

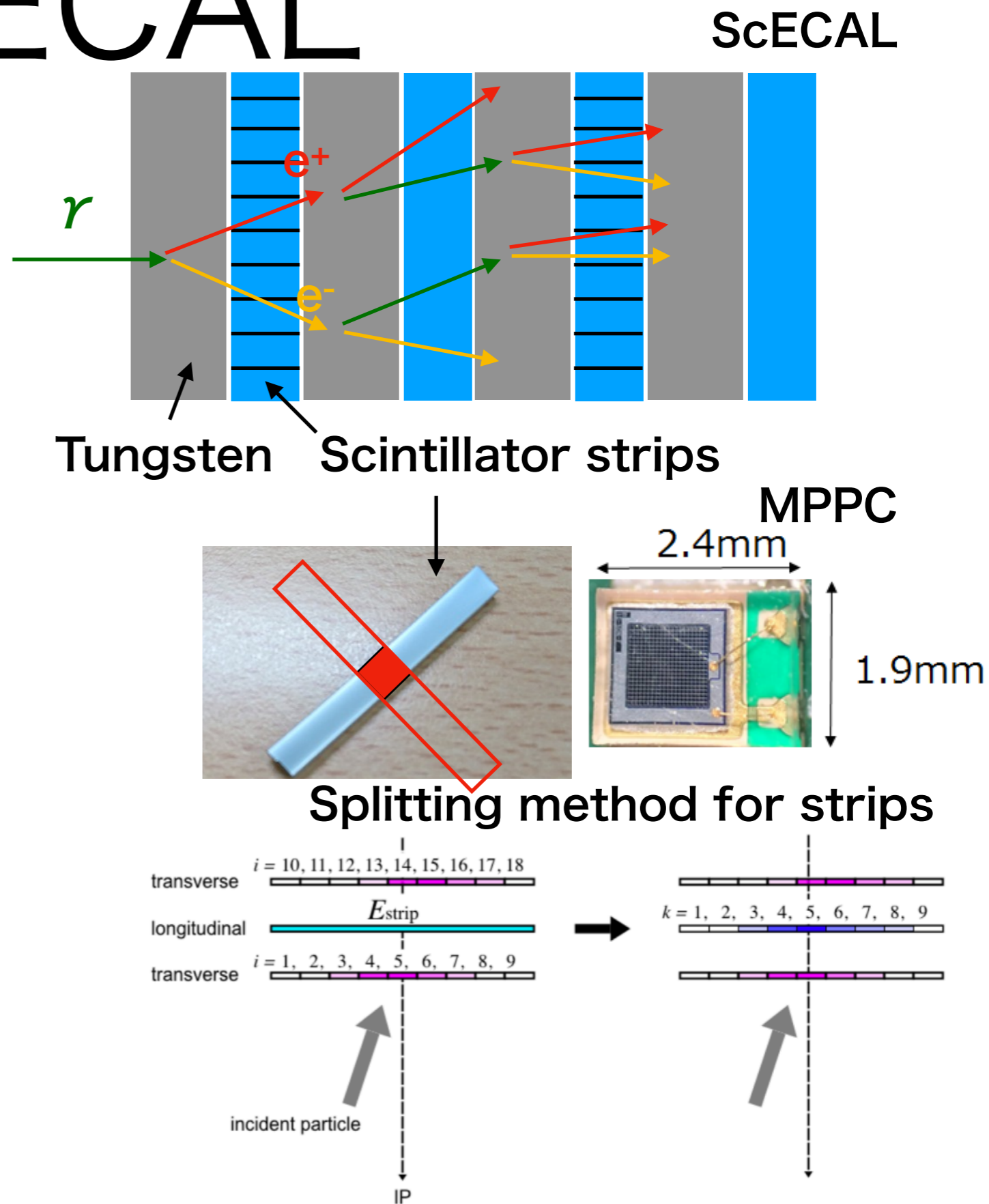
Optimization of Scintillator and MPPC of EBU for ILD ECAL

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ScECAL

- One of candidates of ILD ECAL
- It consists of absorber of tungsten and 45mm x 5mm x 2mm scintillator strip layers rotating strips by 90 deg
- The tungstens develop EM showers and scintillators measure them
- Split each scintillator into 9 virtual cells along its length
 - We are able to achieve to have 5mm x 5mm resolution effectively to satisfy the requirement of PFA
- Scintillator strips are readout by photosensor MPPC

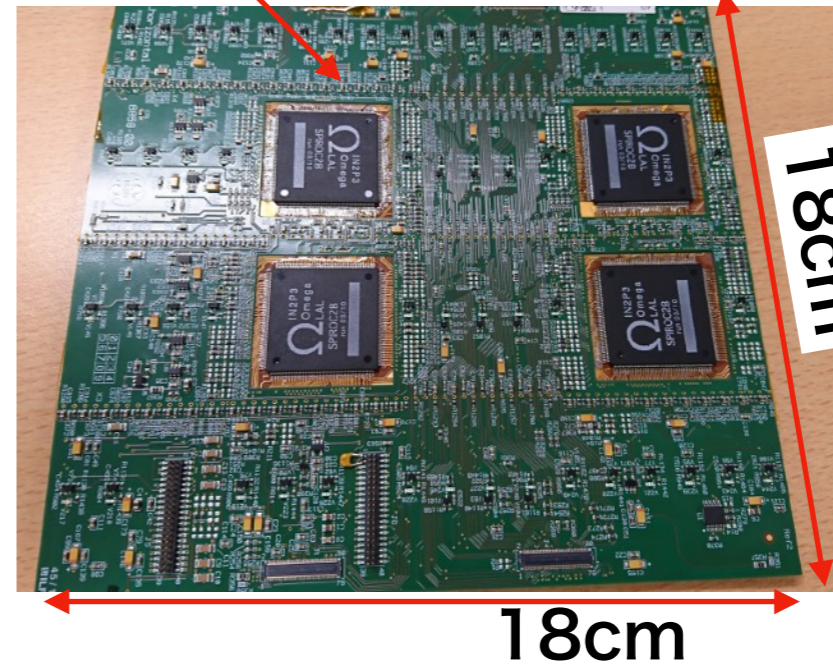


ECAL Base Unit(EBU)

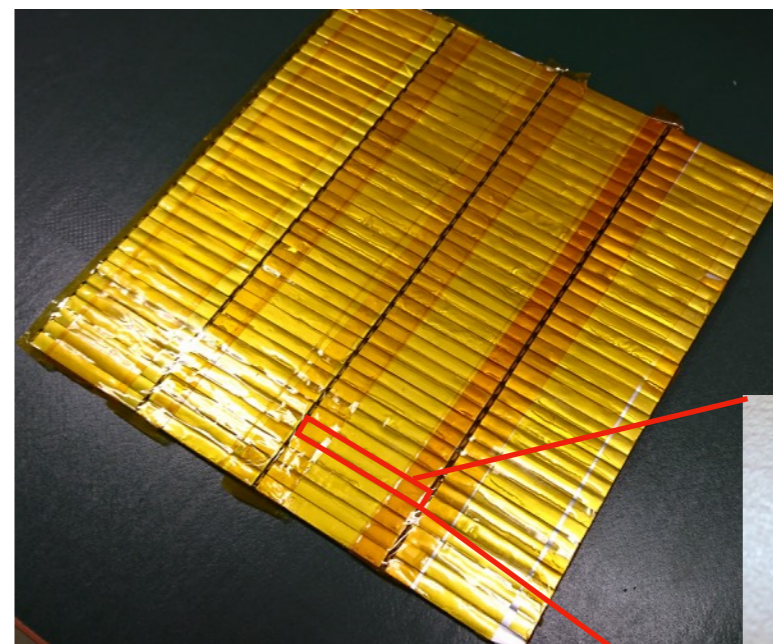
- EBU is an embedded read out electronics board for ScECAL developed by DESY
- 4 SPIROC2b chips developed by OMEGA are mounted on each EBU
- 1 SPIROC2b amplifies and digitizes signals from 36 MPPCs
- SPIROC2b can be only set common threshold to all the MPPCs
- Strips are mounted on the opposite side

SPIROC2b

EBU



Top view



Bottom view

Scintillator layer



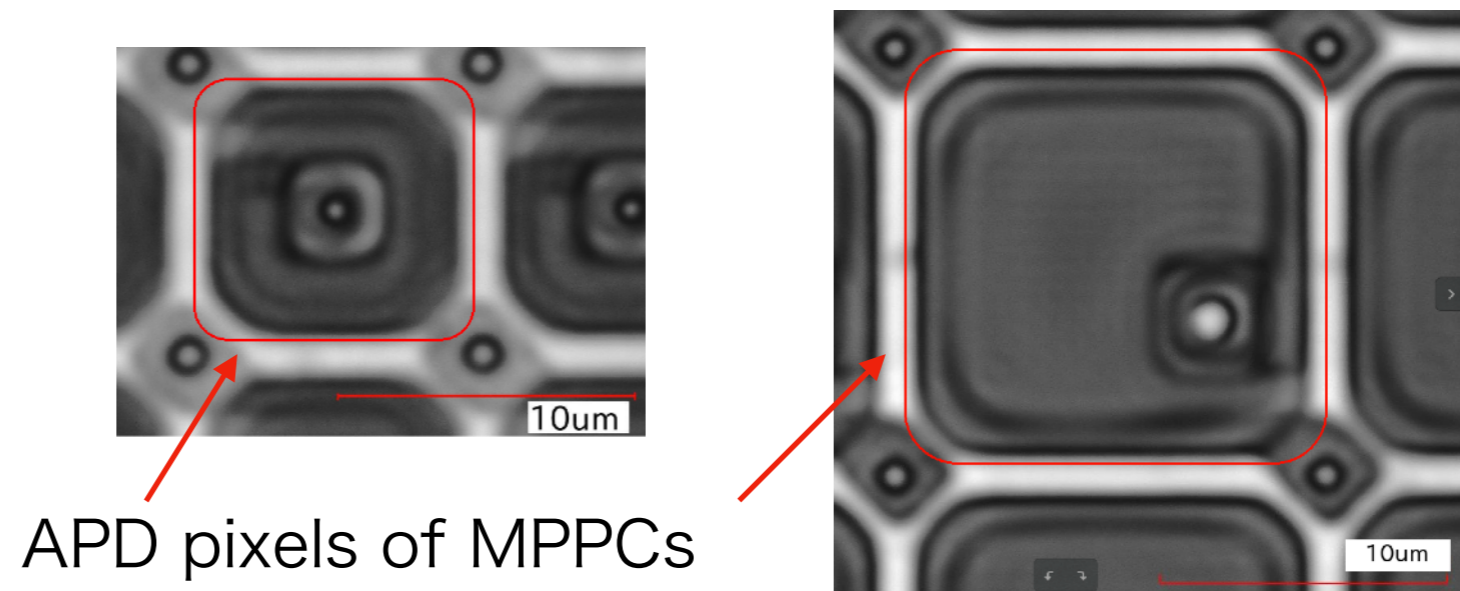
Development and motivation

- We have tested 2 combinations of MPPCs and scintillators on EBU's to separate 1 MIP from noise while maintaining the dynamic range of ECAL.
 - Installing 15 μm pixel MPPCs that have larger photon detection efficiencies (PDE) and gains than those of 10 μm that we have been using
 - Changing scintillator that has 1.4 times higher light yield than that we had been using
- We could detect 1 MIP peak separated from noise in lab by beta ray source, however tuning of those was difficult in short time at the beam
- We need to know the precise bias voltage features for the tuning
 - We have to prepare both limited range of bias voltages and threshold setting which are slightly different channel by channel for MIP separation

MPPCs

Hamamatsu catalog

Model number	S12571-010P	S12571-015P
Pitch size	10um	15um
Number of pixels	10000	4489
Receiving area	1mm ²	1mm ²
PDE	10%	25%
Gain	1.35×10^5	2.3×10^5



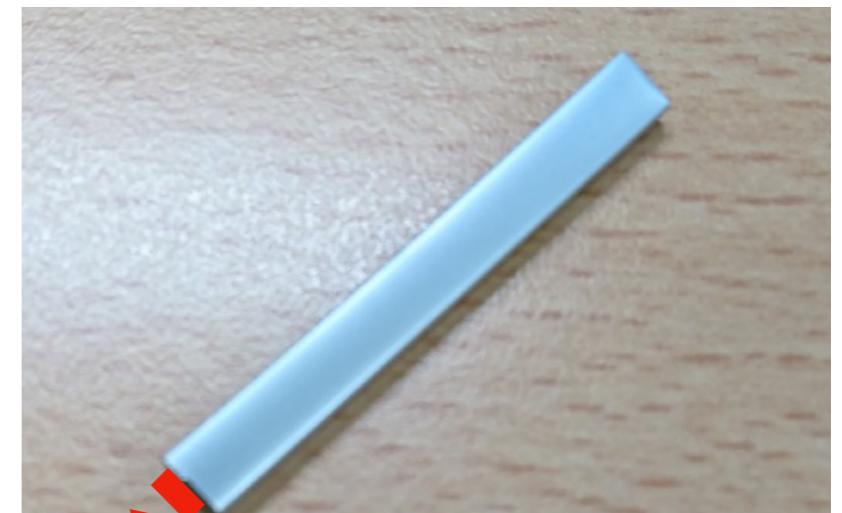
- We expected doubled gain and 2.5 times larger PDE by using 15um pixel MPPC than those of 10um

Scintillators and light read scheme

- All scintillator strips are made of EJ204 fabricated by ELJEN

- 5mm x 45mm x 2mm rectangular strip

Rectangular strip



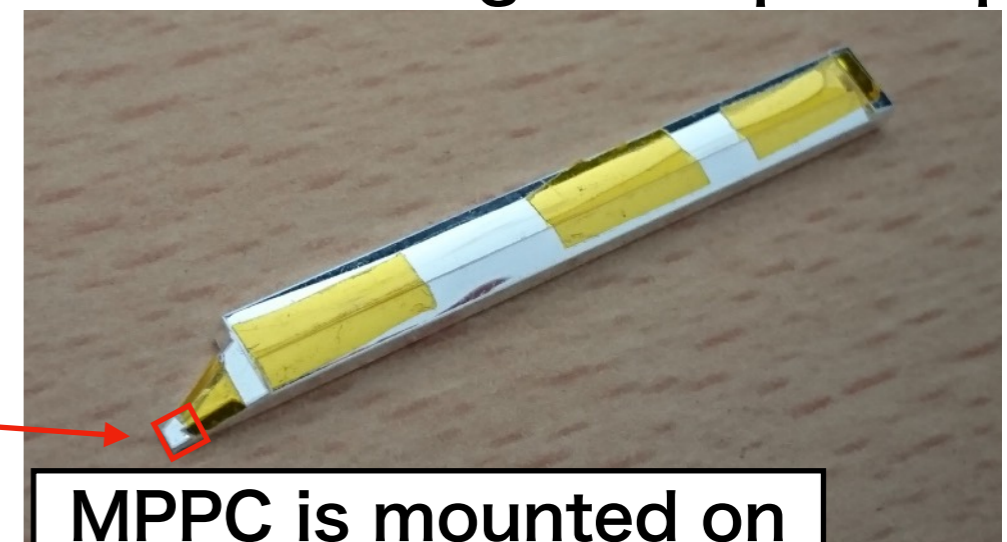
MPPC

- Side readout by 10um pixel MPPC

- Wedged shape strip

- Bottom readout by 15um pixel MPPC

Wedged shape strip

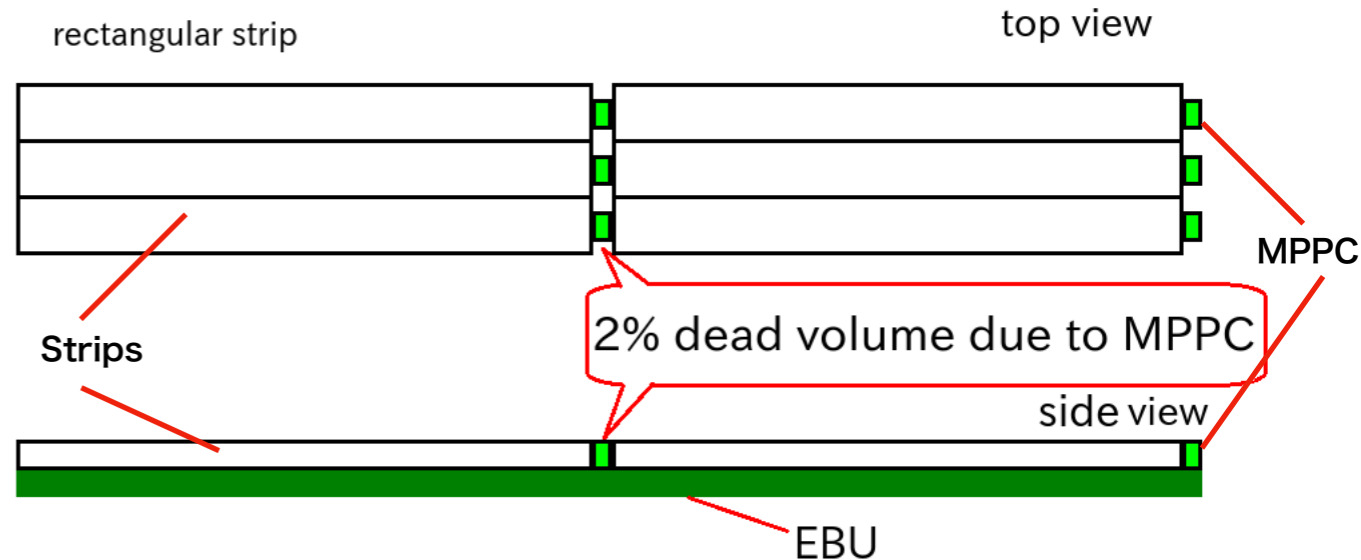


MPPC is mounted on the bottom of strip

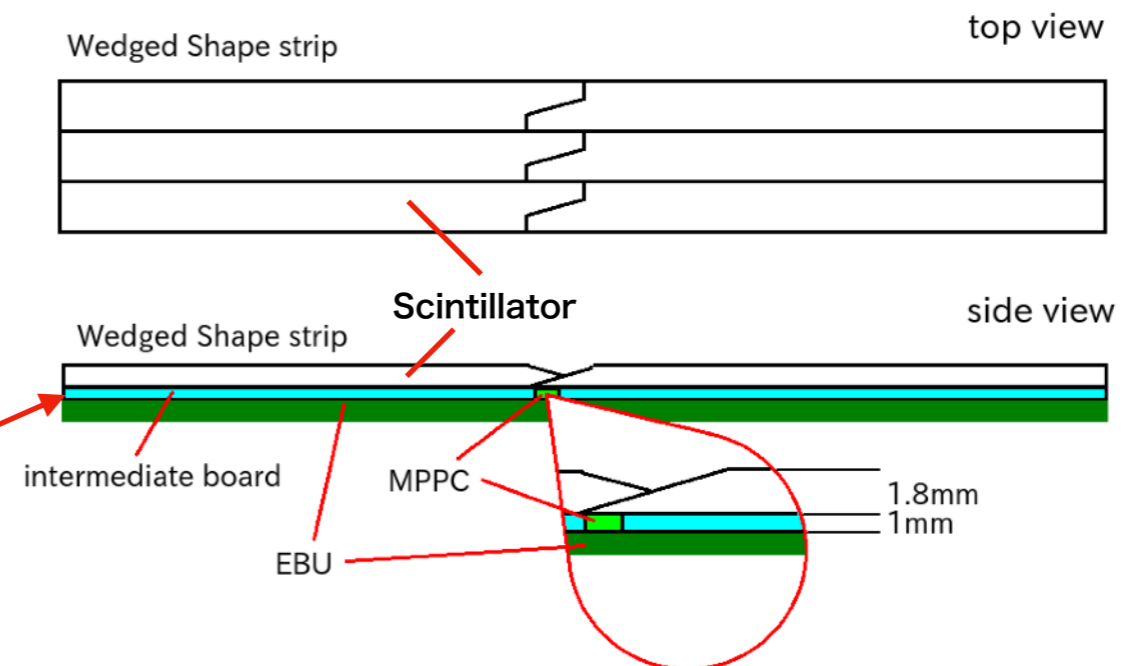
how to readout

- Side readout
 - High light collection efficiency
- Bottom readout
 - No dead volume
 - 30% less light collection efficiency than side readout
 - Makes us easy to mount MPPC on EBU by soldering
 - Needs intermediate board to work with current EBU

Side readout



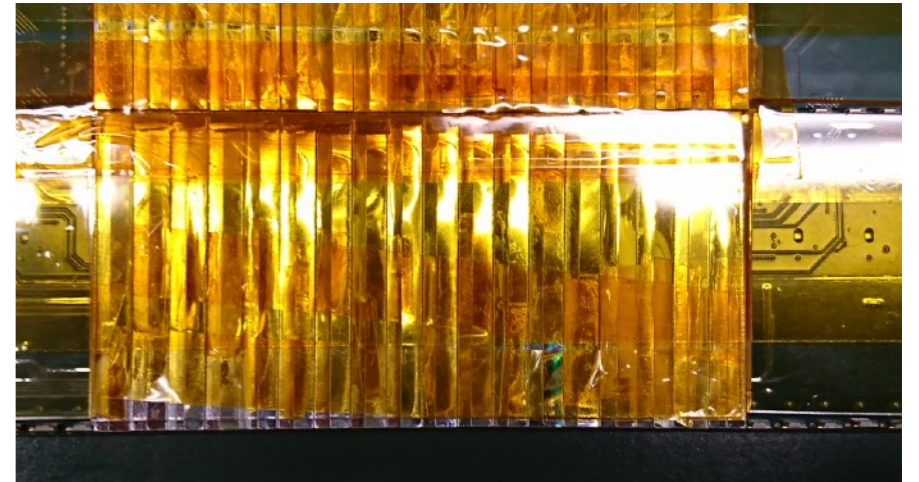
Bottom readout



New EBU prototypes

- We have tested 2 kinds of new EBU prototypes
 - 10um MPPC with 2mm rectangular strip
 - 18 scintillators are mounted on an EBU
- 15um MPPC with wedged shape strip
 - 36 strips are mounted on another EBU

Rectangular strips on new EBU

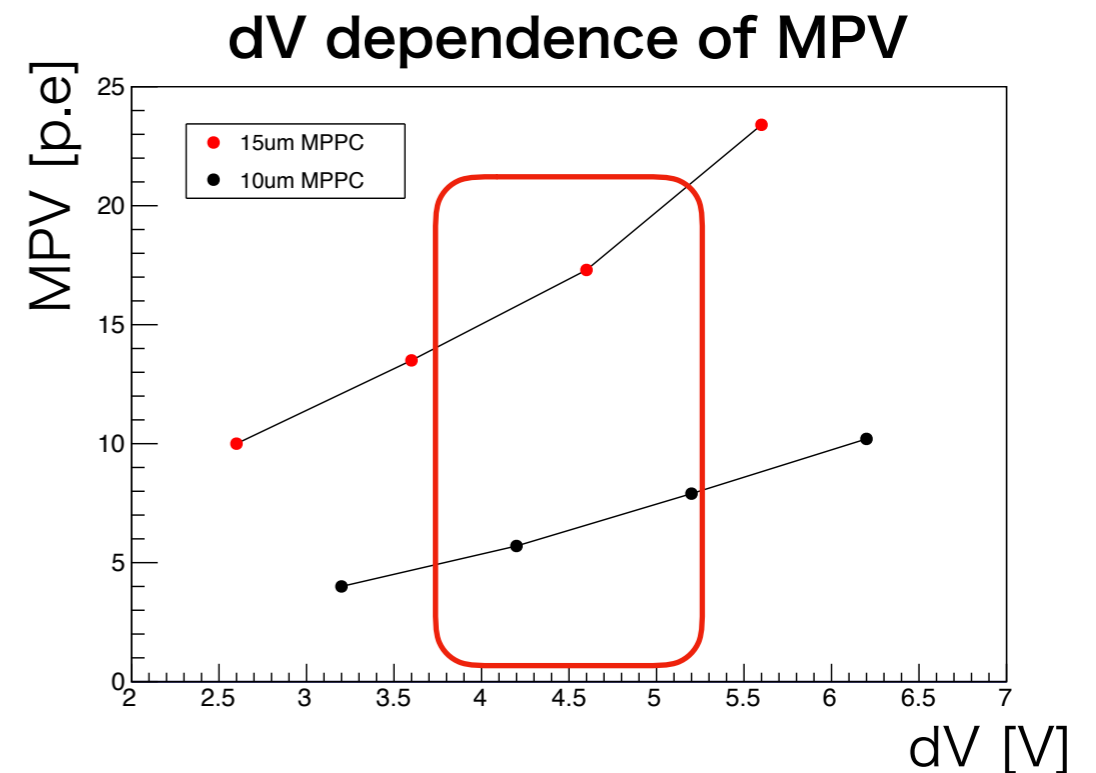
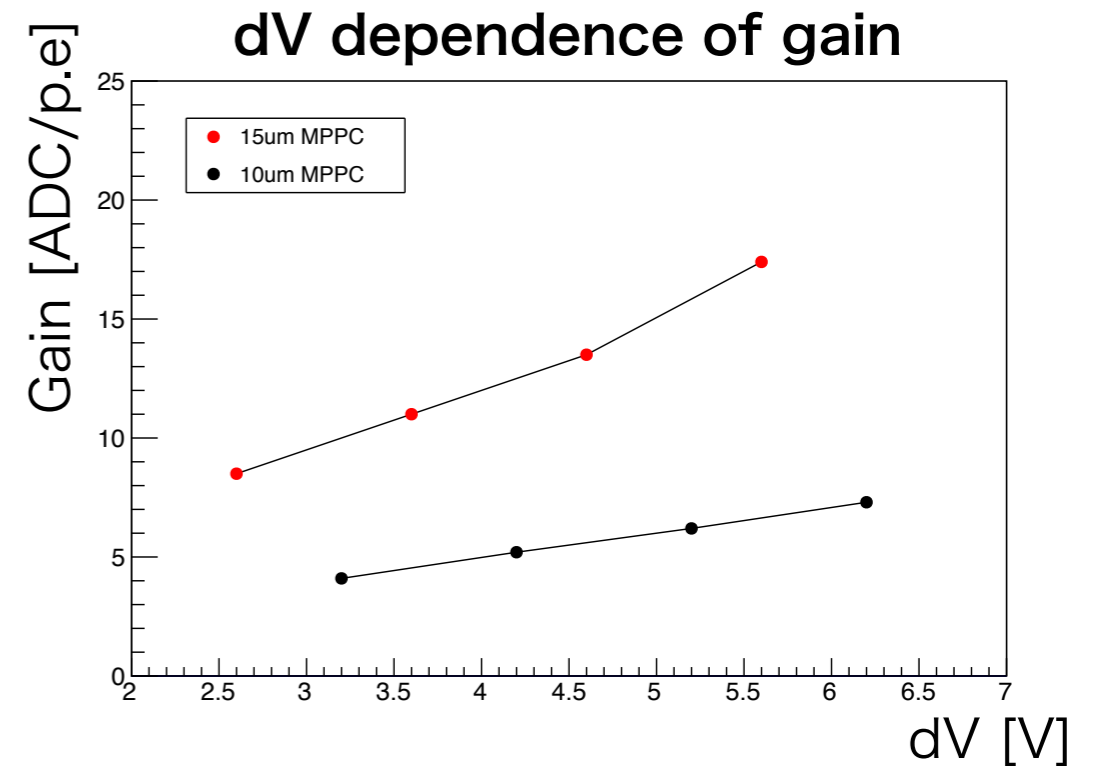


Wedged shape strips on new EBU



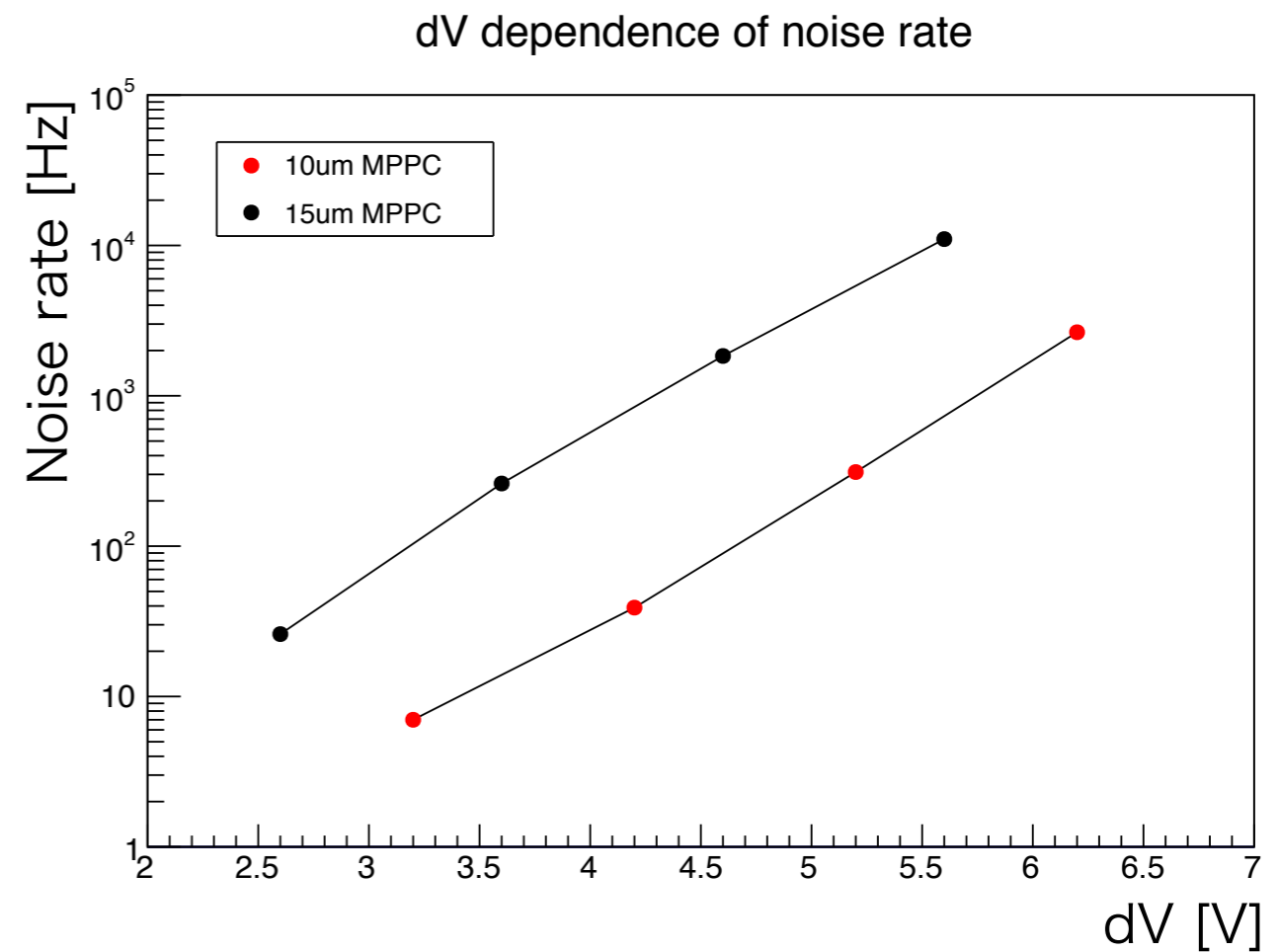
dV dependence of gain and light yield

- $dV = V_{\text{bias}} - V_{\text{breakdown}}$
- We compared light yield for wedged shape strip by bottom readout with 90Sr with CAMAC readout
- We estimated about 5p.e with 10um MPPC and 15p.e with 15um in dV 4V
- We obtained doubled gain and more than doubled light yield by using 15um MPPC instead of 10um



dV dependence of noise rate

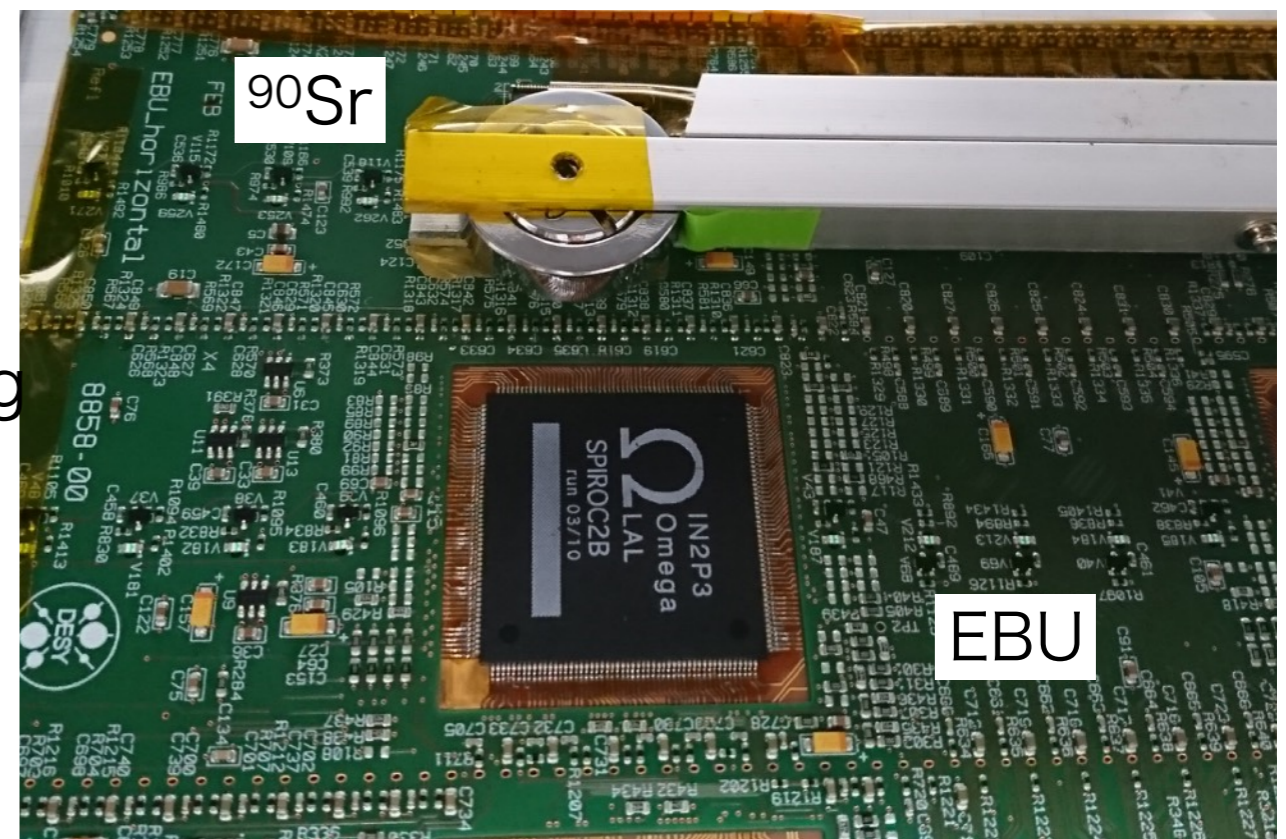
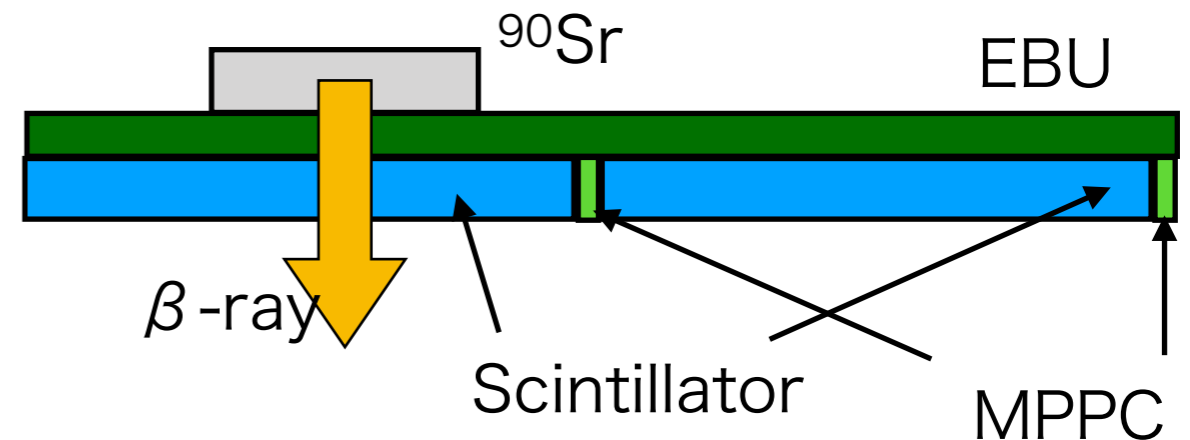
- We will tune 7p.e/MIP to maintain enough dynamic range based on the result of the simulation for Bhabha events
- We will set threshold to 3.5p.e that is 0.5MIP
- We measured noise rate more than 3.5p.e
- 15um MPPC has more than 5 times larger noise rate than that of 10um in spite of less number of APD pixels than that of 10um
- While we can obtain much larger signal for 15um MPPC, we have to pay attention to larger noise rate of 15um in order to deal this MPPC with EBU
 - We are discussing with Hamamatsu



Bench test with ^{90}Sr

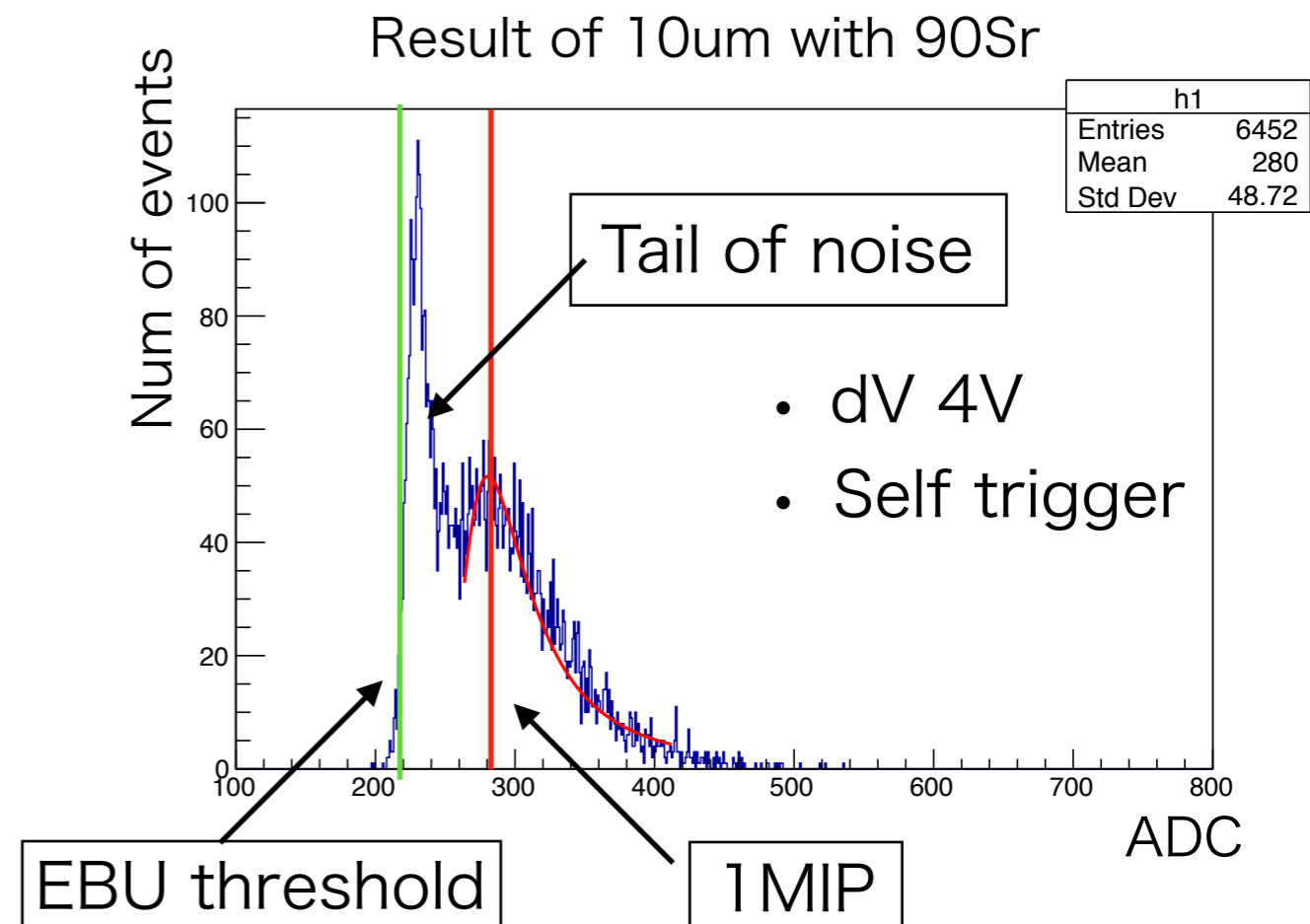
- We tested new prototypes with ^{90}Sr every channel whether these can detect 1 MIP peak separated from noise
- Using beta ray that passed EBU and strip
- We tested all channels with masking other channels in this test
- Measured with self trigger

Set up of bench test



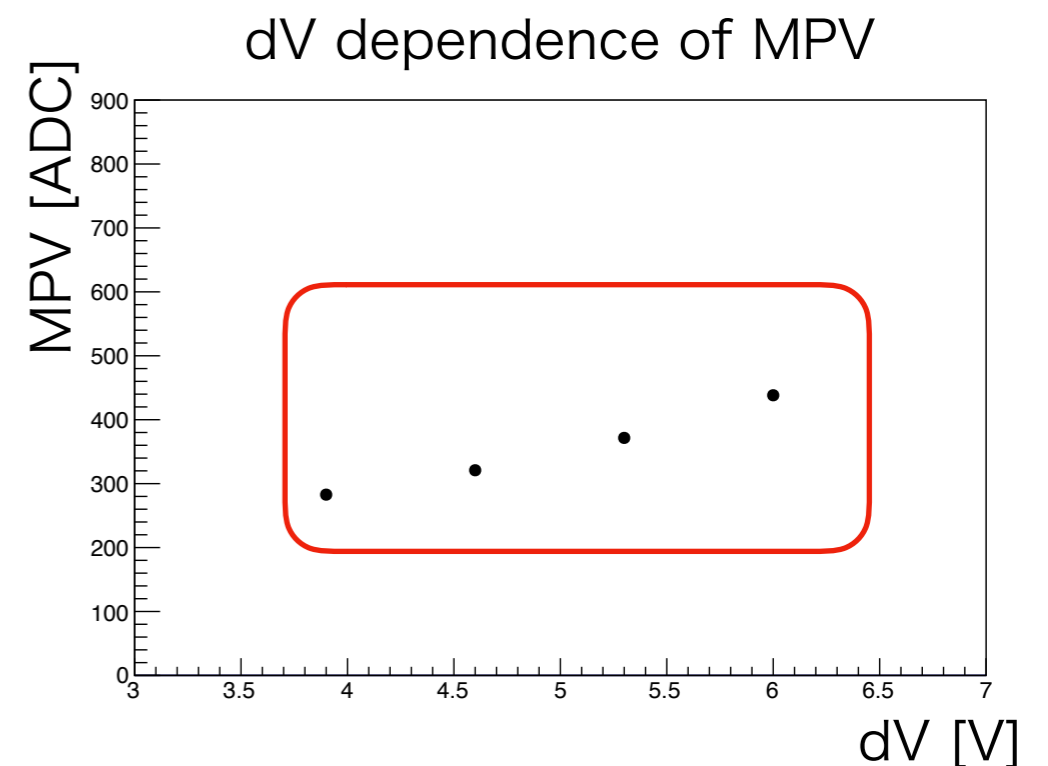
10um MPPC with 2mm rectangular strip

- We could detect 1MIP peak in all channels except dead channels
- We are able to suppress noise by setting 0.5MIP threshold by tuning individually
- 4 channels were dead due to contact failure
- We will repair dead channels and test them later



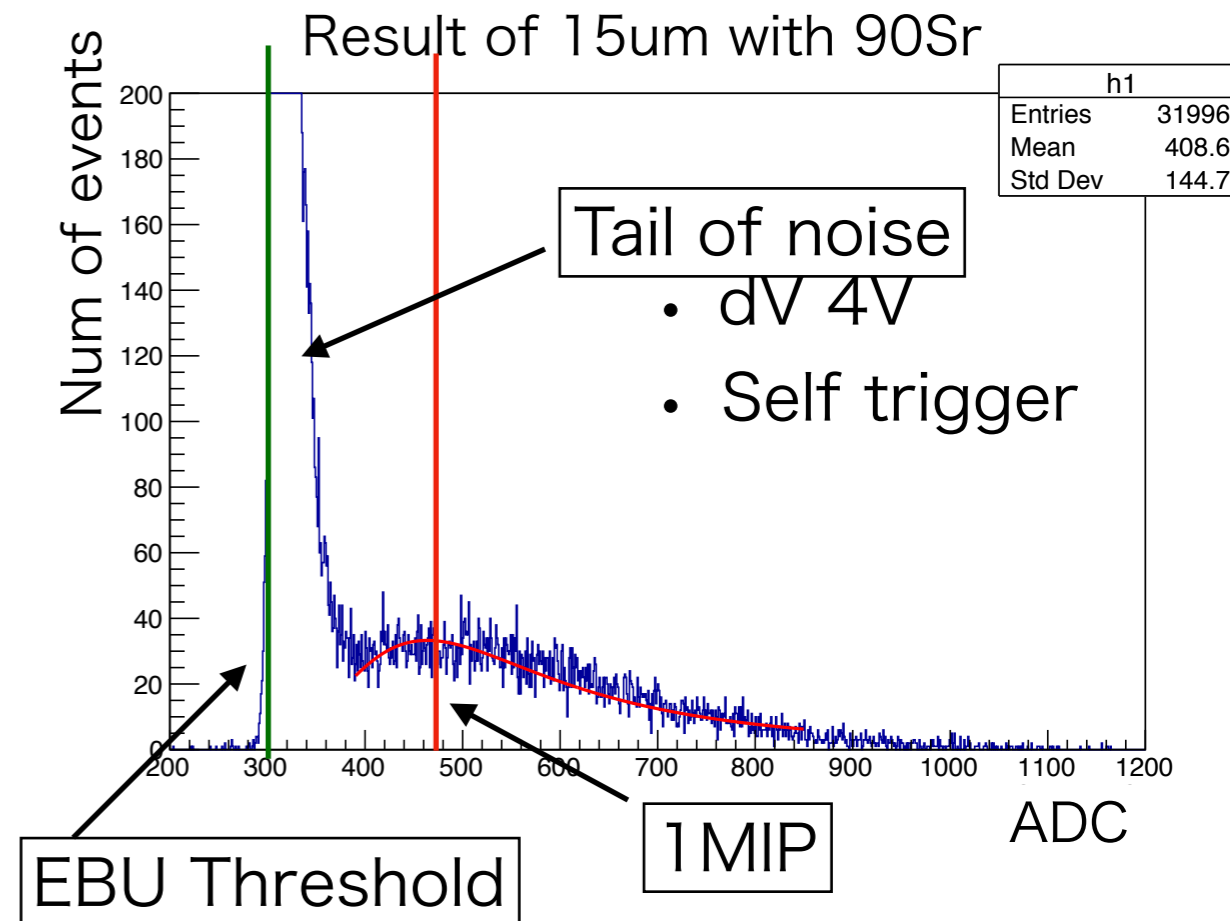
dV dependence of 10um MPPC with rectangular strip

- We measured dV dependence of this prototype using only 1 channel
- We could detect 1MIP peak in dV 4 to 6V
- We could not separate 1MIP from noise in less than dV 4V due to small signal
- We are able to use this prototype under these conditions, however we need to tune carefully
- We will measure bias voltage features in all other channels



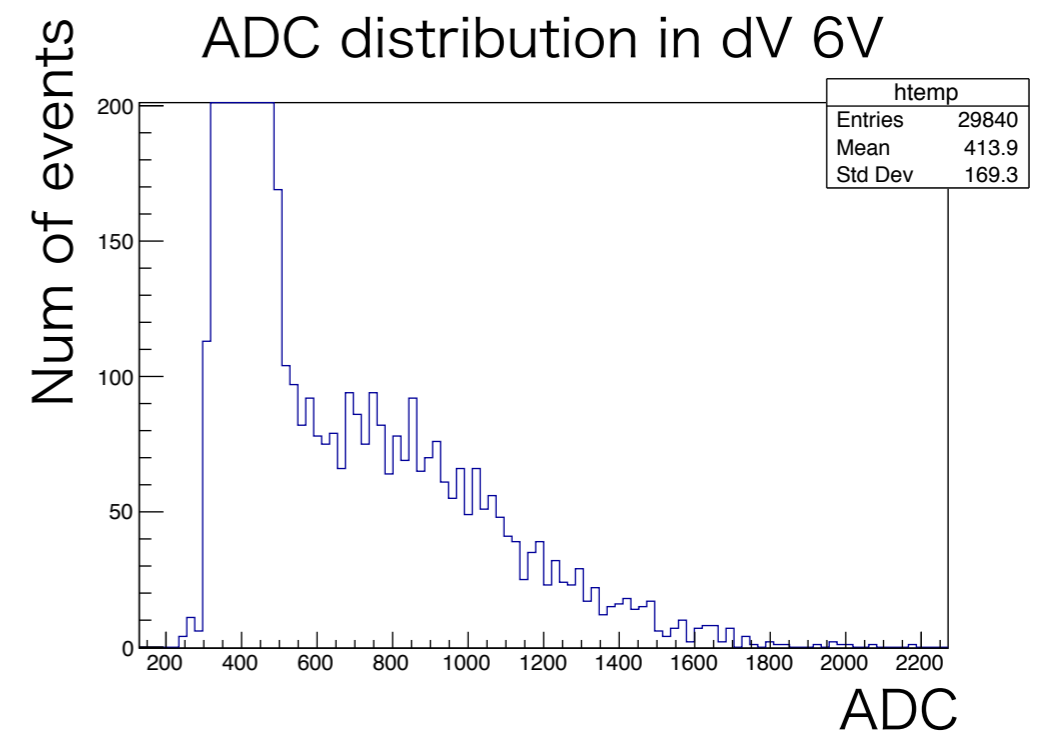
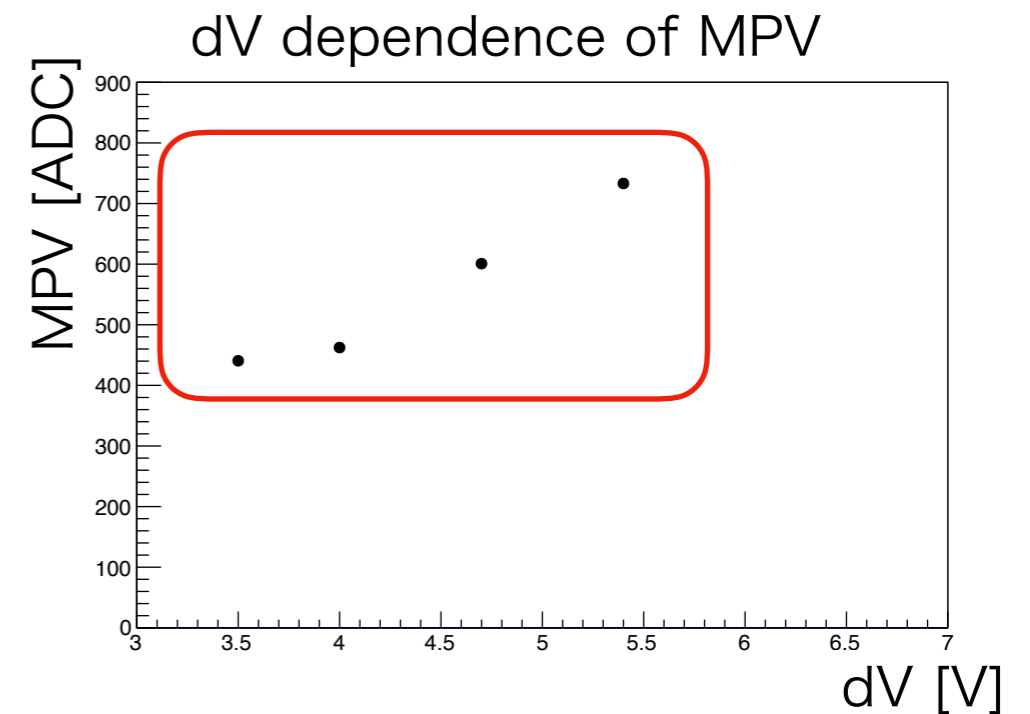
15um MPPC with wedged shape strip

- We could detect 1MIP peak in all channels in bench test
- We are able to suppress noise by setting 0.5MIP threshold by tuning individually
- There is 2.9% of events inefficiency by setting 0.5MIP threshold



dV dependence of 15um MPPC with wedged shape strip

- We measured dV dependence of this prototype using only 1 channel
- Noise rate due to MPPC became larger with dV
- We could detect 1MIP peak in dV 3.5 to 5.5V
- MIP peaks were buried by noise in more than dV 6V
- We are able to use this prototype under these conditions, however we need to tune carefully
- We will measure bias voltage feature in all other channels



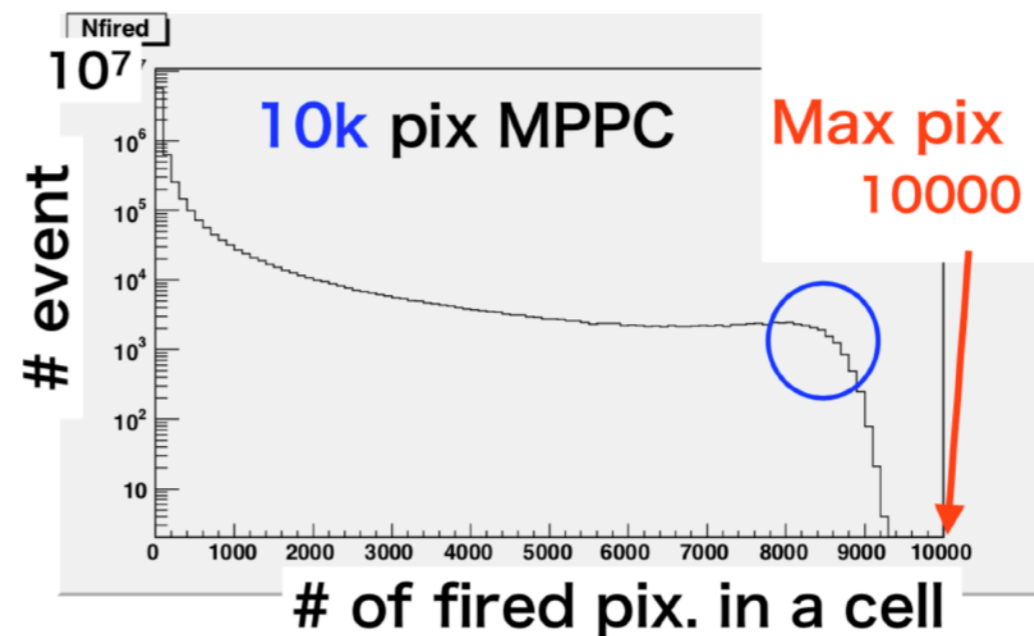
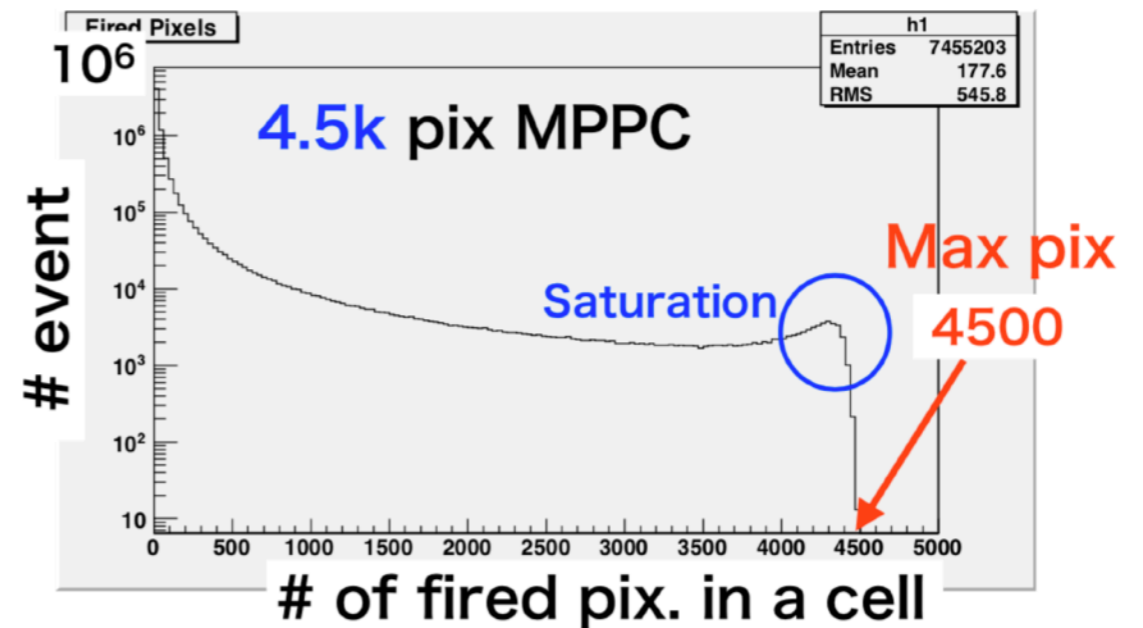
Summary

- We have attempted to use 2 kinds of new combinations of photosensors and scintillators for ILD ScECAL with current EBU/SPIROC2b
- We could detect 1 MIP peak separated from noise in the bench test with ^{90}Sr every channel in the range of about dV 2V
- We will be able to adopt these prototypes for the next test beam
- We plan test beam this year under more experienced condition
- We will try LED calibration with these prototypes

Back up

Result of simulation

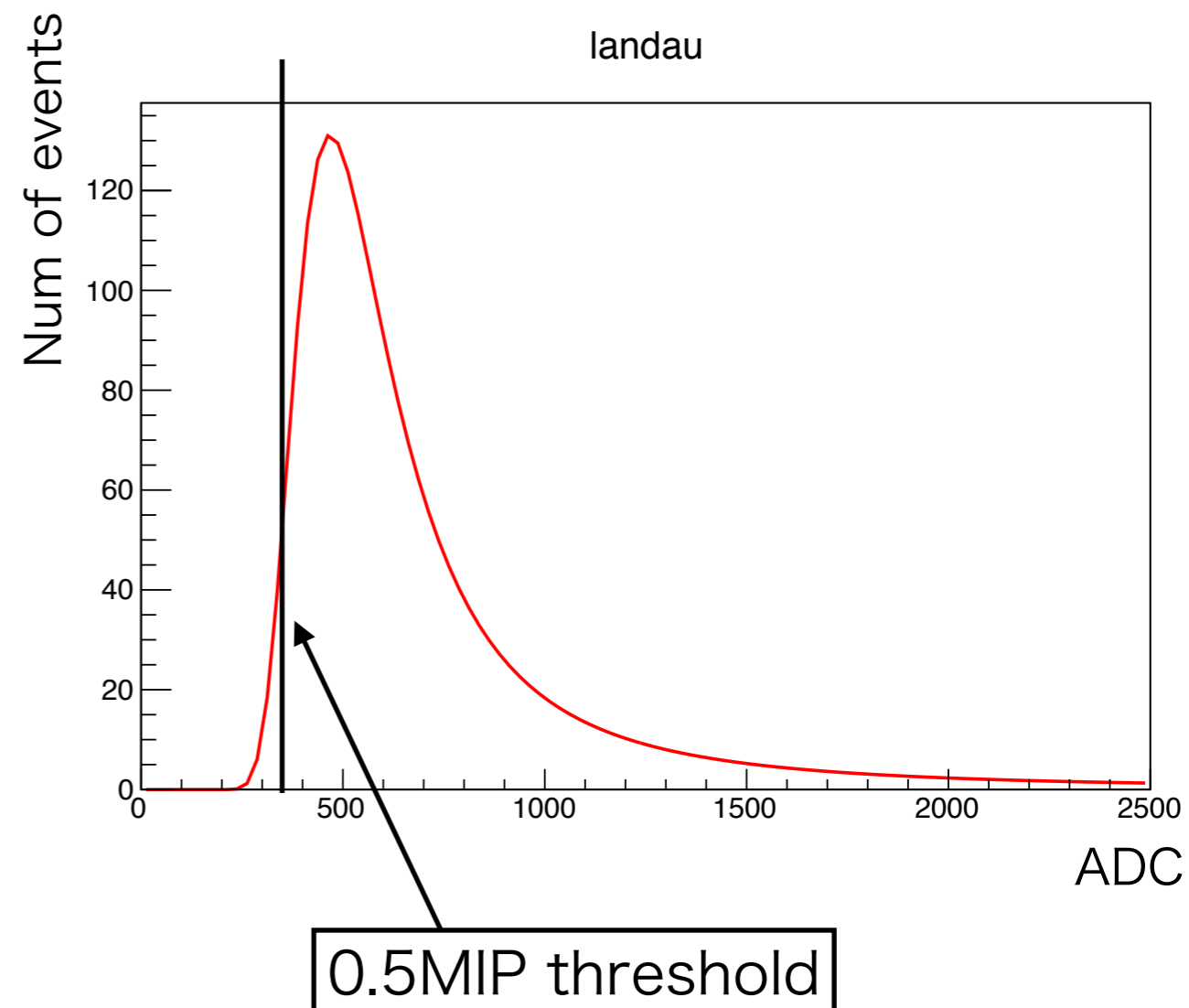
- Uses 250GeV gamma
- 10um pixel MPPC is needed for ILC 500GeV to avoid saturation in Bhabha event
- We think the number of pixels that we need for ILC 250GeV is half of ILC 500GeV due to beam energy
- We think we can use 15um MPPC that has half number of APD pixel than 10um



By Kotera

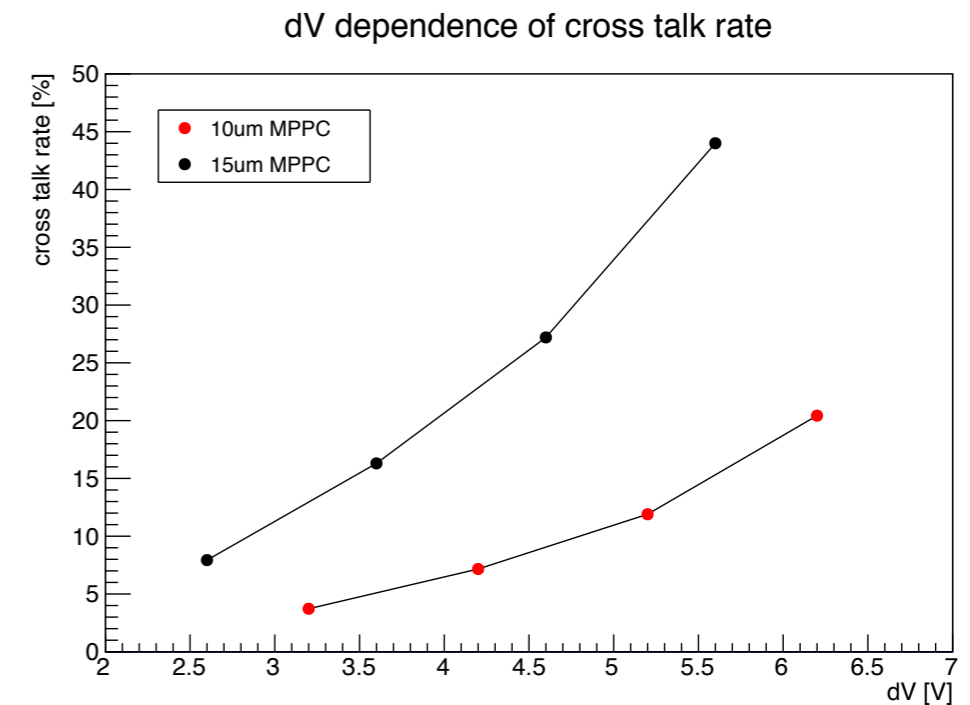
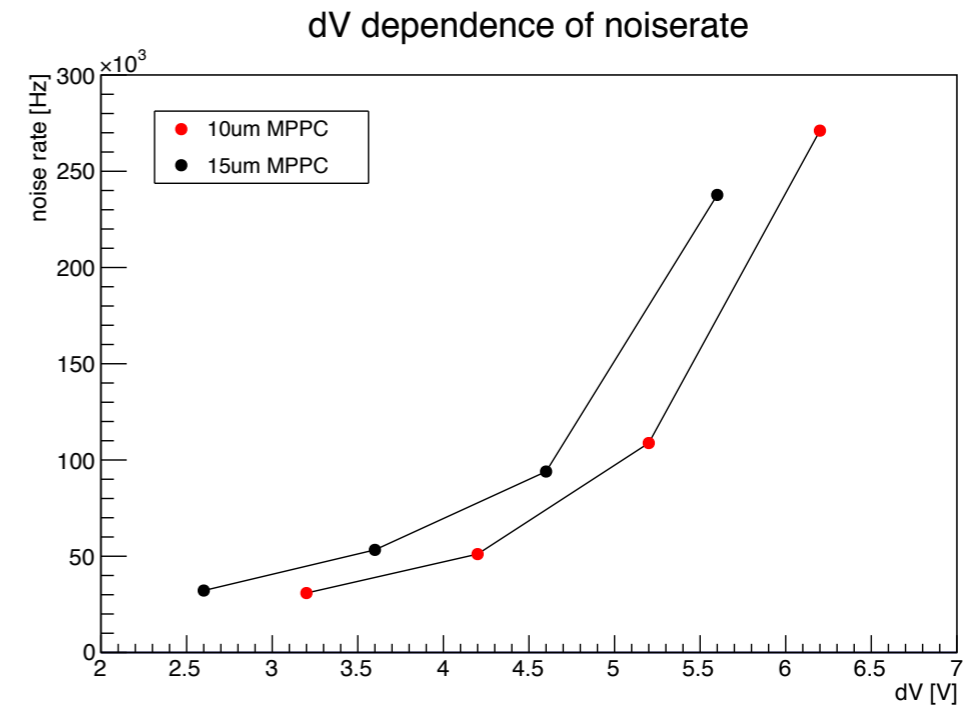
Estimation of inefficiency (15um)

- Using parameter of fitting for the result, we estimated inefficiency
- When we require 0.5MIP threshold, there is 2.9% inefficiency



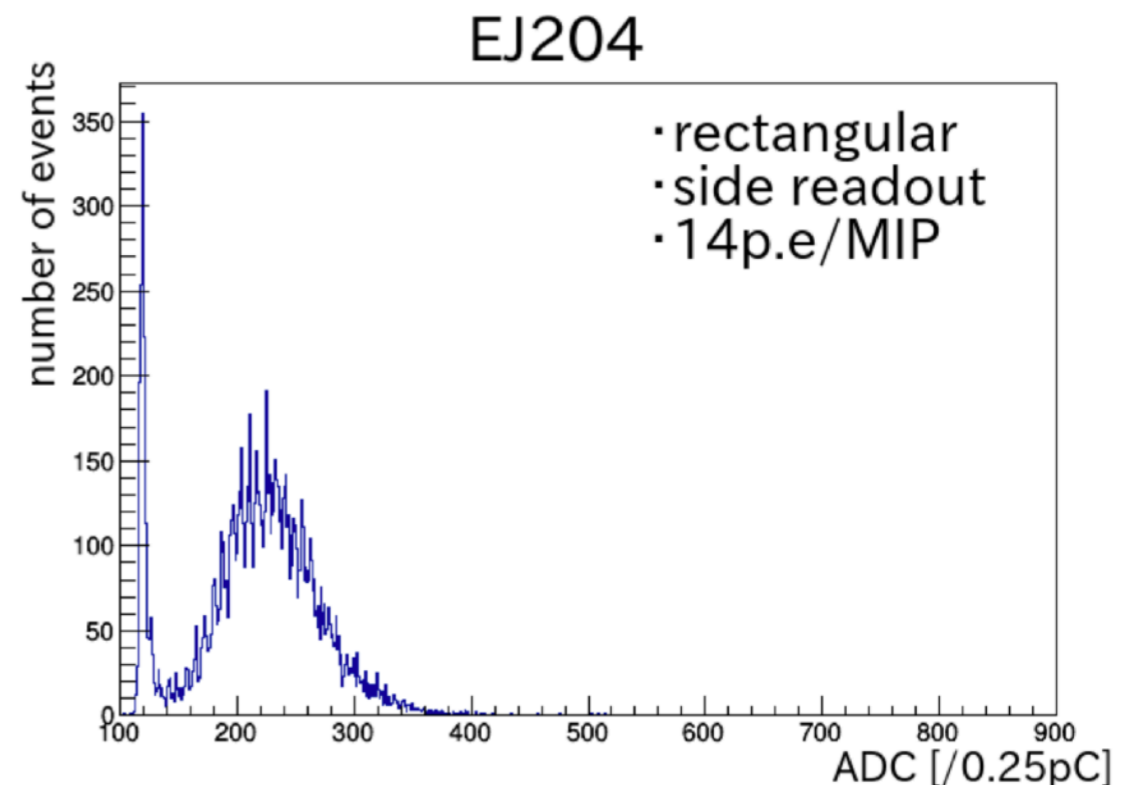
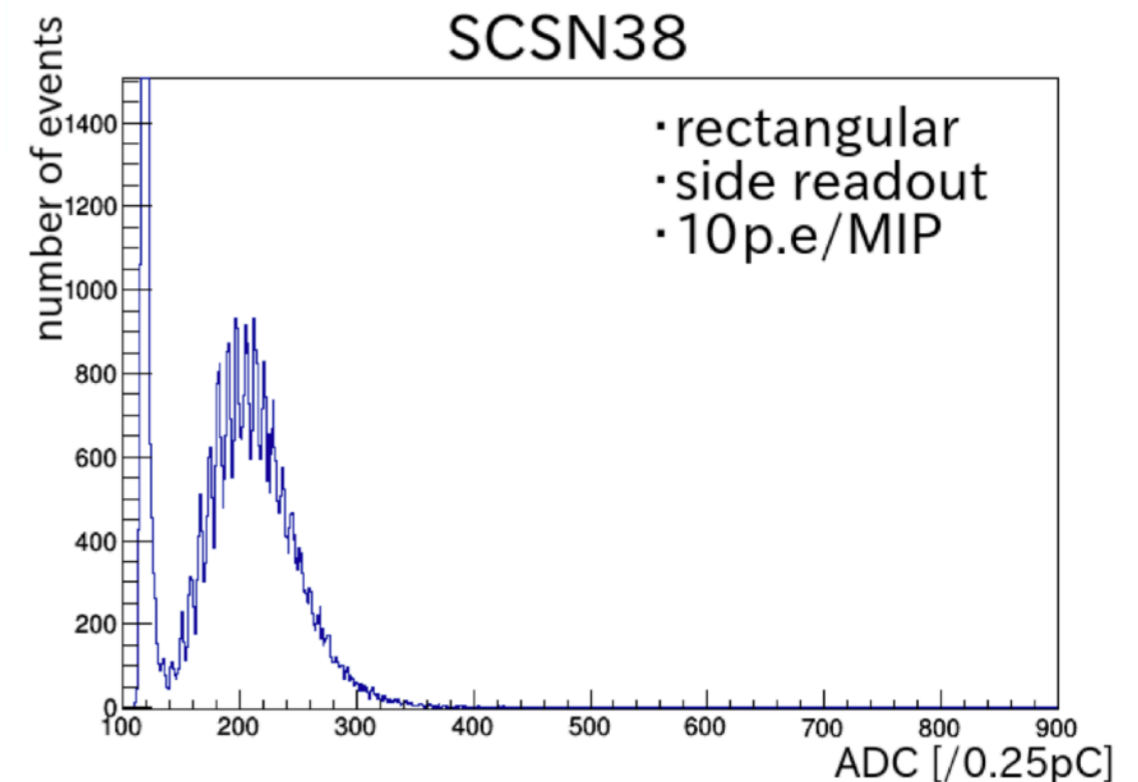
dV dependence of noise

- 15um MPPC has
 - larger noise rate than that of 10um
 - larger cross talk than that of 10um



Comparison Strips

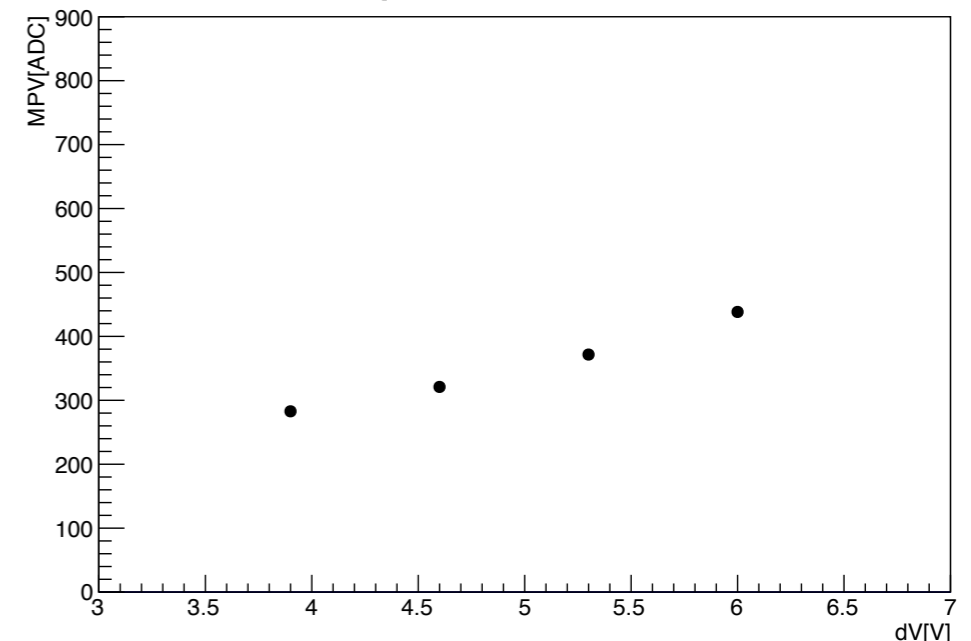
- Strips are readout by 10um MPPC with CAMAC readout
- We seemed to obtain 1.4 times larger light yield by using EJ204 instead of SCSN38 that we had used



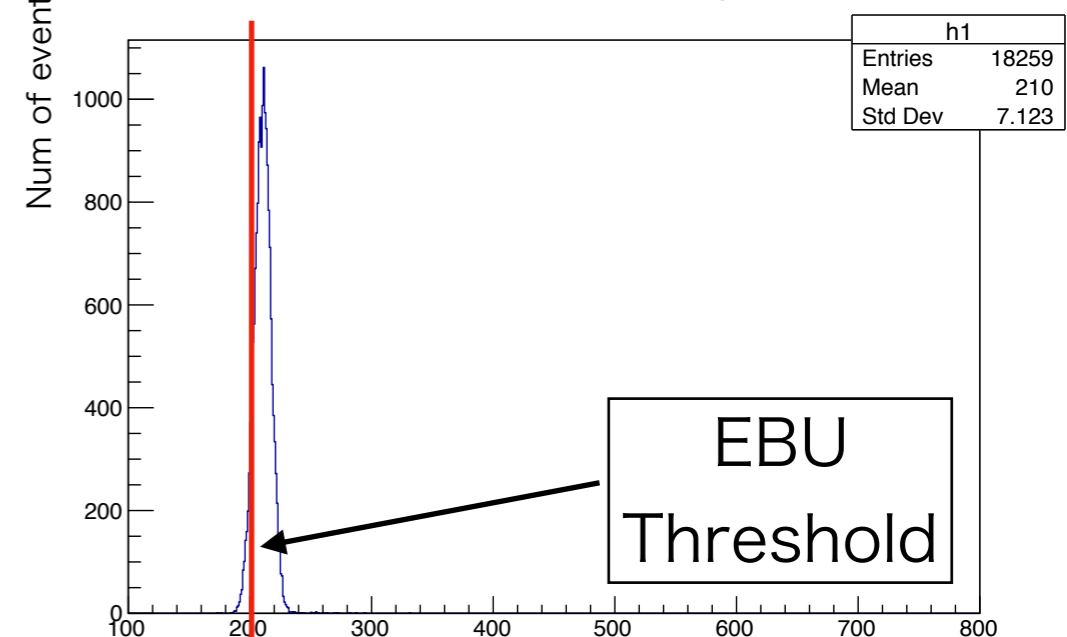
dV dependence of 10um MPPC with rectangular strip

- We measured over voltage dependence of this prototype using only 1 channel
- MIP peak became larger with bias voltage
- We could detect 1 MIP peak in over voltage 4 to 6V
- We could cut noise by setting 0.5MIP threshold in these condition
- We seemed to use this prototype in these condition
- However we could not detect 1 MIP in lower voltage due to low gain of MPPC

dV dependence of MPV

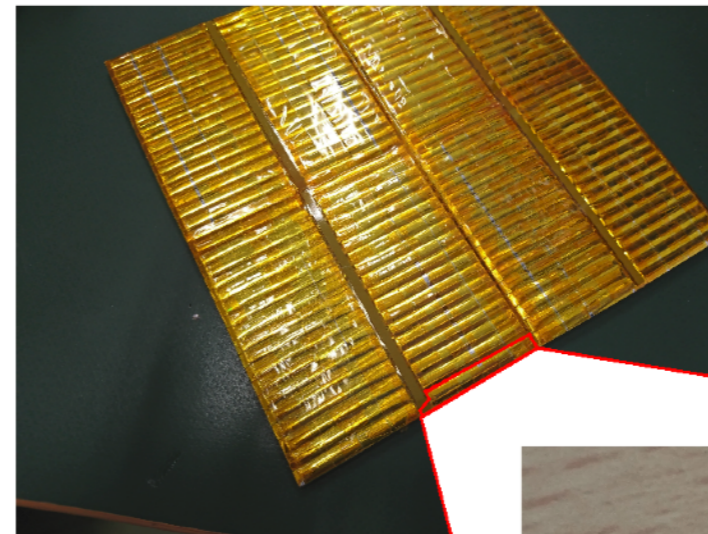


Result of over voltage 3.3V



Wedged shape strip

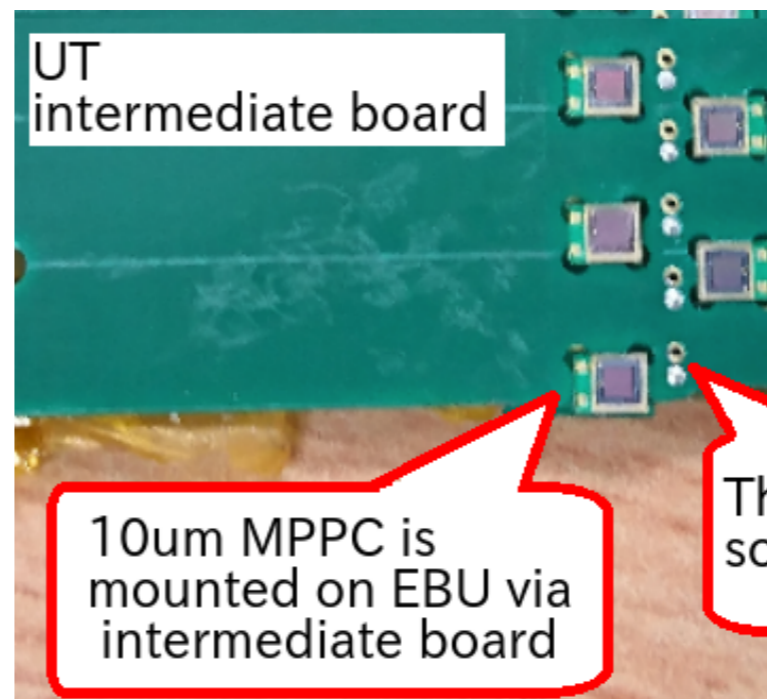
- Developed for bottom readout by UT
- In order to raise light collection efficiency, the tip of strip is shaped like a wedge
- We re-produced an intermediate board with 15um pitch MPPC



Scintillator layer
144 strips in
18cm by 18cm



Wedged shape strip



15um MPPC with wedged shape strip

- We detected MIP peak separated from noise with 15um MPPC

