SPADI Alliance for Standardization of SRO DAQ in Japan

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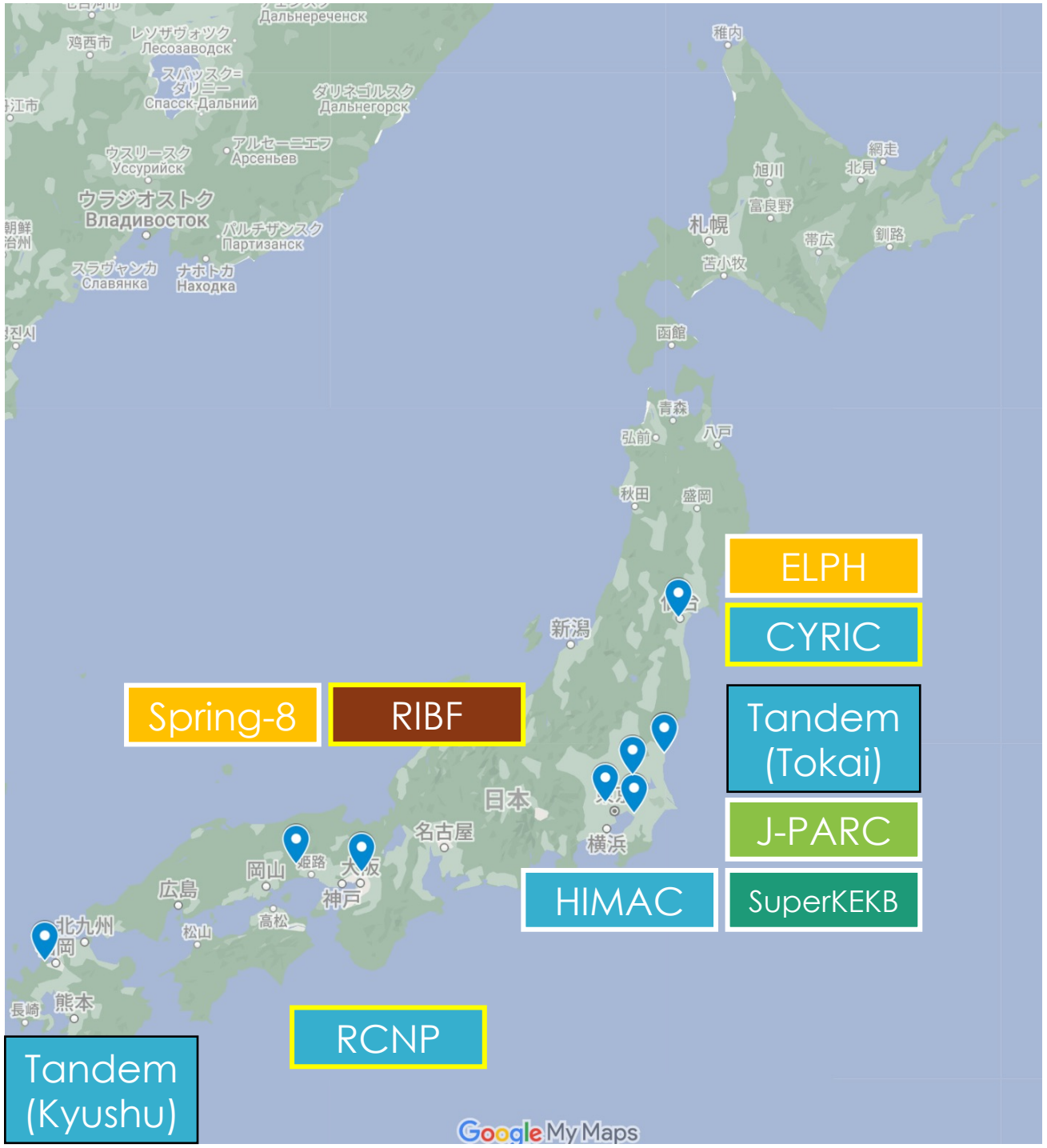
for SPADI Alliance

Why do we need it?

Many types of experiments

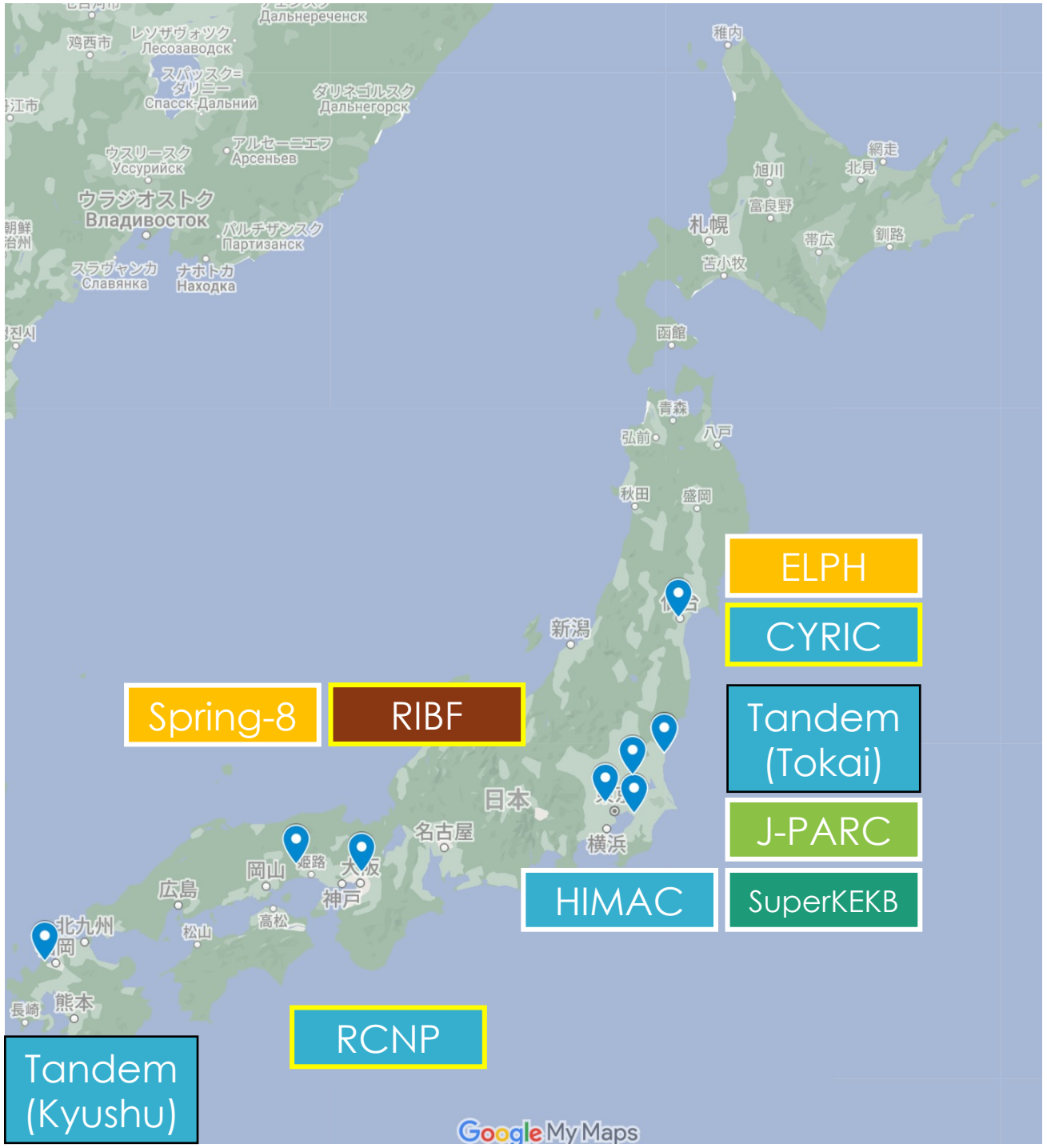
- Not only the large-scale experiments but also the small-size experiments
- Variety of the beam species, the beam energies, the targets and the measured reaction products
- Variety of the lifetime of the experimental setup from one day to several months (or more)
- **Frontend electronics : commercial and designed**
- **Localized DAQ software (and hardware) and analysis tools**



Localized DAQ software

- RIBF : Babirl
  - coupled with NSCL DAQ, Narval, Midas, MBS, Mordicus …
- RCNP : Tamidaq
  - Single system
- J-PARC : DAQ Middleware, HDDAQ,
  - Site by site

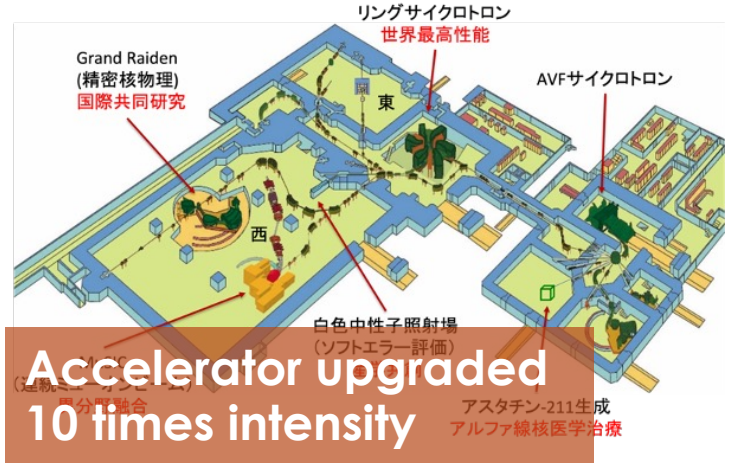
- How to maintain the system and how to develop the next generation system?

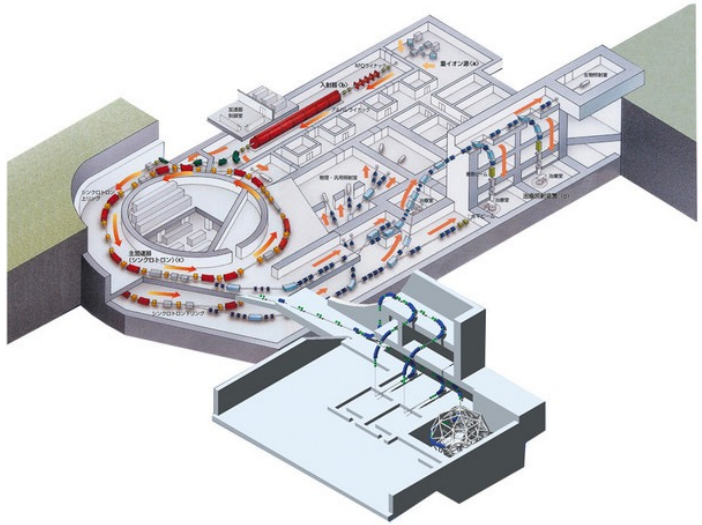


Hadron accelerators in Japan

J-PARC
Z=0,1
MIP

RCNP
Z=0-30
0.1<β<0.7





HIMAC
Z=0-54
0.01<β<0.7

RIBF
Z=0-82
0.01<β<0.7

RHIC, LHC, EIC…

FRIB, …

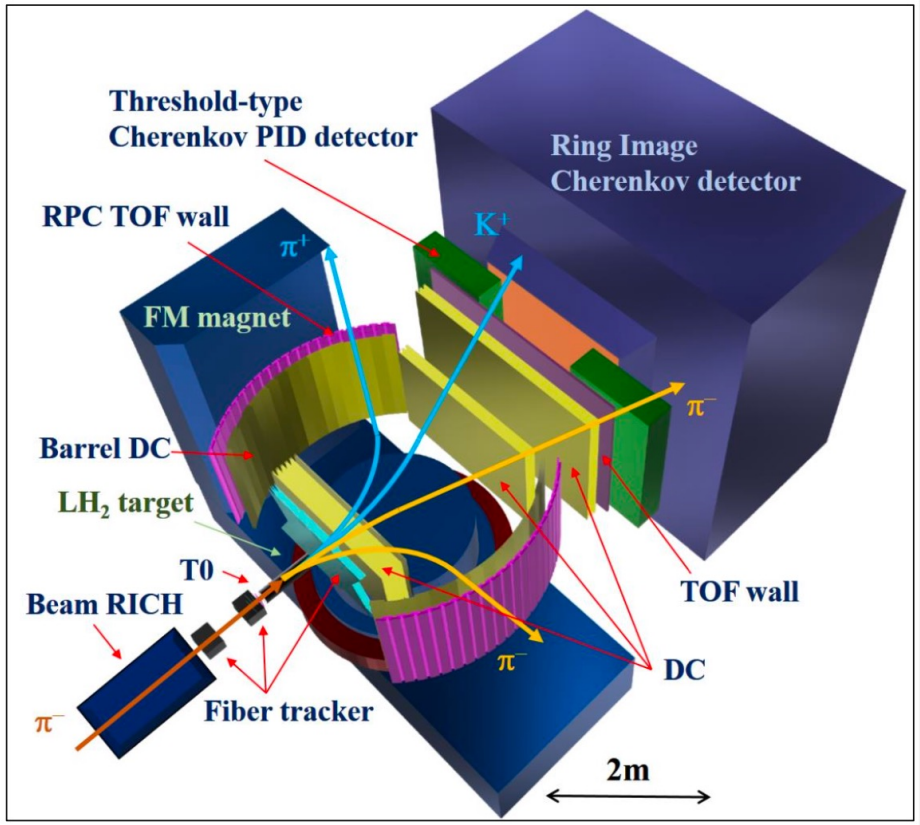
J-PARC : Hadron spectrometer

In-house (facility) : 0 person
Core member in each groups : 5 persons
(including detector developments)

Overview of spectrometer system

– Photon detector
– Gas detector

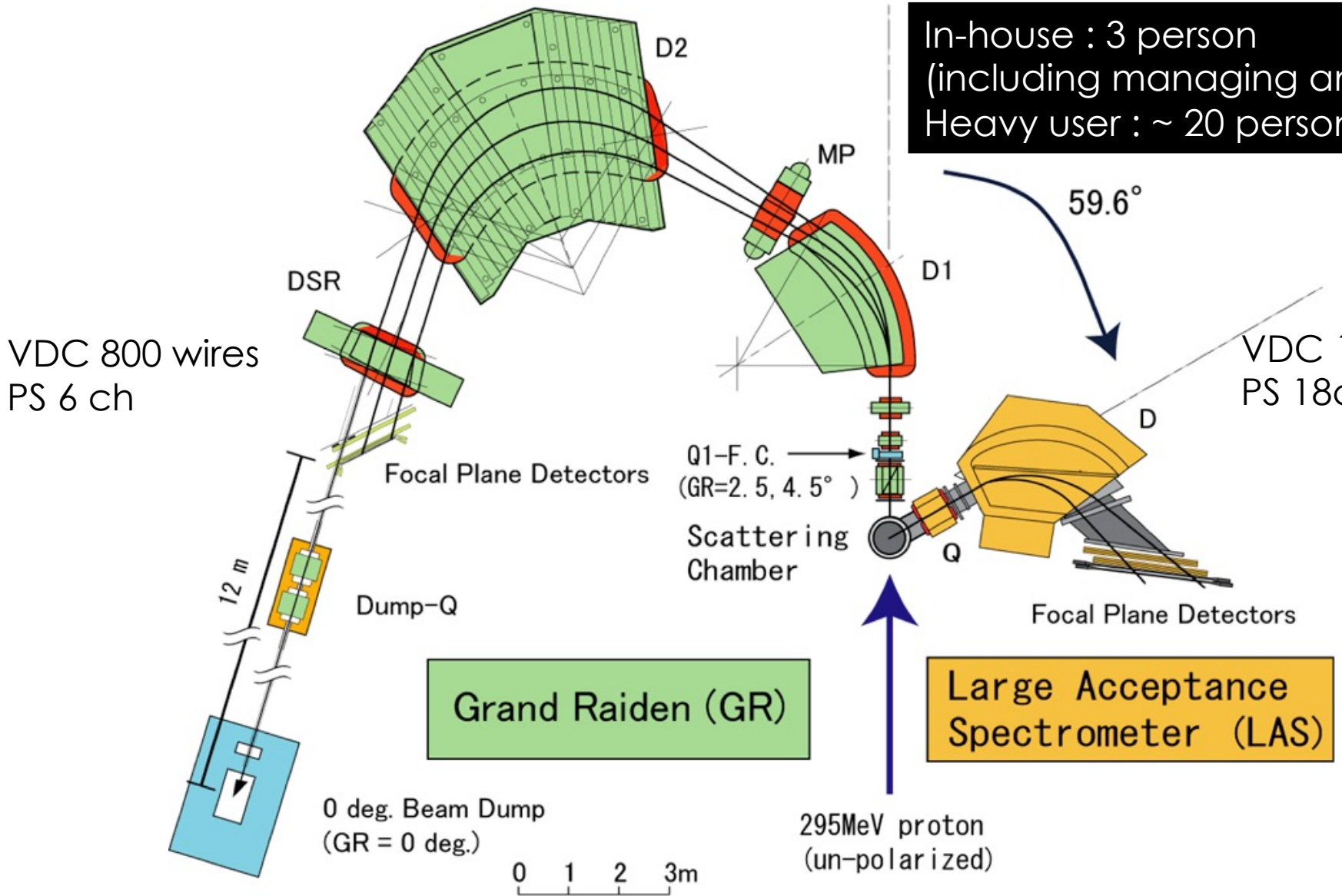
- **High-rate beam detectors**
  - **Scintillation Fiber Tracker**
    - Fiber + MPPC array
  - **Cherenkov Timing detector**
    - Acrylic(PMMA) + MPPC + amplifier
- **High-performance PID detectors**
  - **High timing-resolution TOF wall: RPC**
    - Gas detector + amplifier
  - **RICH & Beam RICH**
    - Aerogel & Gas + MPPC/MPPC array
  - **Threshold-type Cherenkov detector: Vth AC**
    - Aerogel + MPPC array
- **Large size detectors for scattered particles**
  - **Large size drift chambers**
    - Gas detector + amplifier
  - **Forward TOF wall**
    - Plastic scintillator + PMT (+RPC)
  - **Muon detector**
    - RPC (+Plastic scintillator + PMT)



Courtesy of K. Shirotori

RCNP: Grand RAIDEN and LAS

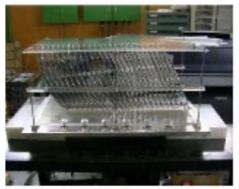
In-house : 3 person
(including managing and maintenance)
Heavy user : ~ 20 person



RIBF

In house : 2 person (for DAQ)
Main apparatus : ~40 person (several groups)

プラスチック



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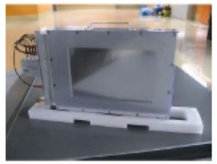
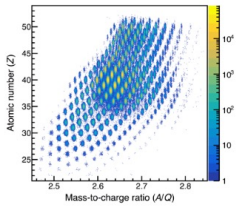
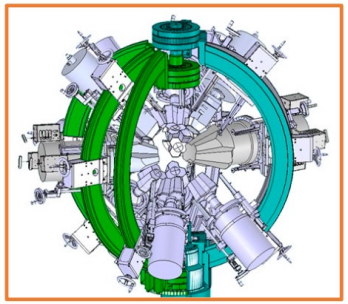
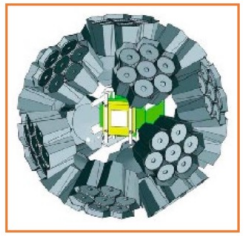
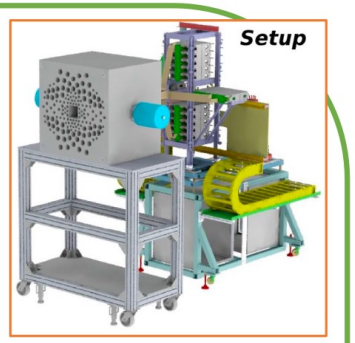


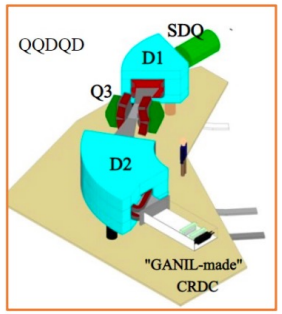
PPAC(位置)

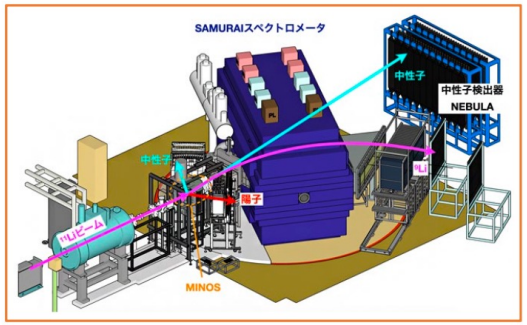


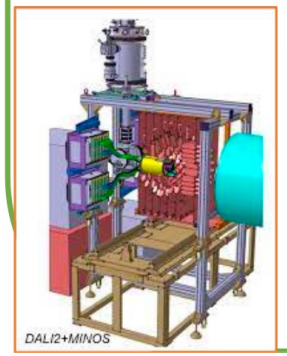


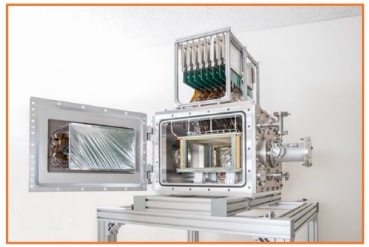


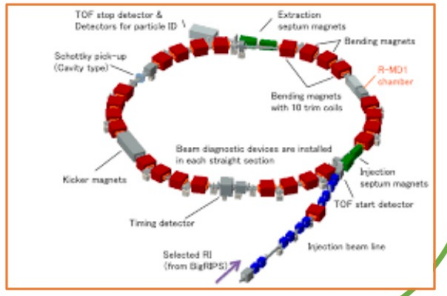










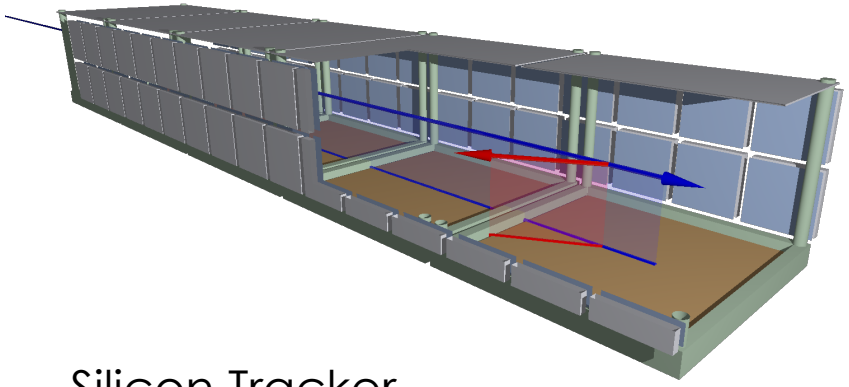


Courtesy of H. Baba

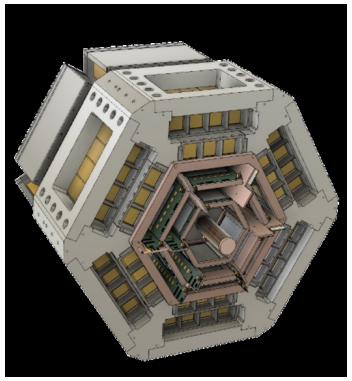
Other devices

Each group has small number of core member.
DAQ development is difficult.

Active Target TPC
20000 ch 12 bit 50 MS/s => 12 Tbps
600 ch 12 bit 30MS/s => 0.2 Tbps



Silicon Tracker
20000 ch 12 bit 30 MS/s => 7.2 Tbps



Courtesy of Baba

Segmented Germanium
~2000 ch 16 bit 100 MS/s => 3.2 Tbps

From the slide of
Y. Yamamoto (RCNP)

64ch 12bit 50MS/s ~ 40 Gbps
64ch 16bit 100MS/s ~ 100 Gbps

Feature of each facility

	RIBF	RCNP	J-PARC	
Accelerator	Cyclotron	Cyclotron	Synchrotron	
Beam	Heavy ion (Z<92)	Light to medium	Meson / Hadron	
Velocity (β)	$0.1 < \beta < 0.7$	$0.1 < \beta < 0.7$	$\beta > 0.9$	
Intensity	10^7 cps	10^{10}-10^{12} cps	10^7 cps	
Measure beam?	Yes	No	Yes	
Reaction rate	10^3 cps	10^4 cps	10^3 cps	
Detection rate	10^6 cps	10^4 cps	10^6 cps	Beam/react.
Energy deposit	2 - >100000	2 - 3000	1	MIP = 1
# of Ch in Std Sys.	200	2500	25000*	* HD spectrometer
User DAQ	Yes	Yes	Rarely	
Life cycle	2 weeks	2 weeks	> 1 month	

FRIB

EIC, sPHENIX, ..

Requirements

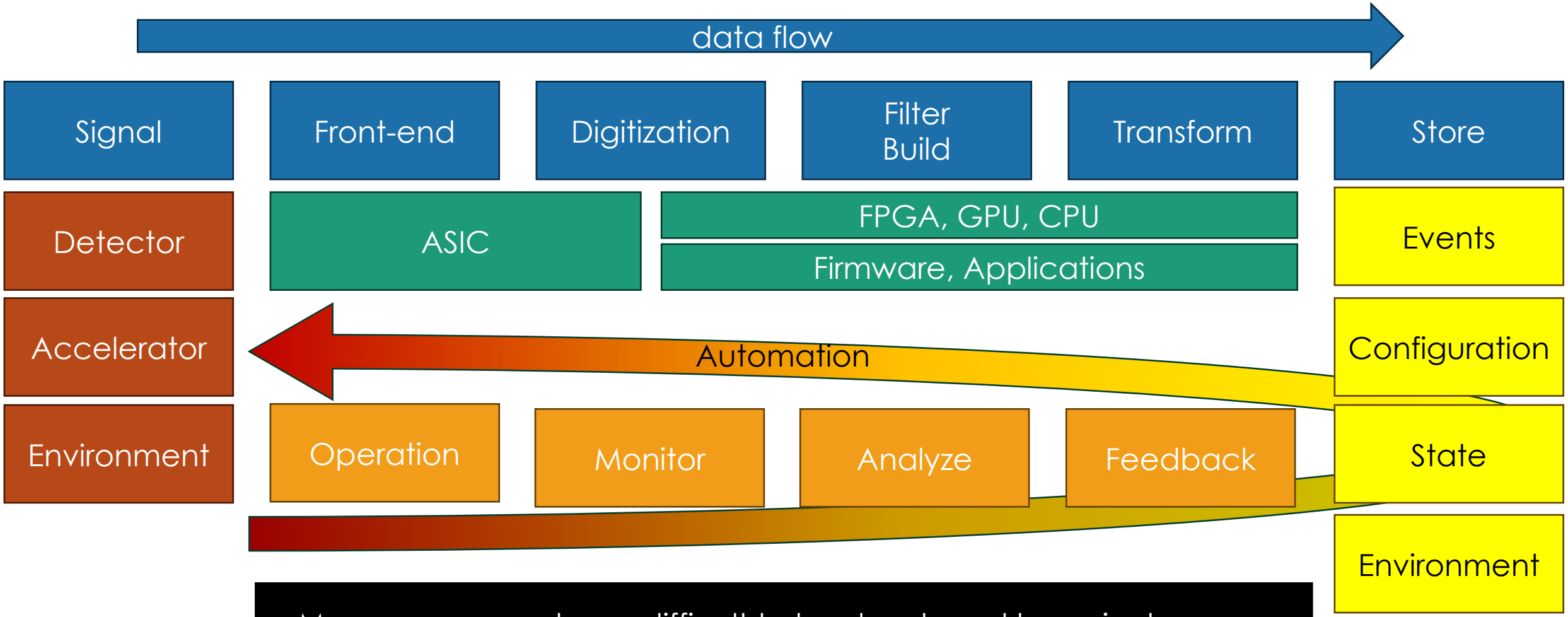
Common

- Similar detectors
- High throughput or compression in FEE
  - 10Gbps or more
- High compression or reduction
  - $(1/10^5)$ 10Tbps => 100 Mbps (Data store)
- Scalability
  - adaptive to 1 – 30000ch or more

Different

- Dynamic range
- Number of channels
- Hit frequency
- Requirement for trigger

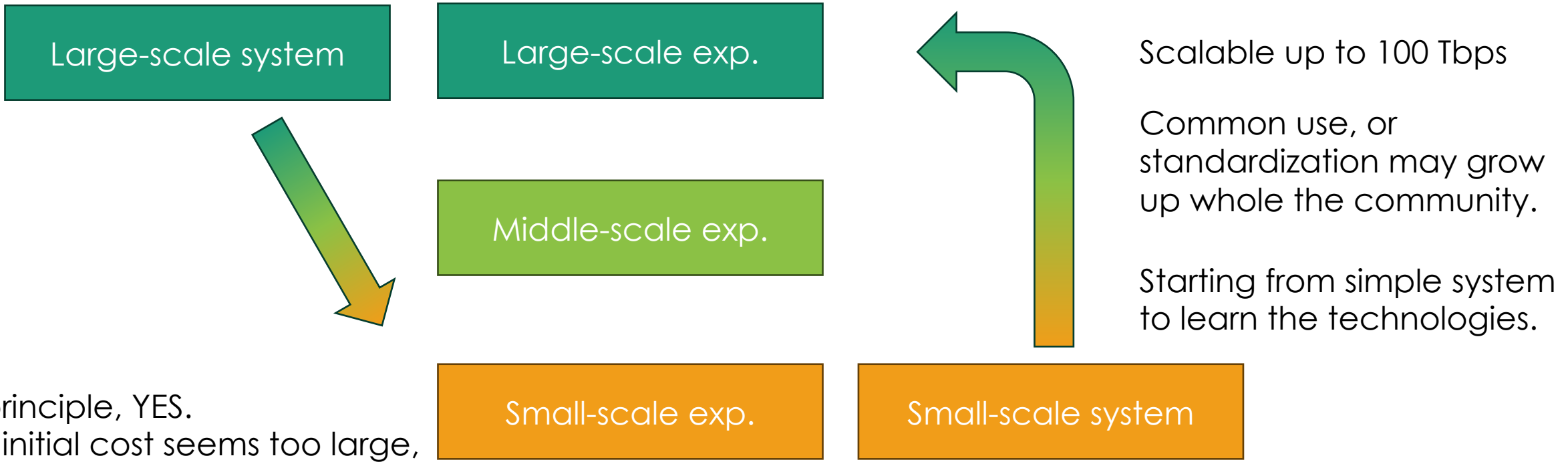
Develop components



Already Exists?

- Many DAQ developments around NP and HEP field are ongoing
  - ALICE O2 system, EIC, GRETA, sPHENX, …
- Streaming type DAQ and online filtering are good candidate and maybe only the solution to manage the increasing data flow.

A large thing will serve for a small one…?
大（だい）は小（しょう）をかねる?



Scalable up to 100 Tbps

Common use, or standardization may grow up whole the community.

Starting from simple system to learn the technologies.

In principle, YES.
But initial cost seems too large, setup, configuration and/or operation are also difficult WITHOUT knowledge and technique.

Both views and requirements are important for the common-use scalable system

Stating from the small, scalable system in cooperation with researchers from different institutes

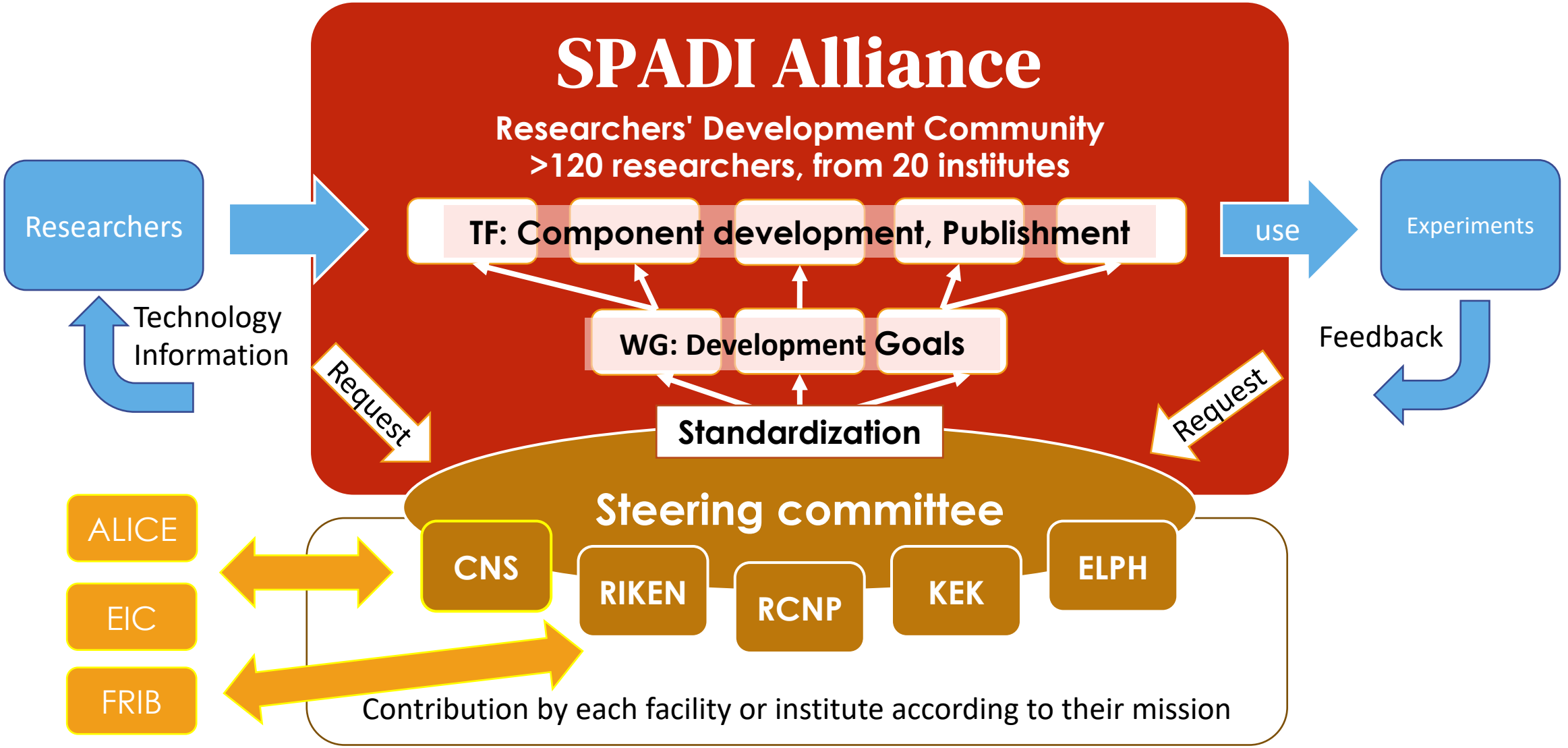
What is it?

SPADI Alliance

Signal processing and data acquisition infrastructure alliance

Organization

In future, management by a group of researchers.



History of SPADI Alliance

- 2022.05 Initiated
  - FY2022 Discussion for the implementation and FEE developments
- 2023.03 Town meeting in JPS and Annual workshop
- 2023.03 Test Implementation of S-DAQ at RCNP
- 2023.06 Test Implementation of S-DAQ at J-PARC
- 2023.06 Bylaws are issued
- 2023.07 First physics experiment with S-DAQ
- 2023.09 Laboratory exercise of DAQ implementation

Working groups and Task forces

WG1
Frontend Electronics

Streaming type
Charge ASD board
Voltage ASD board
WF Digitizer board
Control Firmware dev.

WG2
Clock synch. / Data Transfer

General Clock Synch.
High throughput
Intra-board transfer

WG3
Acquisition software framework (NestDAQ + …)

Streaming type
FairMQ-based Scalable DAQ
Sampling, Time frame build, Event build, Monitoring…
Format

WG4
Event processing

Acceleration using GPU/FPGA
Zero suppression
Calibration, Clustering, Tracking, PID,

WG5
User Interface

Control, Monitor, Configure,

Trial with
SlowDash

WG6
Computing infrastr.

High throughput
Large volume
Flow and Archive
Power consumption
Interconnect
Networking
…

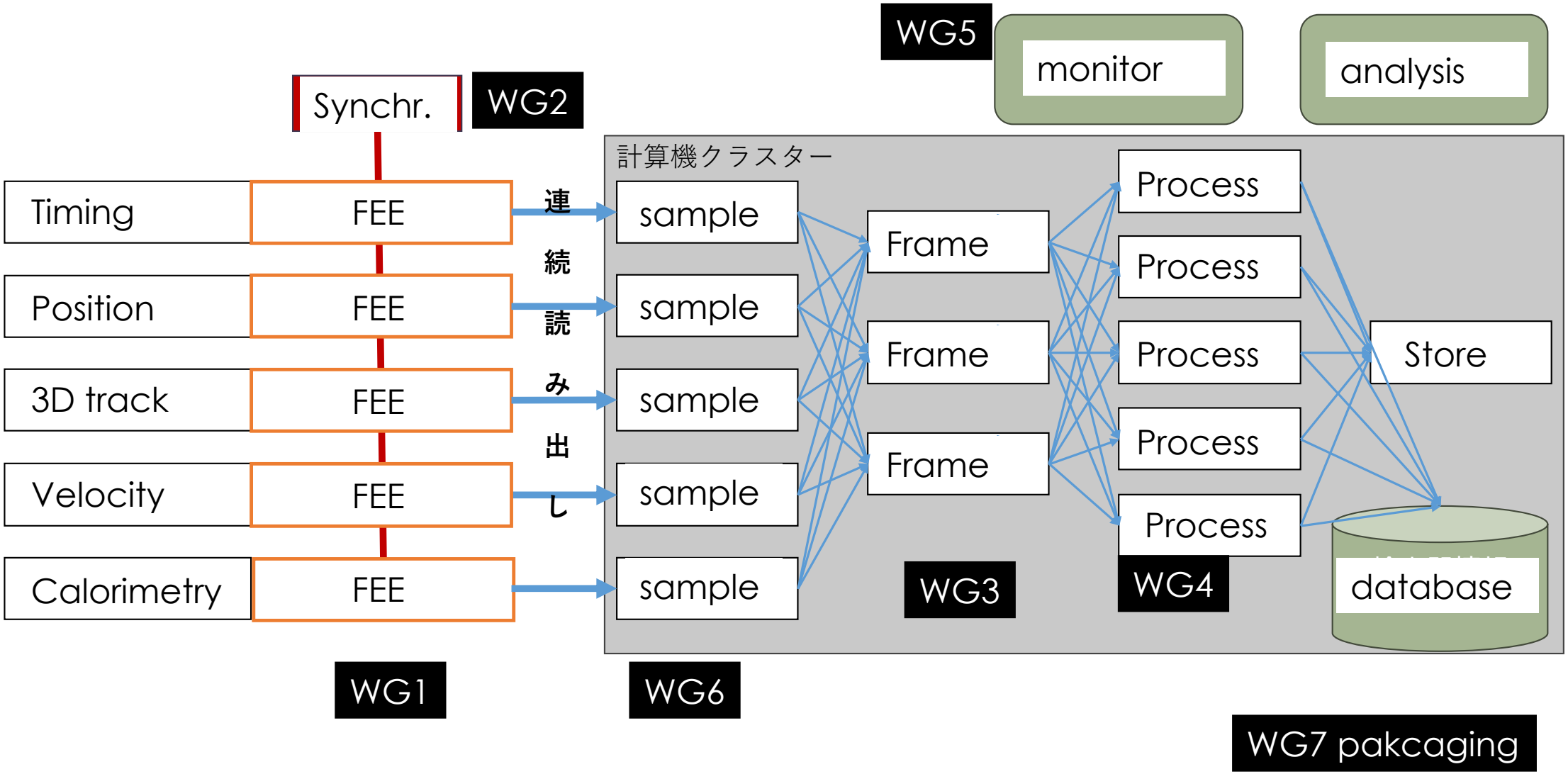
WG7
Packaging

Standalone system
Popularization
Standardization
Market research
User feedback

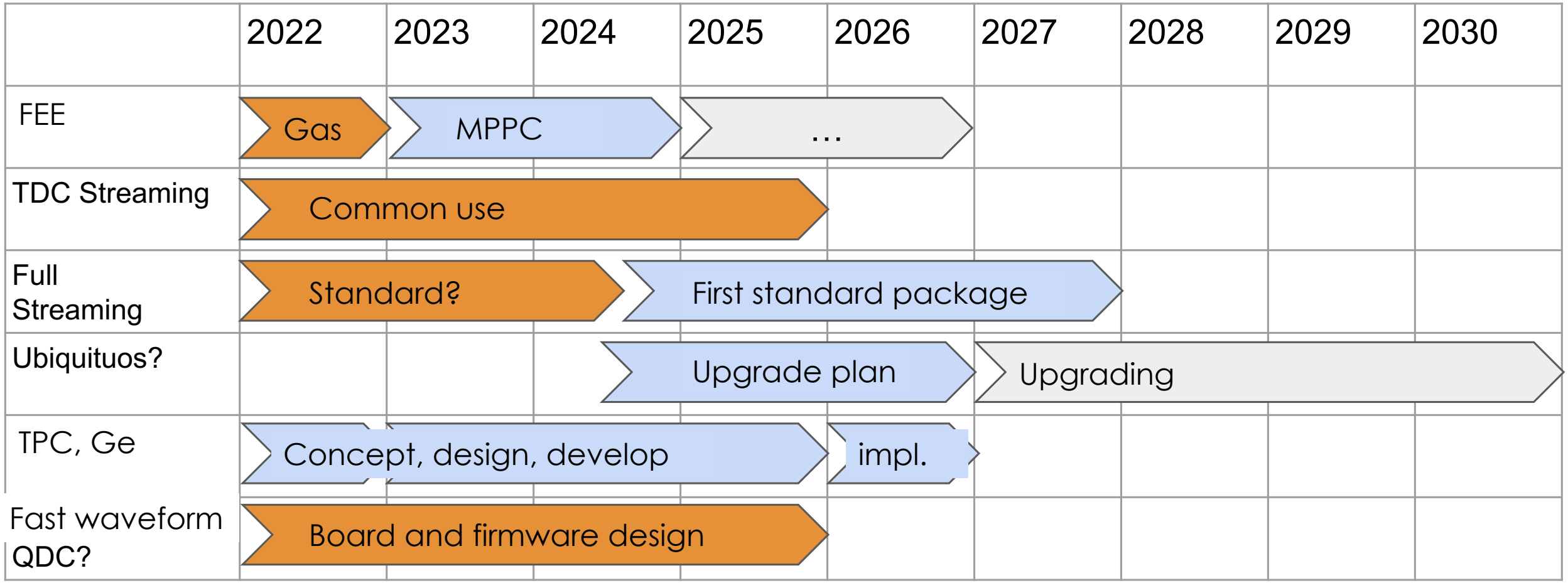
Analysis

Trial with
Artemis

Scalable, Flexible, Zero-loss DAQ?



Timeline


2022
2023
2024
2025
2026
2027
2028
2029
2030
FEE
Gas
MPPC
…
TDC Streaming
Common use
Full Streaming
Standard?
First standard package
Ubiquituos?
Upgrade plan
Upgrading
TPC, Ge
Concept, design, develop
impl.
Fast waveform QDC?
Board and firmware design

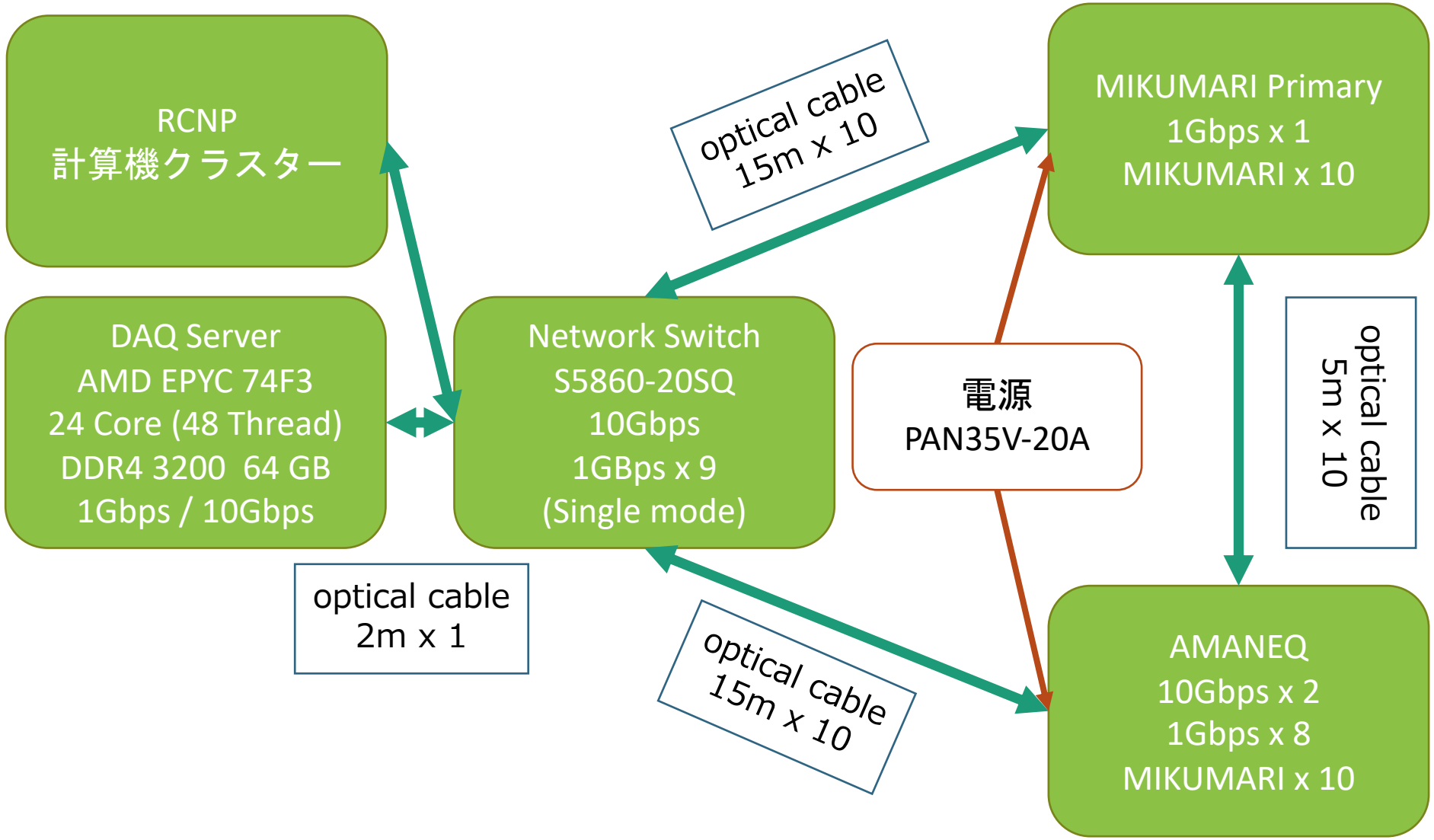
What was achieved?

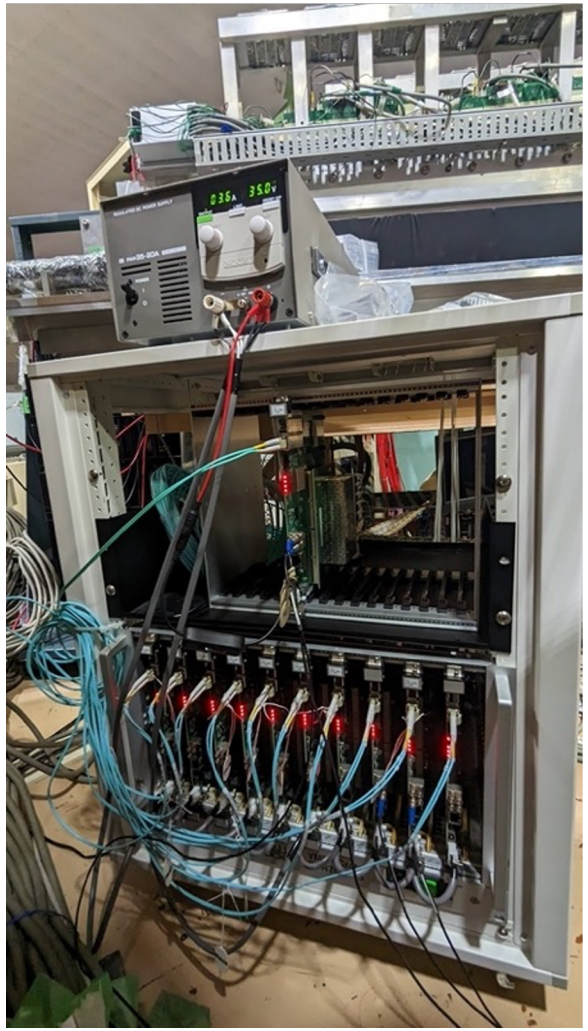
Activities in 1.5 years..

Recent Activities

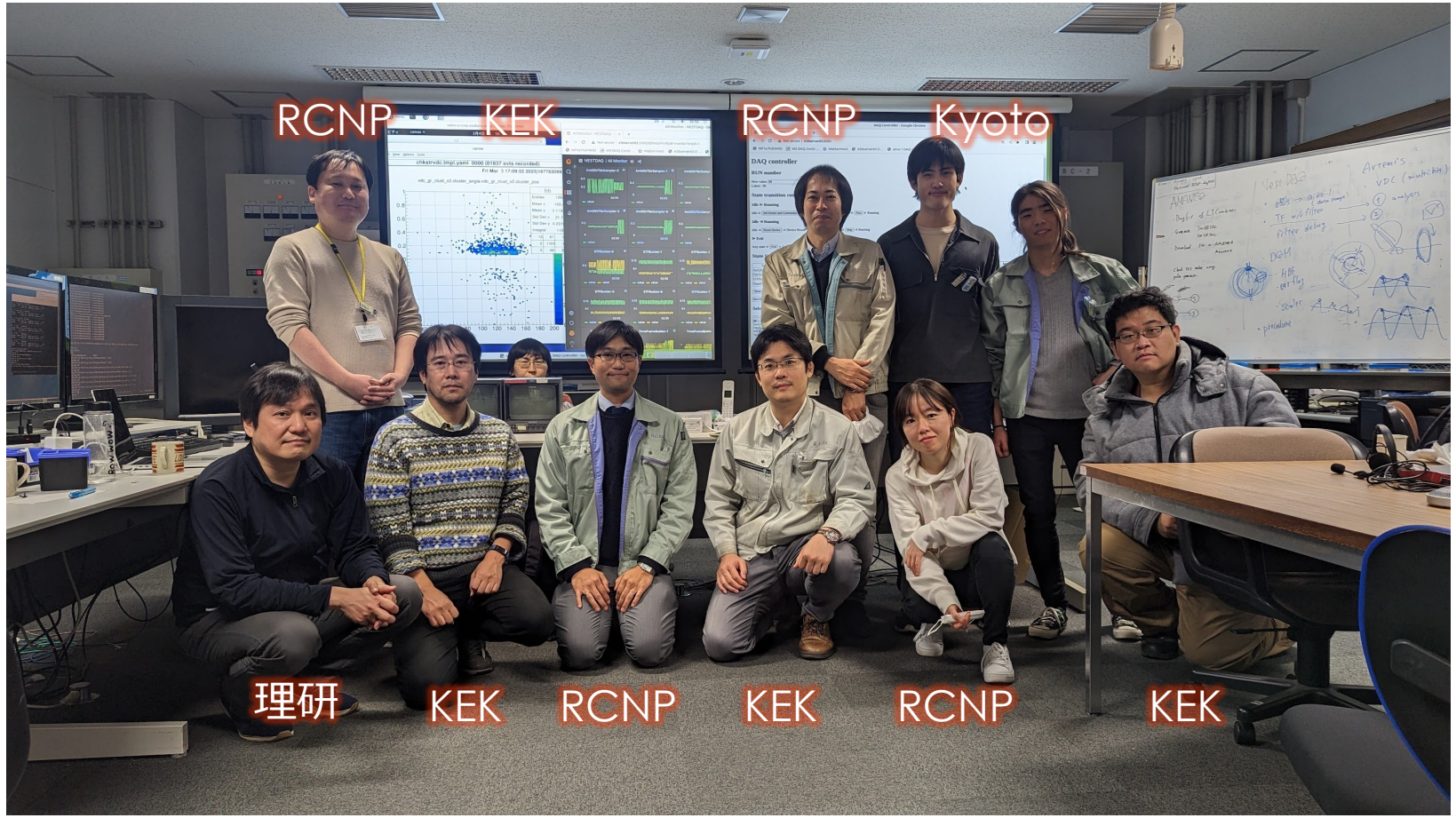
- DAQ implementation test at RCNP and J-PARC
- Packaging of Streaming DAQ with HR-TDC
- Various FEE
- Many meeting to acquire the requirement in various experiments (>20)
- Monthly Meeting
- Training camp for young researchers and students

Test at RCNP

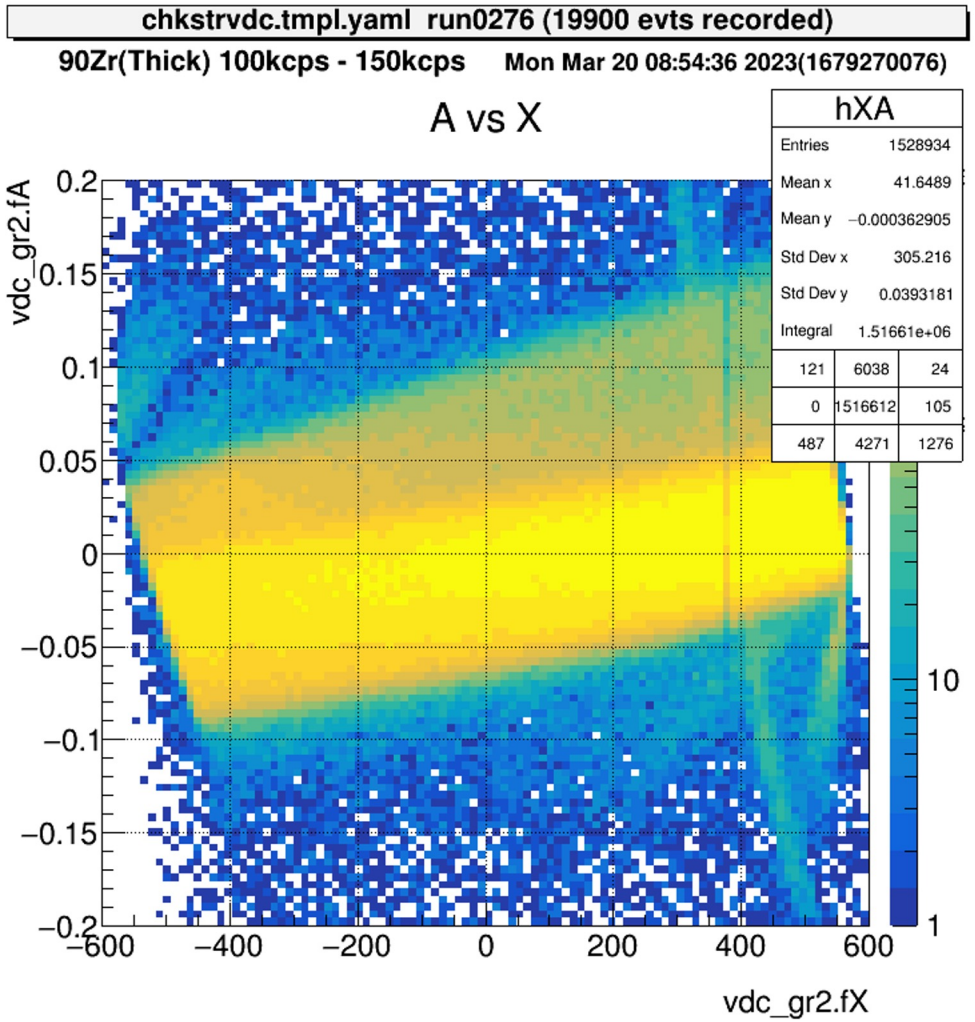

RCNP
計算機クラスター
DAQ Server
AMD EPYC 74F3
24 Core (48 Thread)
DDR4 3200 64 GB
1Gbps / 10Gbps
Network Switch
S5860-20SQ
10Gbps
1GBps x 9
(Single mode)
optical cable
15m x 10
MIKUMARI Primary
1Gbps x 1
MIKUMARI x 10
電源
PAN35V-20A
optical cable
5m x 10
optical cable
2m x 1
optical cable
15m x 10
AMANEQ
10Gbps x 2
1Gbps x 8
MIKUMARI x 10

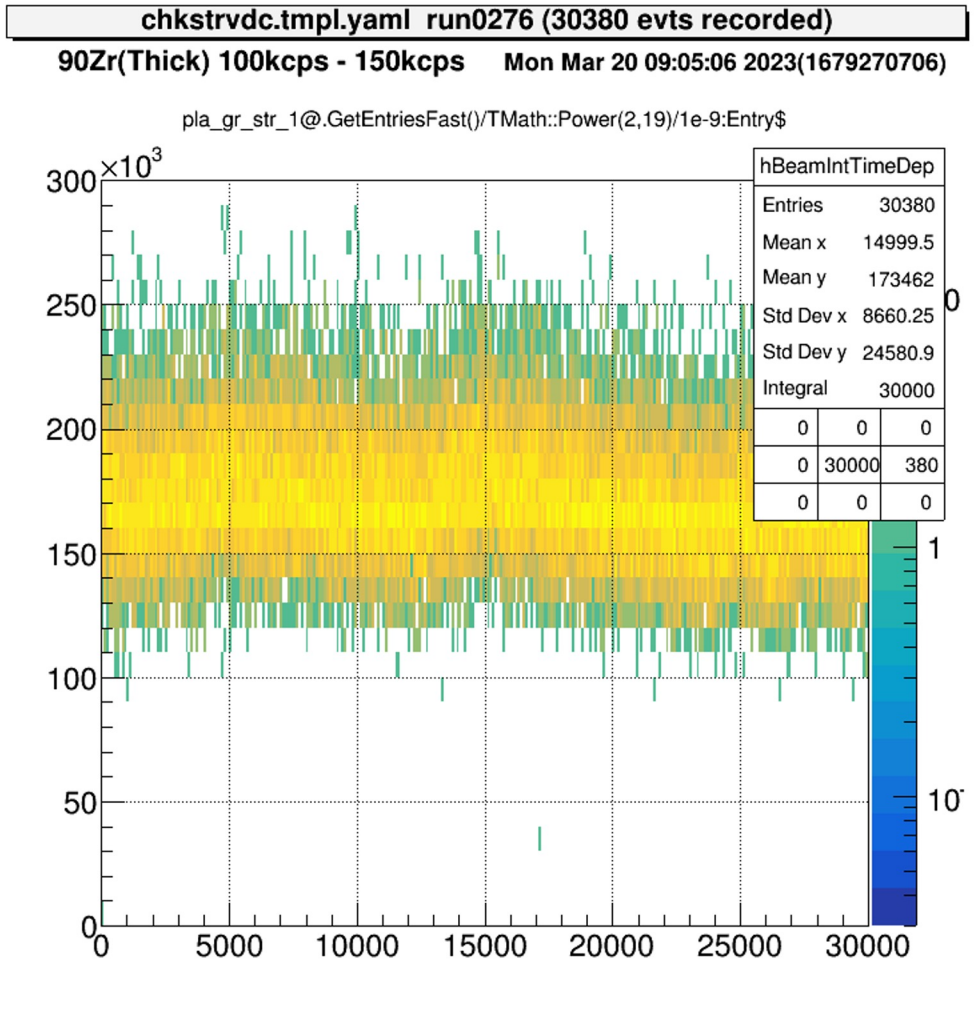


2023/03/02 – 03/04
(このときはビームが出なかったが)

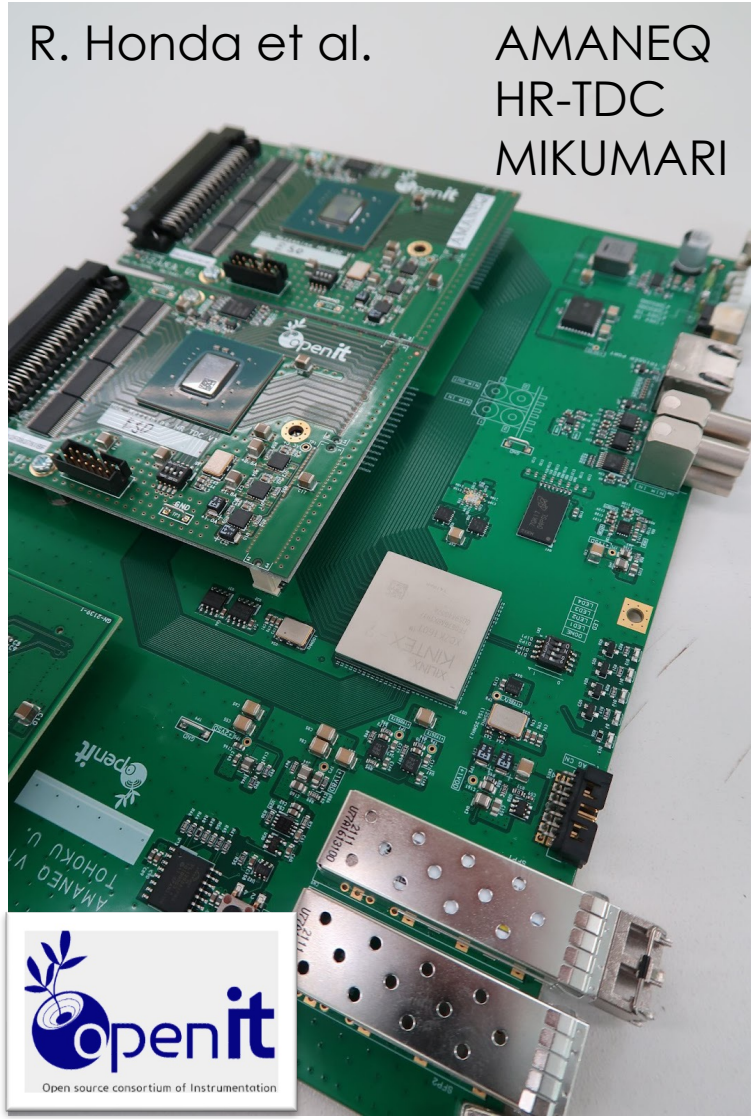


100-200 kcps (40 times faster)

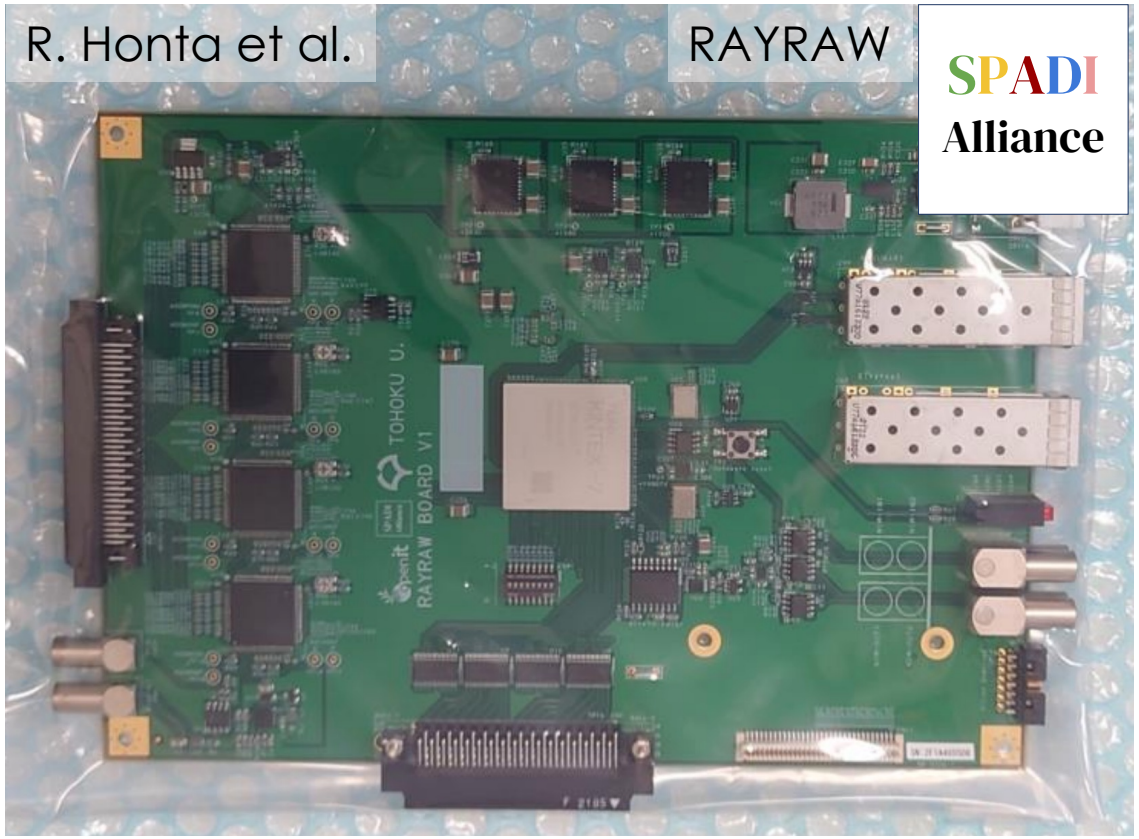




FEE 1

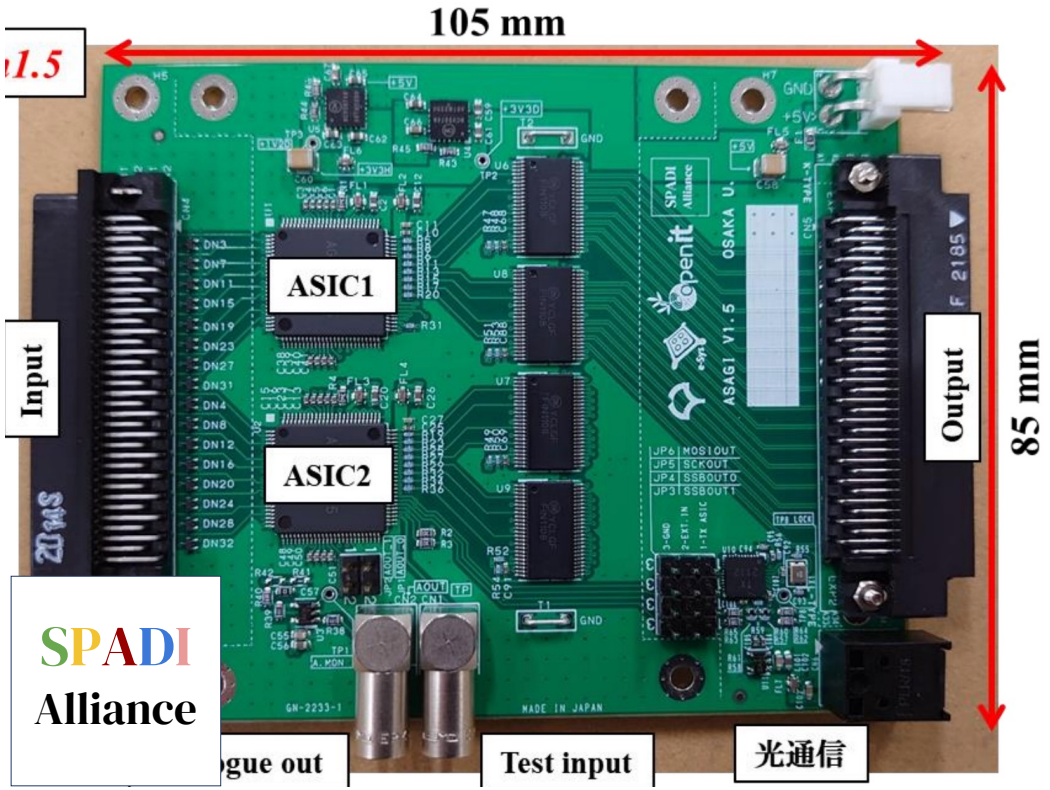


MPPC ASIC Board
(YAENAMI 搭載)

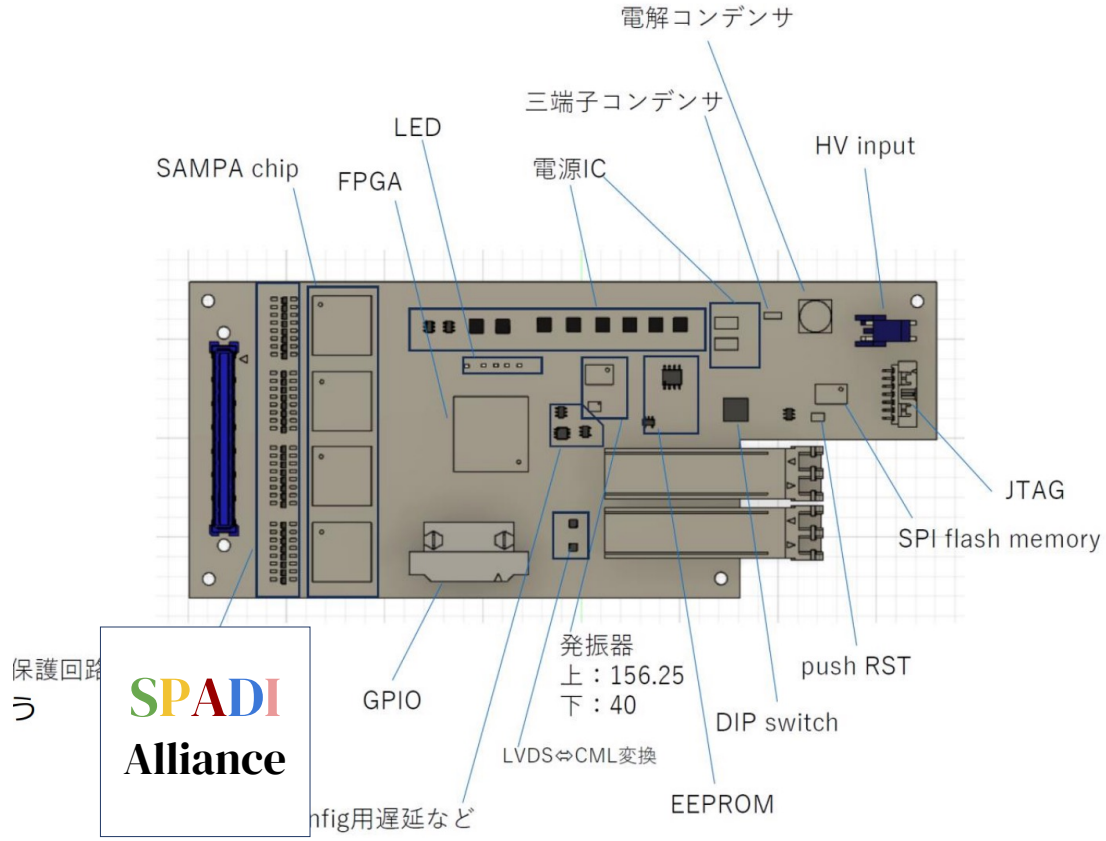


FEE2

Gas chamber ASD
ASAGI (Shirotori, Ikeno et al.)
AGASA ASIC (Miyahara et al.)　搭載



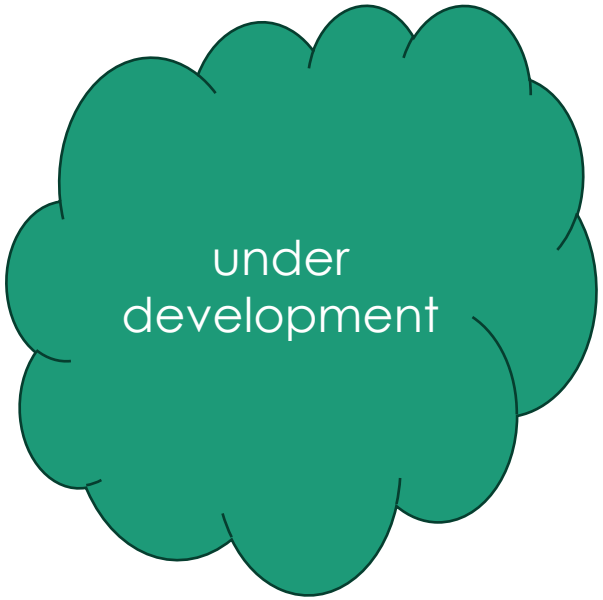
SAMPA chip board SAMIDARE
(Isobe, Nagafusa et al.)



FEE3

High resolution FADC MIRA
(Baba, Kitamura et al.)

QDC without delay cables
Slope ADC …



What is the next and in future?

Development items in next steps

- Time synchronization in FEE. (Modularity and scalability)
- FEE for Ge, Si, Fast charge signals (PMT, MPPC), TPC etc with time synchronization.
- Fast tracking, PID, Calibration, …

- Many ongoing and future project in big collaborations like ALICE, EIC etc.
  - Exchange of knowledge, experiences and technologies
  - Collaborative development and common use ?

Summary and Outlook

- SPADI Alliance is initiated for a standardization of streaming DAQ
  - Many front-end electronics boards are being manufactured
  - Clock synchronization protocol
  - DAQ software framework
  - Analysis software framework
- We need the discussion among the community and other laboratory
  - Experiment group, Facility, Domestic, and **International**
- Many pioneering works exists we should learn from.

How can we proceed?