ARICH

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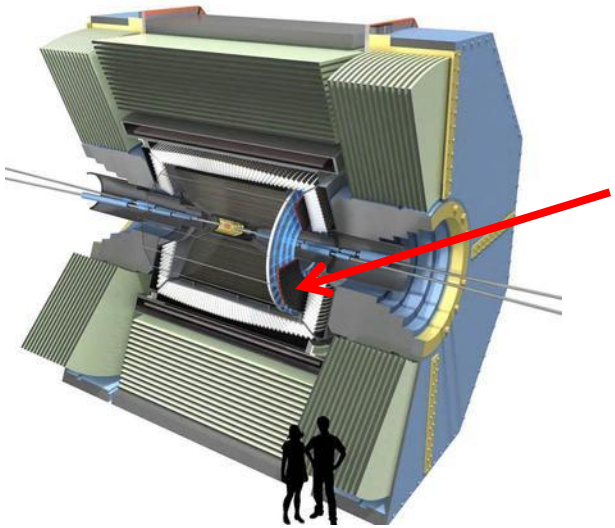
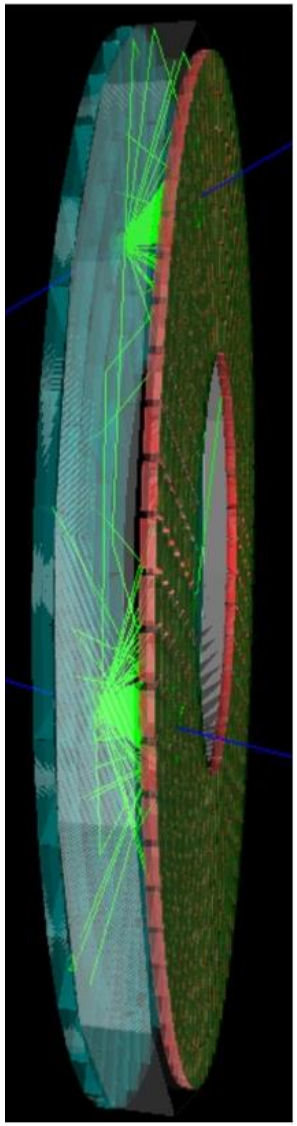
KEK

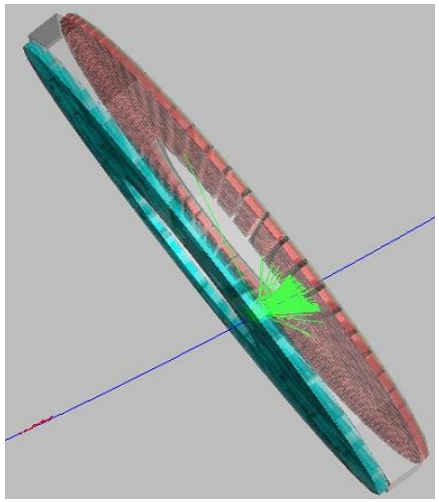
Belle II Trigger DAQ Workshop 2016 @ BINP

Sep. 6, 2016

Aerogel RICH

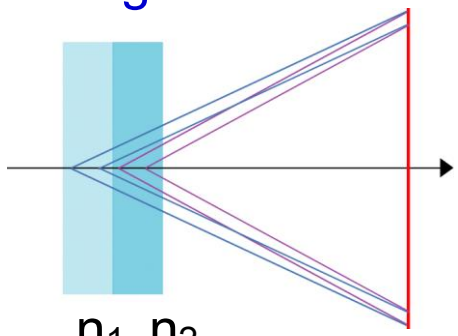




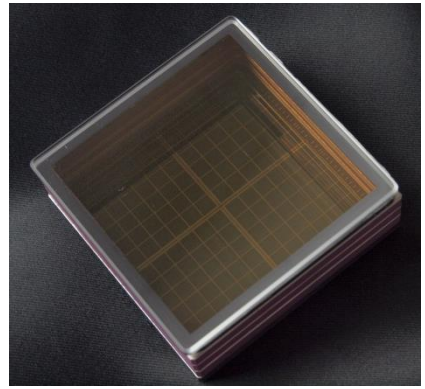


2-layer Aerogel

photo-detector

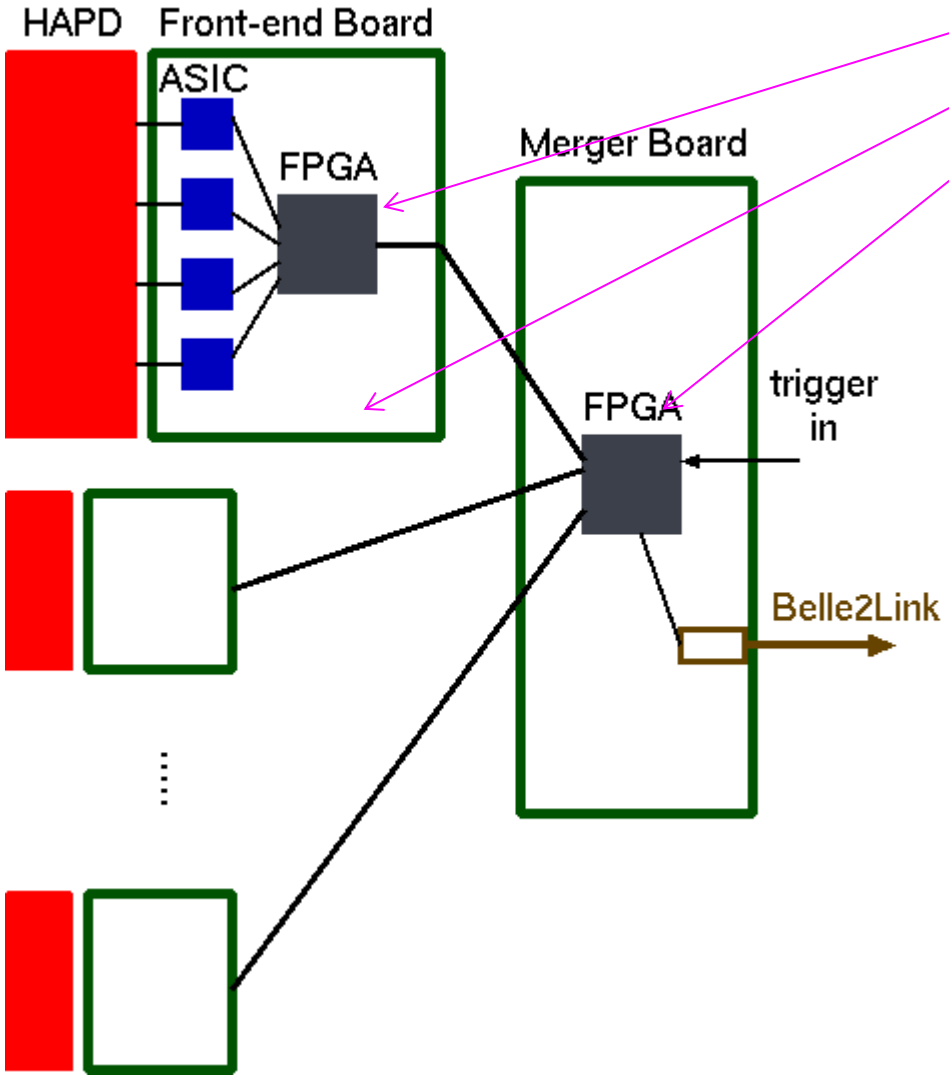


HAPD



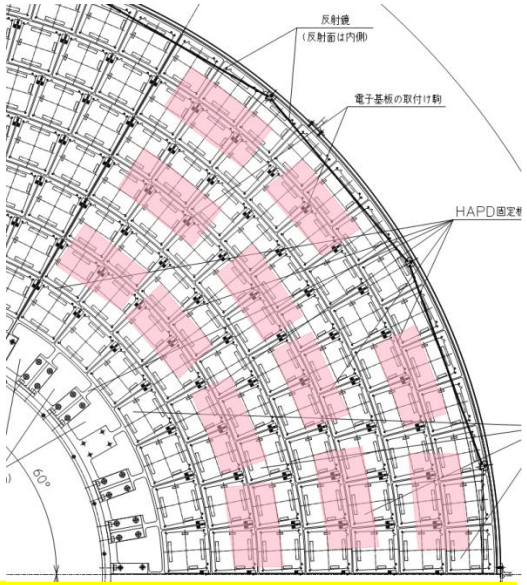
- PID in forward endcap.
- 248 aerogel tiles.
- 420 of 144ch Hybrid Avalanche Photo Detector (HAPD).
- Readout electronics for total 60k channels.

ARICH Readout

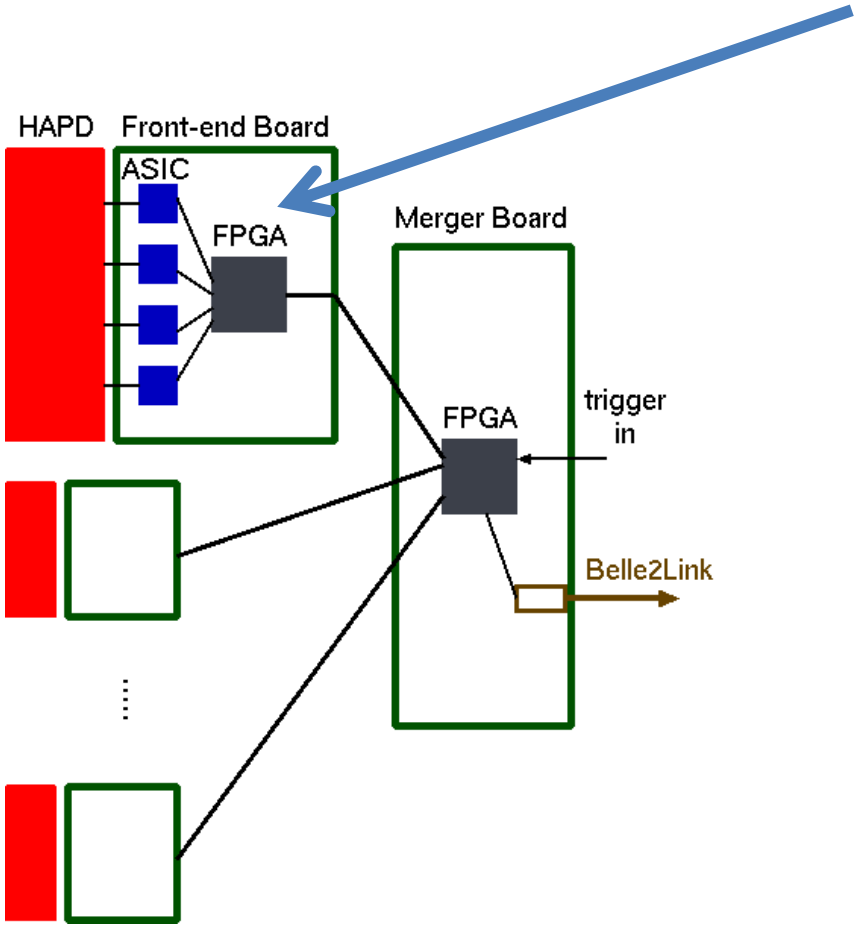


- ASIC
- Front-end Board
- Merger Board

- Total 420 HAPDs.
- 420 Front-end (FE) Boards.
- 72 Merger Boards
  - ✓ 1 Merger ↔ 5-6 FE Board
- ASIC: 36ch per chip (i.e. 4 chip / HAPD).
- Quite limited space (~5cm) behind HAPD.

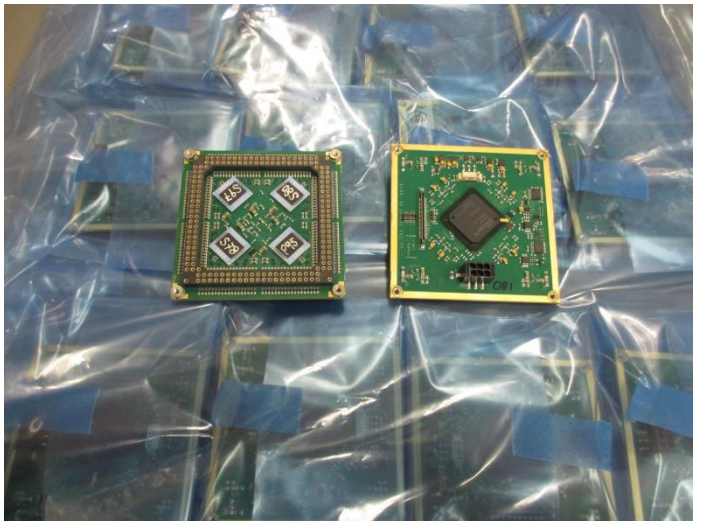


Front-end Board



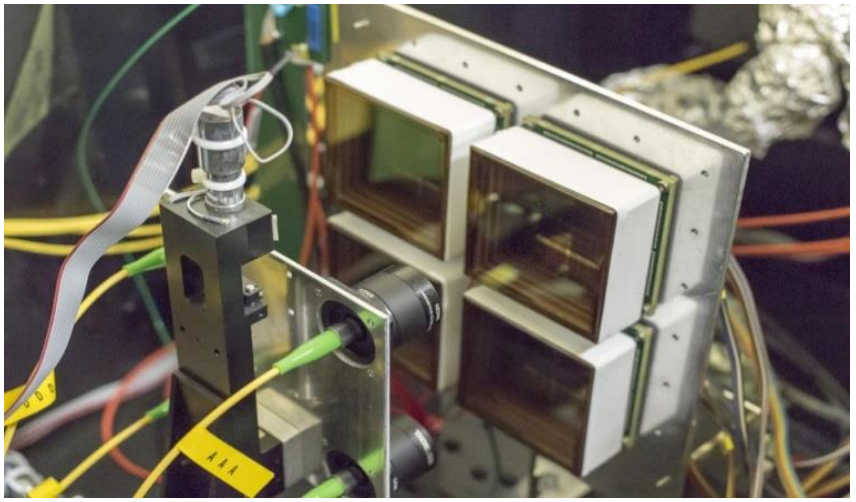
Front-end Board

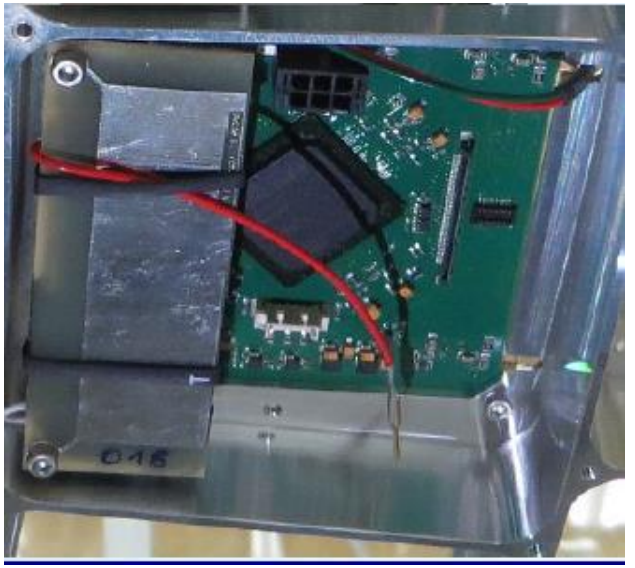
- Front-End Boards (FEB) are attached behind HAPDs.
  - ✓ 4 SA03 ASICs to read one HAPD (144ch).
  - ✓ Spartan 6 FPGA (XC6SLX45) to process the digital data from the ASIC.
  - ✓ Basic data is 1-bit on/off hit information for each channel.
- Final version (4th version) was designed in 2015, and mass production for (420+spare) was finished in March 2016 in Slovenia.
  - ✓ ESD (electro-static discharge) protection to cope with a large pulse that occurs in the magnetic field..
  - ✓ Minor bug fix.
- Quick test was done at JSI before sending to KEK.

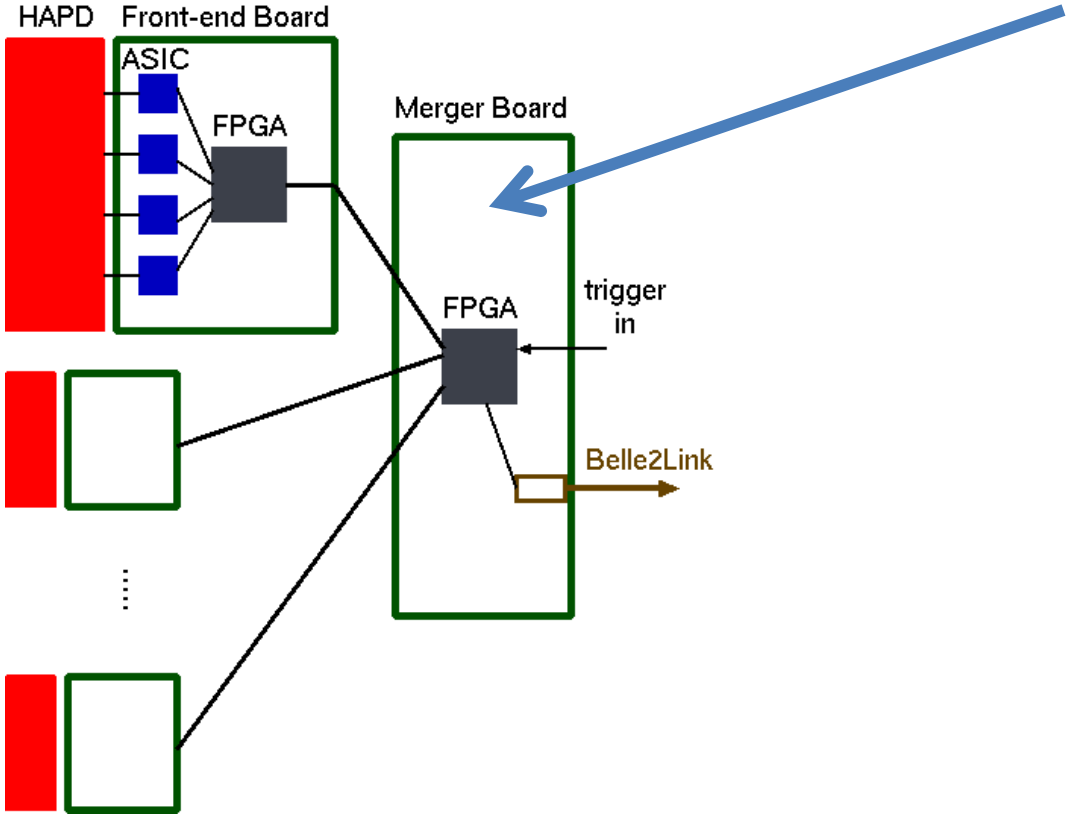


Front-end Board

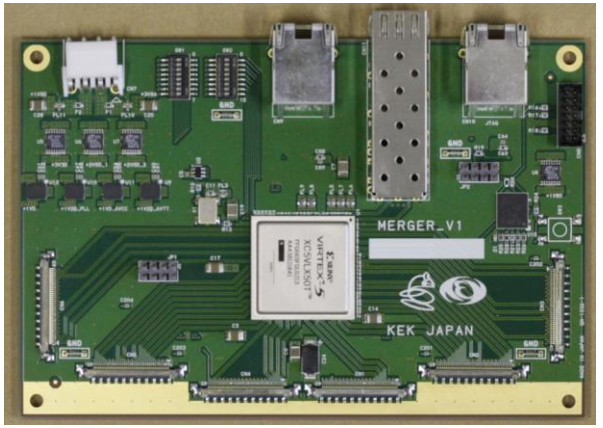
- FEB is attached to an HAPD (we call it a "module") and then tested in Tsukuba B4 [by R.Dolenec and M.Mrvar from JSI].
- Module (HAPD+FEB) production is basically finished.
  - ✓ ~390 modules are ready.
  - ✓ The rest can be done any time, but is waiting for getter activation of HAPDs.
  - ✓ Some of the modules need to be dismantle for getter activation.
- A HV filter is mounted on the module before mounting to the structure.





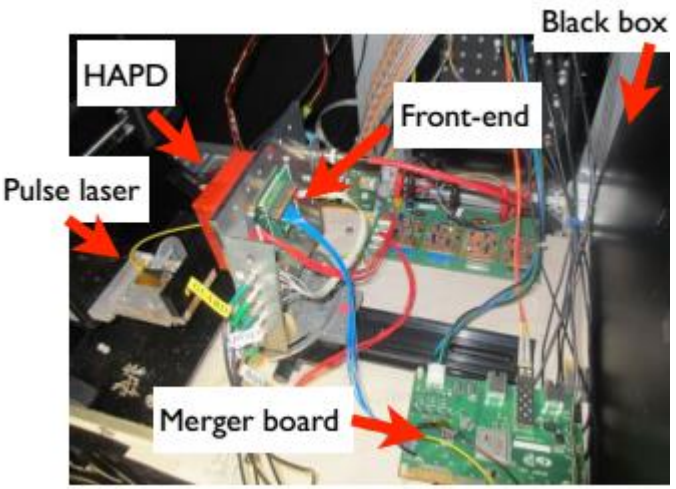

HAPD
Front-end Board
ASIC
FPGA
Merger Board
FPGA
trigger
in
Belle2Link

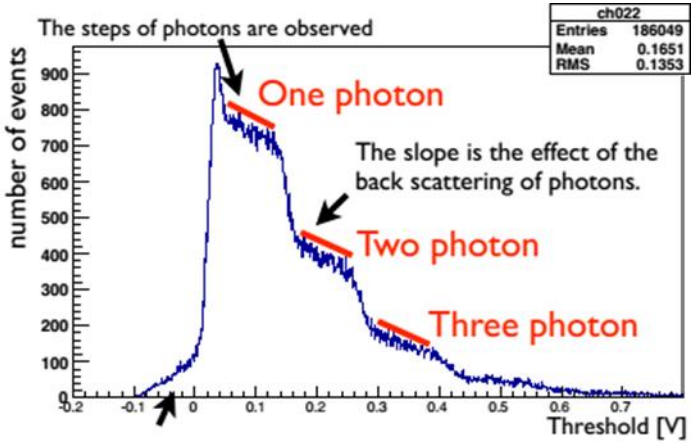
Merger


MERGER_V1
KEK JAPAN

Merger

- In ARICH, the merger board takes care of Belle2Link.
  - ✓ Collect hit data from 5 or 6 FEB.
  - ✓ Zero suppression of FEB data.
  - ✓ Slow control.
  - ✓ FEB firmware download (using slow control).
    - ➢ Merger firmware is downloaded using normal JTAG path.
- Basic test and mass production is done in 2015.
  - ✓ Successful readout with HAPD + FEB + Merger.
  - ✓ Operation in 30 kHz trigger rate.
  - ✓ Readout and slow control with Belle2Link
  - ✓ Hardware test (firmware download, I/O test) for all mergers from mass production.
- Two Pocket DAQ systems.
  - ✓ Tsukuba B4 : for test with cosmic rays.
  - ✓ Advanced Instrument Hall : further test of mergers





Merger

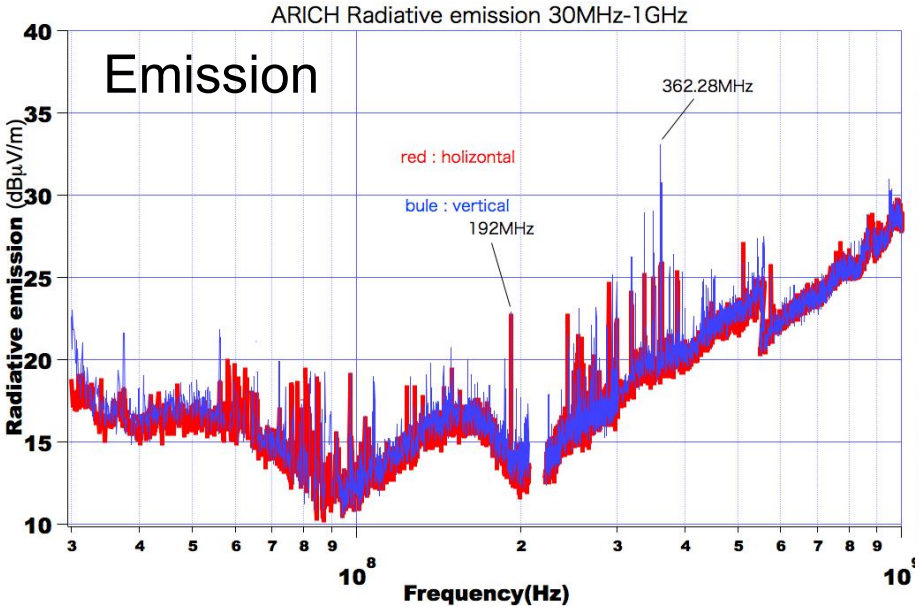
- There were several problems in Merger, Belle2Link, DAQ (beginning of 2016), but I think most of them are solved.
  - ✓ Common Belle2Link problem in reading parameters → solved by DAQ group.
  - ✓ Invalid data (strange channel shift in data) → turned out to be a bug in merger firmware added during other changes.
  - ✓ Empty data while reading in standalone mode (SiTCP) → merger buffer added (no problem for Belle2Link).
  - ✓ Belle2Link DAQ stops (becomes very slow) after ~10 sec in 30kHz → bottle neck at COPPER CPU. Write data in different node. Now use basf2 program.
- Issues about JTAG download.
  - ✓ Merger firmware is downloaded by JTAG through FTSW module, but 3 FTSW modules got broken in ARICH (no broken FTSW in other detectors).
  - ✓ VME CPU cannot access merger FPGA correctly. We now use Xilinx iMPACT program from Windows PC.

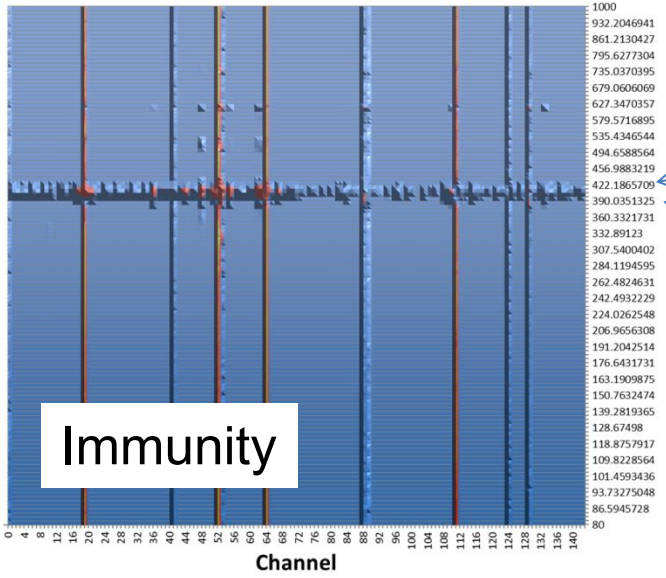
EMC Test

- ARICH performed EMC (electromagnetic compatibility) test in Mar. 2015 in e-Otama in Yamanashi Pref.
- The conclusion was that ARICH electronics has emission at ~360 MHz, and is sensitive to 350-450 MHz : Possibility that ARICH electronics is affected by its own noise?

Emission

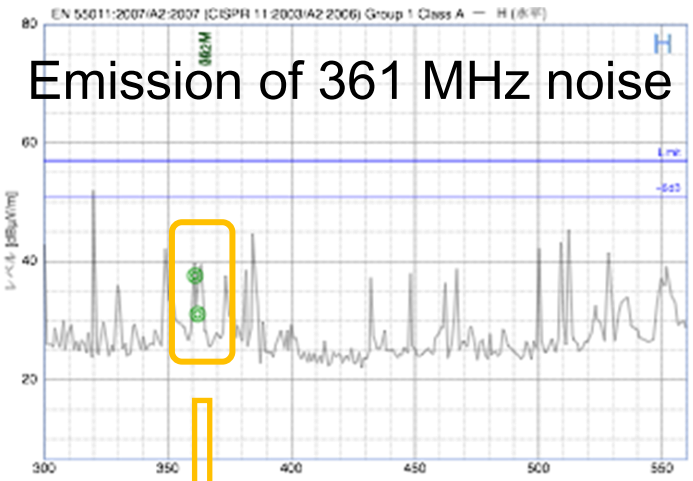
Immunity



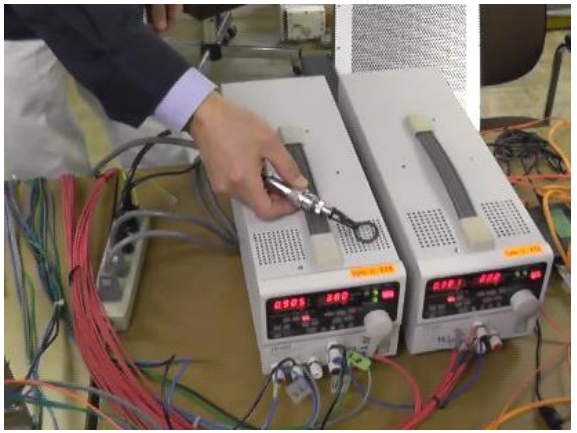


EMC Test

2nd EMC Test was done at Tsukuba Hall on Mar. 10 2016 by Shoji-san (with help of e-Otama company), together with TOP EMC test.

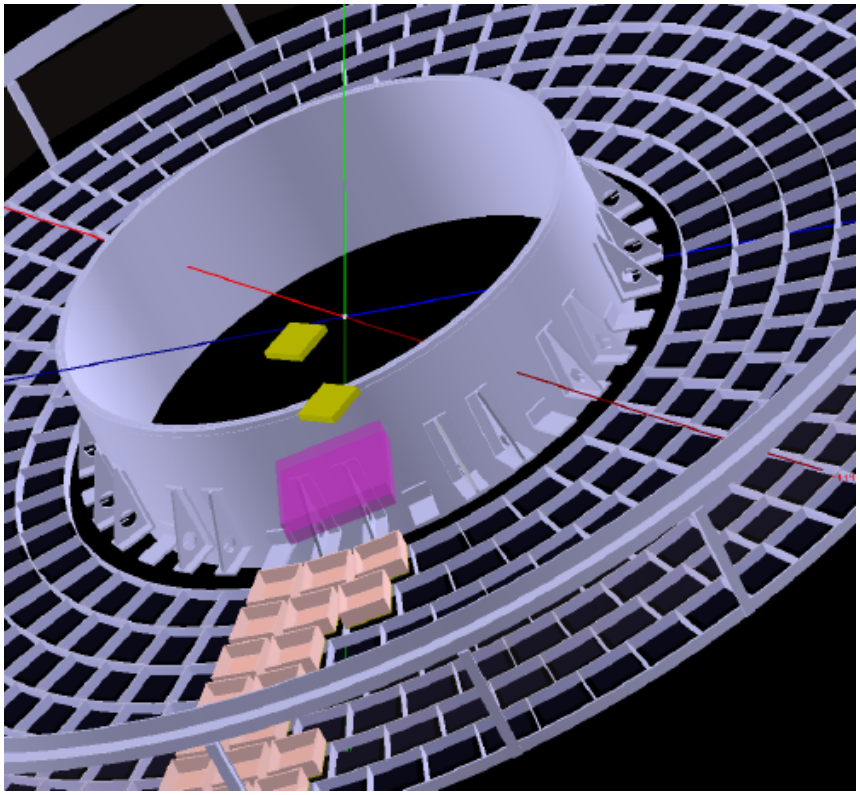


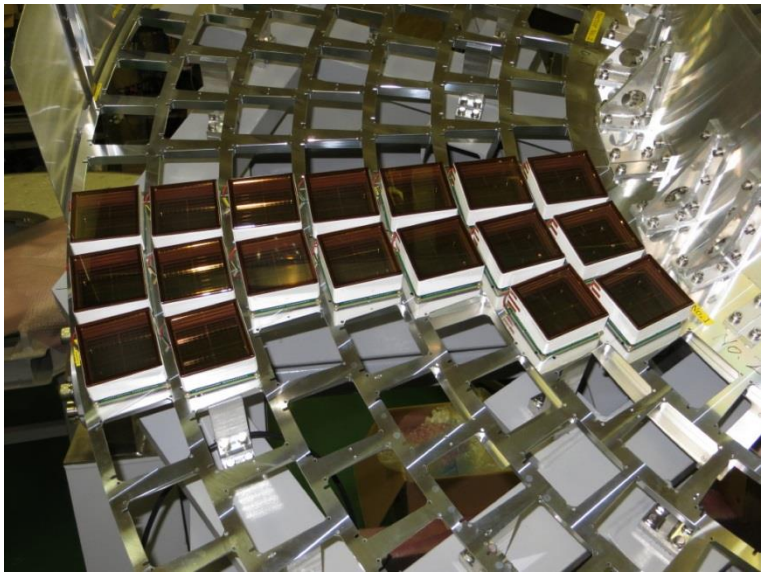
- Emission of 361MHz is generated from the power supply (TEXIO).
  - ✓ Linear power supply, but some digital control is the problem (?)
- Noise was conducted to the merger and the FE through the power cable.
  - ✓ Selection of the power supply is important.



No plan for further test with final power supply though we now decide to use switched-mode power supply…

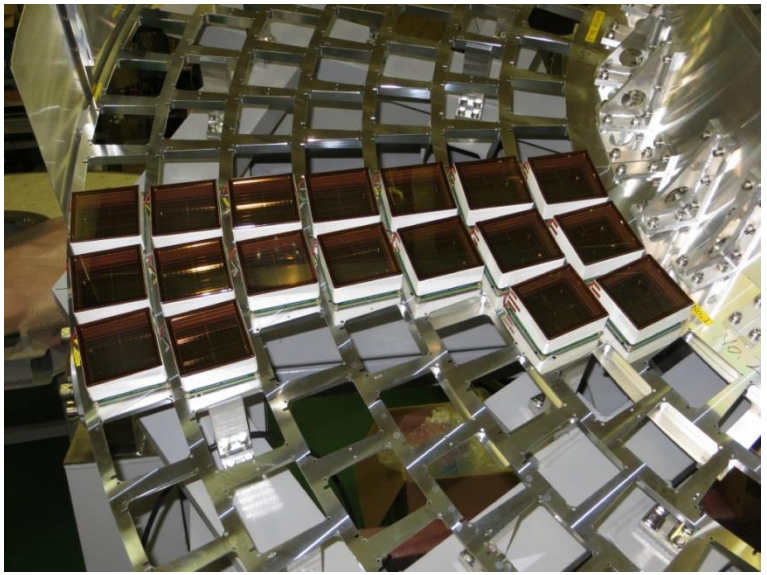
Test with Cosmic Rays

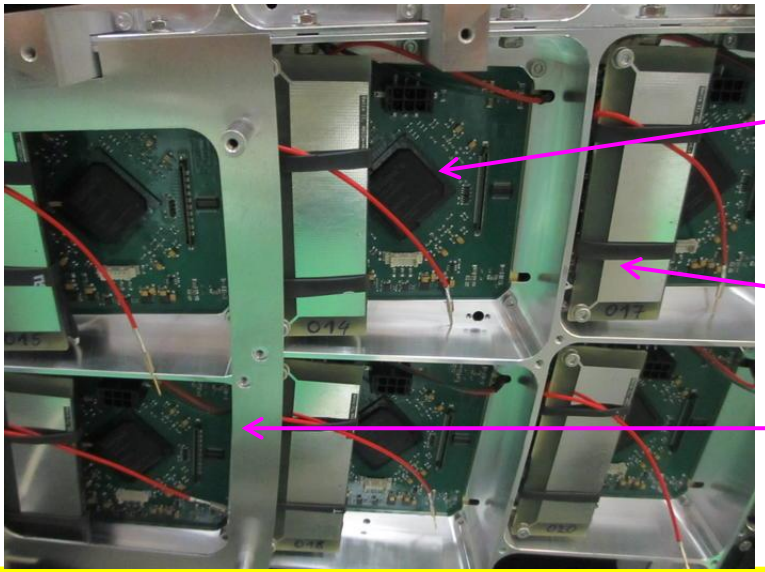




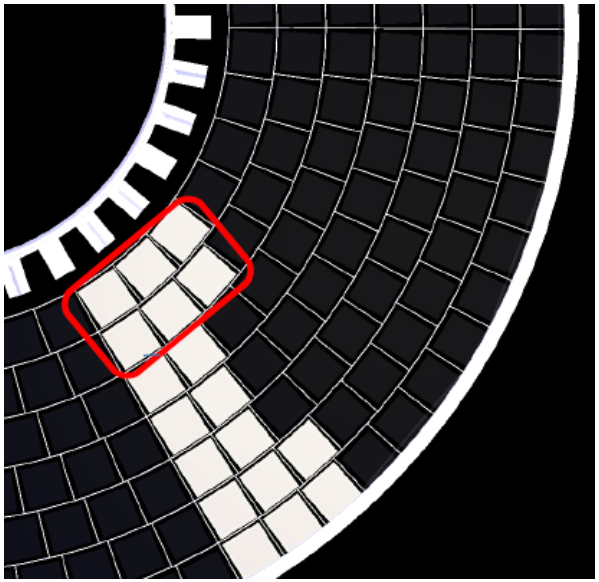
Test with Cosmic Rays

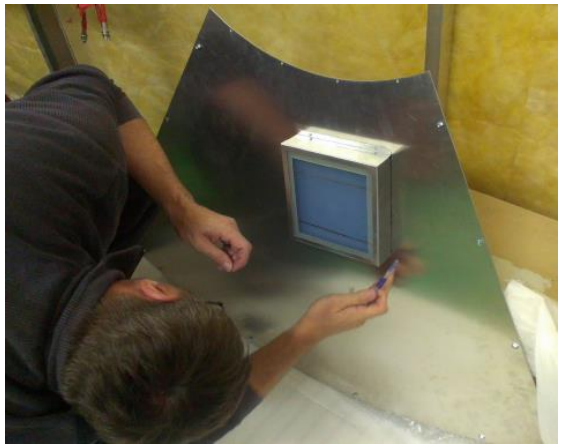
- We are now constructing the ARICH detector in the clean room in Tsukuba B4.
  - ✓ 18 HAPDs are mounted in the structure, which are used for the test with cosmic rays.
  - ✓ 6 of them are now connected to the HV and bias, and to a merger board.
  - ✓ To read more HAPDs, we need to prepare more HV and bias cables. We plan to increase to 16 HAPDs in a month.
  - ✓ Another 70 HAPDs are mounted in another sector, but they will not be connected to DAQ soon.



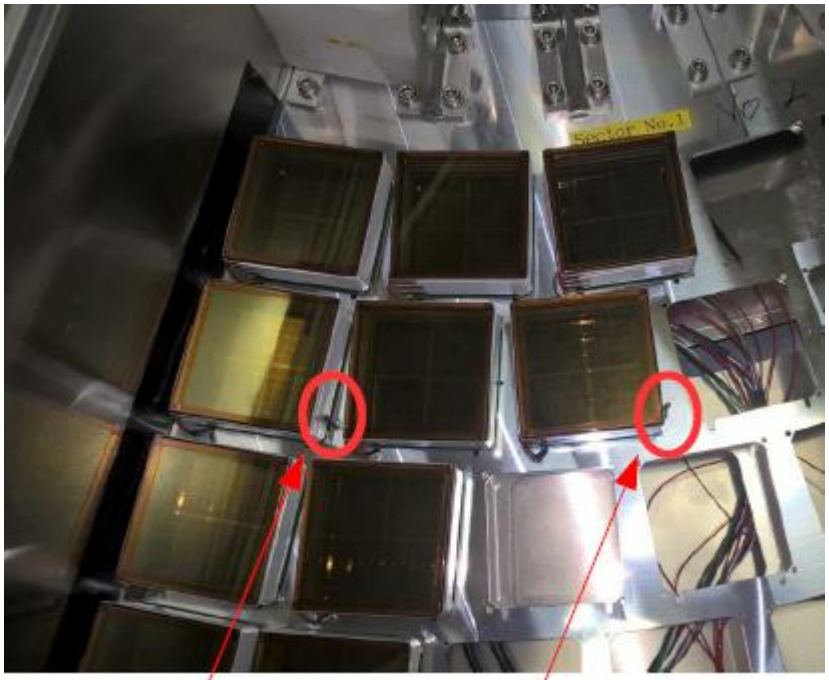


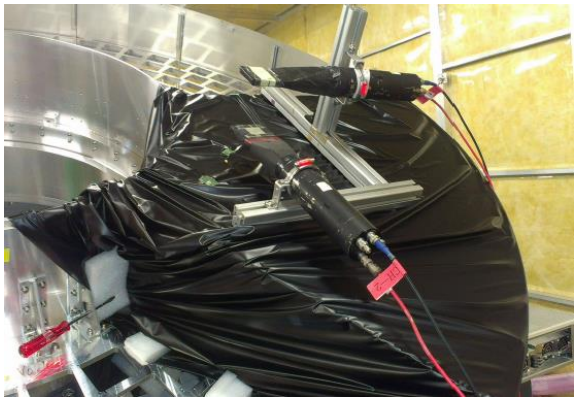
Test with Cosmic Rays





Aerogel for test

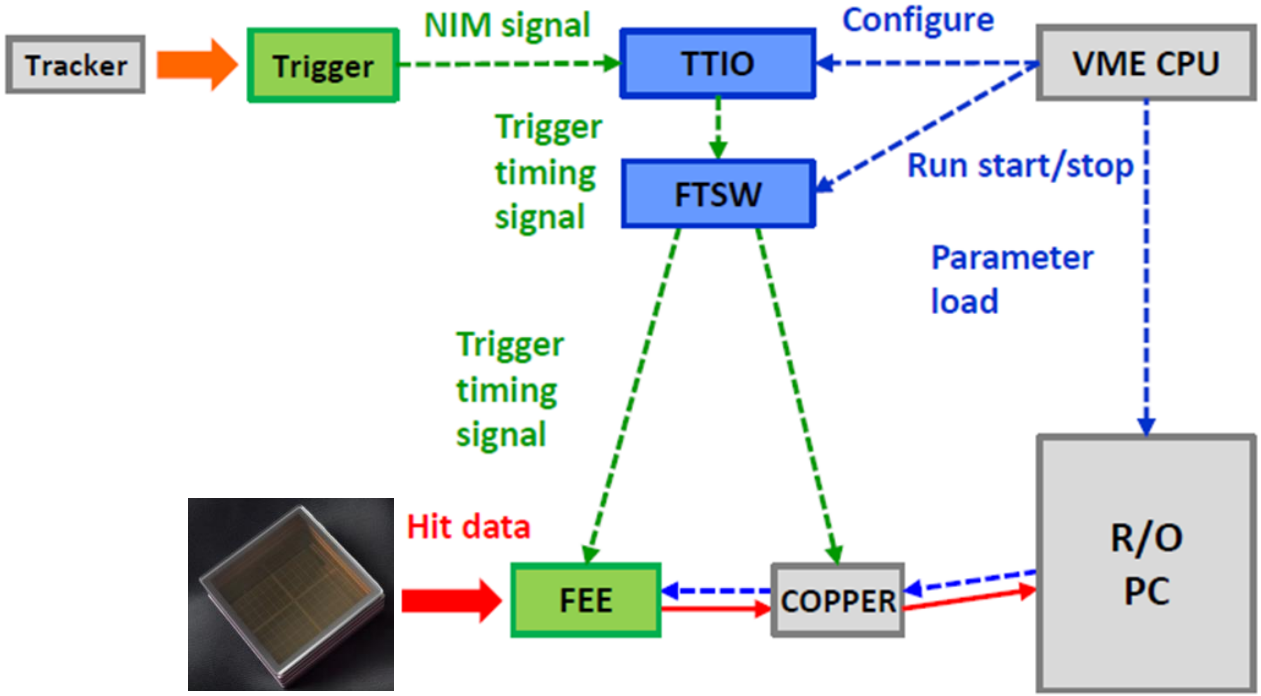


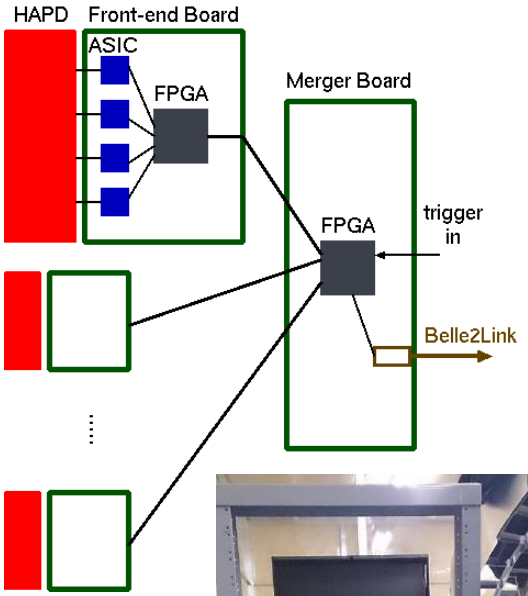


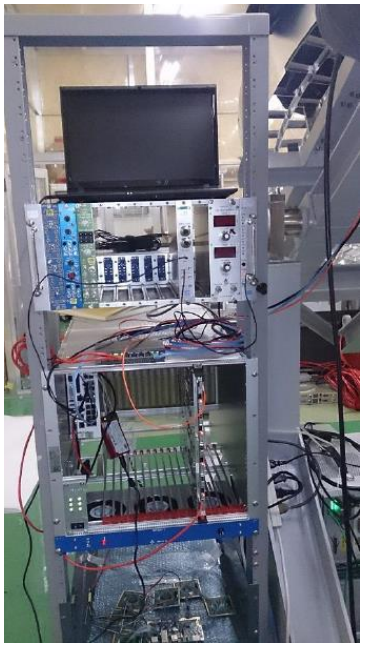
Two optical fibers from the monitor system (LED) are connected.

Test with Cosmic Rays

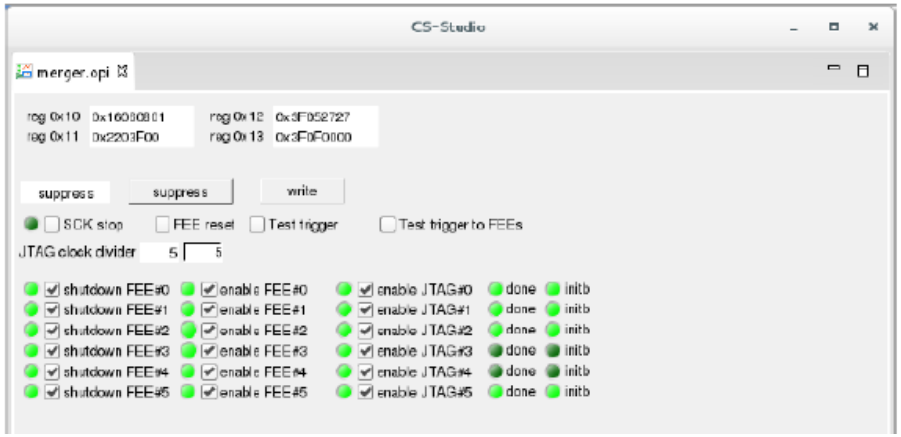
- 6 HAPDs (6 FEBs) are connected to one merger board. So, we now have only one Belle2Link, HSLB, COPPER.
- Trigger is either internal or external (trigger counter)
  - ✓ Through TTIO and FTSW module.
- It should be straightforward to increase mergers and COPPERs, but of course this should be tested.





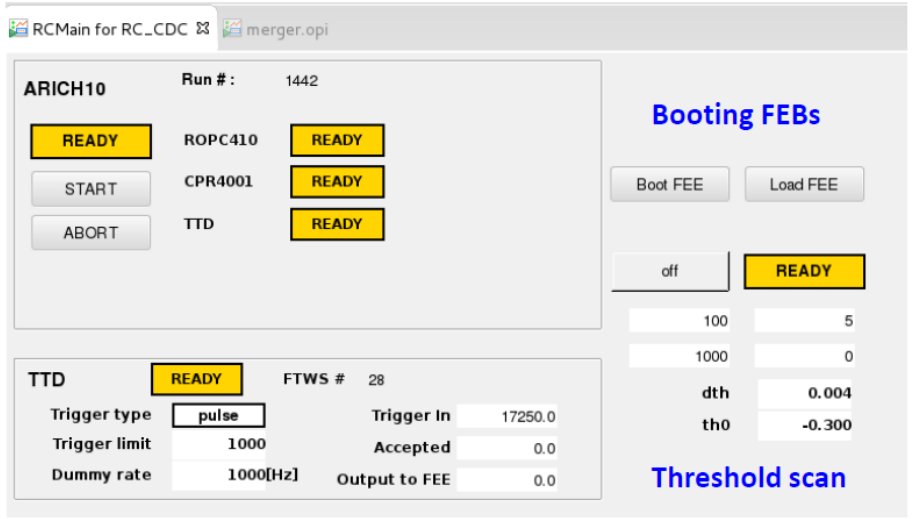


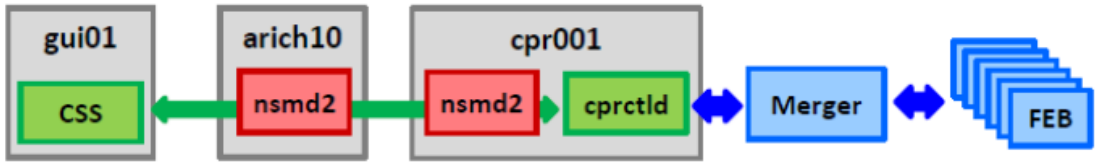
Test with Cosmic Rays

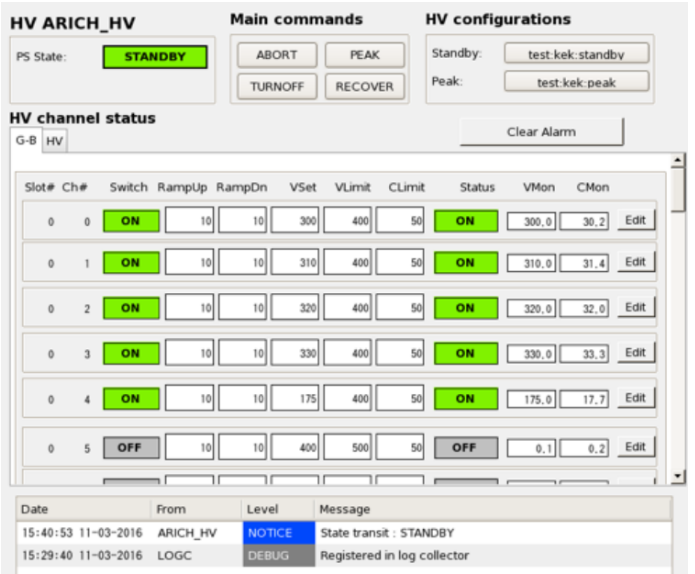


Run control

Trigger info.



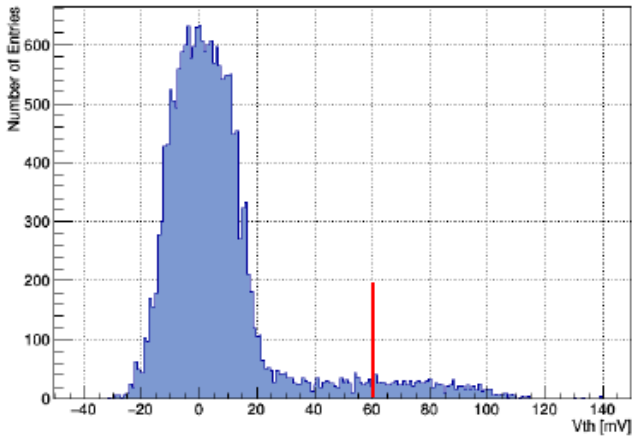


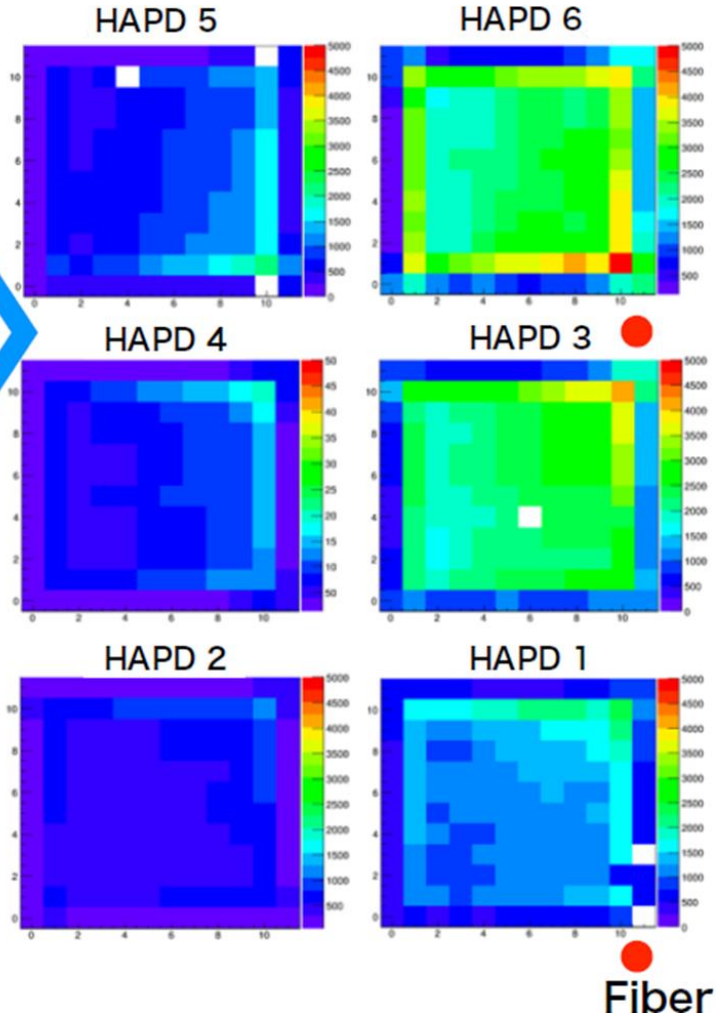


- Konno-san(KEK) and Yonenaga-san(TMU) developed nice GUI for slow control (parameter setting & HV control) and run control.

Test with Cosmic Rays

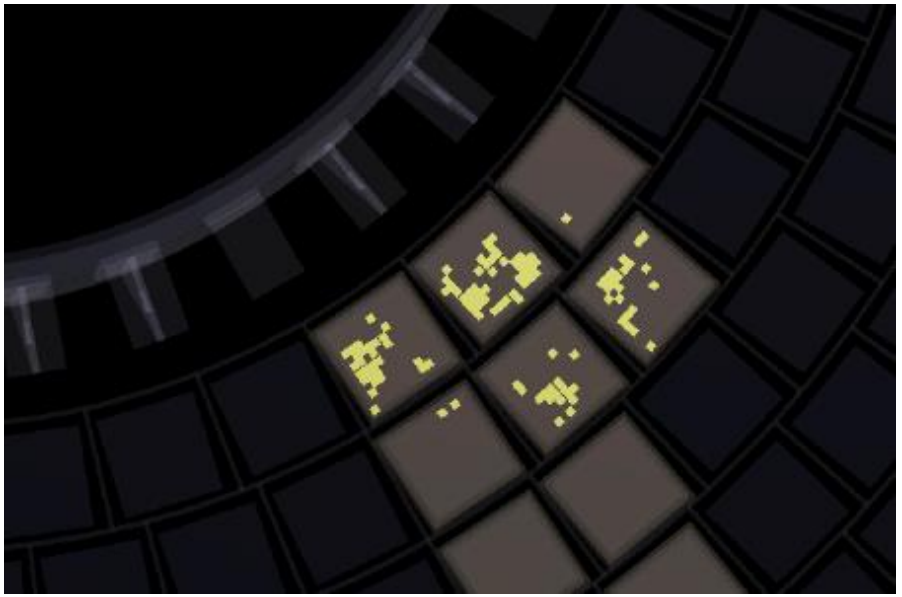
- LED run is taken with 10 kHz trigger.
- Clearly see the light from LED, mostly scattered at the light tight box.
- In the final detector, light will be scattered at aerogel.





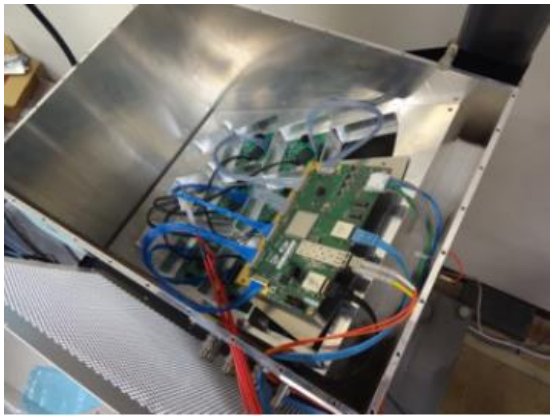
Test with Cosmic Rays

- Test with cosmic rays is done. Trigger rate is ~0.2 Hz.
- At the beginning, COPPER was crashed every hours, but now it is stable. Runs continue at least several hours (O(1000) events).
  - ✓ Need more test in terms of stability of DAQ.
- Nice Cherenkov rings are observed in some events. Many events have incomplete rings, but it is probably due to some geometry.
- We find some events with many hits.



2nd Pocket DAQ

- We built the second pocket DAQ system in Advanced Instrument Lab.
  - ✓ To make a debug for problems (related to mergers) seen in the cosmic ray.
- One merger board has very strange output in the cosmic ray setup. In the test in this setup, the board works only sometimes. It is found that this is due to a problem of FPGA (bad soldering?).
  - ✓ Probably it worked normally during the hardware test.
- We also found strange data collapse of the merger output in this setup.
  - ✓ Some headers go into the header?
- When we tried to start the investigation, the FTSW board got broken.
- We resume the investigation next week.

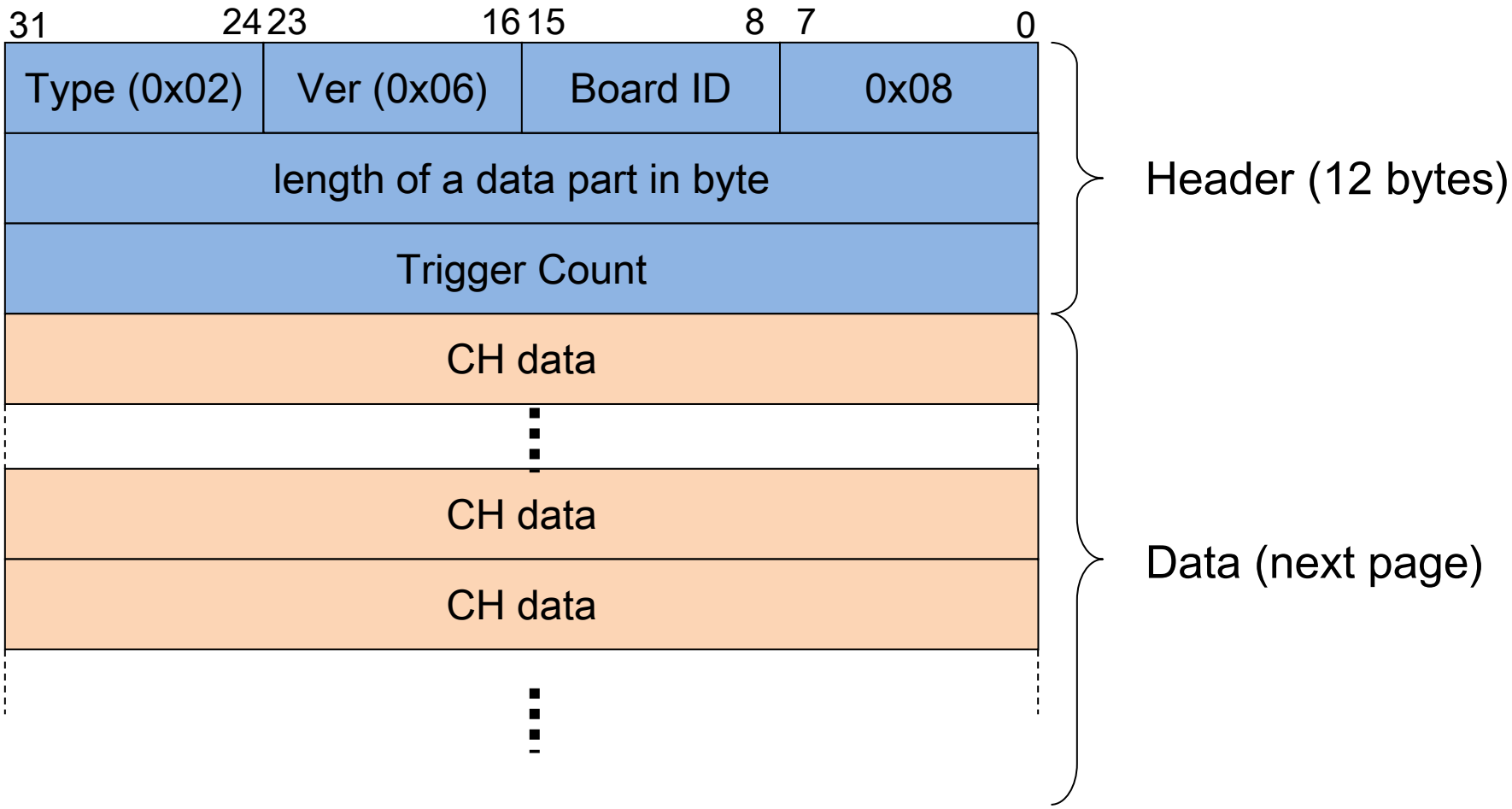


ARICH Data Format and Local Run

	#ch	occ [%]	#link	/link [MB/s]	#CPR	ev sz [kB]	total [MB/s]	/CPR [MB/s]
PXD	8	2	40	455	—	800	1820	—
SVD	223744	1.7(5.5)	48	8.9(33.8)	48	14.9	428	8.9(33.8)
CDC	14336	10	302	0.6	76	6	175	2.3
BPID	8192	2.5	64	1.5	16	3.2	96	8
EPID	~~65664~~	~~1.5~~	~~99~~	~~1.1~~	~~23~~	~~2.8~~	~~84~~	~~4.2~~
ECL	8736	33	52	7.7	26	12	360	15
BKLM	19008	1	24	9.7	6	2	60	10
EKLM	16800	2	16	35.8	9	1.4	42	4.7
TRG			19		10			

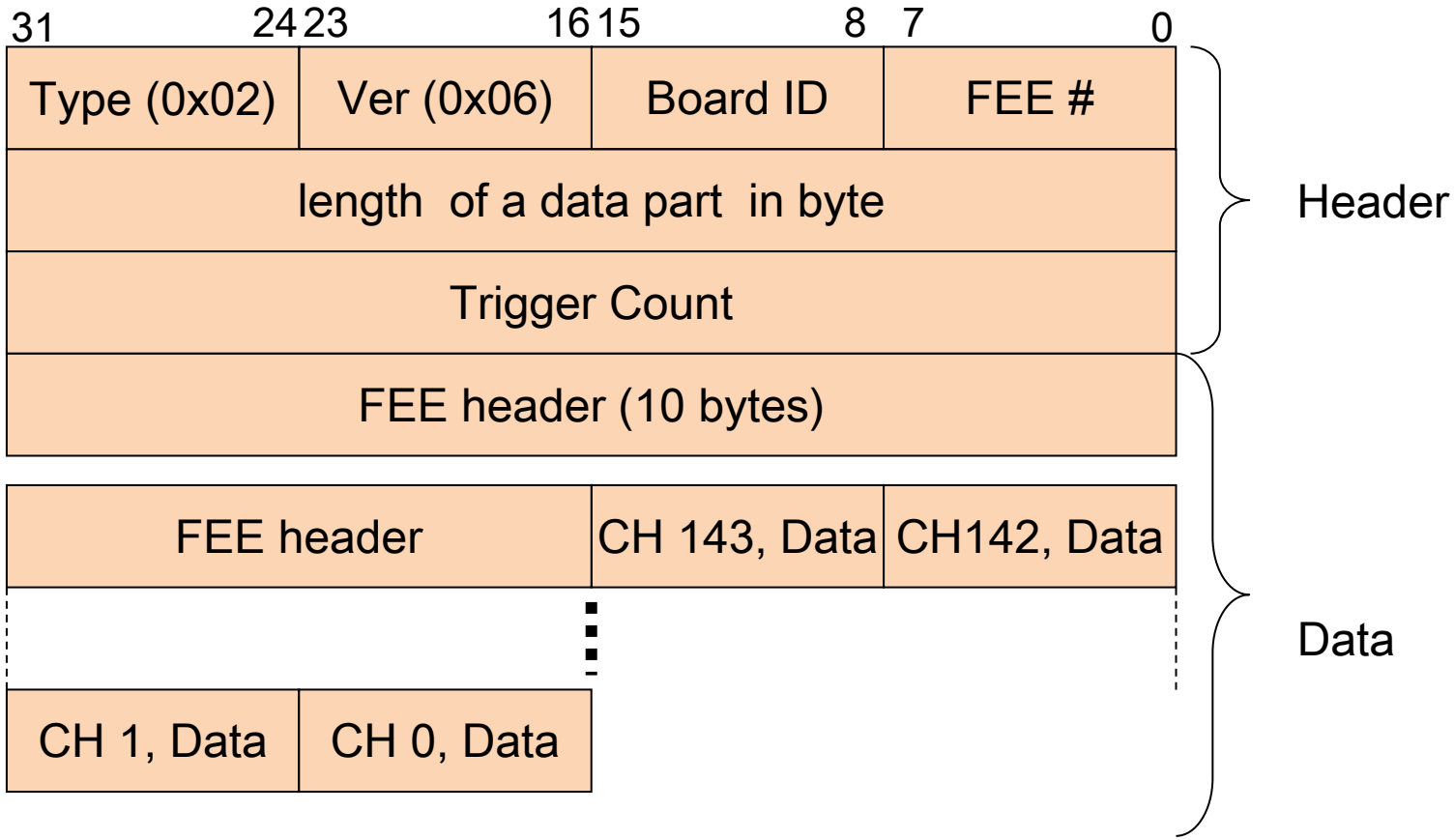
ARICH Data Format

Data format from one Merger Board (= one Belle2Link).



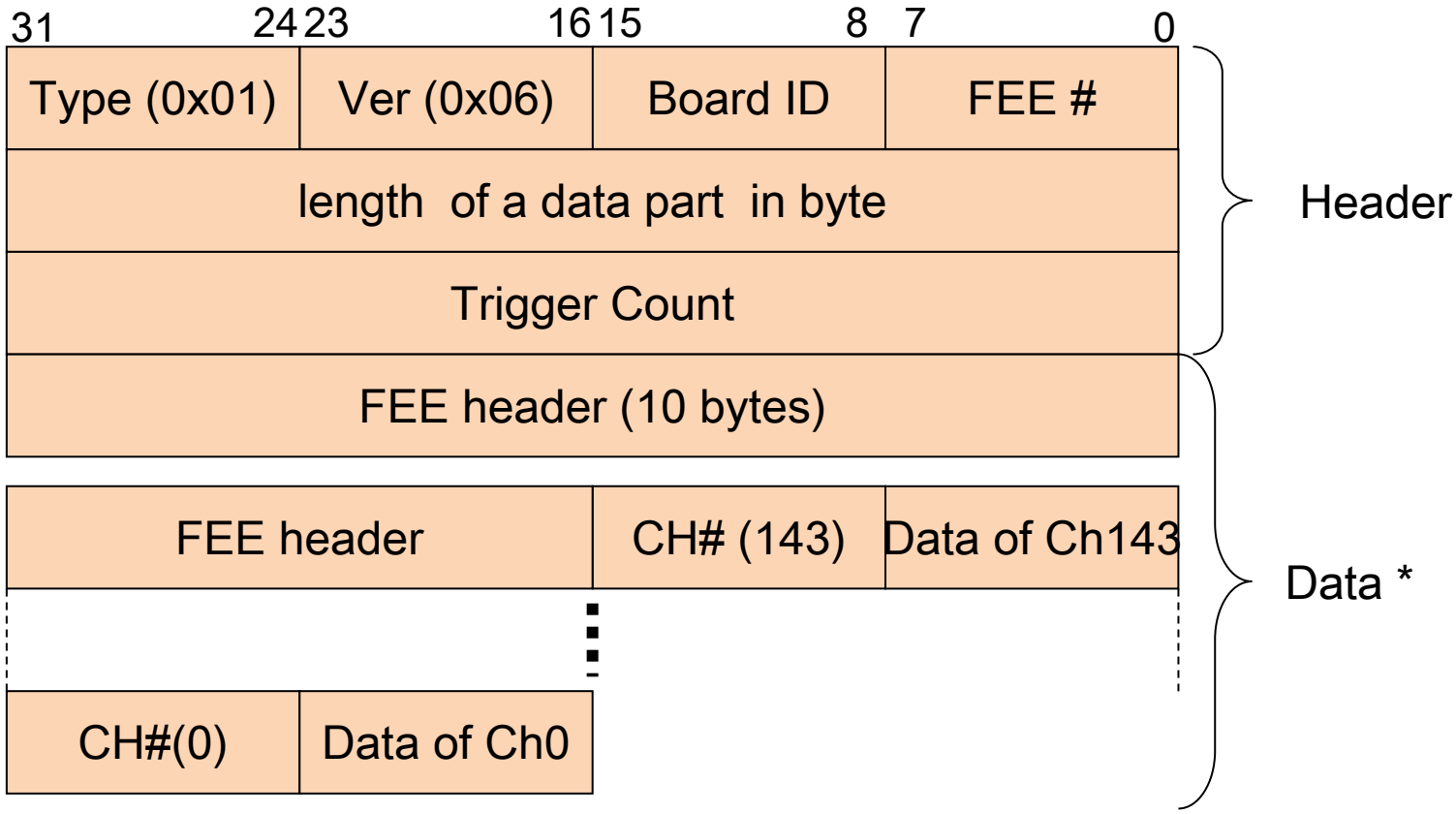
ARICH Data Format

CH Data in Raw Mode



ARICH Data Format

CH Data in Suppressed Mode



* If a ch has no hit data (Zero), its data is not transmitted.

Event Size

<Total 72 MB (Merger Board) and 420 FEB (Front-End Board)>

- Data from one MB.
  - ✓ 12 bytes MB header per MB
  - ✓ 22 bytes FEB header per FEB (10 bytes from FEB, 12 bytes from MB)
  - ✓ 144 bytes FEB data in raw mode, or 2 C bytes in suppressed mode (C: number channels with hit) per FEB.
- Belle2Link header: 36 bytes per Belle2Link.
- Data size for raw mode

  $36 \times 72 + 12 \times 72 + (22 + 144) \times 420 = 72906$ [B] ~ 73 [kB]
- Data size for suppressed mode

  $36 \times 72 + 12 \times 72 + (22 + 2\,C) \times 420 = 12696 + 840\,C$ [B] ~ $(13 + 0.8\,C)$ [kB], where C is average number of hits per HAPD. Typically C=5 ⇒ 17 kB
- Large part of the data is header. We think this is necessary to check the consistency of the FEB data (e.g. to detect event slip), and we have no plan to change the merger format.
  - ✓ We can remove some of it in the software later (after COPPER?). If we remove 22 bytes FEB header, we can reduce the data size by 9 kB.

Event Size

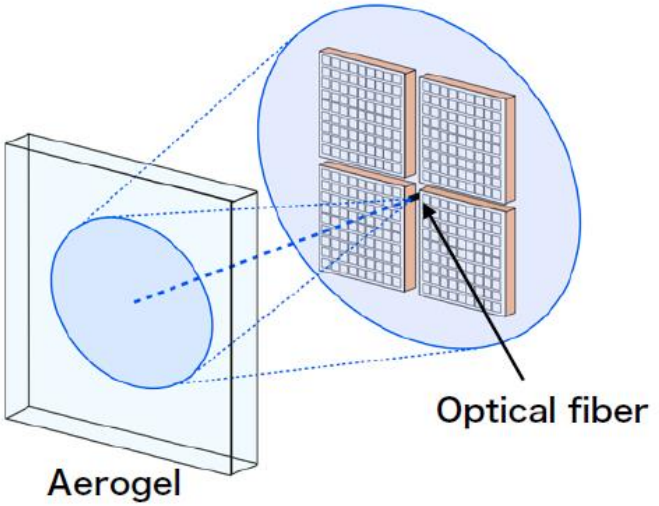
Large discrepancy with previous estimation …

	#ch	occ [%]	#link	/link [MB/s]	#CPR	ev sz [kB]	total [MB/s]	/CPR [MB/s]
PXD	8	2	40	455	—	800	1820	—
SVD	223744	1.7(5.5)	48	8.9(33.8)	48	14.9	428	8.9(33.8)
CDC	14336	10	302	0.6	76	6	175	2.3
BPID	8192	2.5	64	1.5	16	3.2	96	8
EPID	65664	1.5	90	1.1	23	2.8	84	4.2
EPID (updated)	60480	3	72	7.0	18	17	507	28
ECL	8736	33	52	7.7	26	12	360	15
BKLM	19008	1	24	9.7	6	2	60	10
EKLM	16800	2	16	35.8	9	1.4	42	4.7
TRG			19		10			

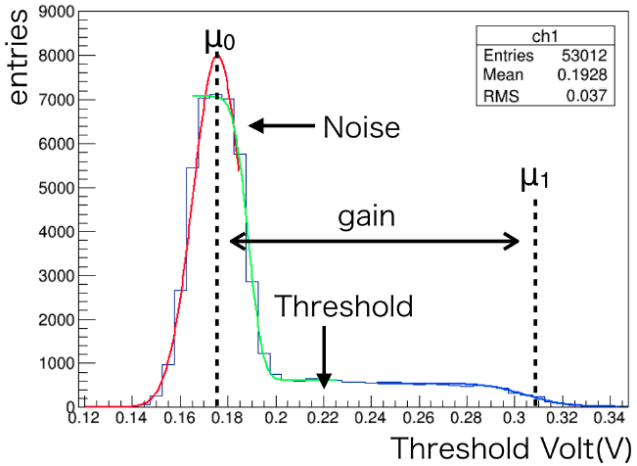
- Configuration change (#HAPD not updated previously? #Merger fixed).
- Occupancy more conservative (we observed some events with many hits).
- Headers too underestimated (now 75% are headers).

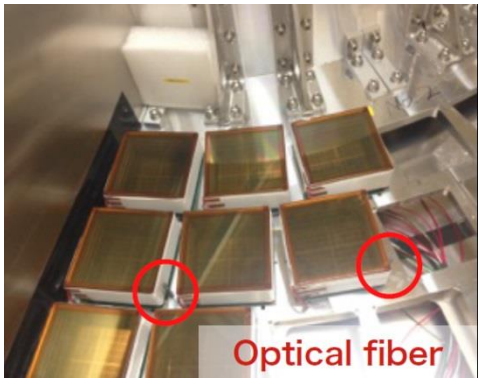
Local Run

- We basically want to see the response of HAPDs with and without LED pulse.
- Monitor system with LED and optical fibers is equipped in ARICH.
- We cannot readout analog signal or ADC distribution. Instead, we perform “threshold scan”, in which we count the hits varying the threshold.
- Typically, we take 1000 events for 200 threshold point (e.g. 5 mV step in [–0.5V,0.5V]).



Need to continue “slow control” → “data taking” 200 times.



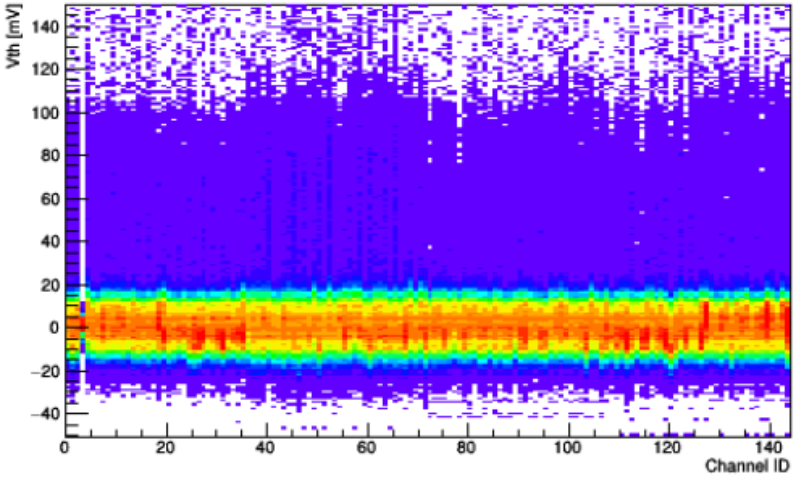


Local Run

Issues on local run

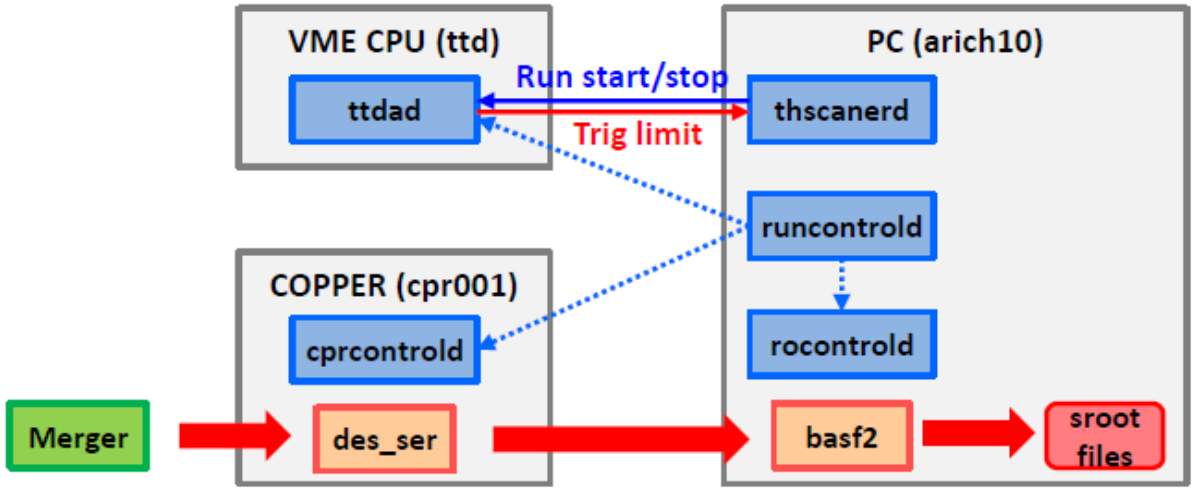
- We assume to use raw mode for local run (data size = 73 kB).
- Suppressed mode may decrease the entire data size in one local run, but double the data size when threshold is near 0V.
  - ✓ Data size ~ 50 kB (assuming 1/3 hits).
  - ✓ Can be used if the bandwidth is enough.

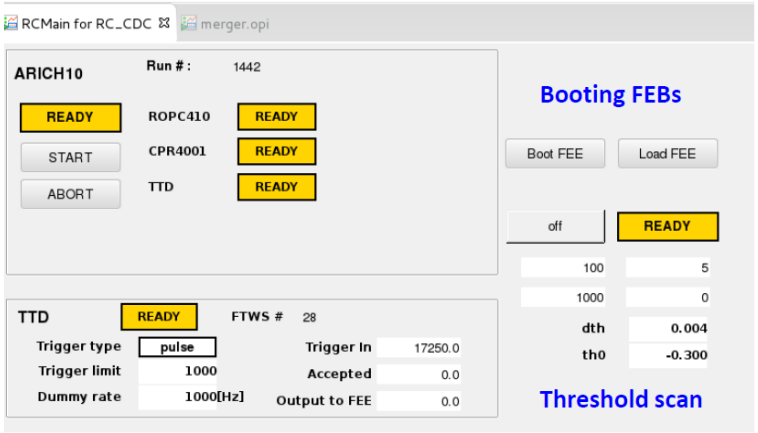
local run with LED (one HAPD)



- Different ASIC, FPGA parameters for the local run (probably no problem).
- Continue the cycle of “slow control” and “DAQ”. Such program is developed by Konno-san for ARICH (next page). Finally it should be prepared as a part of local run program in the global DAQ.
- We need a trigger out signal to be provided in the LED driver (next next page).

Local Run





- Detector local run control (runcontrold) for BelleIIPocketDAQ
  - cprcontrold : register access via Belle2Link and reading out data
  - rocontrold : basf2 process receiving data from COPPER to sroot files
  - ttdad : manage trigger timing system
- thscanerd : control slow control components from threshold scan
  => Repeating run start/stop with chaning threshold
  - Reads trigger output count until maximum of # triggers
  - Write threshold values via COPPER-HSLB
  - Send run start / stop though run control master

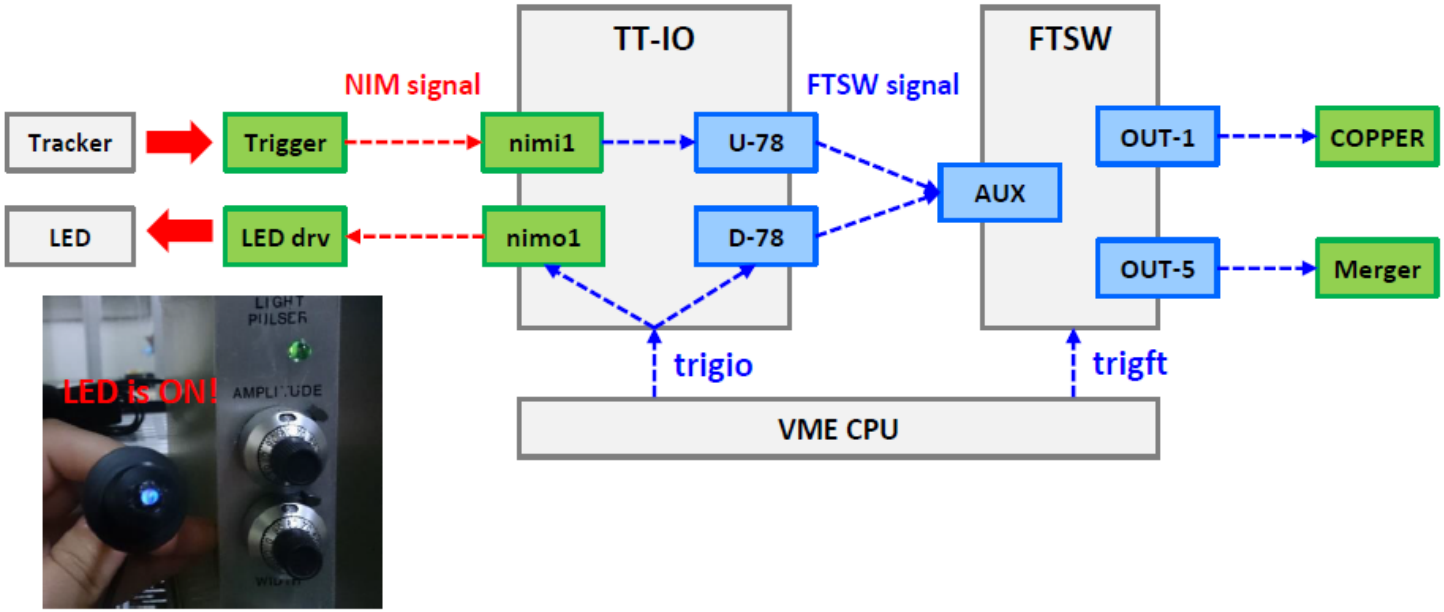
- Setting for threshold scan is editable from GUI
  - # of events per run
  - Difference of threshold value (dth)
  - Initial threshold value (th0)
- Trigger source is also switchable (pulse, aux=LED)

[Konno-san]

Local Run

Present trigger setup for the cosmic run system.

- Only one COPPER, FTSW module.



- We need similar thing in the upstream of FTSW.

Local Run

About local run data.

- Data format is the same as the physics run.
  - ✓ We mainly use Suppressed mode for Physics run, but may use Raw mode for local run.
  - ✓ Data with different threshold is considered as a different (sub-)run. So, we will have 200 (sub-)run per one local run.
  - ✓ The threshold information is associated with the (sub-)run number.
  - ✓ We don't want to have 200 files in one local run; should be merged into one file (already done so in the present program).
- Data size for one local run will be
  - ✓ 73 kB × 1000 × 200 = 15 GB (raw mode).
  - ✓ 50 kB × 1000 × 200 = 10 GB (suppressed mode)

- If we take a local run with LED on and off, the numbers above need to be doubled.

Summary and Plan

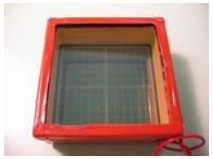
- Mass production of the electronics was finished.
  - ✓ Module (HAPD+FEB) assembly is also essentially finished.
- Test with cosmic rays was performed.
  - ✓ First Cherenkov ring was observed.
  - ✓ DAQ with only 6 HAPDs (= one merger, one Belle2Link, one COPPER) and with low trigger rate is getting stable.
  - ✓ Need to extend the setup with more mergers.
- Need to clarify what is the next DAQ problem.
  - ✓ 2nd pocket DAQ system was prepared.
- Somehow FTSW module gets broken in ARICH.

- We continue the construction of ARICH this year. DAQ continues to use the pocket DAQ system in the clean room.
- ARICH will be installed to Belle II next year (either in Feb. or in summer).
- There is a possibility that we want to read ARICH before installation using global DAQ next year. This has to be discussed after the schedule become clear.

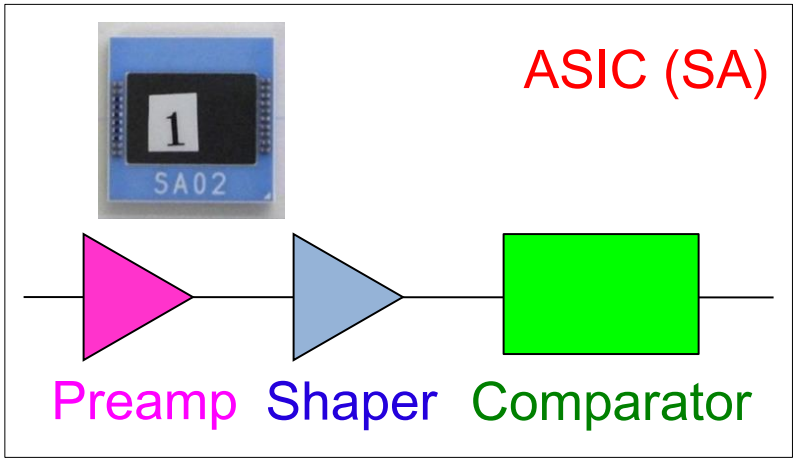
Backup

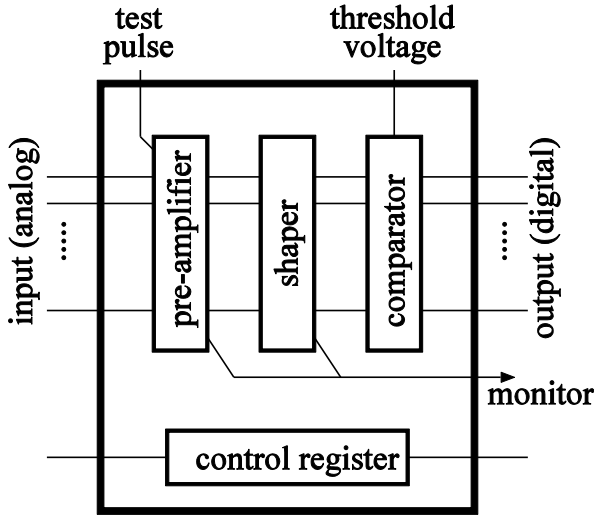
Readout ASIC

SA series ASIC [Ikeda-san (JAXA), TMU, KEK]



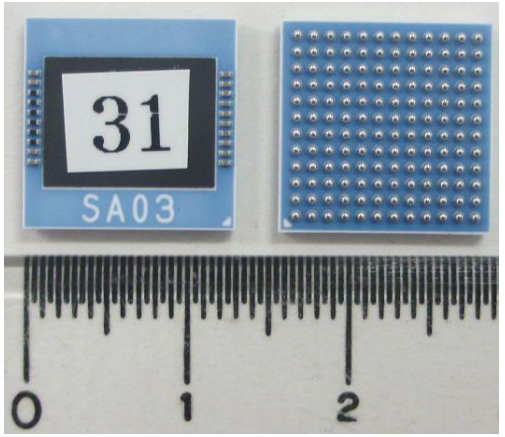
HAPD
(144ch)



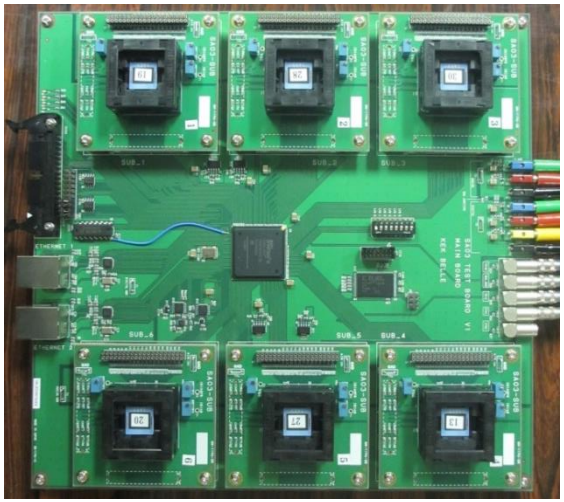


- SA01 (2007)
  - ✓ 12ch only. QFP package.

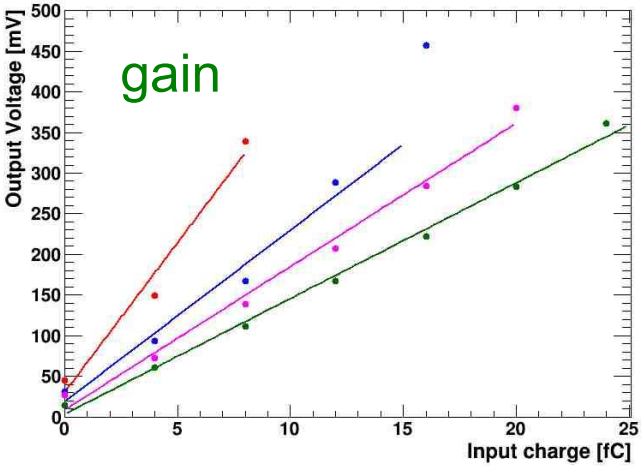
- SA02 (2009)
  - ✓ 36ch only. Gain adjusted (1/4 of SA01).
  - ✓ Low-temperature cofired ceramic (LTCC) package.
- SA03 (2011) : final version
  - ✓ Shorter shaping time for neutron irradiation of HAPD.
  - ✓ Dual Interlocked CEll (DICE) registers for SEU.
  - ✓ Parameter readout (non-destructive).

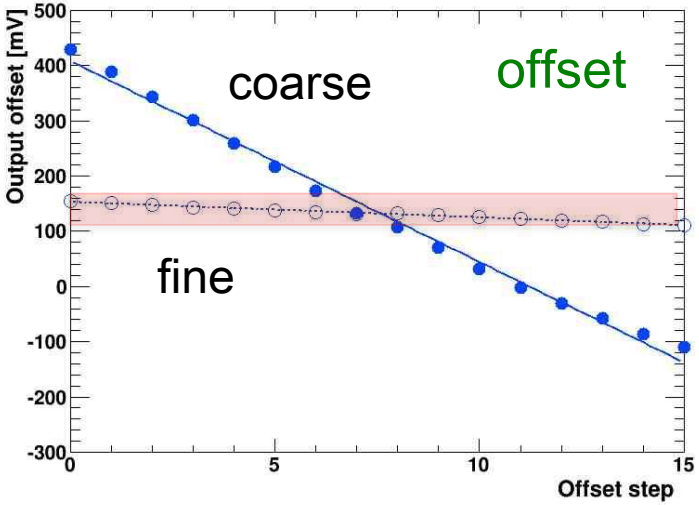


ASIC Test



- All the 2520 ASICs have been tested at TMU.
  - ✓ Measure 6 ASICs in one board (using a sub-board with BGA-type sockets).
  - ✓ 1680 ASICs + spare are necessary.
- Automatic test program was developed.
  - ✓ Parameter loading, dead channels.
  - ✓ Gain (linearity) and offset adjustment.
  - ✓ 1 p.h. detection (assuming irradiated HAPD).





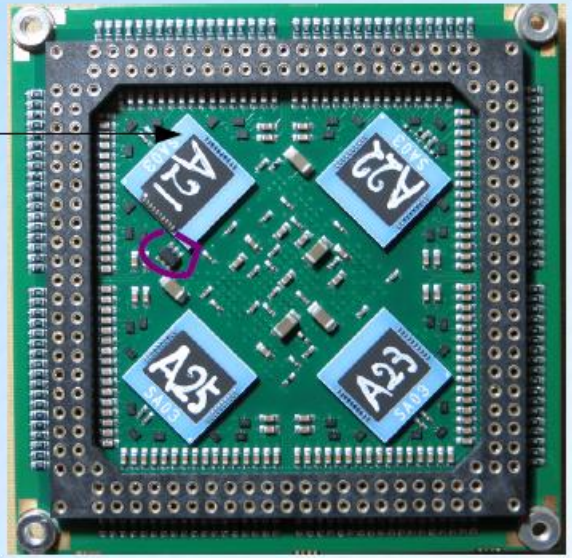
FE board

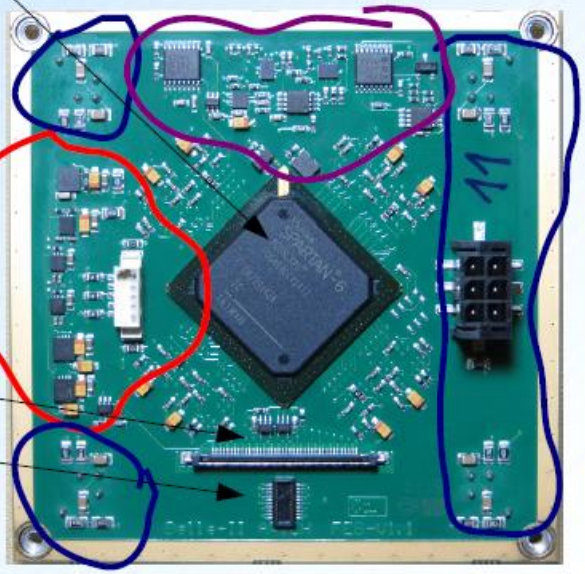
Main components:

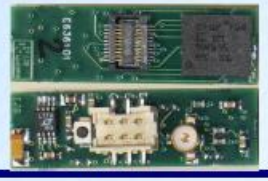
- 4 ASICs + FPGA: Spartan6
- Power distribution
- APD bias distribution
- Threshold, test pulse generation
- Stand-alone clock generation
- Monitoring: threshold, temperature, supply voltages and analog signals

FEB SlowControl data:
TMON0 = 32.1 C
TMON1 = 32.3 C
VDD = 1.649 V
V+2 = 1.904 V
V-2 = -1.839 V
VSS = -1.627 V
VTH1 = 0.745 V
VTH2 = 0.004 V
VCC12 = 1.194 V
VCC15 = 1.491 V
VCC25 = 2.491 V
V+3.8 = 3.768 V

- Merger connection
- Stand-alone operation: PROM, JTAG: detachable







New boards

- New boards were produced end of March
- In addition to ESD:
  - ID chip not mounted (Spartan6 ID used)
  - SMD nuts
  - negative threshold voltage monitoring fixed