Optimization Studies of MPPC Readout for ILD Scintillator ECAL

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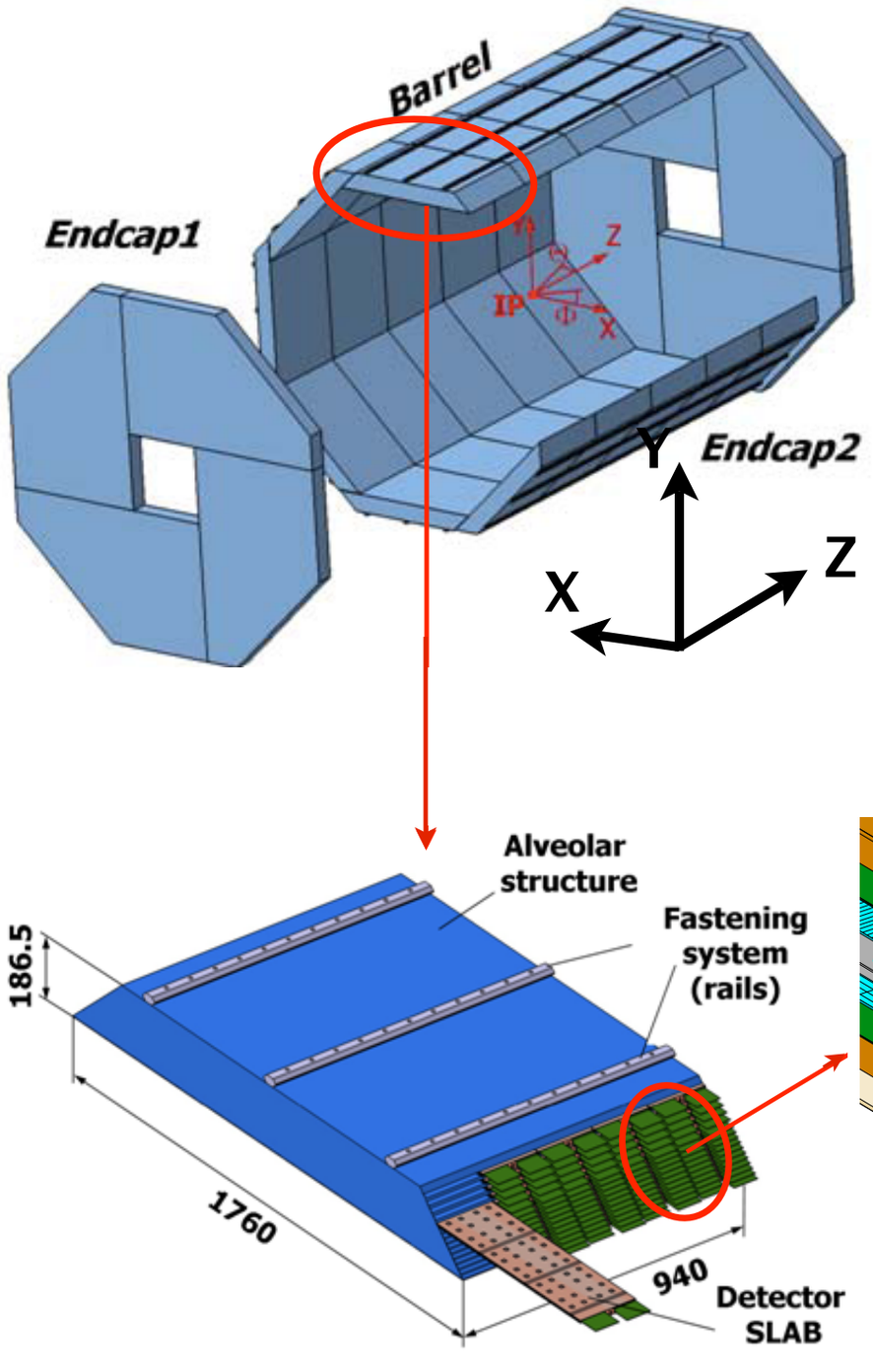
Outline

- Motivation
- New design of MPPC readout for scintillator strip
- Simulation
- Measurement
- Summary

Motivation

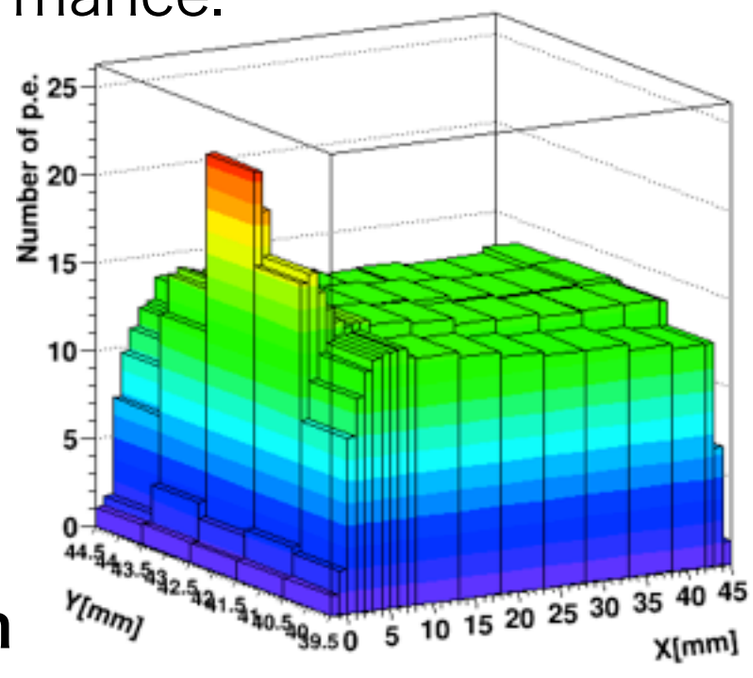


ILD ECAL scintillator strip

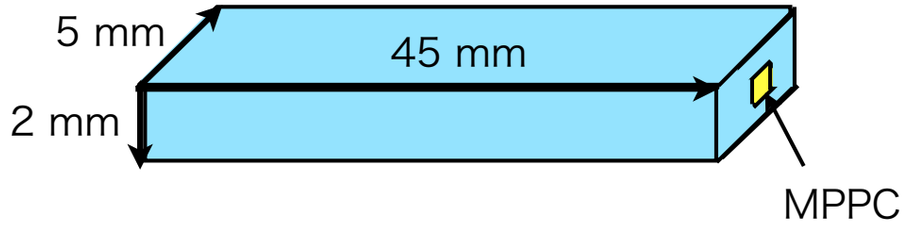
- One of the candidates for ILD ECAL is based on scintillator strip with MPPC readout.
- The baseline design of MPPC readout of scintillator strip developed by Shinshu university group shows good performance.

-Uniform response

-Relatively high Npe



Baseline design



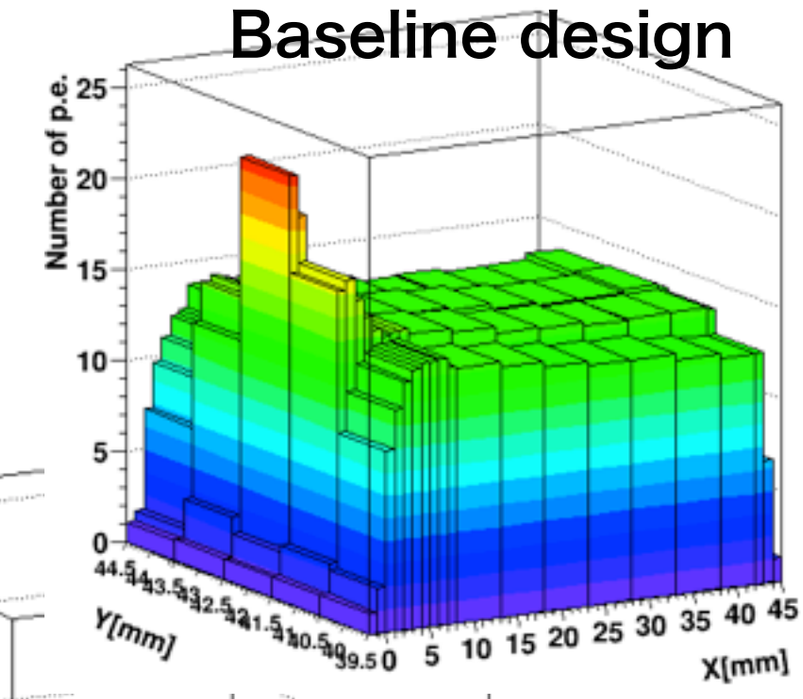
Motivation

- Technical problems exist in baseline design.
  -Possible difficulty in mass production with up-right MPPC installation on PCB.
  -Dead gap between strips due to MPPC installation.
  -Peaky response for hit near MPPC

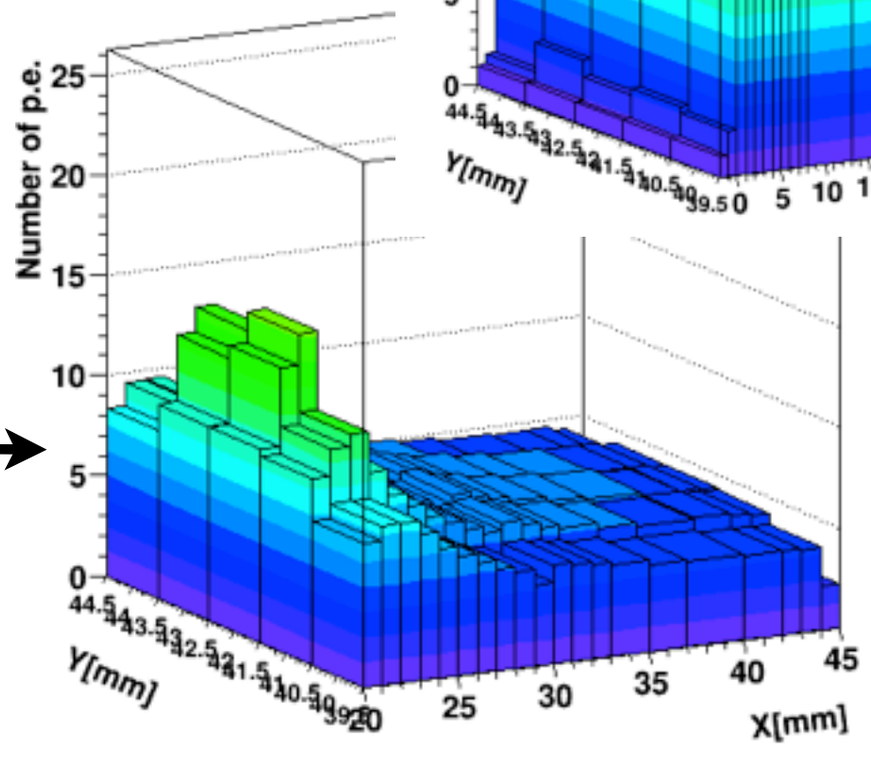
- Simple bottom side readout doesn't work.
  -Degradation of light collection efficiency
  -Peaky response for hit near MPPC

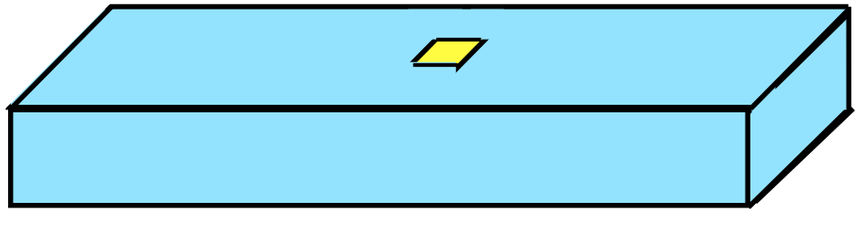
  → New design of MPPC readout is under study to solve these issues.

Baseline design



Simple bottom side readout design →



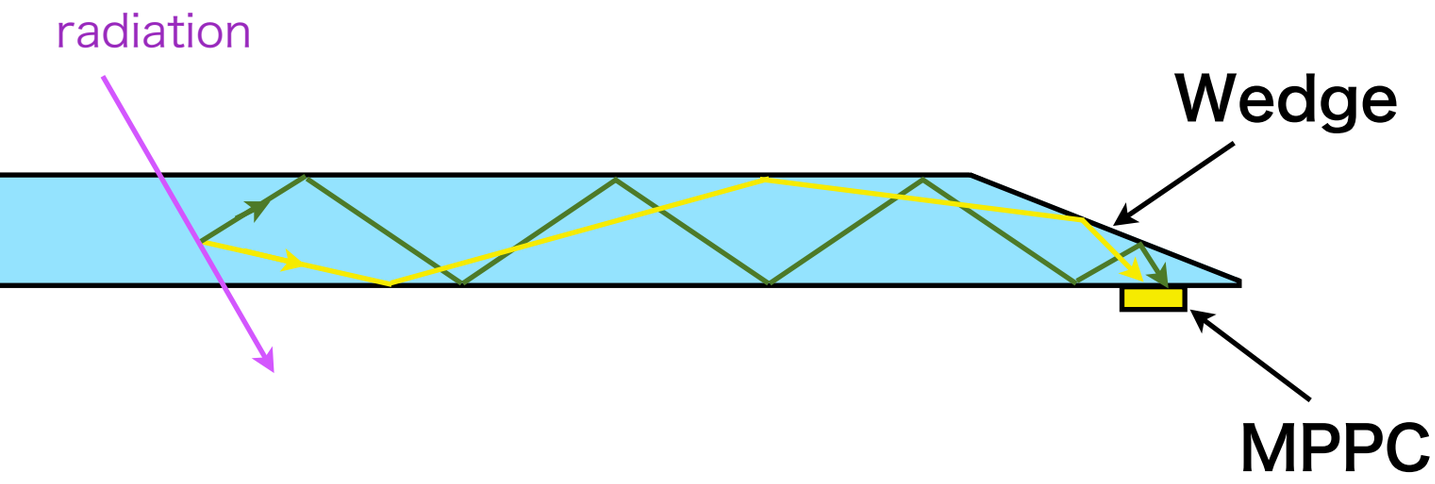


New design of scintillator strip

- New design for scintillator strip readout is under study.
  → MPPC readout at **Wedge-shaped** end

- Expected improvements
  -Wedge works as prism to guide scintillation light to MPPC attached on bottom side of strip
  -Mitigation of peaked Npe for hit near MPPC
  -Easier mass production with MPPC in parallel with PCB
  -No gap between scintillator strips

・Reduced effect of direct photon
・Shorter path length for particle going through near MPPC

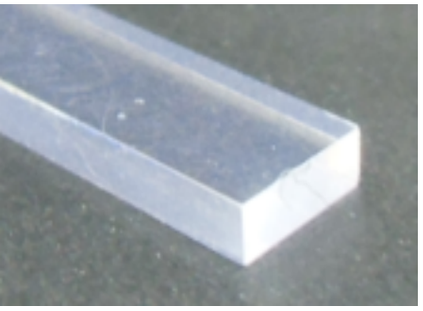


We tested new design by simulation and measurement.

Compared configurations

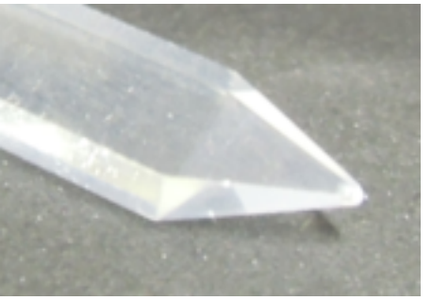
- **Normal** : Baseline configuration (Up-right MPPC installation)
- **Normal bottom** : Bottom side readout with normal strip
- **Wedge**
- **Tapered wedge**

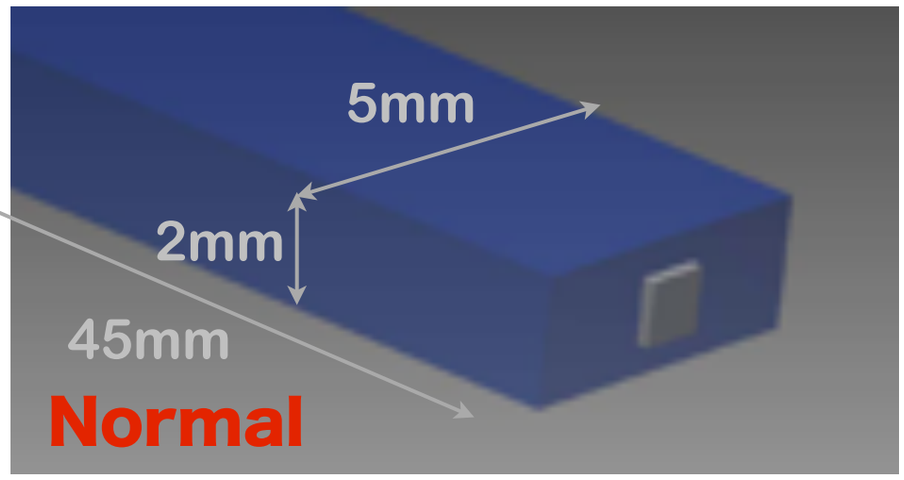
Normal

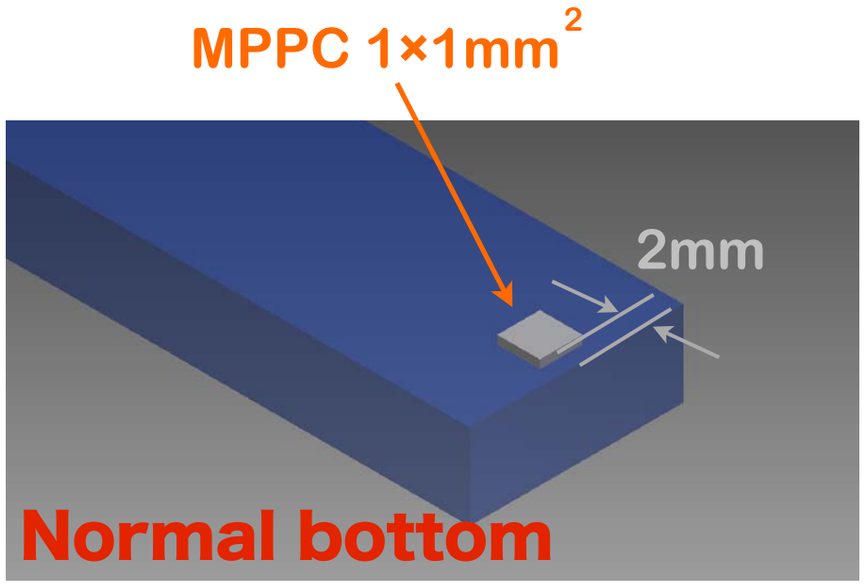


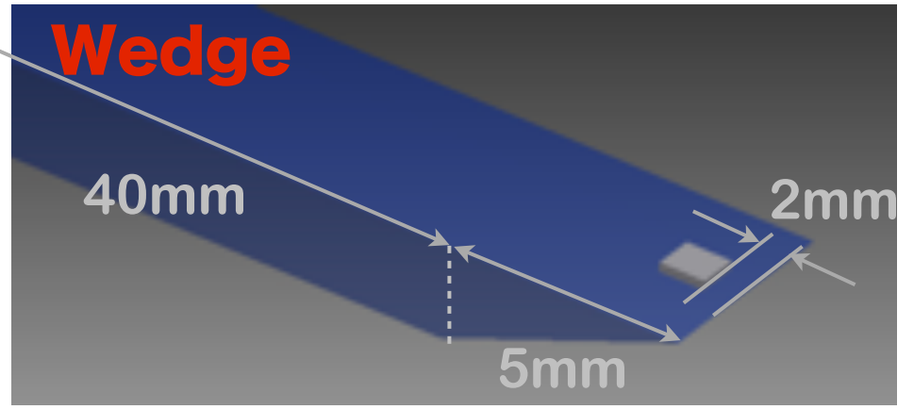
Wedge

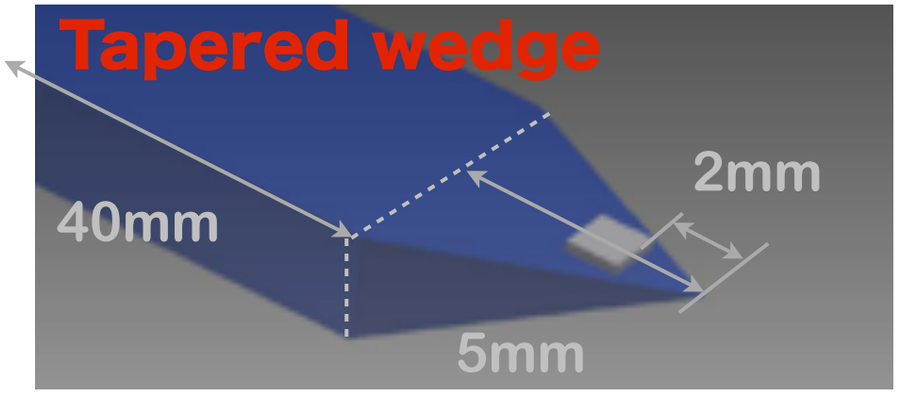
Tapered wedge





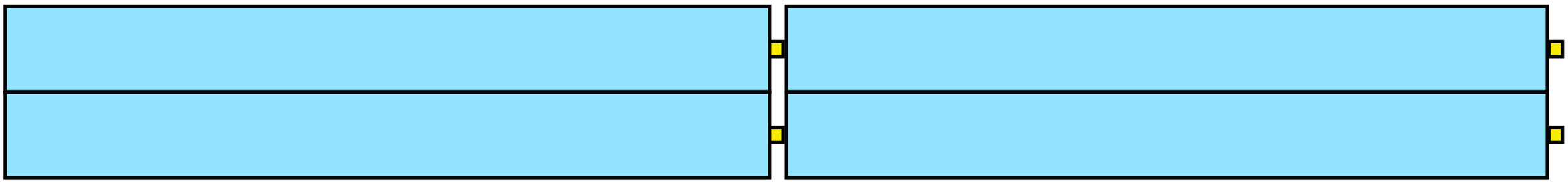






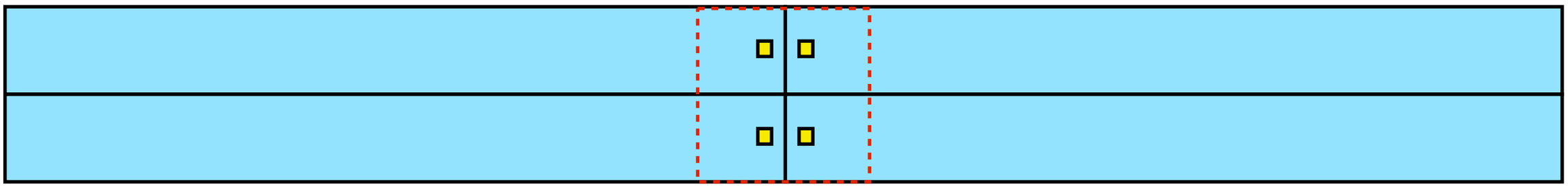
Possible layout for scintillator strip with wedge

Normal

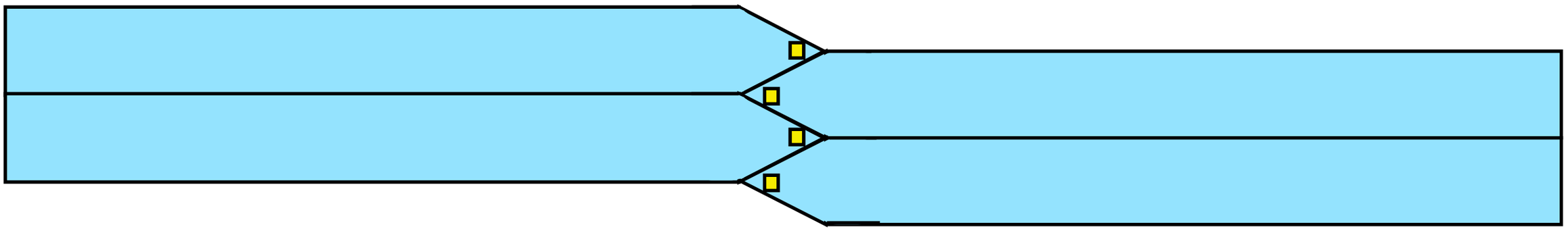


- Gap-less layout is possible for bottom side readout with **wedge/tapered wedge**.

Wedge



Tapered wedge

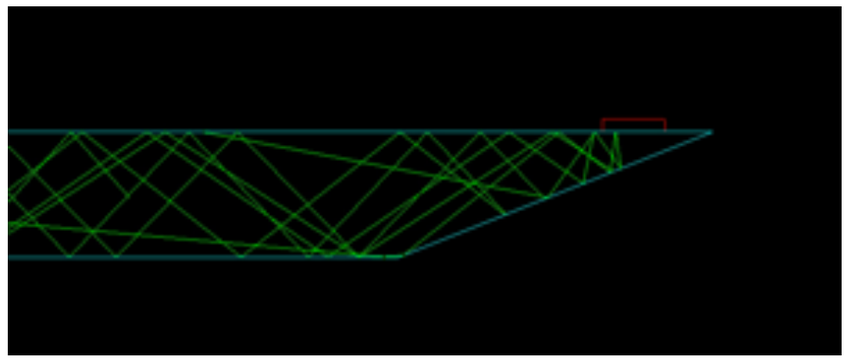


Simulation of scintillation photon propagation

- Geant4-based simulation of scintillation photon propagation

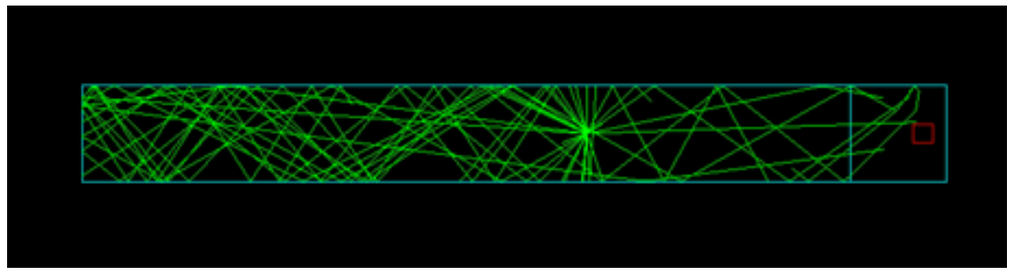
- Scintillator material

  -Emission spectra is similar to BC418(Saint-Gobain)
  -Scintillation efficiency : ~10^4 photon/MeV
  -Absorption length : 80cm
  -Surface model : Polished (only total reflection)
  -Reflectivity : 0.95
  -No reflector



- MPPC

  -PDE : 0.3 (No wavelength dependence)



＊ Monte Carlo simulation parameters are still to be optimized.
＊ Only relative comparison makes sense for the moment.

Simulation of scintillation photon propagation

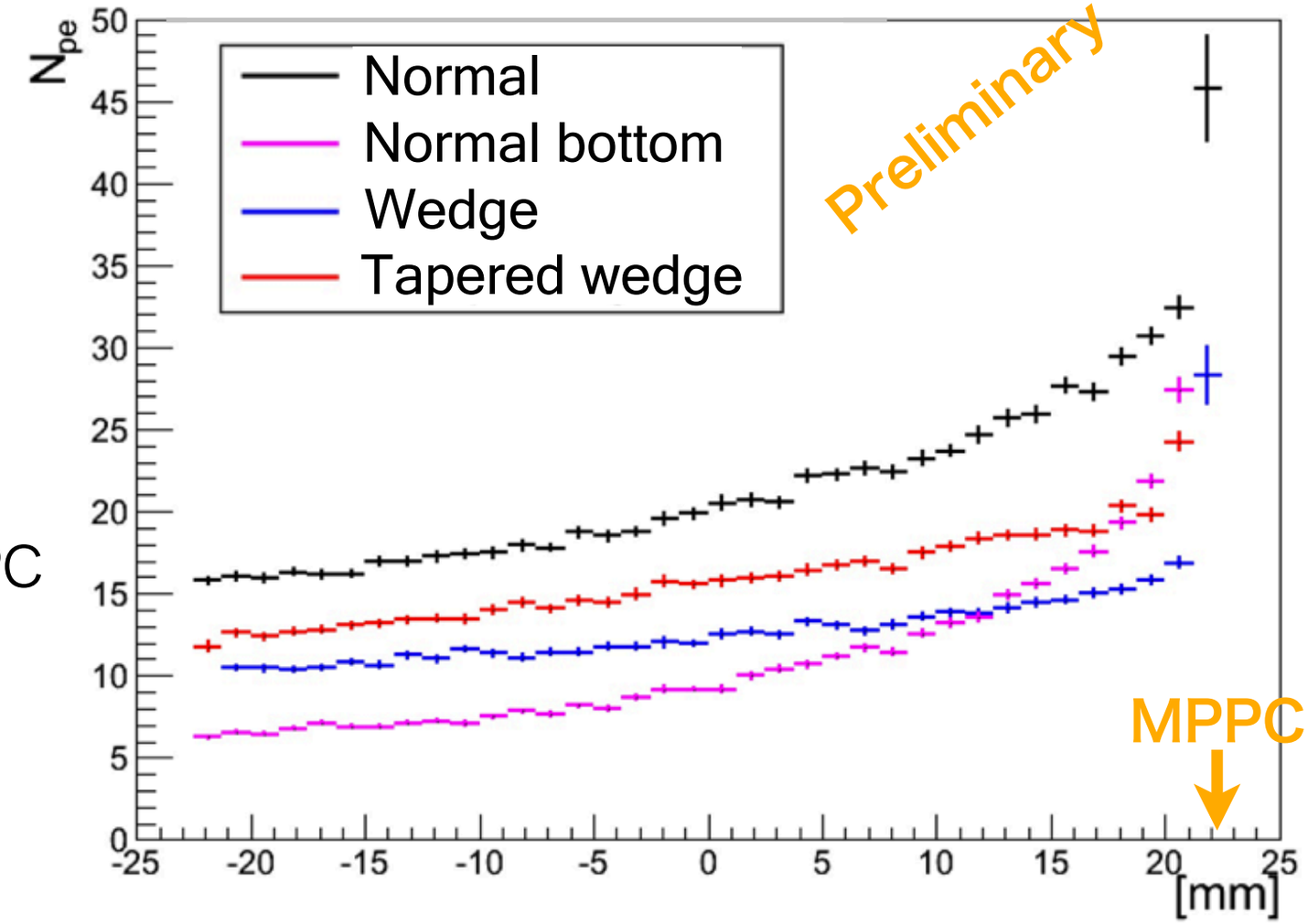
- Responses of **normal** and **normal with bottom side readout** observed in the previous measurements are reproduced, apart from a small continuous increase of Npe toward MPPC.

  -Degradation of Npe with bottom side readout
  -Peak near MPPC

- New design with **wedge** or **tapered wedge** show good performance.

  -Reasonably high Npe
  -Slightly better uniformity
  -Improved response near MPPC

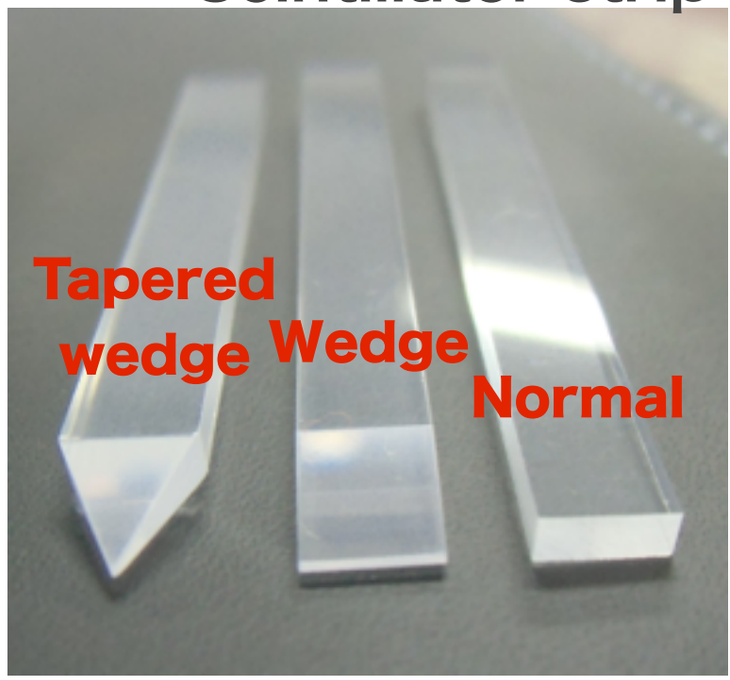
＊ Geometry of wedge (length, MPPC position) is preliminary optimized.

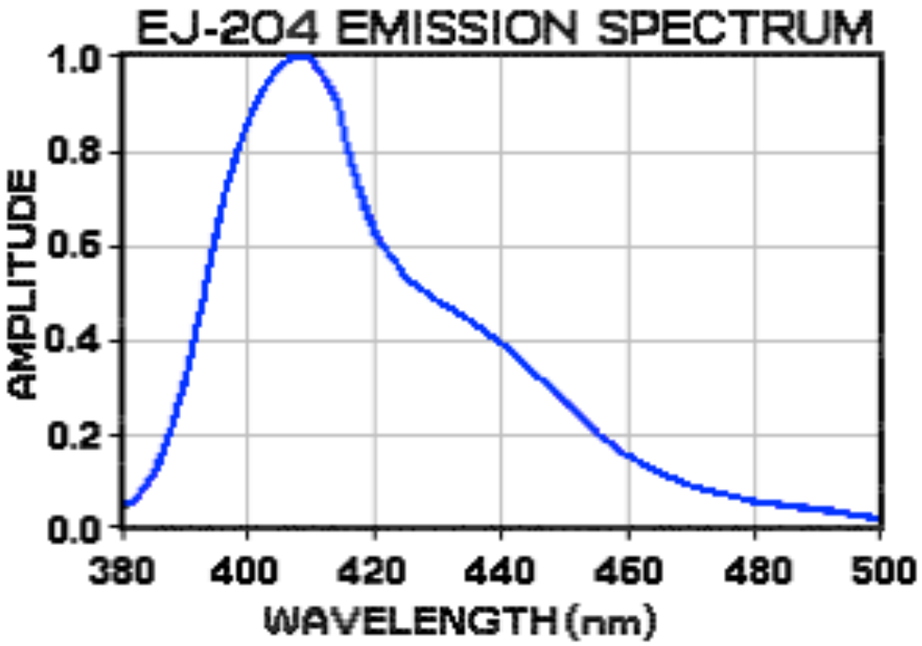


Prototype measurement

- Scintillator : ELJEN EJ-204 (Saint-Gobain BC-404 equivalent)
  -Emission wavelength : near 400nm
  -Scintillation efficiency : 10400 photons/1MeV e^-
  -Rise time : 0.7 ns
  -Refractive index : 1.58
  -Attenuation length : 140 cm (BC404)
- Reflector : 3M radiant mirror film
  -The light with wavelengths from 400 to 700nm is specularly reflected from 0° to 90° incidence angle.

Scintillator strip

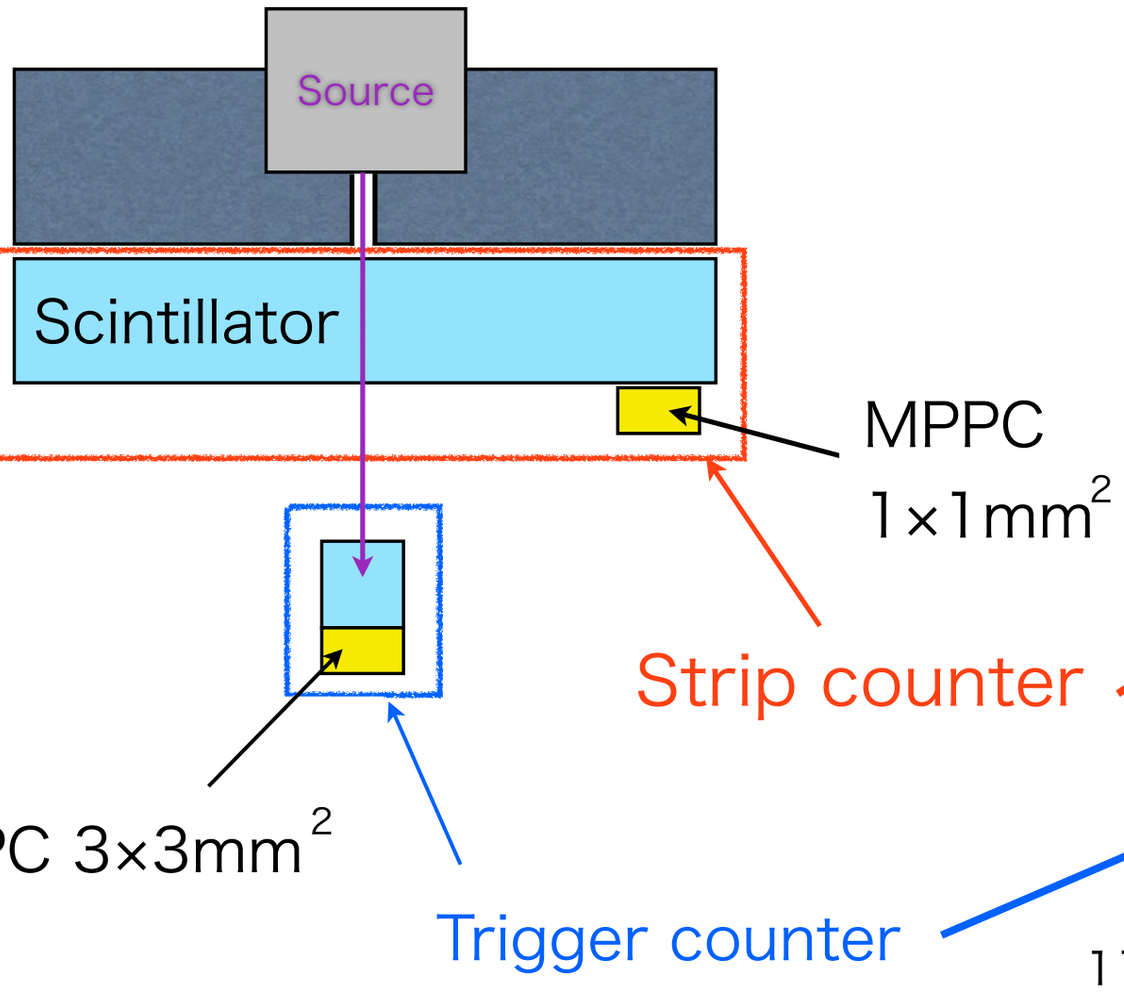




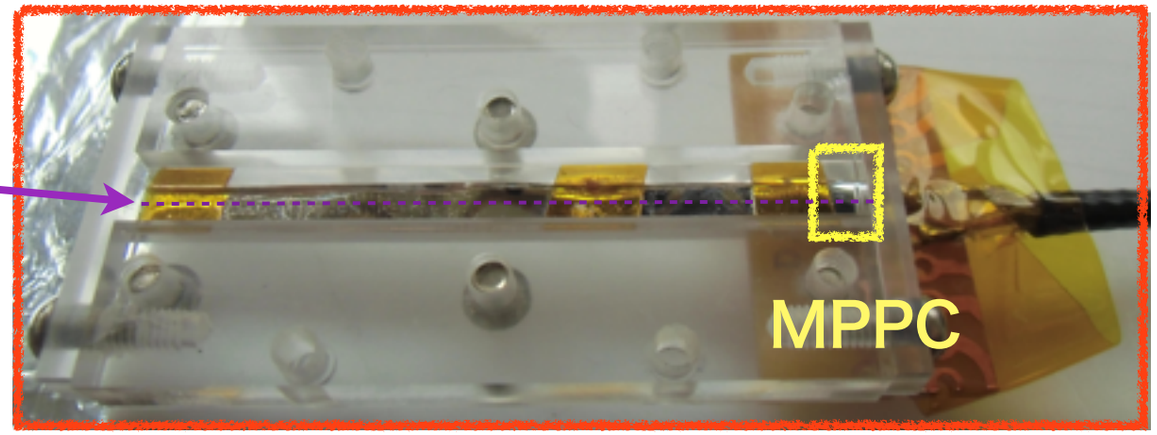
Scintillator strip with reflector

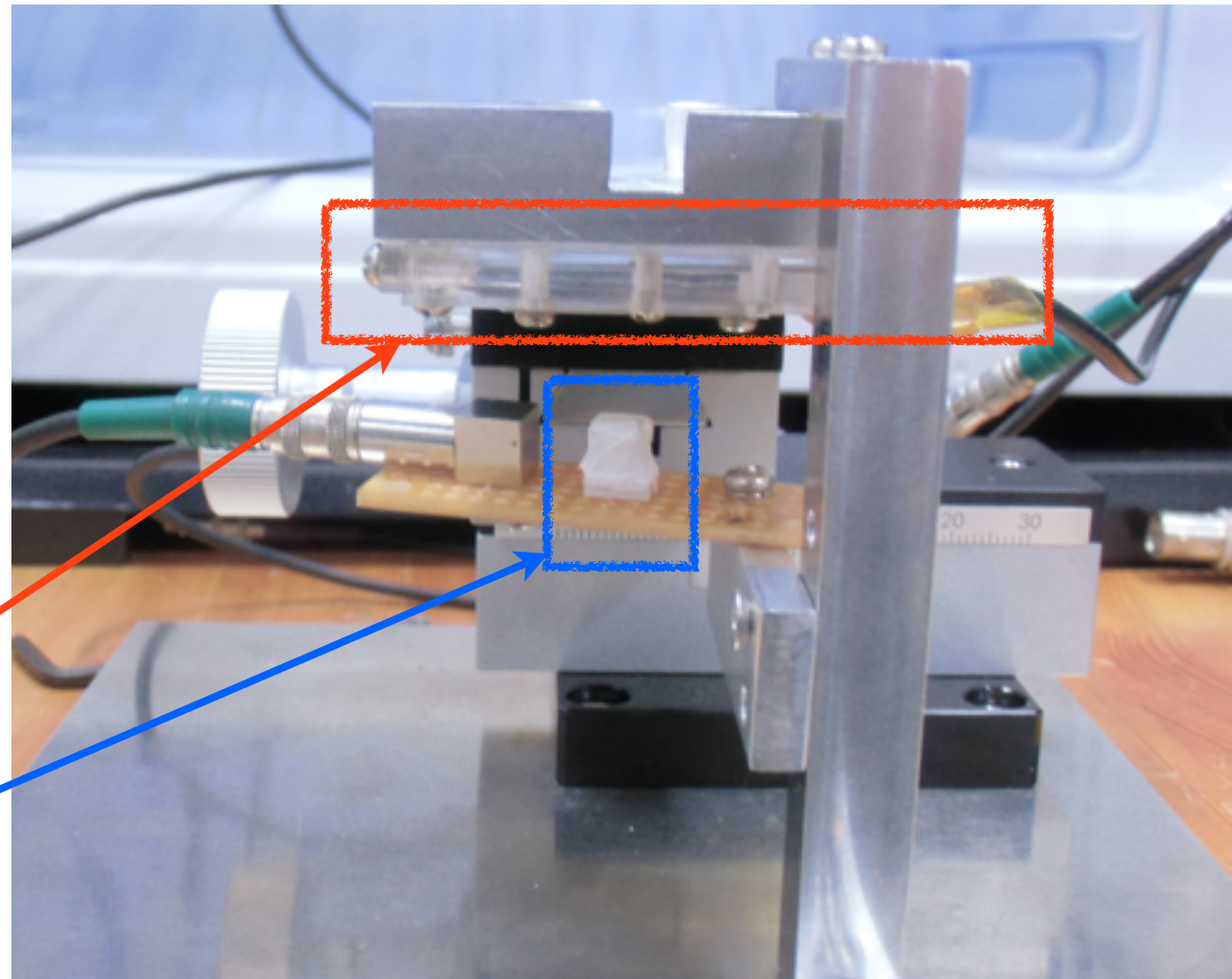
Setup

-MPPC : HAMAMATSU, S10943-8585(X)
1×1mm^2, 1600pix (25μm pitch)
-Irradiated with collimated β (E<2.28MeV)
from Sr-90
-Collimator diameter : 1mm



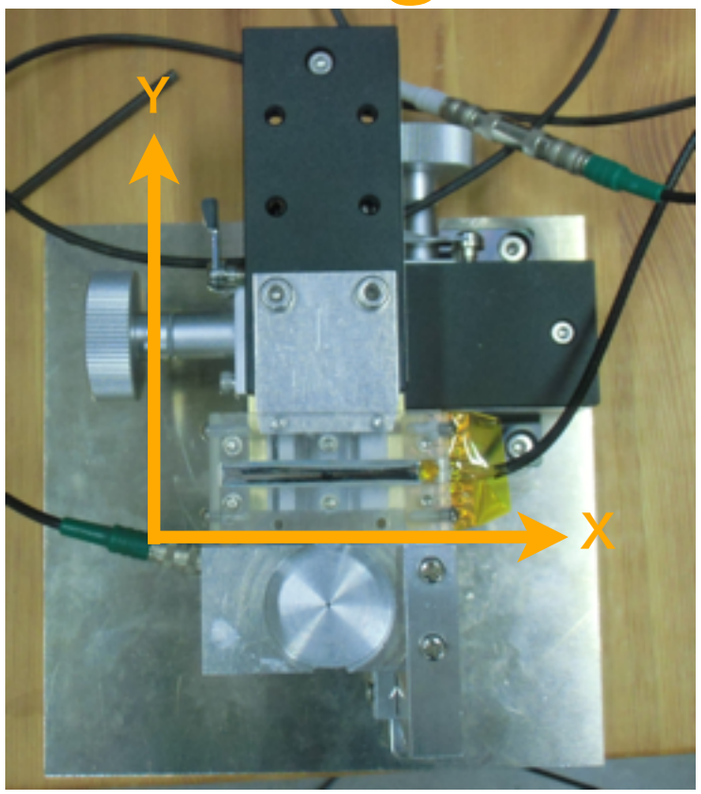
Center of the strip was irradiated.



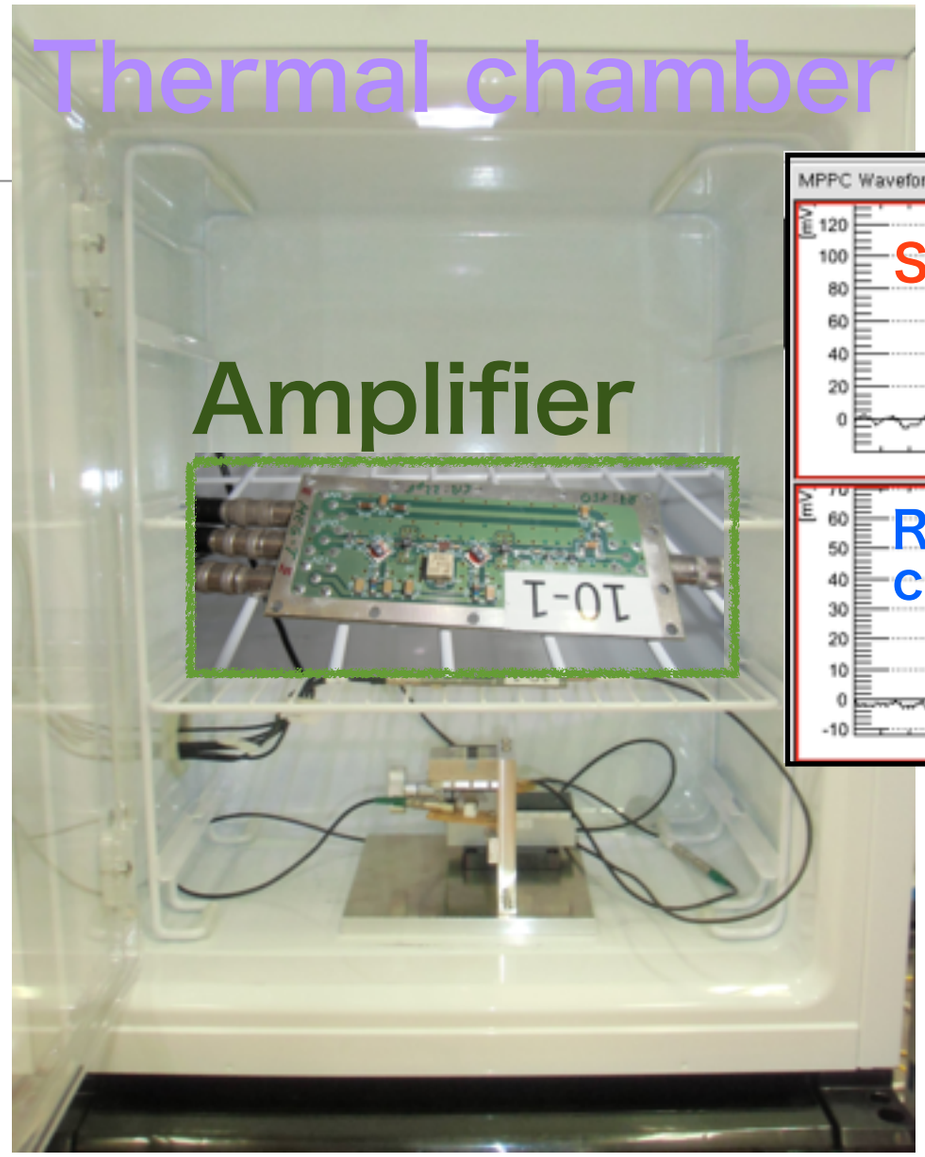


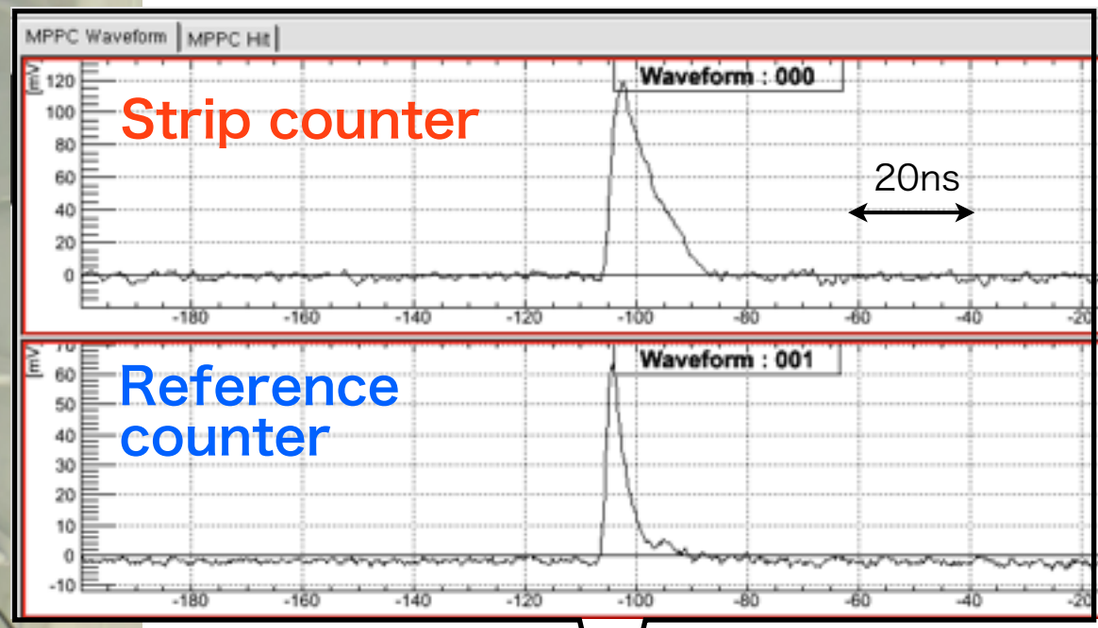
Setup

XY stage



Thermal chamber





Thermal chamber

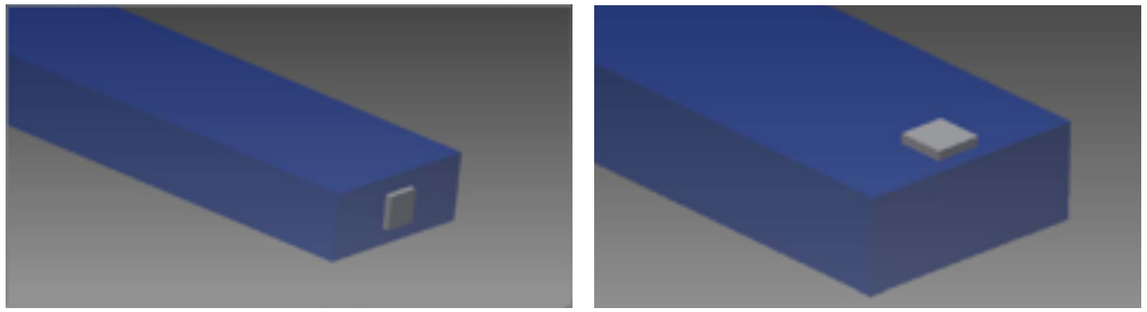
MPPC → AMP → DRS

-Position scan with XY stage.

-Whole set up is put in the thermal chamber. (26 ℃)

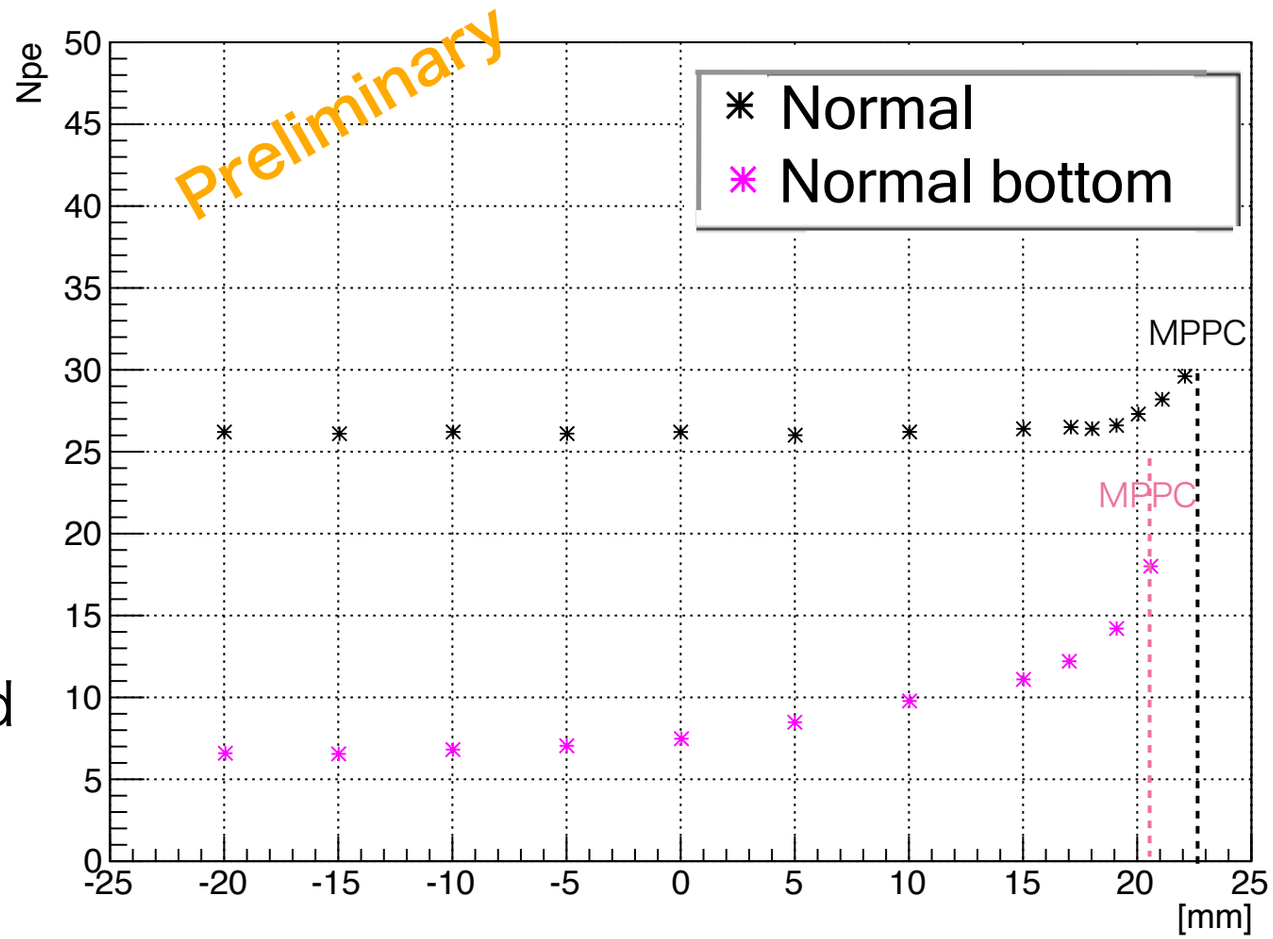
-Signal is amplified and taken with waveform digitizer, DRS which is developed at PSI. (5 Gsps)

Measurement



Normal configuration and Simple bottom side readout

- Almost consistent with previous measurement by Shinshu group.
  -Uniform response
  -High light collection efficiency with baseline configuration
  -Significant reduction of Npe with bottom side readout (by a factor of four)
  -Peaky Npe near MPPC
- Larger Npe than previously measured by Shinshu group probably due to different scintillator material and reflector. It may also include effect of correlated noise.

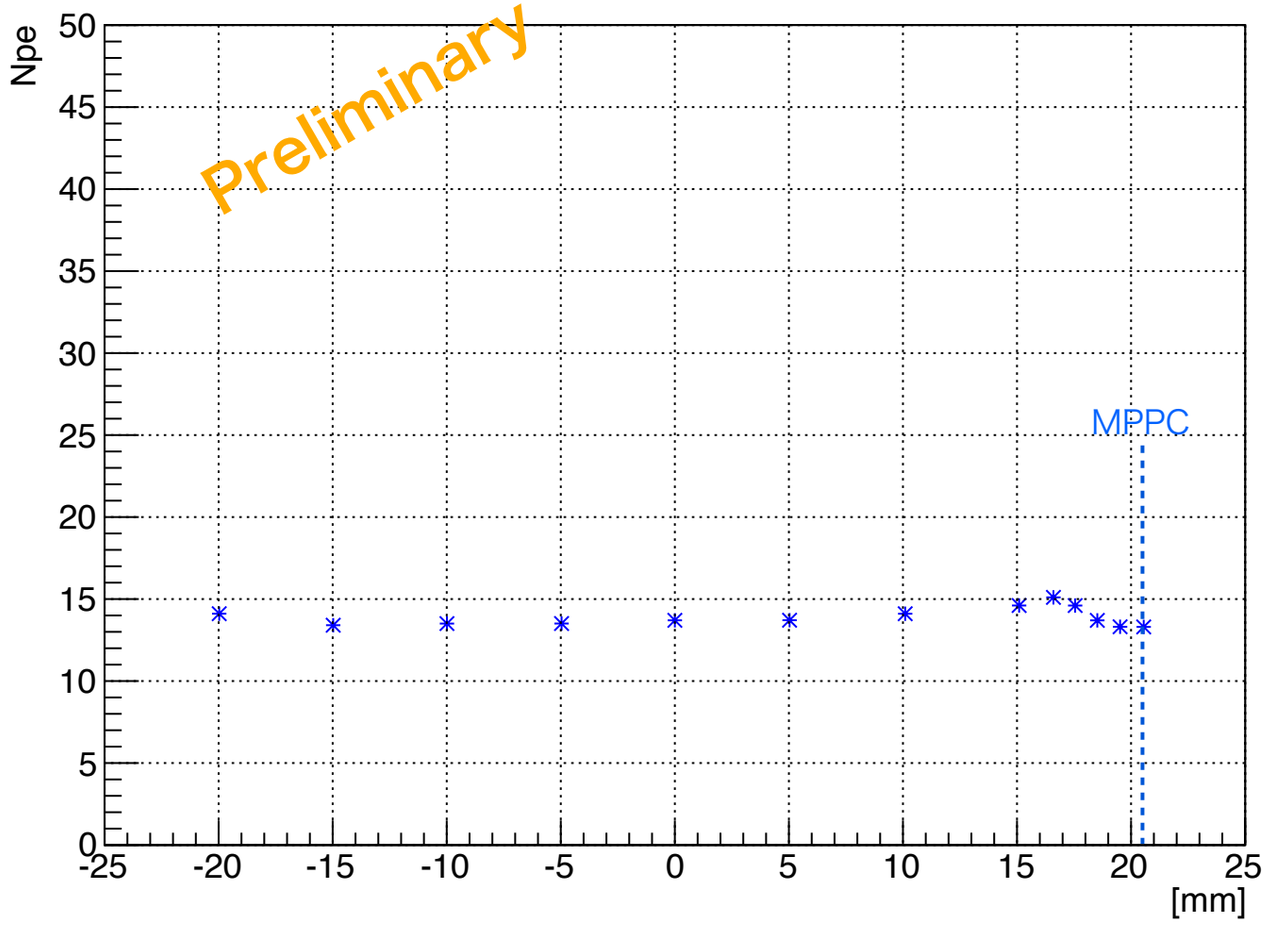


＊Uncertainty is about 10%, which is mainly coming from instability of setup.

Measurement

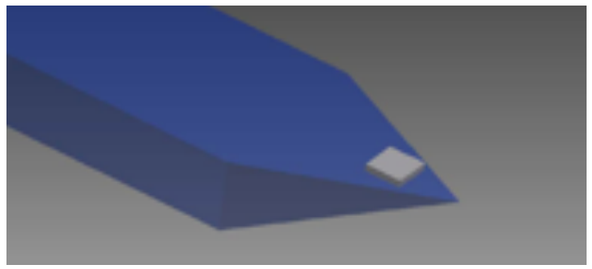
Strip with wedge

- Uniformity and Npe are improved compared to simple bottom-side readout.
- But still ~60% light collection efficiency of normal configuration.

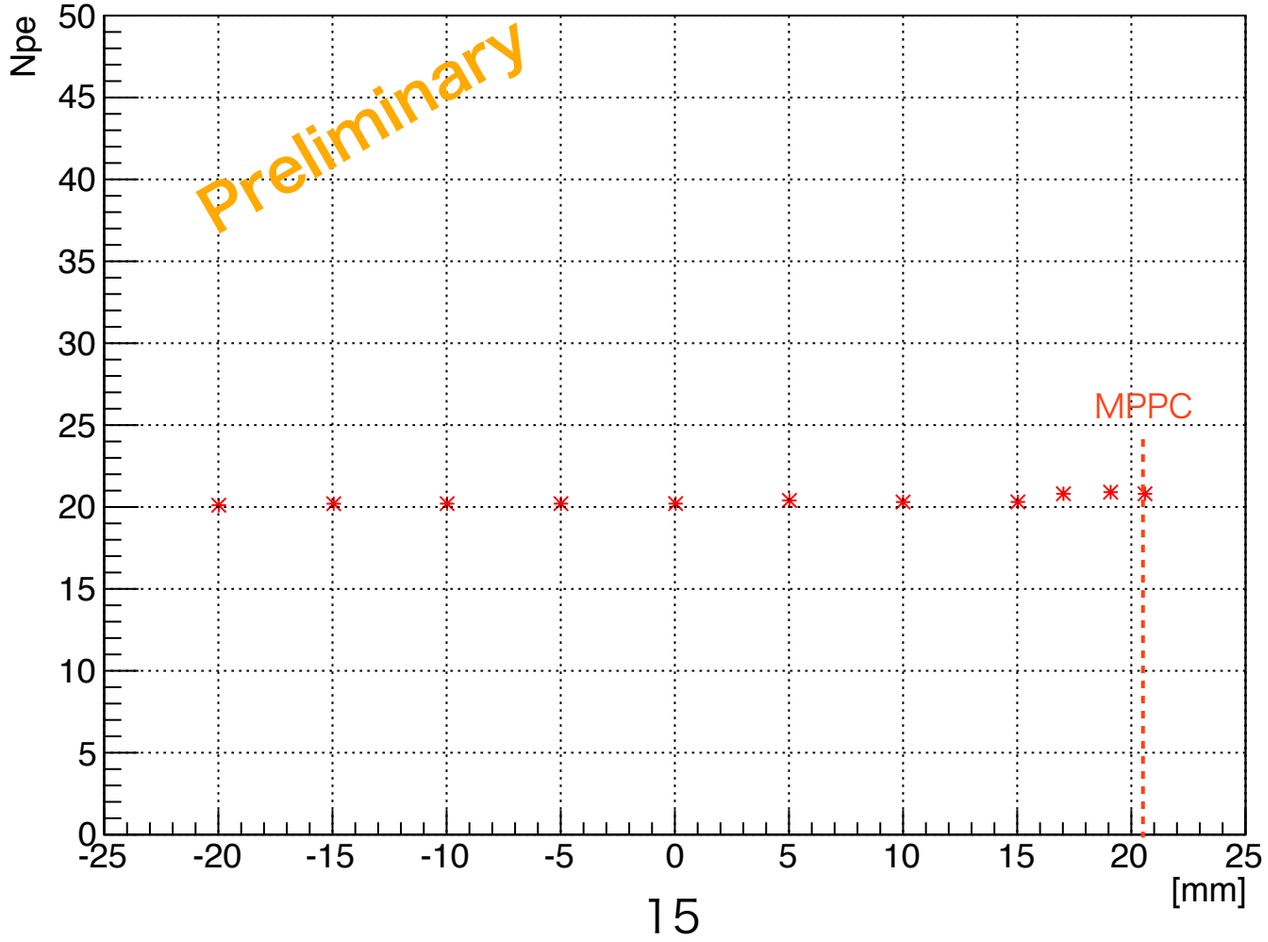


Measurement

Strip with tapered wedge

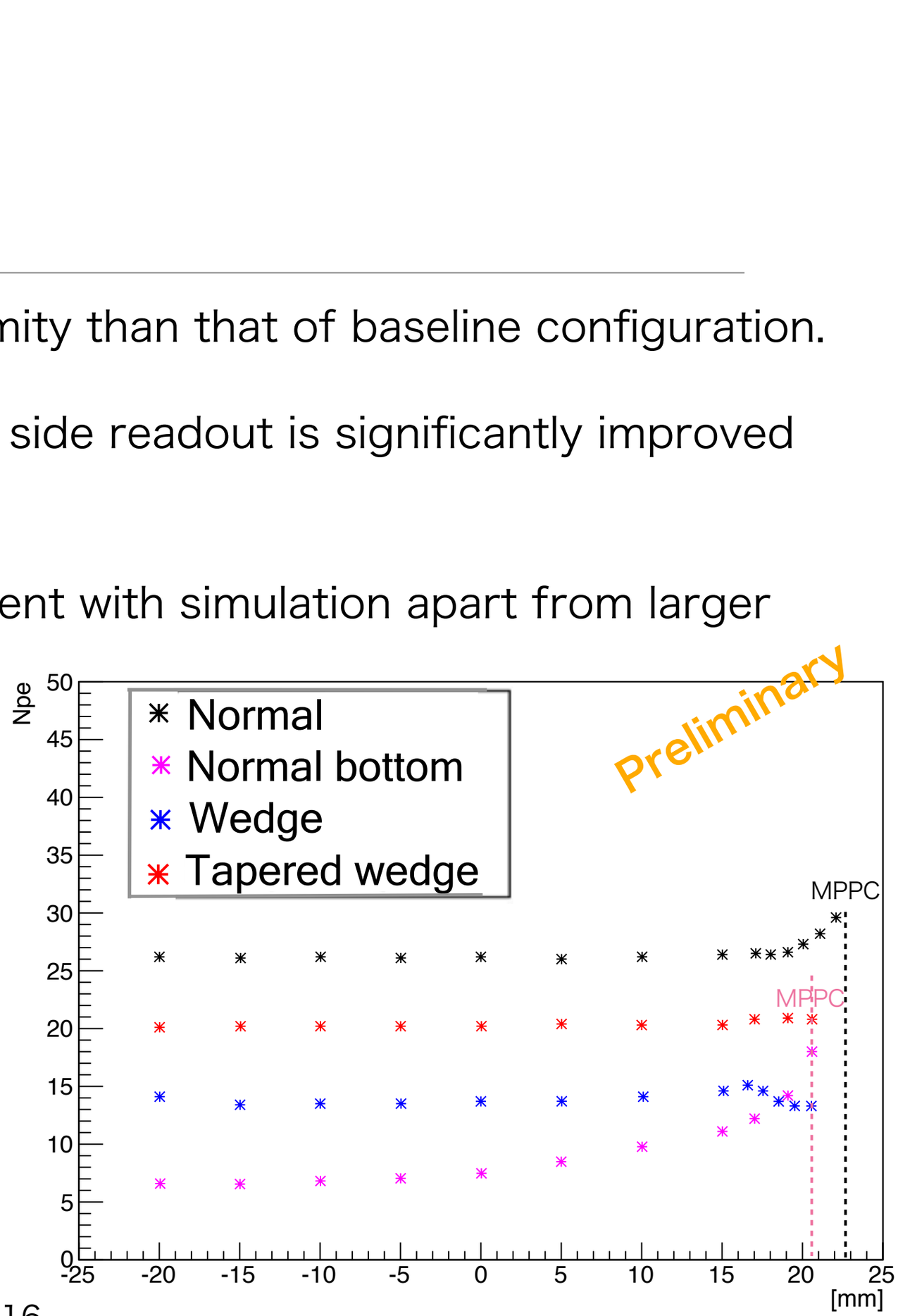


- Excellent uniformity over whole strip length.
- Peaky response near MPPC is significantly improved.
- Npe is further improved. → 70~80% of that of normal configuration



Measurement

- New design shows better uniformity than that of baseline configuration.
- Degradation of Npe with bottom side readout is significantly improved by wedge.
- Measured responses are consistent with simulation apart from larger non-uniformity in simulation.



Summary

- New design of scintillation strip for ScECAL with MPPC readout at wedge-shaped end is proposed in order to solve issues of the baseline design of the scintillator strip.
- Simulation tool of scintillation photon tracking is being developed to optimize the proposed design.
- The performance of the proposed design is measured with prototypes and compared with that of the baseline design.

→ The prototype shows promising performance

-Reasonably high light collection efficiency

→ ~60% with wedge and 70~80% with tapered wedge compared to that of baseline design.

-Excellent uniformity.

-Improved peaky response for hit near MPPC.

-The measured performance of the proposed design is almost consistent with the Monte Carlo simulation.

Summary

- Next steps

  -Further optimization of the proposed design
  →Wedge length, position of MPPC, reflector

  -Further tuning of Monte Carlo simulation

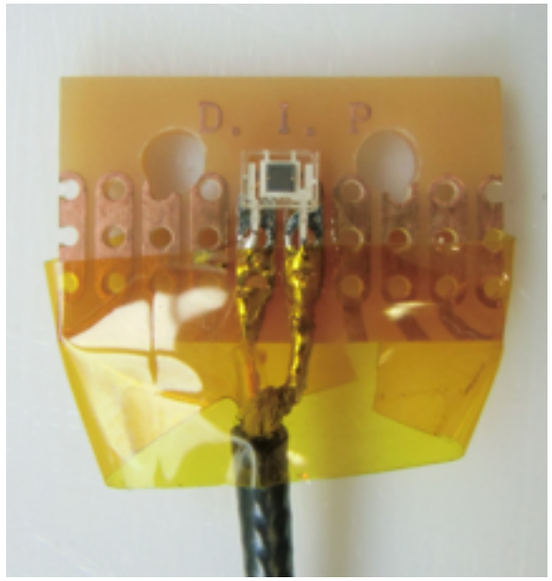
  -Studies on mass production for detector construction

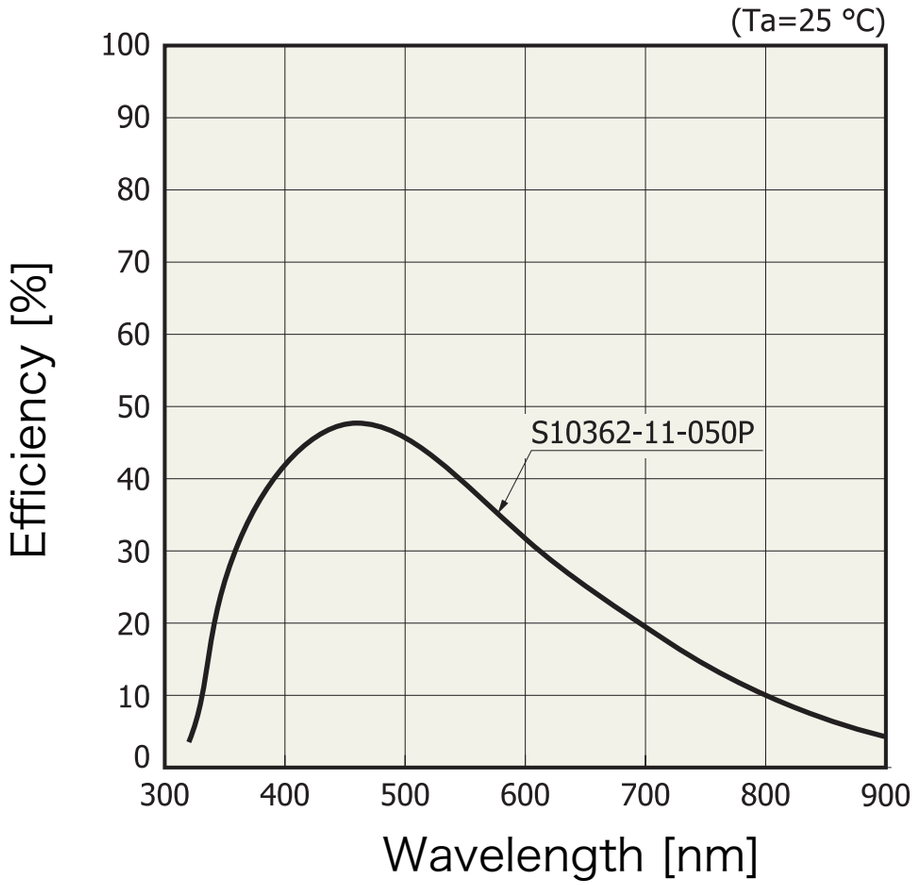
  -How to mass-produce wedge-shape strip
  → Machining or molding?
  -Reflector design
  → How to wrap with reflector in mass production. Or specular coating?
  -PCB design match to the proposed scheme

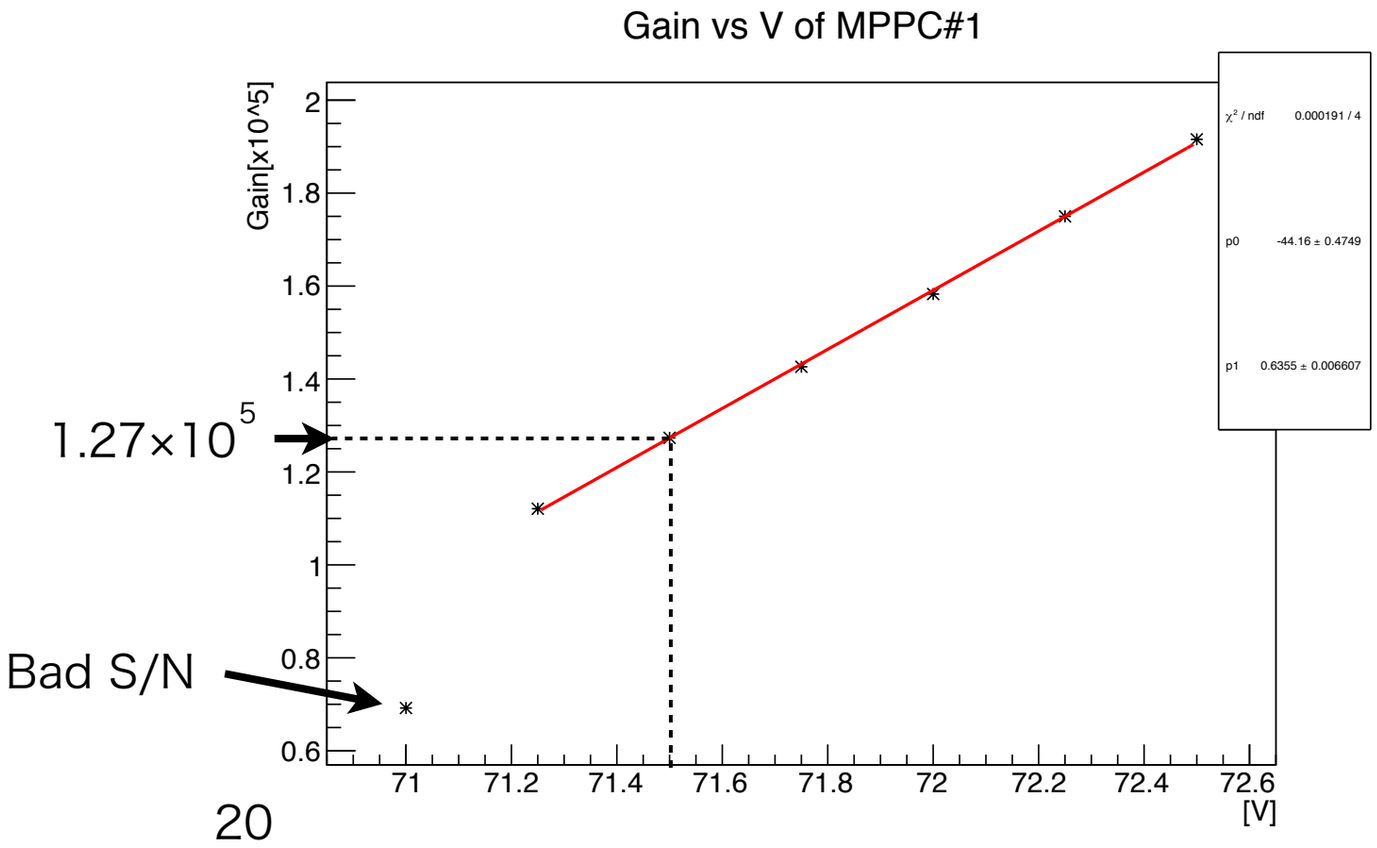
Spare slides

Property of MPPC

- MPPC : HAMAMATSU, S10943-8585(X)
- Size : 1× 1mm^2 , 1600 pixel (25μm)
- Gain : ~10^5
- Bias voltage : 71.5V (Over voltage 1.2V)





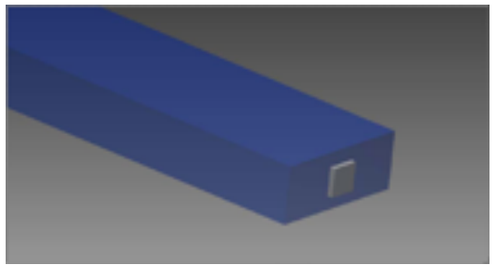


Number of photoelectron

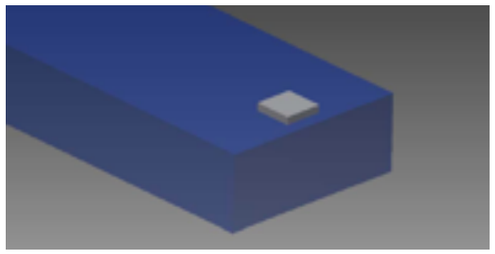
	Normal	Normal bottom
71.5V	26.3	7.7
71.75V	26	7.2
72V	25.2	8.1

＊ Npe do not depend on bias voltage in this region.

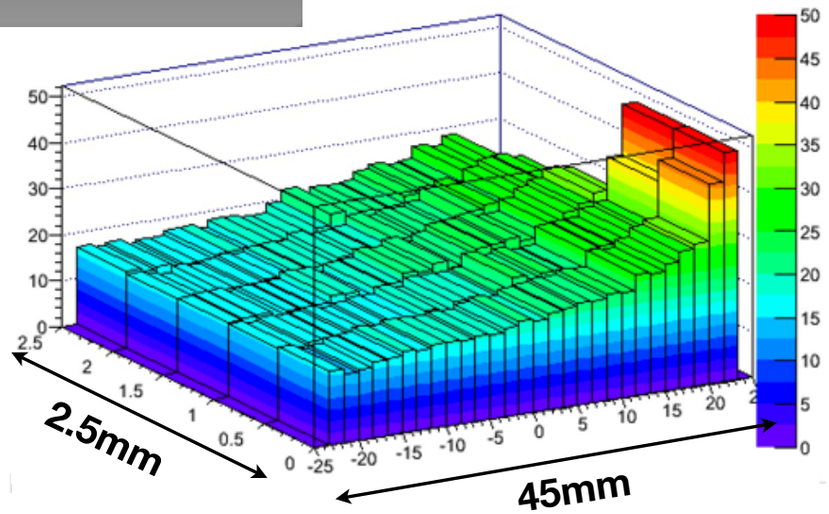
Simulation of photon propagation

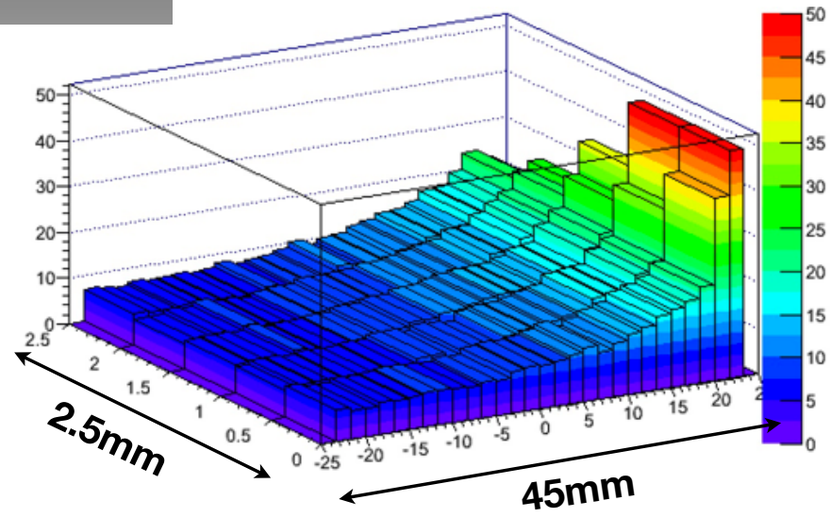


Normal

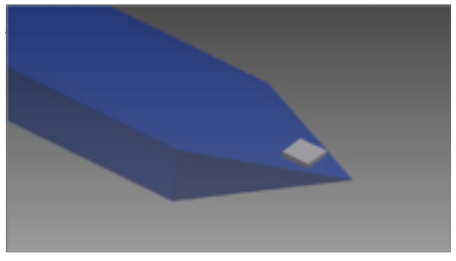


Normal bottom





Wedge



Tapered wedge