

Production of ATLAS ITk - Japan contributions -

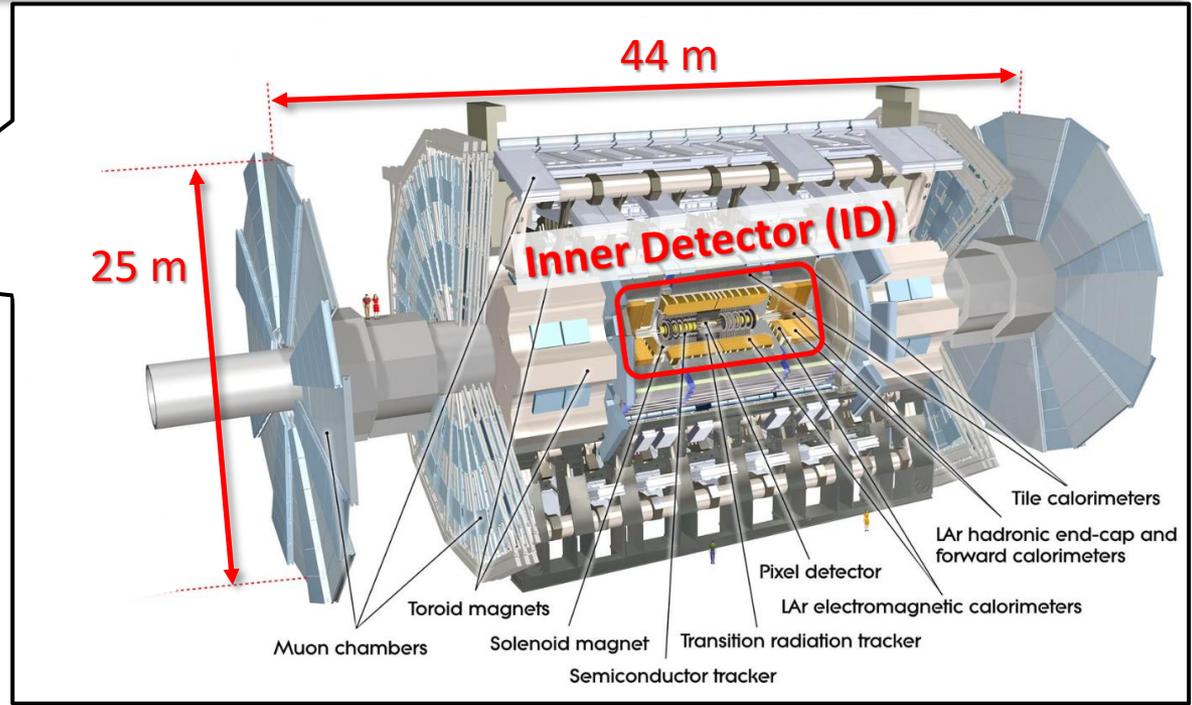
29 March 2021, TCHoU Workshop
Shigeki Hirose (U. Tsukuba)

■ ATLAS experiment at LHC



Large Hadron Collider (LHC)

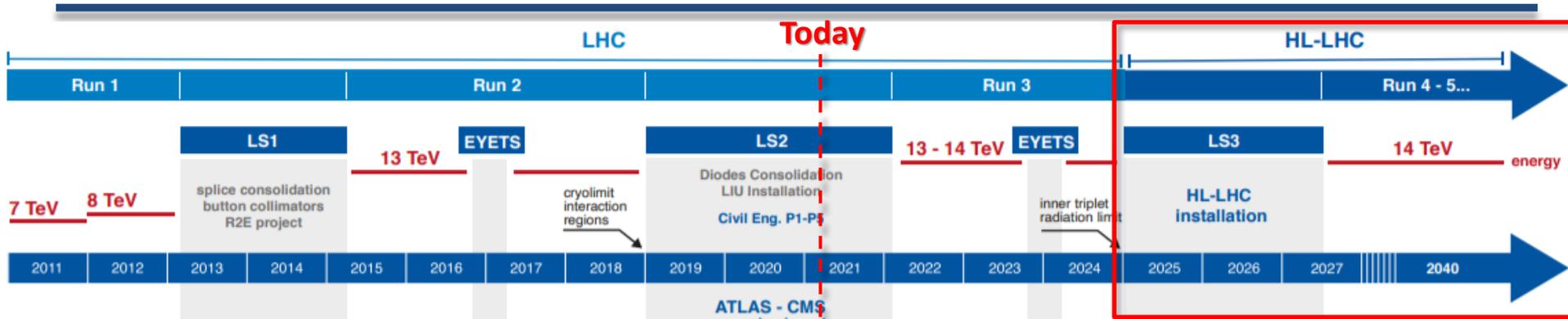
- Circumference = 27 km
- pp collision at $\sqrt{s} = 13$ TeV
- Bunch per 25 ns



• ATLAS detector

- Targets high- p_T objects from decays of heavy particles
- Severe environment of pp collisions due to QCD
- Track finding performance of ID is essential for any physics analyses

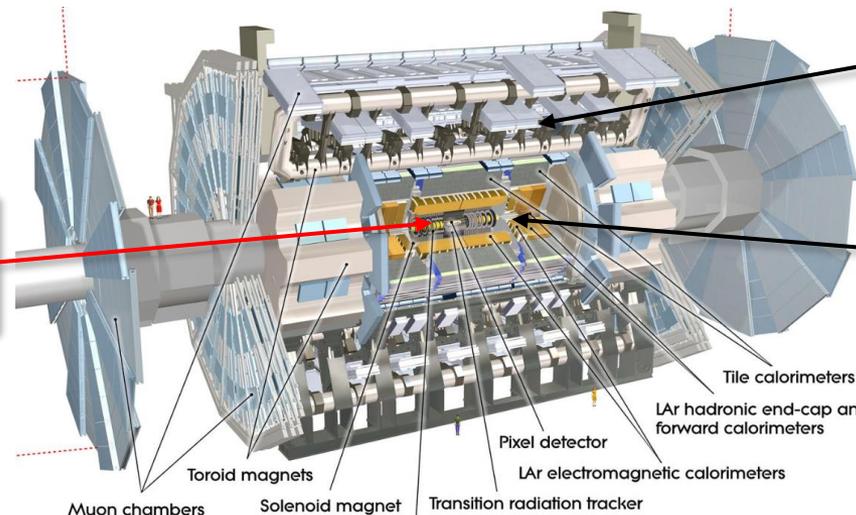
Upgrades for HL-LHC



- High-luminosity LHC from 2027 to 2038
 - Collect $\times 10$ more data with $\times 3$ higher instantaneous luminosity
 - Diverse physics opportunities; Higgs self coupling, SM precision tests, new heavy particle searches such as SUSY, LQ, ...

Our contributions

All-silicon inner tracker
(pixel + strip)

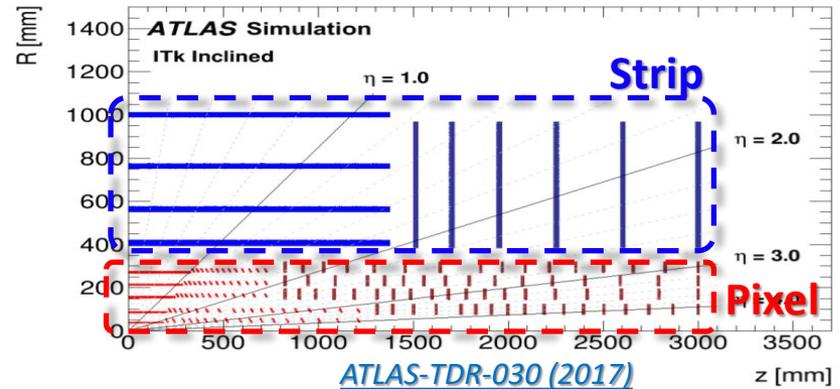
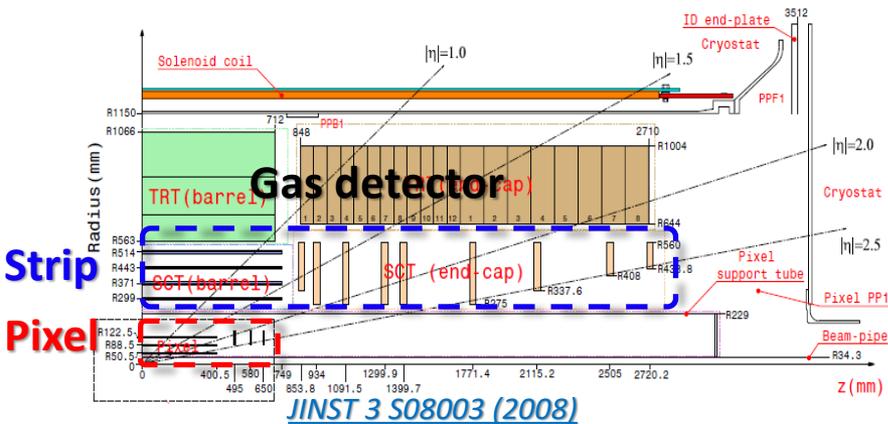


New muon chambers in the inner barrel region

High Granularity Timing Detector with LGAD
($\sigma_t \sim 50$ ps)

Better performance trigger DAQ & electronics systems

ATLAS Inner Tracker (ITk)

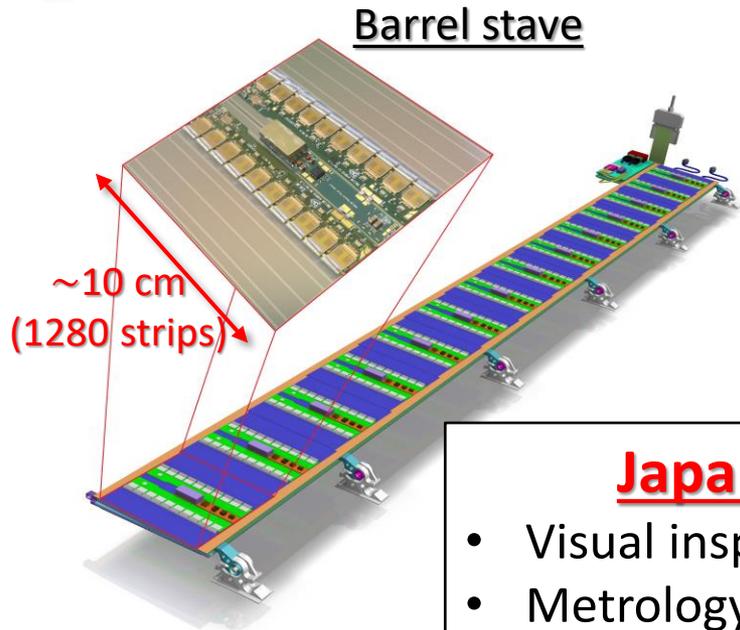


- The ID needs to be replaced before HL-LHC
 - Tolerance to higher particle density and radiation fluences

	Current ID	ITk
Sensor type	n^+ -in-n (pixel) p^+ -in-n (strip)	n^+ -in-p
Coverage	$ \eta < 2.5$	$ \eta < 4.0$
Thickness (innermost)	200 μm	100 μm
Pixel size (innermost)	50 \times 250 μm^2	25 \times 100 μm^2
Surface	$\sim 60 \text{ m}^2$	$\sim 180 \text{ m}^2$
# of channels	86M	5060M

- Very challenging upgrade project! **Collab. with 65 institutes**
 - Stable production & solid QC/QA procedures are essential

Strip sensor QC/QA



Barrel stave

- 20,800 sensors are going to be produced since July 2021
 - Sensor QC/QA is important!
- QC: inspection for all main sensors
 - Shared with Canada, UK, US and **Japan**

Japan

- Visual inspection
 - Metrology
 - Strip test
- All done at HPK

US (Santa Cruz)

- Thickness
- IV stability

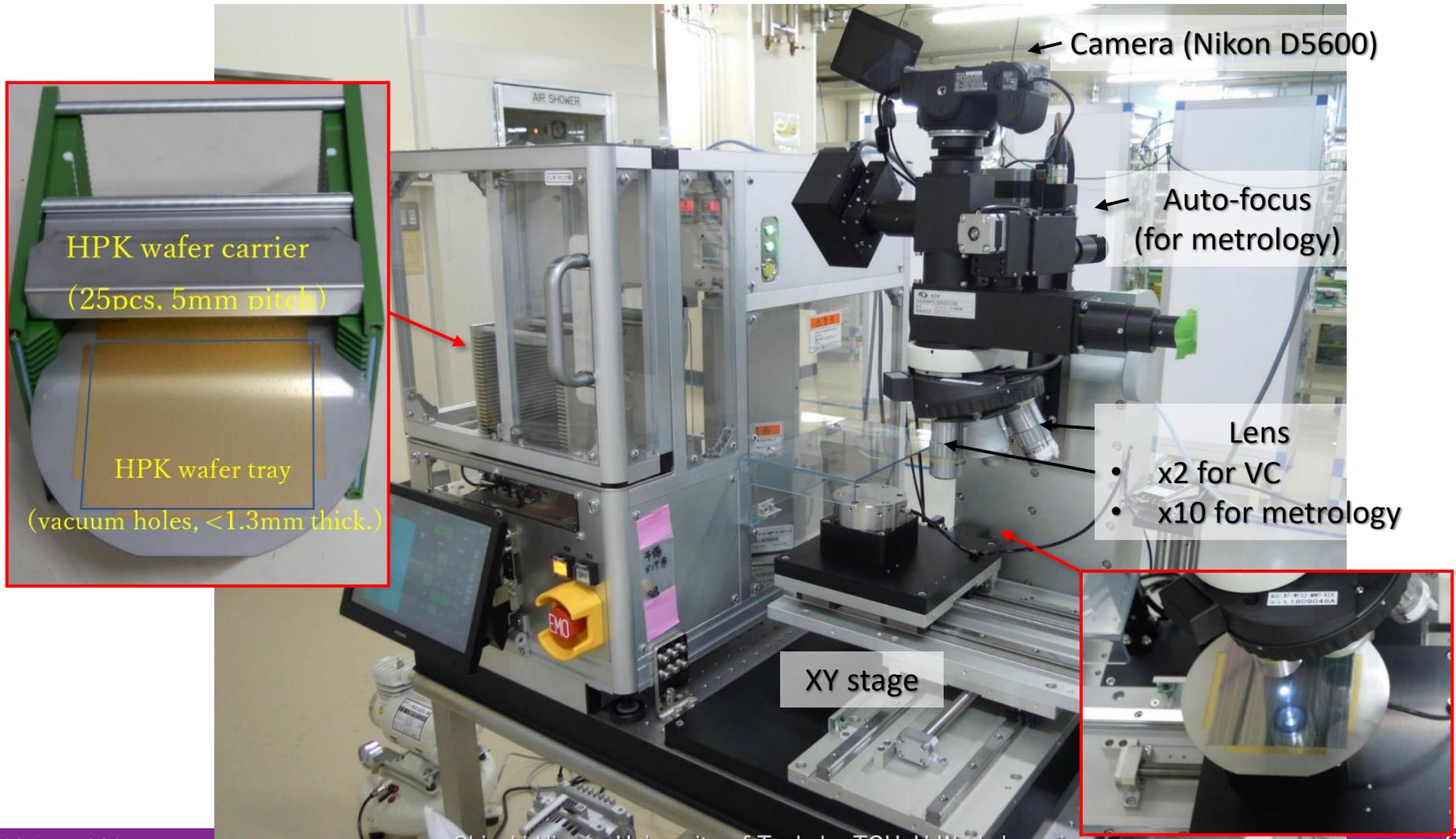
* In charge of 6,000 sensors

Module production sites

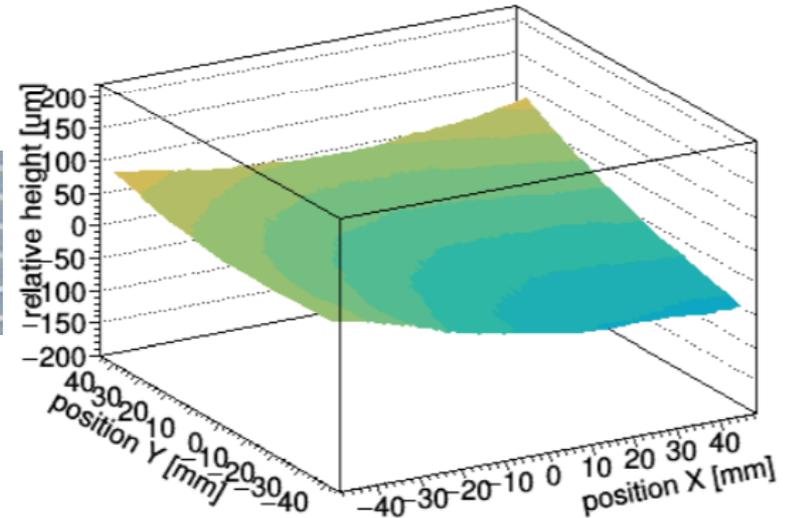
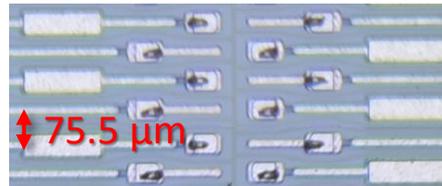
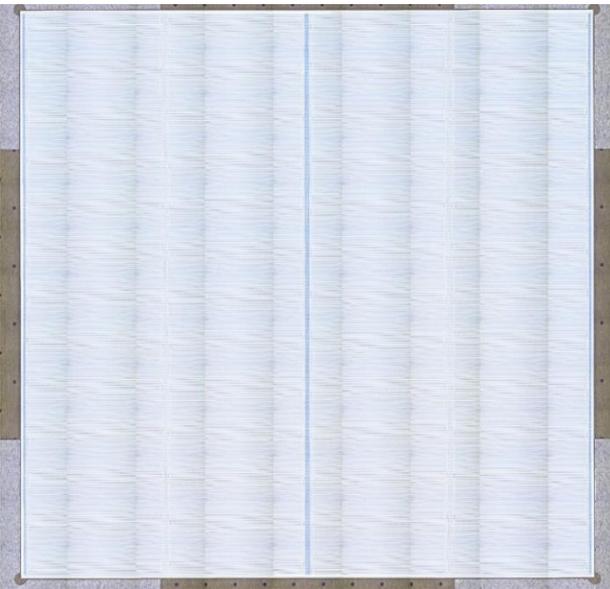
- QA: performance monitoring after irradiation
 - Irradiate protons (**Japan** & UK), neutrons (Slovenia) or gammas (Czechia)
- 70 MeV proton beam at CYRIC, Tohoku U
- Dedicated “QA pieces” are sampled for every ~40 sensors

■ QC machine at HPK

- We established an automated QC machine at HPK
 - Used for VI and metrology (strip tests are done with HPK's equipment)

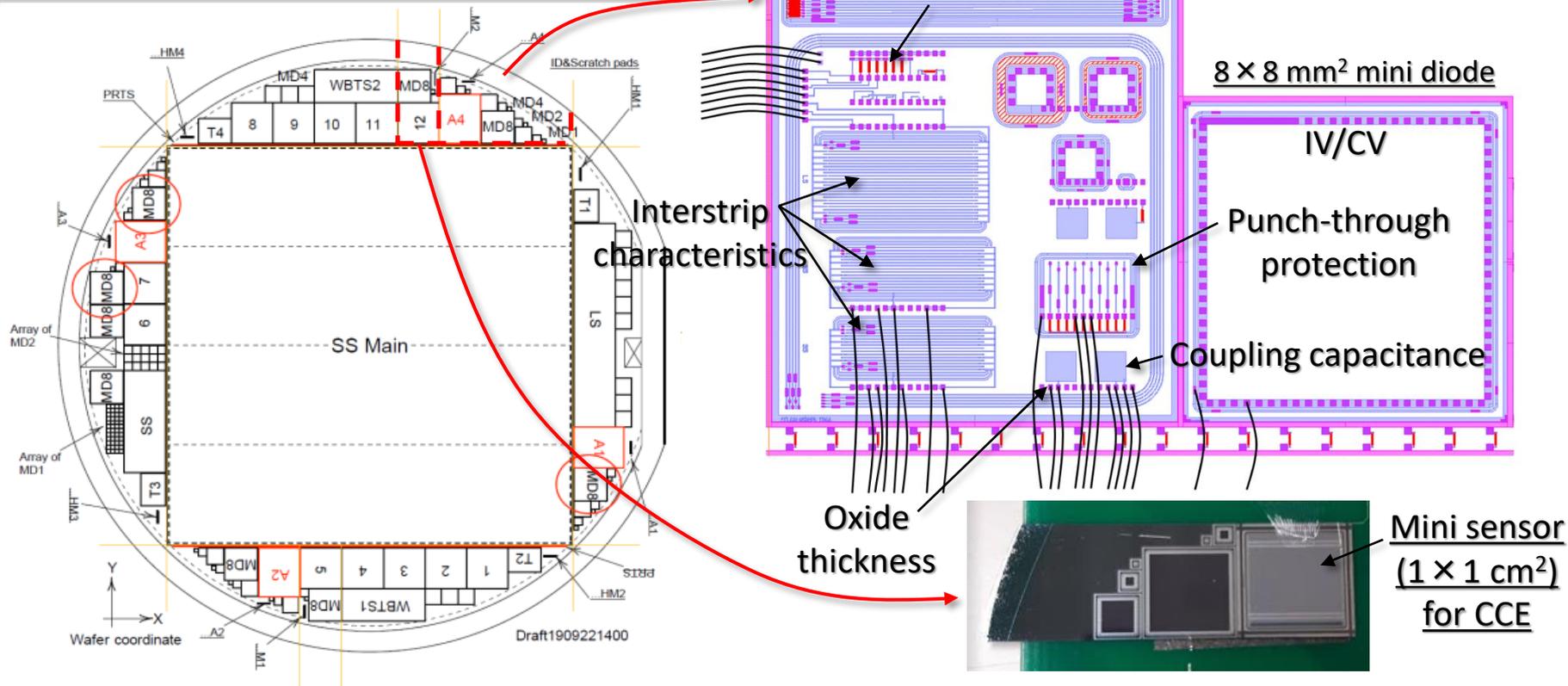


Results from pre-production



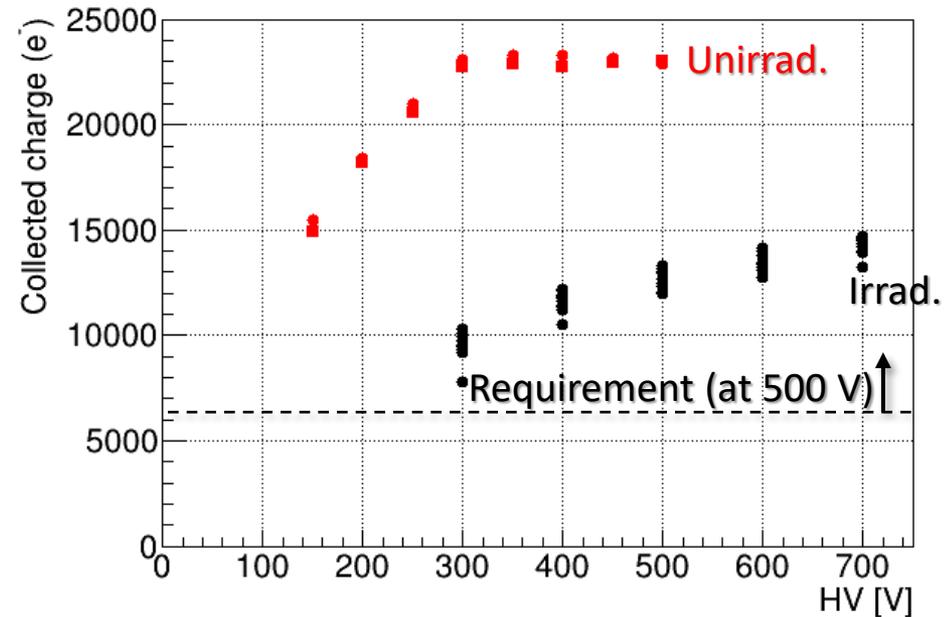
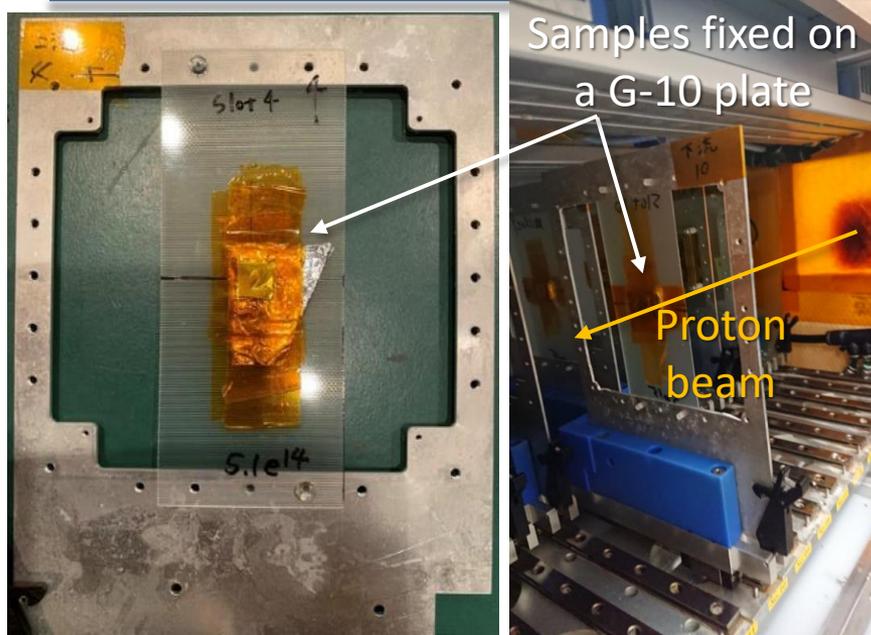
- Sensor photo for visual inspection
 - Possible to catch images of very fine objects (like strip defects)
- Metrology
 - Bowing is at most $\sim 100 \mu\text{m}$ (requirement = $200 \mu\text{m}$)
- QC flows were tested during sensor pre-production
 - 318 wafers were inspected for just three days!

■ Sensor QA



- Inspection for basic silicon properties using QA pieces
 - Test chip: various structures dedicated to every measurement
 - Mini diode: for IV/CV characteristics with the simple structure
 - Mini sensor: $1 \times 1 \text{ cm}^2$ strip sensor for charge collection efficiency
- Irrad. up to $1.6 \times 10^{15} \text{ n}_{\text{eq}}/\text{cm}^2 \leftarrow 1.5 \times [\text{total fluence at HL-LHC}]$

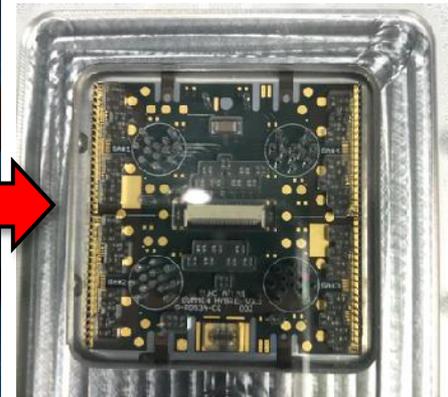
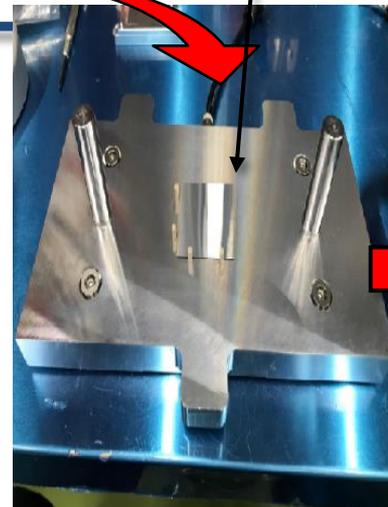
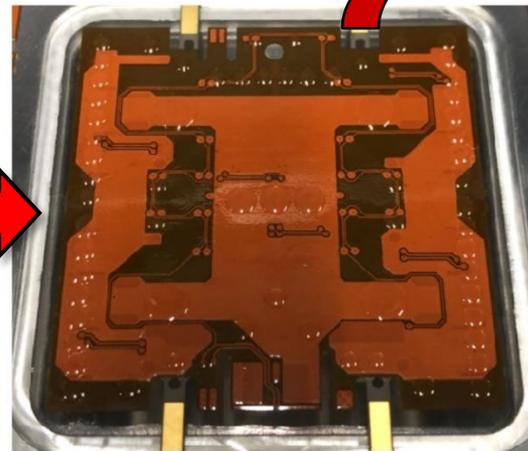
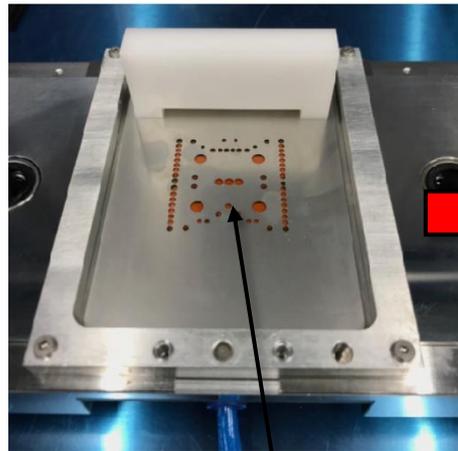
Irradiation tests



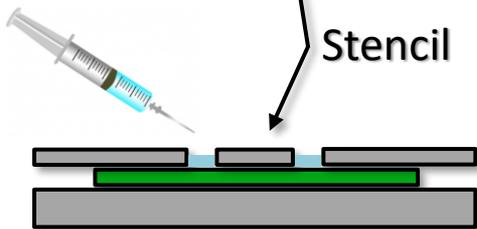
- ~40 samples were irradiated at CYRIC in 2020
- Measurement system established at KEK  [K. Saito, JPS Spring 2021 \[13aT3-02\]](#)
 - Systematic measurements can be performed for test chip (4 h/sample) and mini sensors (1.5 h/sample)
- Overall good performance was confirmed  [T. Ishii, JPS Spring 2021 \[13aT3-03\]](#)
 - Issues observed during the pre-production QA were fed-back to the production as well as improvements on the measurement method

Module production

Sensor + ASIC [D. Kobayashi, JPS Fall 2020 \[14pSF-06\]](#)

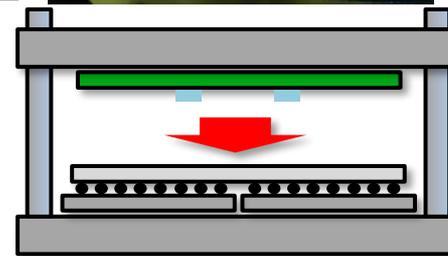


Module assembled!
(after wire-bonding...)



Stencil

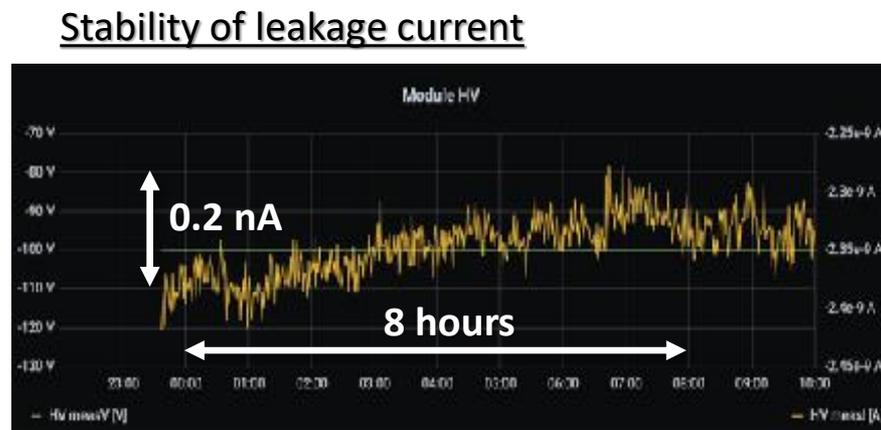
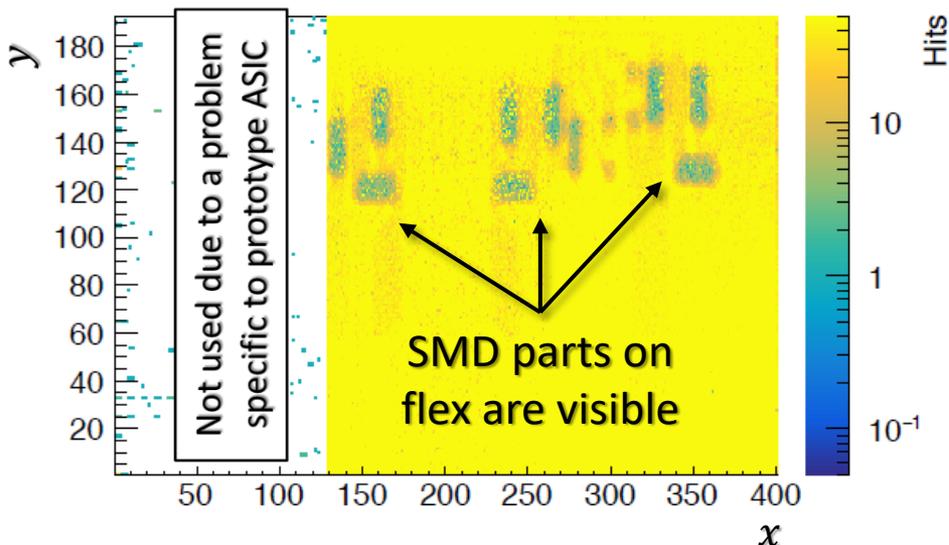
Well controlled amount of glue



- Assembly is now being done at a clean room of KEK
- Procedure has been well developed over years
 - Realised the position precision of $\pm 50 \mu\text{m}$ and bowing within $\pm 25 \mu\text{m}$
 - Japan is the first qualified group as the module assembly site!
- About 10 modules have been already assembled with prototype sensors + ASICs

Readout test

S. Fujii, JPS Spring 2021 [12pT3-13]



- Readout test with X-rays
 - A dedicated X-ray irradiation system has been installed
 - Stopped by materials but at least ~ 10 hits/pixel can be expected in 5 mins.
- Burn-in: stability test for 8 hours is required
 - Established the method at -10°C \rightarrow To be -15°C

■ Summary

- ITk is a key for successful physics at HL-LHC ATLAS
 - Huge all-silicon tracker with 180 m²
- Japan group is strongly contributing to the project
 - Strip: playing a key role in the sensor QC/QA; ready to enter the production phase from July (for 3.8 years)
 - Pixel: responsible for the entire production flow; pre-production will start this year
 - Also planning to (re-)ramp up activities at CERN for preparation of module installation
 - U. Tsukuba is one of the key players (5 students + 2 staffs)
- The entire ITk will be ready by the middle of 2026
 - Be prepared for start of the HL-LHC operation in 2027!