Update on the PID Status for EicC

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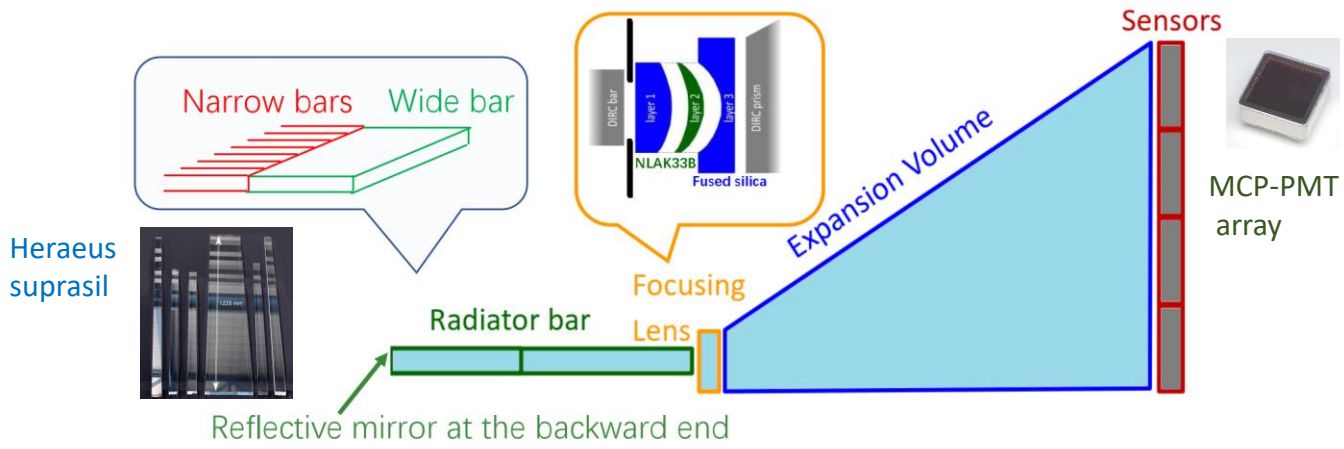
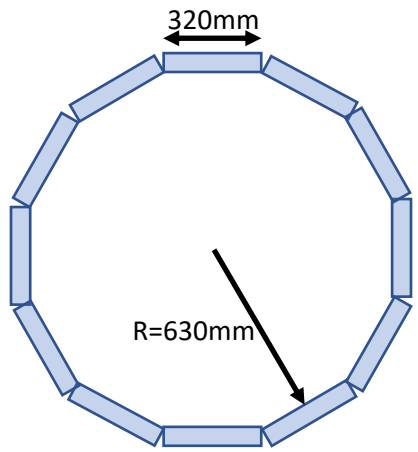
Outline

- DIRC status - Xin Li, IMPCAS
- Cosmic ray platform status - Zheng Liang, Zeyu Wang, USTC
- RICH status – Xu Sun, IMPCAS
- LGAD status – Shuai Yang, Guoming Liu, SCNU
- PID CDR draft

DIRC: Module Design





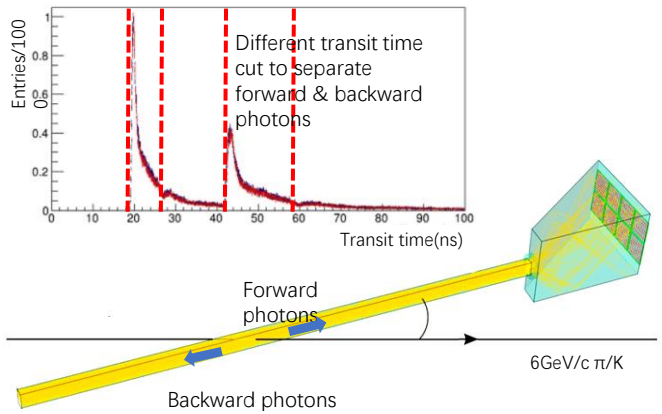
- π/K separation up to 6 GeV/c with Cherenkov angle resolution ~1.0 mrad
- Quartz radiator bar: 15mm x 51mm x 3300mm
- Expansion volume(EV): 208mm x 312mm x 300mm
- MCP-PMT: Hamamatsu R10754 (pixel size: 5.2mm x 5.2mm) or Photonis XP85122 (pixel size: 3mm x 3mm)
- Tray box size: 50mm x 320mm x 4000mm with 6 bar+EV
- 12 trays forms a barrel detector with a minimum radius R = 0.63m
- Focusing: spherical 3-layer lens (Fused silica N-LAK33B) curvature radius: 30cm, Thickness: 10mm

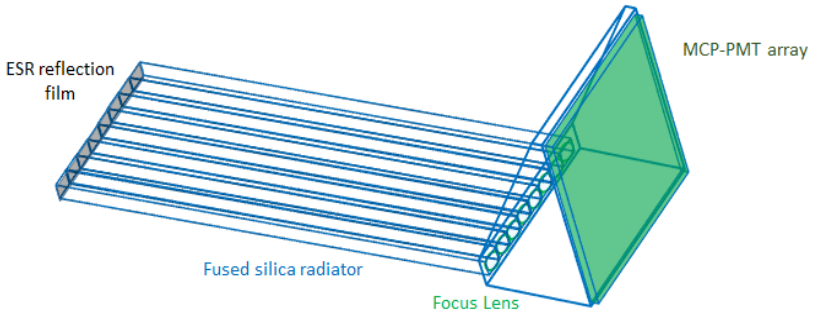
Definition of measured DIRC angular resolution:

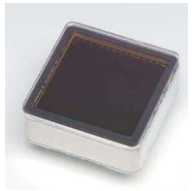
$$\sigma_{\theta_c}(\text{photo}) = \sqrt{\sigma_{chrom}^2 + \sigma_{foc}^2 + \sigma_{bar}^2 + \sigma_{trans}^2 + \sigma_{rec}^2}$$

- σ_{chrom}~5.4mrad, is the dispersion contribution of the quartz radiator (wavelength: 300-700 nm)
- σ_{foc}: error from the optical focusing lens and the pixel size of photosensors
- σ_{bar}: the influence of radiator thickness (flatness) on photon yield and transmission efficiency;
- σ_{trans}: transit fluctuation due to the roughness of the radiator
- σ_{rec}: error from incident particle tracking

DIRC simulation and prototype setup







Hamamastu R10754

GENERAL

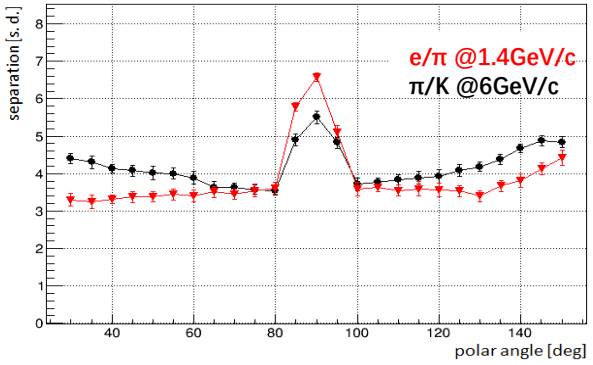
Parameter		Description / Value	Unit
Spectral response		160 to 850	nm
Wavelength of maximum response		380	nm
Window material		Synthetic silica	—
Photocathode	Material	Multialkali	—
	Minimum effective area	23 × 23	mm
Dynode	Dynode structure	2 stages Microchannel plate	—
	Channel diameter	10	μm
Number of anode pixels		16 (4 × 4 matrix)	—
Anode pixel size		5.28 × 5.28	mm
Operating ambient temperature ④		-30 to +45	°C
Storage temperature ④		-30 to +50	°C

MAXIMUM RATINGS (Absolute maximum values)

Parameter		Value	Unit
Supply voltage	Between anode and cathode	2700	V
Average anode current		2	μA

CHARACTERISTICS (at 25 °C, 2200 V)

Parameter		Min.	Typ.	Max.	Unit
Cathode sensitivity	Luminous (2856 K)	80	110	—	μA/lm
	Blue sensitivity index	—	7.5	—	—
Anode luminous sensitivity		22	110	—	A/lm
Gain		—	1 × 10⁶	—	—
Dark current (After 30 minutes storage in darkness)		—	5	30	nA
Time response	Rise time	—	195	—	ps
	Fall time	—	310	—	ps
	Width	—	400	—	ps
	T.T.S. (FWHM) ⑤	—	75	—	ps

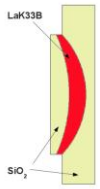


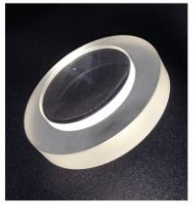
Part done

Photek

The AuraTek-Square has an active area of 53 mm x 53 mm with packaged anode configurations of 32 x 32 with 1.656mm pitch, 16 x 16 with 3.312mm pitch, and 8 x 8 with 6.624mm pitch. A non packaged version with anode confirguration of 64 x 64 with 0.828mm pitch is also available. Custom readout configurations with different anode pitch and signal connectors can be considered.

- True noiseless photon counting
- < 860 ps FWHM pulse width
- Transit time spread of < 40 ps rms



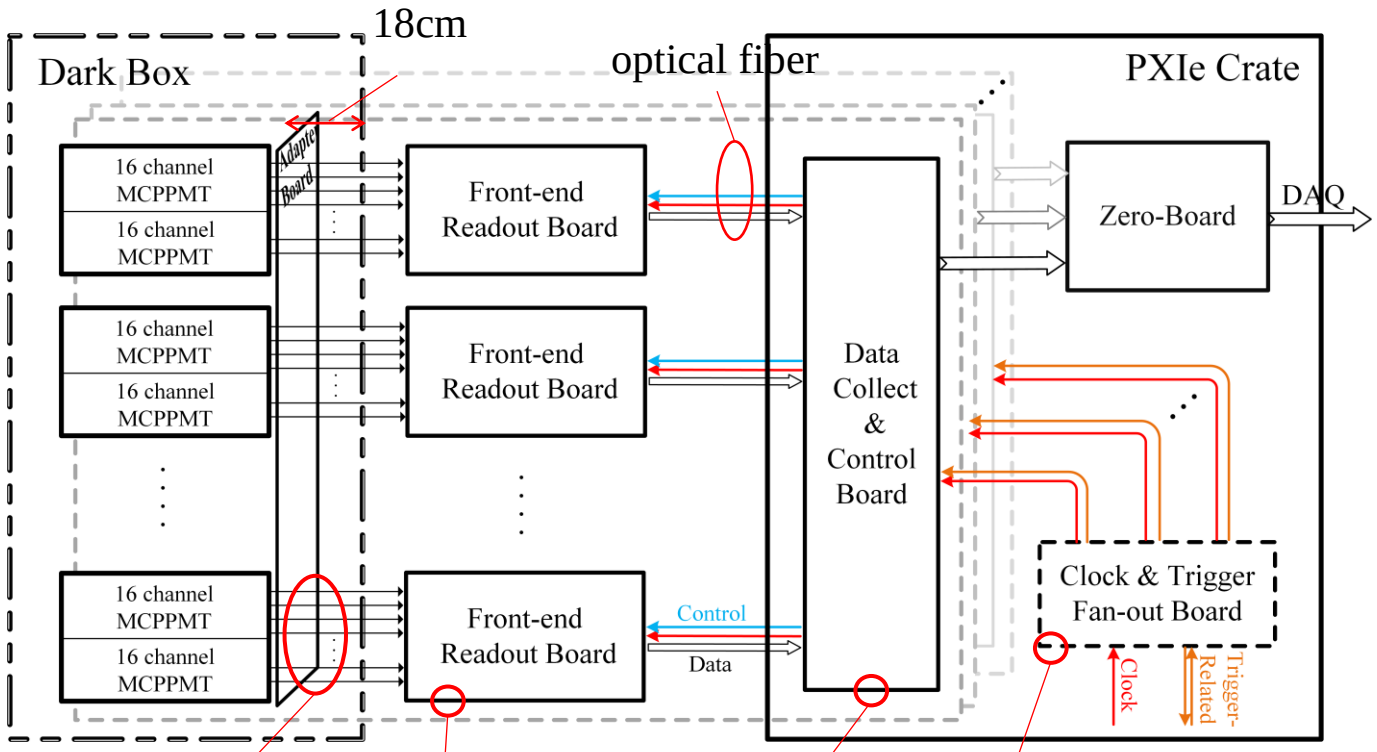


under processing

North night vision N6021

N6021		Min.	Typ.	Max.	Unit.
阴极参数Cathode parameters	光谱范围/Spectral response		280~650		nm
	量子效率峰值波长/Quantum efficiency peak wavelength		380		nm
	积分灵敏度/Luminous sensitivity		70		μA/lm
	量子效率@410nm/QE @410nm		22		%
	辐射灵敏度/Radiant sensitivity@410nm		72		mA/W
阳极参数Anode parameters	工作电压/Supply voltage		2500	3200	V
	增益/Gain		2 × 10⁶		
	暗计数/Dark count rate@0.2pe(单阳极)		500	5000	Hz
	能量分辨率/Charge resolution		35		%
	单光电子谱峰谷比/Peak to valley ratio		3		
时间参数Time Response	上升时间/Rise time		300		ps
	脉冲宽度/Pulse width		650		ps
	下降时间/Fall time		800		ps
	渡越时间弥散/TTS@σ (SPE)		50		ps
	渡越时间弥散/TTS@σ (MPE)		15		ps

Readout Electronics



- 672 channels, 21 front-end boards and flexible boards, 1 T0 timing board, 2 data control boards, 1 clock fanout board, and 1 slot controller are finished
- 1 data control board coupled with 12 front-end readout, the bandwidth of the front-end readout is 320mb/s
- 1 slot controller can have up to 17 data control boards, and supports up to 17 × 12 × 32 = 6528 channels

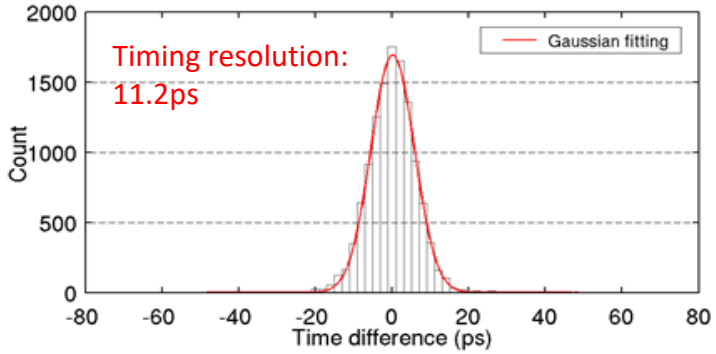
Flexible readout backpanel

Front end readout board

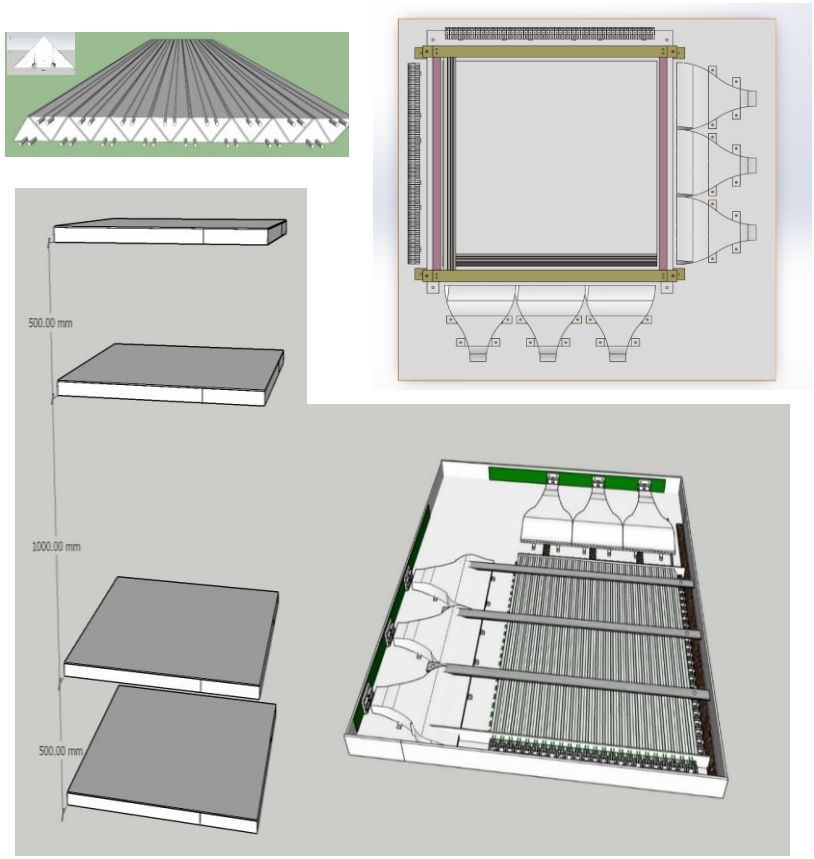
Data control board

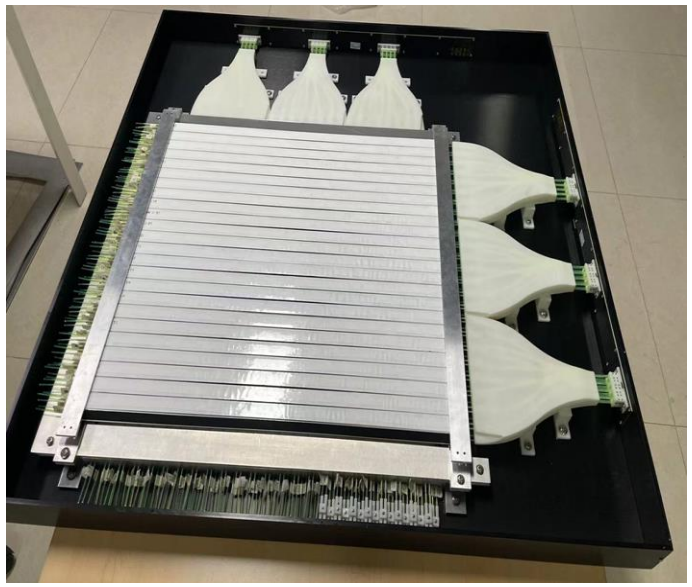
Clock fan-out board

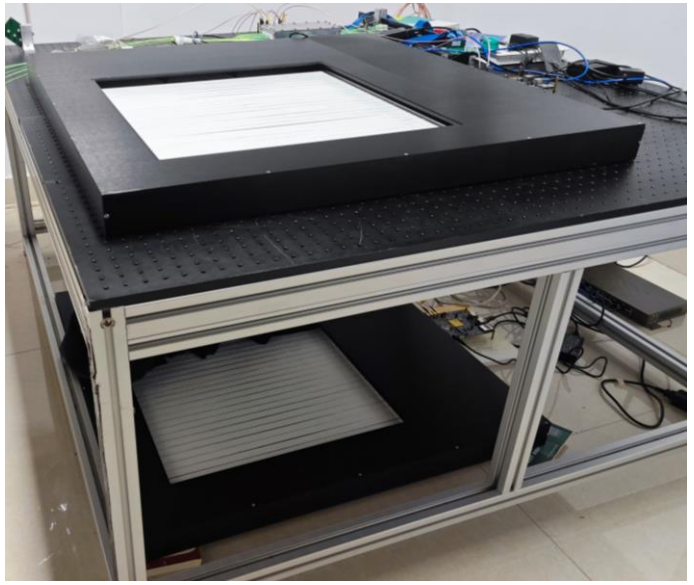
slot controller



Cosmic ray platform: design







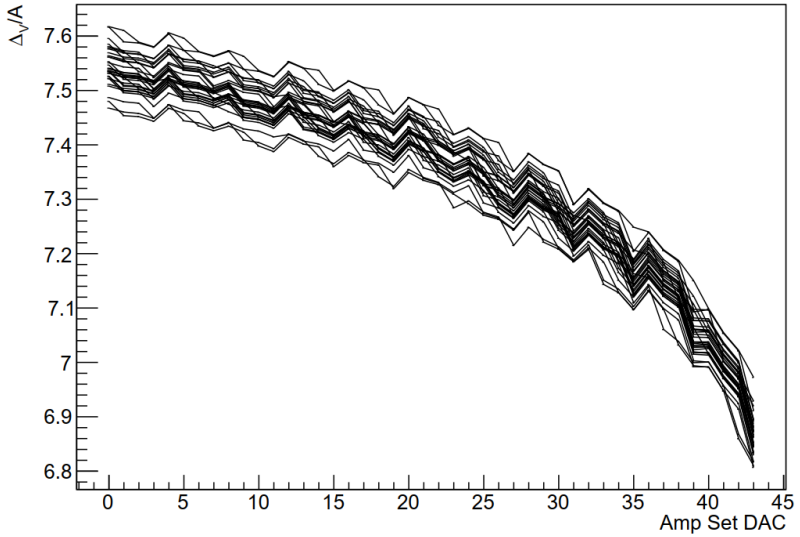
2-D position cosmic ray detector:

- Installed in 80cm x 80cm dark box
- 2 layers (x-y) consist of 6 modules, 96 strips, 192 fibers, and 2 electronic boards
- Position resolution ~ 1mm

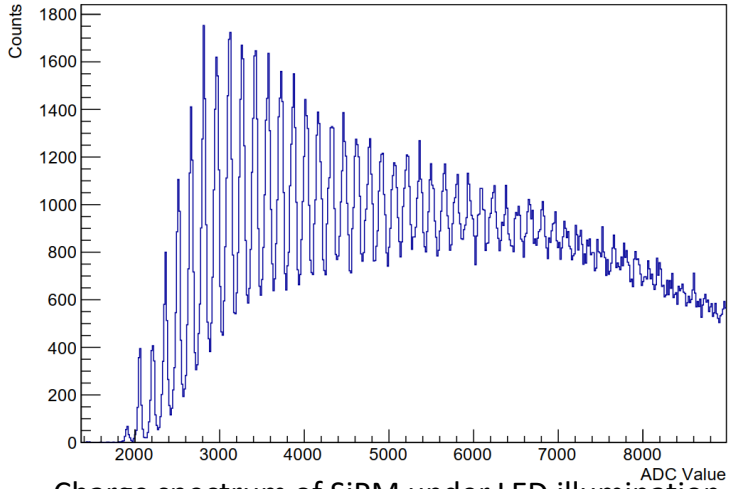
Cosmic ray module:

- 16 scintillator strips & 32 fibers in the same encoding group
- Couple with 8 SiPMs & readout electronic channels

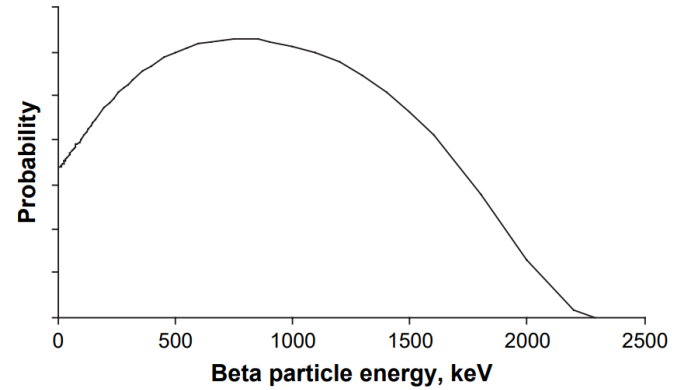
Performance of detector component



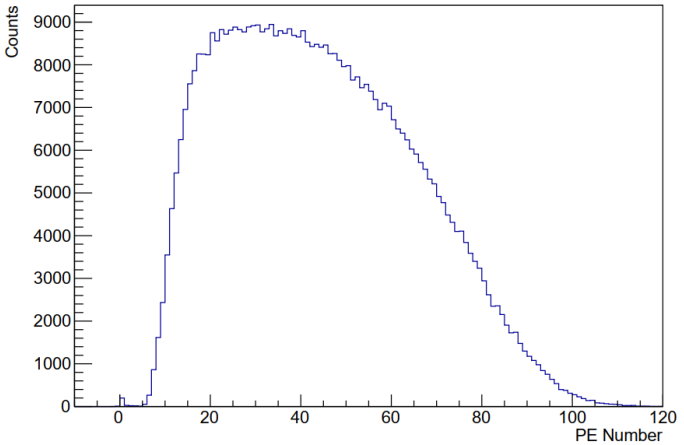
Gain measurement of amplifier, 32 channels



Charge spectrum of SiPM under LED illumination, used to determine PE resolution of SiPM



Spectrum of Sr90/Y90 radioactive source



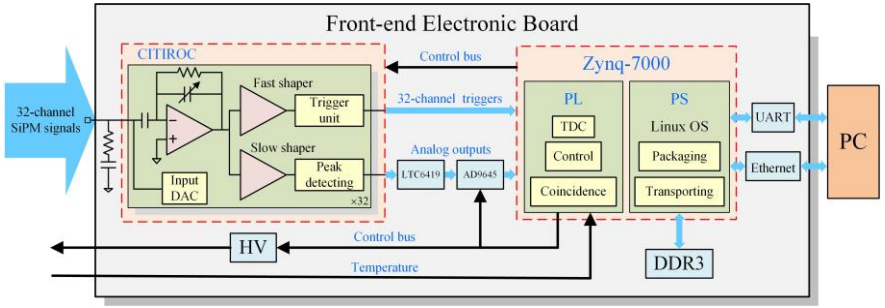
Scintillator spectrum under Sr90, used to estimate photon collection

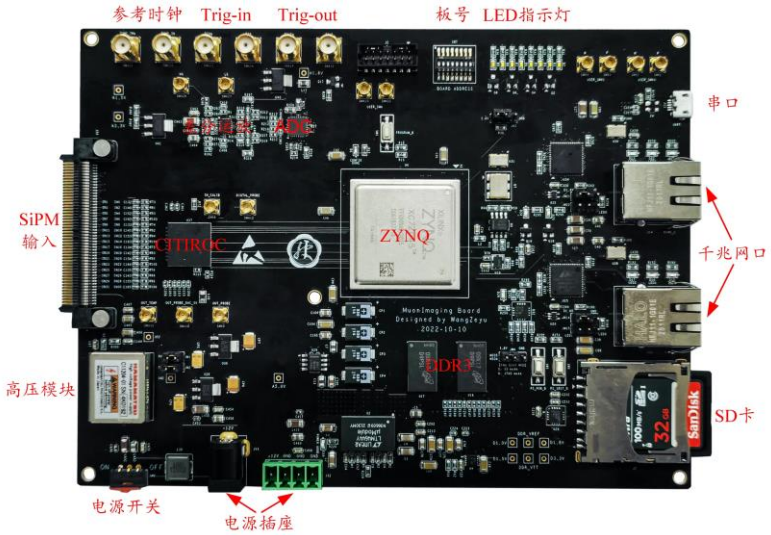
Measure all characteristics of electronic board including:

- Preamplifier gain
- Bias voltage
- noise

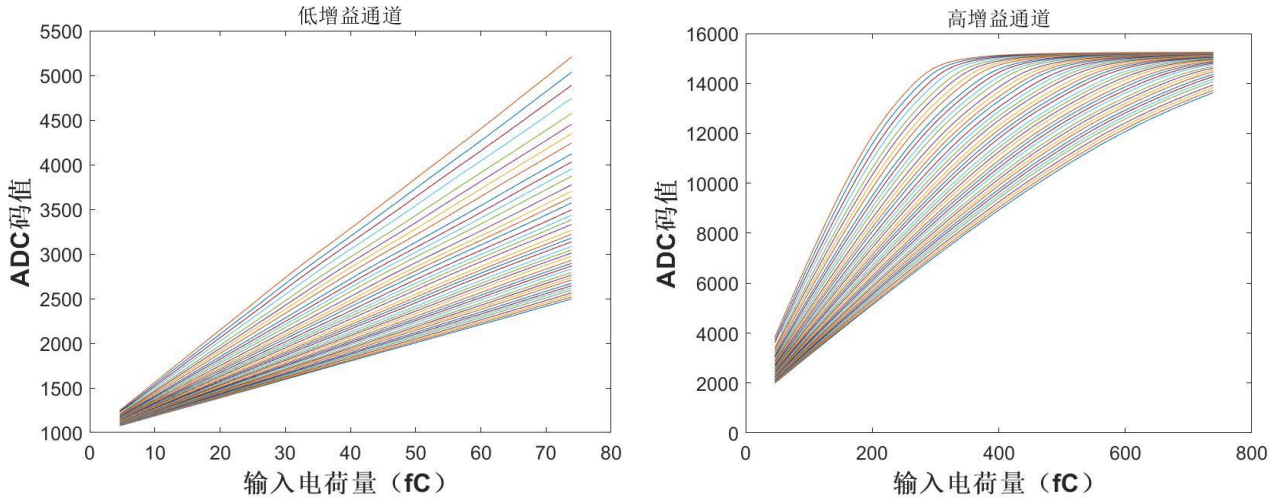
- SPE resolution of SiPM:
  - SPE resolution: $\frac{\sigma_{SPE}}{Gain} = 7.0\%$
- Number of photon collection in 1 fiber:
  - ~ 50 photons/MeV

Cosmic ray readout electronics

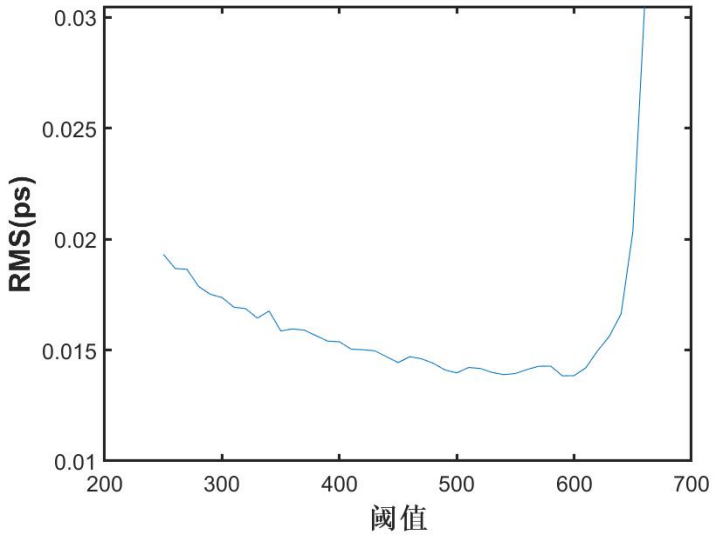




The readout electronics consists of 8 front-end boards. SiPM signals are first sent to the CITIROC chip, which contains high and low gain settings to extend its photon detection and linear dynamic range. After amplification, the integrated signal will output an analog voltage signal, and readout by the ADC. The front-end board uses Xilinx's Zynq-7000 as the main control chip, which contains programmable logic (PL) and processing system (PS) components, recording the time information of each SiPM signal.

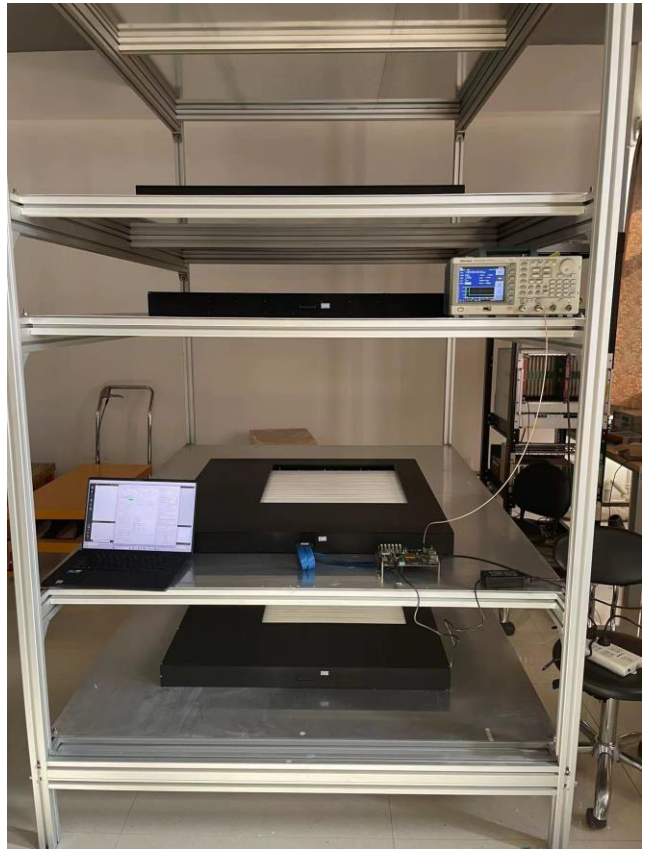


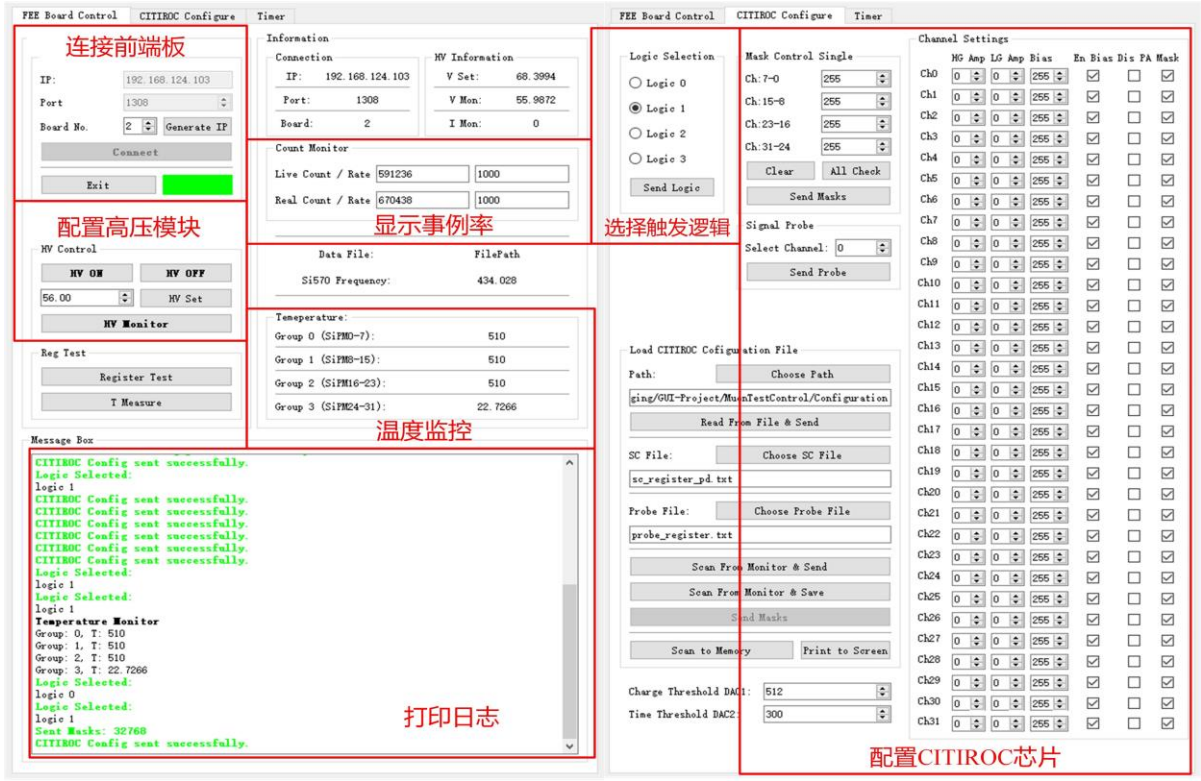
When ADC value below 10000, the charge response keeps linearity



Dependent on the ADC threshold, the time resolution (RMS) of the front-end board can achieve 14ps

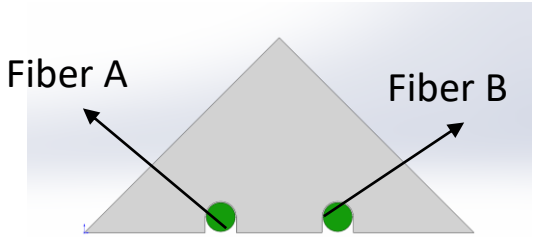
Cosmic ray test

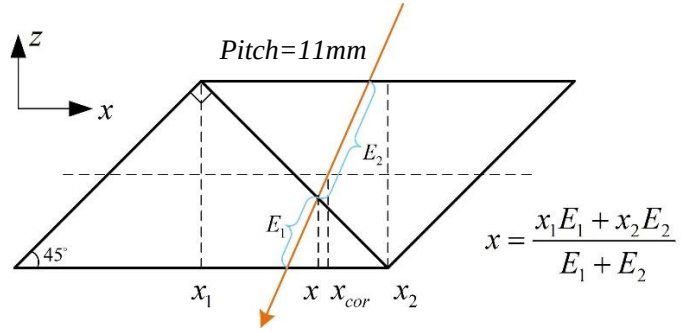




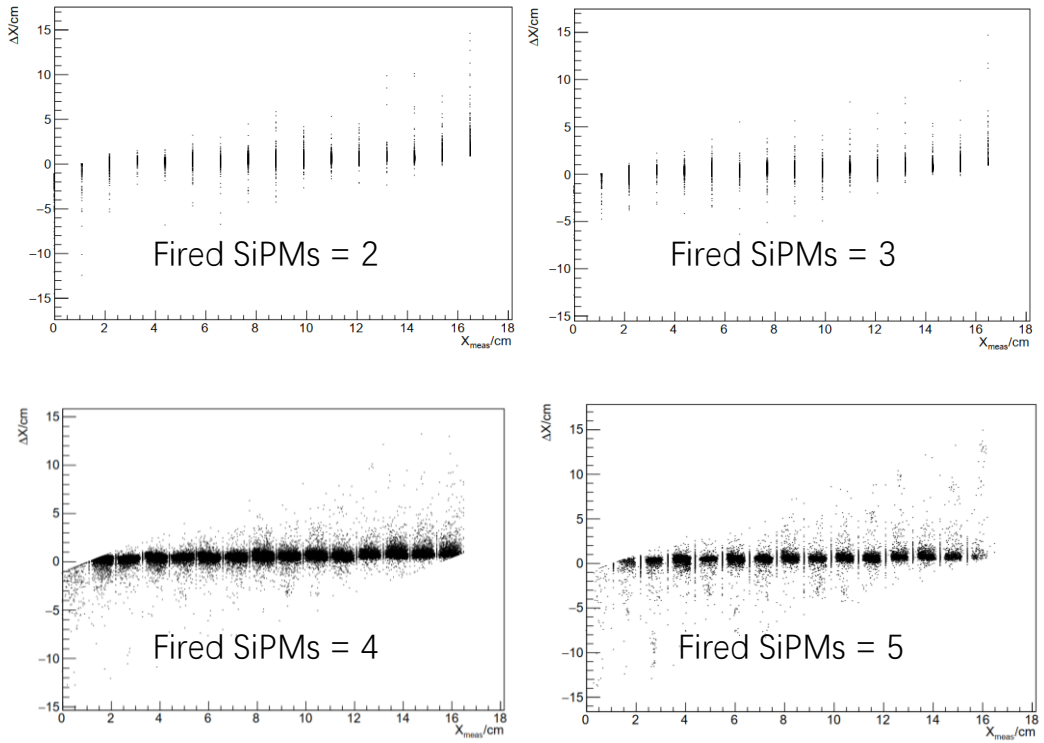
- 4 module completed, has been tested by cosmic ray:

  55 x 55cm sensitive area total
- 1 test module, another 2 modules as trigger & tracker
- Cosmic ray detection efficiency ~ 97%





Performance test results

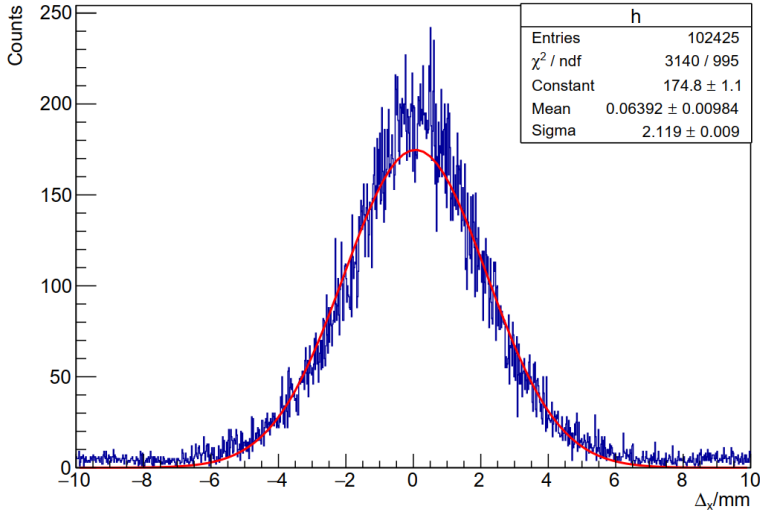


Positioning fluctuation with different fired SiPM counts

- Photon collection efficiency increase 40% with ESR film
- single module's spatial resolution at x, y plane:

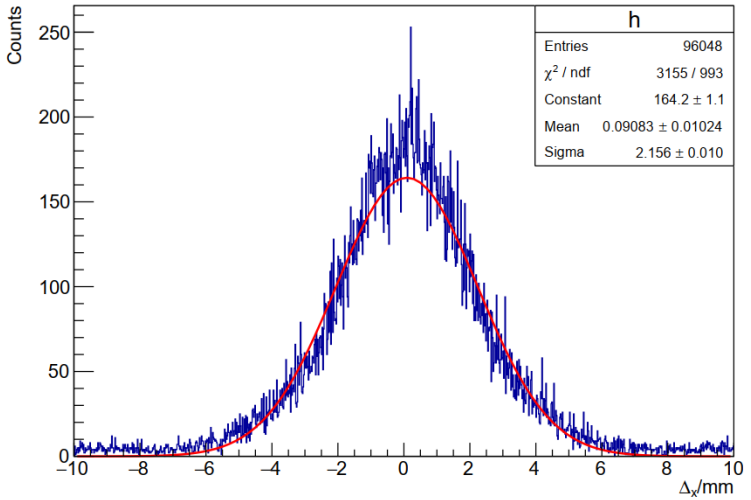
  2.119/√1.5 = 1.73mm, 2.156/√1.5 = 1.76mm
- Estimated overall spatial resolution for 4 modules: $\sigma_{x,y} \sim 0.8$ mm

Status: 4 modules completed, performance as expected, improving 4-layer tracking algorithm.



Measurement fluctuation Δx in x direction

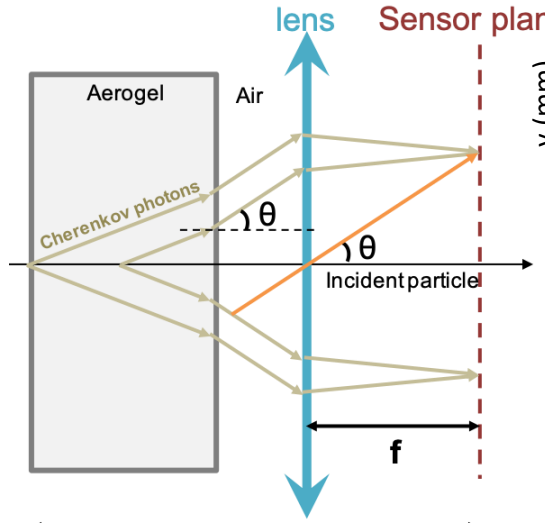
$$\Delta x = \frac{(x_0 + x_2)}{2} - x_1$$



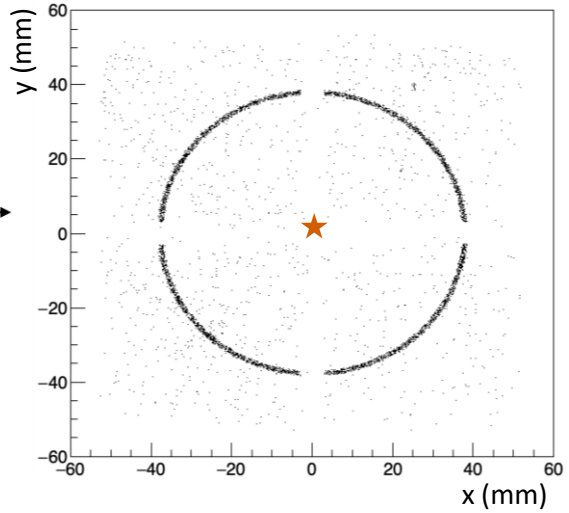
Measurement fluctuation Δy in y direction

RICH: Lens-based Focusing Aerogel Detector Design

Lens-Based mRICH Design

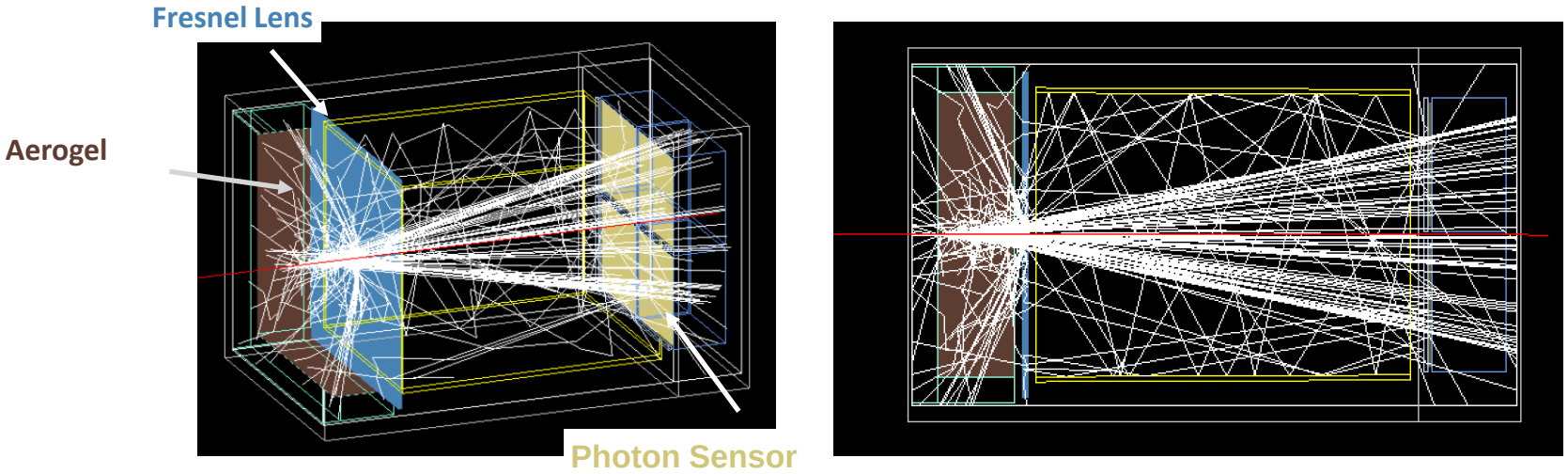


focal length 15.24cm (6”)



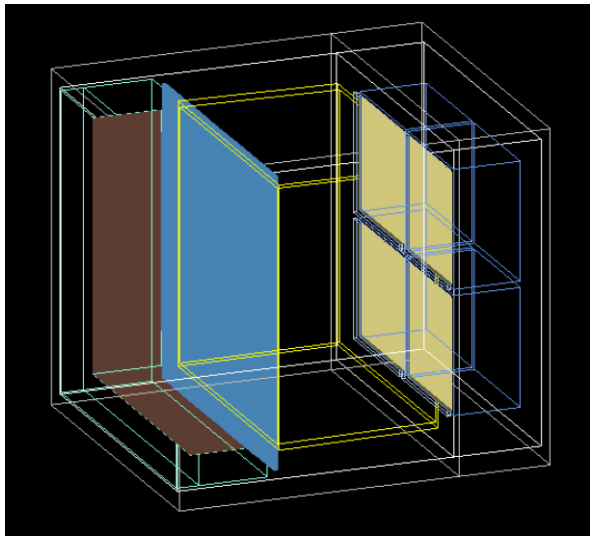
4 GeV/c pion beam launched at the center of xy plane in simulation

f: 7.62cm ~ 15.24cm (3”~6”)

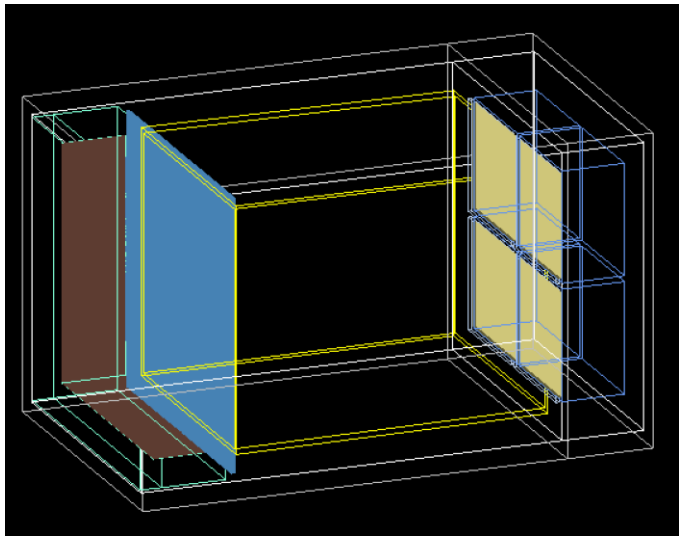


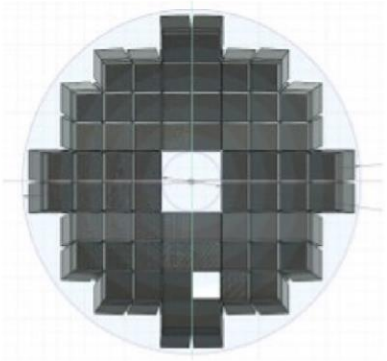
mRICH Layout

focal length 7.62cm (3”)



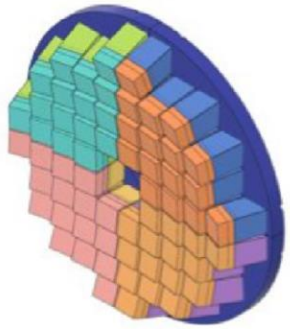
focal length 15.24cm (6”)



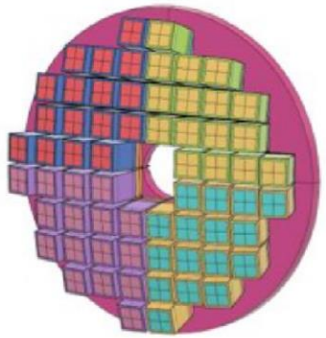


view toward e-going

Side view

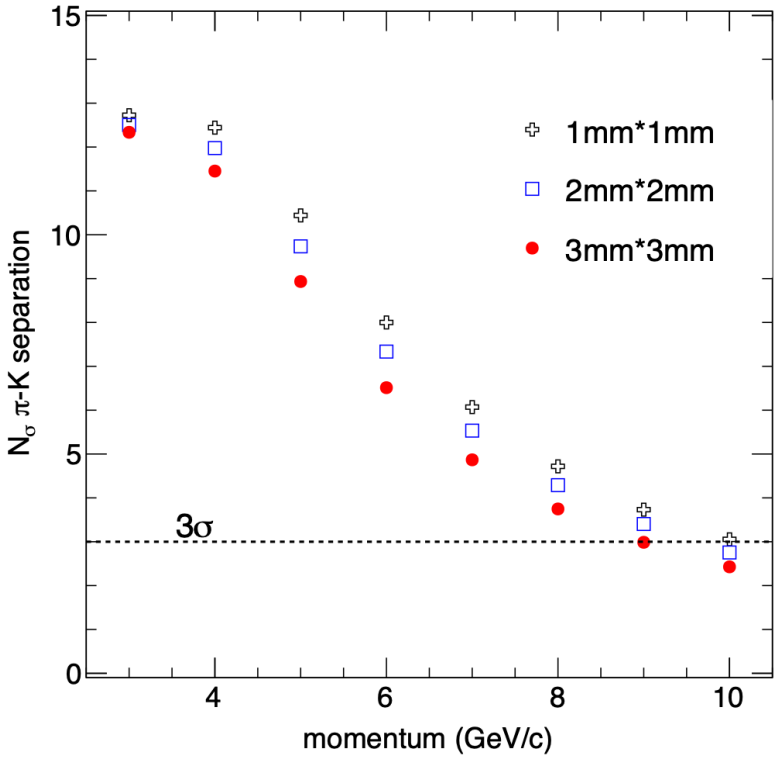


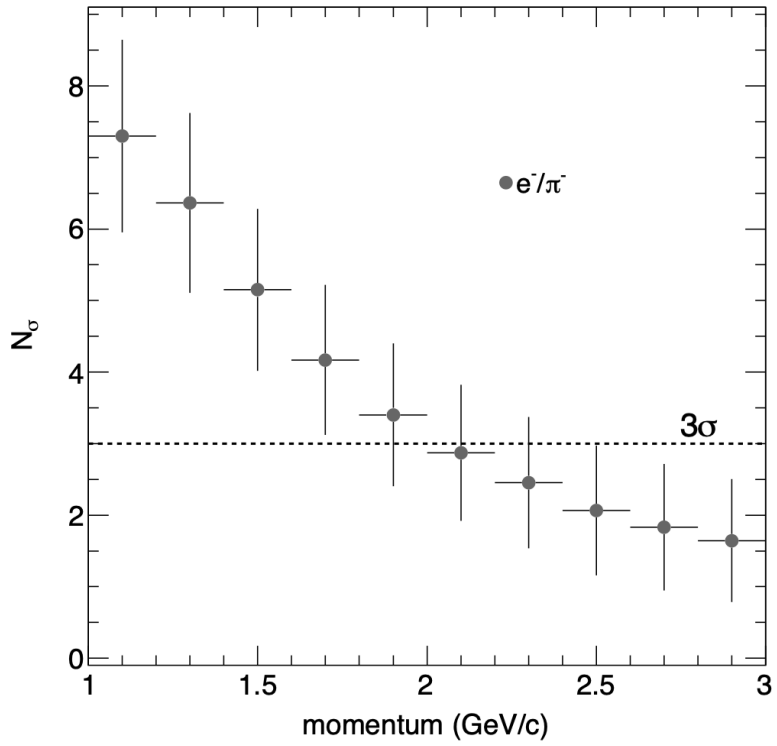
Front-side view



Back-side view

Separation Power for 6” mRICH

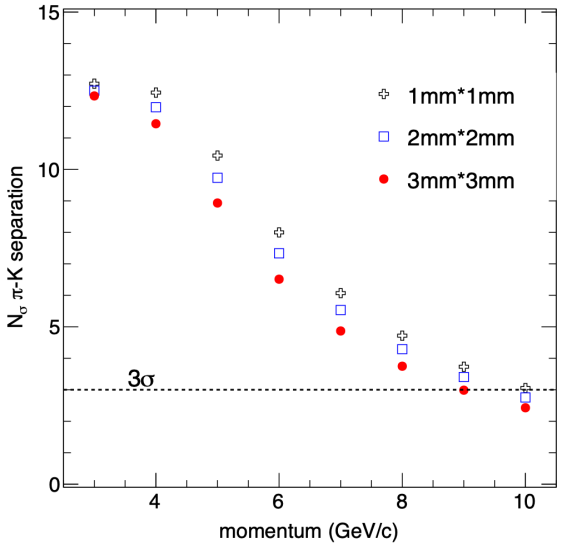




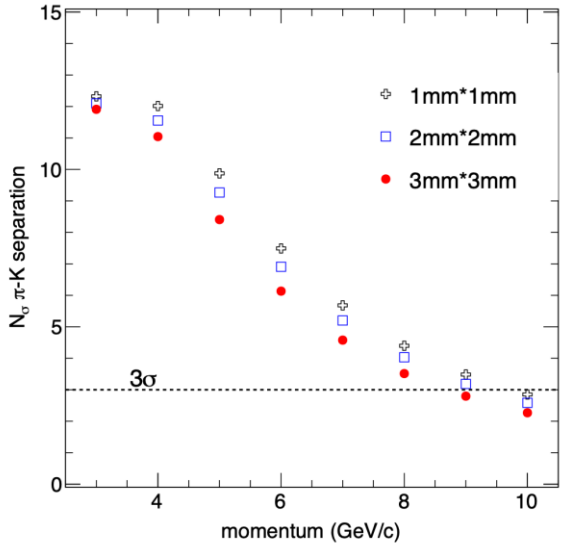
- pi/K separation up to 9 GeV/c
- e/pi separation low to 2 GeV/c

Separation Power for 6” mRICH

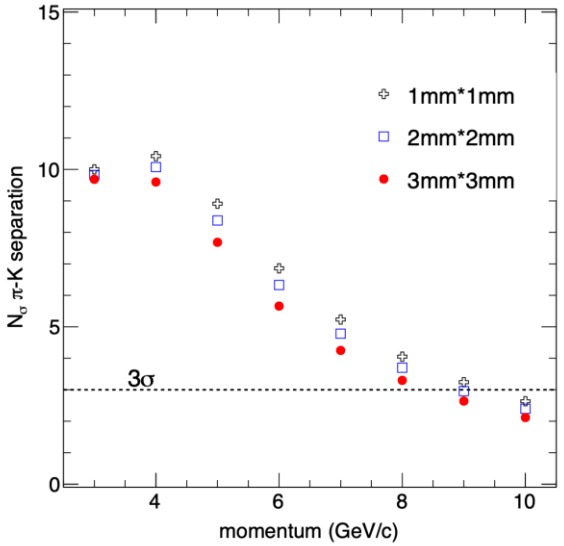
$\theta = 0°$



$\theta = 5°$



$\theta = 10°$



- Separation power decrease with increasing polar angle
- 3 sigma separation up to 9 GeV/c when particle launched at the center of aerogel
- 3 sigma separation up to 8 GeV/c when particle launched at 10 degrees

LGAD: R&D and test platform

➢ Clean Room at SCNU

- The construction of a clean room for detector R&D completed: 80m^2, ISO 7/Class 10000
- Setting up a test platform for LGAD R&D

➢ Probe station for I-V, C-V measurements of semiconductor sensors

- High/low temperature: -100 ~ 300℃
- Micro-positioner resolution: 1 μm

LCR meter

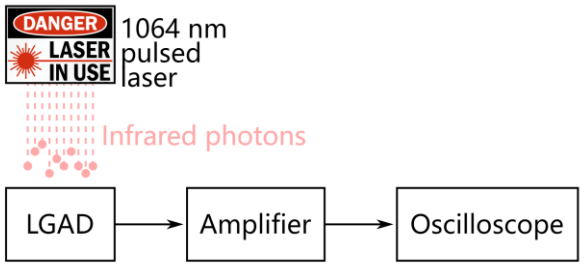
+

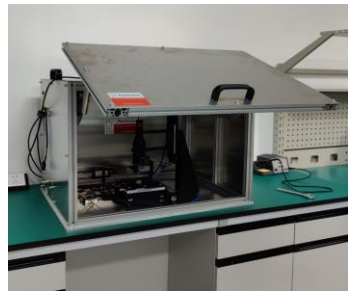
Source Meter SMU

Probe Station

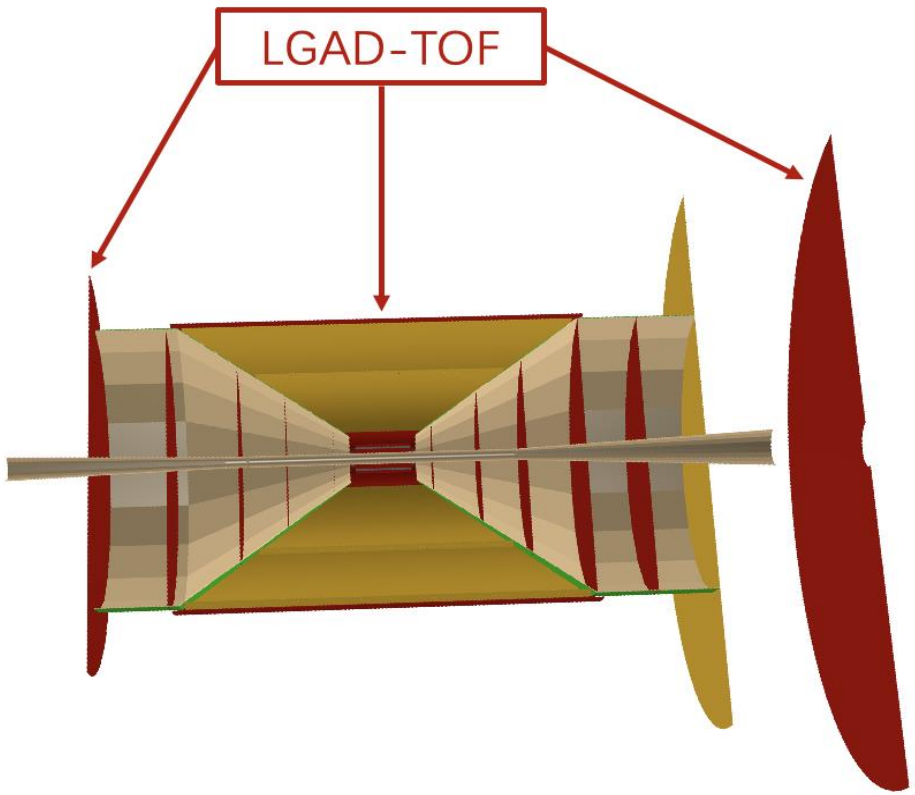
➢ Scanning TCT system

- scanning the detector surface of edge with laser light
- Pico-second IR laser at 1064 nm, spot diameter: ~10 μm
- Moving position resolution: 1 μm
- Could also use a beta-source to scan





LGAD-TOF setup in full simulation



Thanks to Aiqiang and Yuming

- Barrel TOF: right after the tracker system
- Ion-going endcap TOF: right after the RICH system
- E-going endcap TOF: right after the calorimeter system

LGAD-TOF configuration

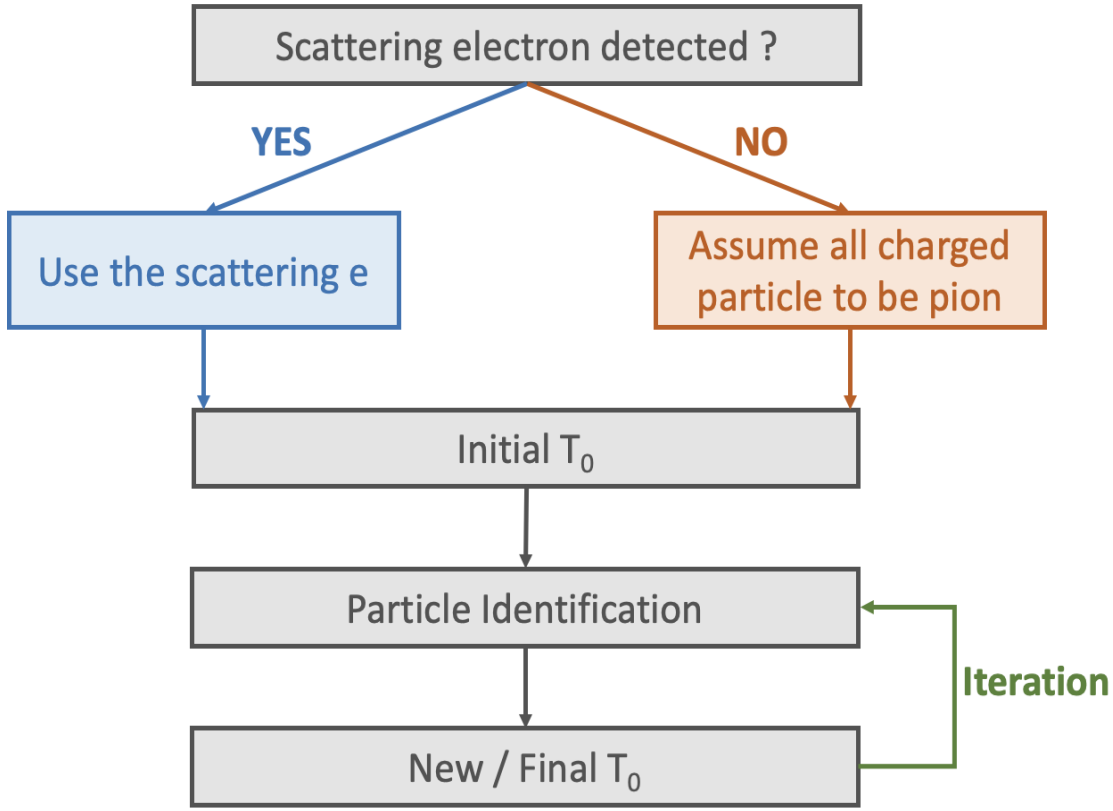
	R^{barrel} (cm)	Length (cm)	Z location (cm)	R_{in}^{endcap} (cm)	R_{out}^{endcap} (cm)	η coverage
Backward			-148	5.4	110.81	[-4.0, -1.1]
Barrel	80	214				[-1.1, 1.1]
Forward			248	12.3	185.7	[1.1, 3.7]

- Current configuration fits to the tracker system well
- Timing resolution: 20-30 ps / layer
- Spatial resolution: ~30 μm

Start time determination (ongoing)

- Event generator: Pythia
- e (3.5GeV) + p (20 GeV)
- Yuming helped to generate 1M e+p event， Aiqiang will report the impact of LGAD-TOF to tracking
- We expect the start time performance to be finished in next 1-2 weeks

Start-time determination strategy



PID CDR Draft

1. Physics Requirements to PIDs

1.1 Reaction type and Kinematics

1.2 Distribution Characteristics of Final State Particles

1.3 Physical Requirements of PID Detector (From EicC white paper, done)

2. Detector options for PID

2.1 Tracking Detectors

2.2 Cherenkov Detectors

2.3 Time-Of-Flight (TOF) Detectors

3. Design for PID Detectors

3.1 The dRICH Designed at Ion Endcap

3.2 The hpDIRC Designed at Barrel

3.3 The mRICH Design at Electron Endcap

3.4 Design of ToF System

3.5 Summary of PID Detector Design

Need supplement for PID association with Calorimeters

4. Critical R&D for PID Detectors

4.1 Cherenkov Detector

4.2 Photosensor

4.3 Fast Timing Silicon Sensor: LGADs

4.4 Readout Electronics

4.5 R&D on Software

4.6 R&D on test platforms

……

PID draft link at overleaf:
https://www.overleaf.com/read/qwsrhvqxbdfp#46e543

Thanks a lot for members of PID group and Chunhua's help!

Summary

- DIRC: improving focus & imaging reconstruction by simulation, manufacturing small prototype
- Cosmic ray test platform: 4-layer modules completed, improving tracking algorithm
- RICH & LGAD: under simulation, setup R&D platform
- PID CDR: 1st draft completed

Thank you!