ATLAS 実験シリコン検出器アップグレードの為のテスト用 DAQ システム

計測システム研究会@J-PARC

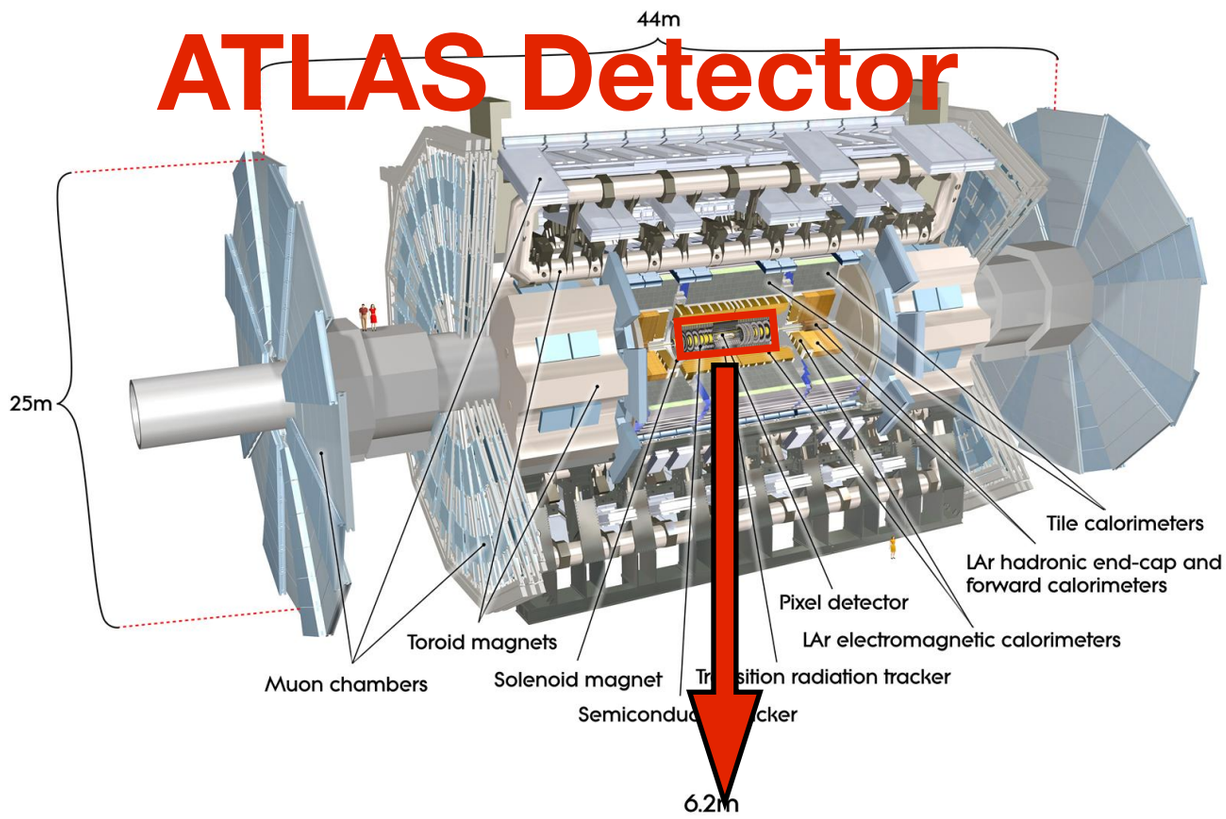
2014/11/20-21

廣瀬穣 for the ATLAS-Japan silicon group

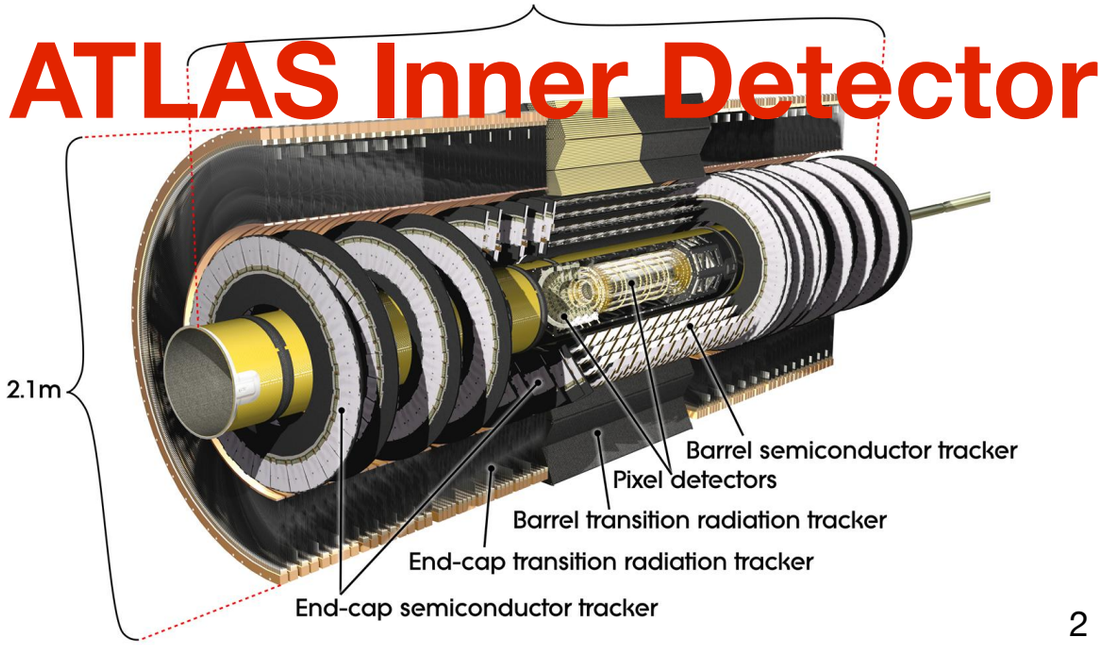
東工大理工

Introduction

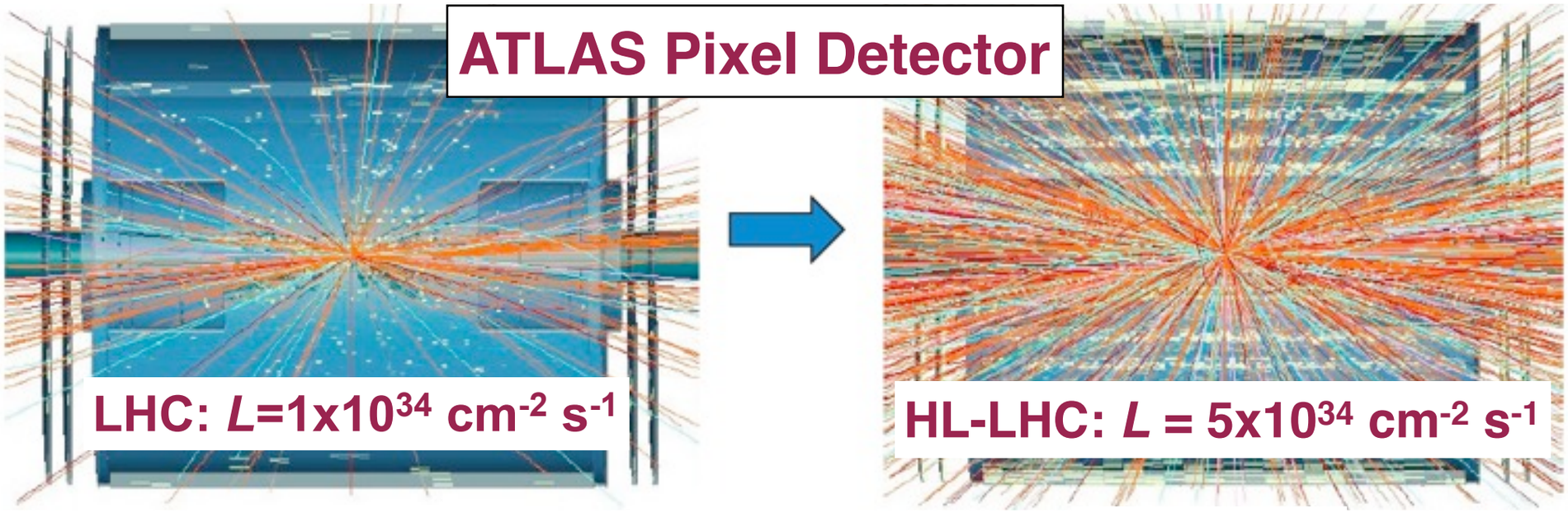
- Inner detector in ATLAS
  - ➡Purpose :
    - Particle tracking
    - Vertexing
  - ➡Provides very important information for “every” reconstructed objects.



- ATLAS-Japan group is involved in the silicon tracker.
  - ➡Pixel detector
  - ➡SemiConductor Tracker (SCT)



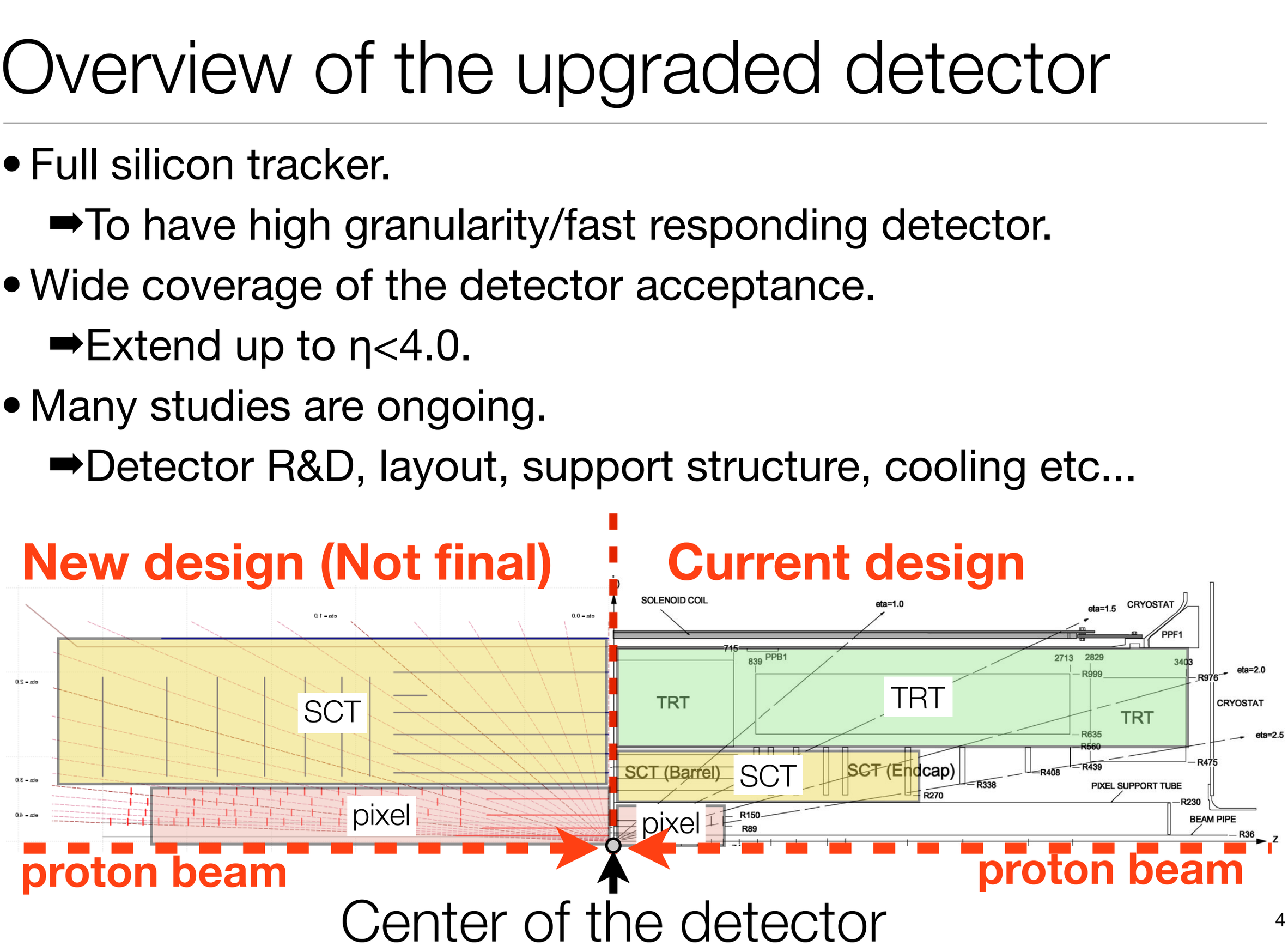
Inner detector in HL-LHC



- Many problems to use the current design.
  - ➡Intolerable radiation damage
    - Fluence of ~10^{16} n_{eq}/cm^2
  - ➡Unacceptable occupancy
    - 23 → 140 *pp* collisions in one bunch crossing.
- **Completely new design is under study for the upgrade.**

Overview of the upgraded detector

- Full silicon tracker.
  - ➡To have high granularity/fast responding detector.
- Wide coverage of the detector acceptance.
  - ➡Extend up to η<4.0.
- Many studies are ongoing.
  - ➡Detector R&D, layout, support structure, cooling etc...



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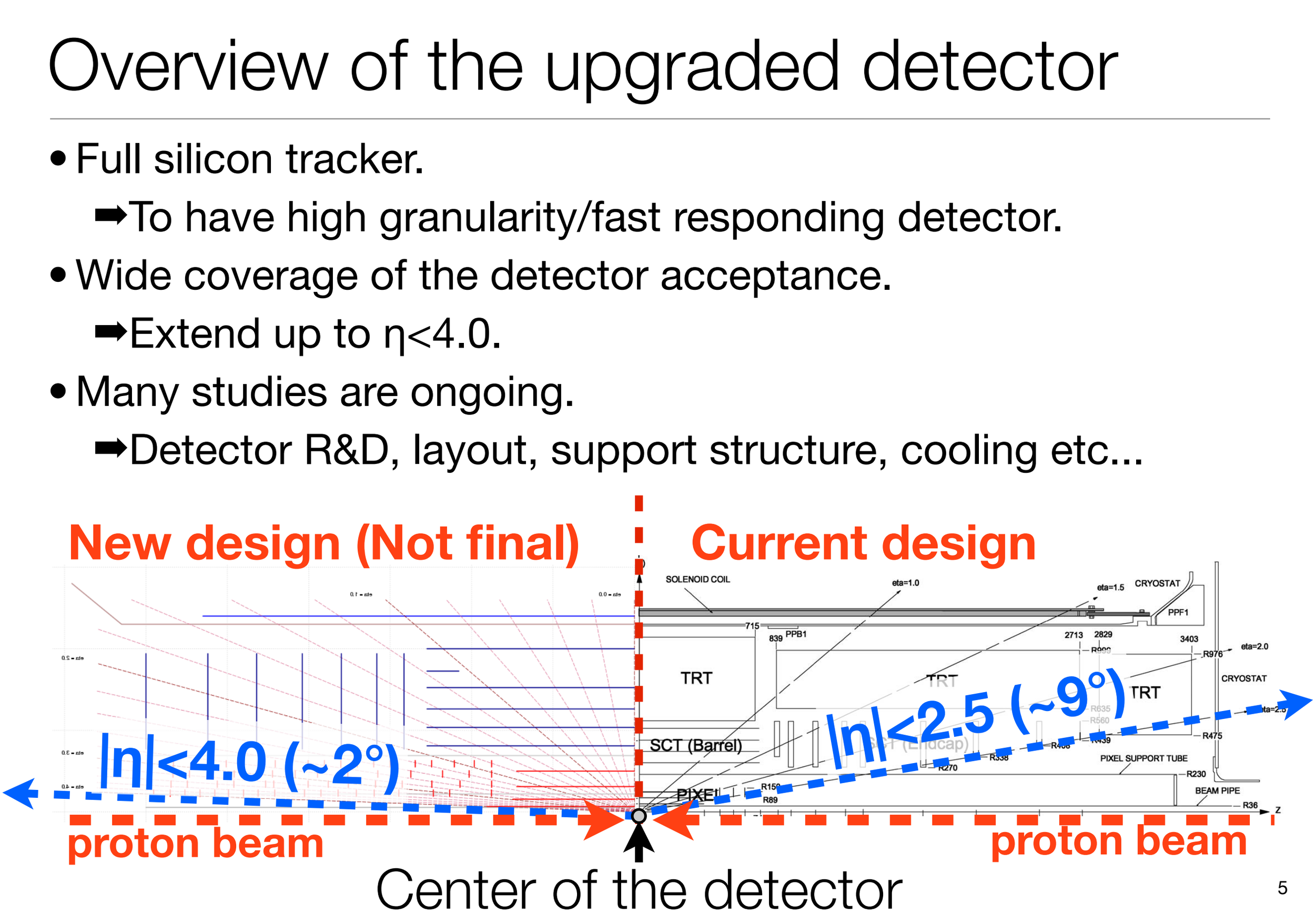

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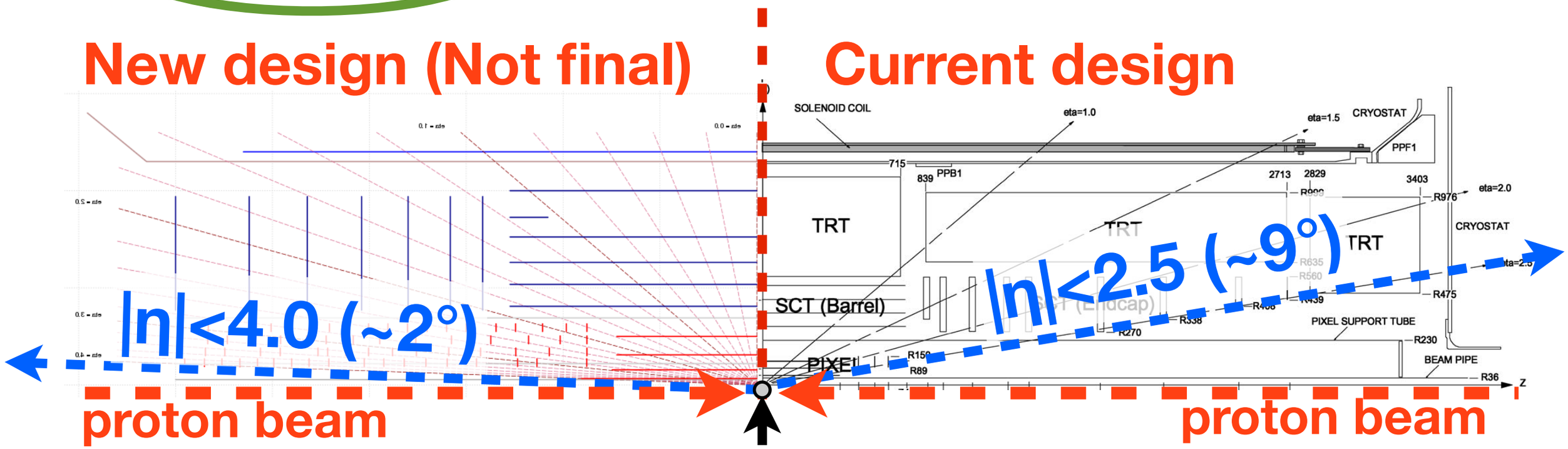
  - ➡**Detector R&D.** layout, support structure, cooling etc...

Japanese group is working mainly on this part.



Work field relating to DAQ

- **Pixel** :
  ➡DAQ development for testing new module design.
- **SCT** :
  ➡DAQ development for testing new module design.
- **Telescope to test the detectors above** :
  ➡DAQ development to readout telescopes.
  - Telescope : reference detector to provide hit position.
  ➡Software to operate the telescope+DUT system.

※DUT : Device Under Test

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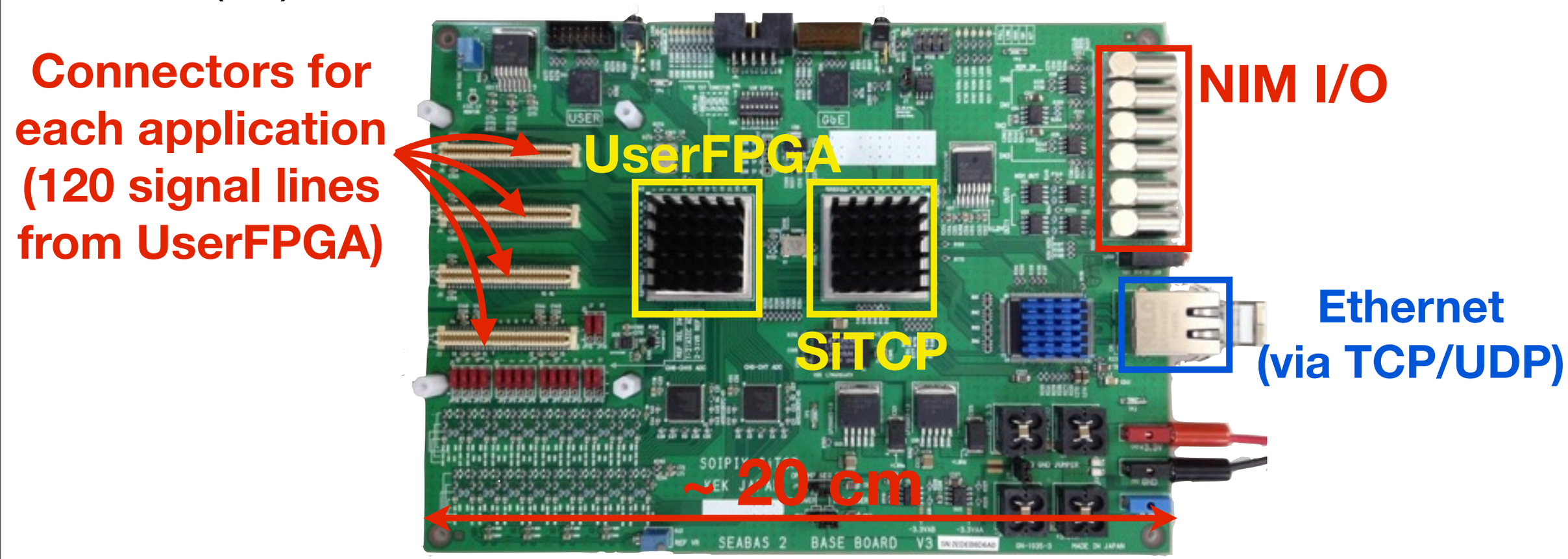
All these DAQ systems are developed based on the “SEABAS” board.

※DUT : Device Under Test

Introduction of the SEABAS board

- SEABAS(2) : general purpose DAQ board with SiTCP.
  - ➡SiTCP : network processor to communicate with PC.
    Maximum data rate : 100 (1000) Mbps.
  - ➡FPGA for each user application.
  - ➡2(4)×NIM_IN, 2×NIM_OUT (trigger, busy etc...).
  - ➡1(16)ch×ADC and 4ch×DAC



Advantage to use SEABAS

- “Compact” and “versatile” DAQ system.

➡Compact :

- Don’t need large crates just for testing prototypes...

✓E.g. NIM, CAMAC, VME, ATCA etc...

- Portable system is preferable.

✓We have to transport the system for the testbeam.

➡Versatile :

- Have to test new features of the prototype quickly.

SEABAS is one of the good solution !!

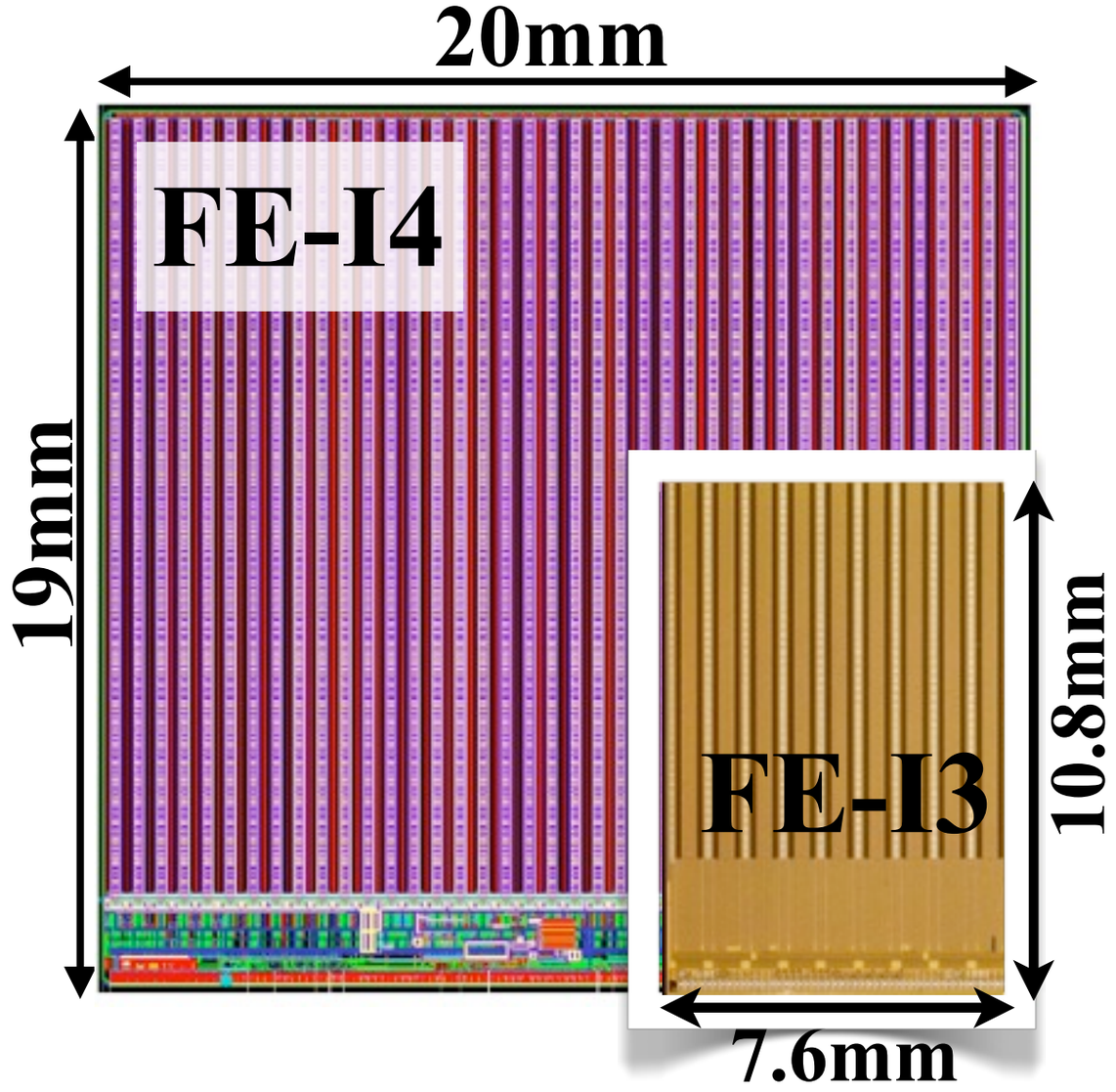
- enough data transfer speed.

-enough I/O ports.

Pixel module readout

Upgrade of the pixel detector

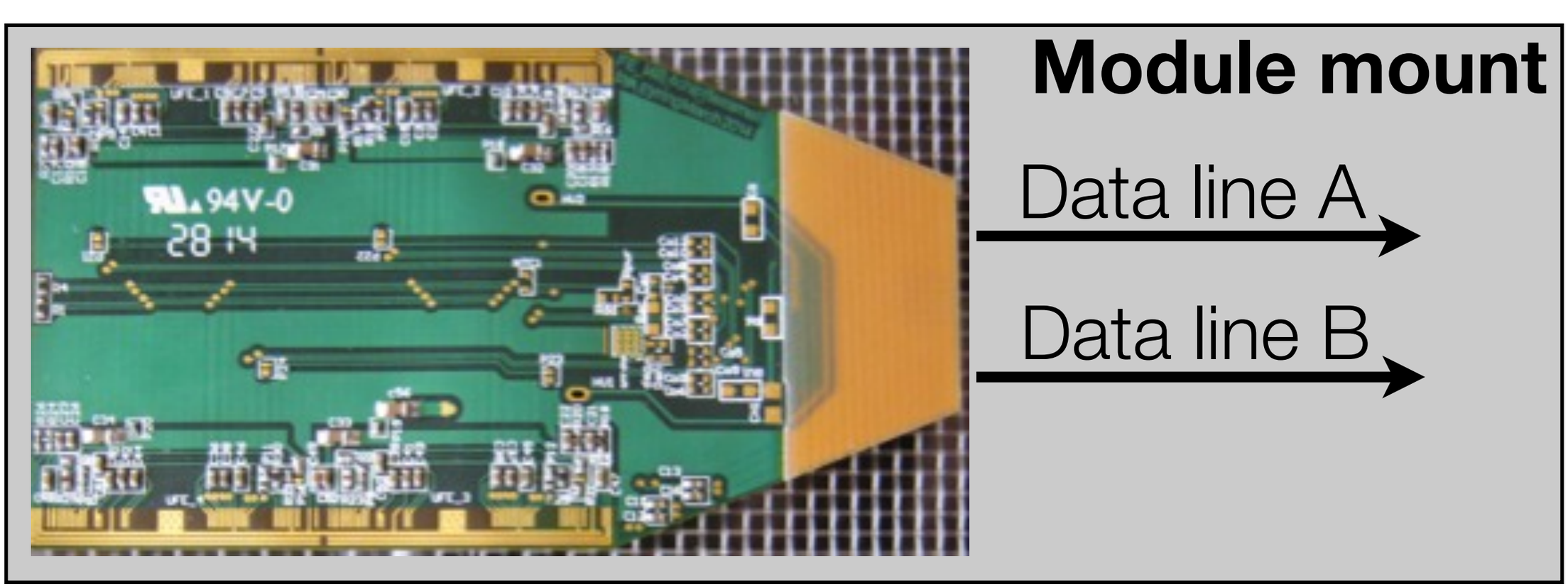
- Readout ASIC : FE-I3 → FE-I4.
  - ➡Smaller pixel size, faster readout speed.
    - To cope with higher hit rate.



	FE-I3	FE-I4
Pixel array	18×160	80×336
Pixel size (um^2)	50×400	50×250
Data rate (Mb/s)	40	160
CMOS process (nm)	250	130

Expected module design

- Final design for the pixel module uses an multiplexer (MUX).
  - ➡Since module mount have only two data line for one module.



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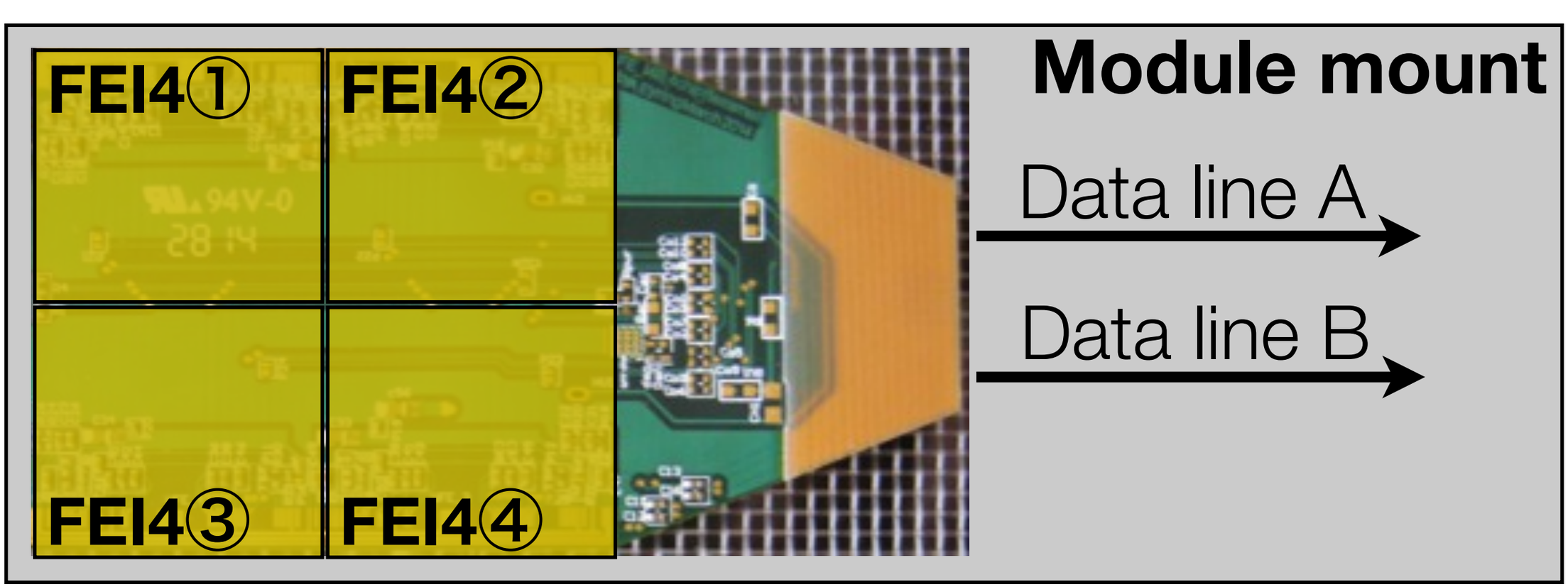

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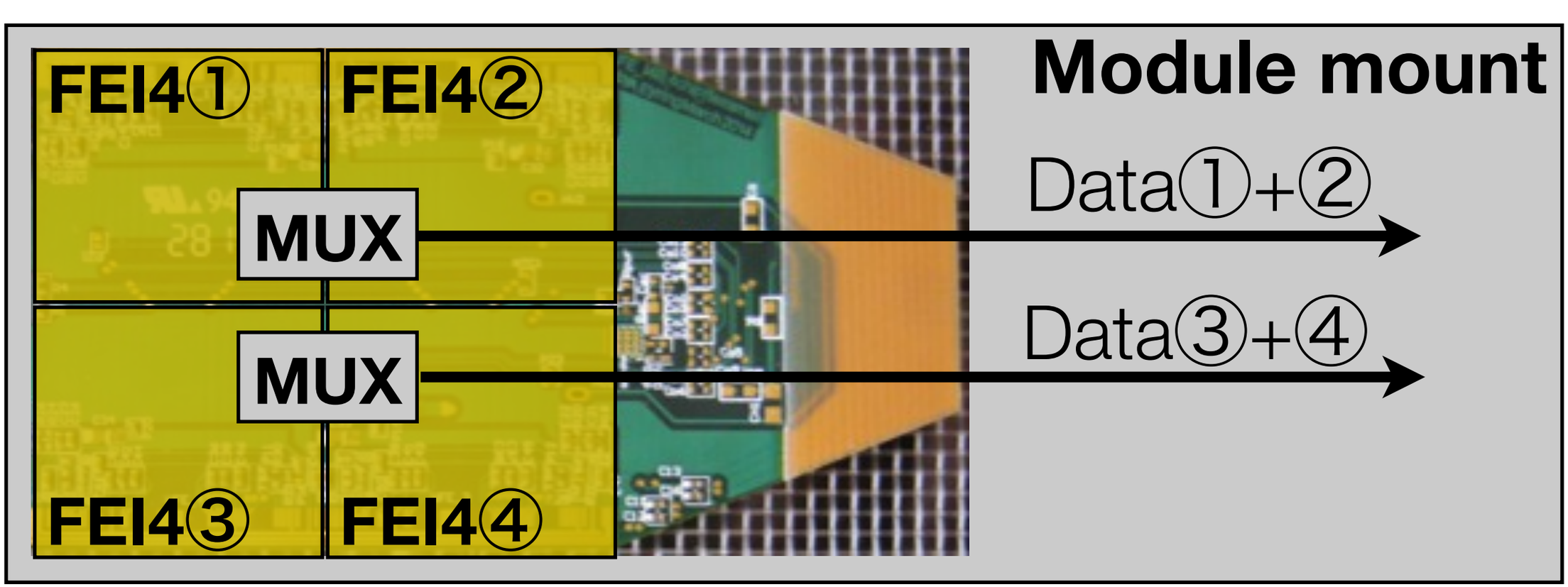
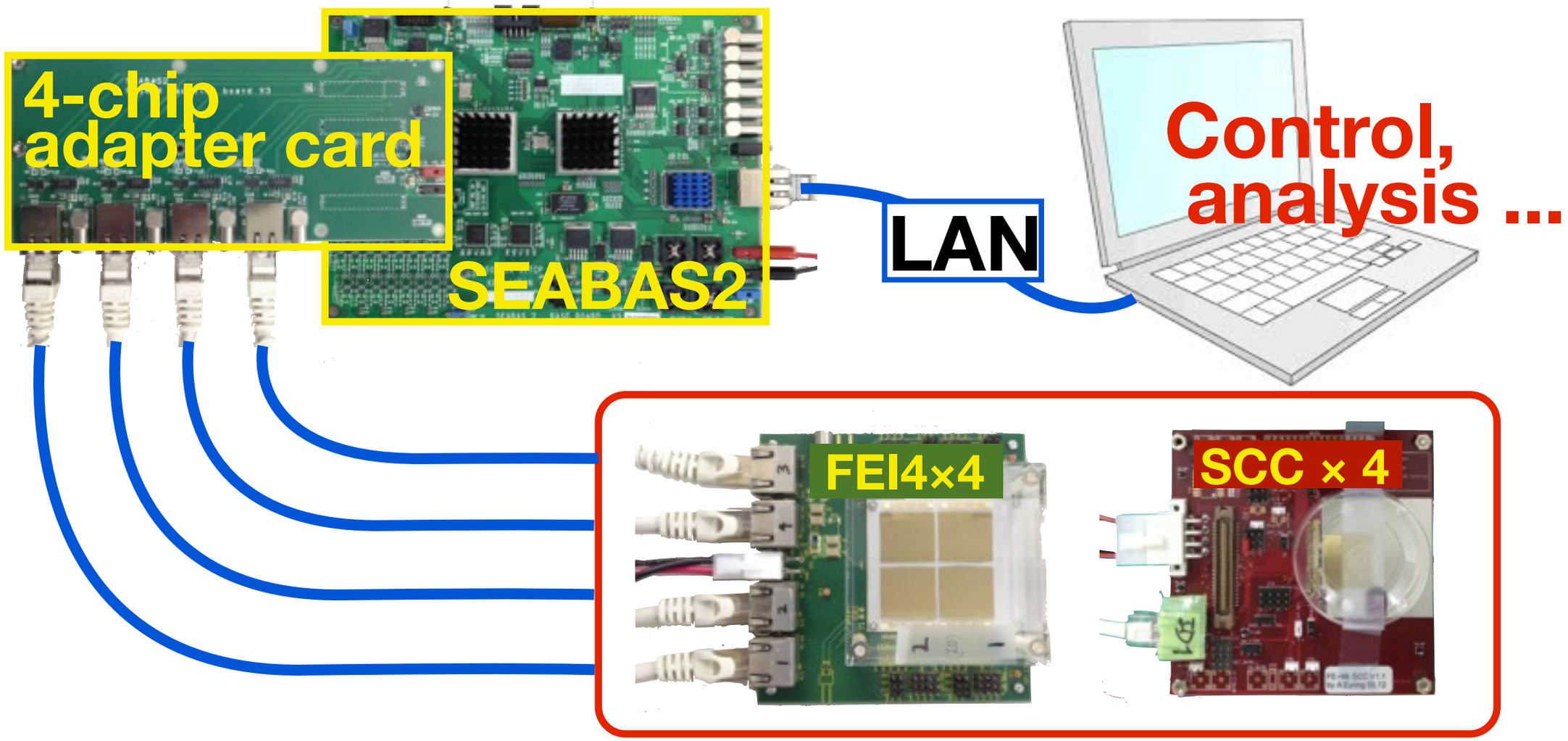


FEI4-SEABAS2 DAQ system

- Can readout up to four FEI4s
  - ➡MUX can be used to readout two FEI4s.



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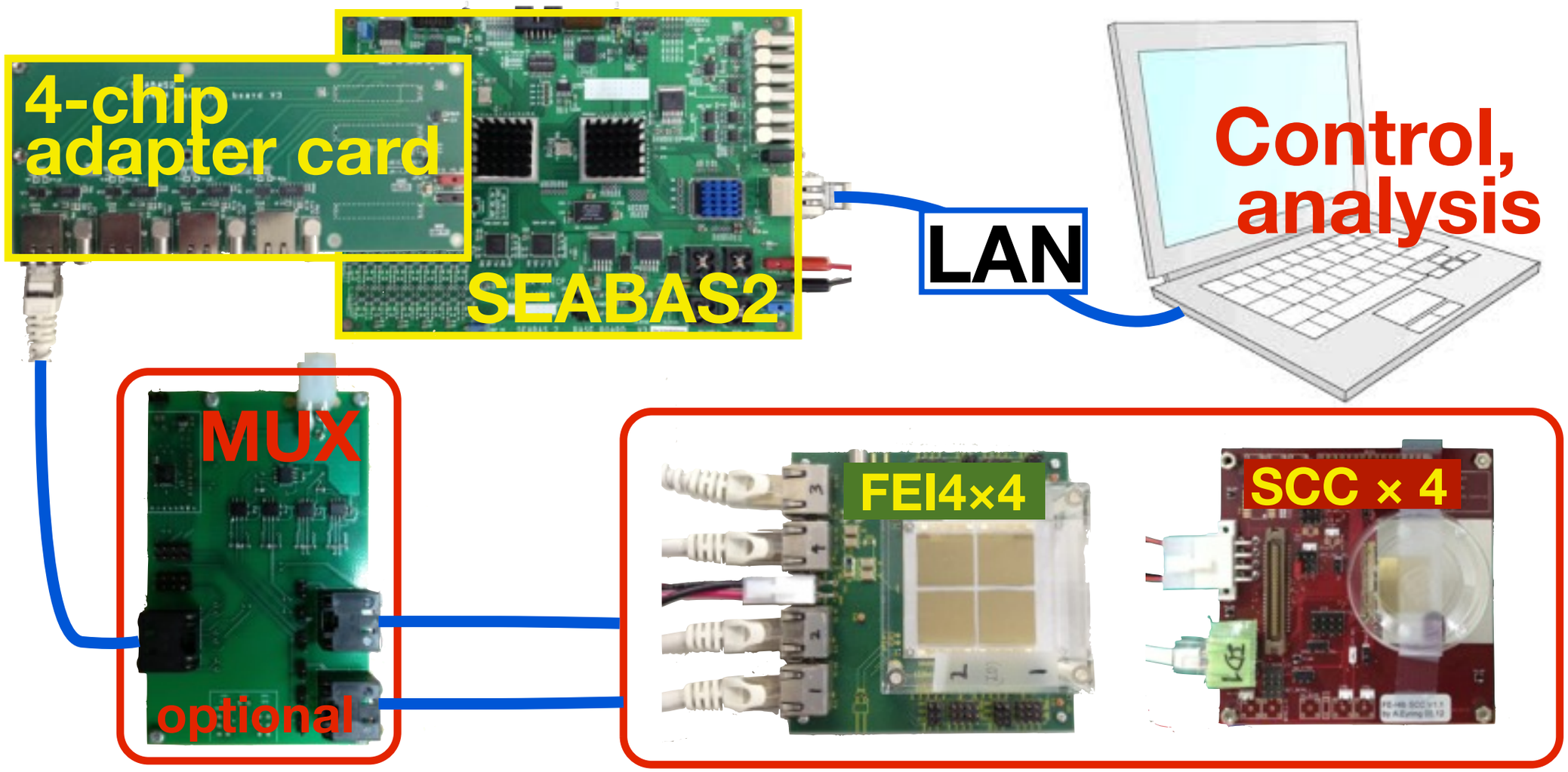
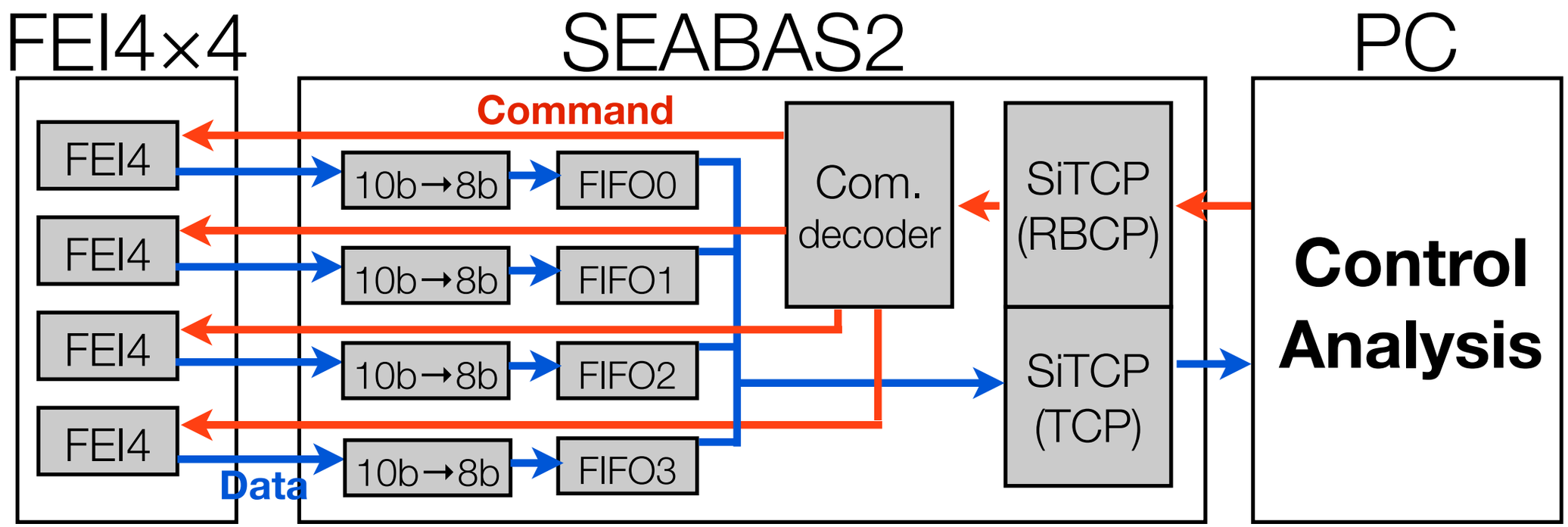


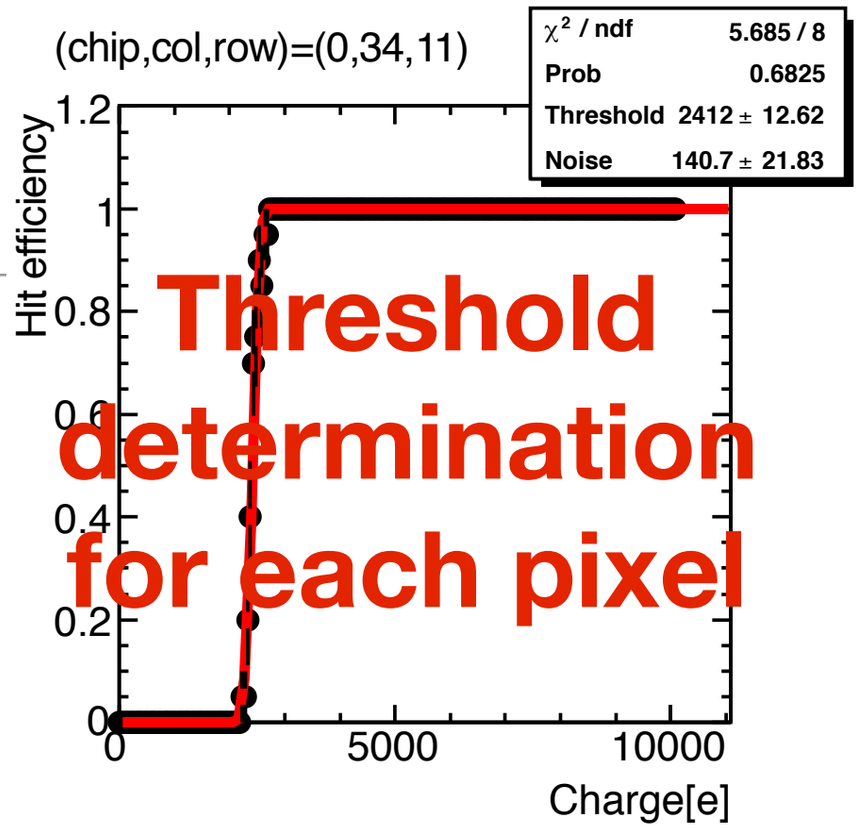
Firmware design

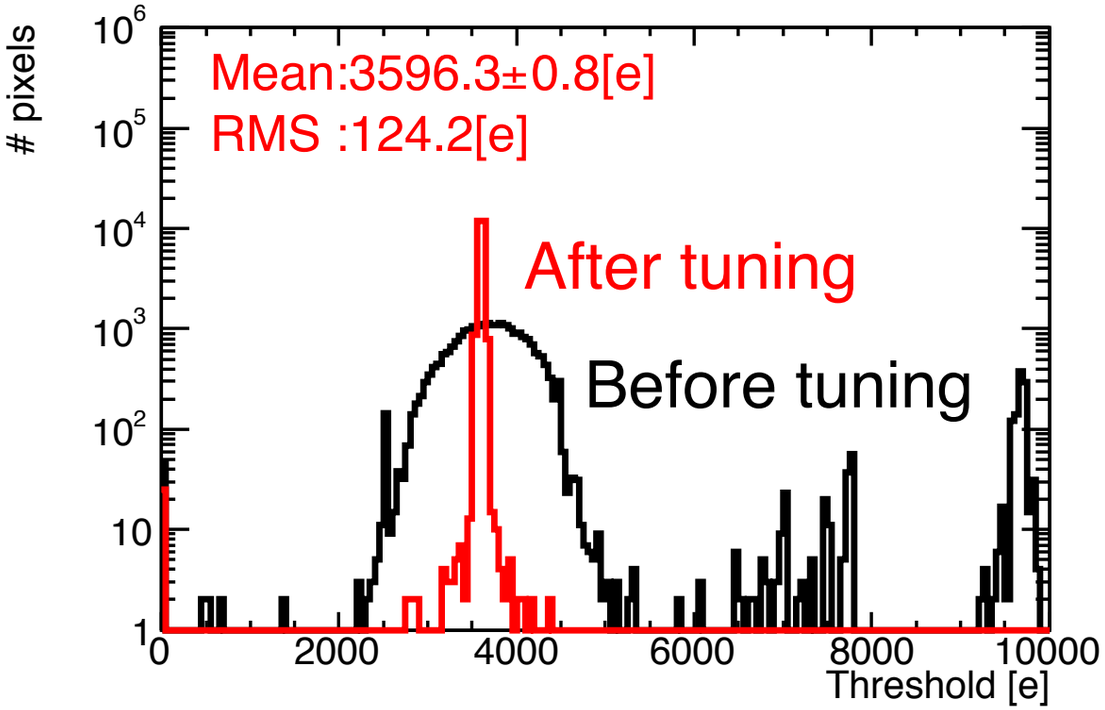
- To make flexible DAQ system
  - ➡Only provide the interface for ten FEI4 commands.
    - e.g. LV1Trigger, CalibrationPulse, WrRegister etc...
  - ➡All meaningful data from FEI4s is sent to PC.
- All operation can be done by software coding.
  - ➡Relatively easy for non-DAQ expert to test new things.

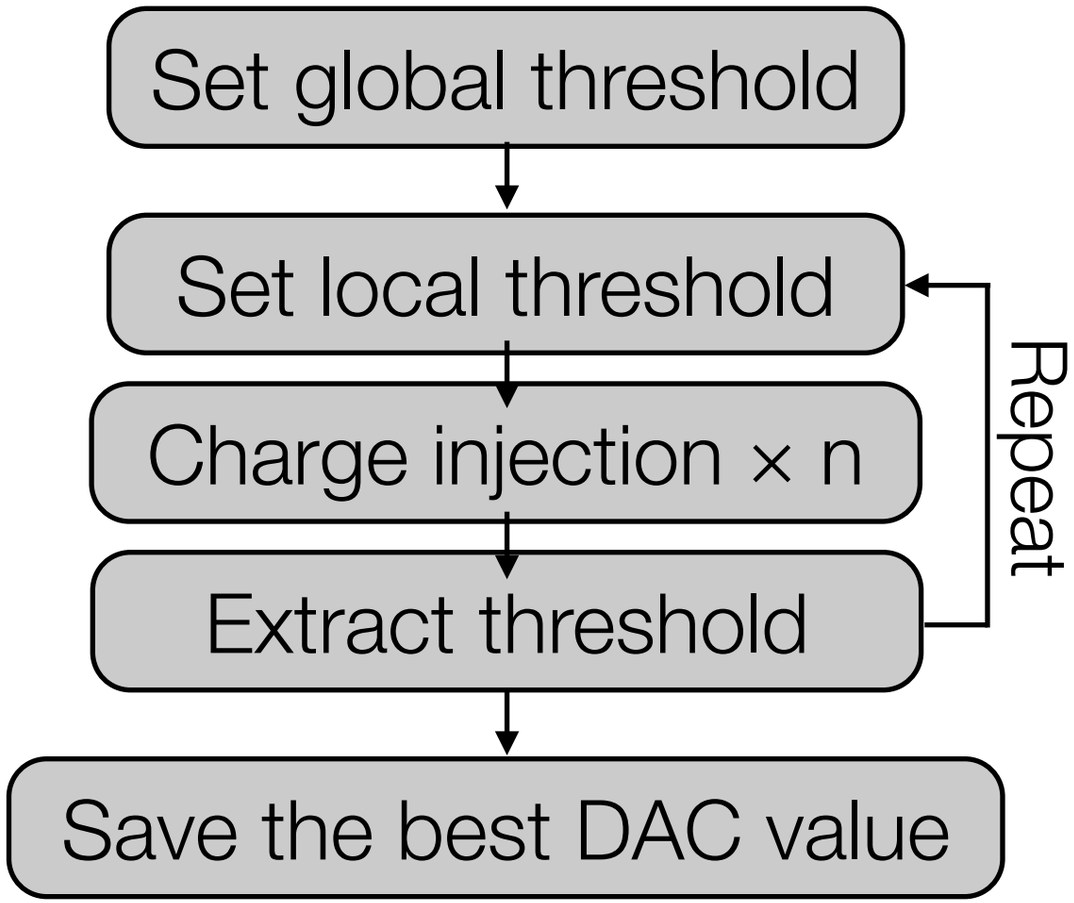


Threshold tuning

- To set same threshold among pixels.
  - ➡Good example of the operation
    - Needs global configuration.
    - Needs pixel local configuration.
    - Charge injection
    - etc...





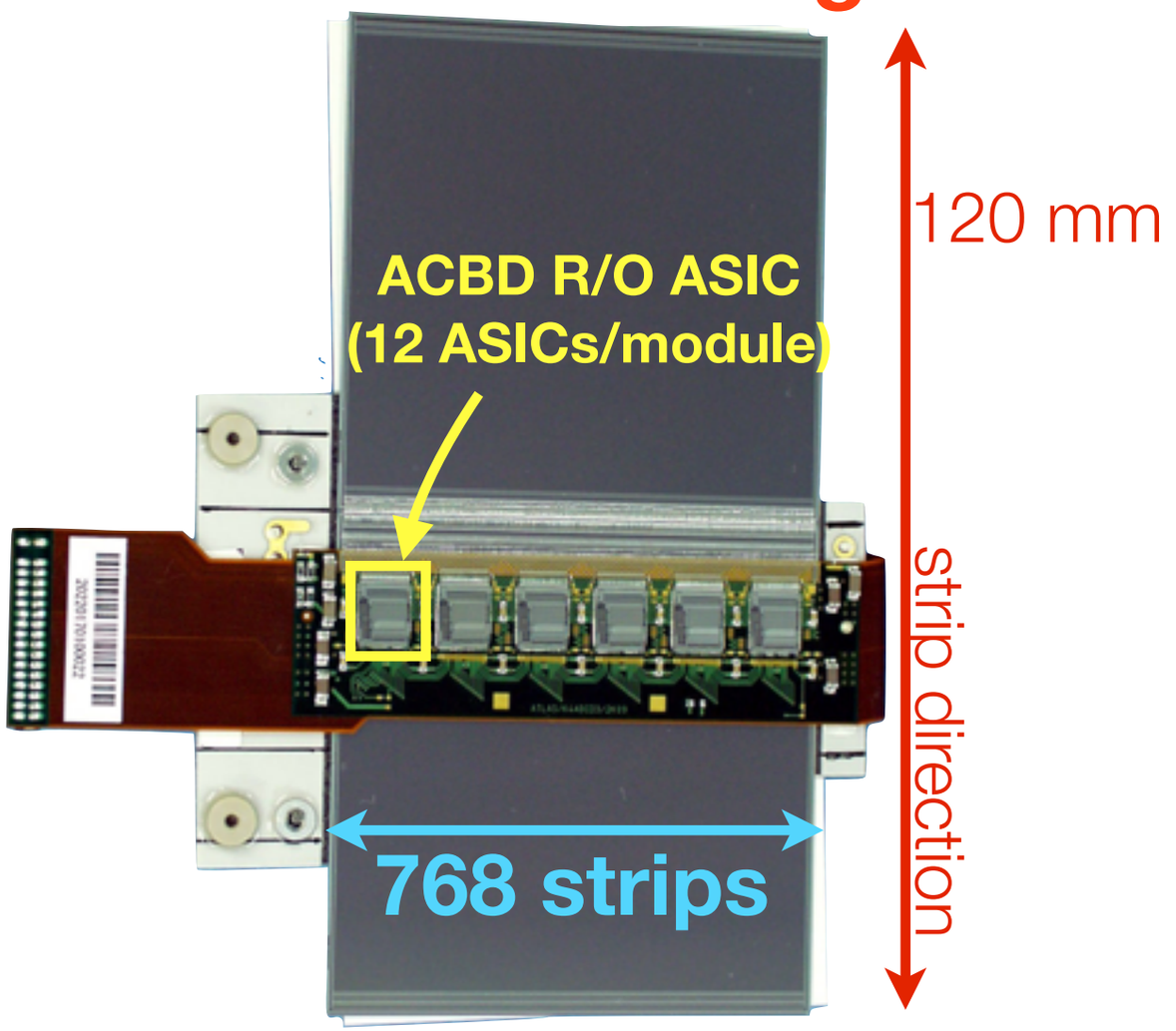


Strip module readout

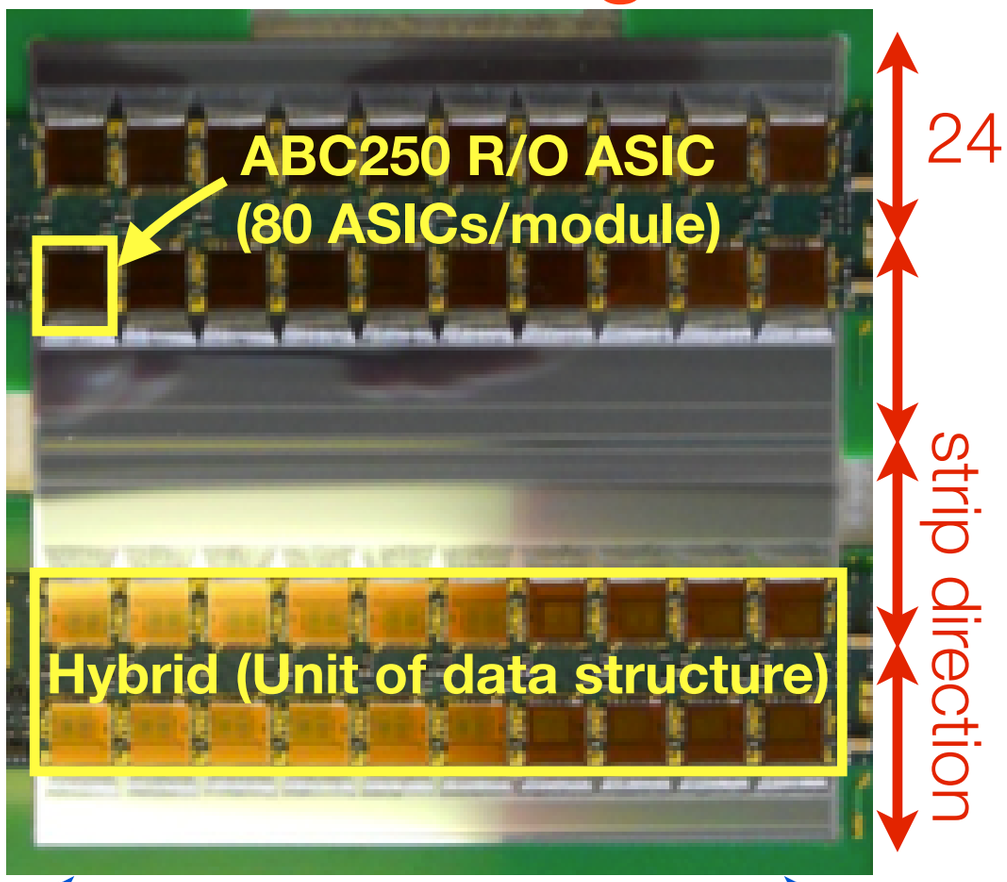
Current/new design of the SCT module

- Shorter strips to cope with high density of the particle.
- Radiation hard ASIC and sensor.

Current design

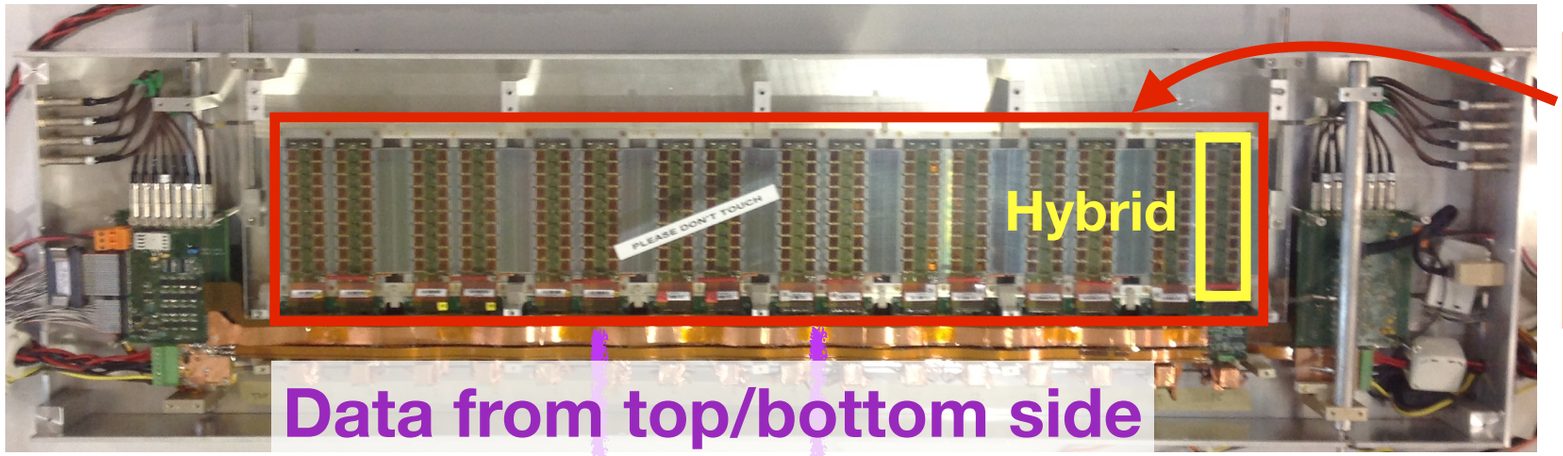


New design



DAQ setup

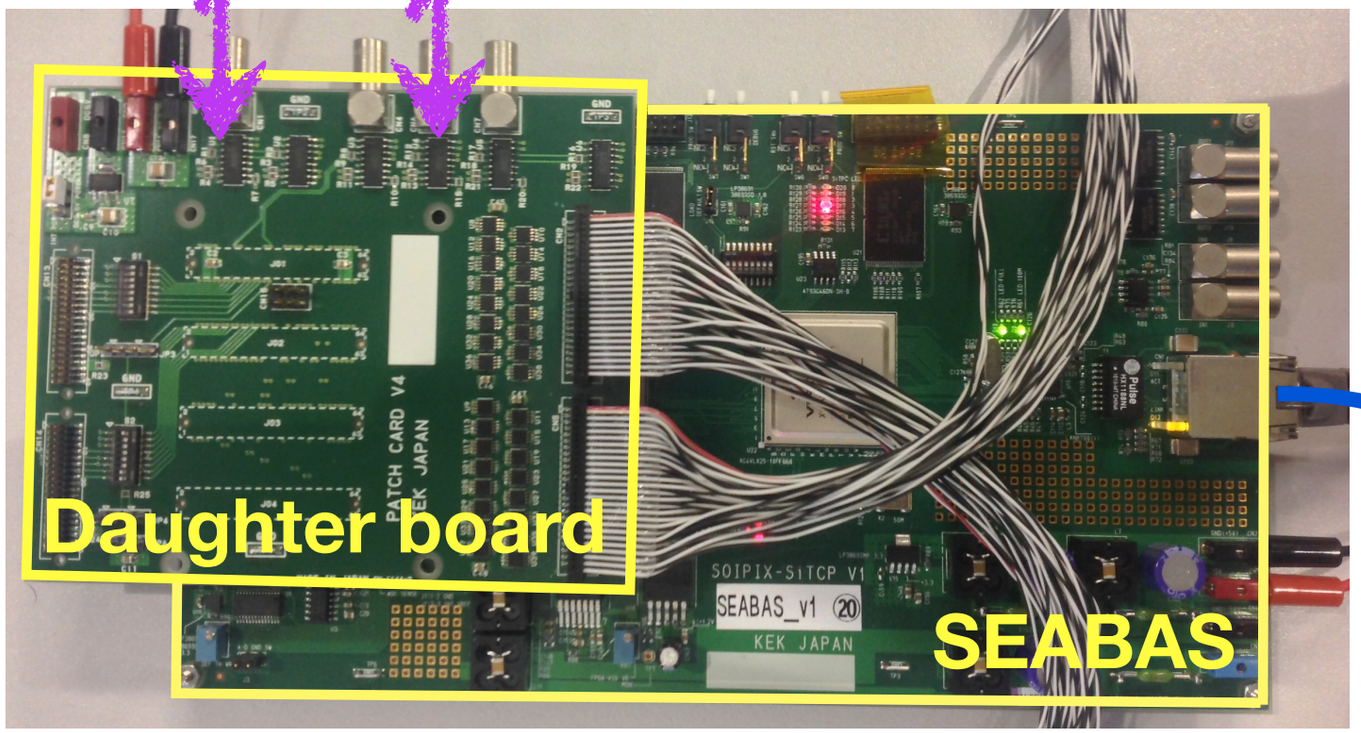
- Relatively large system : readout data from 16 modules.



Detector ladder
- 16 hybrids on top/bottom
- (Total 32 hybrids)

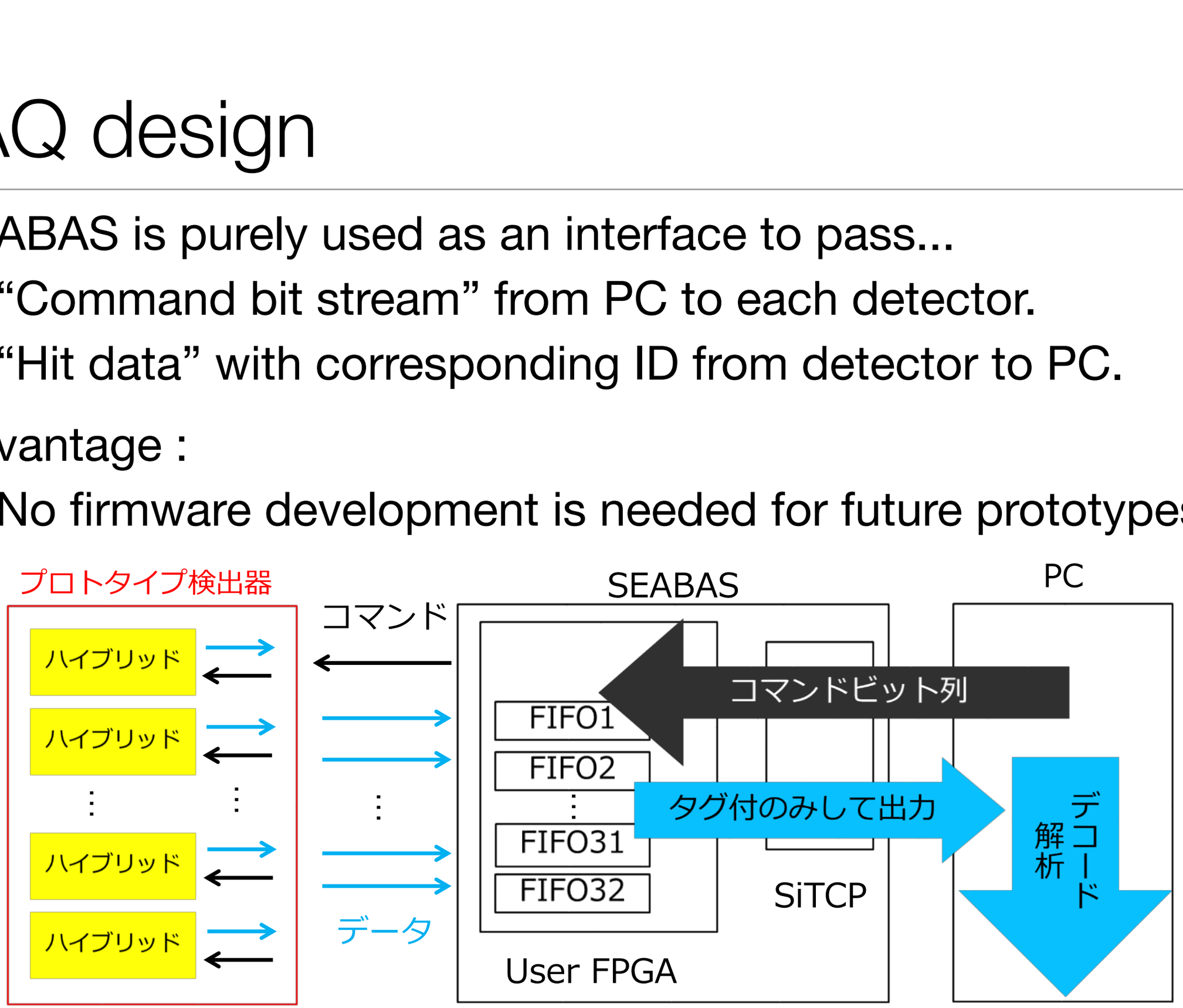
Data from top/bottom side

16 16



DAQ design

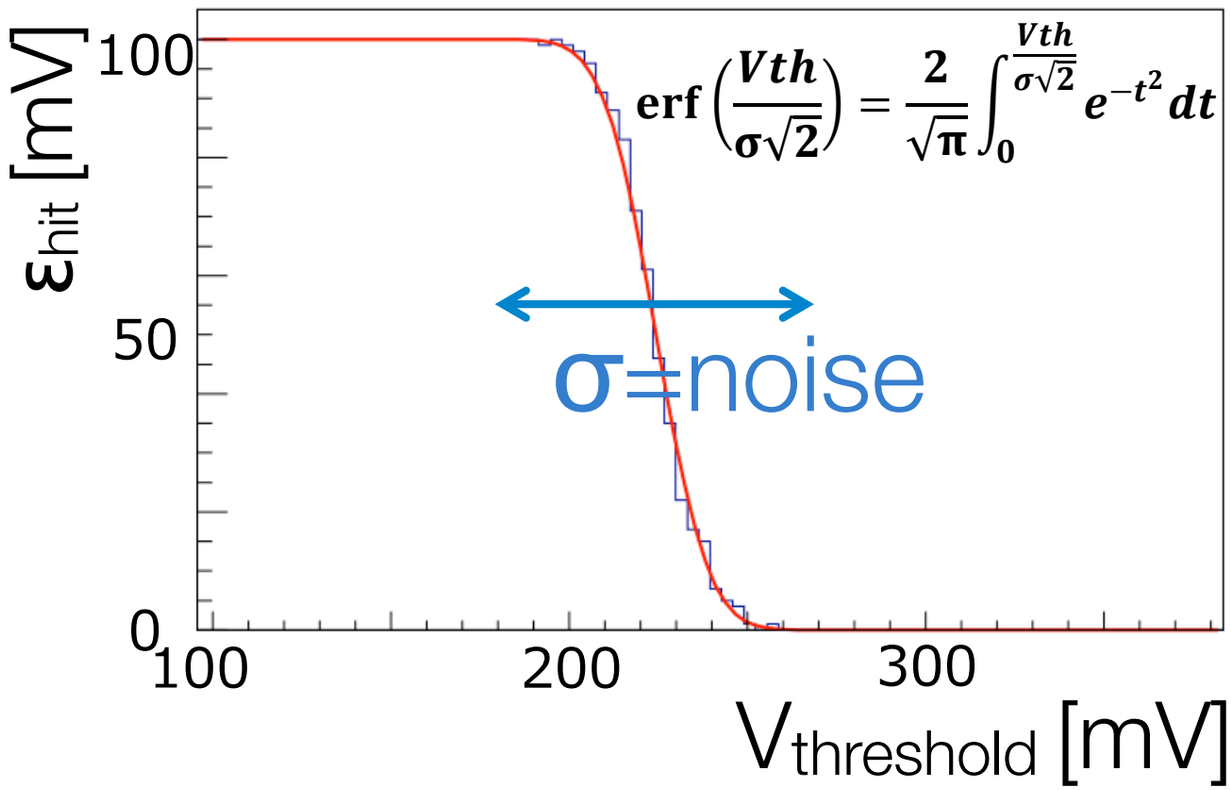
- SEABAS is purely used as an interface to pass...
  - ➡“Command bit stream” from PC to each detector.
  - ➡“Hit data” with corresponding ID from detector to PC.
- Advantage :
  - ➡No firmware development is needed for future prototypes.



Picture written by K. Todome

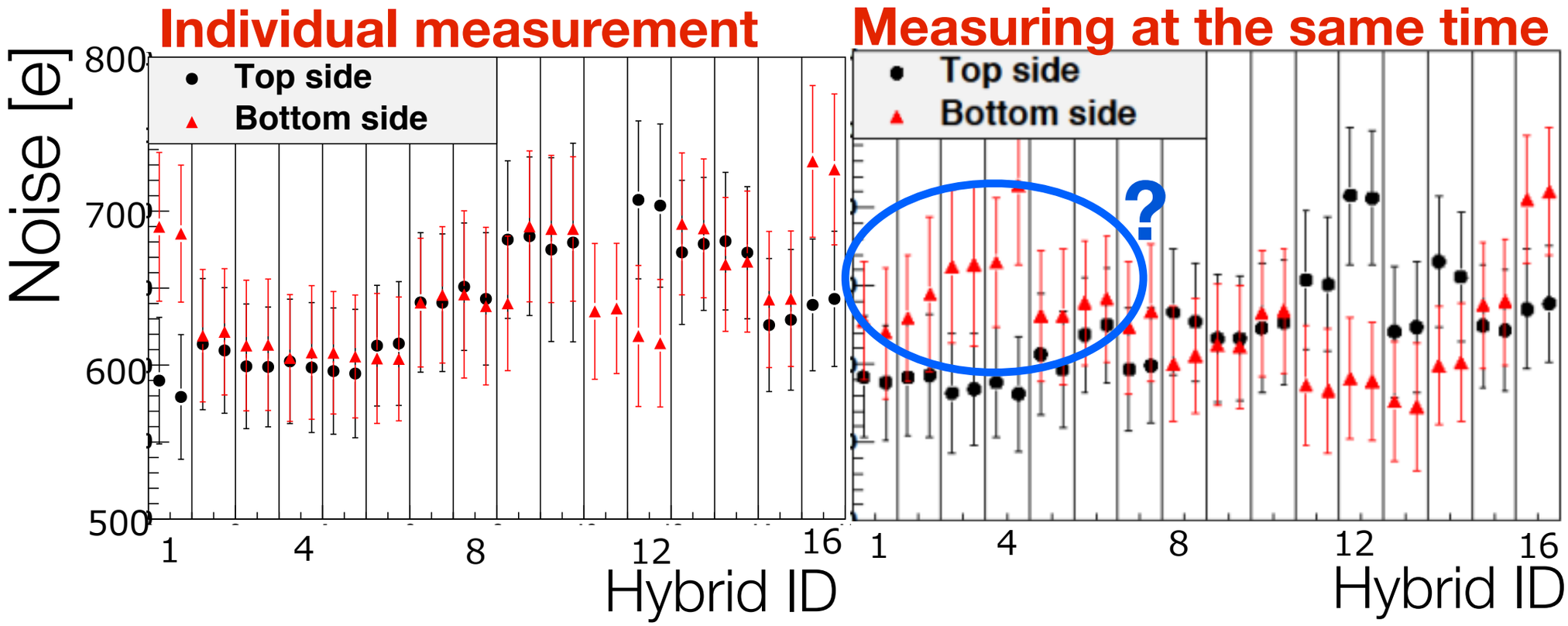
Example of the operation

- Measuring the size of noise.
- Procedure :
  - ➡Injecting a certain amount of charge.
  - ➡Repeat injection by changing the threshold setting.
  - ➡Fitting the efficiency curve by the error function.
- ➡Extract parameter σ as the size of noise.



Result of the noise measurement

- Tried two ways to measure the noise.
  - ➡Measuring hybrid by hybrid.
  - ➡Measuring whole hybrids at the same time.



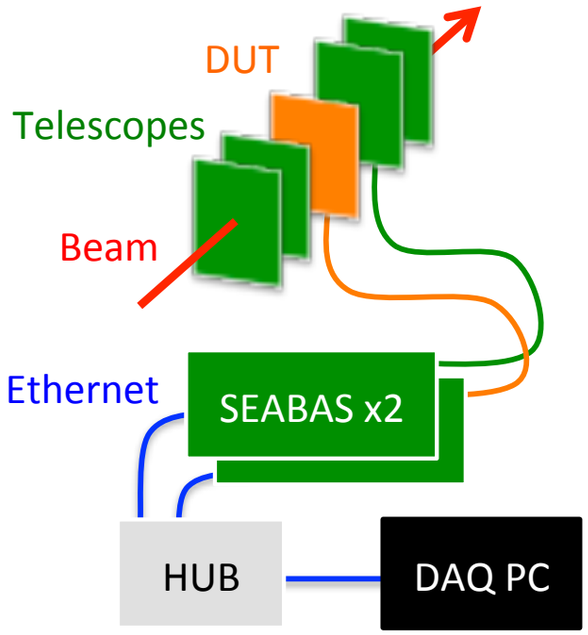
Difference might be caused by the detector design.

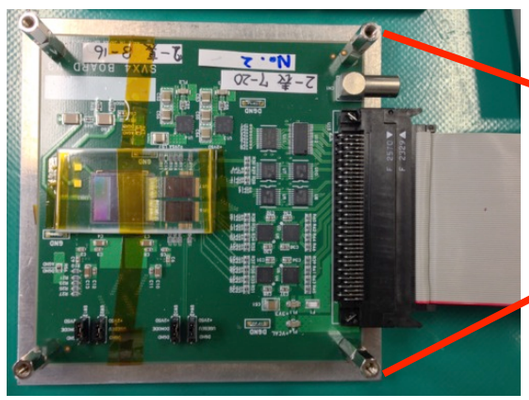
→ Giving a feedback to designers.

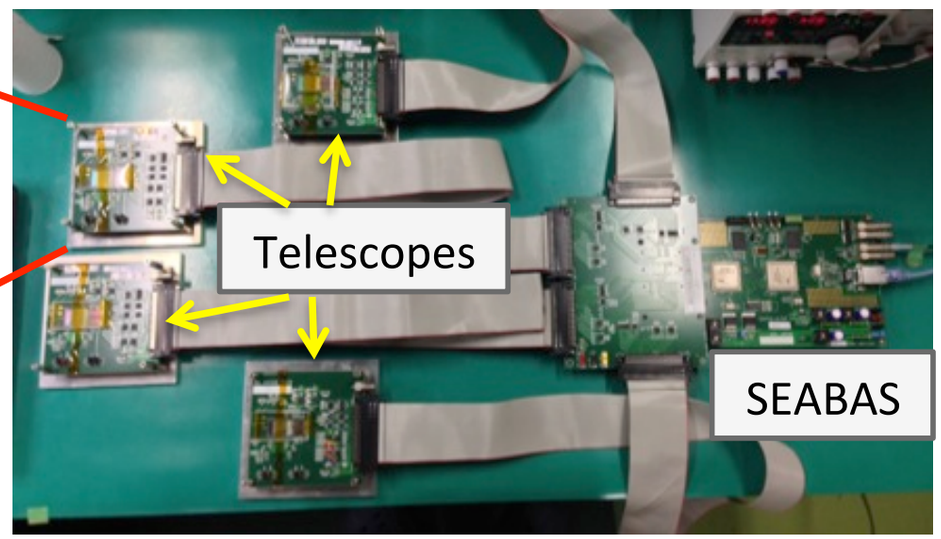
Telescope development

Telescope system for testbeam

- Testbeam is important to check the detector performance.
  - ➡Needed a precise reference detector → silicon telescope.
- Telescope specification :
  - ➡Four layers of the strip sensor pair with 90° stereo angle.
  - ➡256 strips with 50 um pitch (active region ~ 13×13 mm^2)
  - ➡R/O ADC data from each strip by SVX4 ASIC.
  - ➡Expected position resolution of ~3 um.

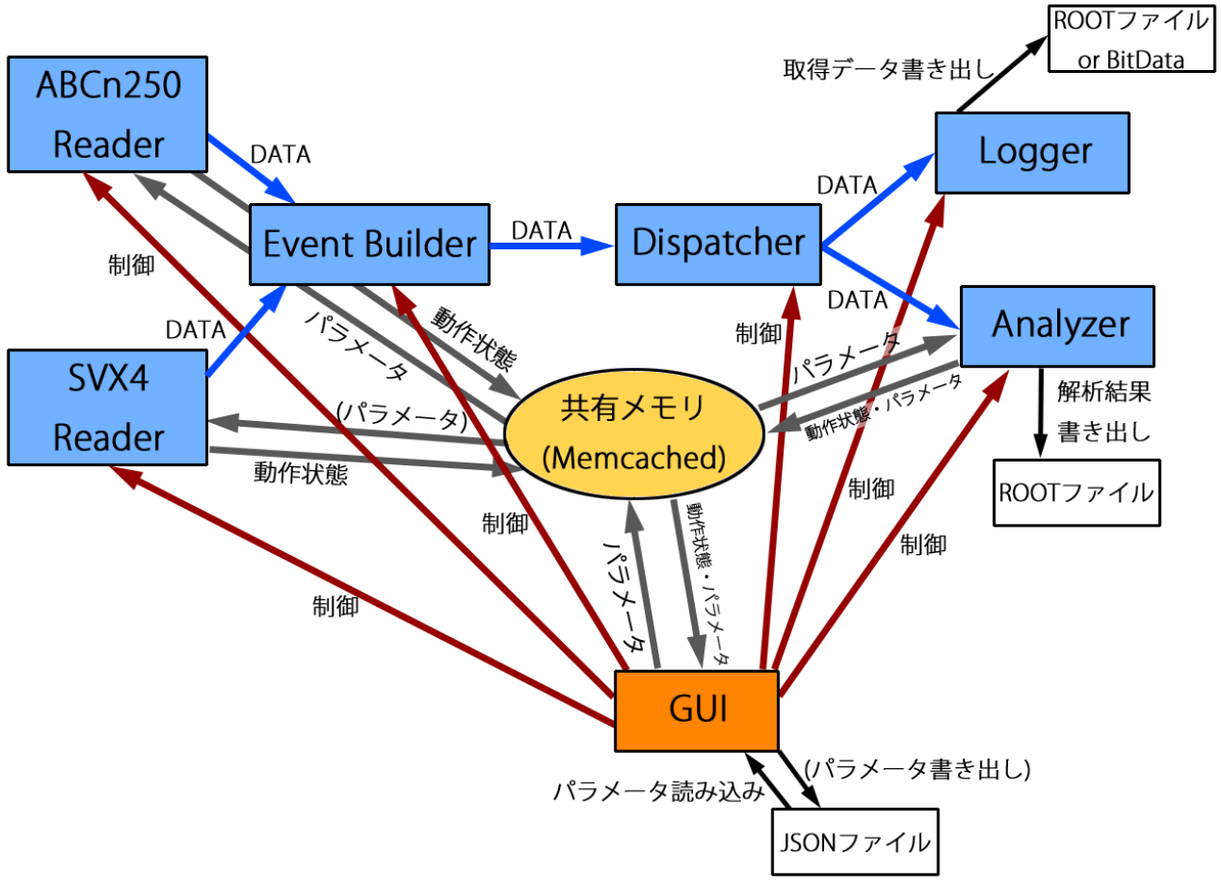


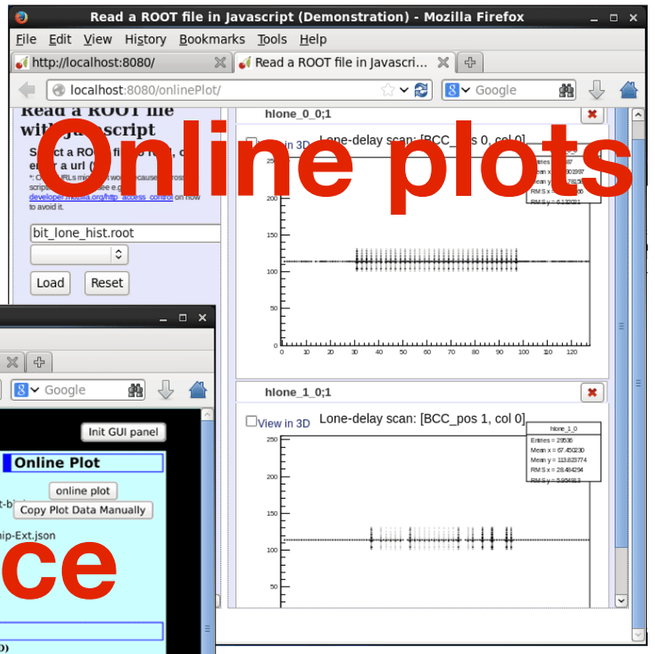




DAQ software

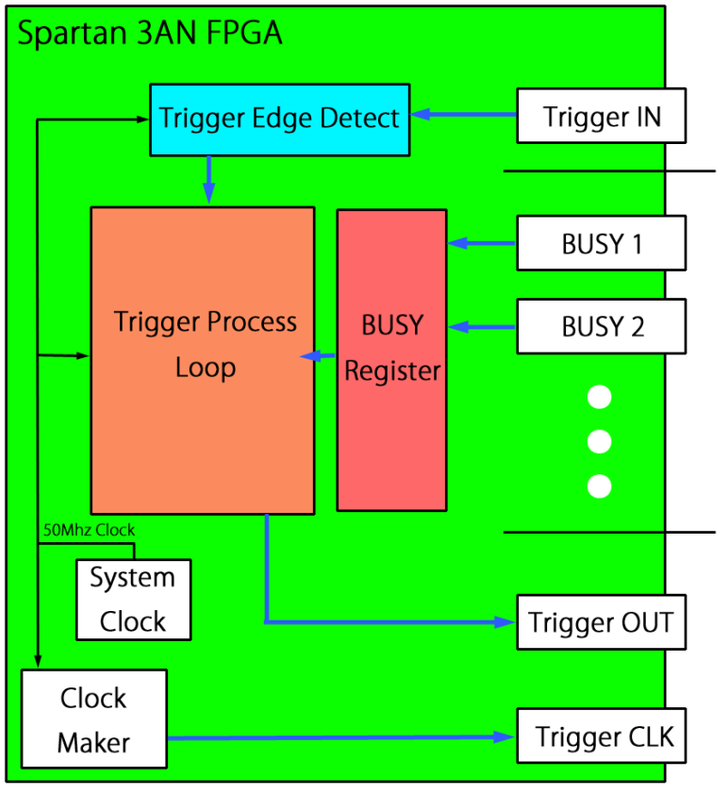
- Web based GUI interface called SCTJDAC.
  - ➡Independent software modules sharing memory.
    - Fast : thanks to multi-processing.
    - Flexible : composed of software modules.

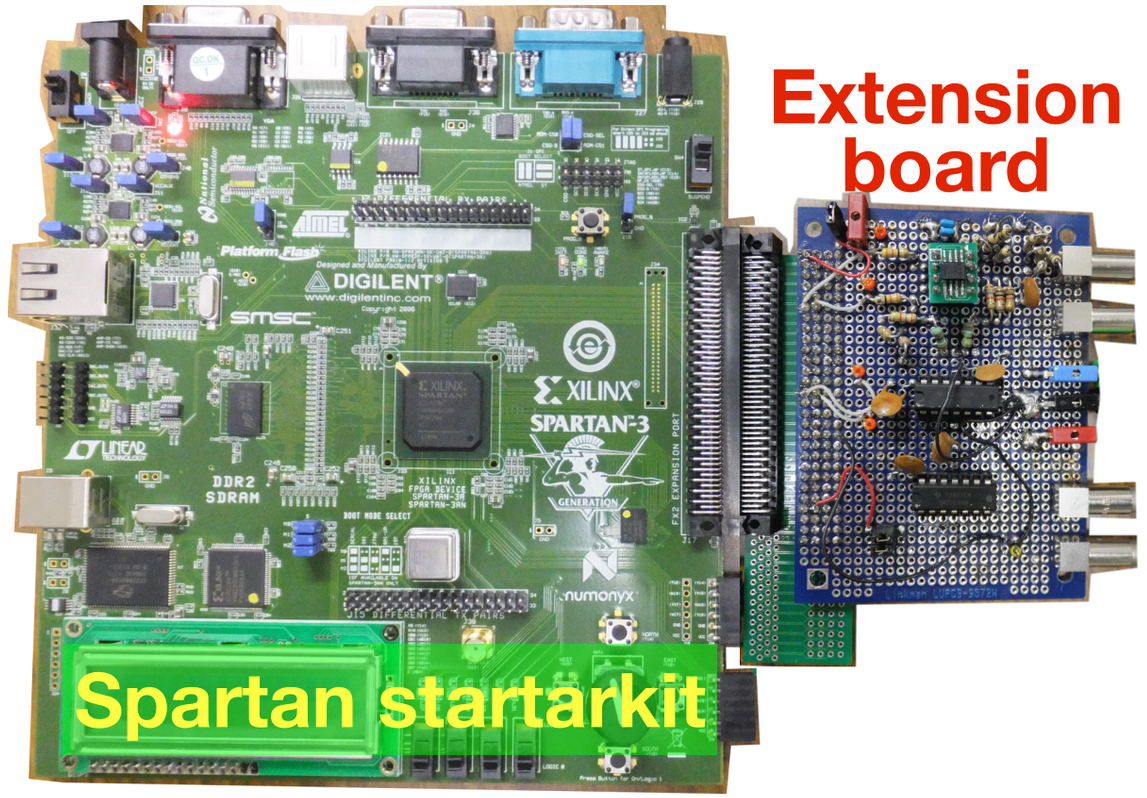




How to synchronize multi-SEABAS

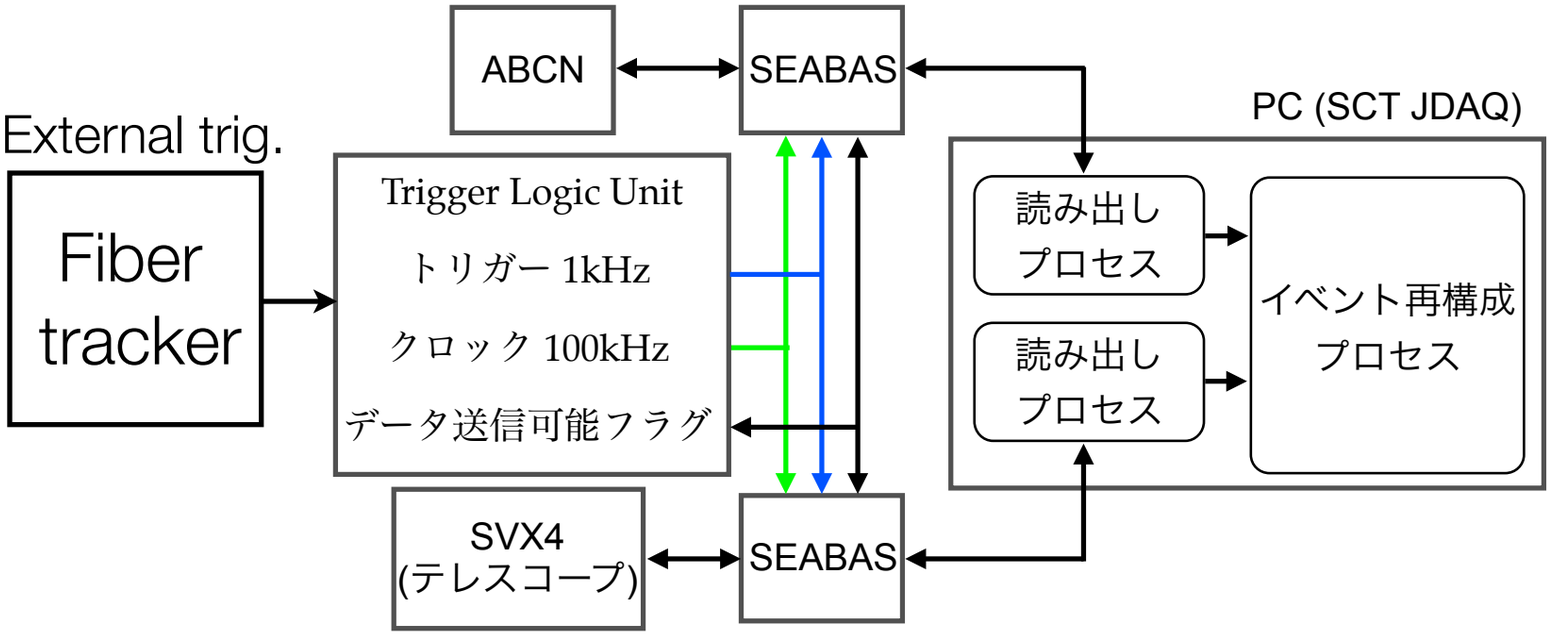
- Trigger logic unit (TLU).
  - ➡Based on Xilinx Spartan 3AN startarkit.
  - ➡Handling external trigger, busy, veto ...
  - ➡Supplying reference clock to two SEABASs.
    - SEABAS sends data with “TimeStamp” bases on this CLK.

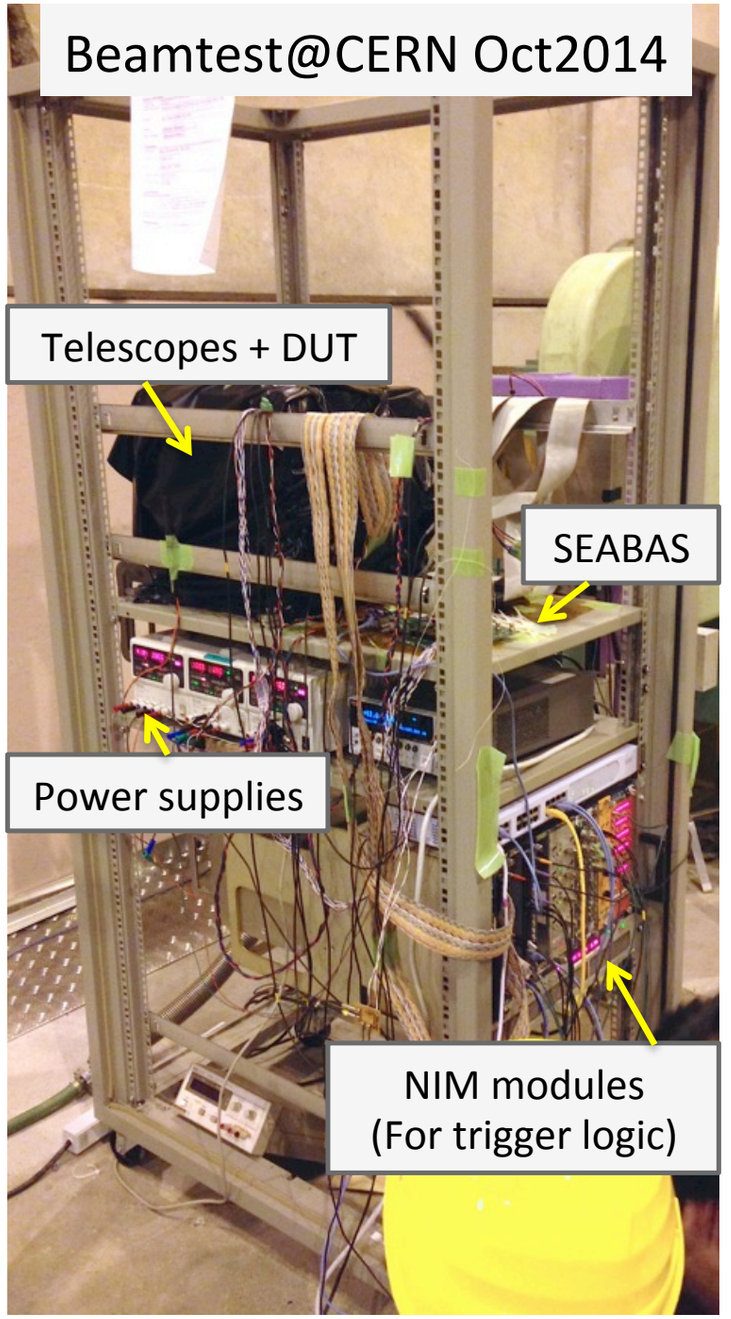




Testbeam @ CERN (Oct. 2014)

- Beam time : 26 Oct. - 3 Nov
- 120 GeV pion beam from SPS.
- Acquired ~10 M events
  - ➡Trigger supplied by a fiber tracker.
  - ➡Analysis is ongoing.

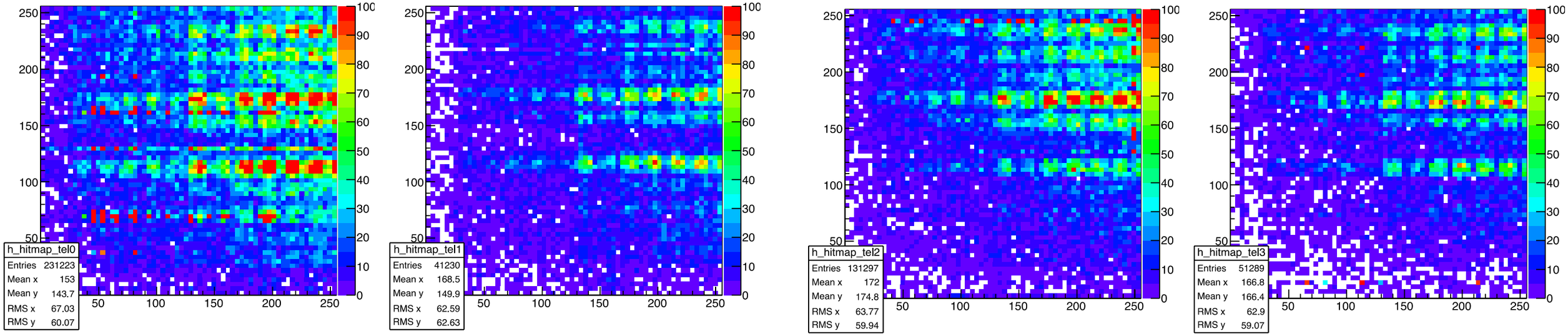




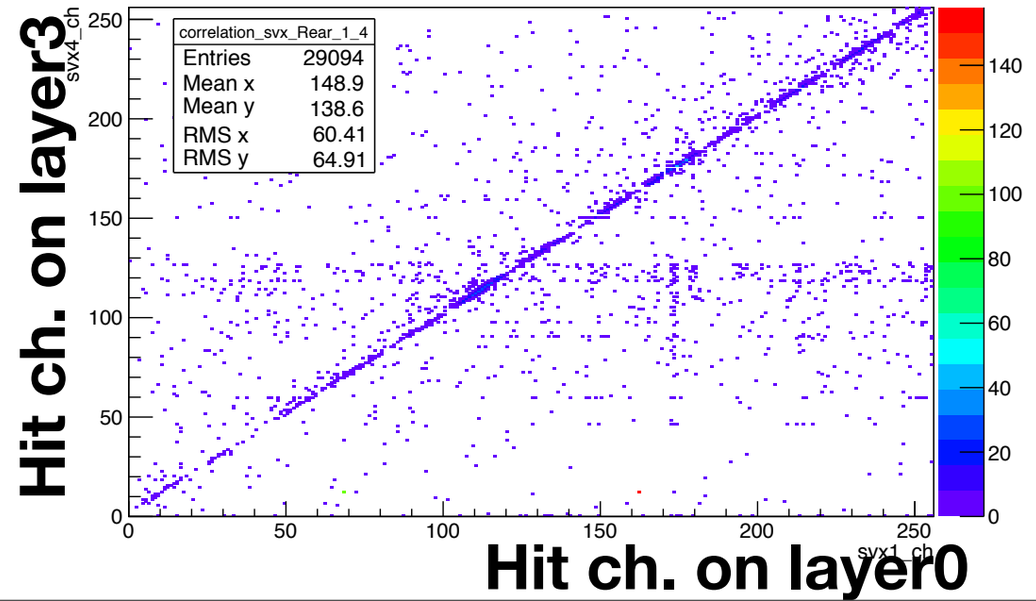
Preliminary result

- Successfully see the correlation between telescope layers.

Layer0 **Layer1** **Layer2** **Layer3**



Clear correlation observed !!



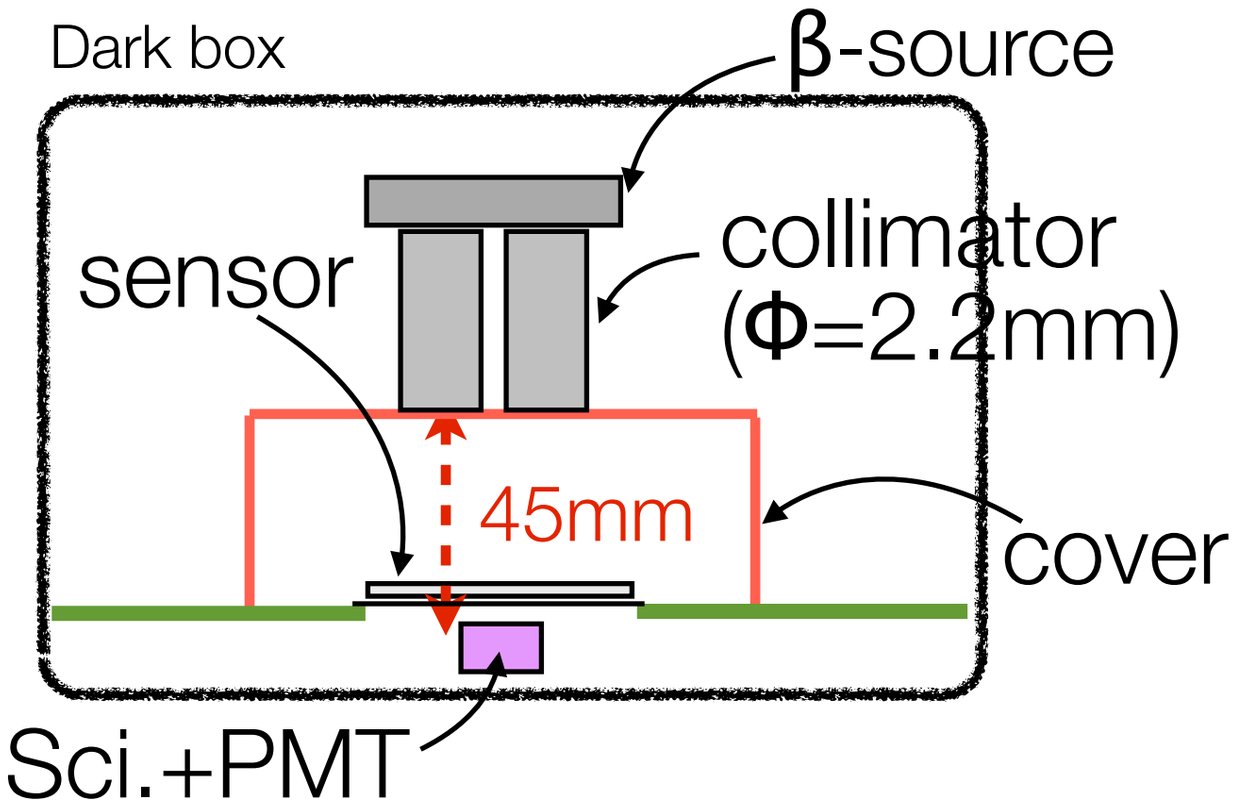
Conclusions

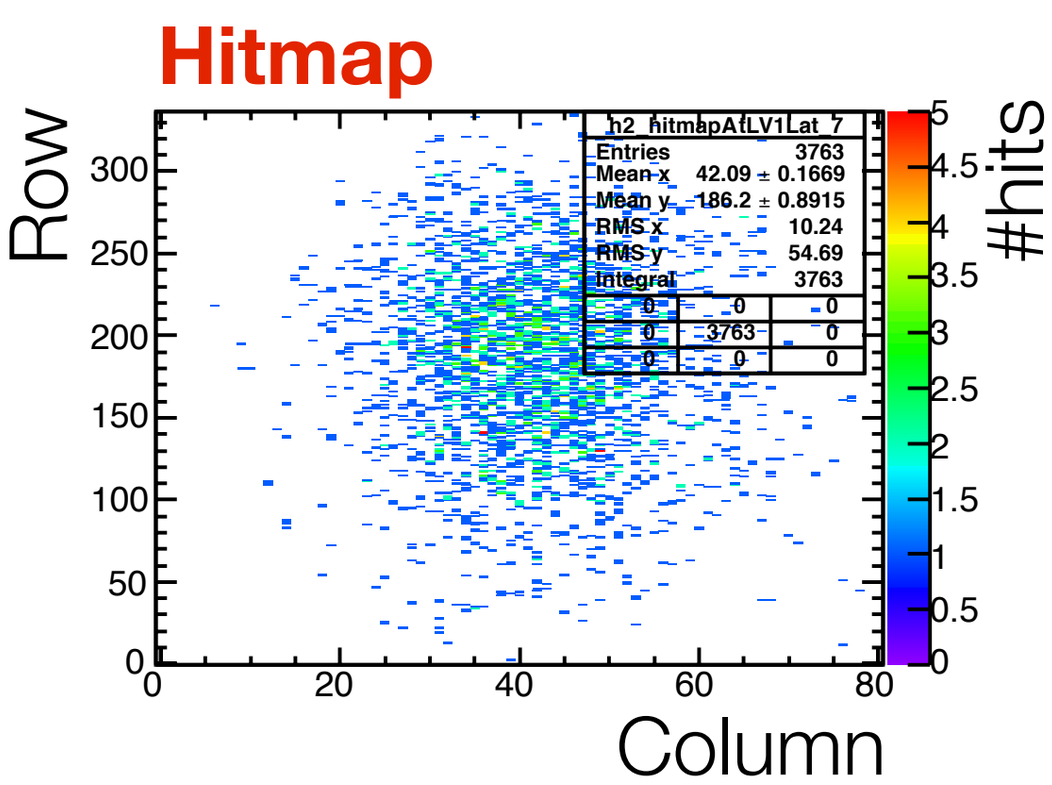
- Development of the DAQ system for testing future silicon detectors in ATLAS.
  - ➡For pixel, strip detector.
  - ➡Telescope system to test detectors above.
- Aiming to develop a compact and versatile system.
  - ➡All DAQ system is based on the SEABAS board.
  - ➡Benefitted from these features.
    - Easily migrated to the new design of modules.
    - Potable for testbeams.
- Little word about our future plan :
  - ➡Keep using SEABAS.
  - ➡Limitation would be caused by the FIFO size/IO speed(?).

Backup

External trigger

- NIM standard input can be used as an external trigger.
  - ➡Maximum DAQ rate : ~400 Hz
- Example of the data taking with β-source.
  - ➡Scintillator + PMT was used for the trigger signal.
  - ➡Hits by collimated β-ray can be seen as expected.





Operation with MUX

- Developed things
  - ➡Firmware : de-multiplexer, data extractor
  - ➡Software : decoder
- Result of charge injection.
  - ➡Two FEI4s are operated successfully.