

# **CNC summary**

**2023/10 Test Experiment at ELPH**

**2024/2/5(Mon)**

# 検出器まとめ

## 基本セット

- trig1,2

Scinti : 100(W) \* 50(H) \* 5(T) mm

PMT : H6410

- ref1

Scinti : 40(W)\*30(H)\*20(T) mm

PMT : H2431-50

- ref2

Scinti : 40(W)\*30(H)\*10(T) mm

PMT : H2431-50



## 試験器

- CNC1,2

Scinti : 2600(W) \*120(H) \* 50(T) mm, PMT : H8409

- TEST

Scinti : 1500(W) \*120(H) \* 50(T) mm, PMT : H8409

- CDH

Scinti : 800(W) \*100(H) \* 30(T) mm, PMT : H8409

- SKM

Scinti : 700(W) \*50(H) \* 50(T) mm, PMT : H8409

(MPPC用)

# DAQ

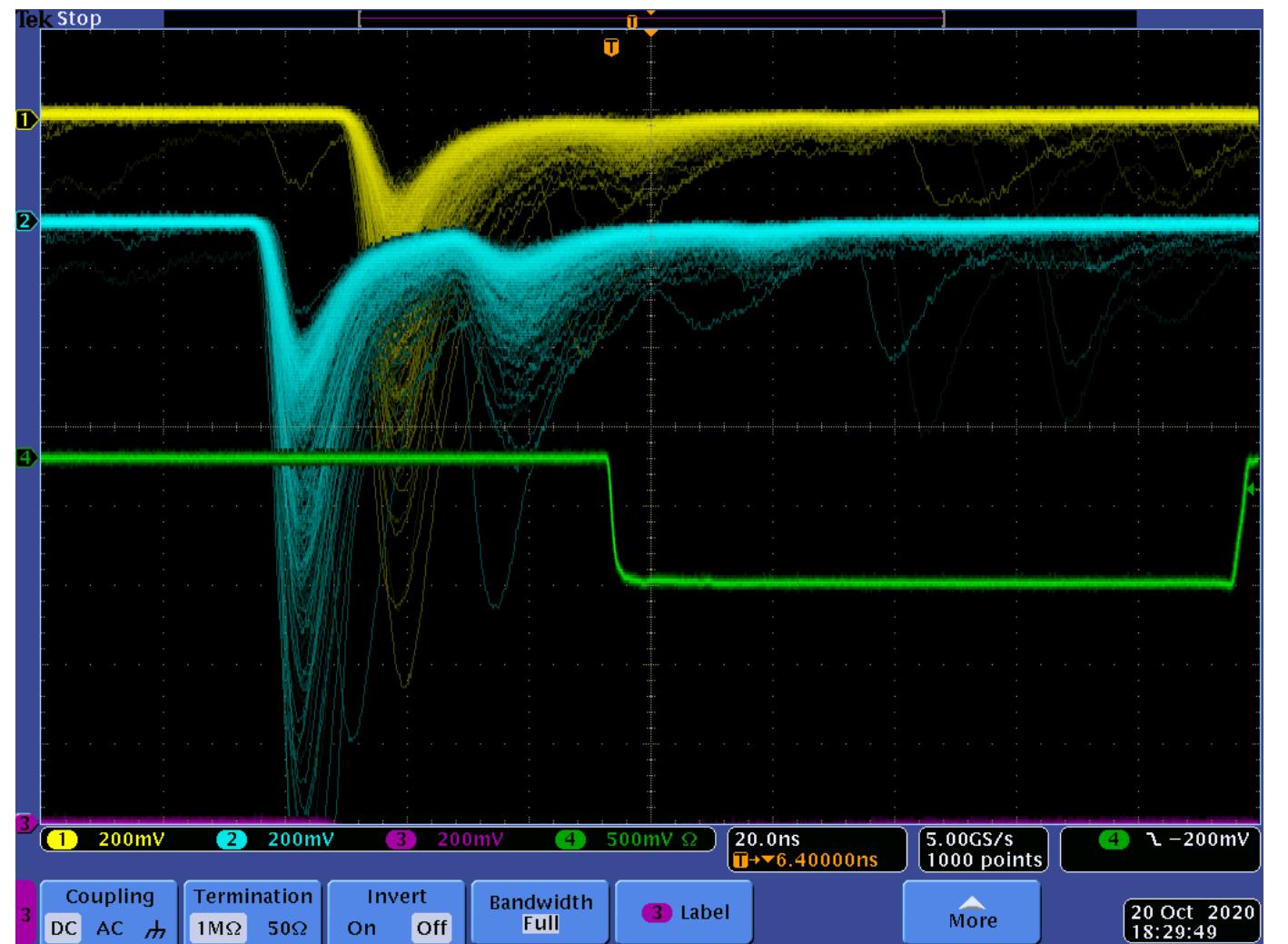
- QDC : CAEN V792

$$1 \text{ ch} = 10 \text{ fC}$$

100 chの差が波高に直すと  
だいたい50~100 mV。  
肉眼で違いが見えるかどうか  
微妙なところ。

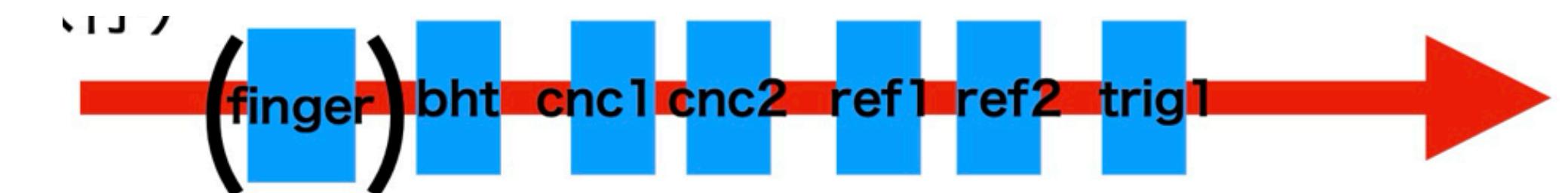
- TDC : CAEN V775

$$1 \text{ ch} = 35 \text{ ps}$$



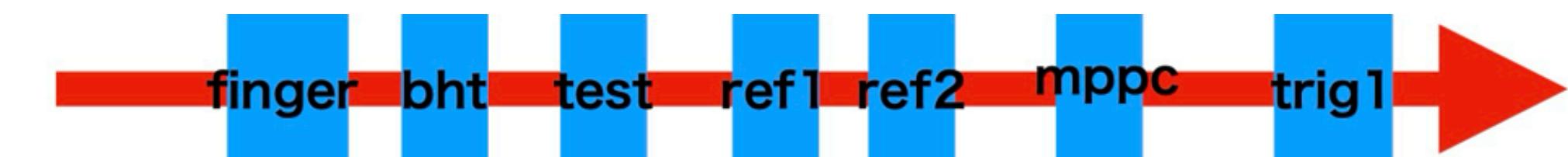
# CNC test Exp. Oct 2023 @ELPH

1. CNC time resolution



2. Light Guide test (using TEST)

3. MPPC (using SKM)



4. PMT vs MPPC (using CDH)



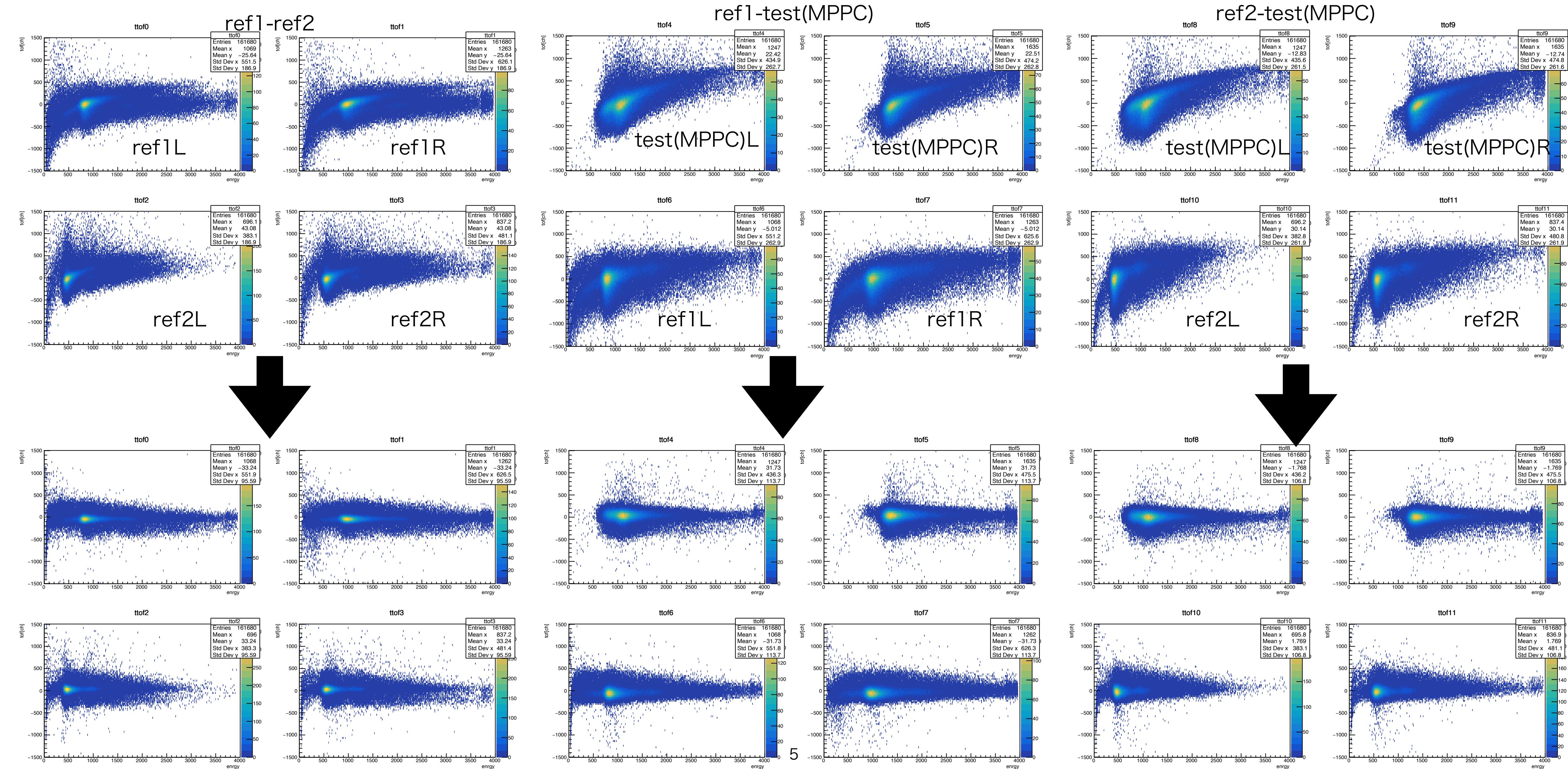
5. MPPC test (using TEST)

6. Black LG vs Normal LG (using CNC)



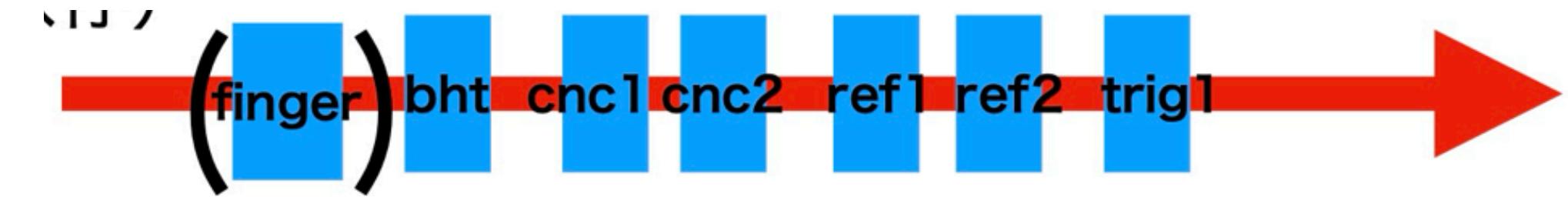
# 0. Example of Slewing Correction

Run175

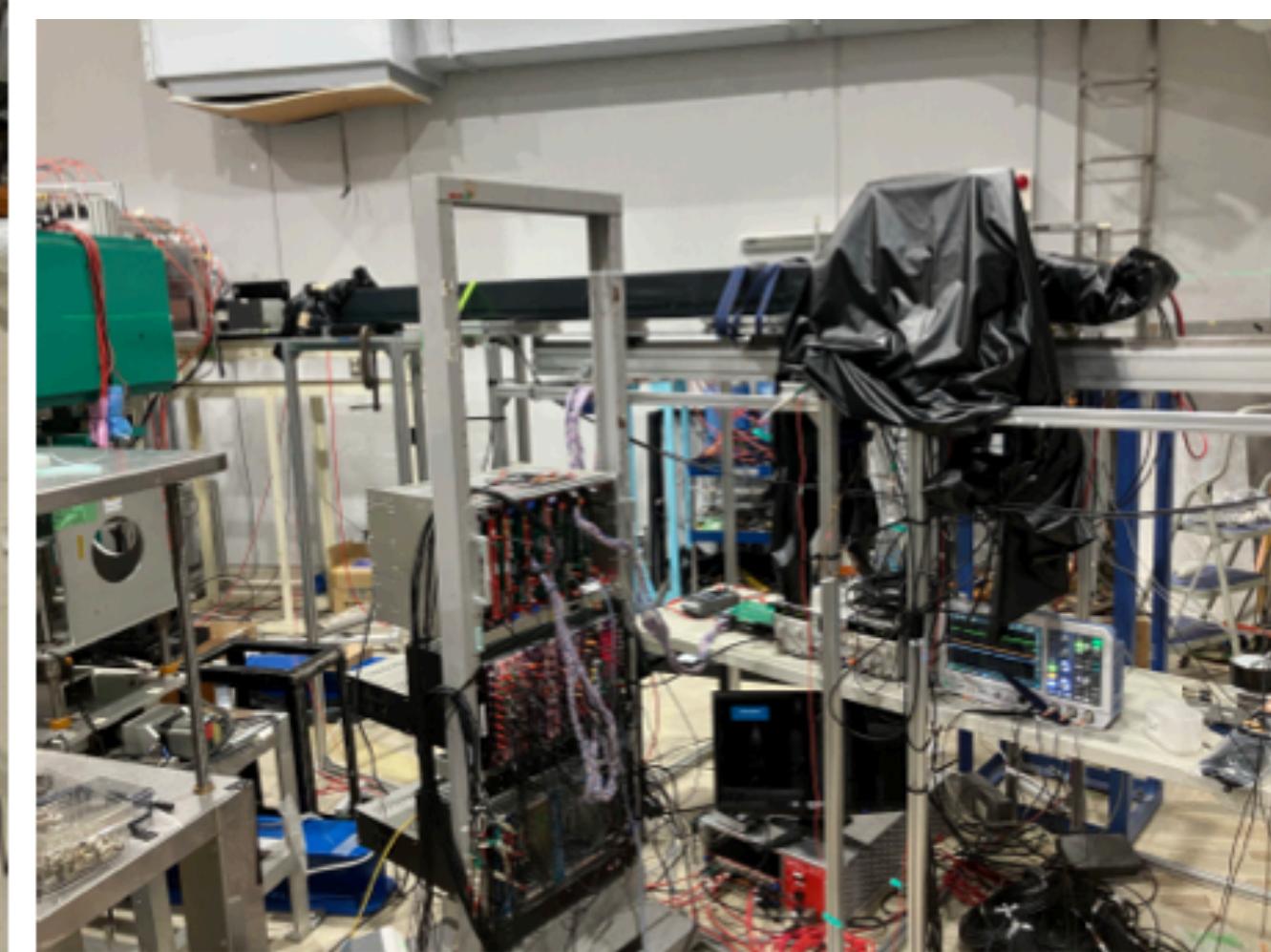
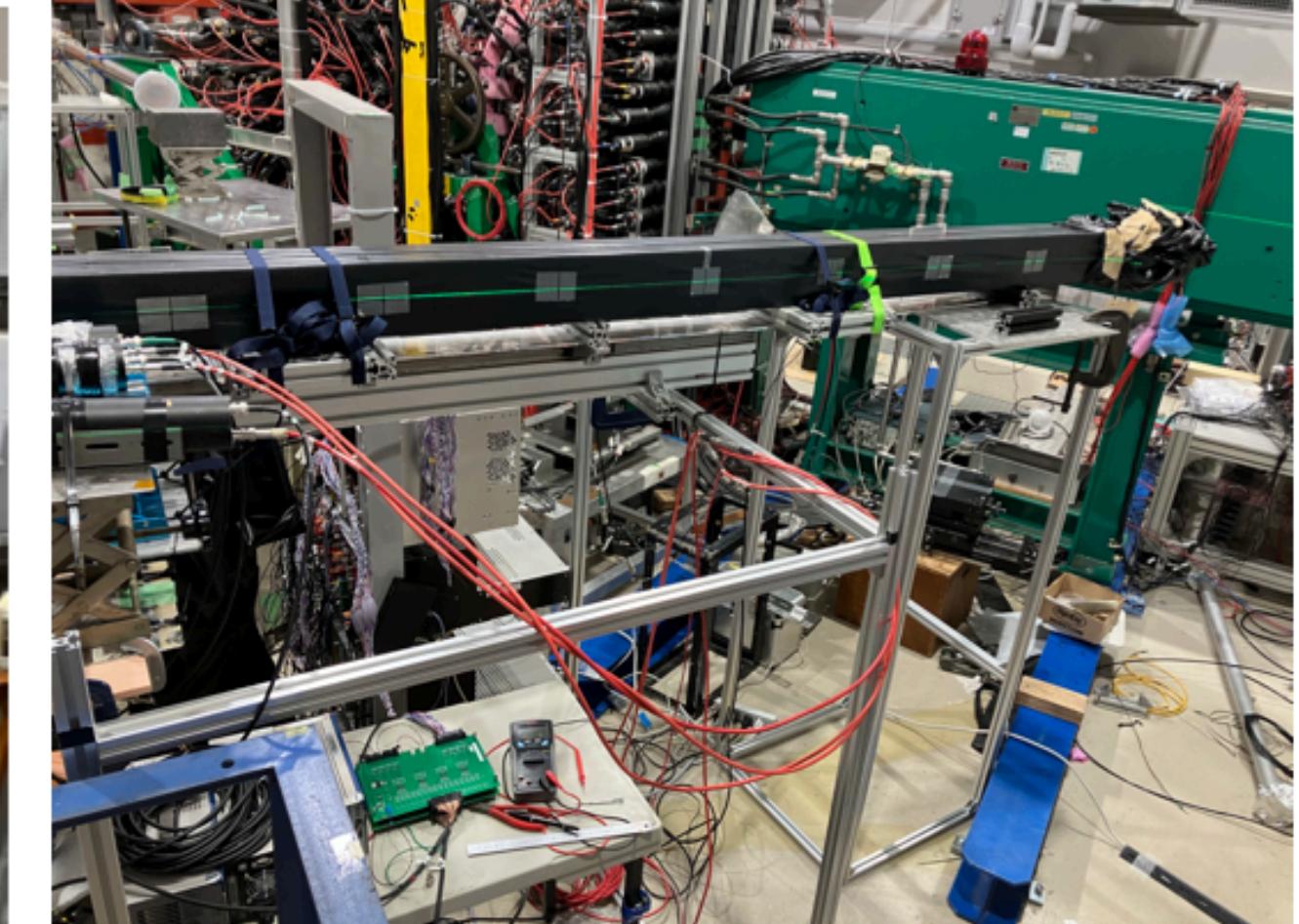
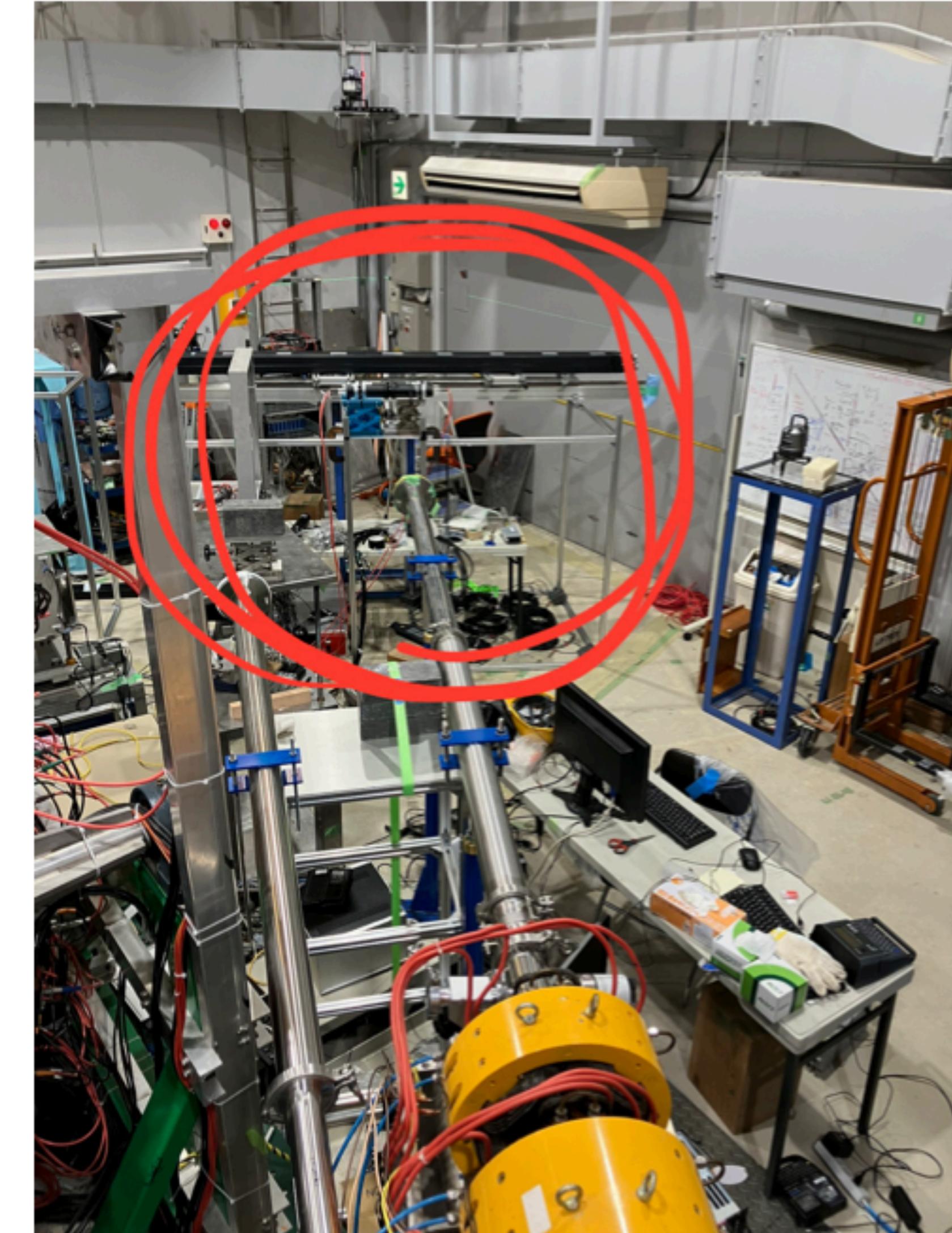
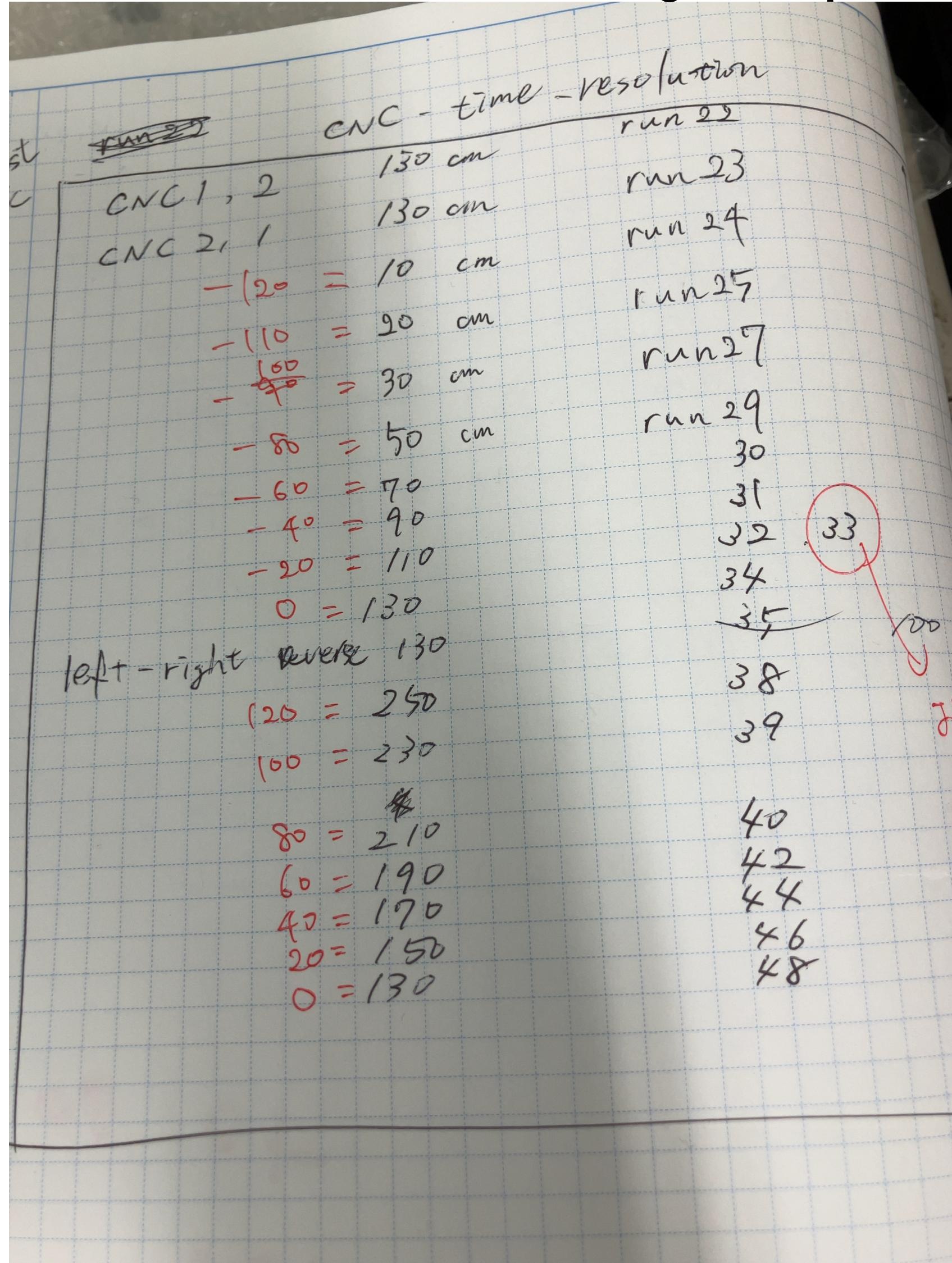


# 1. CNC time resolution

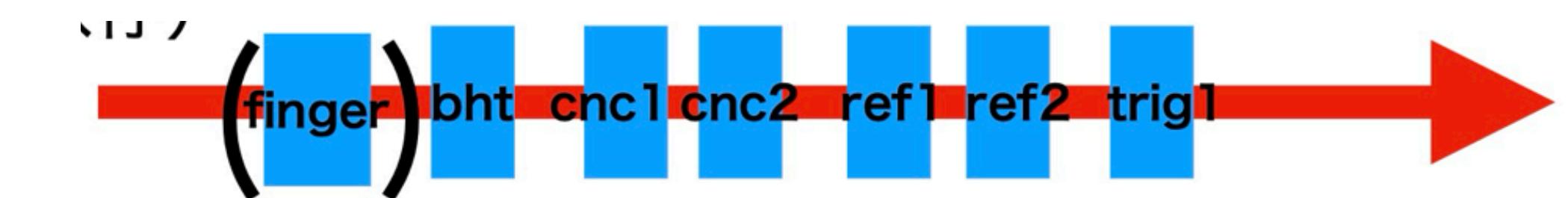
# 1. CNC time resolution



Run number  $\longleftrightarrow$  inject position



# 1. CNC time resolution

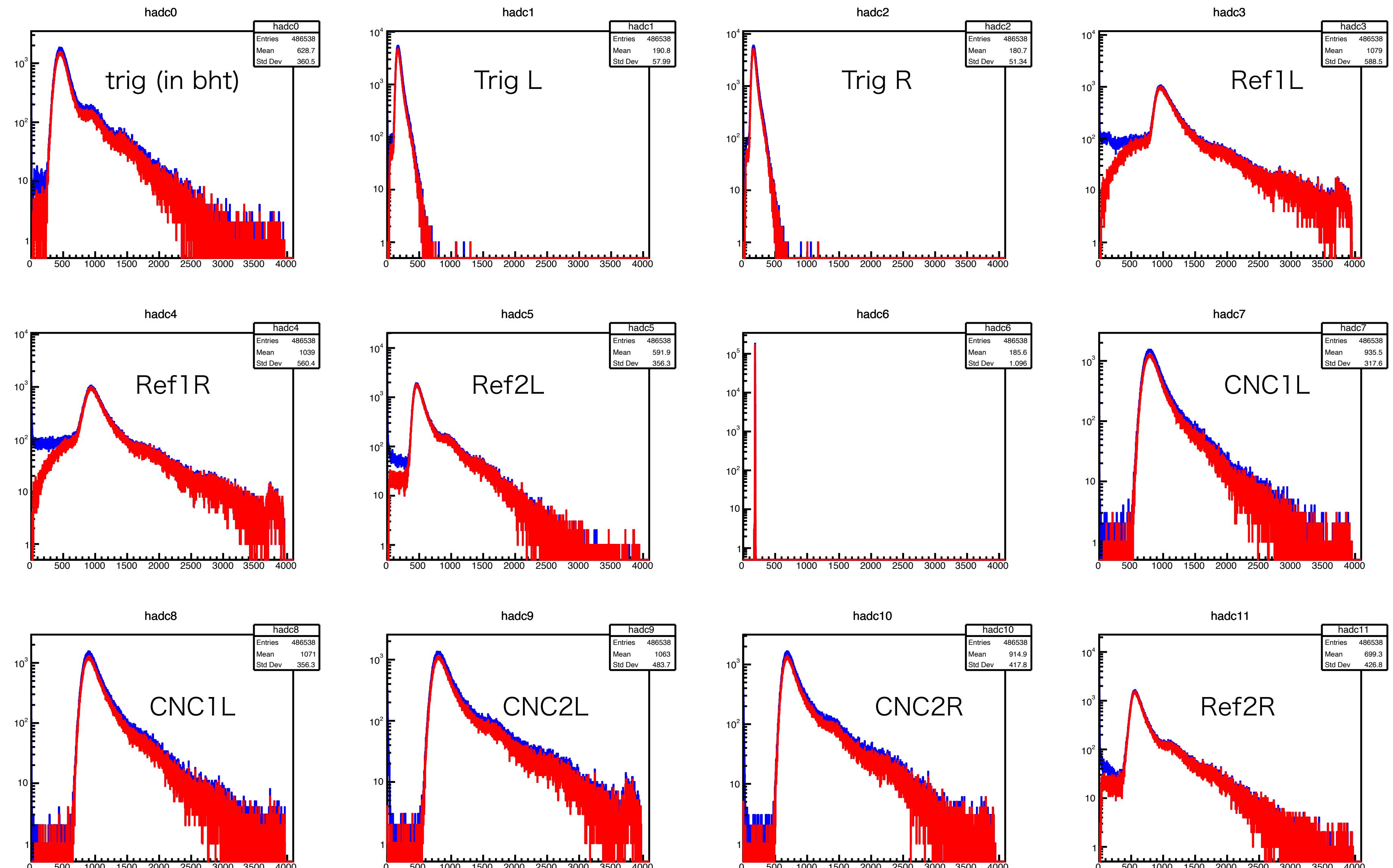


QDC run22

QDC — pedestal

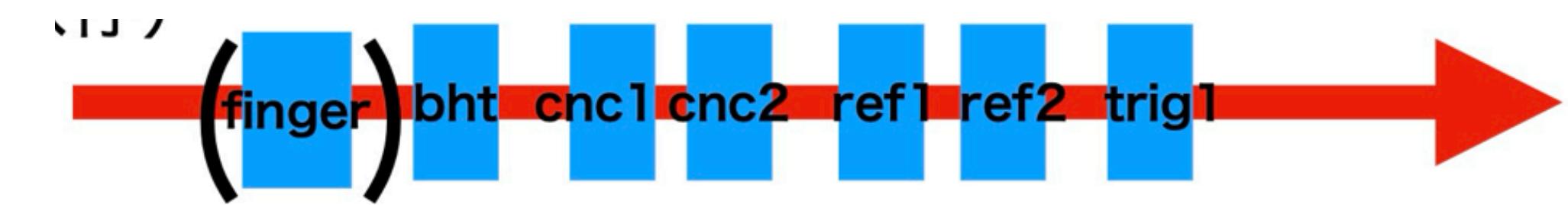
Blue : raw data

Red : all tdc != -1



No oscillo

# 1. CNC time resolution

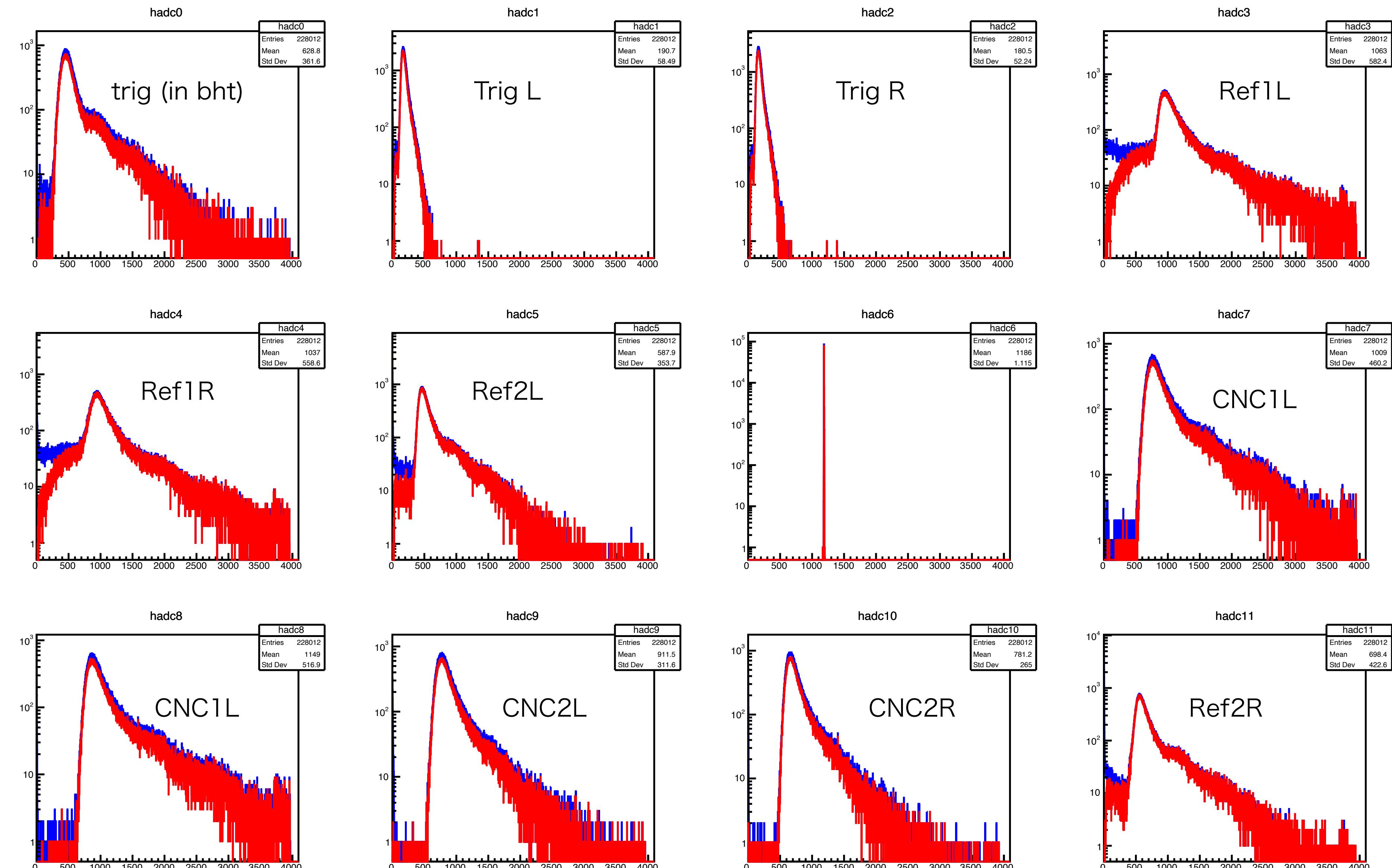


QDC run23

QDC — pedestal

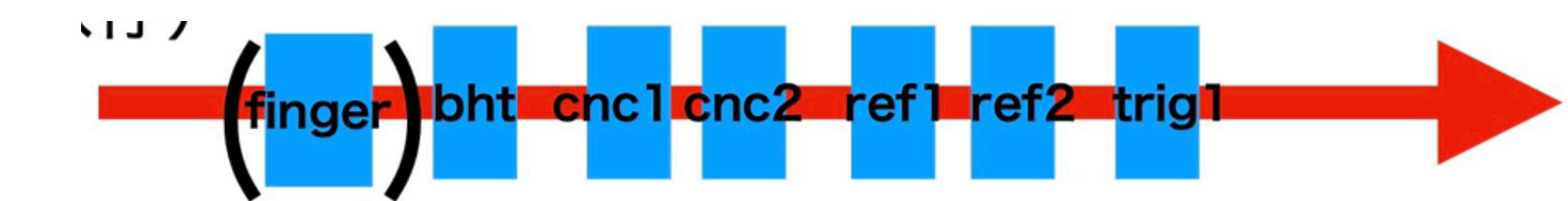
Blue : raw data

Red : all tdc != -1

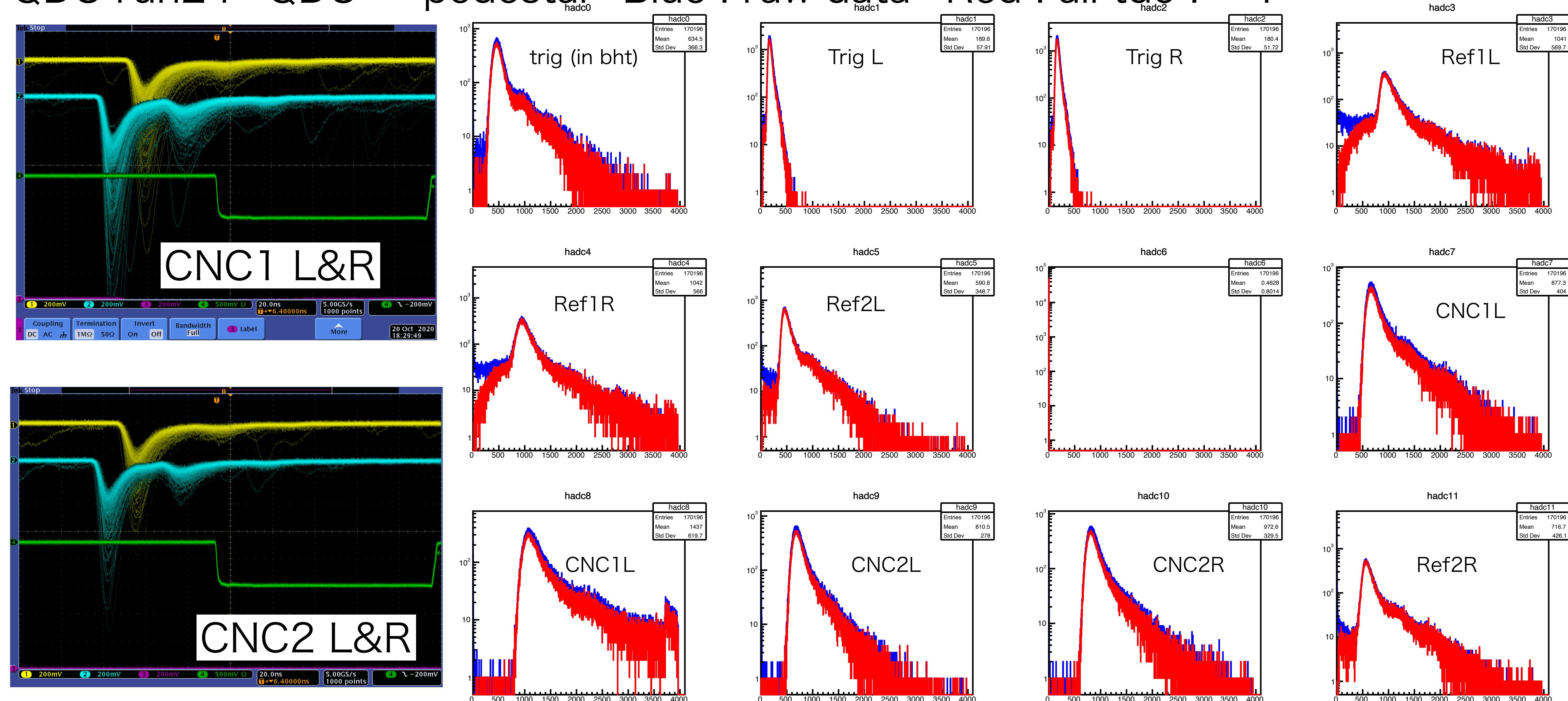


No oscillo

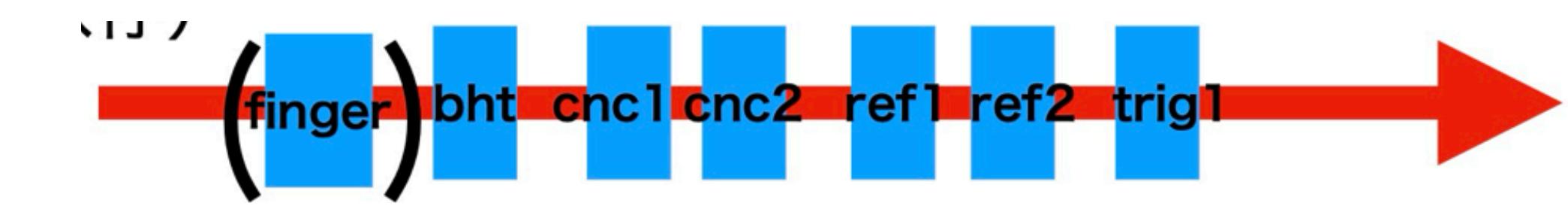
# 1. CNC time resolution



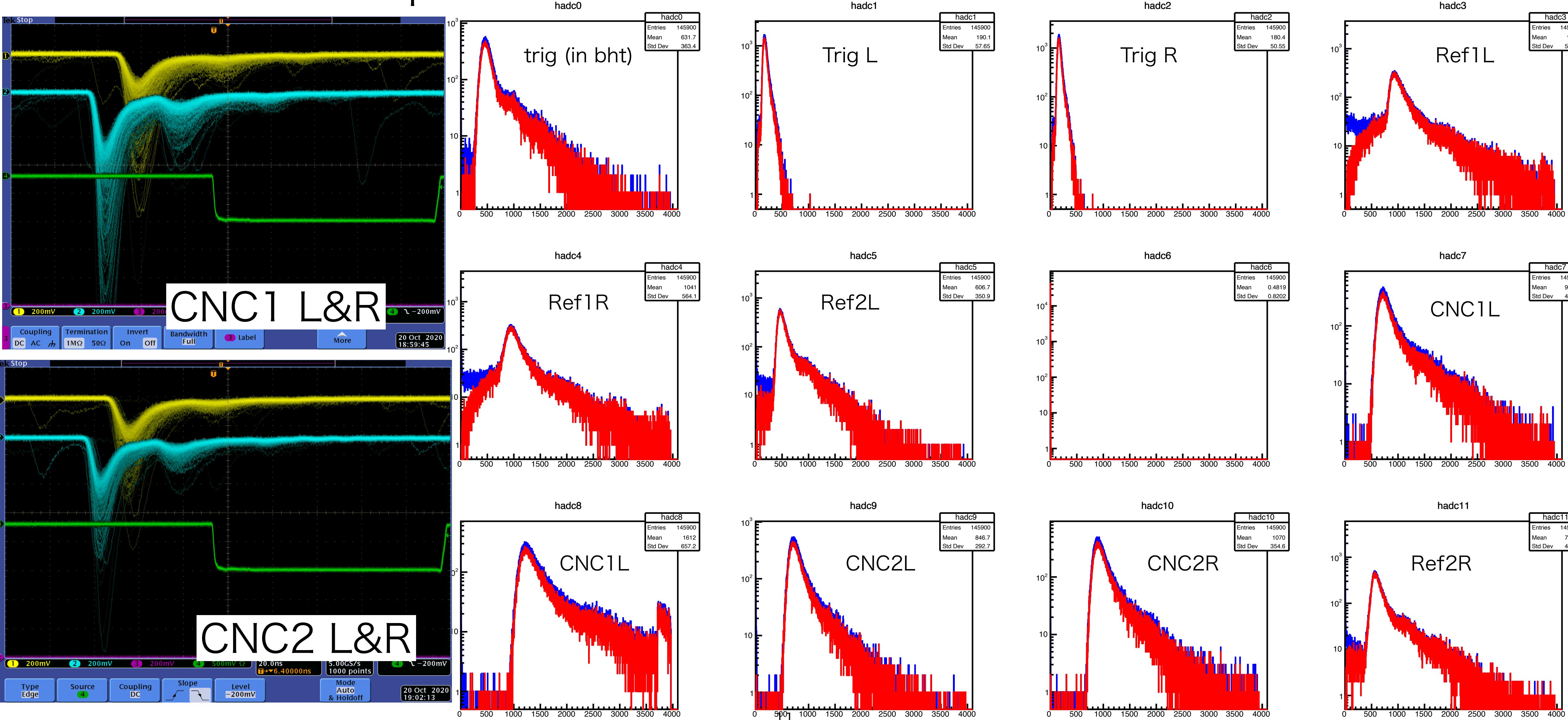
QDC run24 QDC — pedestal Blue : raw data Red : all tdc != -1



# 1. CNC time resolution



QDC run25 QDC — pedestal Blue : raw data Red : all tdc != -1

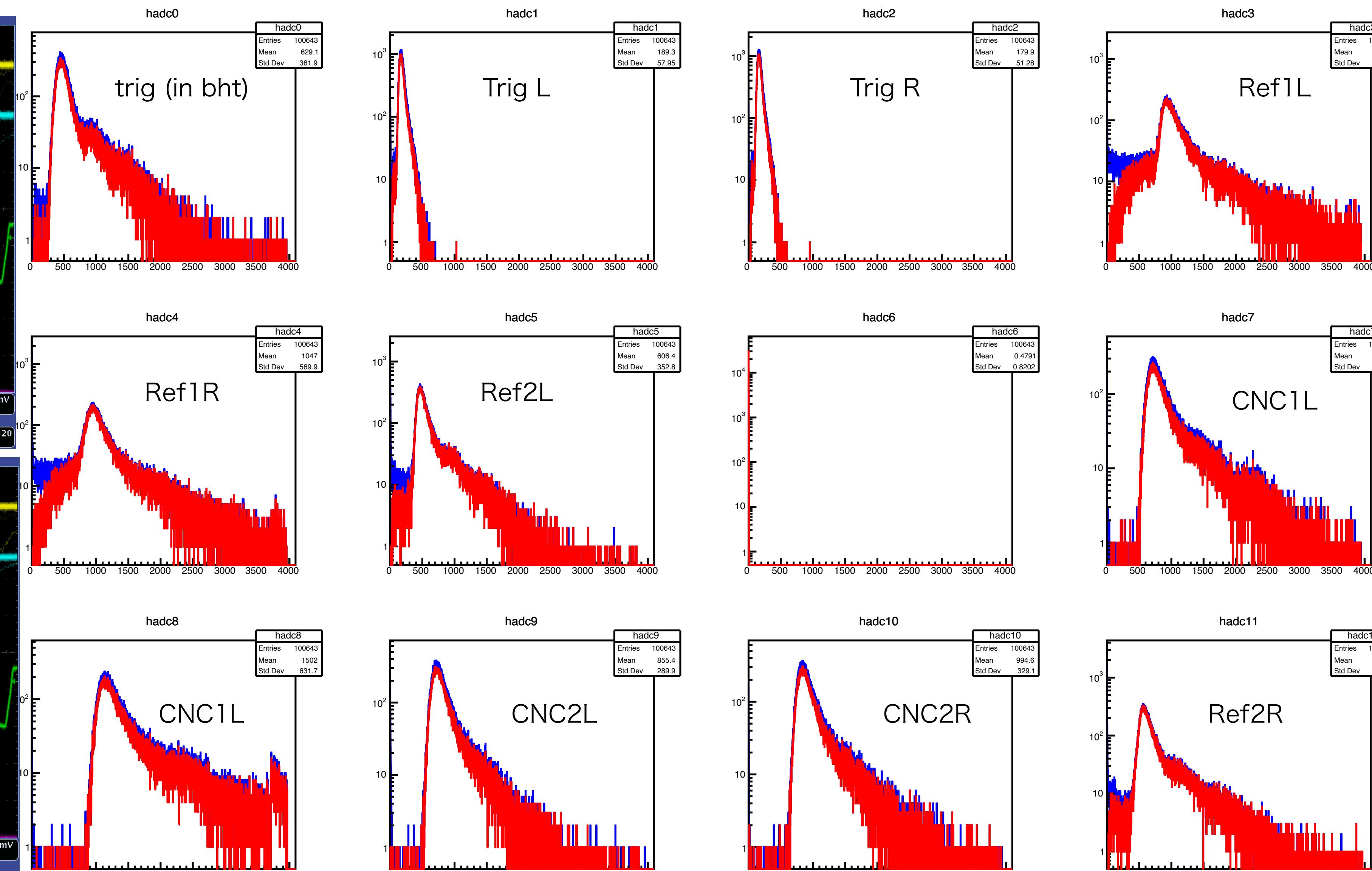
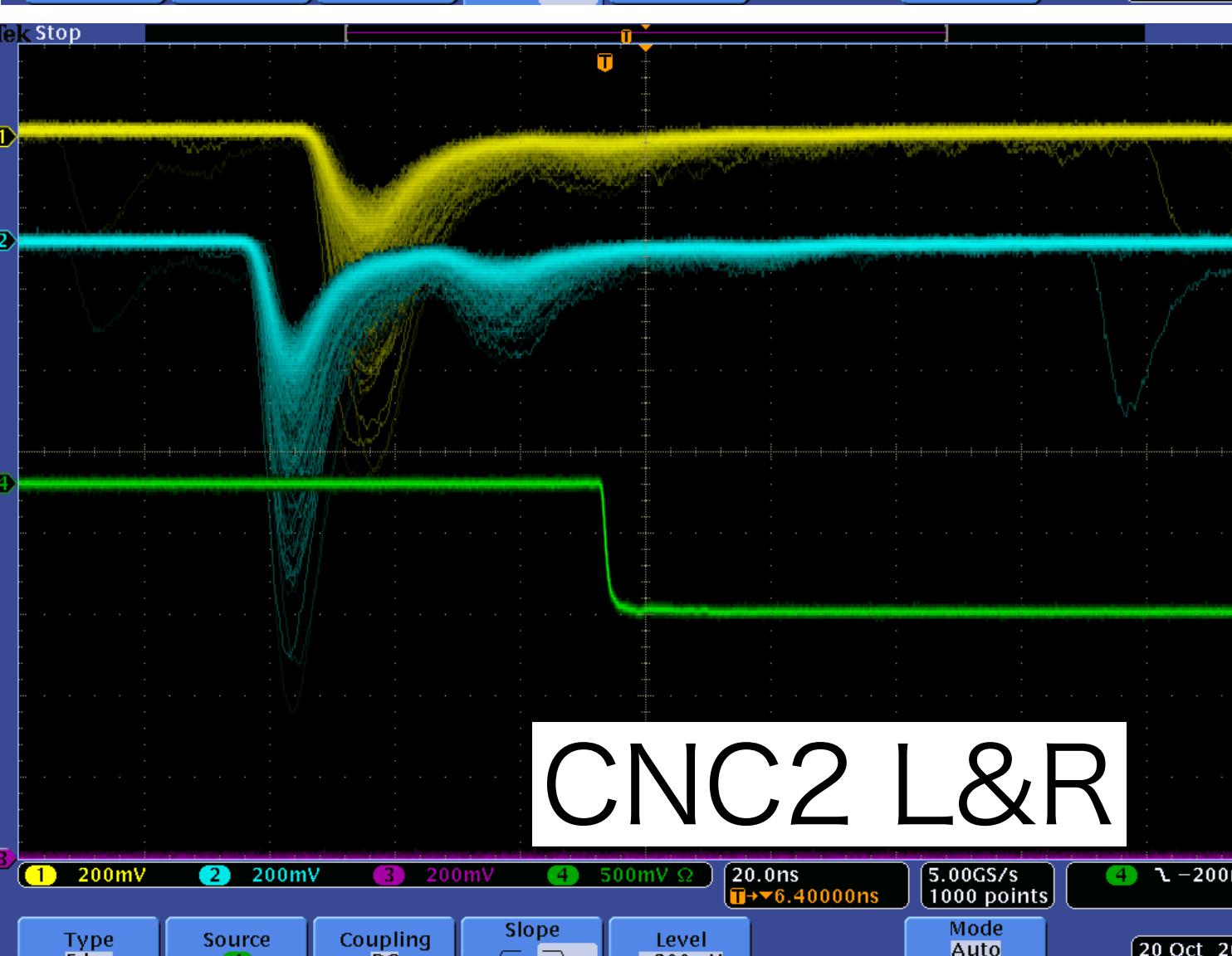
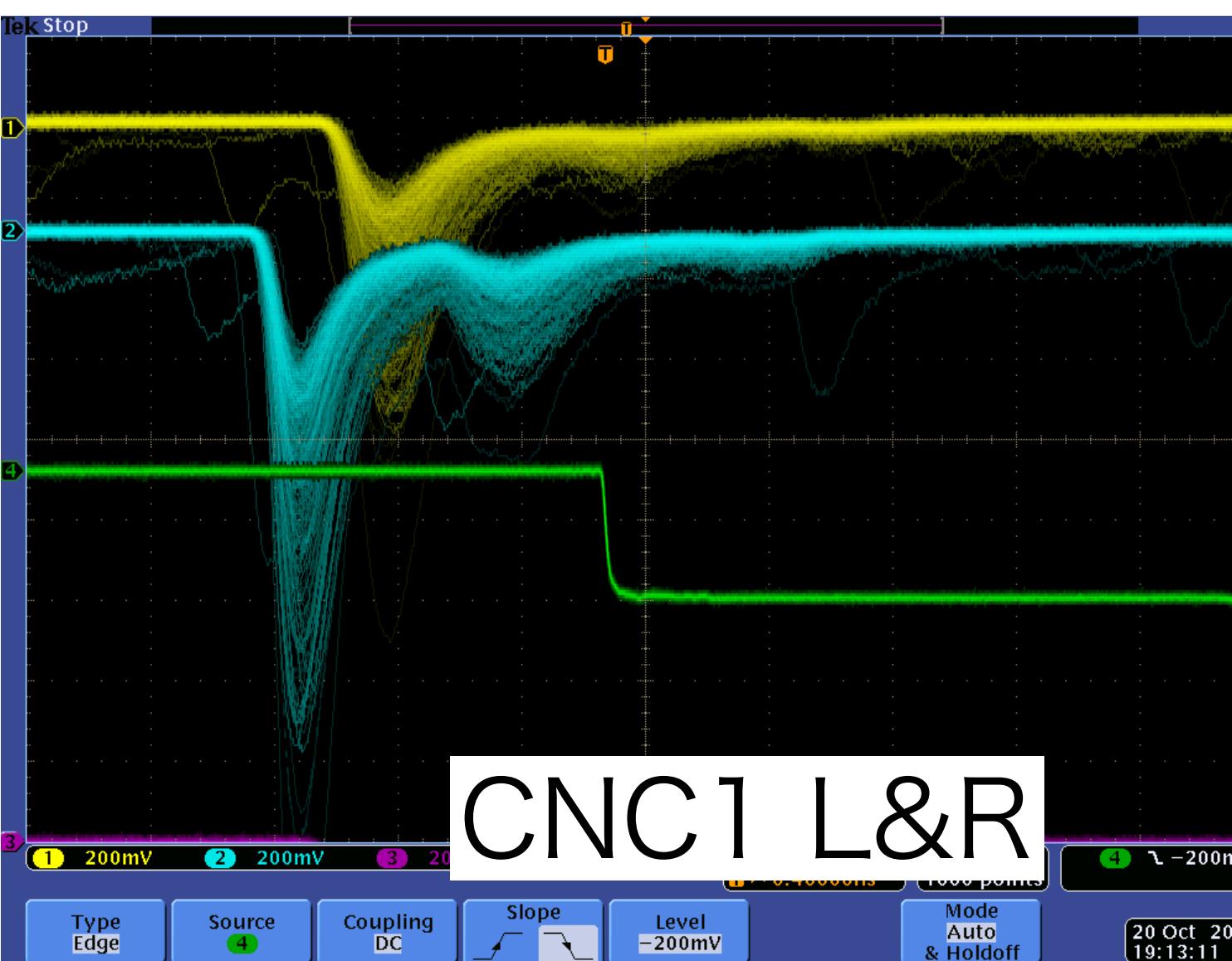
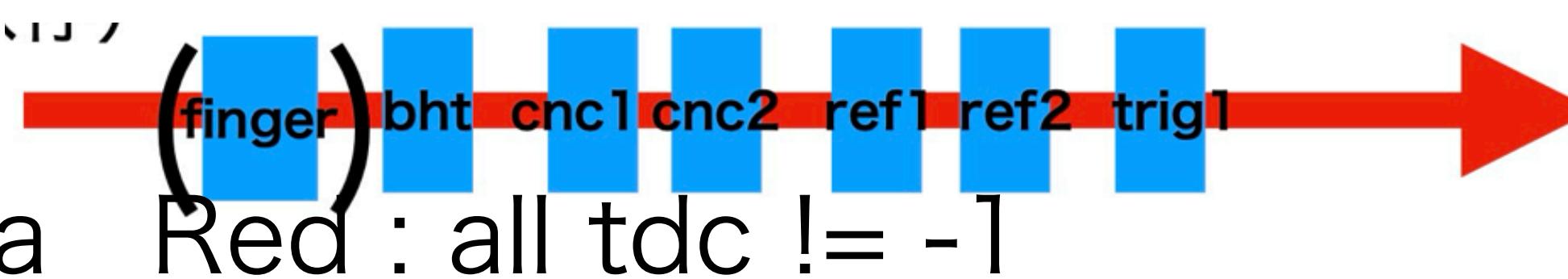


# 1. CNC time resolution

QDC run27

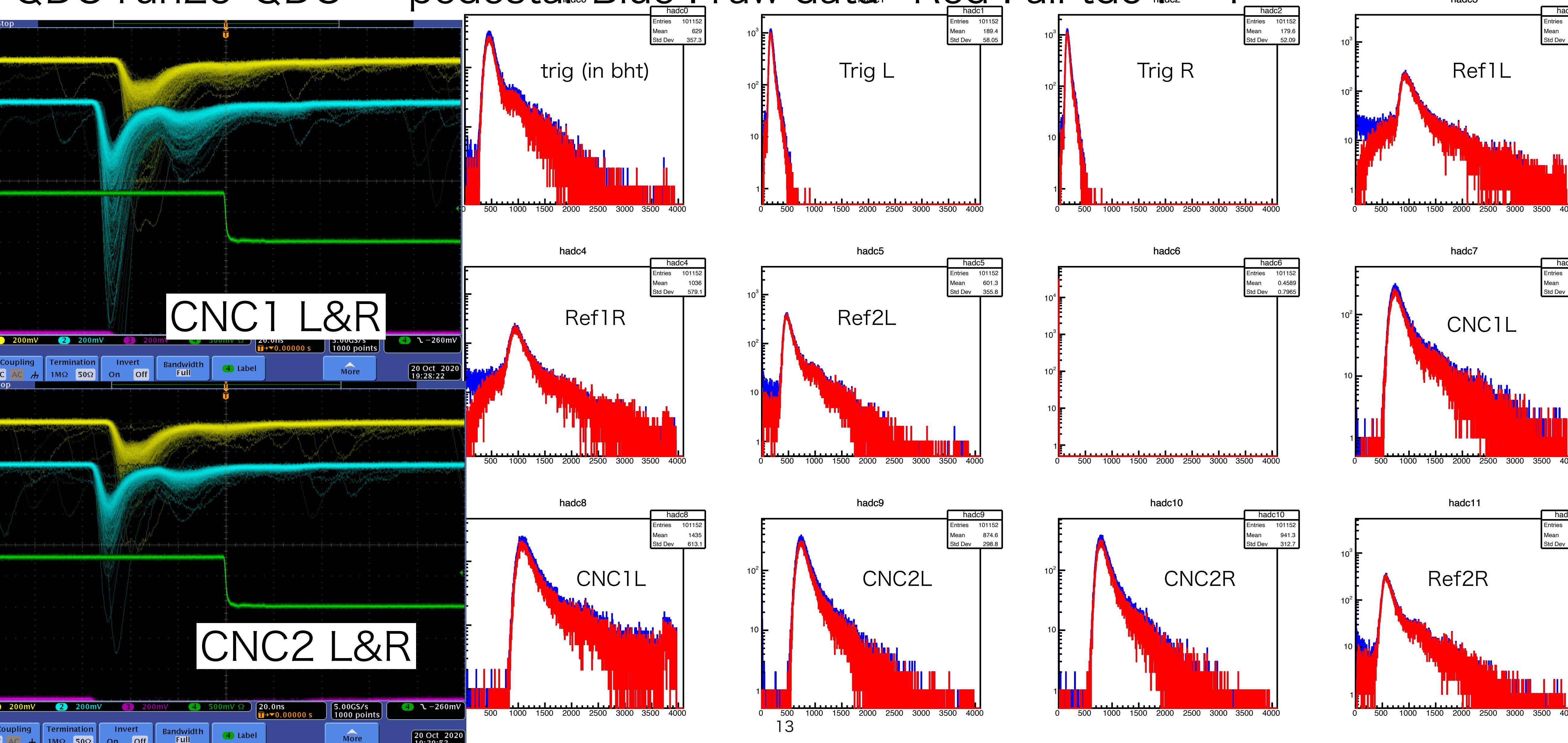
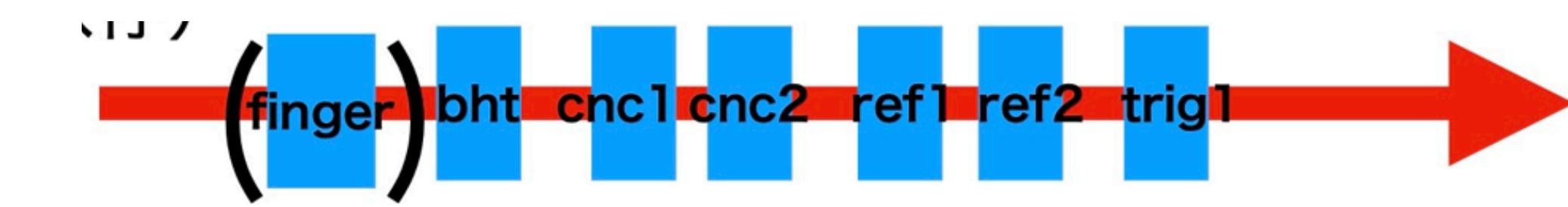
QDC = pedestal

Blue : raw data



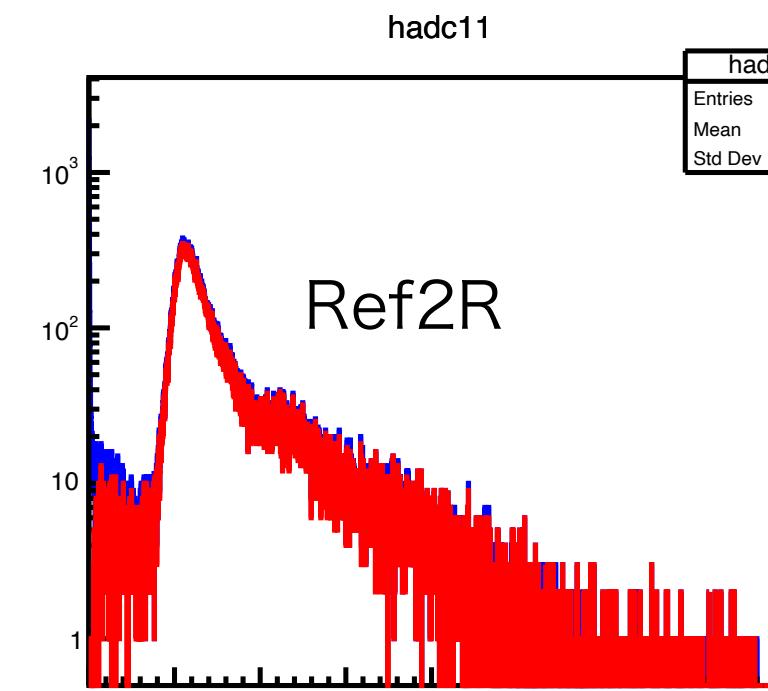
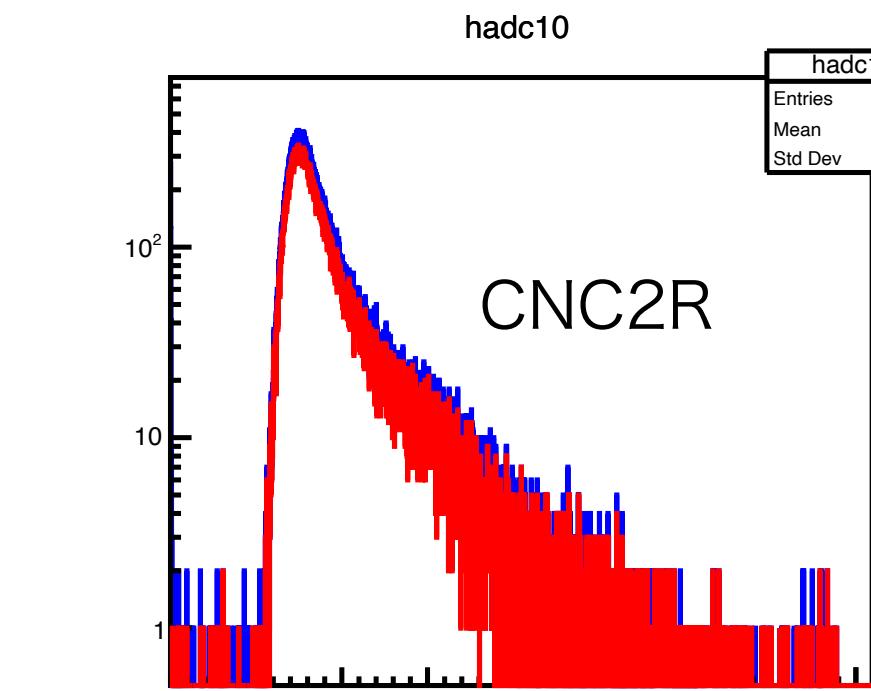
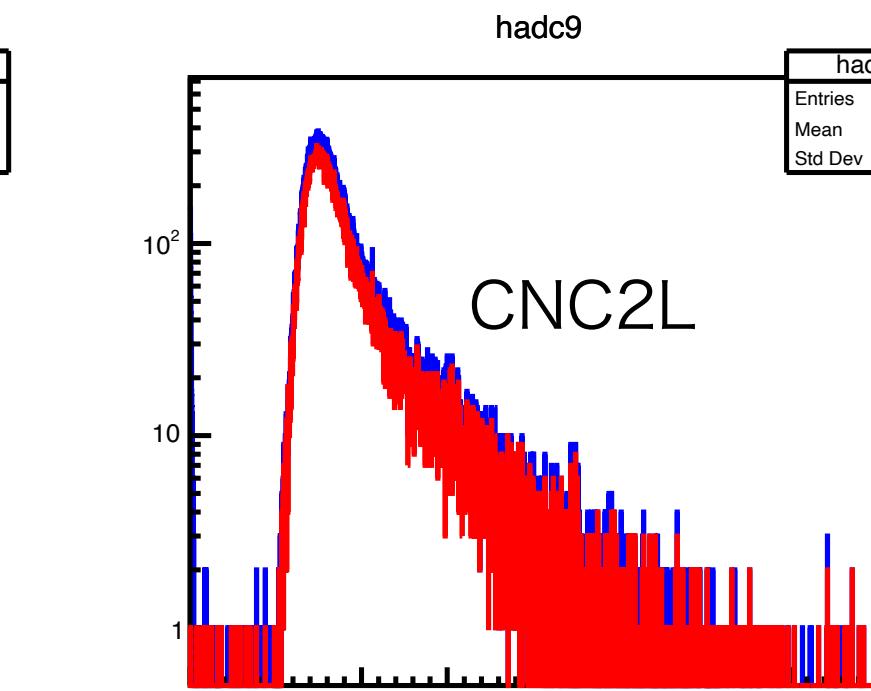
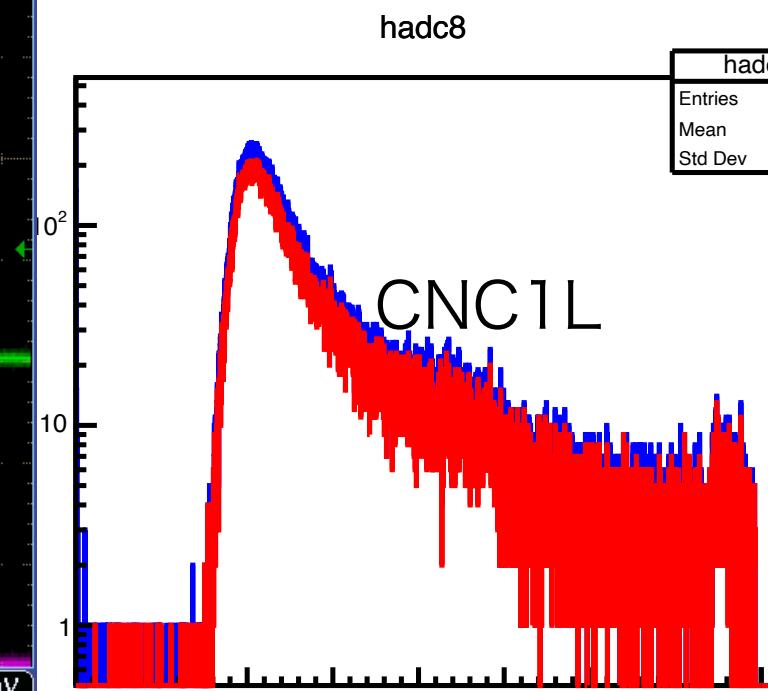
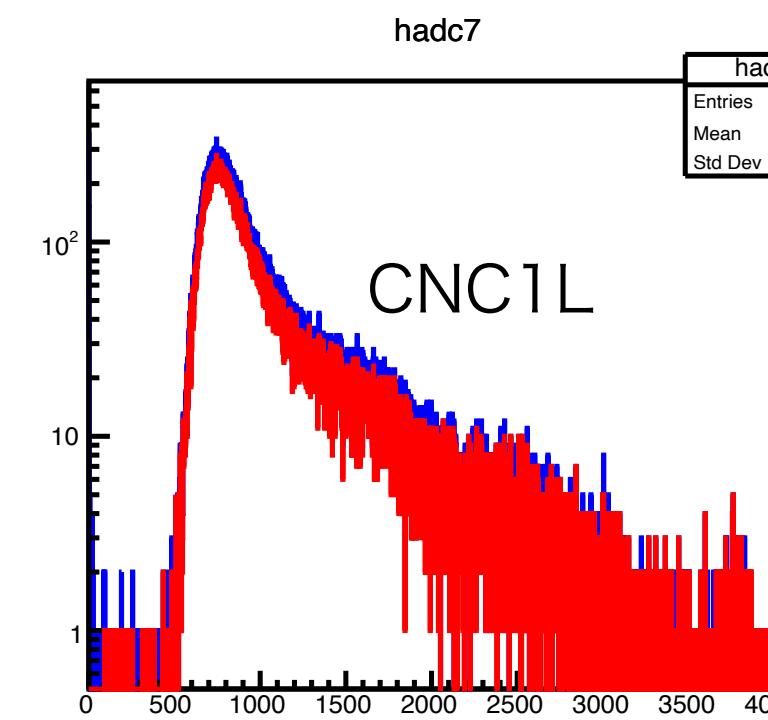
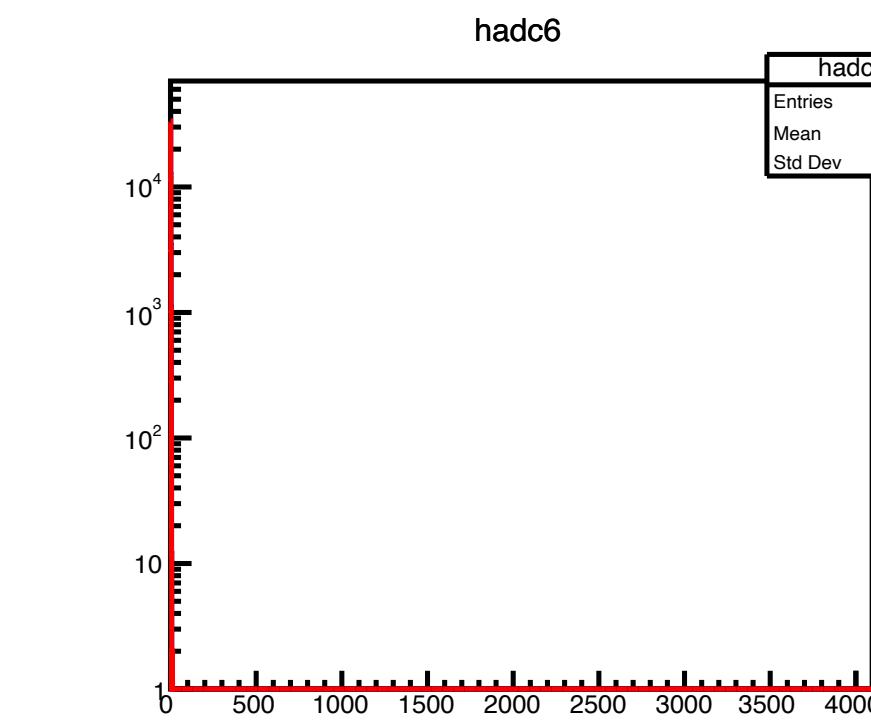
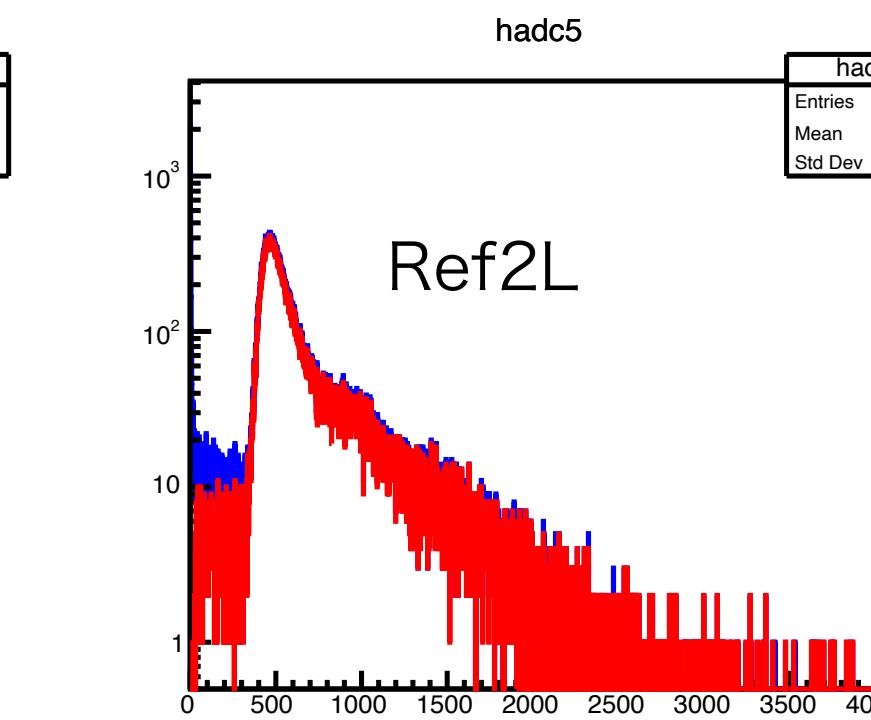
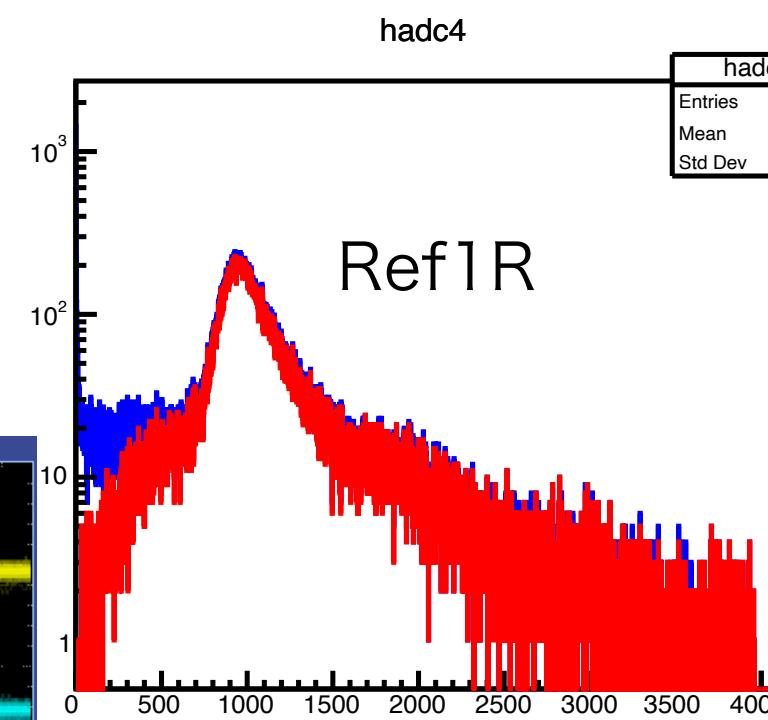
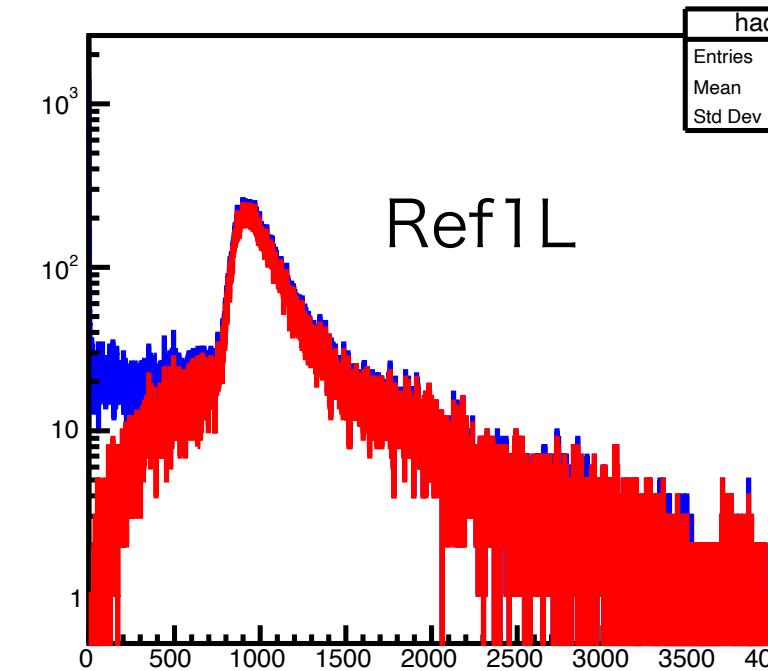
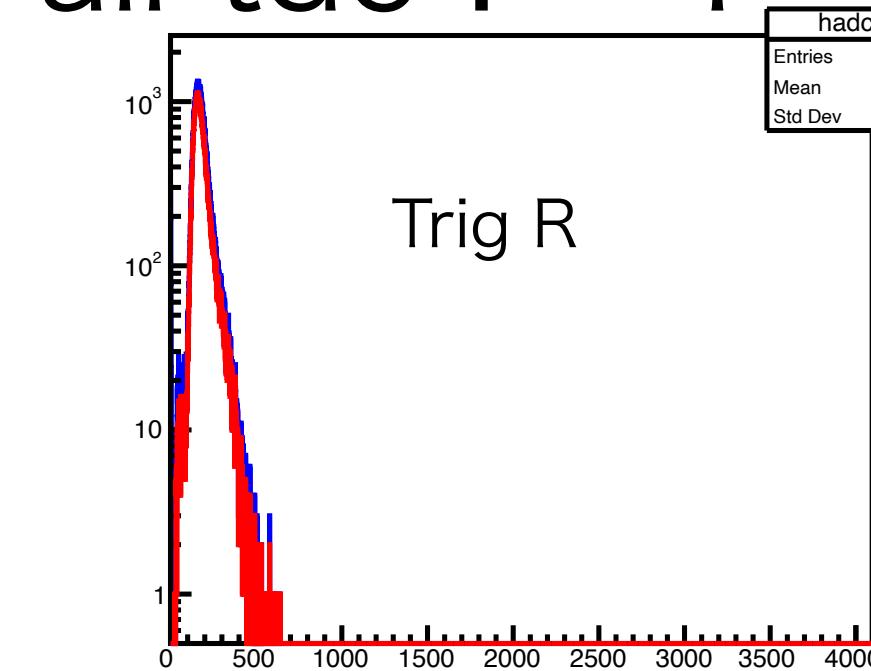
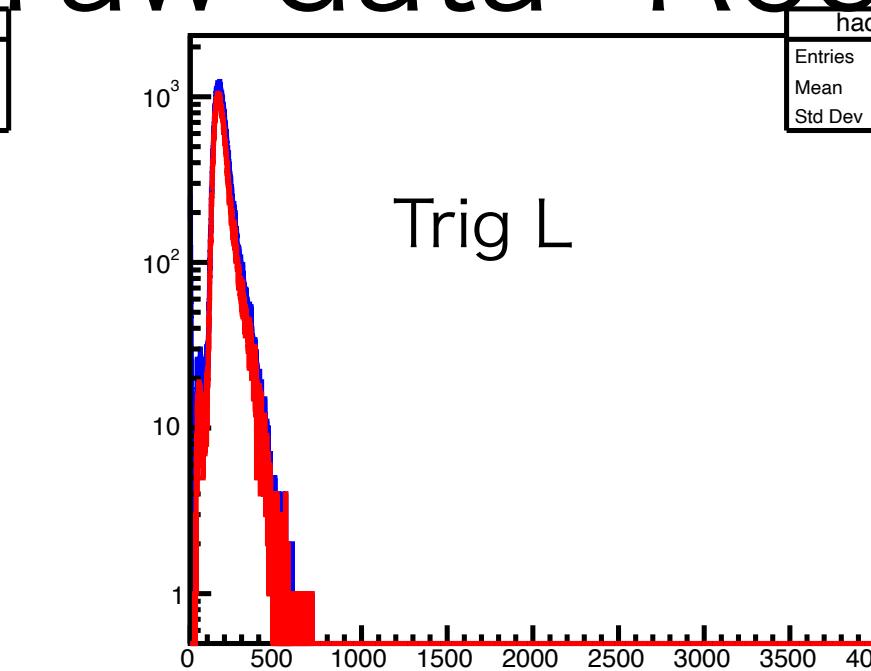
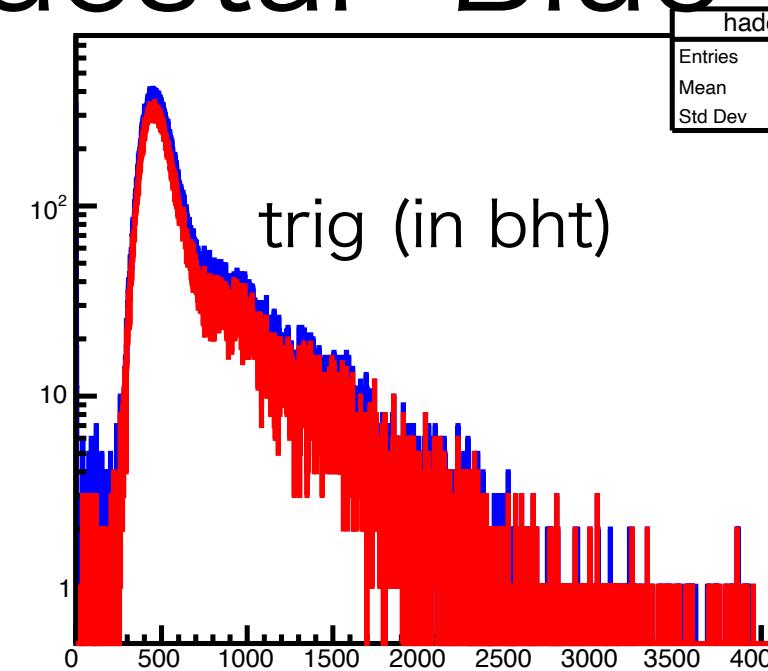
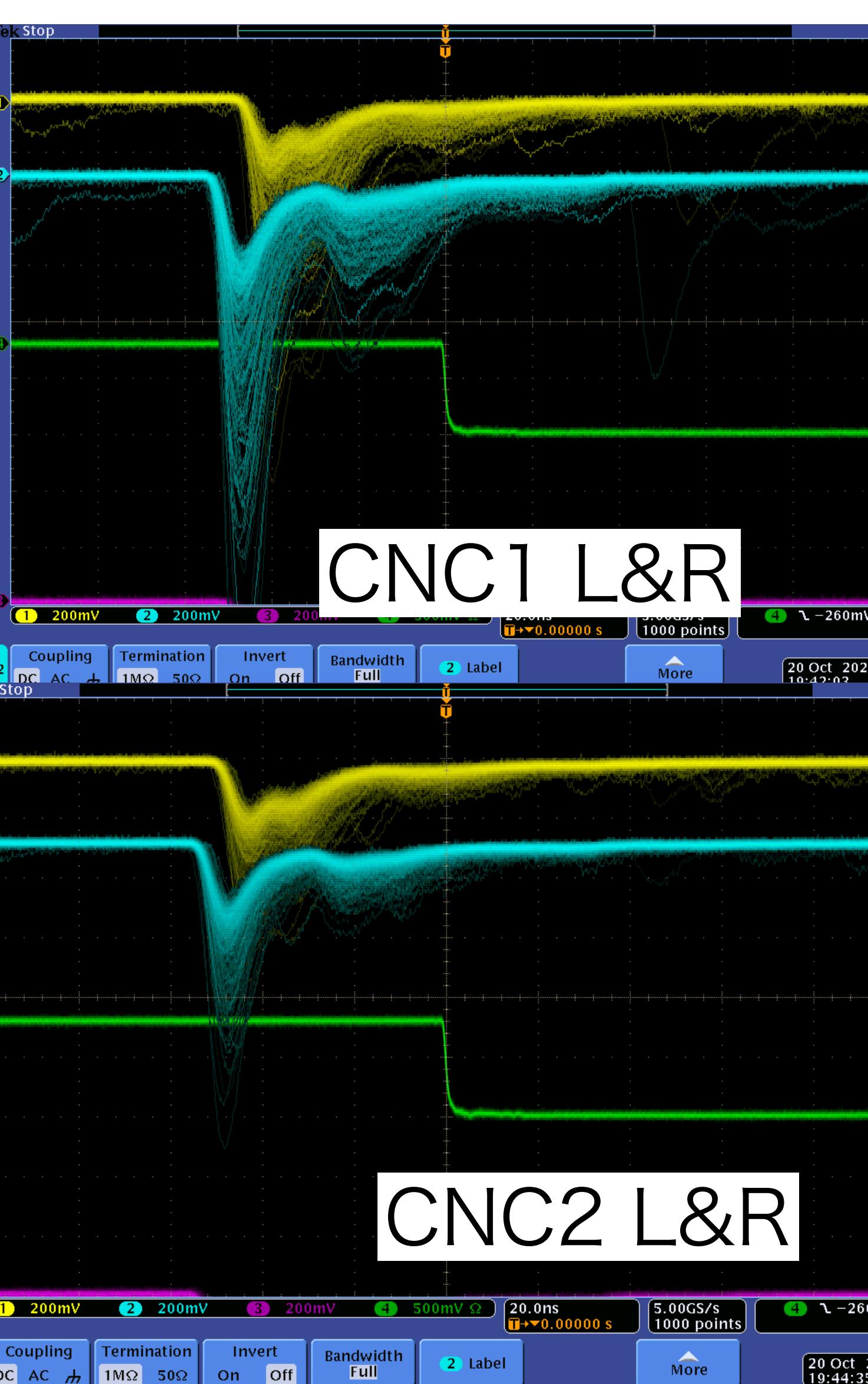
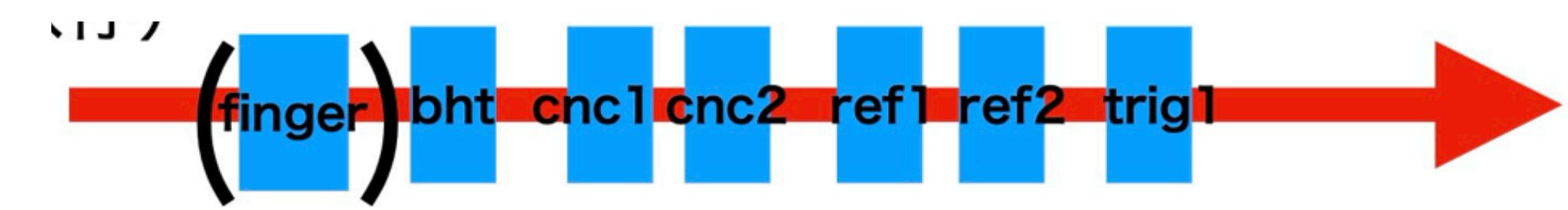
# 1. CNC time resolution

QDC run29 QDC — pedestal Blue : raw data Red : all tdc  $t = -1$

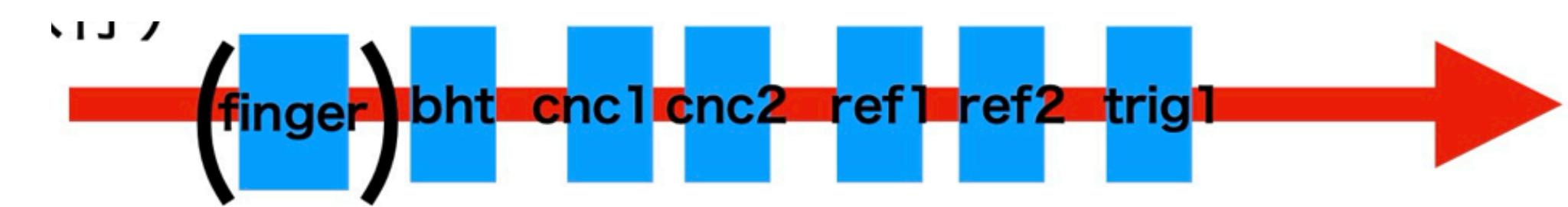


# 1. CNC time resolution

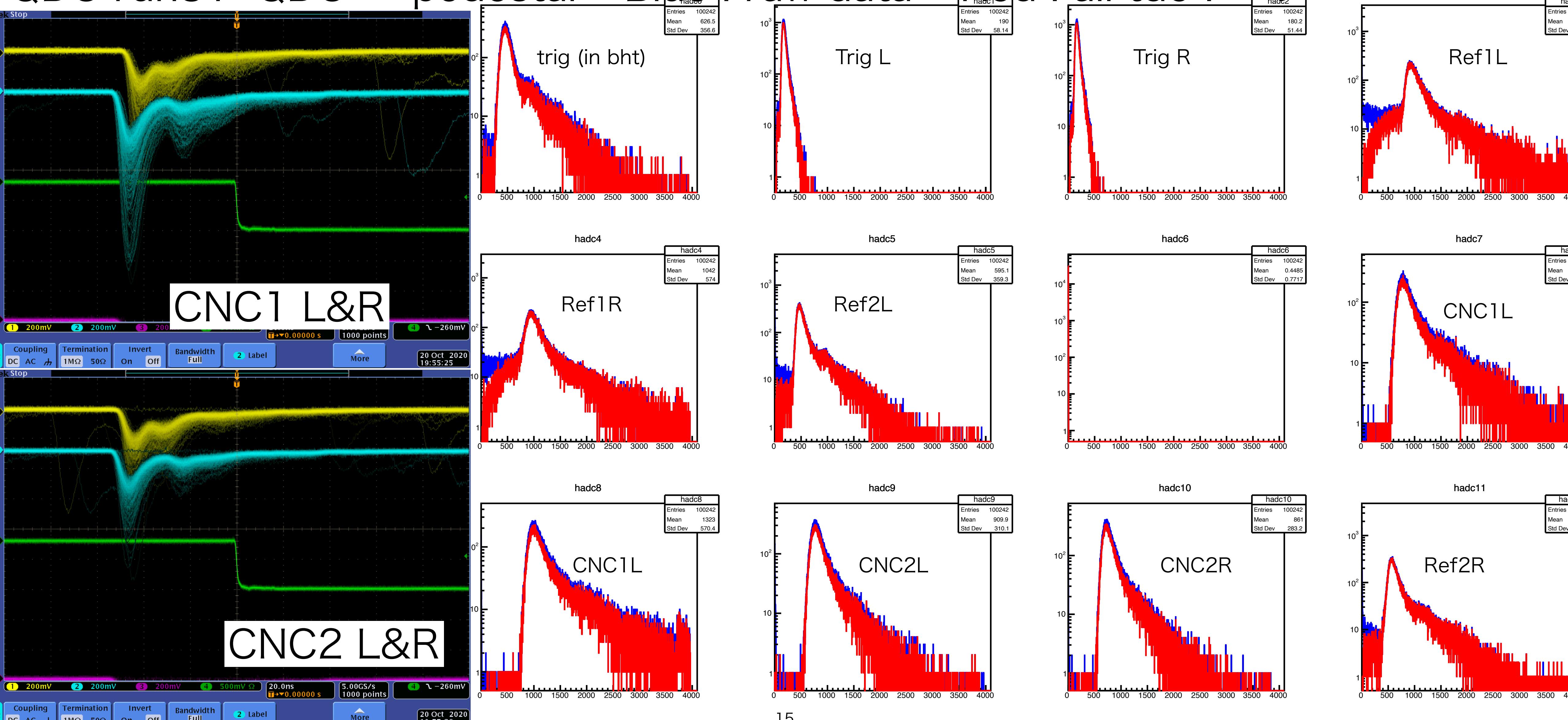
# QDC run30 QDC – pedestal Blue; raw data Red; all tdc != -1



# 1. CNC time resolution

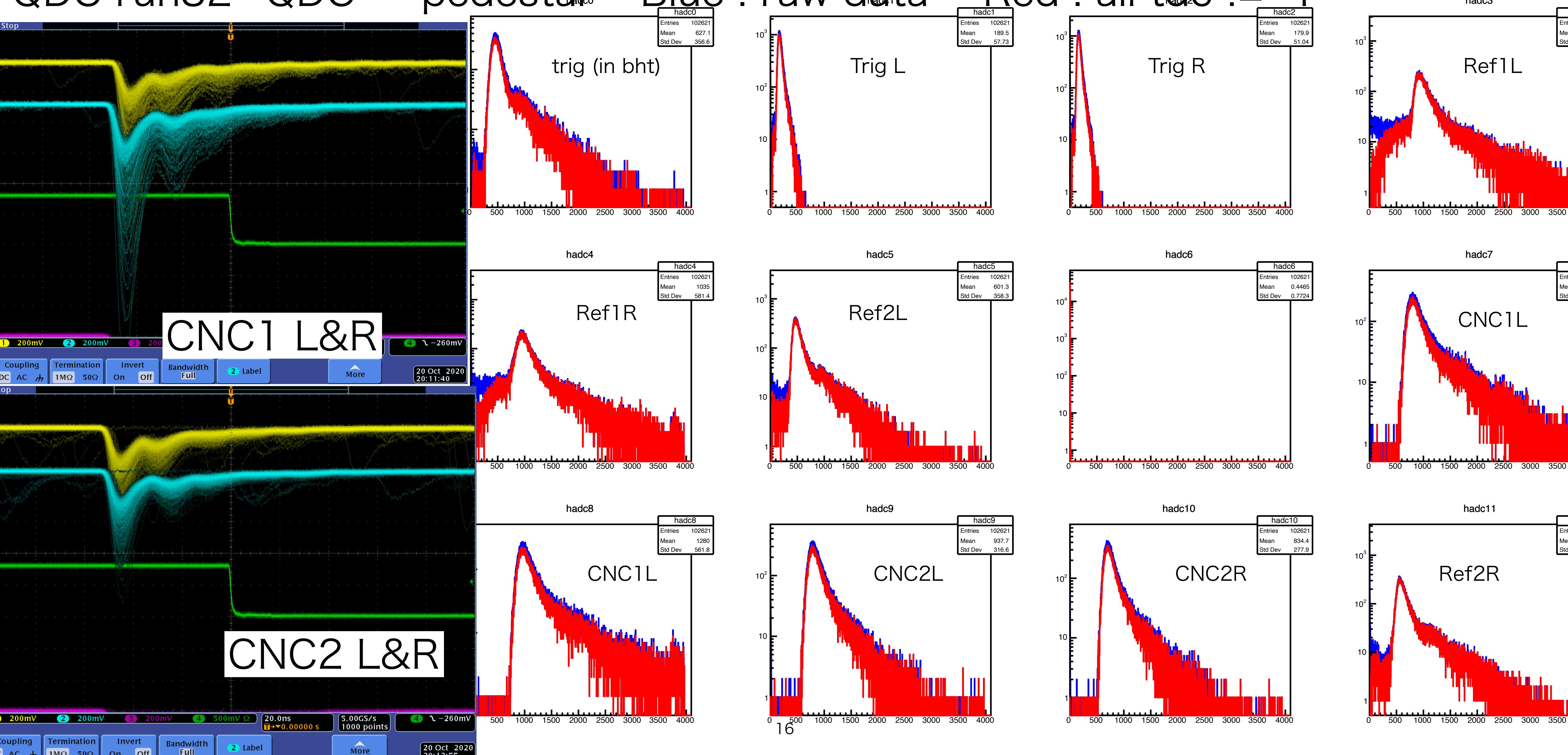


QDC run31 QDC — pedestal



# 1. CNC time resolution

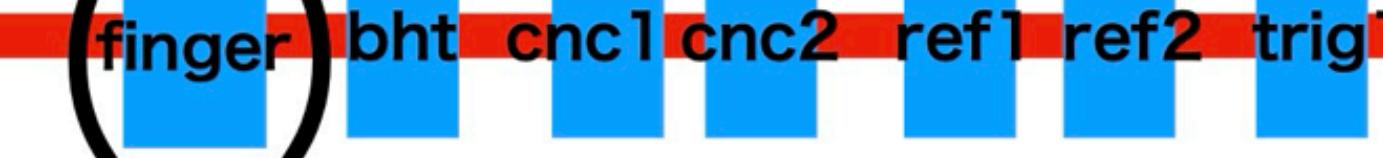
QDC run32 QDC — pedestal Blue : raw data Red : all tdc != -1



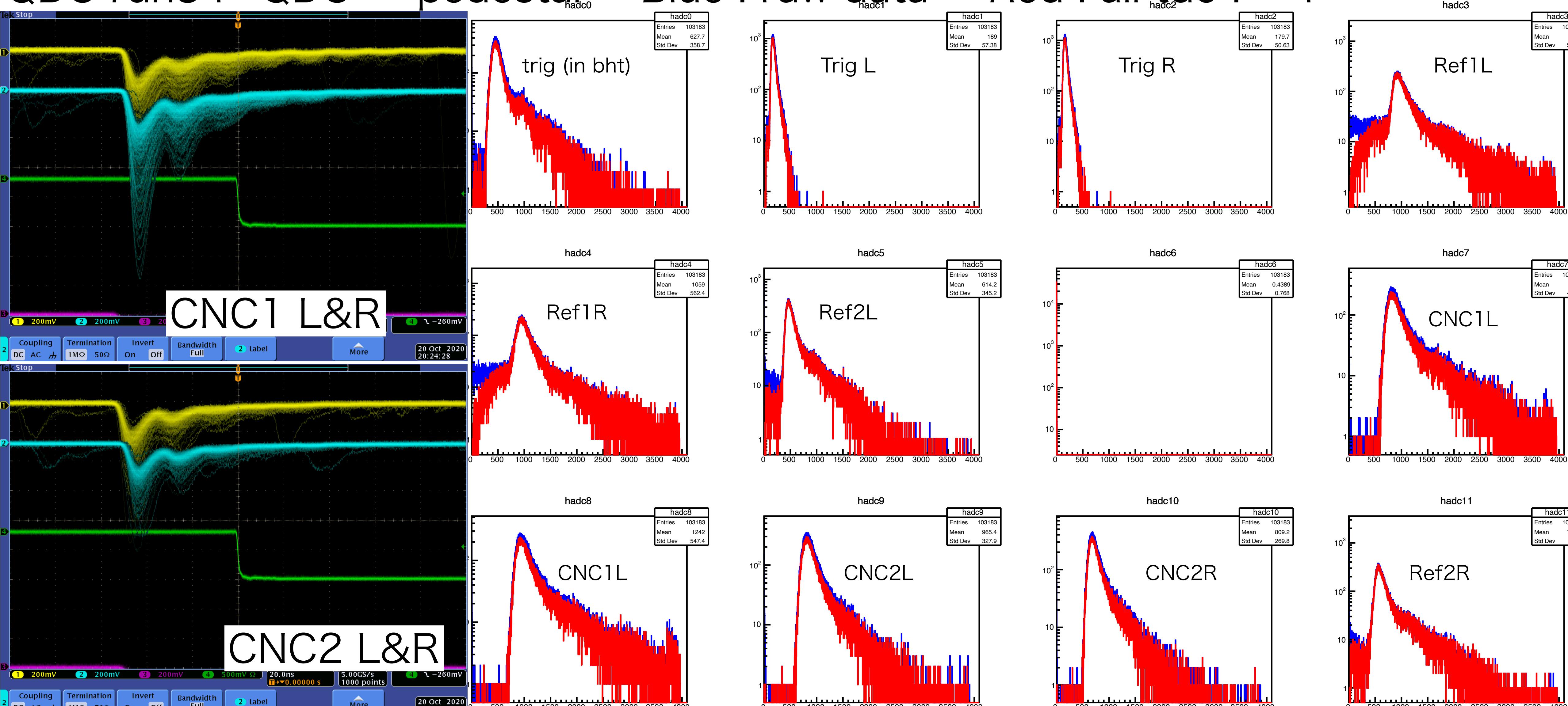
# 1. CNC time resolution

QDC run34 QDC — pedestal

Blue : raw data



Red : all tdc != -1

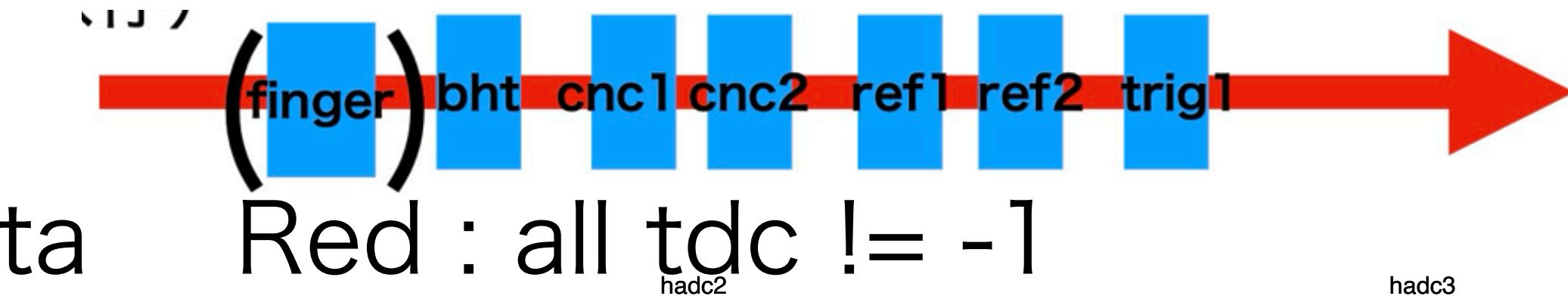


# 1. CNC time resolution

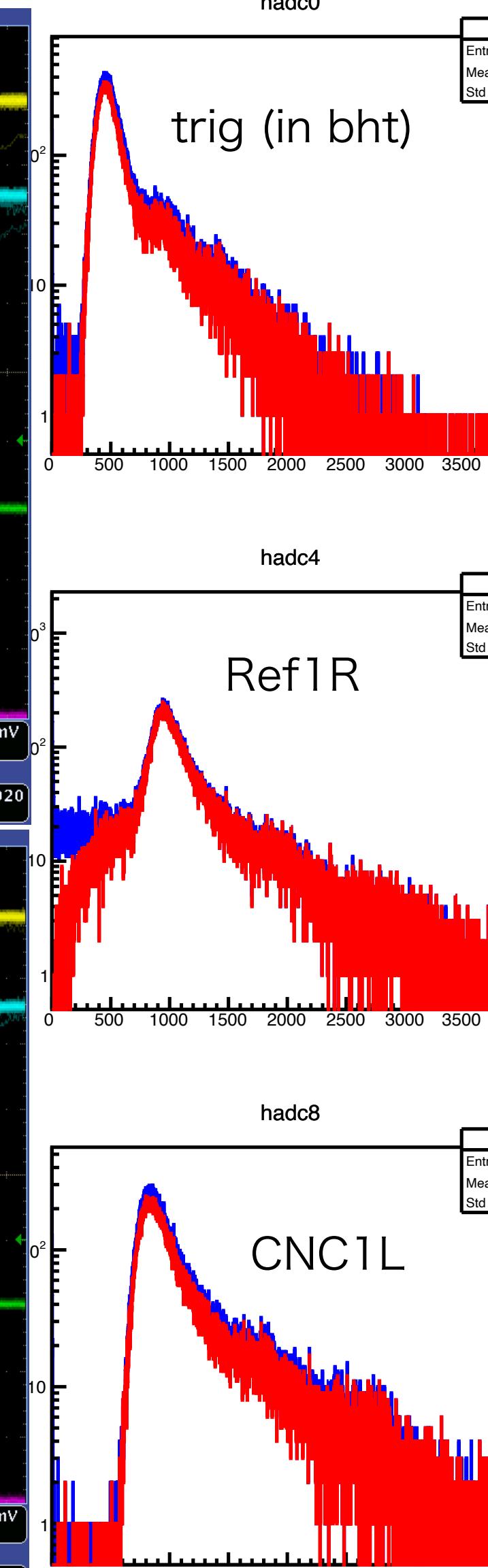
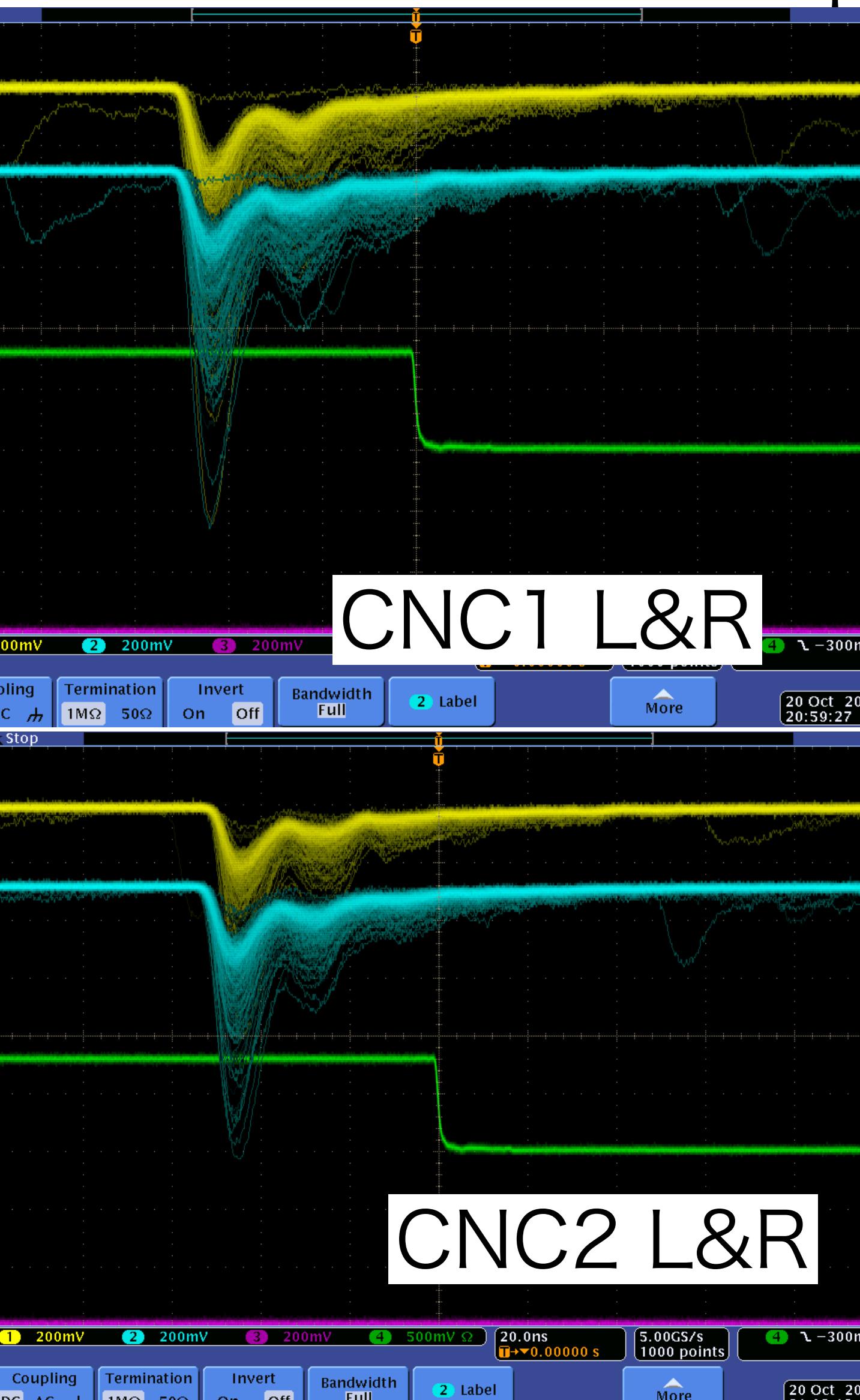
QDC run35

QDC — pedestal

Blue : raw data



Red : all tdc != -1

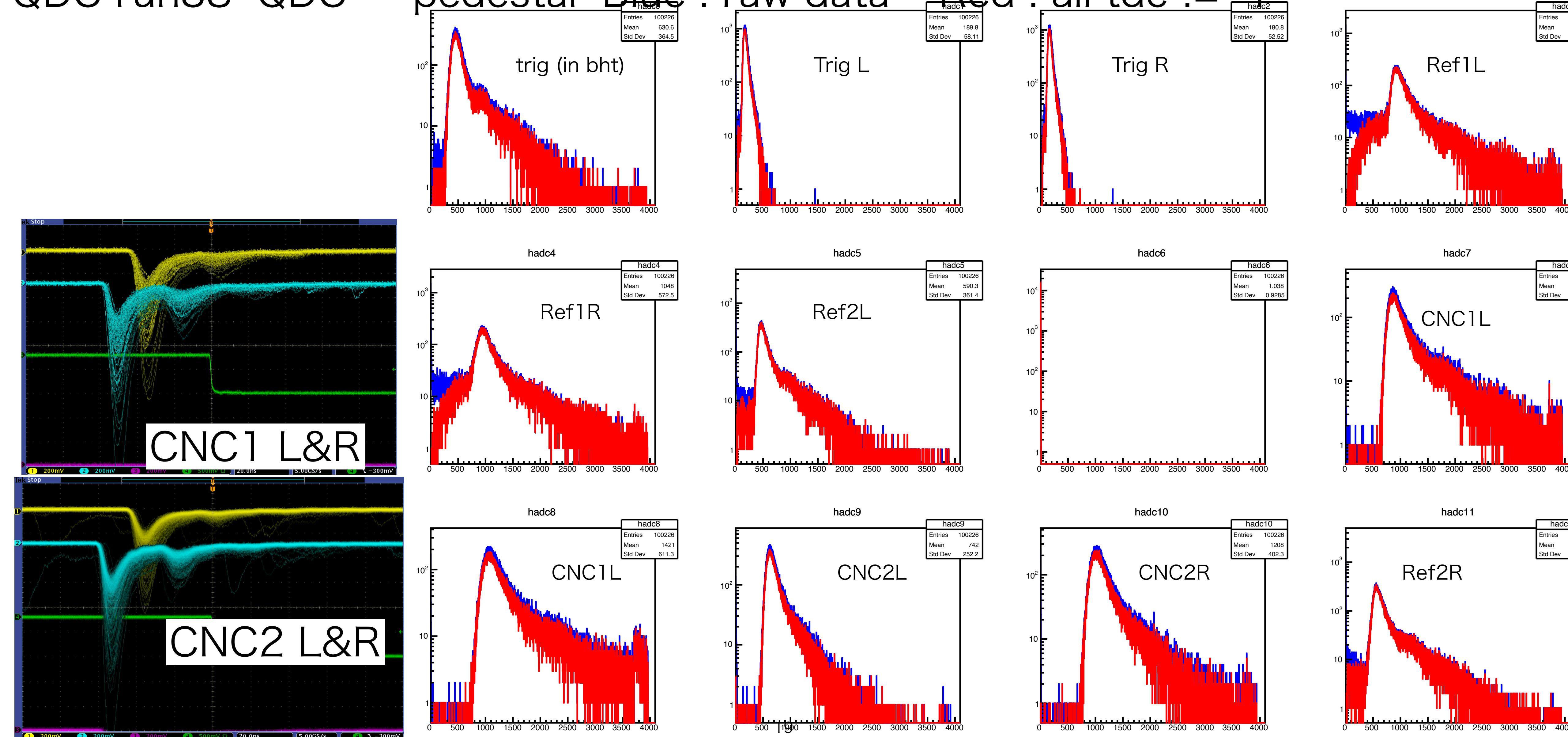


# 1. CNC time resolution

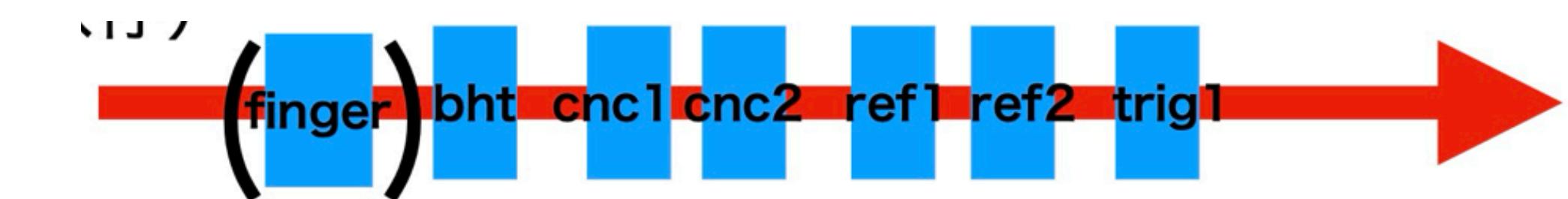
# QDC run38 QDC – pedestal $\frac{\text{hadcr}}{\text{hadcr}}$ Blue : raw data

A horizontal sequence of seven blue rectangular blocks. A red horizontal bar is positioned below the first four blocks. Above the first block is the label '(finger)' enclosed in black parentheses. To the right of the first block is the label 'bht'. To the right of 'bht' is 'cnc1'. To the right of 'cnc1' is 'cnc2'. To the right of 'cnc2' is 'ref1'. To the right of 'ref1' is 'ref2'. To the right of 'trig1' is a large red arrow pointing to the right.

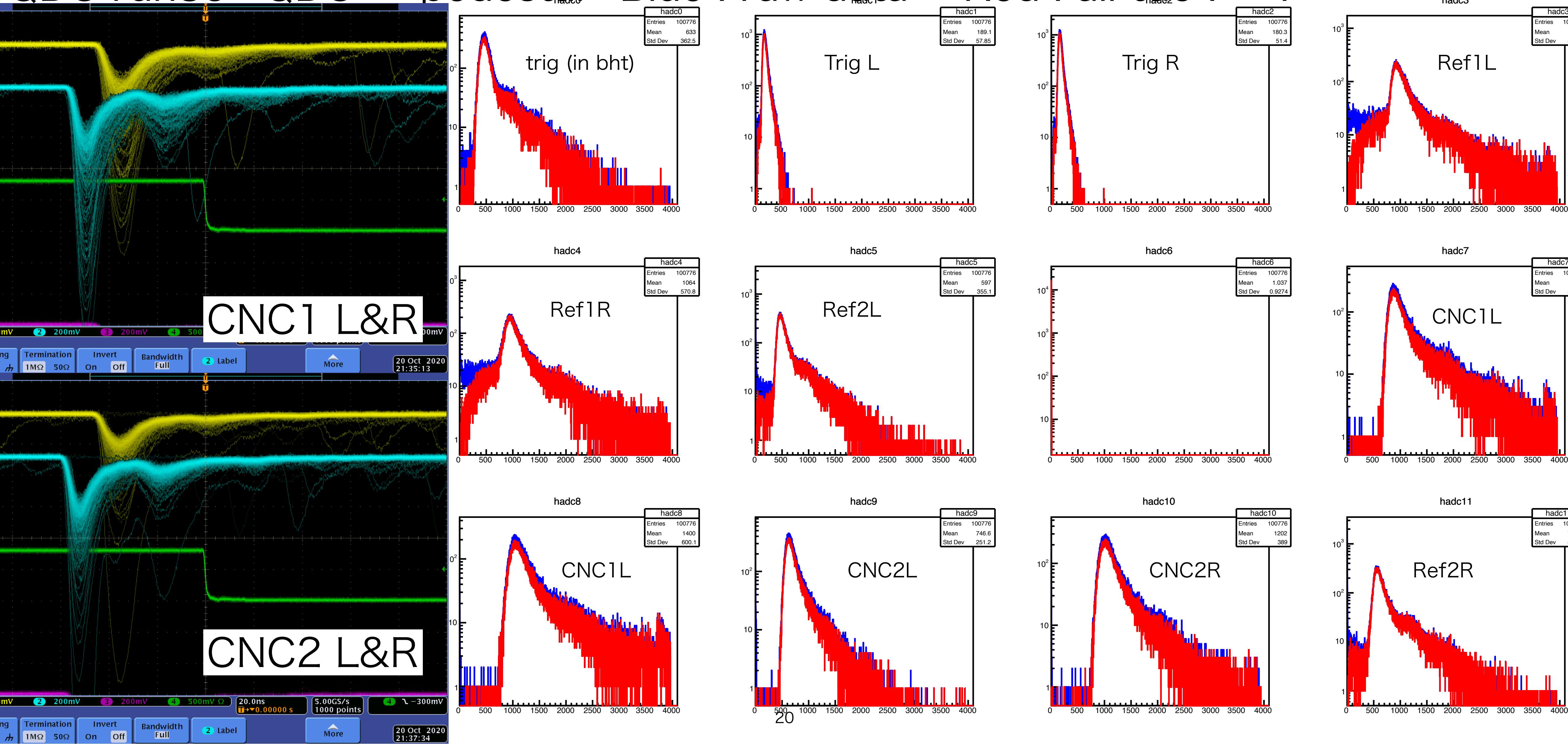
Red : all tdc != -1



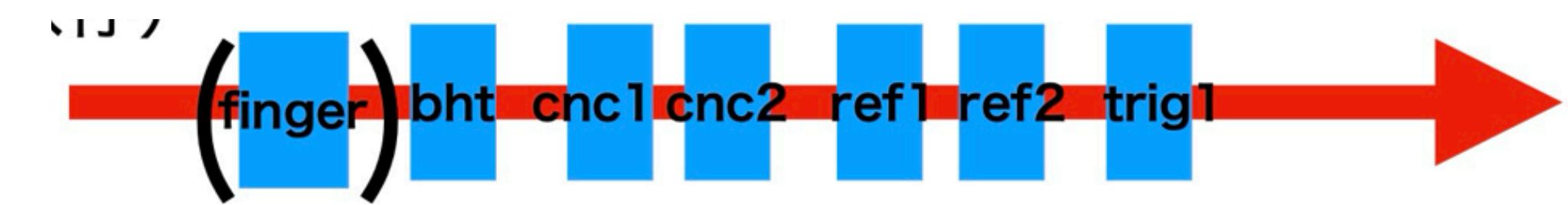
# 1. CNC time resolution



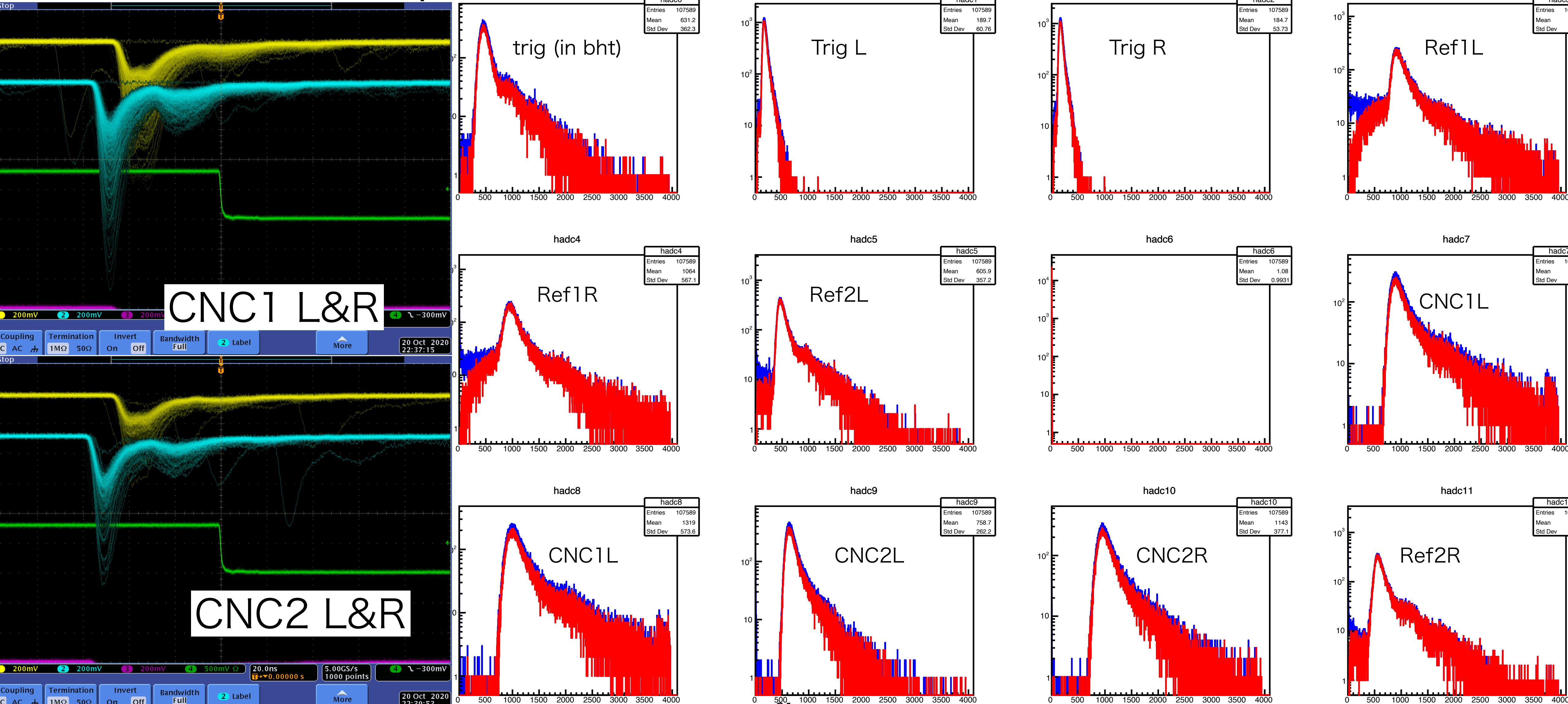
QDC run39 QDC — pedestal Blue : raw data Red : all tdc != -1



# 1. CNC time resolution



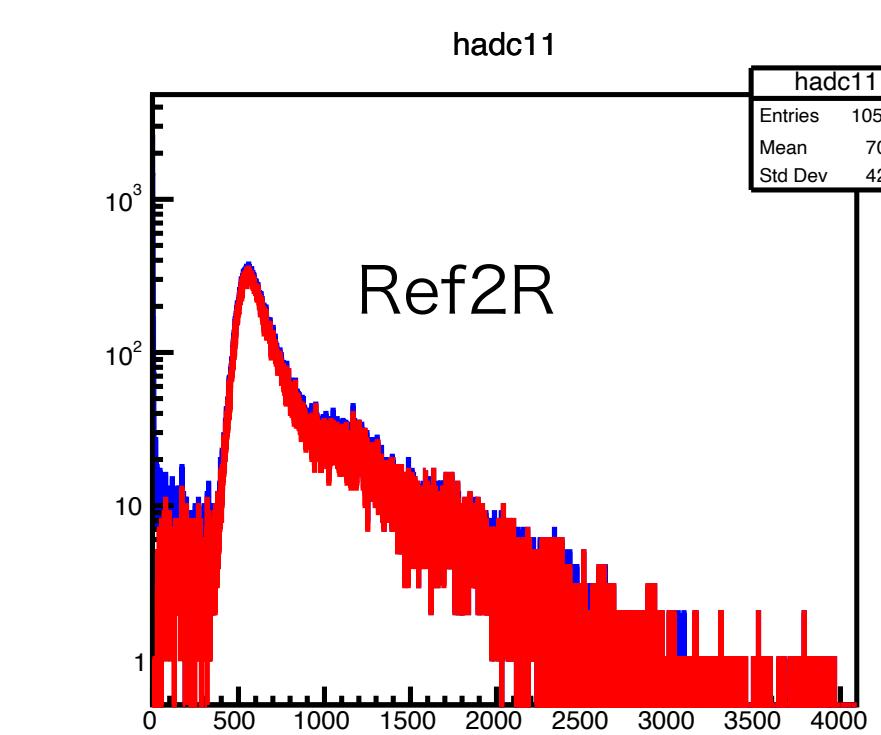
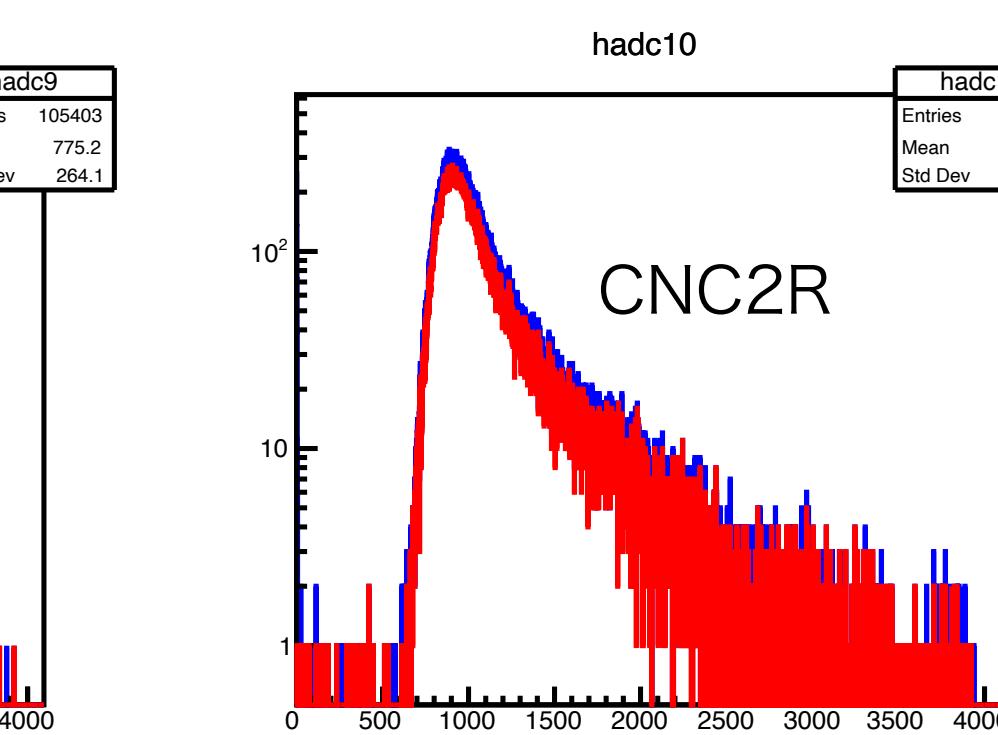
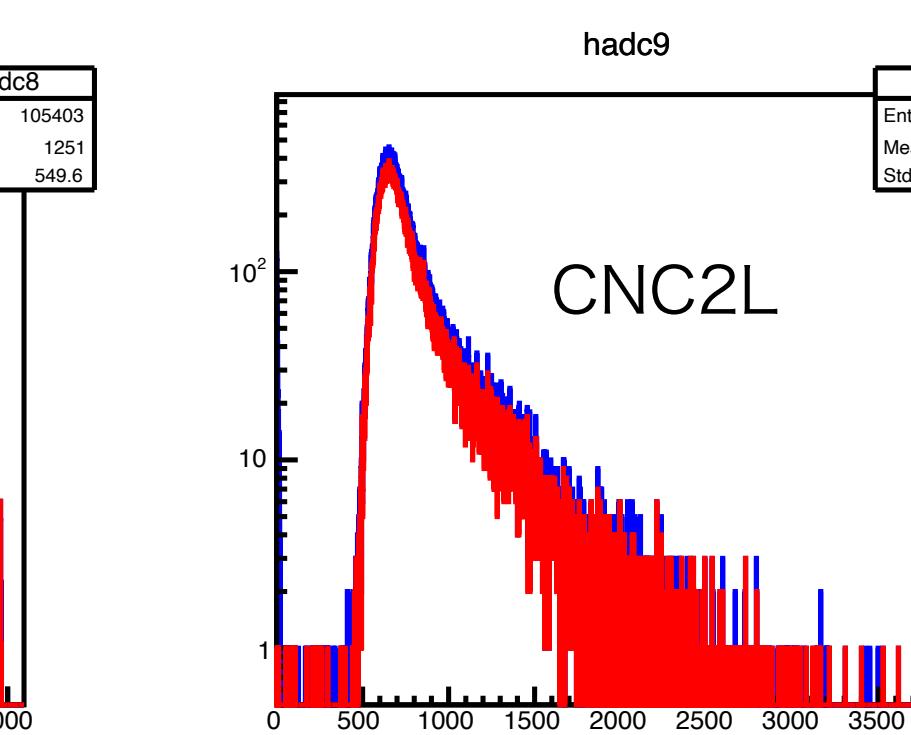
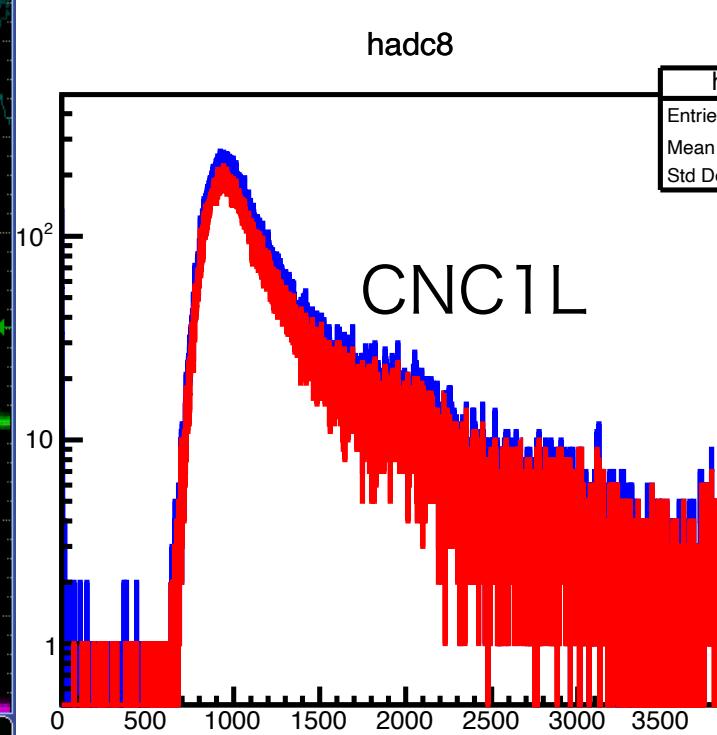
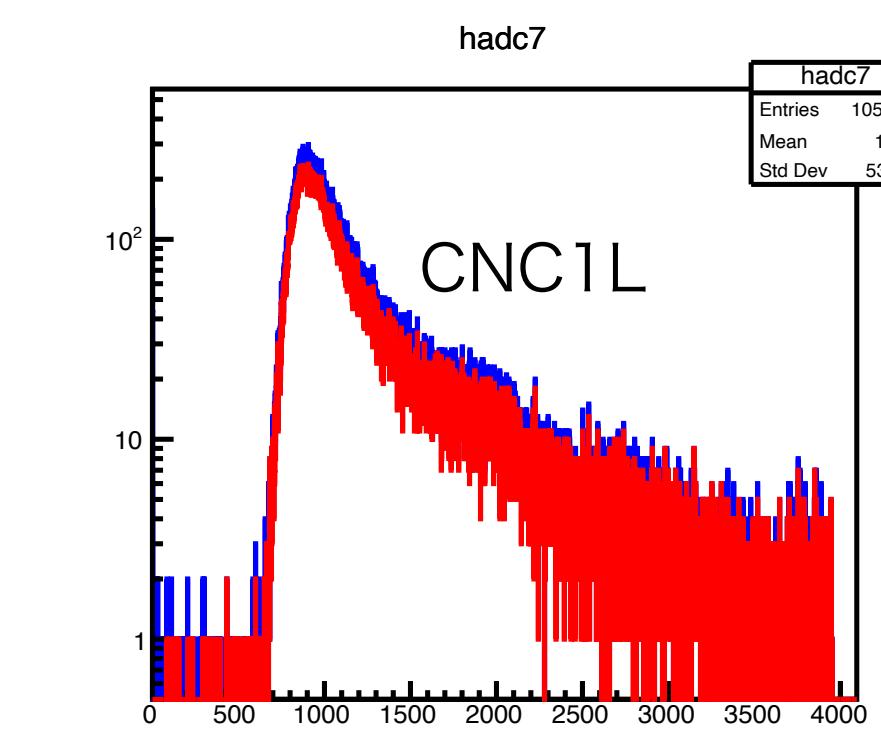
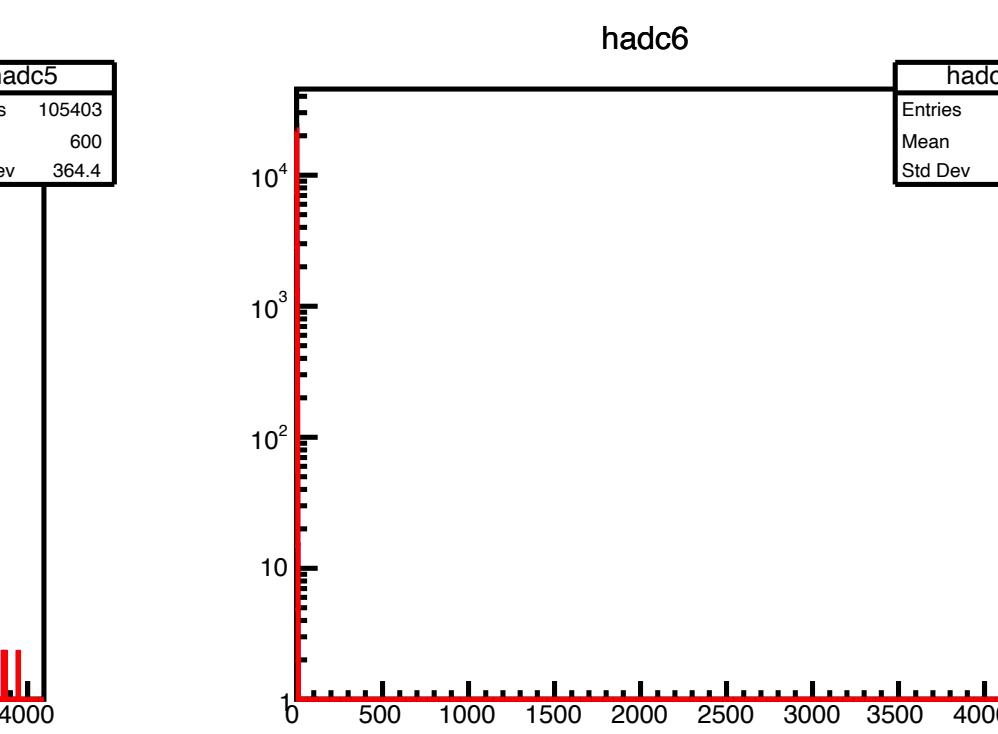
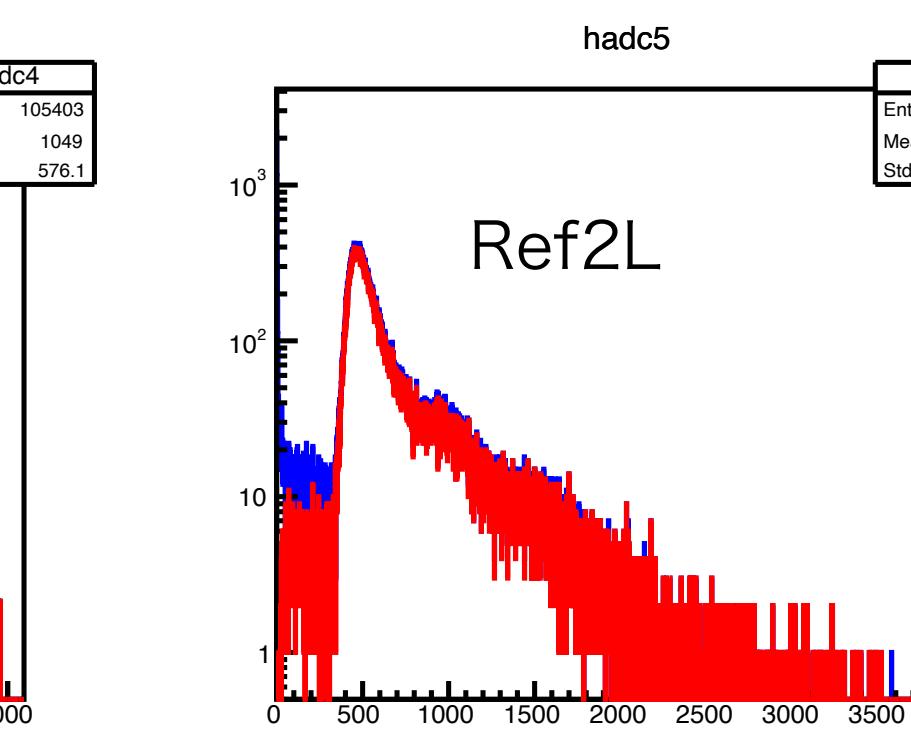
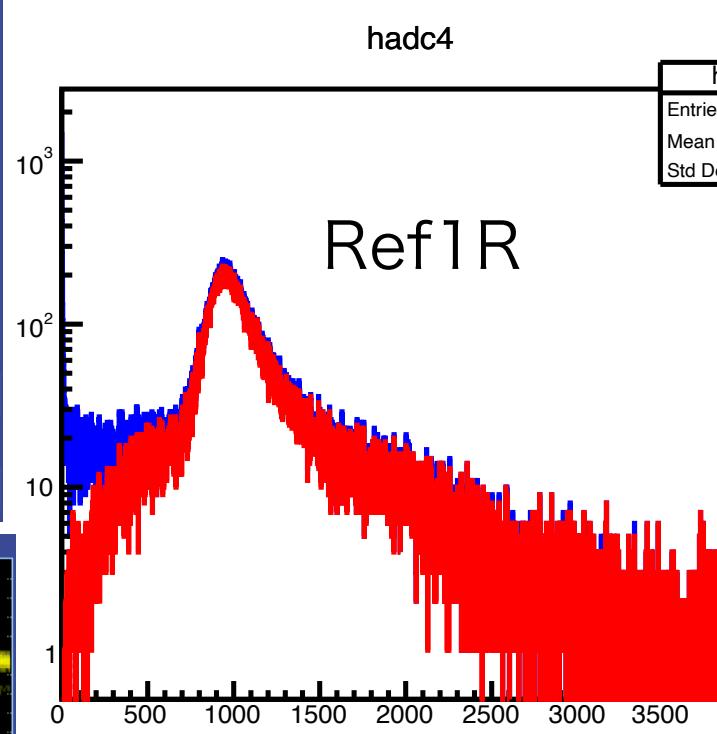
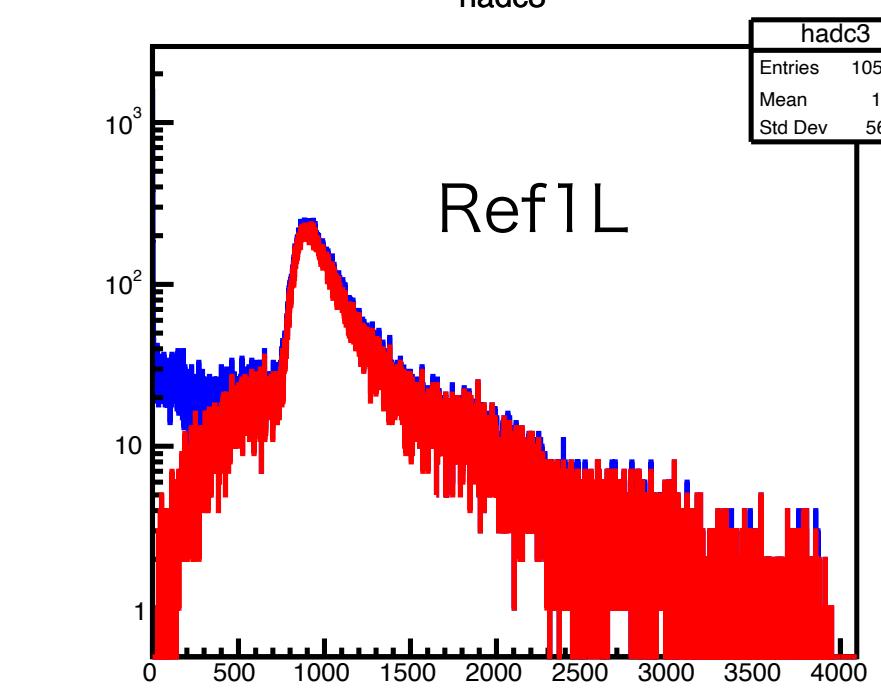
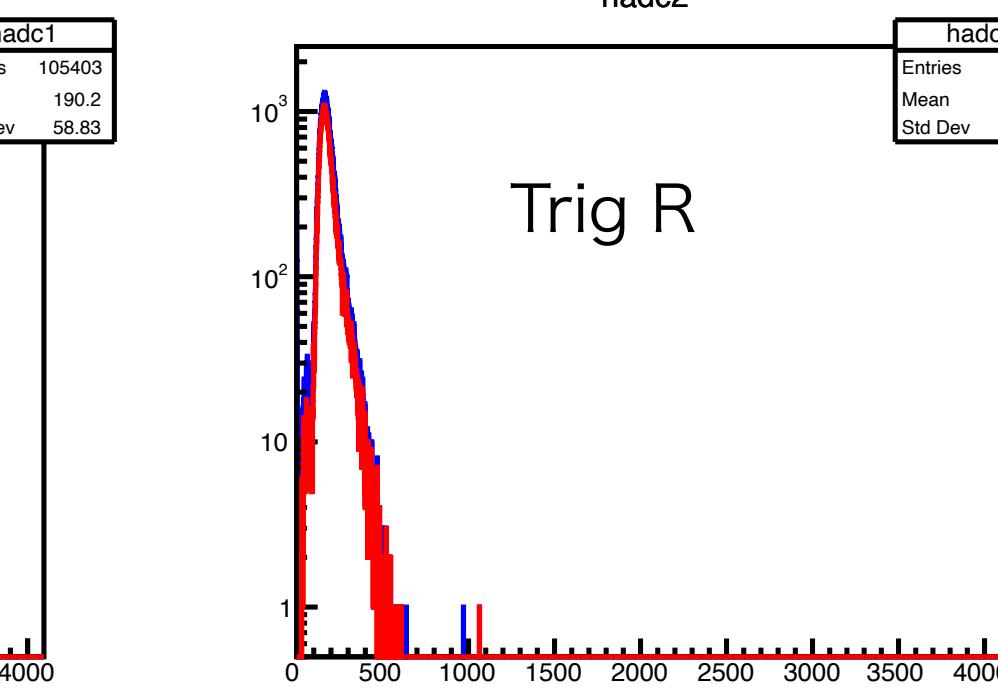
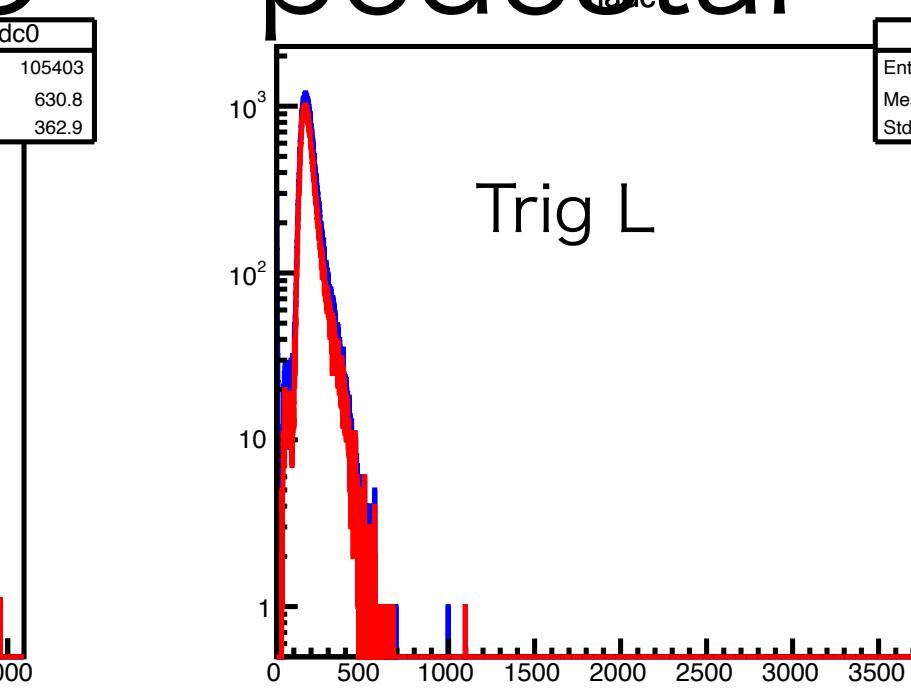
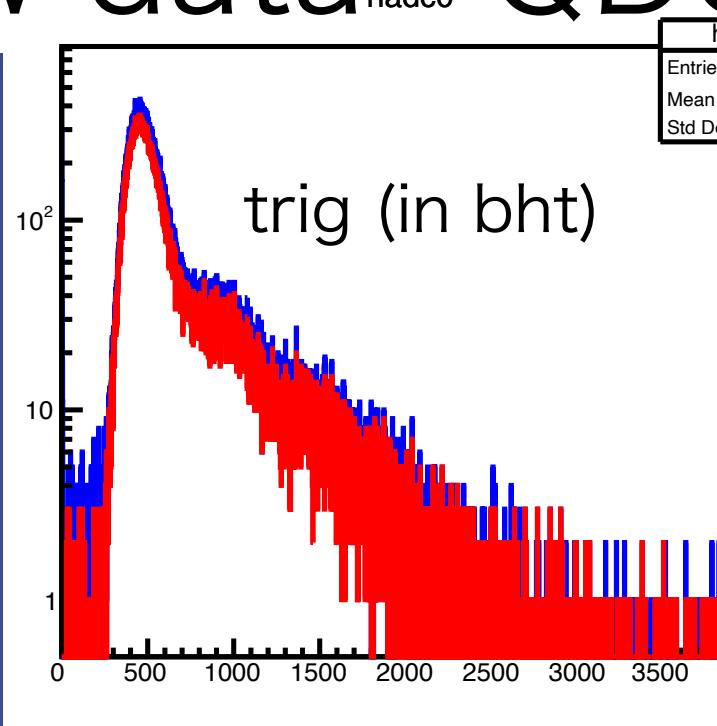
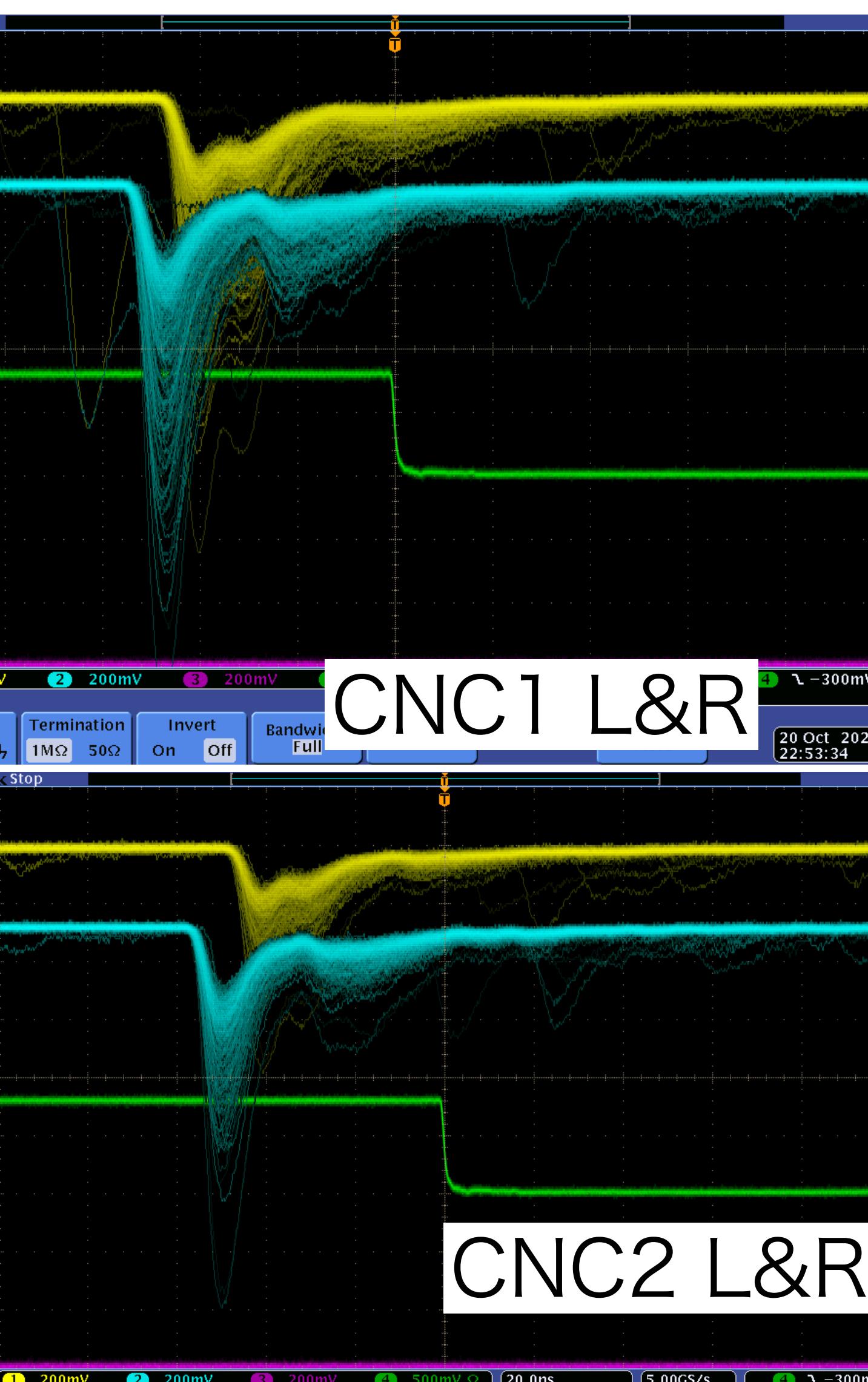
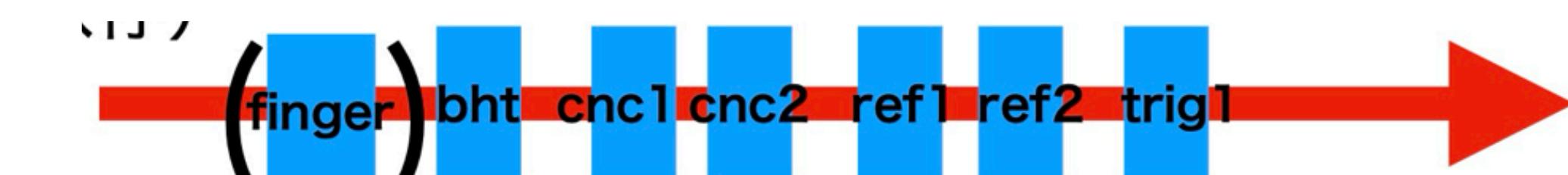
QDC run40 QDC — pedestal Blue : raw data Red : all tdc != -1



# 1. CNC time resolution

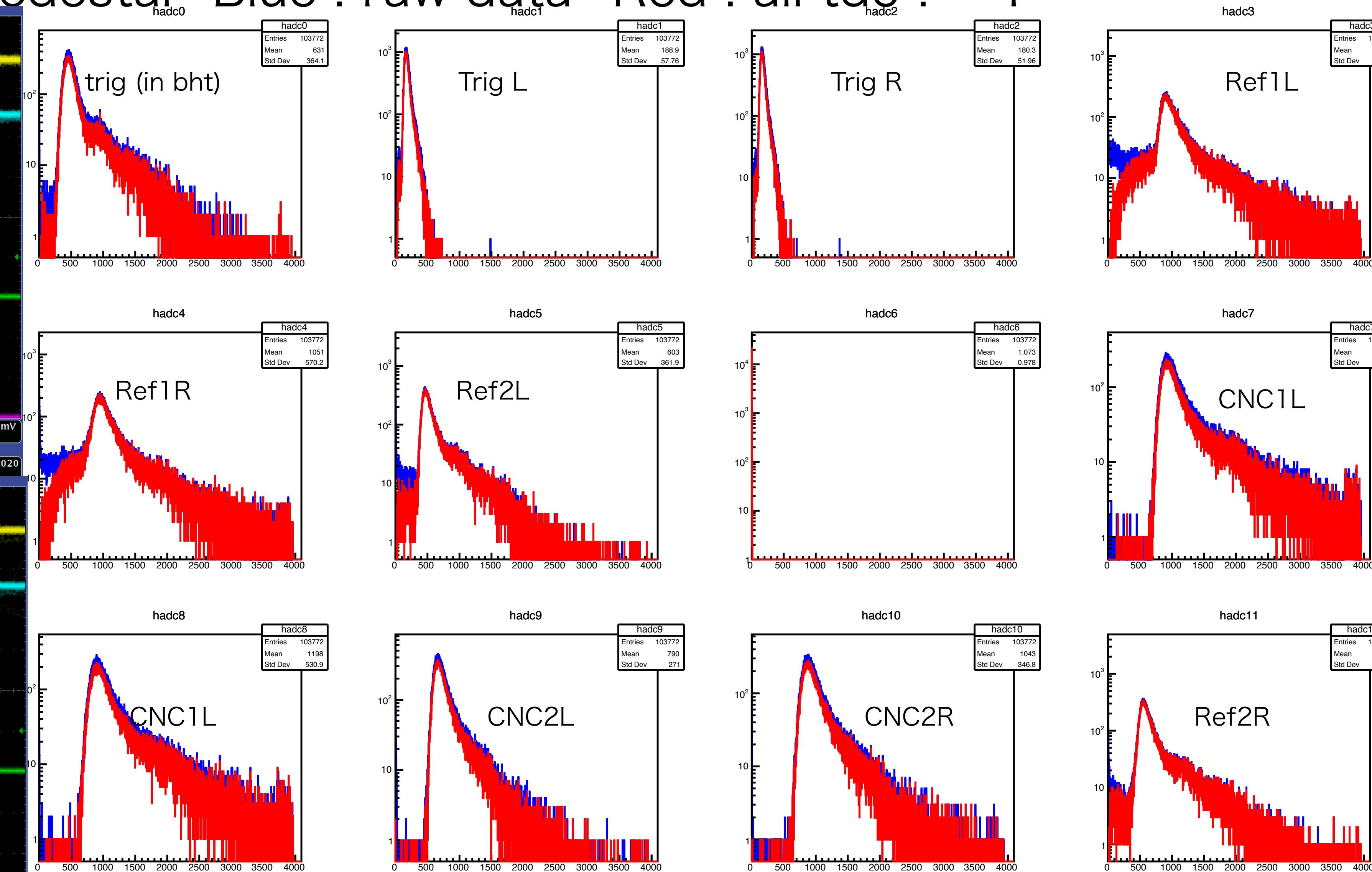
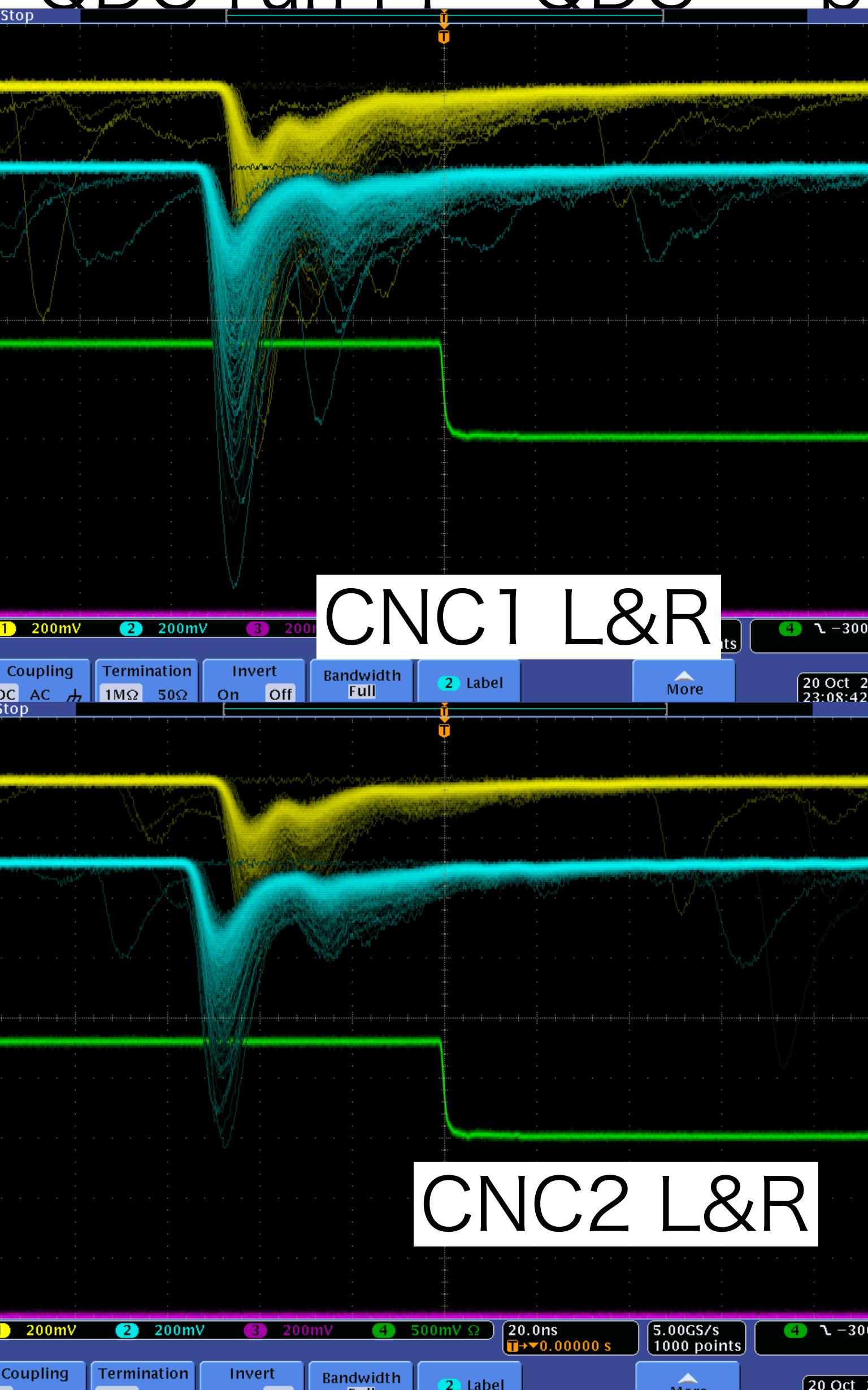
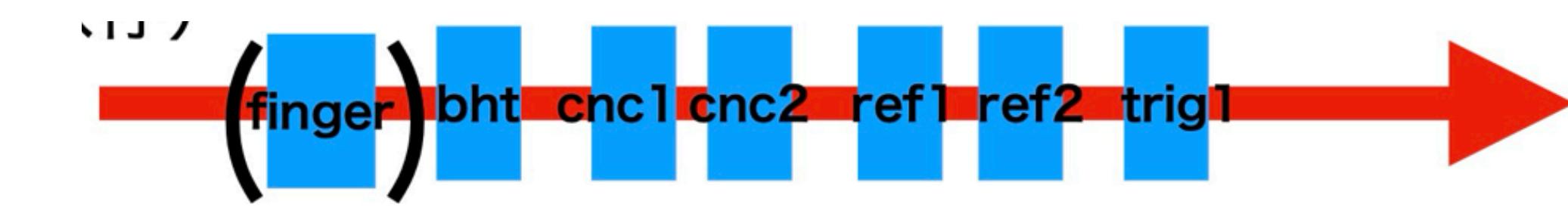
QDC run42

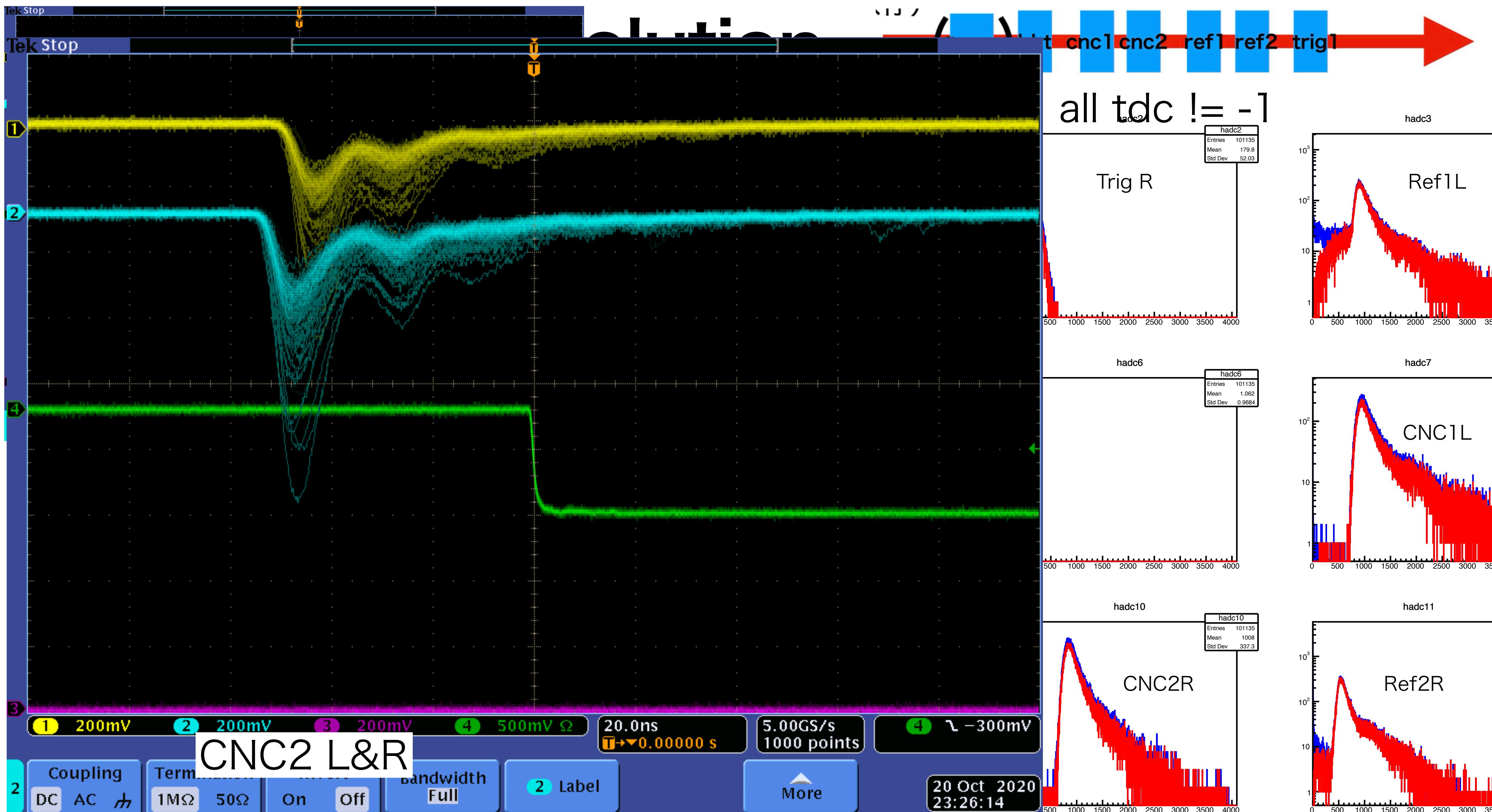
Blue : raw data QDC – pedestal



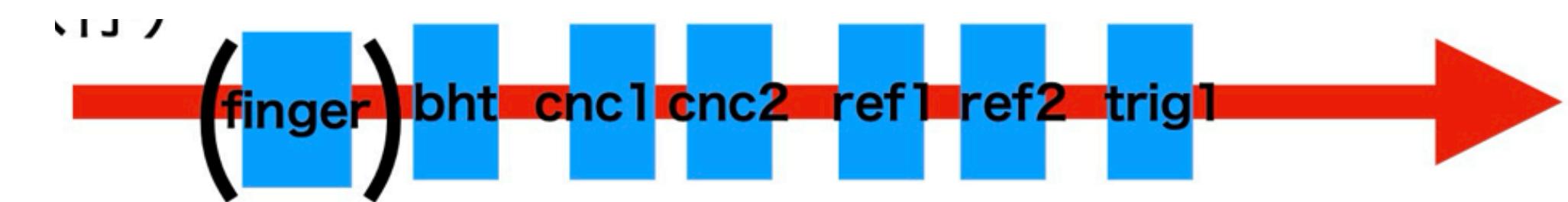
# 1. CNC time resolution

QDC run44 QDC — pedestal Blue : raw data Red : all tdc != -1

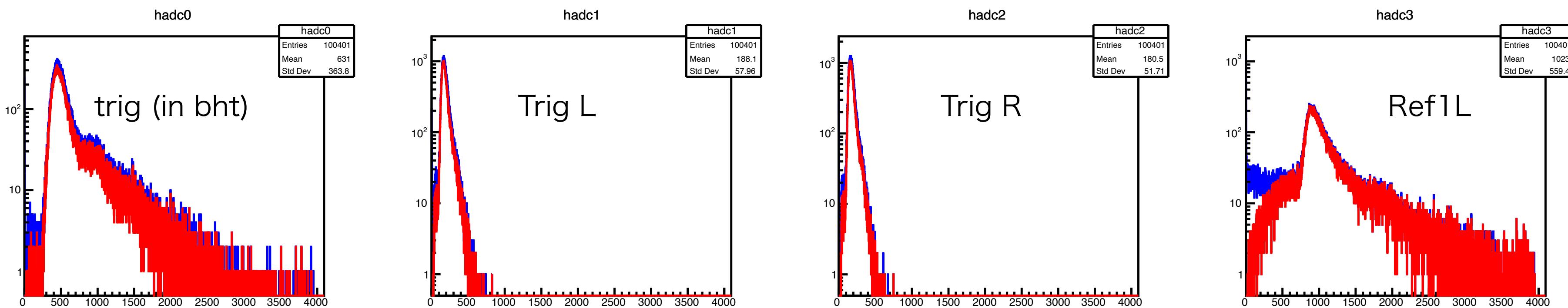




# 1. CNC time resolution



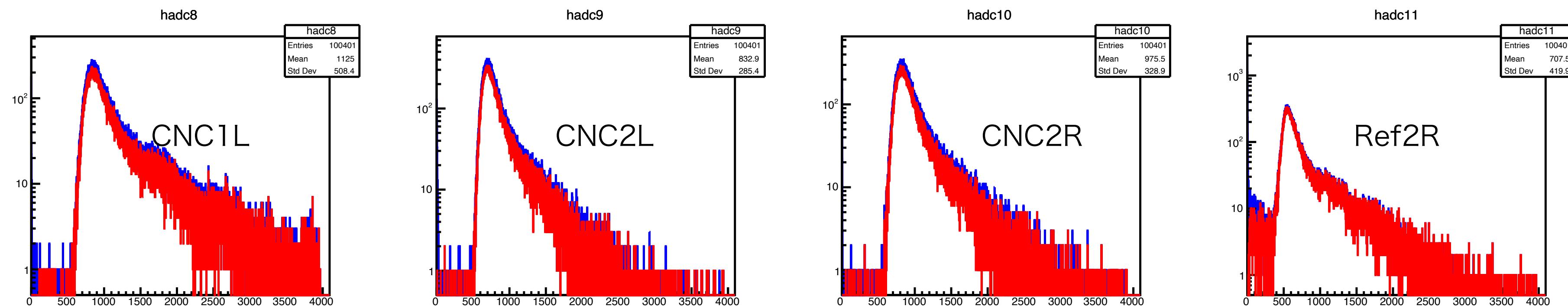
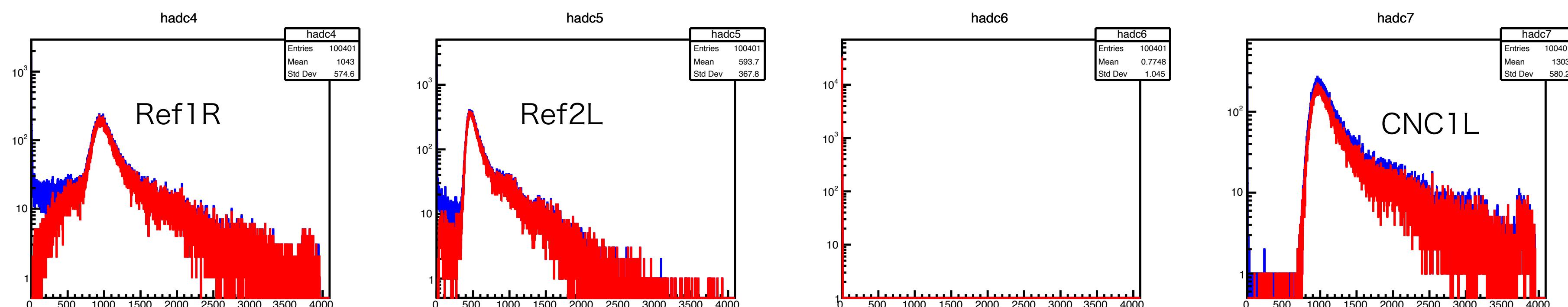
QDC run48



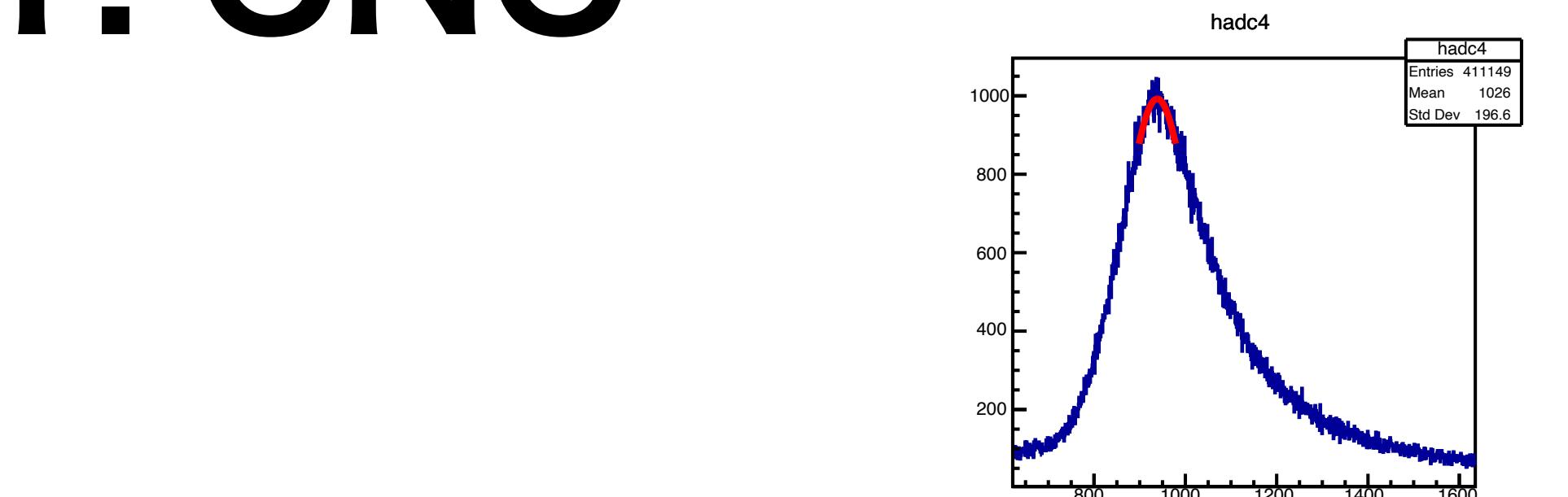
QDC — pedestal

Blue : raw data

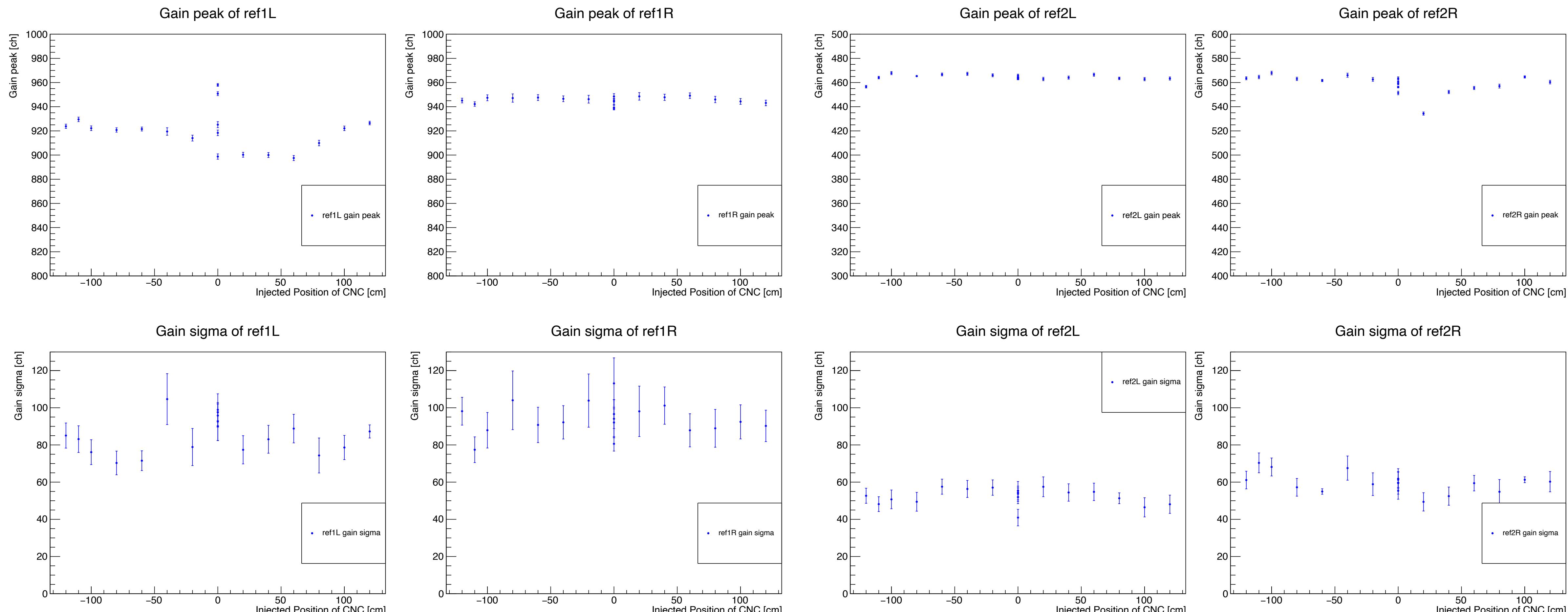
Red : all tdc != -1



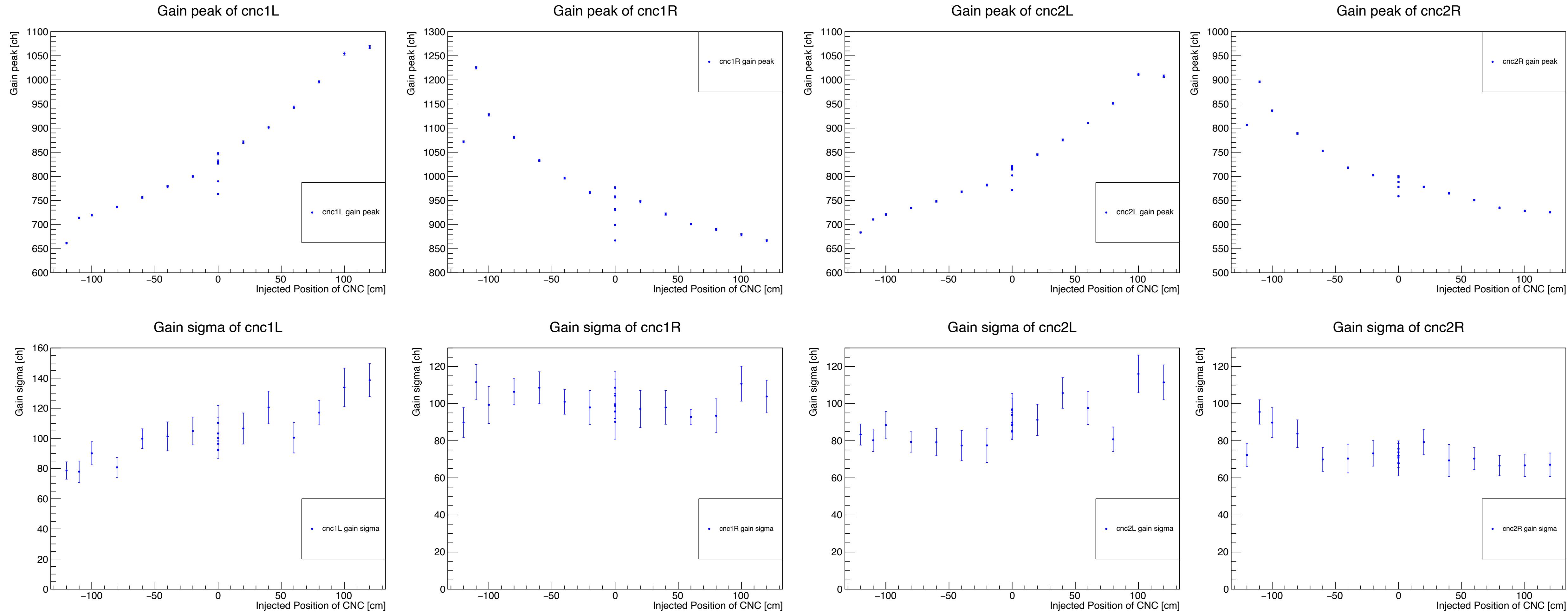
# 1. CNC



・以下、adc histのpeakをガウスでfitした時のmeanとsigmaをプロットしてみた。  
基本的にrefに関しては安定するはずだが、、、  
ref1Lがやや荒れ模様。



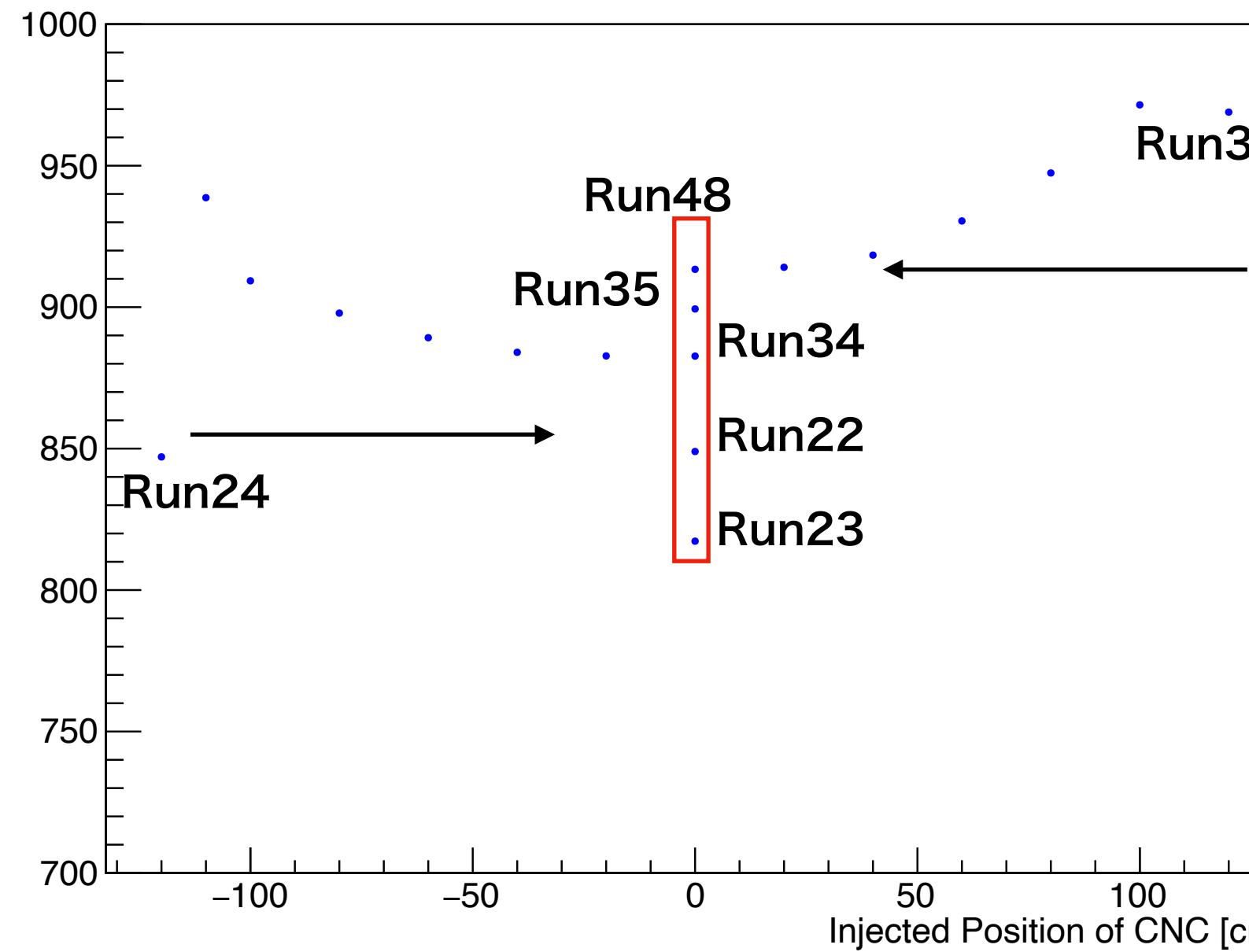
# 1. CNC time resolution



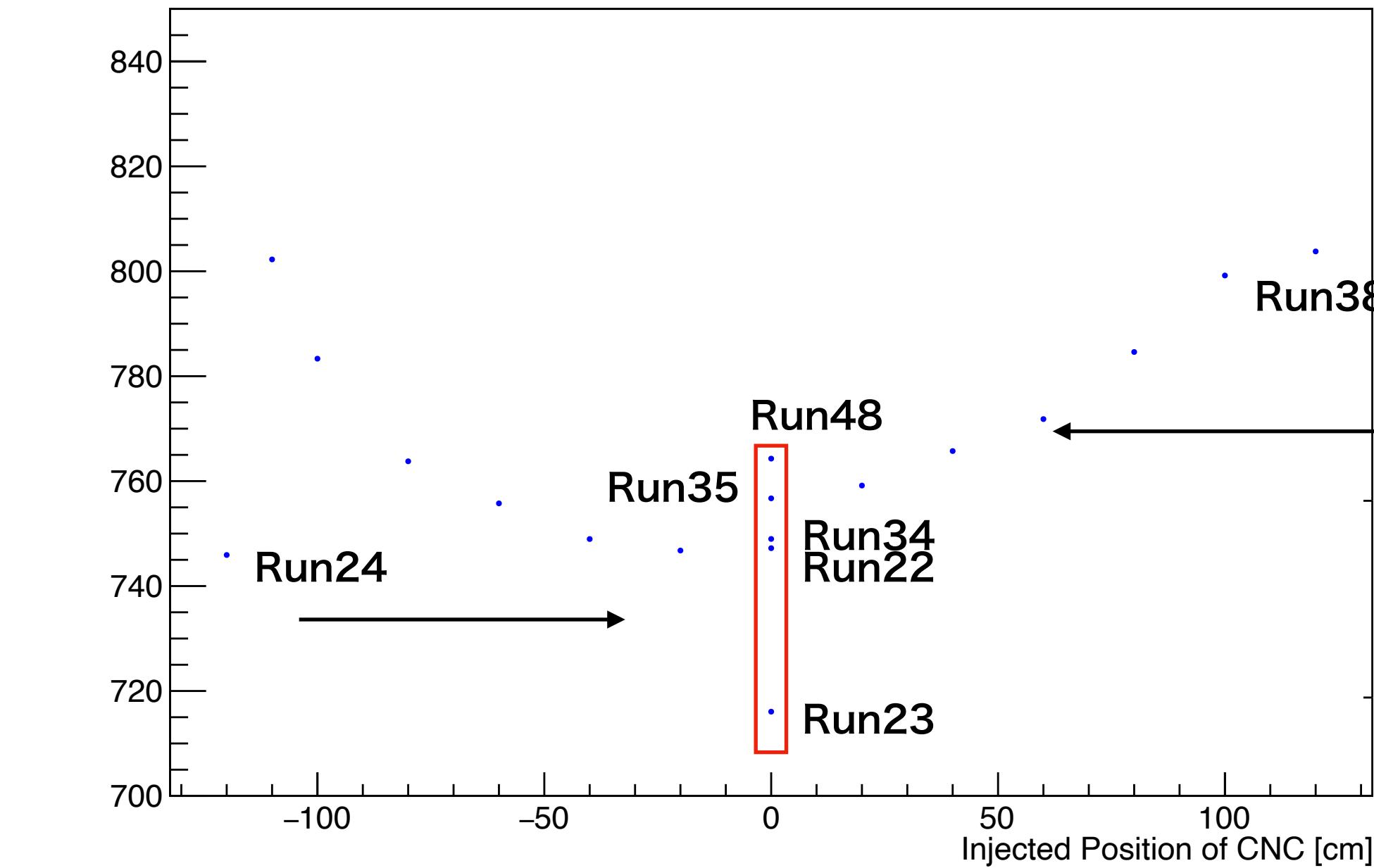
# 1. CNC time resolution

Gain 相乘平均

cnc 1



cnc 2



cnc

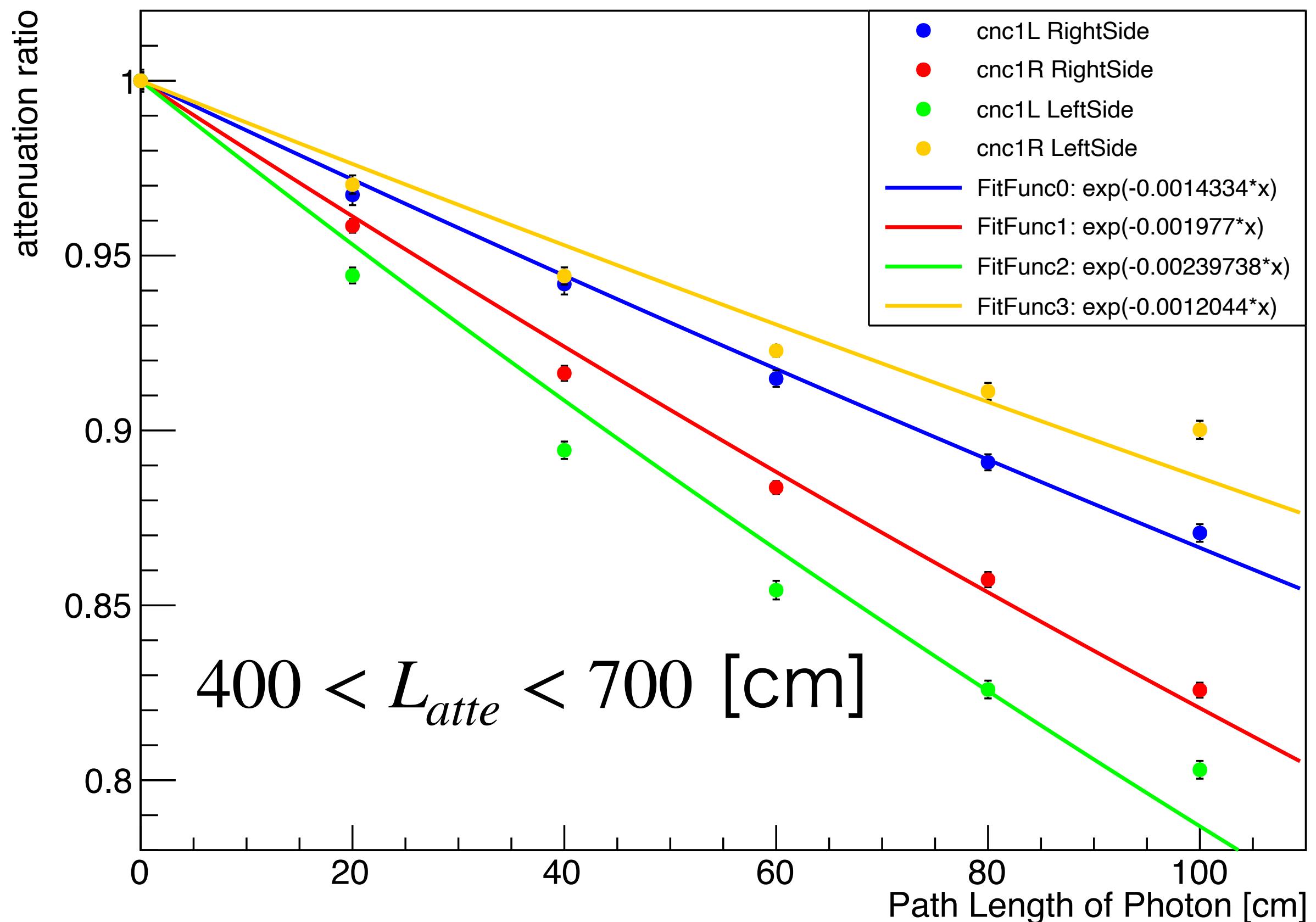
LeftSide

RightSide

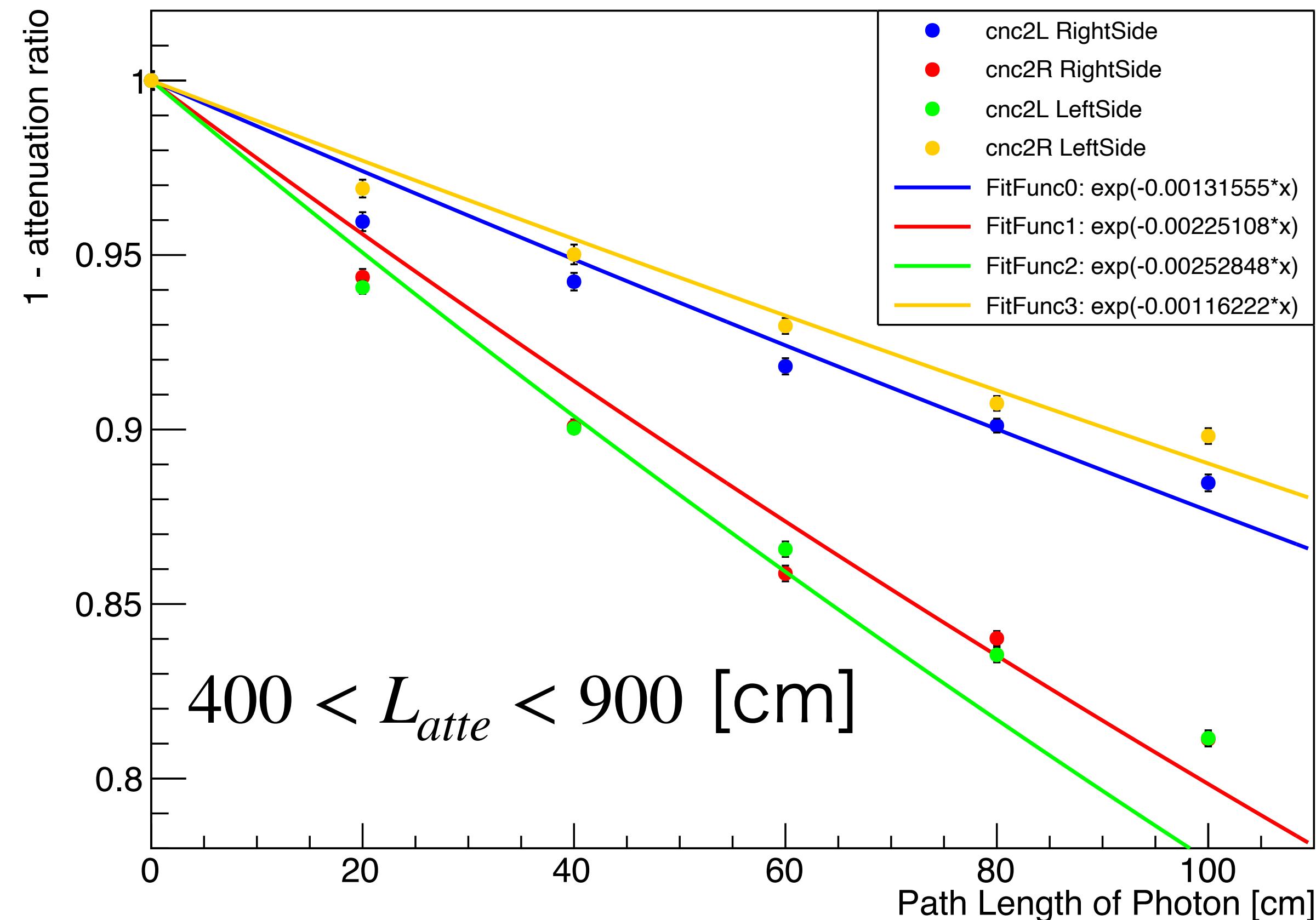
- 用いたデータは $-100 \leq x_{inject} \leq 100$  [cm]。

- 測定領域Left sideとRight sideを切り替えるときに一度HVを落としたので、分けてattenuation lengthを求めた。  
理想的には4通りで同じfit parameterになるはずだったが、、、

Gain attenuation of cnc1



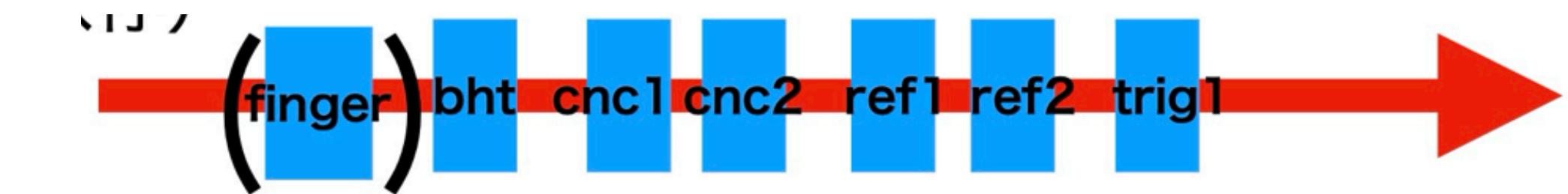
Gain attenuation of cnc2



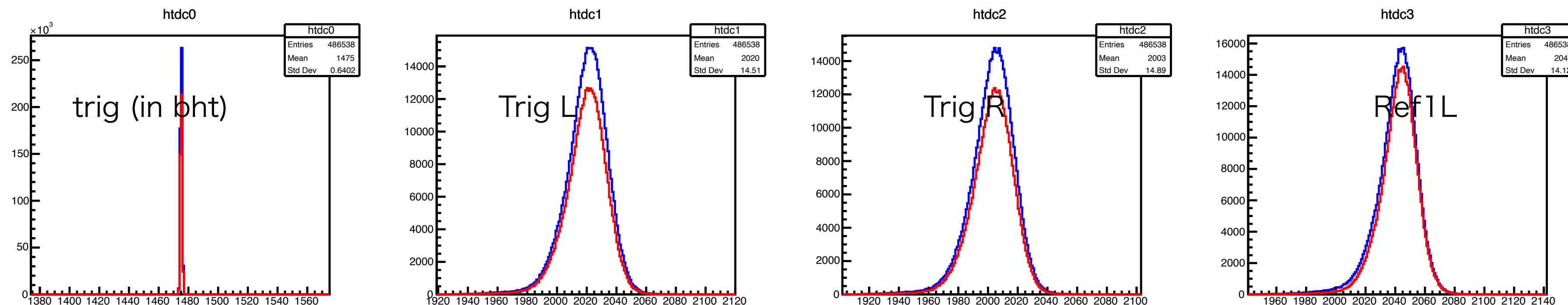
PROPERTIES	EJ-200
Light Output (% Anthracene)	64
Scintillation Efficiency (photons/1 MeV e <sup>-</sup> )	10,000
Wavelength of Maximum Emission (nm)	425
Light Attenuation Length (cm)	380

カタログ値

# 1. CNC time resolution

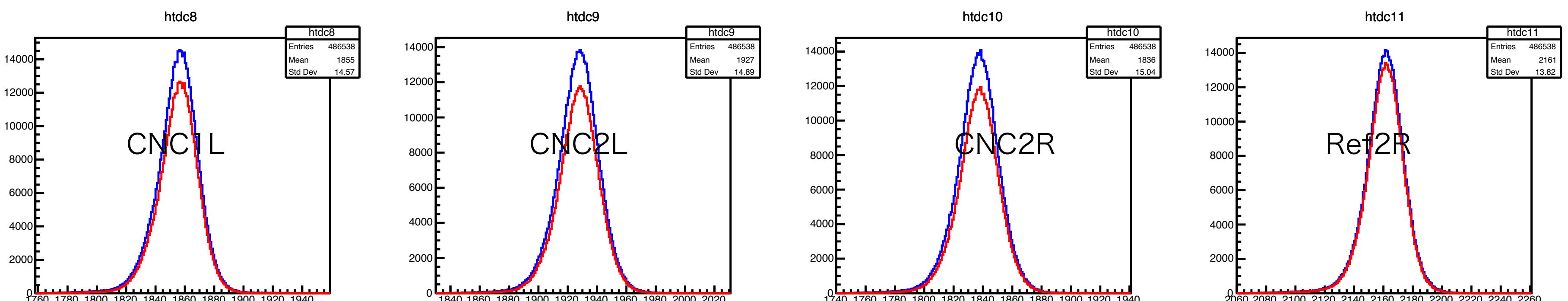
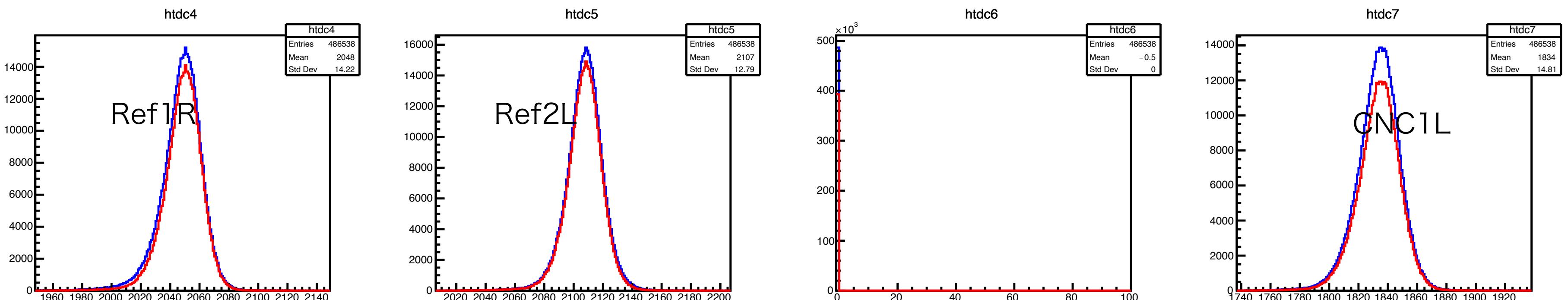


Typical TDC data  
run22

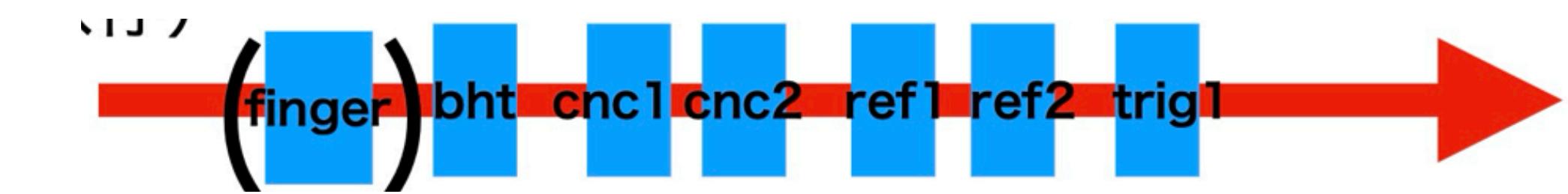


Blue : raw data

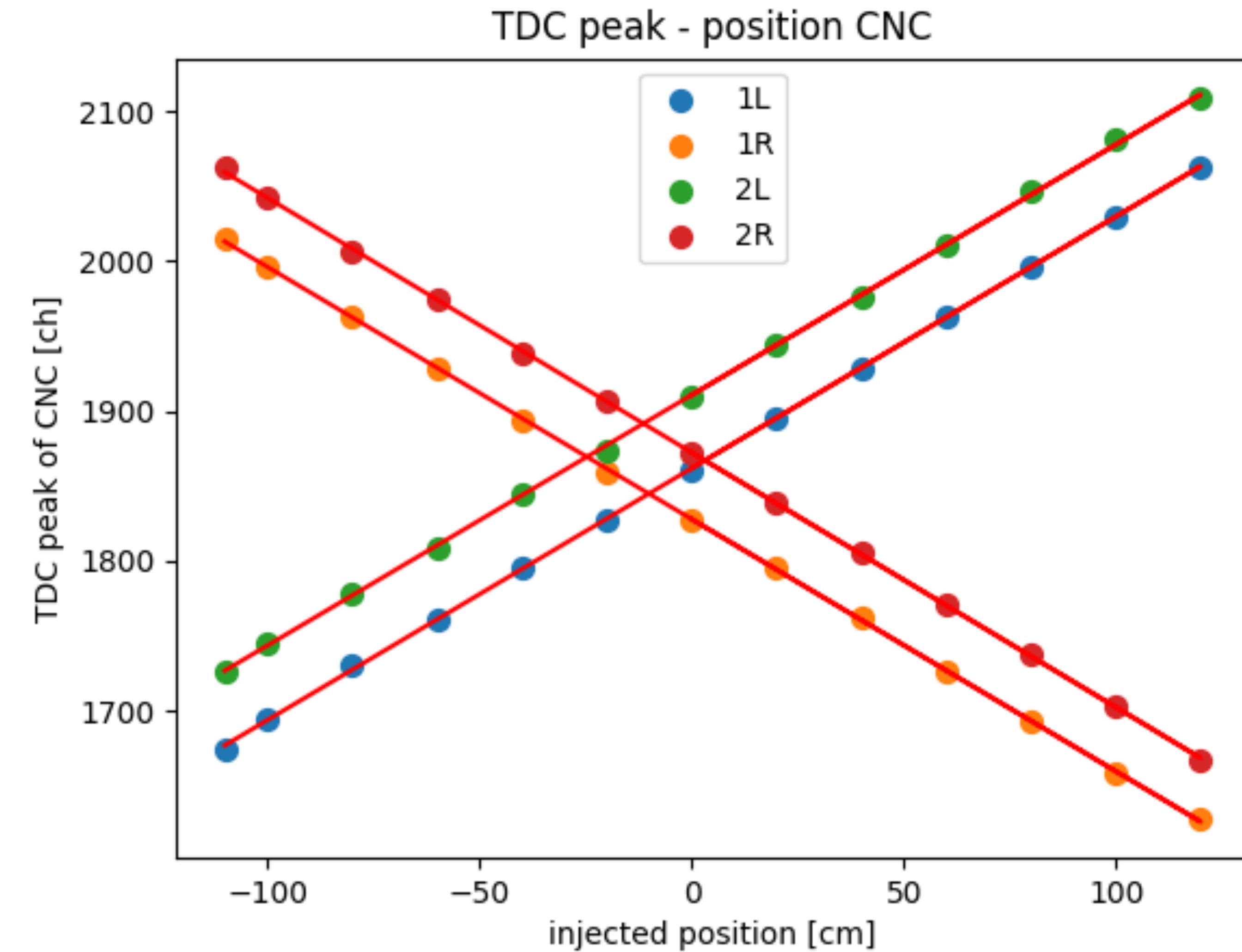
Red : all tdc != -1



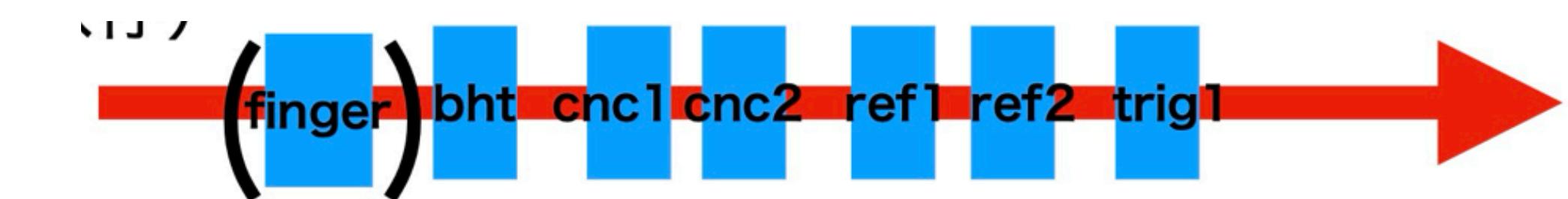
# 1. CNC time resolution



- like disciplined data
- ~18ch/10cm

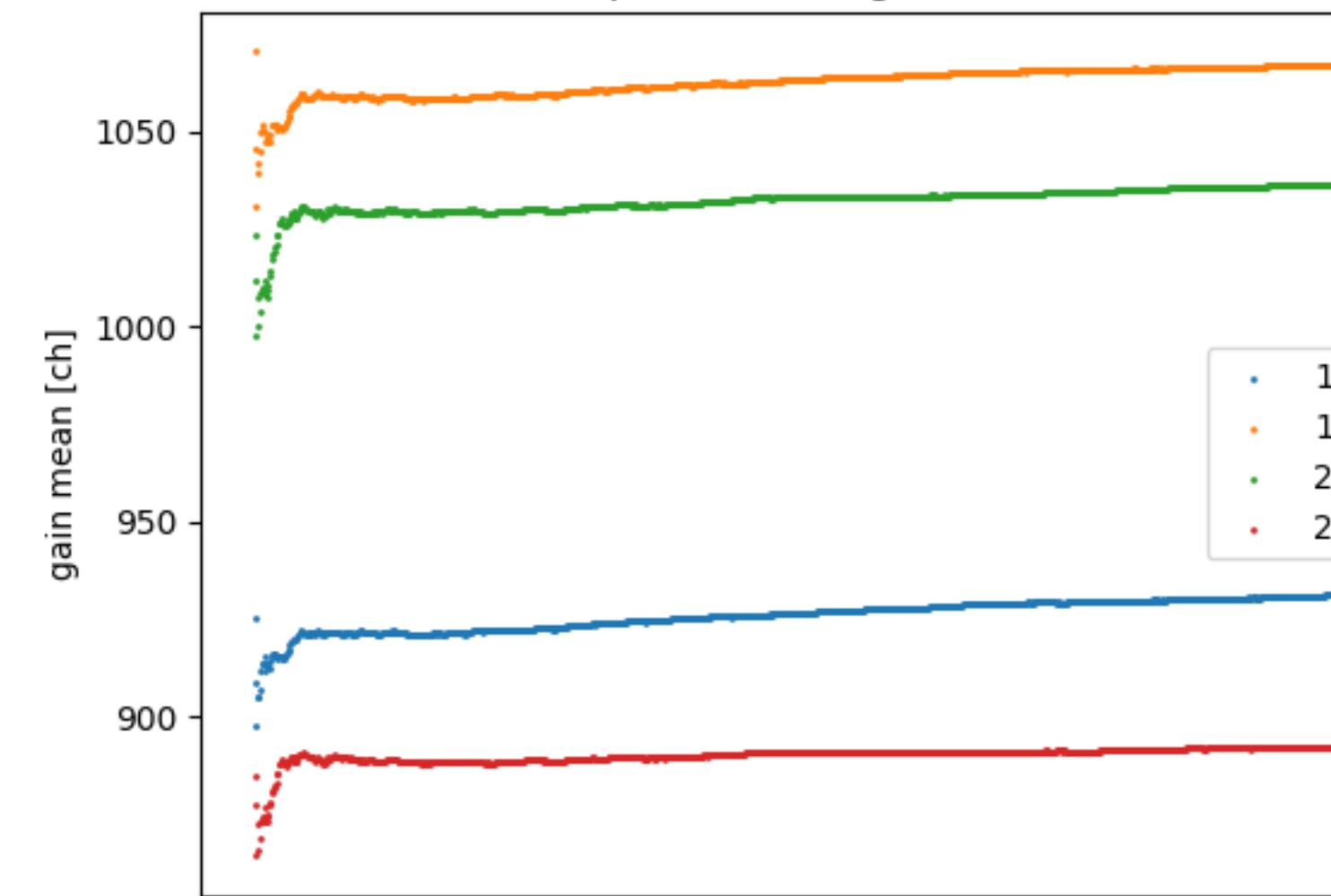


# 1. CNC time resolution

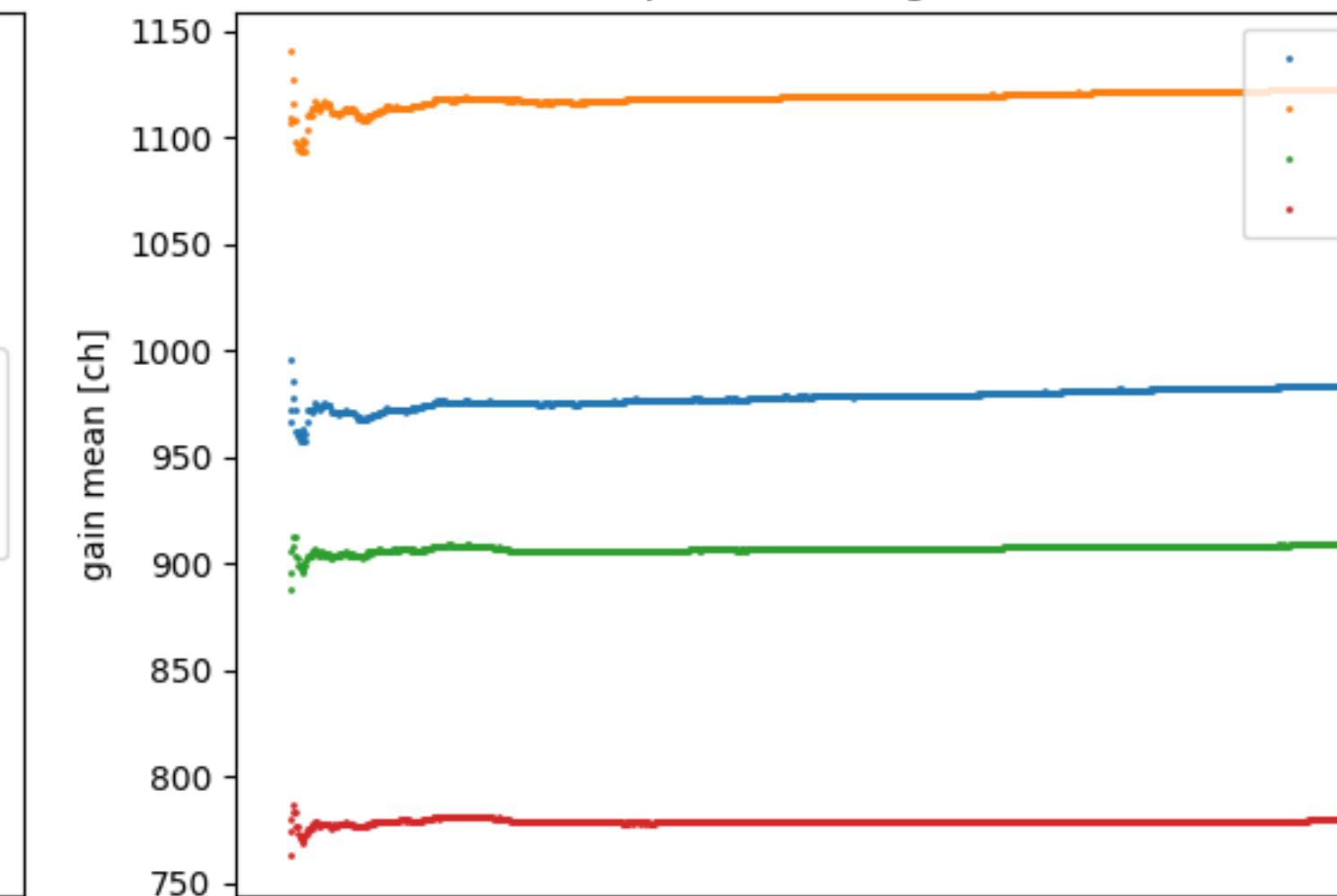


## QDC stability

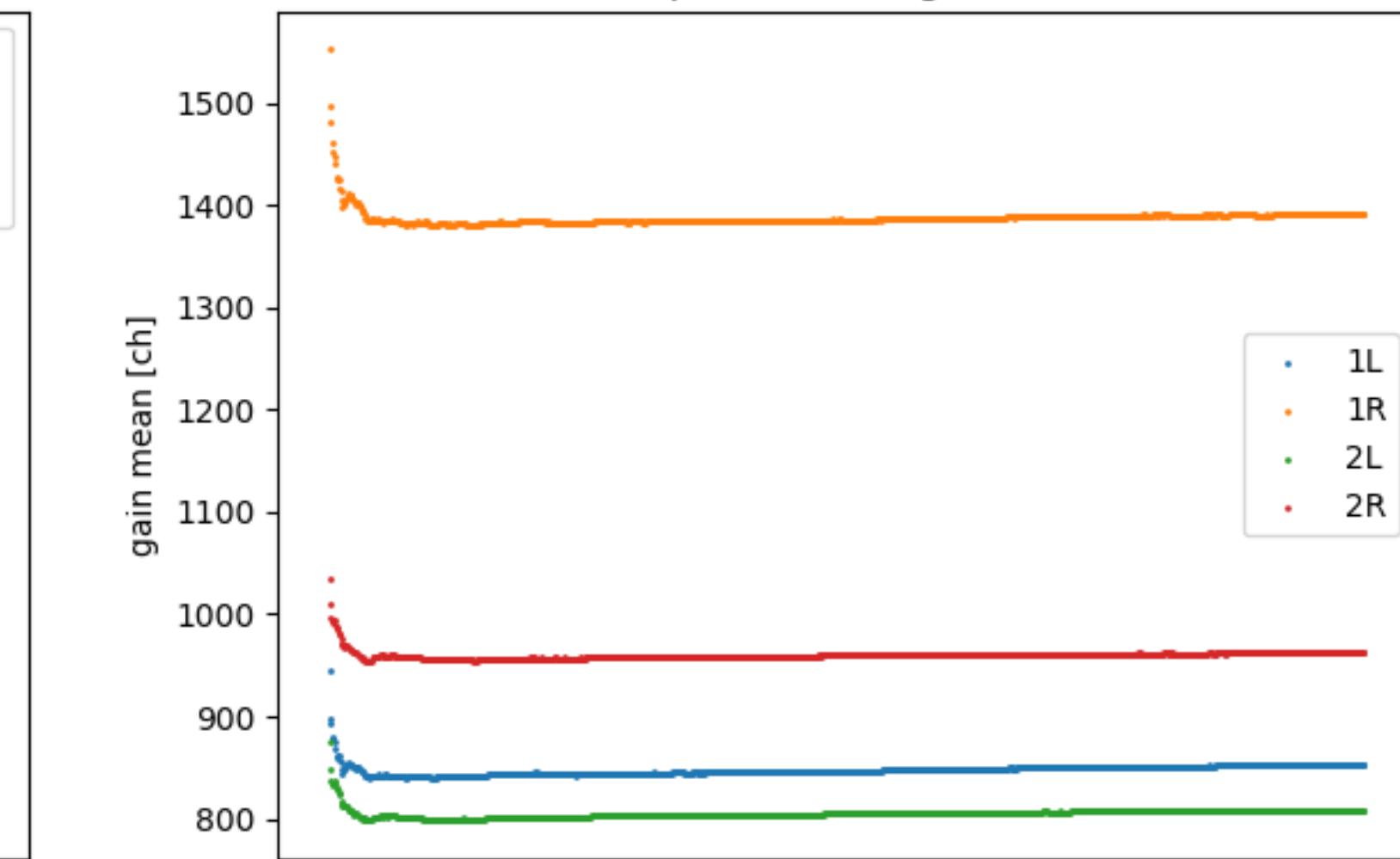
time dependence of gain in run22



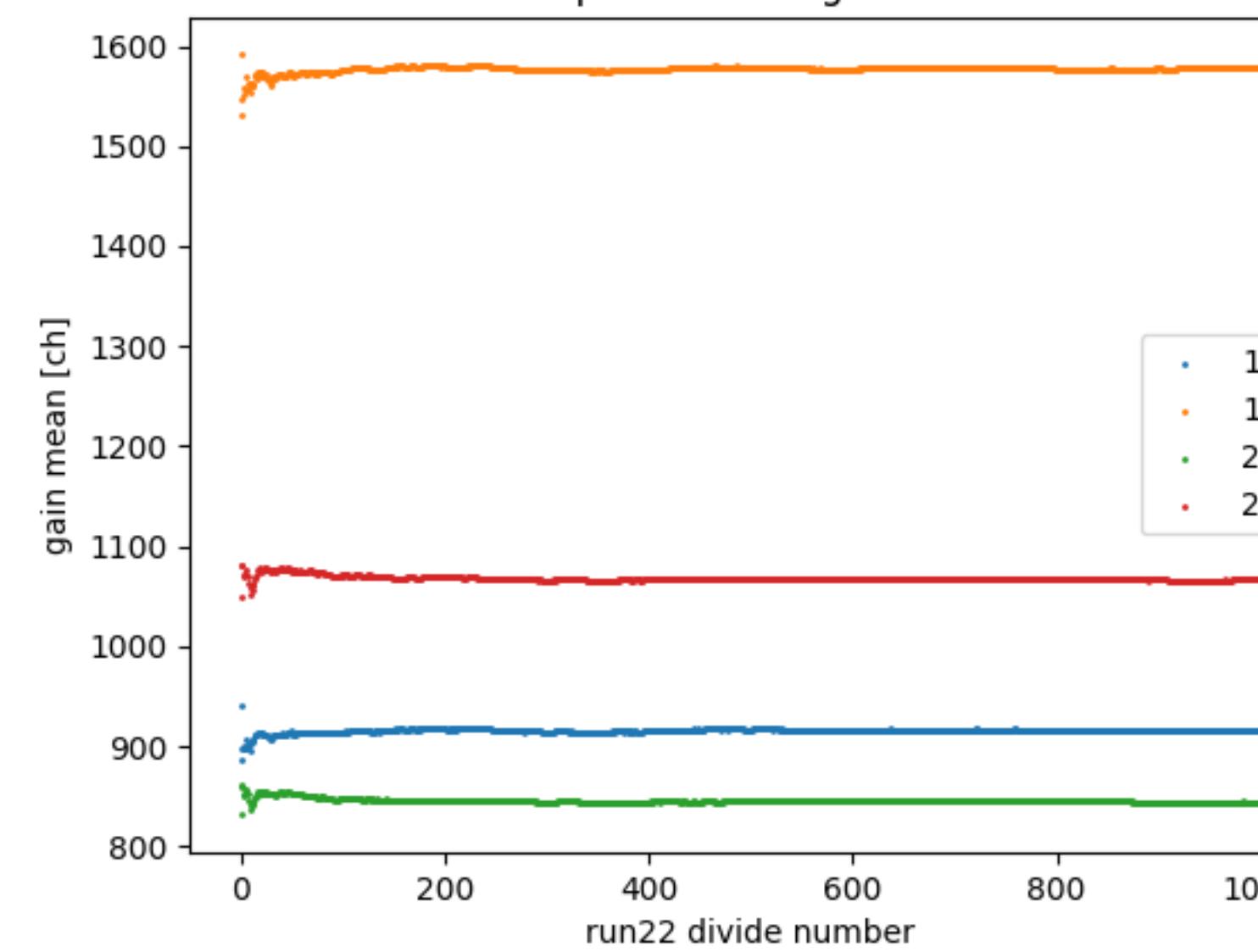
time dependence of gain in run23



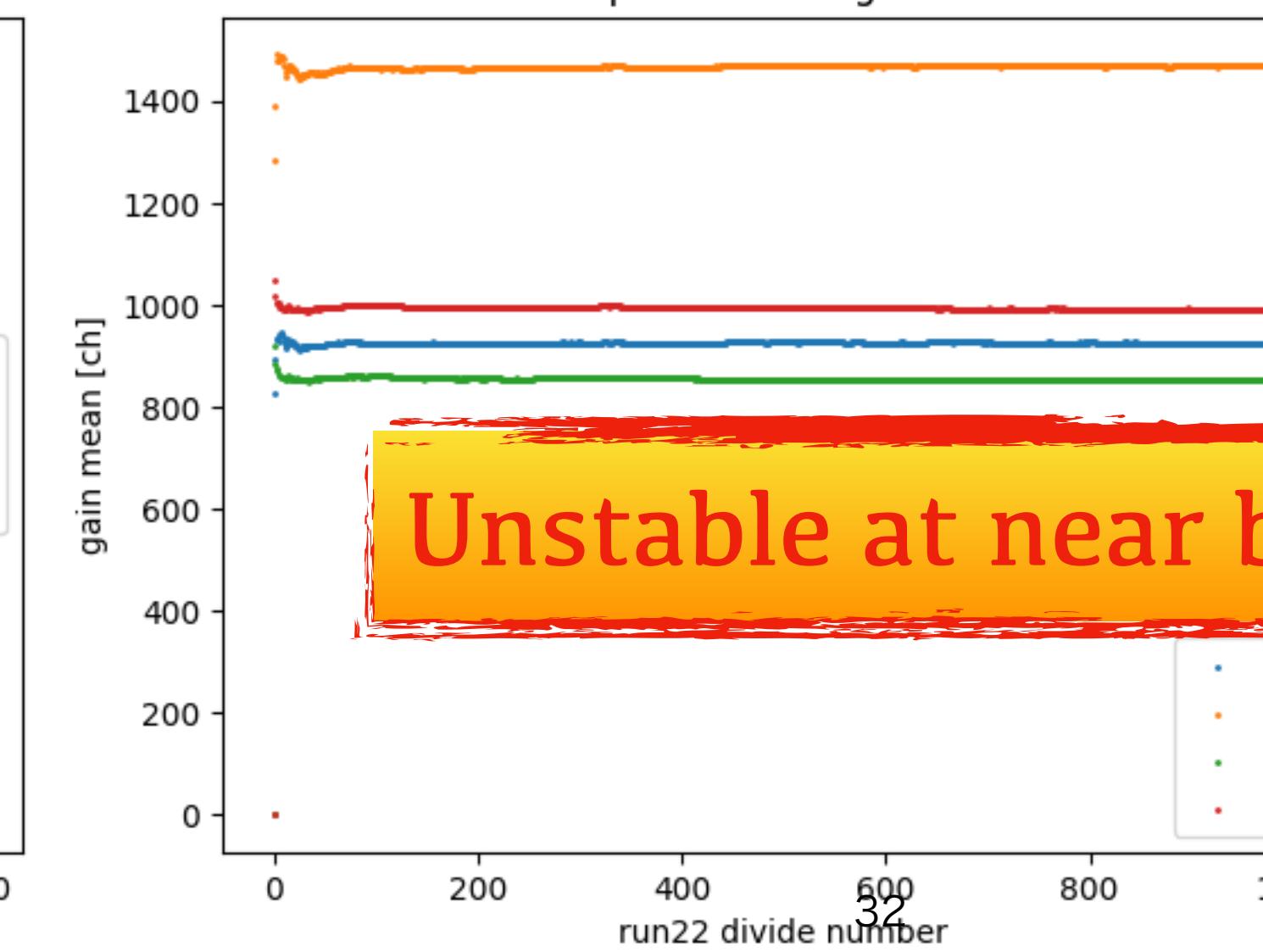
time dependence of gain in run24



time dependence of gain in run25

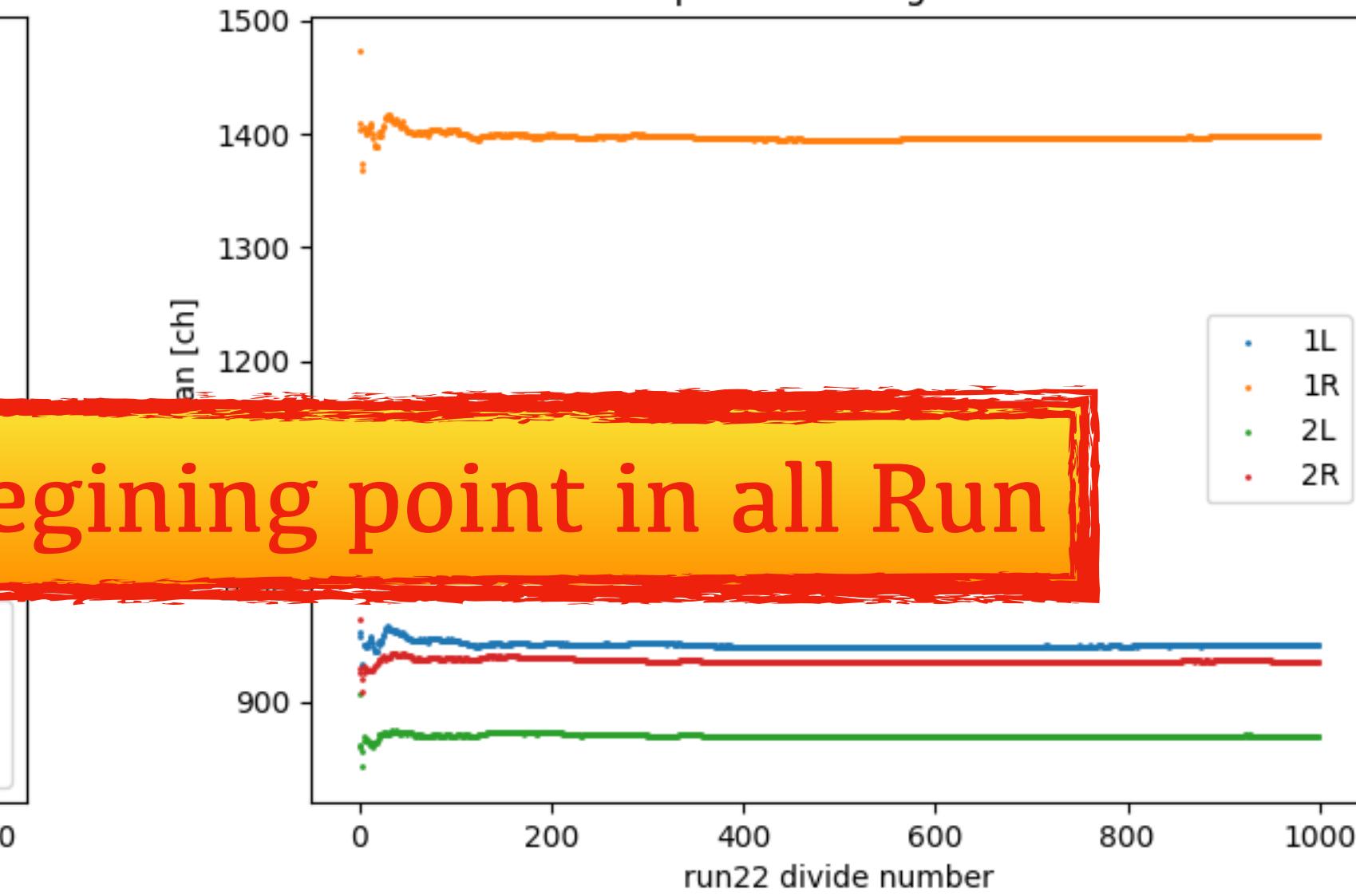


time dependence of gain in run27

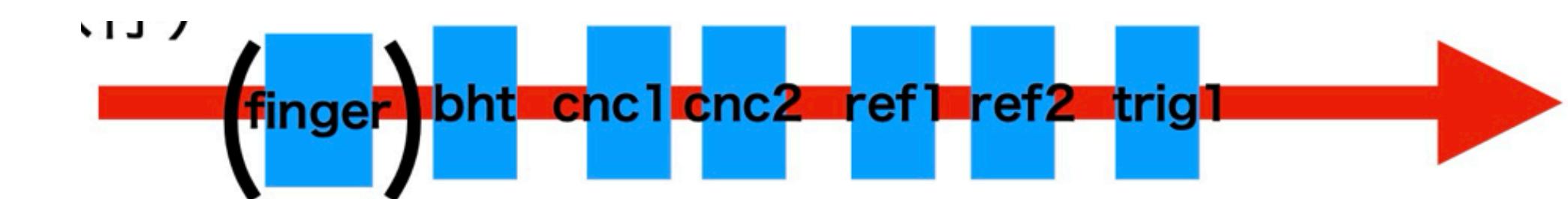


Unstable at near beginning point in all Run

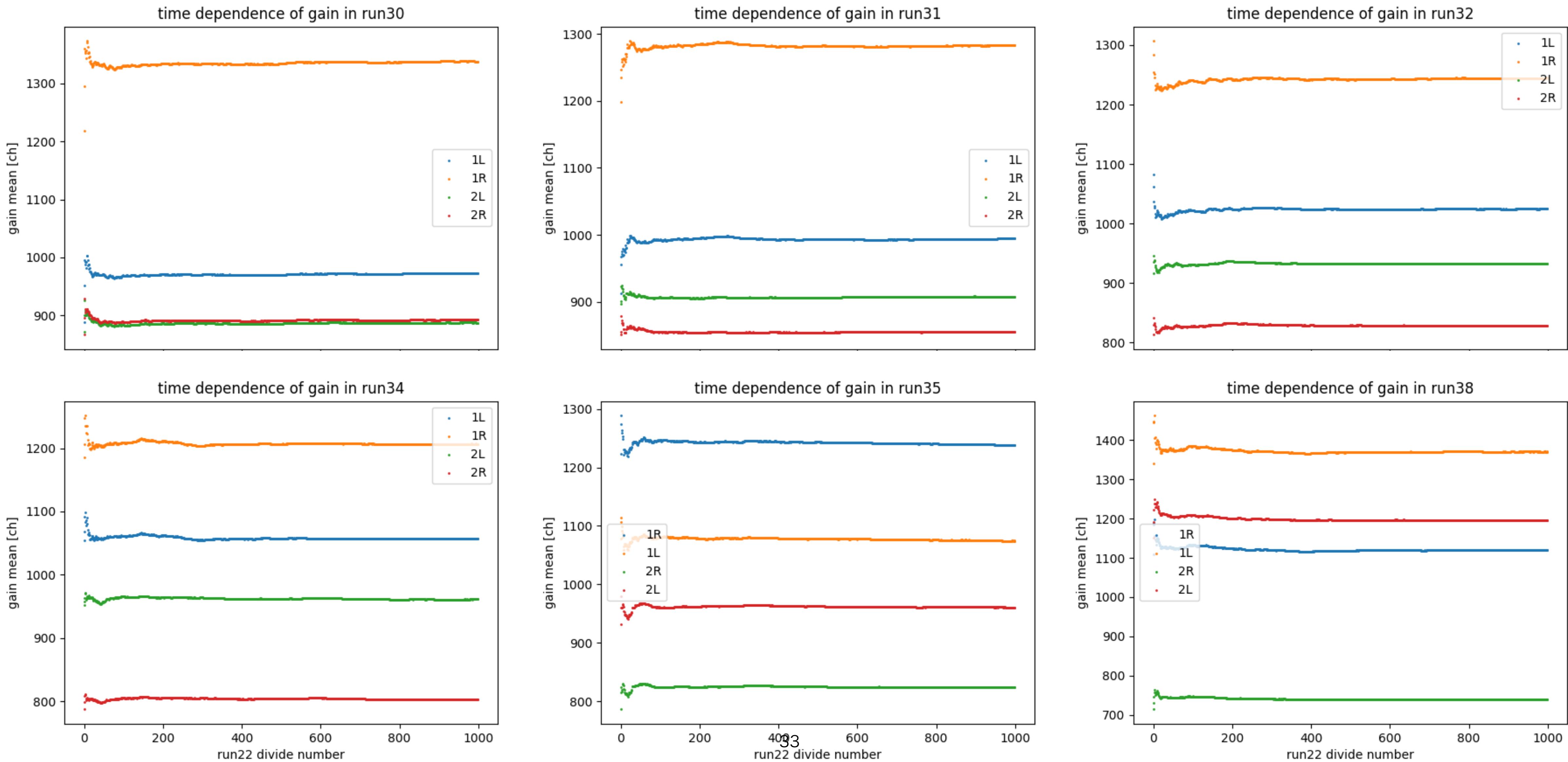
time dependence of gain in run29



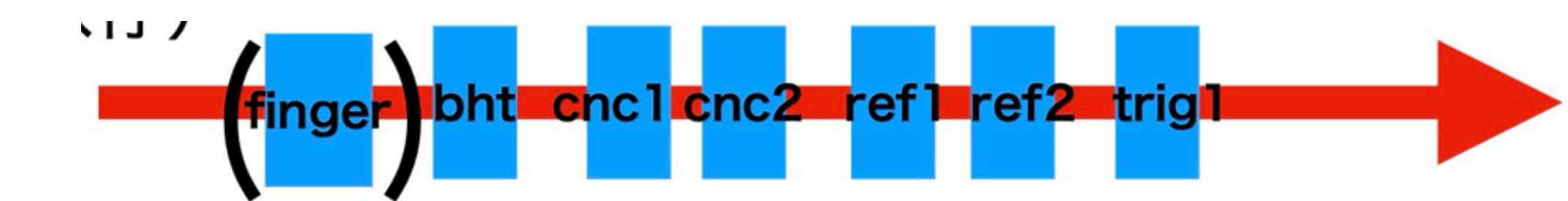
# 1. CNC time resolution



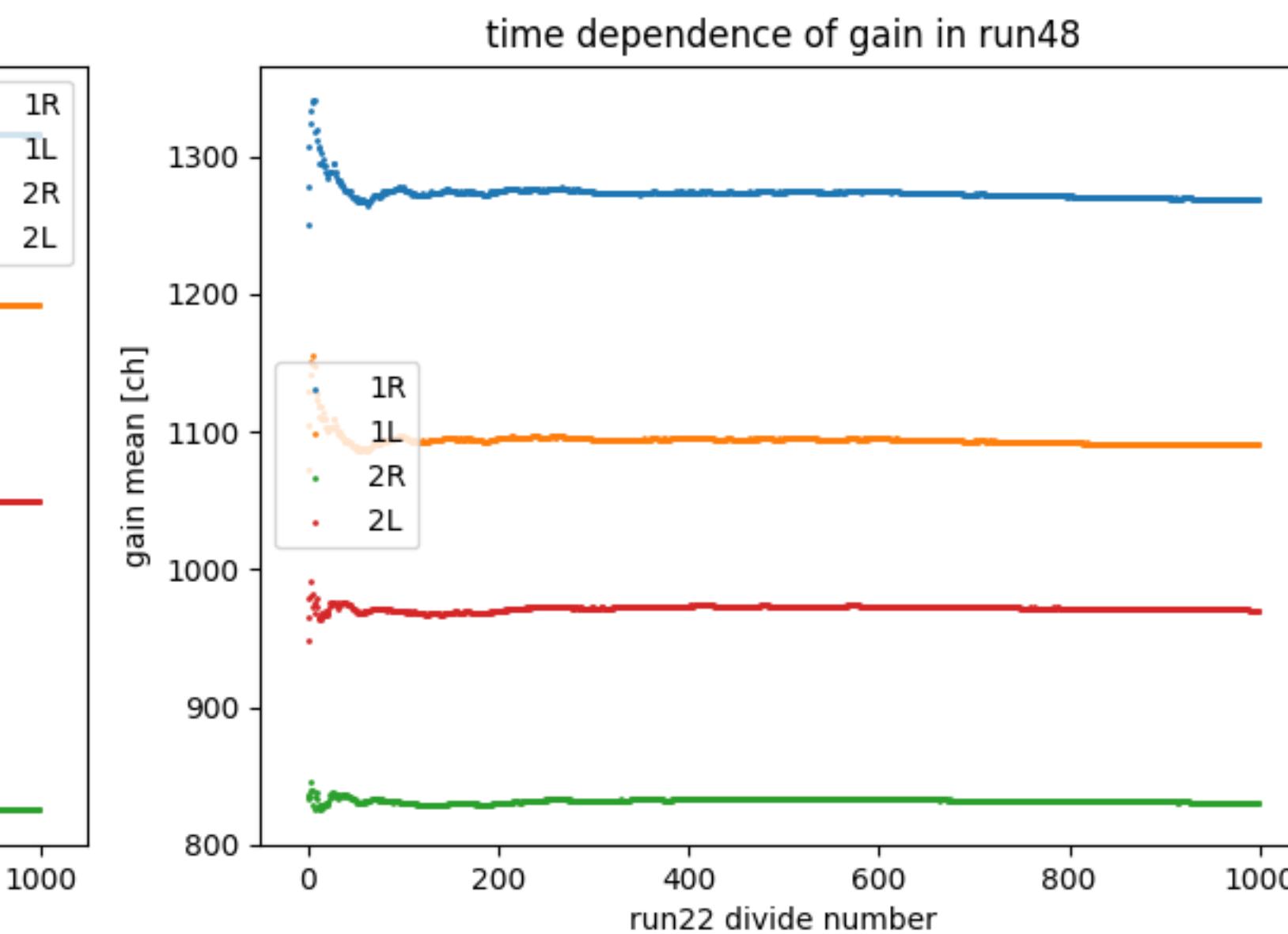
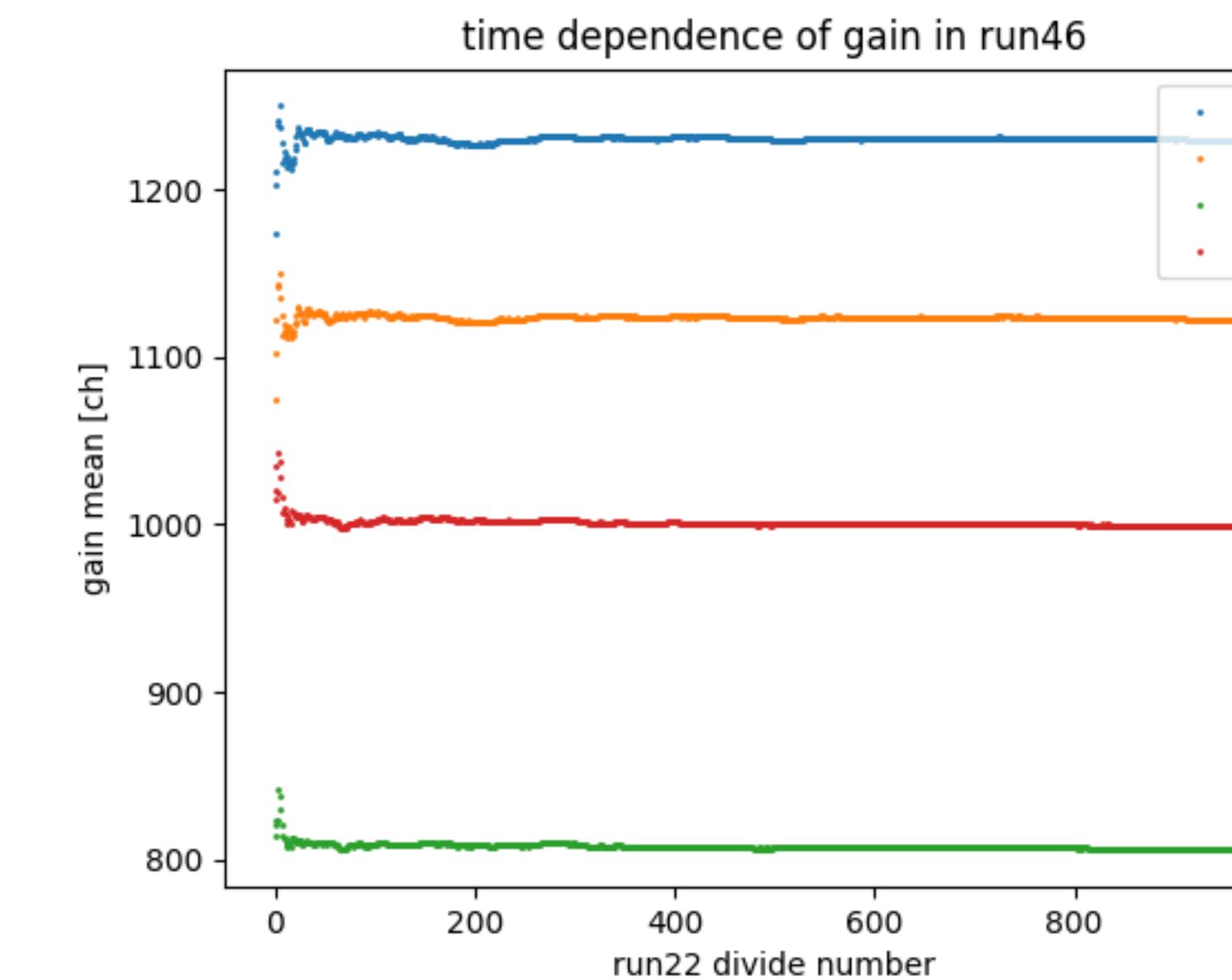
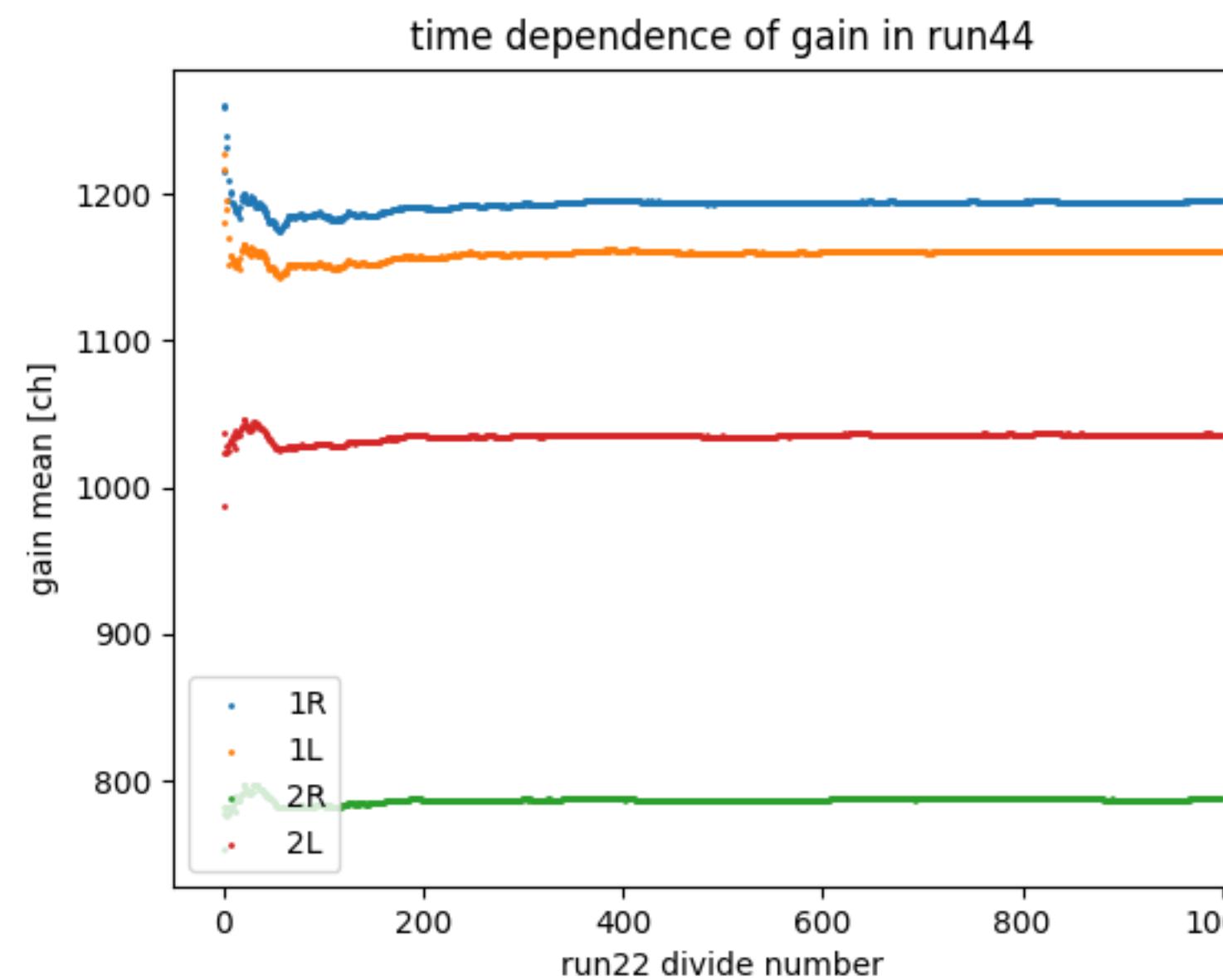
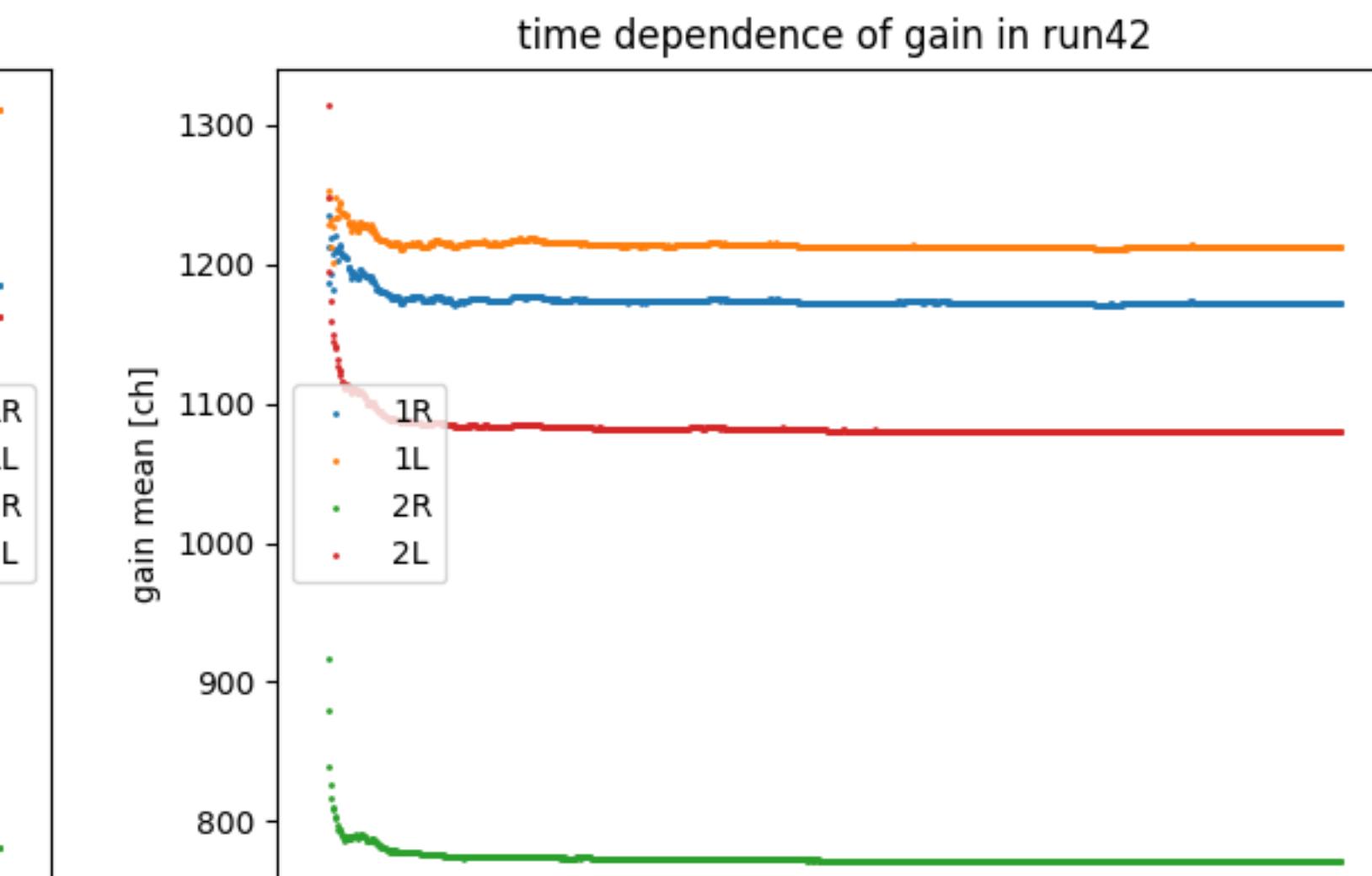
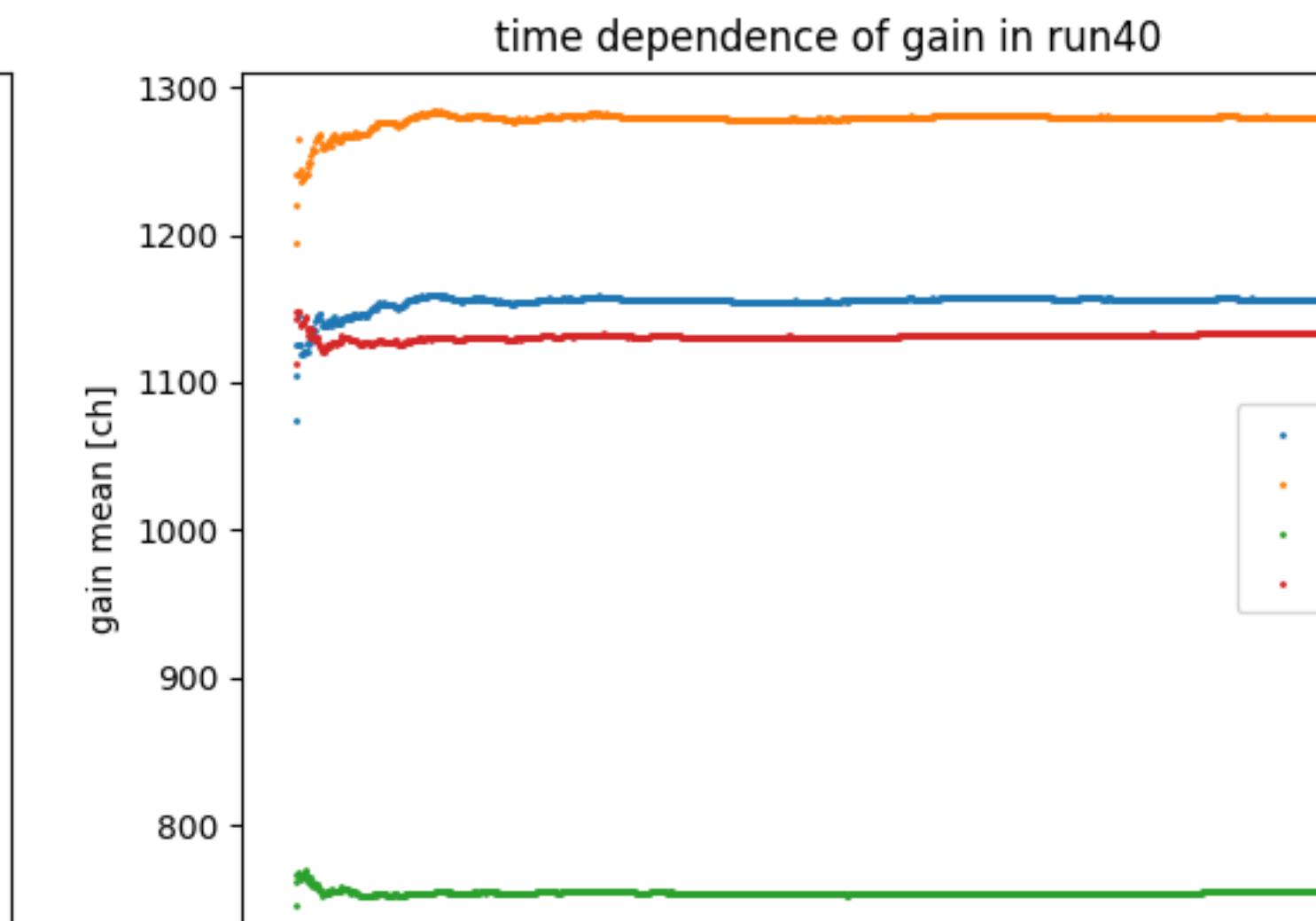
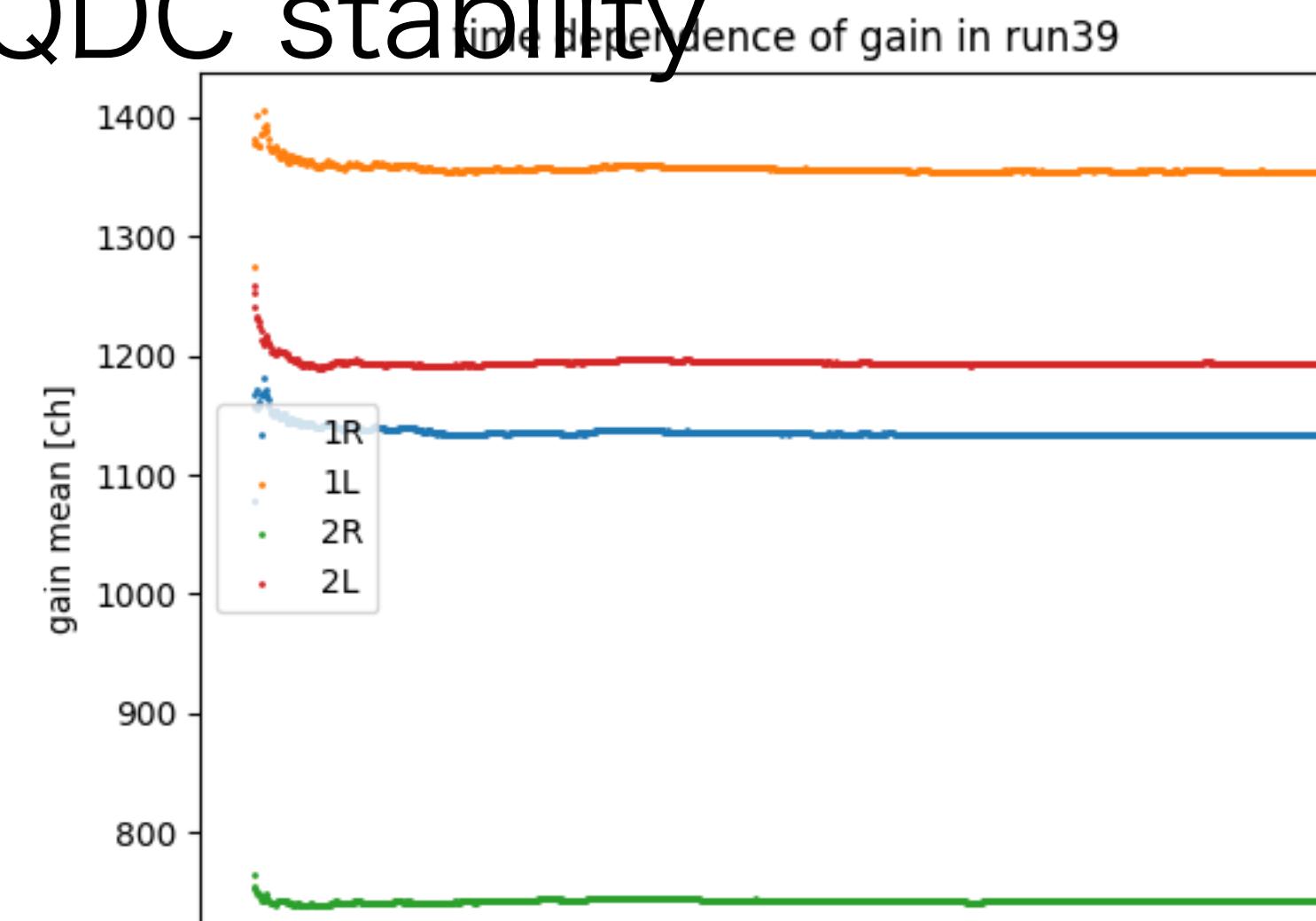
## CNC's QDC stability



# 1. CNC time resolution

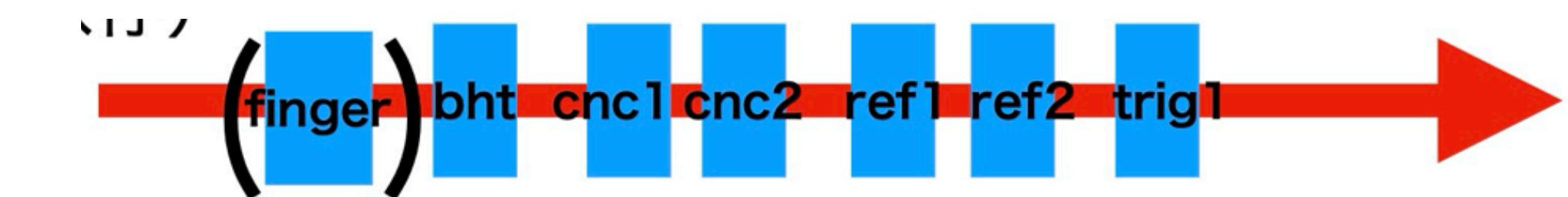


## QDC stability

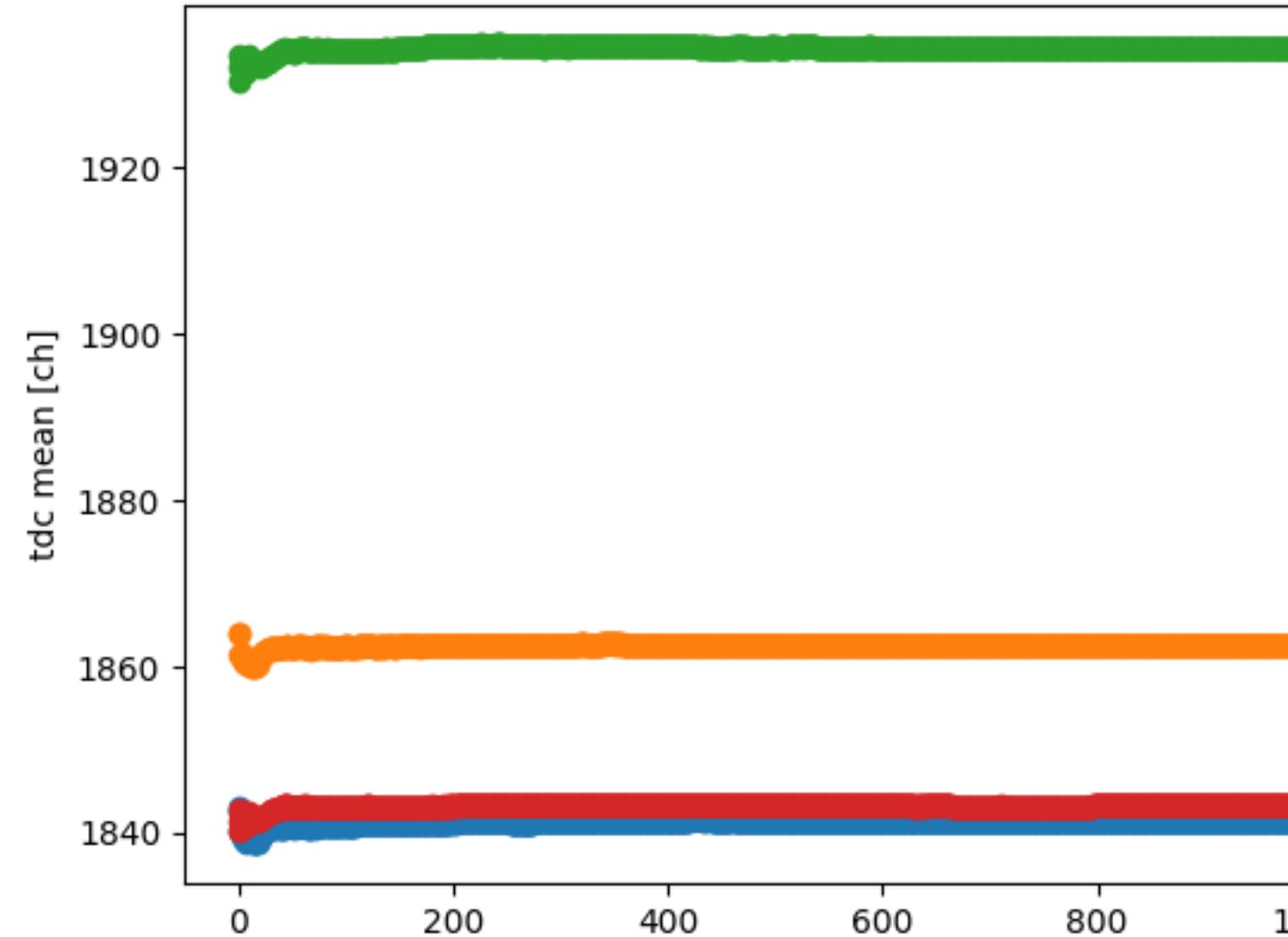


# 1. CNC time resolution

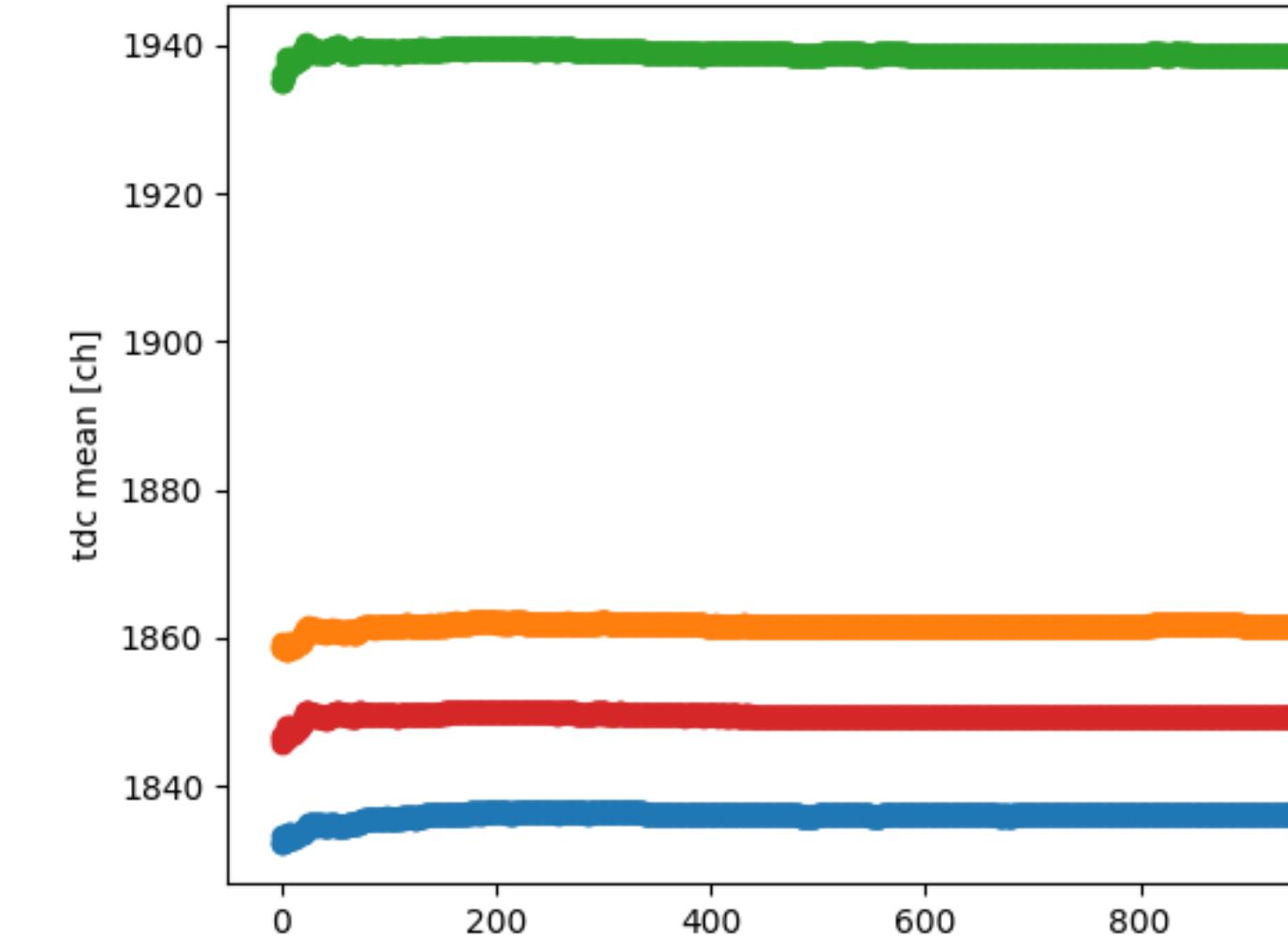
## CNC's TDC stability



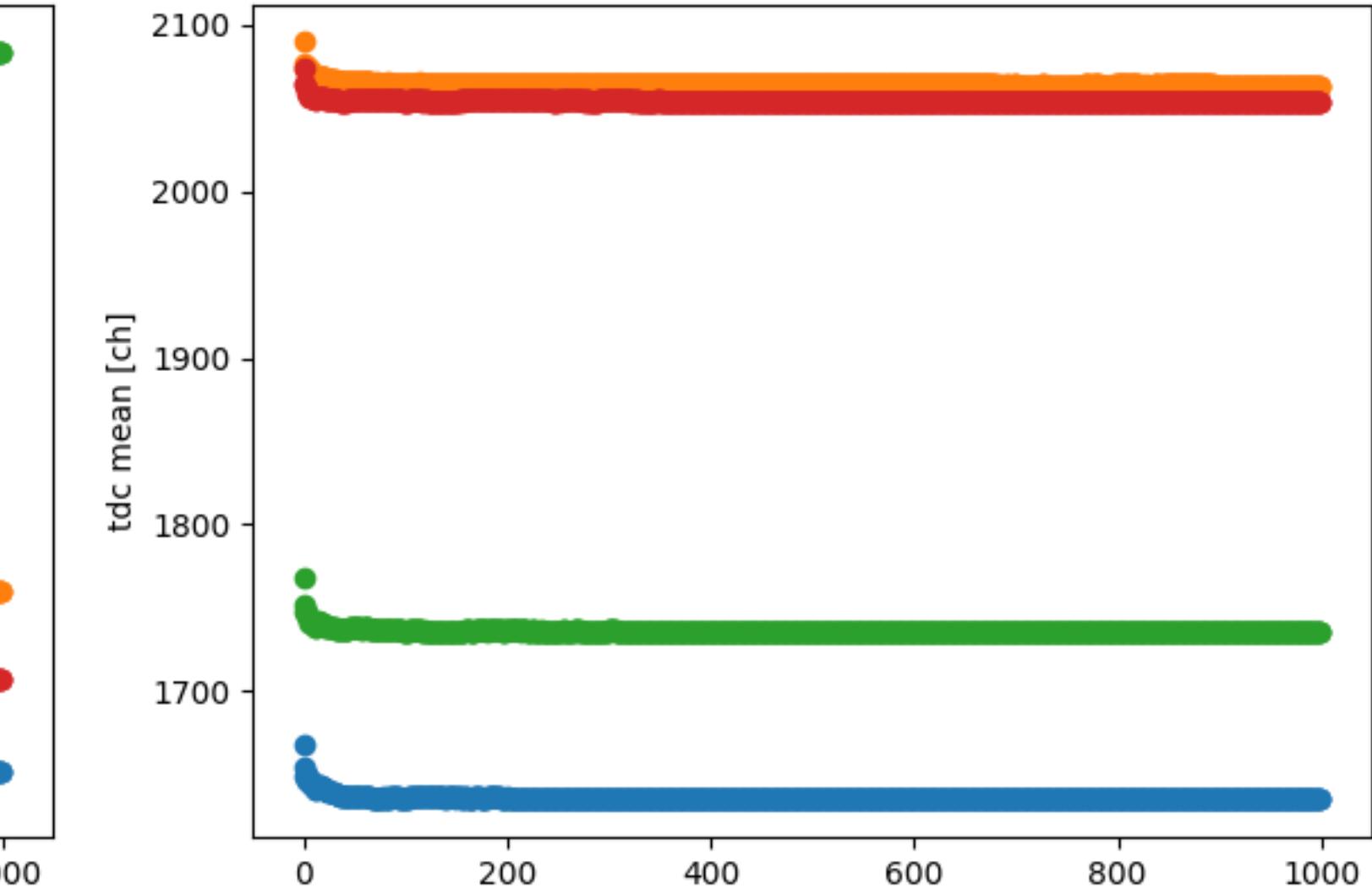
time dependence of tdc in run22



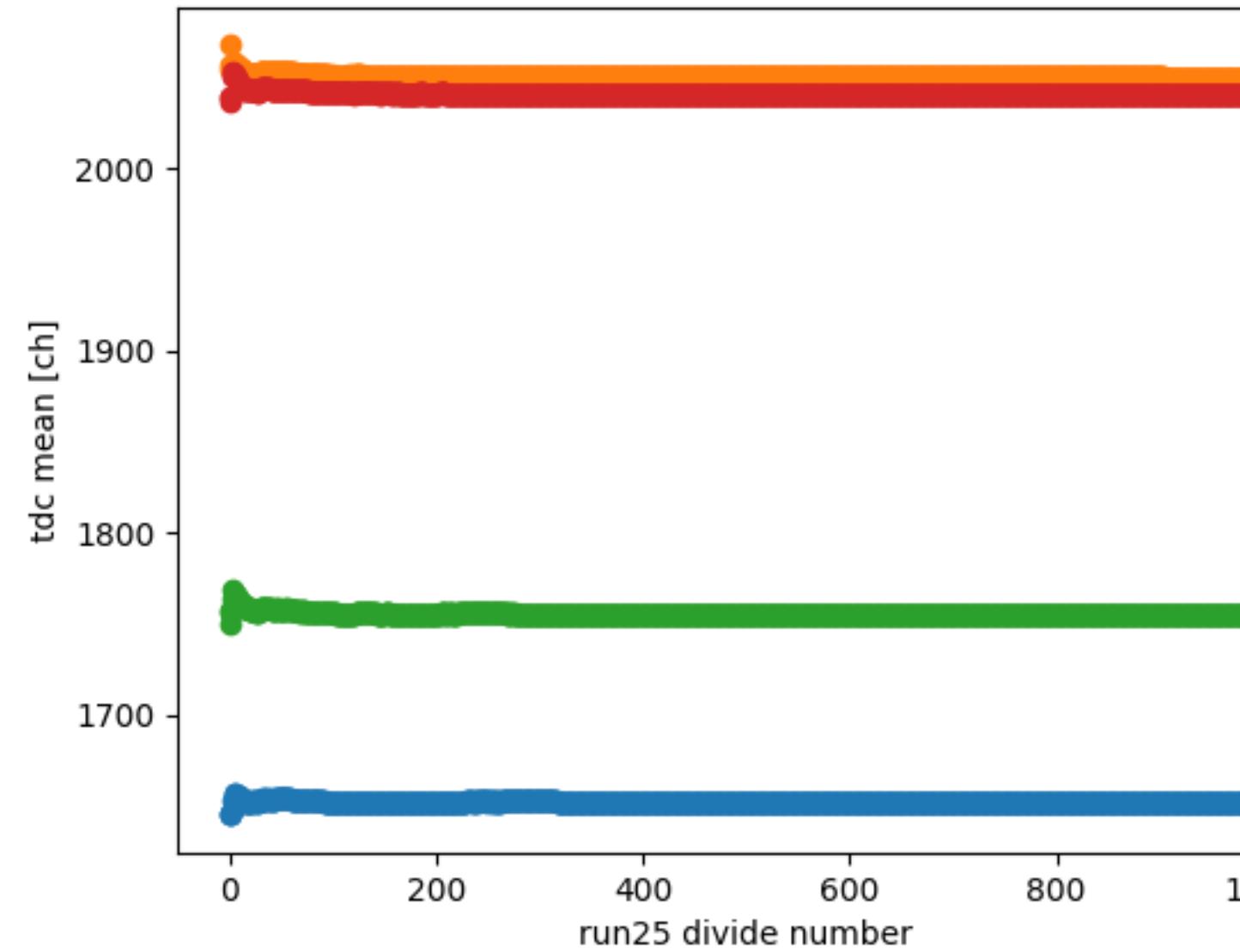
time dependence of tdc in run23



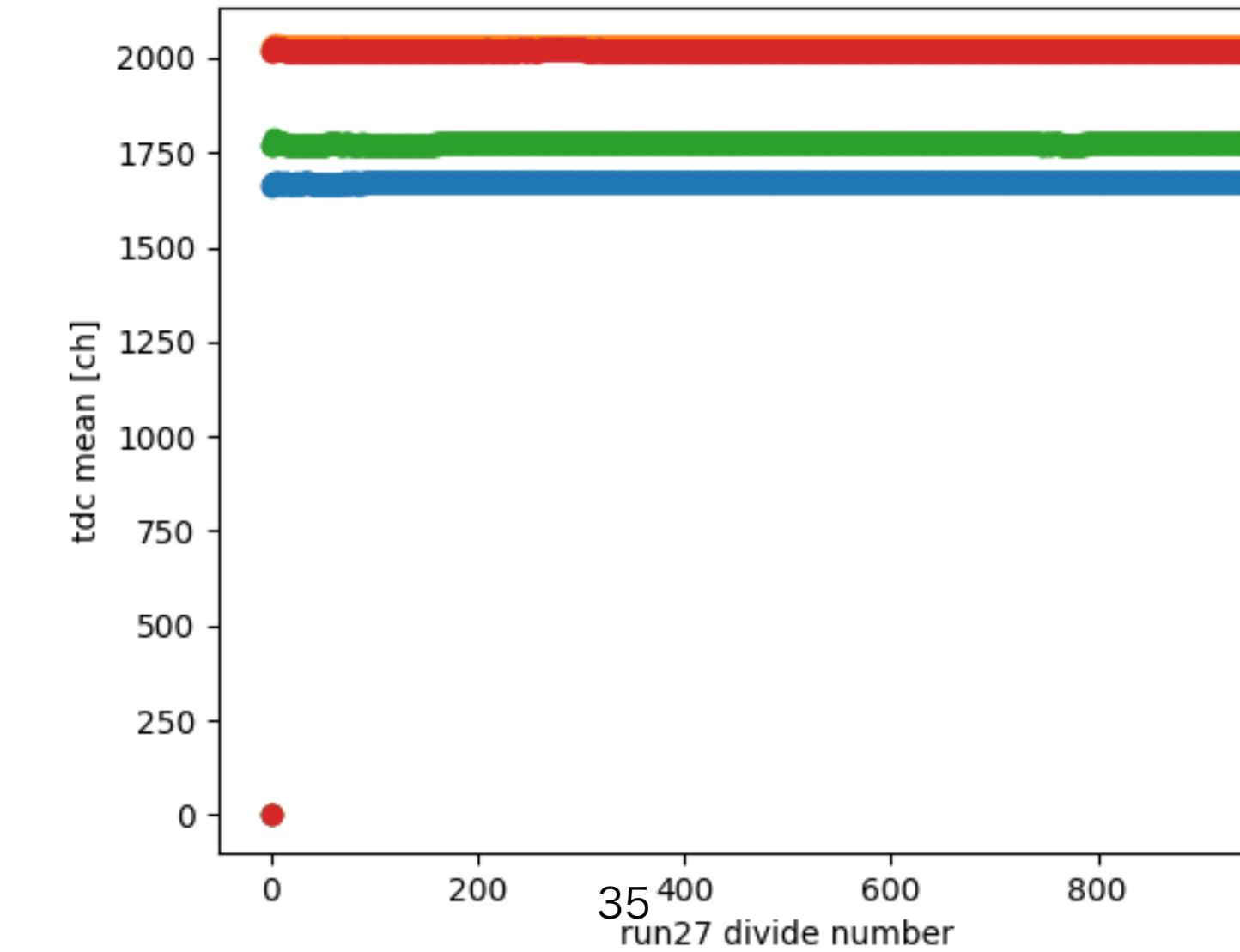
time dependence of tdc in run24



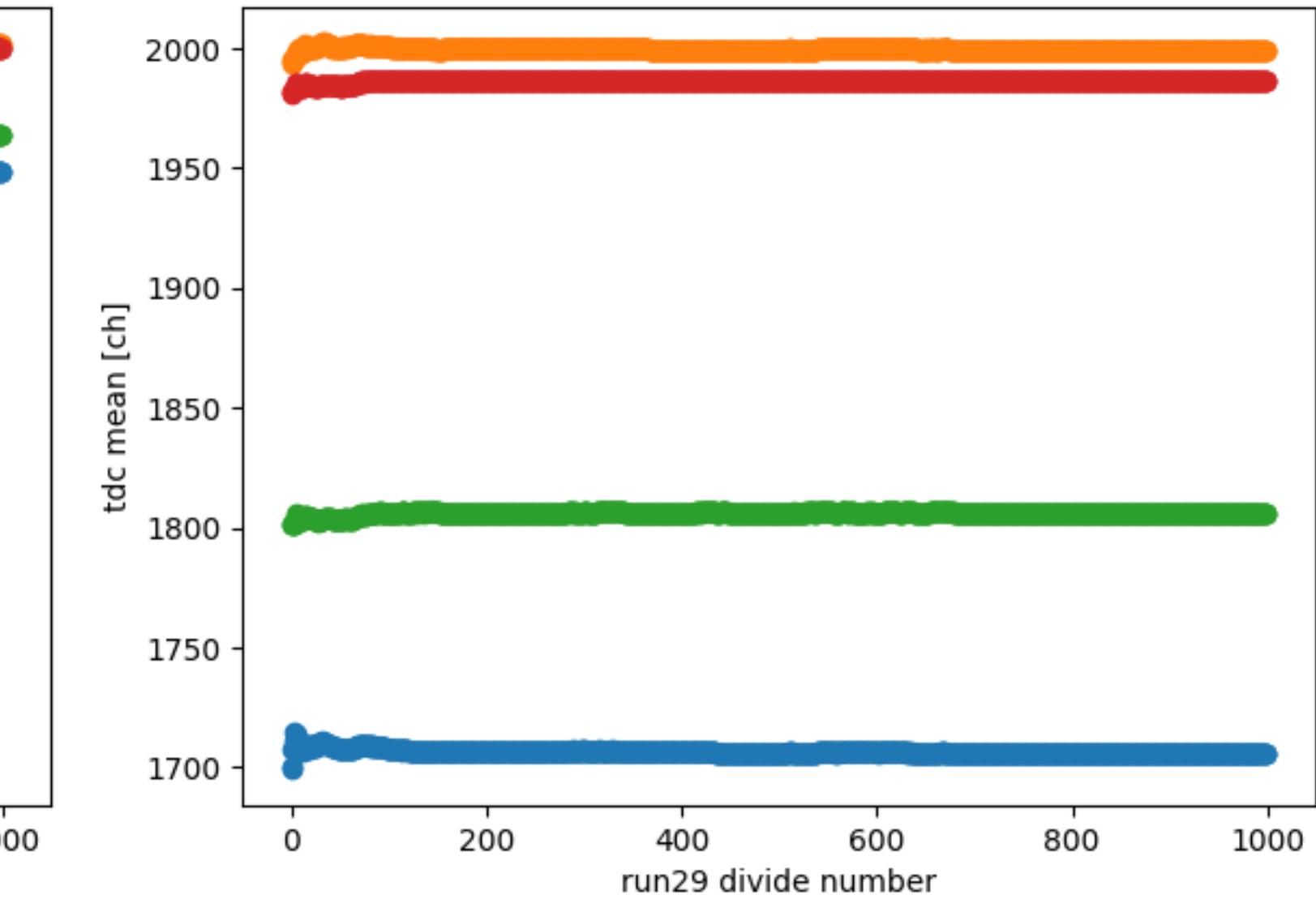
time dependence of tdc in run25



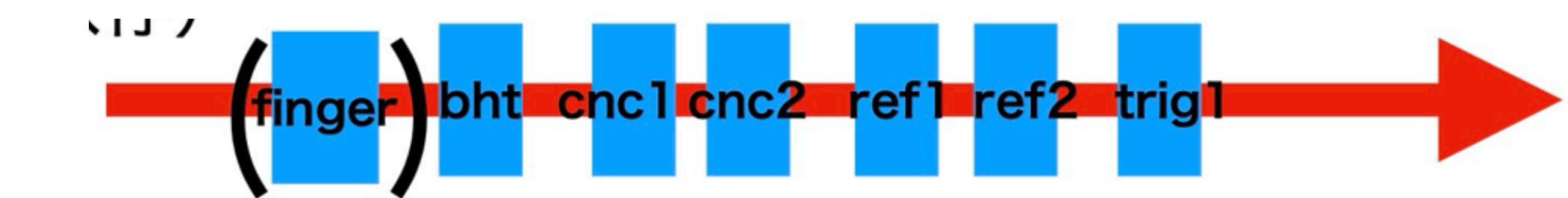
time dependence of tdc in run27



time dependence of tdc in run29

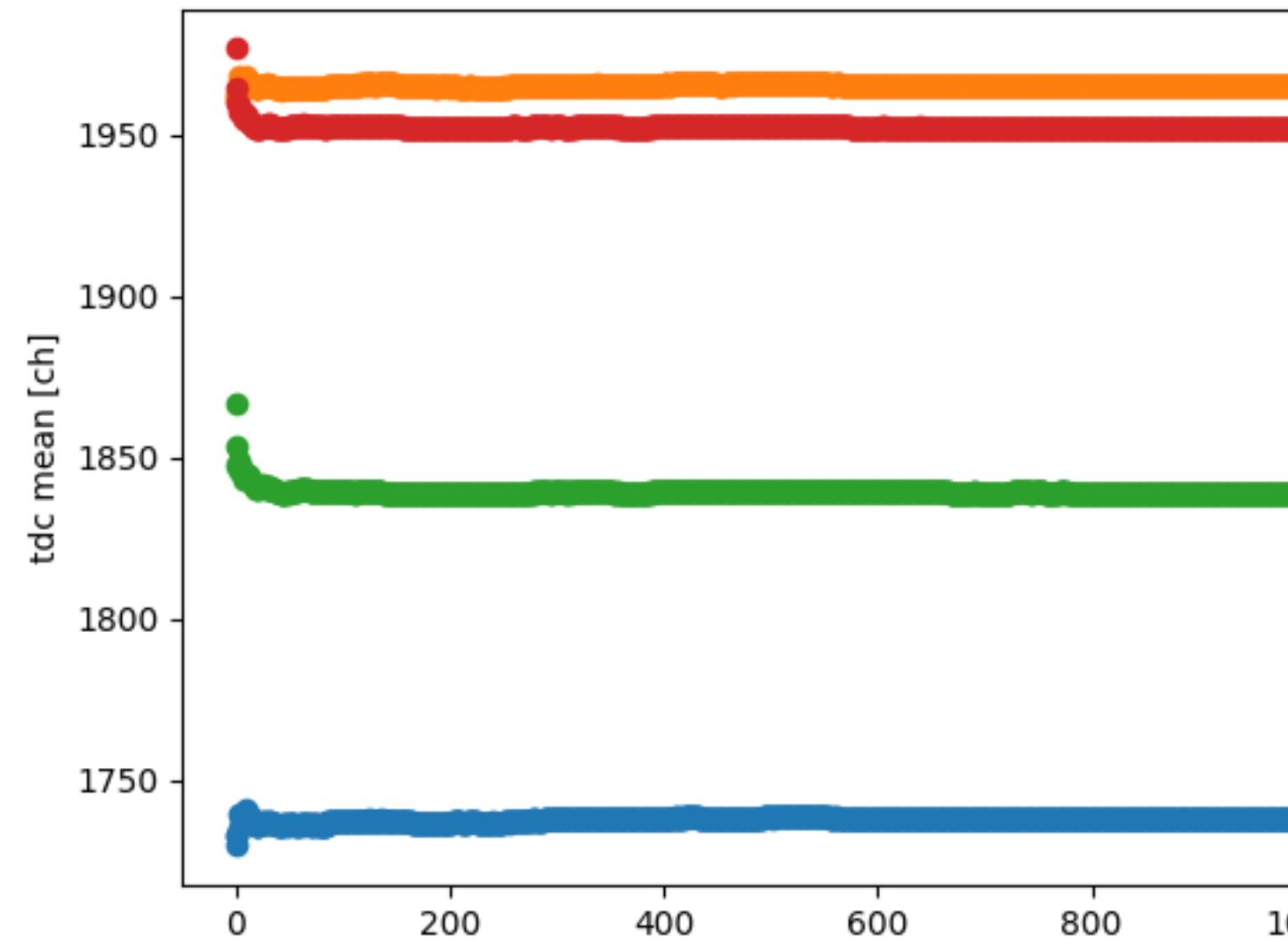


# 1. CNC time resolution

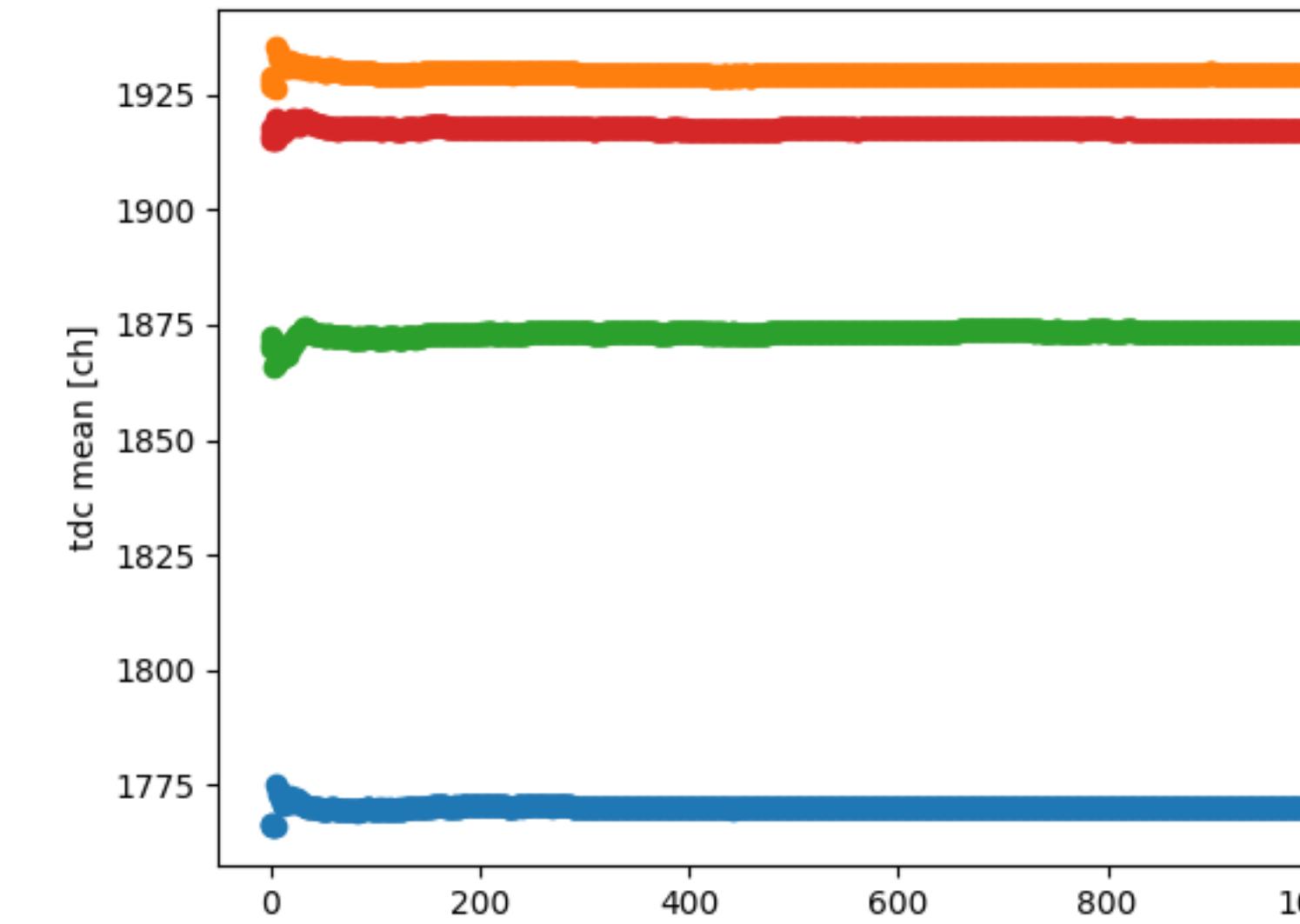


## CNC's TDC stability

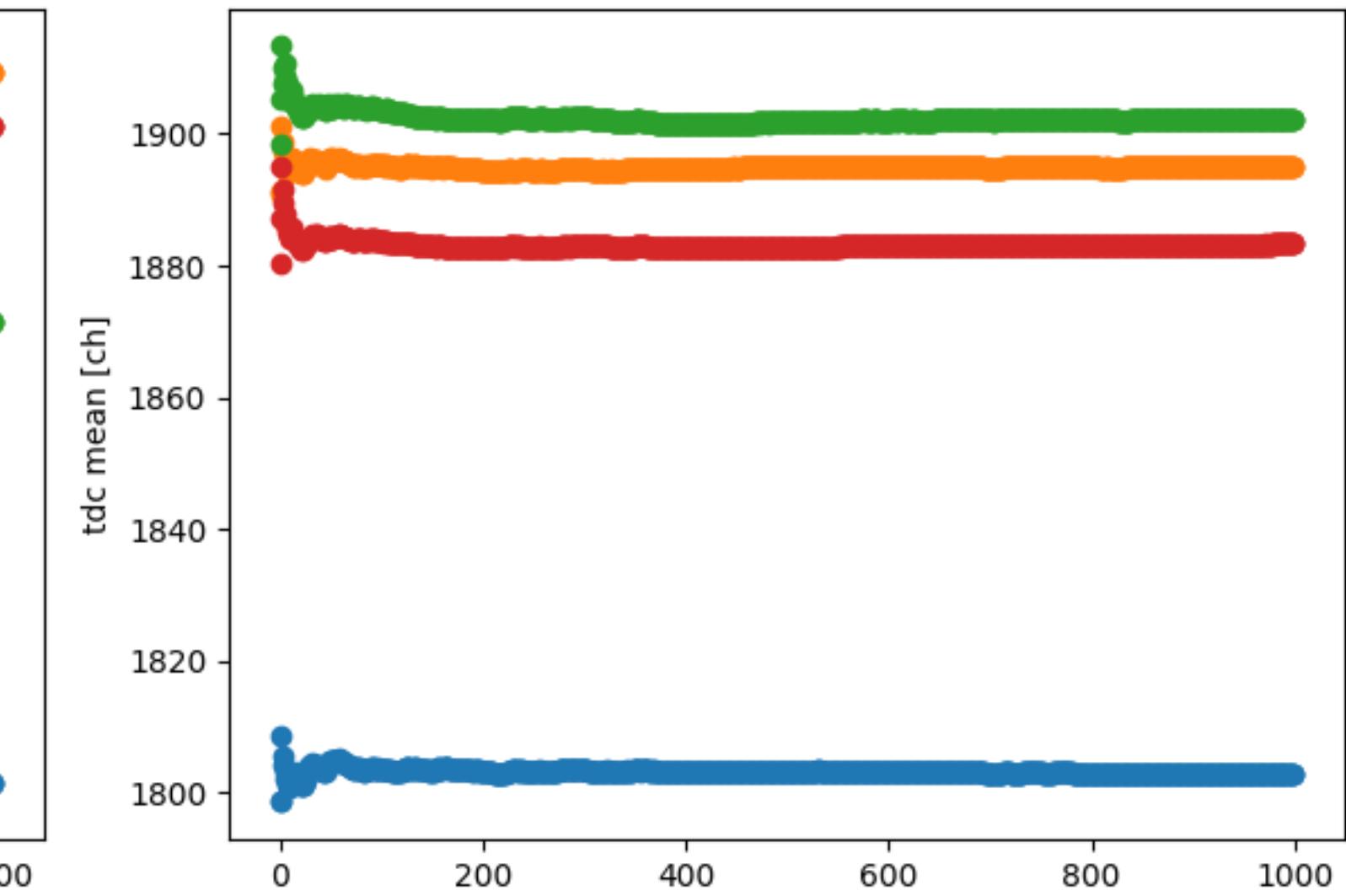
time dependence of tdc in run030



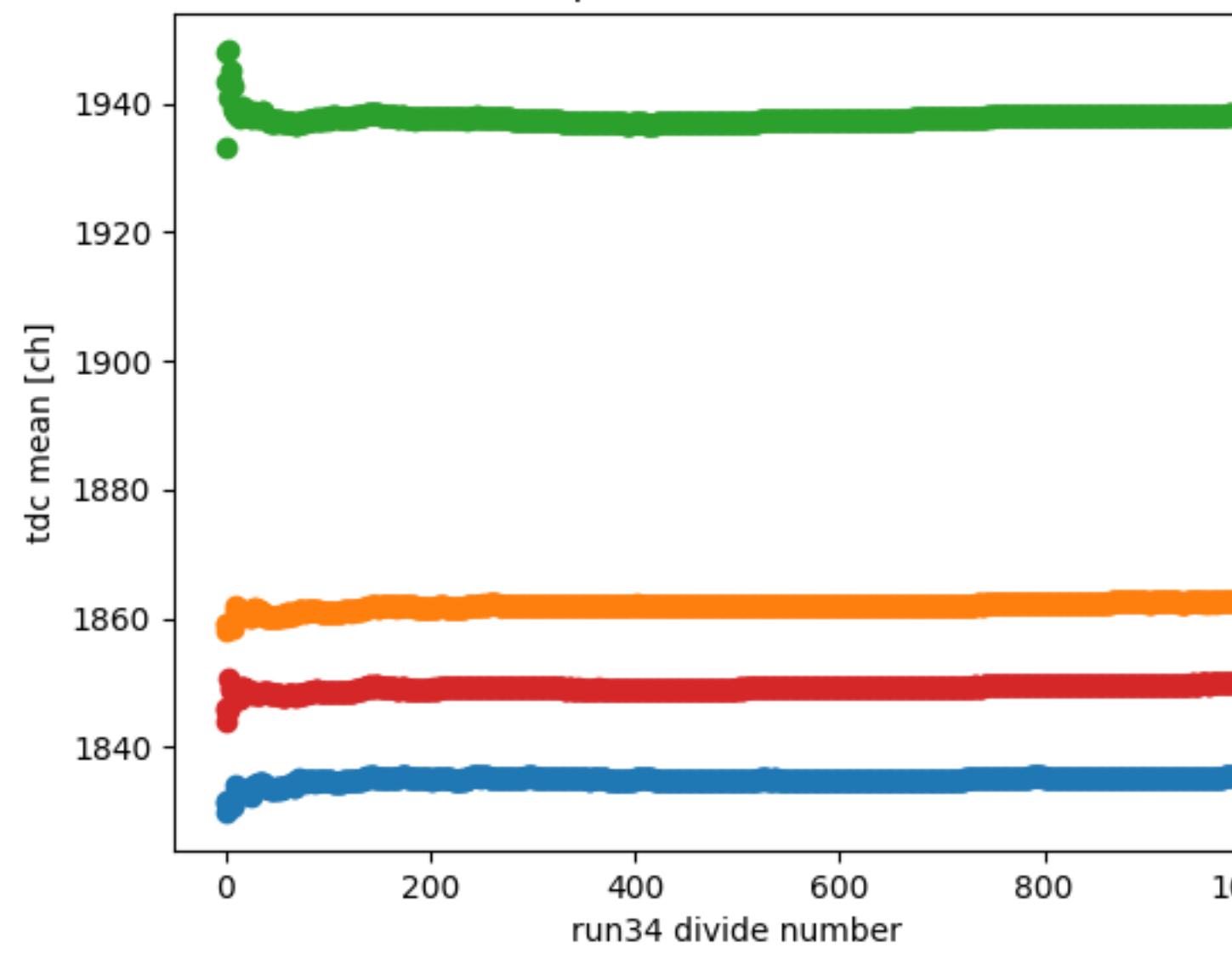
time dependence of tdc in run31



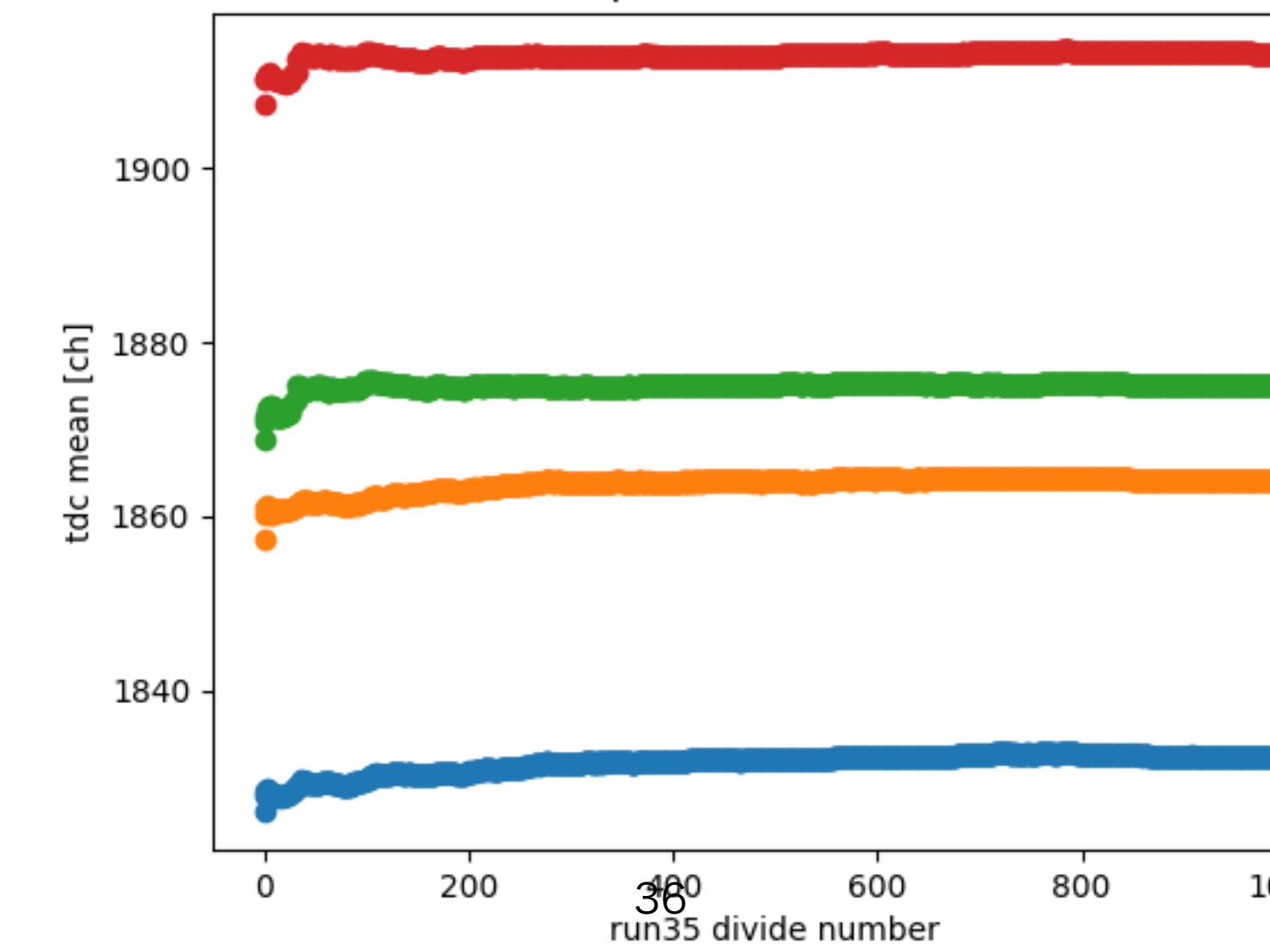
time dependence of tdc in run32



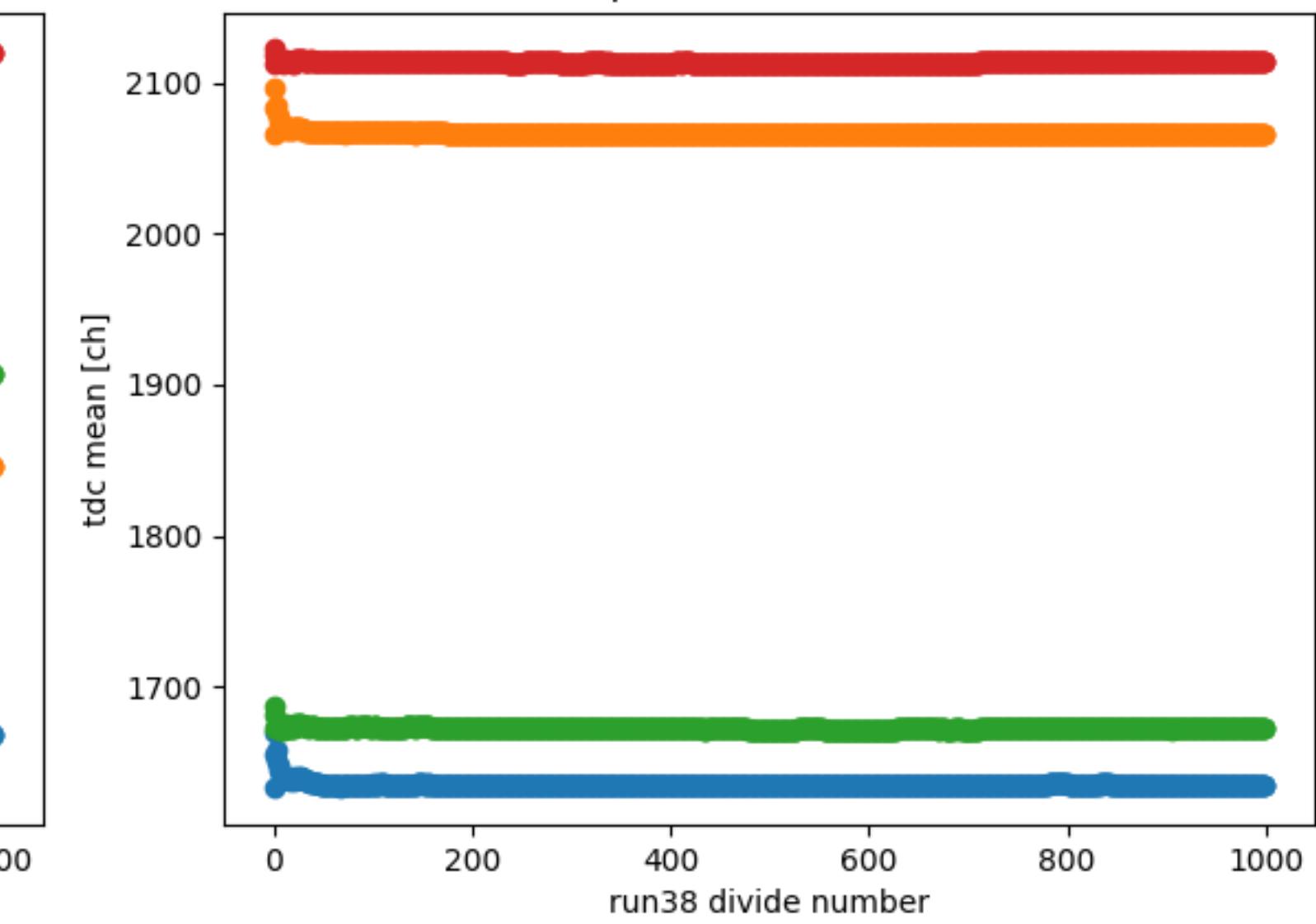
time dependence of tdc in run34



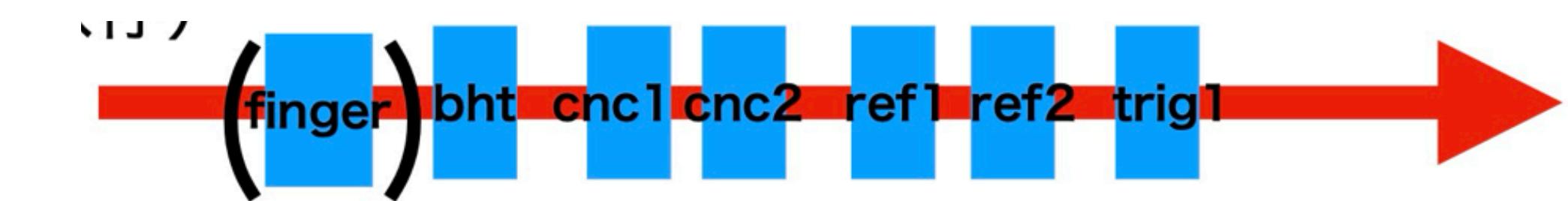
time dependence of tdc in run35



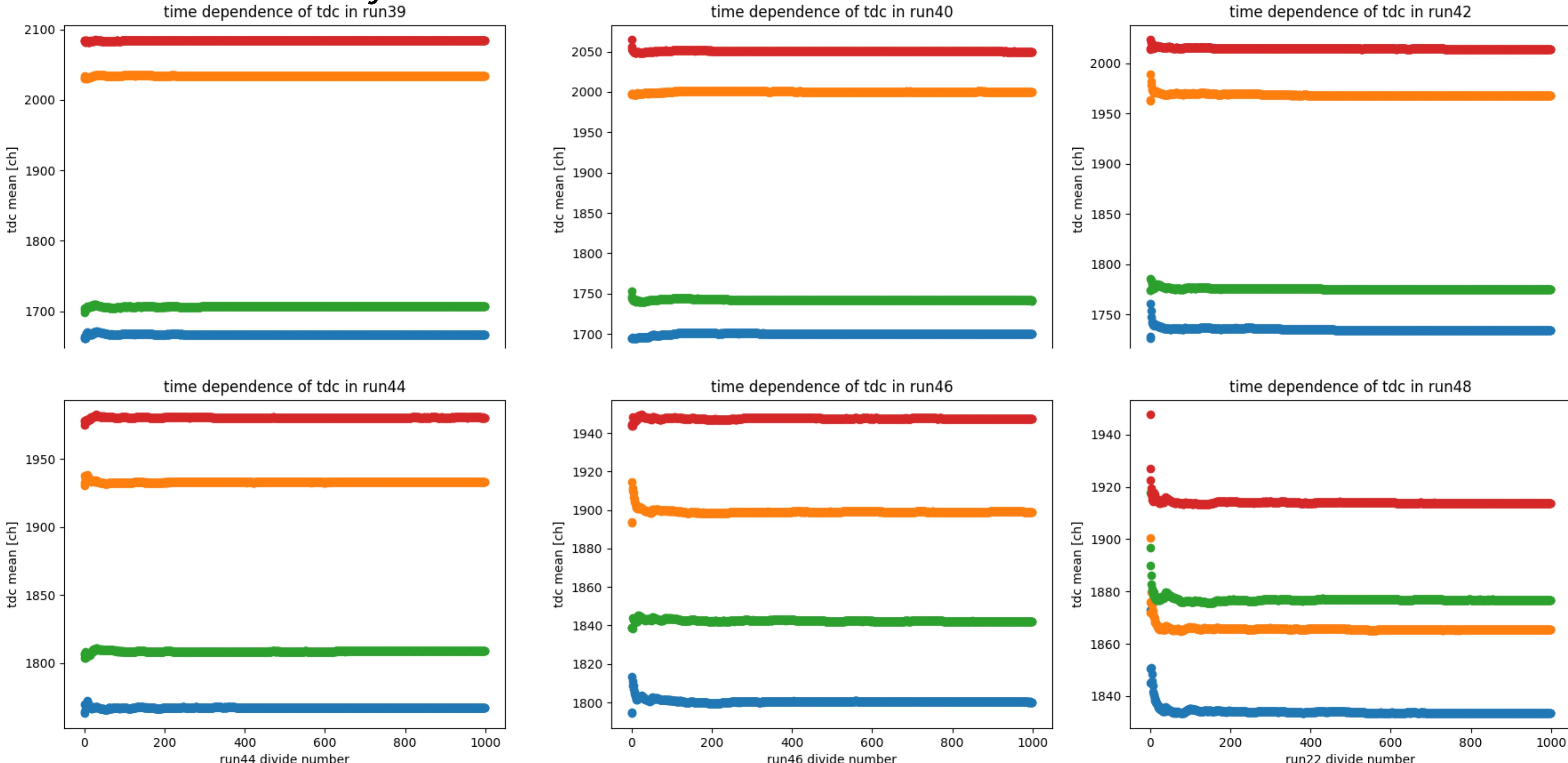
time dependence of tdc in run38



# 1. CNC time resolution



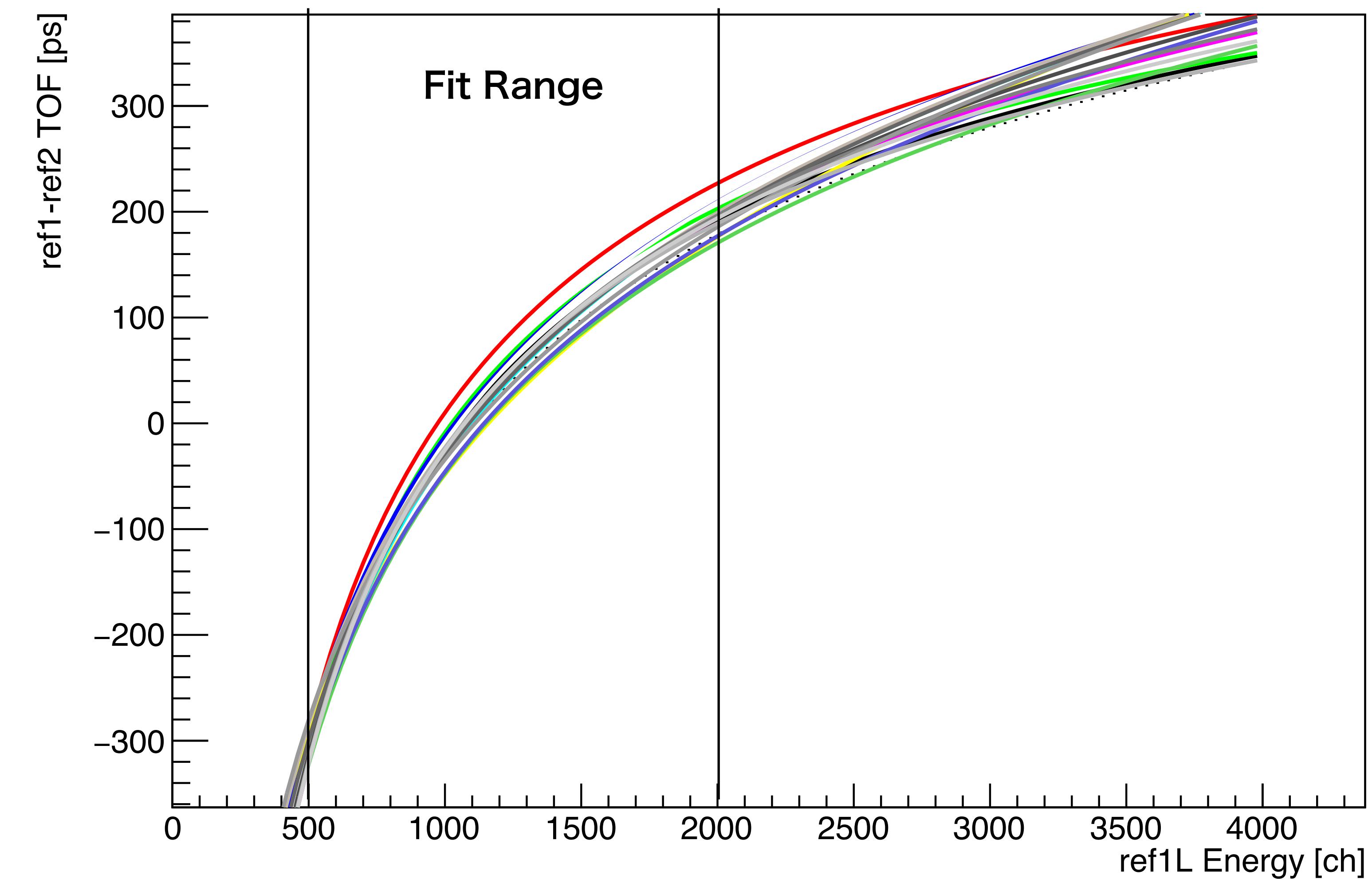
## CNC's TDC stability



# Slewing Function of Ref1L

- 複数の視点からRef1,2の安定性を調べた。
- まずはSlewing関数の形

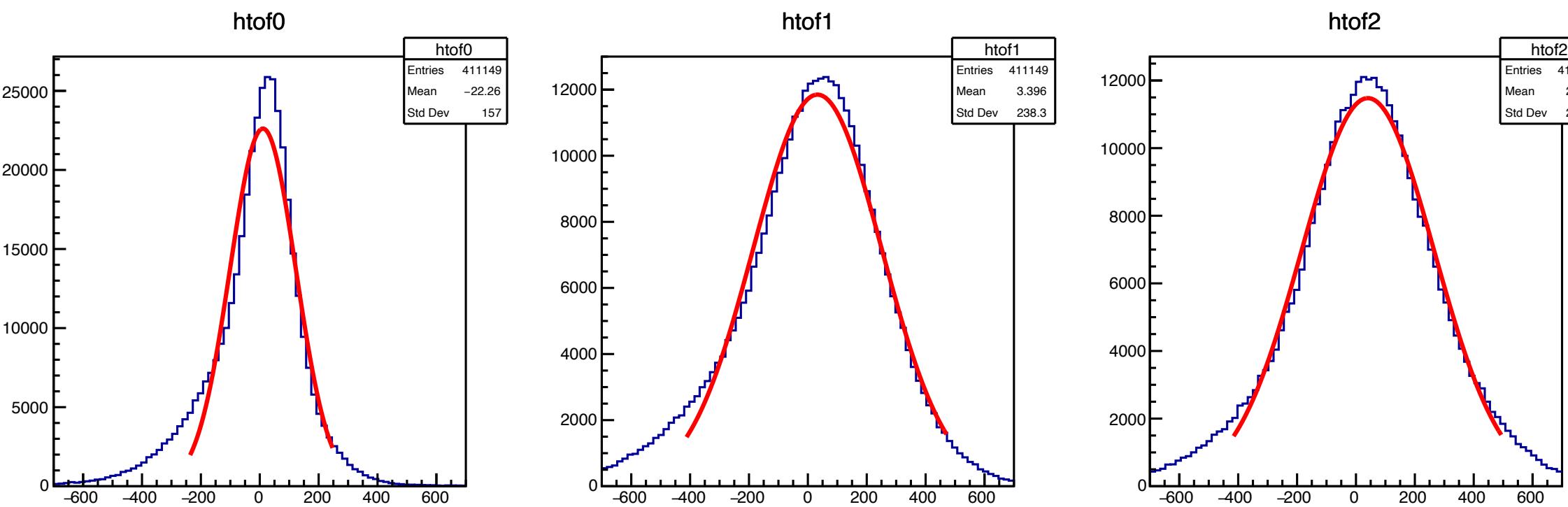
slewfunc0 : [0] + [1]/sqrt(x) + [2]\*sqrt(x)



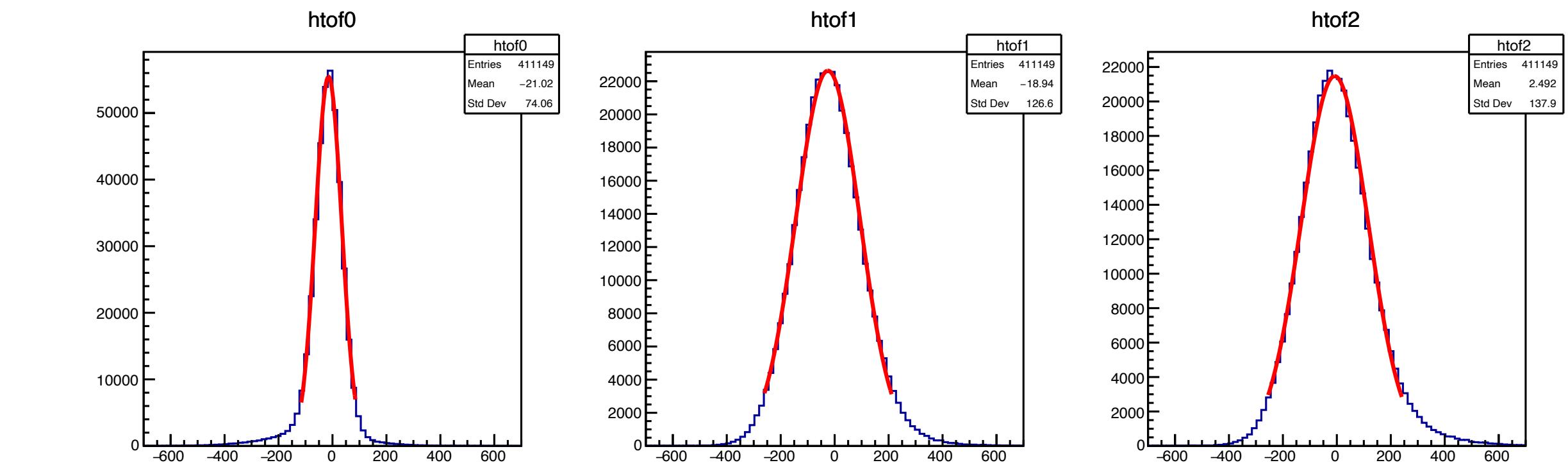
# Typical Gaussian Fitting for TOF

- Fit Rangeをそれぞれ $2\sigma$ に設定した。

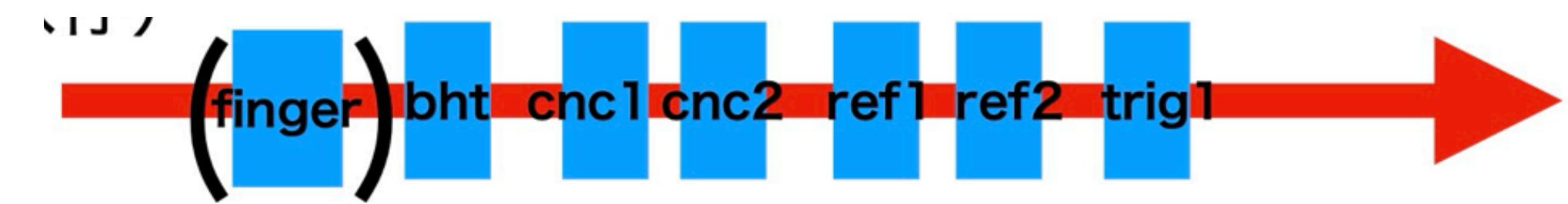
Before correction



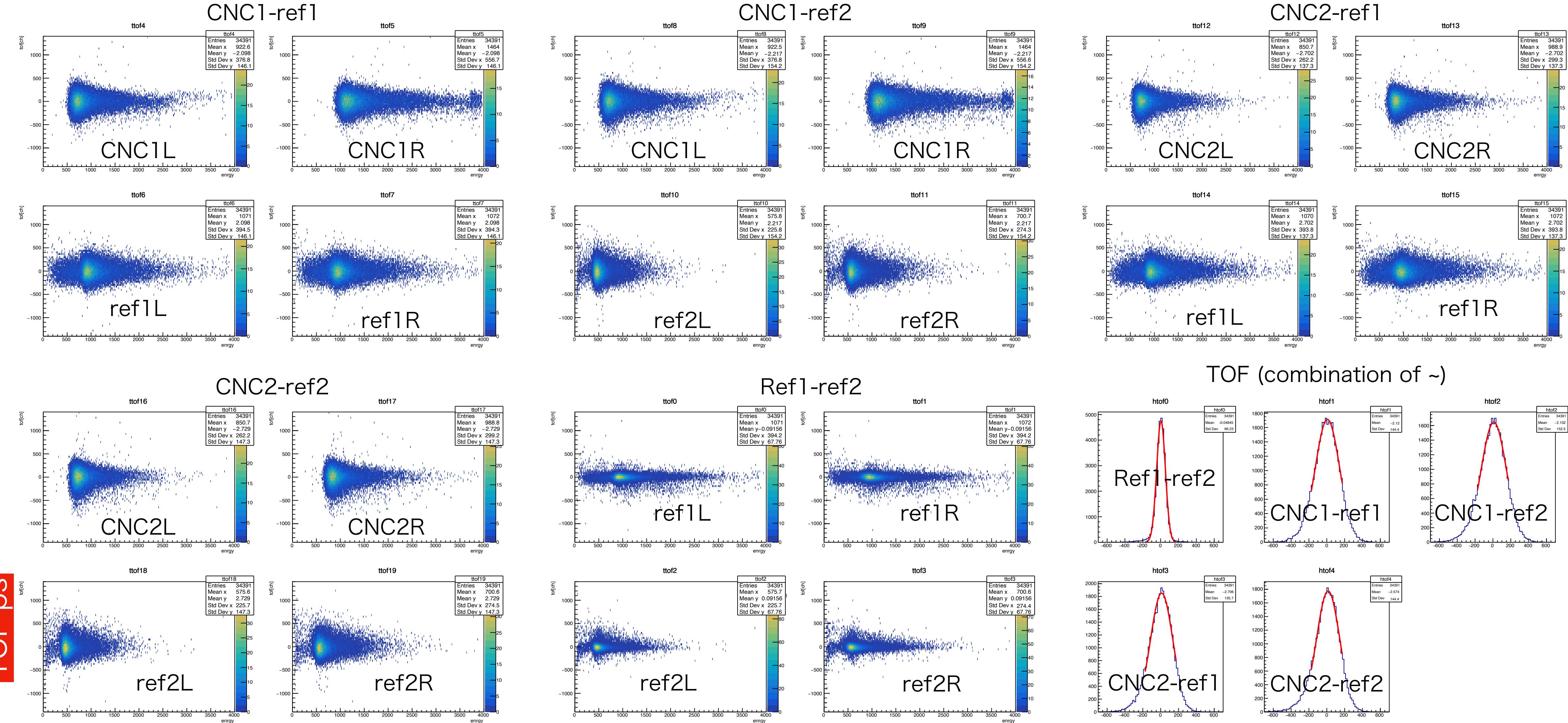
After correction



# 1. CNC time resolution



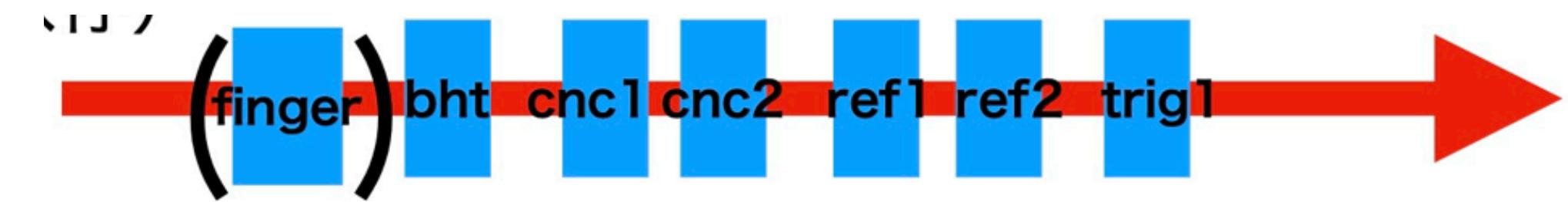
Typical shape of 2D(TOF vs Energy) after slewing correction (run27)



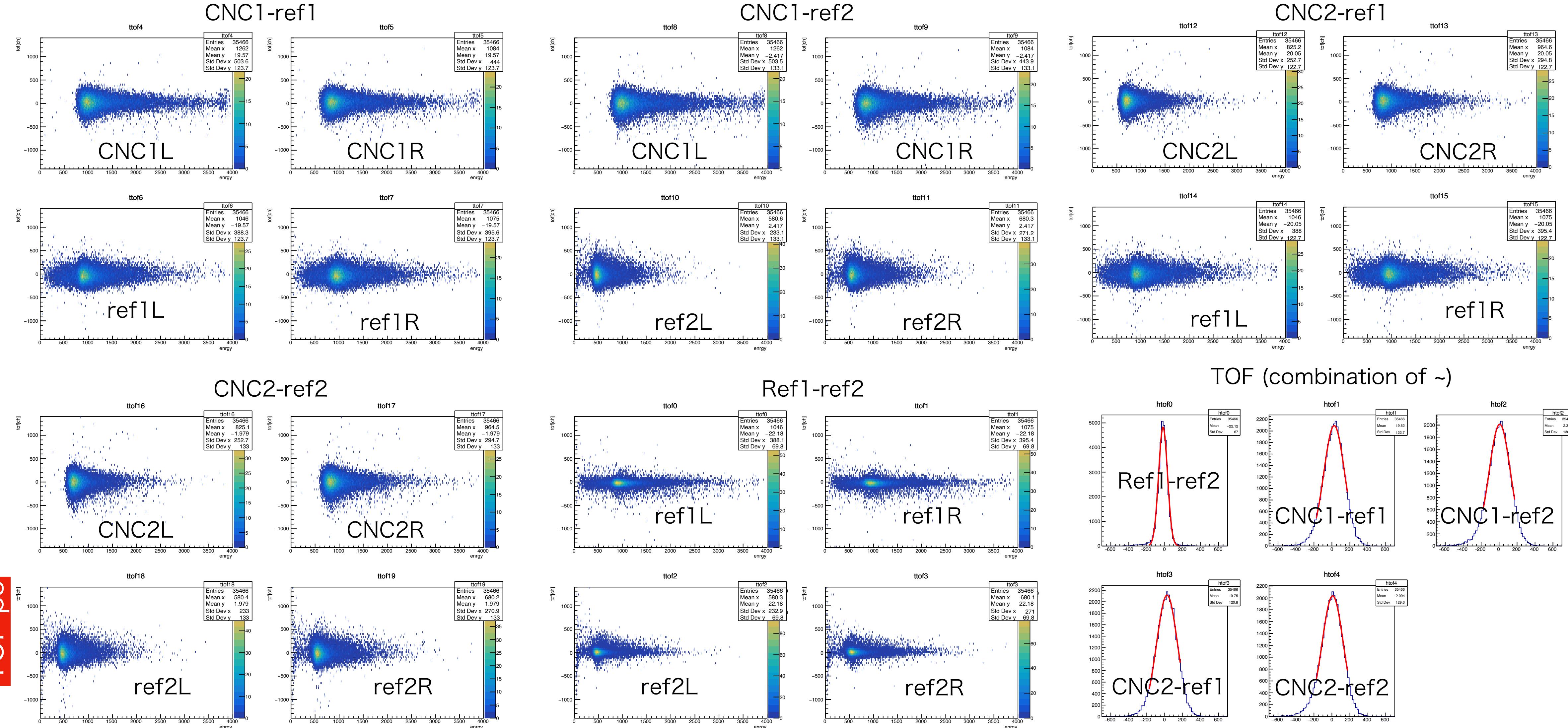
TOF ps

Energy [ch]

# 1. CNC time resolution



Typical shape after slewing correction (run48)



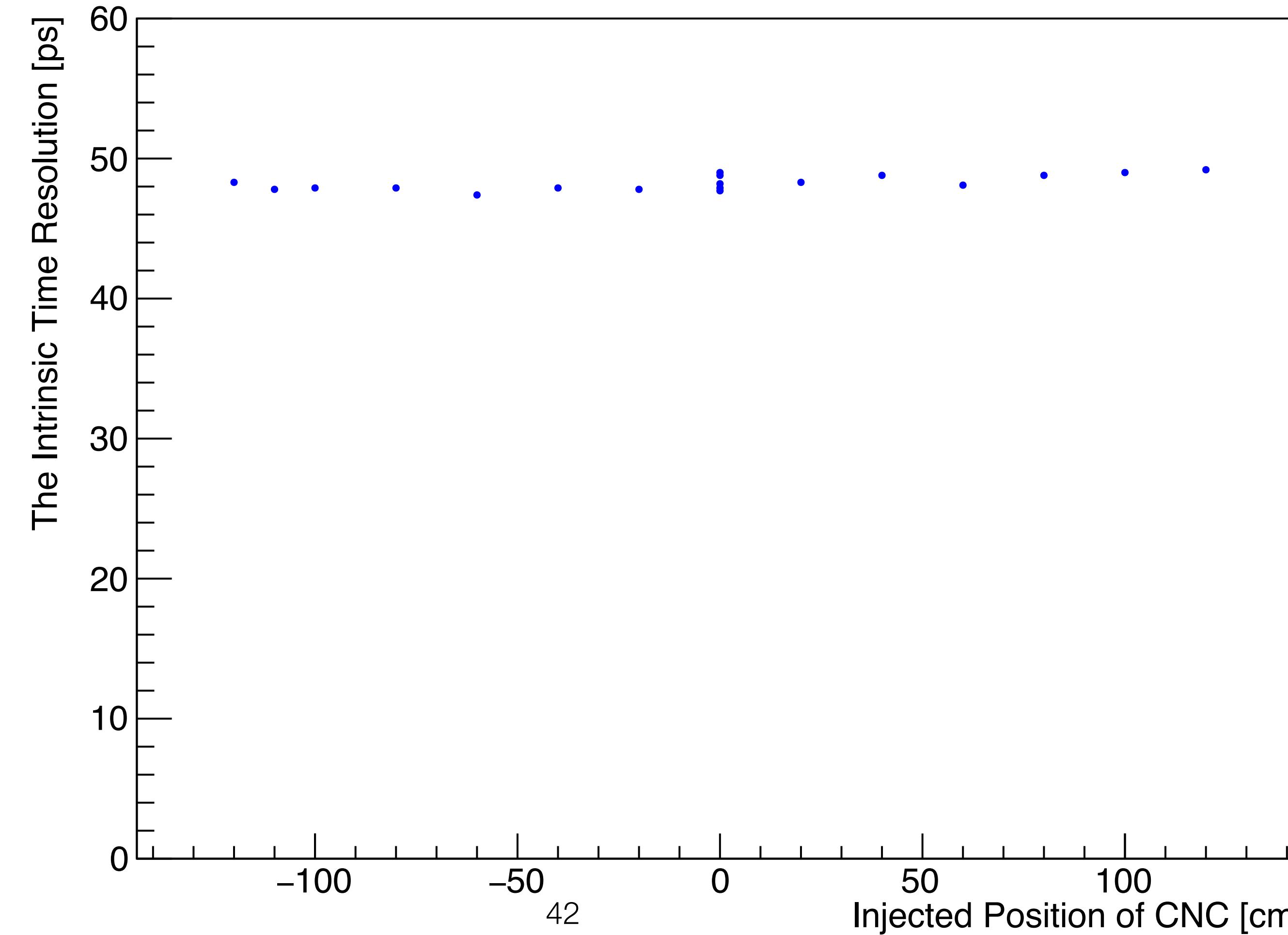
# 時間分解能 $\Delta$ (Ref1 - Ref2)

Resolution

Resolution	Injected position
48.8	0
47.7	0
48.3	-120
47.8	-110
47.9	-100
47.9	-80
47.4	-60
47.9	-40
47.8	-20
47.9	0
48.2	0
48.3	20
48.8	40
48.1	60
48.8	80
49.0	100
49.2	120
49.0	0

- Ref1,2系は時間分解能に関して安定していた( $\pm 1.5$  ps)。

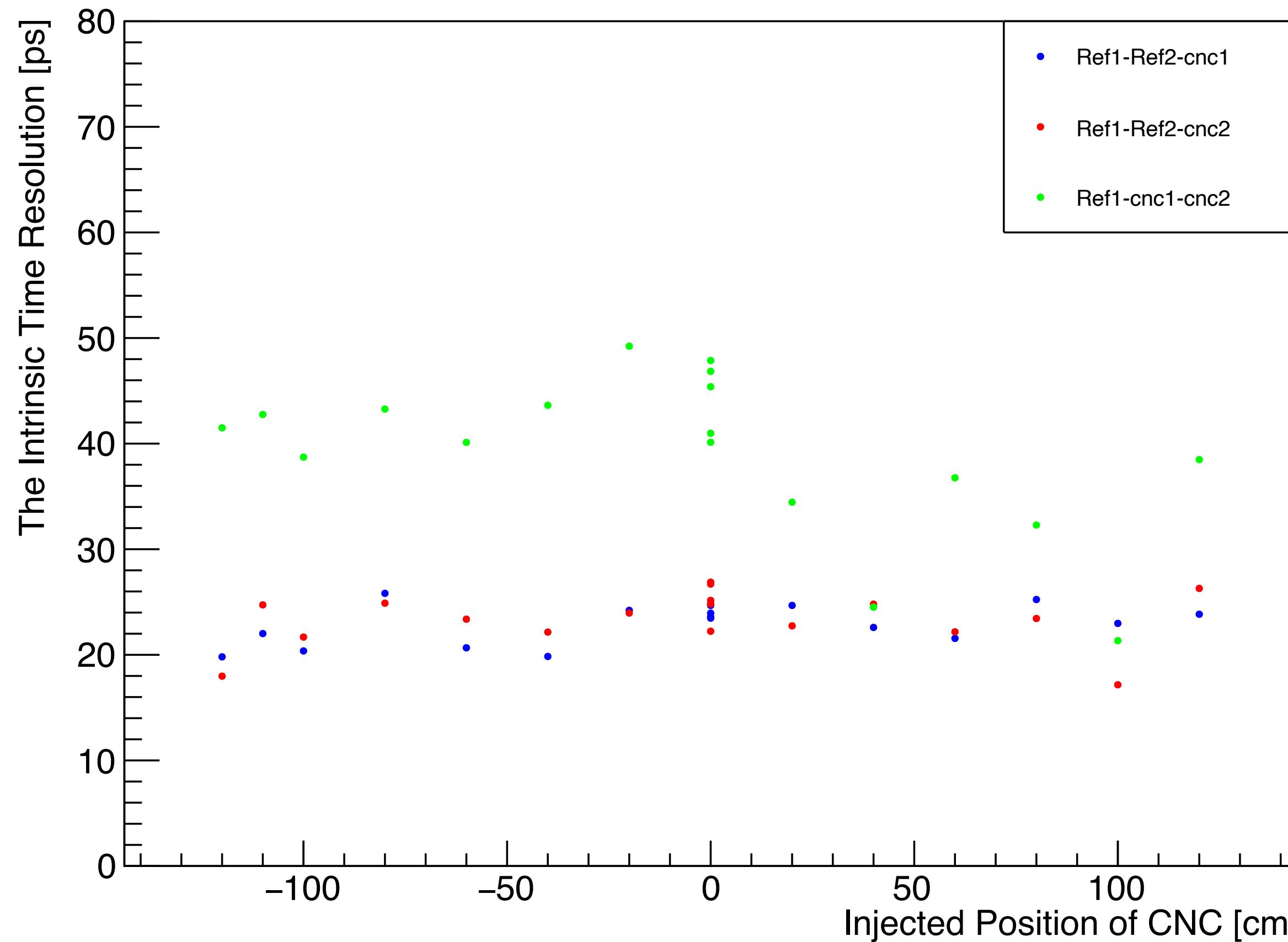
The Intrinsic Time Resolution of Ref1-Ref2



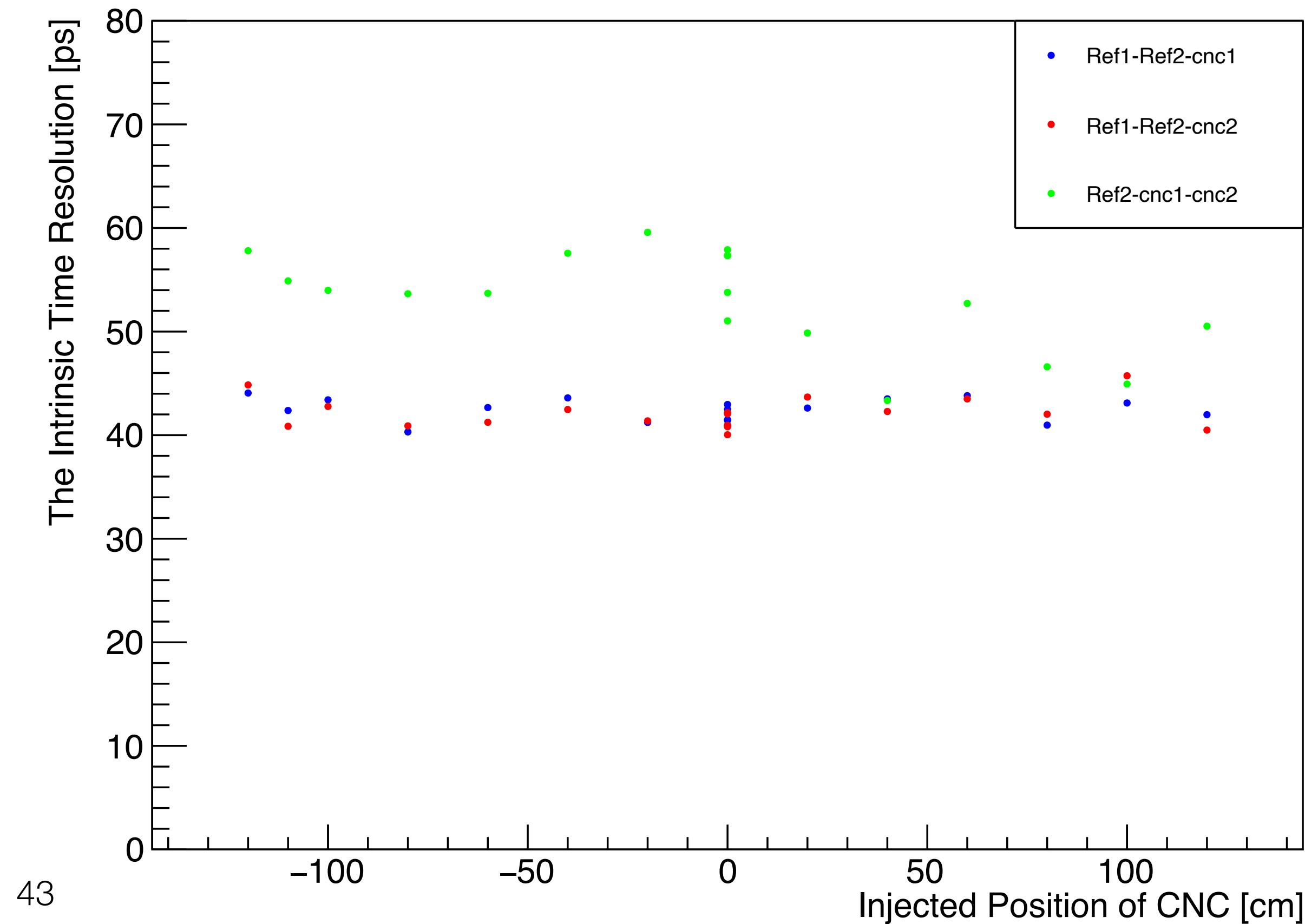
# 時間分解能 Ref1,2

- Fit Rangeをそれぞれ $2\sigma$ に設定した。
- 3通りの連立方程式で固有時間分解能を出した。
- CNCを2個使った連立の時、CNCの悪い時間分解能に引っ張られてRefも悪くなつた。

The Intrinsic Time Resolution of Ref1



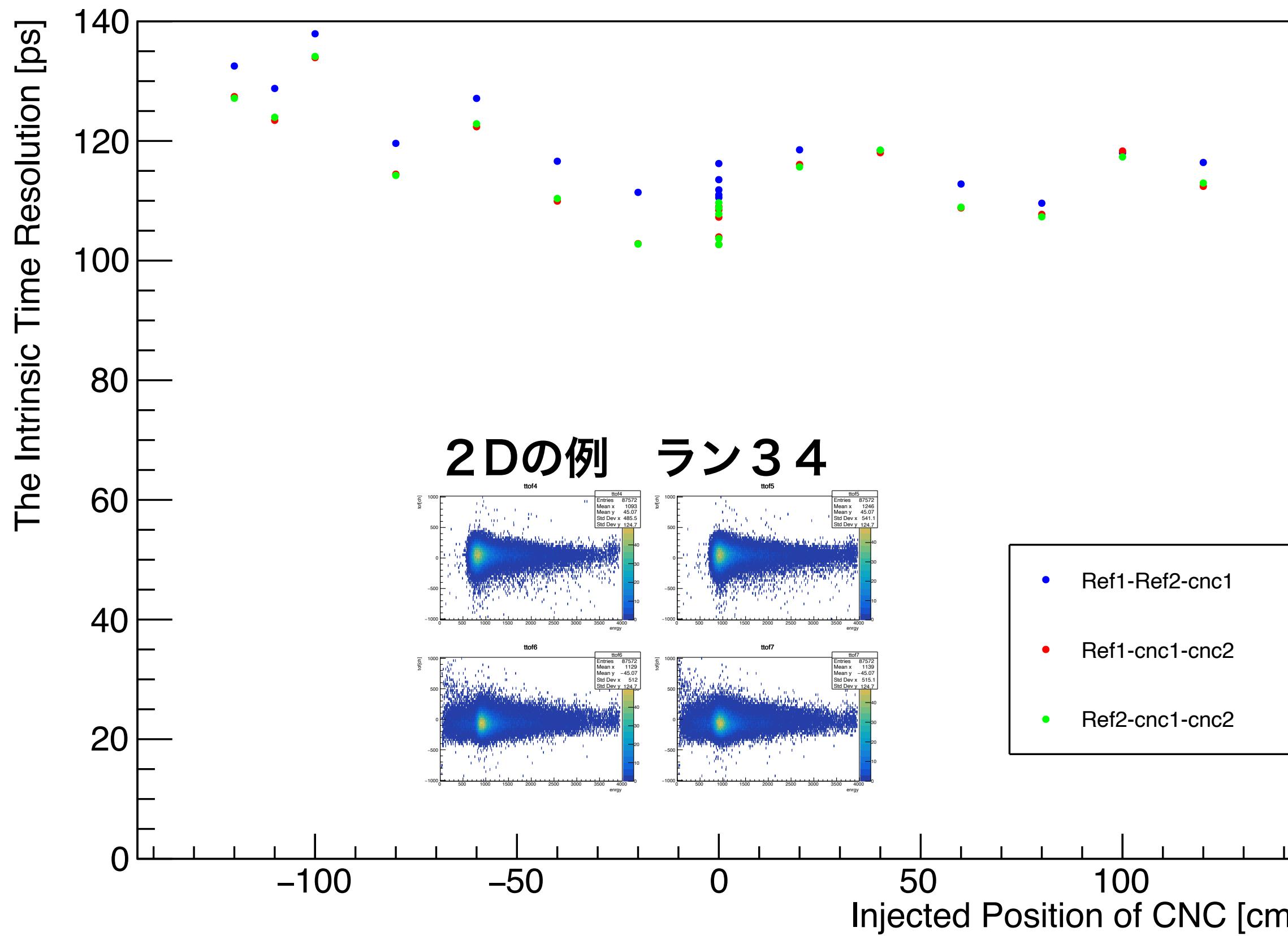
The Intrinsic Time Resolution of Ref2



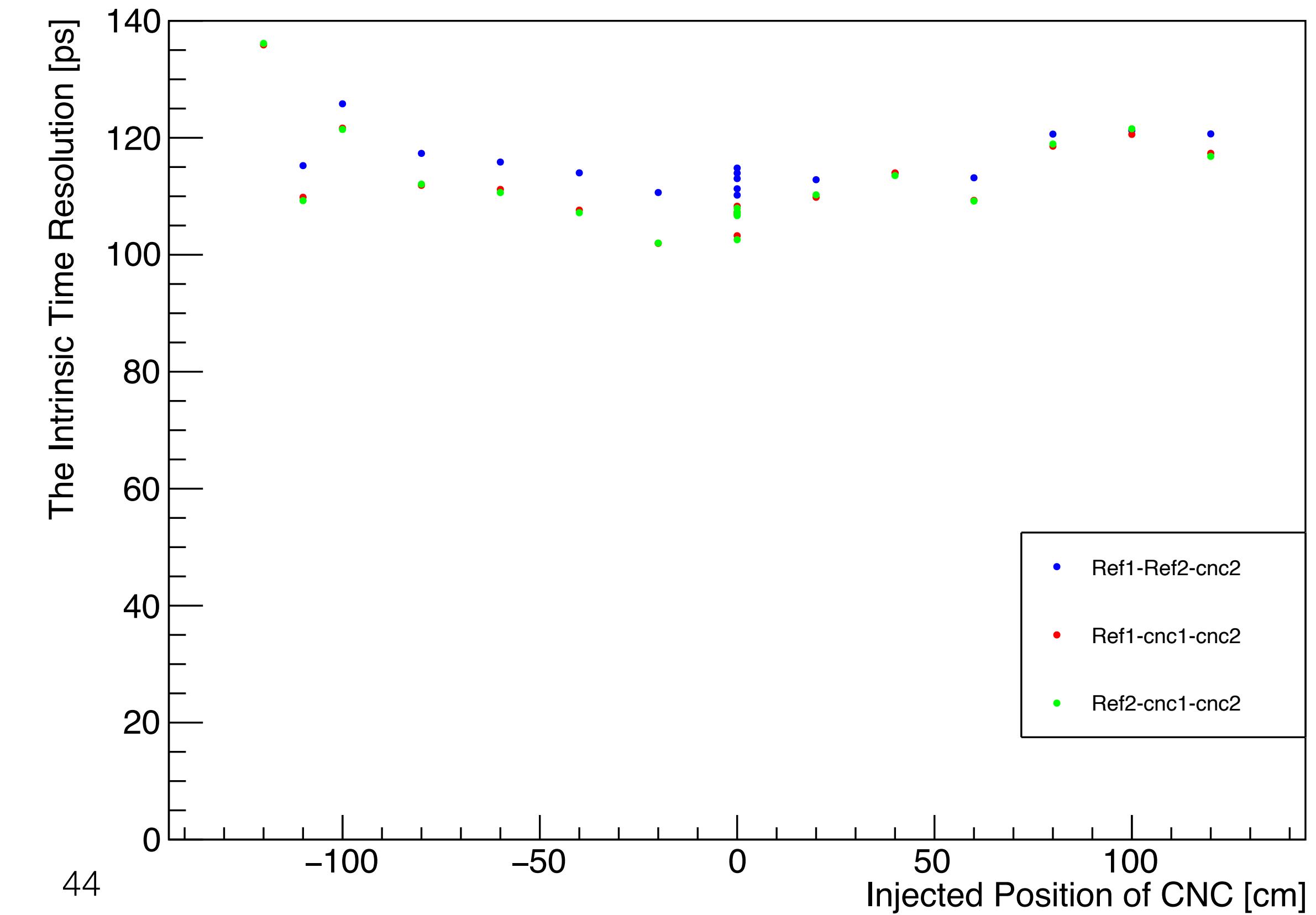
# 時間分解能 CNC1,2

- Fit Rangeをそれぞれ $2\sigma$ に設定した。→ 分布は変わらずでした。
- 3通りの連立方程式で固有時間分解能を出した。
- Refを2個使った連立の時、systematicにCNCの分解能が悪くなつた。

The Intrinsic Time Resolution of cnc1

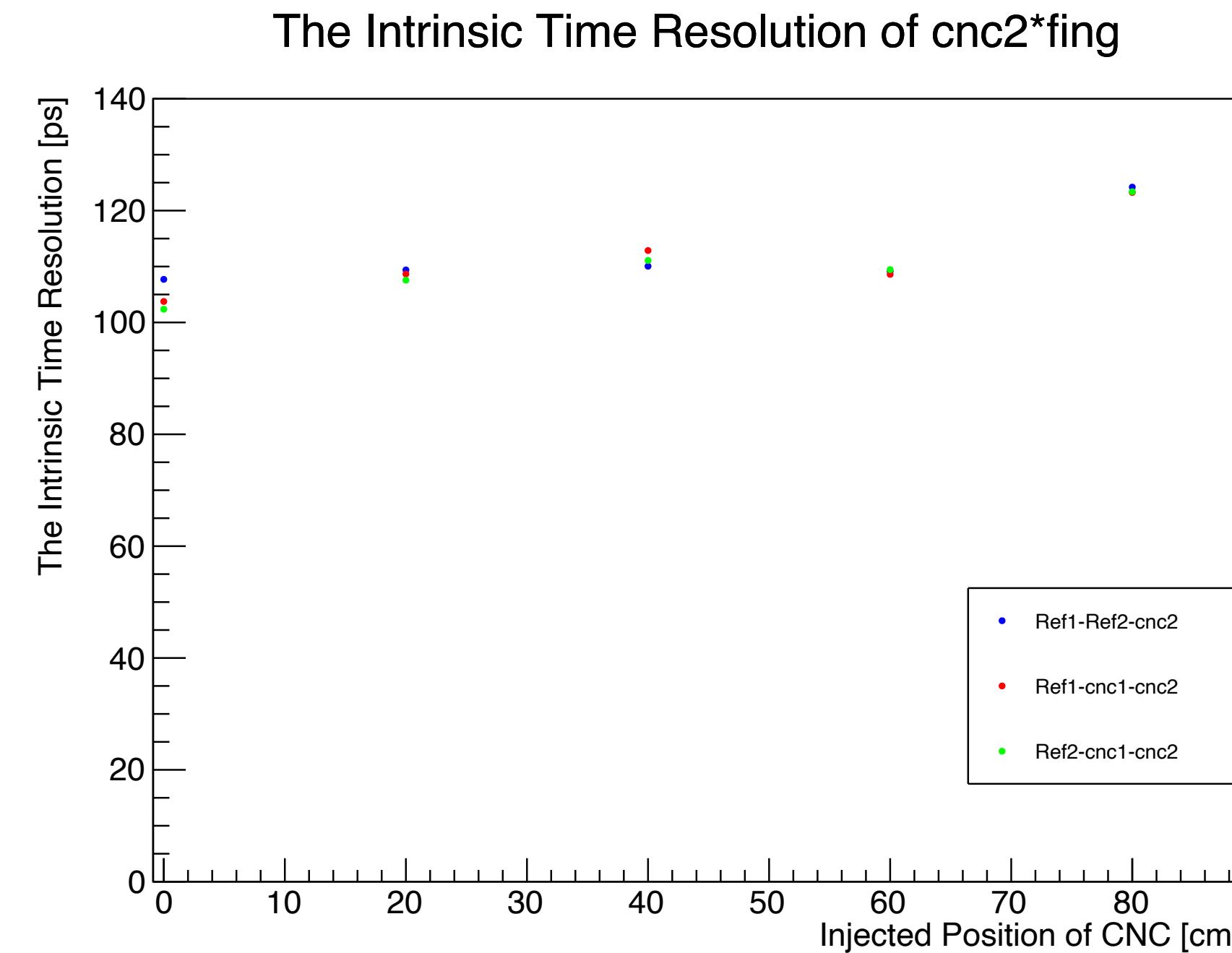
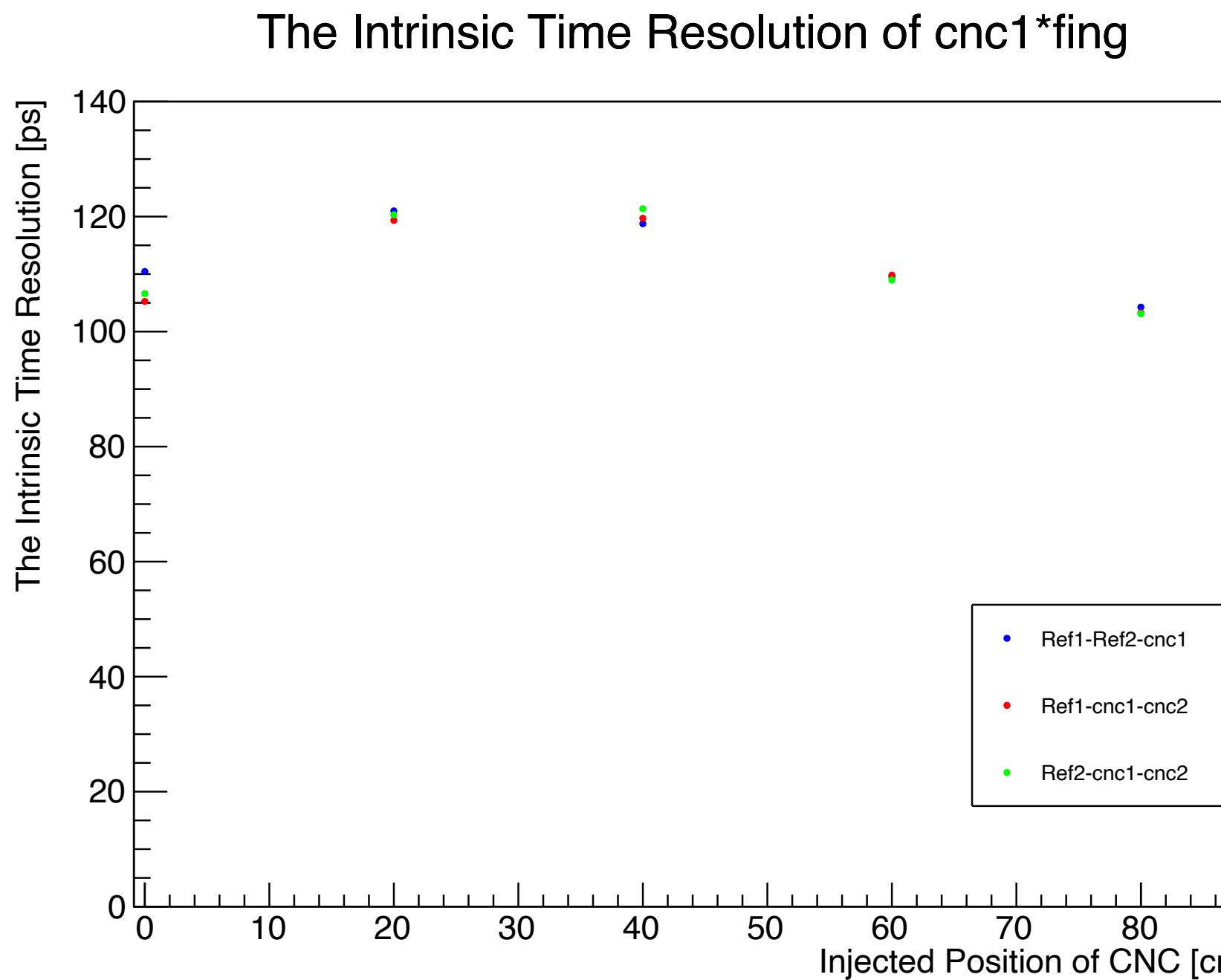


The Intrinsic Time Resolution of cnc2

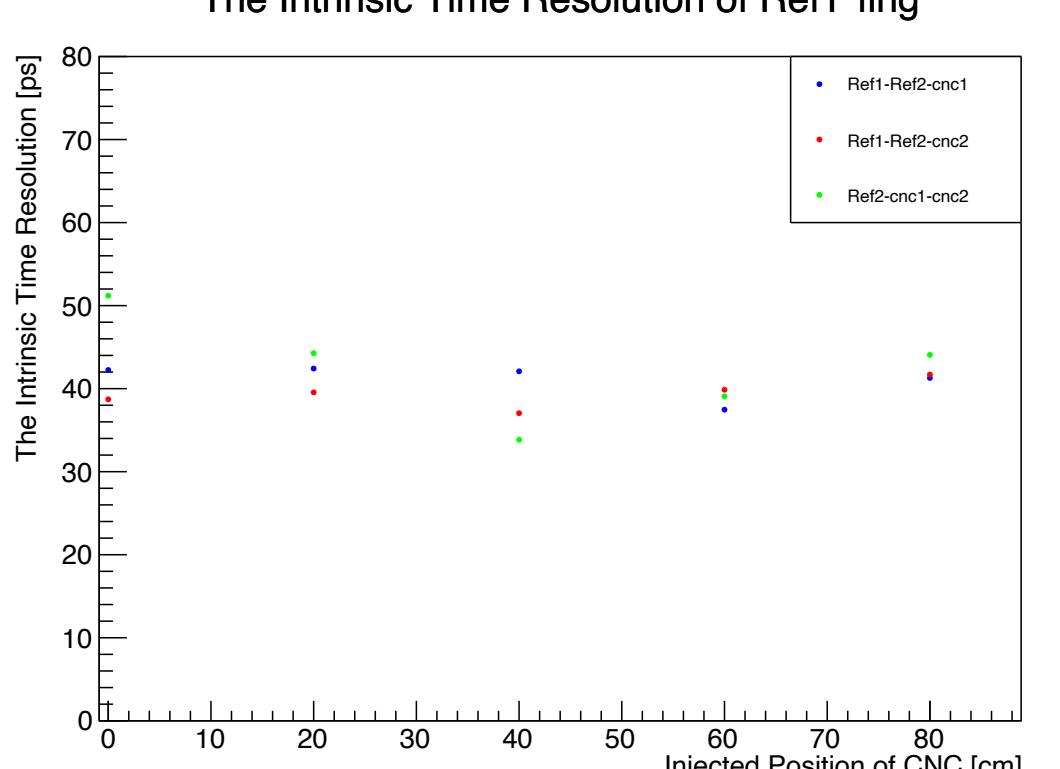
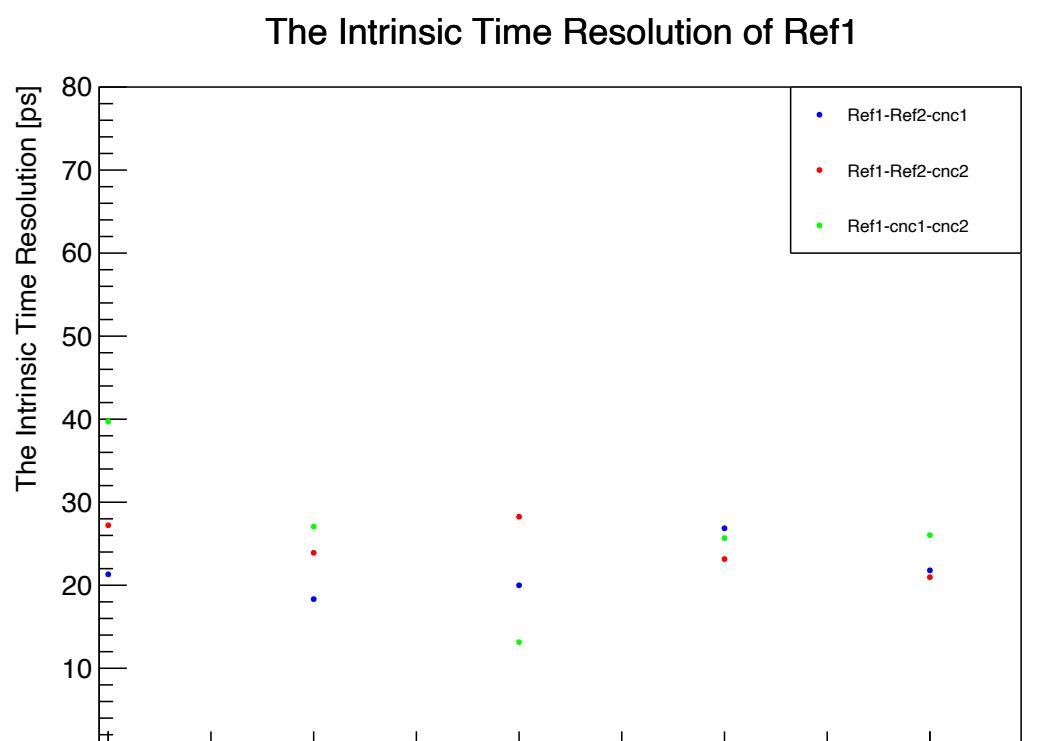


# 時間分解能 CNC1,2 \* finger有り

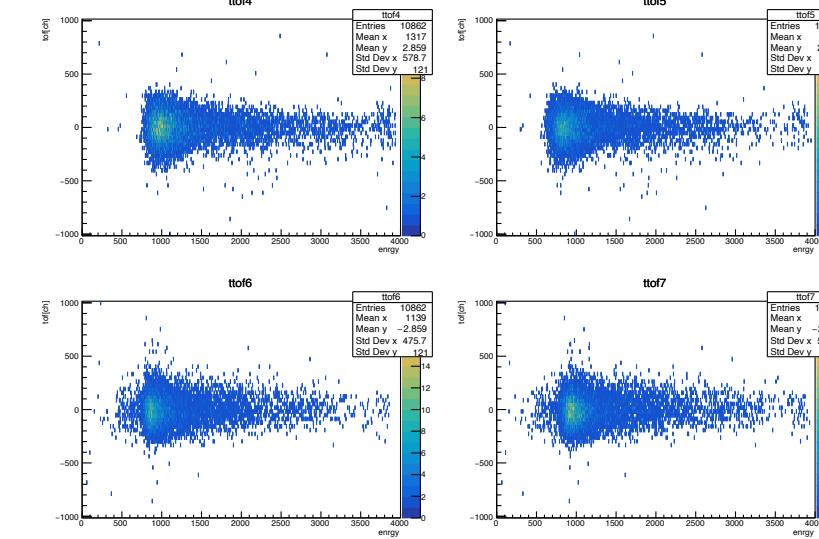
- finger hitを要求すると、分解能がシンチの選び方によらなくなつた。
- ということはこれが眞の固有時間分解能か？



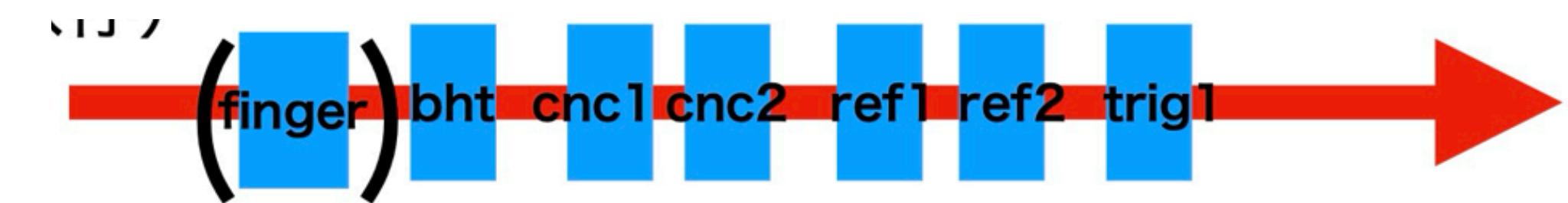
• Refが荒れているように見えるのは  
CNCに引っ張られているからか？



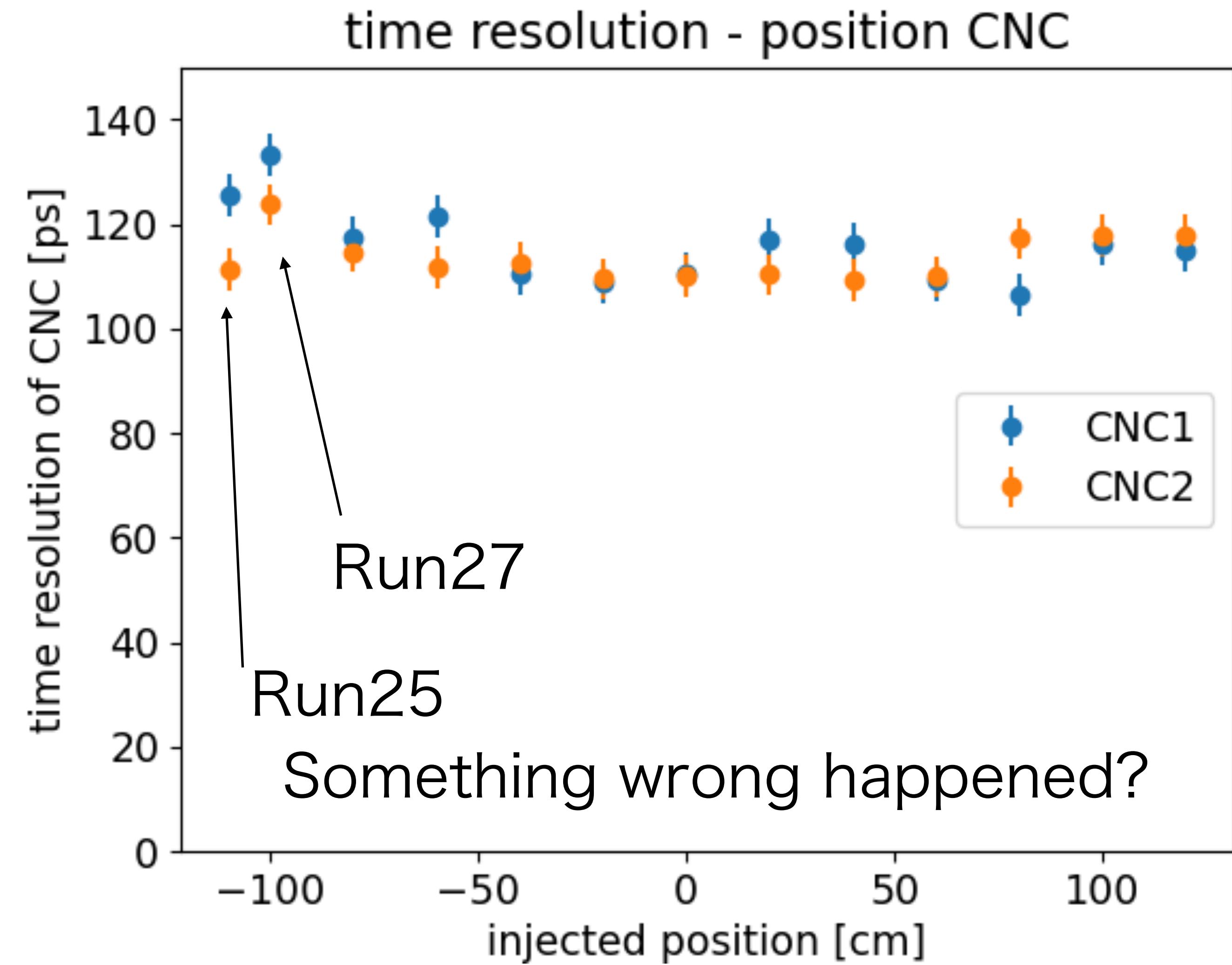
2Dの例 ラン48



# 1. CNC time resolution



- ref1 - ref2 - CNCの組の連立方程式からのintrinsic time resolution
- No clear position dependence
- $\sigma \sim 120$
- Satisfy our requirement, 150 ps

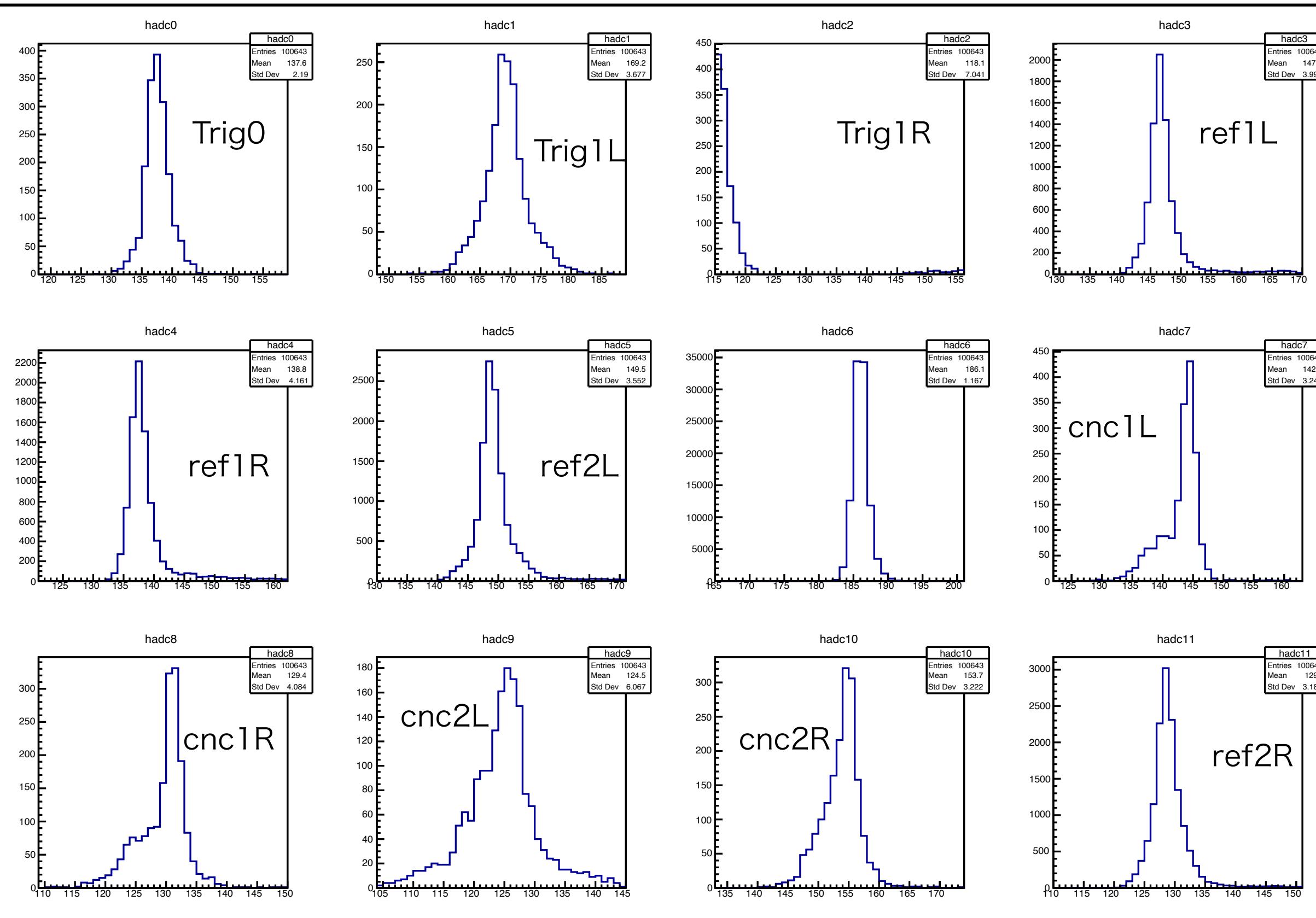


# 1. CNC time resolution

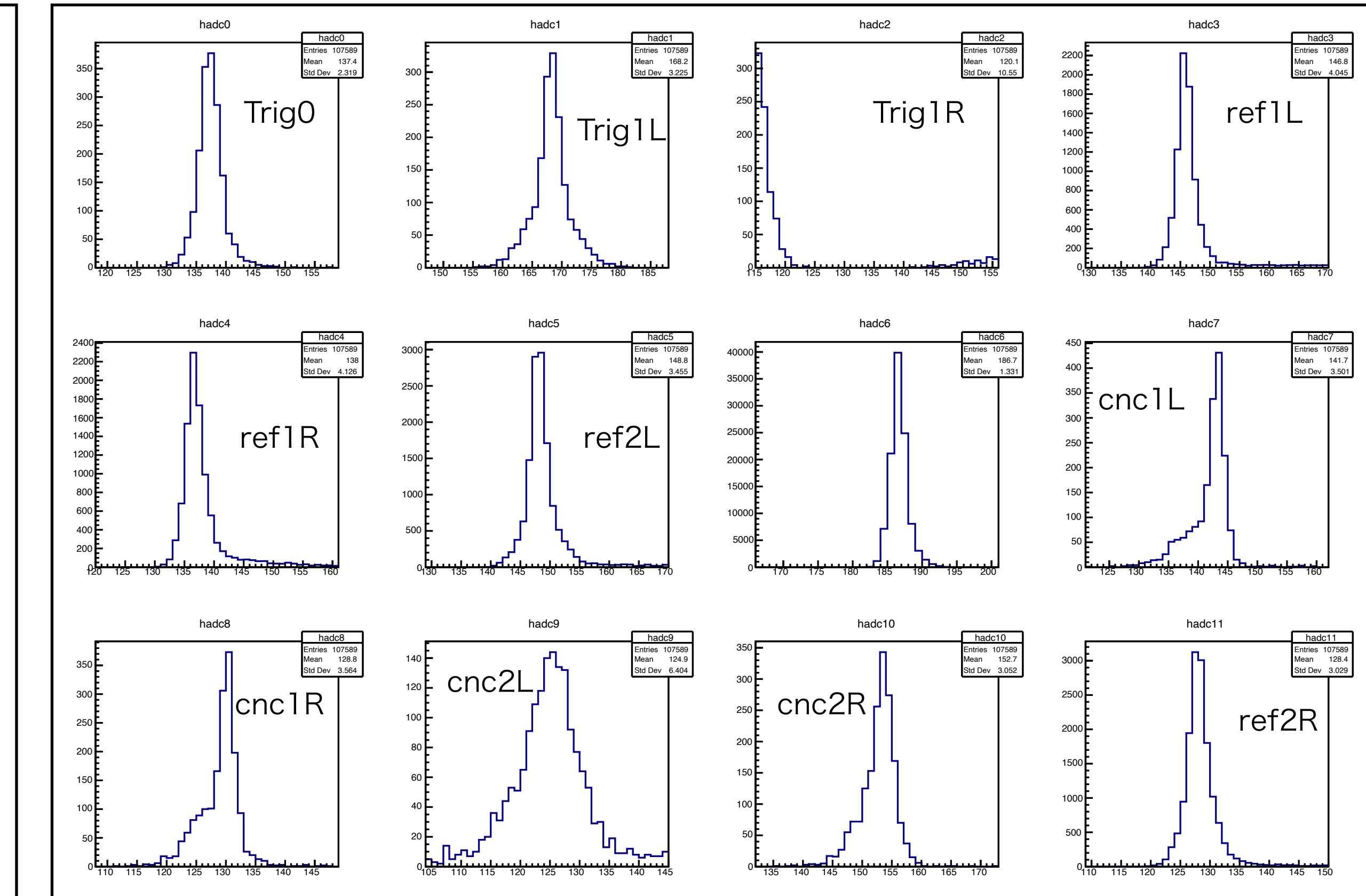
- cnc時間分解能に関しては光漏れの影響は無さそう

↔ 違いが無い

run27 (cncに関して最も悪い分解能が出たrun)



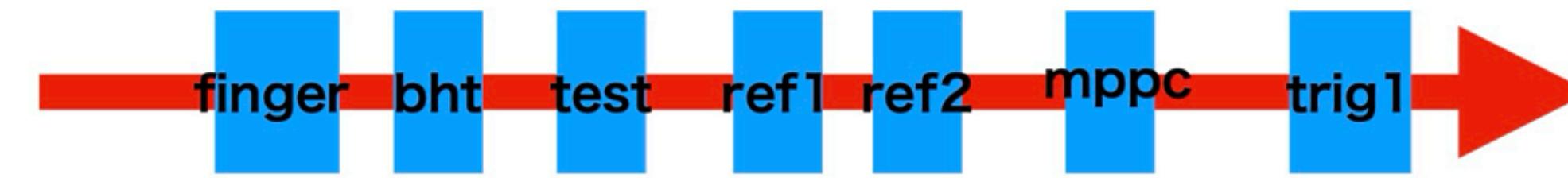
run40 (cncに関して最も良い分解能が出たrun)



2. Light Guide using Test(1500\*120\*50t(mm))

3. MPPC

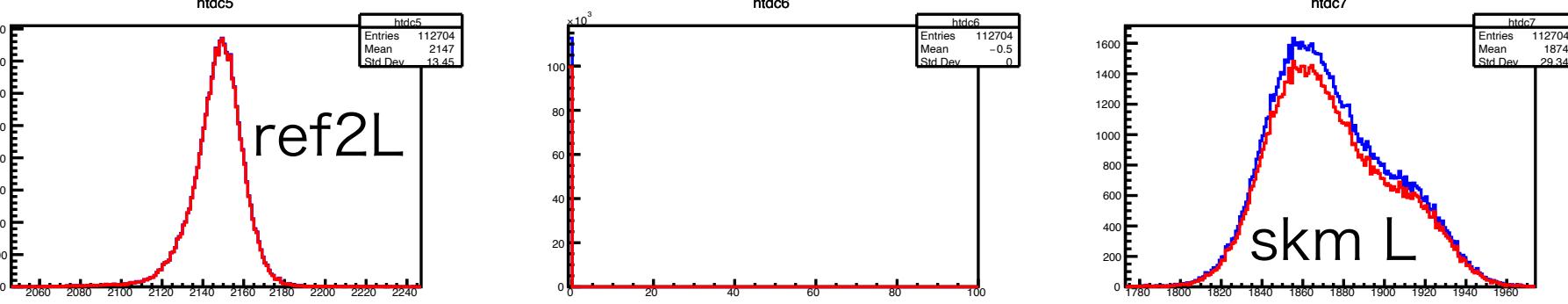
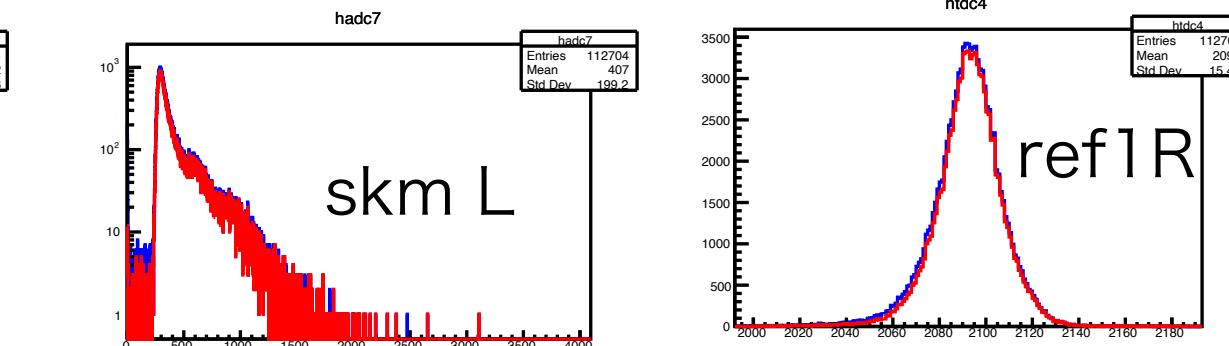
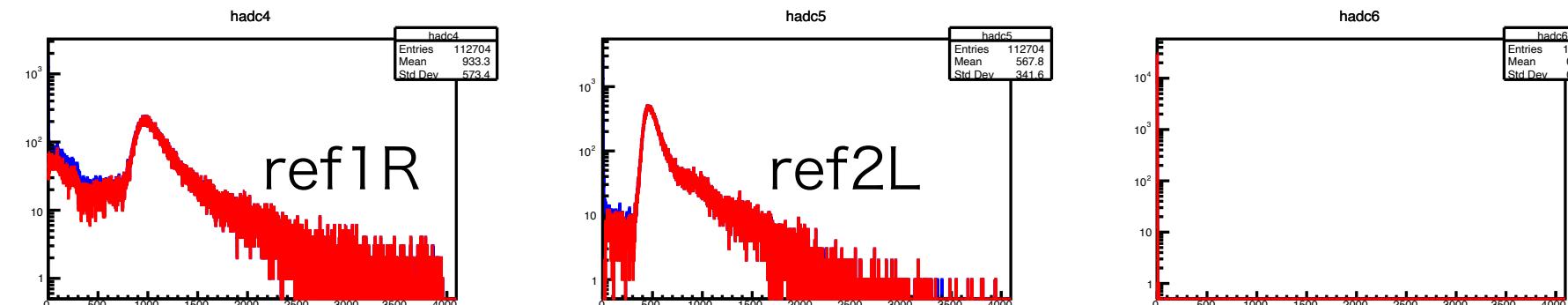
# 2. Light Guide



Blue ; raw data  
Red ; ref & trig tdc != -1

Run68, LG 0mm, pos=75cm(center), MPPC(5\*5\*75cm Scinti), bias 53V

QDC



**hadc8**

Entries	112704
Mean	904.2
Std Dev	443

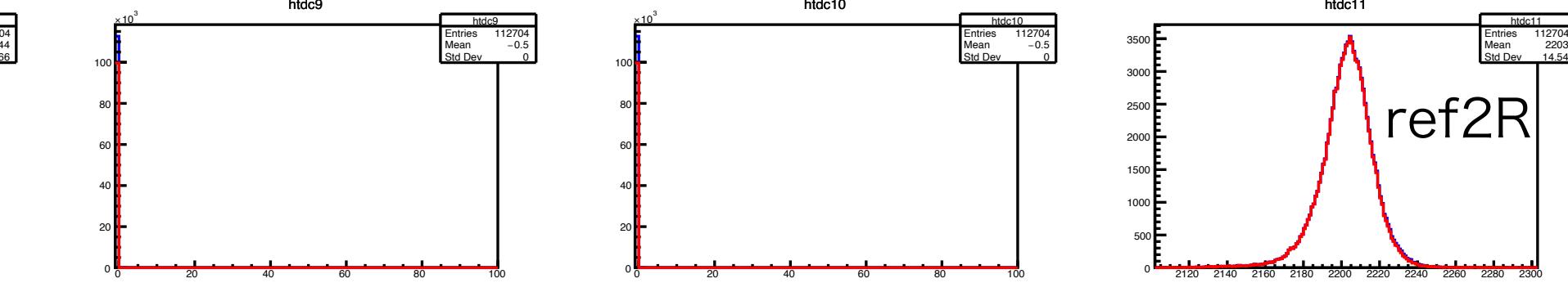
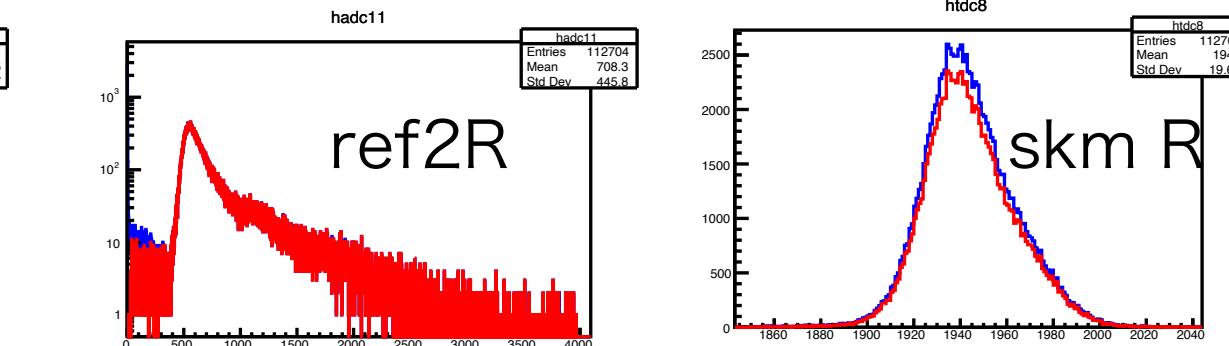
**hadc9**

Entries	112704
Mean	2.951
Std Dev	3.412

**hadc10**

Entries	1
Mean	0
Std Dev	0

skm R



hadc12

Entries	112704
Mean	0.5381
Std Dev	0.7588

hadc13

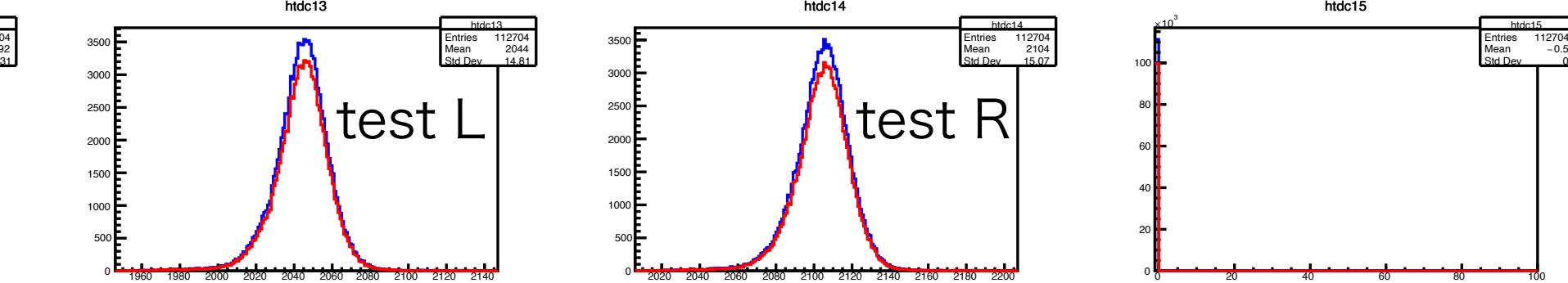
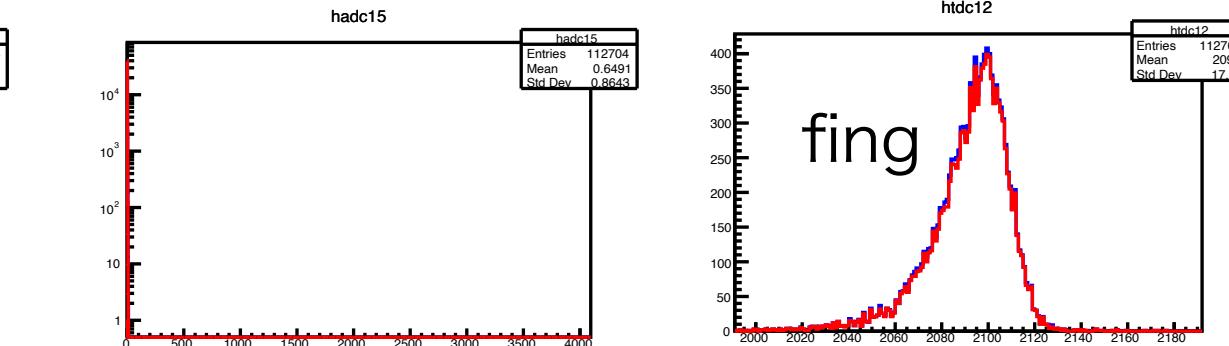
Entries	112704
Mean	1116
Std Dev	364.2

hadc14

Entries	1
Mean	
Std Dev	

test L

test R



TEST L&R

1 200mV 2 200mV 3 100mV 4 1.00 V 20.0ns  
14.8000ns 5.00GS/s 1000 points

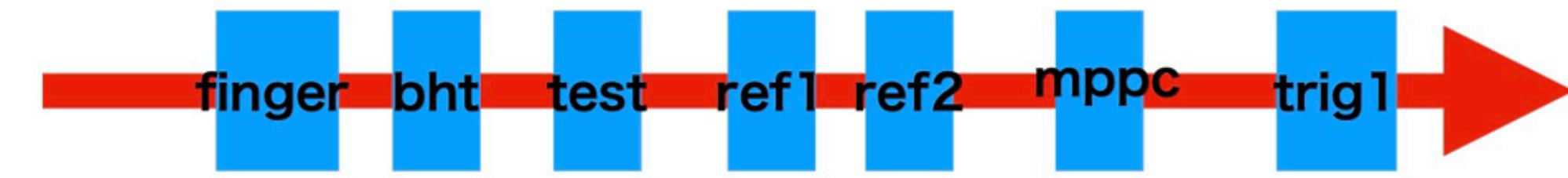
Coupling Termination Invert Bandwidth Label More

DC AC 1MΩ 50Ω On Off Full 3 21 Oct 14:05:41

The figure shows an oscilloscope screen with four channels labeled 1, 2, 3, and 4. Channel 1 (yellow) shows a high-frequency signal with a low-level noise floor. Channel 2 (cyan) shows a signal that is mostly flat at a low level with some noise, but exhibits a sharp, transient dip followed by a recovery phase. Channel 3 (green) shows a signal that is mostly flat at a low level with some noise, but exhibits a sharp, transient dip followed by a recovery phase. Channel 4 (black) shows a signal that is mostly flat at a low level with some noise, but exhibits a sharp, transient dip followed by a recovery phase. A large white watermark "MPPC(skm)" is overlaid across the bottom right of the screen. The top of the screen has a "Tek Stop" label and a horizontal timeline. The bottom features various control knobs and buttons, including coupling (DC, AC), termination (1MΩ, 50Ω), invert (On, Off), bandwidth (Full), label (49, 3), and more (More). The time scale is 40.0ns, and the sampling rate is 2.50GS/s over 1000 points.

- Bias of MPPC is a little small.

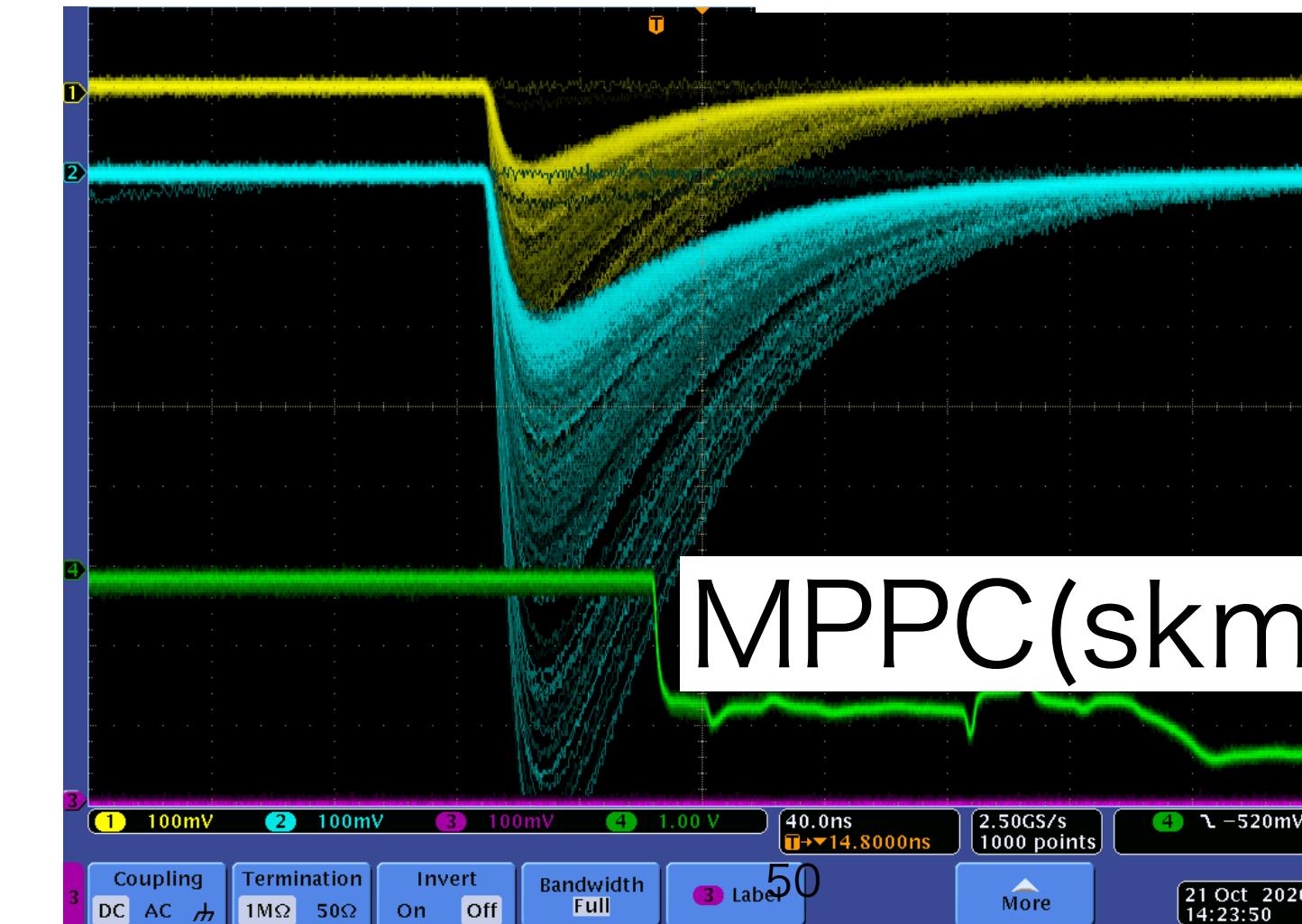
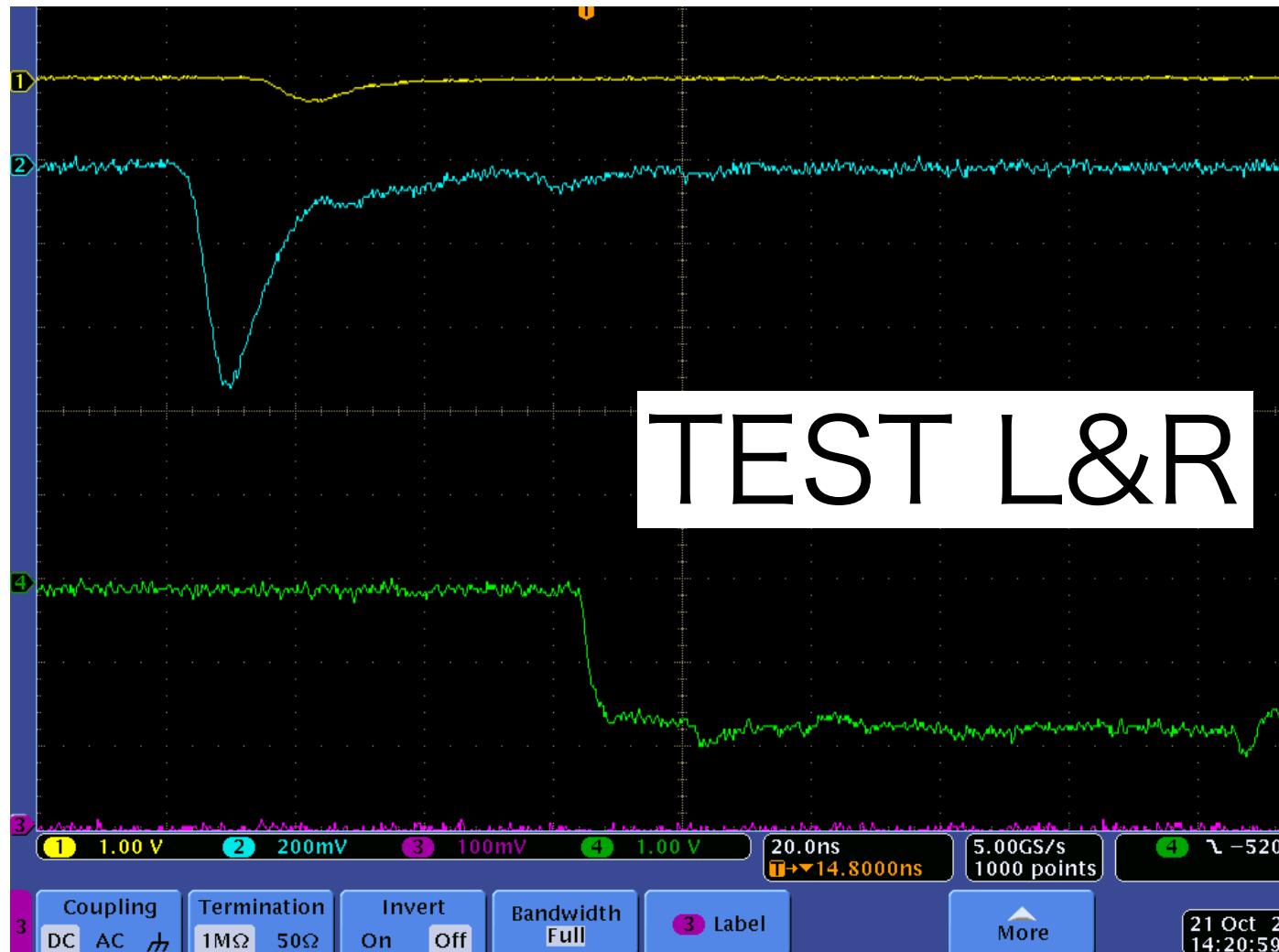
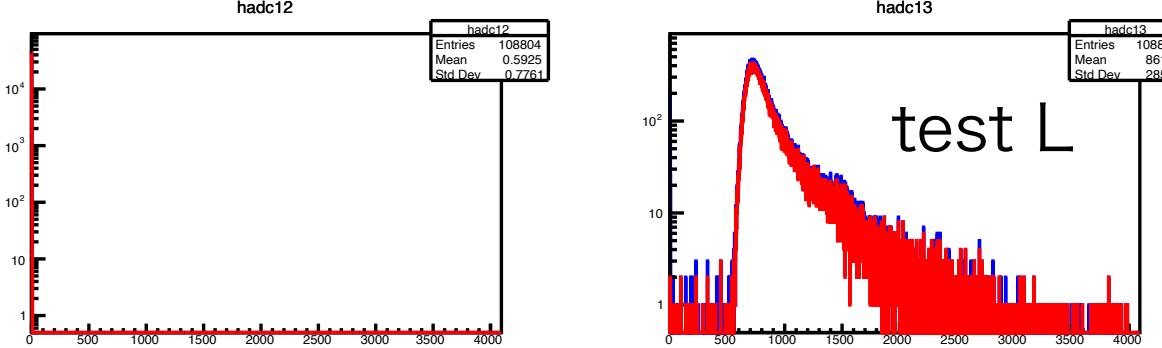
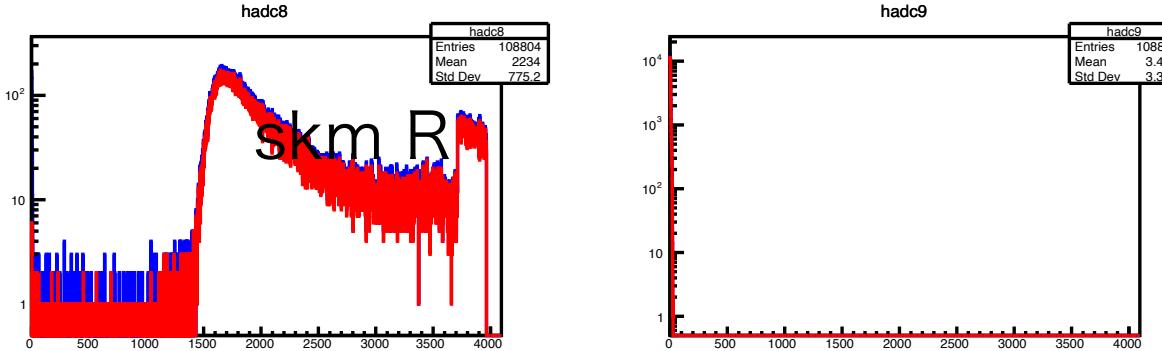
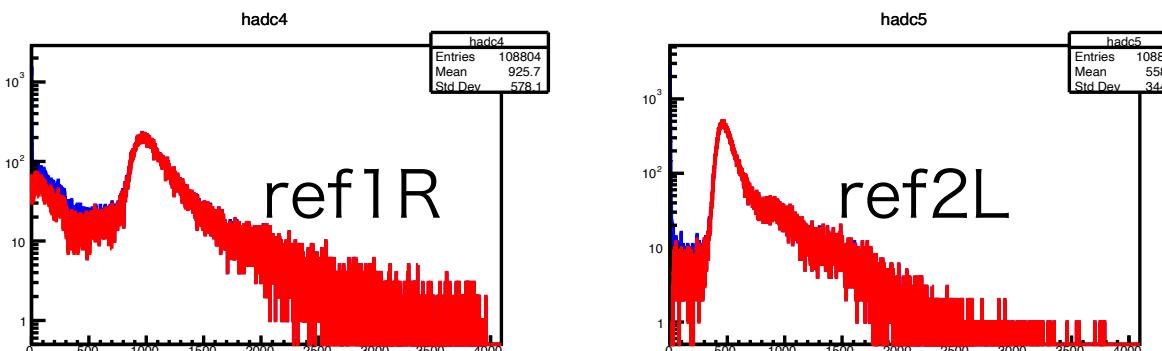
# 2. Light Guide



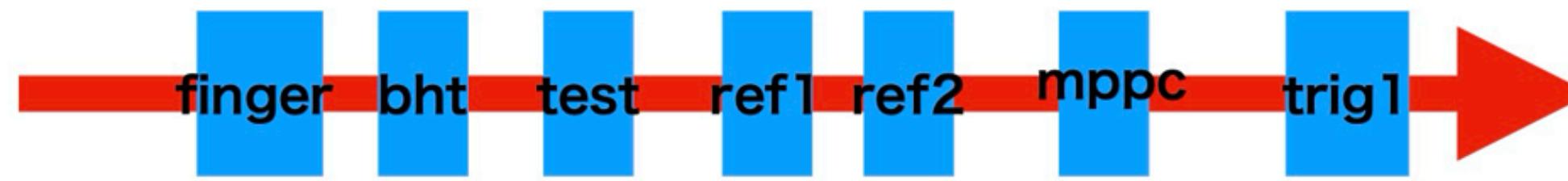
Blue ; raw data  
Red ; ref & trig tdc != -1

Run72, LG 0mm, pos=10cm, MPPC(5\*5\*75cm Scinti), bias 54V

QDC

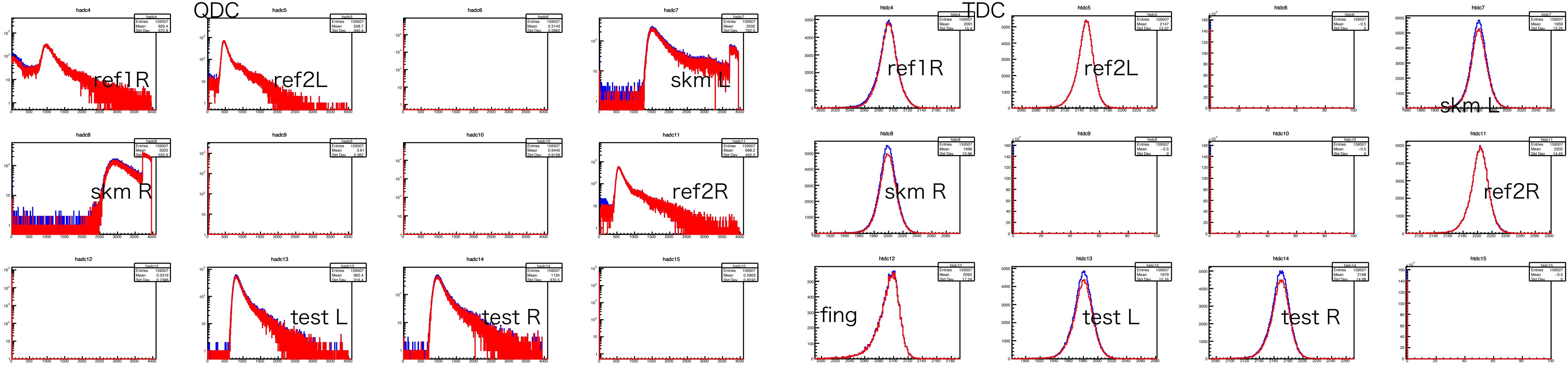


# 2. Light Guide

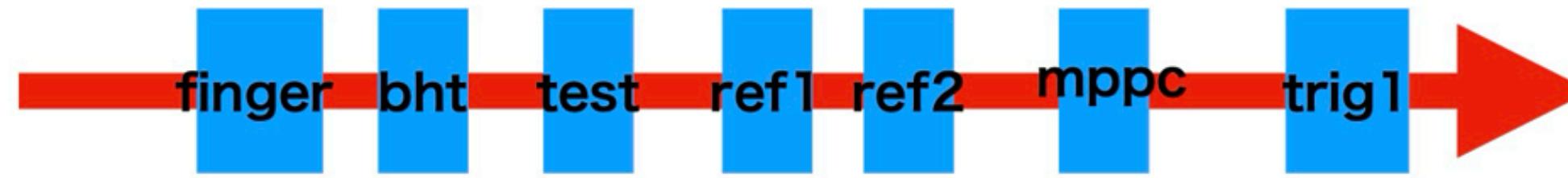


Blue ; raw data  
Red ; ref & trig tdc != -1

Run77, LG 0mm, pos=42.5cm, MPPC(5\*5\*75cm Scinti), bias 55V

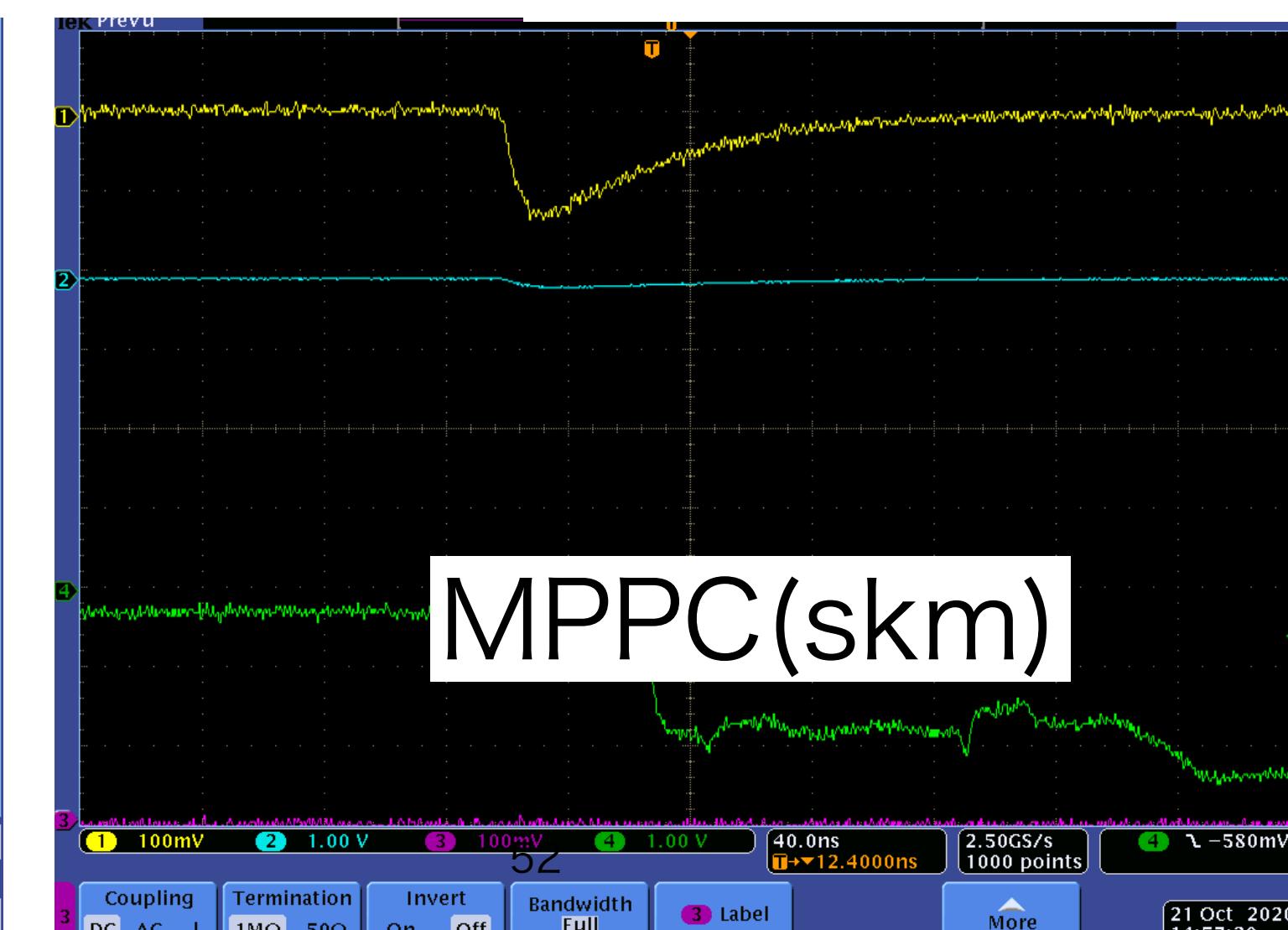
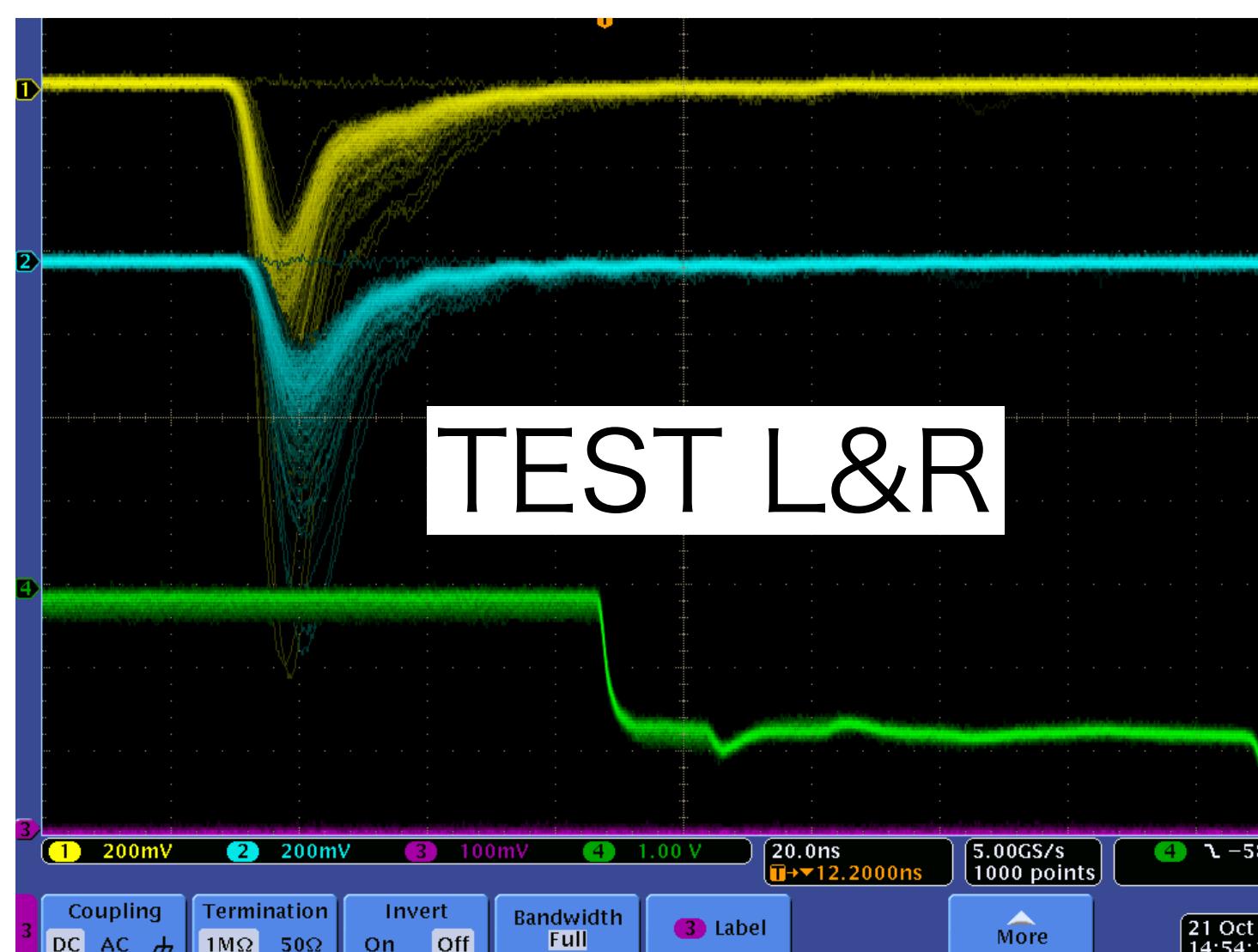
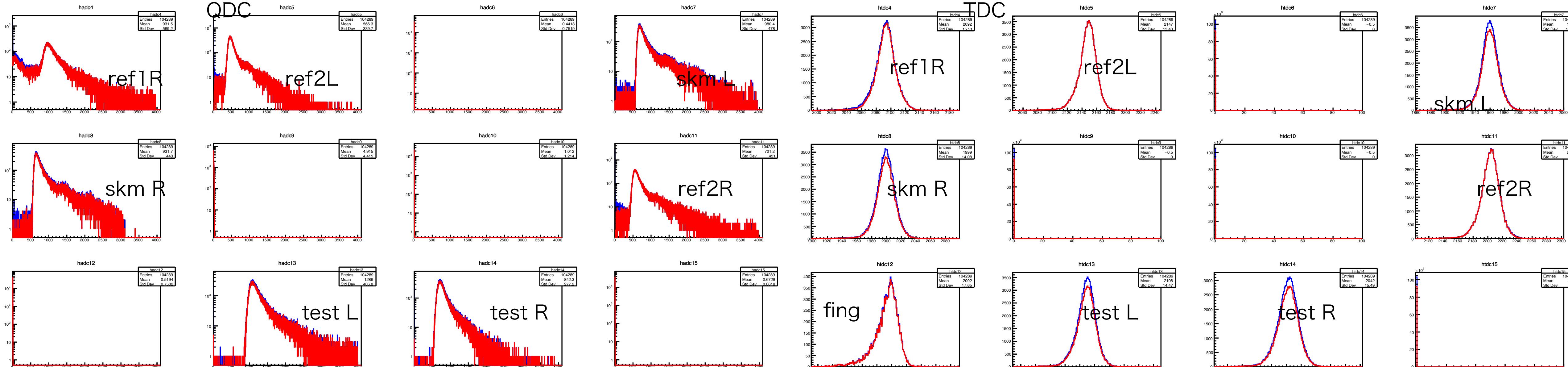


# 2. Light Guide

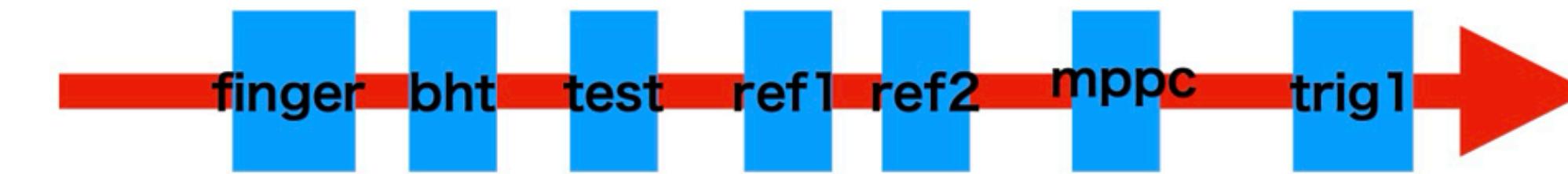


Blue ; raw data  
Red ; ref & trig tdc != -1

Run80, LG 0mm, pos=107.5cm, MPPC(5\*5\*75cm Scinti), bias 55V (w/ atte)



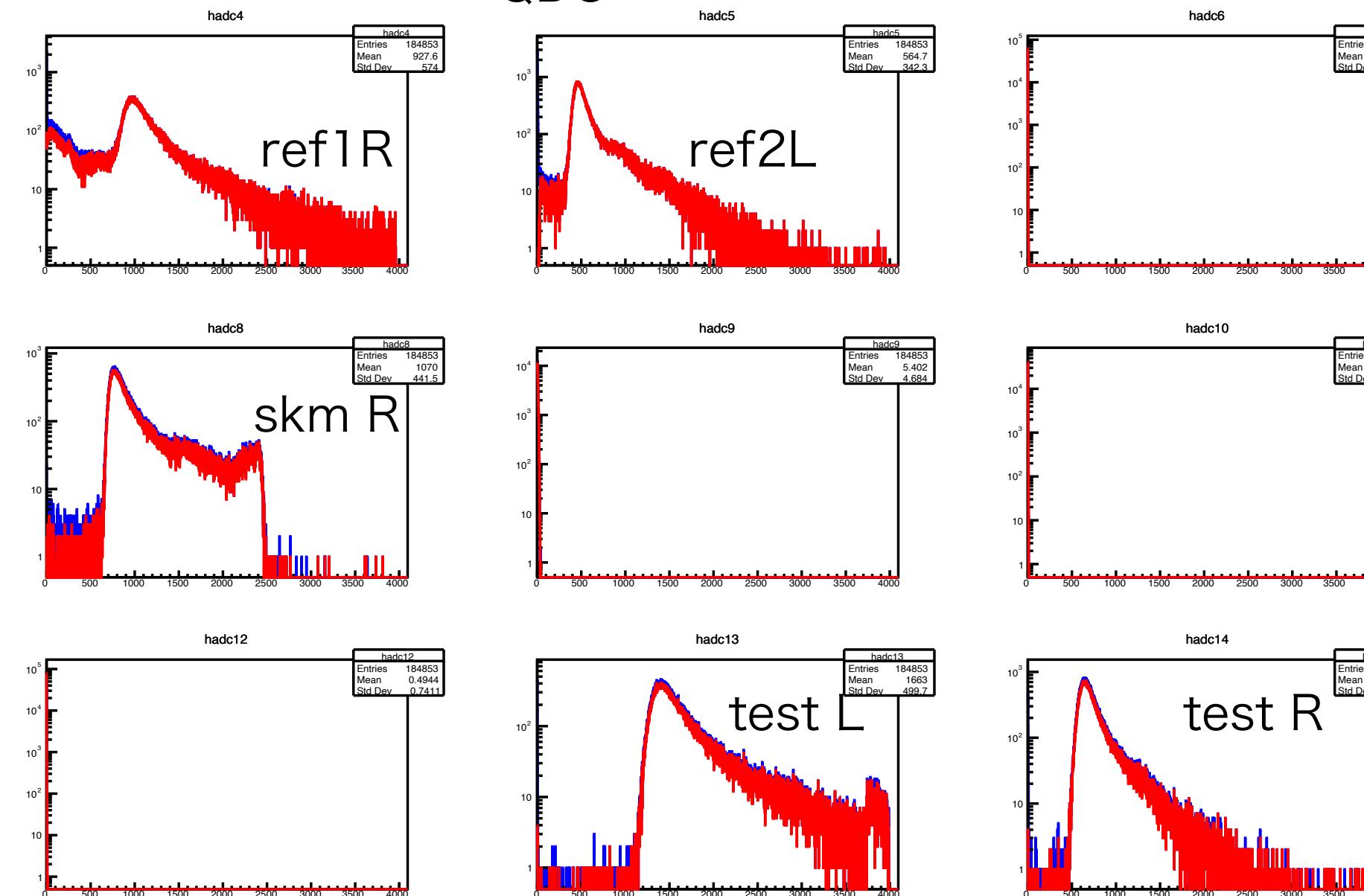
# 2. Light Guide



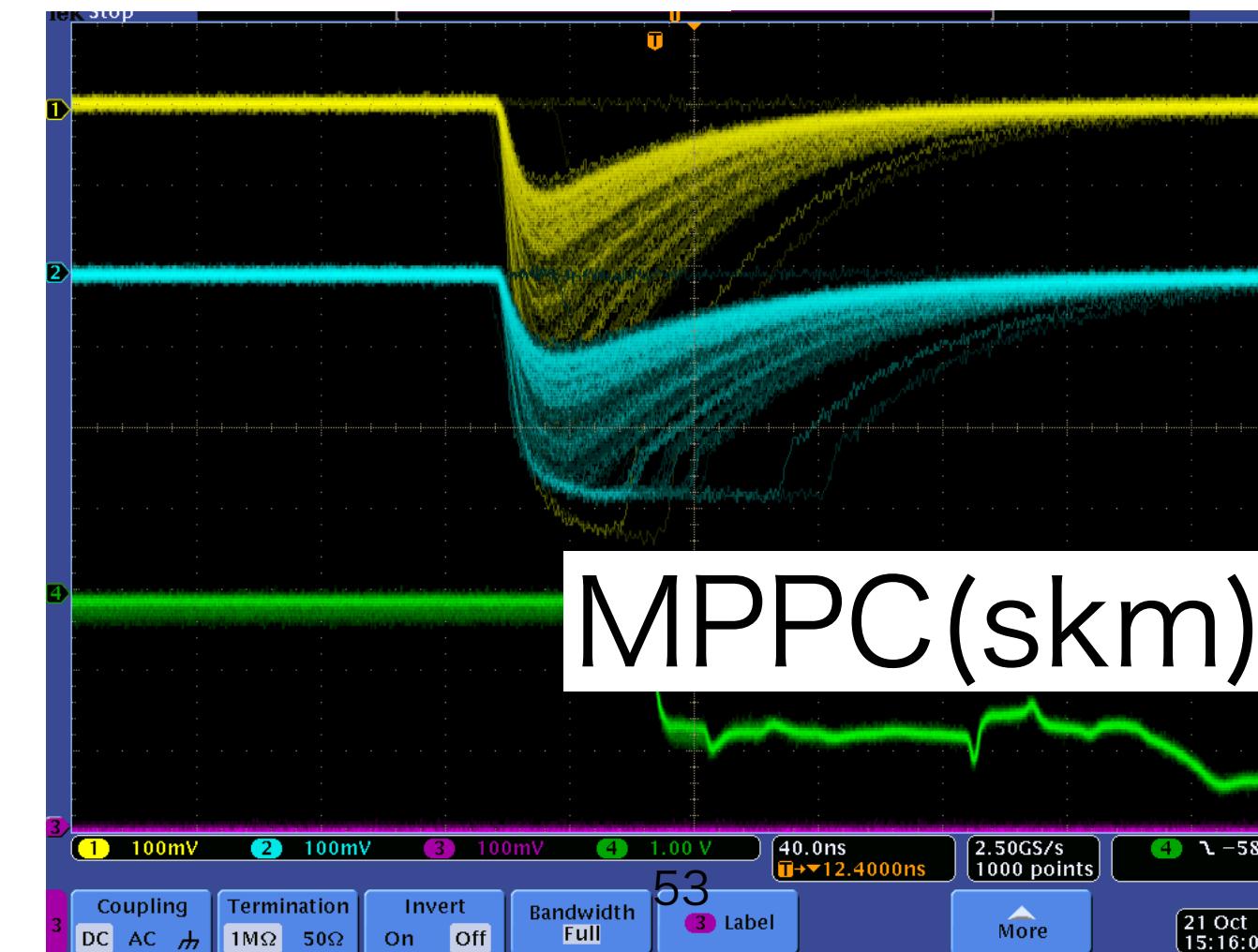
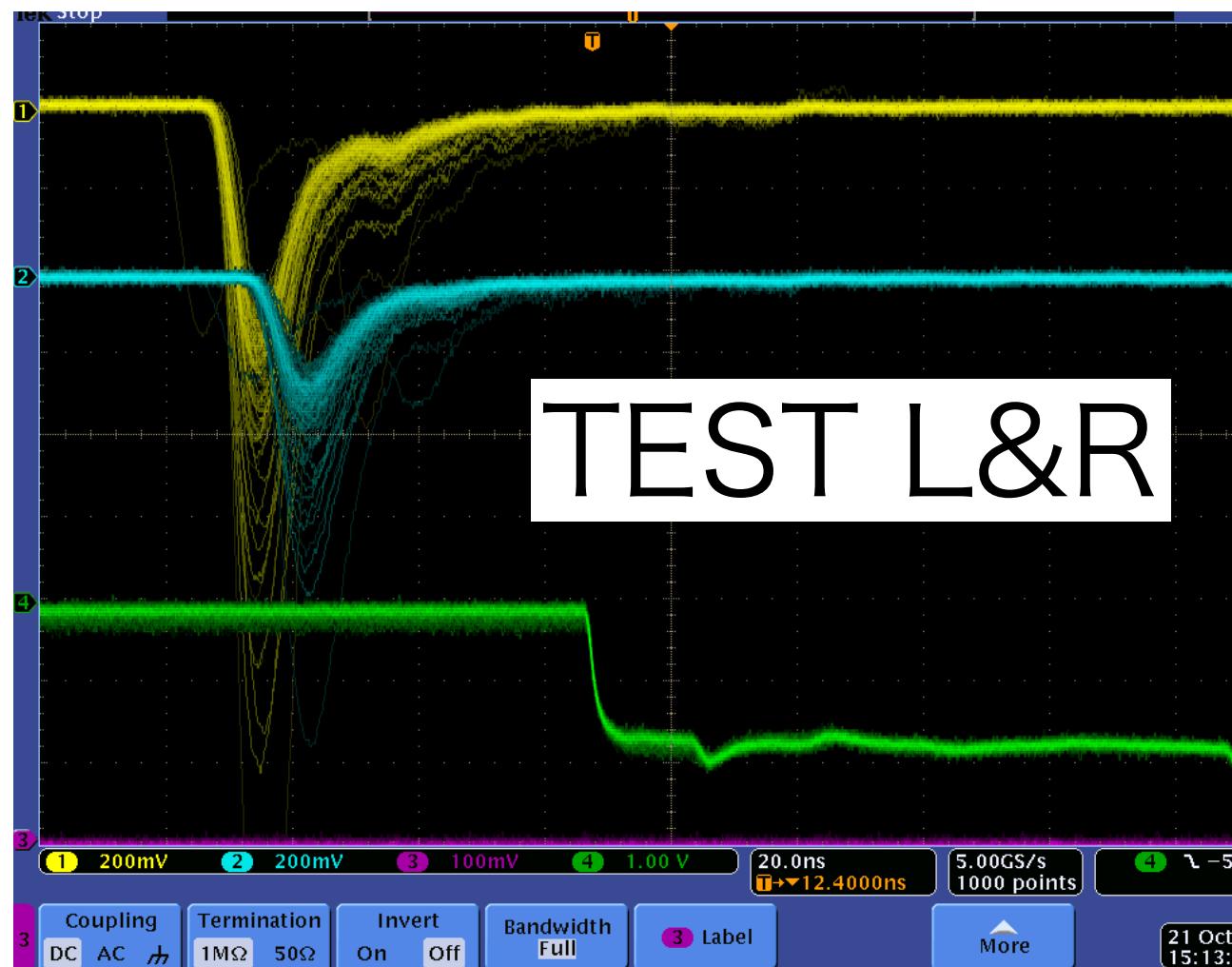
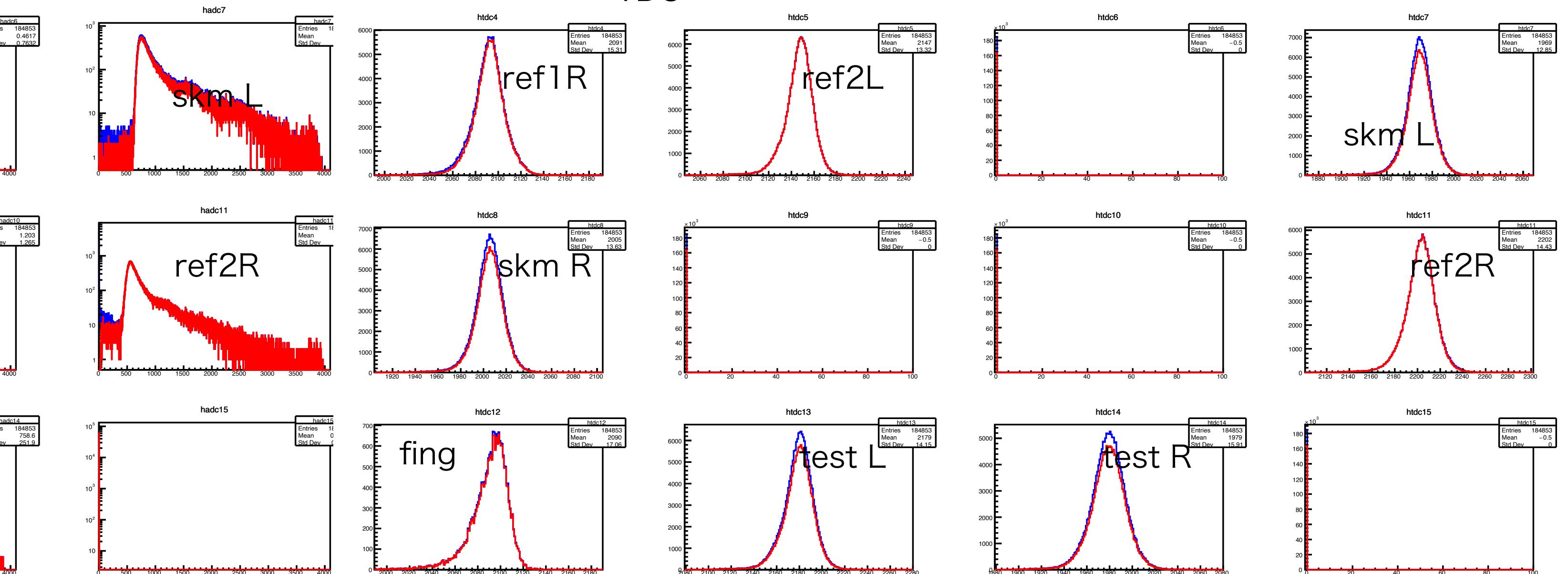
Blue ; raw data  
Red ; ref & trig tdc != -1

Run85, LG 0mm, pos=140cm, MPPC(5\*5\*75cm Scinti), bias 56V (w/ atte)

QDC

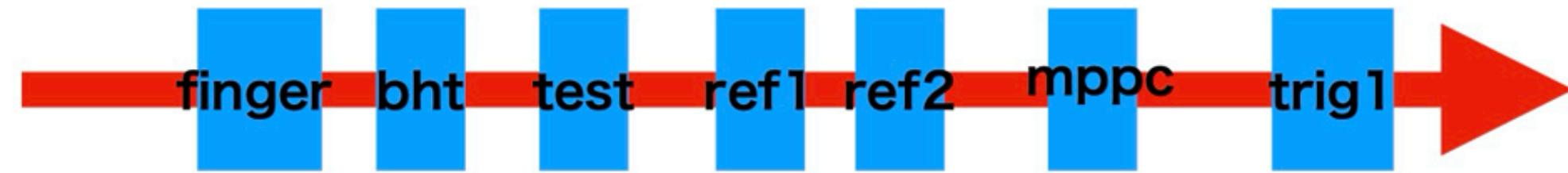


TDC



幸ってる

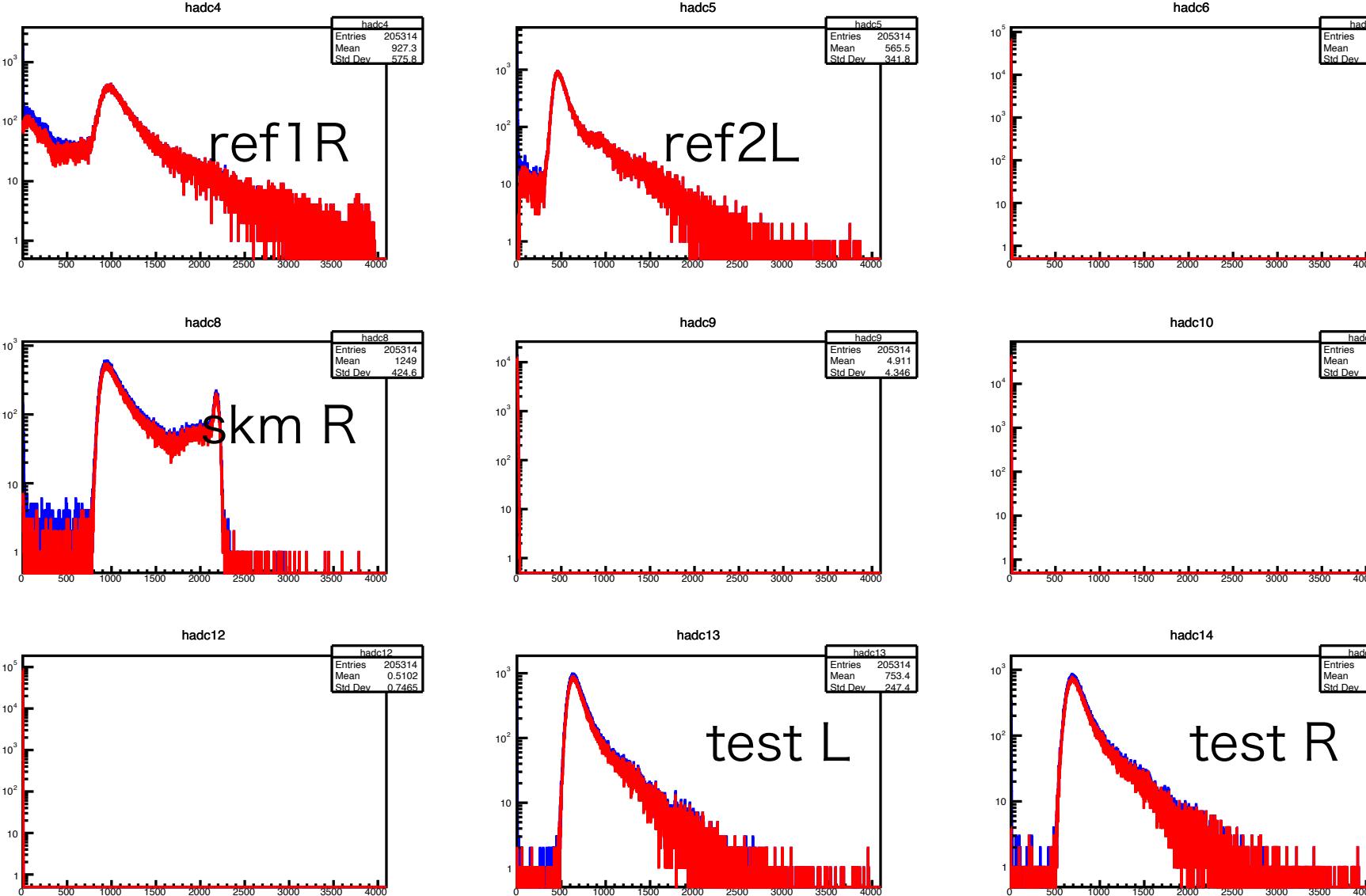
# 2. Light Guide



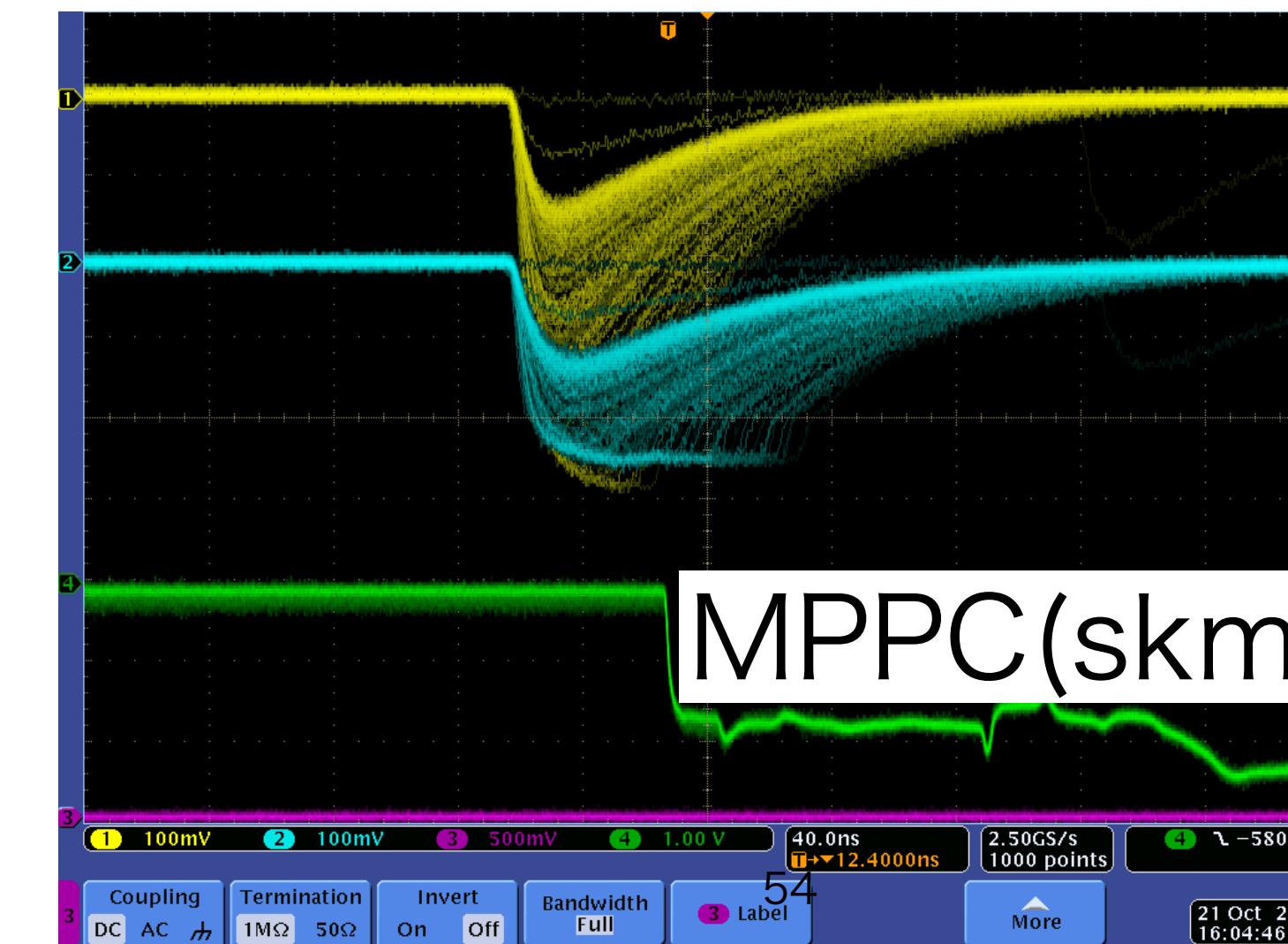
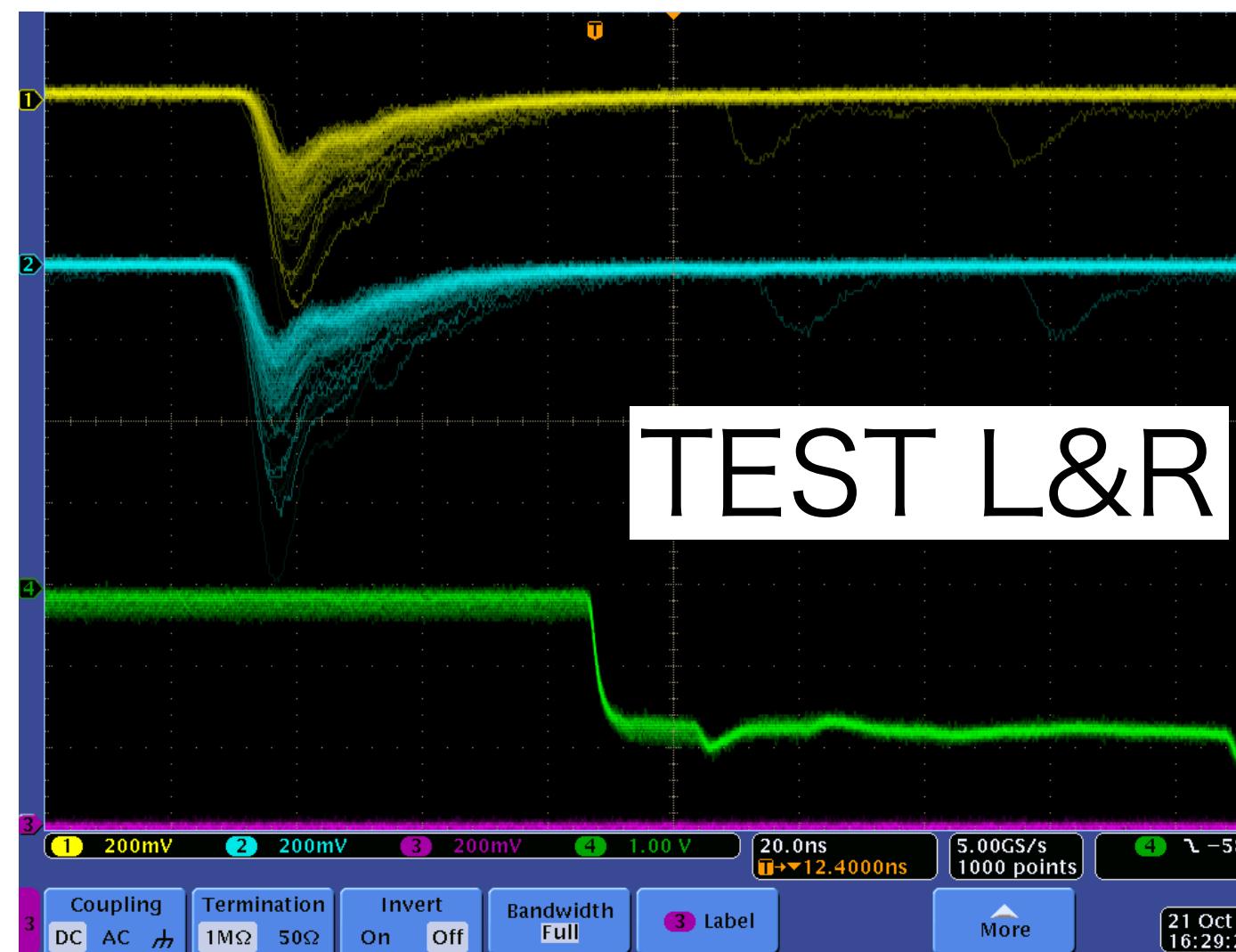
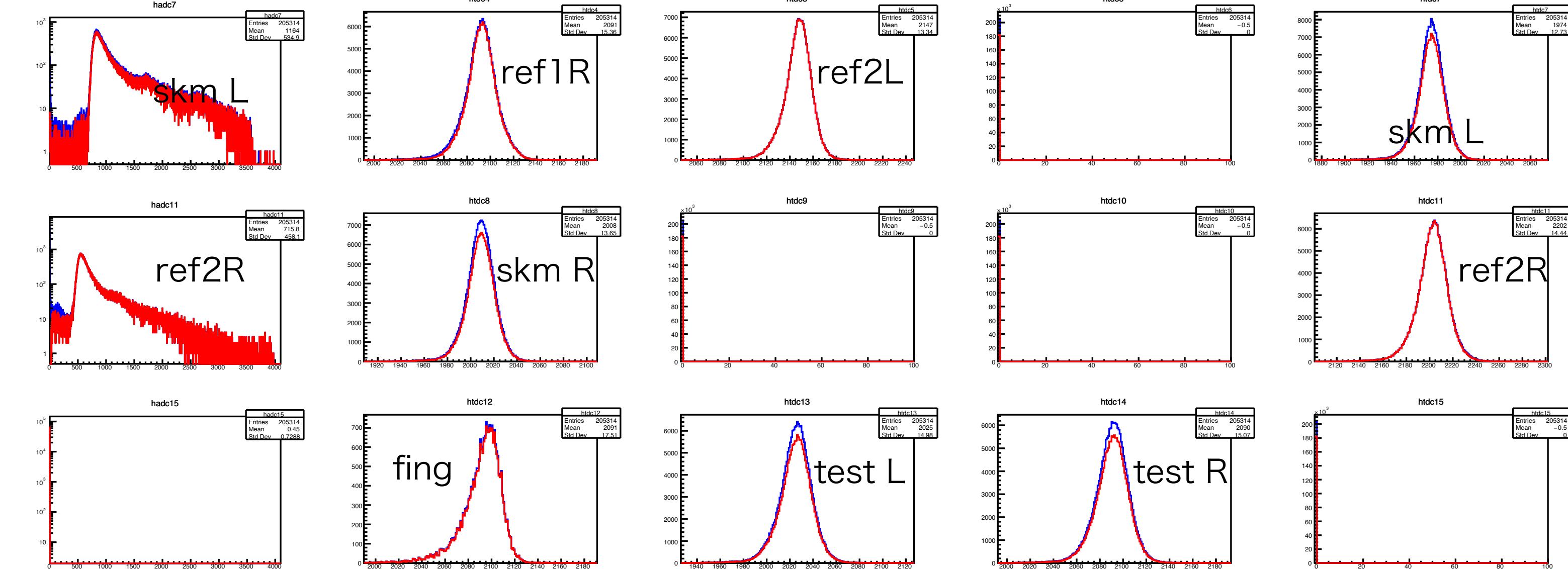
Blue ; raw data  
Red ; ref & trig tdc != -1  
W/ atte  
L : 10 dB  
R : 14 dB

Run89, LG 115mm, pos=75cm(center), MPPC(5\*5\*75cm Scinti), bias 57V

QDC



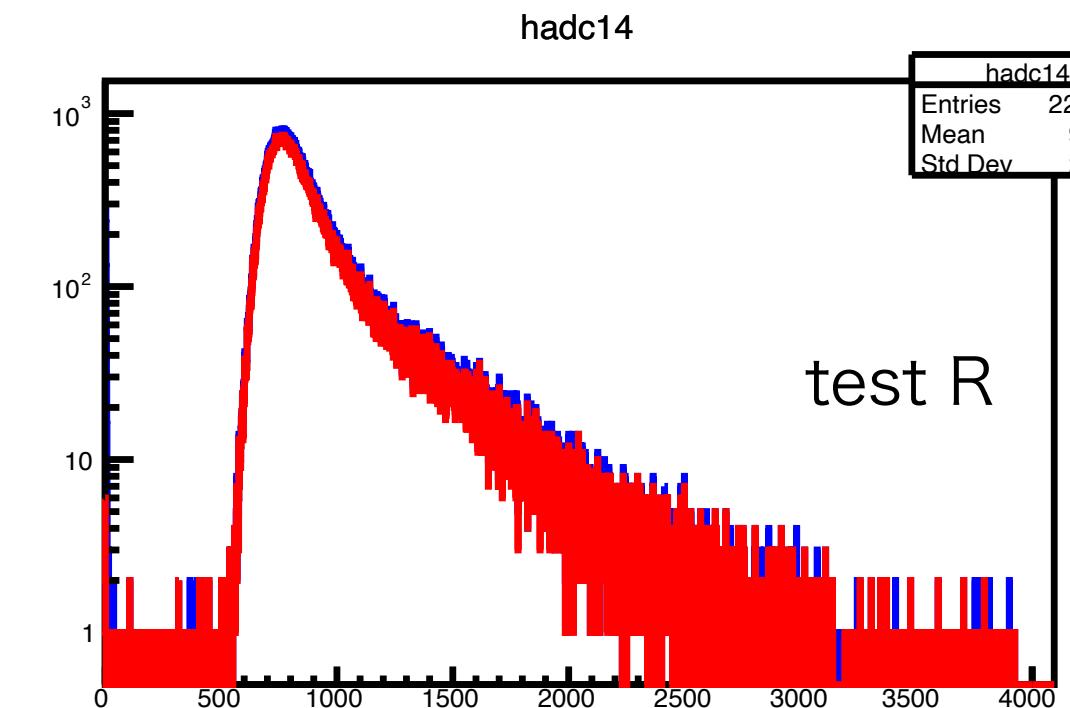
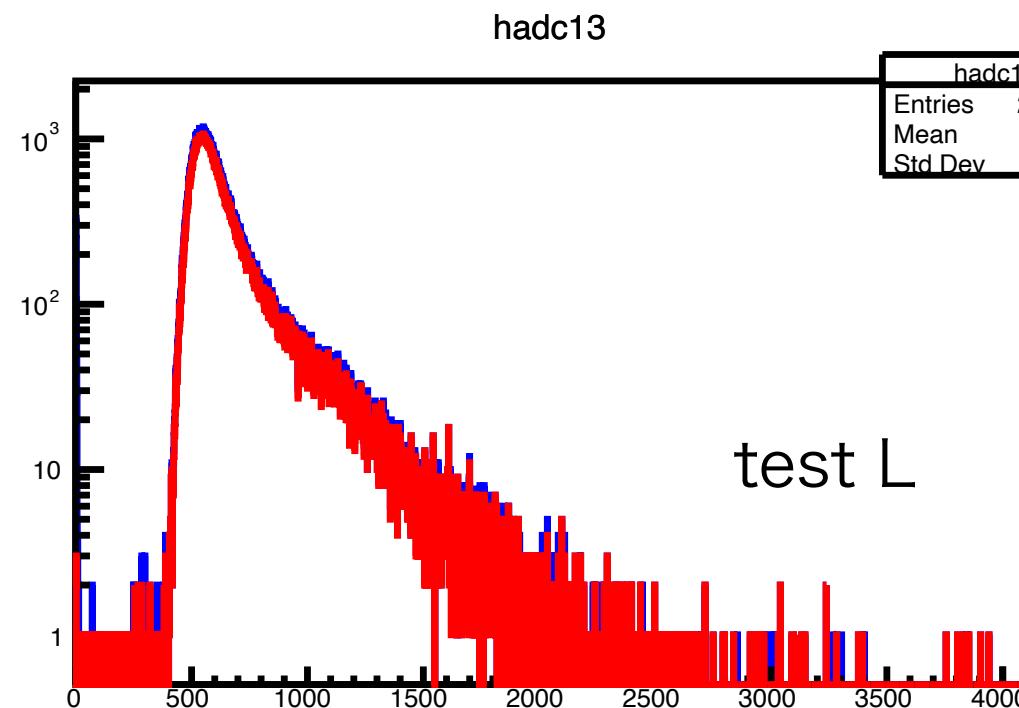
TDC



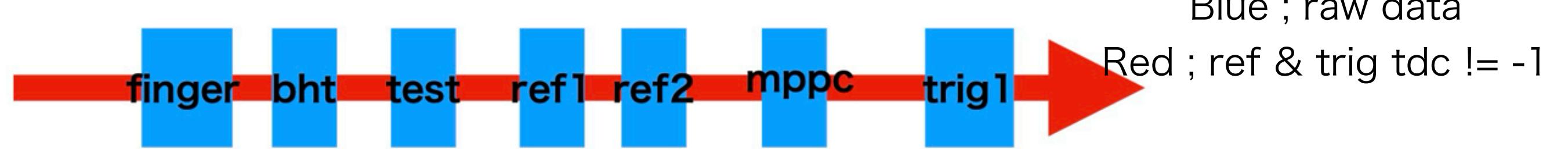
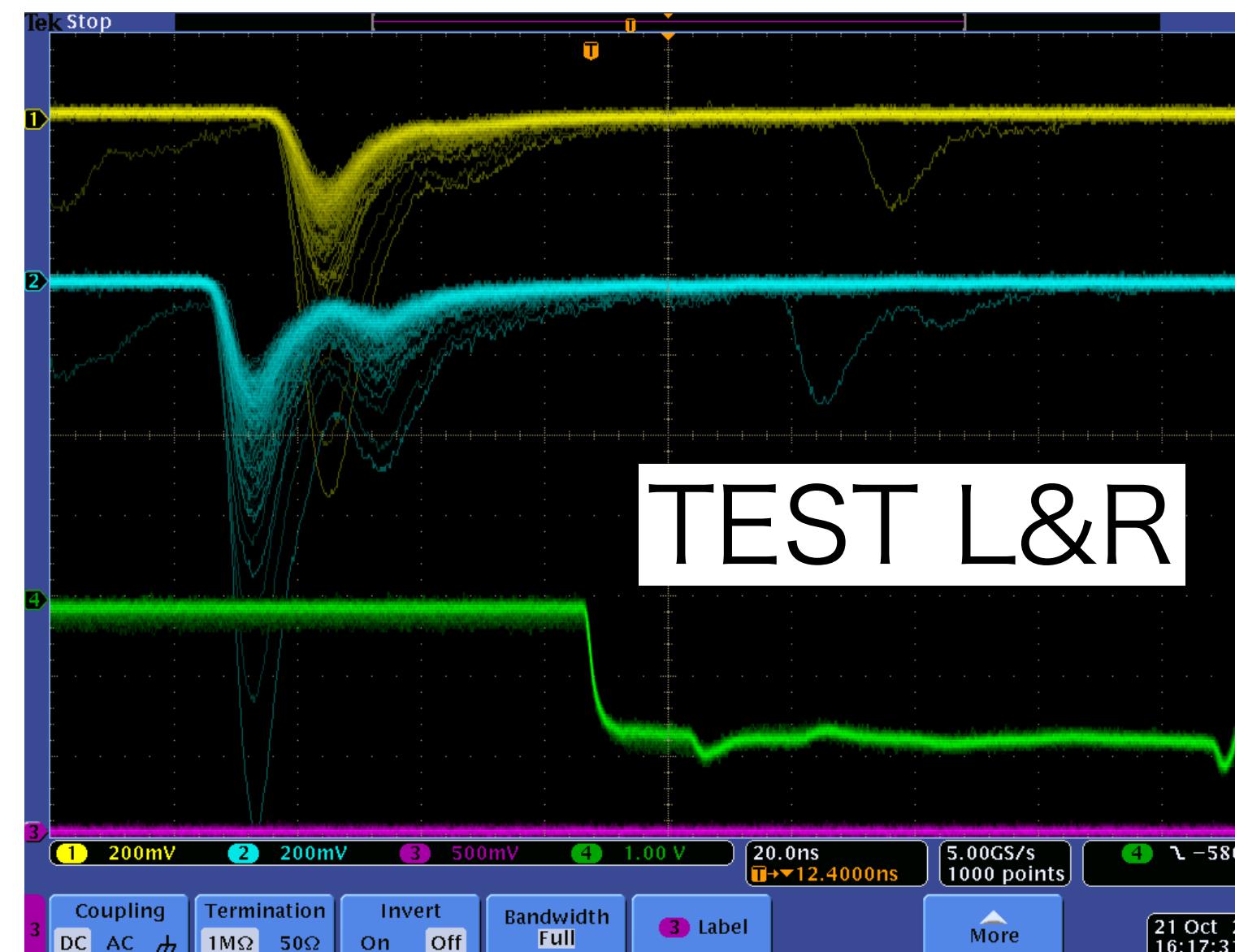
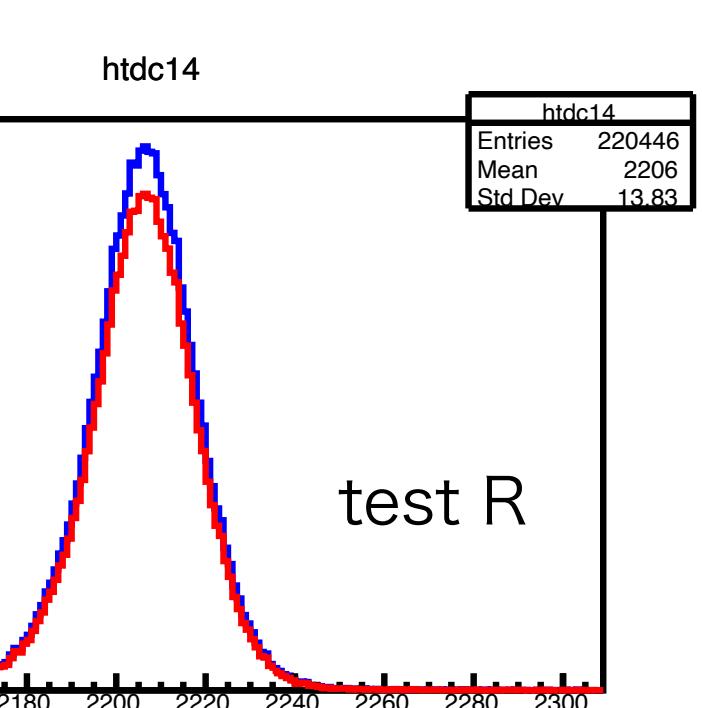
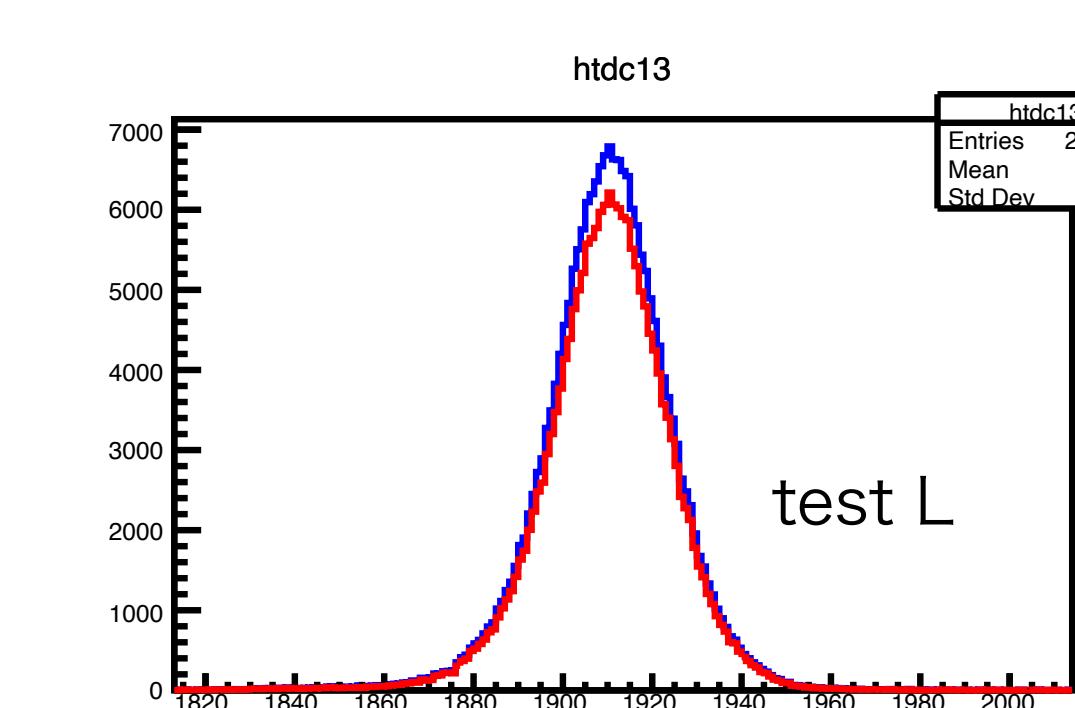
# 2. Light Guide

Run92, LG 115mm, pos=10cm

QDC



TDC

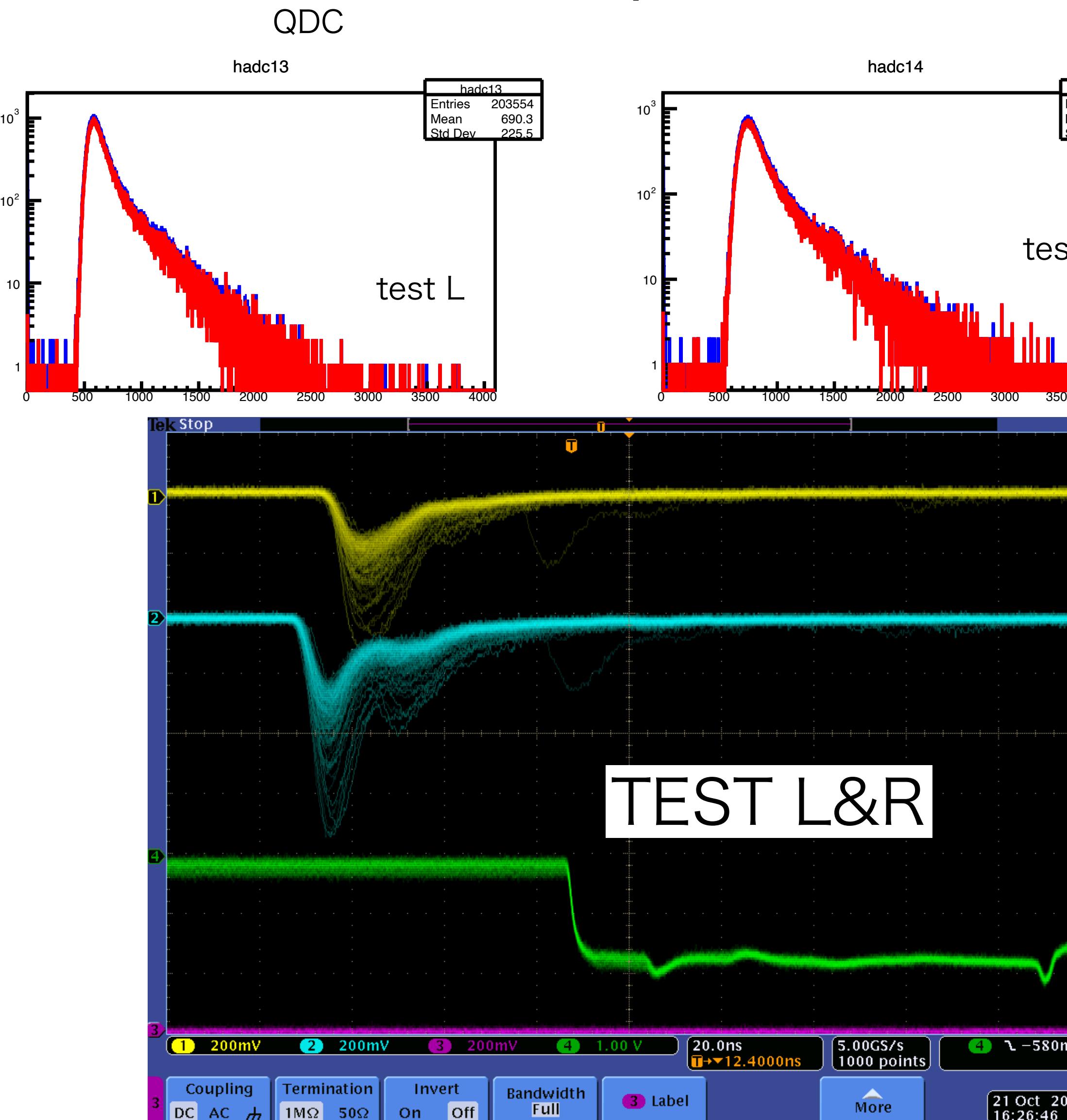
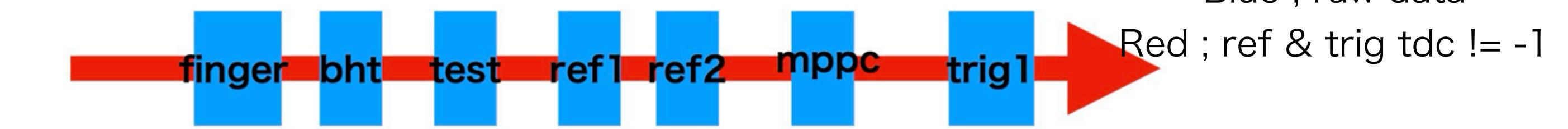


Blue ; raw data

Red ; ref & trig tdc != -1

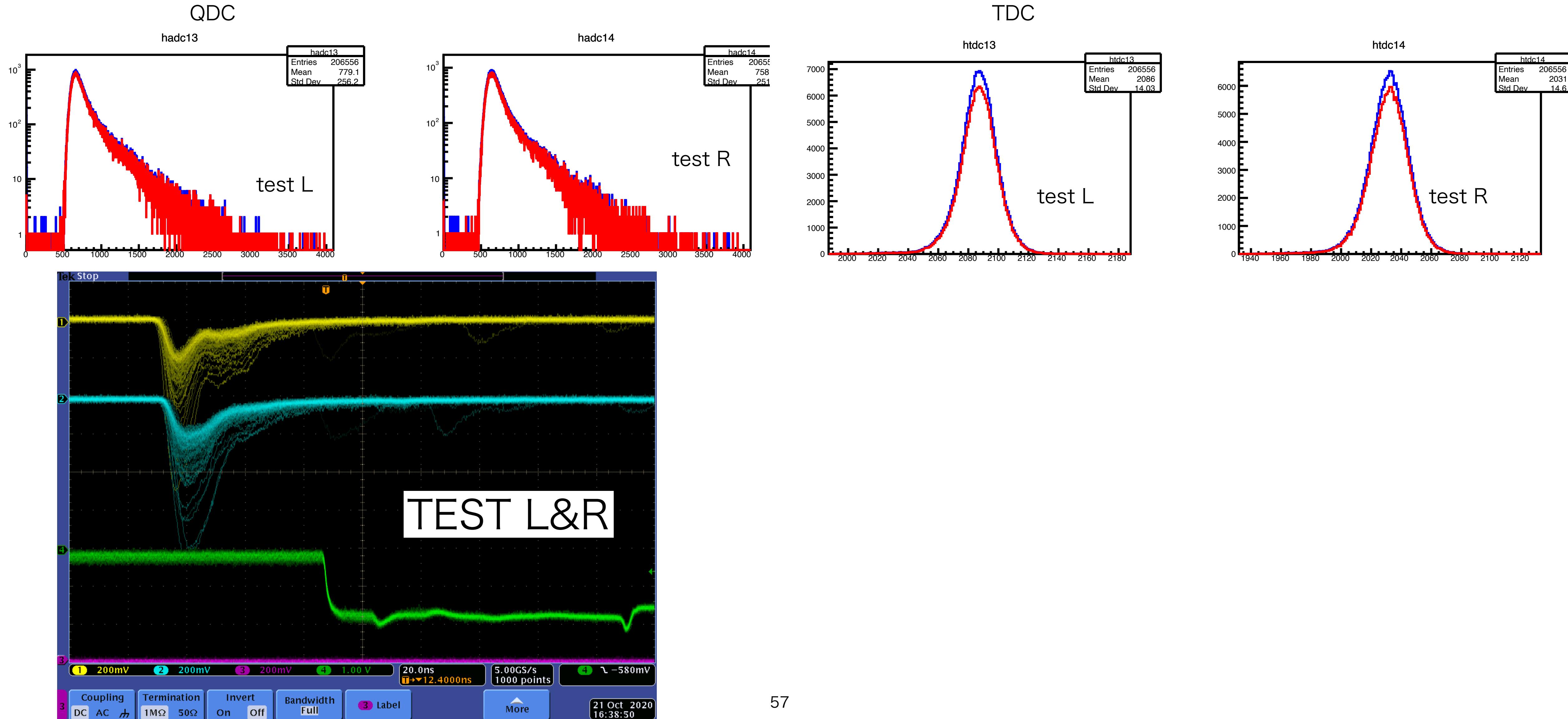
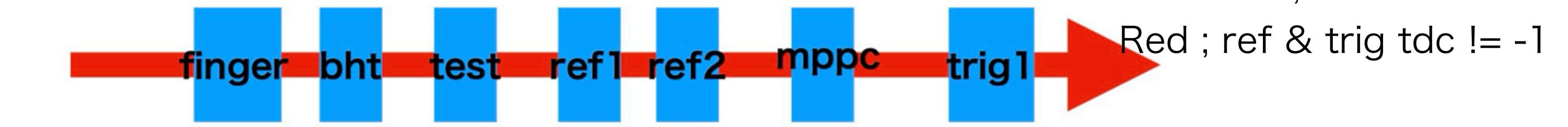
# 2. Light Guide

Run93, LG 115mm, pos=42.5cm

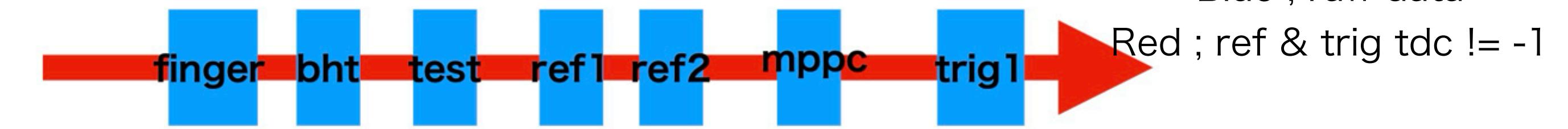


# 2. Light Guide

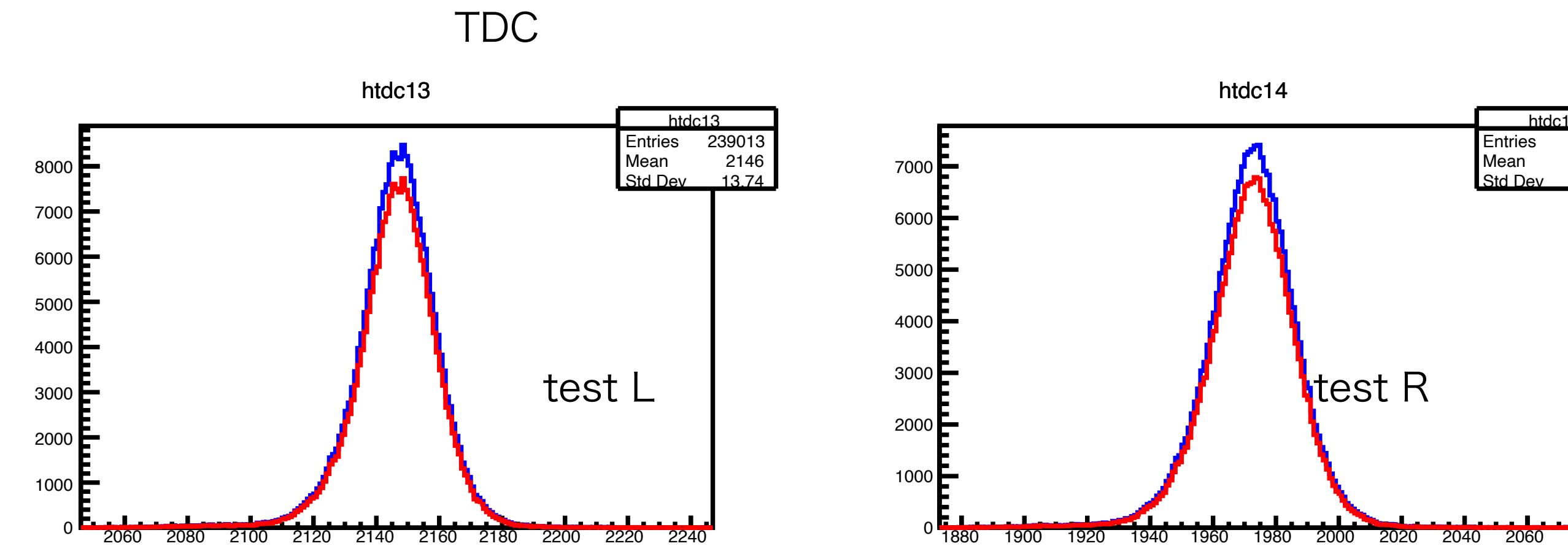
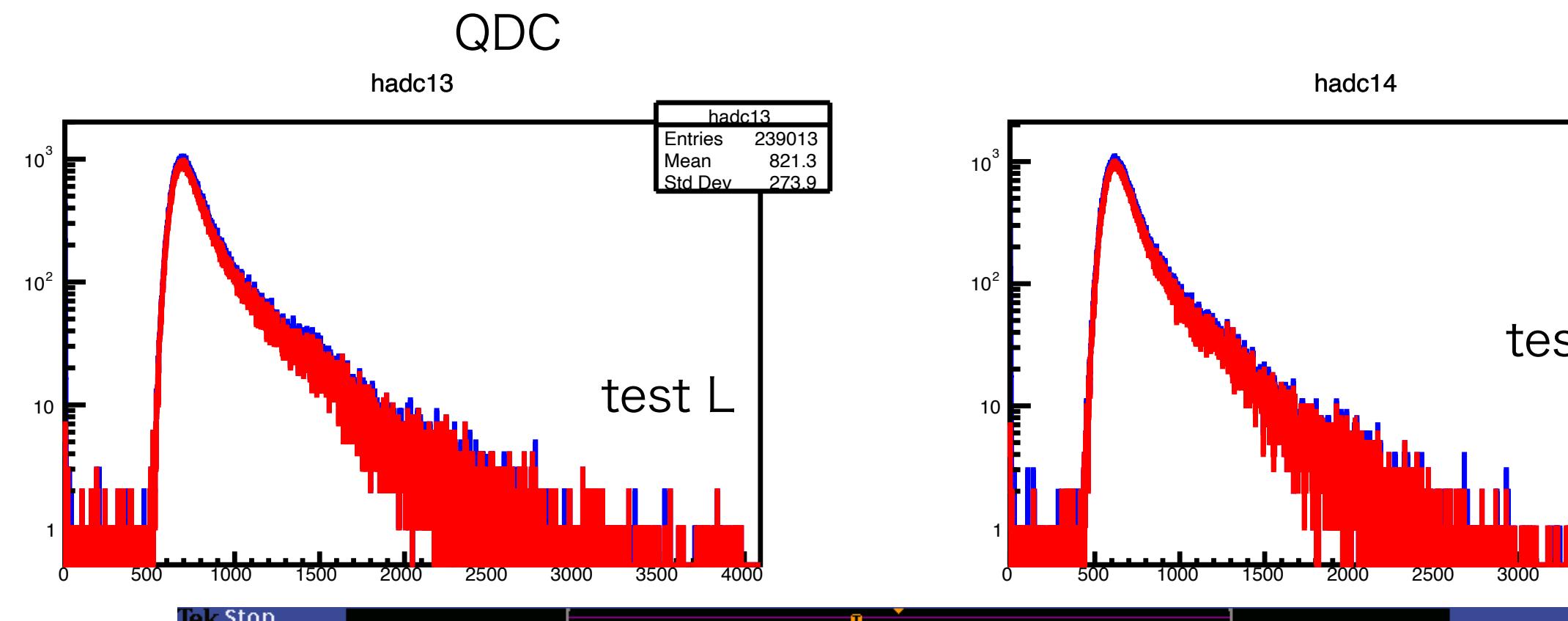
Run95, LG 115mm, pos=107.5cm



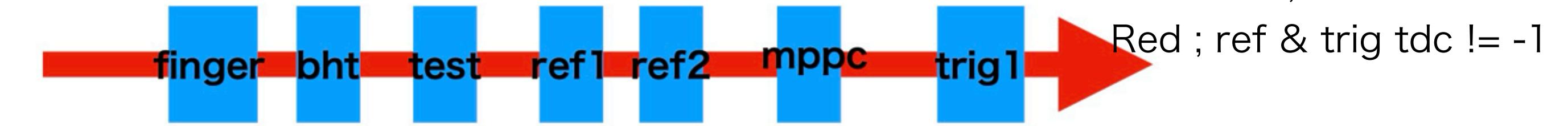
# 2. Light Guide



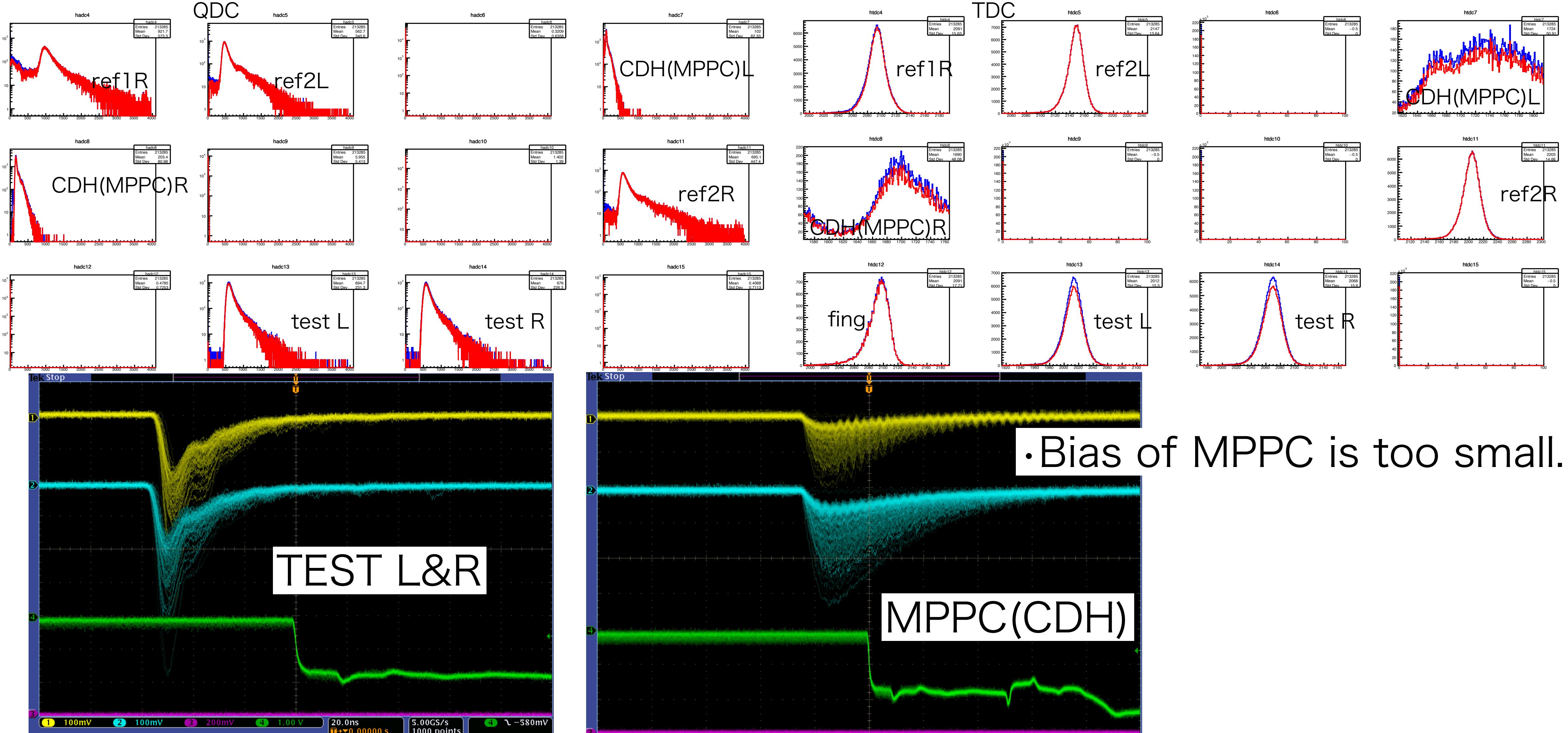
Run96, LG 115mm, pos=140cm



# 2. Light Guide

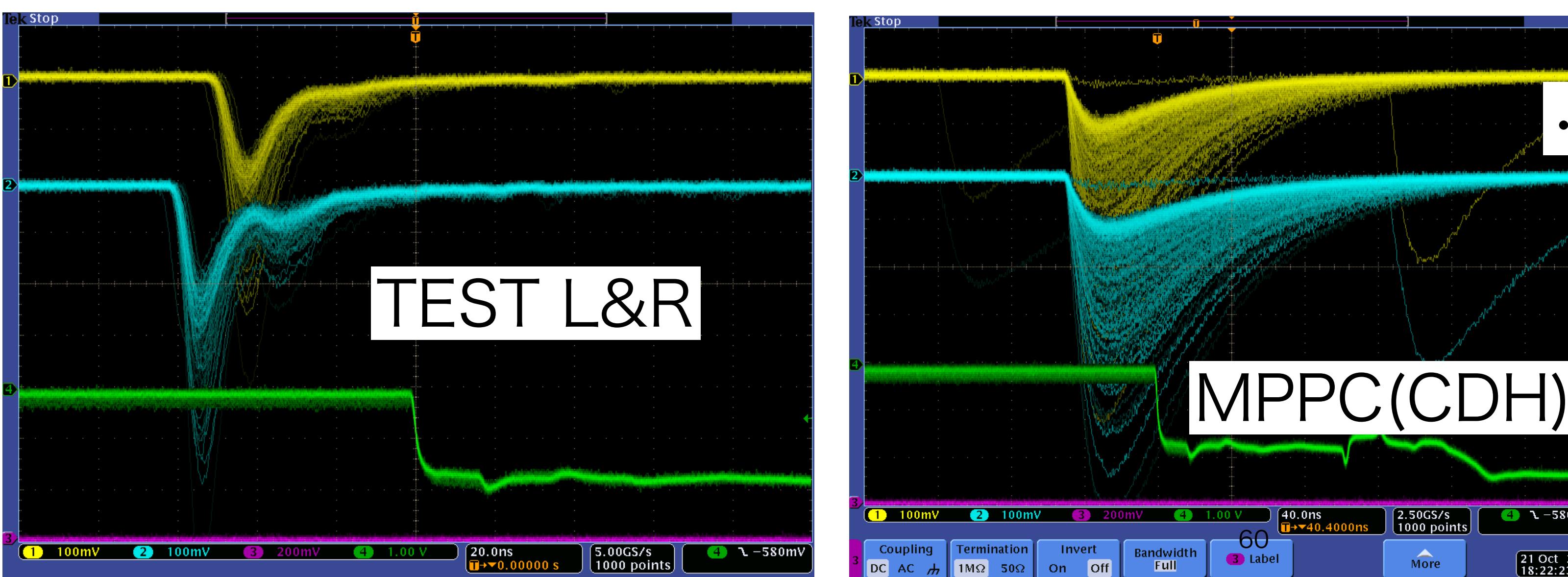
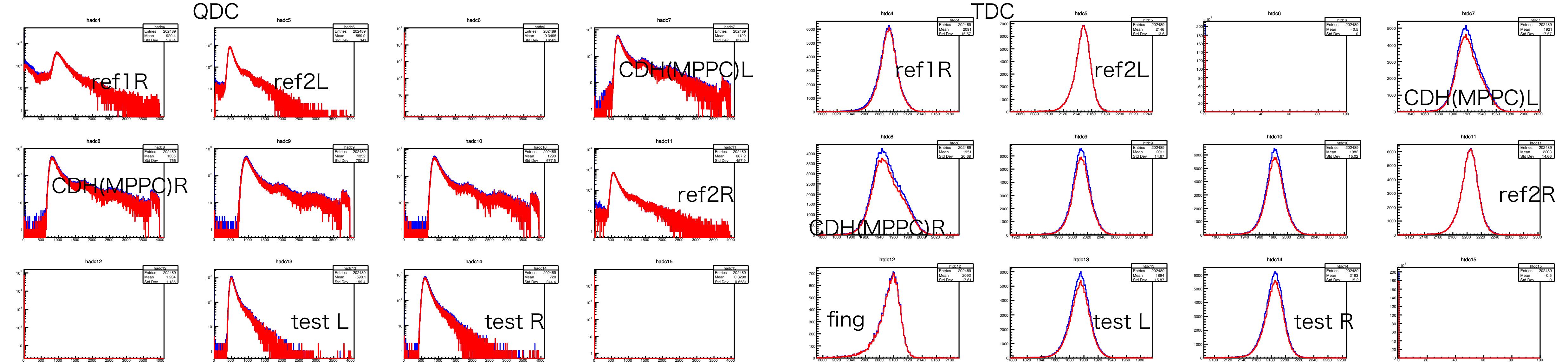
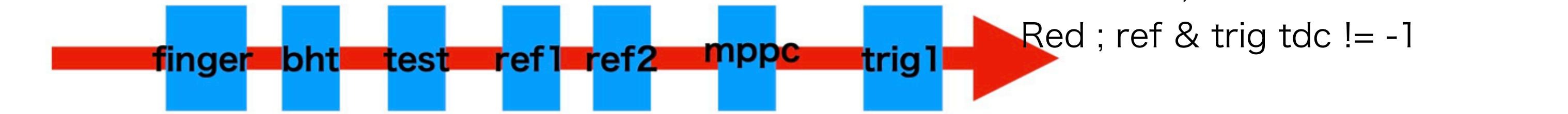


Run97, LG 230mm, pos=75cm(center), MPPC(CDH), bias 53V

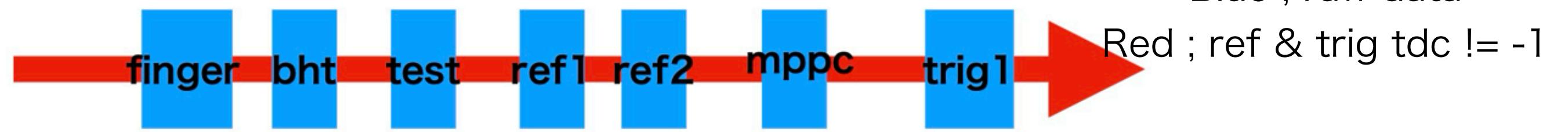


# 2. Light Guide

Run100, LG 230mm, pos=10cm, MPPC(CDH), bias 56V

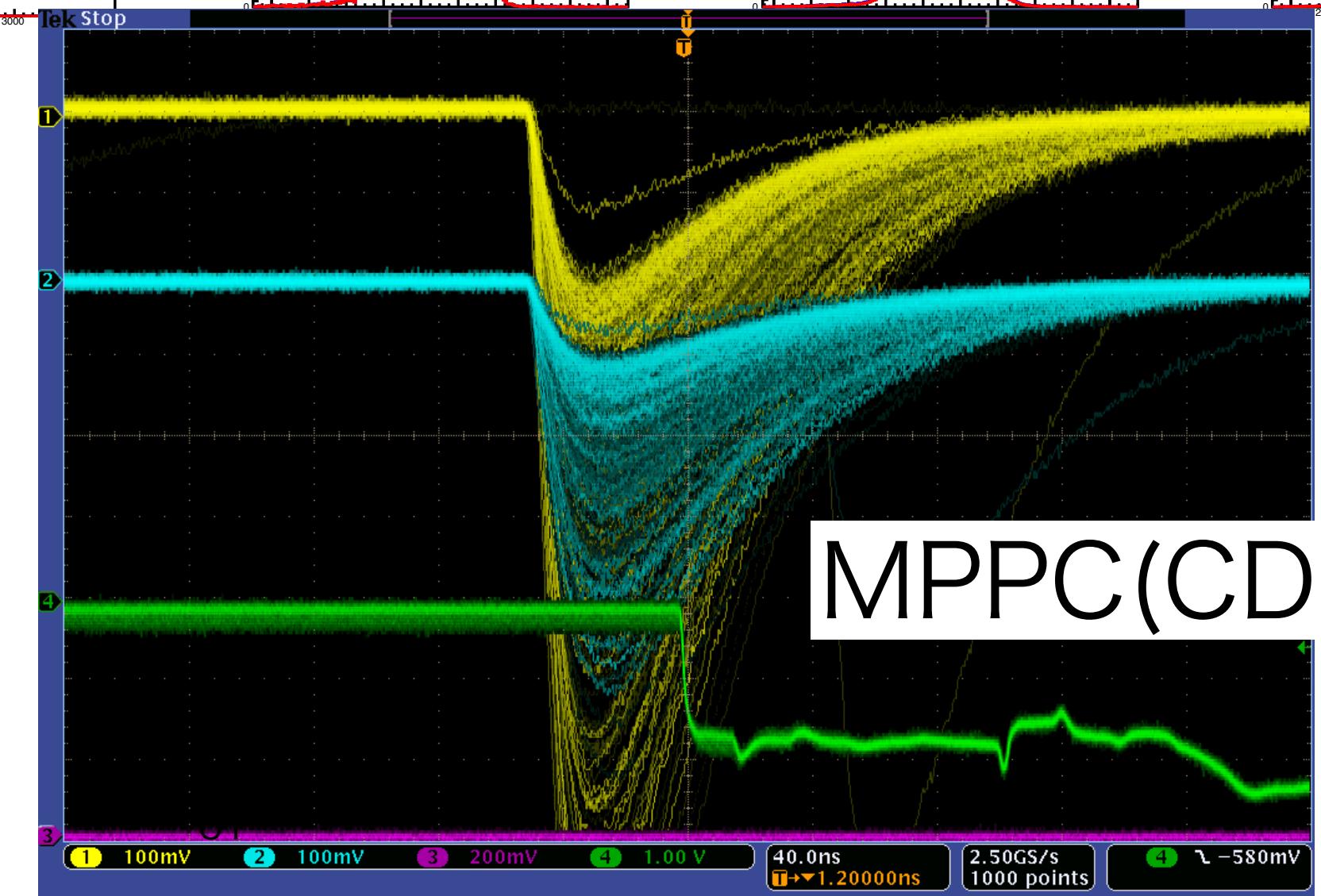
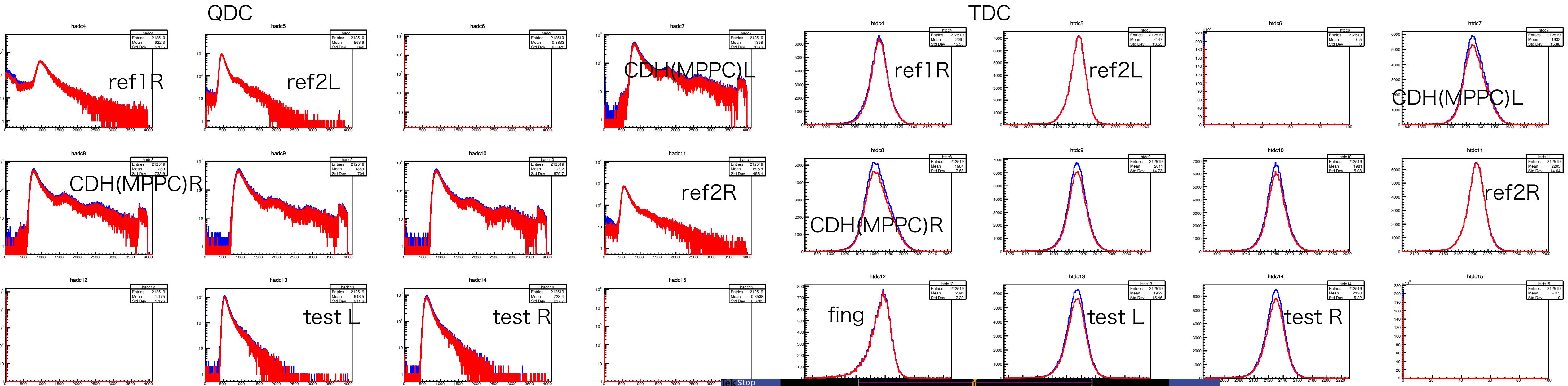


# 2. Light Guide



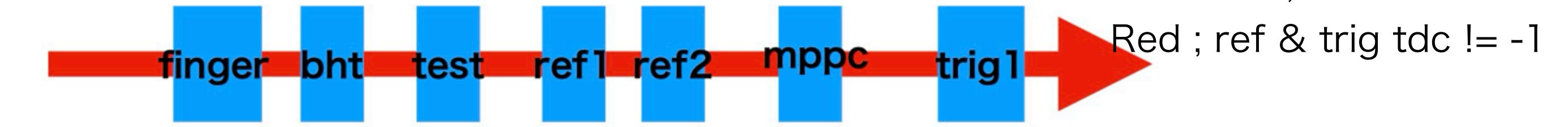
Run104, LG 230mm, pos=42.5cm, MPPC(CDH), bias 57V

L : 1dB  
R : 3dB



# 2. Light Guide

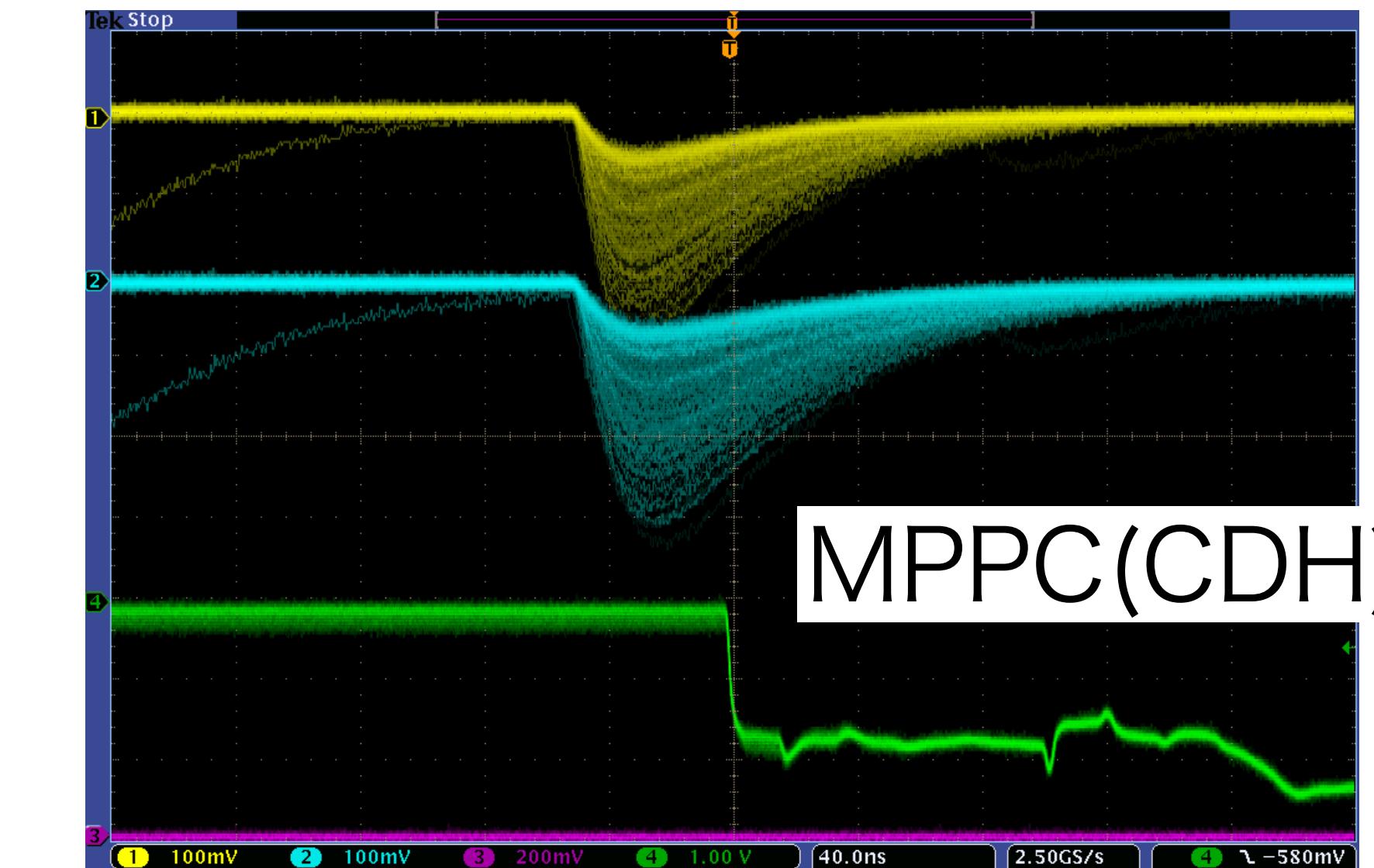
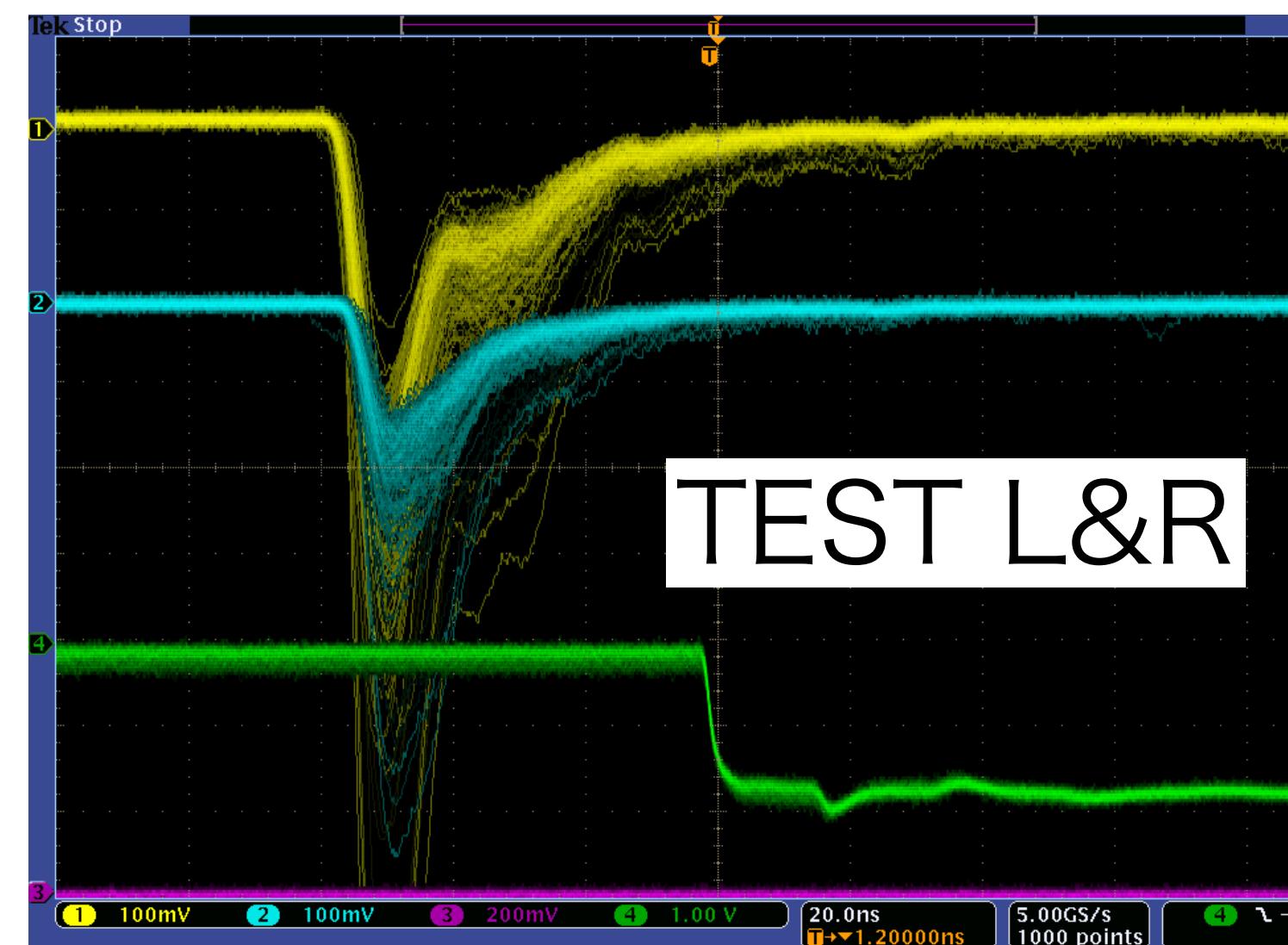
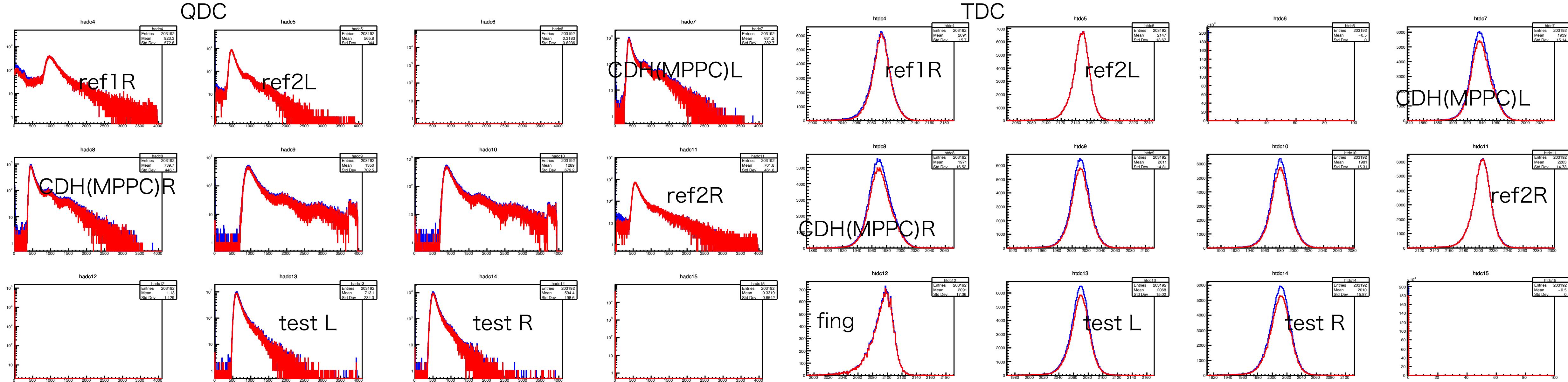
Run109, LG 230mm, pos=107.5cm, MPPC(CDH), bias 58V



Blue ; raw data

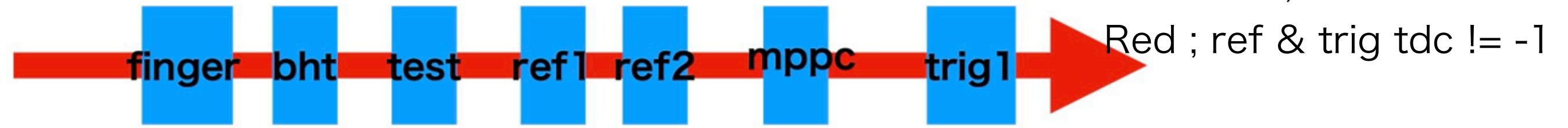
Red ; ref & trig tdc != -1

L : 10dB  
R : 10dB

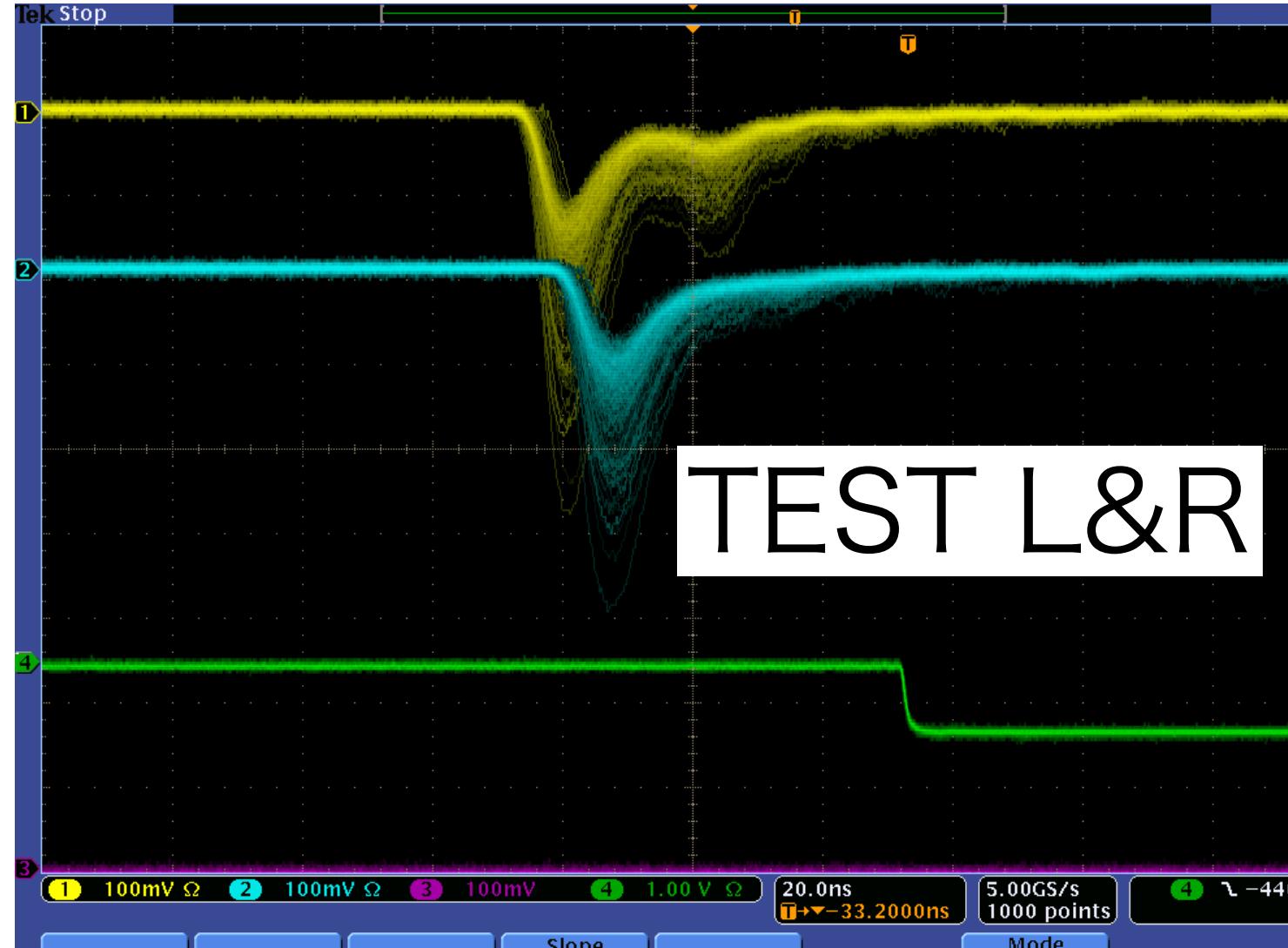
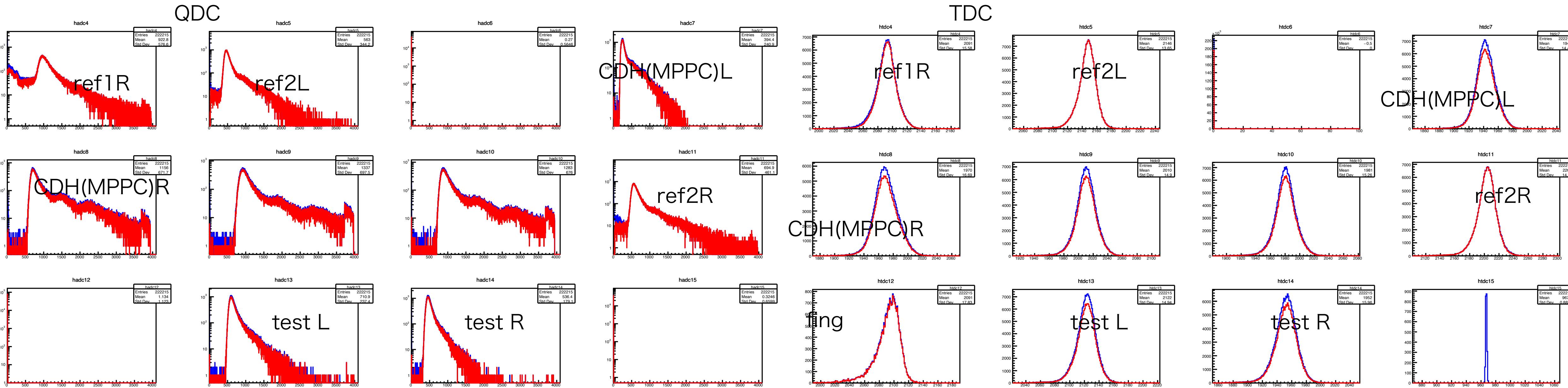


# 2. Light Guide

Run113, LG 230mm, pos=140cm, MPPC(CDH), bias 59V

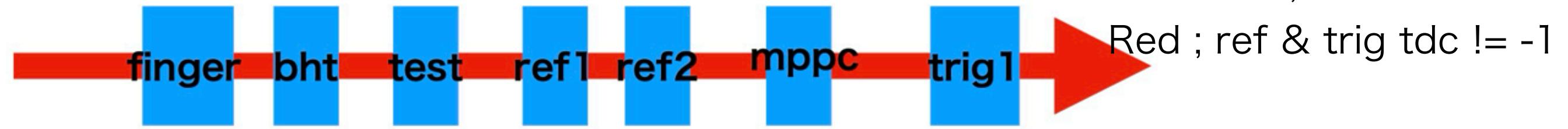


L : 10dB  
R : 10dB



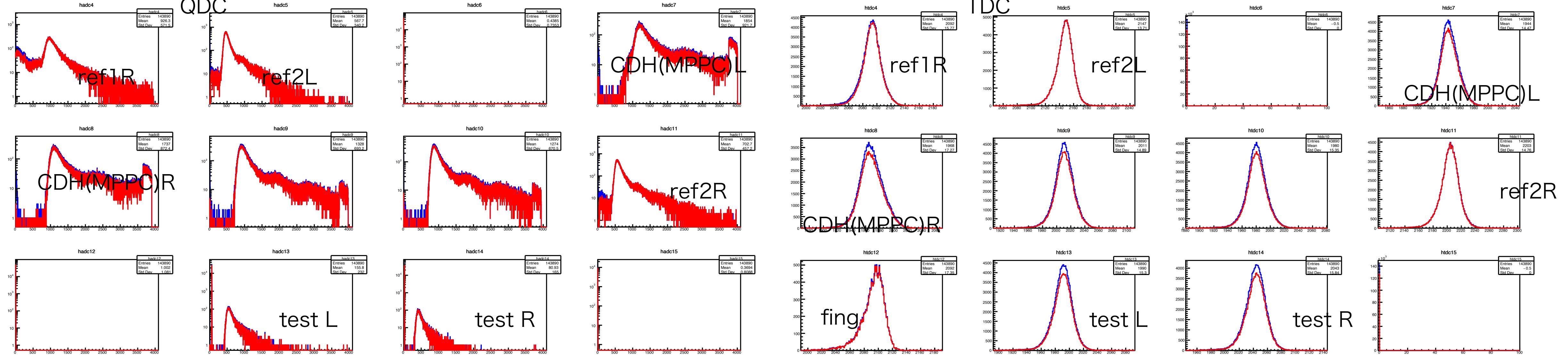
MPPC(CDH)

# 2. Light Guide



Run116, LG 345mm, pos=75cm(center), MPPC(CDH), bias 59V

L : 1dB  
R : 3dB

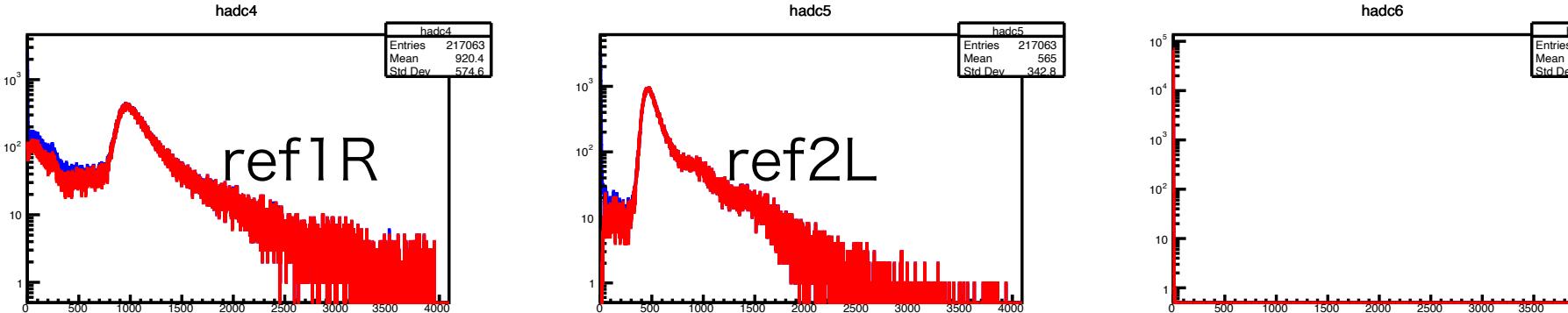


No oscillo

# 2. Light Guide

Run117, LG 345mm, pos=75cm(center), MPPC(CDH), bias 59V

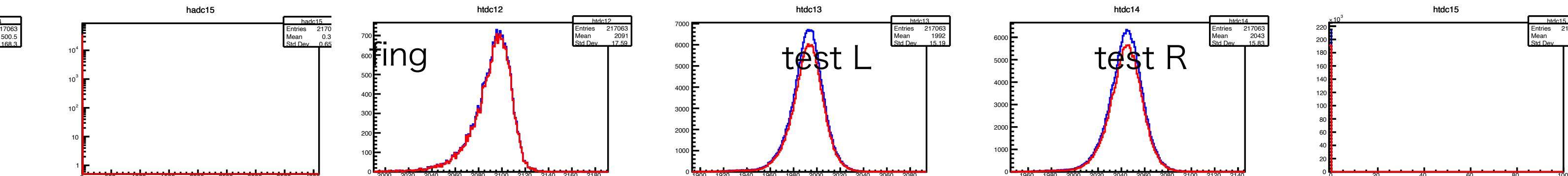
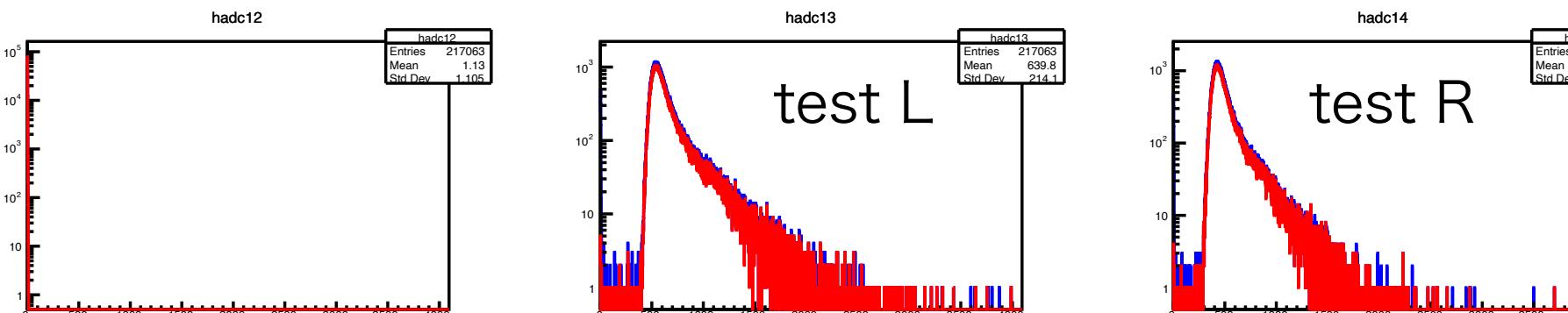
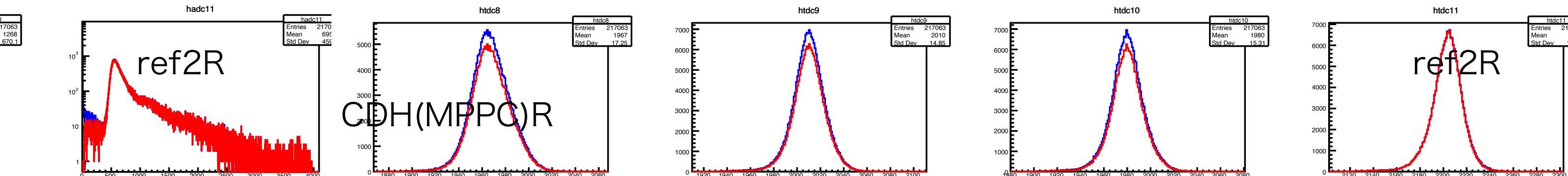
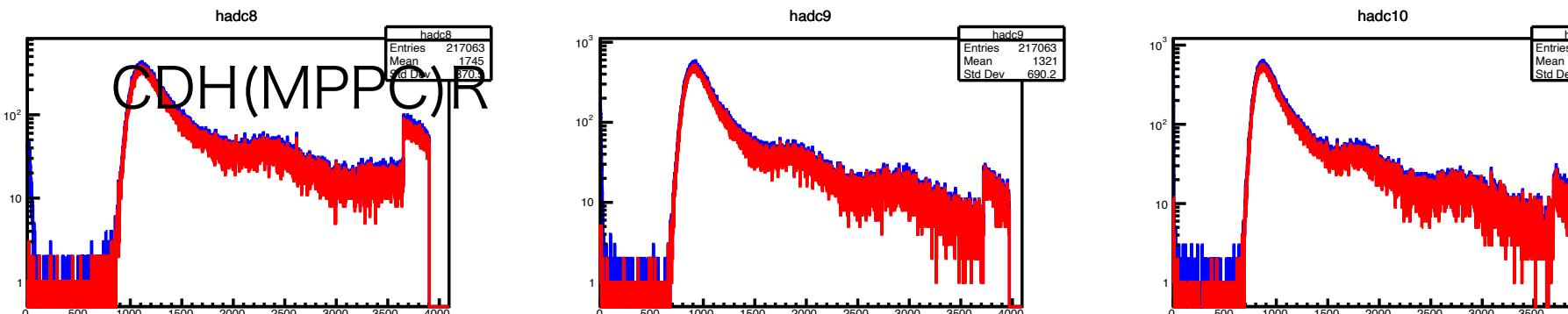
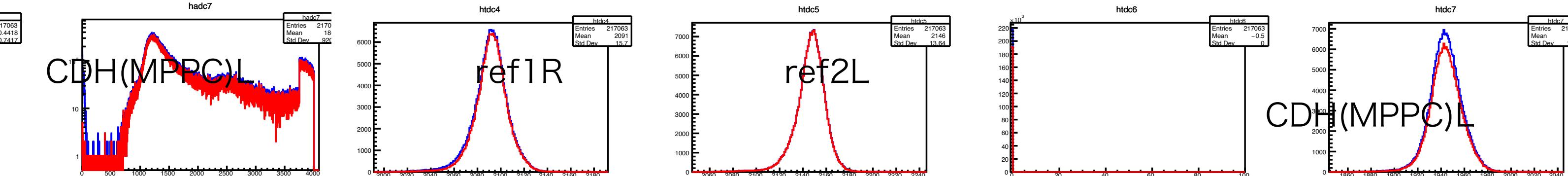
QDC



finger bht test ref1 ref2 mppc trig1

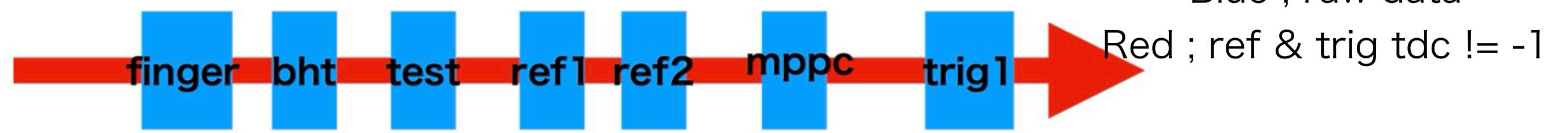
Blue ; raw data  
Red ; ref & trig tdc != -1

TDC



# 2. Light Guide

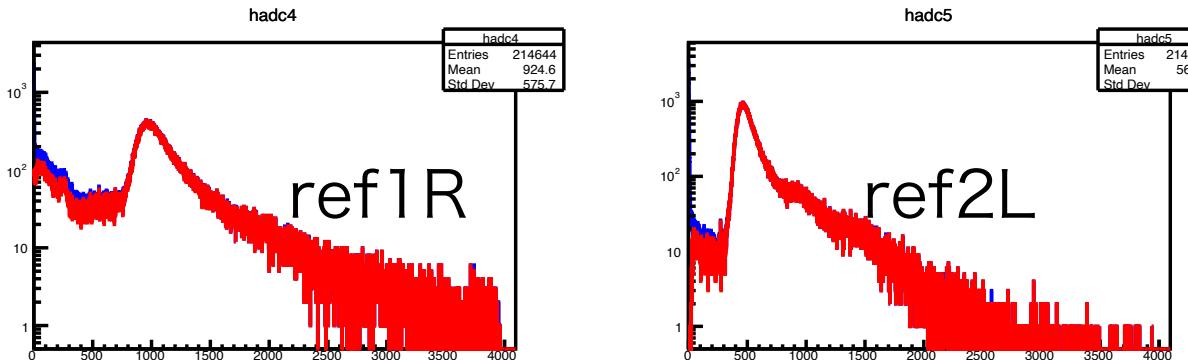
Run120, LG 345mm, pos=10cm, MPPC(CDH), bias 59V



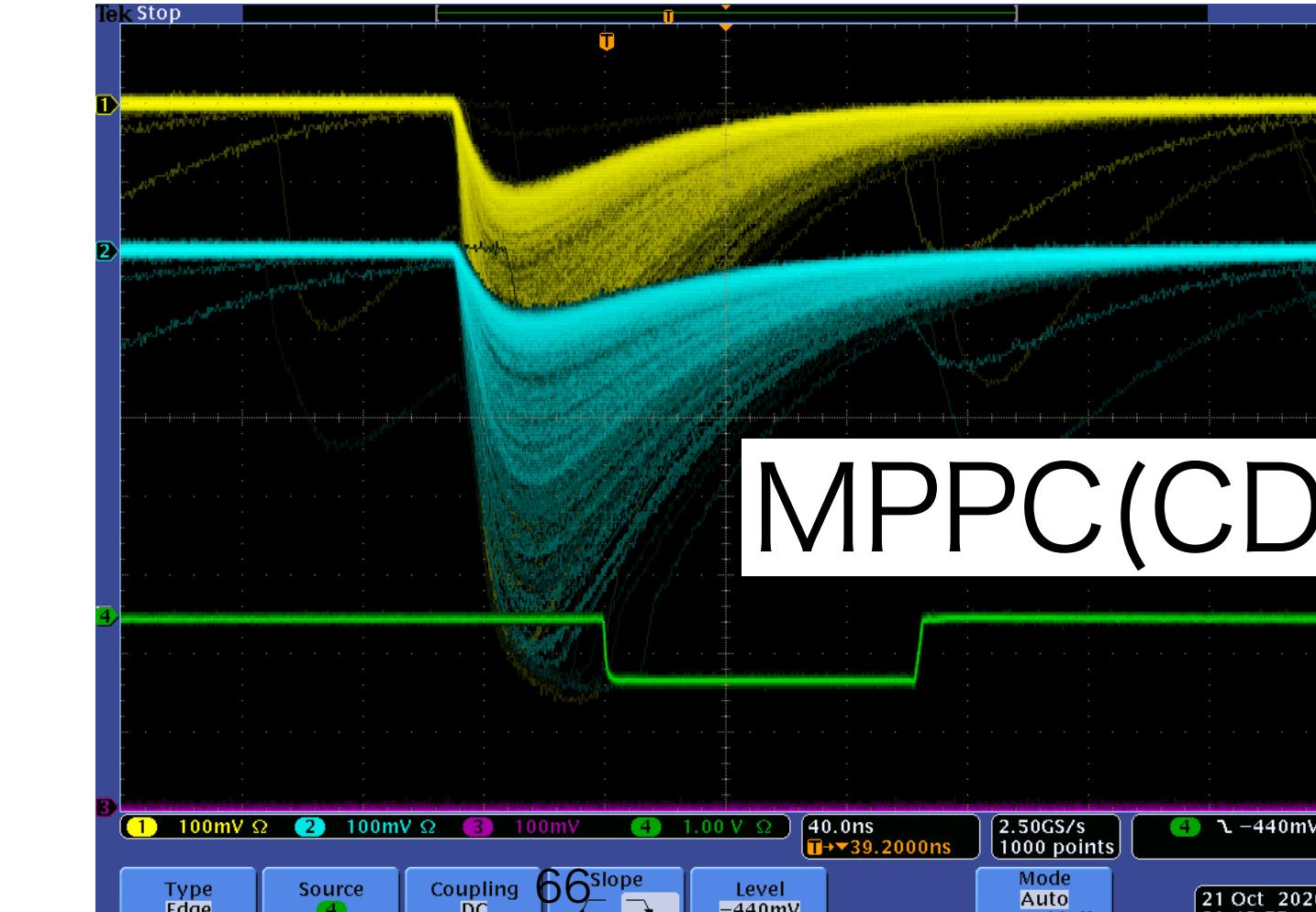
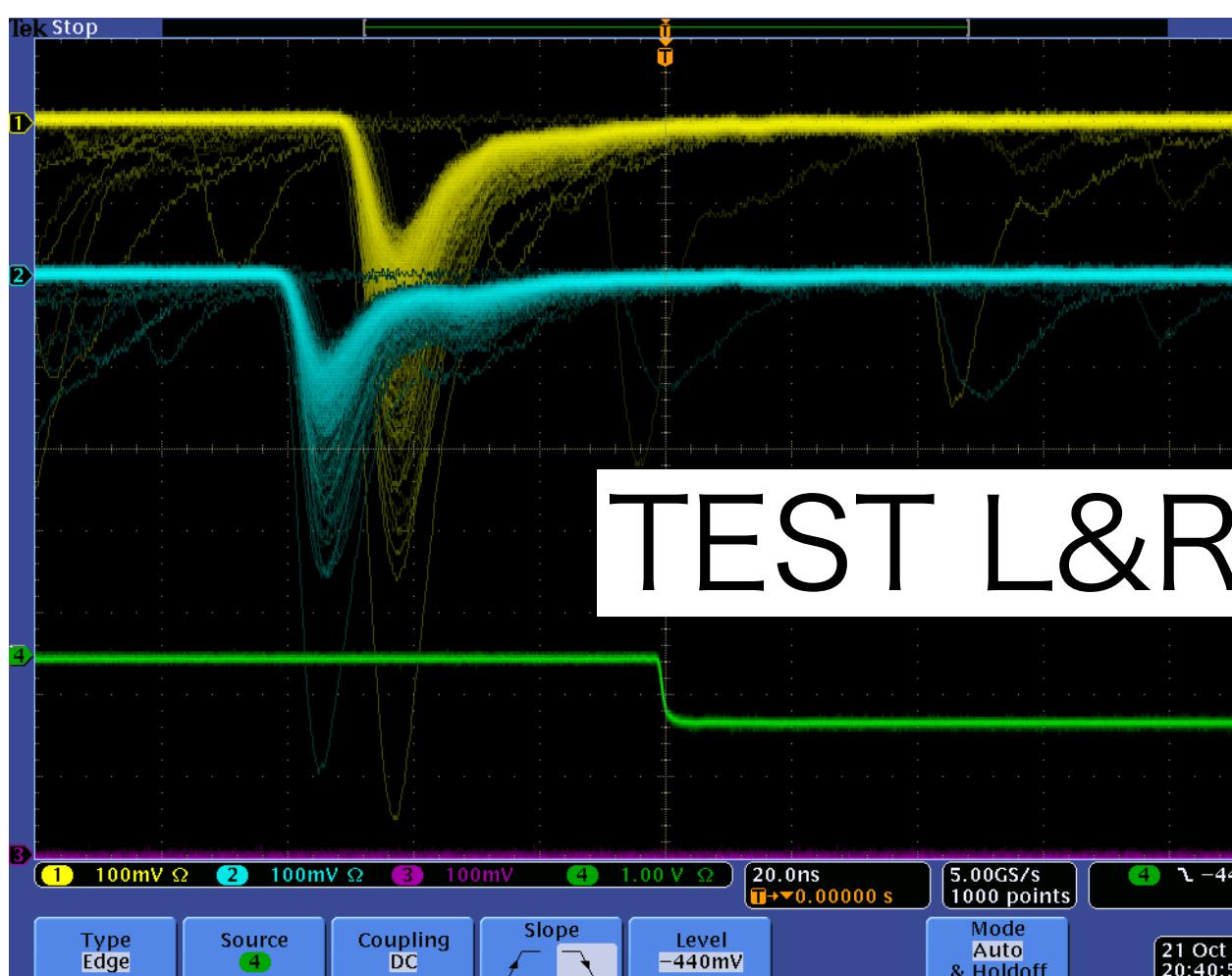
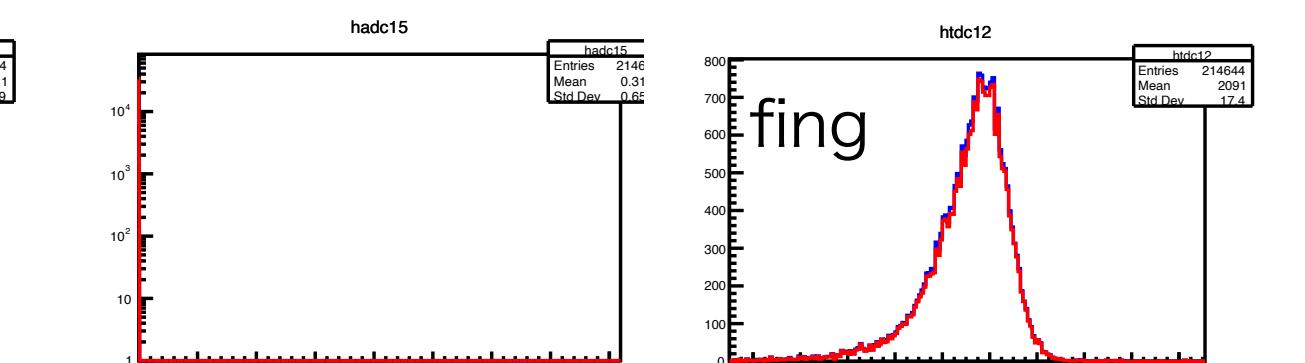
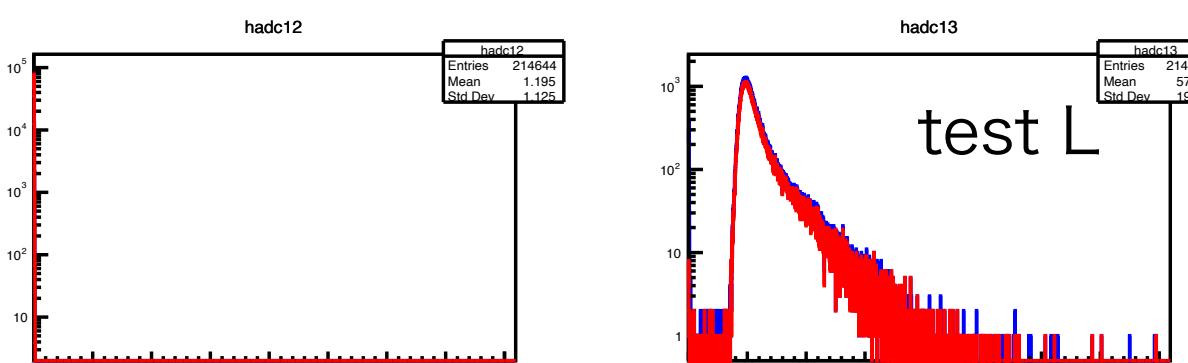
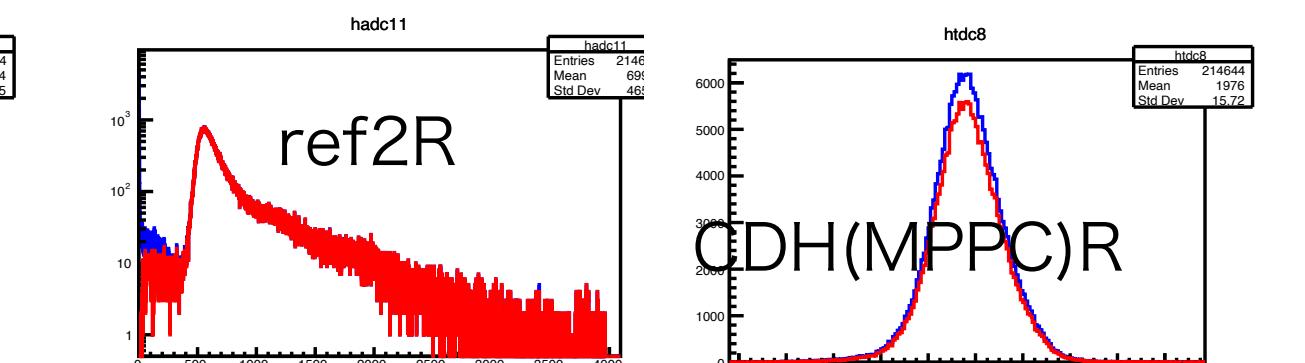
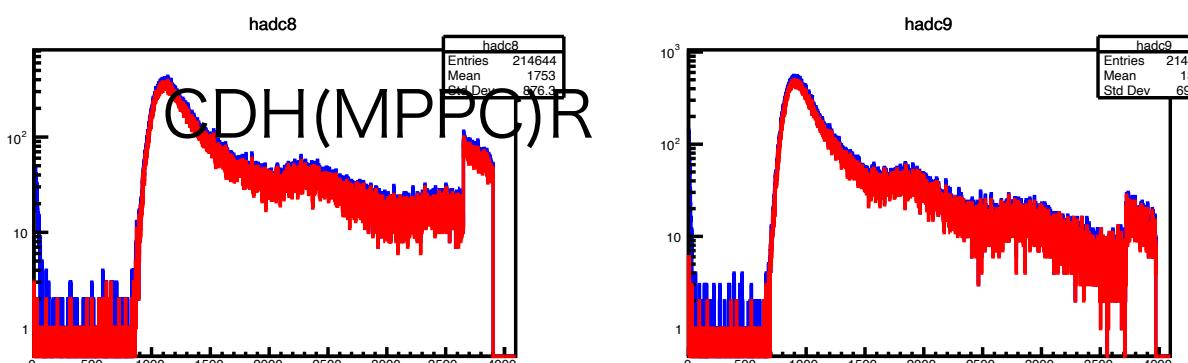
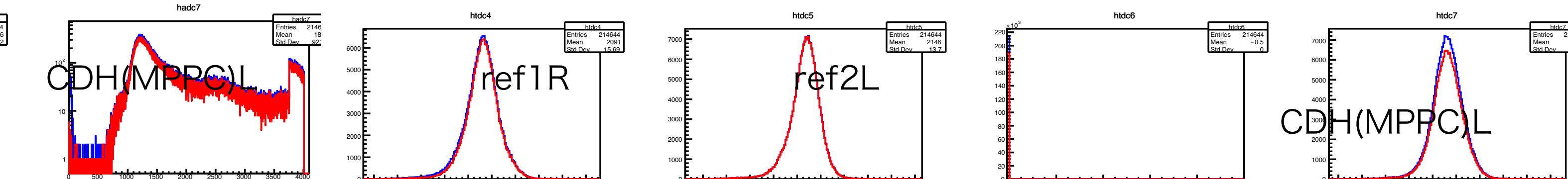
L : 1dB  
R : 3dB

$V_{th} = 23$  mV

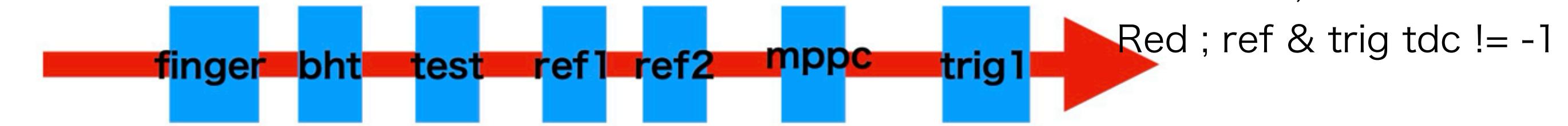
QDC



TDC



# 2. Light Guide



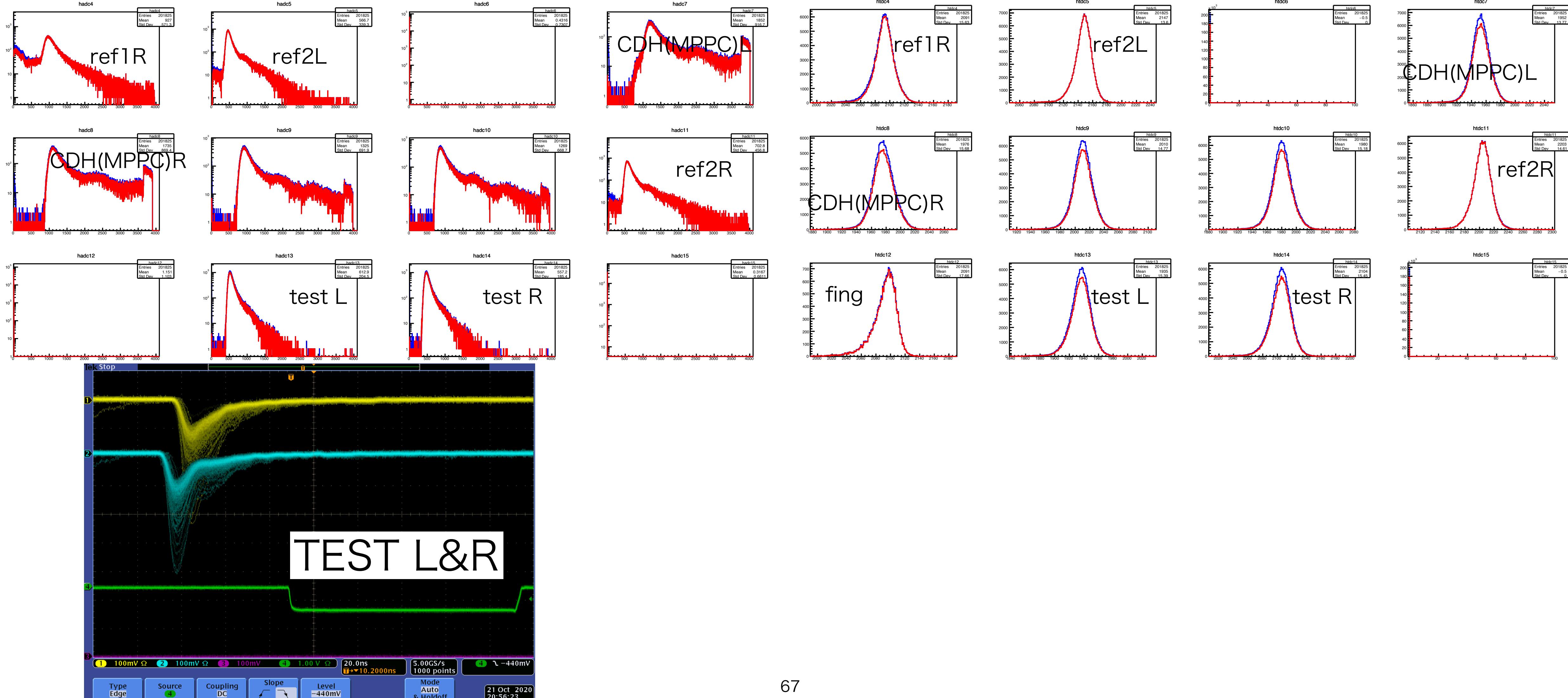
Run124, LG 345mm, pos=42.5cm, MPPC(CDH), bias 59V

L : 1dB  
R : 3dB

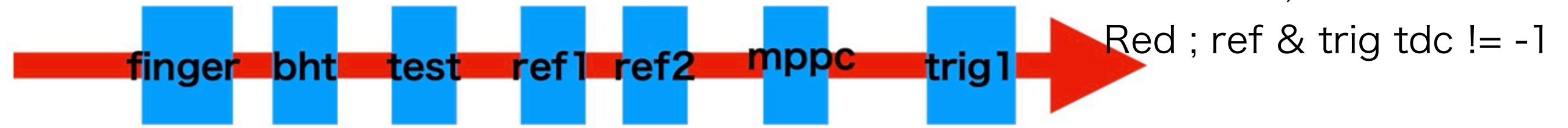
$V_{th} = 23$  mV

QDC

TDC



# 2. Light Guide



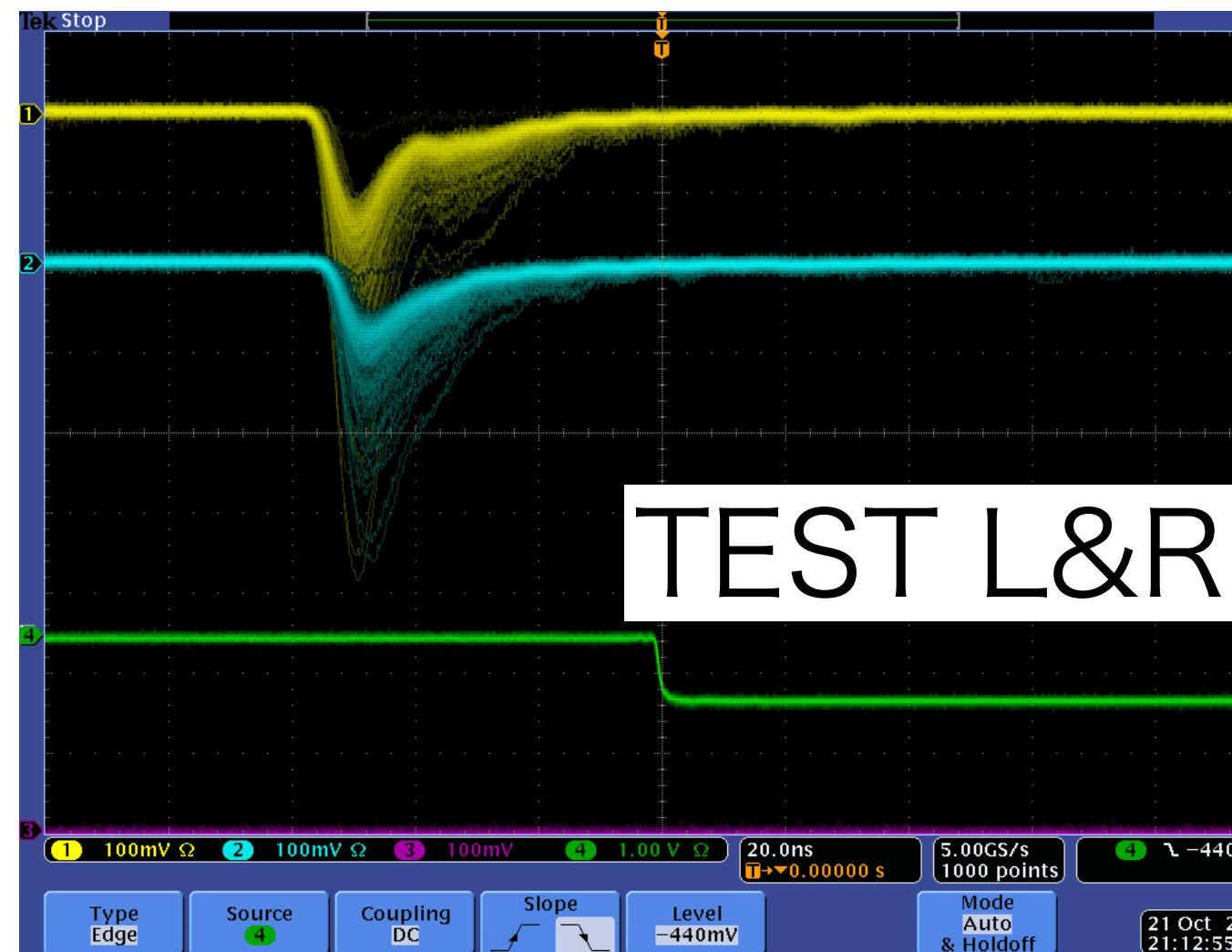
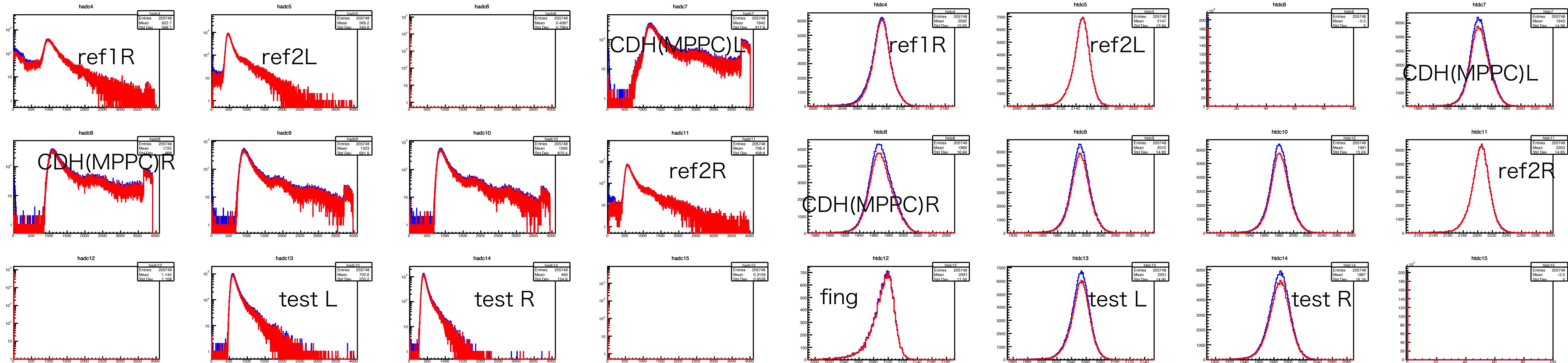
Run131, LG 345mm, pos=107.5cm, MPPC(CDH), bias 59V

L : 1dB  
R : 3dB

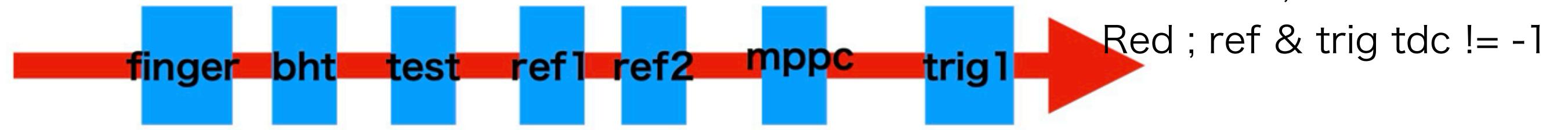
$v_{th} = 30$  mV

QDC

TDC

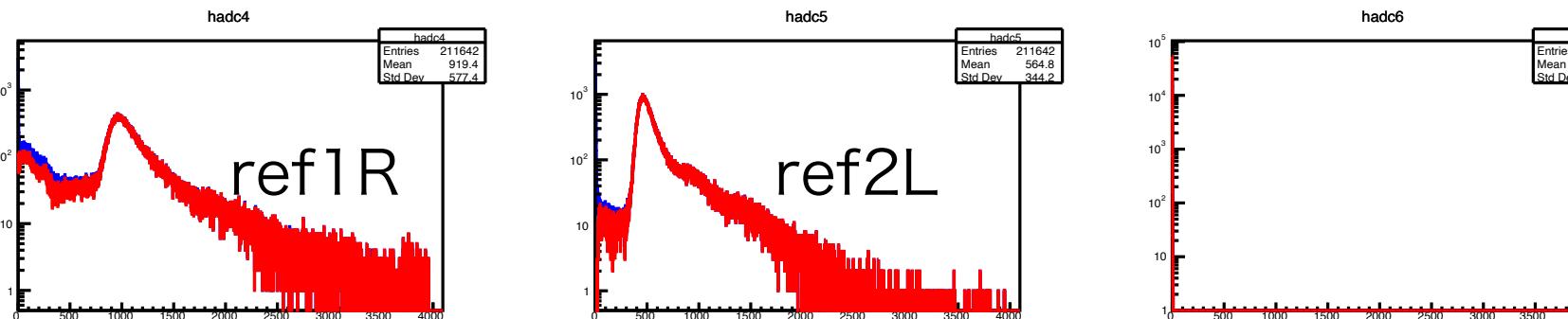


# 2. Light Guide

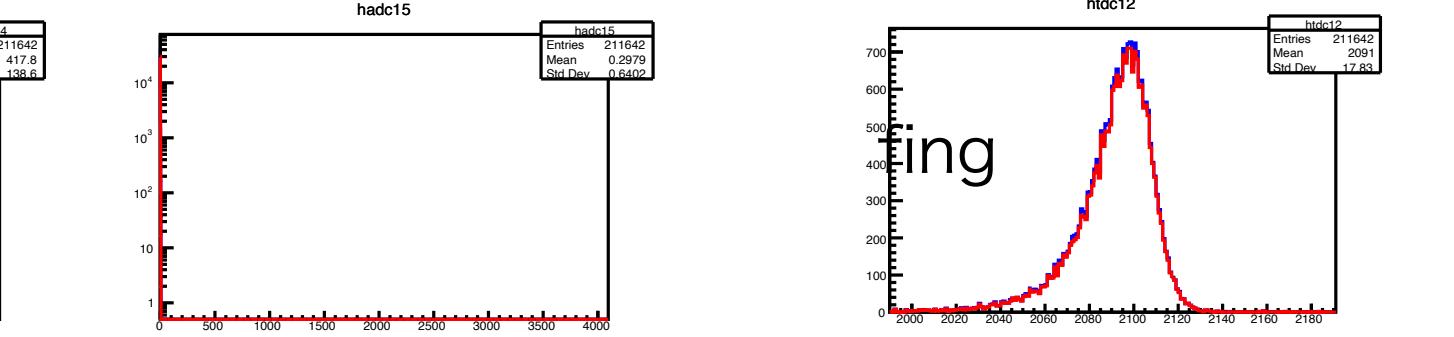
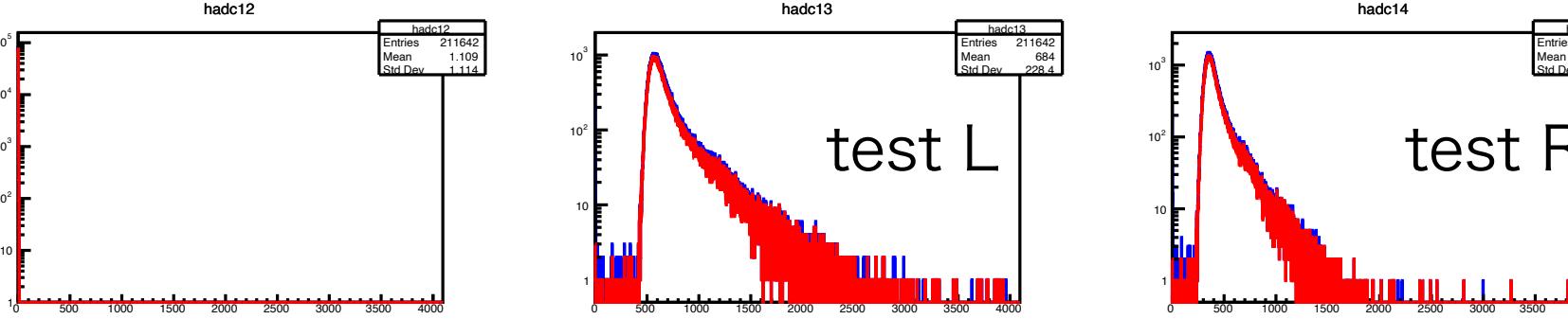
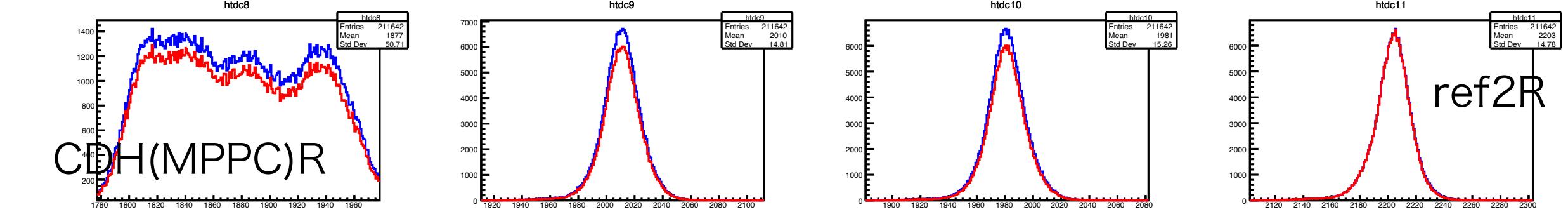
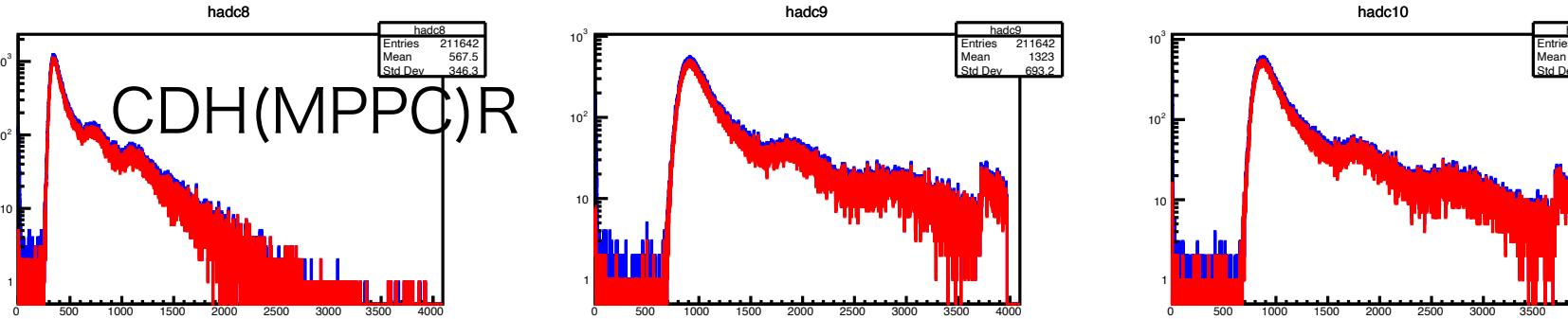
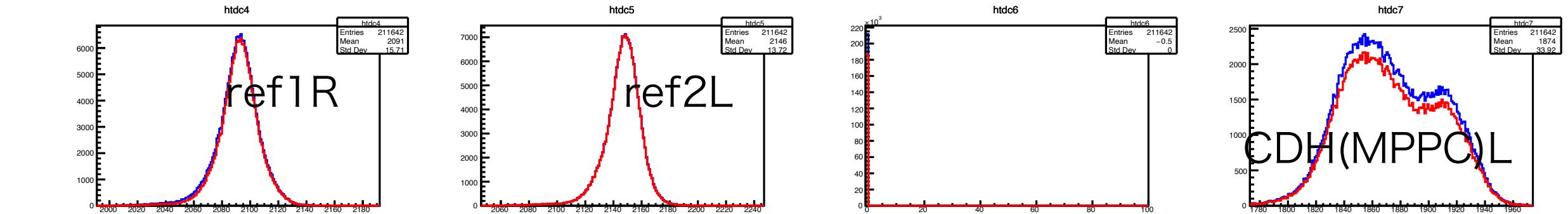


Run138, LG 345mm, pos=140cm, MPPC(CDH), bias 55V  $V_{th} = 30mV$

QDC

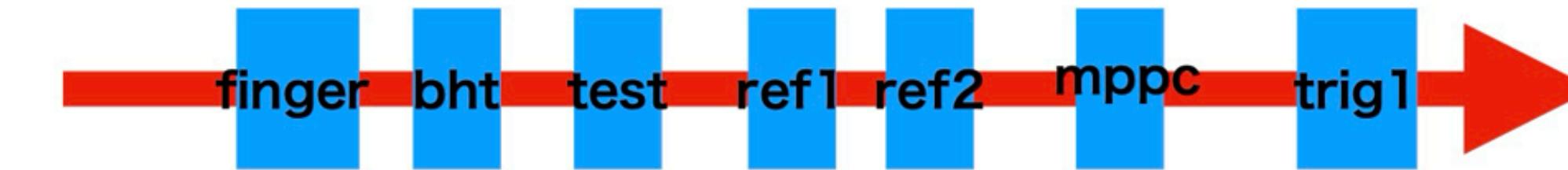


TDC

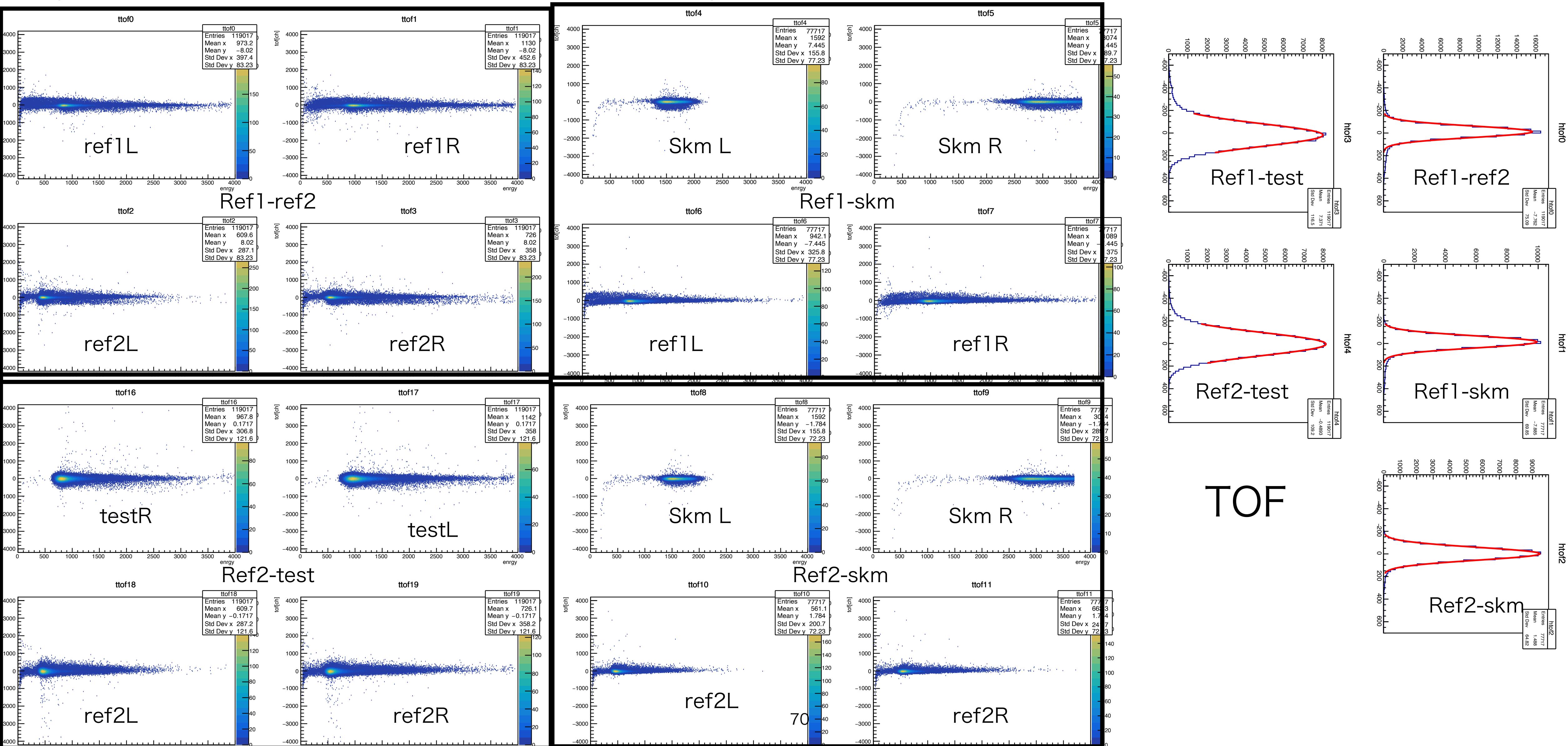


- Bias of MPPC is too small.

# 2. Light Guide



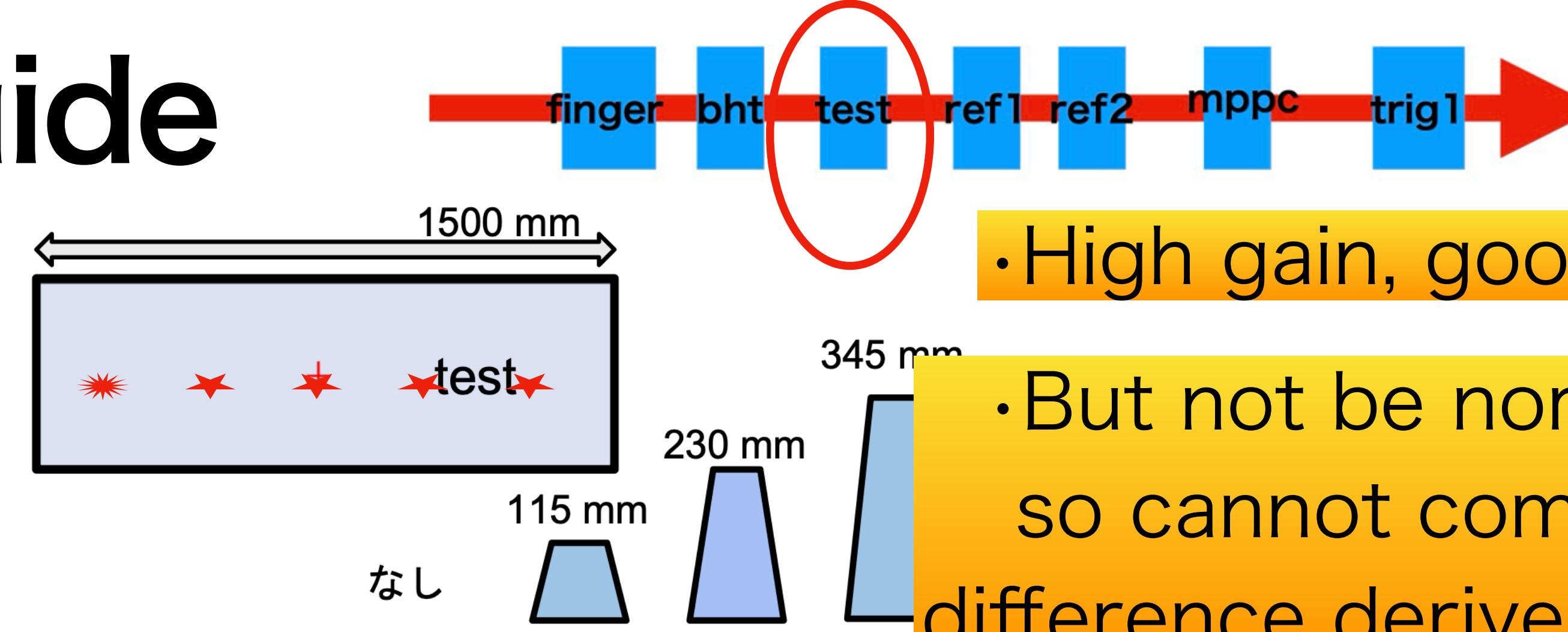
Typical shape of 2D(TOF vs Energy) after slewing correction (run77)



## 2. Light Guide

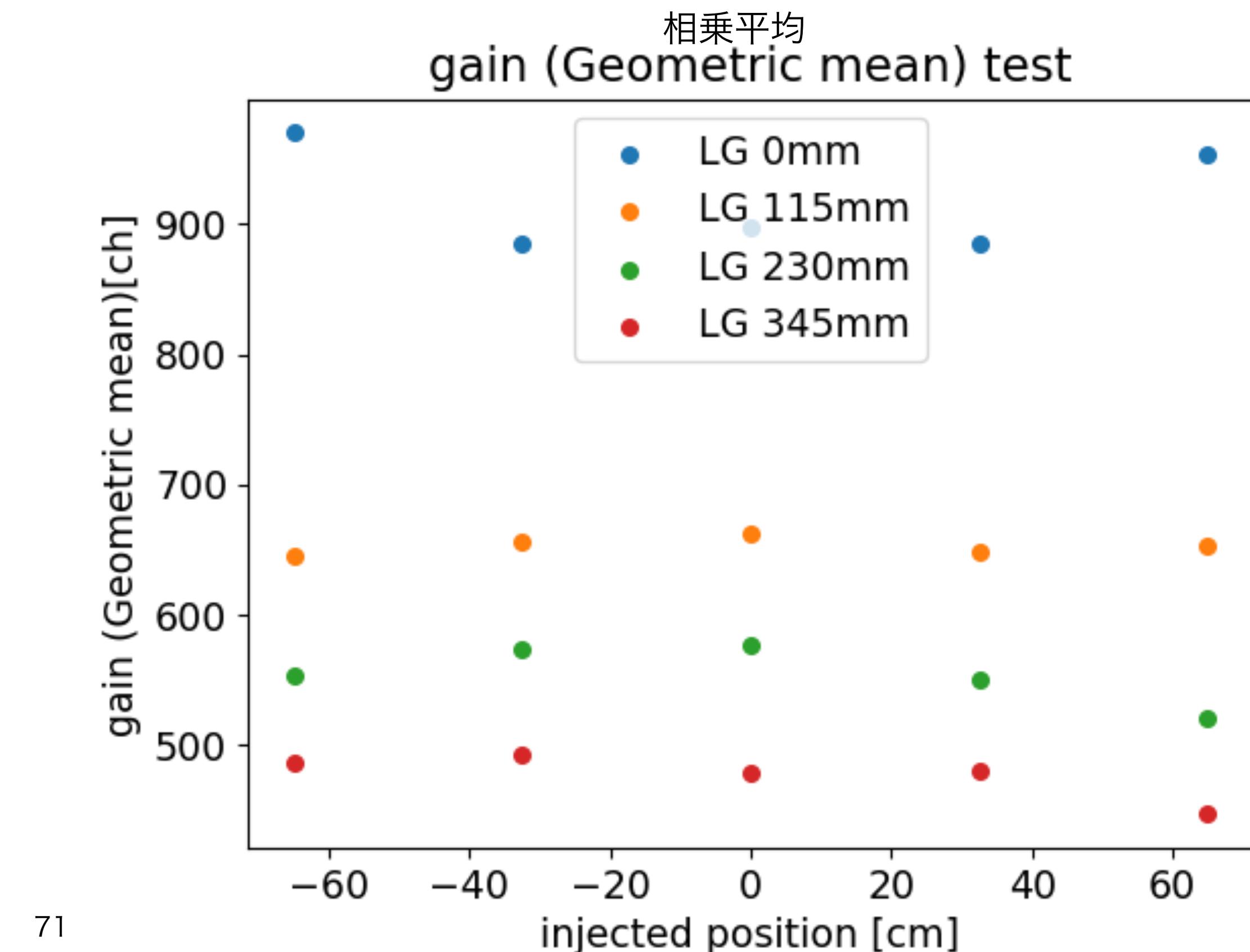
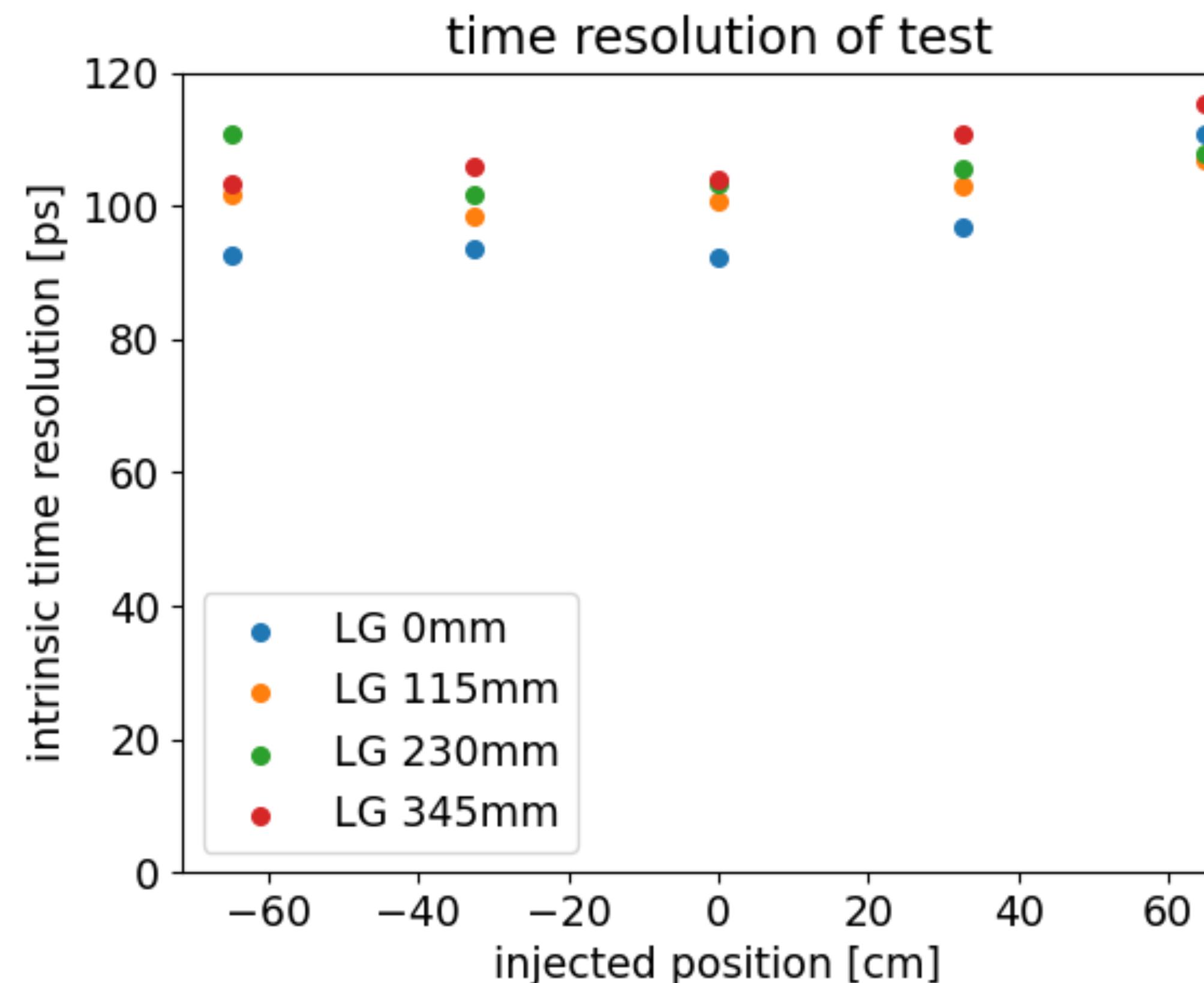
time resolutionのライトガイド依存性

- 1500\*120\*50t(mm)のプラスチックシンチレータ(test)についてライトガイドの長さを変えながら測定。



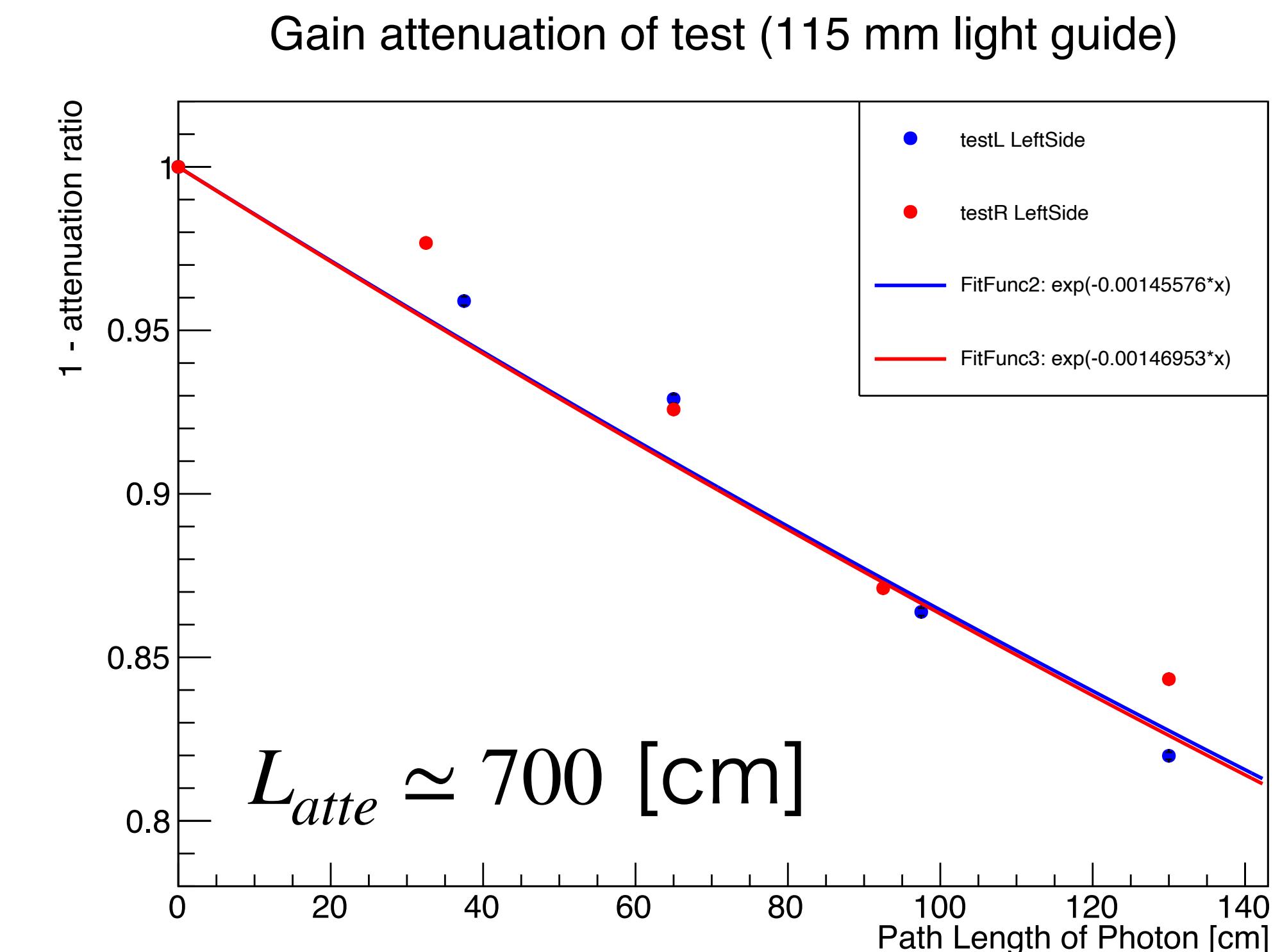
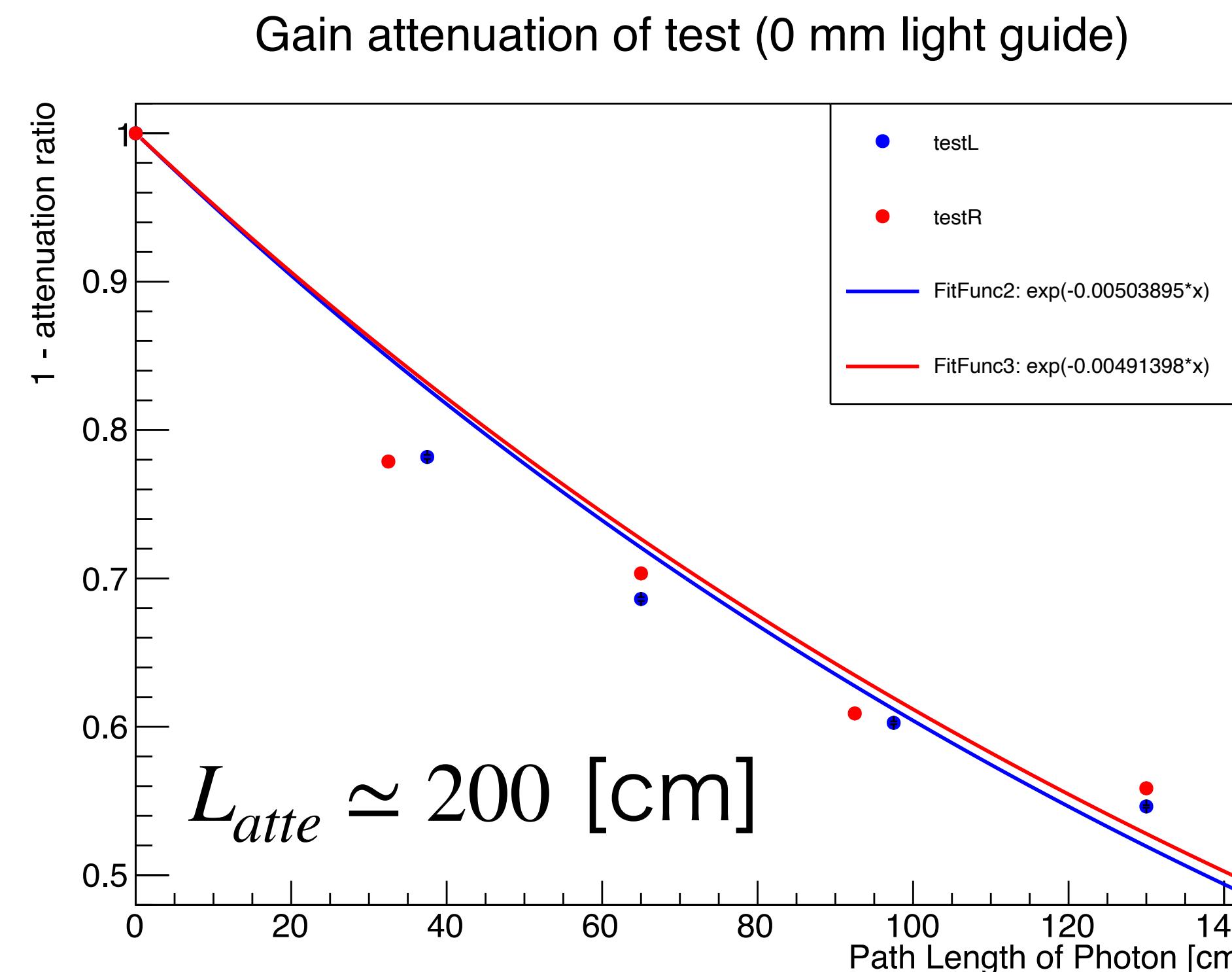
• High gain, good resolution.

• But not be normalized by gain,  
so cannot compare resolution  
difference derived from light guide



# 2. Light Guide

## Attenuation Length (LG 無しと LG 115mm)



PROPERTIES	EJ-200
Light Output (% Anthracene)	64
Scintillation Efficiency (photons/1 MeV e <sup>-</sup> )	10,000
Wavelength of Maximum Emission (nm)	425
Light Attenuation Length (cm)	380

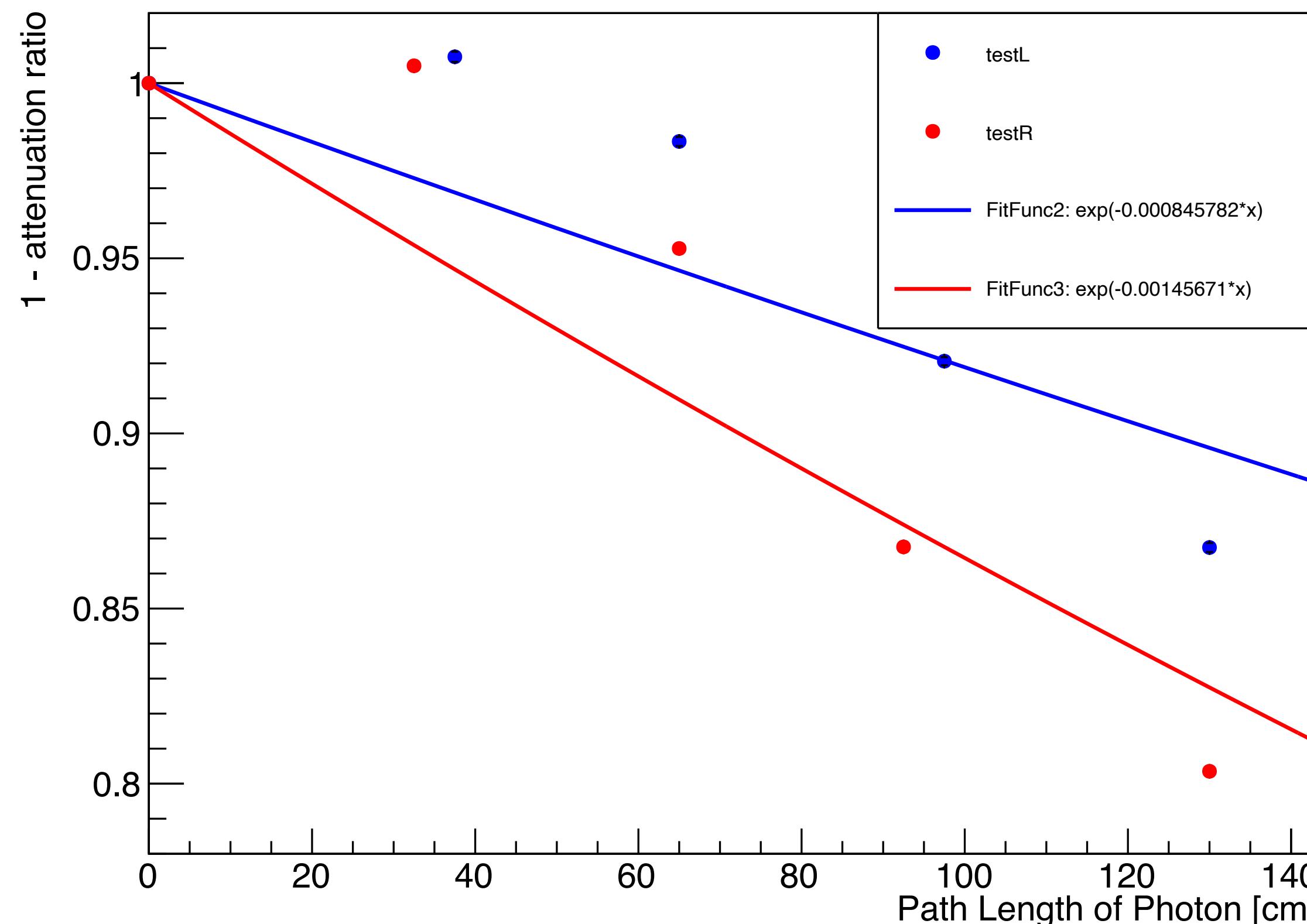
カタログ値

# 2. Light Guide

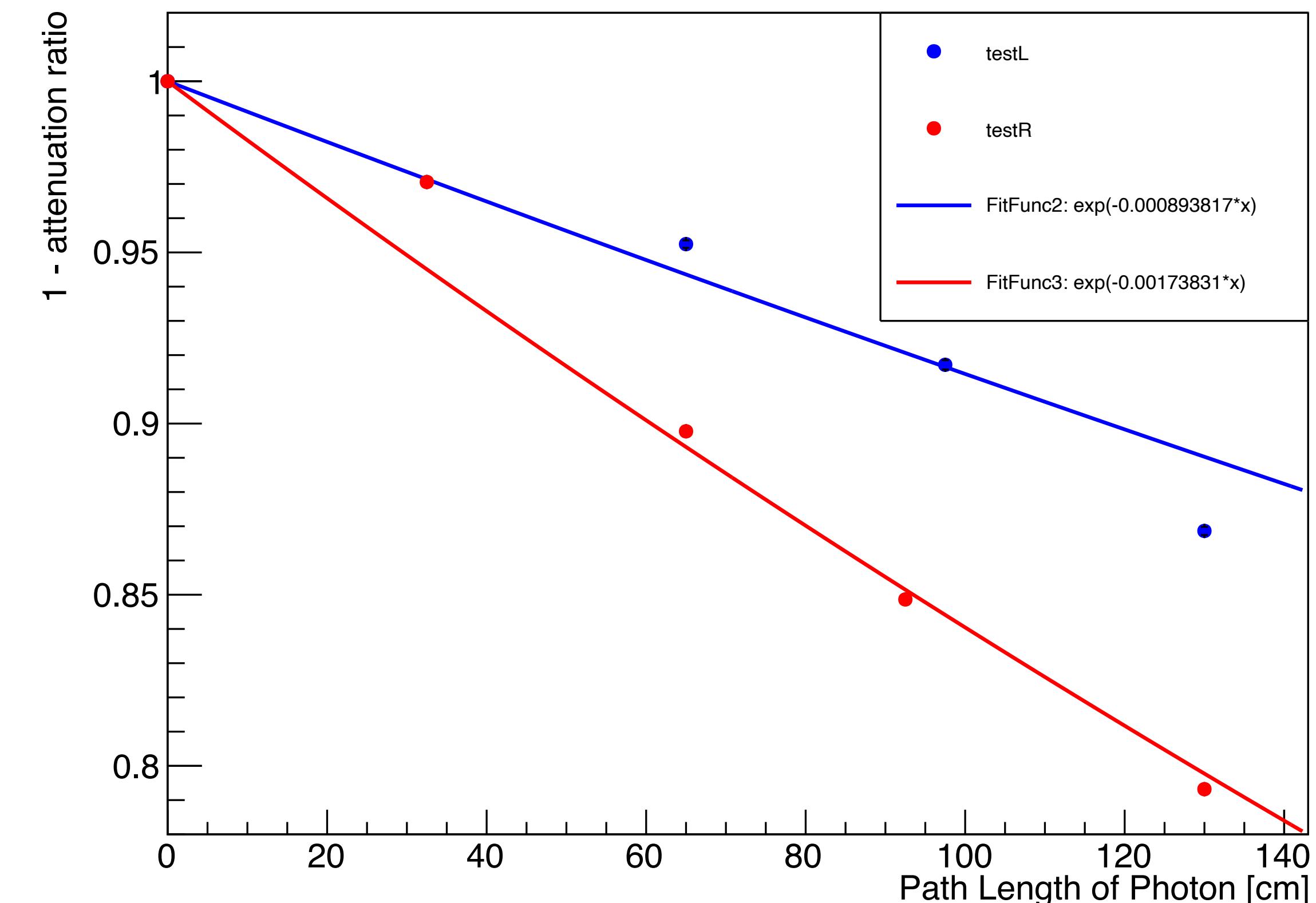
## Attenuation Length (LG 230 mmと LG 345 mm)

- L, Rで違いが見える、なぜだ。
  - Path Length 32.5 cm, 70 cmの時のpeak位置が高いのがよくわからない、ジグが機能していないのであれば、光量は減るはずだからである。

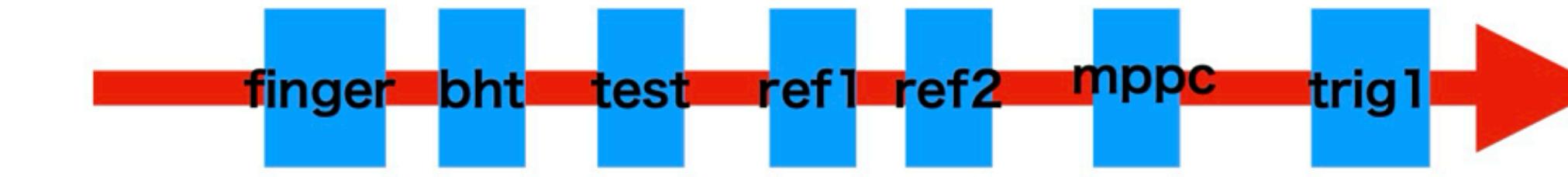
Gain attenuation of test (230 mm light guide)



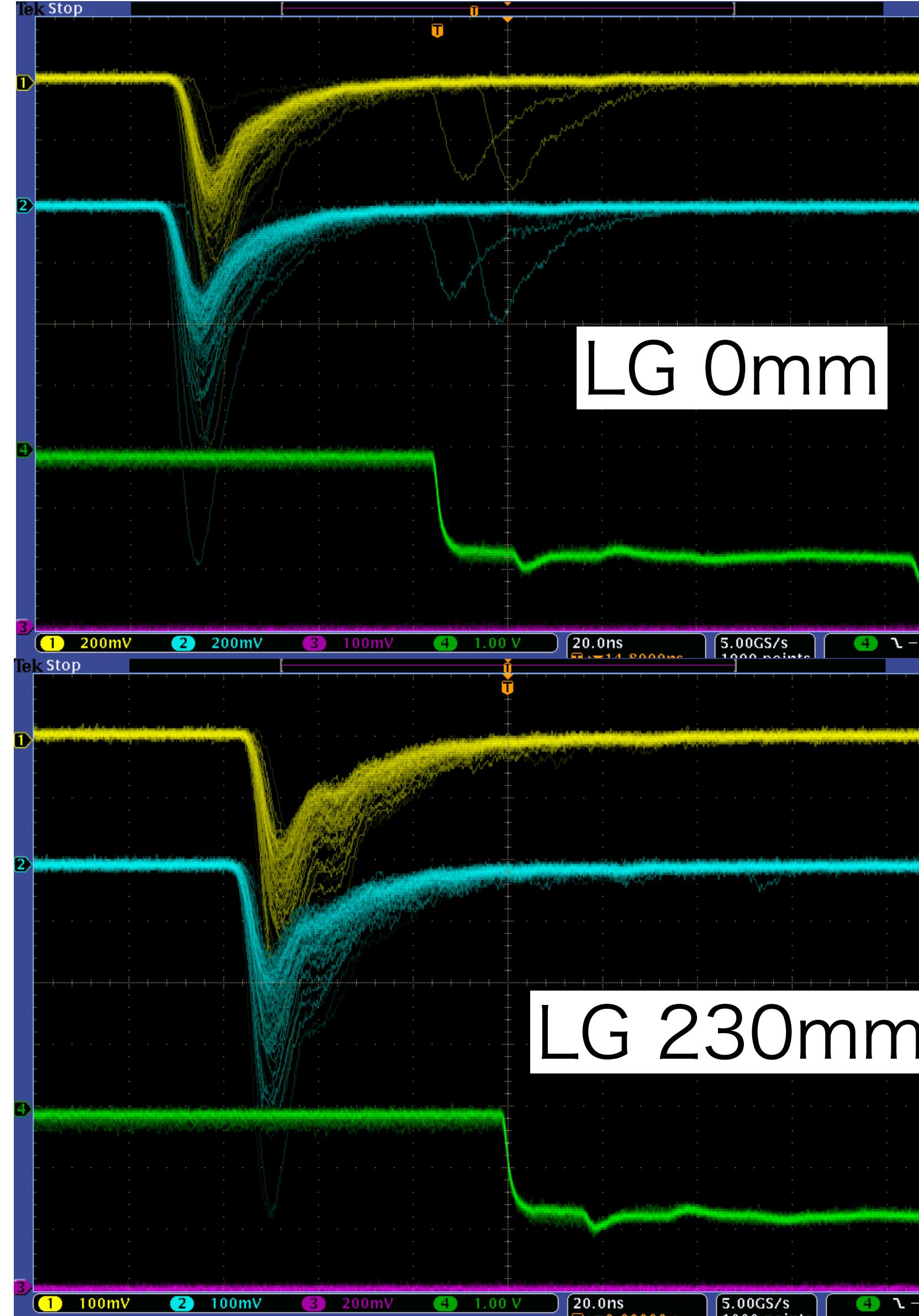
Gain attenuation of test (345 mm light guide)



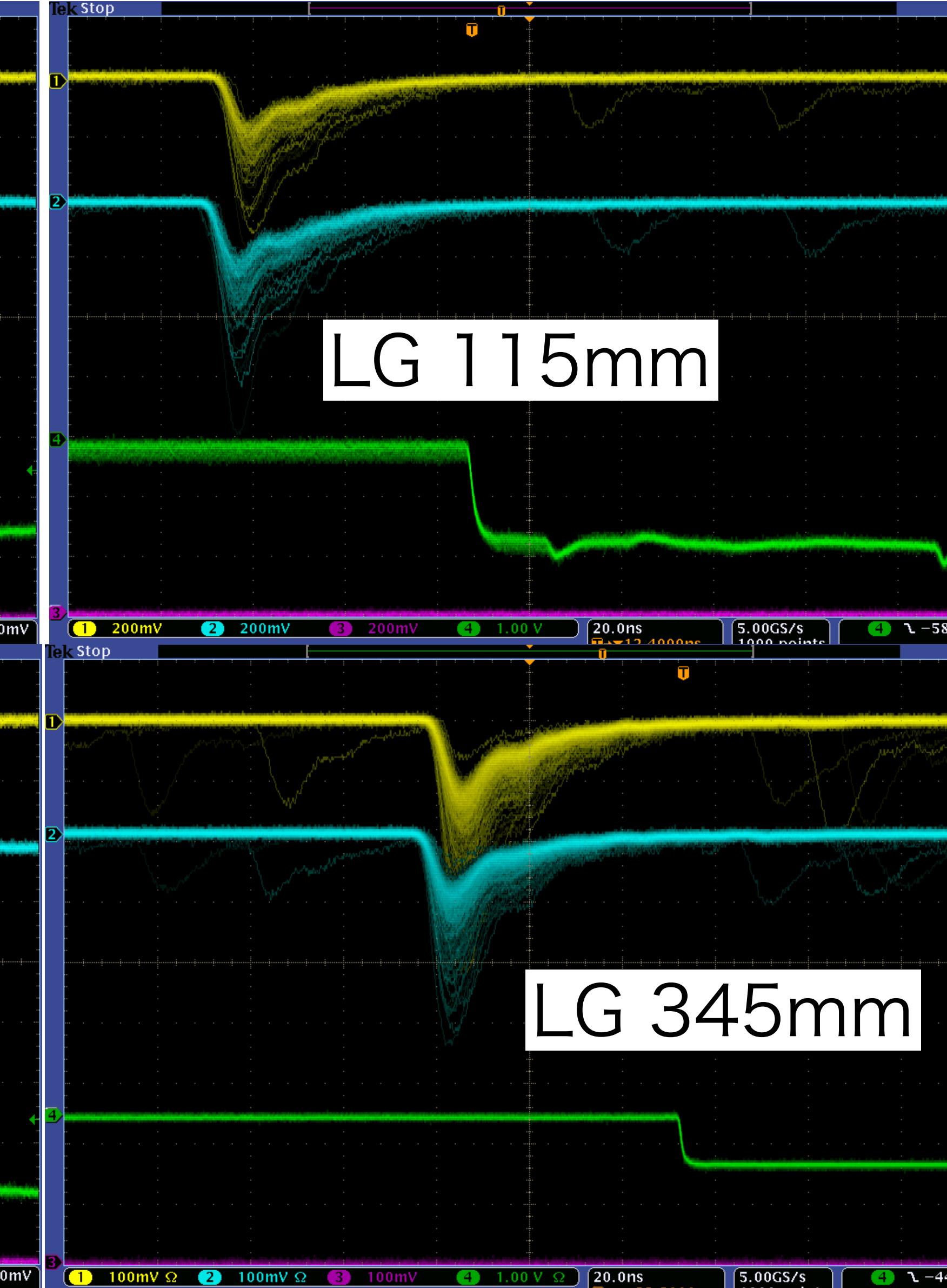
## 2. Light Guide



Comparison of Wave Form on Oscilo between different LG (same injected position)



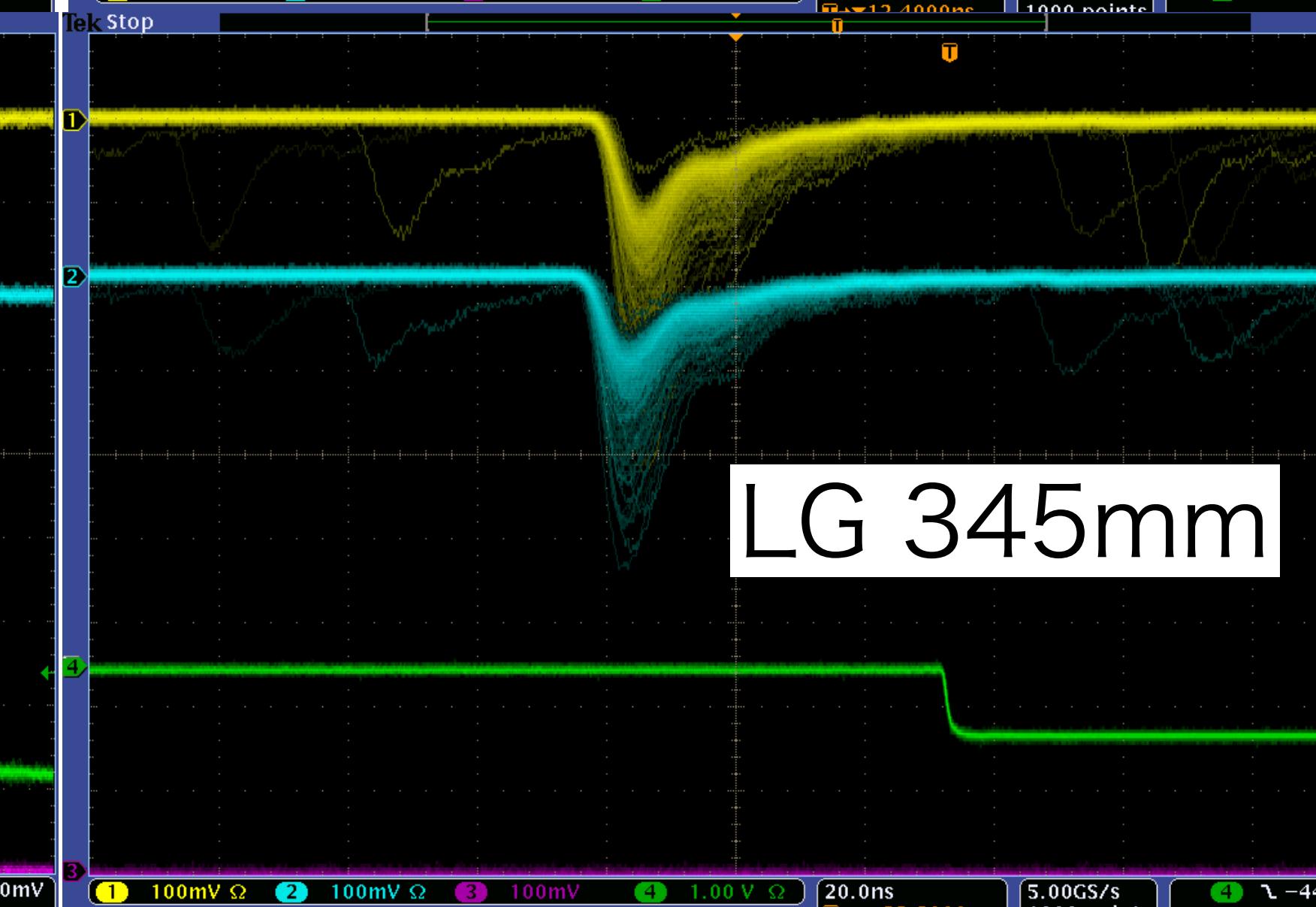
LG 0mm



LG 115mm

LGの長さに関係なく  
およそ一定の大きさの  
反射波があった。

LG 230mm



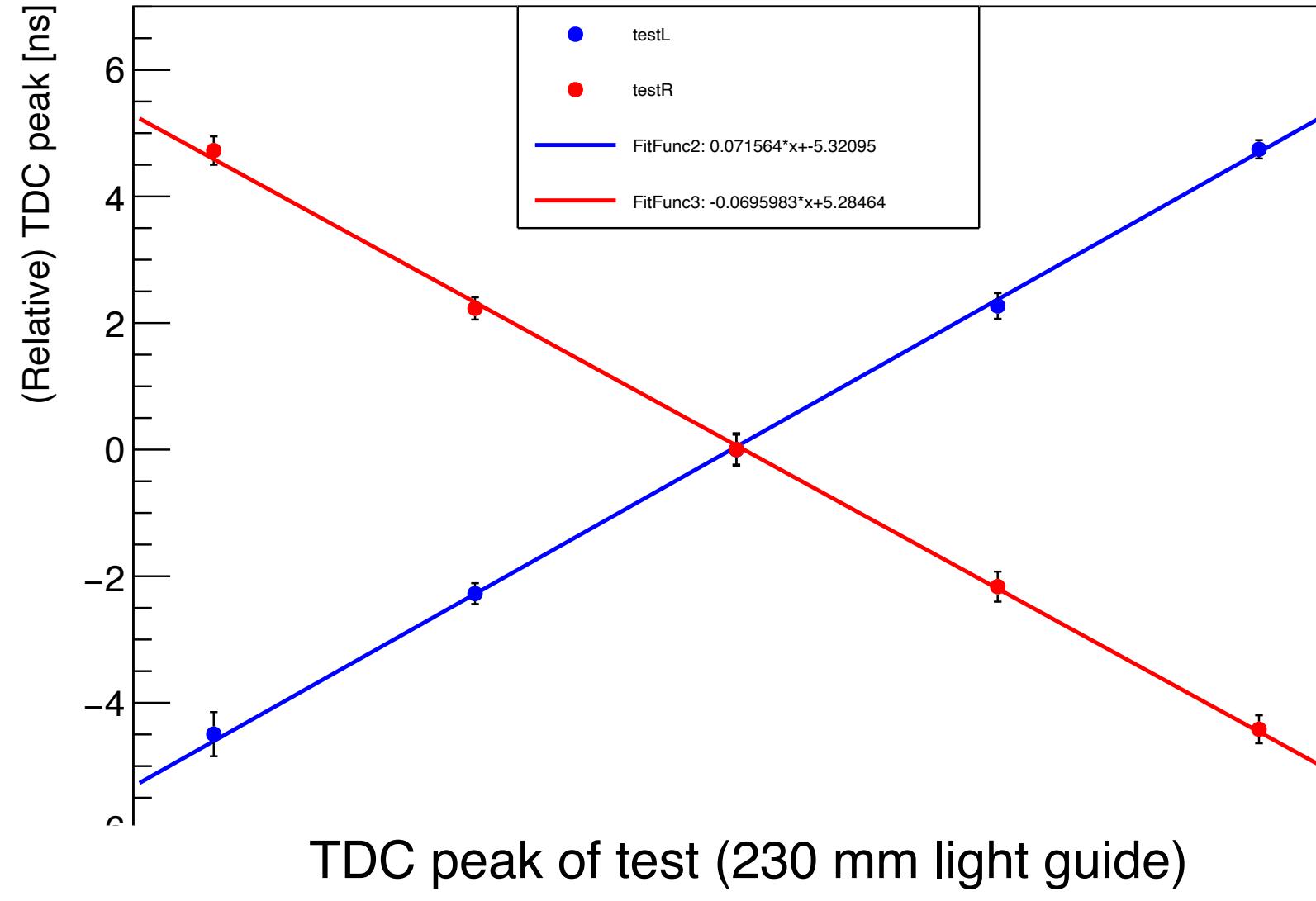
LG 345mm



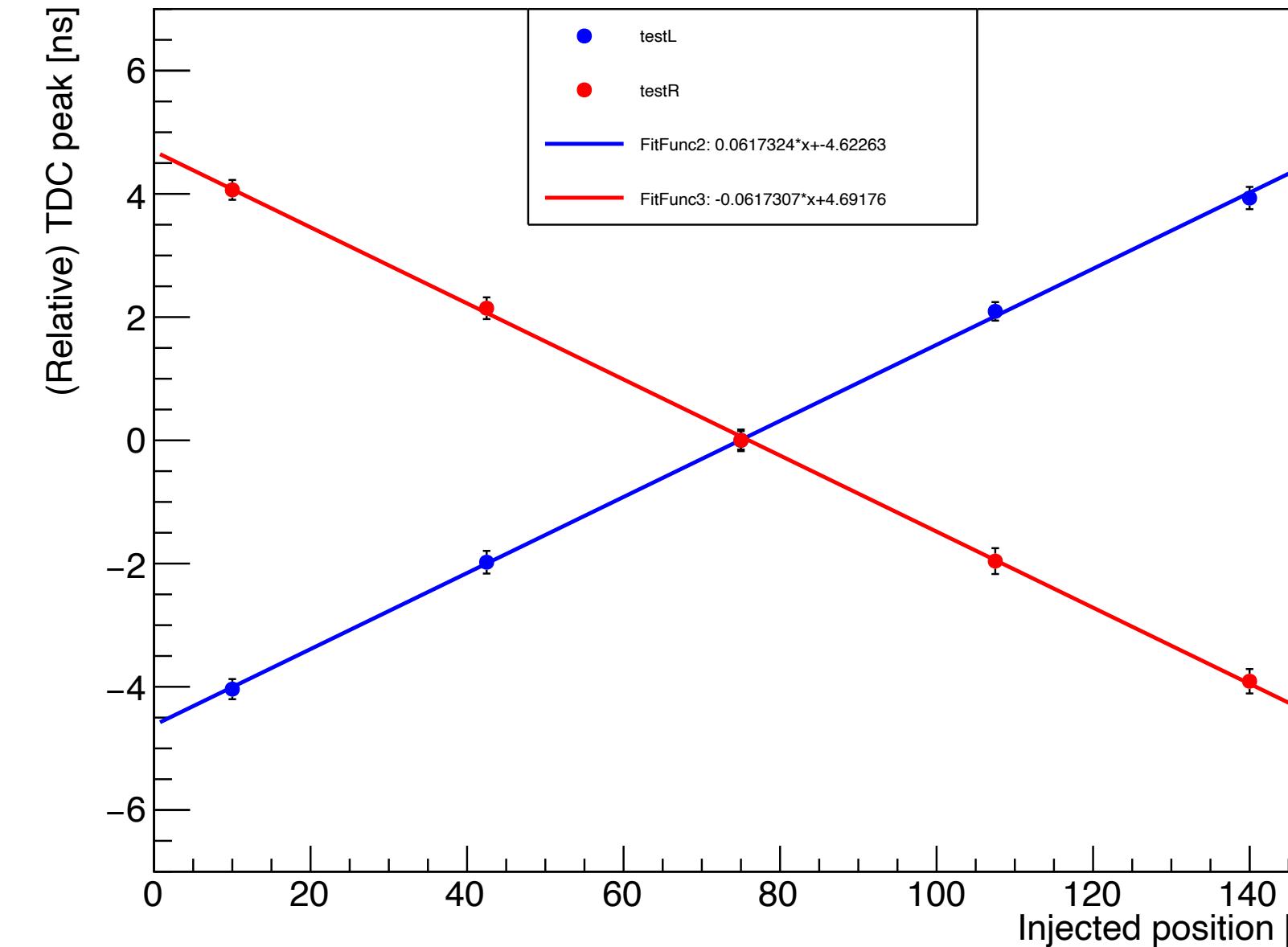
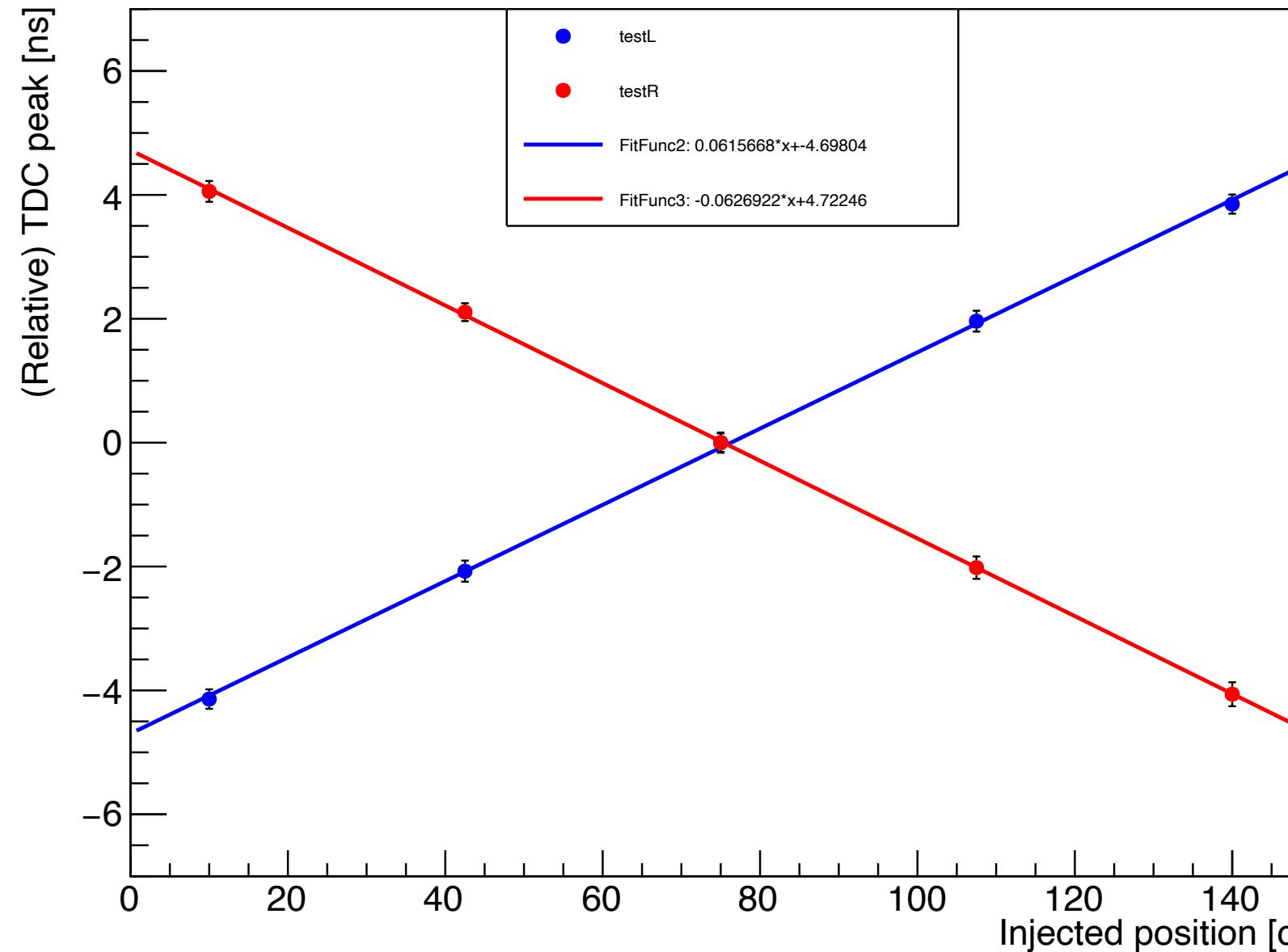
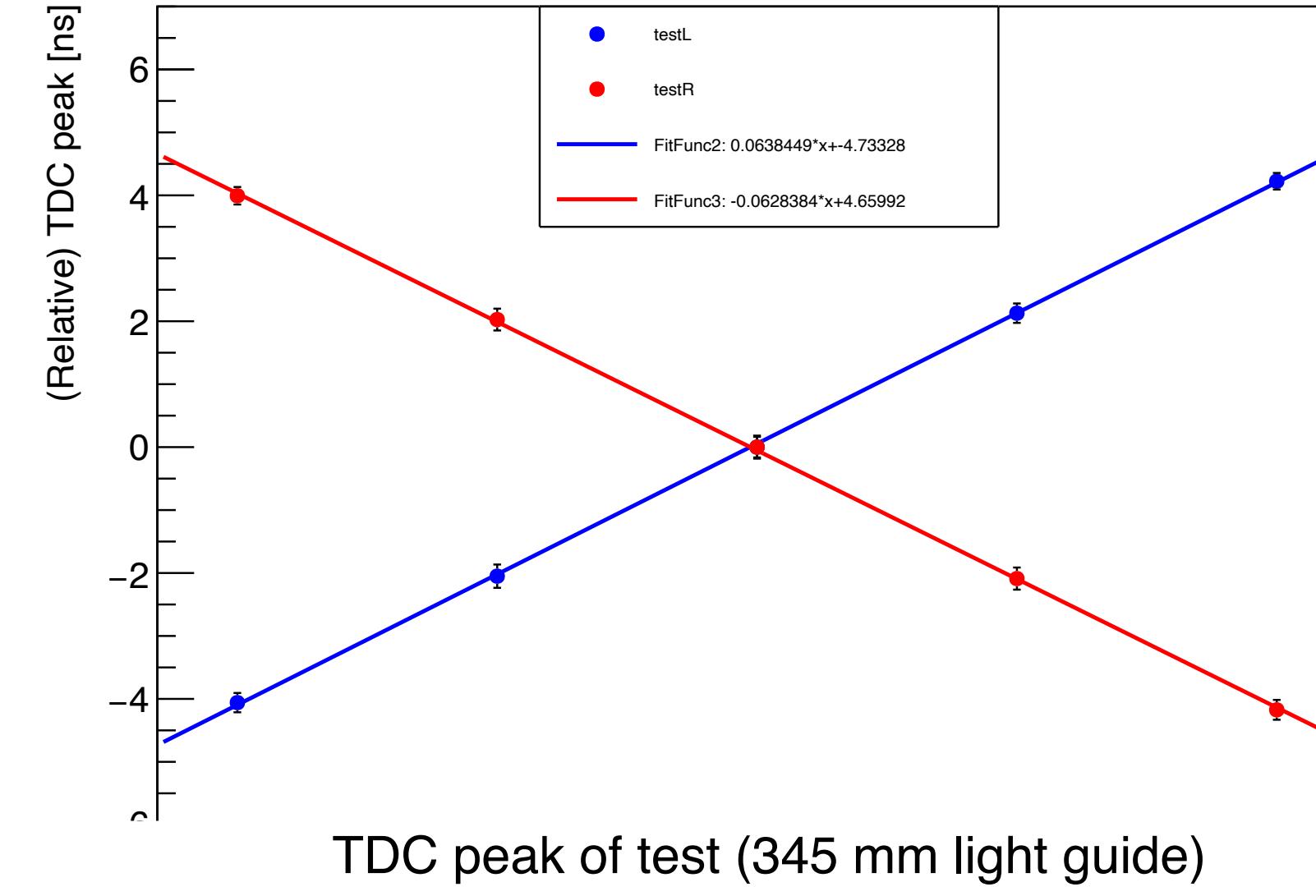
# 2. Light Guide

## TDC peak vs injected position

TDC peak of test (0 mm light guide)



TDC peak of test (115 mm light guide)

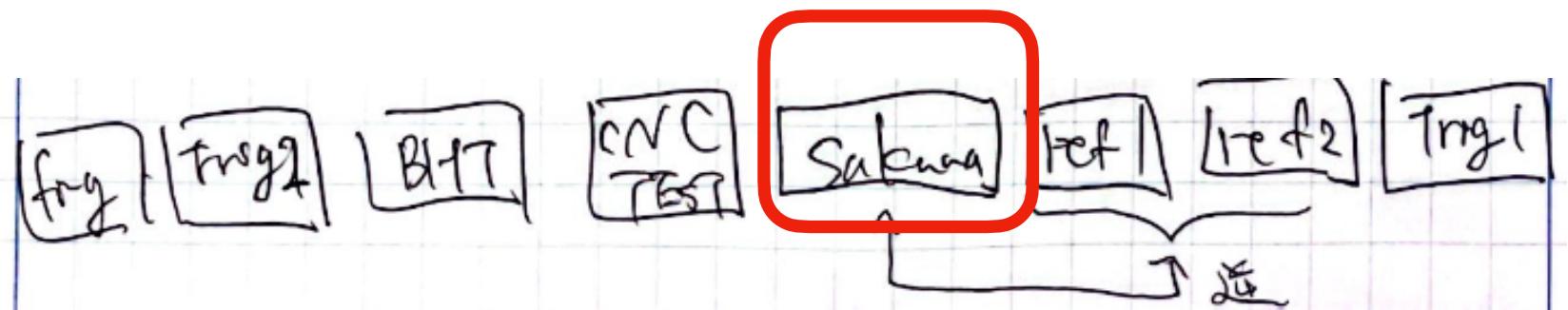


- LG無し : ~7.0 ns/100 cm
- LG有り : ~6.2 ns/100 cm

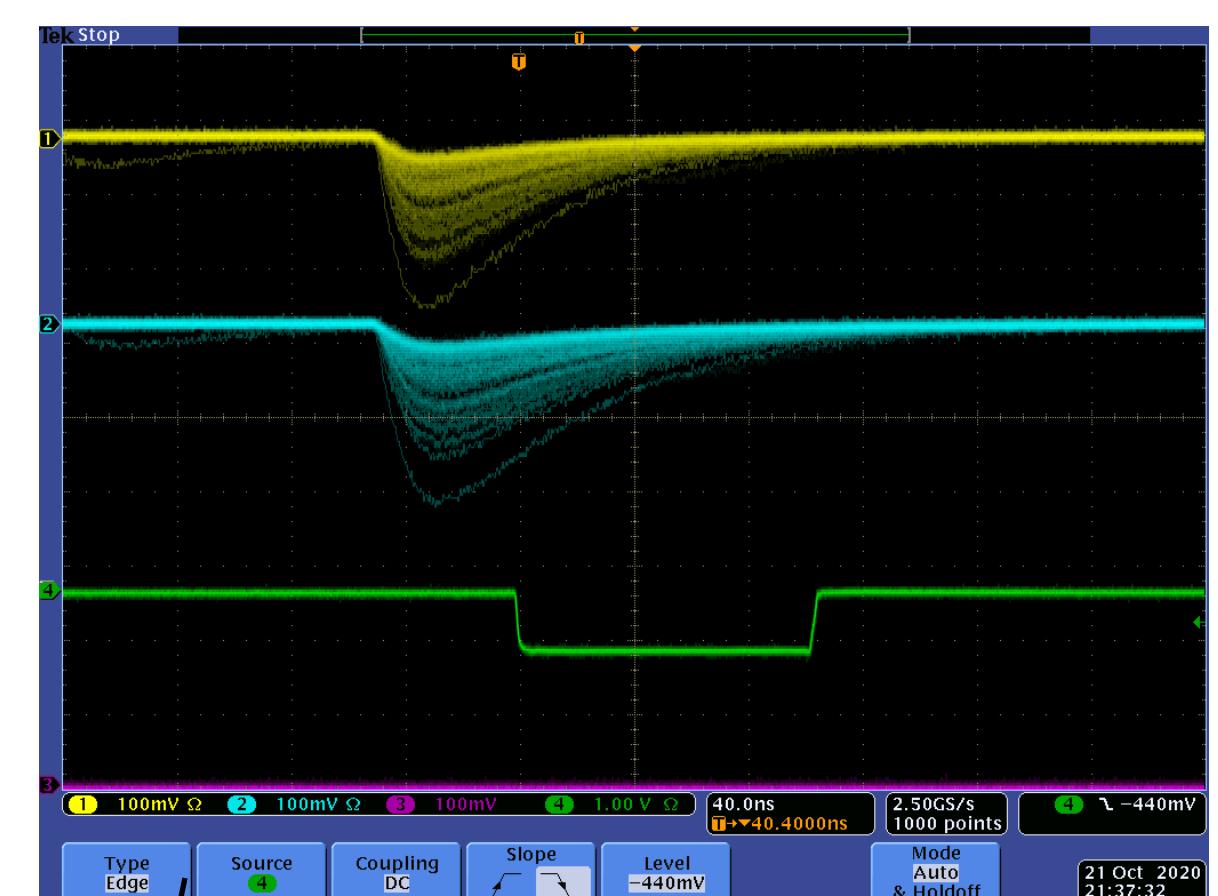
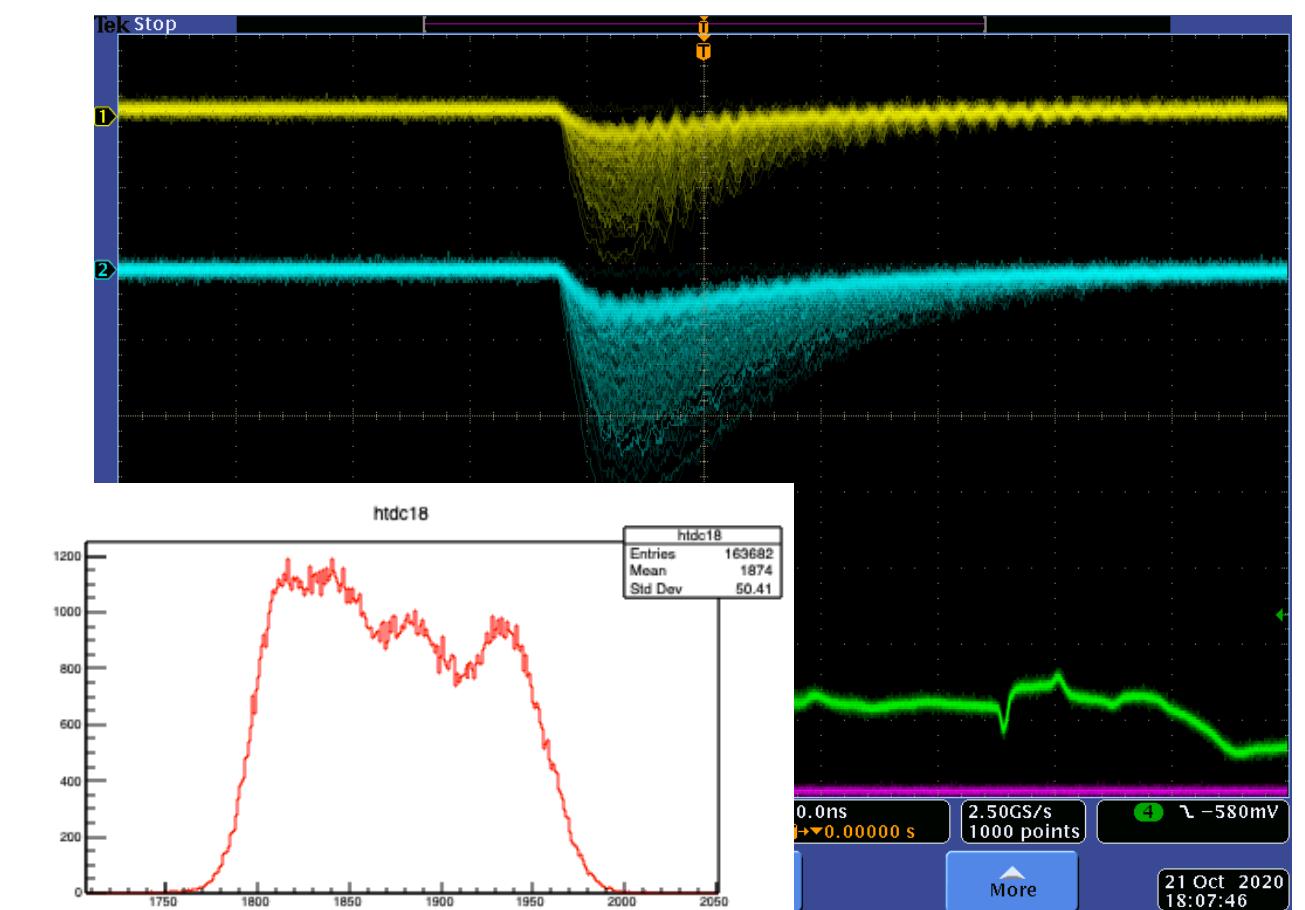
屈折率 1.9~2.1  
(カタログ値 1.58)

PROPERTIES	EJ-200	EJ-204	EJ-208	EJ-212
Light Output (% Anthracene)	64	68	60	65
Scintillation Efficiency (photons/1 MeV e <sup>-</sup> )	10,000	10,400	9,200	10,000
Wavelength of Maximum Emission (nm)	425	408	435	423
Light Attenuation Length (cm)	380	160	400	250
Rise Time (ns)	0.9	0.7	1.0	0.9
Decay Time (ns)	2.1	1.8	3.3	2.4
Pulse Width, FWHM (ns)	2.5	2.2	4.2	2.7
No. of H Atoms per cm <sup>3</sup> (x10 <sup>22</sup> )	5.17	5.15	5.17	5.17
No. of C Atoms per cm <sup>3</sup> (x10 <sup>22</sup> )	4.69	4.68	4.69	4.69
No. of Electrons per cm <sup>3</sup> (x10 <sup>23</sup> )	3.33	3.33	3.33	3.33
Density (g/cm <sup>3</sup> )	1.023	1.023	1.023	1.023
Polymer Base				Polyvinyltoluene
Refractive Index				1.58
Softening Point				75°C
Vapor Pressure				Vacuum-compatible
Coefficient of Linear Expansion				7.8 x 10 <sup>-5</sup> below 67°C
Light Output vs. Temperature				At 60°C, L.O. = 95% of that at 20°C No change from -60° to 20°C
Temperature Range				-60°C to 60°C

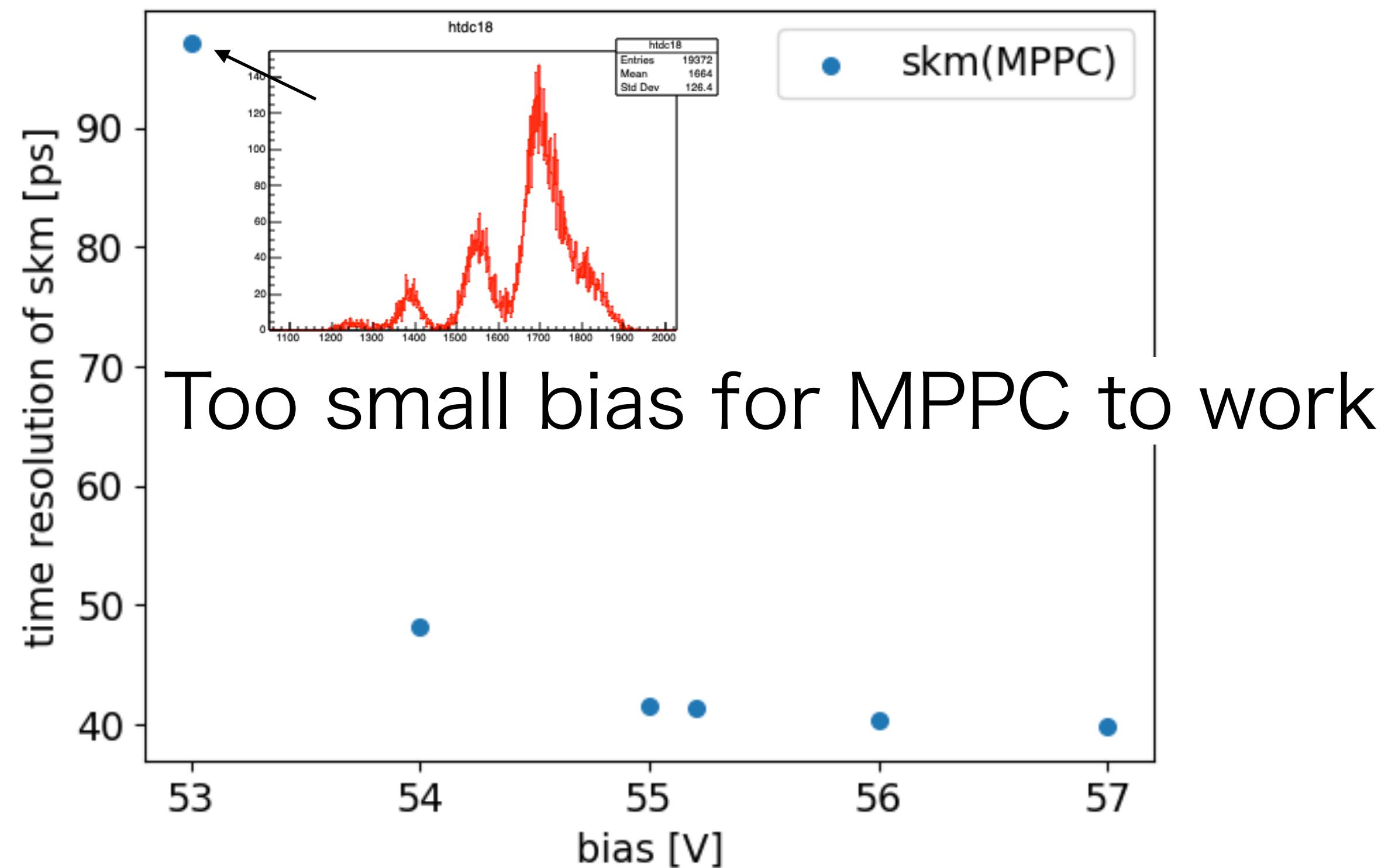
# 3. MPPC



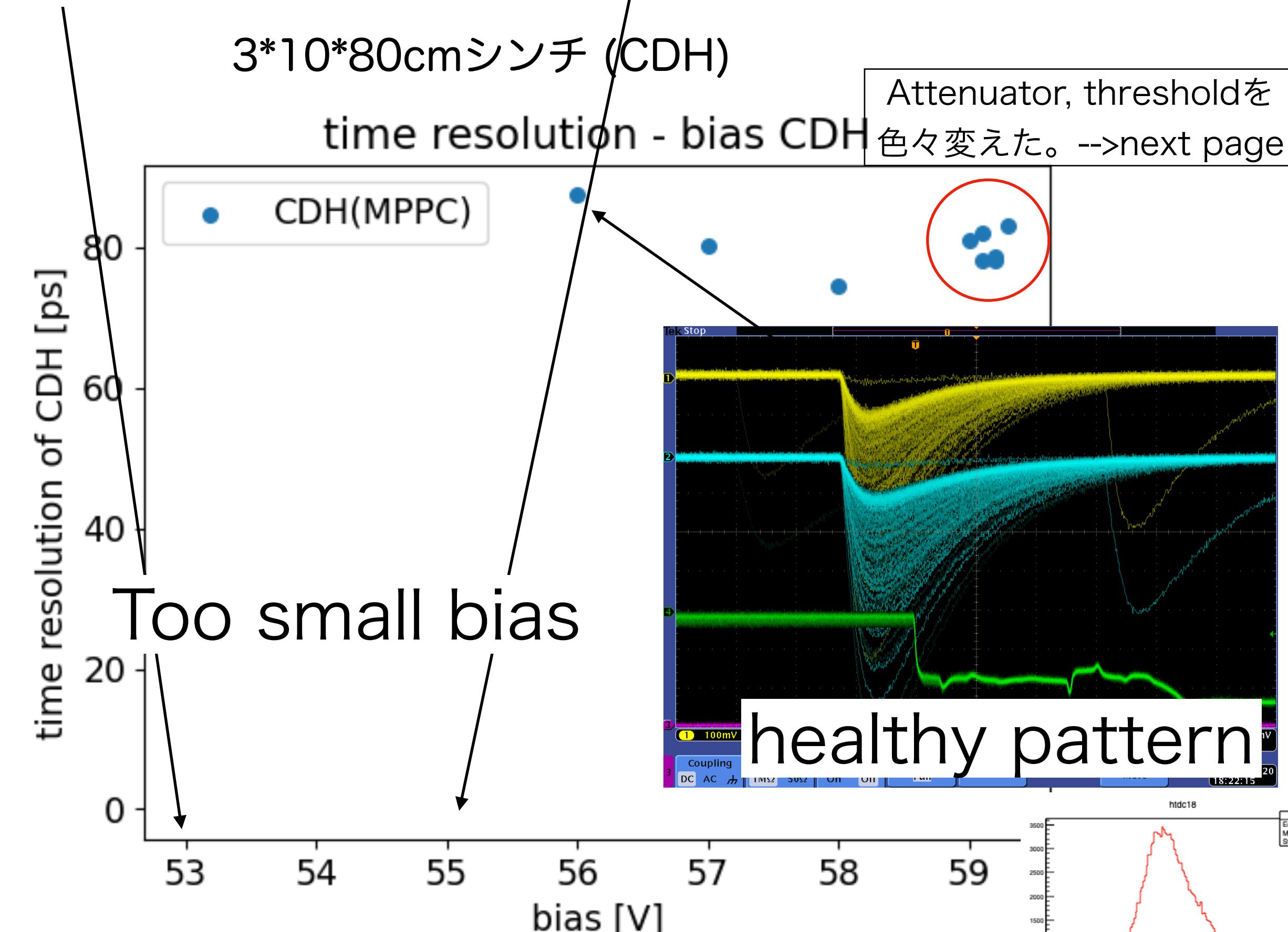
5\*5\*75cmシンチ (skm)



time resolution - bias skm



3\*10\*80cmシンチ (CDH)



- basically, higher bias, better resolution
- 55V is too small, 59 V is too high

# 3. MPPC

## CDH (3\*10\*80cm Scinti)

- Lower threshold, better resolution
- Error caused by gauss fit for TOF is ~0.5% in any case.

bias	threshold	attenuator	Time Resolution
59 V	?	L : 10 dB R : 10 dB	81 ps
59 V	?	L : 1dB R : 3 dB	82 ps
59 V	23 mV	L : 1dB R : 3 dB	78 ps
59 V	23 mV	L : 1dB R : 3 dB	79 ps
59 V	30 mV	L : 1dB R : 3 dB	83 ps

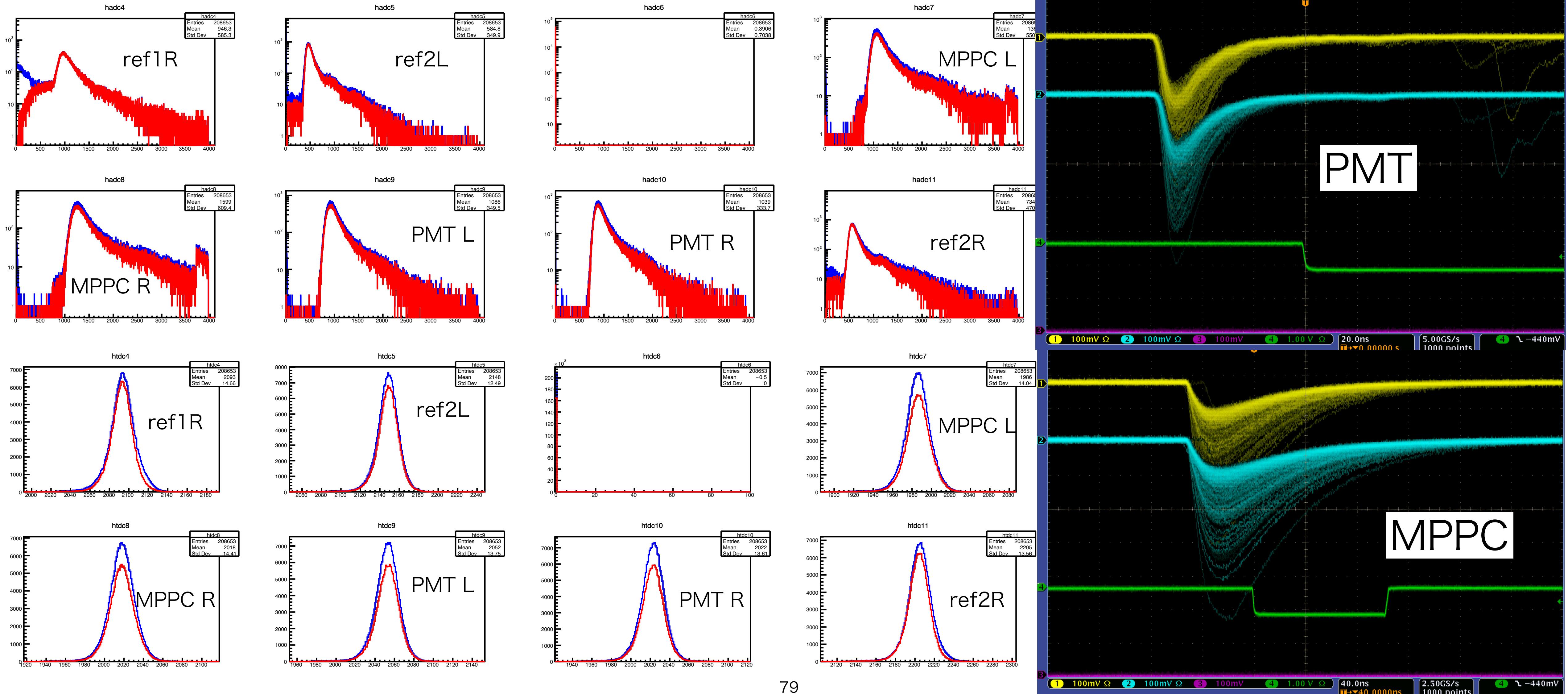
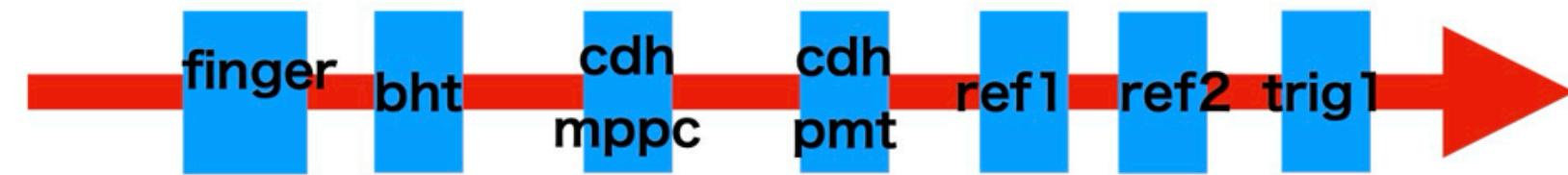
# 4. PMT vs MPPC using CDH

3\*10\*80cm Scinti

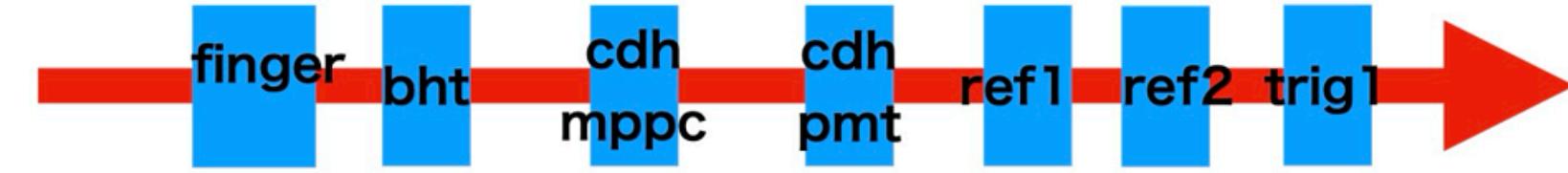
# 4. PMT vs MPPC using CDH

Run143, pos=40cm(center), bias 59V, atte(L:3dB,R:3dB)

Blue: raw data, Red: trig&ref TDC != -1

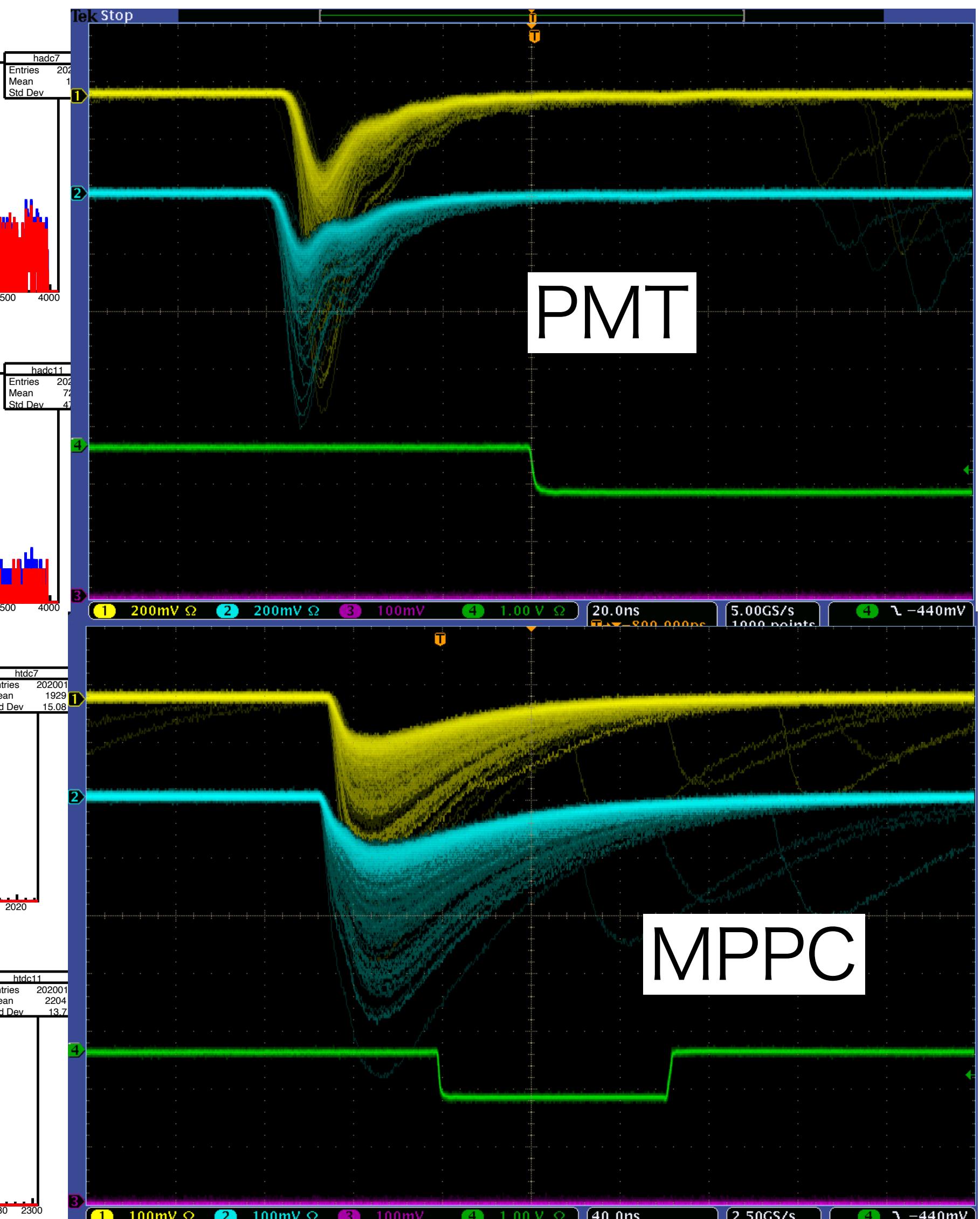
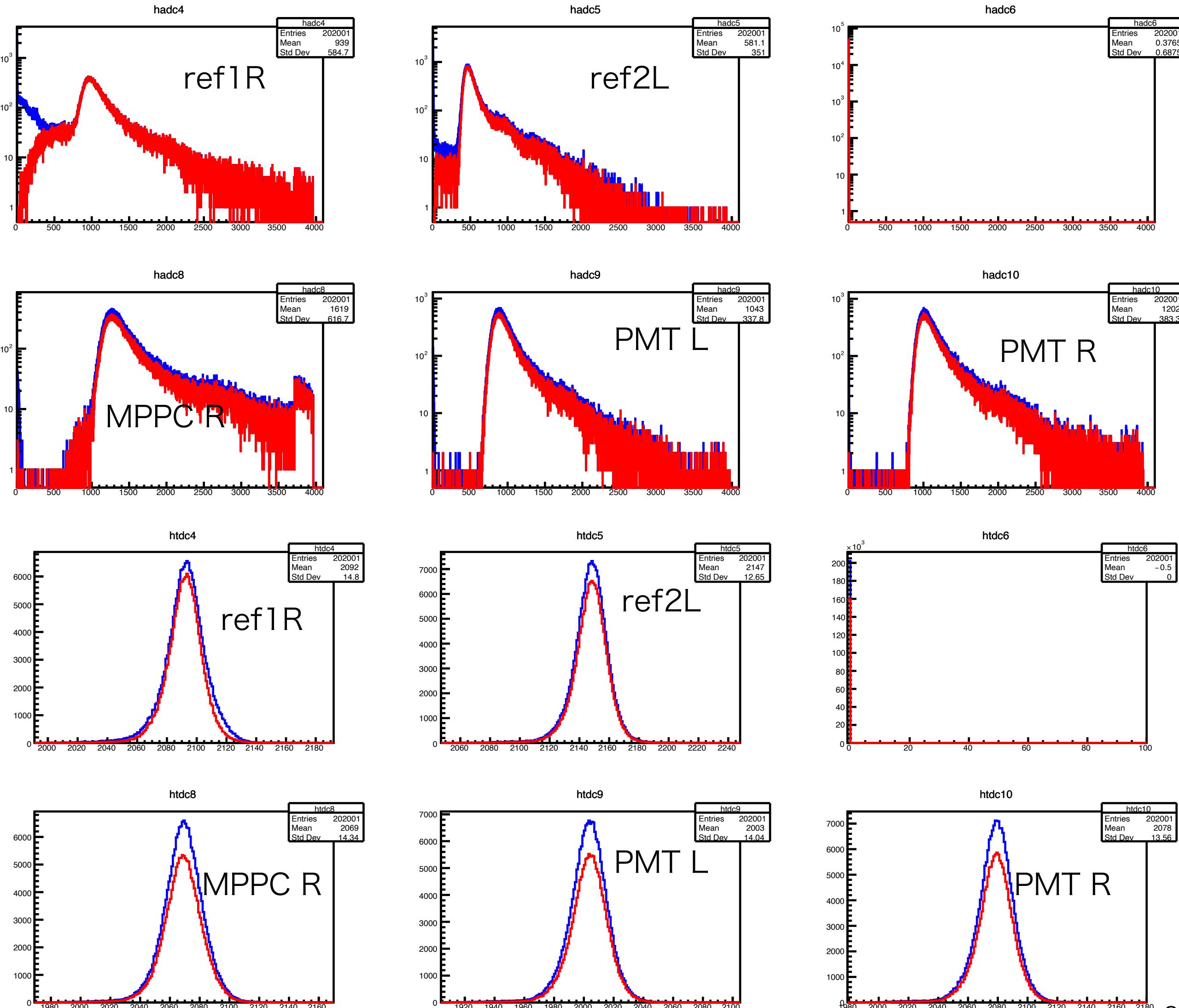


# 4. PMT vs MPPC using CDH



Run148, pos=10cm, bias 59V, atte(L:3dB,R:3dB)

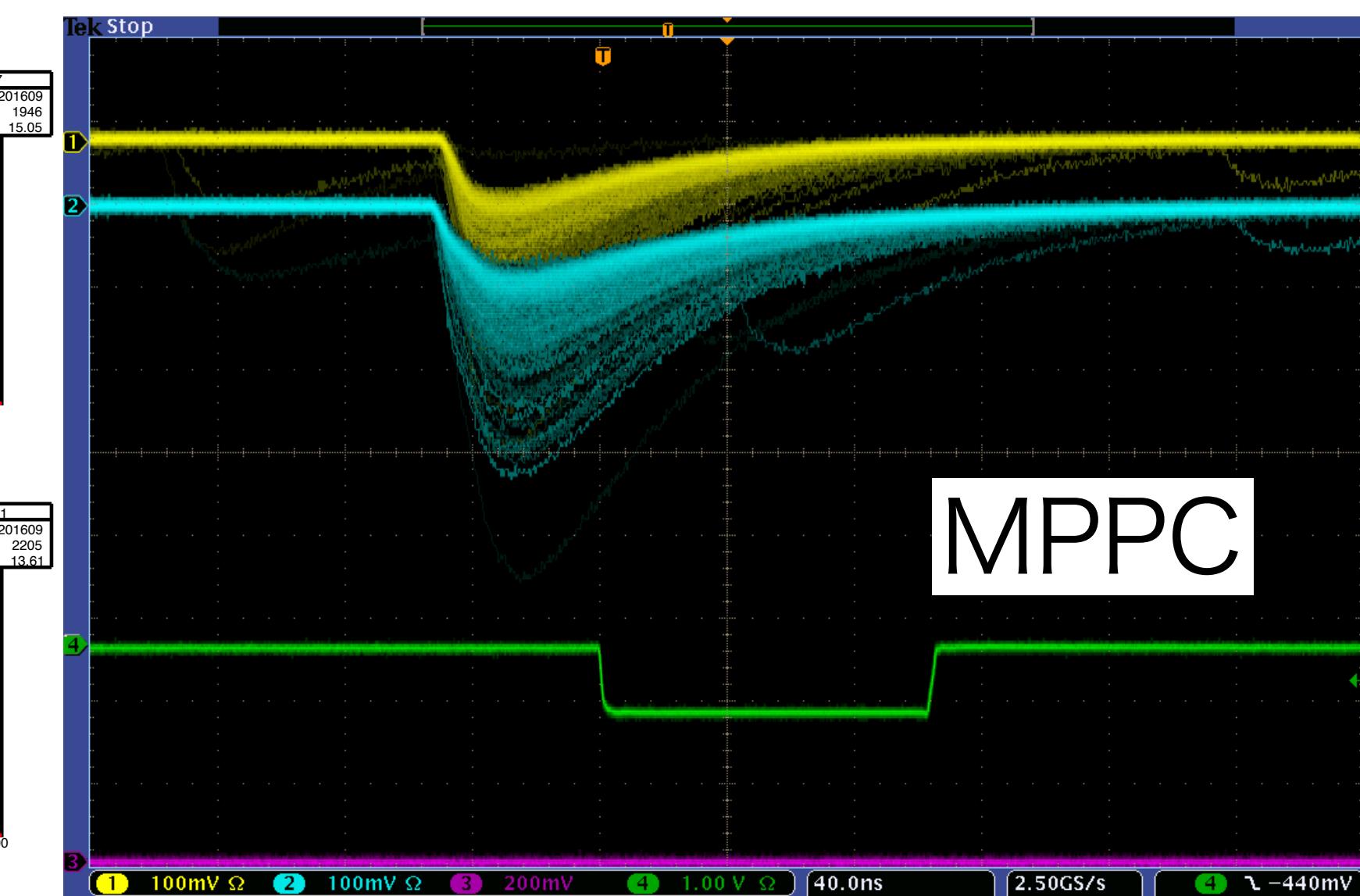
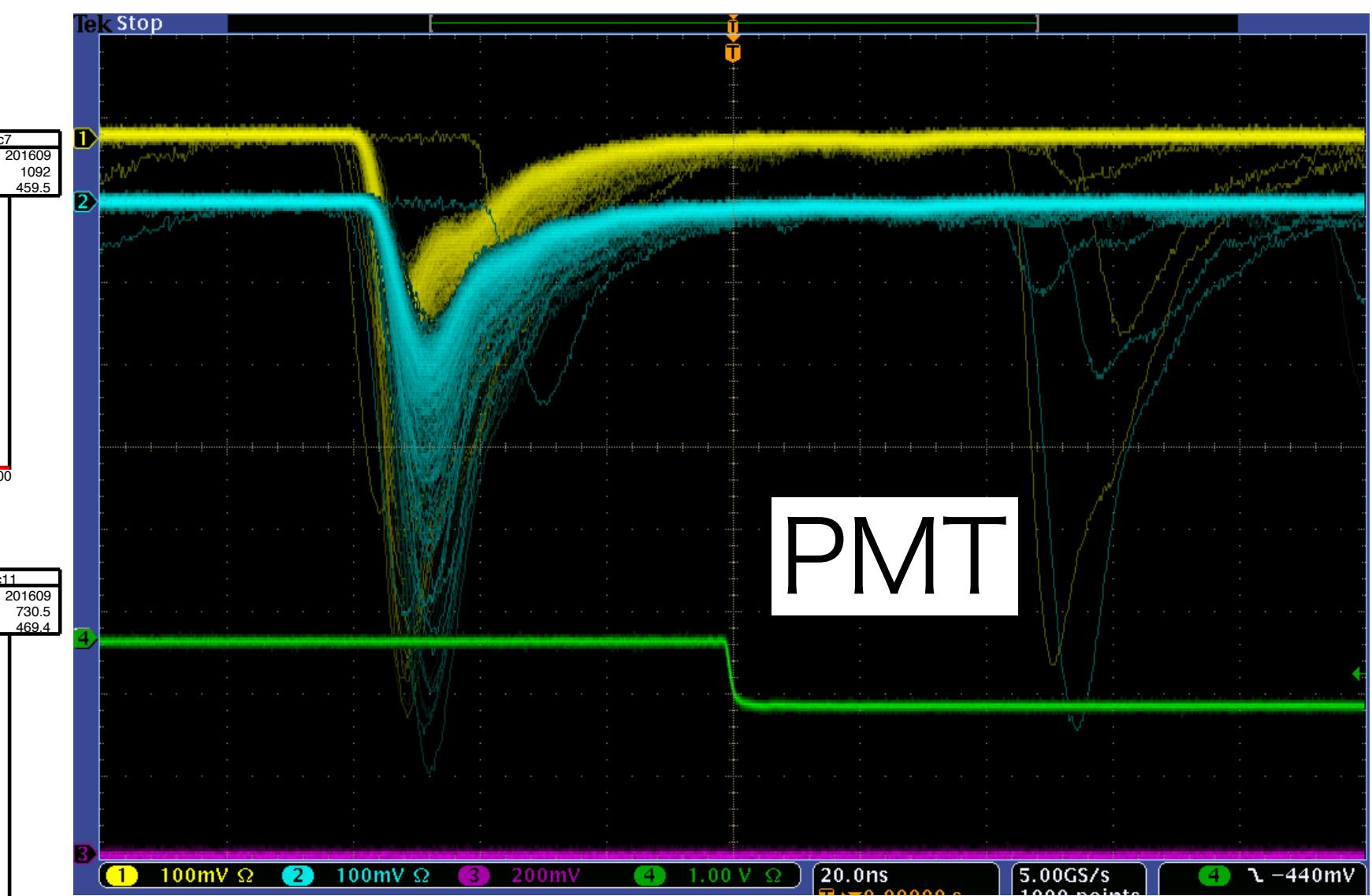
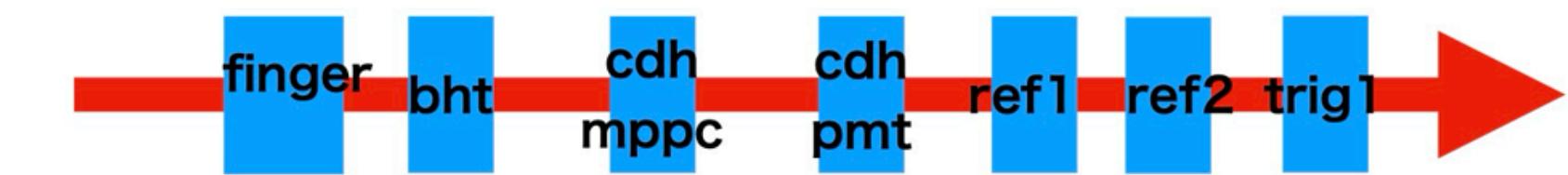
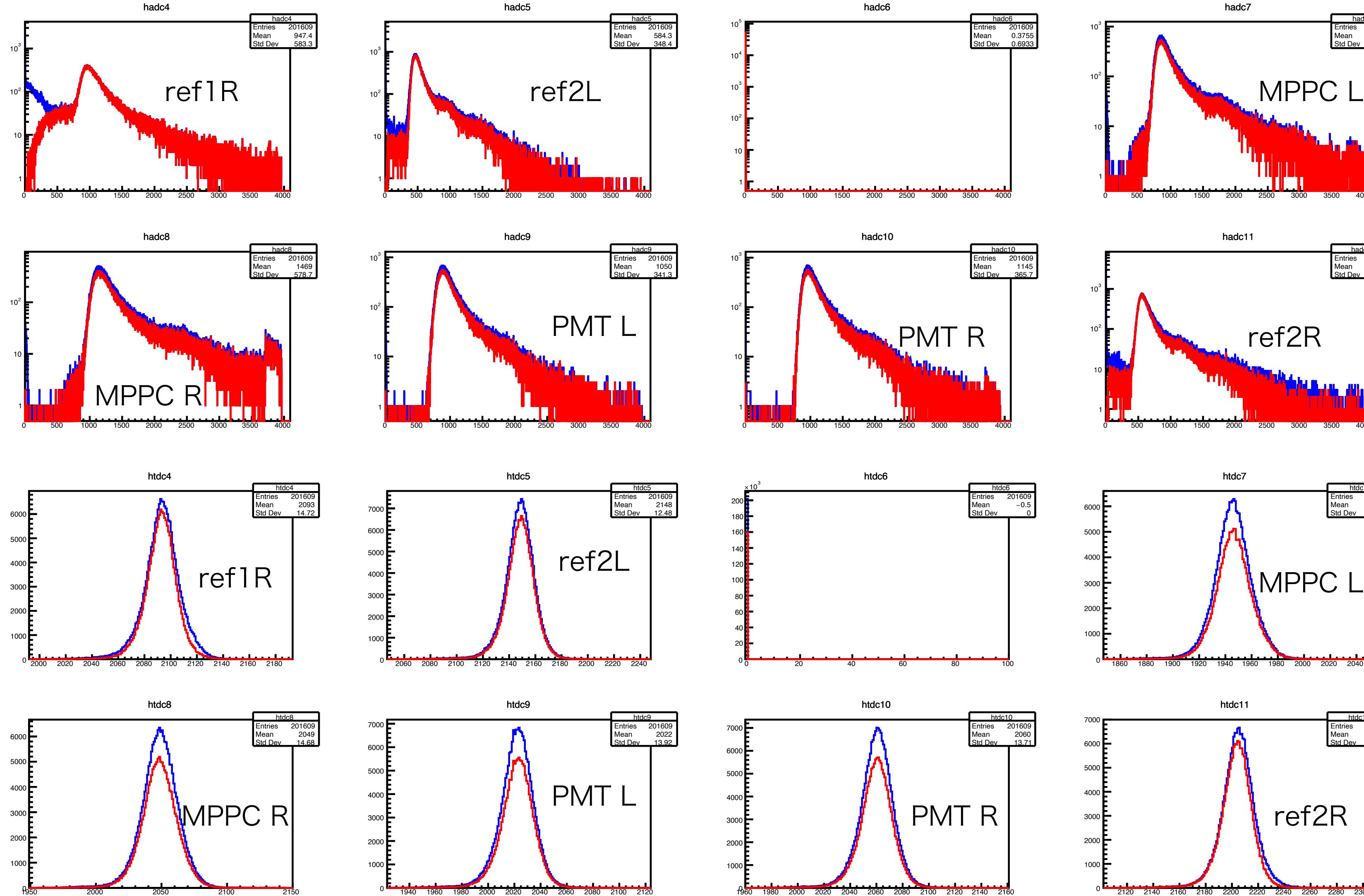
Blue: raw data, Red: trig&ref TDC != -1



# 4. PMT vs MPPC using CDH

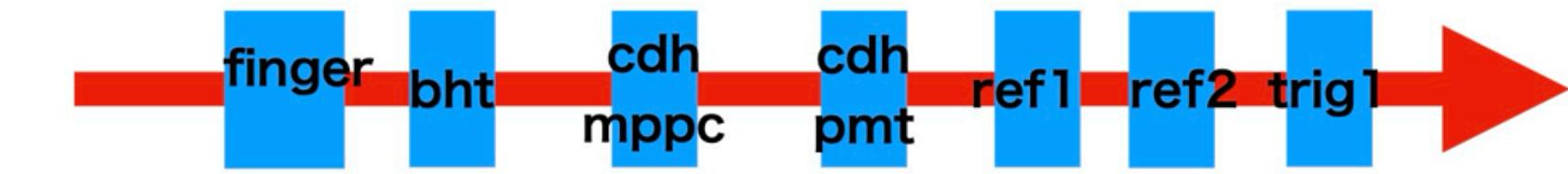
Run154, pos=20cm, bias 59V, atte(L:3dB,R:3dB)

Blue: raw data, Red: trig&ref TDC != -1

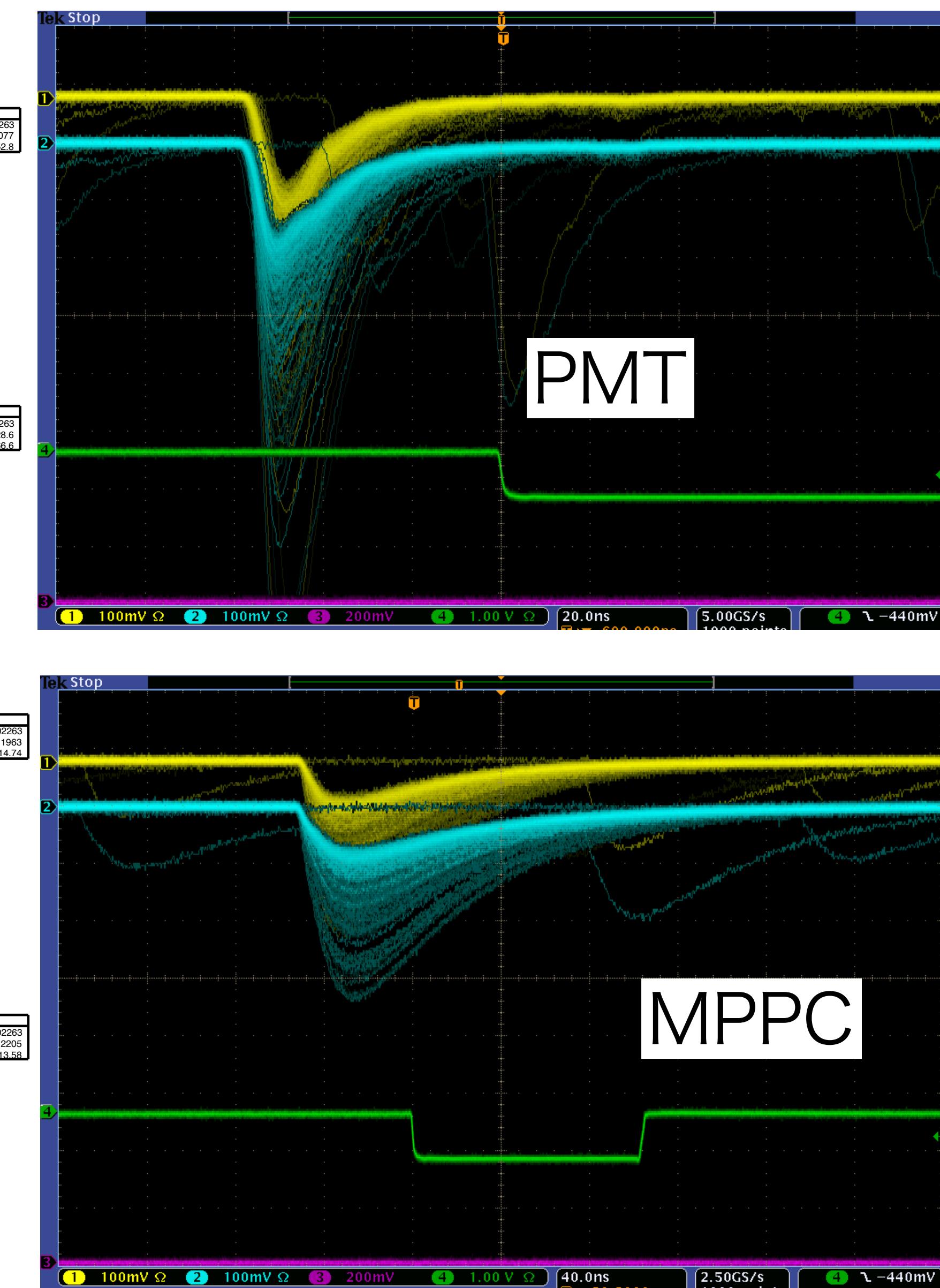
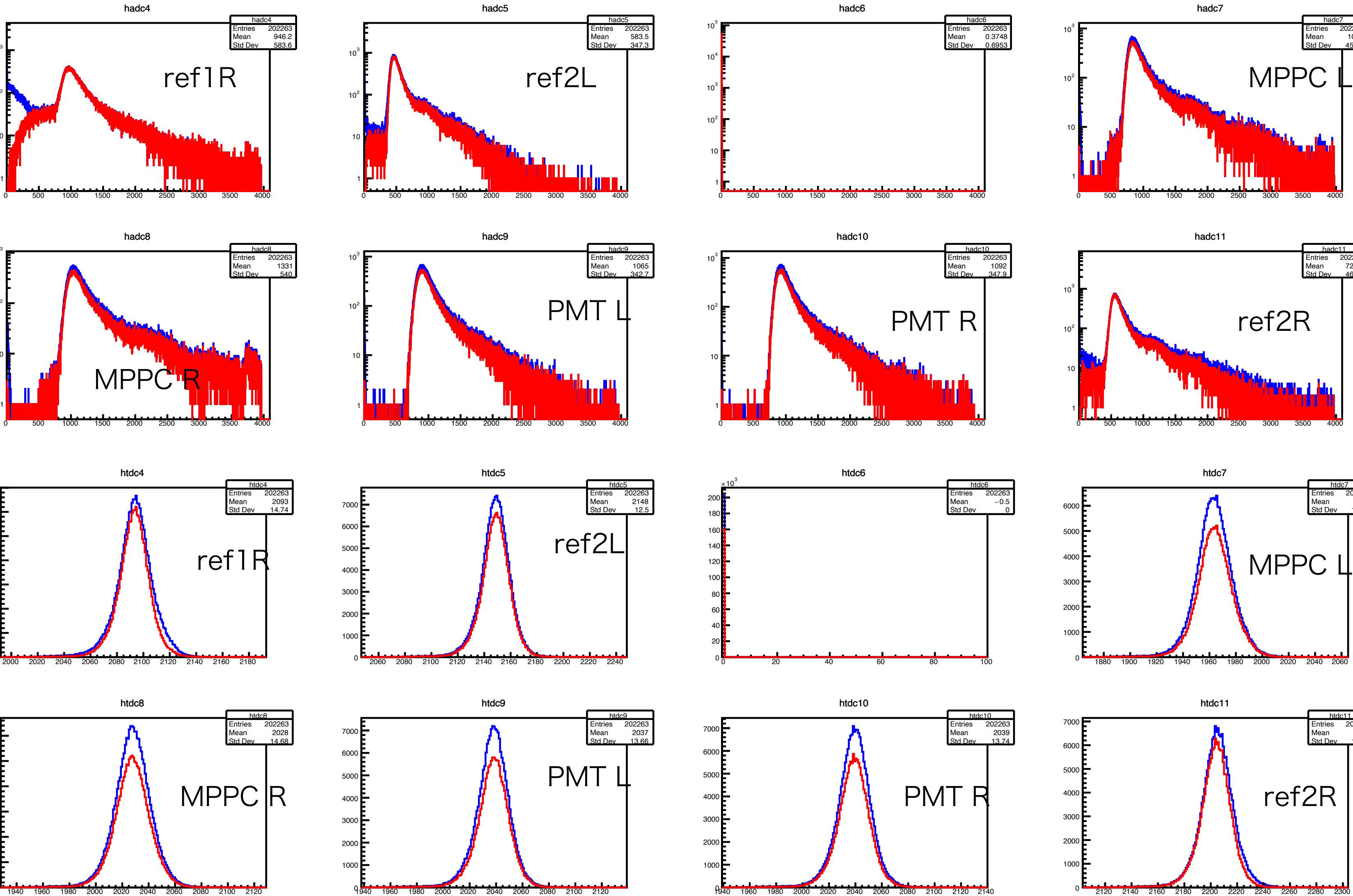


# 4. PMT vs MPPC using CDH

Run158, pos=30cm, bias 59V, atte(L:3dB,R:3dB)



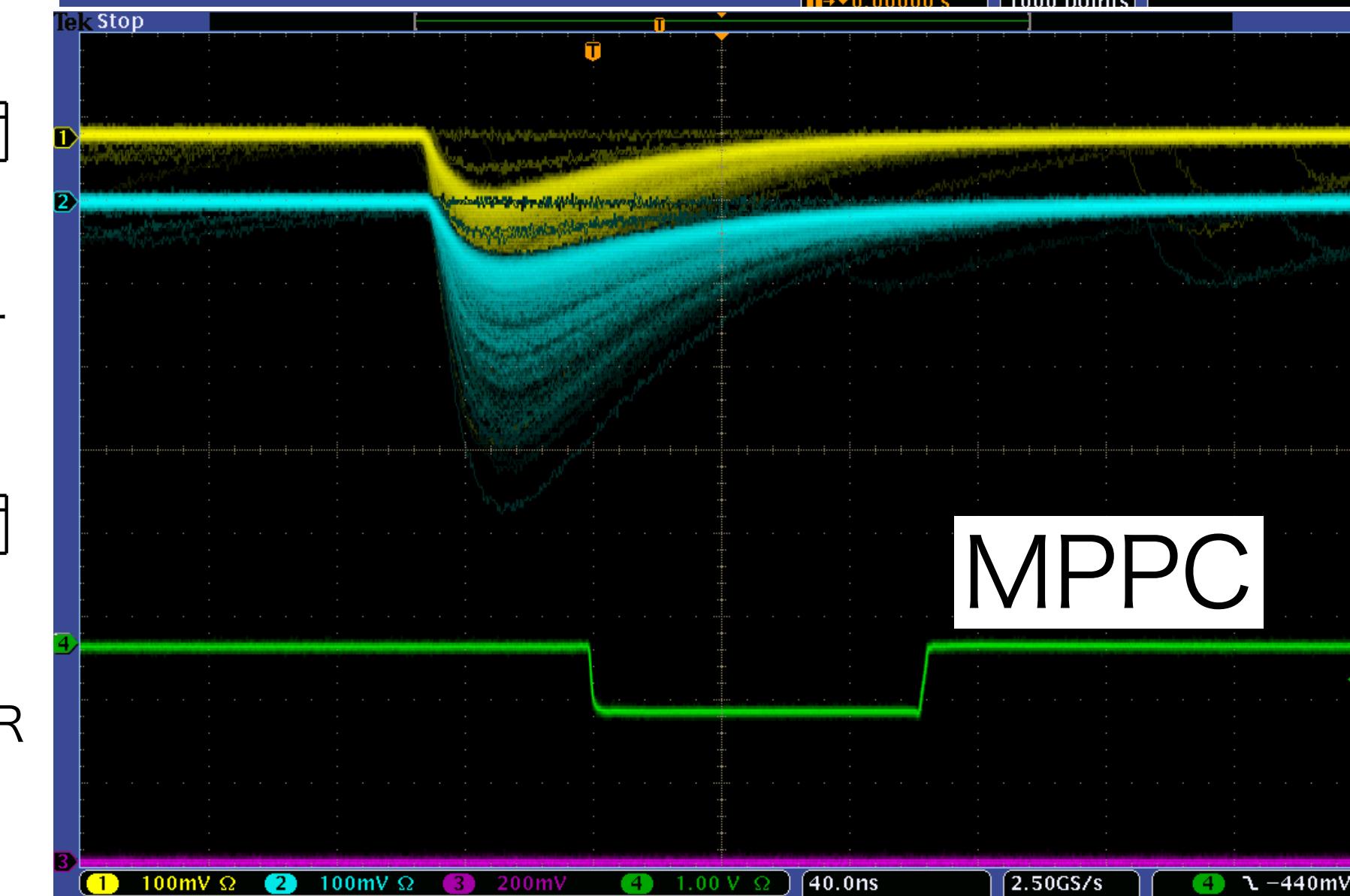
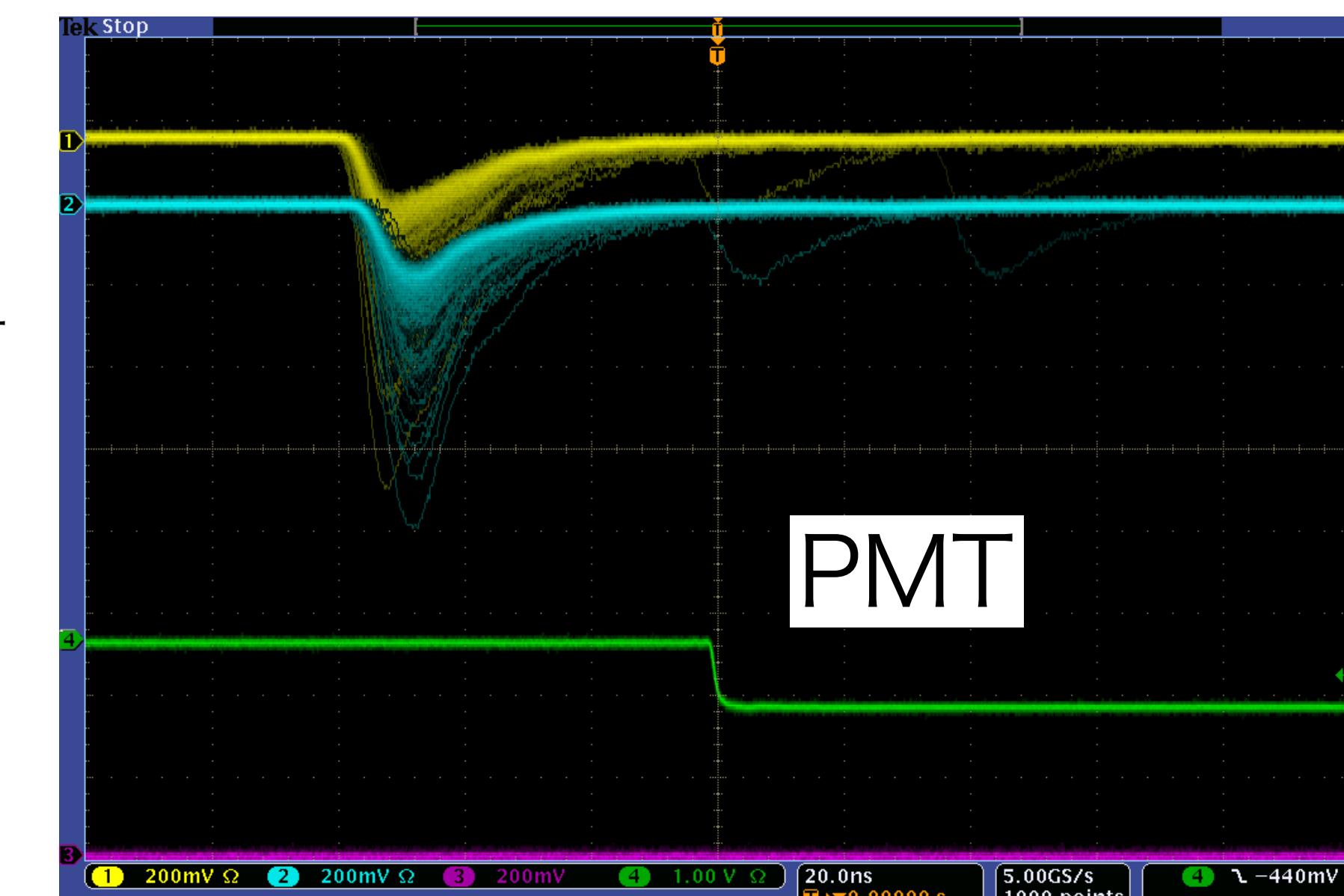
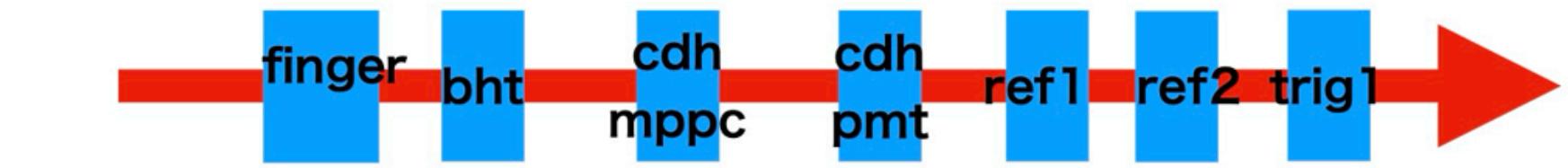
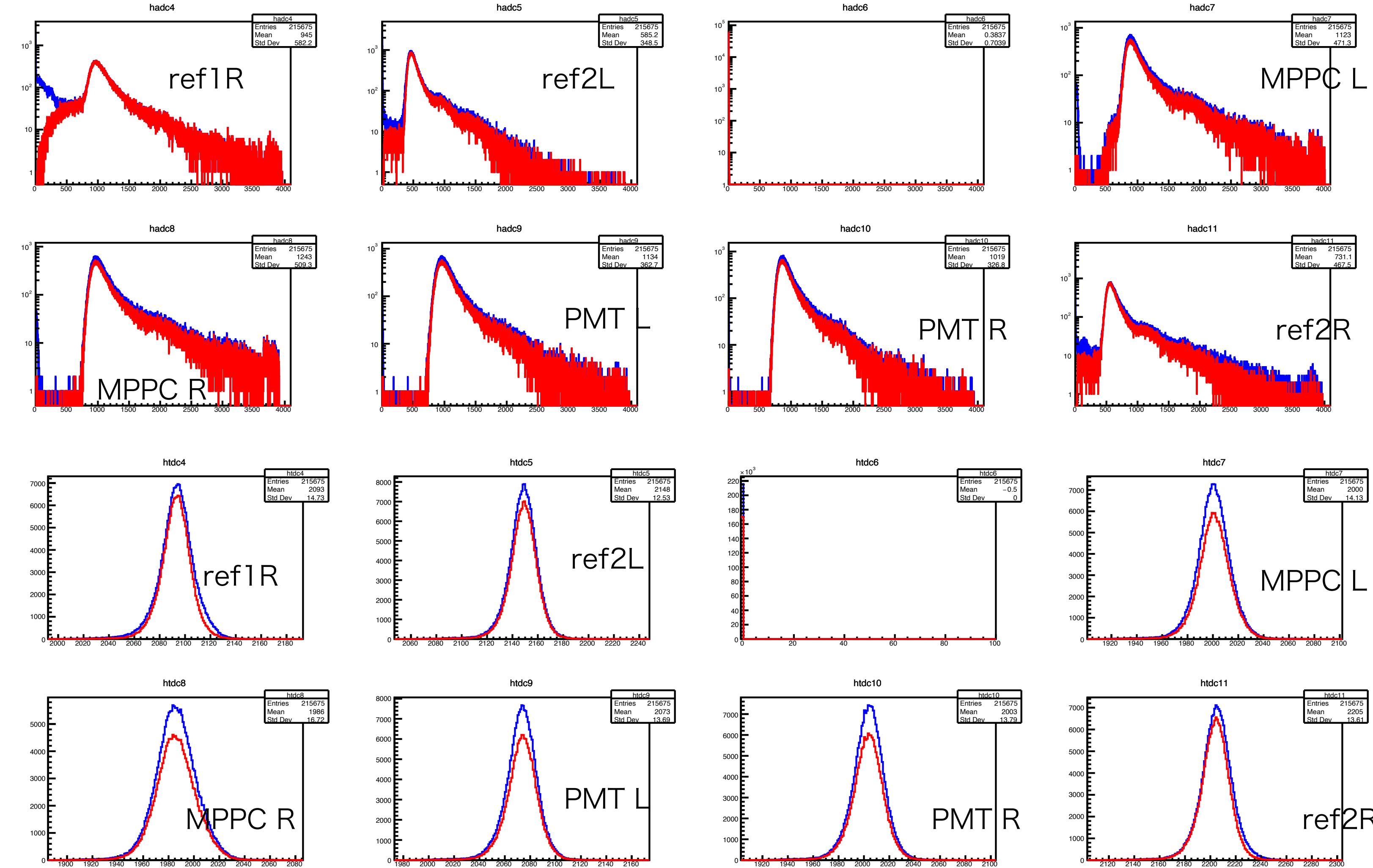
Blue: raw data, Red: trig&ref TDC != -1



# 4. PMT vs MPPC using CDH

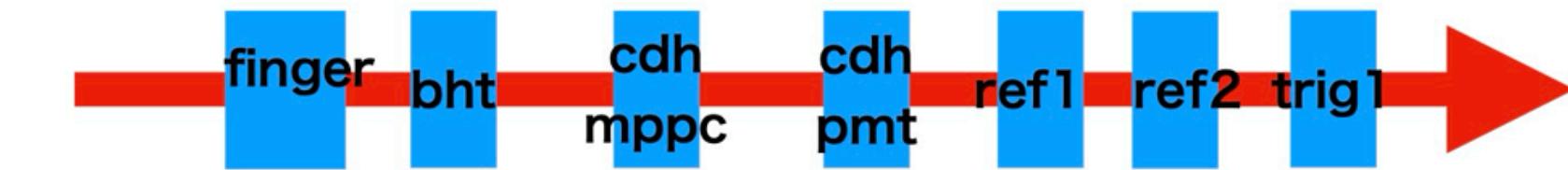
Run163, pos=50cm, bias 59V, atte(L:3dB,R:3dB)

Blue: raw data, Red: trig&ref TDC != -1

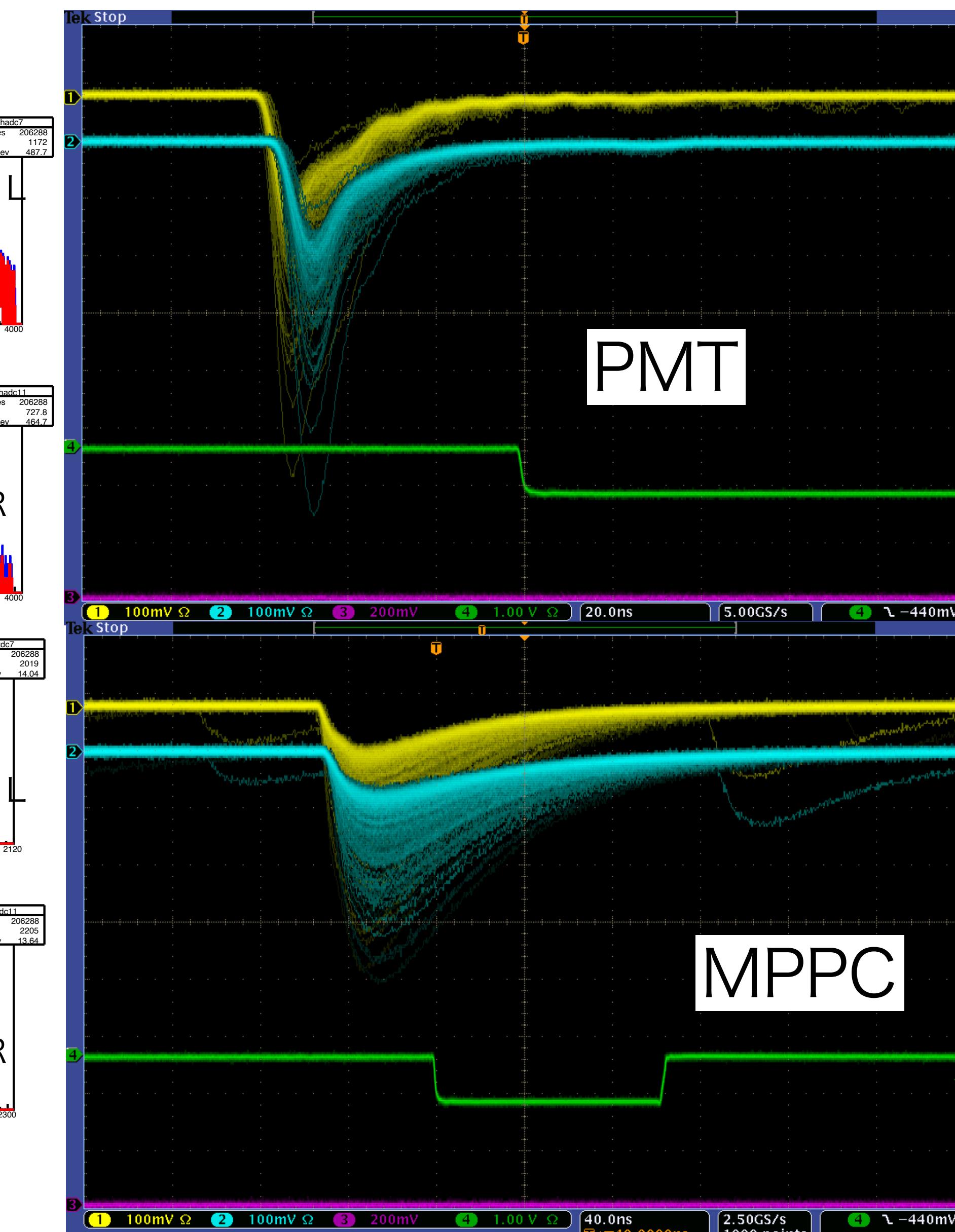
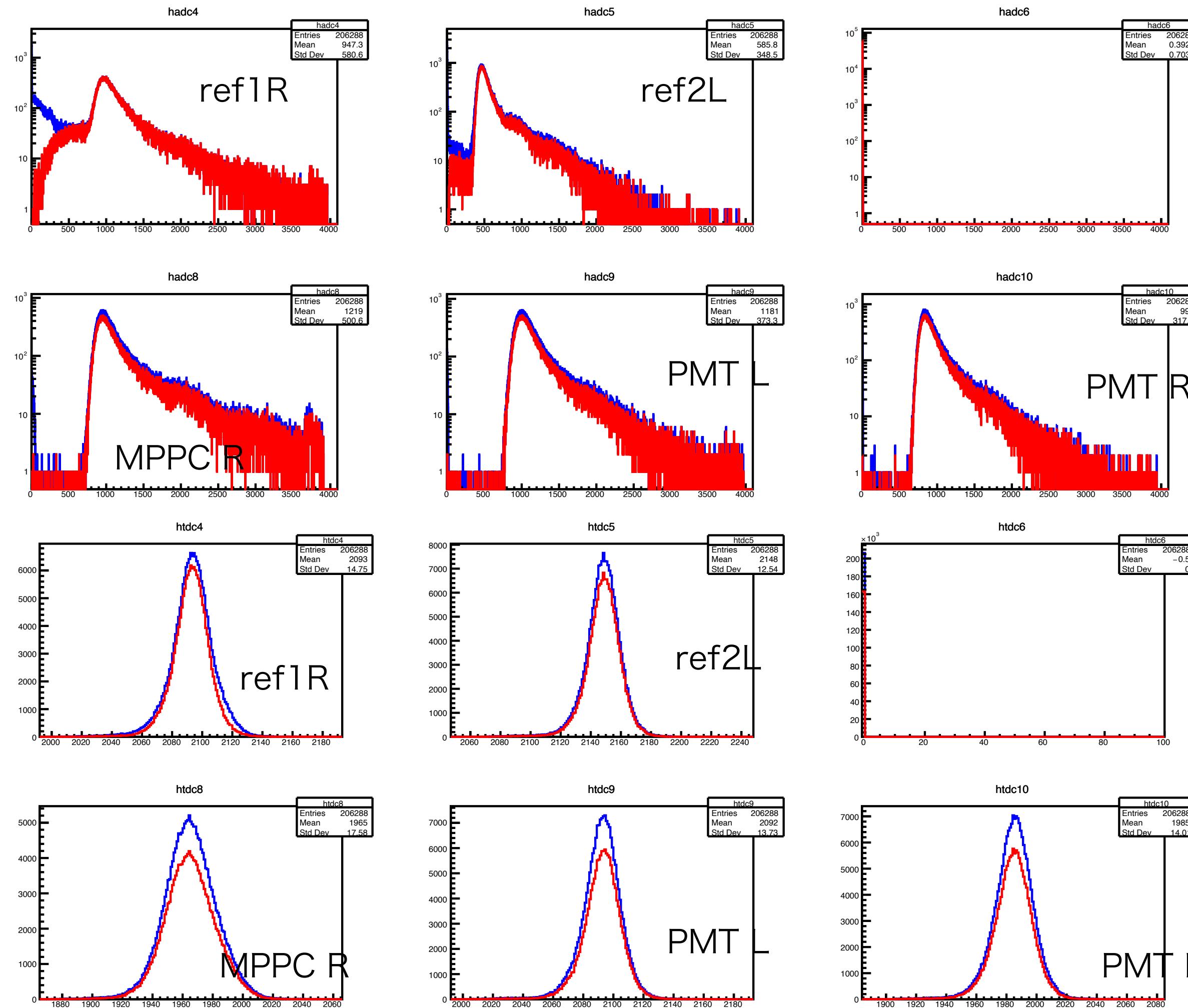


# 4. PMT vs MPPC using CDH

Run168, pos=60cm, bias 59V, atte(L:3dB,R:3dB)



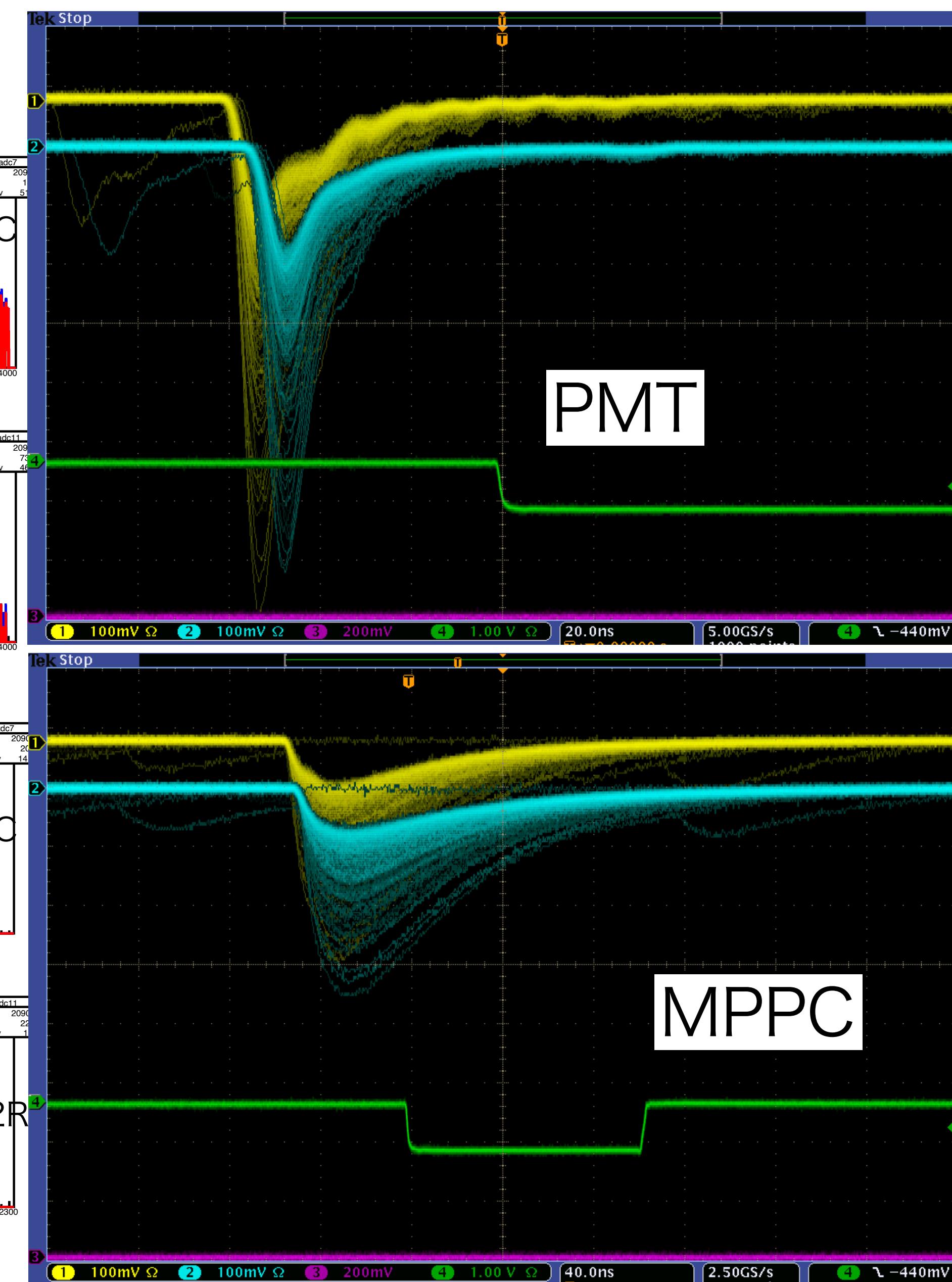
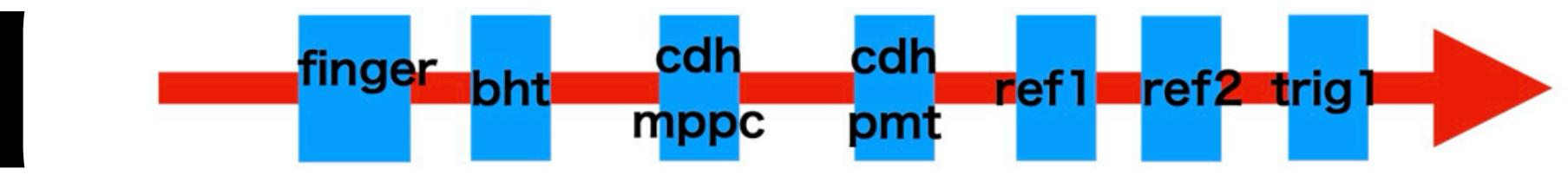
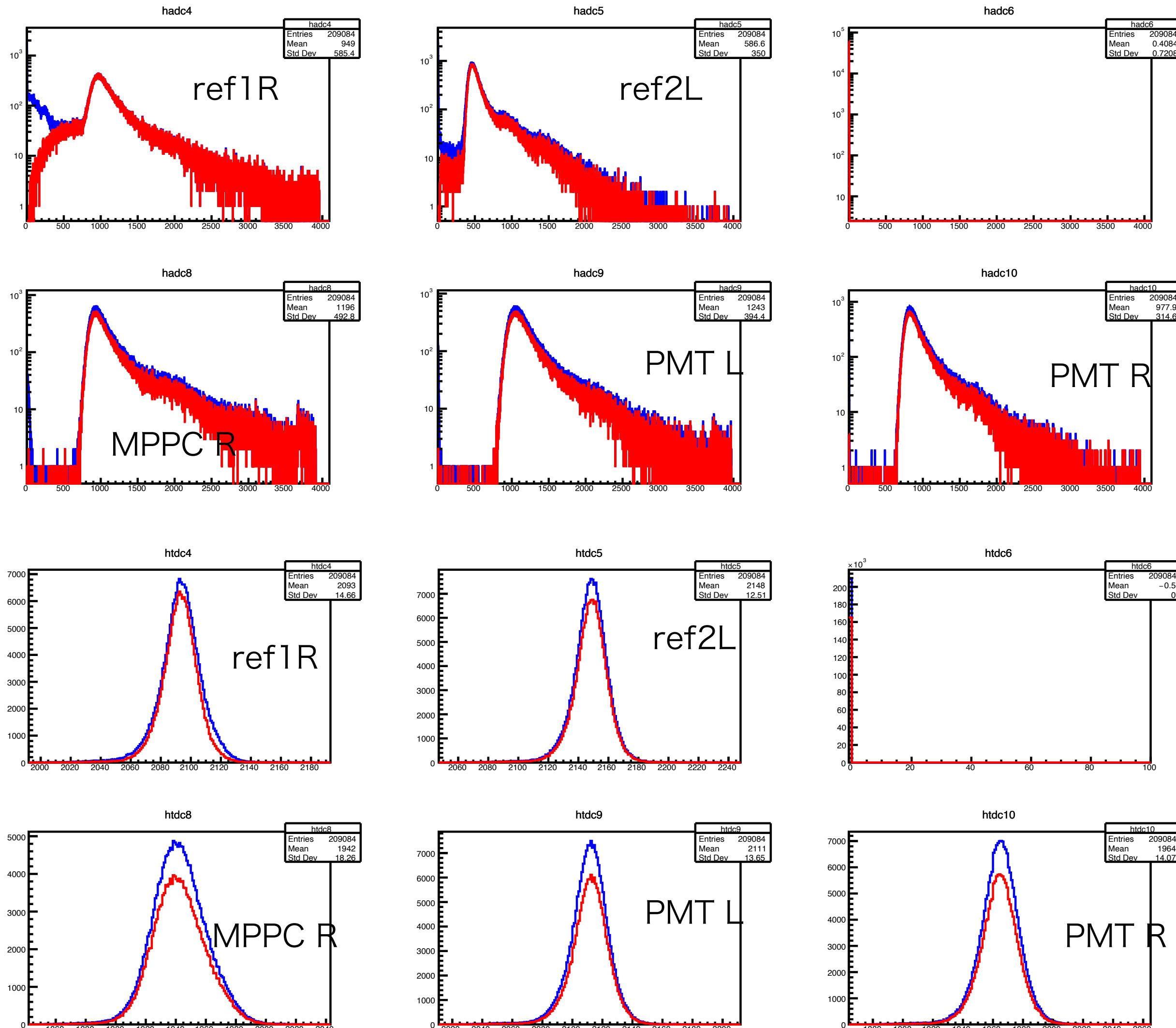
Blue: raw data, Red: trig&ref TDC != -1



# 4. PMT vs MPPC using CDH

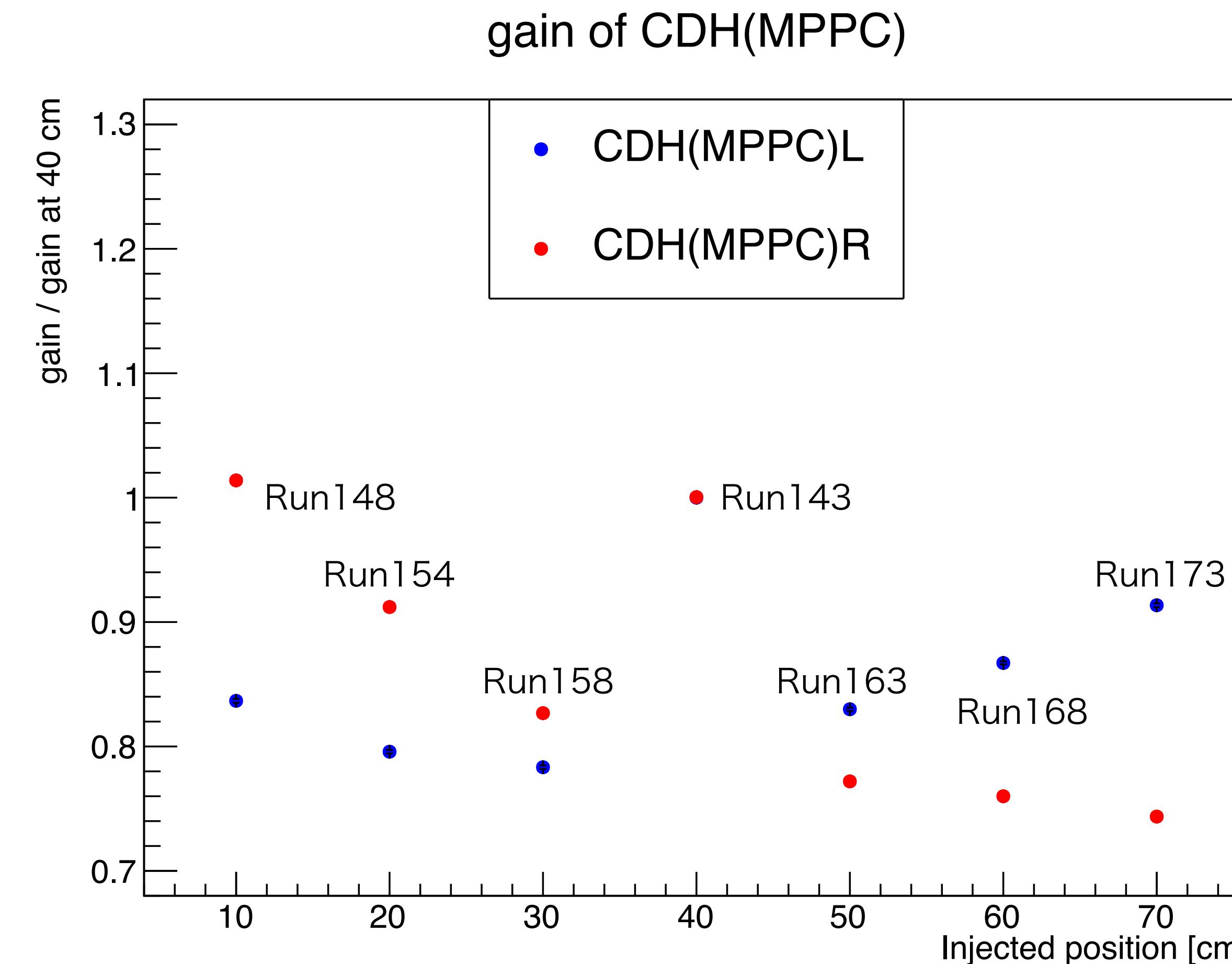
Run173, pos=70cm, bias 59V, atte(L:3dB,R:3dB)

Blue: raw data, Red: trig&ref TDC != -1



# 4. PMT vs MPPC using CDH

- CDH(MPPC)のAttenuation Lengthを求めようとしたが  
よくわからない分布になったので、やりません。

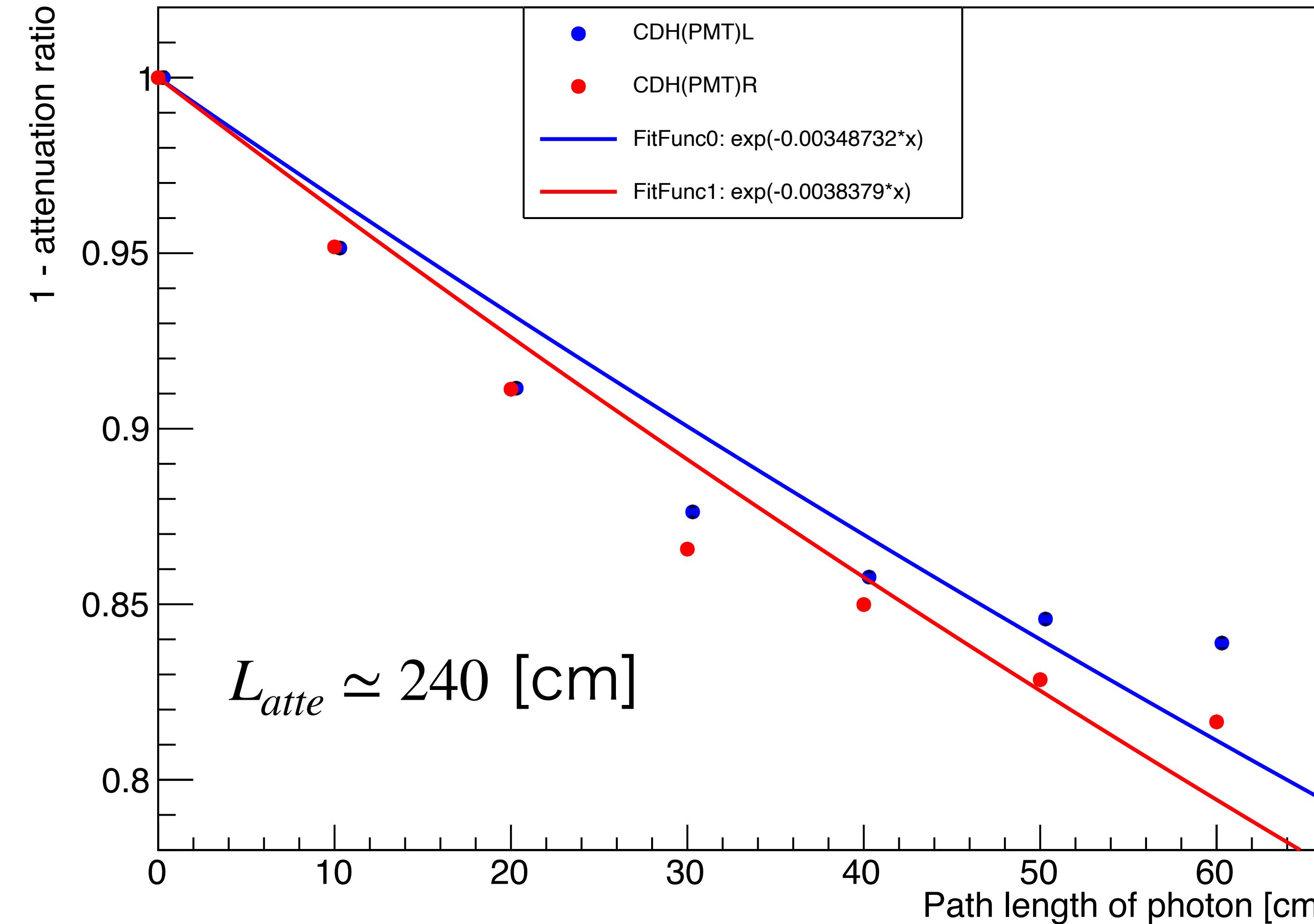


時間経過でなぜかMPPCのgainが減少。

# 4. PMT vs MPPC using CDH

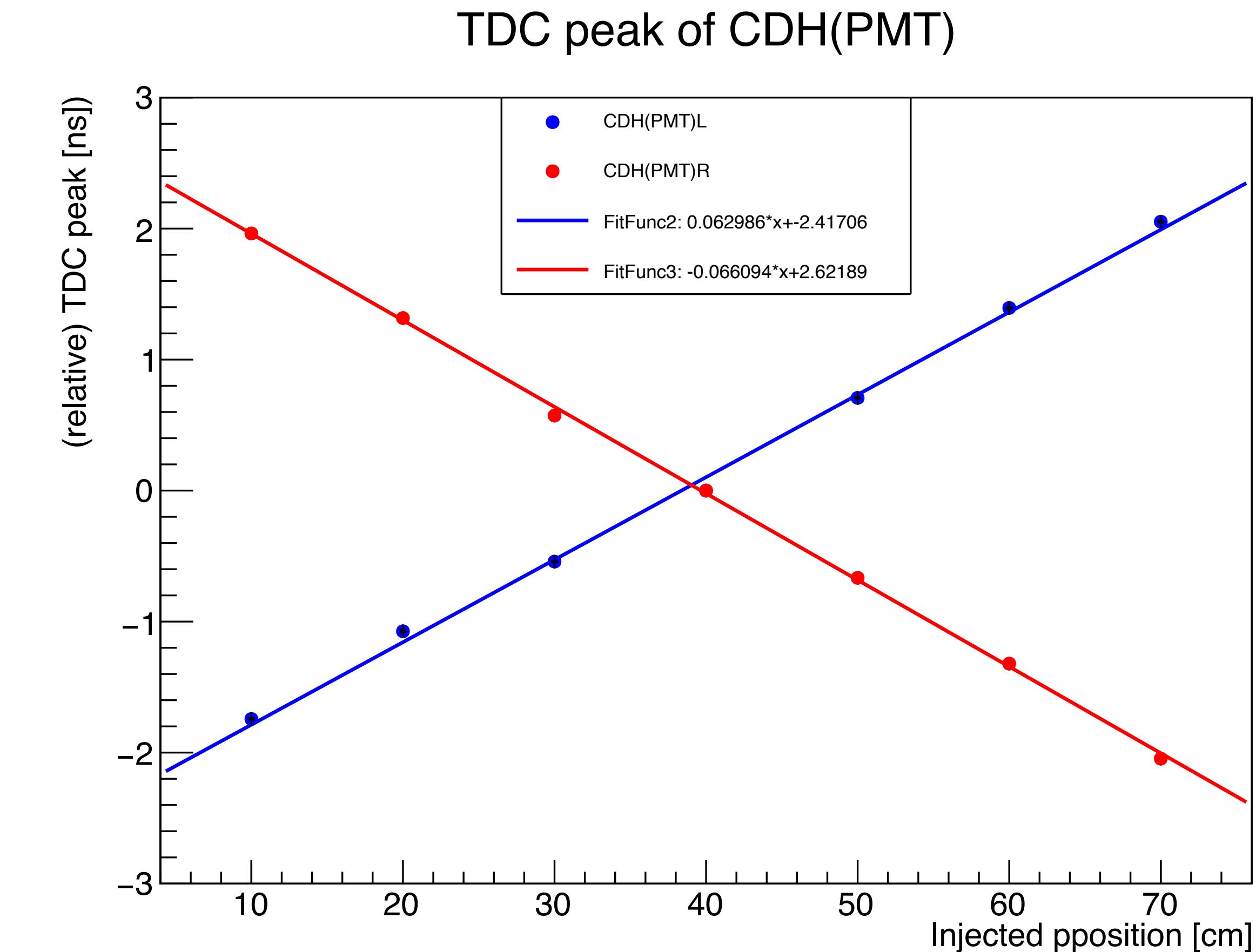
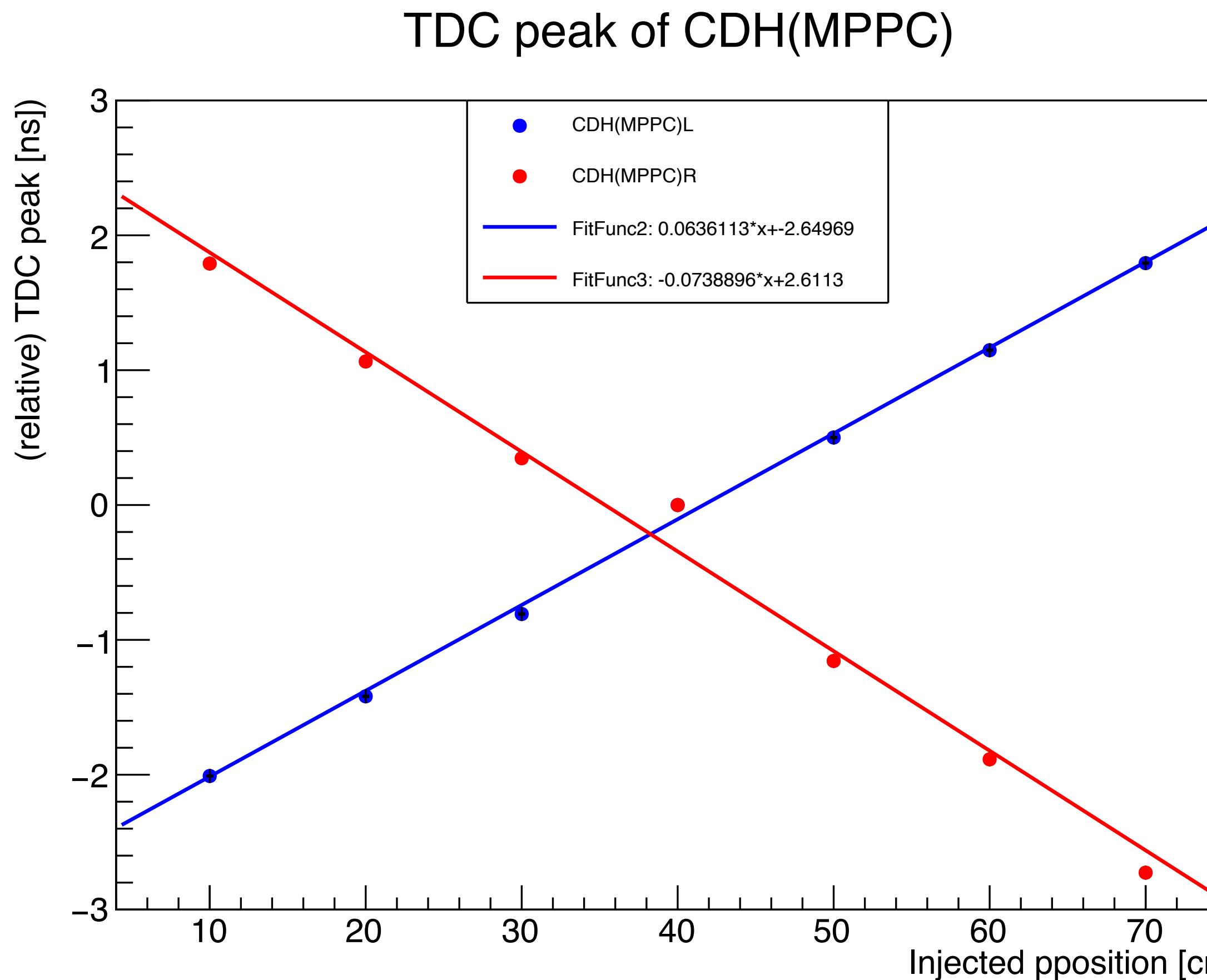
## Attenuation Length of CDH(PMT)

gain of CDH(PMT)



# 4. PMT vs MPPC using CDH

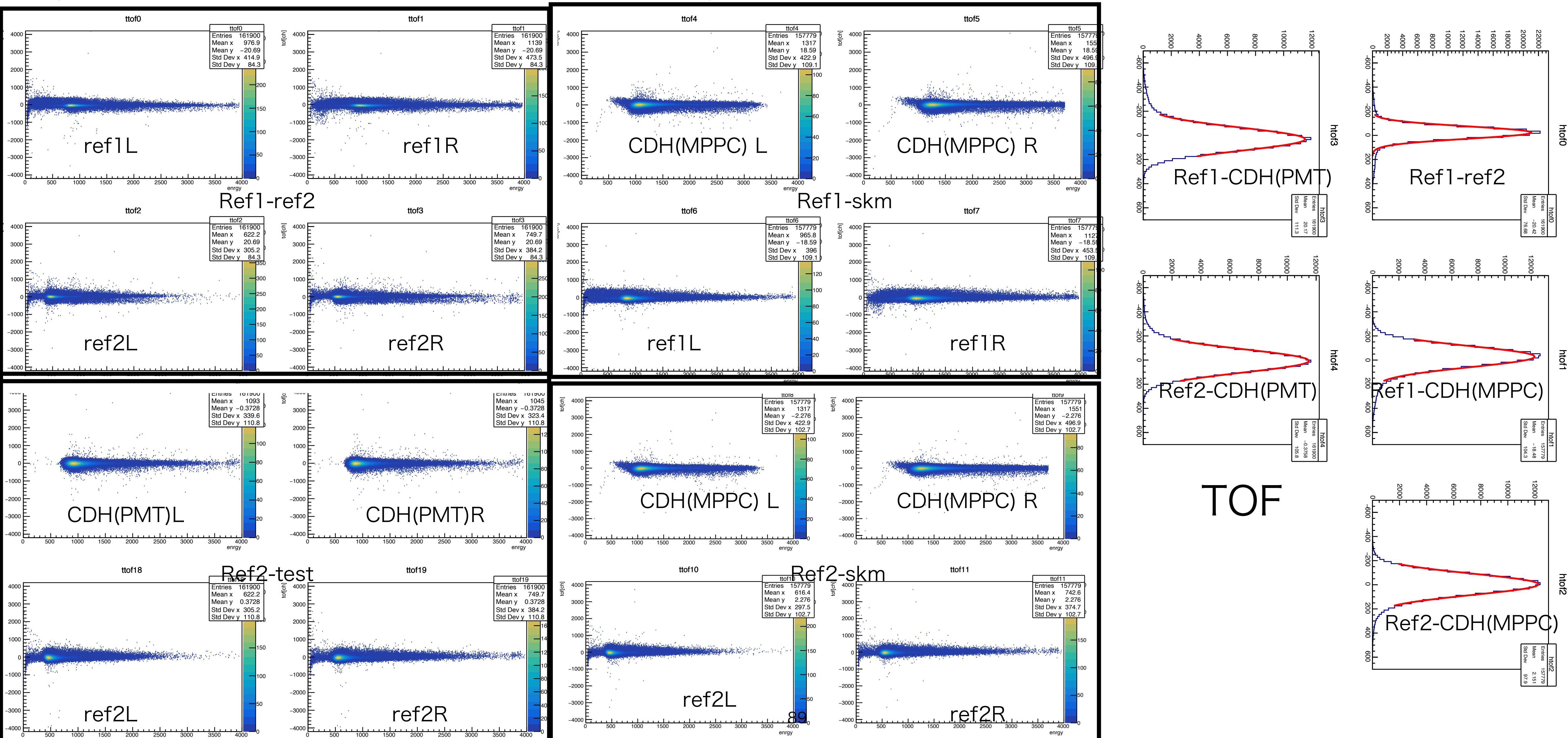
## TDC peak vs injected position



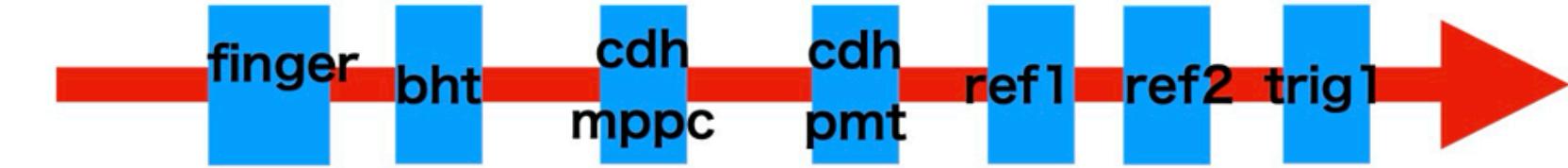
# 4. PMT vs MPPC using CDH



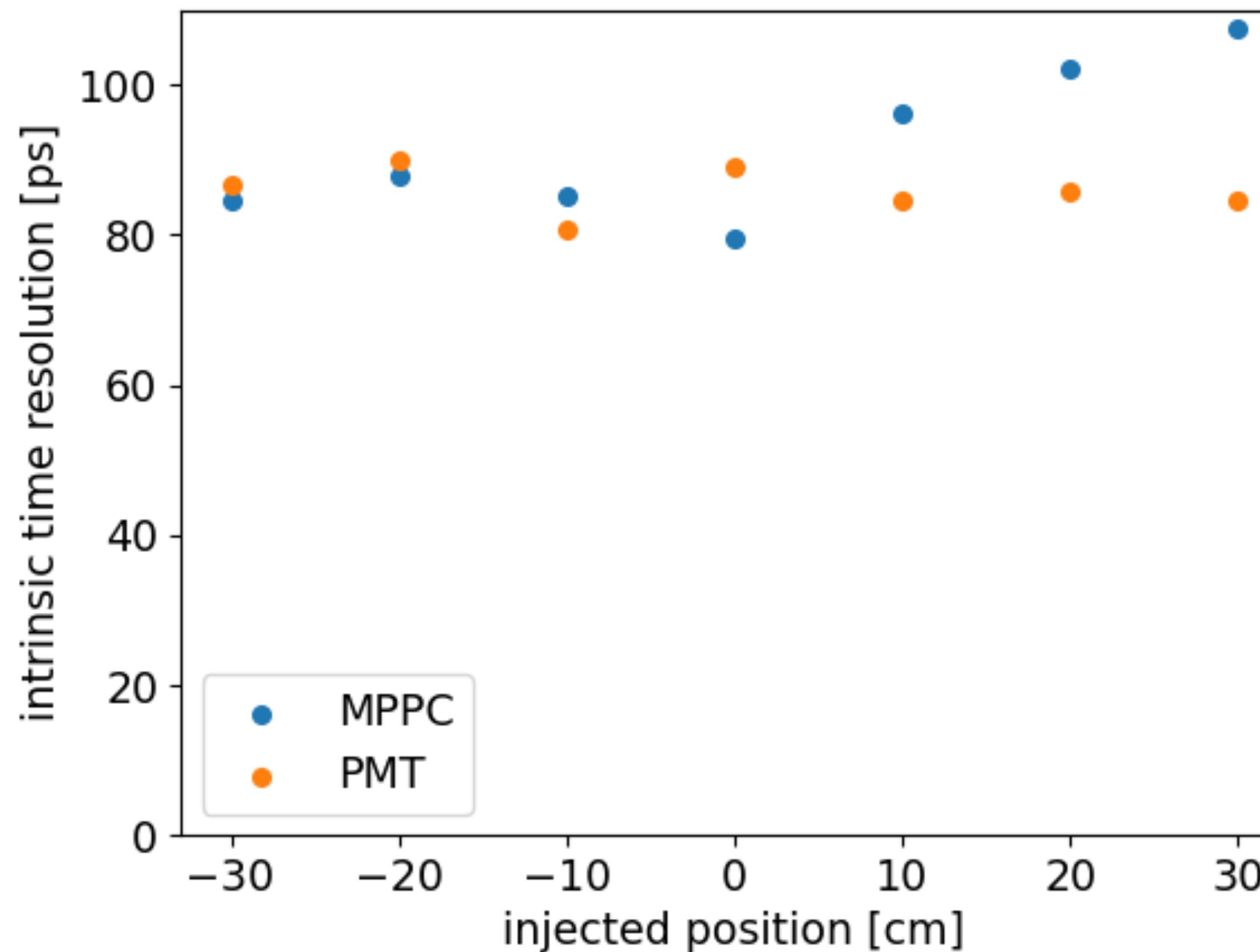
Typical shape of 2D(TOF vs Energy) after slewing correction (run143)



# 4. PMT vs MPPC using CDH



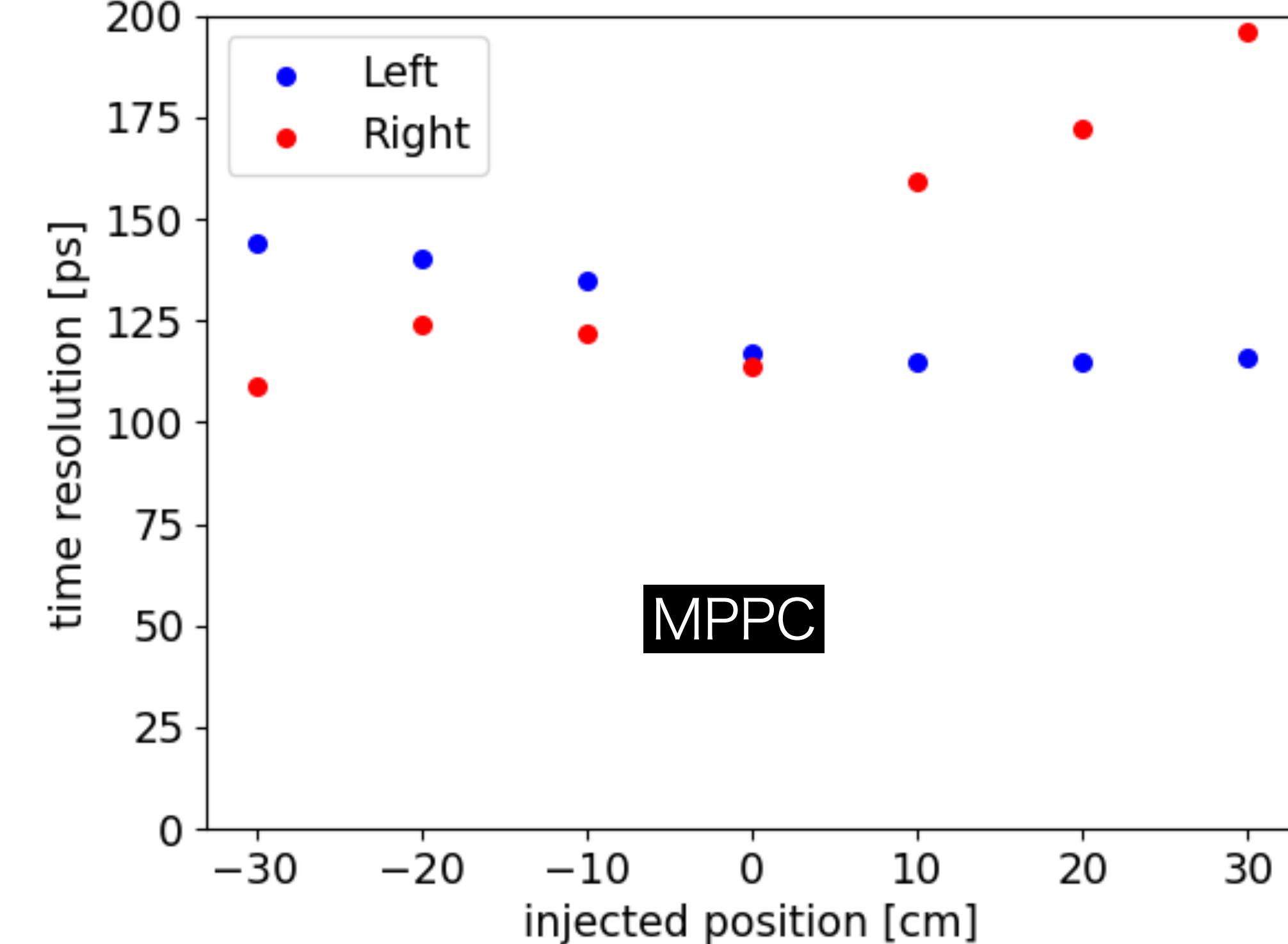
time resolution of CDH



時間経過でなぜかMPPCのgainが減少。結果的に分解能が悪化。

MPPCの方を片側TDCで分解能を出してみた。

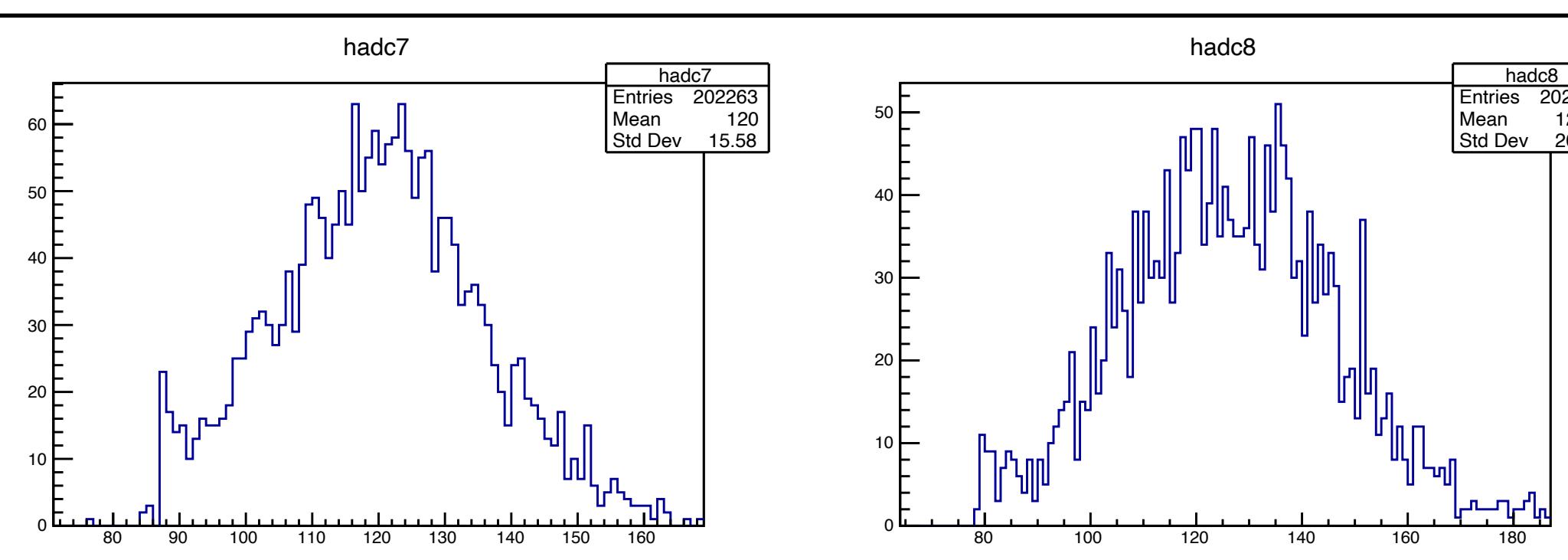
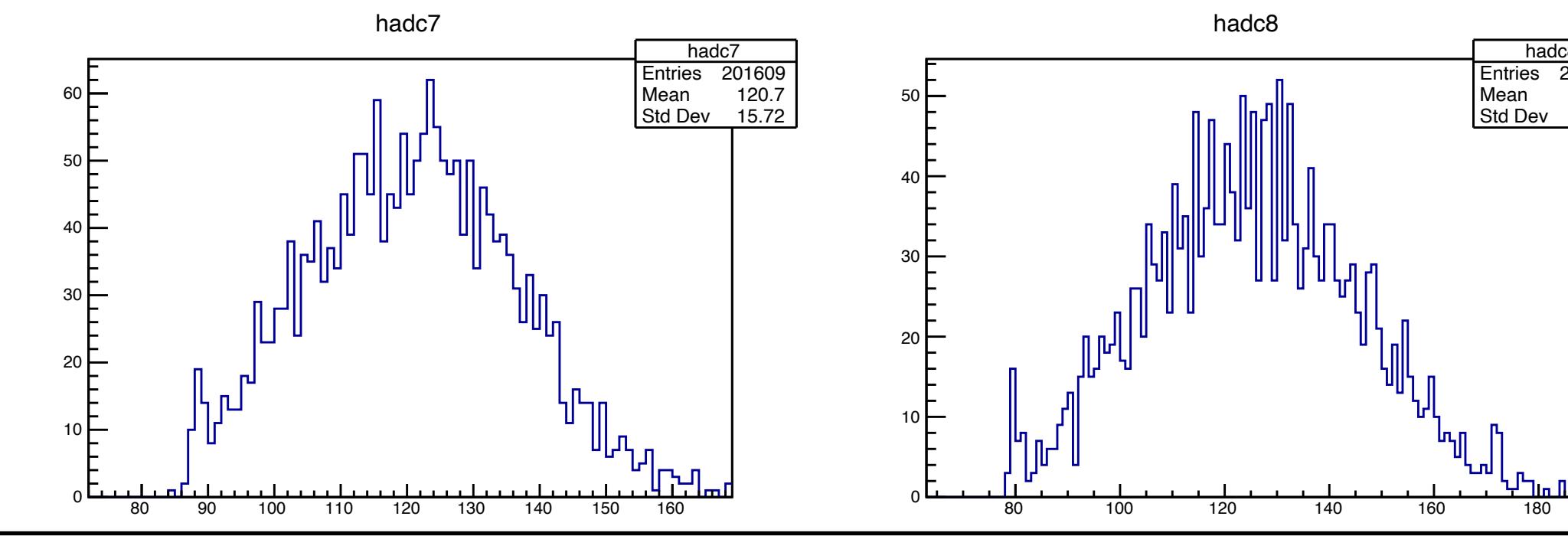
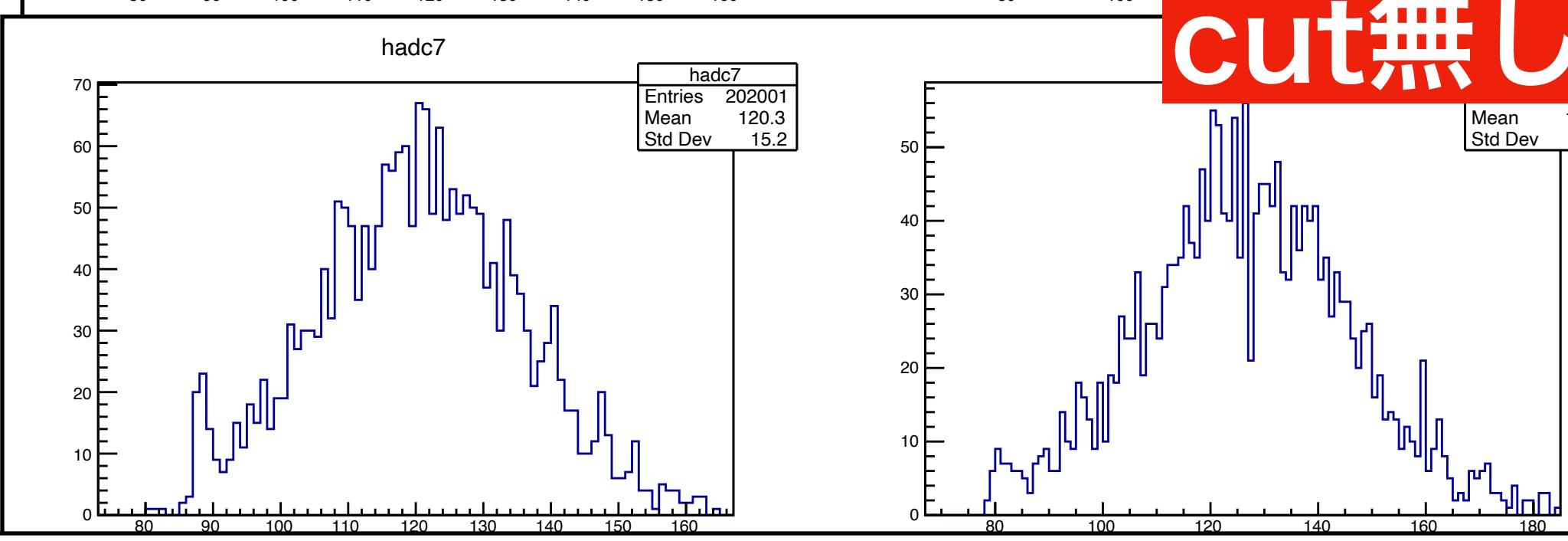
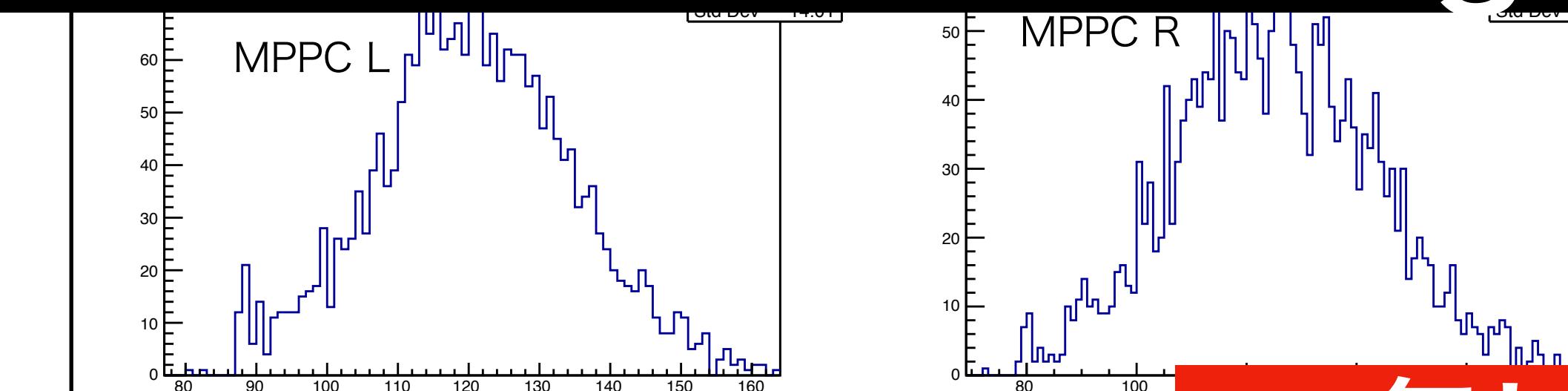
time resolution of CDH



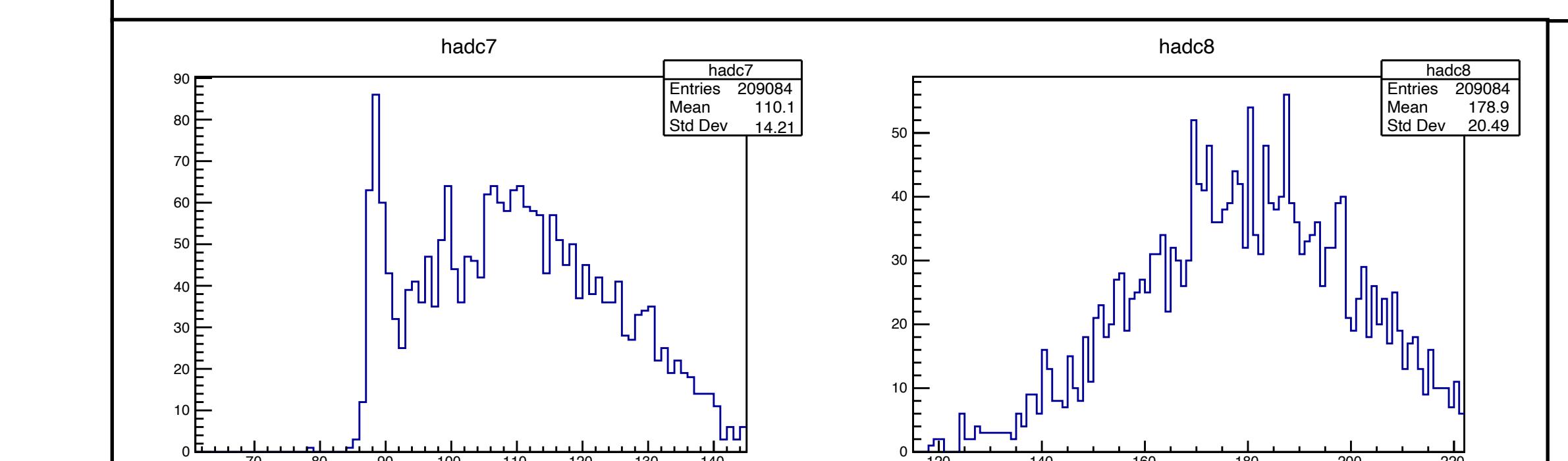
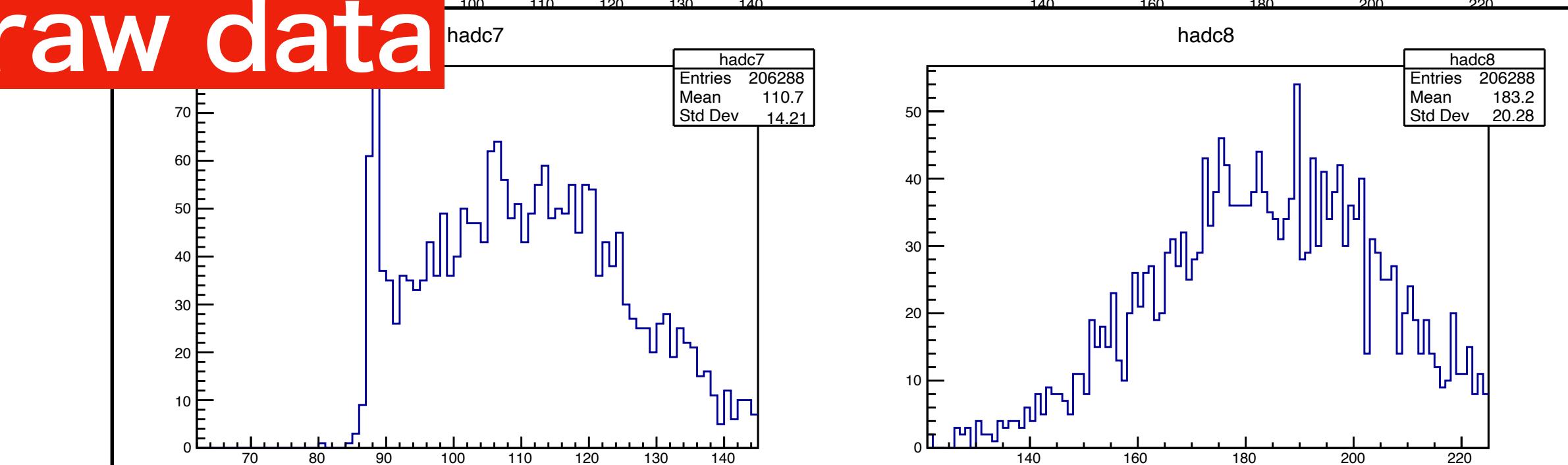
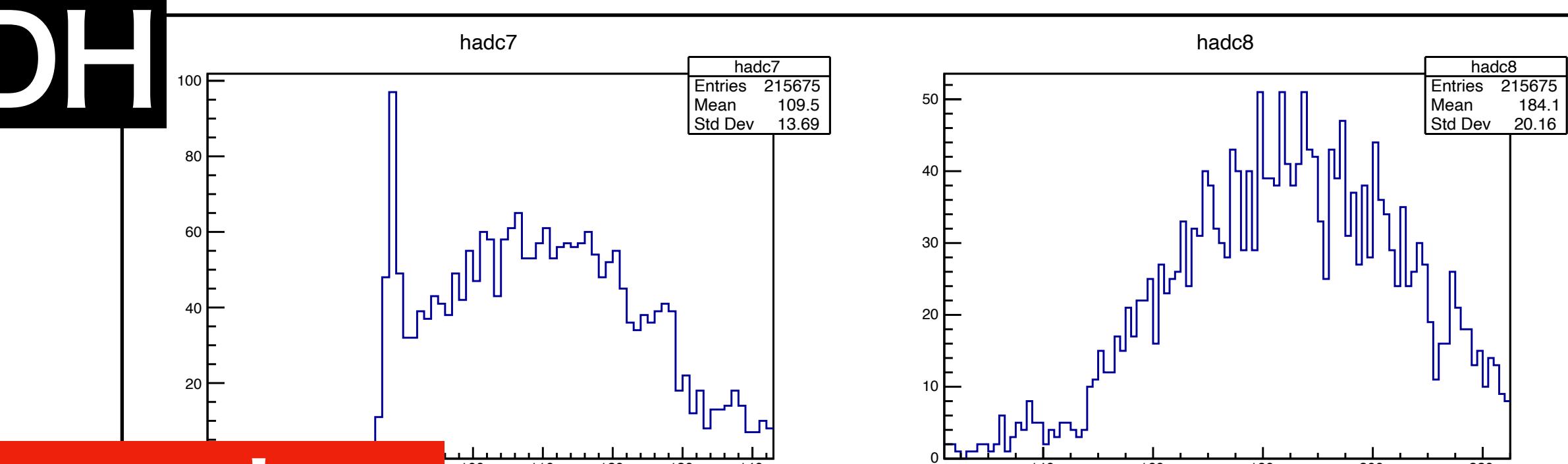
どうやら右側のMPPCが悪さをしていたらしい。

- MPPC bias 59Vだが、最も分解能が良くなった58Vで調べるべきだった。
- PMTよりMPPCが時間経過に弱いことがわかった。

# 4. PMT vs MPPC using CDH



cut無し、raw data



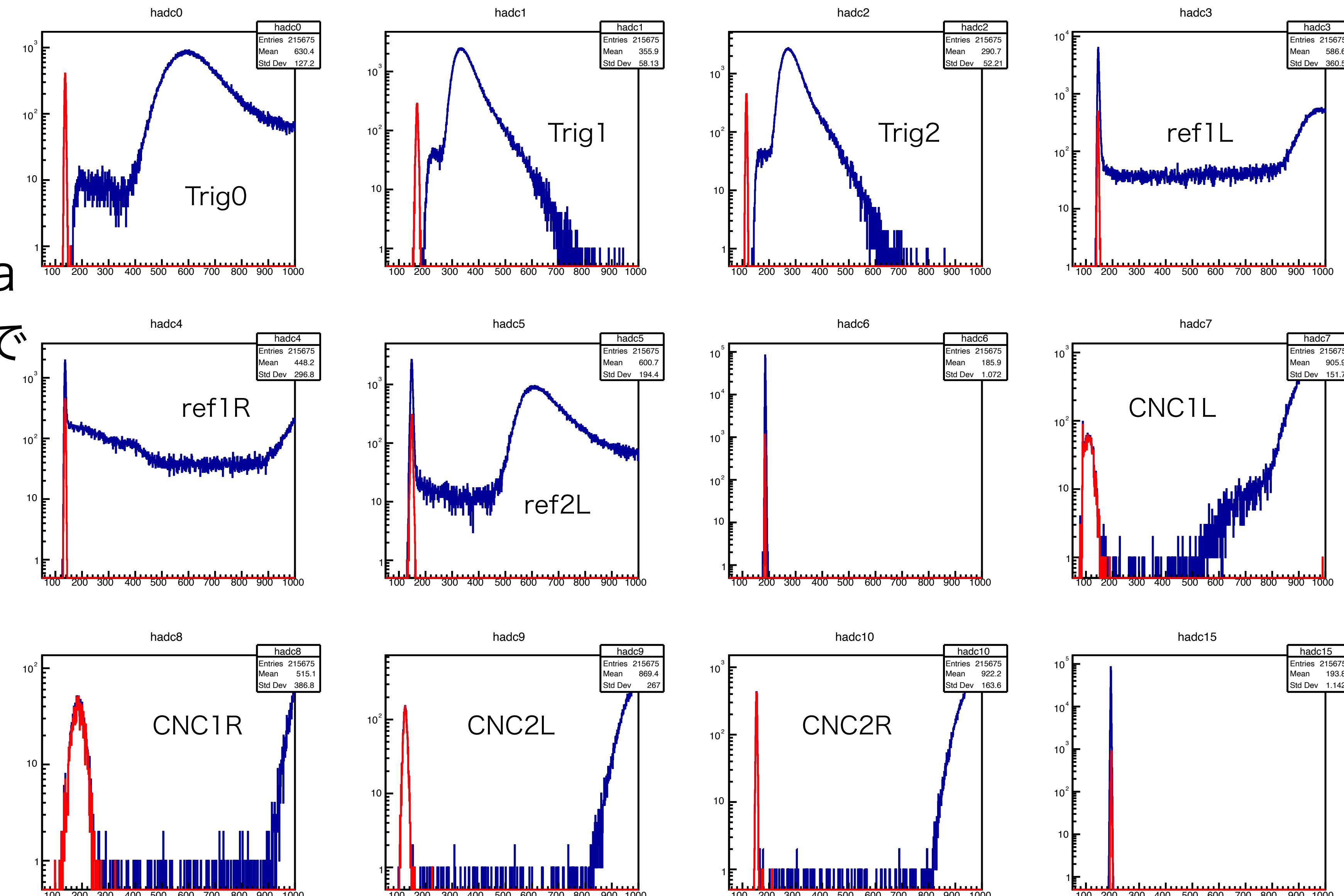
- run163からMPPC RのペデスタルのpeakがHigh gain側に移動している。
- run163からMPPC Rのペデスタルの幅が40 ch → 60 chくらいに。
- MPPC Rの時間分解能悪化の原因か？
- run163からMPPC Lのペデスタル中で謎のアンテナが成長。

# 4. PMT vs MPPC using CDH

Blue : raw data

Red : clock trigger

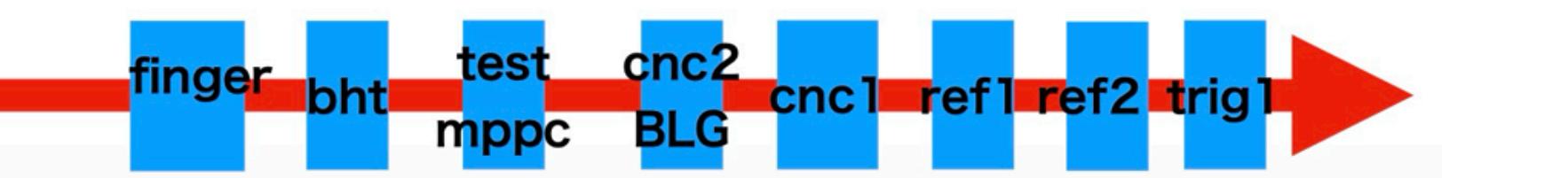
ペデスターの形はraw data  
とclock trigger要求dataで  
変わらない。



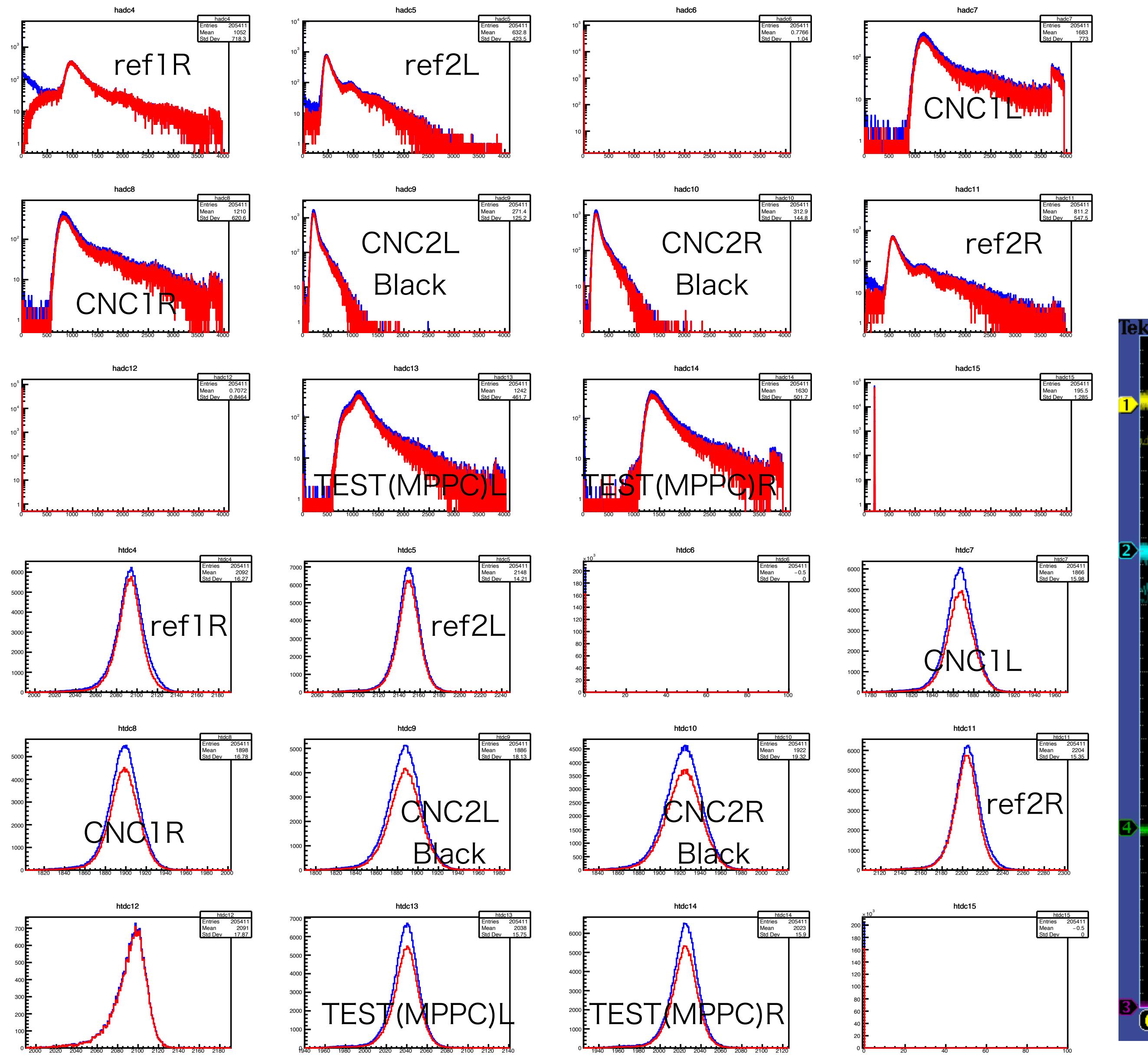
5. MPPC × TEST

6. Black LG vs Normal LG × CNC

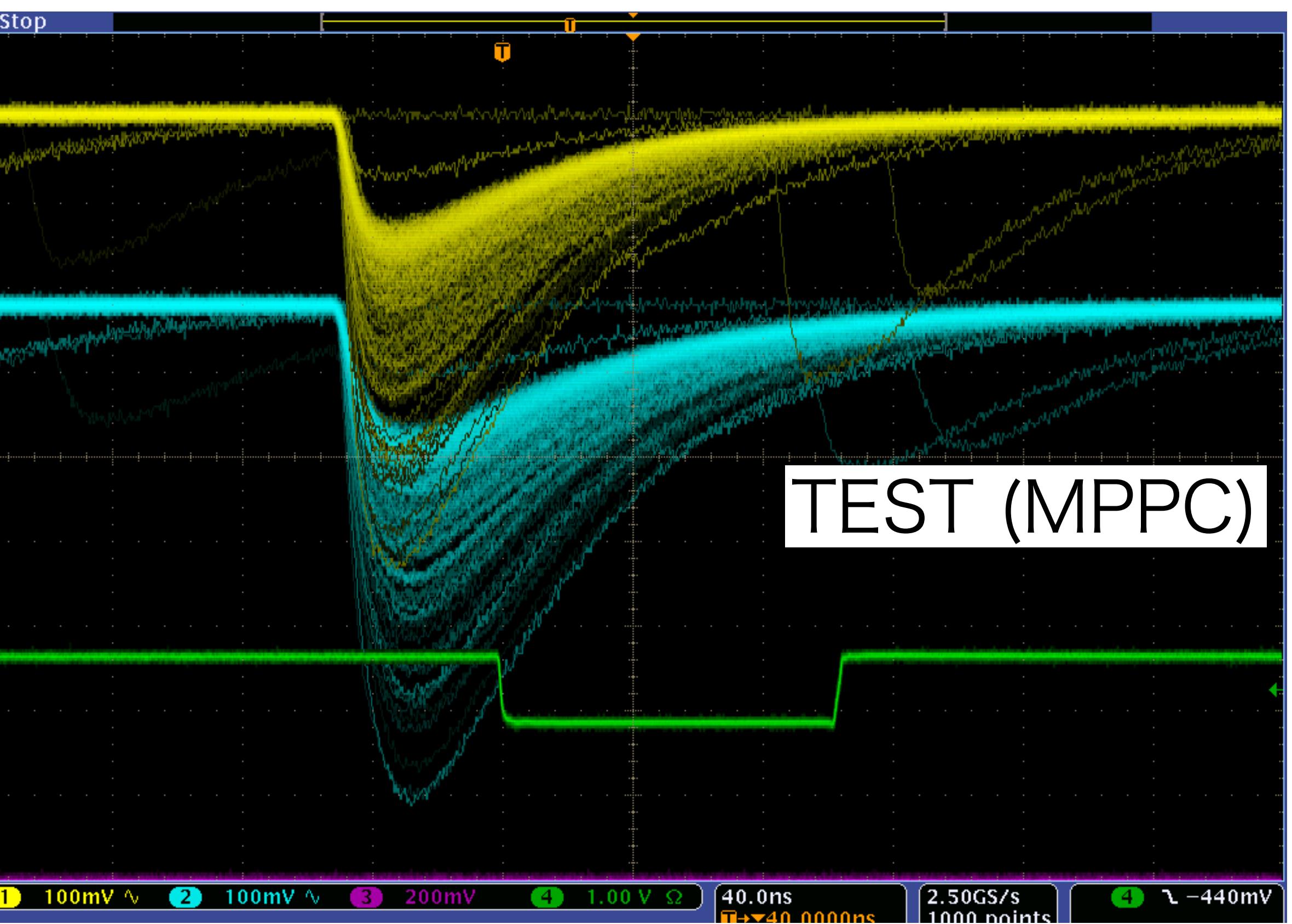
5 & 6.



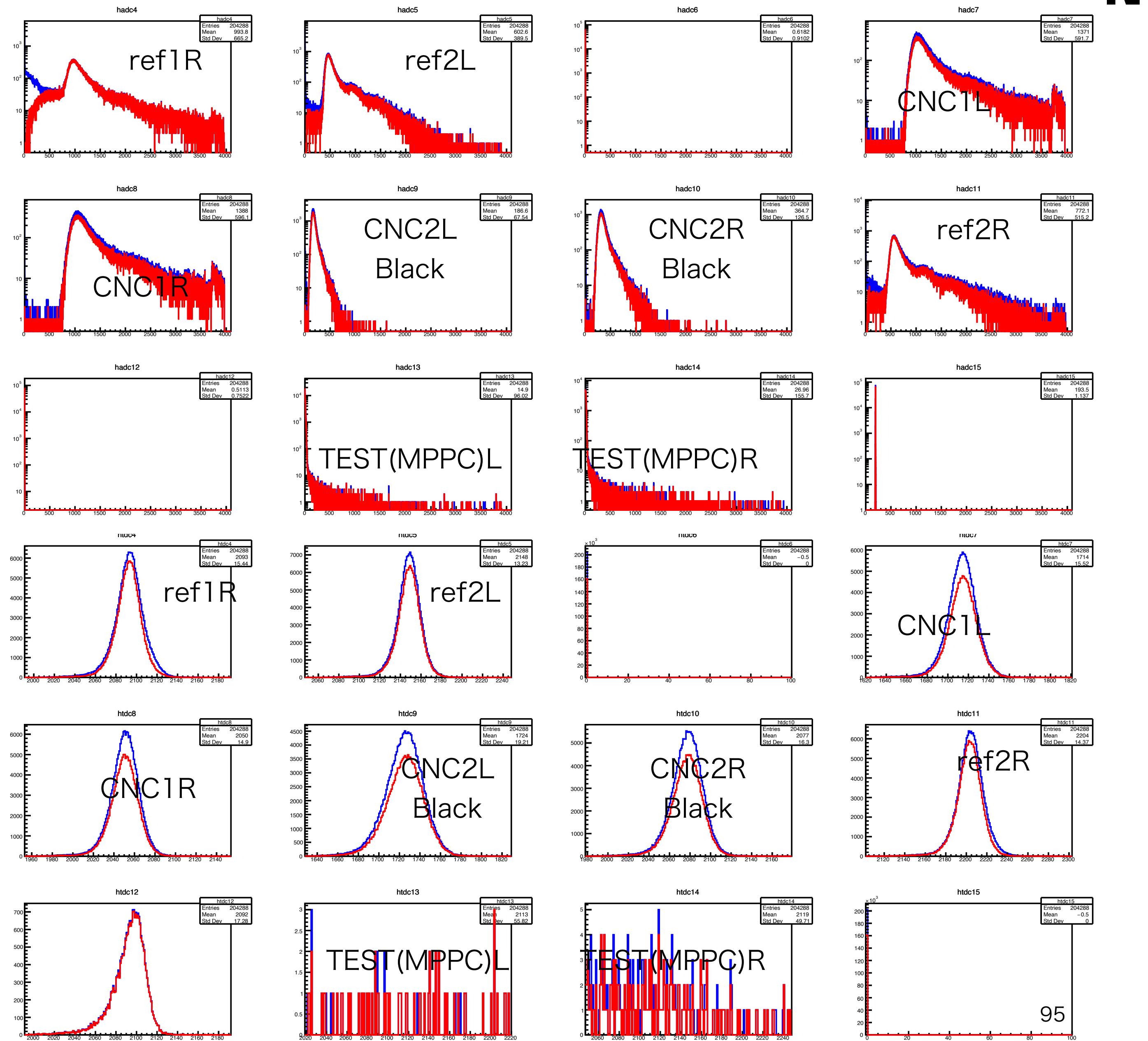
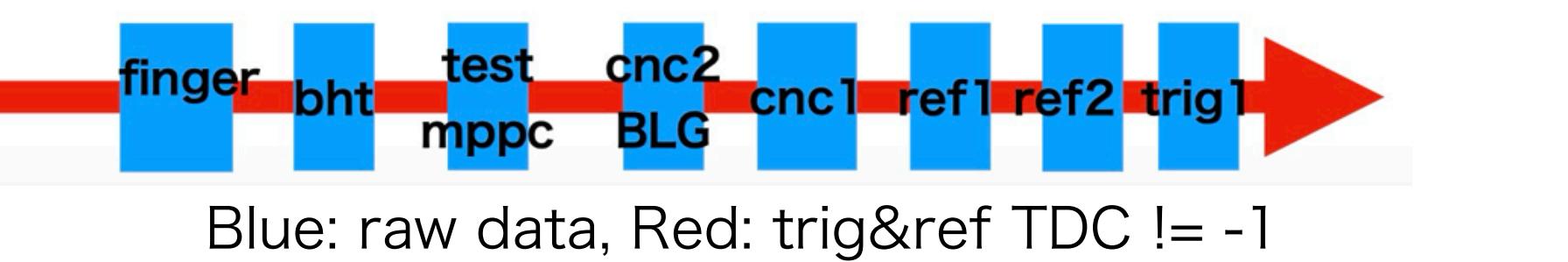
Blue: raw data, Red: trig&ref TDC != -1



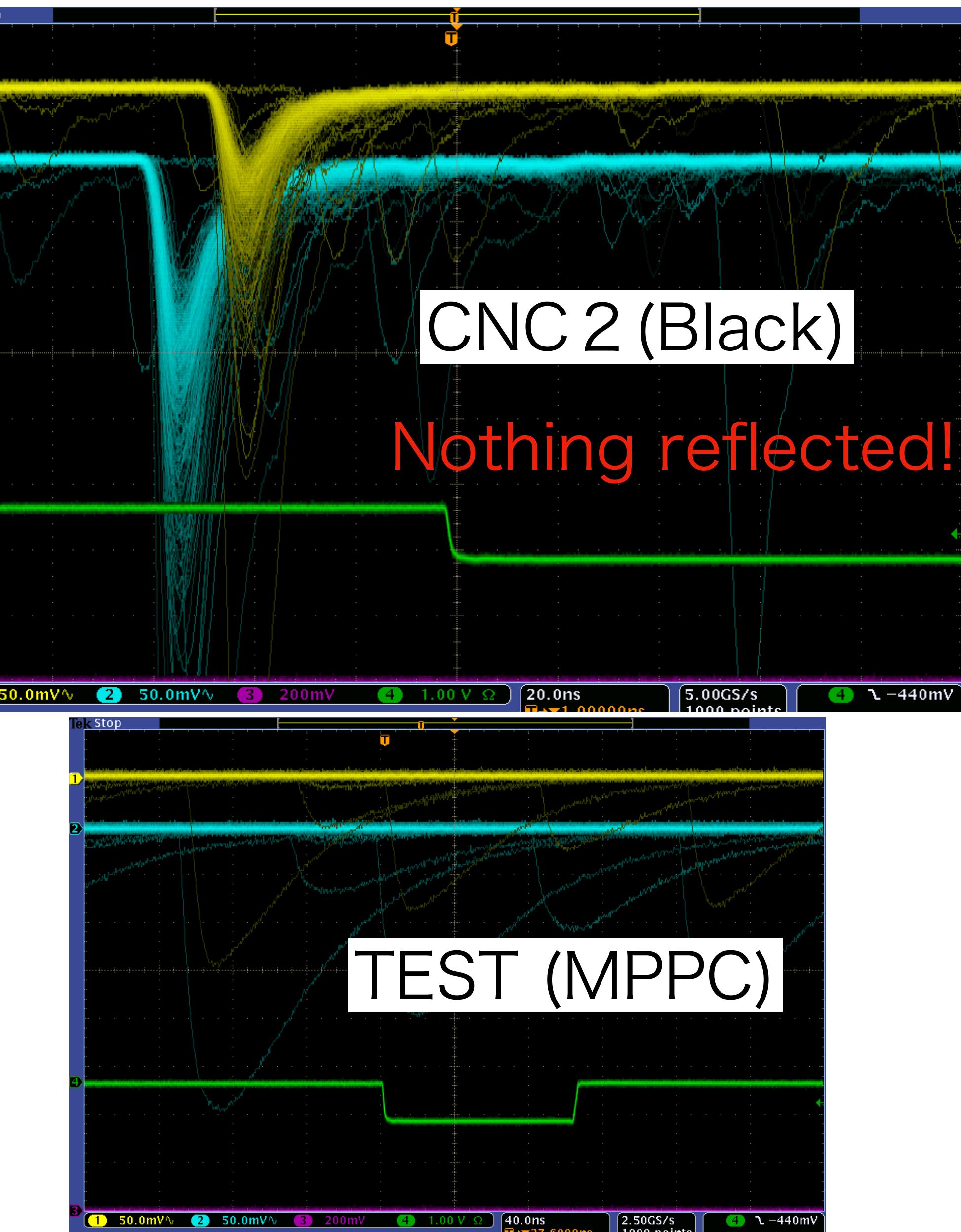
Run175, pos=0cm(center)  
MPPC bias 59V



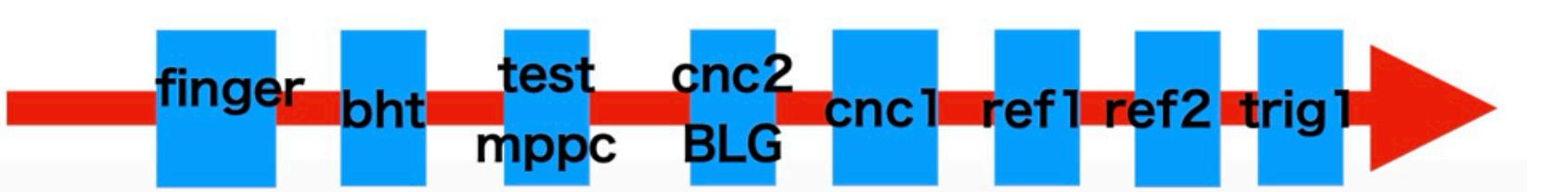
5 & 6.



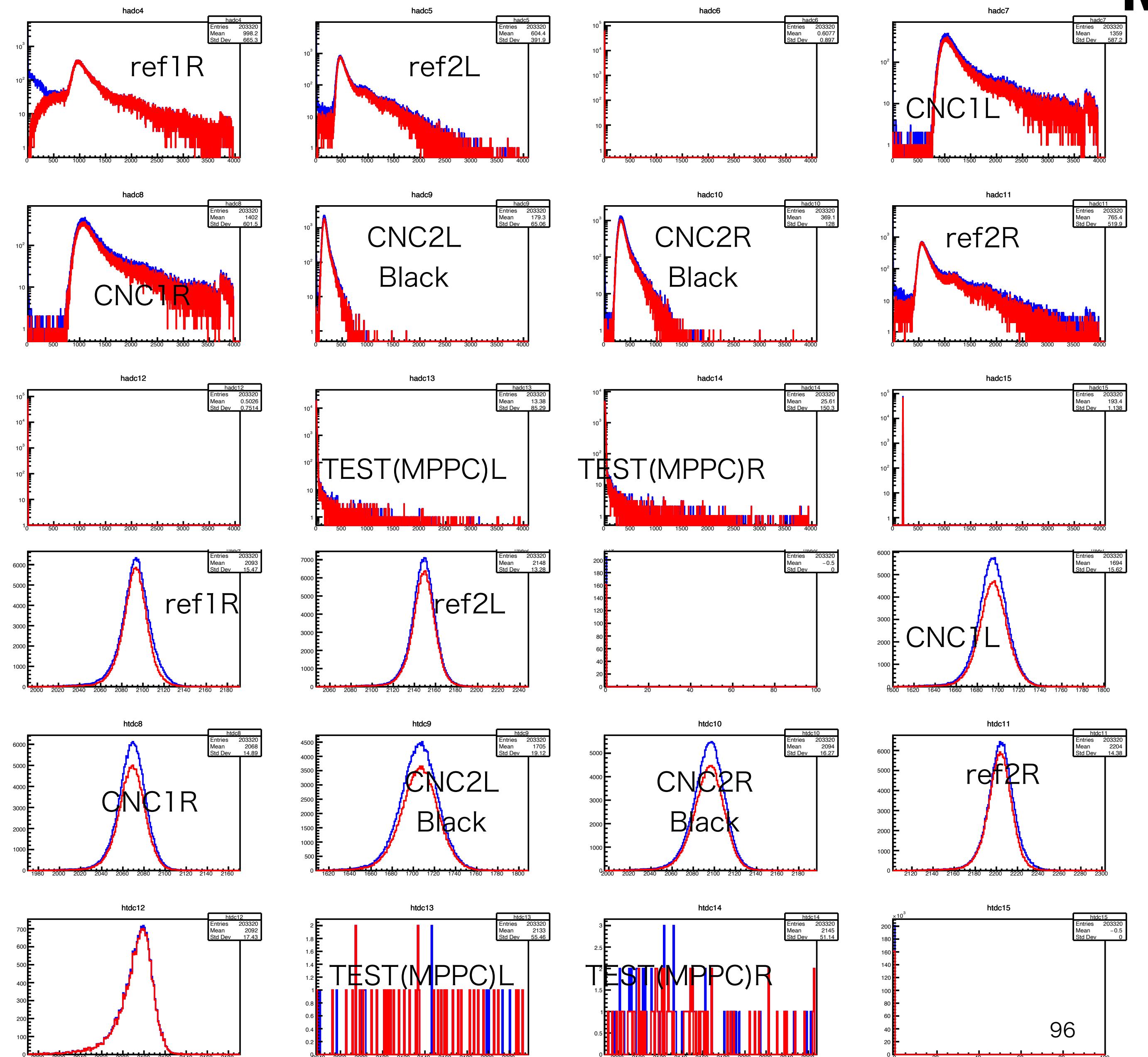
Run181, pos=-90cm, MPPC bias 59V  
Not shot to TEST



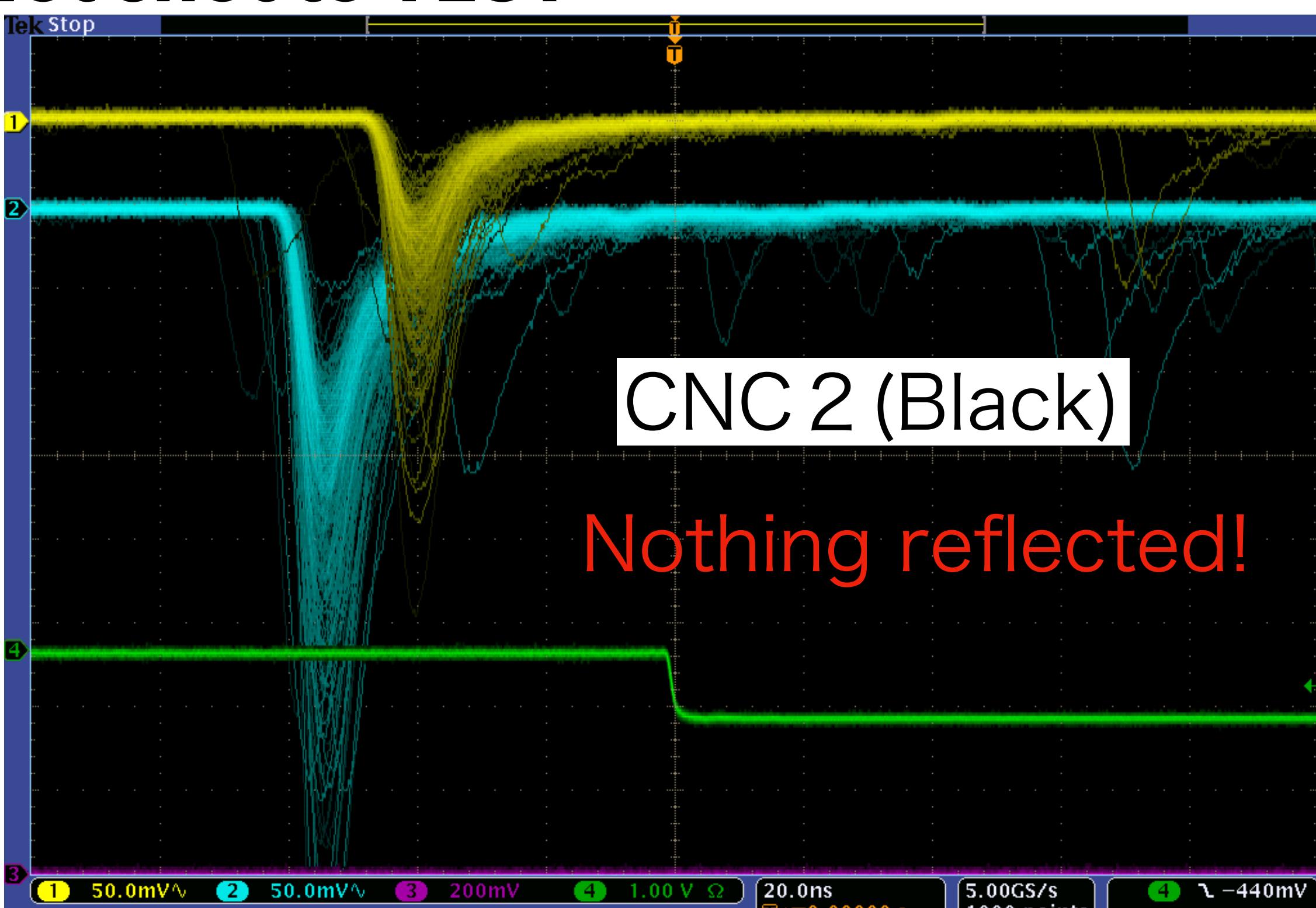
5 & 6.



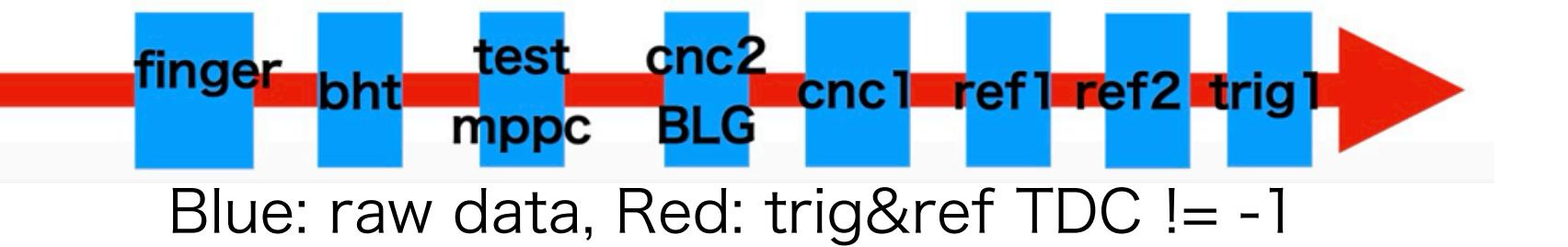
Blue: raw data, Red: trig&ref TDC != -1



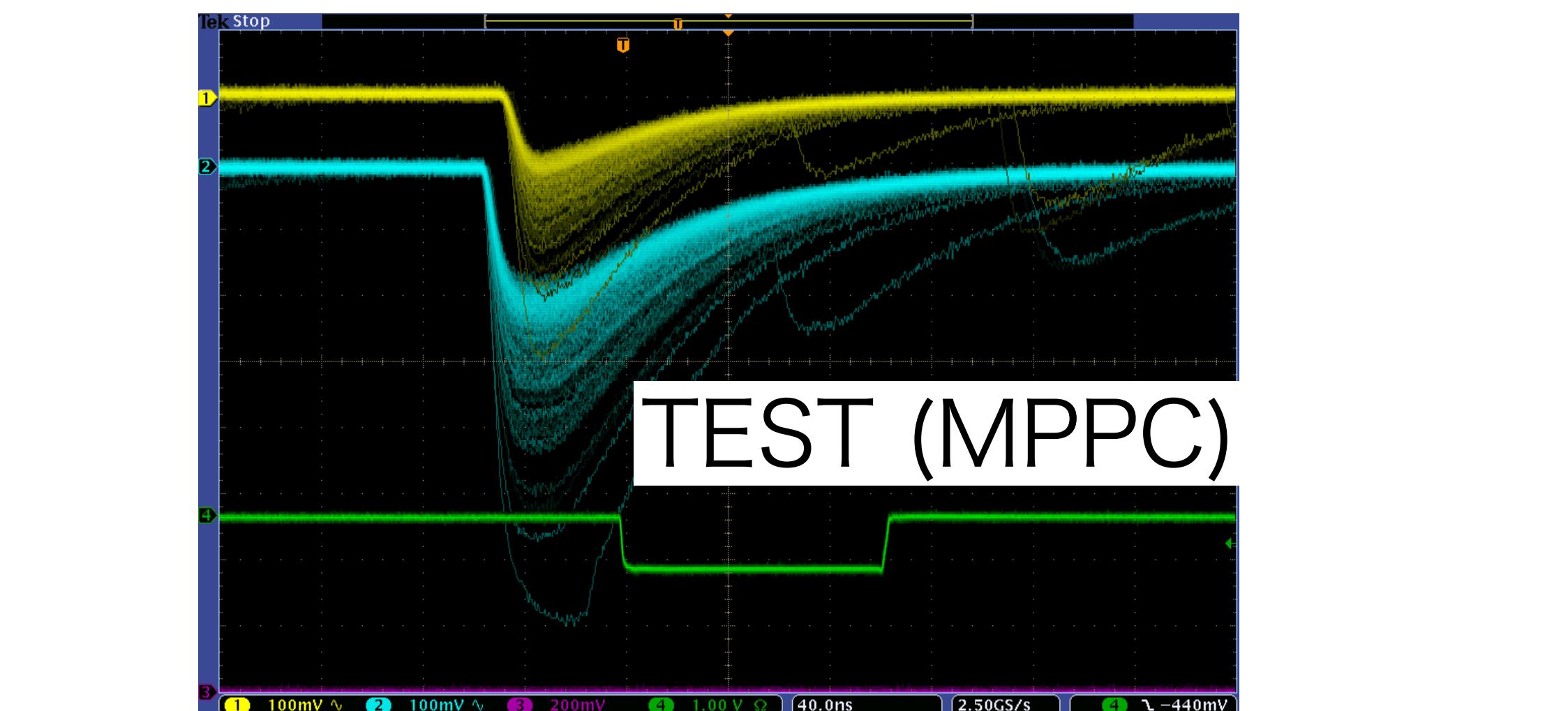
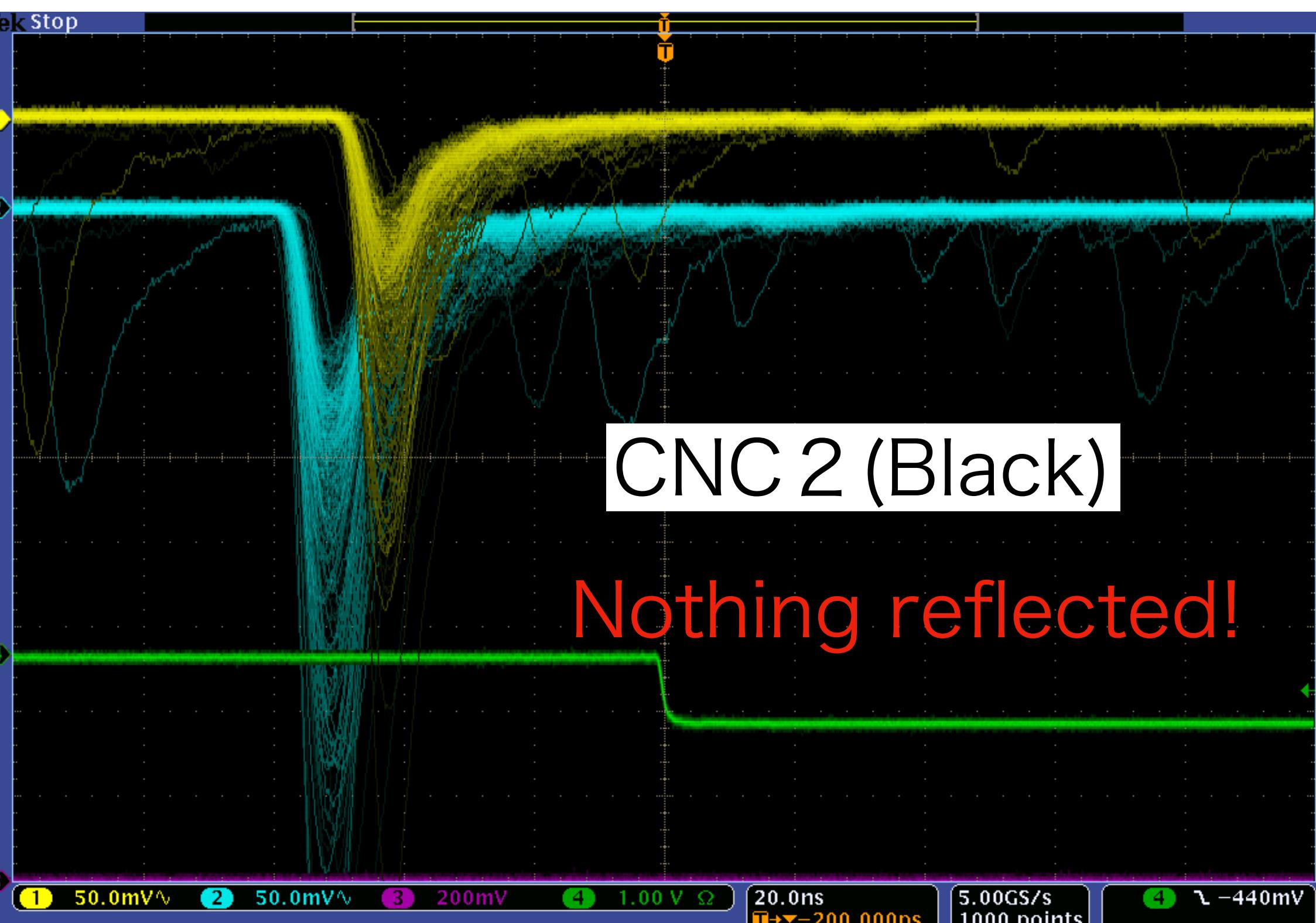
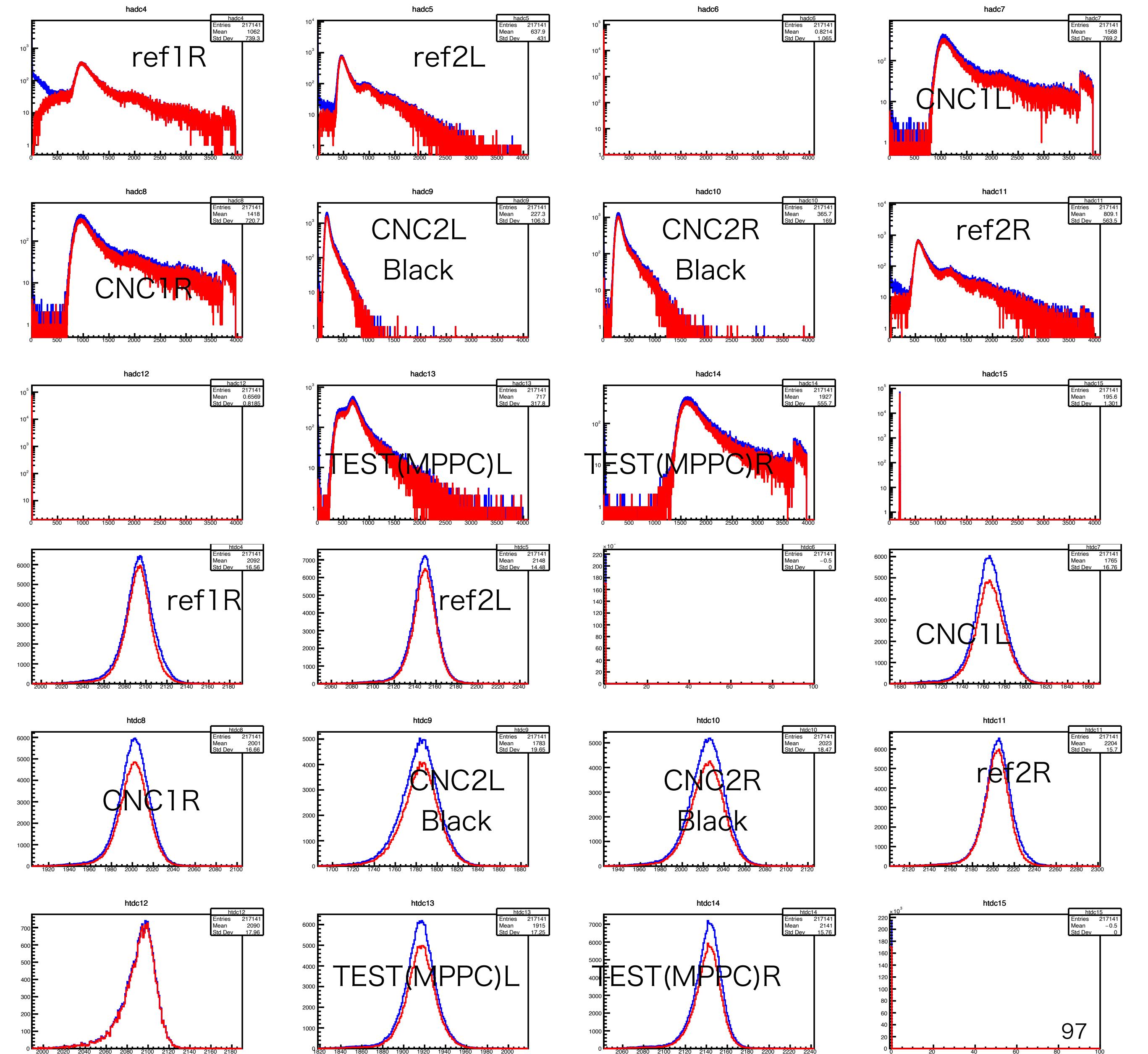
Run189, pos=-100cm, MPPC bias 59V  
Not shot to TEST



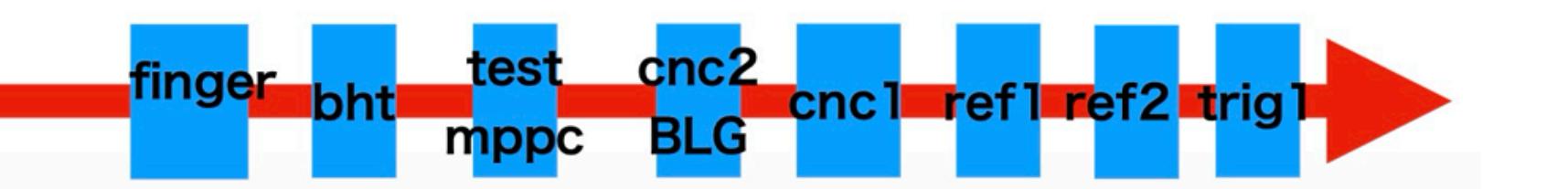
5 & 6.



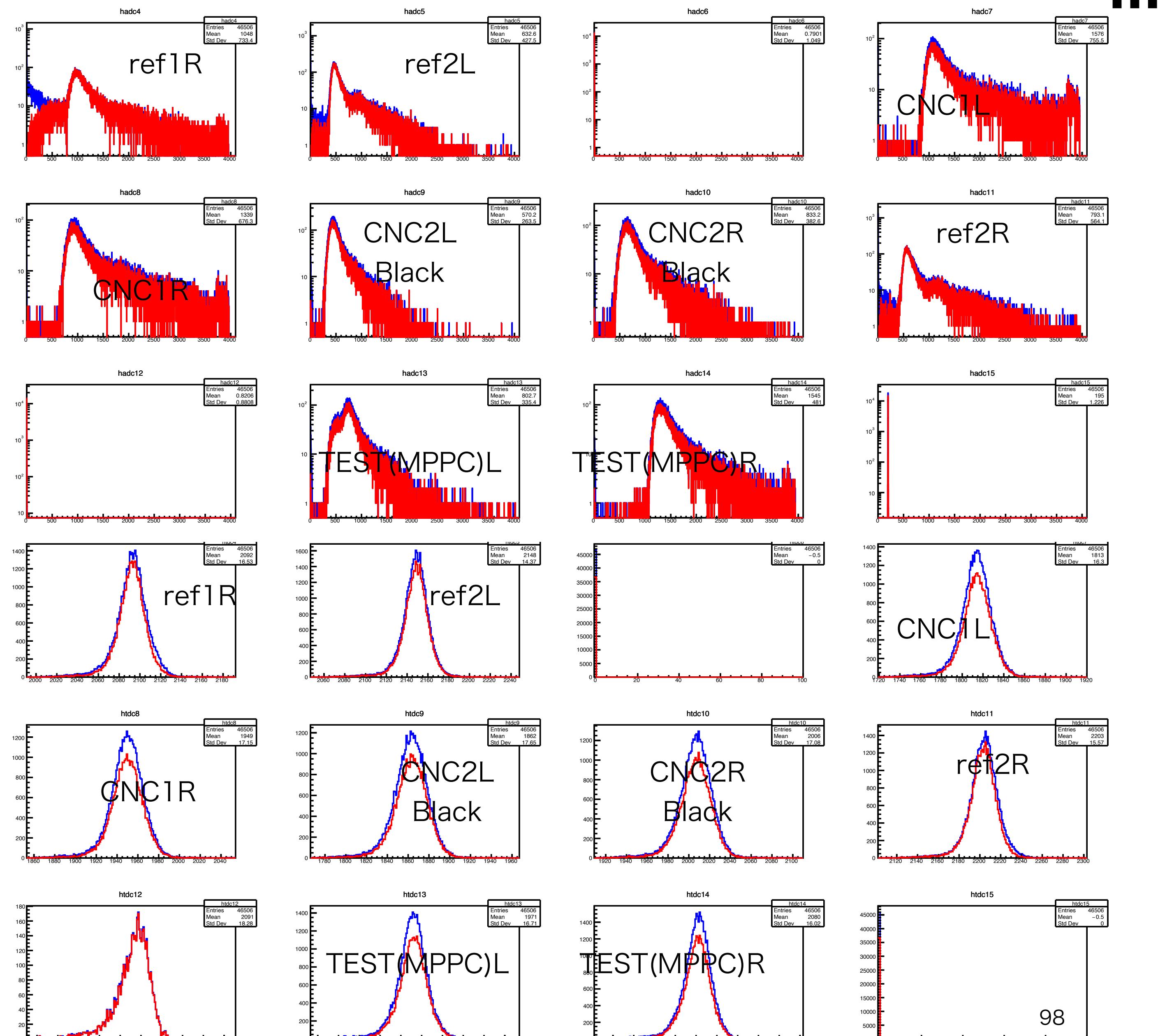
Run192, pos=-60cm, MPPC bias 59V



5 & 6.

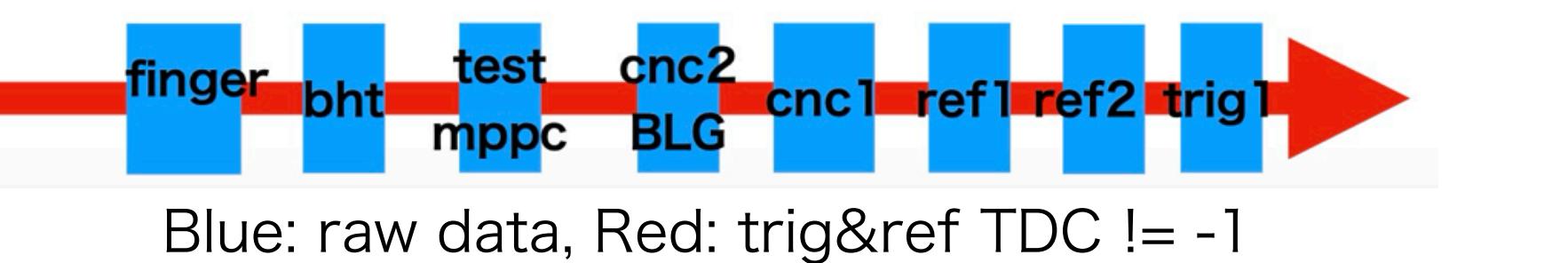


Run198, pos=-20cm, MPPC bias 59V  
make CNC2's HV higher

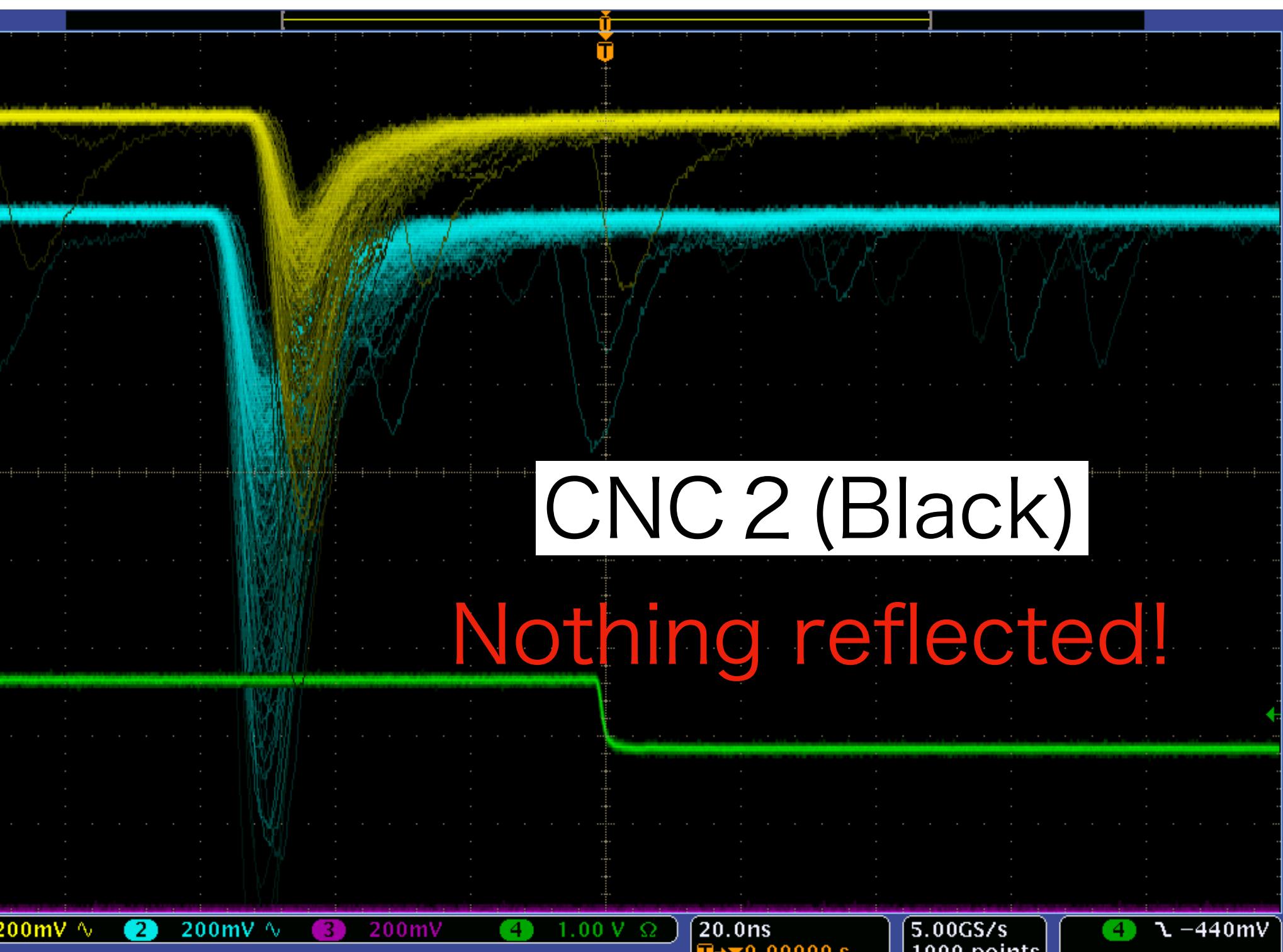
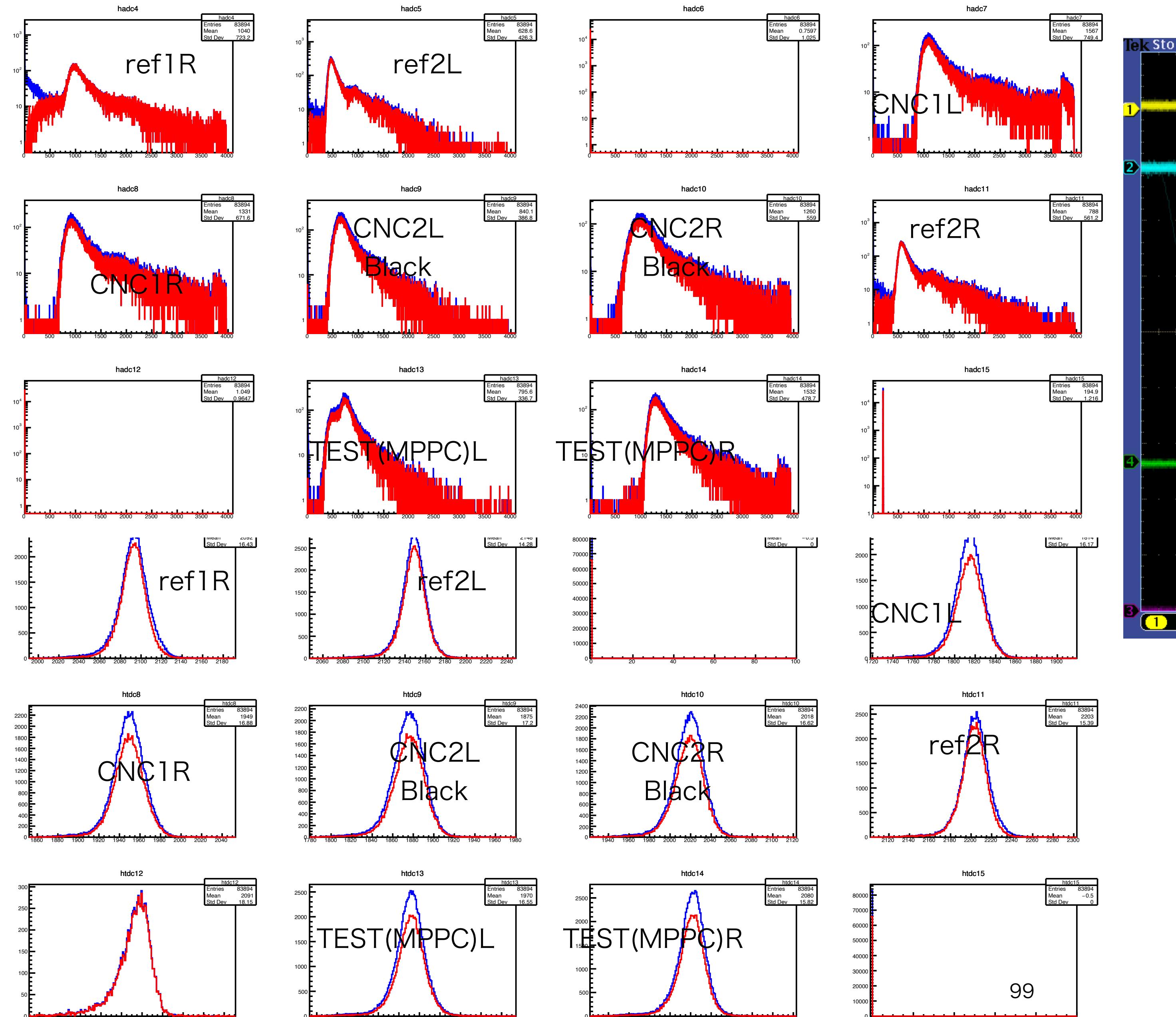


No oscillo

5 & 6.

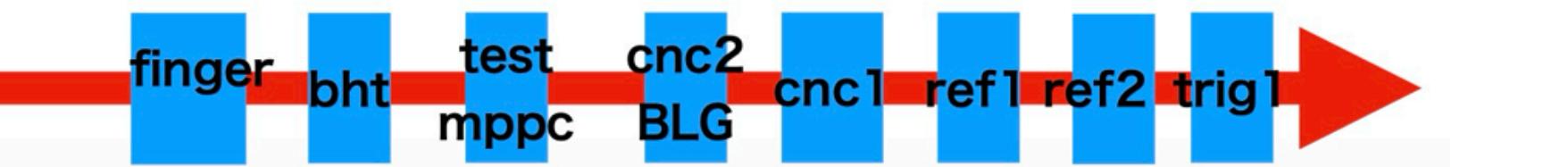


Run199, pos=-10cm, MPPC bias 59V  
make CNC2's HV higher

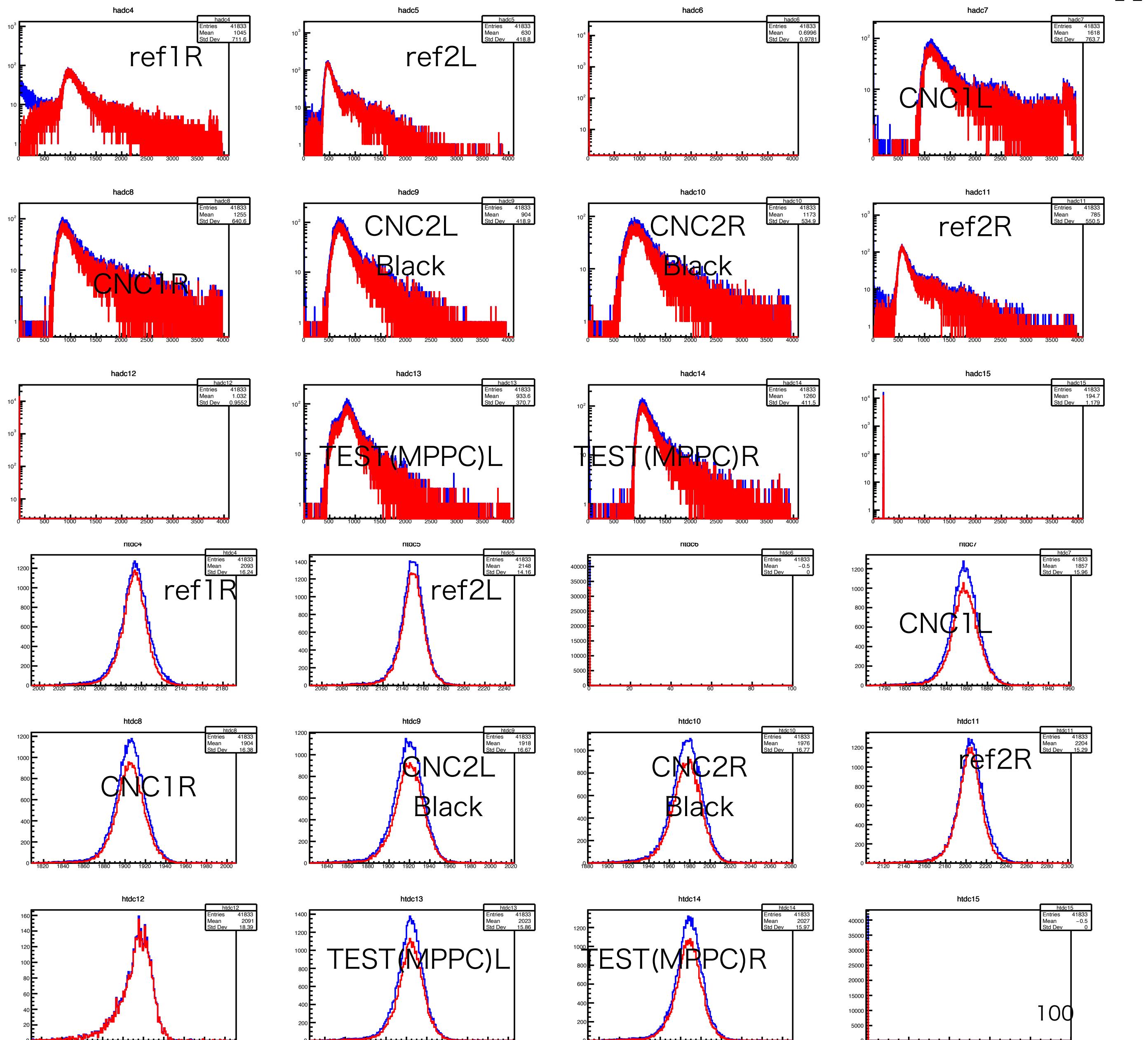


99

5 & 6.



Blue: raw data, Red: trig&ref TDC != -1

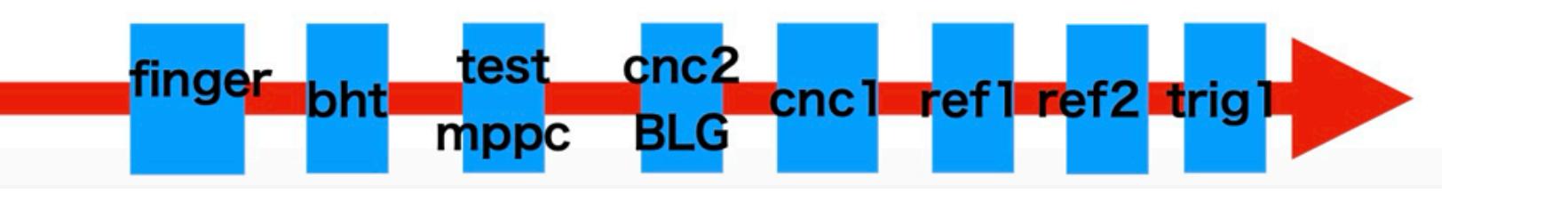


Run203, pos=15cm, MPPC bias 59V  
make CNC2's HV higher

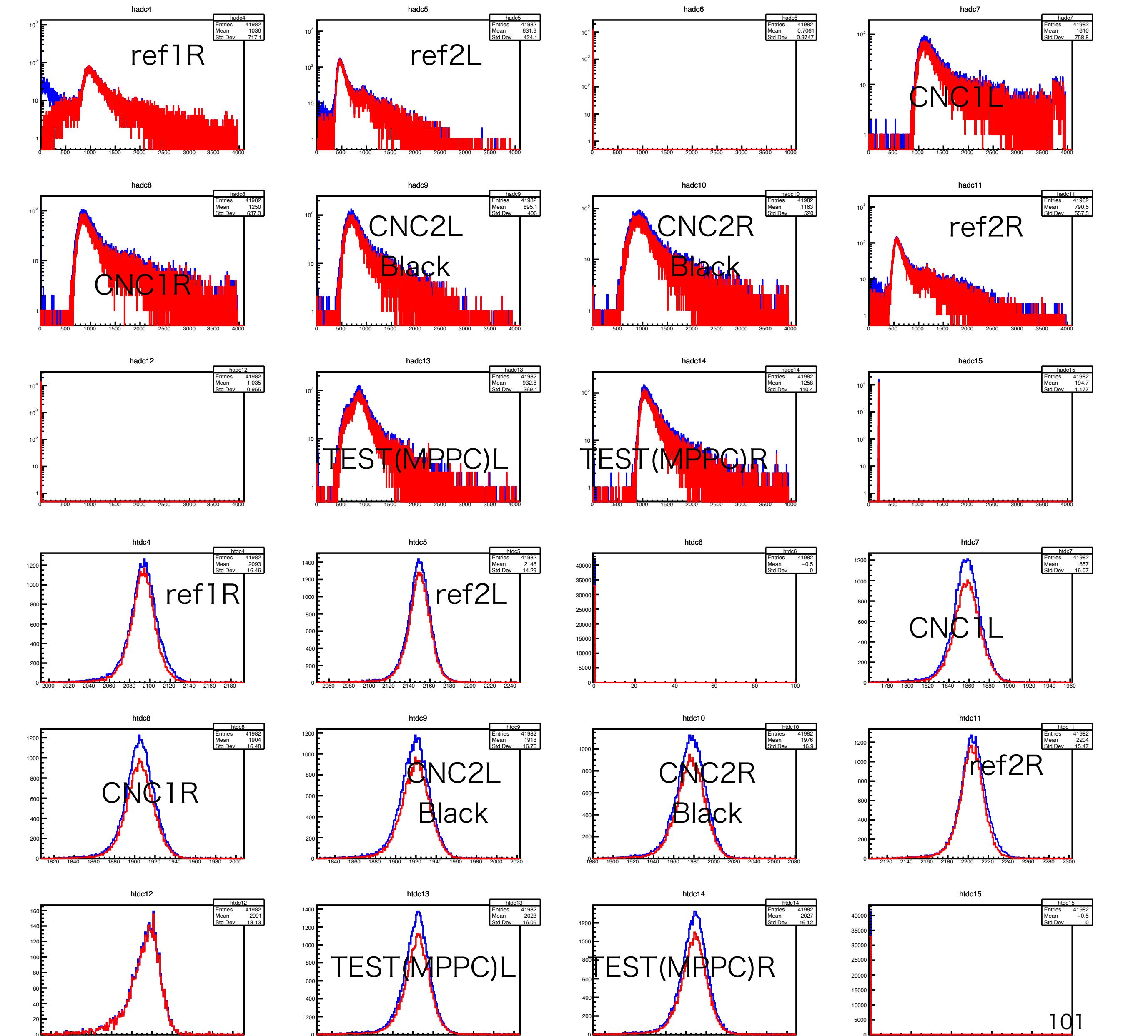
No oscillo

100

5 & 6.



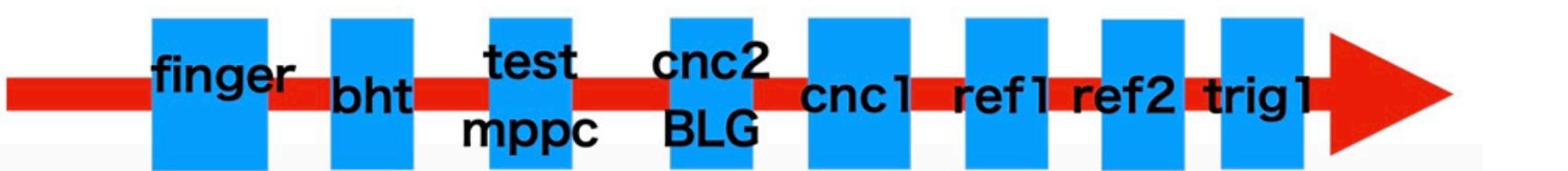
Blue: raw data, Red: trig&ref TDC != -1



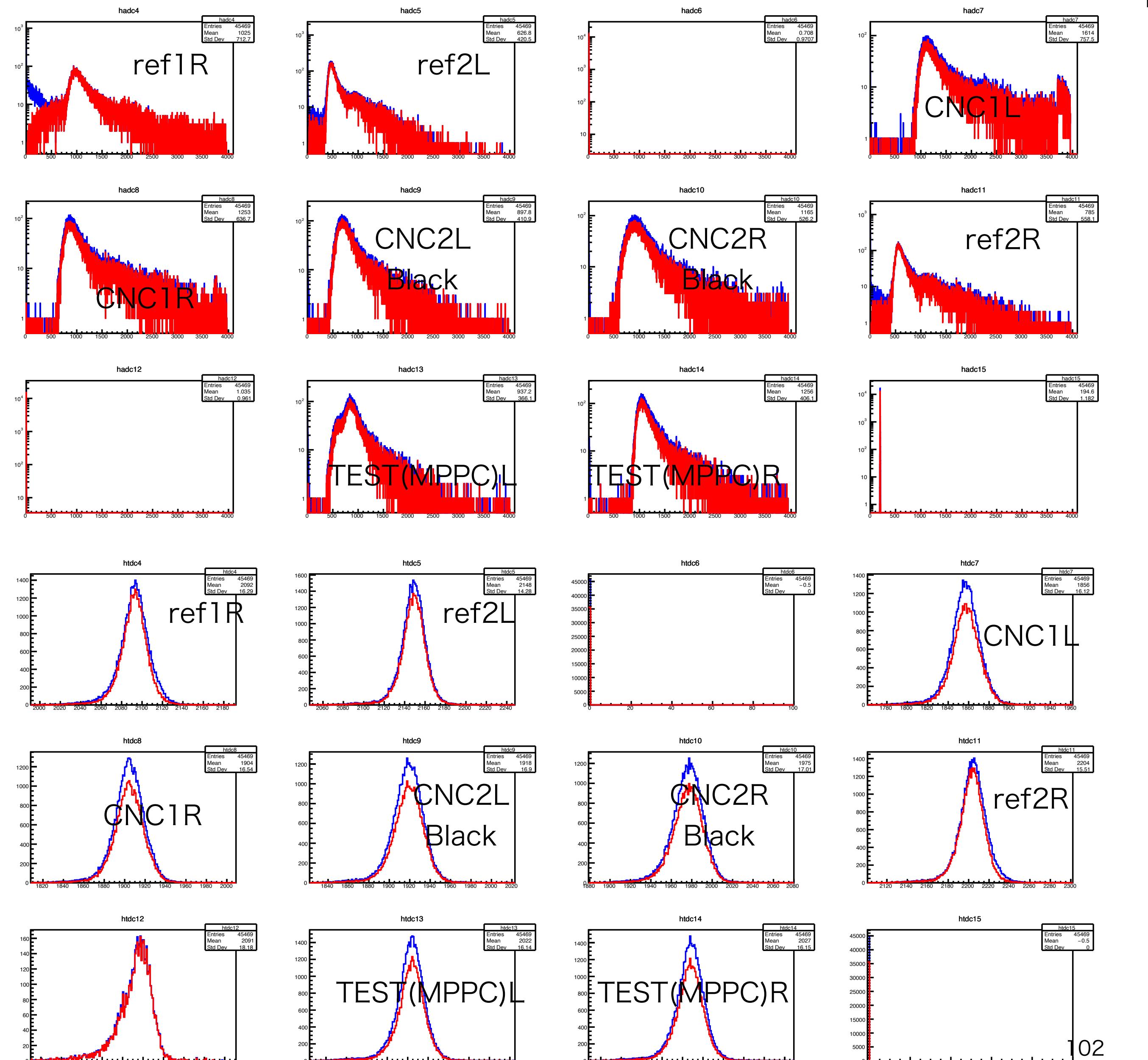
Run204, pos=15cm, MPPC bias 59V  
make CNC2's HV higher

No oscillo

5 & 6.



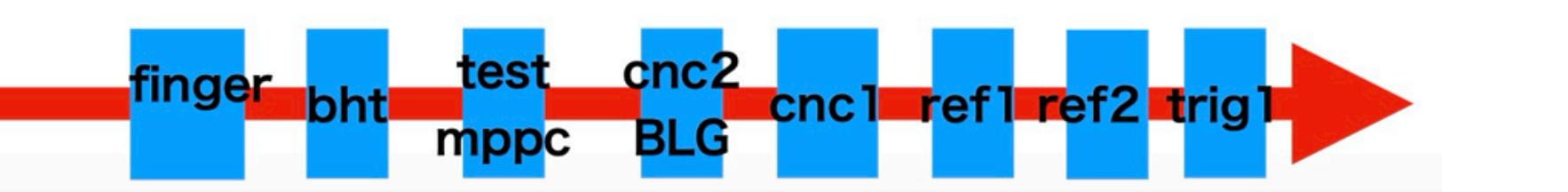
Blue: raw data, Red: trig&ref TDC != -1



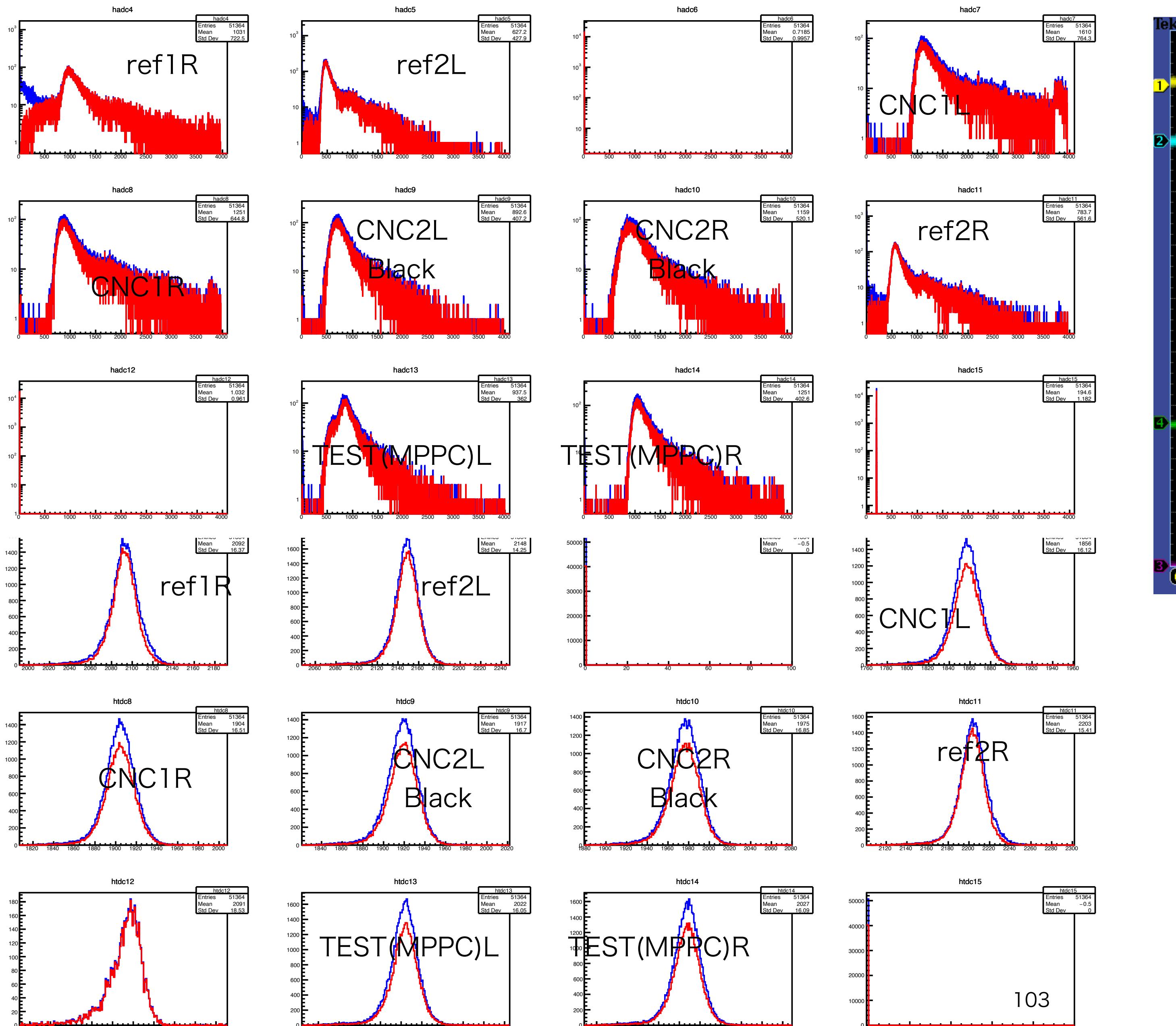
Run205, pos=15cm, MPPC bias 59V  
make CNC2's HV higher

No oscillo

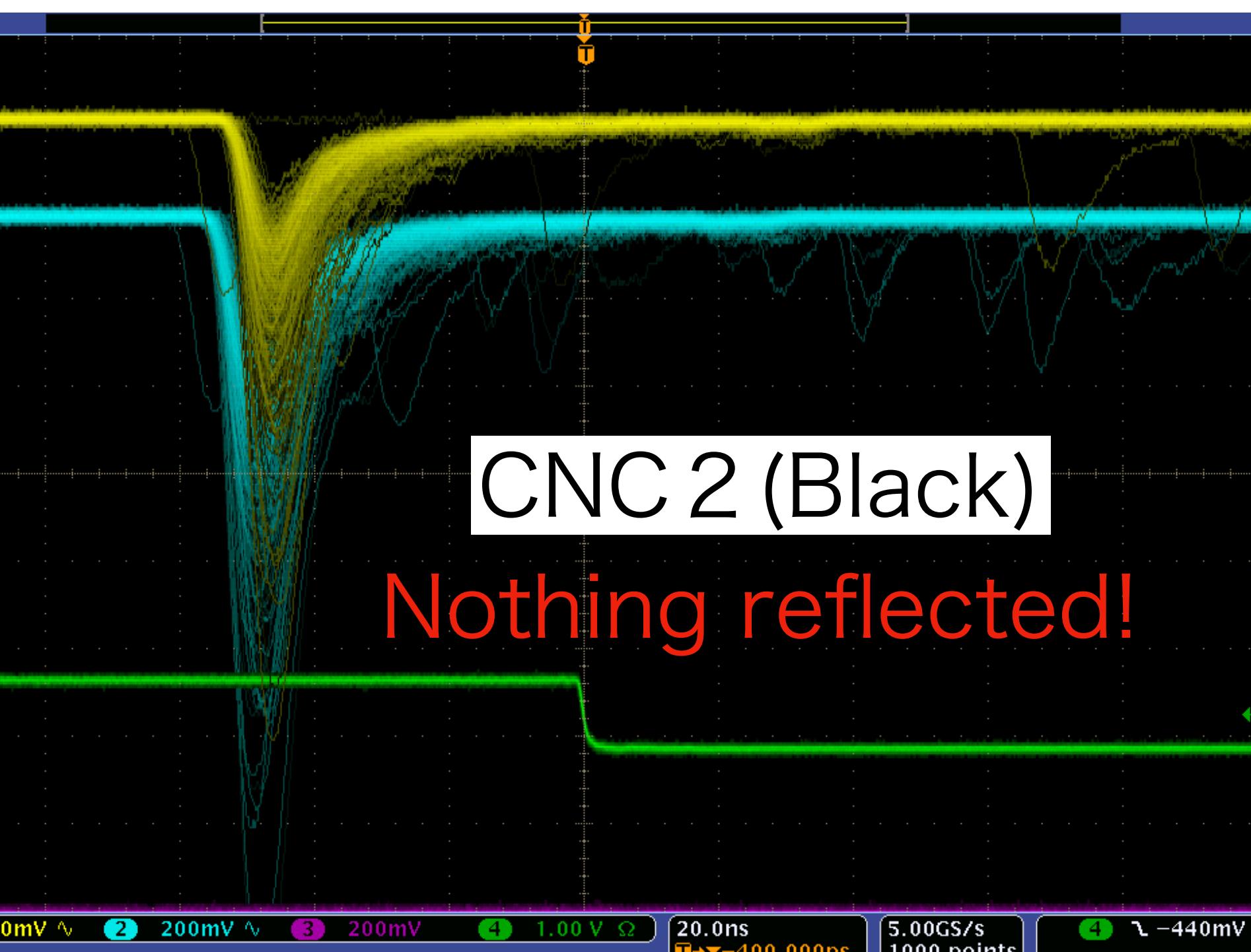
5 & 6.



Blue: raw data, Red: trig&ref TDC != -1



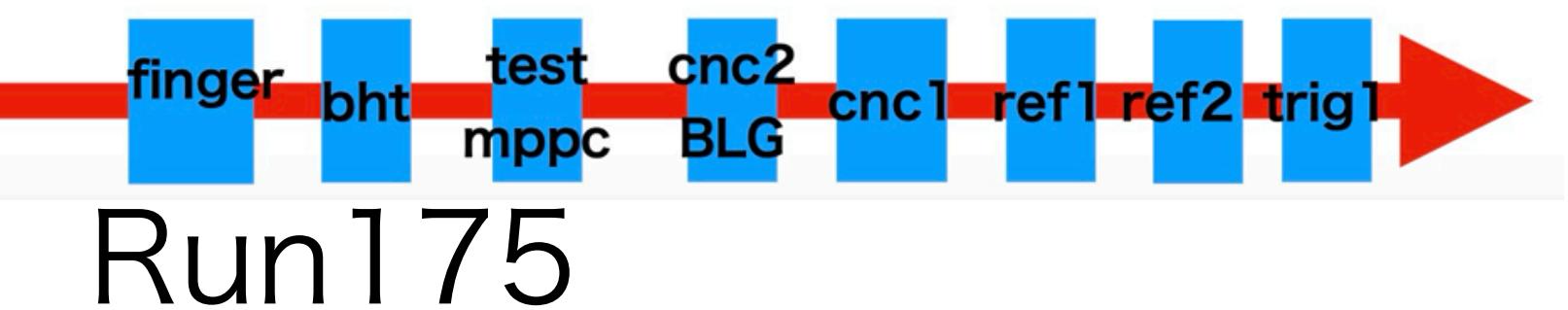
Run206, pos=15cm, MPPC bias 59V  
make CNC2's HV higher



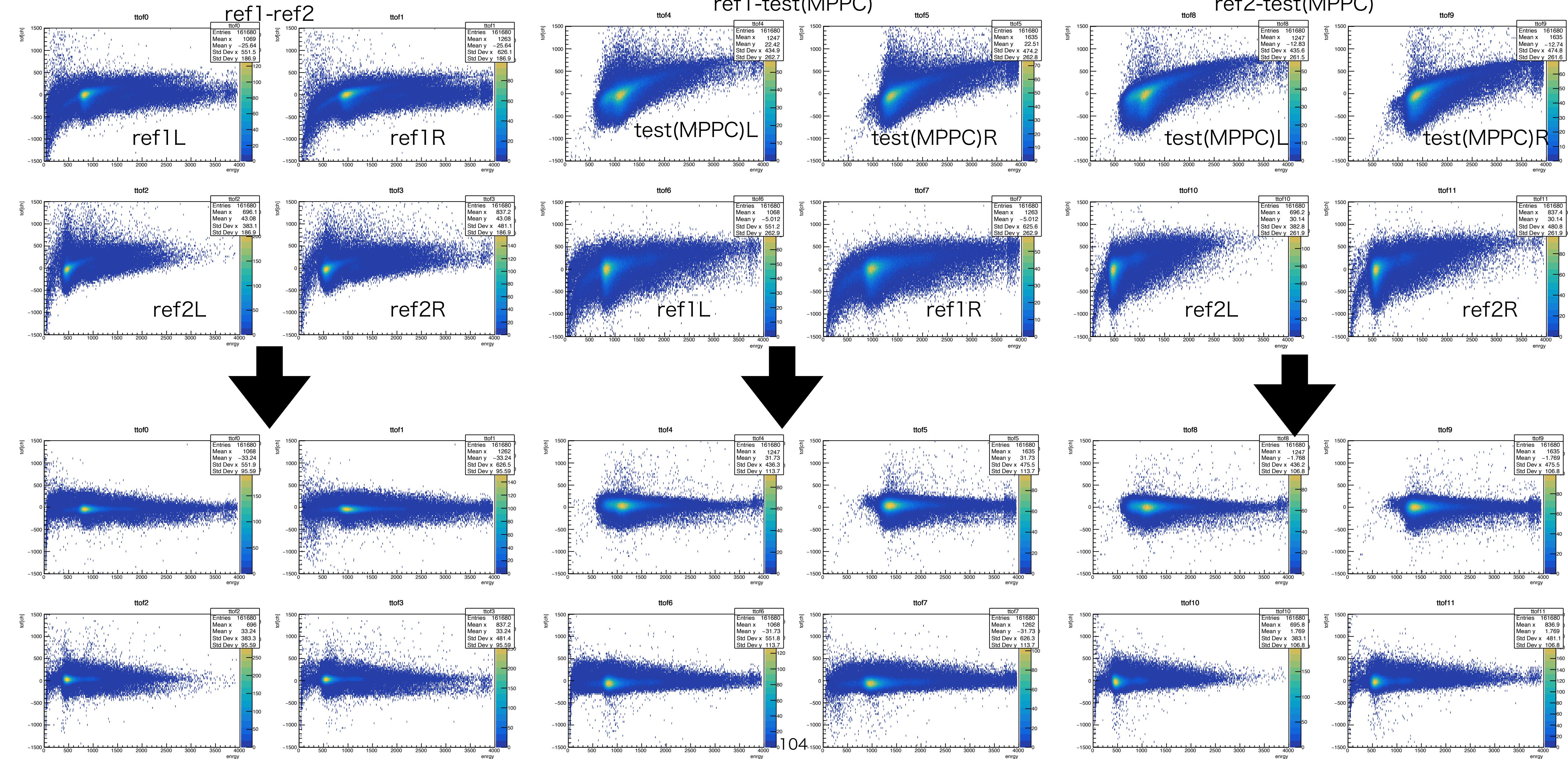
103

# 5. MPPC × test

## Slewing Correction



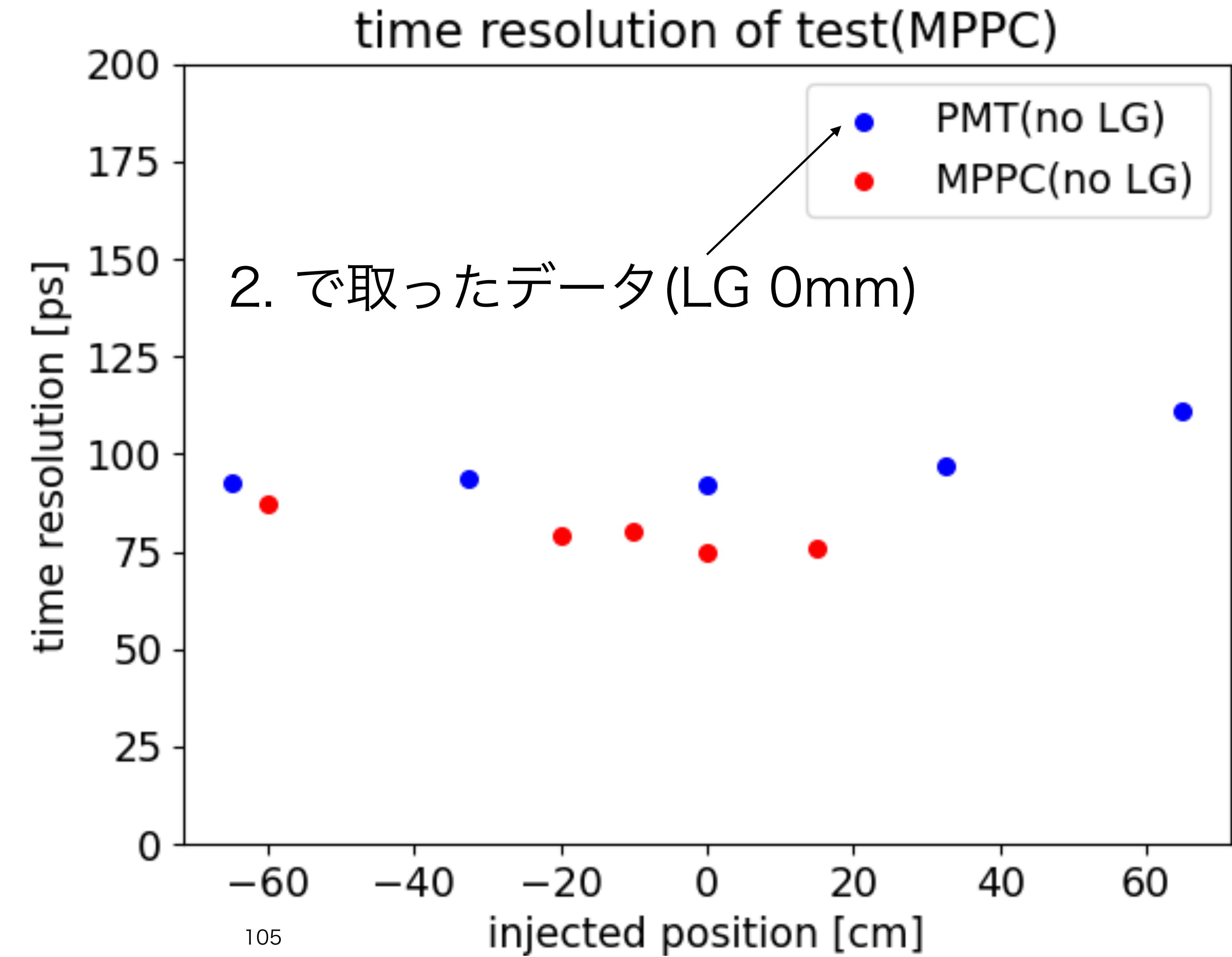
Run 175



# 5. MPPC × test



・MPPCがうまく機能した。

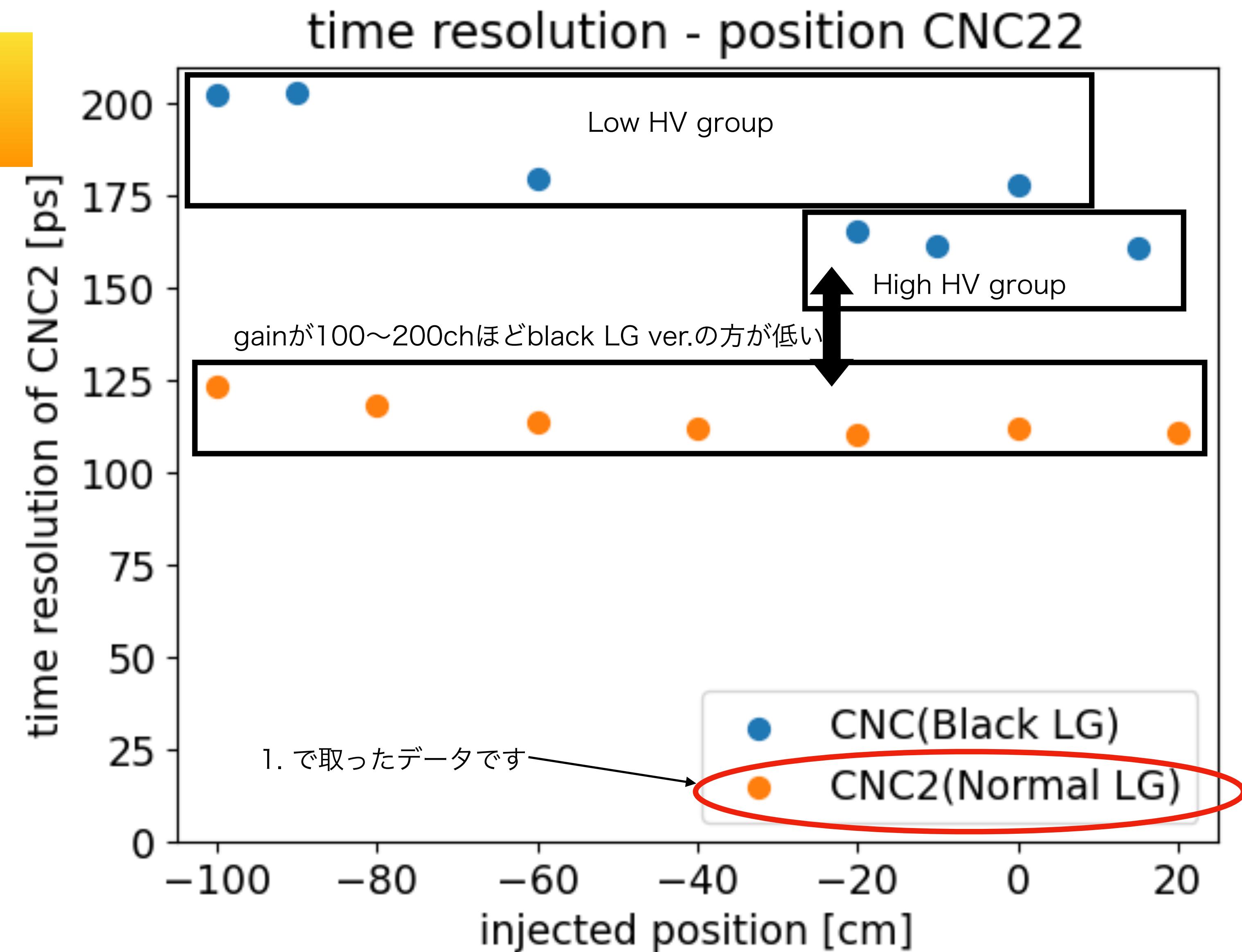


# 6. Black LG vs Normal LG



・反射波が無くなったが  
集光率低下に伴う光量低下が顕著

・gainを揃えて比較したいが、  
そのようなデータは無し。



# 7. Summary

- CNCのintrinsic time resolutionは $\sigma \sim 120$  ps
- 系統的な位置依存は無い。
- 反射波はLGの長さによらないので光量を稼ぐためになるべく短い方が良い（115mmがbestか）。
- MPPCはうまく機能していることがわかったが、何らかの要因（光漏れ？ 温度モニター必要）による変化が心配。さらにbias依存が激しいので扱いがPMTより難しい。
- Black LGは反射波が消えるというメリットがあるが、十分な信号を得るために余計にHVを上げる必要がある→Black LGはうまくない。

# Appendix A. Systematic errors due to uncertainty of fitting range

# A. Systematic errors due to uncertainty of fitting range

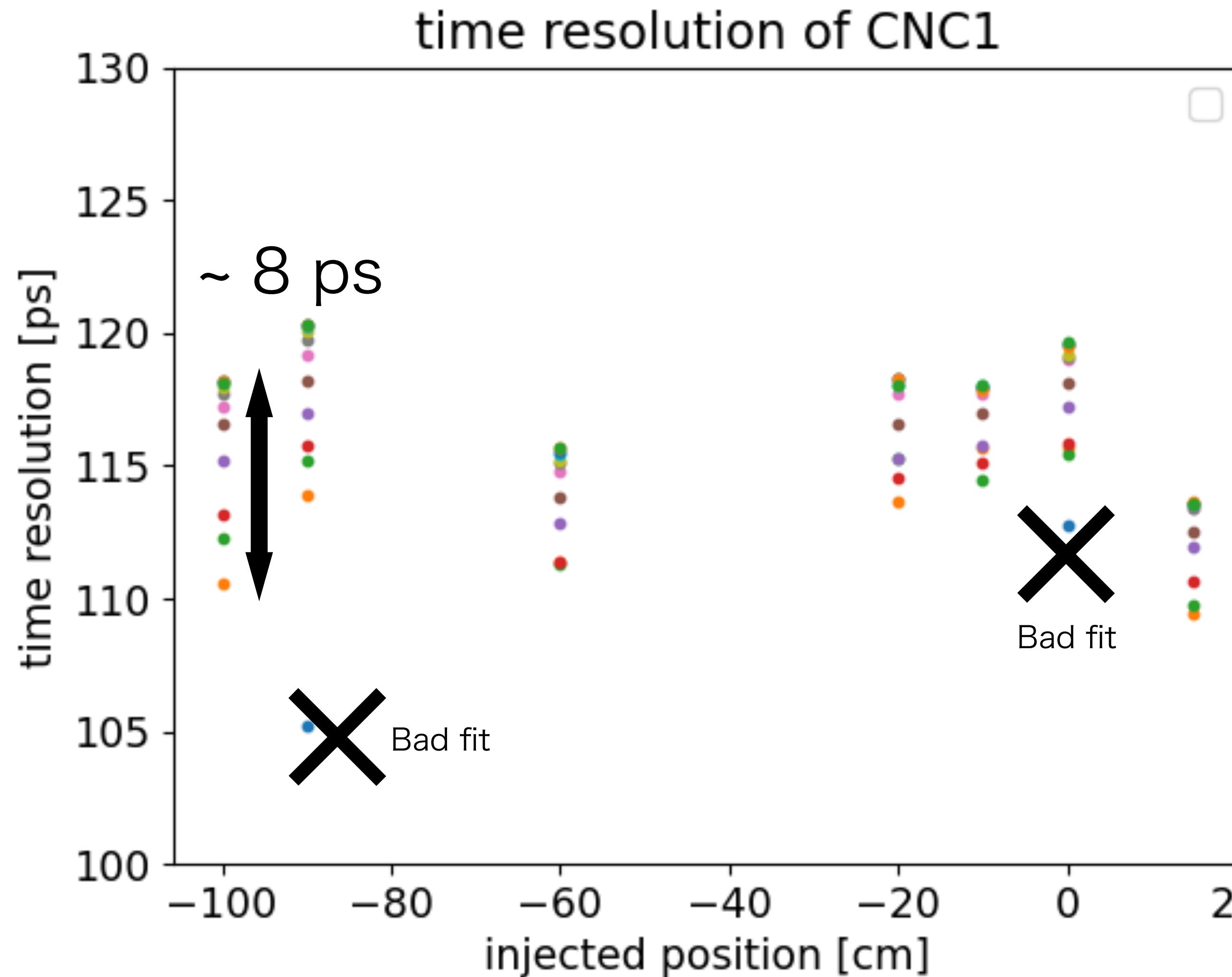
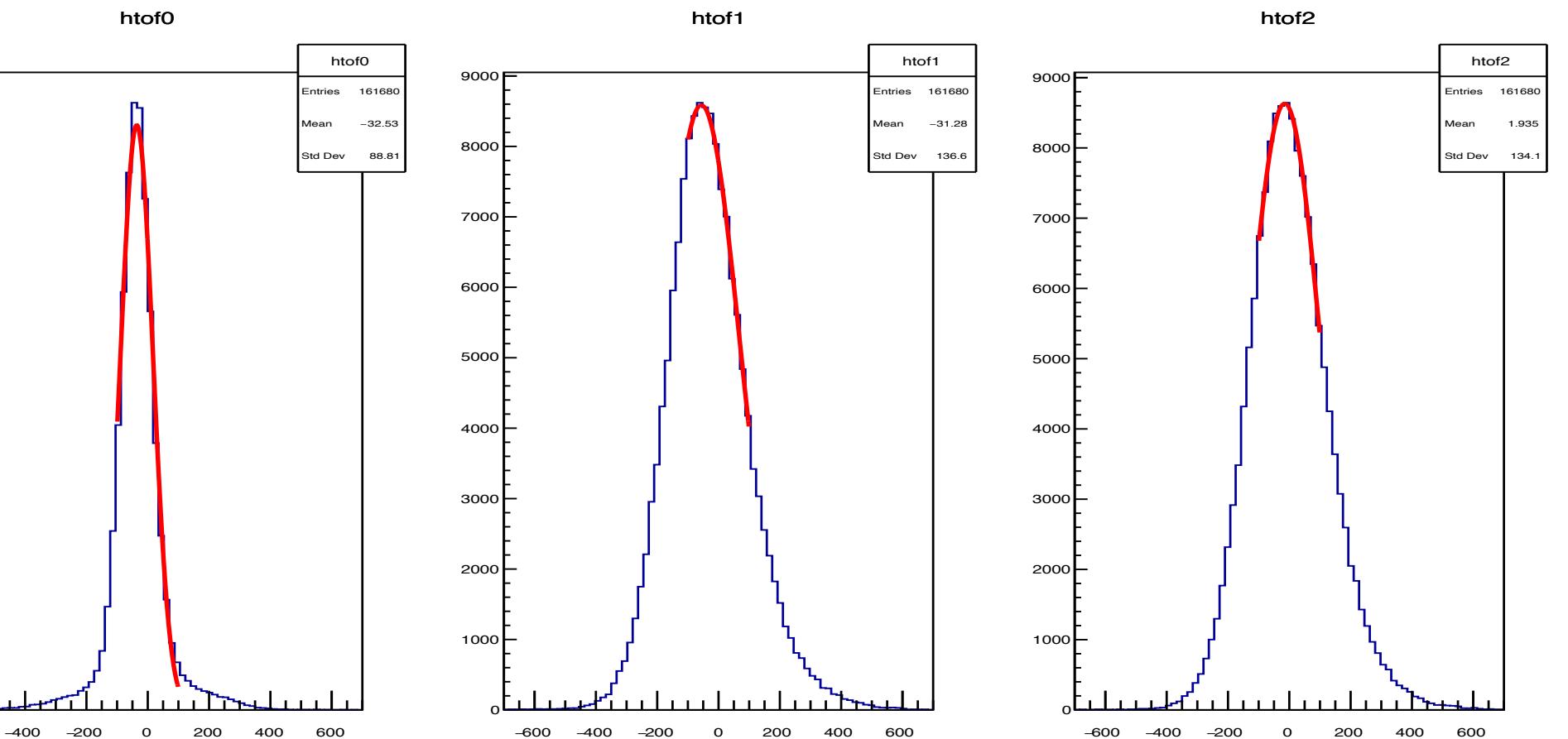


Fig. of TOF  
Run175,CNC,(-100,100)



Run175,CNC,(-800,800)

