

# R&D activities at UMass

**Sayak Chatterjee**

**UMass, Amherst**

## **Group members**

**Undergrad students:**

**Luc Barret  
Steven Zhang**

**Grad students:**

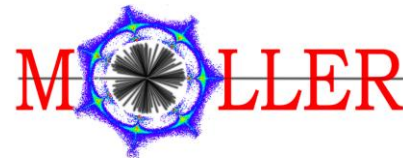
**Jonathon Mott  
Jhih-Ying Su  
Sakib Sarker**

**Postdoc:**

**Andrew Hurley  
Sayak Chatterjee**

**Supervisor**

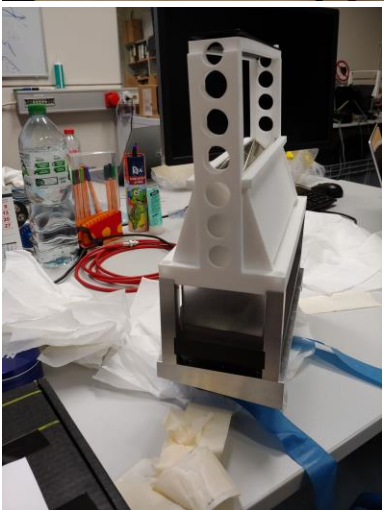
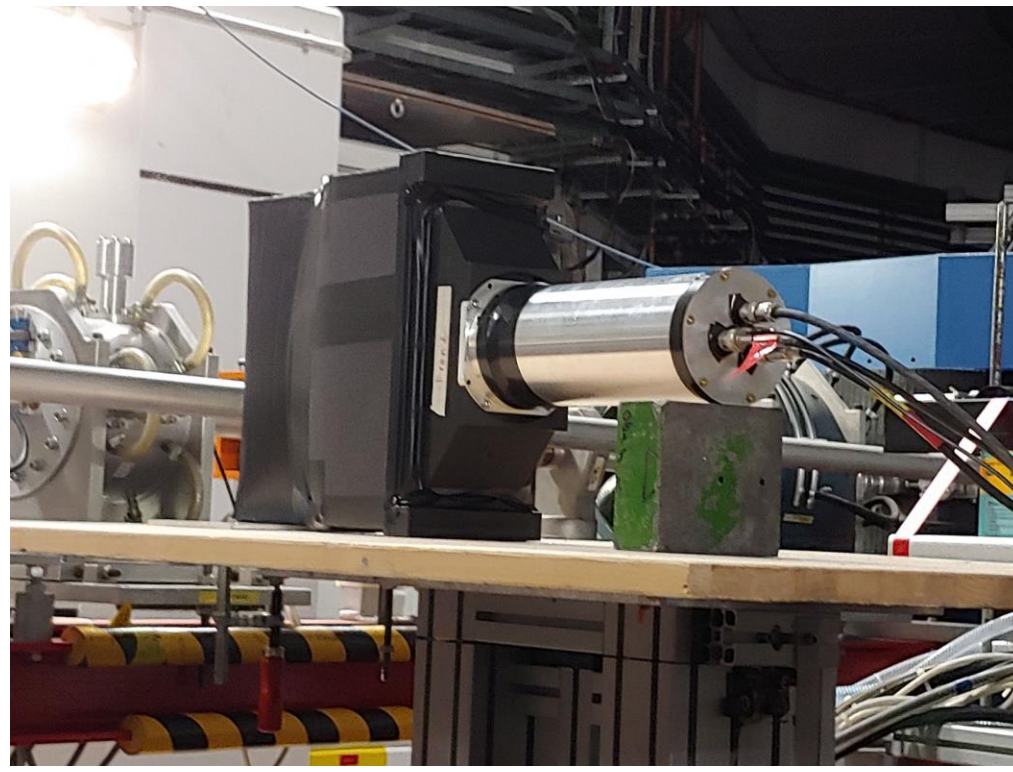
**Prof. Krishna Kumar**



# Outline

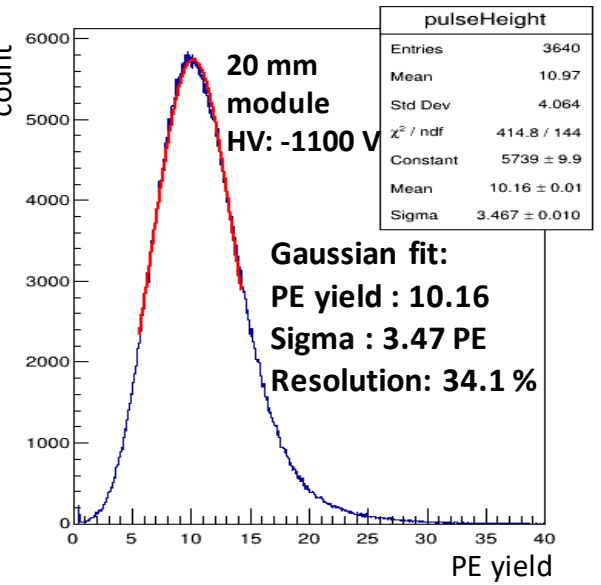
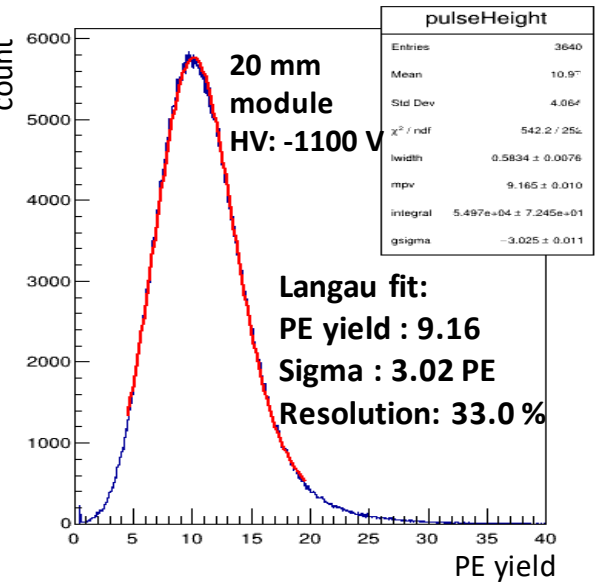
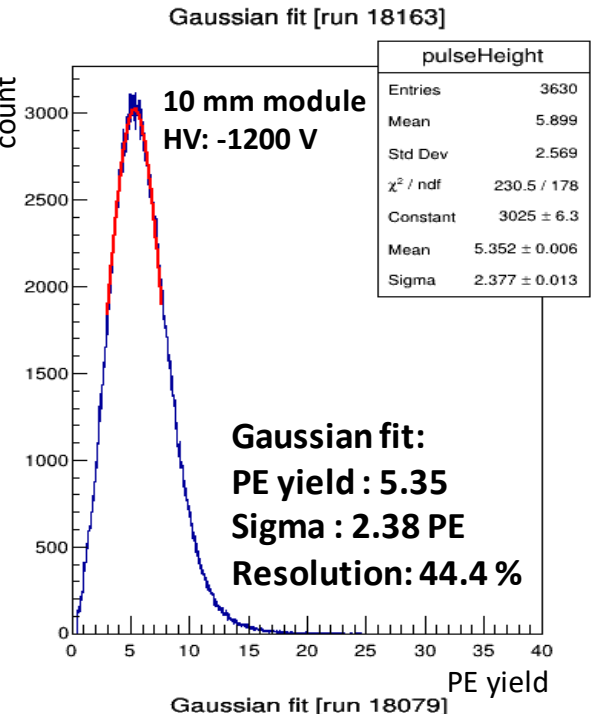
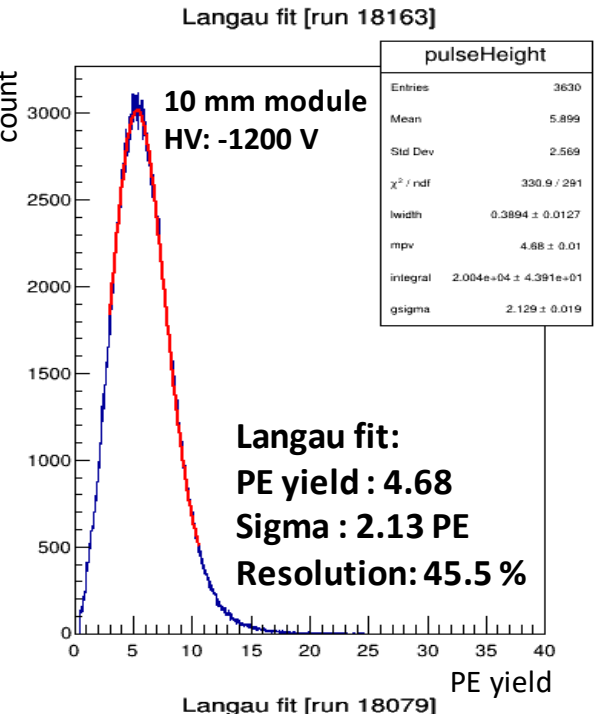
- **R&D on the ring 6 quartz detector**
  - **Performance of the Ring 6 quartz detector at the MAINZ test beam (Nov 2022)**
    - 10 mm R6 module (Heraeus) & 20 mm R6 module (Tosoh)
  - **Performance of the Ring 6 quartz detector with the cosmic muons at UMass**
    - 10 mm R6 module (Heraeus) & 20 mm R6 module (Tosoh)
  - **Comparison of the detector performance with electron beam and cosmic test**
  - **Comparison of the data with simulation**
  - **R&D on the reflective light guide material**
    - Miro-silver & Mylar
- **Large cosmic stand at UMass (80/20 structure)**
- **R&D on single mask triple GEM chamber prototypes**
- **Summary & outlook**

# Beam test at MAINZ (November 2022)



- Tested R6 QUARTZ detectors of 10 mm and 20 mm thicknesses with electron beam
- The 20 mm module used Tosoh QUARTZ (fused quartz tile)
- The 10 mm module used Heraeus QUARTZ
- Miro-silver is used as the light-guide reflecting material for both the modules

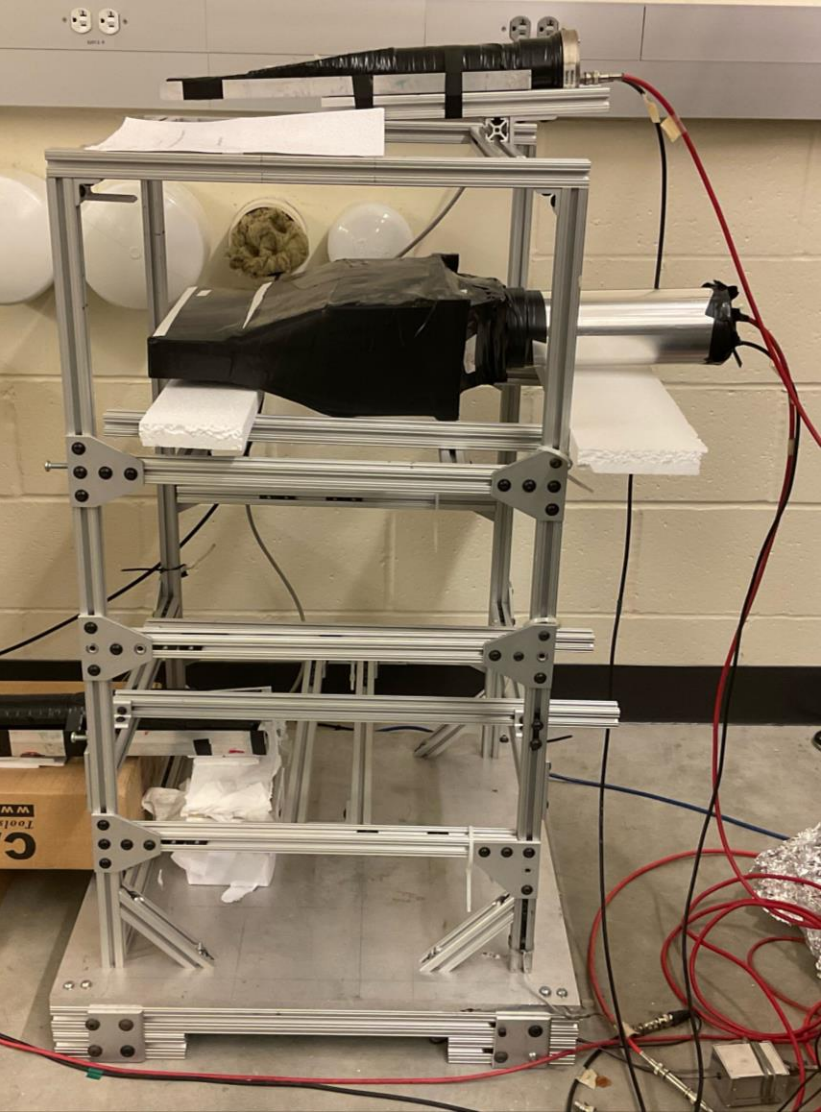
# Beam test at MAINZ (November 2022): Summary



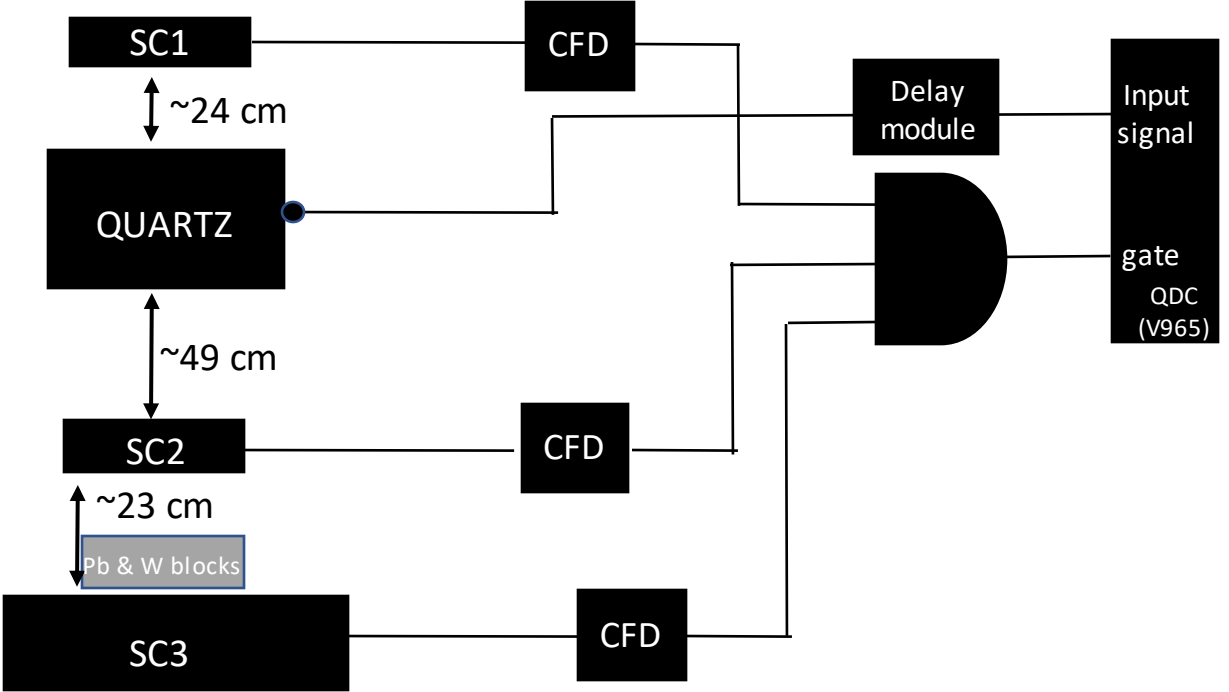
Module	Quartz tile	HV (V)	PE yield	Sigma (PE)
10 mm	Heraeus	-1200	4.68 (Langau)	2.13 (Langau)
			5.35 (Gaussian)	2.38 (Gaussian)
20 mm	Tosoh	-1100	9.16 (Langau)	3.02 (Langau)
			10.16 (Gaussian)	3.47 (Gaussian)

- We got 4-5 PE yield with the 10 mm module and 9-10 PE yield with the 20 mm module
- Probable reason for the low PE yield:
  - Miro-silver as the reflective light-guide material
  - Effect of Tosoh quartz (20 mm module)

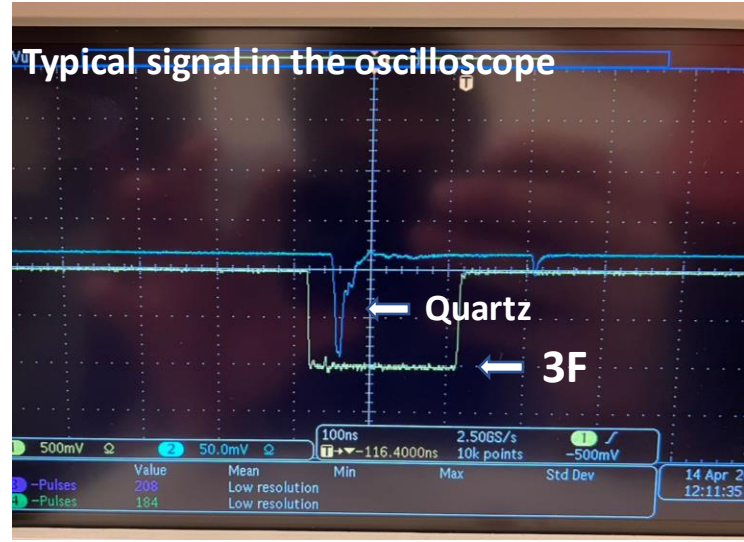
# Cosmic test setup at UMass



Cosmic stand at UMass



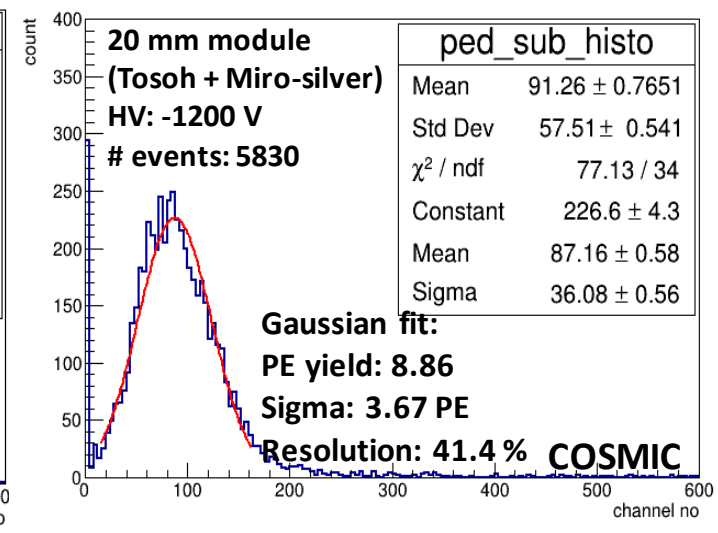
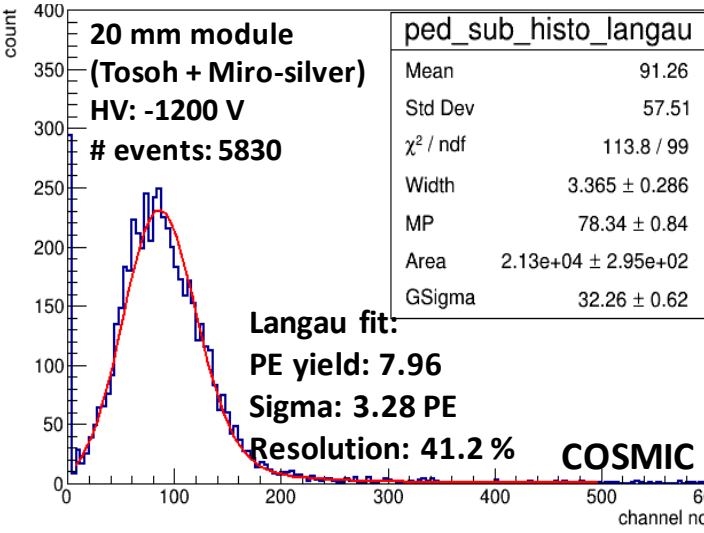
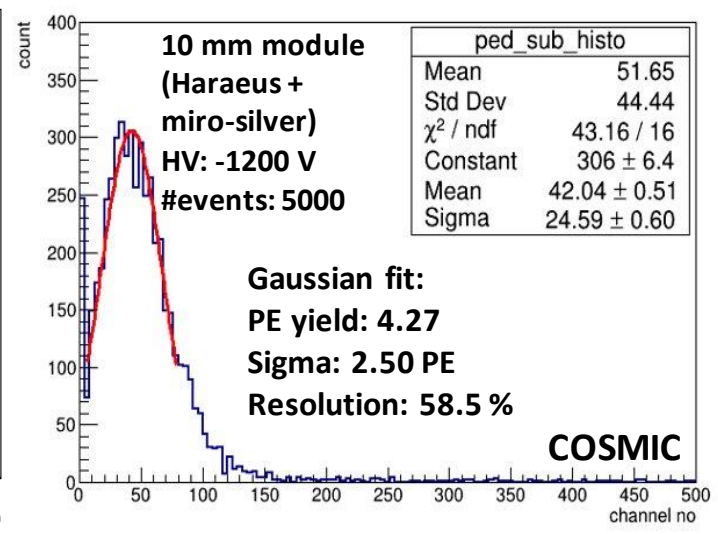
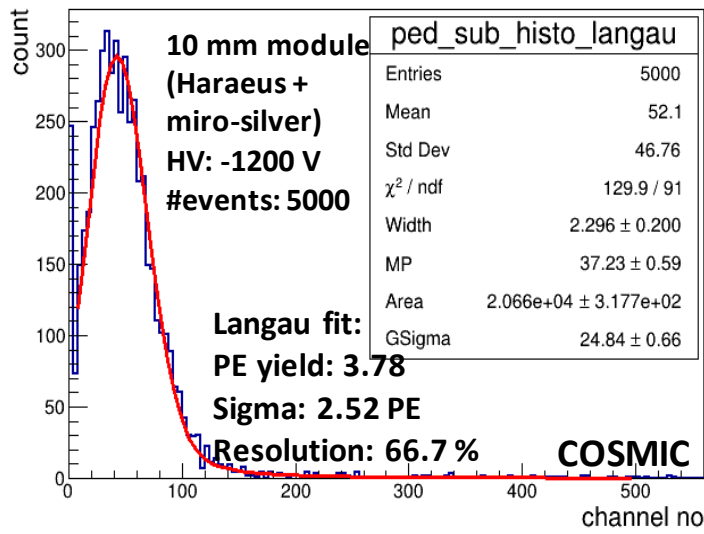
Schematic of the electronic circuit diagram for the cosmic test



Typical signal in the oscilloscope

- Overlap window: 9 cm X 9 cm
- Delay: 60 ns
- HV for the Quartz detector: - 1200 V
- Gain of QDC: 200 fC/channel
- SC1: 9 cm x 9 cm x 1.5 cm
- SC2: 9 cm x 9 cm x 1.5 cm
- SC3: 30 cm x 30 cm x 2 cm
- QUARTZ: 9 cm x 29 cm x 2 (1) cm
- QDC: CAEN V965 (16 CH)

# Cosmic test at UMass: Summary



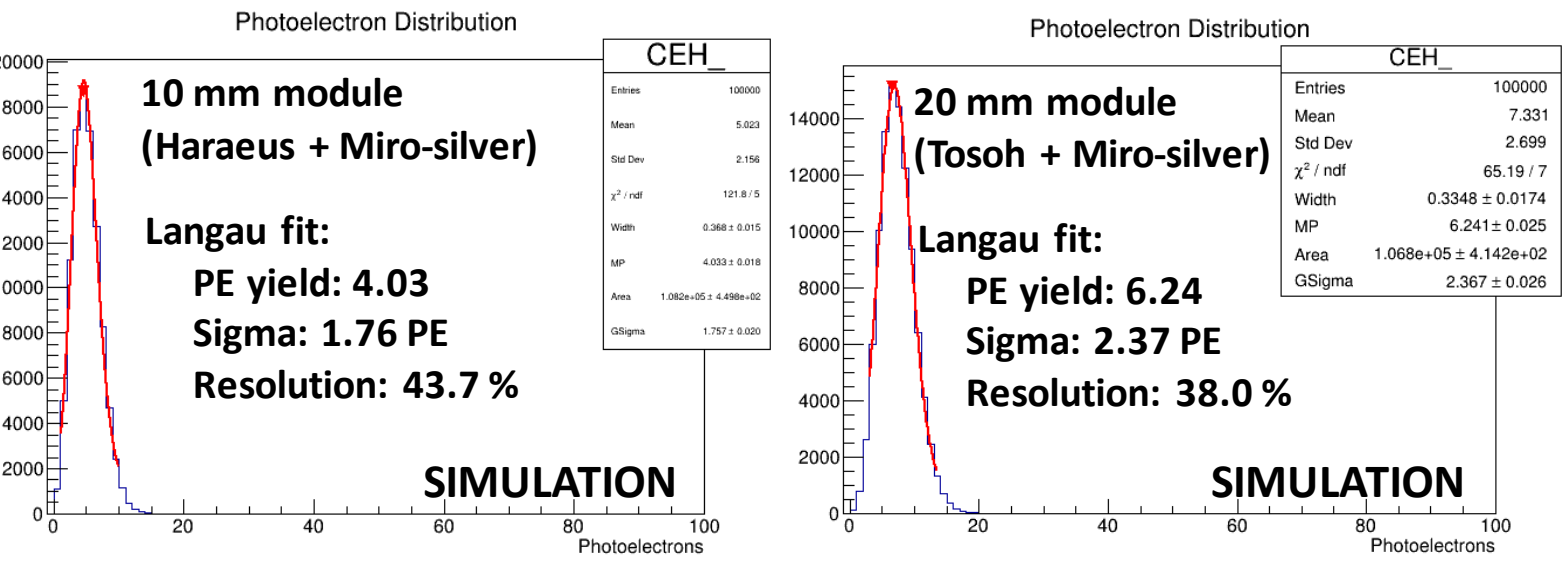
## Comparison of the beam and cosmic data

Quartz tile	PE yield (Beam)	PE yield (Cosmic)	Sigma (PE) (Beam)	Sigma (PE) (Cosmic)
Heraeus (10 mm)	4.68 (Langau)	3.78 (Langau)	2.13 (Langau)	2.52 (Langau)
	5.35 (Gaussian)	4.27 (Gaussian)	2.38 (Gaussian)	2.50 (Gaussian)
Tosoh (20 mm)	9.16 (Langau)	7.96 (Langau)	3.02 (Langau)	3.28 (Langau)
	10.16 (Gaussian)	8.86 (Gaussian)	3.47 (Gaussian)	3.67 (Gaussian)

Red -> Langau fit  
 Blue -> Gaussian fit

- We are getting ~10 – 20 % less PE yield from the modules with cosmic test as compared to the beam test
- We are getting ~ 10% broader spectra from cosmic test as compared to the beam data
- The broader spectrum with cosmic is due to the inclined tracks and that is also affecting the PE yields

# Simulation with Moller Optical framework



- Simulation is performed using Moller Optical simulation framework
- 8 GeV electrons are fired at the center of the quartz
- Simulation is performed with different configuration of quartz tiles and light-guide materials
- Spectra are fitted with Langau distribution to get the PE yield and sigma

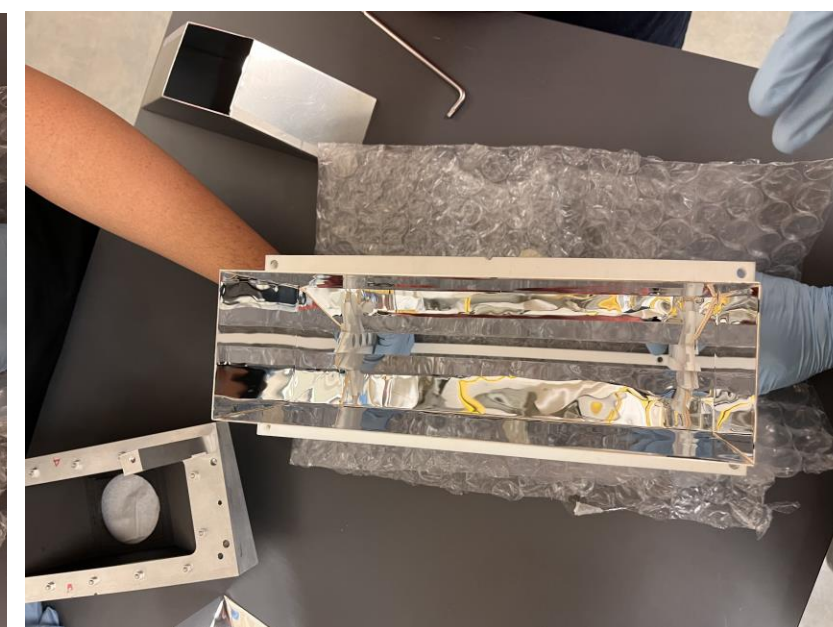
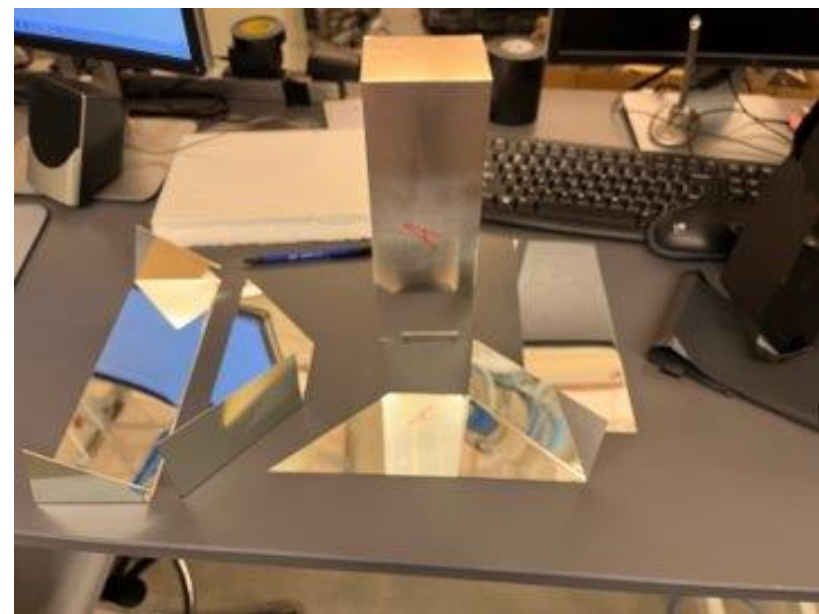
Quartz tile	PE yield (Simulation)	PE yield (Cosmic)	PE yield (Beam)	Sigma (PE) (Simulation)	Sigma (PE) (Cosmic)	Sigma (PE) (Beam)
Heraeus (10 mm)	4.03 (Langau)	3.78 (Langau)	4.68 (Langau)	1.76 (Langau)	2.52 (Langau)	2.13 (Langau)
Tosoh (20 mm)	6.24 (Langau)	7.96 (Langau)	9.16 (Langau)	2.37 (Langau)	3.28 (Langau)	3.02 (Langau)

**Simulation agrees well with beam and cosmic data**

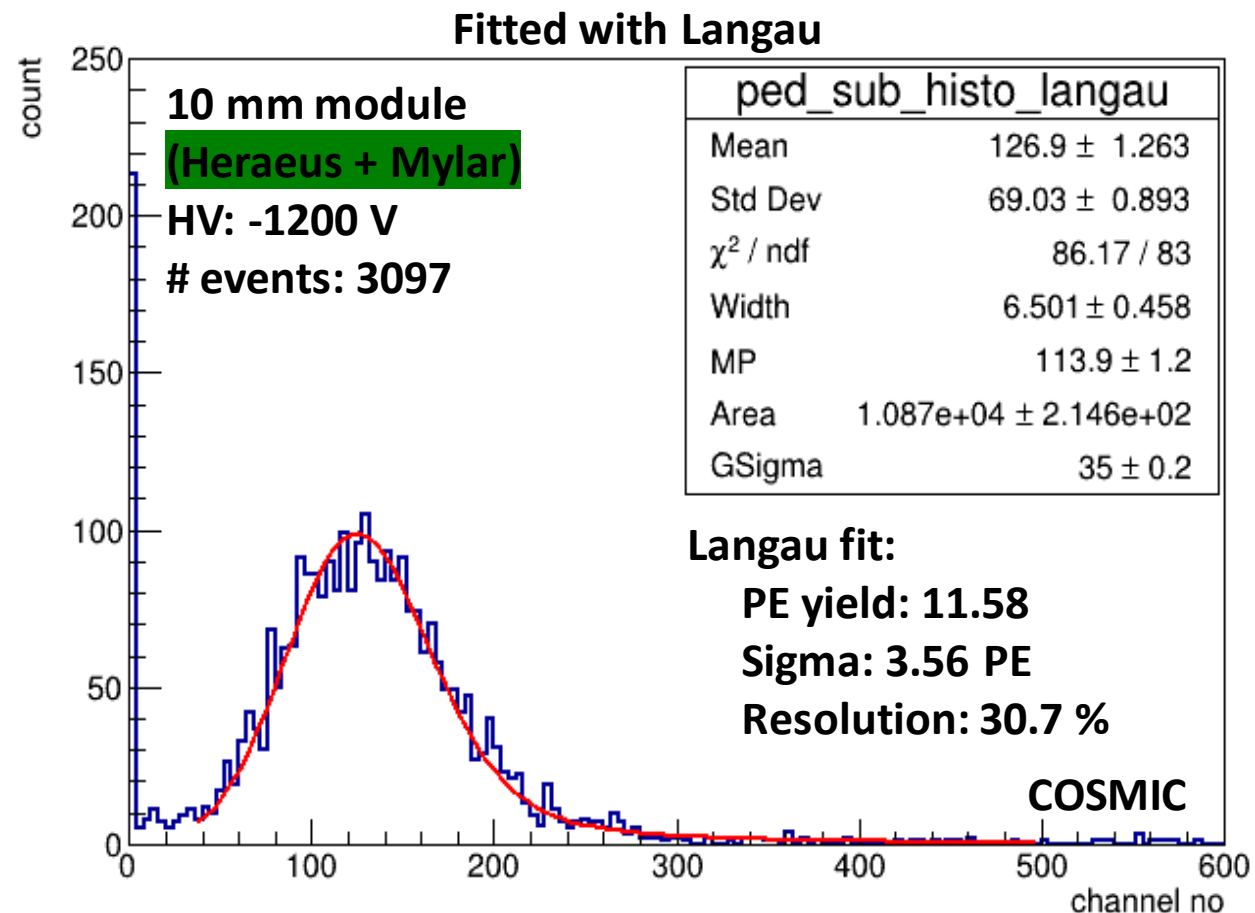
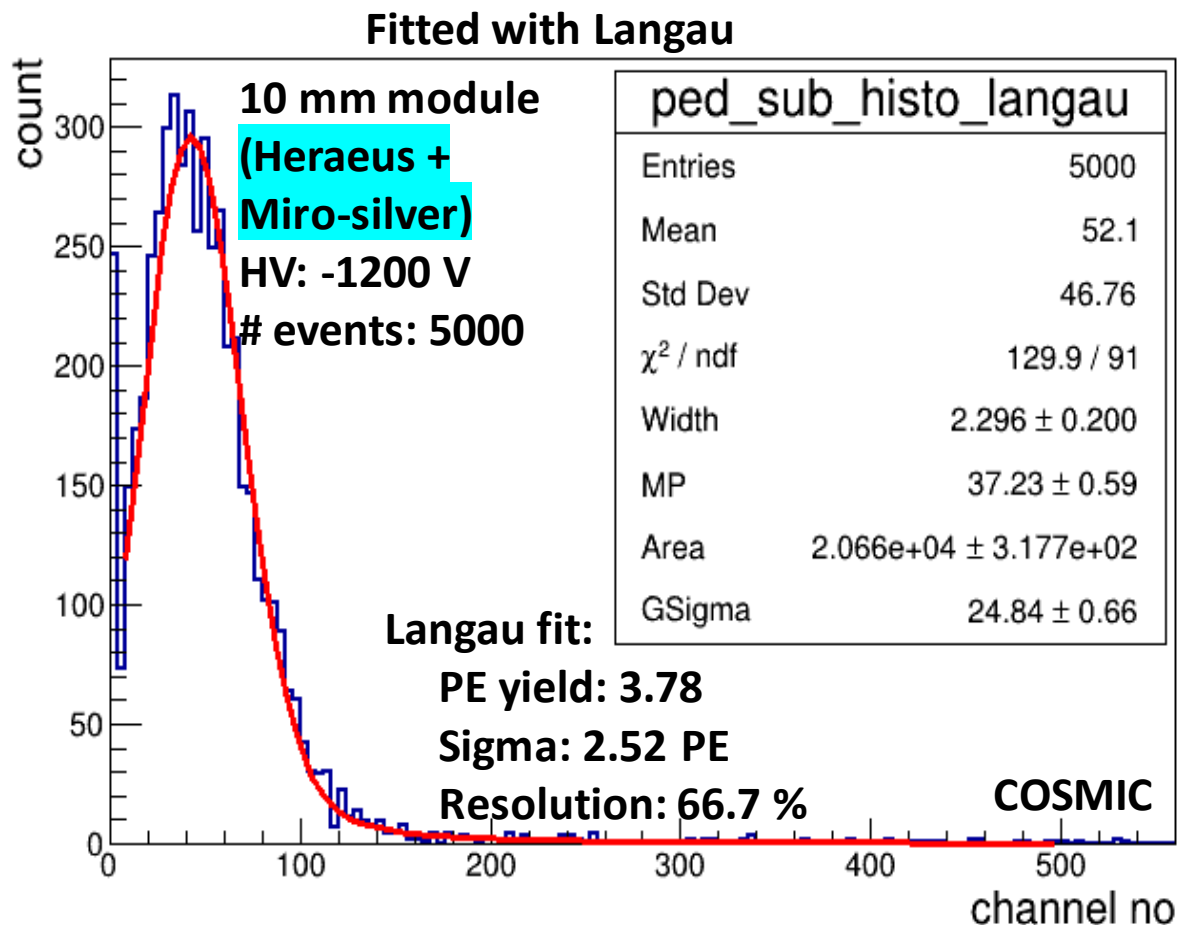
# **Investigation on the reflective light-guide materials**



# Change of reflective material from Miro-silver to Mylar

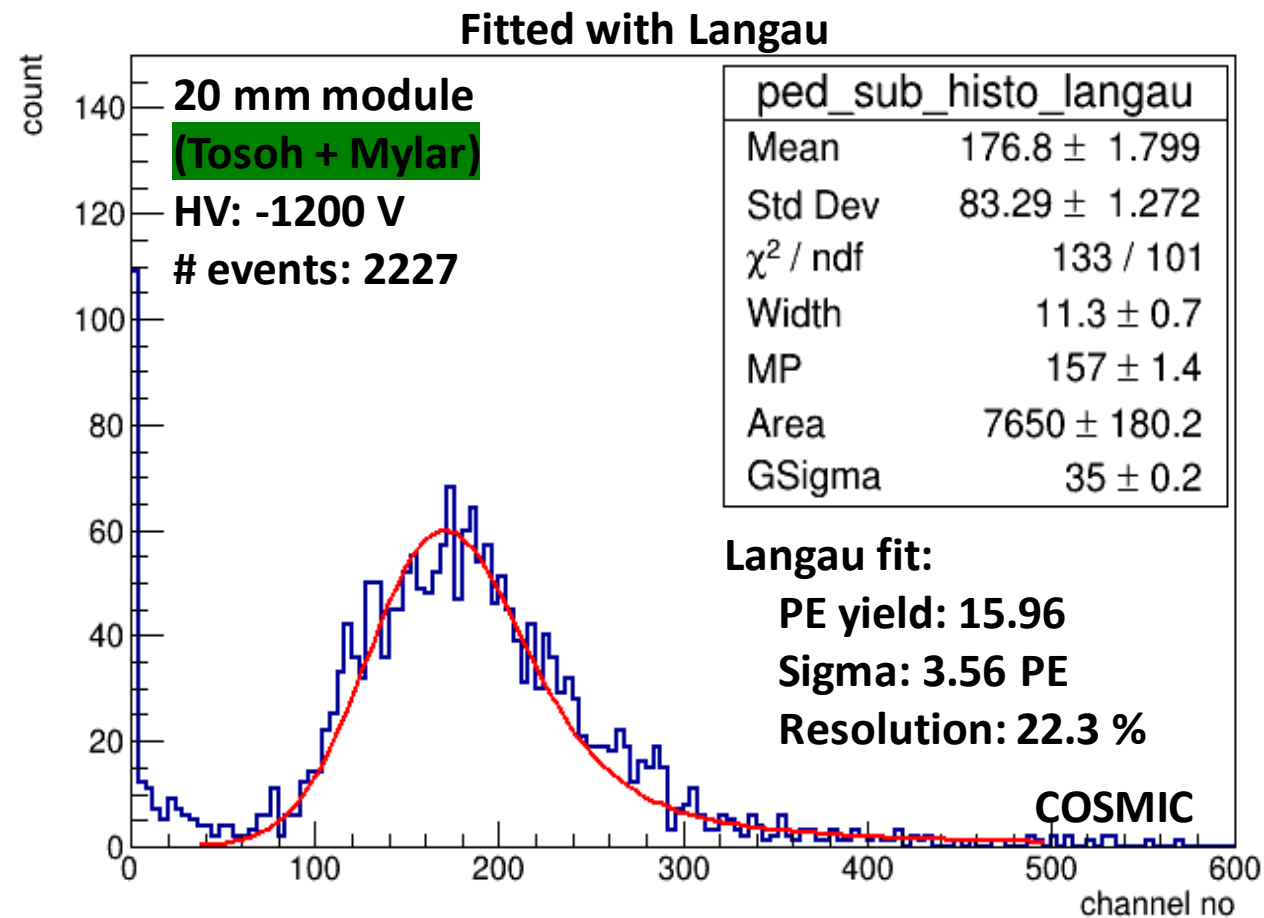
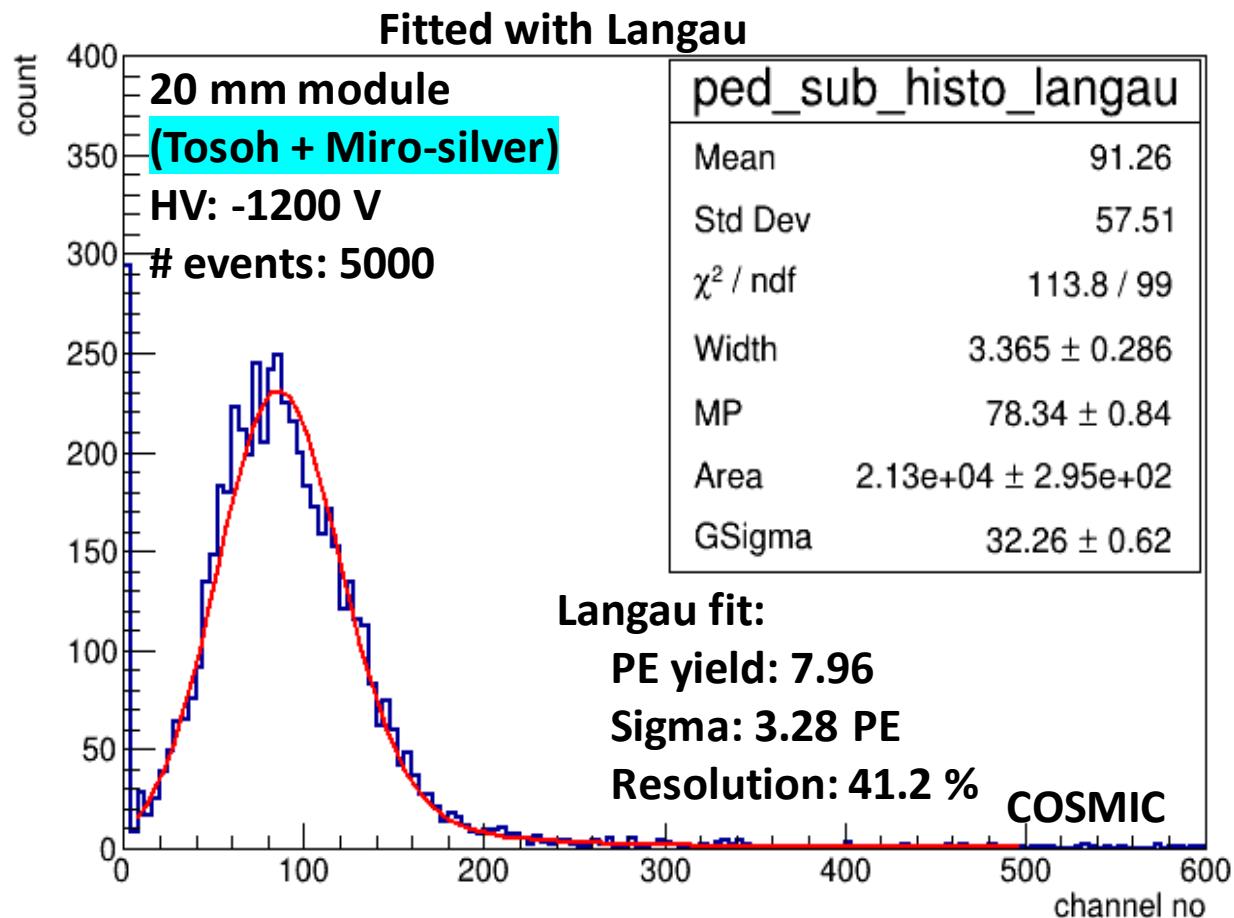


# Comparison of QDC spectra with Miro-silver & Mylar with 10 mm QUARTZ



The PE yield has increased by a factor of  $\sim 3$

# Comparison of QDC spectra with Miro-silver & Mylar with 20 mm QUARTZ



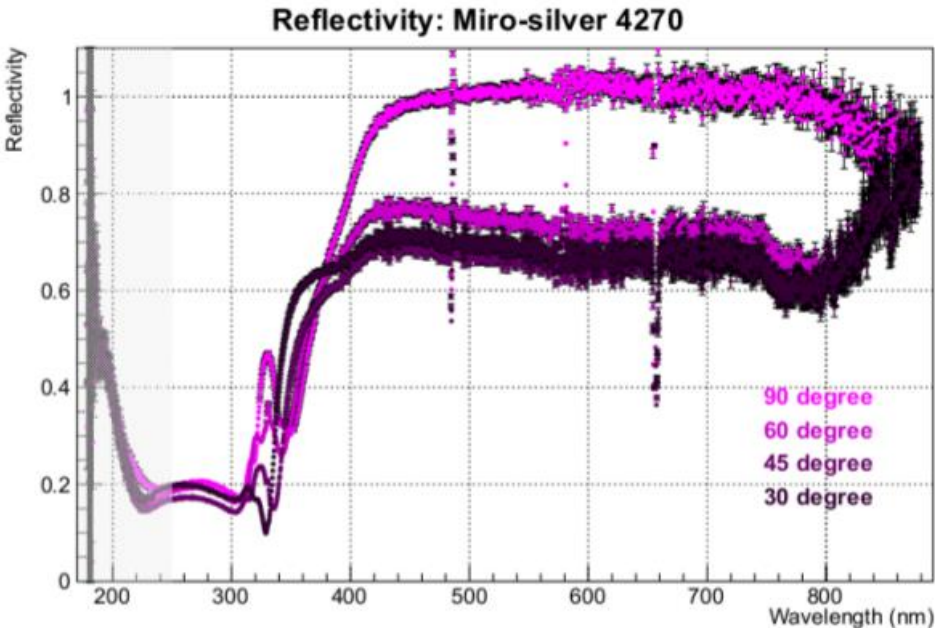
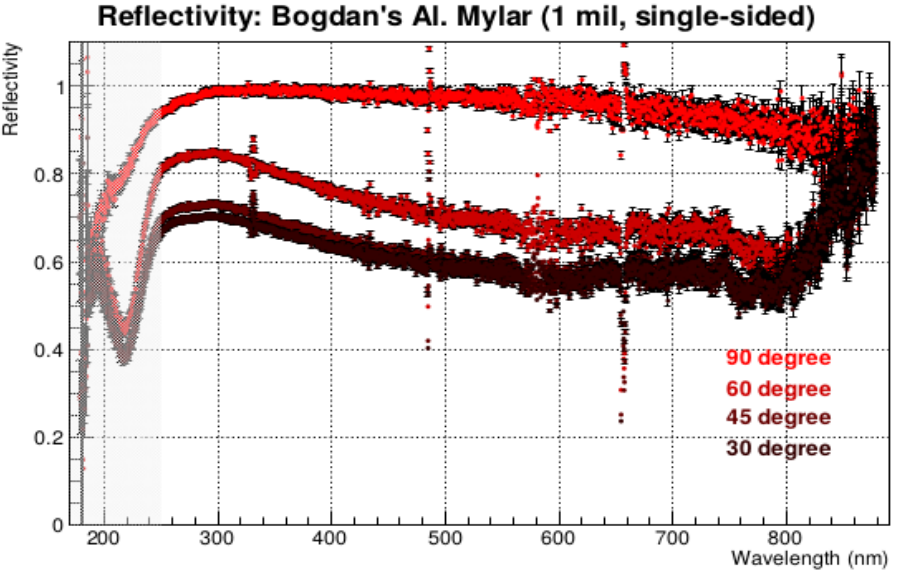
The PE yield has increased by a factor of  $\sim 2$

# Comparison of Miro-silver and Mylar

## Measured data with cosmic muons

Module	Quartz tile	PE yield (Miro-silver)	PE yield (Mylar)	Sigma (PE) (Miro-silver)	Sigma (PE) (Mylar)
10 mm	Heraeus	3.78 (Langau)	11.58 (Langau)	2.52 (Langau)	3.56 (Langau)
		4.27 (Gaussian)	13.14 (Gaussian)	2.50 (Gaussian)	4.44 (Gaussian)
20 mm	Tosoh	7.96 (Langau)	15.96 (Langau)	3.28 (Langau)	3.56 (Langau)
		8.86 (Gaussian)	18.52 (Gaussian)	3.67 (Gaussian)	5.17 (Gaussian)

- Mylar gives better PE yields compared to the Miro-silver
- The resolution (PE yield/sigma) is better with Mylar



# Comparison of simulation with cosmic and beam data

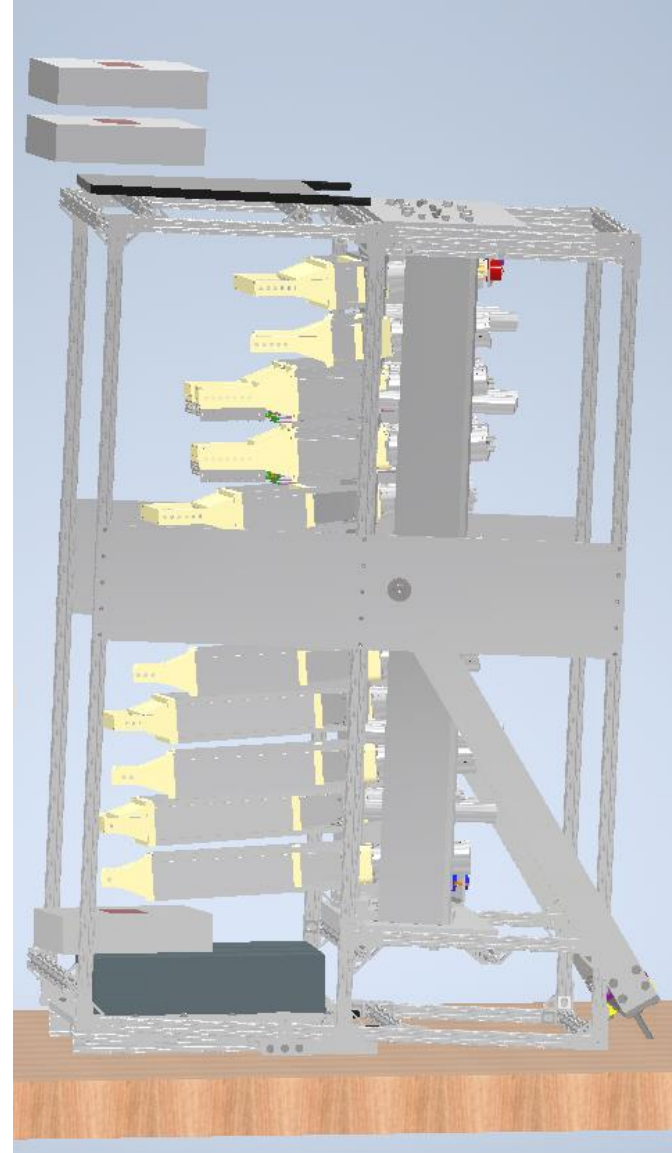
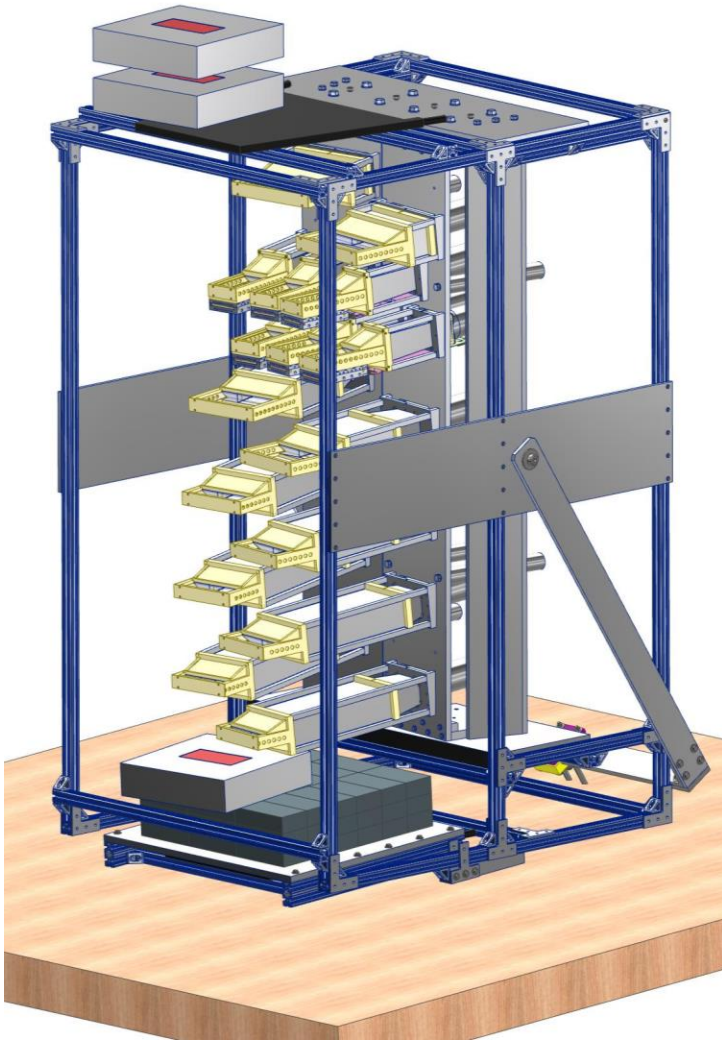
Module	Quartz tile	Data type	PE yield (Miro-silver)	PE yield (Mylar)	Sigma (PE) (Miro-silver)	Sigma (PE) (Mylar)
10 mm	Heraeus	cosmic	3.78 (Langau)	11.58 (Langau)	2.52 (Langau)	3.56 (Langau)
10 mm	Heraeus	beam	4.68 (Langau)	-	2.13 (Langau)	-
10 mm	Heraeus	simulation	4.03 (Langau)	11.4 (Langau)	1.76 (Langau)	3.17 (Langau)

Module	Quartz tile	Data type	PE yield (Miro-silver)	PE yield (Mylar)	Sigma (PE) (Miro-silver)	Sigma (PE) (Mylar)
20 mm	Tosoh	cosmic	7.96 (Langau)	15.96 (Langau)	3.28 (Langau)	3.56 (Langau)
20 mm	Tosoh	beam	9.16 (Langau)	-	3.02 (Langau)	-
20 mm	Tosoh	simulation	6.24 (Langau)	15.1 (Langau)	2.37 (Langau)	3.74 (Langau)

**Good agreement between the simulated data, cosmic and beam data**

# Large cosmic stand at UMass

# Design & plans



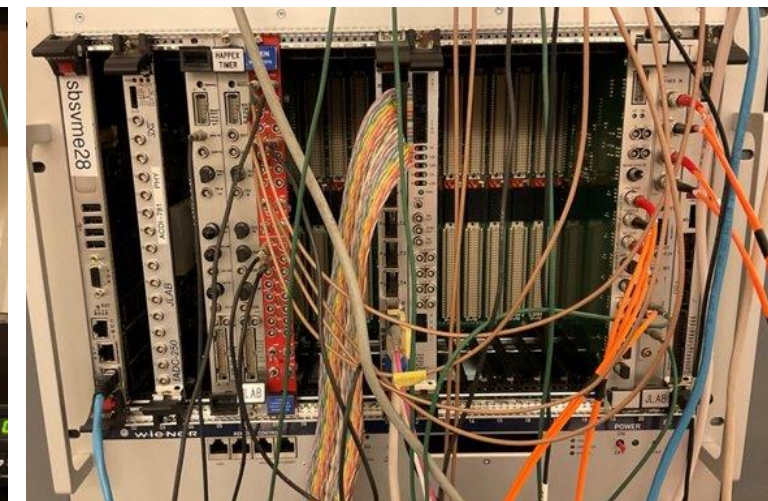
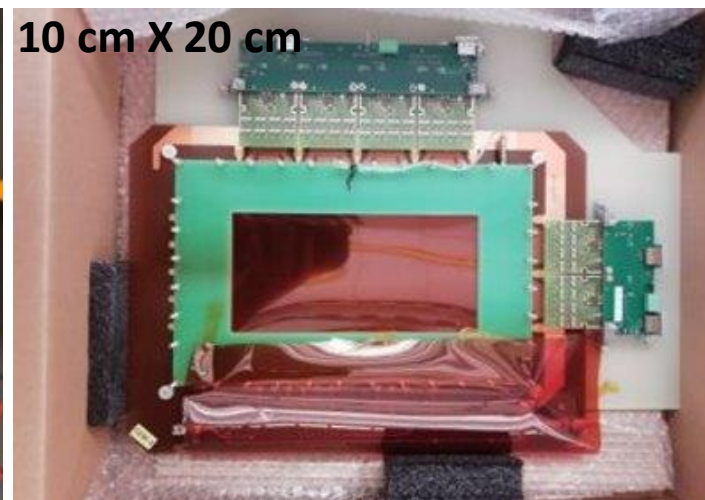
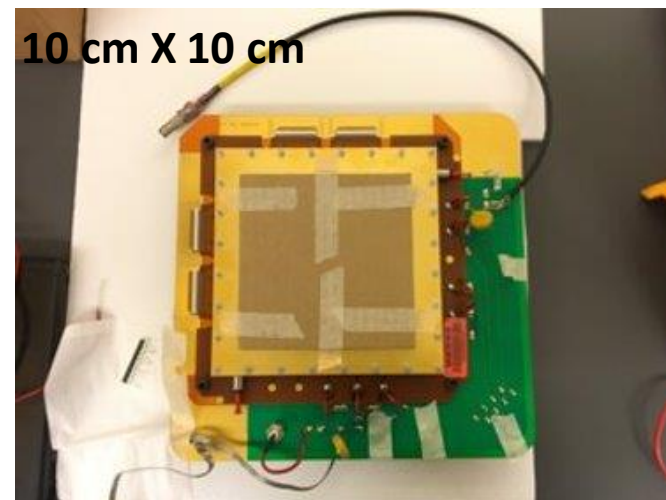
- Two segments each having 8 quartz modules
- Testing of the performance of the modules with the cosmic muons at UMass and with electron beam at MAINZ
- Preparation is ongoing and the purchase of different components will begin soon
- Plan is to start with one segment (8 modules) and then proceed for the entire two segments
- Expecting to have the large cosmic stand running at UMass in this summer

# **R&D with Gas Electron Multiplier chamber prototypes**

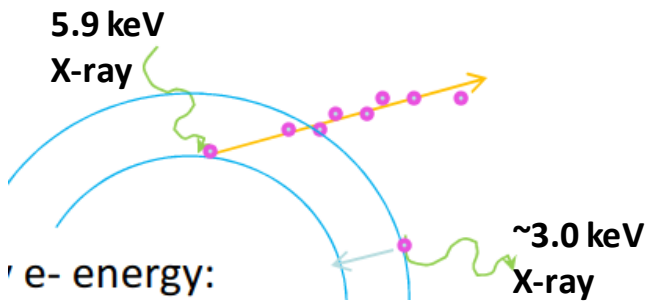
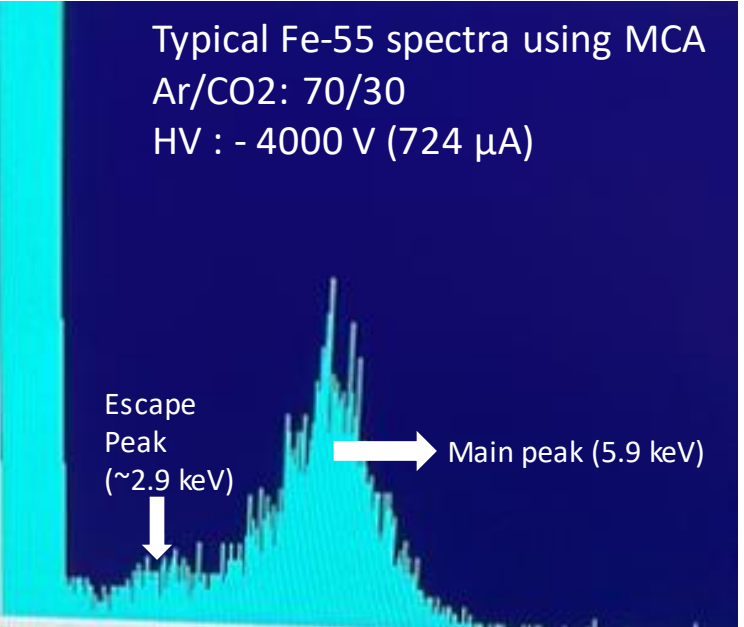
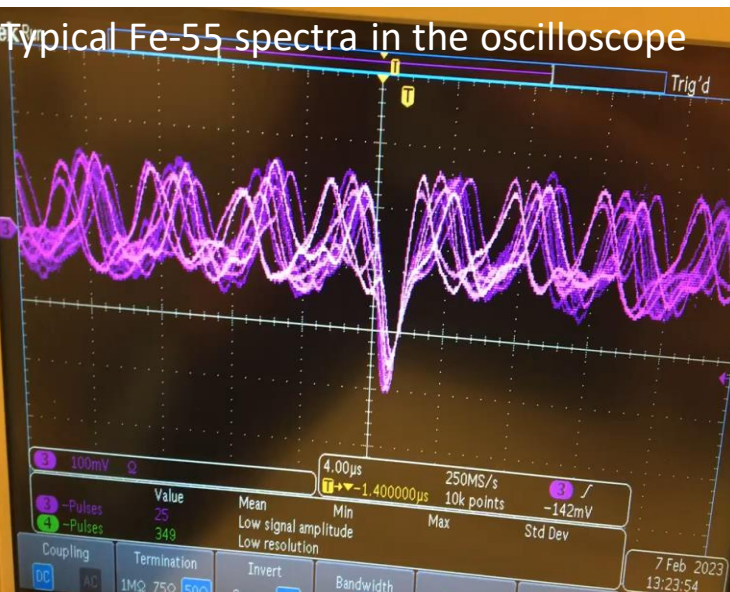


# GEMs at UMass

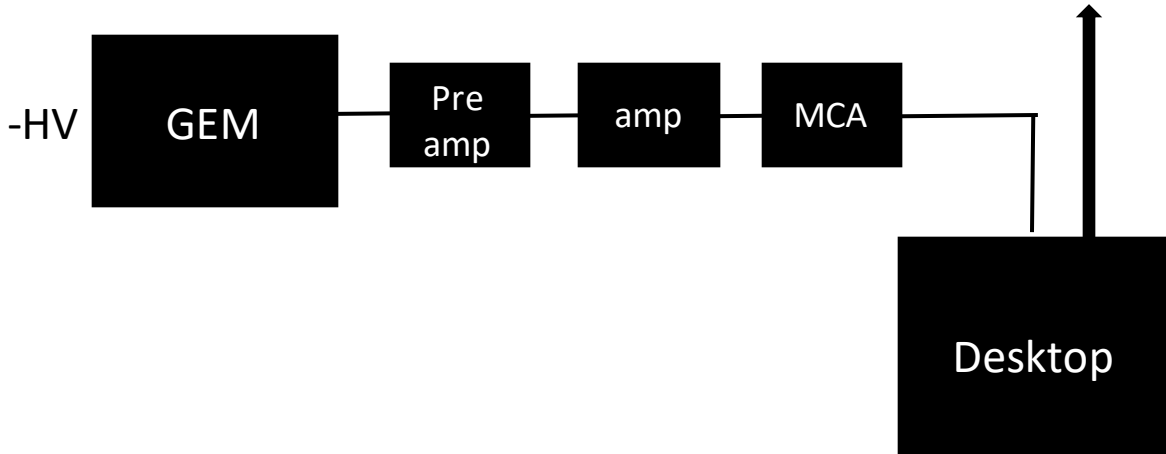
- Four single mask triple GEM chamber prototypes: Three 10 cm X 20 cm and one 10 cm X 10 cm
- 10 cm X 20 cm GEMs have segmented foils
- All the GEM chambers have resistor chains to bias the individual GEM foils
- MPDs, back plans, APV cards, HDMI cables and LV modules are available to run three GEM chambers simultaneously
- Working on the MPD (+CODA) based DAQ system
- The GEMs will be used to track the cosmic muon trajectories and confine the solid angle of our cosmic muon stand



# Preliminary GEM characterization with Fe-55 source



- Single mask triple GEM chamber of dimension 10 cm X 10 cm is operated with Ar/CO<sub>2</sub> gas mixture in a 70/30 volume ratio
- The chamber is irradiated using a Fe-55 X-ray source having characteristic energy of 5.9 keV
- ORTEC EASY-MCA is used to store the X-ray spectra
- The calibration of the MCA is done using external pulse
- Applied HV: -4000 V (724 μA) and distributed across the individual GEM foils using a resistive chain network

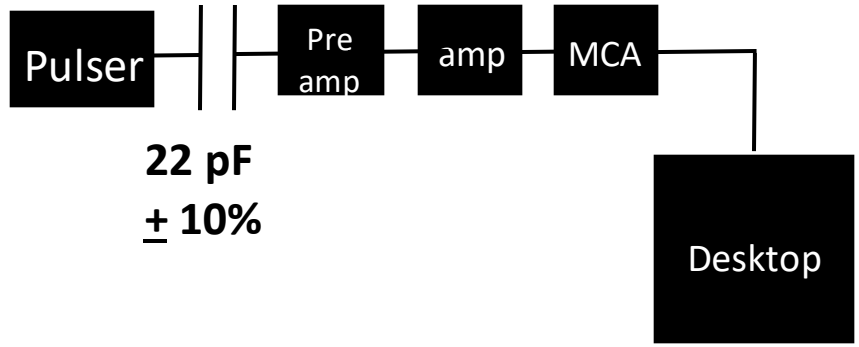
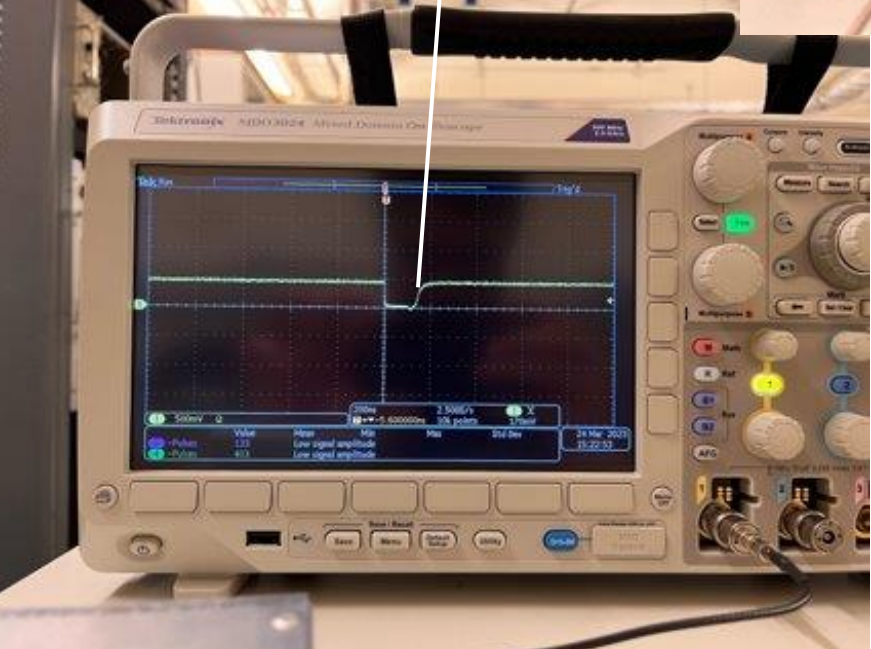
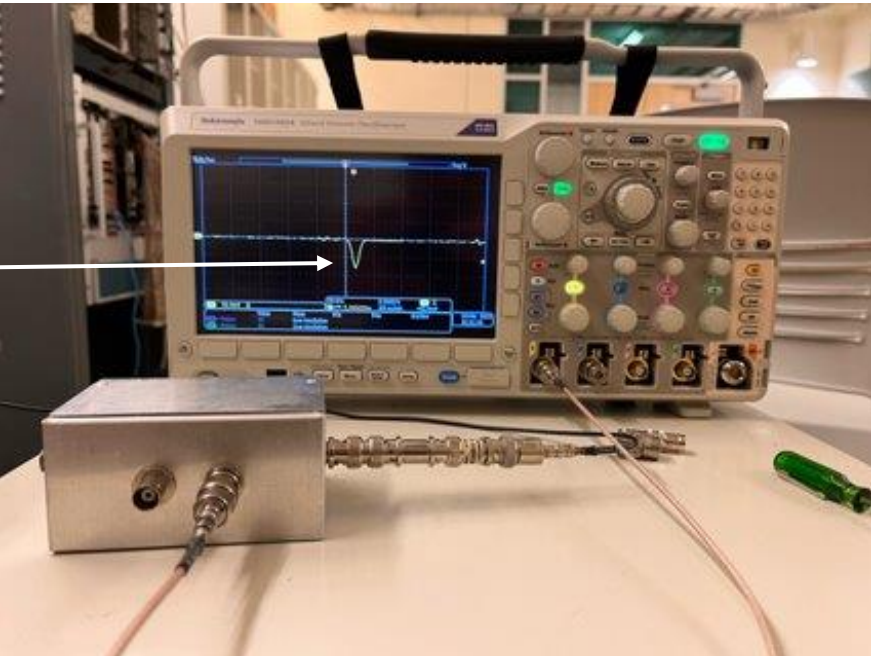
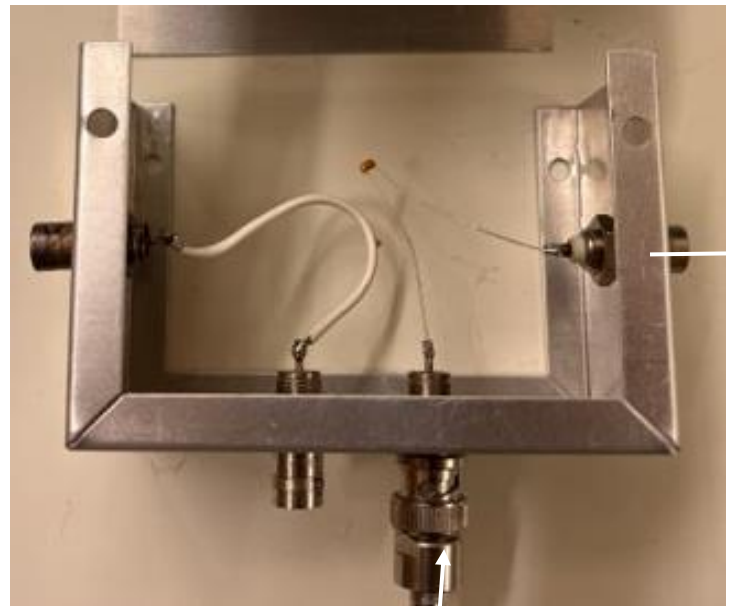


Schematic of the electronic circuit diagram for the Fe-55 test

# MCA calibration and Fe-55 spectrum

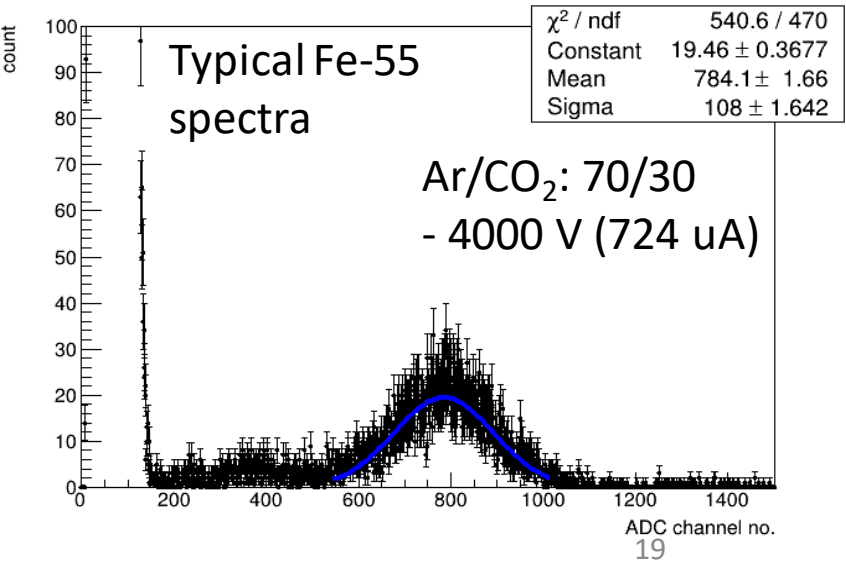
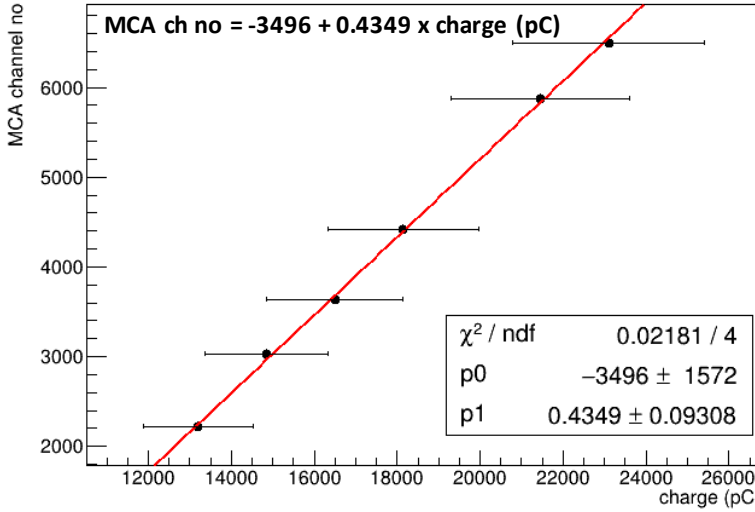
Characterization the GEM chambers using the Fe-55 source:

Measurement of gain, energy resolution, count rate and efficiency measurement with cosmic muons



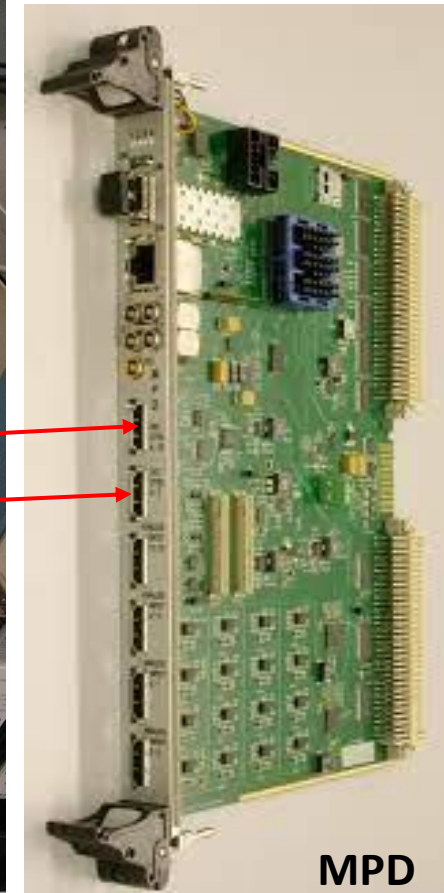
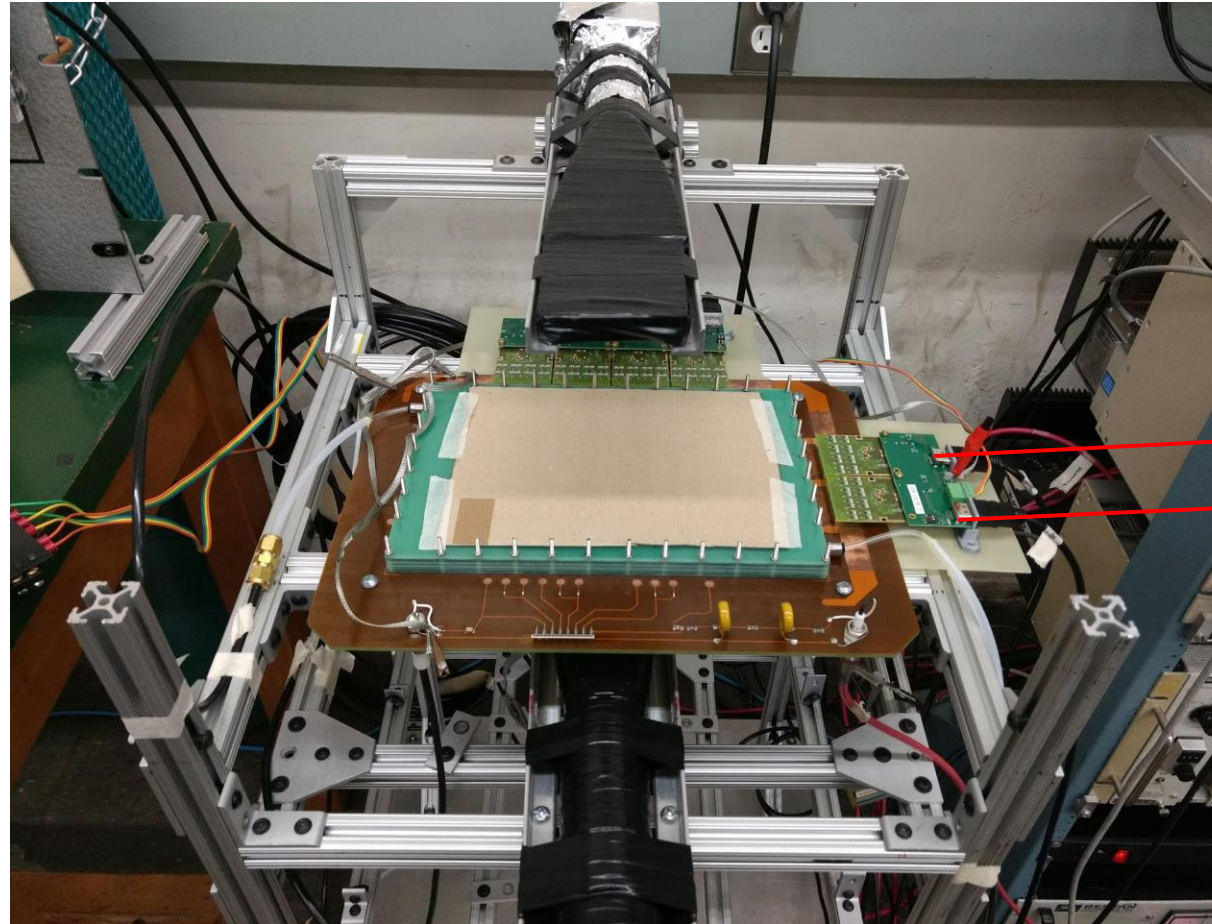
22 pF  
± 10%

Schematic of the MCA calibration circuit



# Setting-up the MPD (+CODA) based DAQ for GEMs

- HDMI cables for backplane and low-voltage (1.25V and 2.5V) power supply
- We have two MPDs, back planes and APV cards, HDMI cables, LV power supply - all parts for a VME-backplane based readout system to run three GEMs simultaneously
- Trying to configure the MPD modules with the VME32 crate using CODA 2.6.2 (always getting errors for invalid data code!)



```
mpdInit: Looking for MPD with Address 0x280000  
mpdInit: VME address = 0x280000: Invalid data code 0x47ffffff (expected 0x43524f4d)
```

# Summary & outlook

- Performance study of the Ring 6 quartz detector
  - Beam and cosmic test data agree well within ~ 10-20%
  - Two different reflective light guide materials (miro-silver & mylar) are tested with cosmic muons
  - Simulation matches well with the measured data
  - Performance study using UVS as the reflective light guide material
  - Characterizing the spectosil 2000 (expecting to have in couple of weeks)
- Preparation is going well to start operating the large cosmic stand at UMass in this summer
- R&D with the single mask triple GEM chamber prototypes
  - MCA based DAQ system is working for basic characterizations
  - The 10 cm X 10 cm chamber shows good Fe-55 spectrum
  - Basic characterization of all the chambers using Fe-55 source and MCA as the DAQ
  - Set up the MPD (+CODA) based DAQ for GEMs

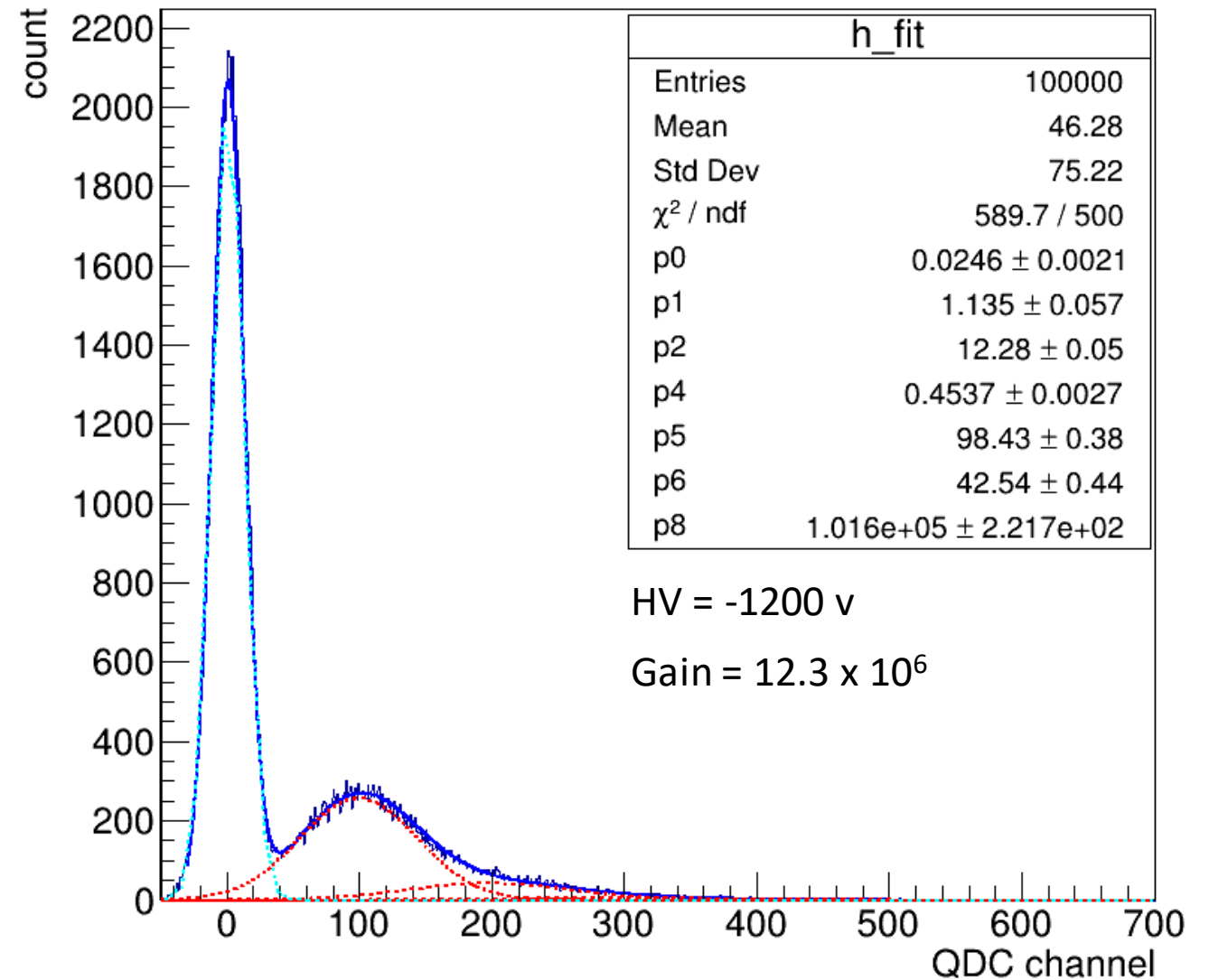
**Thank you for your attention!!!**

# Backup

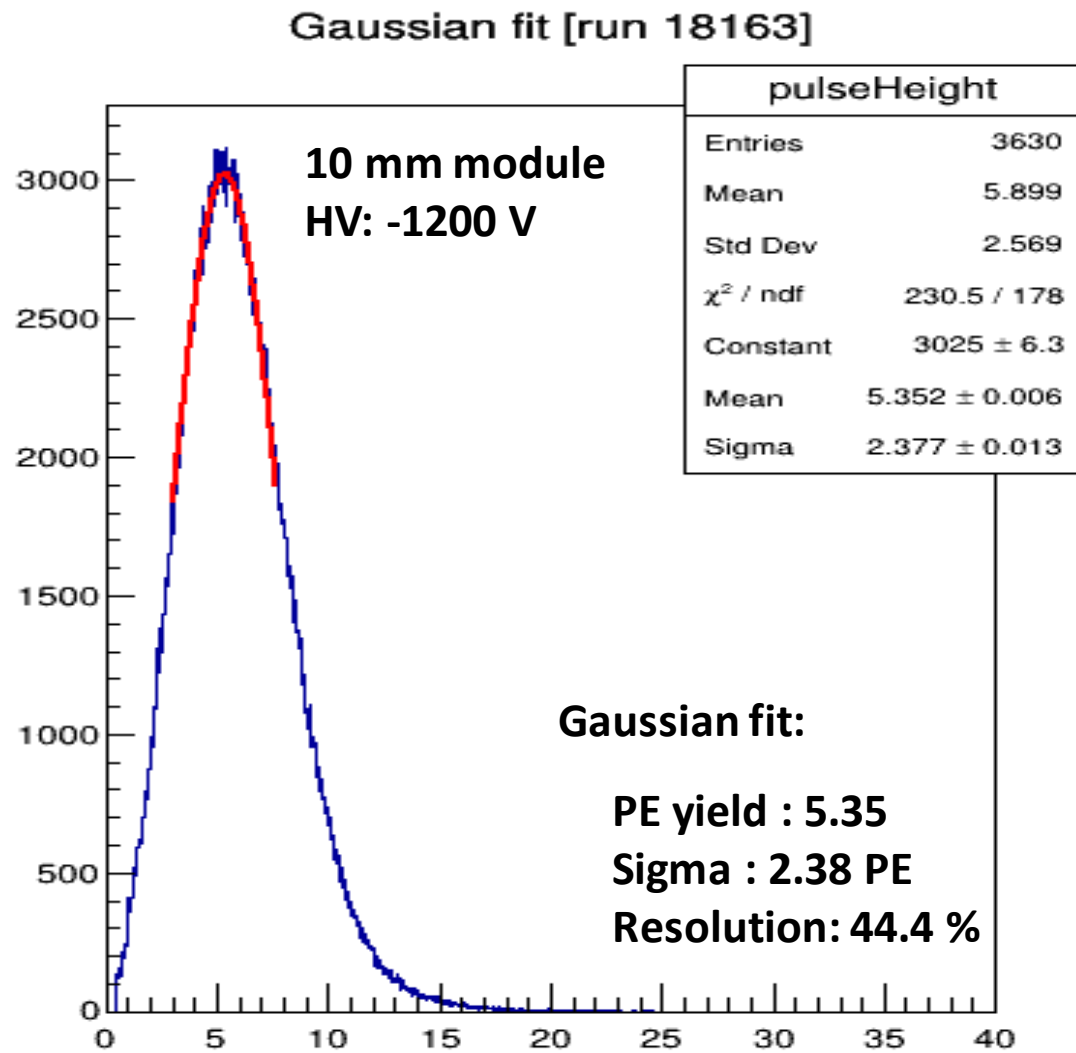
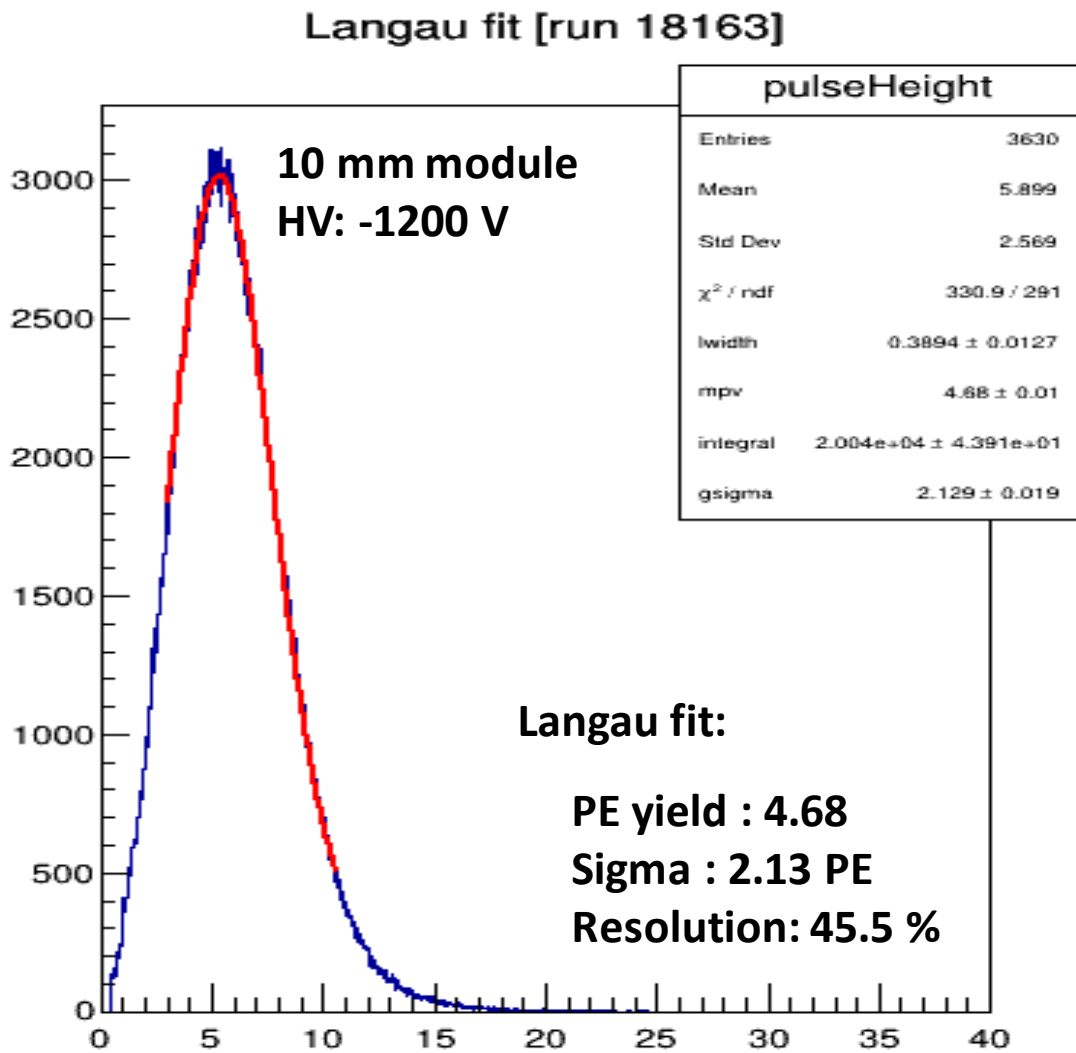
PMT: ET tube (# 541)

DAQ: DRS4

PMT base: Standard base



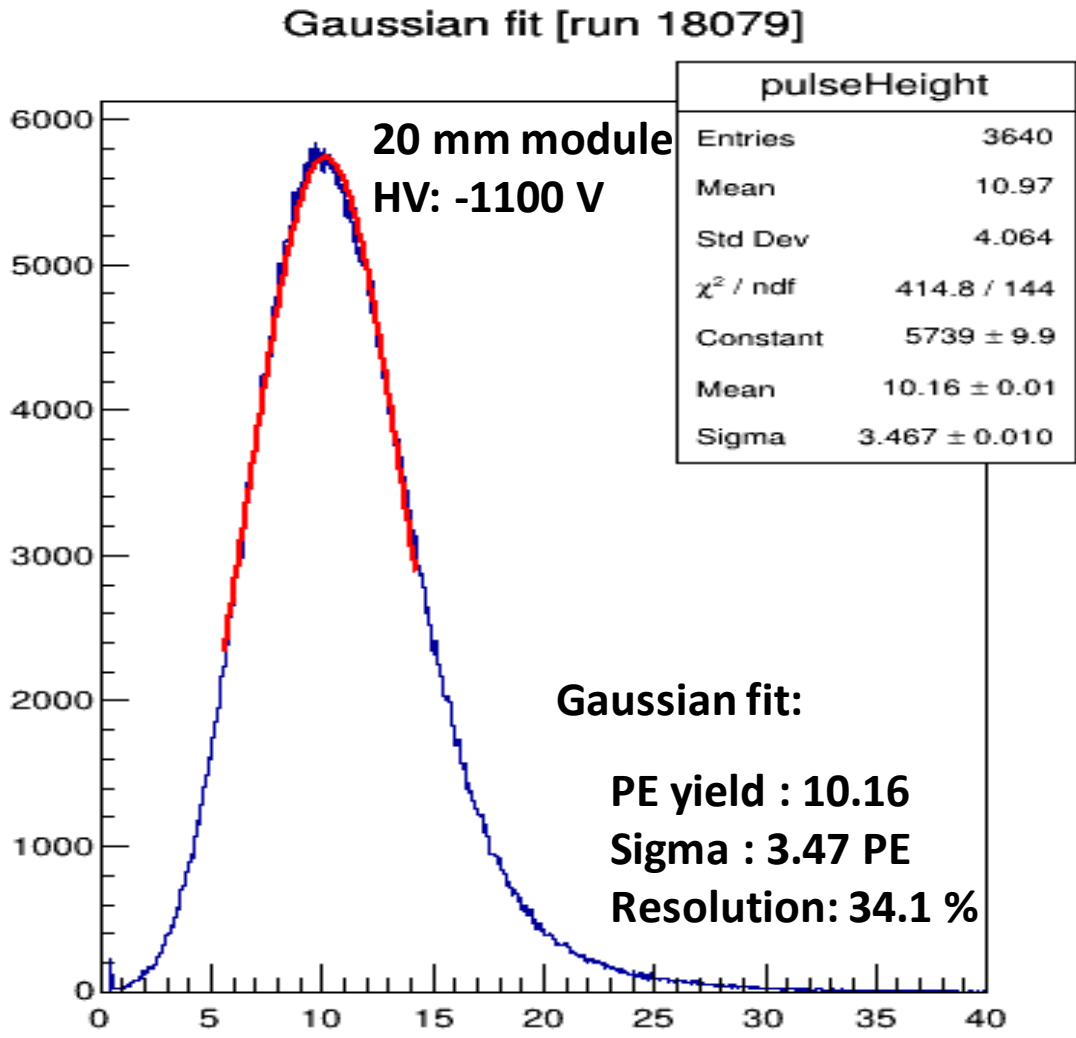
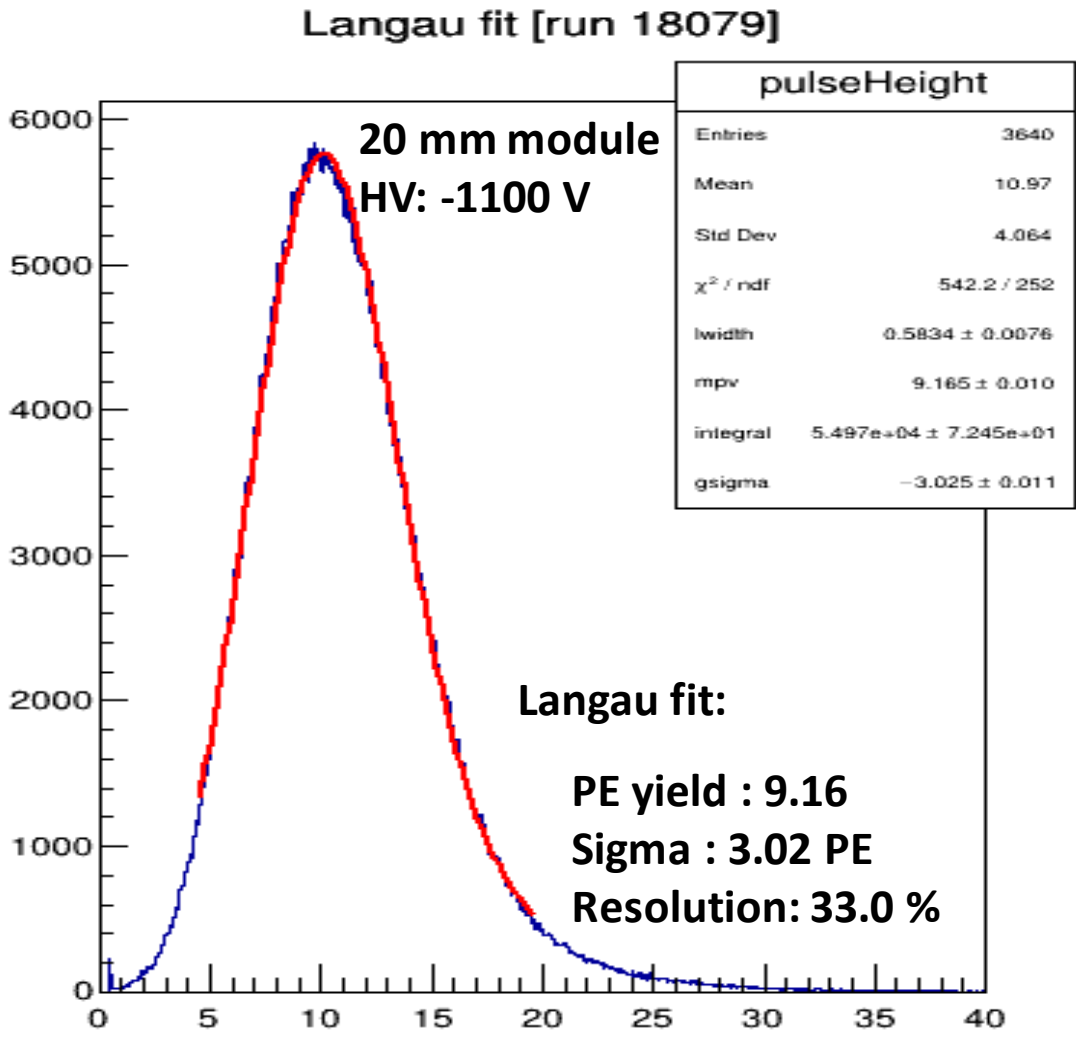
# Results (10 mm Heraeus QUARTZ module)



The beam is hitting at the center of the QUARTZ tiles

Resolution: Sigma/ PE yield

# Results (20 mm Tosoh QUARTZ module)

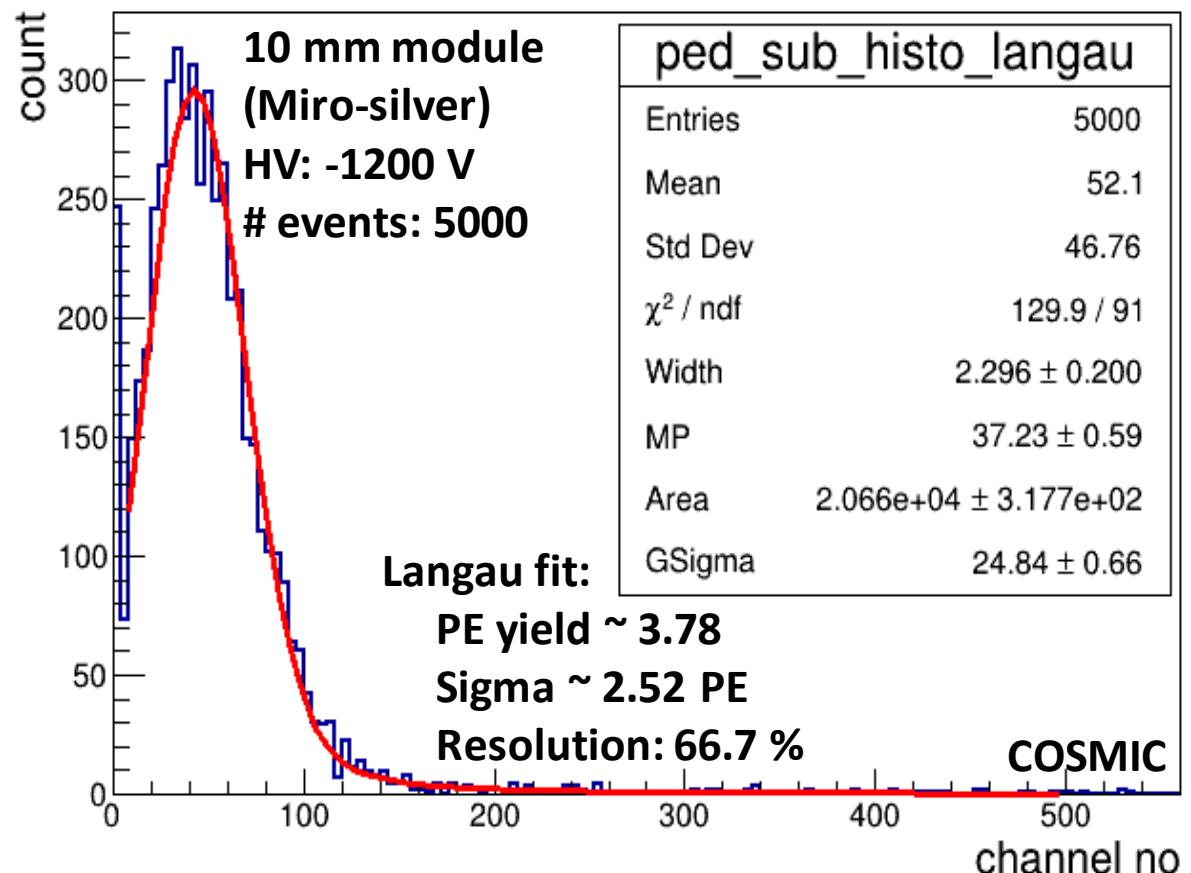
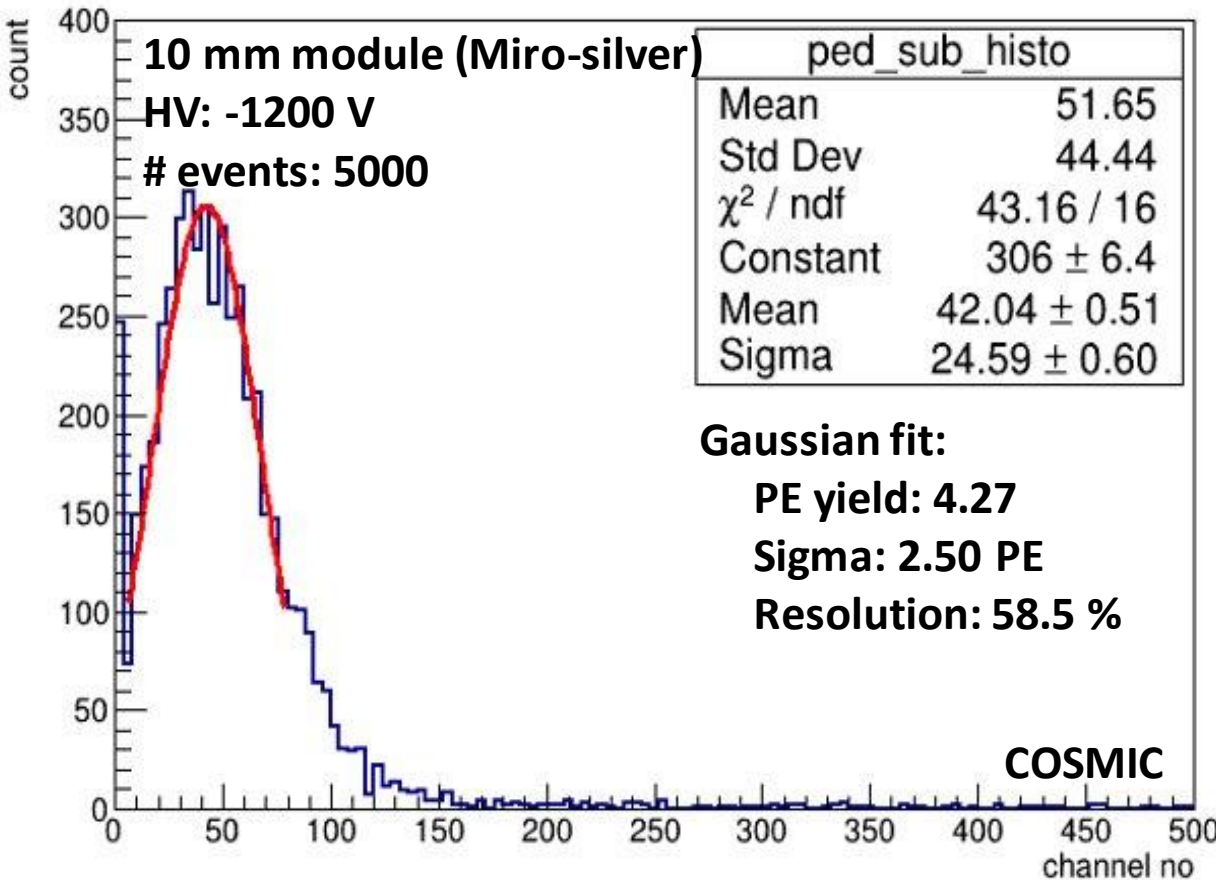


The beam is hitting at the center of the QUARTZ tiles

Resolution: Sigma/ PE yield



# Results from the cosmic test (10 mm Heraeus QUARTZ module)

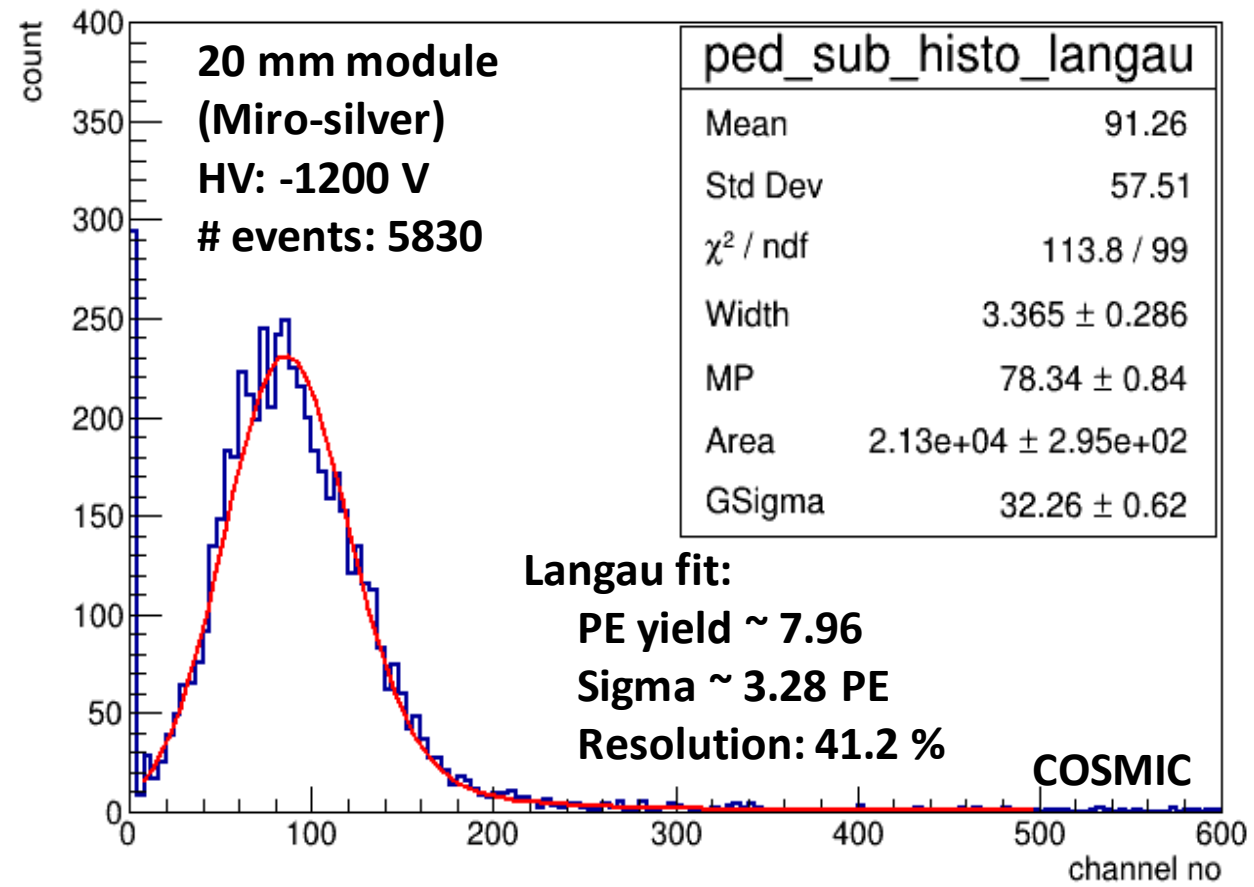
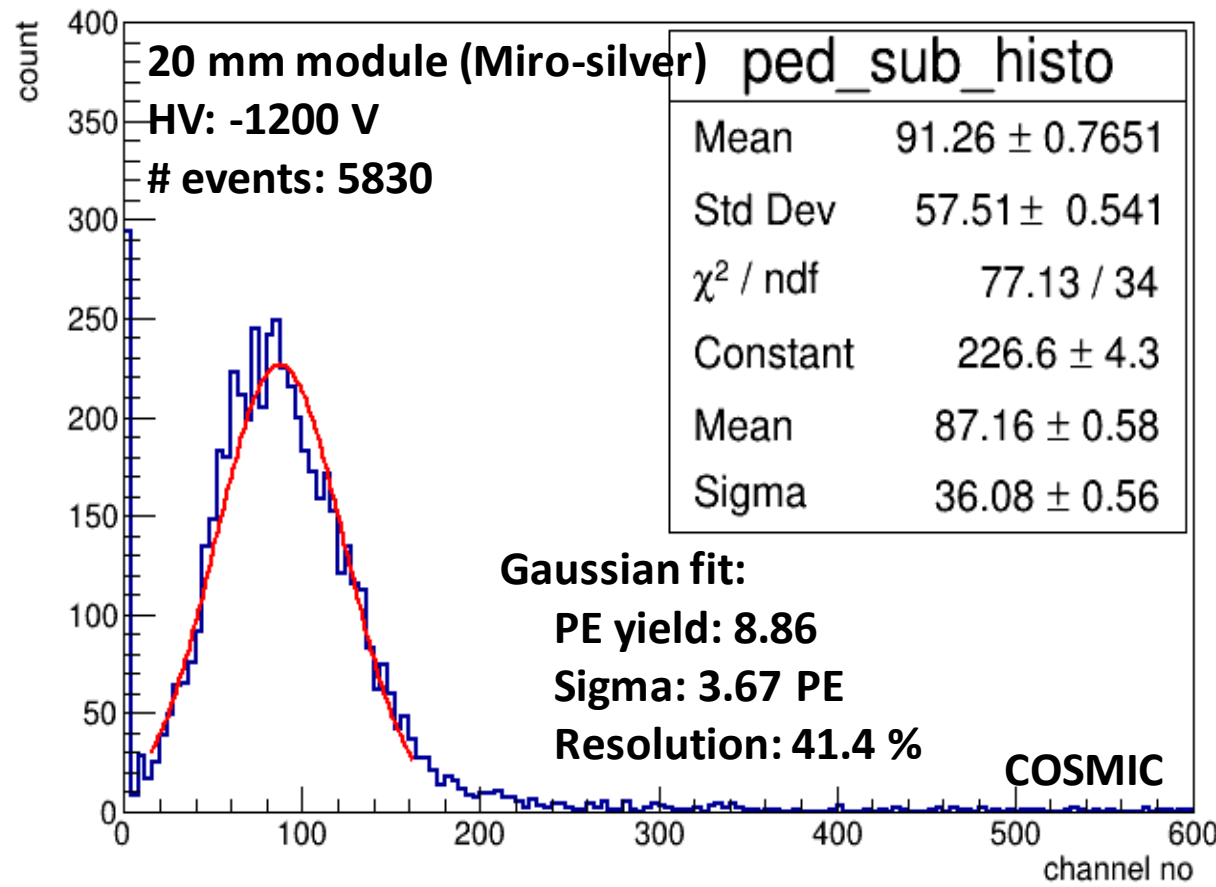


PE yield:  $(\text{Mean} \times 200 \times 10^{-15}) / (12.3 \times 10^6 \times 1.6 \times 10^{-19})$

Sigma (in terms of PE):  $(\text{Sigma} \times 200 \times 10^{-15}) / (12.3 \times 10^6 \times 1.6 \times 10^{-19})$

Gain of the PMT (ET#541 @ -1200 V):  $12.3 \times 10^6$

# Results from the cosmic test (20 mm Tosoh QUARTZ module)

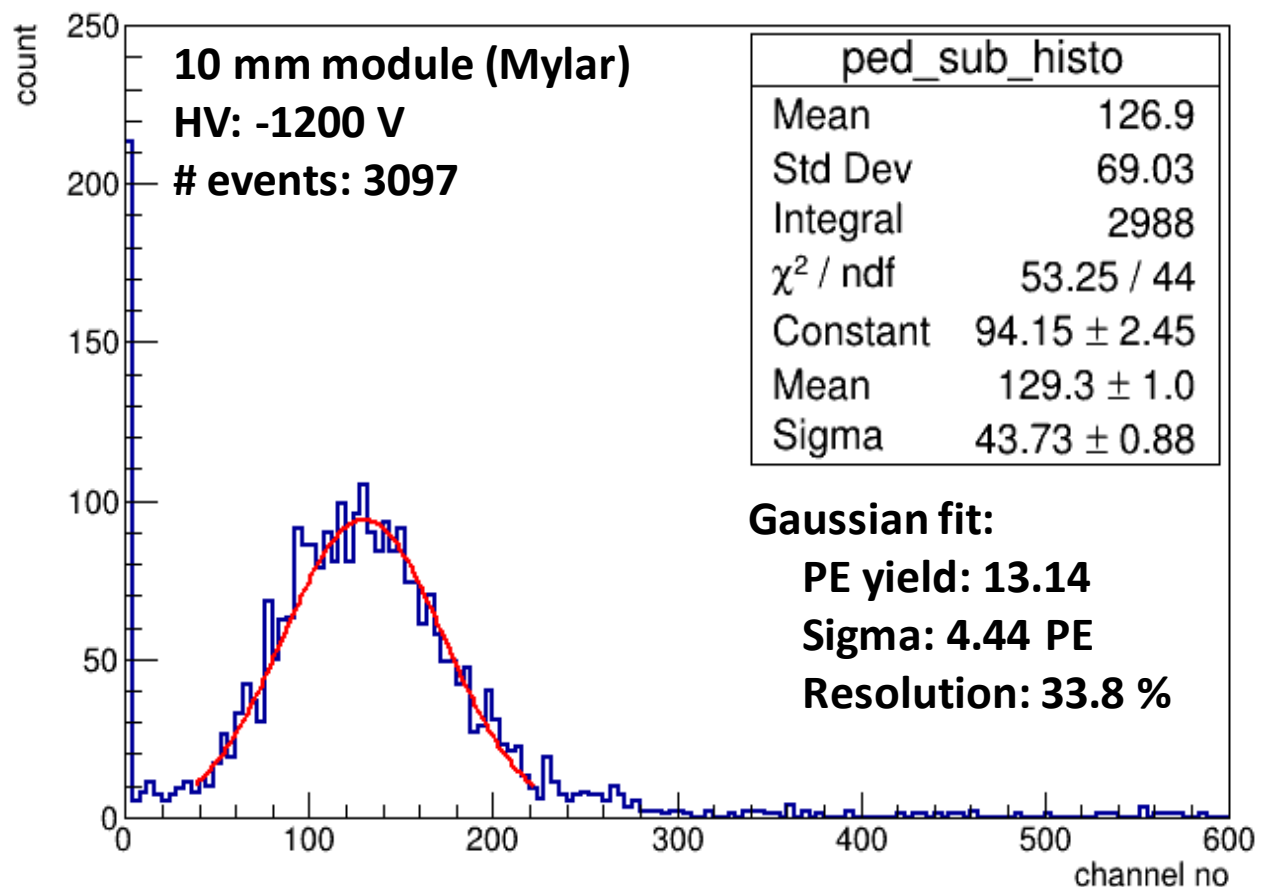
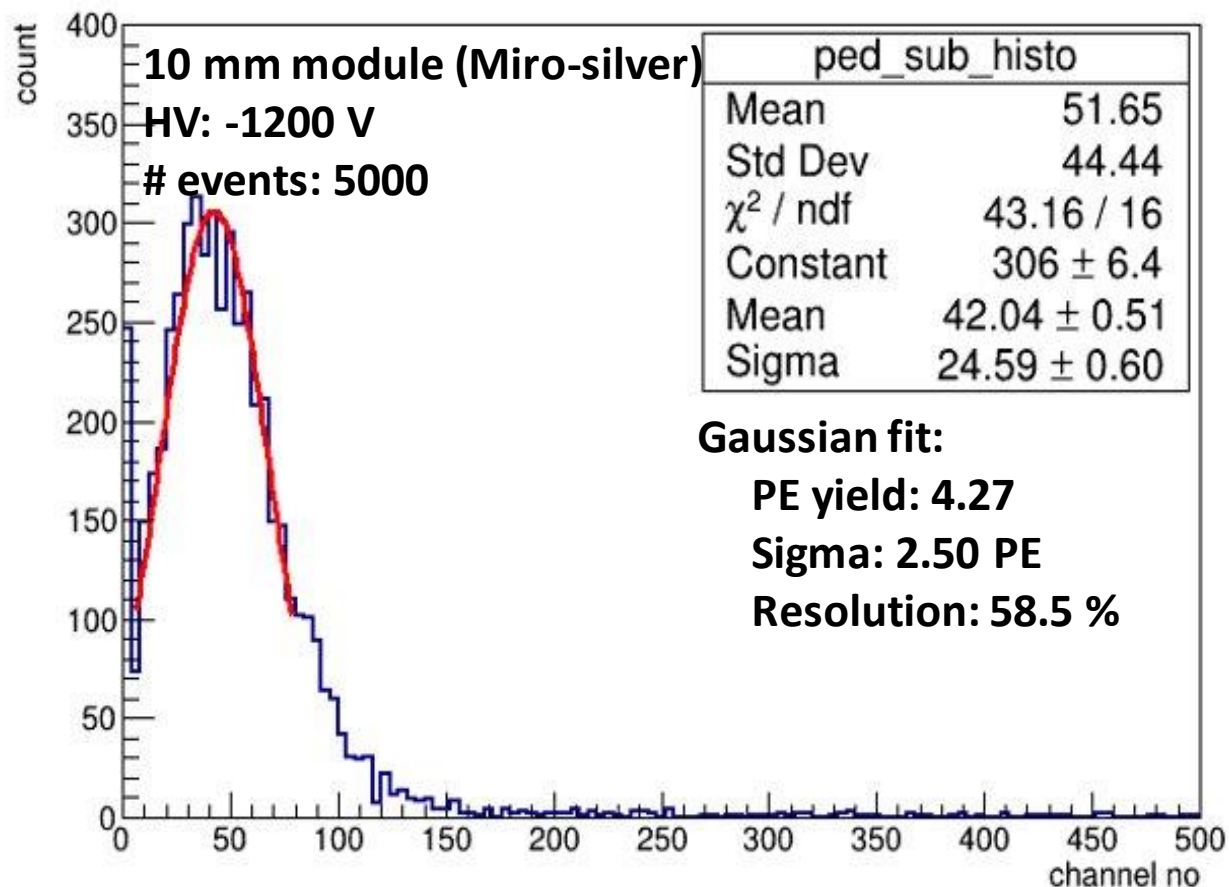


PE yield:  $(\text{Mean} \times 200 \times 10^{-15}) / (12.3 \times 10^6 \times 1.6 \times 10^{-19})$

Sigma (in terms of PE):  $(\text{Sigma} \times 200 \times 10^{-15}) / (12.3 \times 10^6 \times 1.6 \times 10^{-19})$

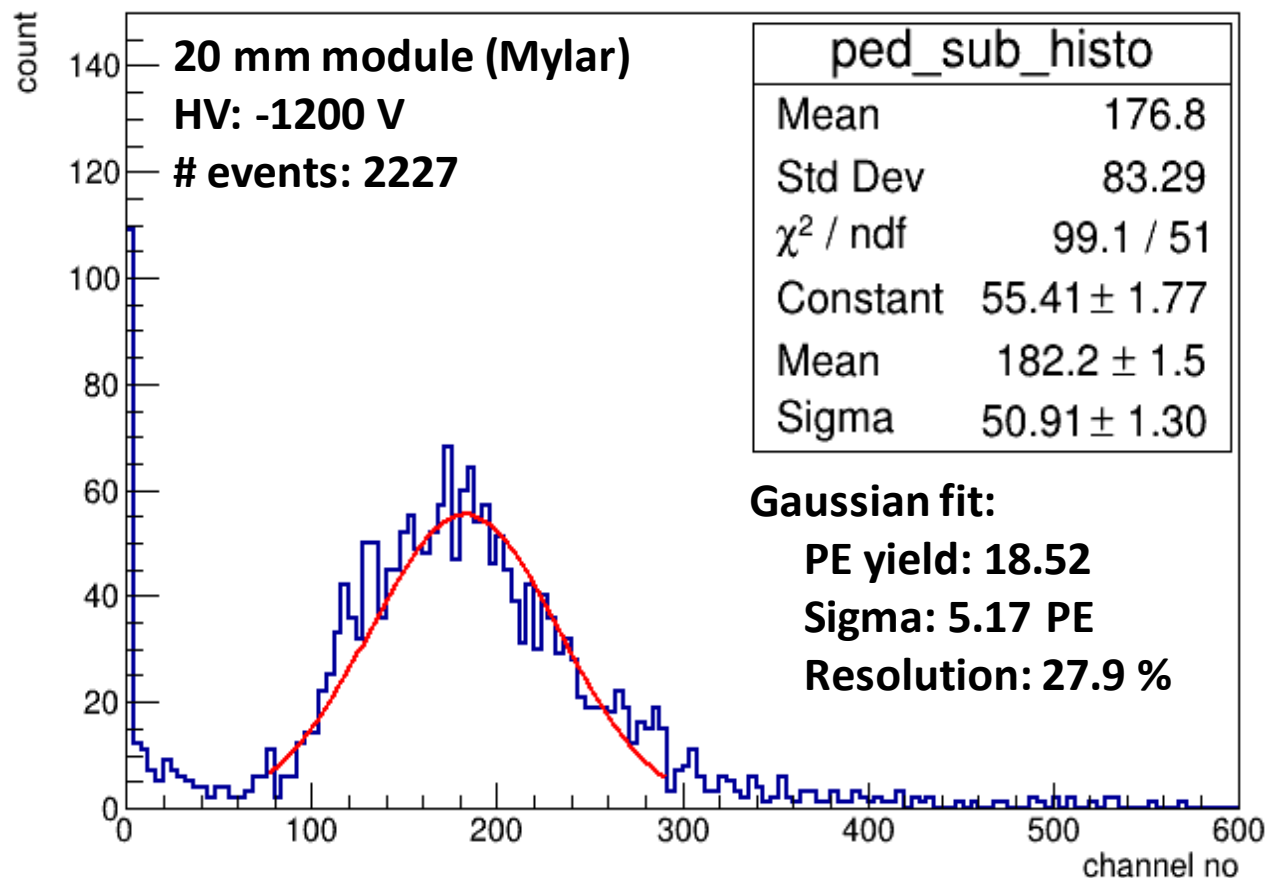
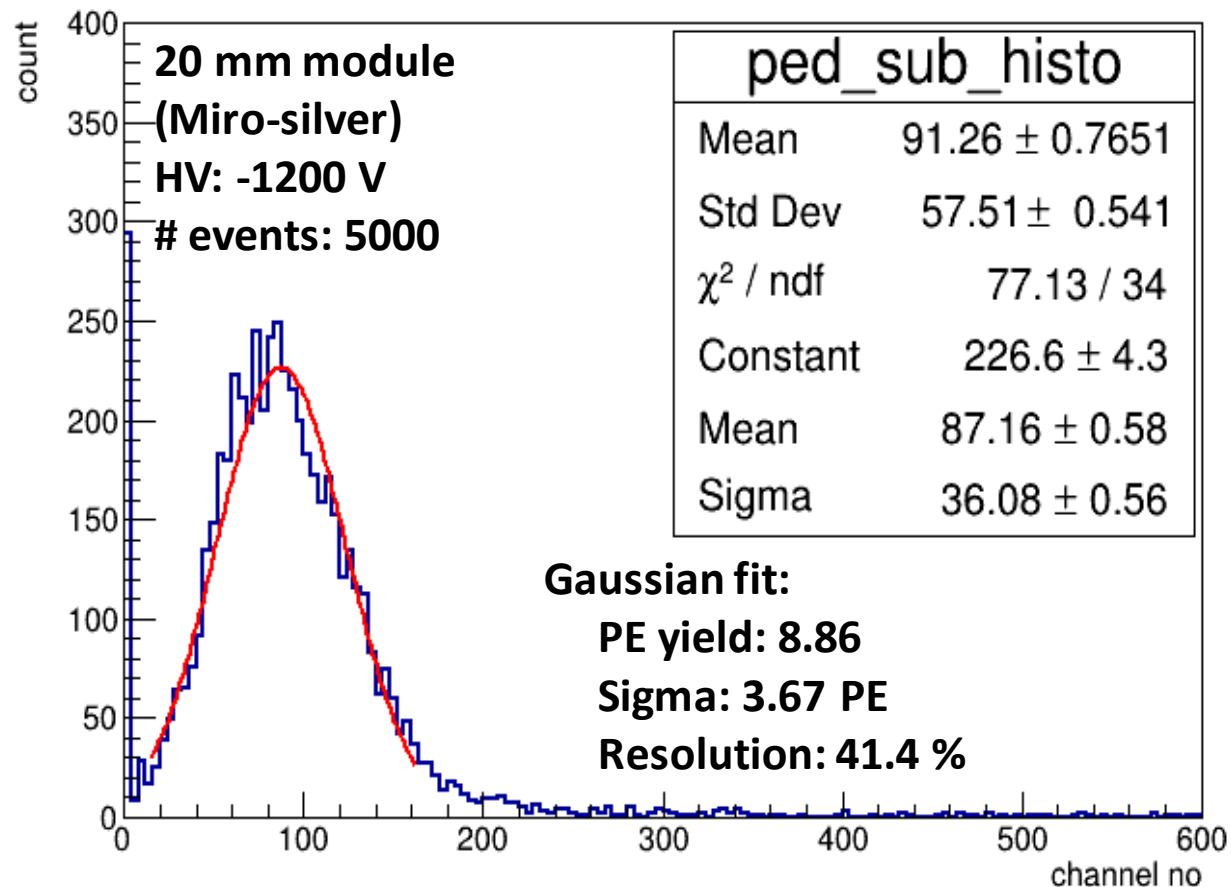
Gain of the PMT (ET#541 @ -1200 V):  $12.3 \times 10^6$

# Comparison of QDC spectra with Miro-silver & Mylar with 10 mm QUARTZ



The PE yield has increased by a factor of  $\sim 3$

# Comparison of QDC spectra with Miro-silver & Mylar with 20 mm QUARTZ

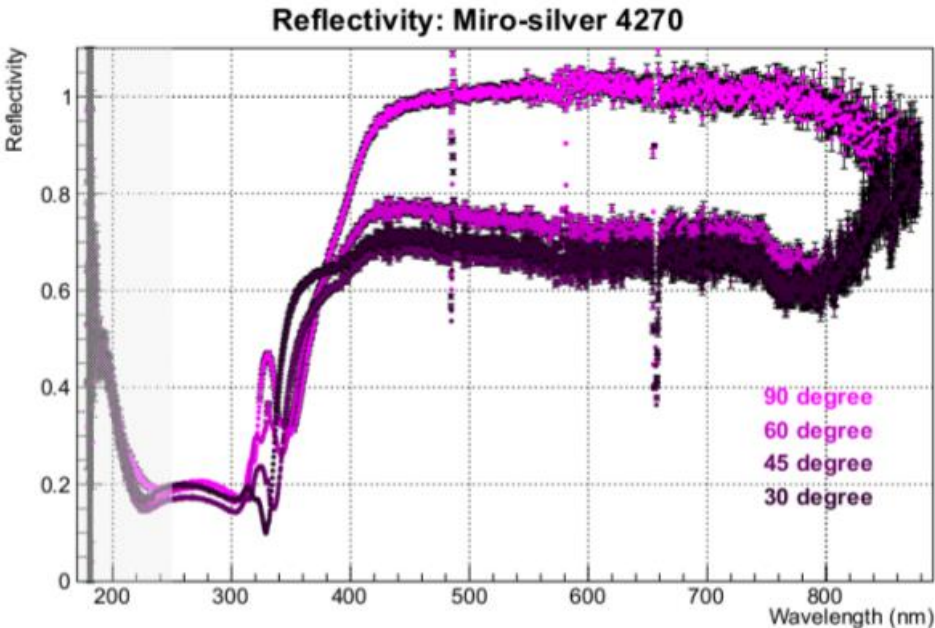
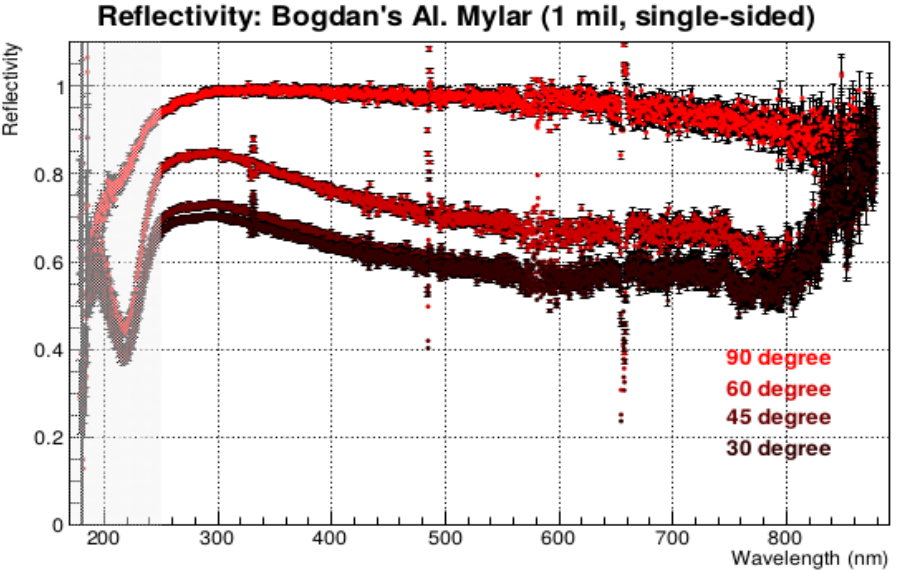


**The PE yield has increased by a factor of  $\sim 2$**

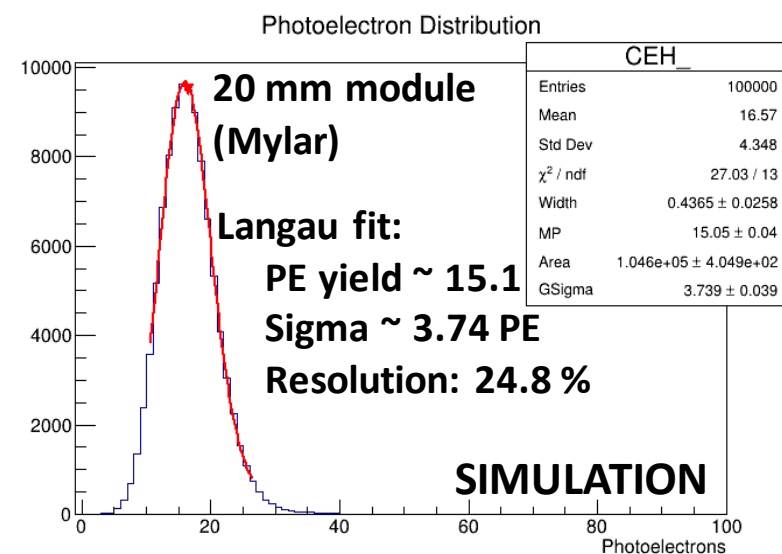
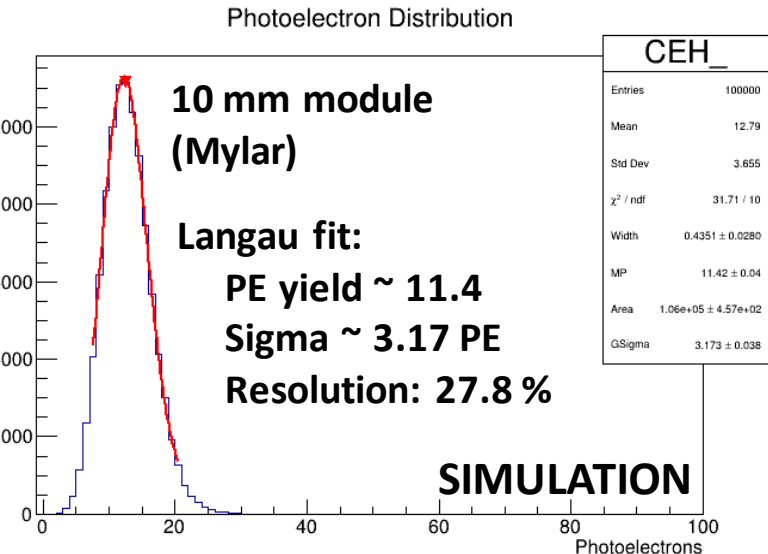
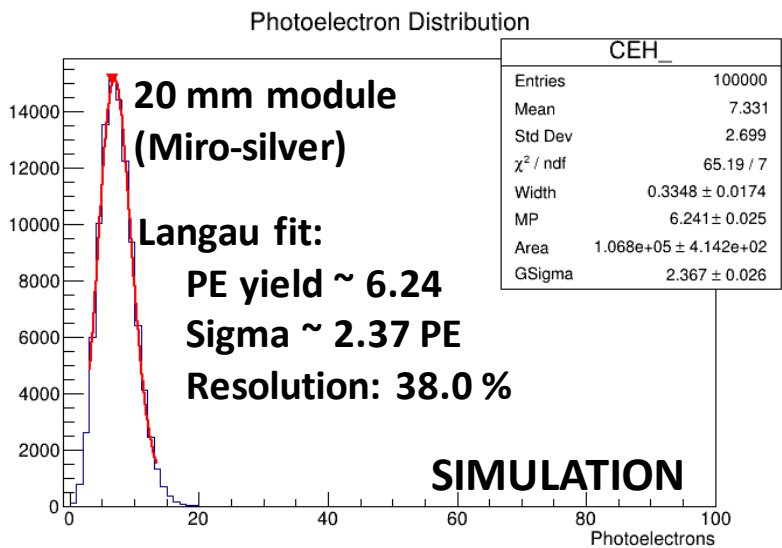
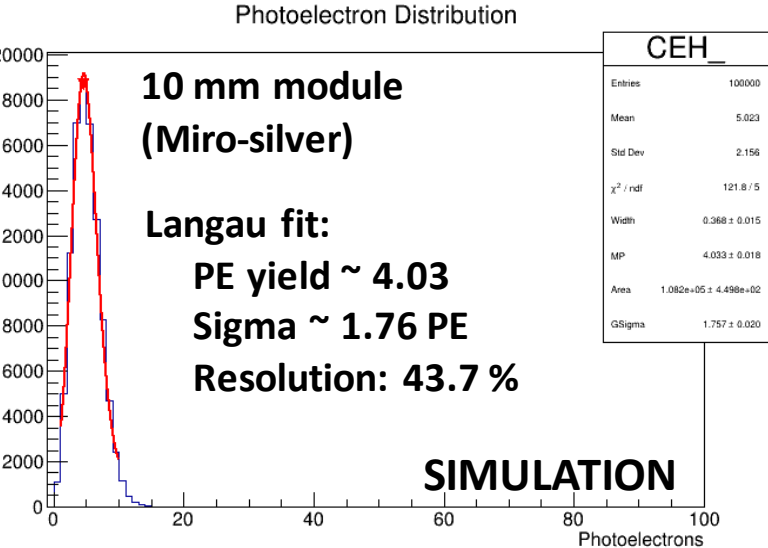
# Comparison of Miro-silver and Mylar

Reflective material	Module	Quartz tile	PE yield	Sigma (PE)	Resolution (%)
Miro-silver	10 mm	Heraeus	3.78 (Langau)	2.52 (Langau)	66.7 (Langau)
			4.27 (Gaussian)	2.50 (Gaussian)	58.5 (Gaussian)
Mylar	10 mm	Heraeus	11.58 (Langau)	3.56 (Langau)	30.7 (Langau)
			13.14 (Gaussian)	4.44 (Gaussian)	33.8 (Gaussian)
Miro-silver	20 mm	Tosoh	7.96 (Langau)	3.28 (Langau)	41.2 (Langau)
			8.86 (Gaussian)	3.67 (Gaussian)	41.4 (Gaussian)
Mylar	20 mm	Tosoh	15.96 (Langau)	3.56 (Langau)	22.3 (Langau)
			18.52 (Gaussian)	5.17 (Gaussian)	27.9 (Gaussian)

- Mylar gives better PE yields compared to the Miro-silver
- The resolution seems to be reasonable with Mylar



# Simulation with Moller Optical framework



- Simulation is performed using Moller Optical simulation framework
- 8 GeV electrons are fired at the center of the quartz
- Simulation is performed with different configuration of quartz tiles and light-guide materials
- Spectra are fitted with Langau distribution to get the PE yield and resolution