大阪大学
THE UNIVERSITY OF OSAKA

RCNP

K Program

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An all-in-one front-end board for the streaming readout of gaseous detectors used in experimental physics

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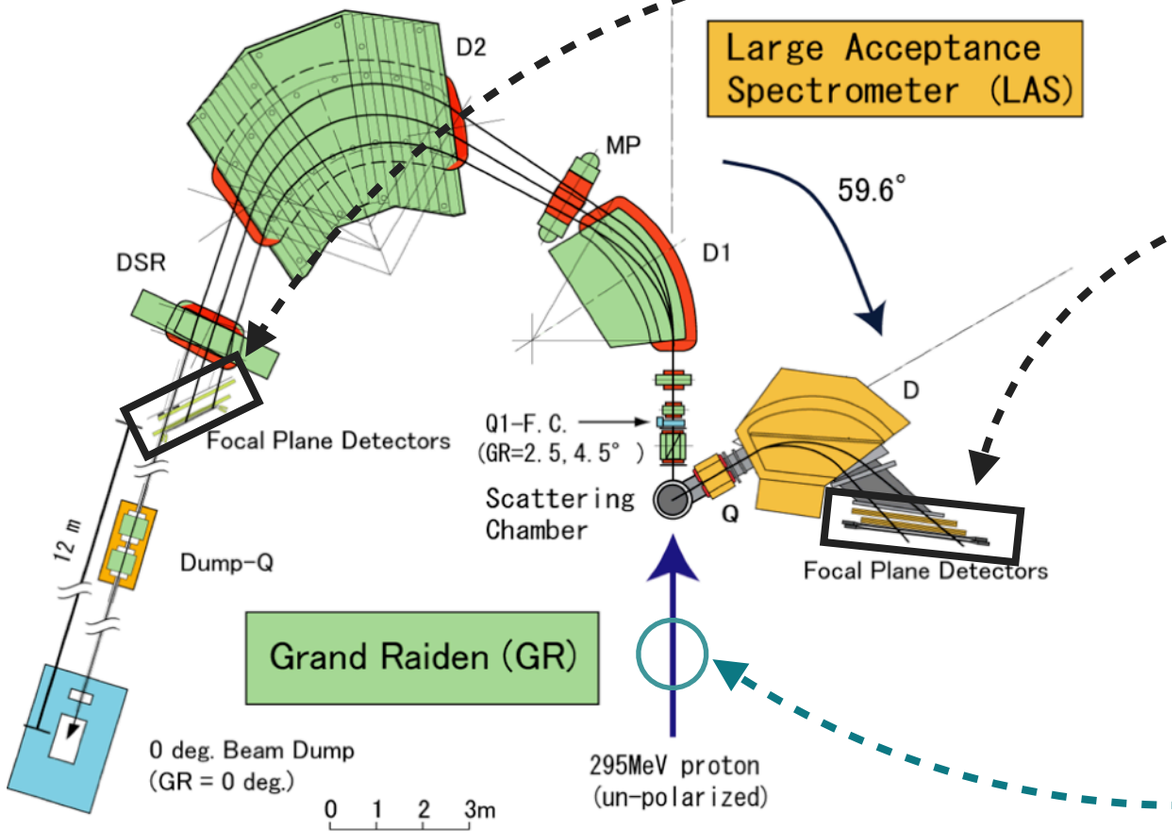
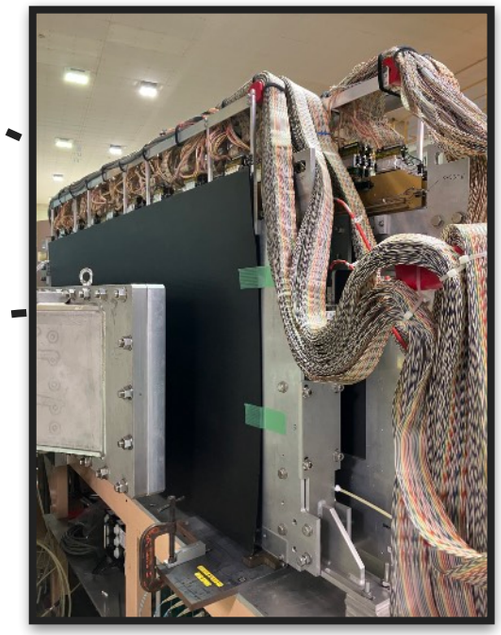
Gaseous detectors in nuclear physics

- Gaseous detectors are one of the most commonly used detectors in experimental physics due to cost-effectiveness, scalability, etc.



Grand Raiden and Large Acceptance Spectrometers, RCNP, The Univ. of Osaka



Drift chambers as ***spectrometer*** focal plane detectors

E.g: RCNP Grand Raiden and LAS

Compact ***beam profile*** monitors

E.g: SR-PPAC, LP-MWDC

Data acquisition (DAQ) from gaseous detectors

Drift chambers as ***spectrometer*** focal plane detectors

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Compact ***beam profile*** monitors

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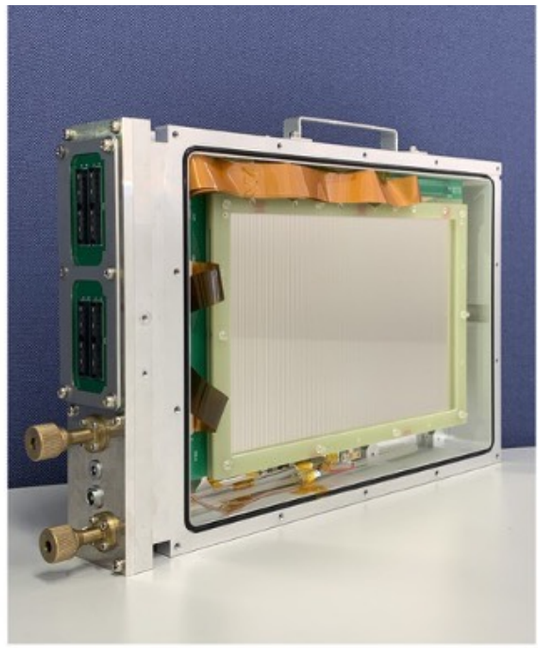
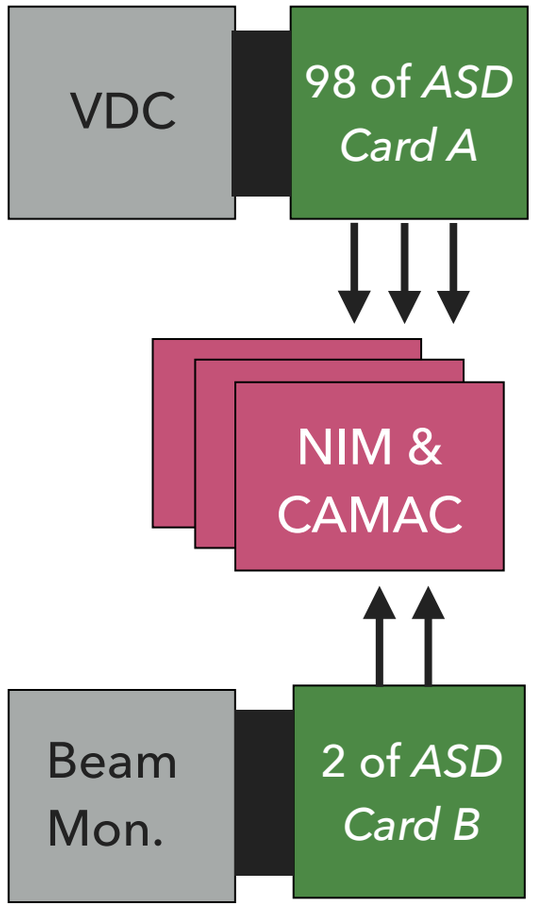
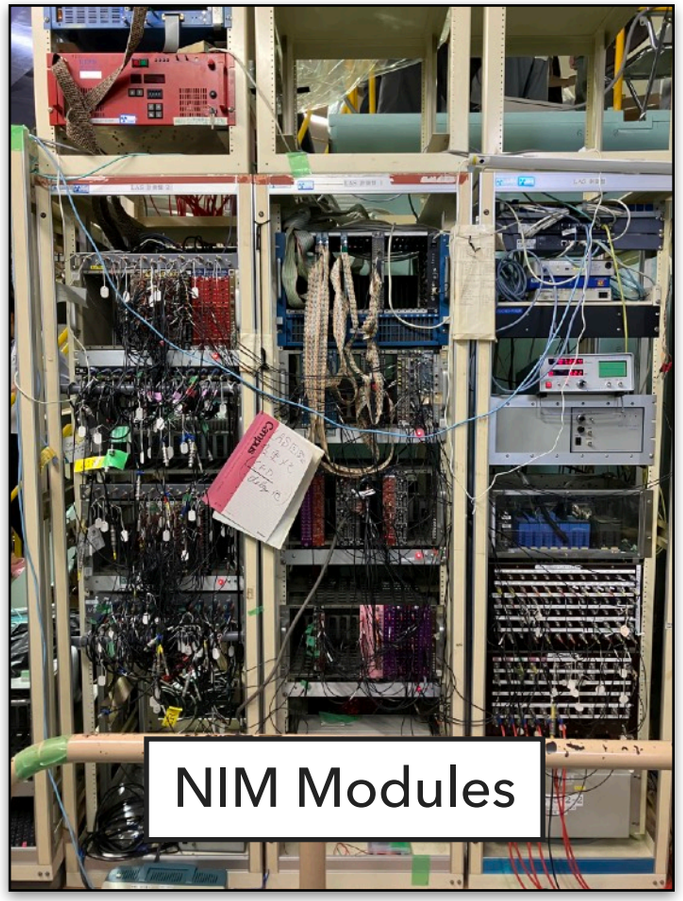


- A legacy DAQ system for gaseous detectors,





ASD:
Amp-Shaper-Discriminator

Could only handle DAQ rates of up to (O)10~(O)100 kcps

Data acquisition (DAQ) from gaseous detectors

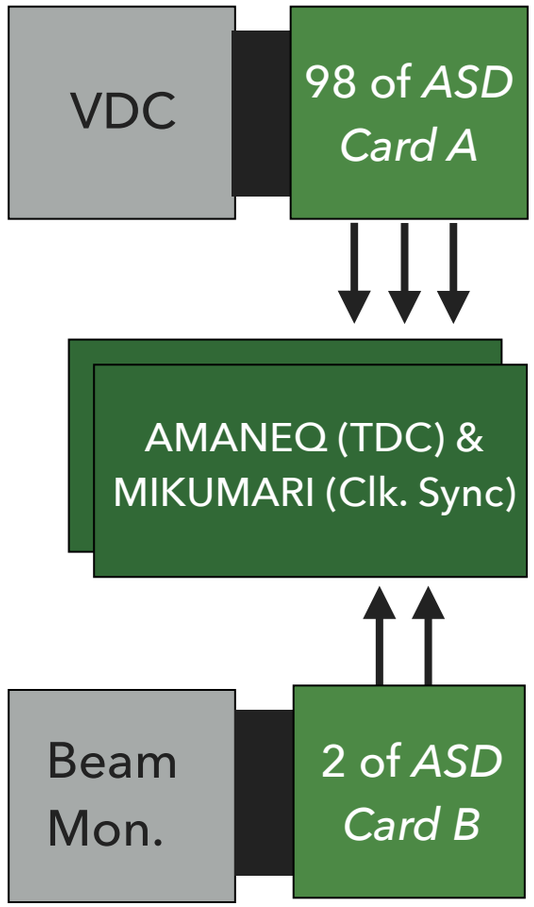
Drift chambers as ***spectrometer*** focal plane detectors

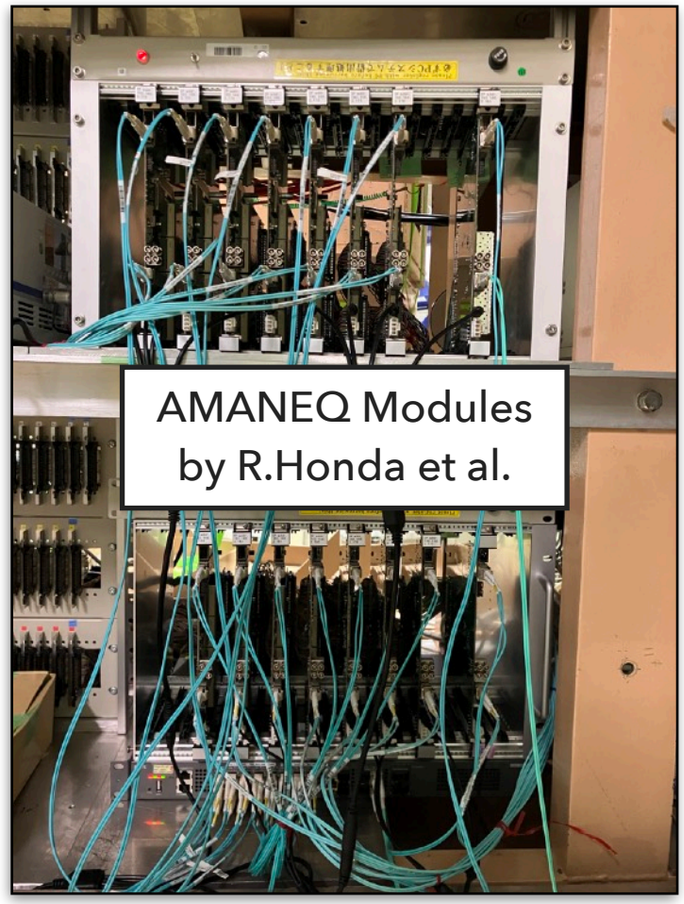
E.g: RCNP Grand Raiden and LAS

Compact ***beam profile*** monitors

E.g: SR-PPAC, LP-MWDC

- A modern DAQ system for such detectors,





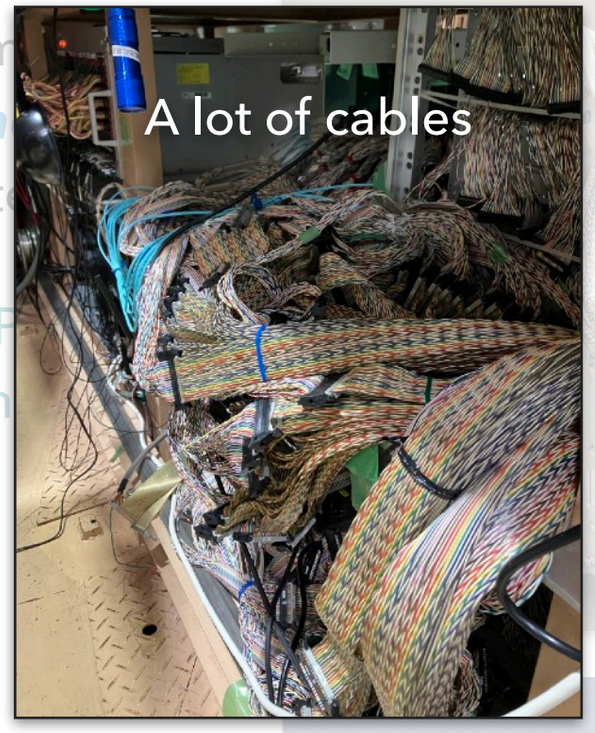
AMANEQ was mentioned also by Sun-Young Ryu, Che-Sheng Lin, and Genie Jhang in their talks

Trigger-less streaming DAQ system ➡
Can handle DAQ rates of ~(O)Mcps

Data acquisition (DAQ) from gaseous detectors

Drift cham
spectrom
plane dete

E.g: RCNP
Raiden an



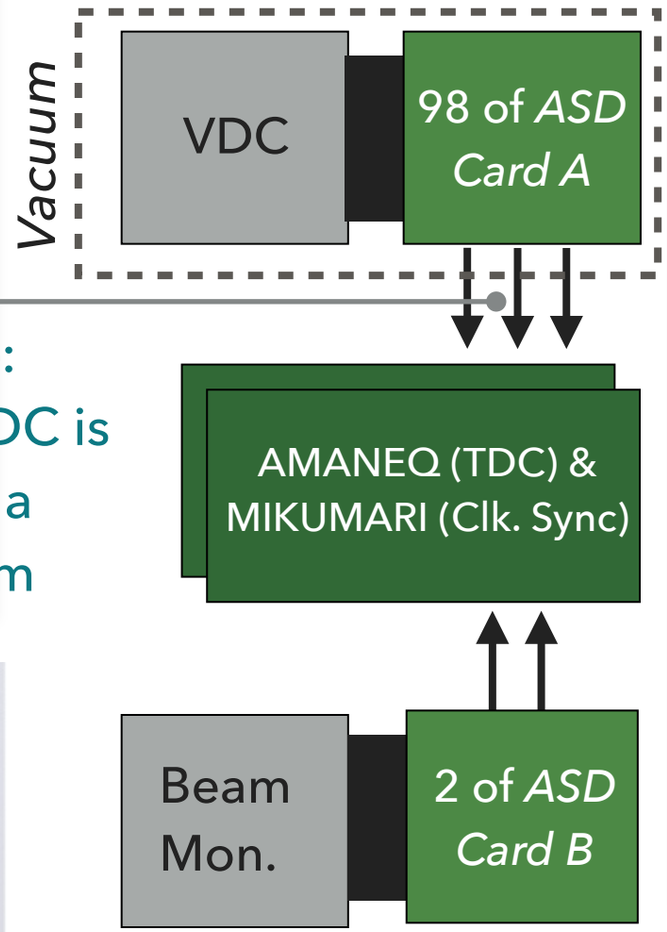
Not feasible in the future!

Compact ***beam profile*** monitors

E.g: SR-PPAC, LP-MWDC

Future:
The VDC is inside a vacuum

- A modern DAQ system for such detectors,



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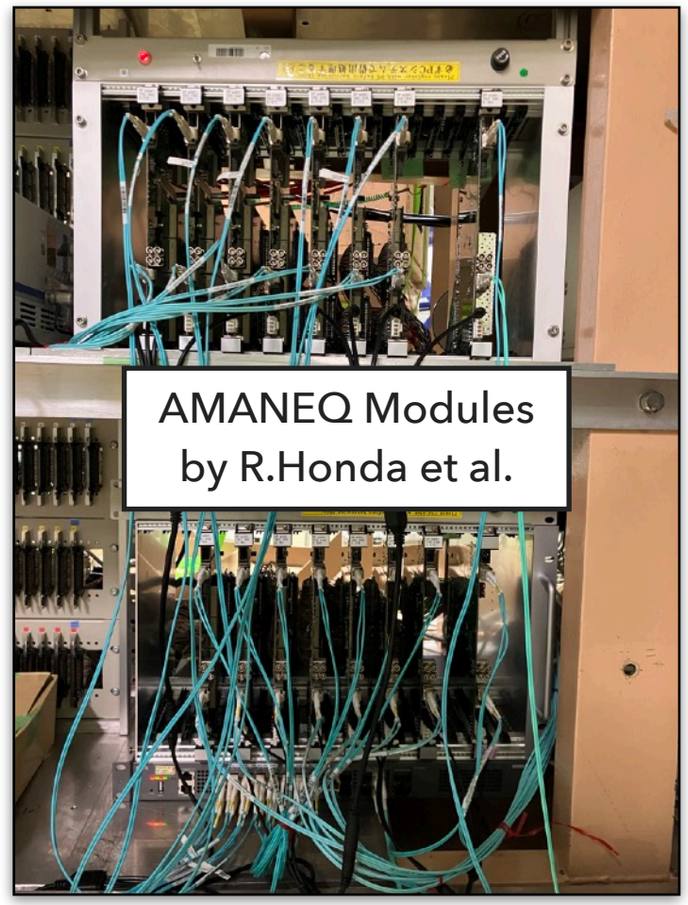

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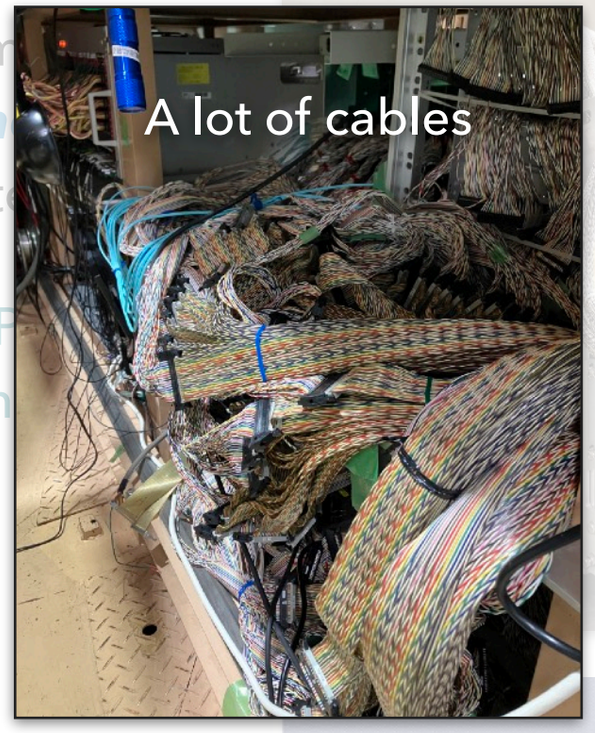
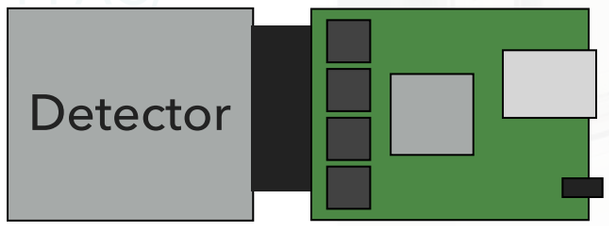
Compact ***beam profile monitor***

E.g: SR-PPAC,
LP-MW



Not feasible in the future!

Can we have a common, all-in-one, scalable system?



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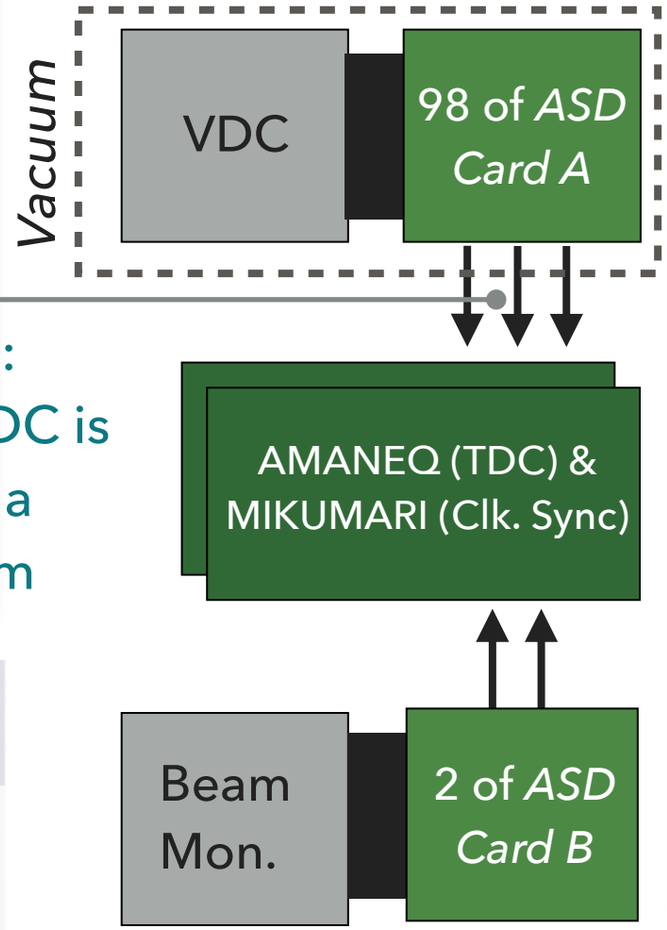
- A modern DAQ system for such detectors,



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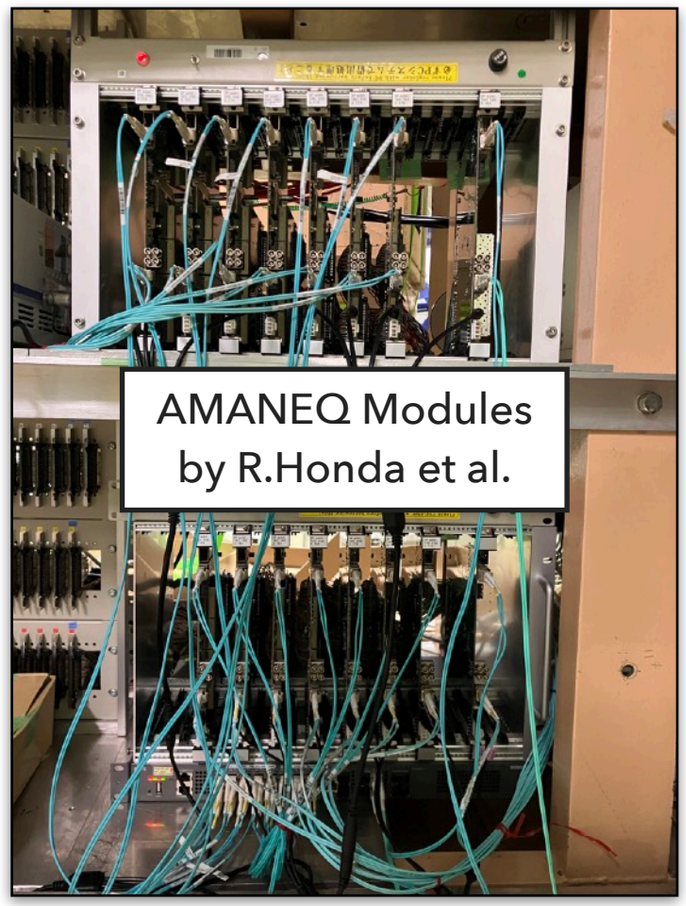
Amp-Shaper-Discriminator



Trigger-less streaming DAQ system ➡
Can handle DAQ rates of ~(O)Mcps

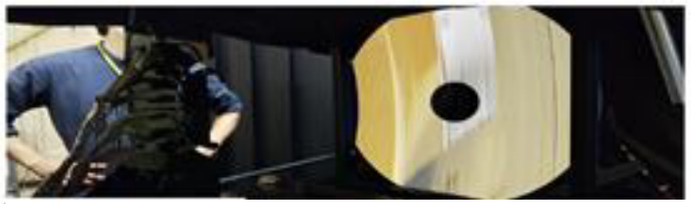
Development of all-in-one cards

- In the JST K-program project "*Real-time distributed data processing methods for virtual reference point reconstruction*", we are developing DAQ technology for air shower detectors. One task is the development of all-in-one cards.

Time Projection Chamber

Track reconstruction

Cherenkov Detector

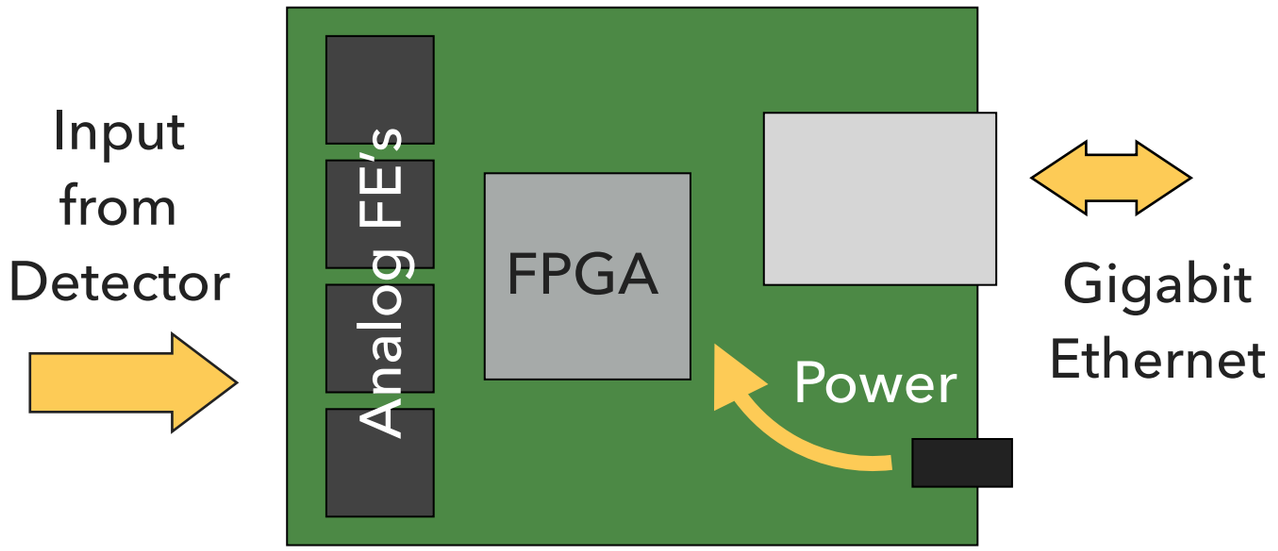


Velocity measurement

Drift Chamber

Position measurement

- ***All in one*** - Analog front end & FPGA in one board, eliminating need for cables.
- ***Compact*** - Ability to fit into compact geometries and spaces like vacuums.
- ***Generic*** - Satisfies requirements of different detectors/experiments.



Development of all-in-one cards

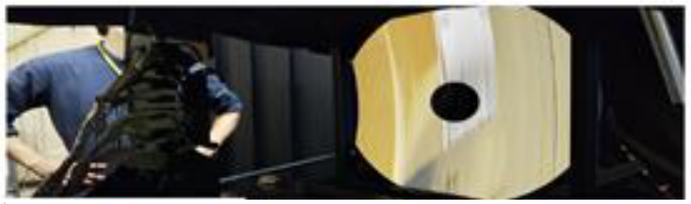
Several talks from my SPADI-A colleagues in RT2026

- The development is ongoing also with the collaboration of SPADI (***S***ignal ***P***rocessing ***A***nd ***D***AQ ***I***nfrastructure) Alliance in Japan.

Time Projection Chamber

Track reconstruction

Cherenkov Detector



Velocity measurement

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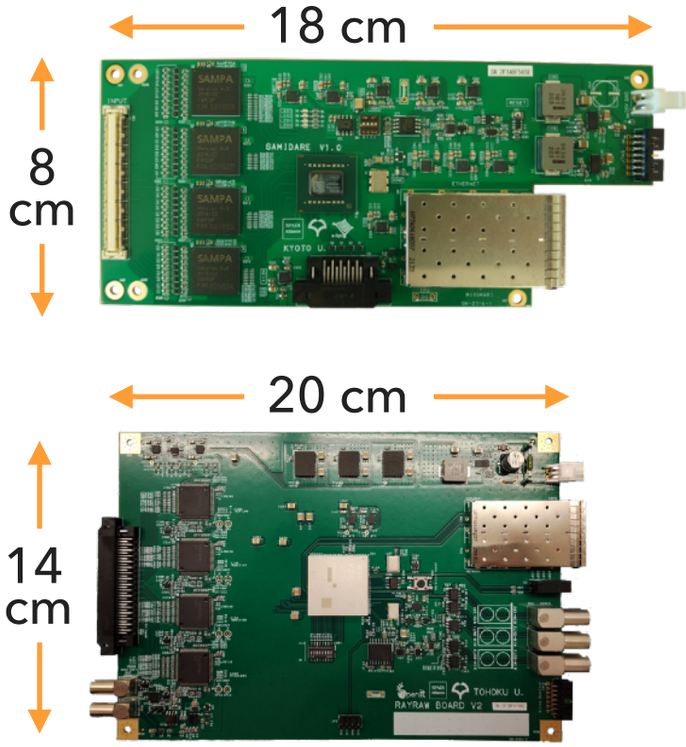
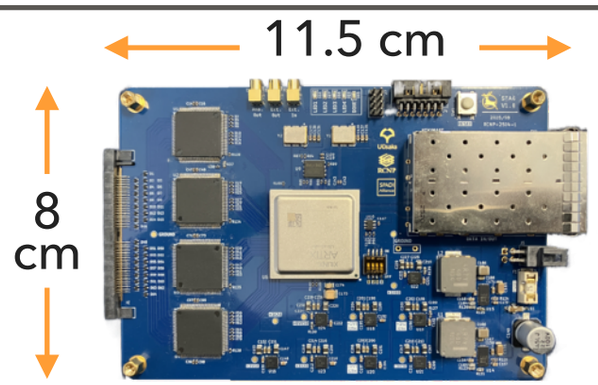


SAMIDARE
PS talks #140 by Claudio S. and #194 by F.Endo

RAYRAW by R.Honda (IPNS, KEK) et al.



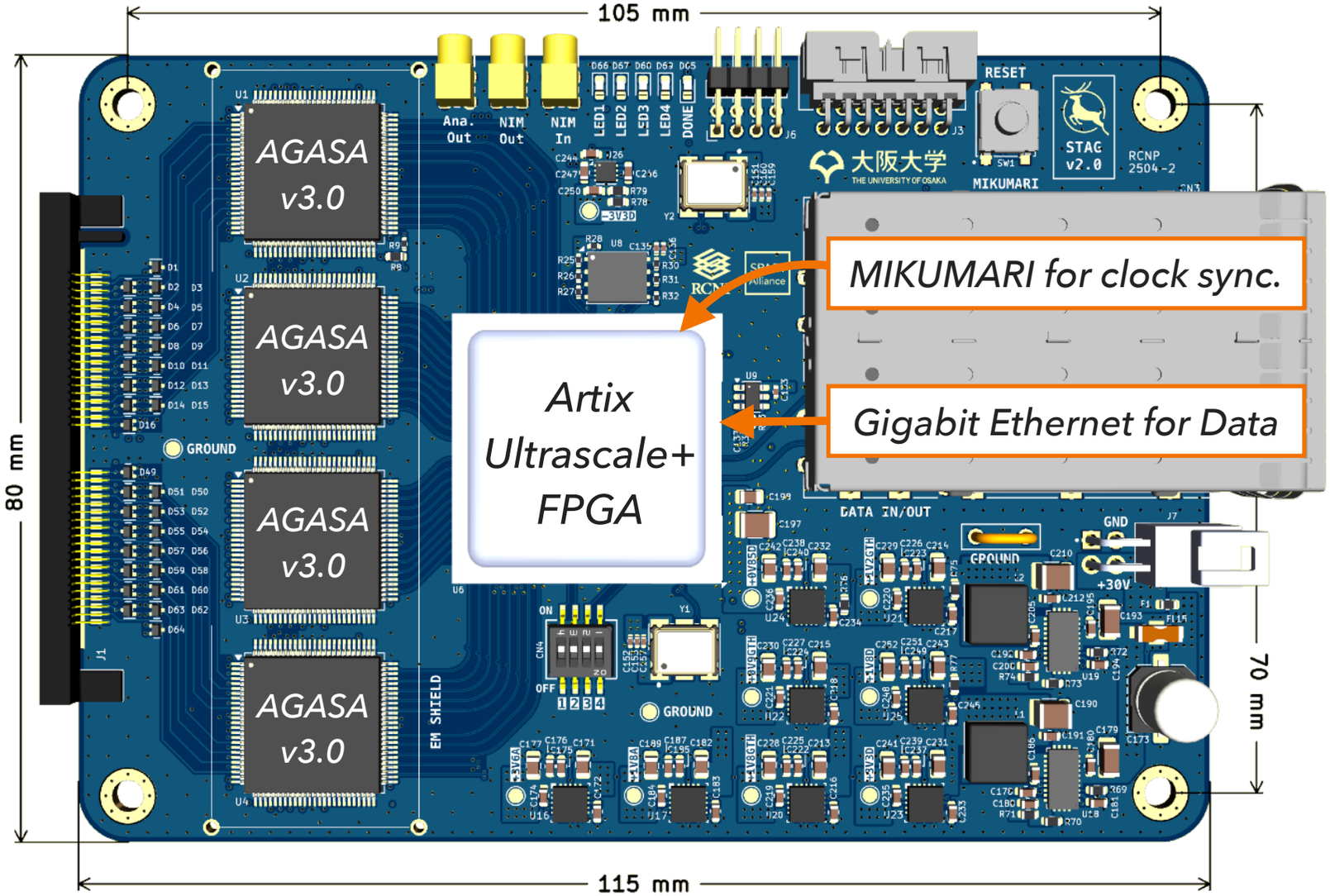
STAG board

Todays Talk!

The all-in-one STAG Board

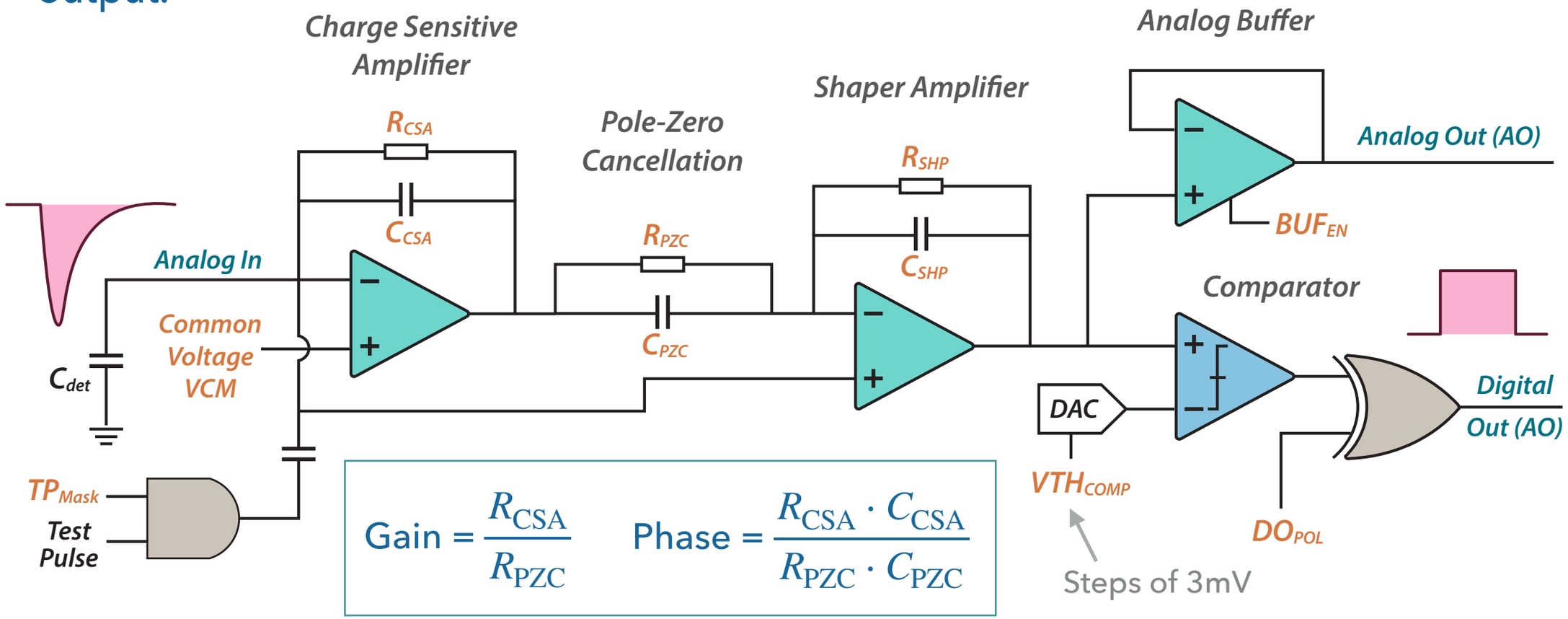
- The STAG (***ST***reaming readout with ***A***GASA for ***G***aseous detectors) board is designed by Lakmin.W and M.Ikeno (RCNP-DAID).
  - ***Analog FE***: AGASA analog ASIC developed by M.Miyahara (KEK), R.Honda (KEK), et al.
  - ***FPGA***: Artix Ultrascale+
  - ***Size***: 8 cm x 11.5 cm
  - ***Aim for low cost***:
    € 800~1100 / board,
    or € 13~17 / channel

Input from 64 VDC channels



AGASA ASIC

- AGASA comprises of a Charge Sensitive Amp, Pole-Zero cancellation, Shaper Amp, and Comparator (i.e Discriminator).
- Meant to be a generic ASIC, to be used in different gas detectors.
  - Hence, the parameters shown in ***Orange*** are configurable. In other words, you can change the gain, phase, comparator thresholds, etc. Also you can monitor the analog output.

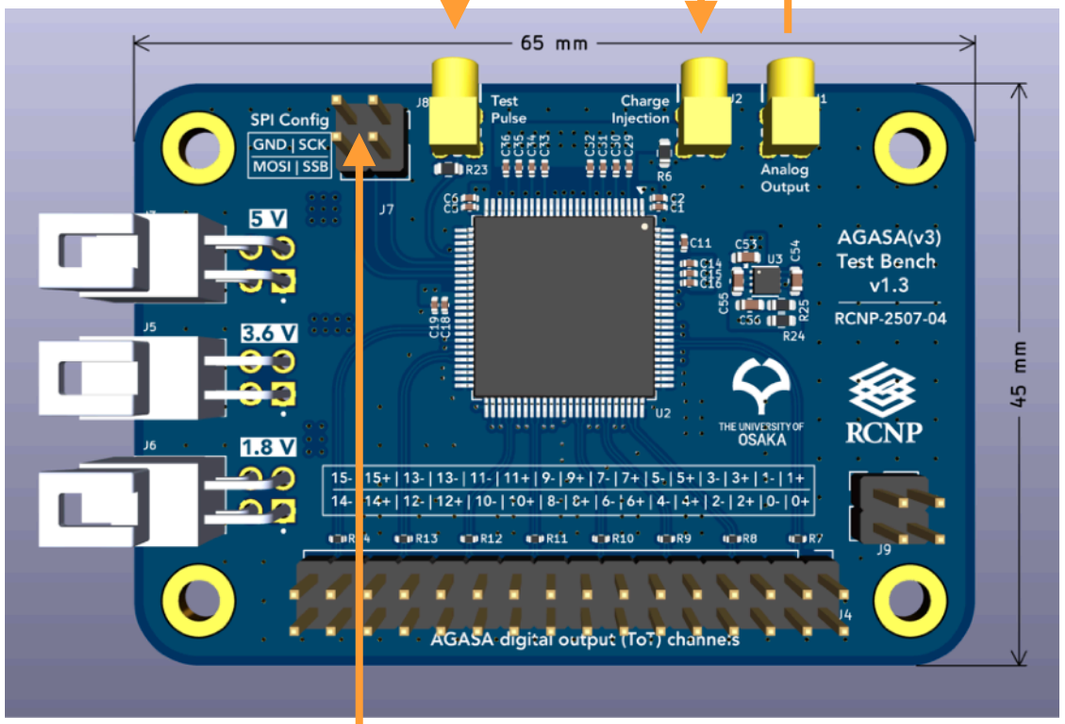


ASIC Test Bench & Control Software

- A dedicated test bench to evaluate the ASIC, which is controlled by the prototype for the STAG control software.

Oscilloscope

Pulse Generator

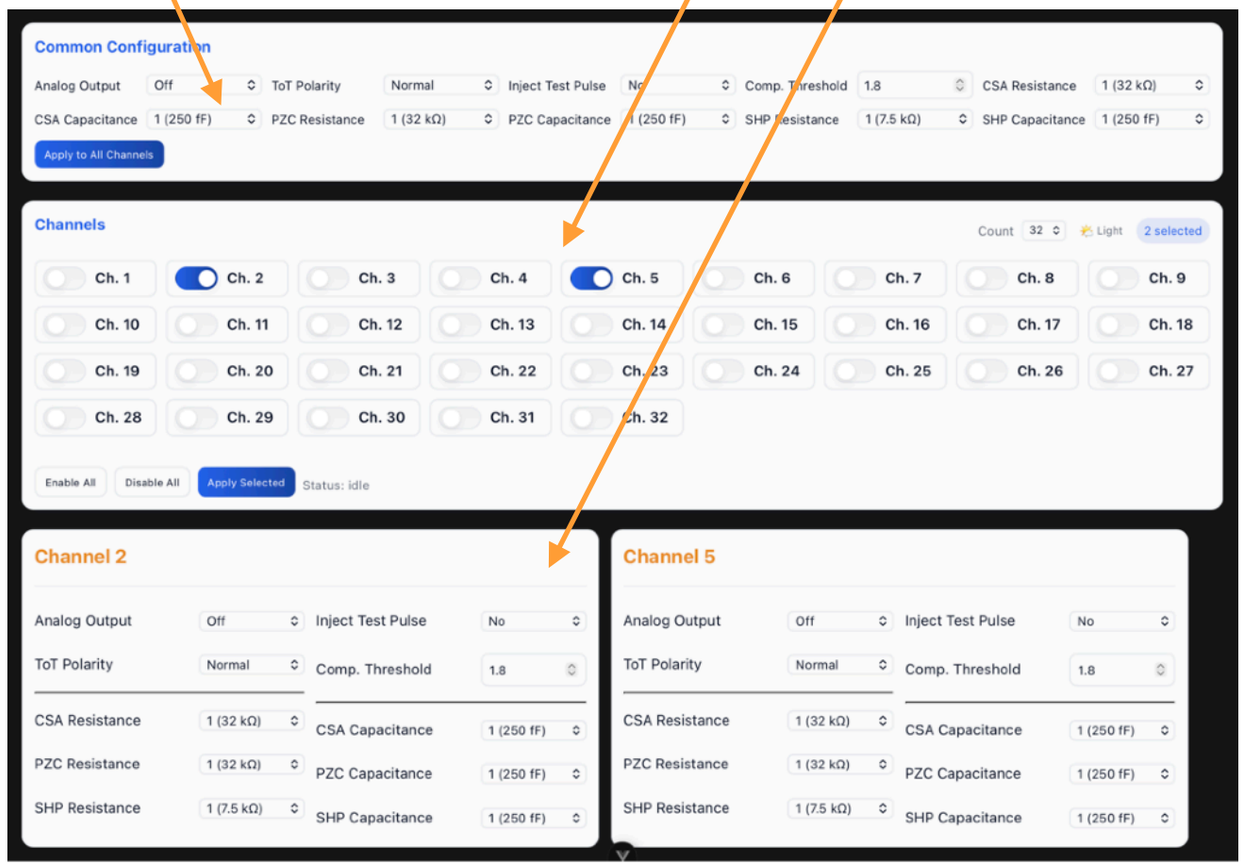


SPI @ 1.25 MHz

Raspberry Pi

Common configuration panel for all channels

Sub-panels for ***channel by channel config***



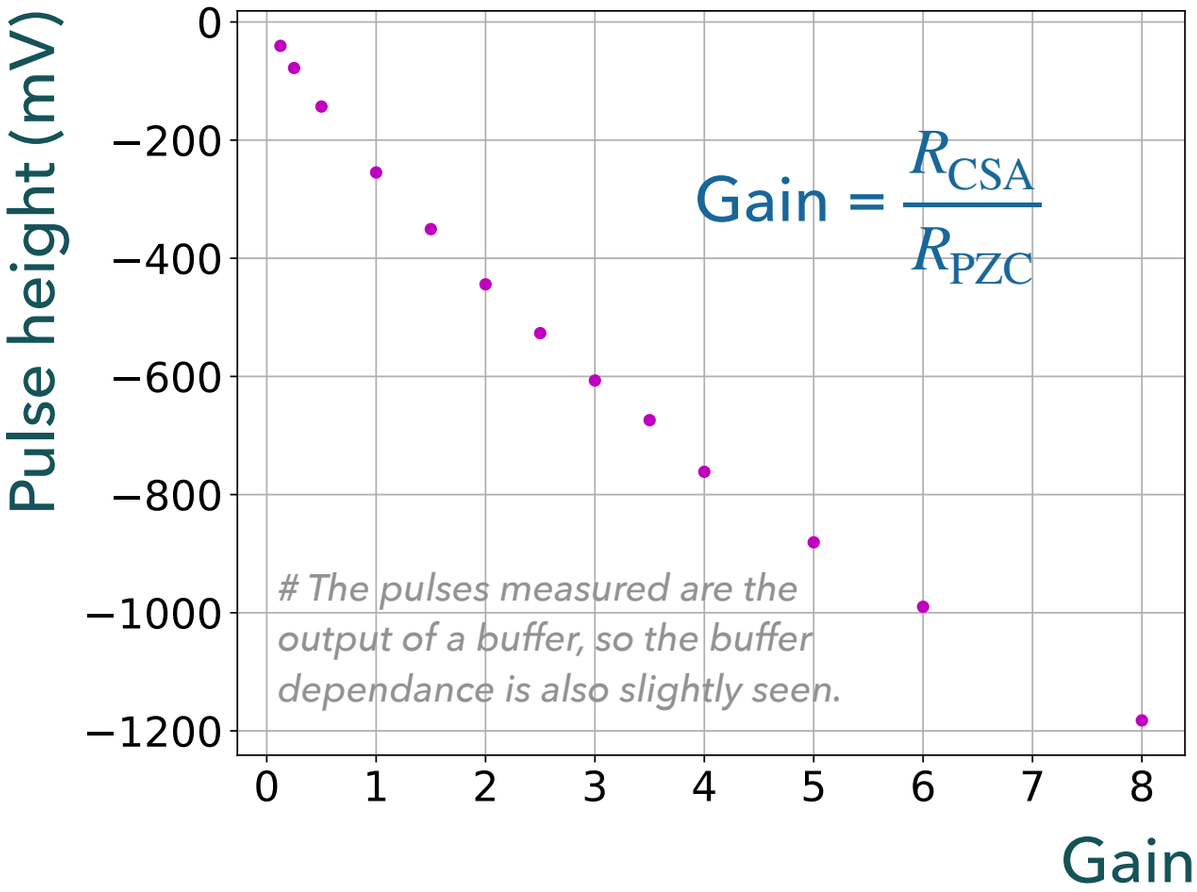
Vue.js *(Front-end)*

FastAPI *(Back-end)*

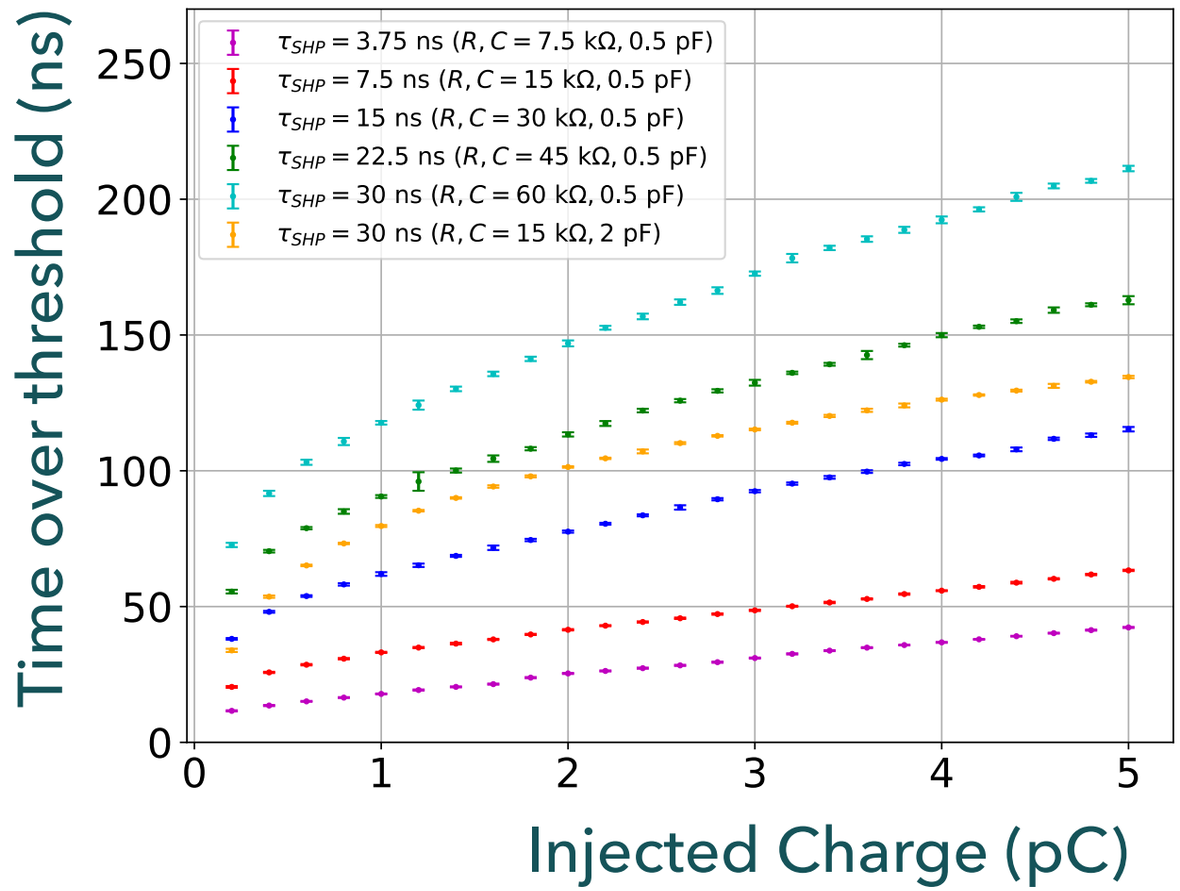
Evaluation of the AGASA v3.0 ASIC

 # Charge Injected using 1 pF capacitor, and ToT threshold at 20 mV

Pulse Height vs ***GAIN*** (0.12 pC pulses)



ToT vs ***Injected Charge***

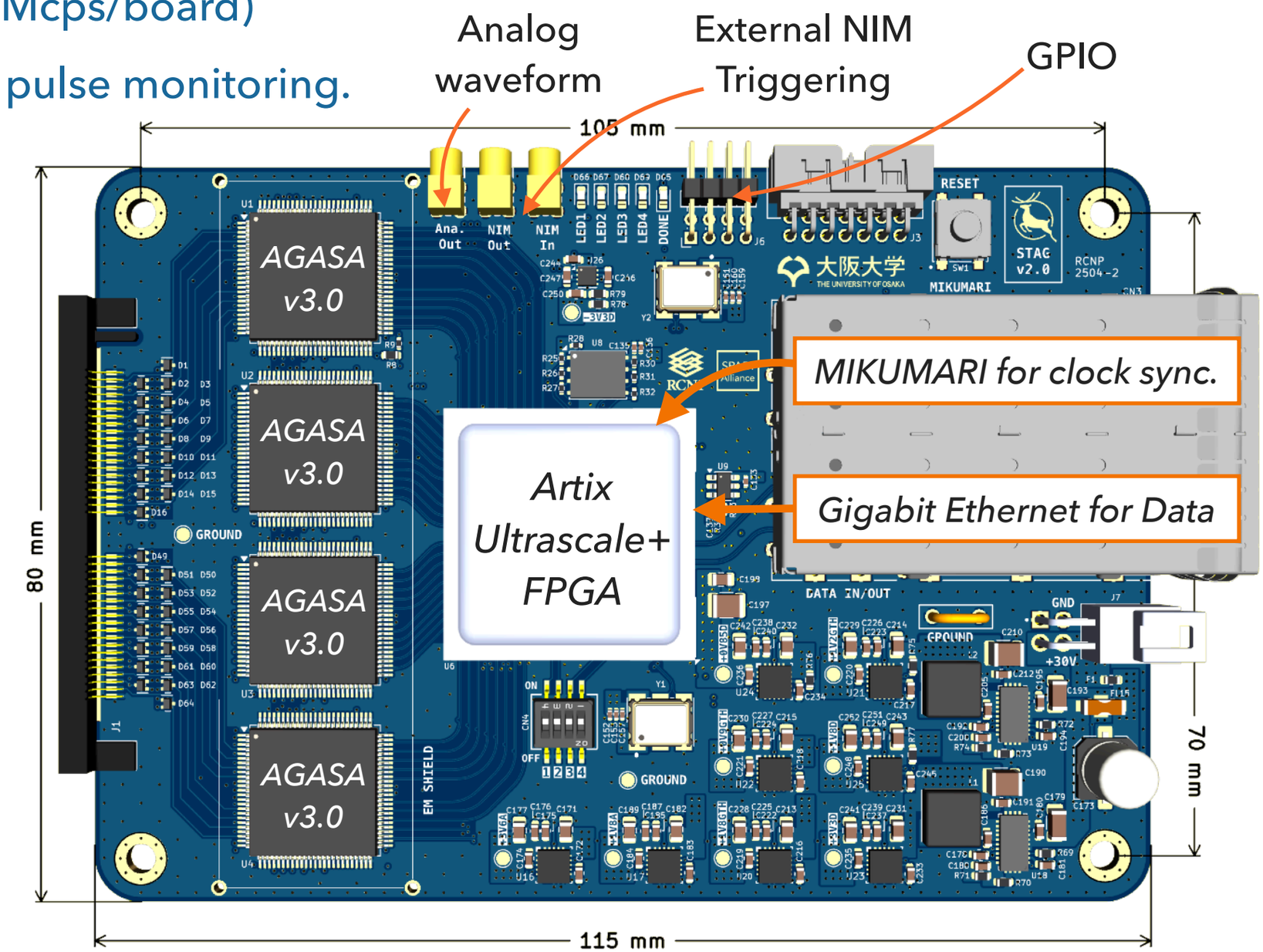


- Mostly linear behavior is seen in the configurable gain.
- ToT linearity is seen for injected charges in our experiment range (between 1~3 pC), as well as at higher injected charges.

The all-in-one STAG Board

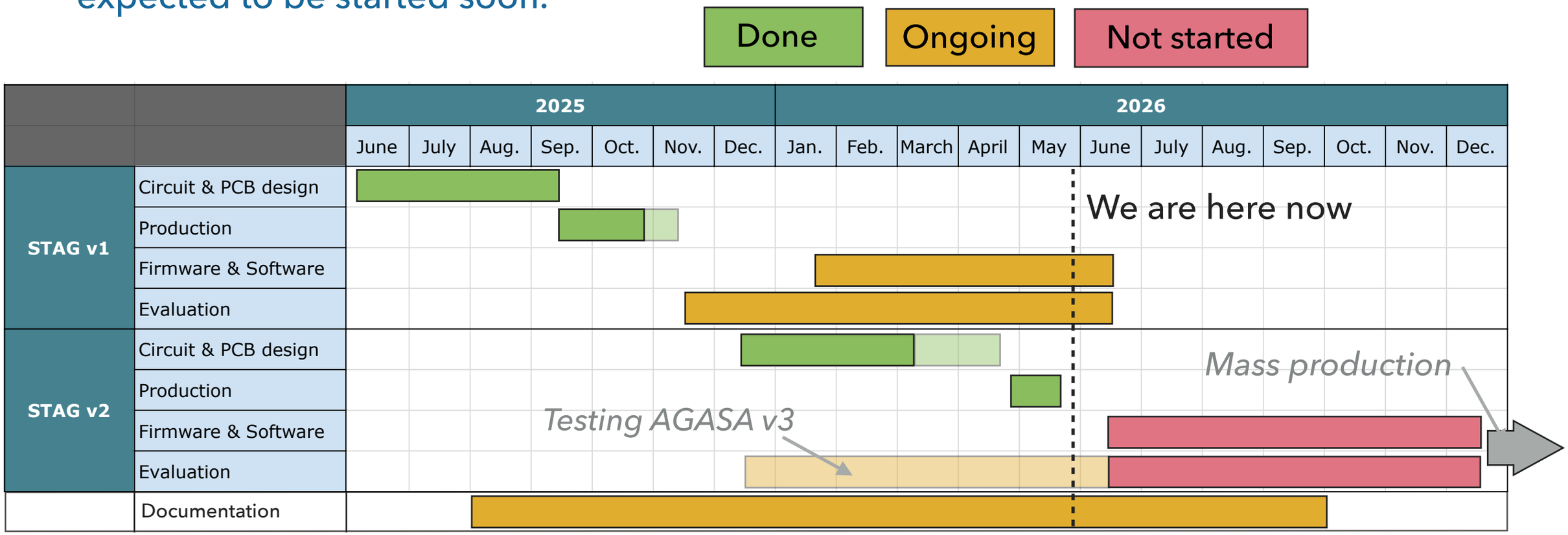
- Other specifications decided by a questionnaire to the nuclear physics community.
  - ***DAQ rates*** ➡ 1 Gbps (~16 Mcps/board)
  - ***Output*** ➡ Mostly ToT, with pulse monitoring.
  - ***Triggering*** ➡ Through MIKUMARI protocol & External NIM signals.
  - ***TDC Resol.*** ➡ 100~300 ps
  - ***Communication*** ➡ SiTCP or Fakernet

N.B : DAQ Rates and TDC resolution is the requirement, and is yet to be validated.



STAG board development timeline

- Several development steps are outlined in the timeline below.
  - STAG v1 board (first prototype) was developed last year, and is under evaluation now.
  - STAG v2 design was started this year, and several prototypes produced. Evaluation is expected to be started soon.



- After R&D in 2026 & 2027, the STAG board and the related streaming DAQ framework is planned to be released in 2027.

Summary & remarks

- We are developing an all-in-one readout boards for different air shower detectors, that are also applicable in many nuclear and HEP experiments.
  - This development is ongoing in collaboration with the SPADI alliance.
- STAG is an all-in-one readout board for gaseous detectors.
  - Combine the ASD and TDC in one board, while being compact and generic.
  - Ability to handle 1 Gbps data rates, 100~300 ps TDC resolution, etc.
- We welcome you to join the SPADI alliance, and related task forces if you're interested!
  - SPADI alliance homepage: https://spadi-alliance.rcnp.osaka-u.ac.jp/en

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K Program
経済安全保障重要技術育成プログラム

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