Analysis of LGAD test beam at Tohoku in February 2021

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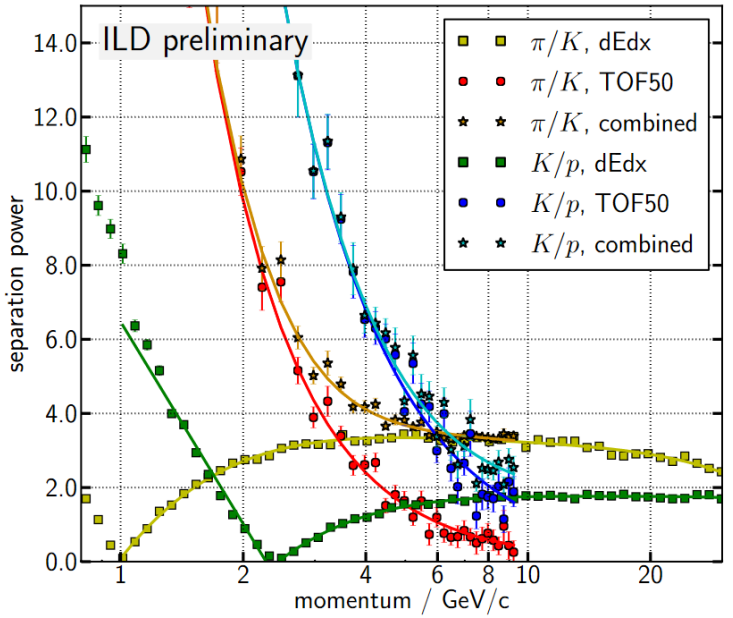
Particle Identification using ToF

- Particle Identification by dE/dx and momentum:
  Region where particle identification becomes ineffecient
- Using the ToF (Time of Flight):
  Improvement of separation power (~5 GeV)

$$v = d/\mathrm{ToF},\ \beta = v/c = m/E = p/\sqrt{m^2 + p^2}$$

$$\Delta m^2 = 2(m^2 + p^2)\frac{\sigma(ToF)}{ToF} \sim 2p^2\sigma\frac{ToF}{ToF} < \frac{m_K^2 - m_\pi^2}{3}$$

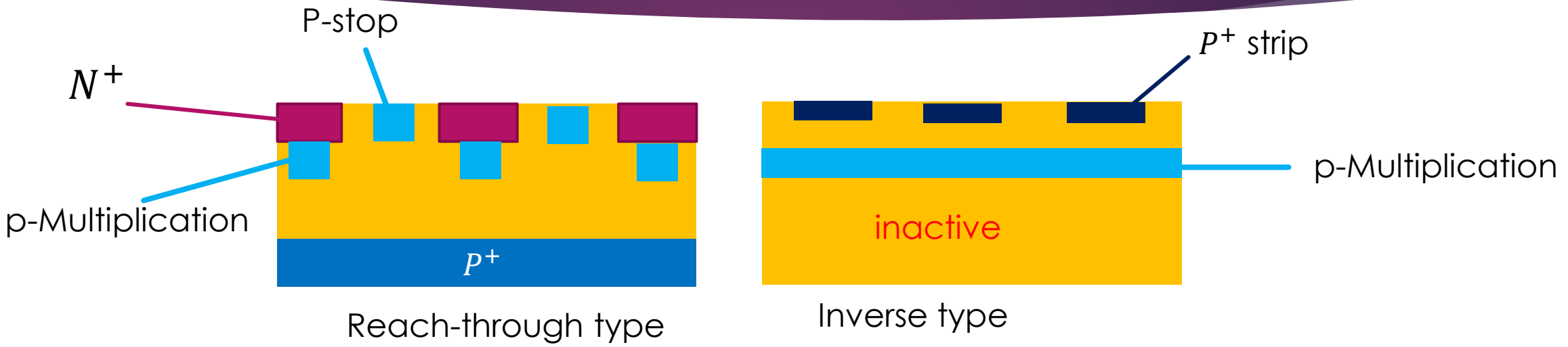
$$\rightarrow p_{max} < \sqrt{\frac{m_K^2 - m_\pi^2}{6 \cdot \sigma(ToF)} \cdot \frac{d}{c}}$$



Lever Arm of 3.0m assumed

Identified Particle	**π/K**			**K / proton**		
Time resolution[ps]	100	50	10	100	50	10
Momentum identified by 3σ[GeV/c]	1.94	2.74	6.12	3.26	4.60	10.29

LGAD silicon sensor

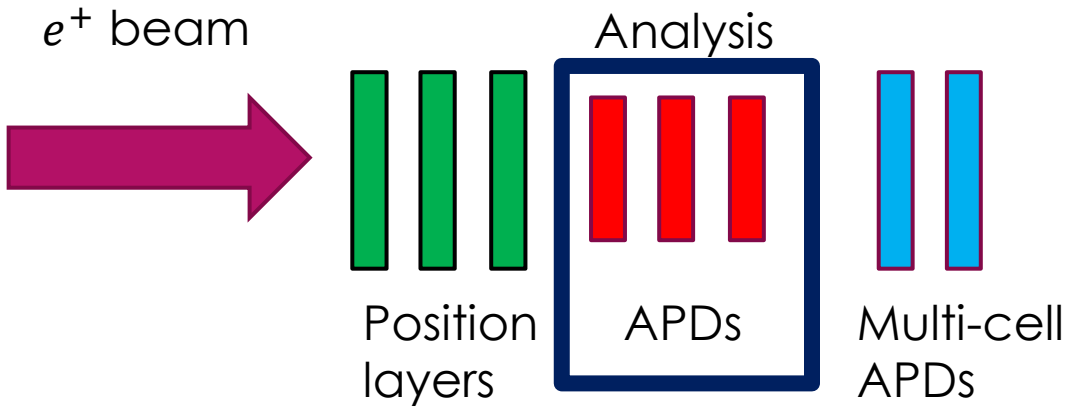


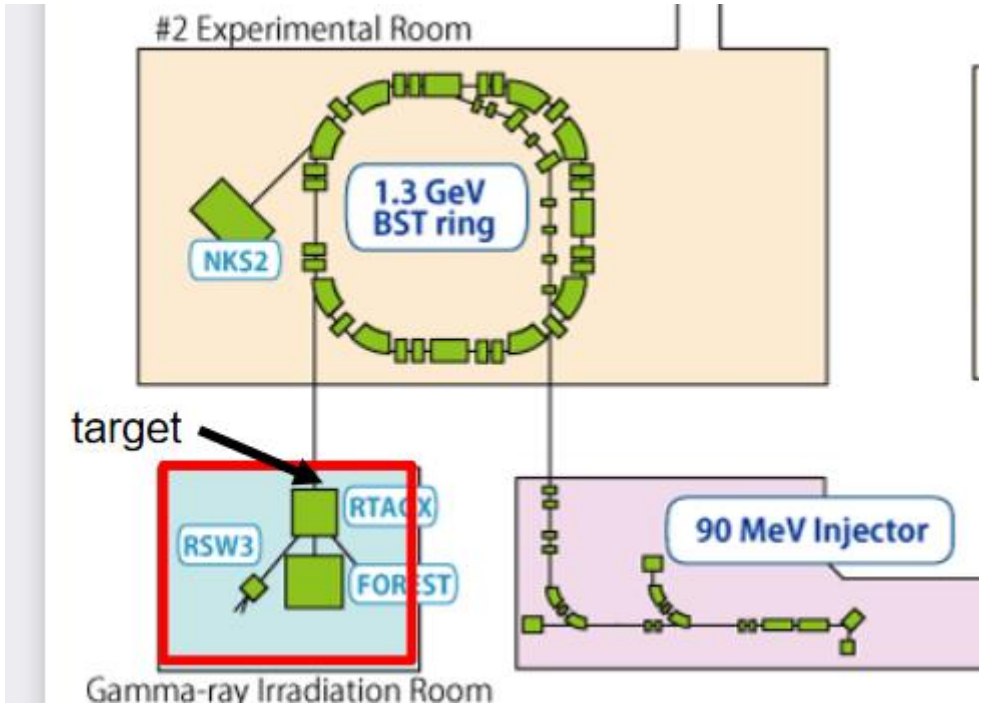
Spec,no	type	VBR[V]	Size[mm]
S8664	Inverse	400	3ϕ, 5ϕ
S5344/5345	Inverse	150	3ϕ, 5ϕ
S2384/2385	Reach-through	150	3ϕ, 5ϕ
S6045	Reach-through	200	3ϕ,5ϕ
S8550-02	Inverse	400	Array

← Used in this analysis

Test beam at ELPH, Tohoku University

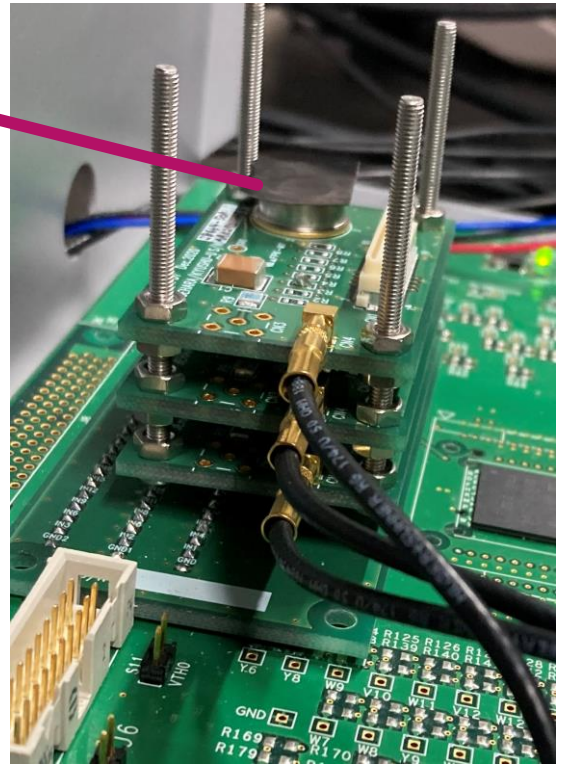
- The positron beams
  Momentum : ~ 770MeV
  Rate : 1kHz with spot of a few cm
  Quasi-CW
- Used data : 60 minutes run

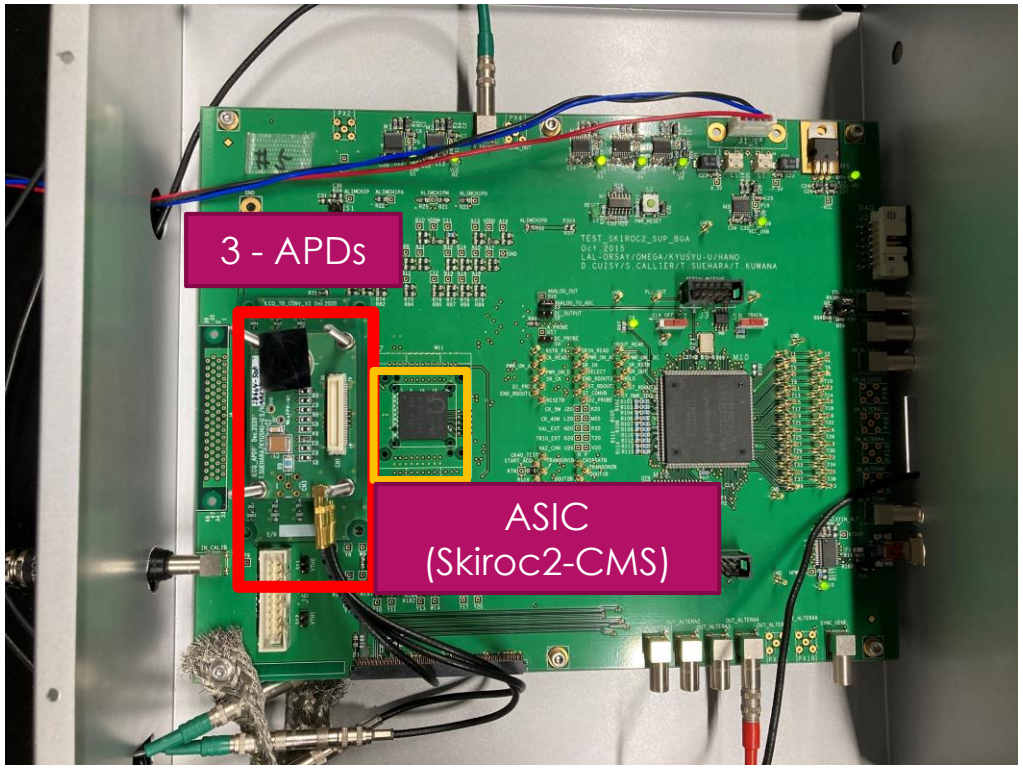




Electronics

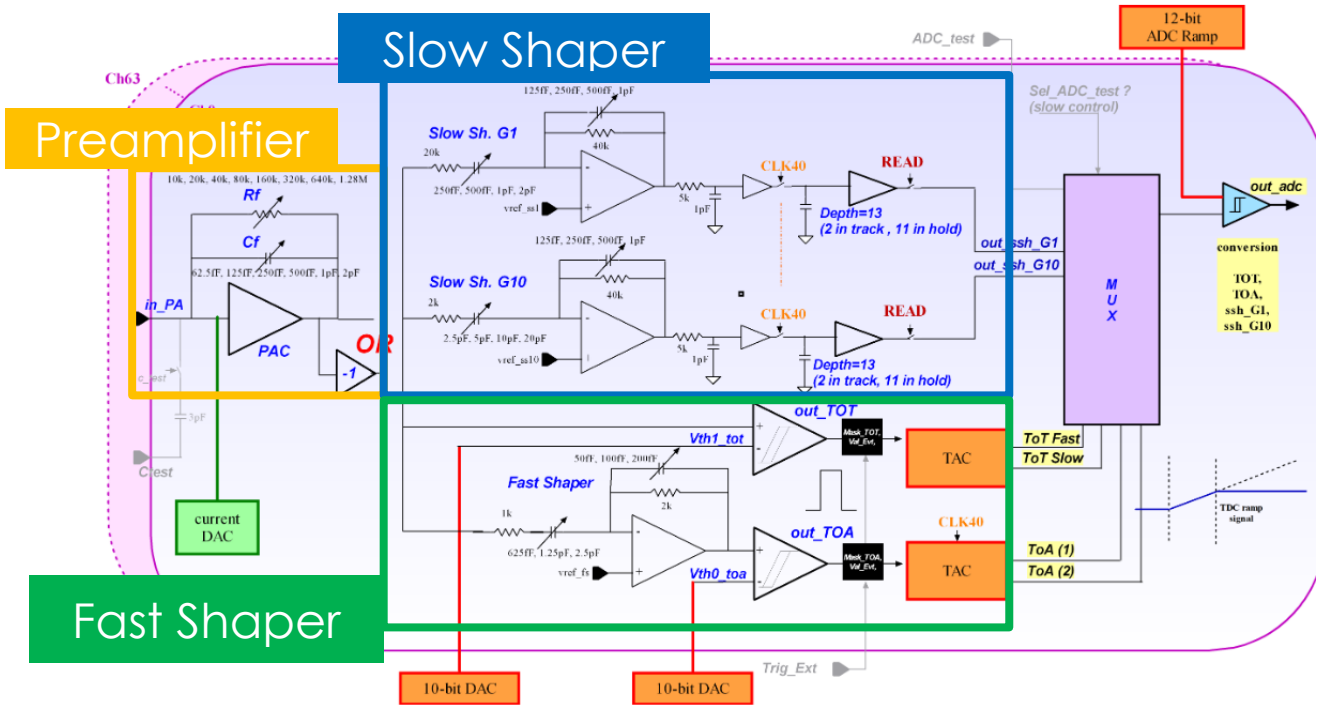
- SKIROC2-CMS Testboard





Skiroc2-CMS

- Skiroc : Compacted readout circuit
- Preamplifier → first stage amplification
- Fast Shaper → Measurement of TOT/TOA
- Slow Shaper → Digital information of ADC

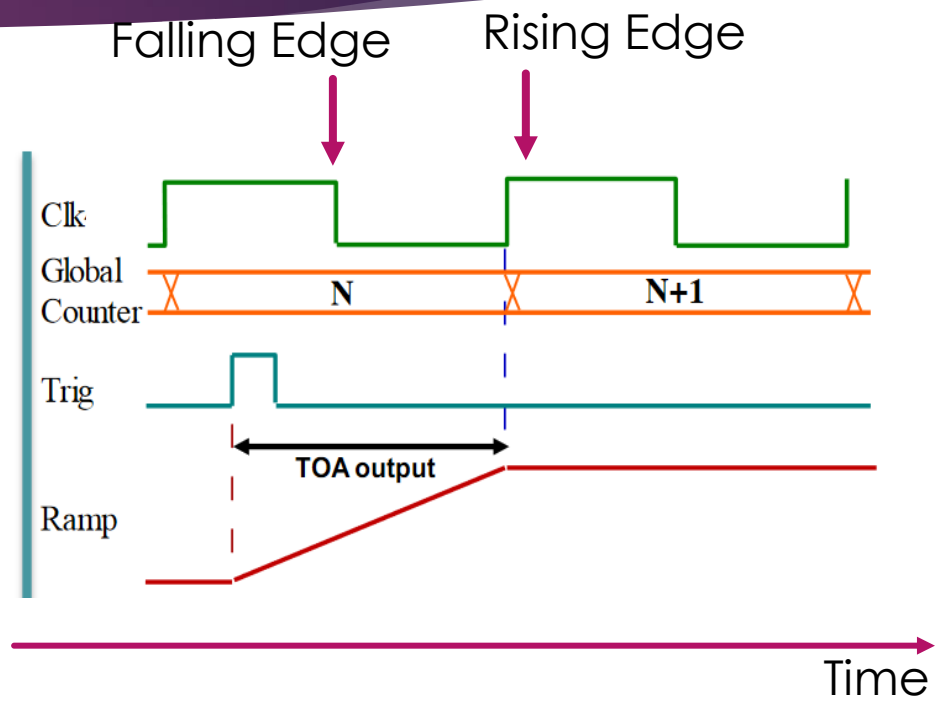


How to measure timing of hits

- TOA (Time of Arrival) :
  Time when the signal exceeds the threshold
  → The time difference between trigger and clock signal

- Charge begins to be accumulated at the time of the trigger.
  → The amount of charge represent TOA.

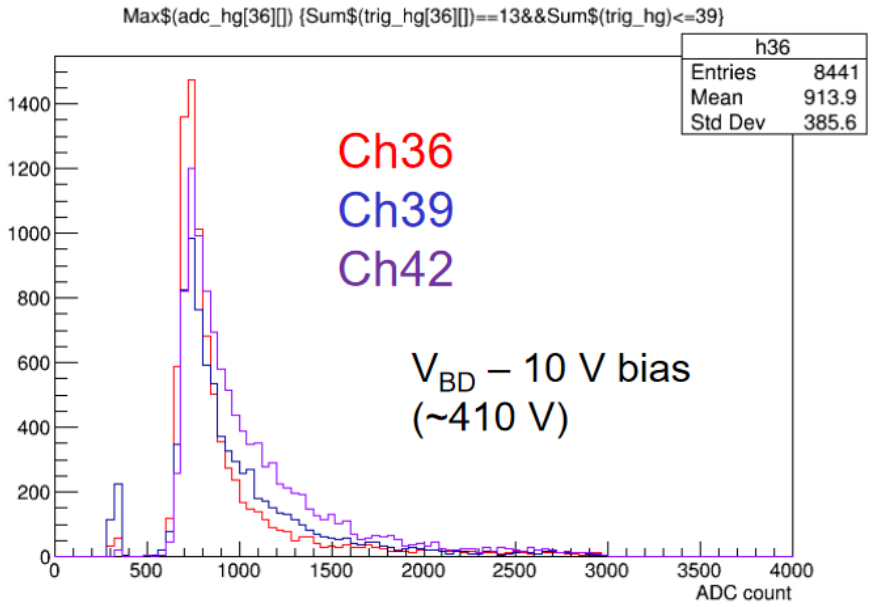
- Time to rising edge : TOA rise
- Time to falling edge : TOA fall

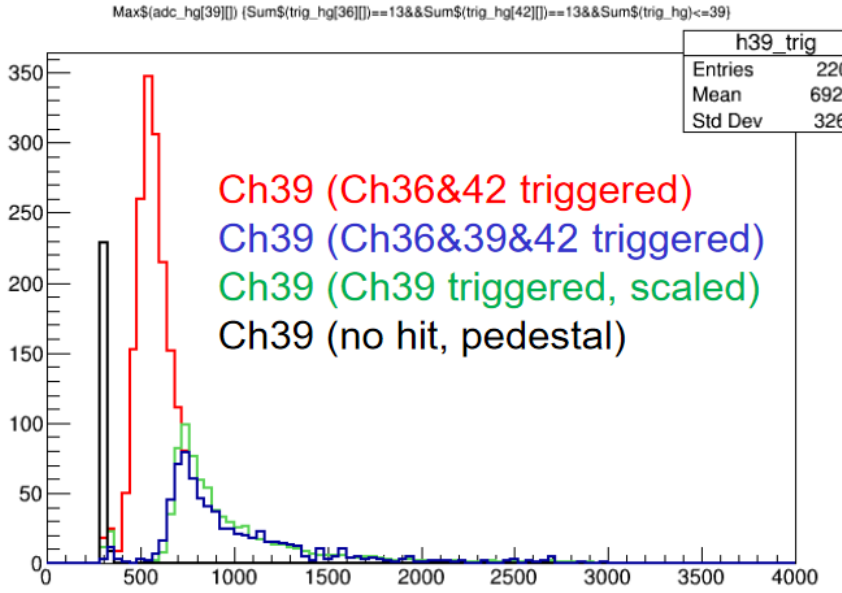


View of the test beam data

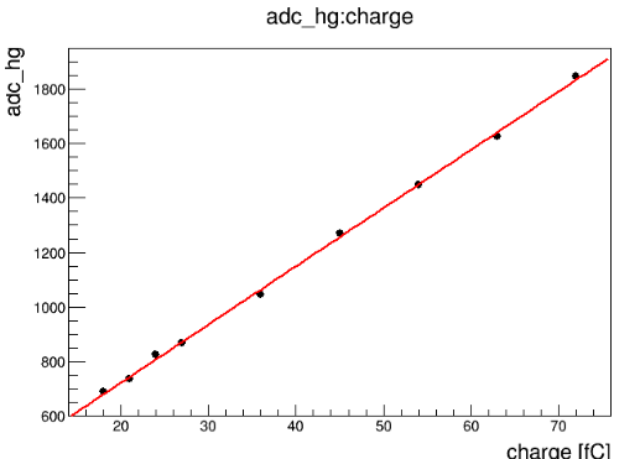
ADC spectrum of test beam data

ch36,39,42(from left)





ADC count

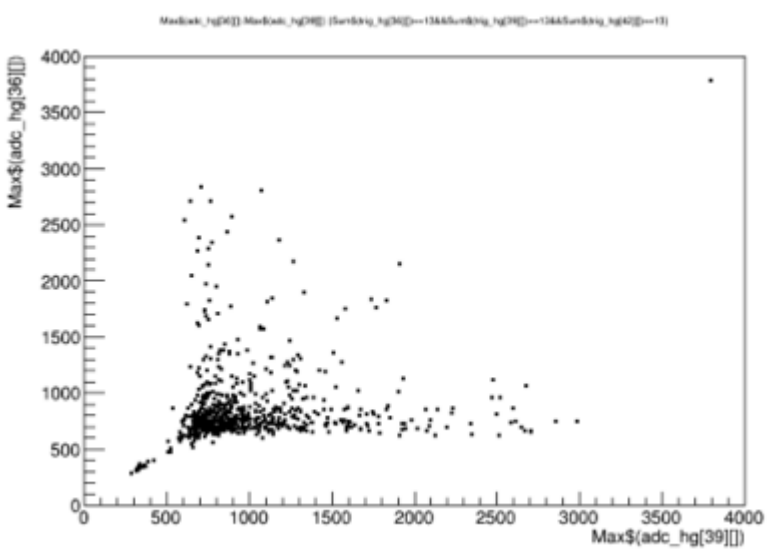


ADC vs charge

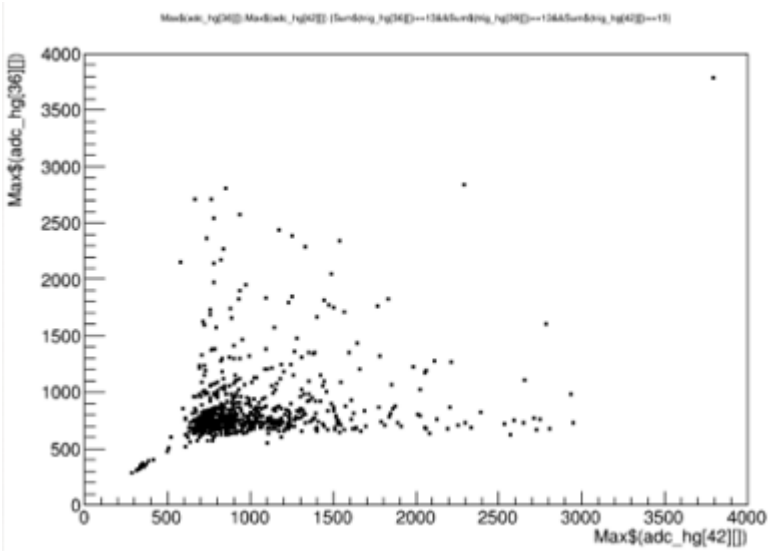
- Thr190 : ADC → Low efficiency
- To lower threshold, necessity to reduce the noise

ADC distribution of test beam data

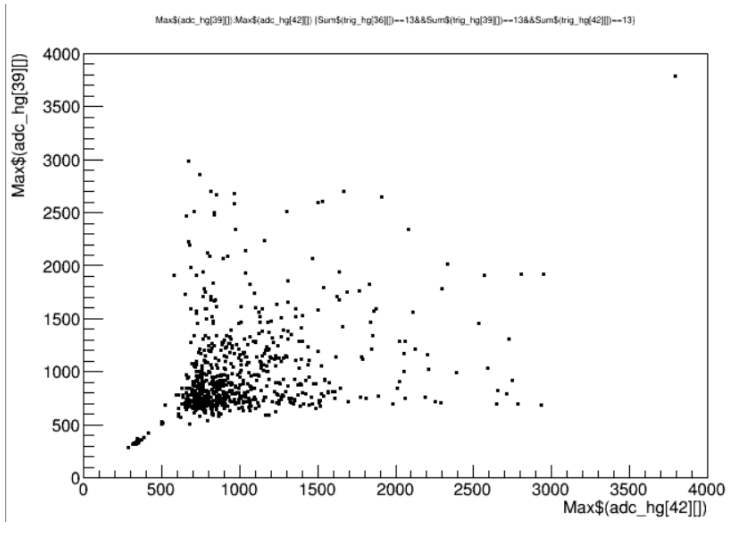
- ADC distribution



Ch 36 vs Ch 39



Ch 36 vs Ch 42



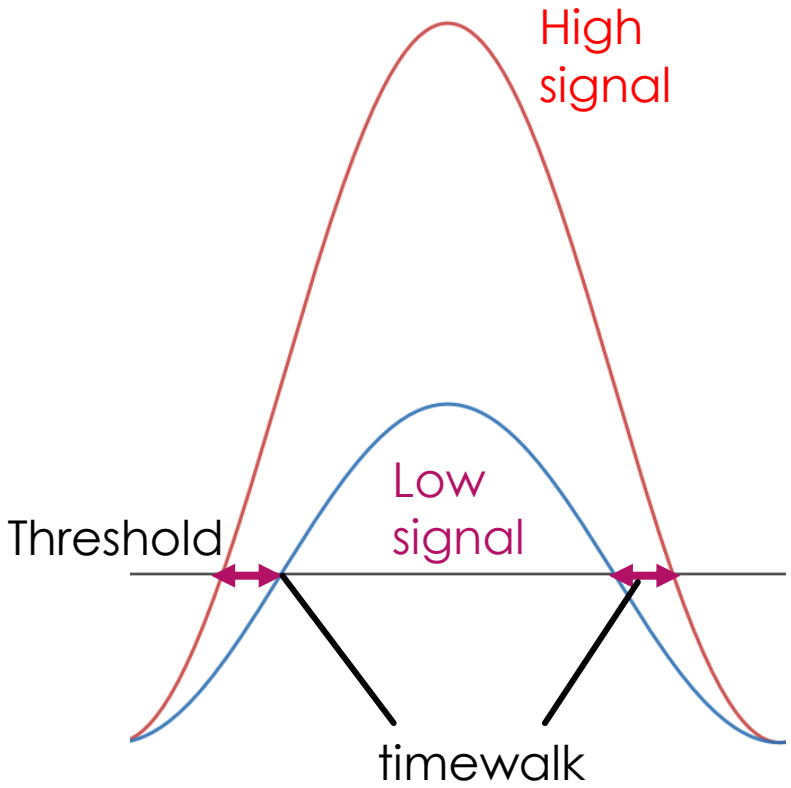
Ch 39 vs Ch 42

No strong correlation between 2 channels
→ Signal-like distribution

Analysis of data

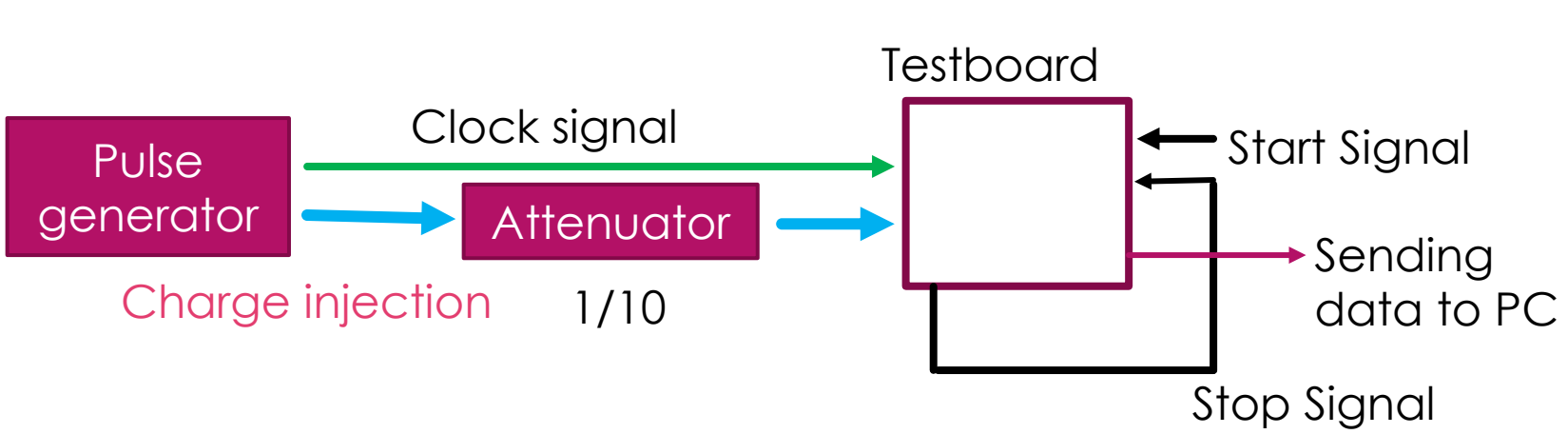
Timewalk correction

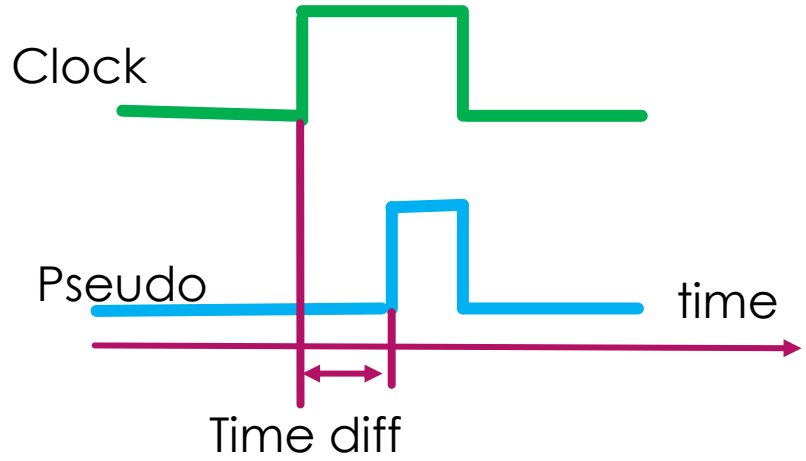
- Timewalk is the time shift depending on signal height.
- Higher signal : Earlier arrival
  Lower signal : Later arrival
  → Correction using signal height
- Using test board and pulse generator,
  the measurement of timewalk against the amount of charge was conducted.



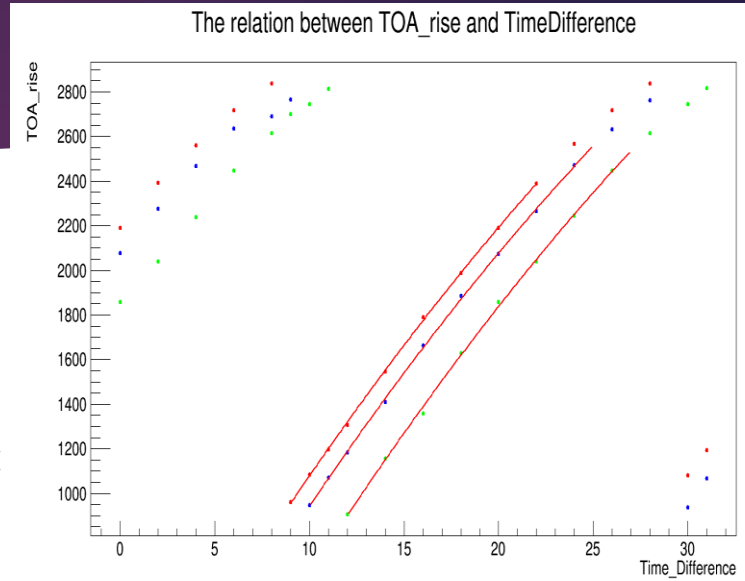
Measurement of Timewalk

1. Calibration of TOA : injection of 21fC/ 30fC/ 39fC; Time diff : 0ns ~ 20ns
2. Sending pseudo-signals with different pulse height to the test board
   Setting : Trigger threshold 190 (corresponding to ~ 14fC)
   Time diff : 0ns, 10ns



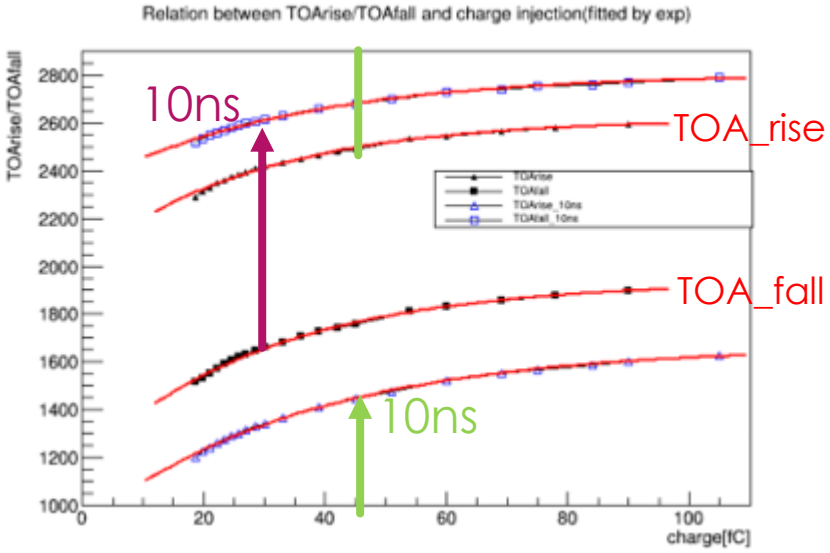


The results of Time walk measurement



- TOArise vs Time
  → The TOA between the two curves is inferred from the left curve (This curve is quadratic function)

Red : 39fC
Blue : 30fC
Green : 21fC



- TOArise vs. Charge
  The timewalk is well fitted by exponential function :
  (charge > 20 fC)

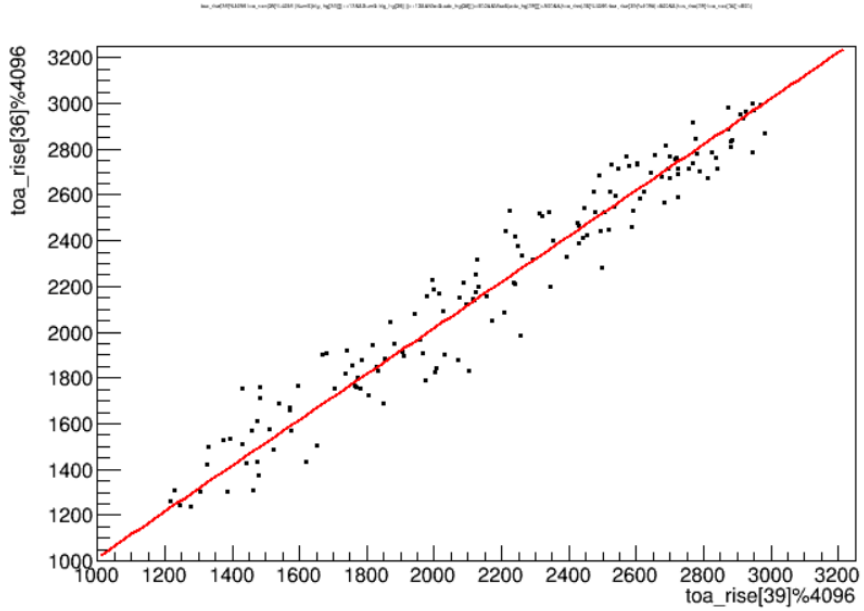
$$f(x) = a\exp(bx) + c$$
$$(a, b, c : \text{parameters})$$

- The shape of the curve have to be considered to be non-linearlity

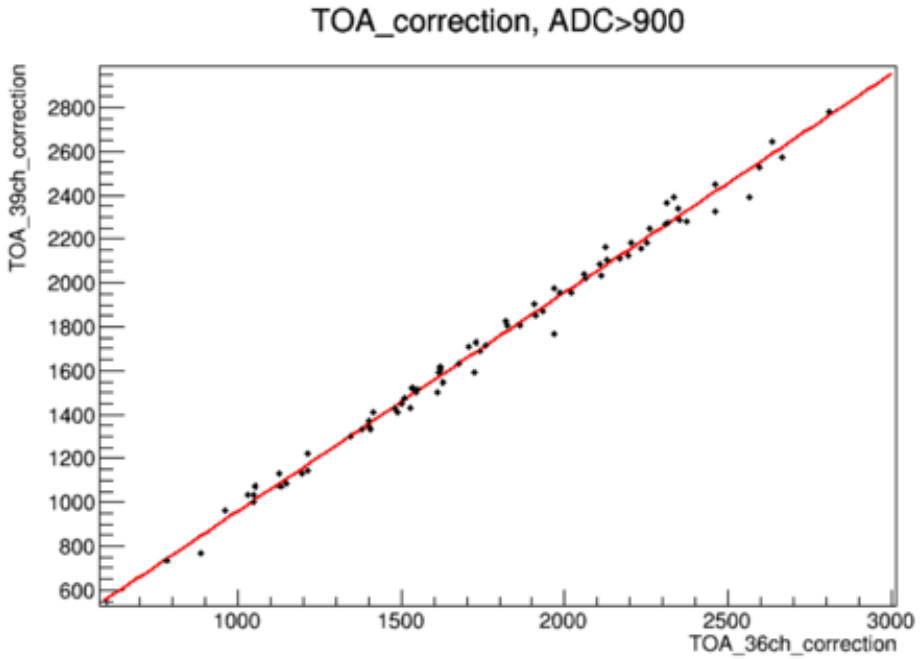
These two information was used to time walk correction

Results of time walk correction

- Without time walk correction (ADC > 900, Ch36 vs Ch39)



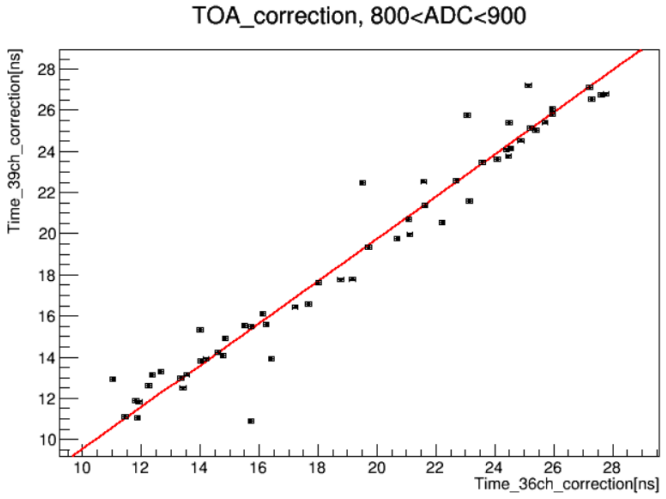
- With time walk correction



Results of time walk correction

Ch36 vs Ch39

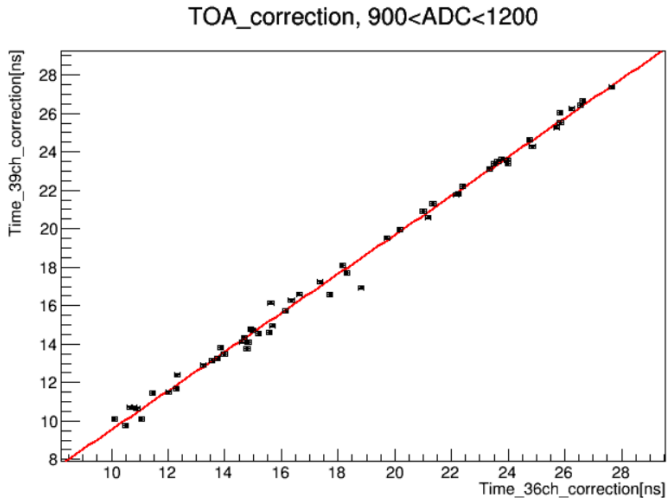
800<ADC<900



Std_dev /$\sqrt{2}$ = 750.2 ps

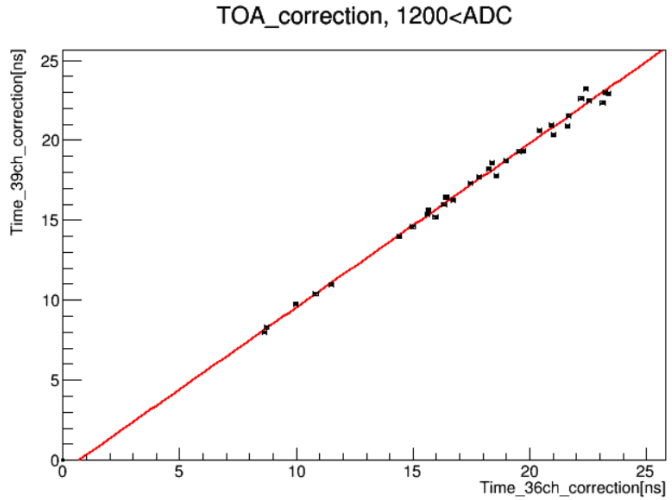
→ Jitter effect ?

900<ADC<1200



Std_dev /$\sqrt{2}$ = 266.7 ps

1200<ADC

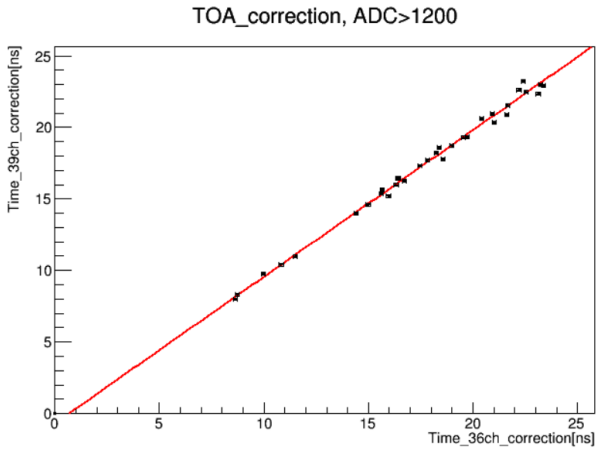


Std_dev /$\sqrt{2}$ = 242.6 ps

Results of time walk correction

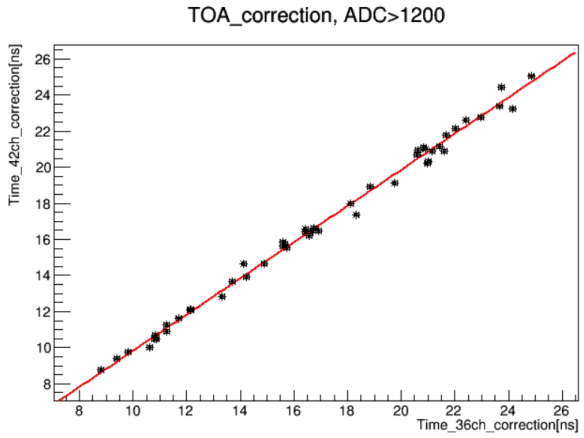
ADC>1200

Ch 36 vs Ch 39



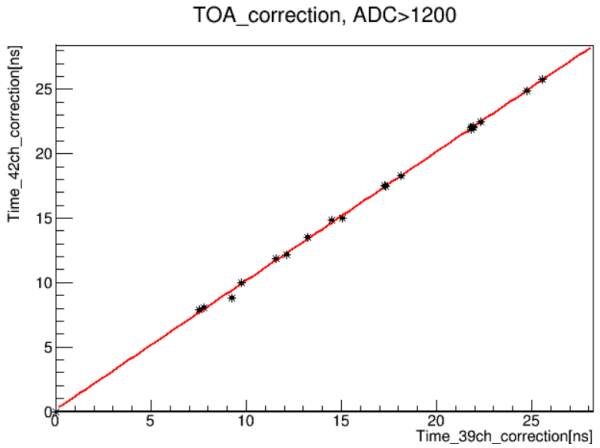
Std_dev /$\sqrt{2}$ = 242.6 ps

Ch 36 vs Ch 42



Std_dev /$\sqrt{2}$ = 256.1 ps

Ch 39 vs Ch 42



Std_dev /$\sqrt{2}$ = 171.6 ps

Summary and Plans

- We have conducted beam test at ELPH in February this year and the analysis of the data was conducted.
- By applying the time walk correction, the time resolution of LGAD in this test beam can be estimated as about 200 ps

Plan

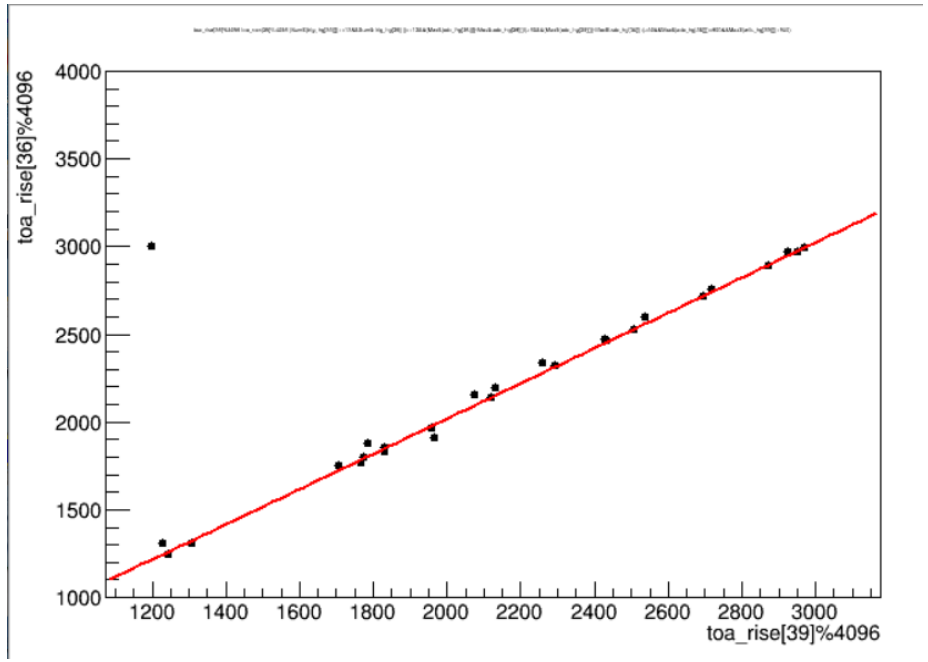
- Necessity : Reduction of the noise which is caused by HV
  Use of the board which has much less jitter
- We will conduct the test beam again at next month and try to use the new discrete ampreﬁed board.

Backup

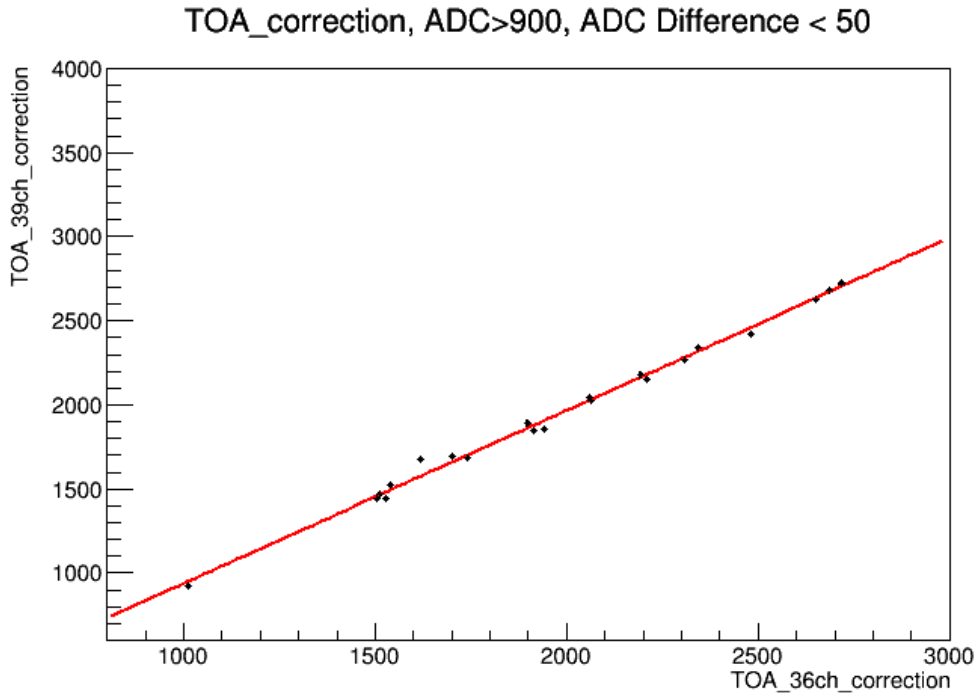
Results of time walk correction (Timewalk effect is small)

| ADC(ch36)- ADC(ch39) | <50

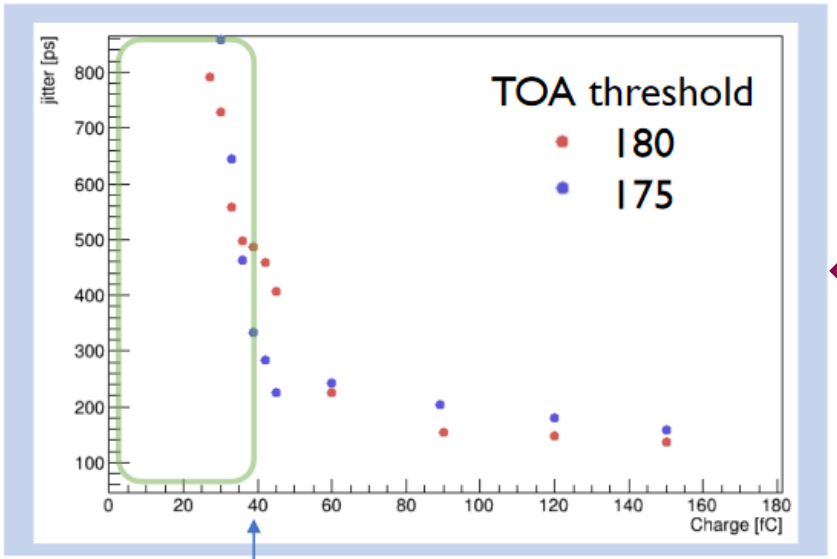
- Without timewalk correction (ADC Diff <50)

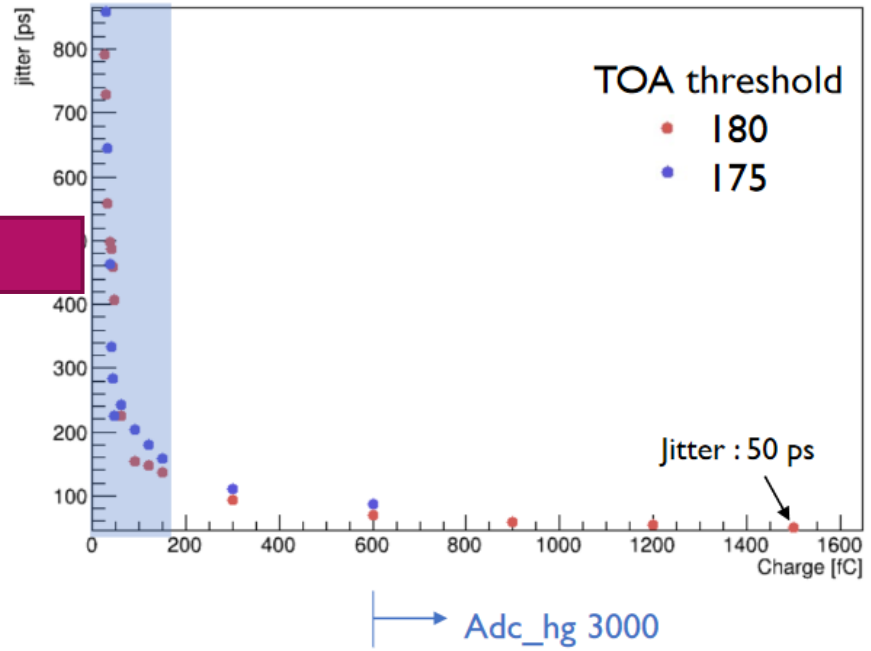


- With timewalk correction



Jitter measurement

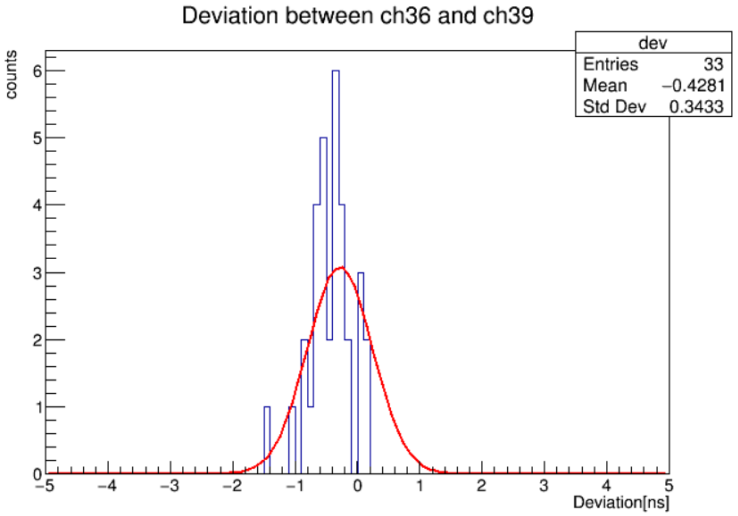




Jitter vs Charge

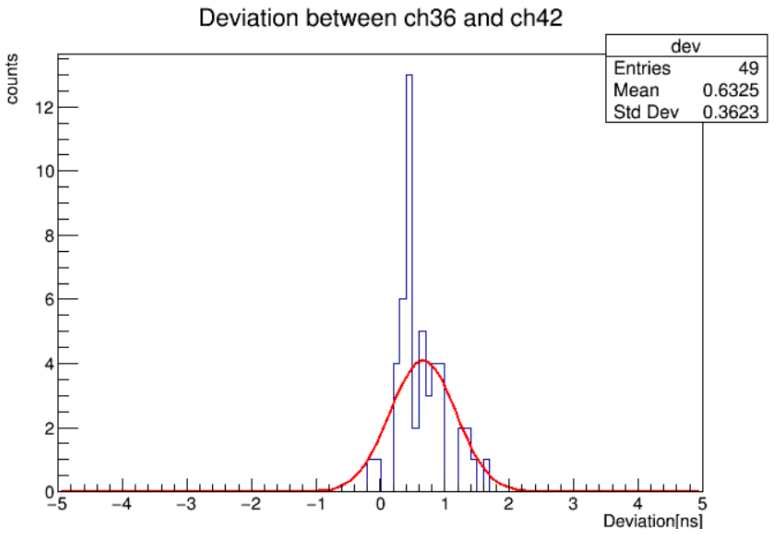
Deviation between channels

Ch 36 vs Ch 39



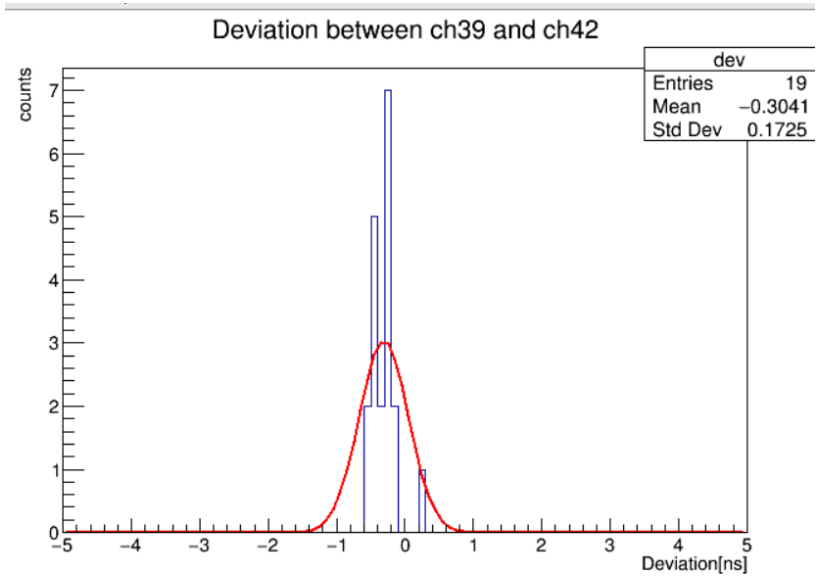
Mean : -0.280
Sigma : 0.525

Ch 36 vs Ch 42



Mean : -0.662
Sigma : 0.508

Ch 39 vs Ch 42



Mean : -0.310
Sigma : 0.360