MPPC読み出しのための汎用モジュールの開発

阪大理　　石島　直樹

大阪大学[A]　高エネ研[B]　岡山大学[C]　東北大学[D]　Open-it[E]

花垣　和則[AE]　東野　聡[A]

吉村　浩司[CE]　中村　勇[BE]　池野　正弘[BE]

内田　智久[BE]　五十嵐　洋一[BE]　田中　真伸[BE]

本多　良太郎[DE]　三輪　浩司[DE]

日本物理学会　2013年秋季大会　　@高知大学　22aSL-8

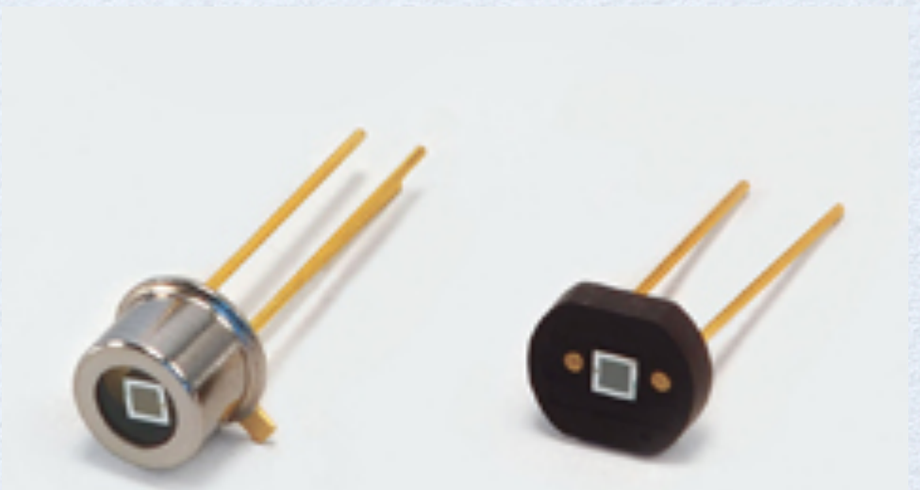
Multi Pixel Photon Counter (MPPC)

MPPC : 優れたフォトンカウンティングデバイス

非常に有用であるが Set up が大変

簡単に使える,汎用の

MPPC用回路があると良い



MPPC用 汎用MODULEの開発

MPPC用 汎用MODULEの開発

EASIROC board
(汎用MODULE試作基板)

(東北大学、 KEK)

make bias voltage on board

board in NIM module

make more robust

EASIROC MODULE
(大阪大学、 KEK)

My works

仕様の決定　前回の学会

部品の選定とテスト

回路図作成

基板設計（業者委託）

DAQ構築　　今回

動作確認、性能評価

openit
Open source consortium of Instrumentation

KEK 測定器開発室
KEK E-Sys
東北大学

試作品

MODULEの主な仕様　　赤 : 新機能

64ch MPPC の同時駆動（32ch→64ch)

各chのbias、gain、shaping time調整

MPPC用bias電源の内蔵（~90V）

ADCデータの取得　　{ MPPC data : (TCP)

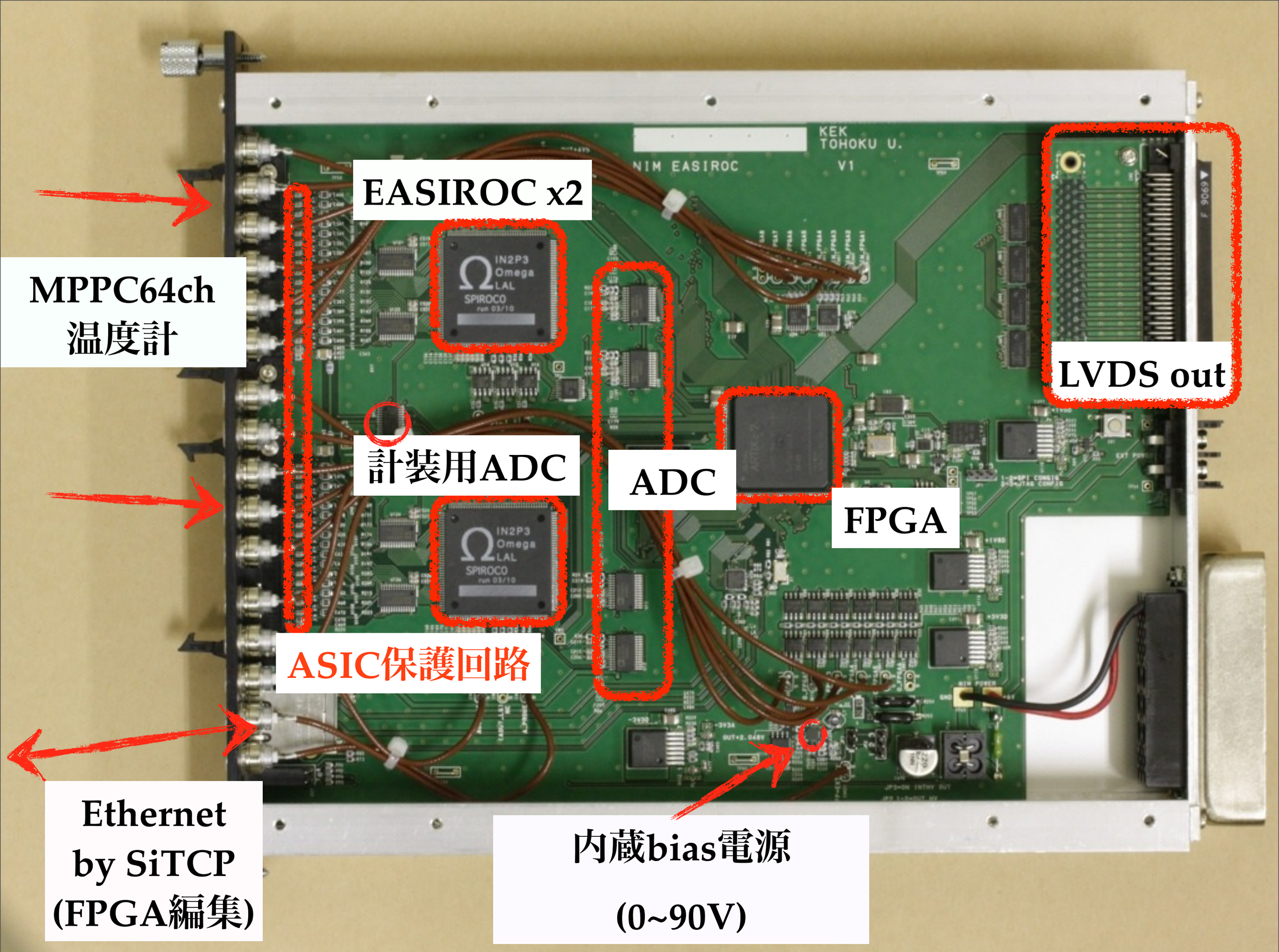
HV, current, bias DAC, TEMP. data : (UDP) }

TDCデータの取得（LVDS or FPGA）

EthernetによるPC制御

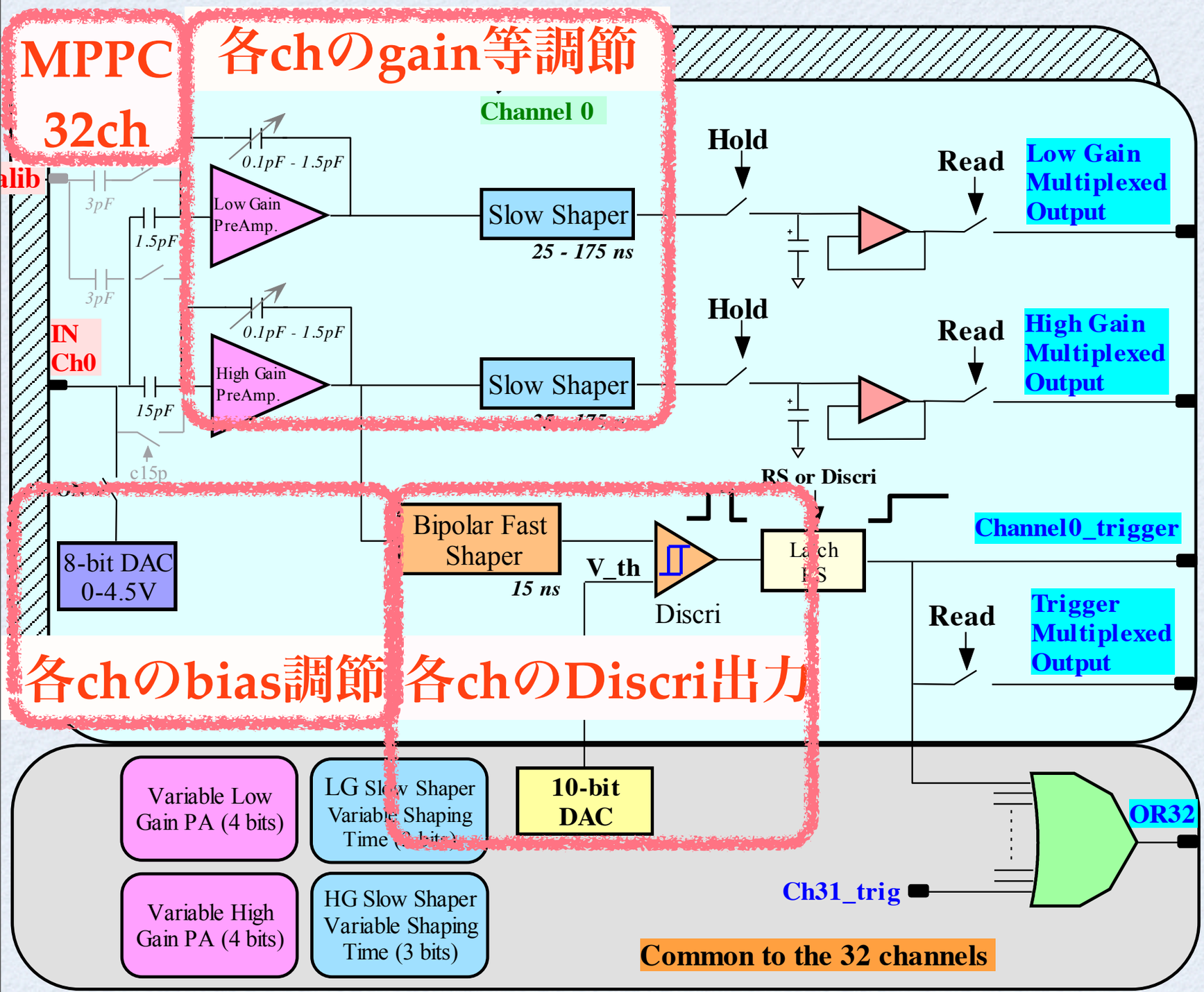
Digital I/O による他機器との同期

NIM or ACアダプタ電源 (+6V)


EASIROC x2
MPPC64ch
温度計
計装用ADC
ADC
FPGA
LVDS out
ASIC保護回路
Ethernet
by SiTCP
(FPGA編集)
内蔵bias電源
(0~90V)
NIM EASIROC
V1
KEK
TOHOKU U.
IN2P3
Omega
LAL
SPIROC0

EASIROC

(Extended Analogue SiPM Integrated Read Out Chip)



spec.

PreAMP

x1 ~ x150

Allowable charge

160 fC ~ 320 pC

@MPPC gain ~ 10^6

Signal Shaping Time

25ns ~ 175ns

signal/noise ~ 10

@MPPC gain ~ 10^6

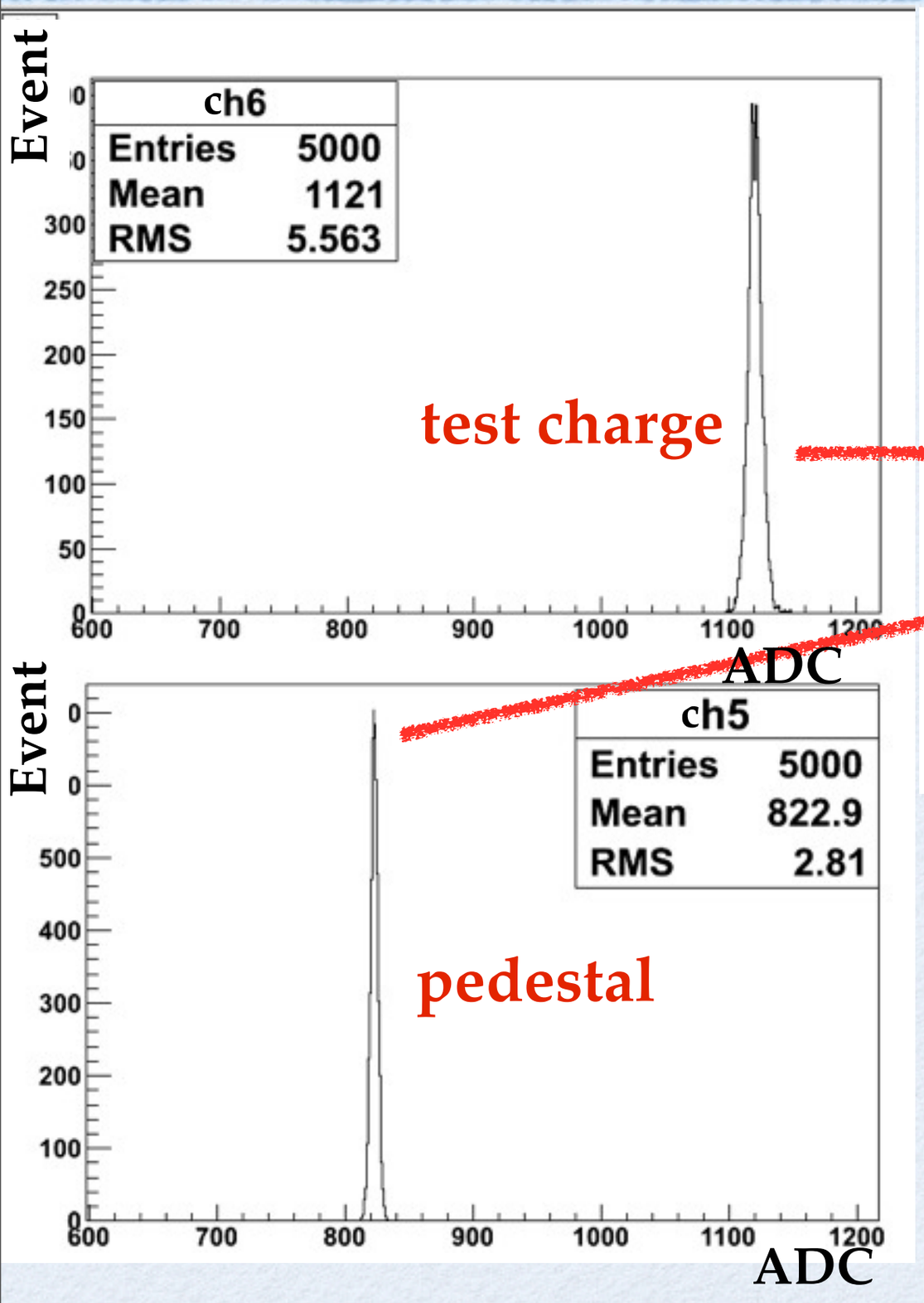
性能評価

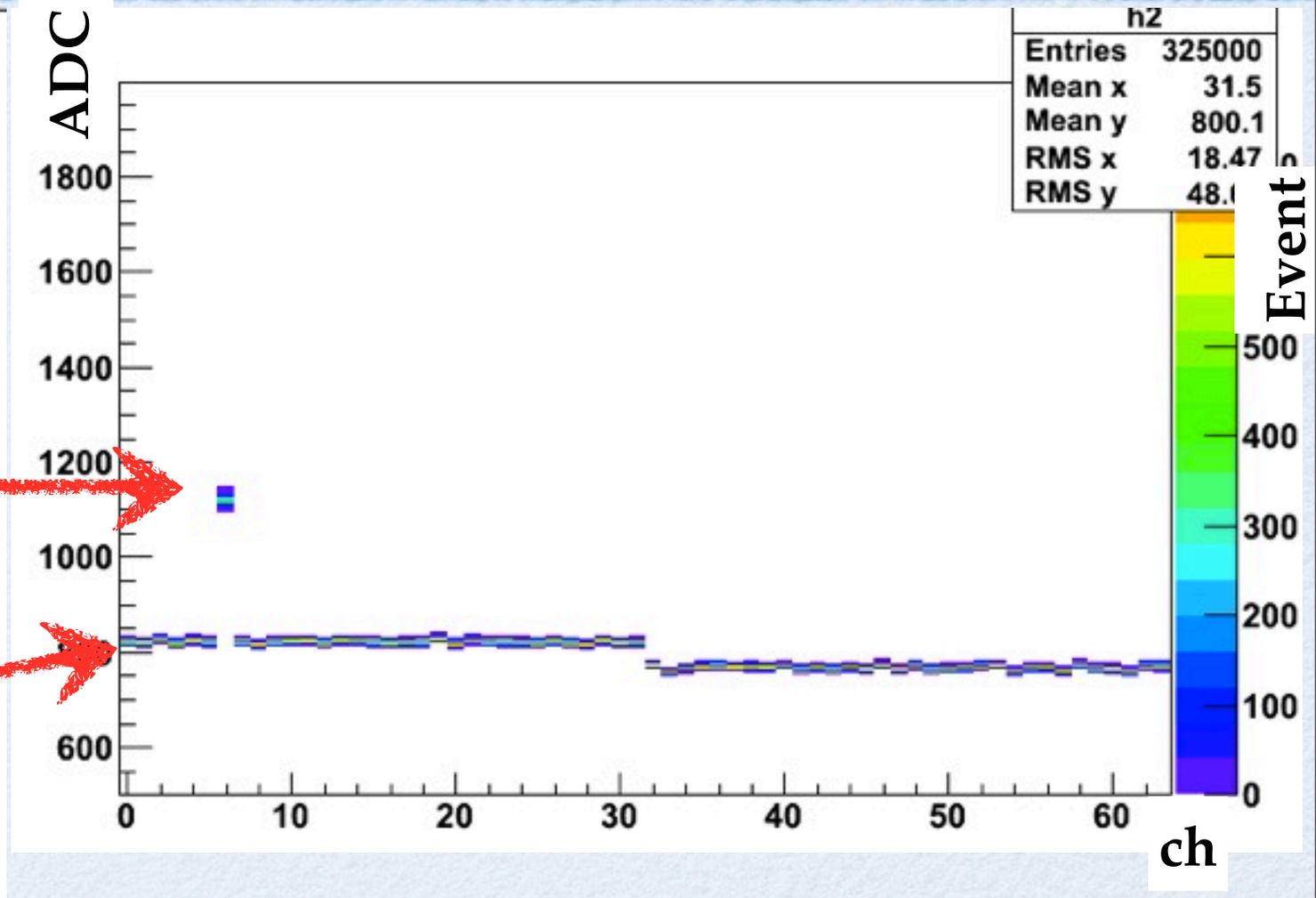
全ての機能が動作するか

仕様通りの性能がでるか

(MPPC信号に対する新規部品の影響)

2chip operation

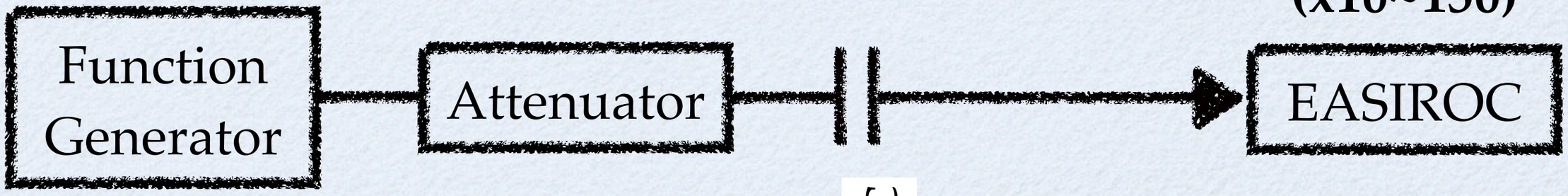


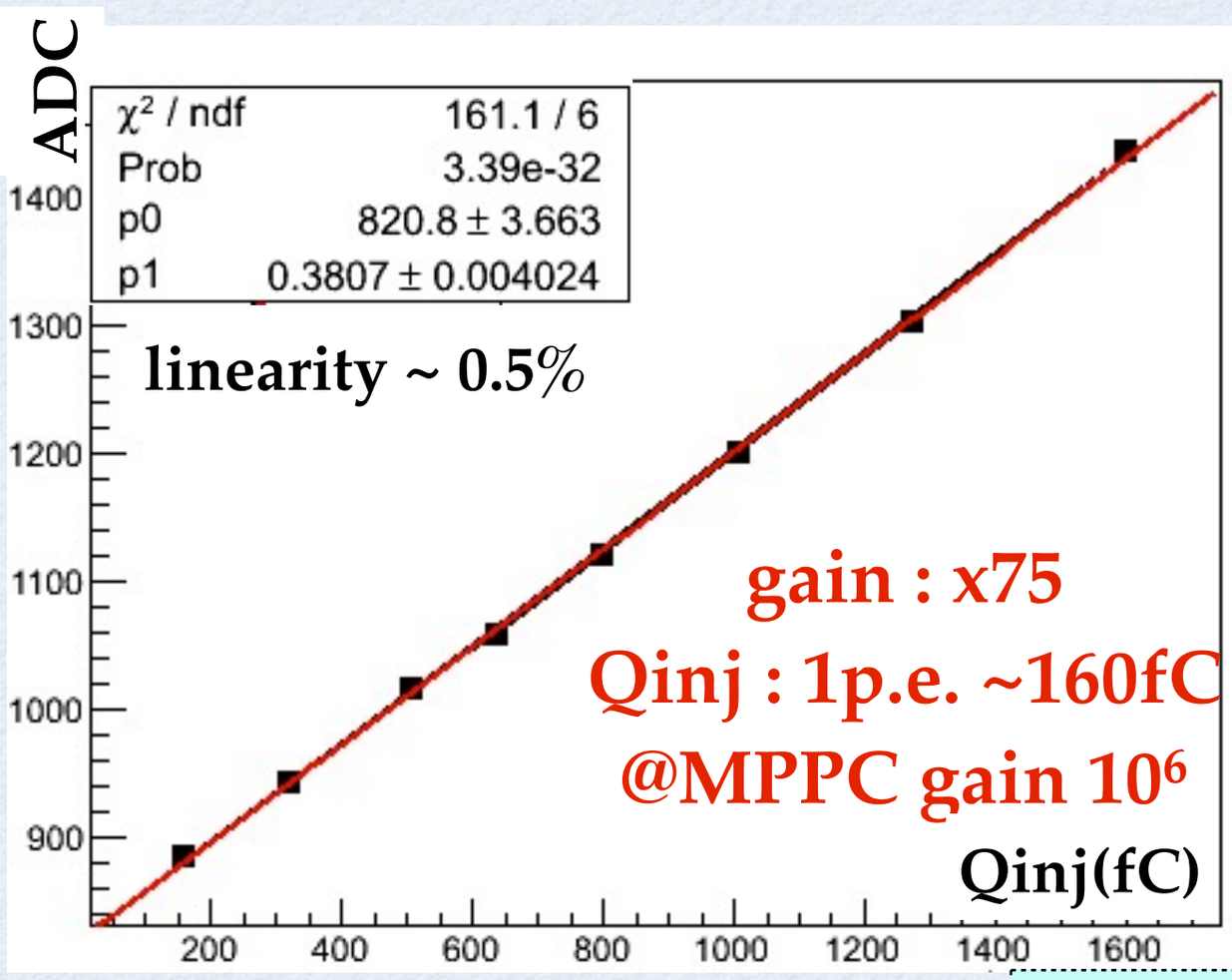


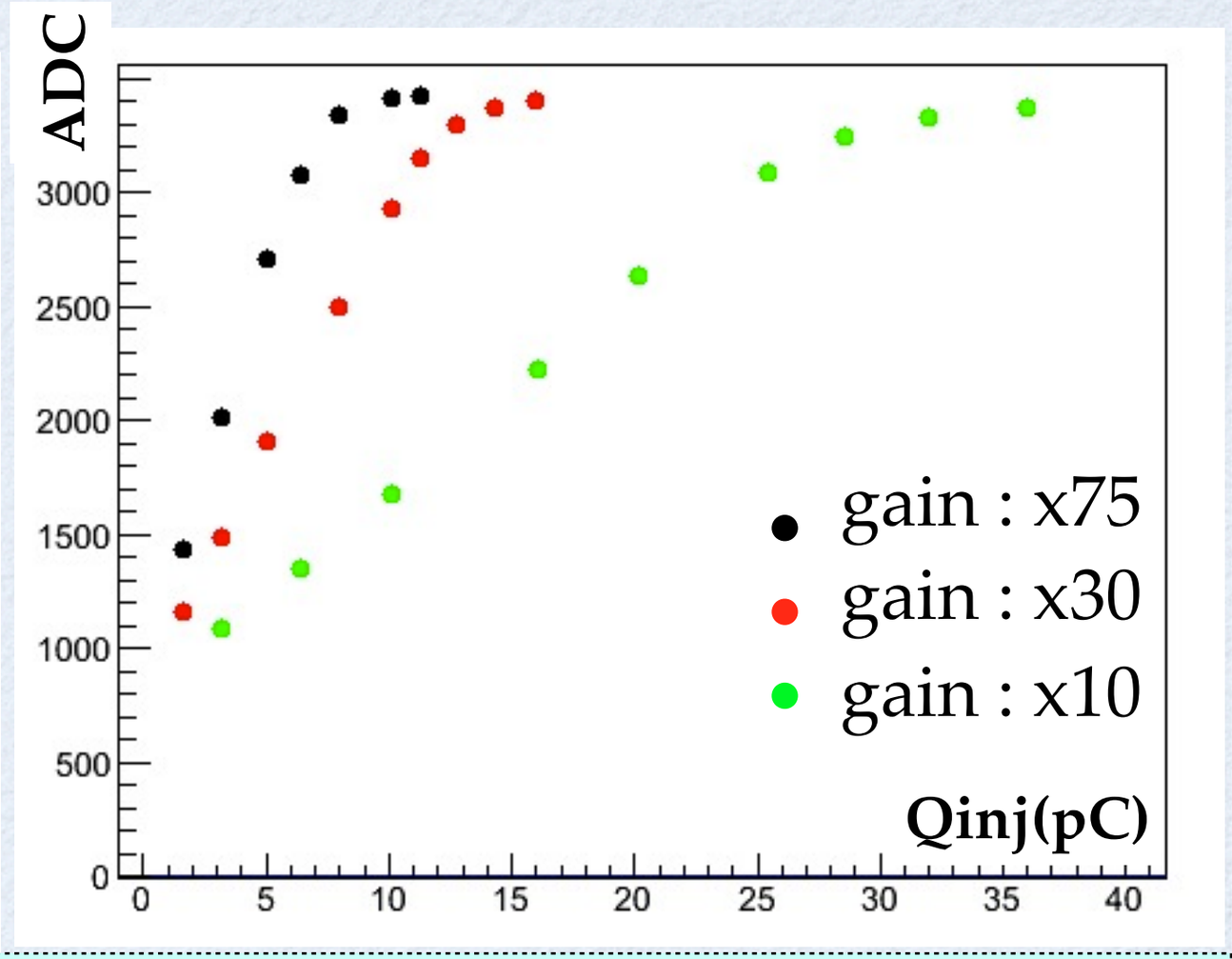
2chip operation working correctly

Analog linearity

160mV pulse **100pF** **high gain AMP (x10~150)**



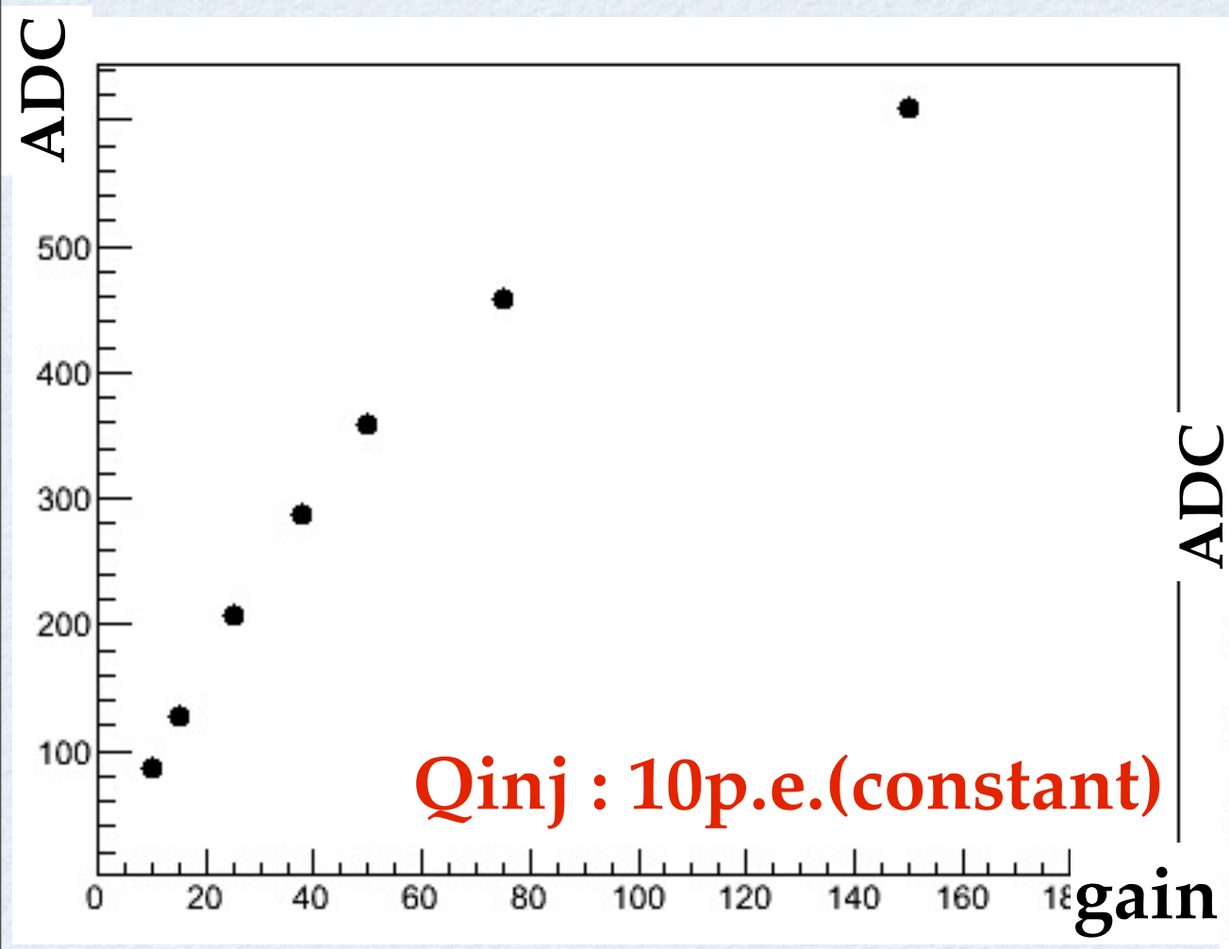




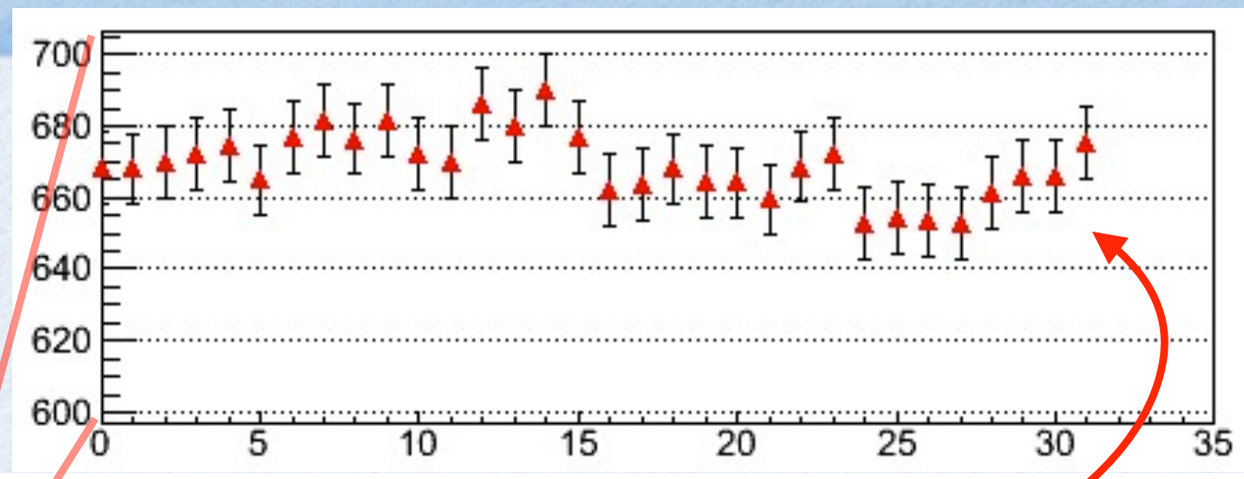
入射電荷とADCcountの線形性

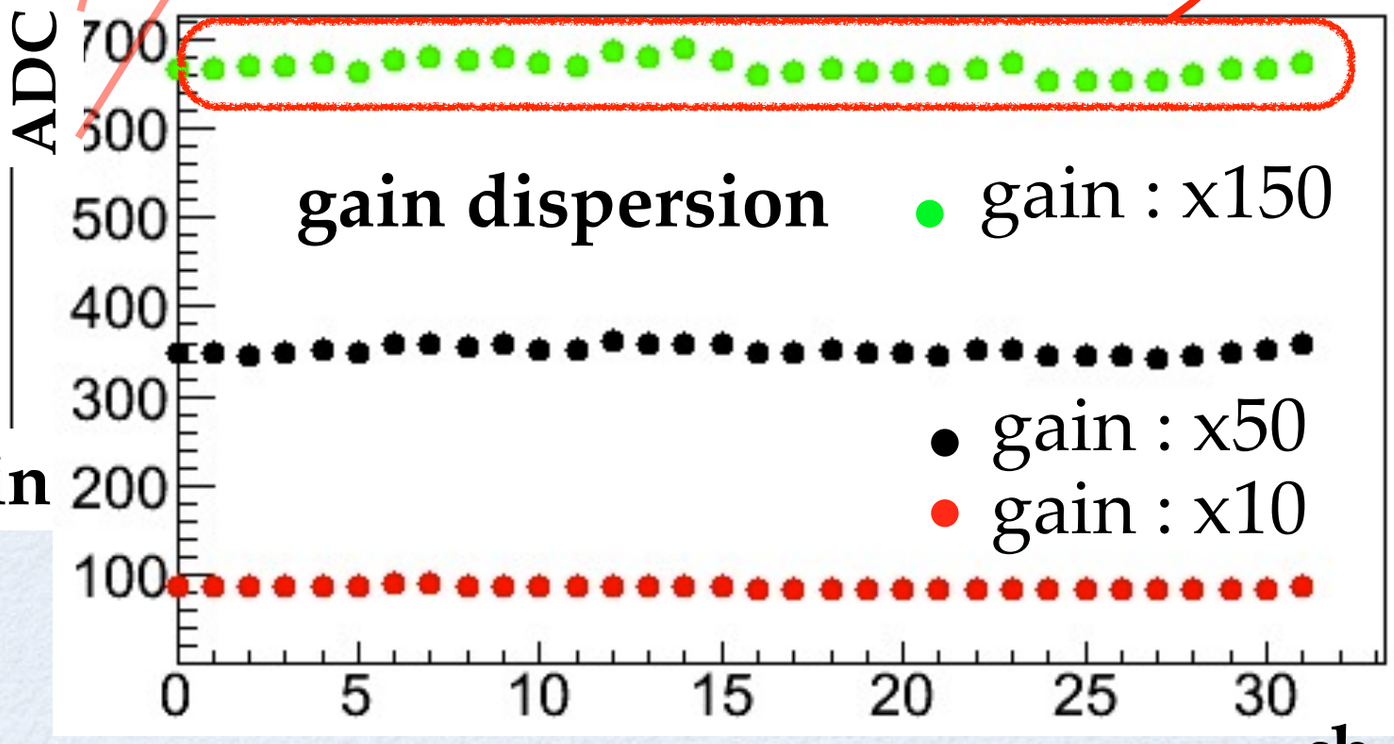
Qinj x gain (許容電荷) < 320pC(2000p.e.)

Pre AMP gain



AMP gain vs ADC値の変化



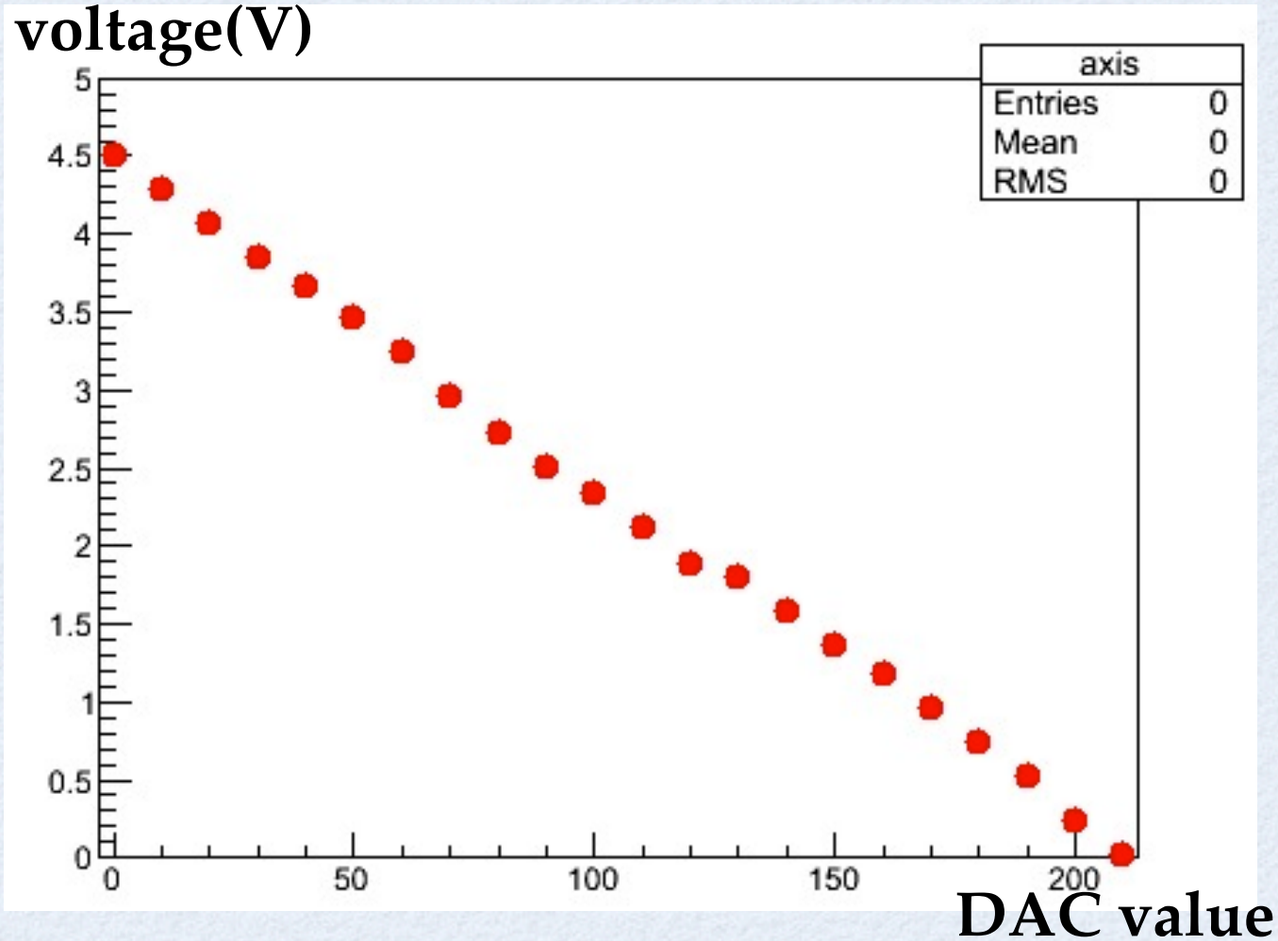


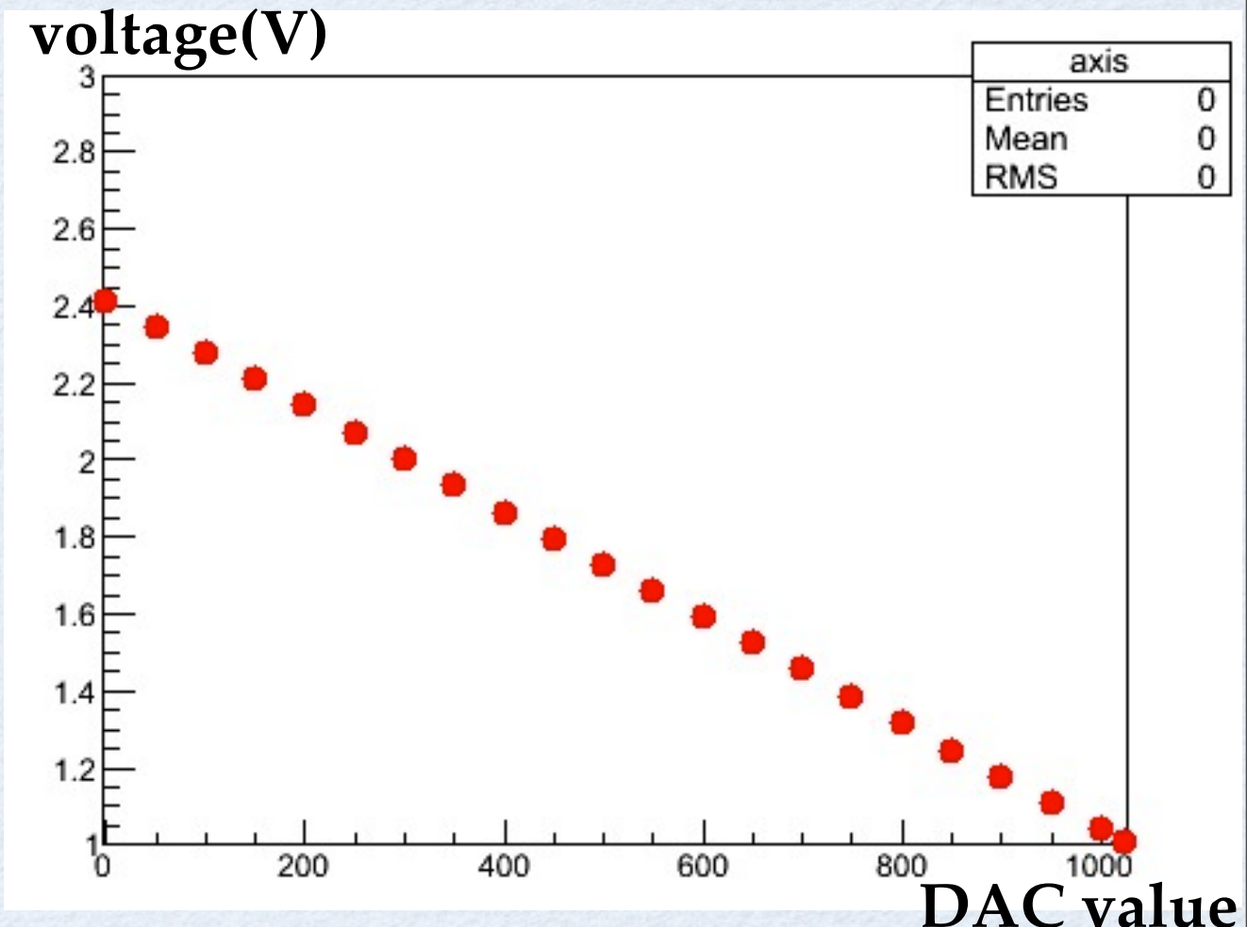
gain/RMS noise ~ 100 ， dispersion ~ gainの2%(x150)

AMPのch間のばらつきは十分少ない

(さらに、biasの調節で補正できる)

DAC (in EASIROC) linearity





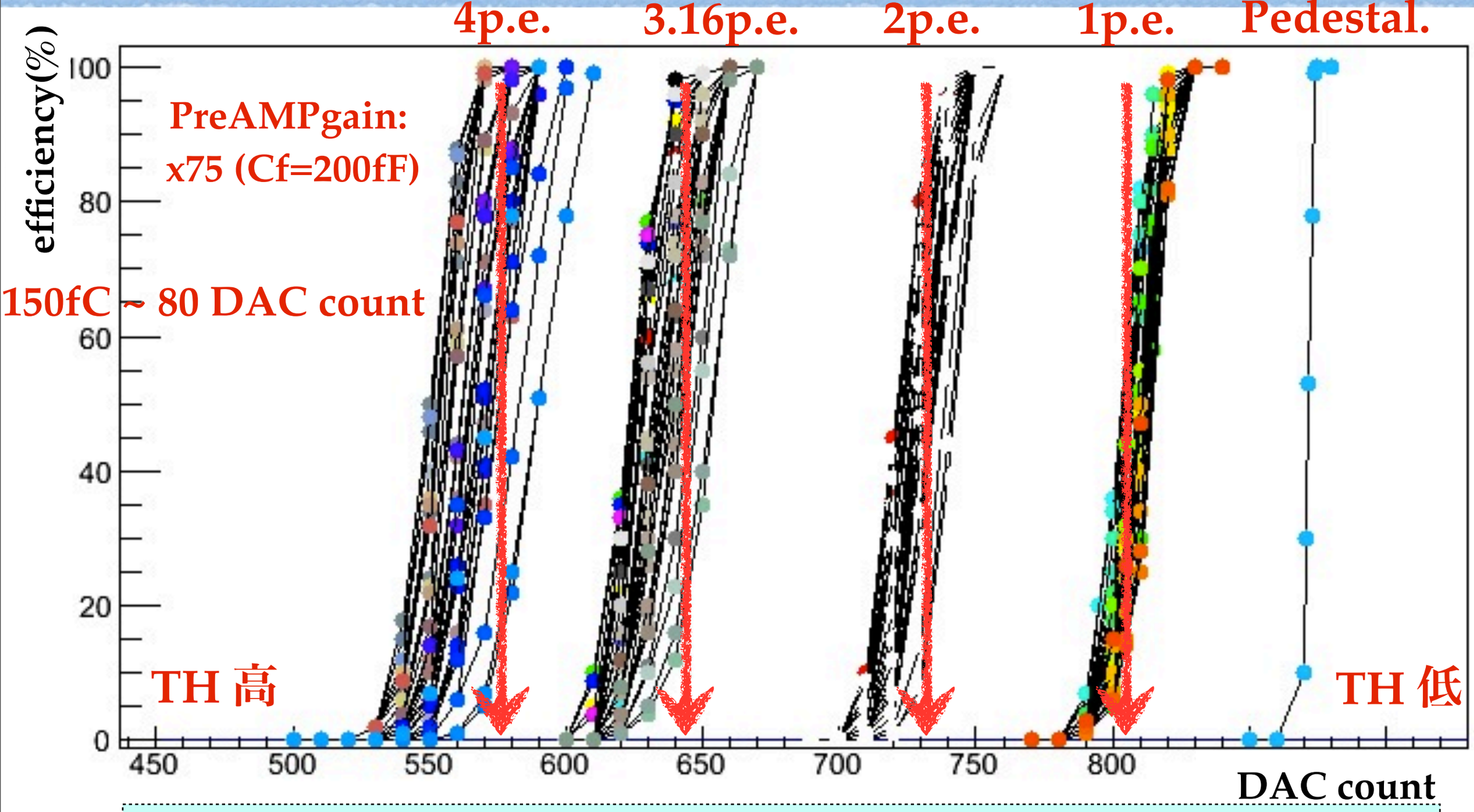
各ch MPPC bias 調整用 DAC (8bit)

→ 21.0±0.02 mV/count

Discri output Threshold 調整用DAC (10bit)

→ 1.364±0.001 mV/count

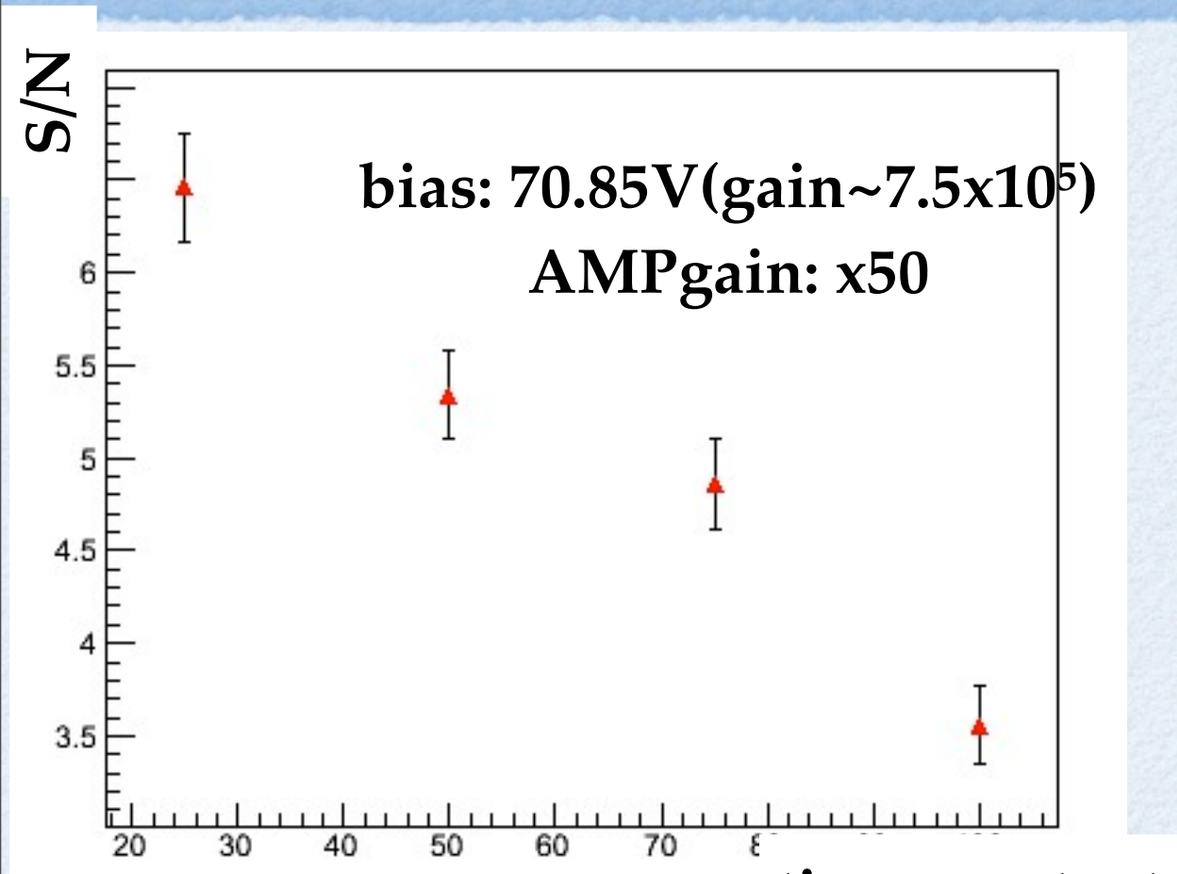
Threshold Curve

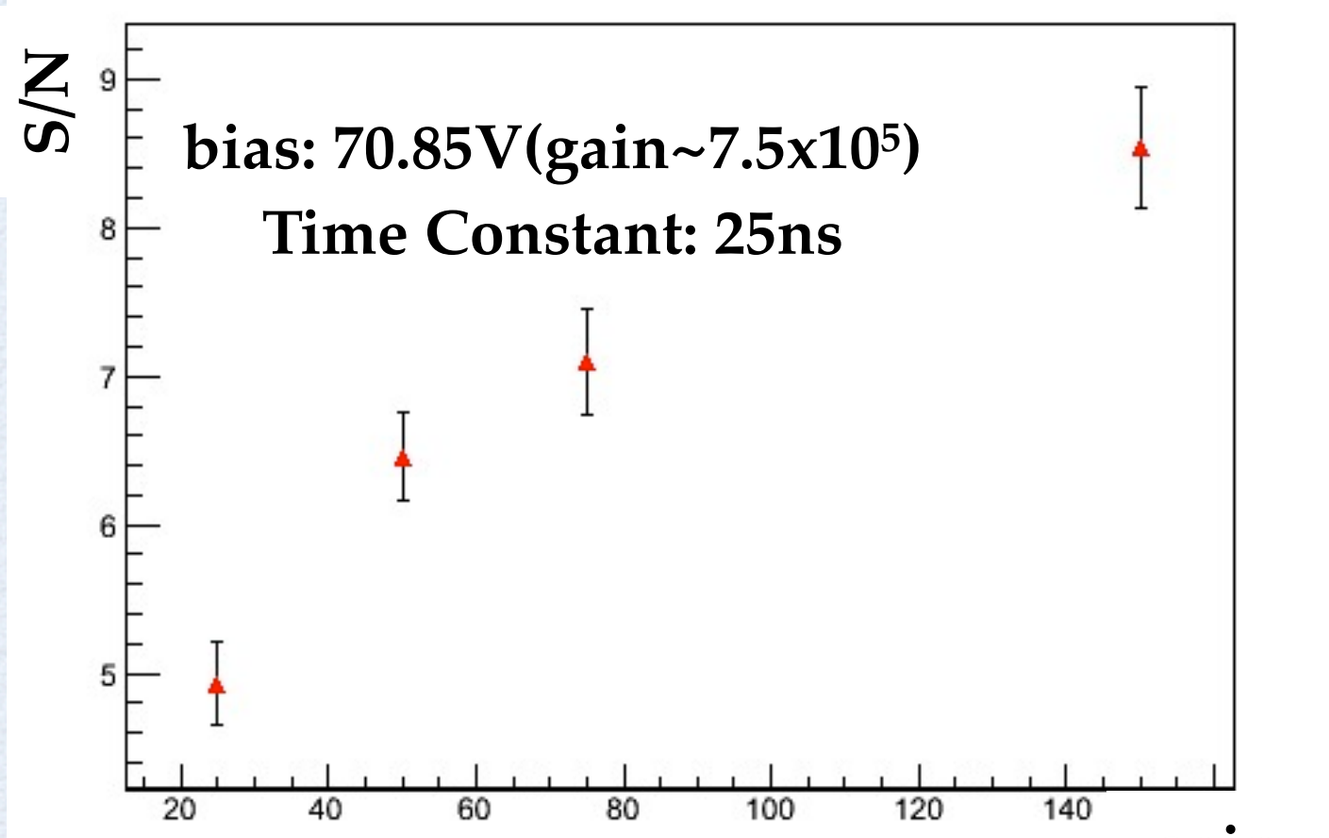


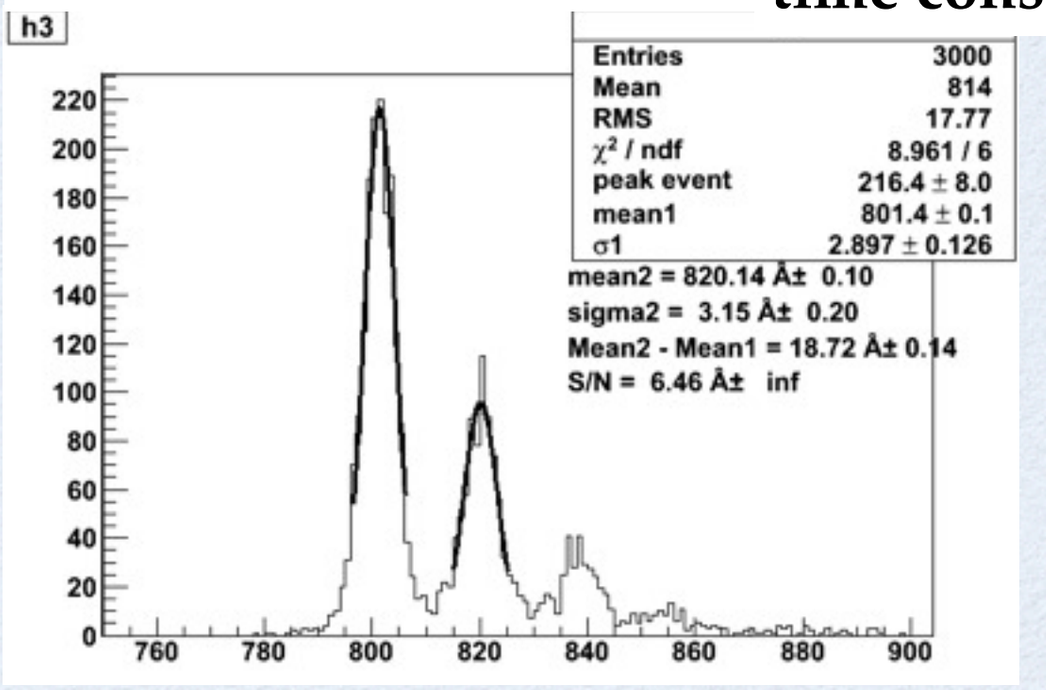
TH50 σ ~ 7

1 p.e/dispersion(1p.e) ~ 4 → consistent with spec.

Signal to Noise







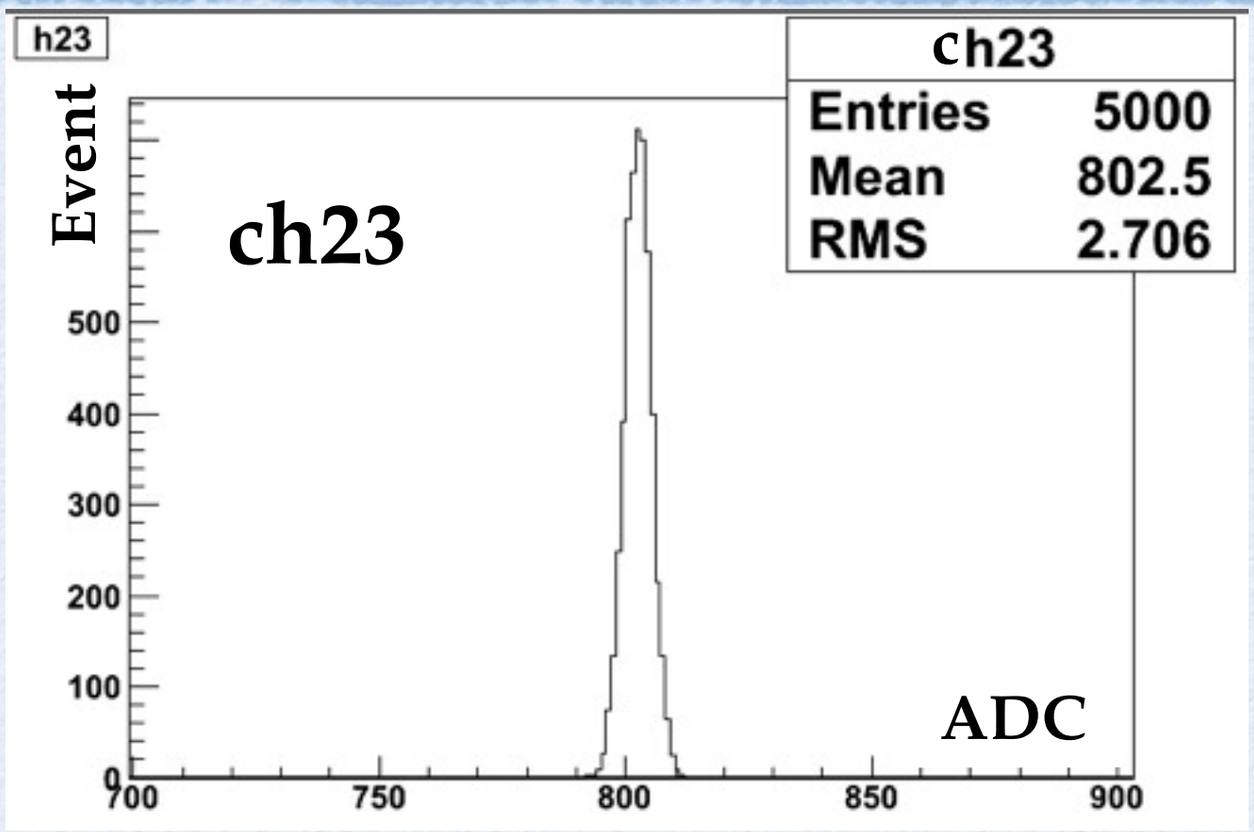
S/N := (1p.e. - ped)/(σ of ped)

SPEC : MPPCのgain ~7.5x10^5のとき

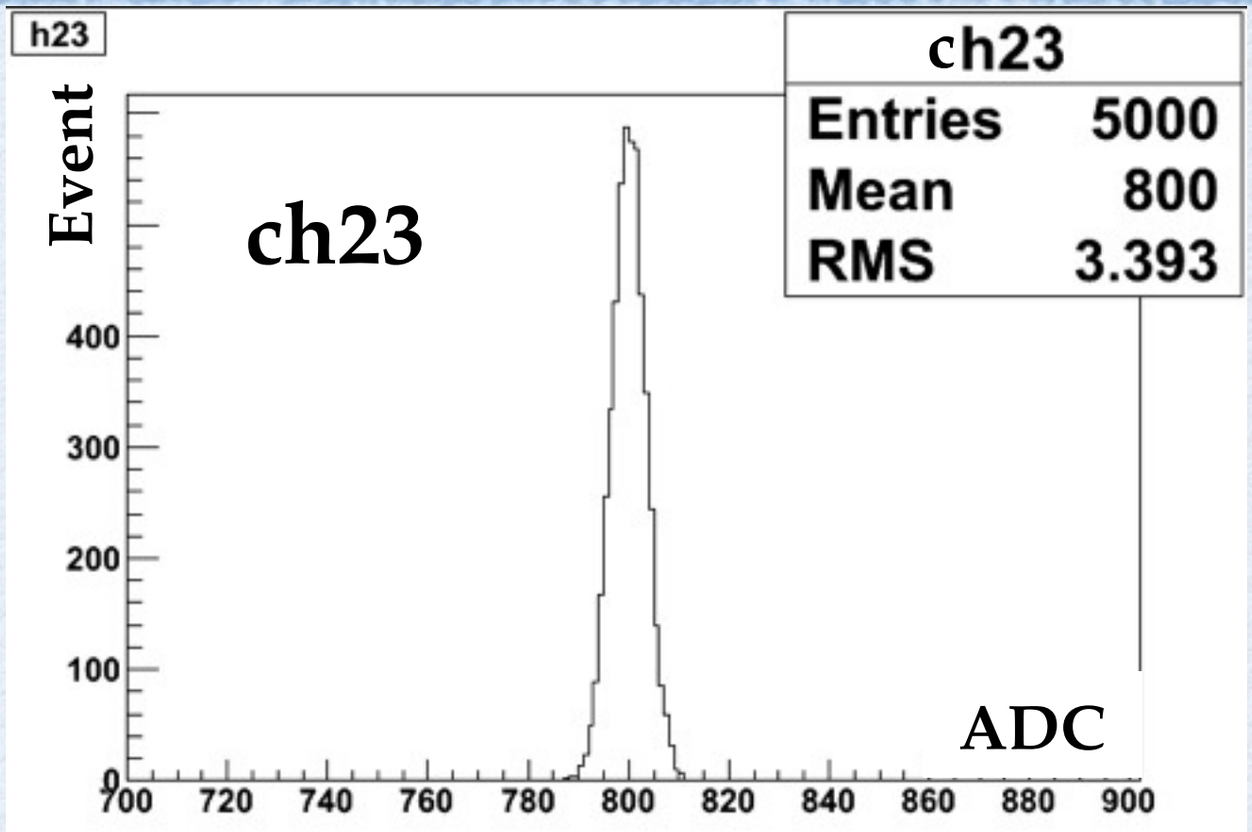
: S/N = ~7.5

SPEC は満たしている

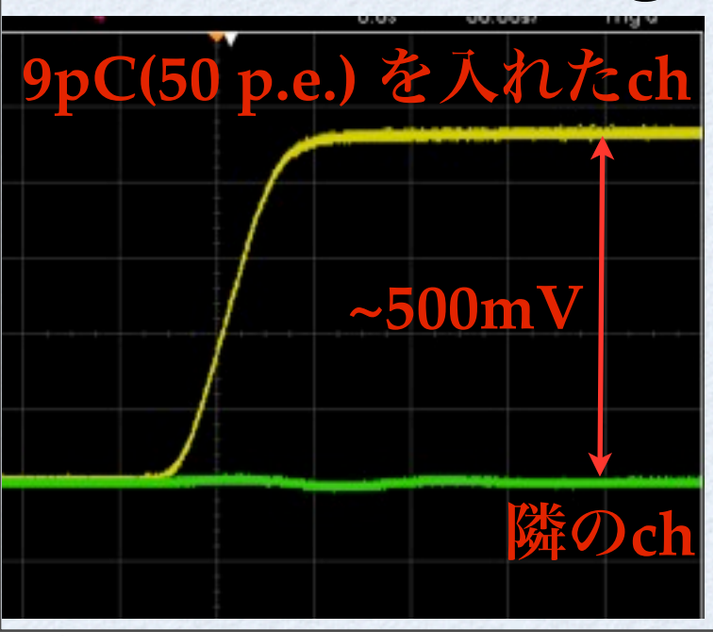
cross talk



No charge to ch24



8pC injection to ch24



ch24のgain ~2000 countに対して

crosstalk noise ~2count

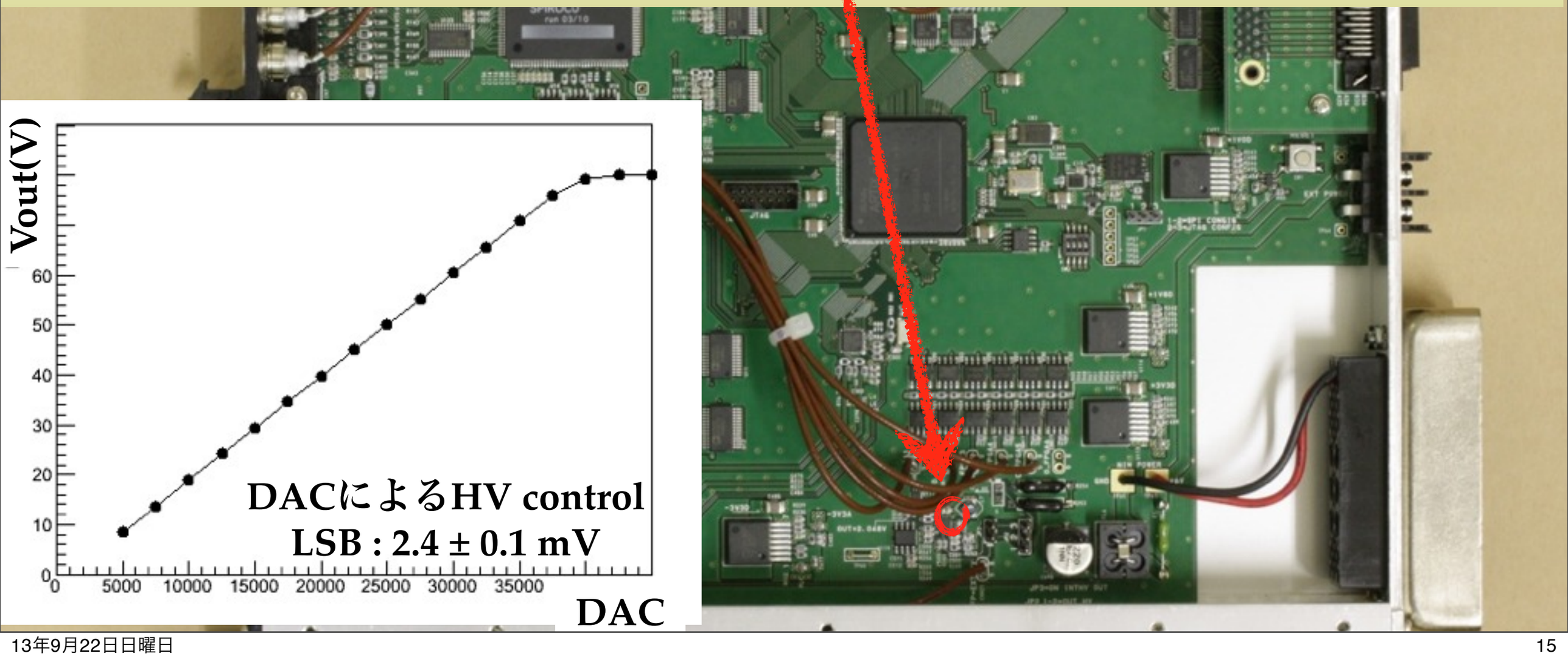
→ ~0.1%

十分小さい

input bias voltage (LT3482)

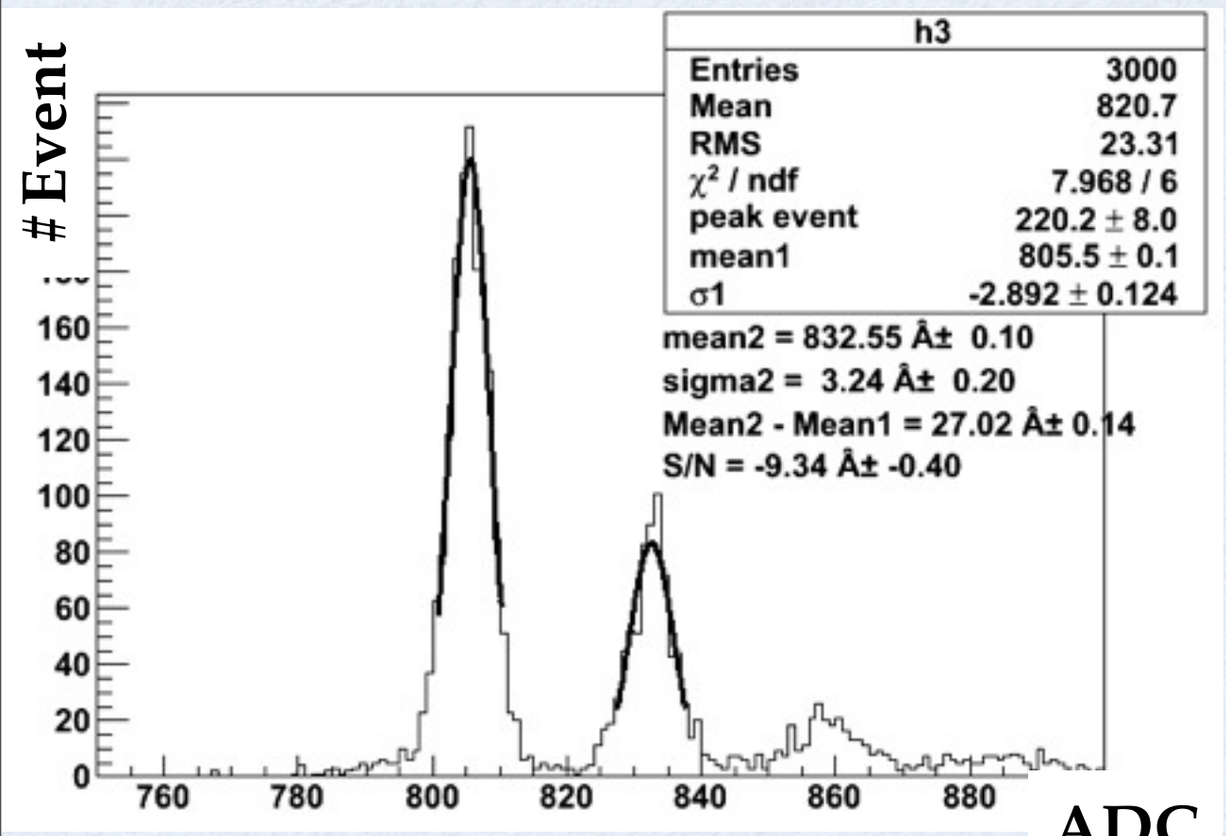
LT3482 (リニアテクノロジー)　　大きさ3 mm x 3 mm

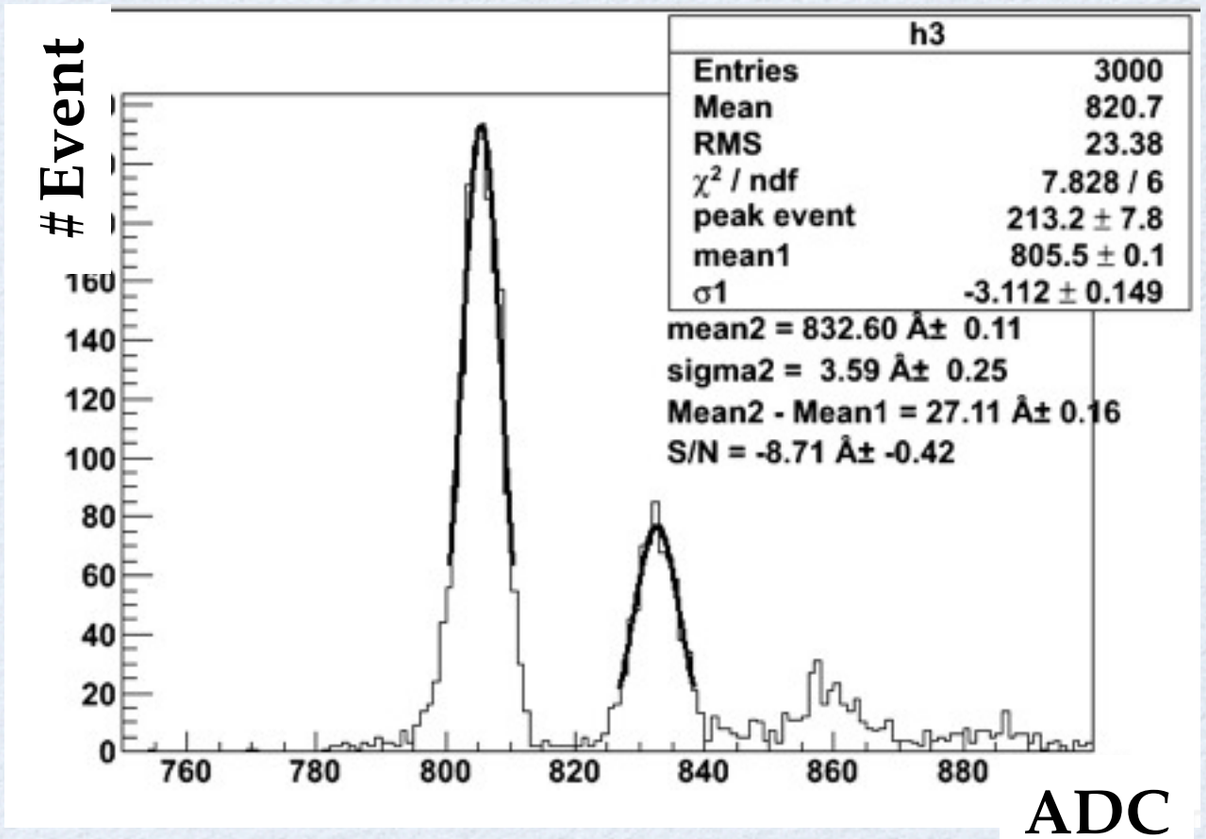
光学レシーバのAPD用 90V昇圧DC/DCコンバータ



LT3482 高負荷時

LT3482にロード抵抗を接続して、電流を流した





LT3482 current : ~200 uA

gain : x75

LT3482 current : ~2 mA

TimeConstant : 25ns

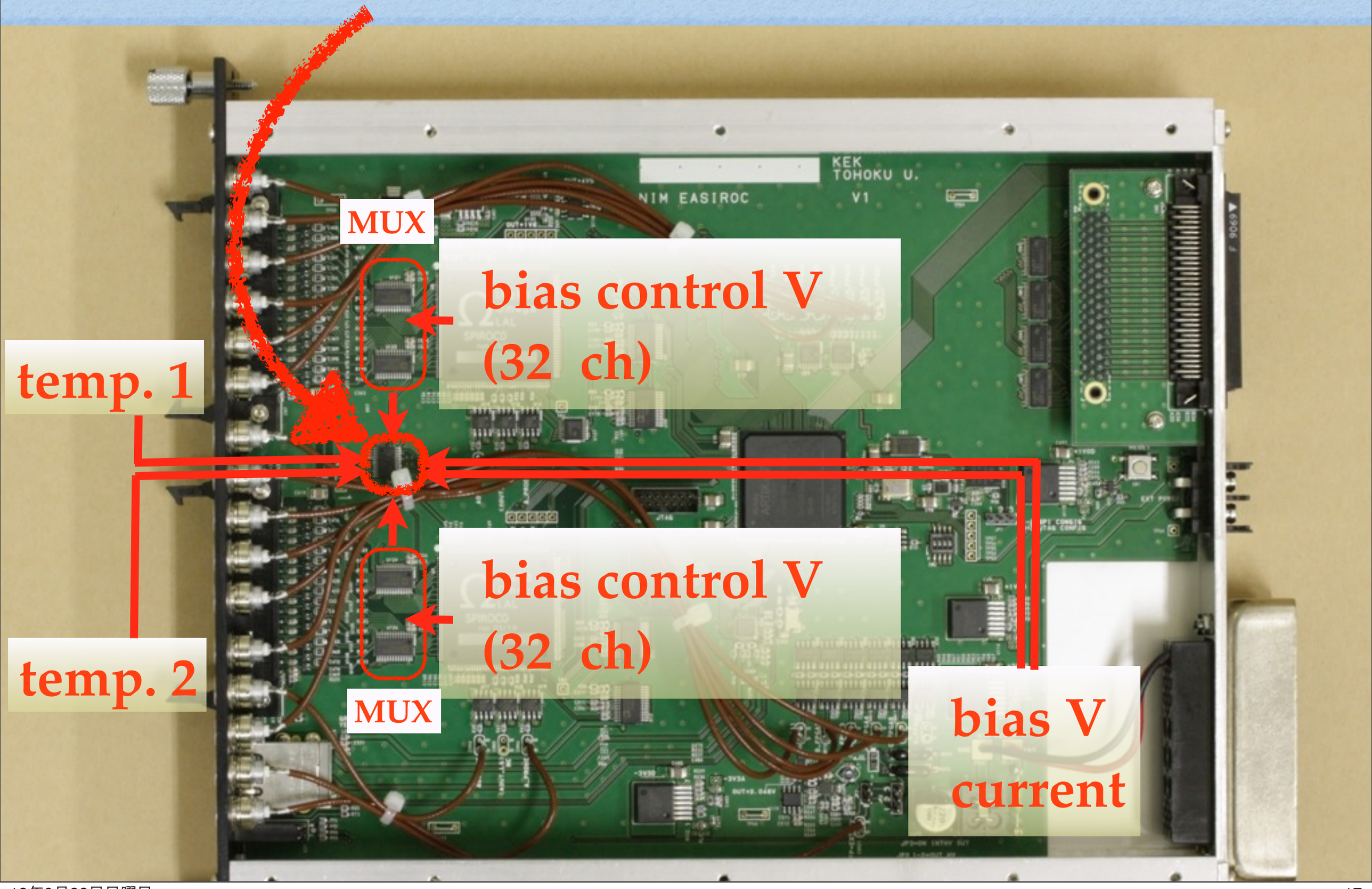
bias V : 71.05V

S/N:9.34±0.40

S/N:8.71±0.42

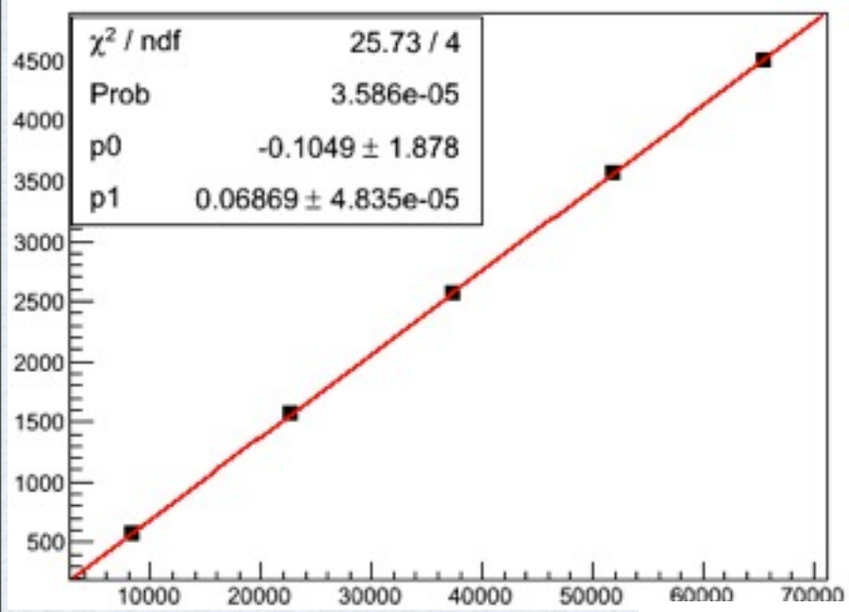
Pedestal、1p.e. ともにノイズ幅変わらず

Monitor ADC


MUX
bias control V
(32 ch)
temp. 1
temp. 2
bias control V
(32 ch)
MUX
bias V
current
KEK
TOHOKU U.
NIM EASIROC
V1

monitor ADC linearity

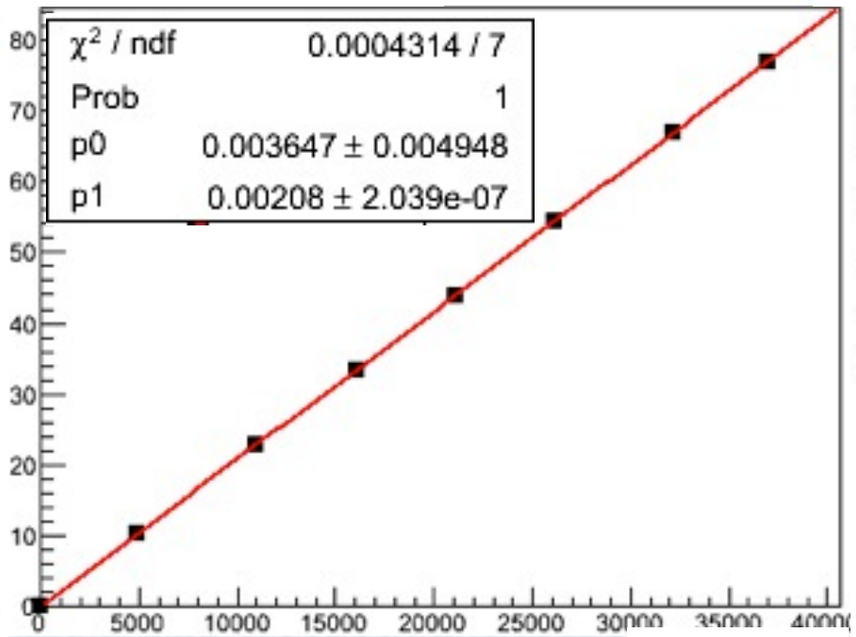
direct probe(mV)



bias control V(1 of 64ch)

0.69 mV/count

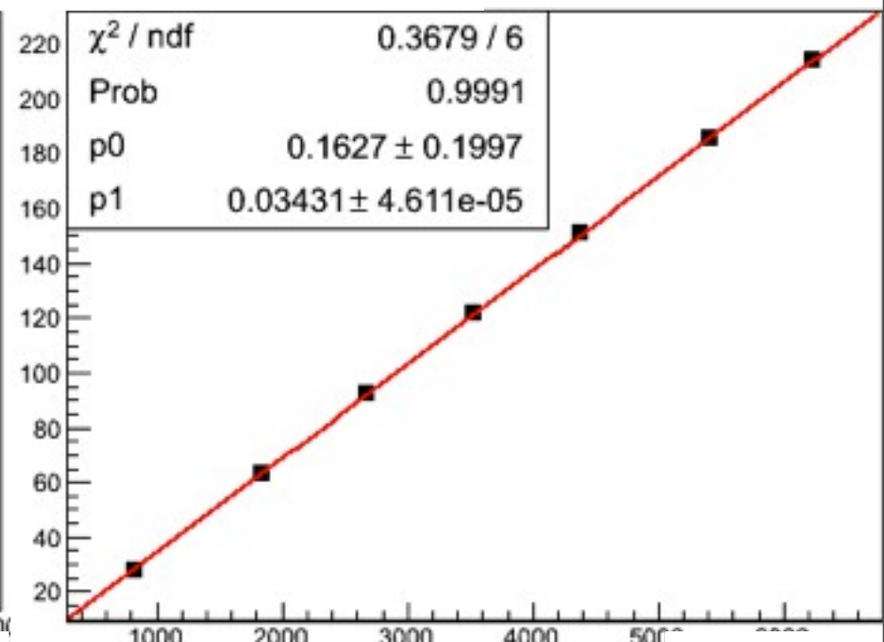
direct probe(V)



biasV (LT3482)

2.1 mV/count

direct probe(uA)



bias V current (LT3482)

0.034 uA/count

全ch正常、線形性も良い(図は一部だけ表示)

Conclusions

- MPPC用 汎用MODULEの試作品が完成

  ➡動作確認＆性能評価　(性能は問題なし、未確認機能あり)

  ➡修正版を製造中（注文済)

- **9月末**に修正版が完成

➡**誰でも買う事ができます**

欲しい！という方は

KEK測定器開発室 : 中村　勇

もしくは

大阪大学 : 花垣、石島　にご相談下さい

~28万円/台

で買えます

１研究室に1台

どうですか！

KEK 測定器開発室

back up

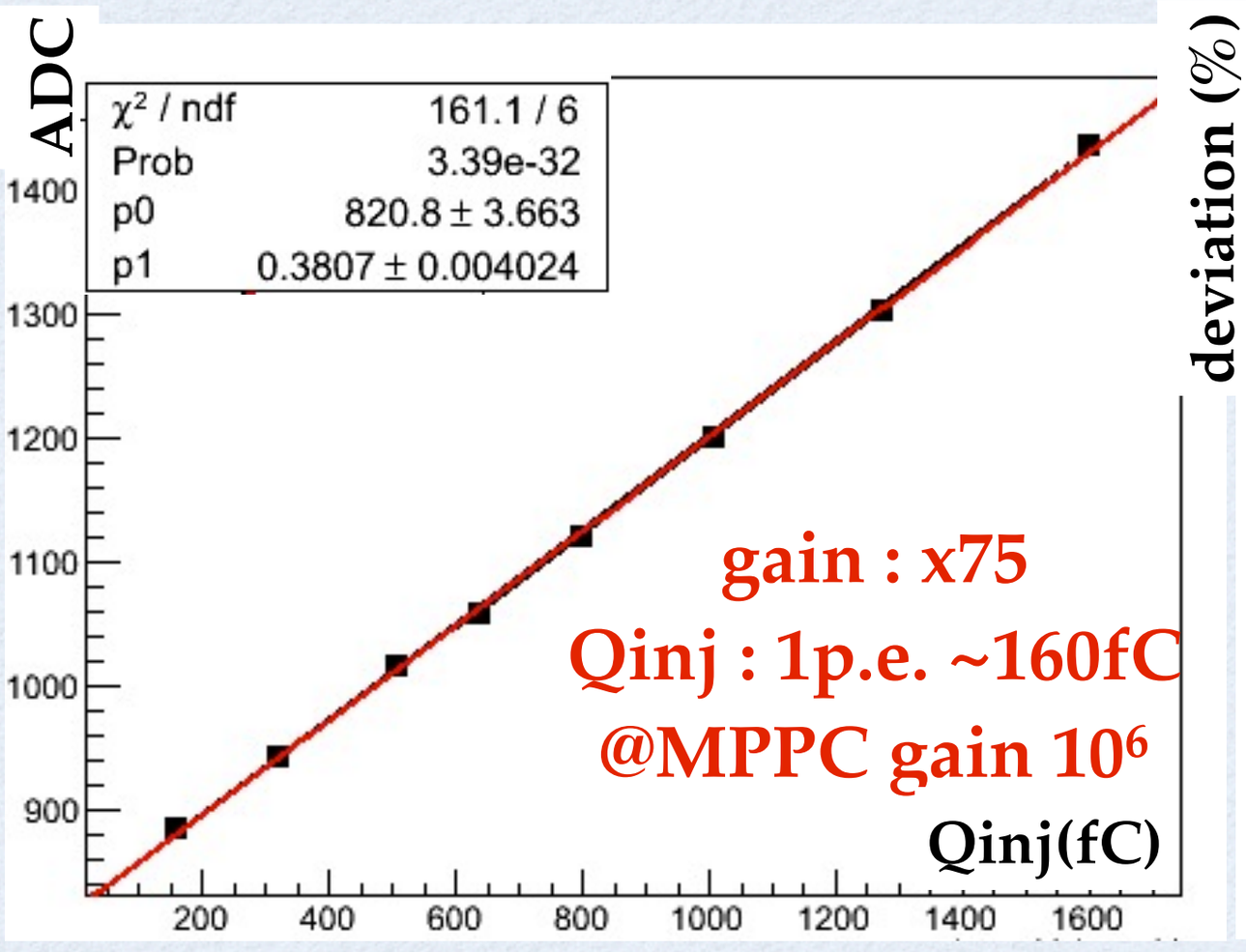
未確認事項

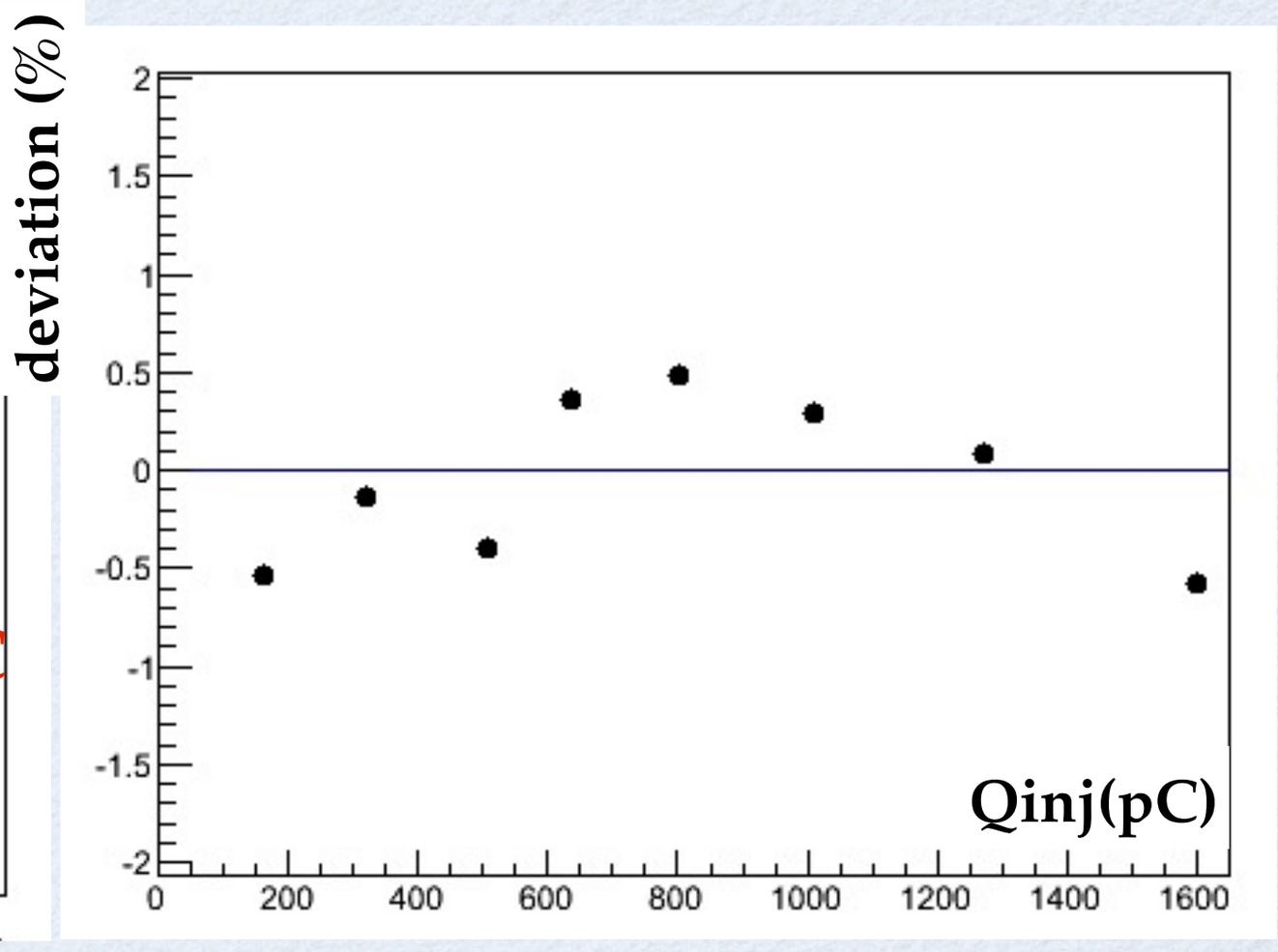
- 保護回路の耐久試験
- Ether net によるFPGA編集機能 (DLケーブル不要)
- 背面の64ch Discri. LVDS出力
- TDC (in FPGA) の導入
- Soft,Firmwareの改良
  - calibrationの自動化、オンラインモニタ etc.

配線は正しくつながっている

Analog linearity

160mV pulse **100pF**



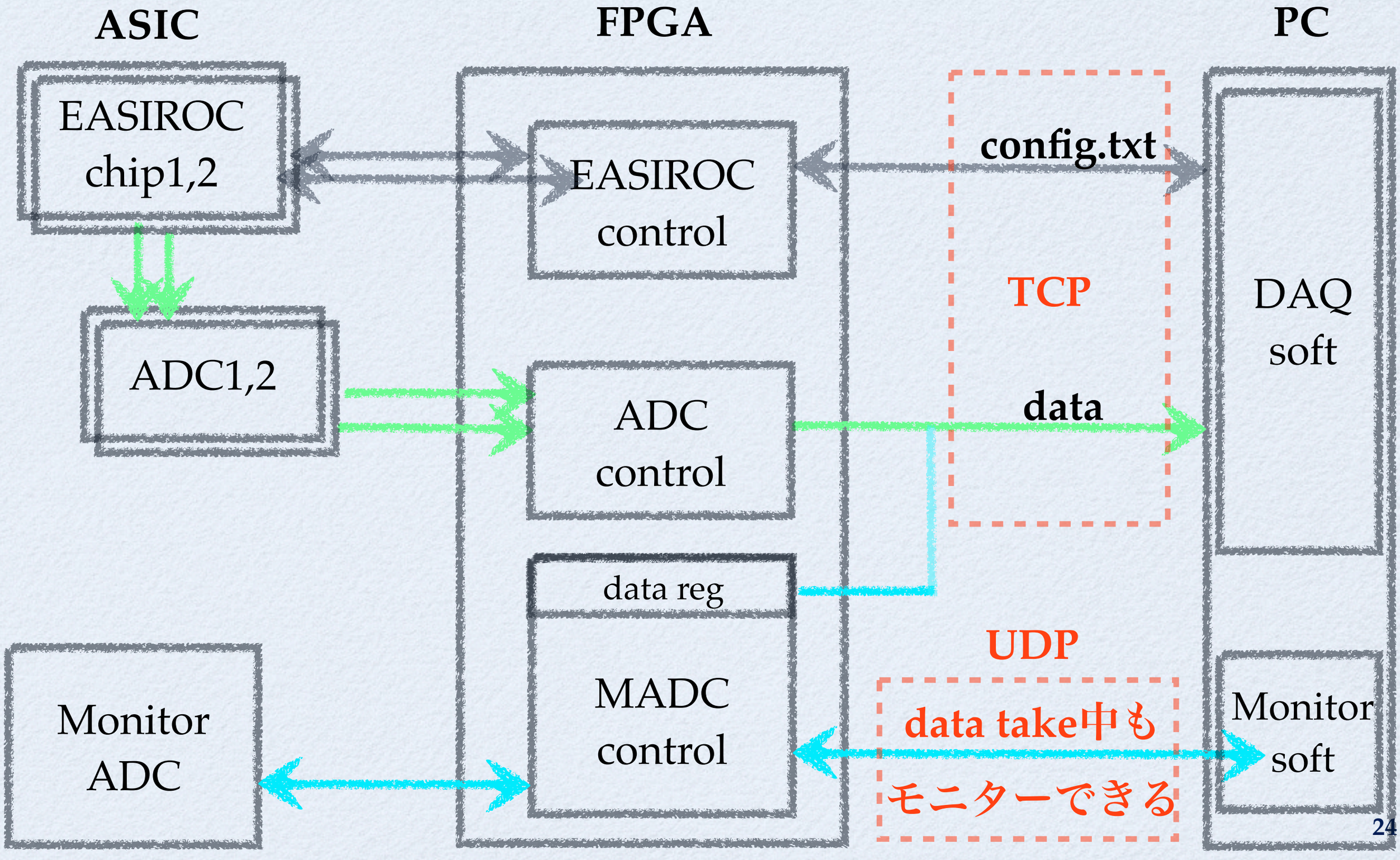


Spec. of EASIROC

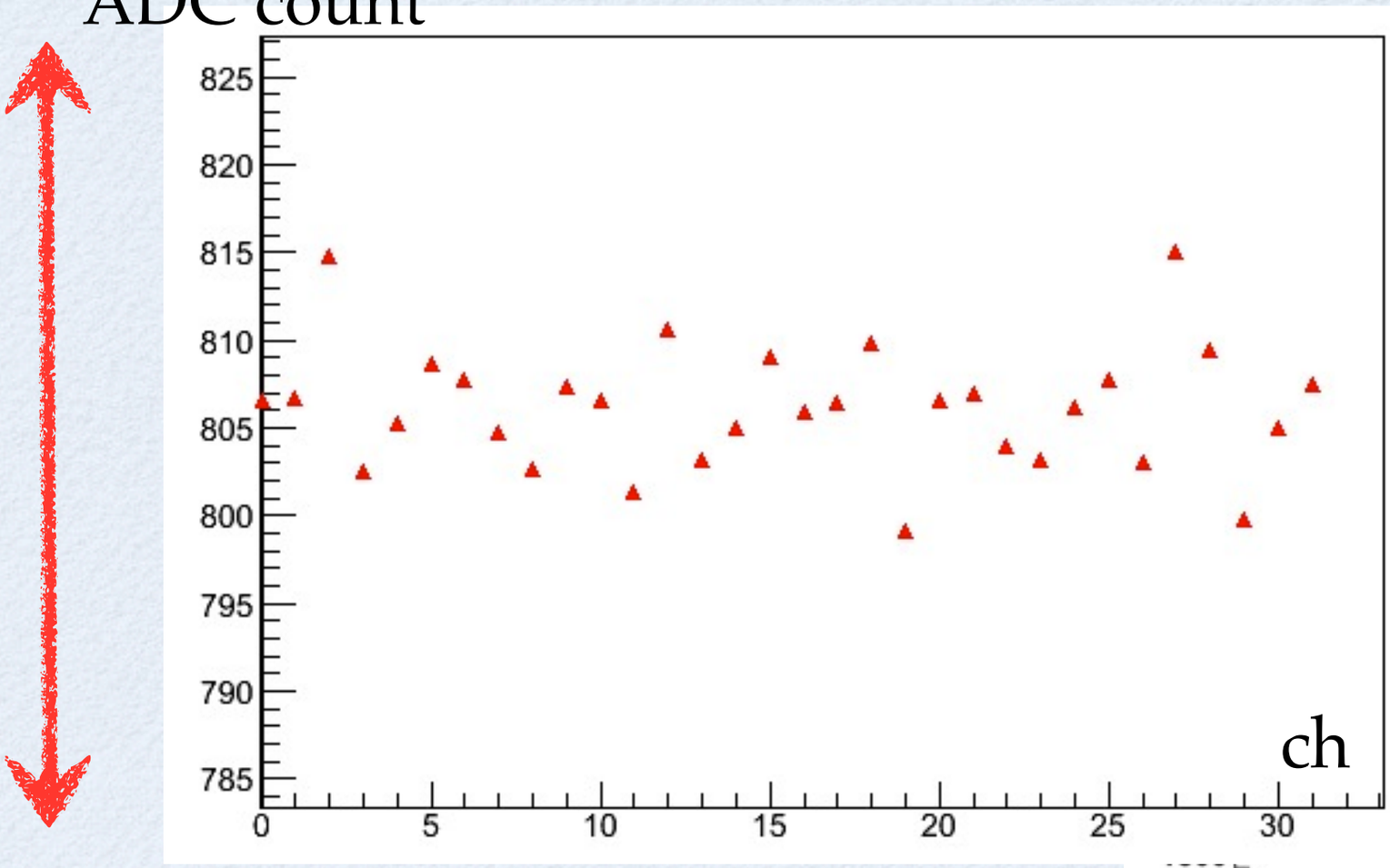
Analogue core :

- Internal input 8-bit DAC (0-4.5V) for individual SiPM gain adjustment
- Individually addressable calibration injection capacitance
- Energy measurement : 14-bit dynamic range
  - 2 tuneable gains followed by 2 adjustable shapers
  - Analogue memory (Track & Hold cell) for low gain and high gain
  - Common 10-bit DAC for threshold adjustment
  - Variable shaping time: from 25 ns to 175 ns
  - from 160 fC → 320 pC (ie. 1 pe → 2000 pe @ SiPM gain = 10^6)
  - pe/noise ratio : ~10 @ SiPM gain 10^6
- Trigger output
  - pe/noise ratio on trigger channel : ~ 25
  - Fast shaper : ~15ns
  - Trigger on 50 fC (ie. 1/3 pe @ SiPM gain = 10^6)

EASIROC MODULE DAQ



Pedestal dispersion

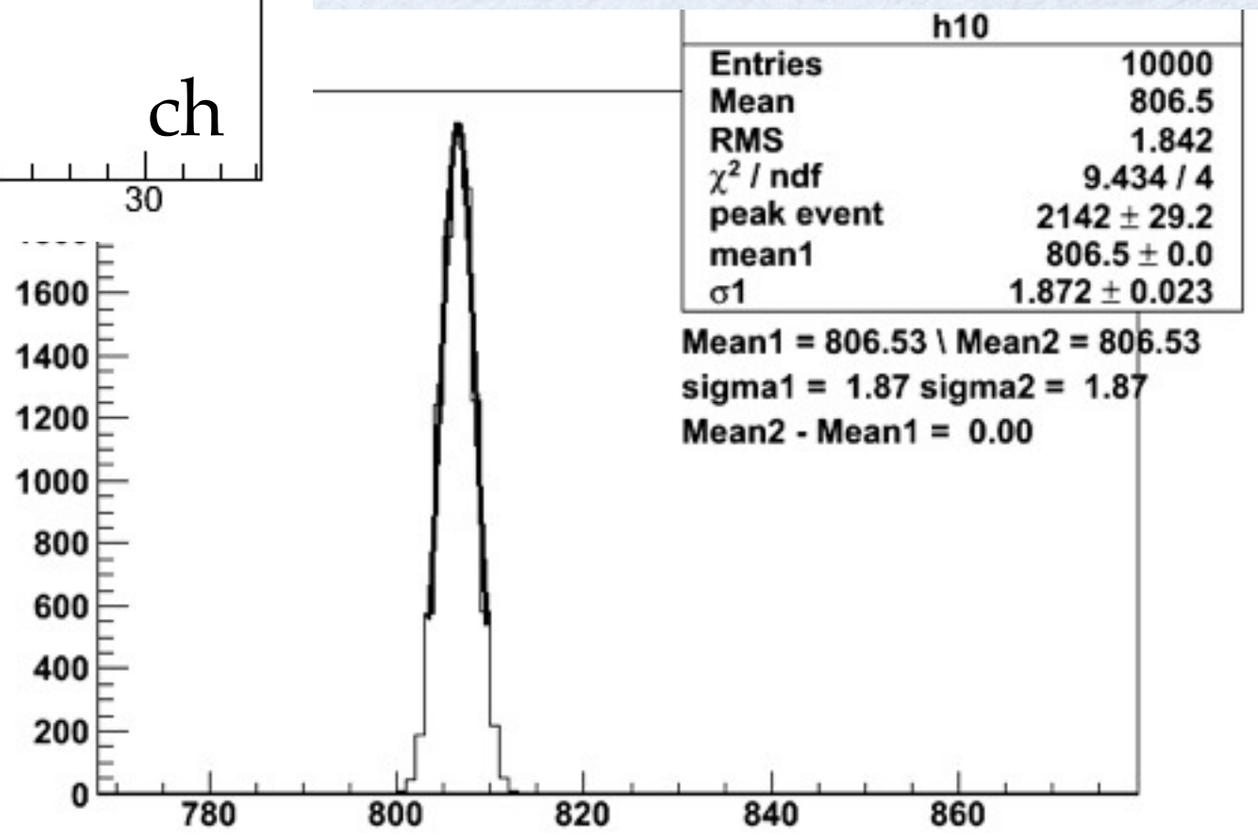


gain = x18.75

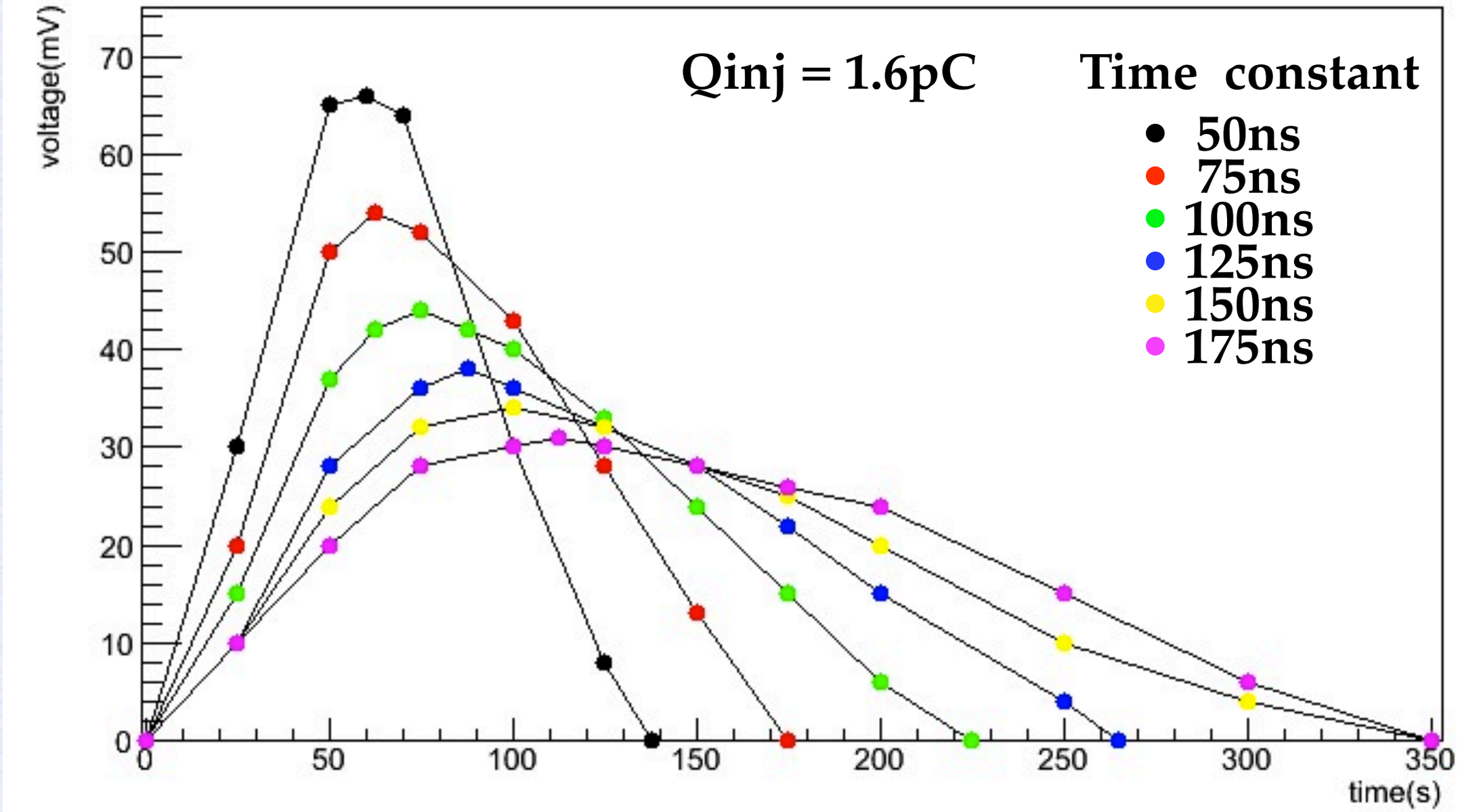
20mV = 40count

dispersion : ~8mV

SPEC : ~10mV

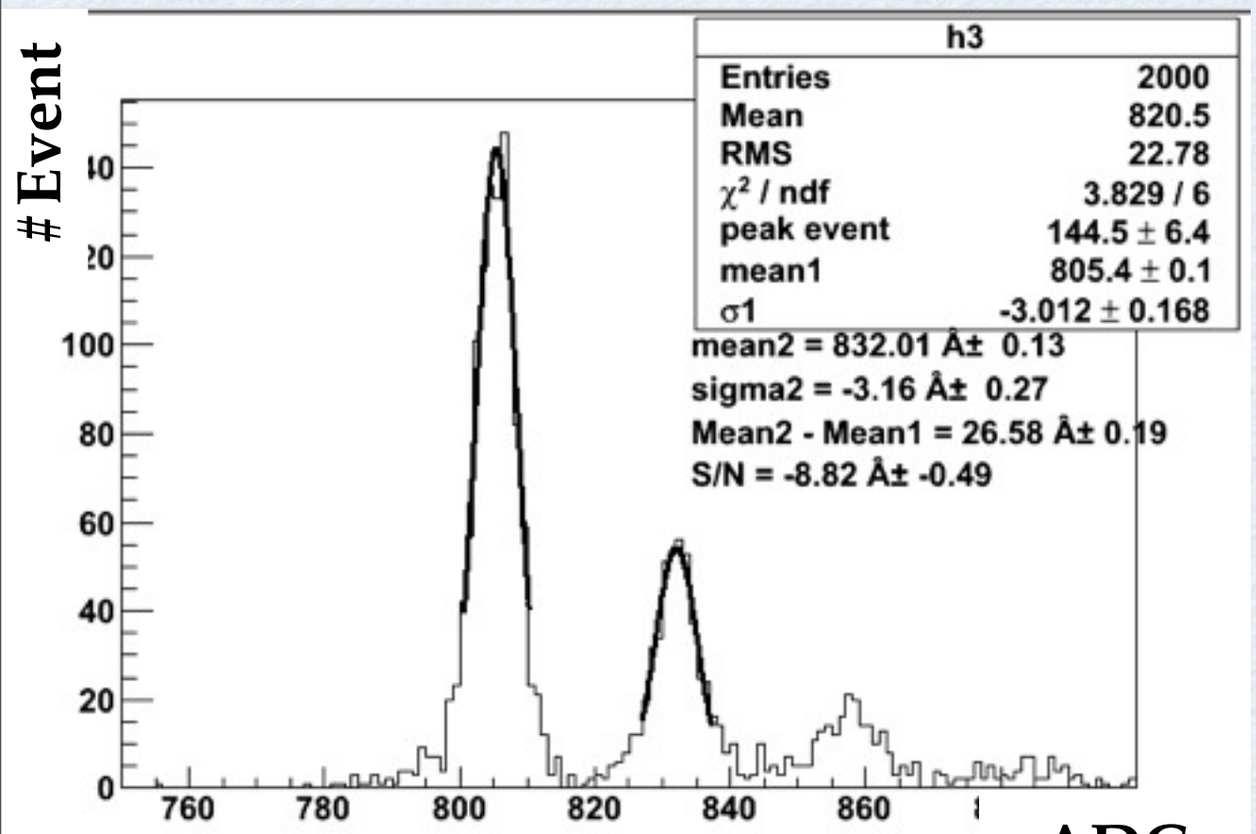


Slow Shaper

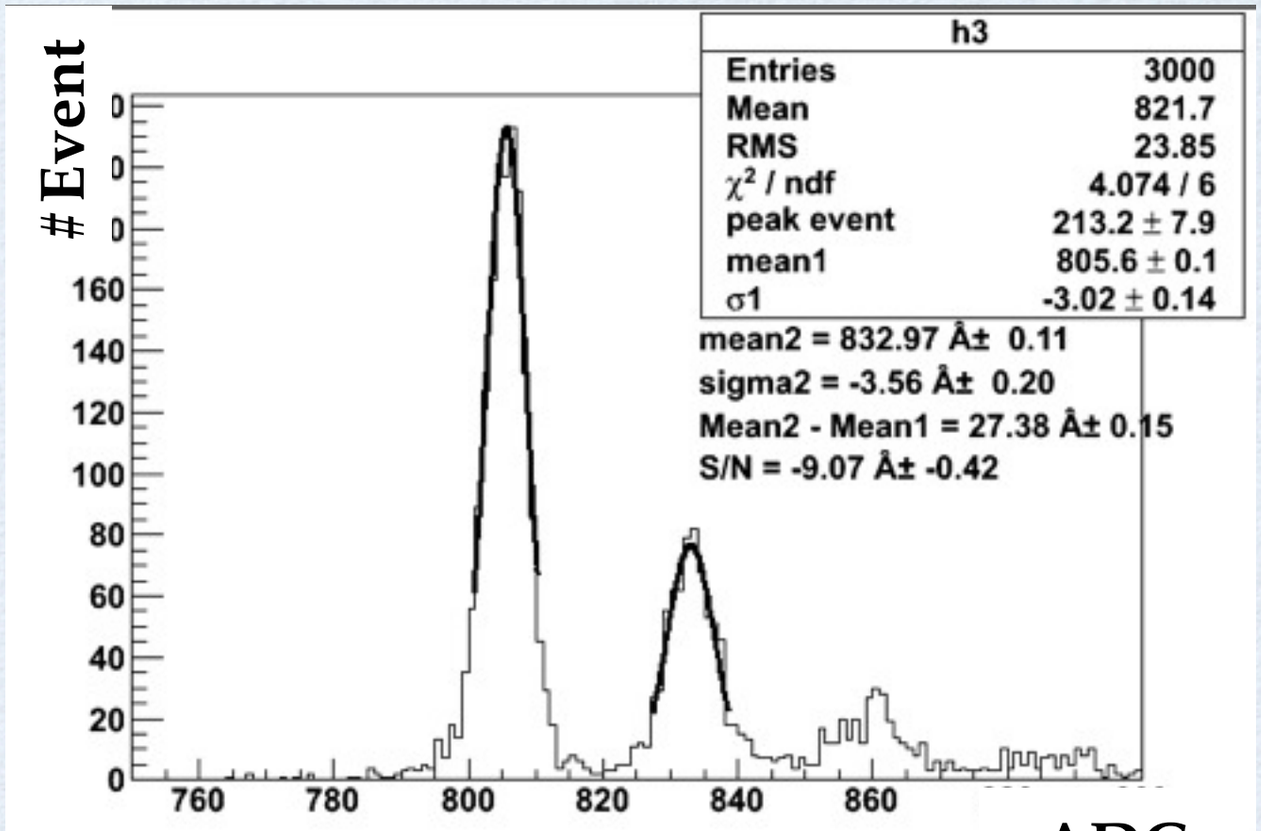


Prove Signal(in front of ADC) by oscilloscope 動作確認

ソースメーター　vs　LT3482



ソースメーター



LT3482

gain : x75

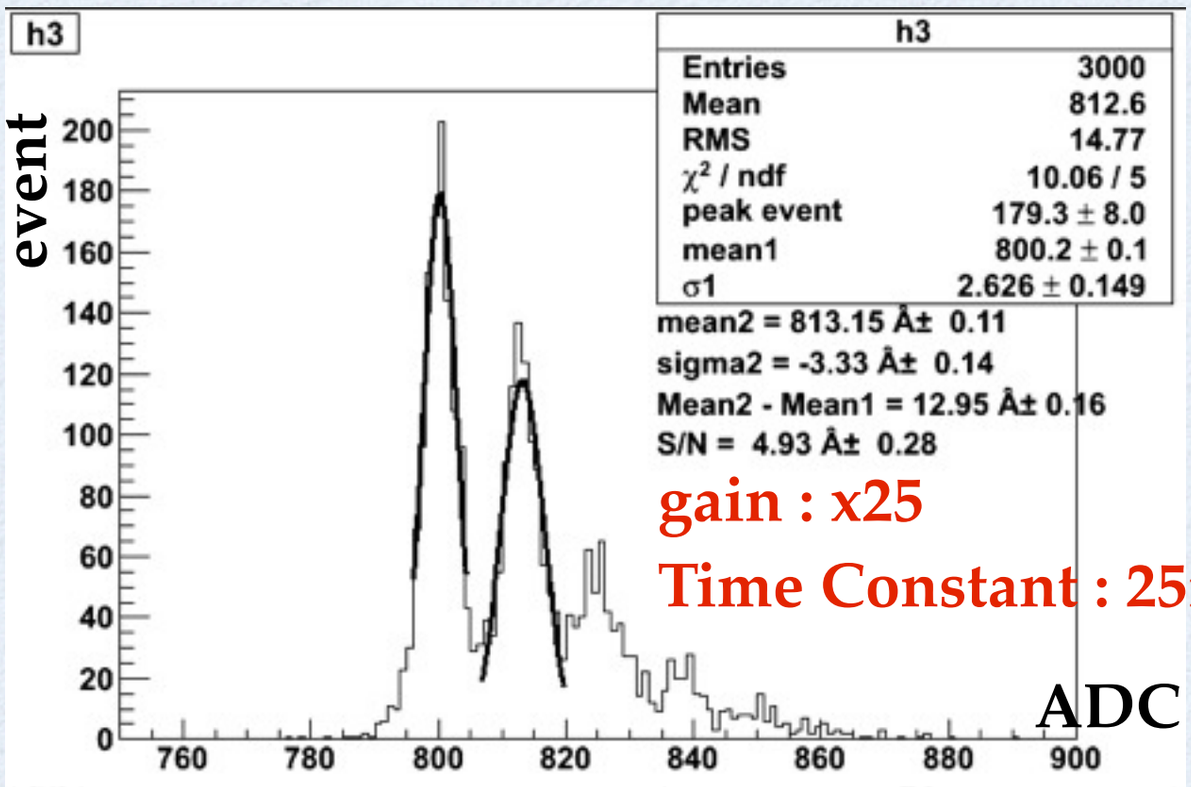
TimeConstant : 25ns

bias V : 71.05V

特に遜色なし（ノイズ幅等、誤差の範囲内で一致）

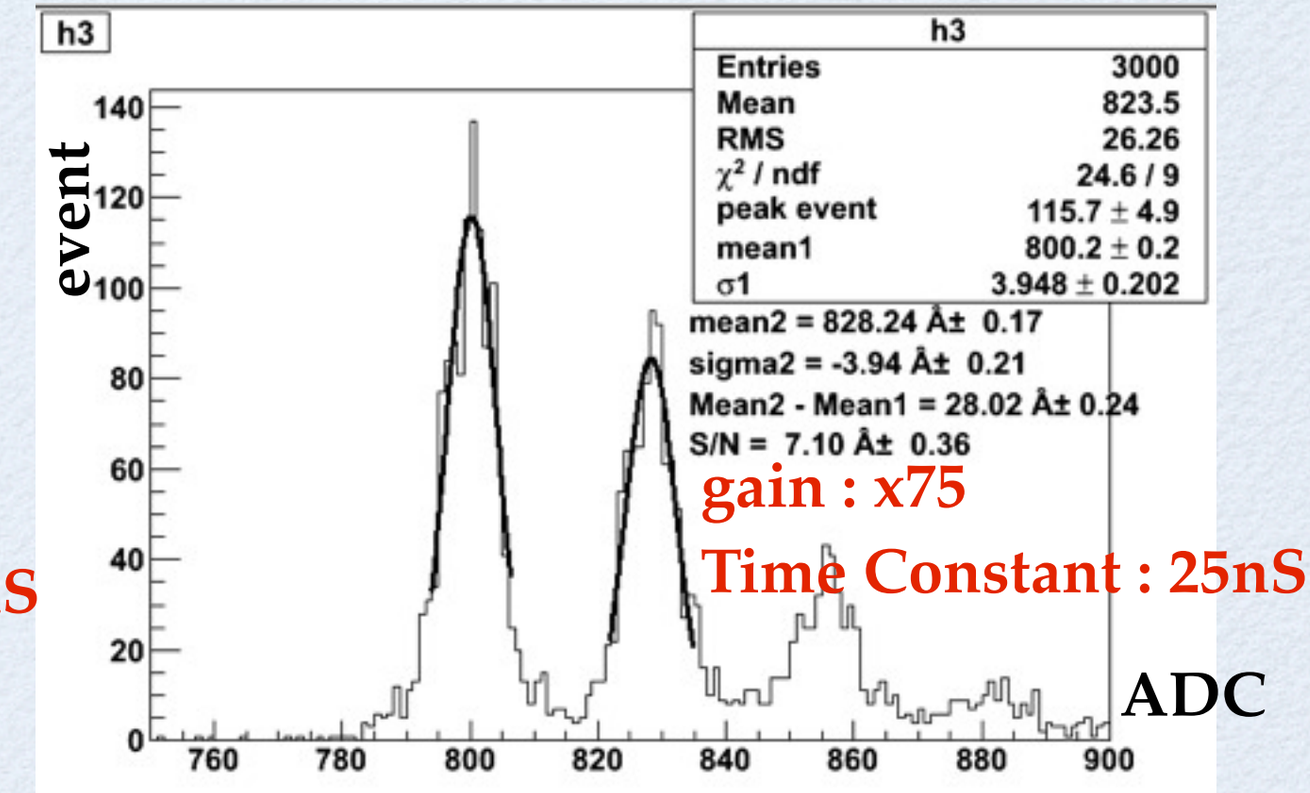
Signal to Noise

bias: 70.85V(gain~7.5x10⁵)
光源 : LED



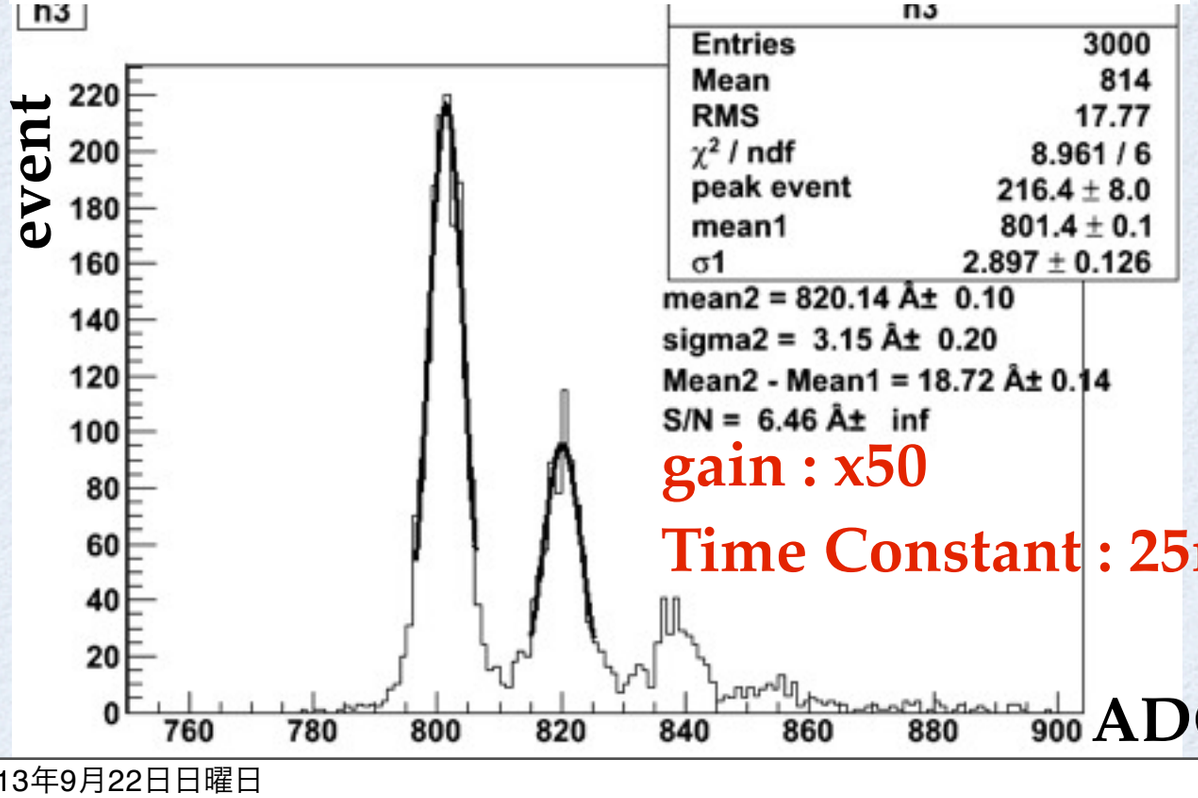
gain : x25

Time Constant : 25nS



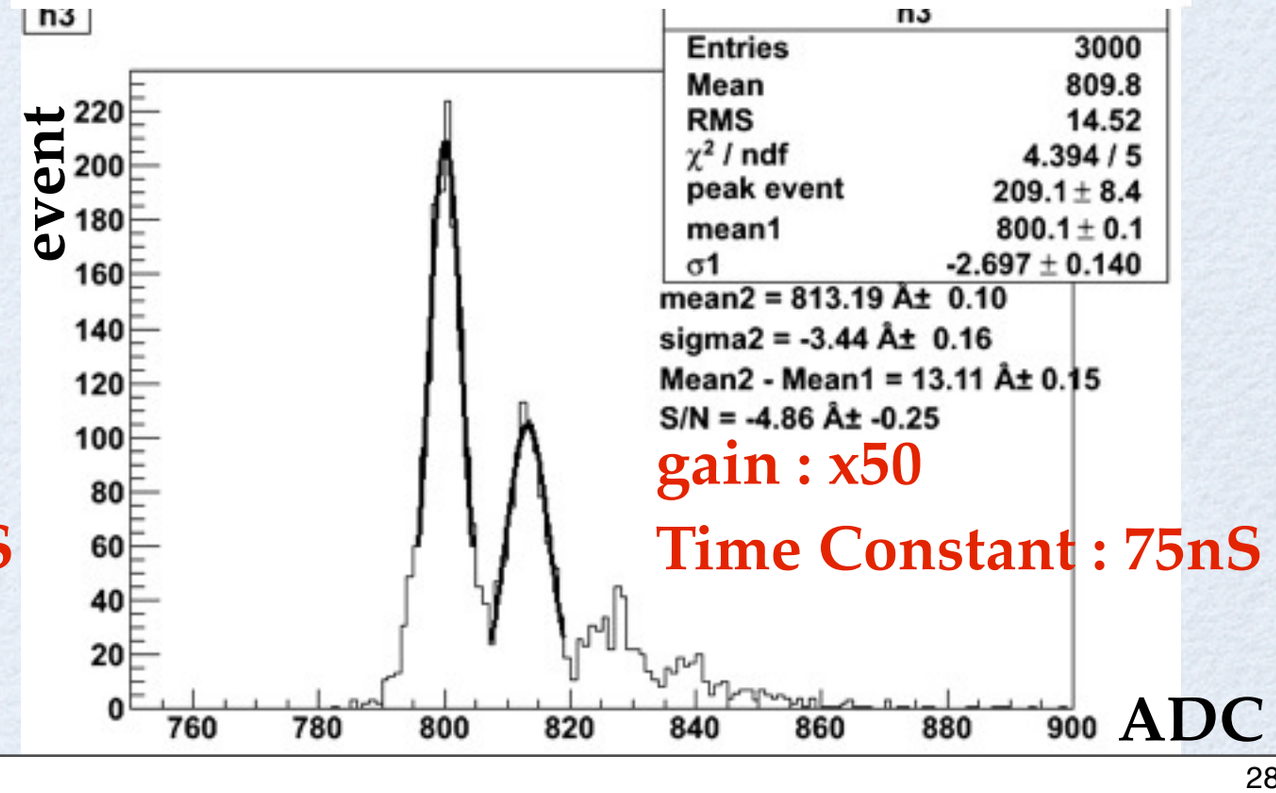
gain : x75

Time Constant : 25nS



gain : x50

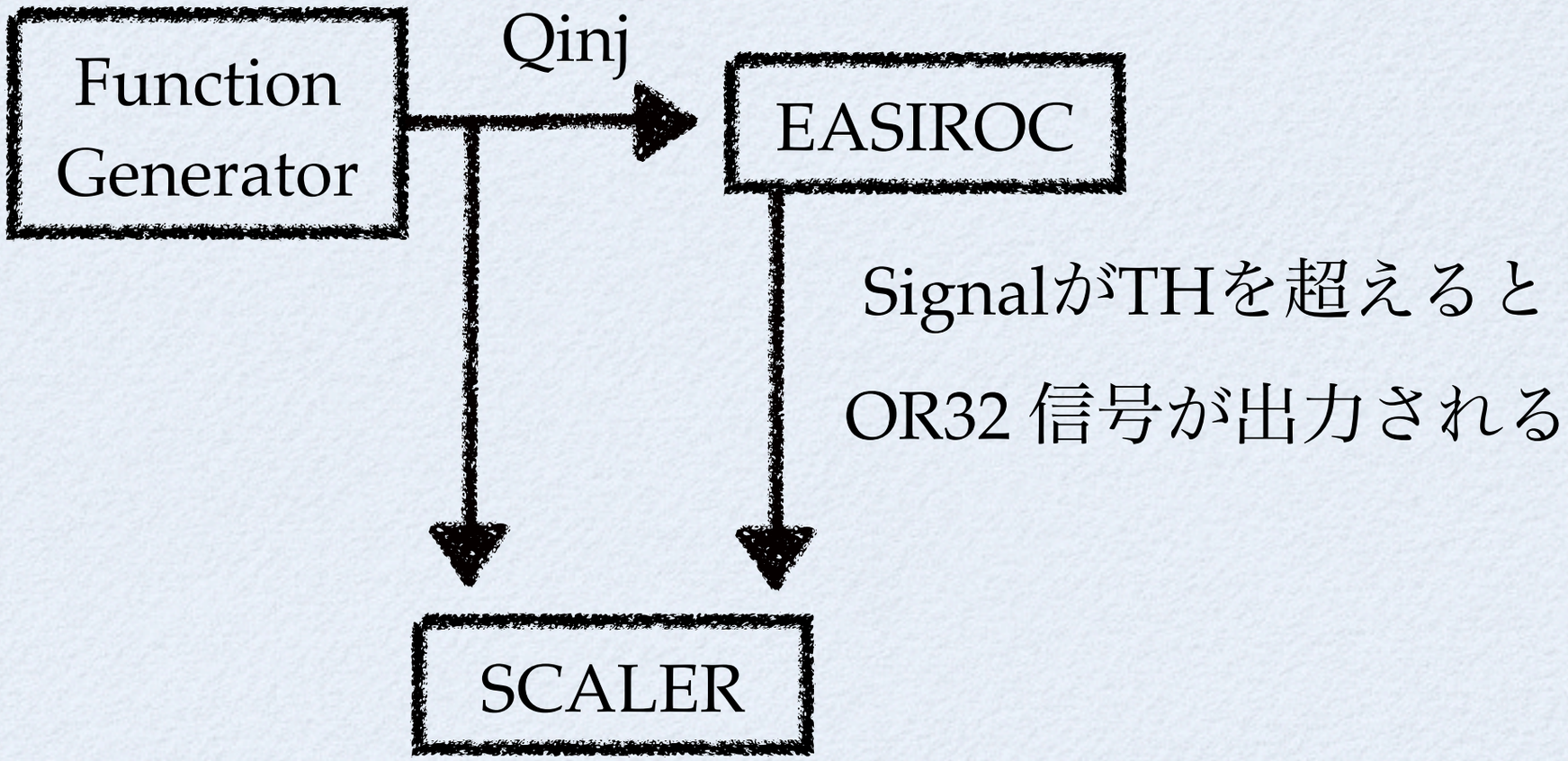
Time Constant : 25nS



gain : x50

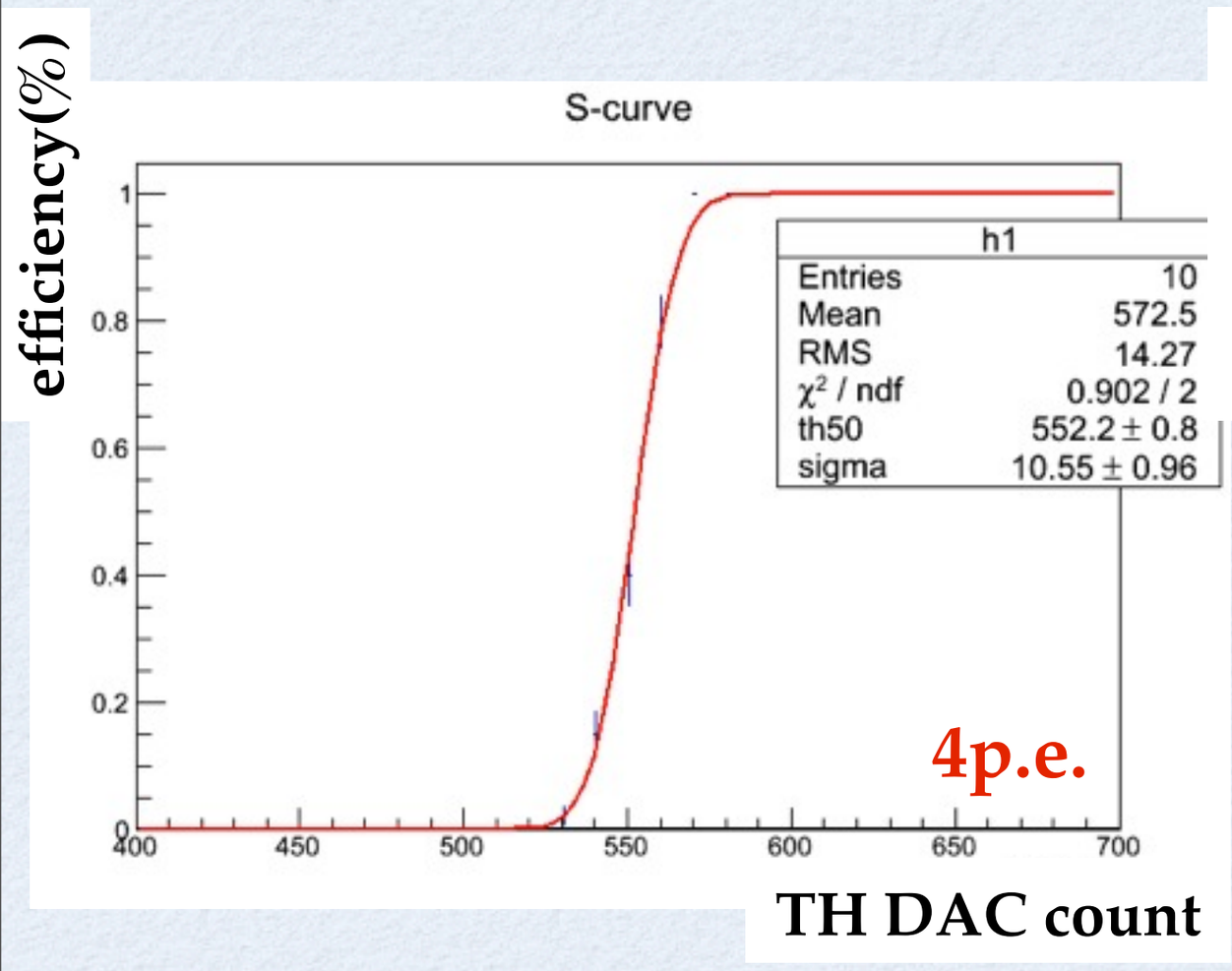
Time Constant : 75nS

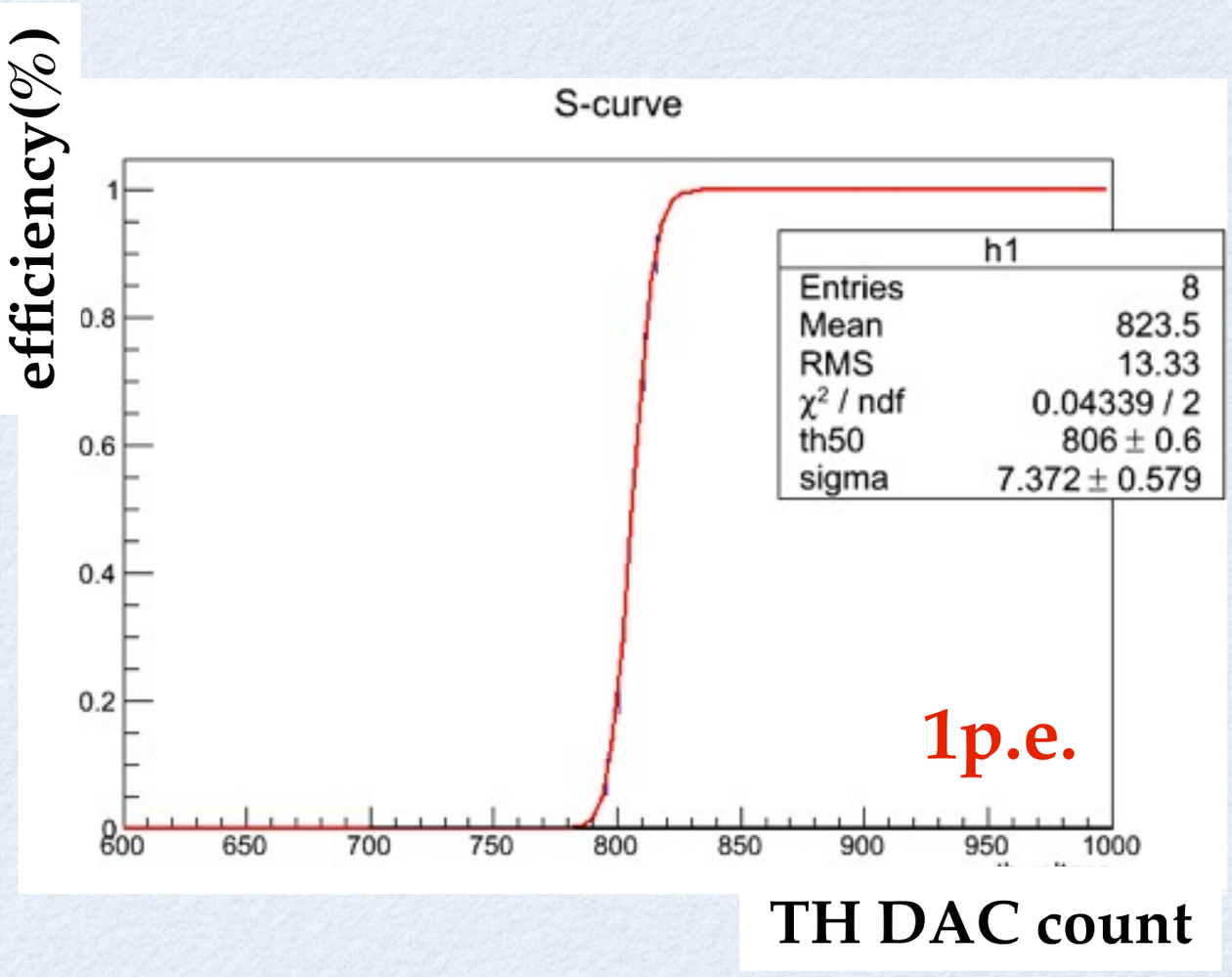
Threshold efficiency



Efficiency = OR32 signal / Qinj pulse

ch0 s-curve fitting



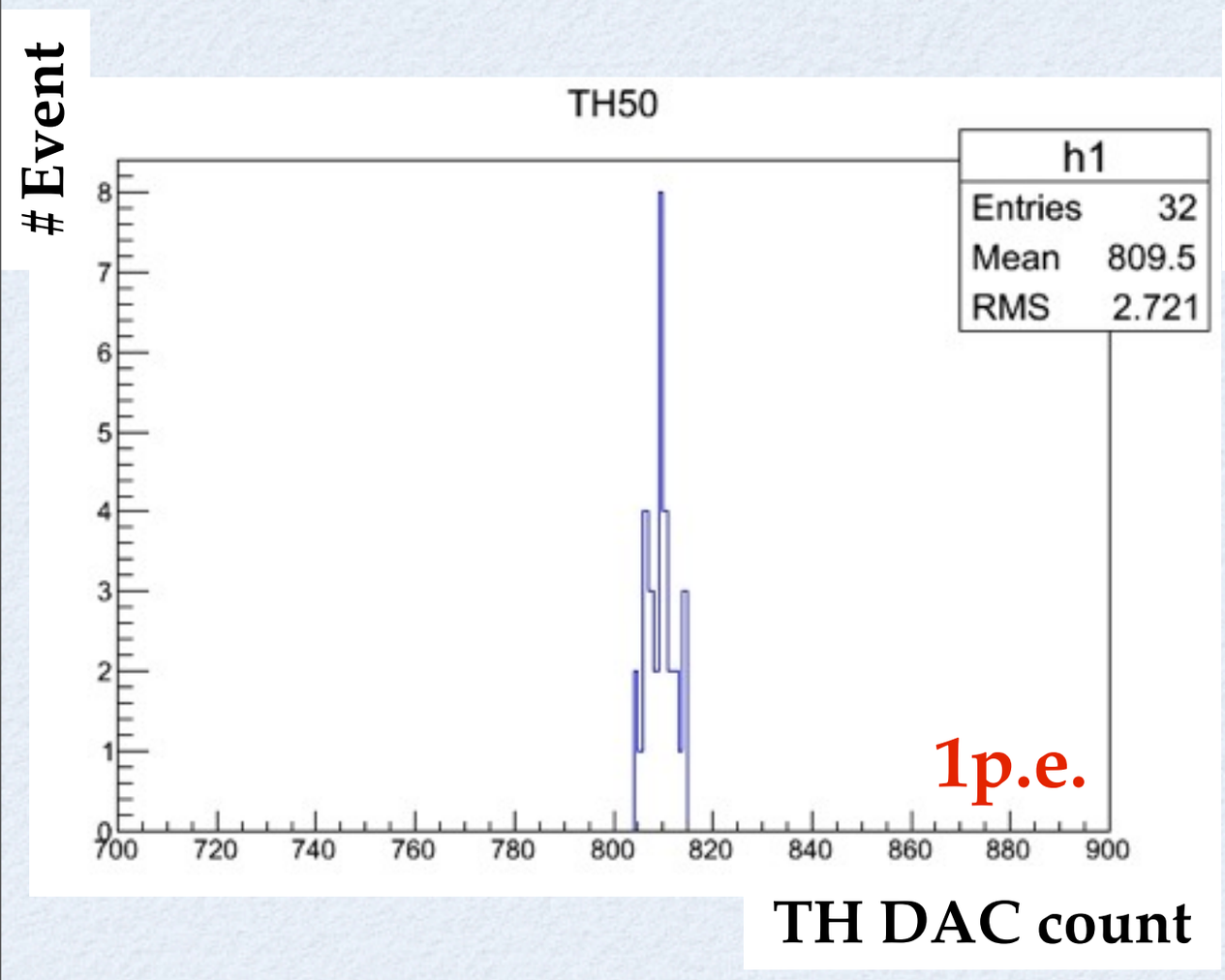


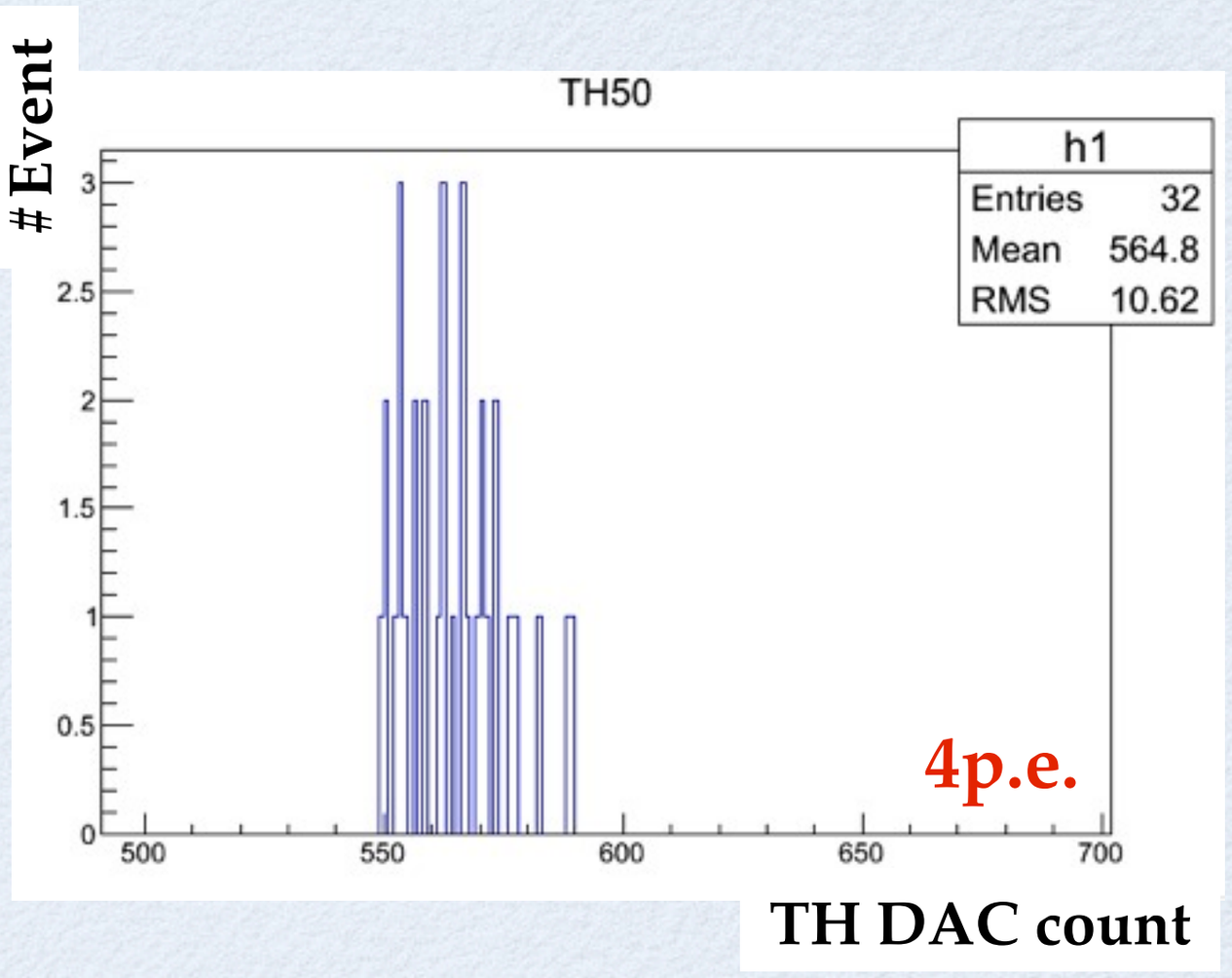
1p.e. ~ 80 DAC count

→ 1p.e./sigma : 7~10

各chについてはTHとして十分（他chも同様）

all ch th50 mean

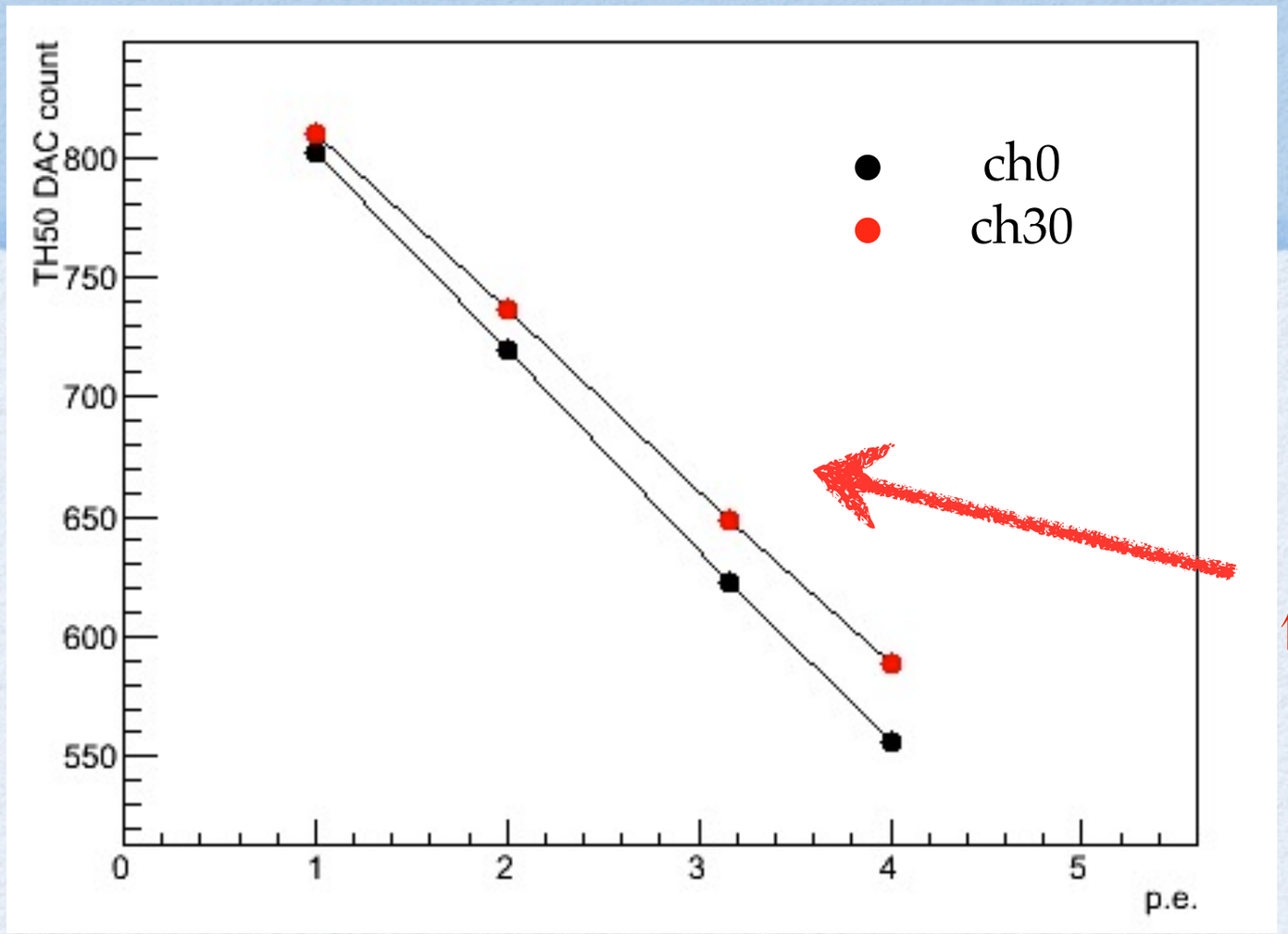




ch間でのばらつきが電荷が増えるにつれ大きくなっていく

→Fast shaper gainにばらつき

補正可能 (back up)



傾きの違いがgainの差？

差が大きかった0chと30chを抜き出してfitting

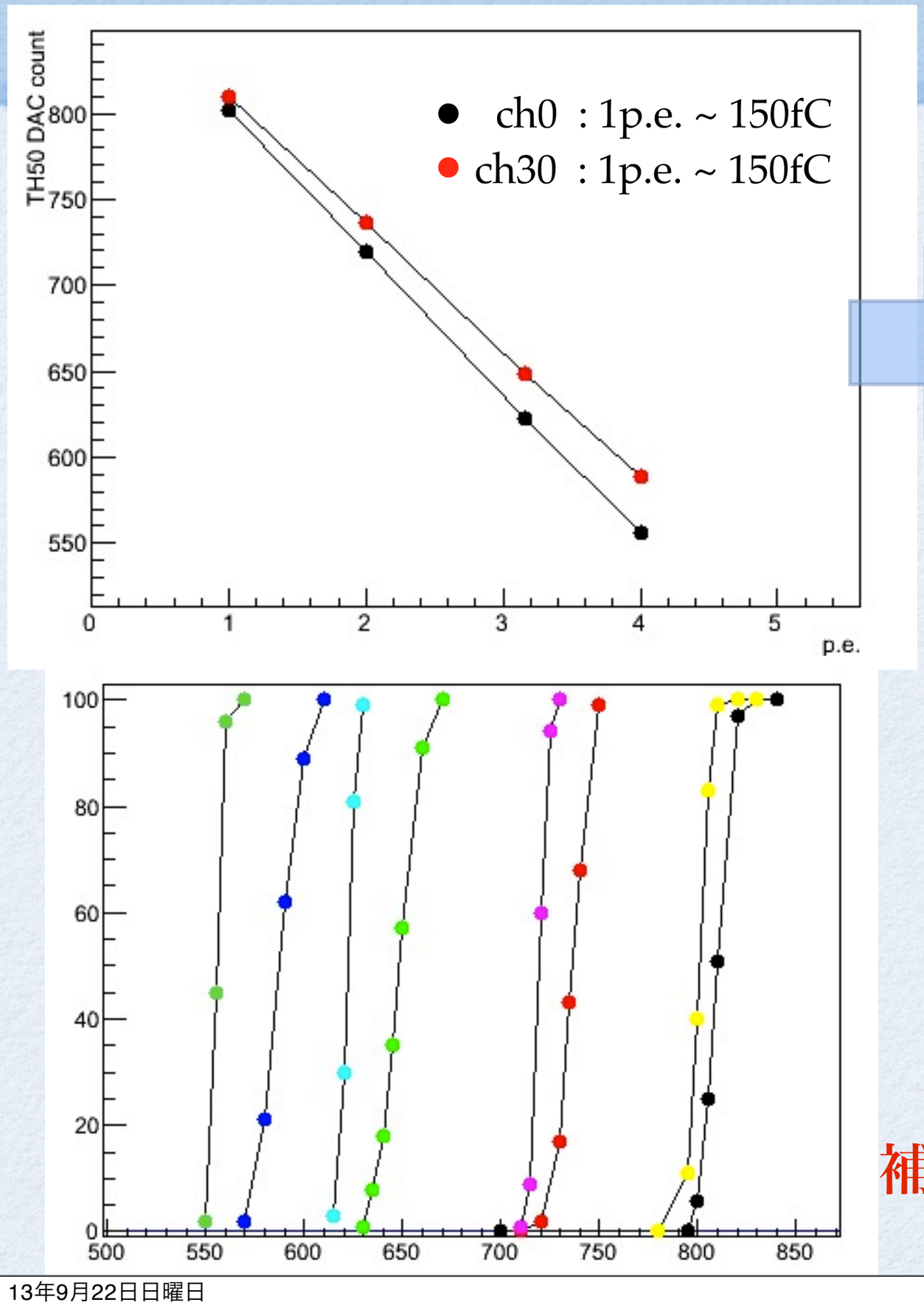
TH50がsignalのピークのmeanとすると、

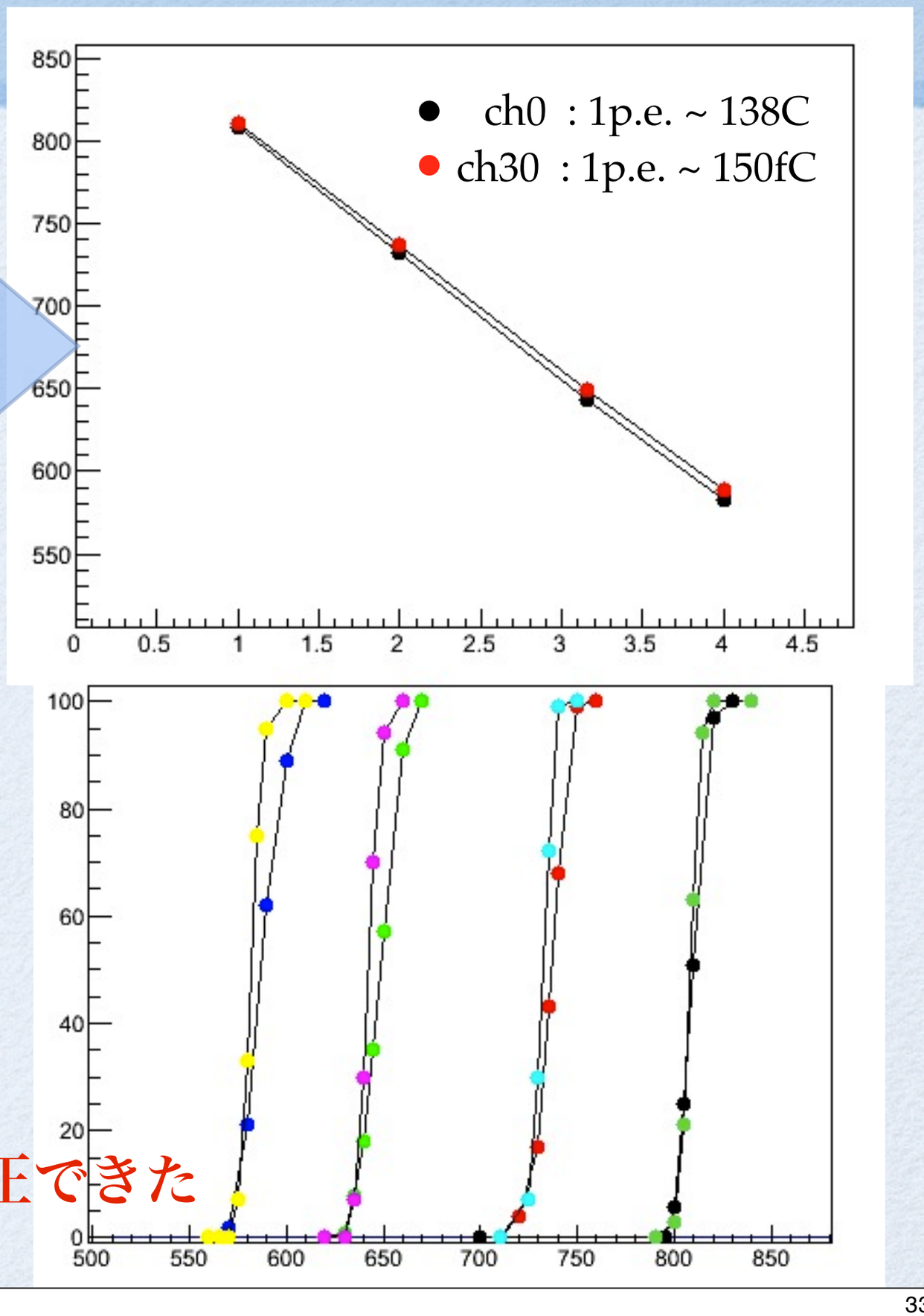
TH50 = Qinj x AMP gain

なので、Qinjを調節してやれば、ばらつきを抑えることができるはず。

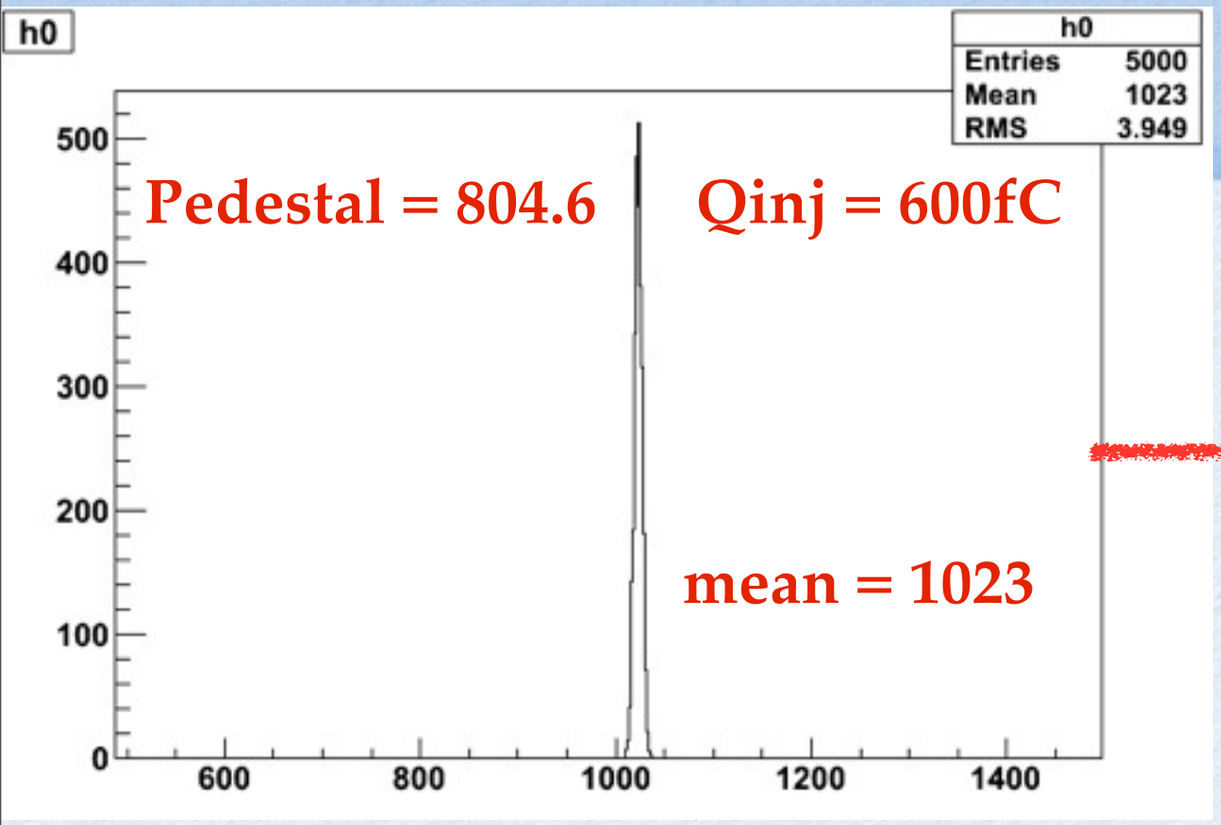
(MPPCでは、input DACの調節で可能)

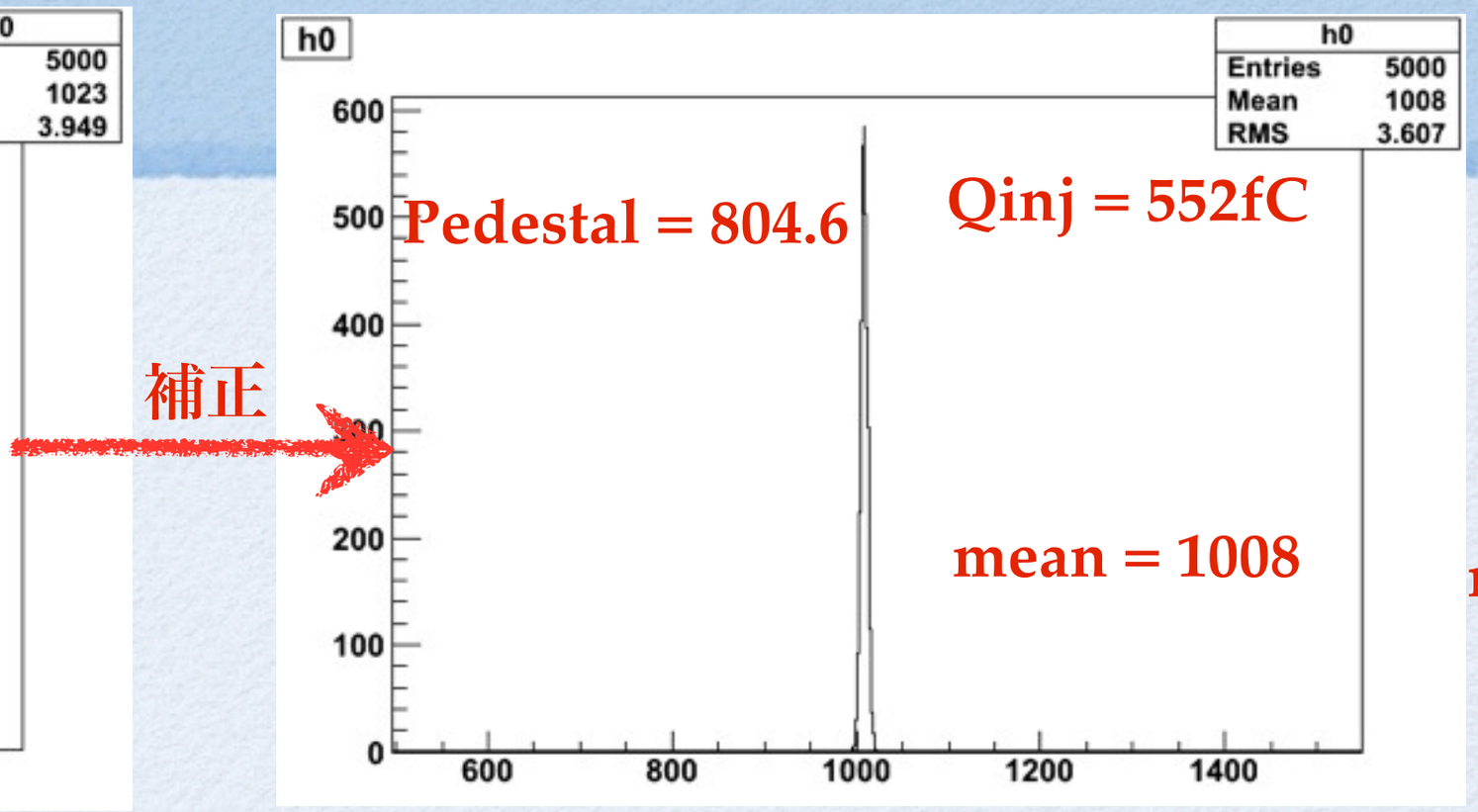
Qinjをchで変える(=MPPCのgainをchで変える)



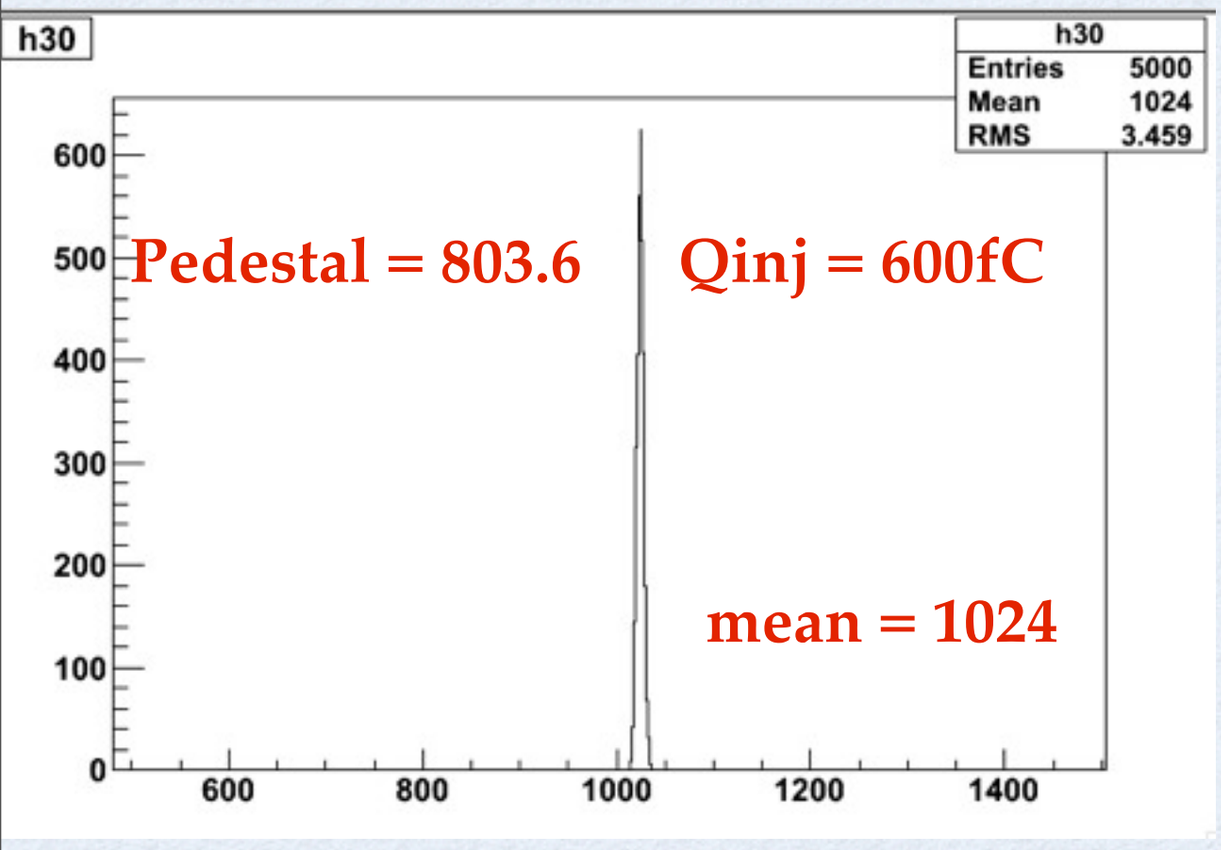


補正できた





補正

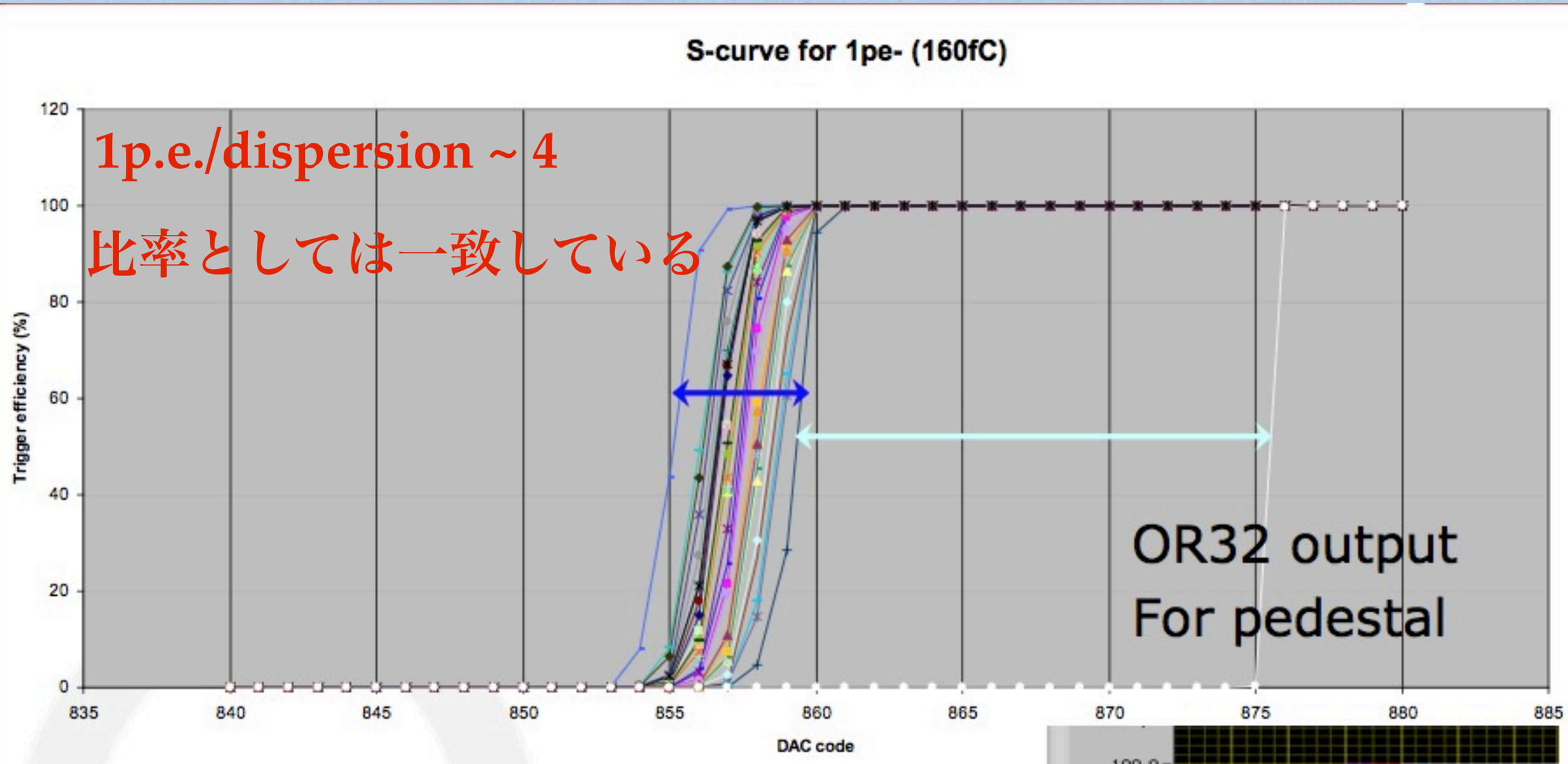


ただし、補正した場合

ADC分布では、逆に差が広がる

→　AMPではなく、FastShaperが原因？

SPEC



1p.e./dispersion ~ 4

比率としては一致している

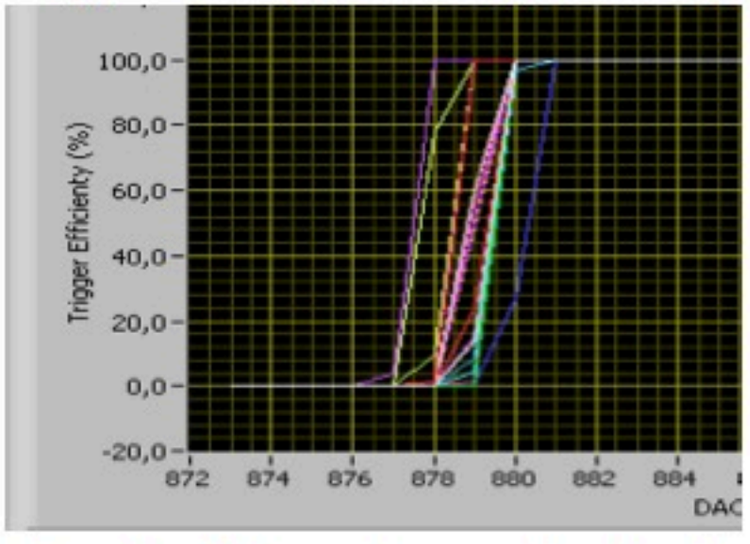
OR32 output for 1pe on each channel

結果から2fC/DAC unit

Dispersion : <5 DAC unit for 1pe

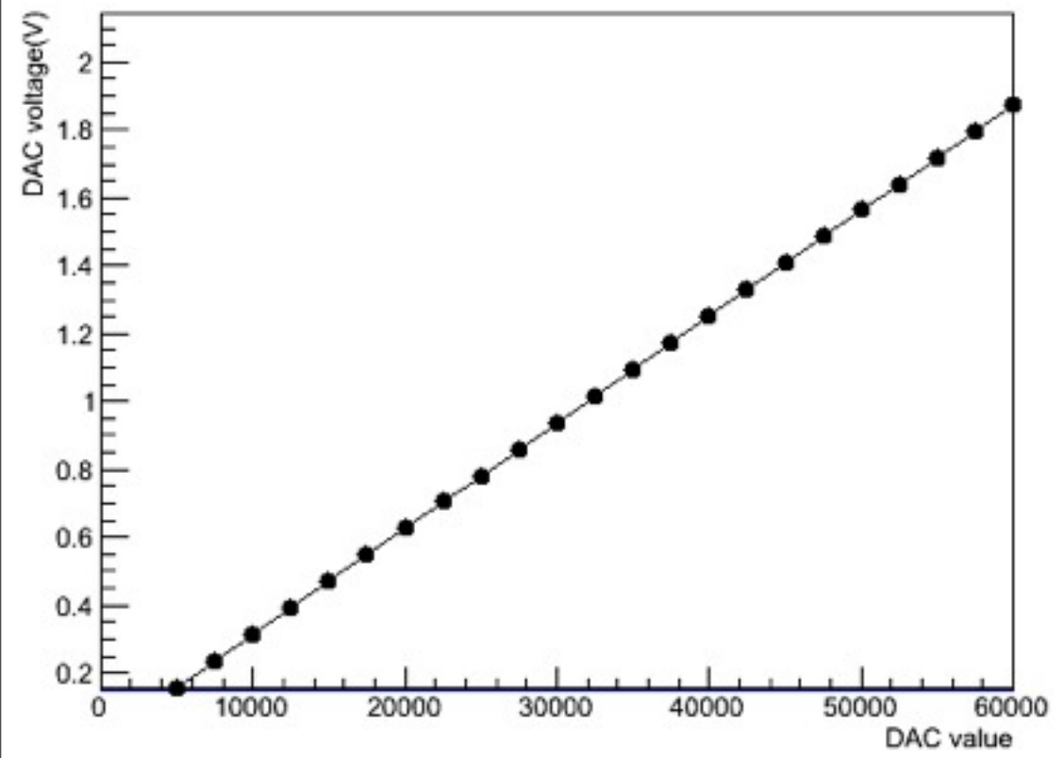
(8fC/DAC unit) *[Cf=200fF]* 条件同じ

なんでgainがそんなに違うのかは謎



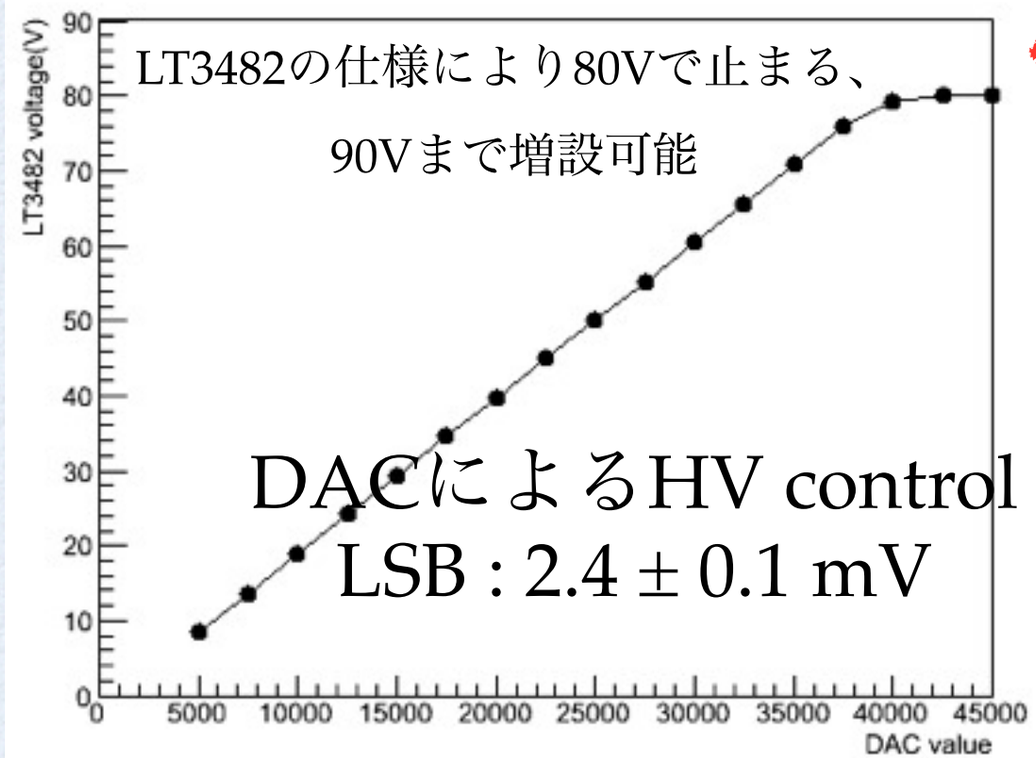
Individual pedestal

LT3482 control



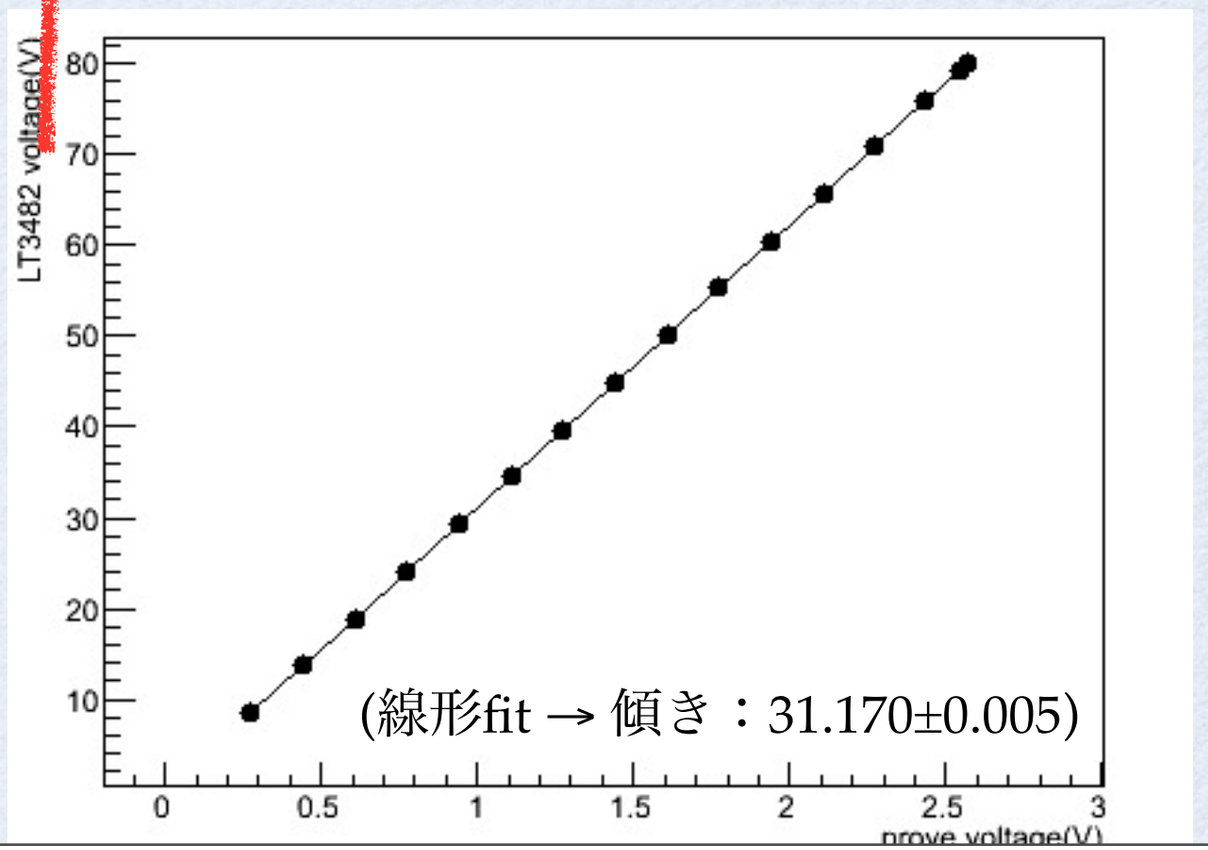
DAC LSB：0.03 mV±0.01%

HV抵抗分割によるmonitoring
(9.67MΩ:0.33MΩ)



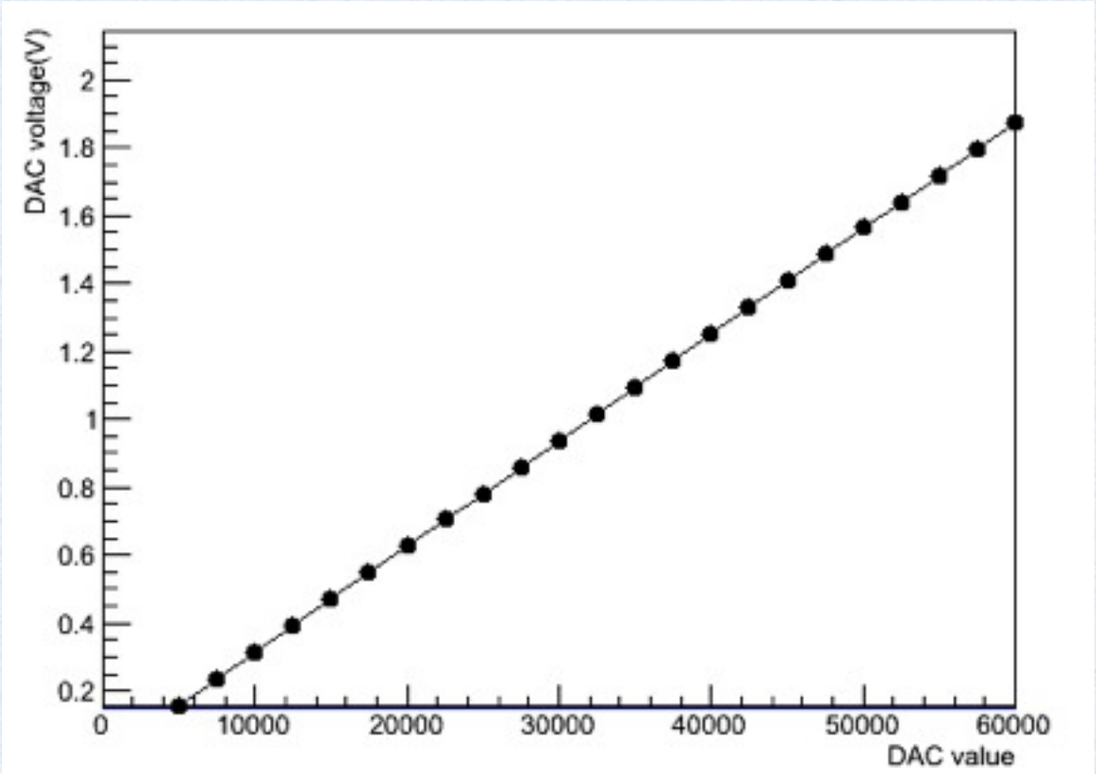
LT3482の仕様により80Vで止まる、
90Vまで増設可能

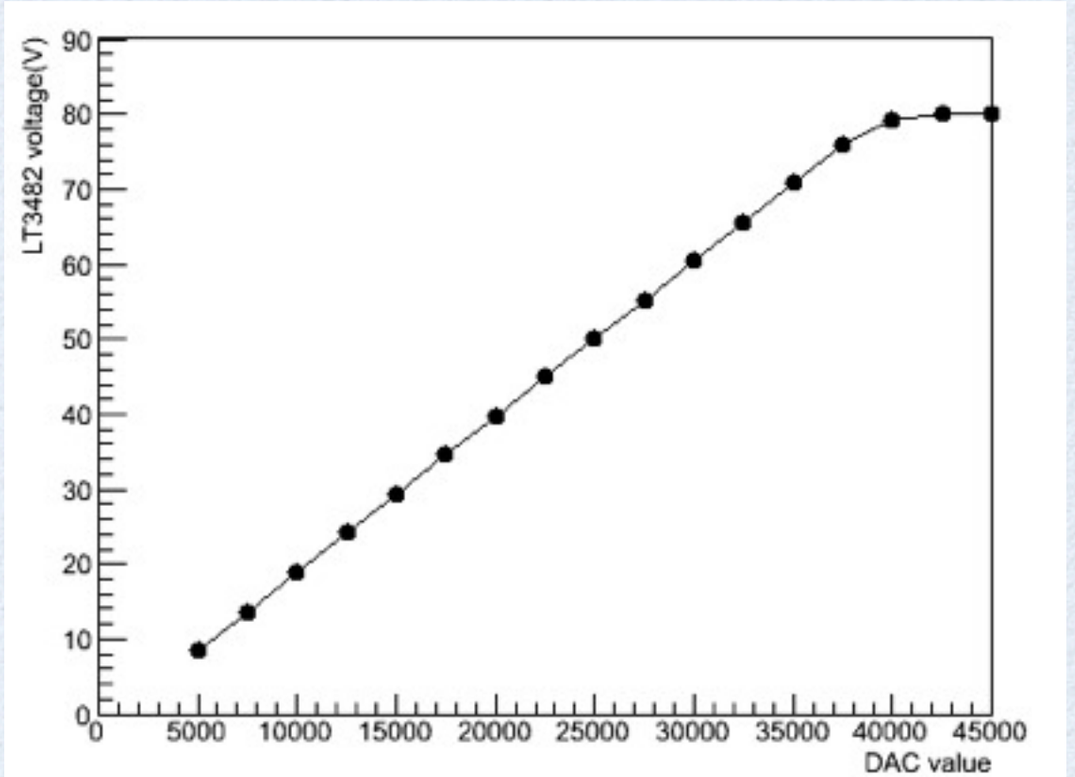
DACによるHV control
LSB : 2.4 ± 0.1 mV



(線形fit → 傾き：31.170±0.005)

input HV control





DAC LSB：0.03 mV±0.01%

DACによるHV control
LSB : 2.4 ± 0.1 mV

~10mVでHV調節可能