Design and performance test of Shashlyk EM calorimeter for the SoLID project at Jefferson Lab

Cunfeng Feng, H. Sun, D. Liu
Shandong University, China
X. Zheng
University of Virginia, USA

TIPP, Cape Town, 4-8, September, 2023

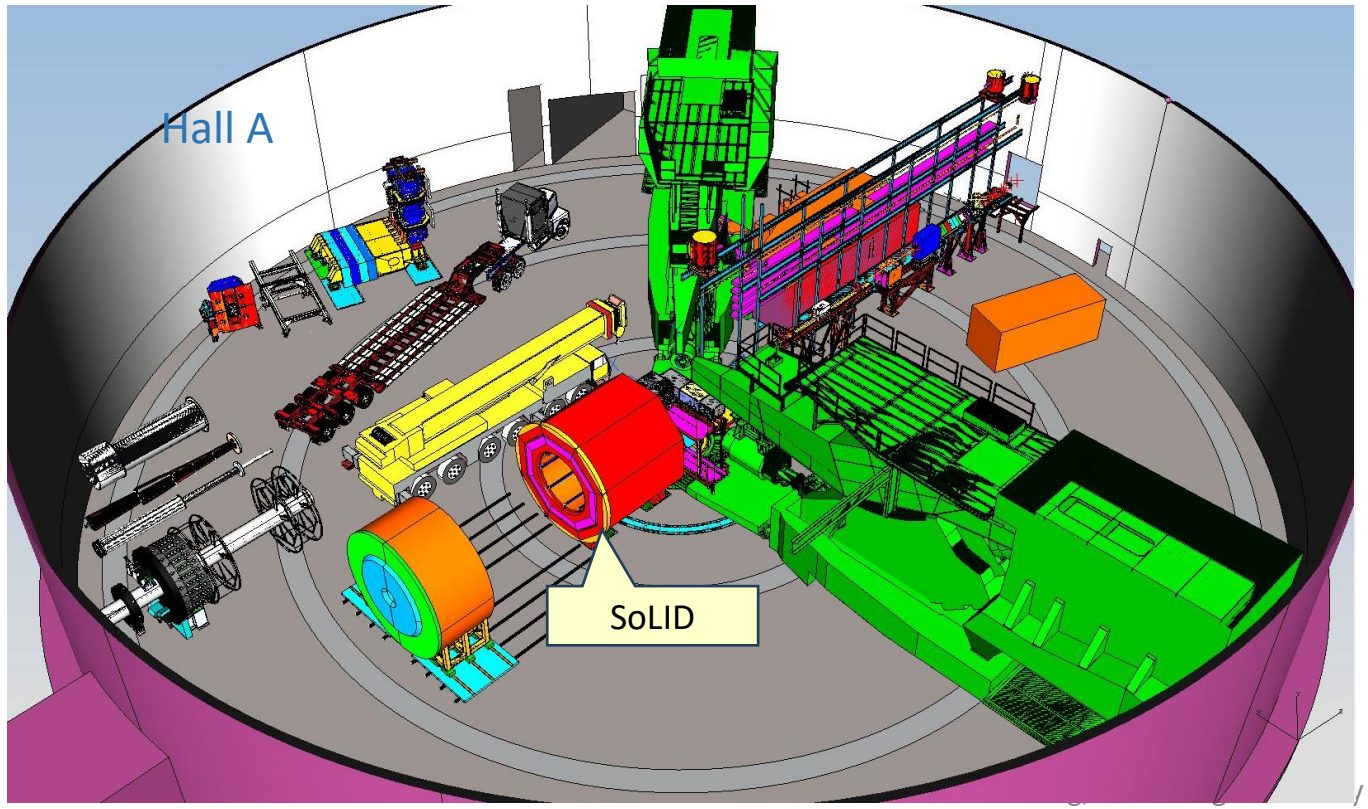
Outline

- SoLID experiment and Electromagnetic Calorimeter
- Material of this Shashlyk Calorimeter
- Fabrication process of the Calorimeter
- Performance test with cosmic ray
- Summary

Solenoidal Large Intensity Device (SoLID)
at Thomas Jefferson National Accelerator Facility (JLab)

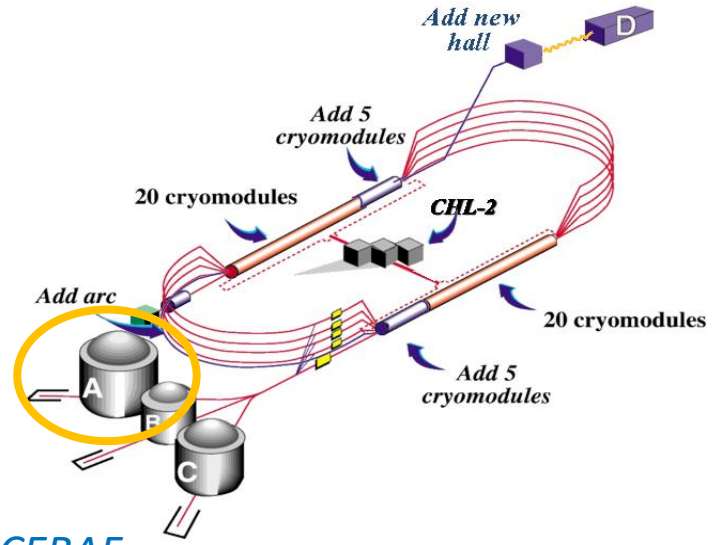
SoLID (Hall-A, Jefferson Lab):

- High Intensity (10^{39} /cm^2.s)
- Large Acceptance



Physics Programs:

- ✓ Parity Violation DIS
- ✓ Near-Threshold J/ Ψ Production
- ✓ Semi-Inclusive DIS w/ polarized targets
- ✓ *NEW*: spin, eA physics, …



CEBAF (The Continuous Electron Beam Accelerator Facility)

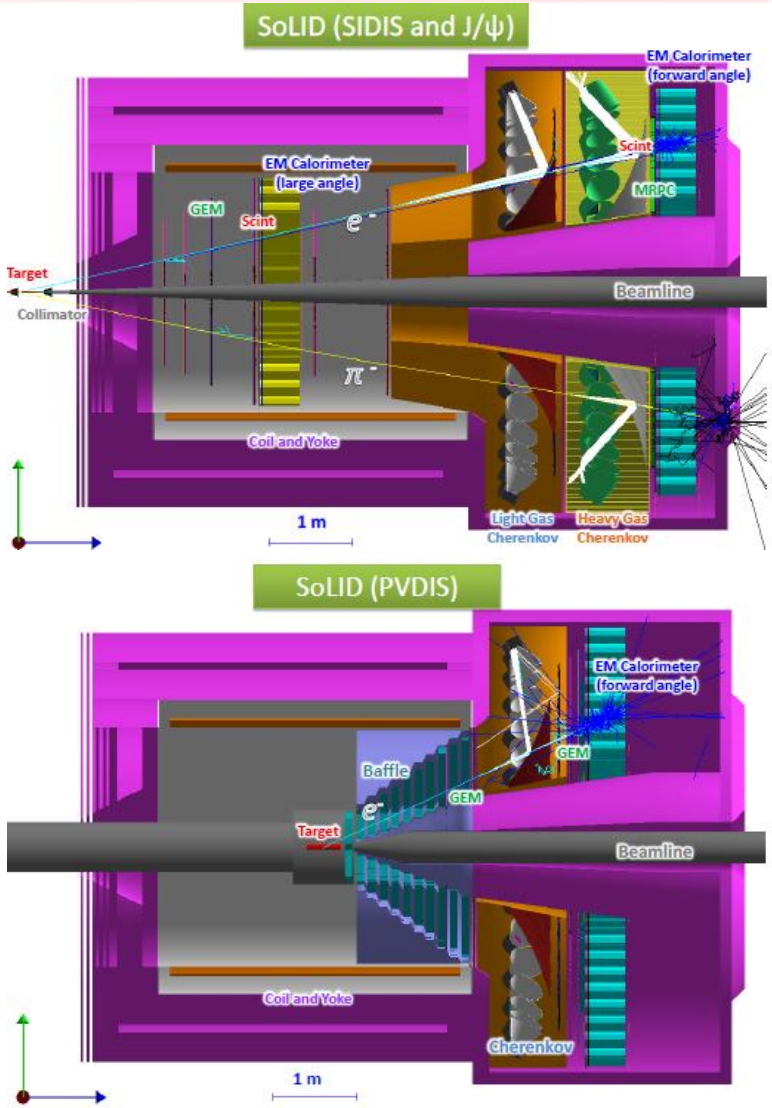
SoLID ECal (Electromagnetic Calorimeter)

SoLID include two configurations:

- SIDIS (Semi-Inclusive Deep Inelastic Scattering)
- PVDIS (Parity-Violating Deep Inelastic Scattering)
- ECal re-arrange between two configurations

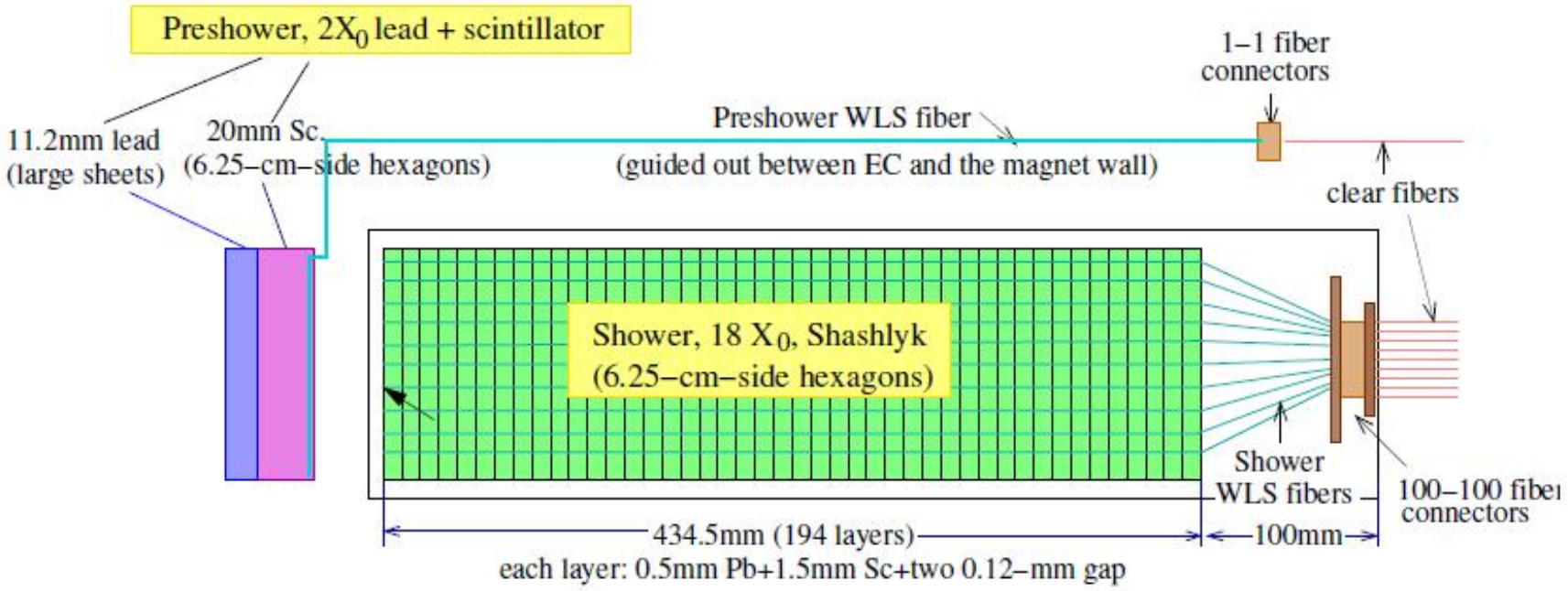
ECal main performance requirements

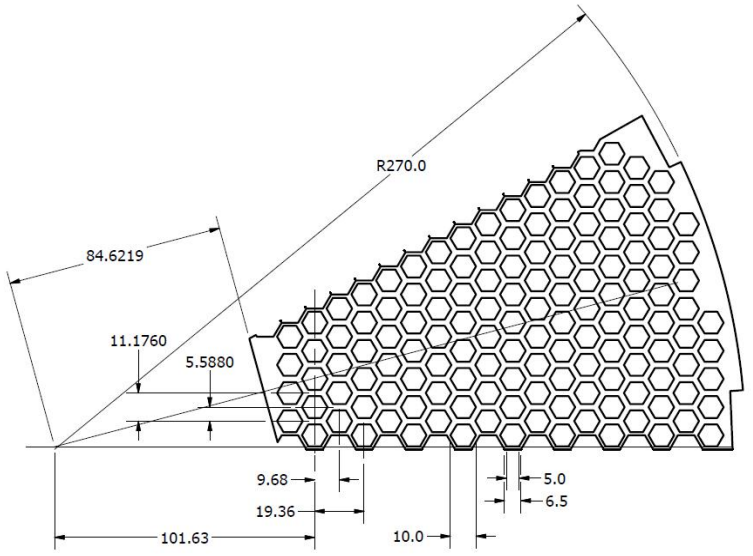
Specification	Desired performance
Energy resolution	<10%/$\sqrt{E}$(GeV)
e^-/π^- sepapartion	50-100:1 for above Cherenkov threshold
e^- efficiency (considering high background)	>95%
Position resolution	<1 cm
Radiation resistance	>2E13 n_{eq}/cm^2
High magnetic filed	1.5 T



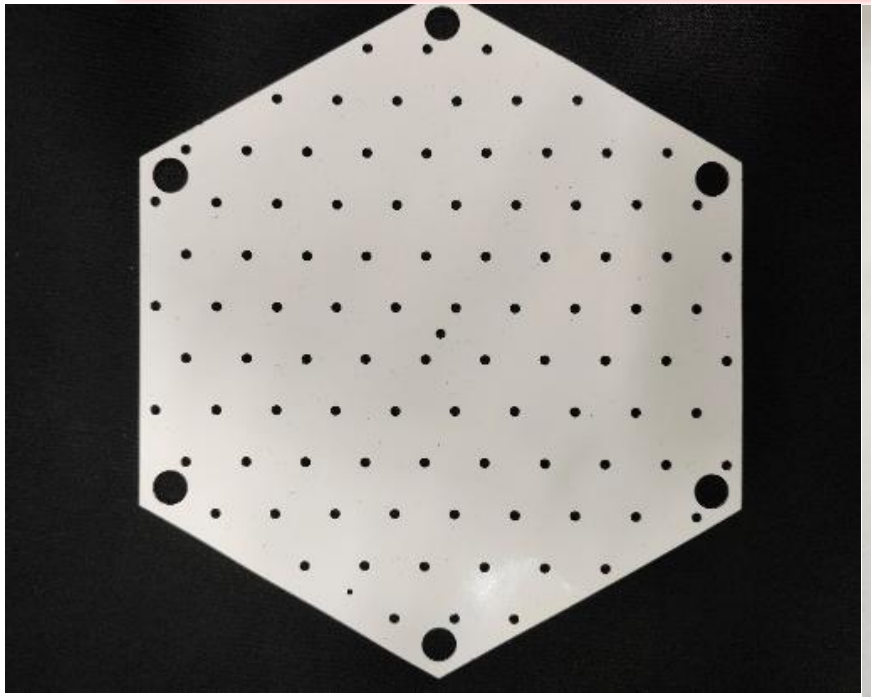
Shashlyk style ECal design

- Longitudinal: preshower + Shashlyk shower (2+18 X_0)
  - Preshower: one layer lead and scintillator.
  - Shower module: (0.5mm lead + 0.1mm reflector × 2 + 1.5mm scintillator) × 194 +96 WLS fibers penetrating.
- Transversal: 100 cm^2 hexagon, arranged in a ring shape

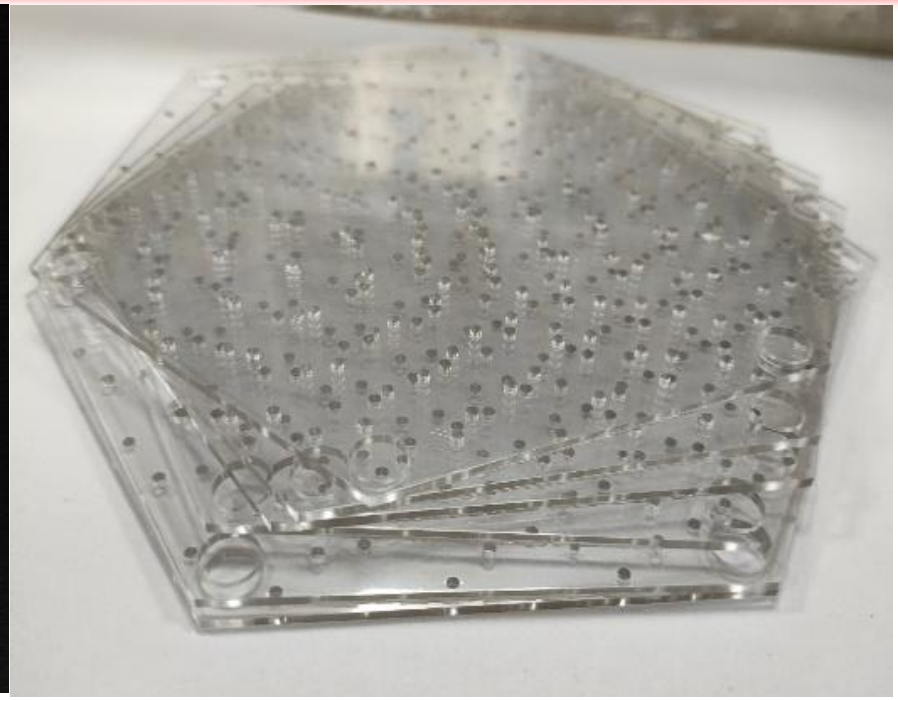




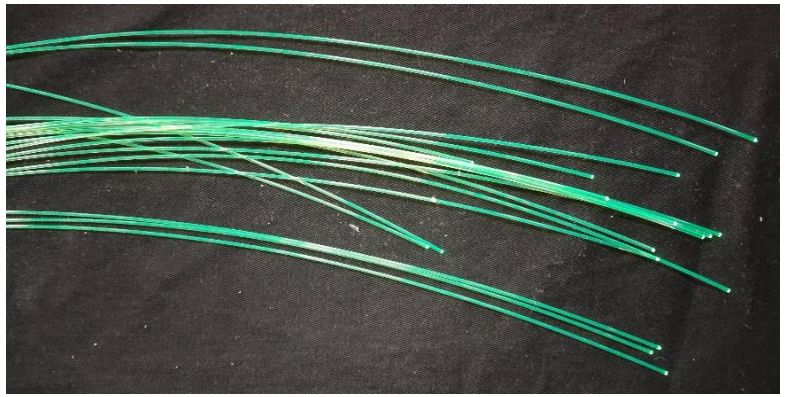
ECal Material Overview



Lead sheet with reflective coating
Hole punched with tool。



plastic scintillator， produced with injection mold



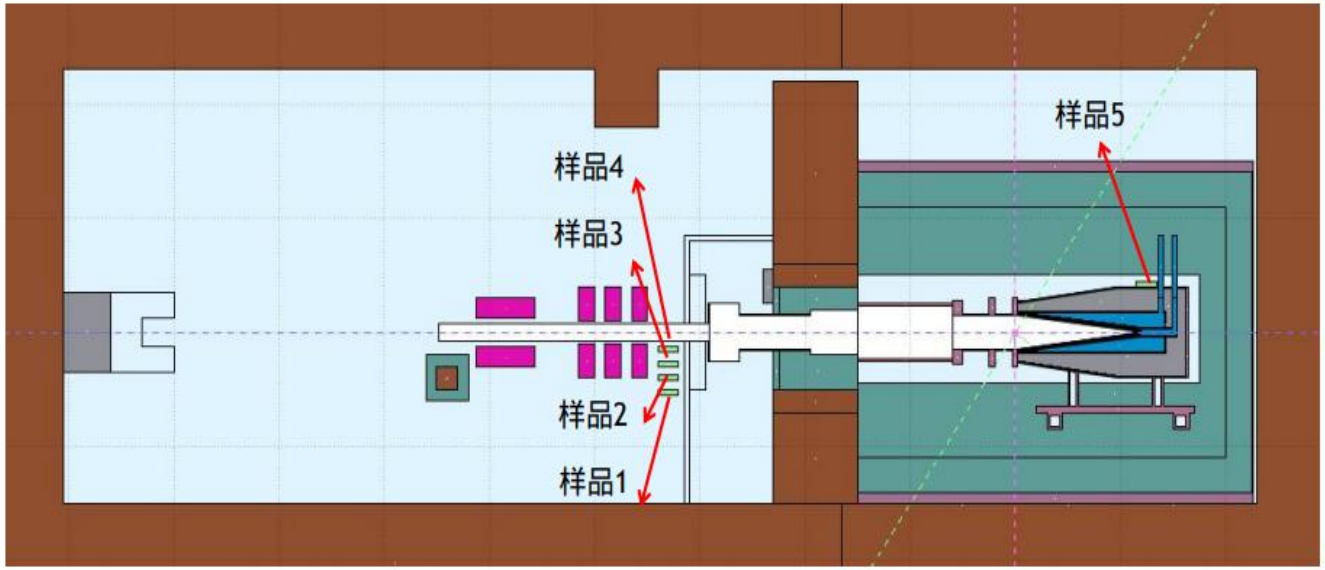
WaveLength-Shifting fiber

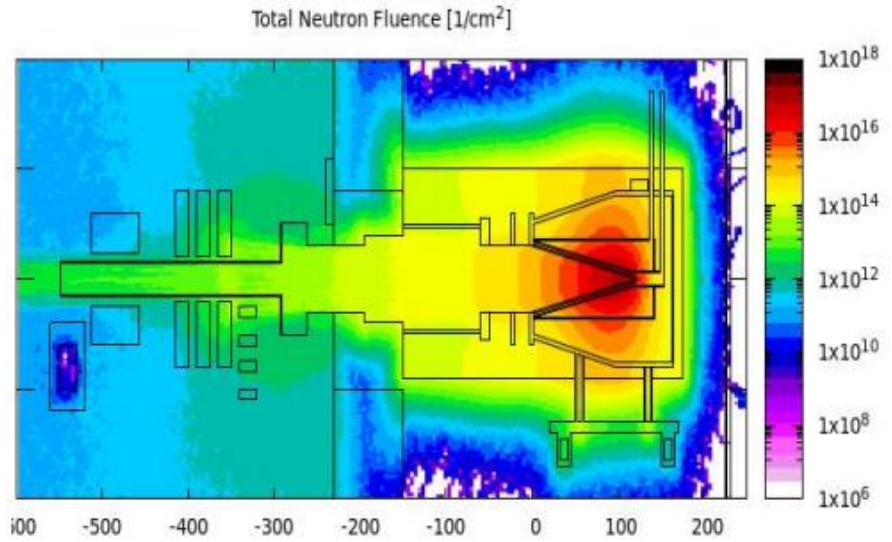
High reflectivity, effectively improve the brightness

3M ESR film as mirror, reflectivity >98%

*instead of reflective layer between lead

Irradiation test
at Institute of Modern Physics, China



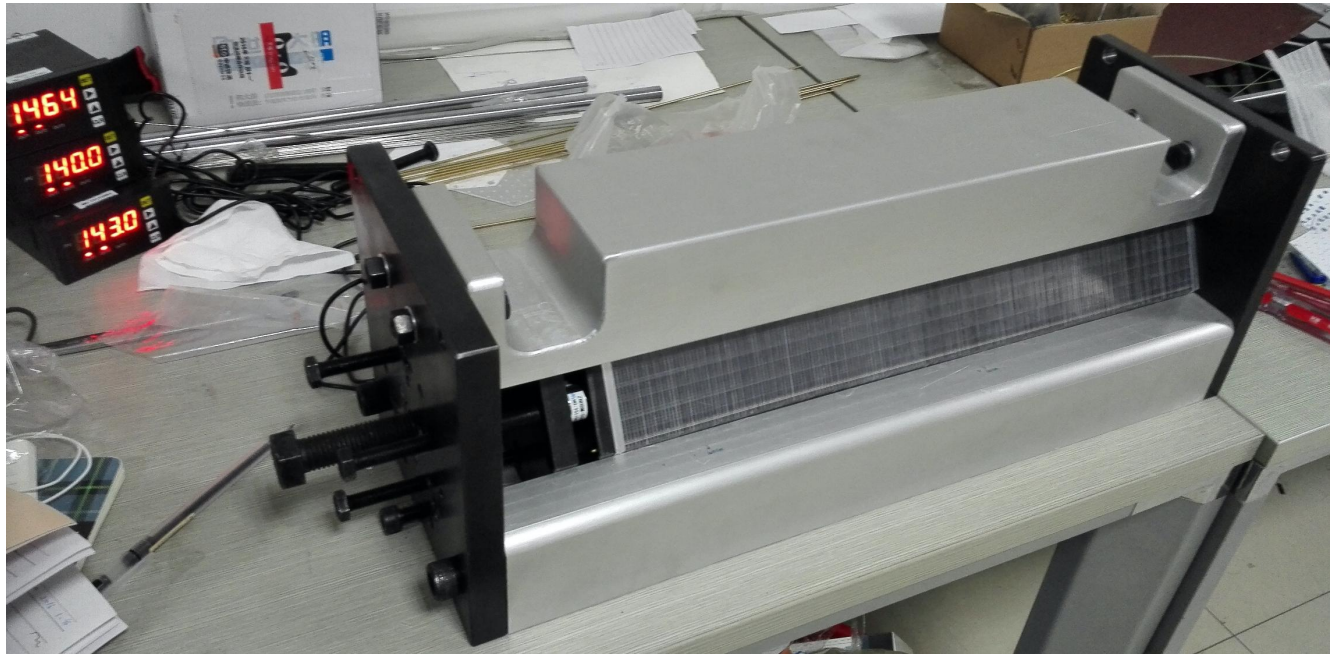


Expected irradiation on SoLID ECal :
2E13 n_{eq}/cm^2

	Sample 1	Sample 2	Sample 3	Sample 4
Total Irradiatio（n_{eq}/cm^2） By simulation(uncertainty 10%)	8.6E11	1.4E12	2.8E12	**3.7E13**
Test material	clear fiber	clear fiber WLS fiber scintillator	clear fiber WLS fiber scintillator	clear fiber WLS fiber scintillator

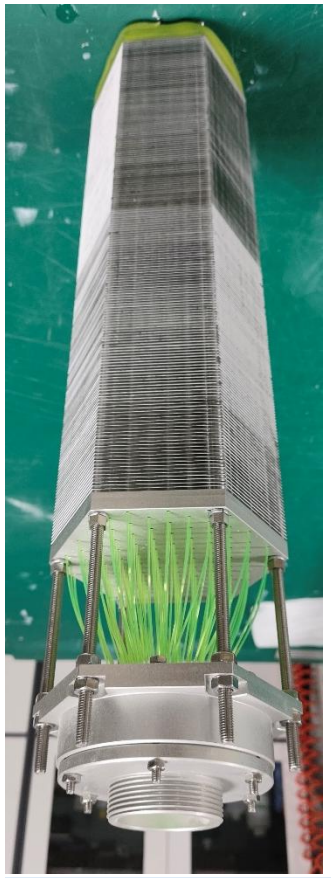
The performance still fine after irradiation.

Shashlyk ECal module assembling



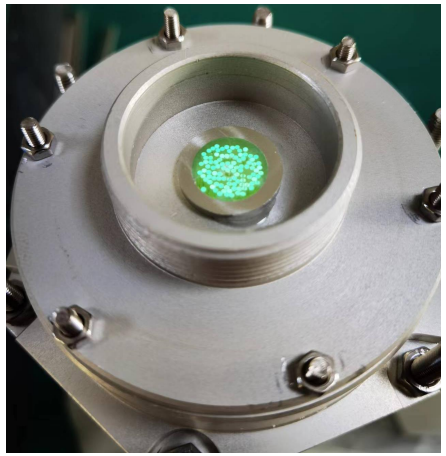
Scintillator tiles and leads are cross stacked in the mould, keeping pressure stable on ECal for hours.

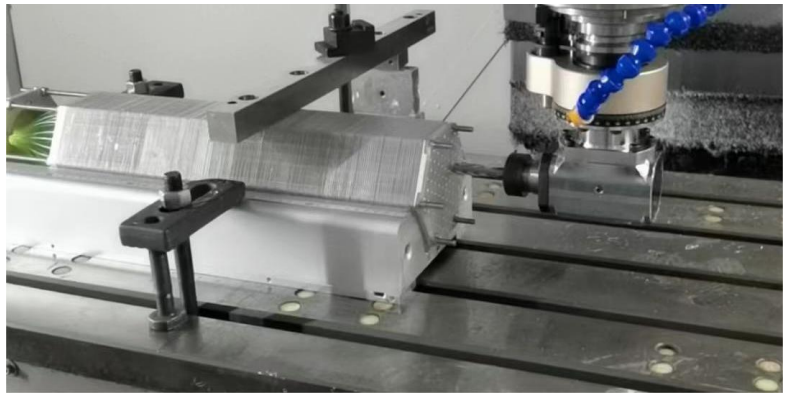
Assembled module。
Tight with nut.



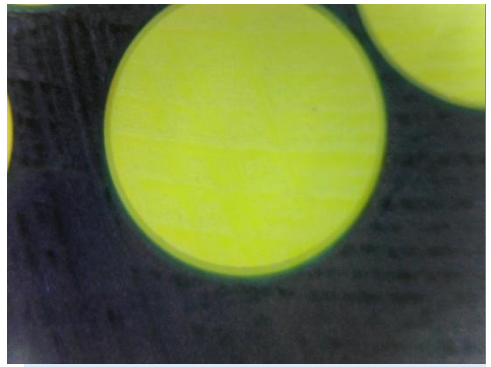
Inserts fibers

Fiber end polish and module coating

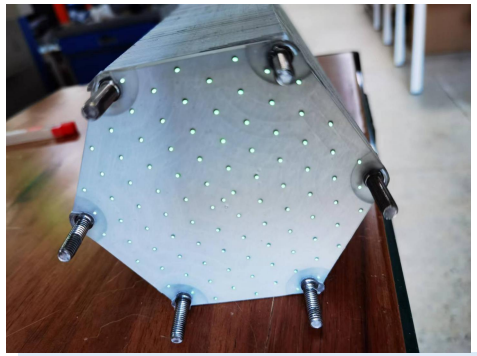




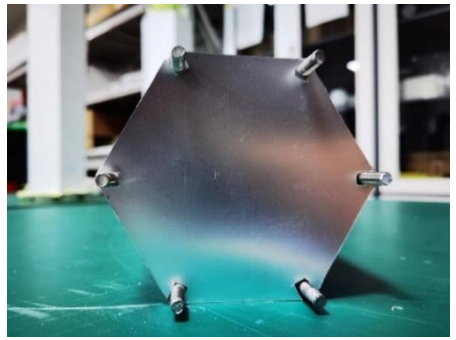
fiber polished with CNC milling machine



fiber end after polished under microscope



fiber end after polished

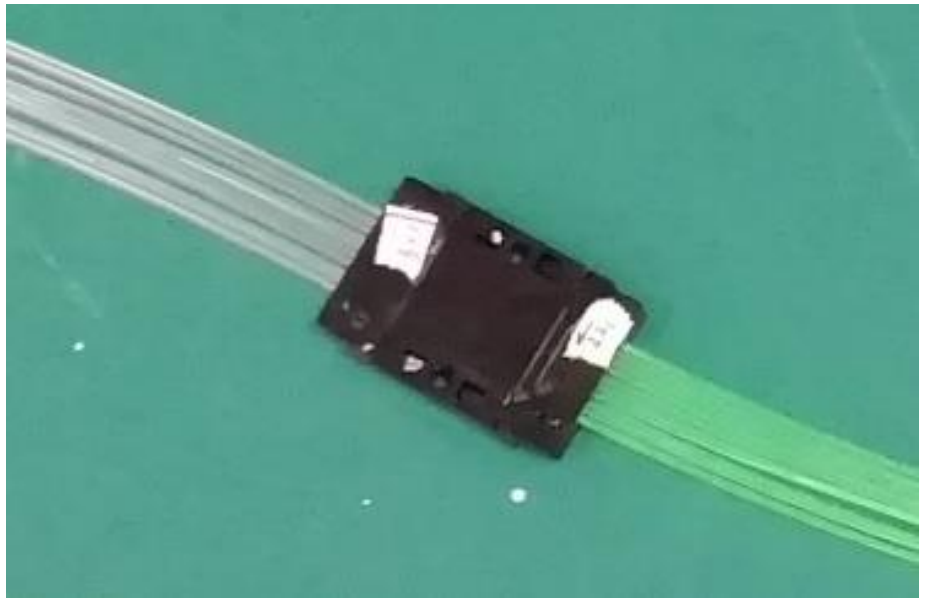


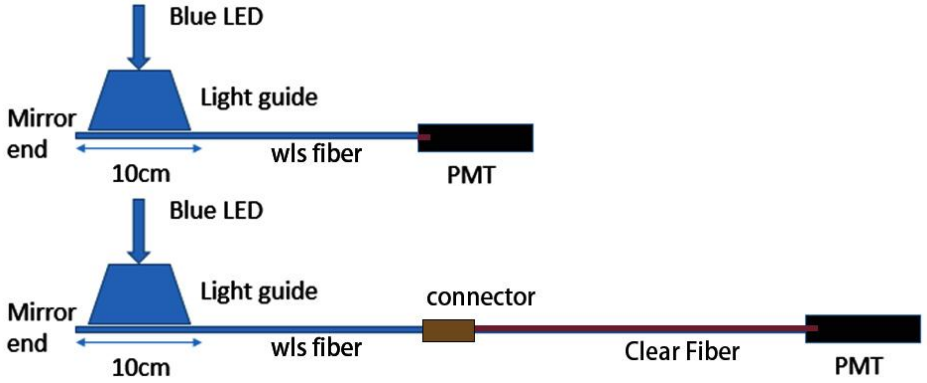
cover ESR over fiber end

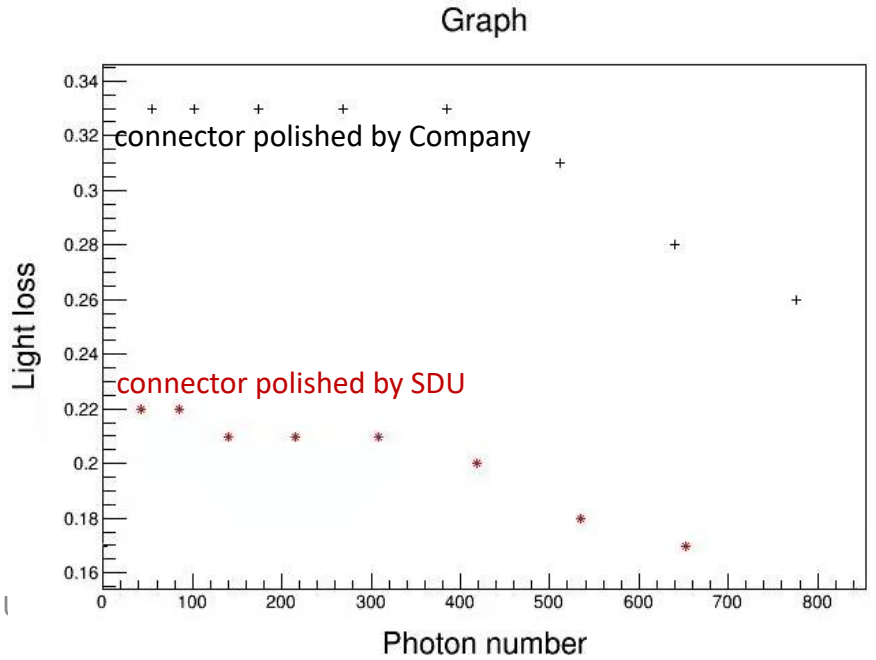
TiO2 reflective layer

Tyvek package

Light loss by Coupling with Clear Fiber





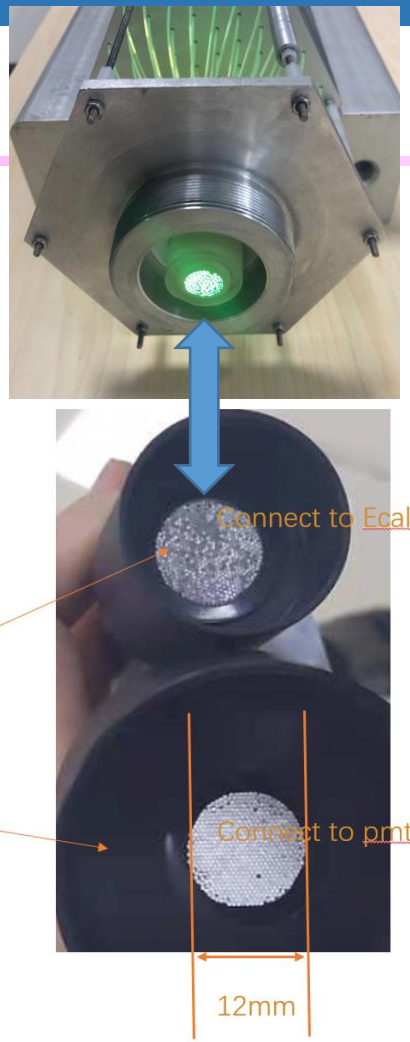


10-10 WLS fibers coupling to clear fibers (length 1 m) with **Fujikura** connector.

The light loss is about 30%~20%, dependent on the polishing of the fiber end.

Chunhui Fiber bundle connector

Chunhui fiber bundle connector

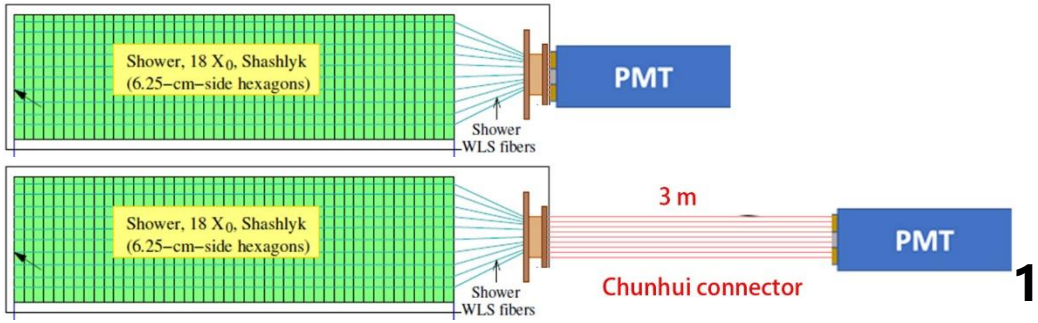


Here are a bundle of 500 clear thin fibers(0.5 mm diameter).

Easy to install, only one piece for one Ecal tower
Soft, could be bend easily
Radiation resistance: the same as 1mm PMMA clear fiber

Chunhui connector： **light loss ~37%**
Clear fiber atenation has been substracted.

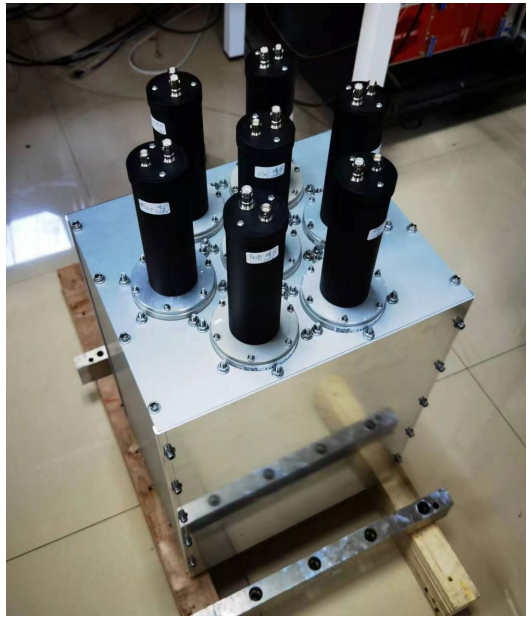
Test setup
Light loss test for all fibers together by cosmic ray



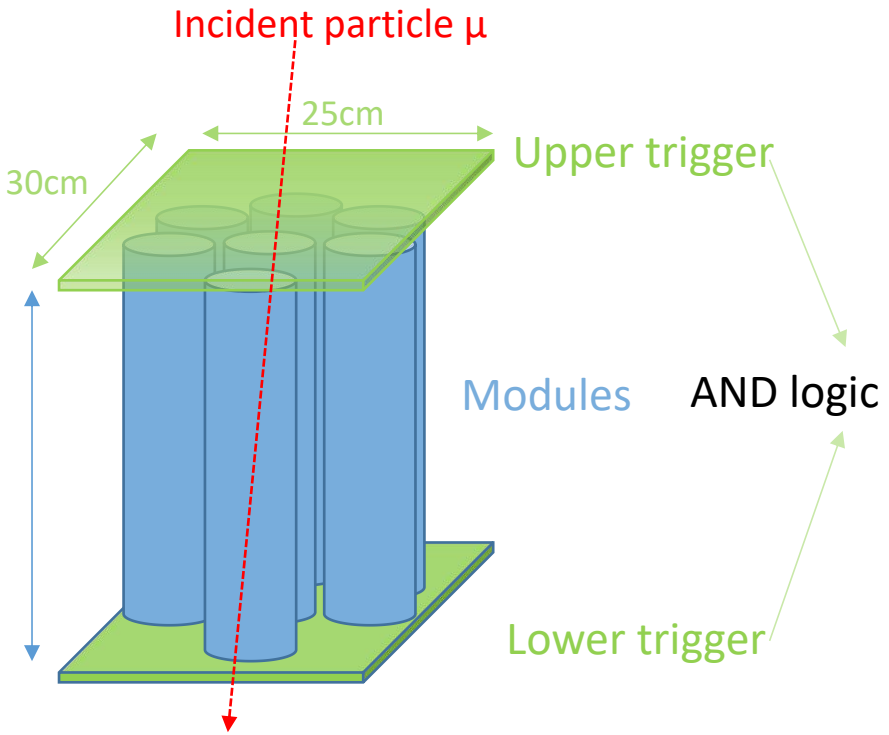
Super-module and Performance test with cosmic ray

➢Super-module

7 modules integrated in light tight frame



PMT mounted



test system simplified diagram

3.2GS/s Digitizer

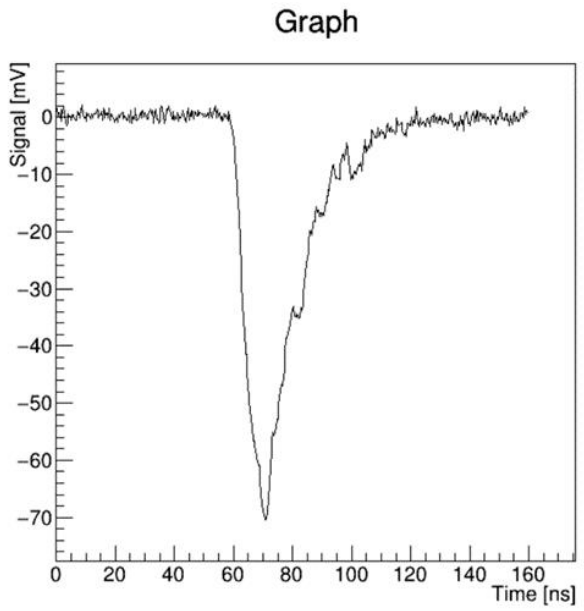
Cosmic ray test with vertical muon

➢ **Calculate number of photo-electrons(NPE)**

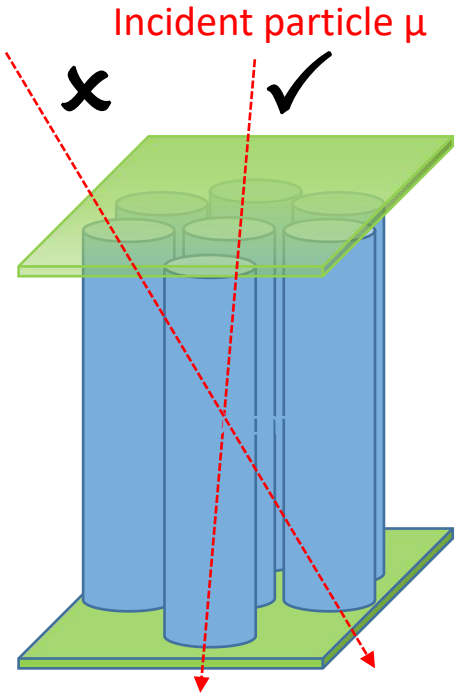
- Calculate **the charge** of signal
  1) perform an integral over the entire waveform
  2) subtract the baseline from the waveform integral
- NPE = charge / (1.6 * 10E-19) / gain

➢ **Select vertical muon events**

- Only one out of 7 modules has a signal,
  indicating nearly vertical incidence



waveform of one event in one module

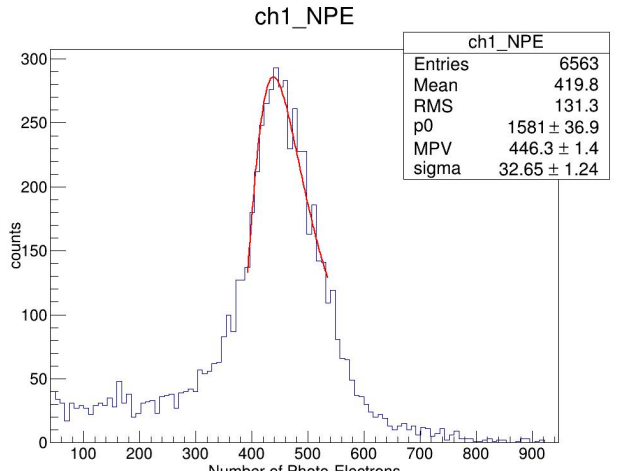


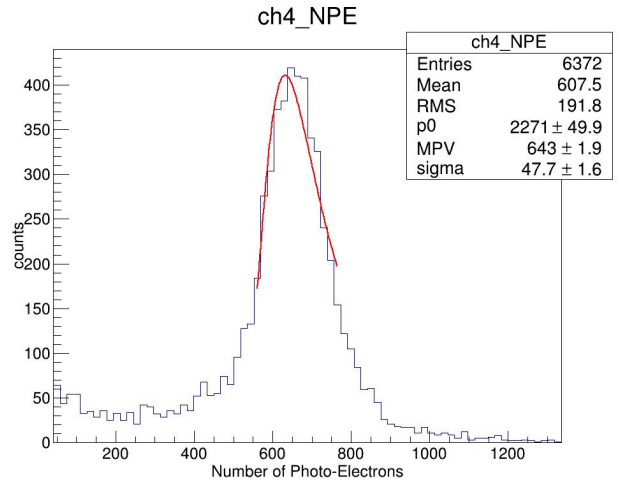
event selection

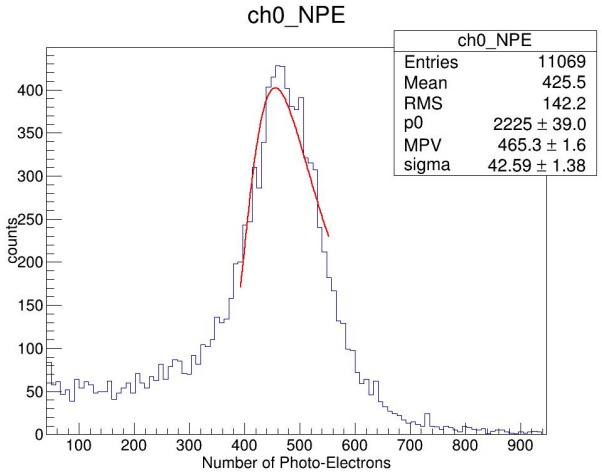
NPE of vertical muon

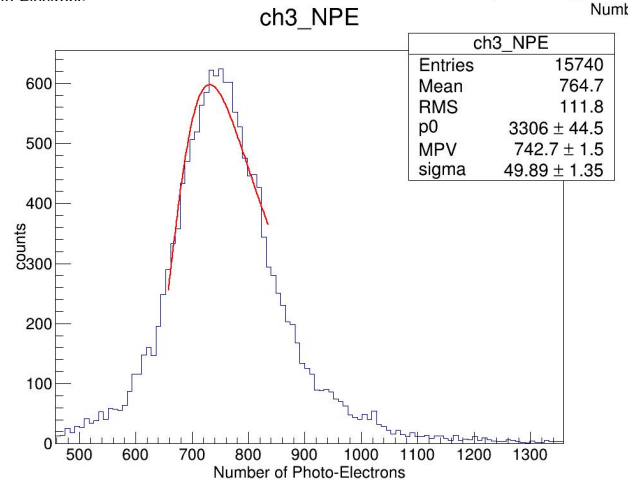
The position of histograms corresponds to the module position in the frame.

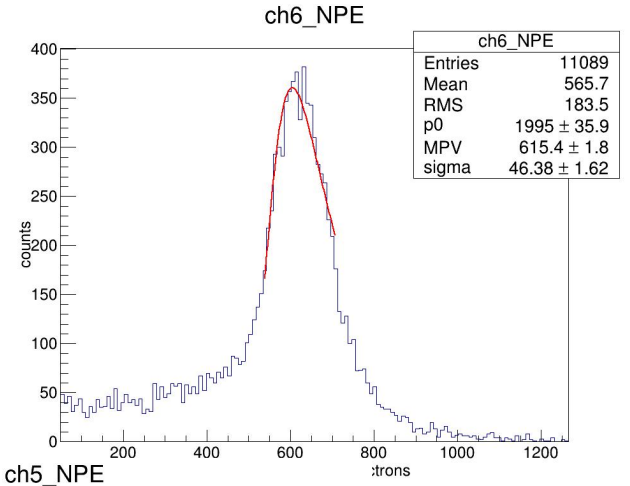
Resolution = sigma/mpv

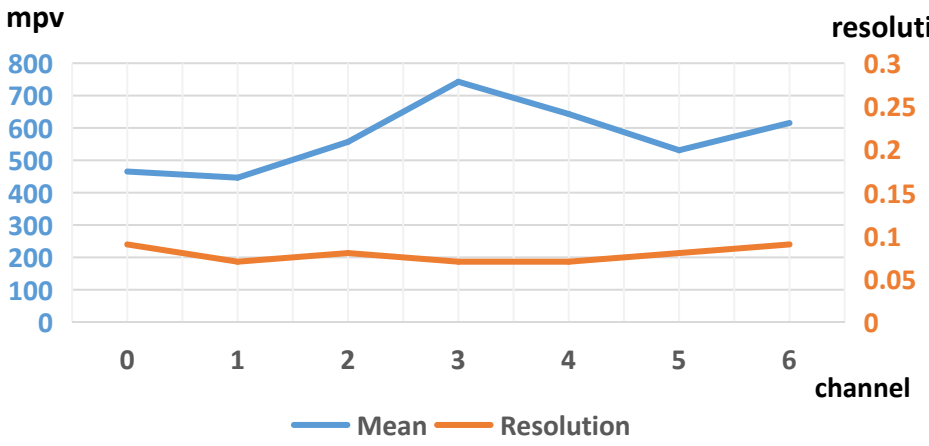


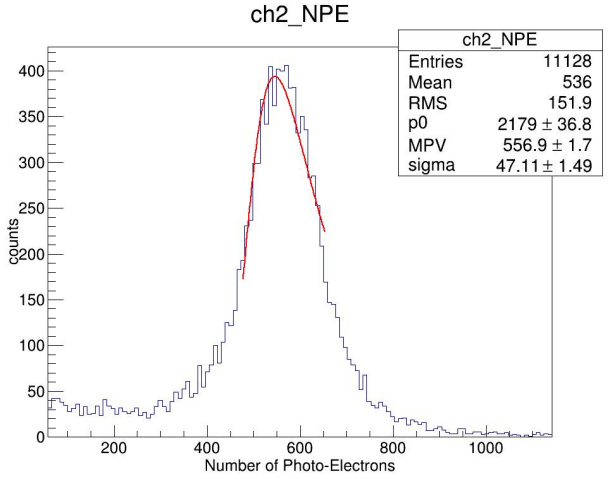


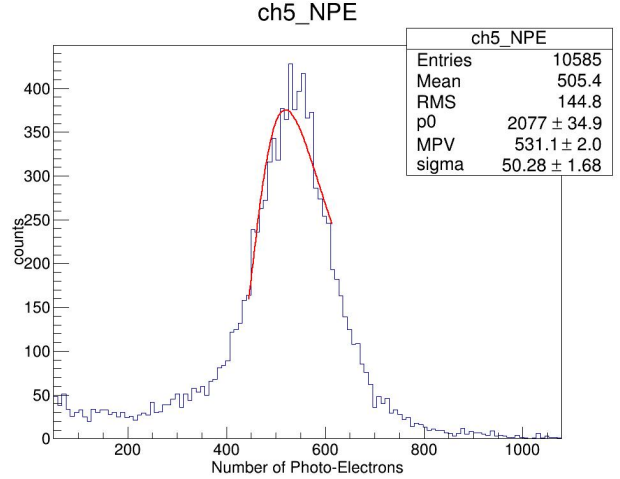




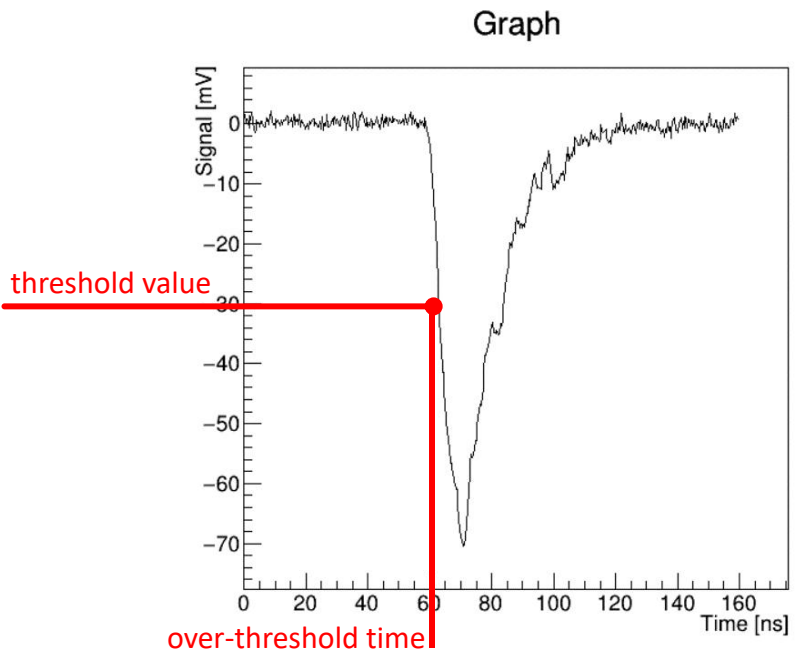




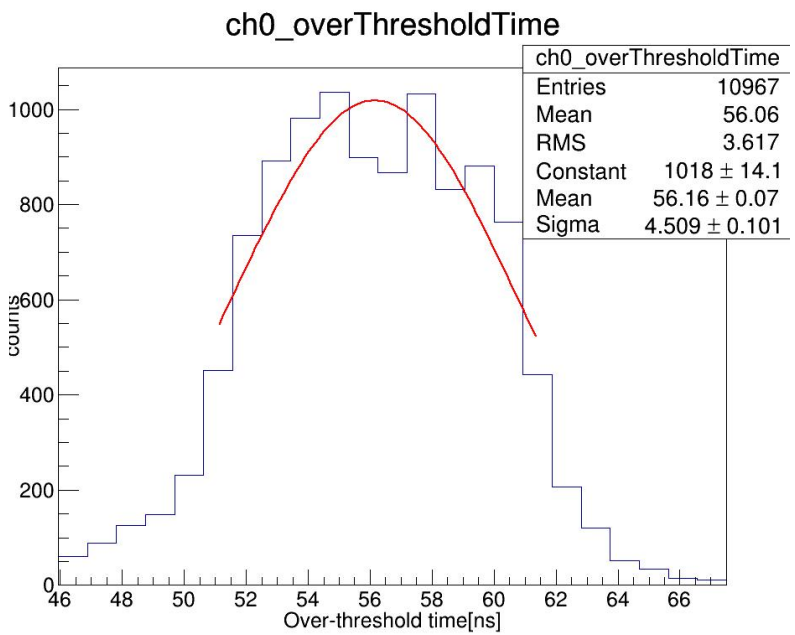




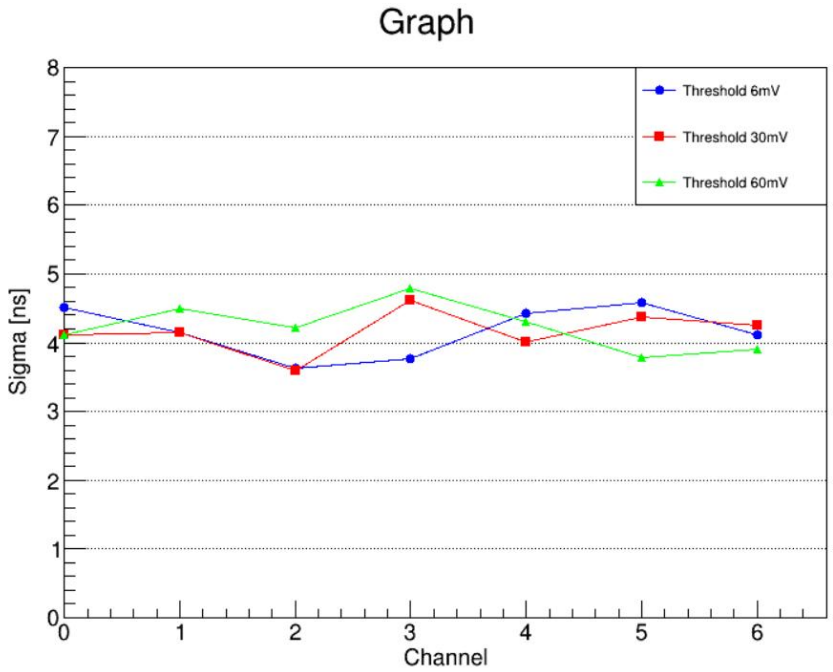
Time performance



leading edge timing to determine over-threshold time



over-threshold time distribution



timing shift

Summary

- Few Shashlyk electromagnetic colorimeters has been build for SoLID experiment at Jlab.
- The irradiation hardness of main material is fine, according the test in IMP.
- Reflect layer and fiber end polish important for the photon collection efficiency.
- For MIP, light yield is higher than 500 PE for most modules, energy resolution lower than 10%.
- The super module will do beam test in future.

Thanks for your attention!