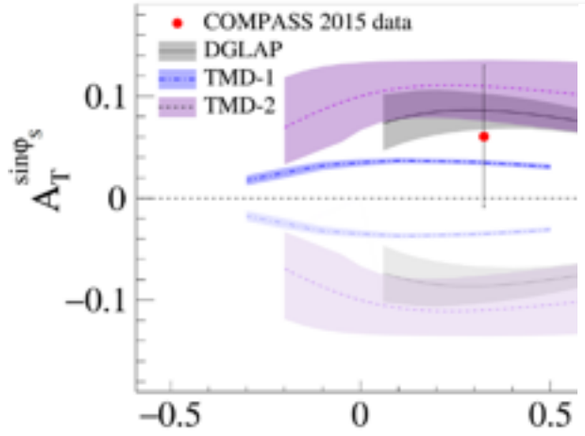
Status of the EIC-Taiwan

Chia-Ming Kuo (NCU, Taiwan)

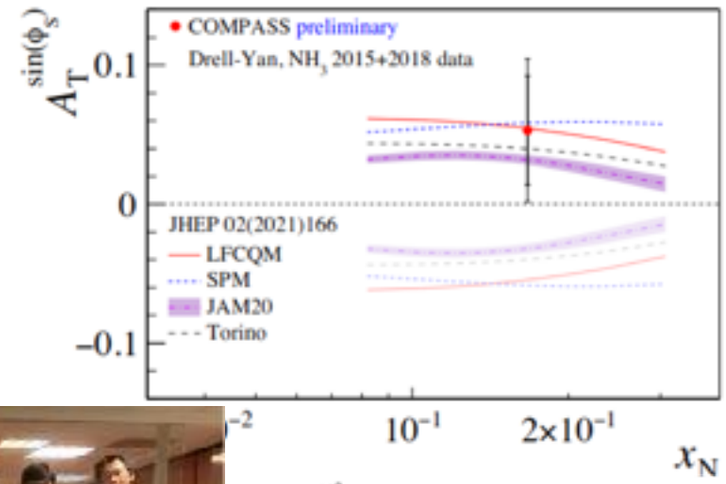
Current/Past Experimental Particle Physics Programs (1/2)

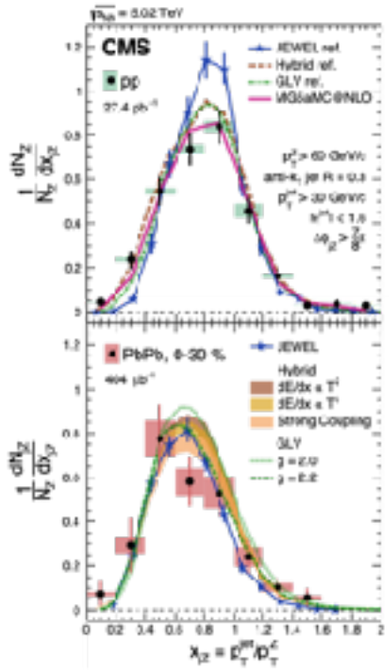
- **Hadron Physics:**
  - LEPS,LEPS2 @ Spring8 (2000 -)
  - E906/SeaQuest @ FNAL (2009 - 2017)
  - COMPASS @ CERN (2012 - 2022)
  - E16, E50 @ J-PARC (2017 -)
  - Hall-A @ JLab (2023 -)
- **Heavy Ion Physics:**
  - PHOBOS @ BNL (1994 - 2004)
  - PHENIX @ BNL (1997 - 2015)
  - STAR @ BNL (2015 -)
  - sPHENIX @BNL (2018 -)
  - CMS @ CERN (1999 -)

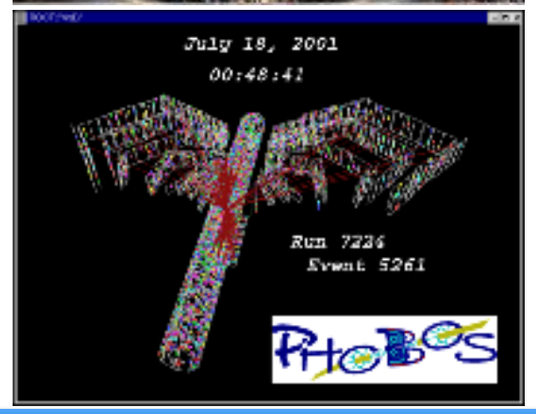
TMD Sivers Asymmetry in Drell-Yan

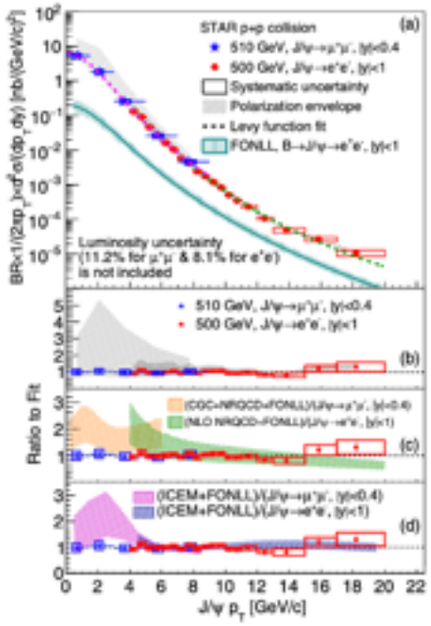


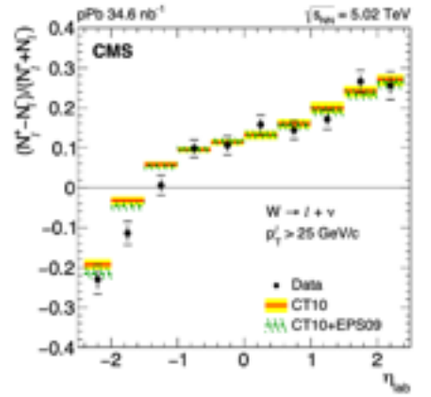
Polarized Drell-Yan: access to TMD PDFs





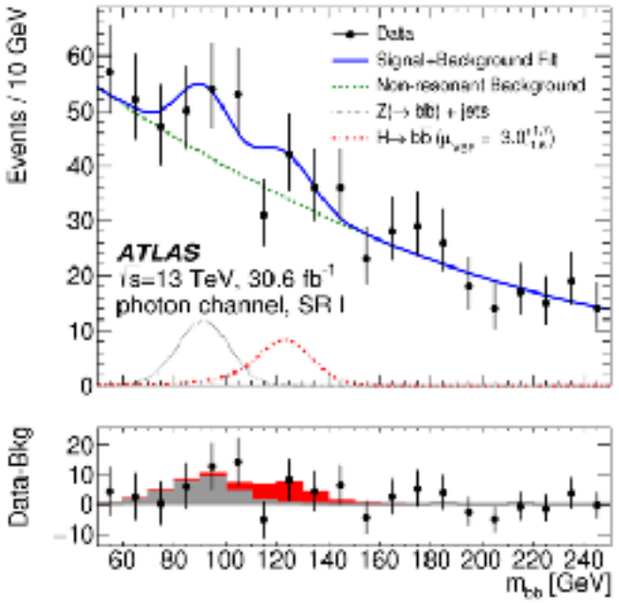


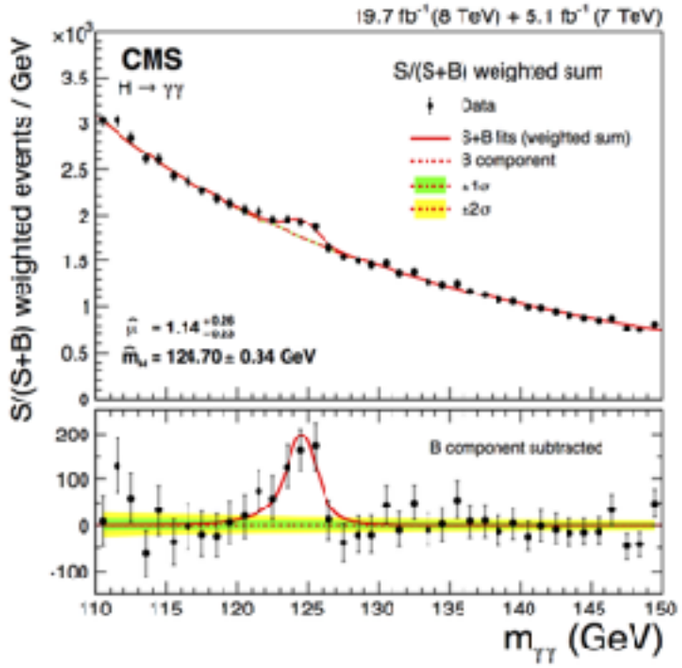


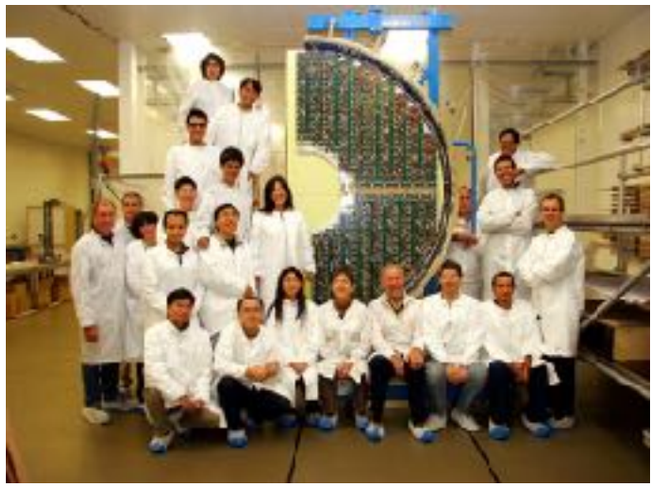


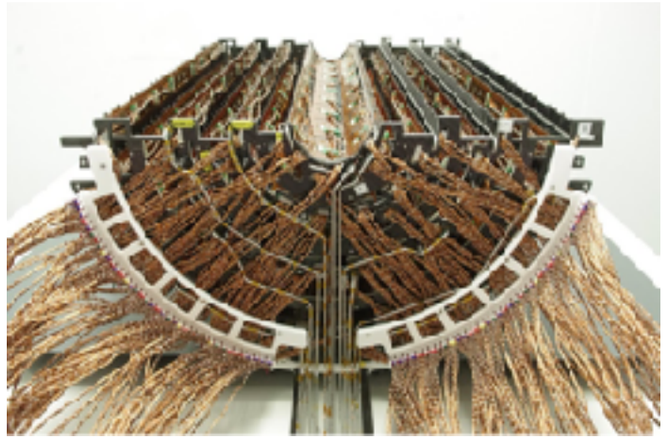
Current/Past Experimental Particle Physics Programs (2/2)

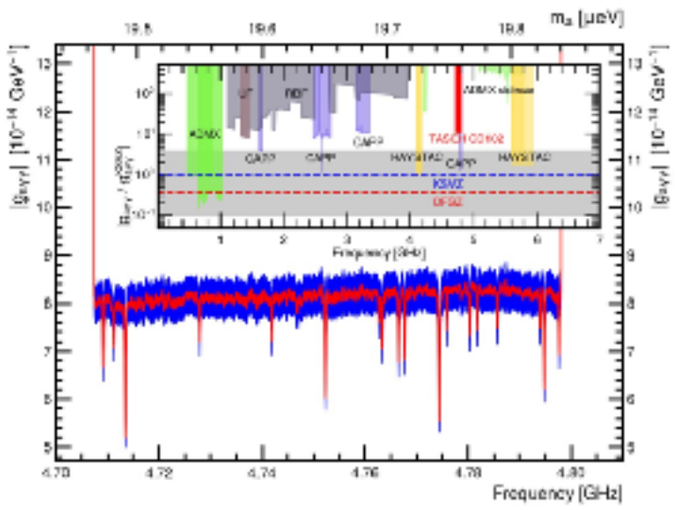
- **High Energy Physics**:
  - Belle, Belle II @ KEK
  - CDF @ FNAL
  - ATLAS, CMS @CERN
- **Astroparticle physics**:
  - AMS @ ISS/CERN
- **Neutrino/Dark Matter Physics**:
  - TEXONO @ KSNL, Taiwan
  - CDEX @ CJPL
  - Daya Bay, JUNO @ Hong-Kong
  - TASEH @ Taiwan

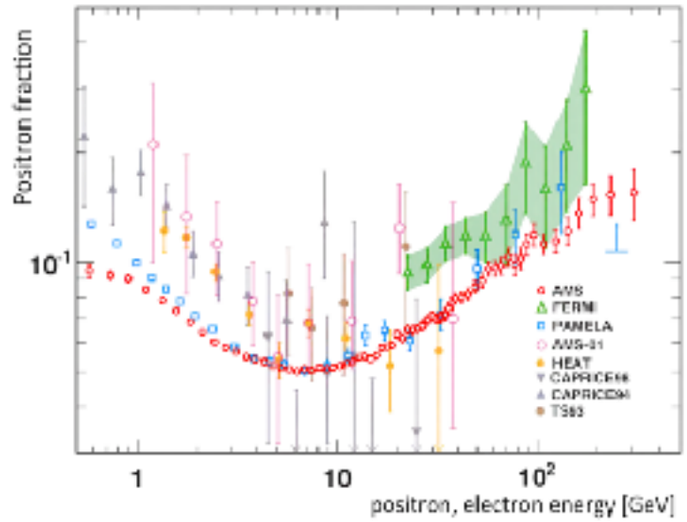












Towards a Common Project for All Taiwanese Groups

- At the end of 2017, all young PIs signed a letter of intent to reach a consensus on future selection

- In spring of 2020, a white paper was submitted to the National Science and Technology Council (NSTC)
  - primary objective: plan for common detector facilities, i.e., Taiwan Instrumentation and Detector Consortium (TIDC)

- In October 2020, the five major experimental particle physics groups in Taiwan signed the EIC EOI

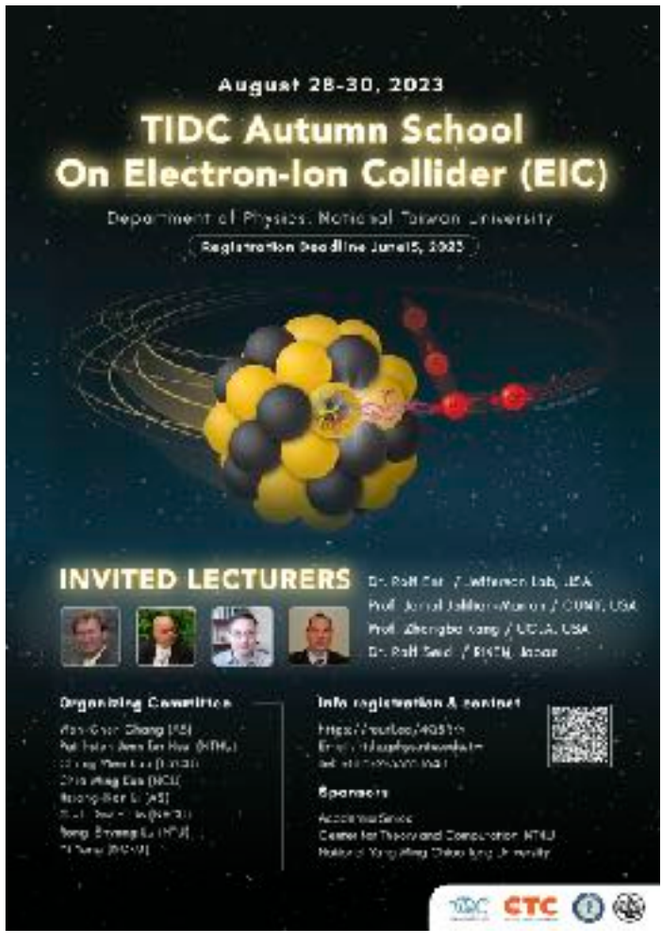
ePIC will be the first experimental project in which major Taiwanese groups collaborate

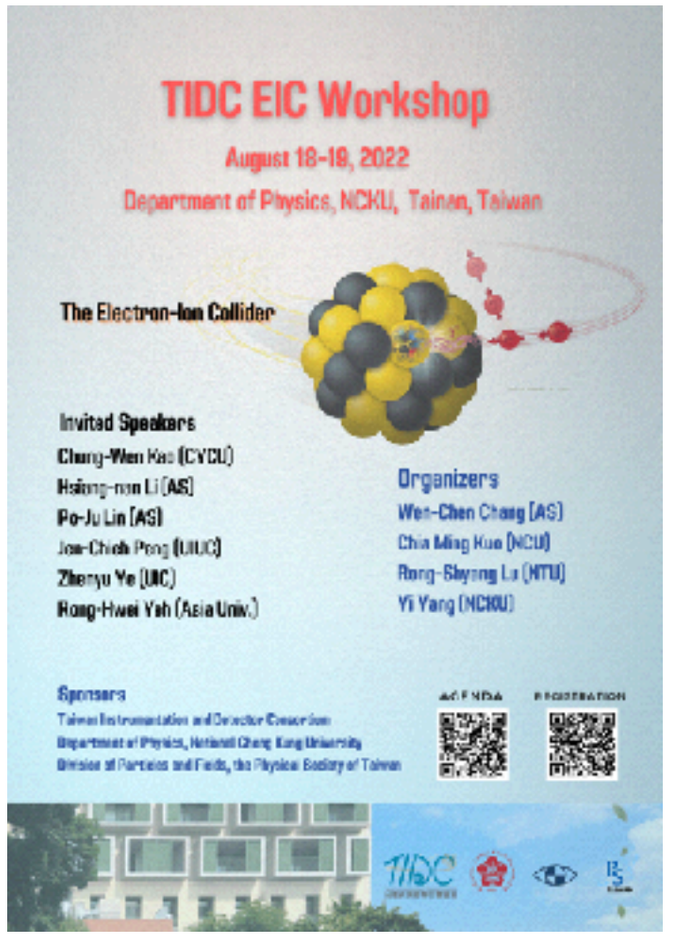
EIC Taiwan Team

- **Academia Sinica**
  - Wen-Chen Chang, Hsiang-Nan Li, Di-Lun Yang, Suen Hou, Chih-Hsun Lin
- **National Taiwan University**
  - Rong-Shyang Lu, Kai-Feng Jack Chen, Stathes Paganis, Juinn-Wei Chen
- **National Central University**
  - Jen-Chieh Peng (UIUC/NCU), Chia-Ming Kuo, Po-Ju Lin
- **Chung Yuan Christian University**
  - Chung-Wen Kao
- **National Tsing Hua University**
  - Pai-Hsien Jennifer Hsu
- **National Yang-Ming Chiao-Tung University**
  - C.-J. David Lin, Anthony Francis
- **National Cheng Kung University**
  - Yi Yang

11 experimental PIs/6 theoretical PIs

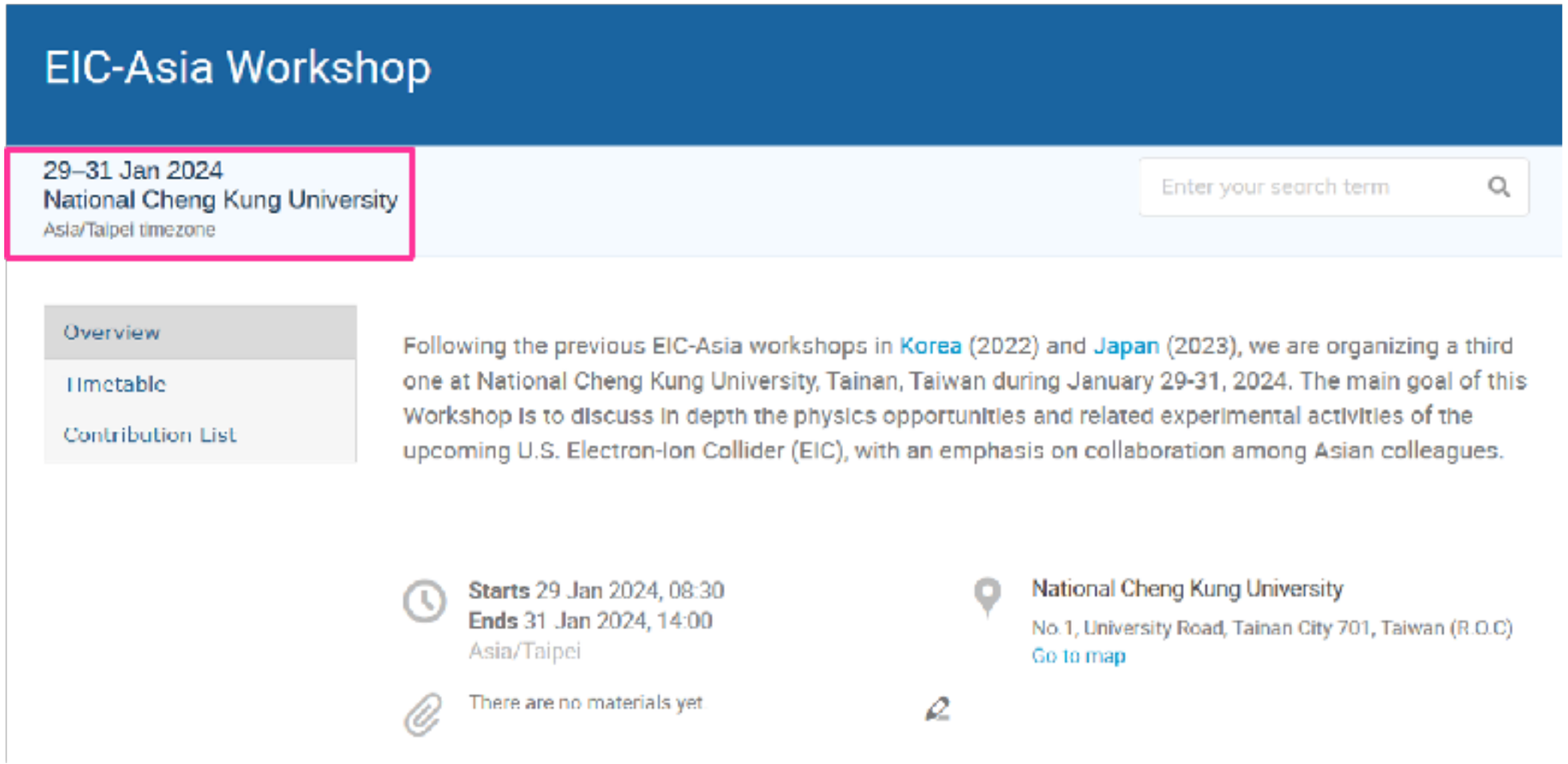
Workshops in Taiwan





EIC-Asia Workshop in Taiwan

https://indico.phys.sinica.edu.tw/event/88/

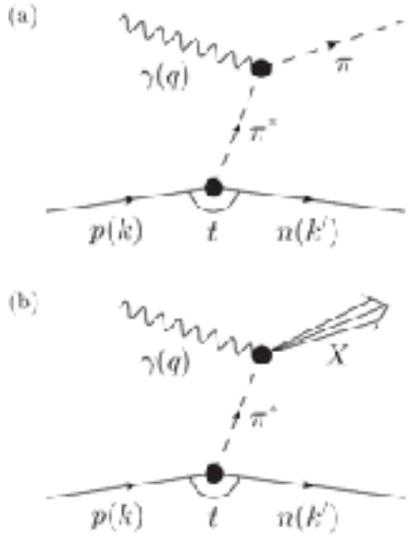


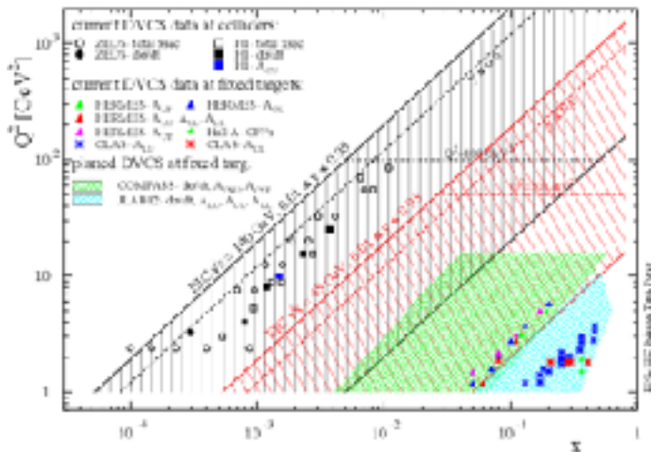
January 29 – 31, 2024 @ Tainan, Taiwan

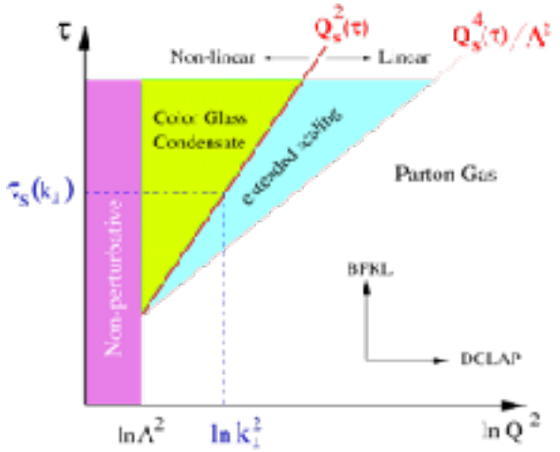
Initial Stage 2025

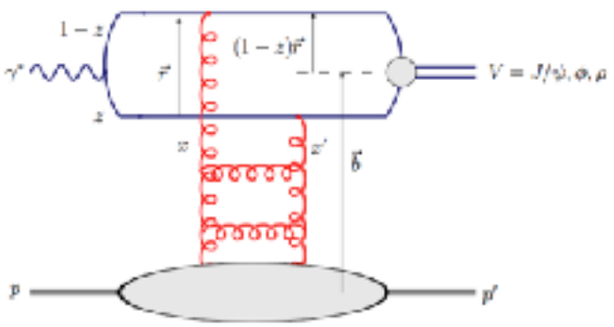
Physics Interests

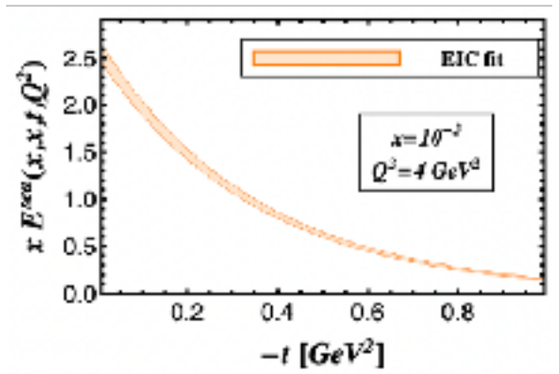
- **Preliminary ideas**
  - **Pion and Kaon PDFs** (tagged-DIS; sec. 7.1.3 of YR)
    - W.C. Chang, J.W.Chen, C.W. Kao, D. Lin
  - **GPDs** (DVCS, TCS, DVMP; sec. 7.2.2 of YR)
    - P.J. Lin, J.W. Chen, C.W. Kao
  - **CGC** (di-jet, di-hardon DIS, e+A->e'+A'+J/Ψ,phi,rho,..; sec. 7.3.1 and 7.3.9 of YR)
    - C.M. Kuo, H.N. Li
  - **hard probes** (jet, heavy quarks; sec. 7.3.6 of YR)
    - Y. Yang
- **Initial simulation studies associated with target jet structure under ep and/or EIC environment** (sec. 7.1.6 of YR)
  - K. F. Chen, Y. T. Chien
  - DIS2023 talk: https://indico.cern.ch/event/1199314/contributions/5188249/

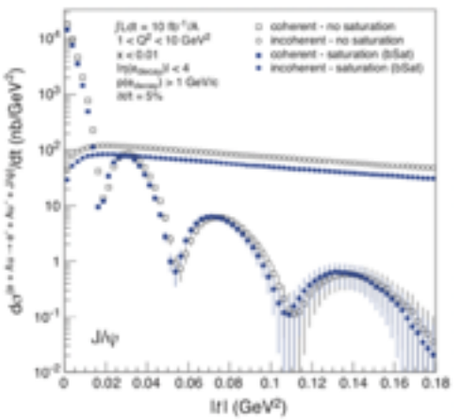












Theoretical Programs

- QCD effective theories and lattice QCD
- Parton distributions functions
- Aspects of atomic and nuclear physics in particle-matter interactions

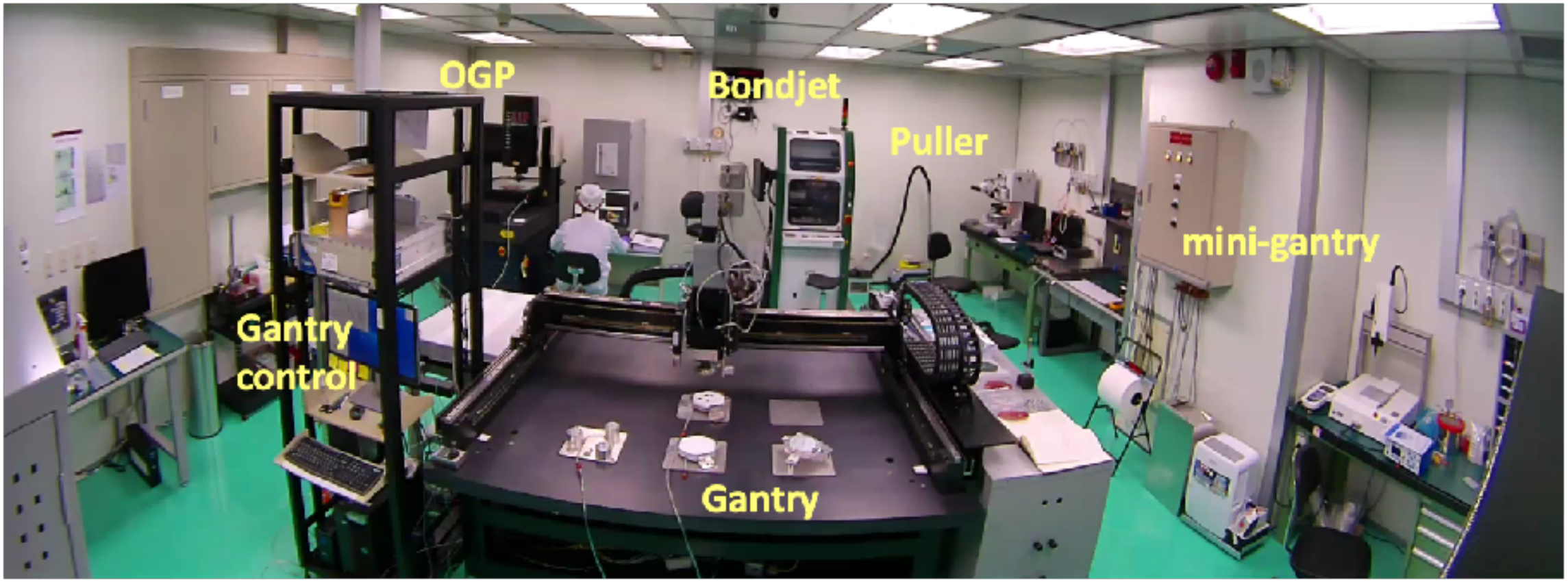





Taiwan Instrumentation and Detector Consortium (TIDC)

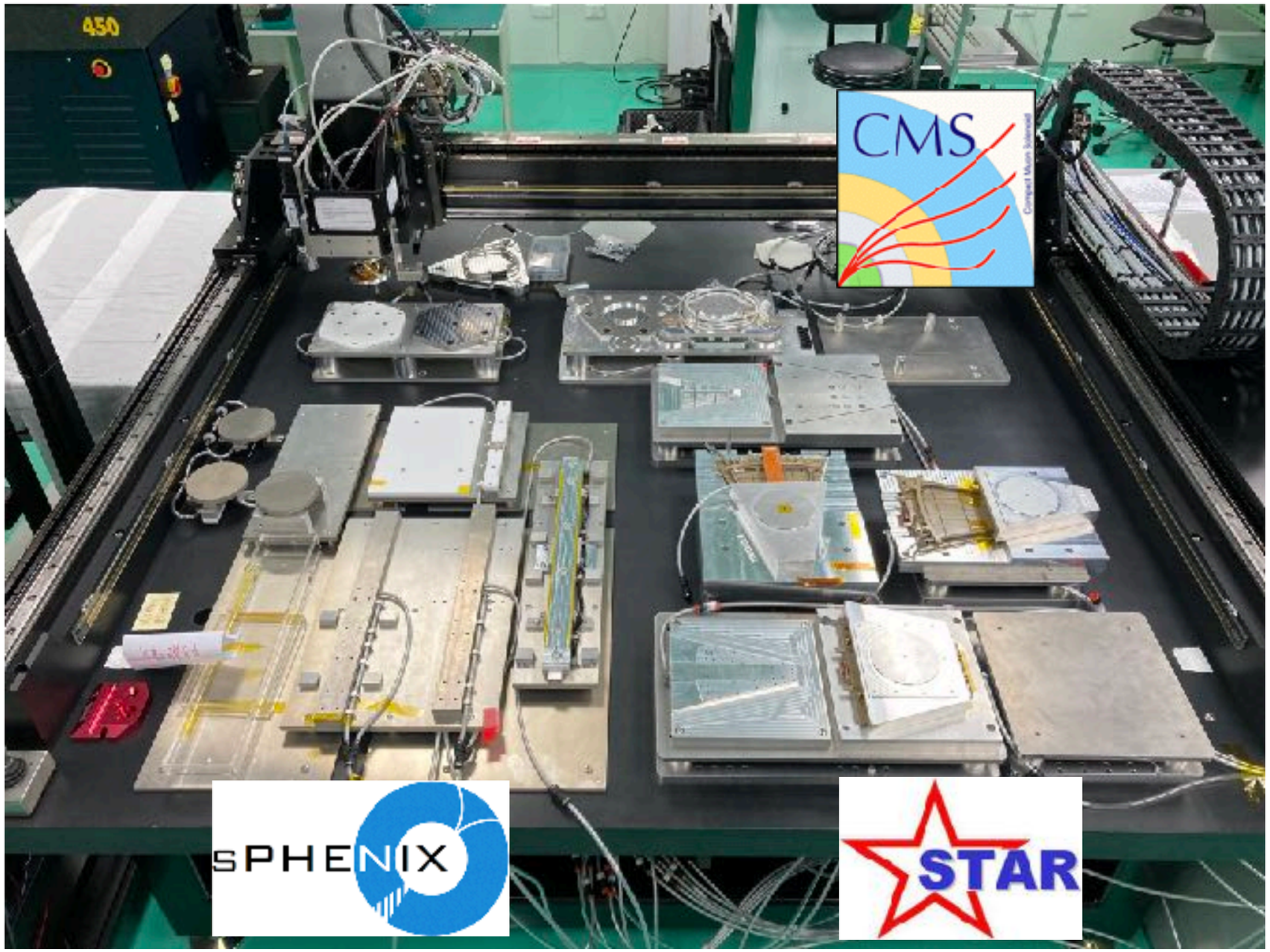
- TIDC was established in 2019 and became an official core facility of NSTC in 2022
- Website: https://tidc.phys.ntu.edu.tw/WordPress/
- Facilities are distributed among four institutes (**NTU**, AS, NCU, NCKU)
- Projects:
  - **CMS HGCal**
    - **one of six module assembly centers (5000 modules)**, silicon QC, production of HD/LD hexabaroads and DC-DC converters
  - **sPHENIX INTT**
    - assembled 1/3 (40) of silicon ladders
  - **STAR forward silicon tracker**
    - assembled the mechanical structure and bond hybrid PCBs
  - **AMS silicon strip tracker**
    - bond hybrid PCBs

Taiwan Silicon Detector Facility (TSiDF) @ NTU

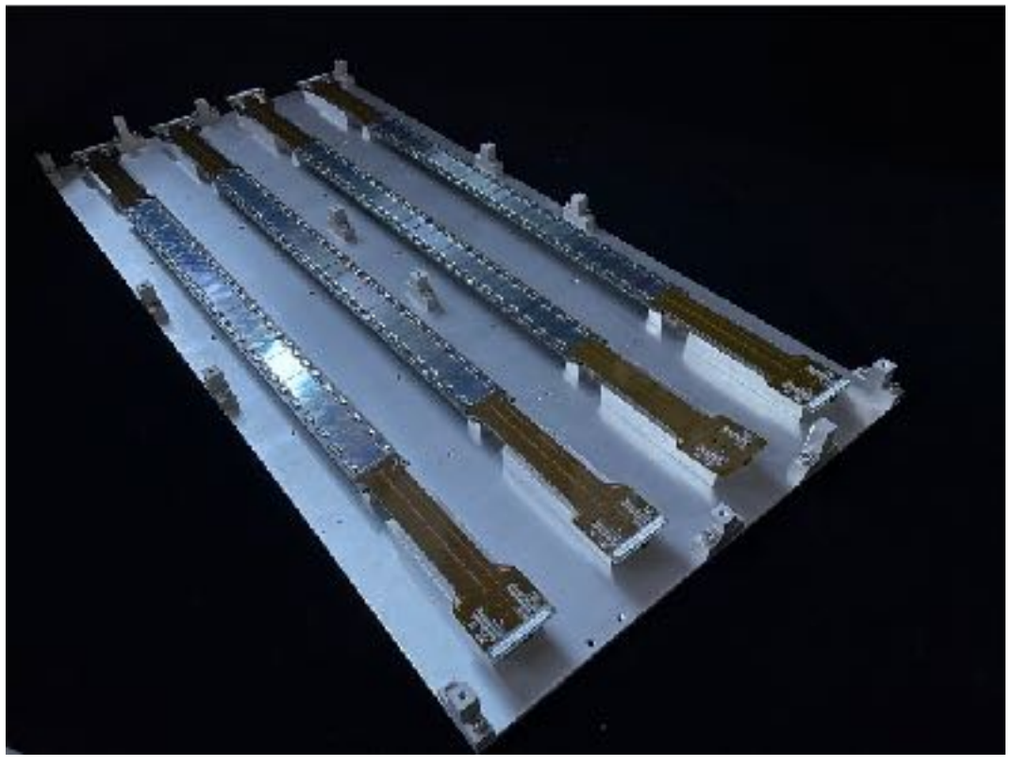


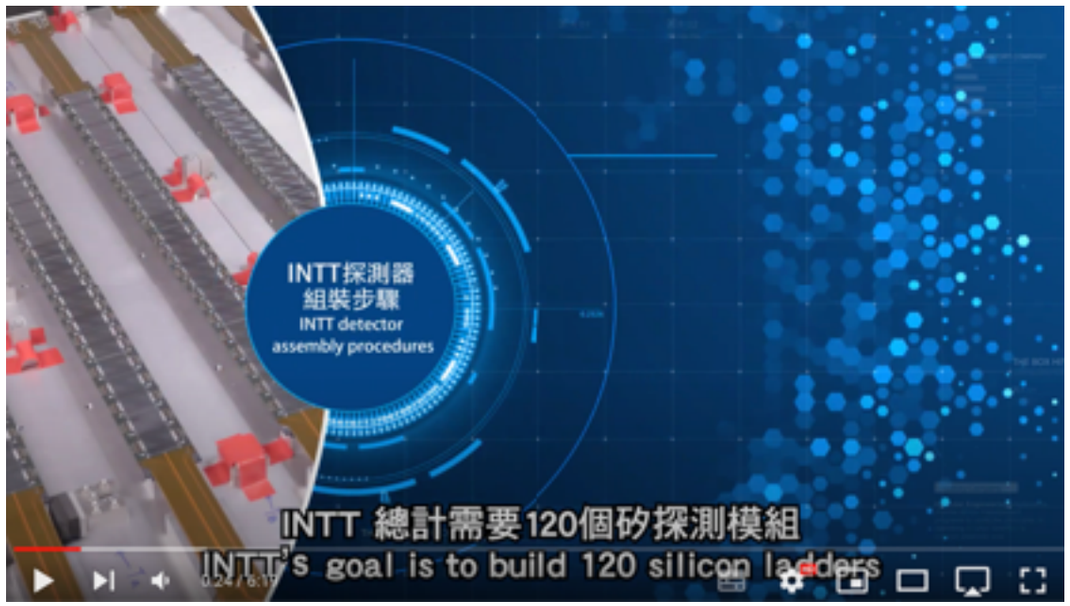
- TIDC's main facility; final detector assembly is performed here

Busy time at TSiDF

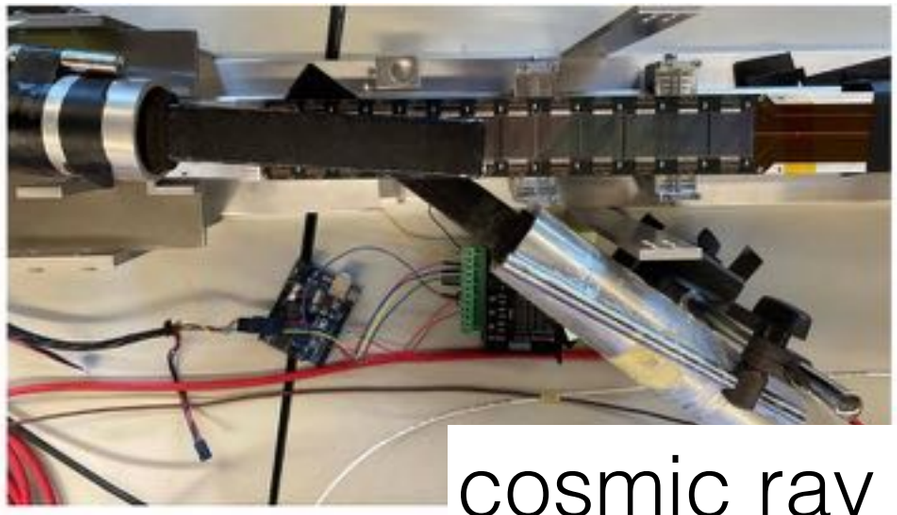


sPHENIX Silicon Ladder Assembly @ TSiDF

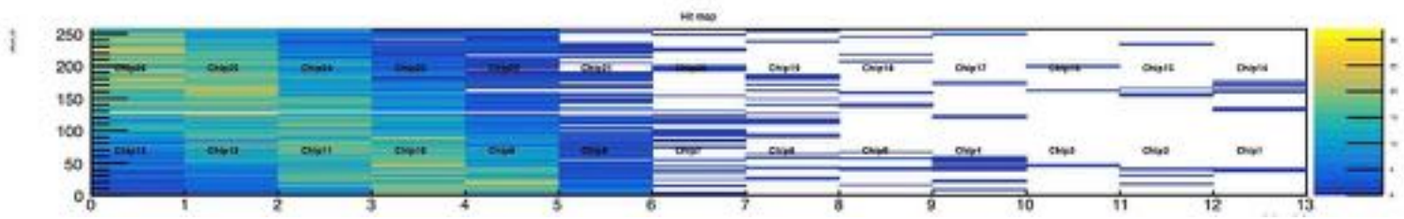




Assembly video: link

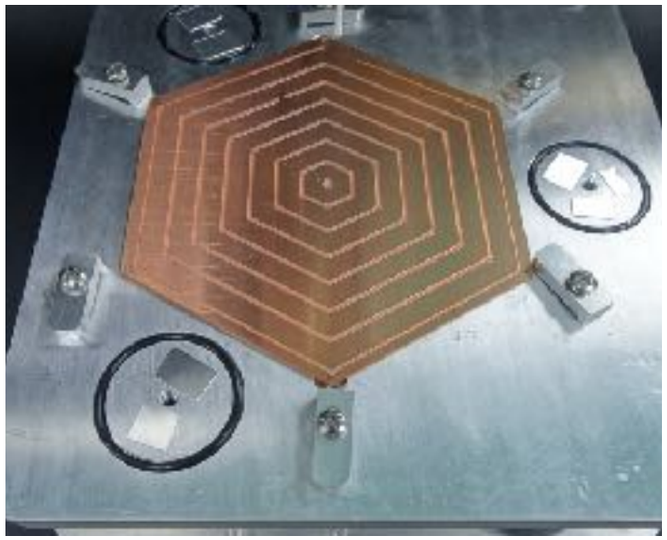


cosmic ray test

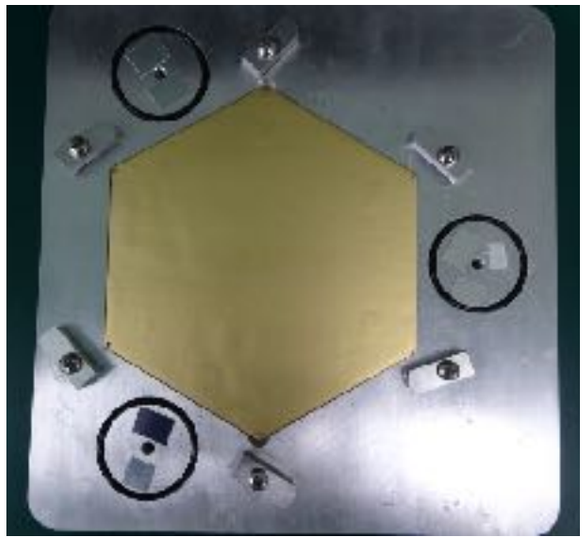


CMS HGCal Module Assembly @ TSiDF

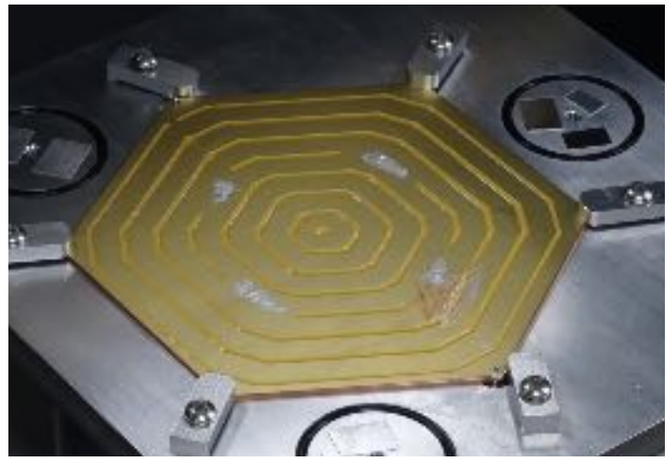
1. Deposit expose on Cu baseplate



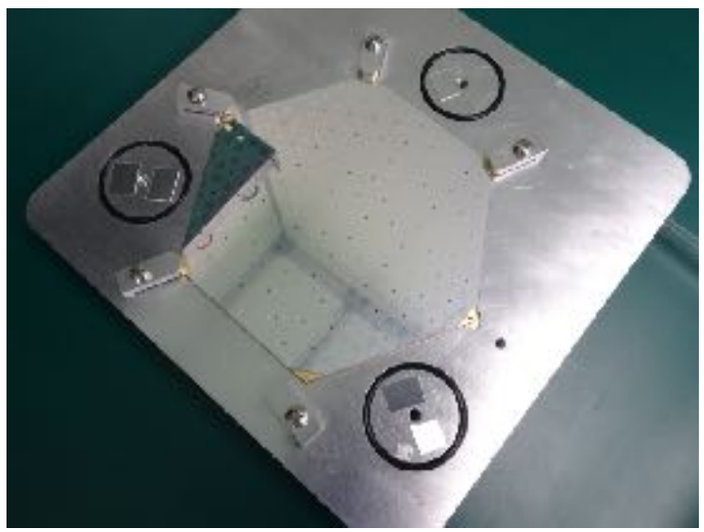
2. Place gold-plated Kapton film



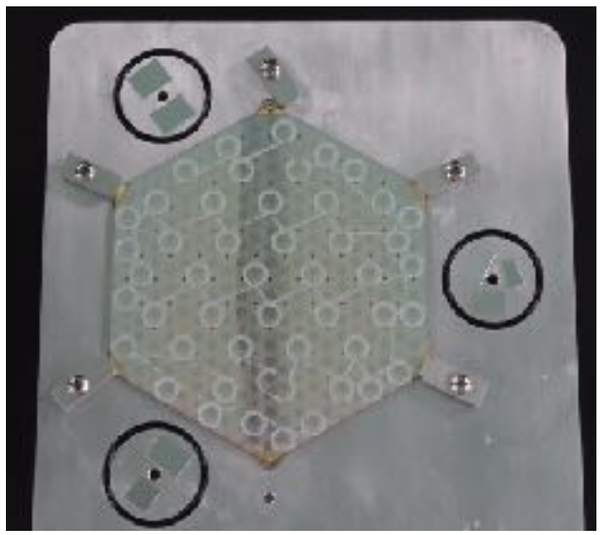
3. Deposit epoxy and silver epoxy on Kapton



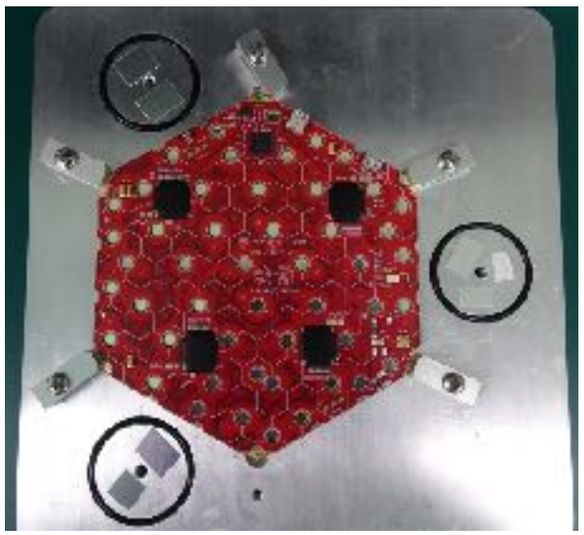
4. Place sensor on top of Kapton



5. Deposit epoxy on sensor, avoiding opening bond pads



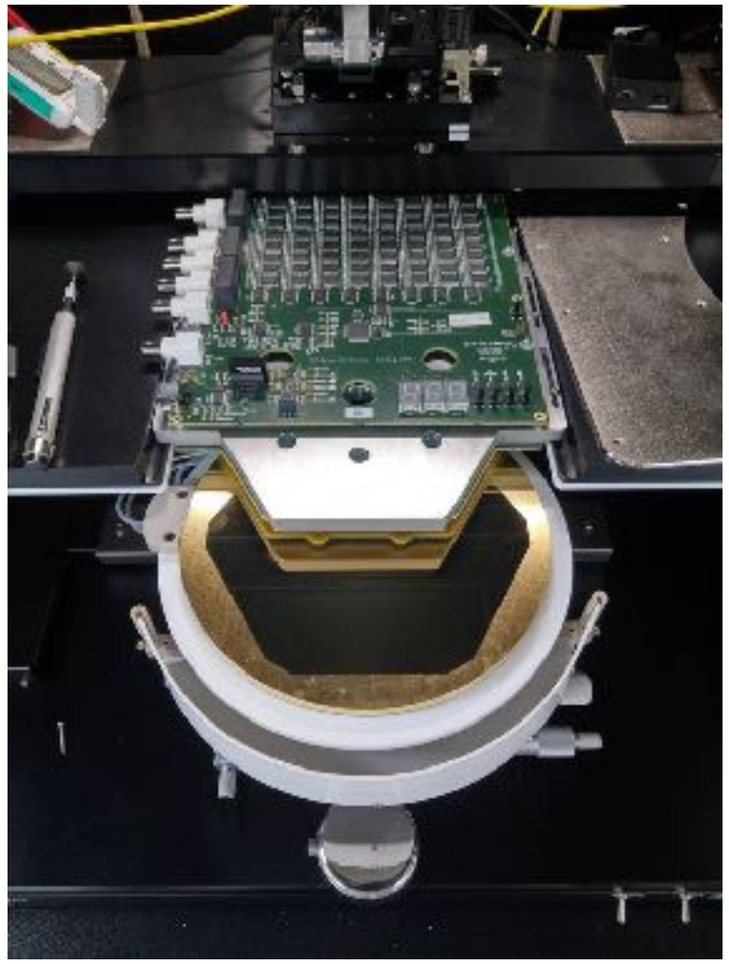
6. Place PCB on top of sensor



Assembly video: link

Silicon Sensor QC @ NCU

All sPHENIX silicon sensors were measured here



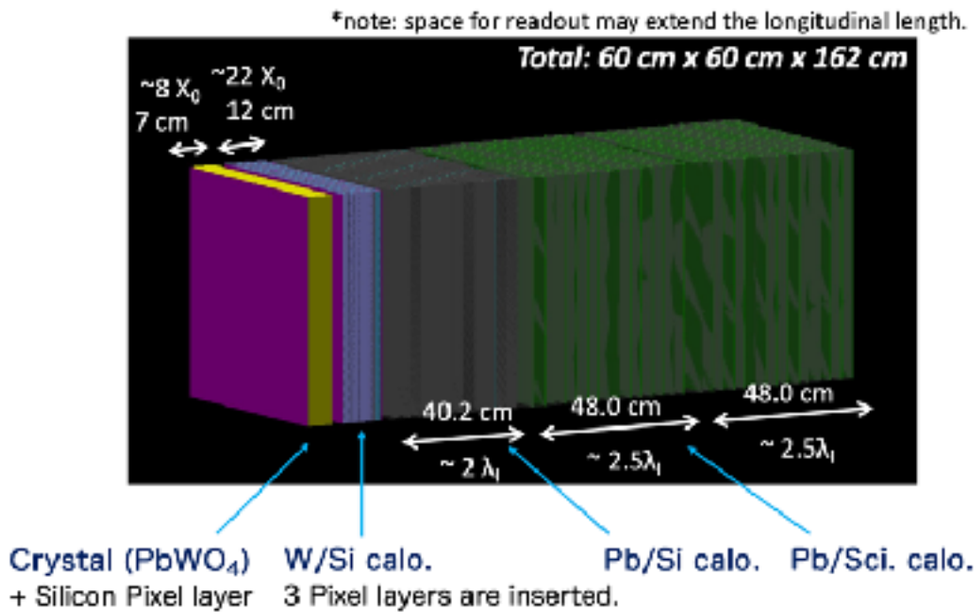
CMS HGCal SQC (2 8-inch sensors/day)

High Precision Machine Shop @ AS

- All assembly tools are produced here

Physics Requirements for ZDC

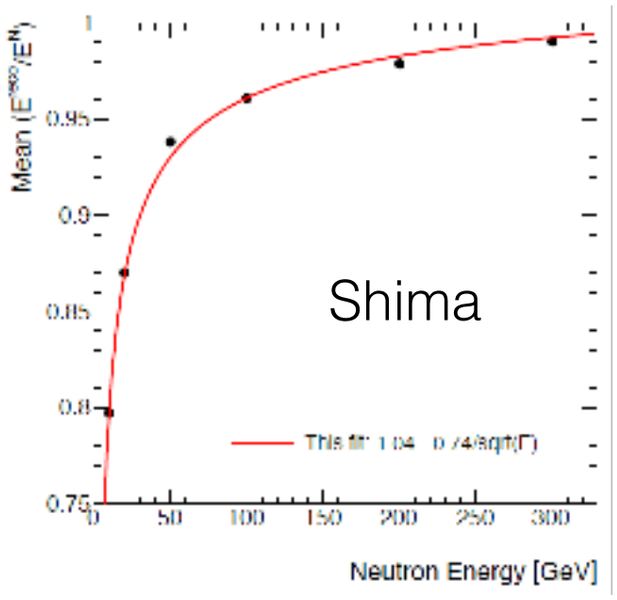
	Energy range	Energy resolution	Position resolution	Others
Neutron	up to the beam energy	$\frac{50\%}{\sqrt{E}} + 5\%$, ideally $\frac{35\%}{\sqrt{E}} + 2\%$	$\frac{3\text{mrad}}{\sqrt{E}}$	Acceptance: 60 cm × 60 cm
		Note: The acceptance is required from meson structure measurement. Pion structure measurement may require a position resoultion of 1 mm.		
Photon	$0.1 - 1$ GeV	$20 - 30\%$		Efficiency: $90 - 99\%$
		Note: Used as a veto in e+Pb exclusive J/ψ production		
	$20 - 40$ GeV	$\frac{35\%}{\sqrt{E}}$	0.5–1 mm	
		Note: u-channel exclusive electromagnetic π^0 production has a milder requirement of $\frac{45\%}{\sqrt{E}} + 7\%$ and 2 cm, respectively. Events will have two photons, but a single-photon tagging is also useful. Kaon structure measurement requires to tag a neutron and 2 or 3 photons, as decay products of Λ or Σ.		



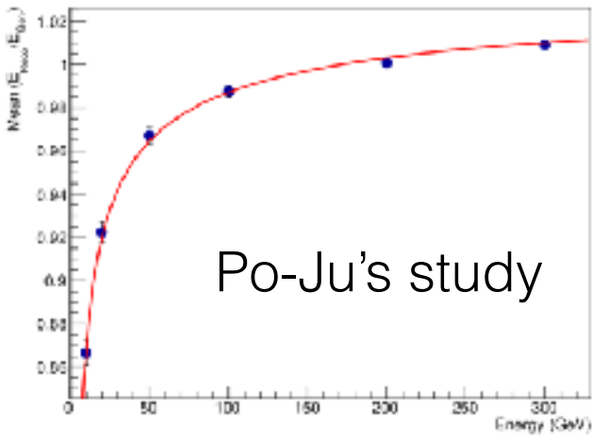
Preliminary ZDC design:
a composition of four different calorimeter configurations

ZDC Monte Carlo Studies

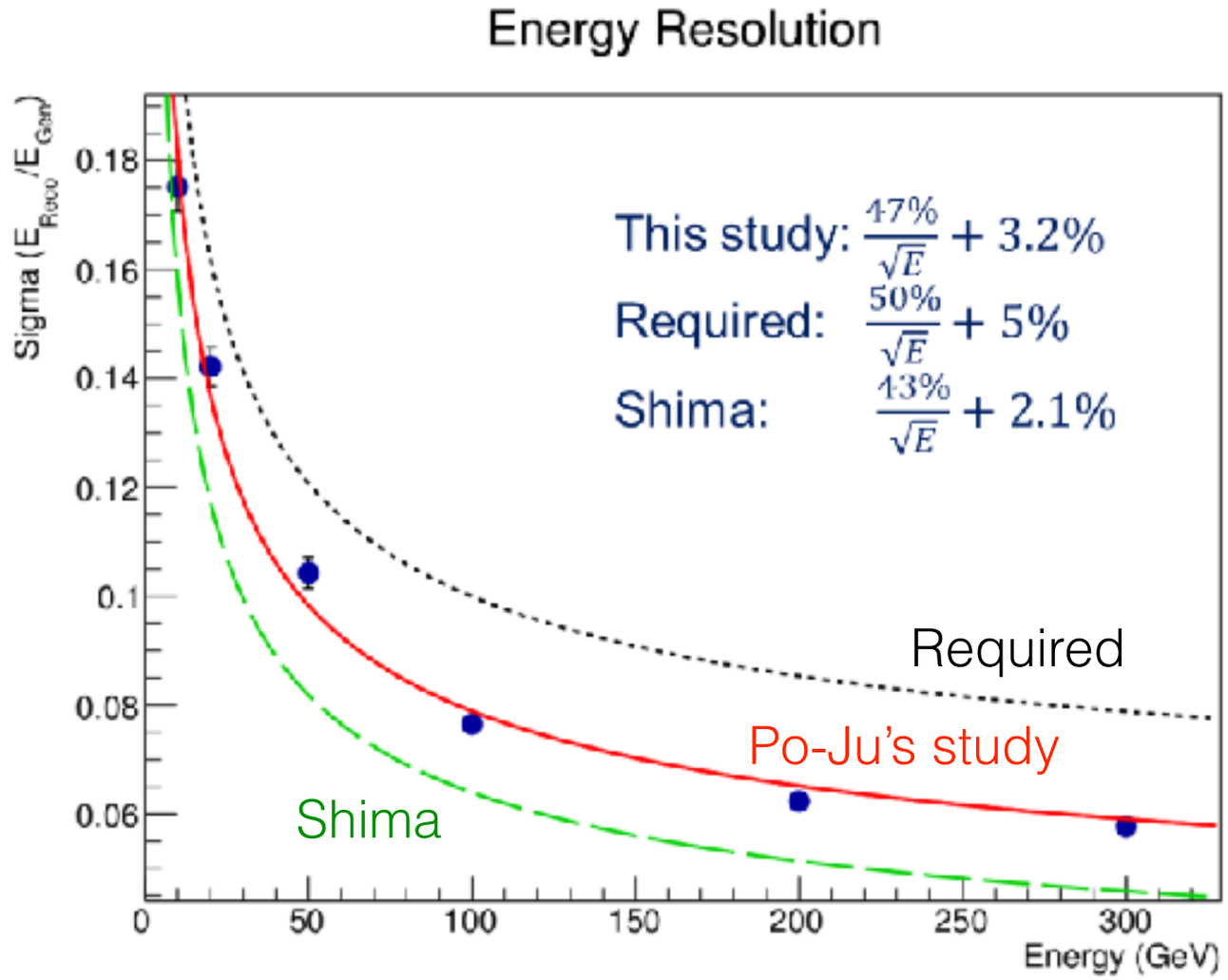
- Energy resolution was much worse than the one obtained in Fun4All by Dr. Shima Shimizu
  - Some changes in ZDC setup
  - Energy dependet calibraiton



Shima

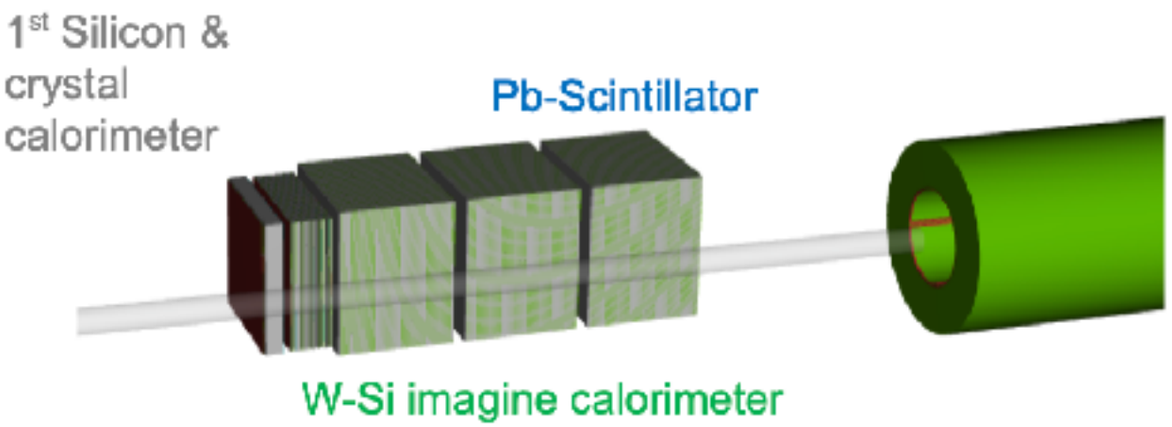


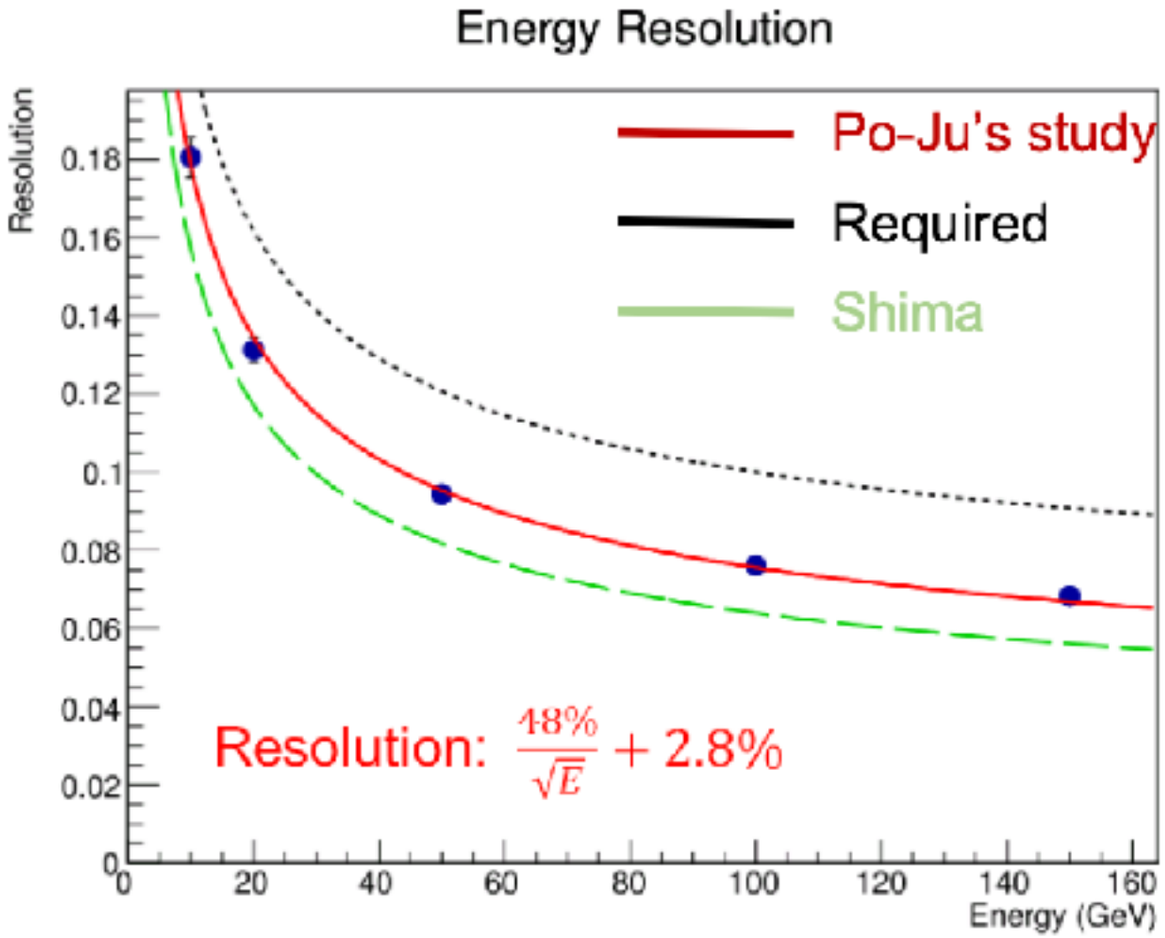
Po-Ju's study

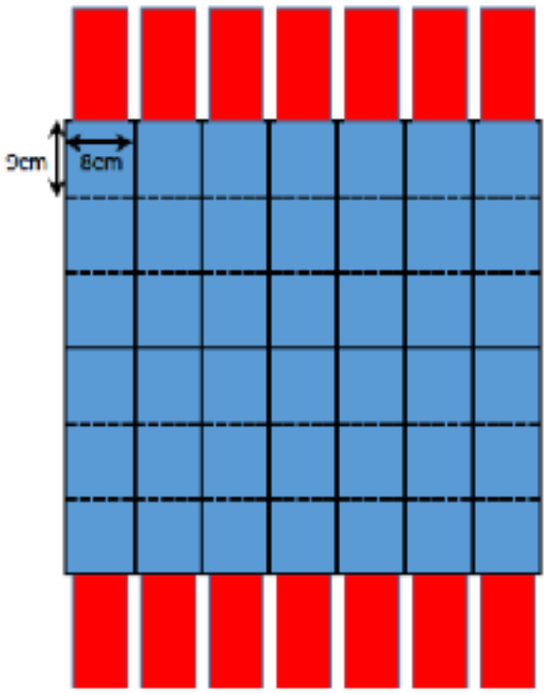


Result not as good as what Shima had, but acceptable

ZDC Monte Carlo Studies







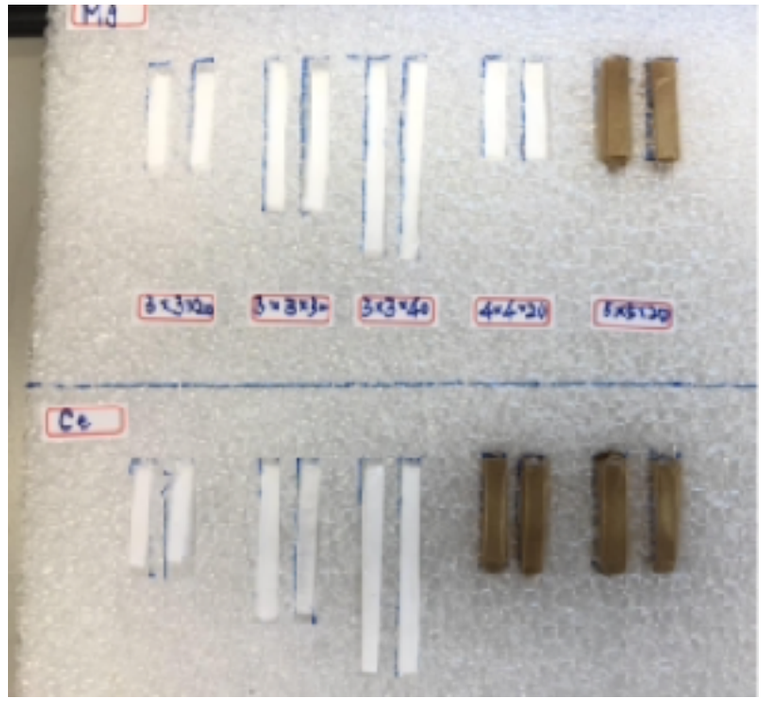
- ZDC simulation updated
  - Upstream modules with smaller lateral size to fit between beam pipes
  - Overall length about 183 cm, within 2 m limit
  - More cost effective, Pb-Silicon module removed
  - HCAL resolution improved
- Base design, meets the resolution requirement

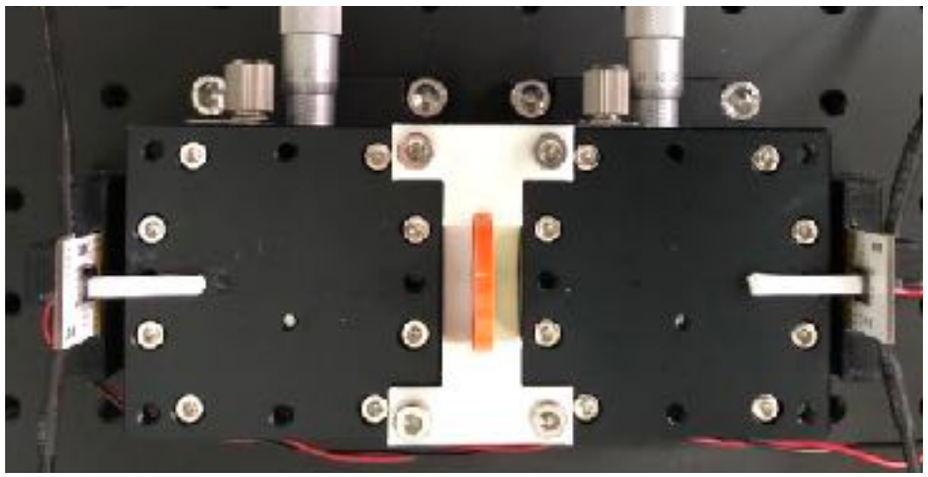
$PbWO_4$ vs LYSO vs SciGlass

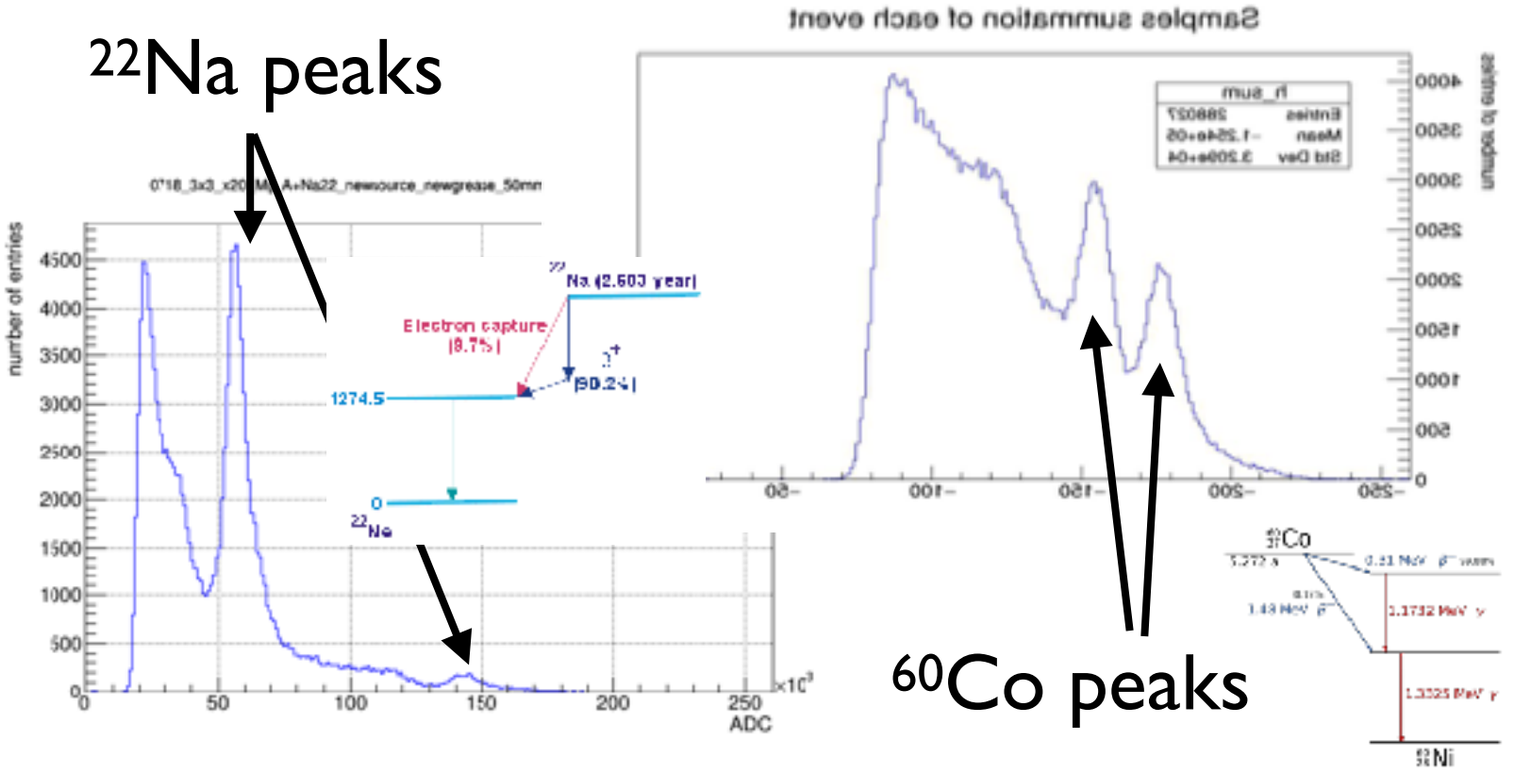
	X_0	LY (ph/MeV)	T dep. of LY (%/K)	Decay time (ns)	λ_{em} nm
$PbWO_4$ (CMS)	0.89 cm	200	-1.98	5 (73%) 14 (23%) 110 (4%)	420
LYSO	1.14 cm	30,000 (market standard)	-0.28	36	420
SciGlass	2.4-2.8 cm	>100		22-400	440-460

LYSO Crystal Characterization

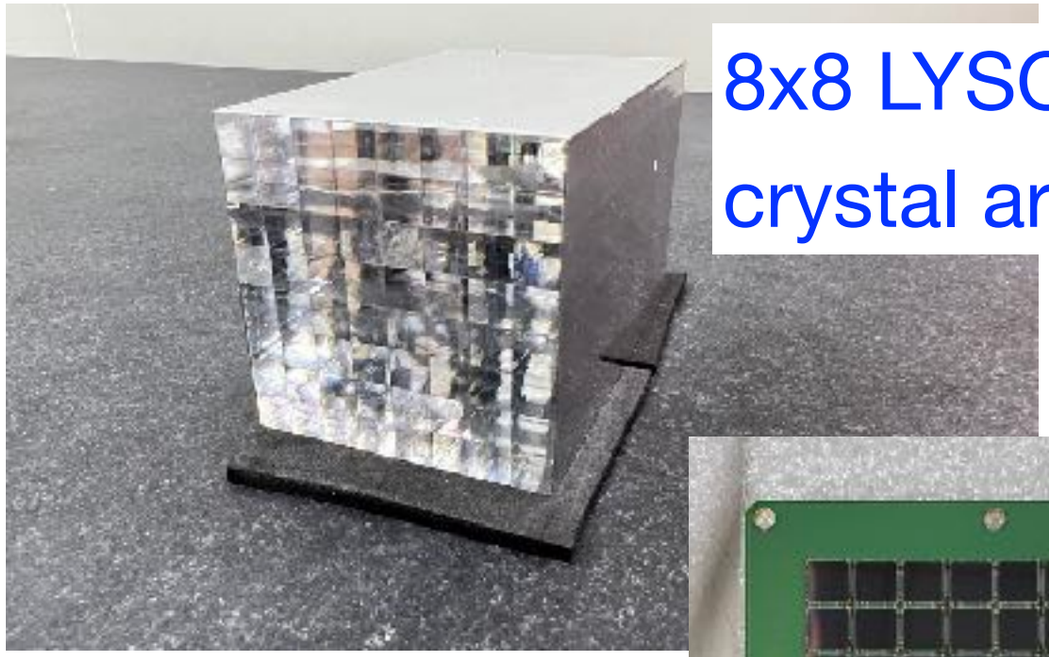
- NTU established test benches for LYSO samples from the TACrystal
  - The light yield is 29 photon/keV (@511 keV, for 3mm x 20 mm x 3mm size)
  - The response time resolution is around 90ps



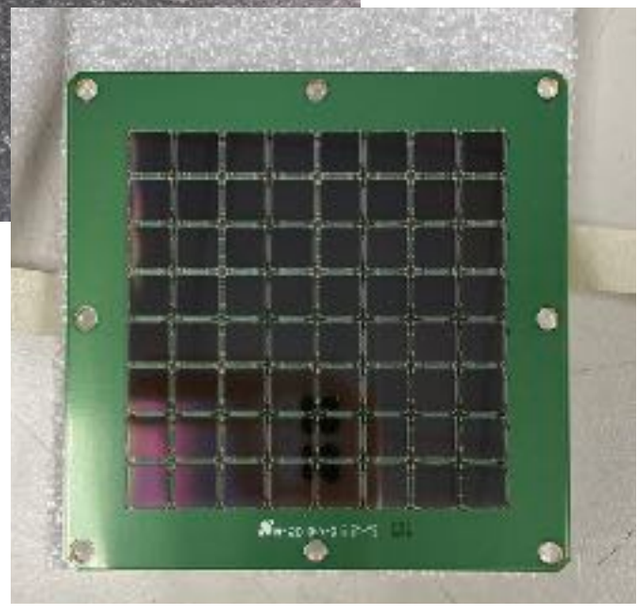




ZDC ECAL Prototype with LYSO Crystals

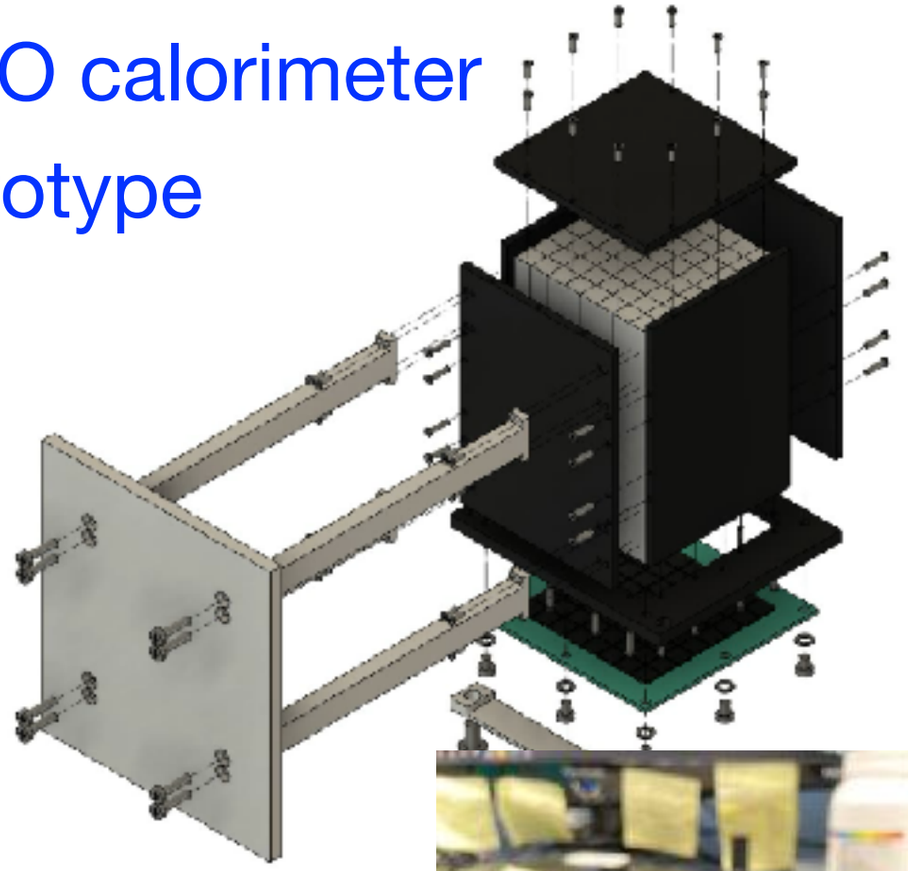


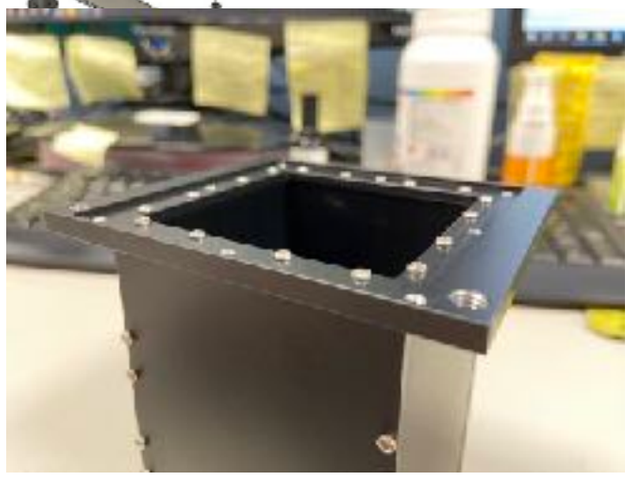
8x8 LYSO crystal array



8x8 SiPM array

LYSO calorimeter prototype

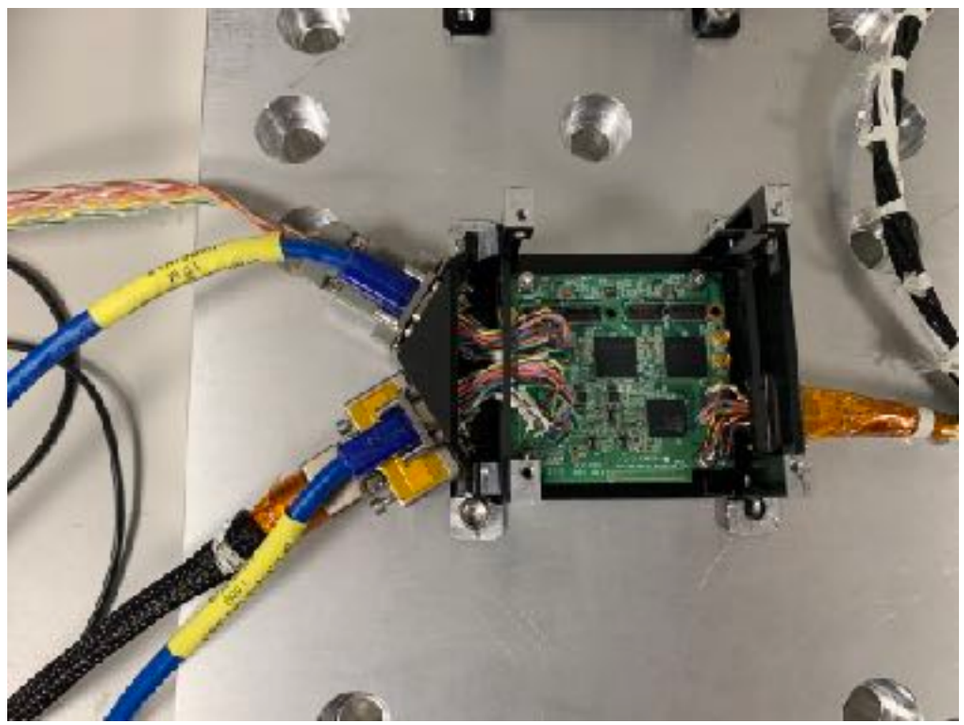




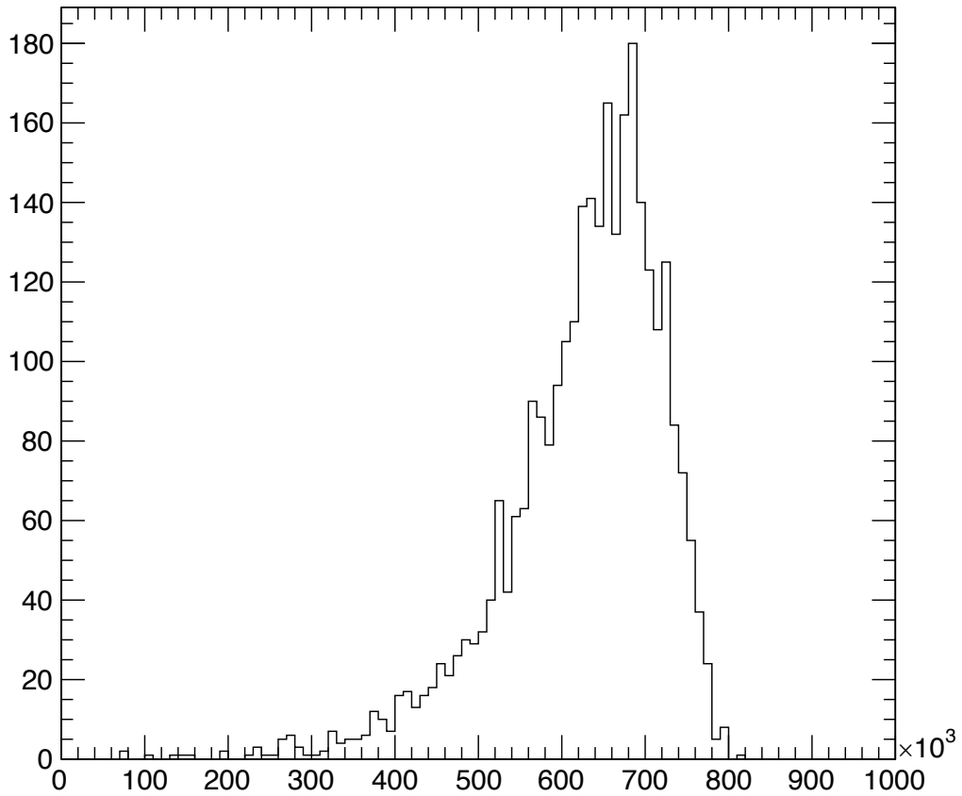
- Aim to have a beam test at the ELPH, Tohoku University, in February 2024 to compare the performance between the LYSO and $PbWO_4$ crystals for 200－822 MeV positrons
- Participants: RIKEN, Tsukuba University, EIC-Taiwan

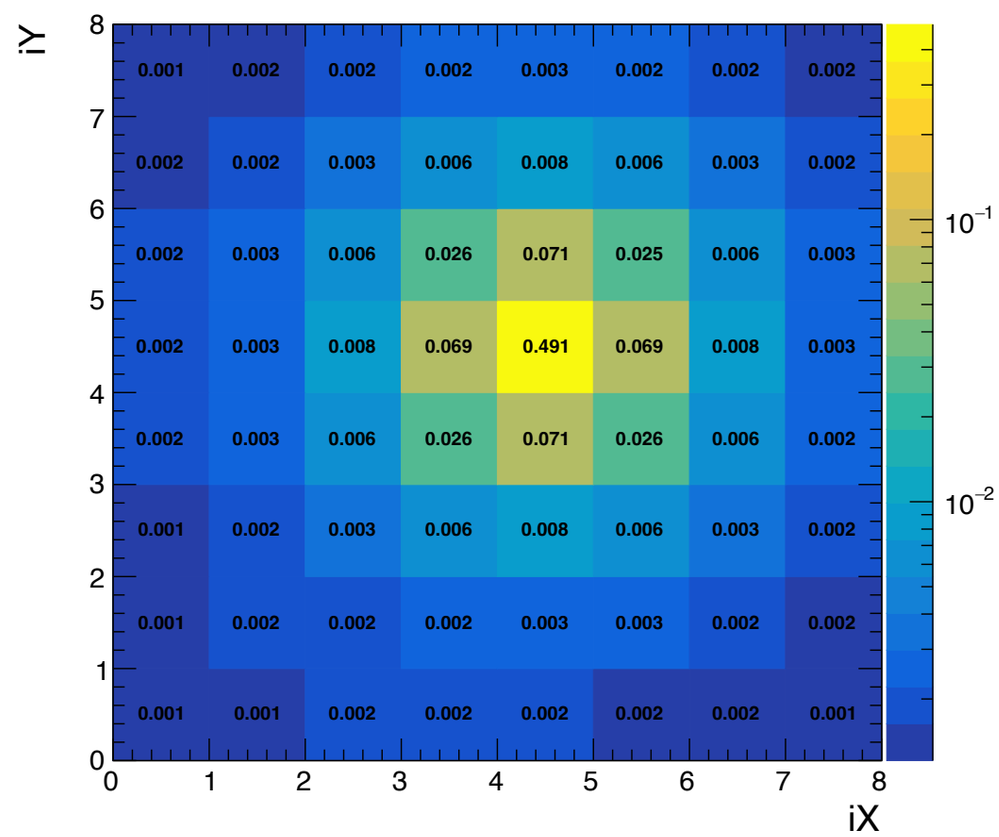
Readout for the ZDC ECAL Prototype with LYSO Crystals

- Designed by Chih-Hsun Lin of Academia Sinica
- 128 channels
- Trigger:
  - Self-triggered
  - Can accept external timing signal → needs to be studied
  - May accept external trigger → needs to be studied



ZDC ECAL MC Study



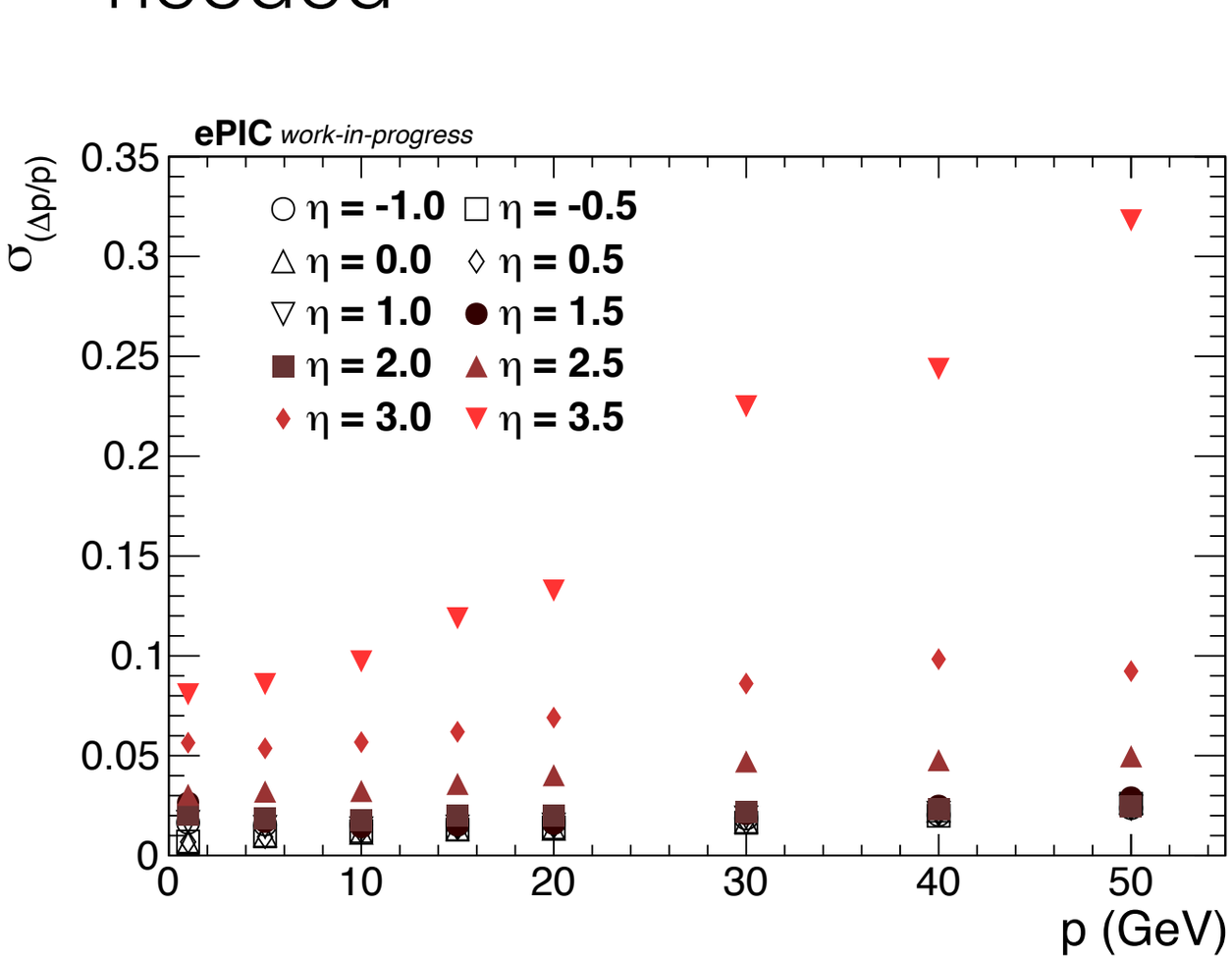


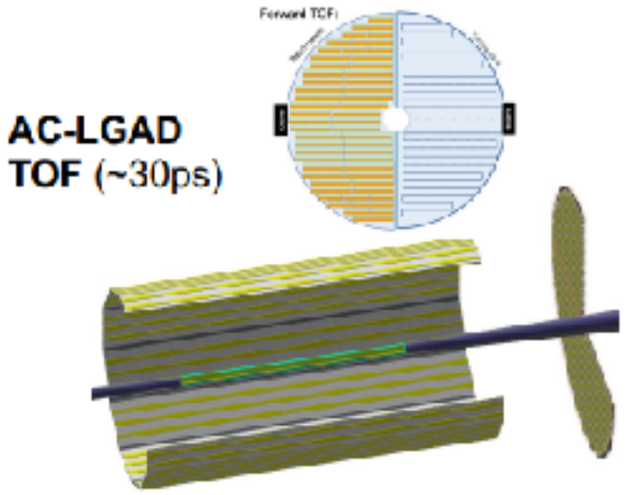
- For the beam test in February 2024
- Various optical properties in the G4 simulation are being studied
- Future plan: optimize the design of ZDC ECAL (homogeneous/sampling/…)

TOF Performance Study

- Started to study the impact of AC-LGAD on the momentum resolution at ePIC

- Goal: optimize the pad size of the AC-LGAD sensors if it's needed

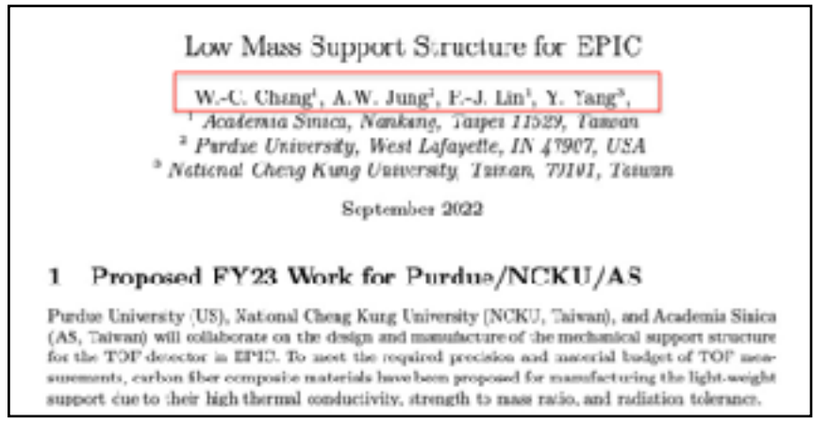




- Simulation with DD4hep and reconstruction
- 1000 π^- using particle gun
- in Collaboration with the Hiroshima Univ.

Mechanical Structure for TOF

- Mechanical support structure design impacts detector performance
- Use the similar concept of STAR IST
- Rather long support (1.35m) with minimal deflection in the barrel
- R&D with carbon fiber composite materials → reduce the material budget by a factor of two or more
  - High thermal conductivity, strength-to-mass ratio, radiation tolerance



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.

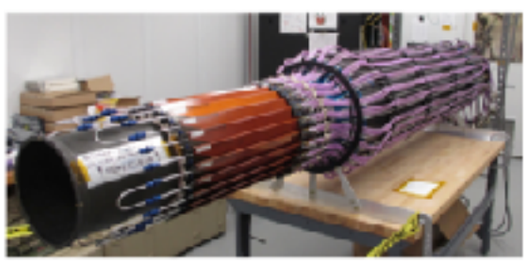
Request for Project Engineering and Design
Support for EPIC TOF Detectors

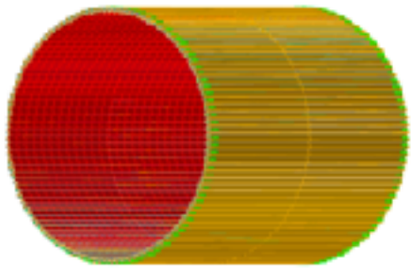
Oskar Hartbrich (ORNL),
Andreas Jung (Purdue),
Po-Ju Lin (AS),
Yi Yang (NCKU),
Zhenyu Ye (UIC)
for the EPIC TOF group.

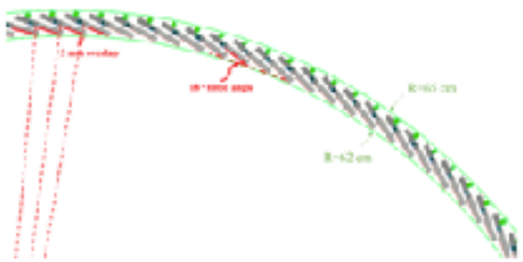
October 2022

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.







From Zhenyu's talk

eRD112 FY23 Report and FY24 Proposal on EIC AC-LGAD R&D

BNL: Alessandro Tricoli (atricoli@bnl.gov), Gabriele Giacomini (giacomini@bnl.gov)
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NCKU: Yi Yang (yiyang@ncku.edu.tw)
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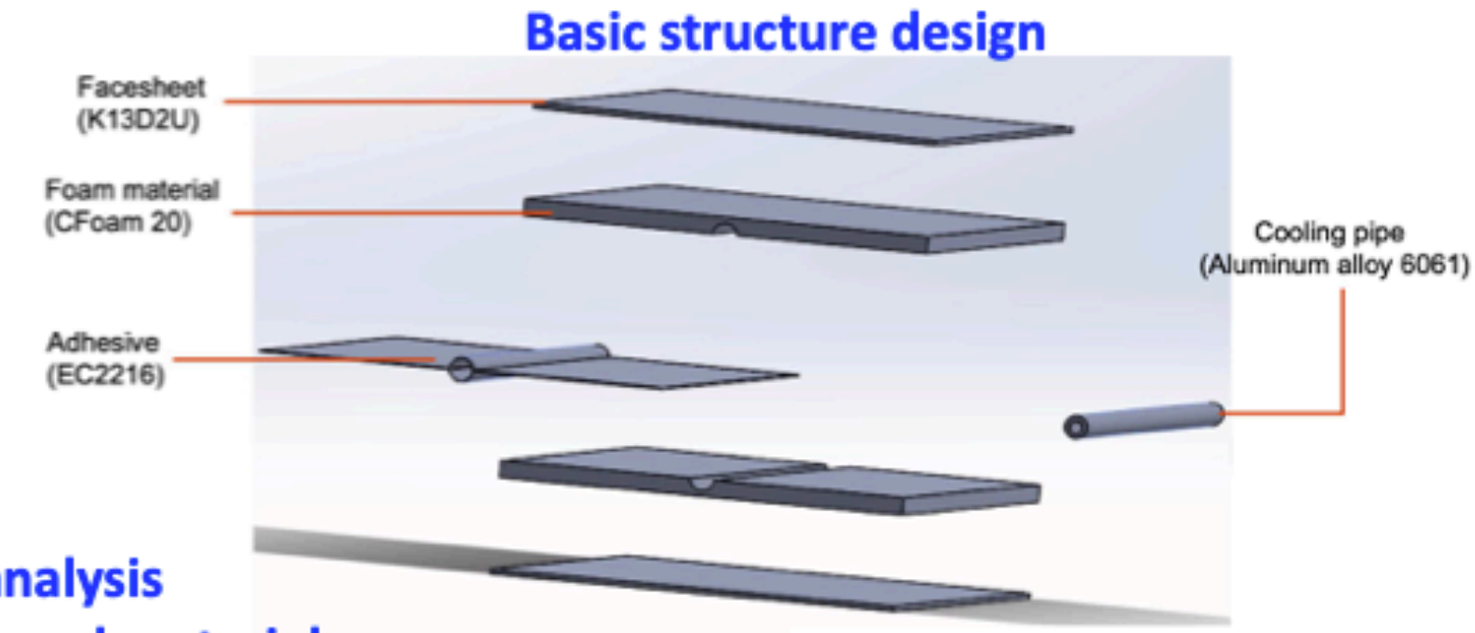
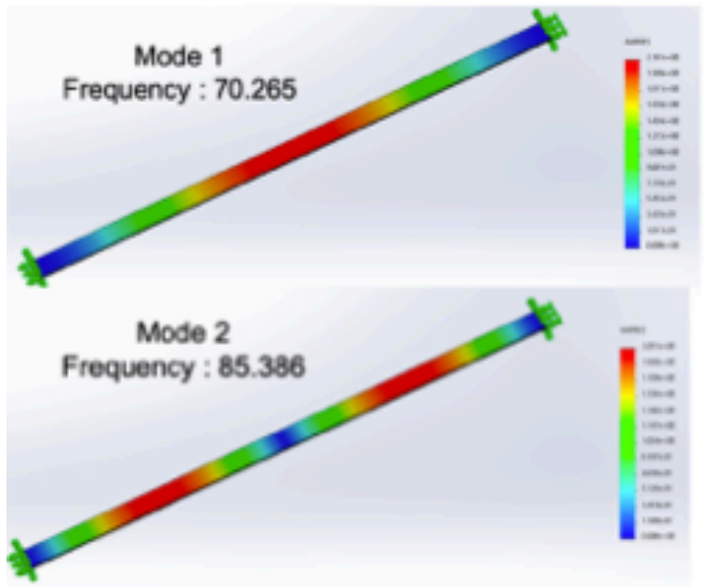
UCSC: Matthew Gignac (mgignac@ucsc.edu)
UIC: Zhenyu Ye (yezhenyu@uic.edu)

Mechanical Structure for TOF: Preliminary Thermal Analysis @ NCKU



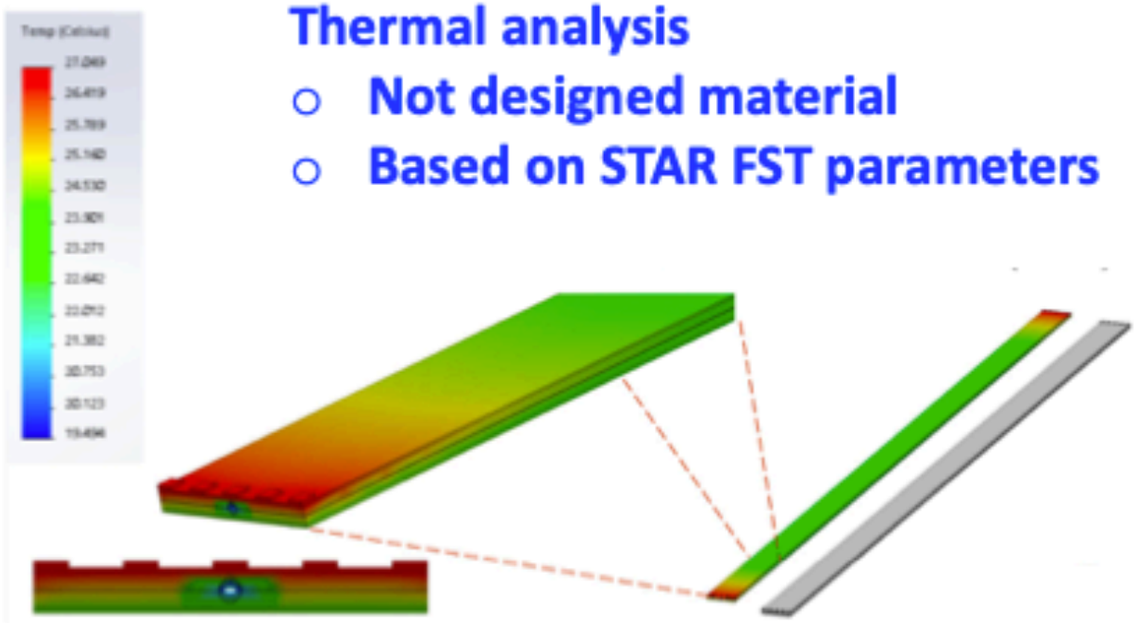
Frequency analysis

- Not designed material



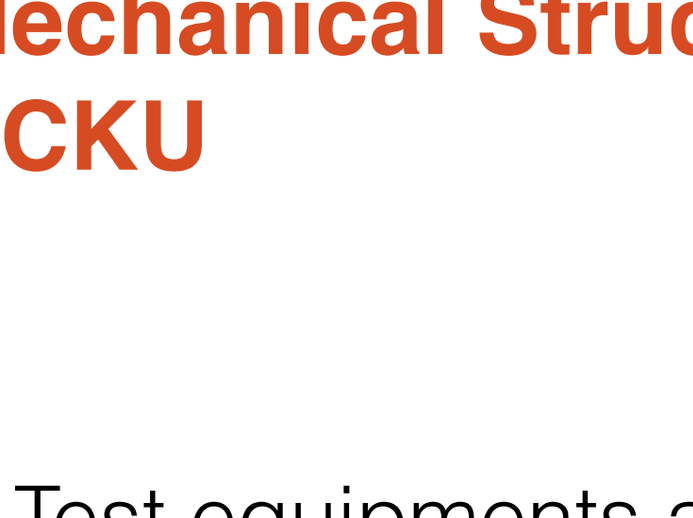
Thermal analysis

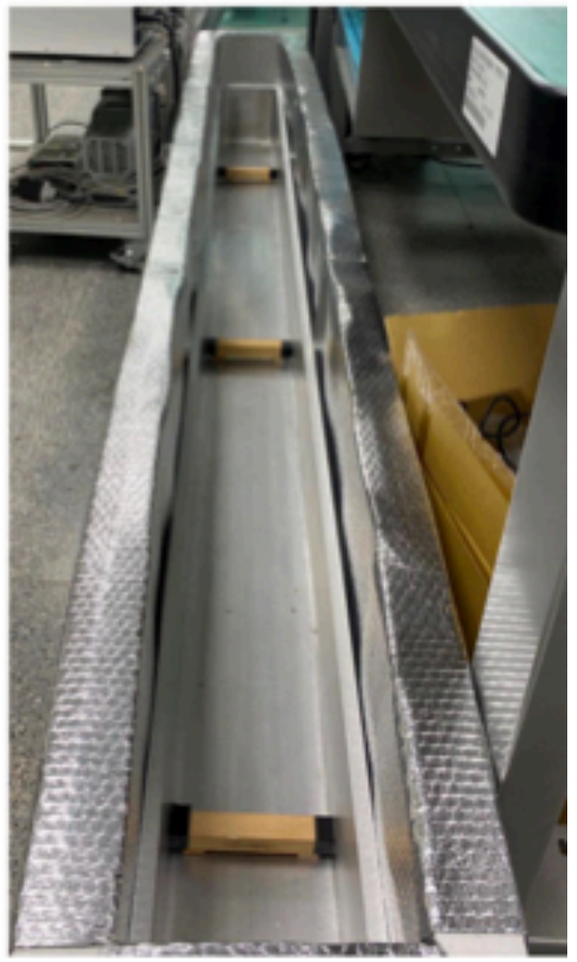
- Not designed material
- Based on STAR FST parameters



Mechanical Structure for TOF: Test Facilities @ NCKU

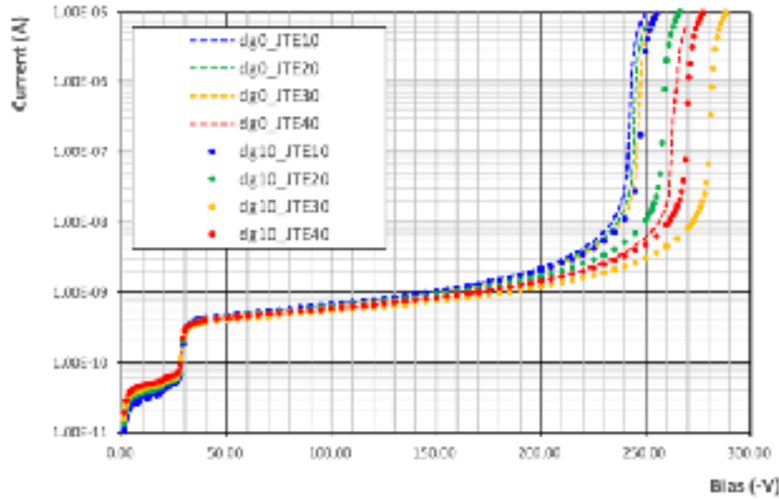
- Test equipments are ready at NCKU

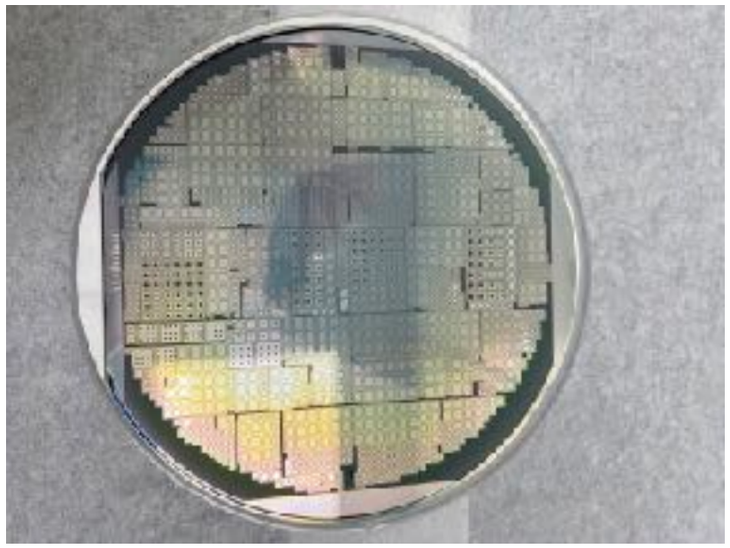




LGAD Sensor R&D

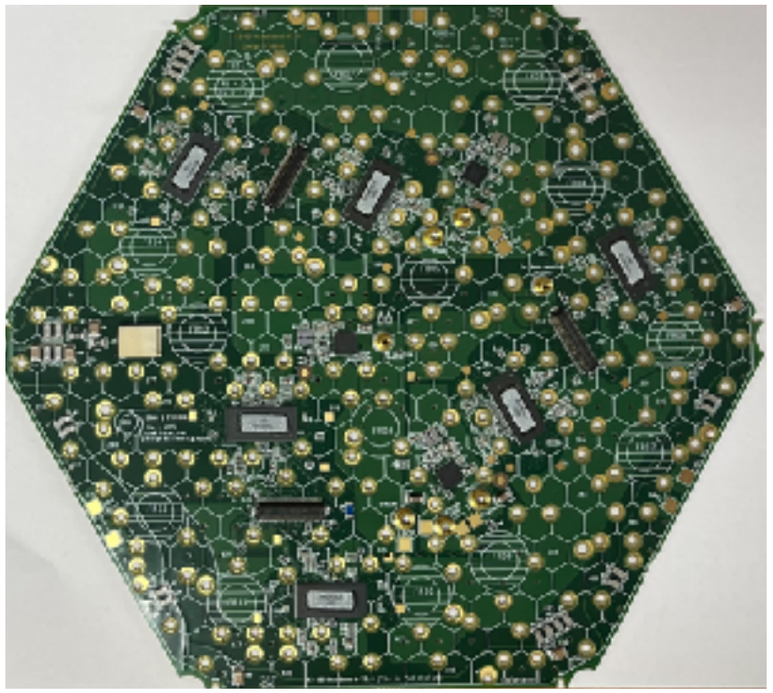
- Started with DC-LGAD
- TCAD simulation is used to decide the LGAD sensor process parameters
- First goal: verify sensor process flow and TCAD simulation
- The first batch of production with TSRI finished at the end of 2022
- In discussion with private sectors on future sensor R&D for the AC-LGAD





Other possibilities

- **Optical readout (fiber-optics)**
  - Taiwan opto-electronics companies contribute to ATLAS upgrades
- **PCB production and assembly**
  - CMS HGCal HD hexaboards
  - DC-DC converters
- **Computing** (ASGC)
  - Academia Sinica Grid Computing Center
  - **ATLAS T1/T2/T3**, **CMS** T1/**T2/T3**
  - ~30K CPU cores/ 128 GPU boards/ >9 PB storage



Summary

- The EIC Taiwan group was formed, including experimentalists and theorists
- Kicked off a couple of detector R&D projects for EIC in Taiwan
  - ZDC ECAL prototype with LYSO crystals
  - Mechanical support for TOF
  - LGAD sensor R&D
- Started to contribute to detector simulation and performance studies
- Other possibilities: detector assembly with TIDC, computing, and so on