Optimizing the Scintillator Shape for the Electromagnetic Calorimeter

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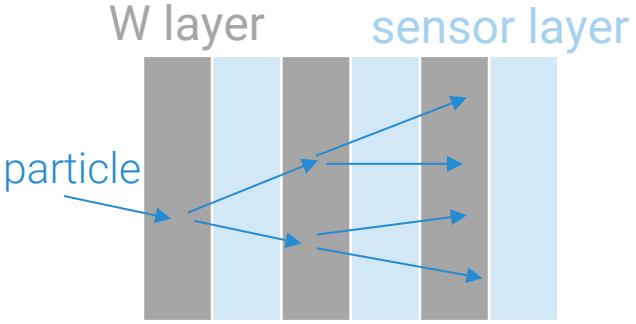
ECAL of ILD

Features

Sampling calorimeter of 30 layers

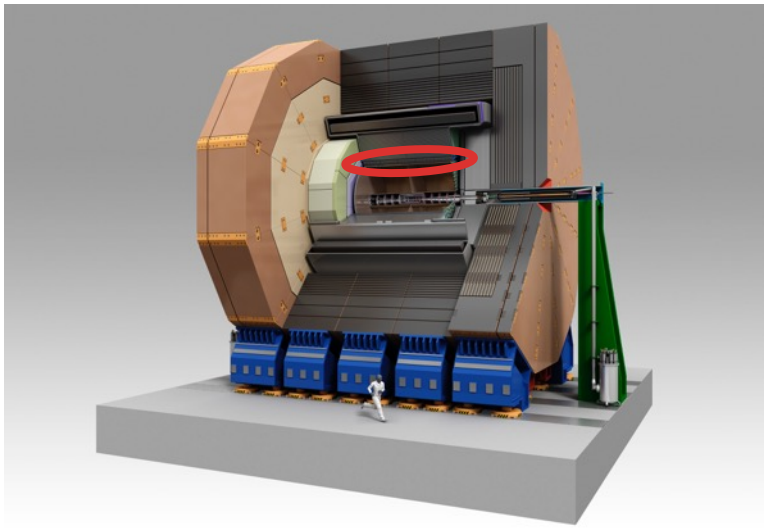
Absorber: W (X_0=3.5 mm, R_M=19 mm)



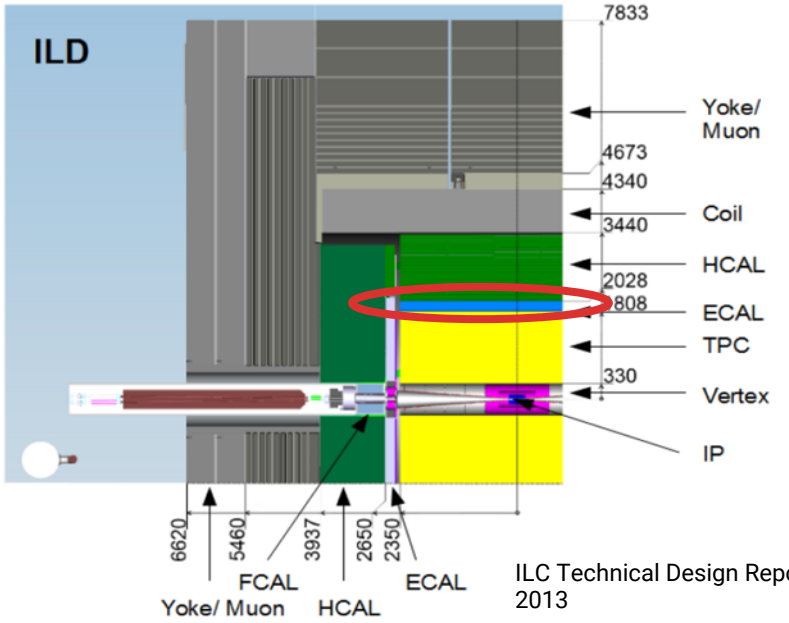
Options of sensor layer

SiECAL(silicon pad): **high precision**, 100 million channels

ScECAL(scintillator): **10 million channels, low cost**



ILD layout ©Rey. Hori



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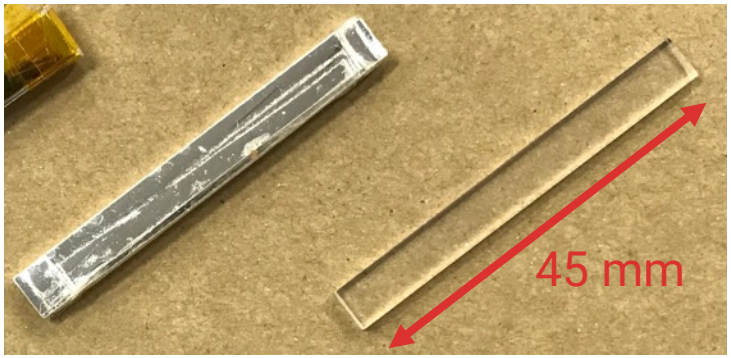
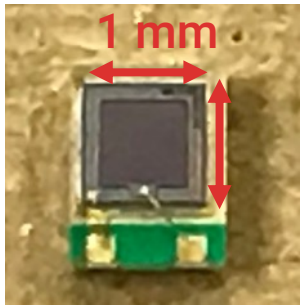
Scintillator ECAL

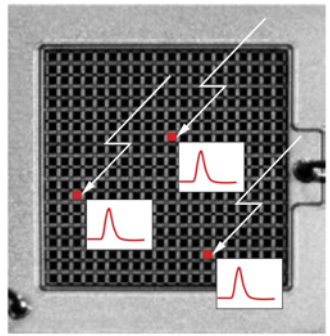
- Scintillator strip + SiPM
  - Scintillator strip
    plastic scintillator with ESR film
    size : 5 mm x 45 mm x 2 mm
  - SiPM (PPD, MPPC®, …)
    photosensitive area : 1 mm x 1 mm
    pixel pitch : 10 um or 15 um, gain : 10^5

$E_{loss} \propto$ num. of photon

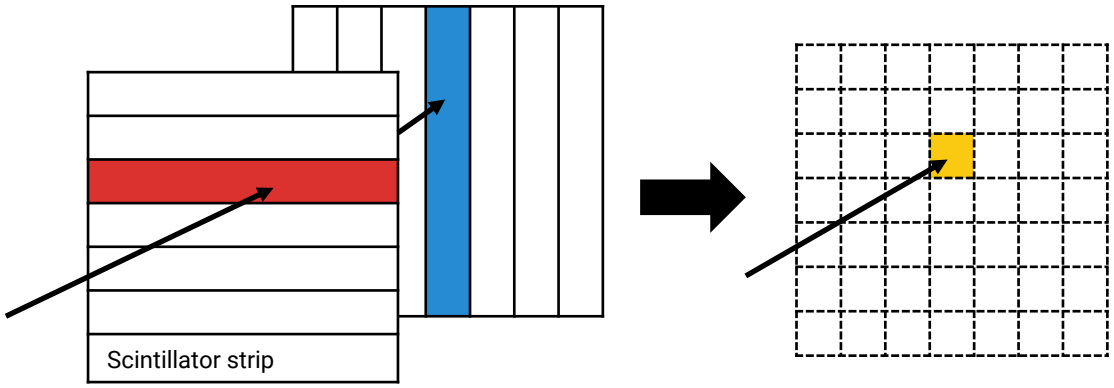




SiPM: S12571-015P



- Strip Splitting Algorithm



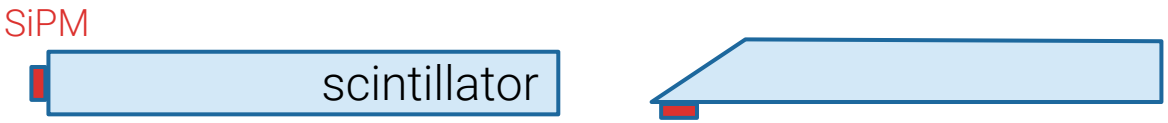
5 mm x 5mm pseudo pixel
→ 10,000,000 channel

1/10 of 5 mm x 5 mm scintillator tile

Readout Method

- Requirement for sci. : **Enough light amount for M.I.P**, **Good uniformity**
- Conventional readout methods

Readout method	Side readout	Bottom readout
Advantage	Good light amount(for M.I.P)	No dead space Good light yield uniformity
Disadvantage	2% dead space Bad light yield uniformity	Poor light yield (~0.5 x side readout)



Recently, another type of readout method was proposed by Chinese group

→**Dimple readout**: SiPM is implanted into a dimple

good light yield?

good uniformity?

→ Confirm characteristics of this readout method

Introduction

- today's talk
  - ~~ScECAL for ILD~~ (Done)
  - Measurement about dimple readout
  - Simulation to reproduce result of measurement
  - Comparison of simulation and measurement

- Goal of my study
  - Optimizing the scintillator shape for ILD by using simulation

Measurement Setup

- Measure light yield in scintillator with dimple

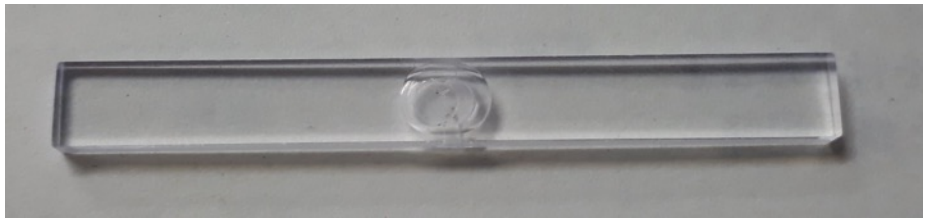
  Depth of dimple: 0.69 mm

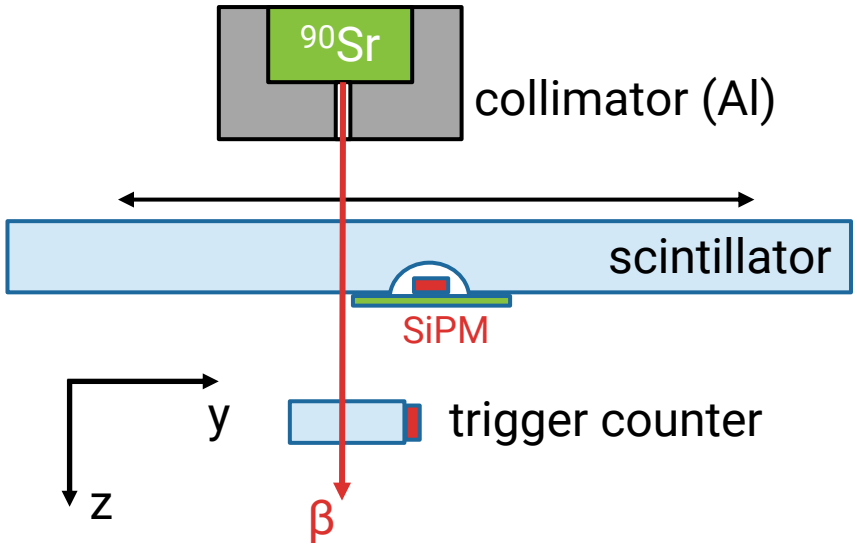
  SiPM: S12571-015P, dV = 4 V

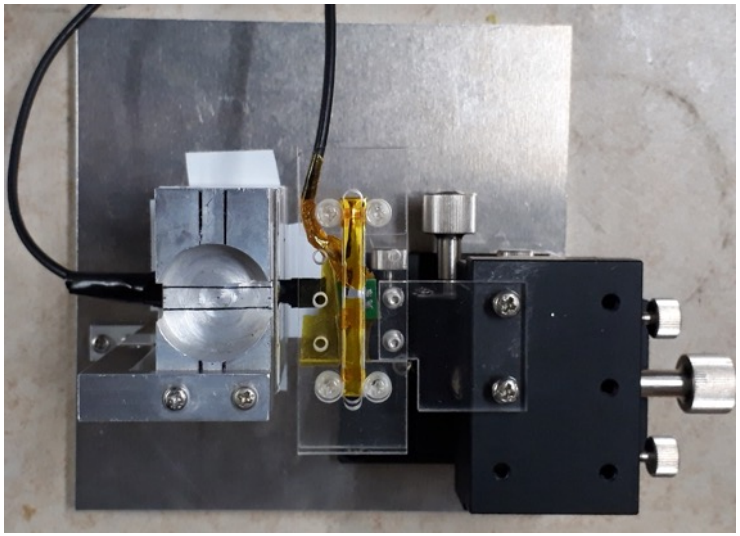
  Checking source : ^{90}Sr

  Collimator : diameter 0.5 mm

  Moving stage : 0 mm(x-direction), ±20 mm(y-direction)





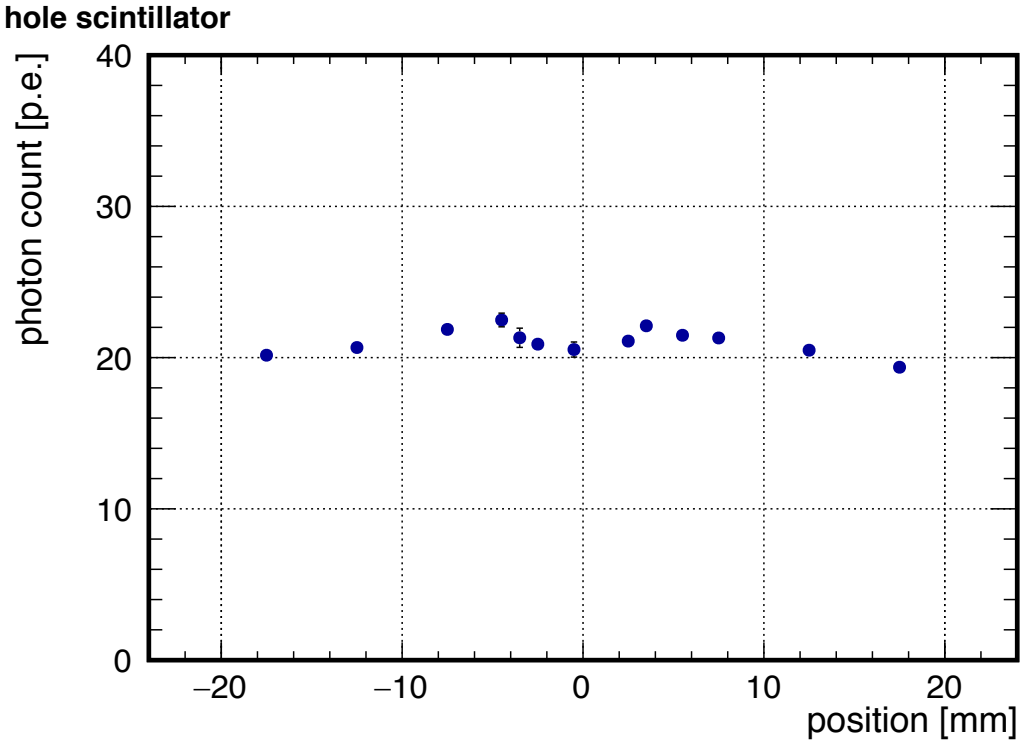


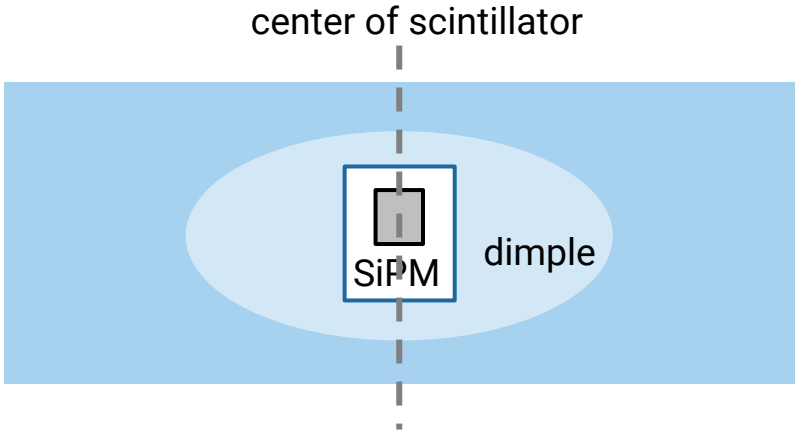
Light Yield vs. Position

- Mean light yield is about 21 photoelectron (p.e.)

  At this measurement, position alignment is not perfect...

  center of scintillator is not 0 mm position





Ideally, light yield should be symmetric

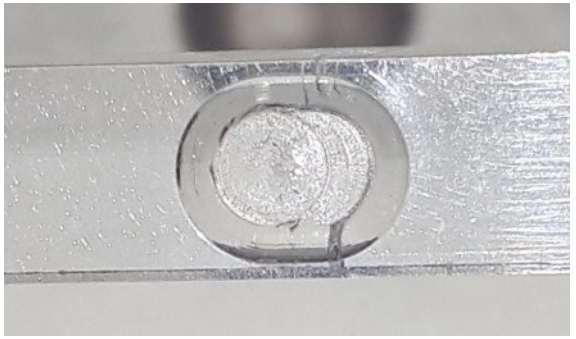
Dimple scintillator has good light yield uniformity

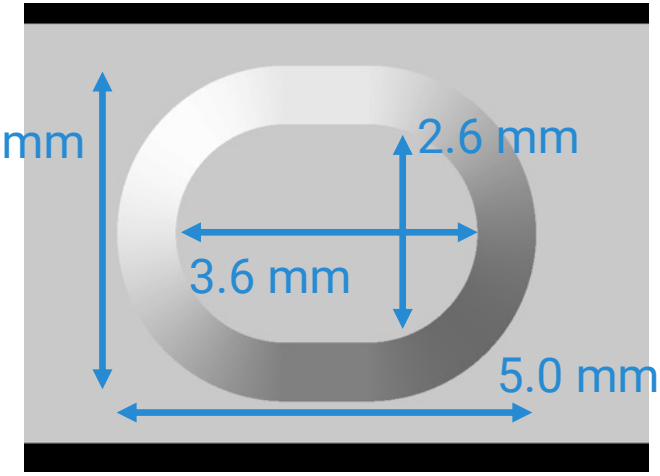
Simulation Method

Reproduce the result of measurement, and optimize scintillator shape by simulation

→Photon tracing simulation using C++ with Geant4

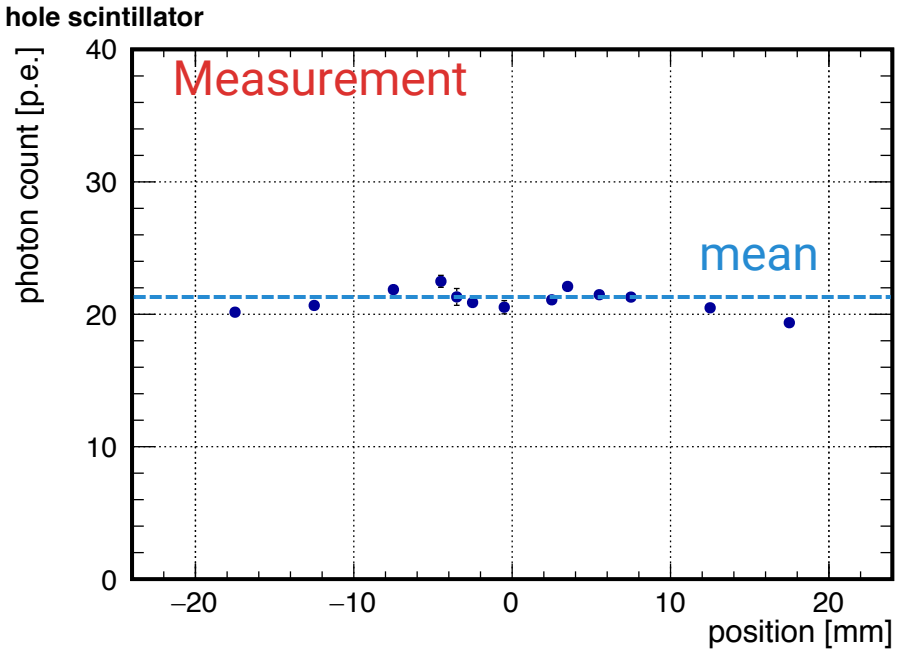
- Condition of simulation
  - Scintillator: 5 mm x 45 mm x 2 mm
  - SiPM: 1 mm x 1 mm (photosens. area)
  - Hole shape: Chinese group type
  - Hole depth: 0.69 mm
  - **reflectivity: 97%**
  - collimator diameter: 1 mm
  - collimator depth: 3 mm
  - trigger scintillator: 5 mm x 5 mm

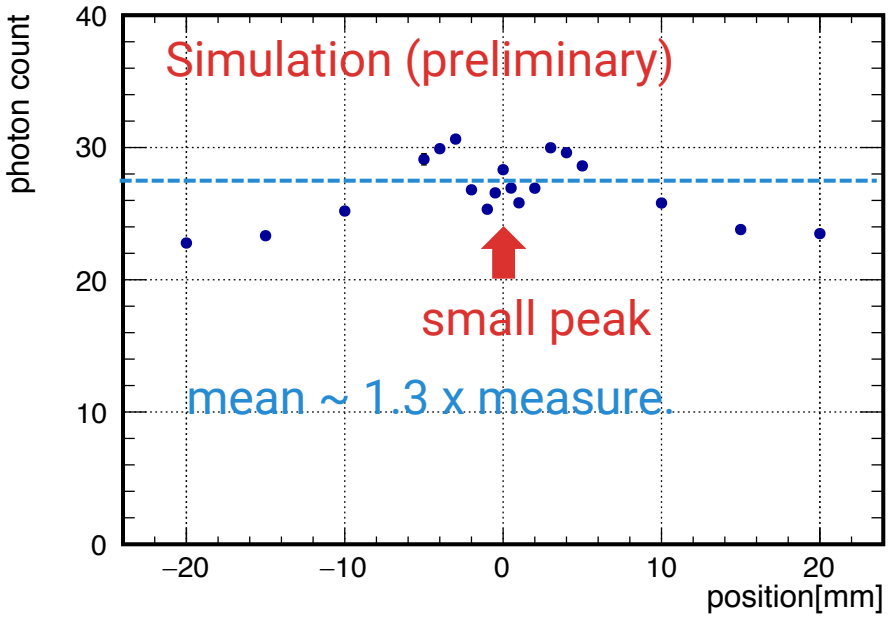




Simulation

- Comparison with measurement
  - Mean light yield of simulation is slightly higher than result of measurement
  - Behaver of position dependence is similar to measurement
  - In simulation result, there is a **small peak** around the 0 mm position

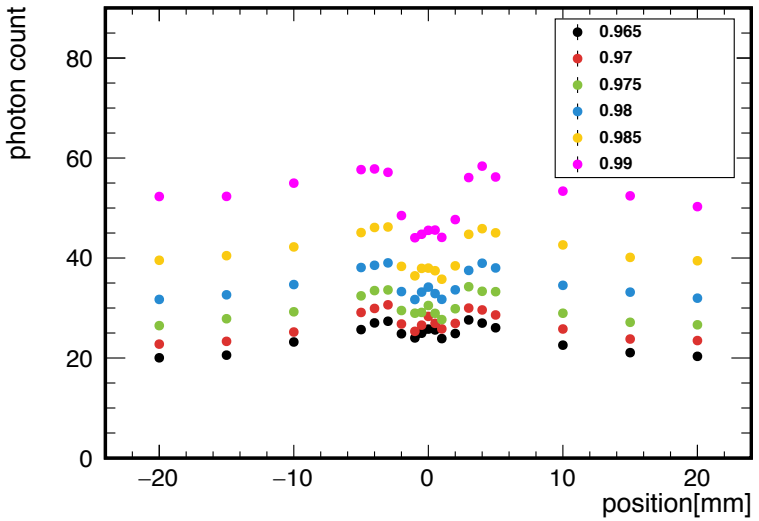




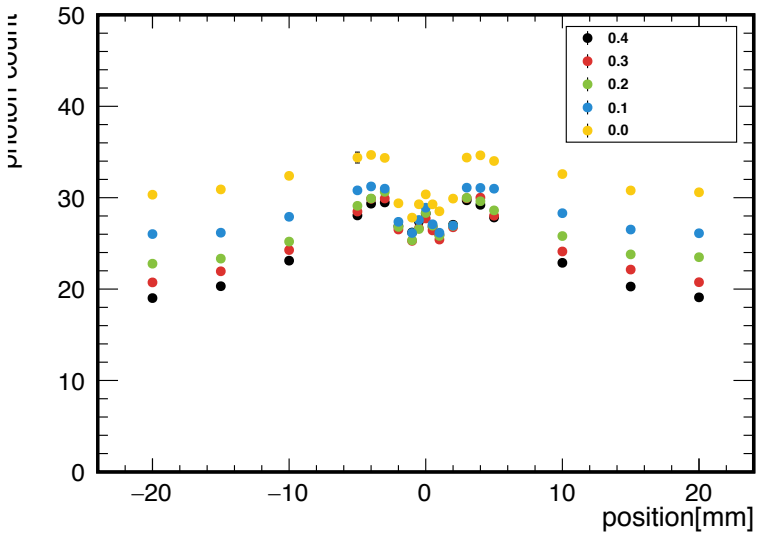
Simulation Parameters

- **parameters** are under tuning...
  - reflectivity
  - reflection rate at scintillator surface
  - surface roughness of scintillator
  - surface roughness of dimple
  - etc.

ex1. Reflectivity



ex2. Prob. of diffuse reflection

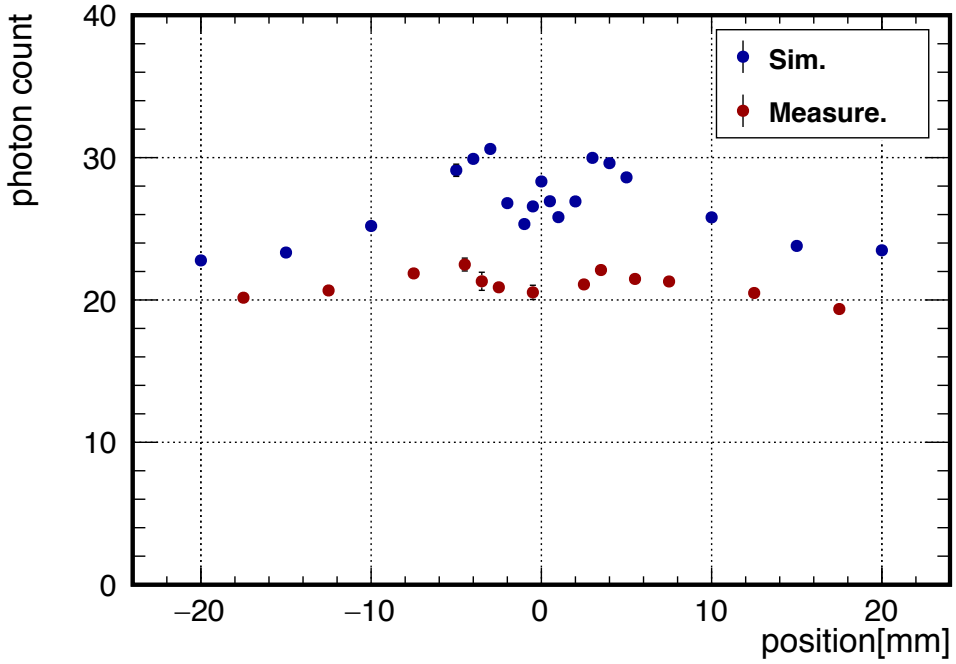


It is necessary to fine-tune these parameters

Summary of Simulation

- Difference between results of simulation and measurement
  - Mean light yield of simulation is slightly higher than result of measurement
  - In simulation result, there is a **small peak** around the 0 mm position

- To optimize shape,
  - Measure light yield more precisely (at interval of 0.5 mm)
  - Estimate exact parameter by measurement result
  - Reproduce result of other readout methods



New measurement is in progress (It will be done in October)

Summary and Outlook

- ScECAL, scintillator strip, readout method, measurement, simulation
- Light yield uniformity of dimple scintillator was confirmed by measurement
- Simulation can reproduce the behaver of the measurement, but light yield is slightly different, and simulation result has small peak around SiPM
- To match result of simulation and measurement, we need to update the setup of light yield measurement

- Future plan

  Determine best shape by simulation, and make the shape to measure light yield

Back up

SiPM

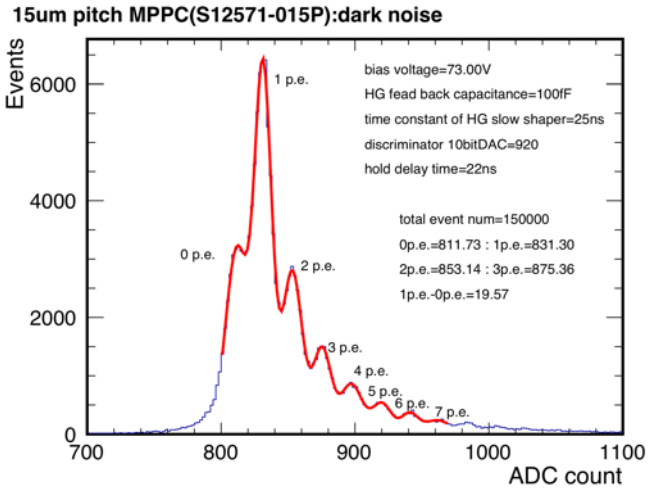
Structure

Parameter	Symbol	S12571				Unit
		-010C	-010P	-015C	-015P	
Effective photosensitive area	-	1 × 1		1 × 1		mm
Pixel pitch	-	10		15		μm
Number of pixels	-	10000		4489		-
Geometrical fill factor	-	33		53		%
Package	-	Ceramic	Surface mount type	Ceramic	Surface mount type	-
Window	-	Silicone resin	Epoxy resin	Silicone resin	Epoxy resin	-
Window refractive index	-	1.41	1.55	1.41	1.55	-

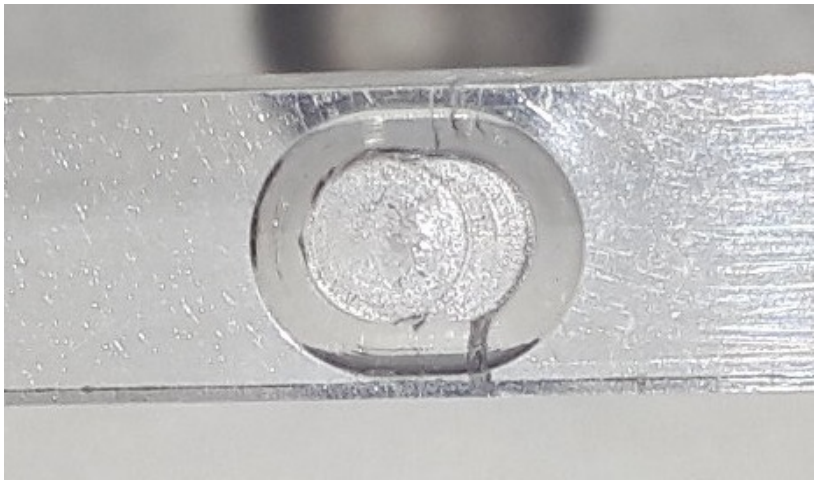
Electrical and optical characteristics (Ta=25 °C, unless otherwise noted)

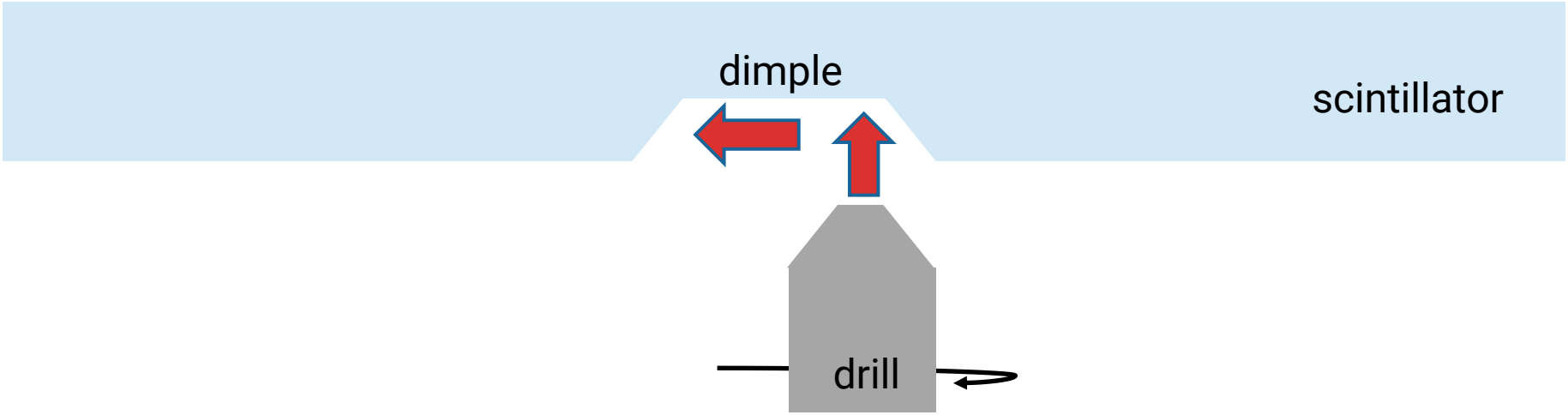
Parameter		Symbol	S12571				Unit
			-010C	-010P	-015C	-015P	
Spectral response range		λ	320 to 900		320 to 900		nm
Peak sensitivity wavelength		λp	470		460		nm
Photon detection efficiency (λ=λp)*4		PDE	10		25		%
Dark count*5	Typ.	-	100		100		kcps
	Max.		200		200		
Time resolution (FWHM)*6		-	300		250		ps
Terminal capacitance		Ct	35		35		pF
Gain		M	1.35 × 10^5		2.3 × 10^5		-
Gain temperature coefficient		ΔTM	1.6 × 10^3		3.5 × 10^3		/°C
Breakdown voltage		VBR	65 ± 10		65 ± 10		V
Recommended operating voltage		Vop	VBR + 4.5		VBR + 4.0		V
Temperature coefficient of recommended operating voltage		ΔTVop	60		60		mV/°C

*4: Photon detection efficiency does not include crosstalk or afterpulses.
*5: Threshold=0.5 p.e.
*6: Single photon level
Note: The above characteristics were measured the operating voltage that yields the gain listed in this catalog.
(Refer to the data attached to each product.)
The last letter of each type number indicates the package type (C: ceramic, P: surface mount type).



Dimple Shape





Dimple Depth