

Study on scintillator strip with double SiPM readout

Ryunosuke Masuda, The University of Tokyo
Linghui Liu, Naoki Tsuji, Wataru Ootani
CALISE Collaboration Meeting at CERN, 1/Oct./2019

Sc-ECAL (reminder)

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

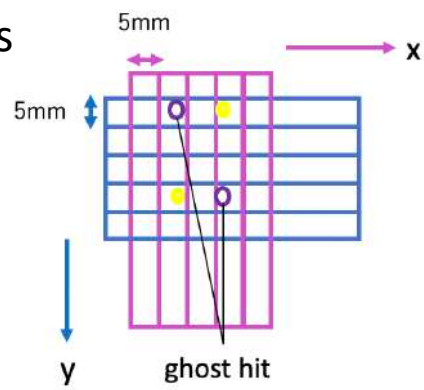
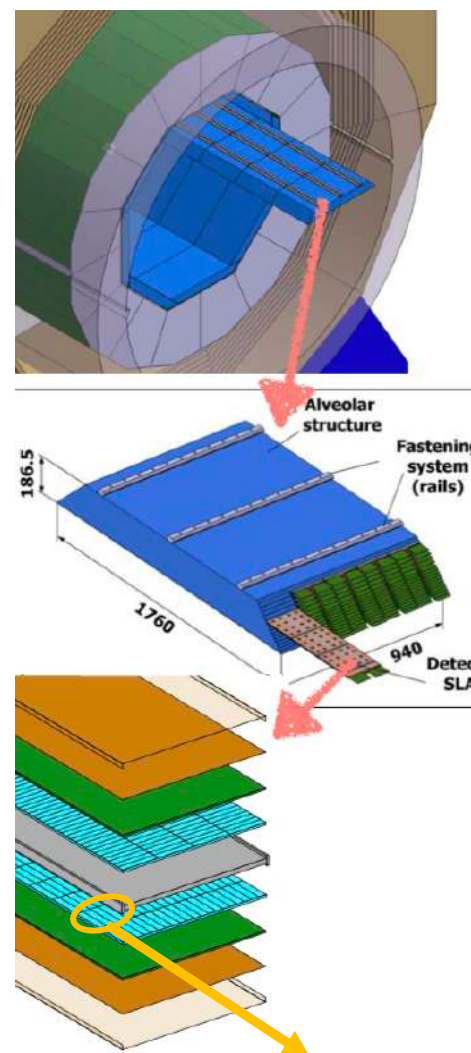
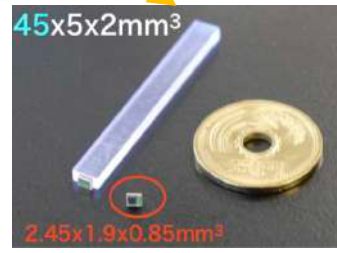
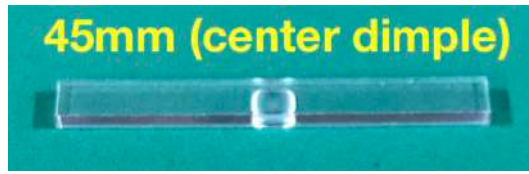
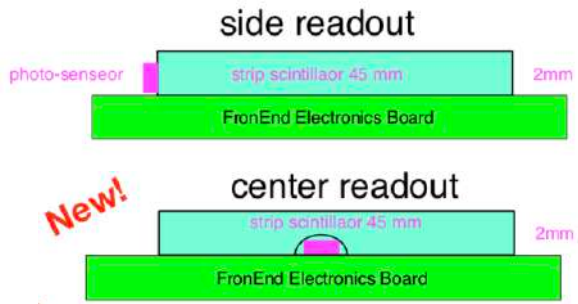
Ghost hit : From two or more simultaneous hits

- Solution

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

- A strip with SiPM in a dimple (a la AHCAL) has been proposed by Chinese group

➔ Suitable for large scale production



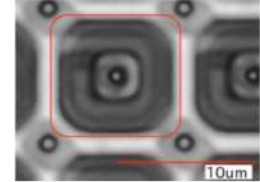
Sc-ECAL (reminder)

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

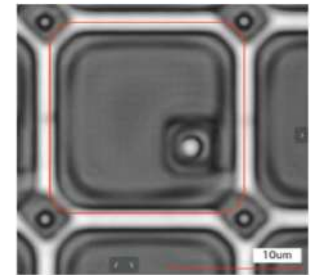
➔ MPPC with 10-15 μm pixel developed by Hamamatsu

Model Number	S12571-010P	S12571-015P
Photosensitive area	1mm ²	1mm ²
Pixel size	10 μm	15 μm
Number of pixels	10000	4489
PDE	10%	25%
Gain	1.35x10 ⁵	2.3x10 ⁵
Geometrical fill factor	33%	53%

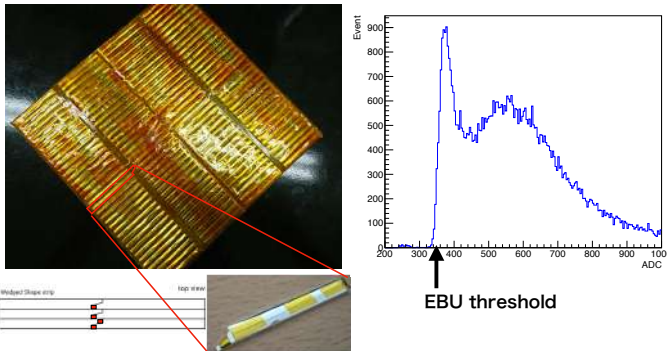
10 μm pitch



15 μm pitch



- ➔ 15 μm with higher gain and PDE would be a better choice from S/N viewpoint
- ➔ However, S/N may not be enough even with 15 μm



Test beam experiment with 15 μm pixel MPPC by Shinshu Univ.

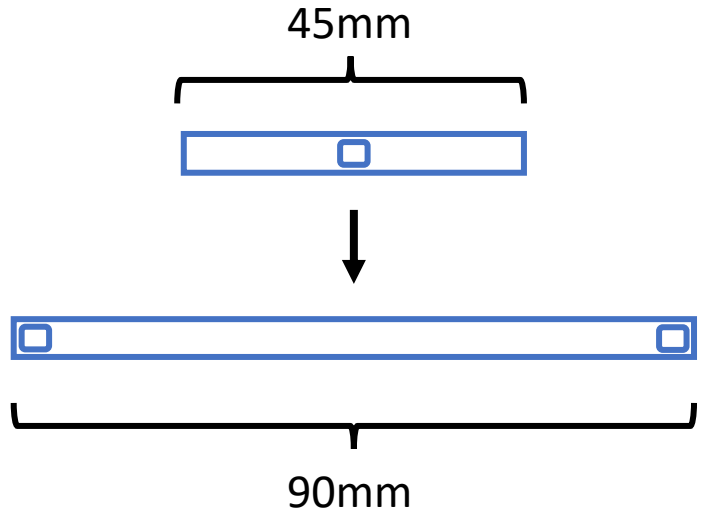
We are developing a new SiPM readout method to improve performance of scintillator strip

Double SiPM readout

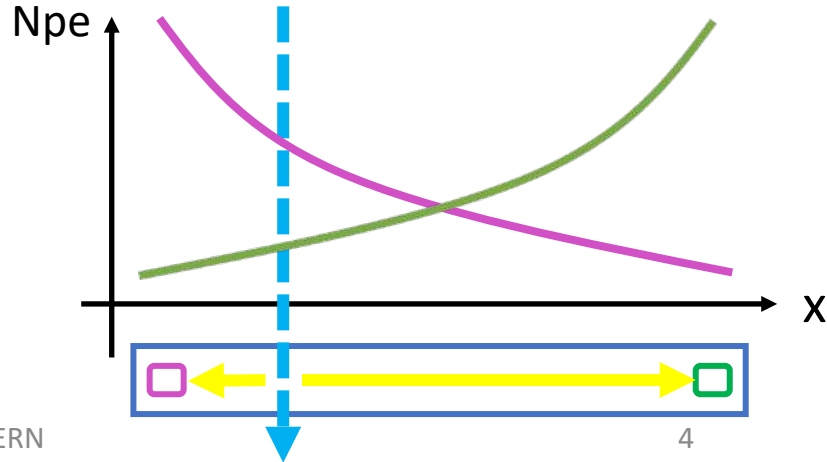
- Readout by two SiPMs at strip ends
- Twice longer strip (L=90mm) to keep the number of SiPMs
- Possible advantages

- **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



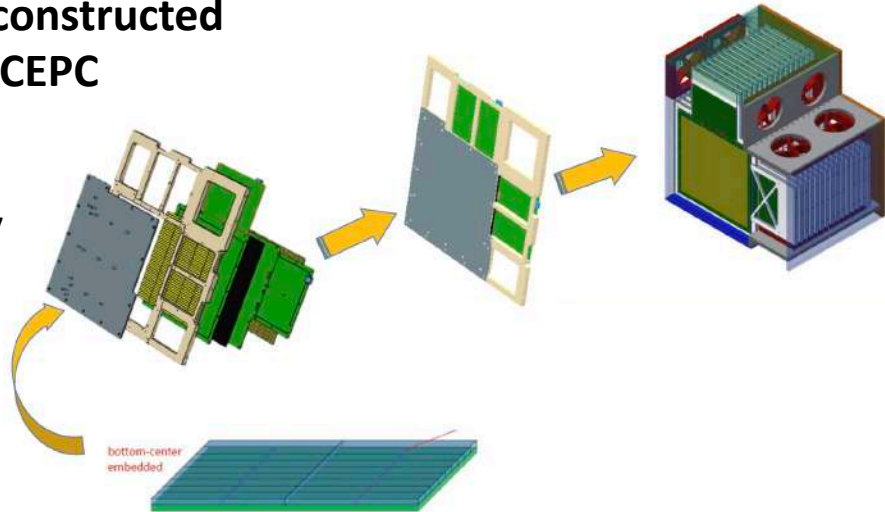
Double SiPM readout for Sc-ECAL prototype

- **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 double SiPM readout to Sc-ECAL prototype**

- Two possibilities of implementation

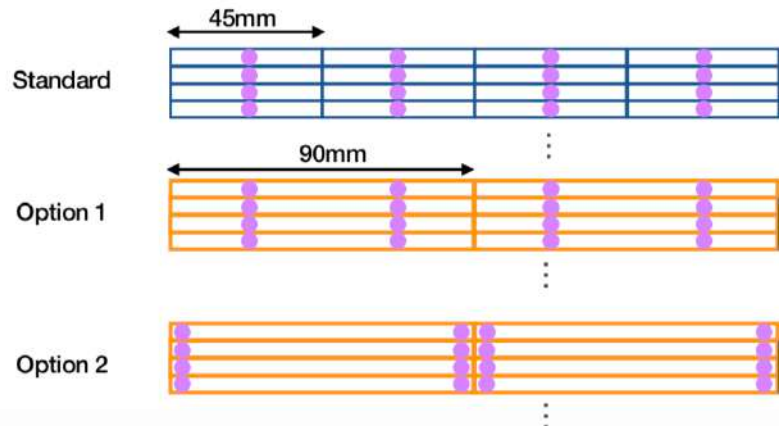


Option 1

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

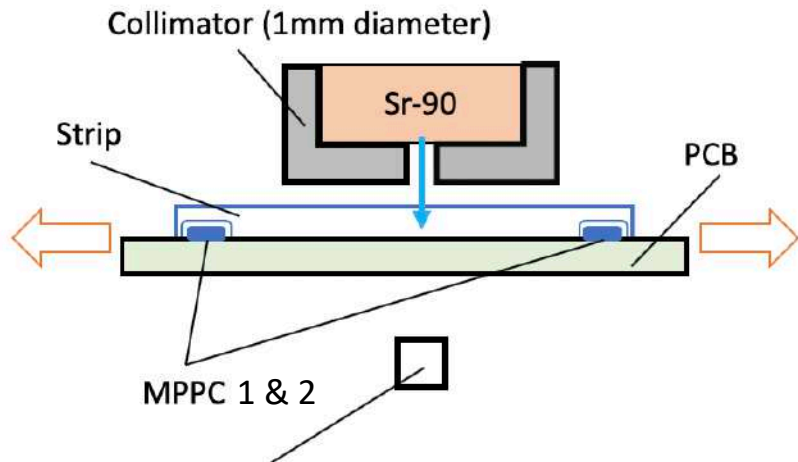
Option 2

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



- **Prototype tests for double readout for two options were performed**

Setup



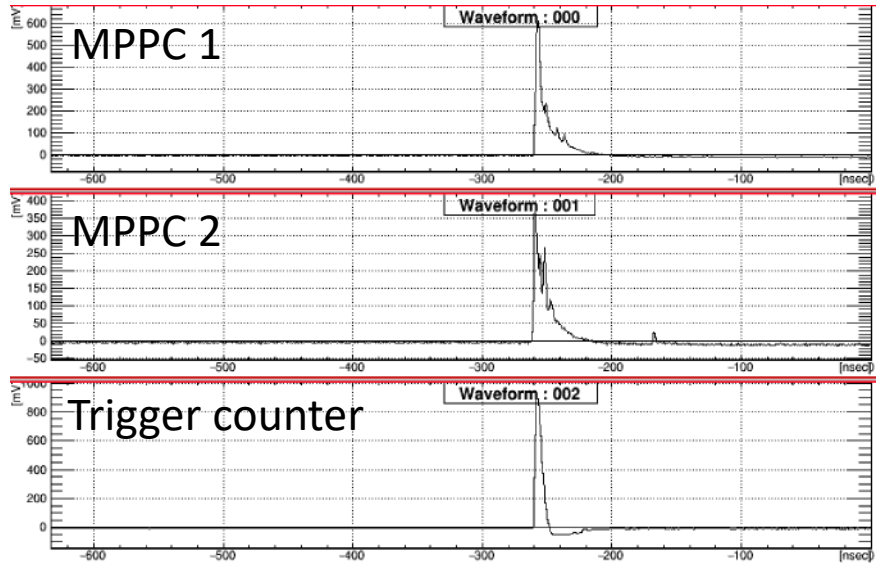
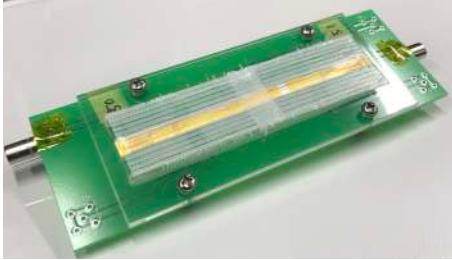
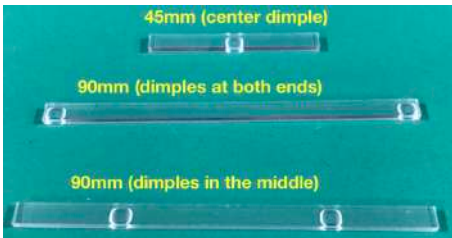
Plastic scintillator : EJ-212

Reflector : ESR2 (laser-cut)

MPPC : S12571-015P
(1 x 1 mm² 15μm-pixel)

V_{op} : ~ 68V

Trigger counter (5 × 5 × 5 m³ plastic scinti.+SiPM)

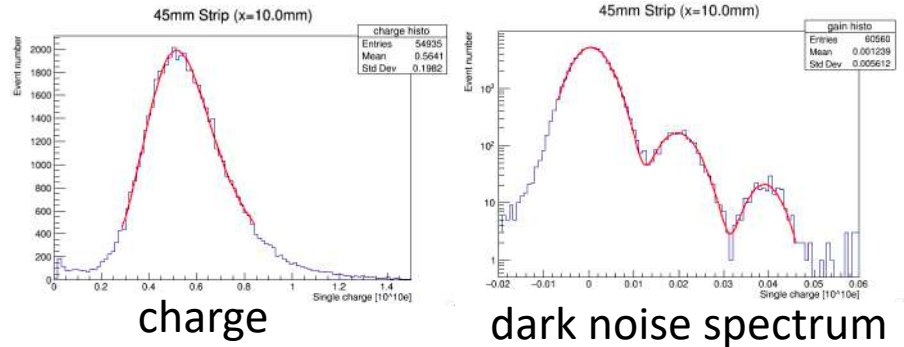
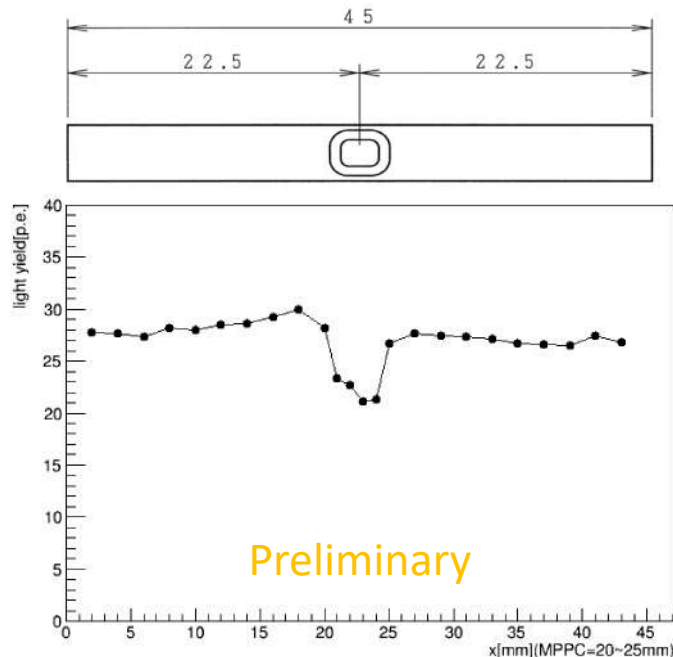


100 ns

• Measurement

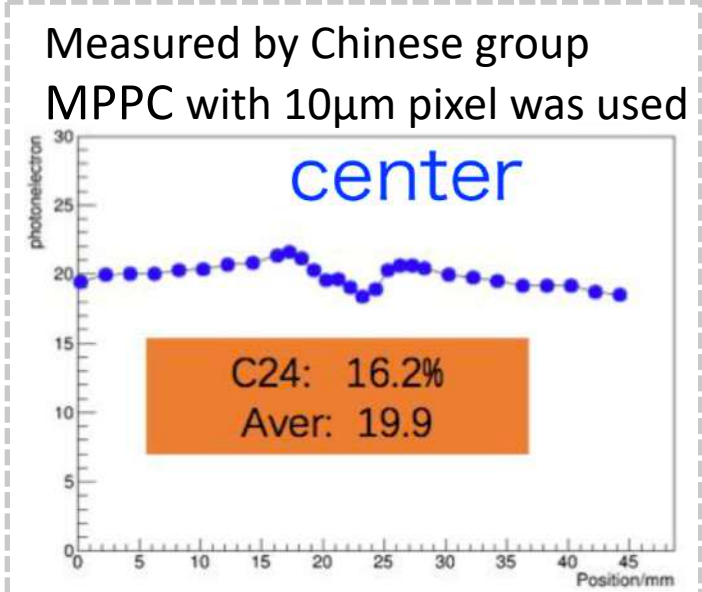
- Position dependence of Npe for 2 types of 90mm strip
- 45mm strip with center dimple was also tested for comparison

Results : 45mm strip with single readout



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

- Npe ~ 27 (average)
- Larger than observed by Chinese group
 - ➔ Higher PDE for 15μm than 10μm 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 is planned



1st Oct 2019

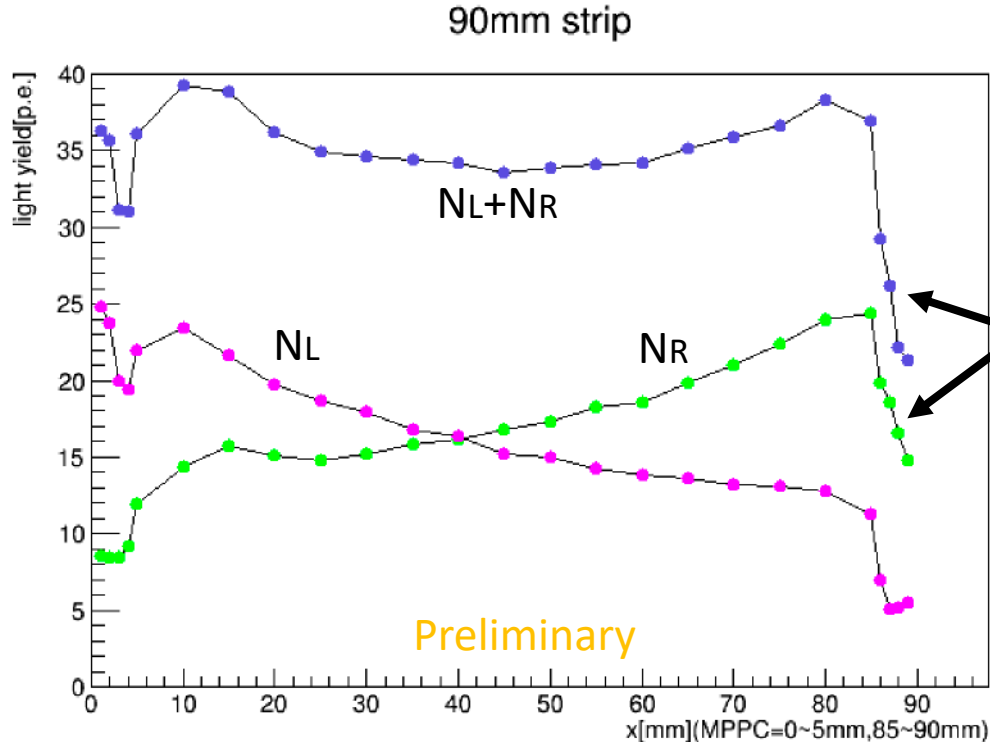
Results : 90mm strip with double readout at strip end



More or less flat response with sum of two readouts

N_{pe} ~ 35 (average)

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



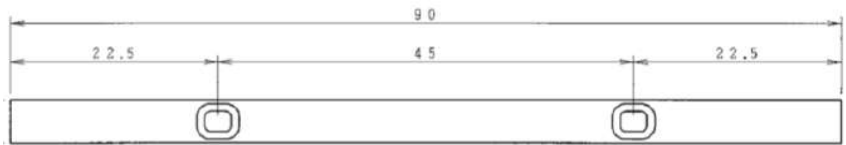
Strange behavior at right end

- Misalignment?
- Under investigation

Position-dependent N_{pe} for each MPPC readout

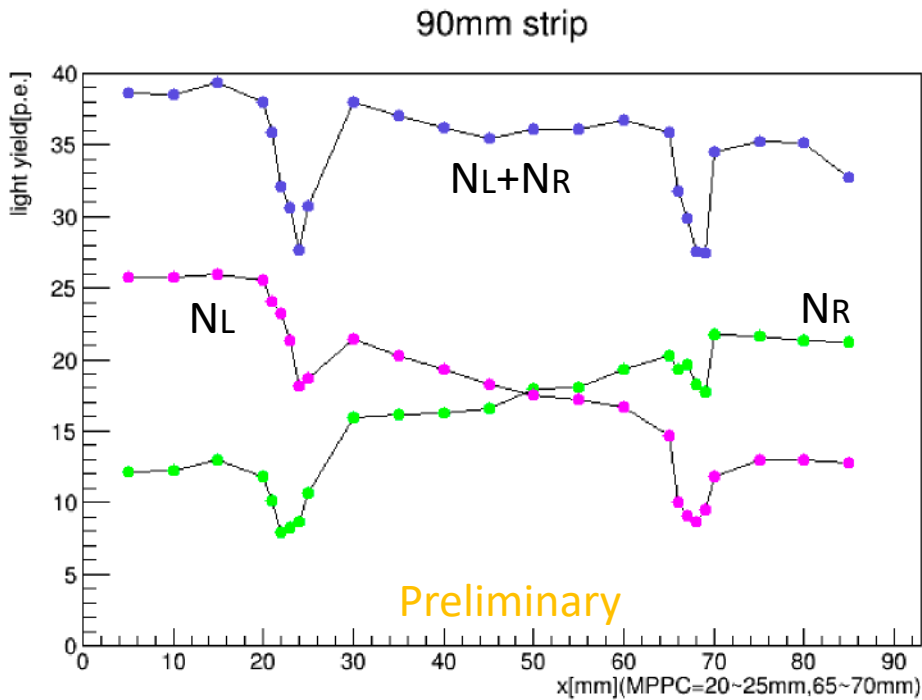
- Possibility of position reconstruction using charge or timing
- Under study

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

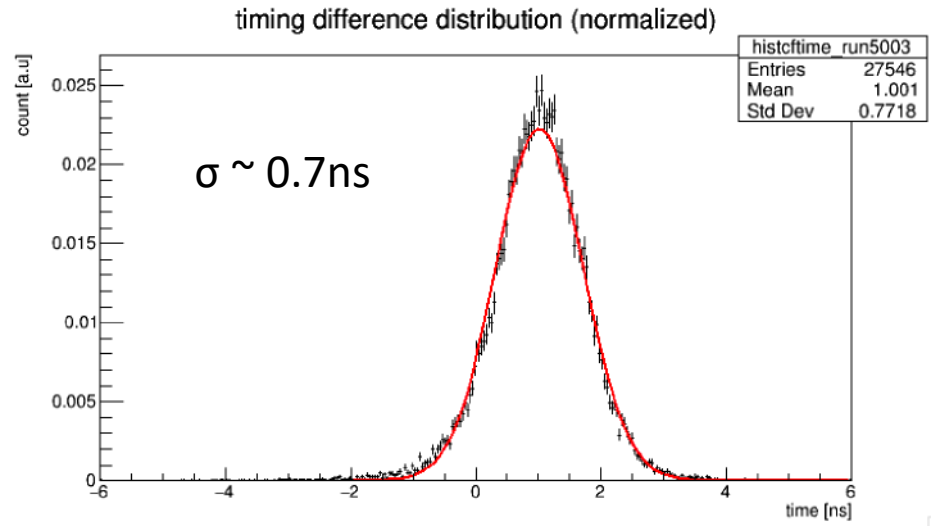
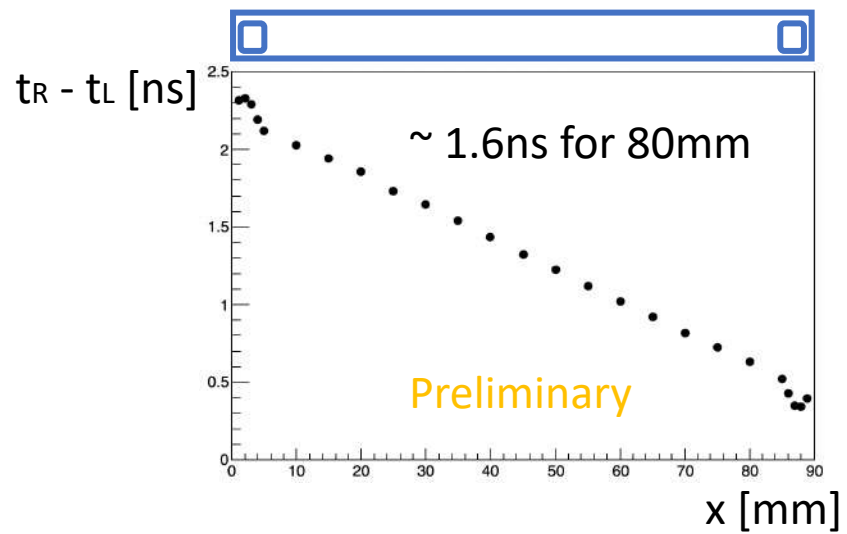
Response curve is slightly slanted

➔ Misalignment?

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
 - ➔ $\sigma \sim 35\text{mm}$ obtained with preliminary setup (for $x = 5 \sim 85 \text{ mm}$)
- 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
- Position reconstruction with charge ratio under study
 - ➔ Further improve position resolution by using both timing and charge ratio?

Summary

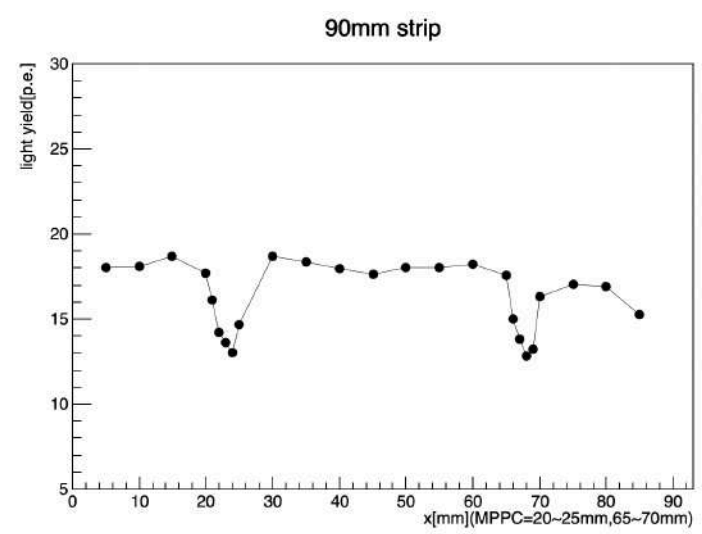
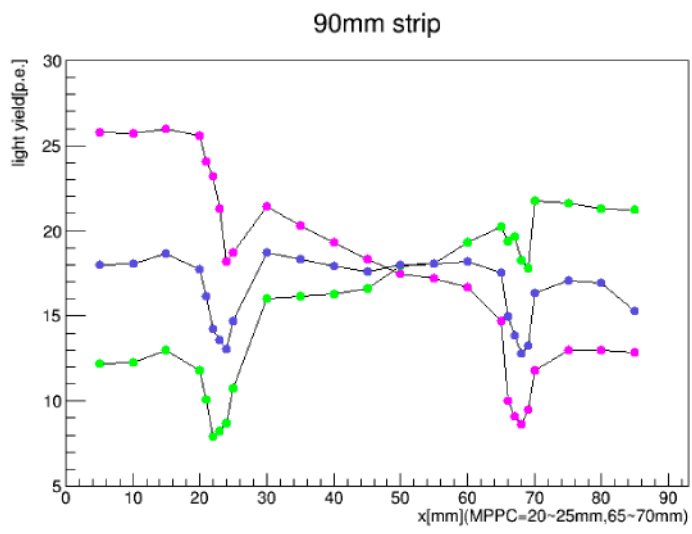
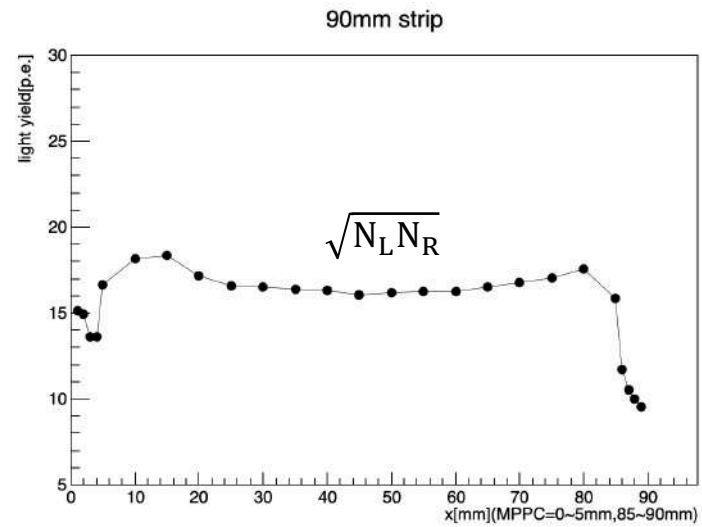
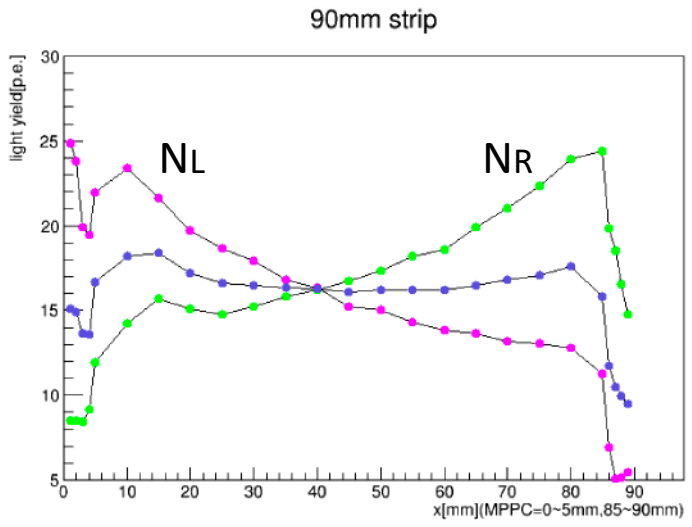
- New readout method with double SiPMs has been proposed to improve performance of scintillator strip for Sc-ECAL
- Two configurations for double SiPM readout with dimples have been tested
- They both work more or less as expected although some issues should still be understood
- Need further optimization of dimple shape

Outlook

- Based on lab. test results, determine the design of double readout strip mounted on Sc-ECAL prototype
 - ➔ Detection layers with double readout will be constructed by end of this year
- Possibility of position reconstruction using charge (or timing) difference is under study

Backup

- Geometric average of 90mm results



Backup

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

