SoLID Detector R&D Tsinghua Side

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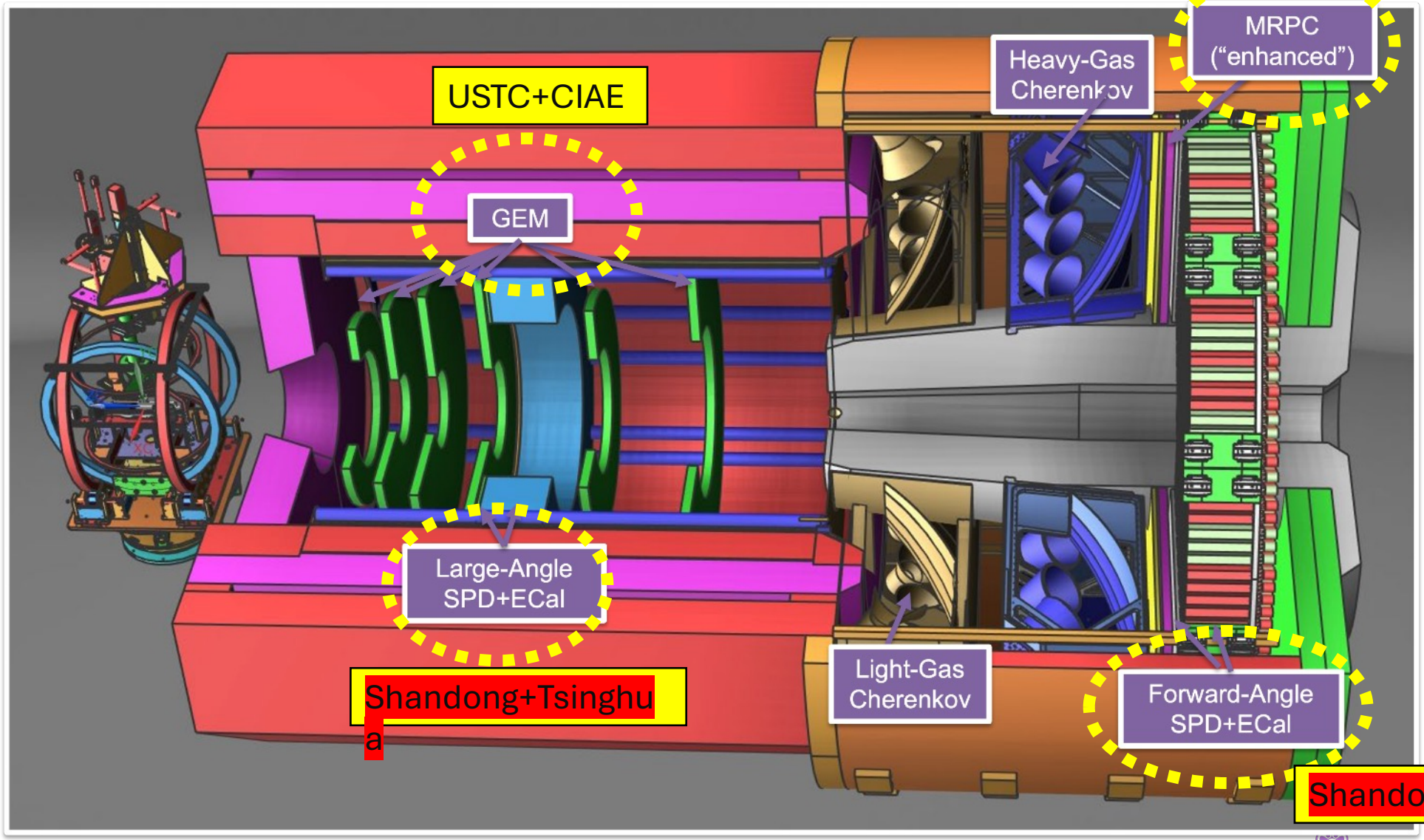
SoLID Collaboration Meeting, Updated on 07/08/2025

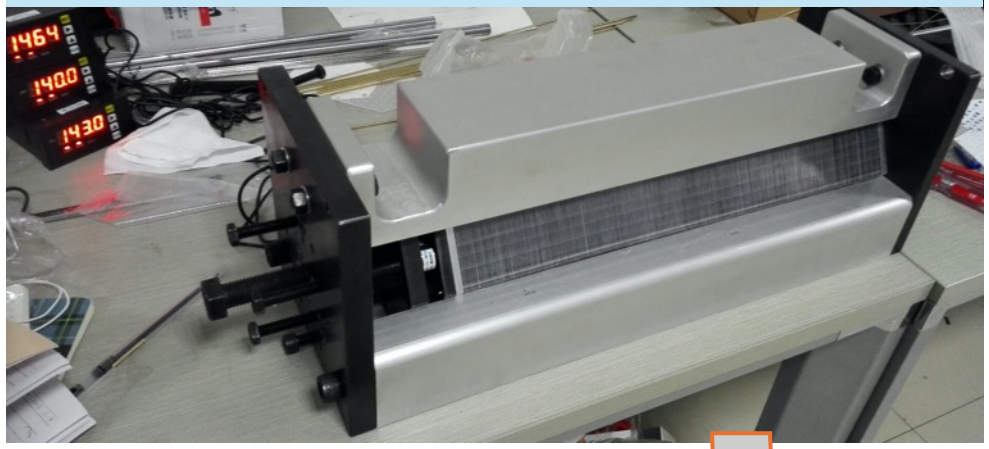
SoLID Detectors

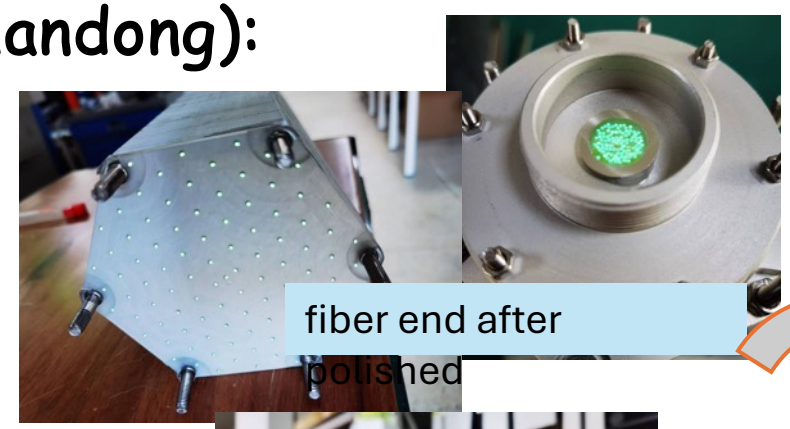


ECAL

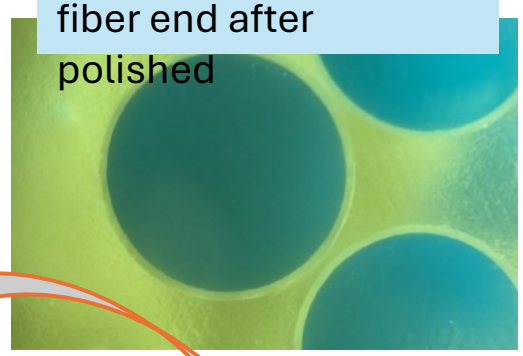
➢ Shashlyk ECal Assembly (by Shandong):

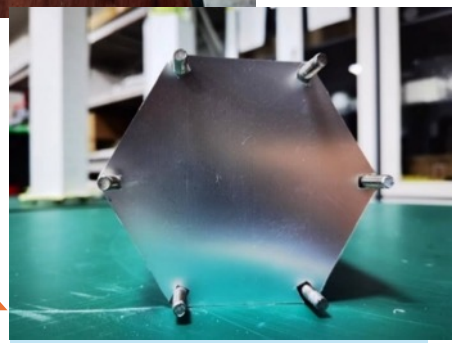
Scintillator tiles and leads are cross stacked in the mold, keeping pressure for one day.





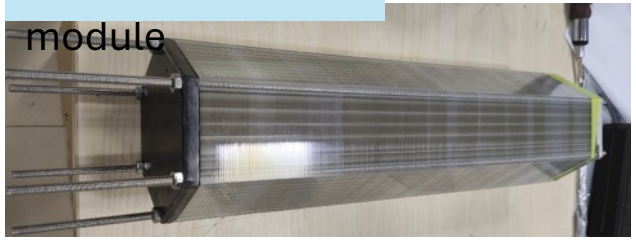
fiber end after polished



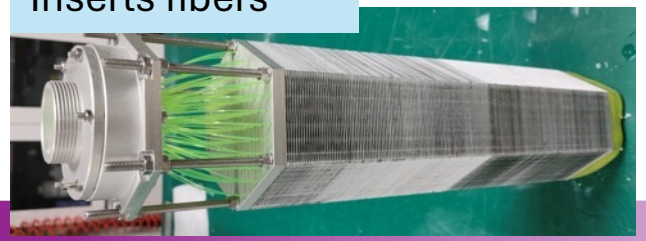


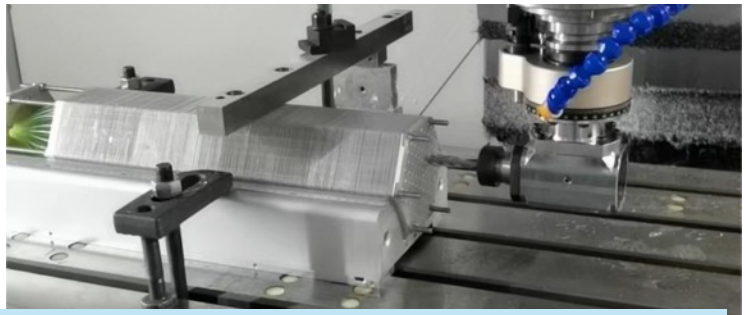
cover plate above ESR

Assembled module



Inserts fibers





fiber polished with CNC milling machine

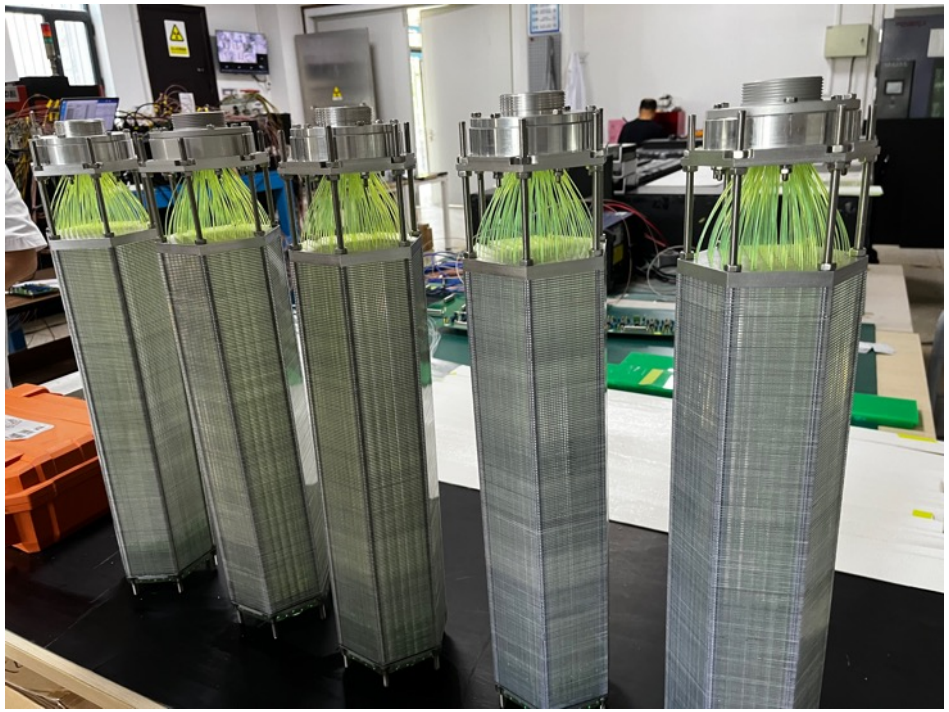
TiO2 reflective layer

Tyvek

ECAL

➢ Shashlyk ECal Assembly (by Shandong):

- First bunch of 7 modules shipped to Tsinghua

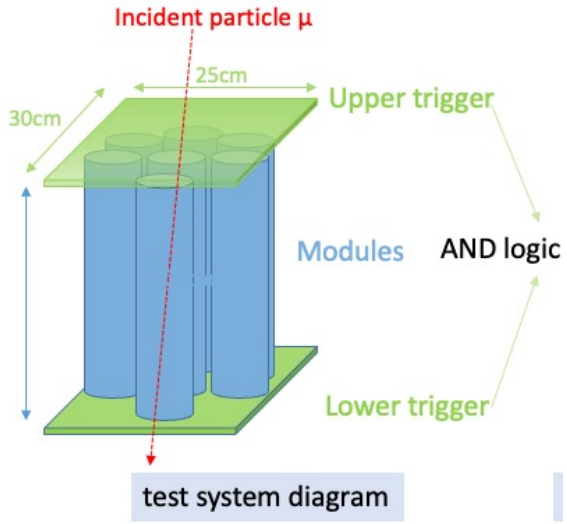


- Second bunch of 7 modules made at Shandong already
- Testing the aging effect of the scintillator pads & fibers now

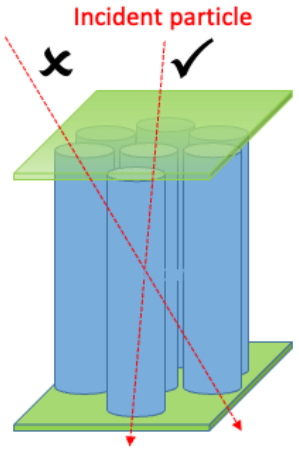
1st ECAL Super-module

清華大學 Tsinghua University

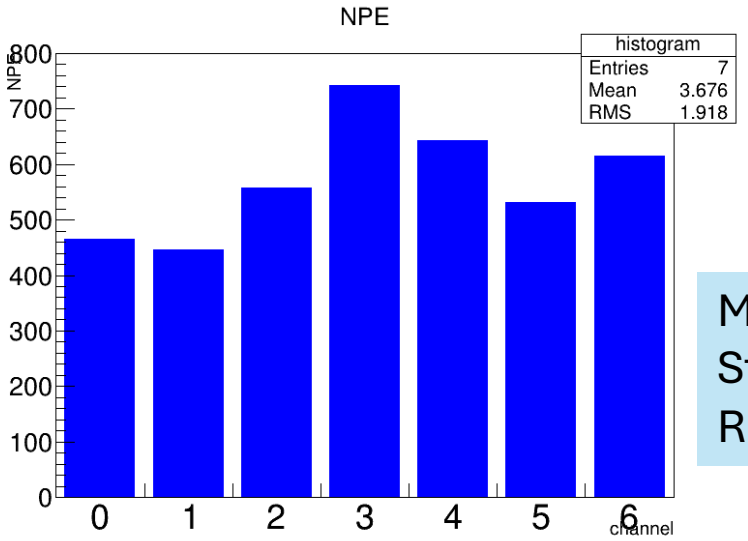
➢ Cosmic-ray Test at Shandong (2023-08)



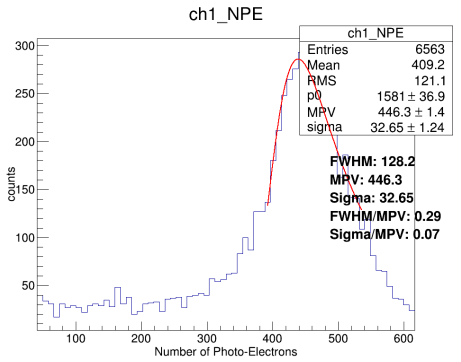
test system diagram

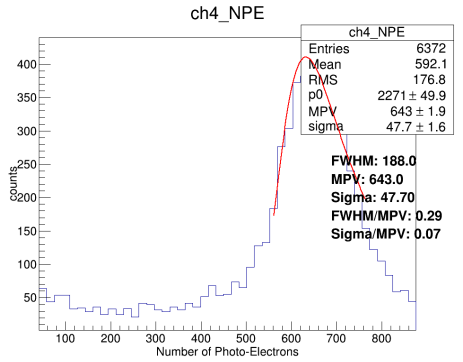


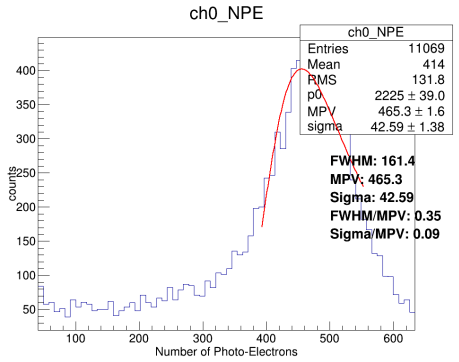
event selection

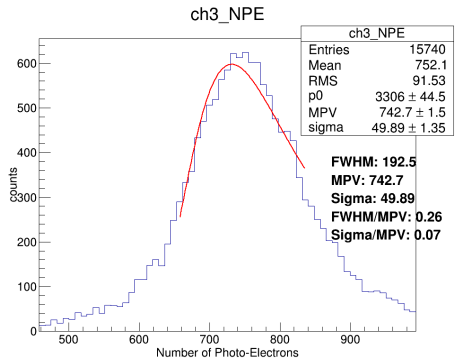


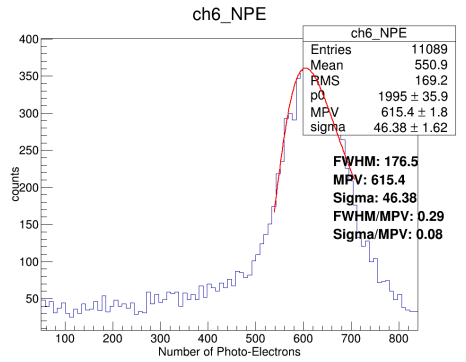
Mean: 571.5
Standard Deviation: 96.5
Ratio:17%

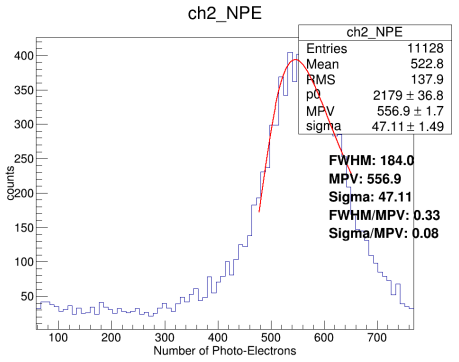


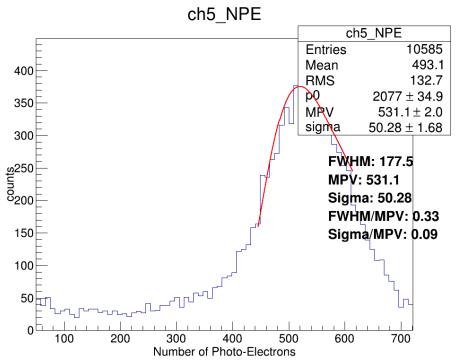










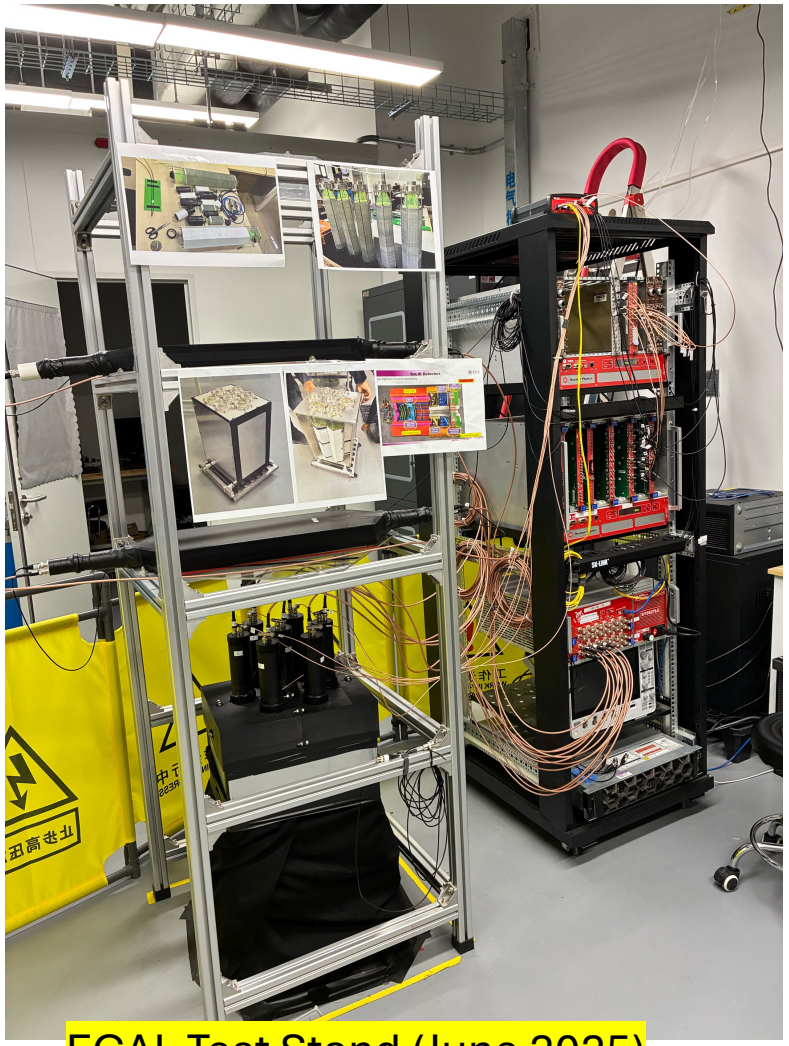


Ye's Lab at Tsinghua

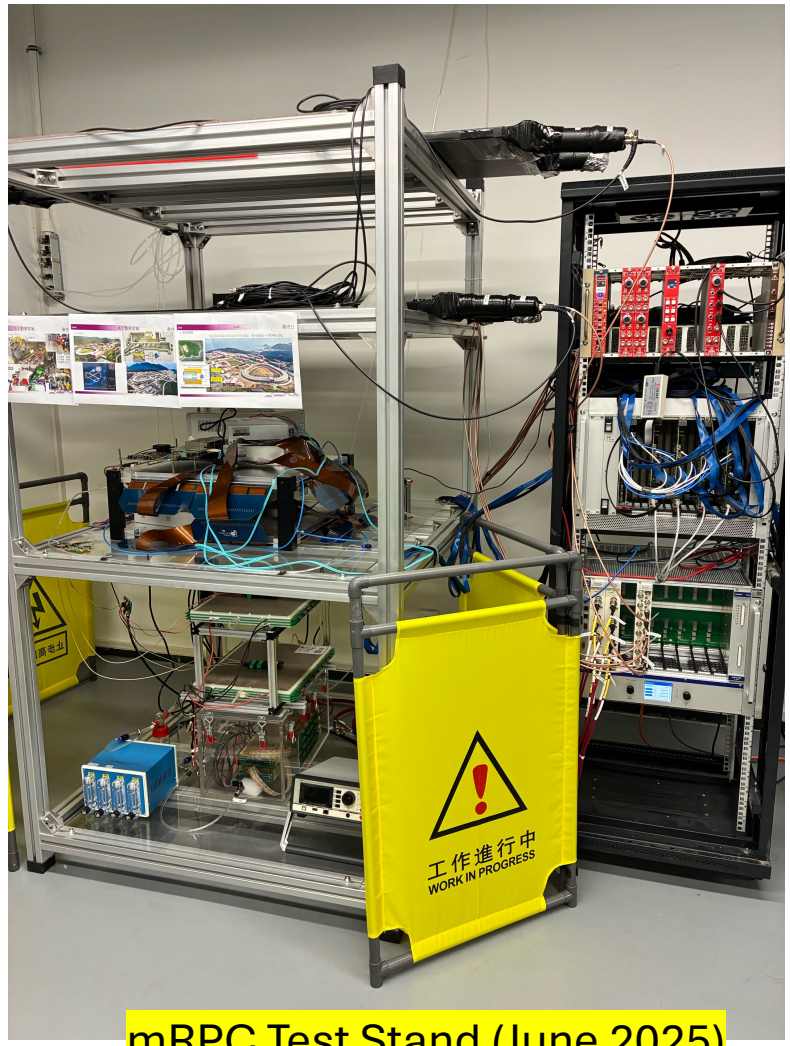
- Underground 2nd floor, 100m^2,
- Two test rooms, one dark/clean room

December 2023

December 2024



ECAL Test Stand (June 2025)

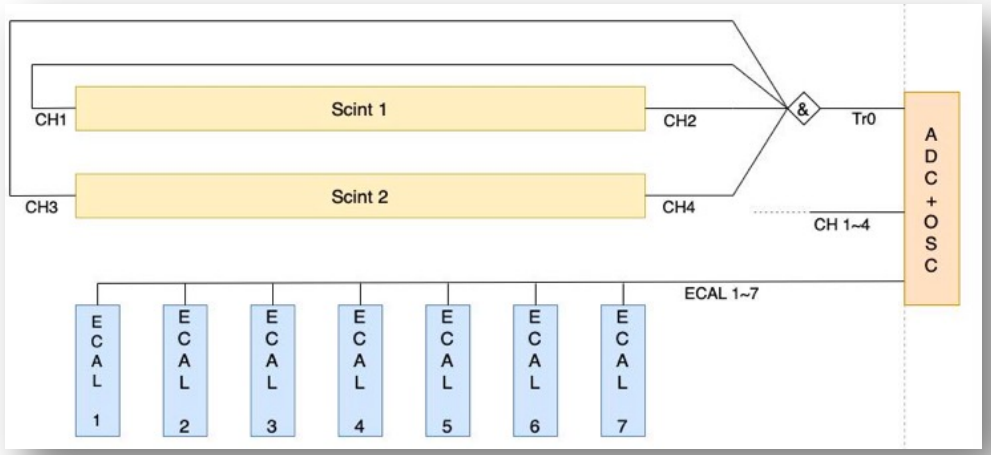


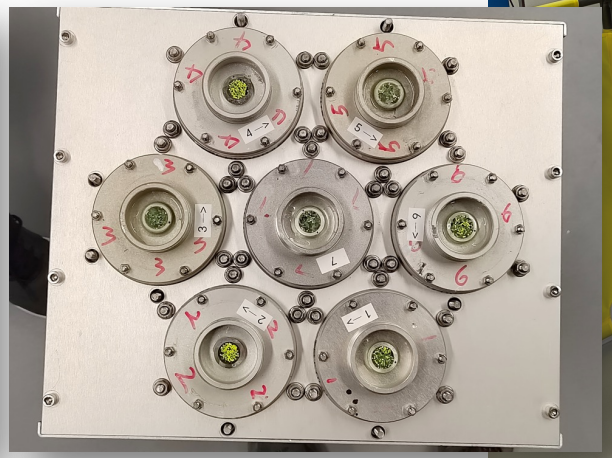
mRPC Test Stand (June 2025)

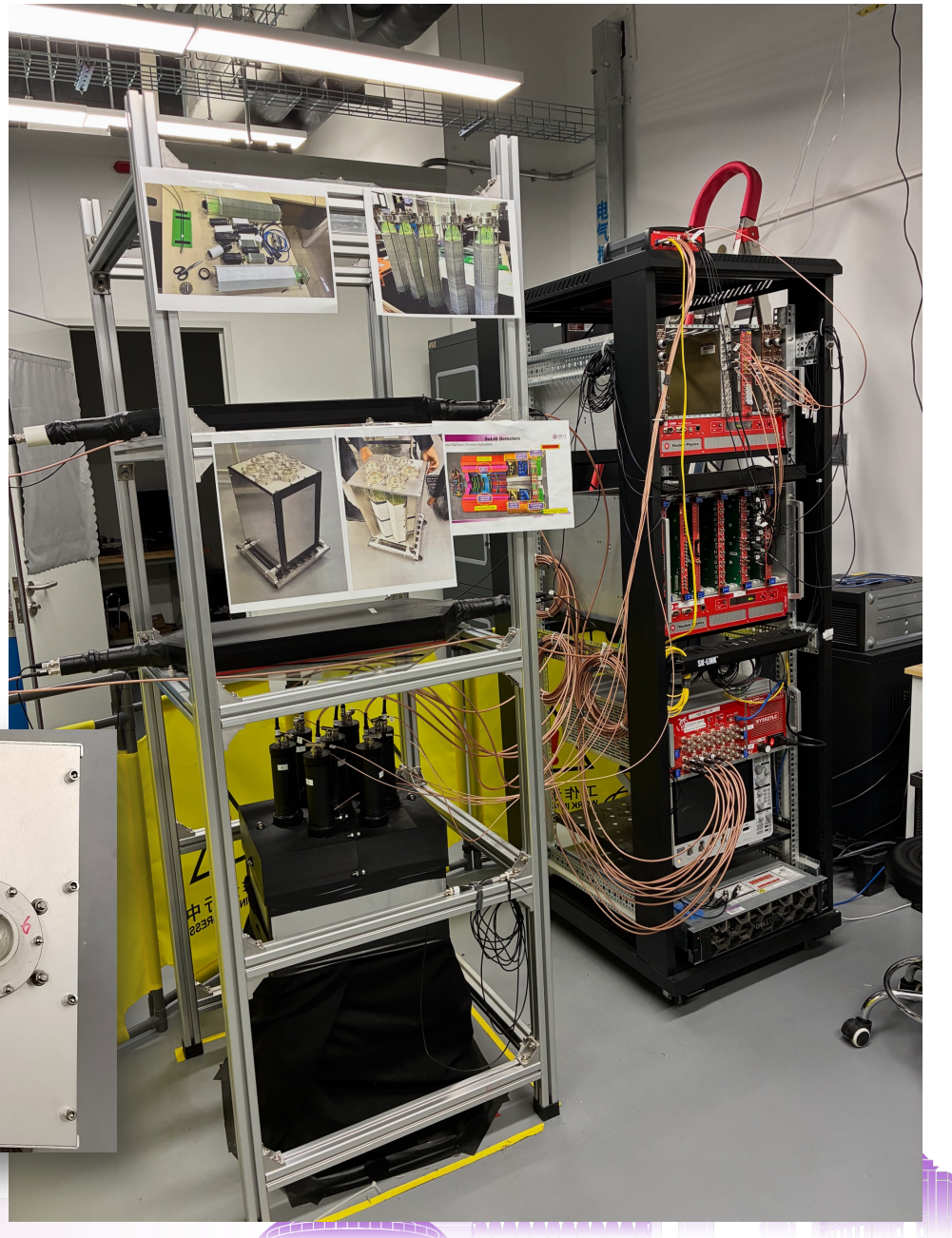
1st ECAL Super-module

➢ Cosmic-ray Test at Ye's Lab

- ☐ Modules shipped to Tsinghua in late 2023
- ☐ Assemble super-modules in summer 2024 (diff. orders vs. Shandong's)
- ☐ DAQ Setup:
  - ✓ 7 new PMTs (diff. from Shandong's)
  - ✓ Two scintillator pads (4 chs)
  - ✓ NIM HV + triggers
  - ✓ Use v1742 to measure waveforms







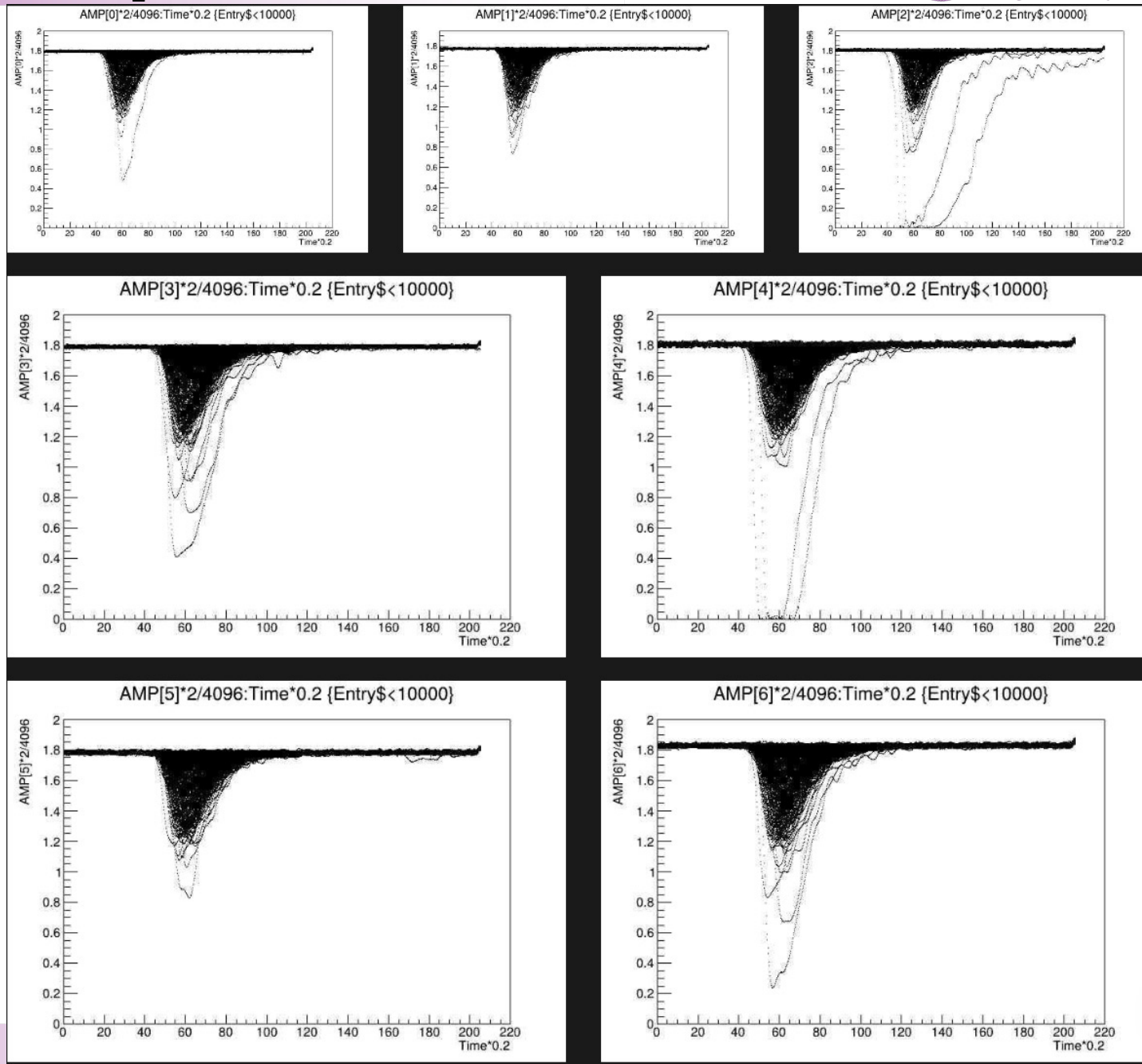
1st ECAL Super-module

➢ Cosmic-ray Test at Ye's Lab

☐ PMT HV Setups (LED test & real values)

Custom	Name	I0Set	V0Set	IMon	VMon	Pw	Sta
00.000	Scint0	800.00 uA	850.00 V	712.108...	850.13 V	On	
00.001	Scint1	800.00 uA	850.00 V	712.364...	850.13 V	On	
00.002	Scint2	800.00 uA	850.00 V	713.164...	850.11 V	On	
00.003	Scint3	800.00 uA	850.00 V	712.406...	850.18 V	On	
00.004	ECAL1	800.00 uA	800.00 V	670.488...	800.17 V	On	
00.005	ECAL2	800.00 uA	860.00 V	721.692...	860.18 V	On	
00.006	ECAL3	800.00 uA	790.00 V	661.814...	790.30 V	On	
00.007	ECAL4	800.00 uA	800.00 V	670.440...	800.14 V	On	
00.008	ECAL5	800.00 uA	870.00 V	729.308...	870.15 V	On	
00.009	ECAL6	800.00 uA	790.00 V	661.686...	790.28 V	On	
00.010	ECAL7	800.00 uA	840.00 V	704.512...	840.09 V	On	

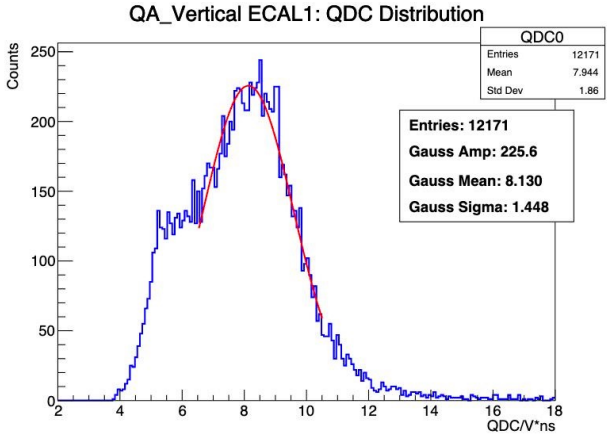
ECAL Chanlls	ECAL1	ECAL2	ECAL3	ECAL4	ECAL5	ECAL6	ECAL7
LED Cali. /V	800	860	790	800	870	790	840
Real Values	800	860	775	785	800	790	790

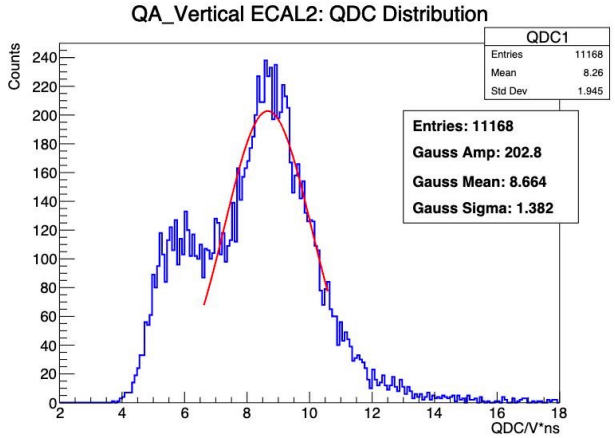


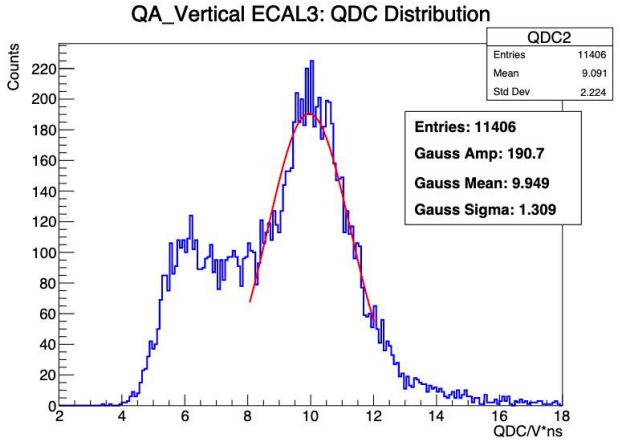
1st ECAL Super-module

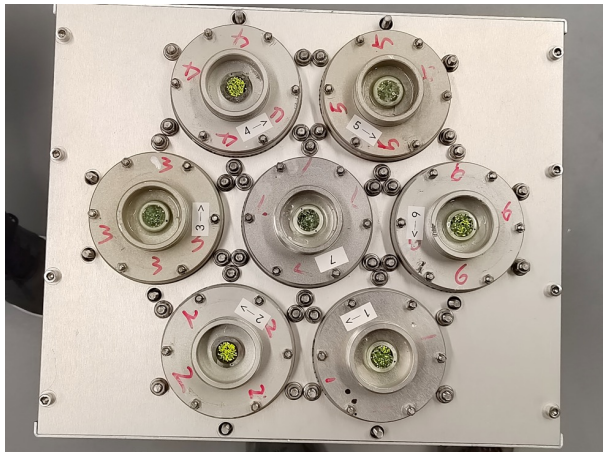
➢ Cosmic-ray Test at Ye's Lab

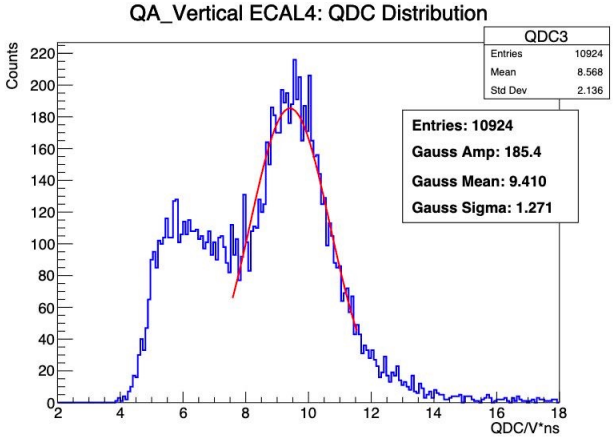
- Note: just total charge of each ECAL, no N.P.E yet!

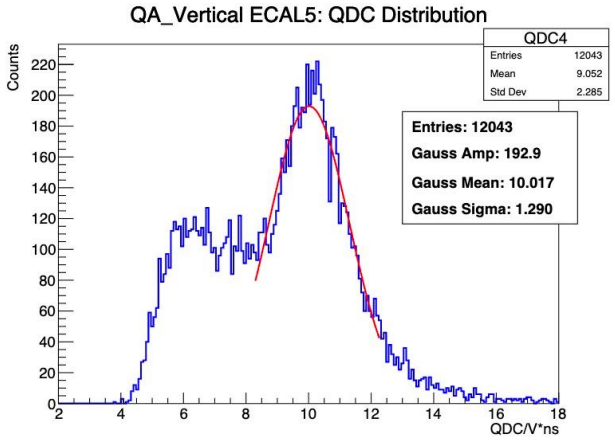


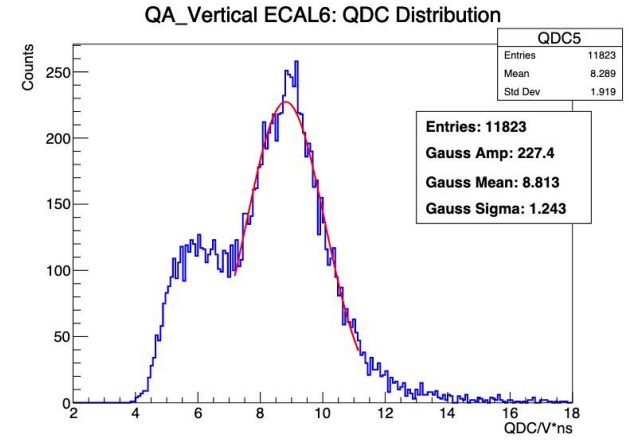


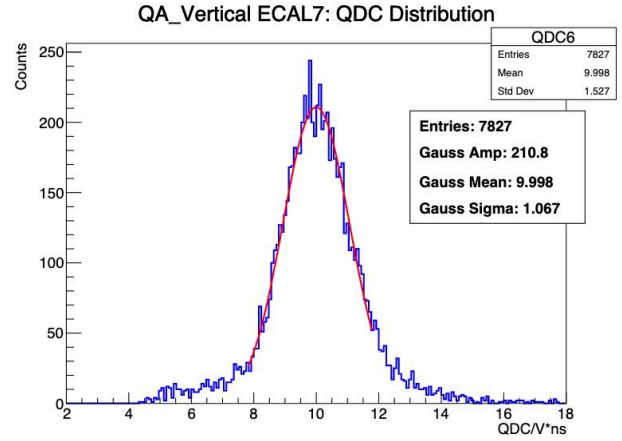








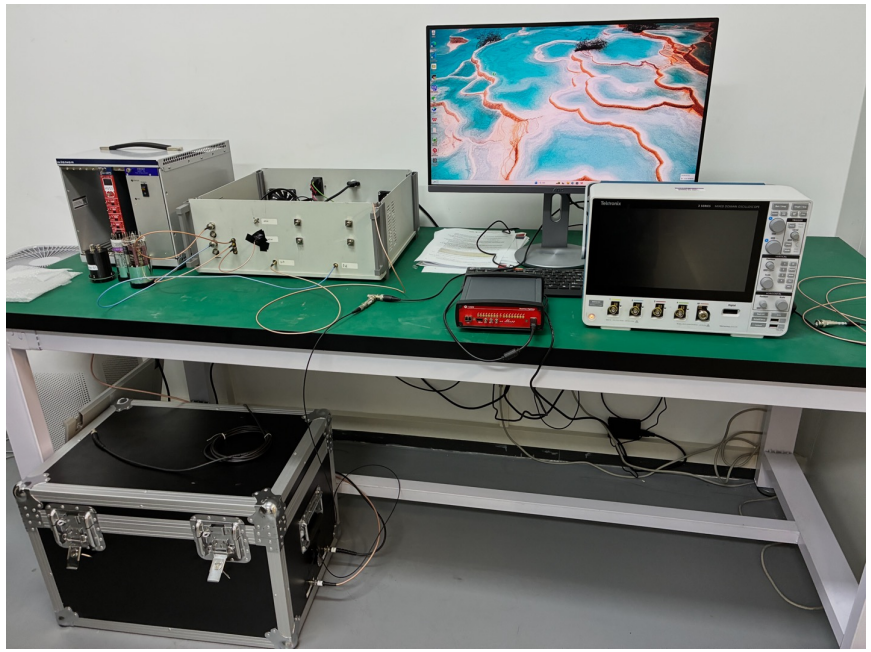




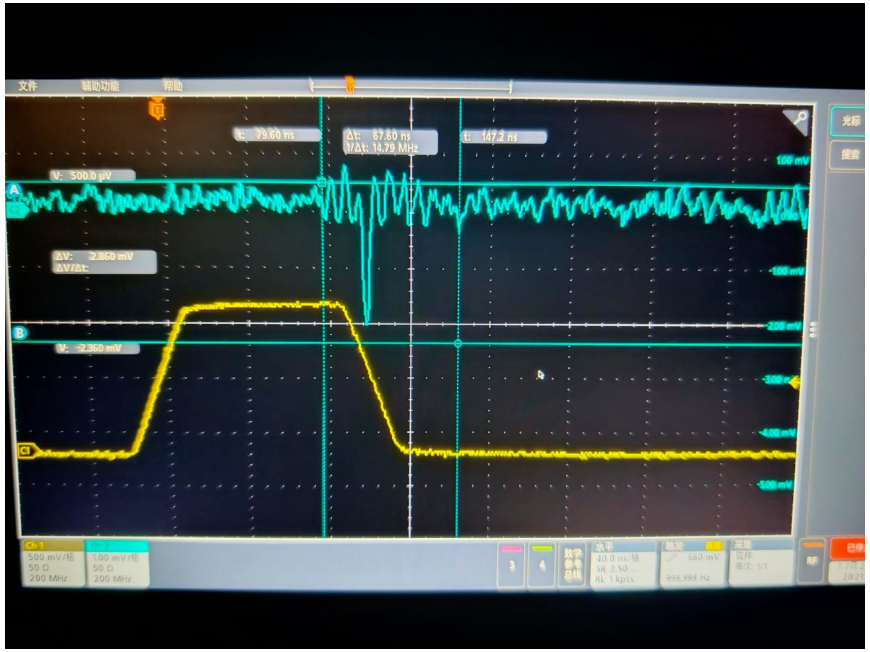
1st ECAL Super-module

➢ Cosmic-ray Test at Ye's Lab

- We are working on getting the S.P.E signals (some noises needed to remove)
- Use our LED test stand to benchmark PMTs



- Just identified the S.P.E signals (07/07)

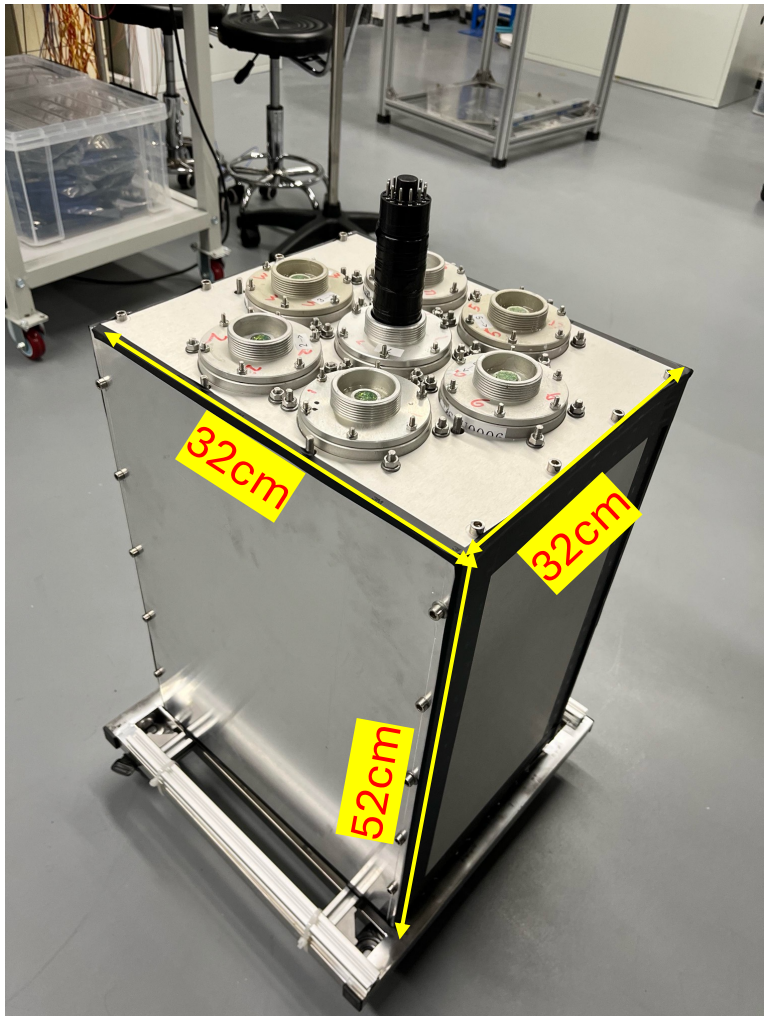


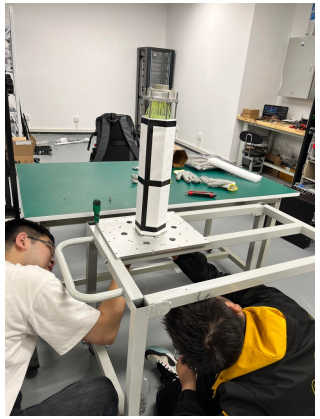
- Also need to clean up some noises in the ECAL test system.
- To do: obtain the muon N.P.E in each ECAL
- Prepare for the second super-modules from Shandong

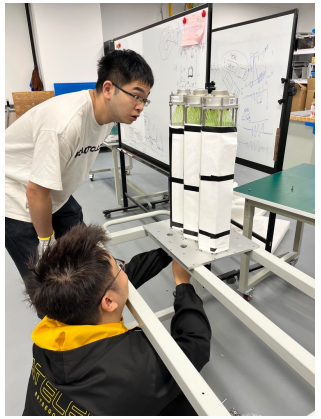
1st ECAL Super-module

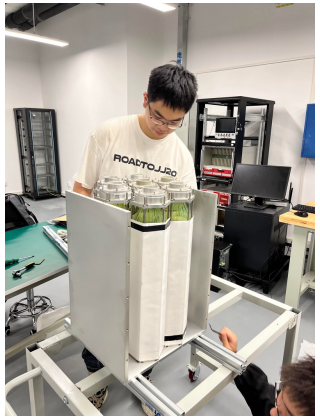
➢ Preparing Shipment to JLab

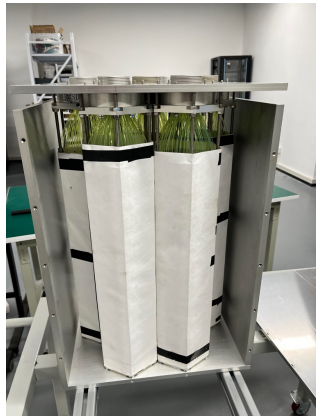
- Weight = 15kg x 7 Modules + 20kg Frame = 126kg for whole
- Geometry: Frame: 32cm x 32cm x 52cm
- Preparing Shipping:
  - Modules will be dissembled
  - 7 Modules & parts of frames to be shipped
  - Do we ship PMTs & bases & holding tubes?
  - Method (by air & sea)?
  - Cost (consider tariff rate is expected to go high)? Who pay?







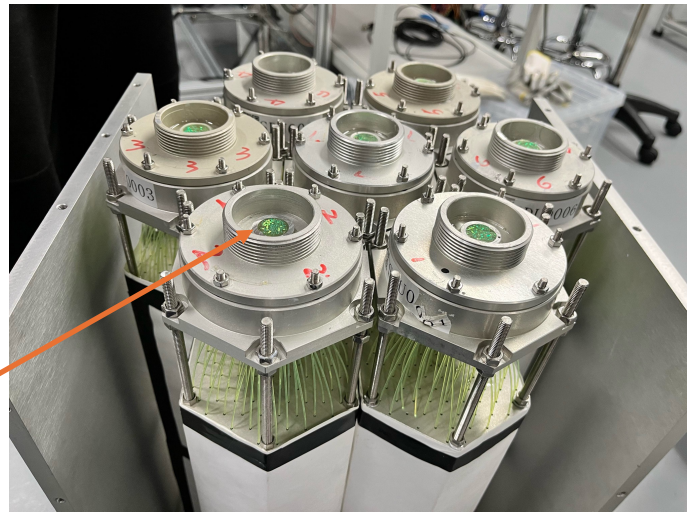


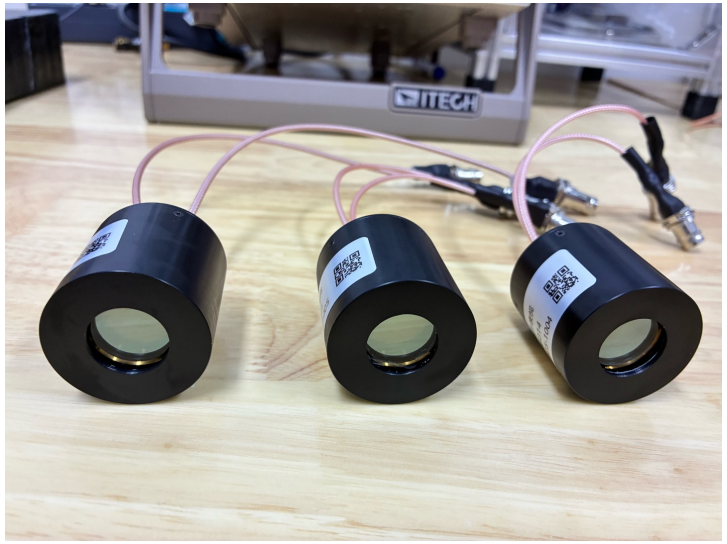


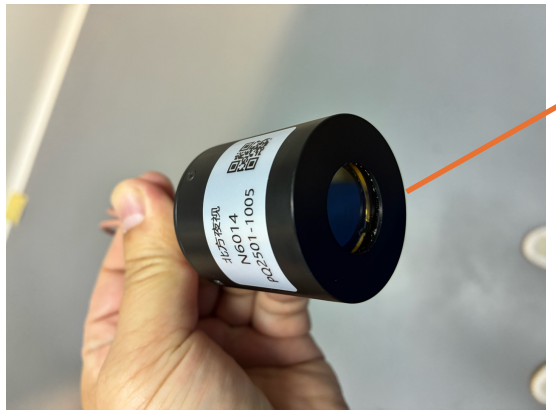
1st ECAL Super-module

➢ Cosmic-ray Test at Ye's Lab

- ☐ 3x MCP-PMT as ECAL's light readout option
  - Night-Vision (China) N6014, Inner Φ18mm, Outer Φ36.6mm
  - Potential to replace current design (WLS fiber+clear fiber+MaPMT)





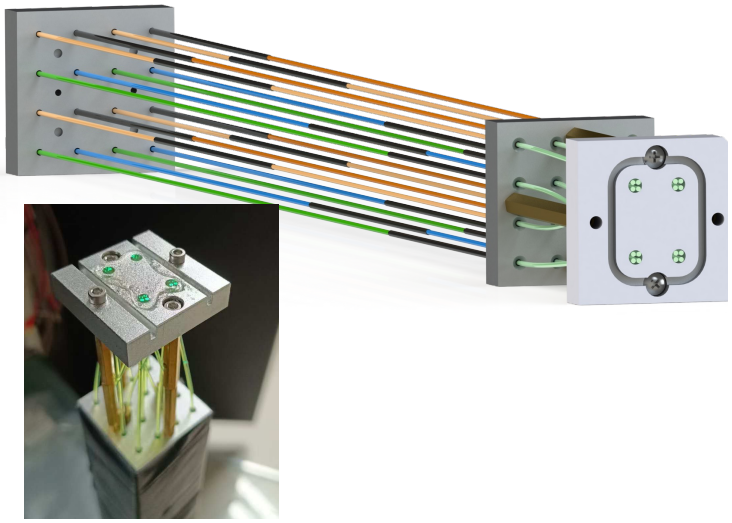


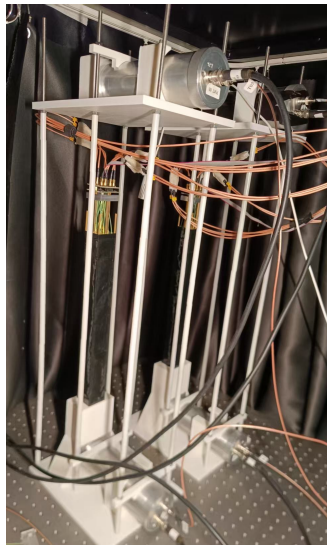
- ☐ Tests to be done (planning now)
  - in strong magnetic field
  - Radiation damage
  - Use on 2nd super-modules

MCP#	HV	Gain	P/V	σ[%]	DR(KHz)	DC(nA)
PQ2501-1005	1990	1.03e6	10.189	21.534	1.27	18.26
	1900	1.02e6	14.9	21.73	0.458	92.48
PQ2501-1007	1870	1.02e6	27.08	19.96	6.13	35.19
	1780	1.05e6	21.67	18.96	3.64	30.76
PQ2501-1004	1600	1.01e6	13.11	22.42	4.21	126.31
	1715	1.08e6	25.16	18.02	13.96	309.8

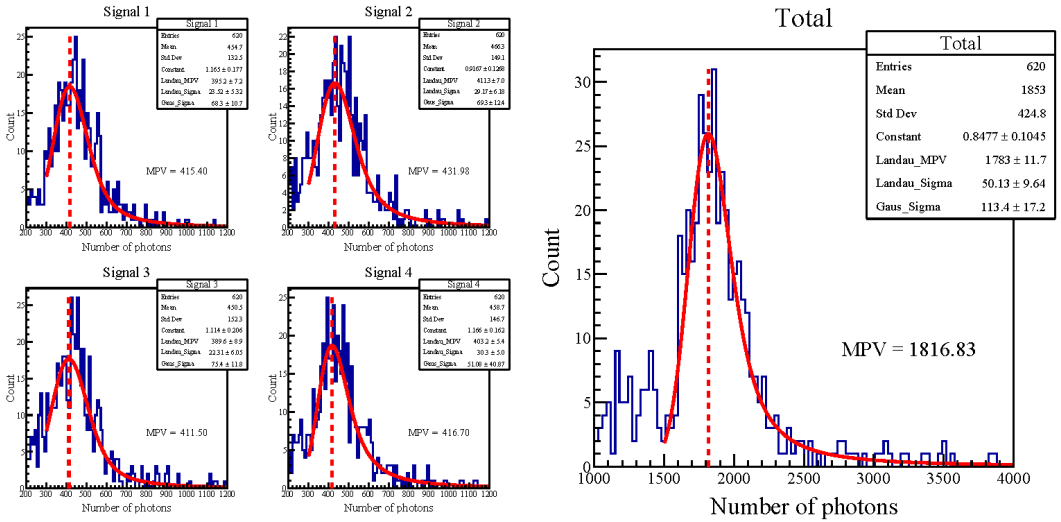
New ECAL R&D

➢ Wang Yi's 5D ECAL Design



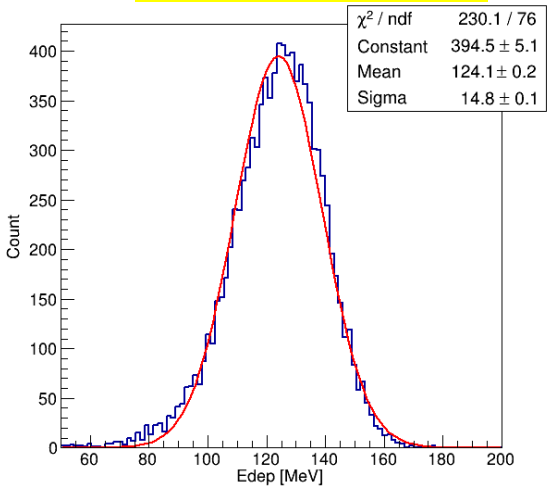


Cosmic Ray

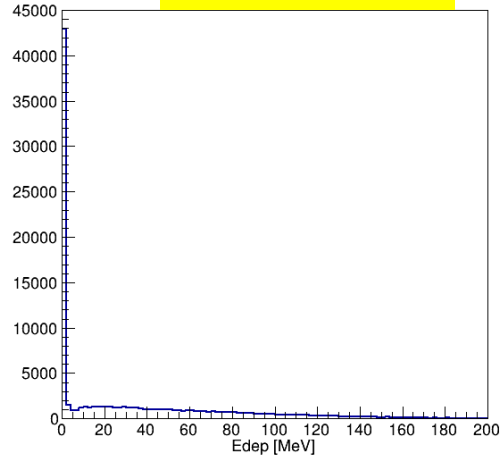


- ❑ Every 54-Layers as one sector (4 sectors totally)
- ❑ Four group of fibers & 4 SiPM readouts
- ❑ Each group of fibers only read lights from 3 sectors
- ❑ Pain black to block lights from the remain sector
- ❑ Contain position (roughly) & time & energy → 5D
- ❑ Detection of photons & neutrons

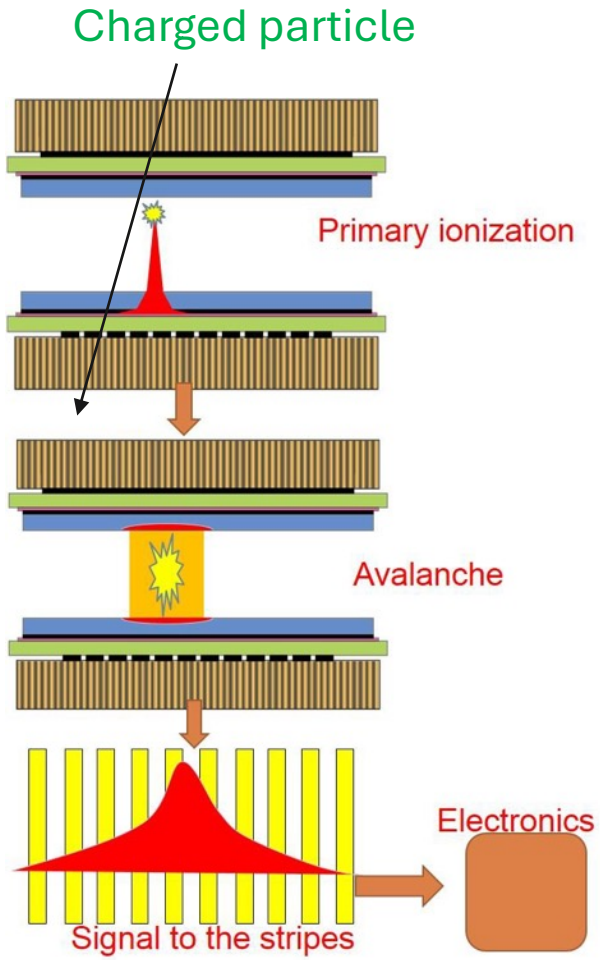
500MeV-Photons



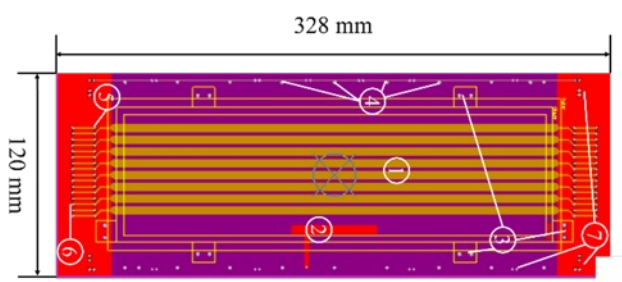
2GeV-Neutron

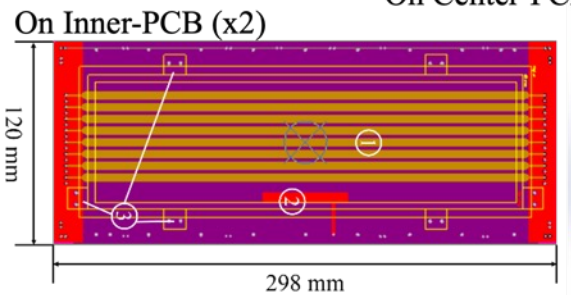


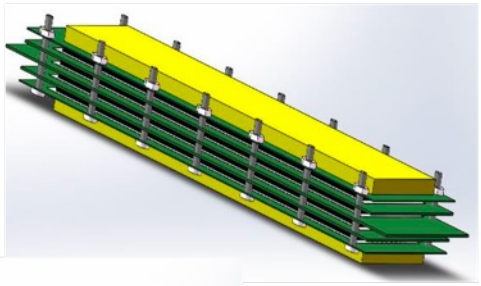
Multi-gap Resistive Plate Chamber (MRPC)

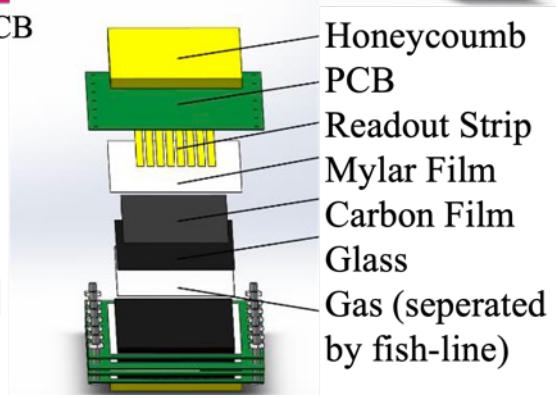


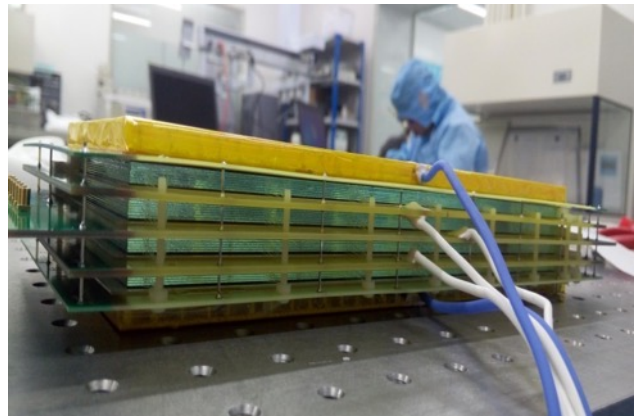
- Low-resistivity glass plates, gas (95% F134a + 5% iso-butane), HV(~12kV)
- Good performances:
  time resolution, efficiency, rates (>30kHz/cm^2), radiation-hard, magnet safe
- Some spatial resolution (by strip pitch, 0.5cm~1.0cm)
- Low cost, easy manufacturing, large sensitive area (up to 1.0mx0.5m)
- Used by ALICE, STAR, CBM, CEE, NICA, etc.









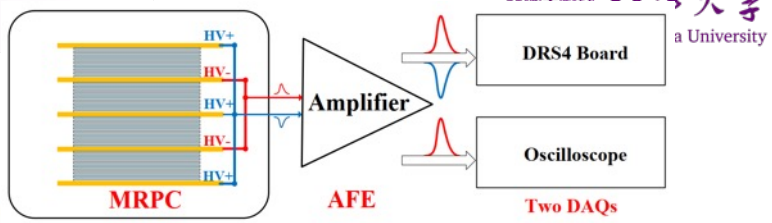


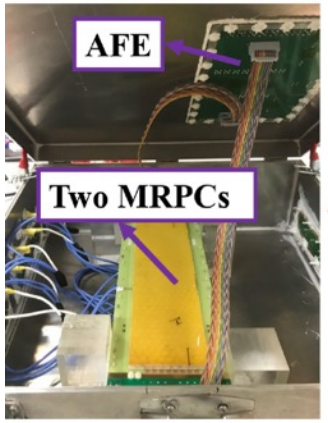
MRPC at Tsinghua

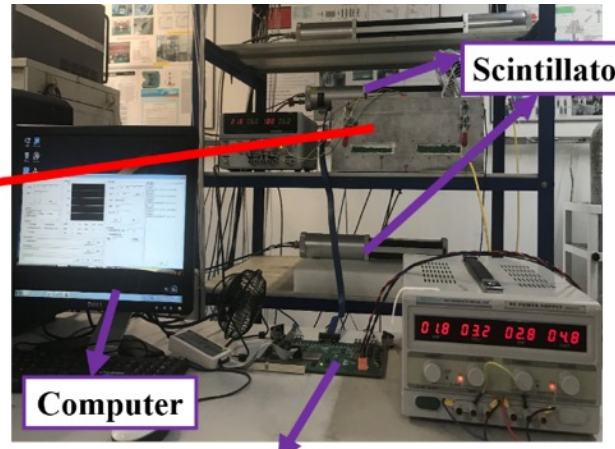
➢ Tsinghua's High-Time Reoslution MRPC

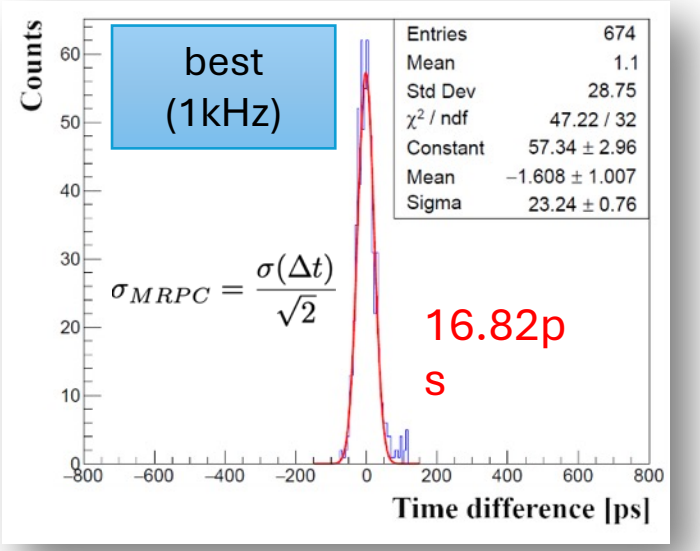
❑ For SoLID's high-rate & high-background environment

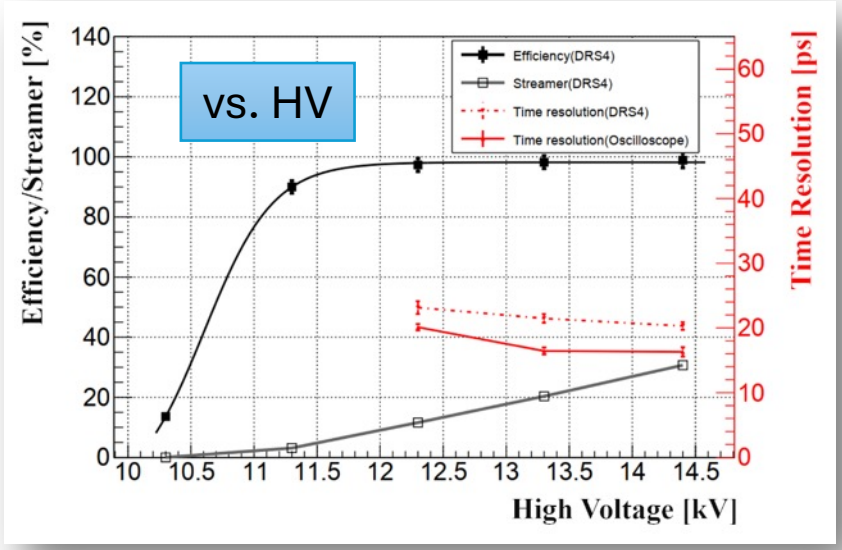
- ✓ Low resistance glass ($10^{10}\Omega \cdot cm$, best quality)
- ✓ 32-gaps (4 stacks), 400um thin glasses
- ✓ 104um gas-gap + waveform-sampling
  → 20ps & 95% efficiency at 15kHz
- ✓ 128um gas-gap + ToT method → 20ps at 15kHz
- ✓ Small sizes & not sealed yet

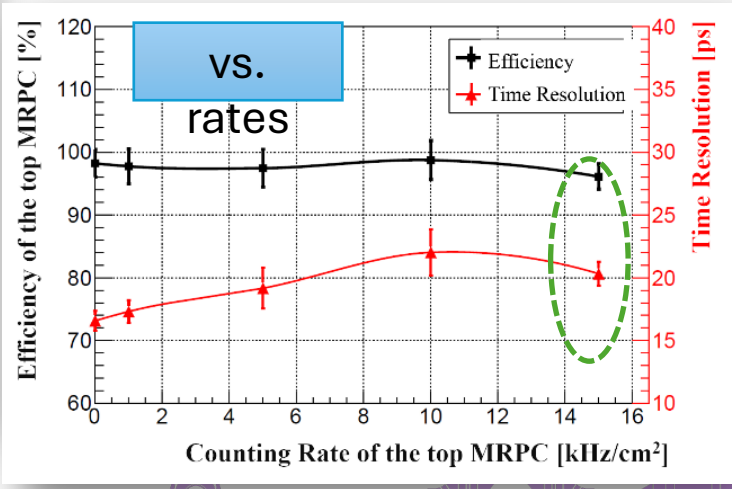












❑ Not proven in real beam!

Y. Yu et al 2022 JINST 17 P02005

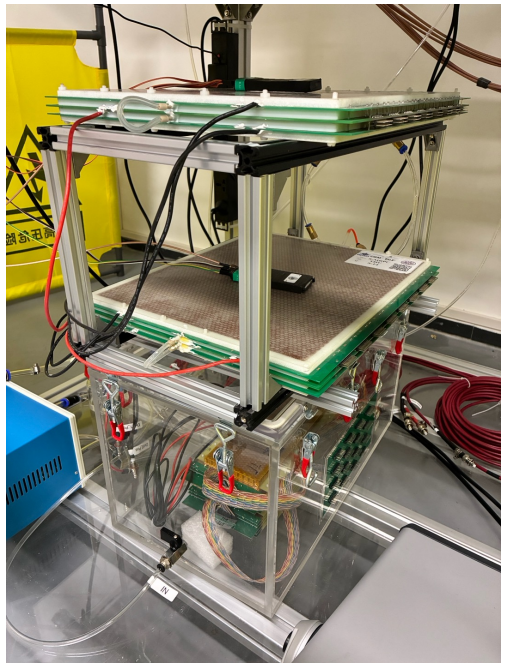
Y. Yu et al 2020 JINST 15 C01049

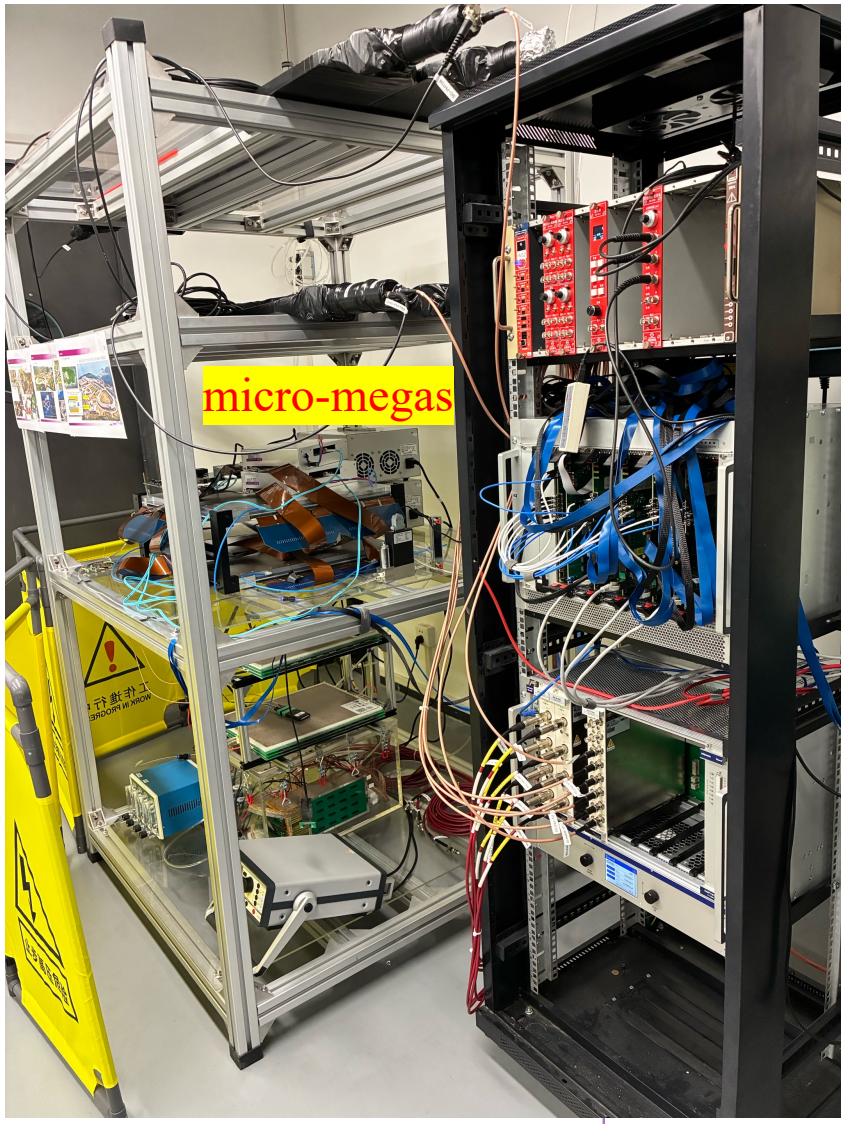
MRPC at Tsinghua

➢ Cosmic-ray Test at Ye's Lab

- ❑ Complete new test setup in the new lab (December 2024)

  (high-rate MRPC + USTC FEE + picoTDC)
- ❑ Gas circulation system completed (March 2025)
- ❑ Added micro-megas tracker (March 2025)
- ❑ Designed new box for high-rate mRPC (March 2025)
- ❑ Tested sealed mRPC (April 2025)

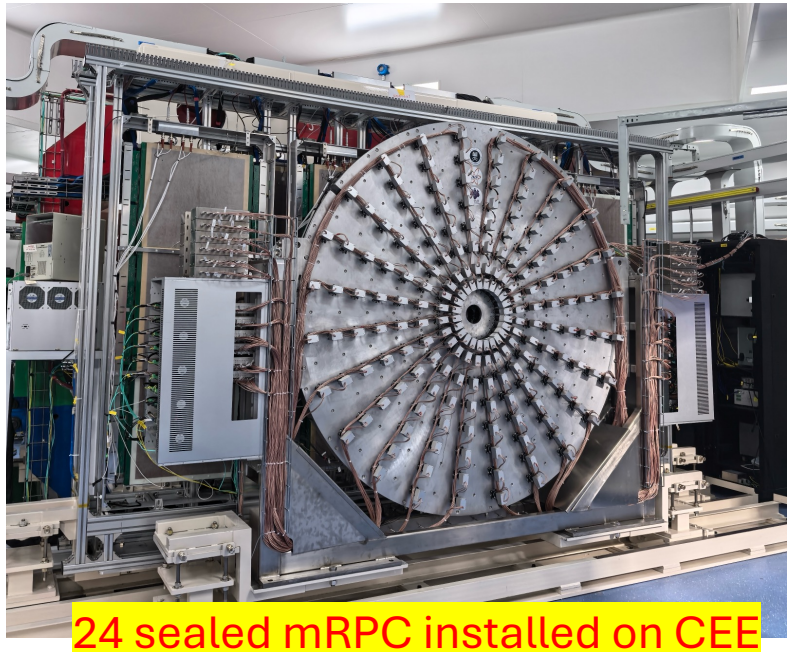




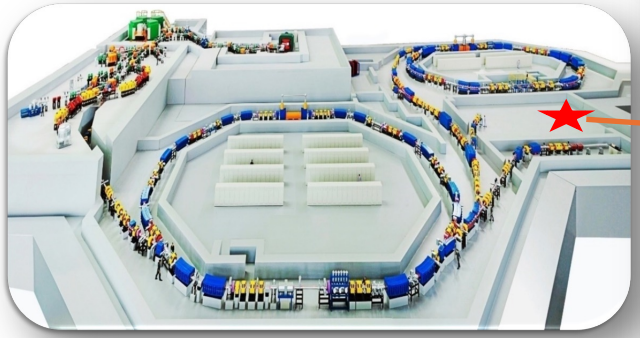
MRPC at Tsinghua

➢ Cosmic-ray Test at Ye's Lab

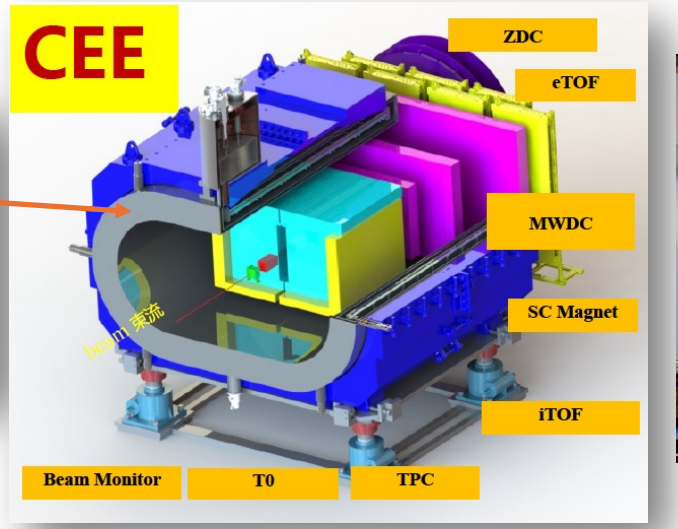
- ❑ The operation of the mRPC test system is not straightfoward
  - Improving mRPC setup, getting familiar with the USTC FEE
- ❑ Orginally planned to do beam test at SPring8@Japan in mid July → failed
  - Aiming for next beam test opportunity.
- ❑ Tsinghua is commissioning mRPC and other CEE detector now

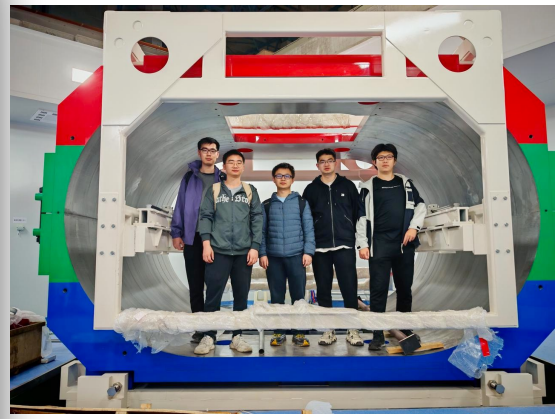


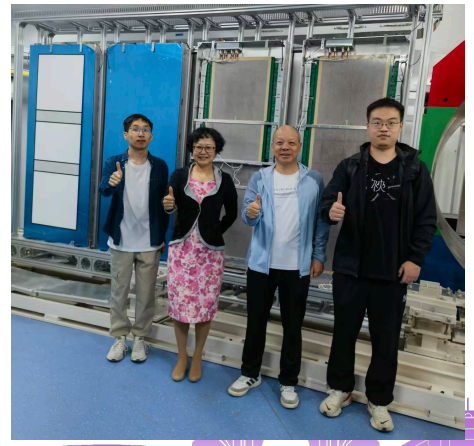
24 sealed mRPC installed on CEE



CSR @ Lanzhou, Gansu







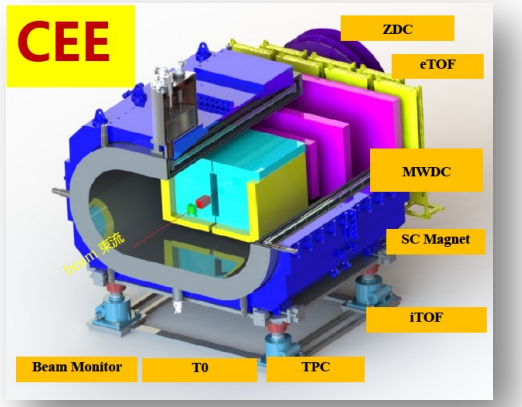
MRPC at Tsinghua

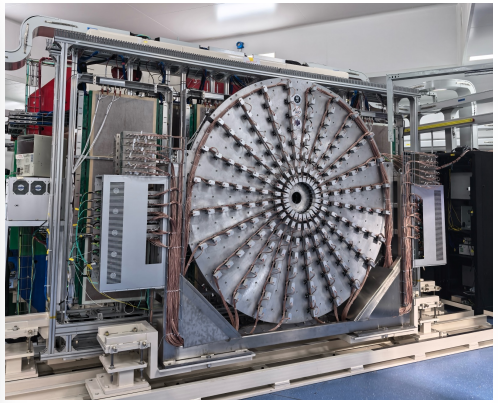
➢ Future mRPC Manufacture (Wang Yi)

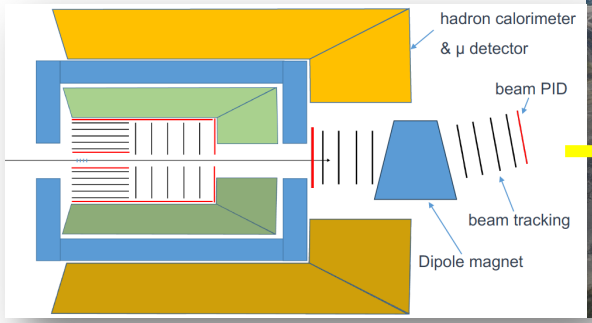
- ❑ Tsinghua's Nuctech was sold to CNNC, not accessable now
- ❑ Wang Yi established anther campany in Miyun (near Beijing)
  - mRPC & ECAL assembly lines
  - Mainly for muon tomography
  - His focus & manpower all shifted to this campany

Summary

- ❑ Tsinghua continue performing cosmic-ray tests on ECAL and mRPC
- ❑ 1st ECAL Super-module ready to ship to JLab for beam test
  - ✓ Second super-modules assembled, under aging test at Shandong Univ.
  - ✓ R&D on MCP-PMT readout options
  - ✓ 5D ECAL by Wang Yi
- ❑ mRPC tests are in underway (real performance on CEE with ion beam)
- ❑ We are seeking application of ECAL & mRPC on domesitc programs







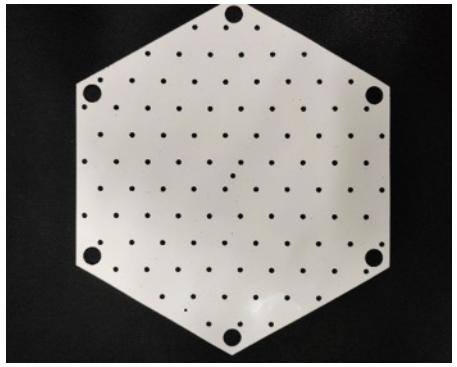
HIAF@Huizhou, Guangdong

THANKS!

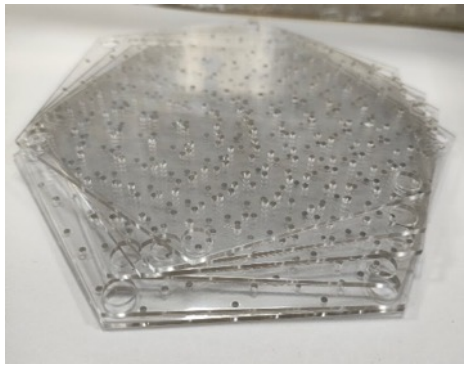
清華大學
Tsinghua University

ECAL

➢ Shashlyk ECal Material Overview:



lead sheet with reflective coating

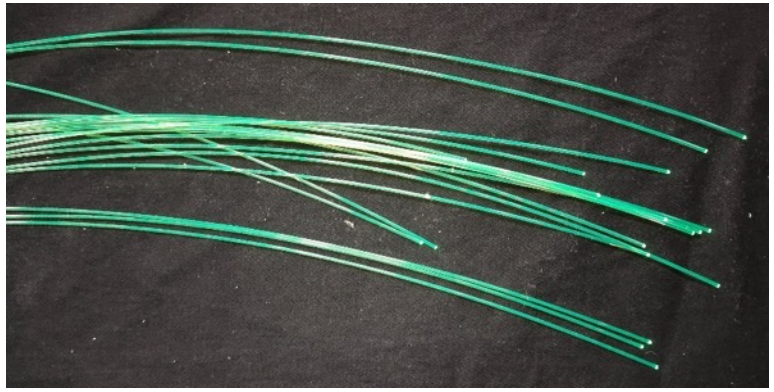


plastic scintillator

ESR with air coupling

optical reflective glue

Tyvek



Wavelength-Shifting Fiber

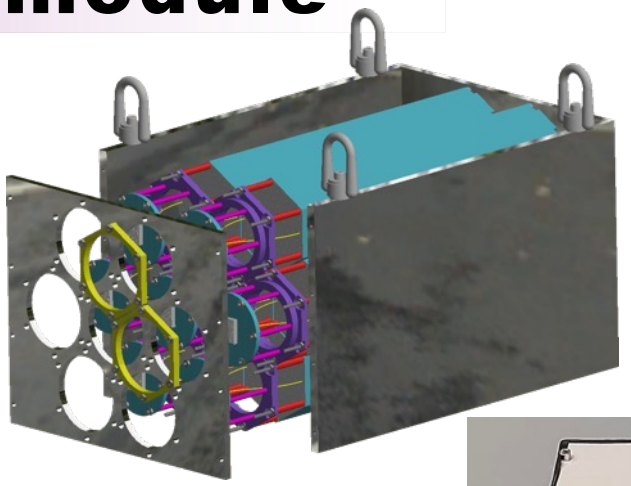
Part	Type/Material
scintillator	KEDI enhanced
WLS fiber	Y11 multi-cladding
outside surface	TiO2
fiber end reflector	ESR film
lead	paint TiO2*

*instead of reflective layer between lead

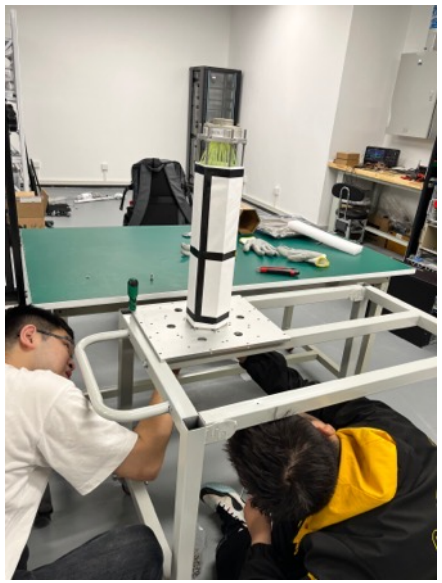
1st ECAL Super-module

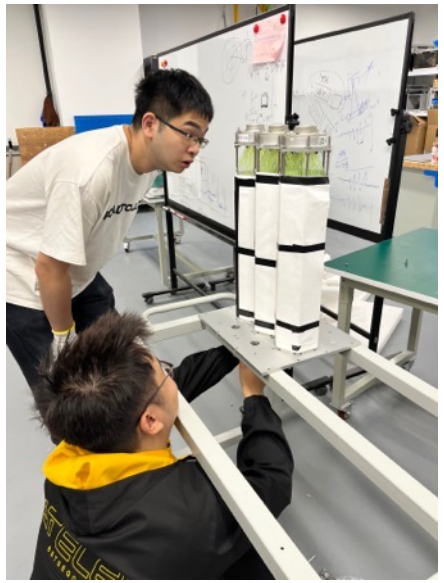
➢ Super-module Assembly (Tsinghua)

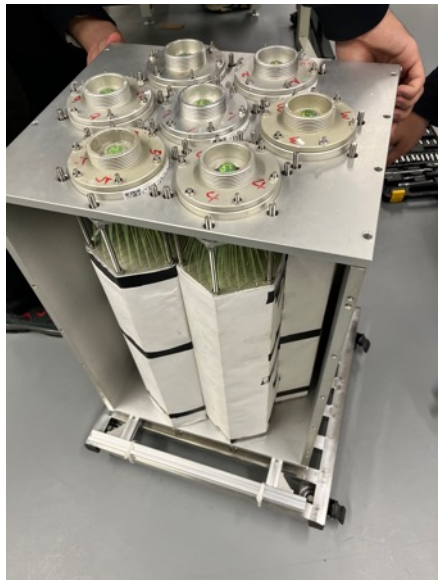
- Better to install all modules in the holes, install covers, then tighten them w/ screw caps → impossible to remove the central one after installation
- Very heavy! Each module weights 15kg → install them on the floor with a wheel-platform
- Light leak at the top and the bottom
- Still need to figure out how to install LED lights



Frame designed by ANL





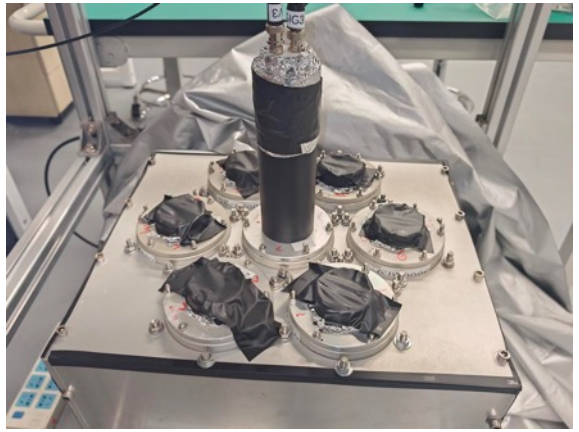


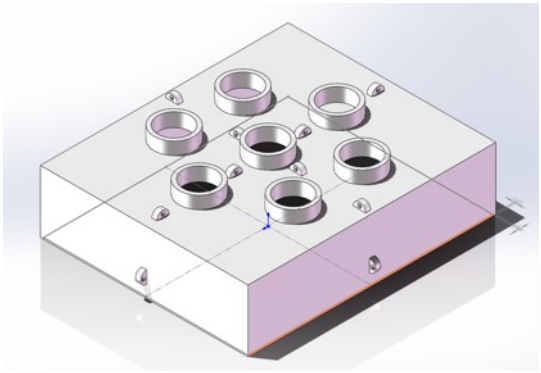
Light-Leak at the top&bottom

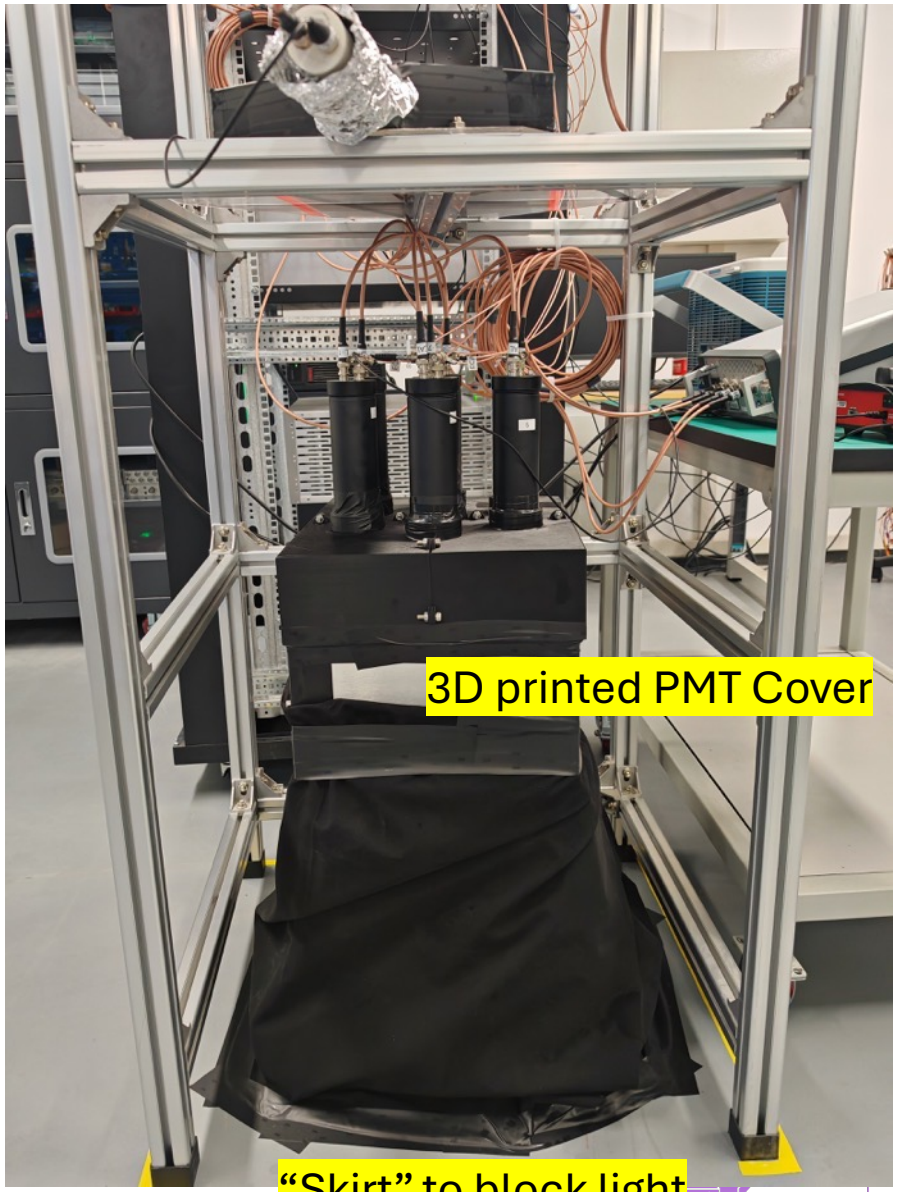
1st ECAL Super-module

➢ Super-module Assembly (Tsinghua)

- ☐ Install 7 Hamamatsu PMTs
- ☐ Design and order 7 metal cover tubes
- ☐ 3D printed a plastic cover to fix PMTs and block out lights on top







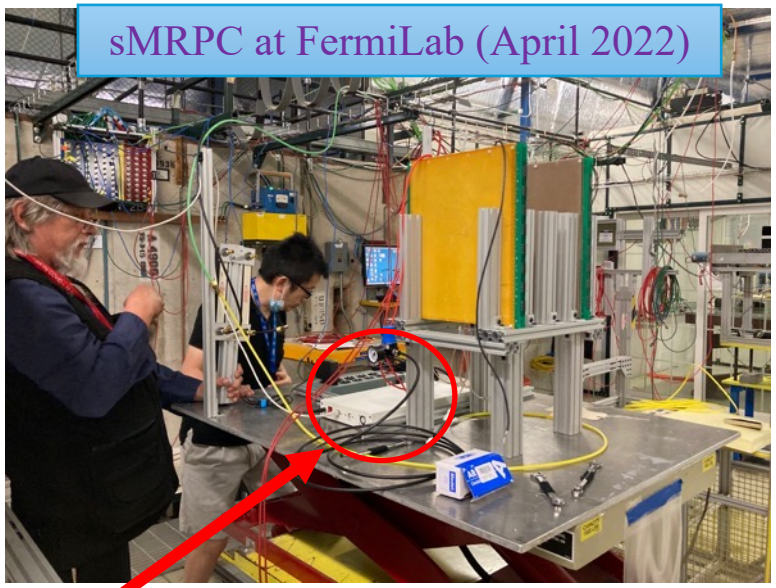
FEE for MRPC

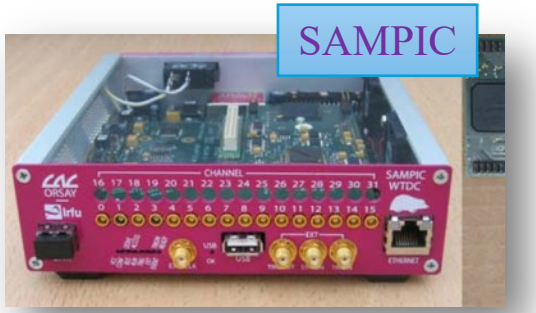
➢ Readout Electronics

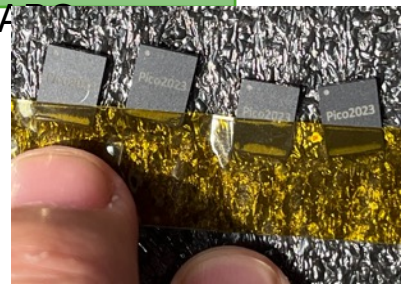
❑ Goals: Test out time-resolution w/ front-end electronics options

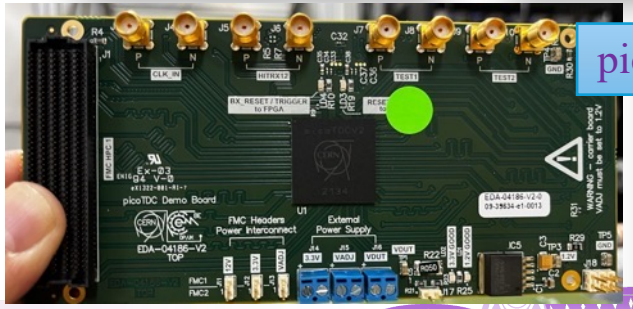
❑ Supports from Crispan Williams, Jorgen Christiansen, David Porret (CERN), Lei Zhao (USTC), & Zhen Hu (Shenzhen Advanced

- ❑ PreAmp + DIS
  - NINO (discontinued)
  - pico2023 (*NEW*)
- ❑ TDC
  - FPGA base (not rad. dard)
  - picoTDC (*NEW*)
- ❑ Waveform Sampler
  - DSR4 (slow)
  - SAMPIC （at Jlab now)
  - NALU AARDVA





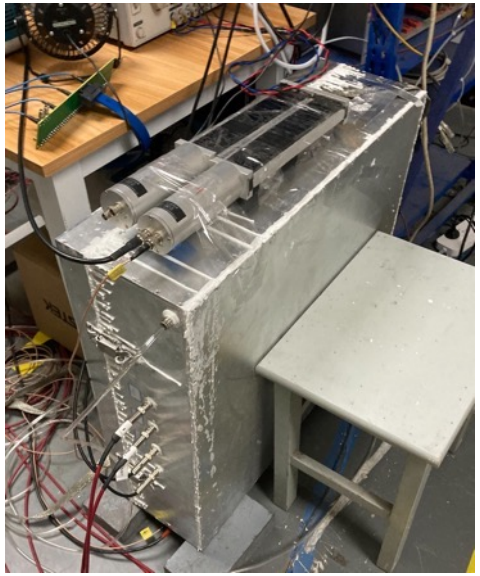


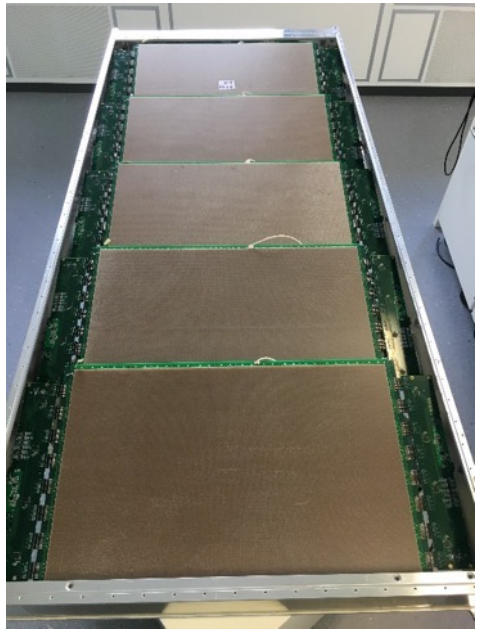


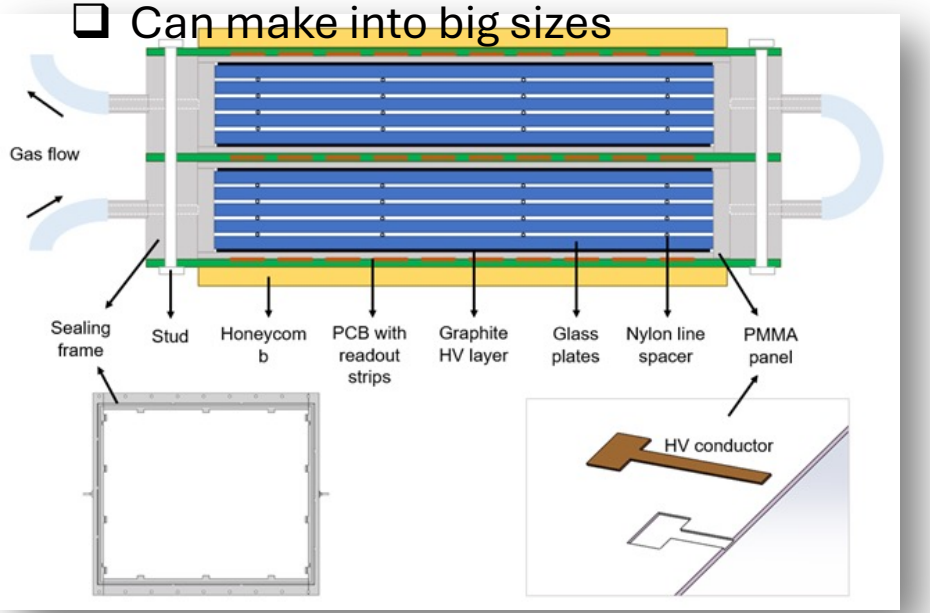
MRPC at Tsinghua

➢ Tsinghua's new Sealed MRPC (sMRPC)

- ❑ Gen3 MRPC with sealed gas → No more boxes!
- ❑ More compact, less radiation length
- ❑ Reduce greenhouse gas emmission (20cc/cm^2/min)
- ❑ Regular glasses (max. rate limited)
- ❑ Can make into big sizes







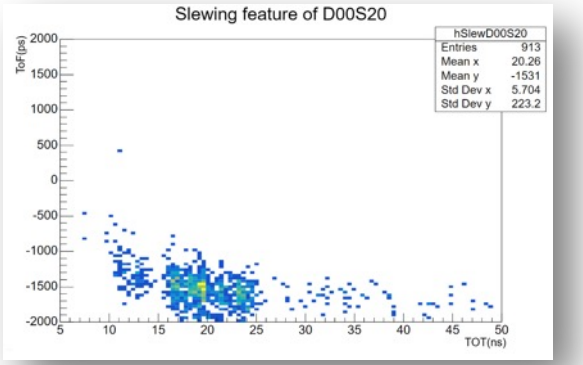
- ❑ sMRPC for CEE & CBM experiments
  - ✓ 32 x 27 cm^2
  - ✓ handle up to 25KHz/cm^2
  - ✓ 8x2 layers at 140um → 60ps!
  - ✓ Readout by NINO+TDC
  - ✓ Mass production at Tsinghua's Miyun workshop

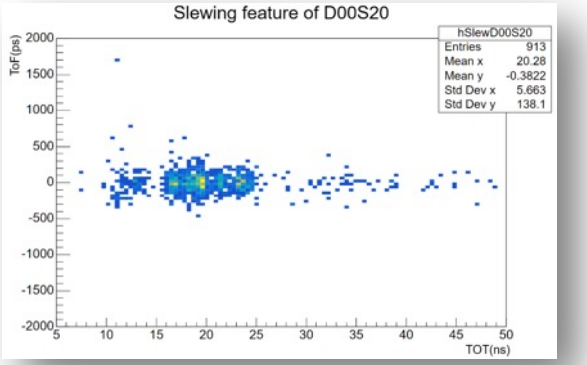
Y. Wang et al 2019 JINST 14 C06015
D. Hu et al 2019 JINST 14 C09014

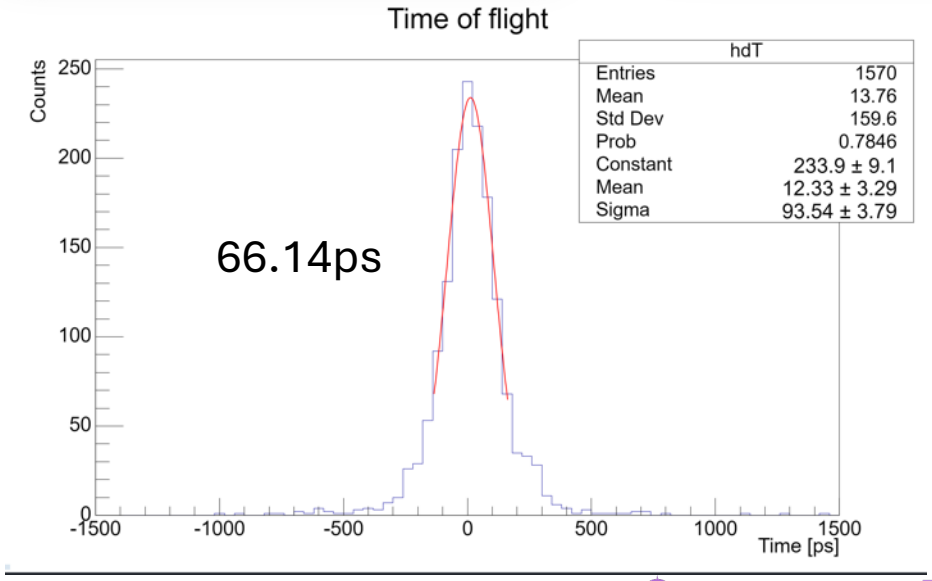
MRPC Test Plan

➢ Cosmic-ray Test at Tsinghua

- ❑ Wang's lab (sMRPC + USTC FEE, diff. gas mixtures)





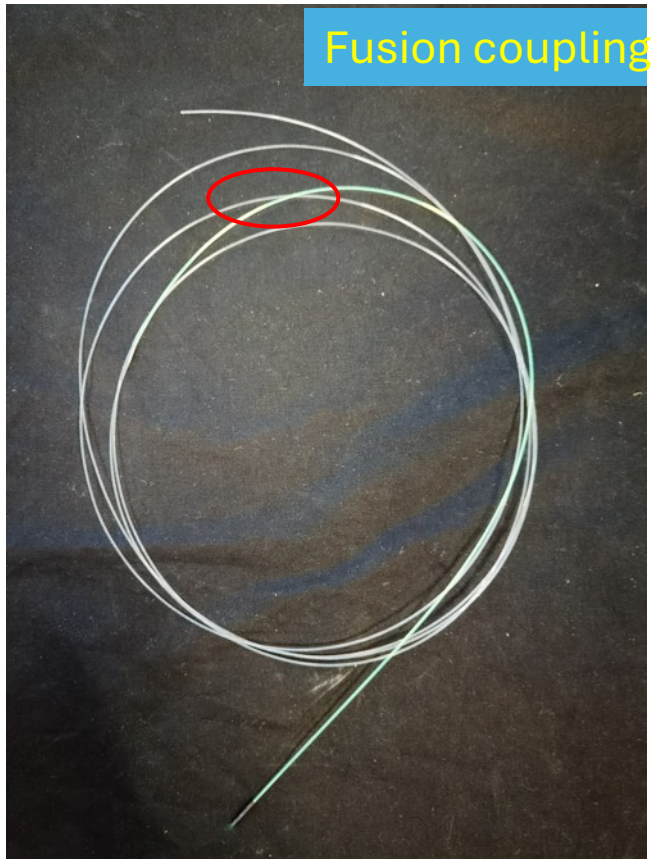


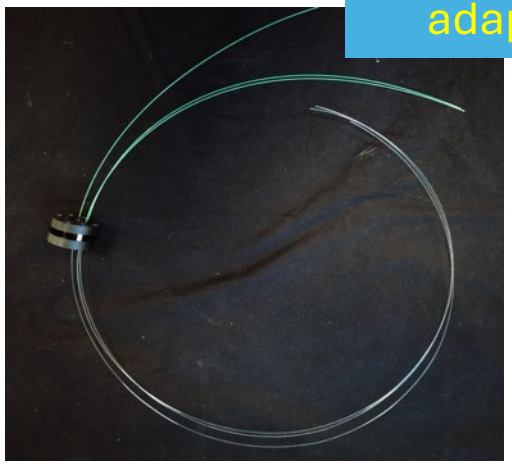
By Kai Sun, Zhaolin Chen

ECAL

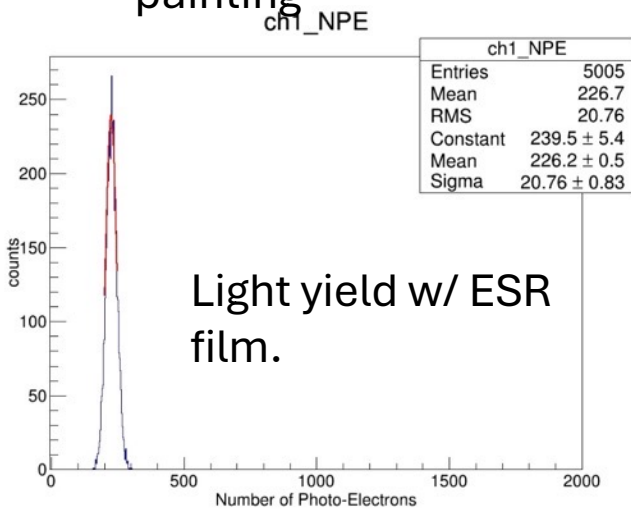
- **Shashlyk ECal Assembly (by Shandong):**

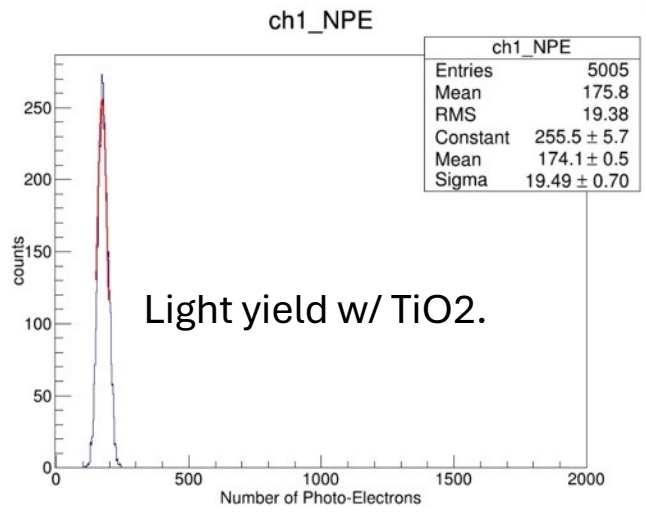
  - The fiber coupling test is ongoing. The new adapter design is easy for assembling, still under study to improve the quality.





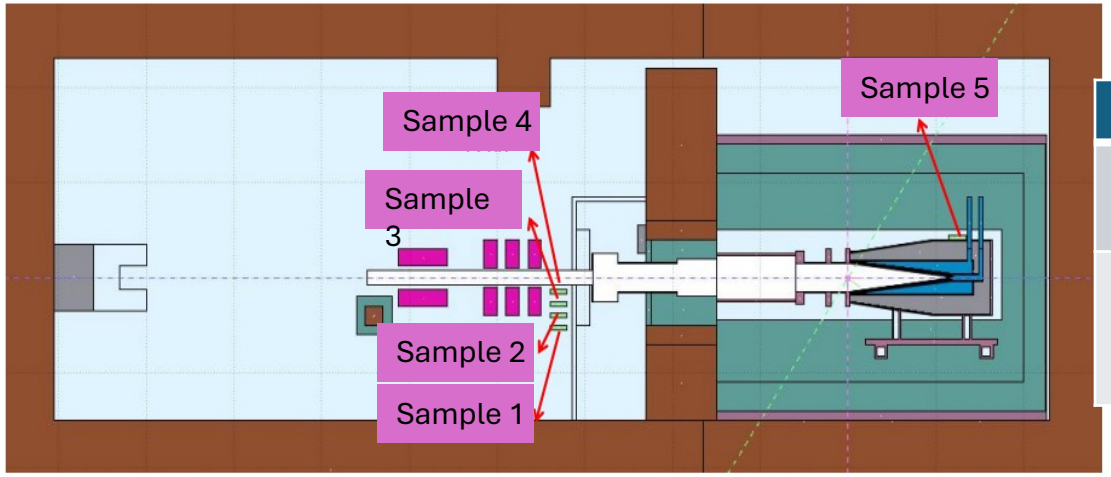
  - The reflectivity of ESR film is better than TiO2 painting





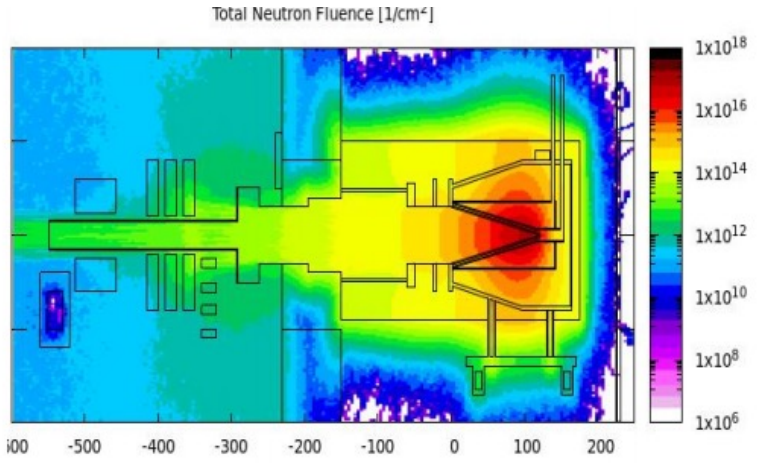
ECAL

- Shashlyk ECal Assembly (by Shandong): :



❑ Irradiation resistance test at IMP

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Total Irradiation(MeV/cm^2) by simulation (uncertainty 10%)	8.6E+11	1.4E+12	2.8E+12	3.7E+13	1.1E+14 **(Not tested)**
Test material	clear fiber	clear fiber BCF91A-MC scintillator	clear fiber BCF91A-MC scintillator	clear fiber BCF91A-MC scintillator	BCF91A-MC scintillator



❑ Satisfy radiation resistance requirement