Status of
the EIC-Taiwan

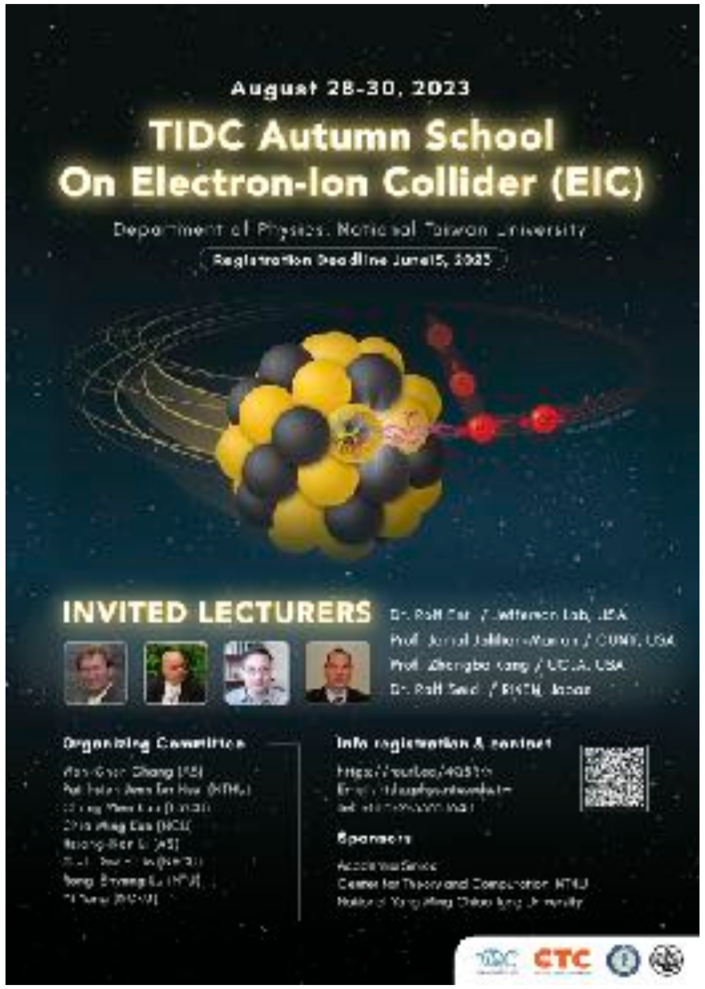
Chia-Ming Kuo (NCU, Taiwan)

EIC-Taiwan Community

- **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



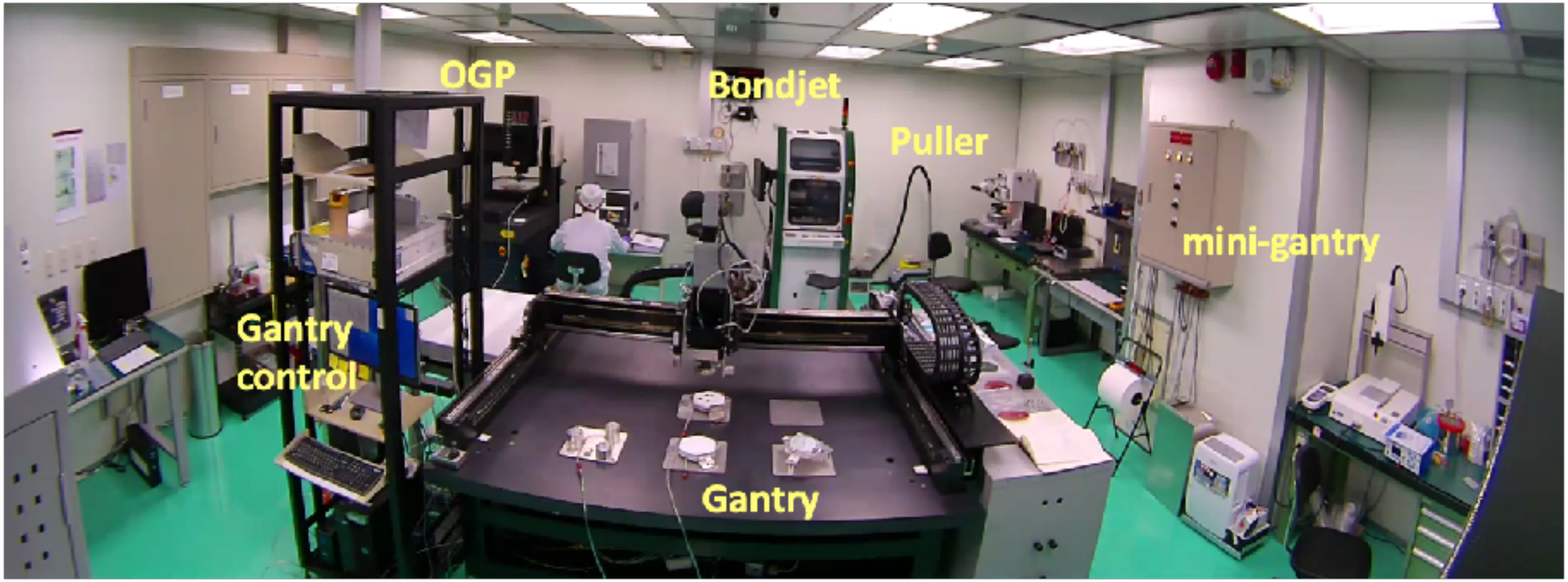
Initial Stage 2025

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

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

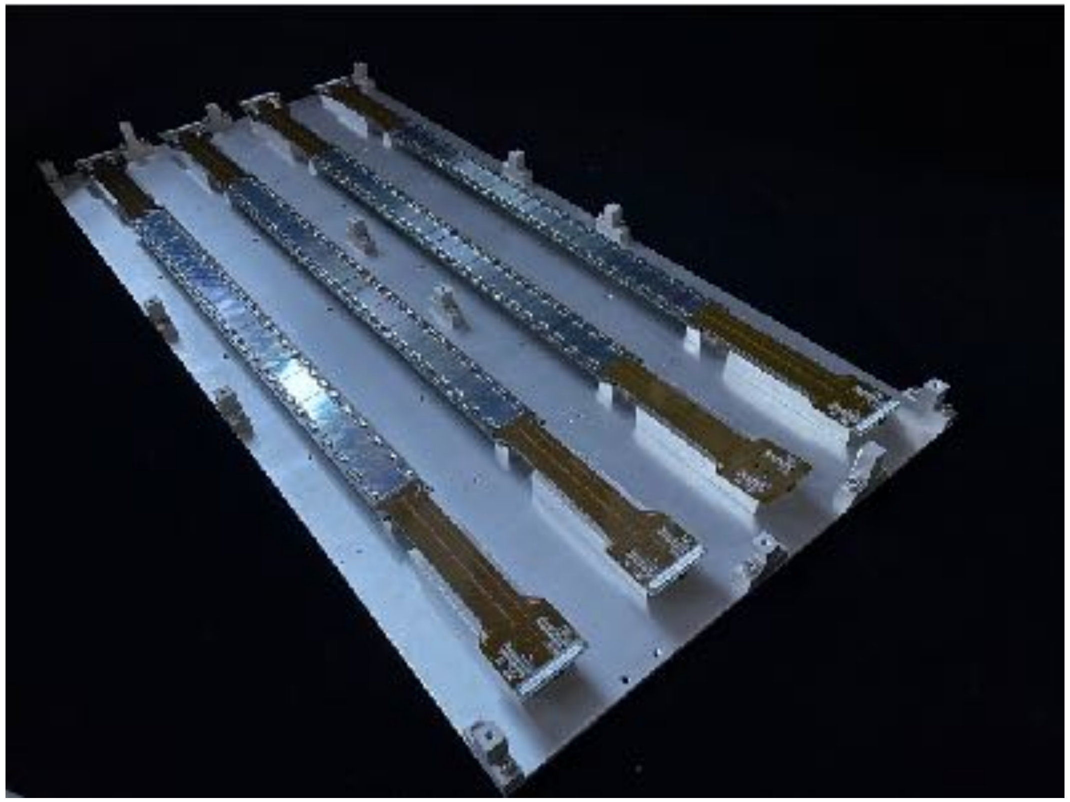
Taiwan Silicon Detector Facility (TSiDF) @ NTU

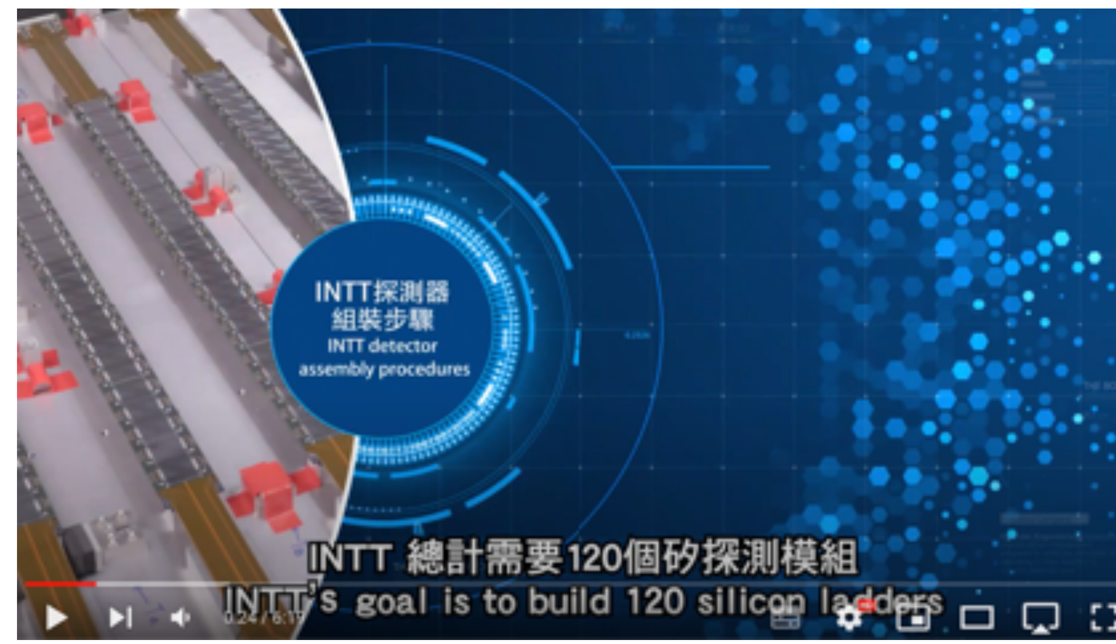


- TIDC’s main facility; final detector assembly is performed here

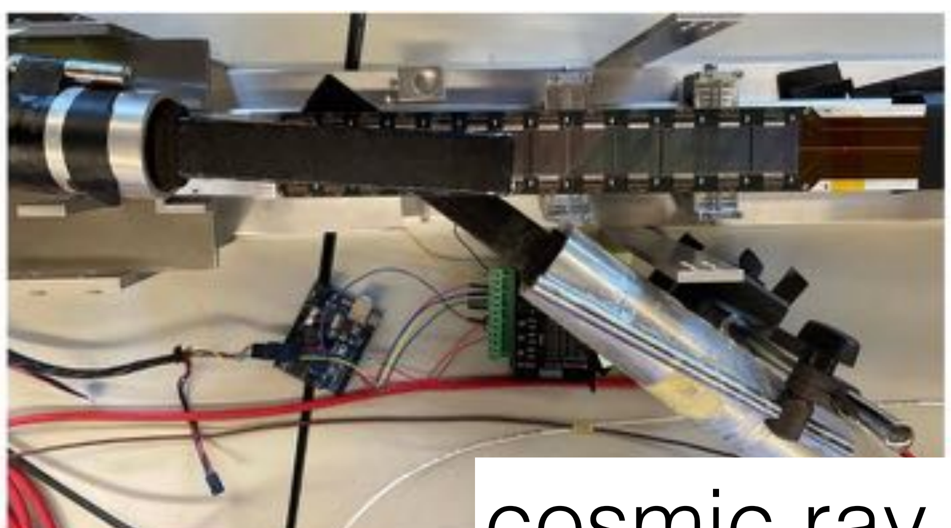
Busy time at TSiDF

sPHENIX Silicon Ladder Assembly @ TSiDF

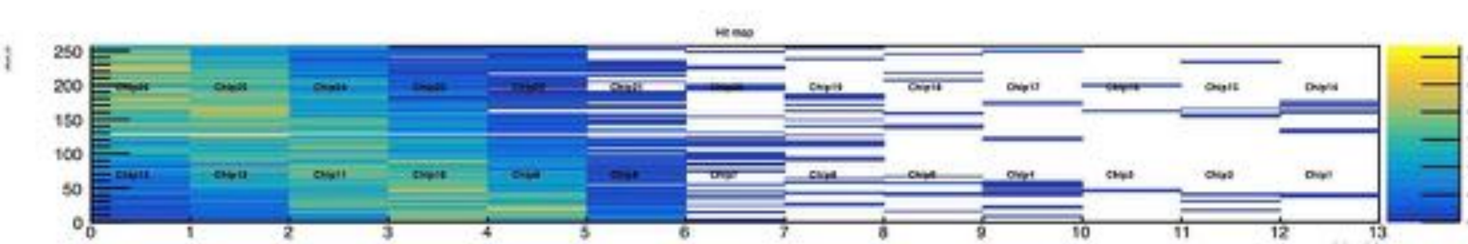




Assembly video: [link]

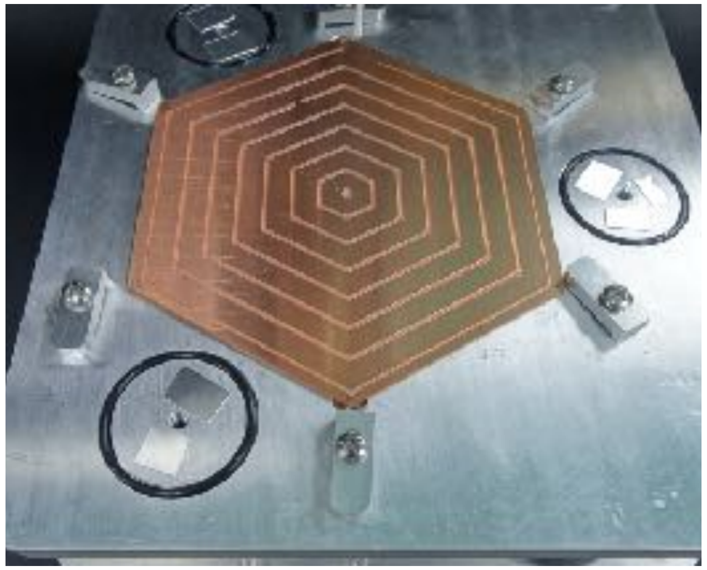


cosmic ray test

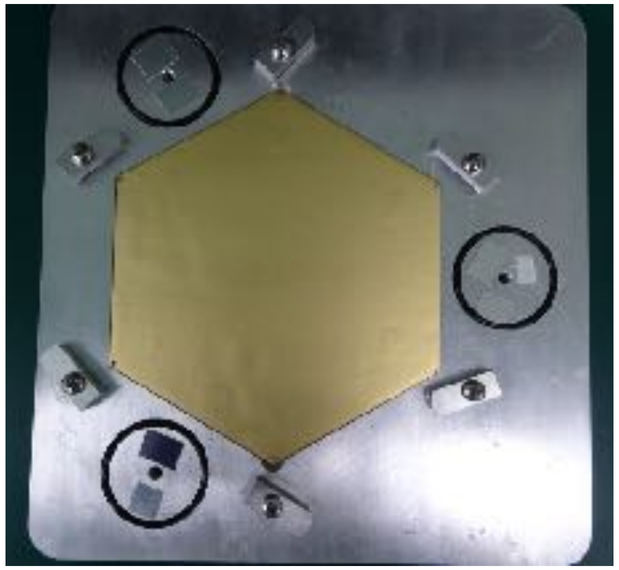


CMS HGCal Module Assembly @ TSiDF

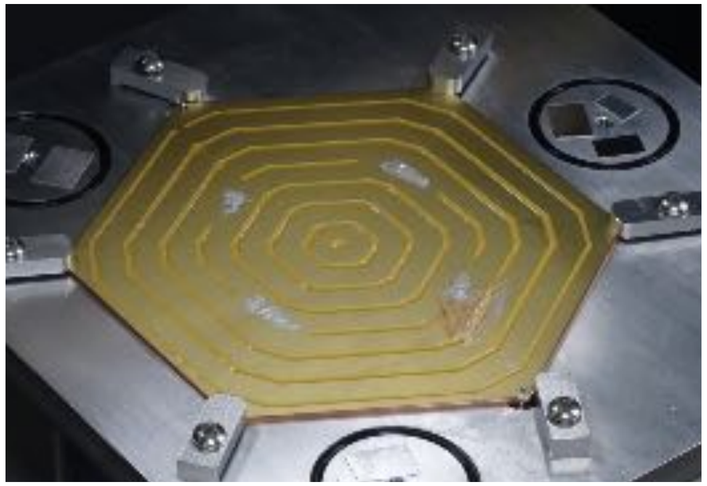
1. Deposit expose on Cu baseplate



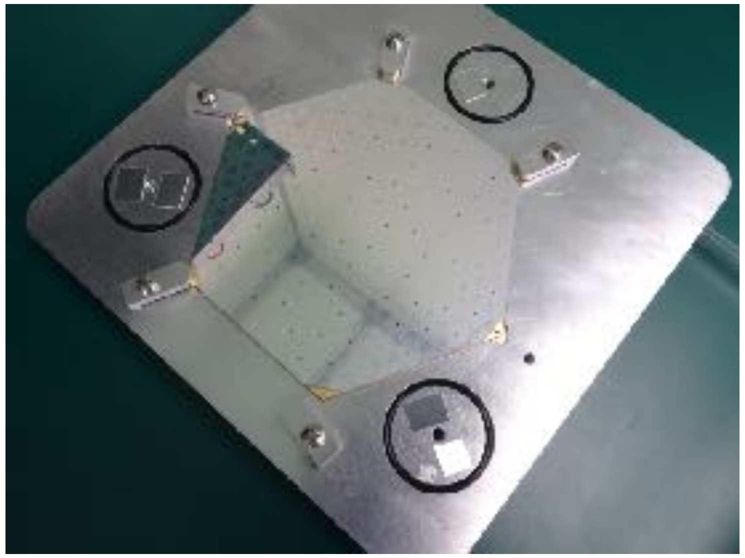
2. Place gold-plated Kapton film



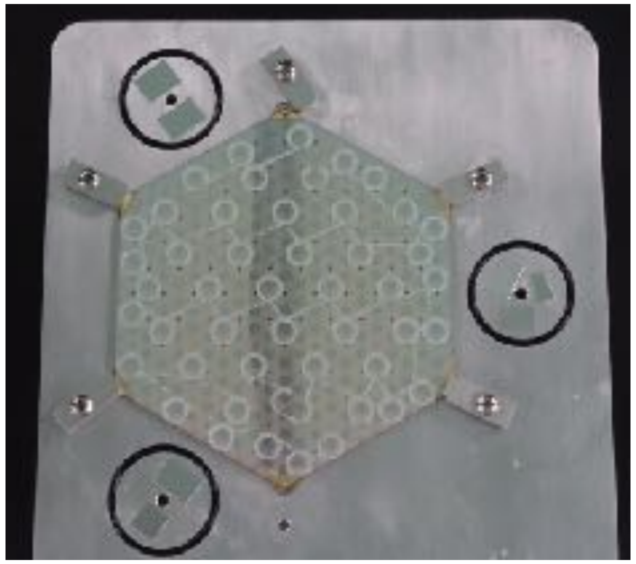
3. Deposit epoxy and silver epoxy on Kapton



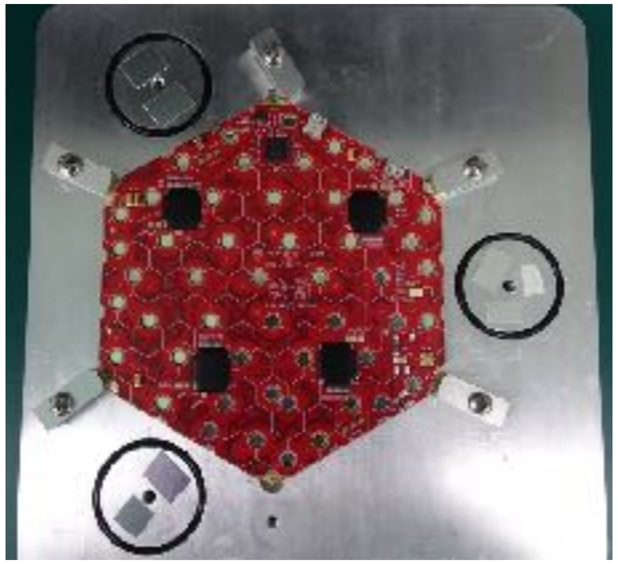
4. Place sensor on top of Kapton



5. Deposit epoxy on sensor, avoiding opening bond pads

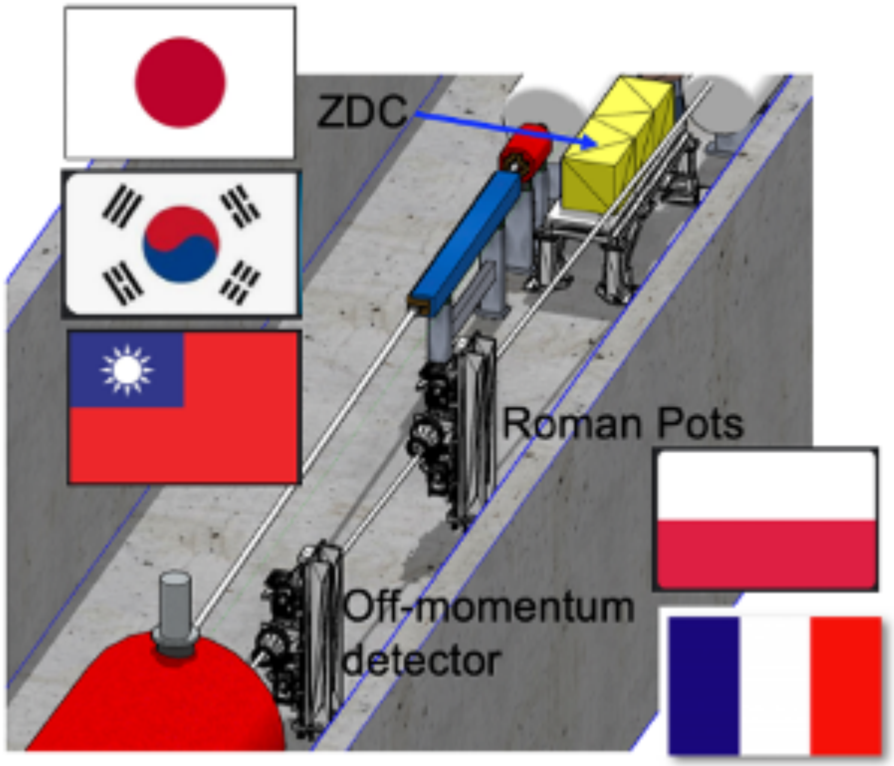


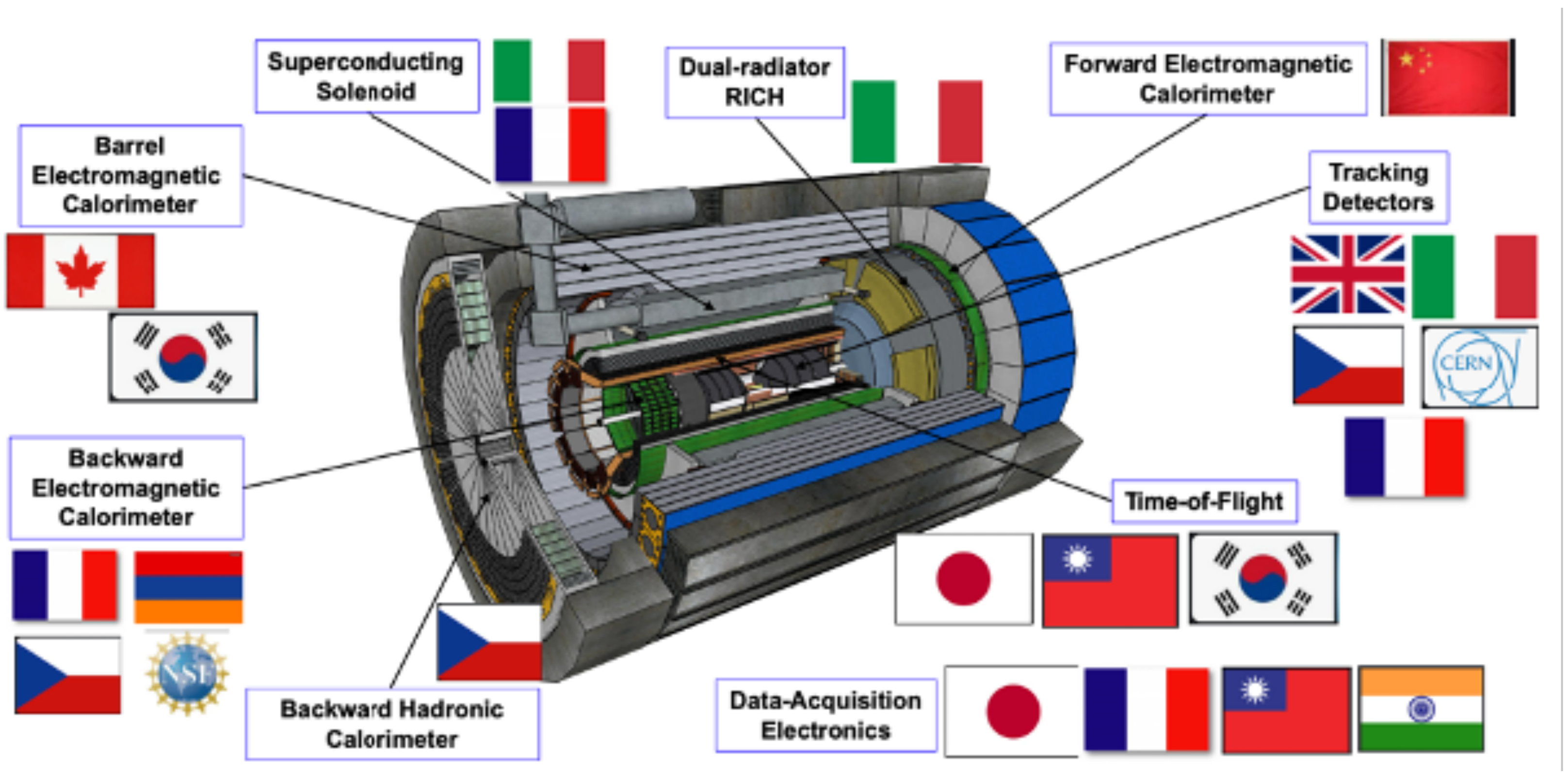
6. Place PCB on top of sensor



Assembly video: link

Two Detector Projects





ZDC

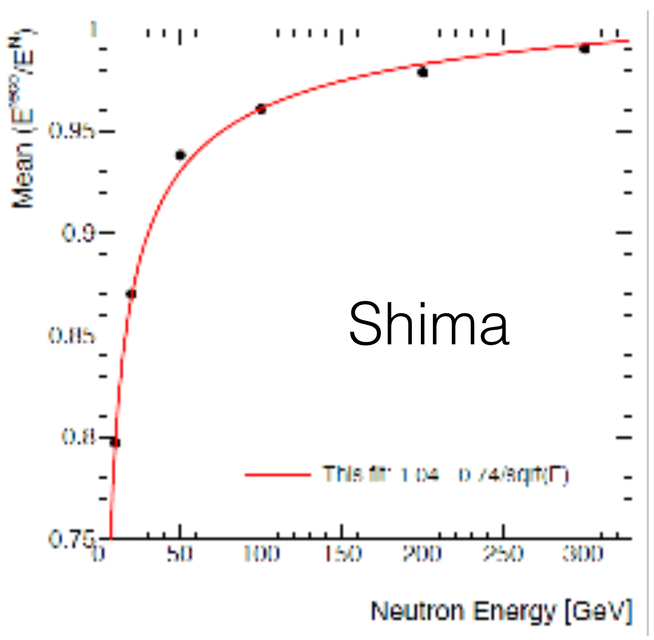
TOF

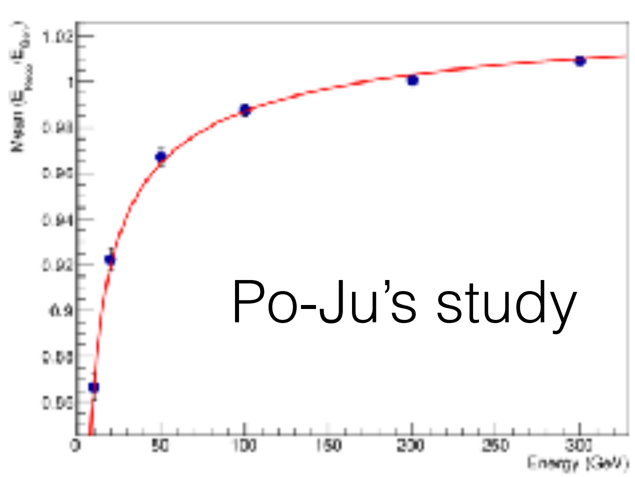
Physics Requirements for ZDC

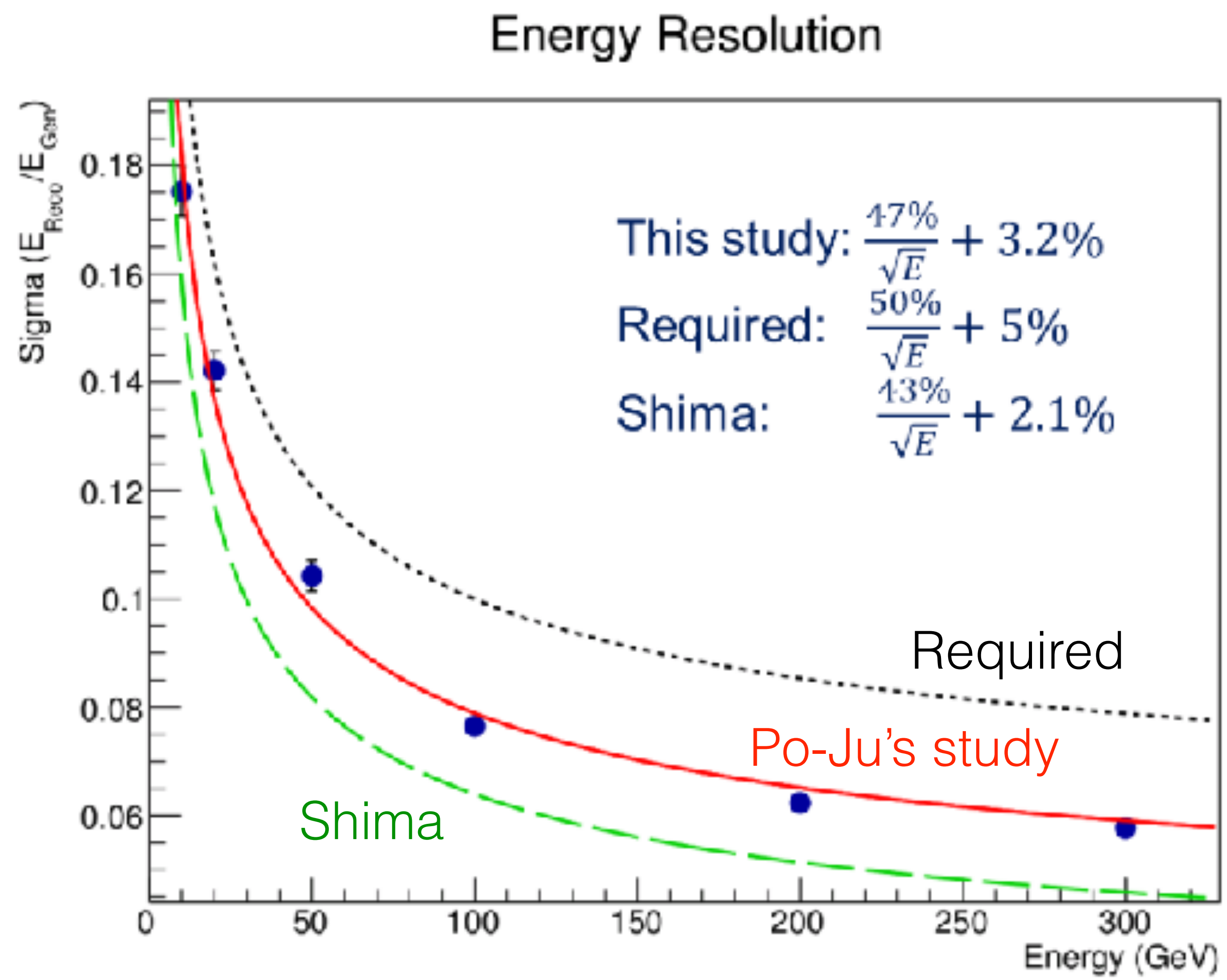
<table>
<tr><th></th><th>Energy range</th><th>Energy resolution</th><th>Position resolution</th><th>Others</th></tr>
<tr><td rowspan="2">Neutron</td><td rowspan="2">up to the beam energy</td><td>$\frac{50\%}{\sqrt{E}} + 5\%$, ideally $\frac{35\%}{\sqrt{E}} + 2\%$</td><td>$\frac{3\text{mrad}}{\sqrt{E}}$</td><td>Acceptance: 60 cm × 60 cm</td></tr>
<tr><td colspan="3">Note:
The acceptance is required from meson structure measurement.
Pion structure measurement may require a position resoultion of 1 mm.</td></tr>
<tr><td rowspan="4">Photon</td><td rowspan="2">$0.1 - 1$ GeV</td><td>$20 - 30\%$</td><td></td><td>Efficiency: $90 - 99\%$</td></tr>
<tr><td colspan="3">Note:
Used as a veto in e+Pb exclusive J/ψ production</td></tr>
<tr><td rowspan="2">$20 - 40$ GeV</td><td>$\frac{35\%}{\sqrt{E}}$</td><td>0.5–1 mm</td><td></td></tr>
<tr><td colspan="3">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.</td></tr>
</table>

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

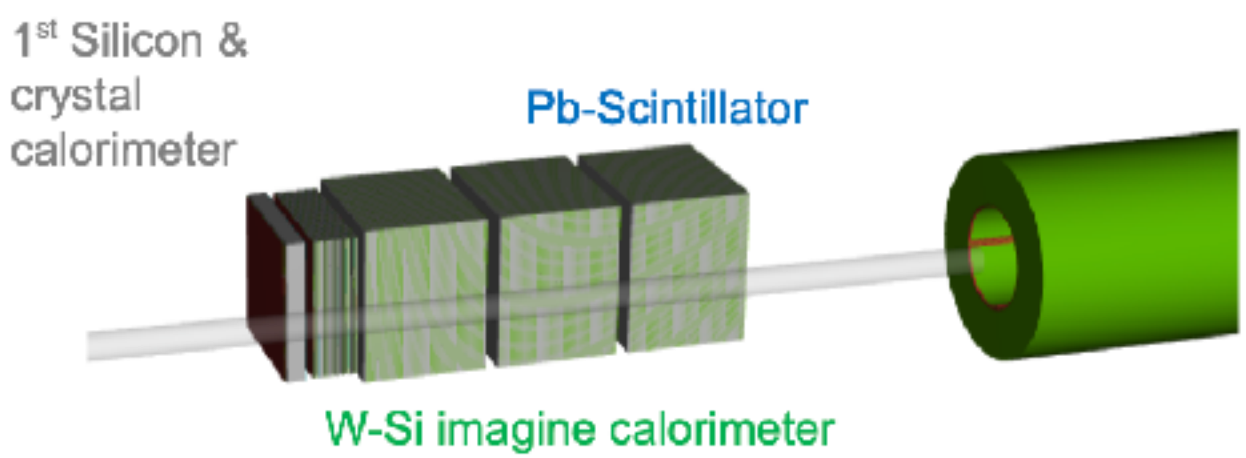


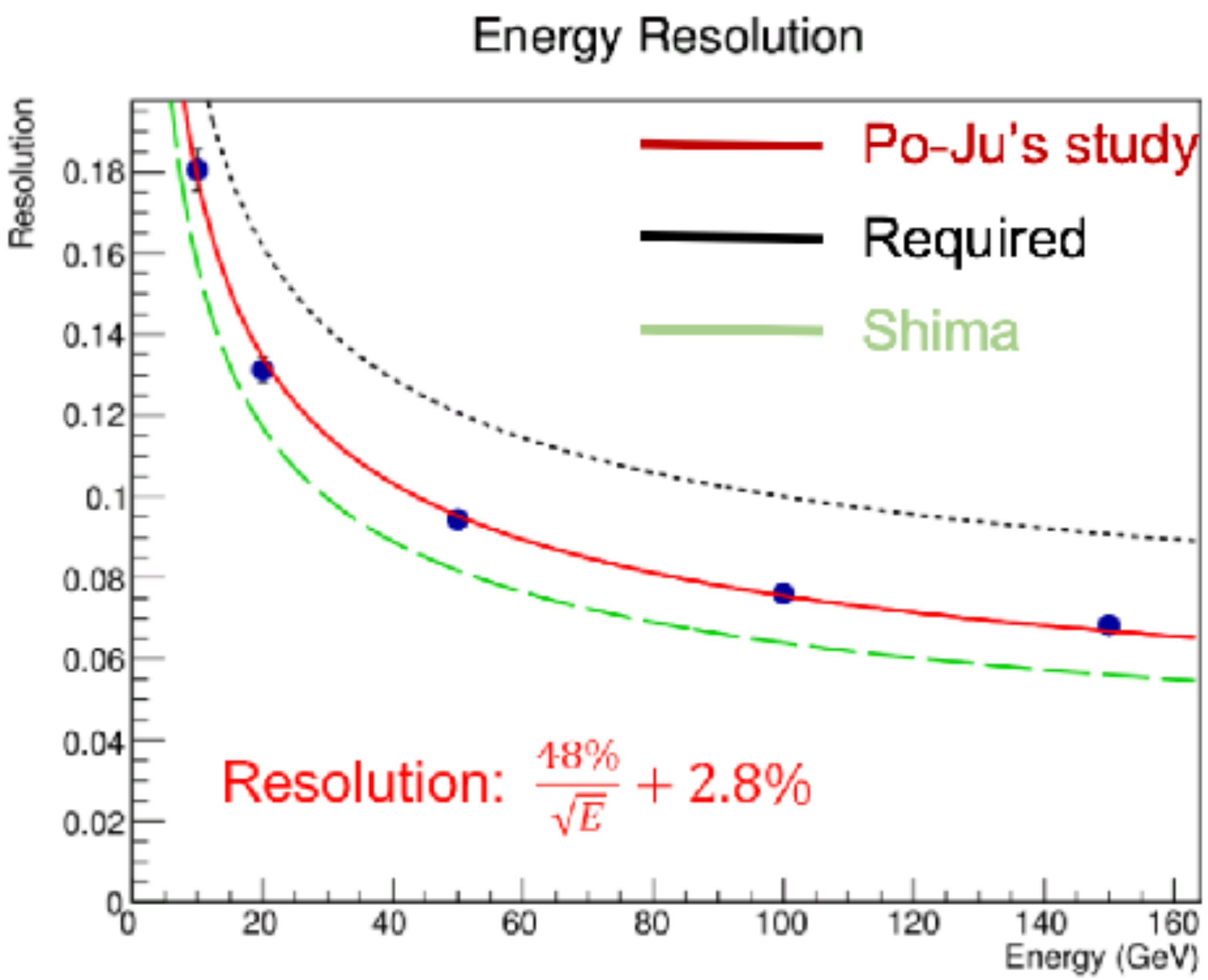


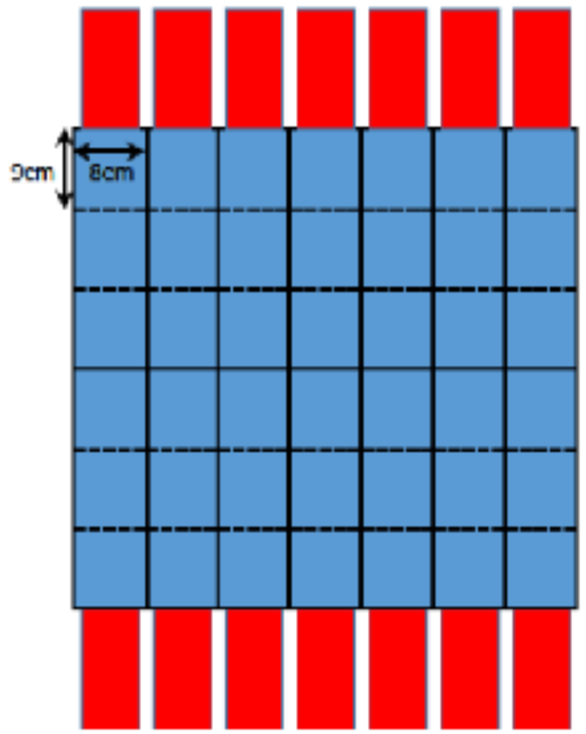


Result not as good as what Shima had, but acceptable

ZDC Monte Carlo Studies



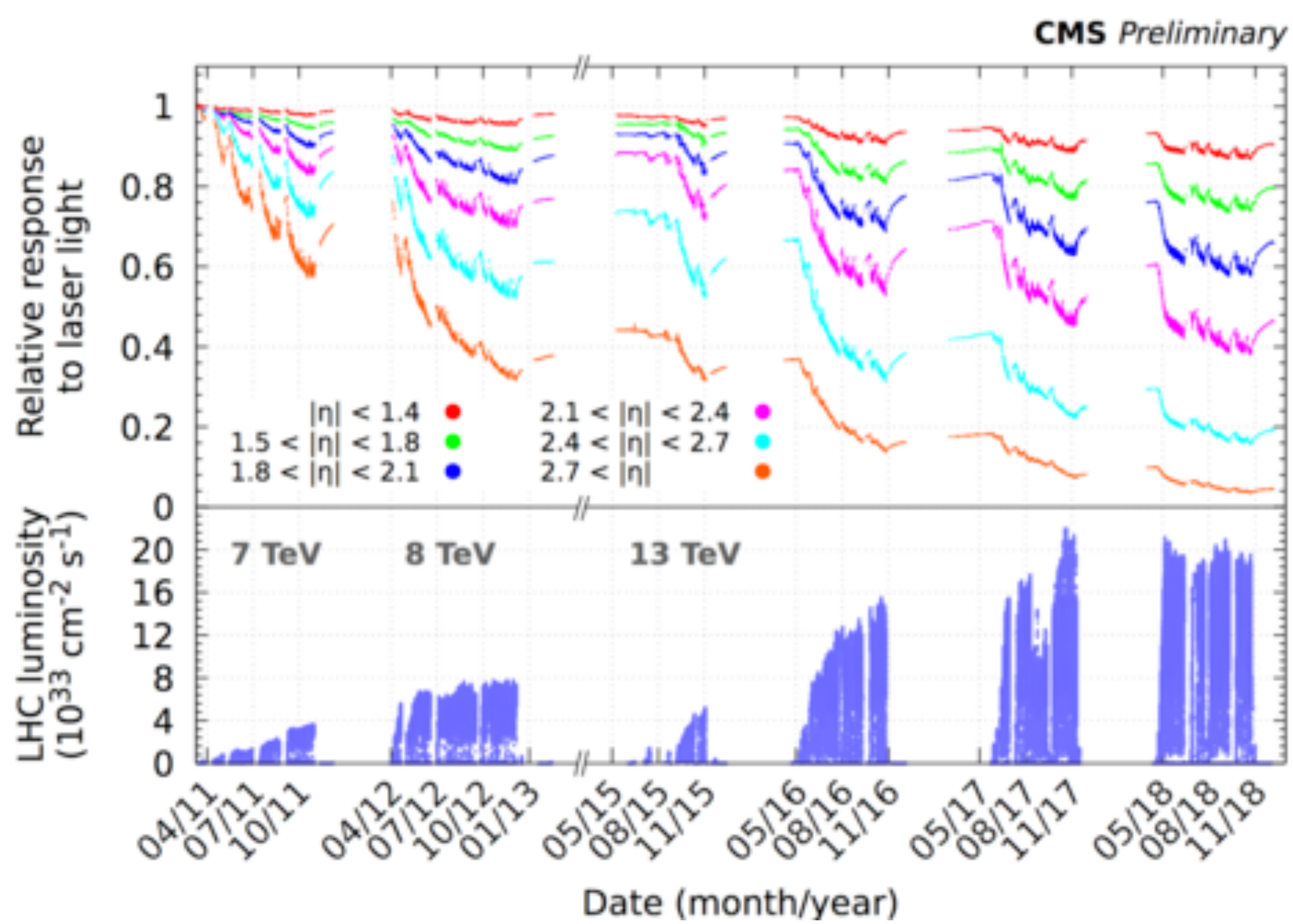




- ZDC simulation updated
  - Upstream modules with smaller lateral size to fit between beam pipes
  - Overall length about 183 cm, within 2 m limit
  - More cost effective, Pb-Silicon module removed
  - HCAL resolution improved
- Base design, meets the resolution requirement

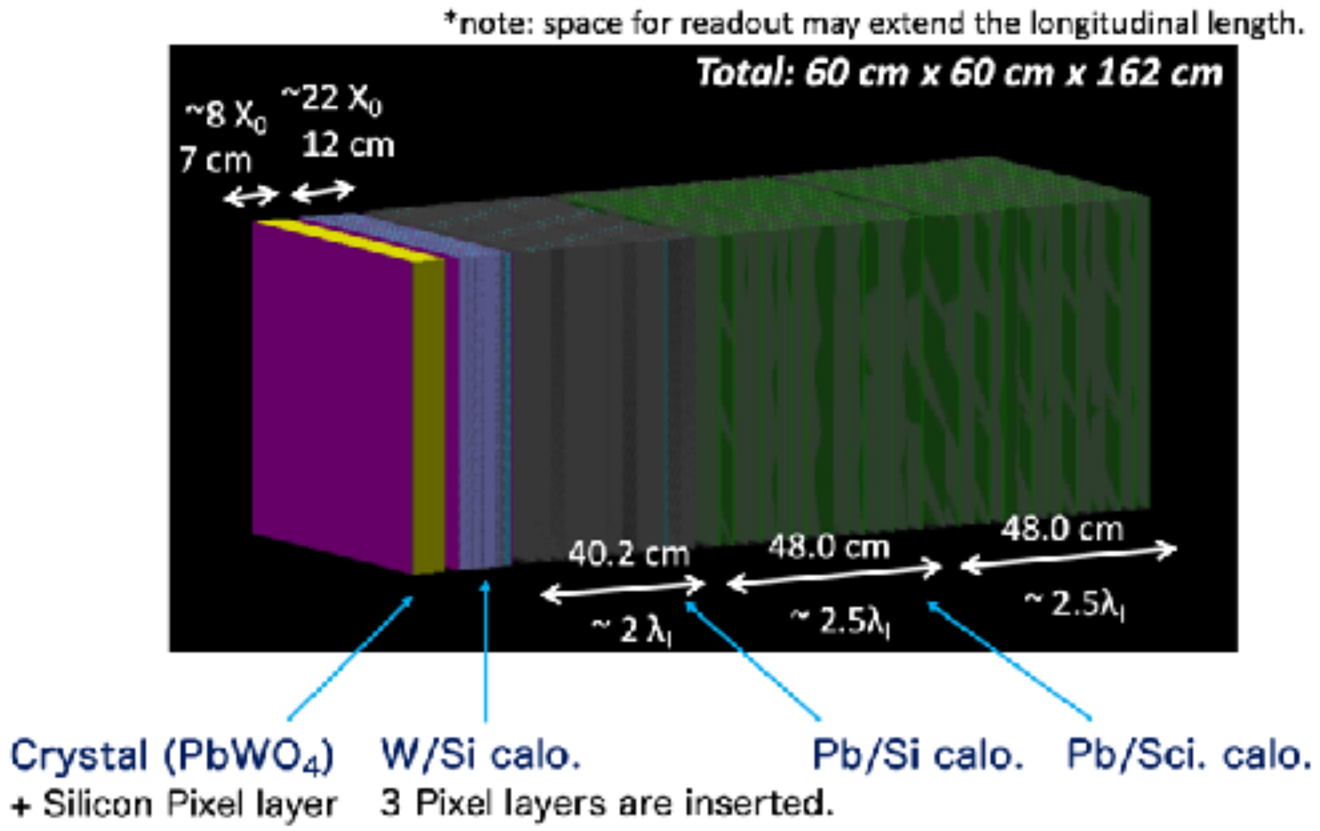
$PbWO_4$ vs LYSO vs SciGlass

	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%)	420
LYSO	1.14 cm	30,000 (market star			
SciGlass	2.4-2.8 cm	>100			

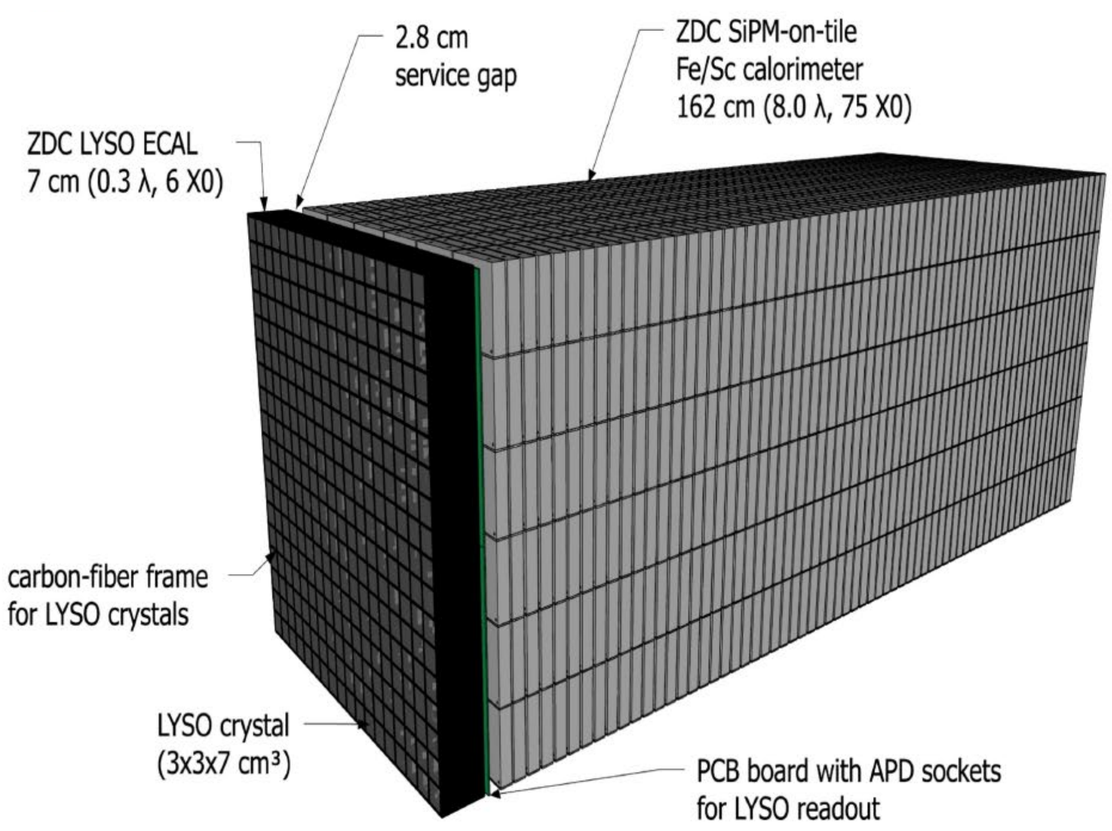


ePIC ZDC Design

Previous ZDC design

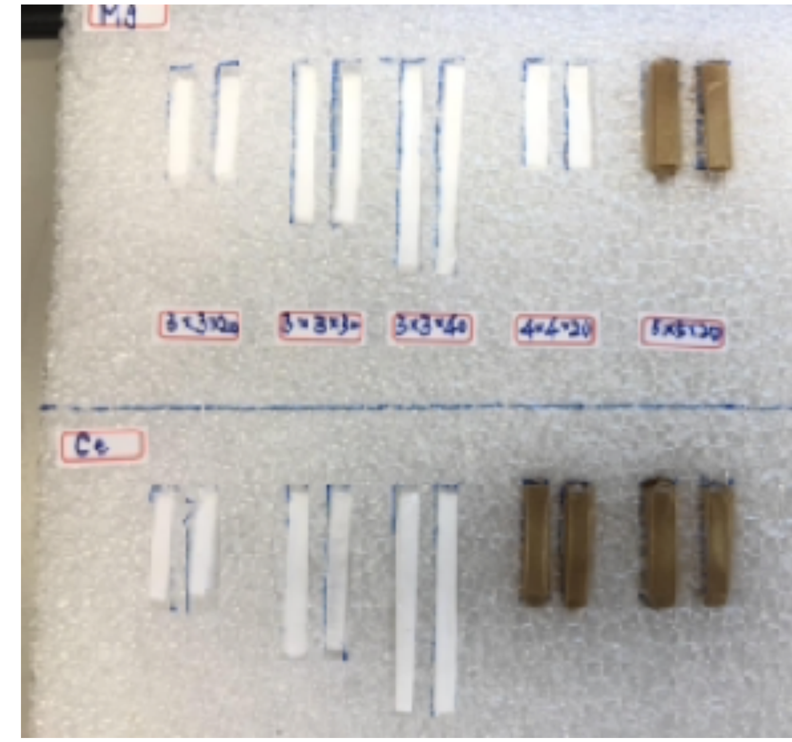


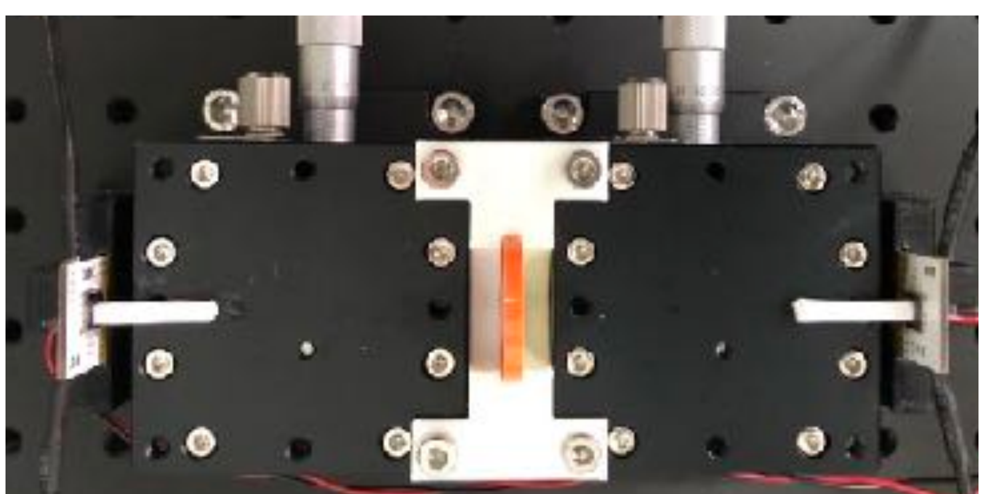
Current ZDC design

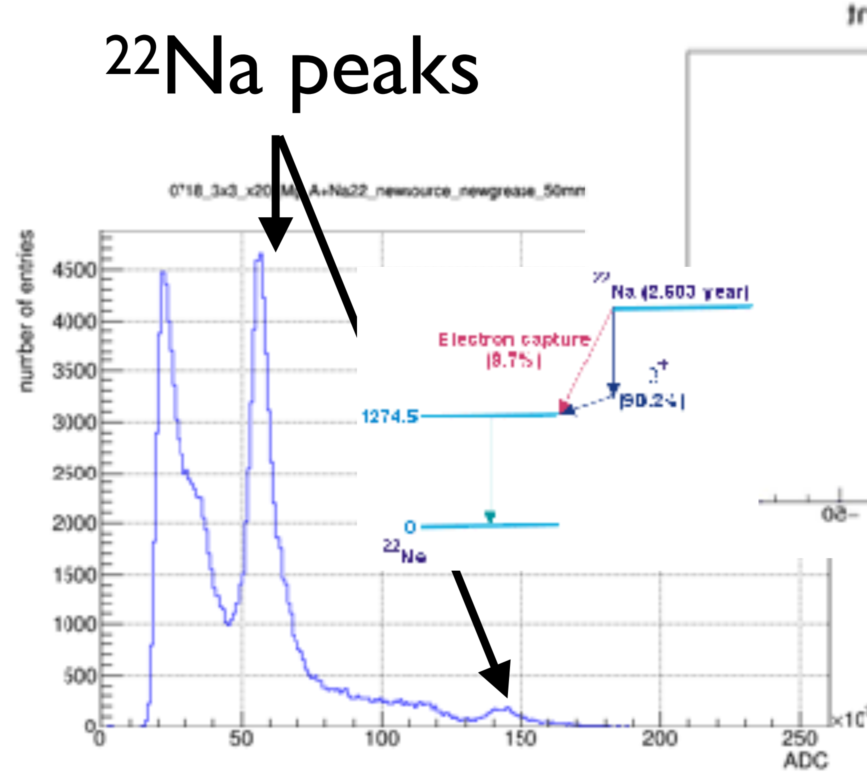


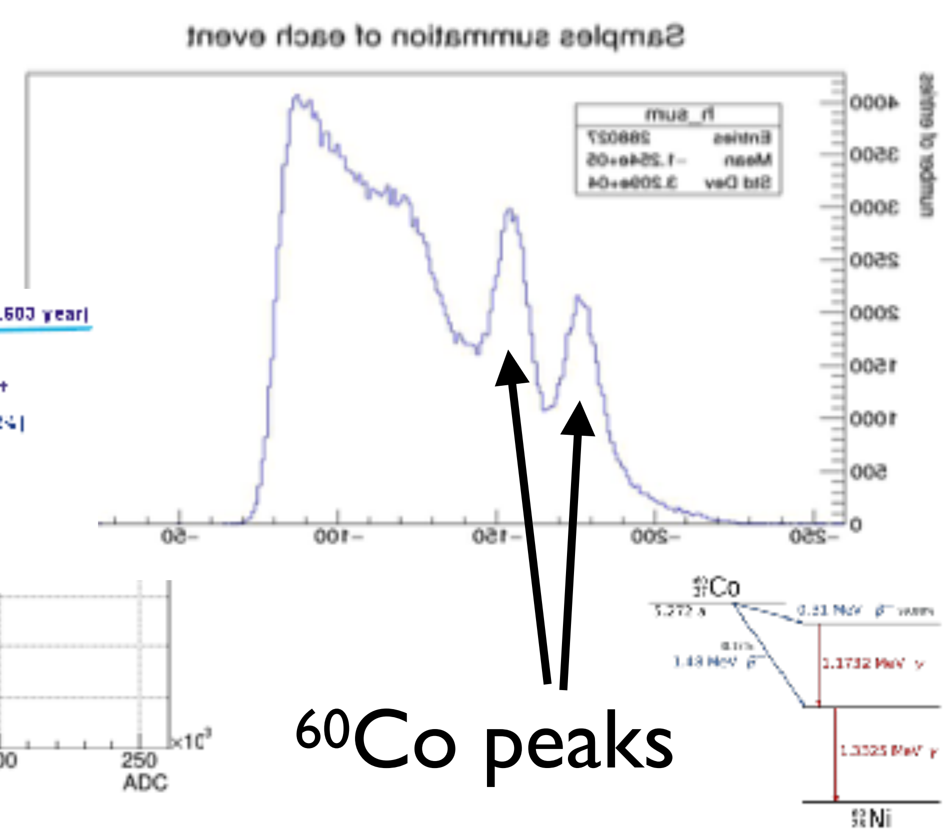
LYSO Crystal Characterization

- 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

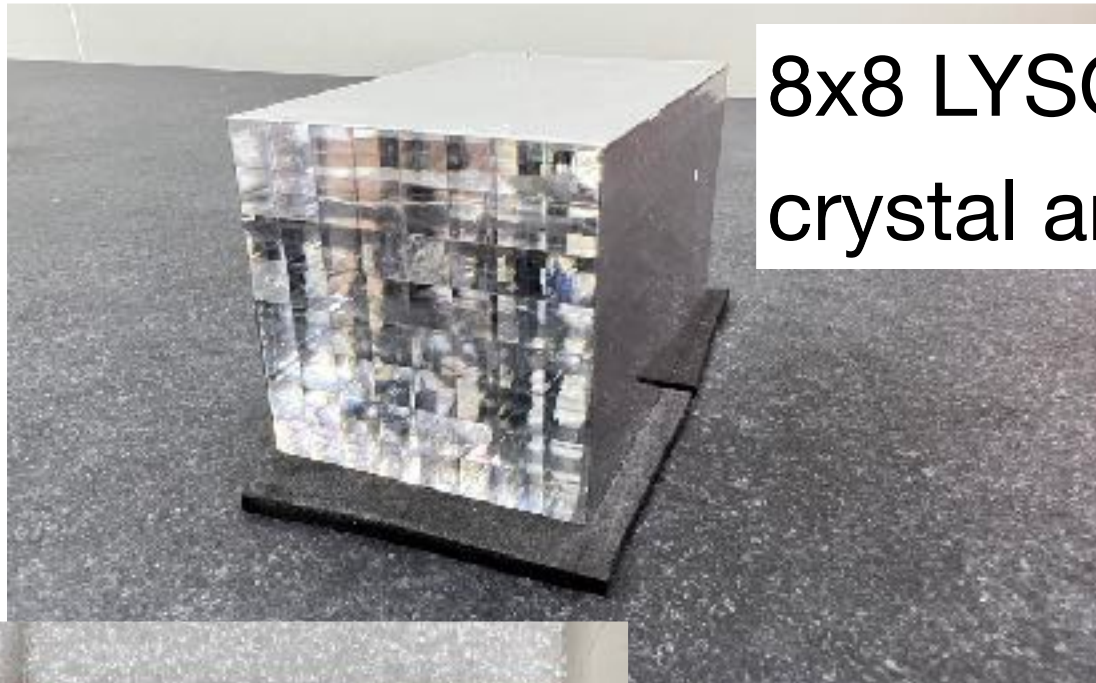




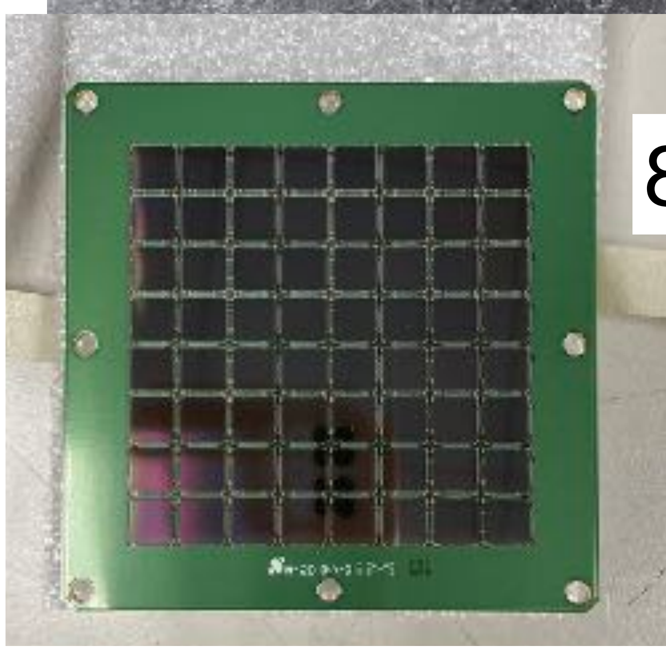




ZDC ECAL Prototype with LYSO Crystals

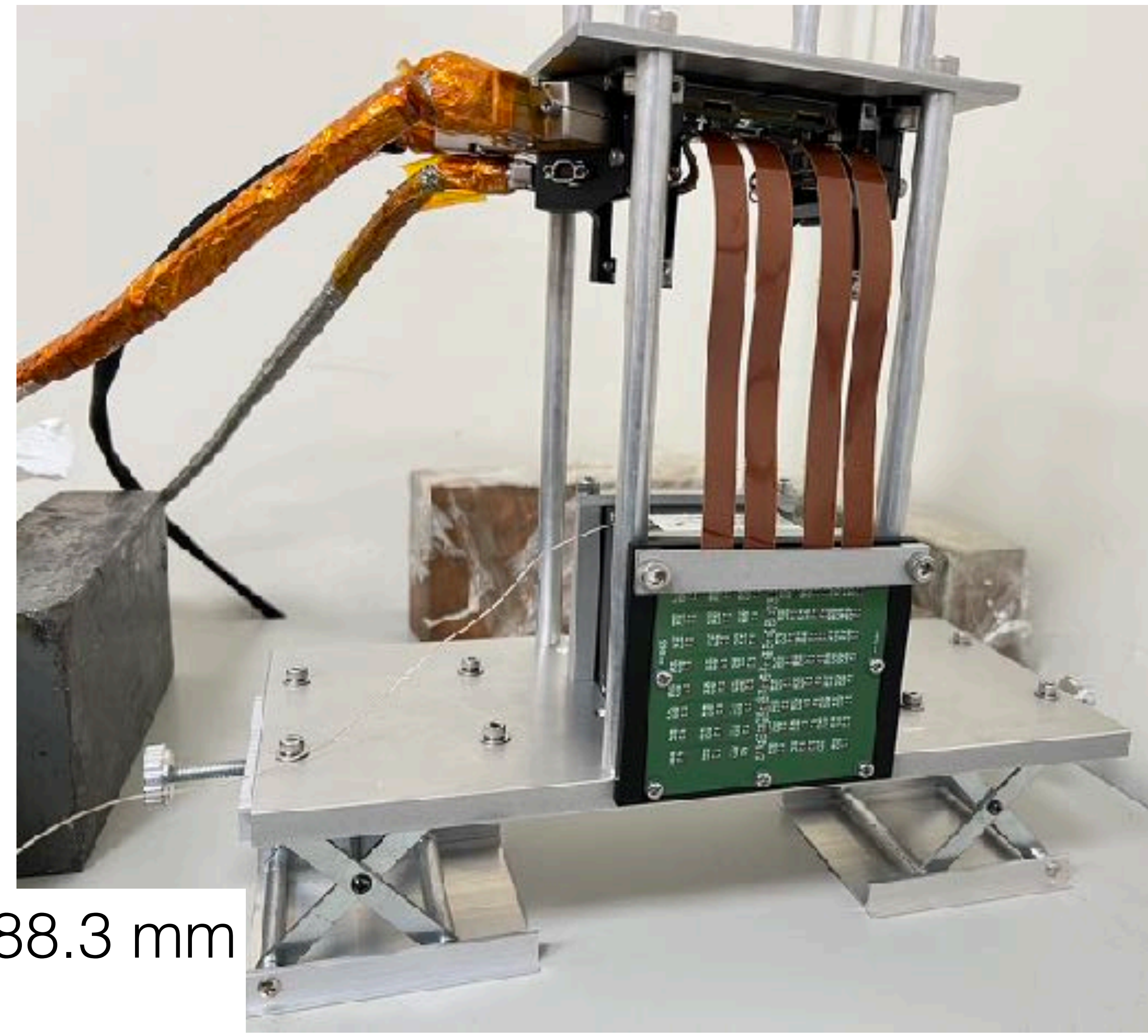


8x8 LYSO crystal array



8x8 SiPM array

LYSO calorimeter prototype

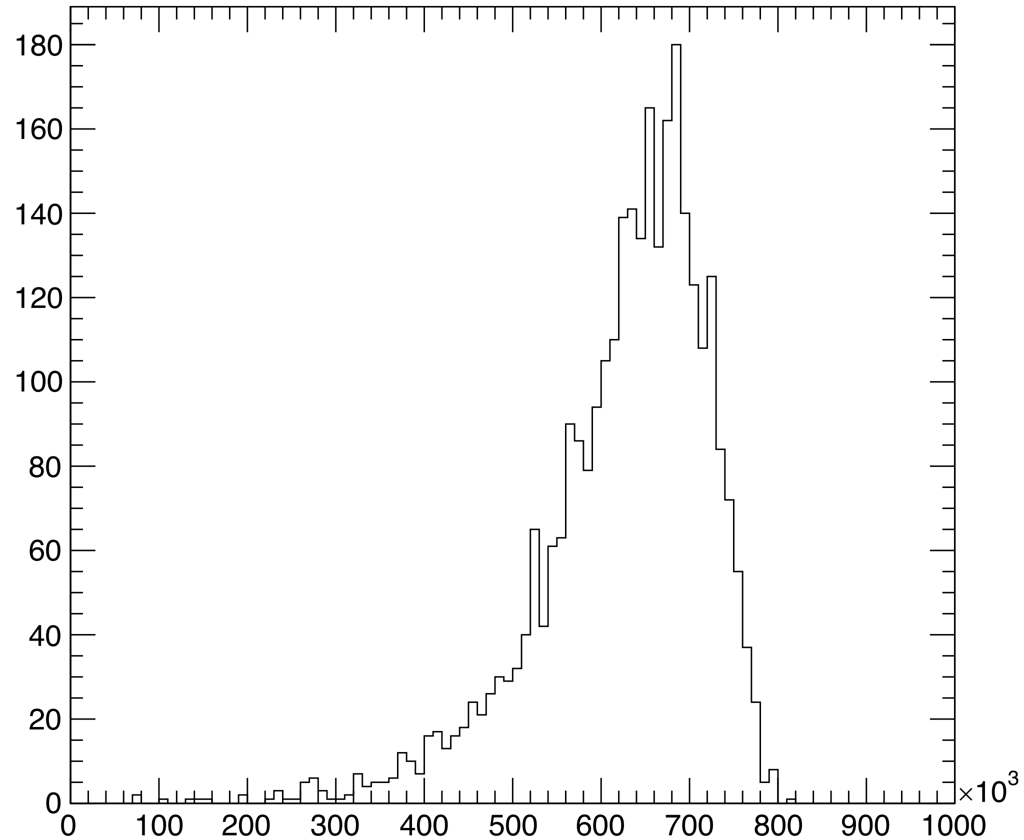


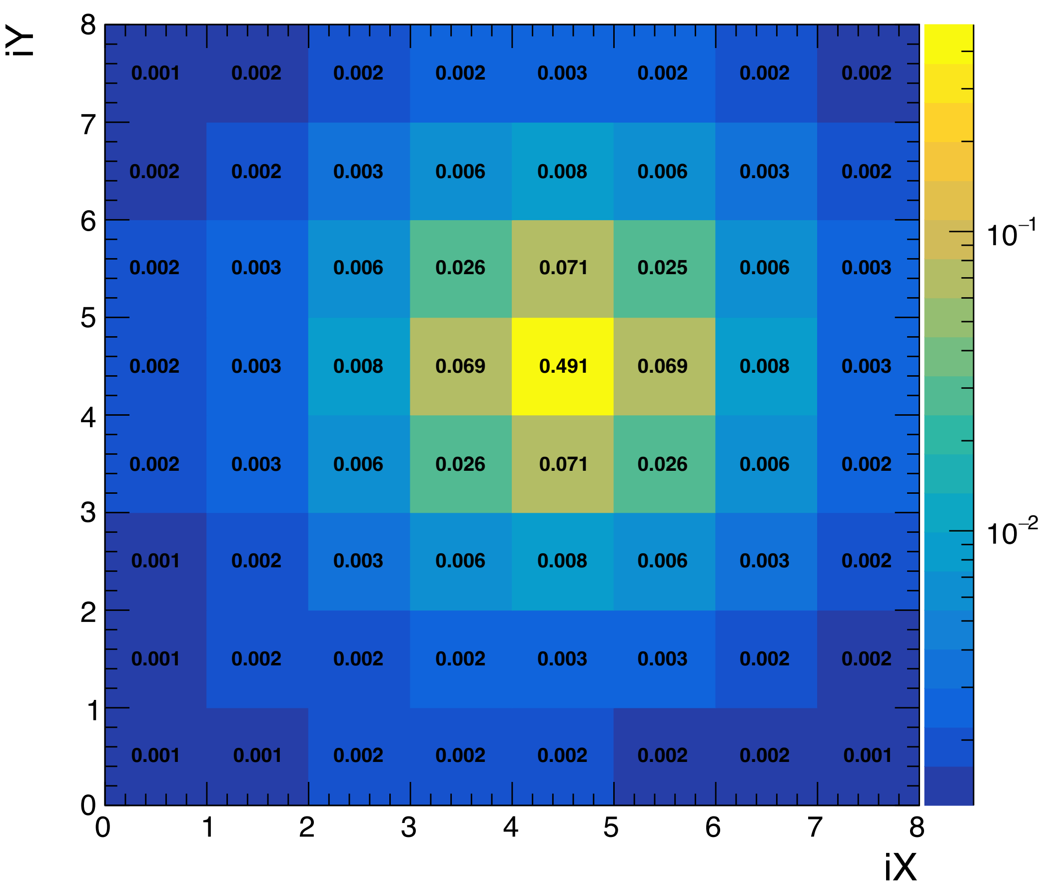
One crystal: 7.12 mm x 7.12 mm x 88.3 mm
8x8 array: 56.96 mm x 56.96 mm

Beam Test @ ELPH

- A beam test with positrons is planned at the ELPH, Tohoku University, between **19 and 21 February 2024**
- Beam time: ~36 hours
- Beam energy: 100 MeV up to 1 GeV possible
- Beam size: 1cm x 1cm
- Rate: 50 Hz at 100 MeV/cm^2 and a few kHz at 600 MeV/cm^2
- Participants: RIKEN, Tsukuba University, Sejong University, EIC-Taiwan

ZDC ECAL MC Study

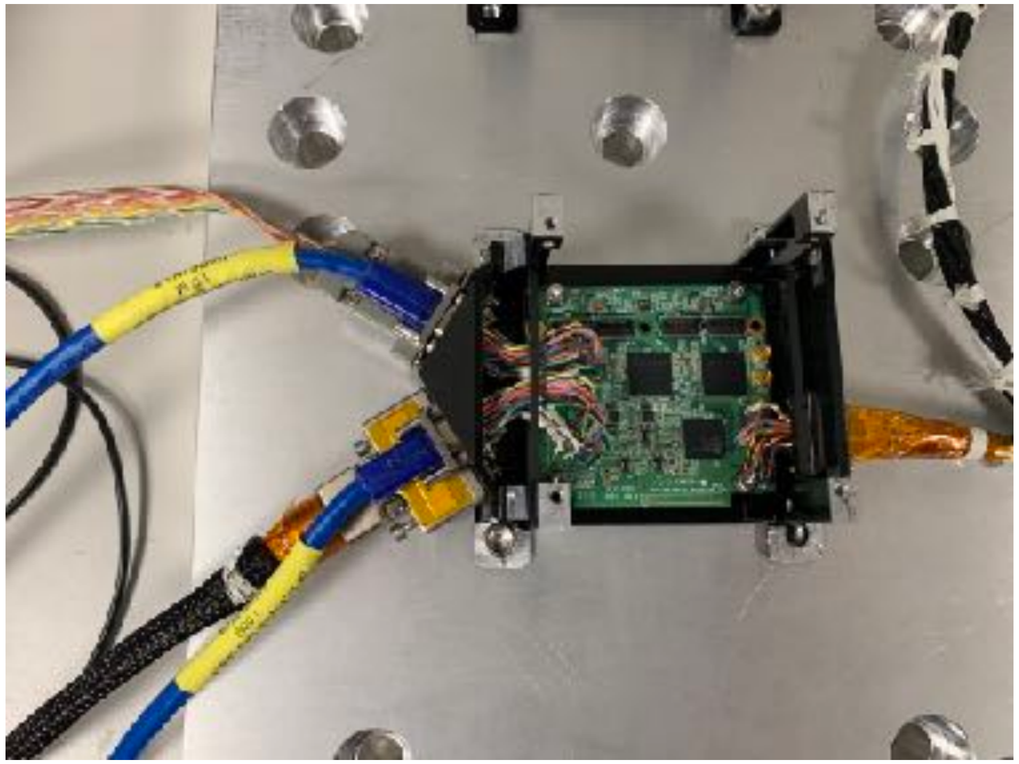




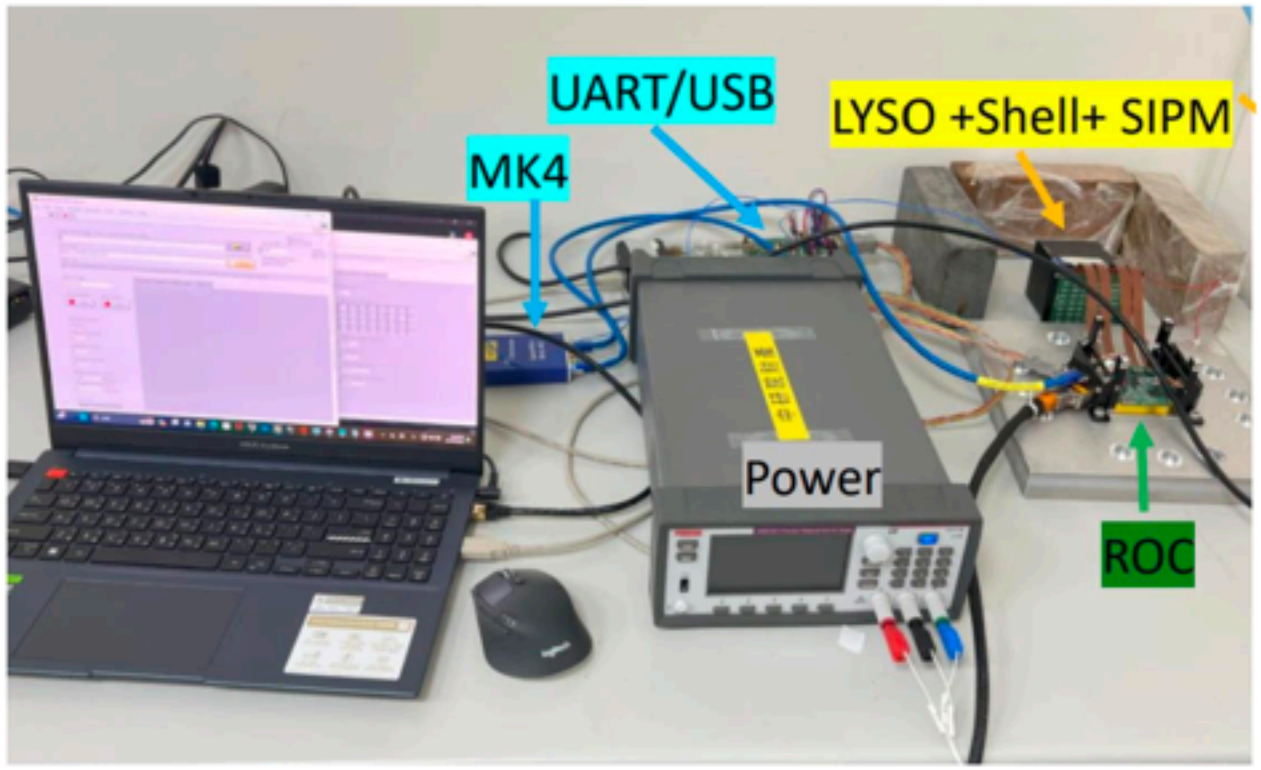
- For the beam test in February 2024
- Various optical properties in the G4 simulation are being studied
- Will compare energy resolution, shower shapes, and so on between simulation and beam test data and also validate the energy regression

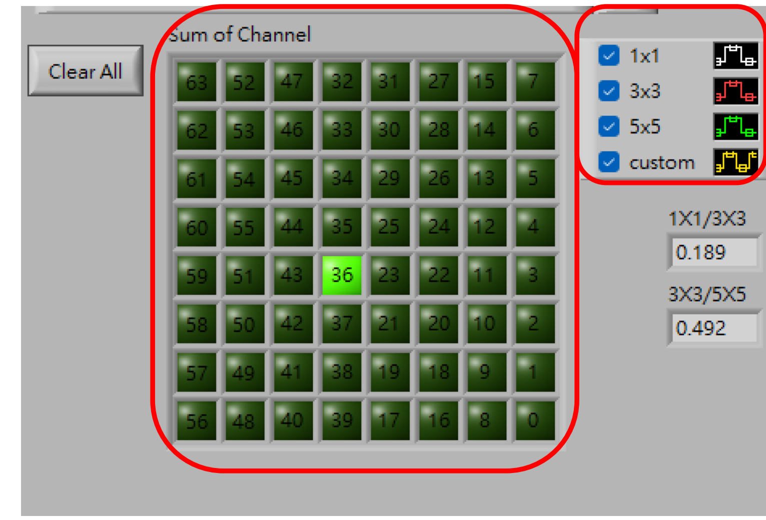
Readout for the ZDC ECAL Prototype with LYSO Crystals

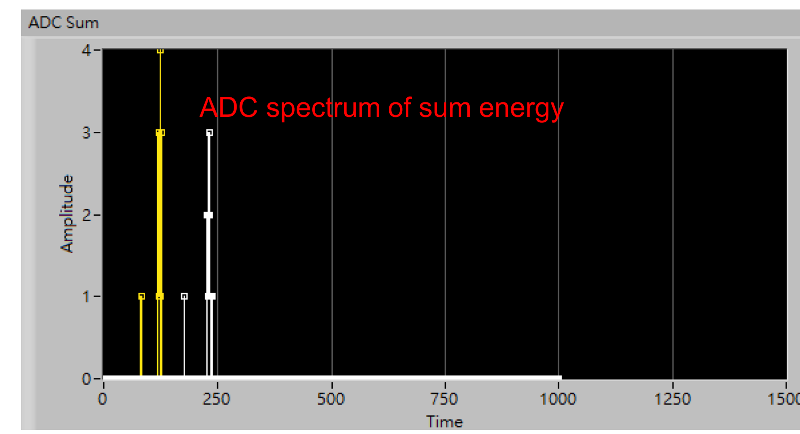
- Designed by Chih-Hsun Lin of Academia Sinica
- 128 channels
- Trigger:
  - Self-triggered
  - Can accept external timing signal → needs to be studied
  - May accept external trigger → needs to be studied

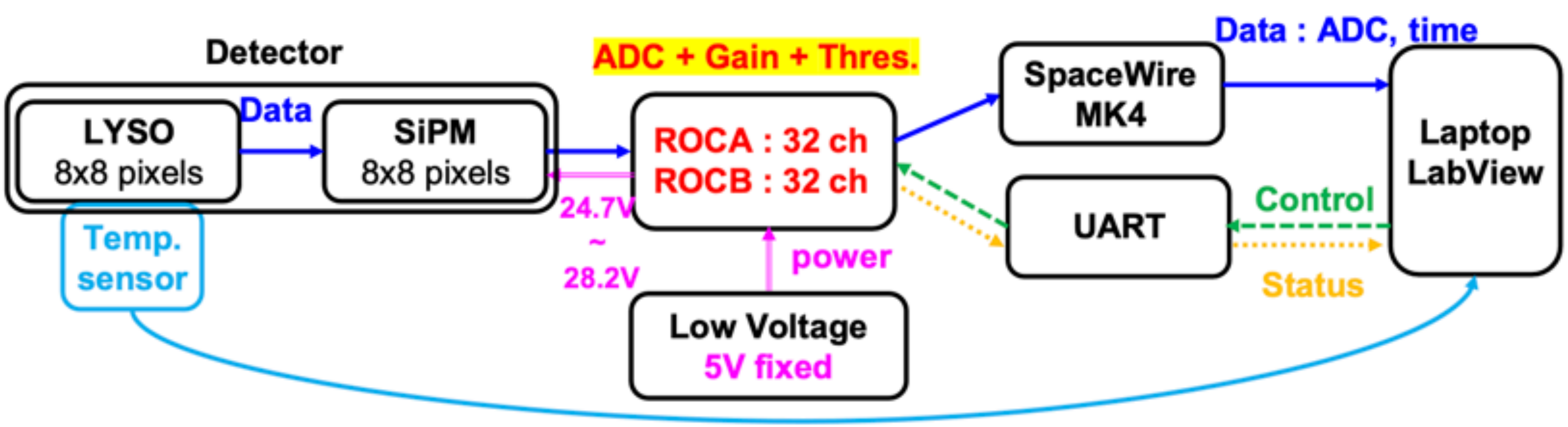


Test Setup



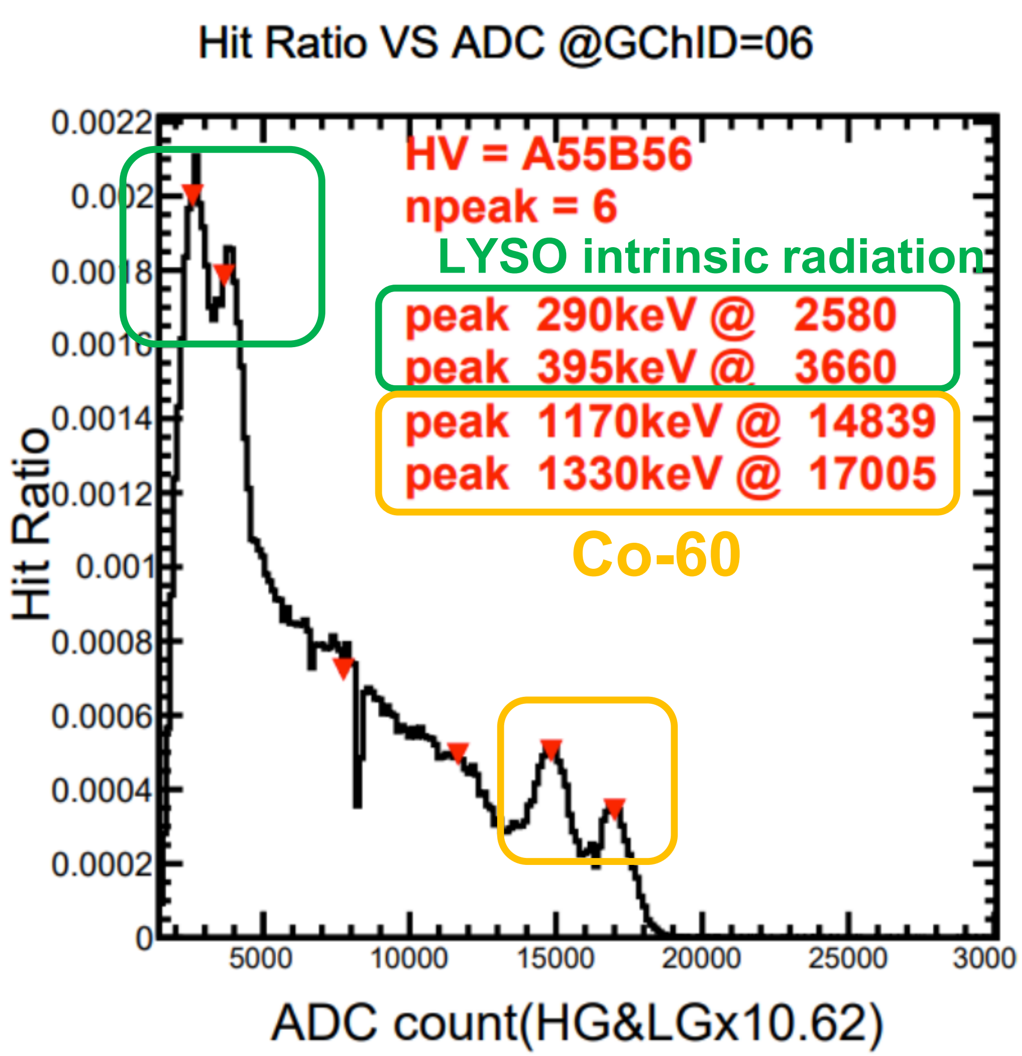






credit: Chia-Yu Hsieh, Kai-Yu Cheng, Yu-Siang Xiao, Shao-Yang Lu, Chih-Hsun Lin, Po-Ju Lin

Tests with Co-60 (2/2)



We use Co-60 and LYSO intrinsic radiation to calibrate the detector.

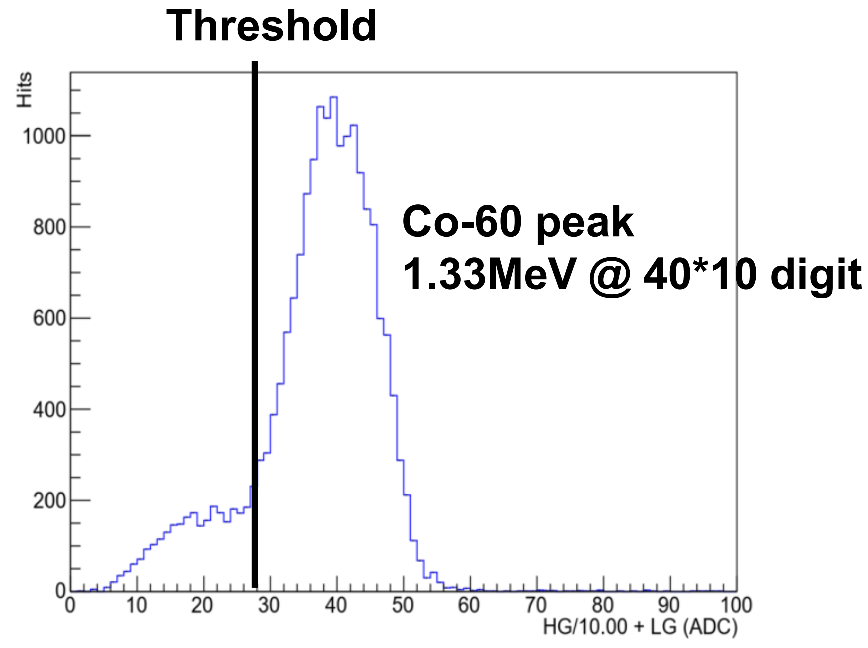
- **@HV = 27.00V**

➔ 1.330 MeV @ 17005 digit
➔ 1.330 MeV / 17005 digit ~ 7.8e-5 MeV / digit
Saturated digit = 11, 0000 digit
➔ 11,0000 digit * 0.1268MeV = 8.6MeV
➔ **Saturated at 8.6MeV**
This HV/gain is too high for our beam test condition.

- HV setting range = 24.7V to 28.2V

credit: Chia-Yu Hsieh, Kai-Yu Cheng, Yu-Siang Xiao, Shao-Yang Lu, Chih-Hsun Lin, Po-Ju Lin

Tests with Co-60 (1/2)



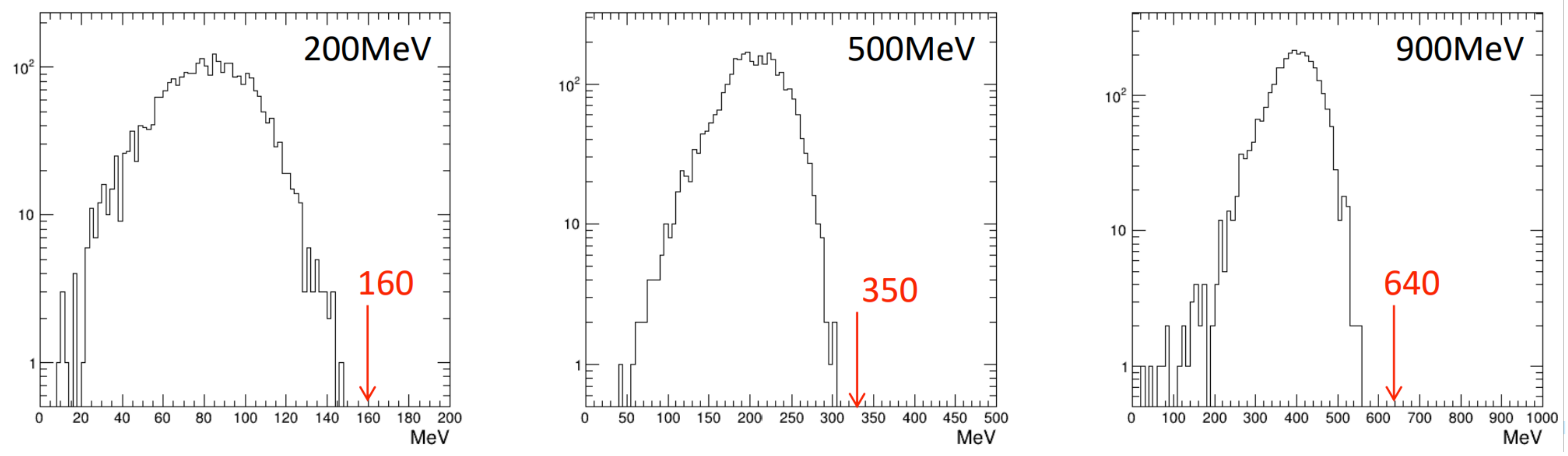
- @HV ~ 24.7V (almost lowest gain, 4D3 digit)

➔ 1.330 MeV @ 400 digit
➔ 1.330 MeV / 400 digit ~3.3e-3 MeV / digit

Saturated digit = 11, 0000 digit

➔ 11,0000 digit * 3.3e-3MeV = 365.75 MeV
➔ **Saturated at 365.75 MeV (one pixcel)**
➔ **We should be able to see 500MeV positron beam at lowest gain.**

Energy deposition of positron in central pixel in YSO LYSO from MC simulation



credit: Chia-Yu Hsieh, Kai-Yu Cheng, Yu-Siang Xiao, Shao-Yang Lu, Chih-Hsun Lin, Po-Ju Lin

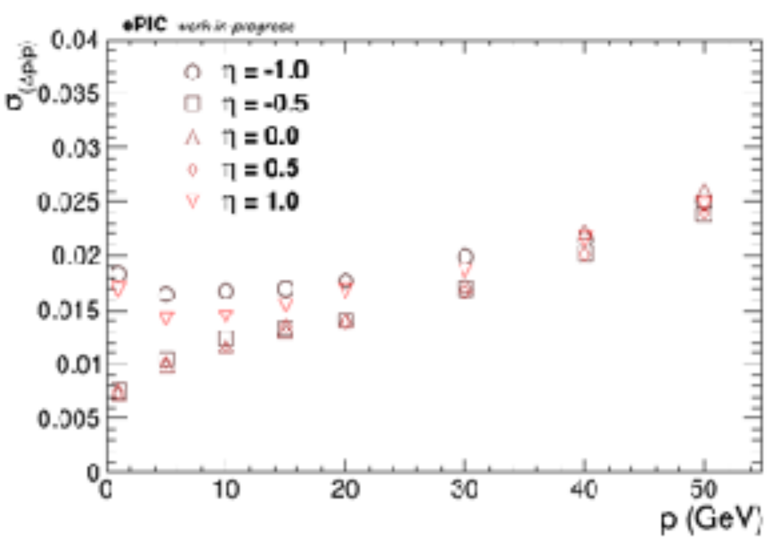
Future Plan:

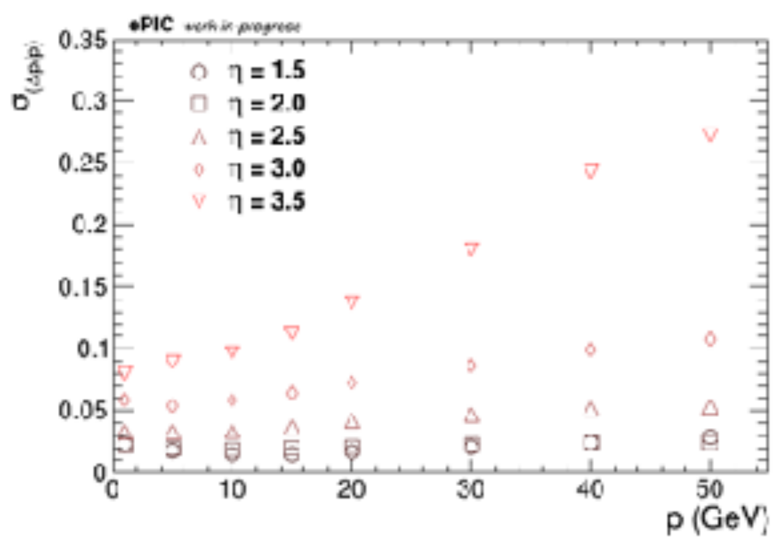
- Construct a prototype with $PbWO_4$ (this summer)
- Revise the readout
- Beam test with 5GeV electrons at KEK

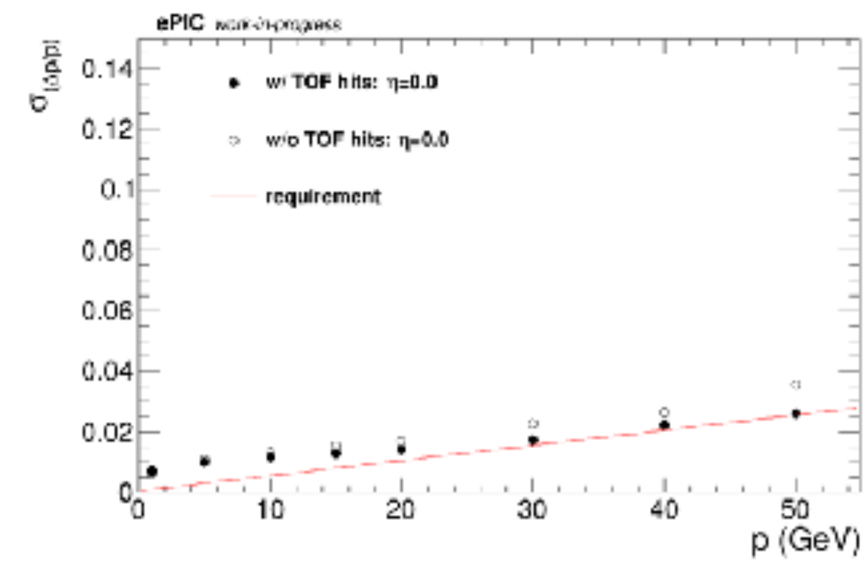
TOF Performance Study

- 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

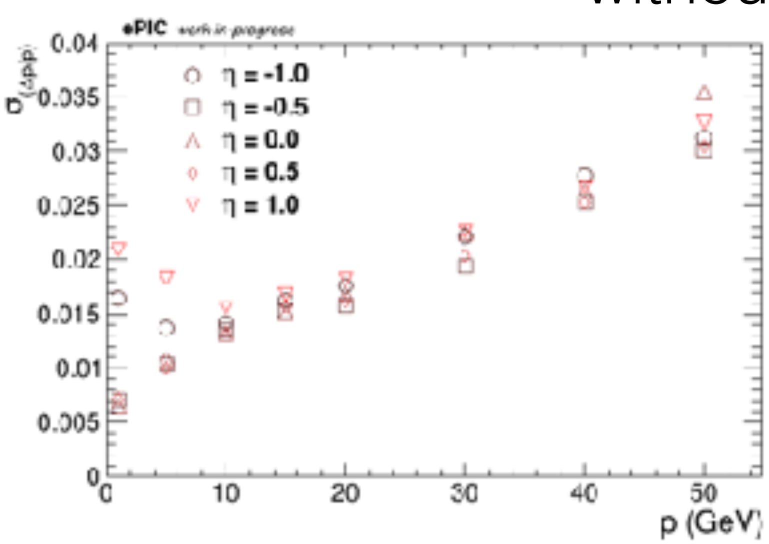
with TOF hits

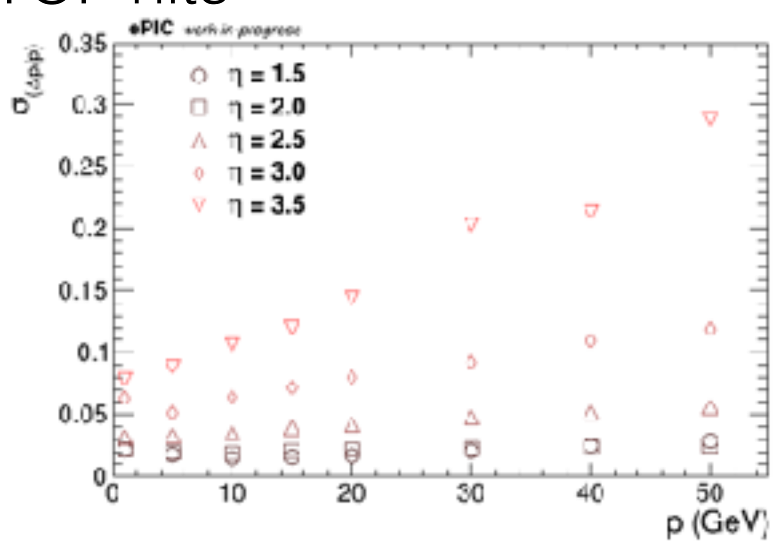






without TOF hits





- Simulation with DD4hep and reconstruction
- Plans:
  - Repeat the study with the craterlake detector setup
  - Study performance with a smaller TOF radius

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], E.-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.

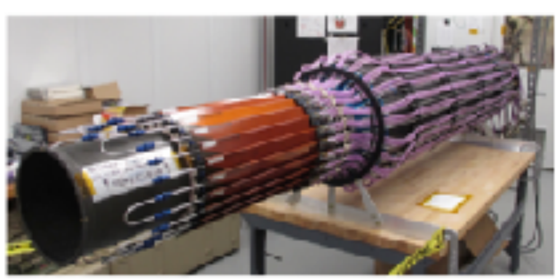
Request for Project Engineering and Design Support for EPIC TOF Detectors

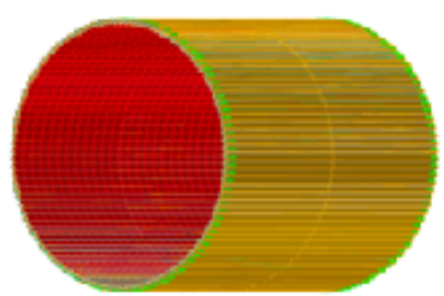
Oskar Hartbrich (ORNL),
Andreas Jung (Purdue),
Po-Ju Lin (AS),
Yi Yang (NCKU),
Zhenyu Ye (UIC)
for the EPIC TOF group.

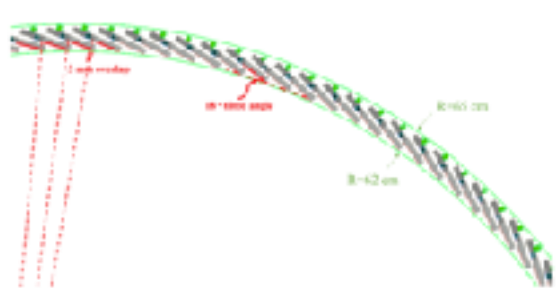
October 2022

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.







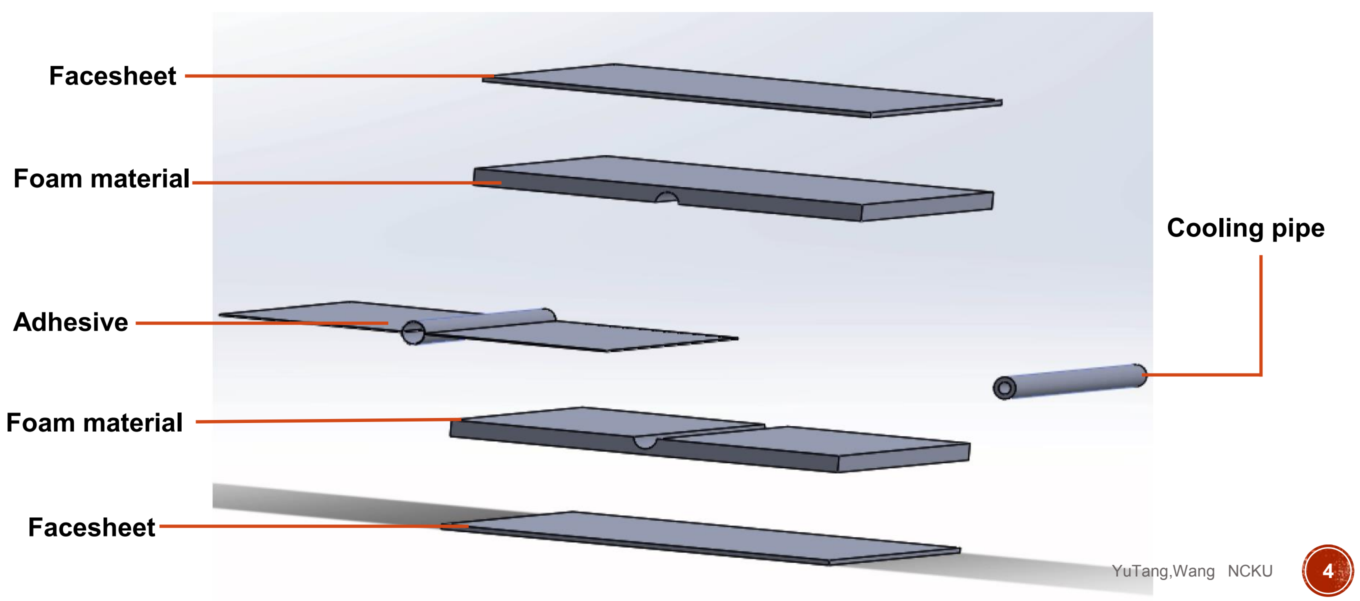
From Zhenyu's talk

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

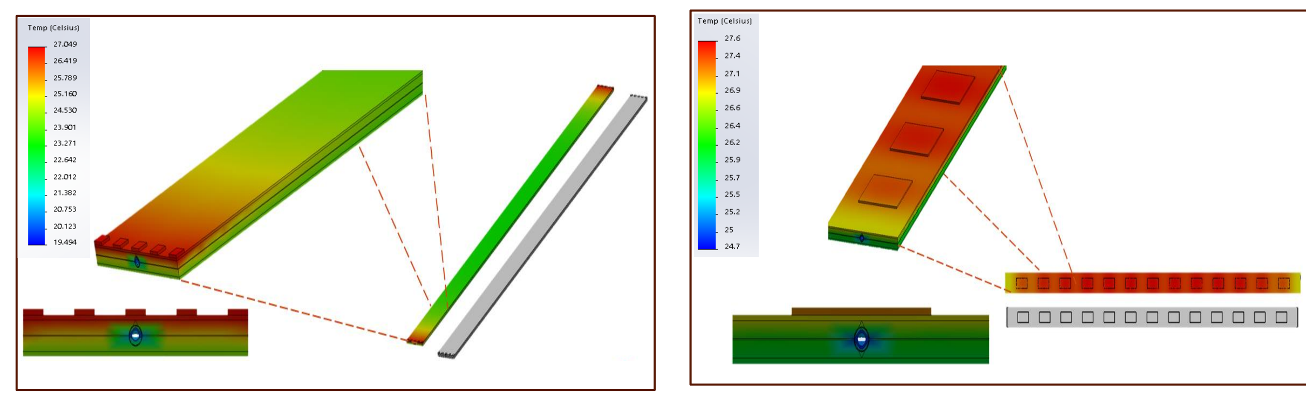
BNL: Alessandro Tricoli (atricoli@bnl.gov), Gabriele Giacomini (giacomini@bnl.gov)
FNAL: Artur Apresyan (apresyan@fnal.gov)
NCKU: Yi Yang (yiyang@ncku.edu.tw)
Purdue: Andreas Jung (anjung@purdue.edu)
UCSC: Matthew Gignac (mgignac@ucsc.edu)
UIC: Zhenyu Ye (yezhenyu@uic.edu)

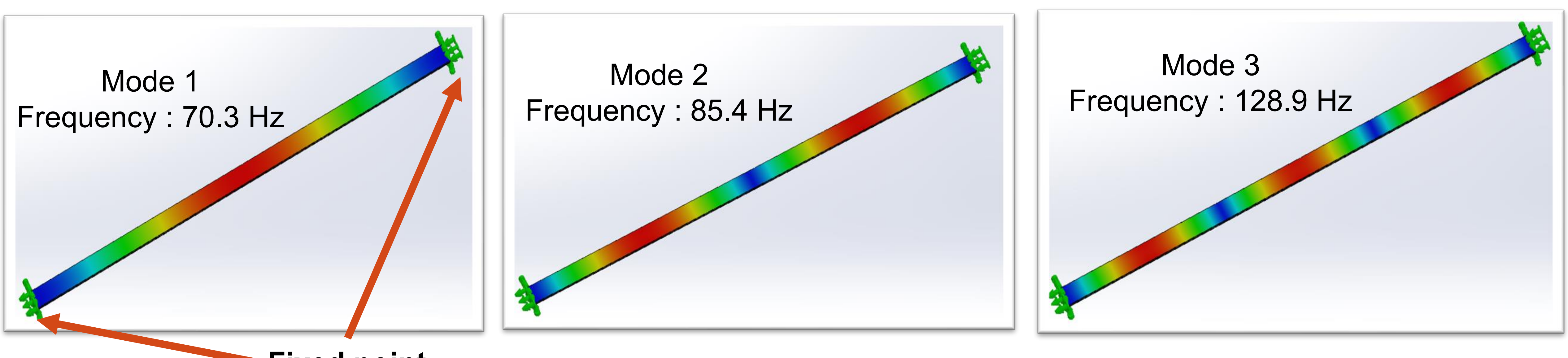
Mechanical Structure for TOF: Preliminary Design and Analysis

Structure of prototype



Preliminary setup for thermal analysis





Preliminary setup for frequency analysis

credit: Yu-Tang Wang, Yi Yang (NCKU)

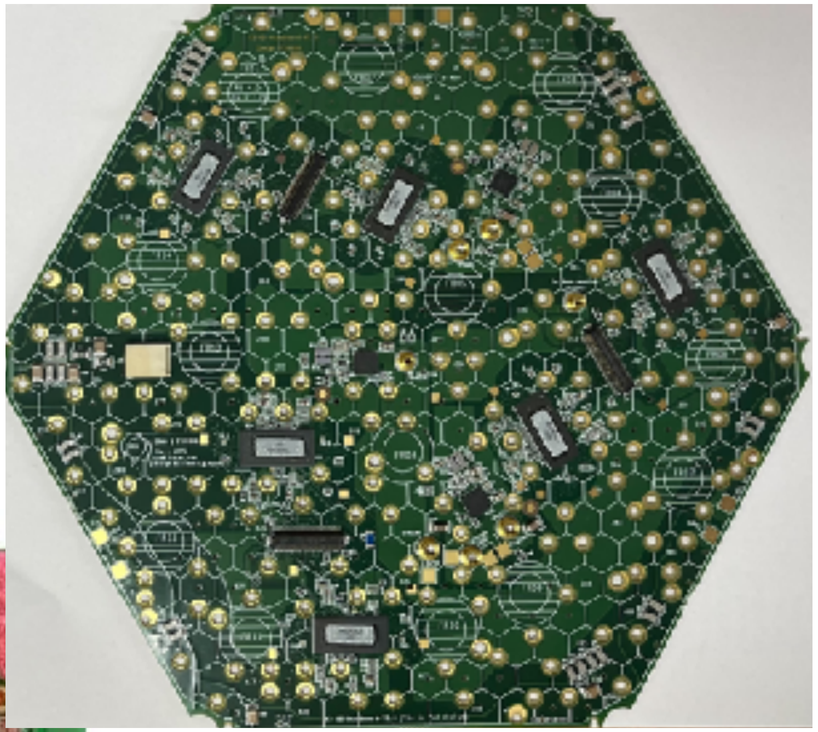
Mechanical Structure for TOF: Test Facilities @ NCKU

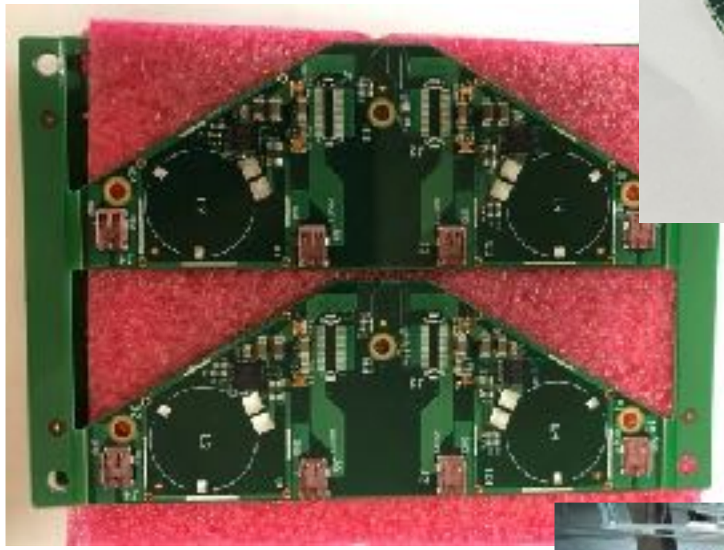
- Preparation for thermal test
- Compare results between simulation and test

credit: Yu-Tang Wang, Yi Yang (NCKU)

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





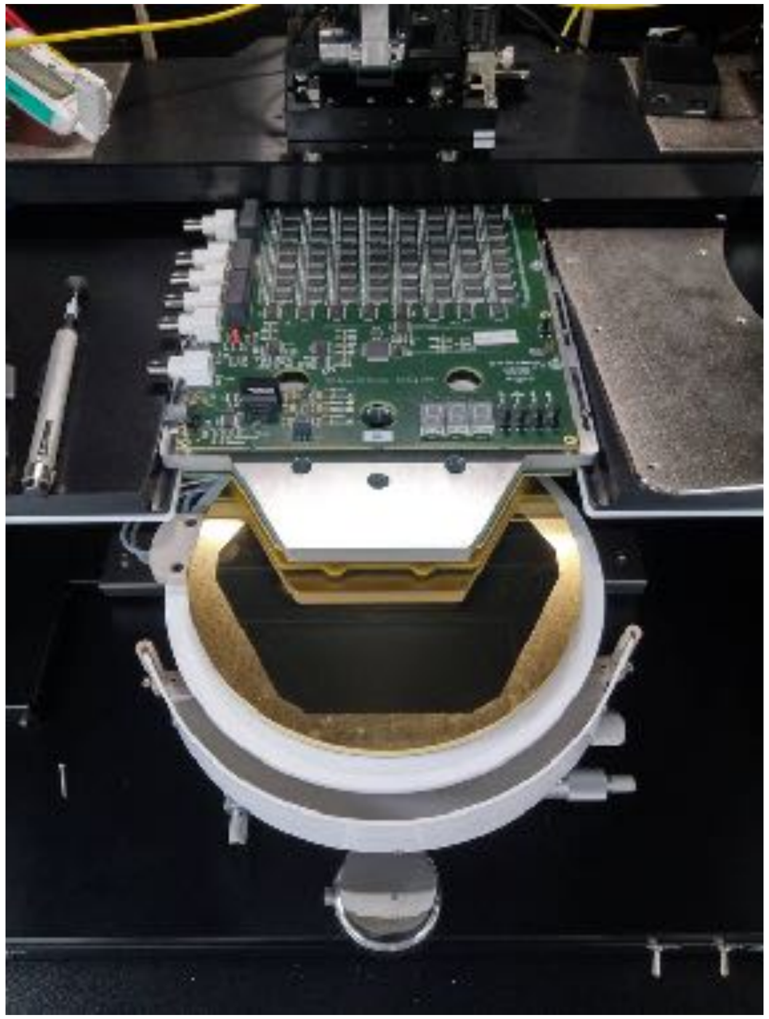
Summary

- 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
- Started to contribute to detector simulation and performance studies
- Other possibilities: detector assembly with TIDC, more contributions to TOF, computing, and so on

- Backup

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

Craterlake detector setup

- Additional MPGD layers added in all regions
- Shifted positions of some MAPS layers
- TOP layers provide solid tracking points and timing information