New Electronics Development for Super-Kamiokande

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for the Super-Kamiokande Collaboration

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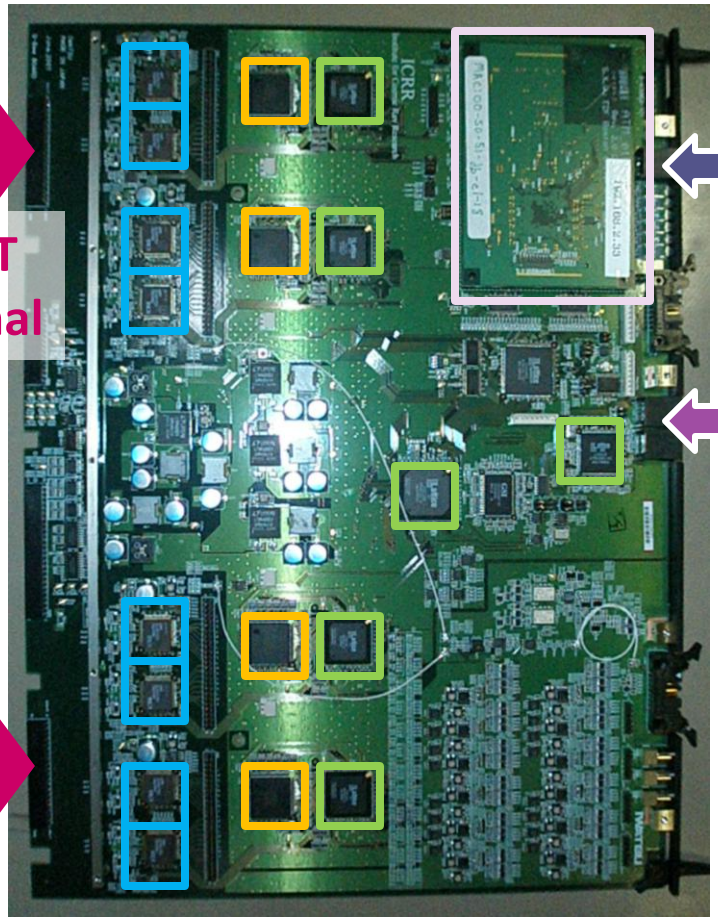
Motivation for new electronics system development

- Stable DAQ for the next 10~20 years
- Wide charge dynamic range
  - Better energy resolution for high energy (> a few GeV) ν events
- Hi-speed (dead-time free) DAQ
  - Nearby SN burst ν / Low energy solar ν / Relic SN ν

New front-end electronics, QBEE

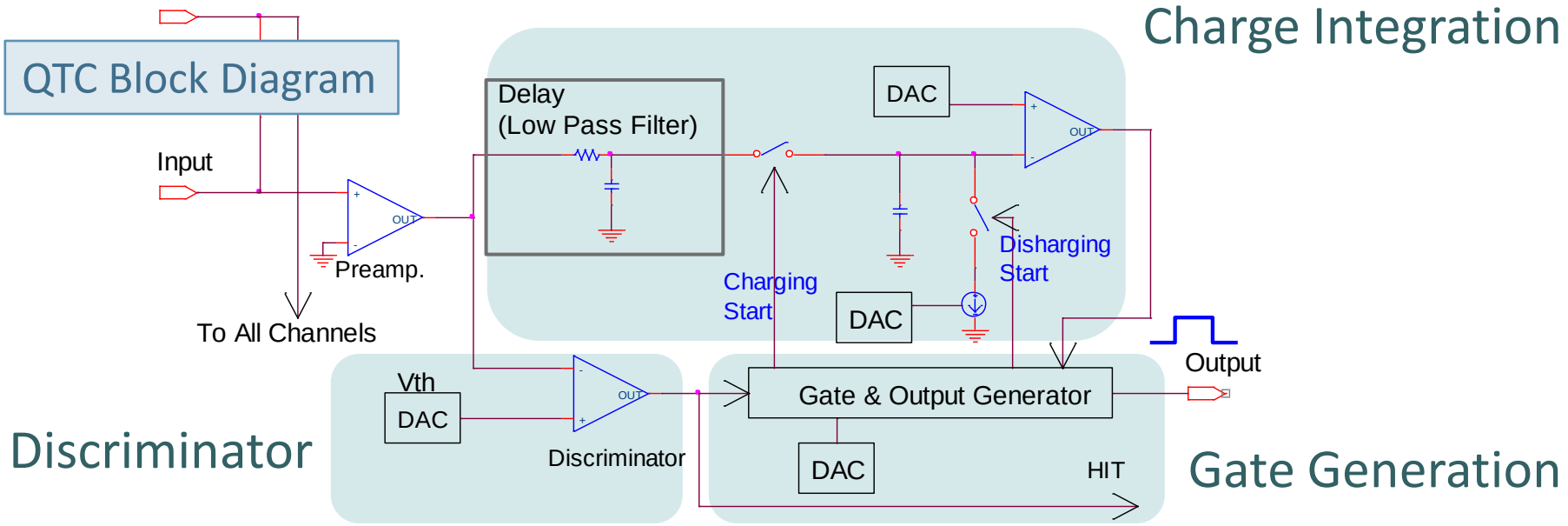
Network Interface Card

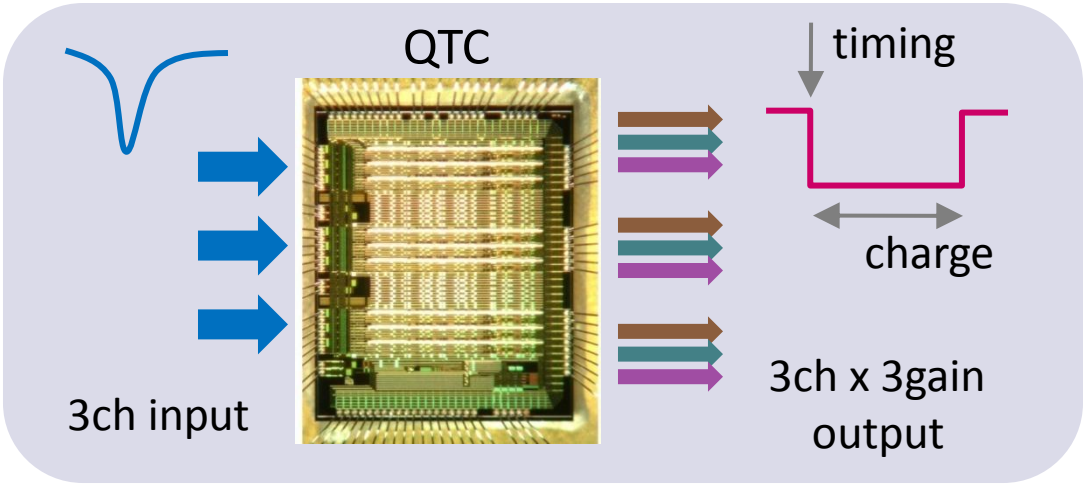


QTC-Based Electronics with Ethernet
(QBEE or QB)

- 24 channel input
  - QTC (custom ASIC)
  - multi-hit TDC (AMT3)
  - FPGA
- External clock (60MHz) input
  Serial timing signal input
- Ethernet readout
- On-board calibration pulser
- Low power consumption
  (< 1W/ch)

Custom ASIC QTC





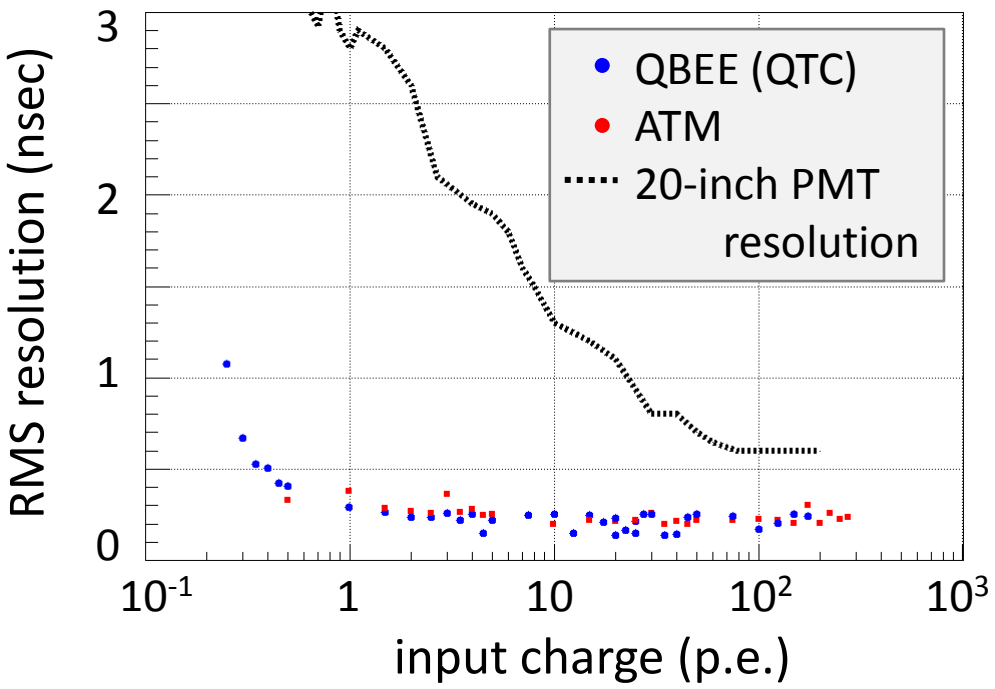
- built-in discriminator
- 400nsec charge gate
  ~ 1μsec / cycle
- 3 gain stages (ratio 1:7:49)

→ Only the data from the proper gain stage are left by FPGA

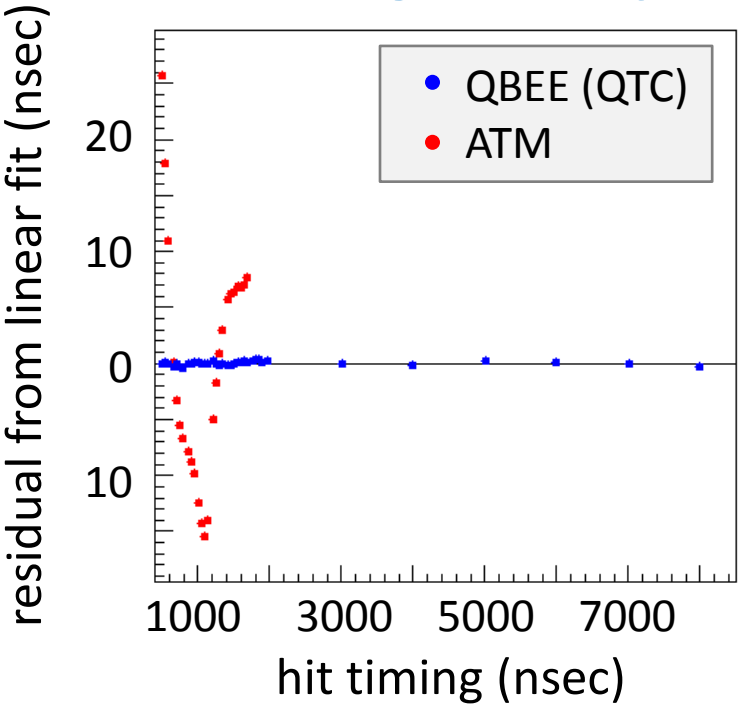
QTC performance (Timing measurement)

T : 0.52 nsec / count

Timing Resolution



Timing Linearity

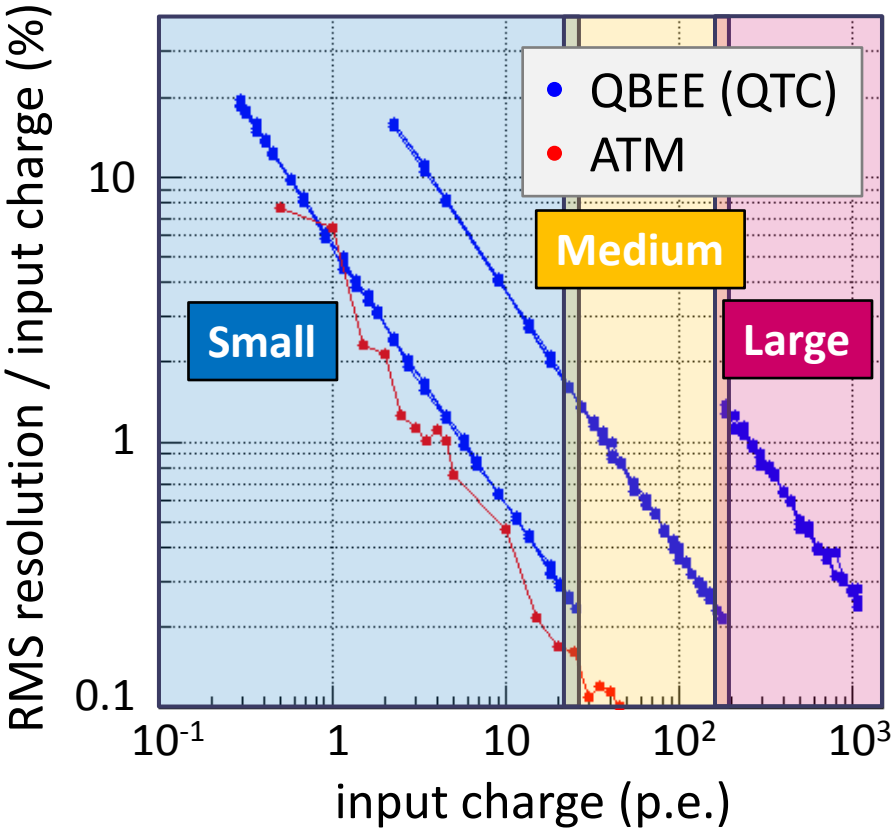


Good timing resolution
for 20-inch PMT signal

Perfect timing linearity !!

QTC performance (Charge measurement)

Charge Resolution

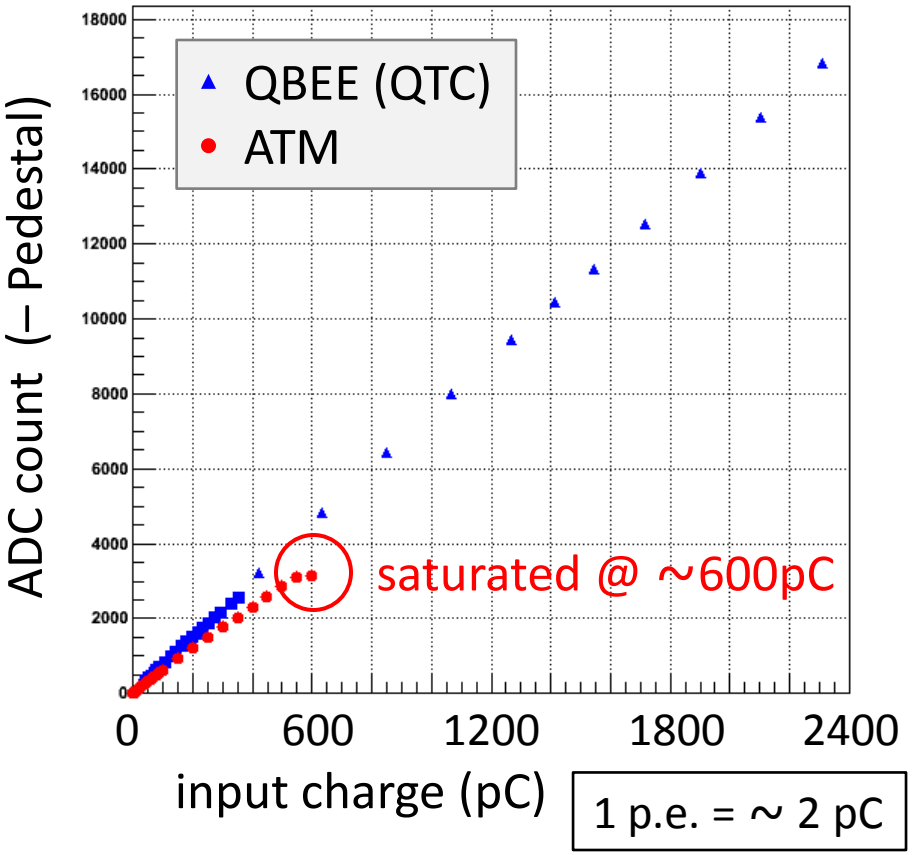


Good charge resolution

~5% @ 1 p.e.

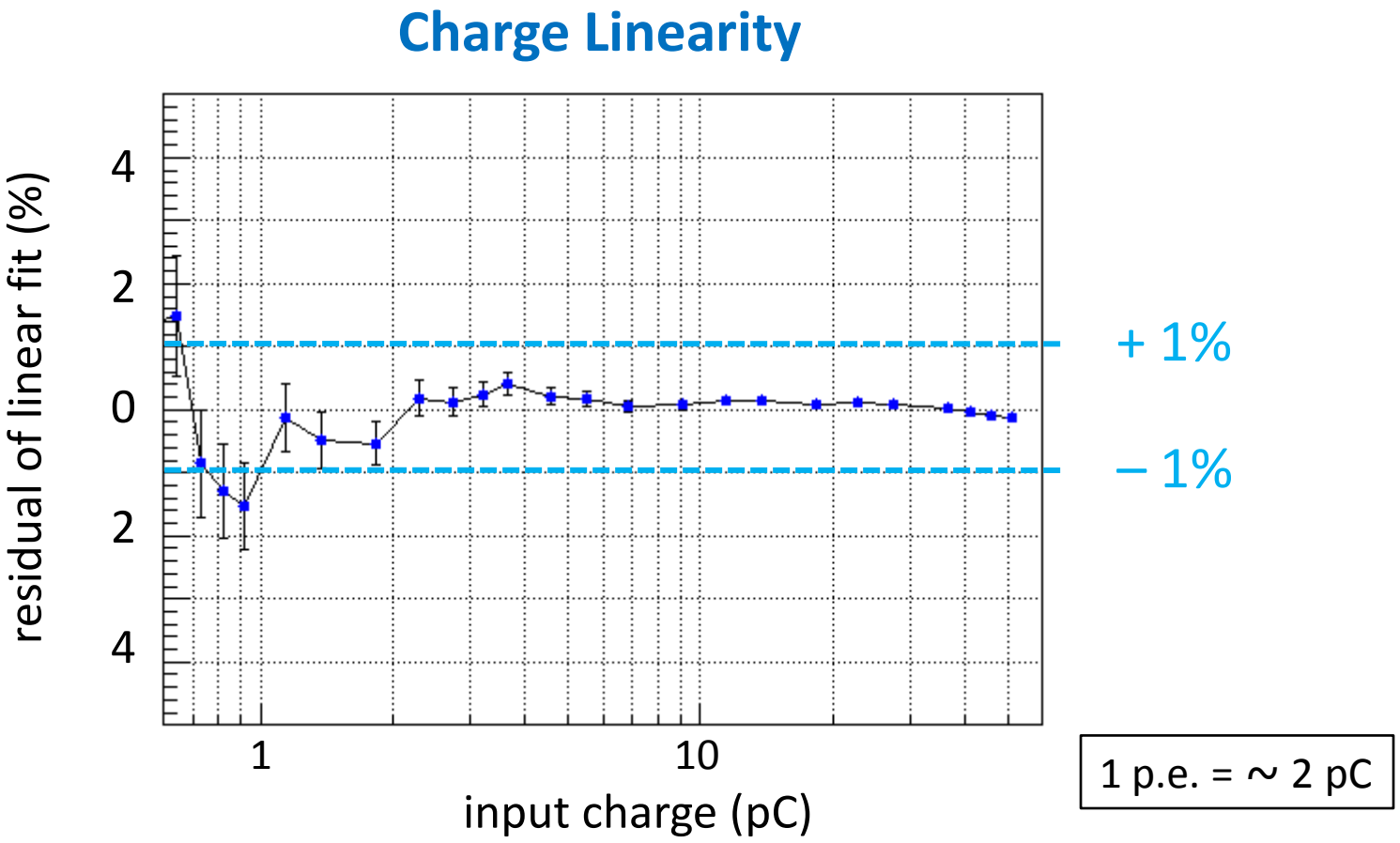
< 2% @ > 3 p.e.

Dynamic Range



No saturation over 1000 p.e. !!

QTC performance (Charge measurement) cont'd



±1% linearity is acheived

Master clock delivery

Master Clock Module (MCLK)

60MHz master clock
Serialized timing signal

Distributor

Central Hut

40 m twin-axial cable

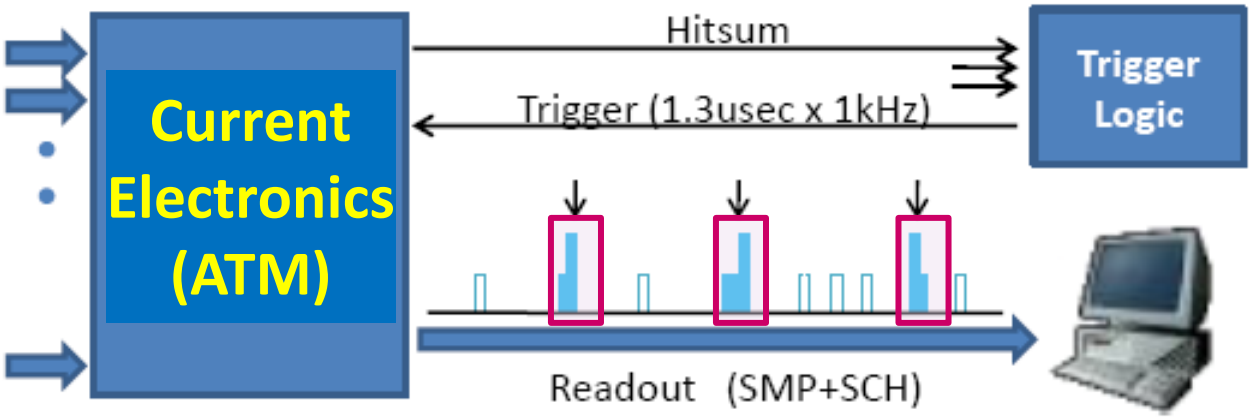
Each Hut

Distributor x 2

QBEE

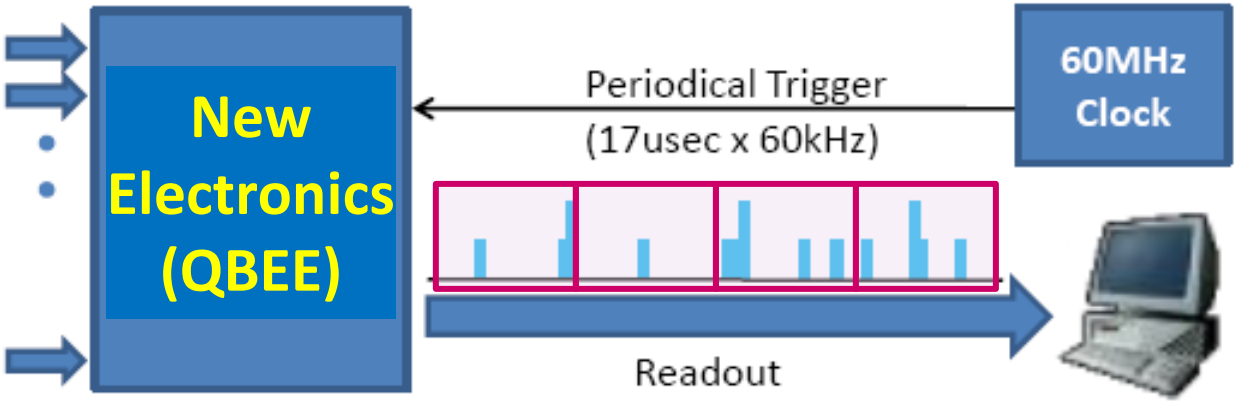
- A common 60MHz (~16.7nsec) master clock
  - QBEE synchronization
- Serialized timing signal (60kHz periodic)
  - TDC trigger, TDC reset
  - w/ 32bit serial number

Hardware trigger-less (record every hit) system



Hardware trigger by hit information (HITSUM)

1.3usec event window



Record every hit by

60kHz periodic timing sig.
x
17usec TDC window

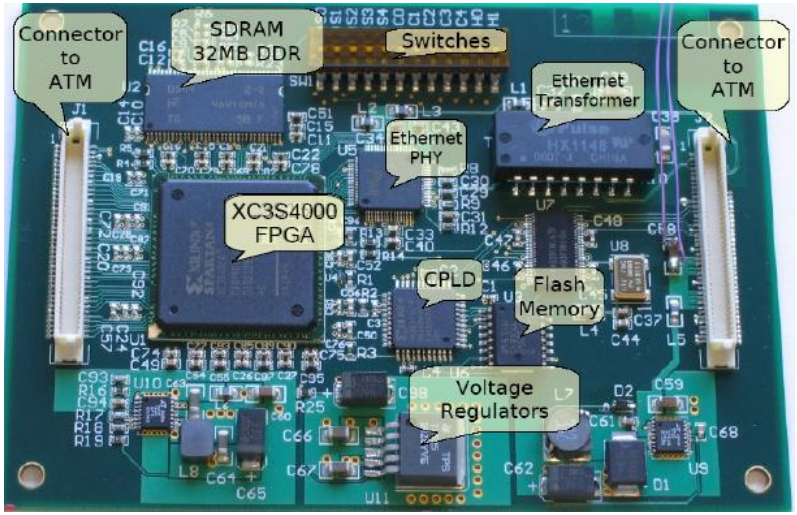
variable event window (by software trigger)

Simple hardware system +

Flexible and intelligent event selection by software trigger

Ethernet readout and QBEE throughput

Custom Network Interface Card

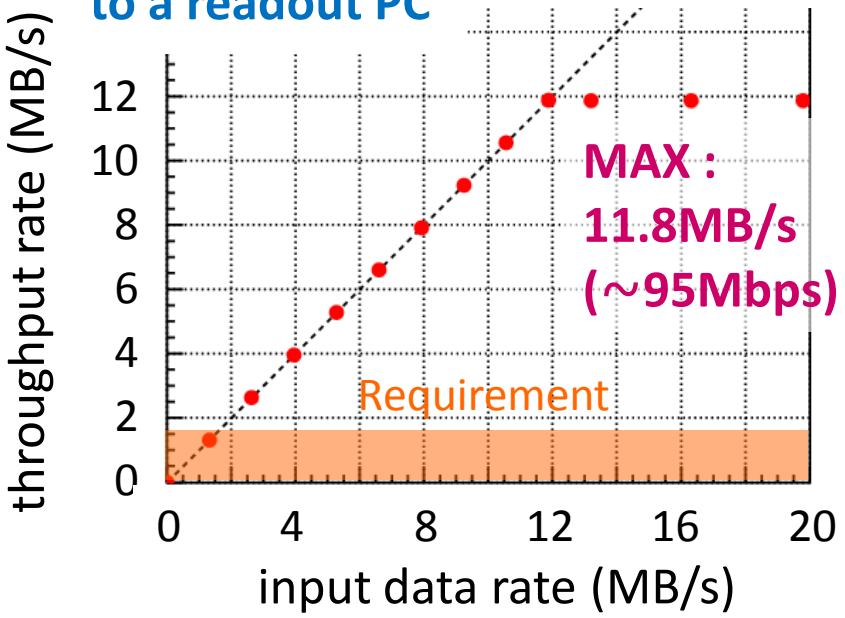


TCP/IP firmware (SiTCP) by
T. Uchida (Univ. of Tokyo)

Hardware and firmware by Boston-U

- Each card has IP address
- 32MB SDRAM
- Data readout : TCP
  Control (resister R/W) : UDP

QBEE throughput from analog input to a readout PC



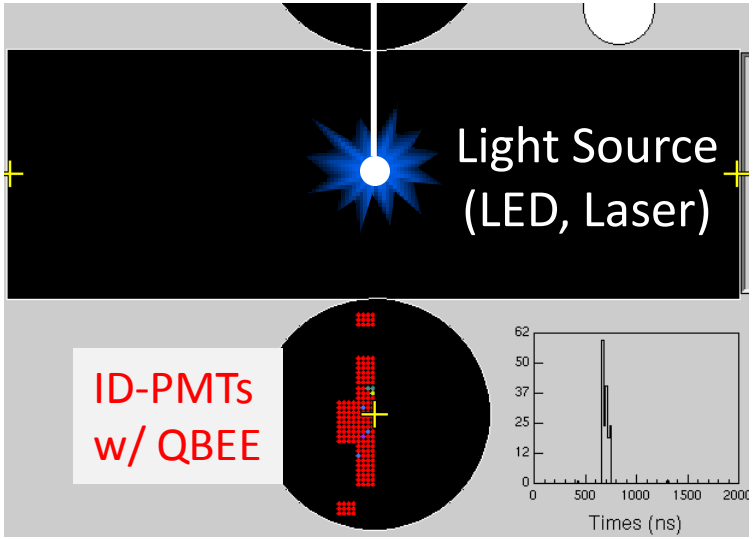
- Required data transfer speed :

  (PMT dark noise) 10kHz x 6byte x 24ch
  = 1.5MB/sec/board

→ Fast enough. Reaches the theoretical limit of 100BASE-TX !!

New electronics system test with the SK detector

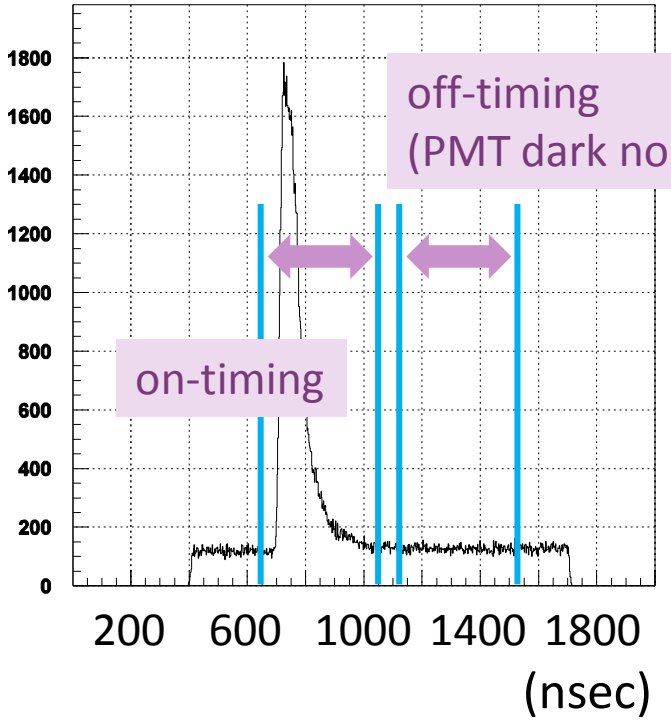
- End-to-end system test with part of the SK detector
  - 7/17/2007 ~ 7/27/2007
  - 9 prototype QBEEs
    - 7 for 168 Inner Detector (ID) PMTs
    - 1 for 24 Outer Detector (OD) PMTs
    - 1 for recording light source flash timing



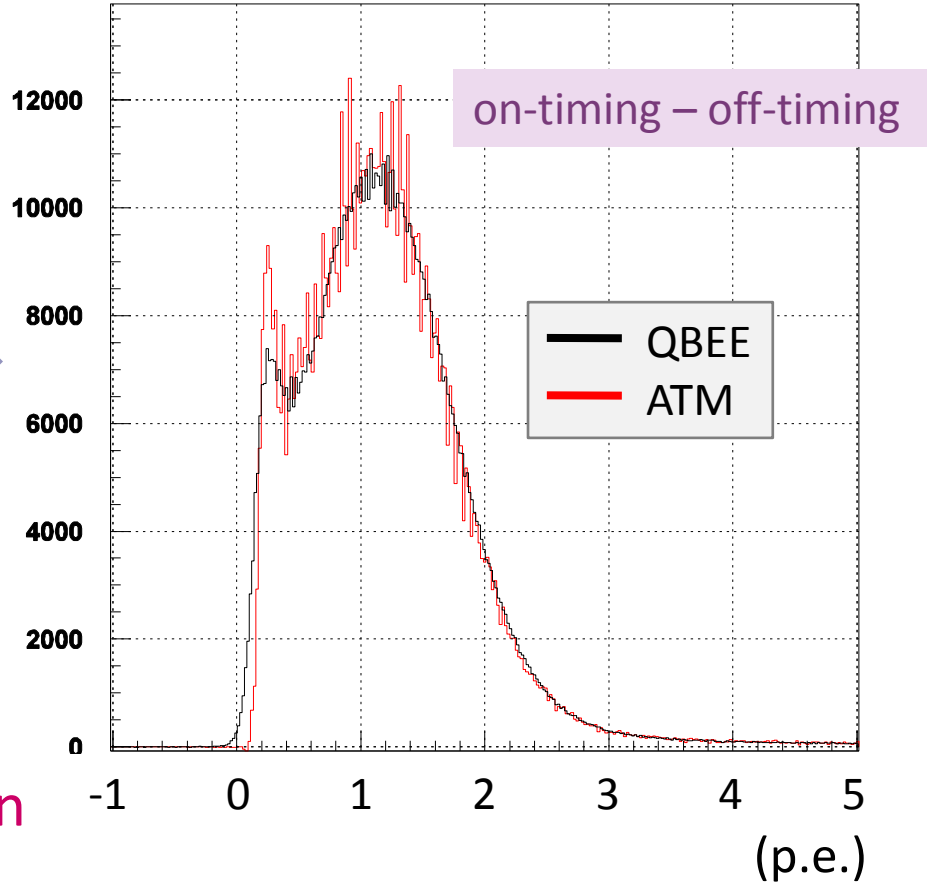
  - Feasibility study of the whole new system
    - QBEE → online → software trigger → data reformat → offline analysis

Single p.e. @ 1/4 p.e. threshold (LED, occupancy ~0.5%)

Hit Timing



Single p.e. Distribution

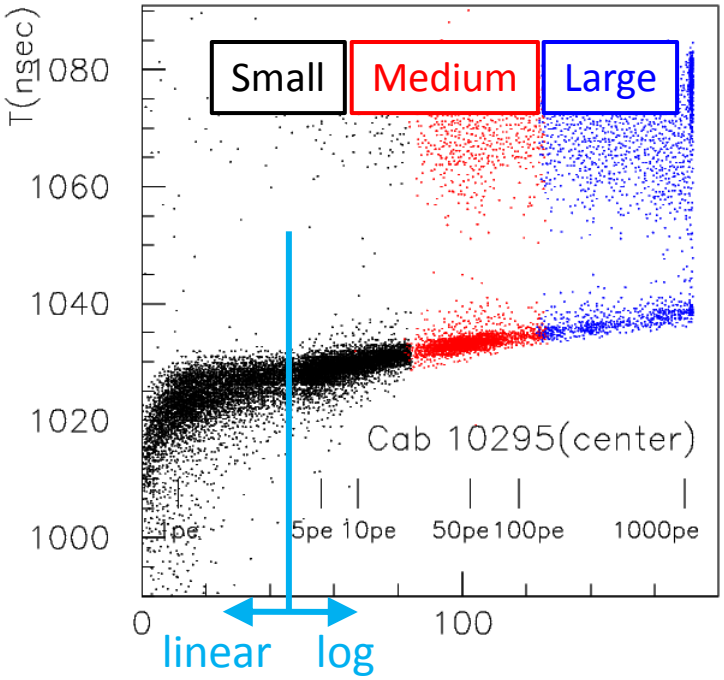


High S/N for single p.e. detection

Good agreement with single p.e. distribution by ATM

Timing response (Laser + PMT + QBEE)

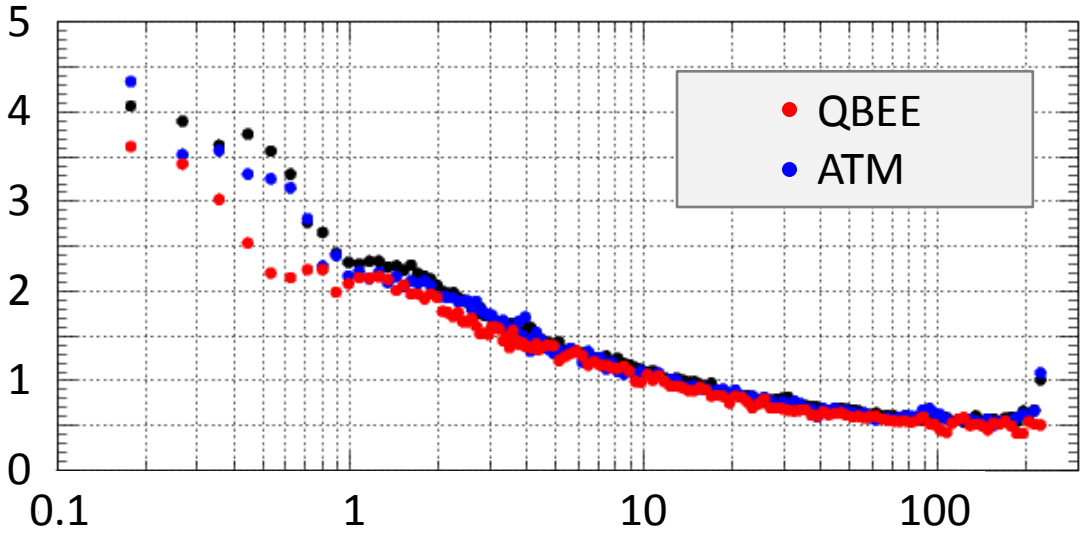
Hit Timing vs. Charge



X : Charge (p.e.)
Y : Hit timing (nsec)
lager value → earlier

Time-walk is visible

Timing Resolution



X : Charge (p.e.)
Y : RMS of Hit Timing (nsec)

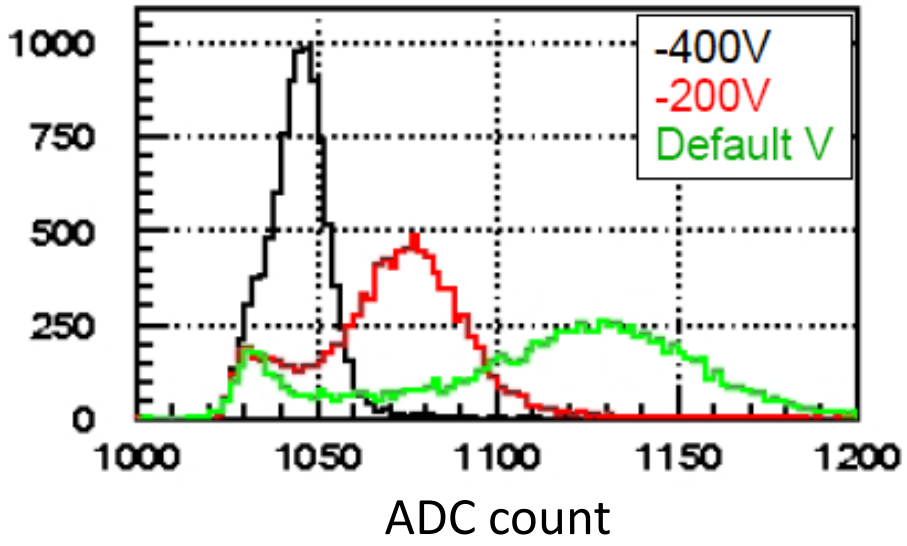
Comparable timing resolution with ATM
~2 nsec @ 1 p.e.
~0.5 nsec @ 100 p.e.

Outer detector with QBEE

- Outer detector electronics : also replaced with QBEE

  → inner detector / outer detector electronics unification

Single p.e. Distribution of
Outer Detector PMT with QBEE



Clear single p.e. peak

Successful end-to-end test of outer detector subsystem !!

Other results of the system test at SK

Satisfactory. Will be further improved by using the on-board calibration pulser

Measurement stability

- Temperature dependence
  - Charge → 1% shift / 10 degree change
  - Timing → negligible shift / 10 degree change
- Event rate dependence
  - → Fine. No change for different event rate

Smooth and transparent data flow

- Ethernet data read → no problem even for 1M-event burst
- " record every hit " + software trigger → successful
- new offline format
  - → realizes easy transition of current analysis tools

Summary

- Developing new electronics system to improve sensitivity and stability of Super-Kamiokande observations
- Successful results of the end-to-end system test using the SK detector
- SK observations with new electronics system 2008~