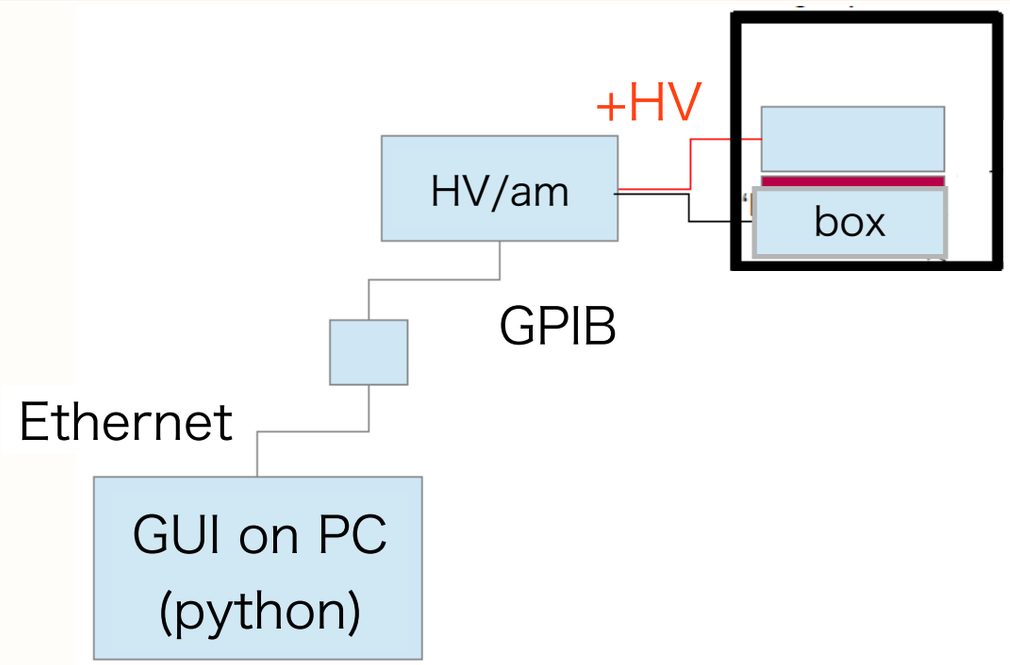
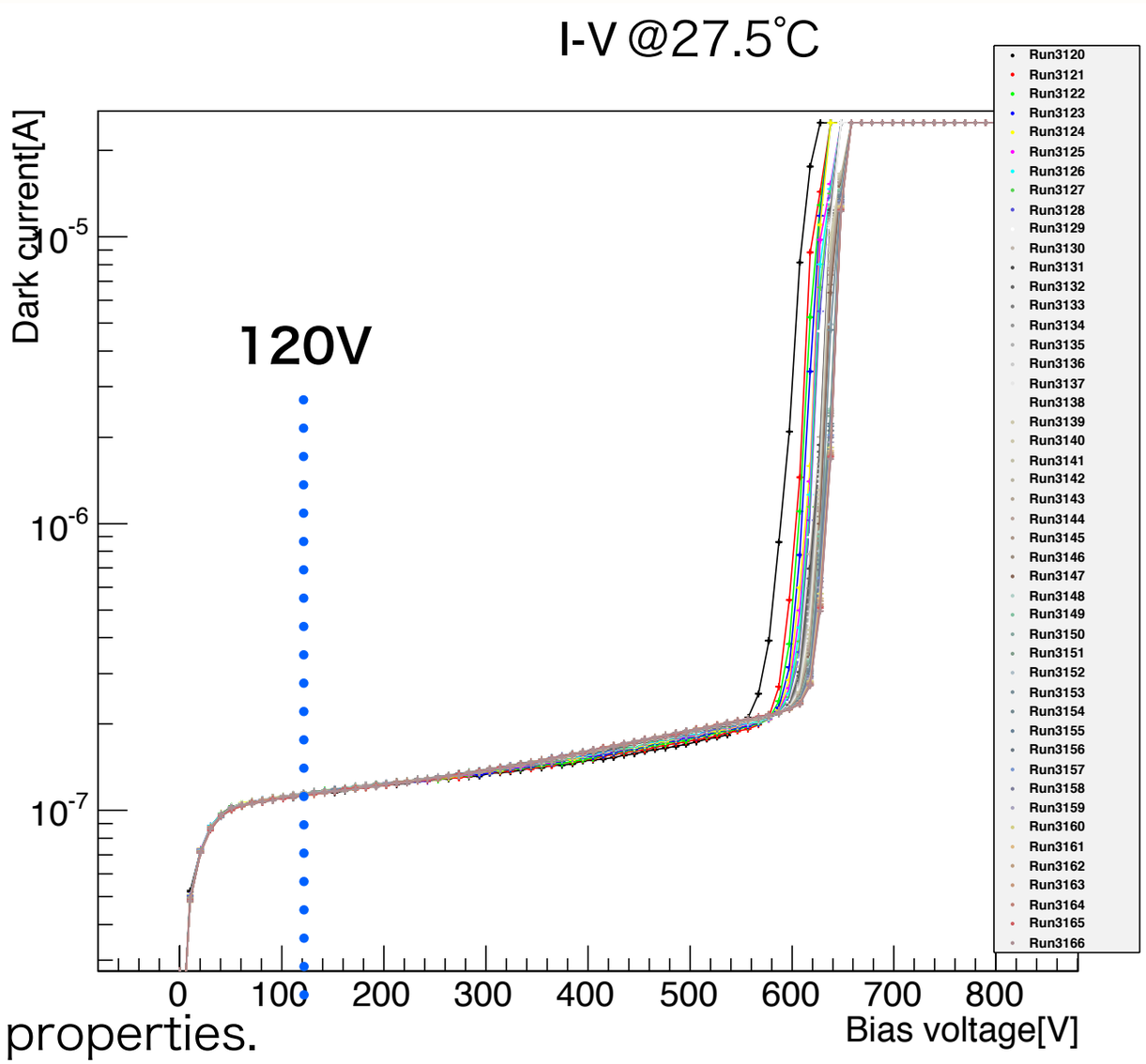
# Current status

- Si chip test-bench system in Tokyo and Kyushu
  - leakage current and capacitance measurement (@Both)
  - radiation test and time characteristics (@Tokyo)
  - guard ring and cross talk study using laser (@Kyushu)
- We are now ready to start measurement for quality control.
- Radiation test is now preparing.
- Guard ring and cross talk effects should be investigated for each type of guard ring(1GR, no GR, 2-split GR, 4-split GR). (We need to upgrade our laser system)

# Leakage current




until 4 or 5 times measurements,
break down voltage went higher by each step

Dark current around 120V (operation V)
is stable (flat) and low(a few hundred nA).

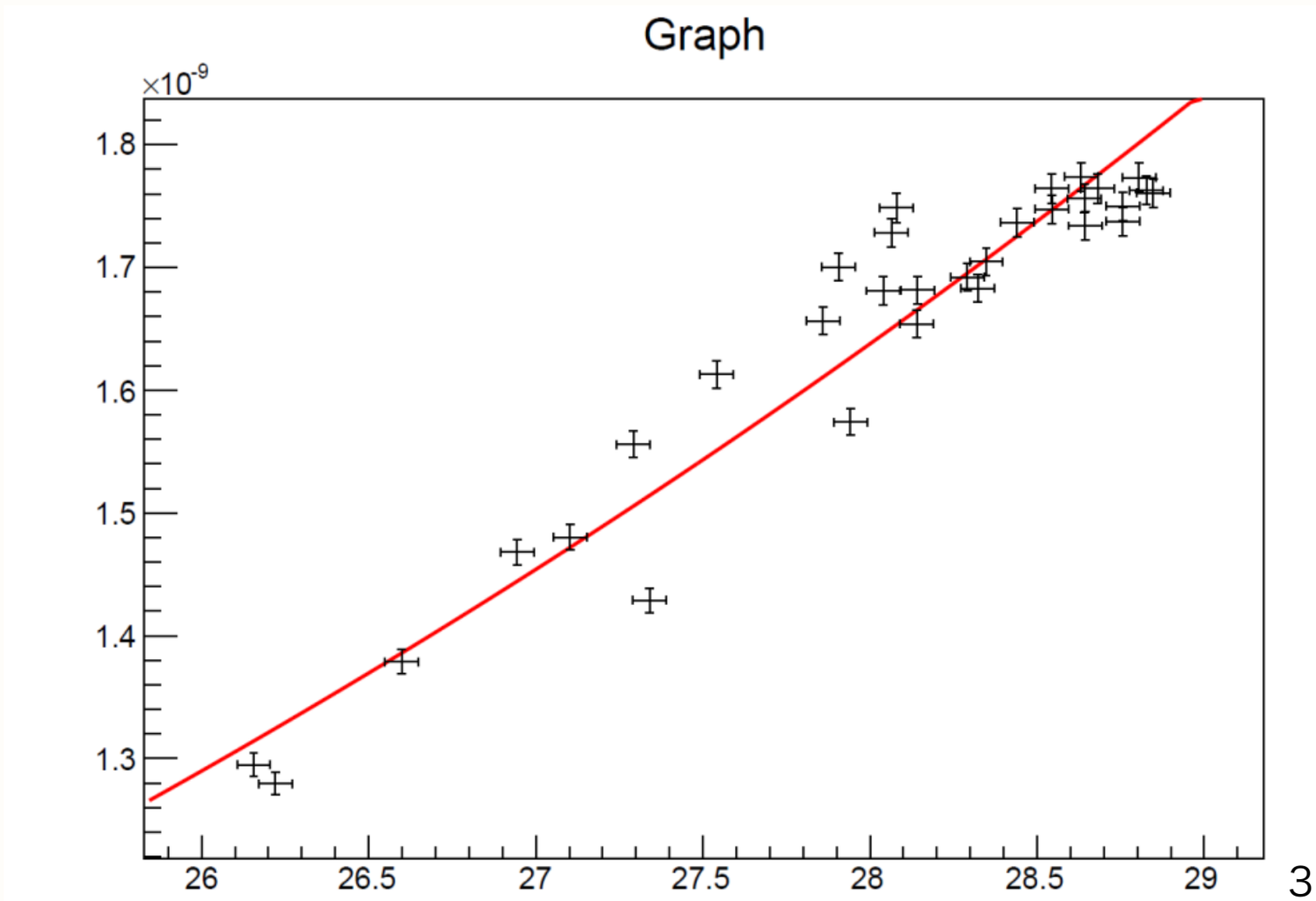
Good chip should have these (flat and low leak) properties.
We can compare this result with the other chips.

# Thermal dependence & diffusion V

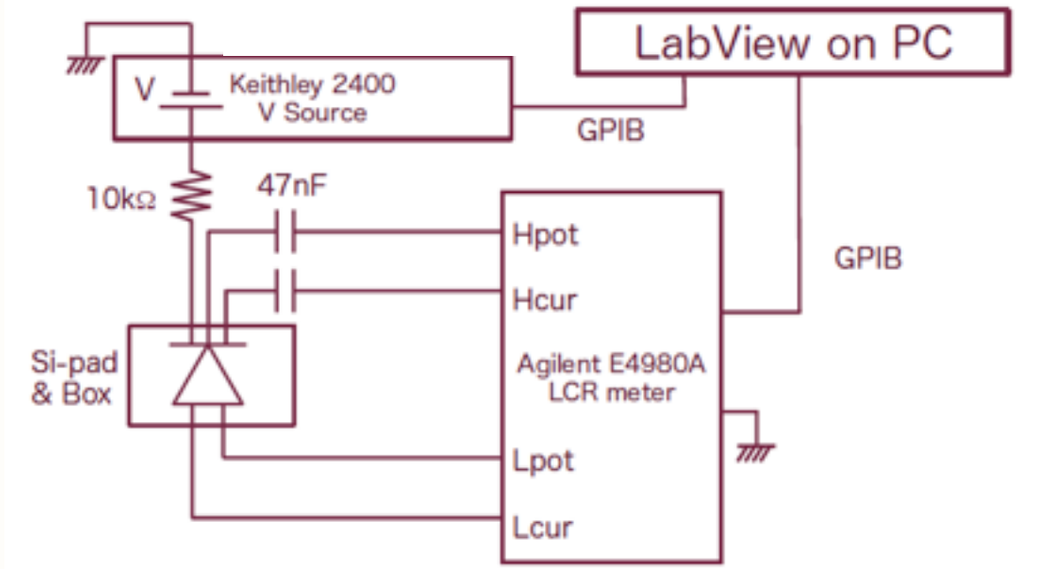
$$I = I_0 \exp\left(-\frac{V_D}{kT}\right)\left[1 - \exp\left(-\frac{\alpha e V}{kT}\right)\right]$$

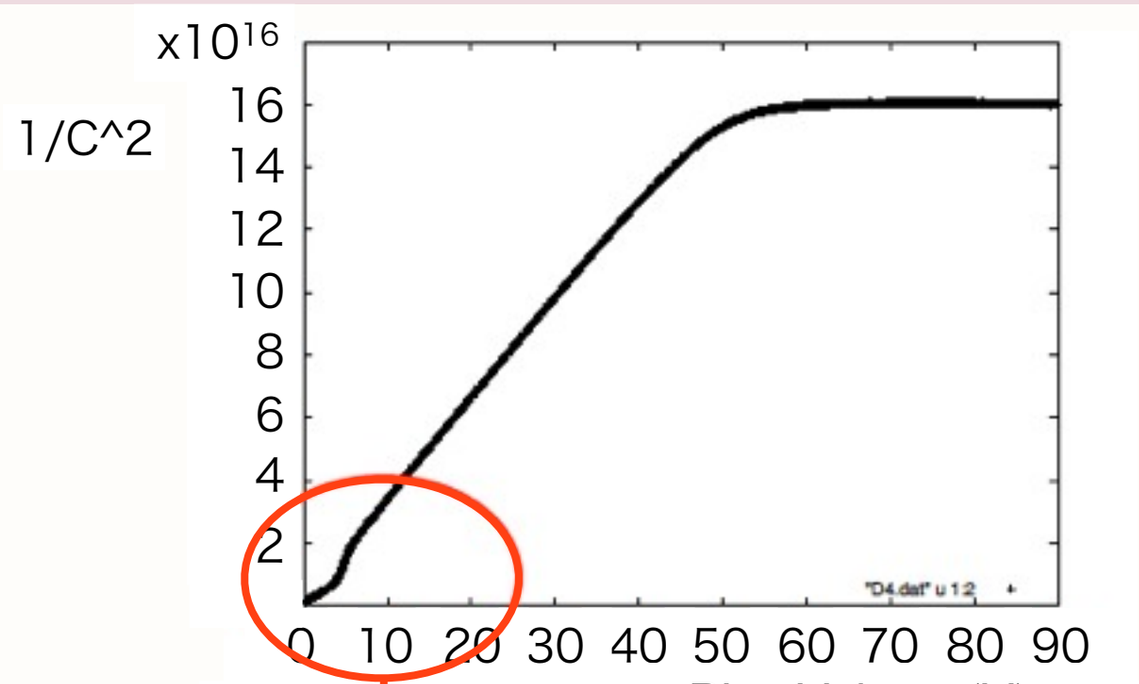
$I_0 = (9.3 \pm 0.2) \times 10^6$ A

$V_D = 0.9418 \pm 0.0007$V



# Capacitance



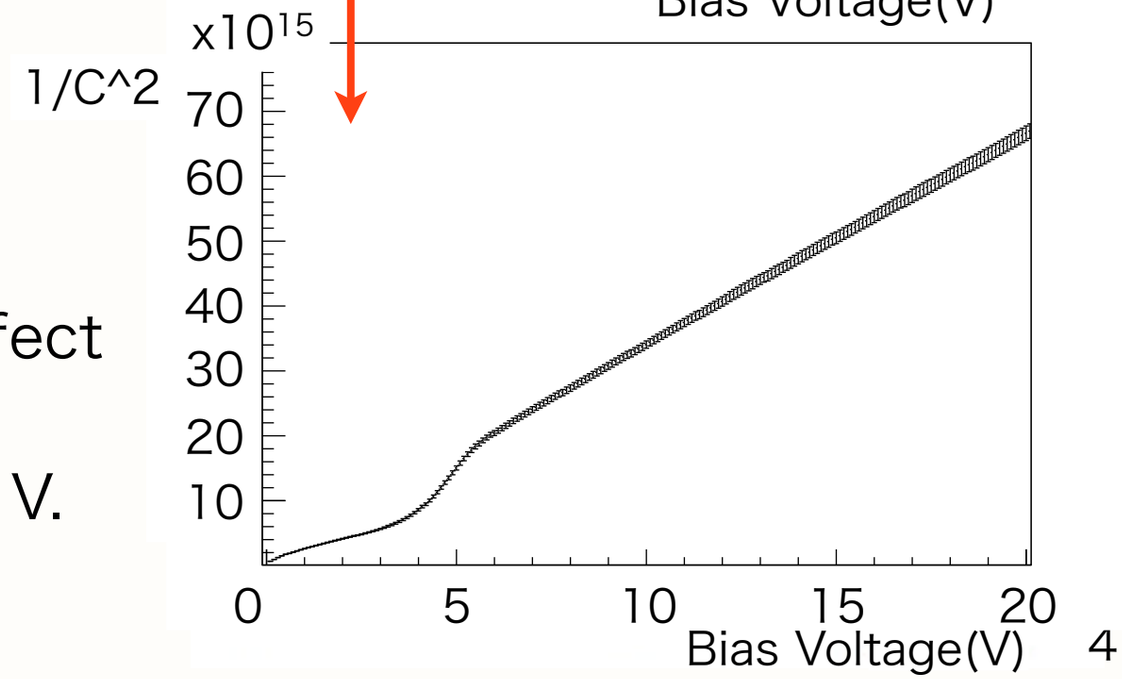




1/C^2 has very good linearity.

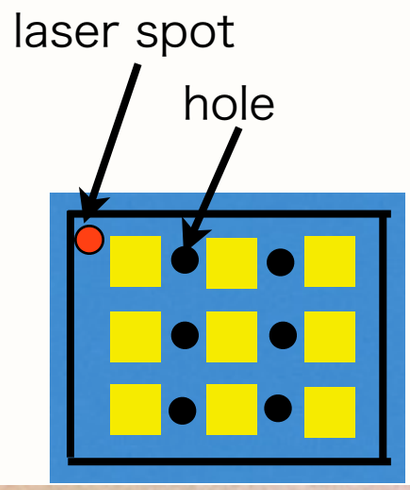
> 50V : saturated ( full depletion )

< 6V : Metal Oxide Semiconductor (MOS) effect

Chip can be fully depleted before operation V.

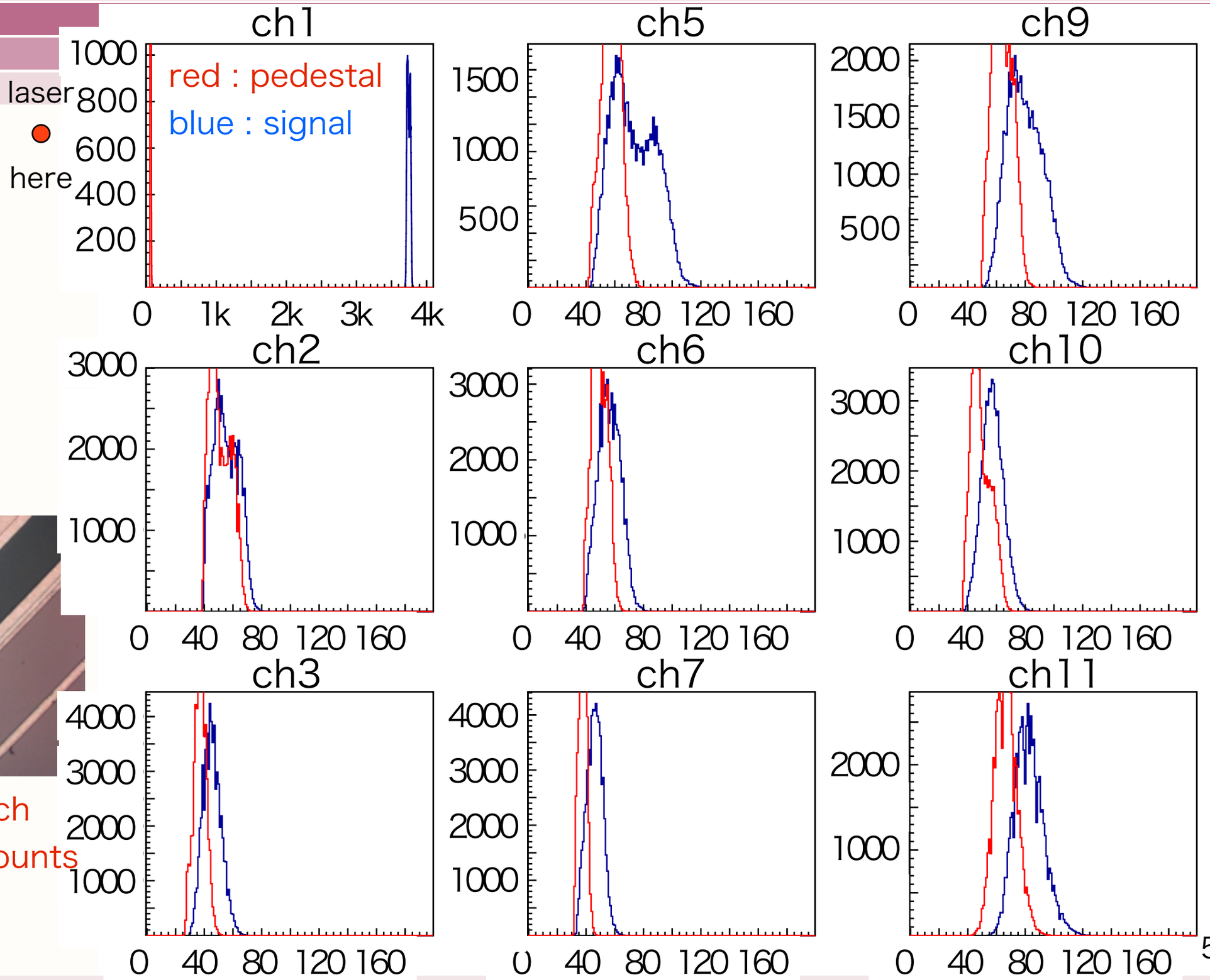


# Multi pixel read out (Cont.)





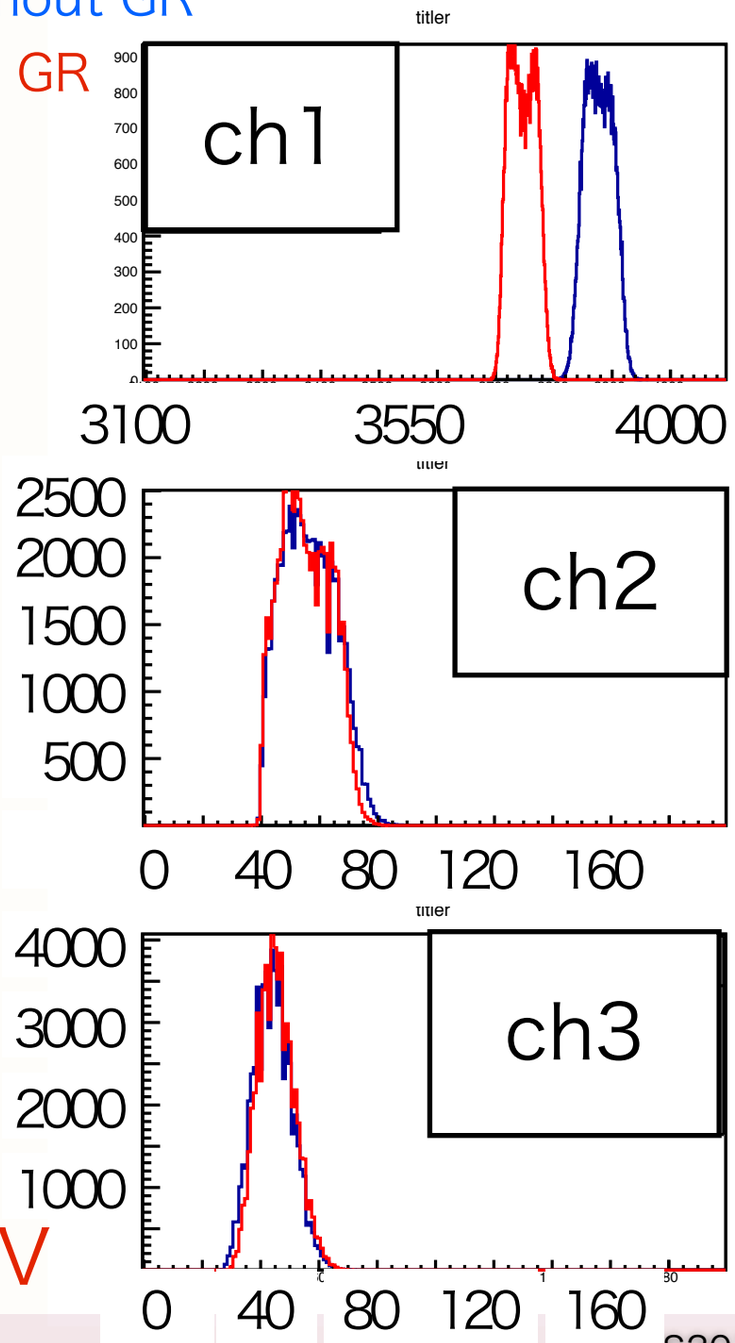
pedestal : 40~80 ADC ch
horizontal axis : ADC counts
vertical axis : counts
@ 100V

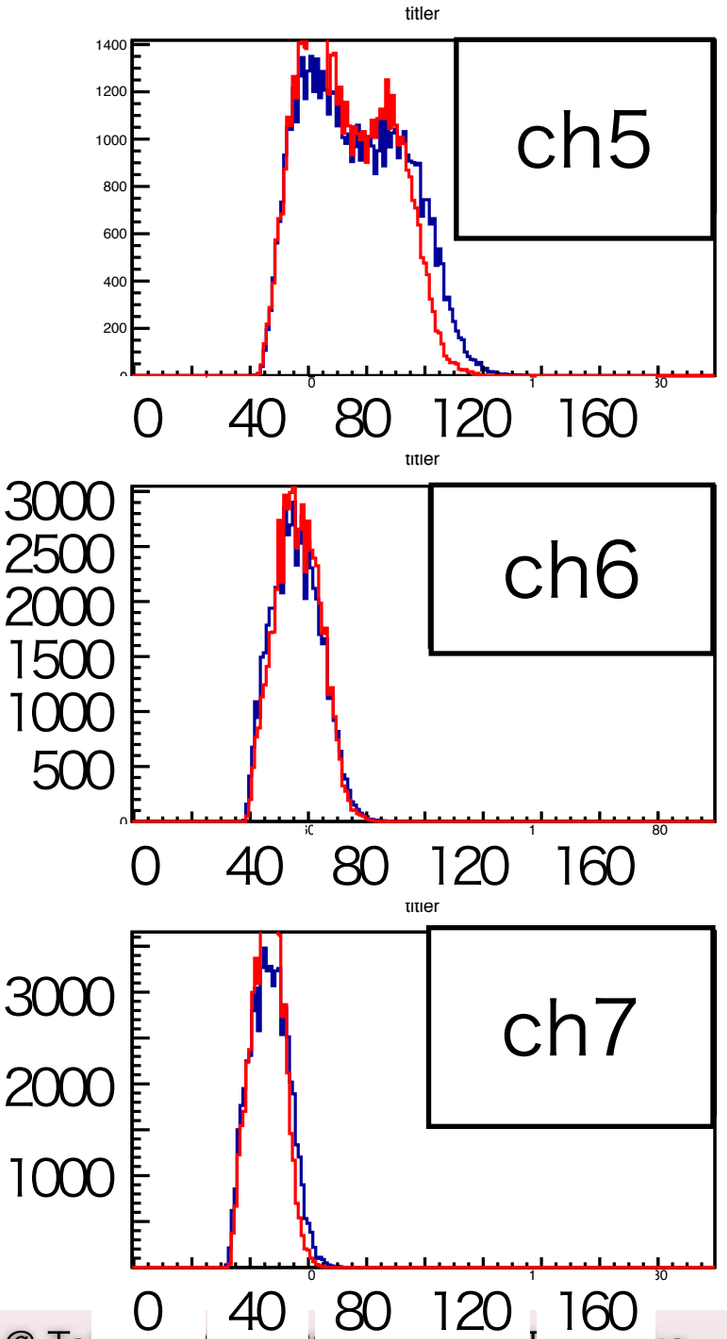


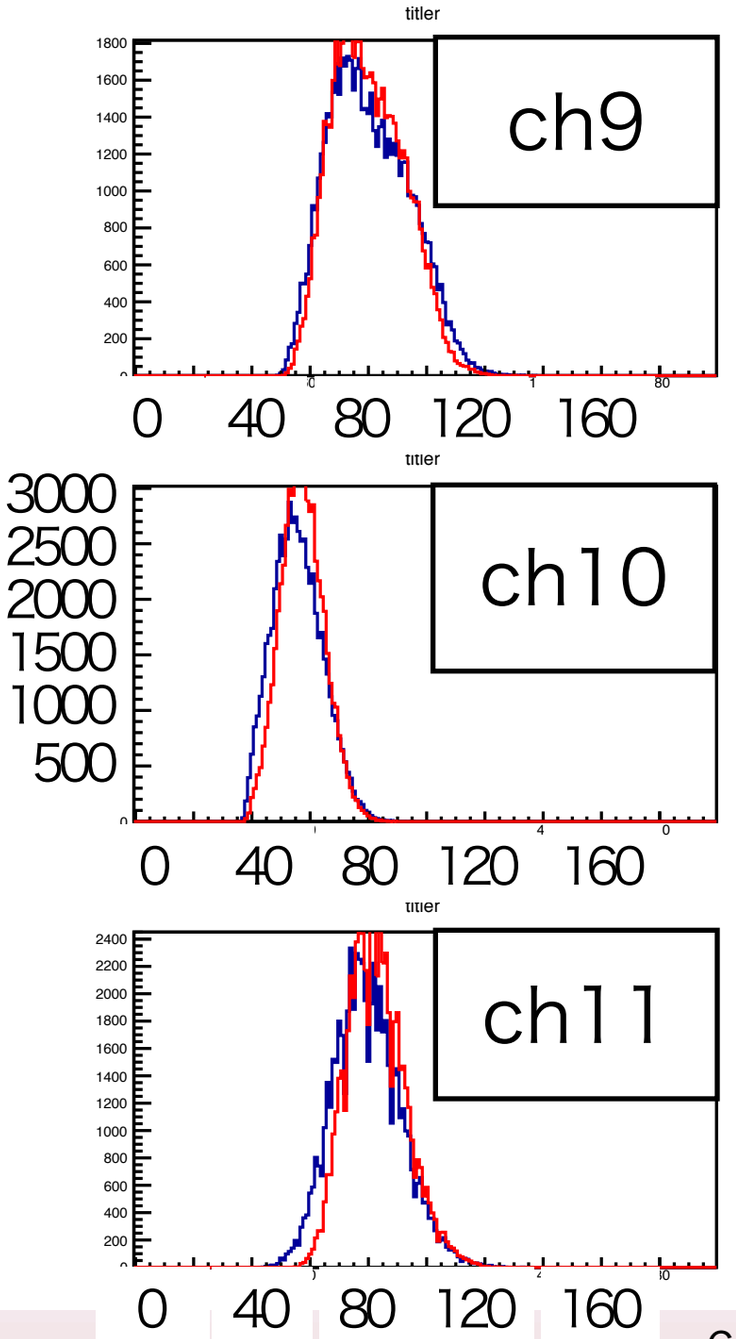
# GR vs no GR

blue : without GR

red : with GR




@ 100V

# Outside of guard ring

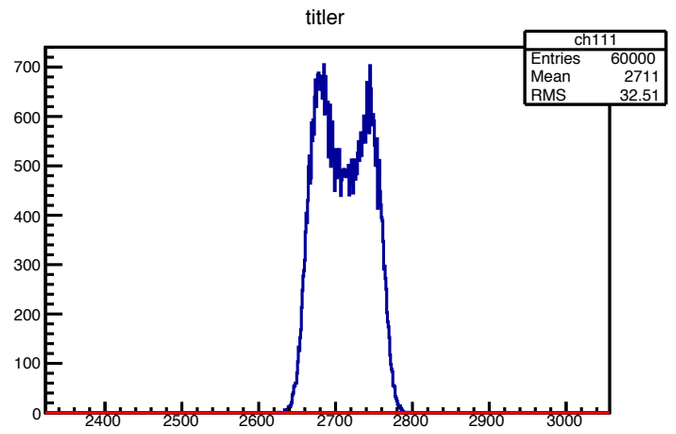
laser

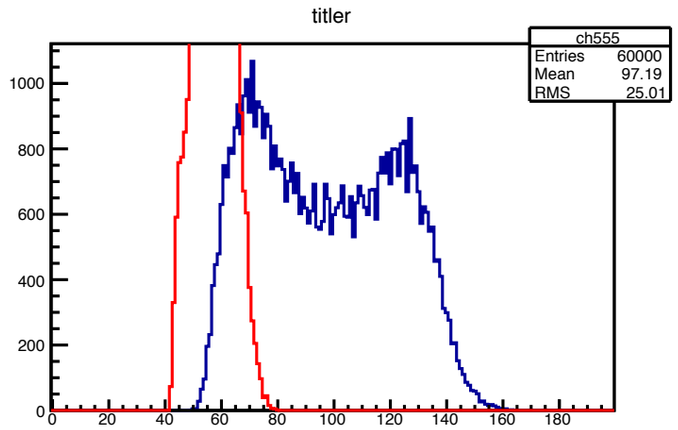
here

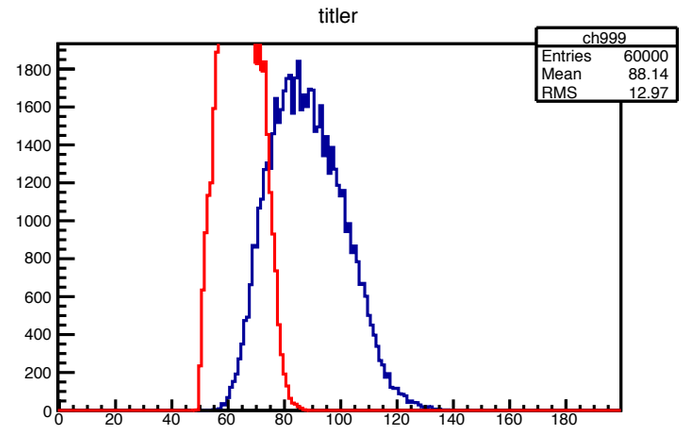

red : pedestal

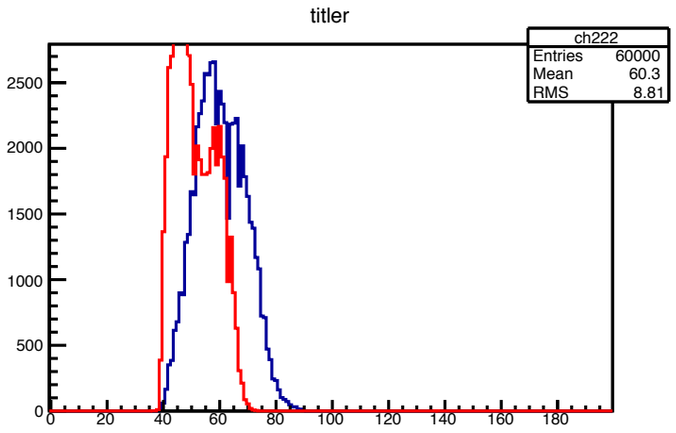
blue : signal

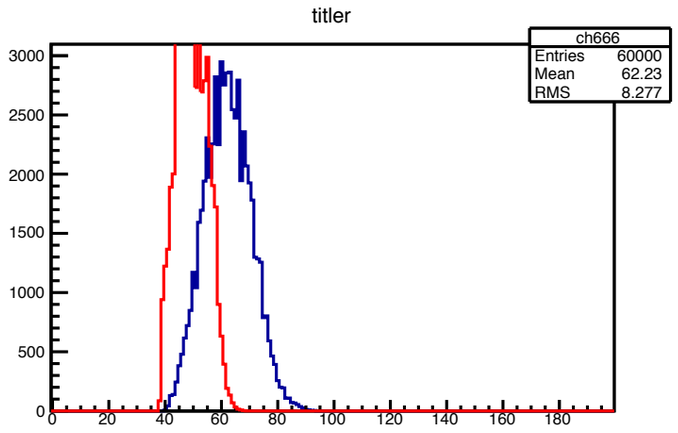
@ 100V

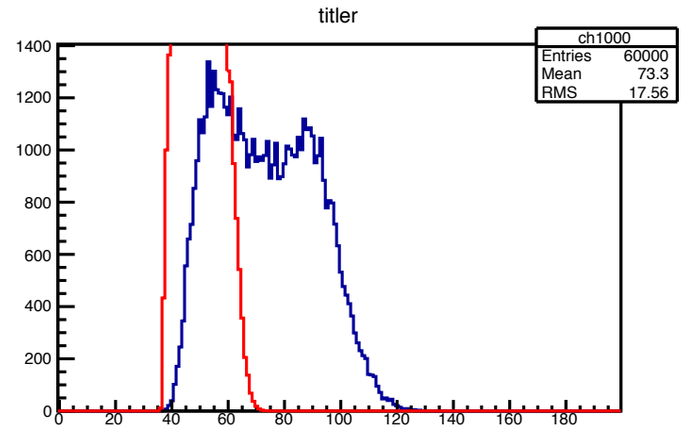


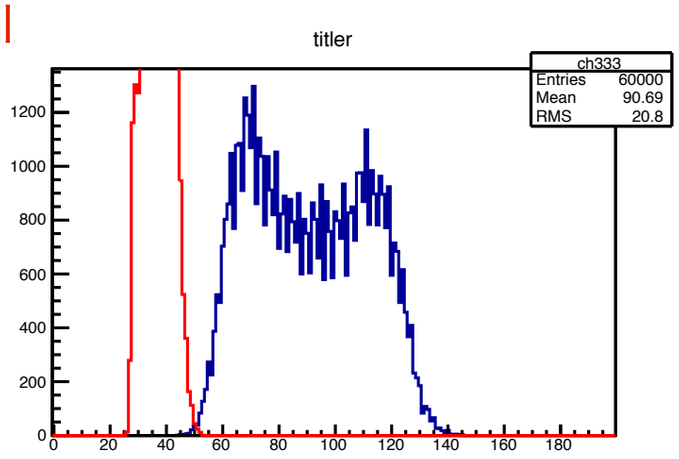



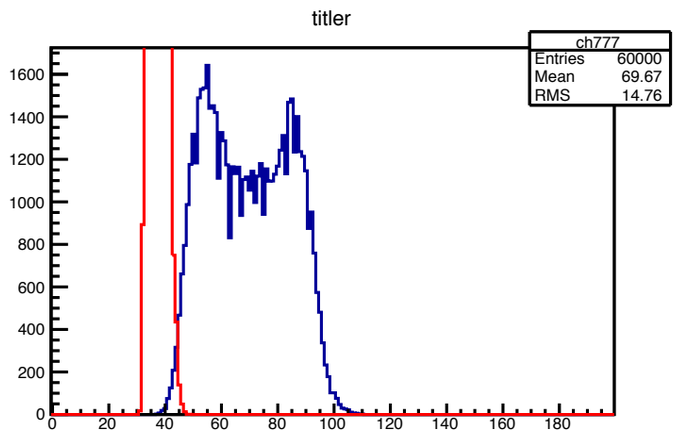



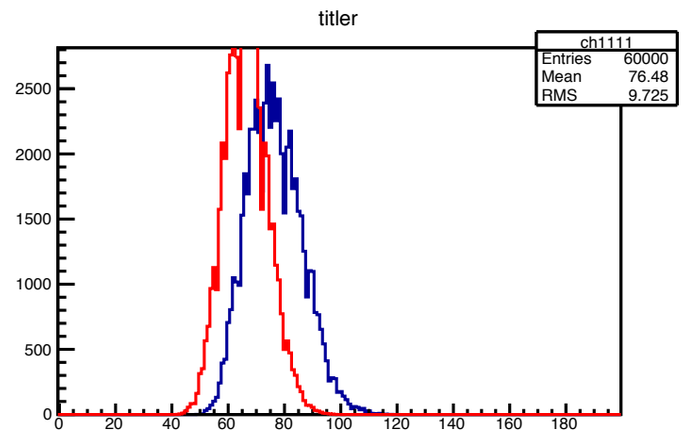



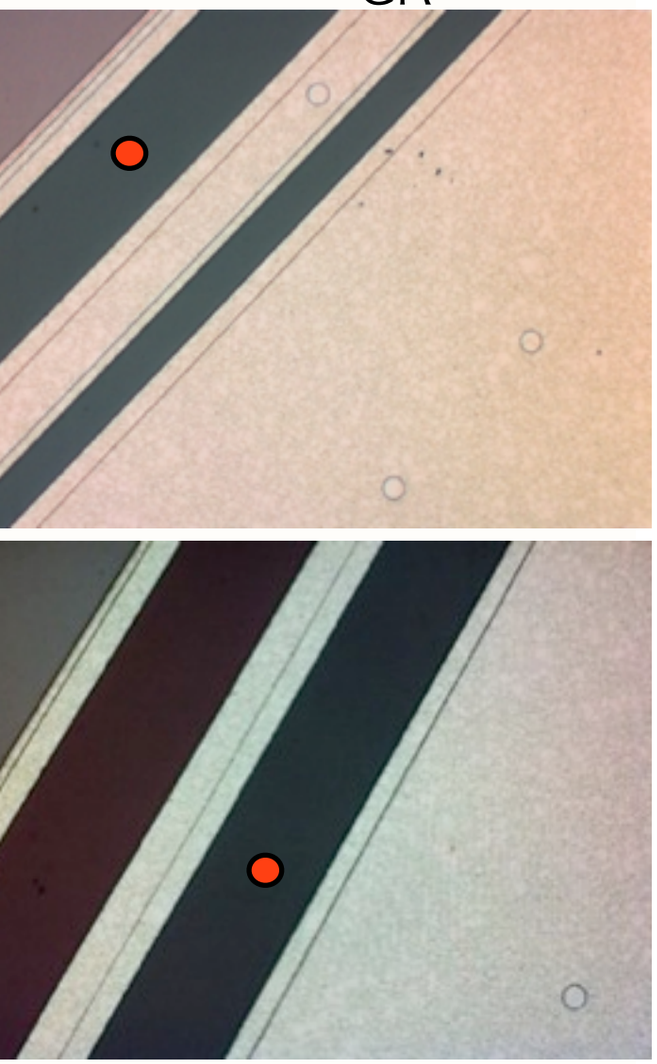



# Out side of GR vs no GR

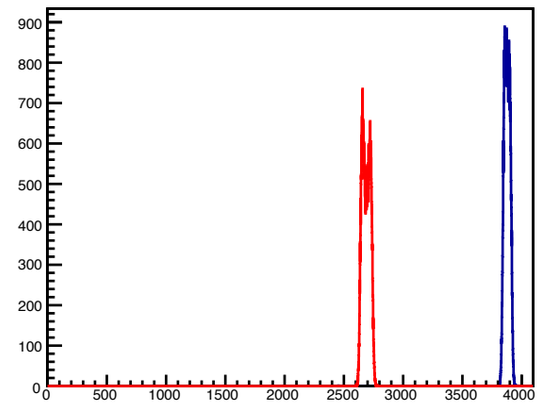
red : out side of GR

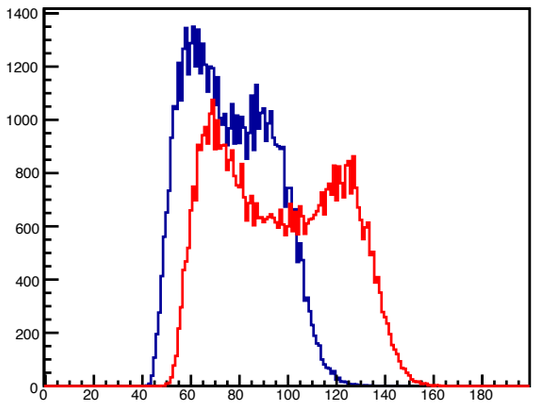
blue : no GR

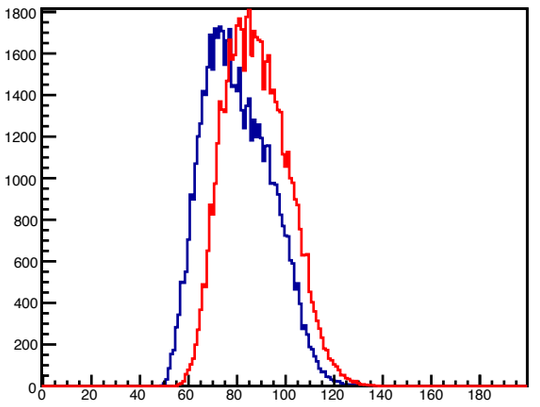
GR

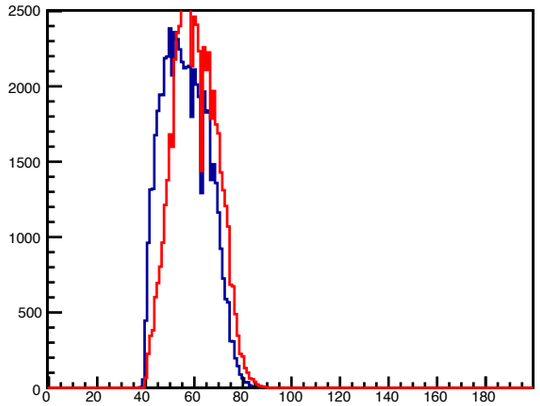


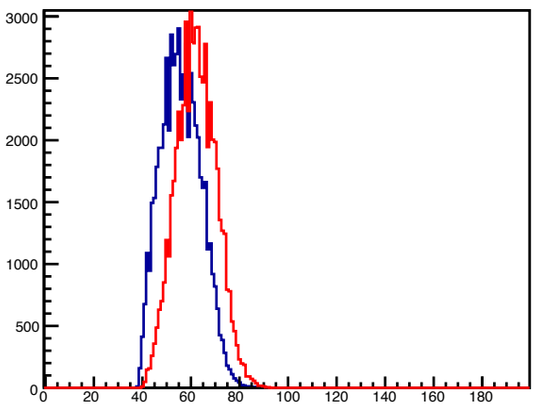
@ 100V

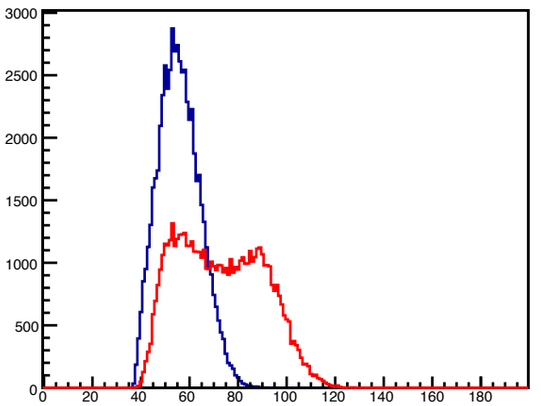


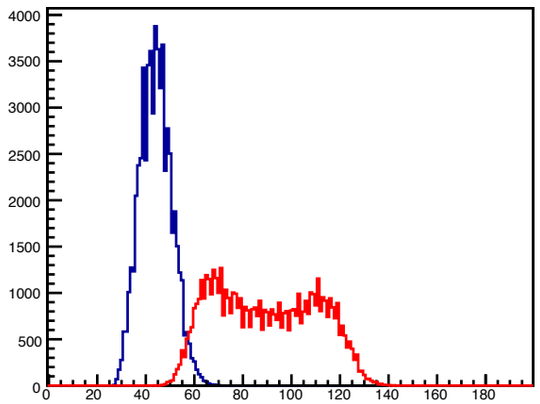


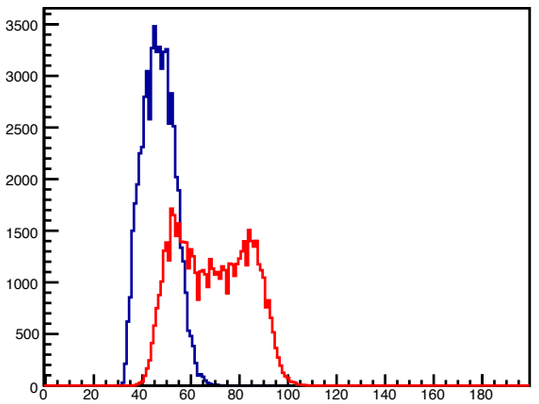


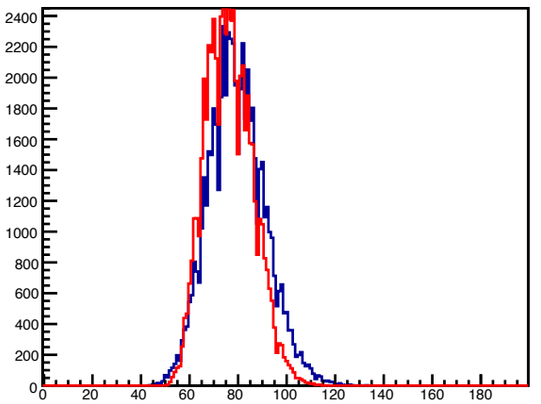






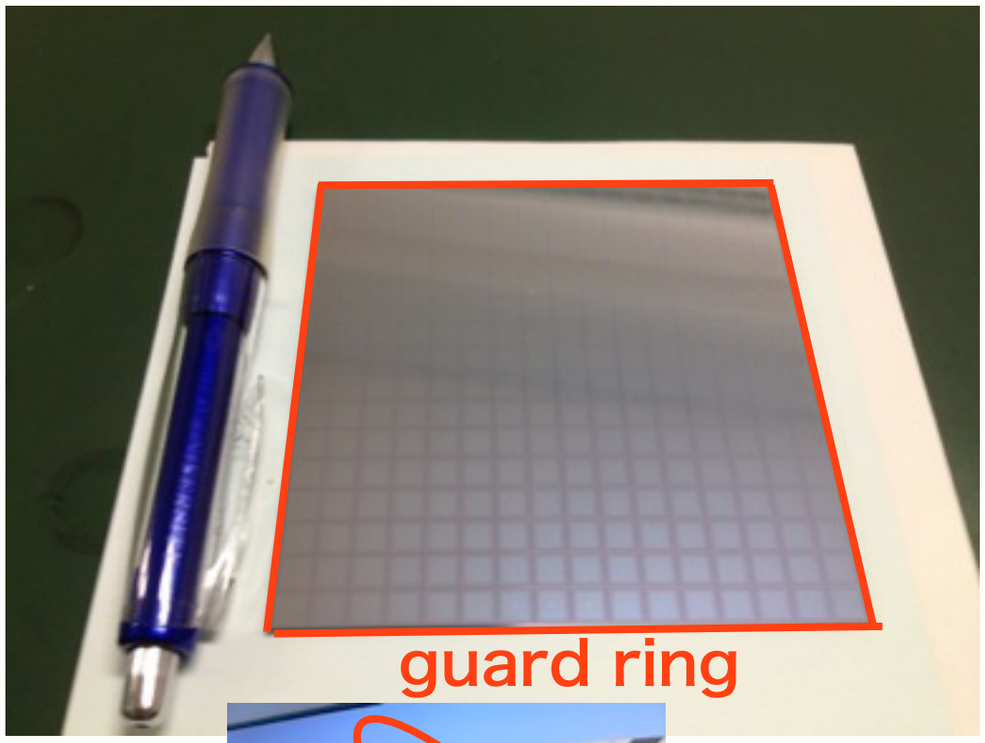


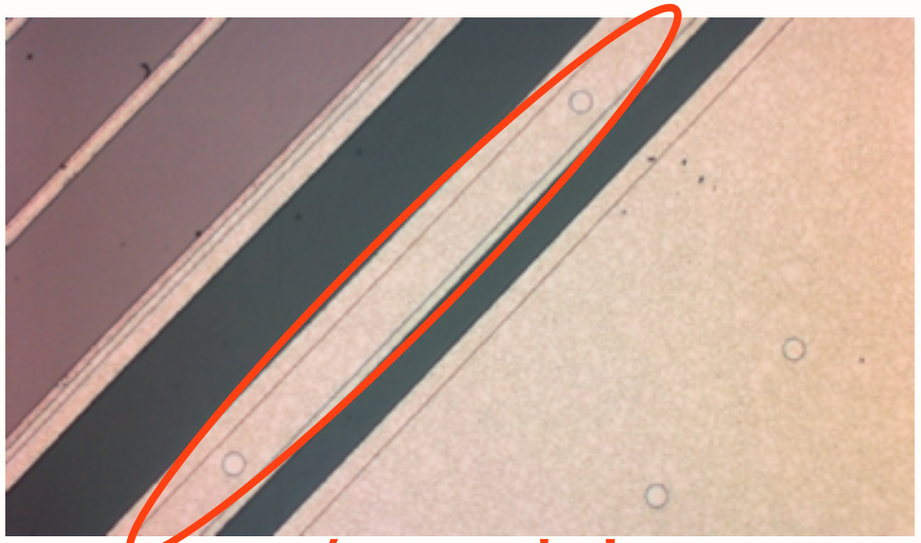




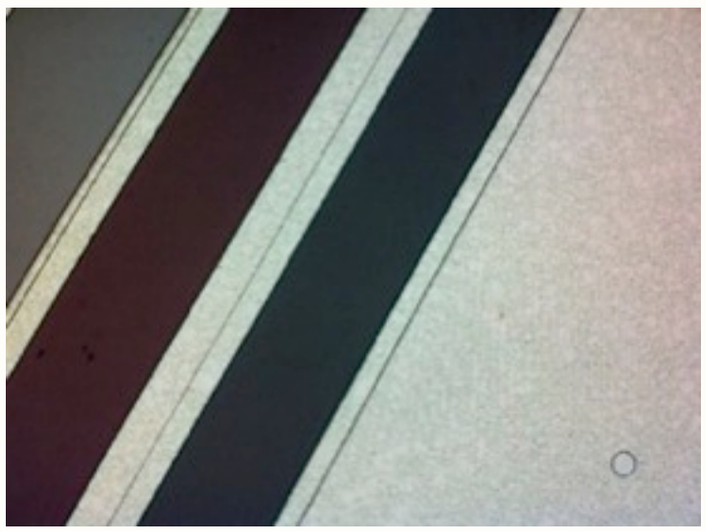
# Si sensor for ILD ECAL

- Produced by HPK
- 1pixel = 5.5mm x 5.5mm
- 16 x 16 = 256 pixels
- Thickness : 320 $\mu$m
- Guard ring width is...
  50$\mu$m(1GR),10$\mu$m(2,4-GR)



w/ guard ring



w/o guard ring

2-split GR

4-split GR

# Future plan

- To decide Si sensor design (guard ring, edge)
  - basic properties measurement (I-V, C-V)
  - laser study (compare each type of GR)

# A study of Silicon sensor for ILD ECAL

Tatsuhiko Tomita

Kiyotomo Kawagoe, Tamaki Yoshioka, Daniel Jeans, Taikan Suehara,
Yuji Sudo, Yoshio Kamiya,
Yohei Miyazaki, Hiraku Ueno, Chihiro Kozakai, Shion Chen,
Kyushu University, University of Tokyo
and CALICE group

九州大学

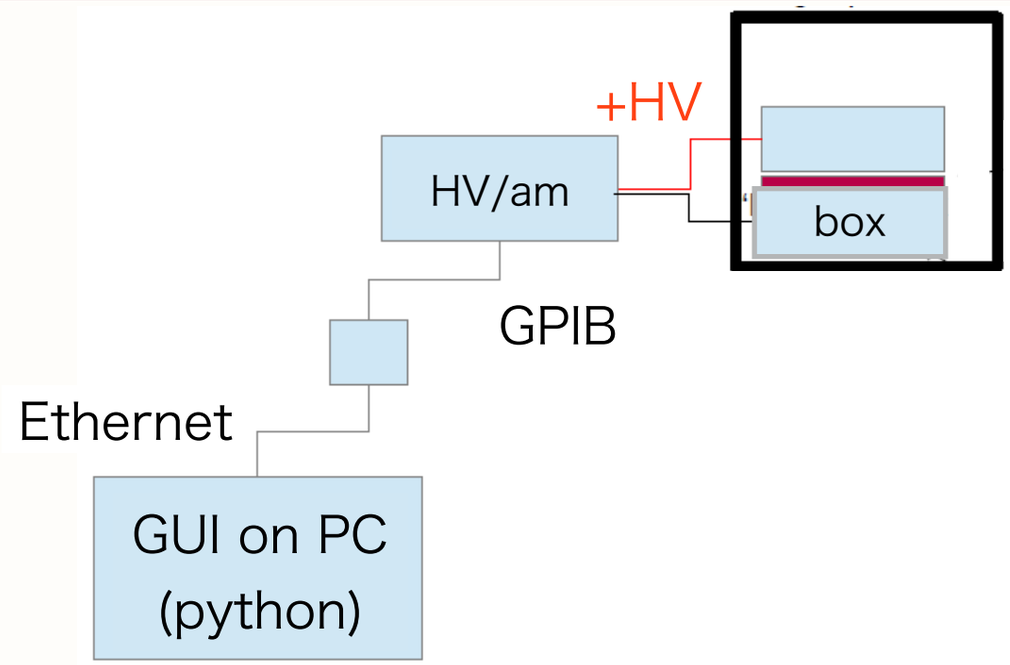
東京大学
THE UNIVERSITY OF TOKYO

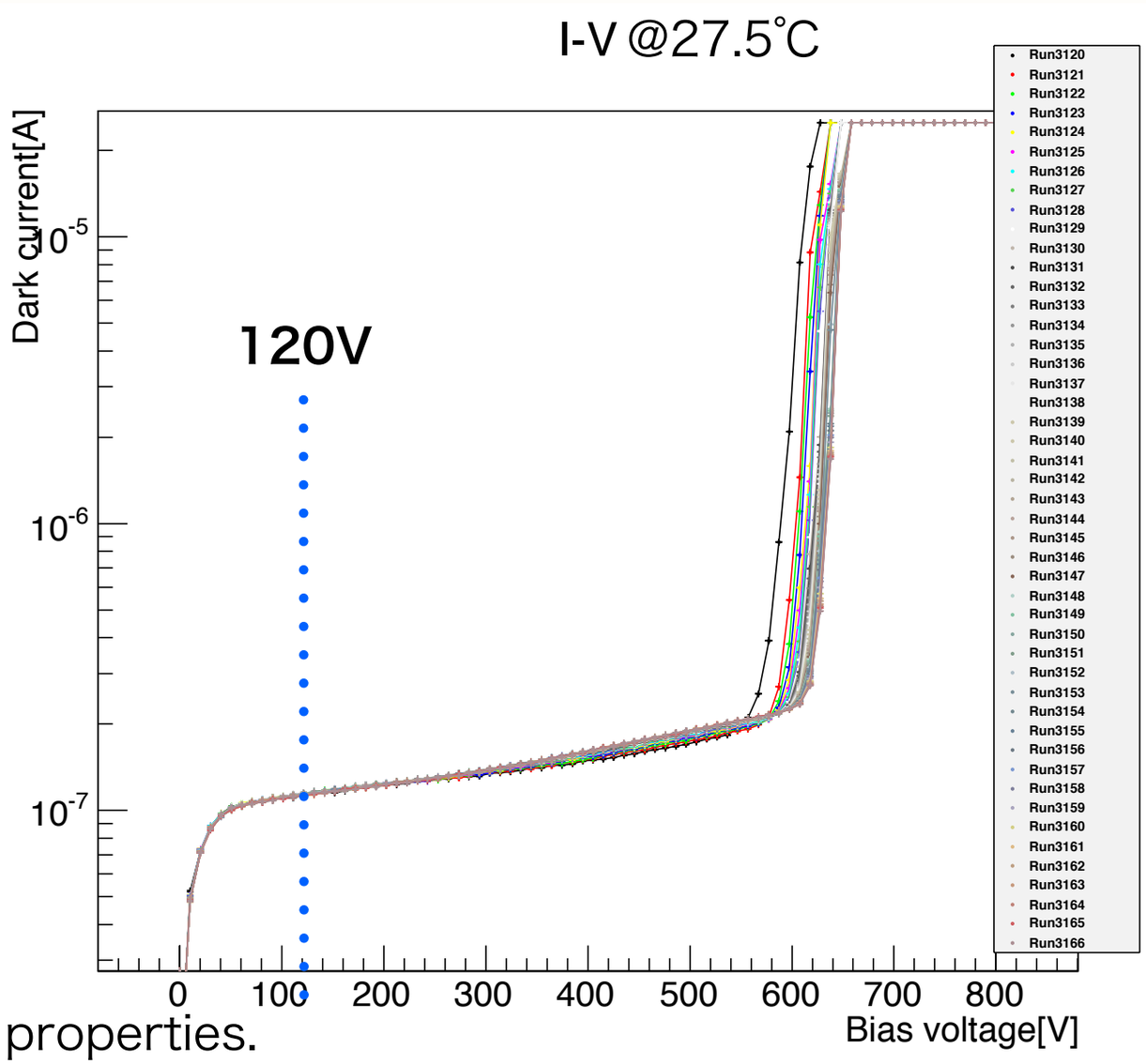
CALICE
Calorimeter for ILC

# Contents

- Thermal dependence and diffusion voltage
- Situation of the laser study
- Summary & prospects

# Leakage current




until 4 or 5 times measurements,
break down voltage went higher by each step

Dark current around 120V (operation V)
is stable (flat) and low(a few hundred nA).

Good chip should have these (flat and low leak) properties.
We can compare this result with the other chips.

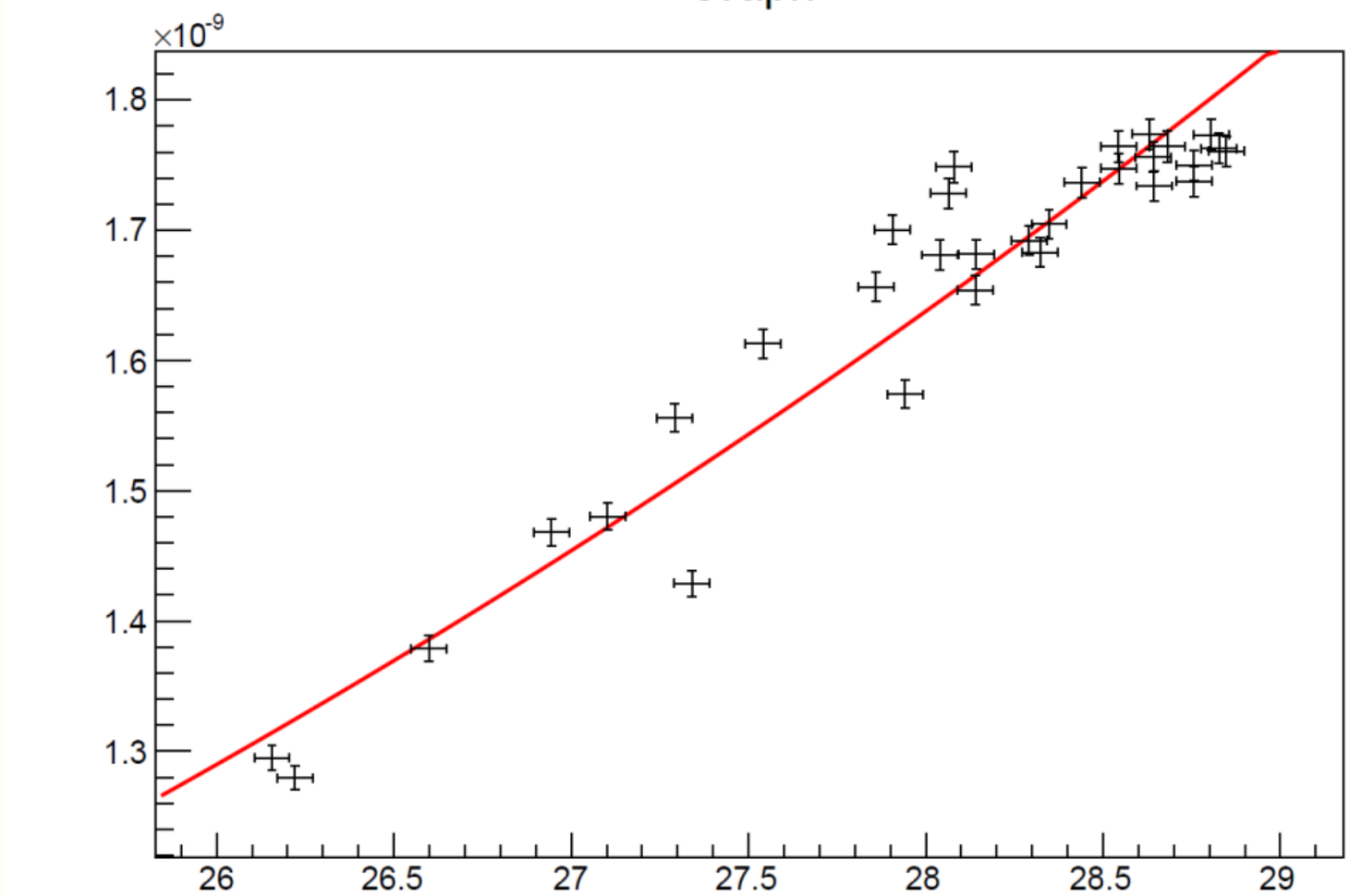
# Thermal dependence & diffusion V

$$I = I_0 \exp\left(-\frac{V_D}{kT}\right)\left[1 - \exp\left(-\frac{\alpha e V}{kT}\right)\right]$$

$I_0 = (9.3 \pm 0.2) \times 10^6$ A

$V_D = 0.9418 \pm 0.0007$V

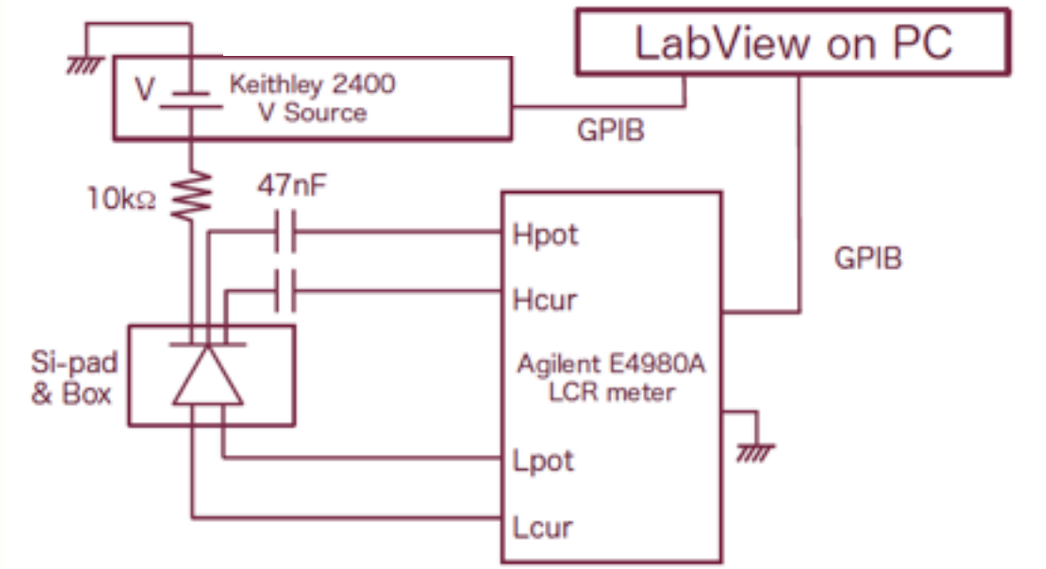
Graph @~~V

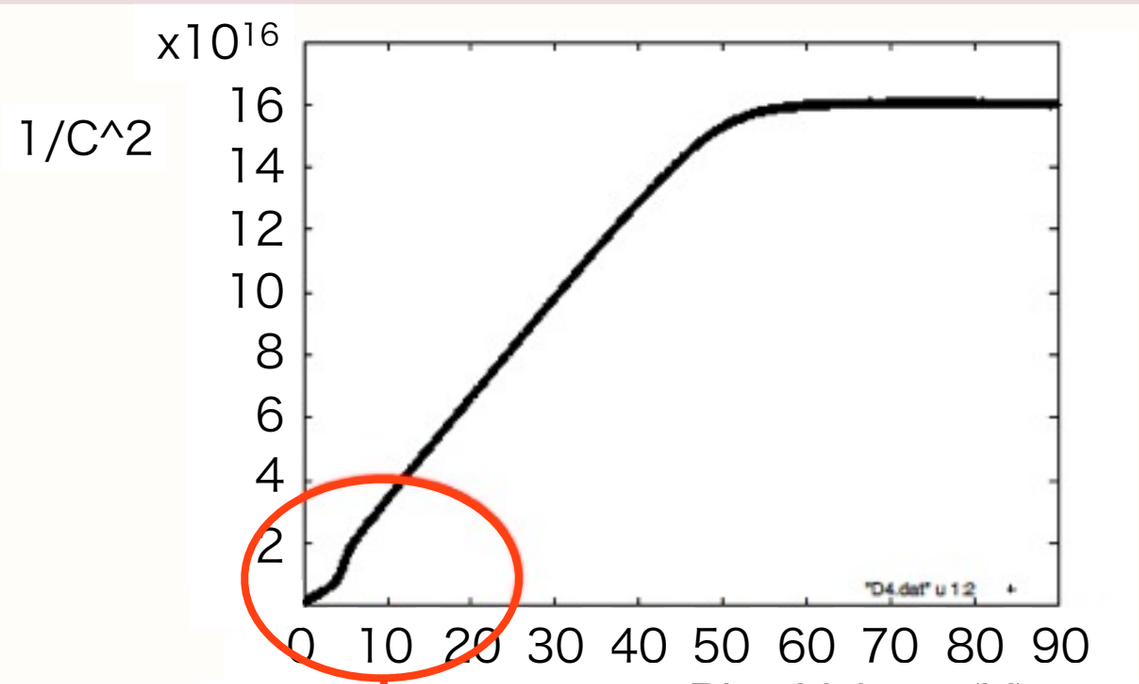


# Motivation

- Measuring some properties
  - To understand Si sensor properties is necessary to develop Si sensor testing station for quality control.
- Response to the laser
  - can investigate what will happen when particle comes into Si sensor.
  - We need to understand some effects of gaps/guard rings to improve Si ECAL performance.
  - If we can investigate GR effect in laboratory, it is very convenient and fast.

# Capacitance



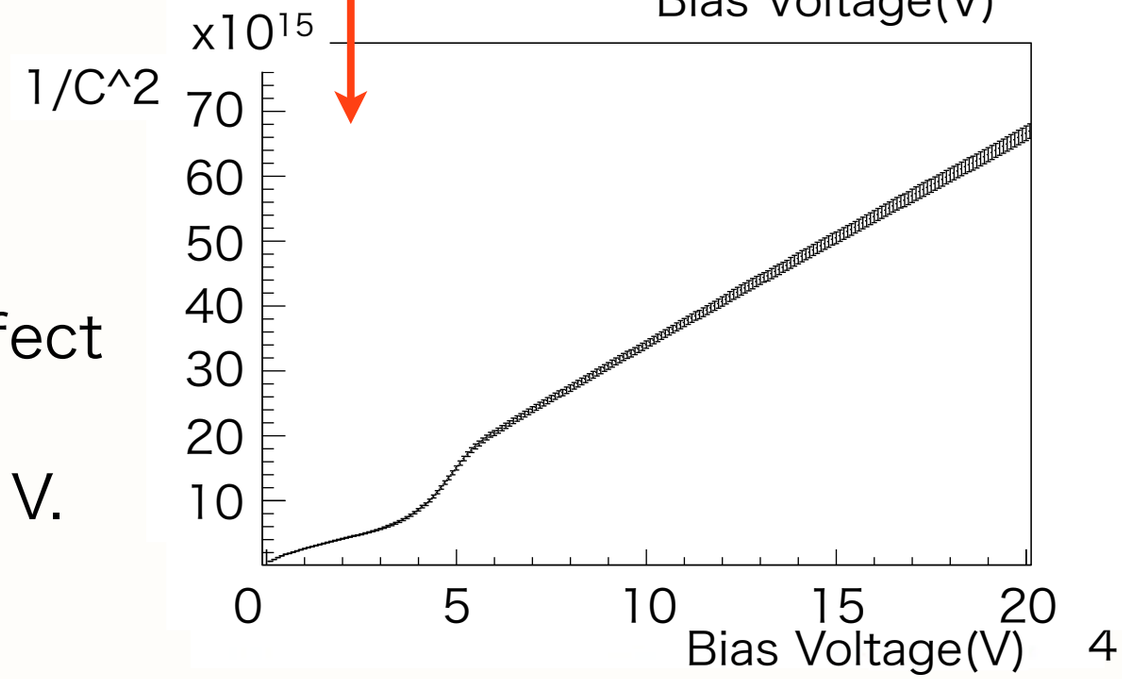




1/C^2 has very good linearity.

> 50V : saturated ( full depletion )

< 6V : Metal Oxide Semiconductor (MOS) effect

Chip can be fully depleted before operation V.



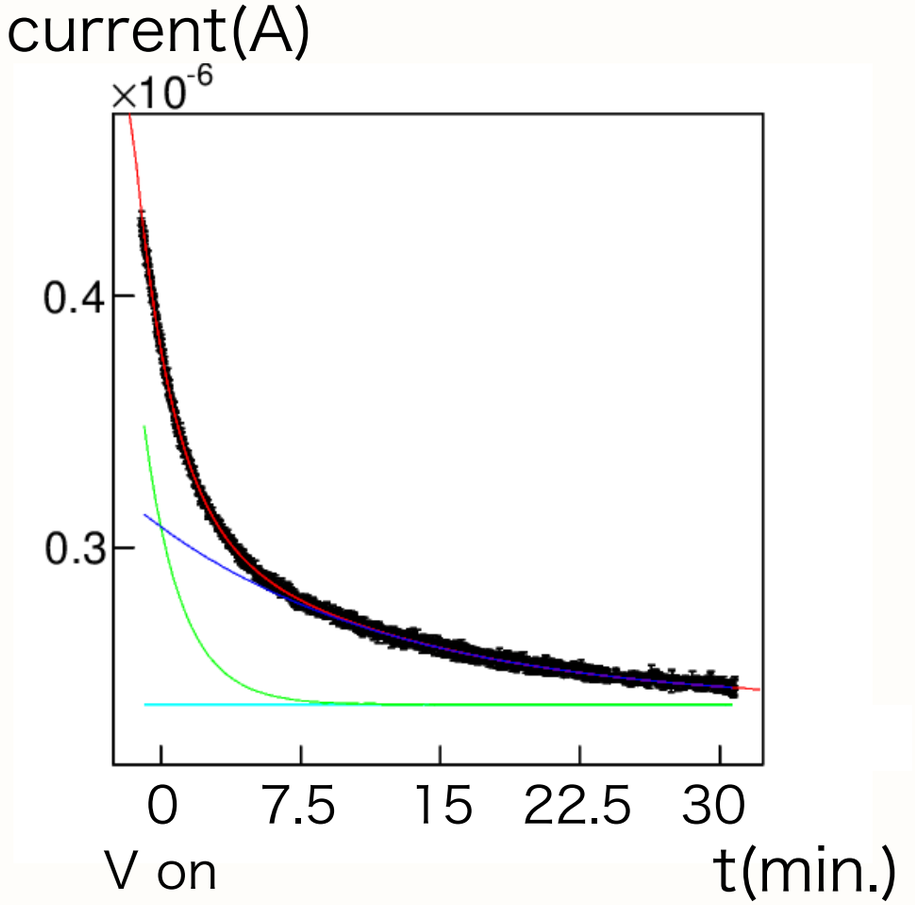
# Time characteristics

Time characteristics mean the time to stabilize leakage current.
When one turn on the HV on chip, one should wait certain time.

There are two time components.

$$I = A\exp(-t/\tau_1) + B\exp(-t/\tau_2) + const$$

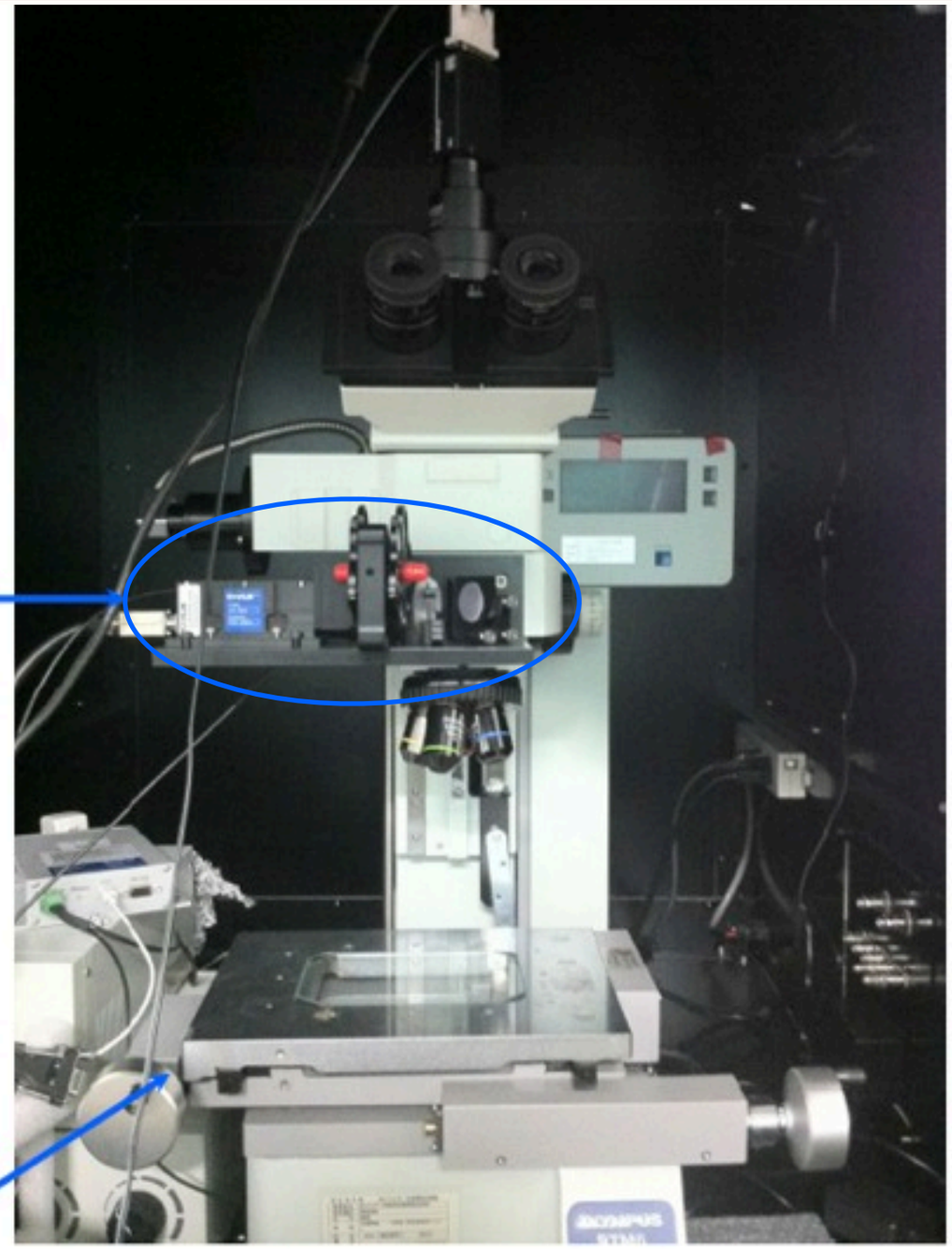
| | fast component( $\tau_1$ ) | slow component( $\tau_2$ ) |
|---|---|---|
| generation time @ 250V | 40 s | 600 s |
| recombination time @ 0V | 7000 s | 9000 s |



# Laser system

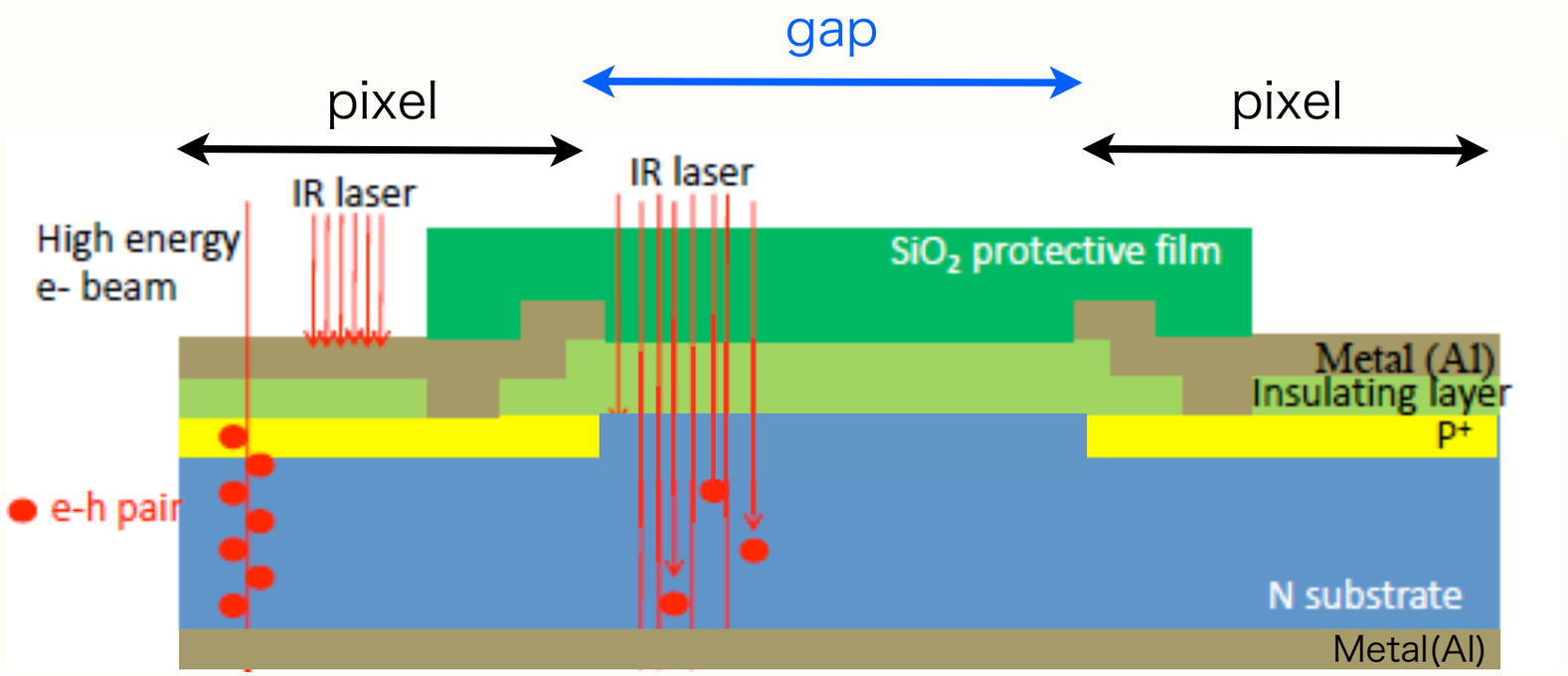
CRYLAS GmbH
DSS1064-Q2 (Class 3B)
Wave length : 1064 nm
Pulse width : ~ 1.5 ns
Pulse energy : > 20 μJ/pulse
~ $10^{14}$ photons/pulse
Peak power : > 13kW
Reputation rate : 1 ~ 10kHz

Interface of the control software

# Infrared laser

- wave length -> 1064 nm = 1.16 eV
  band gap energy of Si = 1.12 eV
- We want to know GR and gap effect,
  we inject the laser to Si gap.
  (btw. pix. and pix. or pix. and guard ring)

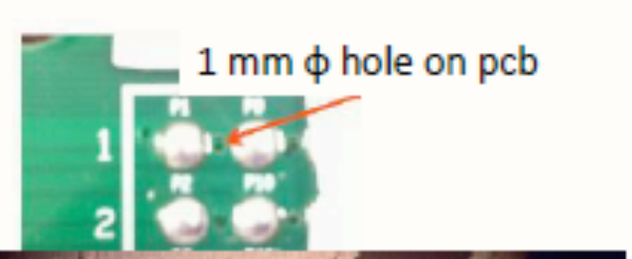


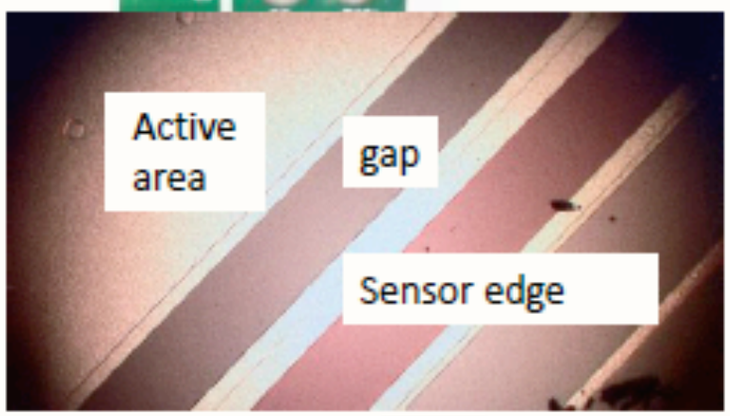
# SETUP

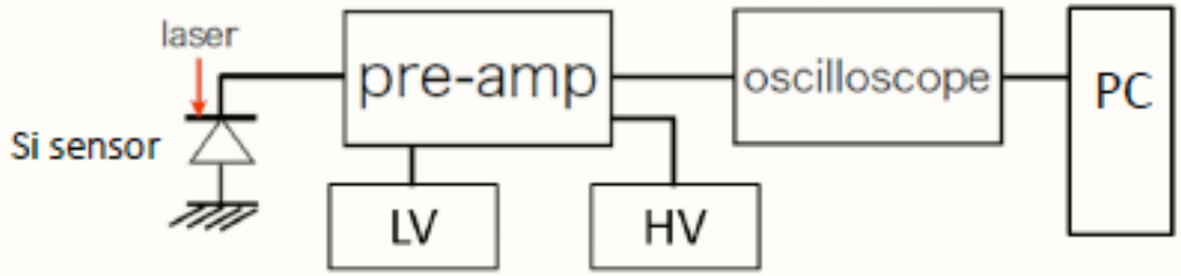
- Laser diameter at the focus point is less than 23$\mu$m.
- The gap size between pixel and guard ring is 32$\mu$m. This size is enough small to put the laser into it.

To expose Si to the laser directly, we make a 1mm hole on PCB.

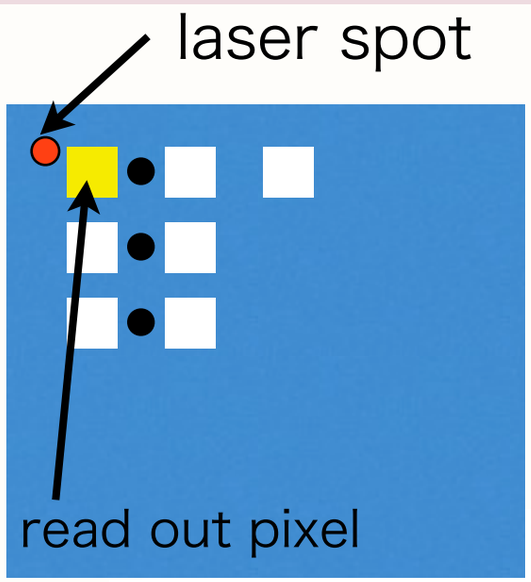
Connection of Si and PCB is being done by 2mm spring (BeCu)



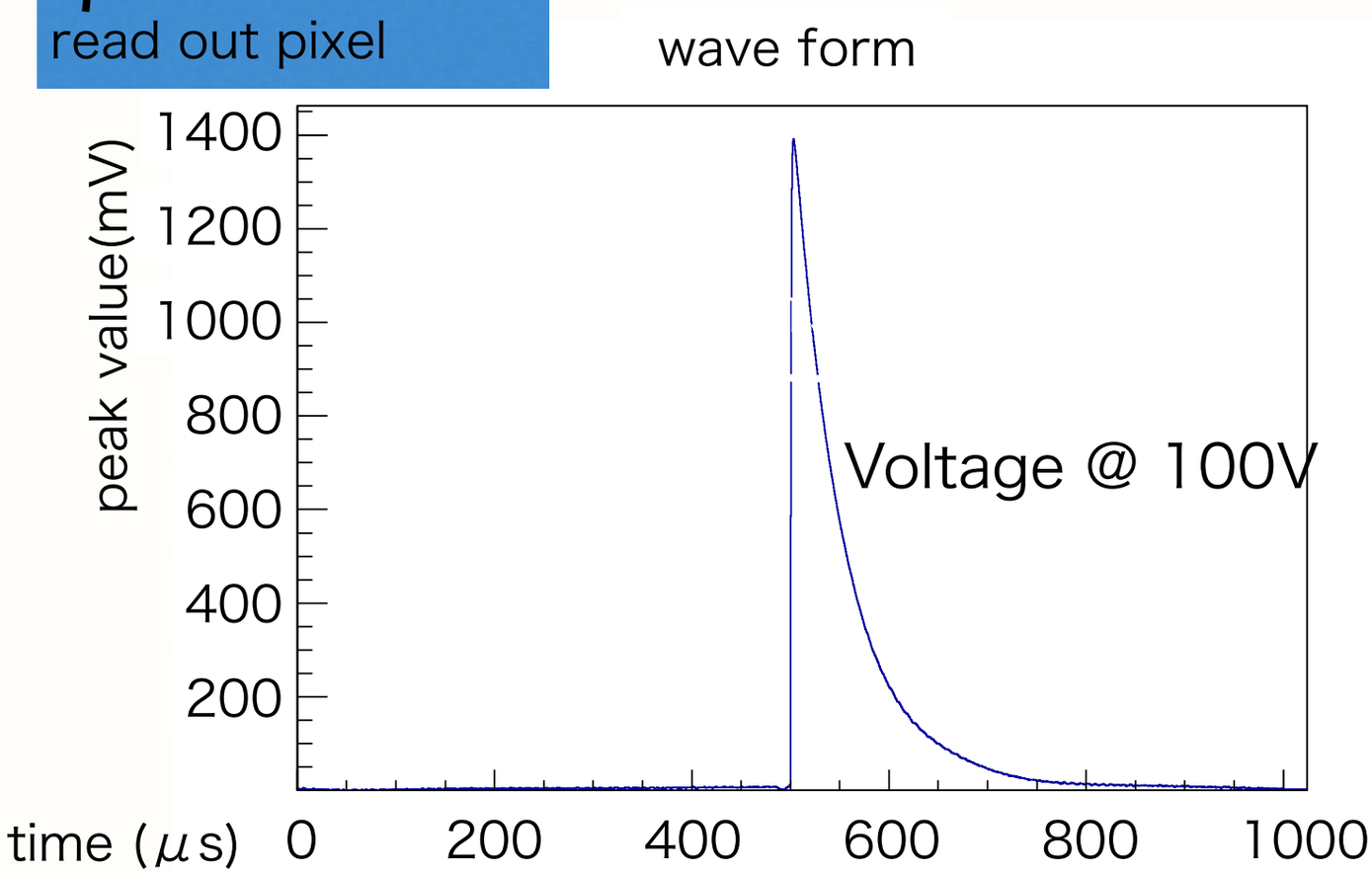



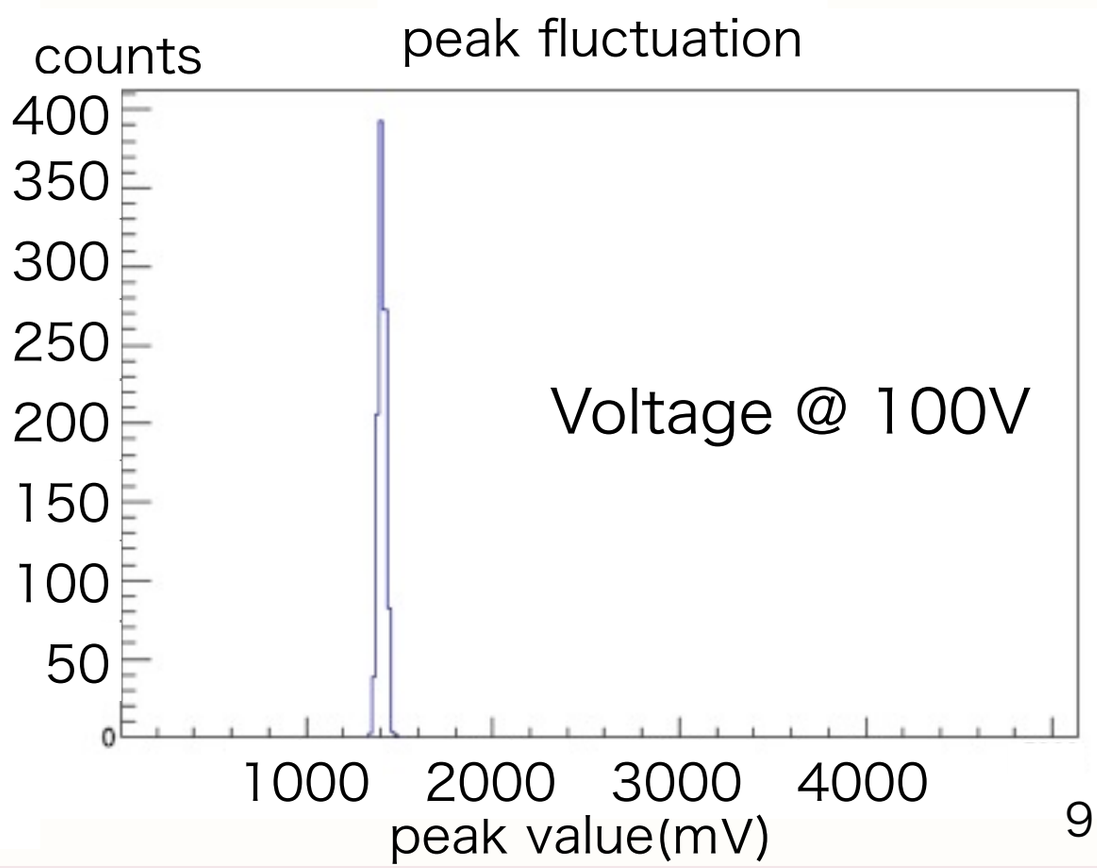



# Response to the laser




- First, we measured the laser signal using oscilloscope.
- fluctuation of peak value ~3%

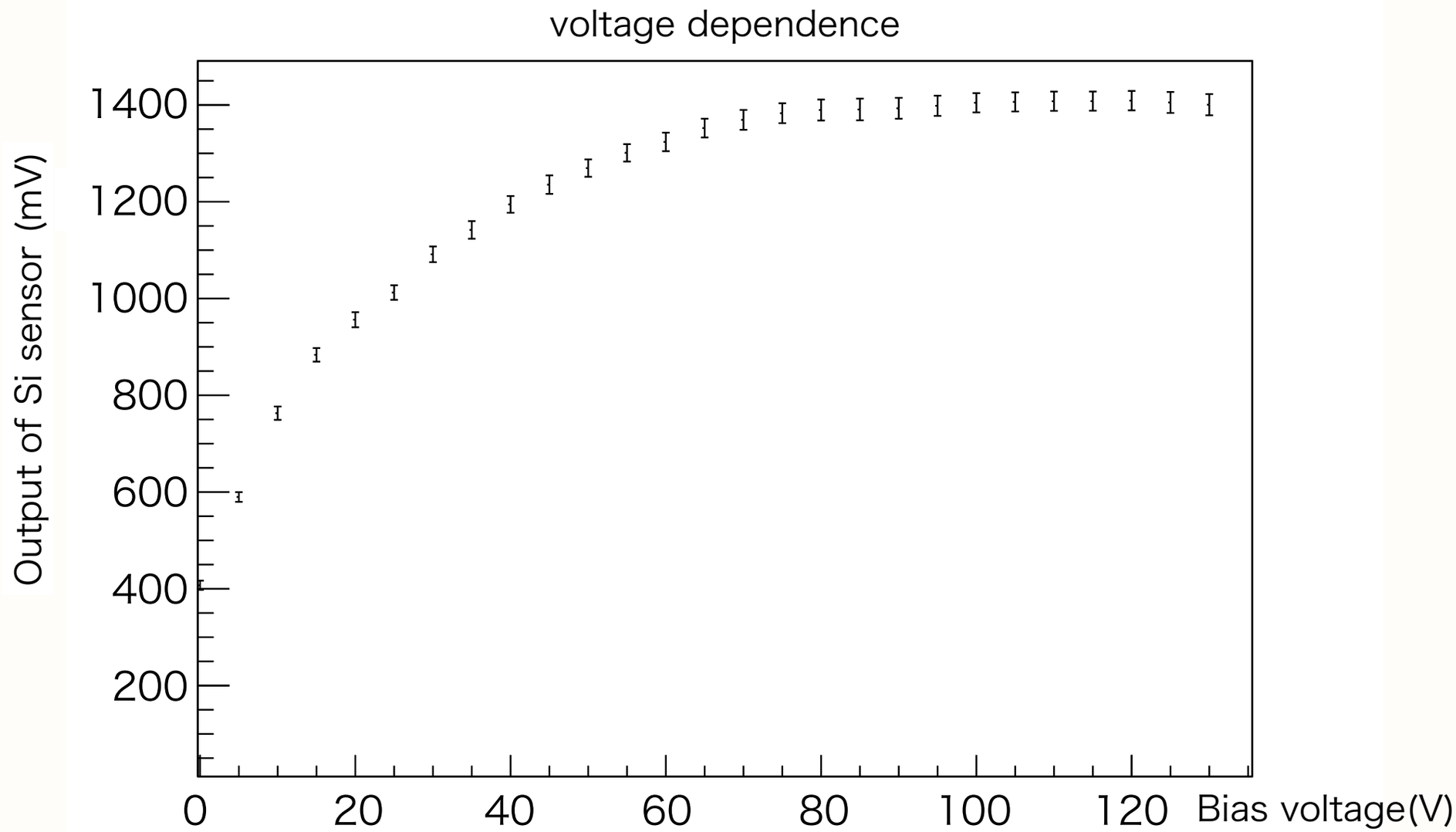



# voltage dependence

Saturation occurred at full depletion voltage.

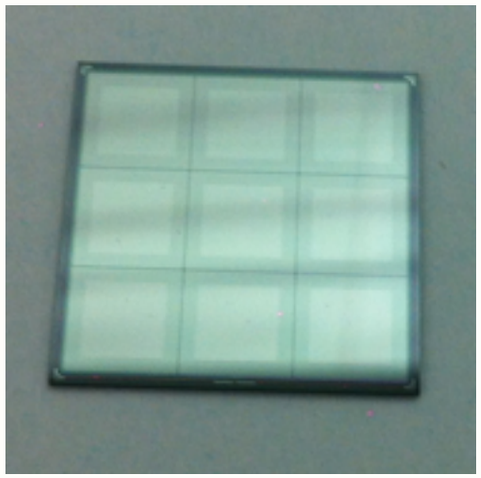
This result almost corresponds to 1/C^2 result.

(1/C^2 : 50V, laser : 80V, this gap is under investigation)

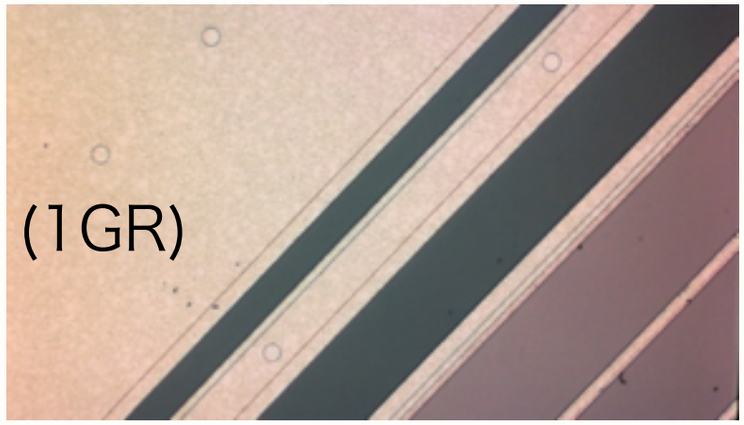


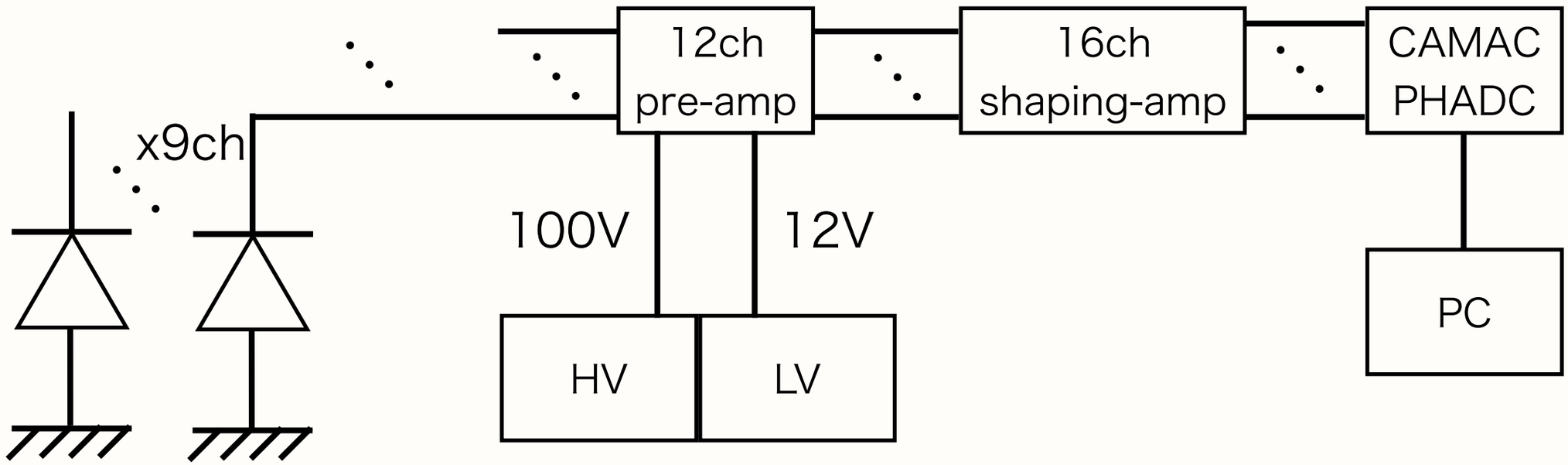
# Setup for multi read out

To do multi read out, we changed our read out system slightly.
We use baby chip during multi read out measurement.



baby chip has 3x3 = 9 pixels
guard ring is same as main chip. (1GR)





# Multi pixel read out


baby chip

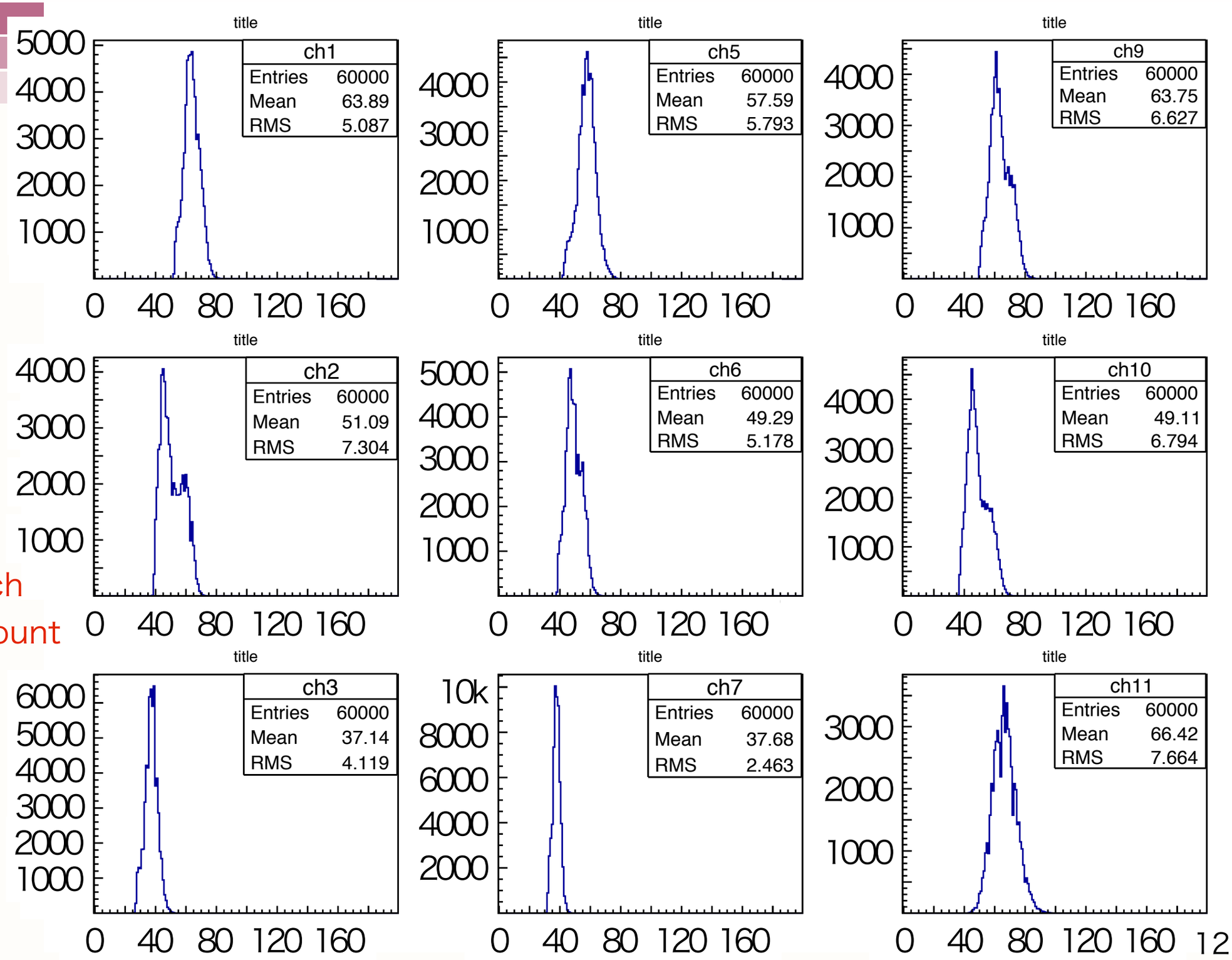
3 x 3 = 9 pix.

pedestal :40-80 ADC ch

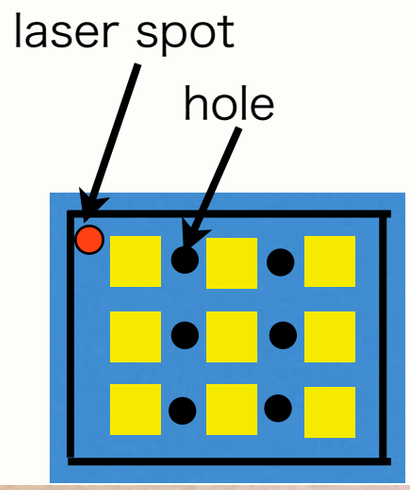
horizontal axis :ADC count

vertical axis :counts

@ 100V

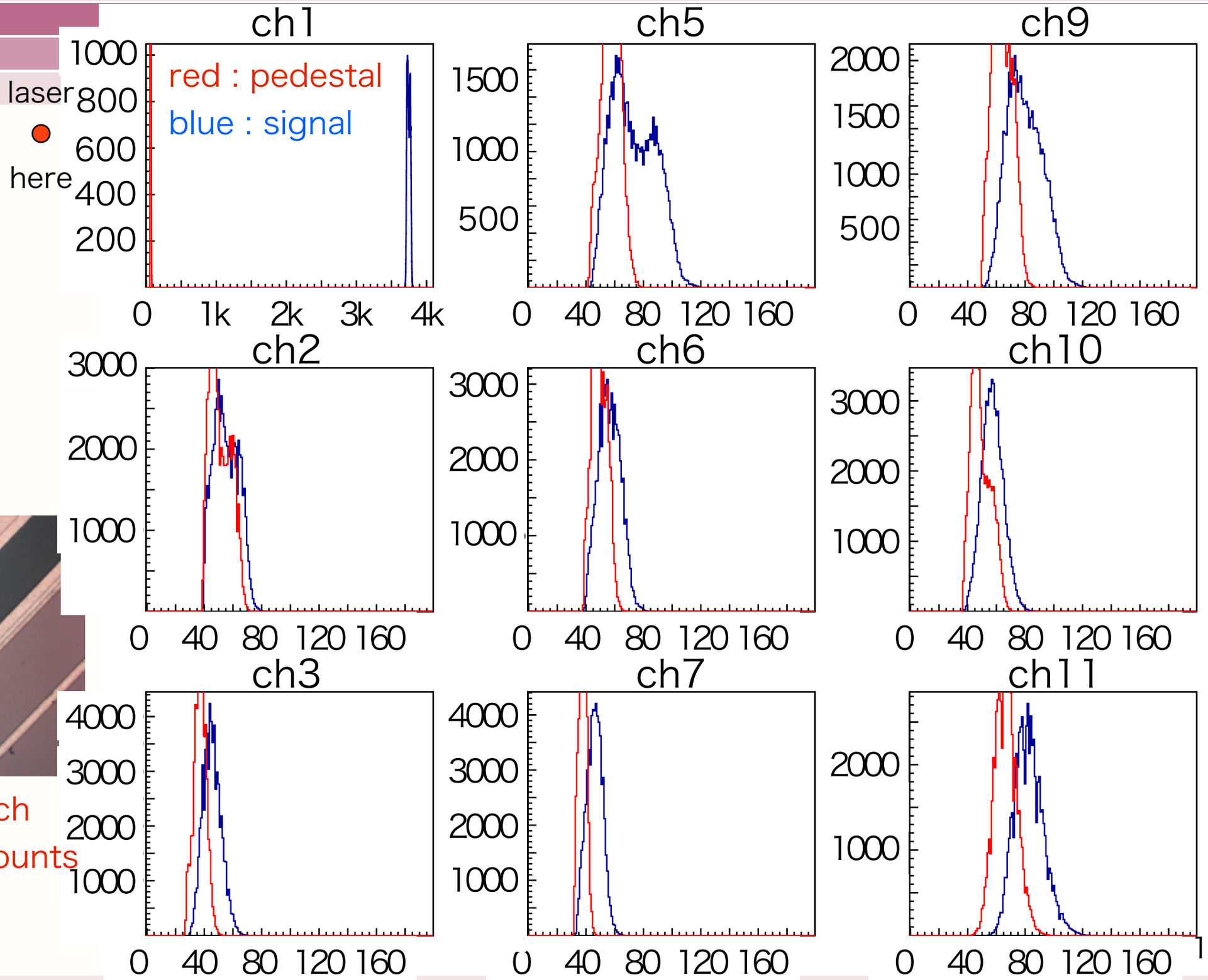


# Multi pixel read out (Cont.)

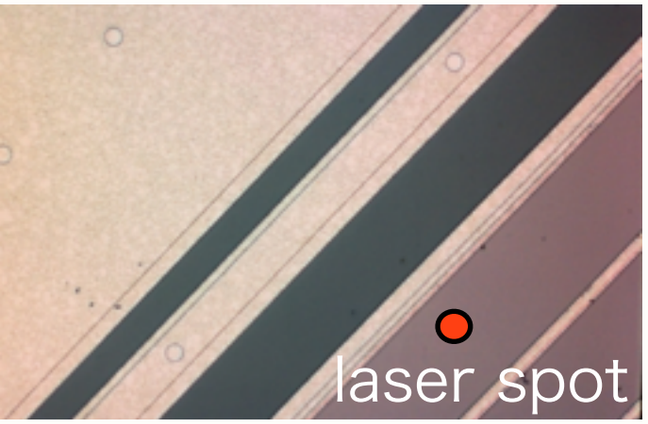




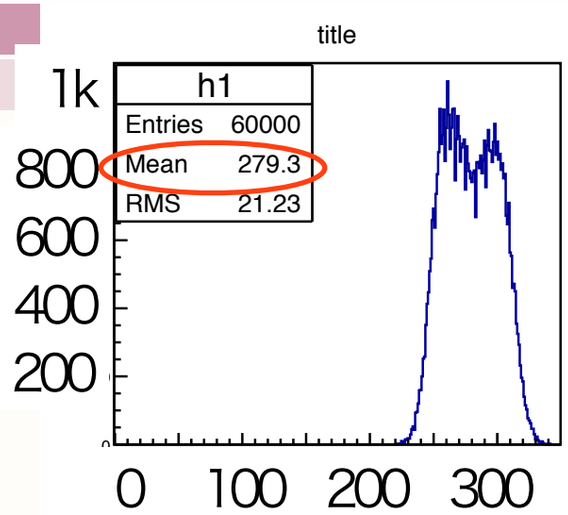
pedestal : 40~80 ADC ch
horizontal axis : ADC counts
vertical axis : counts
@ 100V

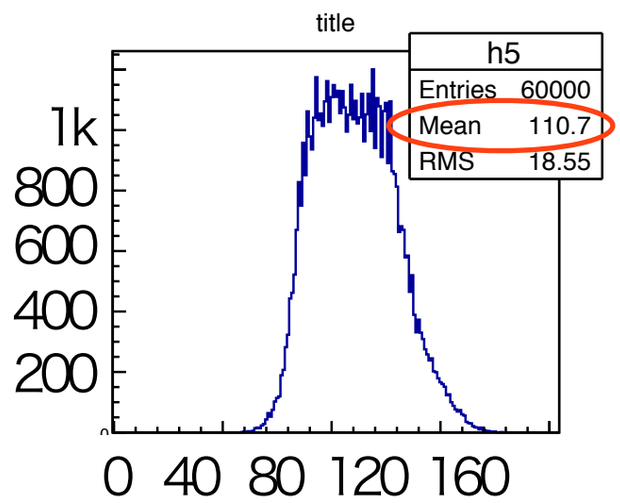


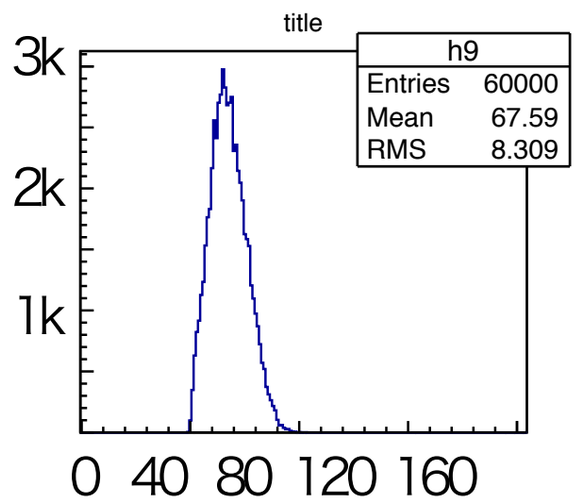
# Response of edge of chip

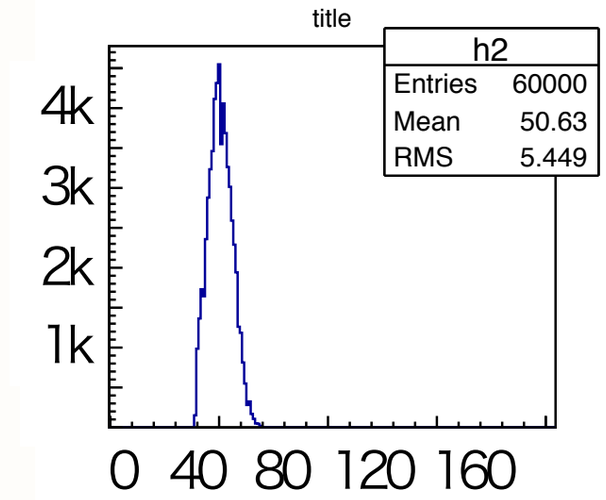


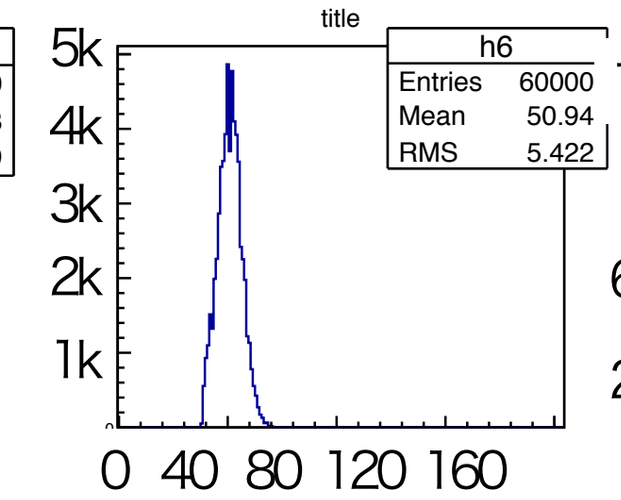

pedestal : 40~80 ADC ch
horizontal axis : ADC counts
vertical axis : counts
@ 100V

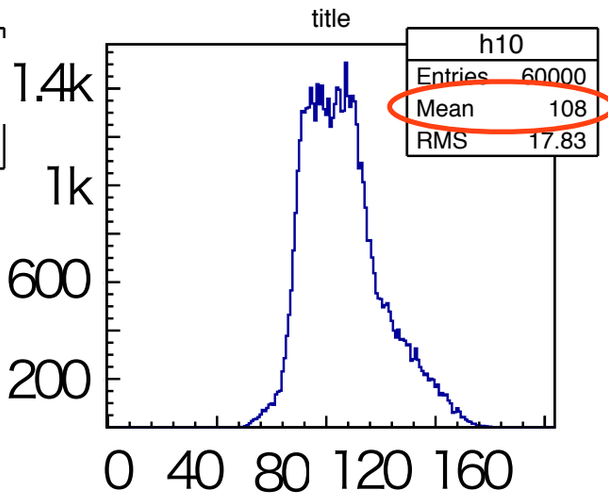


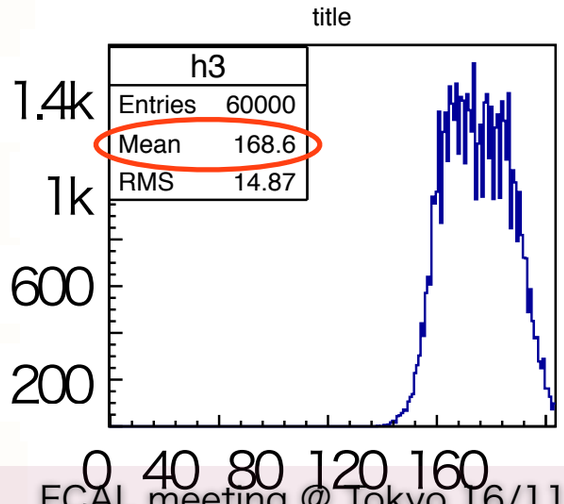



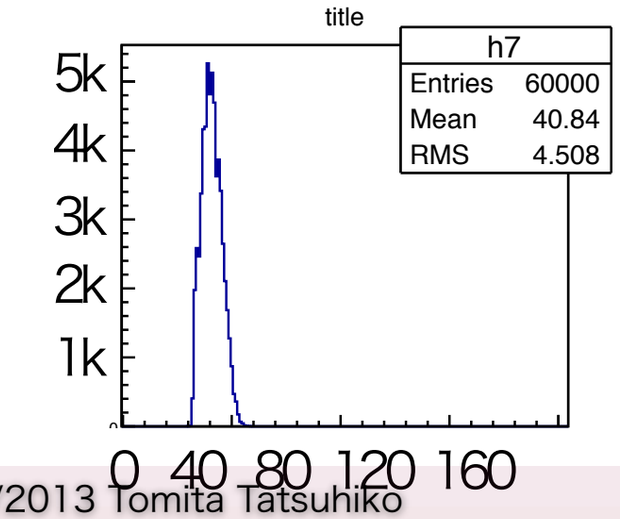



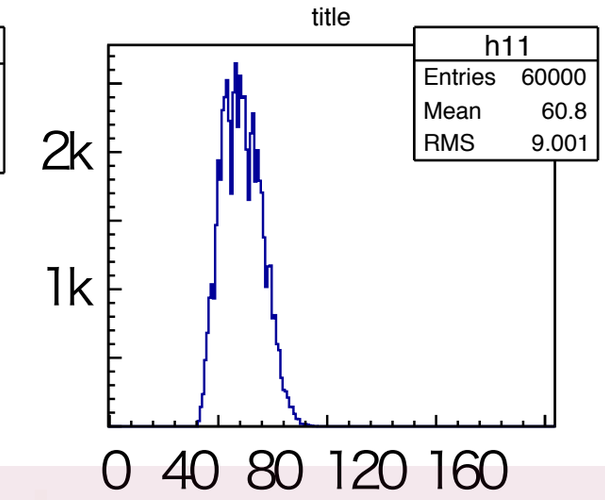



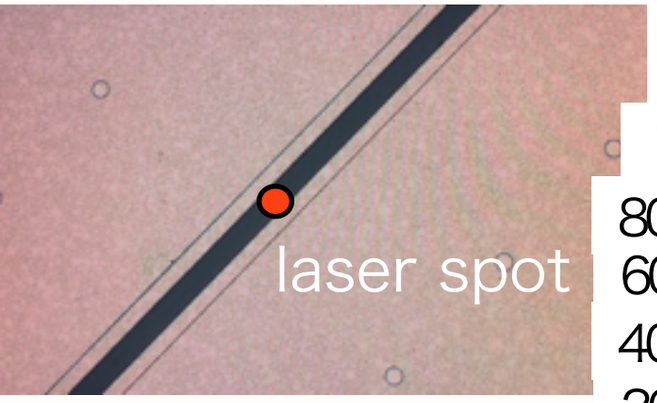



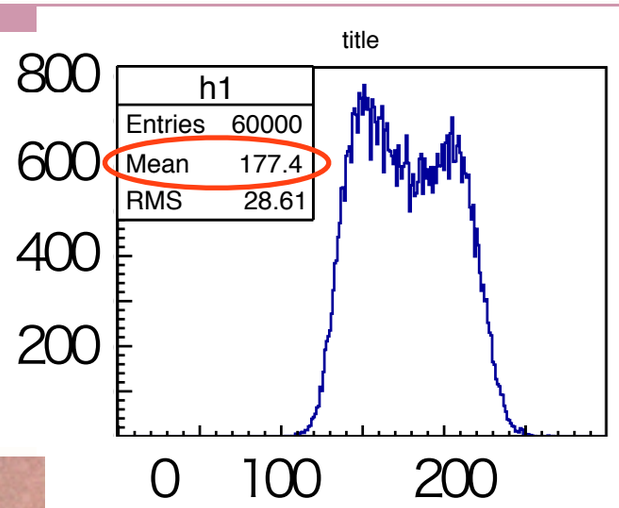



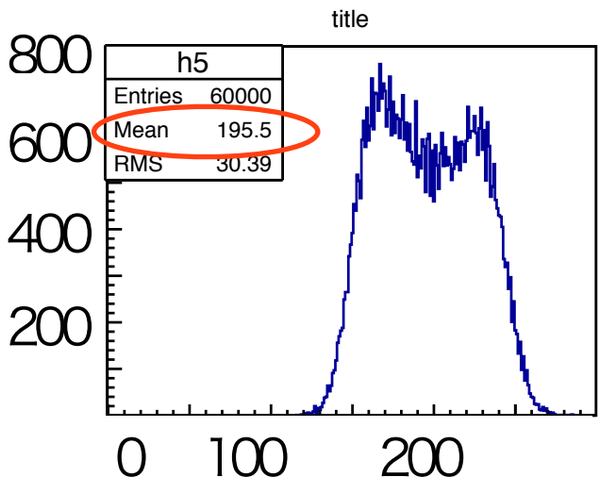



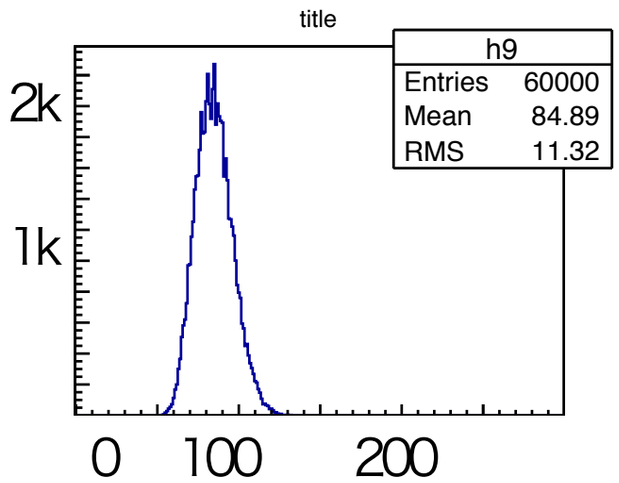
# Between pix. and pix.

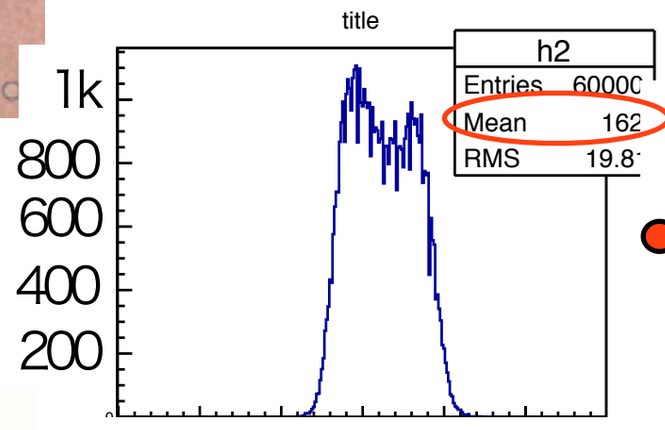


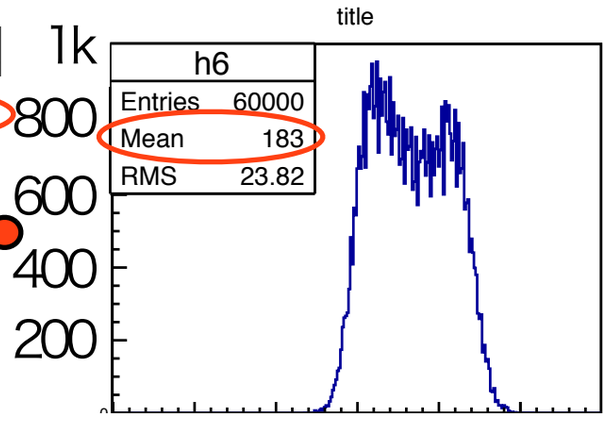

pedestal : 40~80 ADC ch
horizontal axis : ADC counts
vertical axis : counts
@ 100V

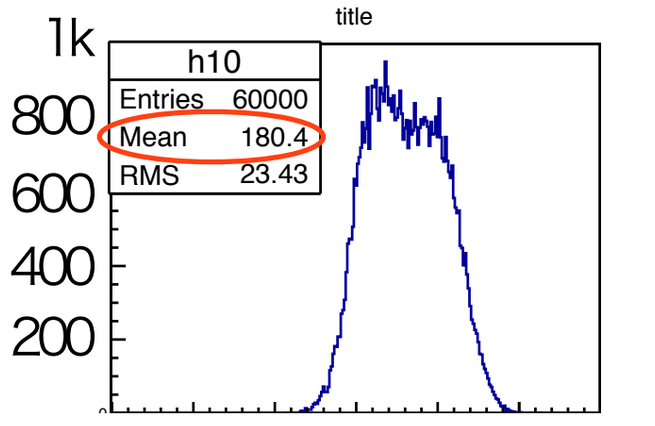


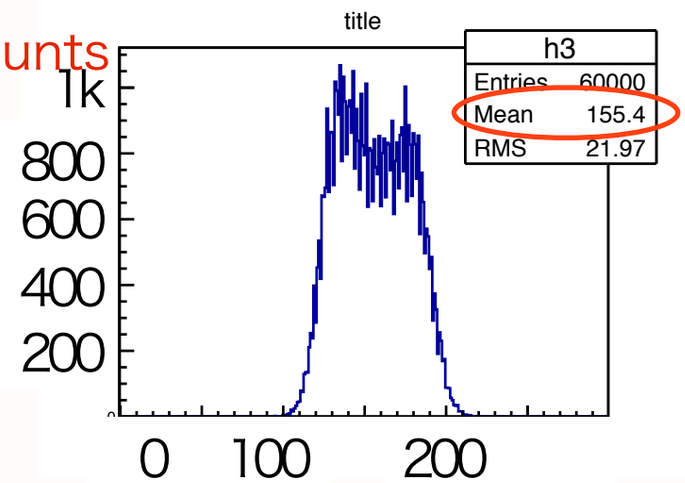



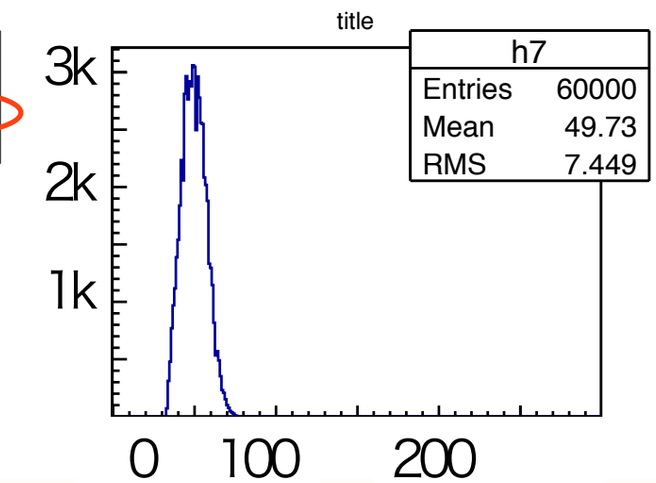



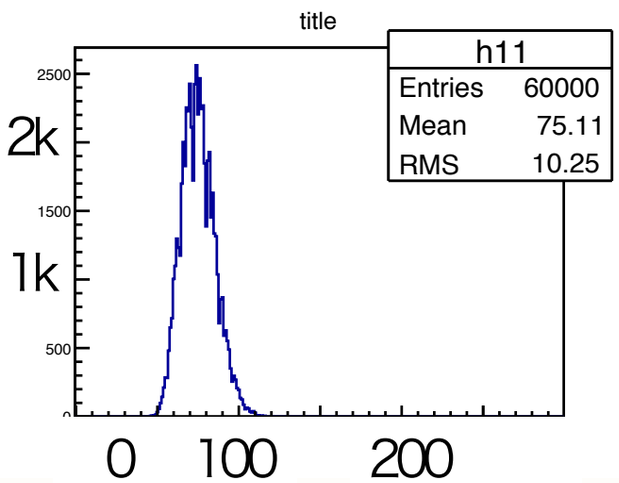



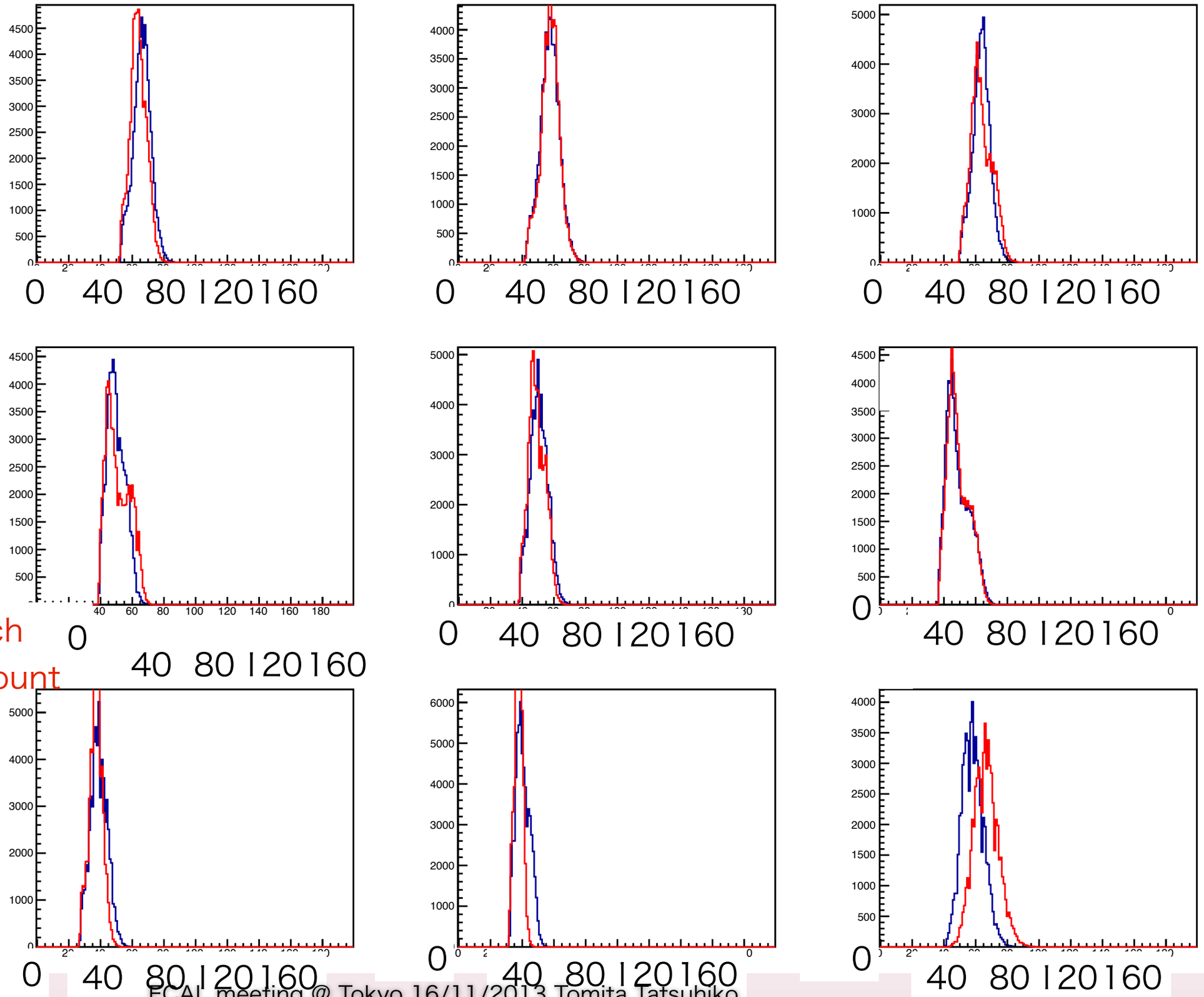



# Multi pixel read out(GR,NGR)


baby chip
3 x 3 = 9 pix.

pedestal :40-80 ADC ch
horizontal axis :ADC count
vertical axis :counts
@ 100V



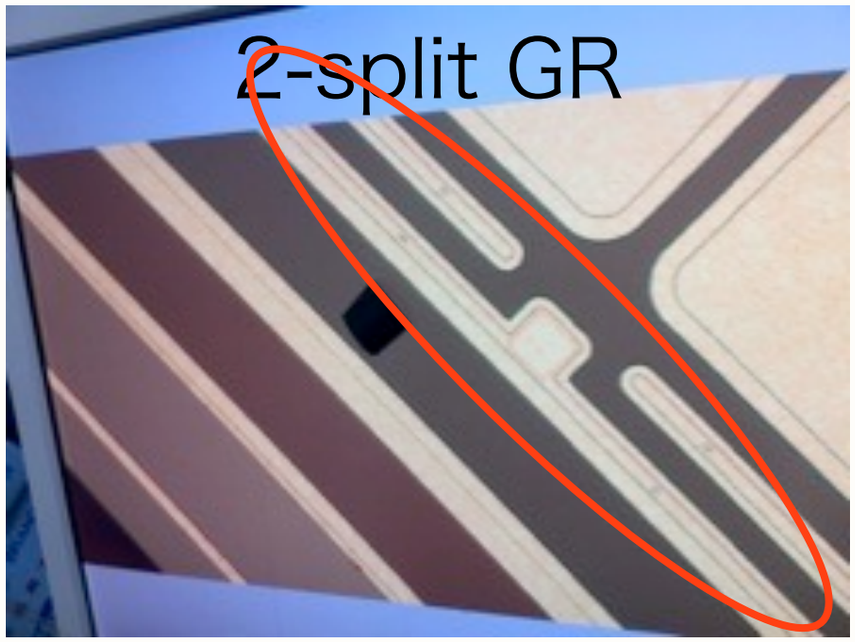
# Summary & Prospect

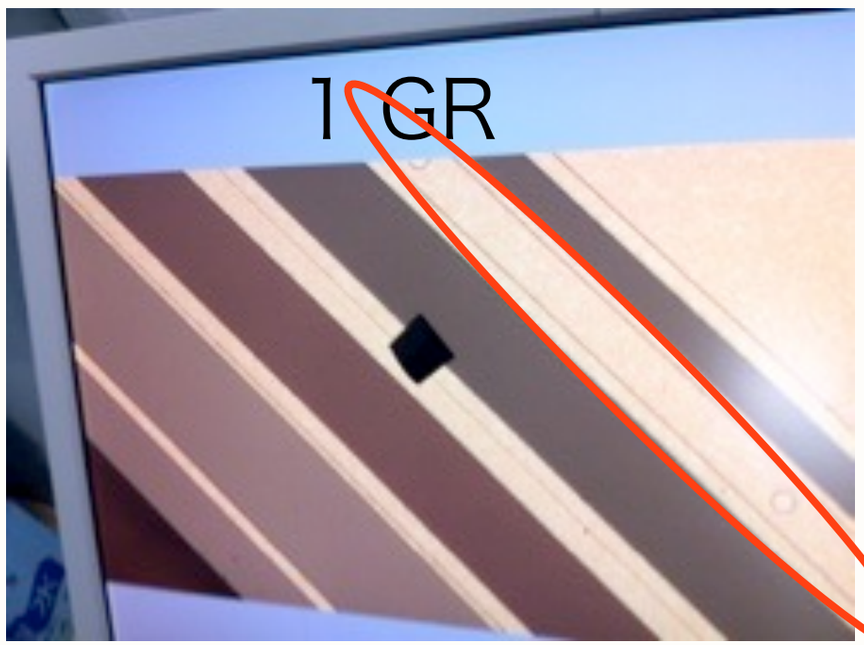
- We established the Si chip test-bench system both in Tokyo and Kyushu.
  - leakage current and capacitance (@Both)
  - radiation test and time char. (@Tokyo)
  - guard ring and cross talk (@Kyushu)
- We are now ready to start measurement for quality control.
- Radiation test is now preparing.
- Guard ring and cross talk effects should be investigated for each type of guard ring(1GR, no GR, 2-split GR, 4-split GR). (We need to upgrade our laser system)

# Thank you for listening!!

# back up slides

# type of guard ring


# recombination time

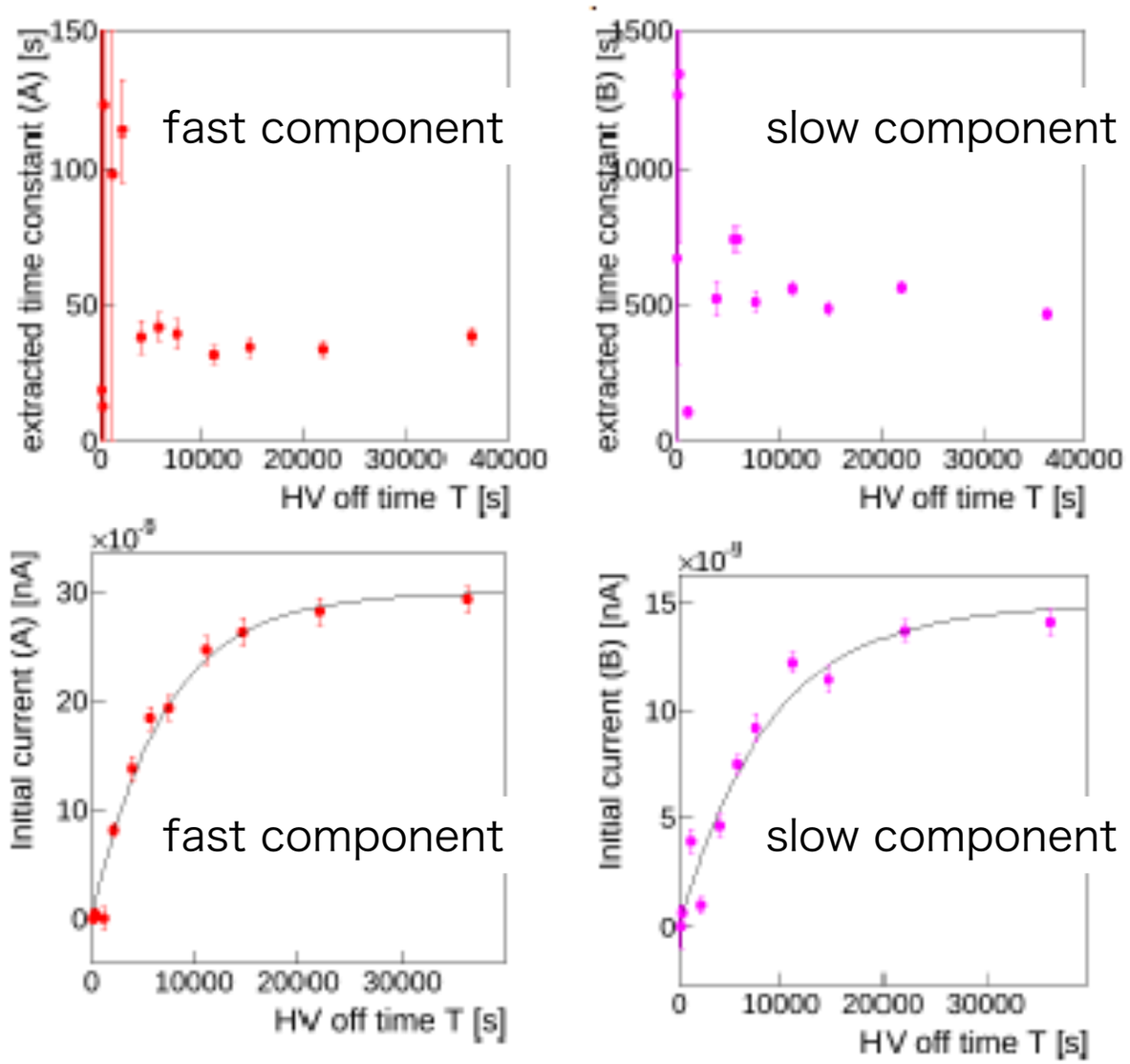
Recombination time is calculated from constants A, B.

$$A = C_A(1 - \exp(-T/\tau_T))$$

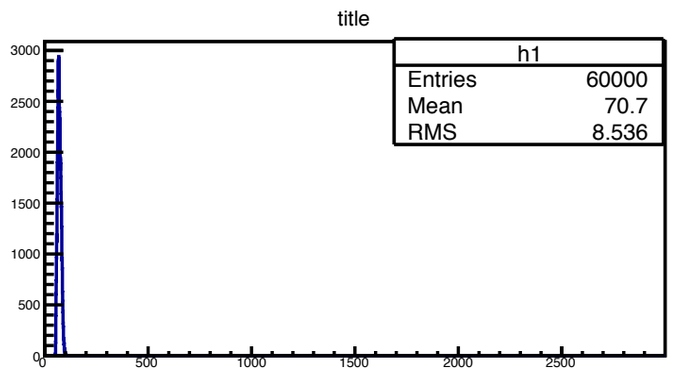
$C_A$ showed A at infinity region.

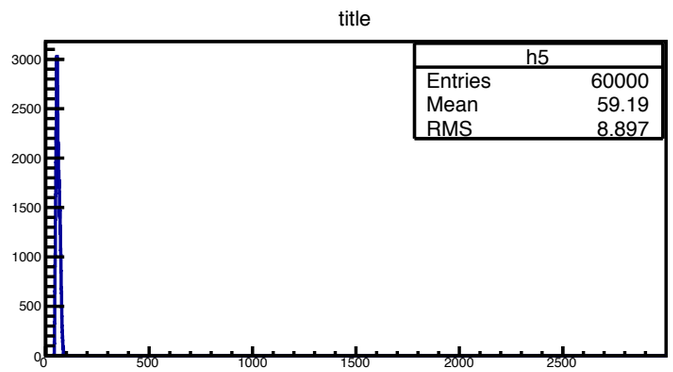
fitted by...

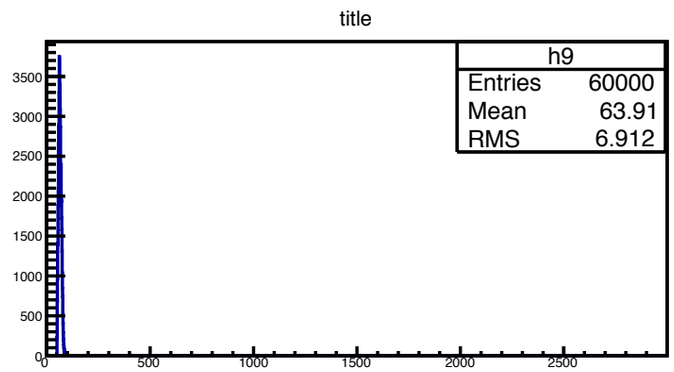
$$I = A\exp(-t/\tau_1) + B\exp(-t/\tau_2) + const$$

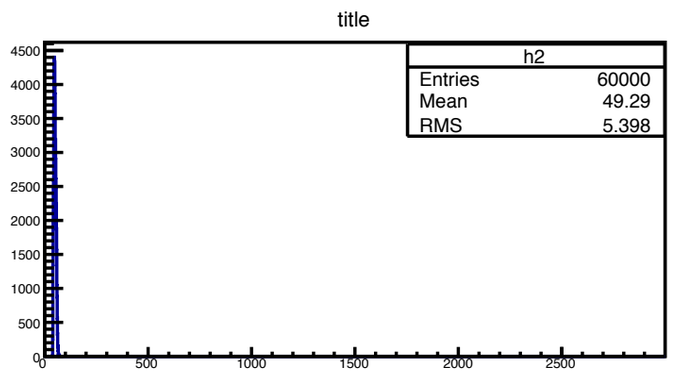


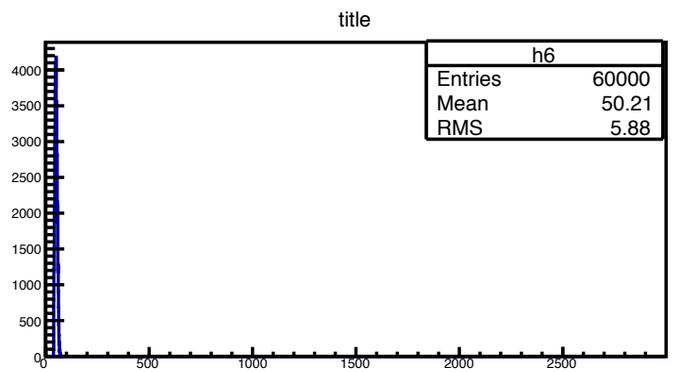
# pedestal

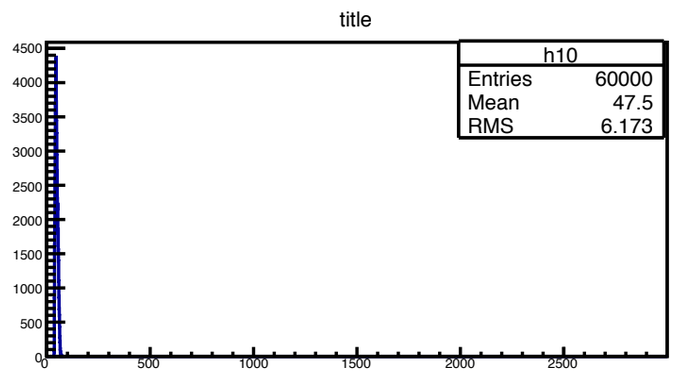

title
h1
Entries 60000
Mean 70.7
RMS 8.536

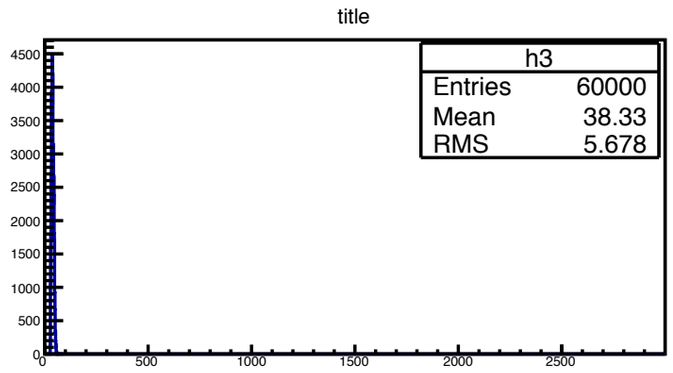

title
h5
Entries 60000
Mean 59.19
RMS 8.897

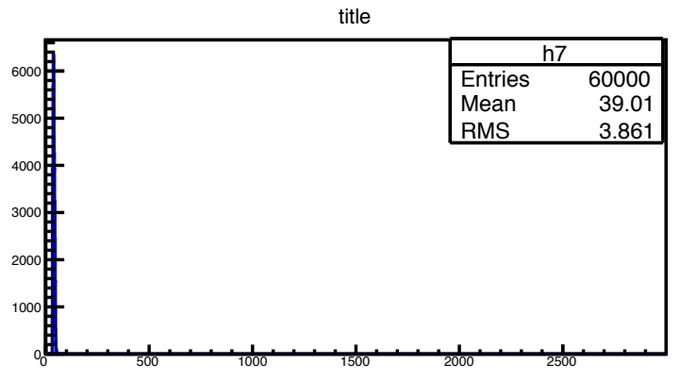

title
h9
Entries 60000
Mean 63.91
RMS 6.912

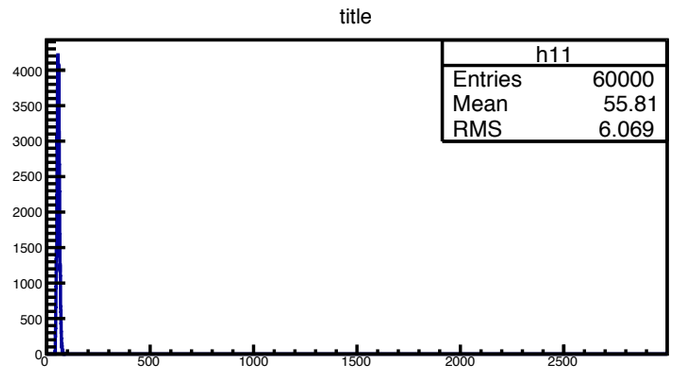

title
h2
Entries 60000
Mean 49.29
RMS 5.398


title
h6
Entries 60000
Mean 50.21
RMS 5.88


title
h10
Entries 60000
Mean 47.5
RMS 6.173


title
h3
Entries 60000
Mean 38.33
RMS 5.678


title
h7
Entries 60000
Mean 39.01
RMS 3.861


title
h11
Entries 60000
Mean 55.81
RMS 6.069