# MPPC Sensor-1
# (MPPC Response)

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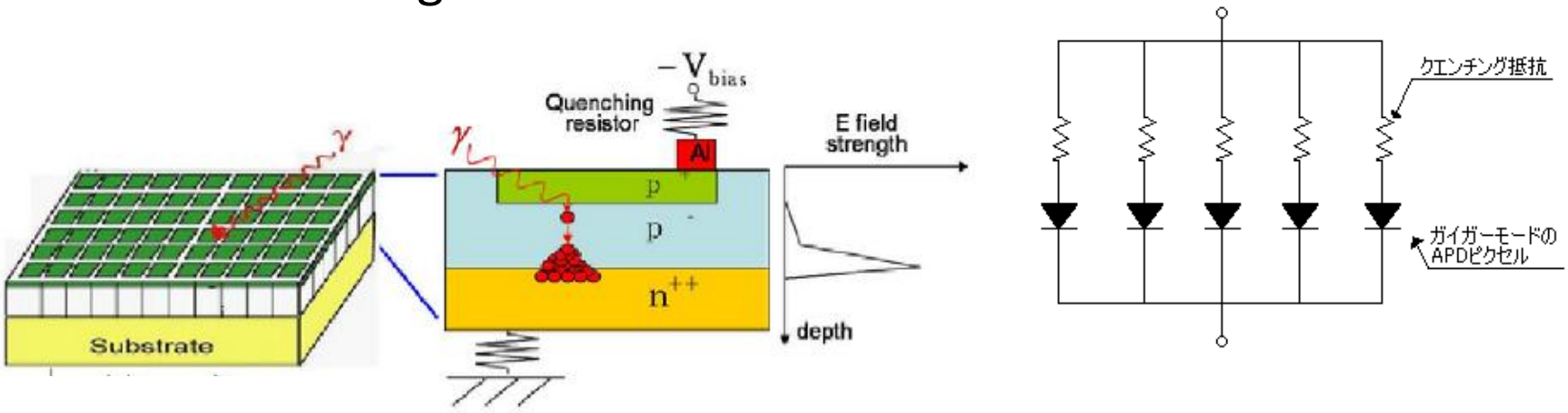
# Outline

- Introduction
- Motivation
- Response Curve
- Summary

# Introduction

MPPC is a photon detector which is considered for the ILD electromagnetic calorimeter in ILC.




MPPC is composed of multi-pixel photo-diodes with a single, ganged output, hence the MPPC output saturates with an increasing number of incident photons.

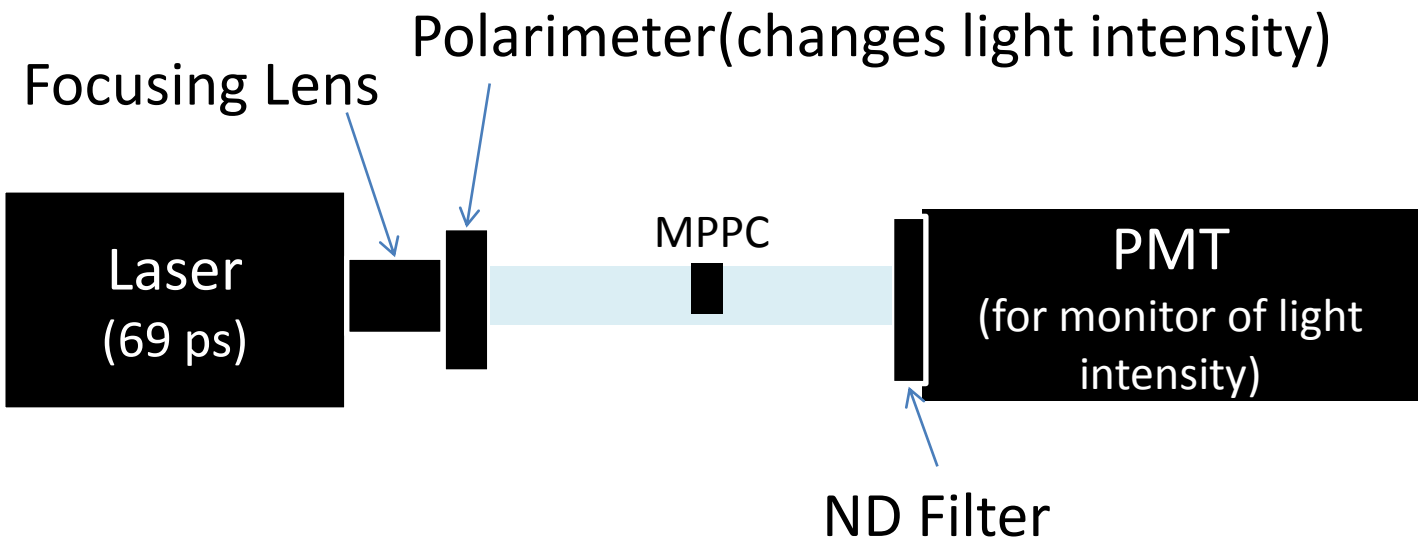
→ to know characteristic features of MPPC Response Curve is important

# Motivation

・To know characteristic features of MPPC Response Curve is important, because to estimate the number of detected photons needs response correction

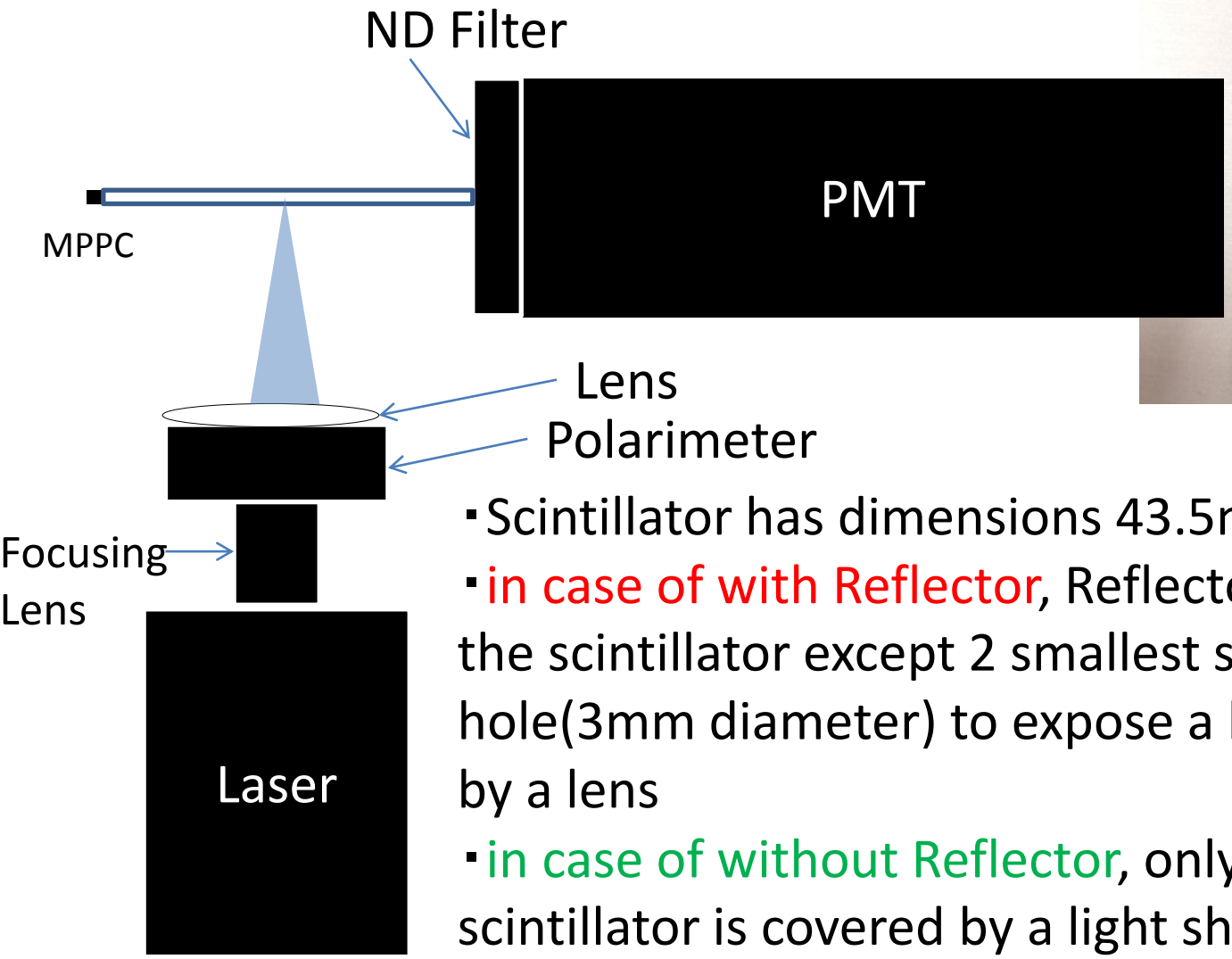
・To know uncertainty of Response Curve is also important, because it gives uncertainty for photon energy estimation

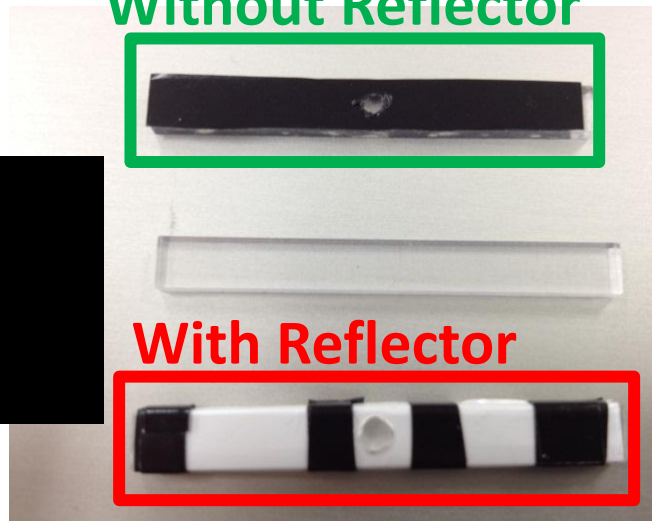
# Setup (MPPC only)




- Laser has very short time structure of 69 ps
- Laser beam incidents on an MPPC directly, and the grazing light is monitored by PMT behind the MPPC
- Light intensity is changed by the polarimeter

# Setup (MPPC+Scintillator(+Reflector))



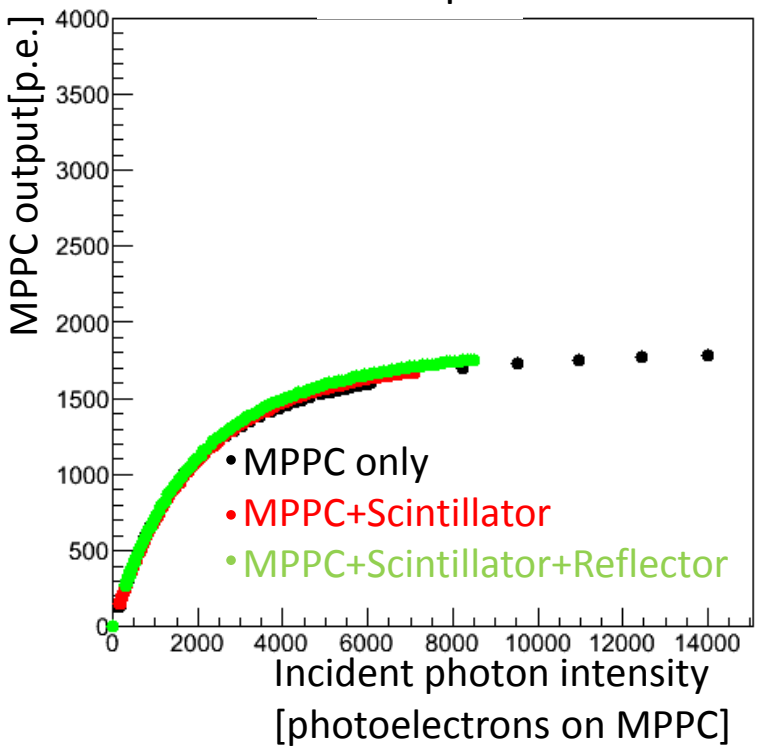

・Scintillator has dimensions 43.5mm × 5mm × 2mm

・in case of with Reflector, Reflector covers 4 sides of the scintillator except 2 smallest sides, and has small hole(3mm diameter) to expose a laser beam focused by a lens

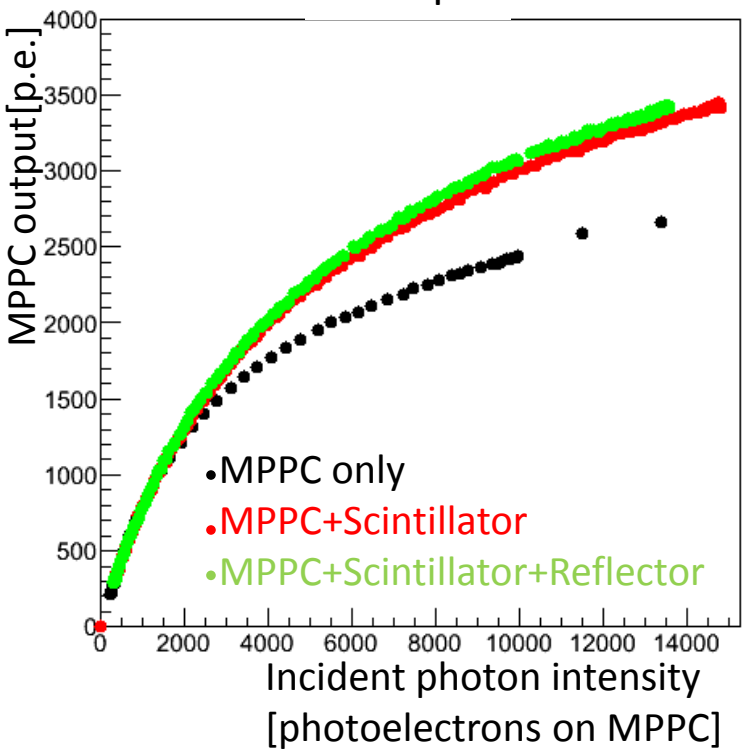
・in case of without Reflector, only front face of scintillator is covered by a light shielding tape with small hole(3mm diameter)

# Response Curve

1600 pix




2500 pix




・horizontal axis is scaled to be the number of photoelectrons on MPPC, instead of PMT ADC counts

・2500pix MPPC has larger dynamic range than 1600pix MPPC

・MPPC+Scintillator+Reflector has slightly larger dynamic range than MPPC+Scintillator

→because of photon reflection, time structure becomes longer

・2500pix MPPC has larger difference between MPPC only and MPPC+Scintillator(or +Reflector) than 1600pix MPPC

→indicate 2500pix MPPC has shorter recovery time than 1600pix MPPC

・in case of MPPC+Scintillator+Reflector, 1MIP~10 photoelectrons (from β ray)

# Response Curve
# differences among individual pieces

**same piece × 5 (reproducibility)**
**5 different pieces**

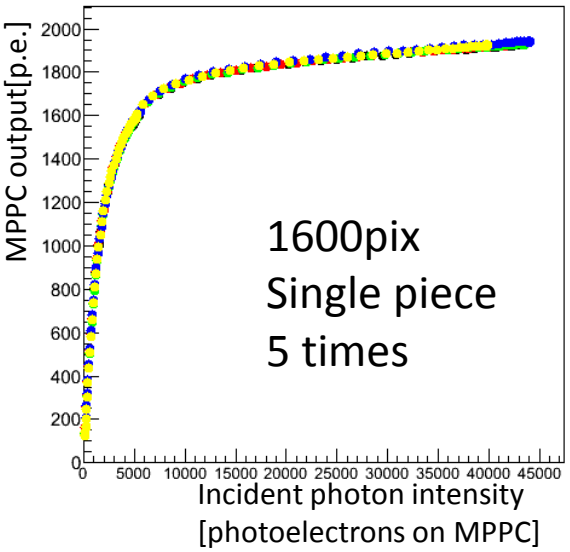
# Response Curve(MPPC only)

Left side plots: 1600pix

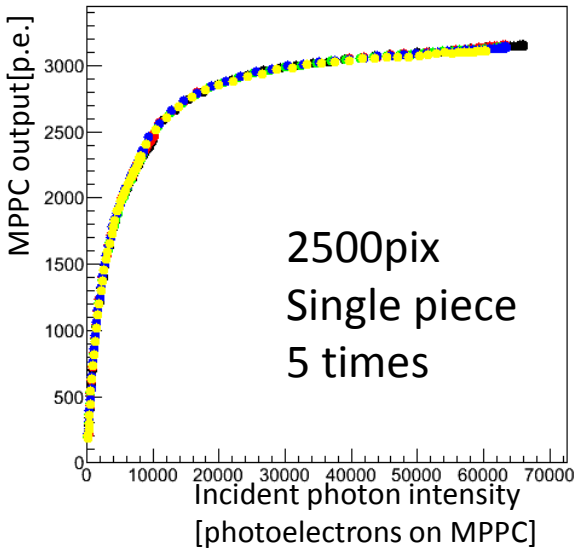
Right side plots: 2500pix

Top plots:
5 times measurements of Response curve for same piece

1600 pix(same piece)

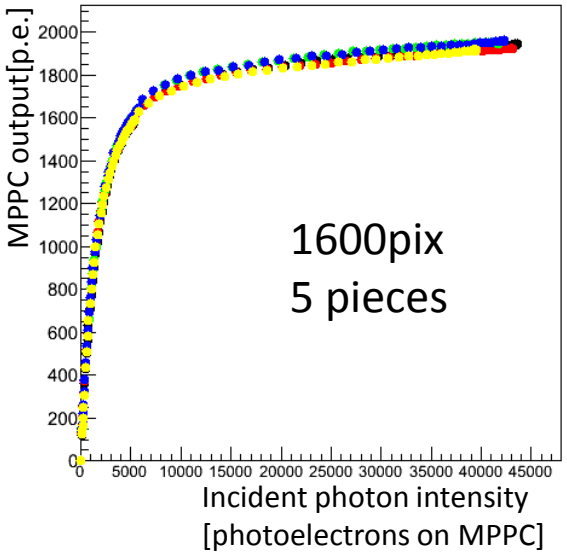



2500 pix(same piece)

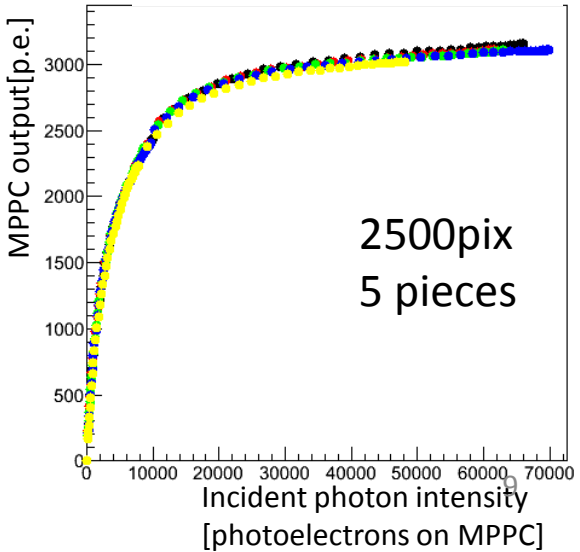



Bottom plots:
measurements of Response curve for 5 difference pieces

1600 pix(different pieces)

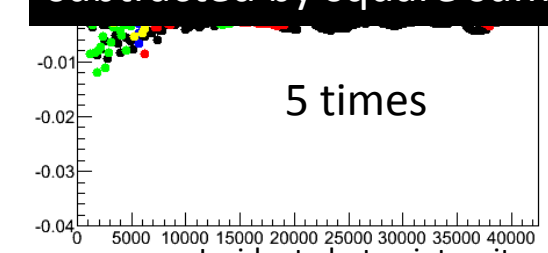



2500 pix(different pieces)

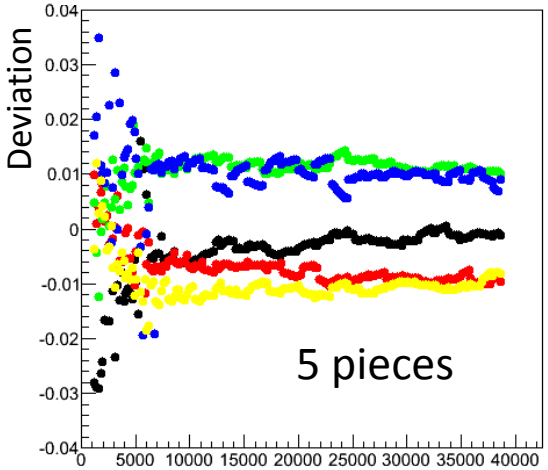


# MPPC only(1600pix)

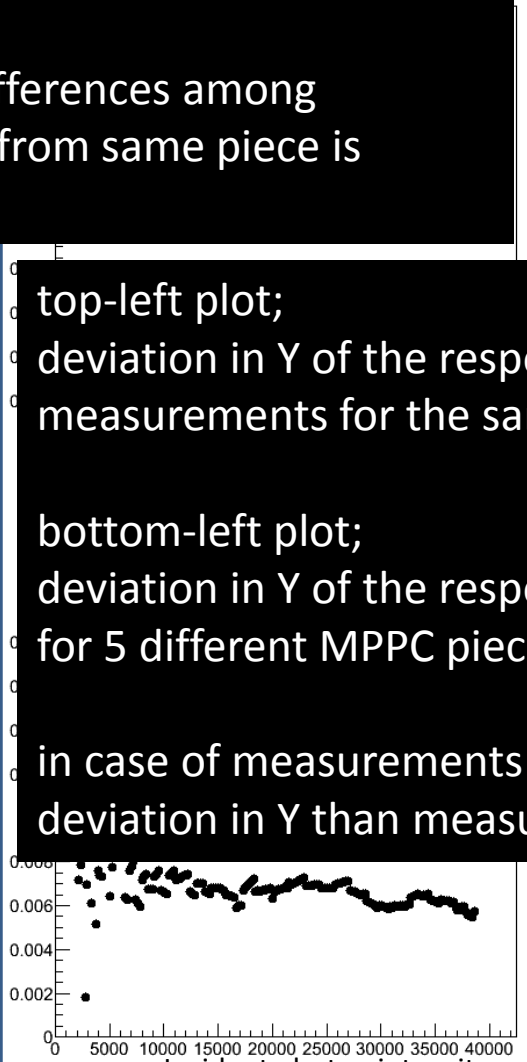
Deviation of Y(same piece)




Deviation of Y(different pieces)




RMS(same piece)




Right side plot;
to take into account only differences among individual pieces the effect from same piece is subtracted by square sum

top-left plot;
deviation in Y of the response measurements for the same 1(

bottom-left plot;
deviation in Y of the response curve in case of measurements for 5 different MPPC pieces

in case of measurements for different pieces, there is larger deviation in Y than measurements for same piece

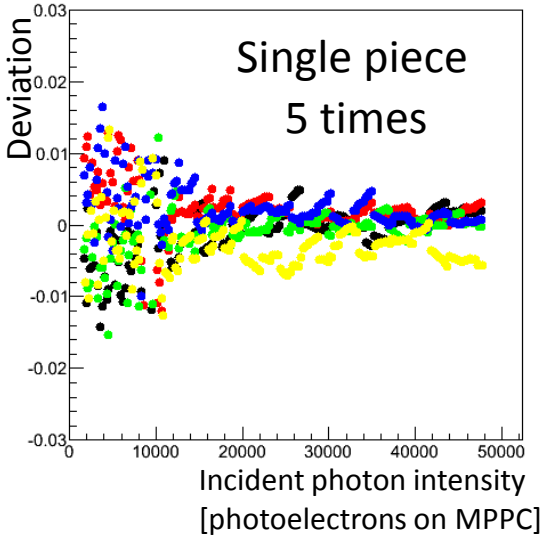
top-center plot;
RMS in case of 5-time measurements for same MPPC piece

bottom-center plot;
RMS in case of measurements for 5 different pieces

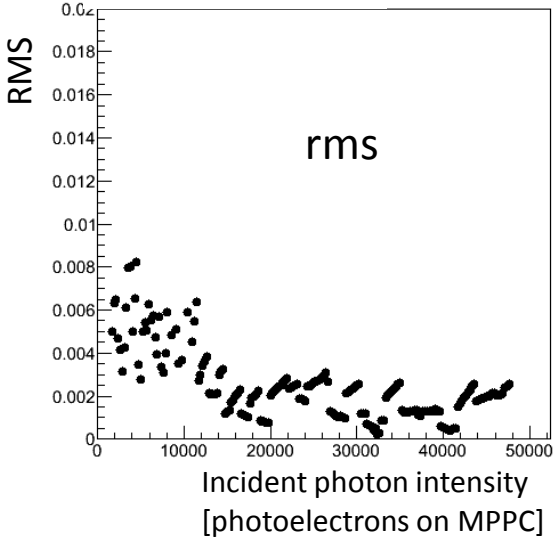
- for case of 1600pix MPPC only, differences among individual pieces is about 0.6%

# MPPC only(2500pix)

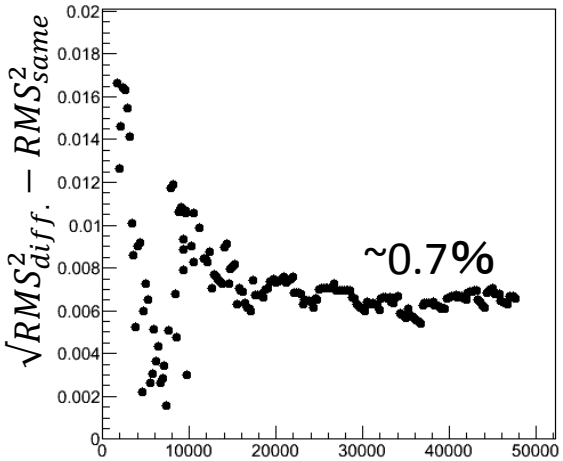
Deviation of Y(same piece)



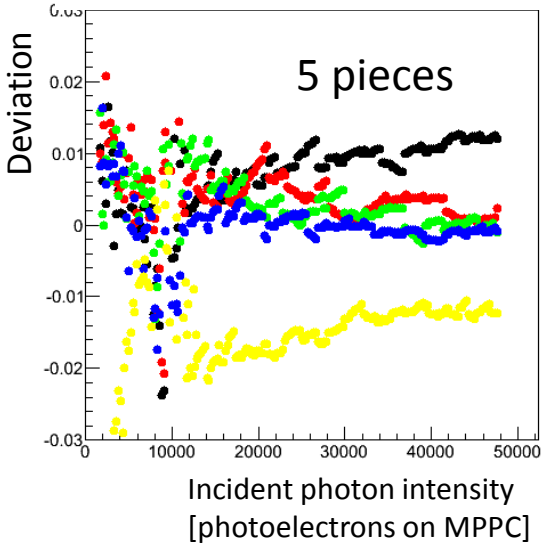

RMS(same piece)



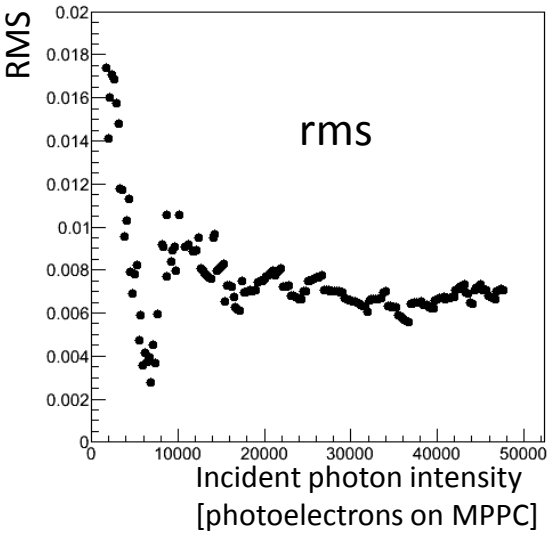

differences among individual pieces




Deviation of Y(different pieces)



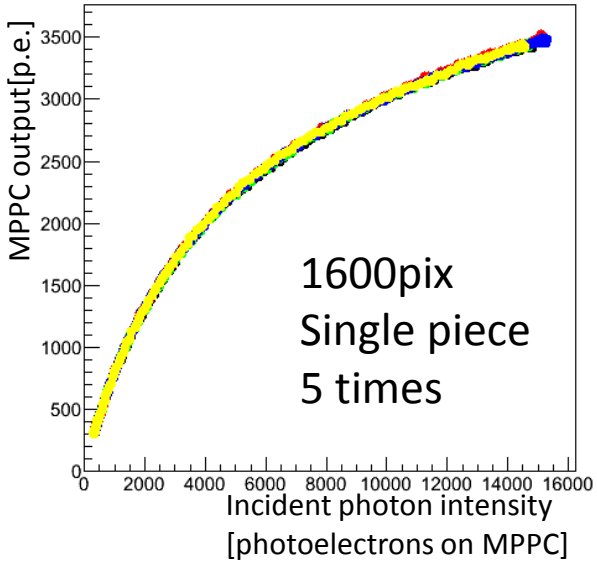

RMS(different pieces)



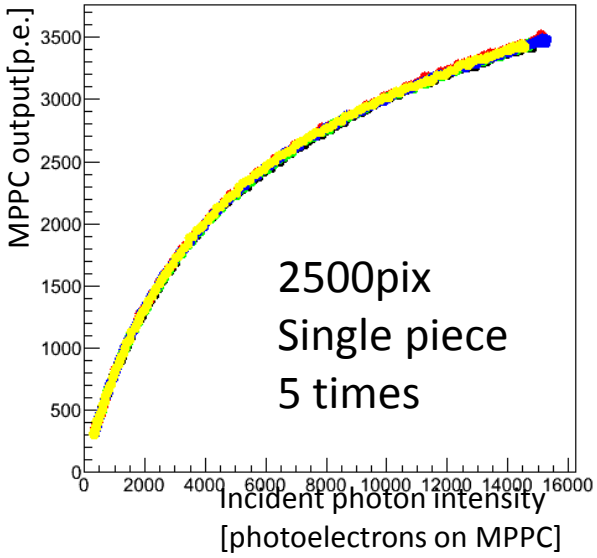

・in case of 2500pix MPPC only, differences among individual pieces is about 0.7%

# Response Curve(MPPC+Scintillator)

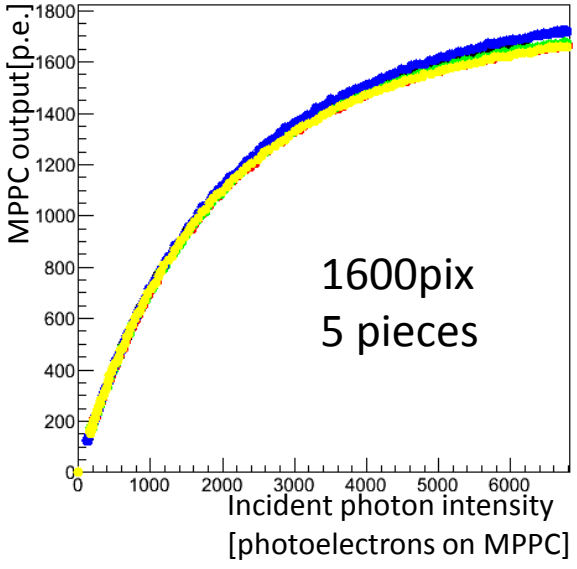
1600 pix(same piece)



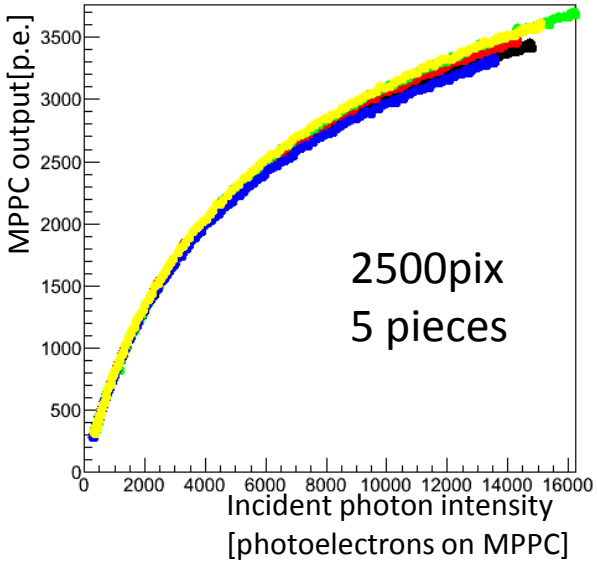

2500 pix(same piece)




1600 pix(different pieces)

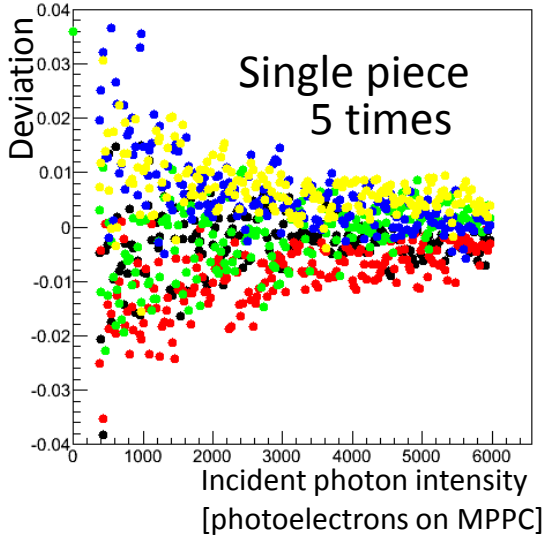



2500 pix(different pieces)

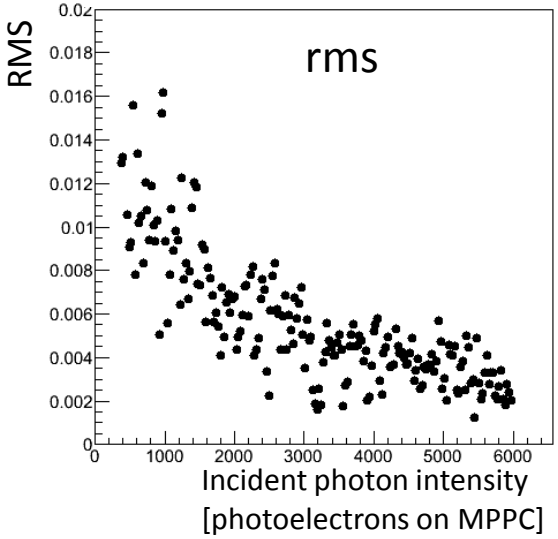


# MPPC+Scintillator(1600pix)

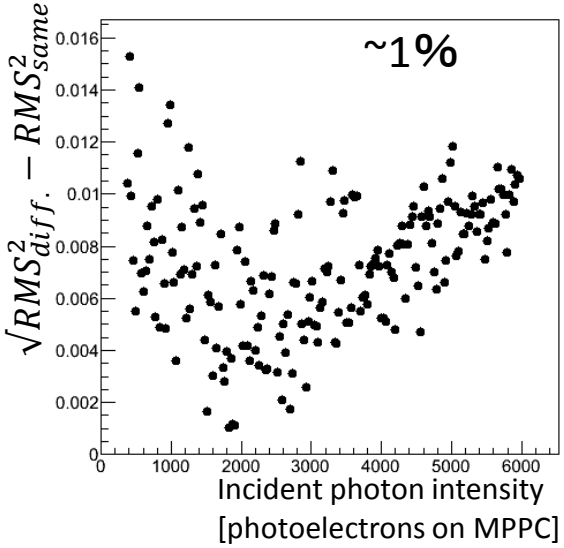
Deviation of Y(same piece)



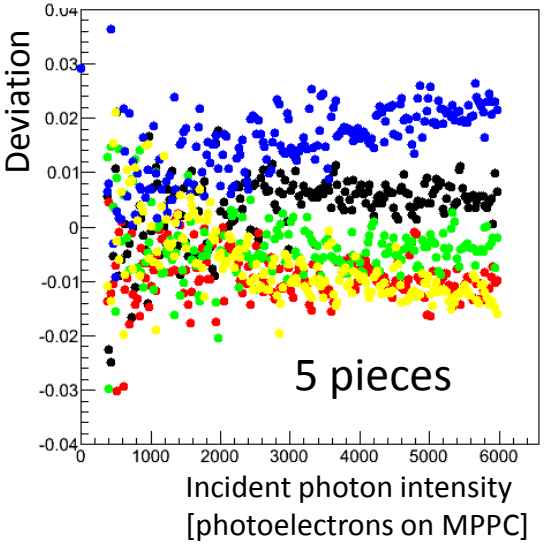

RMS(same piece)



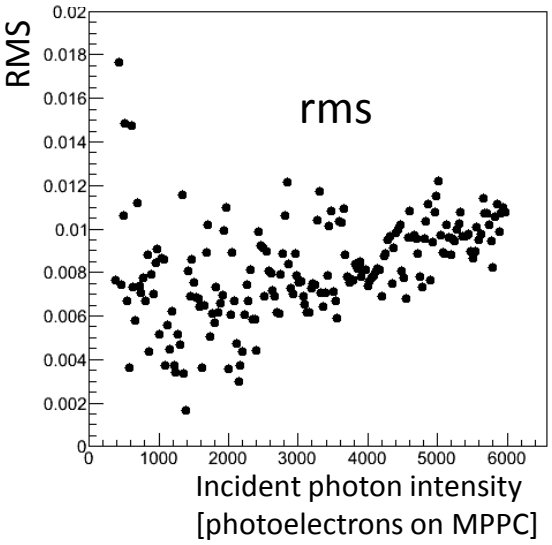

differences among individual pieces




Deviation of Y(different pieces)



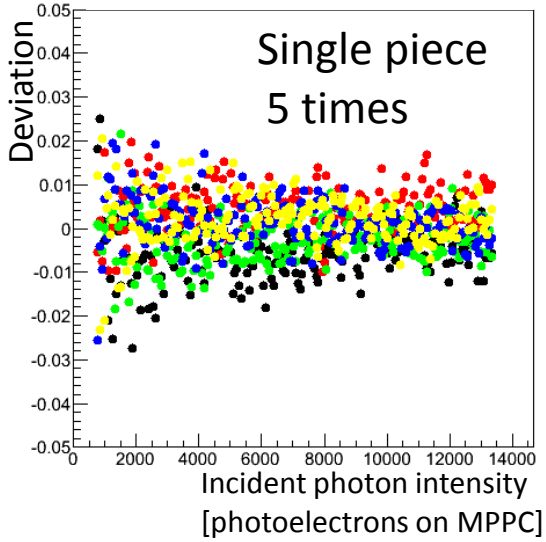

RMS(different pieces)



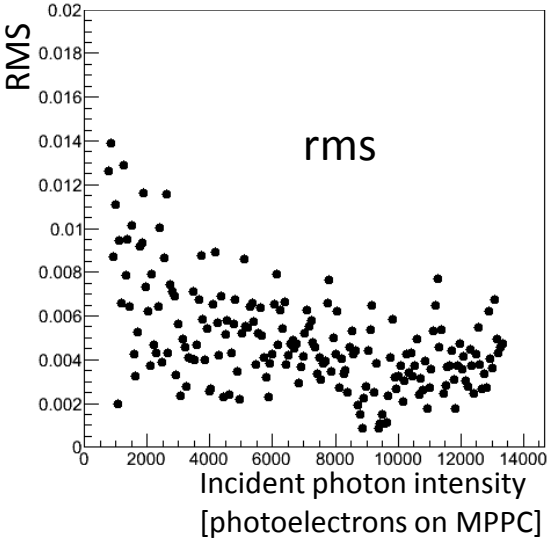

・for case of 1600pix MPPC+Scintillator differences among individual pieces is about 1%

# MPPC+Scintillator(2500pix)

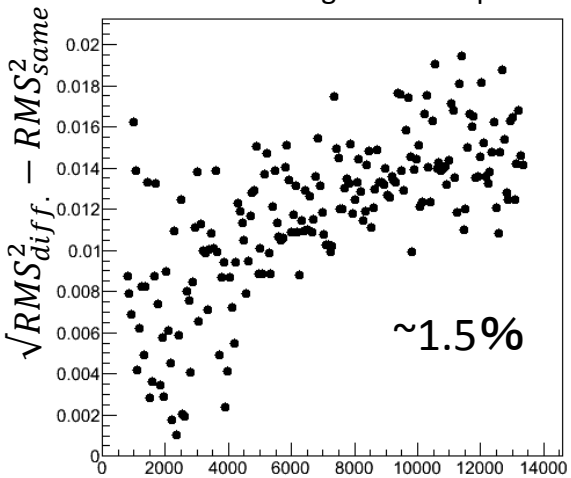
Deviation of Y(same piece)



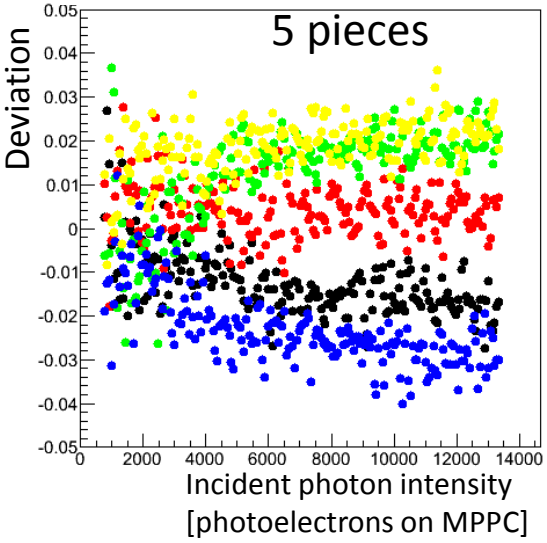

Sigma Y (type B)(same piece)



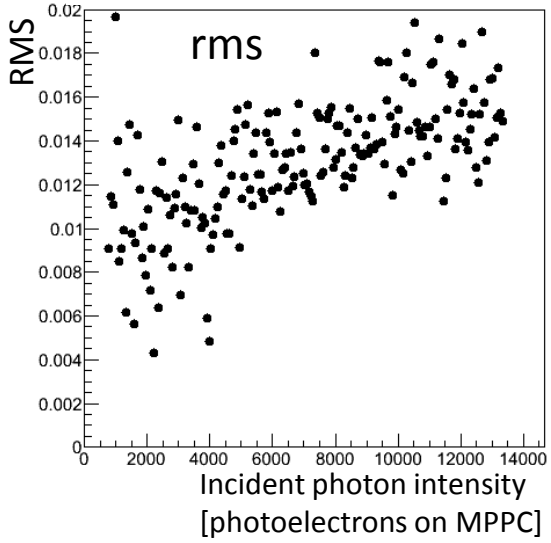

differences among individual pieces




Deviation of Y(different pieces)



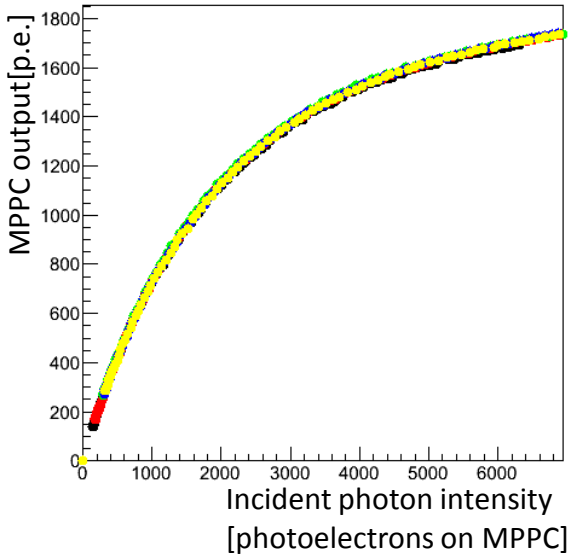

Sigma Y (type B)(different pieces)



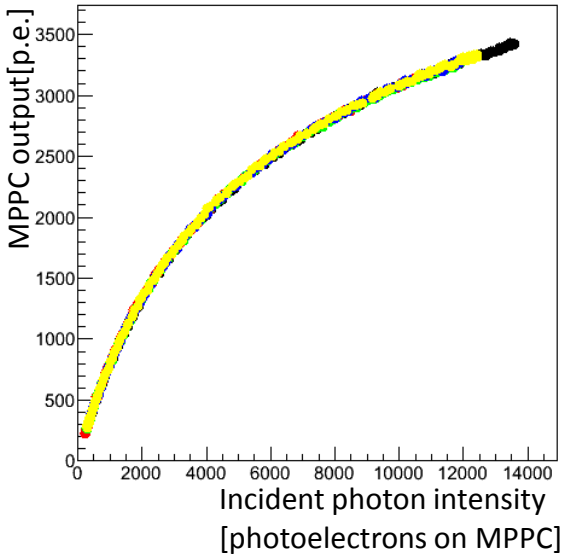

・in case of 2500pix MPPC+Scintillator, differences among individual pieces is about 1.5%

# Response Curve(MPPC+Scintillator+Reflector)

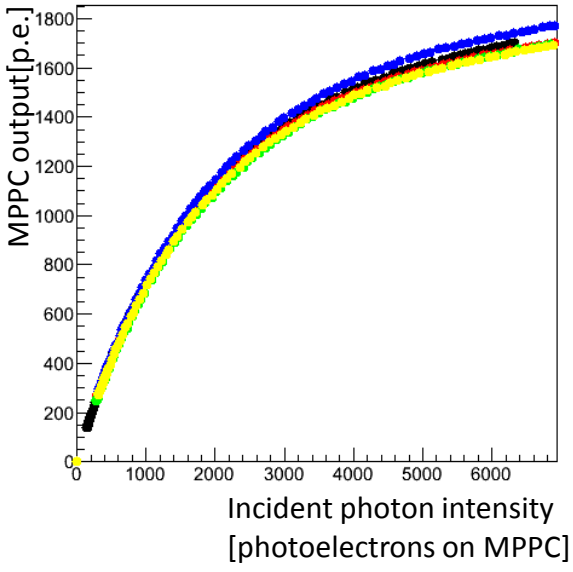
1600 pix(same piece)



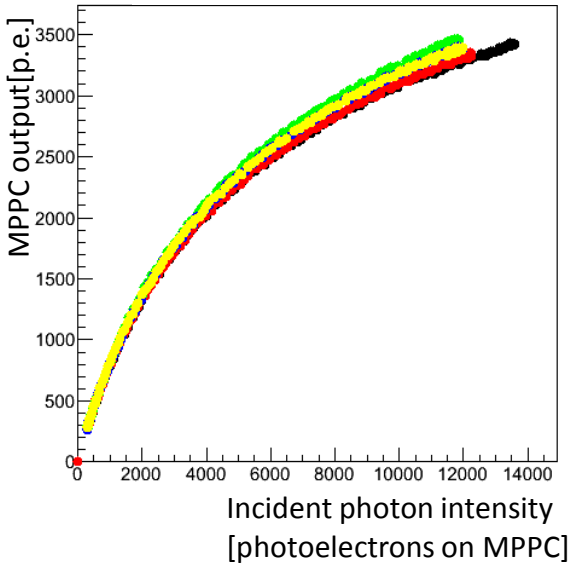

2500 pix(same piece)




1600 pix(different pieces)

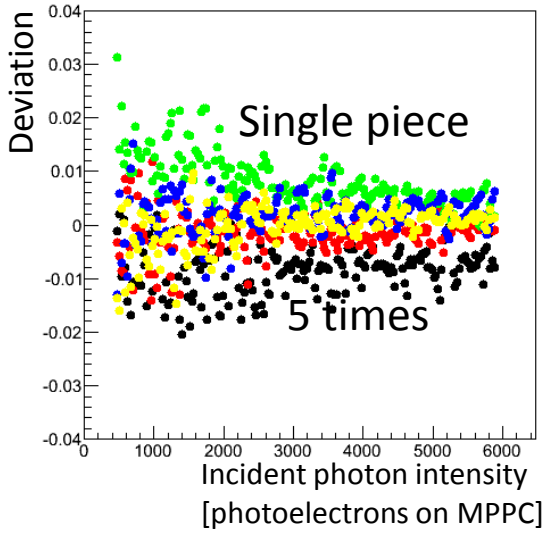



2500 pix(different pieces)

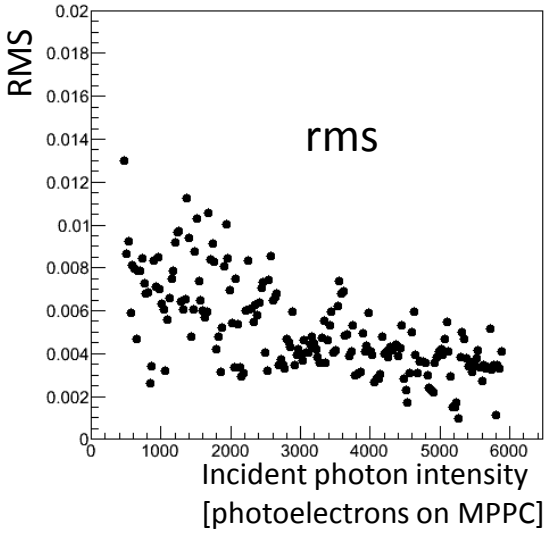


# MPPC+Scintillator+Reflector(1600pix)

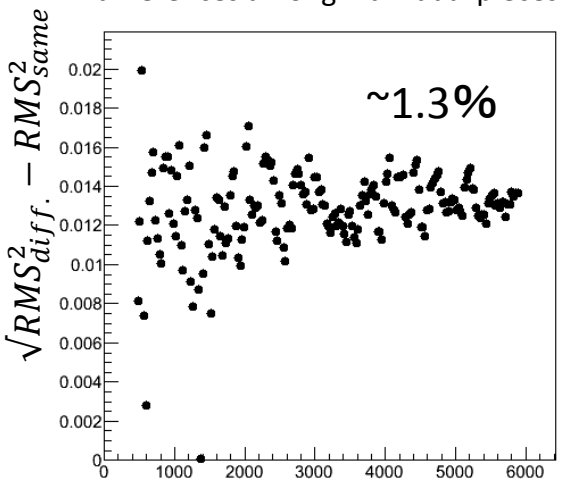
Deviation of Y(same piece)



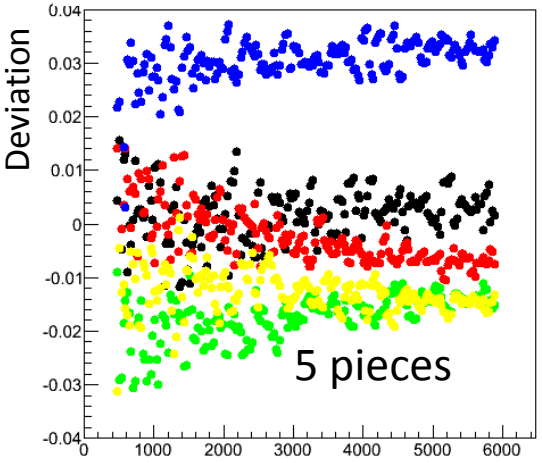

RMS(same piece)



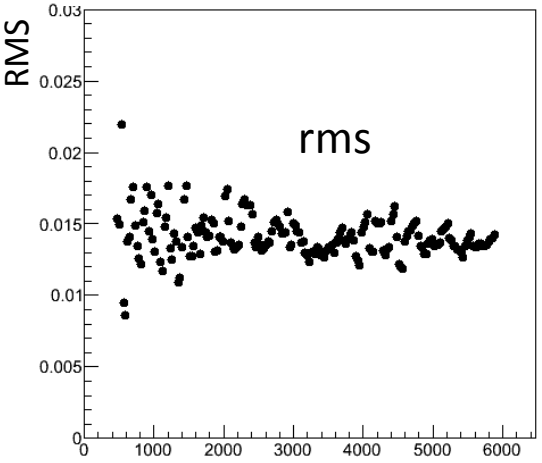

differences among individual pieces




Deviation of Y(different pieces)



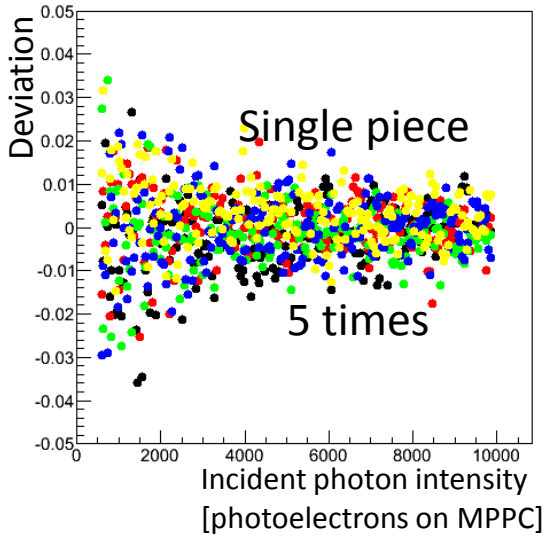

RMS(different pieces)



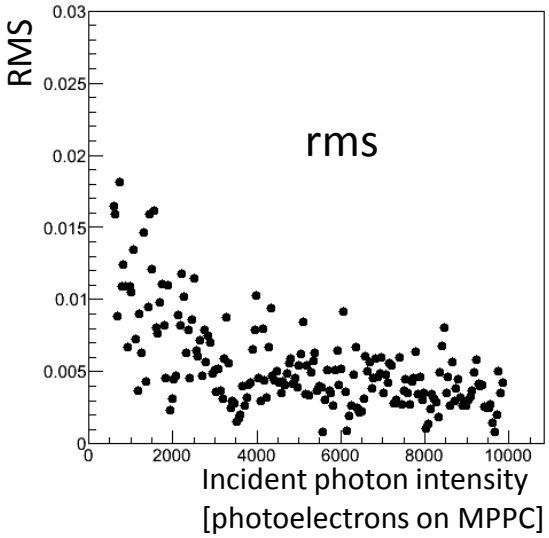

・for case of 1600pix MPPC+Scintillator+Reflector, differences among individual pieces is about 1.3%

# MPPC+Scintillator+Reflector(2500pix)

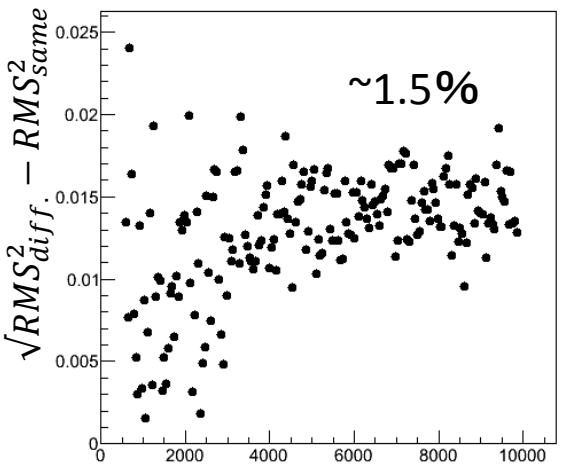
Deviation of Y(same piece)



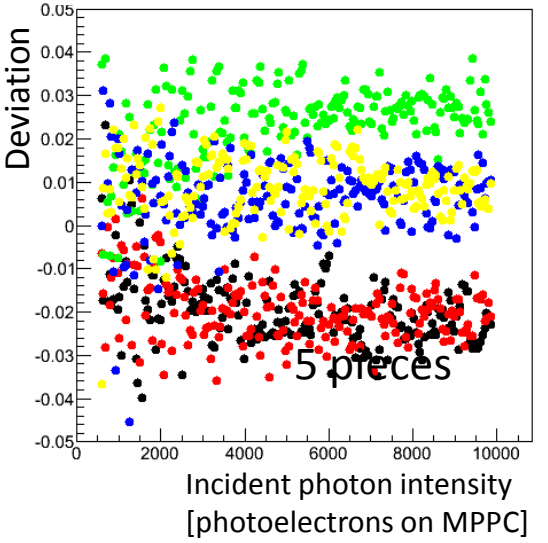

RMS(same piece)



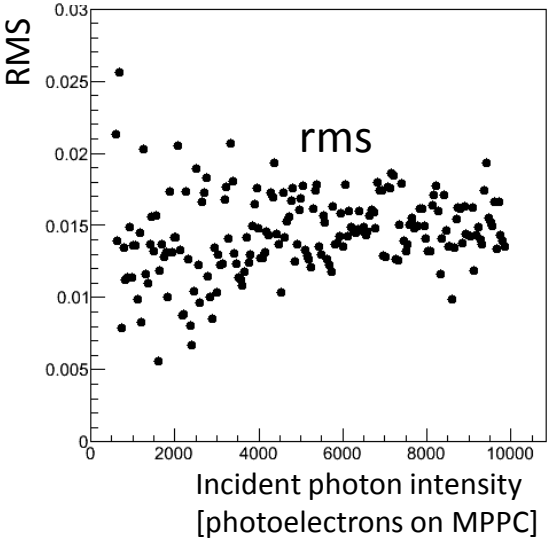

differences among individual pieces




Deviation of Y(different pieces)




RMS(different pieces)



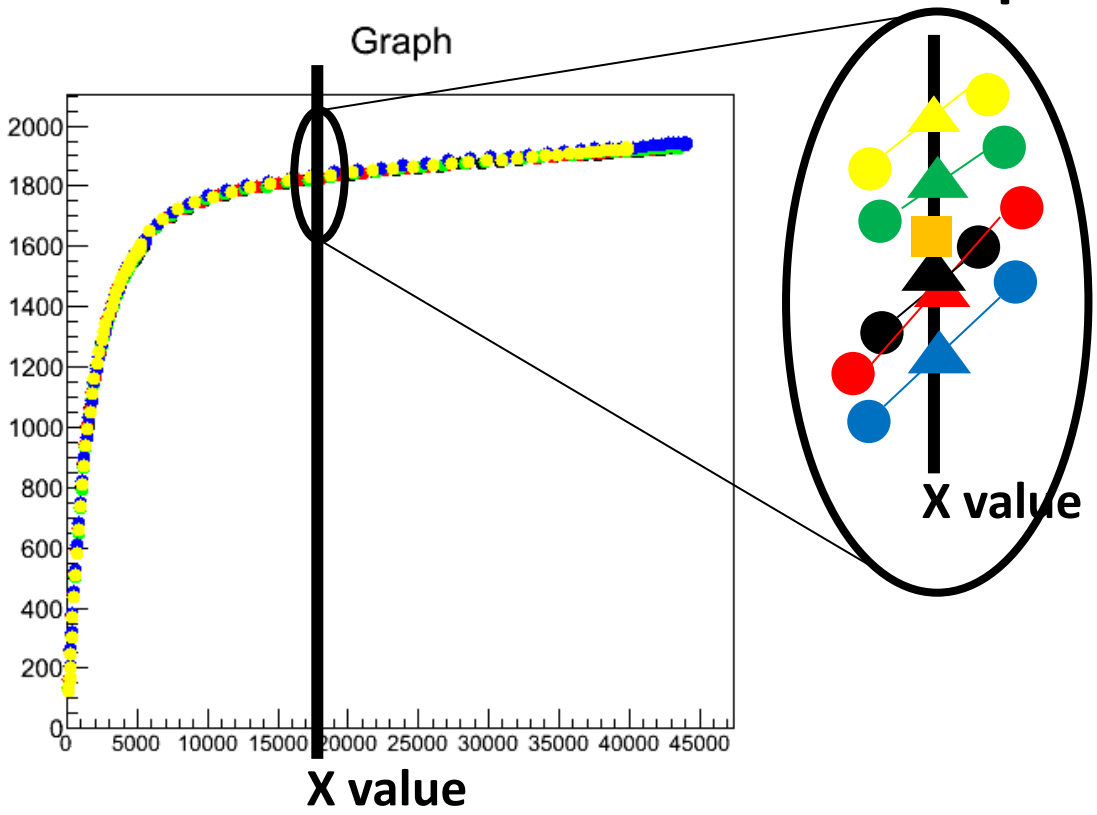

・for case of 2500pix MPPC+Scintillator+Reflector, differences among individual pieces is about 1.5%

# Summary

・We have measured  the response curves for various cases, such as with and without a scintillator in front of the MPPC.
・2500pix MPPC has larger dynamic range than 1600pix MPPC
・MPPC+Scintillator+Reflector has slightly larger dynamic range than MPPC+Scintillator.
・We have evaluated the differences among individual pieces
・for response curve, about 1% uncertainty is expected, if no calibration.

# Back UP

# Evaluation of differences among individual pieces







Measured fact act data

Intersection(approximation data)

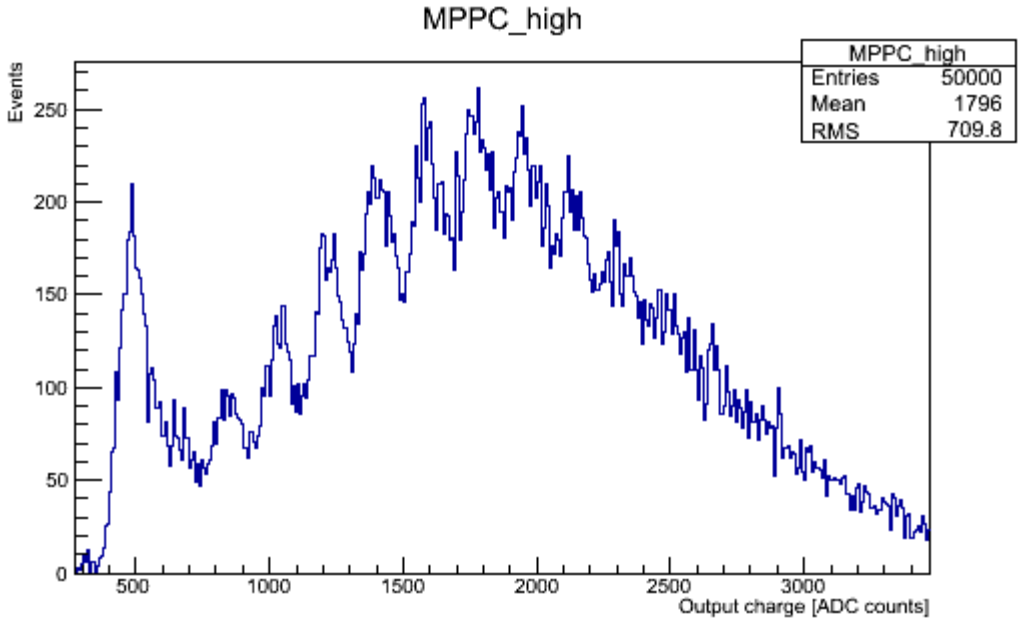
average of all different pieces

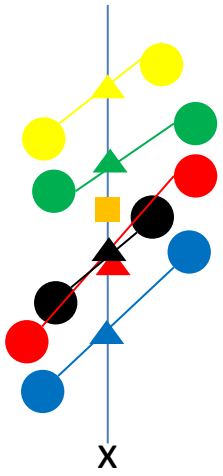
deviation of Y = $\frac{\text{▲} - \text{■}}{\text{■}}$

・when some X values are given, point at the intersection of X with the line of two points, most closest right and left data from X , is used as measured value, as approximation of the fact data

・deviation of Y is defined as $\frac{measured(intersection) - average}{average}$

# MIP


MPPC_high
MPPC_high
Entries 50000
Mean 1796
RMS 709.8
Events
0
50
100
150
200
250
500
1000
1500
2000
2500
3000
Output charge [ADC counts]



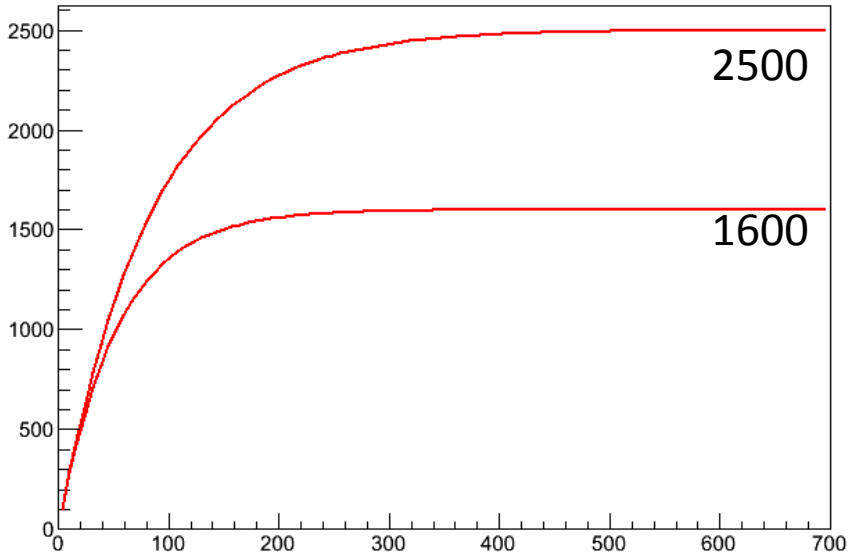

data

intersection

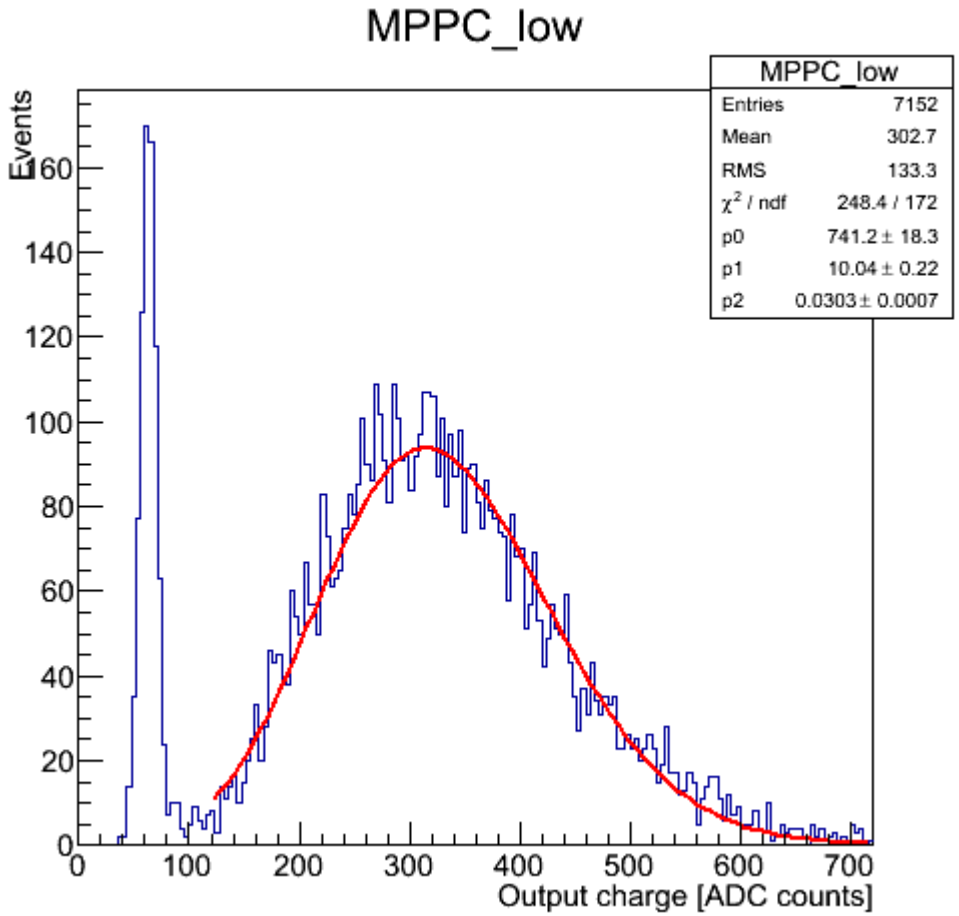
average of all different pieces

deviation of Y = $\frac{\triangle - \square}{\square}$

Theoretical Formula of Response Curve
(no time structure is considered)

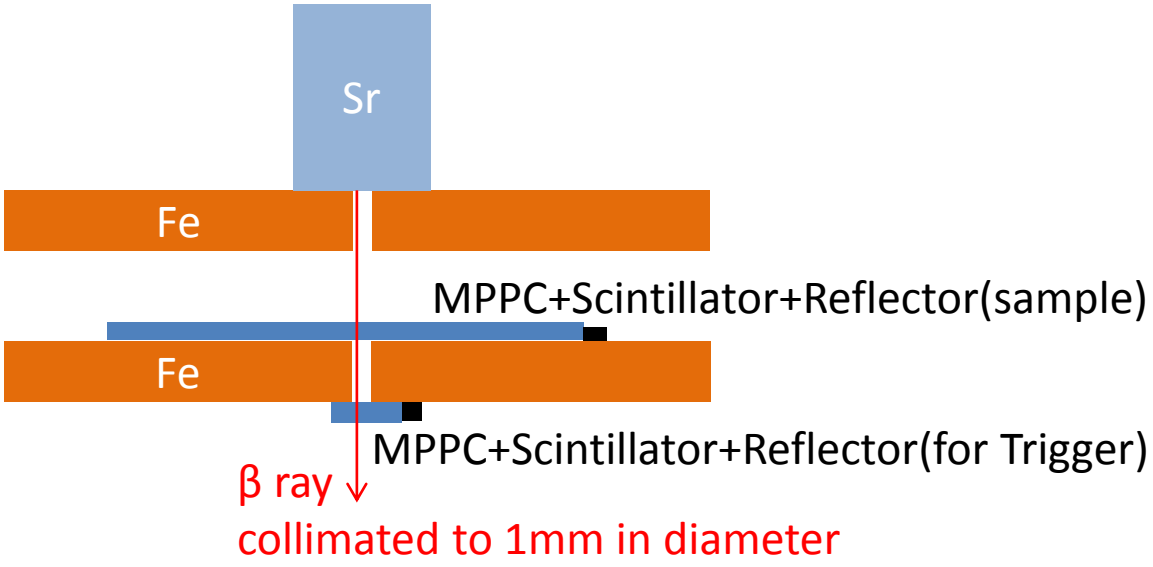


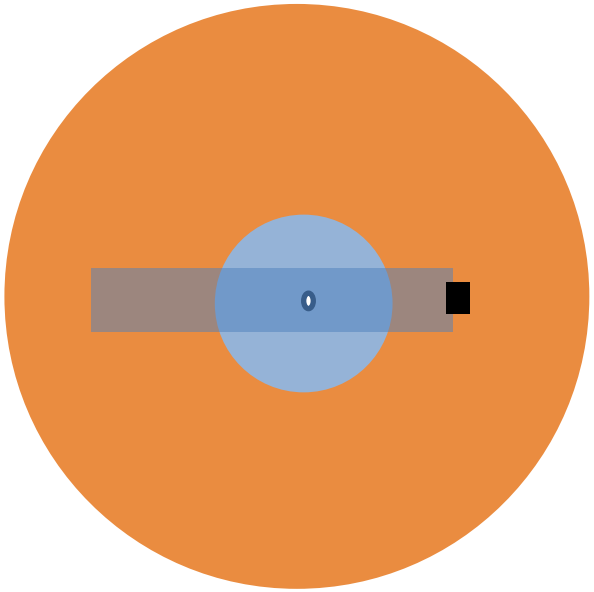

$$F(x) = p0 * \left(1 - \exp\left(\frac{-p1 * x}{p0}\right)\right)$$

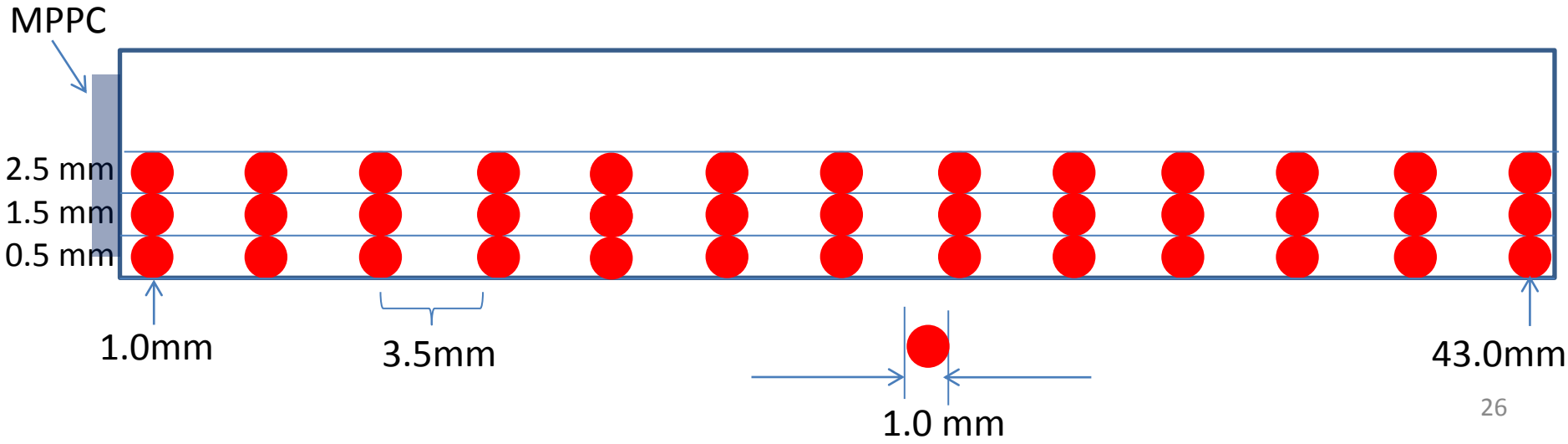

MPPC_low
MPPC_low
Entries 7152
Mean 302.7
RMS 133.3
χ² / ndf 248.4 / 172
p0 741.2 ± 18.3
p1 10.04 ± 0.22
p2 0.0303 ± 0.0007
Events
0
20
40
60
80
100
120
140
160
0
100
200
300
400
500
600
700
Output charge [ADC counts]

# Measurement of Uniformity of Scintillator

# Set up

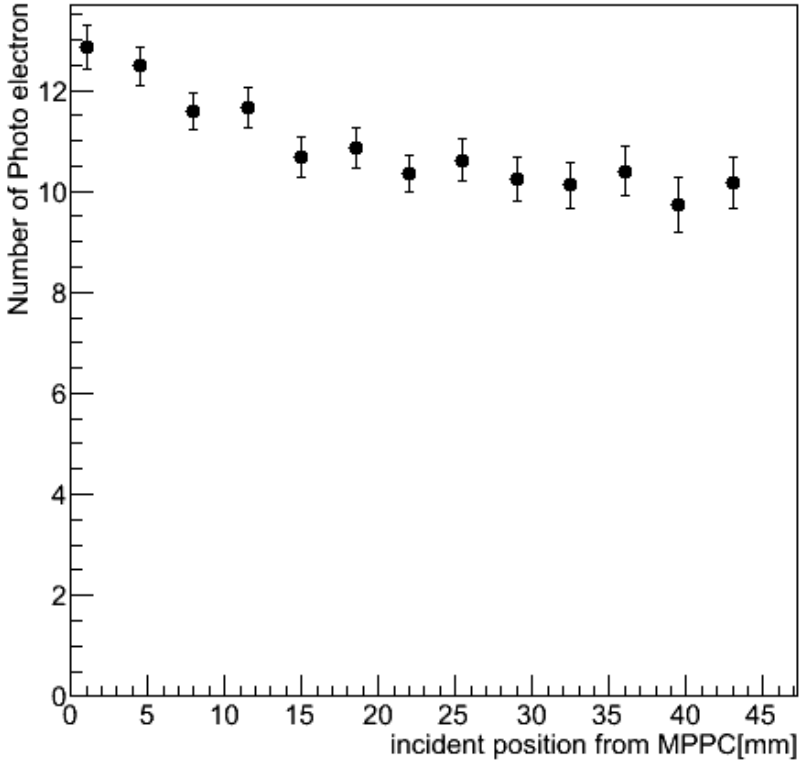

Sr
Fe
MPPC+Scintillator+Reflector(sample)
Fe
MPPC+Scintillator+Reflector(for Trigger)
β ray
collimated to 1mm in diameter

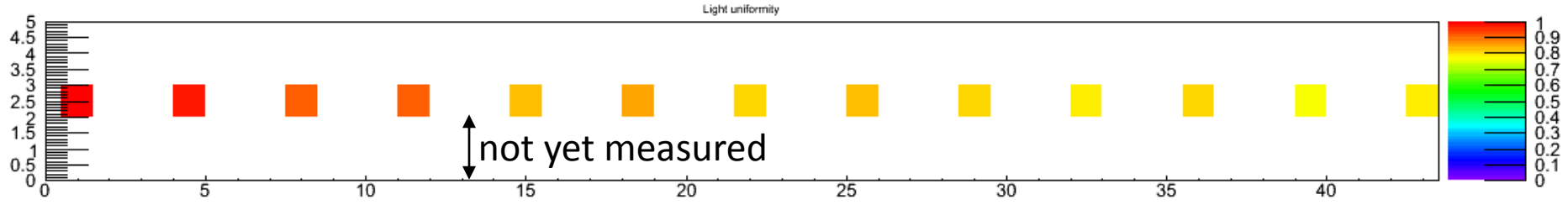



MPPC
2.5 mm
1.5 mm
0.5 mm
1.0mm
3.5mm
1.0 mm
43.0mm

# Uniformity

2.5mm from edge of Scintillator(center)

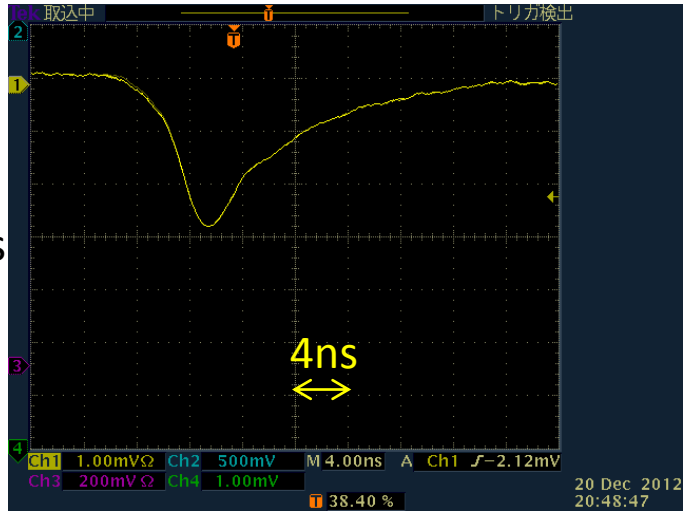


# Signal

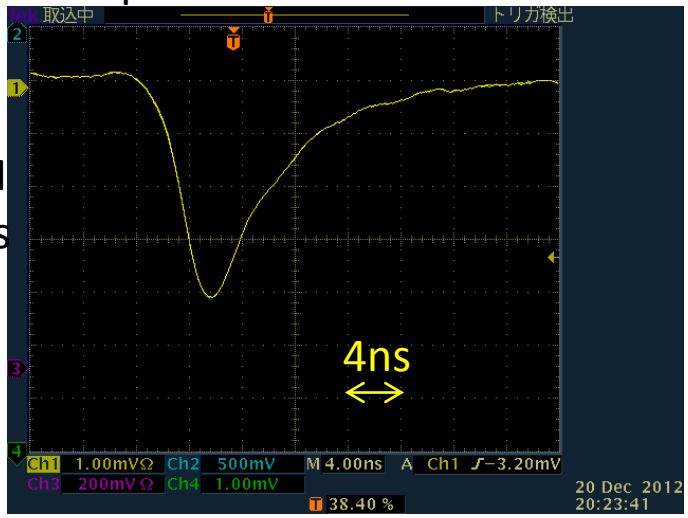
1600 pix MPPC+Scintillator

FWHM
~7.2 ns



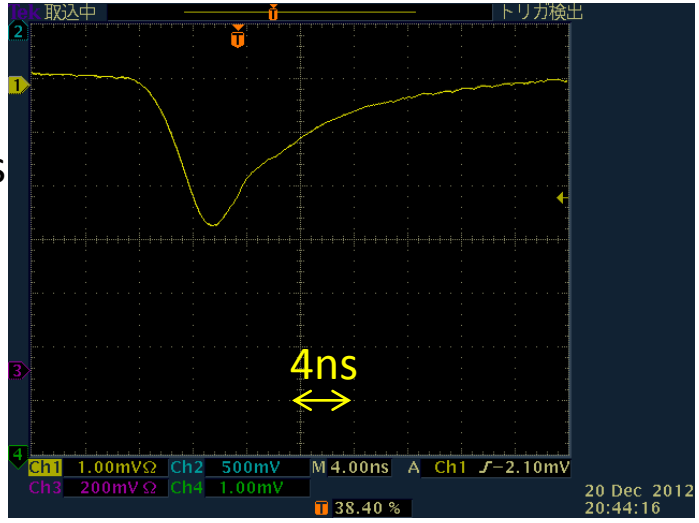

2500 pix MPPC+Scintillator

FWHM
~7.2 ns



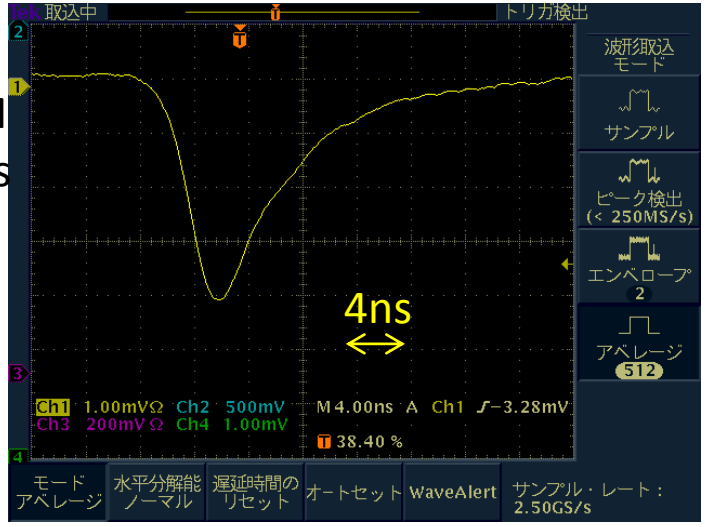

1600 pix MPPC+Scintillator+Reflector

FWHM
~7.2 ns




2500 pix MPPC+Scintillator+Reflector

FWHM
~7.2 ns



1600pix

MPPC only