

Taiwan Instrumentation and Detector Consortium (TIDC) Involvement in Collider Experiments

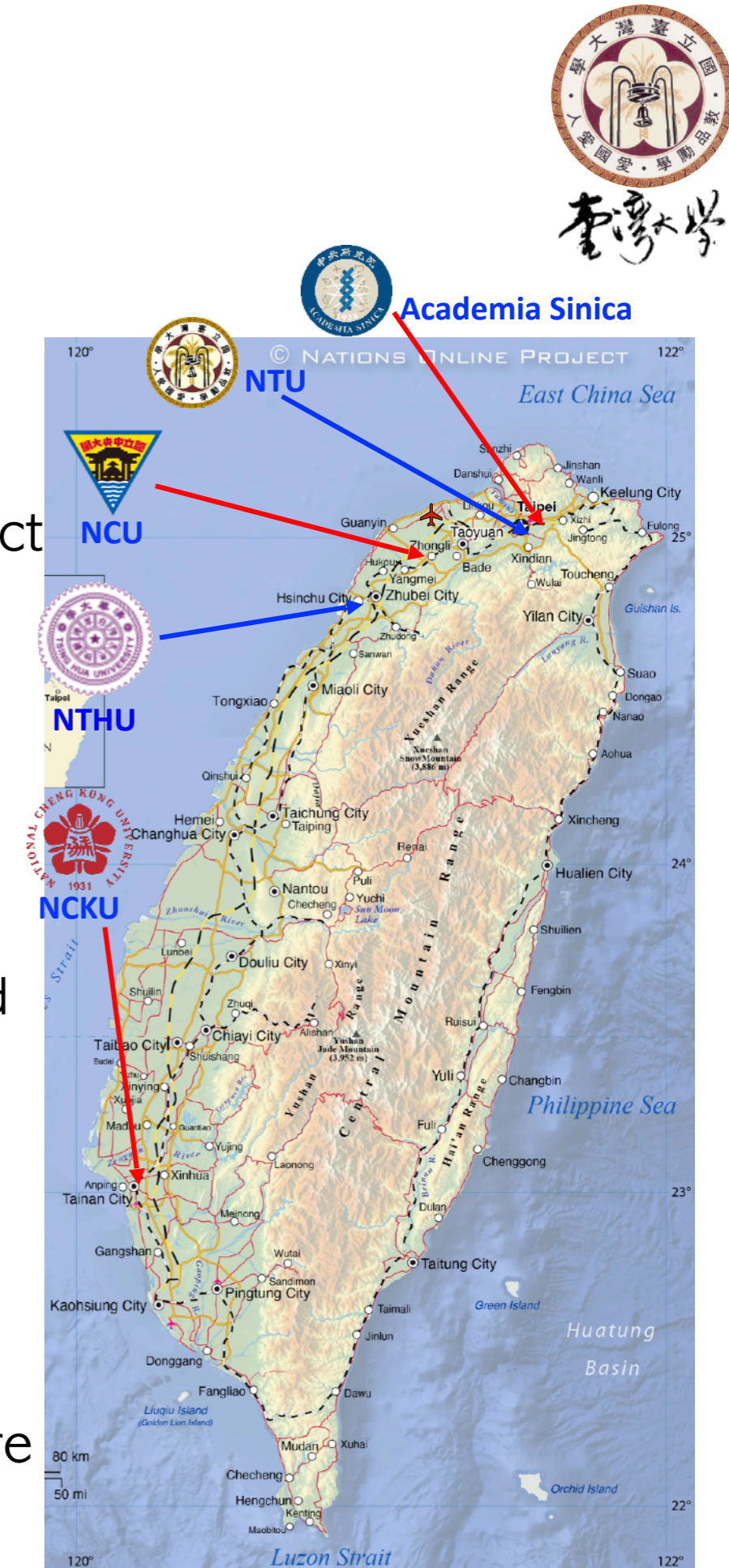
Rong-Shyang Lu
National Taiwan University



The screenshot shows the TIDC website with a dark green header. The TIDC logo is in the top left, and a navigation menu with links for HOME, ABOUT TIDC, PROJECTS, CORE FACILITIES, ACTIVITIES, and CONTACT US is in the top right. A yellow URL <https://tidc.phys.ntu.edu.tw/> is overlaid on the left. The main content area features a night cityscape background and text in English and Chinese. The English text reads: "TAIWAN INSTRUMENTATION AND DETECTOR CONSORTIUM (TIDC)". The Chinese text reads: "台灣偵測器聯合實驗室". Below this, a paragraph in English states: "With the support of NSTC (國科會), we have integrated the High-Energy-Physics Experiments (ex-HEP) group members of Academia Sinica, National Central University, National Cheng Kung University and National Taiwan University to form the Taiwan Instrumentation Detector Consortium (TIDC) now named as "Taiwan Instrumentation and Detector Consortium" (台灣偵測器聯合實驗室)." The Chinese text below this paragraph is partially visible.

Introduction

- In 2019, the initiative of Taiwan Instrumentation and Detector Consortium (TIDC) was formed among AS, NCU, NTHU, and NTU to join R&D and construction efforts for HL-LHC (ATLAS and CMS) projects.
- Later, NCU and NTU brought in RHIC-sPHENIX project and NCKU joined TIDC with RHIC-STAR project.
- Roles and support offered
 - ◆ **中央研究院 Academia Sinica**: microelectronics design, machine shop, radiation-hardness test, Grid computing
 - ◆ **中央大學 Natl. Central Univ.**: Silicon sensor design and probing, muon detector Lab.
 - ◆ **成功大學 Natl. Cheng-Kung Univ.**: Silicon detector and scintillator Labs. Silicon detector mechanical design.
 - ◆ **清華大學 Natl. Tsing-Hua Univ.**: Silicon detector beam-test analysis
 - ◆ **台灣大學 Natl. Taiwan Univ.**: Silicon detector assembly cleanroom, testing lab, microelectronics design and testing, jigs design.
- TIDC gets strong support and become one of the core facilities in NSTC.



- Silicon Detectors

- ◆ Taiwan HEP has long tradition of silicon based detector involvements. Including

- ❖ Sensor design and production for RHIC-Phobos-SiliconD and LHC-CMS-Preshower
- ❖ Readout electronics Tevatron-CDF-SVX, KEKB-Belle-SVD
- ❖ Most recently, constructing silicon detector modules of RHIC-STAR-FST, RHIC-sPHENIX-INTT, and LHC-CMS-HGCAL
- ❖ R&D in LGAD technology (See Prof. R-H Yeh's talk)

- Crystal Calorimeters

- ◆ HEP has participated LEP-L3-EMCAL and built a KEKB-Belle-EFC both based on homogeneous BGO crystals
- ◆ Also various applications with photosensors technology, such as medical application and recent LYSO investment for HL-LHC-MTD detector.

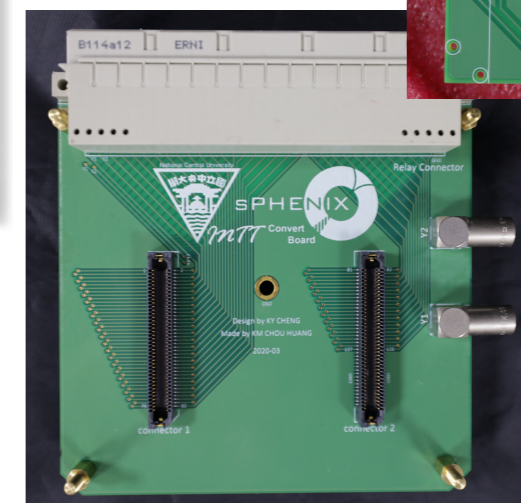
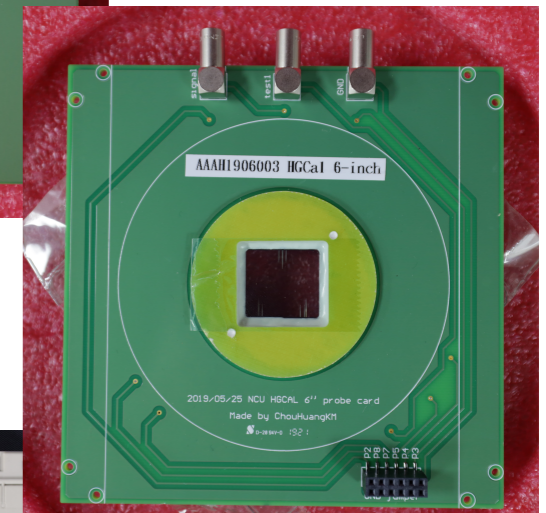
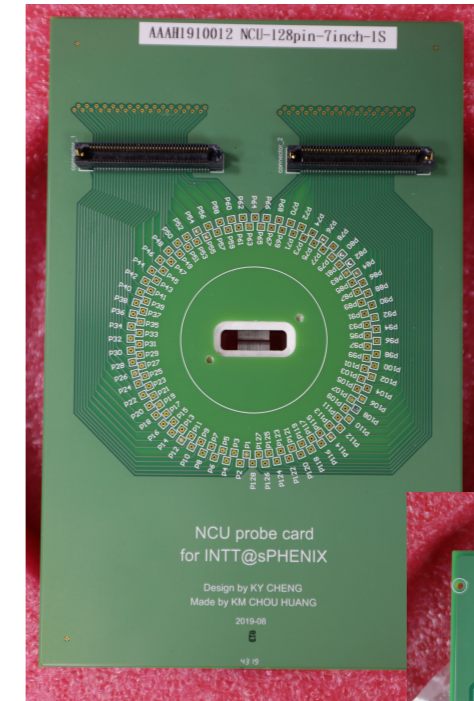
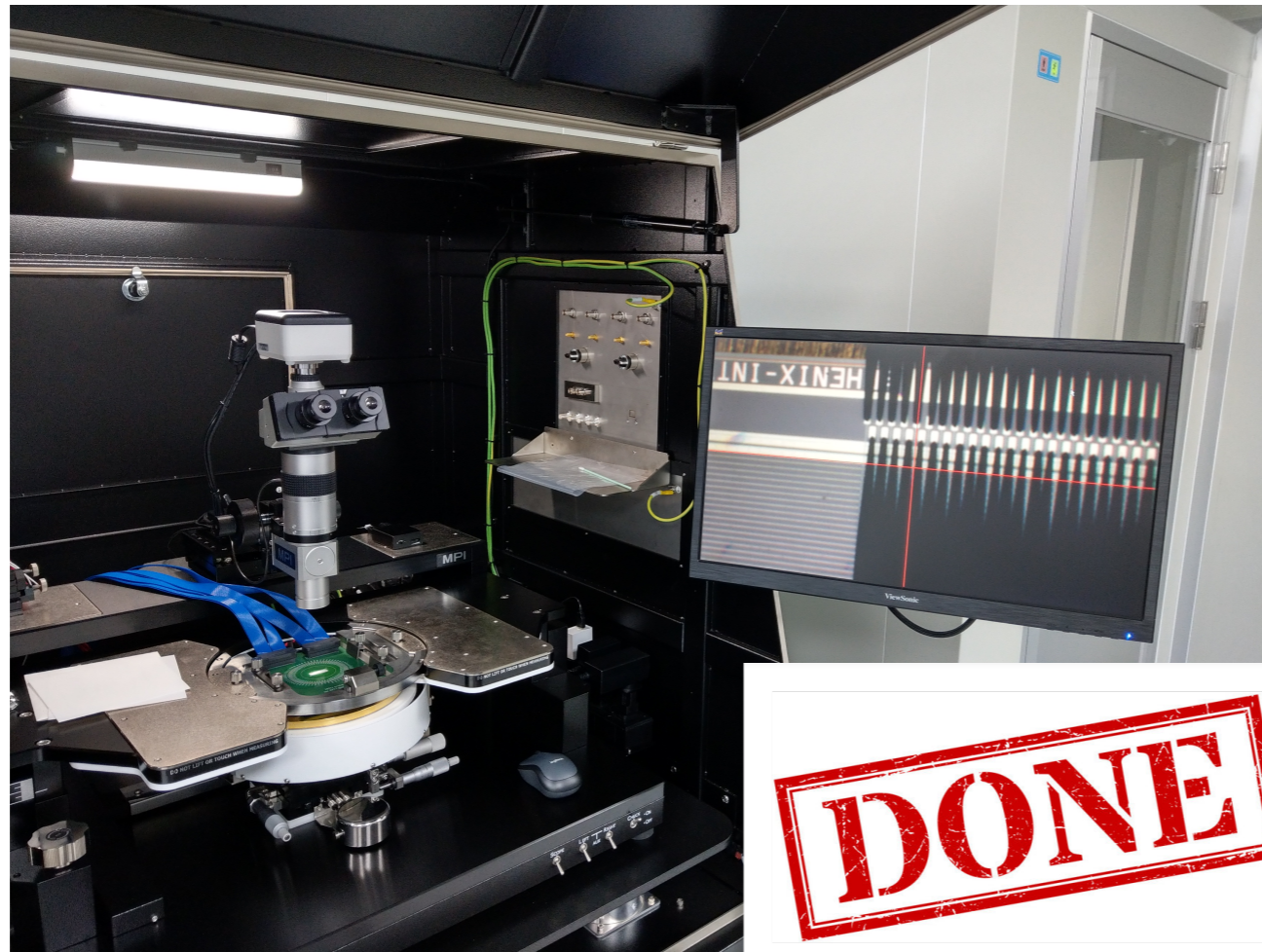
- Electronics, Firmware, OPT-Readout, Computing, ..., etc.

Silicon Detectors

Hybrid Style Silicon Detector

- Recent projects have formed a production flow as
 - ◆ Silicon sensor probed (QA/QC) in NCU
 - ◆ Assembly jigs design in NTU/NCKU and fabricated in AS
 - ◆ Silicon module assembled and tested (QA/QC) in NTU/NCKU
- Completed STAR-FST hybrid and sPHENIX-INTT ladder production. On-going CMS-HGCAL module production project until 2026

INTT Silicon Sensor QC

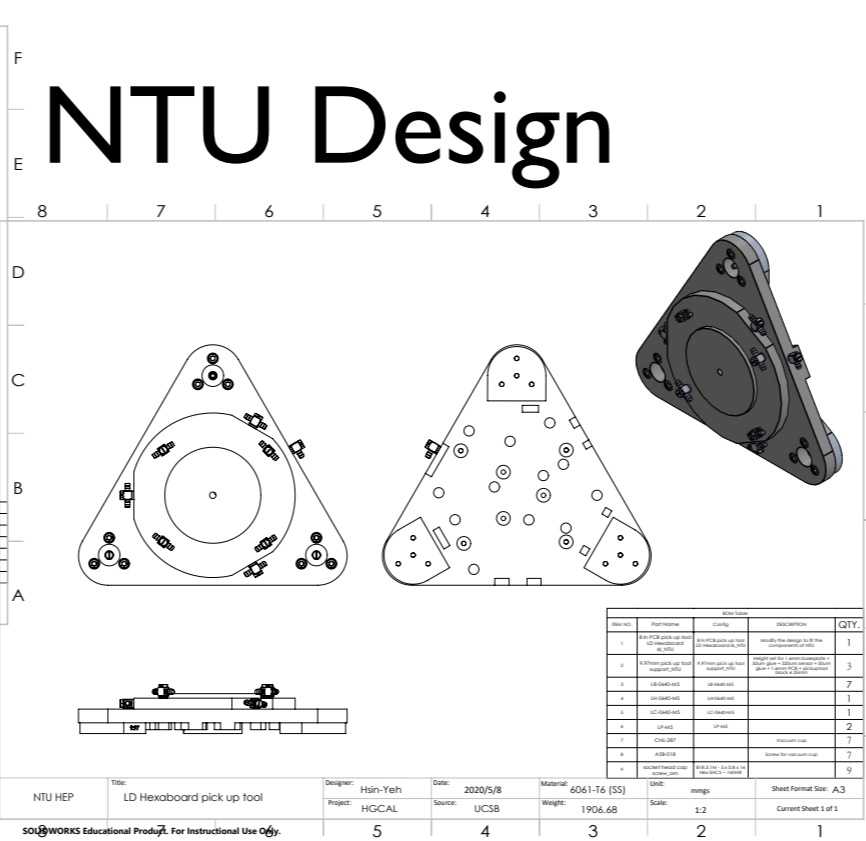
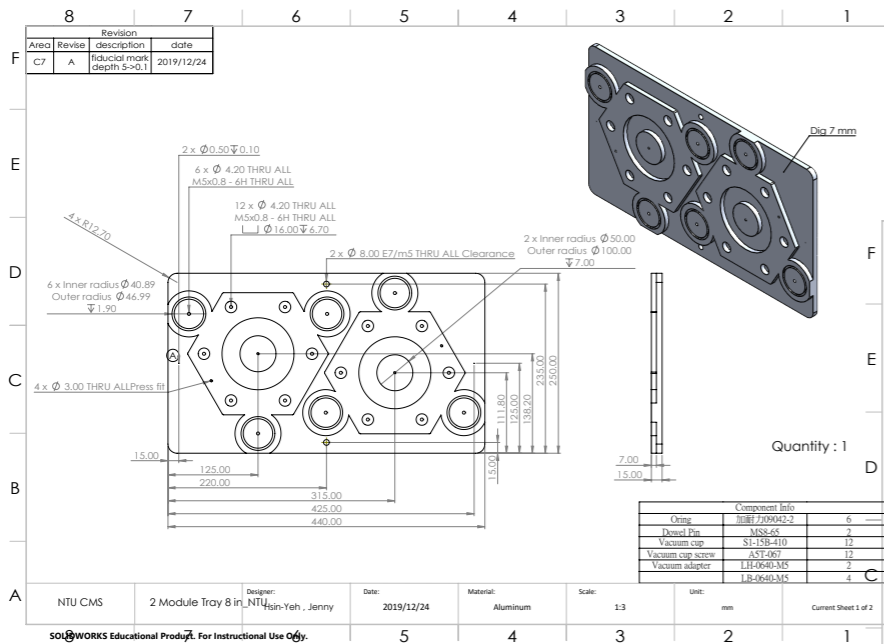


- procedures, probe cards and database were all designed by Taiwan-sPHENIX team
- The majority of the INTT silicon sensors were electrically measured in NCU

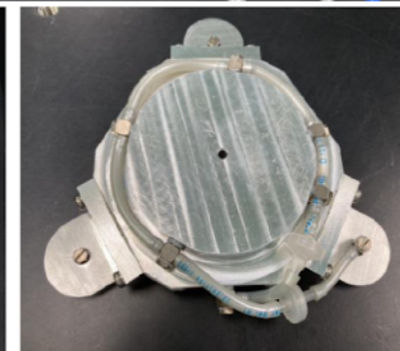
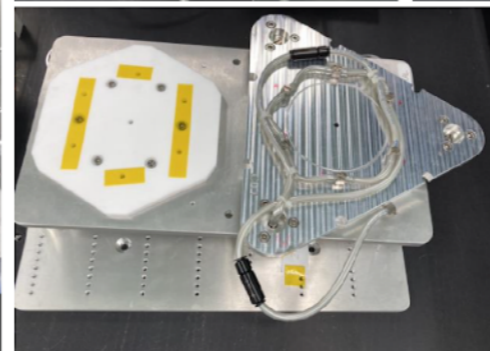
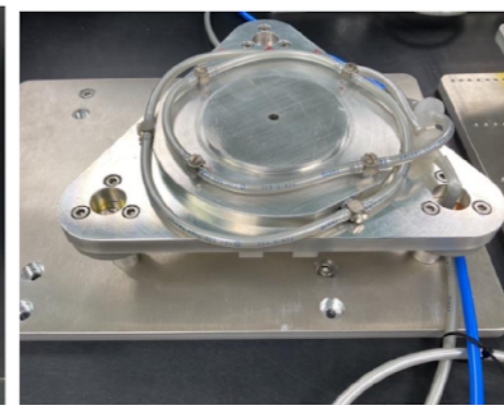
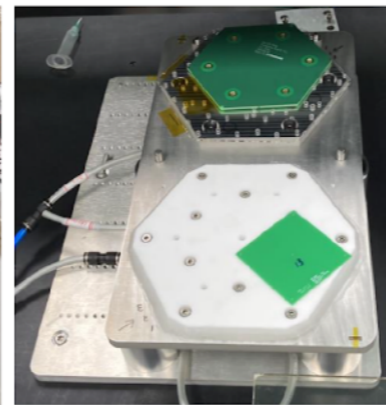
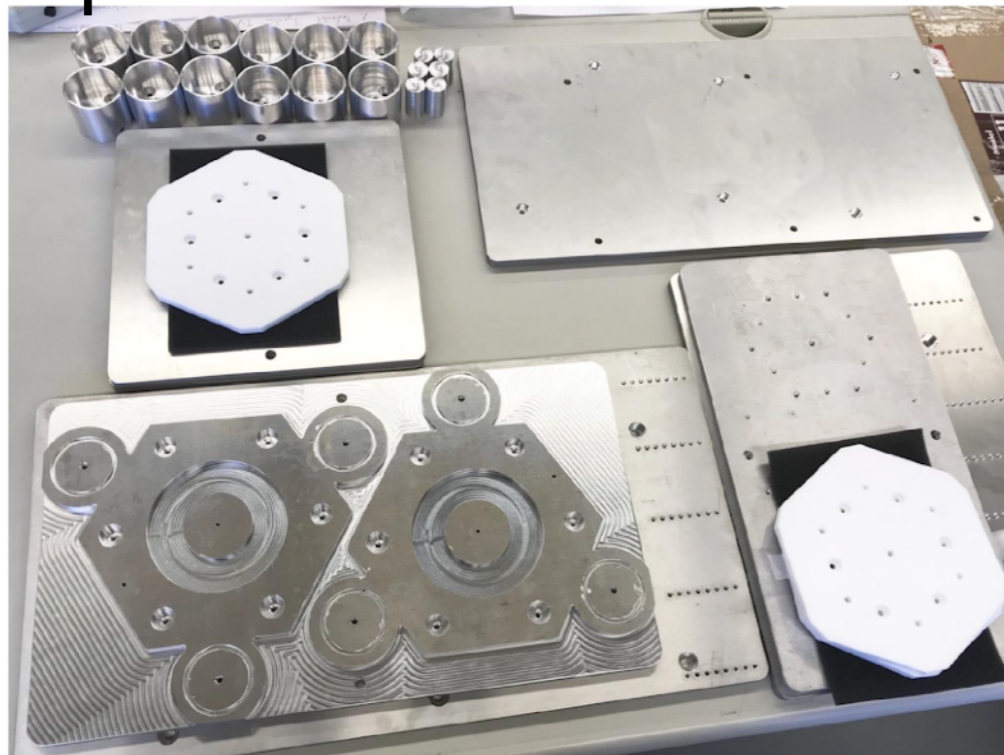
Jig design and production

NTU Design

AS Machine Shop



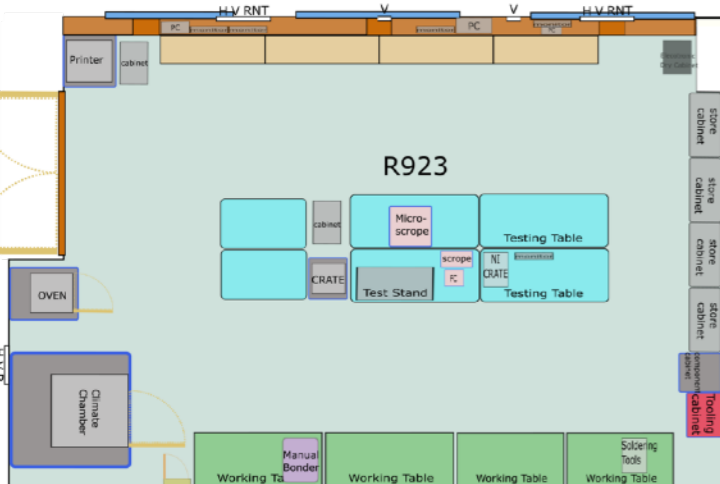
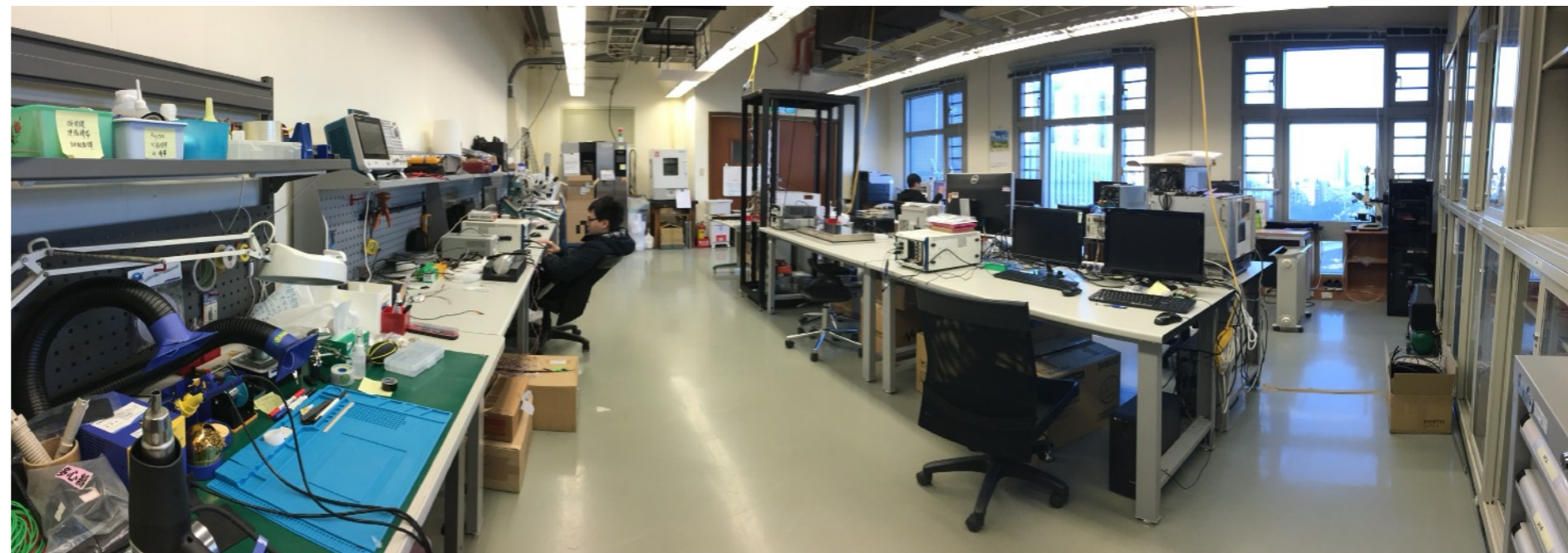
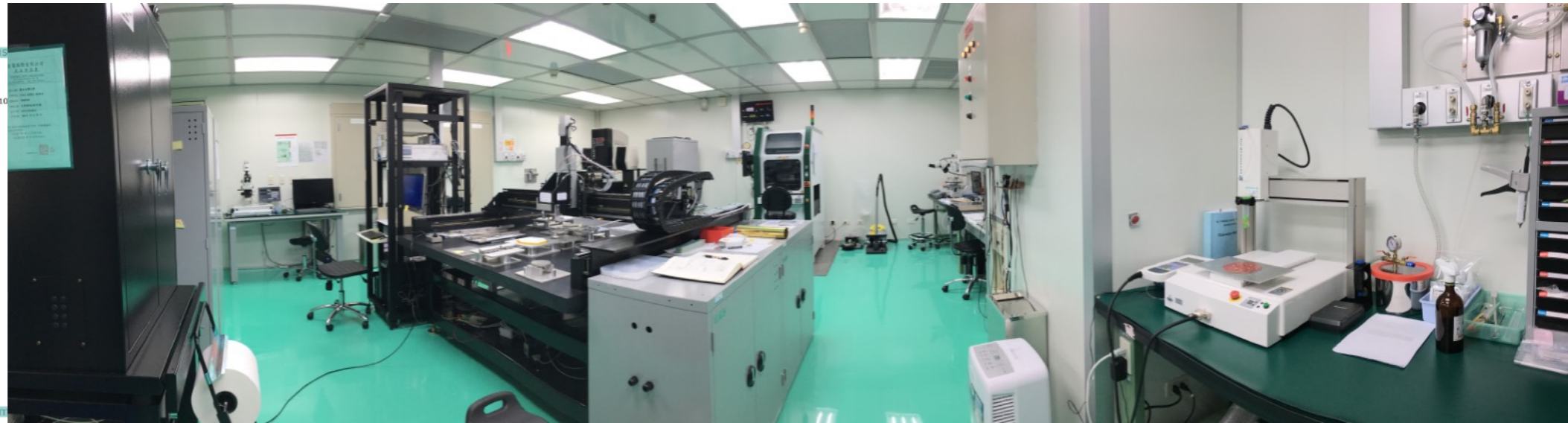
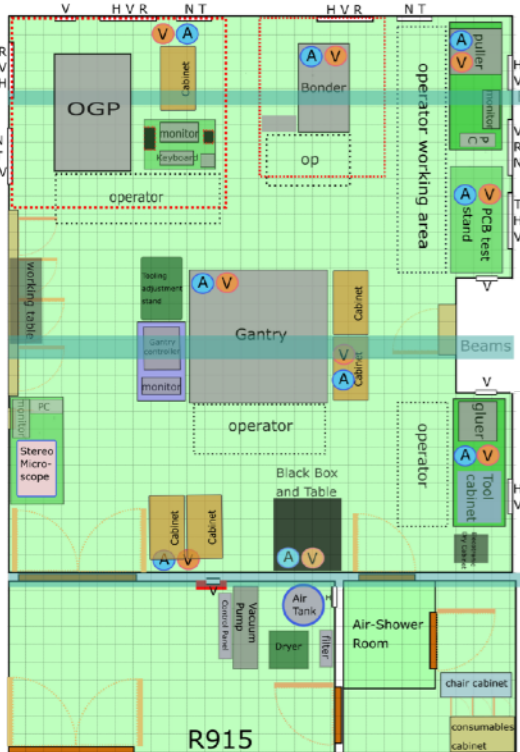
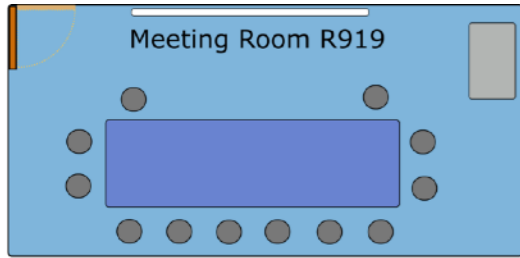
AS production



Assembled jigs
in NTU lab

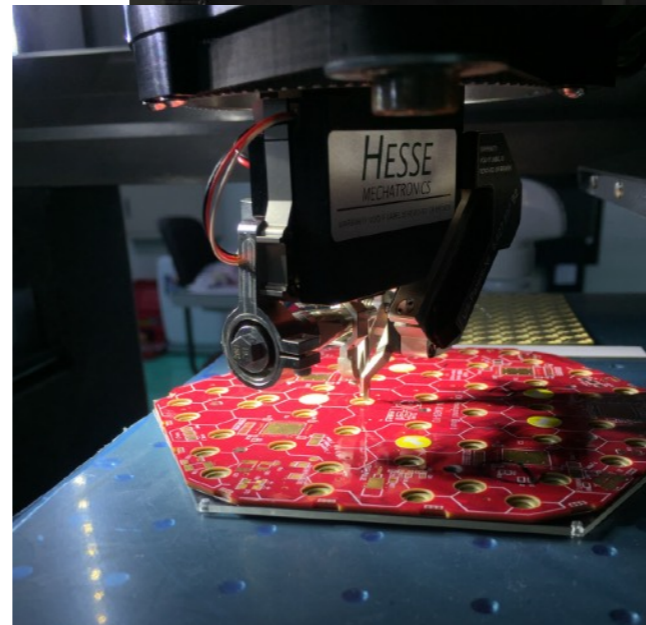
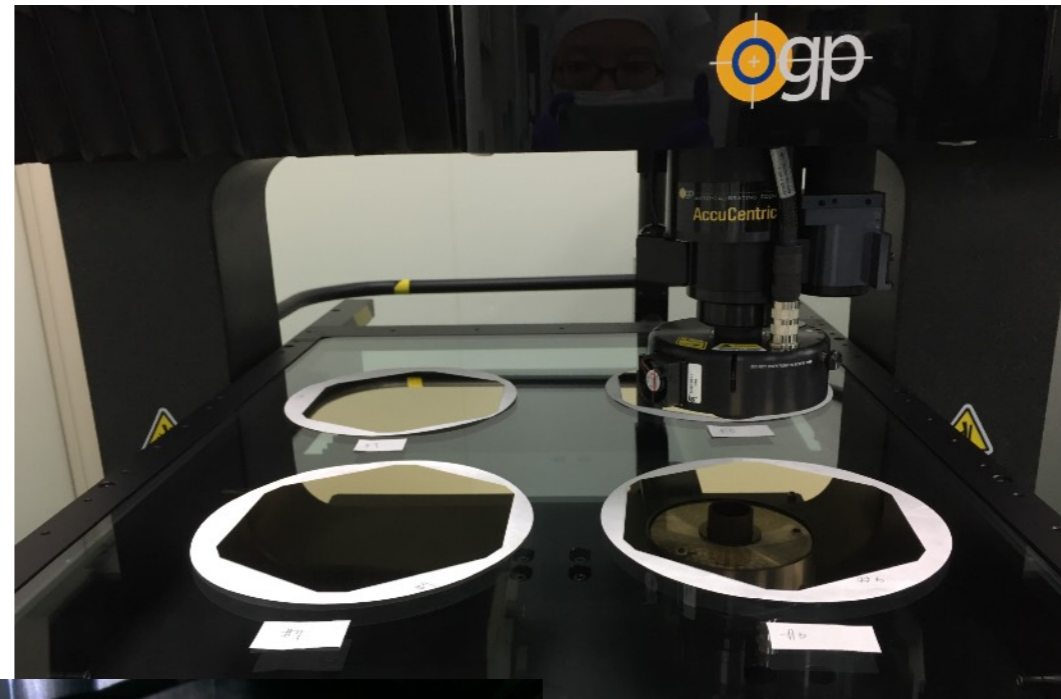
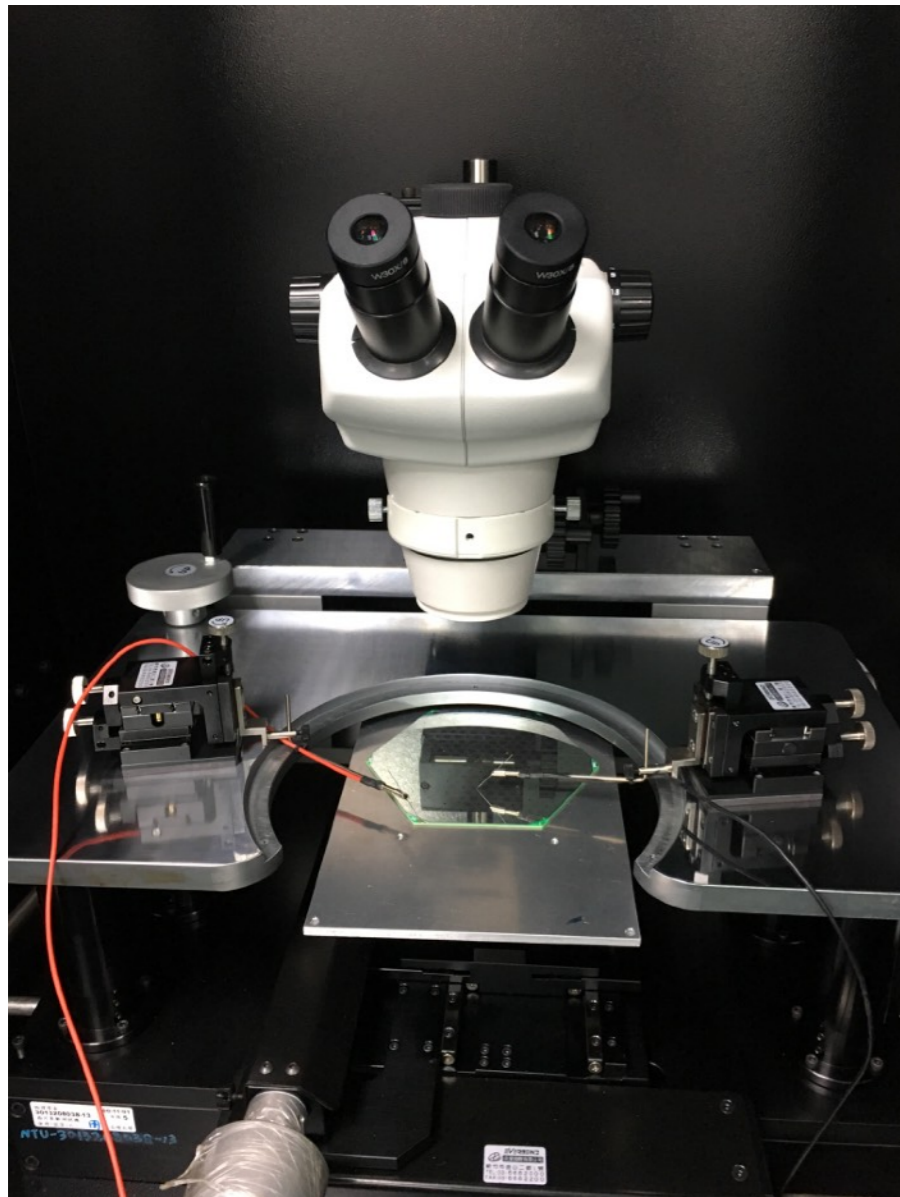
NTU Facility

- Complete the cleanroom (915) setup including robotic gantry, wire-bonder, probe station and services in spring 2019.
- Setup testing lab (923) with test-stands, climate chamber in 2020.
- Acquired a buffer room (910) in 2021 until 2025.



Lab equipments

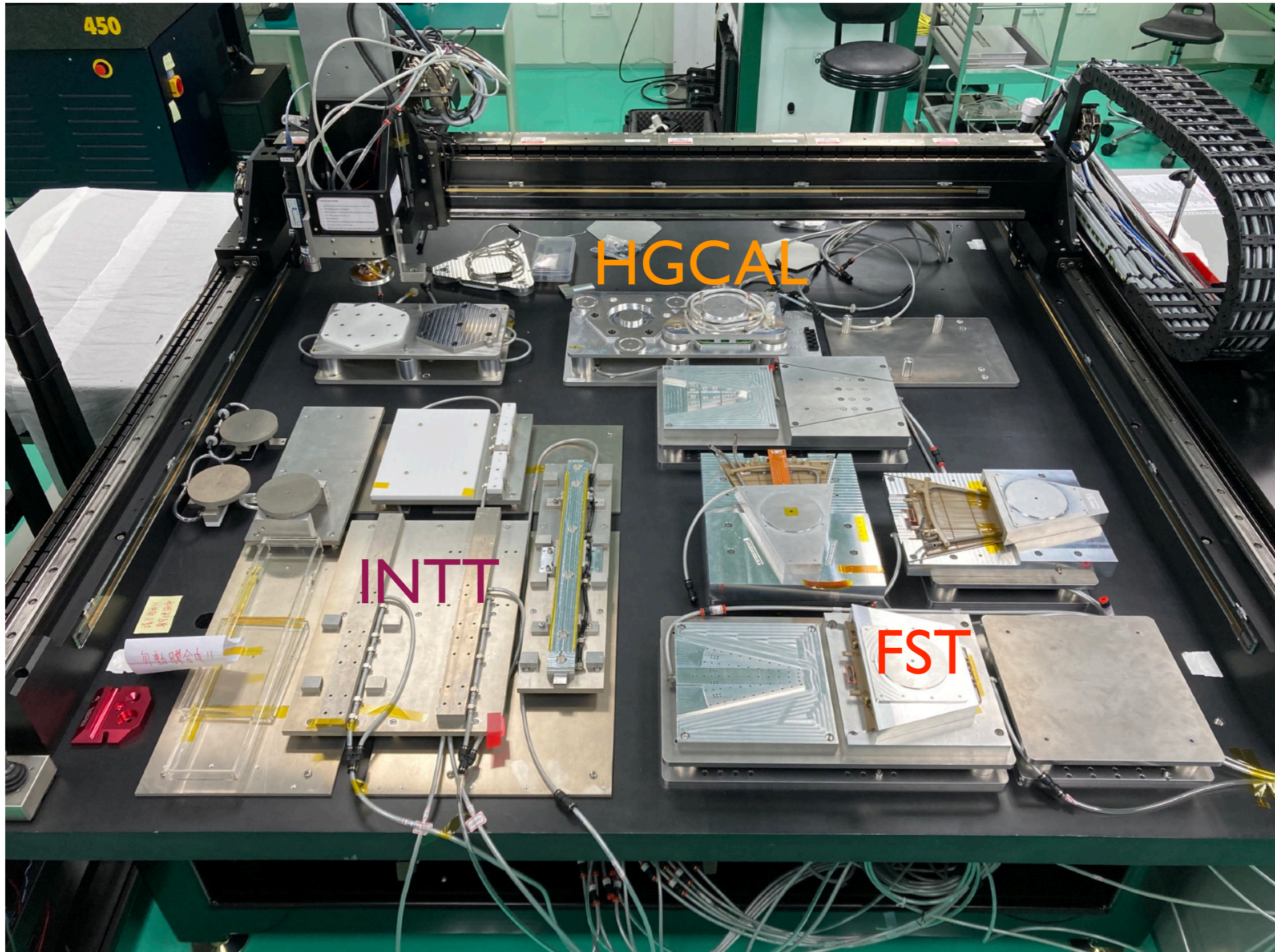
- We have equipped robotic gantry, wire-bonder, pull tester, probe station, NI crates, OGP optical measuring system, scopes, HV/LV supplies ... etc. Essential equipments needed to build silicon detector.



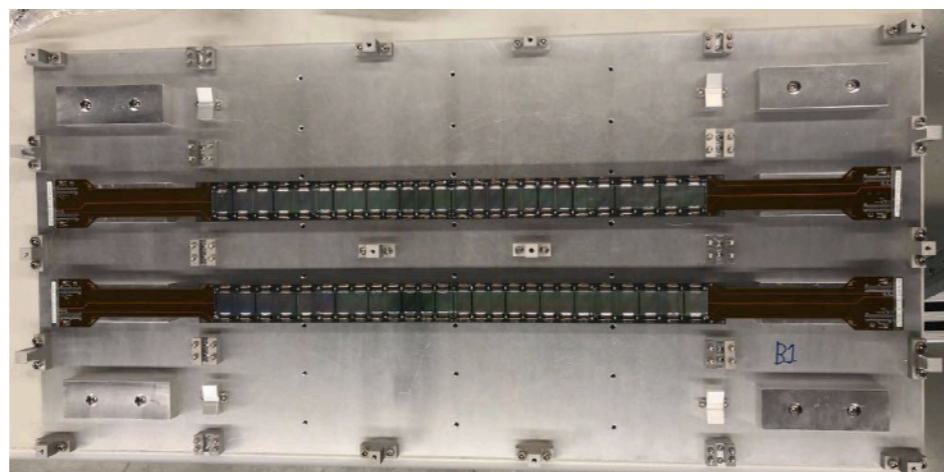
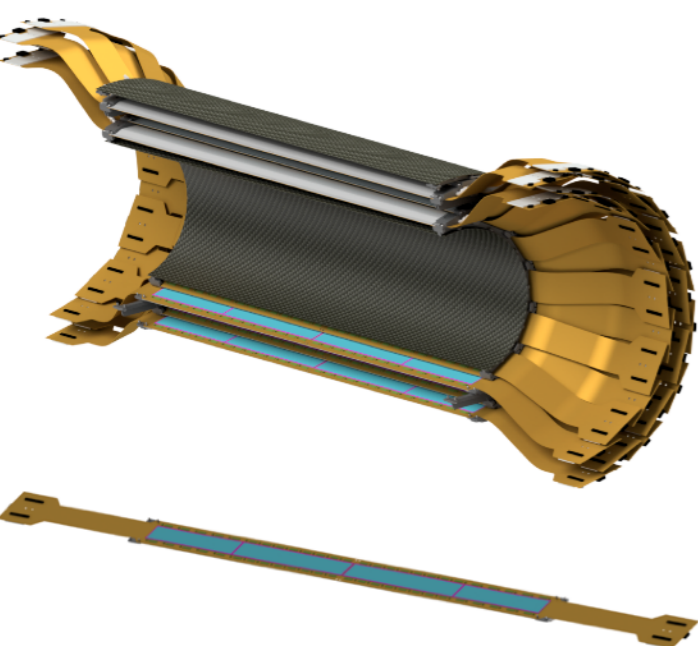
NCU workshop on EIC

Dec. 9th, 2022

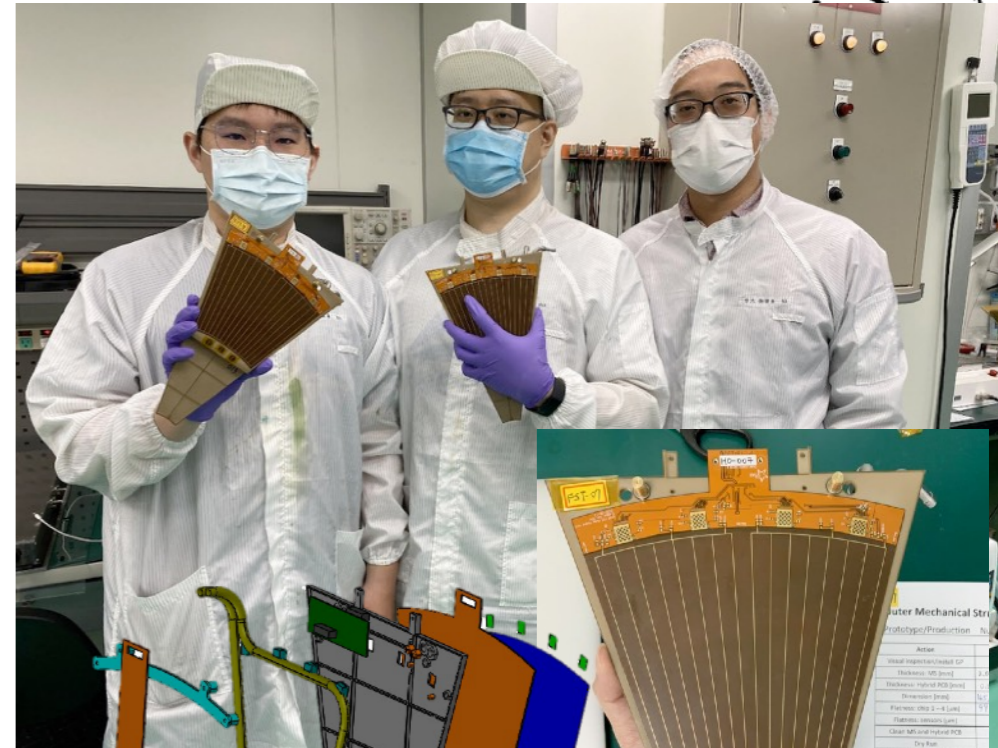
Main Gantry for Assembly



Assembled Silicon Modules

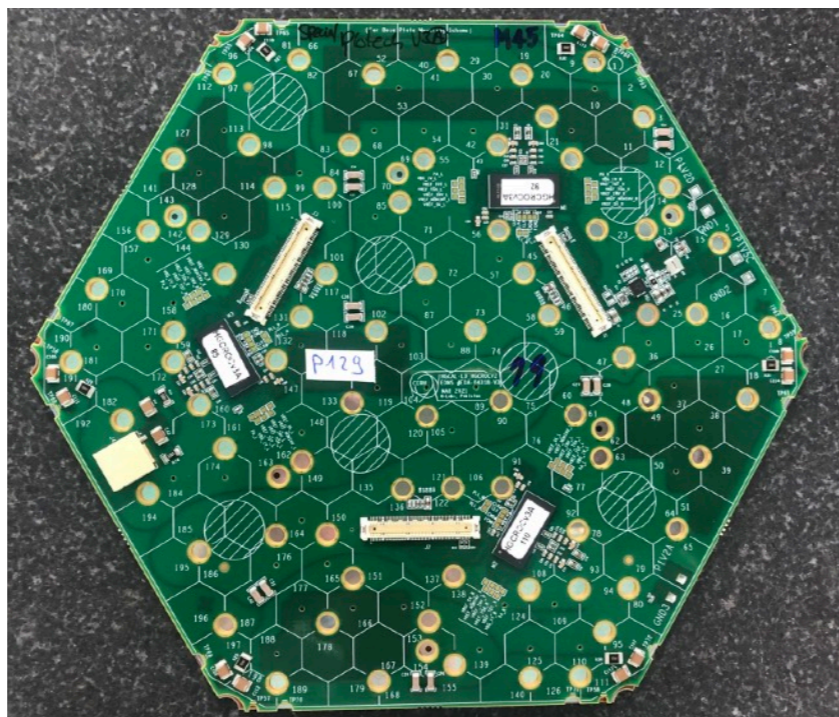
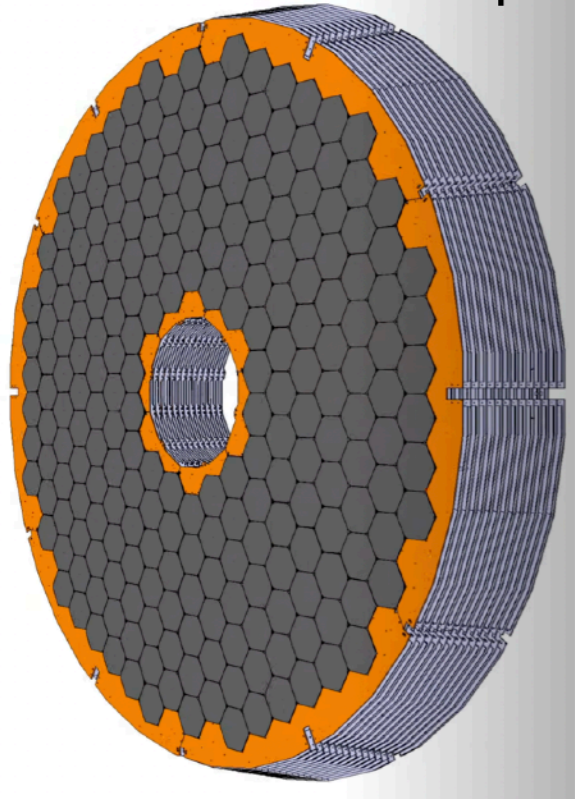


Assembly of INTT ladders

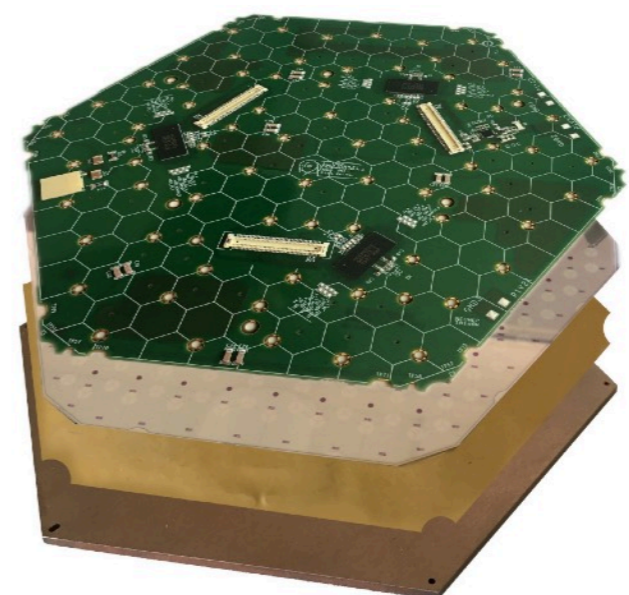


Design and Fabrication of STAR FST hybrids

CMS CE-E Endcap

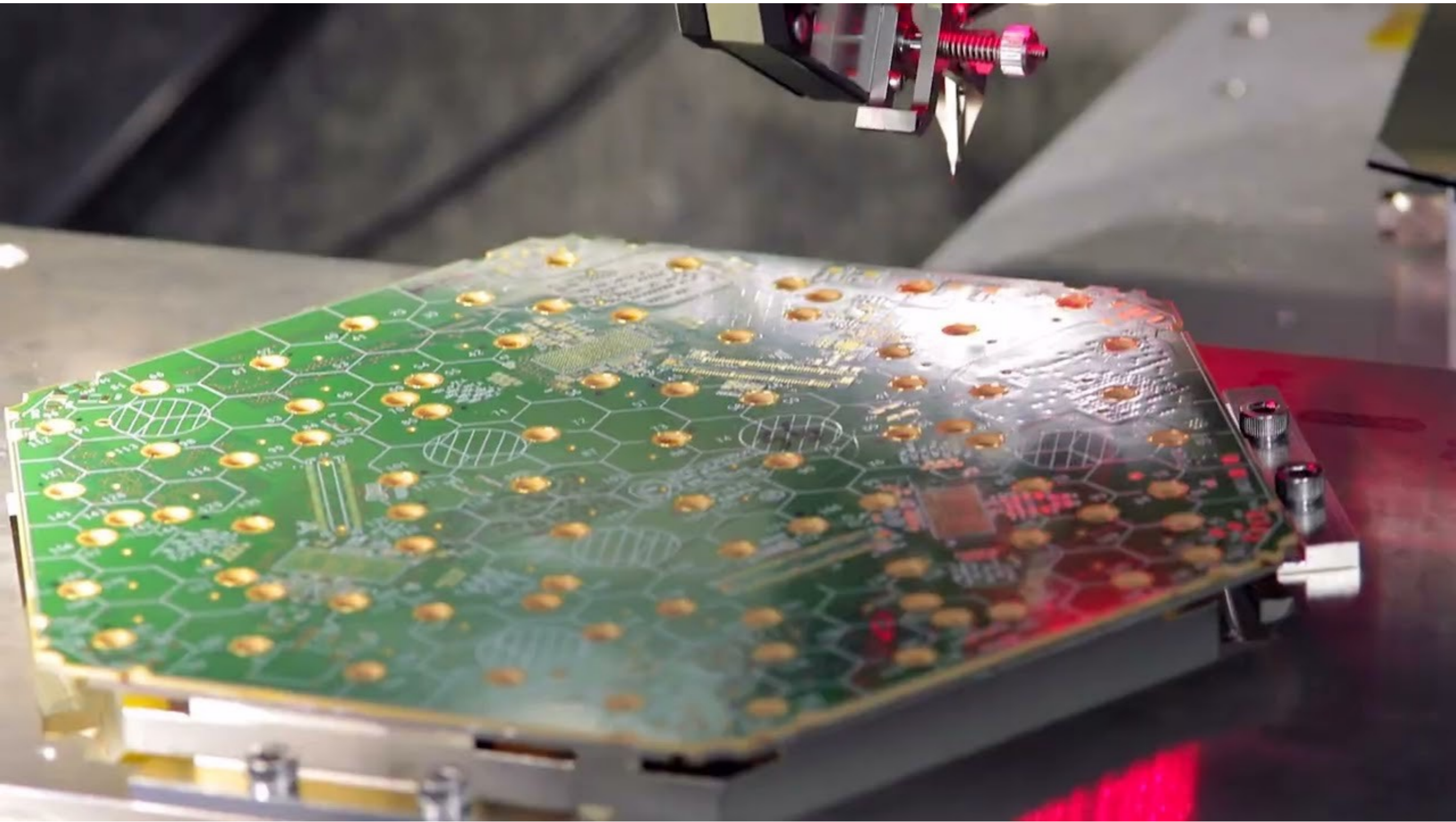


Assembly of HGCal modules



Rong-Shyang Lu / NTU

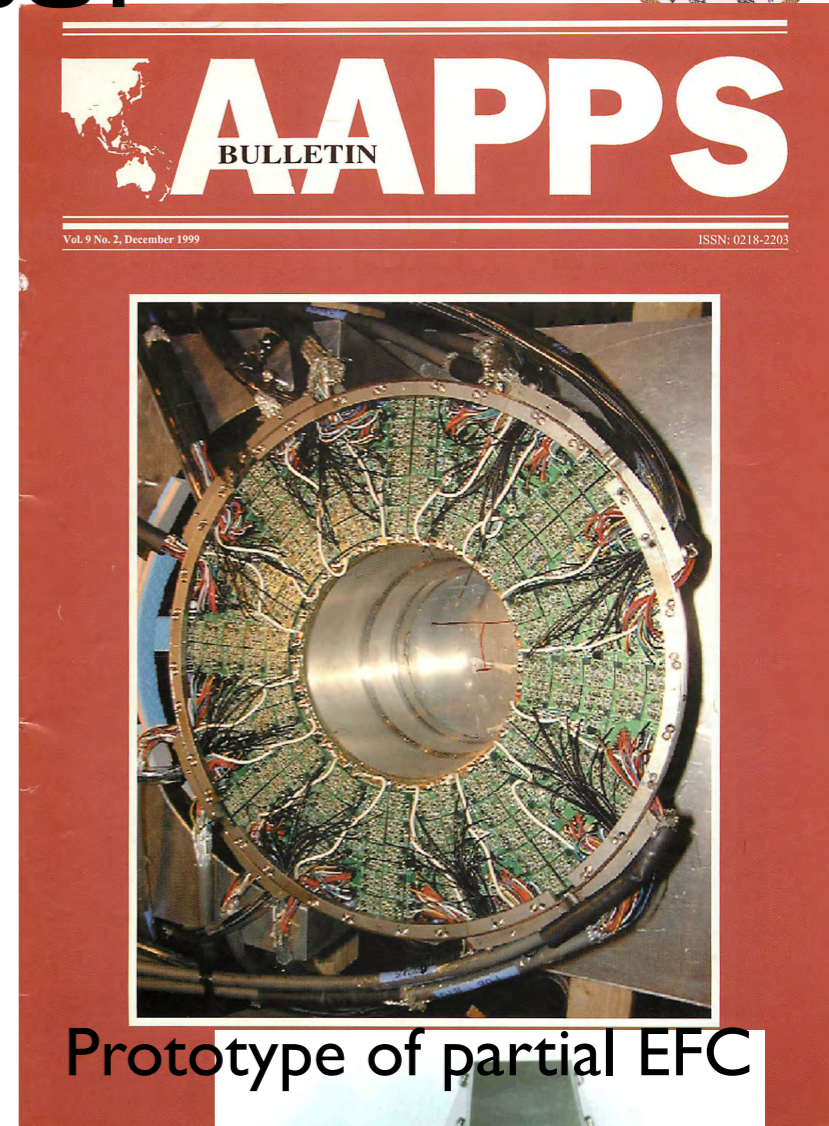
HGCAL Module Assembly



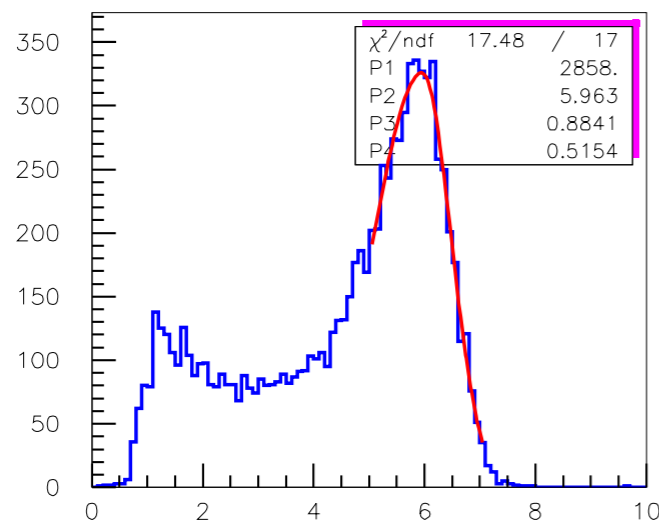
Crystal Calorimeters

Crystal Calorimeter

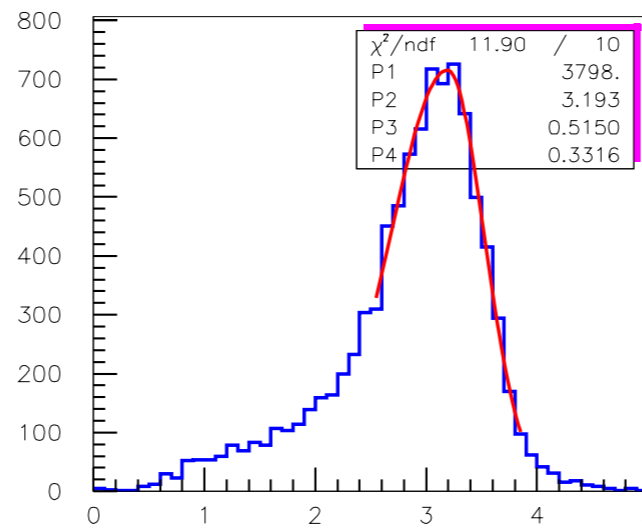
- NTU designed and built a BGO crystal small angle Calorimeter in Belle.
- Provided :
 - ◆ luminosity measurement in Bhabha Scattering;
 - ◆ extend the fiducial coverage for τ analysis.



Energy Spectrum of EFC Bhabha



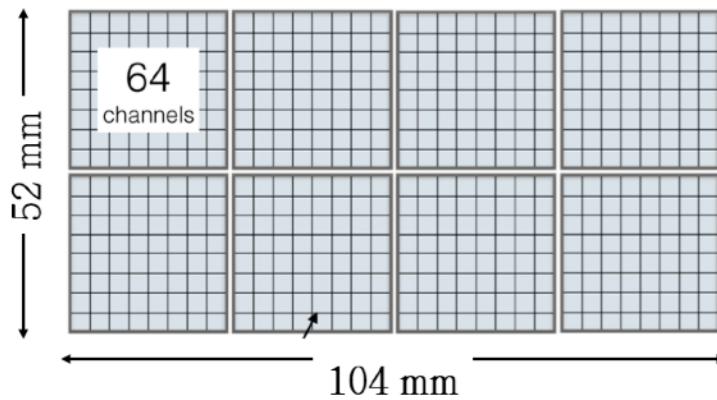
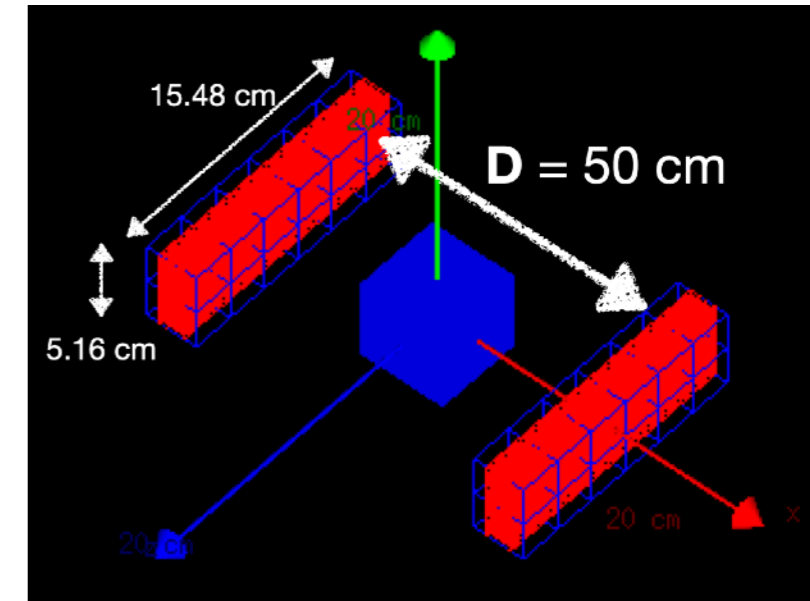
E FEFC



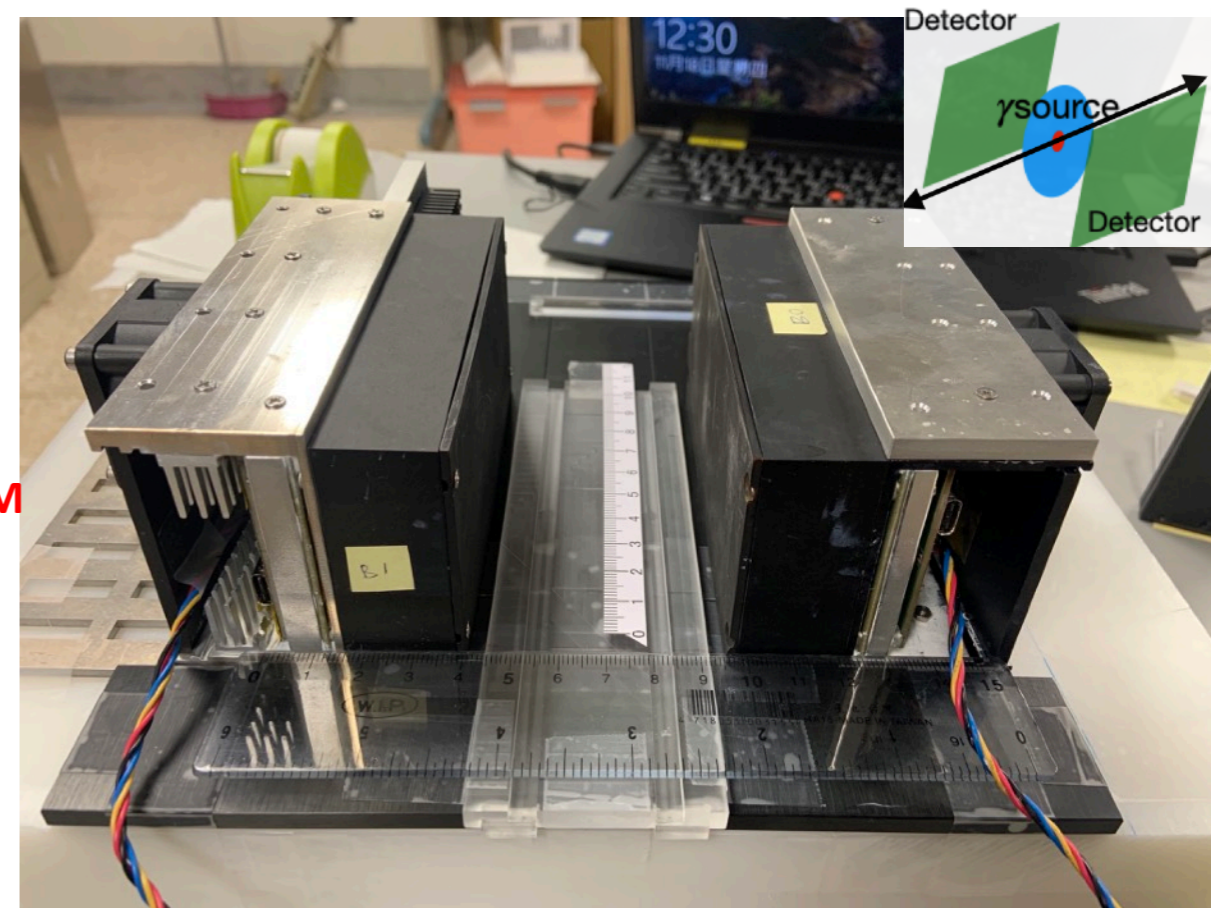
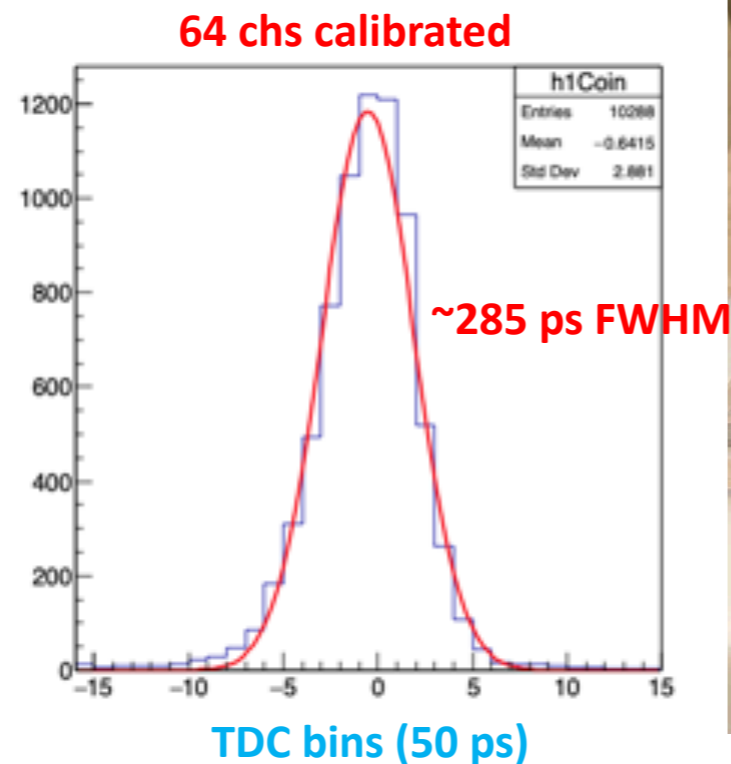
E BEFC



- Photons with timing forms “vertex”
- AS is developing ToF-PET Detector for medical imaging
- Light readout by SiPM to have fast response



- 512 channels per module
- 8 pcs of 8x8 LYSO array
Pixel size = 3 x 3 x 20 mm³
- 8 pcs of 64 ch FE ASICs

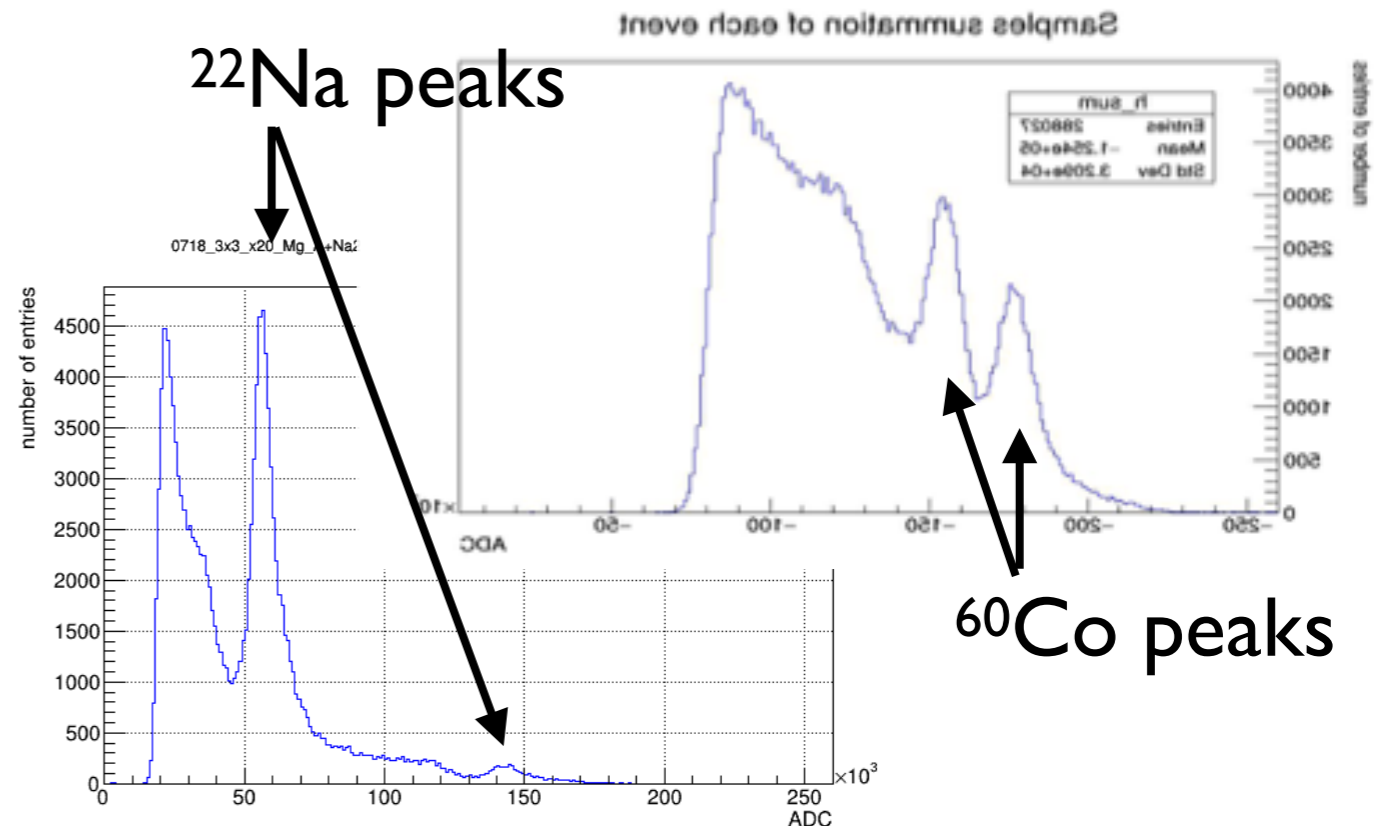
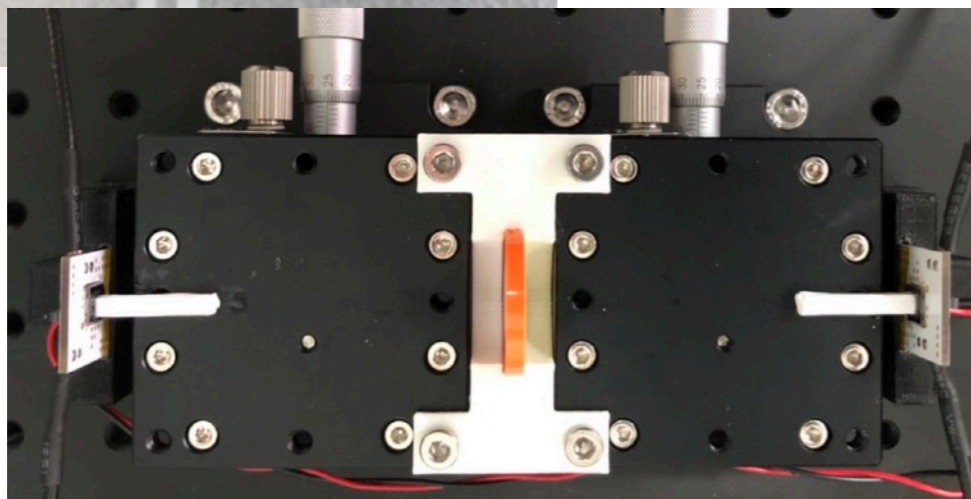
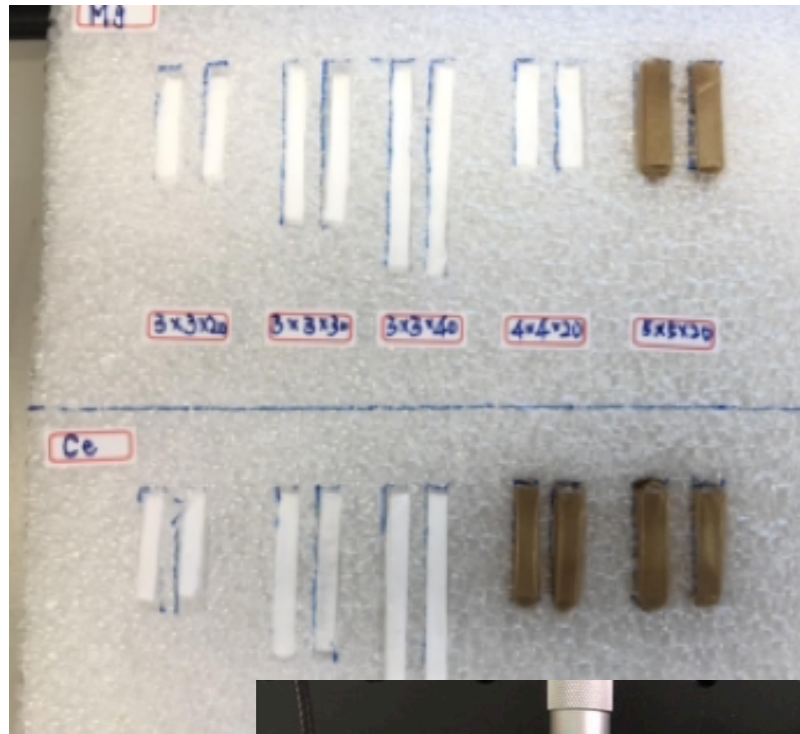
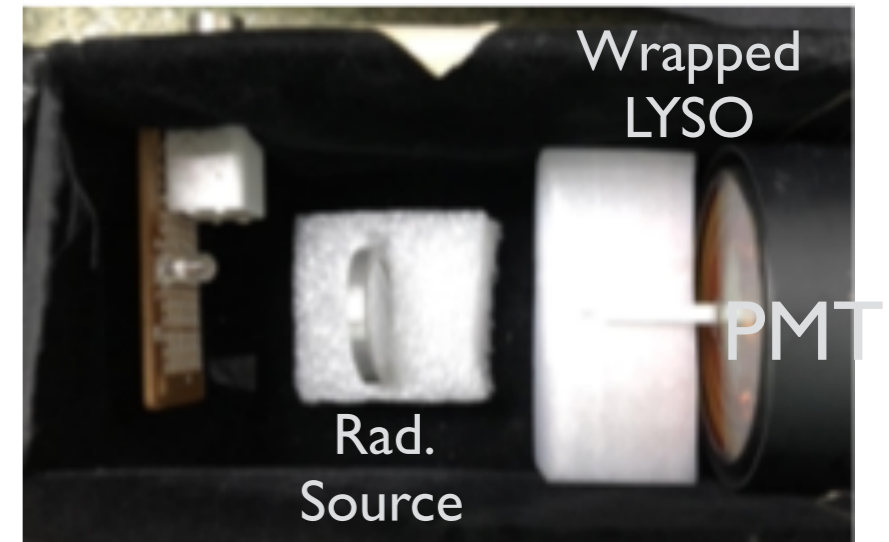


Collaboration with TCECM

TCECM : Taiwan Consortium of Emergent Crystalline Materials

臺灣大學

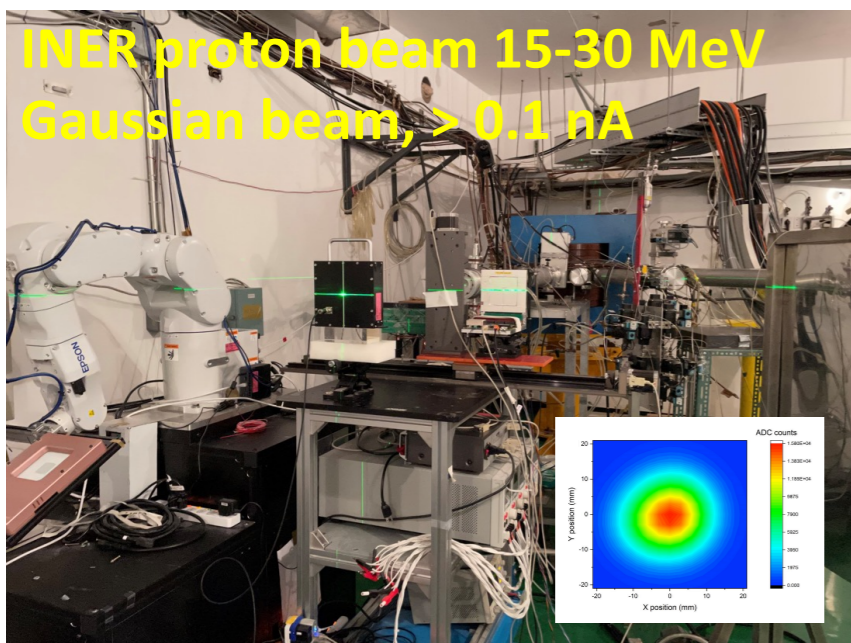
- NTU is setting up measurements for
 - ◆ Absolute light yield of LYSO crystal using PMTs
 - ◆ Time resolution of LYSO using SiPM
 - ◆ Reach $\sigma \sim 130$ ps CTR



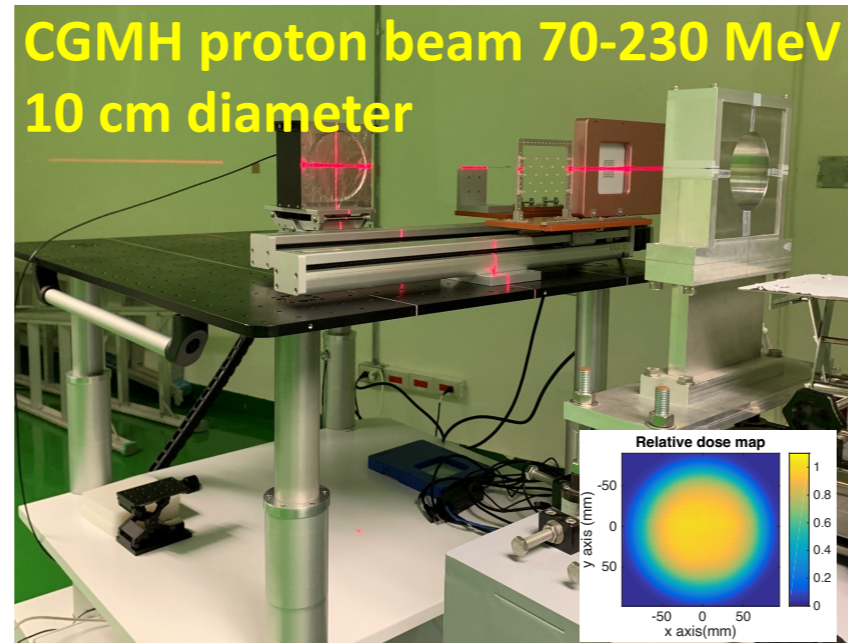
Others

Radiation Facilities

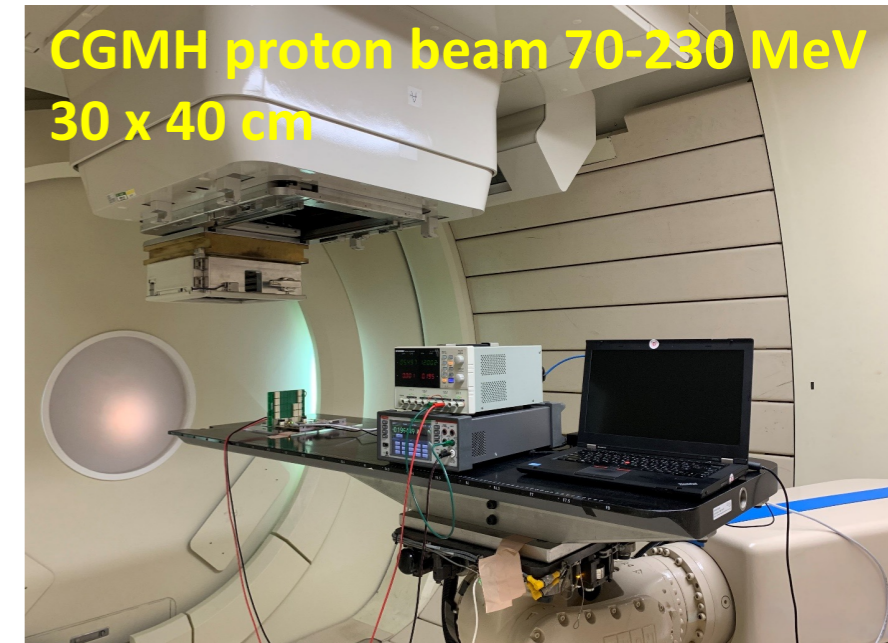
- Proton 15-30 MeV & 30 -70 MeV
 - ◆ Institute of Nuclear Energy Research (INER)
- Proton 70-230 MeV
 - ◆ Chang-Geng Memorial Hospital (CGMH)
 - ◆ National Taiwan University Hospital (NTUH), Taipei Medical University Hospital (TMUH), China Medical University Hospital (CMUH)
- Carbon (138 - 430 MeV/u)
 - ◆ Taipei Veterans General Hospital (TVGH)
 - ◆ $LET(Si) = 0.083 - 0.162 \text{ MeV} \cdot \text{cm}^2 \text{mg}^{-1}$



NCU workshop on EIC



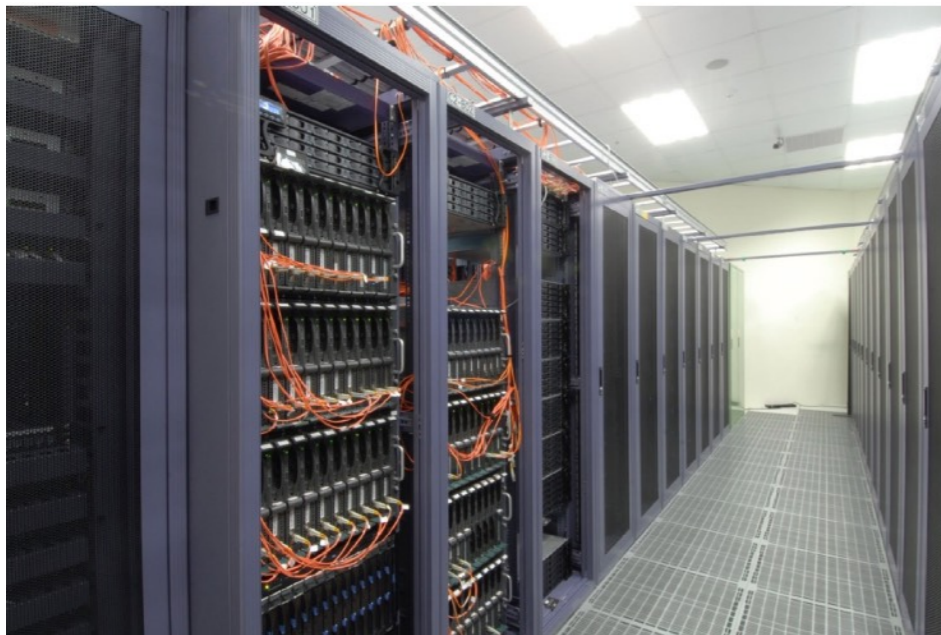
Rong-Shyang Lu / NTU



Dec. 9th, 2022

Computing Resources in Taiwan

- Academia Sinica Grid Computing Centre (ASGC) was established in 2005, whose founding goal is to build up the global distributed computing infrastructure for Large Hadron Collider (LHC) experiments – Worldwide LHC Computing Grid (WLCG), coordinated by CERN
- All these resources are shared to all ASGC users on First-Come-First-Serve basis
- Resources of IOC, CMS and newly procured ASGC Storage (1.5PB) will be online in late 2022 or early 2023.
- All users need to pay for the ASGC resource and services based on the collaboration model with ASGC → Pricing model will be finalized and announced in late 2022



NCU workshop on EIC

	Shared Resource	Priority Resource						Total
		IOP	CryoEM	ASIAA	IOC	WLCG - ATLAS	WLCG - CMS	
GPU (#Boards)	168	8	32		12			220
CPU (#Cores)	2,976			1,792	1,536	4,736	768	11,808
Storage (TB)	12,398		1,024	1,024	1,152	12,384	1,728	29,710

Rong-Shyang Lu / NTU

EIC Projects

EIC Workshop in Taiwan

- The aims for this workshop are bringing all QCD enthusiasts in Taiwan together, discussing the physics topics and potential detector developments for EIC, educating ourselves to have a smooth transition from “high energy physics” to “nuclear physics”.

<https://indico.phys.sinica.edu.tw/event/52/>



TIDC EIC Workshop

August 18–19, 2022
Department of Physics, NCKU, Tainan, Taiwan

Agenda: <https://indico.phys.sinica.edu.tw/event/52/>

Invited Speakers:
Chung-Wen Kao (CYCU)
Hsiang-nan Li (AS)
Po-Ju Lin (AS)
Jen-Chieh Peng (UIUC)
Zhenyu Ye (UIC)
Rong-Hwei Yeh (Asia Univ.)

Organizers:
Wen-Chen Chang (AS)
Chia Ming Kuo (NCU)
Rong-Shyang Lu (NTU)
Yi Yang (NCKU)

Sponsors
Ministry of Science and Technology (MOST)
Taiwan Instrumentation Detector Consortium (TIDC)
National Cheng Kung University (NCKU)
Department of Physics, NCKU



TIDC
Taiwan Instrumentation and Detector Consortium
台灣偵測器聯合實驗室



成功大學
Physics@National Cheng Kung University



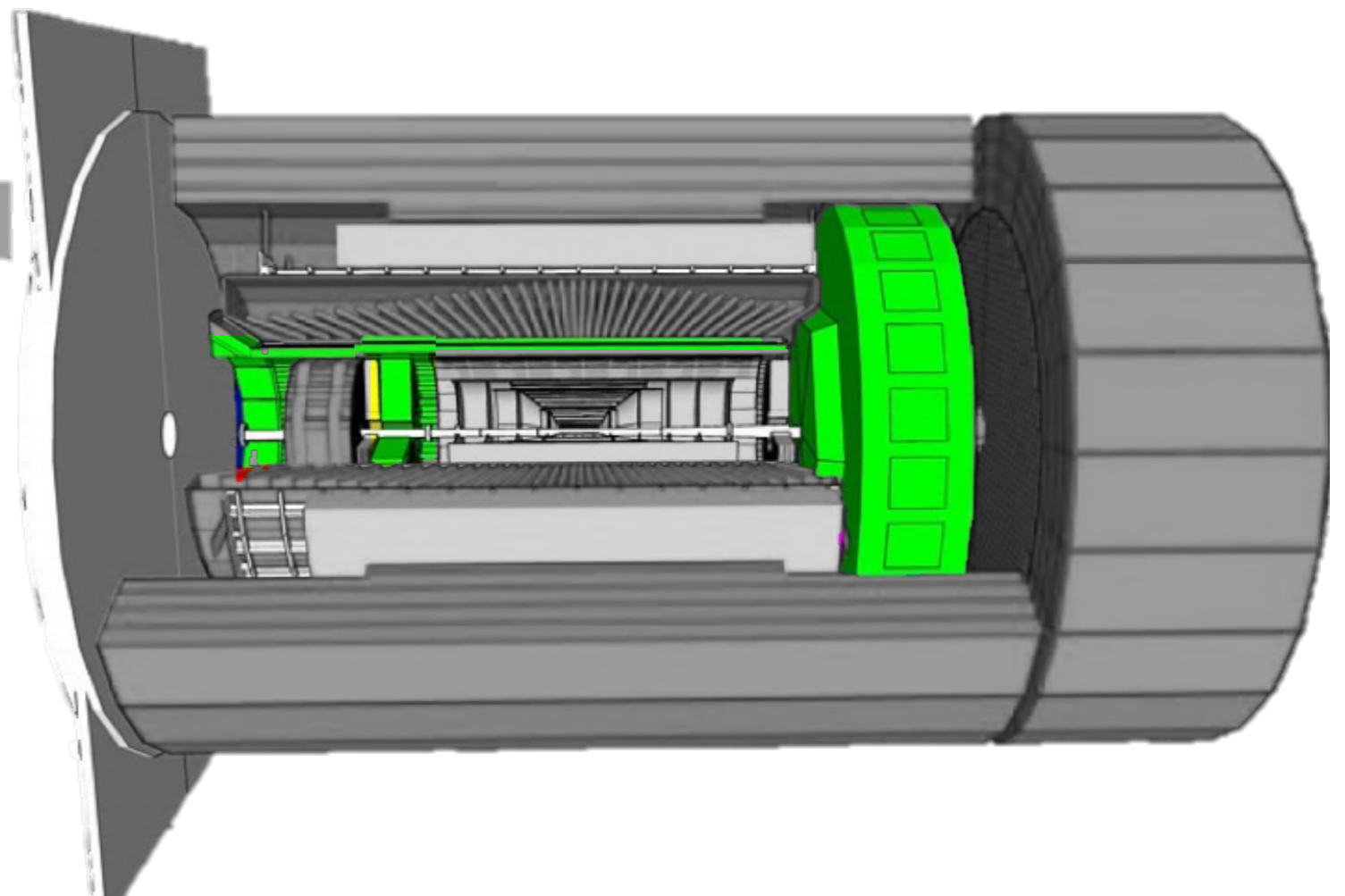
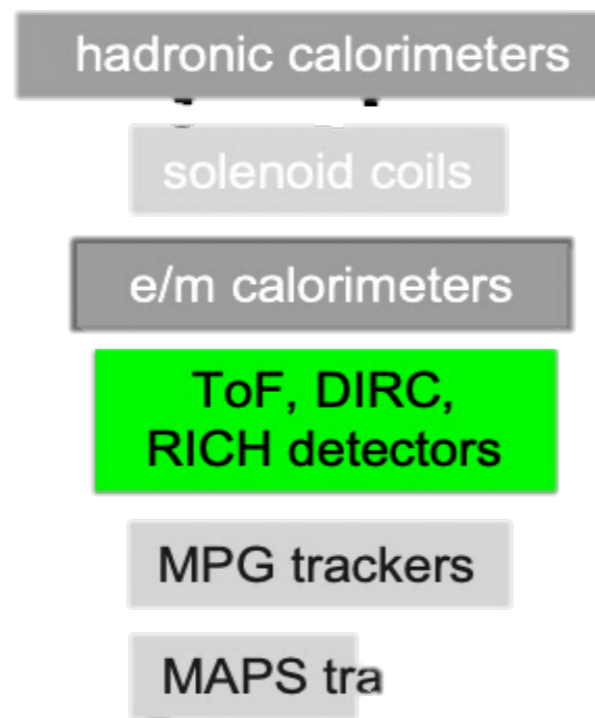
NCU workshop on EIC

Rong-Shyang Lu / NTU

Dec. 9th, 2022

EIC Project

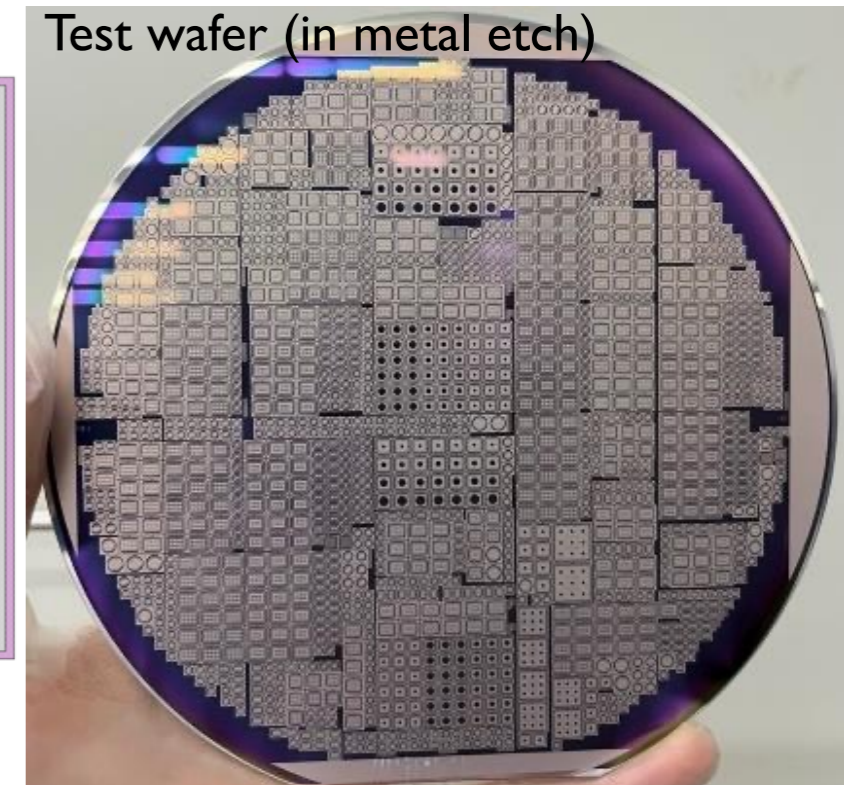
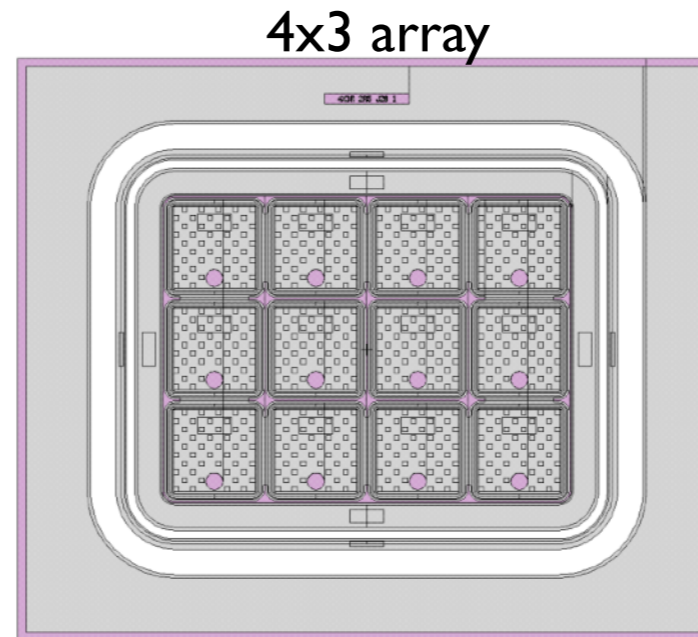
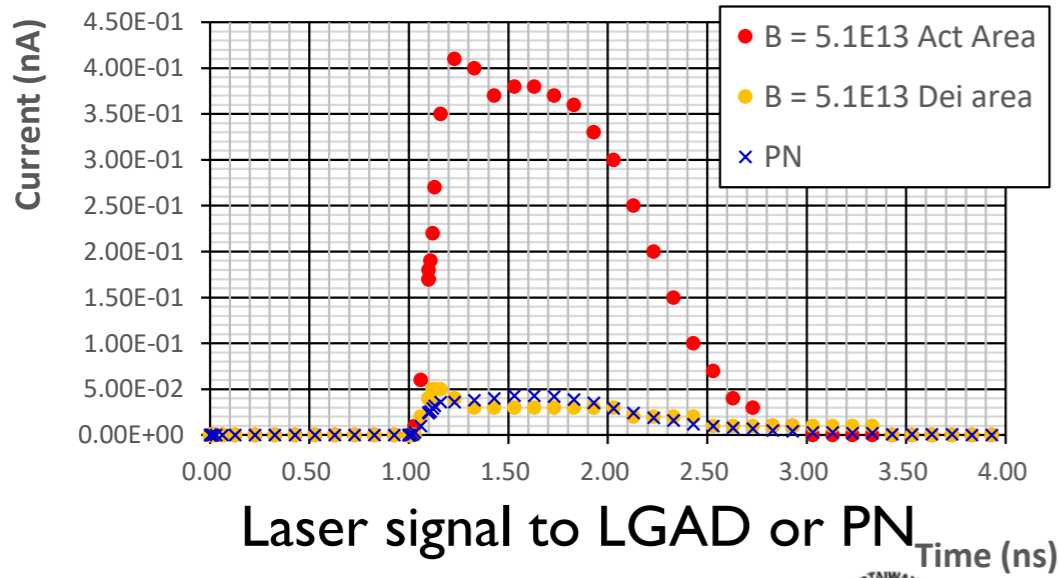
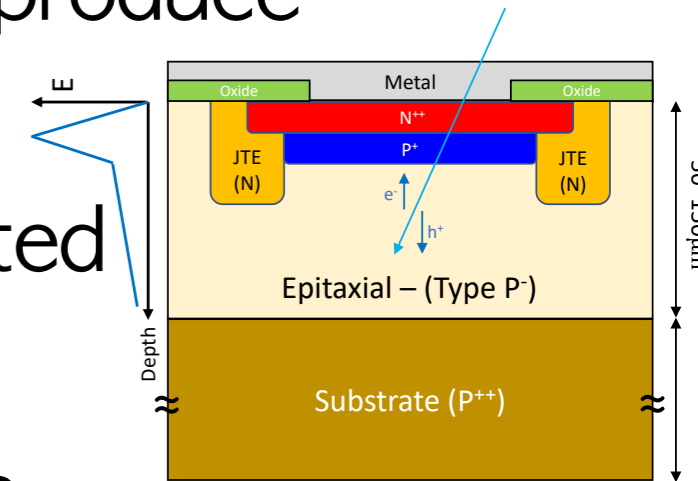
- Lots of opportunities and interesting stuffs in EIC
- Taiwan EIC consortium concentrates on the TOF (LGAD/
silicon related) detector R&D for now
 - ◆ DC-LGAD
 - ◆ Mechanical structure
 - ◆ Optical readout



DC/AC LGAD

See Kai-Yu Cheng's talk

- Collaborating with local institute/company to produce DC-LGAD. Exploring the fabrication possibility
- Designed various LGAD structure and submitted mask for production
- Gain and signal simulation done. Await for the sample to confirm



- NCKU/AS and Purdue University will work together on the mechanical structure for TOF
 - ◆ eRD112 proposal
 - ◆ Project Engineering & Design (PED) Request for Project Engineering and Design Support for EPIC TOF Detectors

Low Mass Support Structure for EPIC

W.-C. Chang¹, A.W. Jung², P.-J. Lin¹, Y. Yang³,

¹ Academia Sinica, Nankang, Taipei 11529, Taiwan

² Purdue University, West Lafayette, IN 47907, USA

³ National Cheng Kung University, Tainan, 70101, Taiwan

September 2022

1 Proposed FY23 Work for Purdue/NCKU/AS

Purdue University (US), National Cheng Kung University (NCKU, Taiwan), and Academia Sinica (AS, Taiwan) will collaborate on the design and manufacture of the mechanical support structure for the TOF detector in EPIC. To meet the required precision and material budget of TOF measurements, carbon fiber composite materials have been proposed for manufacturing the light-weight support due to their high thermal conductivity, strength to mass ratio, and radiation tolerance.

Oskar Hartbrich (ORNL),
Andreas Jung (Purdue),
Po-Ju Lin (AS),
Yi Yang (NCKU),
Zhenyu Ye (UIC)
for the EPIC TOF group.

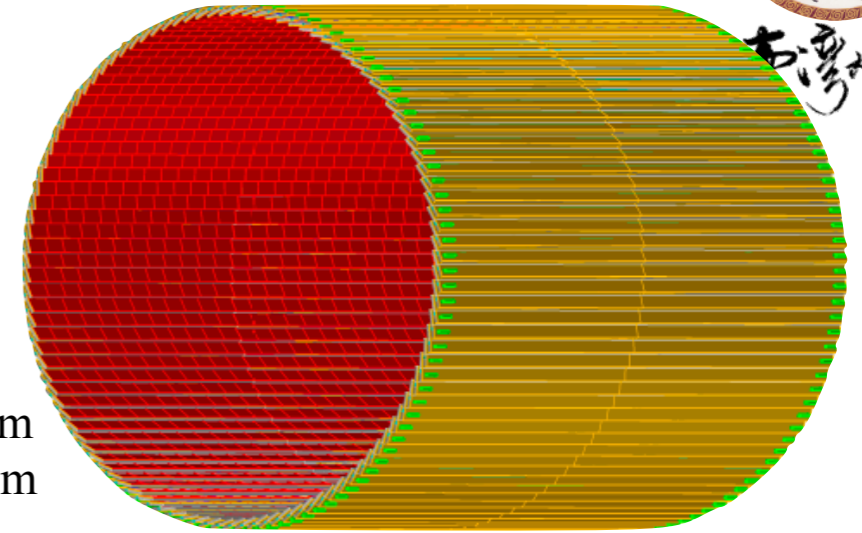
October 2022

1 Introduction

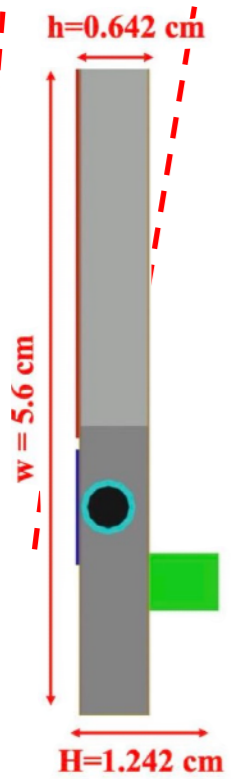
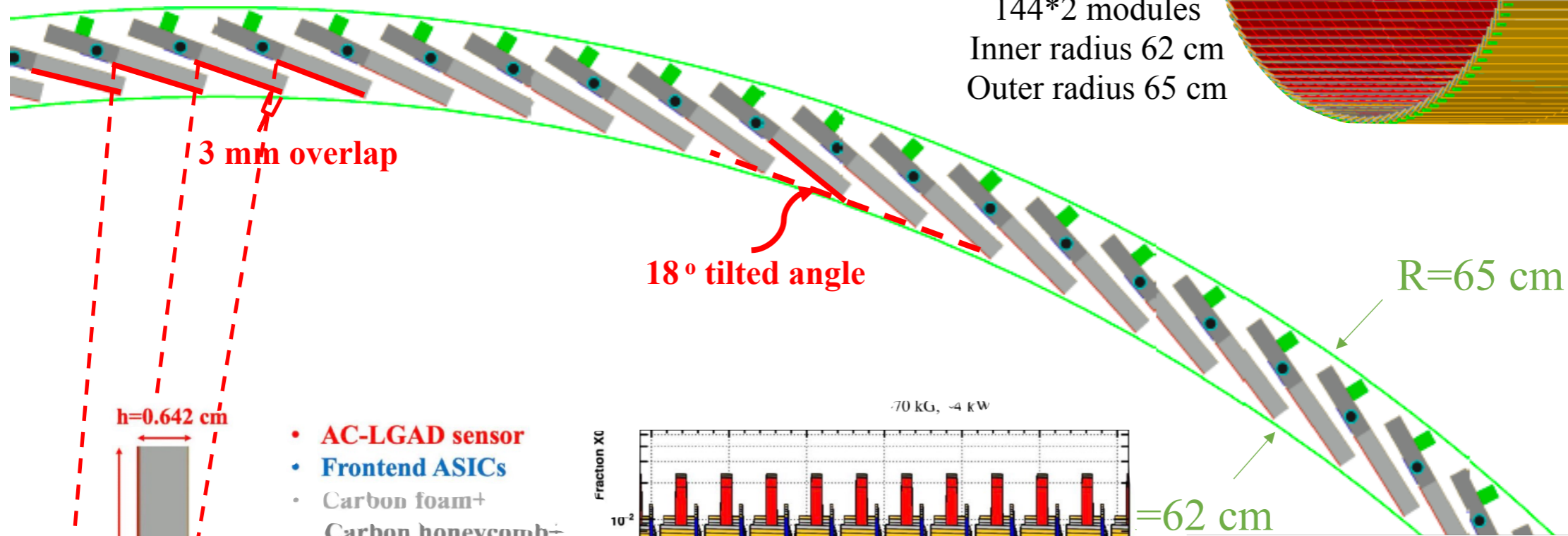
A number of AC-LGAD detector system aspects which constitute project engineering will need to be addressed in time for the CD2/3a review. This includes preliminary mechanical engineering design of the barrel and endcap TOF detector systems to be able to connect all electrical, optical and cooling services and provide a realistic plan of pre-assembling modules and services onto the mechanical structure, so that the assembled detectors can be integrated into EPIC with minimal post-assembly. Prototype mock-up structures will need be constructed to demonstrate the feasibility of production and assembly of individual parts where necessary. A detailed study of an appropriate cooling system will also be needed to quantify potential heating effects of surrounding detector systems, specifically the very temperature sensitive backwards ECAL crystals. The details of the plan and funding requests will be described in this Project Engineering and Design (PED) request.

EPIC Barrel TOF

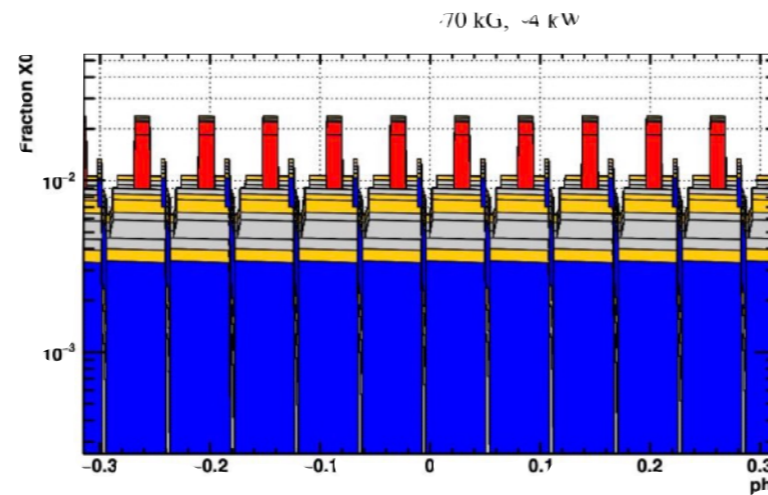
- Single layer of strip AC-LGAD sensors
 - ◆ $62 < R < 65$ cm, 2.7 m long, ~ 11 m² area
- Use the similar concept of STAR IST



144*2 modules
Inner radius 62 cm
Outer radius 65 cm

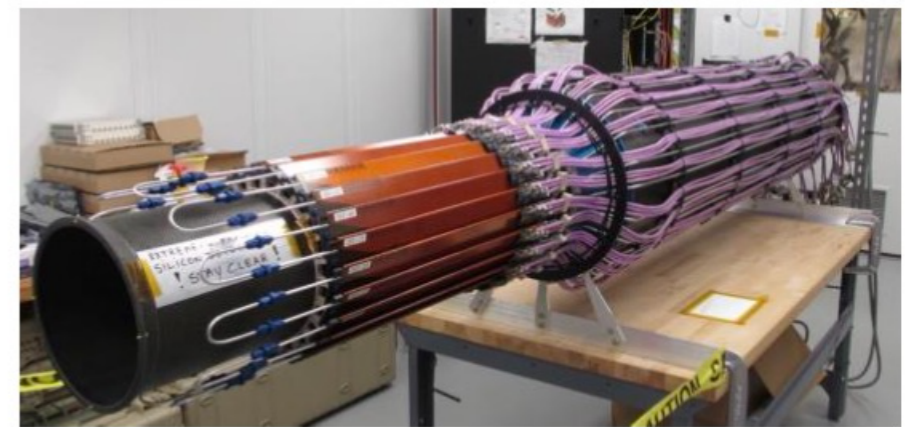


- AC-LGAD sensor
- Frontend ASICs
- Carbon foam+
Carbon honeycomb+
CF skins
- Al cooling tube
- Liquid coolant
- Kapton PCB
- Connector



$l = \frac{1}{2} L = 1.35$ m

From Zhenyu's talk
<https://indico.bnl.gov/event/1>



- In total 288 modules,
 - 9216 sensors, 18,432 ASICs, 2.4 M channels
 - ~ 70 kG, ~ 4 kW

Optical Readout

- DAQ and data links will be totally Fiber-optics
- Taiwan opto-electronics IT is the primer production choice. LHC upgrade electronics are TW made.
 - ◆ With small funding on R&D
 - ◆ stay on Rad-hard Opto-electronics.
 - ◆ TW as the production site
- collaborate with US groups on opto-ASICs and data-link protocol



Suen Hou
Academia Sinica

Opto-fiber RD items

- **Fiber Rad-hard**
MM Ge-doped @INER Co60 TID study is finishing
COTS, Fluorine-dope, pure Silica fiber Rad-hard study
- **Rad-hard Active opto-electronics**
850 nm VCSEL, PD characteristics, COTS 光環, II-VI, ..
NIEL @INER 30 MeV protons
- **ASICs, laser driver, PD TIA** ← **deadly issue!**
lack of expertise!!
Collab. with HEP groups, acquire known chips
check on COTS
- Transceiver >10 Gbps
fabrication vs speed: PCB, passive, connectors, design, 前鼎, 源傑,
coupling: active, lens, to fiber-ends
NIEL, Ageing to Bit-Error-Rate
- **Facilitate INER proton beam for Rad-hard studies**

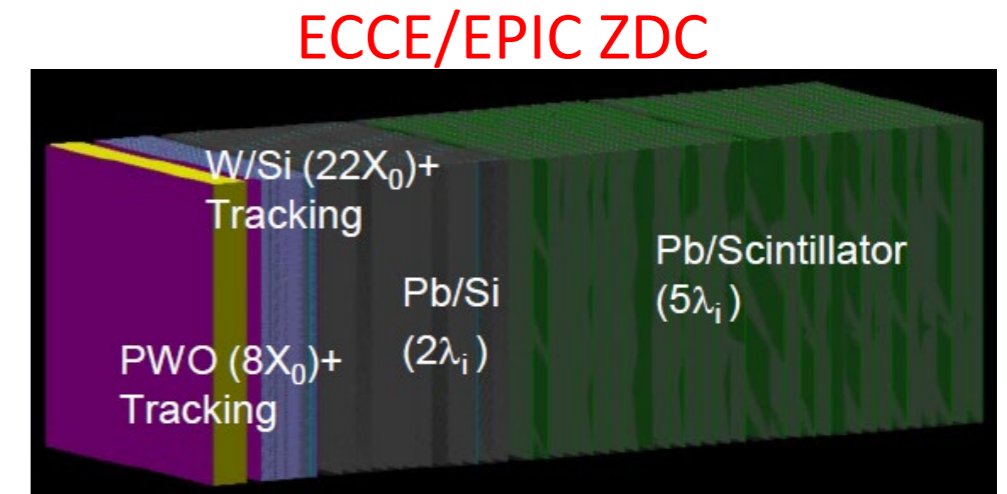
https://indico.phys.sinica.edu.tw/event/52/contributions/248/attachments/202/337/EIC_NCKU2022_v2.pdf

Slides from Yuji Goto

Collaboration opportunities

- EPIC ZDC

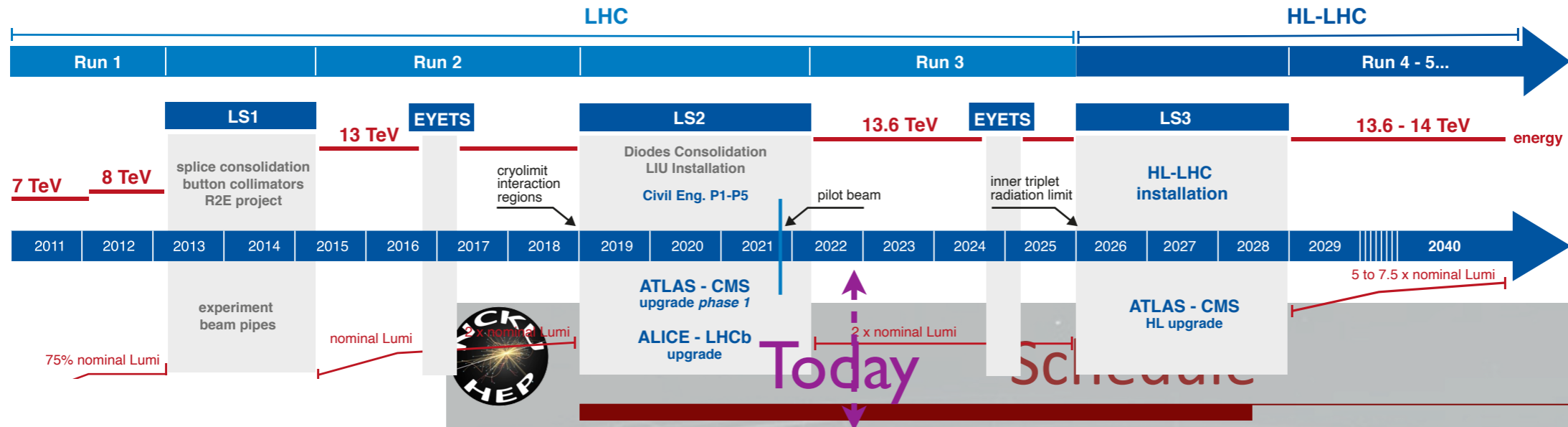
- Soft photon detection
 - Crystal calorimeter (PWO, LYSO, ...)
 - Readout device (APD, PMT, ...)
- EM hadron calorimeter



- There is an interest in building a prototype calorimeter with LYSO possibly read out by SiPM.
- It complements with PWO prototype effort.
- We have a local supplier linked through TCECM.

Timeline

<https://hilumilhc.web.cern.ch/content/hl-lhc-project>



Today

	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34		
Critical Decisions		★ CD-0(A) Dec 2019	★ CD-1(A) Jun 2021			★ CD-2/3A Jan 2024	★ CD-3 Apr 2025							★ CD-4A Approve start of operations Apr 2032	★ CD-4 Approve proj. completion Apr 2034			
Research & Development		Accelerator Systems Detector	Research & Development											↑ Early CD-4A Completion Apr 2031	↑ Early CD-4 Completion Apr 2032			
Design		Conceptual Design	Infrastructure					Accelerator Systems	Detector									
Construction & Installation				Infrastructure	Conventional Construction													
				Accelerator Systems	Procurement, Fabrication, Installation & Test										Full RF Power Buildout			
				Detector	Procurement, Fabrication, Installation & Test													
Commissioning & Pre-Ops							Accelerator Systems	Commissioning & Pre-Ops										Full RF Power Buildout
							Detector	Commissioning & Pre-Ops										

Planned Conclusion of RHIC Operations

Key	(A) Actual	Completed	Planned	Data Date	Level 0 Milestones	Critical Path	Schedule Contingency
------------	------------	-----------	---------	-----------	--------------------	---------------	----------------------

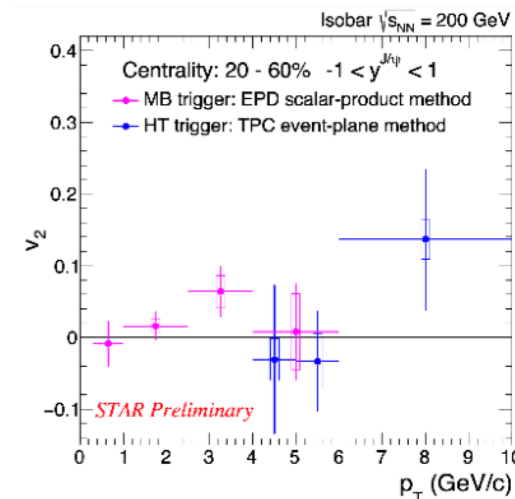
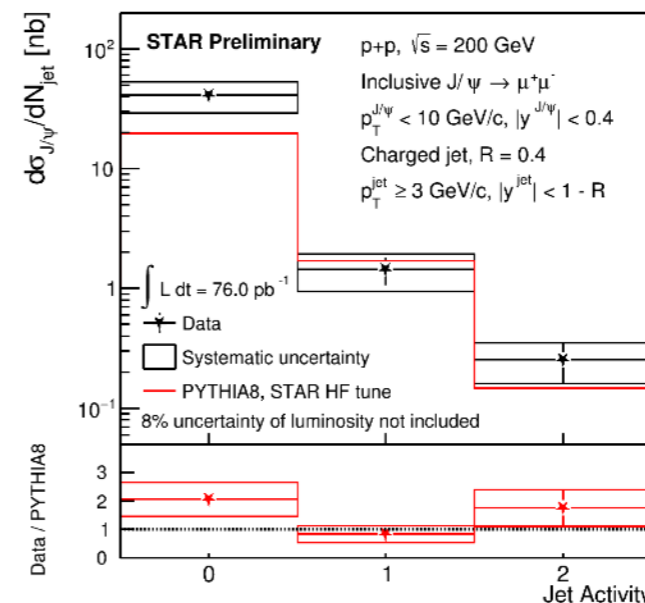
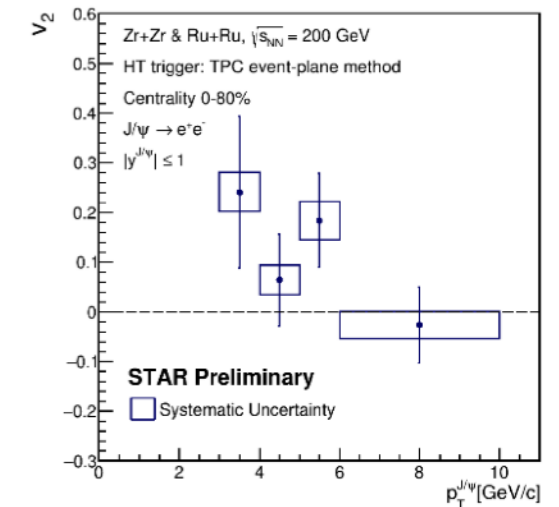
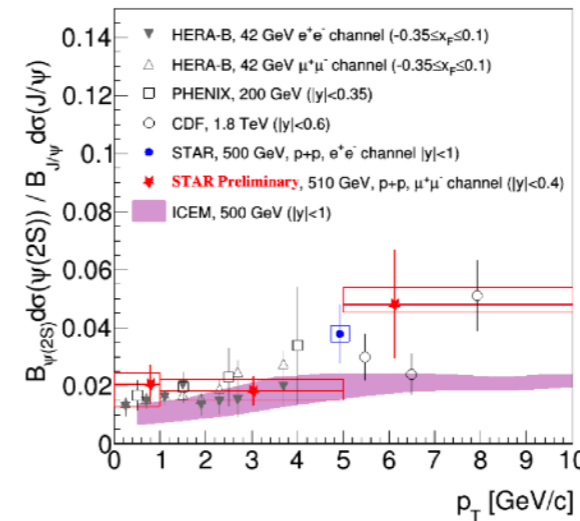
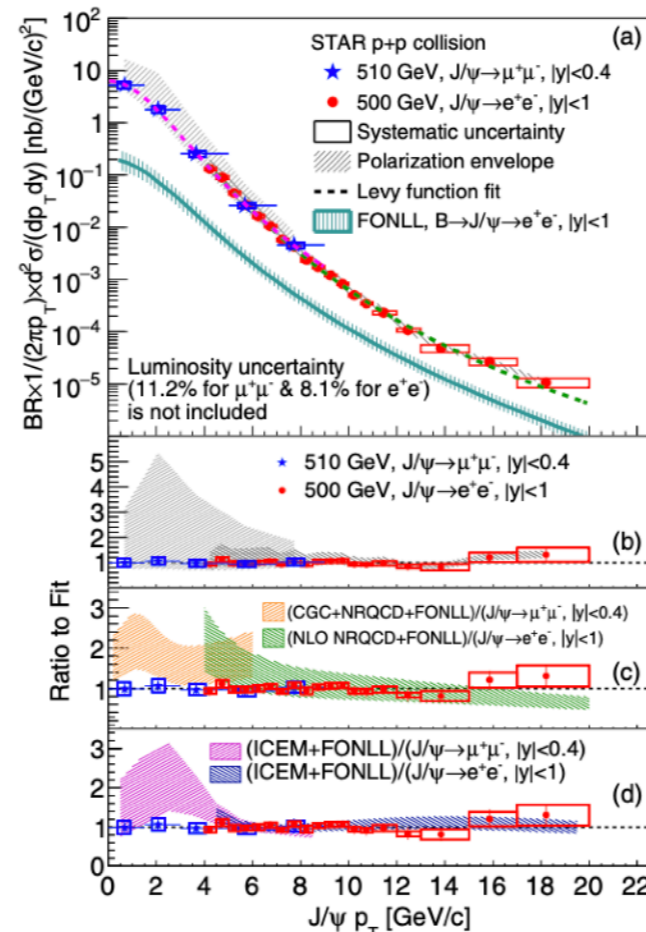
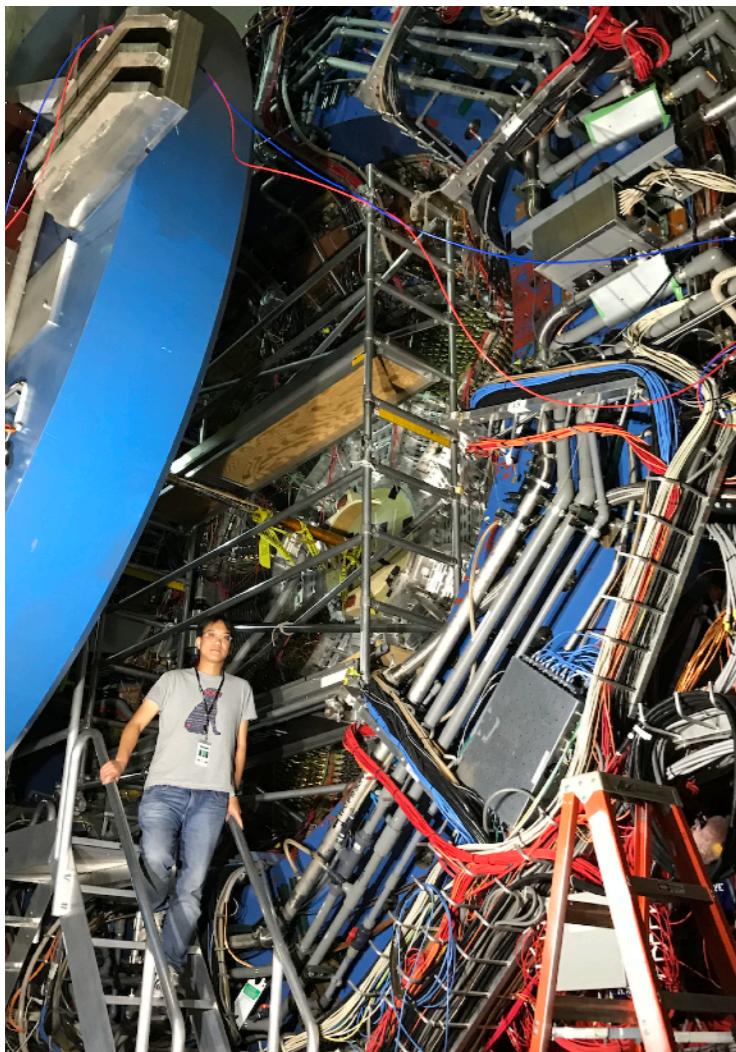
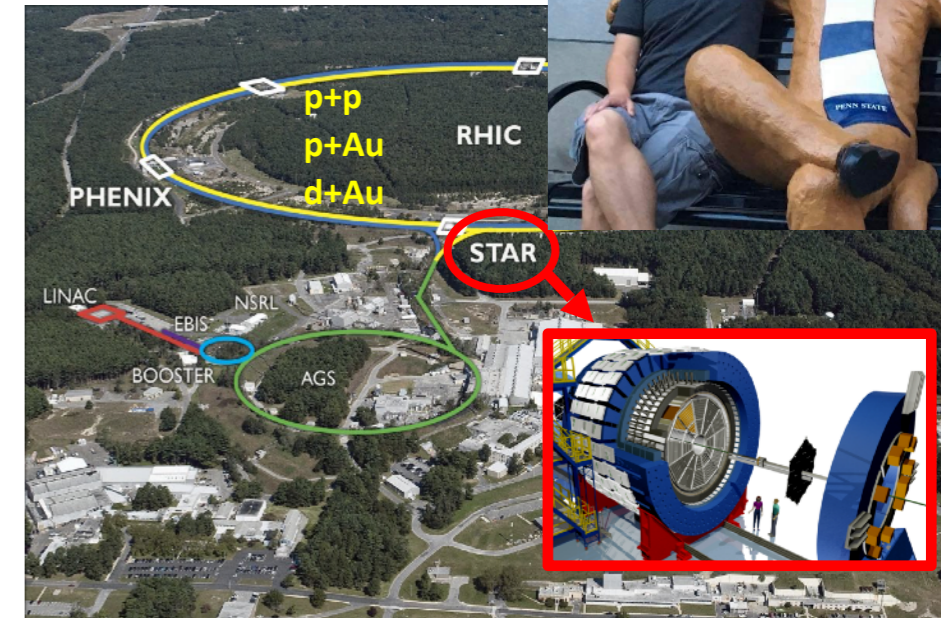
Summary

- After the HL-LHC upgrade, the next hardware project is likely to be with EIC.
- TW-HEP have expertises in Silicon detector and is progressing R&D of LGAD. We can definitely contribute to either/both silicon tracker and PID-ToF.
- There may be other opportunities for contributions, such as Calorimeter, electronics, and computing.

Backup Slides

Heavy Ion Physics @ STAR

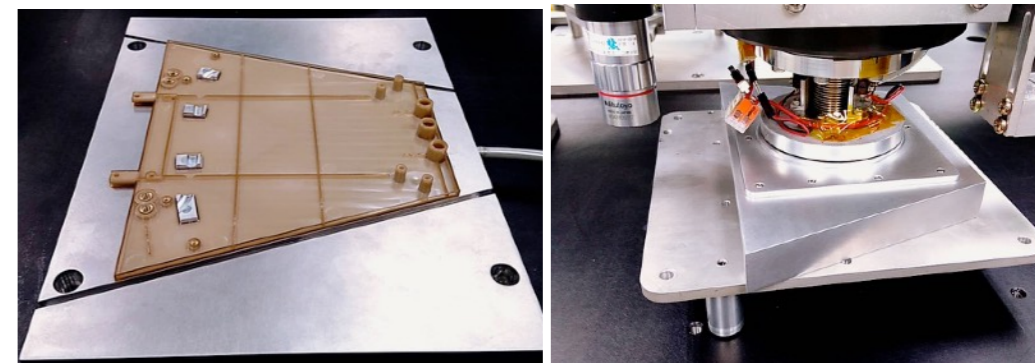
- Yi Yang @ NCKU (Hard Probe convener)
- NCKU (2014 ~) is heavily involved in the operation and performance of Muon Telescope Detector, and forward upgrade.
- Main physics results are the production of J/ψ , $\psi(2S)$, and Y in p+p, p+A, and A+A collisions



STAR Upgrade: Forward Silicon Tracker

- Yi Yang @ NCKU (Deputy project manager)
- NCKU designed, manufactured, and assembled the mechanical structure
- NCKU is also developing silicon strip detector with Taiwan Semiconductor Research Institute

Assembly @ TiDC



Inner Signal Cable: **BNL**

T-Board: **SDU/IU**

Mechanical Structure: **NCKU**

Flexible hybrid PCB: **SDU/IU**

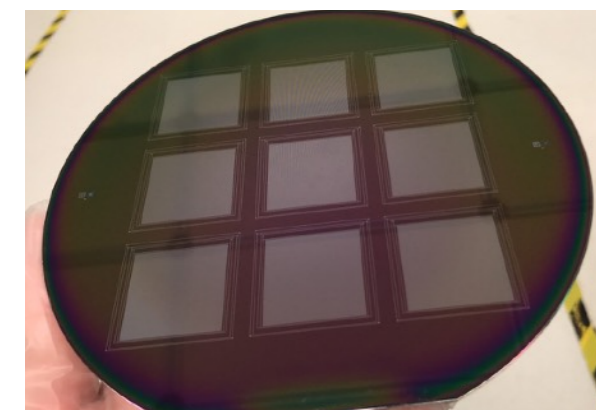
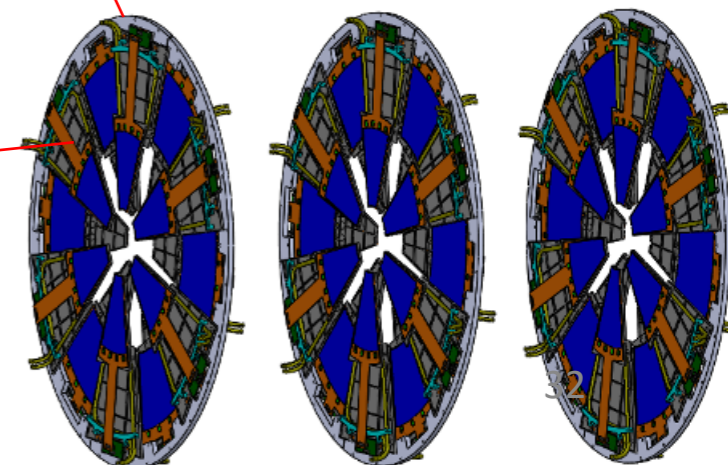
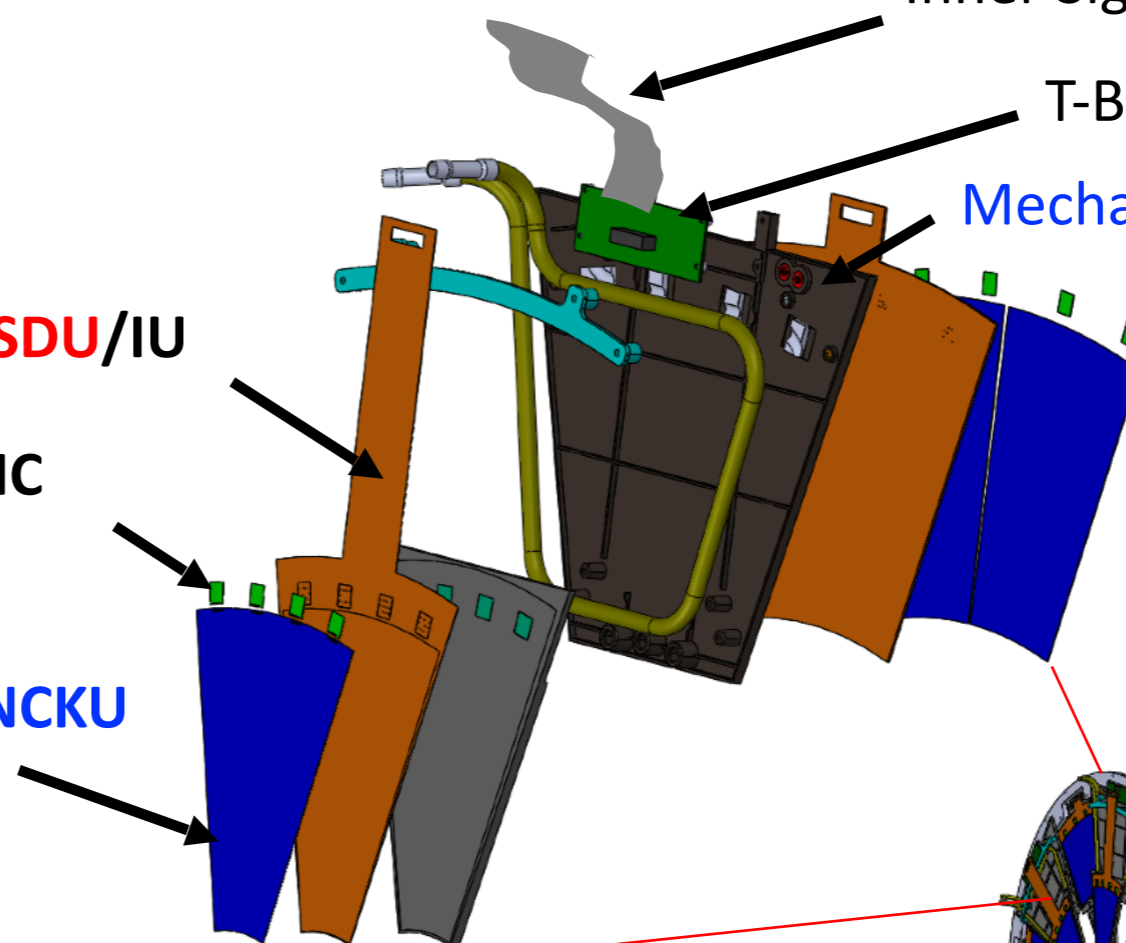
APV25 Chip: **BNL/UIC**

Silicon sensor: **UIC/SDU/NCKU**

Cooling: **BNL/NCKU**

Simulation: **NCKU/IISER/BNL**

Supporting Structure & Integration: **BNL**



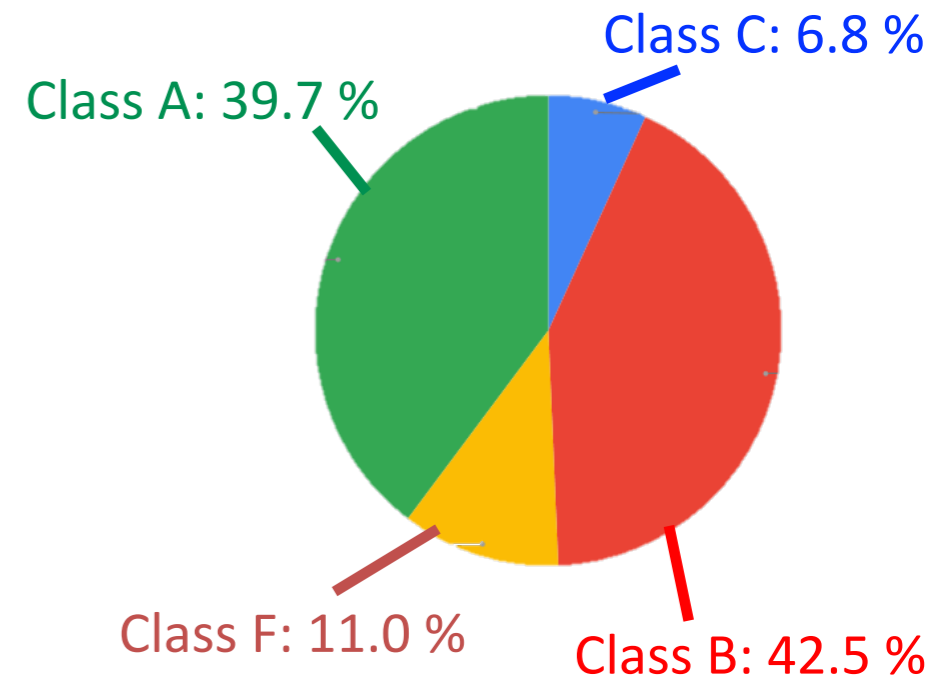


Example: STAR Forward Tracker

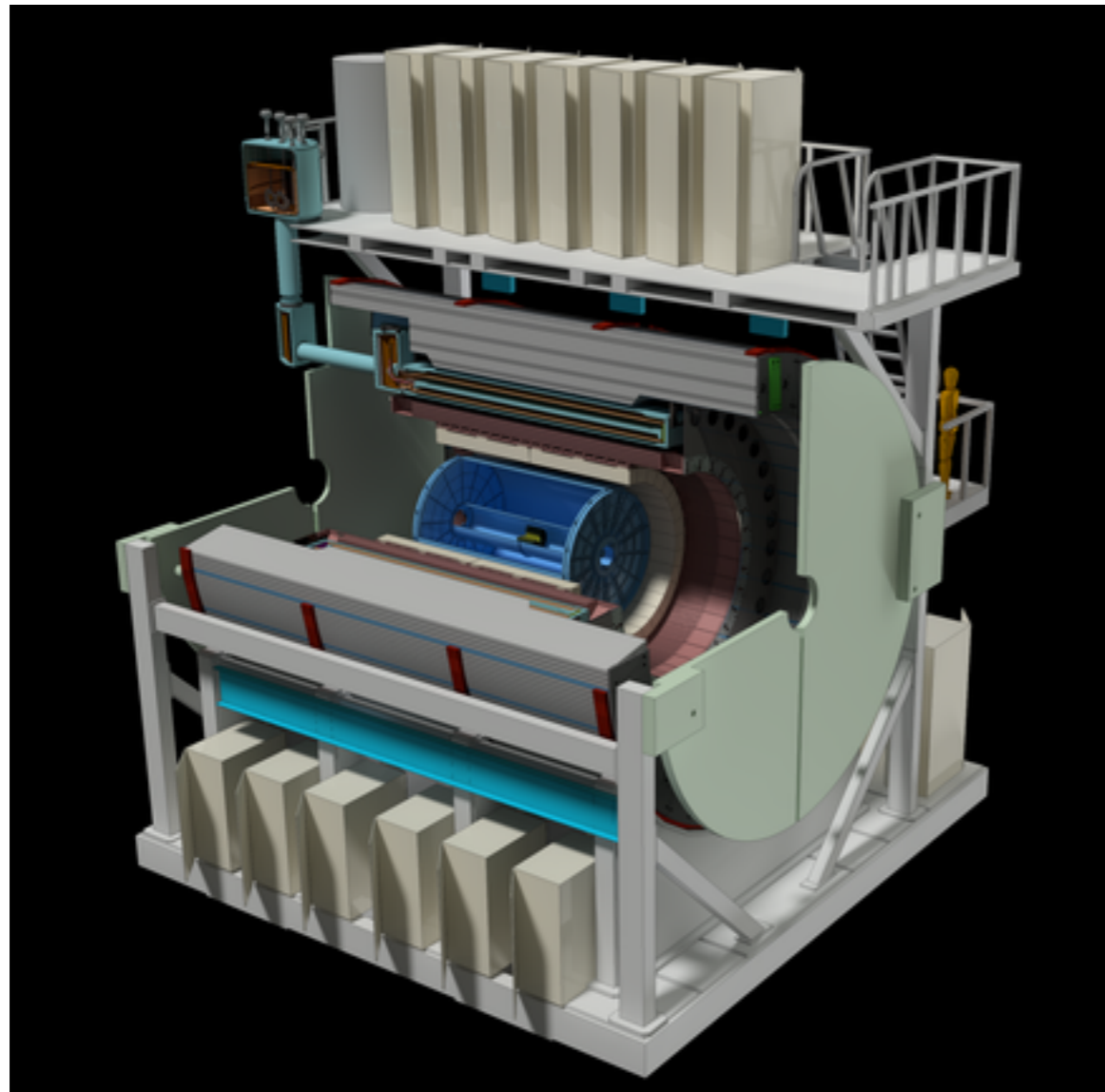
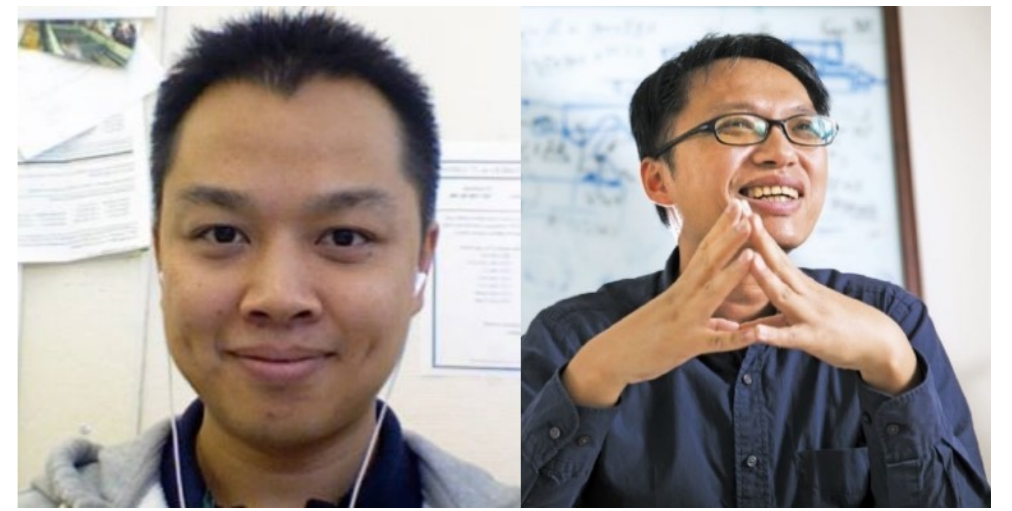


○ Total 73 modules (48 needed) are produced

→ Successful rate ~89%



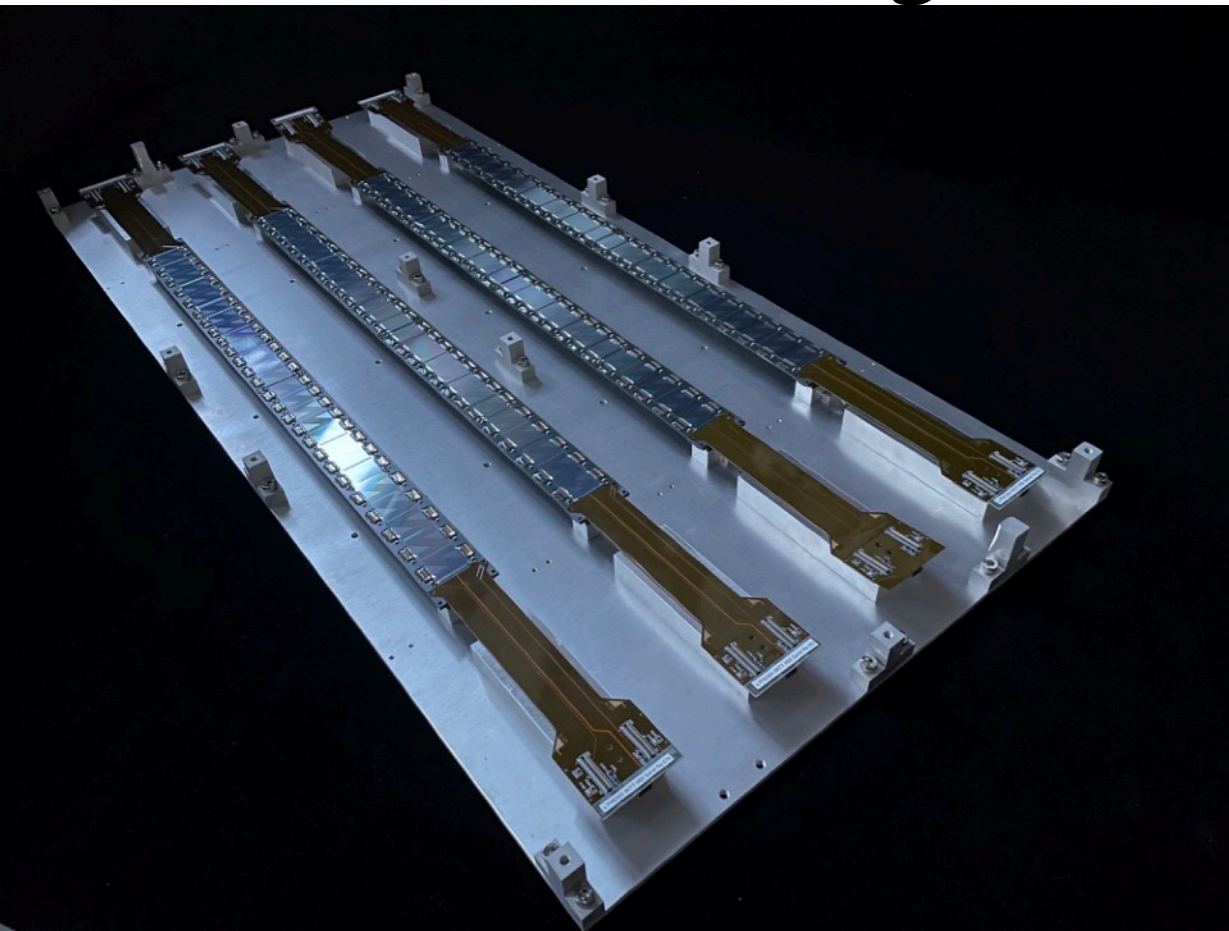
sPHENIX @ RHIC, BNL



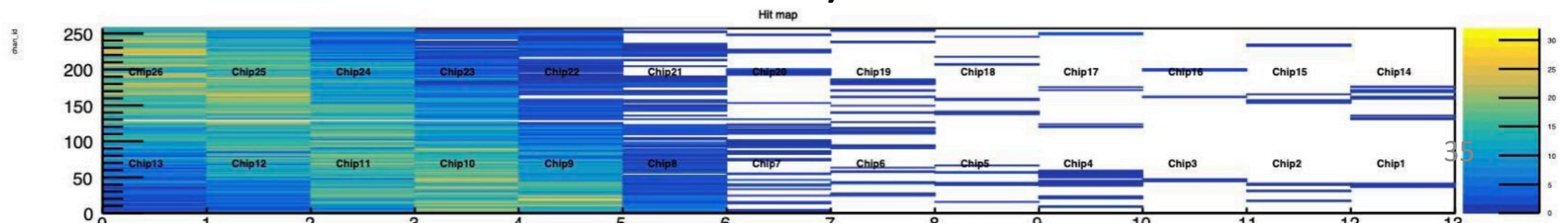
- Two institutes (NTU and NCU) are in the sPHENIX collaboration
- Involve in the beam test, silicon sensor QC and silicon ladder assembly for **the INTT (INTermediate Tracker) detector.**
- **We are working on the construction and commissioning of INTT detector now!**

sPHENIX: to study the strongly interacting quark-gluon plasma using jet and heavy-flavor observables.

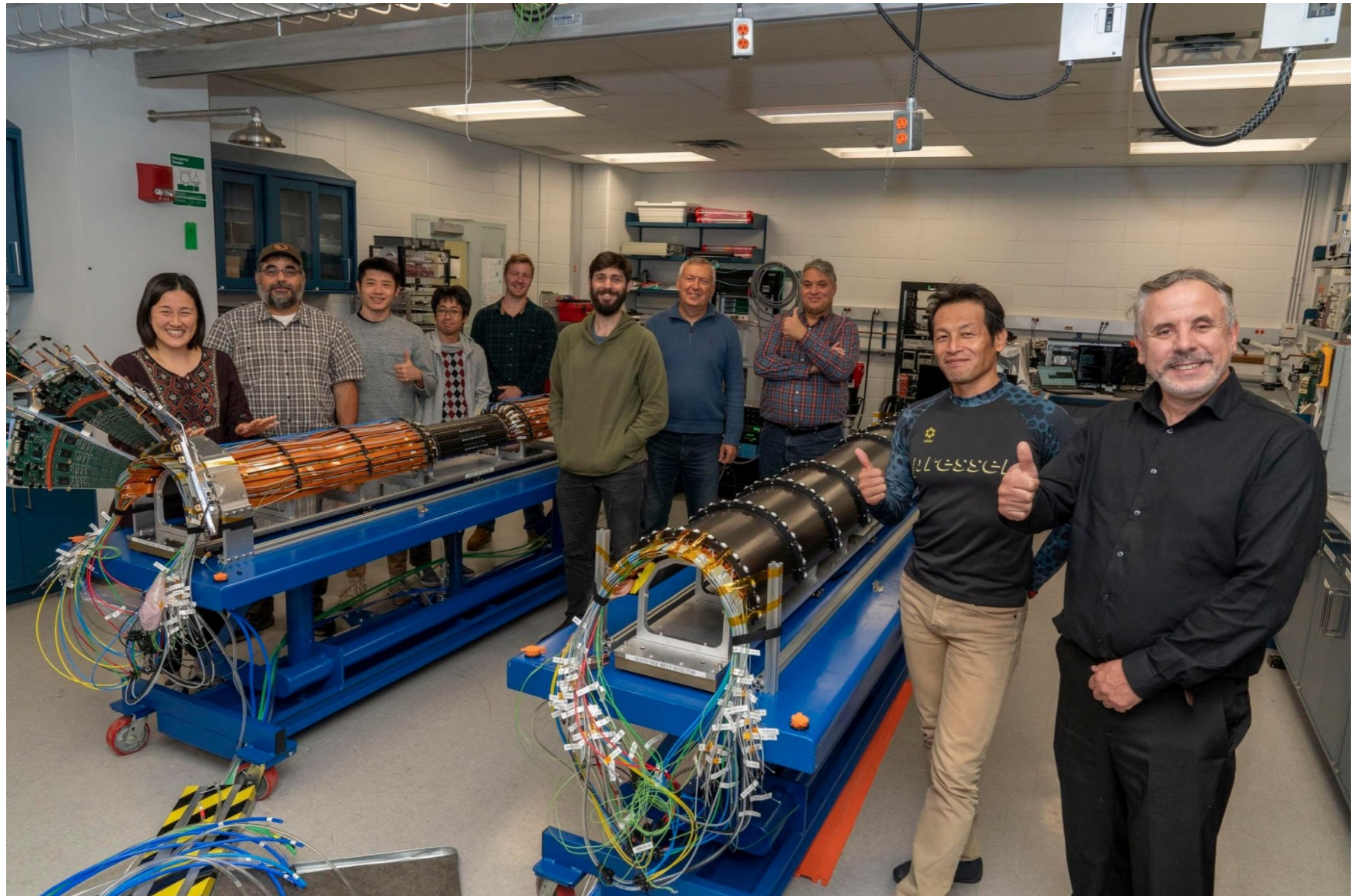
sPHENIX Silicon Ladder Assembly



Cosmic ray test



INTermediate silicon strip Tracker (INTT)



sPHENIX in Asia Meeting

Nov. 15-17, 2022, NCU

