in the BIC (No space)
- Too many SiPM & Lightguide ⇨ compact LED setup are required
- SiPM temperature dependence ⇨ monitoring system !!
- New LED system ⇨ attached with lightguide ⇨ Light monitoring system (LMS)

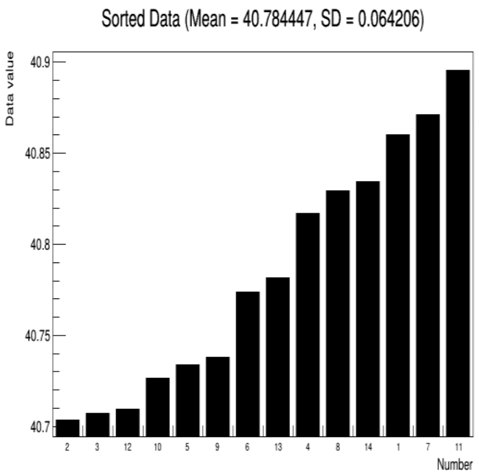
LMS – Simulation for KNU Board

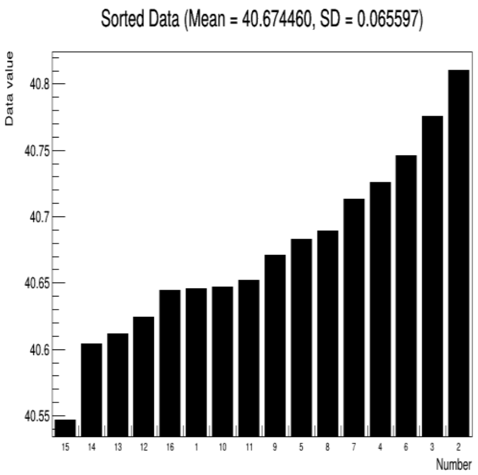


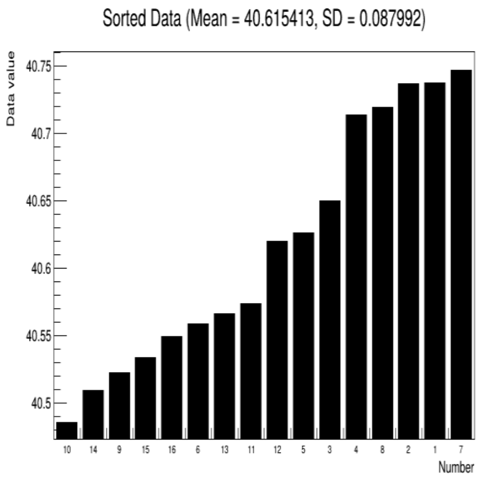
- Simulation with LTSpice
- Combine Controller board & LED board

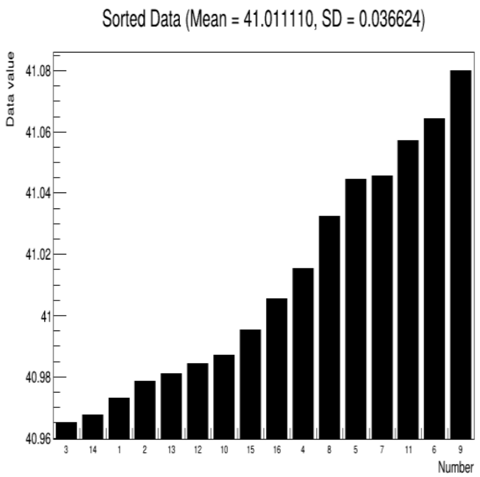
Bias voltage per each channel

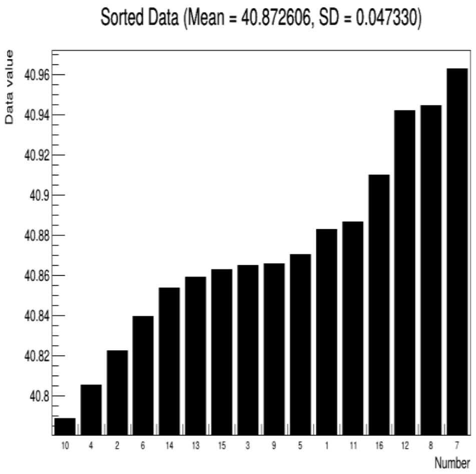


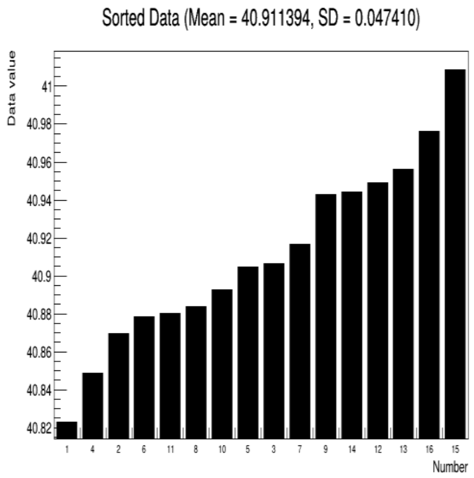


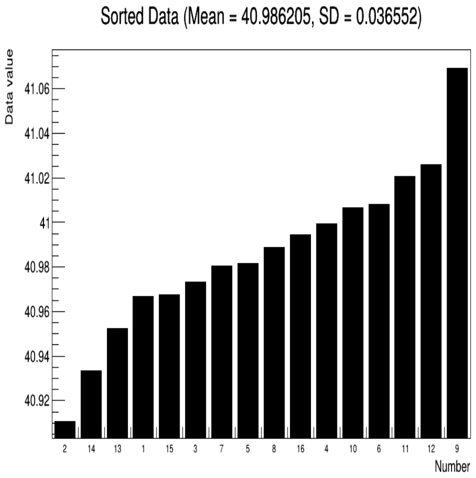


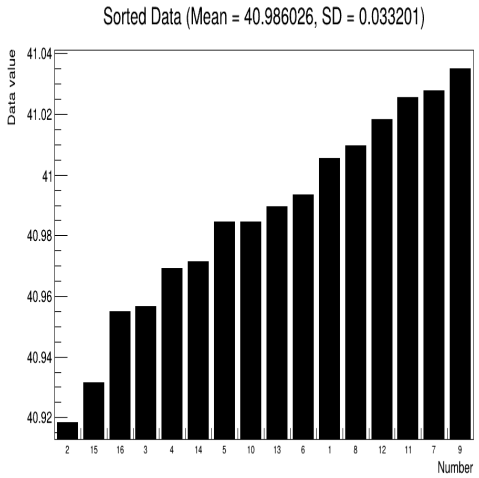






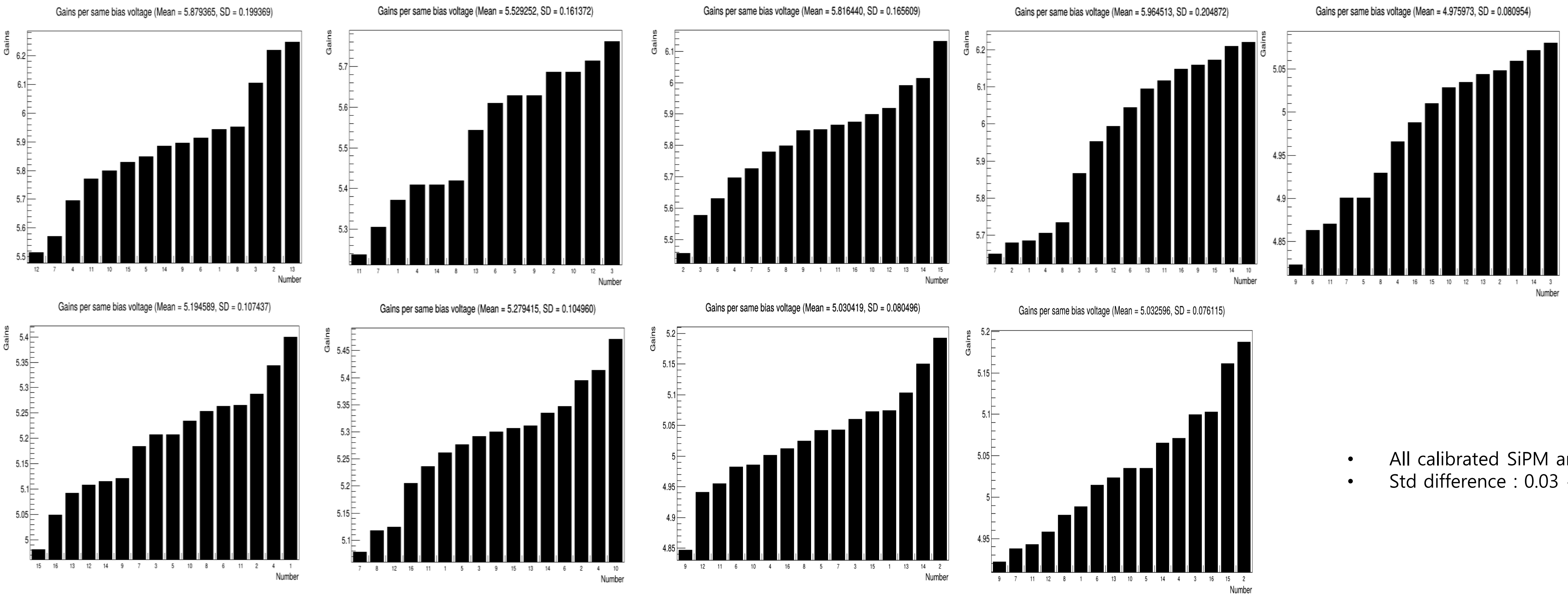






- All calibrated SiPM arrays
- Std difference : 0.03 ~ 0.08

SPE (ADC) per each channel



- All calibrated SiPM arrays
- Std difference : 0.03 ~ 0.08