

Update on Radioactive Source & Cosmic-ray Test of BGO Crystal

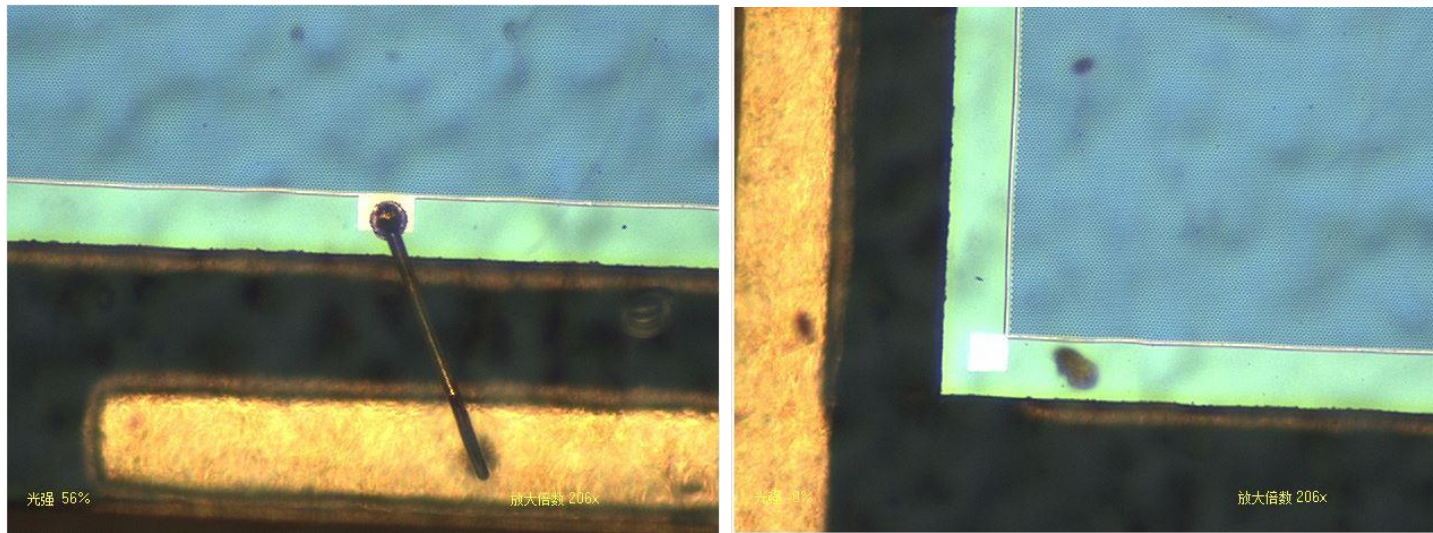
Baohua Qi

June 14, 2022

CEPC Scintillator Calorimeter Meeting

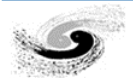
Motivation

- BGO crystal: $40 \times 1 \times 1 \text{ cm}^3$ long bar with ESR wrapping
- SiPM: NDL EQR06 series, $6 \mu\text{m}$ pixel, $3 \times 3 \text{ mm}^2$
 - Response check with NDL SiPM candidate



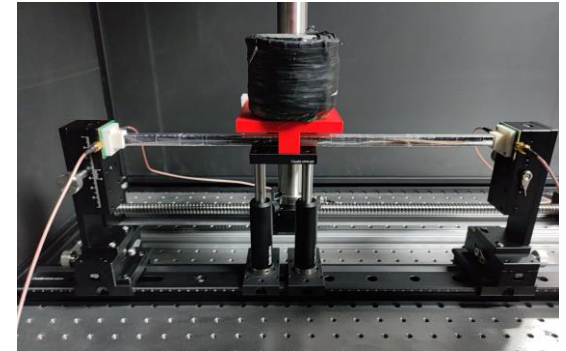
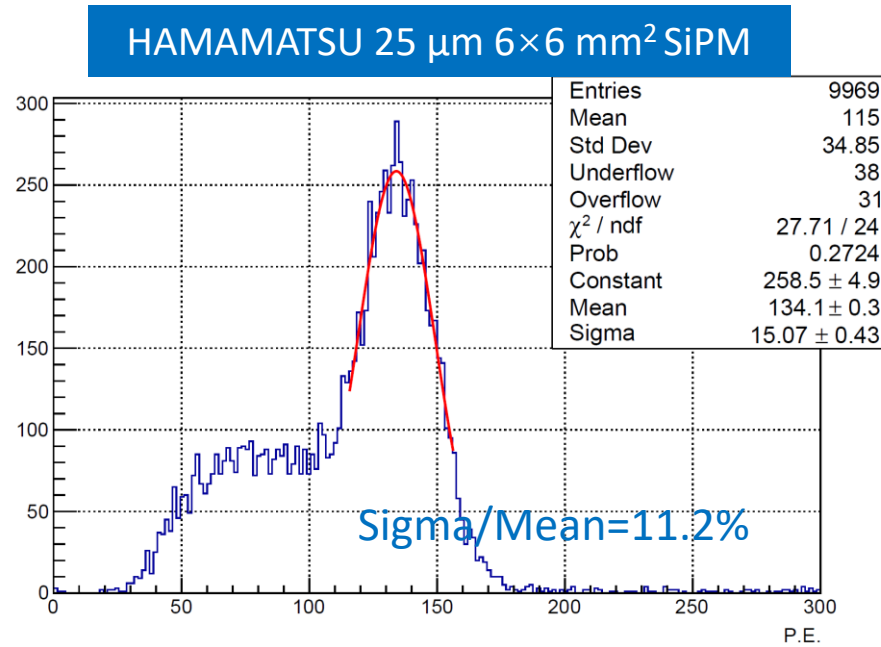
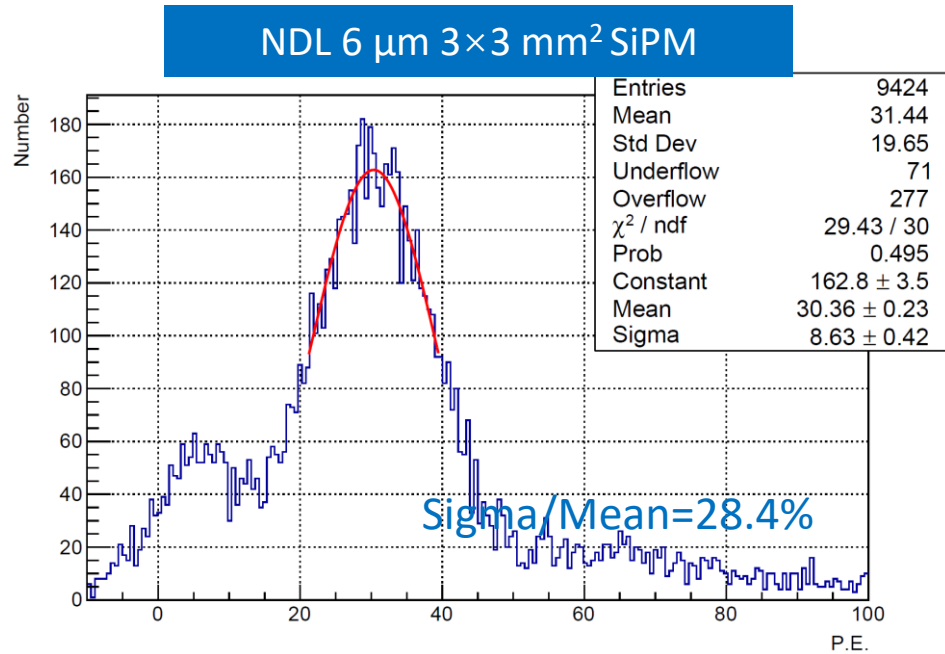
Type	EQR06 11-3030D-S
Effective Pitch	6 μm
Element Number	1 \times 1
Active Area	3.0 \times 3.0 mm^2
Micro-cell Number	244720
Typical Breakdown Voltage (V_B)	24.5 V
Temperature Coefficient for V_B	23 mV / $^\circ\text{C}$
Recommended Operation Voltage	$V_B + 8 \text{ V}$
Peak PDE @420nm	30 %
Gain	8.0×10^4
Dark Count Rate (DCR)	276 kHz / mm^2
Terminal Capacitance	5.1 pF / mm^2

Above parameters are measured at their recommended operation voltage and $20 \text{ }^\circ\text{C}$.

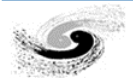
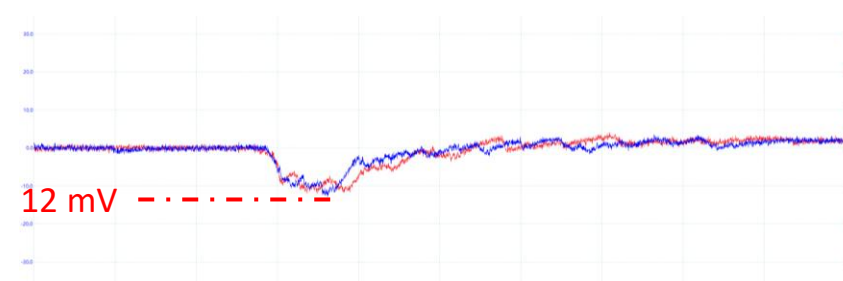
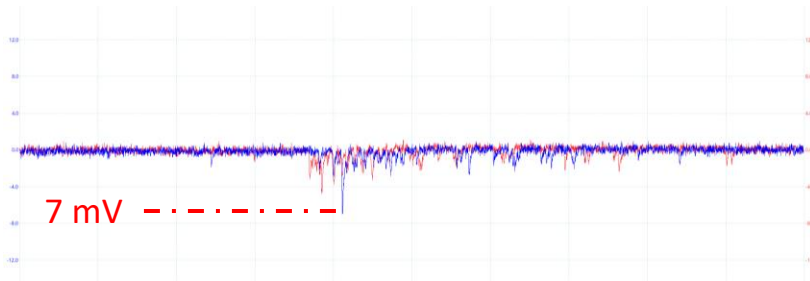


^{137}Cs radioactive source test

- Comparison of NDL EQR06 series and HAMAMATSU S13360 series

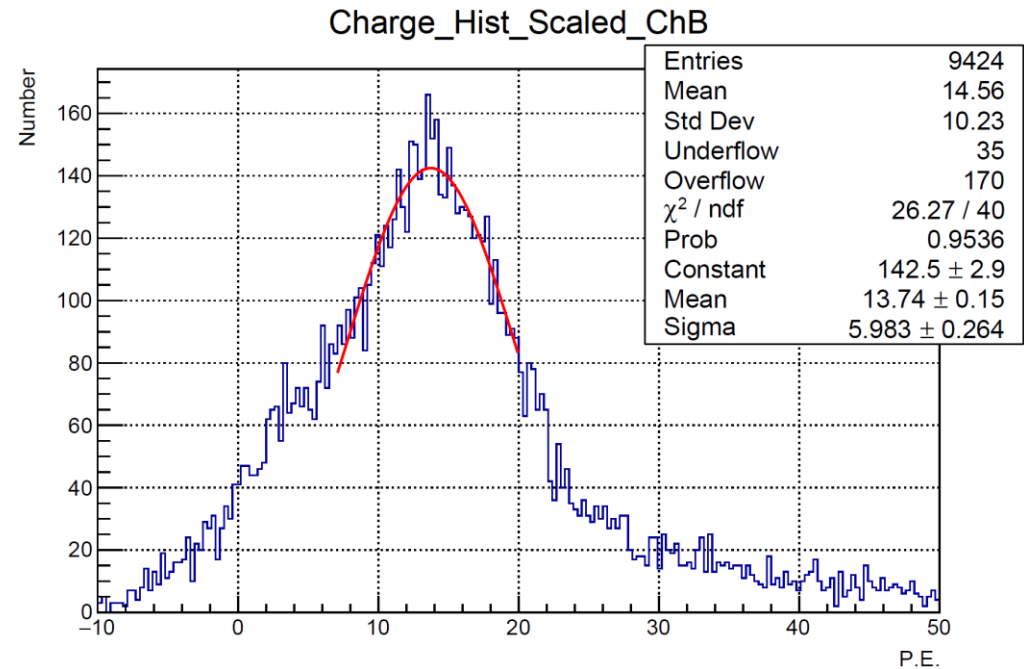
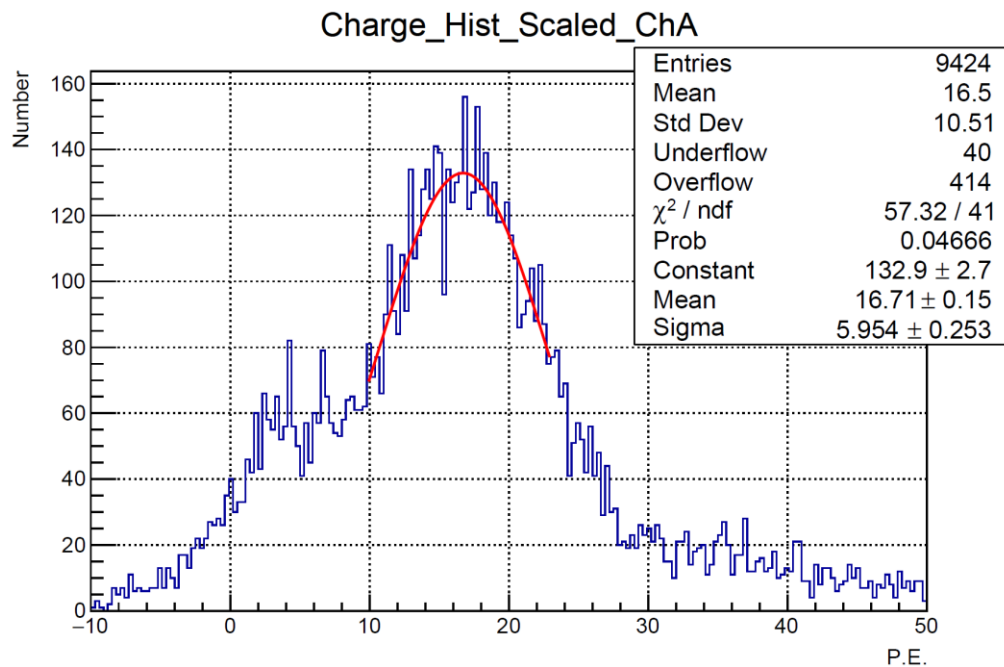


- Detected photons: ~ 4.5 times
- Sharp signals with NDL SiPMs
 - Difficulty on trigger threshold setup
 - Contamination of thermal noise and cosmic-ray events



^{137}Cs radioactive source test

- Uniformity of signals from both ends of crystal

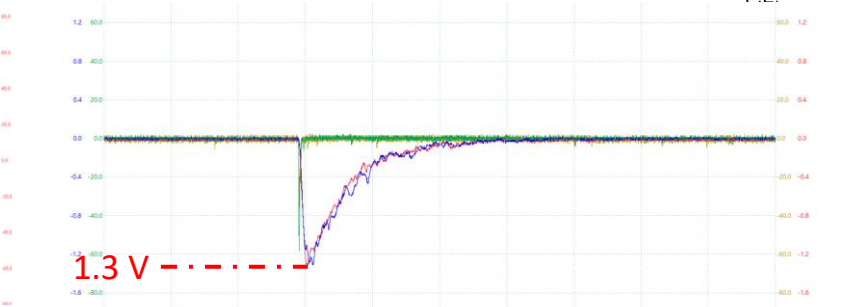
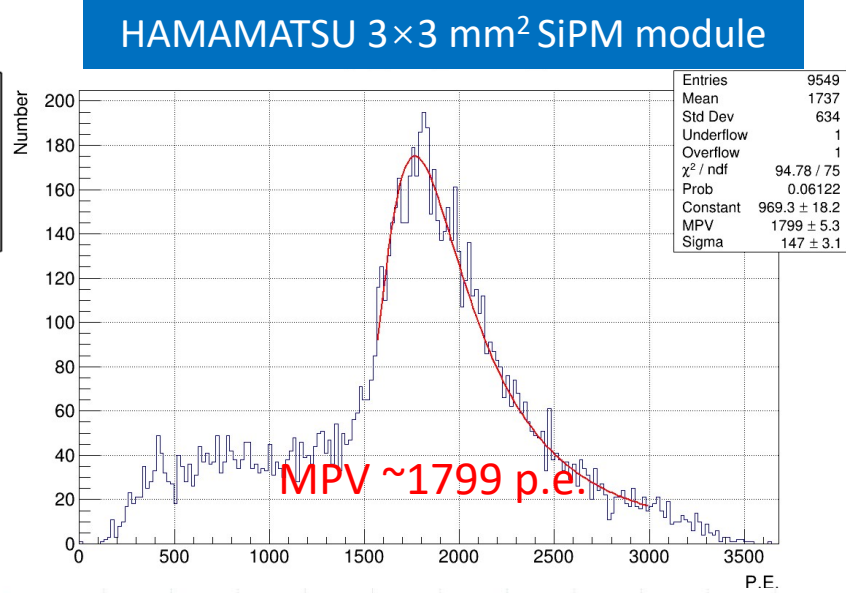
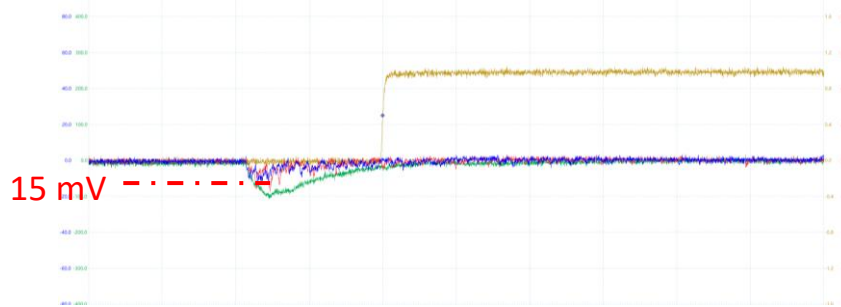
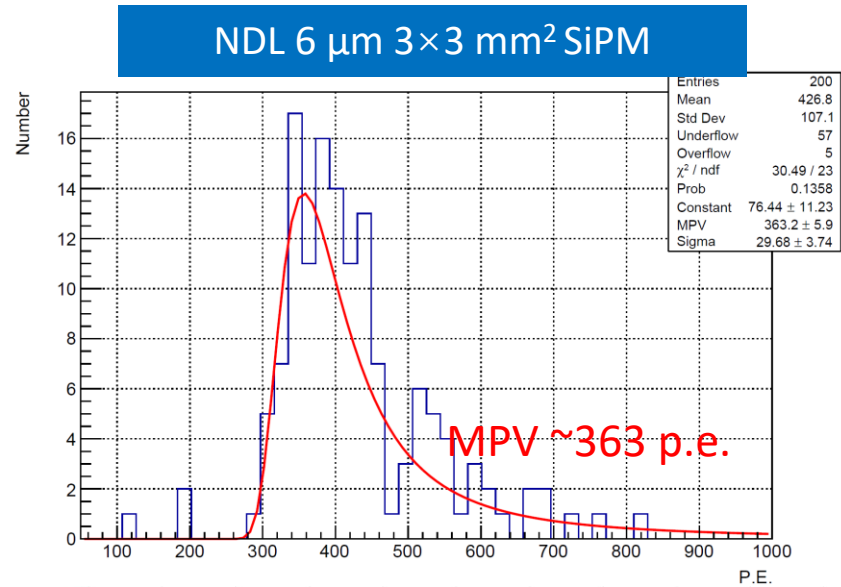


- Relatively low response near one side
 - Still need further tests

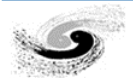
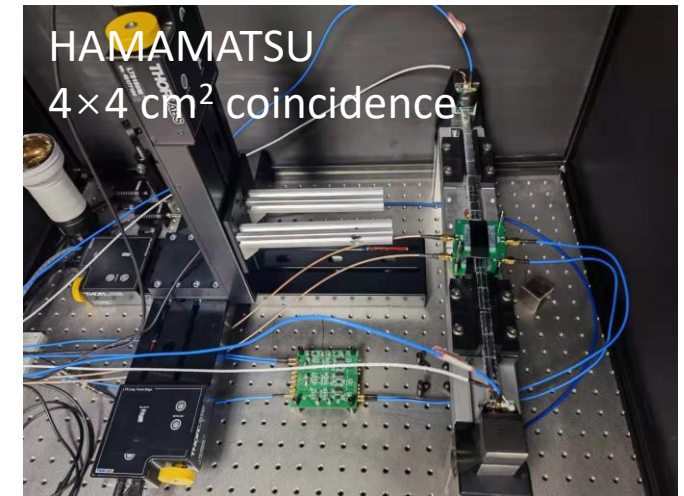
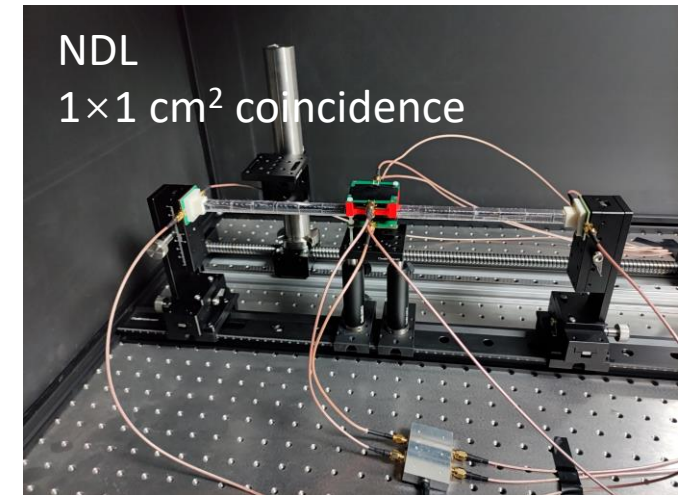


Cosmic-ray test

- MIP response of BGO crystal with NDL SiPM (preliminary result)



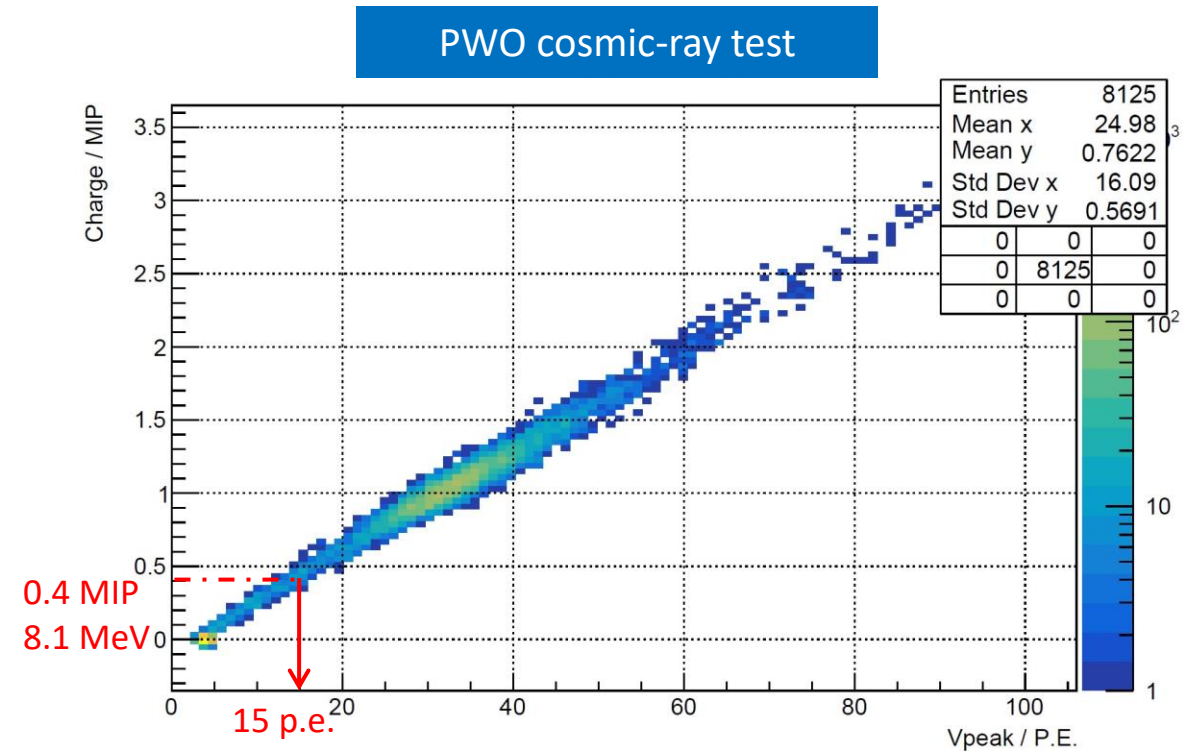
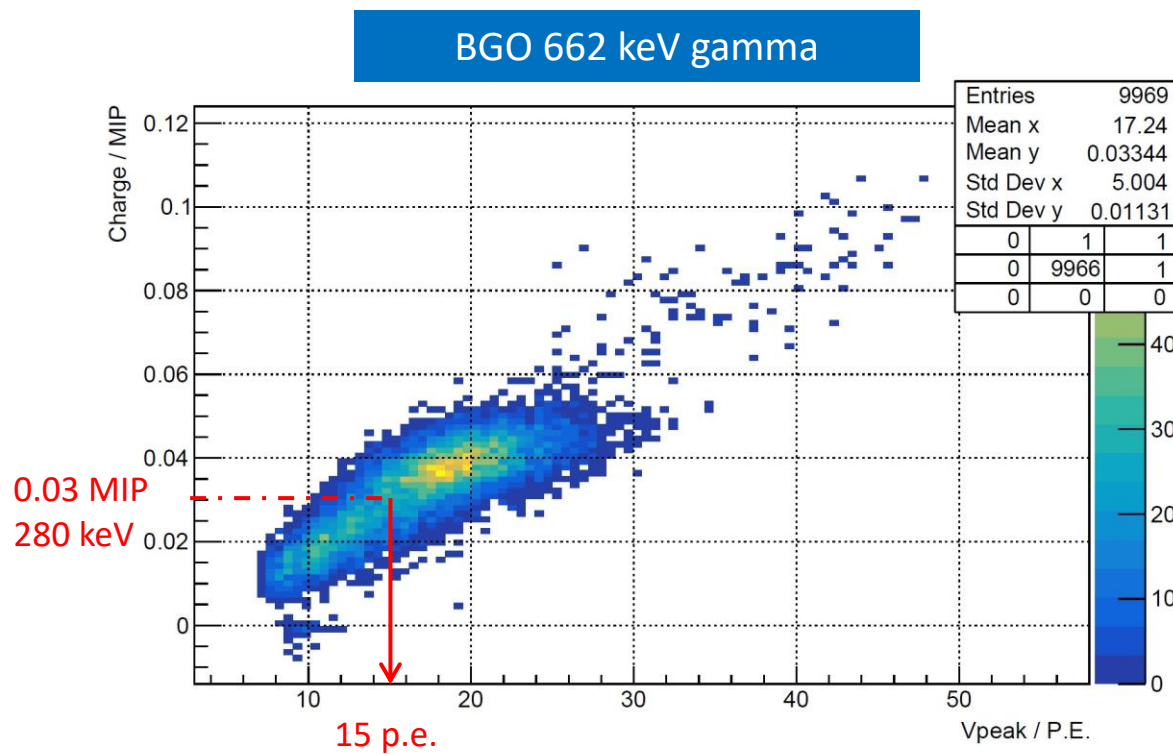
- Detected photons: significant difference, need more data
 - PDE: 30% vs 40% at 420nm, coupling: air vs silicone



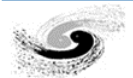
Backup

Relationship between ADC channel and QDC channel

- ADC channel corresponds to peak voltage of the signal



- Generally linear relationship between ADC (Vpeak in p.e.) and QDC (charge/energy in MIP)
- Same voltage threshold corresponds to very different energy thresholds



Summary of crystal ECAL specifications

Key Parameters	Value	Notes
MIP light yield	>100 p.e./MIP	9.1 MeV/MIP in 1 cm BGO
Dynamic range	0.05~10 ³ MIP	About 500 keV~10 GeV
Energy threshold	15 p.e.	Feasible for 0.05 MIP signal
Timing resolution	~400 ps	Expected value from simulation
Crystal non-uniformity	<1%	After calibration
Temperature stability	Stable at the level of 0.05 Celsius	CMS ECAL value
Gap tolerance	—	TBD through module development

Further issues:

- Temperature control
 - Temperature dependent properties (SiPM crystal)
 - Cooling system for Front-end electronics
- Calibration schemes
 - LED single photon calibration of SiPMs
 - Transmittance of crystal: radiation damage
 - Operation and maintenance: MIP calibration

