An application of 500 Msps FADC DAQ system to the NSCL LANA Detector

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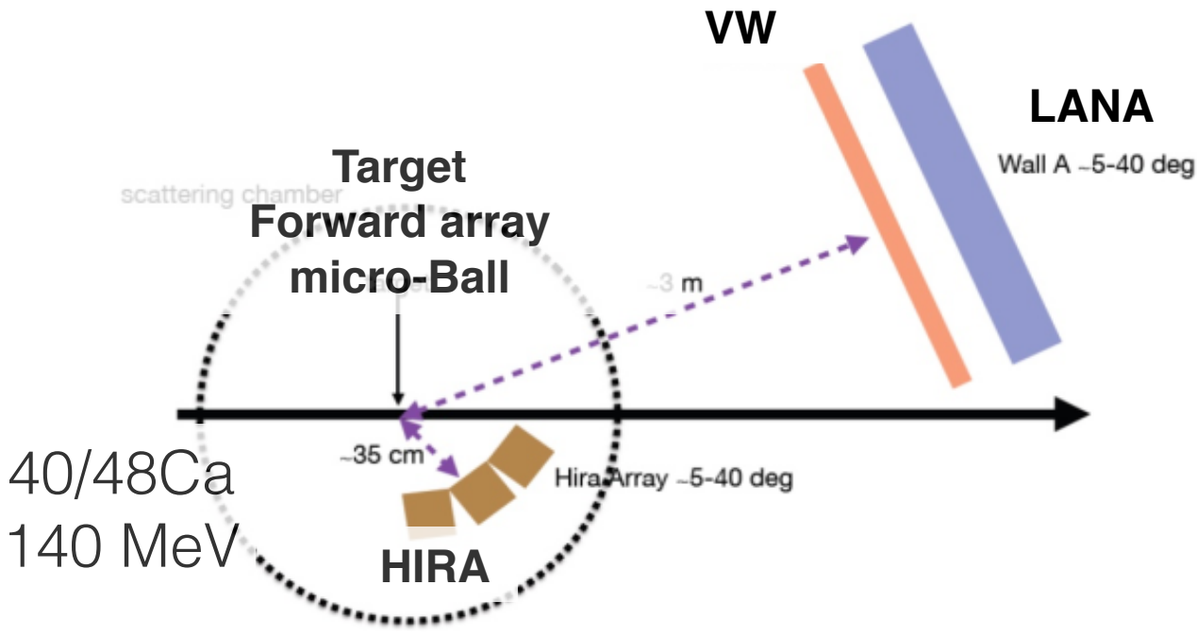
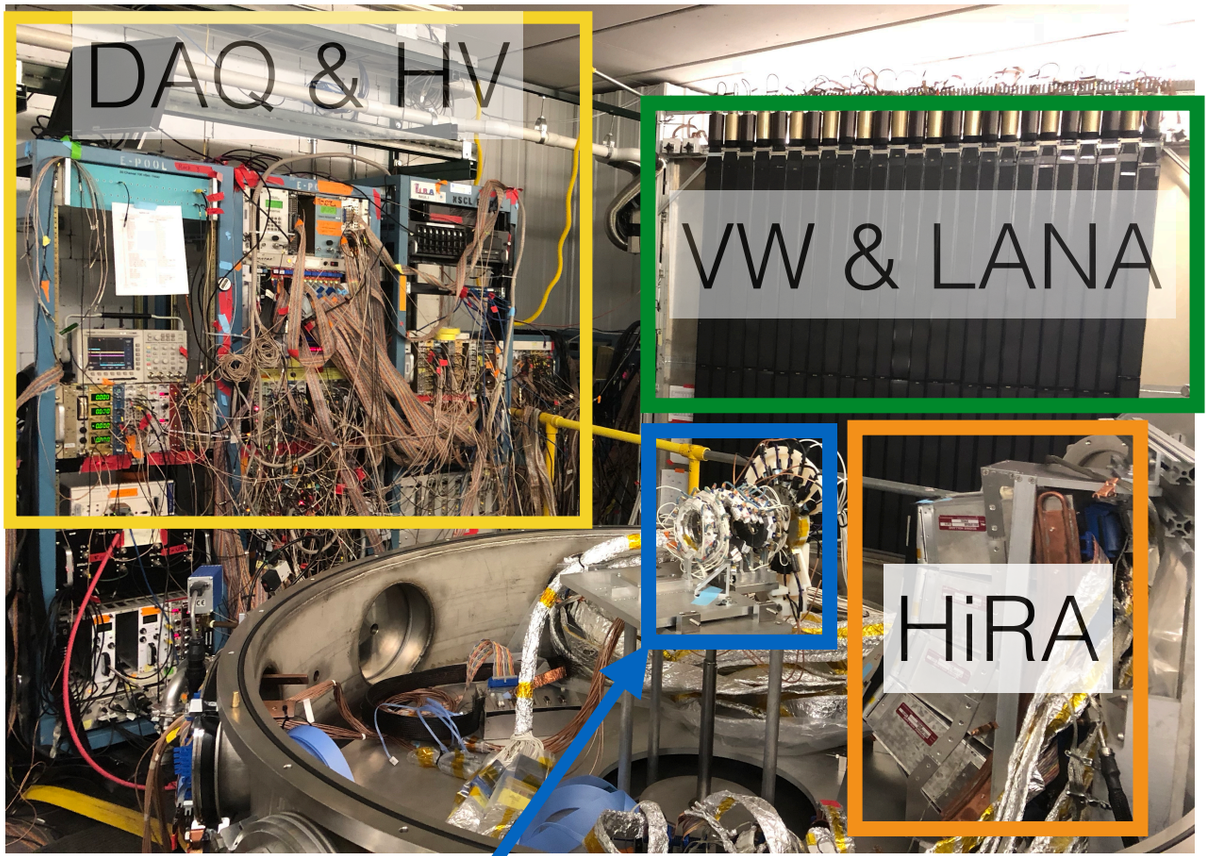
Sep. 9th, 10:00-10:20

NSCL e14030, e15190 experiment



1. Measure n/p ratio and momentum in neuclear reaction.

2. LANA (Large Area Neutron Array)
    1. Liquid scintillator
    2. Neutron detector
    3. TOF, PSD(pulse shape discrimination)
3. VW : Veto charged particle for LANA
4. HiRA(High Resolution Array)
    1. Si-CsI detector
    2. dE/dx(Si strip) vs Total E(CsI)
5. micro-Ball
    1. Small scintillator + pmt
    2. Measure multiplicity
6. FA(Forward Array) : Measure event timing



Target & micro-Ball & FA

Neutron detection in LANA

Charged particle : Vetoed by VW(veto wall)
Gamma : Hard to remove

Pulse Shape Discrimination (PSD)

=> Different time structures of gamma and n/charged particle signal.

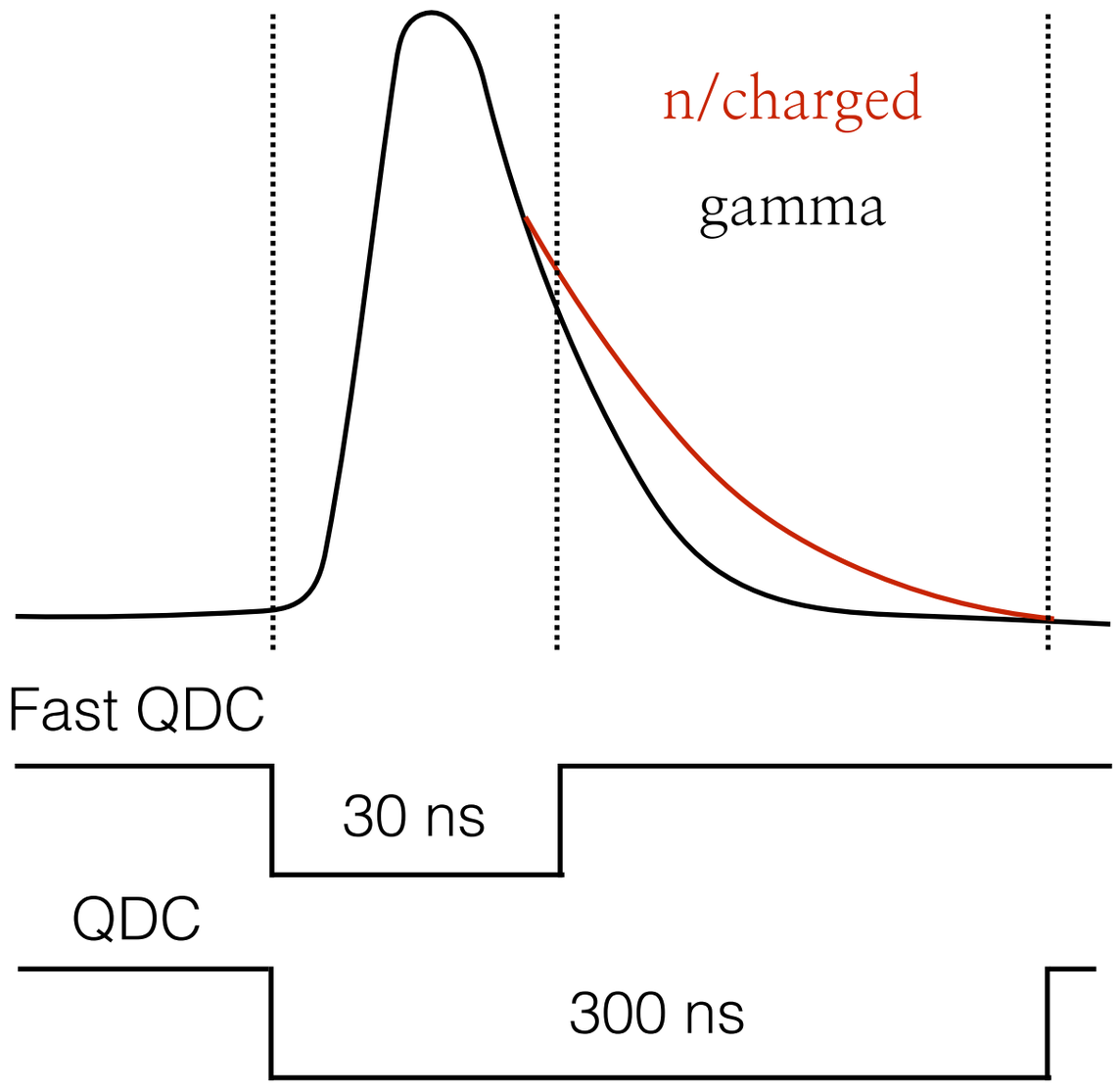
Gamma

- Produce EM shower. Fast decay time

n/Heavy charged particle

- Denser energy loss, longer scintillation decay

Sample waveform



In case of LANA, PSD is measured by two ADCs with different gate width.

How about using FADC to record whole waveform?

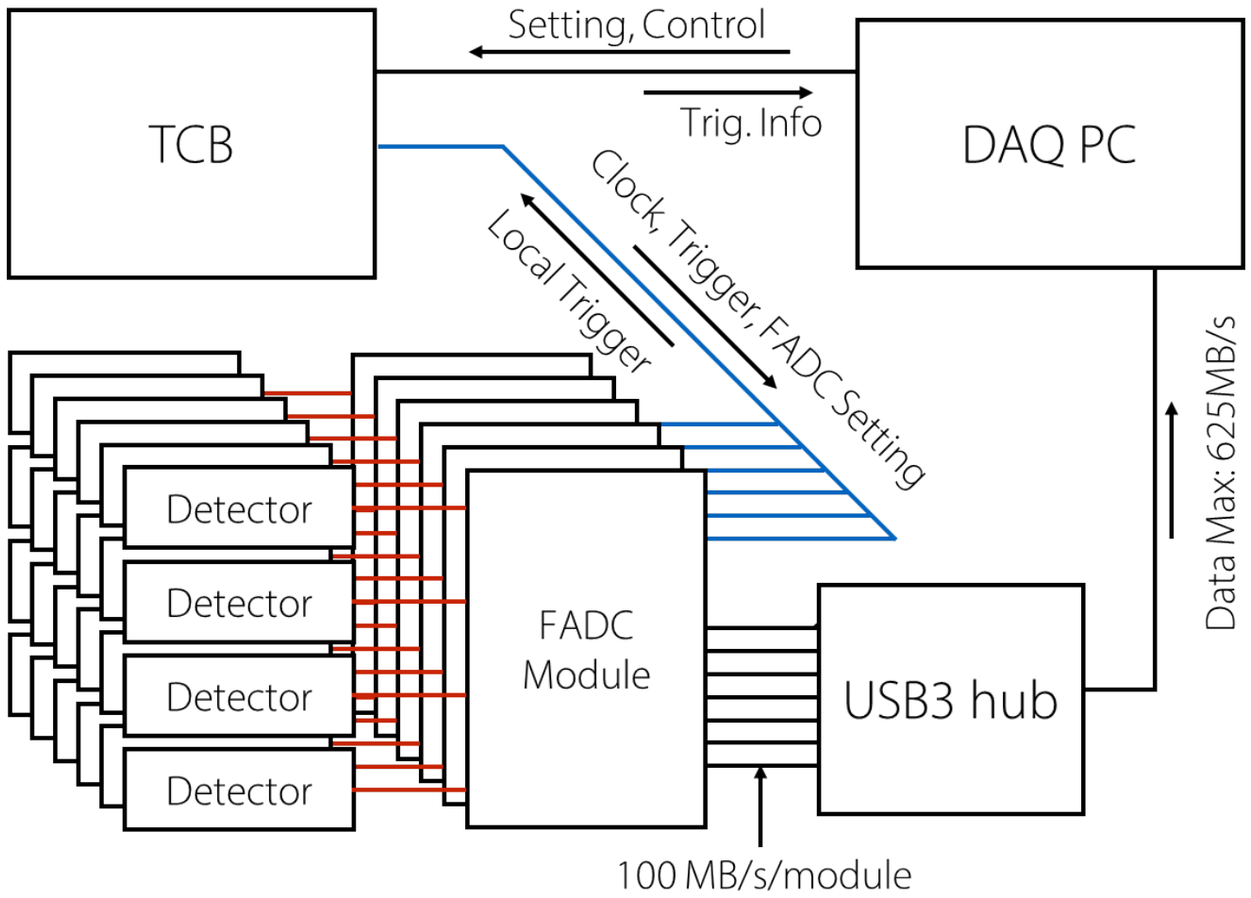
500 Msps FADC DAQ system

1.Developed for LAMPS experiment

2.TCB: Trigger control, Clock distribution

3.FADC： Data measure and transfer

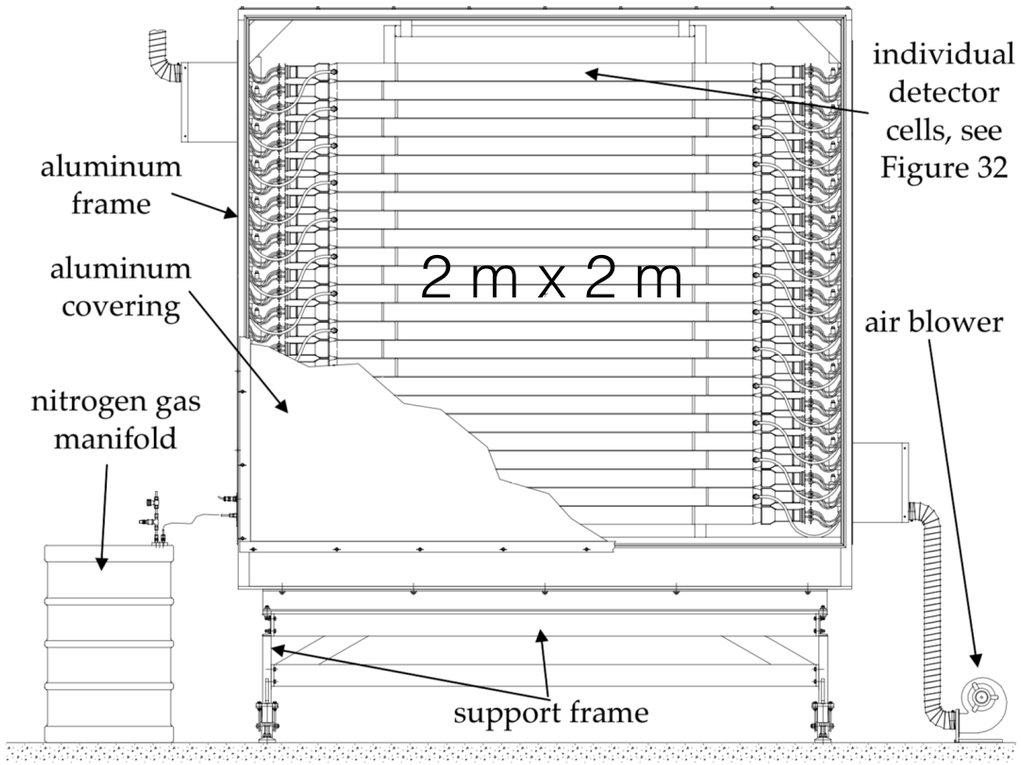
4.Data readout：USB3 or Optical Link



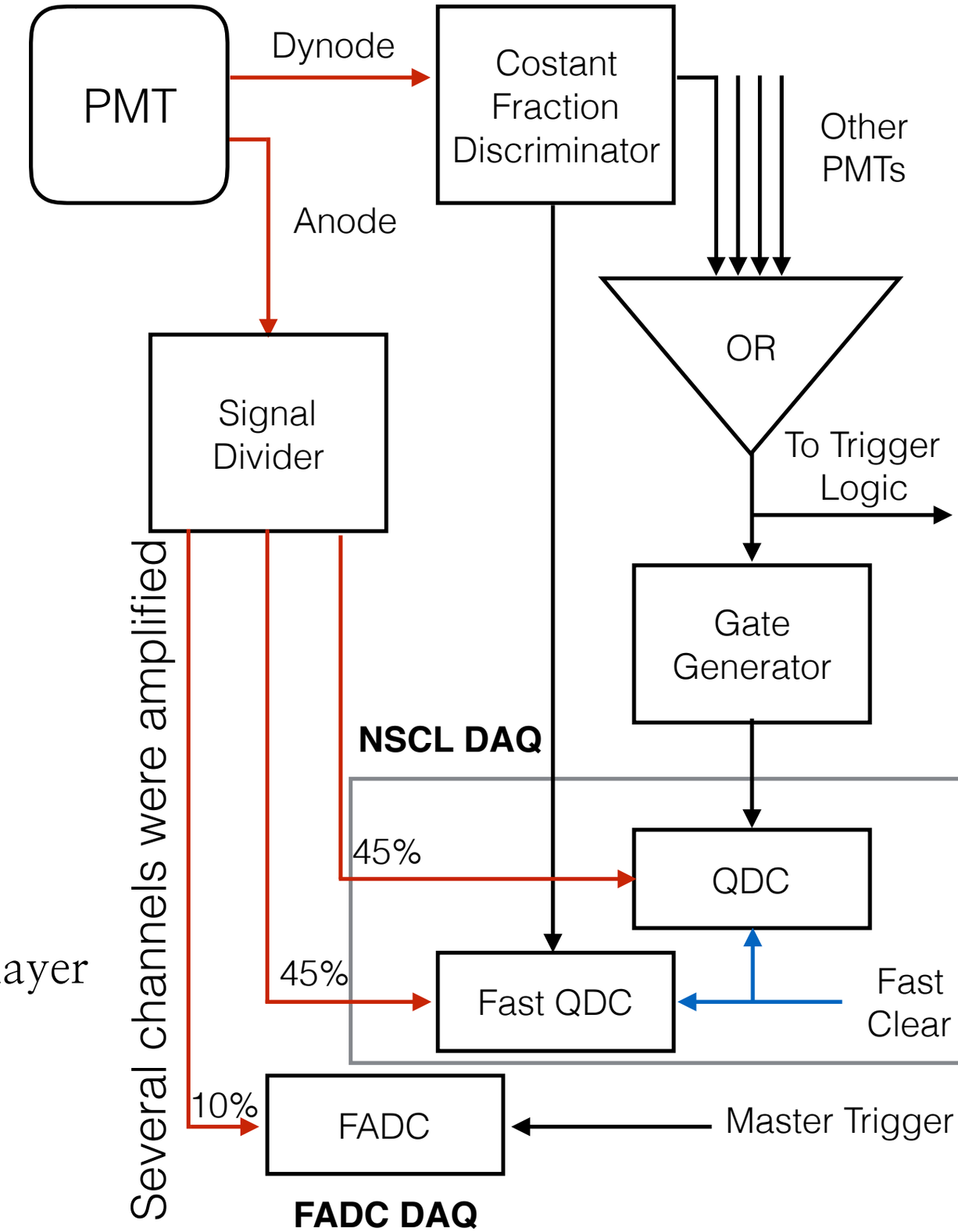
Basic performances of LAMPS FADC DAQ system

Manufacturer	Notice Korea Co.
Sampling speed	500 Msps (2 ns interval)
Maximum Trigger rate	upto 500 kHz
Recording length	128 ns ~ 32 us
Maximum Data transfer speed	5 gbps for 4 ch (USB3.0 or optical Link)
Dynamic range	2V, offset adjustable (-2 to 0 V, ~ 0 to 2 V)
Resolution	12 bit
ADC zitter	less than LSB (0.5 mV)
Timing resolution	< 40 ps

NSCL LANA detector



1. Large Area Neutron Array
2. 2 m x 2m detection area
3. 2 layer
4. 25 Pyrex cells (200 x 7.62 x 6.35 cm^3) / layer
5. NE-213 liquid scintillator
6. Signal to FADC : 10% of original signal



DATA status

Beam intensity：1 nA　　Trigger：LANA + micro-Ball

Beam Particle	Target	Trig. rate	Data throughput
48Ca 140 MeV/u	64Ni	2.5 k	7 MB/s
48Ca 140 MeV/u	58Ni	2.3 k	7.0 MB/s
48Ca 140 MeV/u	112Sn	2.5 k	7.5 MB/s
48Ca 140 MeV/u	124Sn	2.7 k	7.4 MB/s
Cosmic (self)	-	22 k	13 MB/s

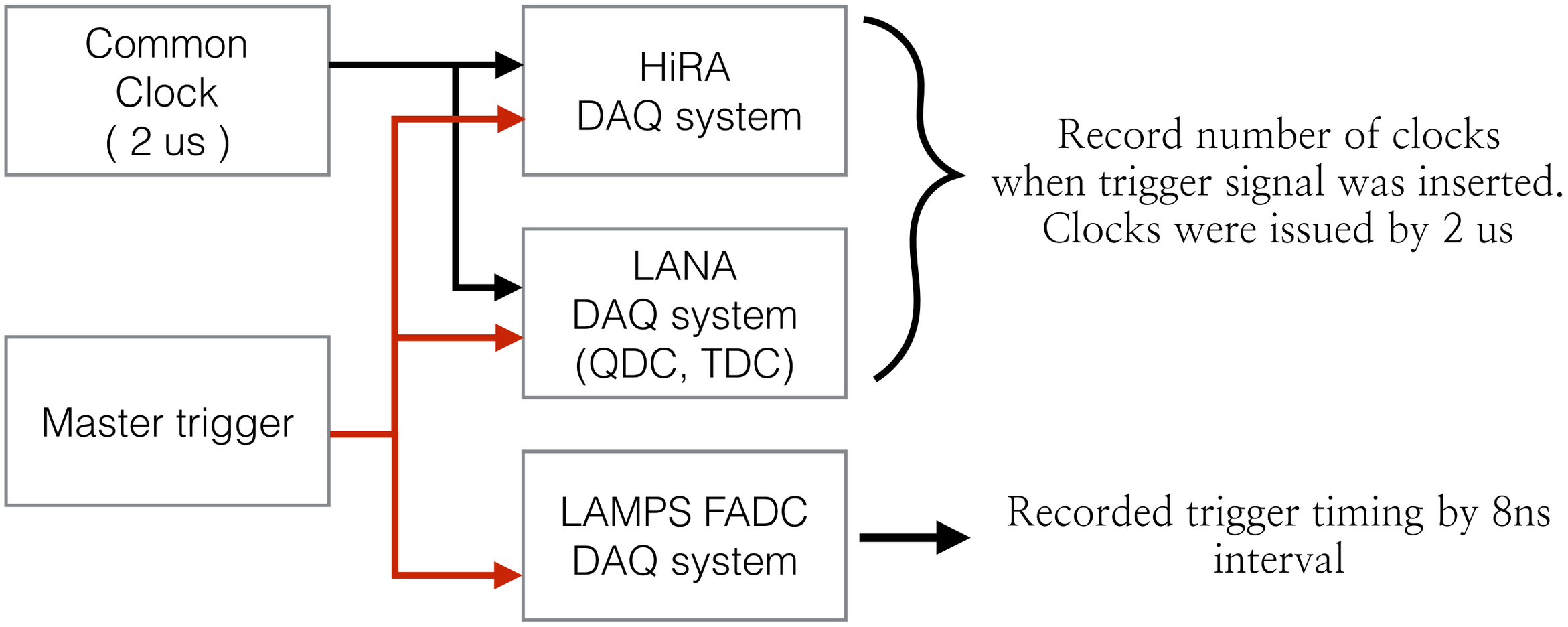
Total raw data size：4.6 TB

Problem is…

1.How to matching data sets from independent DAQs.

2.Waveform analysis and checking performance of FADC DAQ

Event matching



Two data sets with different timestamp types

How to matching initial data, and to confirm data was sychronized event by event?

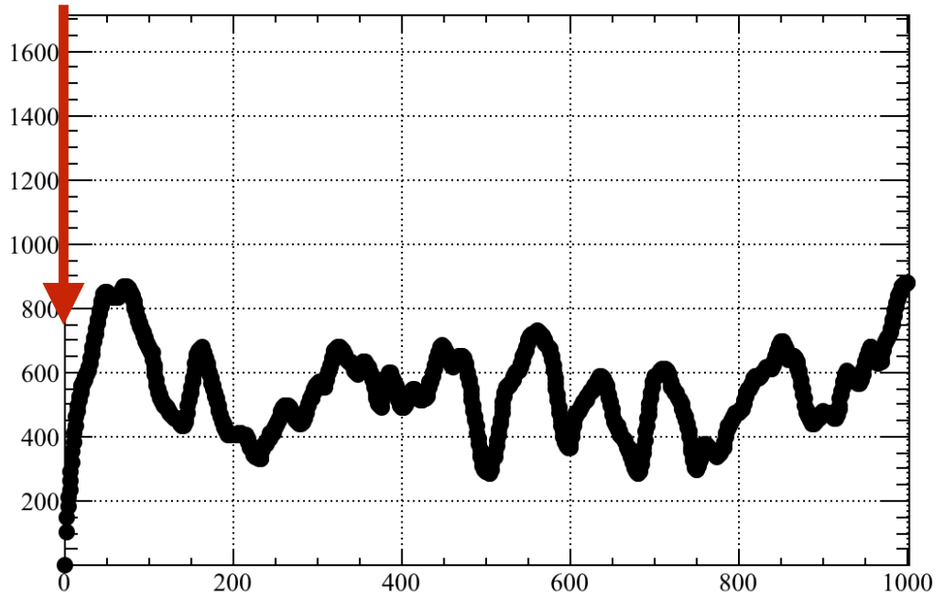
Event matching method

$T_F(i)$: FADC timestamp of i−th event (1 ns unit)
$T_N(i)$: Clock timestamp of i−th event (2 us unit)

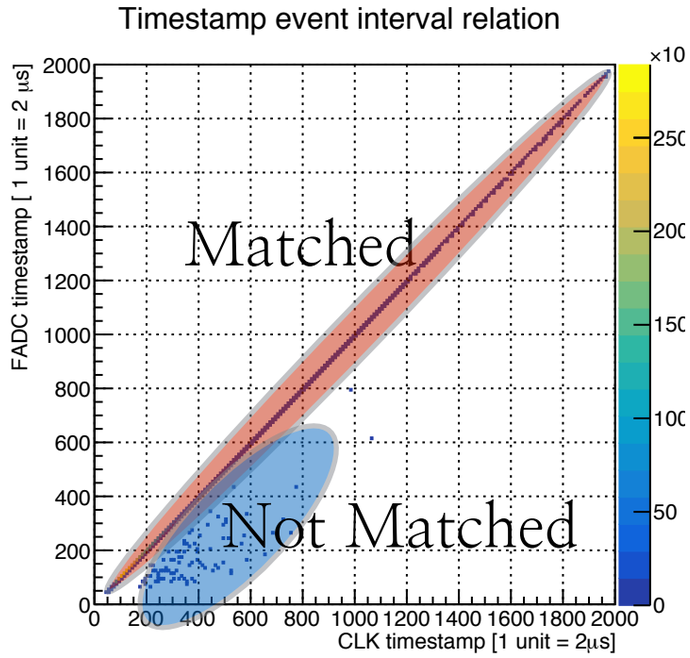
$$\Delta(i,j) = \sum_{k=0}^{100} \left(\frac{T_F(i+k)}{5000} - T_N(j+k) \right)^2 / 100$$

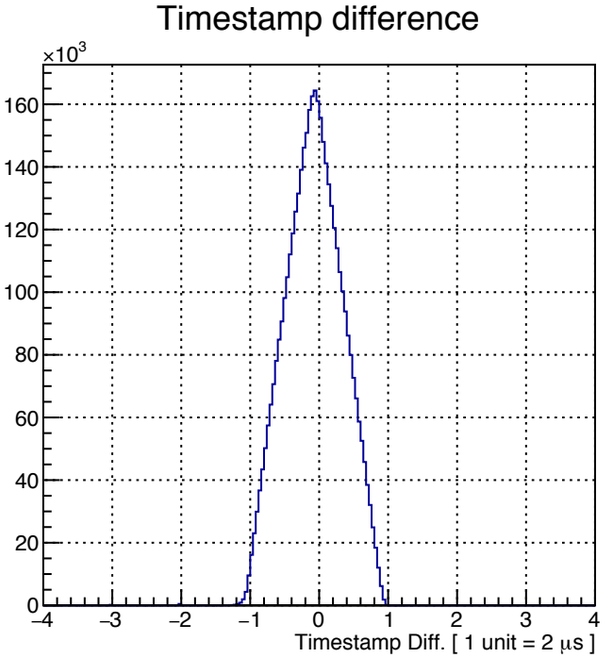
Matched!

$\Delta(i,j)$



i = 0, j = 0 ~1000,
Matched at (i,j)=(0,0), Delta : 0.3

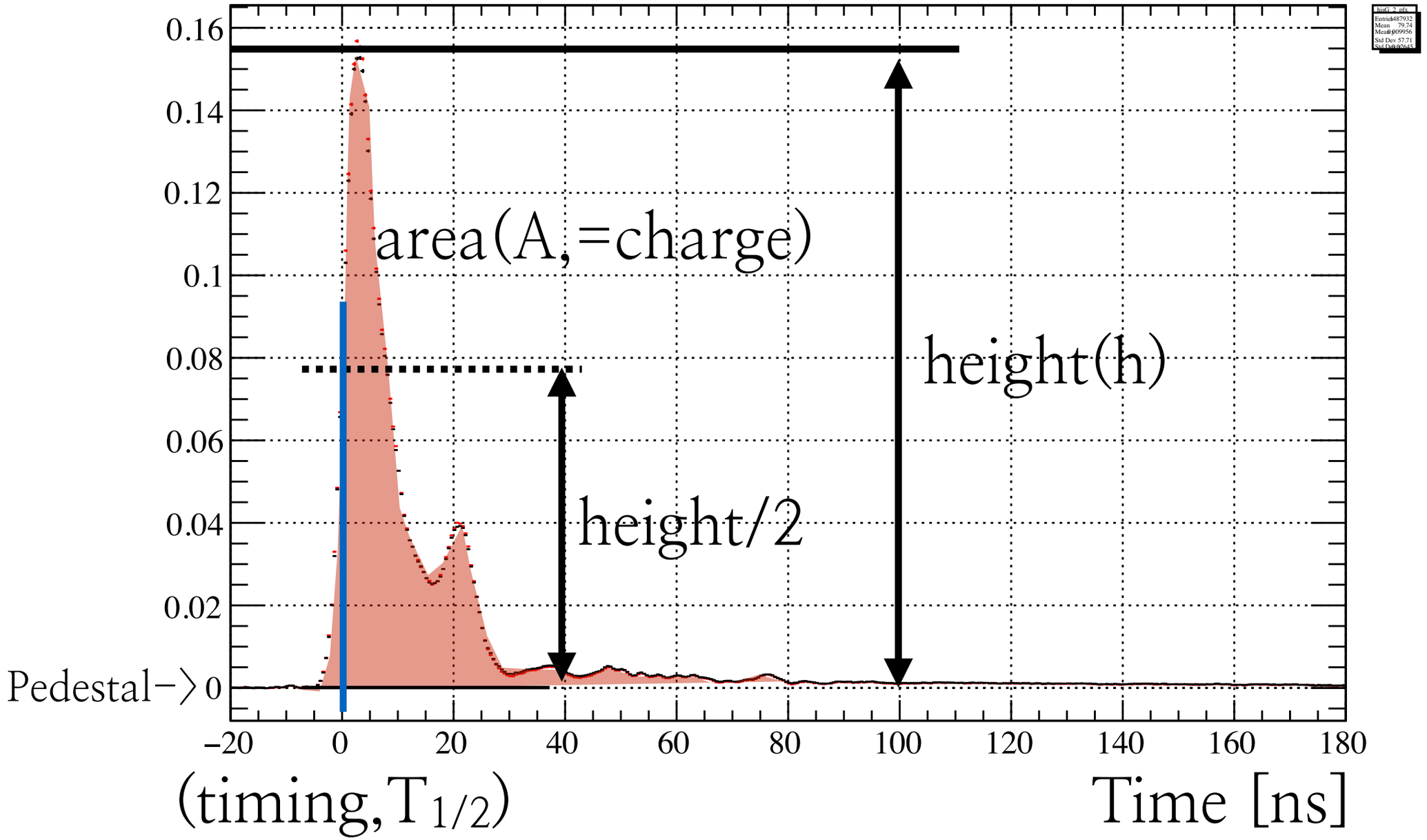




$$\frac{\text{N(Not matched)}}{\text{N(Matched)}} = 0.005\%$$

Two data set were matched each other

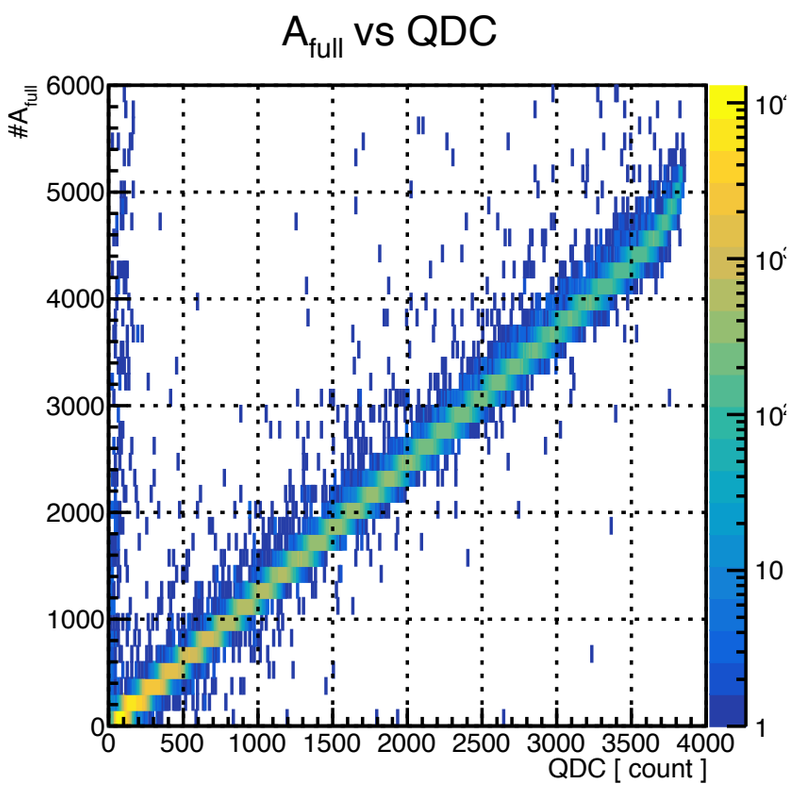
Compare two DAQs' data – waveform analysis

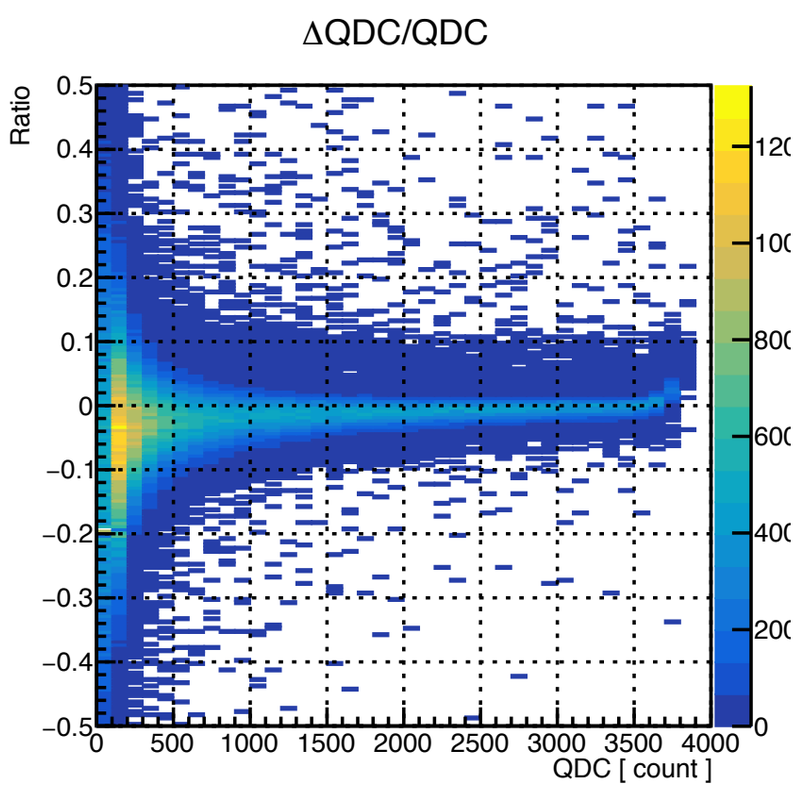


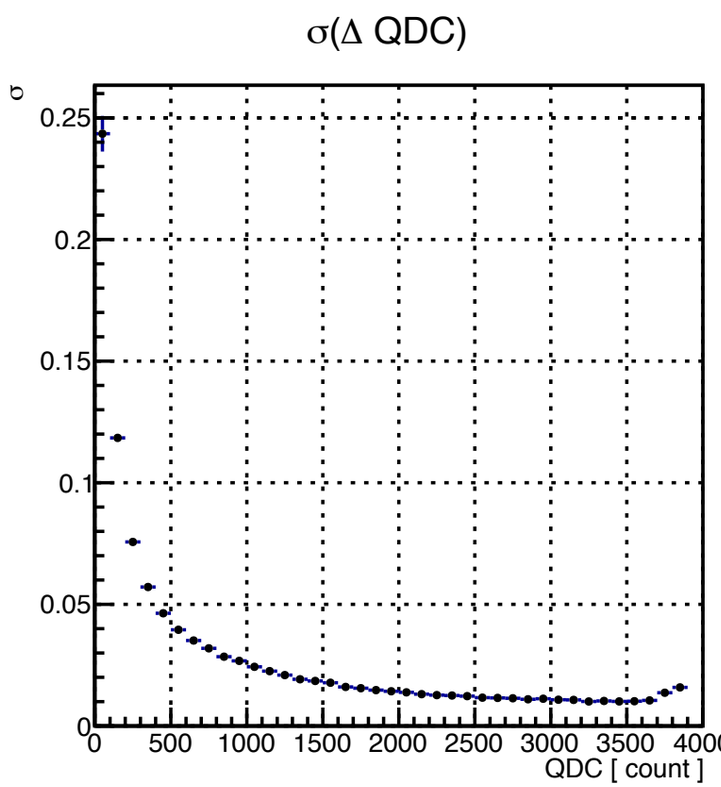
To calculate QDC and fast QDC, $A_{full} = \sum_{T_{1/2}-20}^{T_{1/2}+140} A_i$, $A_{part} = \sum_{T_{1/2}-20}^{T_{1/2}+40} A_i$ were defined.

~ QDC ~ fast QDC

Checking matched data-QDC

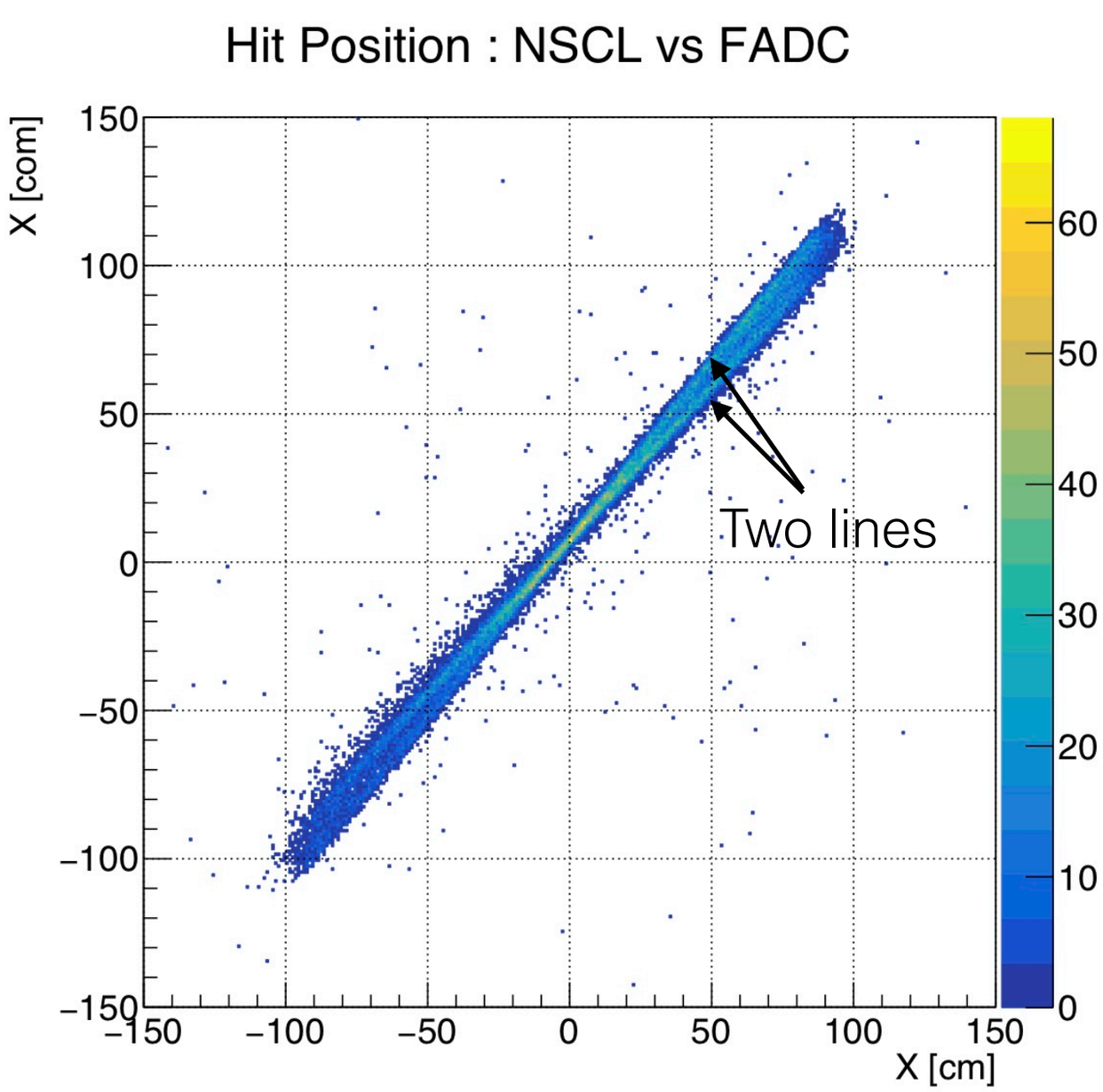




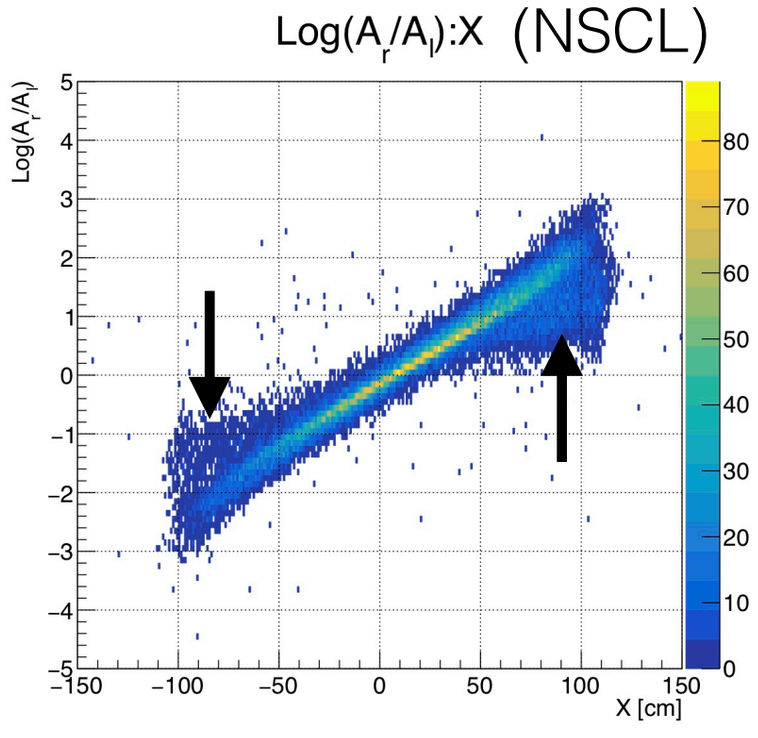


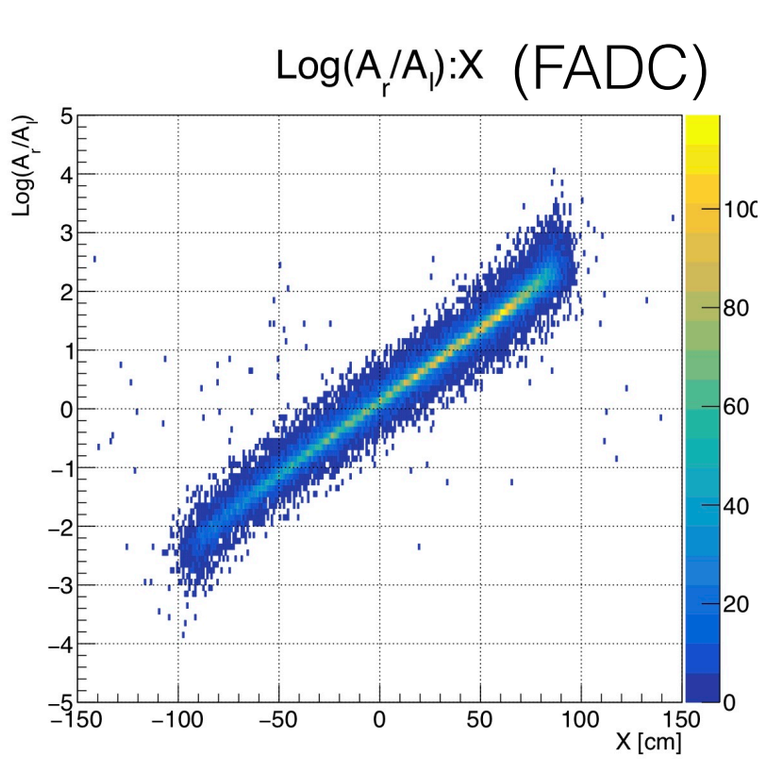
Compared QDC value from commercial QDC and FADC
QDC values were coincided each other less than 5% when QDC was larger than 400 count

Checking matched data–Timing data

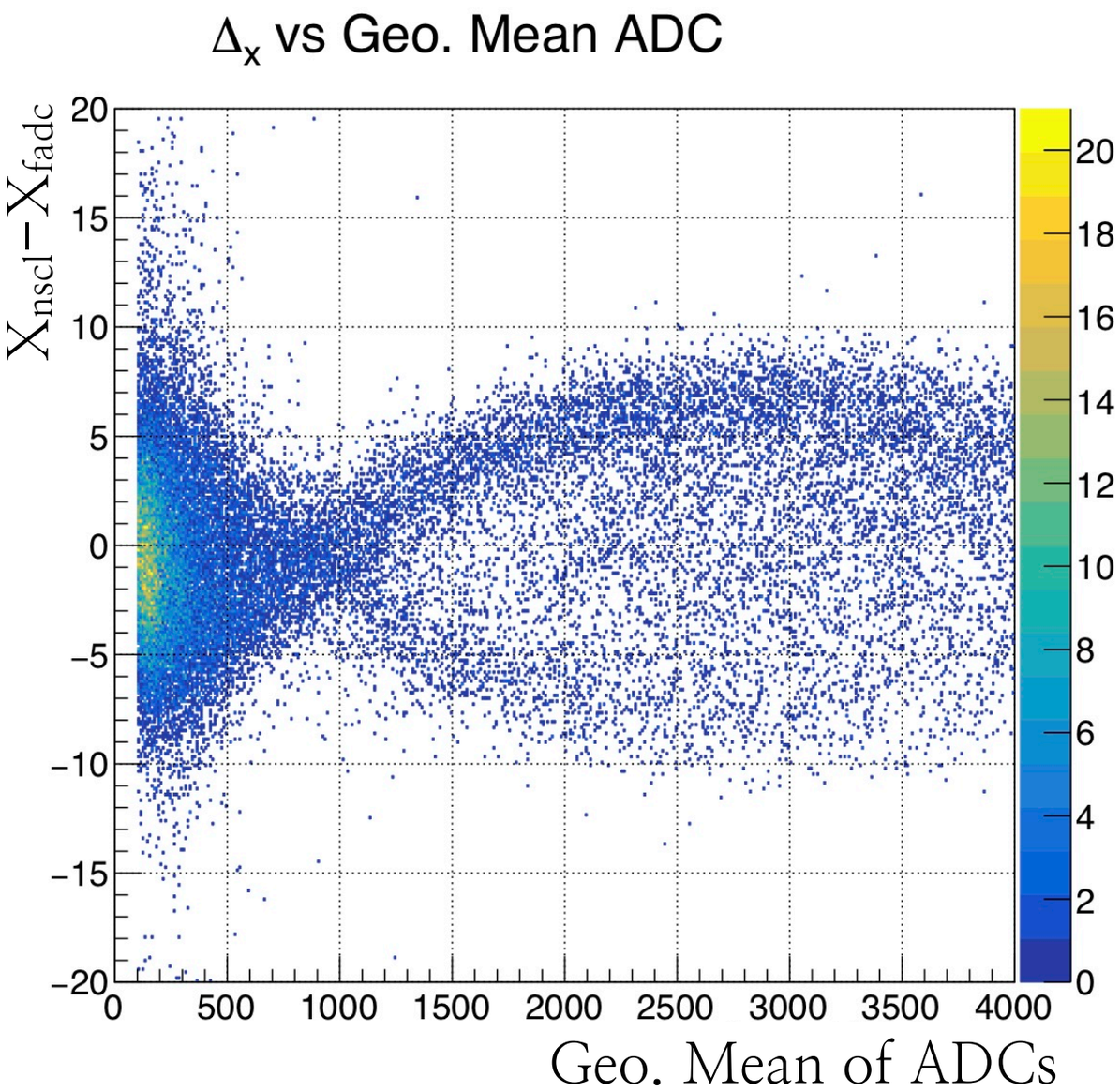


$X = (T_R - T_L)/2 * v_{scinti}$





Checking matched data–Timing data

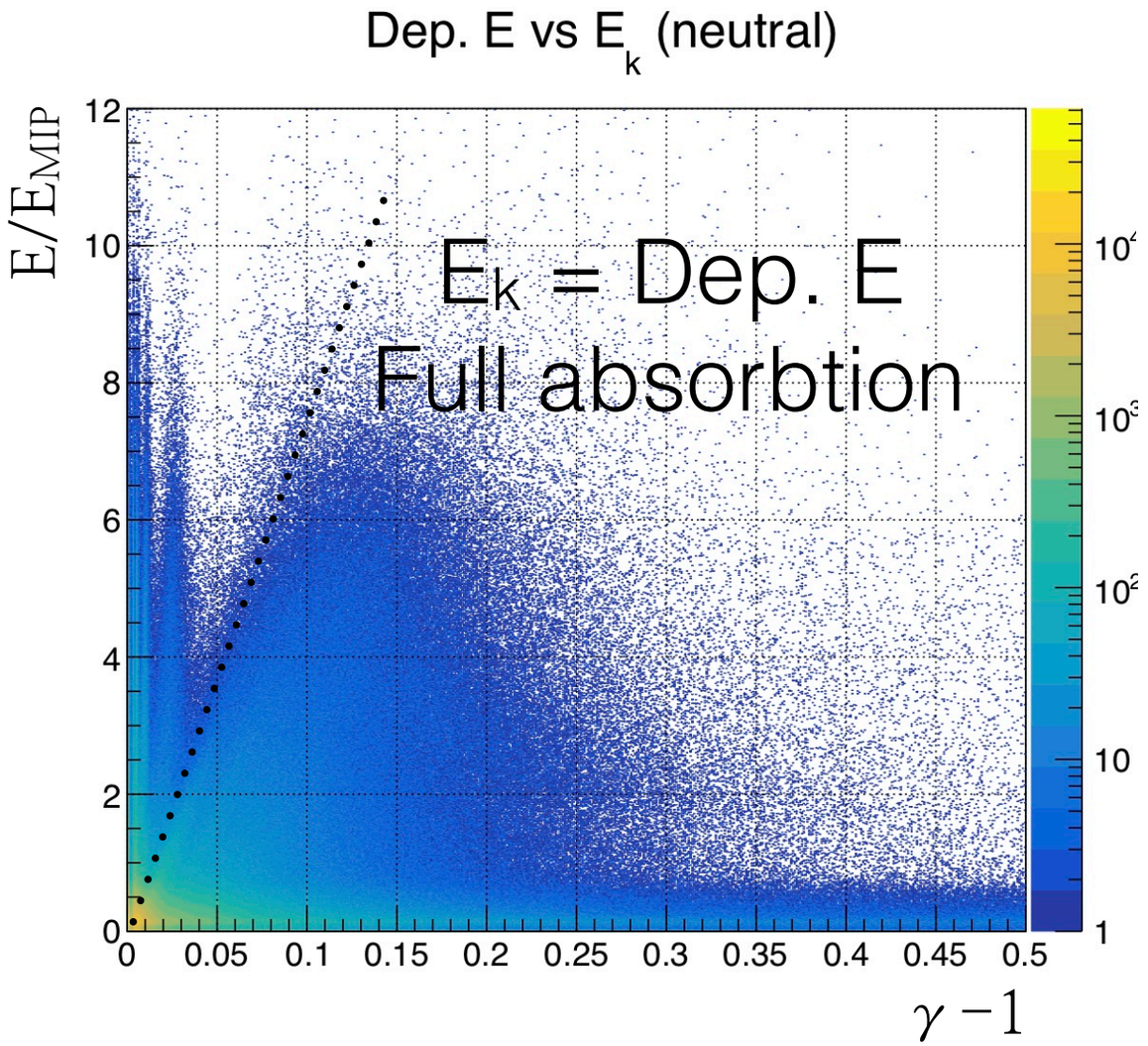


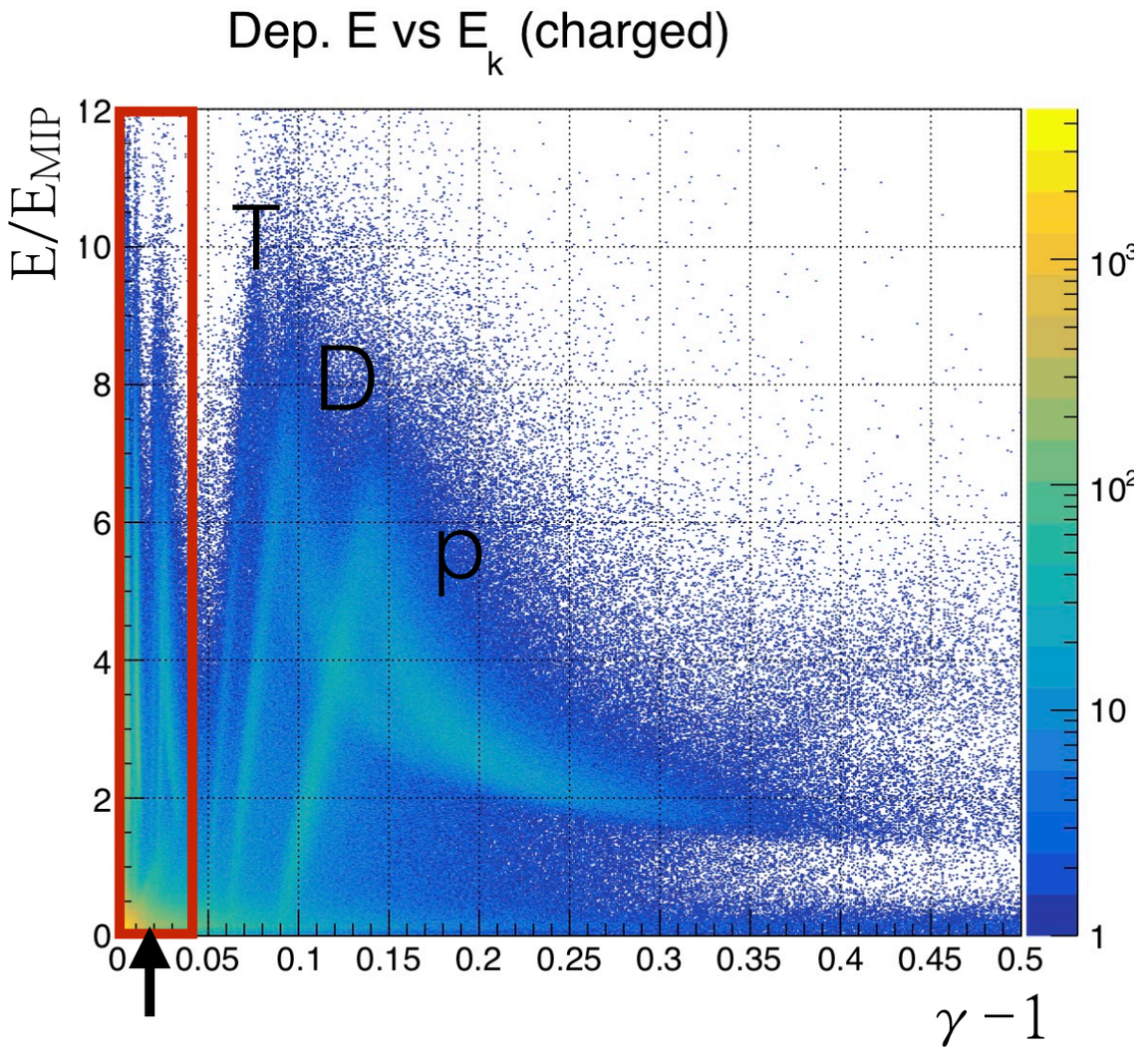
Slewing corrction for TDC data (CFD) was not perfact
In common, there are no need to timing correction to the FADC data

Charge and timing data from FADC is good enough to use.

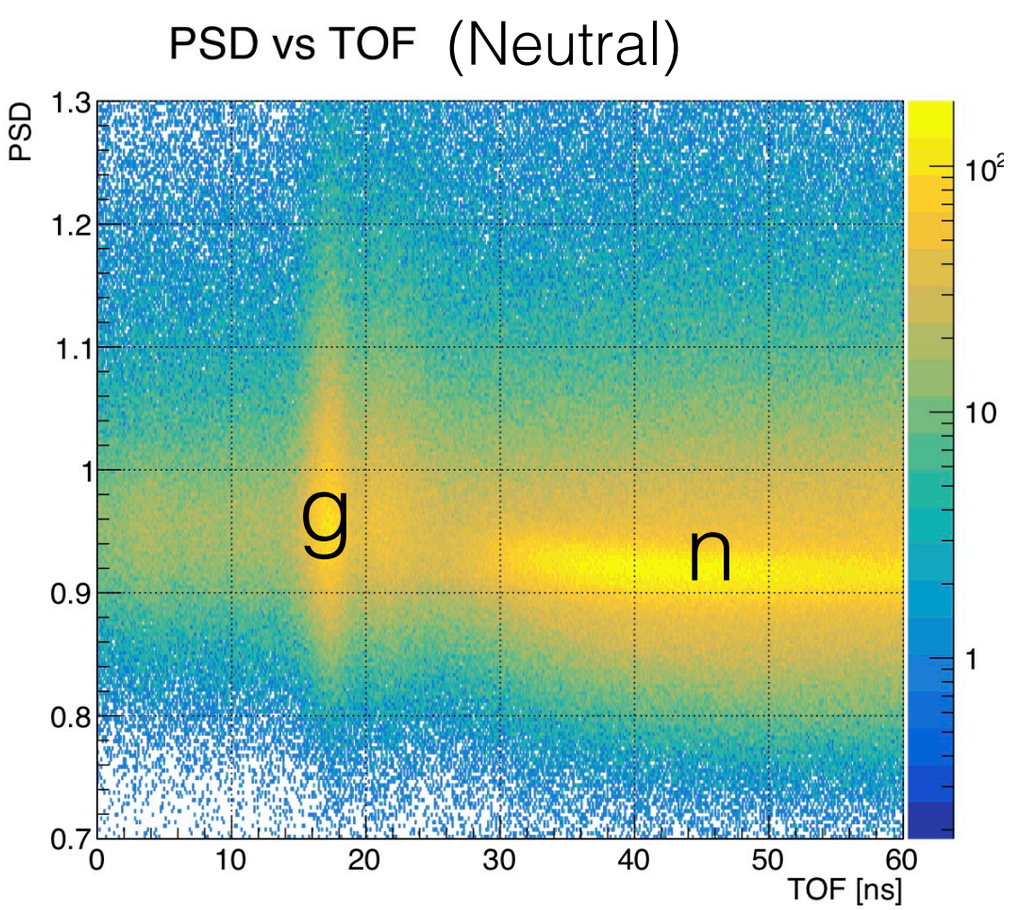
Measured data

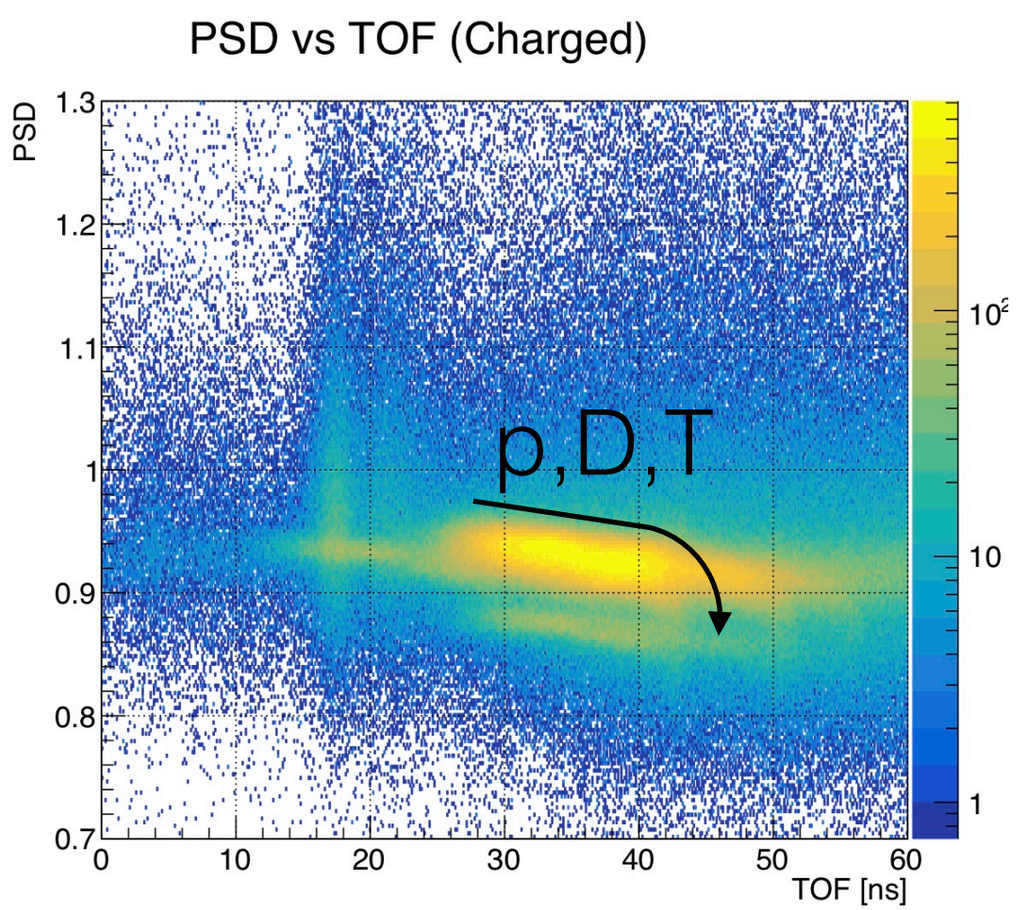
Beam ：140MeV ^{48}Ca 140 MeV
Target：^{64}Ni

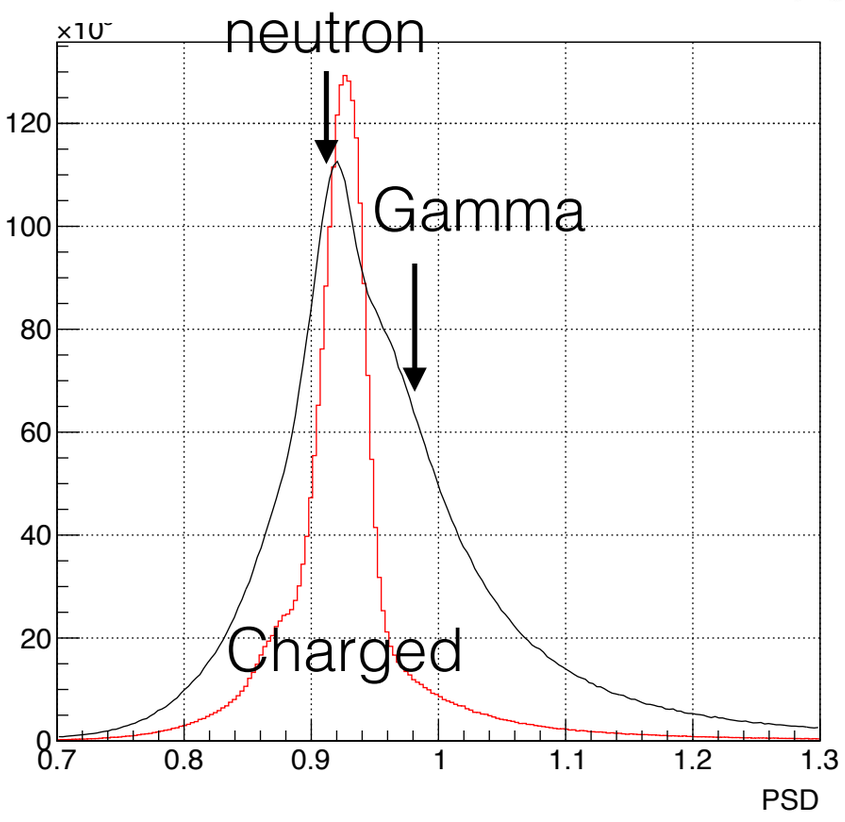




FADC for PSD – Non Amplified channel



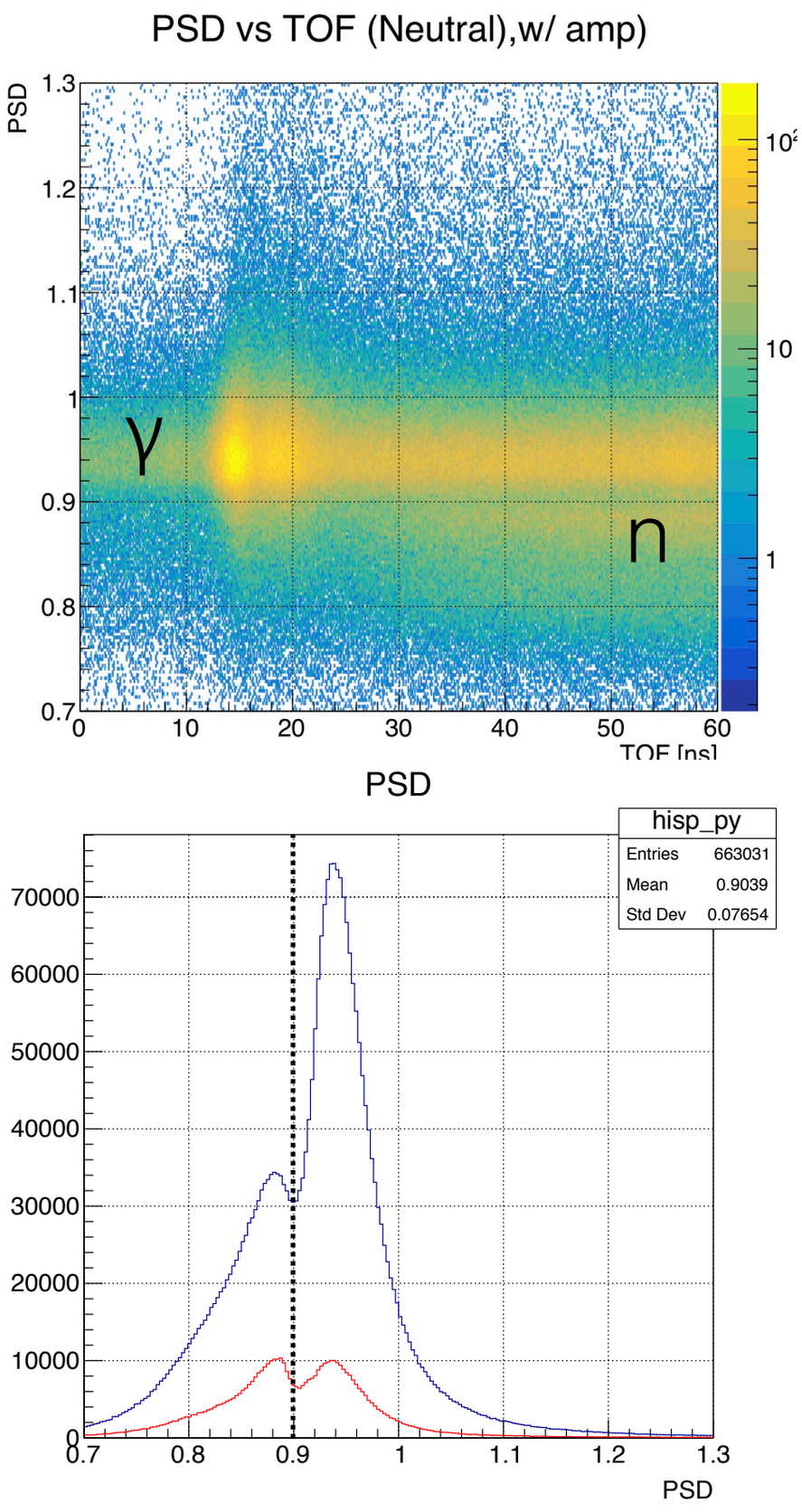


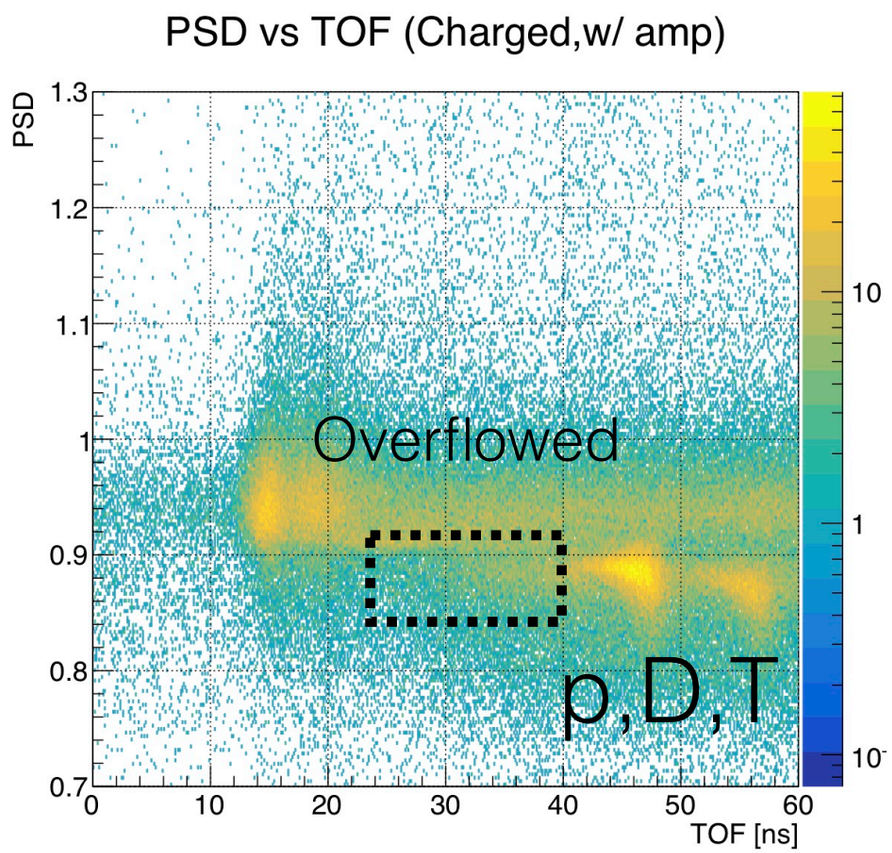


$$PSD = \frac{\sum_{T_{1/2}-20}^{T_{1/2}+40} A_i}{\sum_{T_{1/2}-20}^{T_{1/2}+140} A_i}$$

PSD was changed by particle energy

FADC for PSD – Amplified channel





We confirmed gammas and low energy neutrons can be distinguish with PSD value 0.9.

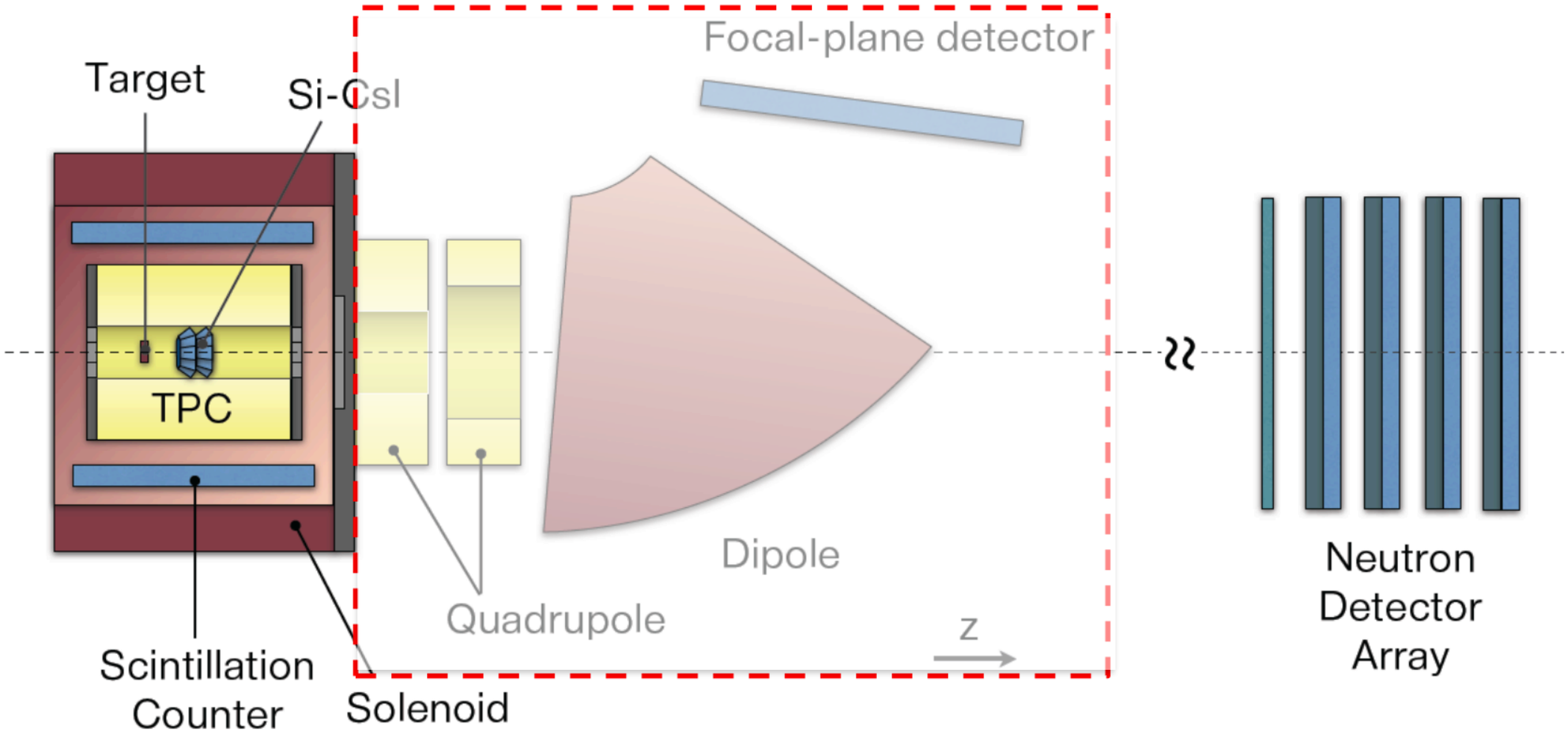
Summary

- We tested new FADC DAQ system with full size (112 channel) at NSCL and confirmed it worked same performance with the commercial DAQs.

- We took data from nuclear interaction experiment, and confirmed data was successfully reconctructed.

Thanks.

Large-**A**cceptance **M**ulti-purpose **S**pectrometer experiment at RAON

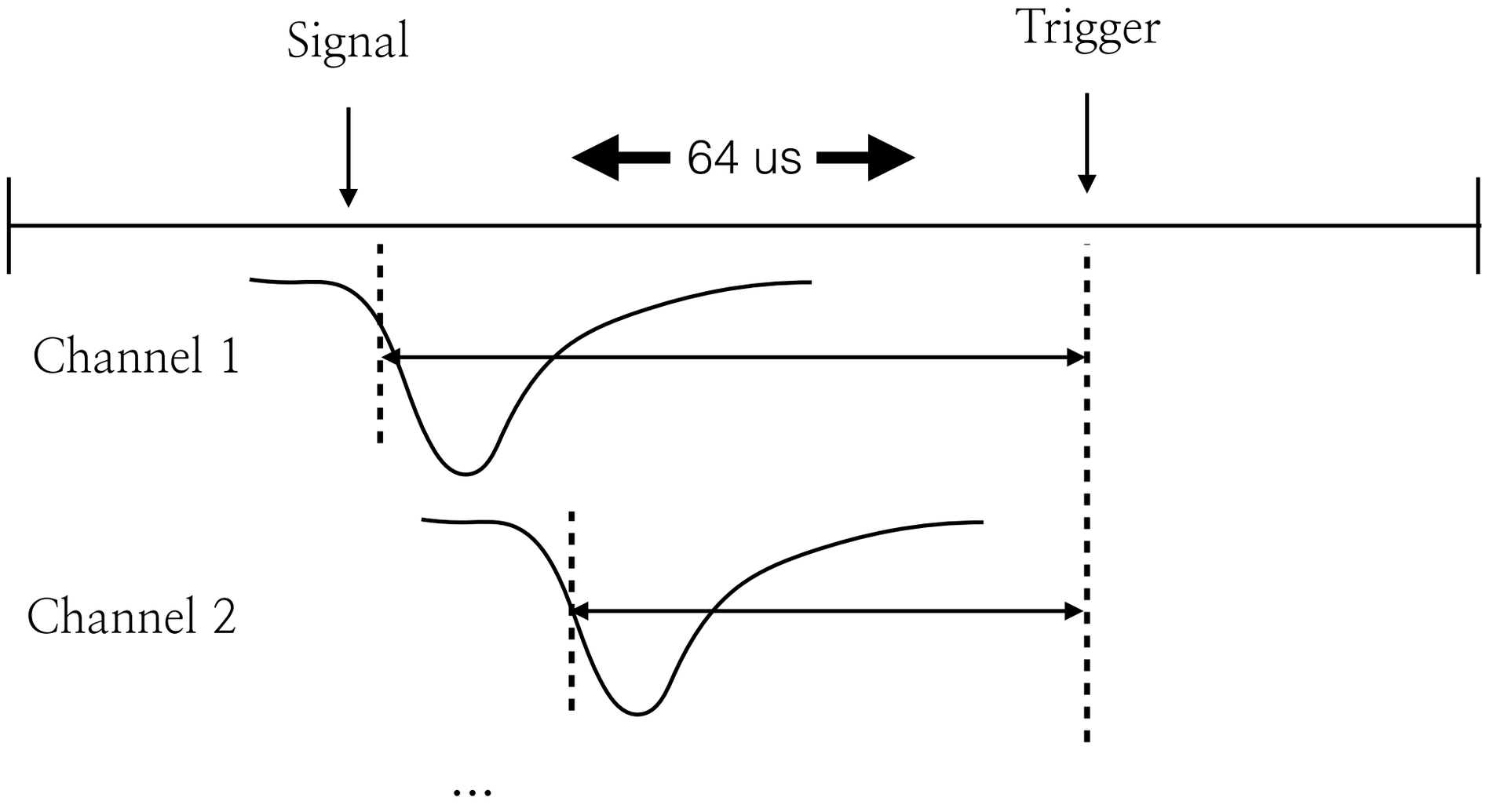


Experiment for symmetry energy
TPC for charged particle measurements
Neutron detector array for neutron measurements

Functions and Characteristics of FADC DAQ system

-Digital delay applied for each channel independently

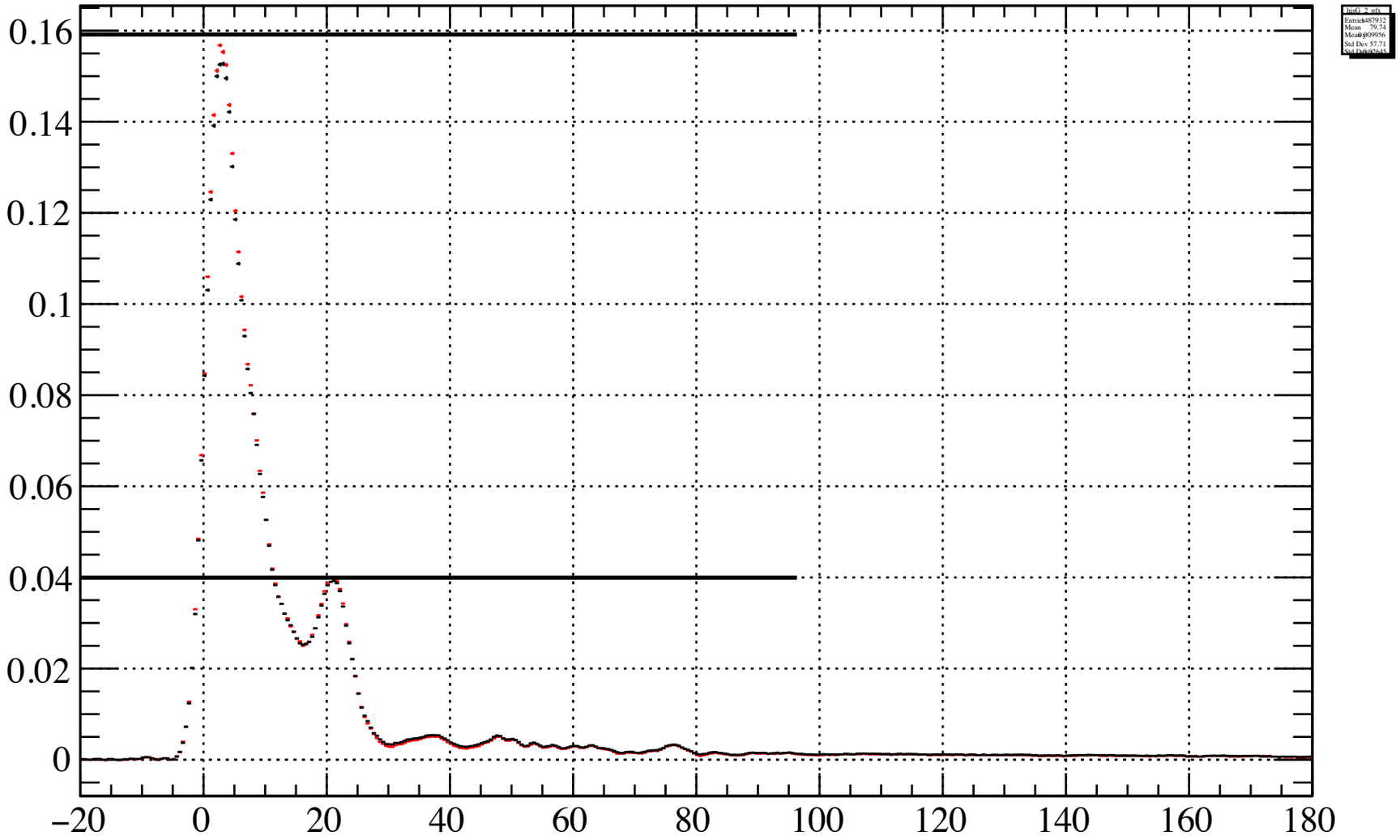
Ring buffer : 64 kB (= 64 us)



Delay cables can be omitted. -> Simple setup

Functions and Characteristics of FADC DAQ system

if threshold > Max height : not recorded

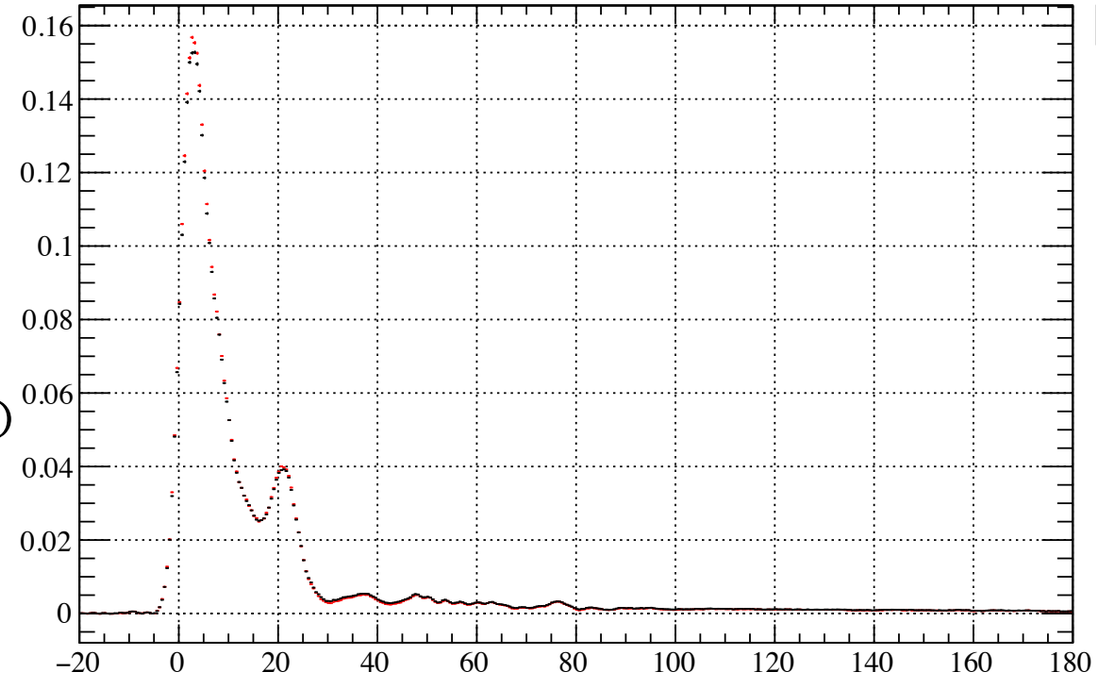


elif threshold < Max height :
record whole points in recording length

DAQ setup (1) – PC and FADC

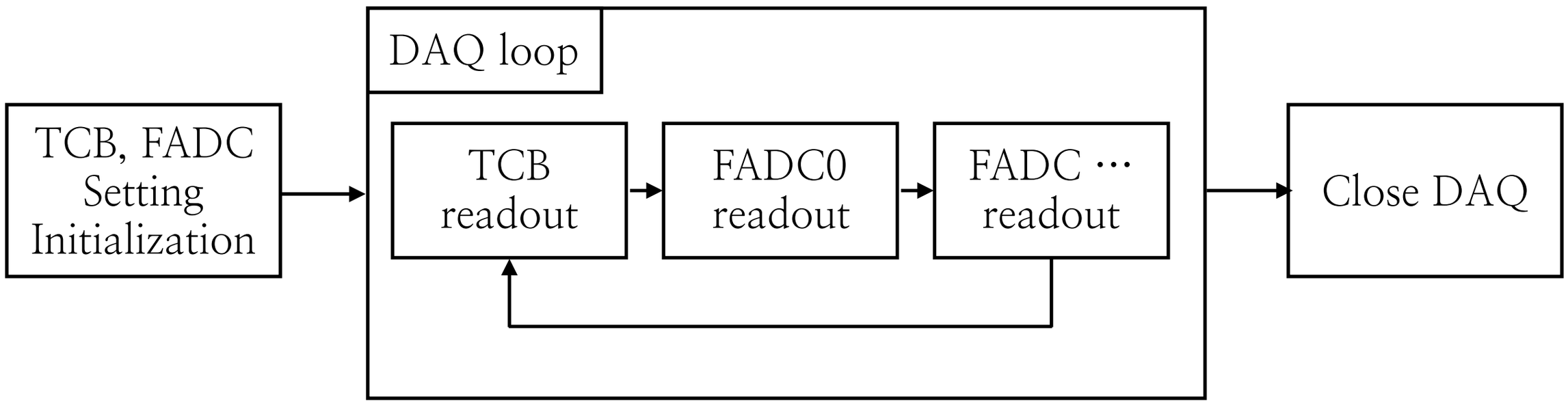
1. DAQ PC
    1. 32 thread cpu + 32 GB memory
       (Avg. CPU usage during data taking : 15%)
    2. 4 x 7 port USB3 pci card
    3. 4 x 6 TB HDD for waveform data, 2 x 2 TB HDD for tcb data, 1 240 GB SSD for event building
2. FADC
    1. Total 97 Channel : 96 (LANA) + 1 (FA)
    2. Estimated data throughput (1~10kHz, Recording length : 480 ns)
        1. 1 ~ 10 MB/sec with zero suppression => Set zero suppression.
        2. 96 ~ 960 MB/sec without zero suppression (Unabailable)
    3. Recording length : 480 ns
        1. Width of waveform : 200 ns
        2. Time of flight diffrence : 100 ns
        3. Timing diffrence between two walls : 15 ns
    4. Zero suppression threshold : 5 mV for low energy events

Typical Waveform



DAQ setup (2) – DAQ program

FADC DAQ-Ordinary Notice version



1. Single process
2. Loop for sequential data readout for TCB and FADCs

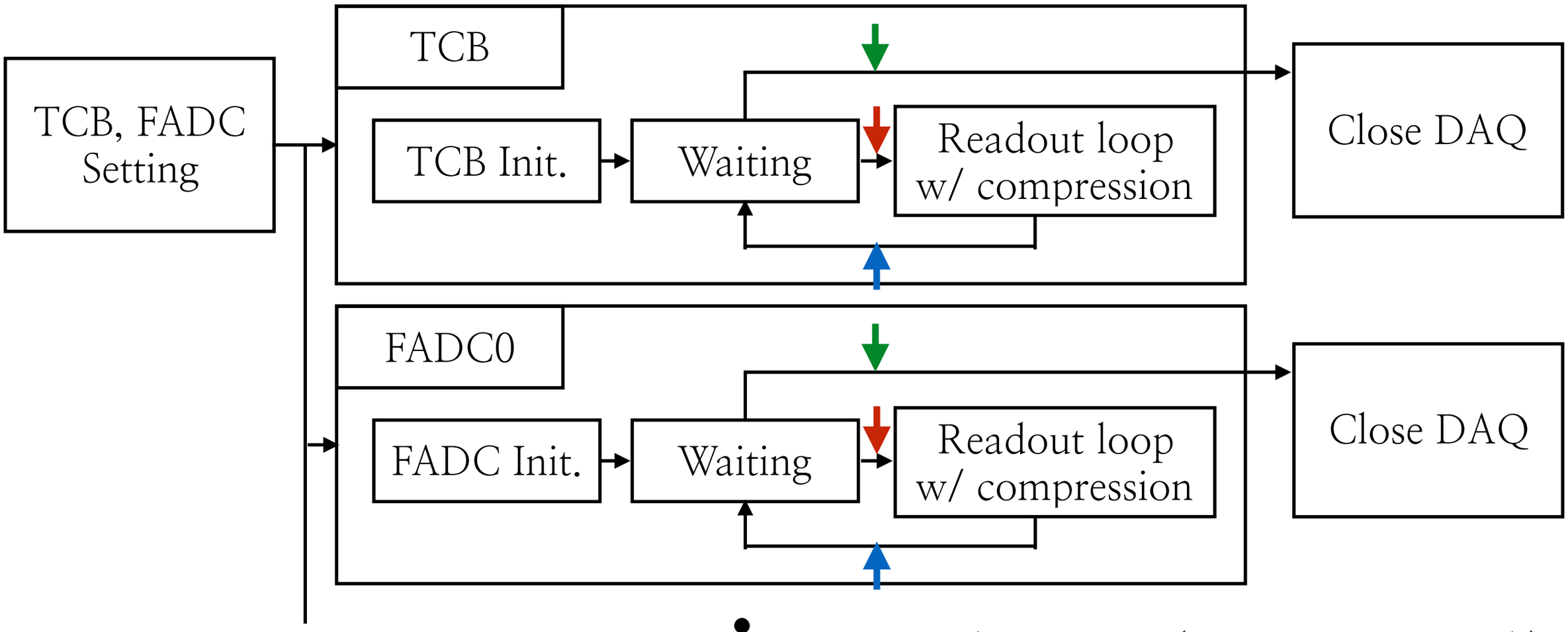
   => By increasing number of FADC boards and recorded data size per second, the processing bottle neck is generated in the program and recoring HDD

3. 1~10 MB/s (2.6 ~ 26 TB for 30 days)

Multi-process DAQ program
Many Large HDD **are required**

DAQ setup (3) – DAQ program

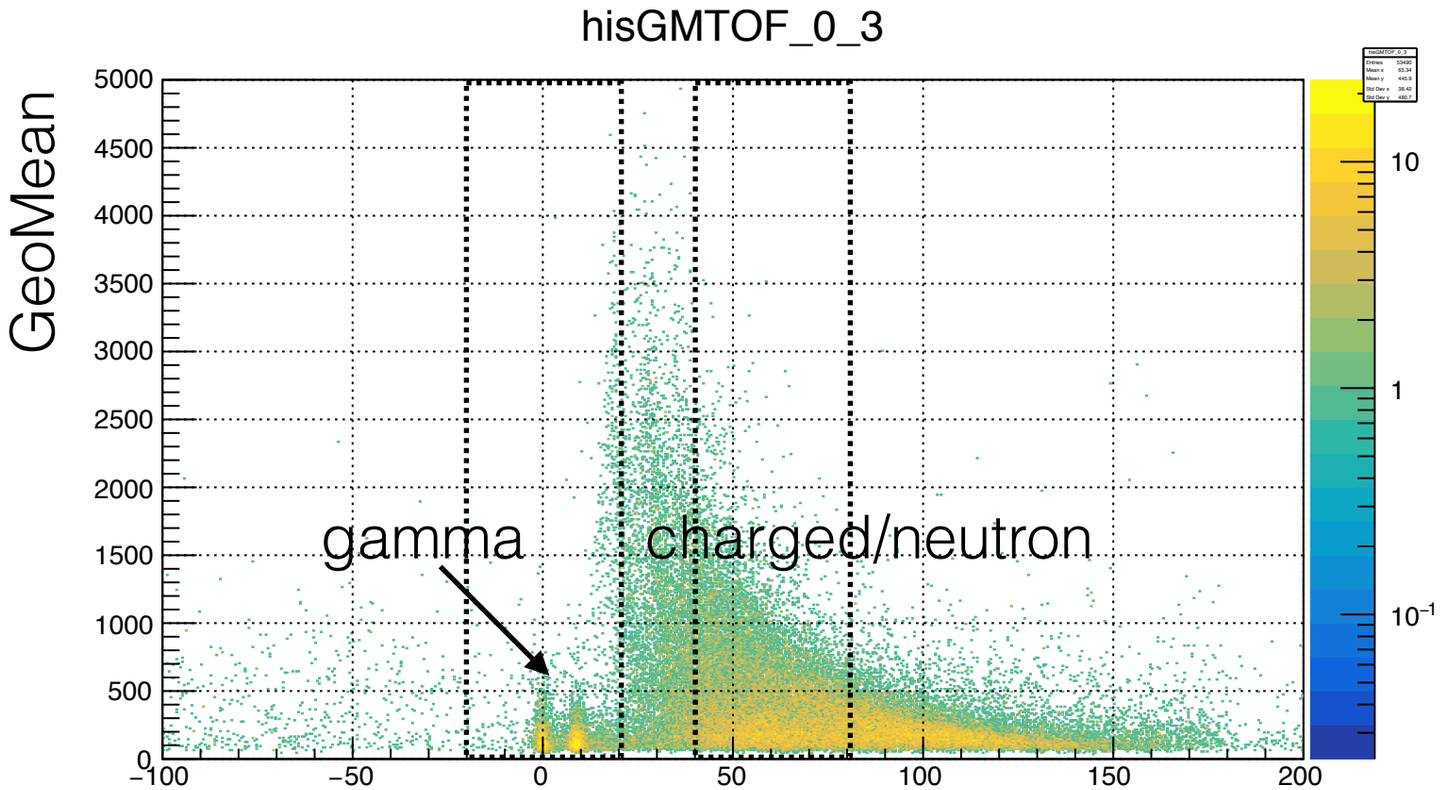
FADC DAQ–Multi process version



Start DAQ signal
Stop DAQ signal
Exit DAQ signal

1. Multi–process (29 process in total)
2. Synchronized using linux system signal
3. One 6TB HDD assigned per 7 FADC mod. (28 TB in total)

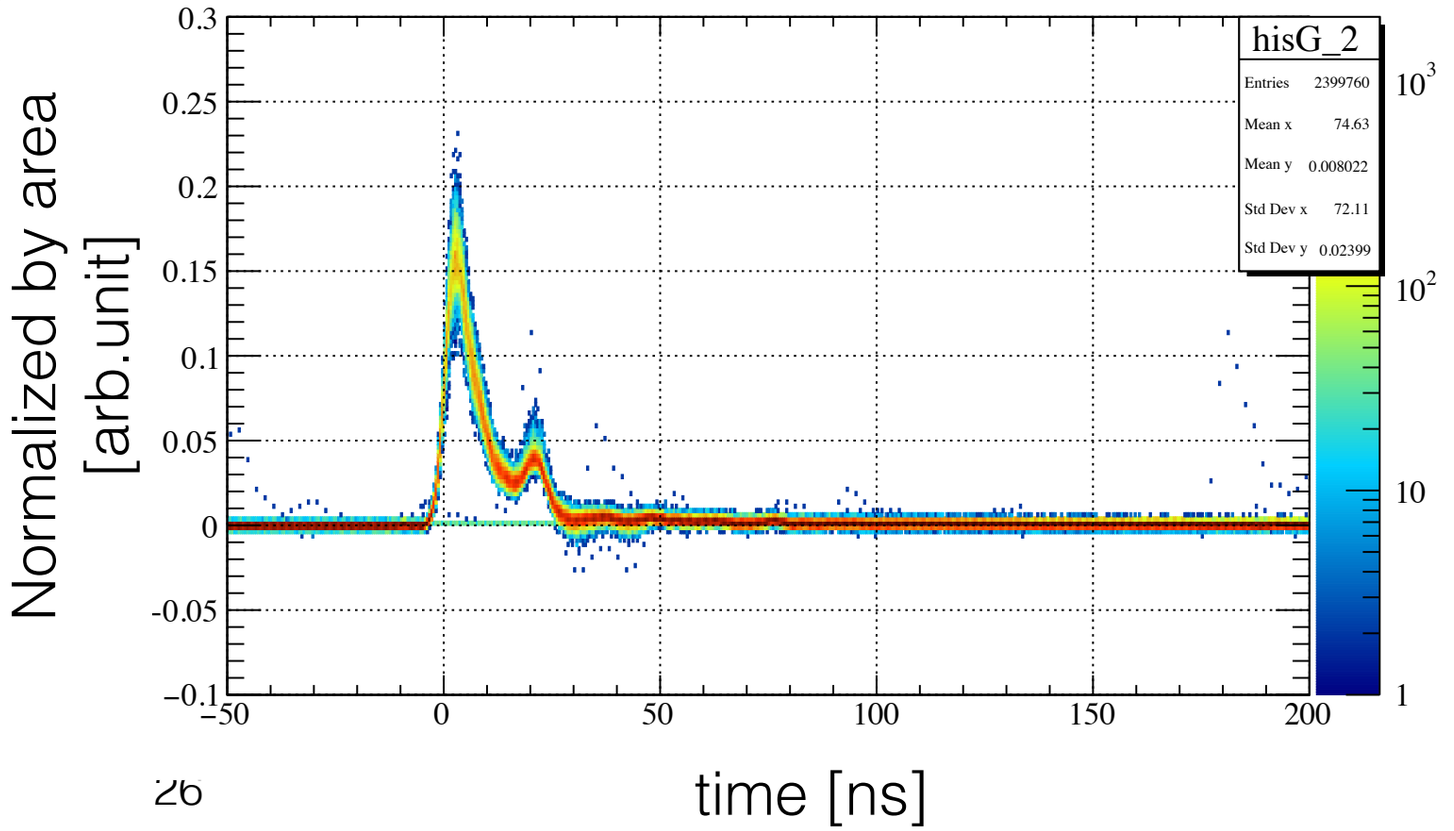
Data selection



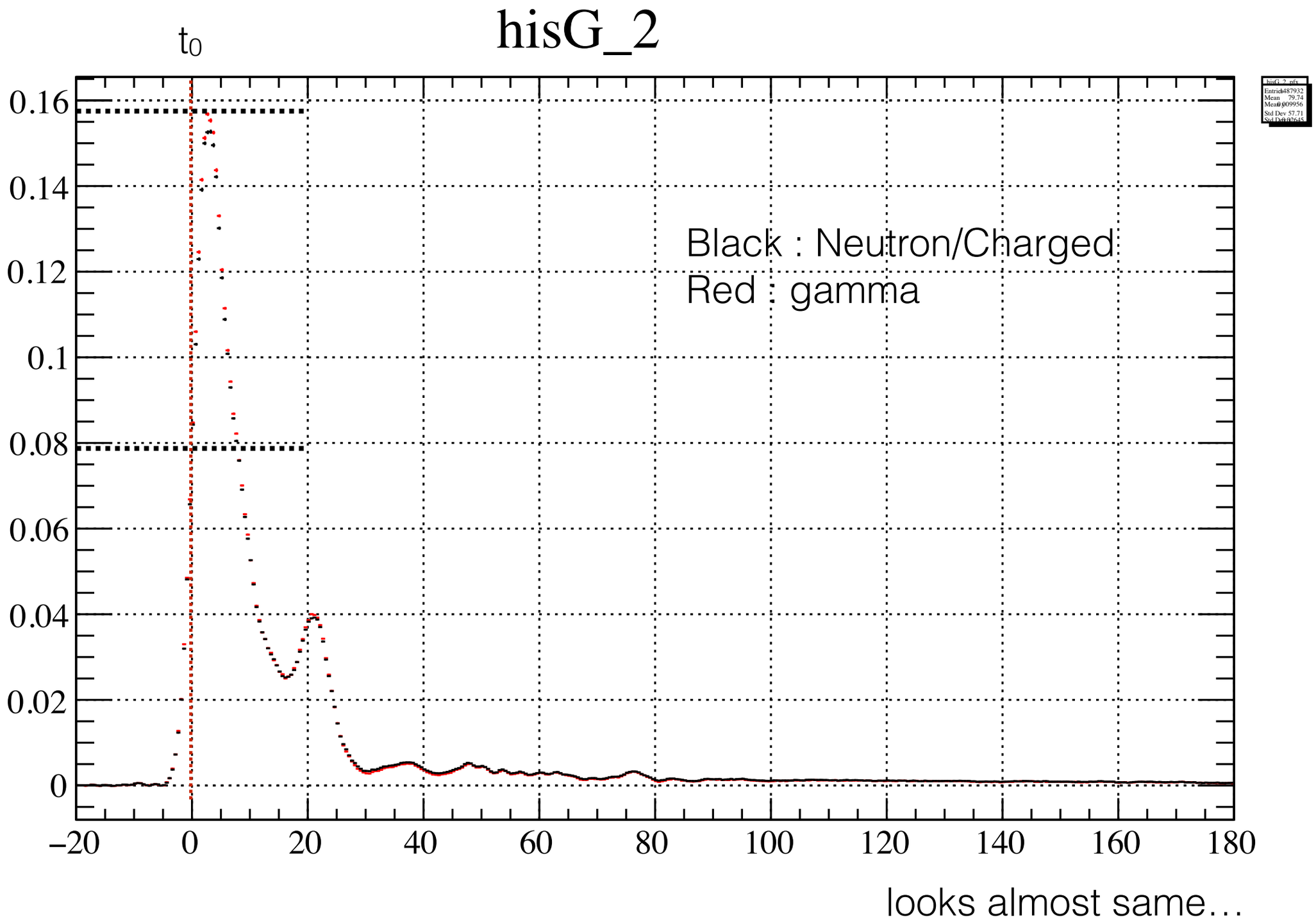
Waveform selection
peak height :
  100 - 200 cnt(50mV~100mV)
Area/peak :
  > 3 for both pmt signals of a mod.
gamma like : -20~20 ns
comparison : 40~80 ns

TOF(MeanTime - FA_time)

Waveform normalization
-All waveforms were aligned their half-peak time
-Nomalization factor :
  integral from -20 ns to 180 ns.

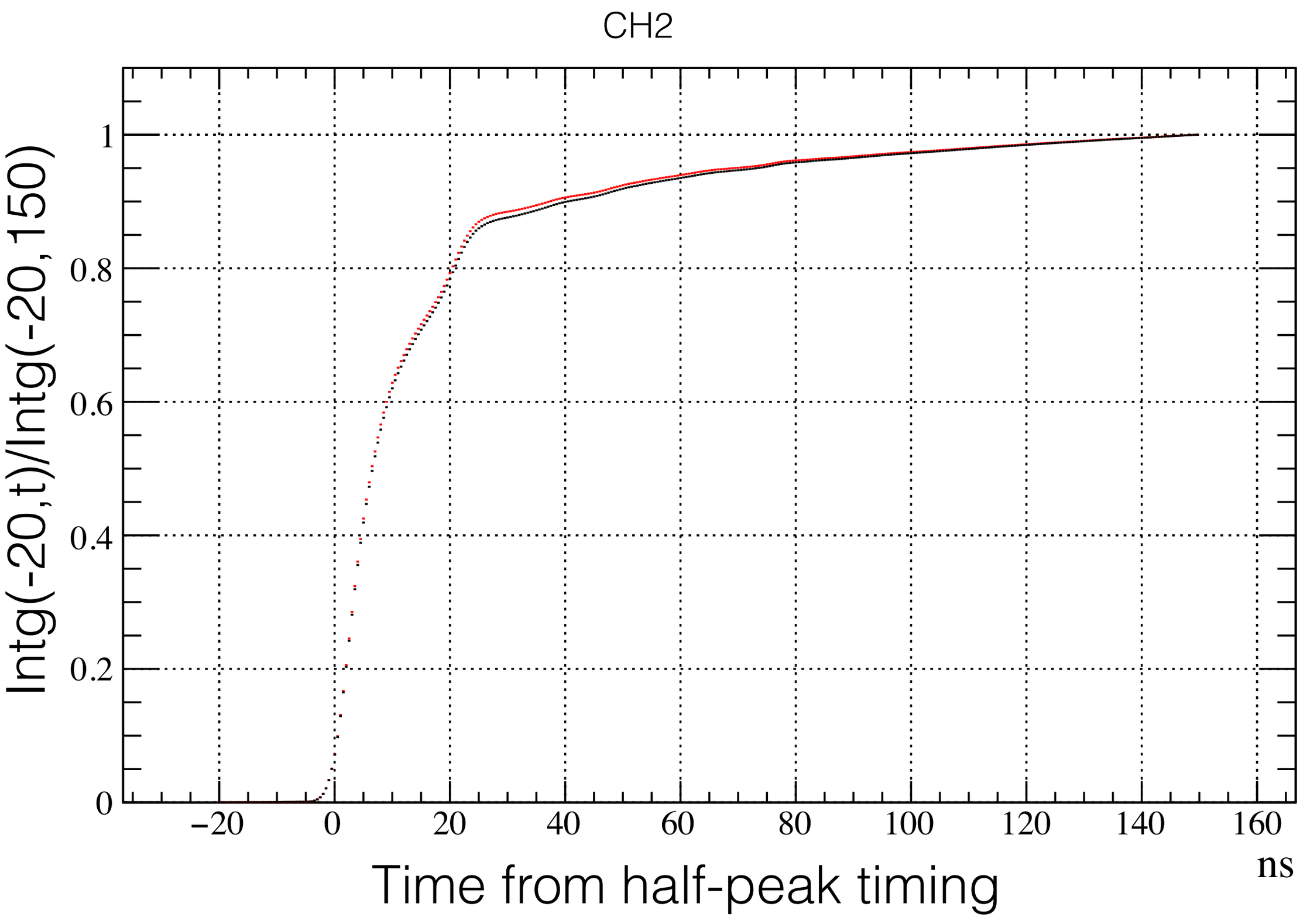


Common waveform of gamma and neutron/charged

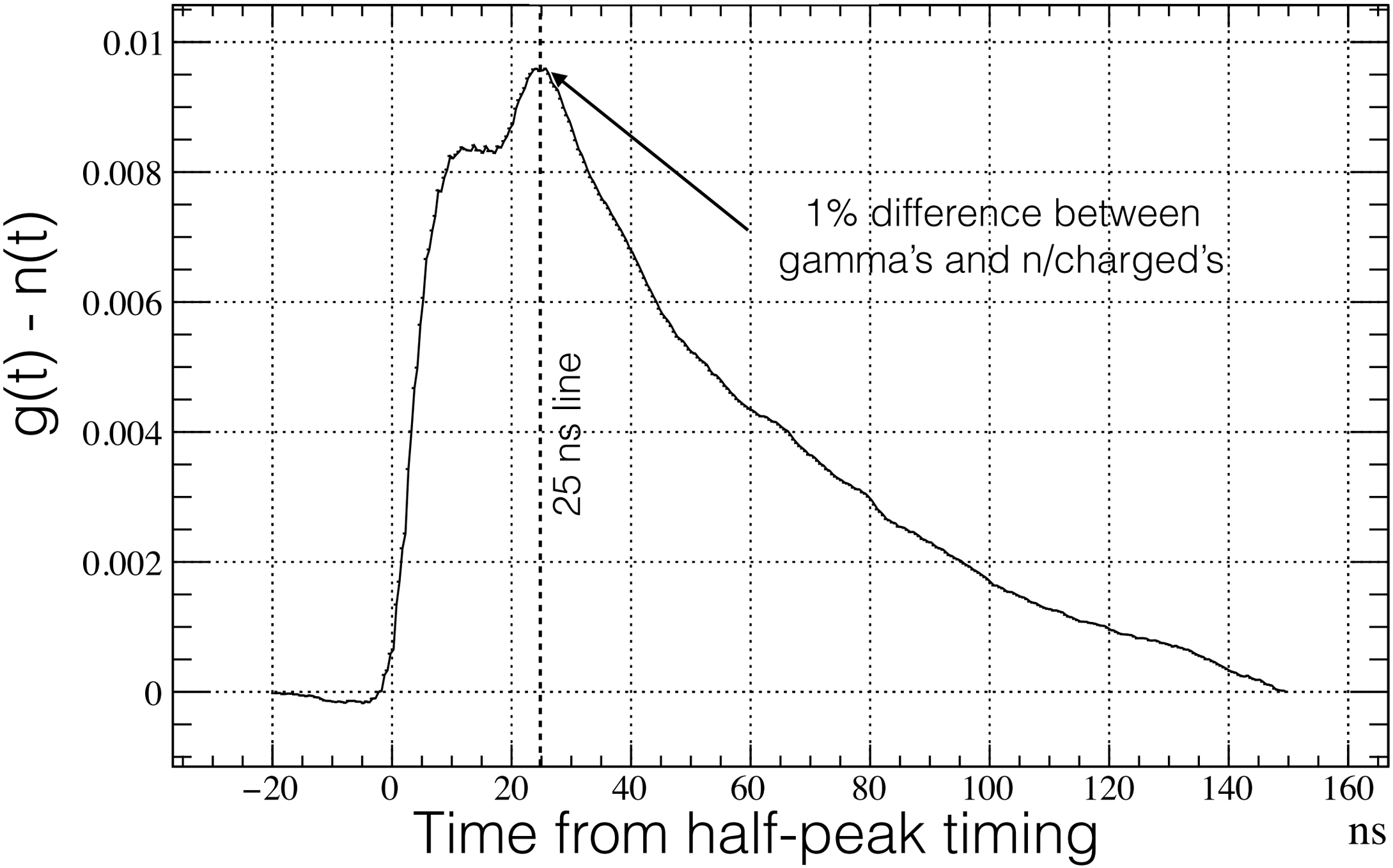


looks almost same…

Integral test



Difference


0.01
0.008
0.006
0.004
0.002
0
g(t) - n(t)
1% difference between
gamma's and n/charged's
25 ns line
−20
0
20
40
60
80
100
120
140
160
Time from half-peak timing
ns