ScECAL activity in 2013

18th December 2013

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Shinshu University

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5. Plan in future
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Group

Kungpook National (Korea)

A. Khan→got PhD., D. Kim, M. Kim, D. Kong, S. Uozumi,

Nippon Dental:

H. Ono,

Shinshu:

R. Hamasaki, K. Kasama, T. Ogawa, T. Takeshita, L. Teh, R. Terada, T. Tsuzuki, and K.Kotera,

Tokyo:

S. Ieki, W. Ootani,

Tsukuba:

T. Honda, A. Murasame, K. Yoshida, F. Ukegawa

Kyushu and ICEPP study on SiECAL, and hybrid together. Those all join CALICE group.

a brief introduction of ScECAL

Why we study Sc-strip ECAL

(again for new comers)

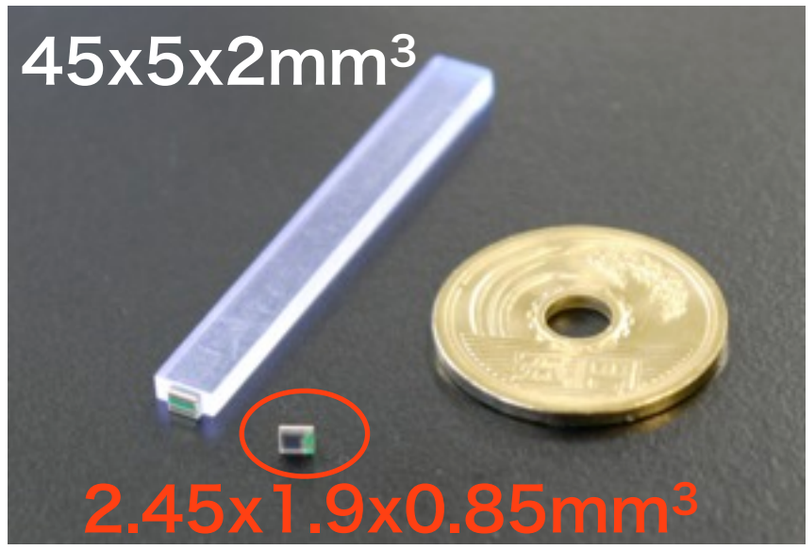
1. Requirements:
   a. 5 mm x 5 mm lateral segmentation

      robustness for ~ 10^8 channels.

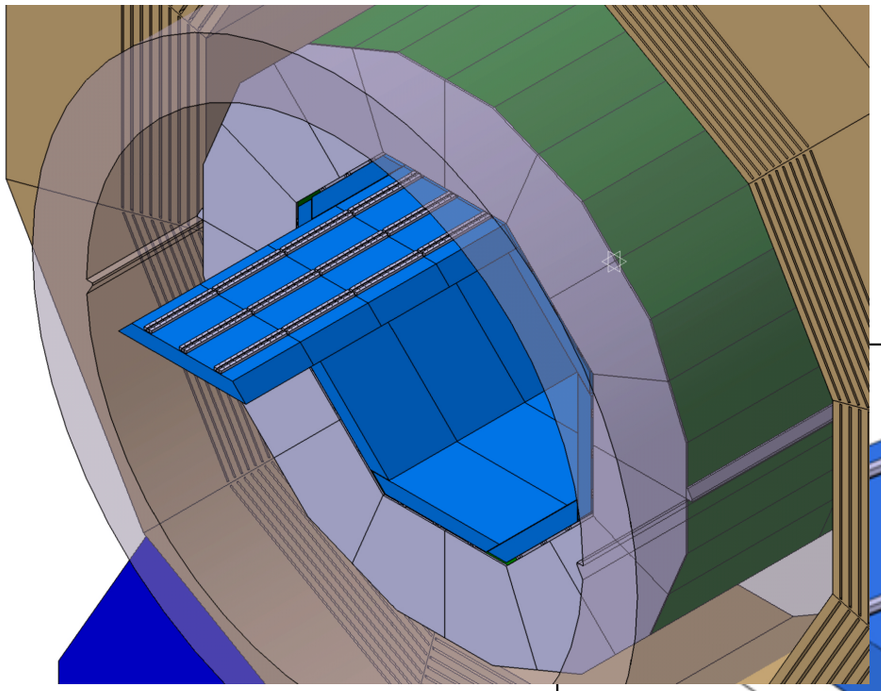
   b. Low cost.
2. Drastic development of the SiPM(MPPC) in this decade,

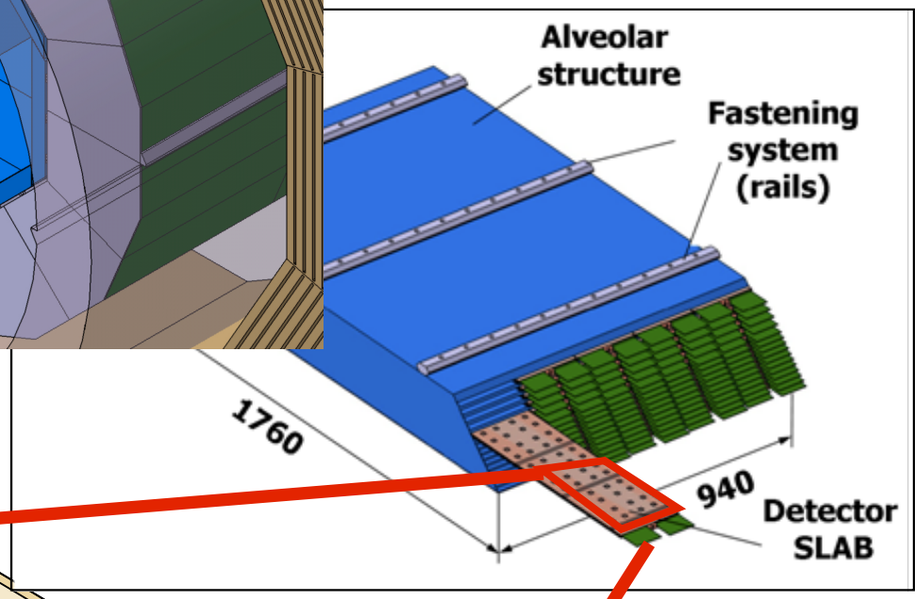
   high gain, small package, no effect from magnet
3. Idea of strip segmentation;

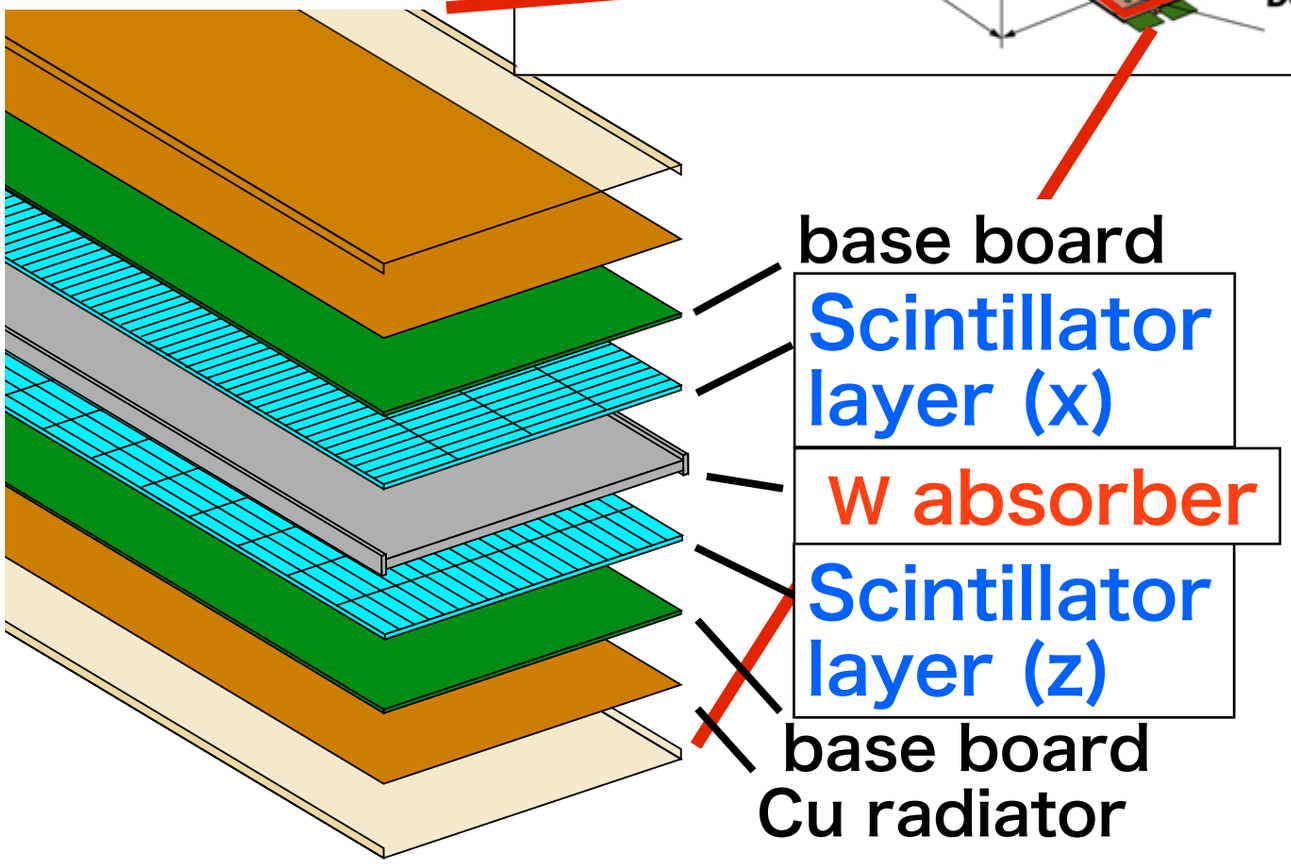
   the strips in odd layers are aligned orthogonally to those in the even layers. 10^8 → 10^7
4. Timing measurement with resolution < 1 ns.



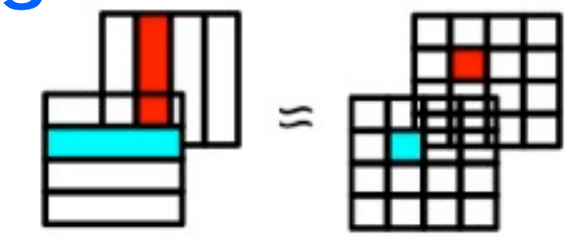
Strip ScECAL in ILD







1. Mechanical design of the barrel and the endcaps is developed by CALICE ECAL group.
2. “Alveolar” structure itself is made with W absorbers.
3. Two scintillator layers in an alveolar make a sandwich structure with a tungsten absorber.
4. Strip directions are orthogonal to each other.

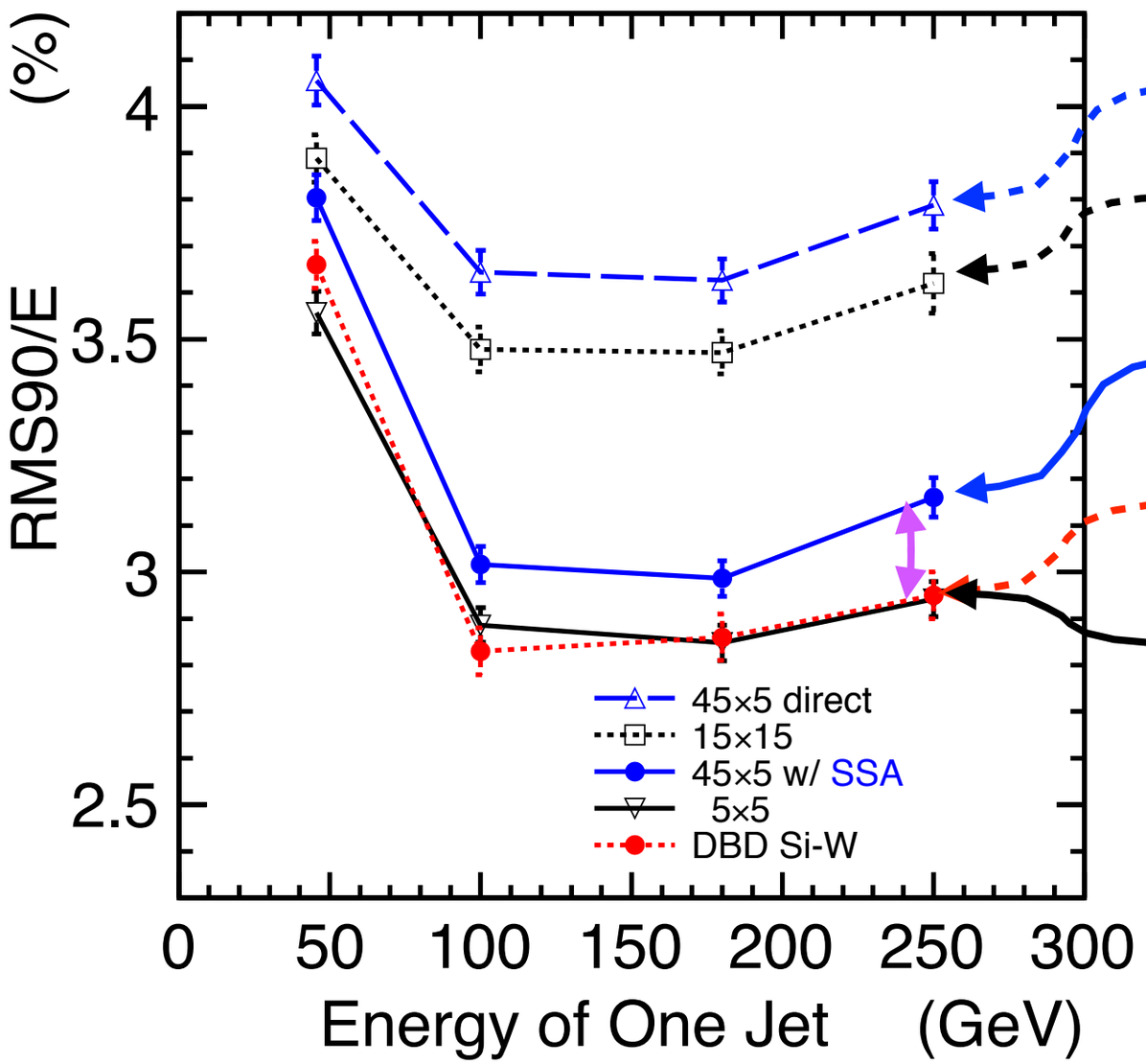


Reconstruction and performance

Reconstruction of Strip ECAL

Algorithm to extract 5x5mm² from strip cells (SSA)

$$Z' \longrightarrow q\bar{q} \qquad q = u, d, s$$



45 x 5 mm² ScECAL w/o SSA

10 x 10 mm² tile ScECAL

45 x 5 mm² ScECAL w SSA

DBD result (SiW ECAL)

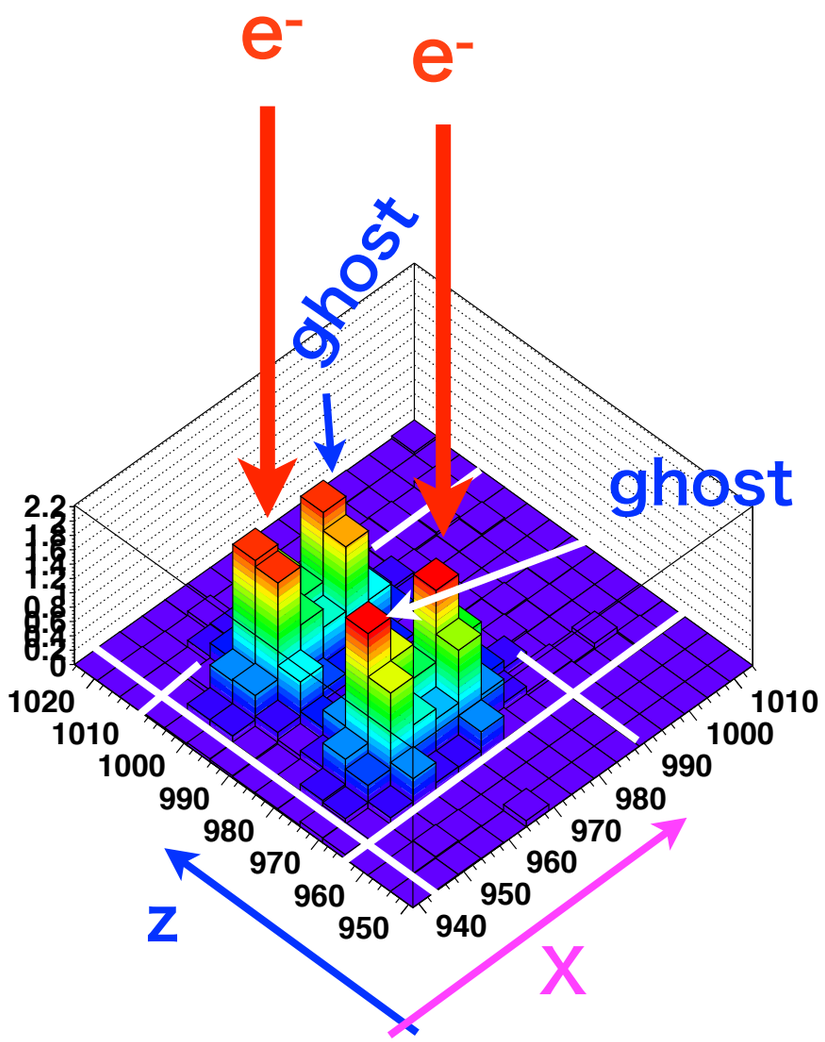
5 x 5 mm² tile ScECAL

cos(θ_Thrust) < 0.7 (Barrel)

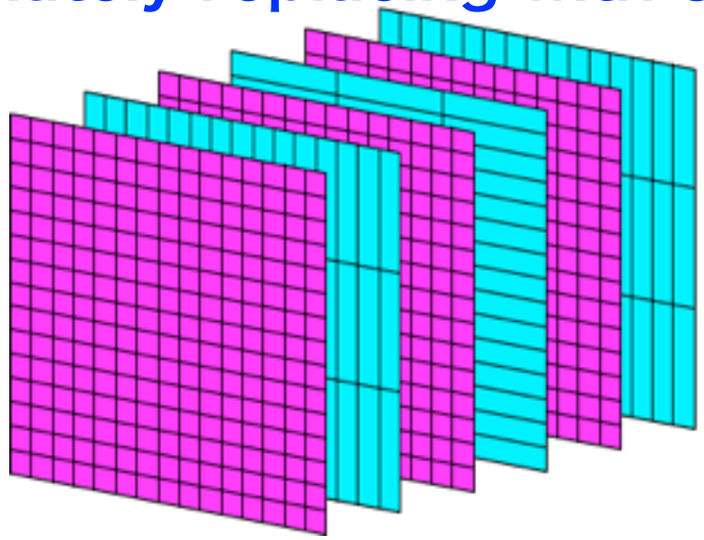
RMS90: RMS of 90% of center events

SSA makes JER of strip ECAL close to 5 x 5 mm² tile ECAL
Difference is only 0.2-0.3%.

Improve more



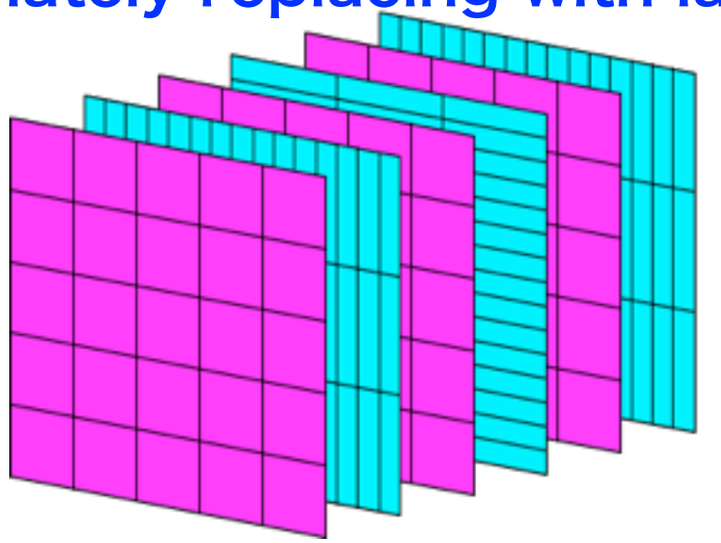
Alternately replacing with 5x5mm² tile layers.



note:
merit of orthogonal setting of strip layers does not work.

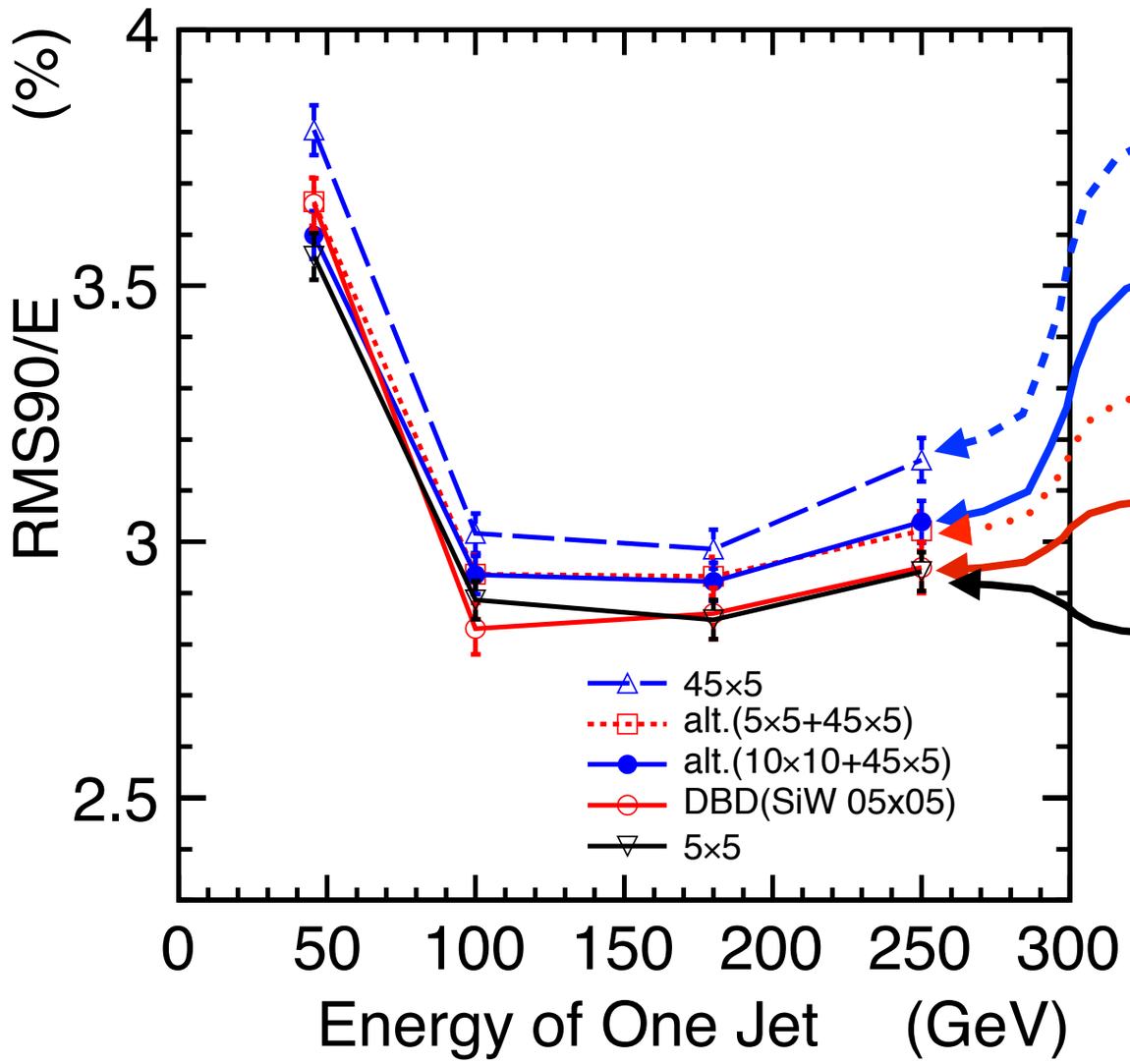
5x5mm² tile Si layer is one of option ▶ hybrid ECAL

Alternately replacing with large tile layers.



10x10 or 15x15mm² is reasonable to make pure scintillator ECAL

large tile-layers between strip-layers



45 x 5 mm² ScECAL w SSA

Alt.10x10 ScECAL w/ SSA

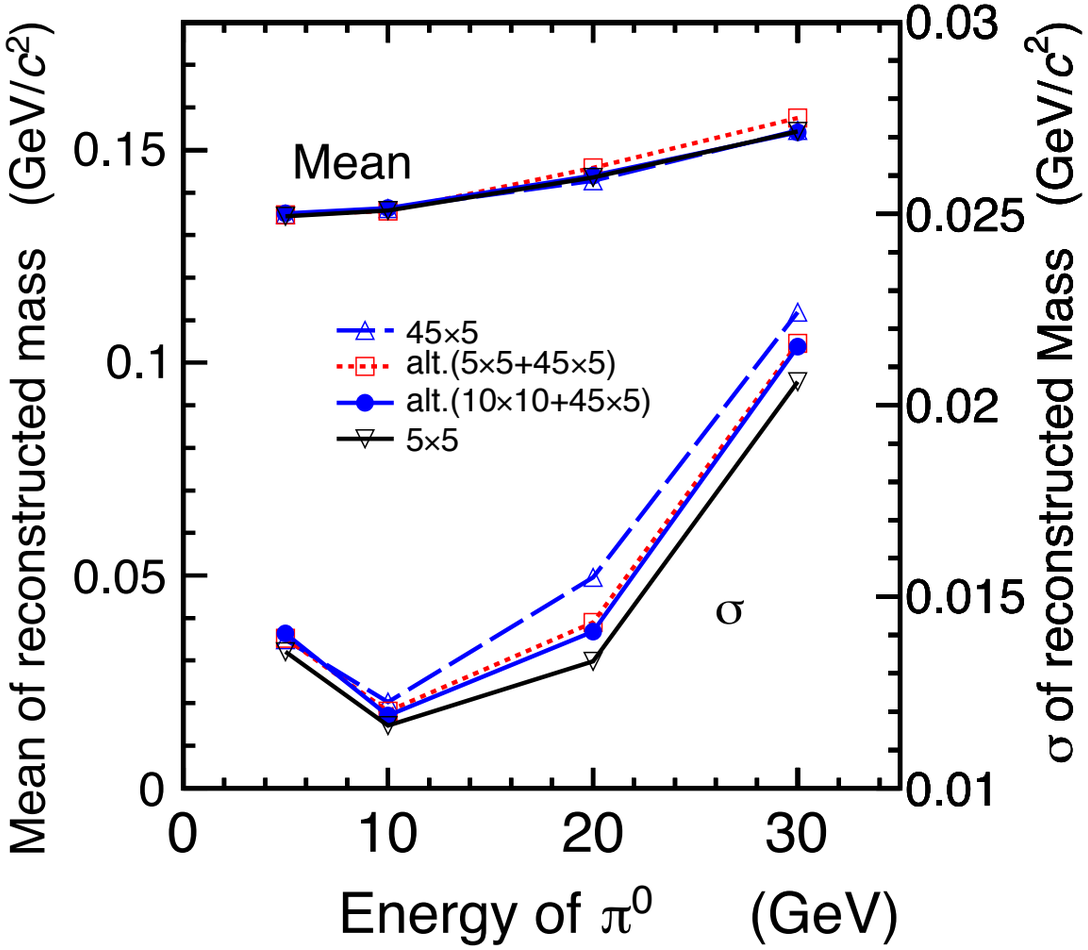
Alt.5x5 ScECAL w/ SSA

DBD result (SiW ECAL)

5 x 5 mm² tile ScECAL

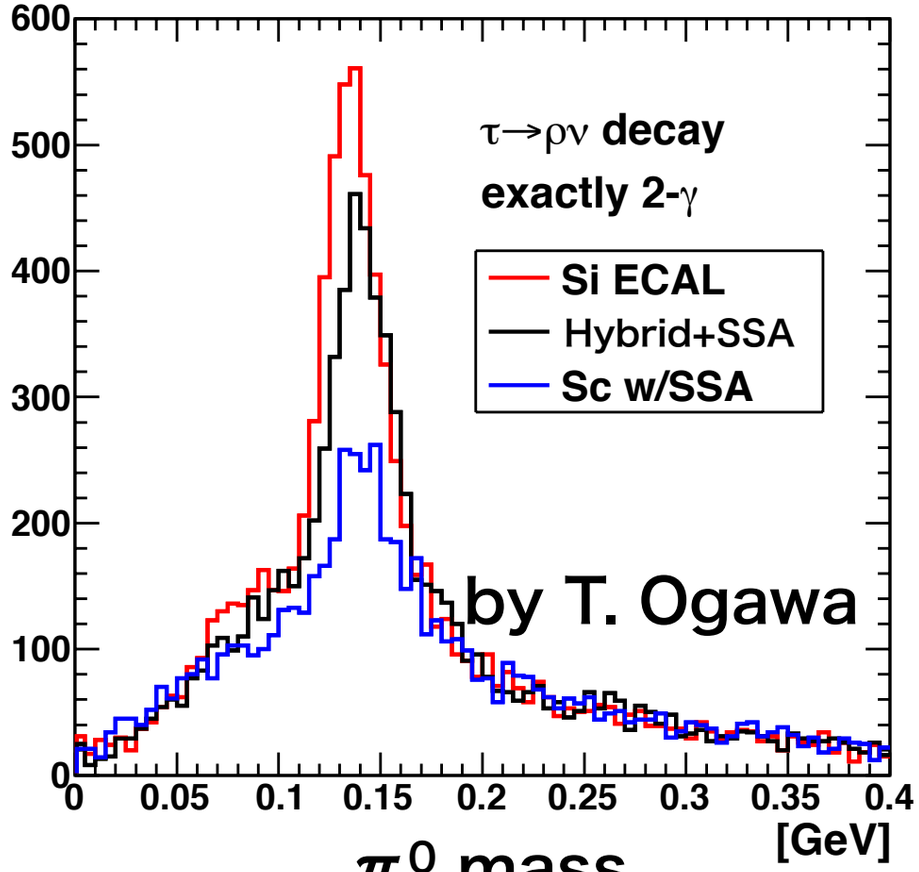
ScECAL **alternately** replaced strip layers with **10x10 mm²** layers has similar energy resolution to 5x5 mm² tile ScECAL (also DBD result with SiW ECAL) at $E_{jet} \leqq 100$ GeV, only **0.1%** degrades at **high energy.**

Performance on π^0 reconstruction



$\tau^{\pm} \rightarrow \rho^{\pm} \rightarrow \pi^{\pm}\pi^{0}$

τ pair in $\sqrt{s}$ = 500 GeV



π^0 mass

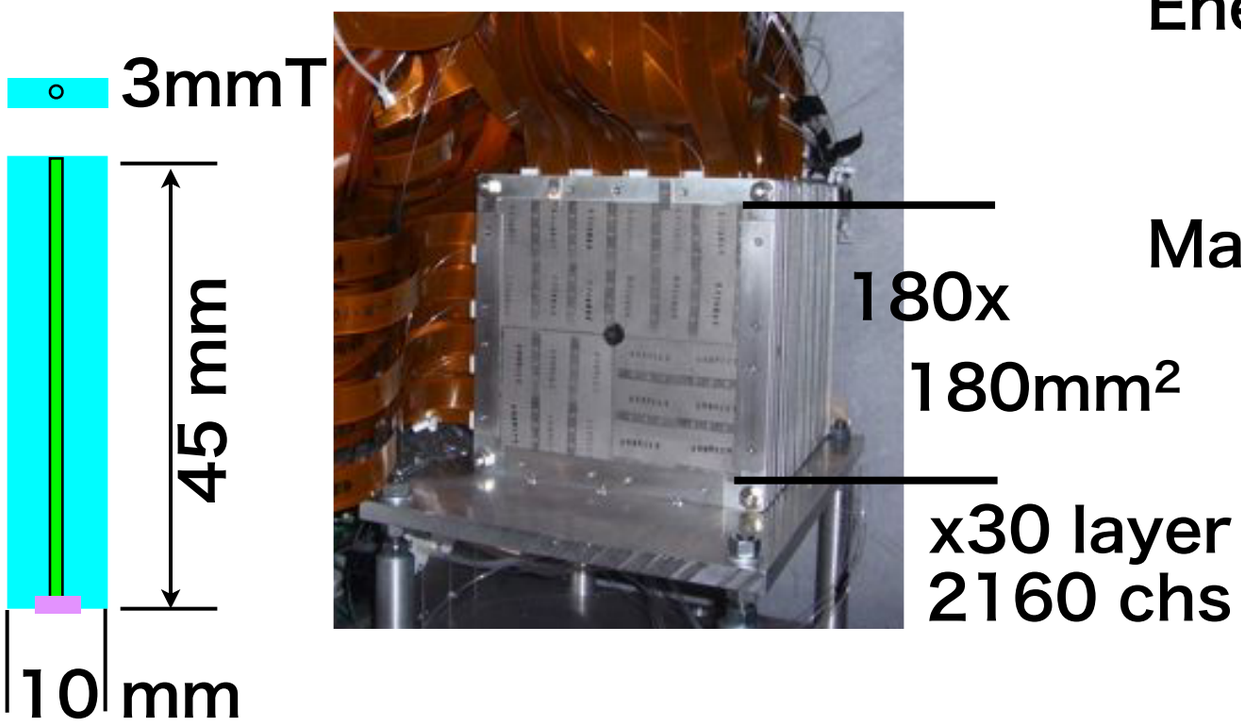
π^0 reconstruction is drastically improved with hybrid.

With tile layers, performance of ScECAL is more promising.

Realization of ScECAL in ILD

- Technological prototype -

Physics prototype



Test beam at FNAL 2009

Energy resolution (σ_E/E) 2 - 32 GeV e^-

$= (12.9 \pm 0.4/\sqrt{E} \oplus 1.2^{+0.4}_{-1.2})\%$

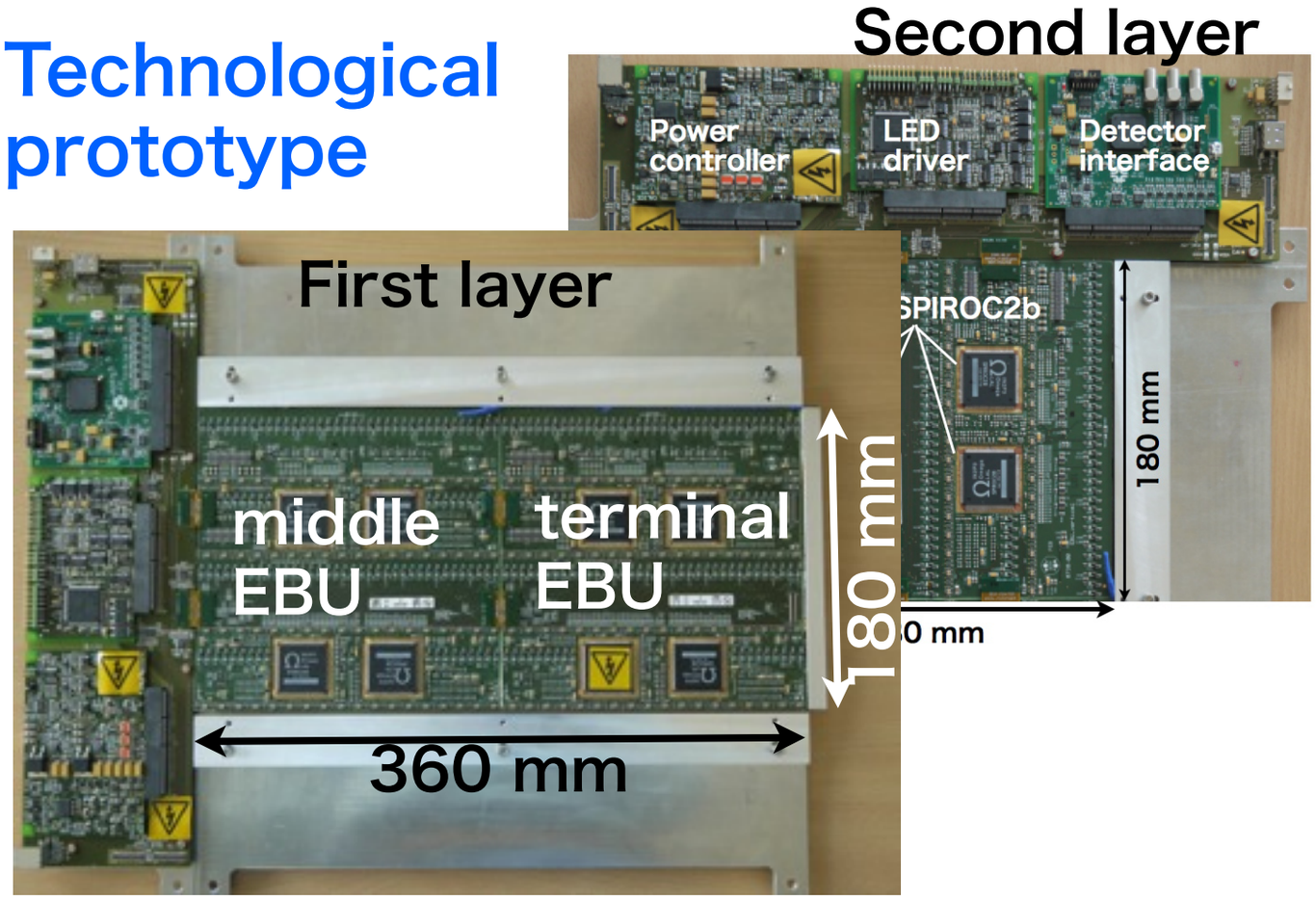
Max deviation from linear < 2%

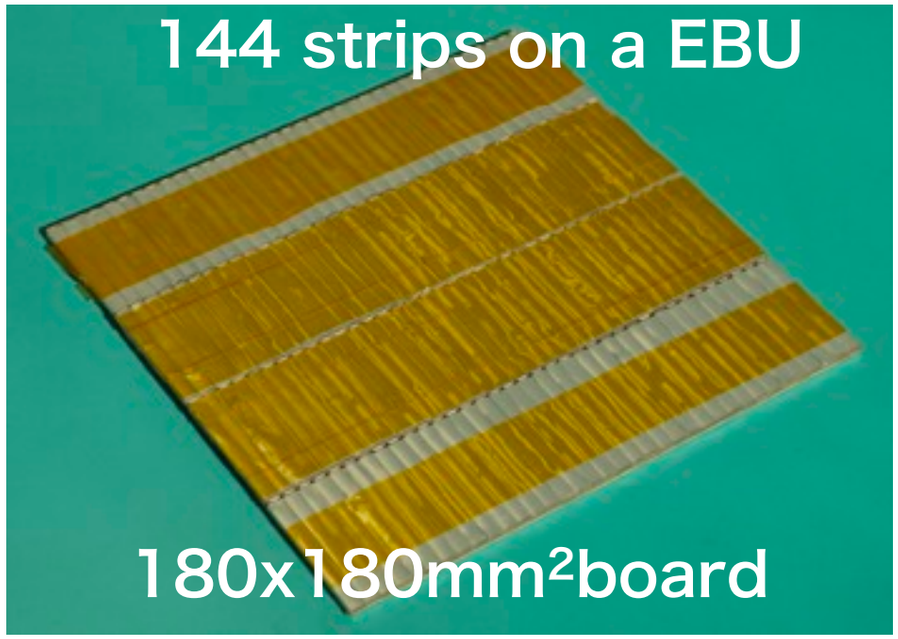
need to implement this system into real ILD-ECAL.

Technological prototype

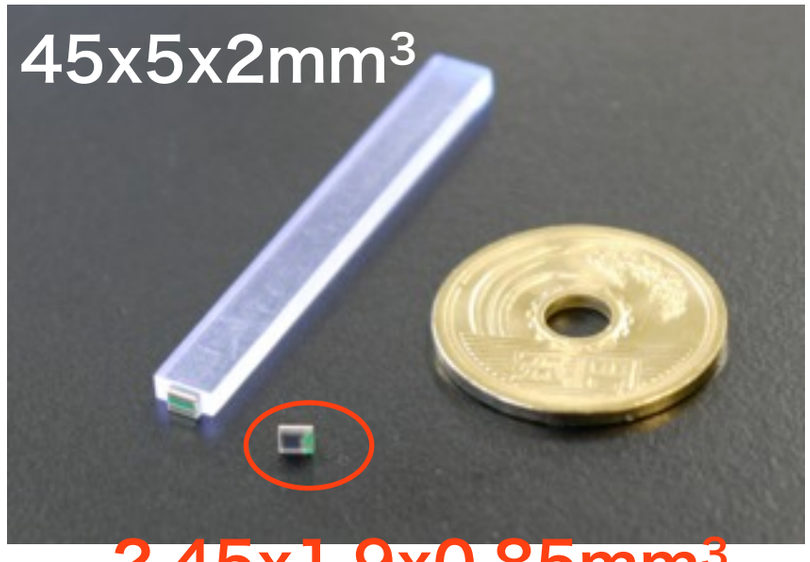
Technological prototype

Technological prototype



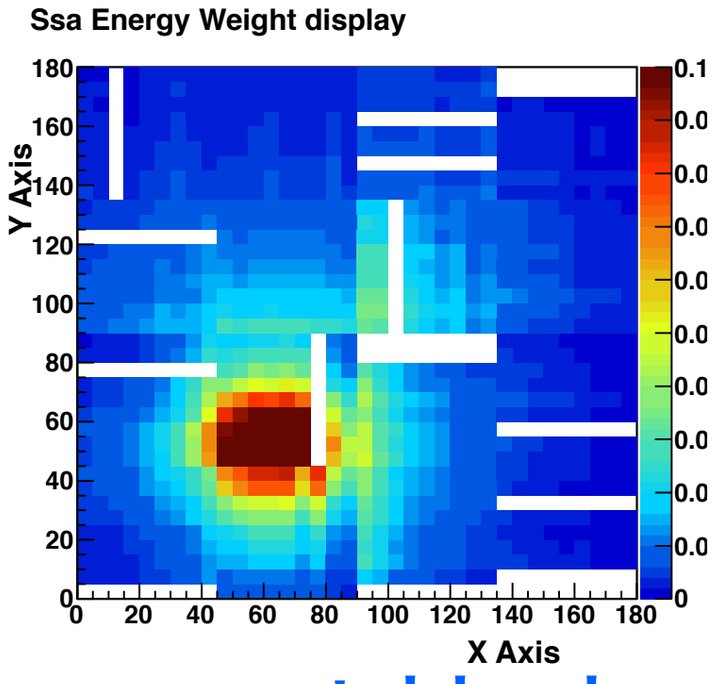


Front-end is embedded between layers



2.45x1.9x0.85mm³

Beam test at DESY July 2013

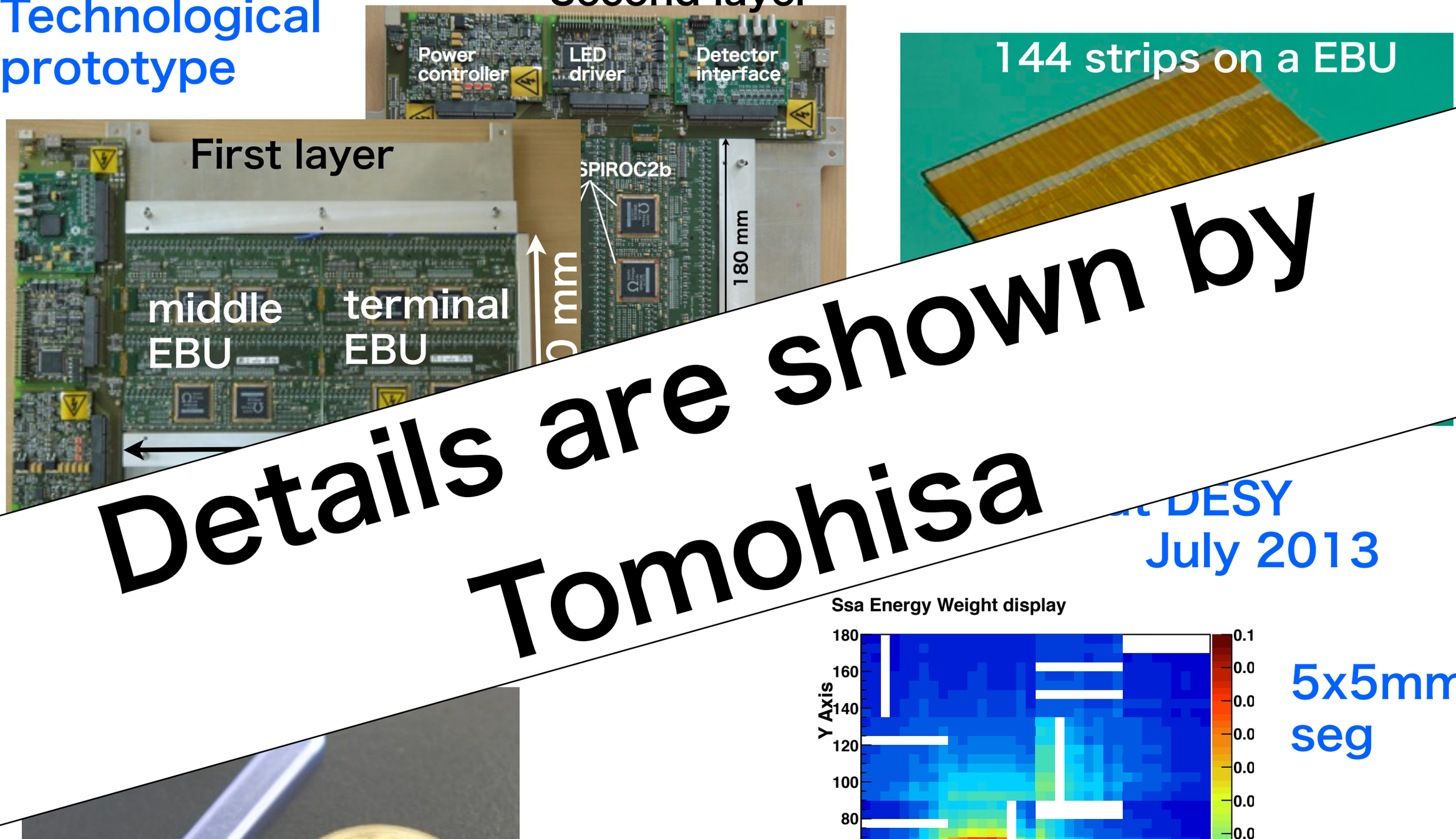


5x5mm² seg

Some unstable channels

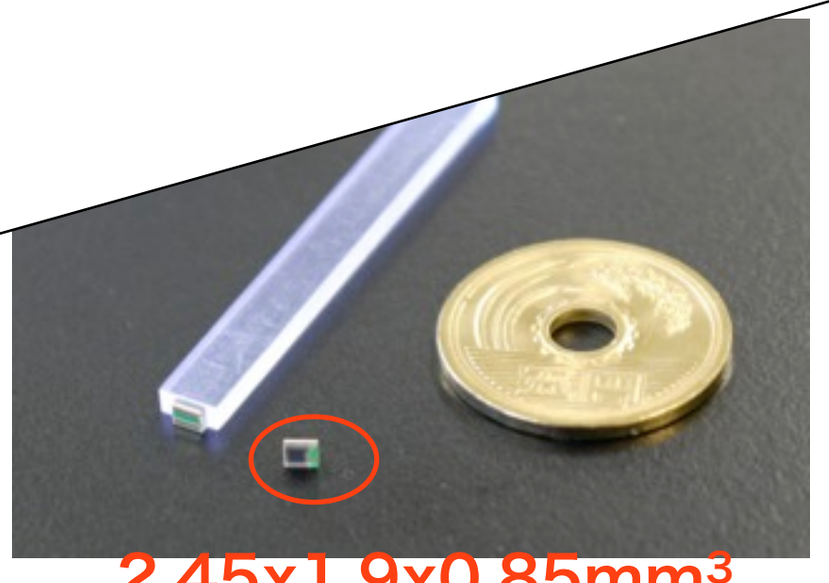
Technological prototype

Technological prototype



Details are shown by Tomohisa

at DESY July 2013



2.45x1.9x0.85mm³

5x5mm² seg

Some unstable channels

Scintillator/MPPC unit

Design is not yet fixed

Thickness of scintillator:

Reduction of total thickness : for the EM shower spread and also cost.
Thickness of readout baseboard : limited with industrial technology.
thinner scint. is better if we can make it w/o performance degrading.
▶Current effort: 1 mm thick scintillator tech. instead of 2 mm.

MPPC scintillator coupling:

Uniformity
Photon yield
Dead volume

We are gradually close to the best method

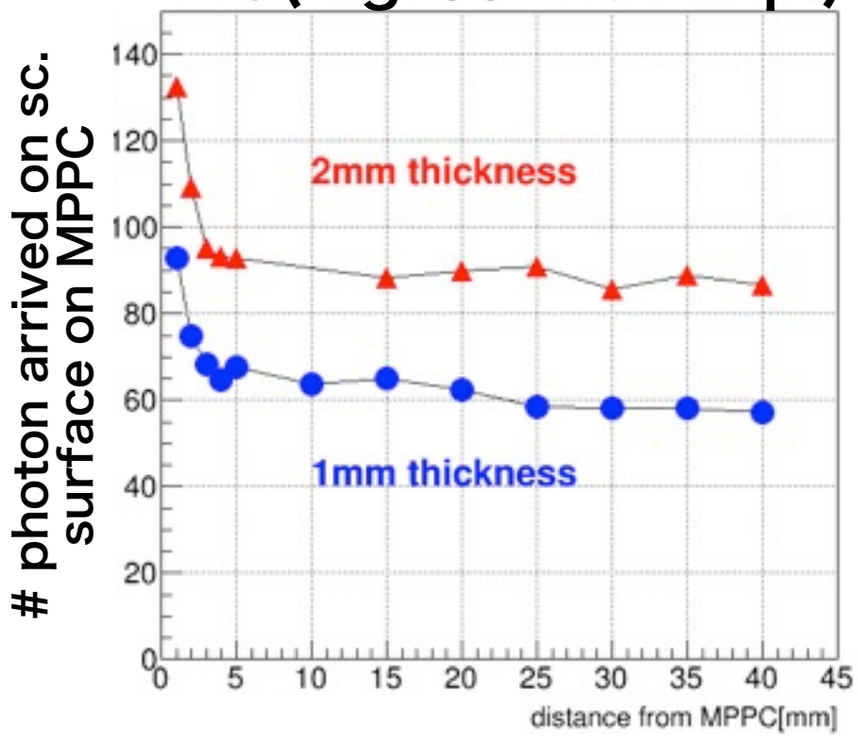
Reduction of thickness

- 1 mm thick corresponds to ~0.5 mm thick of Si sensor because of difference of the thickness of the baseboard.
  Sc: 1.2 mm, Si: ~2mm

- Ideal photon yield optimized between noise ratio and saturation is 7 p.e.

- Current design 45x5x2mm³, has ~ 7 p.e. yield at DESY TB
  1 mm thick reduces factor 2/3 ▶ need more p.e.

MC(agree with Exp.)

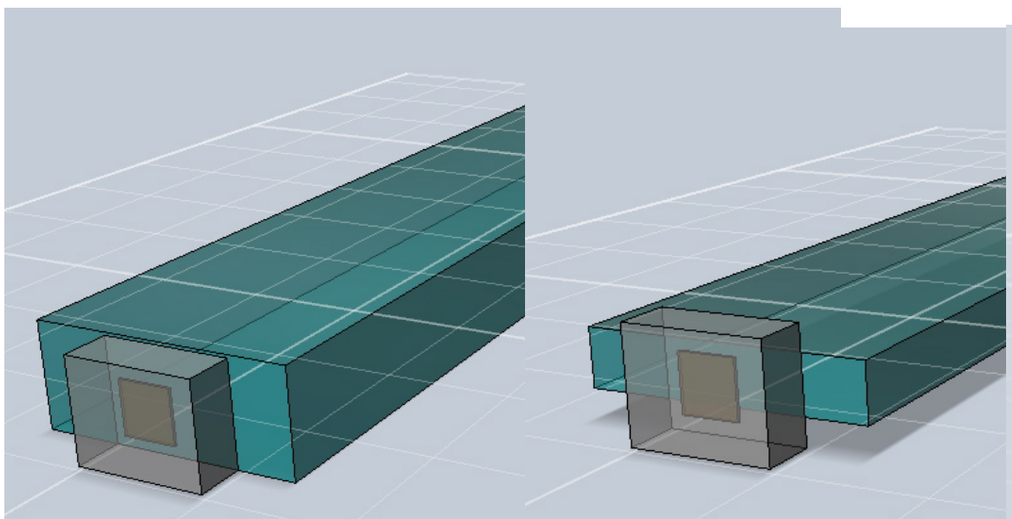


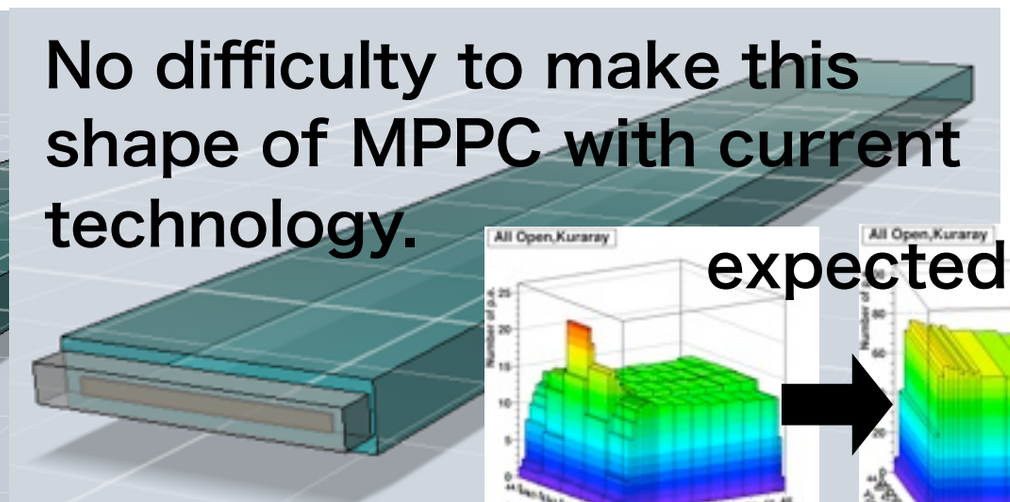
Tokyo group measured ~1.6 times larger photon yield with beta source than Shinshu with different scintillator material.

We are cross-checking together.

Scintillator / MPPC connection

- MPPC sensor area ▶ 0.25 mm x 4 mm for 1mm thick scintillator,

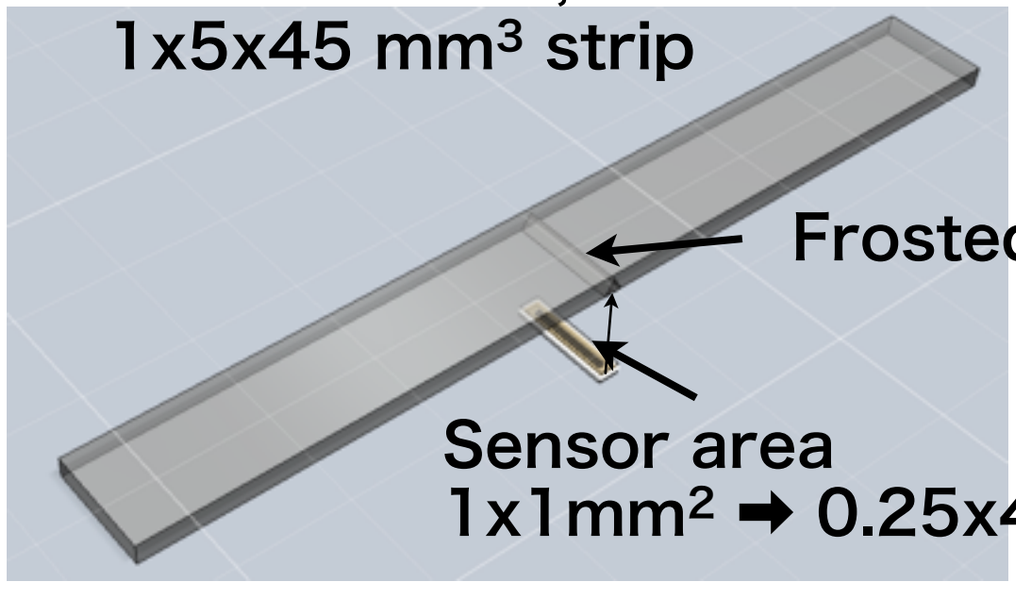




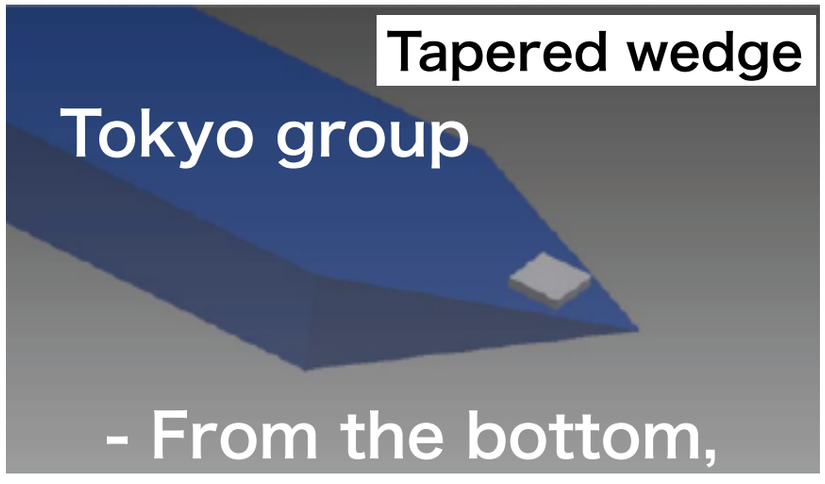
No difficulty to make this shape of MPPC with current technology.

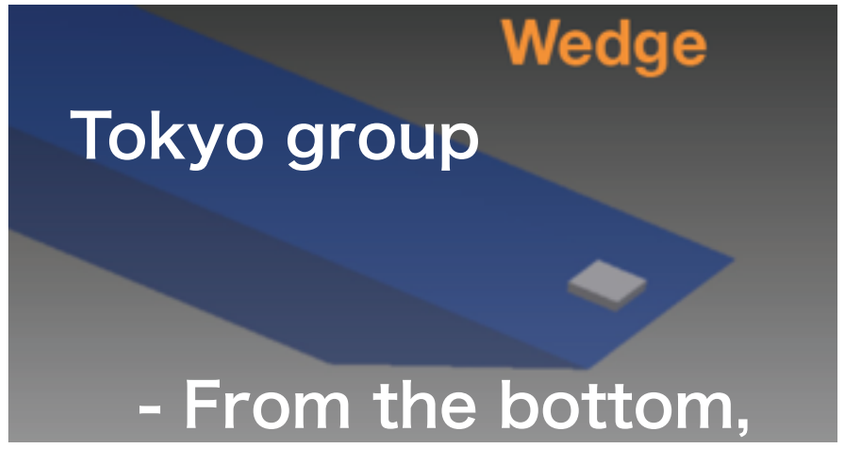
expected

- From the bottom,



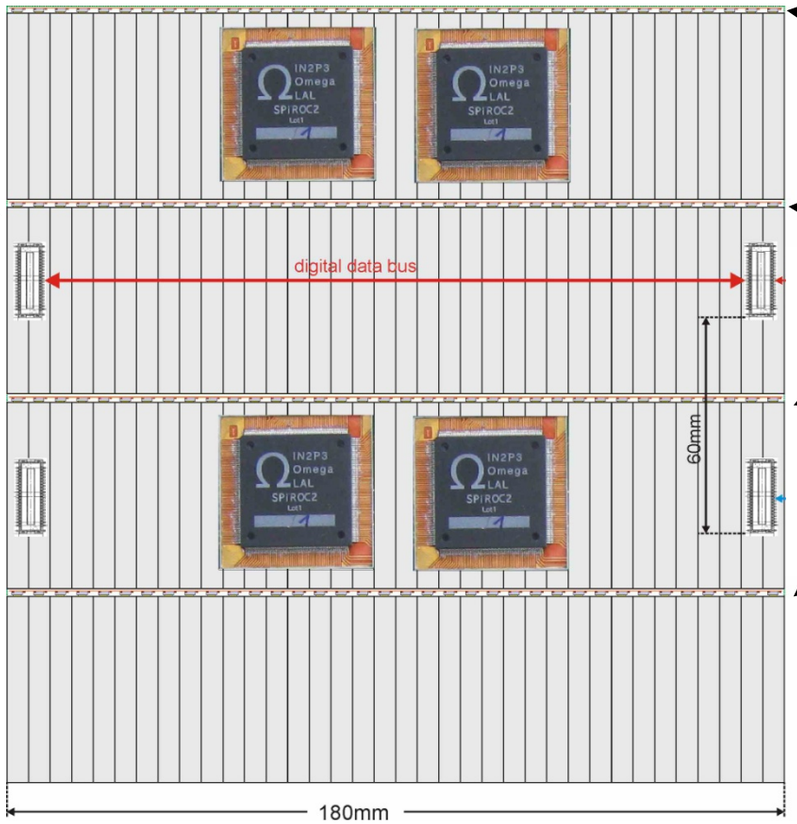
Bottom methods remove dead volume from MPPC





No dead volume from MPPC

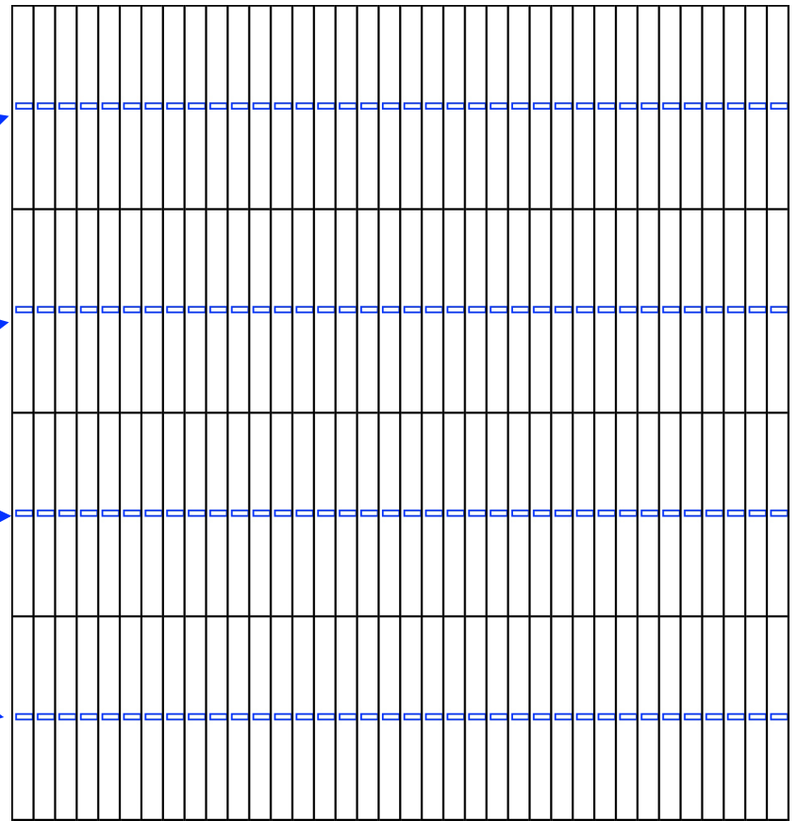
EBU (current design)



MPPC ladder
on edge

MPPC ladders
make dead
volumes

EBU (bottom readout)

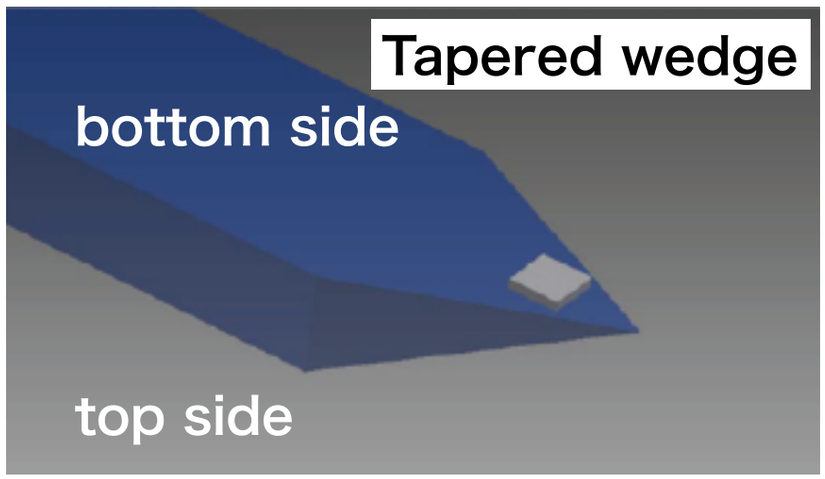


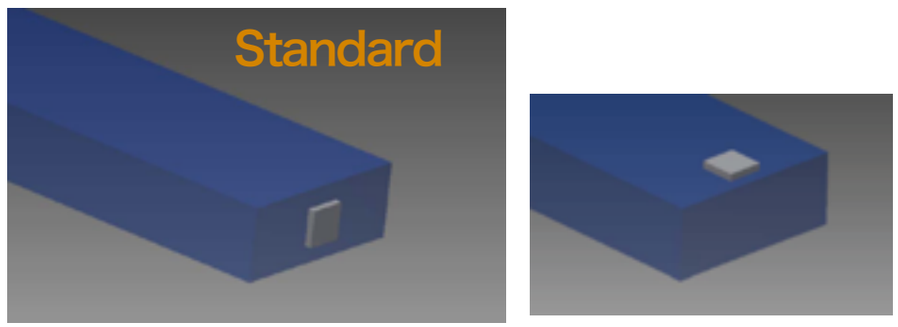
MPPC ladders
no dead volume

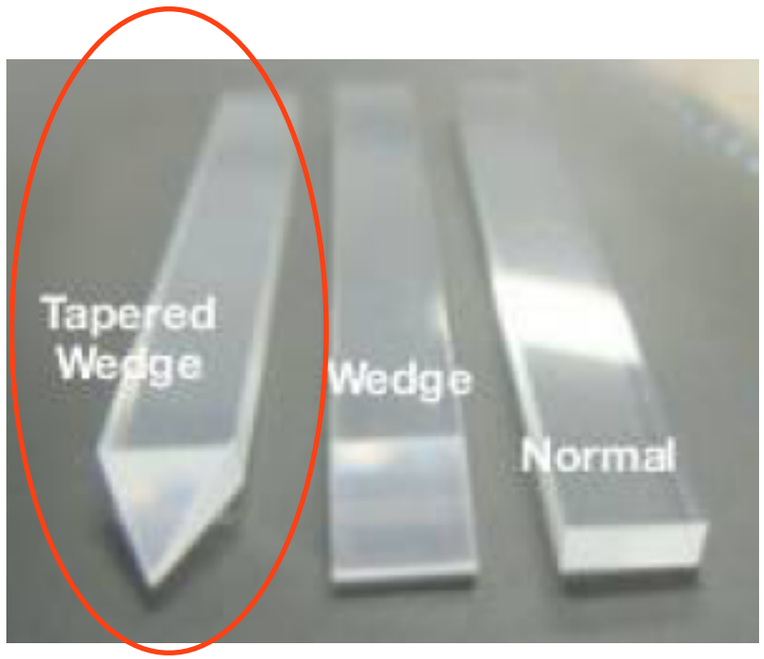
Stable MPPC

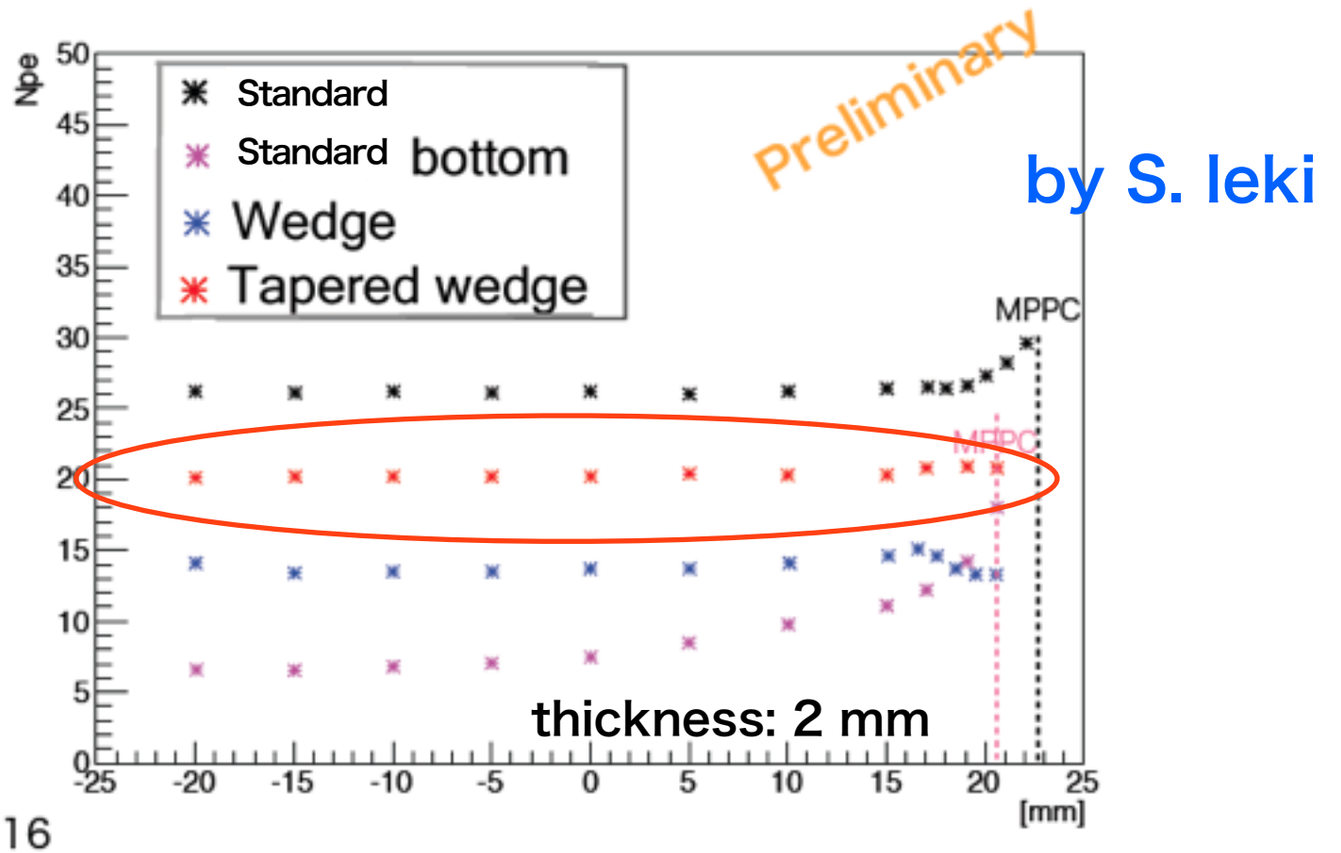
Tapered wedge has good uniformity and photon yield

- From the bottom with wedge by W. Ootani,





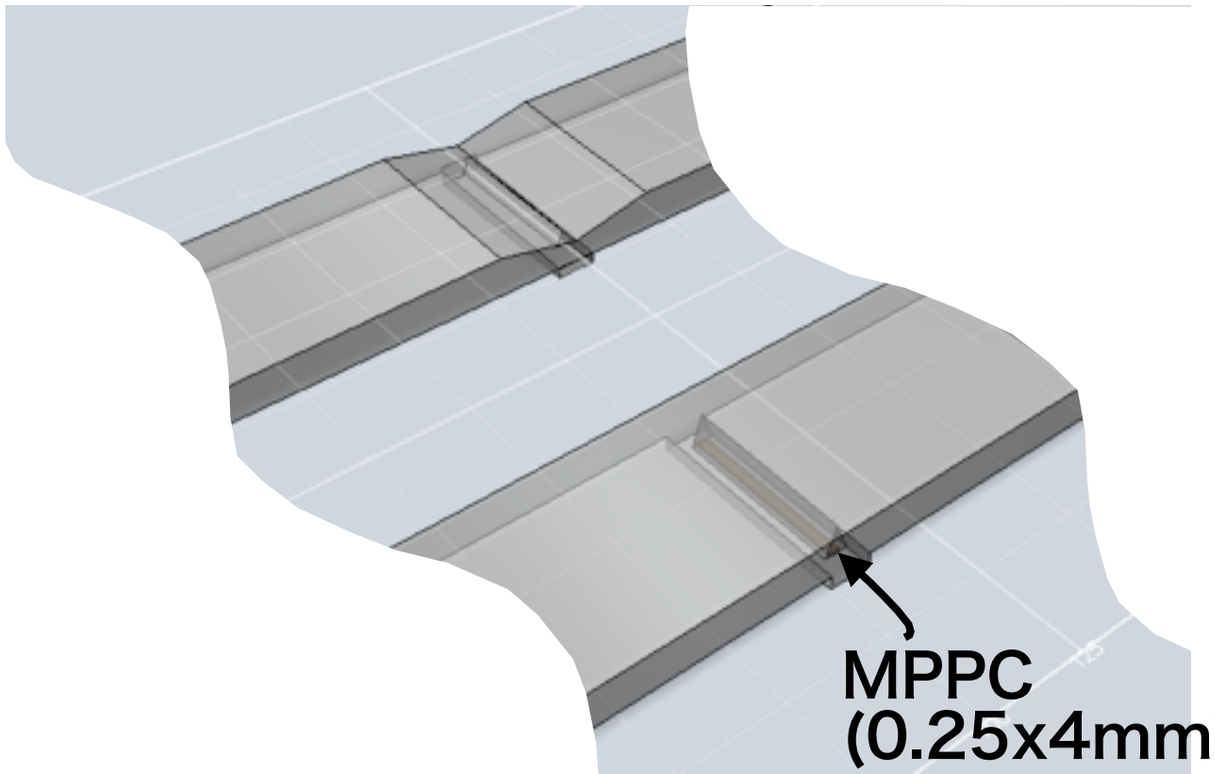


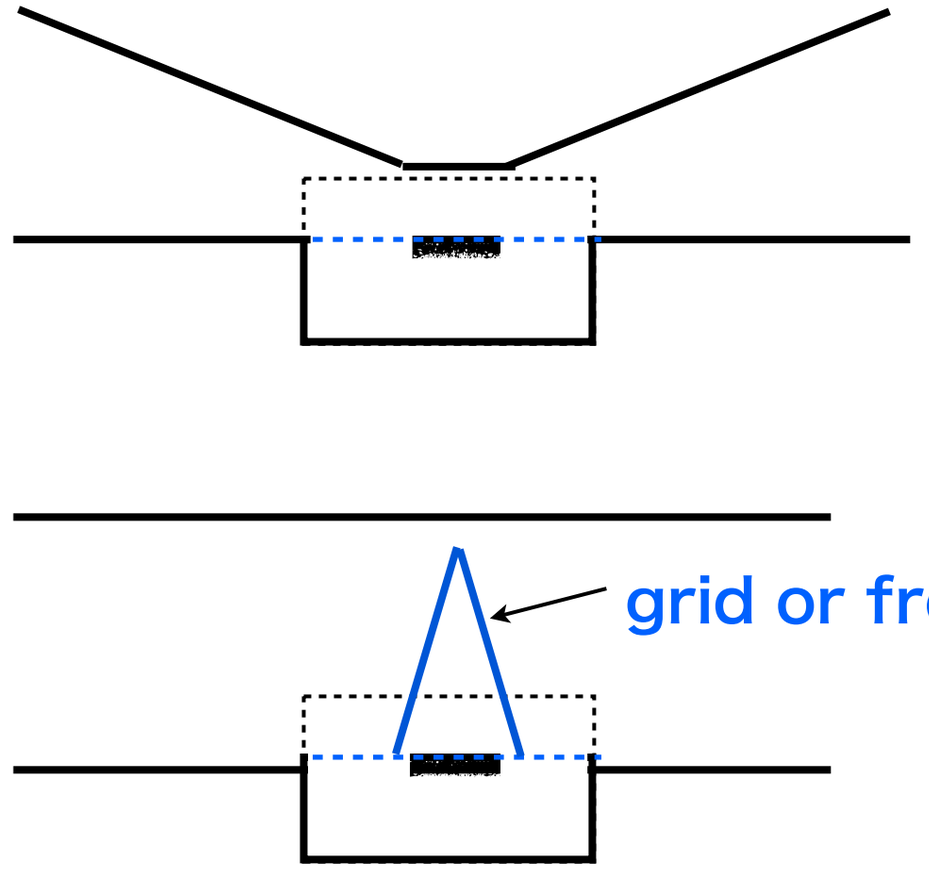


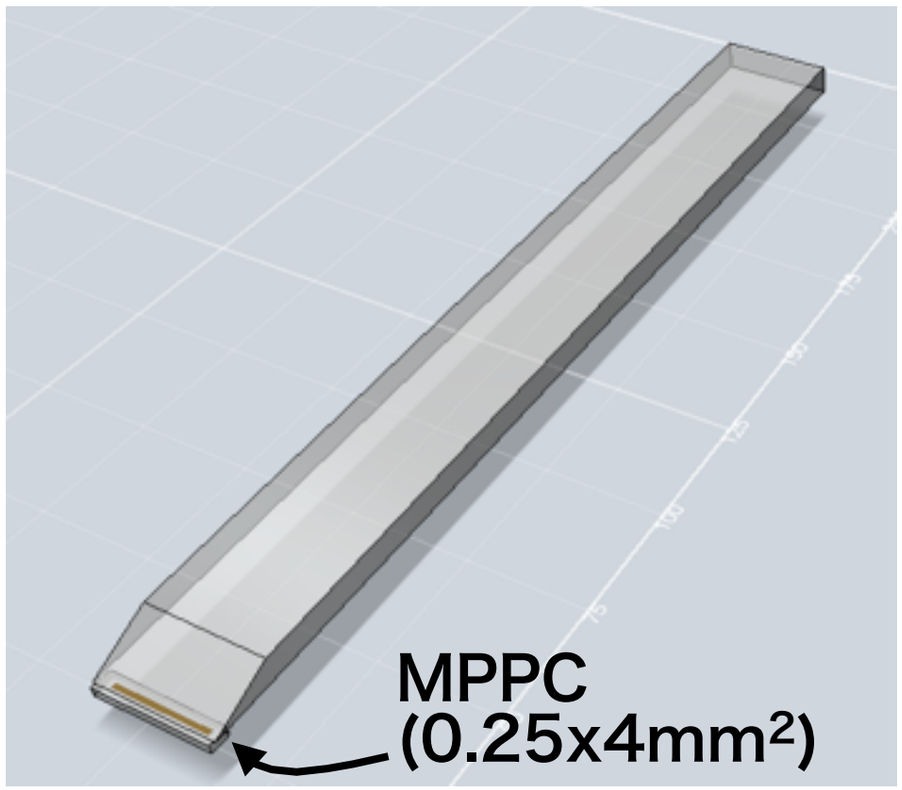
by S. Ieki

good photon yield and uniformity

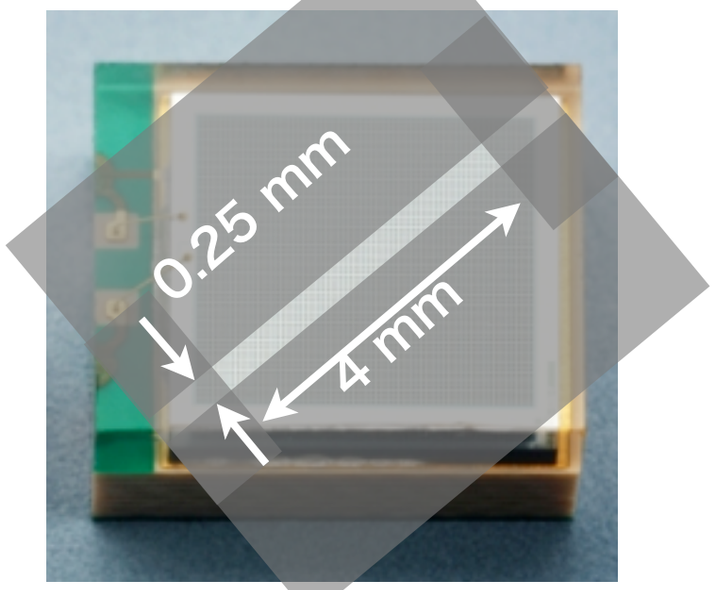
Wedge and long shape MPPC





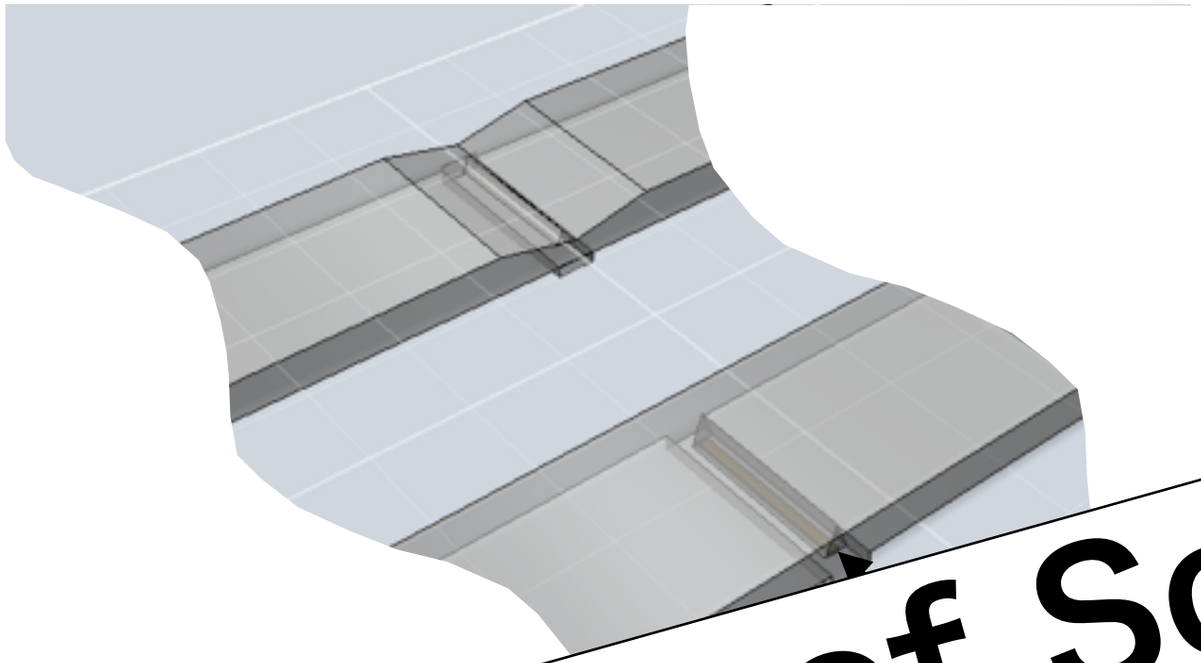


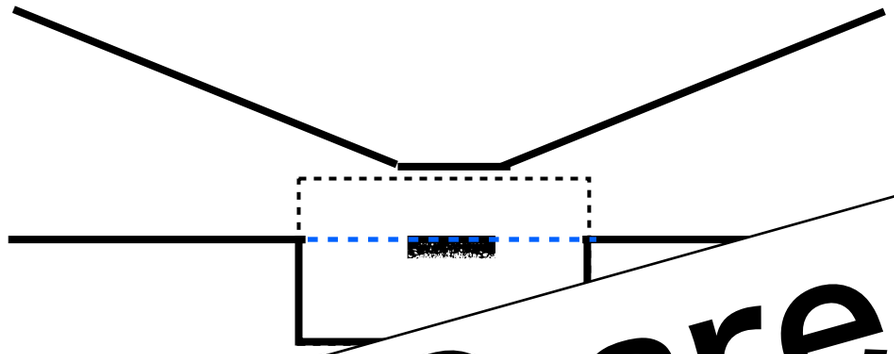
Temporary use 3x3mm² MPPC



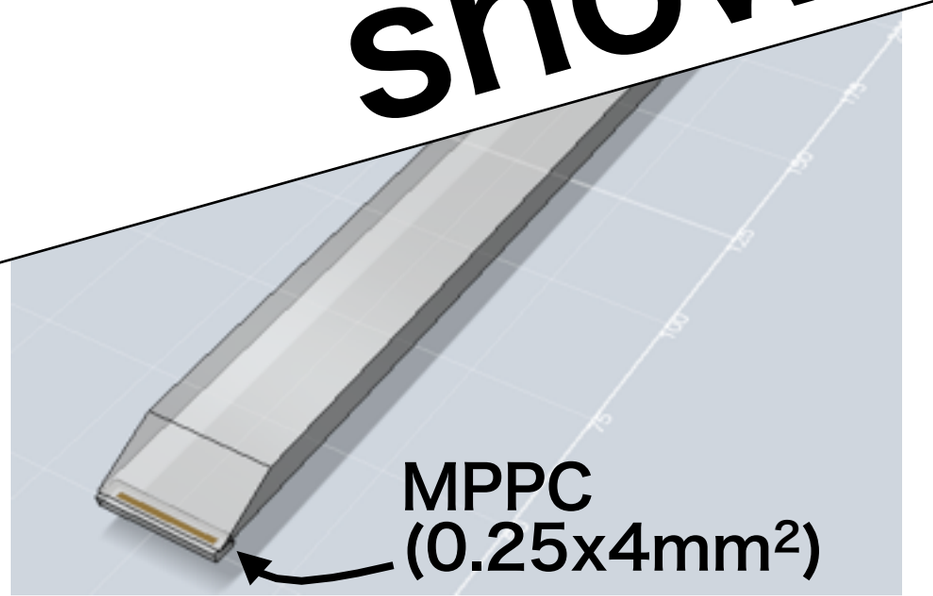
We have already discussed with HPK for new design.

Wedge and long shape MPPC

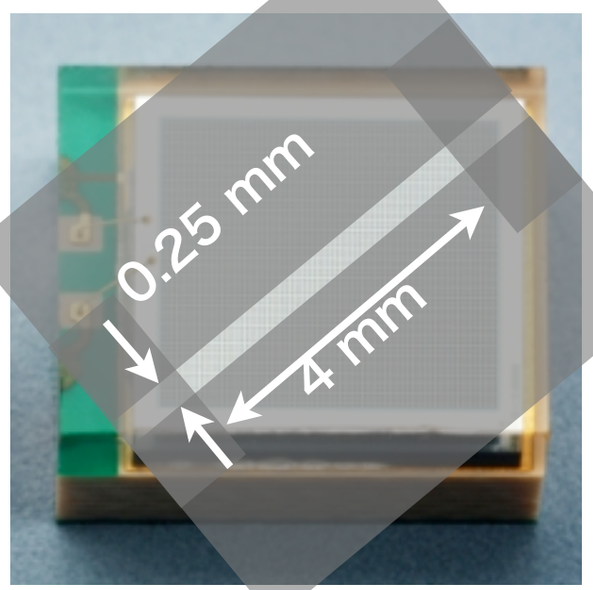




Details of Sci.MPPC are shown by Takuya



Temporary use 3x3mm² MPPC



We have already discussed with HPK for new design. Concerning thing is that small overhead of silicon makes a bit higher cost

MPPC development

MPPC development

previous
1600 pix MPPC

previous
2500 pix MPPC

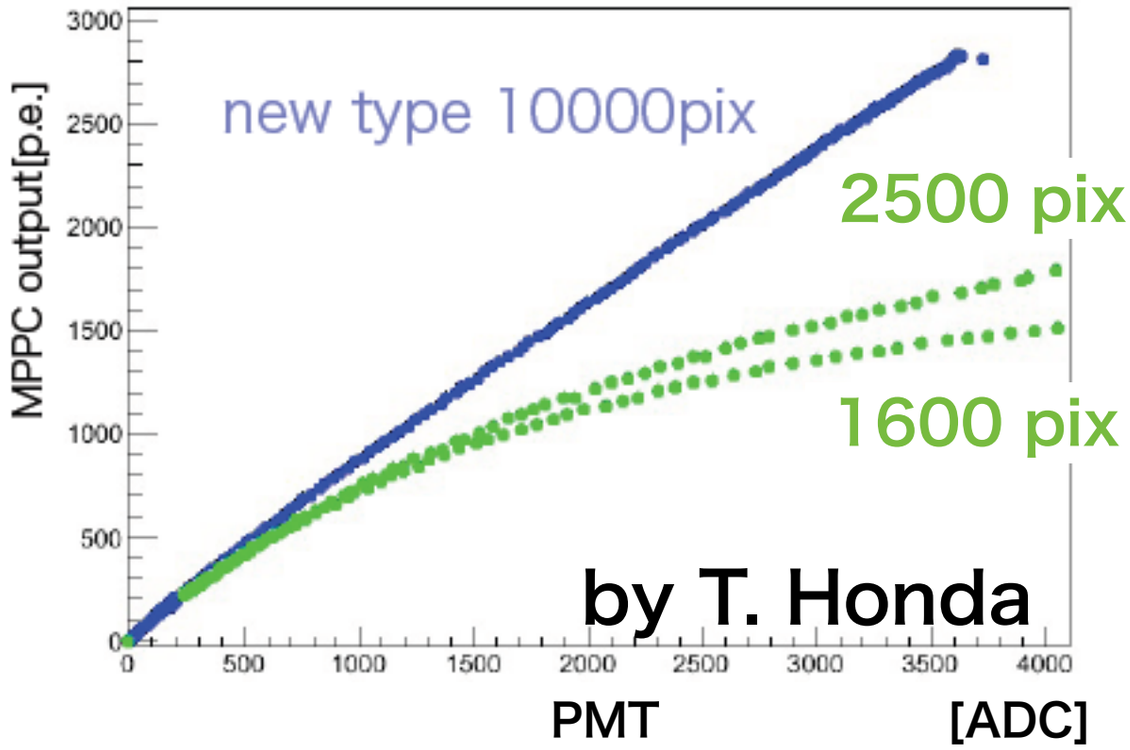
previous
4489 pix MPPC

Small dead area of new MPPC

New 1600 pix

New 4489 pix

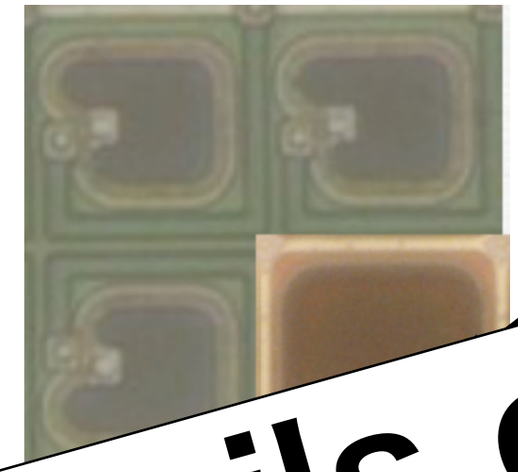
10000 pix with new technology



Low noise, low temp. dependence, high PDE

MPPC development

previous
1600 pix MPPC



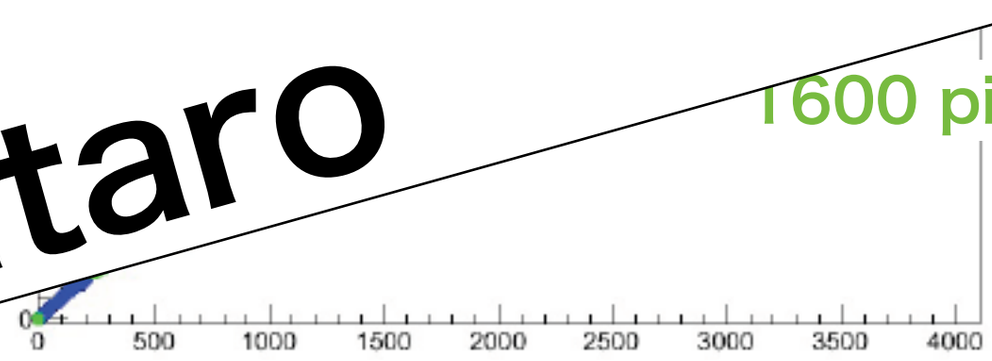
Small dead area of new MP

New 16

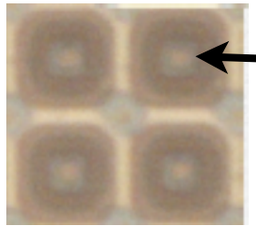
previ

Details of MPPC development are shown by Ryutaro

1600 pix



New 4400 pix



10000 pix with new technology

Low noise, low temp. dependence, high PDE

Next plan

Design:

- Fix scintillator/MPPC design in next year
- Study on combination of 10000 pix MPPC and scintillator
- Study of thinner readout board

Technological prototype:

- robust readout electronics
- Power pulsing technique

Performance in ILD (JER, particle separation, physics)

Effect from:

noise, saturation of MPPC, non-uniformity of scintillator strip, and dead channels

should be studied

Hybrid construction with SiECAL group

Mass production

We started contact with scintillator makers, a tungsten maker and a company who makes machines for chewing gam wrapping.

More application

Strip AHCAL by using SSA,

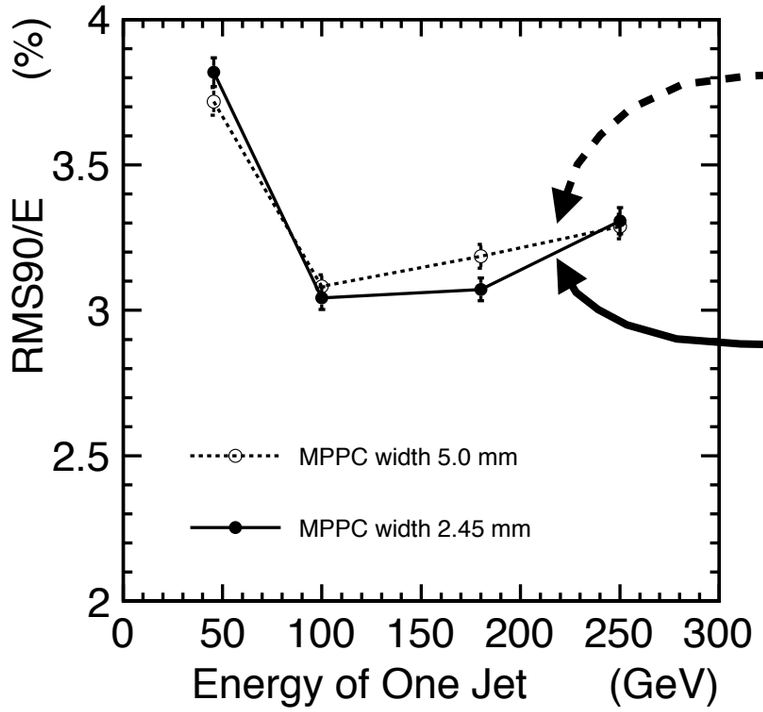
Summary

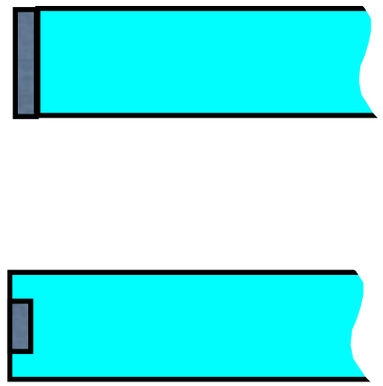
- We are developing a scintillator strip ECAL for linear colliders with scintillator strips and MPPC.
- Performance in ILD is already promising with SSA.
  - Options for higher goal,
    - alternately replacing w/ 5x5mm^2➡hybrid,
    - alternately replacing w/ 10x10mm^2➡pure ScECAL,
- Efforts for reality are exerted to,
  - detail optimizations of Sc./MPPC connection to get higher goal and we are gradually getting the goal,
  - robust readout electronics.
- In next step,
  - we will fix detail design,
  - test beam:
    - the power pulsing technology,
    - hybrid ECAL.

Paper: DESY → submitted to NIM, FNAL → under brushing up.

Back up

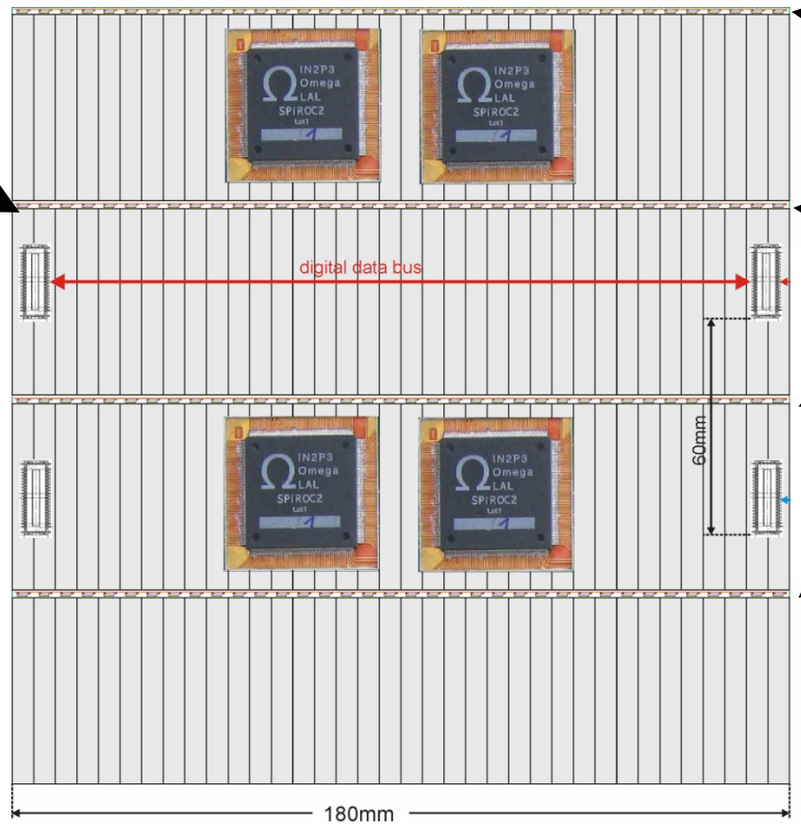
No dead volume from MPPC





Although not so serious for JER, ...

EBU (current design)



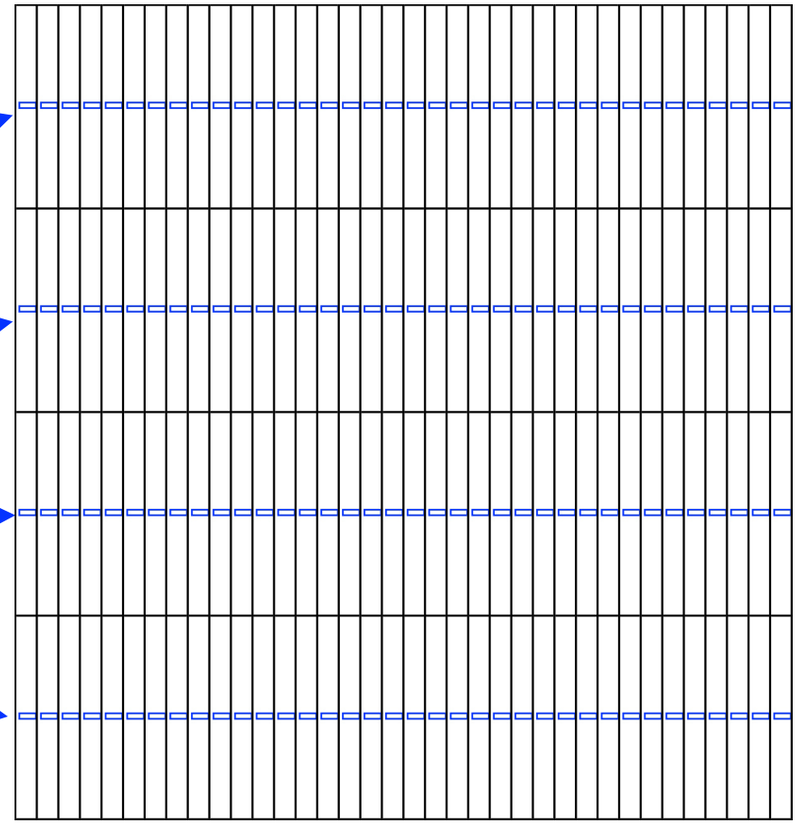
MPPC ladder on edge

MPPC ladders make dead volumes

EBU (bottom readout)

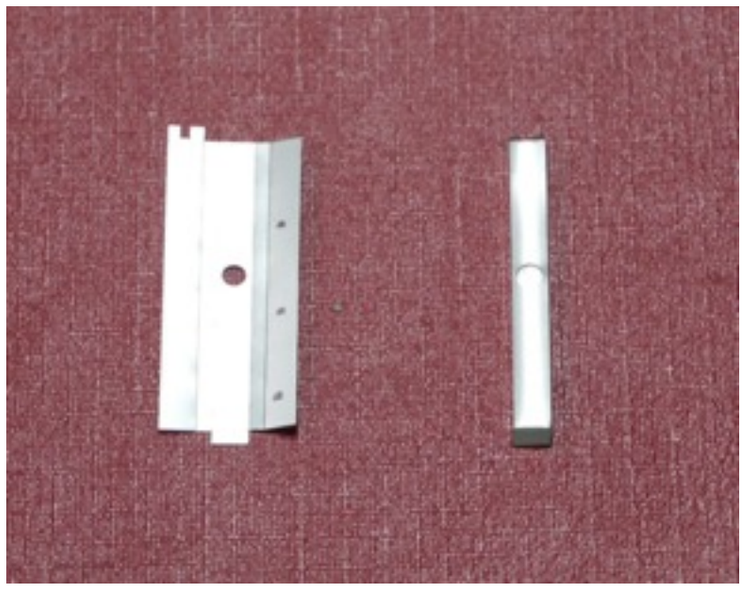
MPPC ladders no dead volume

Stable MPPC



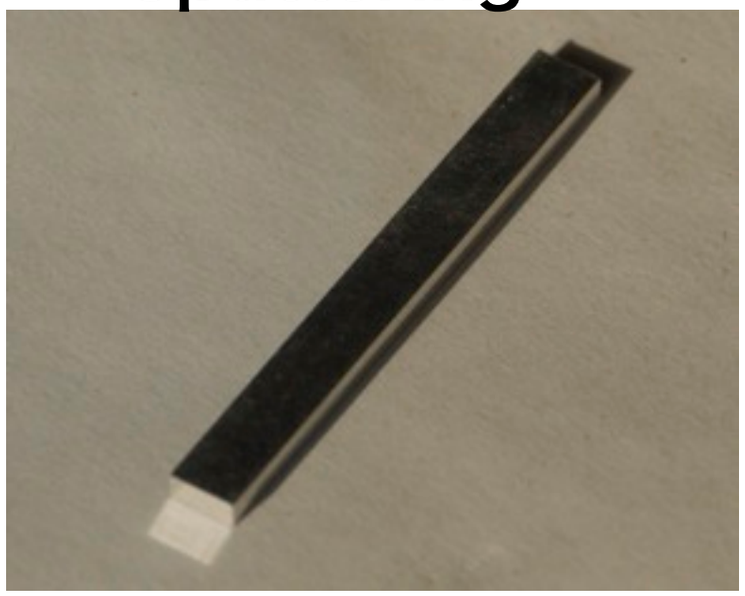
Persistent challenge to spattering

Reflector film



- Already enough reflection,
- a little complex procedure to make,

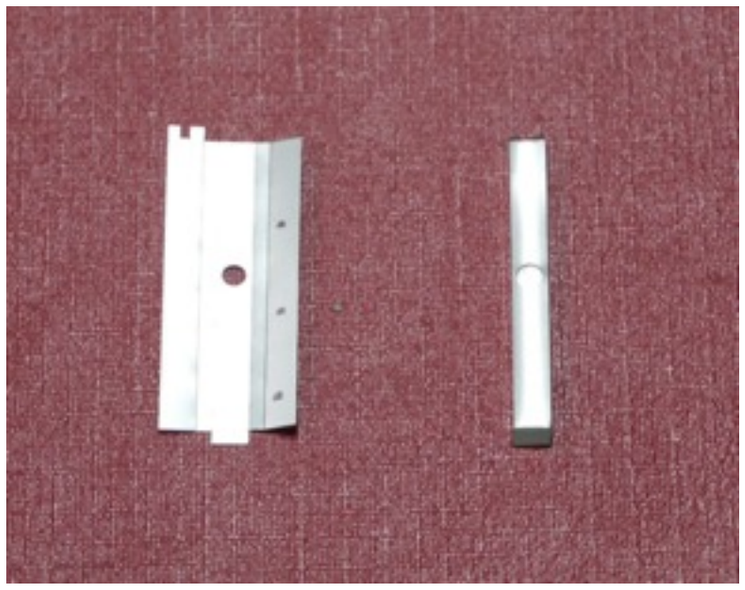
Spattering



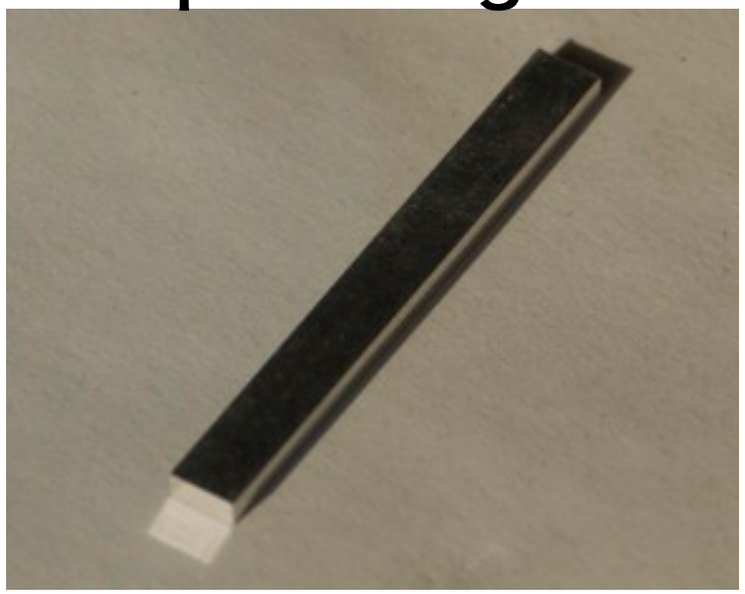
- So far, not enough reflection,
- Once we resulted that spattering method does not work!
- help easy construction,
- One more challenge with 200 nm silver alloy,
  ▶ongoing (at LCWS),

Persistent challenge to spattering

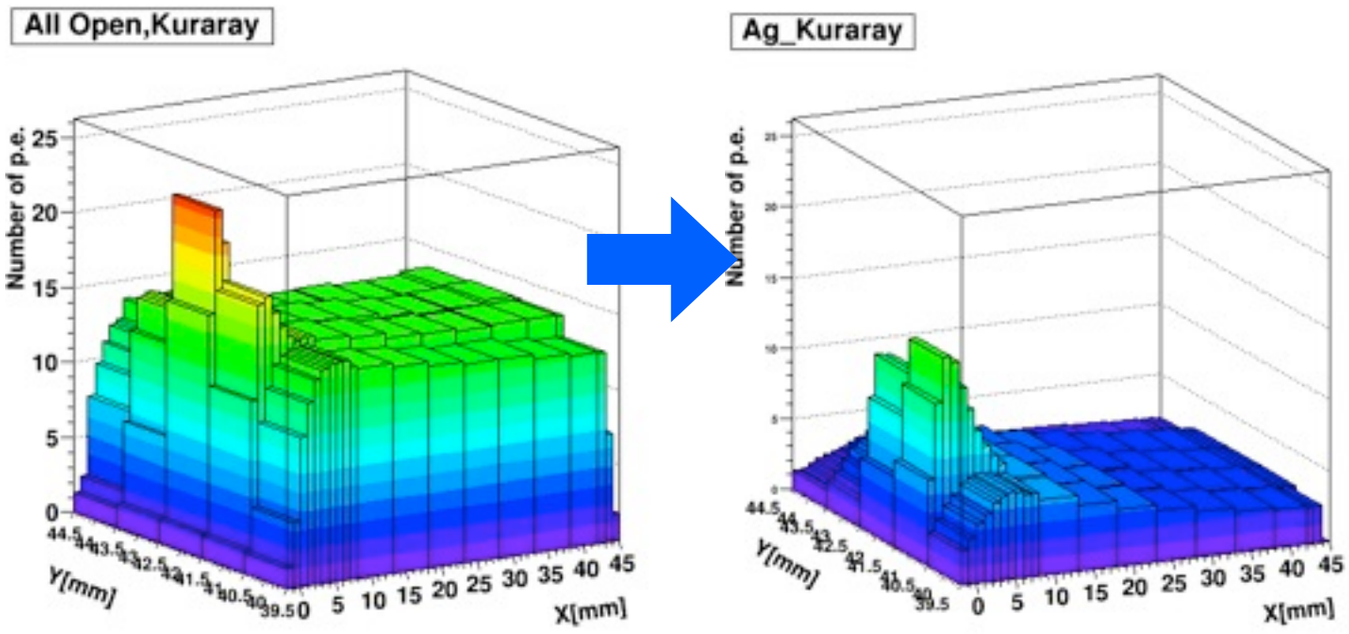
Reflector film



Spattering

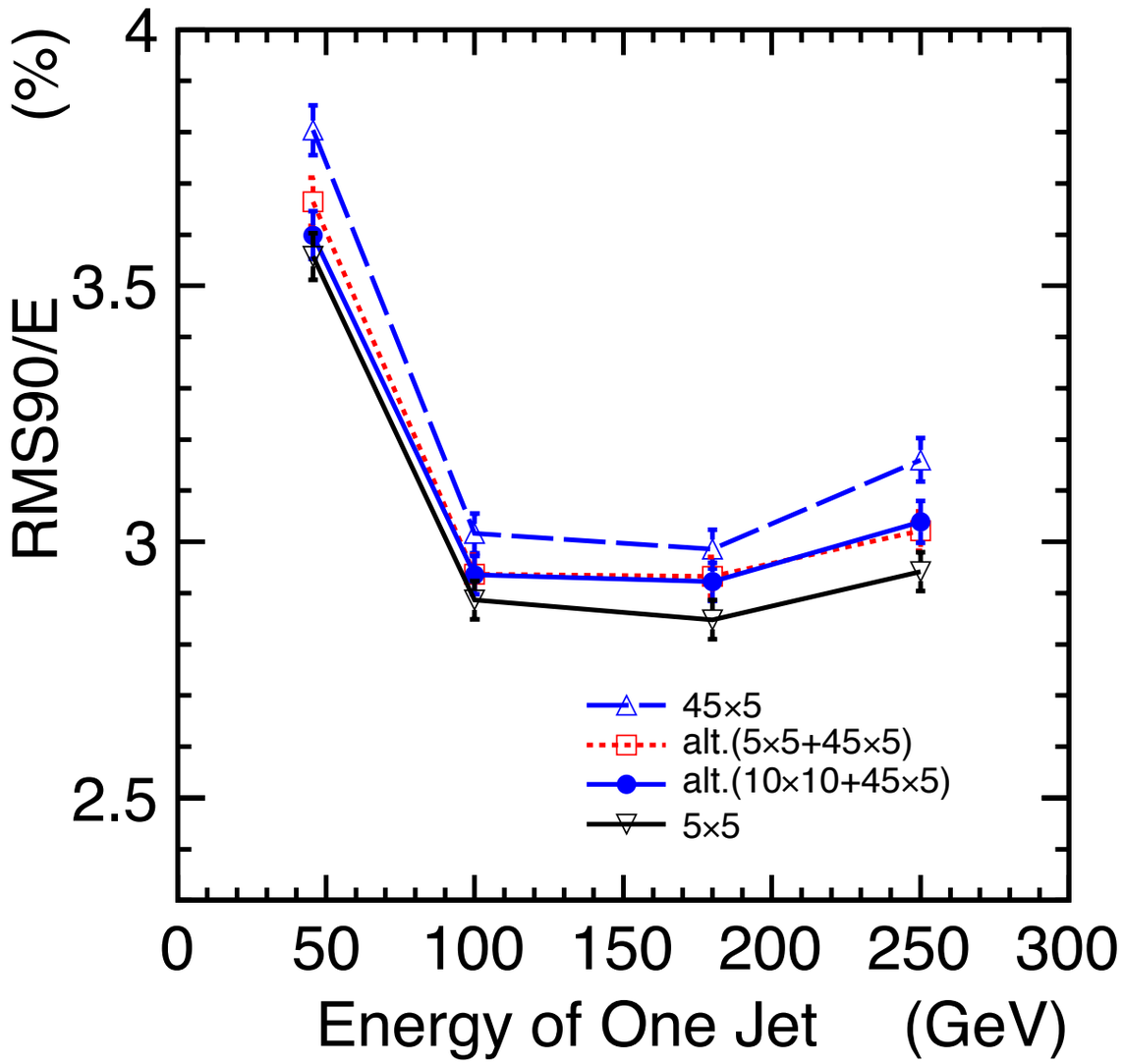


- Already enough reflection,
- a little complex procedure to make,



- So far, not enough reflection,
- Once we resulted that spattering method does not work!
- help easy construction,
- One more challenge with 200 nm silver alloy,
  ▶ongoing (at LCWS),

Jet energy resolution of the case alternately replaced with tile layers



- alternately replacing with tile layers have significant improvement of jet energy resolution,
- effect of 10x10 mm² layers is the same as 5x5 mm² layers,
- effect of 15x15 mm² layers is not so large, although the plot is not shown here.

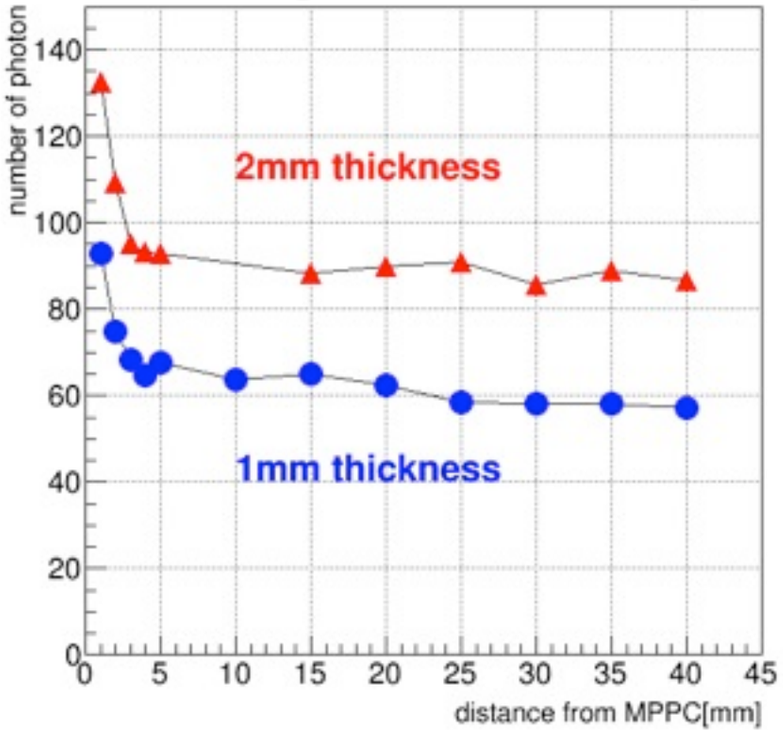
Challenges to be overcome

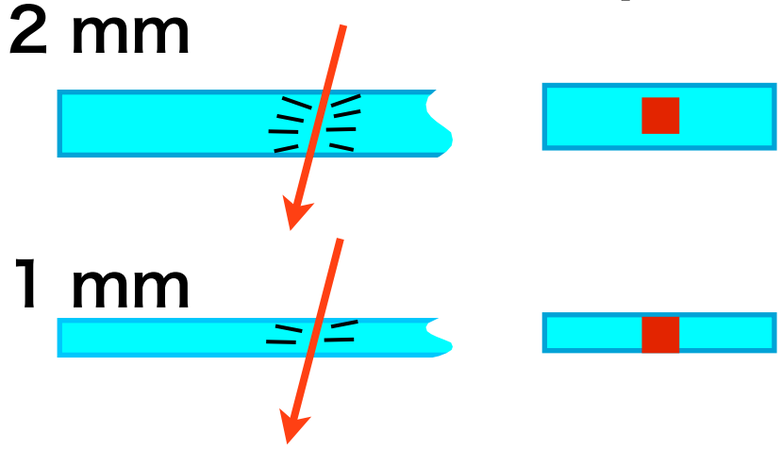
MPPC/Scintillator Unit(1)

Thickness 2mm ▶ 1mm, Thinner Ecal ▶
Short radius ▶ Small Magnet ▶ Low cost.

Confirm Energy resolution of 1 mm thick scintillator,
- photon yield (> 7 p.e.),
  current design 45x5x2mm^3, has ~ 7 p.e. yield at DESY TB
  1 mm thick reduces factor 2/3 ▶ need more p.e.

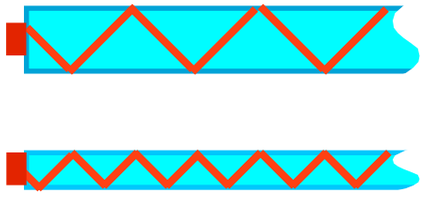
MC(agree with Exp.)





thick(mm)	photon yield@sc	MPPC/ Sci cross section
1	1 : 2	
2	2 : 1	

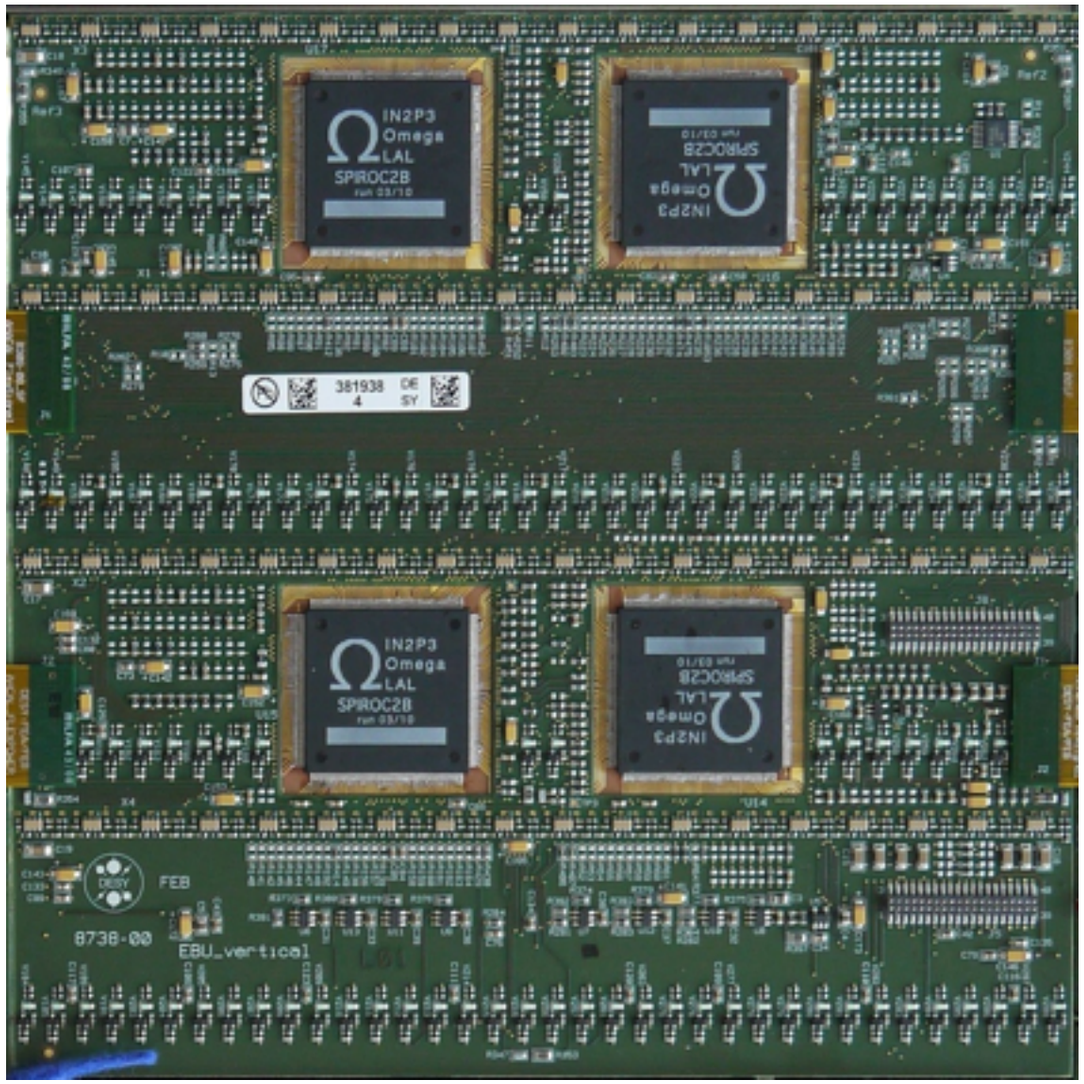
Compensate



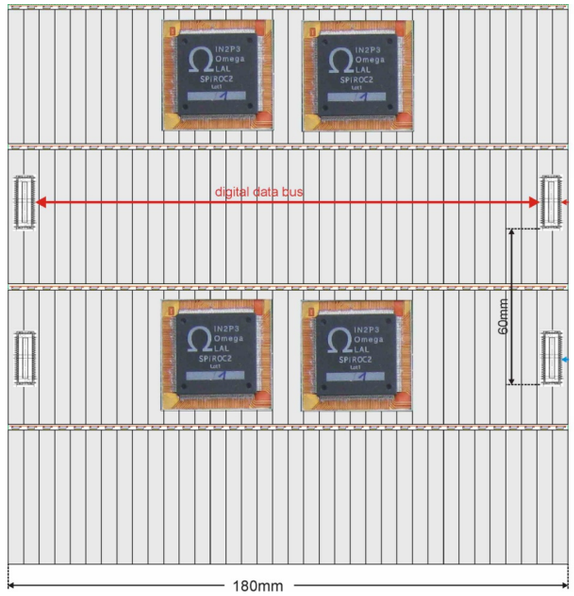
: the number of reflection times is doubled in
1mm T scintillator ▶ 2/3 ~ (ref.ratio)^(ref times)

Challenges to be overcome

Thinner EBU

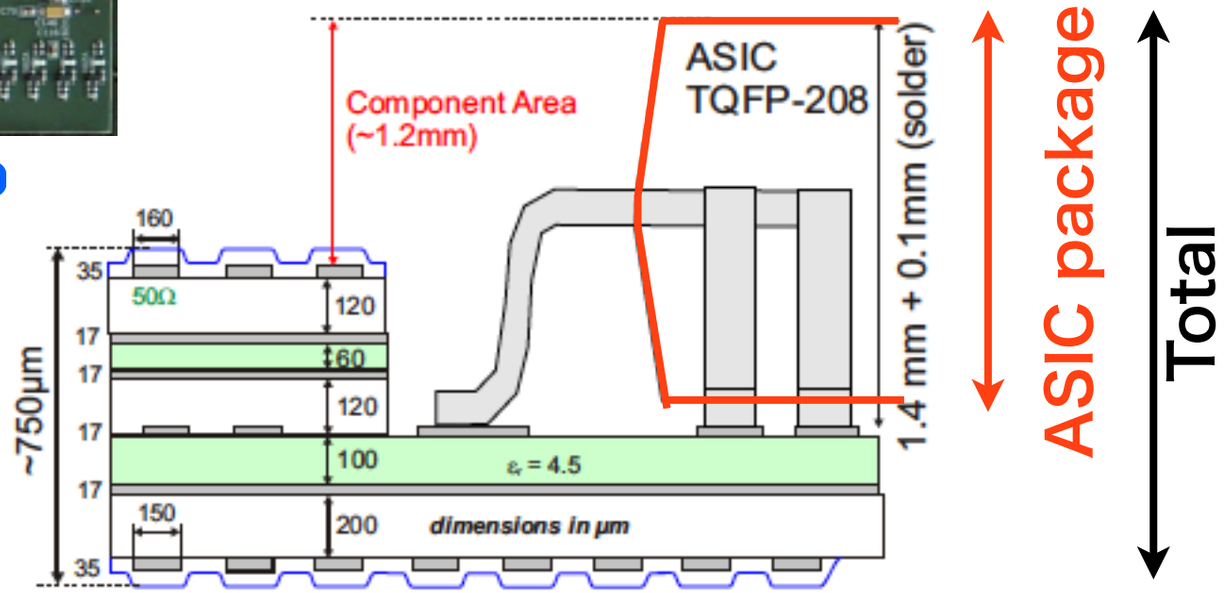


Developed by AHCAL group

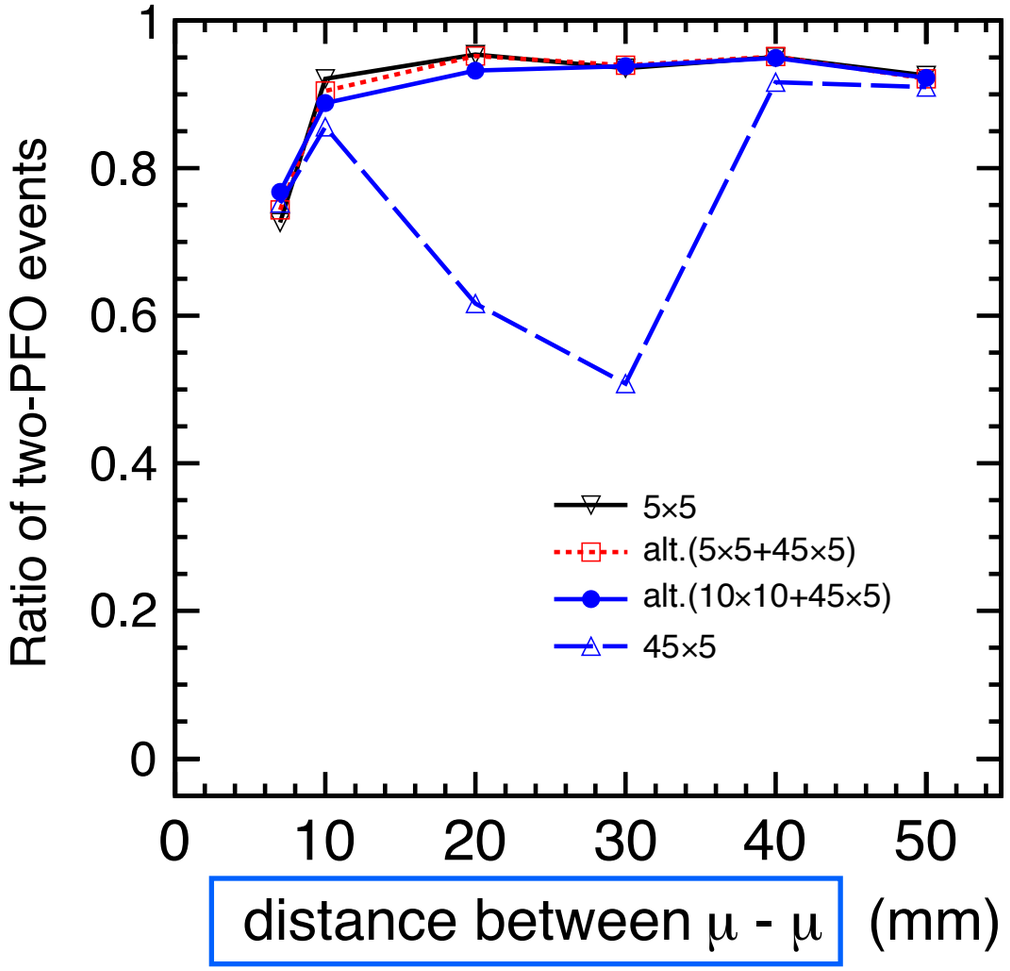


36 x 4 channels / EBU
4 chips / EBU

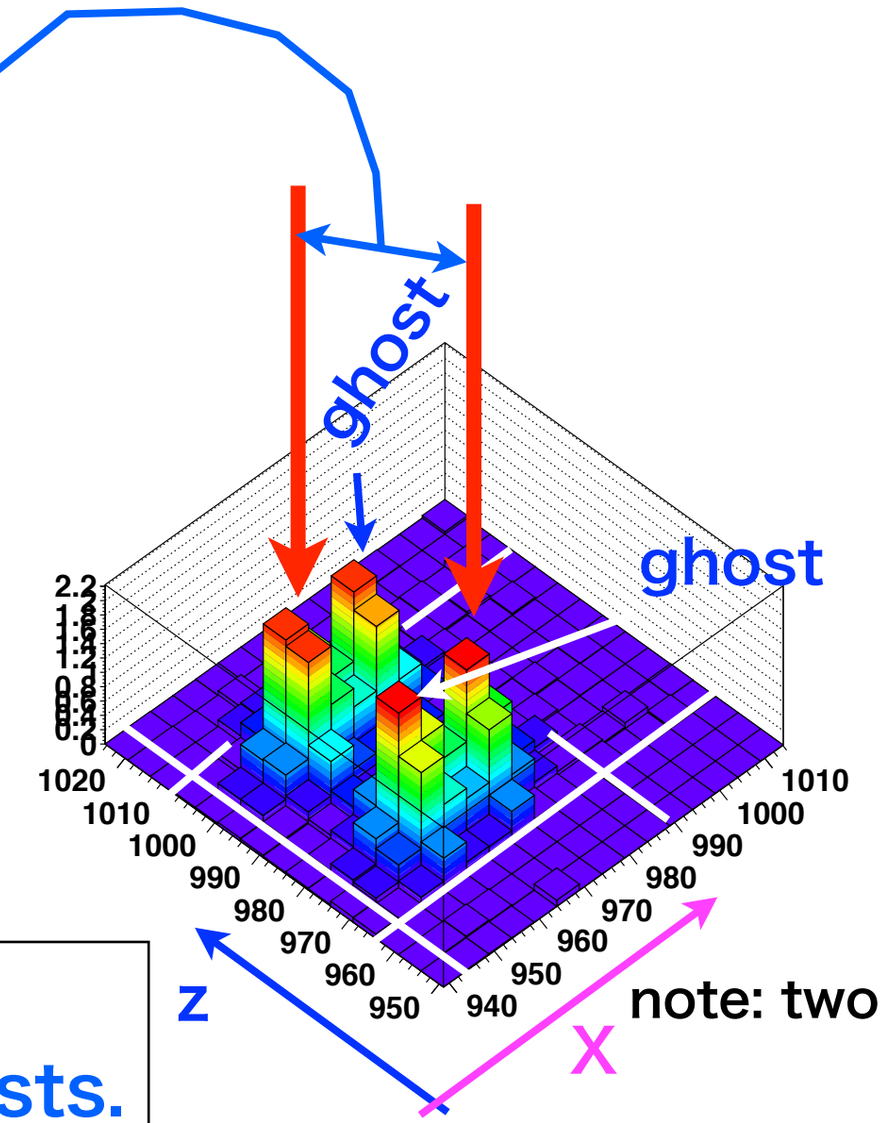
1.8 mm ▶ 1.2 mm req.



Study on ghost clusters with μ-μ



With 30 mm of distance btw. muons, the number of μ-μ events is significantly reduced with 45x5 mm2 ScECAL with SSA.



10 x 10 mm² tile layers between strip layers clearly remove the ghosts.

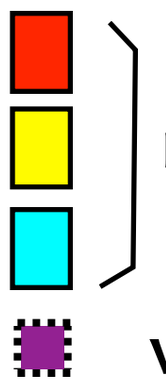
How to do SSA with large tiles

1st Step

45x5 mm²

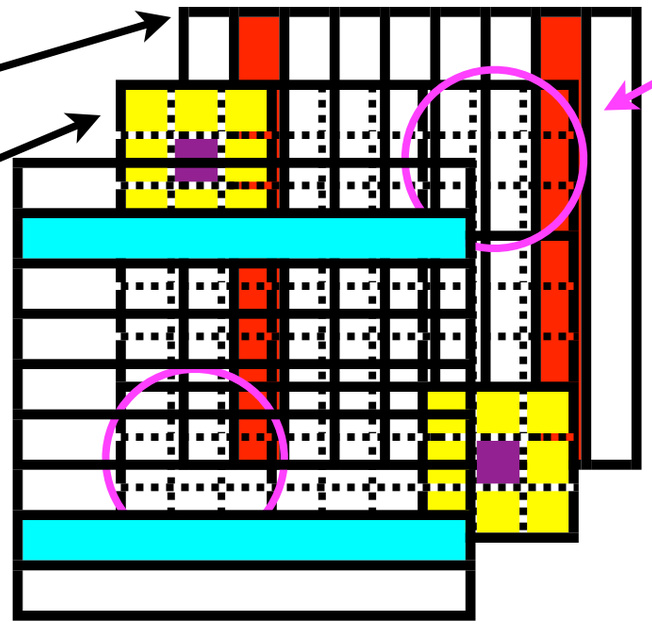
15x15 mm²

5x45 mm²



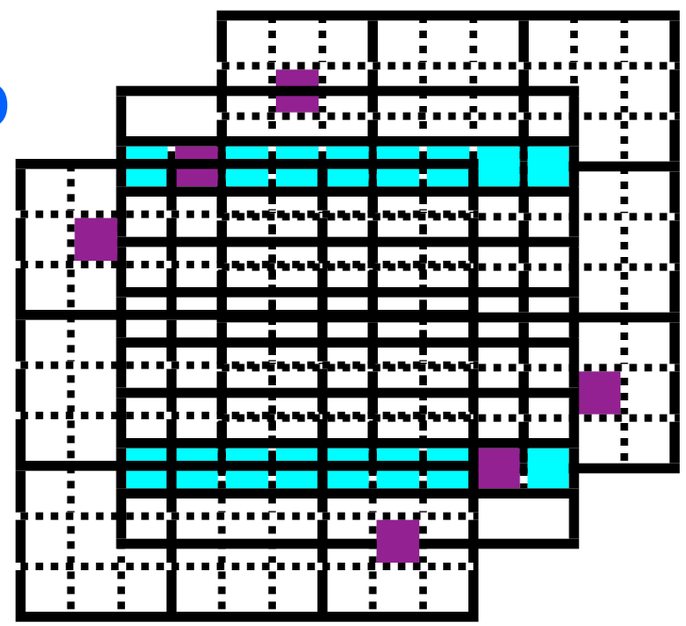
real hit

virtual hit



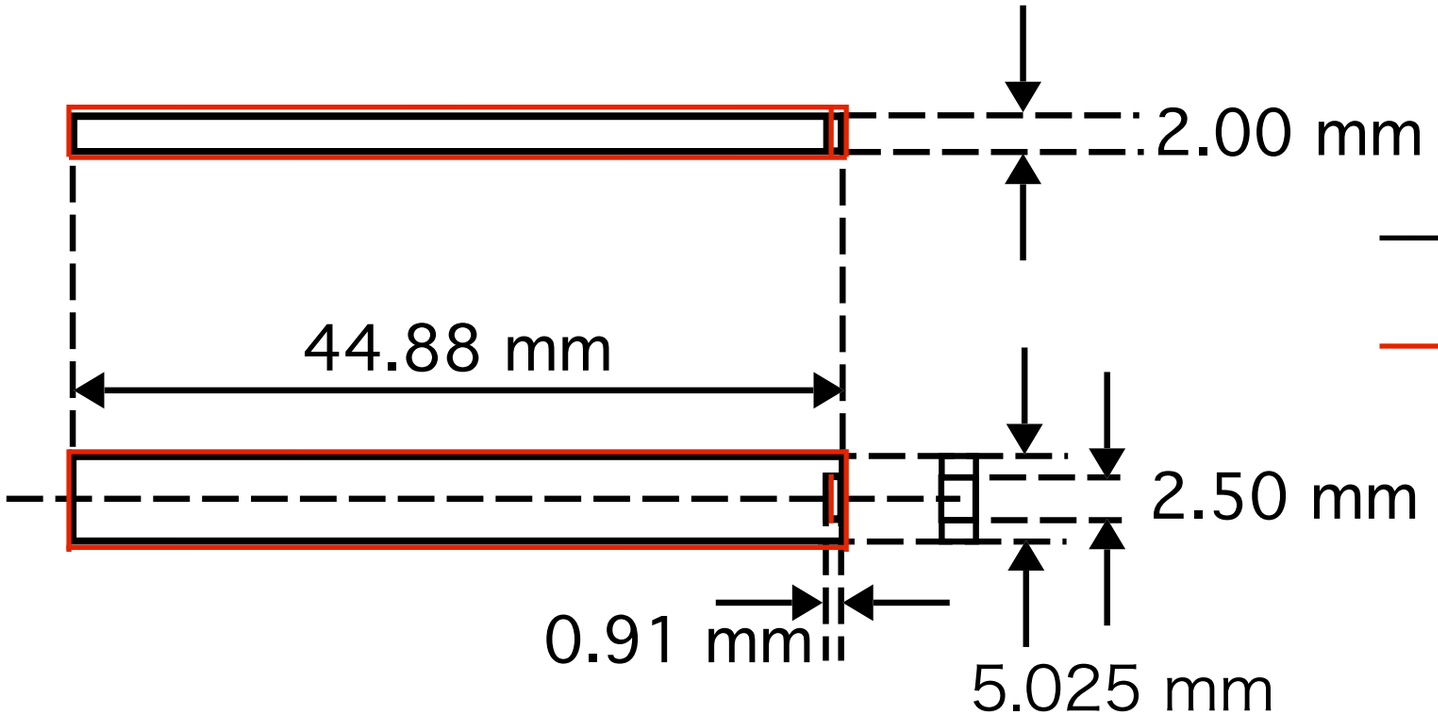
no ghost

2st Step



a layer is affected by the second nearest layers

Default design of ScECAL in Mokka and changed film thickness of reflector



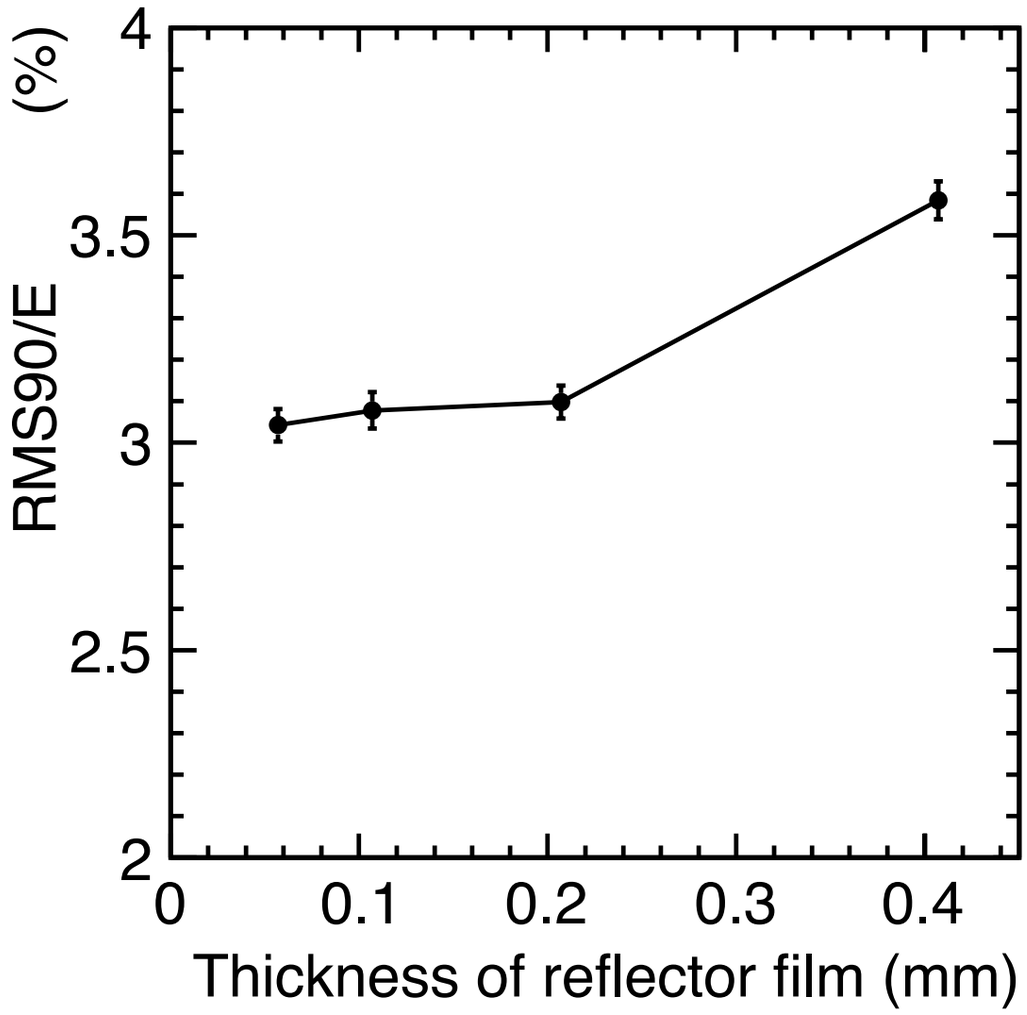
— : Scintillator surface

— : Reflector film (0.057 mm)

In this study thickness of reflector is changed to:
0.107 mm, 0.207 mm and 0.407 mm.
keeping;
- width of scintillator + reflector to 5.14 mm (default),
  replacing a part of scintillator with excess of reflector film,
- thickness of scintillator = 1.0 mm,
- thickness of scintillator + reflector + PCB = 1.914 mm,
  replacing a part of PCB with excess of reflector film,

very ideal design in order only to see effect of side dead vol.

Effect of reflector thickness



There is no significant deterioration of jet energy resolution due to the dead volume comes from reflector thickness at least up to 0.2 mm.