Taiwanese Involvement in EIC

03 November 2022 @ APCTP EIC Workshop

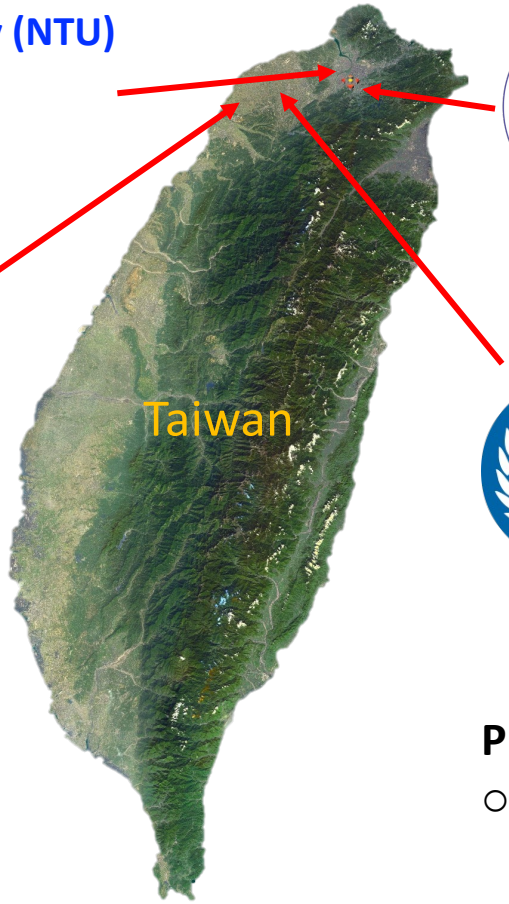
Yi Yang

National Cheng Kung University

Theoretical Groups

National Taiwan University (NTU)
Prof. Jiunn-Wei Chen

Academia Sinica (AS)
Prof. Hsiang-Nan Li
Prof. Di-Lun Yang



National Yang Ming Chiao Tung University (NYCU)
Prof. C.-J. David Lin

Chung Yuan Christian University (CYCU)
Prof. Chung-Wen Kao

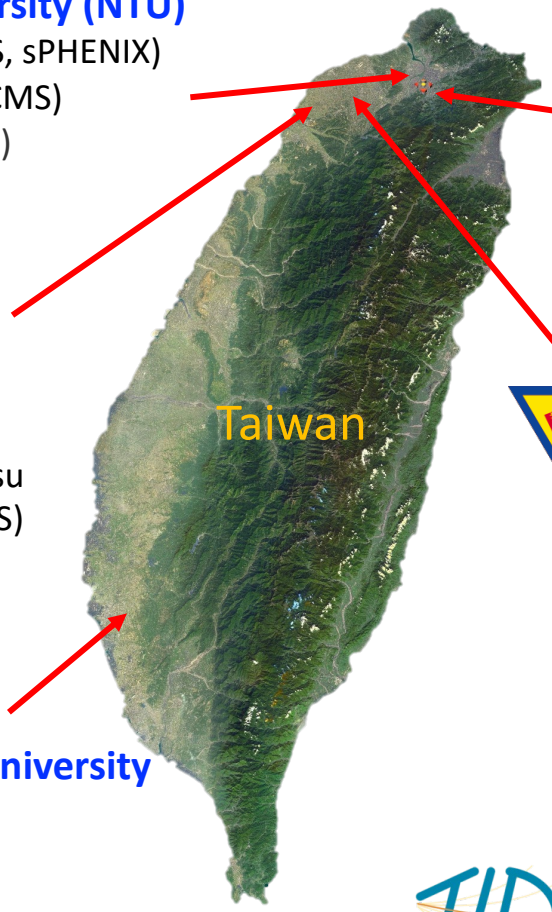
Physics interests:

- Nucleon/hadron physics with QCD effective theories & Lattice QCD
- Parton distribution functions
- Spin physics
- …

Experimental Groups

National Taiwan University (NTU)
Prof. Rong-Shyang Lu (CMS, sPHENIX)
Prof. Kai-Feng Jack Chen (CMS)
Prof. Stathes Paganis (CMS)

Academia Sinica (AS)
Prof. Wen-Chen Chang (COMPASS)
Prof. Suen Hou (ATLAS)
Prof. Yuan-Hann Chang (AMS)
Prof. Chih-Hsun Lin (AMS)



National Tsing Hua University (NTHU)
Prof. Pai-Hsien Jennifer Hsu (ATLAS)

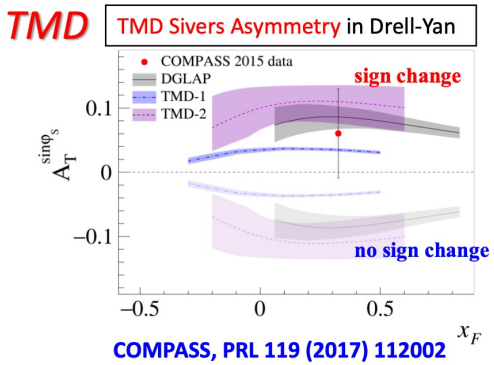
National Central University (NCU)
Prof. Chia-Ming Kuo (CMS, sPHENIX)

National Cheng Kung University (NCKU)
Prof. Yi Yang (STAR, AMS)

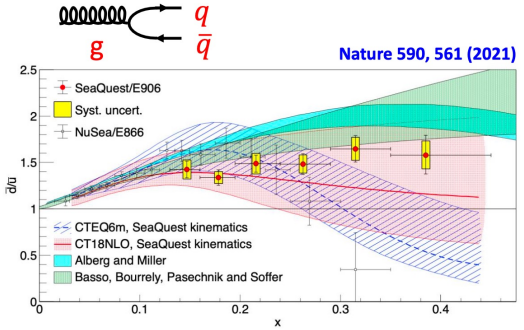
Taiwan Instrumentation and Detector Consortium (TIDC)
Director: Prof. Rong-Shyang Lu (NTU)
https://tidc.phys.ntu.edu.tw/WordPress/

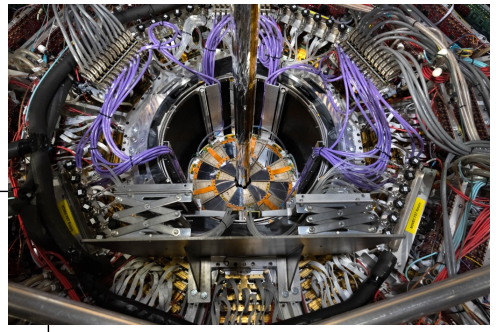
Previous Experimental Experiences

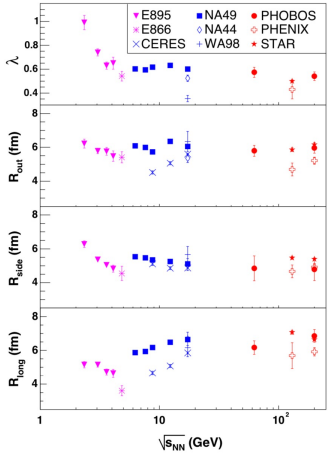
- **Hadron Physics**
  - LEPS (Spring-8)
  - SeaQuest (FNAL)
  - COMPASS(CERN)
- **Heavy-Ion Physics**
  - PHOBOS (BNL)
  - STAR (BNL)
  - sPHENIX (BNL)
  - CMS (CERN)

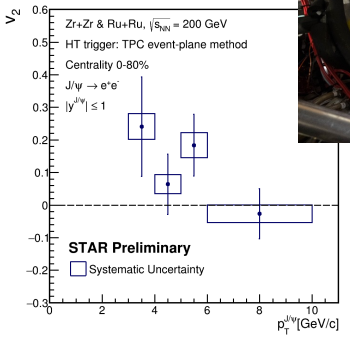


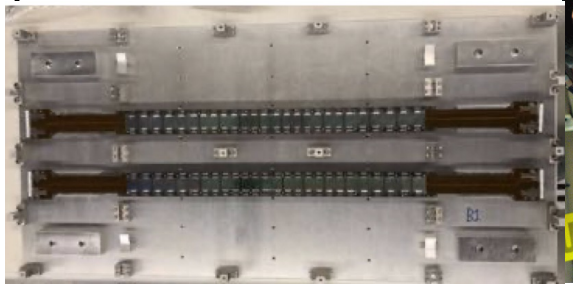
COMPASS, PRL 119 (2017) 112002

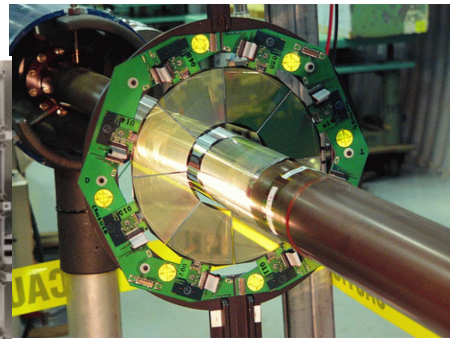


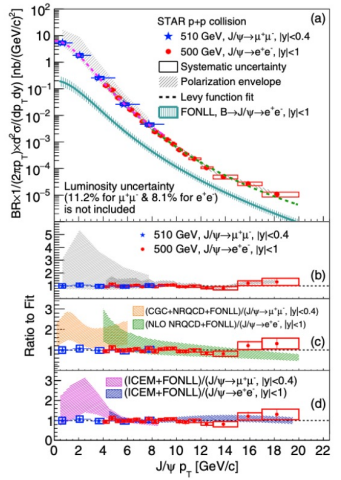






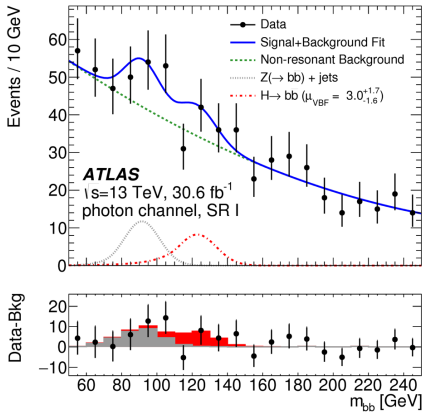


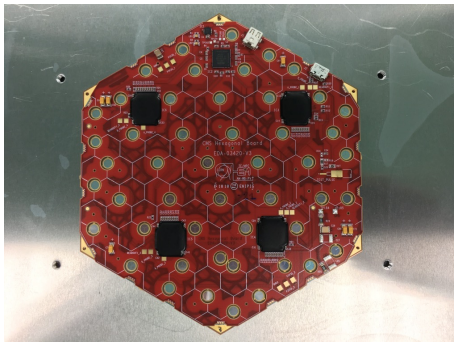


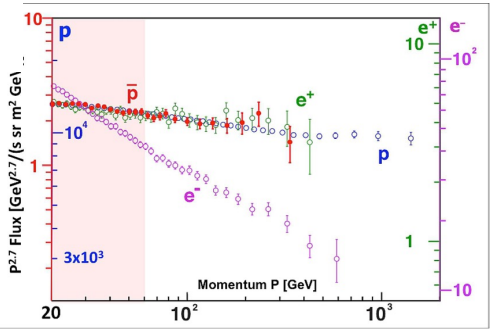


Previous Experimental Experiences

- **Particle Physics**
  - Belle (KEK)
  - CDF (FNAL)
  - ATLAS (CERN)
  - CMS (CERN)

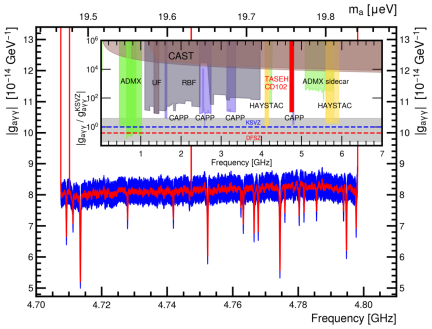


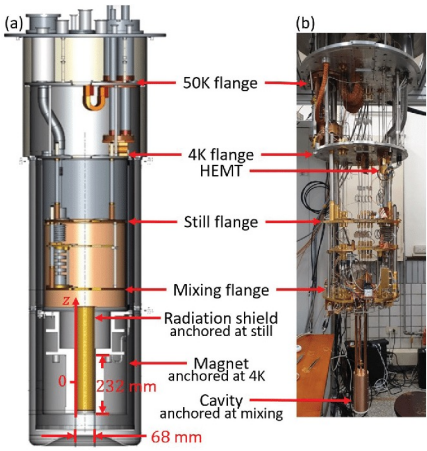




- **Astroparticle Physics**
  - AMS (ISS/CERN)

- **Neutrino/Dark Matter Physics**
  - TEXONO (KSNL)
  - CDEX (CJPL)
  - TASEH (NCU/AS)





EIC Workshop(s) in Taiwan

2022-08-18/19 @ NCKU

- 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/

Physics Interests (initial thoughts)

- **Pion and Kaon PDFs** (tagged-DIS; Sec. 7.1.3 of YR):

  W.C. Chang, J.W. Chen, C.W. Kao, D. Lin

- **GPDs** (DVCS, TCS, DVMP; Sec. 7.2.2 of YR):

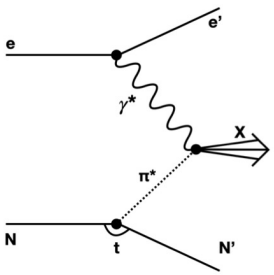
  P.J. Lin, J.W. Chen, C.W. Kao

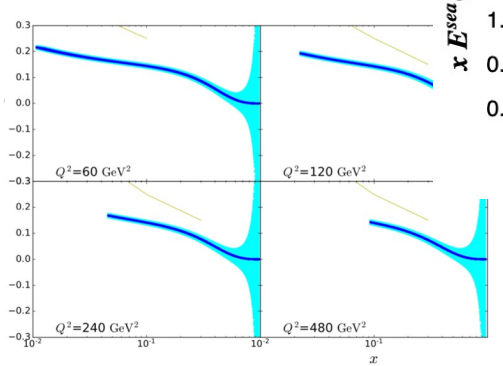
- **CGC** (di-jet, di-hadron DIS; Sec. 7.3.1 of YR):

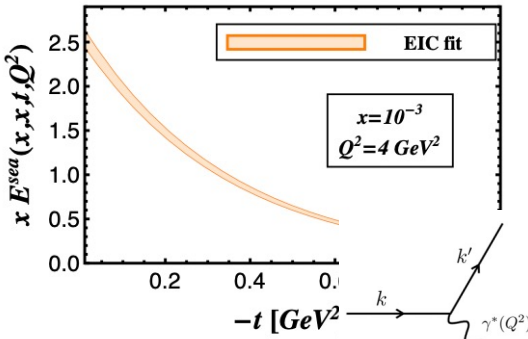
  C.M. Kuo, H.N. Li

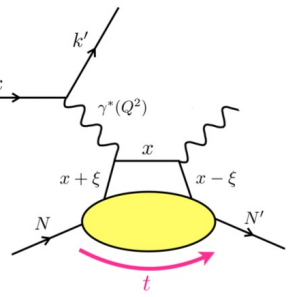
- **Hard Probe** (jet, heavy quarks; Sec. 7.3.9 of YR):

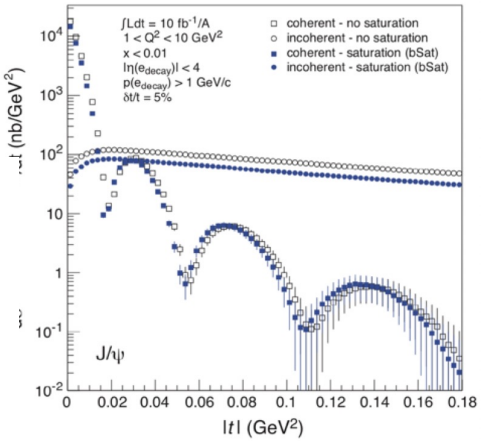
  Y. Yang





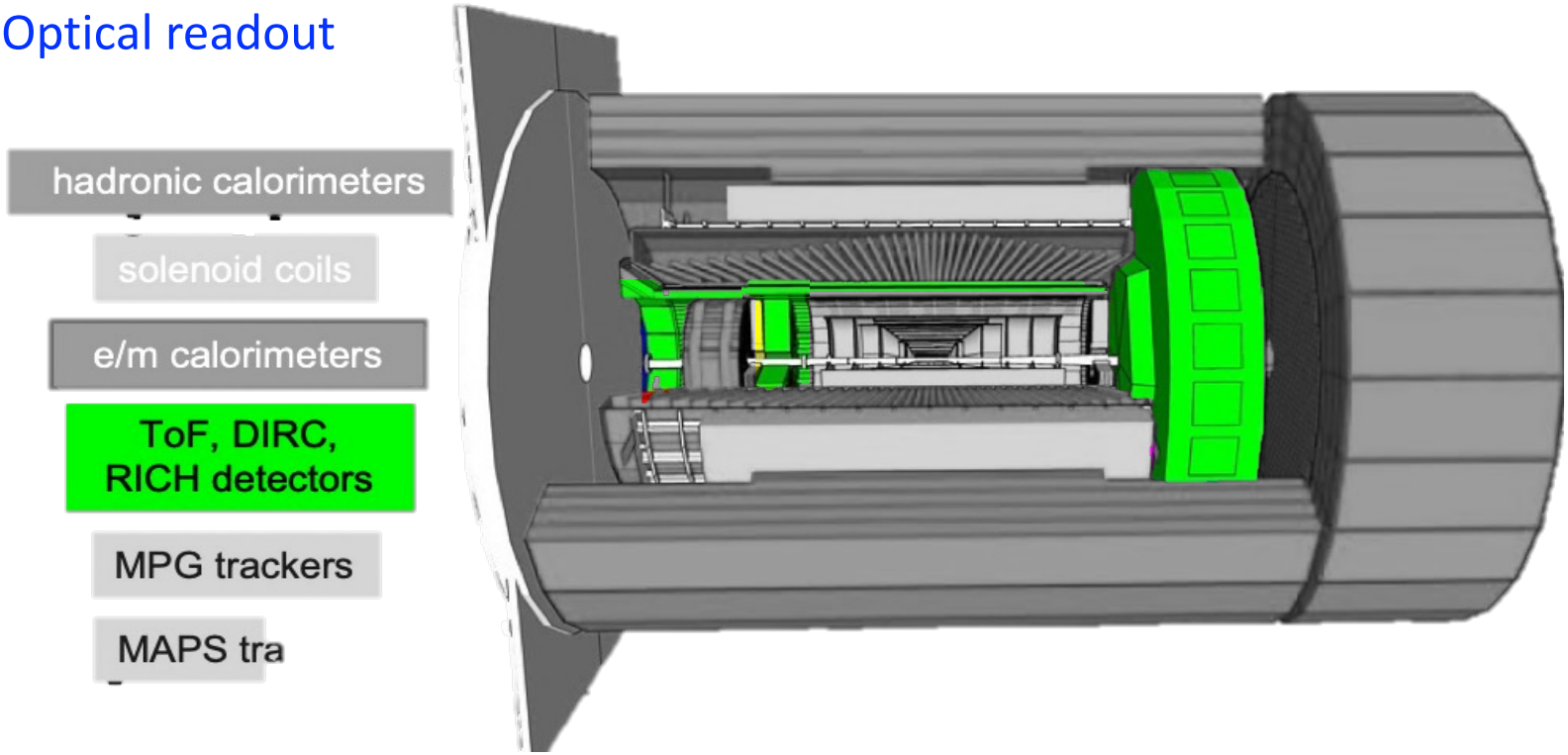






EIC Hardware Project

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



DC-LGAD sensors

Low Gain Avalanche Detector (LGAD)

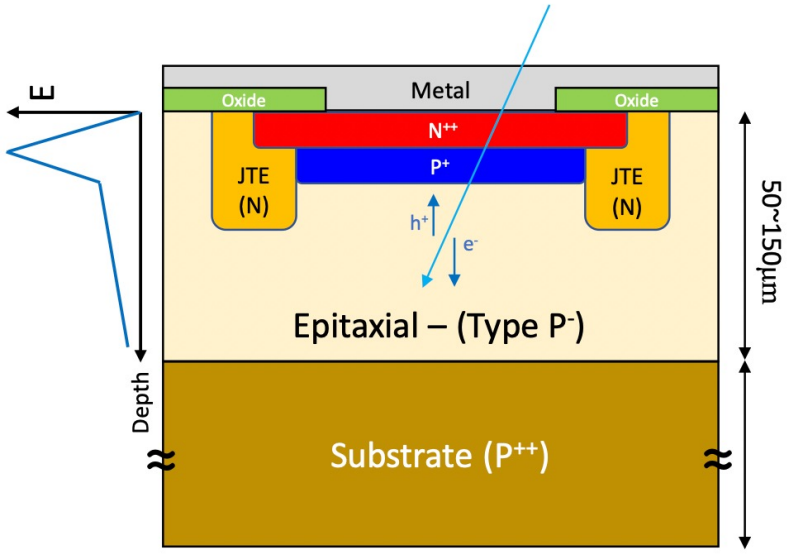
Feature

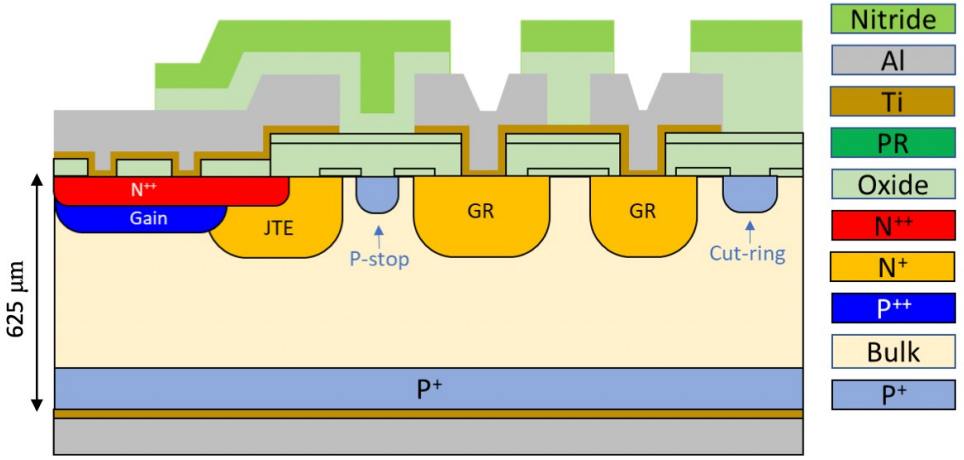
- High field obtained by adding an extra p^+ below the n^+
- controllable moderate internal gain ~10
- High time resolution of ~50ps
- Thin active layer

Real status

- 6" p-type, 625 μm, FZ-wafer with 5KΩ-cm resistivity (due to equipment of TSRI)
- Gain layer parameter control
- Junction Termination Extension (JTE)
- P-Stop

TSRI: Taiwan Semiconductor Research Institute





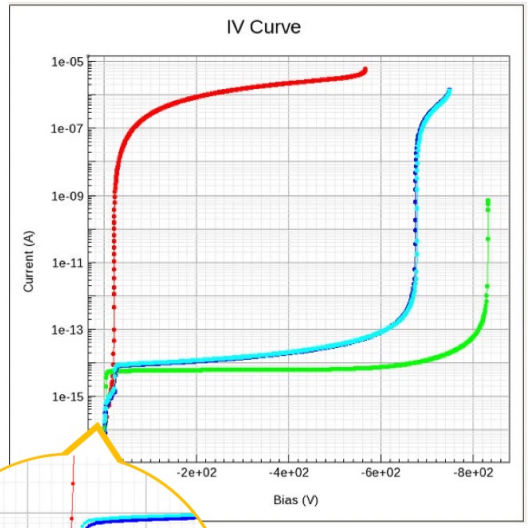
Ref. Design and fabrication of an optimum peripheral region for low gain avalanche detectors; NIMA, Volume 821, 11 June 2016, Pages 93-100
Ref. Technology developments and first measurements of Low Gain Avalanche Detectors (LGAD) for high energy physics applications; NIMA, Volume 765, 21 November 2014, Pages 12-16

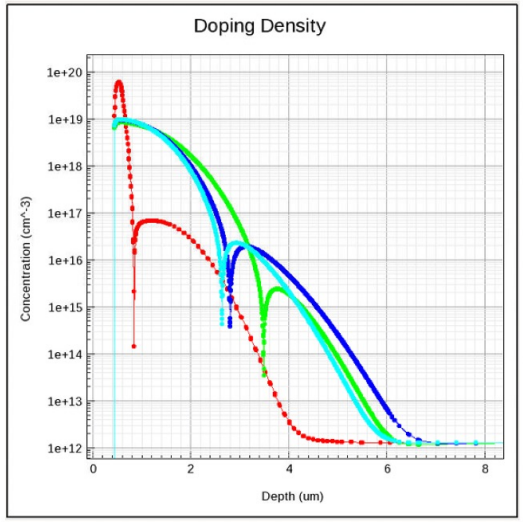
R.H. Yeh's Talk: https://indico.phys.sinica.edu.tw/event/52

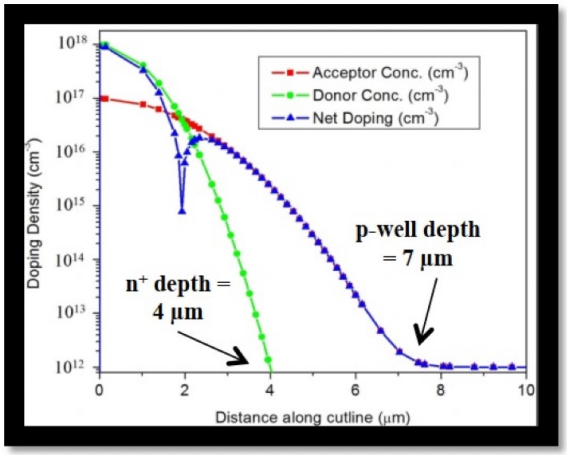
DC-LGAD sensors

LGAD Process parameter decision by TCAD simulation

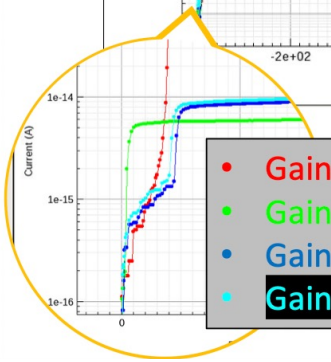
- Various gain layer and N^{++} process parameters
- The suitable parameter: Gain 5e13/180keV 1100C/200min N^{++} 1e15/100keV 1100C/200min







Ref. TCAD simulation of Low Gain Avalanche Detectors; NIMA, Volume 836, 11 November 2016, Pages 113-121



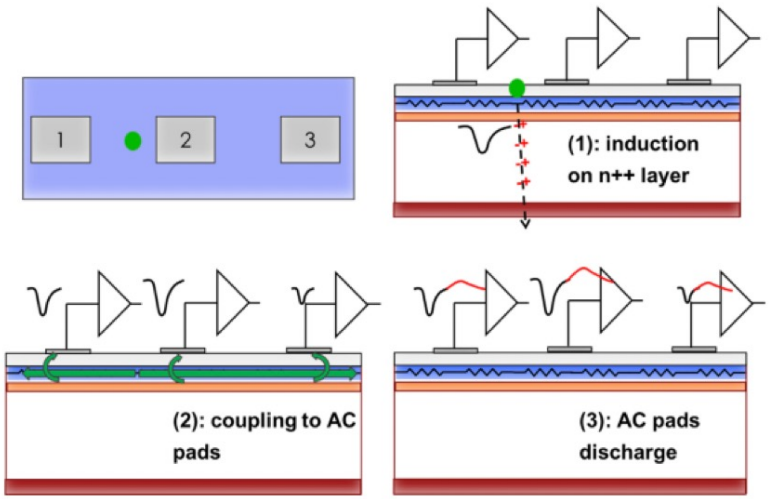
- Gain 1e13/200keV 1100C/140min N^{++} 1e15/80keV 900C/30min
- Gain 3e13/300keV 1100C/100min N^{++} 1e15/120keV 1100C/300min
- Gain 3e13/300keV 1100C/300min N^{++} 1e15/120keV 1100C/200min
- Gain 5e13/180keV 1100C/200min N^{++} 1e15/100keV 1100C/200min

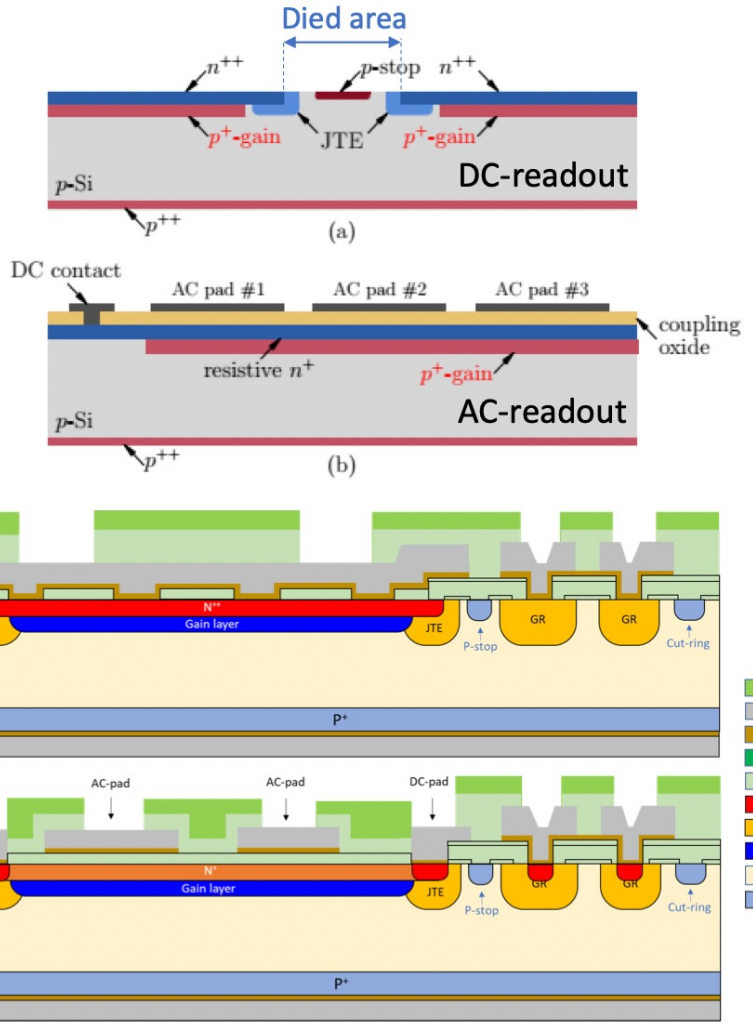
R.H. Yeh's Talk: https://indico.phys.sinica.edu.tw/event/52

DC-LGAD sensors

Future plans: AC-LGAD

- Almost 100% Fill Factor can be
- The signal is collected on the n++ electrode
- The metal AC pads act as capacitors, they are charged by the signal
- AC-PAD LGAD by change three masks of the DC LGAD masks :1. metal, 2. contact, 3. passivation



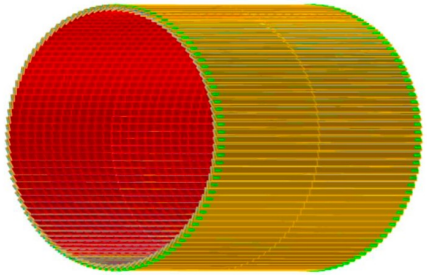


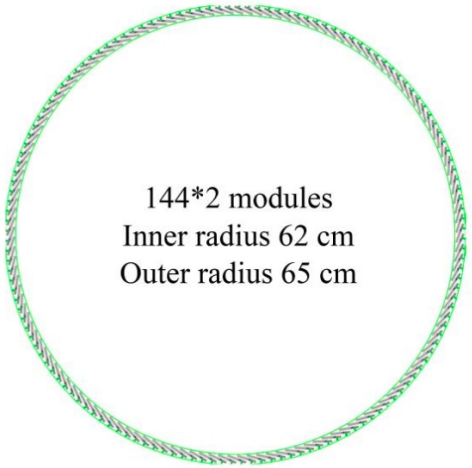
Ref. First demonstration of 200, 100, and 50 µm pitch Resistive AC-Coupled Silicon Detectors (RSD) with 100% fill-factor for 4D particle tracking; IEEE Electron Device Letters PP(99):1-1, September 2019
Ref. LGAD designs for Future Particle Trackers; NIMA, volume 979, 2020, 164383

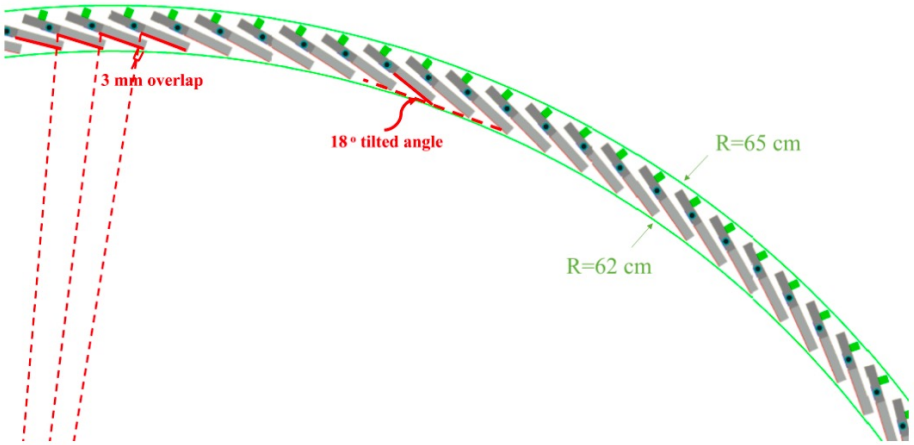
R.H. Yeh's Talk: https://indico.phys.sinica.edu.tw/event/52

Mechanical structure for TOF

- **eRD112 proposal**
- For v0 design of Barrel TOF, pixels of 0.5 x 10 mm^2 strips proposed
- Single layer of strip AC-LGAD sensors
  - 62 < R < 65 cm, 2.7 m long, ~11 m^2 area
- Strip metal electrodes, with 500 μm pitch in $r\phi$ and 1 cm* in z



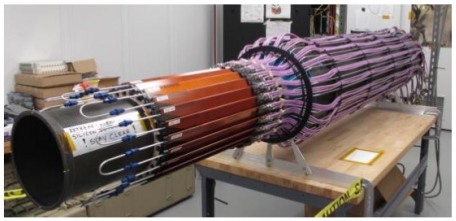




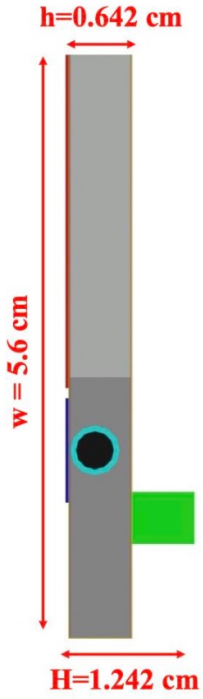
From Zhenyu's talk
https://indico.bnl.gov/event/16765/

Mechanical structure for TOF

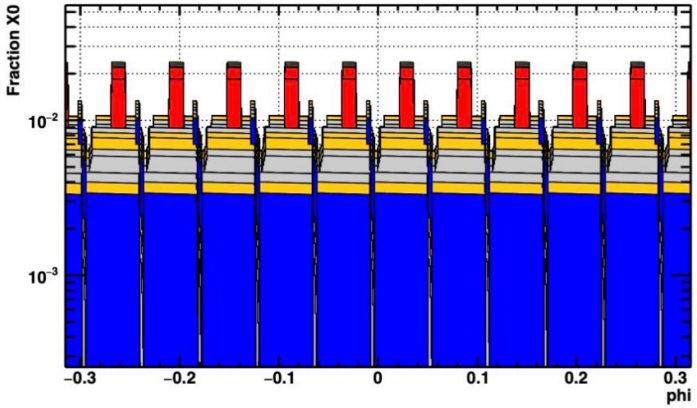
- Use the similar concept of STAR IST
- Rather long support (1.35m) with minimal deflection
  - R&D with carbon fiber composite materials

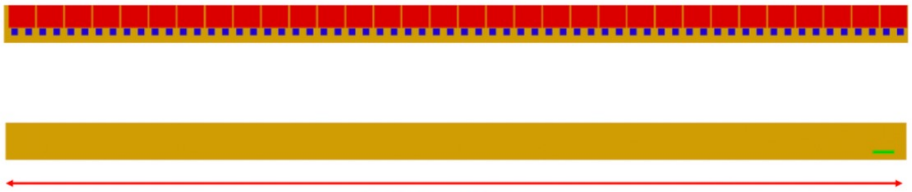


- In total 288 modules,
  - 9216 sensors, 18,432 ASICs, 2.4 M channels
  - ~70 kG, ~4 kW



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





From Zhenyu's talk
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Mechanical structure for TOF

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

Low Mass Support Structure for EPIC

W.-C. Chang[1], A.W. Jung[2], P.-J. Lin[1], Y. Yang[3],
[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.

Request for Project Engineering and Design Support for EPIC TOF Detectors

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.

Optical Readout

Proposal to EIC

- DAQ and data links will be totally Fiber-optics
- Taiwan opto-electronics IT is the primer production choice
  LHC upgrade electronics are TW made
- Join EIC, take up data-link duty for DAQ or a sub-det.
- ***Goal ➔***
  small funding on RD
  stay on Rad-hard Opto-electronics
  TW as the production site

S. Hou's Talk: https://indico.phys.sinica.edu.tw/event/52

Optical Readout

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,
  - coupling: active, lens, to fiber-ends
  - NIEL, Ageing to Bit-Error-Rate
- **Facilitate INER proton beam**
  - for Rad-hard studies

S. Hou's Talk: https://indico.phys.sinica.edu.tw/event/52

About TIDC

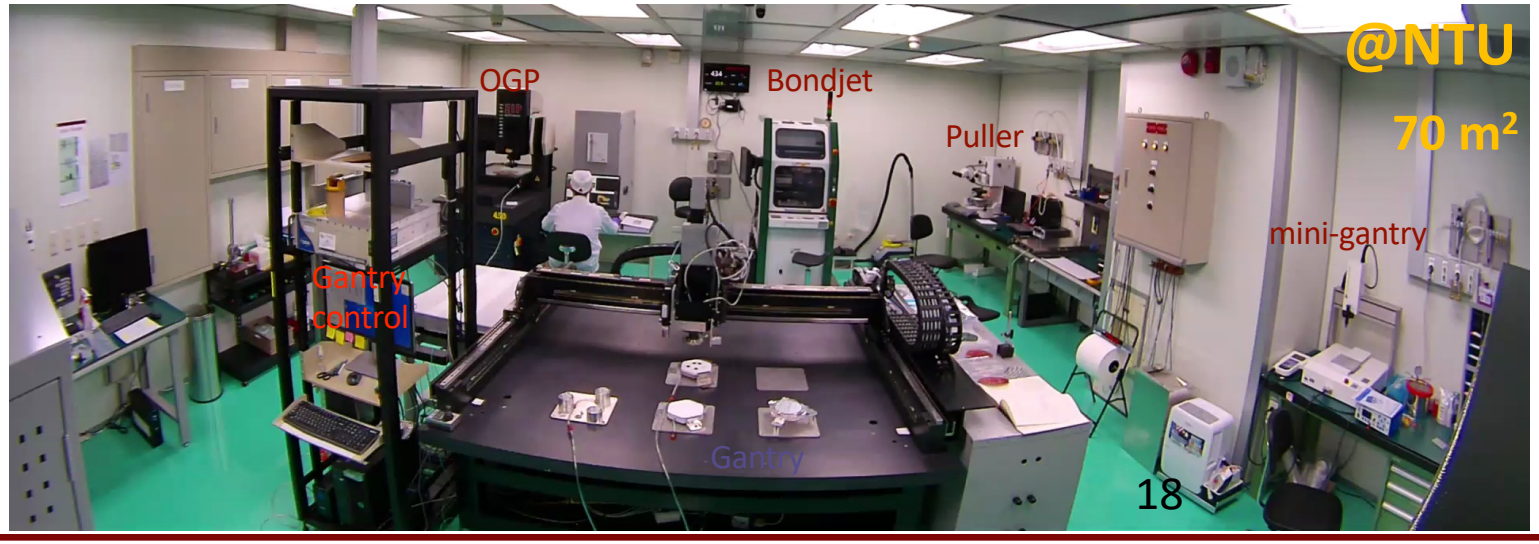
- **Taiwan Instrumentation and Detector Consortium (TIDC)** was established in 2019 by 5 institutes (AS, NCU, NTHU, NCKU, and NTU) in Taiwan (supported by National Science and Technology Council in Taiwan)

  ➔ Form a strong team to participate the EIC

  https://tidc.phys.ntu.edu.tw/WordPress/

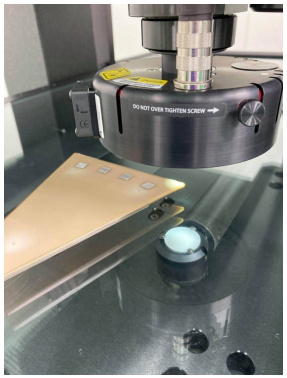
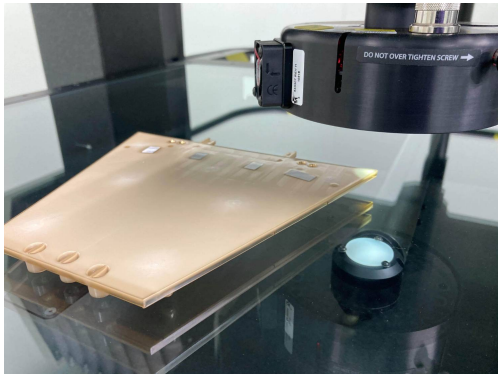
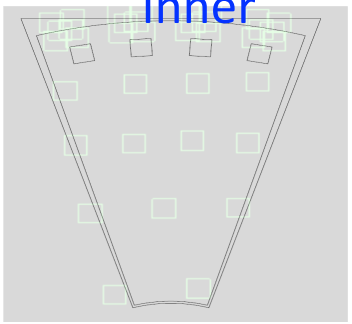
TIDC: Silicon Detector Facility

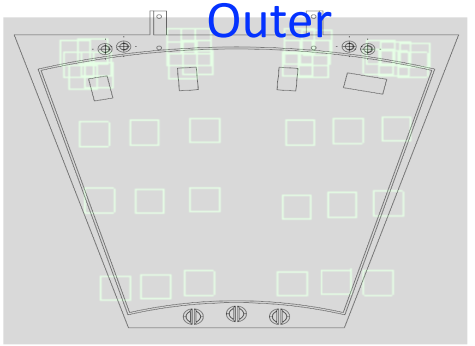
- Class 10,000, with temperature and humidity controlled at 23 ^{o}C and RH 50% all year round
- Fully operation with Pressured dry-air supply and vacuum services
- Aerotech 1.25x1.25 m^2 robotic gantry with Labview control
- OGP optical 3D measurement
- Hesse BJ820 automatic Bondjet and DAGE 4000 Bondtester (puller)
- Manual probe station and picoprobes
- Glue dispensers, mini-gantry, microscope, degassing chamber, Keithley 2410 and tools …



Example: STAR Forward Tracker

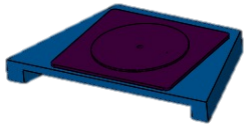
1. Use OGP to measure the flatness

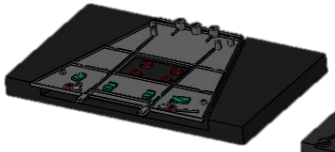


2. Assembly Outer MS with Hybrid PCB using robotic gantry

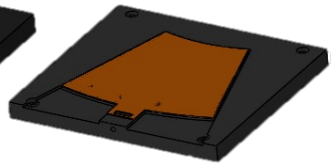
pickup tool

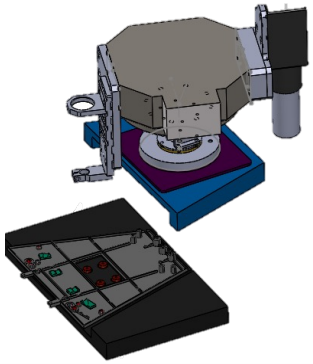
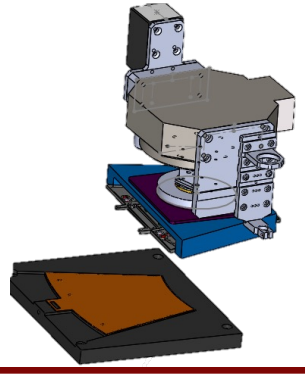
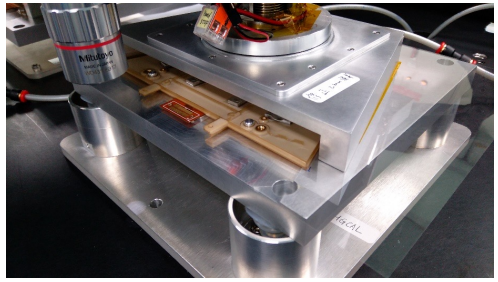


Outer MS + tray



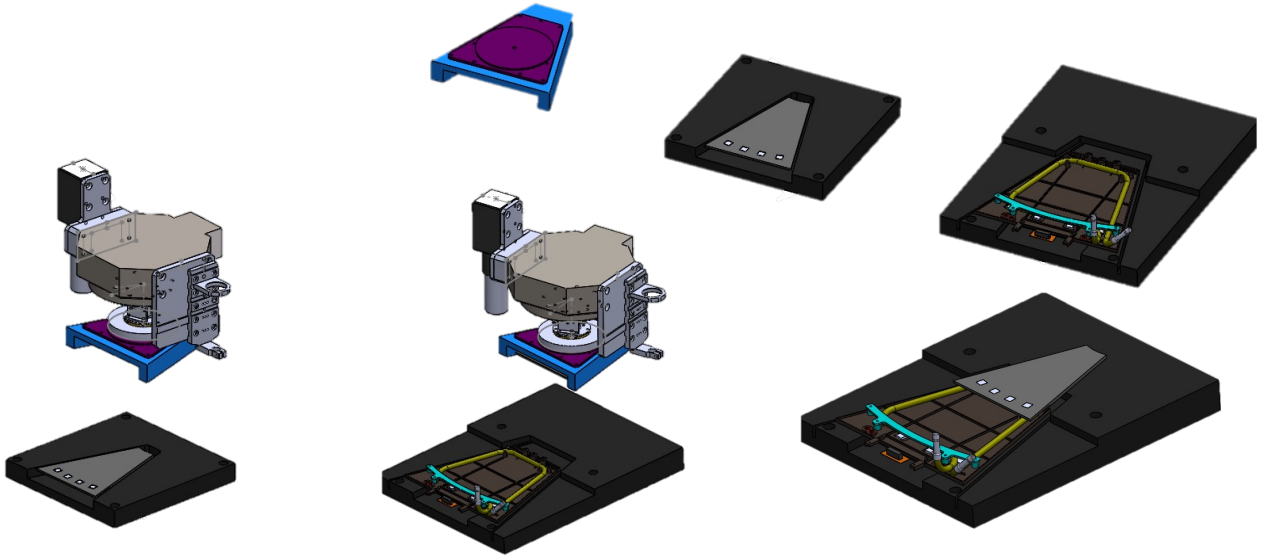
Outer Hybrid + tray



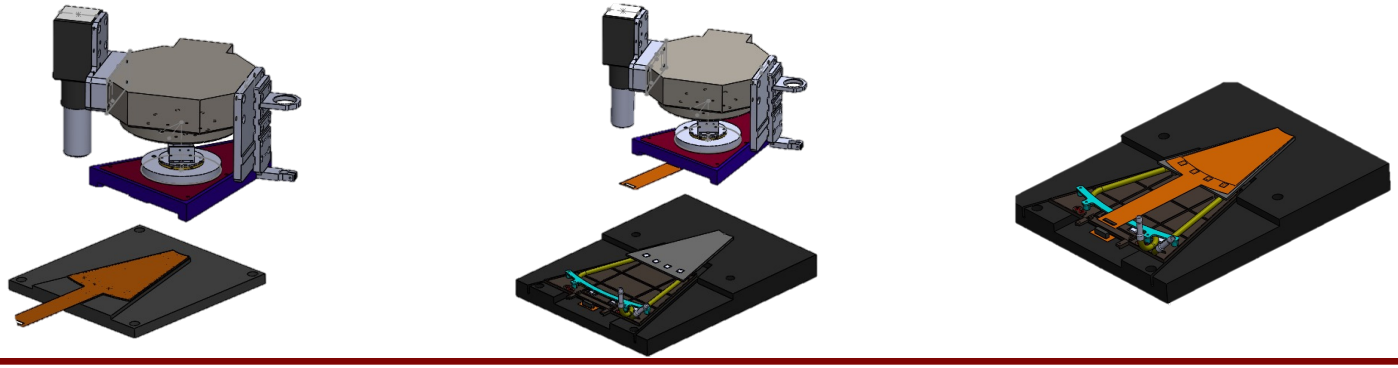




Example: STAR Forward Tracker

3. Glue the inner MS using robotic gantry



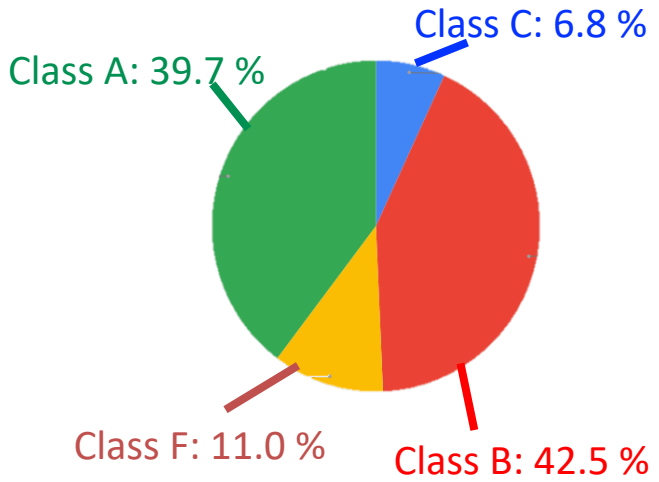
4. Glue the inner Hybrid PCB using robotic gantry

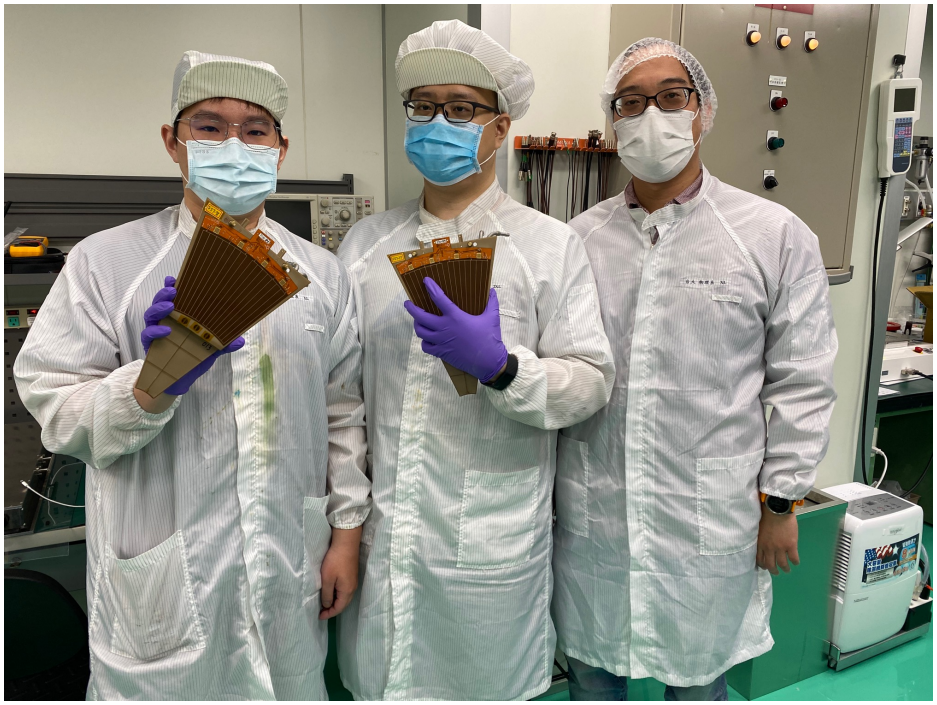


Example: STAR Forward Tracker

- Total 73 modules (48 needed) are produced

  → **Successful rate ~89%**



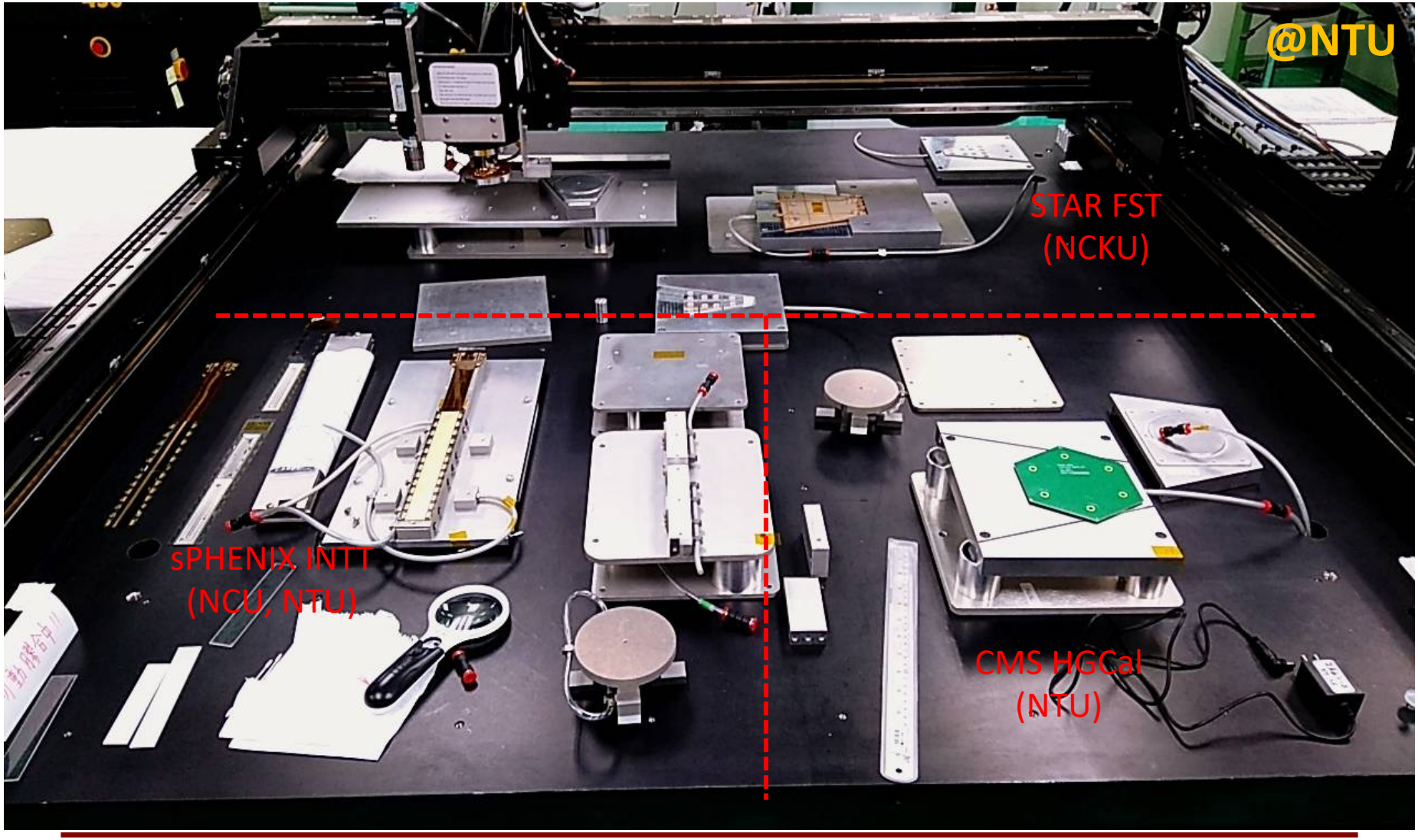


TIDC: Silicon Detector Facility

- Lab space for after-assembly testing and repair
- Equipped with workstations with tools and soldering iron
- Yamato Oven to cure epoxy and Hitachi Climate Chamber (-70 °C ~ 100 °C) for thermal stress tests
- Oscilloscopes, function generators, Keithley 2410, NIM crate and modules, NI PXIe crate and modules
- PCs and Mac's for LabVIEW and SolidWork

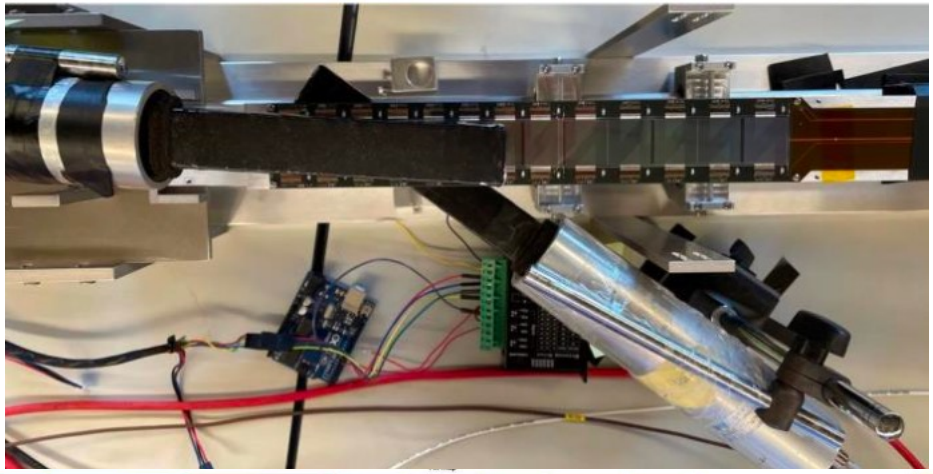
TIDC: Silicon Detector Facility

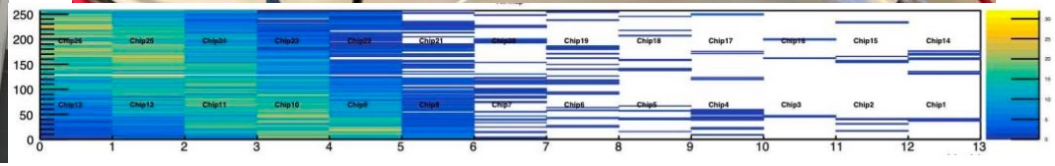
- Very productive period of TIDC (2019-2020)



TIDC: Silicon Sensor Development Facility

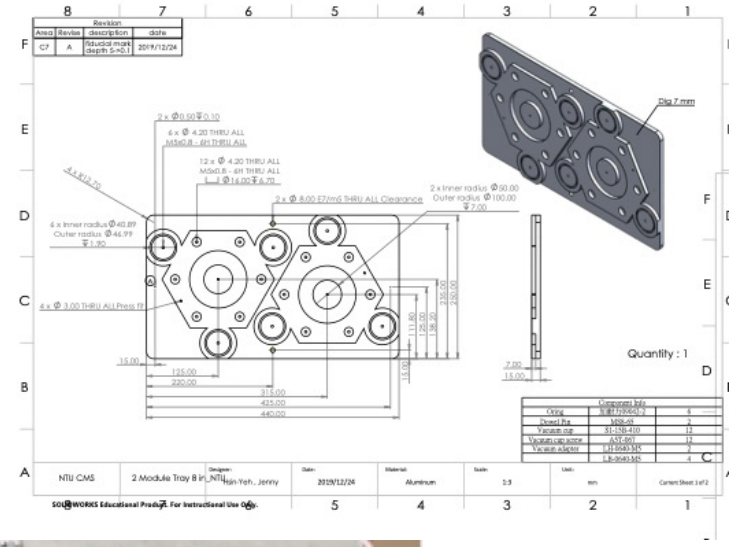
- 3 probe stations (1 for 8-inch and 2 for 6-inch silicon sensors)
- Capability to design the probe cards
- Perform the IV/CV measurements
- Silicon sensor R&D with the local semiconductor companies
- Silicon QC center for CMS HGCal and sPHENIX INTT
- Work with a local PCB company to produce high quality readout board for CMS HGCal

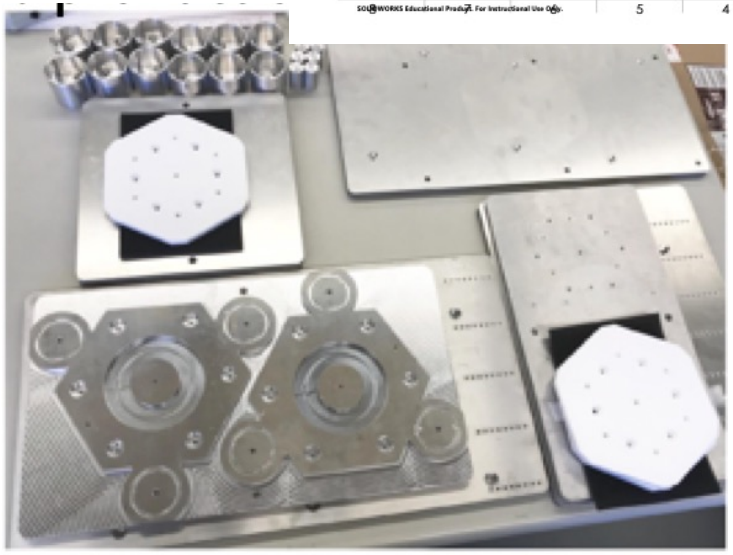




TIDC: High Precision Machine Shop

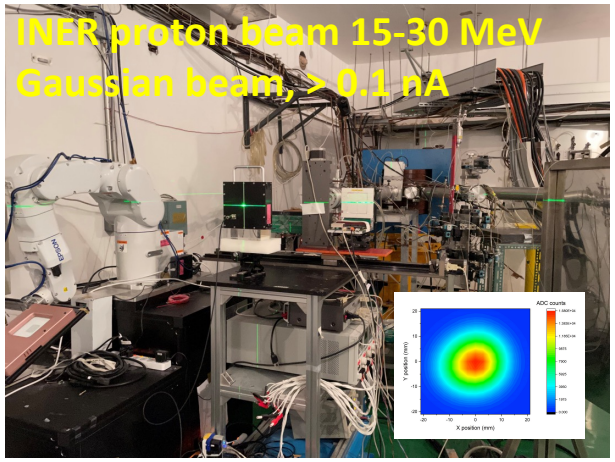
- Experienced engineers, effective production @ AS

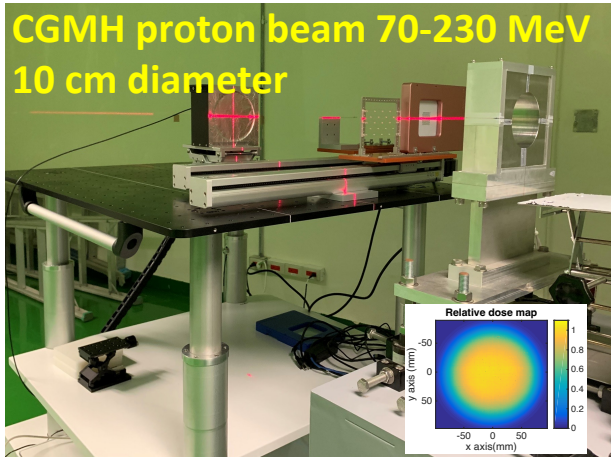


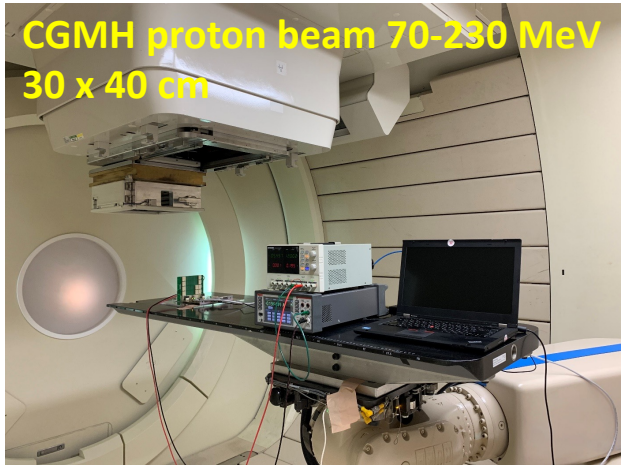


Radiation Test Facility in Taiwan

- **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 MeV*cm^{2}mg^{-1}







Computing Resources in Taiwan (AS)

- **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

Status: 2022 Oct

	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

Summary

- Theorical group in Taiwan on EIC related topics is relatively small but very strong
- Experimental group in Taiwan has lots of experience on various detector projects and physics analyses
- All Taiwanese PIs will work together on TOF/Silicon-based detector projects, including sensor and mechanical structure
- A new local facility of (silicon) detector construction (TIDC): open to international collaborations
- Strong computational resources can be shared with EIC experiment(s) in the future
- Look forward to collaborating with our Asia friends on EIC