



LAL



KEK



Tsukuba HEP



## 2020 Joint workshop of FKPPPL and TYL/FJPPL

### Continuation of the project [D RD 20]: New challenge for Inner Pixel Tracker construction

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# Framework : ATLAS Upgrade for HL-LHC

## • High Luminosity LHC (HL-LHC)

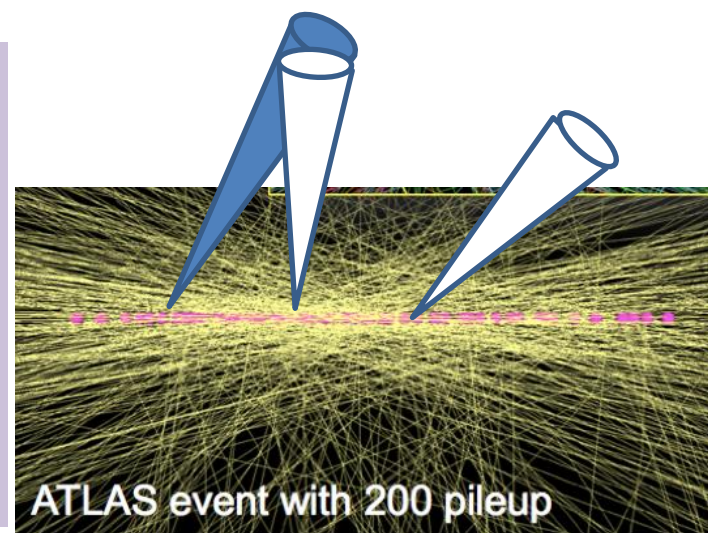
- Start around 2026- with new crab cavity in the interaction region.
- Target :  $\sqrt{s}=14\text{TeV}$   $L=5-7 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$   $\int Ldt=3000-4000\text{fb}^{-1}$
- Physics program focus on the precise measurements of the Higgs couplings (e.g.  $Y_{\tau}$ ,  $Y_b$  and  $\lambda_{HHH}$ ) and BSM searches.

## • Tracking detector is key element

- To keep B/ $\tau$ -tagging performance up to  $\mu=200$  pileup in an event.
- Need to launch innovative solution for detectors, mechanics, efficient triggering and advanced analysis technics.

The ATLAS upgrade plans full replacement of Inner Tracker

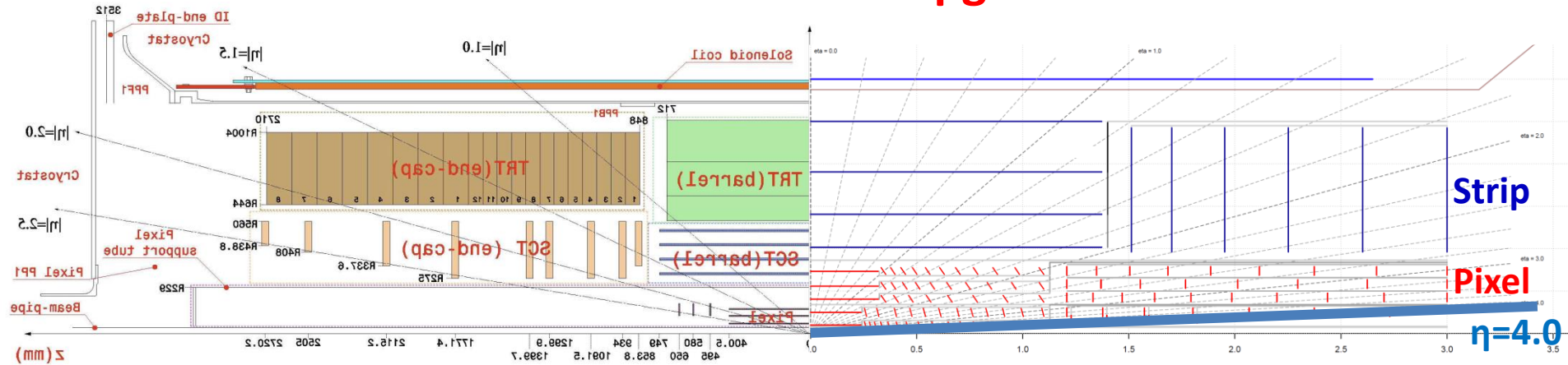
- All silicon tracker (Pixel & Microstrip)
- ***Requirements for Pixel detector***
  - Pixel Size : 50 $\mu\text{m}$  x 50 $\mu\text{m}$  (or 25 $\mu\text{m}$  x 100 $\mu\text{m}$ )
  - Radiation @ outer layer :  $3 \times 10^{15} n_{\text{eq}}/\text{cm}^2$
  - Thickness : 100 or 150 $\mu\text{m}$
  - Low noise (<100e)  $\rightarrow$  600e stable threshold
  - High Readout Rate : 5.2Gbps (or 4x1.28Gbps)



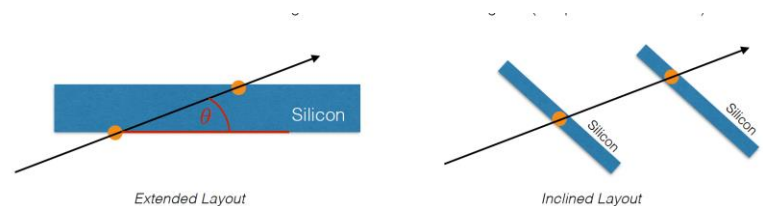
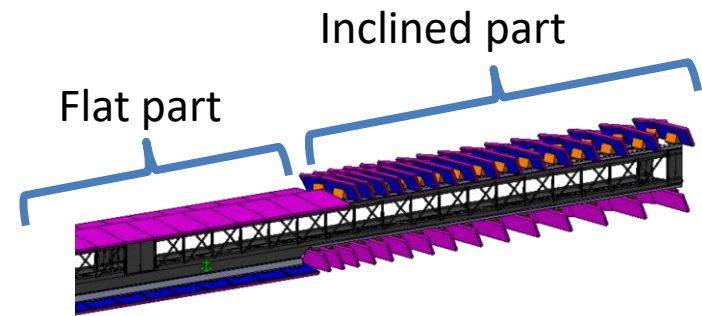
# ATLAS inner tracker(ITK) project for HL-LHC

## Current ATLAS Detector

## ITK upgrade detector



- Larger coverage area
  - Pixel : current  $2.7\text{m}^2 \rightarrow$  **upgrade  $8.2\text{m}^2$**
  - Strip : current  $34\text{m}^2 \rightarrow$  upgrade  $165\text{m}^2$
- Higher Forward coverage
  - Current  $\eta < 2.5 \rightarrow$  **upgrade  $\eta < 4.0$**
  - **Better Pileup removal**
- Mechanics : inclined
  - Reduce material
  - Higher tracking resolution.



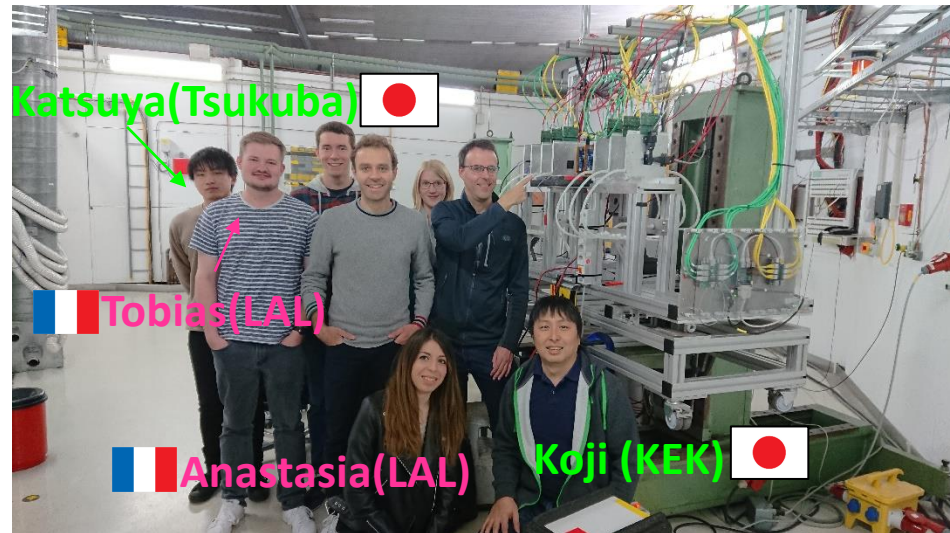
# D\_RD\_20 program proposal

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- Building production modules based on the developed pixel detector.
  - **2019-2020 : preparation of production**
  - **2021-2024 : Production of the modules**
- Constructing ITK pixel detectors is an extremely challenging project
  - **>10000 quad planar pixel modules to be produced. About 20% of modules are build by us.**
  - **Finalize the design and construction method.**
  - **Development of Quality Control and Quality Assurance.**
- **Mainly we ask funding for exchange people between FR-JP**
  - **Share experience/common development**

# Activity in 2019

- Finalizing design of the n+-in-p type Pixel Module towards Production of ITk upgrade.
- Final vendor qualification process (Market survey) is on going
  - Tested characteristics of sensor.
  - Check of Module performance by testbeam.
  - Irradiation to test radiation tolerance.
- Three testbeams at DESY
  - 22<sup>nd</sup> -29<sup>th</sup> July, 2019
  - 23<sup>rd</sup> Sep – 7<sup>th</sup> Oct, 2019
  - 25<sup>th</sup> Nov – 9<sup>th</sup> Dec, 2019
- Operation of these testbeams by RD\_20 group as major contribution.
- Successful data taking of Market survey detectors.



# Plan for 2020

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- Finalize vendor qualification (Market survey)
  - Planned a testbeam as soon as COVID-19 situation get better.
  - Finalize all performance measurements by ITk pixel sensor Final design review (FDR) : scheduled in Summer.
- Start Pre-production
  - ITk pixel sensor will start pre-production (10% of whole production) in 2020.
  - Define and setup quality control(QC) and quality assurance(QA) procedure for the pre-production.
- Exchange students and staff to accelerate the effort described above.
  - Collaborative work for testbeam operation and analysis →France
  - Irradiation campaign in Tohoku-University Japan France→Japan
  - Share the test setup for the QC/QA during production France<-> Japan

# backup

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**Finalize the design  
and construction method.**





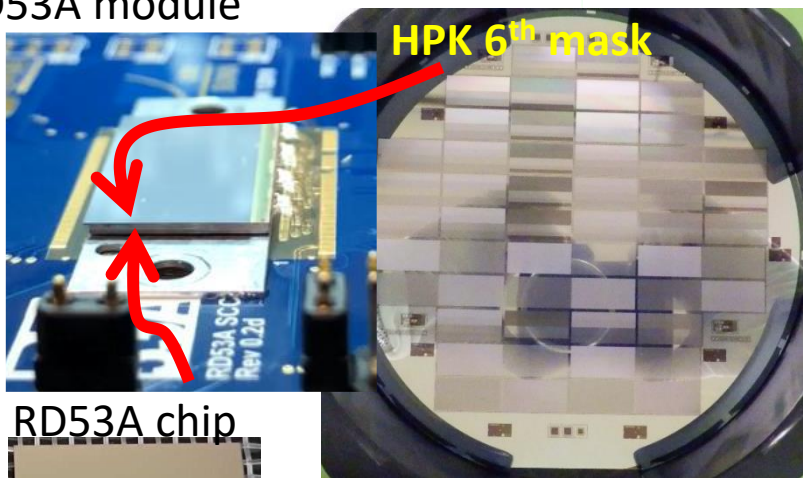
# Final Sensor design

- Basic Sensor structure is almost final after years of development.
- Current fine pitch (50umx50um) pixel size sensors are attached to half size prototype ASIC (RD53A).
- Full size sensor and ASIC need to be produced in 2019.
  - RD53B (ITKpix-v1) and 7<sup>th</sup> HPK mask.

10mm x 20mm half size prototype modules

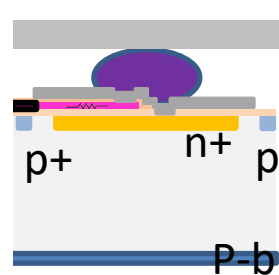
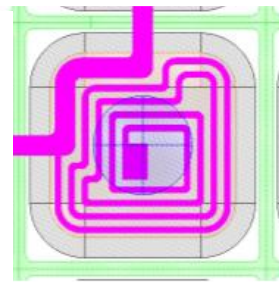
40mm x 40mm production modules  
(20mm x 20mm ASIC size)

RD53A module

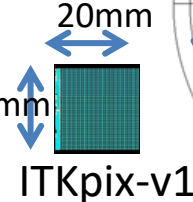
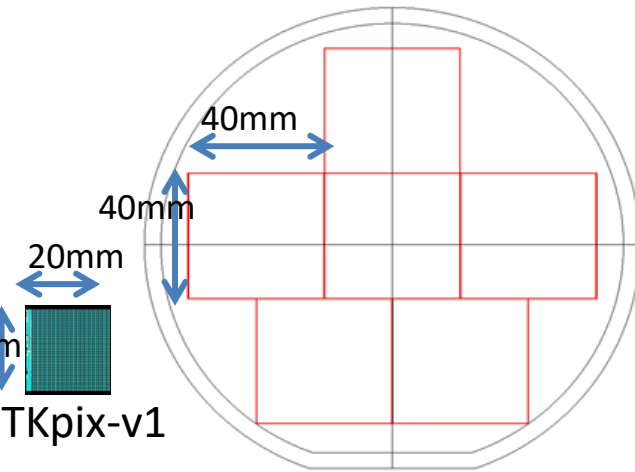


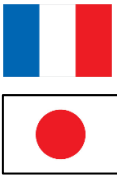
HPK 6<sup>th</sup> mask

RD53A chip



HPK 7<sup>th</sup> mask

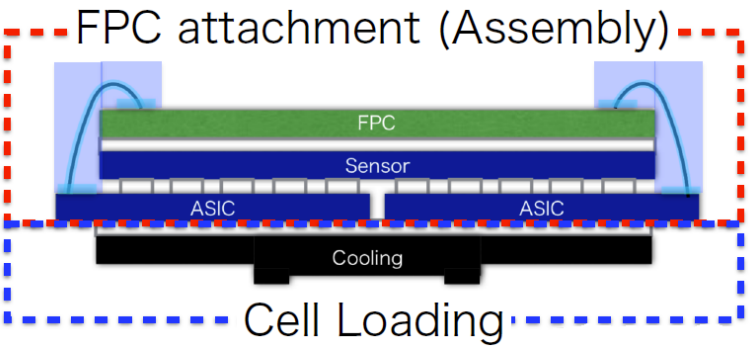
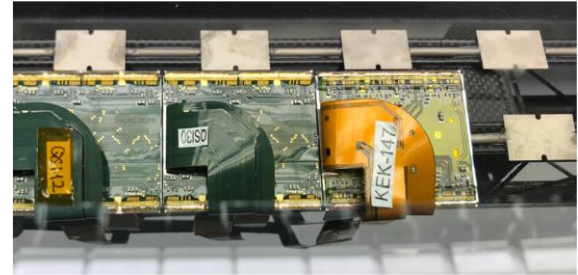




# Module Assembly

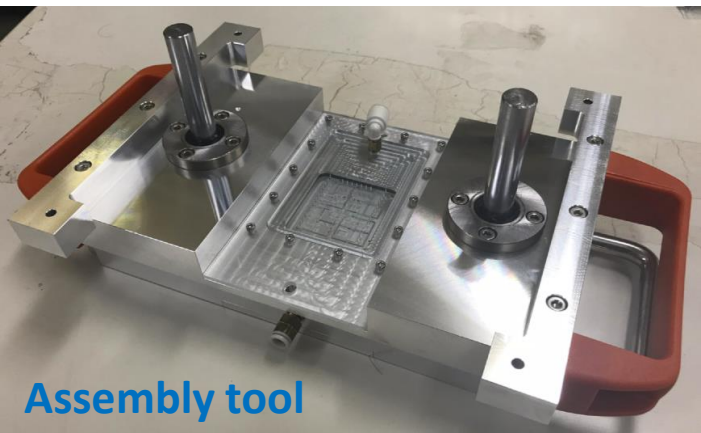
- Assembly of Quad module to the Flex Printed circuit.
  - Radiation hard glue choice
  - CTE matching to avoid stress for modules.
  - Cooling cell on the back side of modules

Module loading to support



Flex Printed Circuit

Cooling Cell



Assembly tool

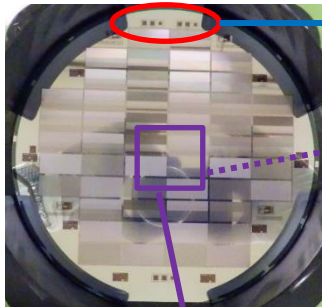
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# Development of Quality Control and Quality Assurance.



# QC/QA flow for module production

Sensor from vender

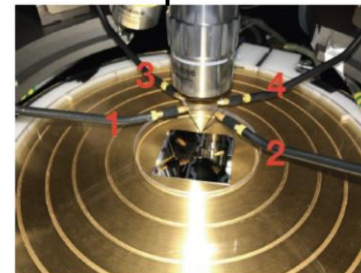


Test structure

Sensor reception  
Quality Assurance

1% of sensor

Sensor probe test

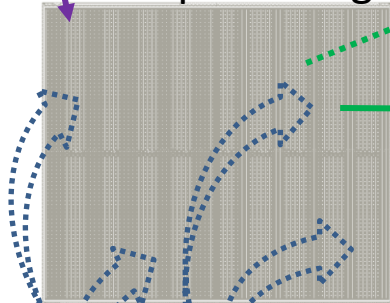


Bare module  
Quality Assurance

ASIC probing

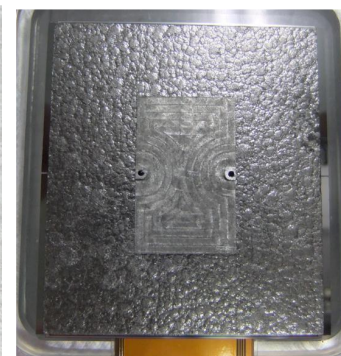


Bump bonding



Module Assembly

- Flex gluing
- Wire bonding
- Cooling cell gluing



1% of module

Module QA  
Thermal Cycling  
Irradiation/Testbeam

Module QC  
Electrical test

loading to Local support.

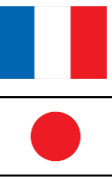
ITKpix ASIC

ASIC probe test  
Quality Control

Front End ASIC



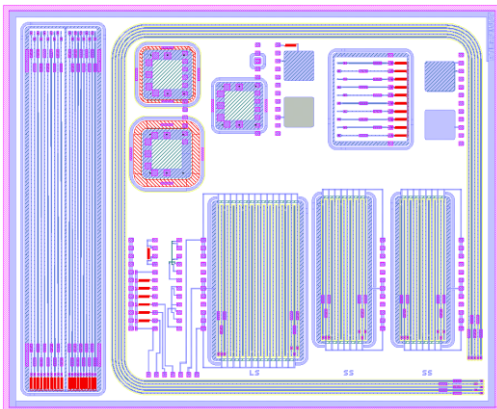
# Sensor QC/QA preparation



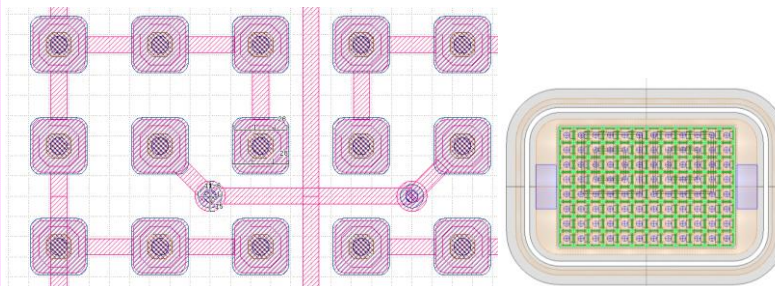
- Most of the measurement : rely on the vender
- IV/CV measurement cross check
  - 1% of sensor will be re-measured by ATLAS ITK
- Test structure to control the quality of the wafer during production.
  - IV/CV measurement for Miniature diode
  - To measure inter-pixel capacitance, low noise probe station necessary.



## Test structure



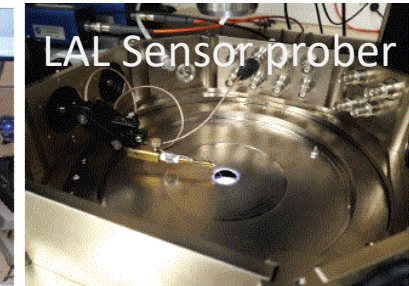
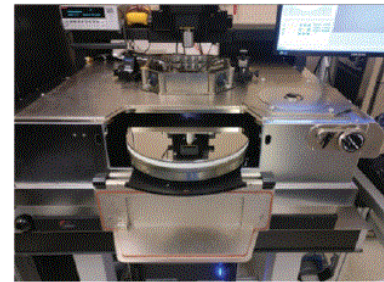
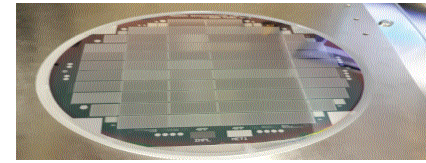
Inter-pixel cap/res test str.



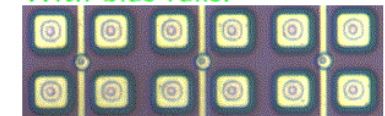


# Contribution for ATLAS pixel Market survey

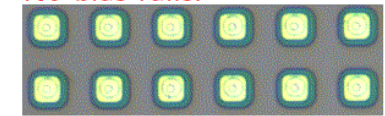
- Work carried within task force IN2P3 French Cluster (LAL+ LPNHE)
  - Characterization of pixel sensors of various designs through different actions, namely:
    - Visual Inspection
    - Planarity and bow evaluation
    - IV, CV measurements
- Outcome from MS measurement
  - Measurement consist with the values by foundry.
  - Infrastructure ready and operational for mass production



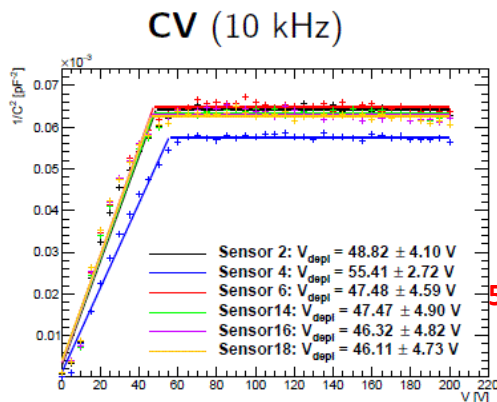
With bias rails:



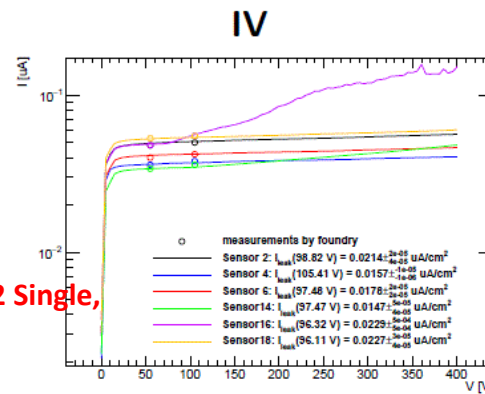
No bias rails:



Special bias rails:



50x50  $\mu\text{m}^2$  Single,



Japan will measure samples from the other vender who delivers samples later this year.

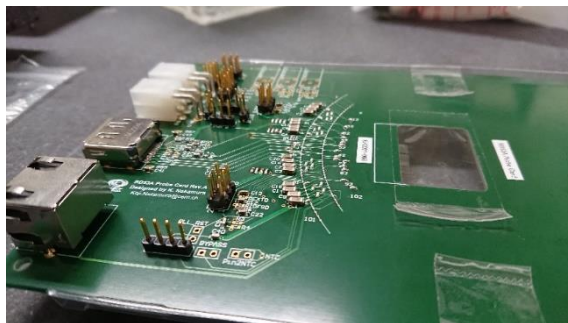
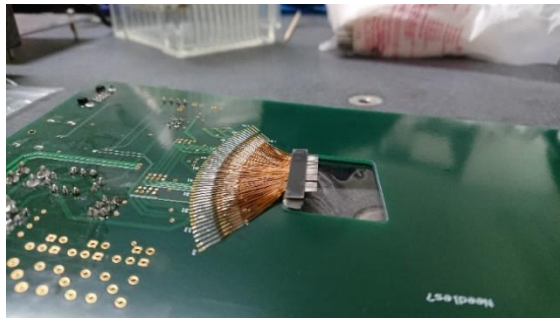




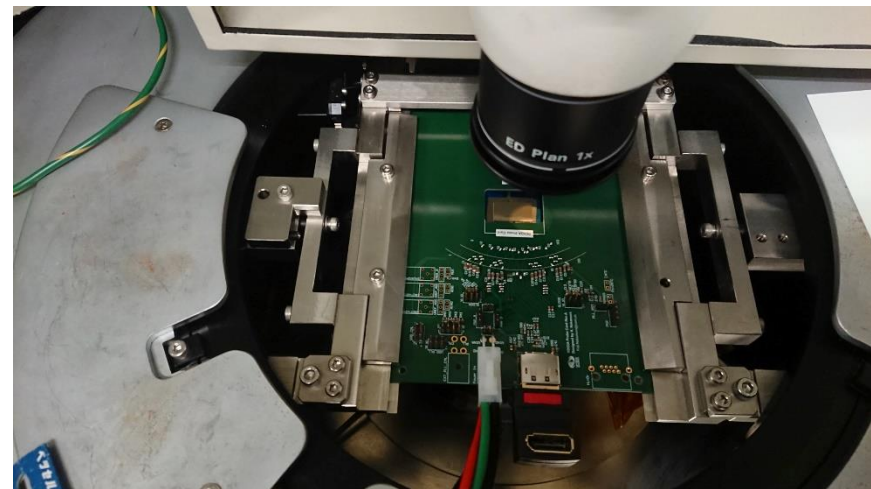


# Module measurement

- Probe card for RD53A module has been developed in Japan.
  - Immediate feedback of Bumpbonding quality in HPK.
  - Highly needed tool that could be provided by KEK for the community for ASIC Chip testing.
- Test for RD53A module successfully done.
  - Will be tested modules for the local support demonstrator.
- **Probe card for Pre-production ASIC will be designed this year.**



Probe station at KEK

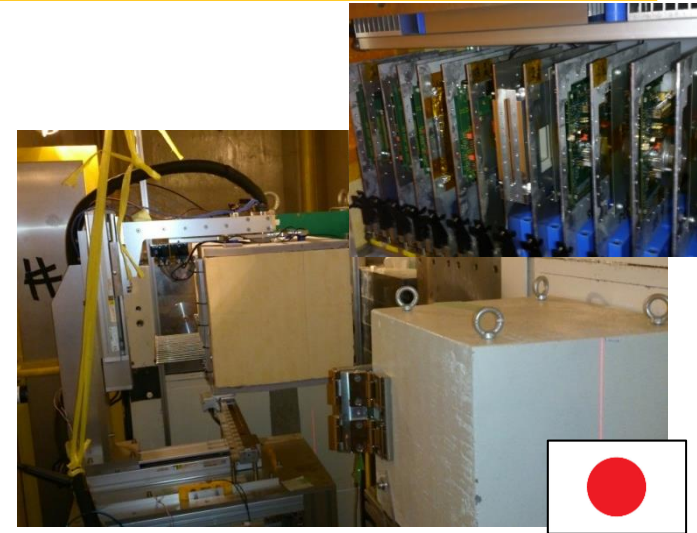




# Irradiation and Testbeam

- CYRIC@Tohoku Univ.

- An irradiation facility with **70MeV proton beam** ( **$\sim 1\mu\text{A}$  beam current**).
  - 3-5 hours for  $3 \times 10^{15} n_{\text{eq}}/\text{cm}^2$  irradiation with (600nA beam)
- This allows 2-3 pixel modules with Al plate at the same time (3% E loss/module).
- Operated at  **$-15^\circ\text{C}$  temprature** with dry  $\text{N}_2$  gas.
- Scanning over full pixel surface at irradiation.



- **Testbeam**

- **Extremely important to test device performance**
- Efficiency/Noise monitoring during production
- Testbeam facility
  - **CERN SPS : 120GeV  $\pi^+$  beam**
  - DESY : 4-5GeV  $e^+$  beam
  - FNAL : 120GeV proton beam
- Telescope planes (Track pointing to device)
  - EUDET based on MIMOSA26 monolithic CMOS detector placed in beamline at CERN/DESY/SLAC ( **$\sim 3\mu\text{m}$  pointing resolution**).
  - Huge experience of the testbeam operation as having testbeam 3-4 times a year

