ALICE FoCal Update
(mainly on FoCal-J activities)

Tatsuya Chujo
Univ. of Tsukuba
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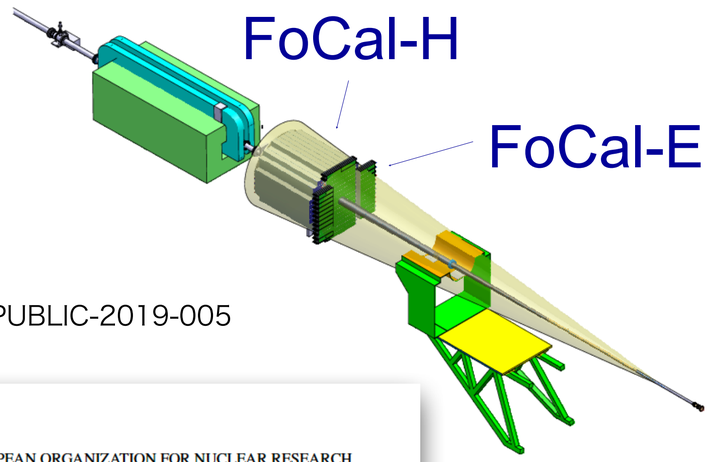
LHC-EIC meeting

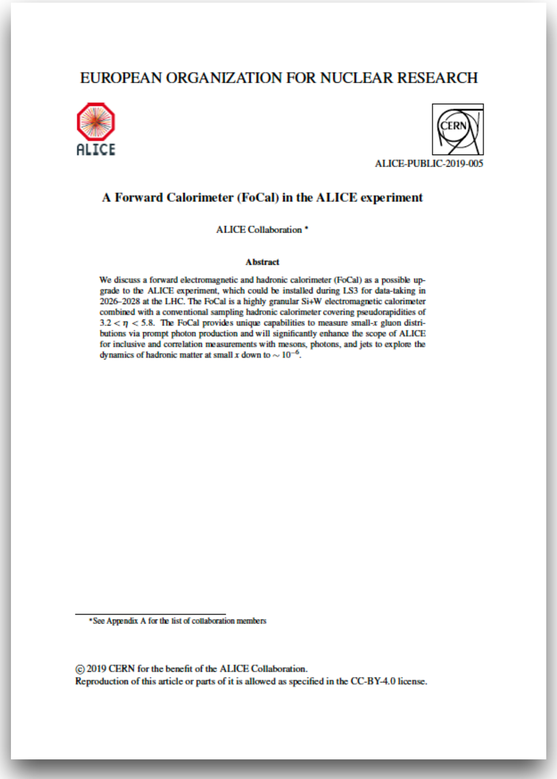
筑波大学
University of Tsukuba

ALICE FoCal status

- ALICE public note (~FoCal LoI) has been submitted to CDS, ALICE-PUBLIC-2019-005, on Nov. 1st, 2019
  - https://cds.cern.ch/record/2696471
  - (update) http://cds.cern.ch/record/2719928
- Discussed the ALICE FoCal at LHCC meeting on Nov. 2019.
- ALICE internal review of FoCal: Jan. 15th, 2020.
- Discussed LHCC meeting on Feb. 2020
- FoCal readout meeting in April 1-3.
- ALICE management approval on April 30.
- Approved by the ALICE collaboration board on May 15.
- **FoCal LoI has been approved by LHCC on June 5, 2020**



ALICE-PUBLIC-2019-005



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE

CERN

ALICE-PUBLIC-2019-005

A Forward Calorimeter (FoCal) in the ALICE experiment

ALICE Collaboration *

Abstract

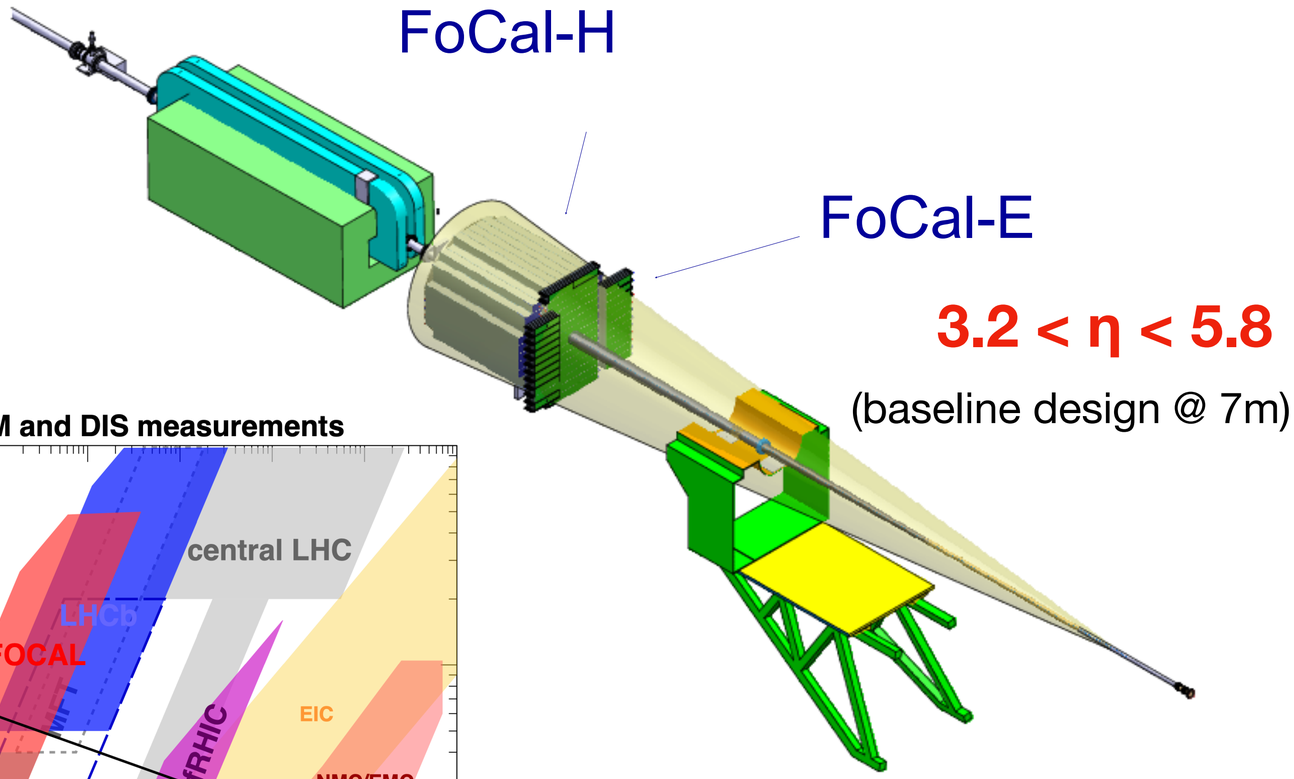
We discuss a forward electromagnetic and hadronic calorimeter (FoCal) as a possible upgrade to the ALICE experiment, which could be installed during LS3 for data-taking in 2026-2028 at the LHC. The FoCal is a highly granular Si+W electromagnetic calorimeter combined with a conventional sampling hadronic calorimeter covering pseudorapidities of $3.2 < \eta < 5.8$. The FoCal provides unique capabilities to measure small-x gluon distributions via prompt photon production and will significantly enhance the scope of ALICE for inclusive and correlation measurements with mesons, photons, and jets to explore the dynamics of hadronic matter at small x down to $\sim 10^{-6}$.

*See Appendix A for the list of collaboration members

ALICE FoCal upgrade for LHC-Run4 (2027-)

FoCal-E (PAD & PIXEL): high-granularity Si-W sampling calorimeter for photons and π^0

FoCal-H: conventional Cu-Sc sampling calorimeter for photon isolation and jets

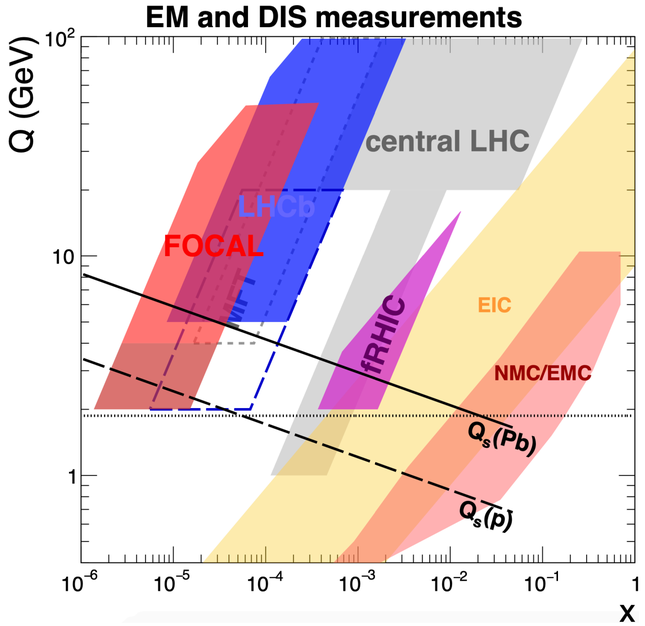


$3.2 < \eta < 5.8$

(baseline design @ 7m)

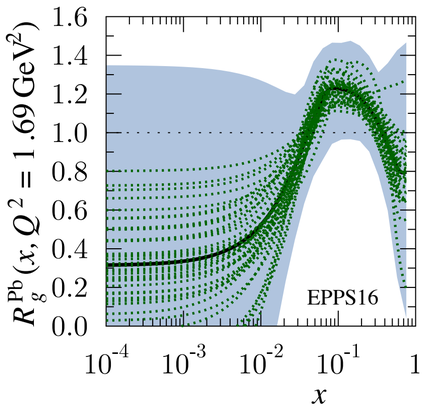
Observables:

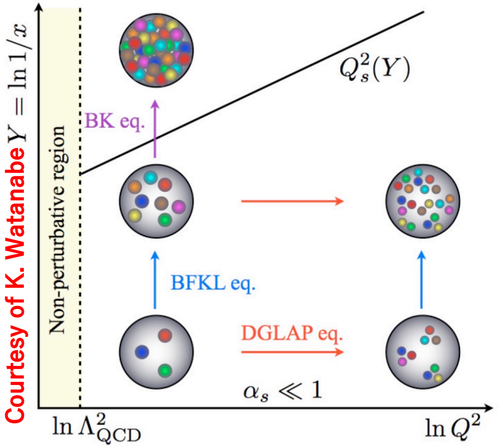
- π^0 (and other neutral mesons)
- Isolated photons
- Jets (and di-jets)
- J/ψ (Υ) in UPC
- W, Z maybe possible
- Event plane and centrality

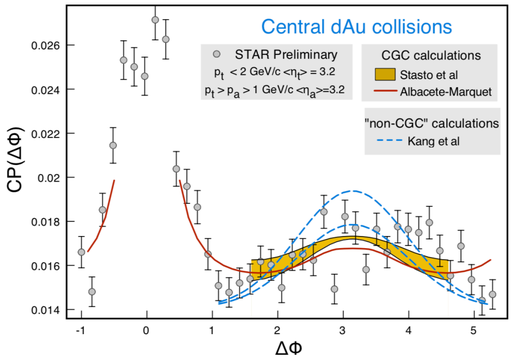


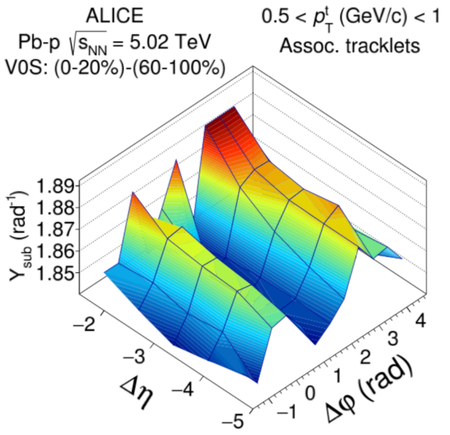
Physics goals

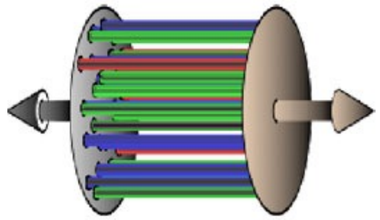
- **Quantify nuclear modification of the gluon density at small-x**
  - Isolated photons in pp and pPb collisions
- **Explore non-linear QCD evolution**
  - Azimuthal π^0-π^0 and isolated photon-π^0 (or jet) correlations in pp and pPb collisions
- **Investigate the origin of long range flow-like correlations**
  - Azimuthal π^0-h correlations using FoCal and central ALICE (and muon arm?) in pp and pPb collisions
- **Explore jet quenching at forward rapidity**
  - Measure high p_T neutral pion production in PbPb

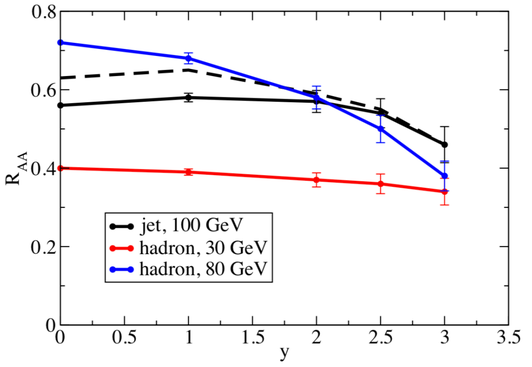












Key questions

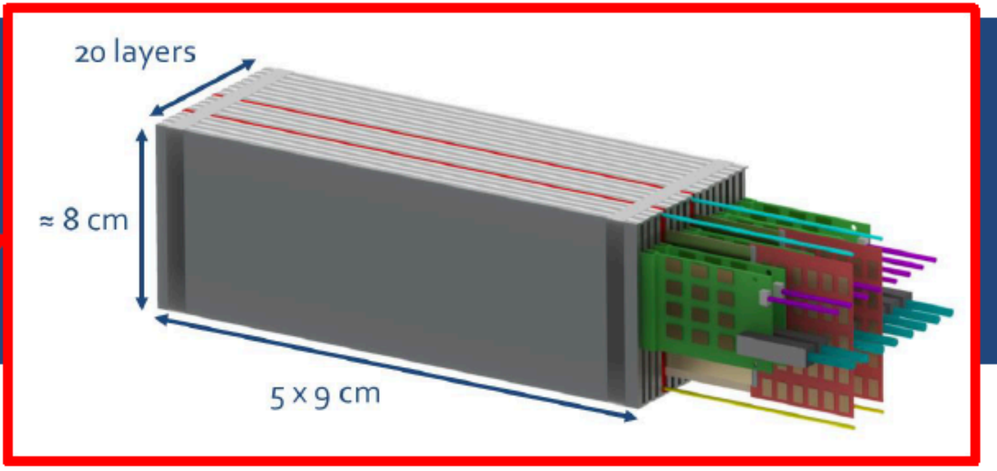
* How QGP is created in heavy ion collisions and how thermalized?
* Is there any difference between QGP in the early universe and QGP produced in heavy ion collisions?

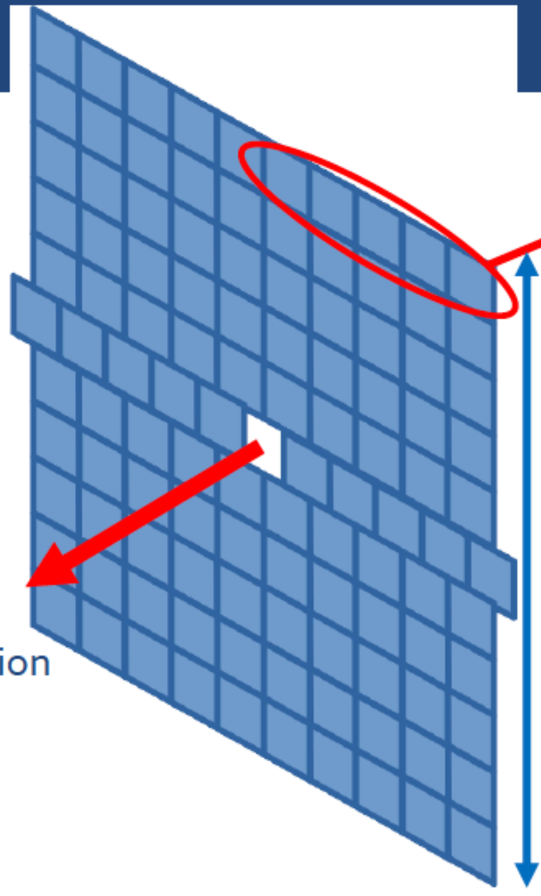
Main Institutes

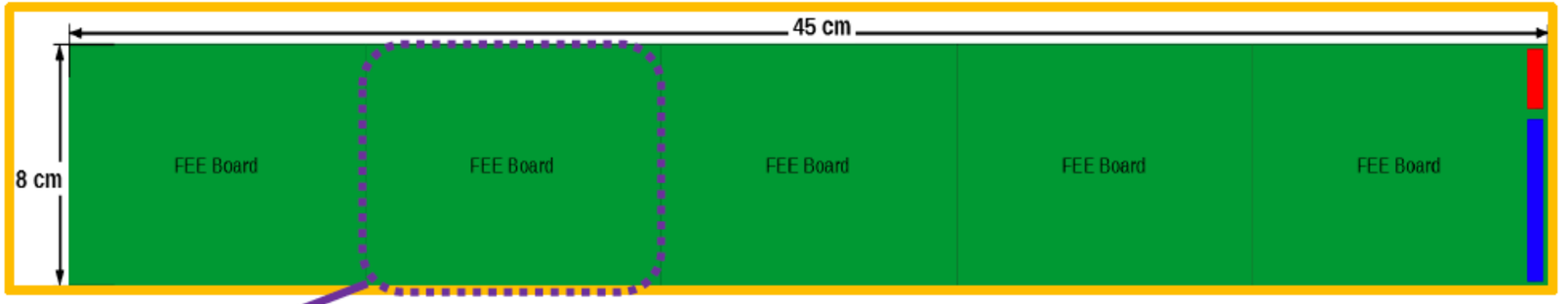
- FoCal-E PAD: Tsukuba, Tsukuba Tech, Nara W., Hiroshima, RIKEN*
- FoCal-E PAD readout: Grenoble LPSC
- FoCal-E PIXEL: Bergen, Utrecht/Nikhef, (ORNL)
- FoCal-H: Copenhagen
- Integration: ORNL

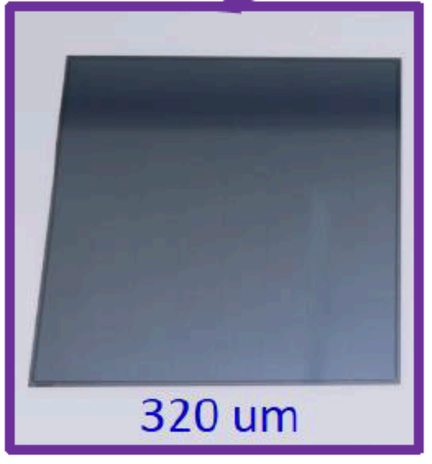
* Joined FoCal collaboration on May, 2020

FEW DEFINITIONS









Module:

Composed of 18 **pad-layers** + 2 MAPS layer

Pad layers:

Composed of 5 **pads sensors** + associated FEE-PCB

1 FEE-PCB linked to readout PCB (Aggregator board)

Si-pad:

Built up from silicon pad sensors with a granularity of 1 x 1 cm^2

Sensitive area of 9 x 8 cm^2 for each sensor: total of **72 pixels**

Plan in 2020-2021 in Japan/France

- Finalizing the final design of FoCal, towards TDR, to be submitted to 2021.
- New mask will be made, and produced new silicon sensor (p-type) and tested in 2021 at lab and test beams (ELPH and CERN/FNAL(?)).
- Readout: HGCROC from Omega group, CMS HGCAL, via Grenoble LPSC.
- In parallel, we will perform the following tests.

  (1) p-type silicon test (monitor PD from Hamamatsu)

  (2) Readout test of SkiROC and HGCROC evaluation board

  (3) Measurement with laser system (dynamic rage and position scan)

  (4) Radiation hardness tested in Japan.

Today's focus

1. New silicon PAD sensor design

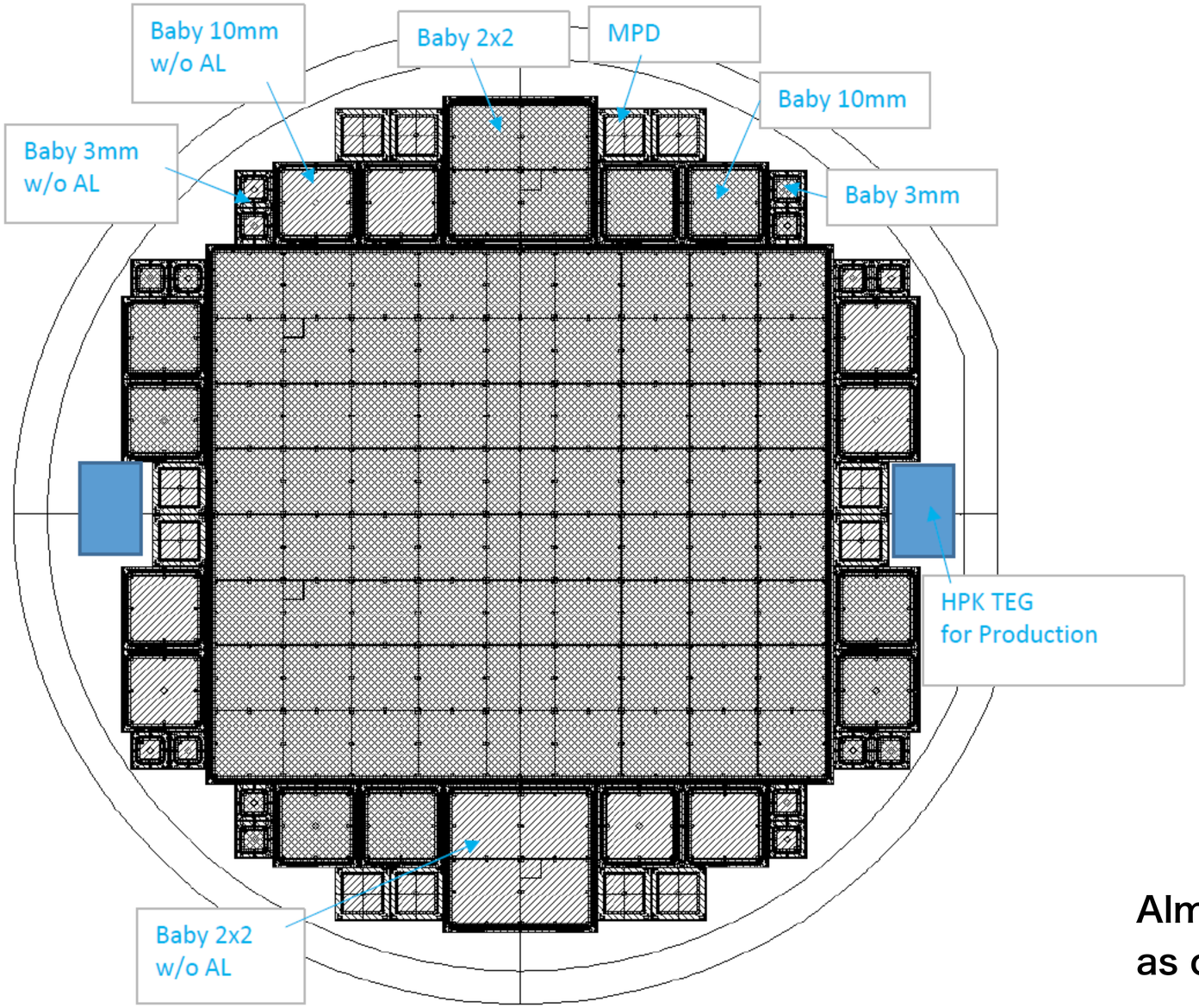
2. New readout HGCROC (and SkiROC CMS)

3. ELPH test beam proposal (Feb. in 2021)

4. Irradiation test at RIKEN neutron source?

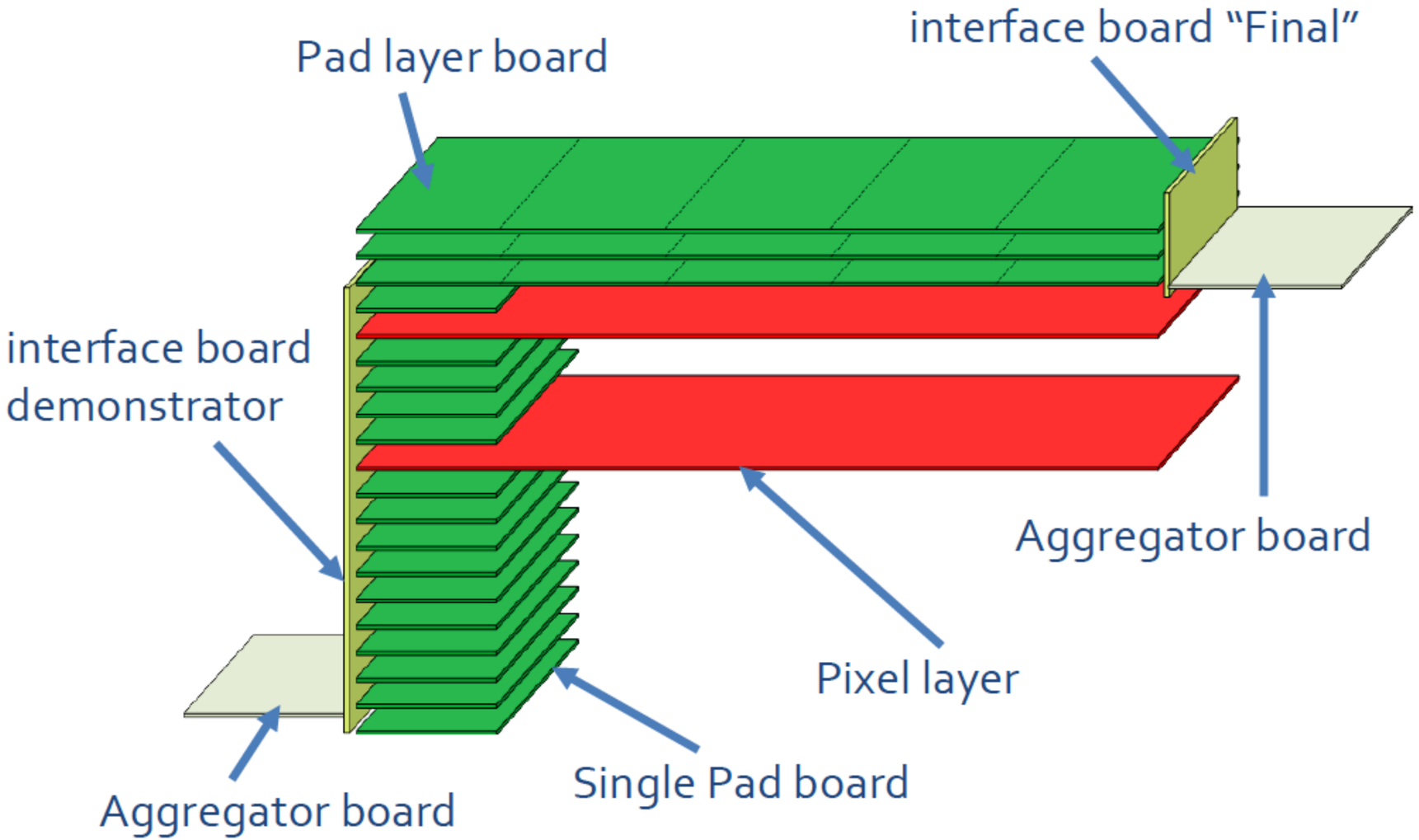
5. KEK silicon platform

1. New silicon pad sensor for final FoCal



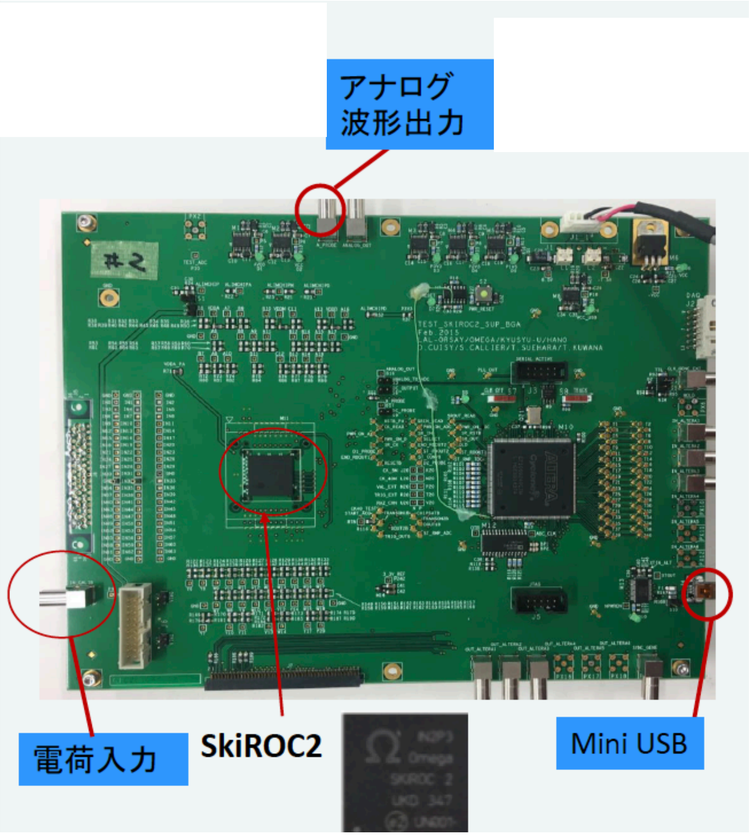
Almost final version
as of Aug. 19, 2020

Prototyping in 2020-2021

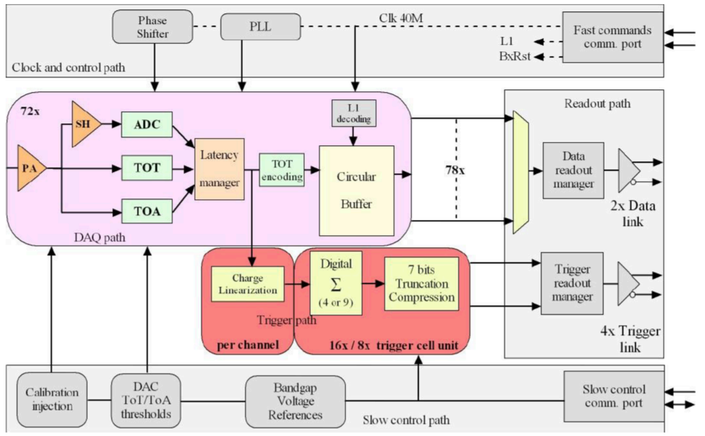


2. Readout chip: HGCROC (SkiROC-CMS)

- In 2019-2020, we started to use SkiROC (for CALICE, ILC-ECAL), with help by Kyushu U. group (T. Suehara)
- Right now, we are using SkiROC2-CMS (w/ TOT, time-over-threshold) from Kyushu G.
- **[Plan]** test pulse injection to SkiROC, monitor PD readout, beta source test, and laser test, check the linearity in TOT etc.
- At Grenoble, there is a HGCROC(ver.2) evaluation board.
- **[Plan]** shipping this HGCROC(ver.2) evaluation board to Japan, and tested with silicon sensor, in Oct/Nov?

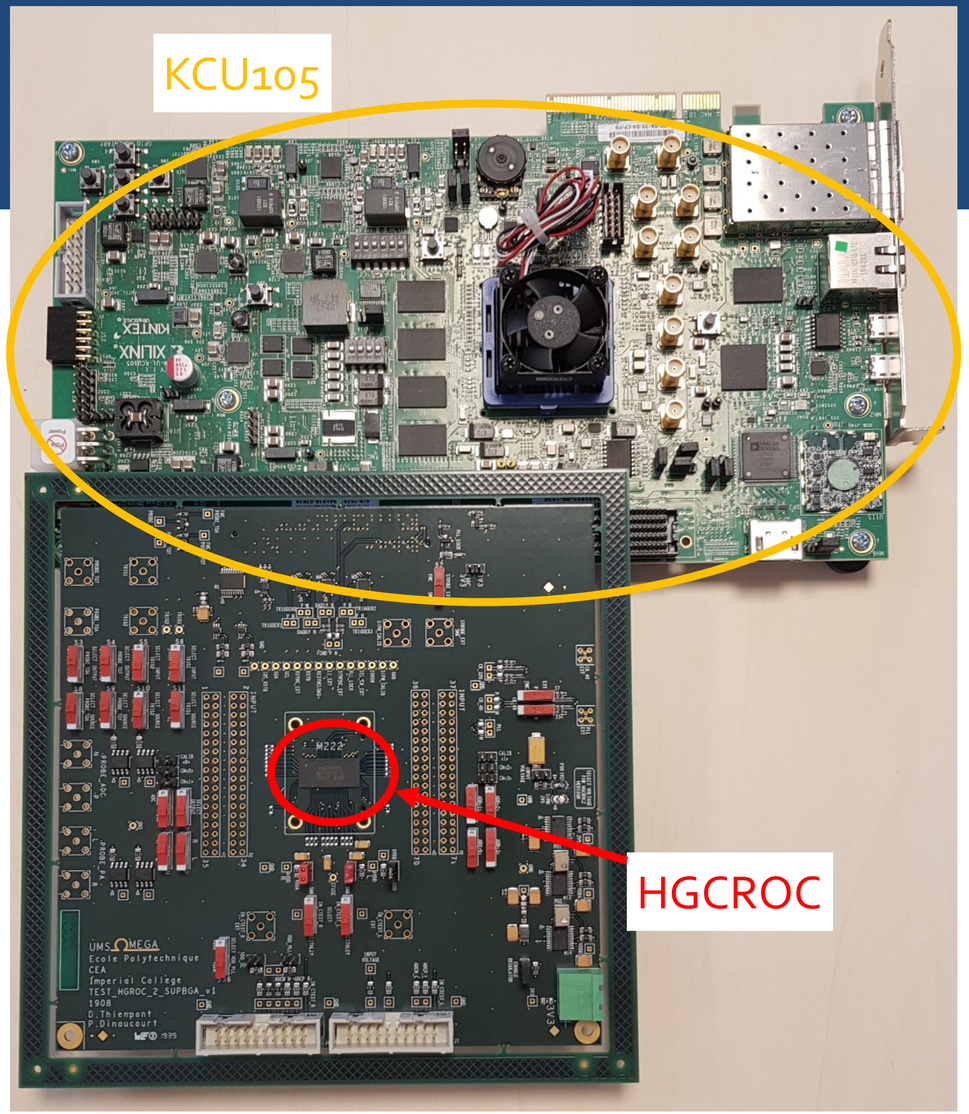


SkiROC2a board from Kyushu U.



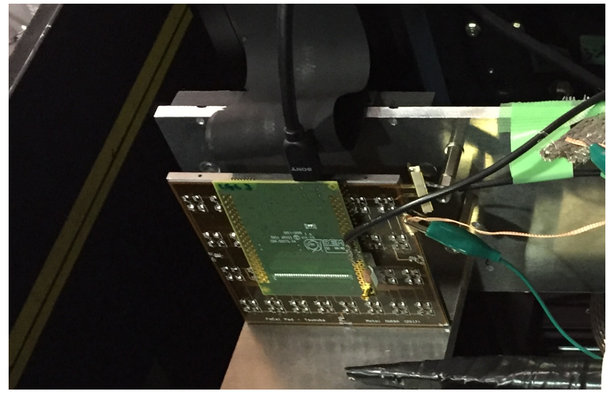
WORK IN PROGRESS

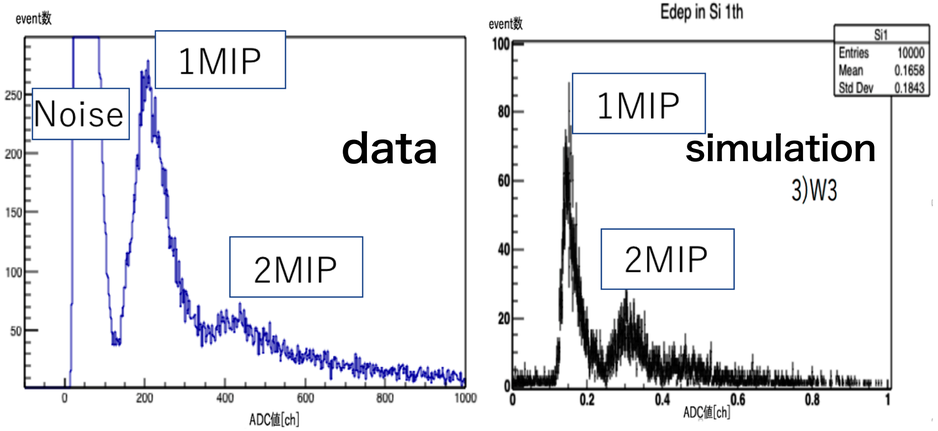
- HGCROC received from OMEGA group
- KCU105: Xilinx Dev. Kit already used in lab.
  - **Phase 1:** understand both Firmware and software
    - Work in progress to get used to operate the HGCROC chip
  - **Phase 2:** design a FEE board of pad-layers + an Aggregator board



3. ELPH test beam

- By Dec. 2020, the new silicon PAD sensor (p-bulk, 8x9, 320 um) from Hamamatsu will be deliverd.
- ELPH beam test is planed in Feb. 2021, beam line will be shared with Suehara-san's team.
- Measure MIP response on each PAD (8x9 + 2 calibration cells)
- EM shower by putting material in front position dependence
- Read-out test, ideally use HGCROC with new silicon PAD sensor (8x9).





ELPH test beam experiment in 2017, Dec.

4. Irradiation test using monitor PD

- We would like to test the radian tolerance for both n-type and p-type.
- Monitor PD will be used.
- Seeking possibility to use RIKEN Accelerator-driven compact Neutron Sources (RANS), with support by Nakagawa-san, Goto-san and Taketani-san.
- Need to perform PHITS simulation and monitor of neutron dose before we propose the irradiation test.

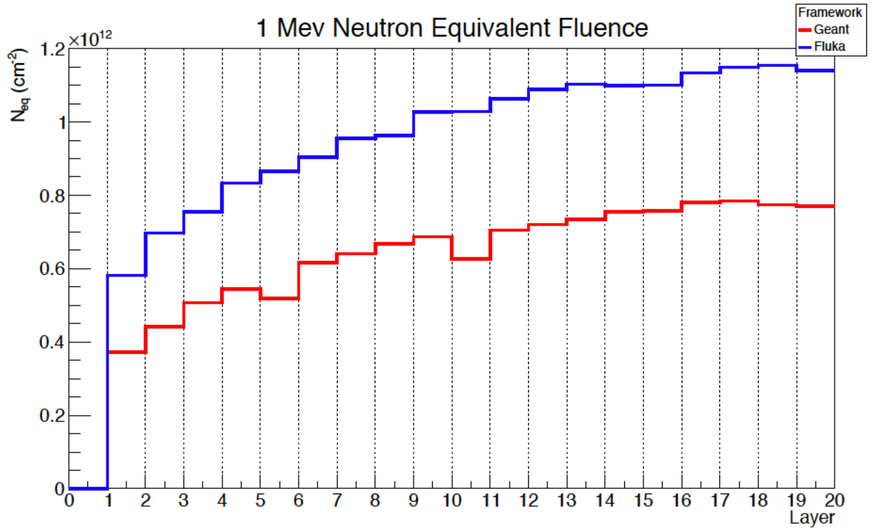
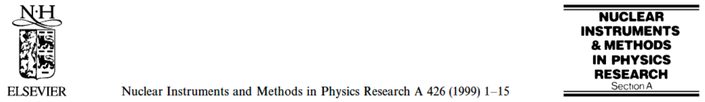


Figure 12: NIEL weighted 1 MeV Neutron equivalent fluence for an integrated luminosity of 10 nb^{-1} Pb-Pb + 50 nb^{-1} p-Pb + 6 pb^{-1} pp for each layer in FoCAL.



Radiation hardness of silicon detectors – a challenge from high-energy physics

G. Lindström*, M. Moll, E. Fretwurst

II. Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany

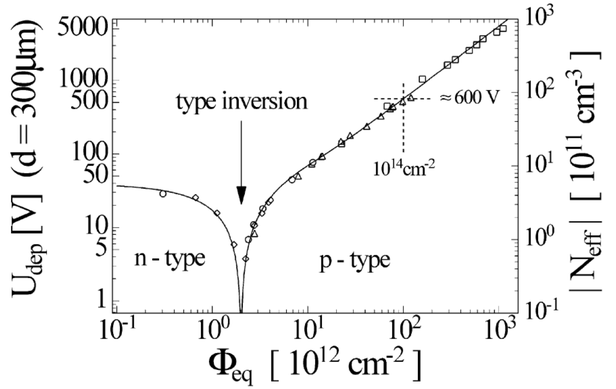


Fig. 4. Change in the bulk material as measured immediately after irradiation [20].

5. KEK silicon platform

- In 2019-2020, we presented FoCal activities in Japan and R&D, production plan using KEK silicon platform.

- During the review and at LHCC approval, utilizing KEK Silicon Platform for ALICE FoCal has been received as a strong point in the FoCal project by reviewers.

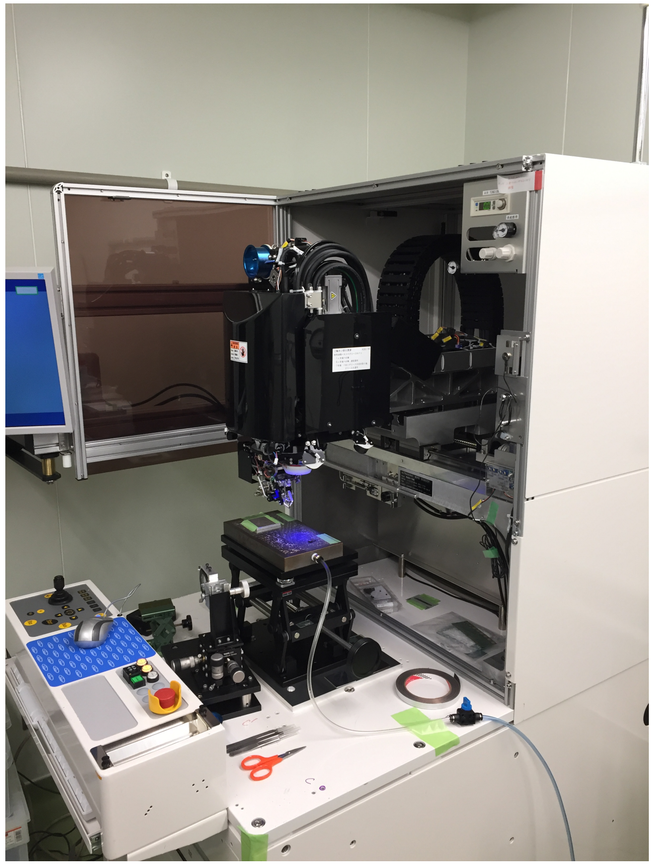
- Due to the COVID-19, progress is slow now, but we would like to resume the discussion and some work, e.g. p-type silicon characteristics (IV, CV), mechanical design, assembly procedure, gluing etc.

モジュールR&D, 製作: KEK シリコンプラットホーム

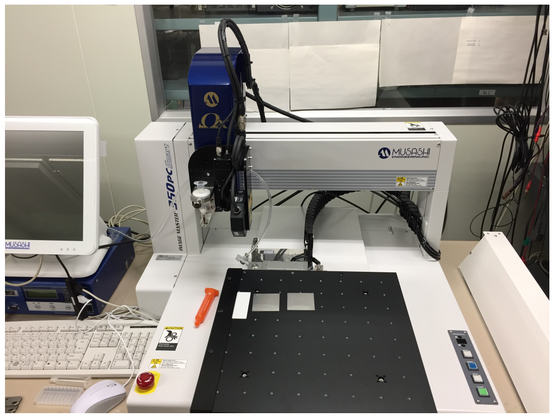
Silicon detector platform at KEK: BELLE, ATLAS Itk, J-PARC g-2 experiments

・筑波大と KEK との地の利を活用

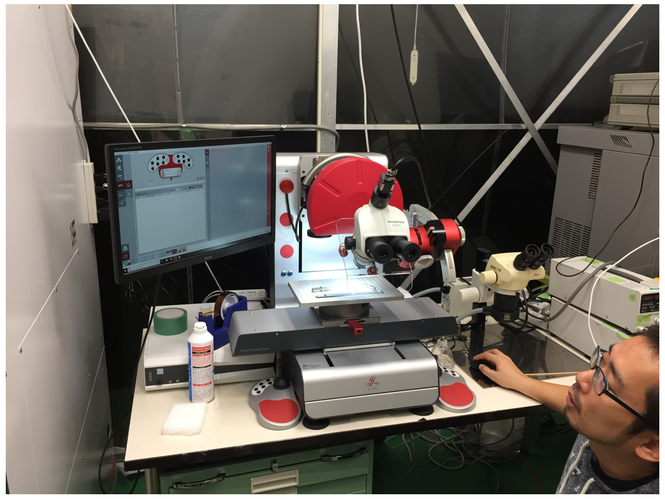
・R&D でプラットホームの活用合意済、プロダクションに関しても議論を続けることで合意



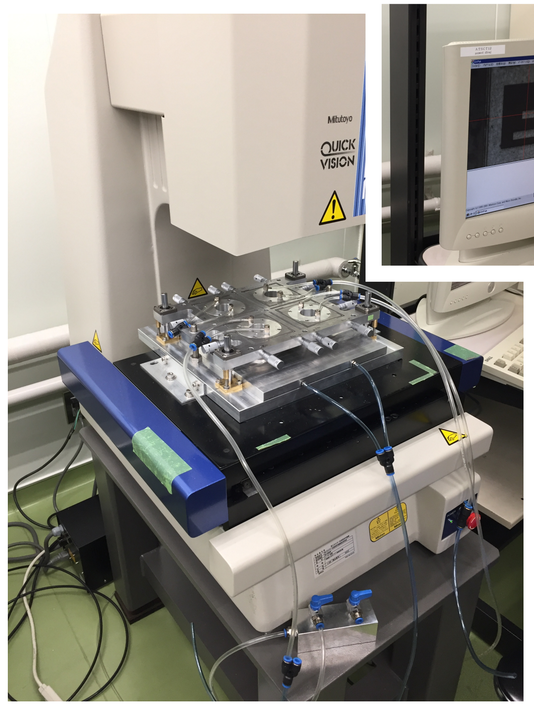
Automatic wire bonder (Belle-2, g-2)



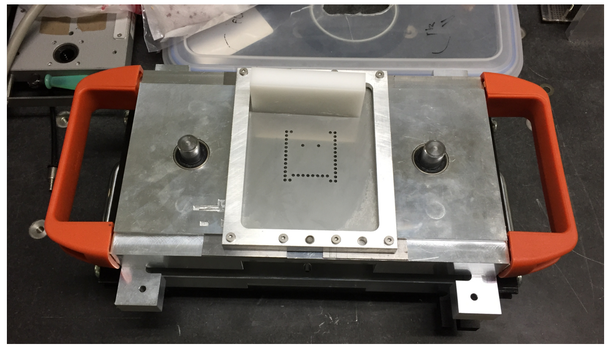
Automatic dispenser (ATLAS)



Wire pull test (ATLAS)



3D measurement (Belle-2, g-2)



Stencil jig for glue (ATLAS)

Backup