Taiwan Instrumentation and Detector Consortium (TIDC) Achievements and Ongoing Projects

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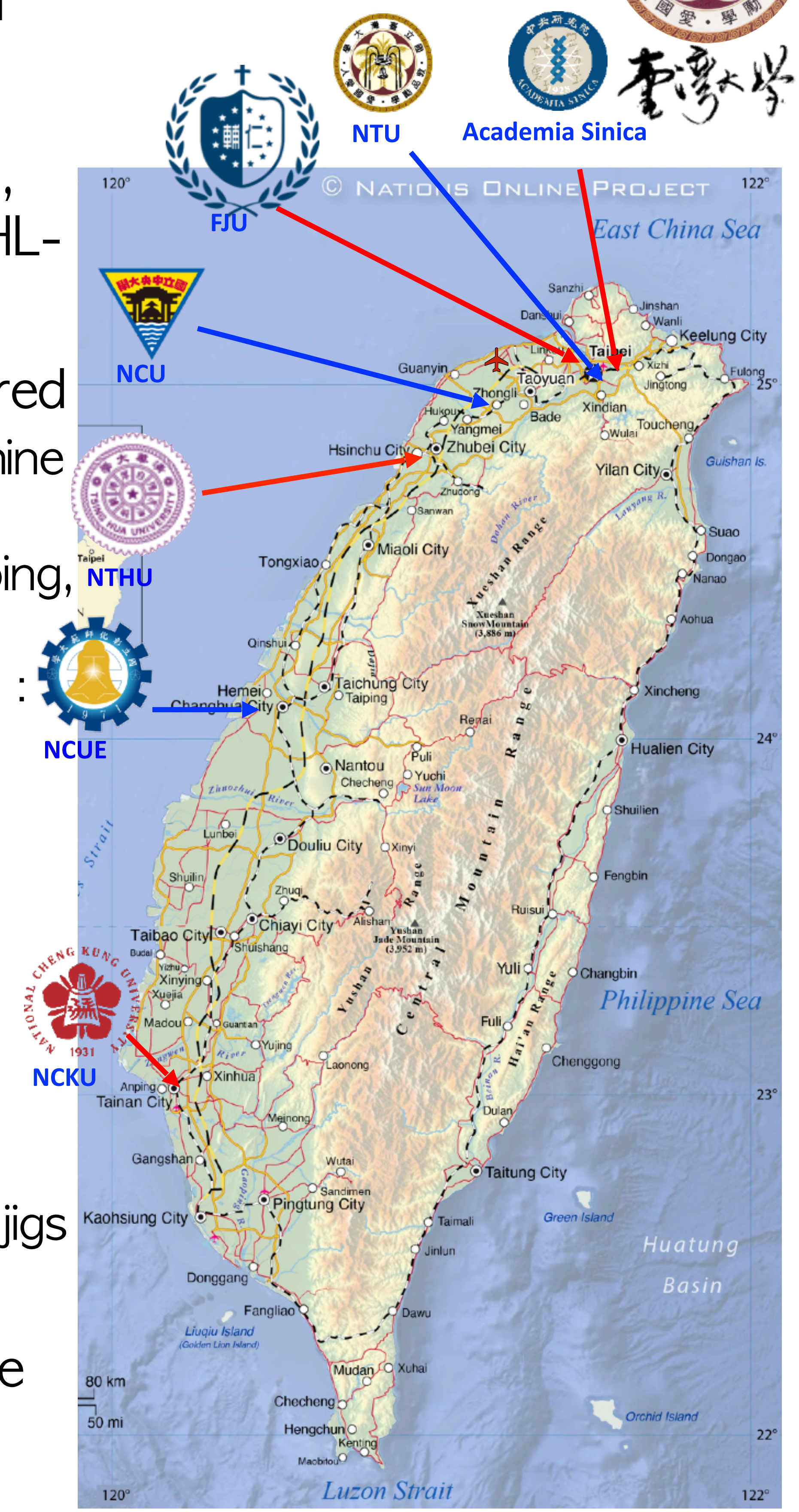
Introduction

- 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.
- Since then, several groups joined. 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.
  - ✦ 彰化師範大學 National Changhua University of Education : trigger and readout electronics (KOTO@J-PARC)
  - ✦ 成功大學 Natl. Cheng-Kung Univ.: Silicon dectector and scintillator Labs. Silicon detector mechanical design.
  - ✦ 輔仁大學 Fu Jen Catholic Univ. : Readout and trigger electronics (Belle-II@KEKB)
  - ✦ 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 received strong support and became one of the core facilities in NSTC.



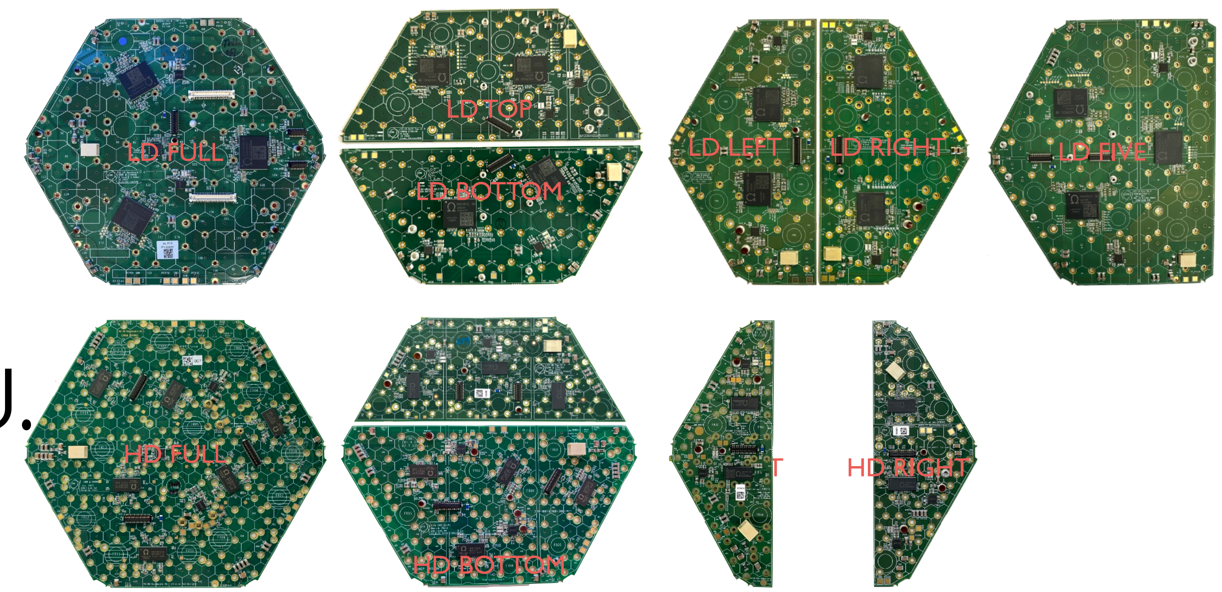
Recent ex-HEP Detector Projects

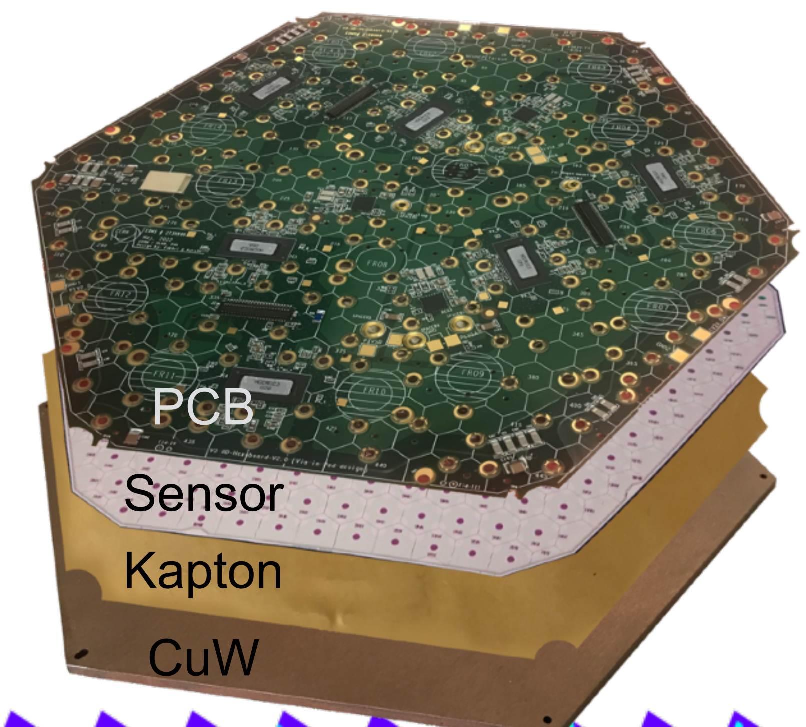
- Silicon Detectors
  - Taiwan HEP has a long tradition of silicon-based detector involvement. Including
  - Sensor design and production for RHIC-Phobos-SiliconD and LHC-CMS-Preshower
  - Readout electronics Tevatron-CDF-SVX, KEKB-Belle-SVD
  - Construct LHC-CMS-Preshower and LHC-CMS-Pixel-phase1 detectors
  - Most recently, constructing silicon detector modules of RHIC-STAR-FST, RHIC-sPHENIX-INTT, AMS-L0-Tracker, and LHC-CMS-HGCAL
  - R&D in LGAD technology
- Crystal Calorimeters
  - HEP has participated in LEP-L3-EMCAL and built a KEKB-Belle-EFC, both based on homogeneous BGO crystals
  - Also, various applications with photo-sensor technology, such as medical applications and recent LYSO investment for HL-LHC-MTD detector.
  - R&D in EIC-EPIC-ZDC crystal section
- RPC, SNSPD (DRD5), and Cryogenic Germanium and Liquid Argon (LEGEND, See Prof. Pin-Jung Chiu's talk)
- Electronics, firmware, OPT-Readout, Computing, etc.

Ongoing Projects

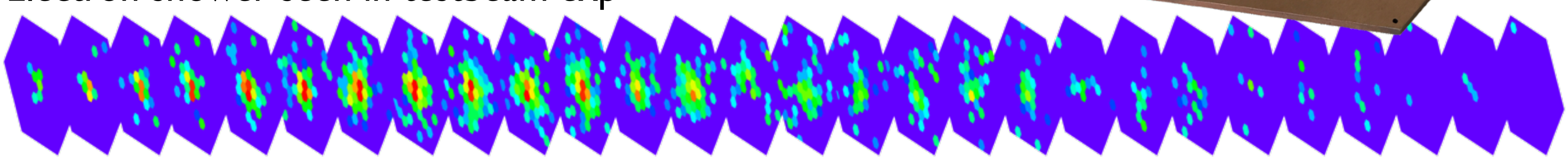
CMS HGCAL Silicon Modules

- Silicon modules in the sampling calorimeter. Variants of shape to fill the endcap plane.
- Sensor QC is carried out at NCU, and modules are assembled at NTU.
- HGCROC with ADC/TOA/TOT, capable of wide dynamic range measurement with good timing resolution.
- Various prototype modules have gone through irradiation test and beam test.





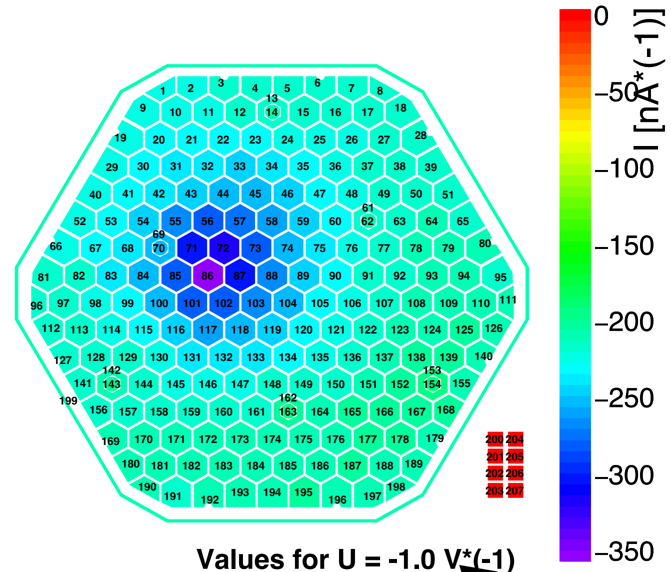
Electron shower seen in testbeam exp

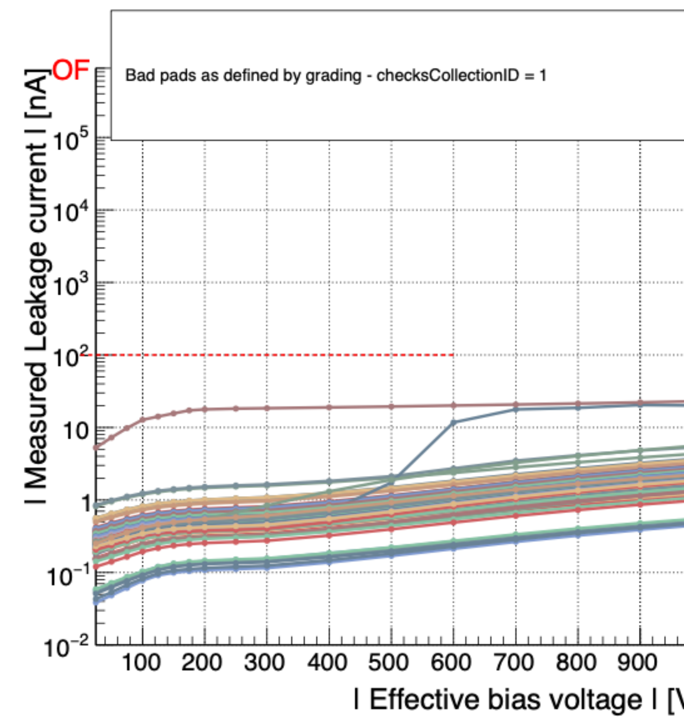


80 GeV electron: 14 double sided layers with 6” Si modules

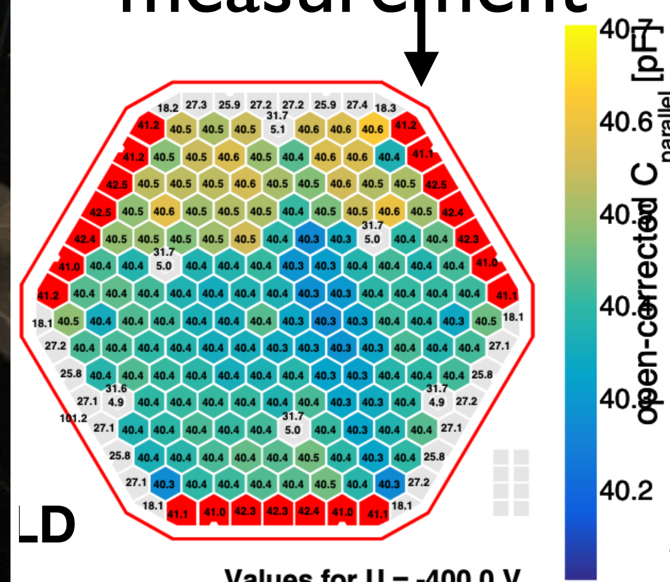
HGCAL Sensor QC @NCU

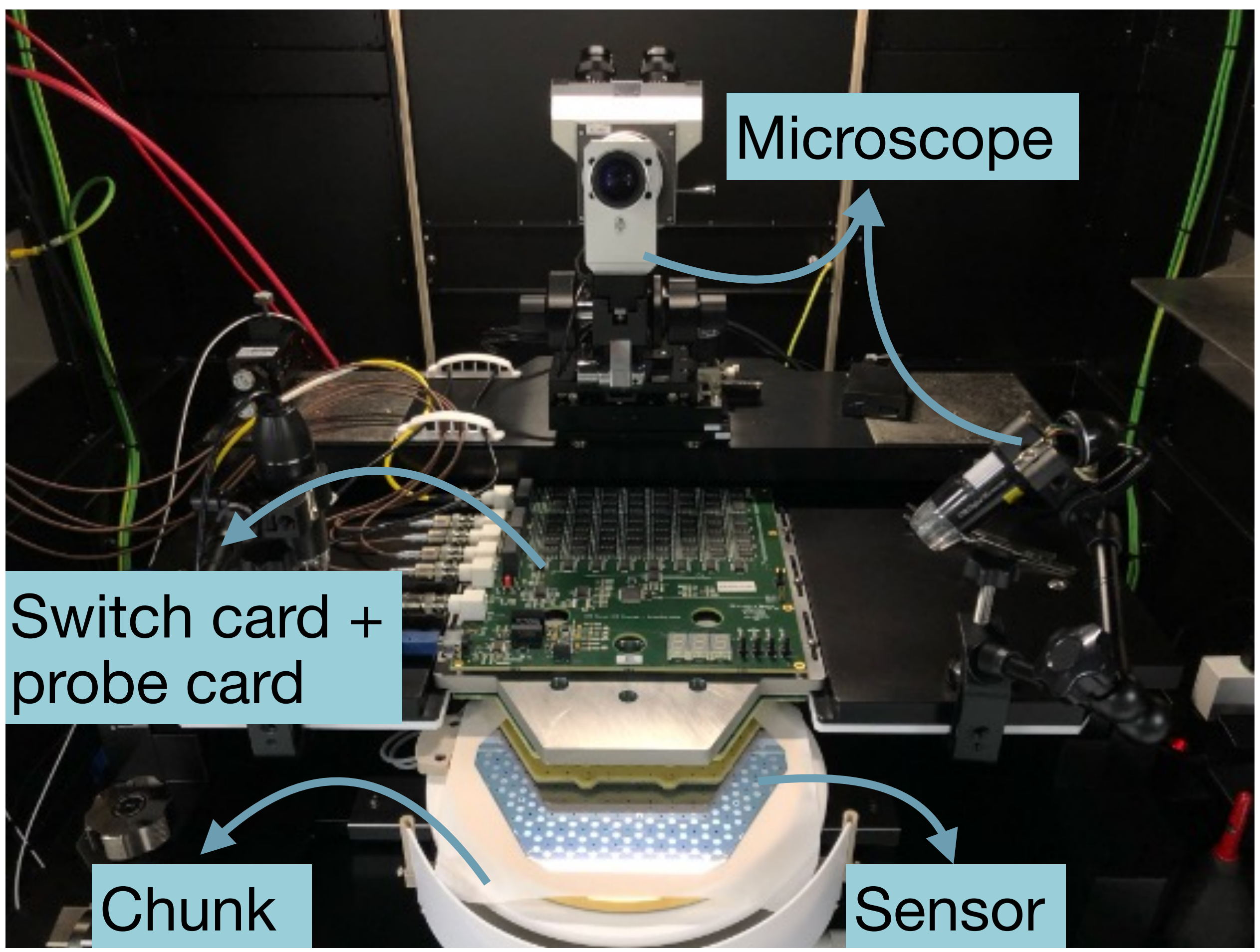
- Probe station with probecard to perform IV and CV measurement with all channel connected.
- Results compatible with Hamamatsu measurement

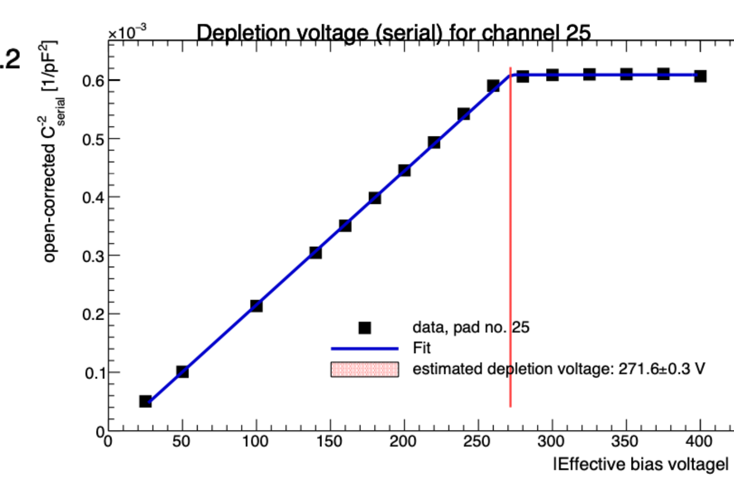




IV & CV measurement



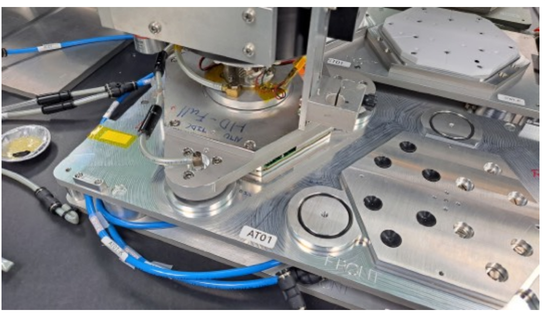


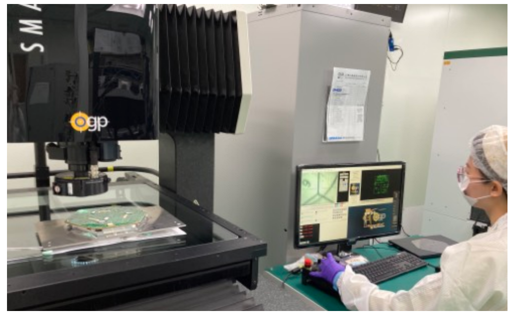


Module Assembly @NTU

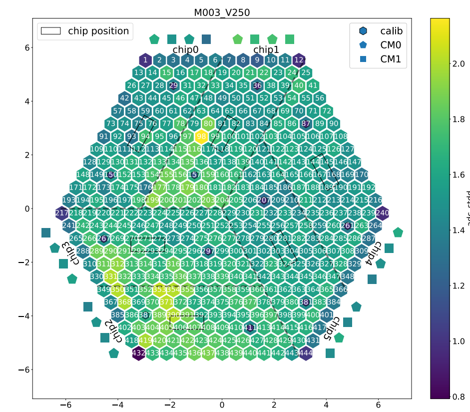
Material

Assembly



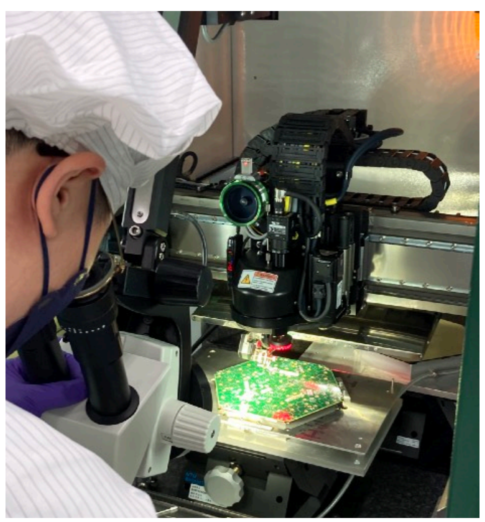


OGP QC



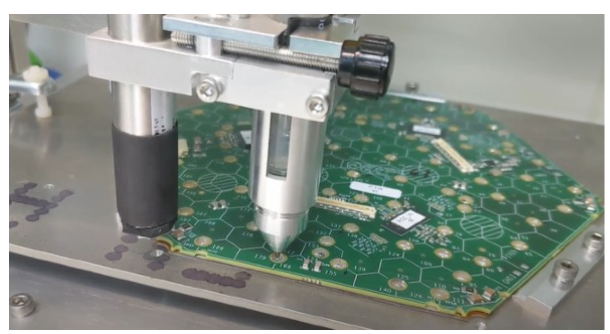
Electronic test

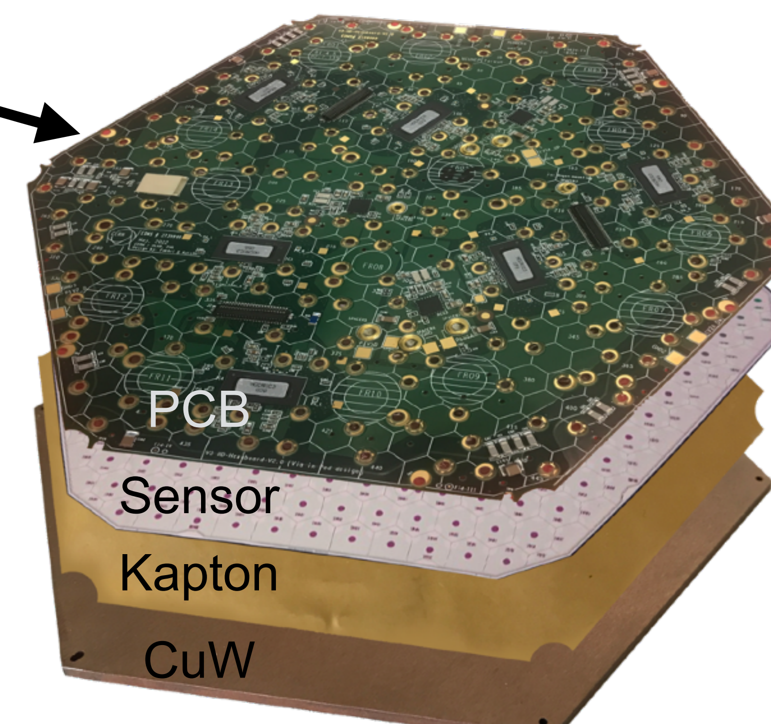
Wire bonding

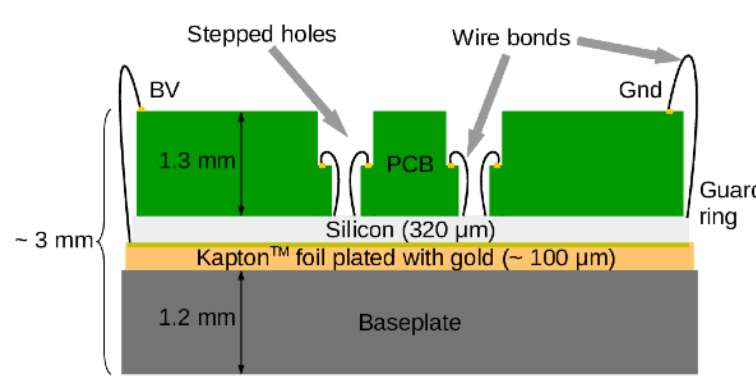


Thermal cycle

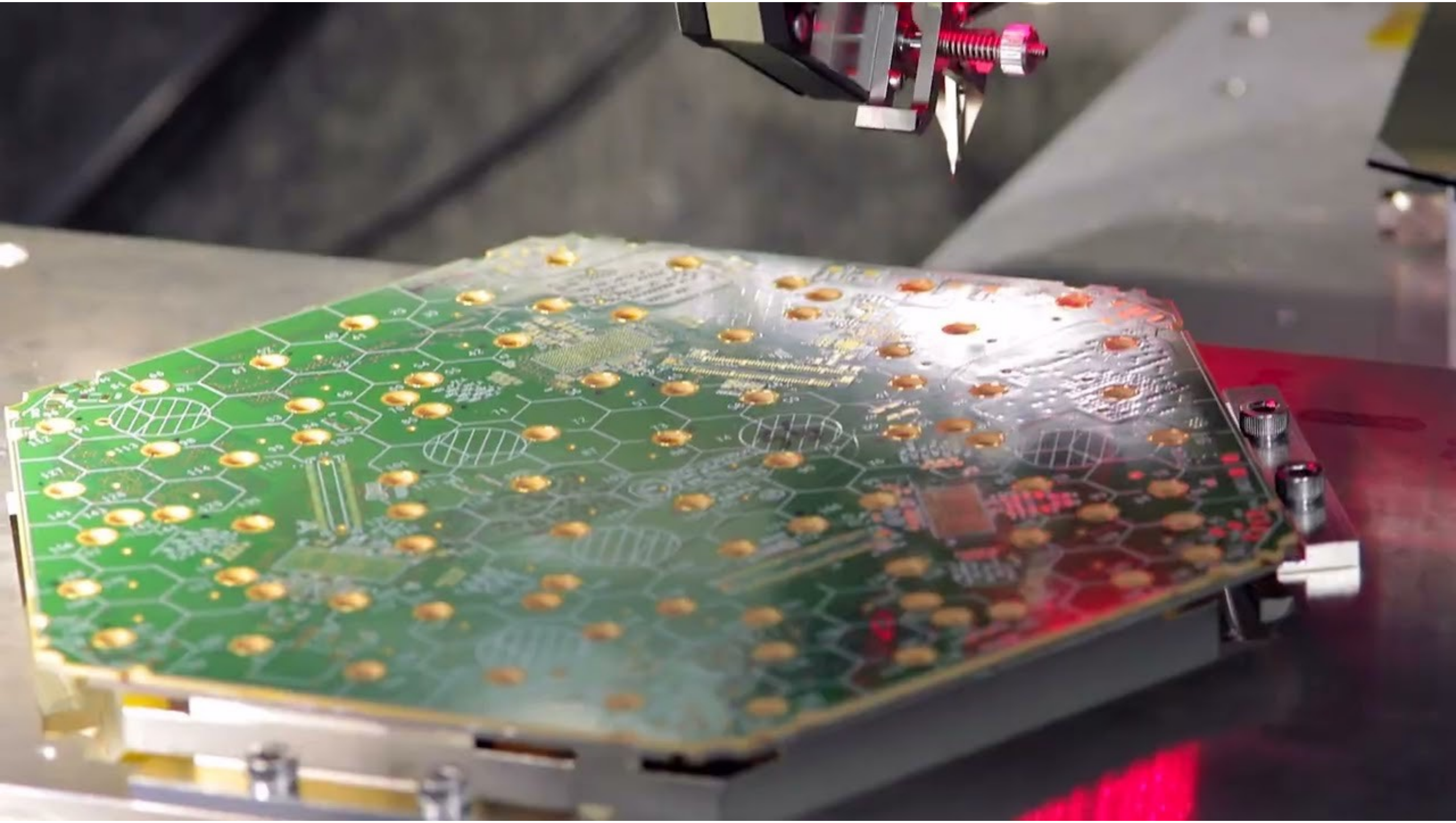
Encapsulation





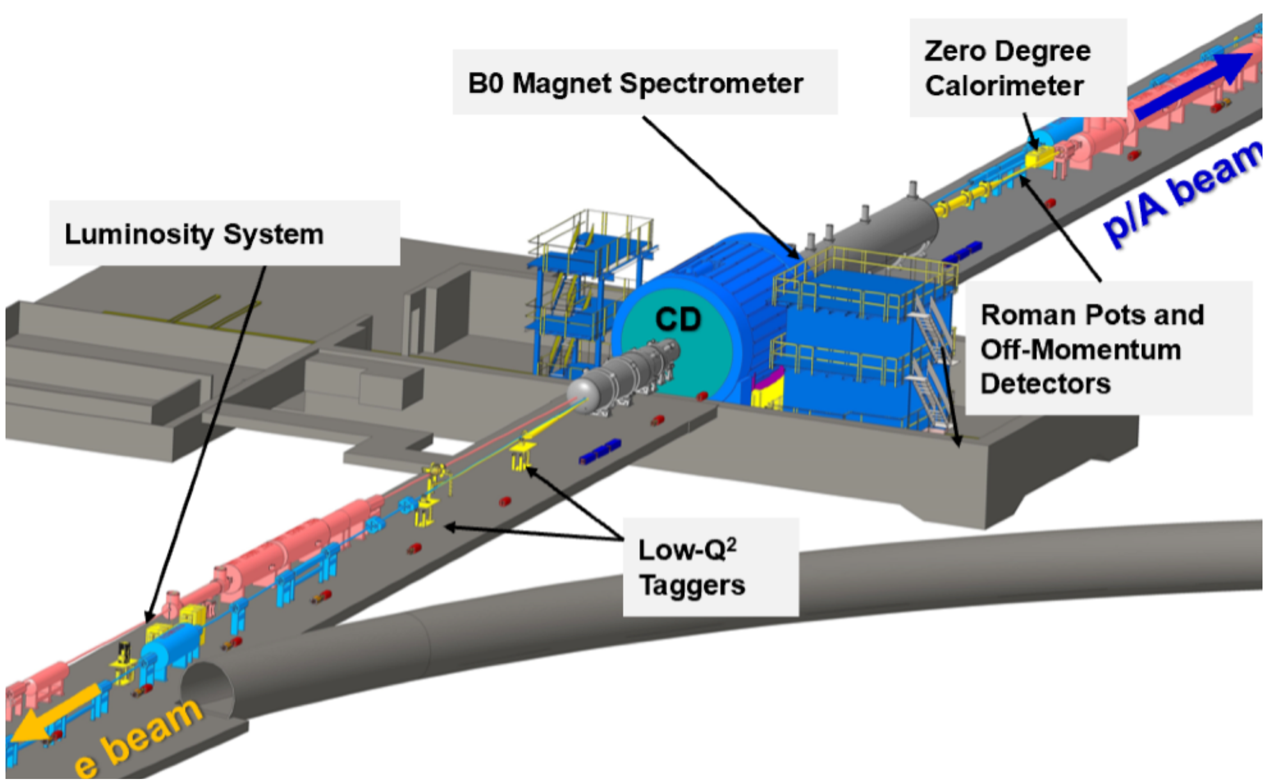


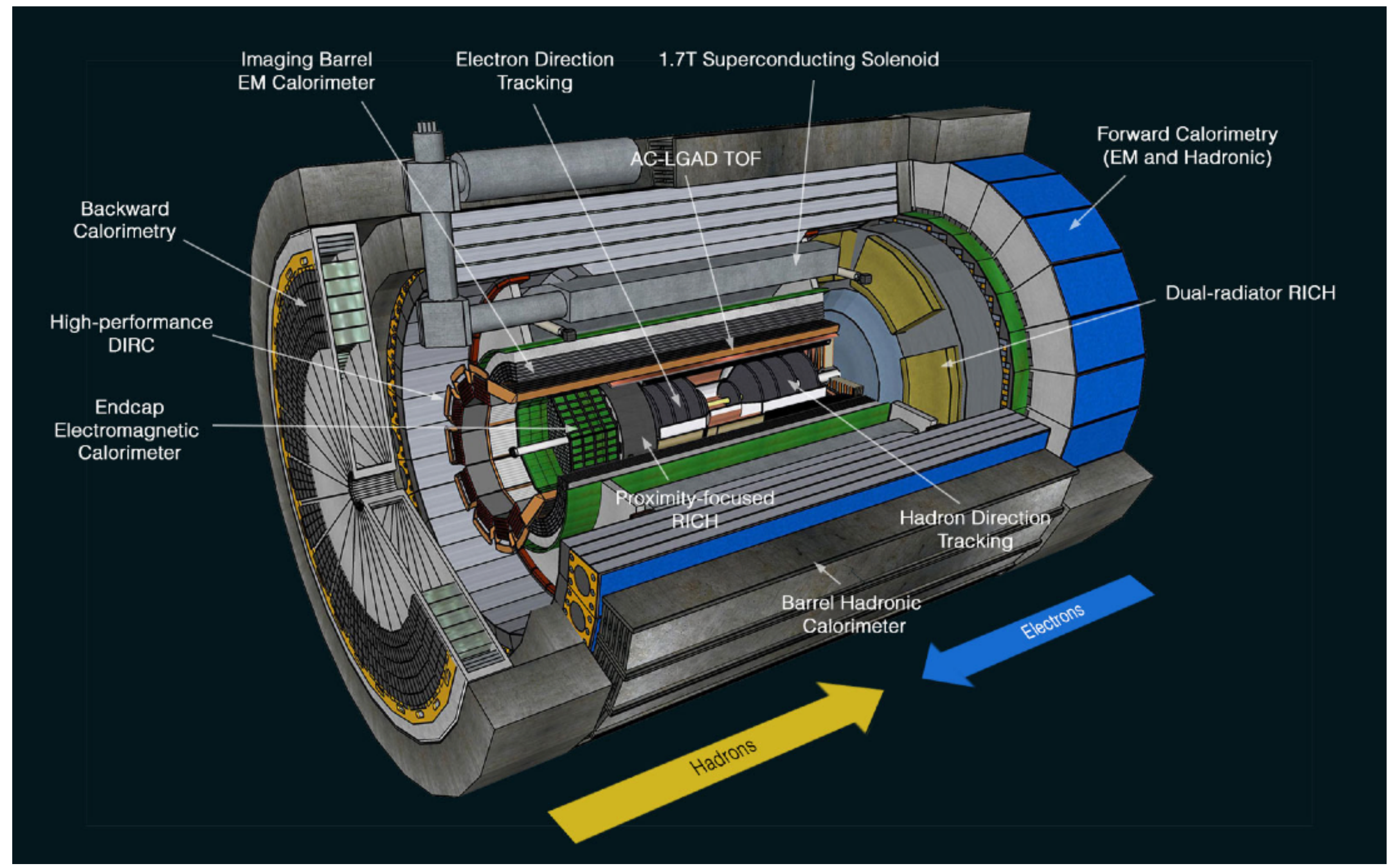
HGCAL Module Assembly



EIC-ePIC Project

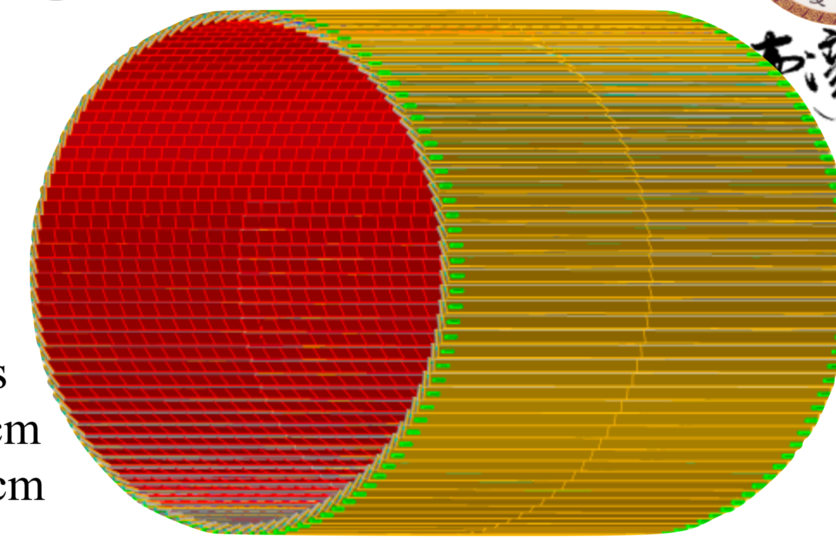
- Lots of opportunities and interesting stuff in EIC-ePIC
- Taiwan ePIC community is participating in
  - ✦ ZDC detector especially the crystal section
  - ✦ TOF (LGAD) detector R&D
    - ✤ LGAD sensor and module
    - ✤ Mechanical structure



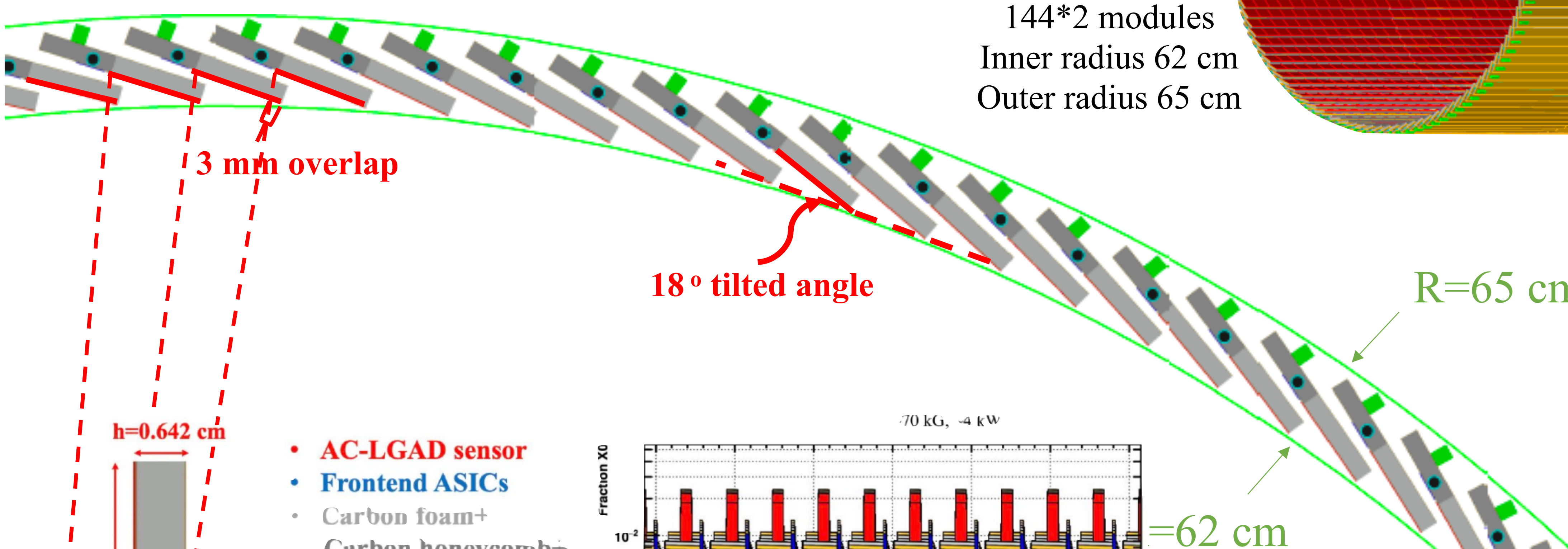


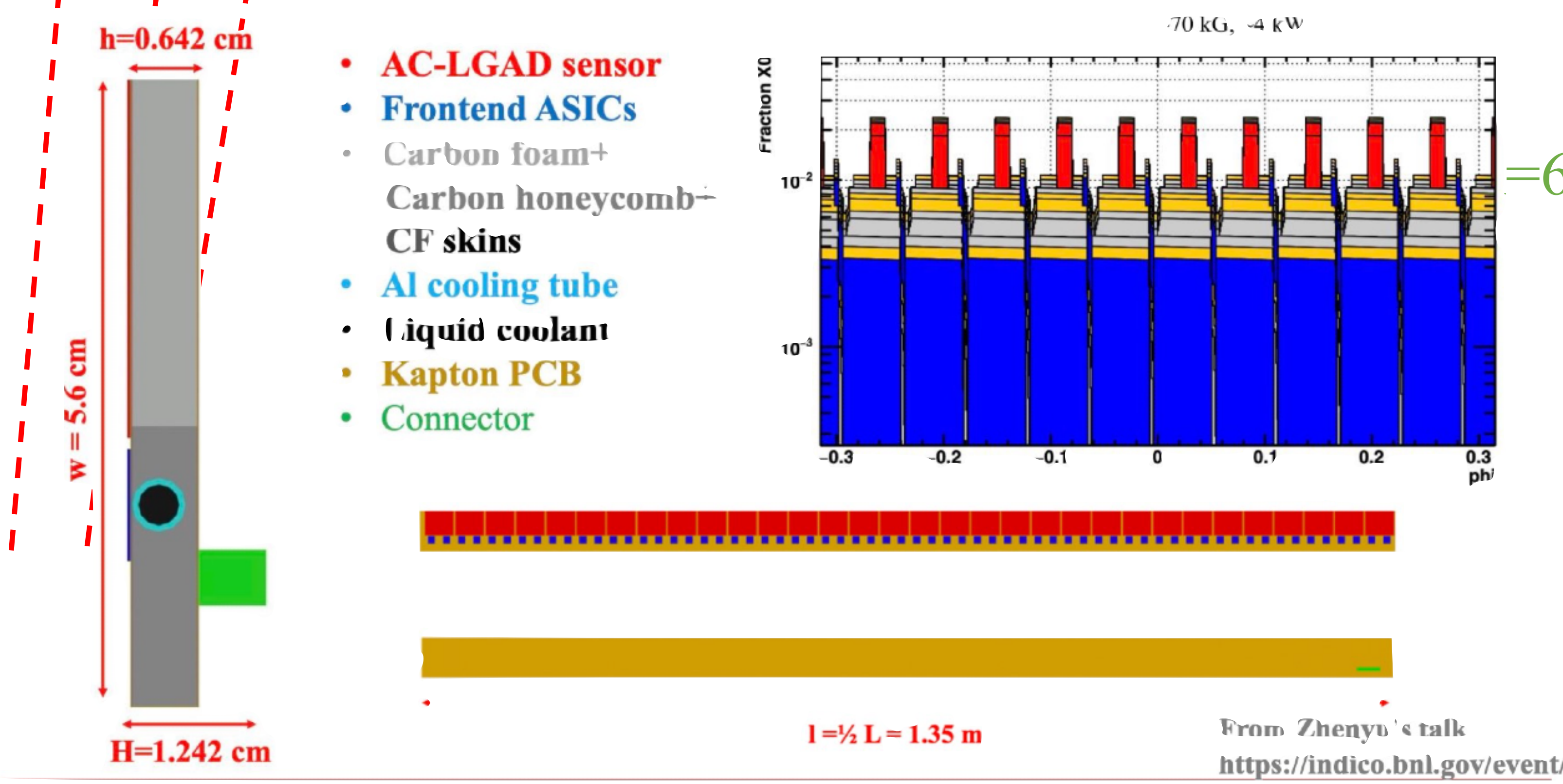
EPIC Barrel TOF

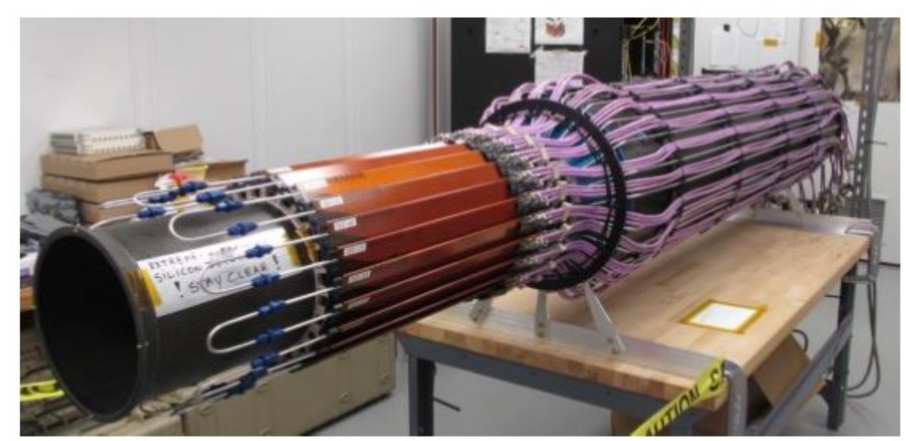
- Single layer of strip AC-LGAD sensors
  - ✦ 62<R<65 cm, 2.7 m long, ~11 m² area
- Use the similar concept of STAR IST



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



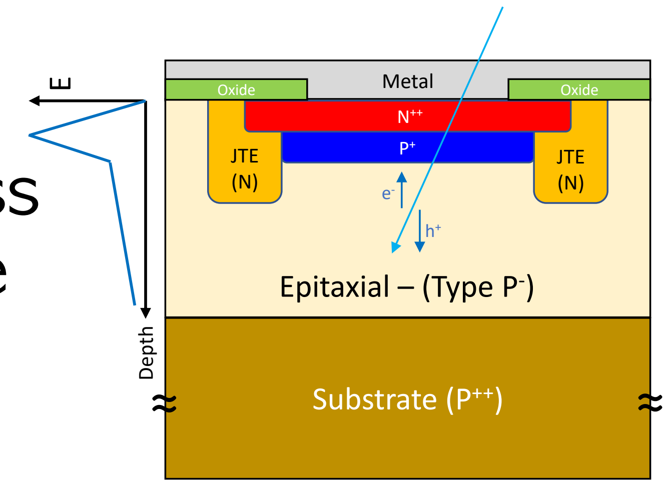




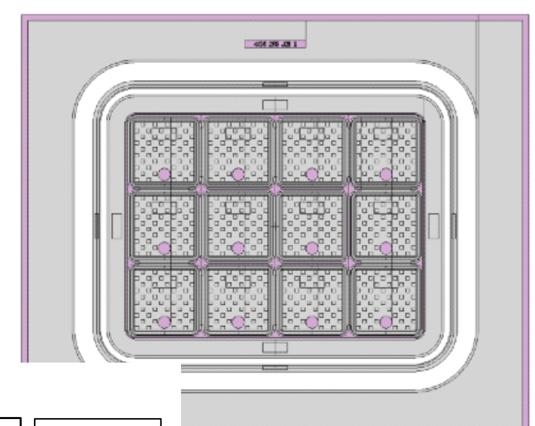
- In total 288 modules,
  - 9216 sensors, 18,432 ASICs, 2.4 M channels
  - ~70 kG, ~4 kW

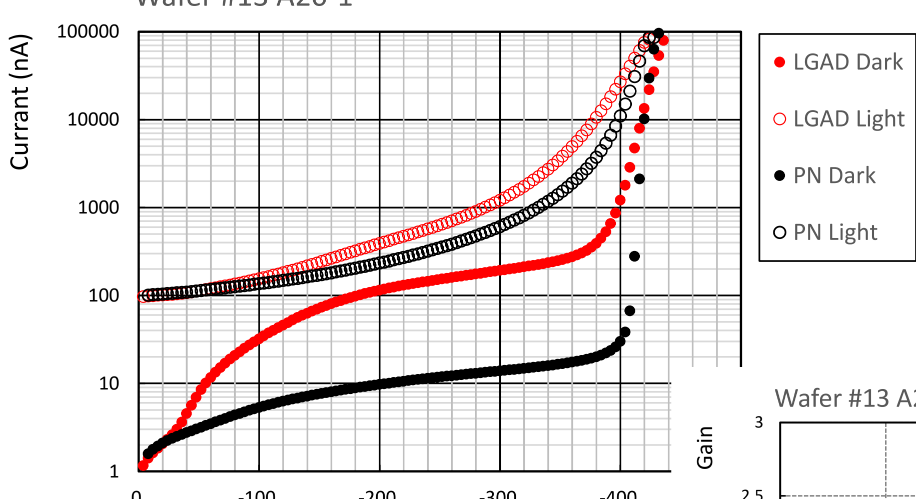
DC-LGAD Sensor R&D

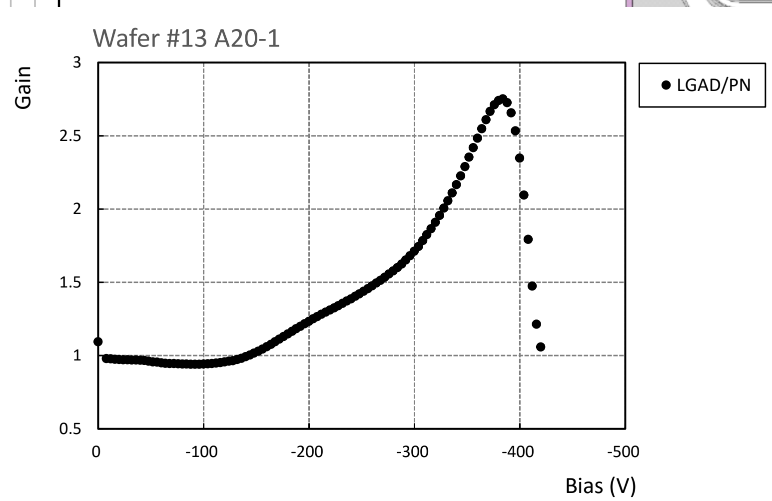
- Collaborating with local institute/company to produce DC-LGAD. Exploring the fabrication possibility.
- Designed various LGAD structures and submitted masks for production.
- Gain and signal simulation done. Wafers produced in TSRI were measured with little gain. Suspecting the doping process control is not uniform and not reaching the concentration we need.



4x3 array

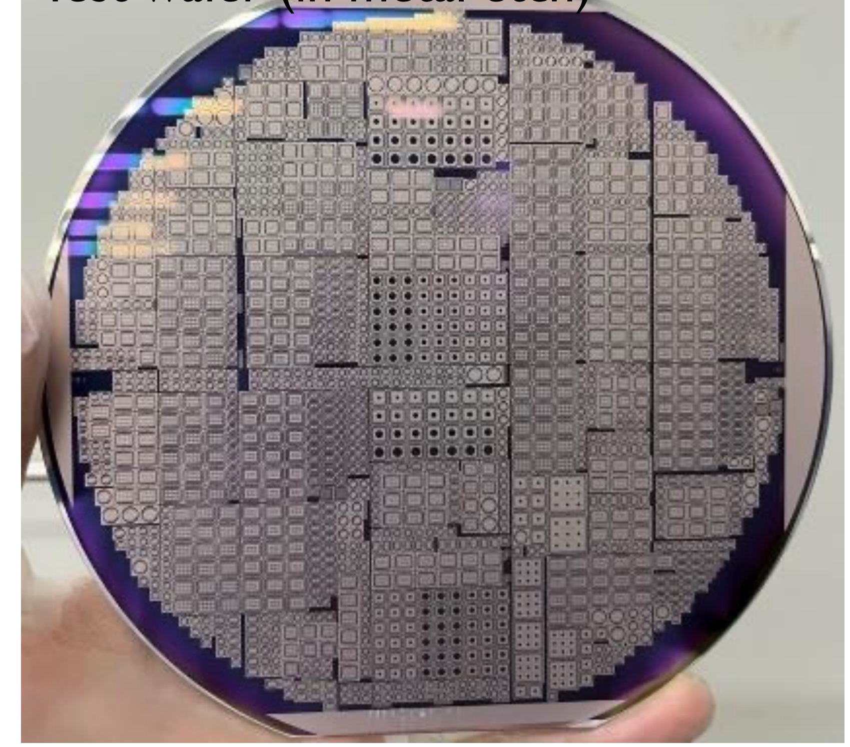






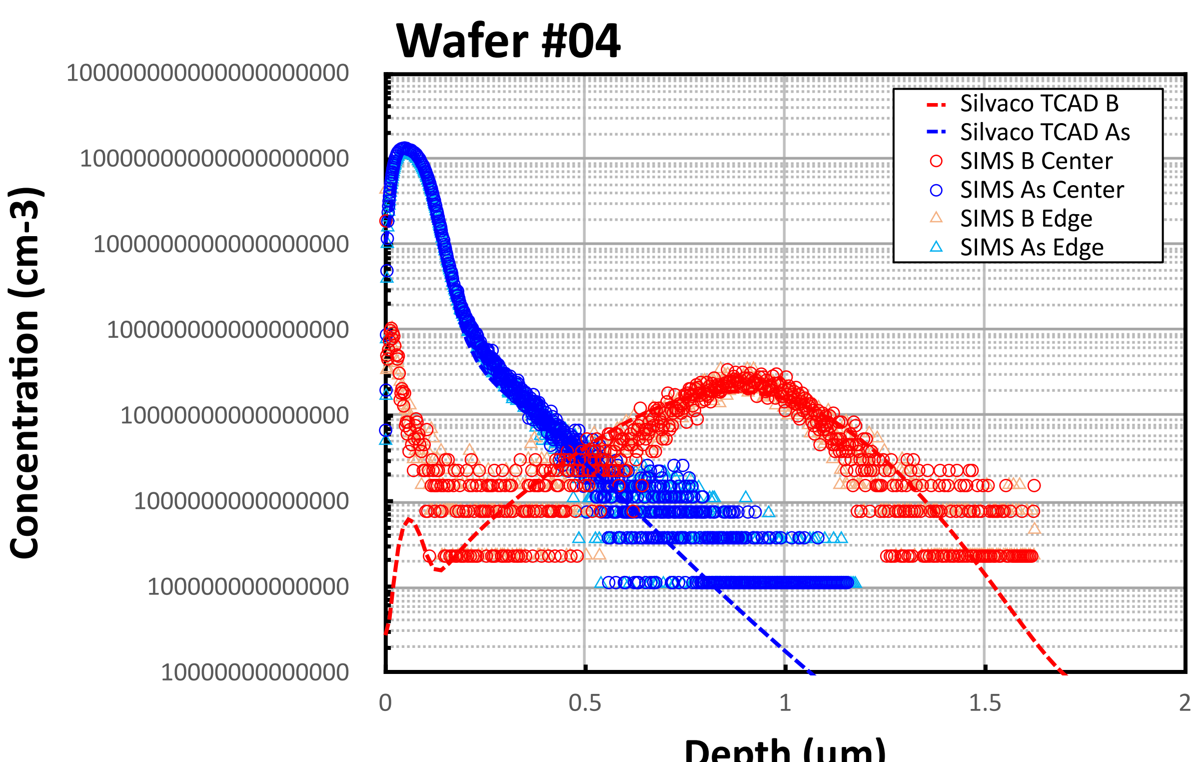
Laser signal to LGAD or PN

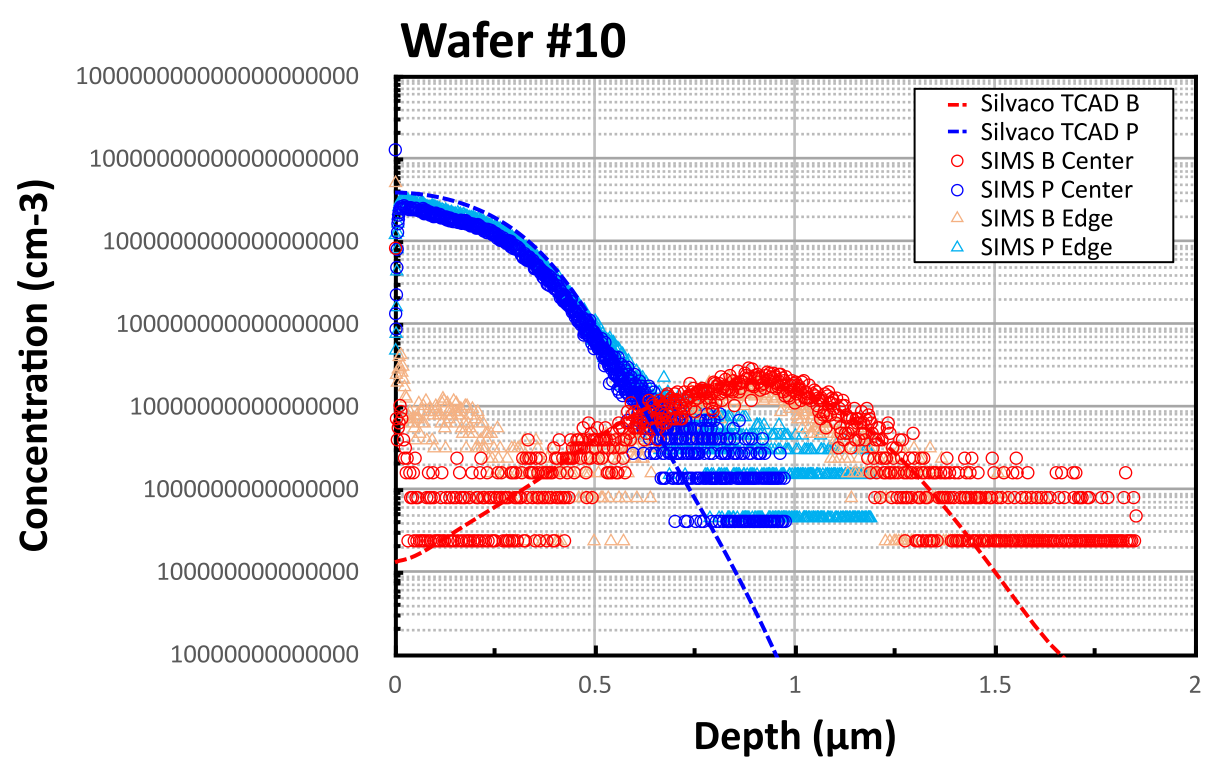
Test wafer (in metal etch)



AC-LGAD Sensor R&D

- Collaborating with BNL to implement the design to Taiwan fabs and seek for substantial amount of production.
- First attempt with Tyntek (鼎元光電) in progress. Two batches were returned in July 2025 to check the stability of process.
- Measurements of doping concentration show compatible results with simulation.
- Will do the EPI wafter next, with our own mask, and compare with BNL sample.
- May try also back to TSRI for our own wafer.





	Implant 1			Diffusion 1		Implant 2			Diffusion 2	
	impurities	Dose(cm-2)	Energy	°C	min	impurities	Dose(cm-2)	Energy	°C	min
#03-06	B	1.00E+12	380keV	800	20	As	1.00E+14	90keV	800	20
#07-10						P		80keV		

Mechanical Structure of 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

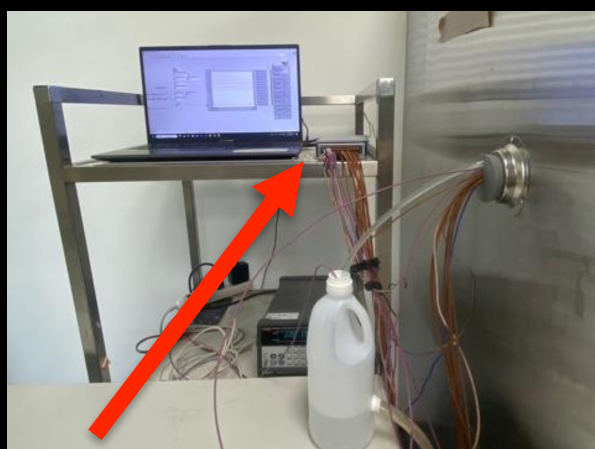
Oskar Hartbrich (ORNL),
Andreas Jung (Purdue),
Po-Ju Lin (AS),
Yi Yang (NCKU),
Zhenyu Ye (UIC)
for the EPIC TOF group.

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.

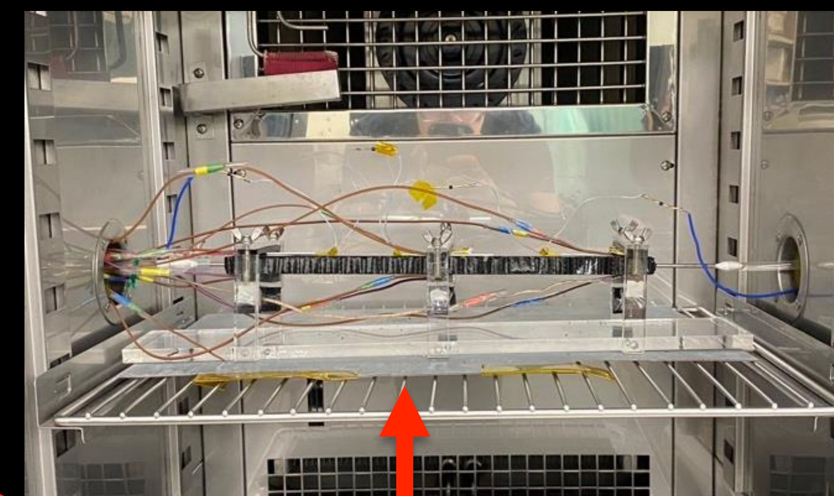
Thermal Test Setup @ NCKU (300 mm)



NI 9213 DAQ
- 16 channels
- Accuracy:
  - High-resolution mode : <0.02 ˚C
  - High-speed mode : <0.25 ˚C

Heat source (x 9)
- Ceramic plate (5Ω): ~500˚C

Thermocouple (x 16)
- Type E: -250˚C ~ 900˚C



Environmental chamber
- Inner dimensions: 40 x 50 x 60 cm^3
- Temperature: -40 ˚C ~ 100 ˚C (± 0.2 ˚C)
- Humidity: 10% ~ 98% (± 2.5%)

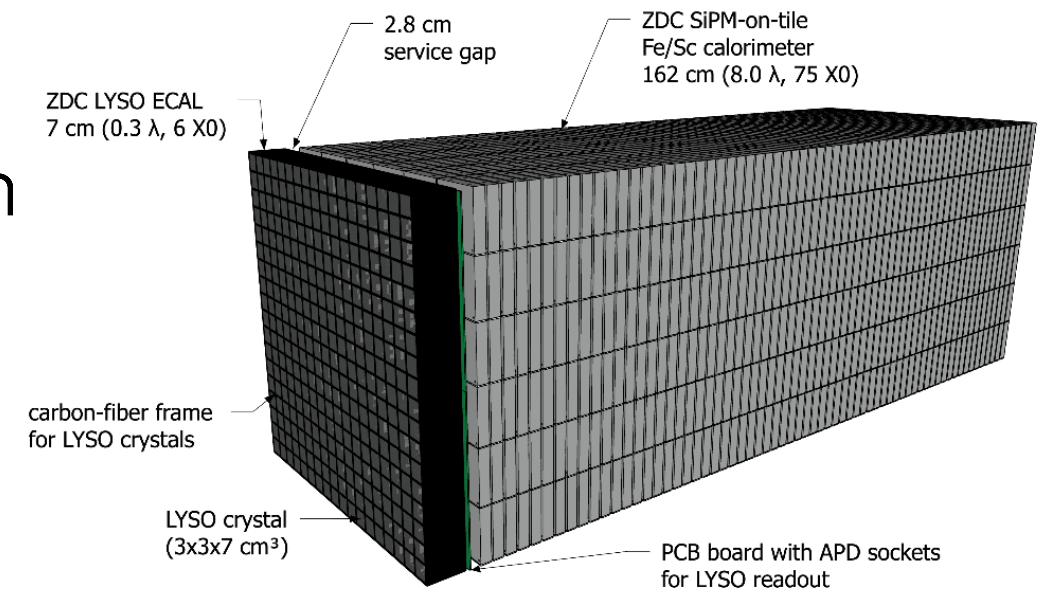
Flow meter
- 20 – 300 cc/min

Cooling system
- Temperature: 3 ˚C ~ 32 ˚C

ZDC - ECAL+HCAL

- Crystal calorimeter as first layer. Requires to have 2-5% energy resolution and 1-2 cm position resolution for up to 40GeV gamma.

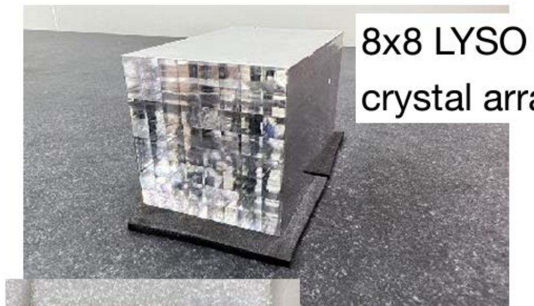
- Constructing prototypes with beamtest evaluation. Propose to try LYSO (high light yield, TCECM crystal) and PbWO4 (CMS ECAL)

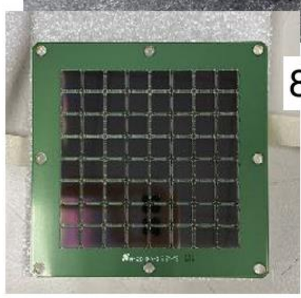


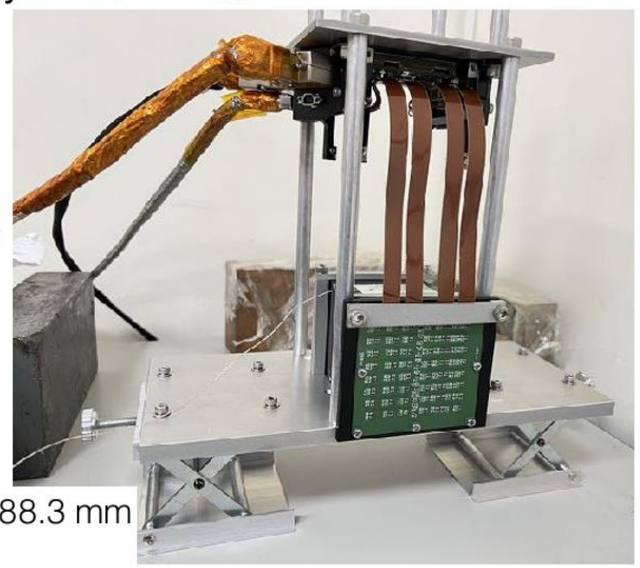
	Detector	Crystal				Sensor		DAQ
		name	**Size of one cell**	**Length**	**Array**	**Type**	**sensor/crystal**	
1st prototype 2023-2024	**LYSO + SiPM**	LYSO	1cm*1cm	6.6cm (6X0)	8x8	SiPM Onsemi MICROFC-60035	1	CITIROC
2nd prototype 2024-2025	**LYSO + APD**	LYSO	1cm*1cm	6.6cm (6X0)	8x8	**APD C30739ECERH**	1	CITIROC
	PbWO4 + SiPM	**PbWO4**	2cm*2cm	5.3cm (6X0)	6x6	SiPM Onsemi MICROFC-60035	2	CITIROC
3rd prototype 2025-2026 (developing)	**LYSO + filter +SiPM**	LYSO	1cm*1cm	6.6cm (6X0)	8x8	**SiPM Hamamatsu S14160-3015PS**	4	**HGCROC**
	PbWO4 + SiPM	PbWO4	2cm*2cm	5.3cm (6X0)	6x6	**SiPM Hamamatsu S14160-3015PS**	16	**HGCROC**

ZDC prototypes for cystal section

1st Prototype of ZDC ECal

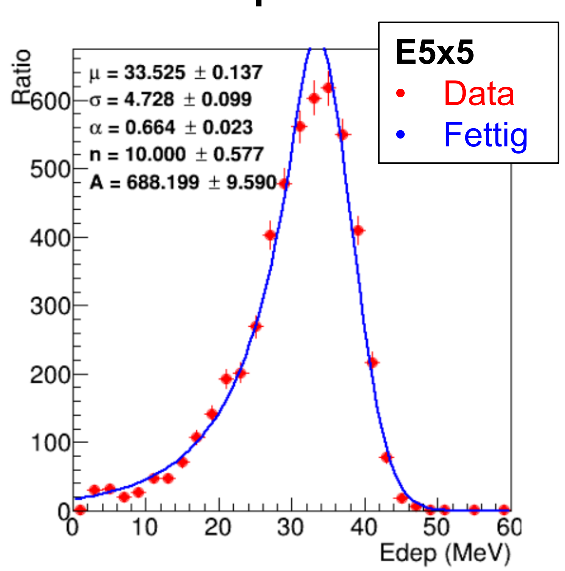




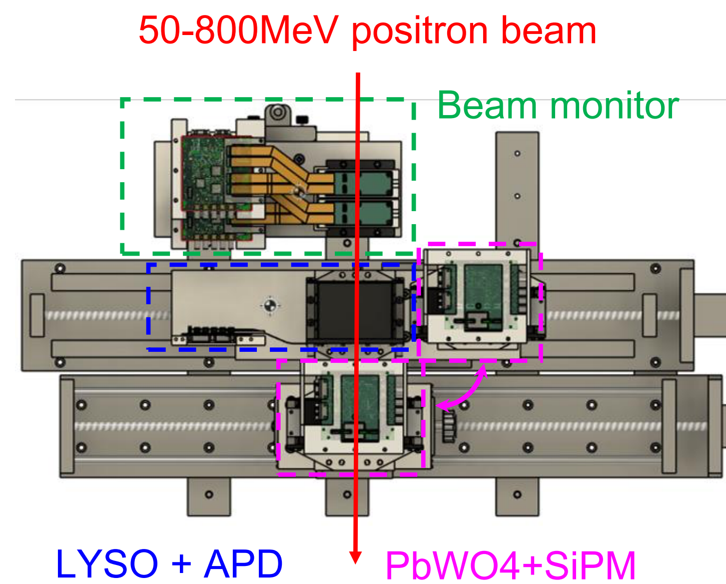


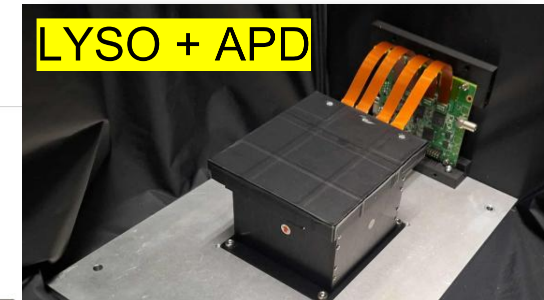
One crystal: 7.12 mm x 7.12 mm x 88.3 mm
8x8 array: 56.96 mm x 56.96 mm

- Non-linearity energy behavior above 20 MeV due to the saturation of SiPM response.
- Achieve ~11% resolution of 47 MeV beam energy

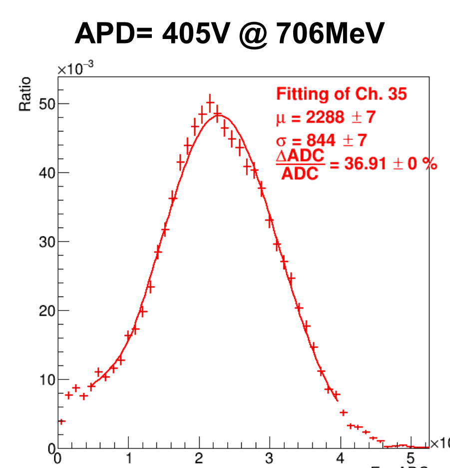


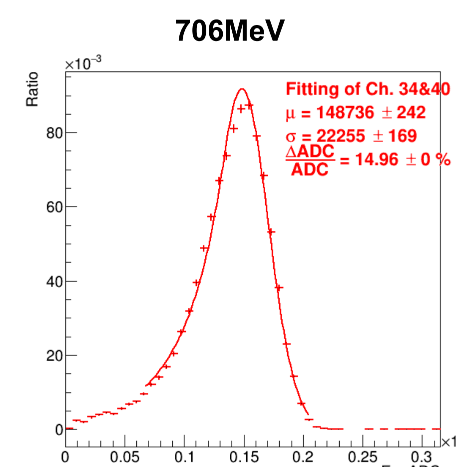
2nd ZDC ECal Prototype





- LYSO + APD. The gain of an APD is about 1000 times lower than that of a SiPM.
- PbWO4+ SiPM. The light yield of $PbWO_4$ is about 100 times lower than that of LYSO.
- Reaching 35%/ 15% resolution.



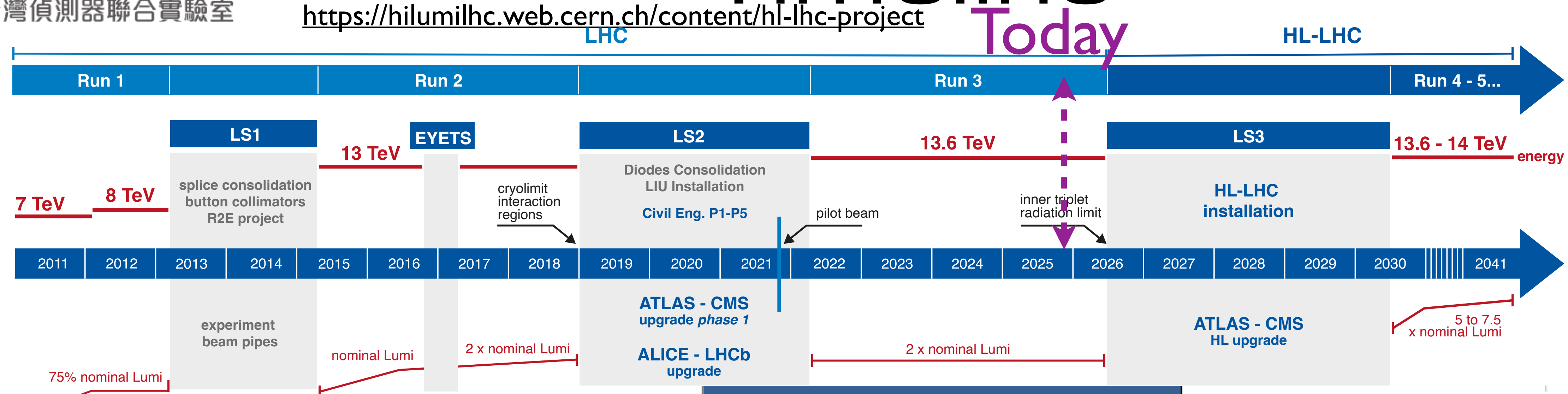


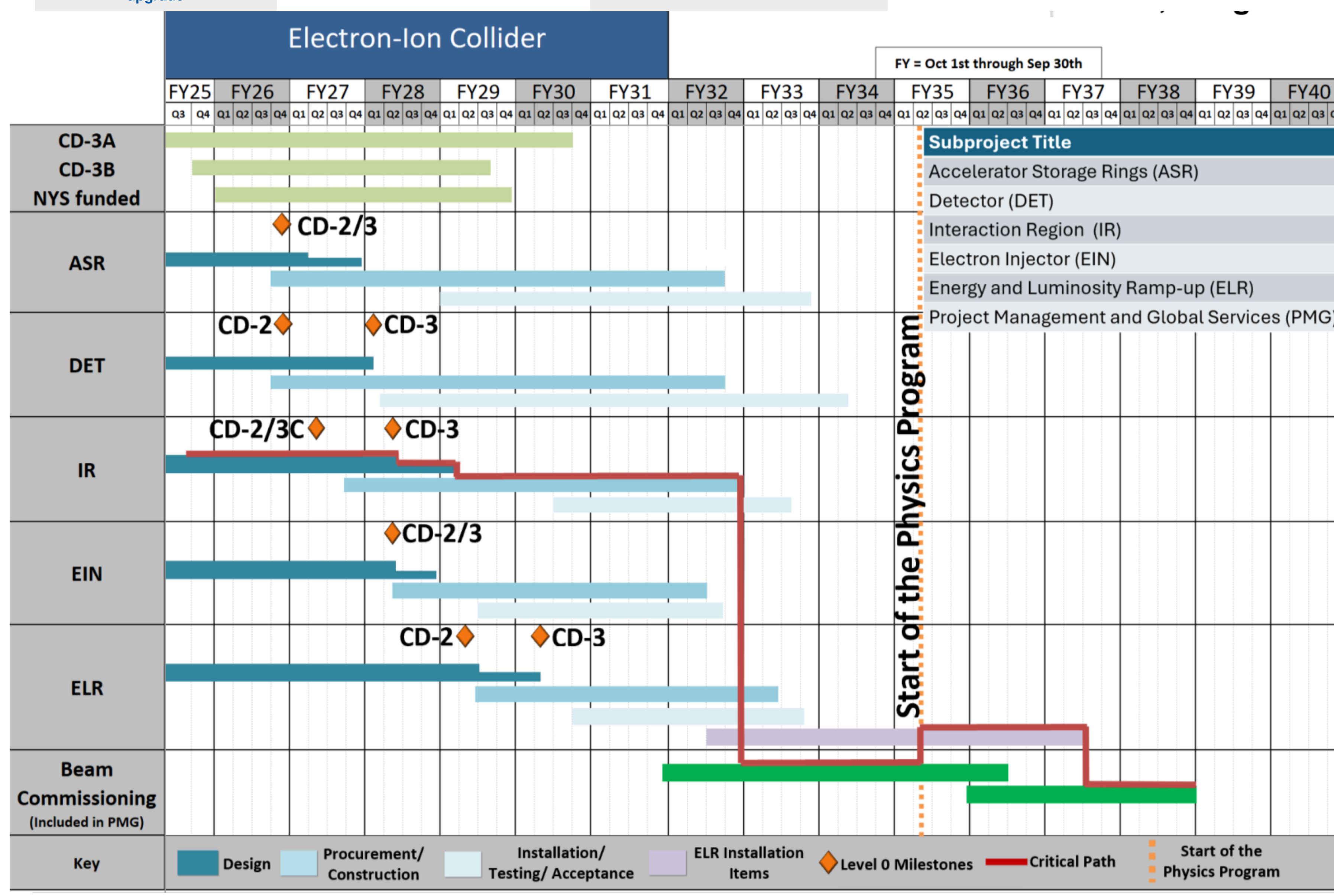
ZDC - Crystal Section

- Preliminary results of 2nd prototypes obtained energy resolutions: LYSO+APD:35%; PbWO4+SiPM:15%.
- Not far from the simulation results. However, not satisfied with the updated requirement = 2%-5%. Redesigning ECAL might be necessary.
- Detail analysis to improve resolution further. Debug APD operation
- Build 3rd prototype with PbWO4 crystals, new SiPM chip (Hamamatsu S14160-3015PS), and new ROC (H2GCROC)

Timeline

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



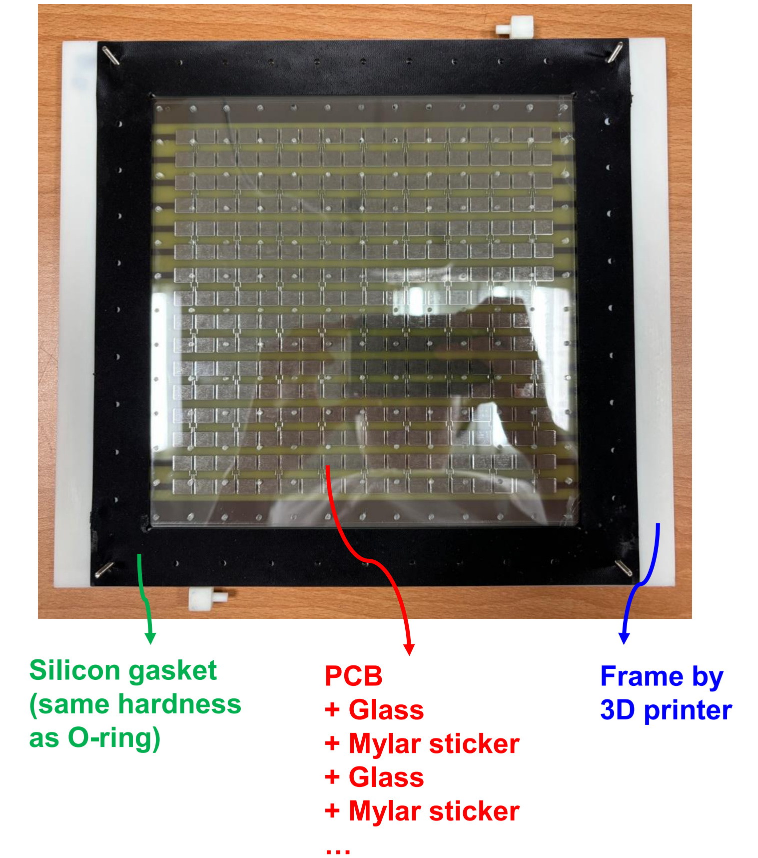


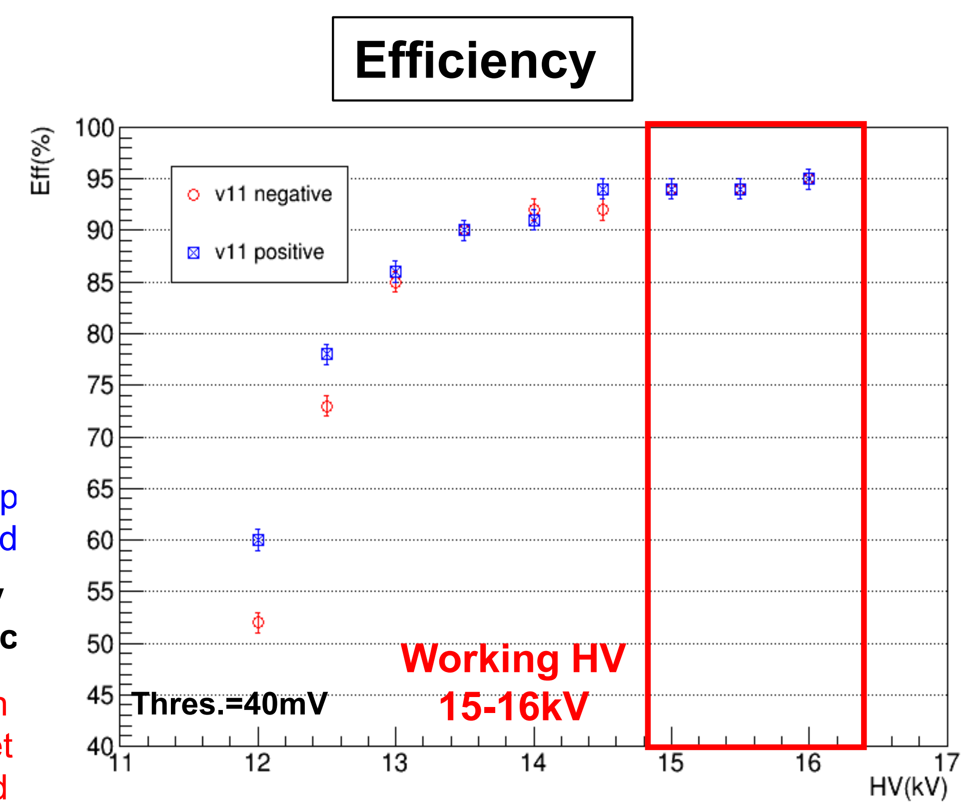
Carlos Camacho
Initial Stage 2025

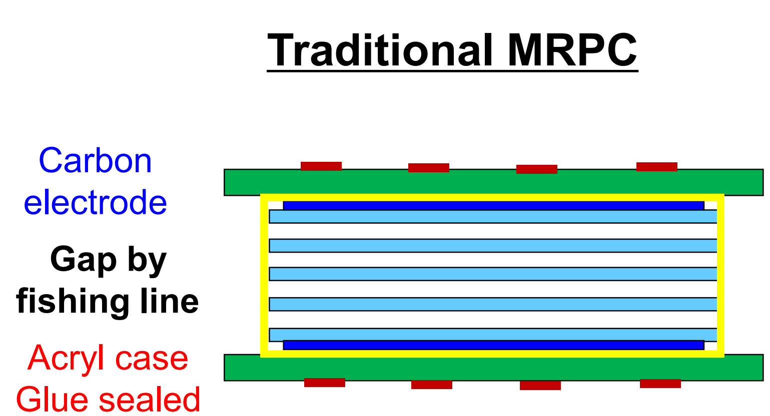
RPC R&D

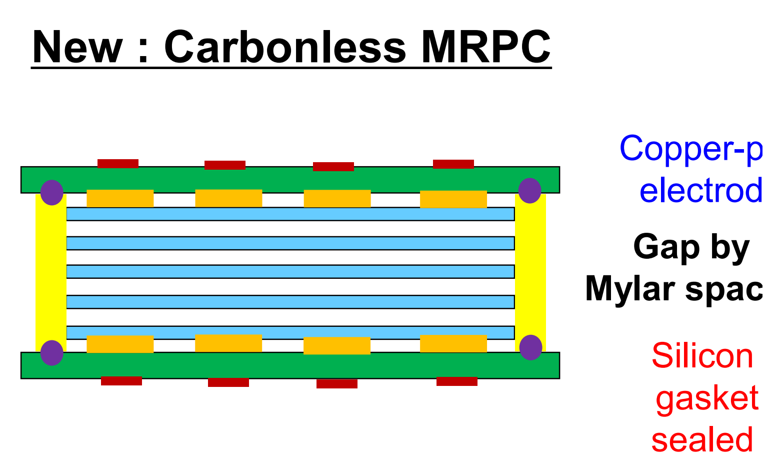
RPC development, Chia-Yu Hsieh

- AS collaborates with Osaka and Kyoto to develop RPC for MARQ@J-PARC project.
- Initiated carbonless MRPC since 2022 with NCU.
- Carbon paint/spray/tapes (MOhm) ➔"copper pads" with resistors (~MOhm) connected in between. It is easily manufactured by PCB technique. Assembling of RPC becomes more standardized.
- In beamtest, obtained 95% efficiency and 95ps time resolution, but stability requires investigation





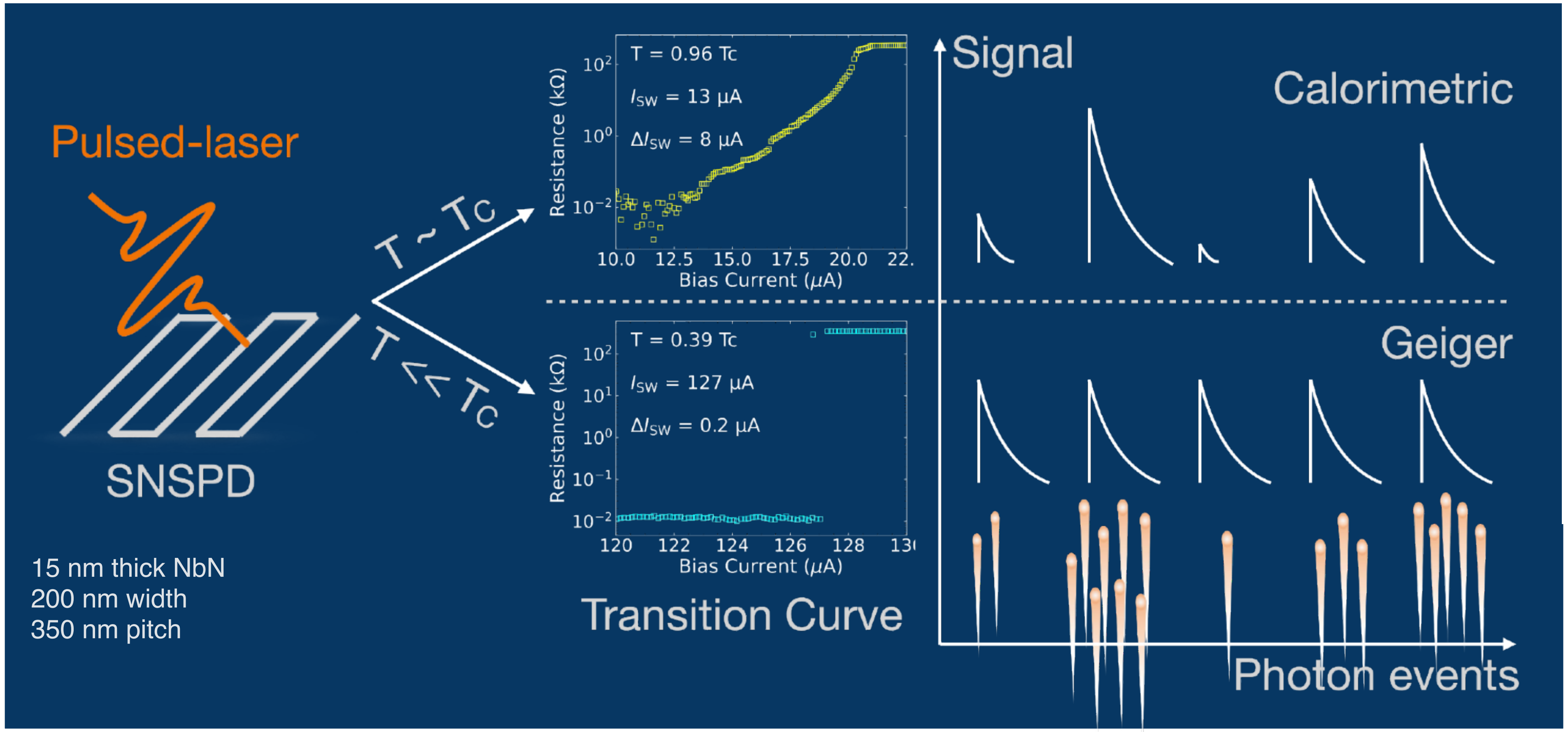




Others

R&D of Superconducting Nanowire Single Photon Detector (SNSPD)

- Dual-operation mode SNSPD ([APL Quantum 2, 026118 (2025)])
- Switch between conventional event counting and energy measurement by adjustment of operating temperature and bias current
- Geiger mode @ 4.7 K (0.39 Tc) ↔ Calorimetric mode @ 11.5 K (0.96 Tc)



State-of-the-art SNSPD

Near-IR (0.8μm-2μm)

- ~100% efficiency @ 1550nm
- Low timing jitter (<15ps)
- Low Dark Count (<0.01Hz)
- Fast recovery (MHz rate)
- Multi Pixelated array

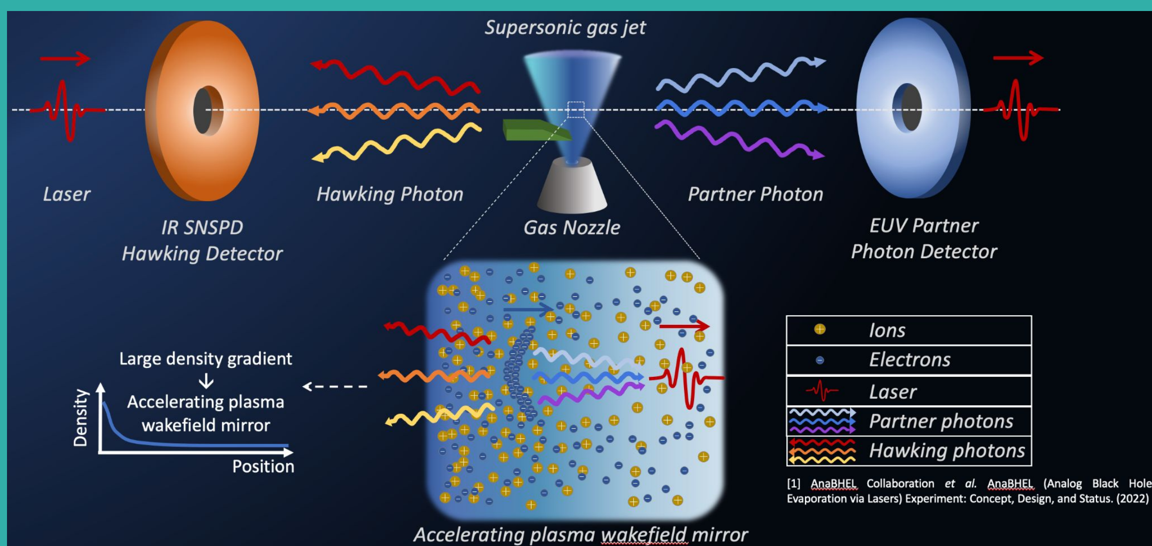
R&D Goal

Extend to Mid-IR (2μm-20μm)

- Energy resolving power
- Broadband spectrometry
- Polarization distinguishability

R&D of Superconducting Nanowire Single Photon Detector (SNSPD)

Applications



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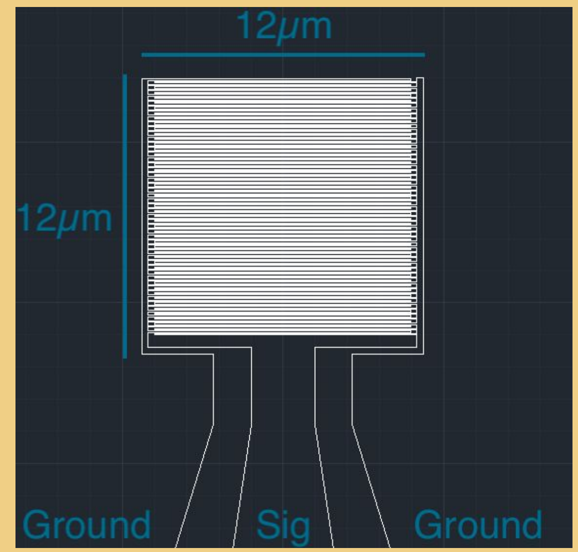
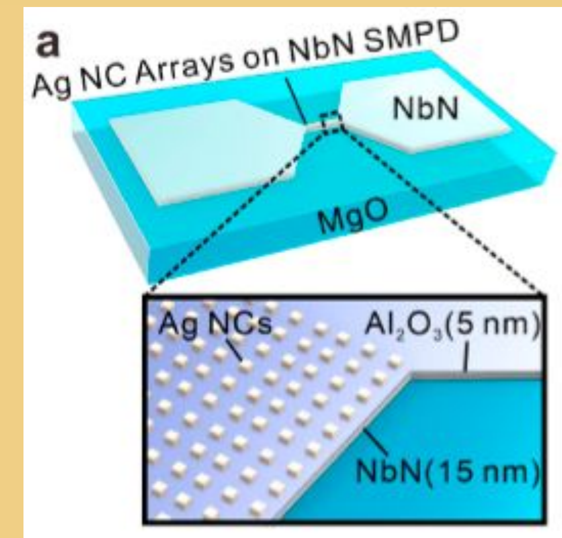
Design and Simulation

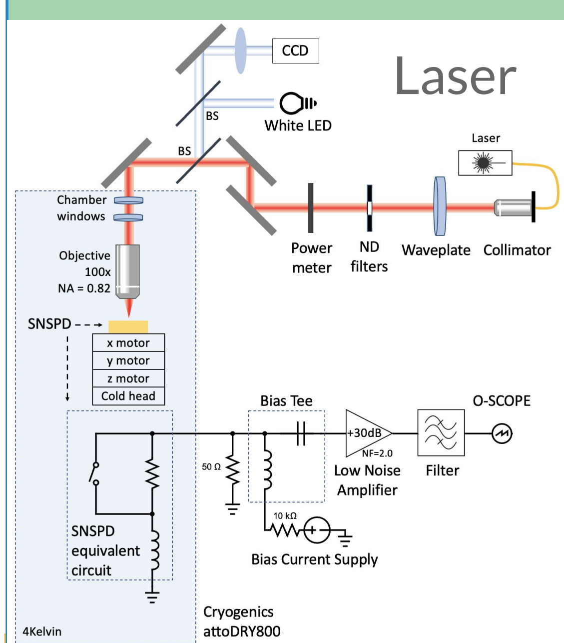


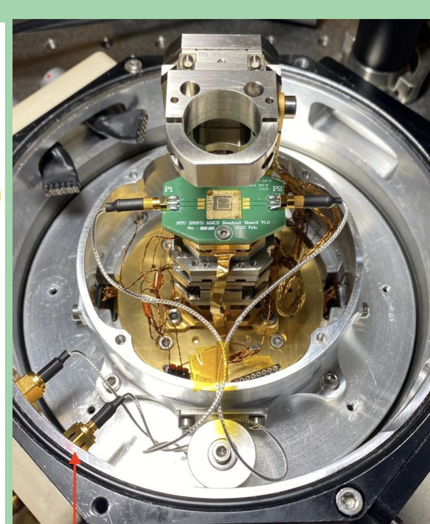
Nanowire meander



Nanocube plasmonic enhancement structure

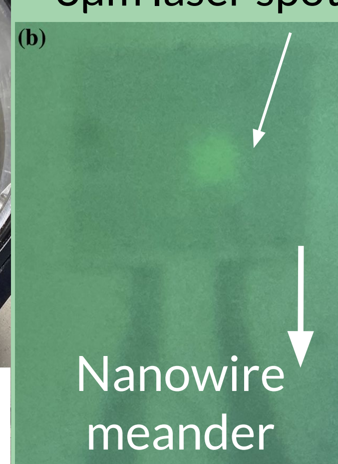
Characterization



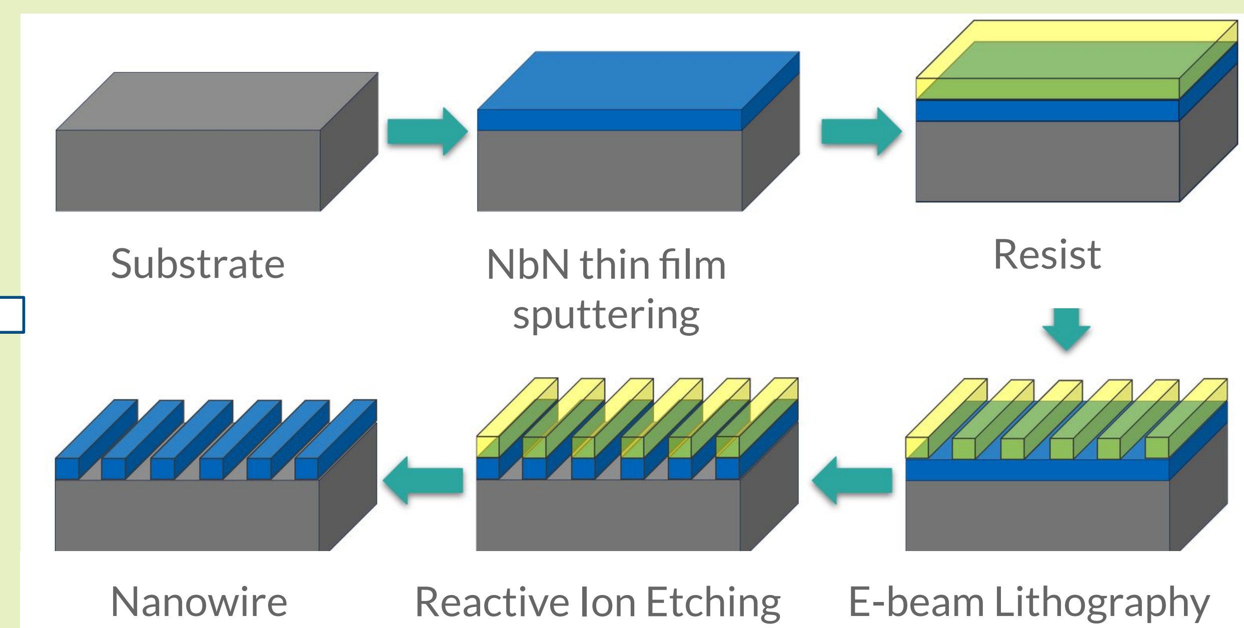


4K Cryostat

Pulsed-Laser
100ps width
3μm laser spot

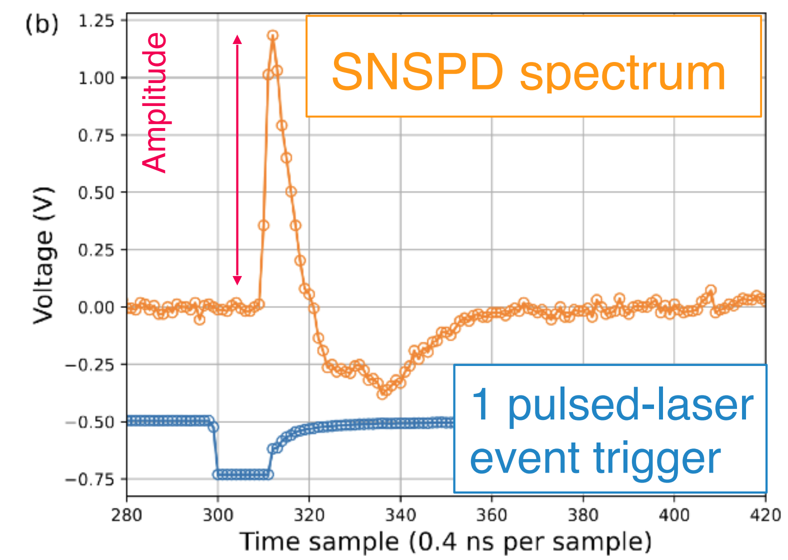


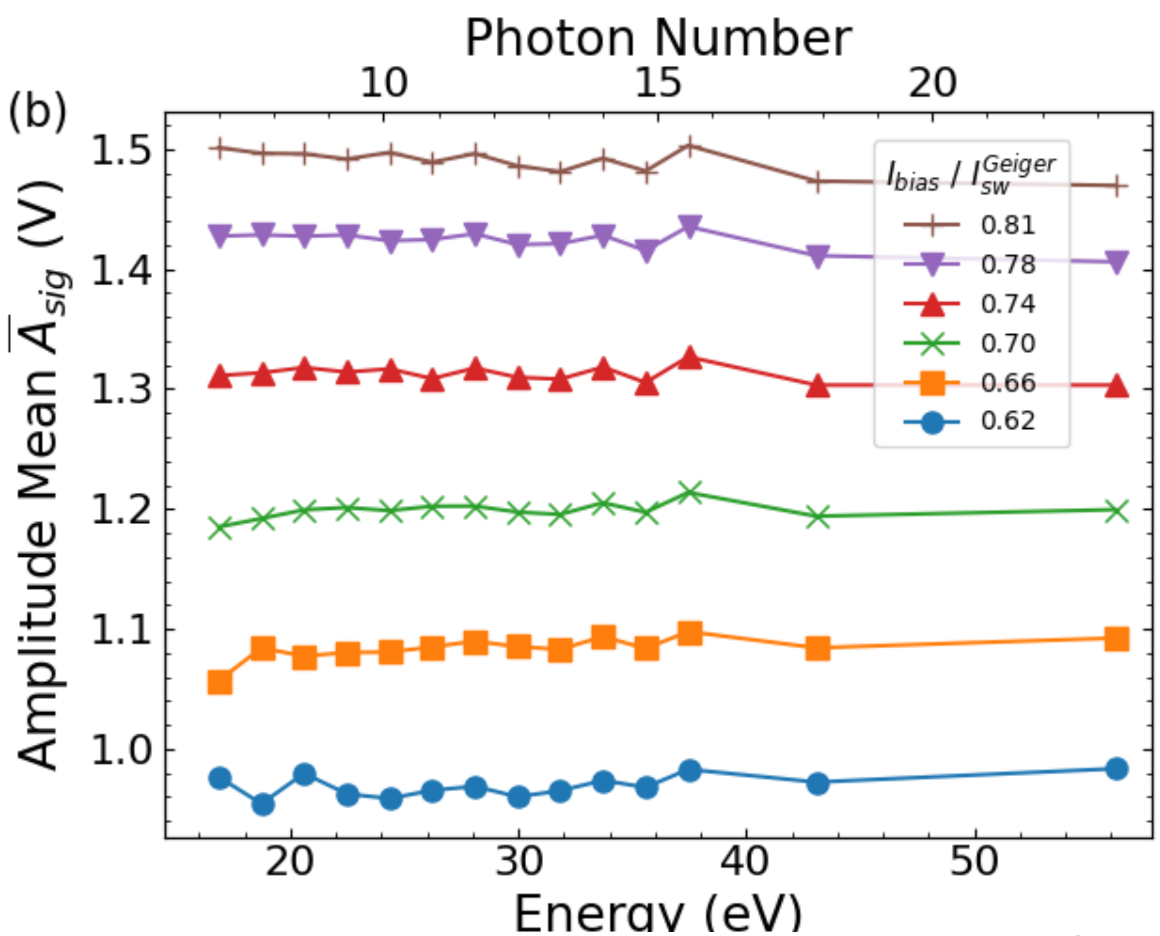
Fabrication

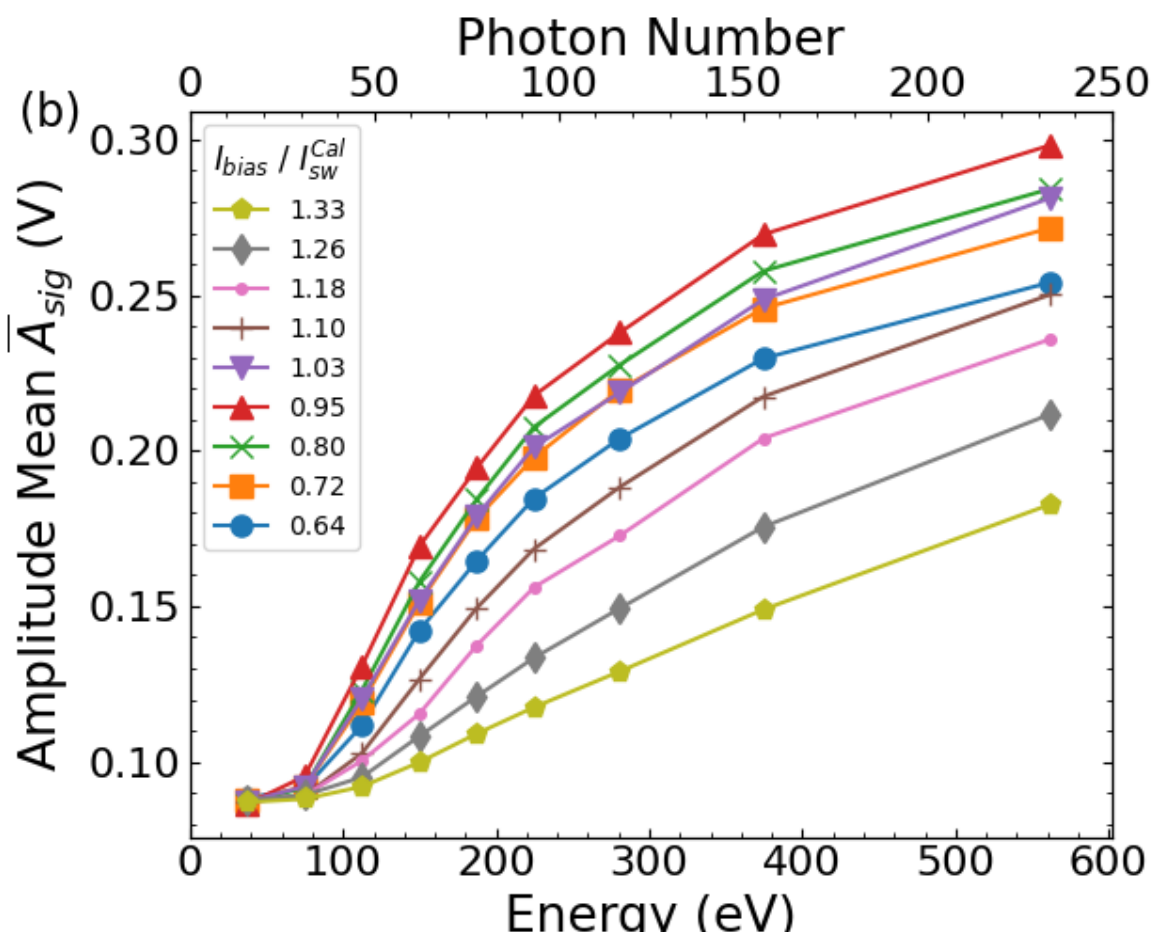


SNSPD Highlights

- Geiger ↔ Calorimetric
  - ✦ Vortex-crossing-induced full transition ↔ Joule heating partial transition
  - ✦ No energy dependence in signal amplitude ↔ depend on N(absorbed photon)
  - ✦ Fast event counting ↔ Potential fast photon number resolving spectroscopy







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

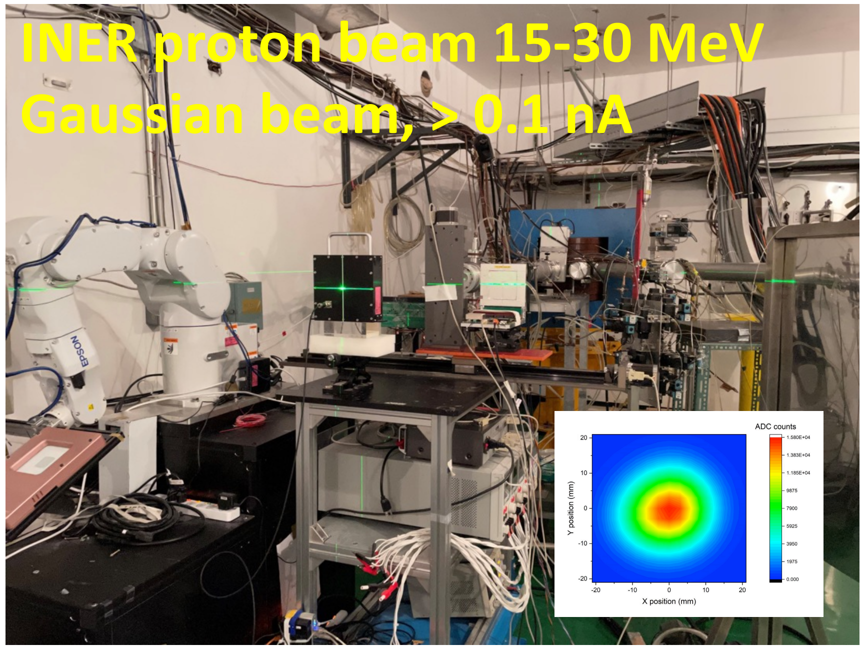
Opto-fiber RD items

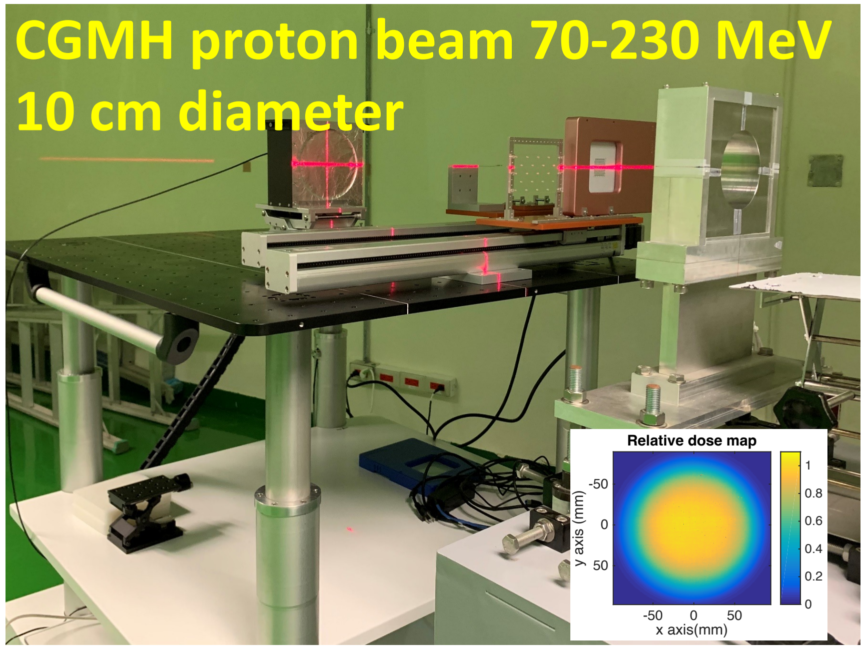
- **Fiber Rad-hard**
  MM Ge-doped @INER Co60 TID study is finishing
  COTS, Fluorine-dope, pure Silica fiber Rad-hard study
- **Rad-hard Active opto-electronics**
  850 nm VCSEL, PD characteristics, COTS 光環, II-VI, ..
  NIEL @INER 30 MeV protons
- **ASICs, laser driver, PD TIA** ← **deadly issue!**
  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

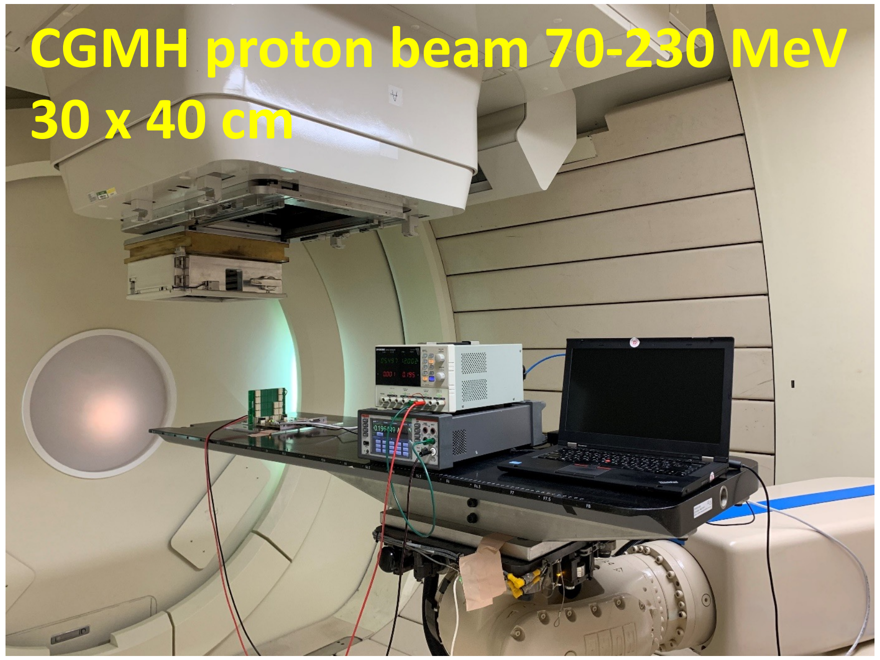
https://indico.phys.sinica.edu.tw/event/52/contributions/248/attachments/202/337/EIC_NCKU2022_v2.pdf

Radiation Facilities

- Proton 15-30 MeV and Co60
  - ✦ 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*cm2mg-1

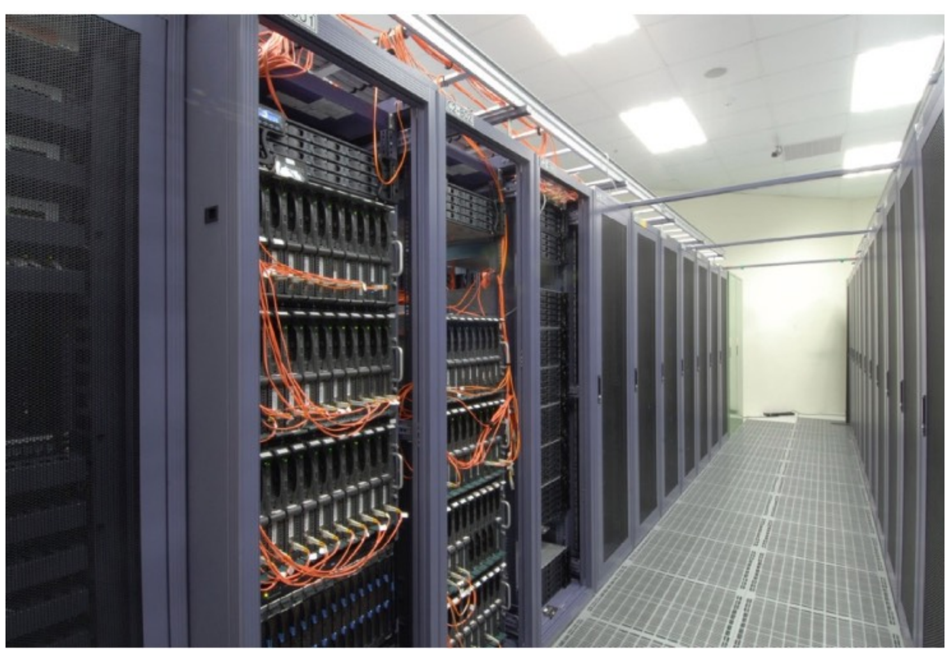






Computing Resources in Taiwan

- 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



	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

- TW-HEP has expertise in silicon, crystal and other detector technologies. We will contribute to future detector projects, such as ePIC sub-detectors.
- There may be other opportunities for contributions, such as electronics, opto-electronics, and computing.

Backup Slides