

# Development of double-sided readout method for scintillator strip for ILD Sc-ECAL

6/9/19

ICEPP, UTokyo

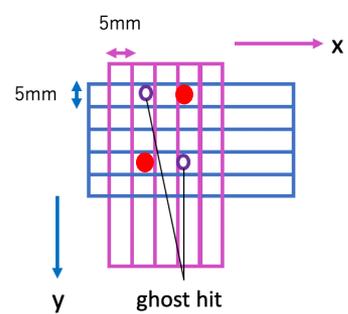
Ryunosuke Masuda

# Sc-ECAL

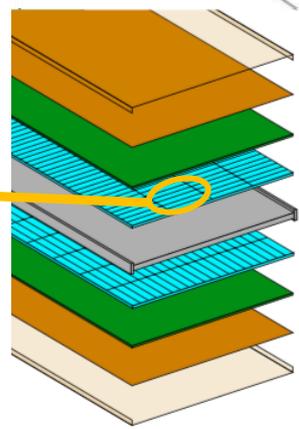
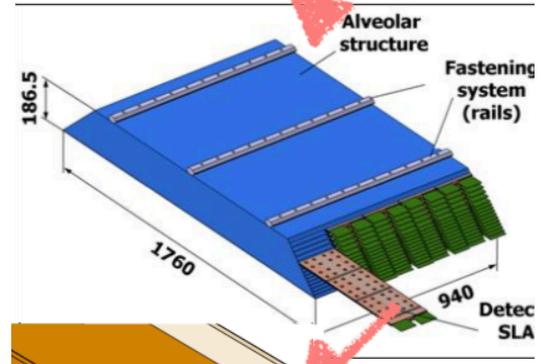
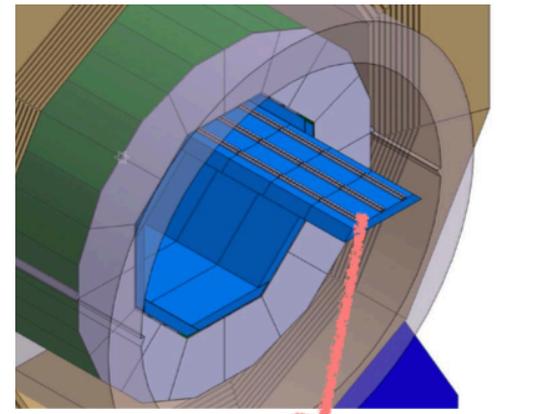
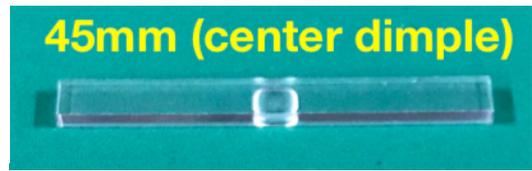
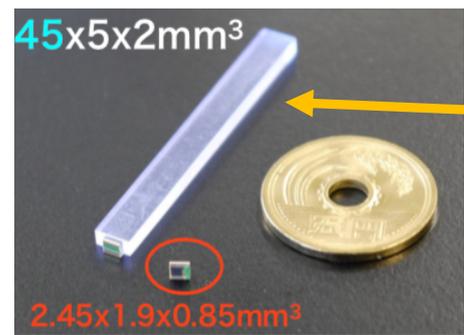
- EM calorimeter with strip-shaped plastic scintillator readout by SiPM
- Virtual  $5 \times 5 \text{ m}^2$  cell segmentation by strip x-y configuration

Ghost hit : Virtual hits from two or more simultaneous hits

- Solution
  - ➔ Interleaving square tile (a la AHCAL) to solve ambiguity



- A new design for strip was devised in collaboration with China



- ➔ Uniform response
- ➔ Produced at lower cost

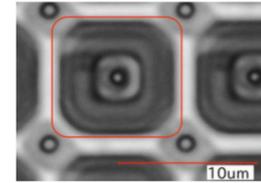
# SiPM for Sc-ECAL

- Need SiPM with small pixel ( = large  $N_{\text{pixel}}$  ) for wide dynamic range

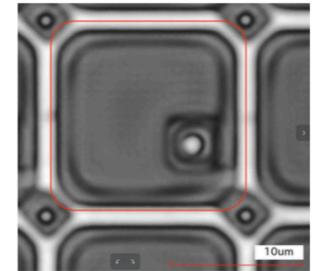
➔ MPPC with 10-15 $\mu\text{m}$  pixel developed by Hamamatsu

Model Number	S12571-010P	S12571-015P
Photosensitive area	1mm <sup>2</sup>	1mm <sup>2</sup>
Pixel size	10 $\mu\text{m}$	15 $\mu\text{m}$
Number of pixels	10000	4489
PDE	10%	25%
Gain	1.35x10 <sup>5</sup>	2.3x10 <sup>5</sup>
Geometrical fill factor	33%	53%

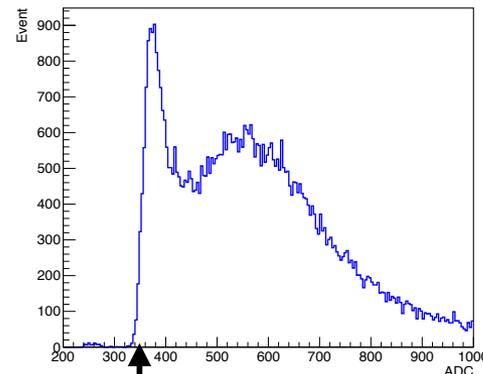
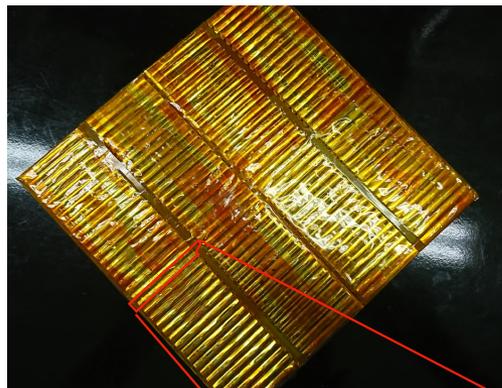
10 $\mu\text{m}$  pitch



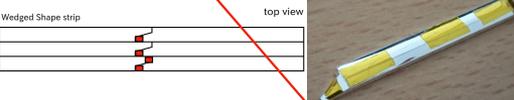
15 $\mu\text{m}$  pitch



- ➔ 15 $\mu\text{m}$  with higher gain and PDE would be a better choice from S/N viewpoint
- ➔ S/N may not be enough even with 15 $\mu\text{m}$



Test beam experiment with 15 $\mu\text{m}$  pixel MPPC by Shinshu Univ.

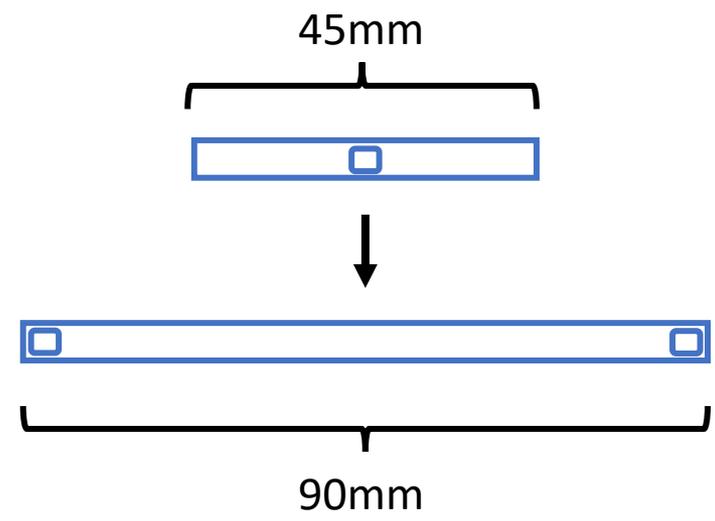


# Double-Sided readout method

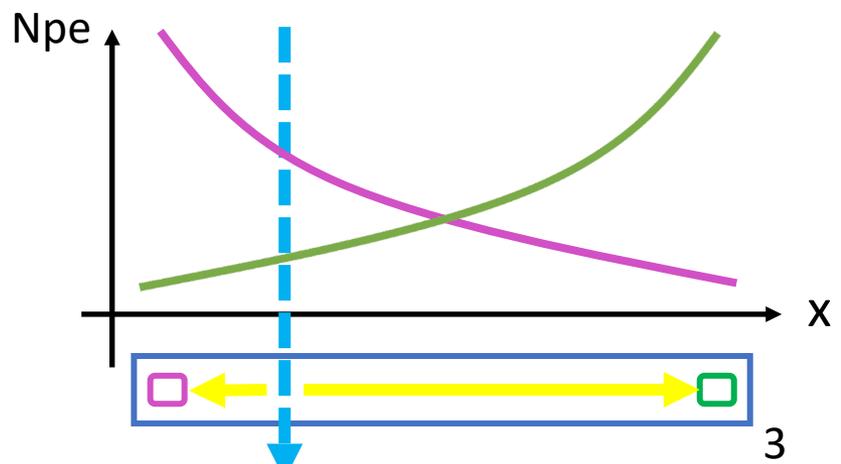
- Readout by two SiPMs at strip ends
- Twice longer strip (L=90mm) to keep the number of SiPMs
- Possible advantages

- **Eliminating noise by coincidence**

- Higher light yield by summing two SiPM readouts
- Even lower light yield for each SiPM (→ less saturation)
- Still operational even if one of SiPMs is dead



- Position reconstruction by charge or timing difference between two readouts  
→ Challenging

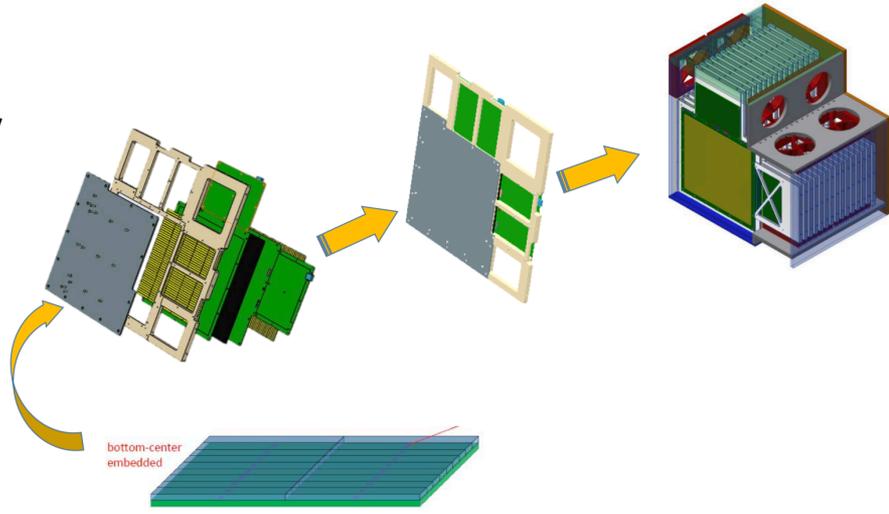


# Double SiPM readout for Sc-ECAL prototype

- Large technological prototype for Sc-ECAL to be constructed as a joint effort with Chinese groups working on CEPC

- ➔ Full 30 layers
- ➔ To be constructed and tested in beam by end of next year

- Proposing to add a few detection layers with two SiPM readout channels to Sc-ECAL prototype



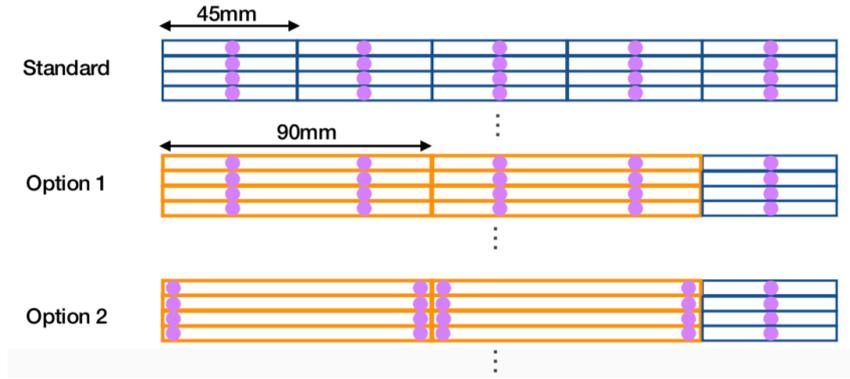
- Two types of implementation

## Option 1

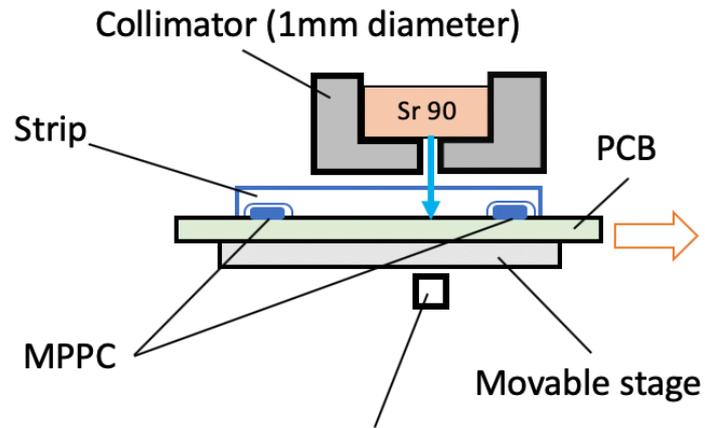
- Two SiPMs in the middle of the strip
- SiPM positions compatible with standard EBU

## Option 2

- Two SiPMs at the strip ends
- Need to modify SiPM positions on EBU



# Setup



Plastic scintillator : EJ-212

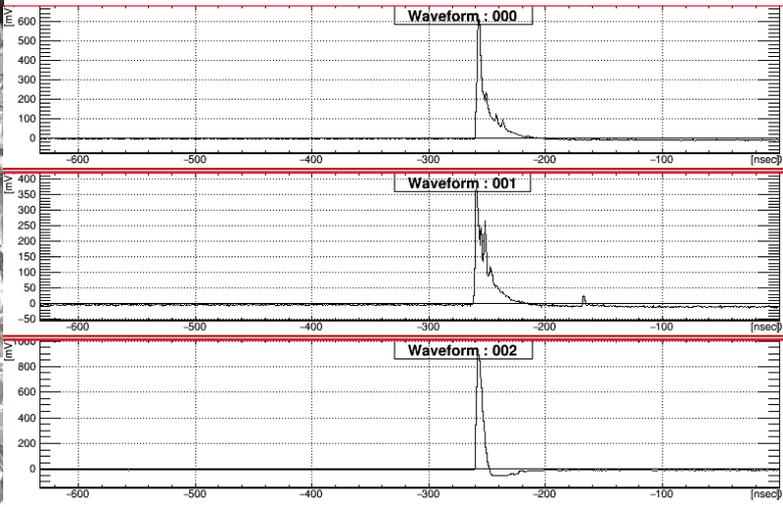
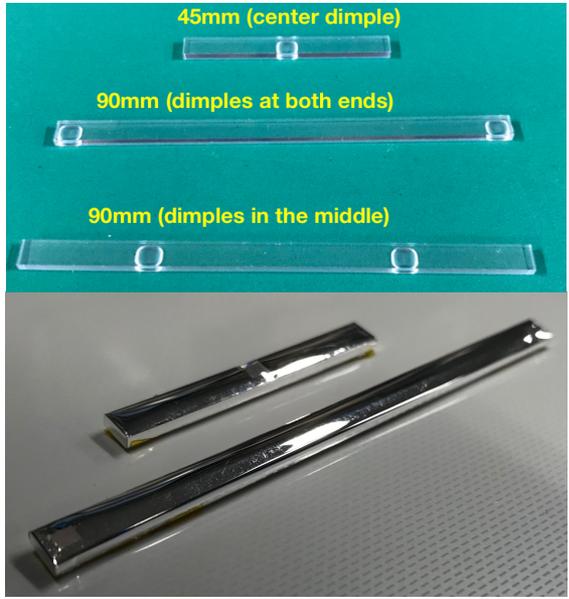
Reflector : ESR2 (laser-cut)

MPPC : S12571-015P  
(1 mm<sup>2</sup> 15μm-pixel)

V<sub>op</sub> : ~ 68V

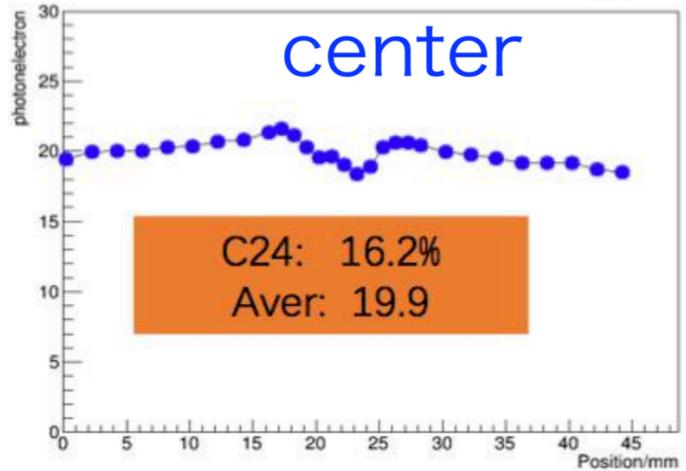
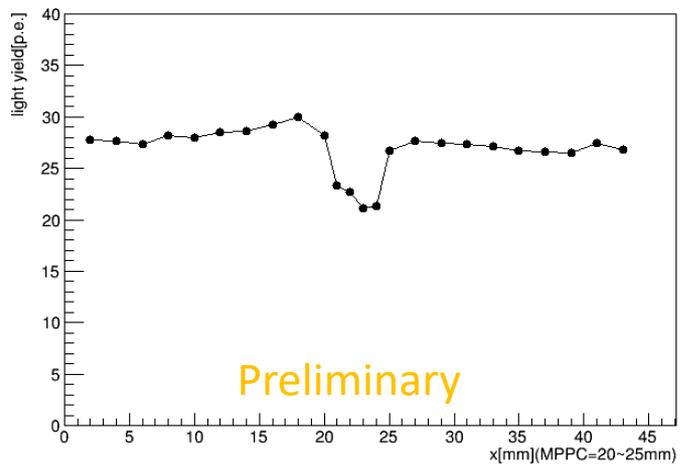
Analyzer : Waveform digitizer

Trigger counter (5 × 5 × 5 mm<sup>3</sup> plastic scinti.+SiPM)

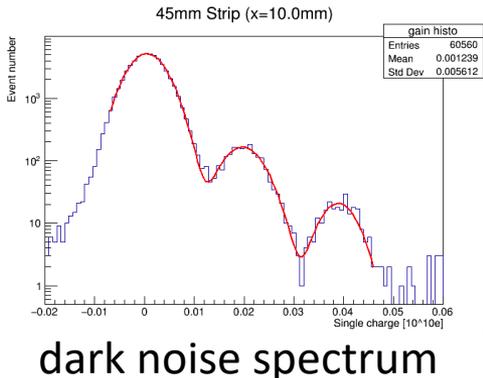
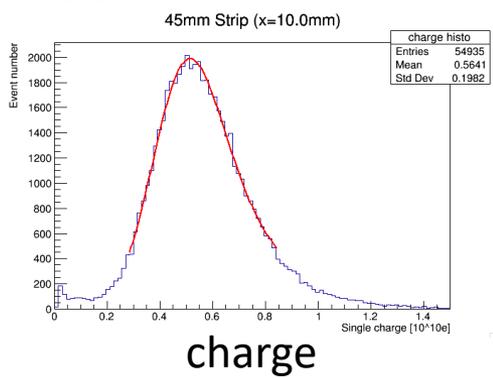


- Measurement
  - Position dependence of Npe for 2 types of 90mm strip
  - 45mm strip with center dimple was also tested for comparison

# Results : 45mm strip with single readout



Measured by Chinese group  
MPPC with 10 $\mu$ m pixel was used



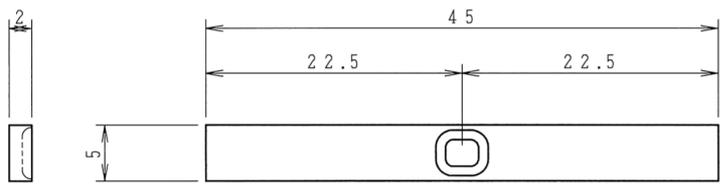
Light yield = (charge peak)/(single p.e. charge)

N<sub>pe</sub> ~ 27 (average)

- Larger than observed by Chinese group
- ➔ Higher PDE for 15 $\mu$ m than 10 $\mu$ m MPPC used for Chinese setup
- ➔ Lower over-voltage (~5V) compared to 7V for Chinese setup

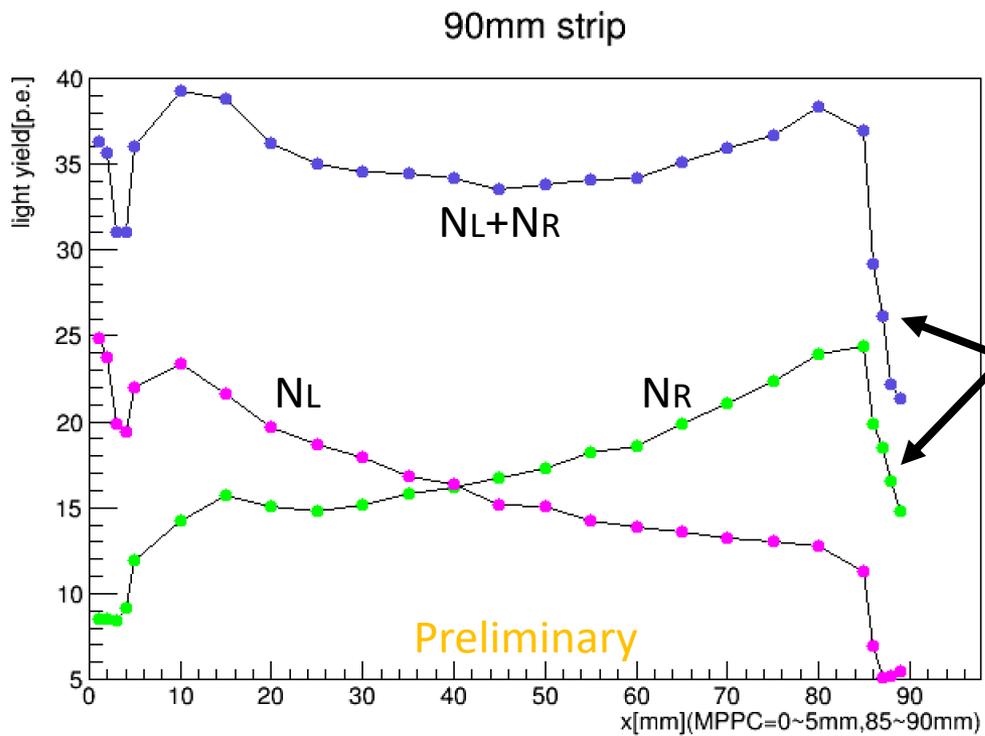
Larger reduction of light yield around dimple

- Difference in shape of dimple?
- Further optimization of dimple shape by means of simulation is planned



# Results : 90mm strip with double readout at strip end

More or less flat response with sum of two readouts



$N_{pe} \sim 35$  (average)

- Larger than 45mm strip
- Even lower for each MPPC (less saturation)

Strange behavior at right end

- Misalignment?
- Under investigation

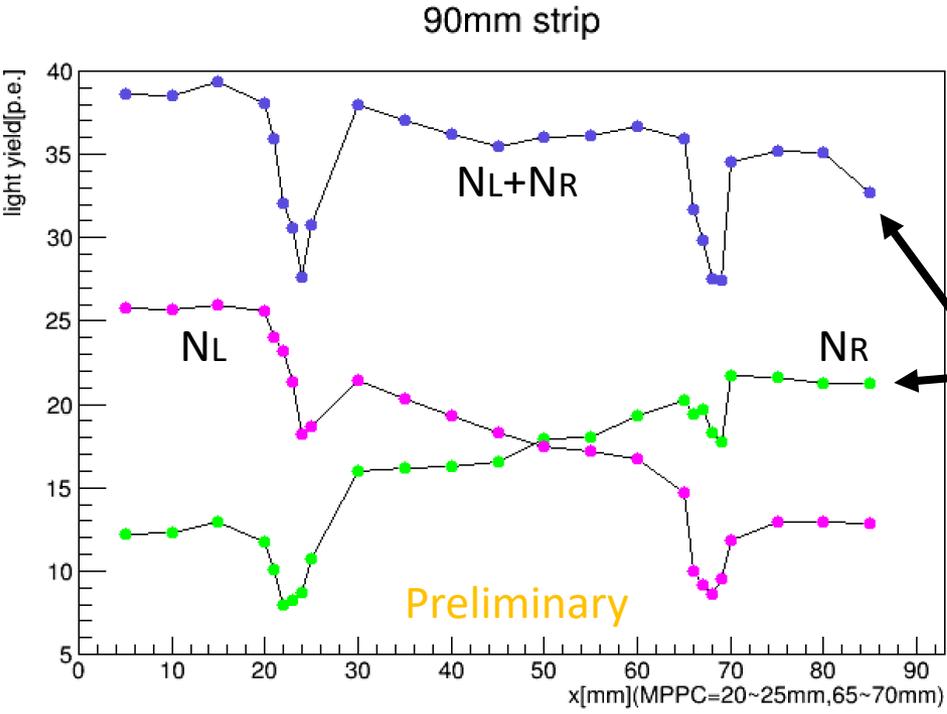
Position-dependent  $N_{pe}$  for each MPPC readout

- Possibility of position reconstruction using charge or timing
- Under study



# Results : 90mm strip with double readout in middle of strip

More or less flat response with sum of two readouts



$N_{pe} \sim 35$  (average)

- Larger than 45mm strip
- Even lower for each MPPC (less saturation)

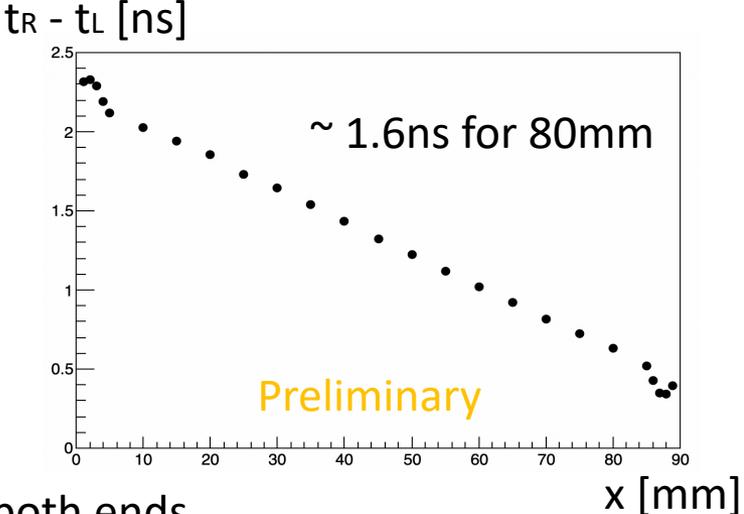
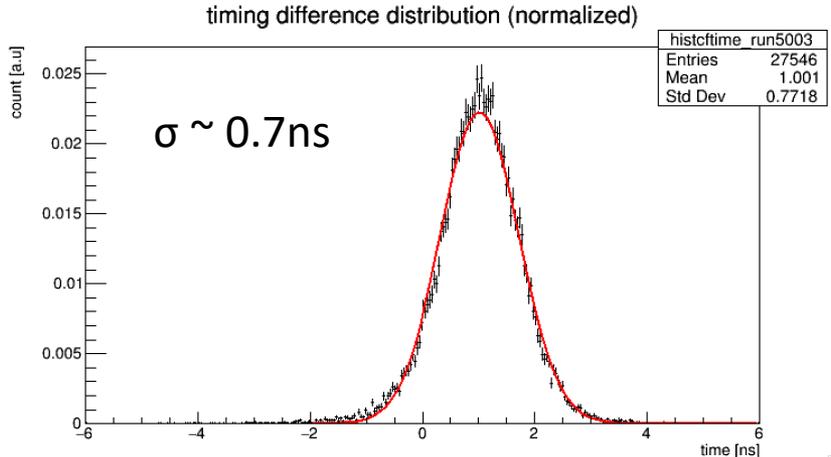
Slightly strange behavior at right end

No position dependence outside dimples

- No chance of position reconstruction outside dimples at least by charge difference



# Results : position reconstruction



dimples at both ends

- Possibility of position reconstruction by Time difference
  - ➔  $\sigma \sim 35\text{mm}$  measured with preliminary setup ( for  $x = 5 \sim 85$  mm )
- Not good enough.
  - ➔ Might be improved with further optimization of timing analysis
- This lab. study was performed with waveform digitizer, but it's not possible in the detector.
  - ➔ Need to improve timing performance of readout electronics

# Summary

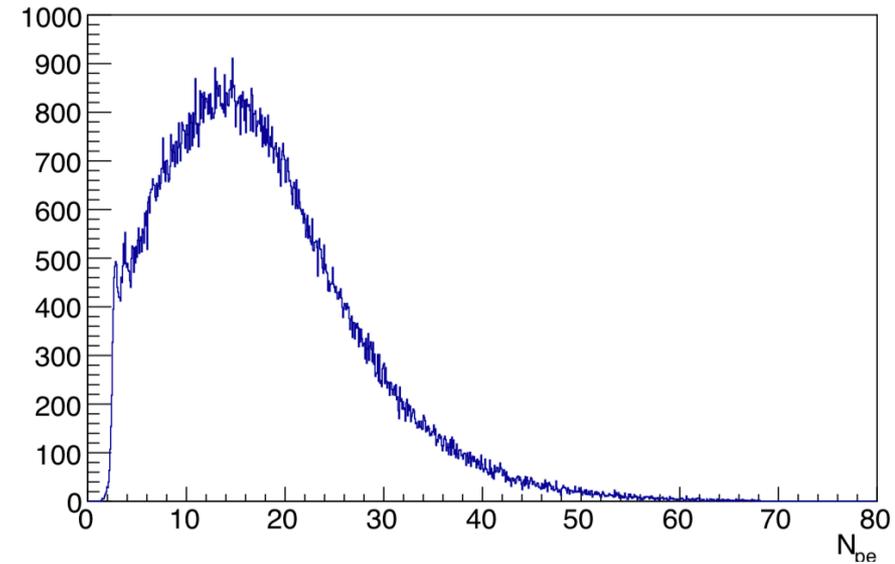
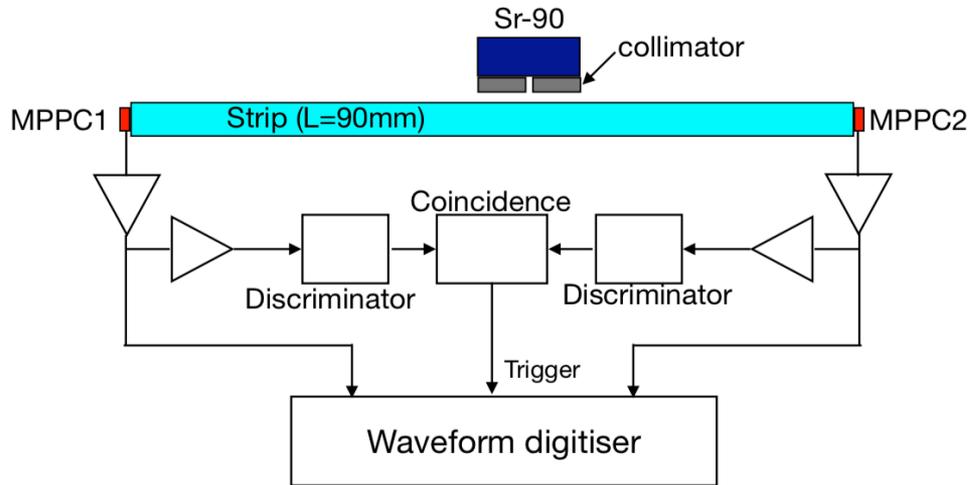
- Two configurations for double SiPM readout with dimples have been tested
- They both work more or less as expected although some issues should still be understood
- Probably need further optimization of dimple shape
  - ➔ Try exactly same shape as Chinese design
  - ➔ Optimization by simulation

# Outlook

- Based on Lab. test results, determine the design of double readout strip mounted on Sc-ECAL prototype
- Possibility of position reconstruction using charge (or timing) difference is under study

# Backup slides

- Noise suppression by taking coincidence on previous study



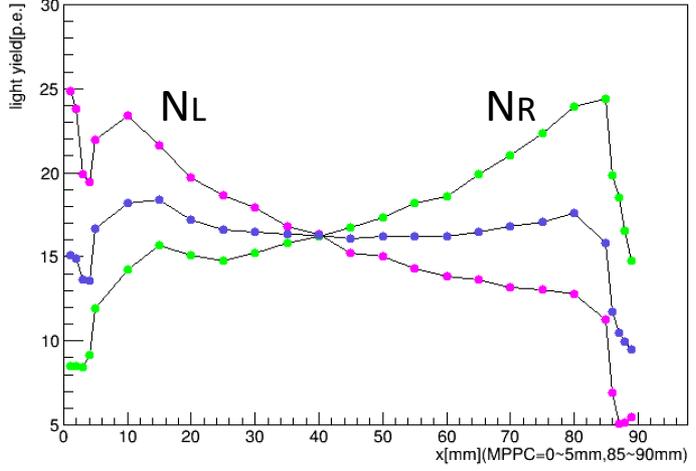
- Very low threshold ( $\sim 0.5$  p.e.)

➔ Dark count rate  $\sim 150$ kcps for each MPPC  $\gg$  Sr-90 hit rate ( $< 10$ kHz)

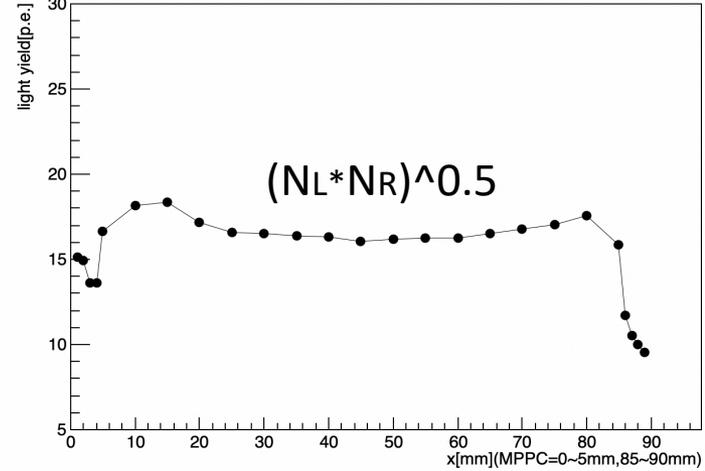
# Backup slides

- Geometric average of 90mm results

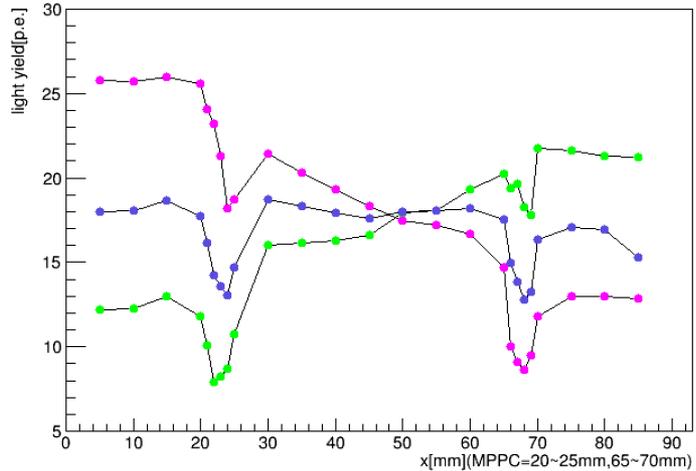
90mm strip



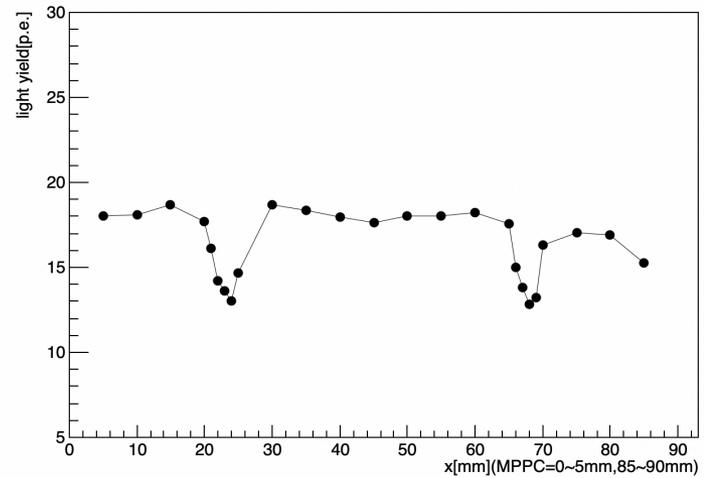
90mm strip



90mm strip



90mm strip



# Backup slides

- Position dependence of timing difference for 90mm strip with double readout in middle of strip

