Summary of calibration on ground and the application to flight data

Waseda Univ.

Shoji Torii,

Y.Asaoka and Y.Akaike

CALET-TIM @ Pisa 2015.6.24

Calibration done on ground for Flight Model

N.B. All of the results shown are PRELIMINARY.

- ☐ Muon run (by Y.Akaike)
  - Pedestal
  - One MIP peak
  - S/N for one MIP
  - Check for low gain channels

✧ Calibration necessary on-board by protons and/or heavy nuclei

- Position dependence
- Temperature dependence

  Temperature distribution will be give by an exact thermal analysis using the real data during thermal-vacuum test
- MIP peak dependence on the rigidity cut-off (i.e mostly latitude)

☐ Laser calibration for TASC PWO's (by Y.Asaoka)

- Relation between APD-high/low and PD-high/low was measured by UV Laser in dynamic range of several MIPs – 10^6 MIP
- Especially, in region of APD signal overflow, the PD signal is affected by small cross talk (~0.1%) , which cause a signal equivalent to PD due to the gain difference of about 1000.

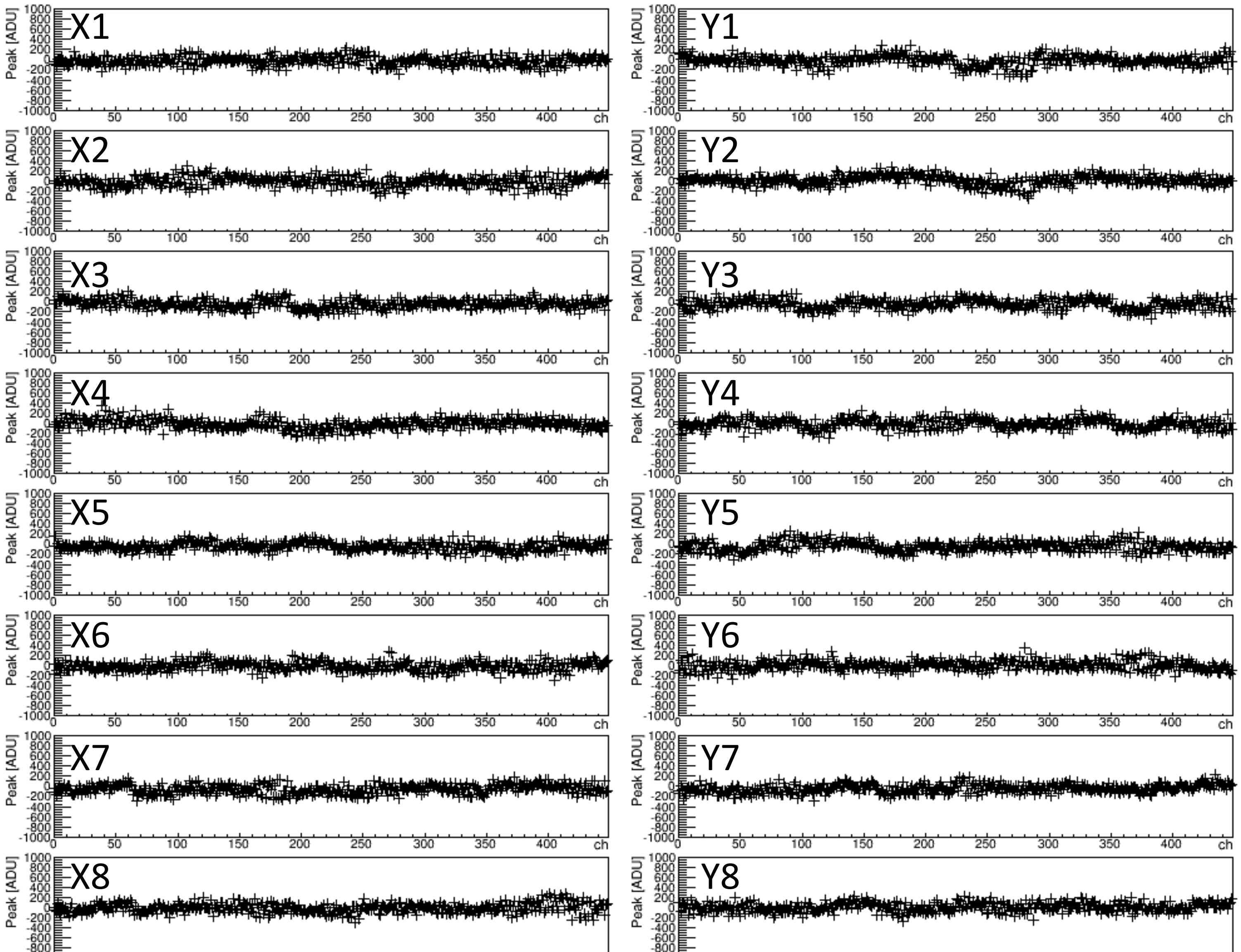
Preliminary fitting curves are given for each channel.

IMC calibration

- ☐ Anode
  - Pedestal
  - r.m.s noise
  - Pulse height distribution of muon signals
  - Distribution of hit numbers in each channel
- ☐ Dynode sum for Trigger
  - Pulse height distribution of muon signals

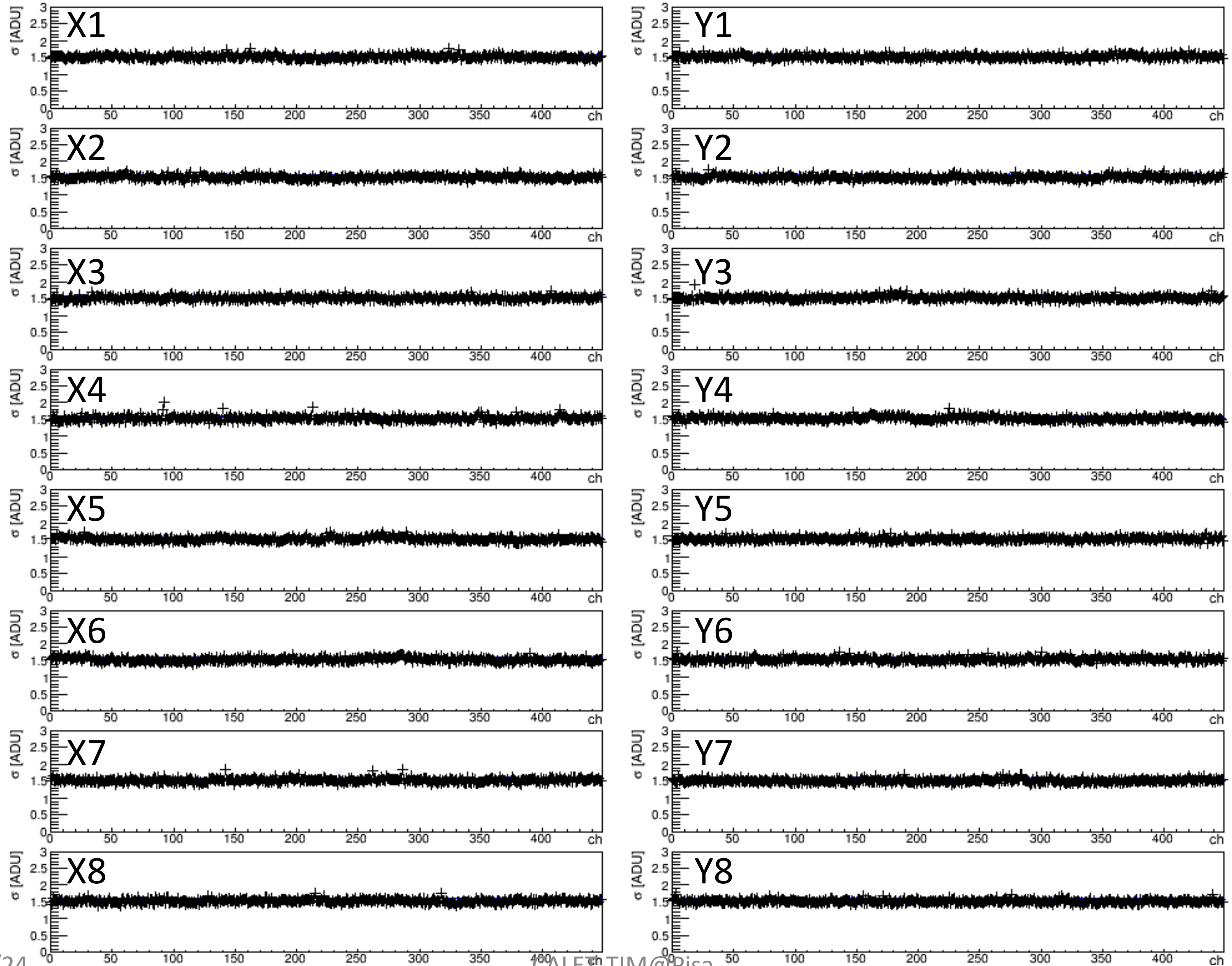
●Period.①

Mean of IMC Pedestal

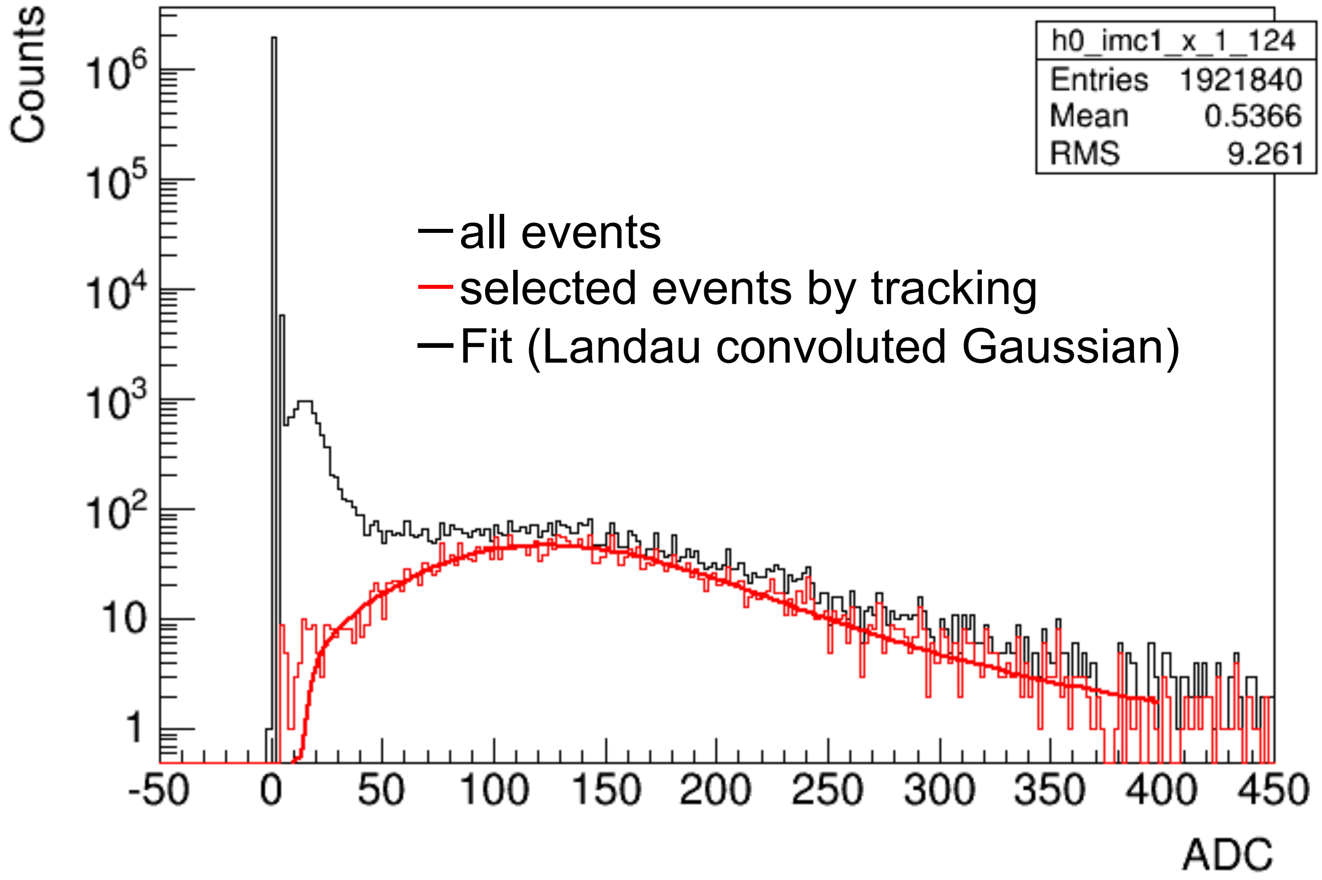


●Period.①

Sigma of IMC Pedestal

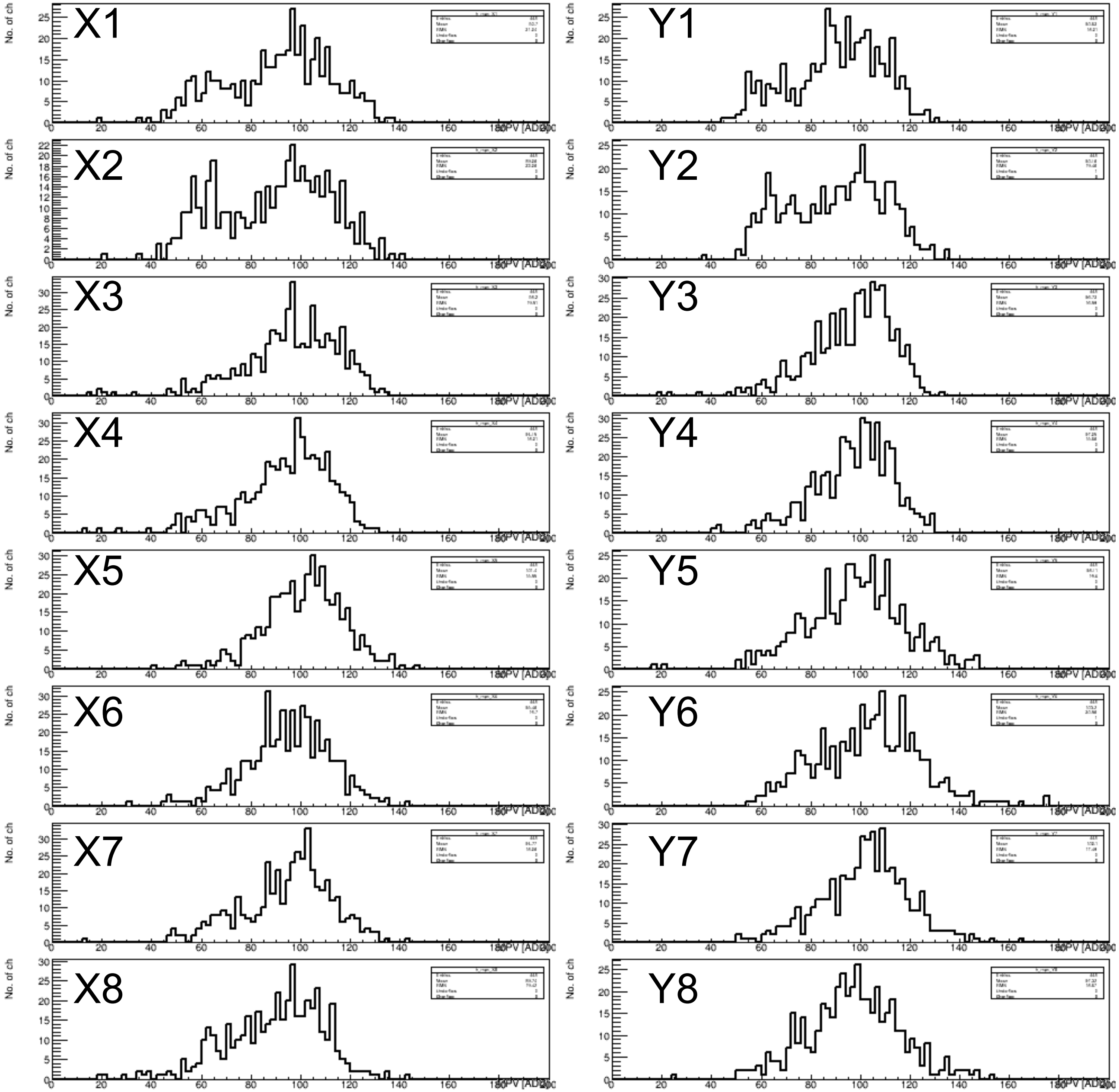


An example of Muon signal

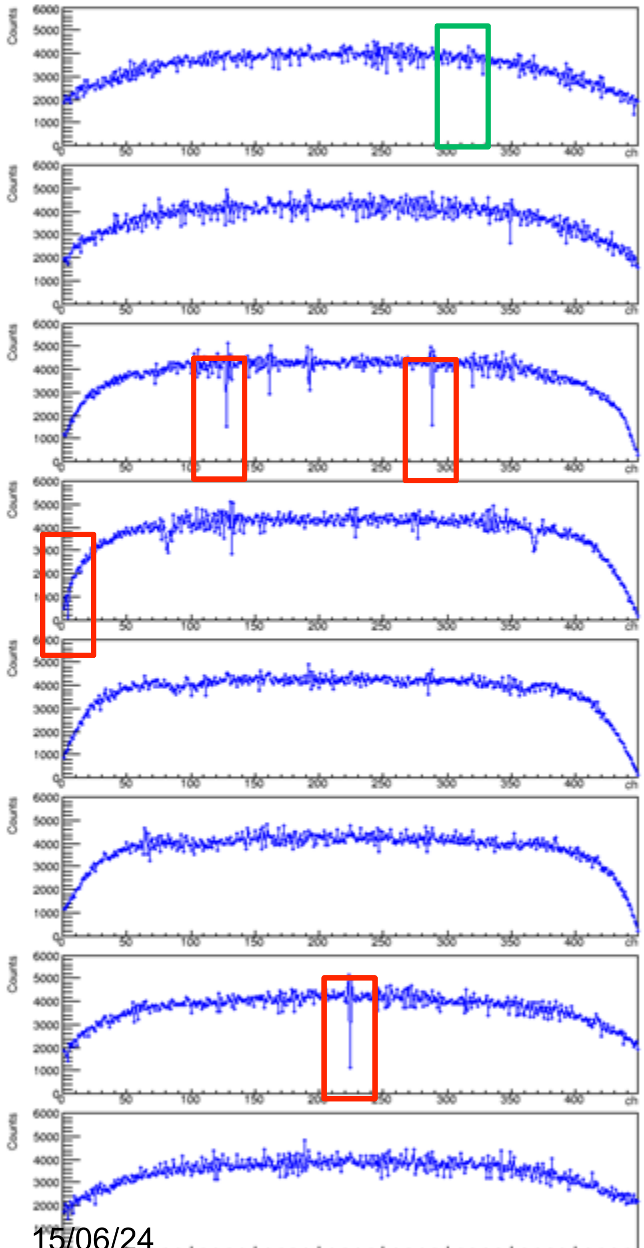


MPV of IMC muon signals

HV=-800V



Distribution of hit numbers in each channel (X-side)



X1

X2

X3

X4

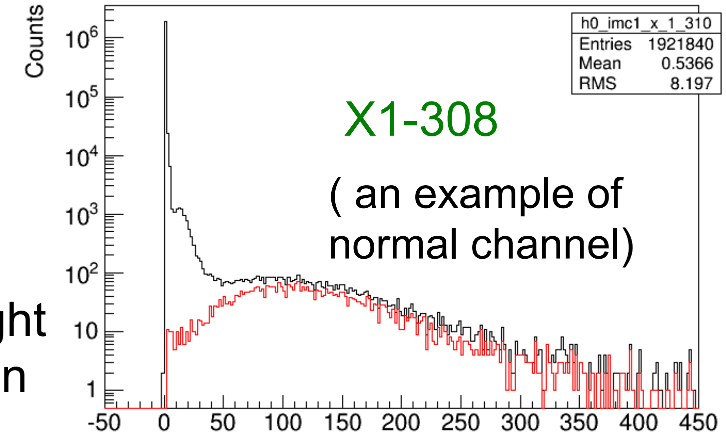
X5

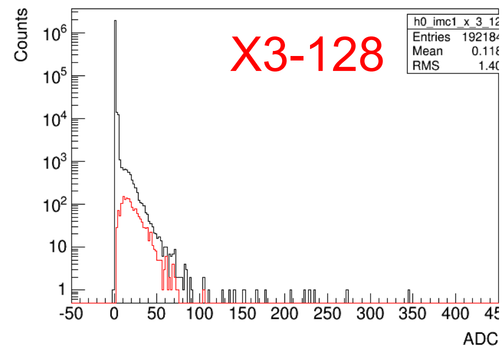
X6

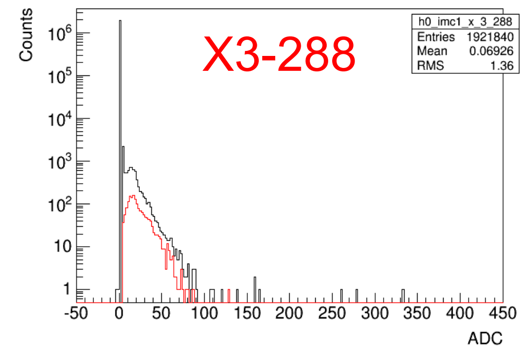
X7

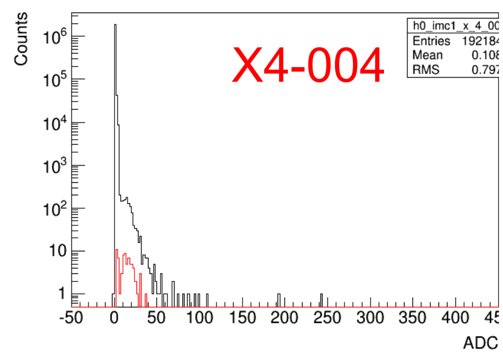
X8

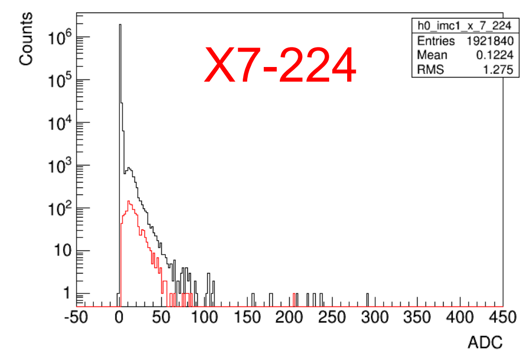
Pulse height distribution





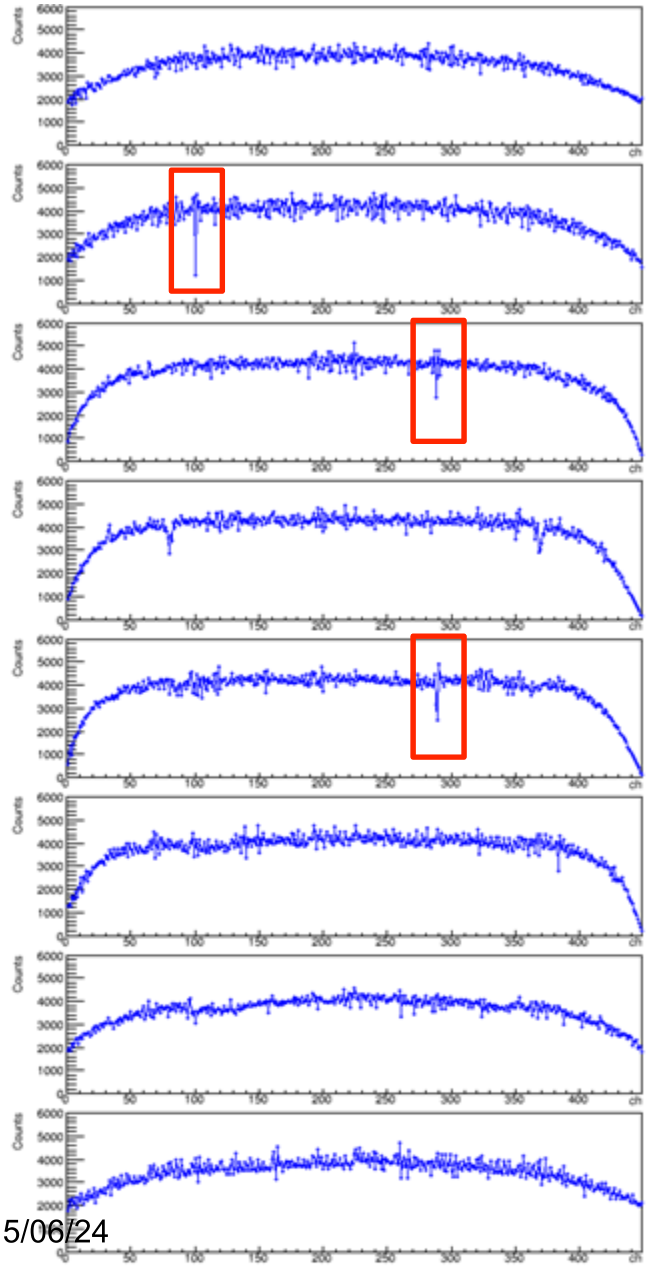






“low gain” channels

Distribution of hit numbers in each channel (Y-side)



Y1

Y2

Y3

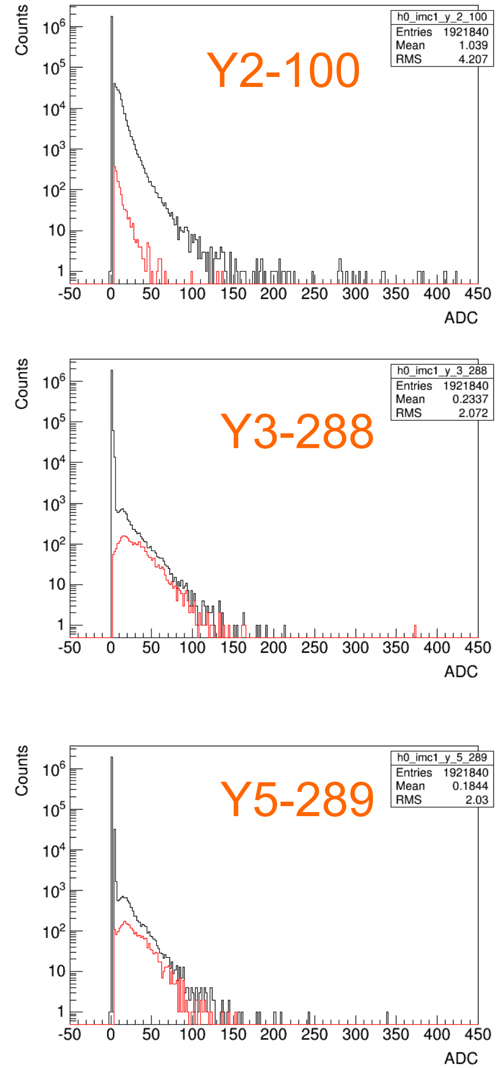
Y4

Y5

Y6

Y7

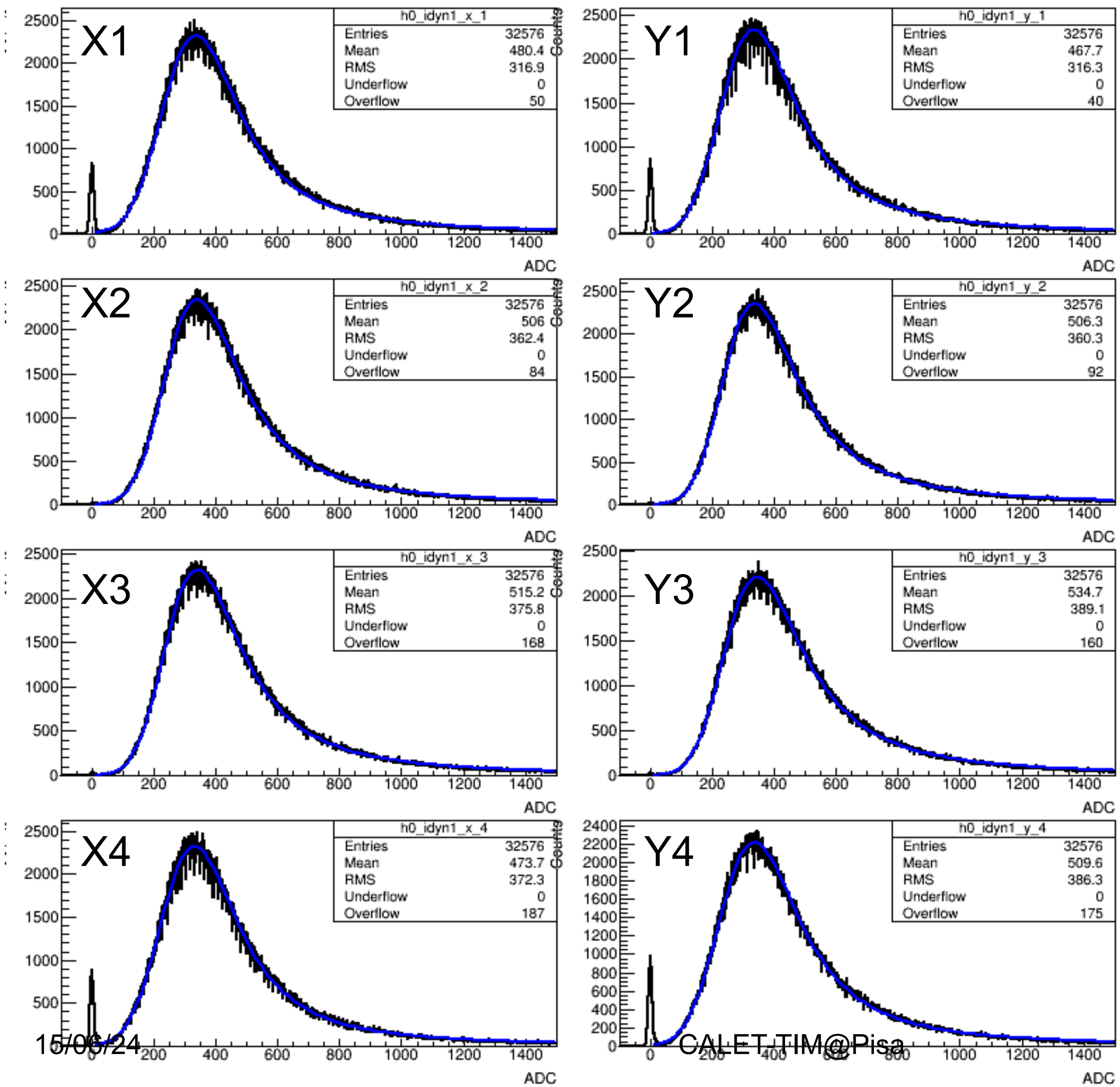
Y8



“low gain” channels

IMC Dynode

HV: -800V



	MPV [ADU]		MPV [ADU]
X1	319.6	Y1	320.2
X2	329.0	Y2	328.2
X3	330.5	Y3	338.5
X4	314.3	Y4	320.3

Summary of IMC calibration

- In IMC, most of the anode signals achieve a significant S/N (~7）at ~800 V.

- Even if we supply 600V to X4 and Y4 layers, which is used for High Energy Shower Trigger, one MIP peak can be separated.

- The 7 channels (0.1% in number) are classified as” low gain channe” due to possible disconnection of Scifi to PMT.
$\Rightarrow$ the effect of number of “bad channel” to the detector performance is strictly evaluated (for review of development, see later)

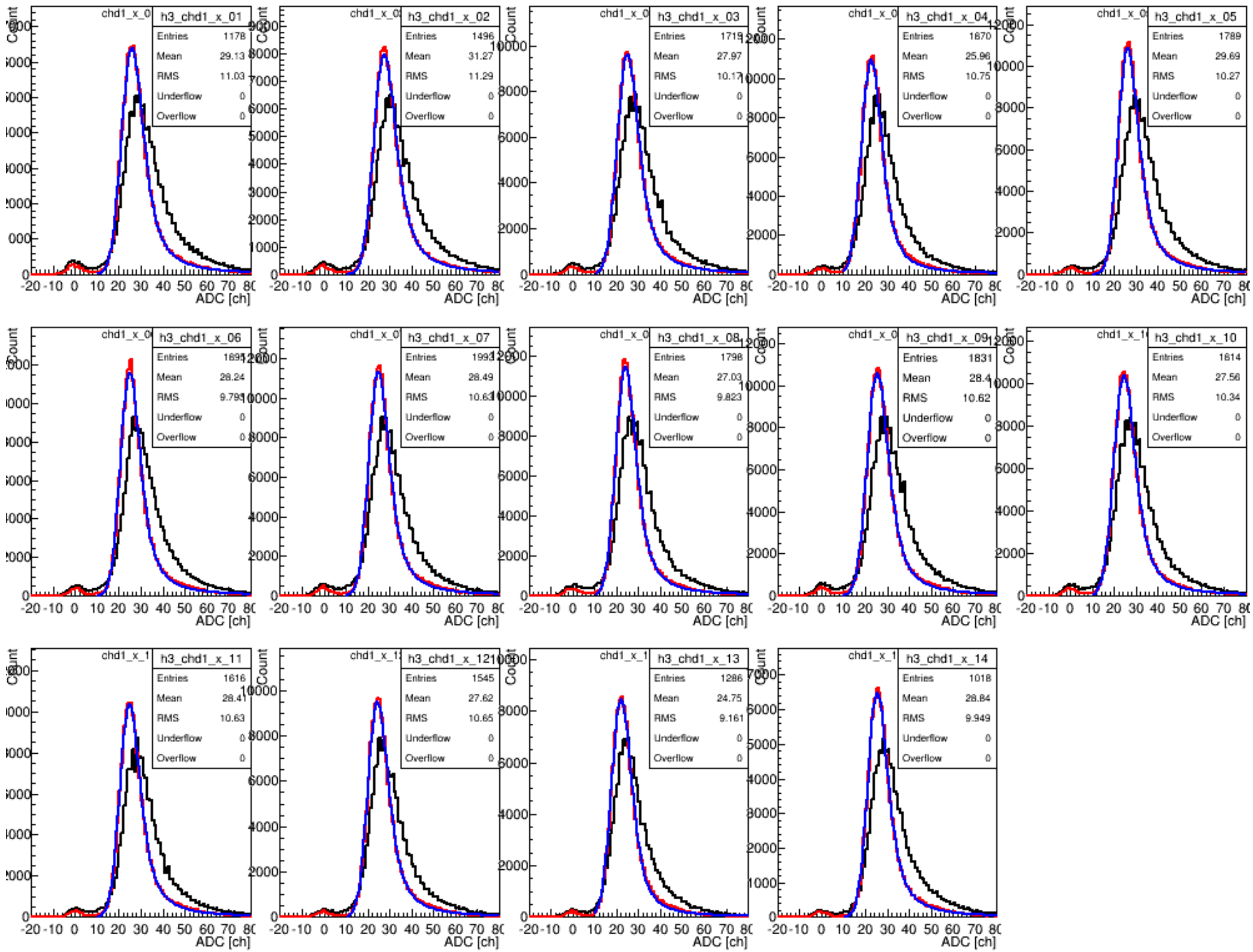
- The gains are adjustable by changing HV supply in unit number of 5, 4 and 5 in each layer.

- The dynode sum signals have an excellent capability to trigger the events over 0.5 MIPs.

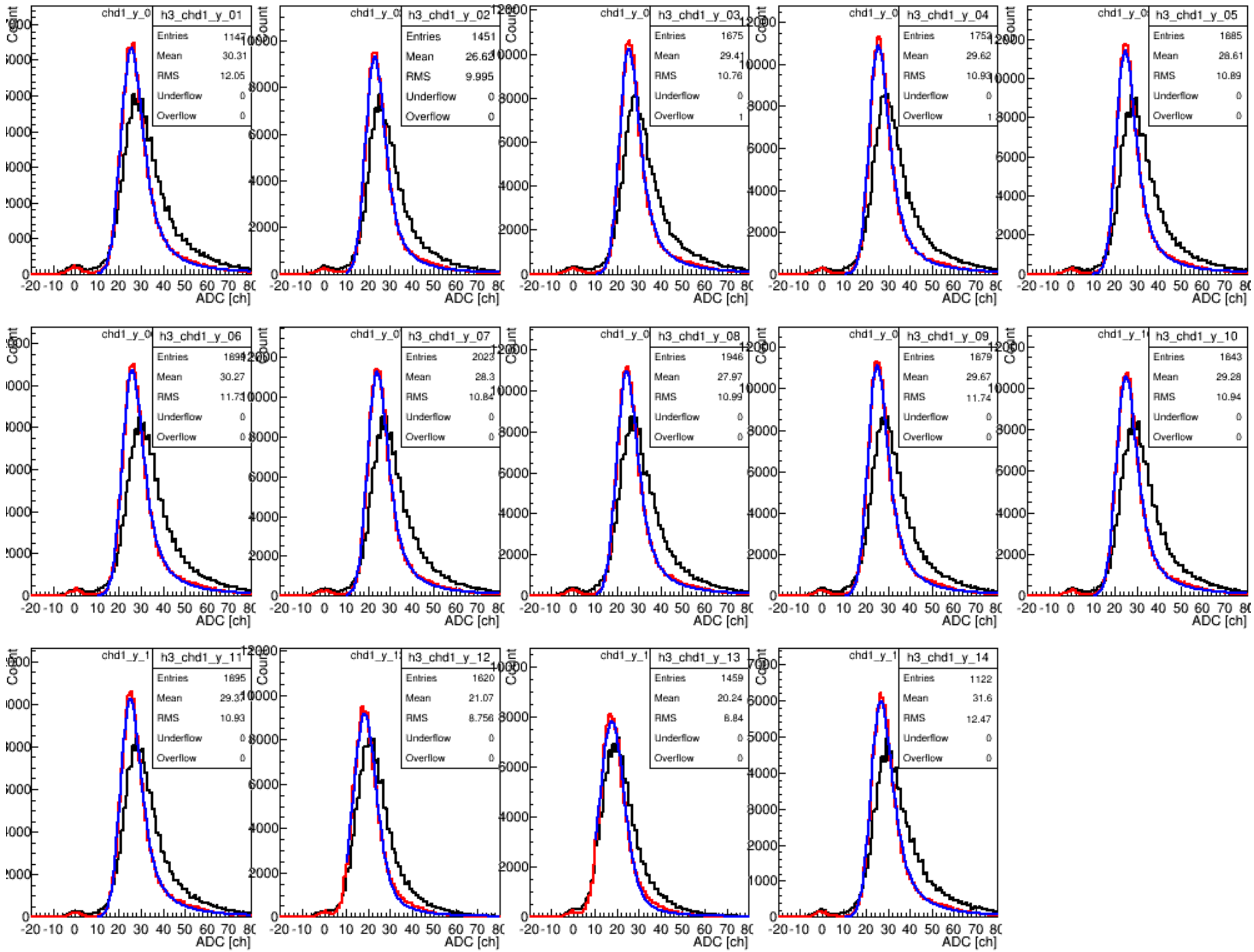
CHD calibration

- Pulse height distribution of muon signals
- Muon Peak pulse height (MPV)
- S/N ratio

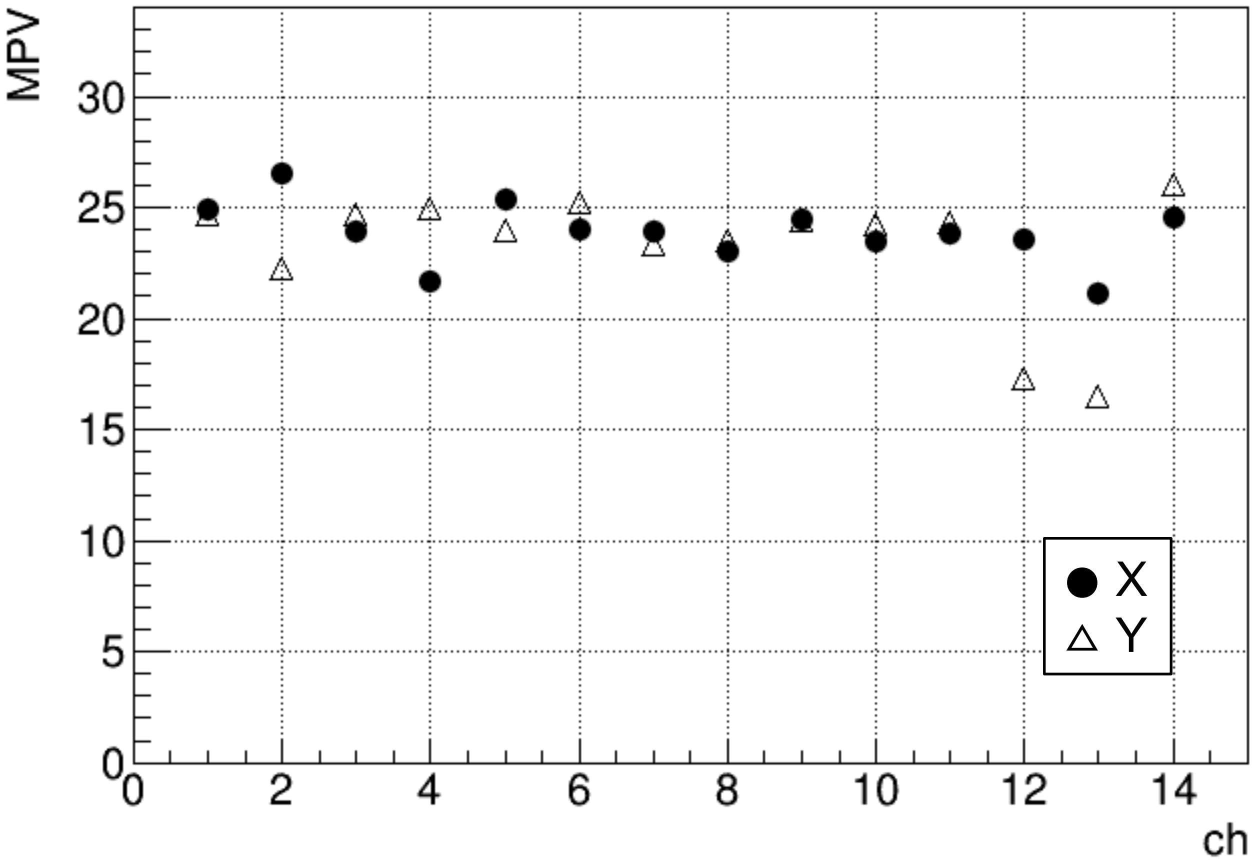
CHD-X Pulse Height Distribution



CHD-Y Pulse Height Distribution

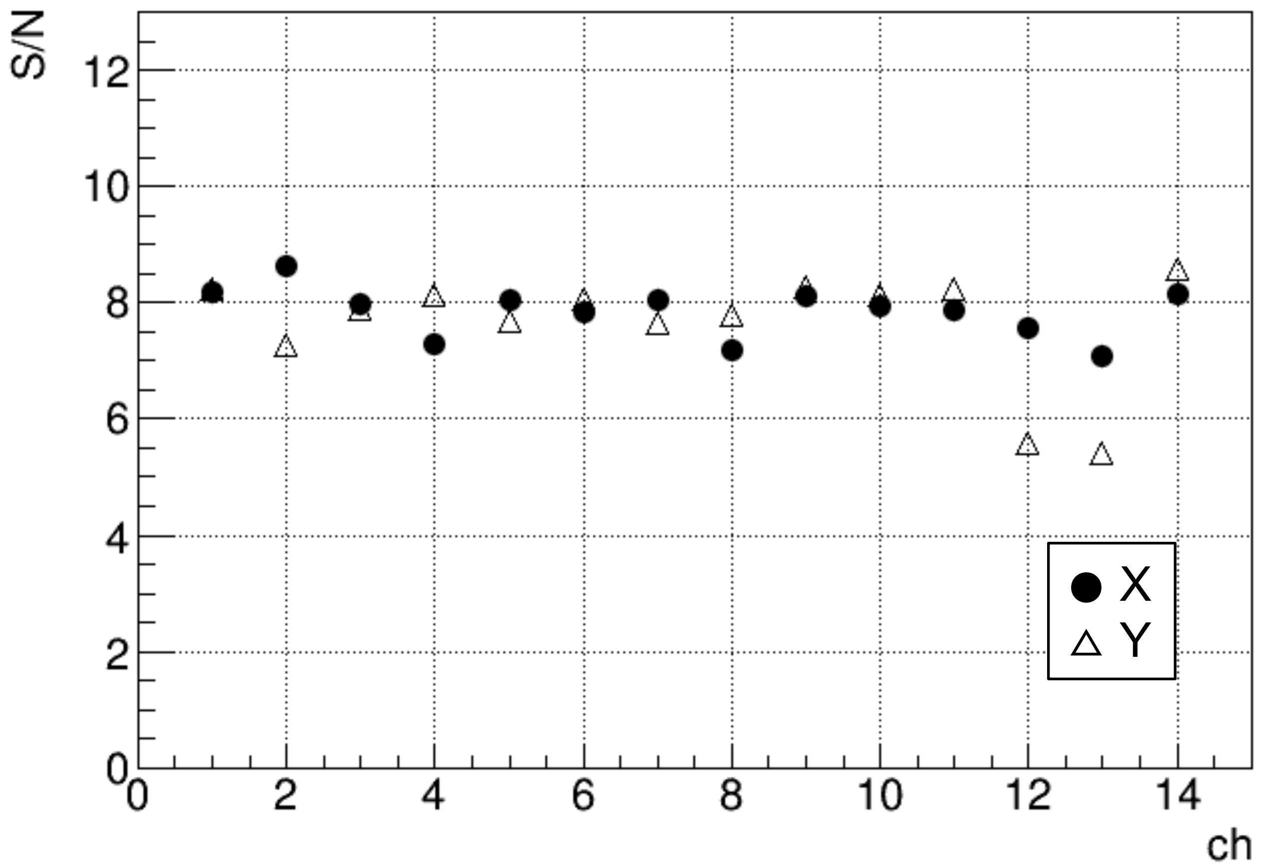


MPV of CHD



S/N of CHD

S: MPV of muon signal
N: r.m.s noise



Summary of CHD calibration

- CHD channels have excellent performance in overall for MIP calibration with a significant S/ N (∼8) to select one MIP.
- Although two channels (Y12 and Y13) looks worse in S/N due to lower signal, these are adjustable by increasing the HV values since the HVs in CHD are supplied independently to each channel.

TASC calibration

□ X1 (PMT in high gain)

- r.m.s noise
- Pulse height distribution of muon signals

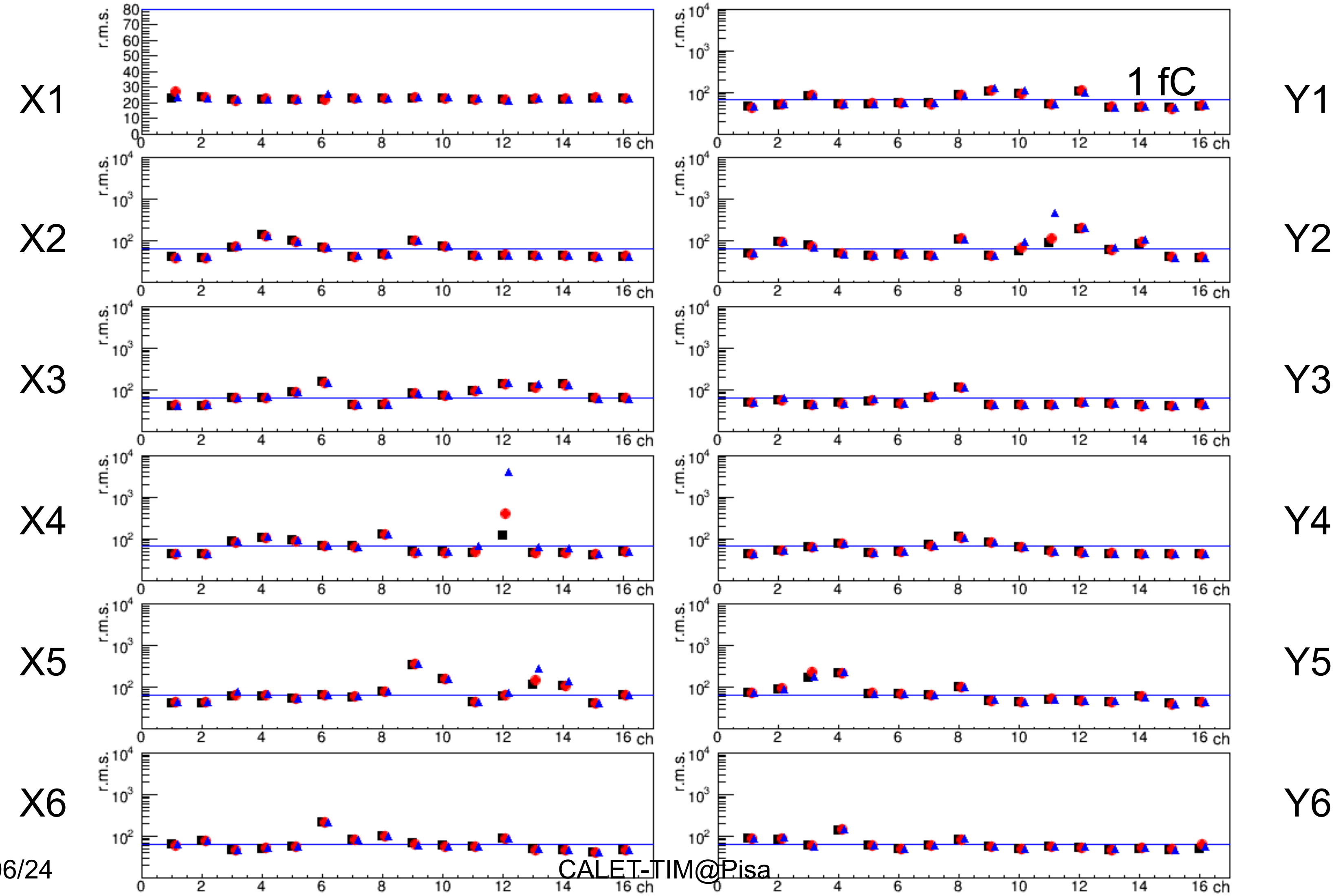
□ X2-X8, Y1-Y8 (APD/PD in High gain)

- r.m.s. noize
- Pulse height distribution of muon signals (examples of better S/N and worse S/N)
- S/N distribution for APD high gain

RMS Noise (X1: PMT, X2-Y8:APD-H)

Period.①
Period.②
Period.③

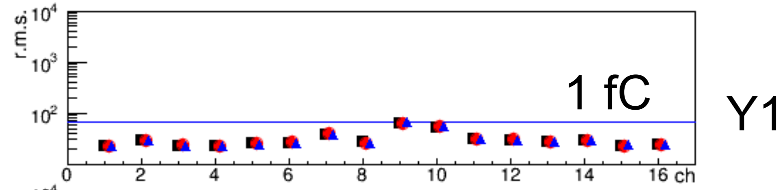
Due to increase of noise from 0.7 fC to 1.0 fC with a similar signal of one MIP(~ 2.0fC) after assembling, the S/N ratio becomes worse to 1.8 σ from 2.8 σ on average

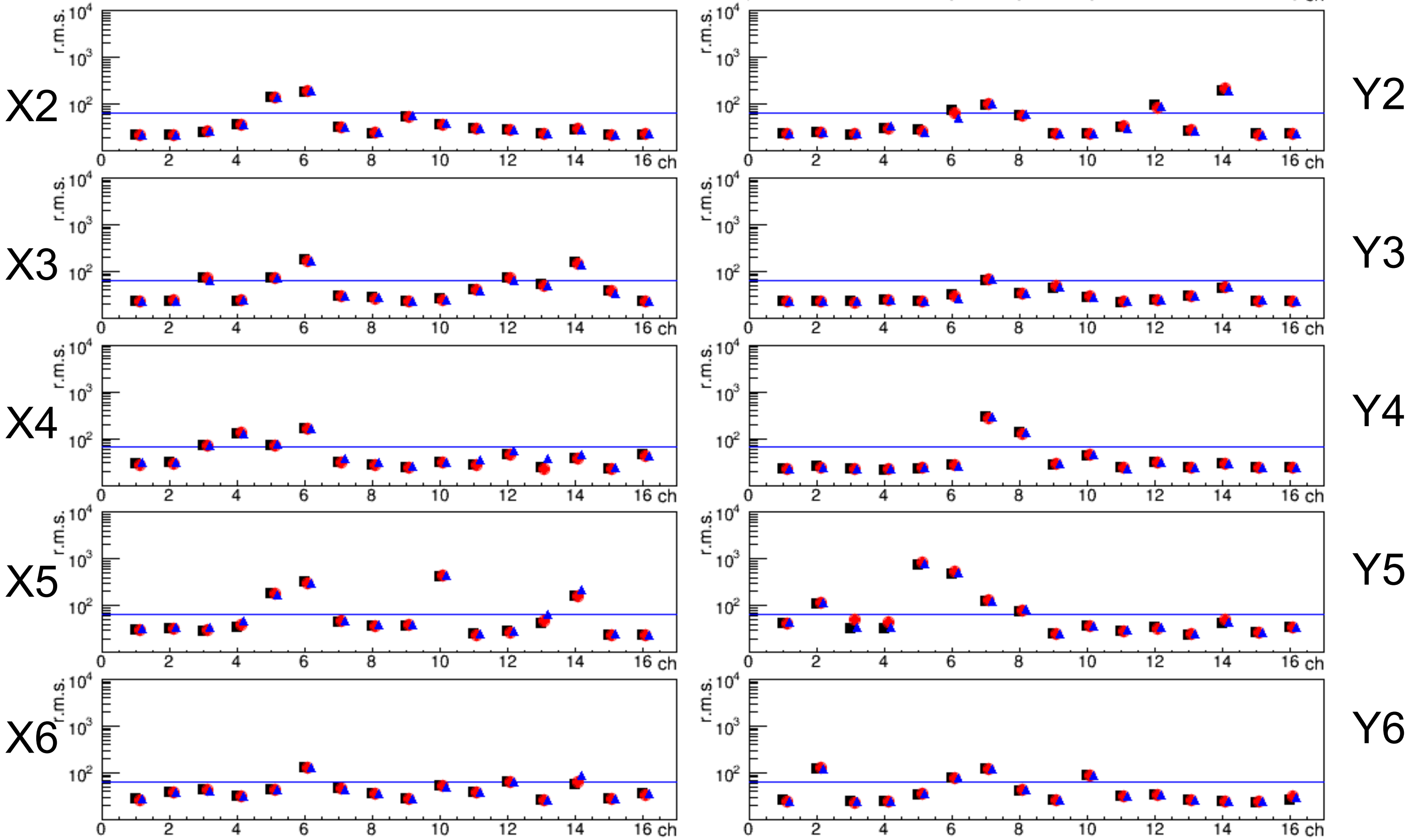


RMS Noise (X2-Y8:PD-H)

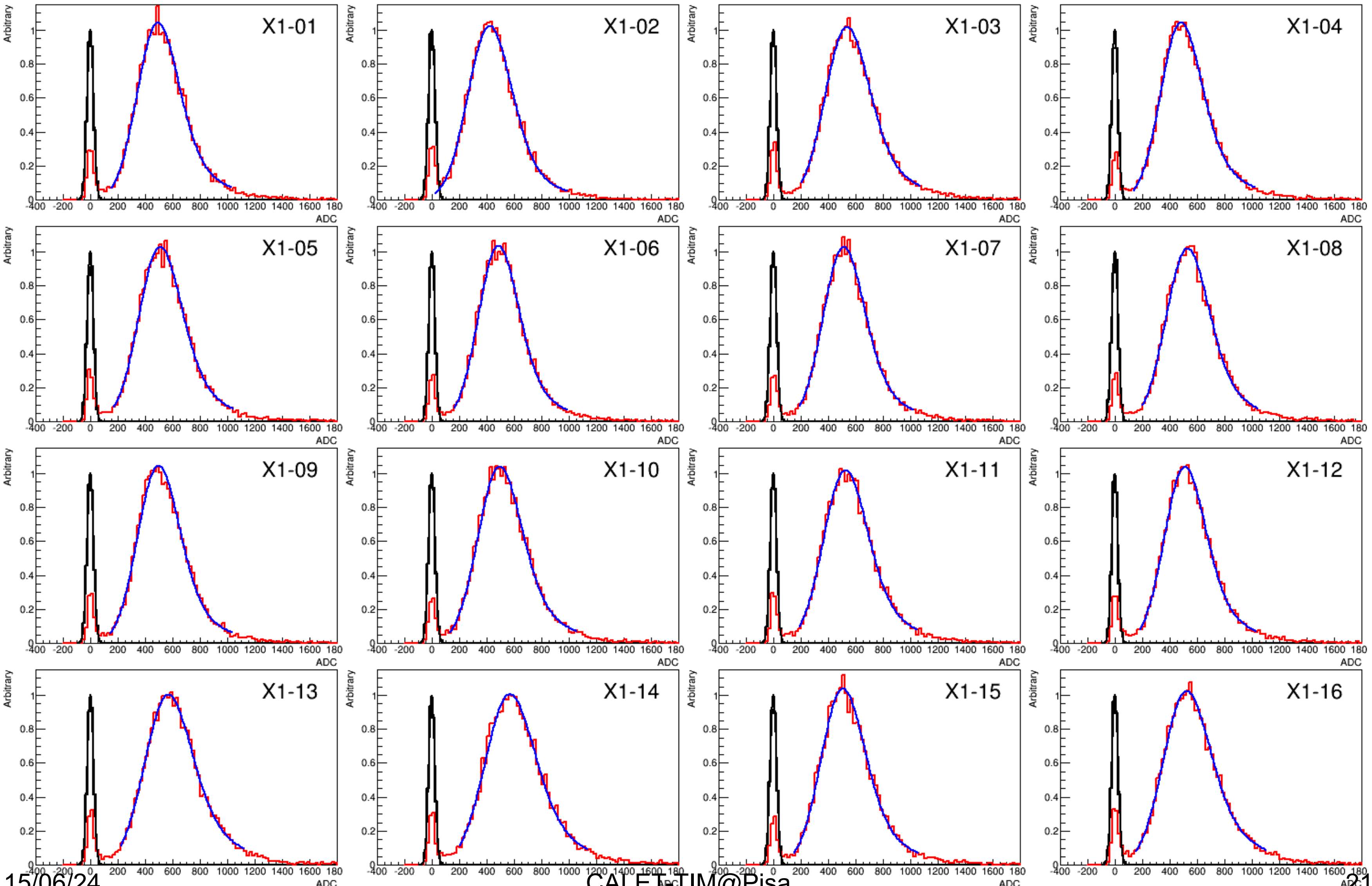
●Period.①
●Period.②
●Period.③

Noise is lower than APD on average
The noise in PD channel is not problem since these are not used for calibration

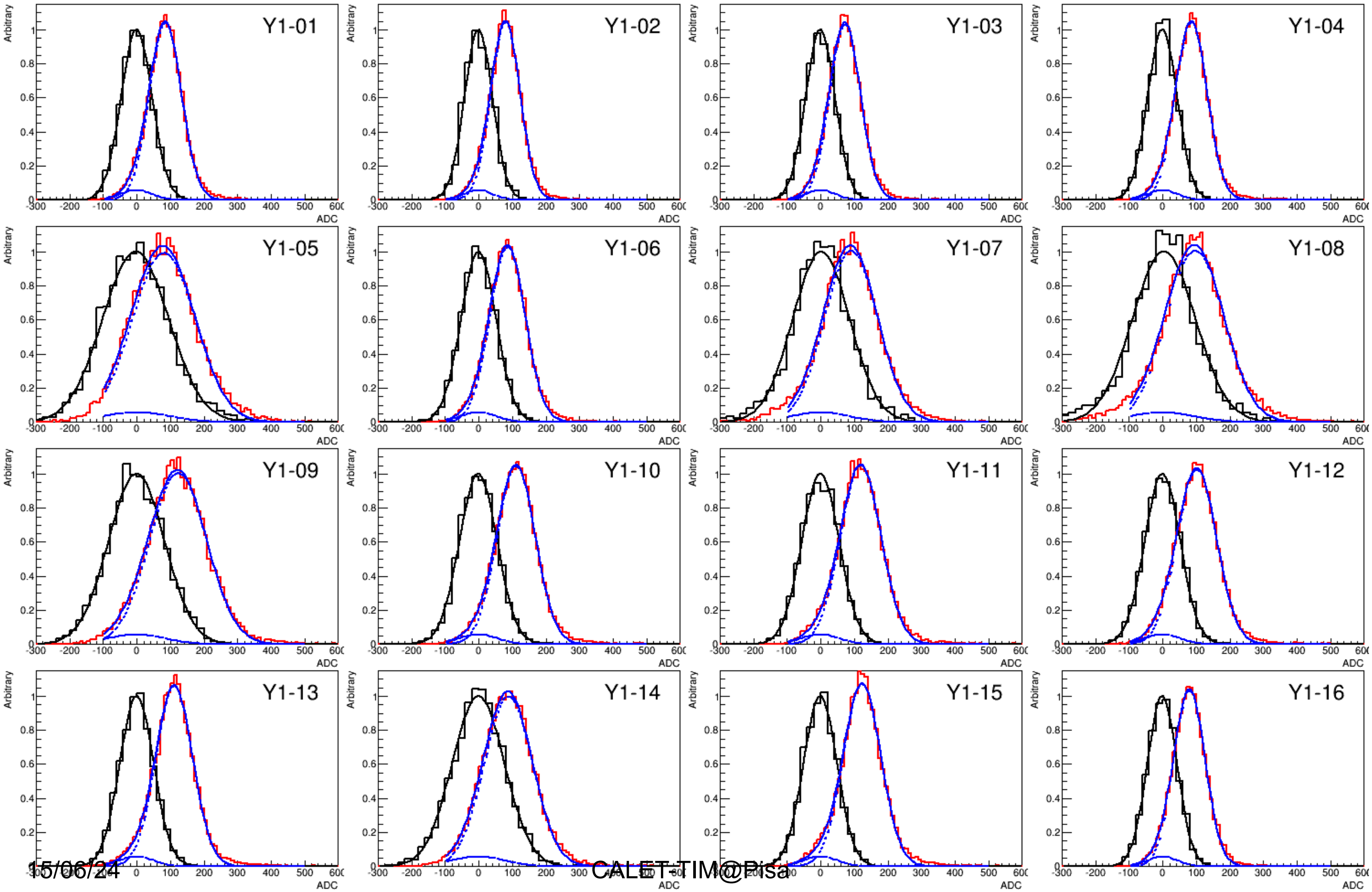




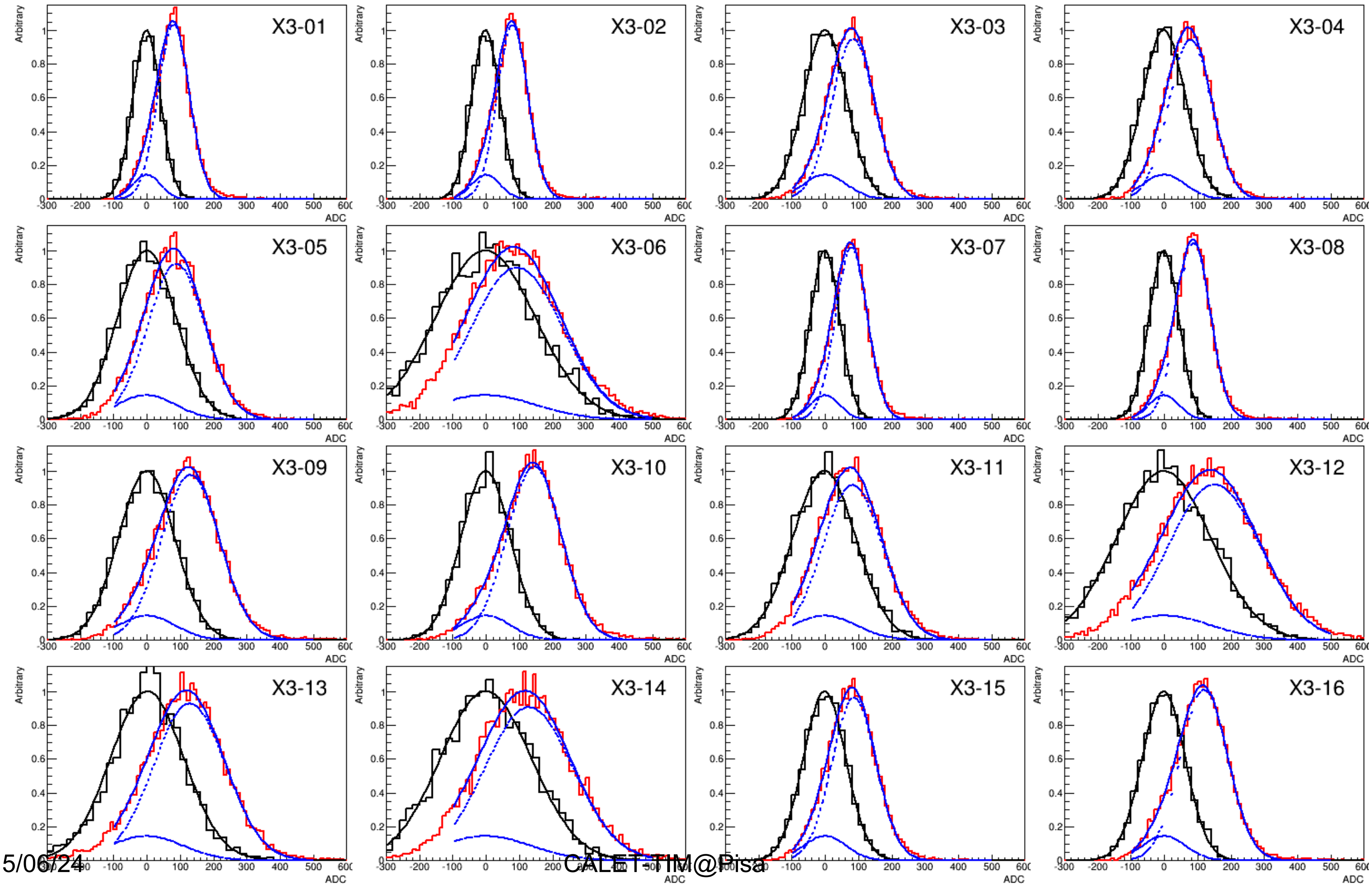
TASC X1 PMT high gain: Pulse height distribution by tracking (S/N~20)



TASC Y1 APD high gain: Noise and Signal distribution by tracking (S/N ~2： better layer)

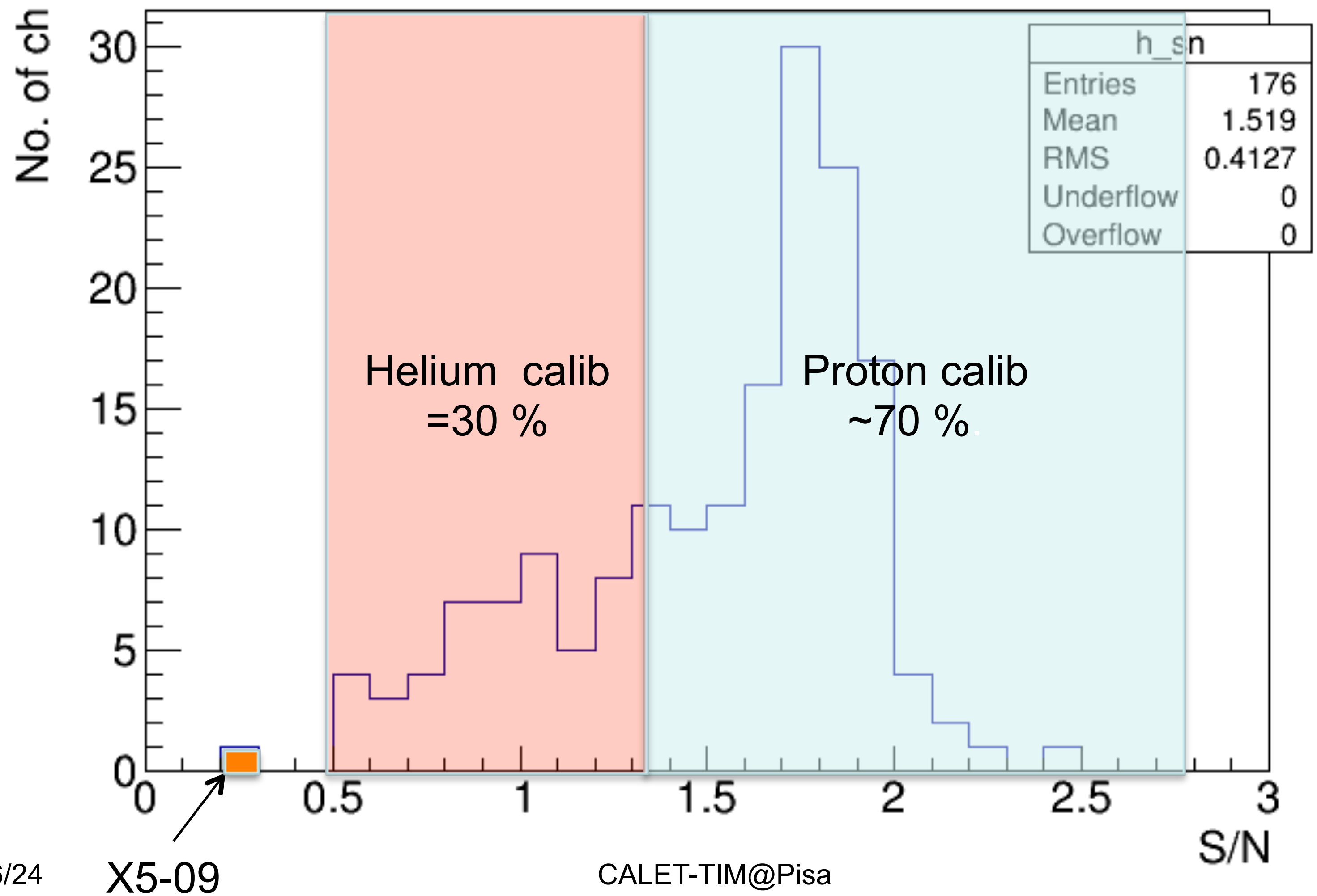


TASC X3 APD high gain: Noise and Signal distribution by tracking (S/N=1~2, a few channels worse)



S/N distribution of TASC APD-high

From our beam test experience, the PWOs with S/N >1.3 can be calibrated by protons.



Summary of TASC calibration

- TASC X1 PMT layer for trigger has excellent S/N ratio ~20. Since the HV of each PMT is independently supplied, the signal can be very similar between different channels.

- In TASC X2-X8 and Y1-Y8 APD high gain channels:

- The S/N ratio distributes from 0.5 – 2.5 except one channel of 0.3.
- The channels with S/N over 1.3 will be calibrated by protons, and these with S/N in 0.5-1.3 by Helium and heavier nuclei.
- Some channels have a time-dependent noise caused at different set up by unknown reasons.

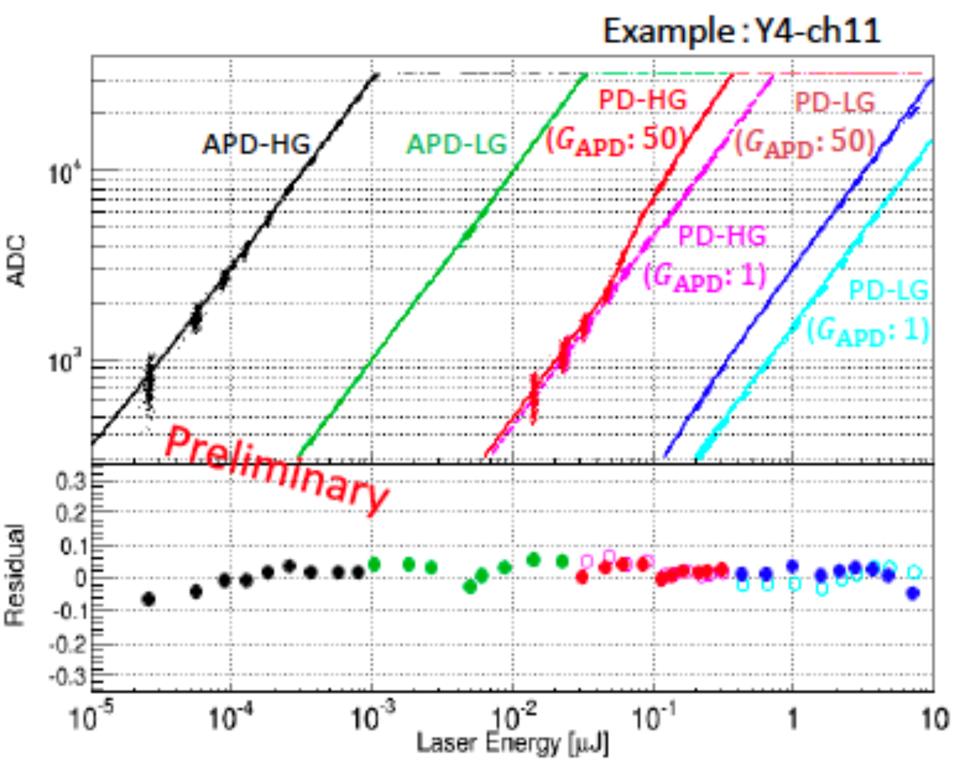
- In TASC X2-X8 and Y1-Y8 PD high gain channels, the noises are relatively smaller than APD.

N.B. The temperature condition was worse (one degree higher) due to malfunction of the ATCS system. Therefore, we can expect larger signals, and the 80% of PWOs will be calibrated by protons as expected in the other tests done at nominal temperature condition.

UV Laser Calibration

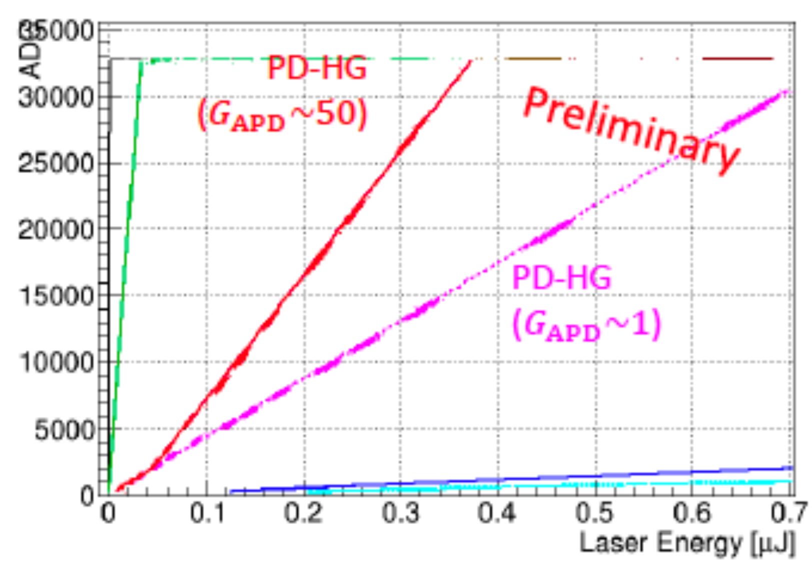
Result of UV Laser Calibration（Example）

By scanning pulse laser intensity through 6 order of magnitude, Four APD/PD output responses are measured in detail for all of 176 PWO logs



Cross talk from APD to PD

- After APD-CSA saturates, crosstalk proportional to input charge becomes significant.
- The response looks complicated in the Log-Log plot, but it is just a simple connection of two linear relations.



What is needed for TASC Energy Calibration

From On-Orbit Data

1 MIP at APD High Gain

- APD_H [ADU/MIP]

Relation between PD_H vs APD_L

- PD_H/APD_L

Calibration method :

APD: uJ to MIP using 1MIP
PD: uJ to MIP using 1MIP
and PD/APD coeff.
Calculate saturation point in MIP using APD-CSA saturation point and use coefficient with crosstalk after the saturation point.

From UV Laser Calibration Data

APD-CSA Saturation Point

- APD-L [ADU]

Coefficients

- APD_H [ADU/uJ]
- APD_L [ADU/uJ]
- PD_H [ADU/uJ]
- PD_H(S) [ADU/uJ]
- PD_L [ADU/uJ]
- PD_L(S) [ADU/uJ]

Estimated Error

- estimated error as a function of laser energy

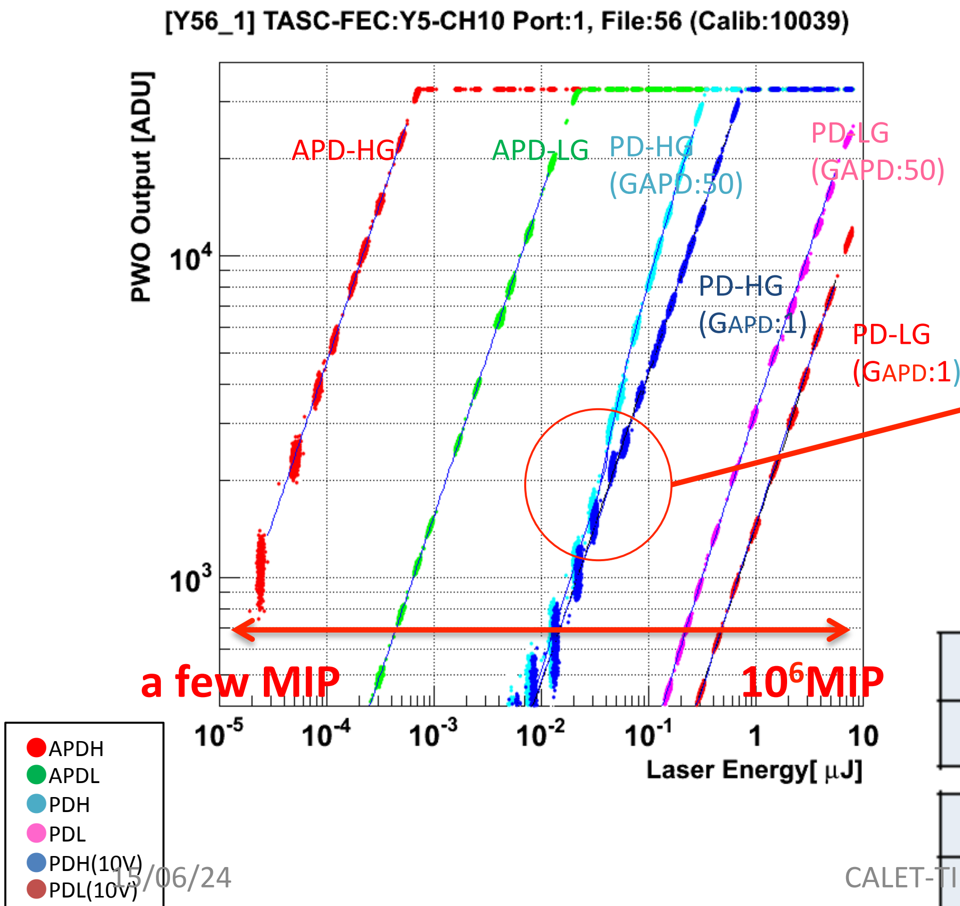
Calibration of TASC using UV Laser

◆ **All PD/APDs in CALET-TASC are calibrated using UV laser**

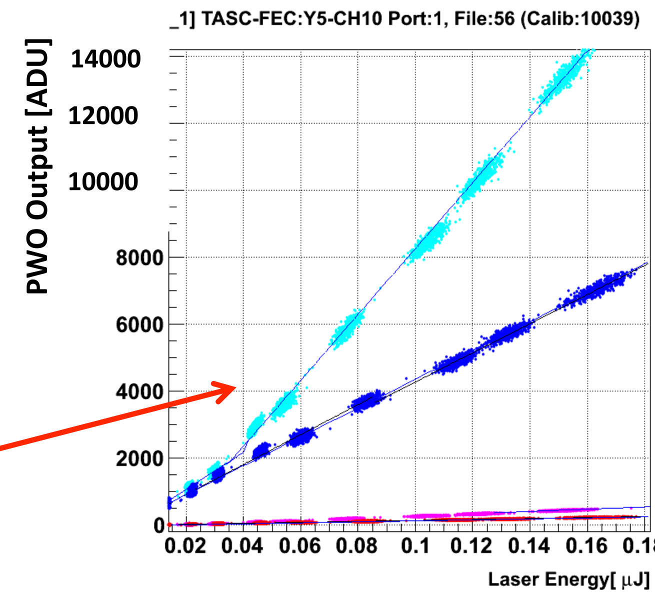
- Calibration data were taken for all 176 PWOS from a few MIP to 10^6 MIP

⇒ Calibration parameters were retrieved using parameters described before

Example of UV Laser calibration data



Input/output relation around APD-CSA saturation



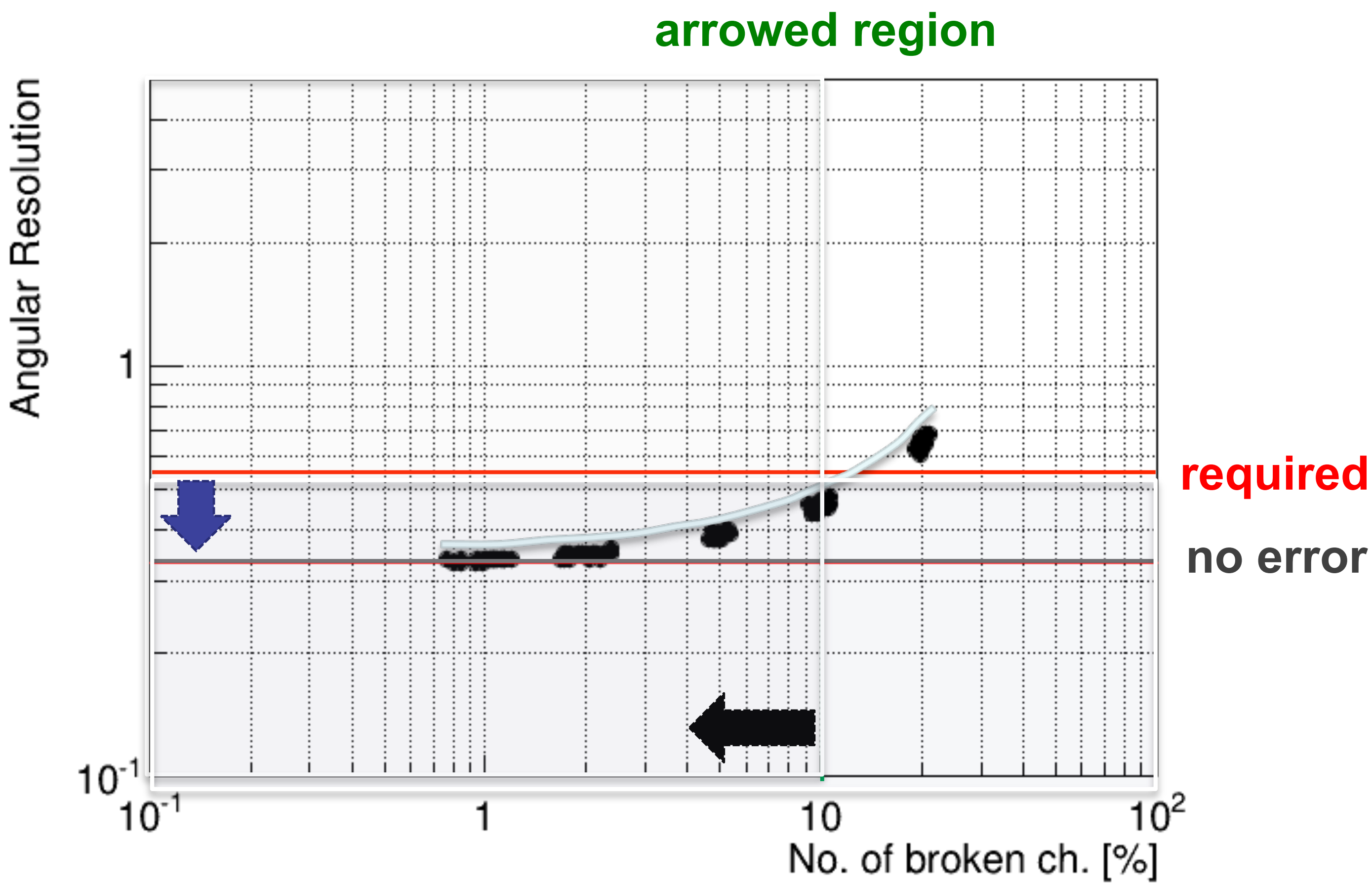
Calibration Parameters

k_{ah} [ADU/uJ]	k_{al} [ADU/uJ]	k_{ph} [ADU/uJ]	$k_{ph}{}^{sat}$ [ADU/uJ]
2.63×10^7	8.85×10^5	3.57×10^4	6.29×10^4

$Q_{ph}{}^{sat}$ [ADU]	$k_{pl}{}^{sat}$ [ADU/uJ]	$Q_{pl}{}^{sat}$ [ADU]	E^{sat} [uJ]
2.96×10^3	2.11×10^3	9.43×10^1	8.28×10^{-2}

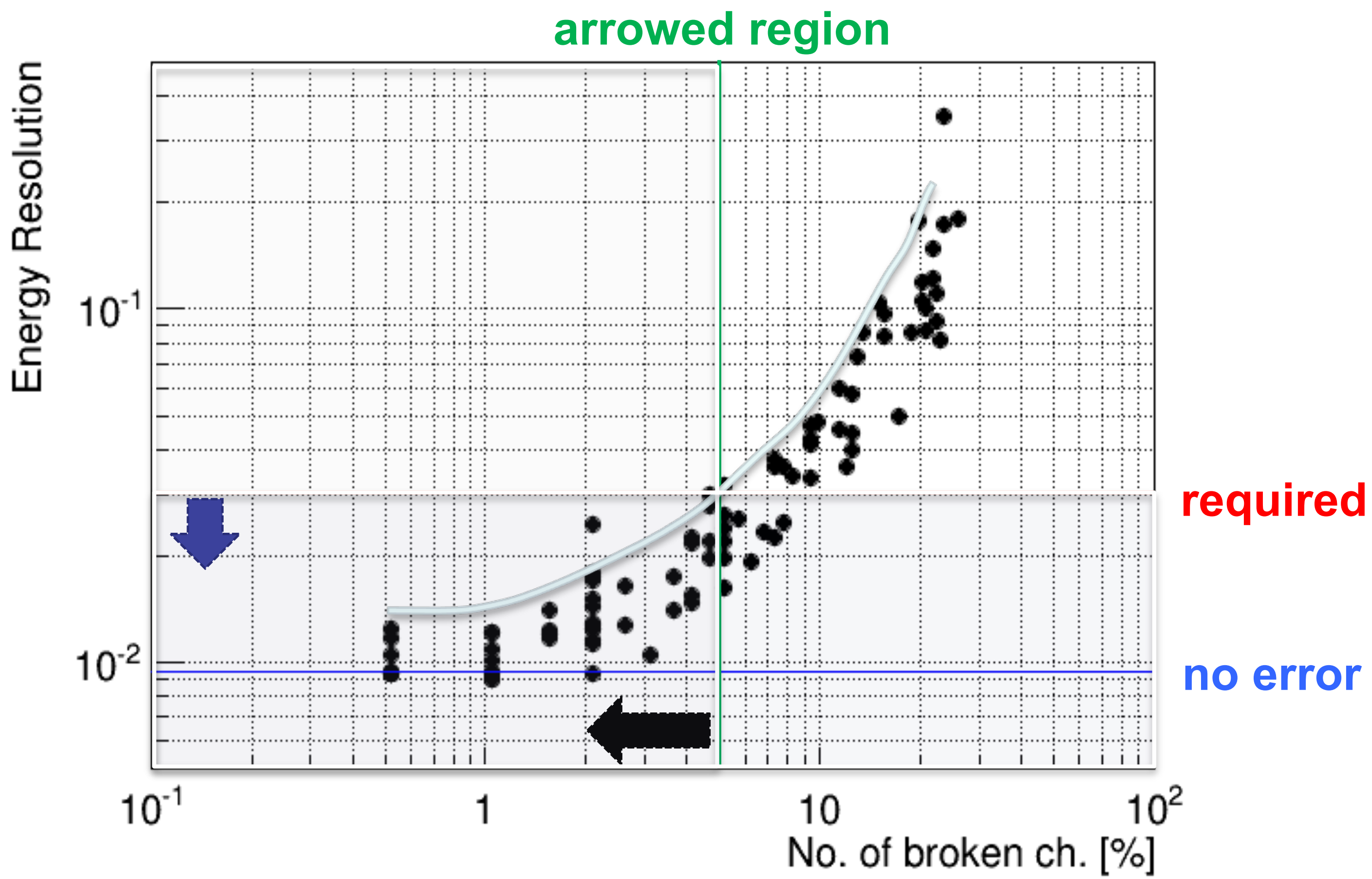
Simulation study for impacts to detector performance by degradiation of sensors

Gamma-ray 10GeV Angular resolution（IMC）



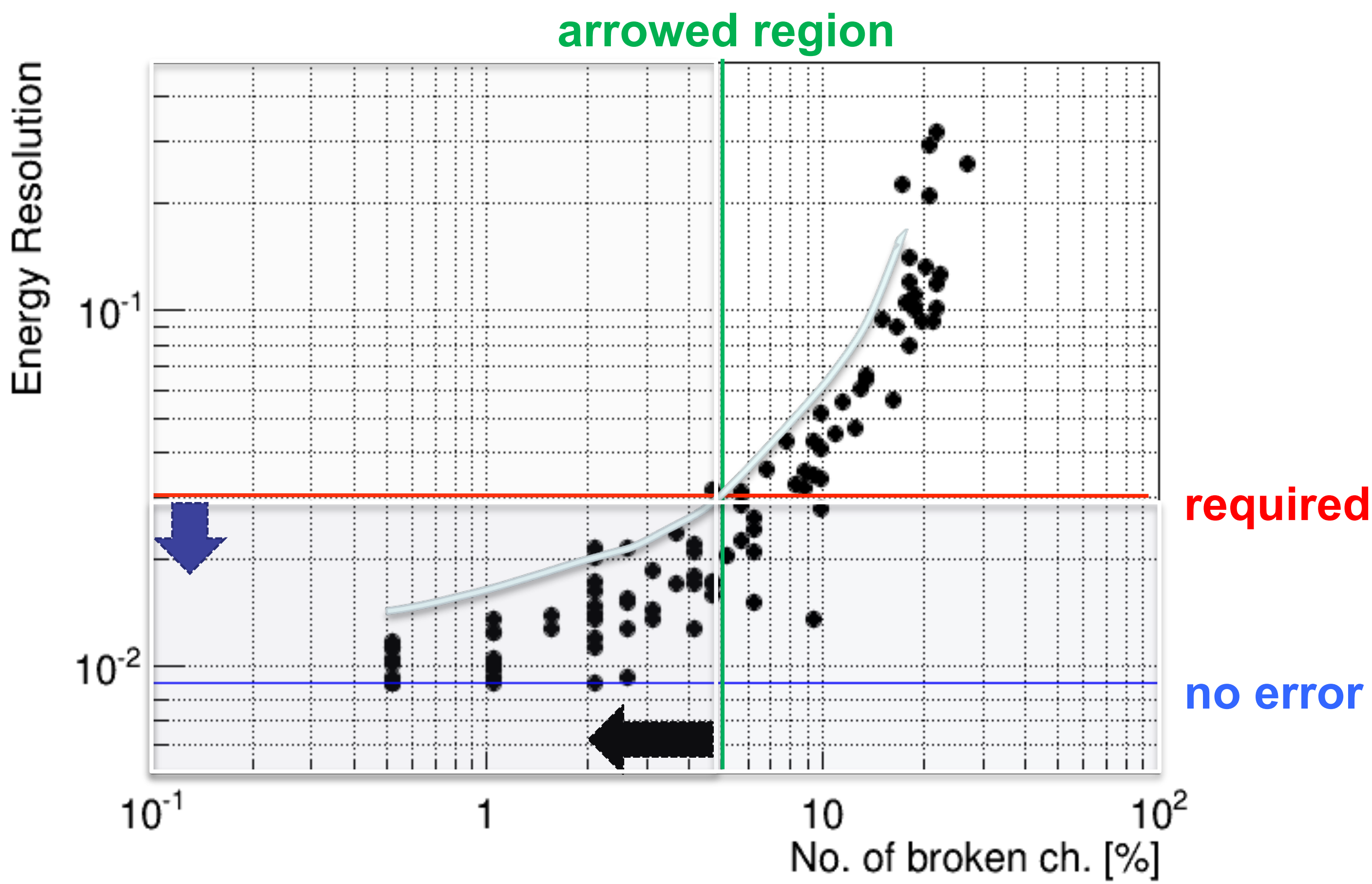
Acceptable up to 10 % in total channel

Electron 100GeV energy resolution（TASC）



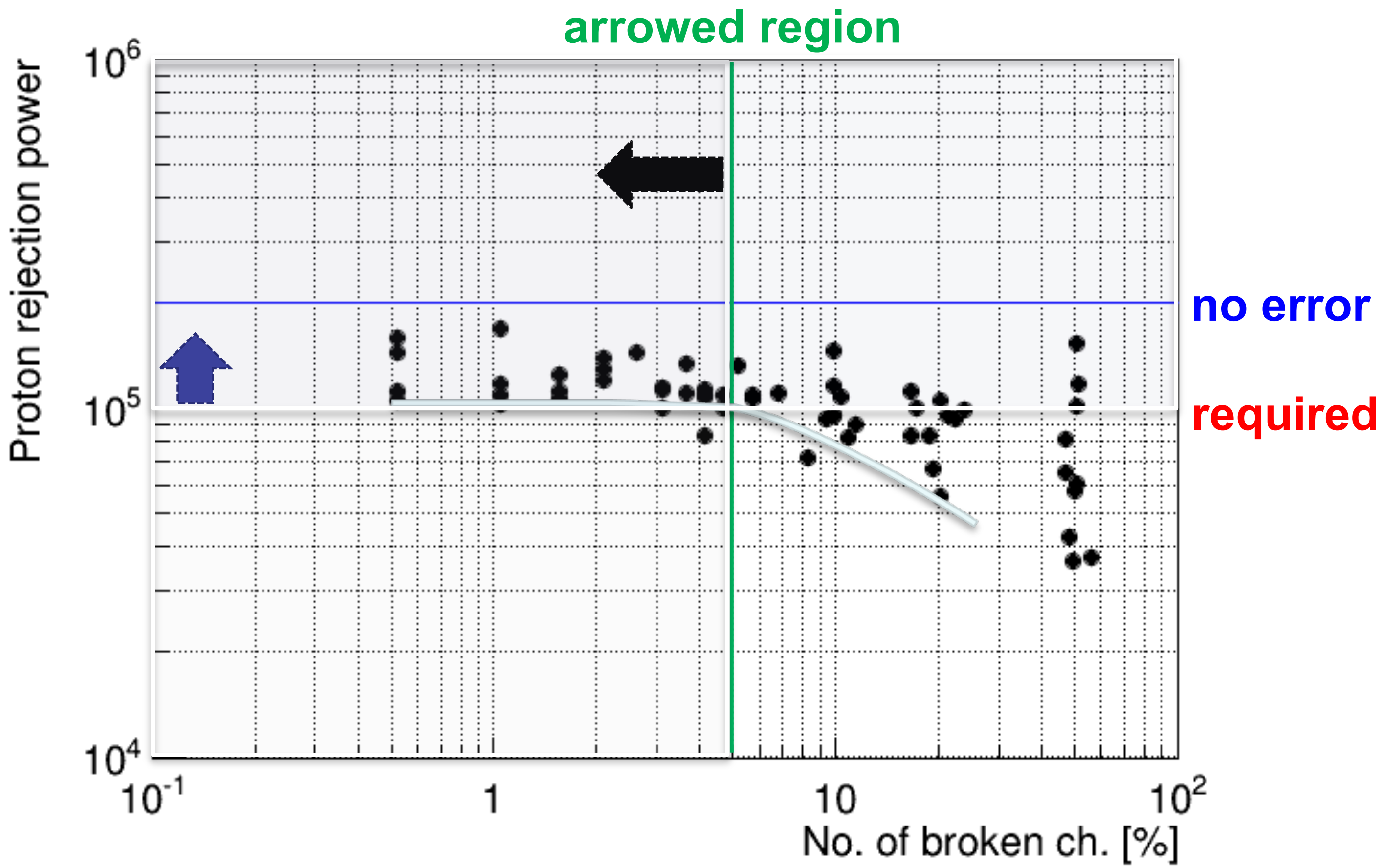
Acceptable up to 5 %(~10/192) in total channel

Gamma-ray 100GeV energy resolution（TASC）



Acceptable up to 5 %(~10/192) in total channel

e/p separation at 1 TeV（TASC）



Acceptable up to 5 %(~10/192) in total channel