COMMISSIONING AND PERFORMANCE OF THE COMMON READOUT SYSTEM FOR THE BELLE II EXPERIMENT

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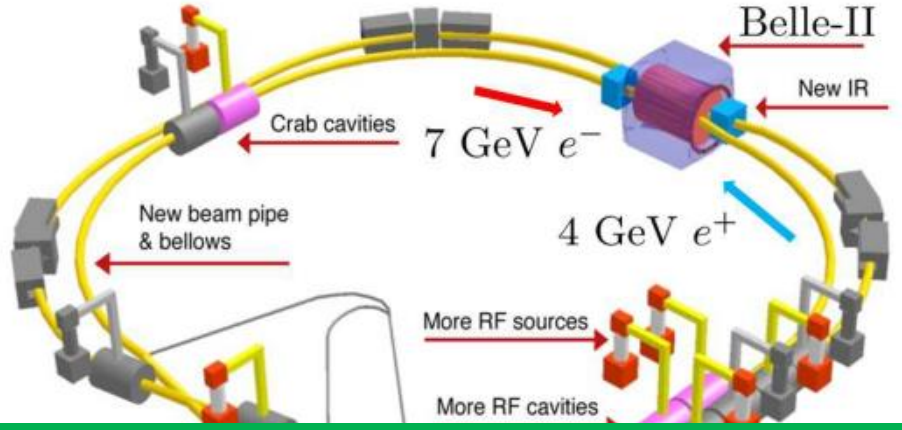
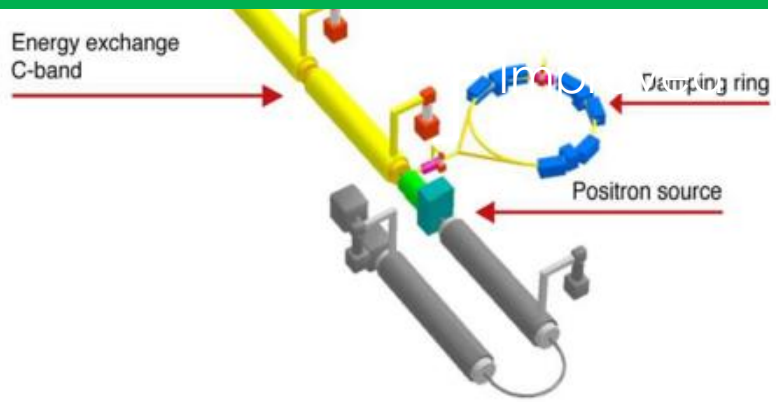
THE BELLE II EXPERIMENT

- Search for new physics beyond the Standard Model(SM) via high precision measurement with high statistics samples of B/D/tau decays.

- **SuperKEKB accelerator**
  - Designed luminosity: 40times as large as KEKB
  - 50 ab^{-1} in 10 years
    (cf. 1ab^{-1} @ Belle experiment)



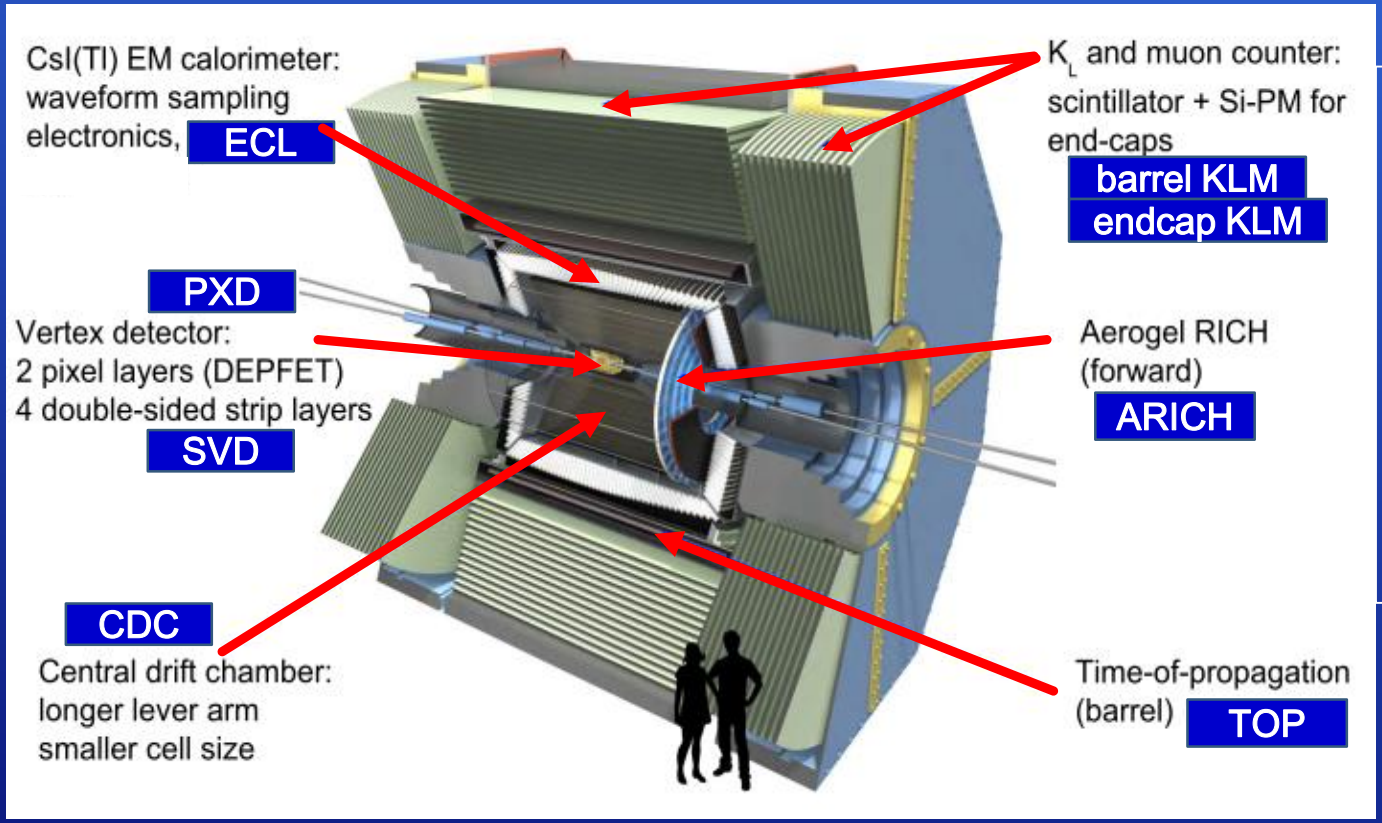
Increase of beam current	x2	luminosity
Smaller beam size	x20	x40



Belle II collaboration :
～600 collaborators from 23 countries

Belle II detector

- consists of 7 sub-detectors.



Sub-detectors

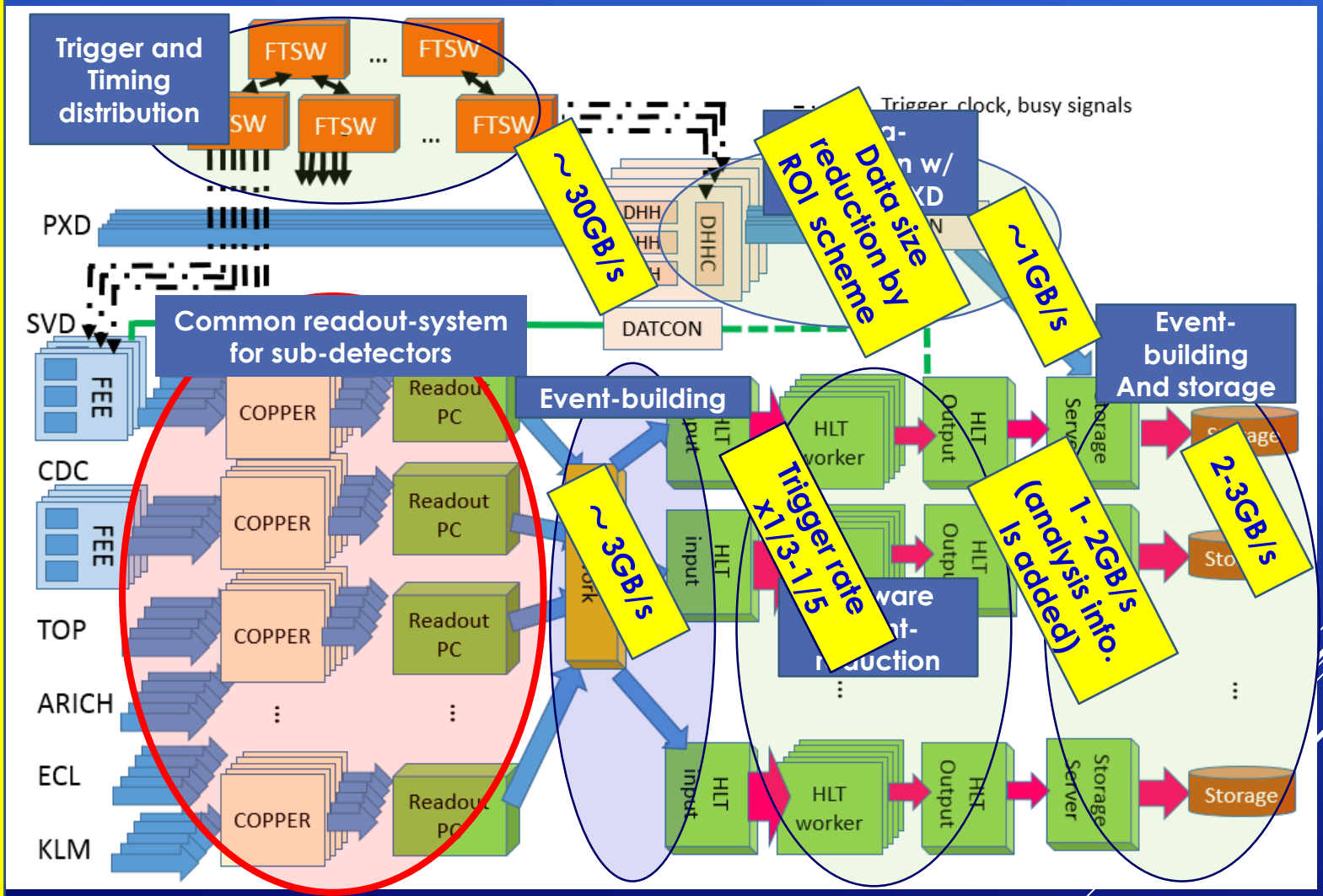
- Vertex finding:
→ **PXD, SVD**
- Tracking
→ **CDC**
- Particle ID
→ **TOP, ARICH**
- Calorimeter
→ **ECL**
- Muon, neutral Kaon
→ **KLM**

Schedule :

2016 – phase I run (accelerator commissioning and beam b.g. study(BEAST))
2017 : phase II run (with the belle II detector except for the vertex sub-detectors)
2018 : phase III run (with the full Belle II detector)

BELLE II DAQ SYSTEM

Level1 trigger ~ 30kHz (max. value for DAQ development)



X210 readout boards

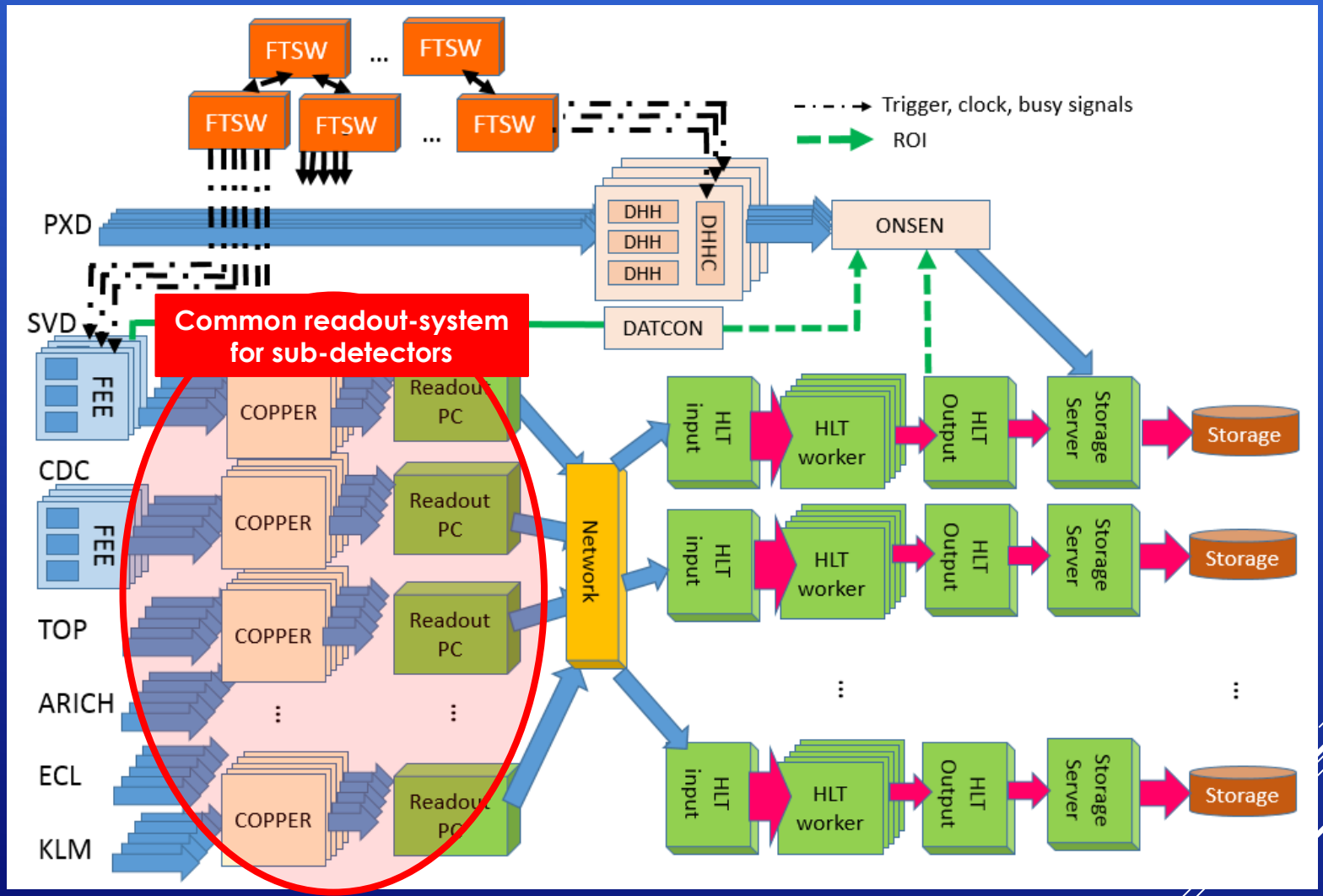
X40 Readout PCs

1GbE/10GbE switch

x10 High Level Trigger+storage unit
HLT: (20nodes x 16cores)/ unit

READOUT SYSTEM FOR BELLE II EXPERIMENT

READOUT SYSTEM IN BELLE II DAQ



- Readout data from FEEs for six sub-decteors other than Pixel detector
- Formatting, data-checking and partial event-building should be done

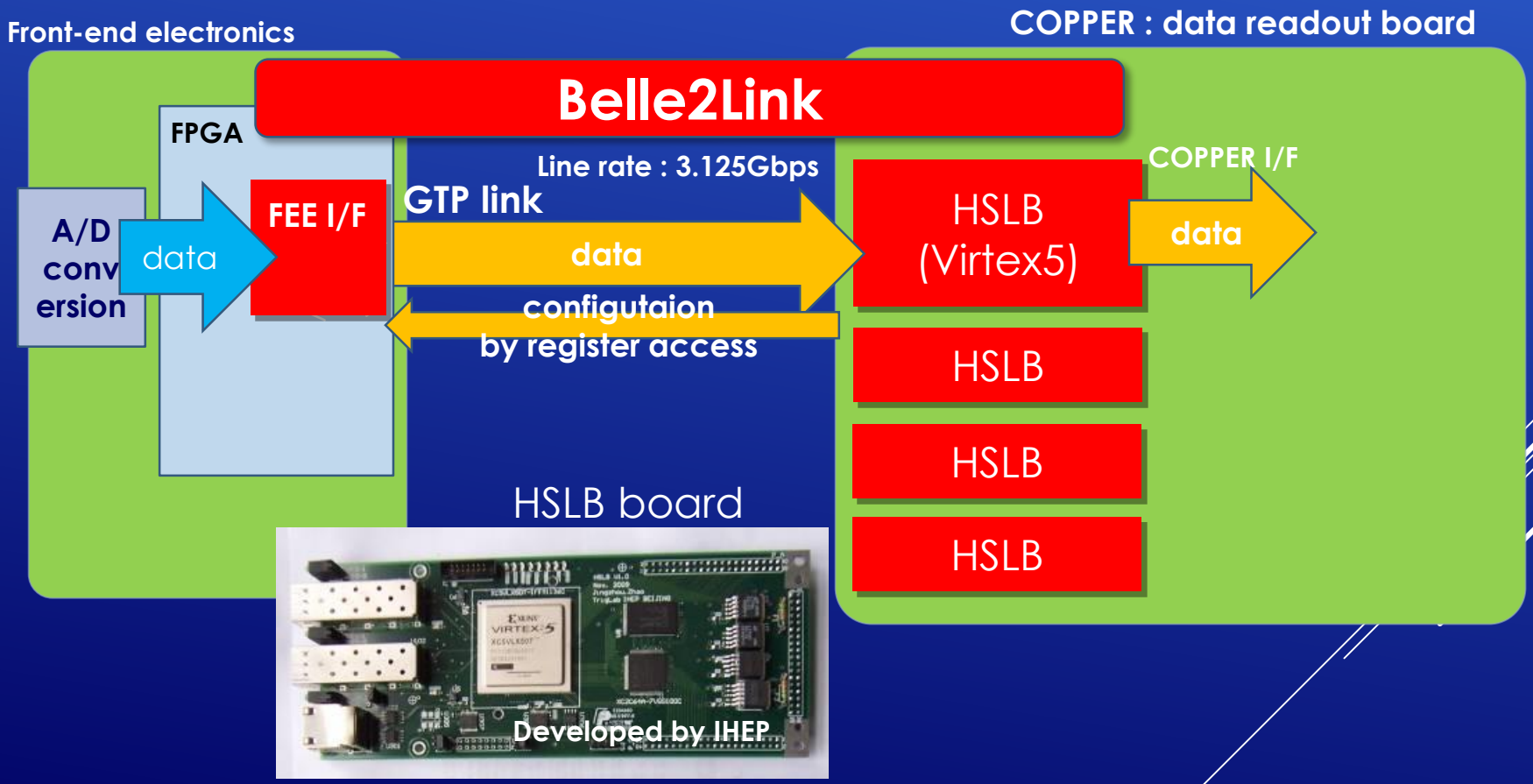
DATA TRANSMISSION FROM FRONTEND ELECTRONICS

Belle2Link : (D. Sun et. all, hysics Procedia Volume 37, 2012, pp. 1933-1939)

Unified high speed link which connects Front-End Electronics (FEE) and DAQ system for signal with data transmission based on Rocket I/O

FEE side : Functions for I/F with FEE and Trigger Timing Distribution on FPGA

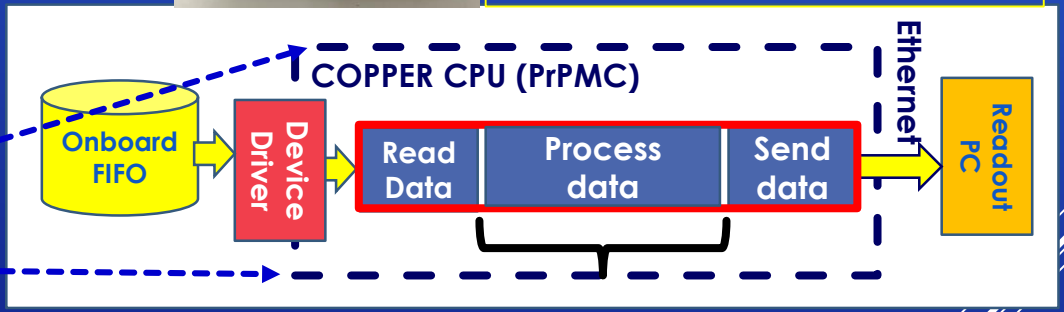
DAQ side : High Speed Link Board(HSLB) as a data receiver



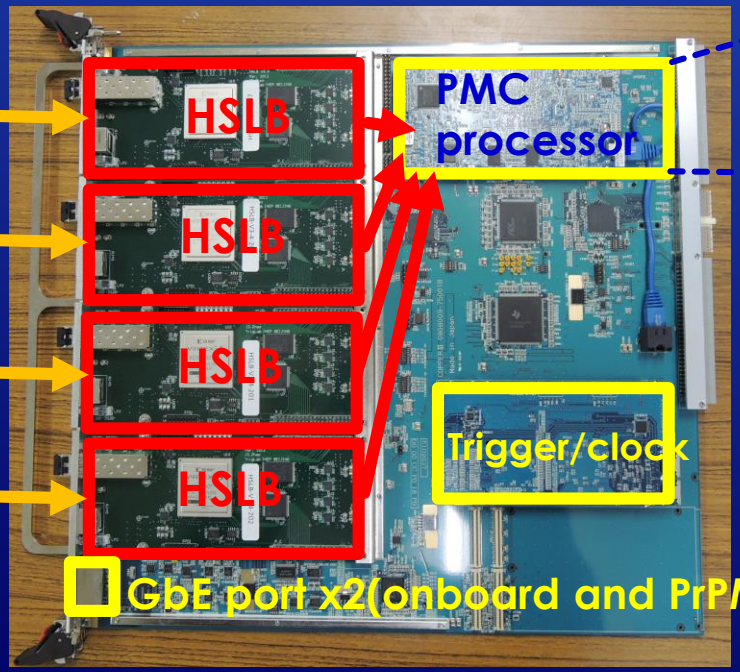
DATA PROCESSING ON READOUT BOARDS

- Readout board : COPPER (COmmon Pipelined. Platform for Electronics Readout)
  - Versatile DAQ board developed at KEK
    -> basically same functionality in the previous Belle experiment
  - can be equipped with various I/O cards and CPU card
    -> new daughter-boards for Belle II are used

- CPU: Intel Atom 1.6GHz Z530P
- DDR2 SDRAM 512MB
- PXE boot from ROPC
- Gigabit Ethernet x1



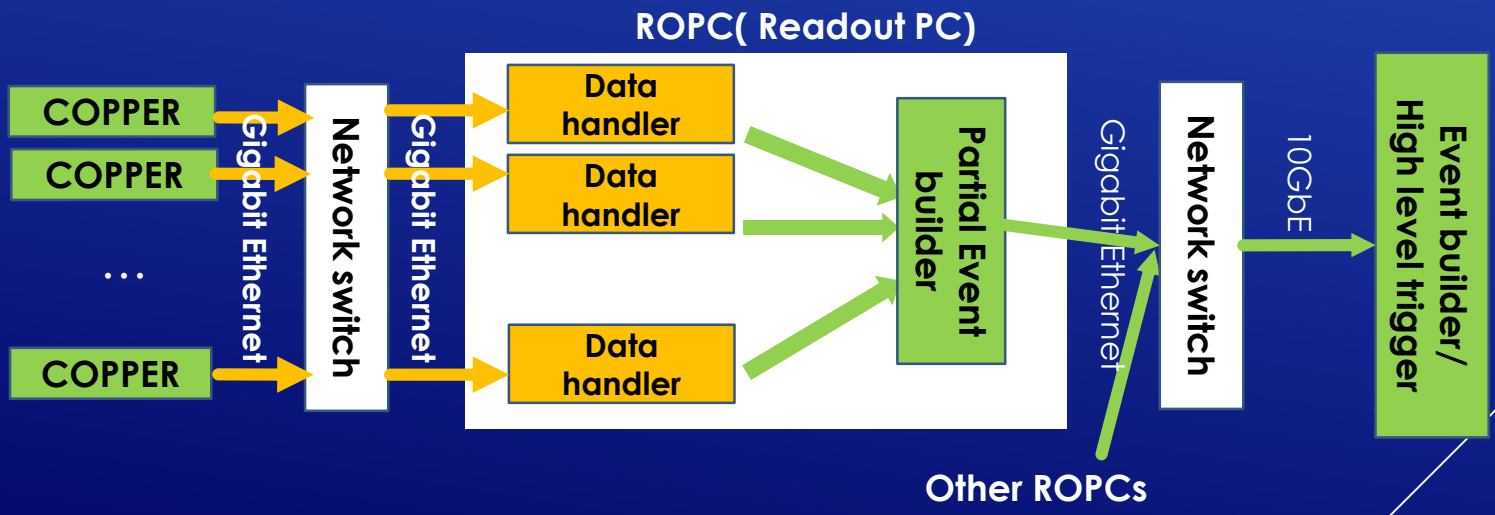
COPPER board



- **Data processing on COPPER CPU**
  - Data formatting (Add header and trailer to raw data)
  - Plain data check
    - Event incrementation, check magic word etc.
  - Add XOR checksum
  - Report data-flow status to slow control

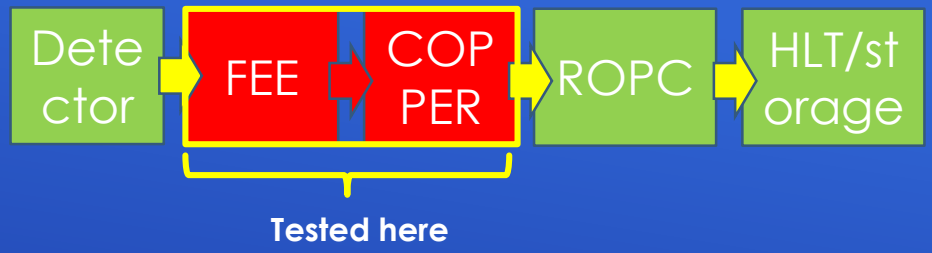
DAQ SOFTWARE ON READOUT PC

I. data check by data-handler process
   I. Calculate CRC16 and compare CRC value attached by FEE
   II. XOR checksum calculated by software on COPPER
II. Data size reduction
   merging redundant header/trailer attached by b2link and COPPER)
   Reduction by 15MB/s/ROPC at 30kHz trigger rate(<- 5COPPERs/ROPC, 4HSLB/COPPER)
III. Collect data from several COPPERs and do partial event-building and send data to High level trigger unit.

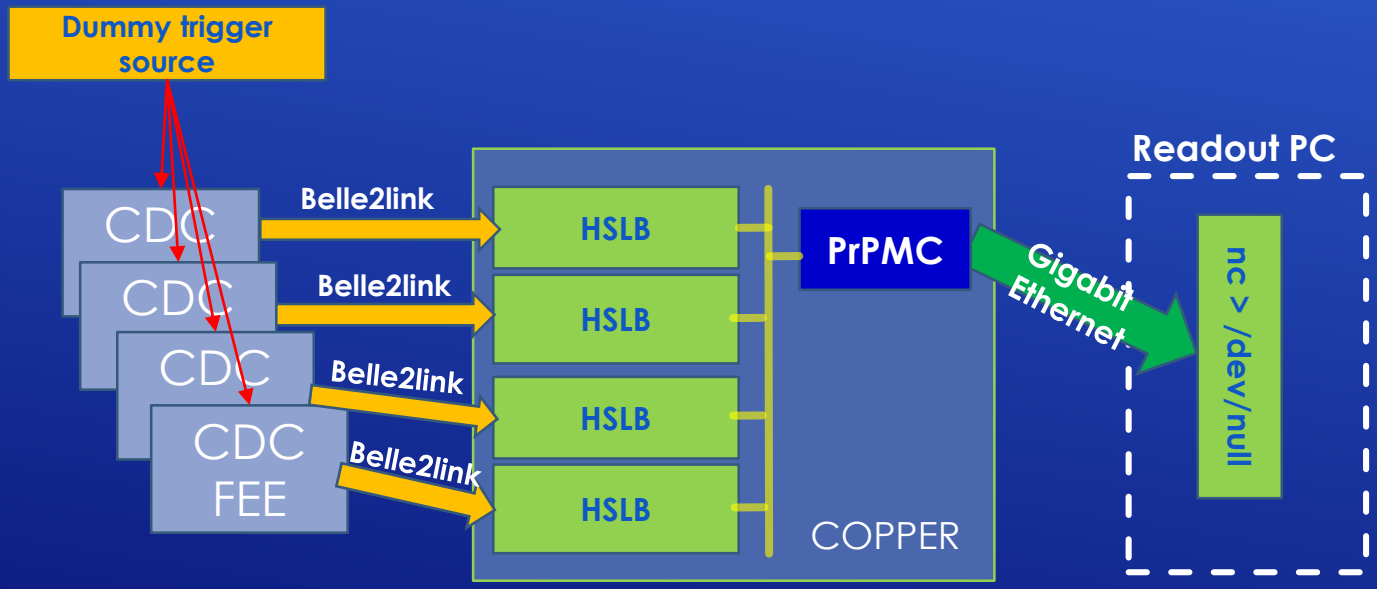


PERFORMANCE TEST OF THE READOUT SYSTEM

Performance test(1): between FEE and COPPER



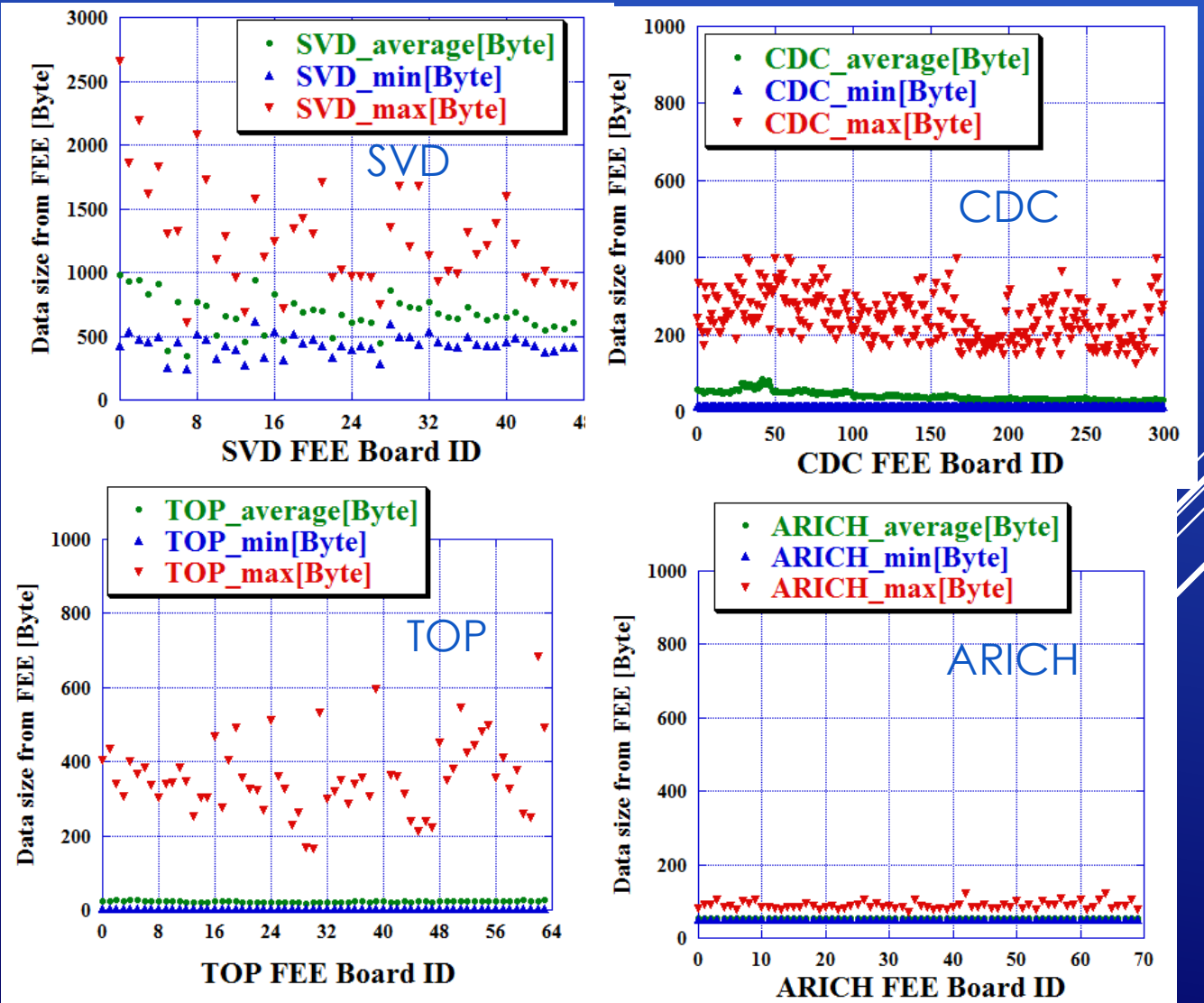
- Test setup



We can test
- data-transfer performance of belle 2link
- CPU usage on COPPER PrPMC

Event-size estimation from MC simulated data

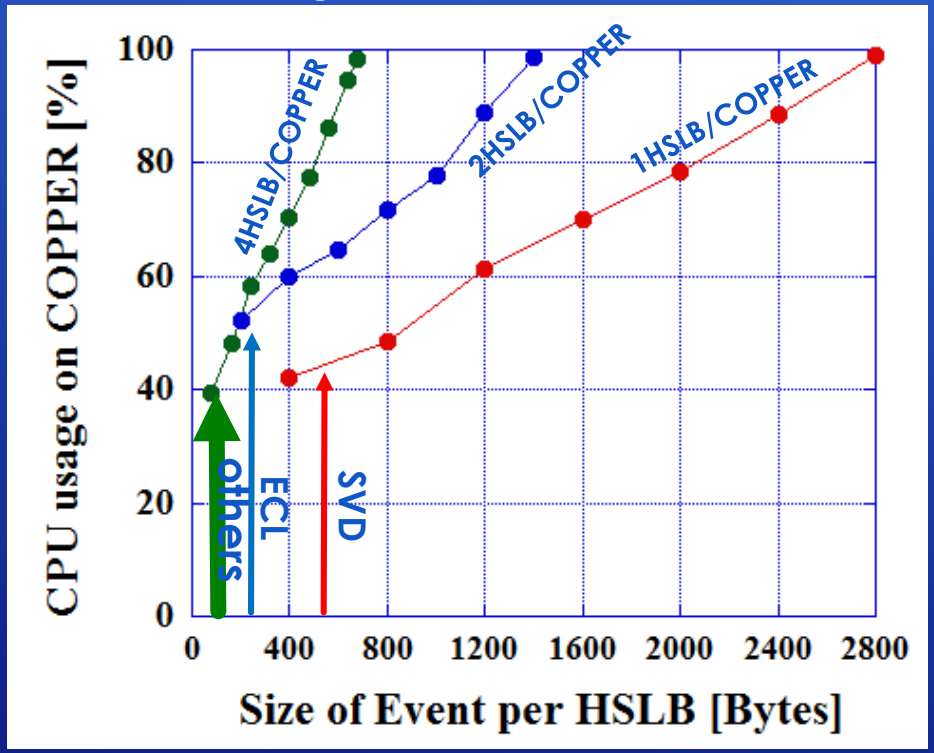
More detailed data size estimation for some sub-detectors with MC data to consider assignment of readout boards.



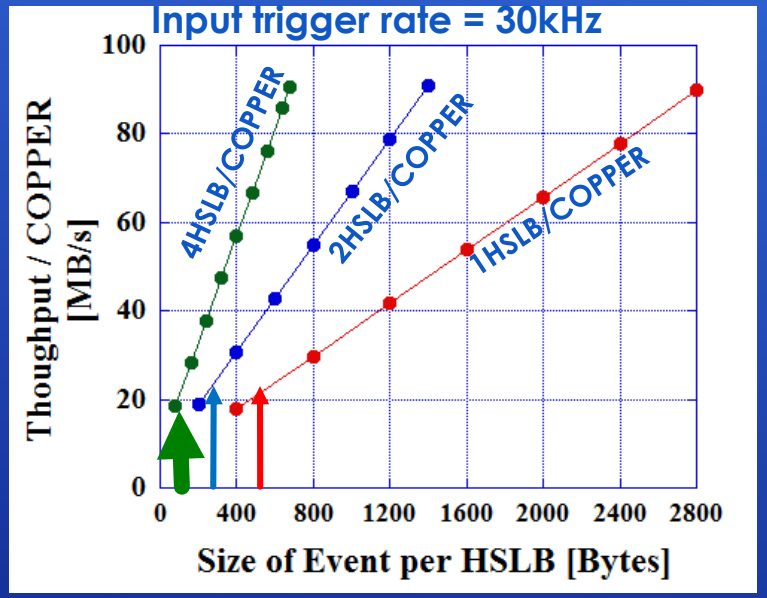
- Difference of event size is handled by the number of receiver cards on COPPER
- SVD : 1HSLBs/COPPER
- ECL : 2HSLBs/COPPER
- CDC/TOP/ARICH/KLM : 4HSLBs/COPPER

RESULTS :

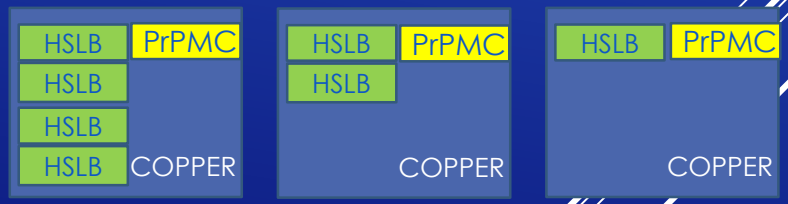
CPU usage on COPPER PrPMC



Throughput from COPPER



- 30kHz operation was achieved.
- CPU usage will be the bottleneck when the event size becomes larger than expected.
- Throughput in Belle2link and Gigabit Ethernet to a readout PC has still enough remaining room.



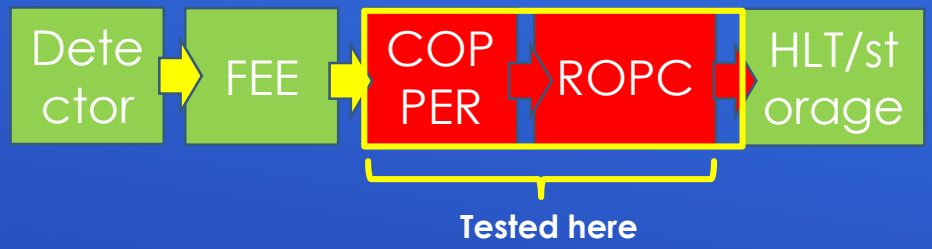
CDC
TOP
ARICH
KLM

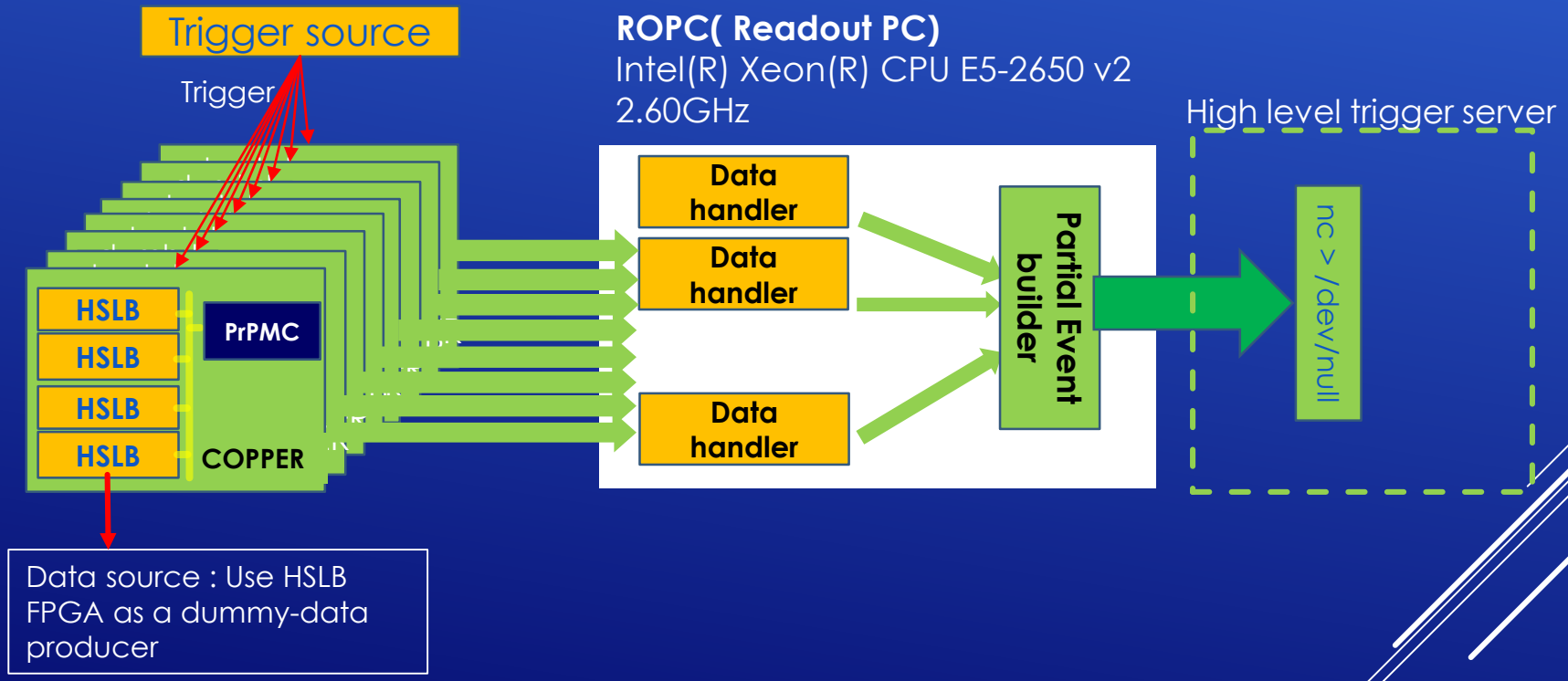
ECL

SVD

Performance test (2): with COPPER and Readout PC

- 1ROPC and several COPPERs.
- # of COPPERs differs over sub-detectors due to the difference of event size
- Provide trigger to COPPER board to produce dummy data by HSLB.



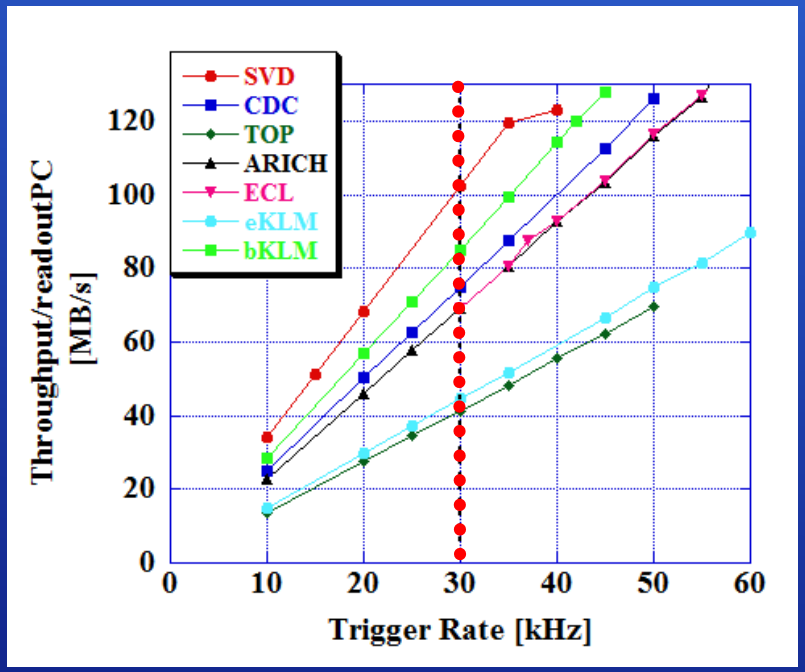


We can test

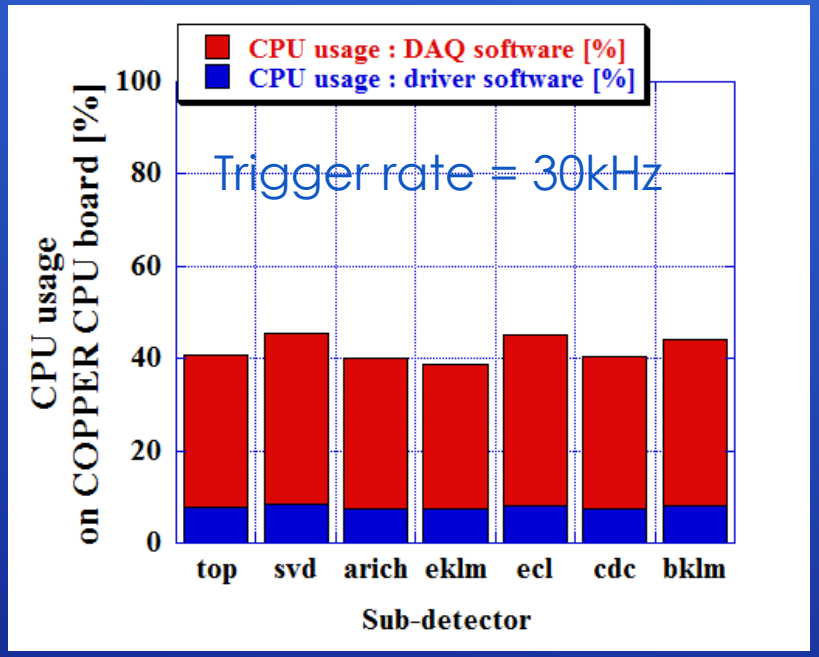
- Processing power of COPPER and ROPC
- data-transfer performance between COPPER and ROPC, ROPC and HLTin.

RESULTS :

Throughput on ROPC



CPU usage on COPPER



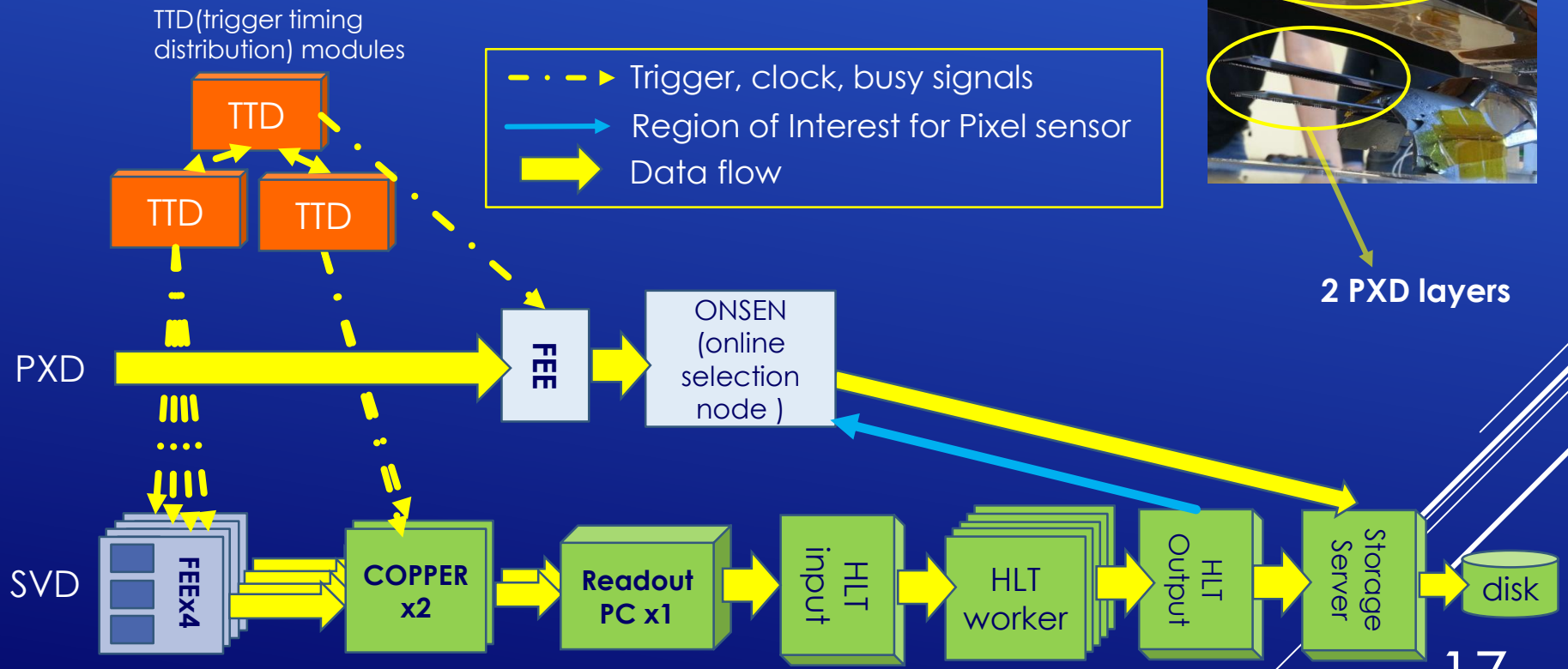
- 35kHz for SVD is the max. event rate.
- Bottleneck : Output data flow to HLT is near the limit of GbE.
  - CPU usage on COPPER CPU is still room to increase the rate
- Increase # of Readout PCs or increase throguhtoput between ROPC and HLT will increase the limit.

COMMISSIONING OF THE READOUT SYSTEM

Beam test with vertex detectors

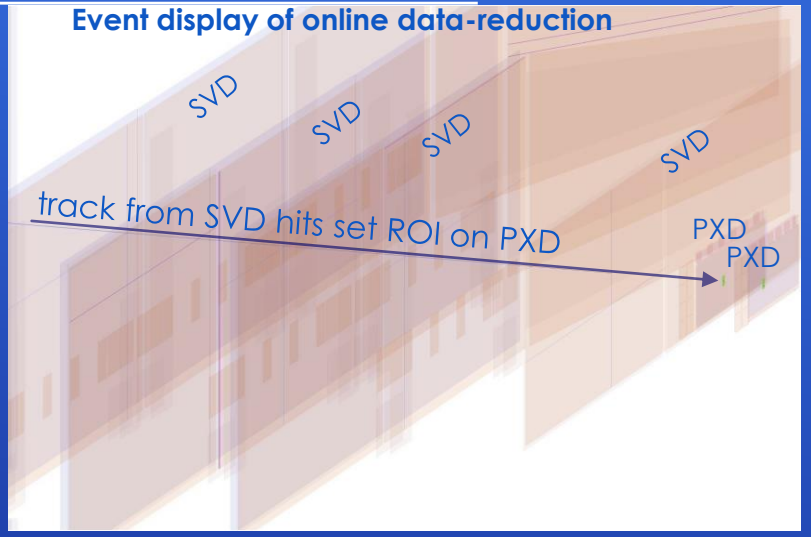
Sensors of two vertex detectors were irradiated with multi-GeV electron beam at DESY.

-> Demonstrate a full read-out chain from sensors by the setup of the Belle II DAQ system

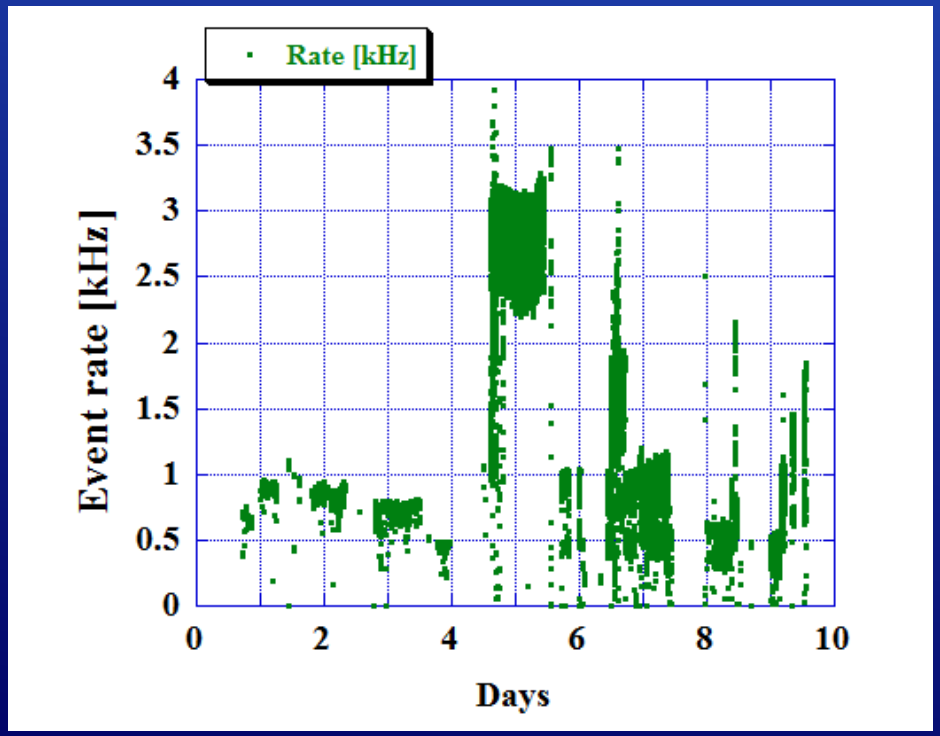


EVENT RATE AND RUNNING TIME DURING THE BEAM TEST

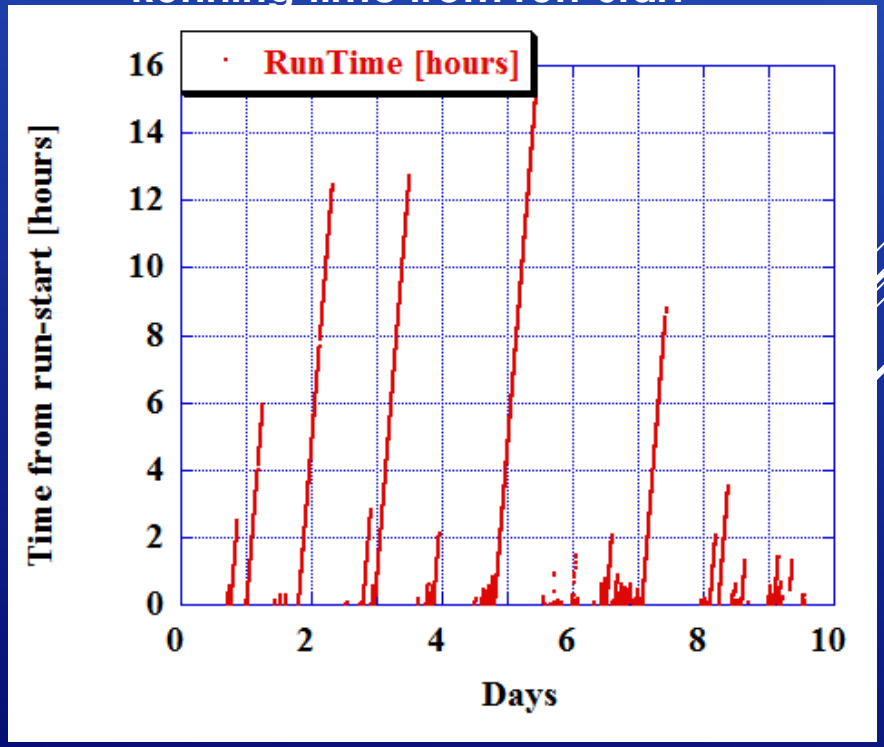
- DAQ operation during the beam test
  - Beam trigger Rate : 500Hz- 3kHz,
  - DAQ was stable for hours during over-night data-taking.



Event processing rate

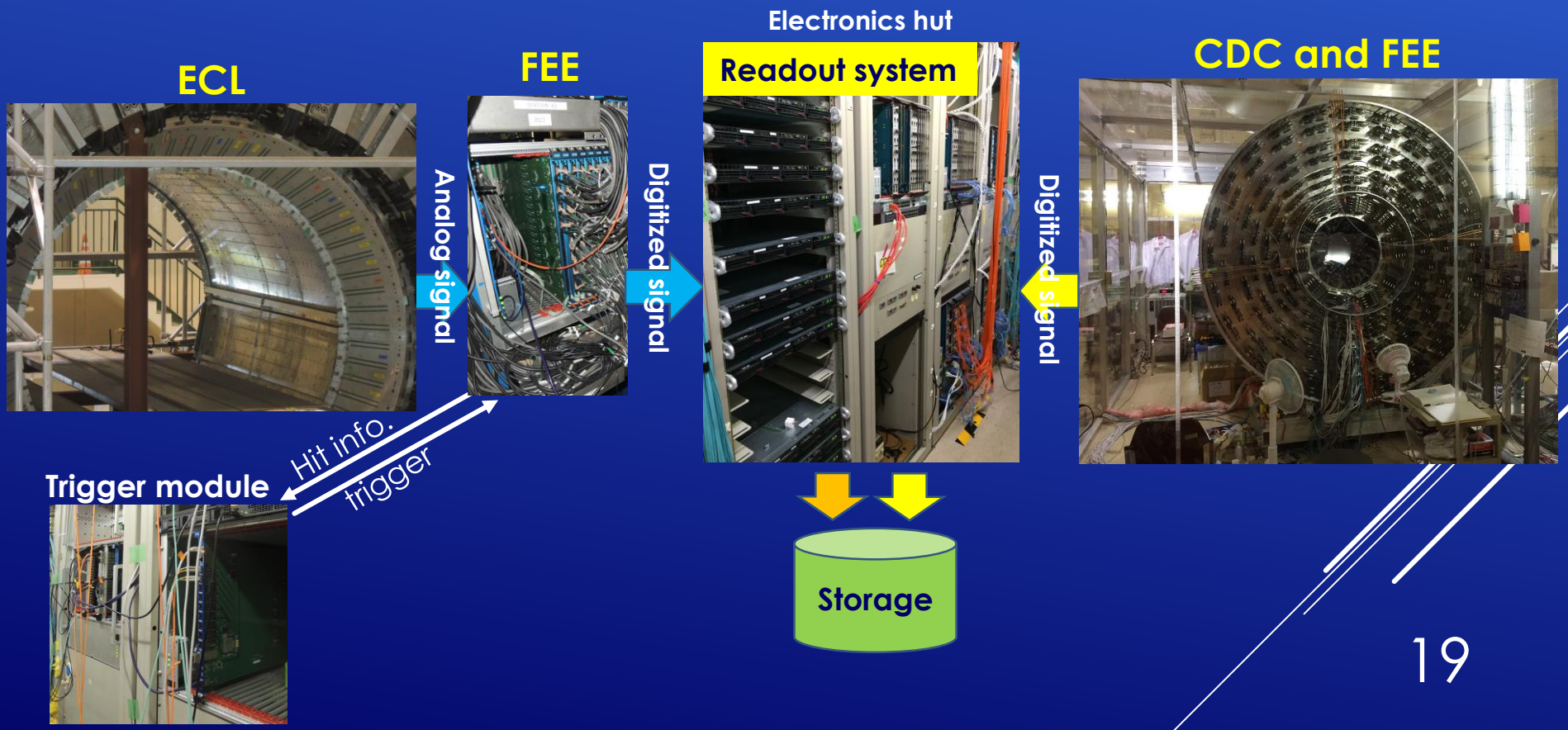


Running time from run-start

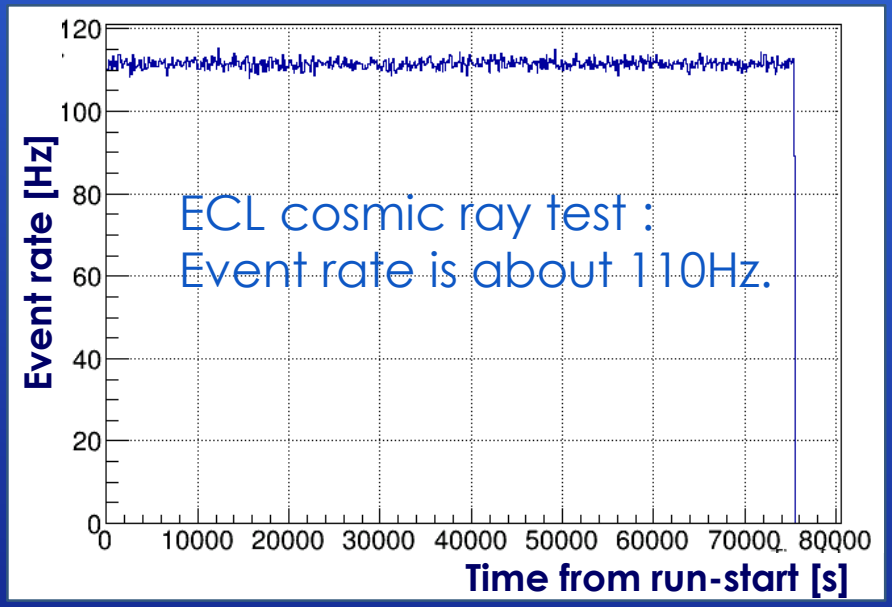


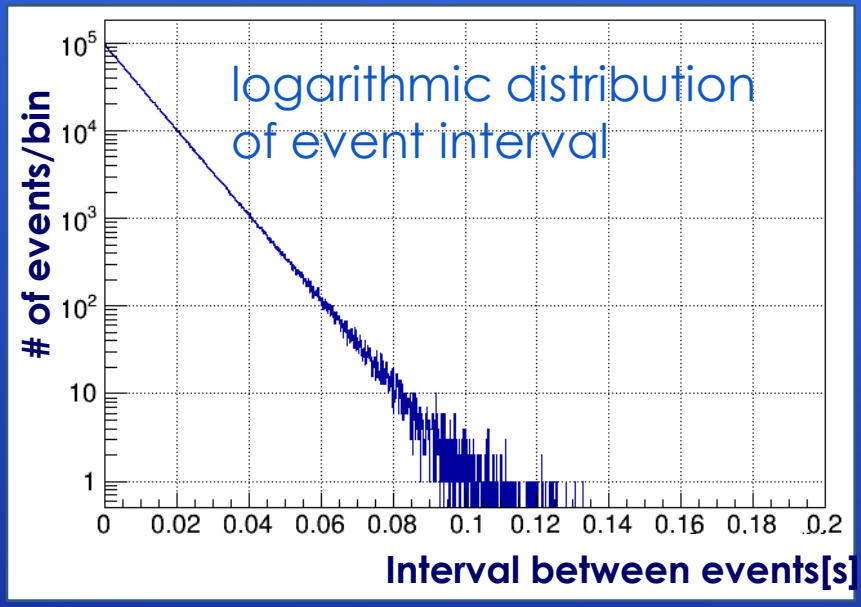
3. Cosmic-ray measurement at the Belle II experimental Hall

- Some of the Belle II sub-detectors are now in the Belle II experimental hall and started cosmic-ray test
- Good commissioning for the readout system to take data from the actual FEE and sensors.

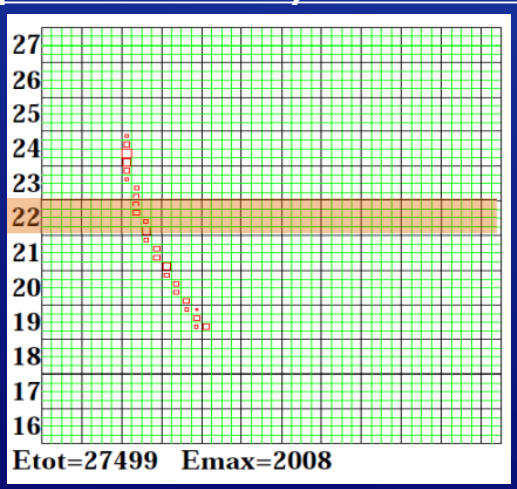


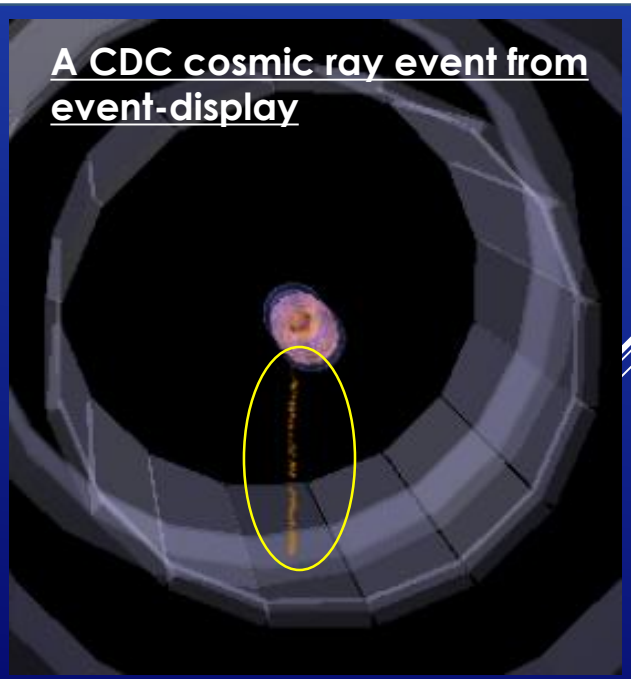
Some plots about data stream



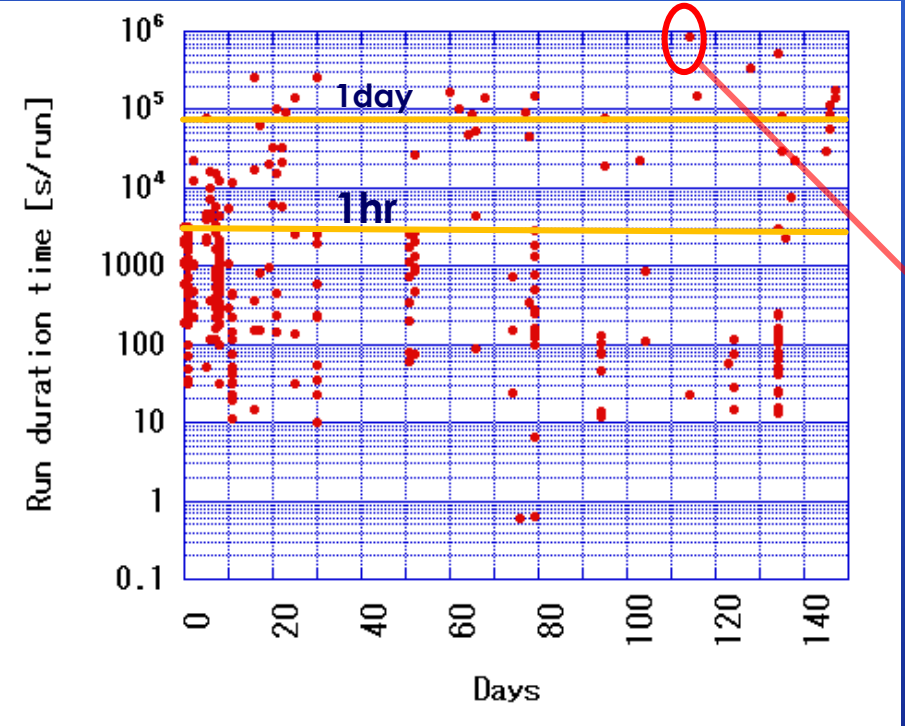


Example of cosmic ray event from ECL hit map





Long term stability of DAQ system



- Long term operation for DAQ is on-going.
- Not all the runs stopped due to errors (We usually intentionally stopped runs).
- The longest run was about 10 days long.

Integration plan for the Belle II DAQ

2016 -2017: cosmic ray campaign with installed sub-detectors.
2017 : implementation for phase II run (without vertex detectors)
cosmic ray test for vertex detectors.
2018 : implementation for phase III run (with the full detector)

SUMMARY

In the Belle II experiment, DAQ system needs to handle data-flow with 40times larger luminosity than the former Belle experiment.

We have developed a common readout system for sub-detectors except for pixel detector

- It consists of COPPER, Belle2Link and readout PC and interconnects FEE and high-level trigger.

- Data-processing performance have been tested using dummy data and trigger
  - High rate test with FEE and COPPER
  - High rate test with COPPER and readout PC

-> The target value of 30kHz event rate can be achieved.

- Data-taking with actual sub-detectors and FEEs have been started.
  - Beam test : SVD and PXD
  - Cosmic ray test : ECL and CDC

  In both case, the readout system works stably and have enough performance.


THANK YOU FOR YOUR ATTENTION.