中国科学院高能物理研究所
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Progress on the Crystal ECAL

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On behalf of CEPC Calorimeter Working Group

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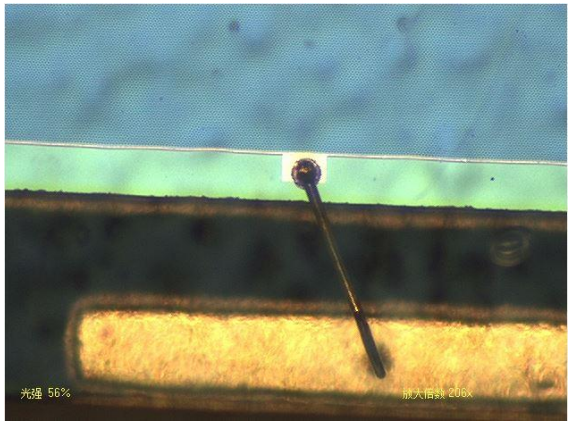
Outline

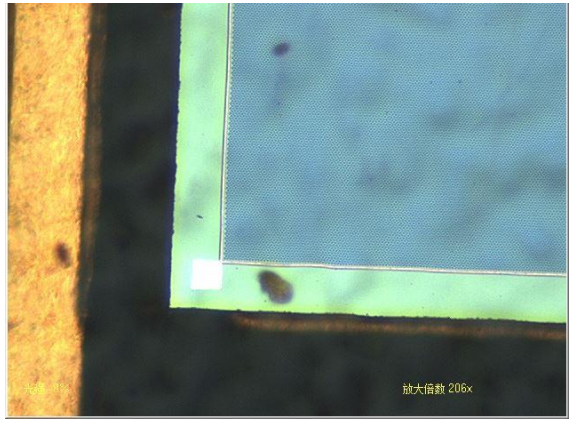
Development of crystal ECAL:

- SiPM & crystal tests
  - Cosmic-ray test and radioactive source test
  - SiPM laser test: dynamic range and time resolution
- Small-scale detector module design
  - Simulation study of gaps

Motivation

- SiPM: NDL EQR06 series, 6 μm pixel, 3×3 mm^2
  - Response check with NDL SiPM candidate

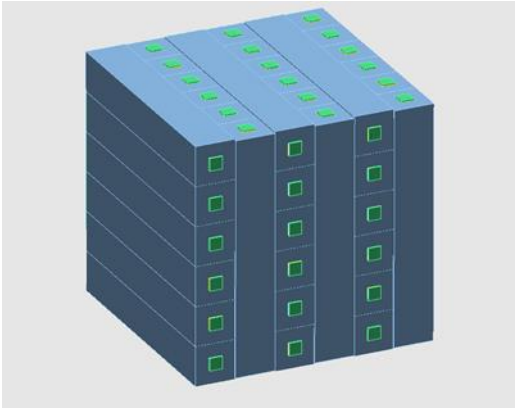


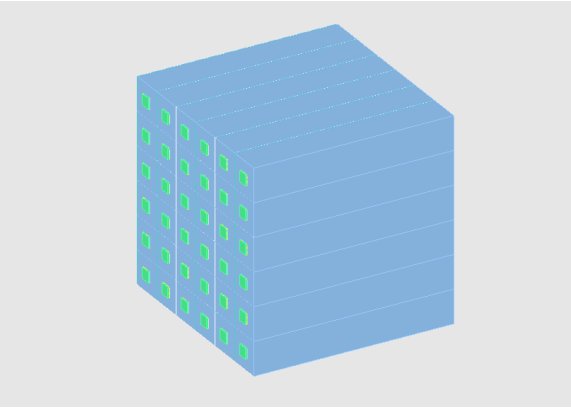


Type	EQR06 11-3030D-S
Effective Pitch	6 μm
Element Number	1×1
Active Area	3.0×3.0 mm^2
Micro-cell Number	244720
Typical Breakdown Voltage (V_B)	24.5 V
Temperature Coefficient for V_B	23 mV / ℃
Recommended Operation Voltage	V_B + 8 V
Peak PDE @420nm	30 %
Gain	8.0×10^4
Dark Count Rate (DCR)	276 kHz / mm^2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

Above parameters are measured at their recommended operation voltage and 20 ℃.

- Small-scale detector module
  - Requirements on mechanical design
  - Impact of gaps

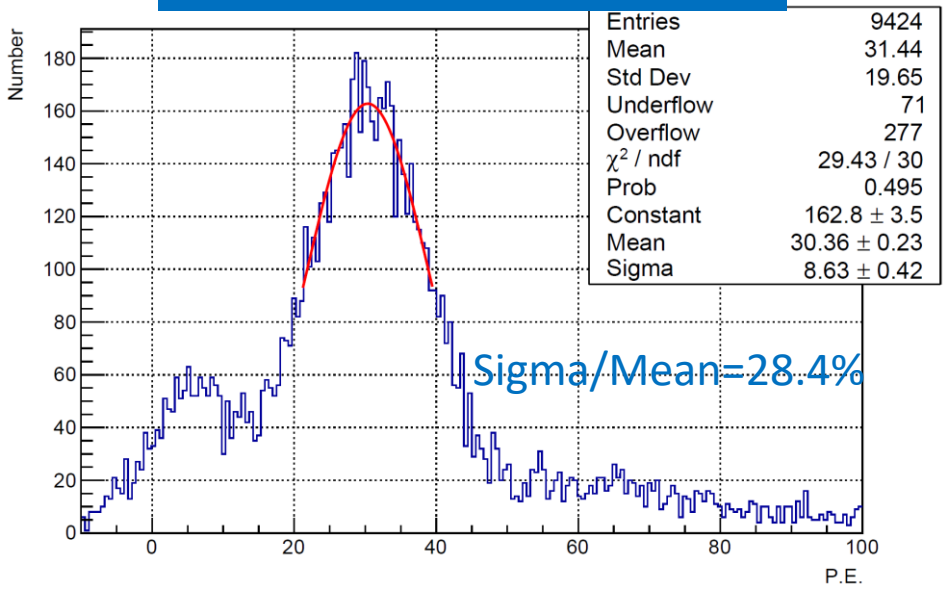


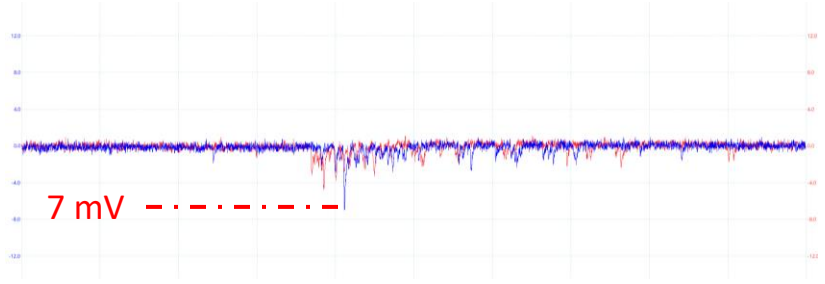


^{137}Cs radioactive source test

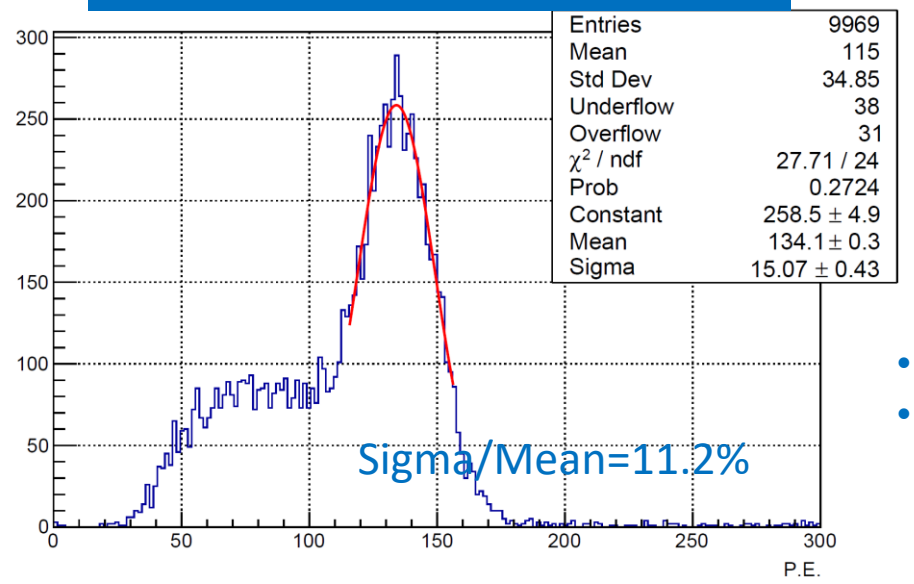
- Comparison of NDL EQR06 series and HAMAMATSU S13360 series
  - Active area: 9 mm^2 vs 36 mm^2, detected photons: 30 vs 134

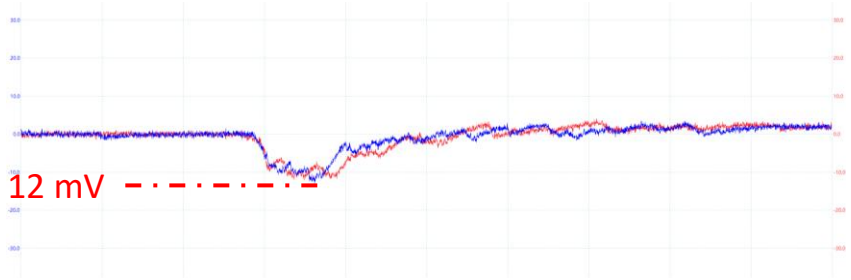
NDL 6 μm 3×3 mm^2 SiPM

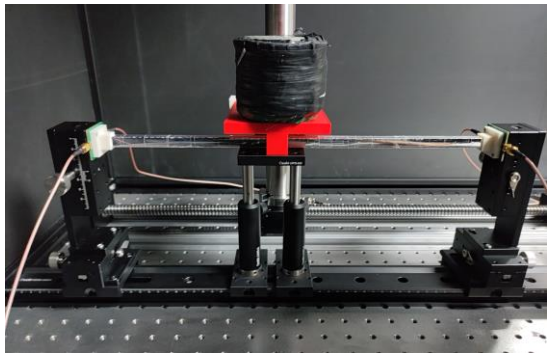




HAMAMATSU 25 μm 6×6 mm^2 SiPM





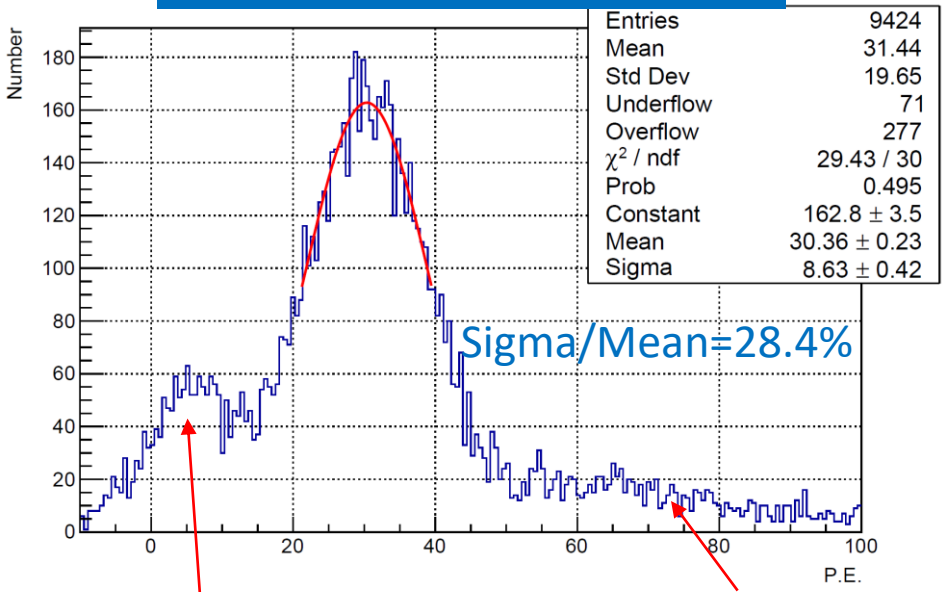


- Detected photons: ~4.5 times
- Sharp signals with NDL SiPMs
  - Difficulty on trigger threshold setup (reduction of trigger rate)
  - Contamination of thermal noise and cosmic-ray events

^{137}Cs radioactive source test

- Comparison of different length of crystal bar
  - Mean value of detected photons: 30→77 (400mm→160mm crystal)
  - The attenuation effect is stronger than expected: geometry effect included

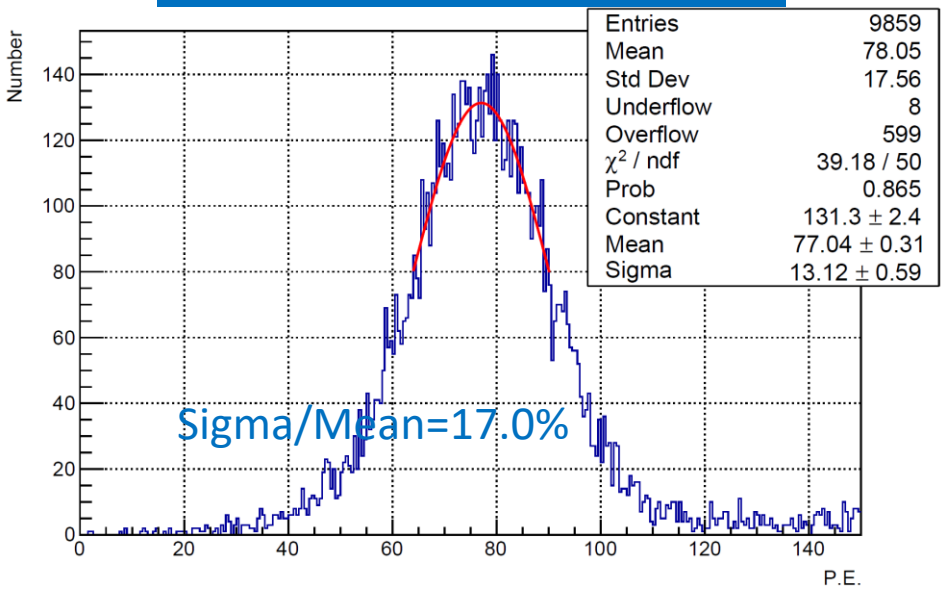
400×10×10 mm BGO



- Including contamination of thermal noise
- Trigger threshold is lower

- Contamination of cosmic-ray events

160×10×10 mm BGO

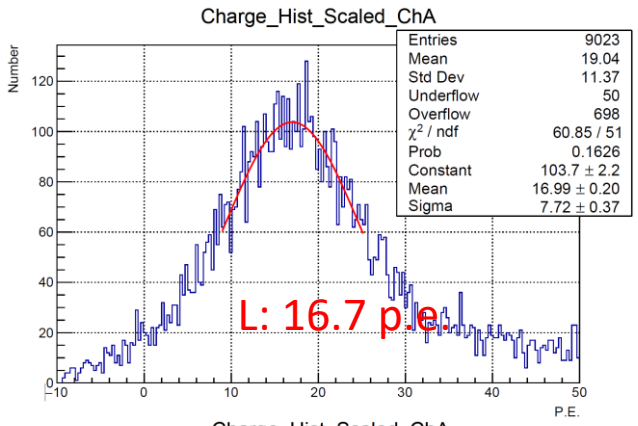


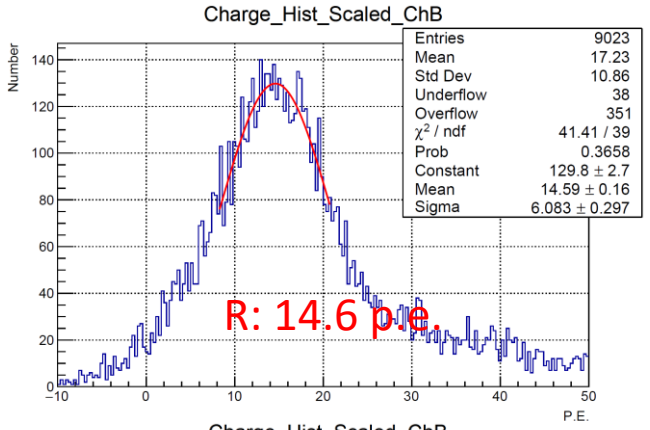
- Using higher threshold here
- Energy spectrum of ^{137}Cs is not clear enough

^{137}Cs radioactive source test

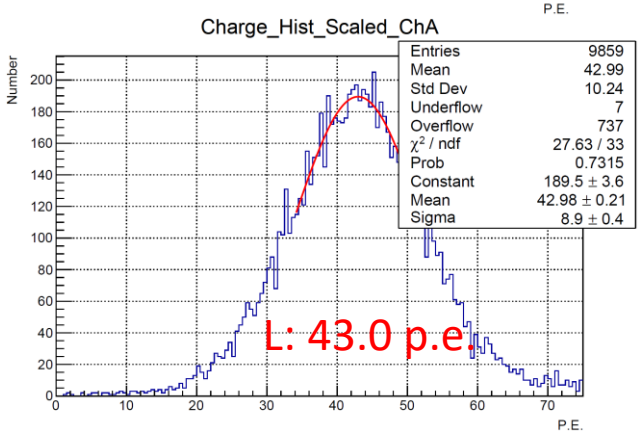
- Uniformity of signals from both ends of crystal

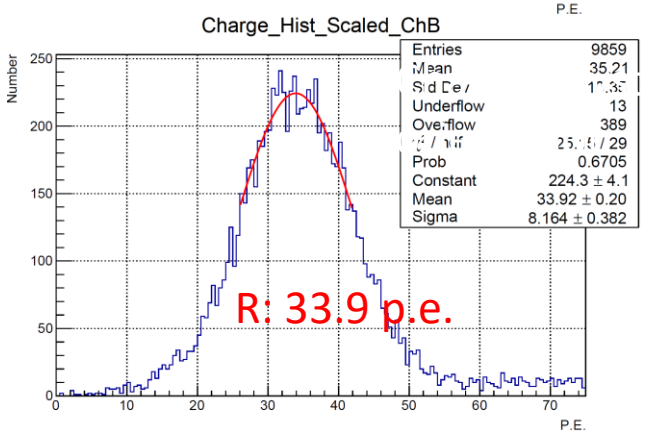
400 mm



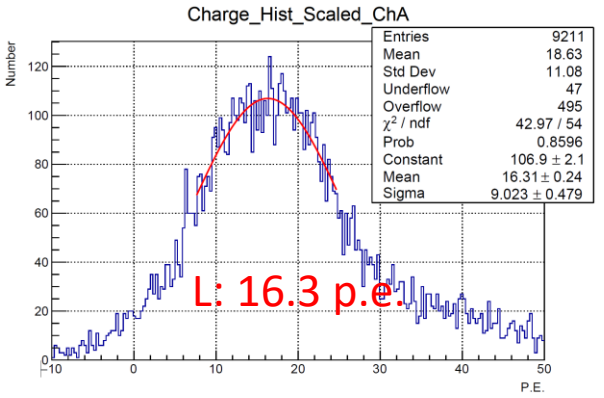


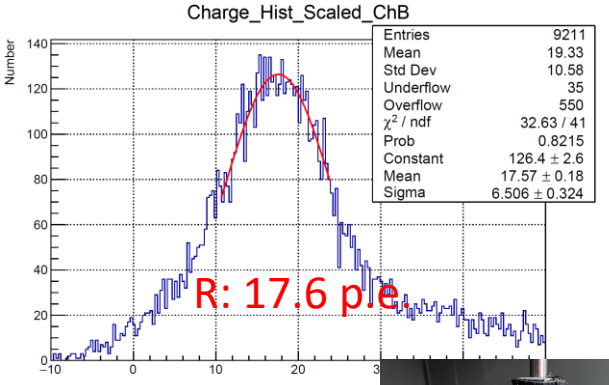
160 mm

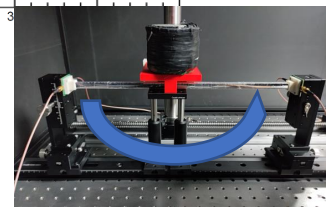




400 mm change crystal orientation





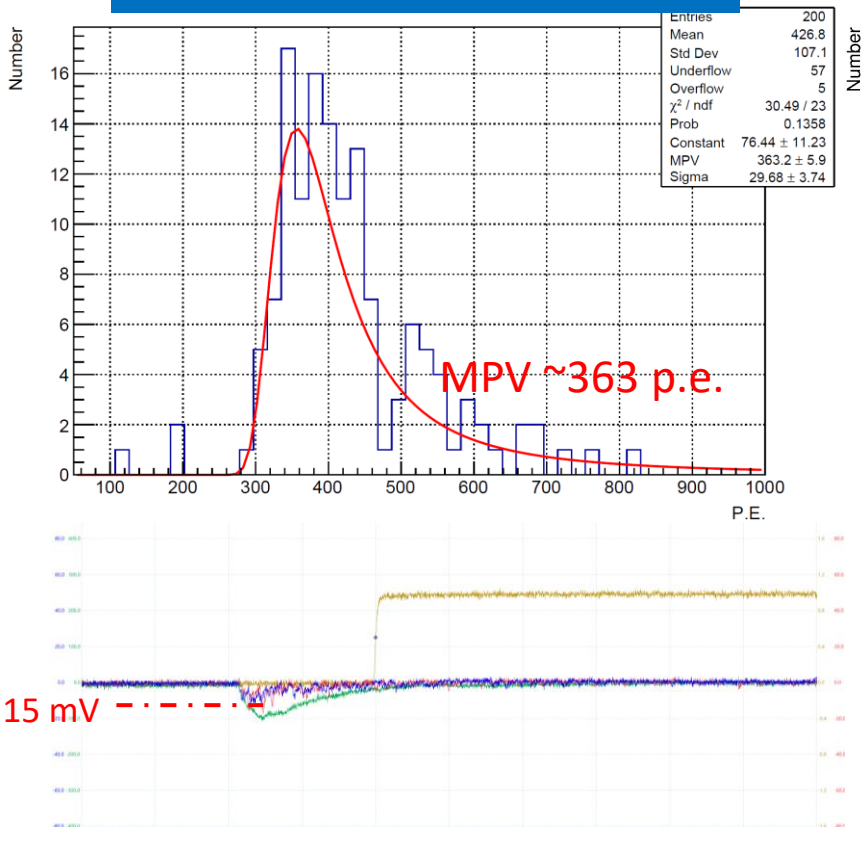


- Response non-uniformity of the 2 ends still exists
  - Main cause: crystal surface treatment difference, uncertainty of coupling
  - Need further tests

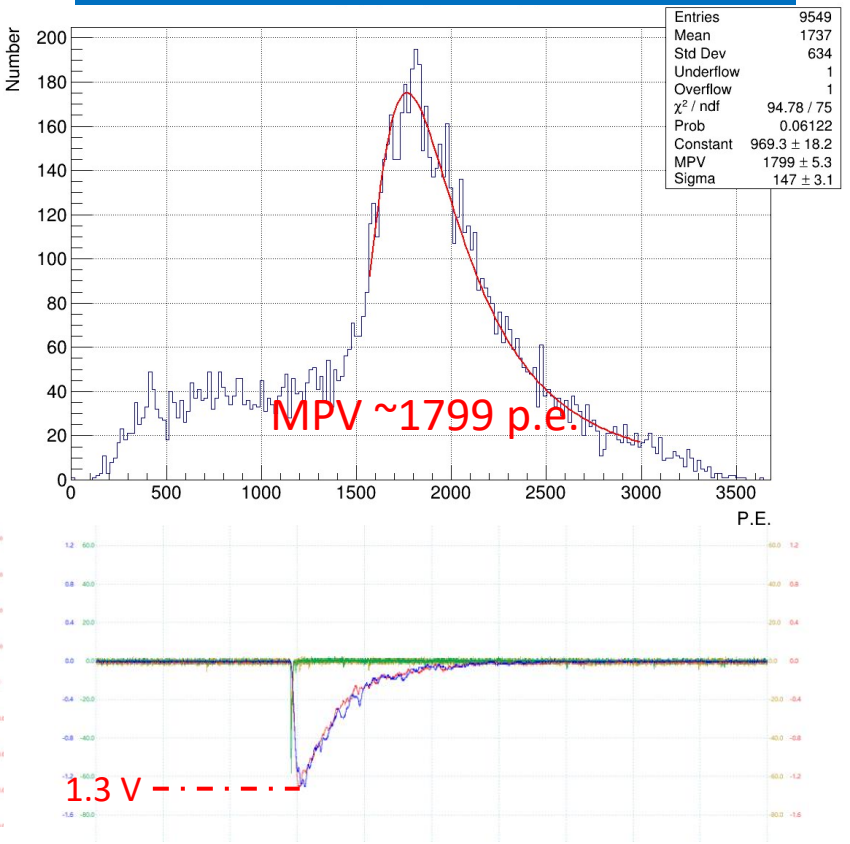
Cosmic-ray test

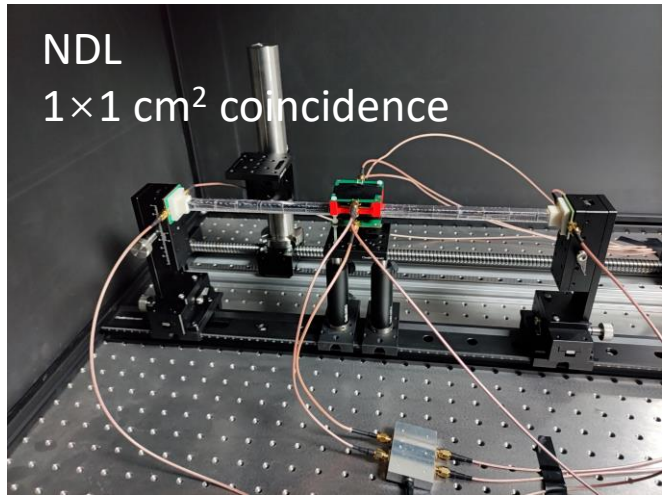
- MIP response of BGO crystal with NDL SiPM (preliminary result)

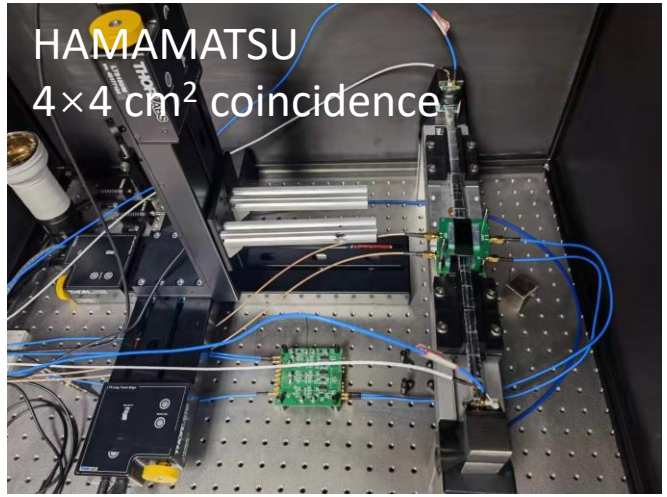
NDL 6 μm 3×3 mm² SiPM



HAMAMATSU 3×3 mm² SiPM module





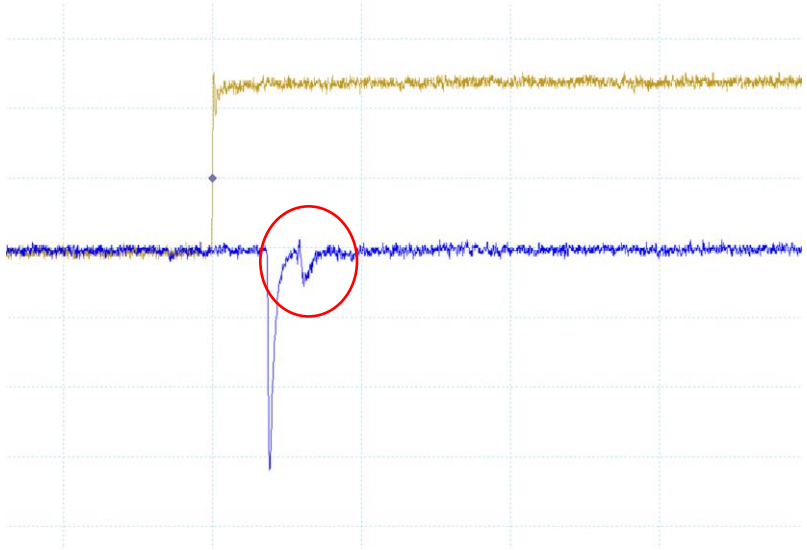


- Detected photons: significant difference, need more data
  - PDE: 30% vs 40% at 420nm, coupling: air vs silicone, trigger tile: 1 cm vs 4 cm

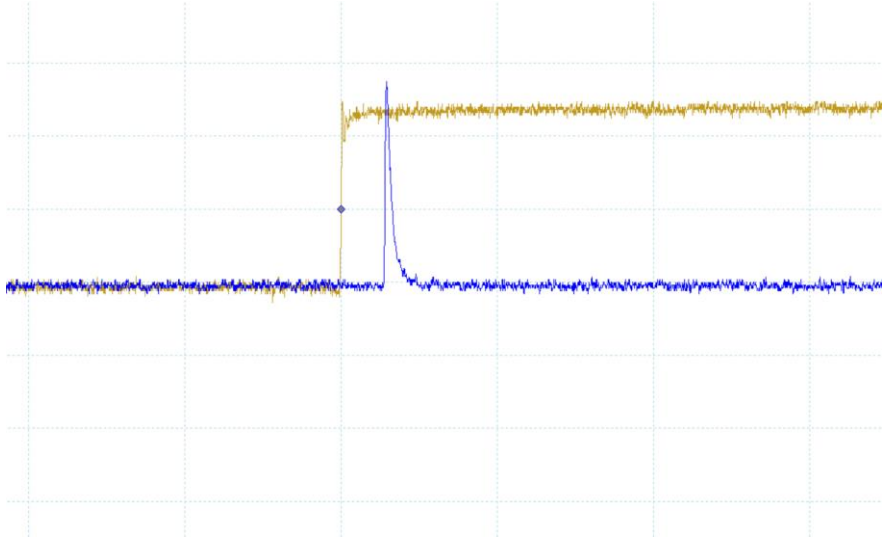
Laser test: dynamic range

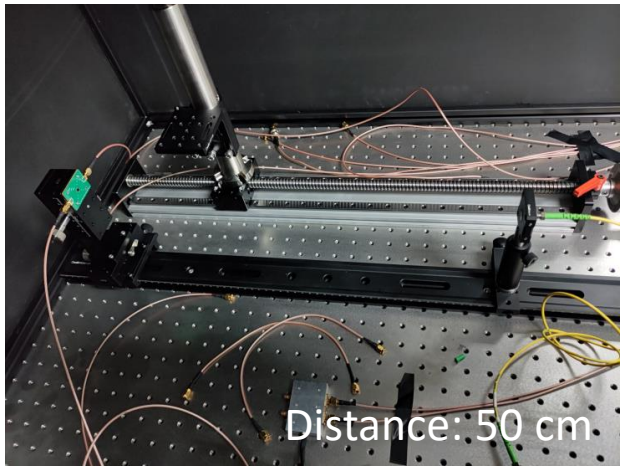
- Laser test of NDL EQR06 SiPM (preliminary result)

Signal with preamplifier



Signal without preamplifier



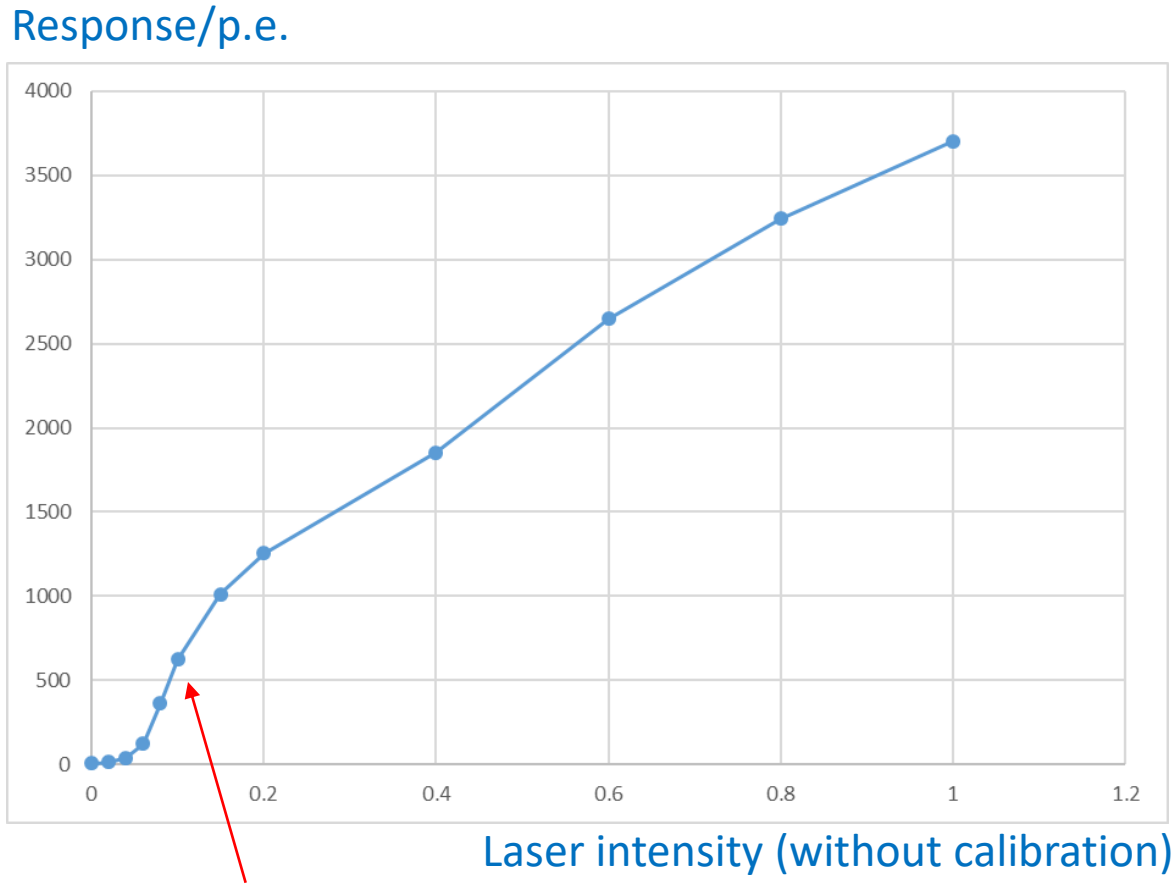


- Strange structure shapes in the signal
- Preamplifier will saturate at 1.6 V (< ~2000 p.e.)
- The test conducted without preamplifier

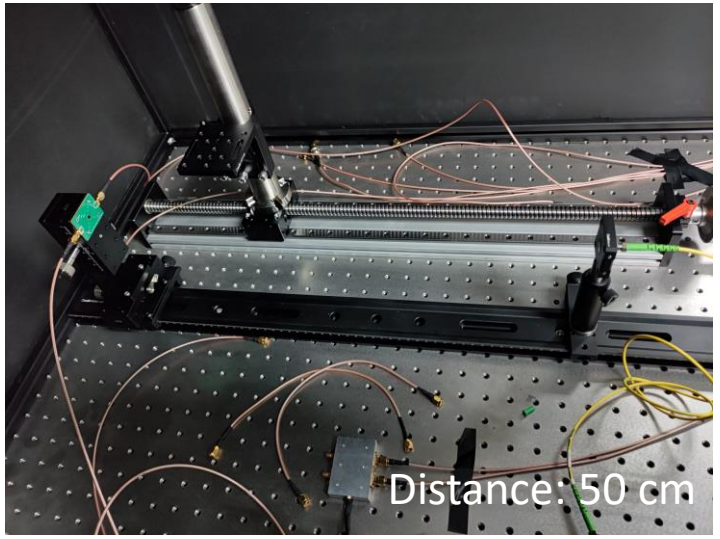
- 405nm picosecond laser
  - Pulse width typically < 60 ps
  - Timing jitter < 3 ps rms

Laser test: dynamic range

- Laser test of NDL EQR06 SiPM (preliminary result)



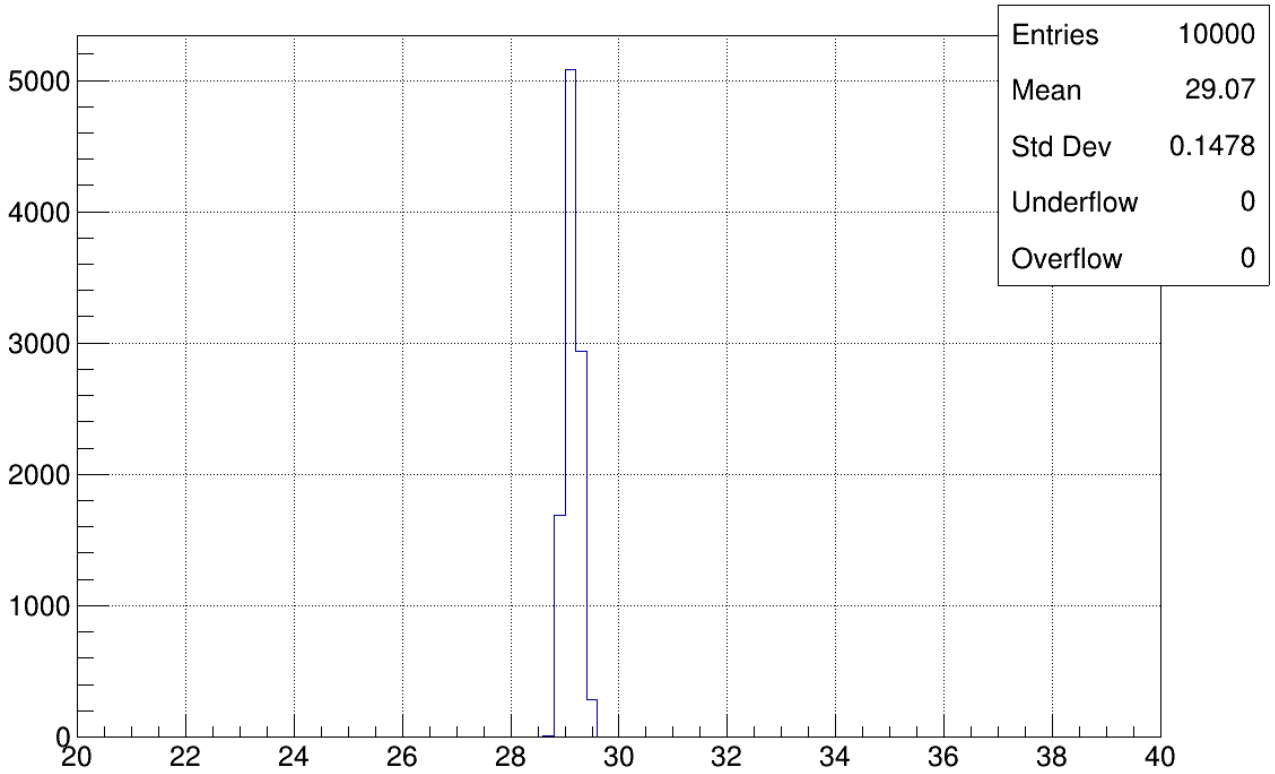
- Non-linearity of laser?



- Shorten the distance to get stronger laser intensity
- Laser intensity need to be calibrated
  - Is the laser intensity sufficient to test SiPM saturation?

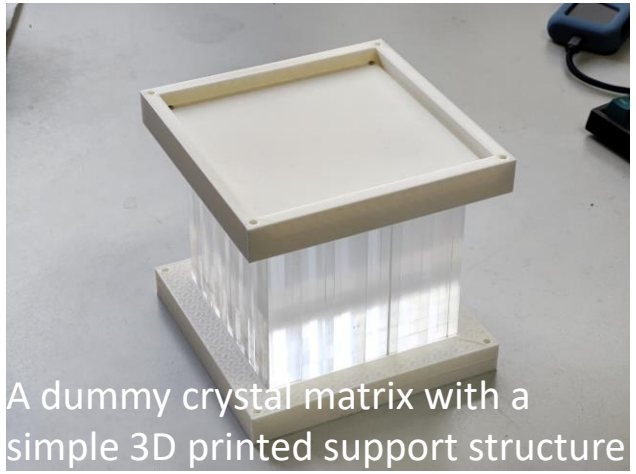
Laser test: a simple timing study

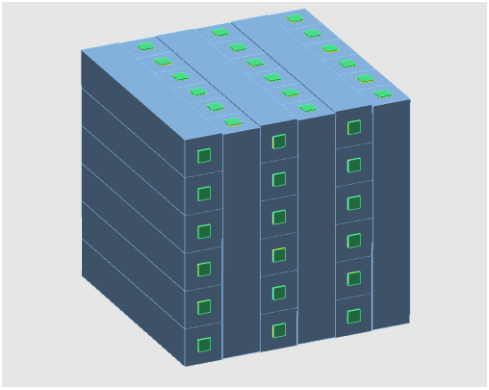
- Timing study: find the peak time of the signal (without interpolation)
  - Using experiment data under max laser intensity
  - Time resolution: 147.8 ps (Std Dev)

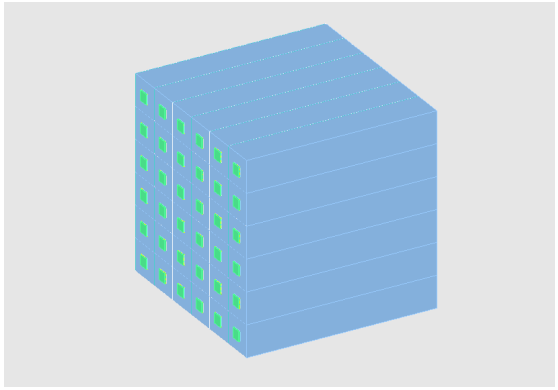


Small-scale detector module design

- Motivations: to develop crystal modules
  - Small-scale modules is sufficient for compact EM showers
  - Identify critical questions/issues on system level
- Key issues
  - Temperature control and monitoring
  - Mechanical design: crystal fixture, tolerance, gaps
  - Space for readout electronics
  - Dynamic range of SiPMs and FEE
- Preparations for future beam tests
  - Energy resolution, shower profiles


A dummy crystal matrix with a simple 3D printed support structure


1) crossed crystal bar


2) 6×6 crystal matrix


KlauS6 chip


A5202 unit (FERS-5200)

Simulation study of gaps

- Gap between crystals: dead material (air)
- Incident particle: 5 GeV e-
- 2 modules: 24 cm BGO