

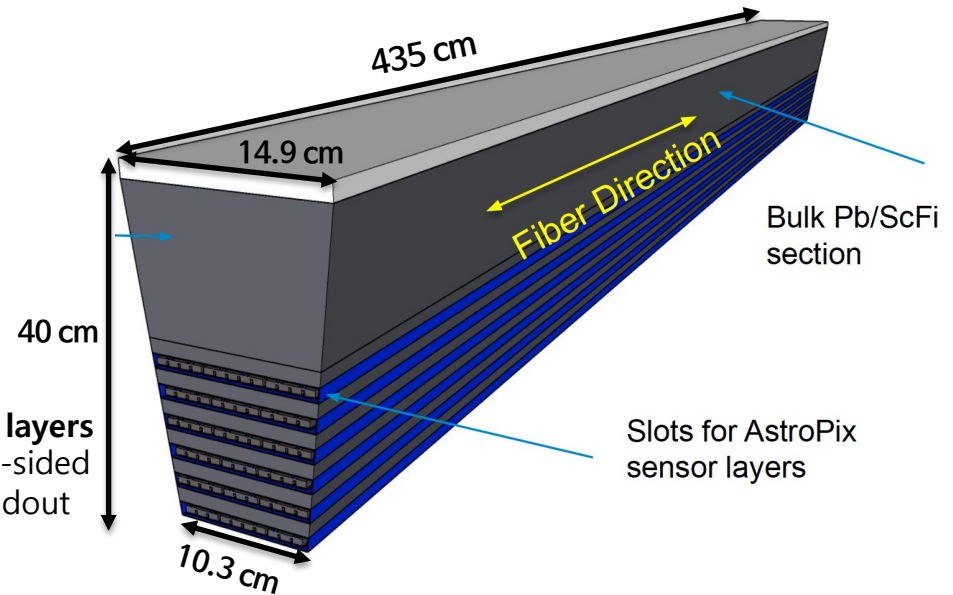
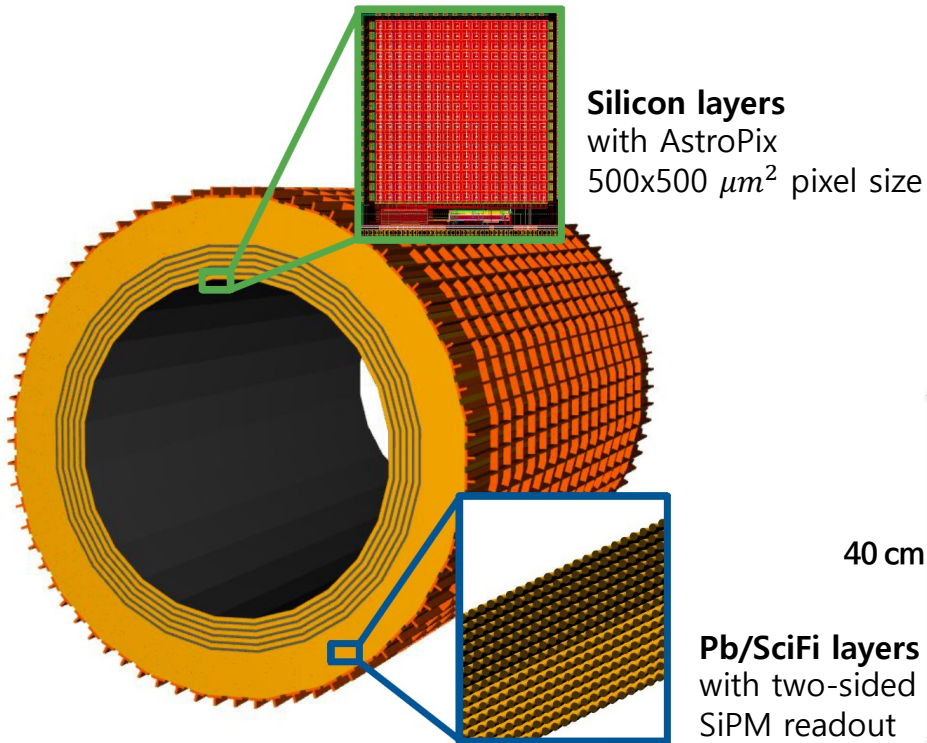
Activity in Korea on the Barrel Imaging Calorimeter

Sanghoon Lim
Pusan National University

EIC Asia meeting

Korean institutions for the BIC

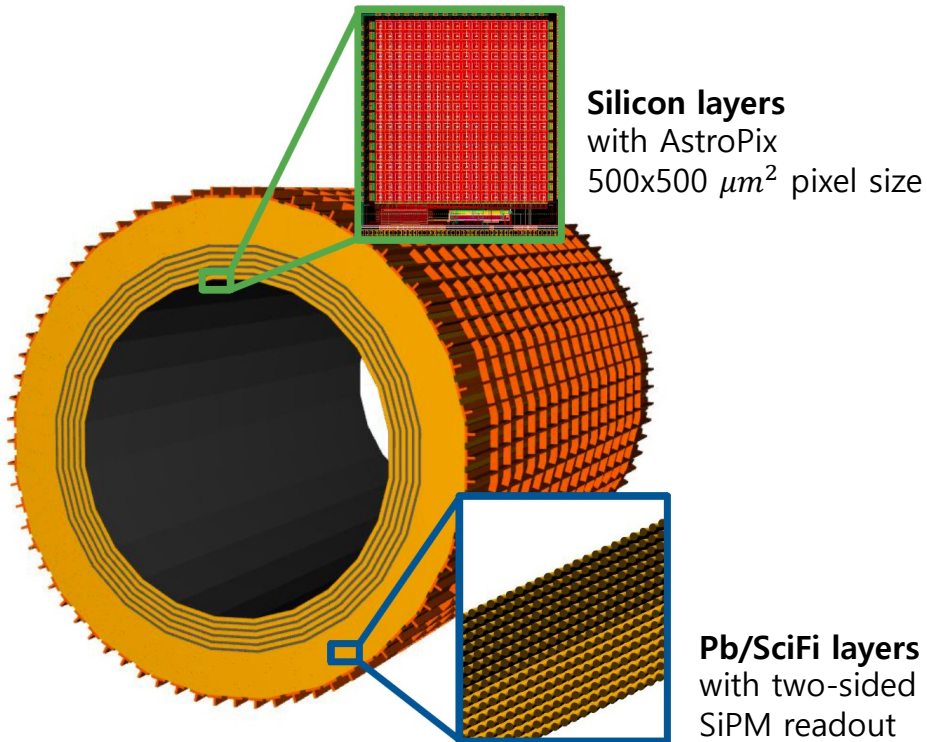
- 4(+2) layers of imaging Si sensors interleaved with 5 Pb/SciFi layers
- Followed by a bulk section of Pb/SciFi section
- Total radiation thickness $\sim 17.1 X_0$
- Sampling fraction $\sim 10\%$



Energy resolution: Primarily from Pb/SciFi layers (+ Imaging pixels energy information)

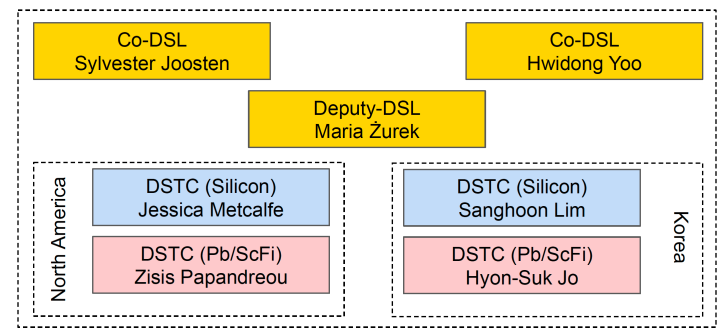
Position resolution: Primarily from Imaging layers (+ 2-side Pb/SciFi readout and radial segmentation)

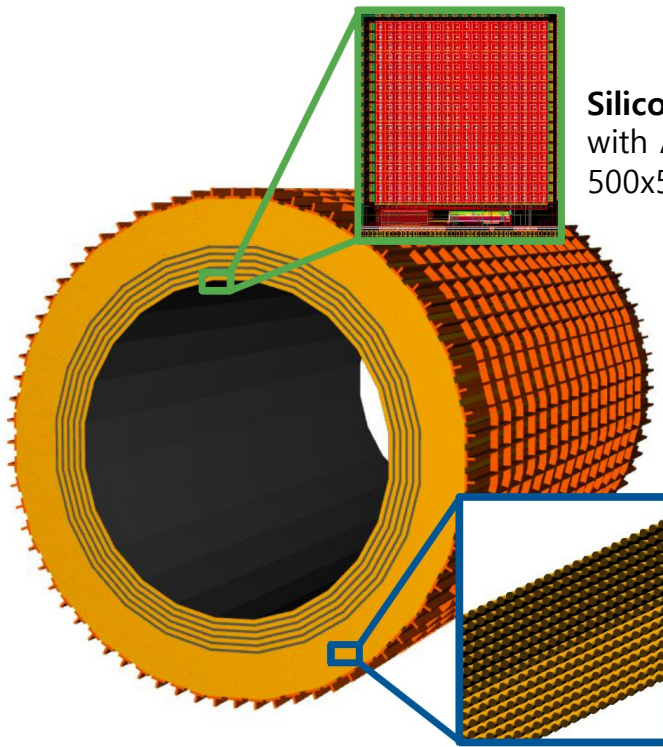
Korean institutions for the BIC



USA	Argonne National Laboratory	NASA Goddard Space Flight Center	Oklahoma State University	University of Connecticut	University of California Santa Cruz
Canada	University of Manitoba	University of Regina	Mount Allison University	NSERC	Canada Fund for Innovation
Korea	Kyungpook National University	Yonsei University	University of Seoul	Pusan National University	Korea University
Germany	Sungkyunkwan University	Hanyang University	Gangneung-Wonju National University	KIT	University of Giessen

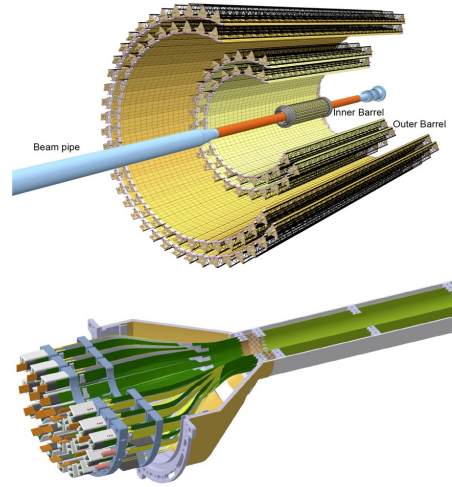
ePIC BIC Detector Subsystem Collaboration



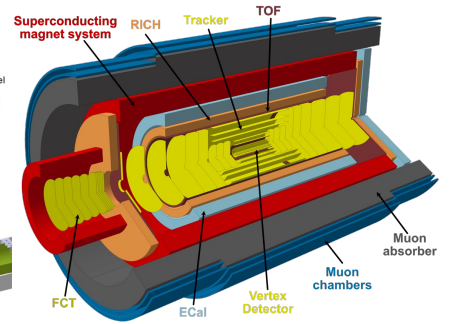


Silicon layers
with AstroPix
 $500 \times 500 \mu\text{m}^2$ pixel size

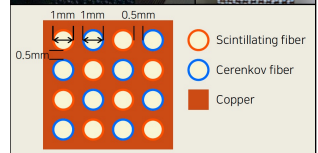
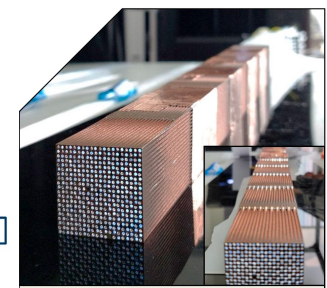
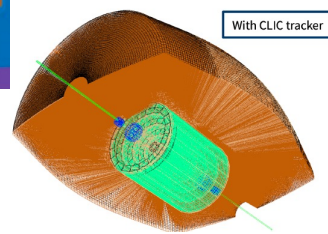
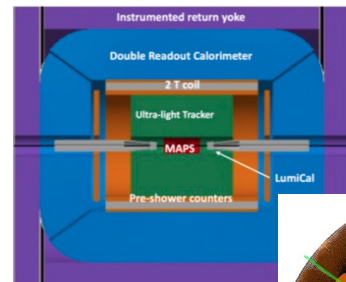
Pb/SciFi layers
with two-sided
SiPM readout



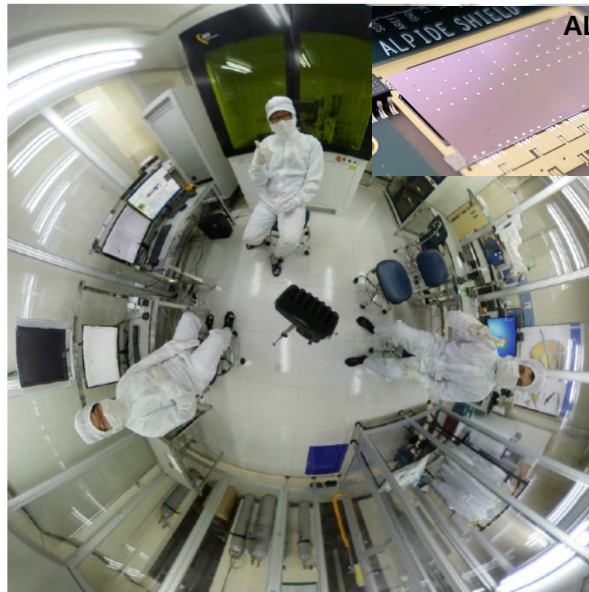
Silicon trackers for ALICE



Dual-Readout Calorimeter



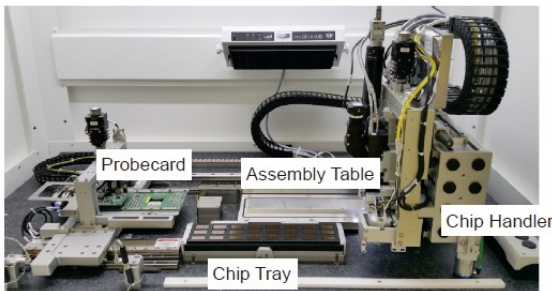
Silicon detector R&D for ALICE ITS2



PNU/Inha University



Yonsei University

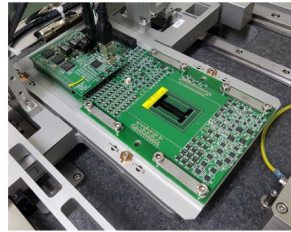


- Design of Pixel Sensor Chip
- Characterization of Pixel Sensor Chip
- Chip production (thinning & dicing)
- Chip test
- Detector module production and test

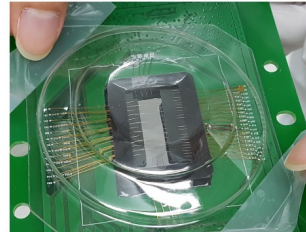


Silicon detector R&D for ALICE ITS2

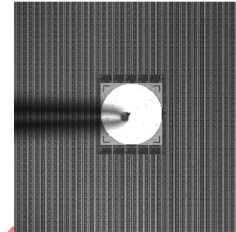
- Mass chip test
 - Dimension inspection
 - Electrical test
 - Total test: ~5 min/chip
 - Yonsei and PNU
- Note: wafer-level chip test for the BIC AstroPix



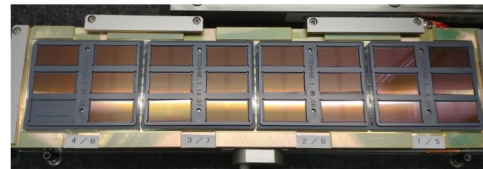
Probecard



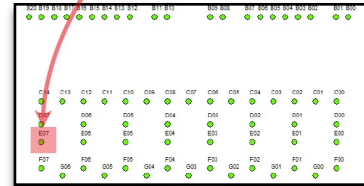
Needles of Probecard
67 needles to contact



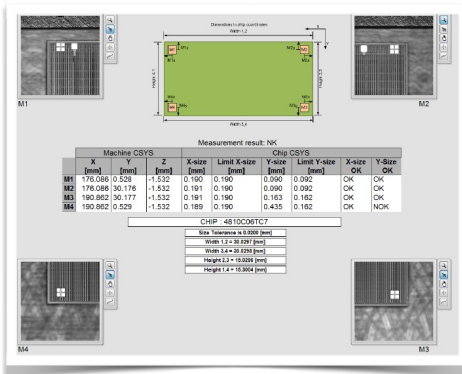
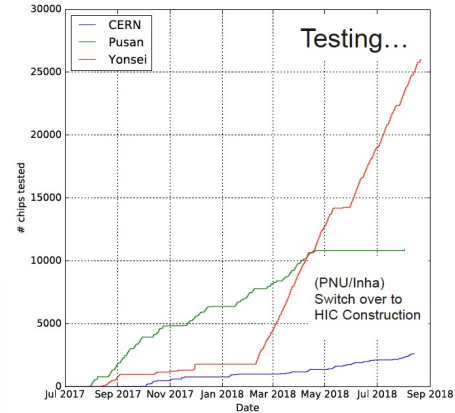
Needle on pad



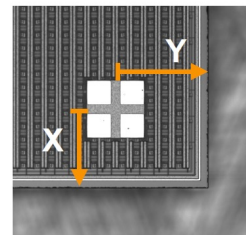
23 of ALPIDE Chips in Tray



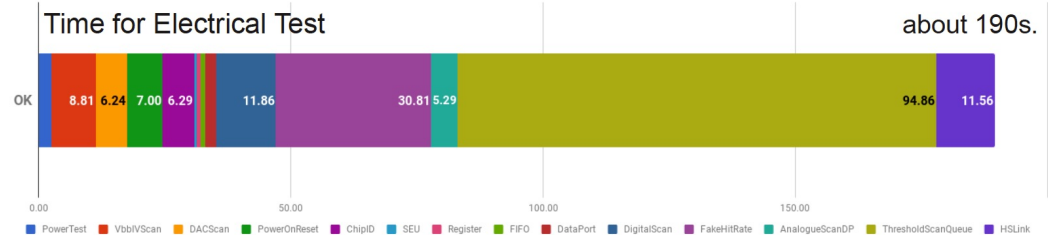
Pads on ALPIDE



Dimension Inspection

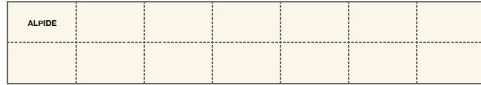


Measuring Dimensions

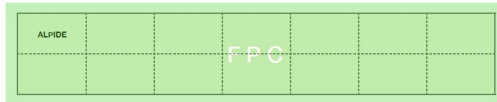


- **HIC Production**

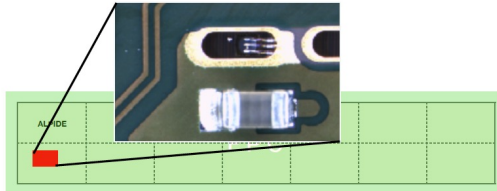
- PNU (one of 5 production sites)



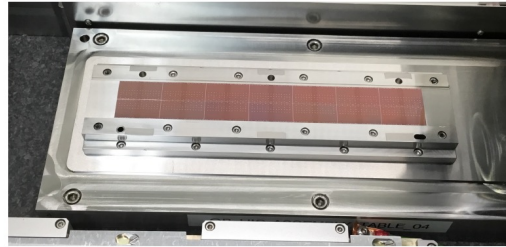
Aligning ALPIDEs
in Position precision < 5 μ m



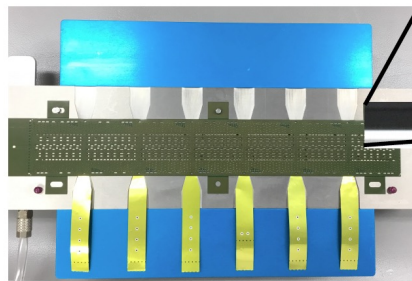
Gluing FPC to chips
Mechanical connection



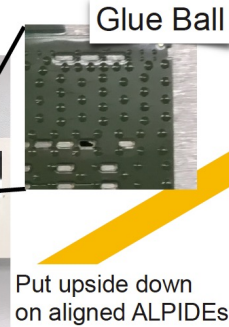
Wire-bonding
Electrical connection



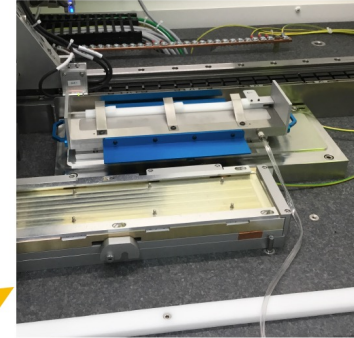
ALPIDE Aligned in ALICIA



Glued FPC on Gripper

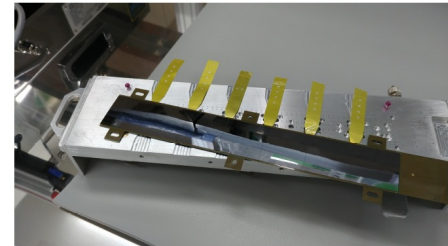


In Pusan/Inha Team, wire-bonding is being done by out-sourcing company, MEMSPACK



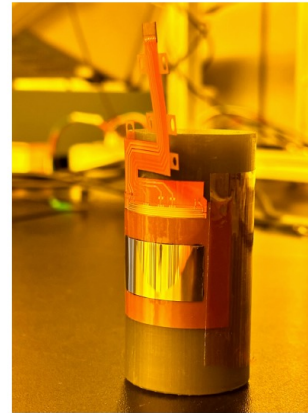
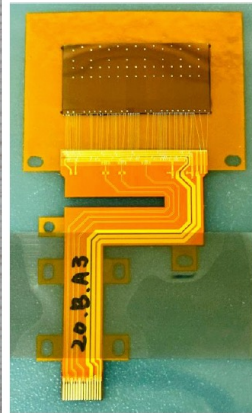
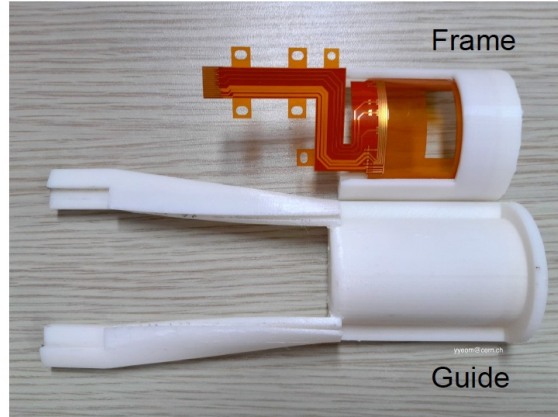
Pre-Curing in ALICIA
(min.) 5 hrs

Detach HIC
from ALICIA

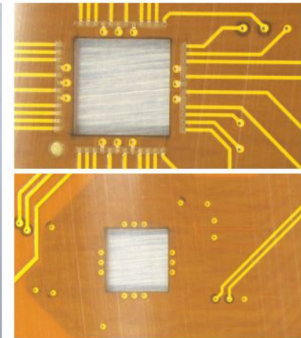
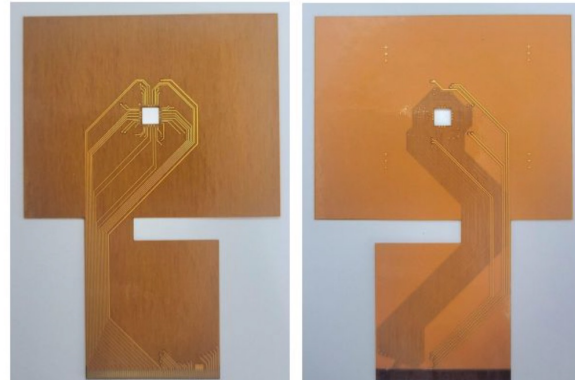
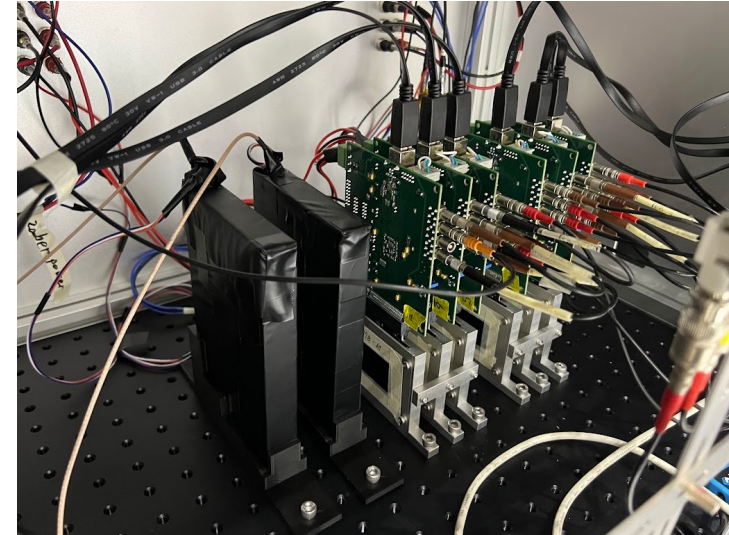


Glue HIC (Opposite side)

Bent chip (ALPIDE and APTS)



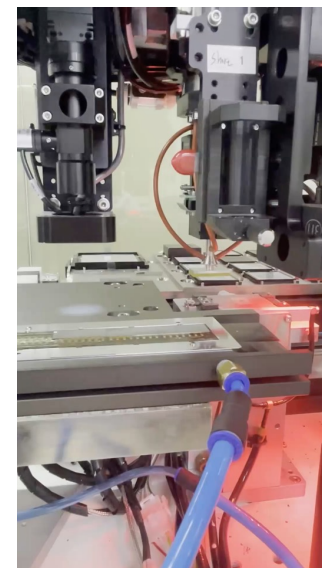
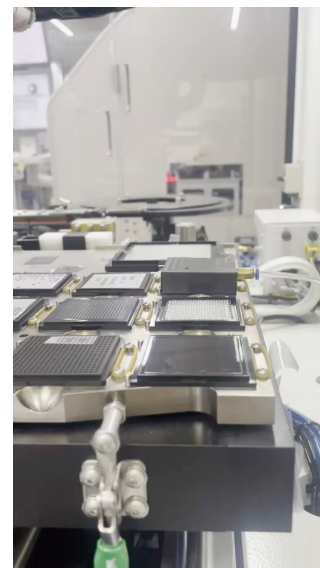
Telescope with ALPIDE



- **Successfully built a telescope with 6 ALPIDE layers and just finished test beam at KEK PF-AR (1-6 GeV electron beam) on March 11-18**
 - 6 ALPIDE layers + 2 APTS layers (or 1 bent ALPIDE)
 - Possibility to integrate other DUTs later (AstroPix)

Silicon detector R&D for ALICE 3 Outer Tracker

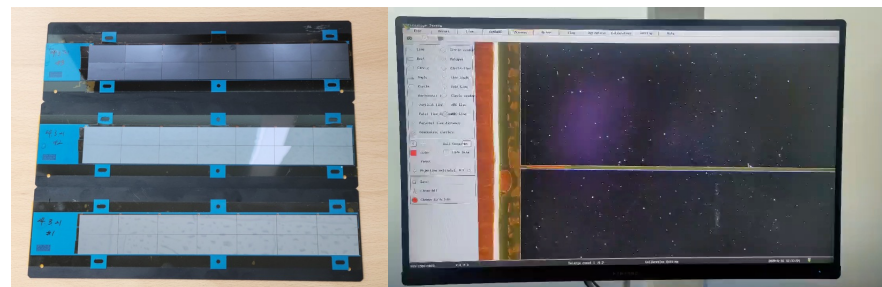
- **Automatization and industrialization of module assembly**
 - 60 m² of silicon sensor
 - x5 more modules (12500) than the ITS2 (2500)
 - Collaboration with a local company (MEMSPACK) for ALICE 3 Module assembly with a multi-purpose machine die bonder



Datacon 2200 evo+

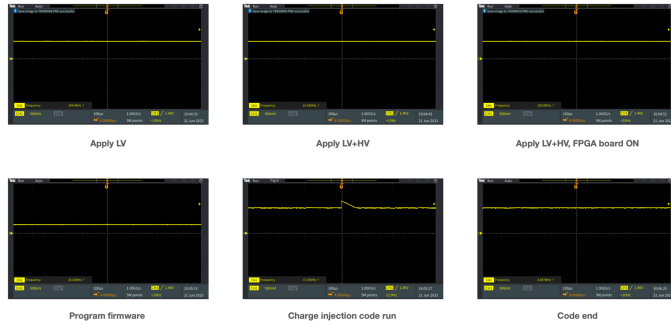
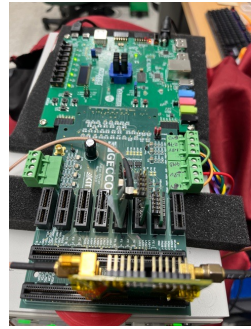
MRSI 705

General purpose die attach machine



- **Testbench with AstroPix v2**

- Built a testbench and performed a basic operation with charge injection



- **Testbeam with ALPIDE telescope**

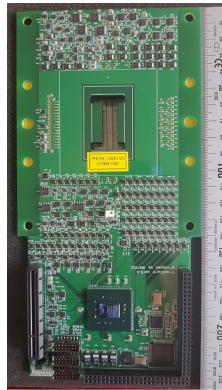
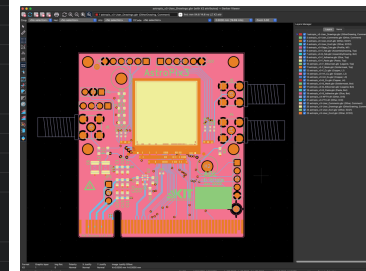
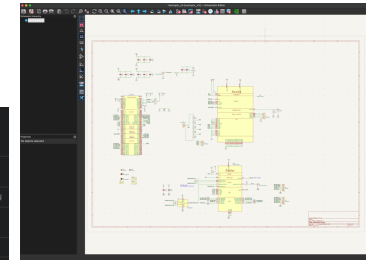
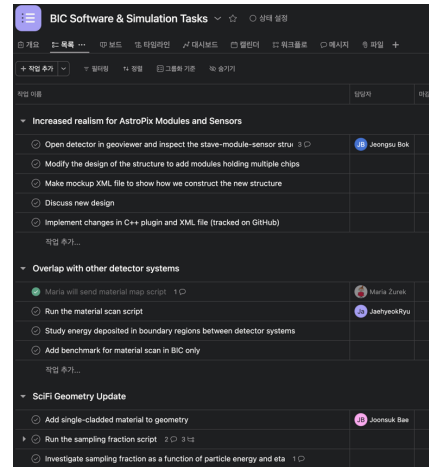
- 6 ALPIDE layers for reference tracks:
Excellent tracking with position resolution of 5 μm
- DUT (AstroPix v3 or v4):
Position resolution and hit efficiency

- **Simulation development for TDR**

- Detailed geometry implementation and performance study

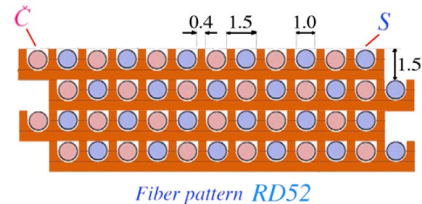
- **Chip test machine**

- Initial discussion with C-ON Tech and NOTICE
- Based on the design files of the single-chip carrier board of AstroPix v3, a probe card design will be started in April
- Plan to make a probe card for AstroPix chip as the exact dimension of ITS2 ALPIDE to utilize the probe station



Dual-Readout Calorimeter R&D in Korea

- DRC offers high-quality energy measurement for both EM particles and hadrons
 - DRC consists of two different optical fibers (S, C) in a single component
 - The main culprit of poor hadronic energy resolution is fluctuations of the EM shower components of hadron showers (f_{em})
 - f_{em} can be determined using the measured values of scintillation and Cerenkov signals



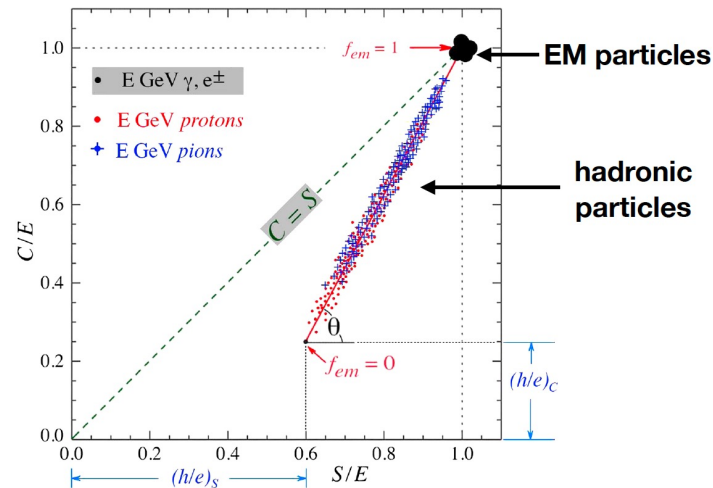
$$S = E \left[f_{em} + \frac{1}{(h/e)_S} (1 - f_{em}) \right],$$

$$C = E \left[f_{em} + \frac{1}{(h/e)_C} (1 - f_{em}) \right],$$

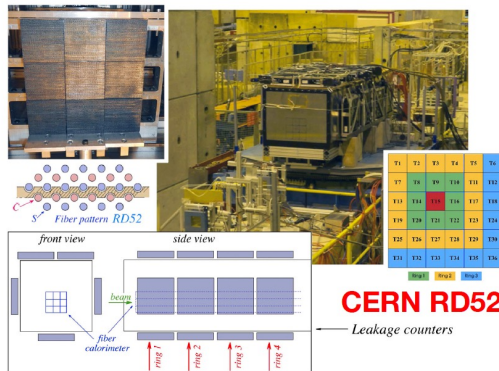
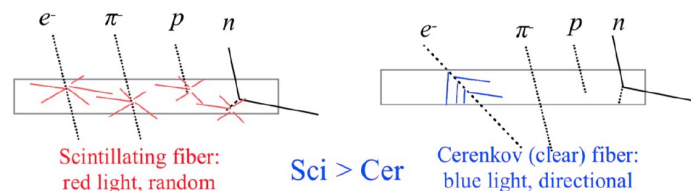
$$f_{em} = \frac{(h/e)_C - (C/S)(h/e)_S}{(C/S)[1 - (h/e)_S] - [1 - (h/e)_C]}$$

$$E = \frac{S - \chi C}{1 - \chi}$$

$$\cot \theta = \frac{1 - (h/e)_S}{1 - (h/e)_C} = \chi,$$

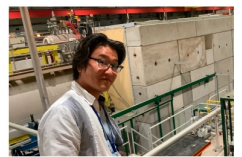
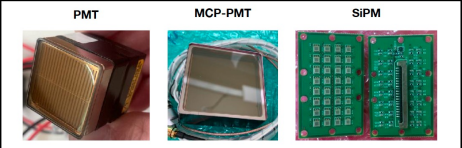
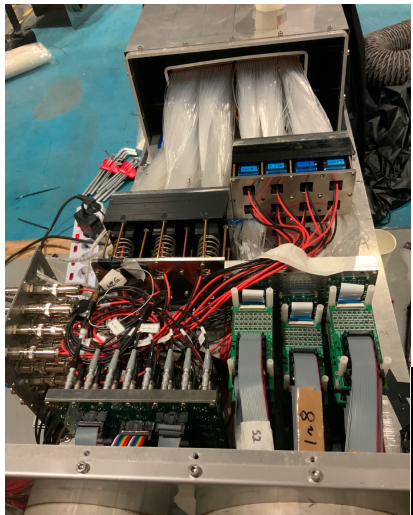


Signal generation: Scintillating & Cerenkov fibers



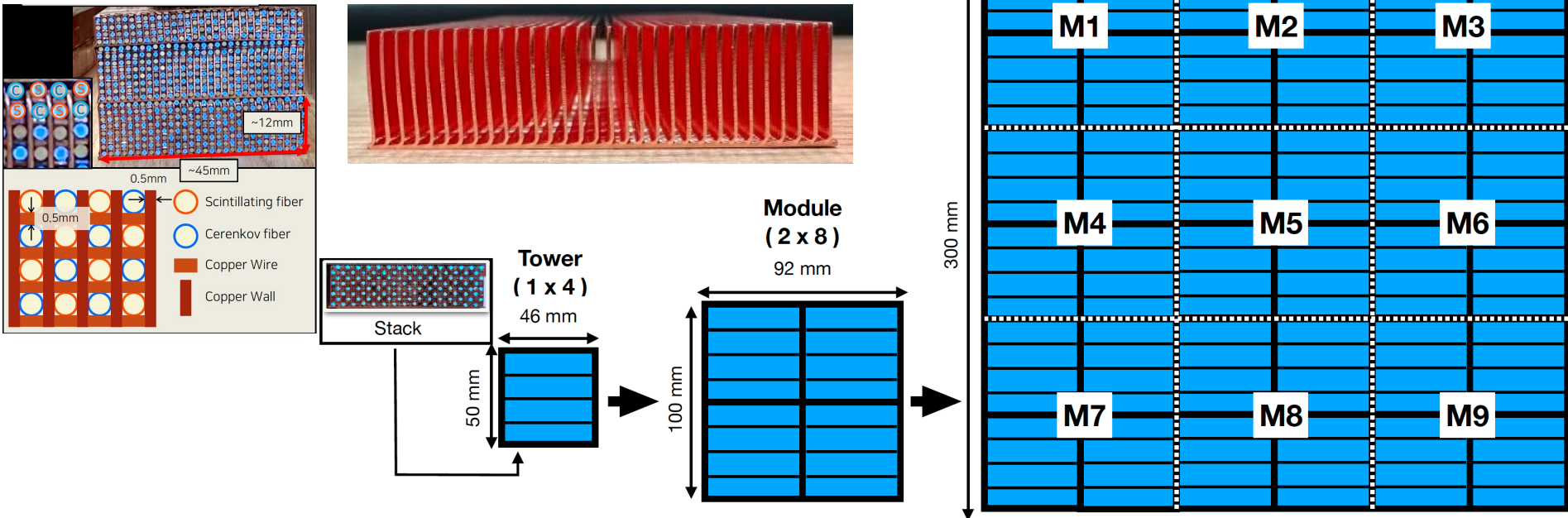
Dual-Readout Calorimeter R&D

- Testbeam with various module types: 2022 (CERN SPS), 2023 (CERN PS), 2024 (CERN SPS)



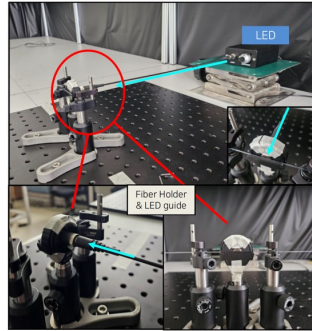
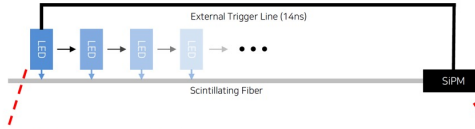
Dual-Readout Calorimeter R&D: TB2024

- Build full-size prototype module
 - Contain almost full energy of a jet
 - Achieve the goal of the jet energy resolution
- Develop an engineering solution for 4 pi detector
 - Using Skiving Fin Heatsink



Fiber attenuation measurement

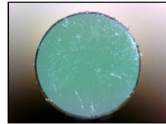
- Comparison between single and double cladding
- Under development of automated process



Measured light yield, point by point, while inducing LED light on side of fiber.

Test setup is based on using SP5600E. Data taking is done by trigger of LED.

SiPM is used for detection, attached to SP5600E module kit. All optical contact is done with custom 3D-printed jigs.

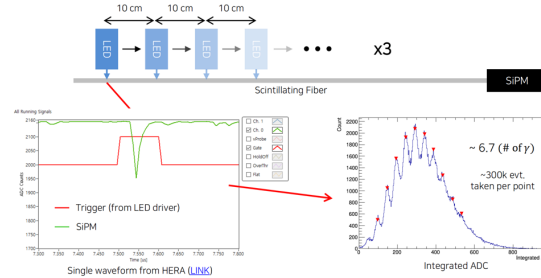


Scintillating Fiber (SCSF-78 Kuraray)
3m length, 1mm diameter

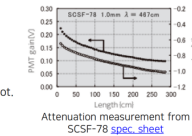


S14169-1310PS
Hamamatsu

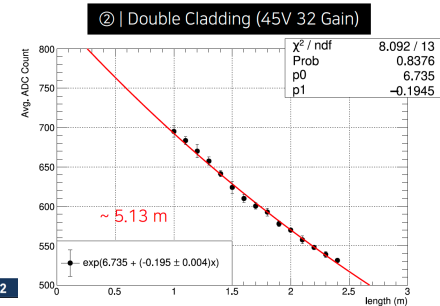
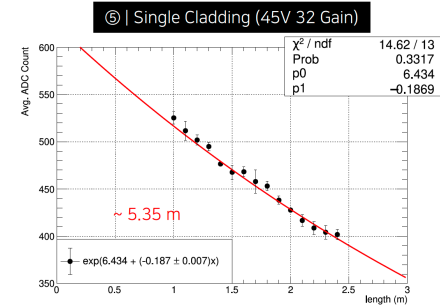
1



- Used HERA, which software is provided by CAEN, for controlling SiPM & data taking.
- Measured 1.0~2.4m, 10cm Interval 15 points | 3 measurement per points
- Made 3 iterations of measurement, each following through guide line.
- Used # of γ as light yield, which can be obtained from multi-photon peak of integrated ADC plot.
- Used average of 3 measurements as value, RMS as error of the points.
- Fit points using single exponential function - Light Yield(x) = $I_0 \exp(-\frac{x}{\lambda})$, (λ : Attenuation length)



2

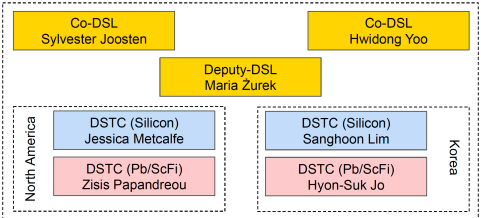
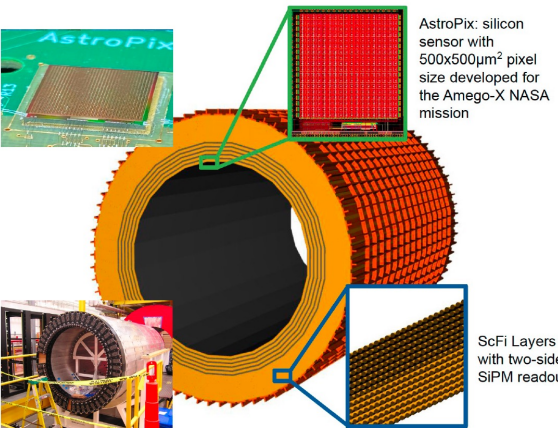


Prototype Pb/SciFi production

- A similar design to the GlueX prototype
- Under development of processing Pb layers
- Prototype can be used for further developing read-out box and testing with silicon layers

	SC	DC
Avg.	5.19 m	4.87 m
Stdev.	0.45 m (~9%)	0.18 m (~4%)
Measured Attenuation length		

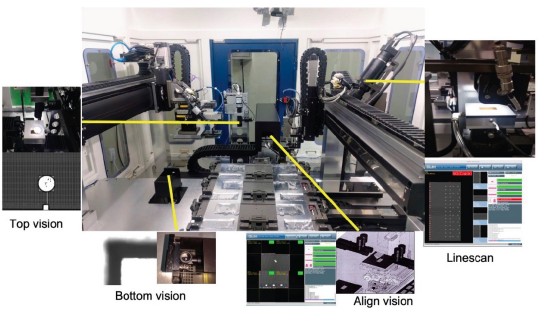
- Korean BIC group aims to make a significant contribution to the construction and relevant R&D
- We are closely communicating with the Korean government for the funding of the barrel ECAL R&D and construction, and very promising progress is expected in 2024



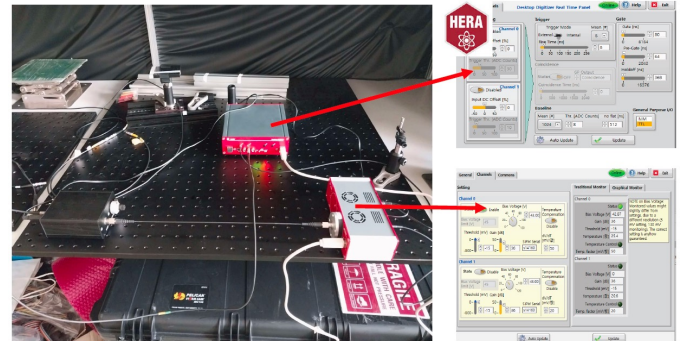
K-BIC members: 8 institutions and 10 faculties



Silicon chip test & module assembly



Optical fiber test setup

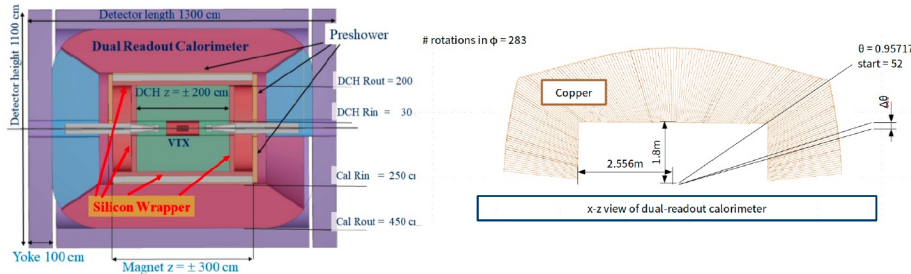


Collaborate with local companies:
C-ON Tech, MEMSPACK

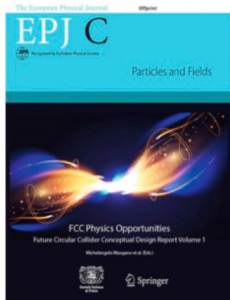
BACKUP

Dual-Readout Calorimeter R&D in Korea

- Korean team led the design of the Dual-Readout Calorimeter (DRC) for IDEA detector
 - Included in the CDRs of both FCC-ee and CEPC, published at the end of 2018



4 CDR volumes submitted to EPJ in December 2018.



FCC Physics Opportunities

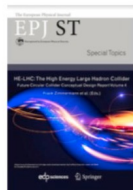
Copies can be requested at <http://get-fcc-cdr.web.cern.ch>



**FCC-ee:
The Lepton Collider**



**FCC-hh:
The Hadron Collider**



**HE-LHC:
The High Energy
Large Hadron Collider**

Released November 2018

IHEP-CEPC-DR-2018-02
IHEP-EP-2018-01
IHEP-TH-2018-01

CEPC
Conceptual Design Report
Volume II - Physics & Detector

<http://cepc.ihep.ac.cn/>

The CEPC Study Group
October 2018

405 pages

CEPC CDR, Vol. 2 — Physics and Detector

- Executive Summary
- 1. Introduction
- 2. Overview of the Physics Case for CEPC
- 3. Experimental Conditions, Physics Requirements and Detector Concepts
- 4. Tracking System
- 5. Calorimetry
- 6. Detector Magnet System
- 7. Muon Detector System
- 8. Readout Electronics, Trigger and Data Acquisition
- 9. Machine Detector Interface and Luminosity Detectors
- 10. Simulation, Reconstruction and Physics Object Performance
- 11. Physics Performance with Benchmark Processes
- 12. Future Plans and R&D Prospects
- 13. Summary
- Glossary
- Author List

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The CEPC Study Group
October 2018

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CEPC CDR, Vol. 1 and Vol. 2 — authorship

1149 authors from 222 institutions

29% from foreign institutions

24 countries

Australia	3
Belgium	3
Canada	3
Denmark	1
France	18
Germany	11
Indian	1
Israel	4
Italy	95
Japan	6
Korea	14
Mexico	1
Morocco	1
Netherlands	1
Pakistan	2
Russia	11
Serbia	6
South Africa	2
Spain	5
Sweden	2
Switzerland	9
UK	16
US	119

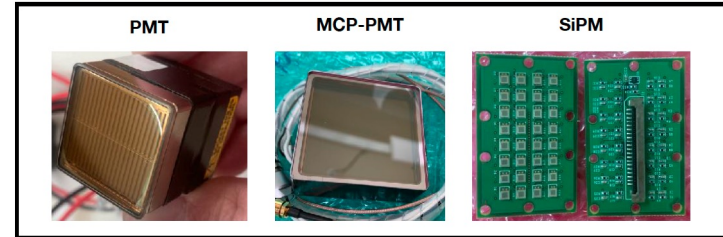
Dual-Readout Calorimeter R&D: TB2022

- Duration : Aug. 4th ~ 24th
- Measurement Goal

Module 1	<ul style="list-style-type: none"> - Shower depth - Longitudinal shower profile - Light attenuation length
Module 2	<ul style="list-style-type: none"> - Position resolution - Lateral shower profile - EM energy resolution - Uniformity study

- Schedule of test beam preparation

- Location : CERN North area (H8)
- R&D Goal
 - Readout system test (MCP-PMT & SiPM)
 - Study of various type of optical fibers (scintillation)



- Training Goal
 - Training next generation experts for DRC HW

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	
Module	Building Module (fiber+Cu)		Attach readout			Test Commissioning	Packing/ Shipping	Install @ CERN(H8)	-
DAQ	Test Mutichannel operation						Packing/ Shipping	Install @ CERN(H8)	-
Test beam							Packing/ Shipping	8/3 ~ install	Preparation & commissioning @ cern (~8.16)
									Taking test beam (8.17~8.24)



Dual-Readout Calorimeter R&D: TB2023

- Test beam experiment at T9 (CERN PS): June 28 - July 13
 - New prototype modules

