Electromagnetic calorimeter prototype for the SoLID project at Jefferson Lab

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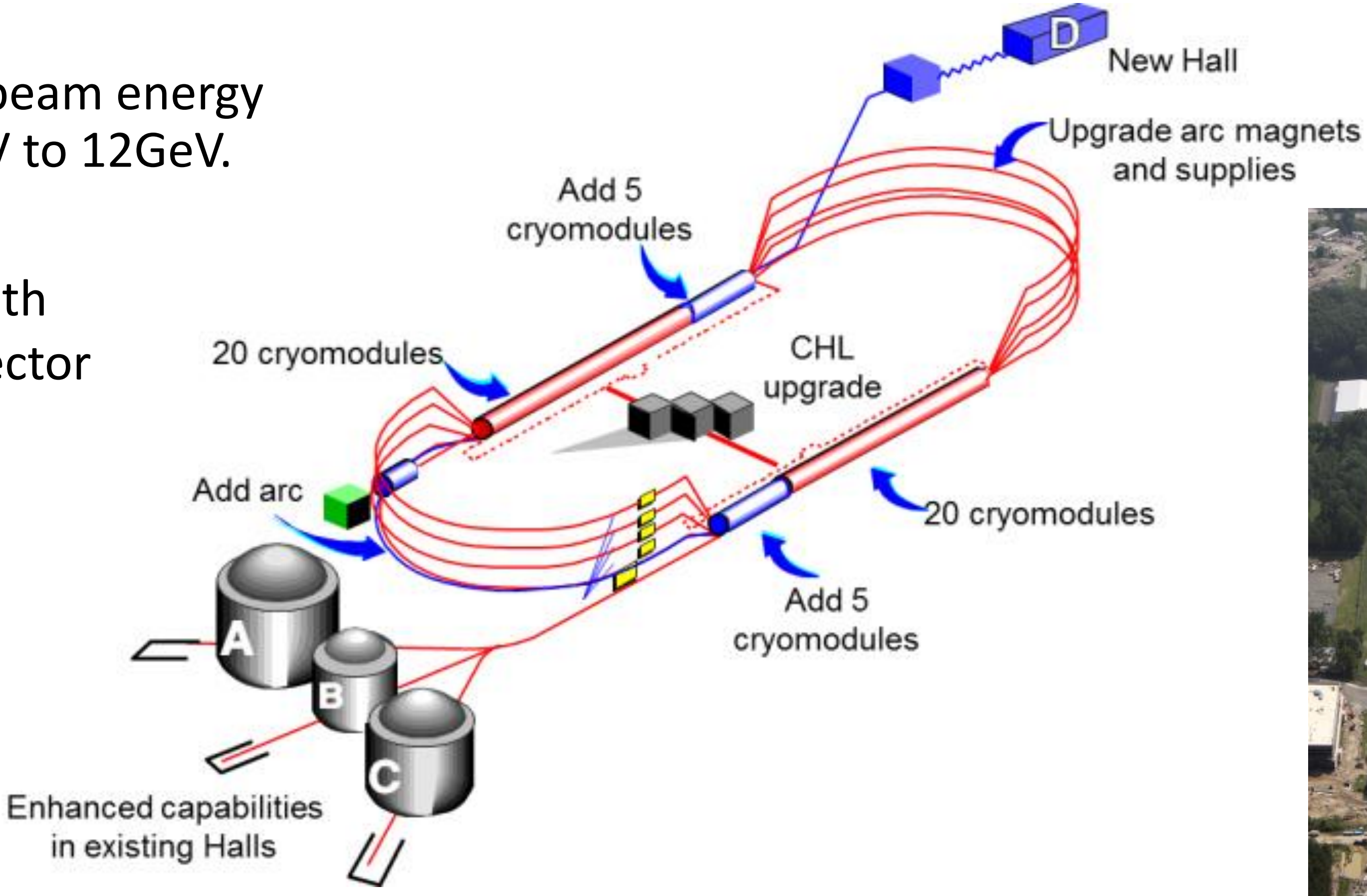
Jefferson Lab Thomas Jefferson National Accelerator Facility

UNIVERSITY of VIRGINIA

JLab 12GeV upgrade

Maximum electron beam energy upgraded from 6GeV to 12GeV.

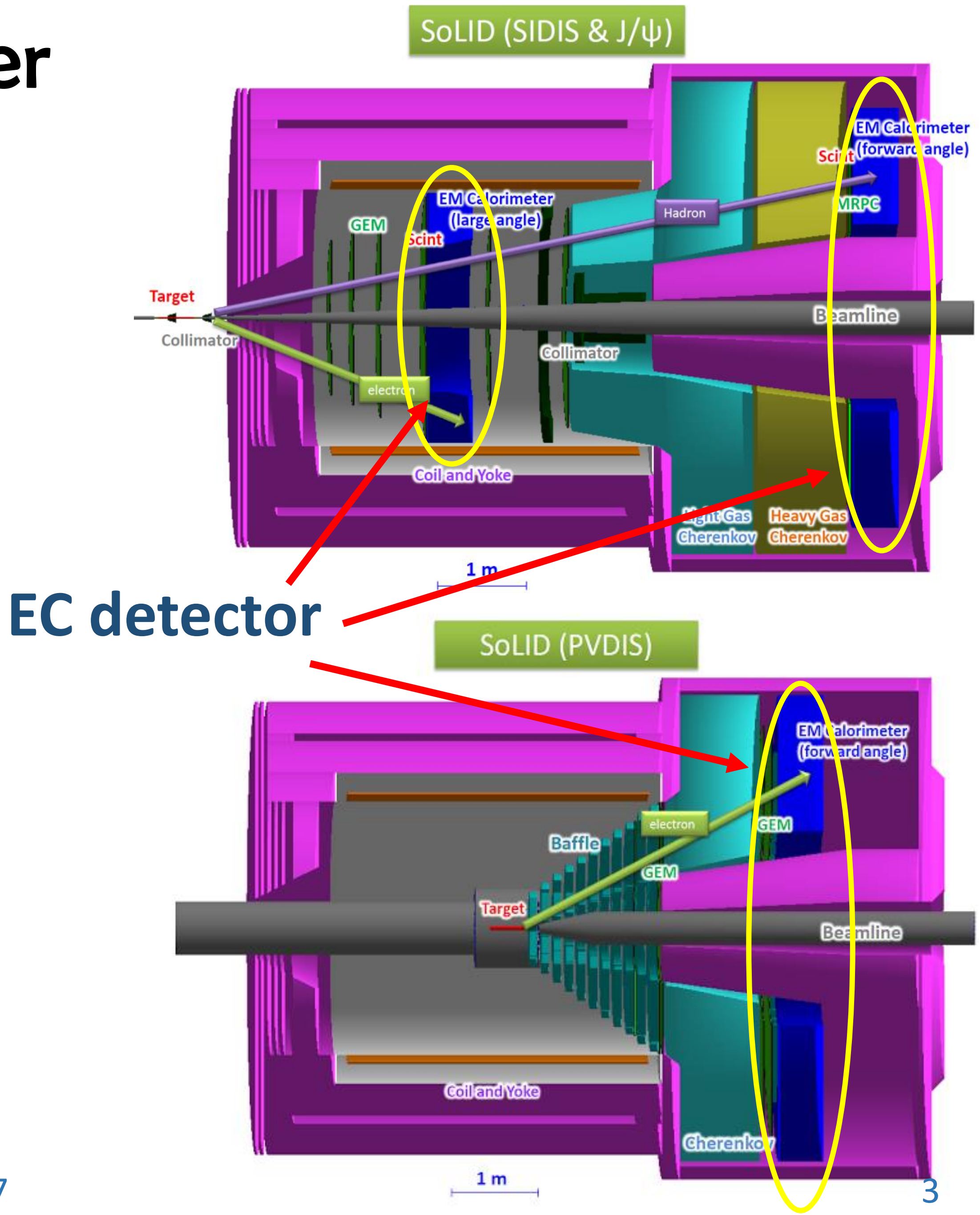
Upgrade includes both accelerator and detector in each Hall.



Continuous Electron Beam Accelerator Facility (**CEBAF**)

SoLID project and EM calorimeter
(Solenoidal Large Intensity Device)

- SoLID proposed in Hall A for 5 approved experiment in 12 GeV era.
  - Requires high luminosity and large acceptance.
- Two detector configurations:
  - "SIDIS" (Semi-Inclusive Deep Inelastic Scattering)
  - "PVDIS" (Parity-Violating Deep Inelastic Scattering)
  - Electromagnetic calorimeter(EC) shared in both configurations



EC Design Requirements

1. Provide trigger: coincidence with Cherenkov detector, suppress background

2. Electron- hadron separation:
   - >100:1 π rejection ;
   - Electron efficiency > 95%;

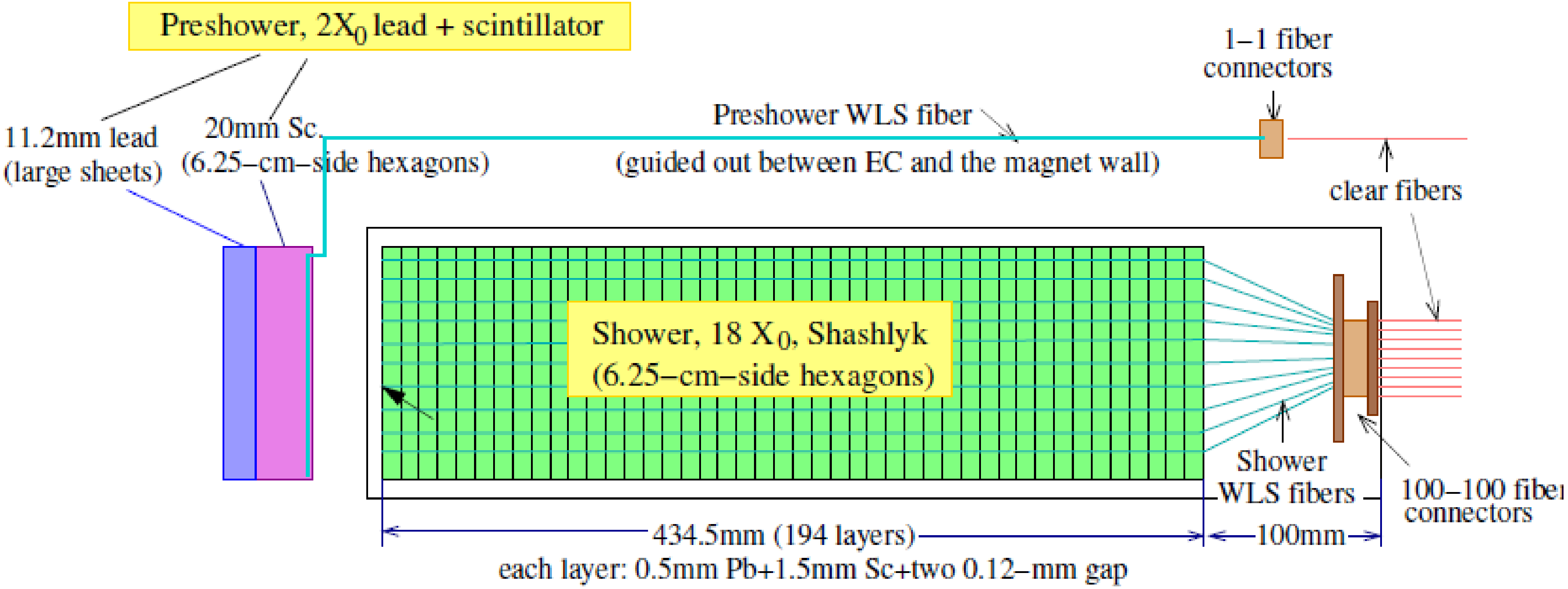
3. Provide shower position to help tracking/suppress background
   - σ ~ 1 cm

4. Modules easily swapped and rearranged for PVDIS ↔ SIDIS;

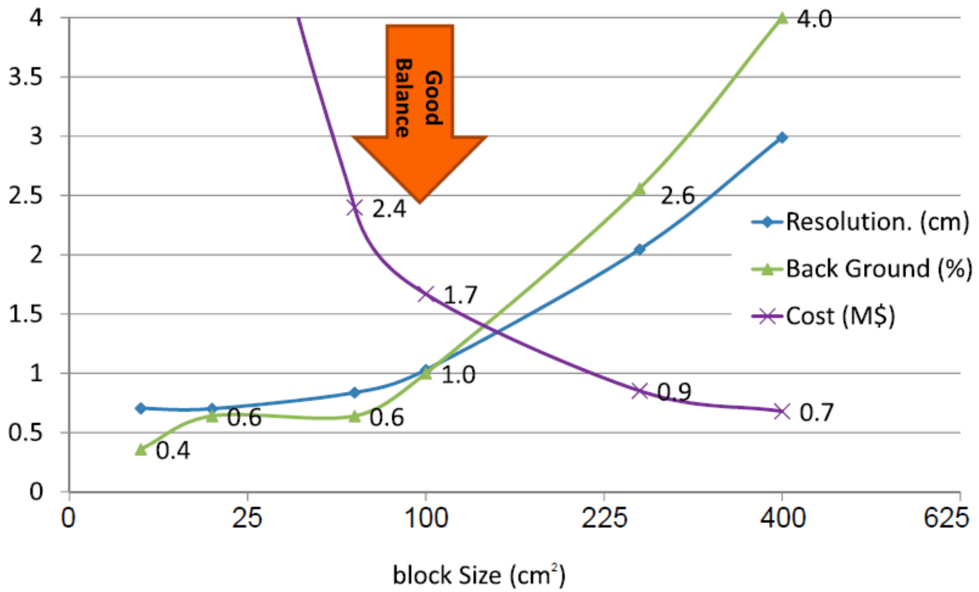
Shashlik EC Longitudinal design

- Preshower: 2 X_0 lead + 20 mm plastic scintillator, WLS fiber embedded in scintillator.
- Shower: shashlik module (0.5mm lead + 1.5mm scintillator + 0.1mm paper sheet×2) ×194,

  WLS fiber×96 penetrating layers longitudinally.
- Overall: 20 X_0(<2% leakage), energy resolution less than $10\%/\sqrt{E}$(GeV)

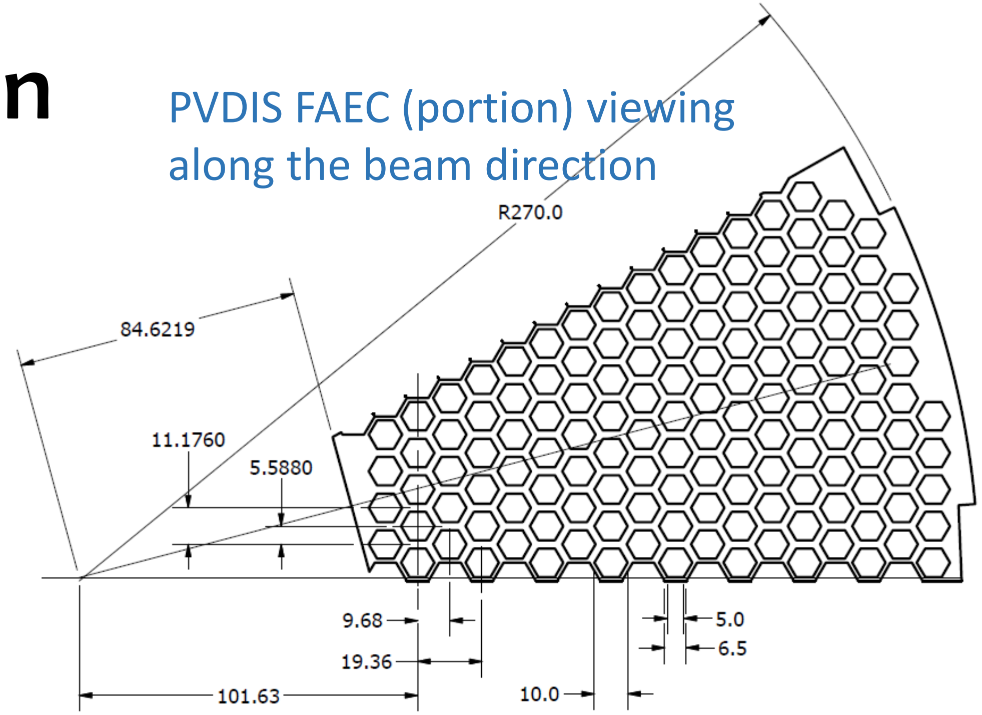


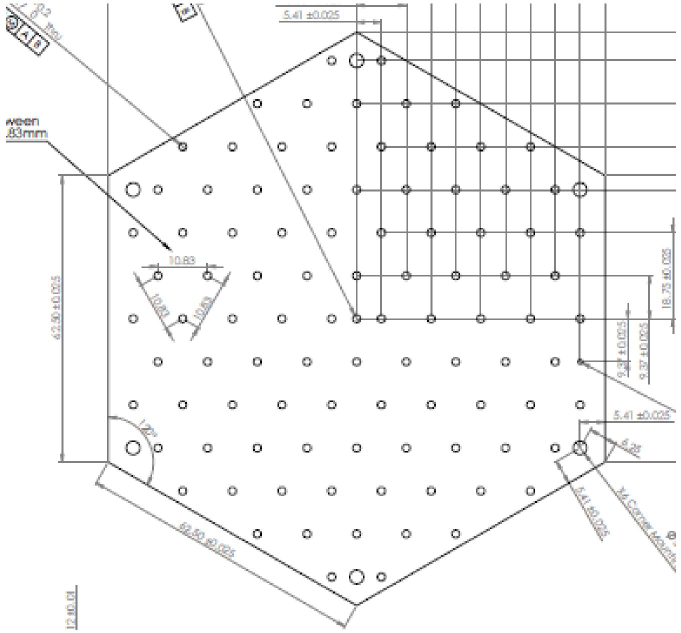
Shashlik EC Lateral design



Good balance between resolution, background and cost(simulation) for 100cm^2 block size.

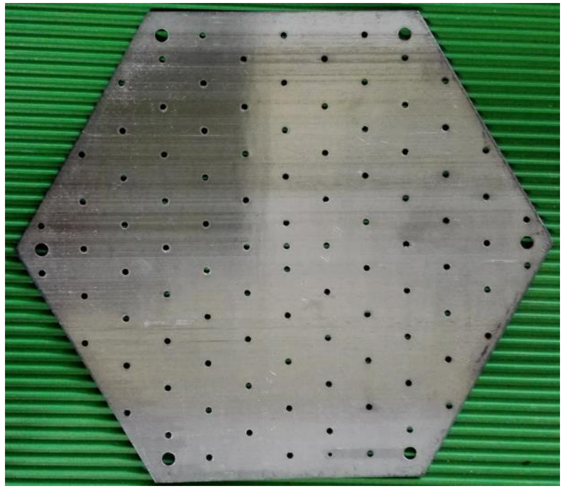
PVDIS FAEC (portion) viewing along the beam direction

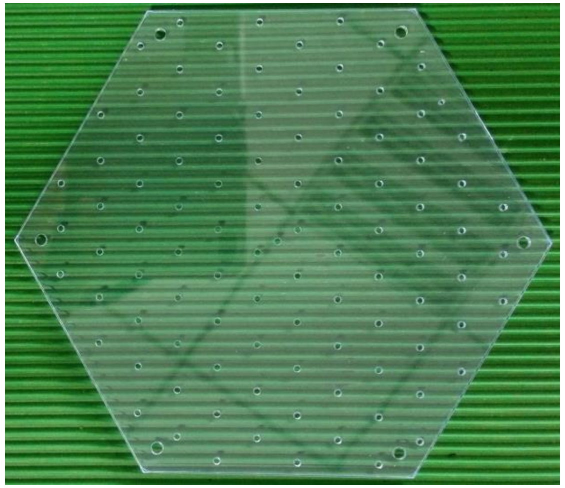


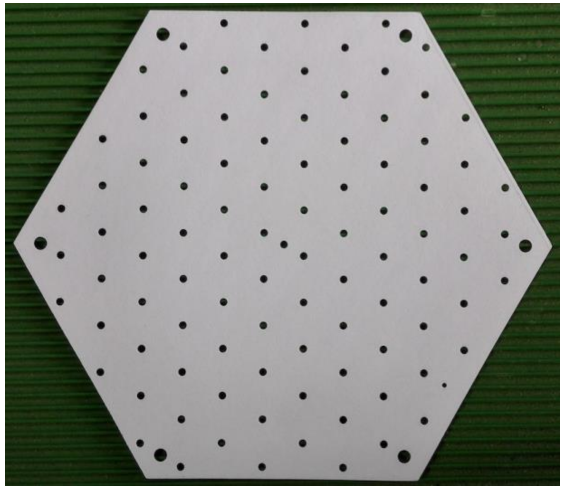


- 100 cm^2 of hexagon shape with 6.25cm side length

Main materials in Shashlik EC detector


Lead plate


Scintillator tile

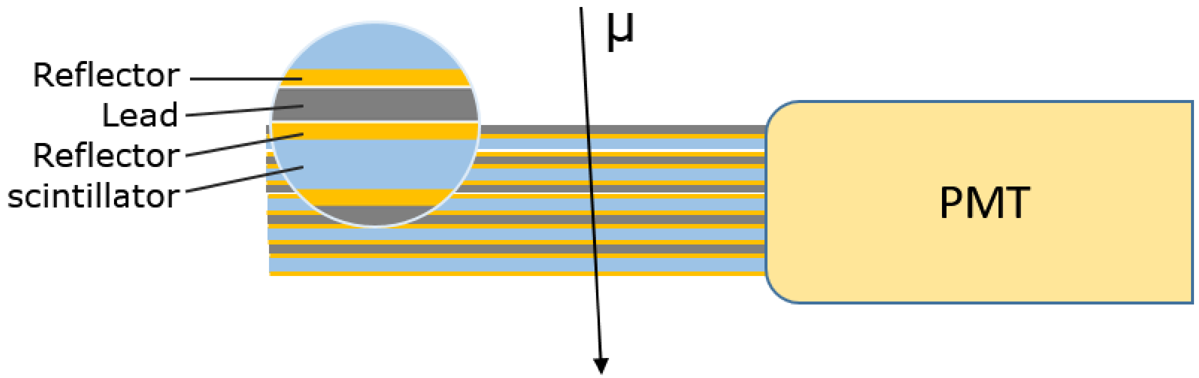

Reflector layer (paper)

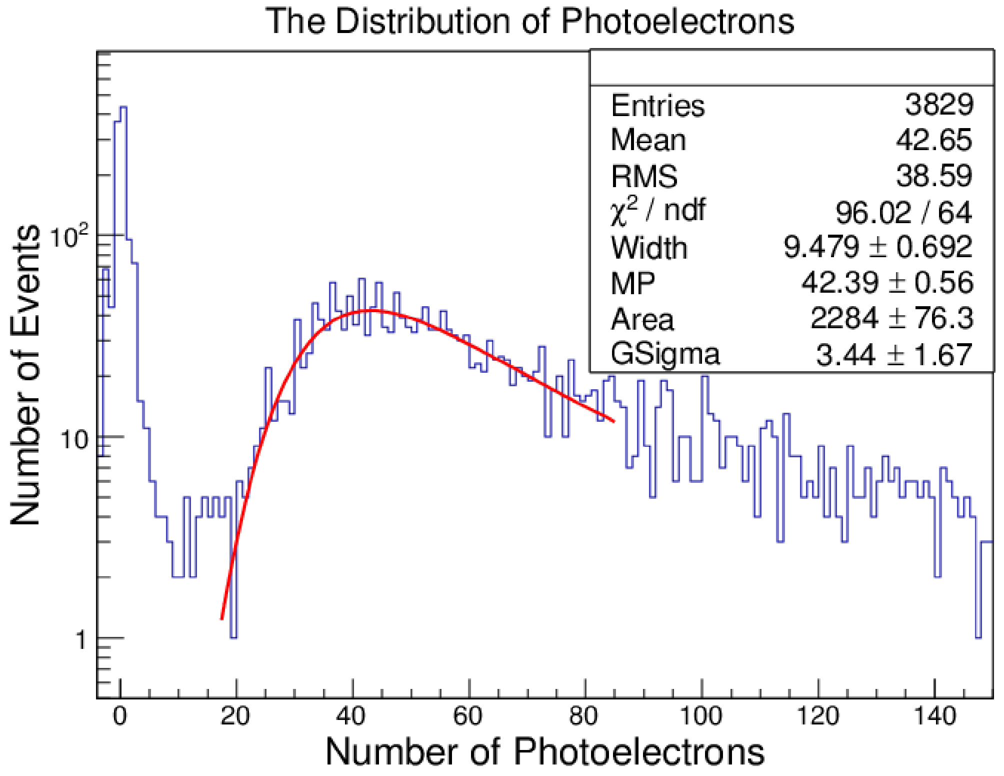

1mm WLS fiber

- Scintillator Tile:
  - Manufacture in Kedi, China
  - Casting with special mould
  - 2 formulas: normal/enhanced
  - Match the absorption spectrum of WLS fiber
- Lead Plate: punching
- Reflection Layer: print paper
- WLS Fiber:
  - BCF91A (Saint-Gobain)
  - Y11 (Kuraray)

Reflector layer selection

Cosmic ray test setup: 5 layers of shashlik style





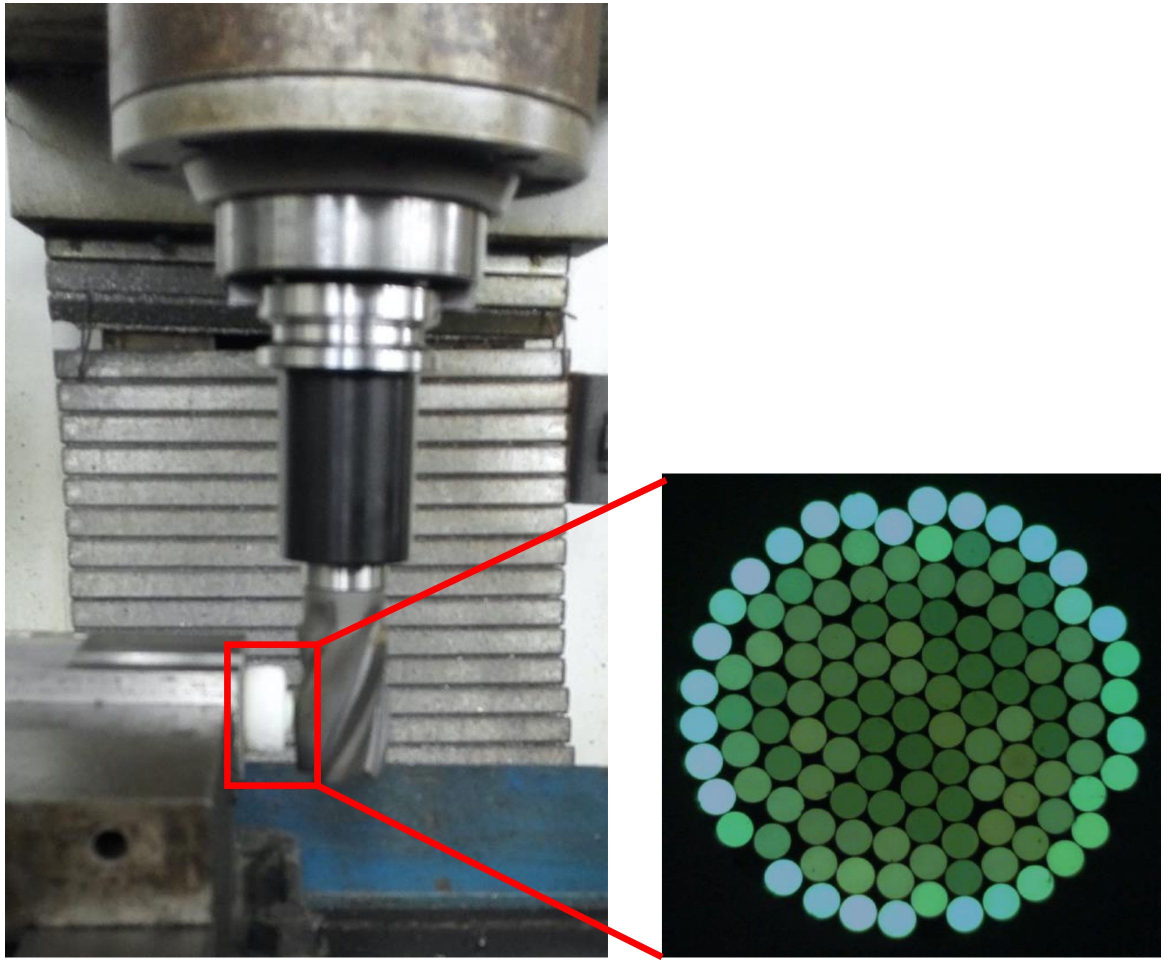
Typical number of photoelectrons distribution

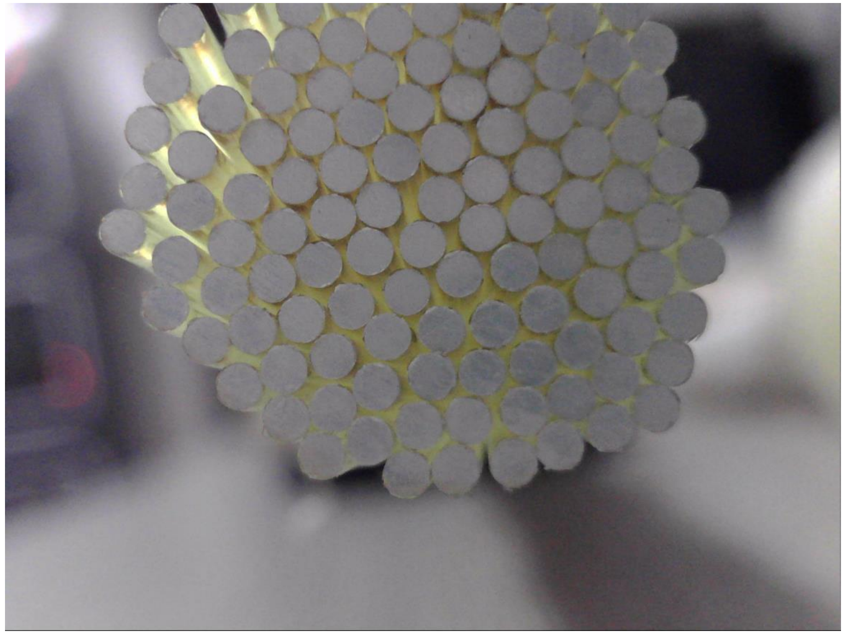
Reflector layer test result

Reflector material	No reflector	Printing Paper	Aluminum foil	Tyvek paper	MCPET
Relative light yield	0.85±0.02	1.00±0.06	0.97±0.08	1.61±0.16	1.24±0.05

Fiber polishing and mirror

Fiber polishing in bundle by milling machine



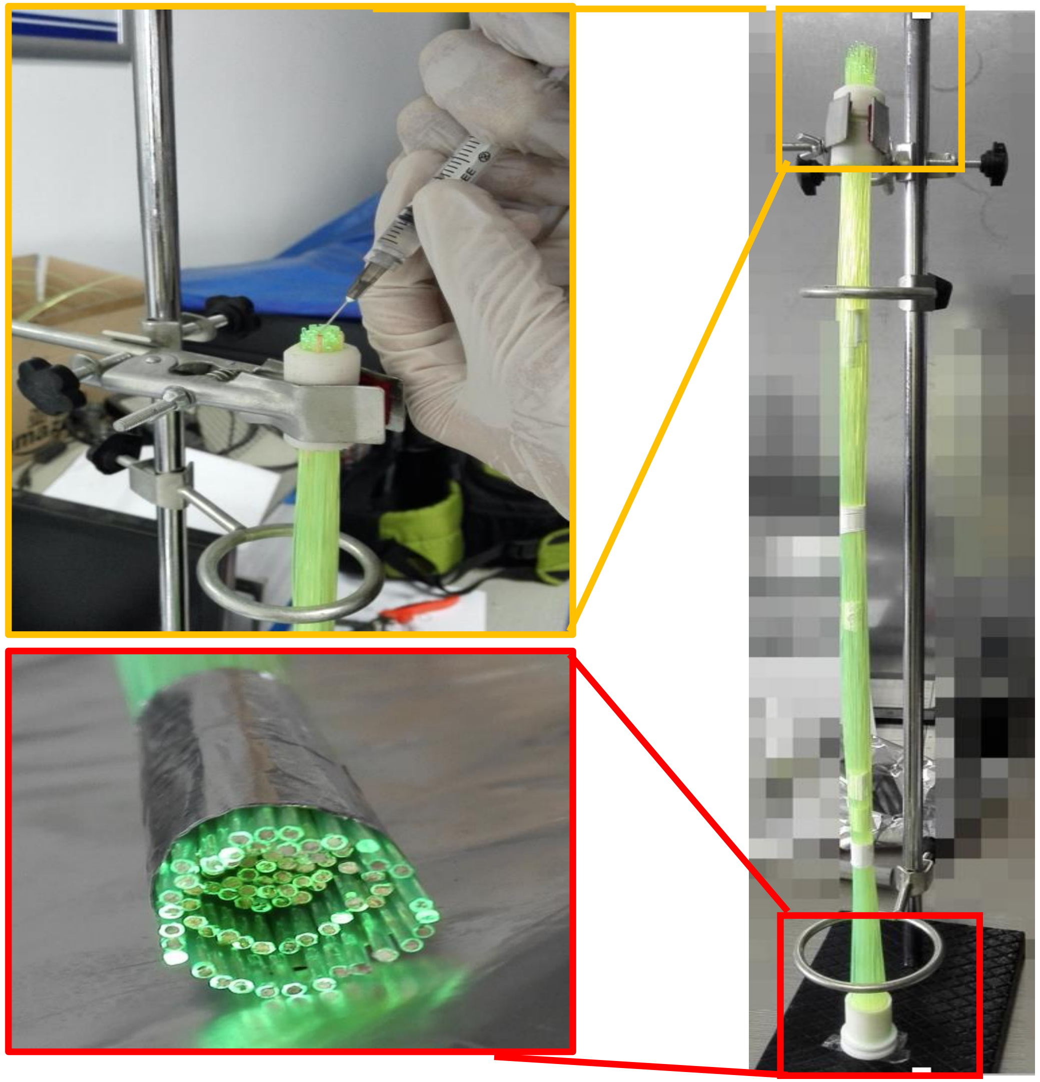


After mirror coating by sputtering.
Light yield **increase 70%** than without mirror.

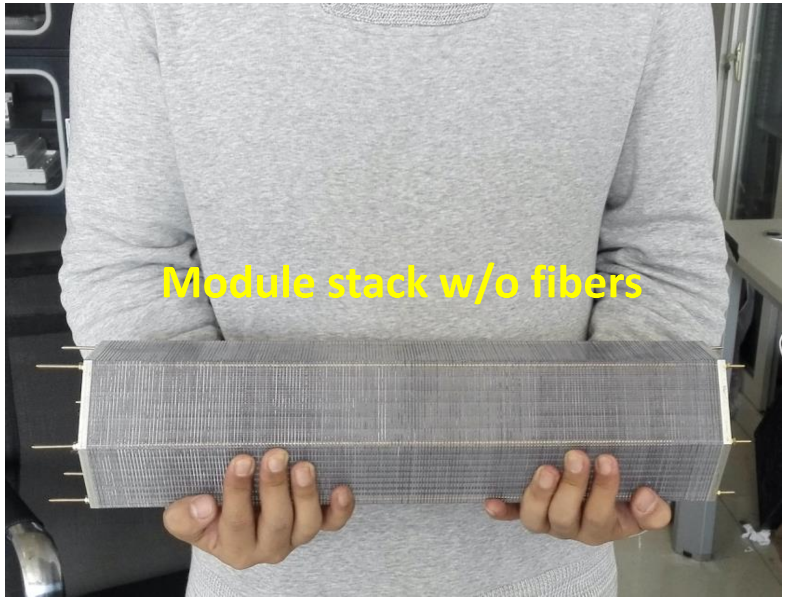
Fiber Shaping

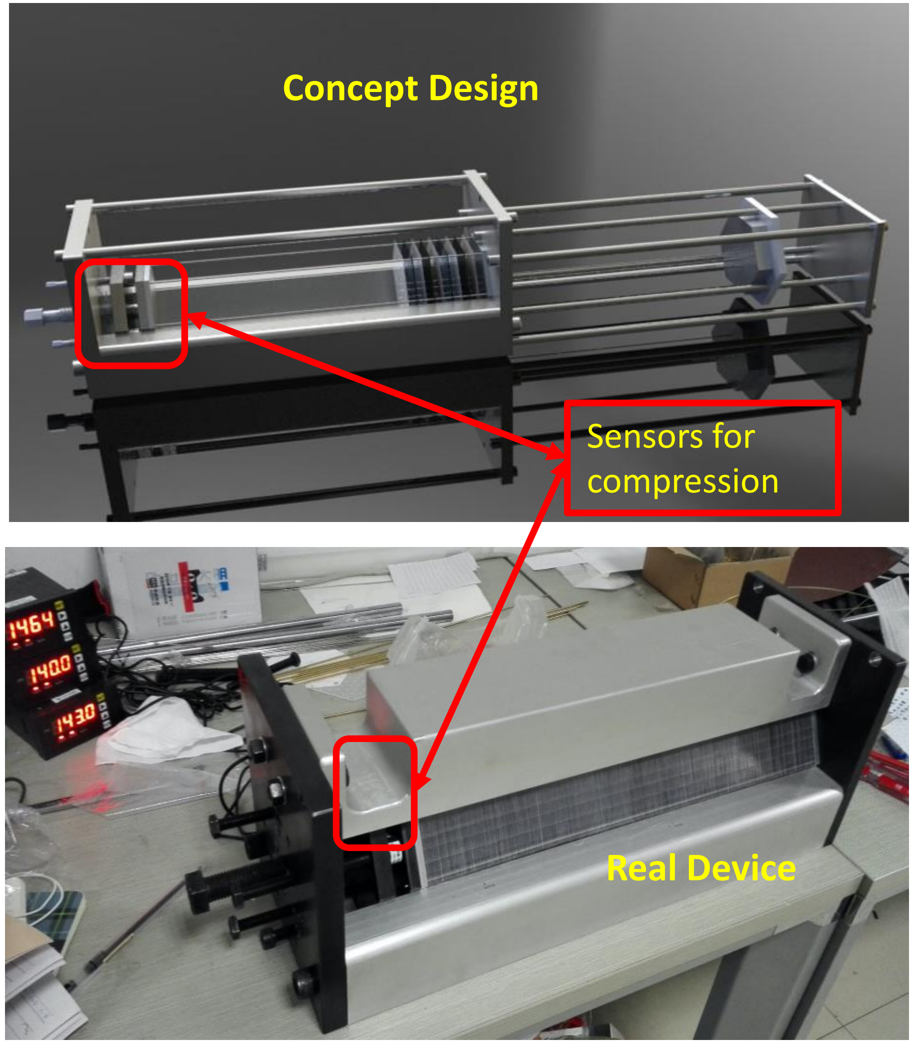
Glue fibers & hold together,
Polishing by milling machine also

The unbundled end of fibers with mirror,
separated into 3 different lengths for fiber insertion



Assembly tool





- Stack all the scintillator tiles, lead plates, and reflectors together
- Compress the module stack for 48 hours

Prototypes

- Three shashlik prototypes assembled in Shandong University.

PMT: Hamamatsu R11102 (Set the Gain equal to 5*10^6 in test)

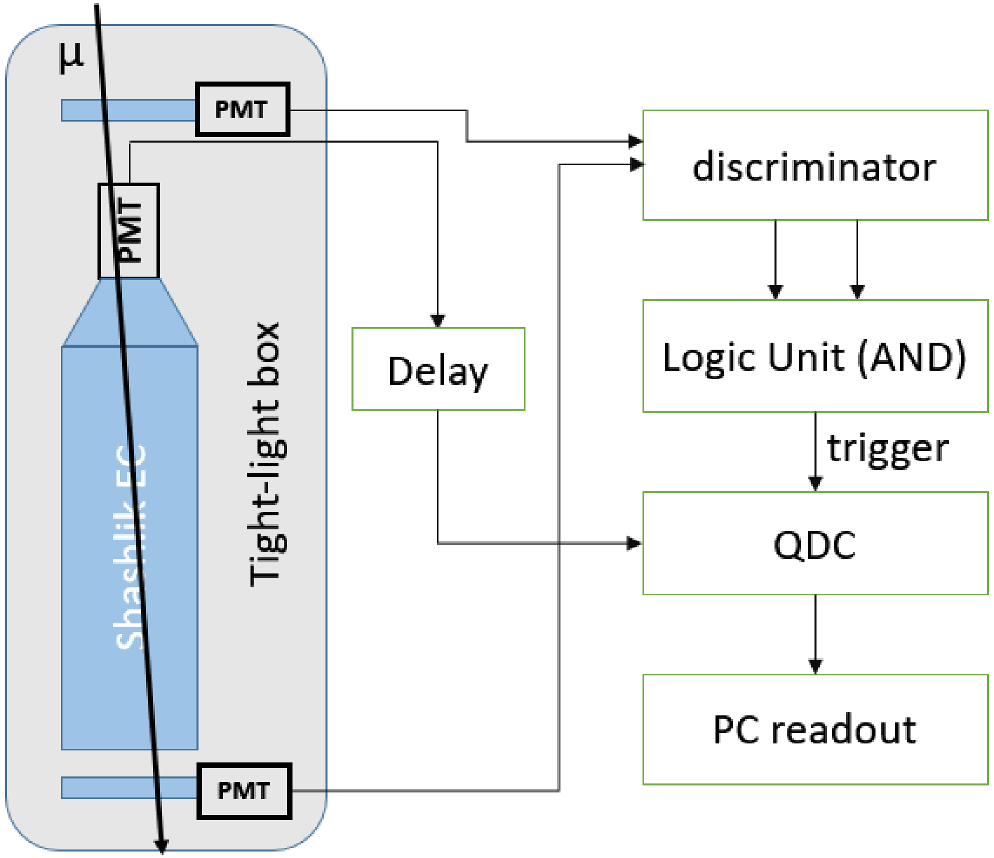
wrapped by Tyvek paper

Coated by the mixture of TiO2 and glue.

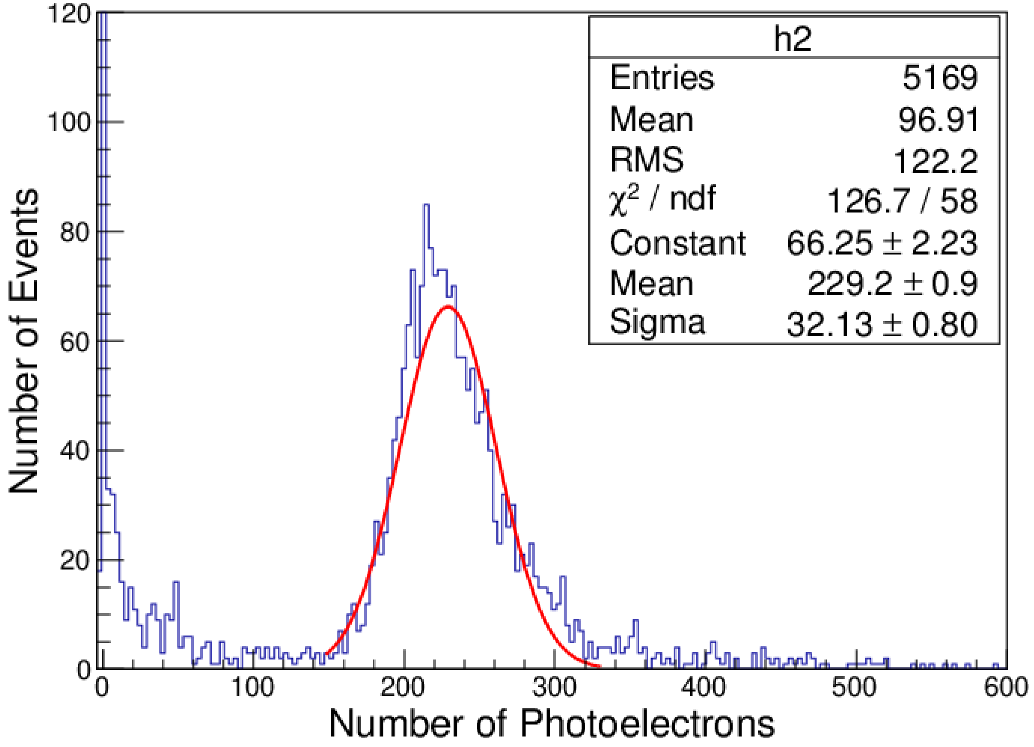
Three shashlik prototypes material list:

Prototype No.	WLS fiber	Fiber reflector	Scintillator	Painting	Reflector layer
#1	BCF91A	No reflector	Original	TiO2+glue	Paper
#2	BCF91A	Silver mirror	Enhanced	TiO2+glue	Paper
#3	Y11	Silver mirror	Enhanced	TiO2+glue	Paper

Cosmic ray test setup and typical photo-electron distribution

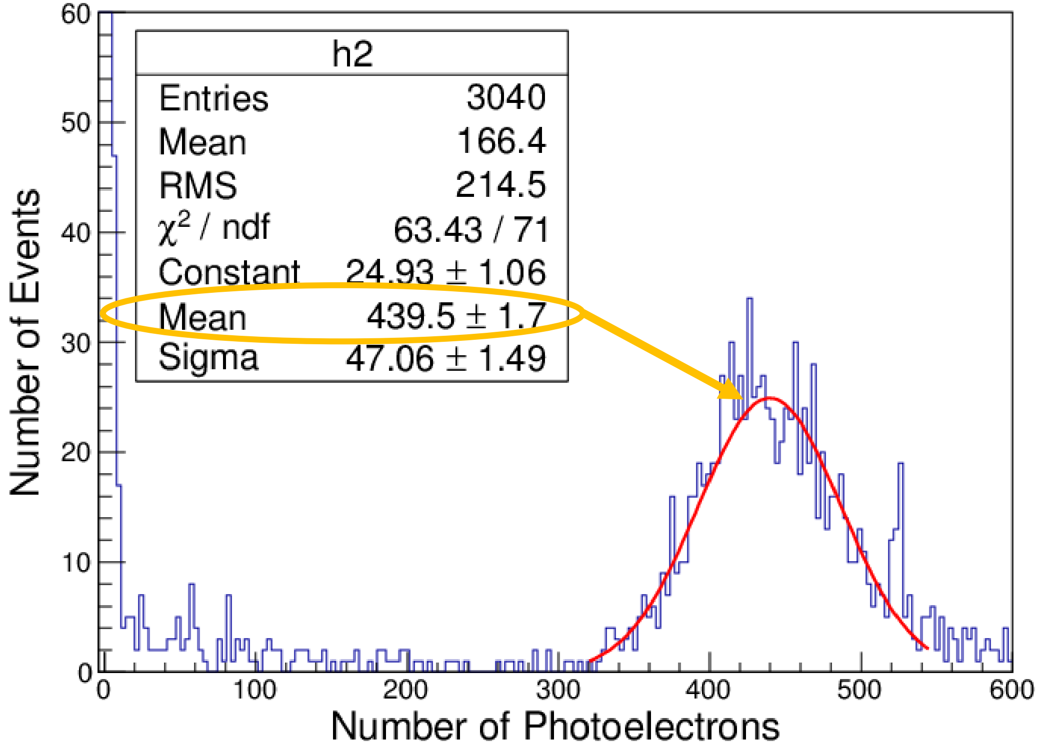


First module #1 result.

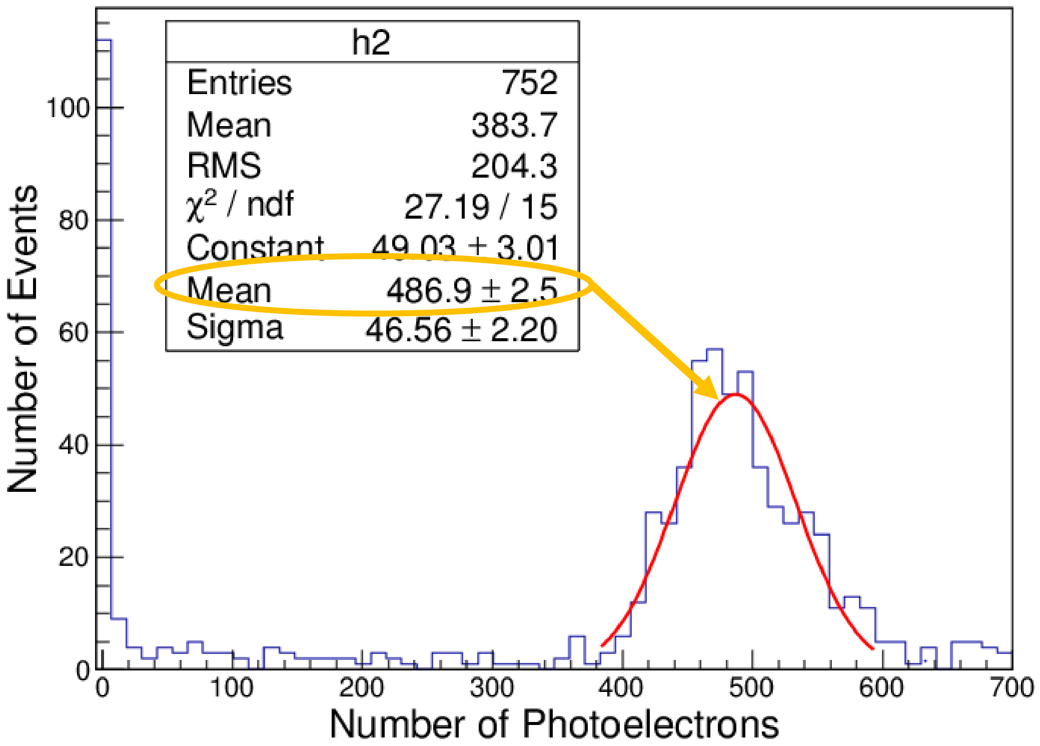


Prototype module cosmic ray test result

Prototype #2 test result



Prototype #3 test result



Cosmic ray test result

Module No.	NPE	NPE (W/O TiO2)	WLS fiber	Scintillator	Fiber reflector	Painting	Reflector layer
SDU #1	229.2		BCF91A	Kedi	No mirror	TiO2+glue	Print paper
SDU #2	439.5		BCF91A	Kedi(enhanced)	Silver mirror	TiO2+glue	Print paper
SDU #3	486.9	381.3	Y11	Kedi(enhanced)	Silver mirror	TiO2+glue (1:1)	Print paper

- Enhanced scintillator and mirror: light yield increase 95%
- Coating with TiO2: increase 26.2%
- Y11 compared with BCF91A: increase 17%

Summary

- All the machining accuracy is well controlled.
  - problem for tyvek punching resolved recently.
- Know well of assembling the shashlik module.
- maximum light yield near 500 photoelectrons for single muon in the best module.
  - Still lower than SoLID proposal.
- Finding the way to increase the light yield.

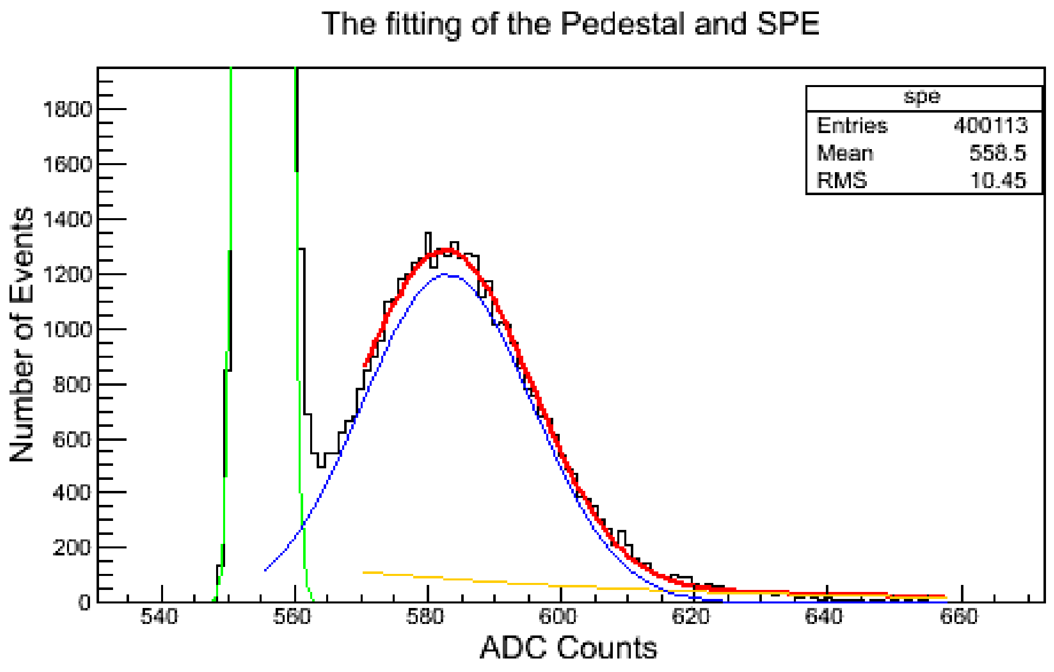
Thanks for your attention!

Thank You

Backups

PMT absolute gain and NPE(number of photoelectrons)

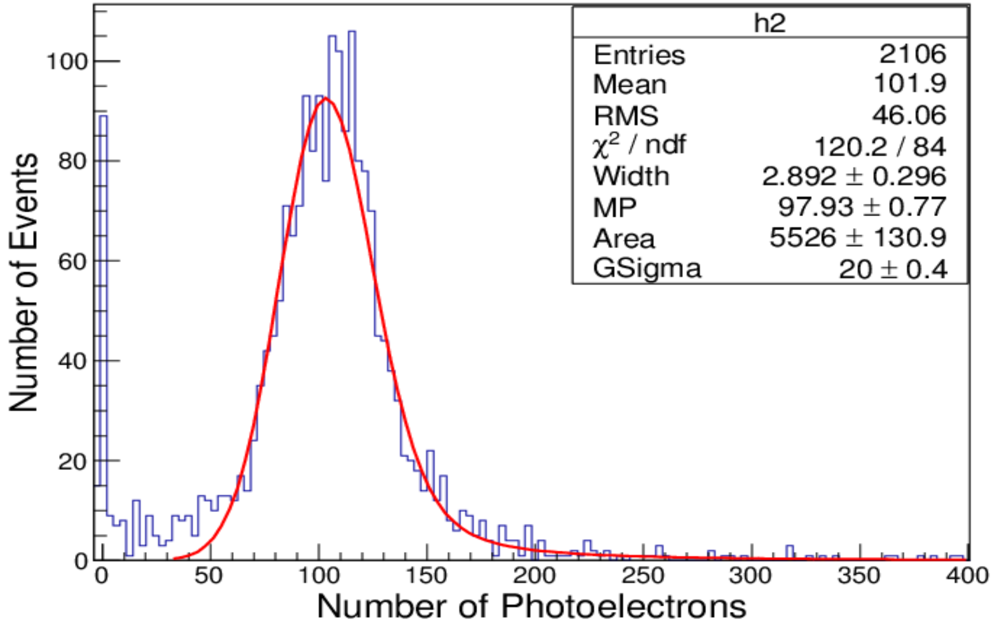
Single photoelectron spectrum



$$Gain=(ADC_{signal}-ADC_{pedestal})\times LSB/e$$

- LSB is the QDC least significant bit which is equal to 0.029 pC
- e is single electron charge.

Prototype NPE spectrum



$$NPE=Q/(e\times Gain)$$

- Q is charge acquired from QDC with pedestal subtracted.
- Fitted by convolution of Gauss and Landau.