Study of Strip-HCAL

19th March 2014
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Shinshu University

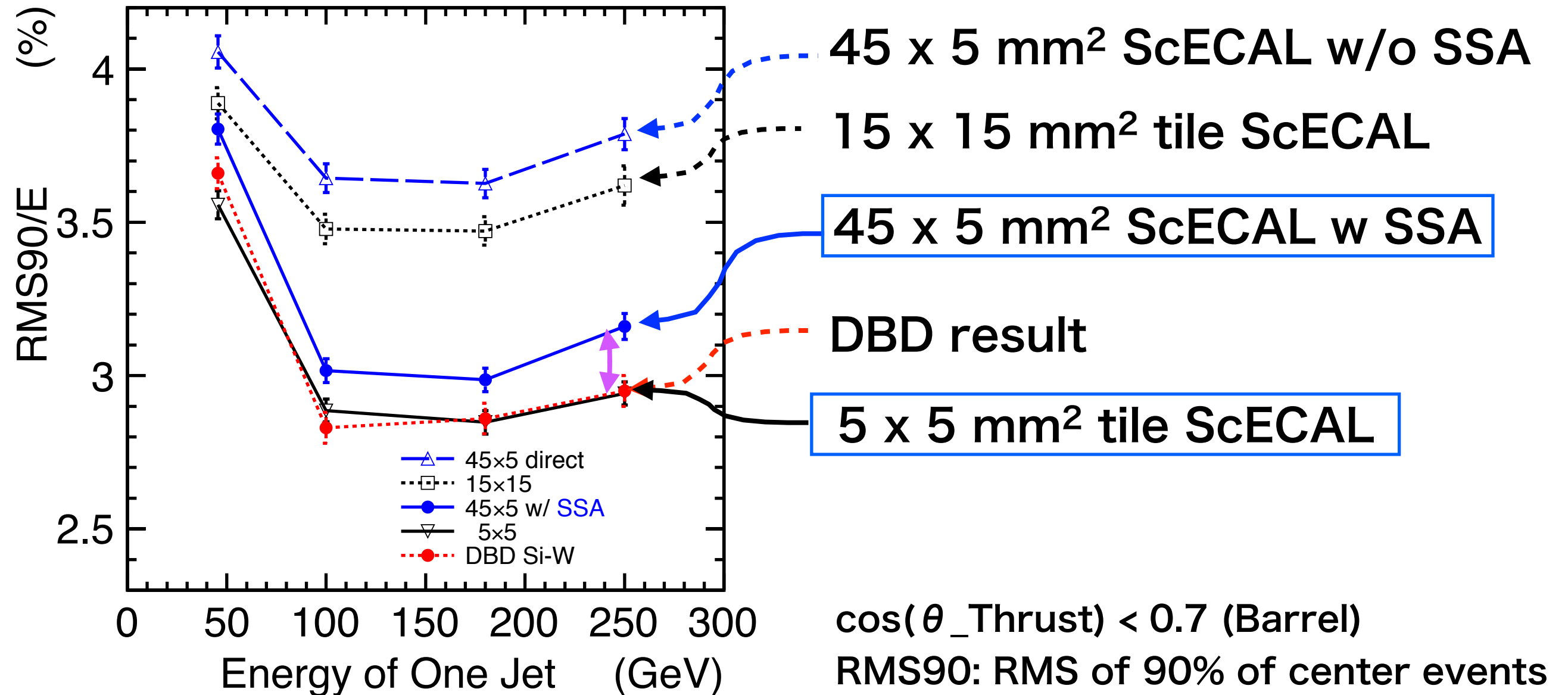# Motivation

- Minimum pixel size of the Digital HCAL is 10 x 10 mm^2 so far.
- Digital HCAL has good performance on position measurement,
- Analog HCAL has good performance on energy measurement,
- and the Semi-digital HCAL is being developed adding three levels of energy discriminations to improve the energy resolution.
- We suggest another way to make 10 x 10 mm^2 segmented "full analog" HCAL as an AHCAL option by using scintillator strip technology.
- To make such an HCAL with 10 x 90 mm^2 scintillator strips, there is no more additional requirement of the cost nor mechanical technology from the current analog HCAL with 30 x 30 mm^2 tiles.
- Challenge is to extract the best performance from two alternate directions of strips in x and y.

ECAL case with Strip Splitting method

Jet energy resolution (with 30x30mm² AHCAL)

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

45 x 5 mm² ScECAL w/o SSA

15 x 15 mm² tile ScECAL

45 x 5 mm² ScECAL w SSA

DBD result

5 x 5 mm² tile ScECAL

Legend on plot:
- 45×5 direct
- 15×15
- 45×5 w/ SSA
- 5×5
- DBD Si-W

X-axis: Energy of One Jet (GeV)
Y-axis: RMS90/E (%)

cos(θ_Thrust) < 0.7 (Barrel)
RMS90: RMS of 90% of center events

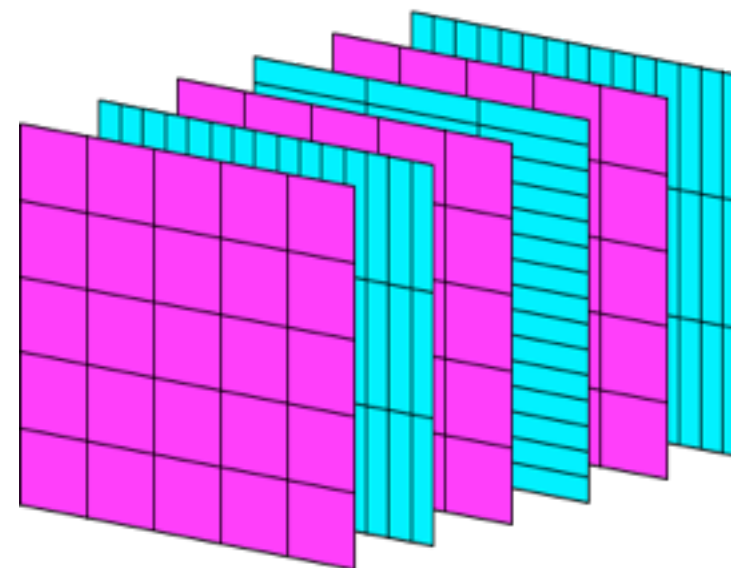SSA makes JER of strip ECAL close to 5 x 5 mm² tile ECAL
Difference is only 0.2-0.25%.

additional option:
alternate tile and strip

Alternately replacing with 5x5mm² tile layers.
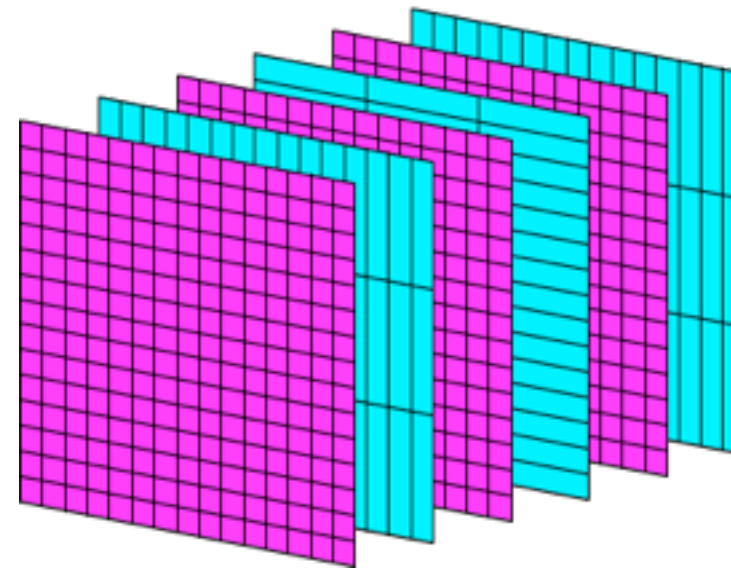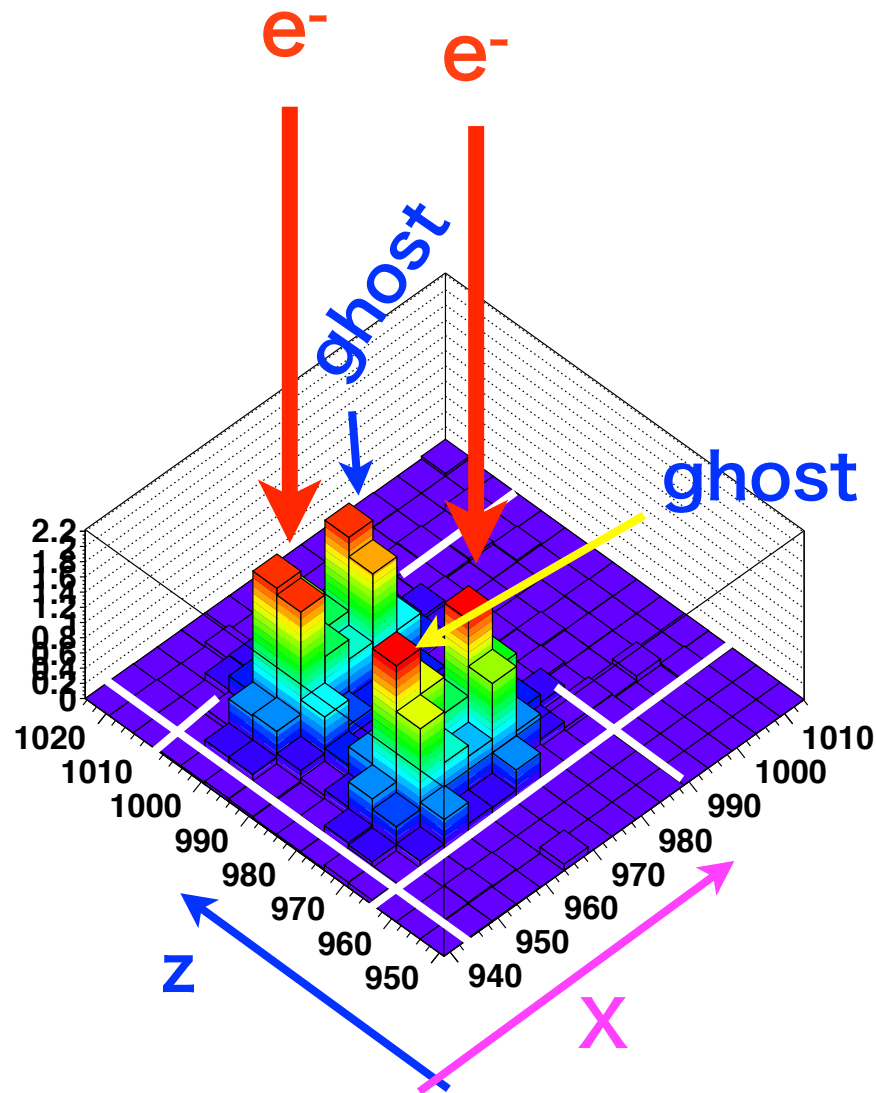
note:
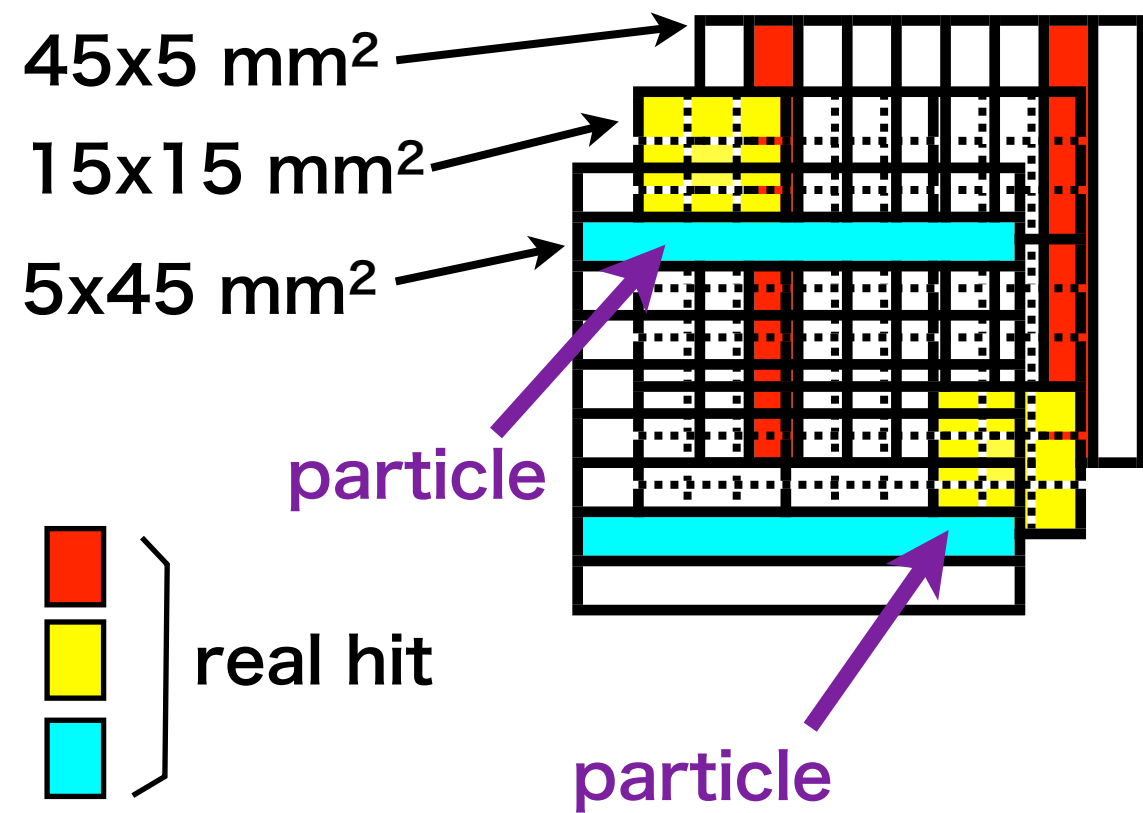merit of orthogonal
setting of strip layers
is not used.

Alternately replacing with large tile layers.

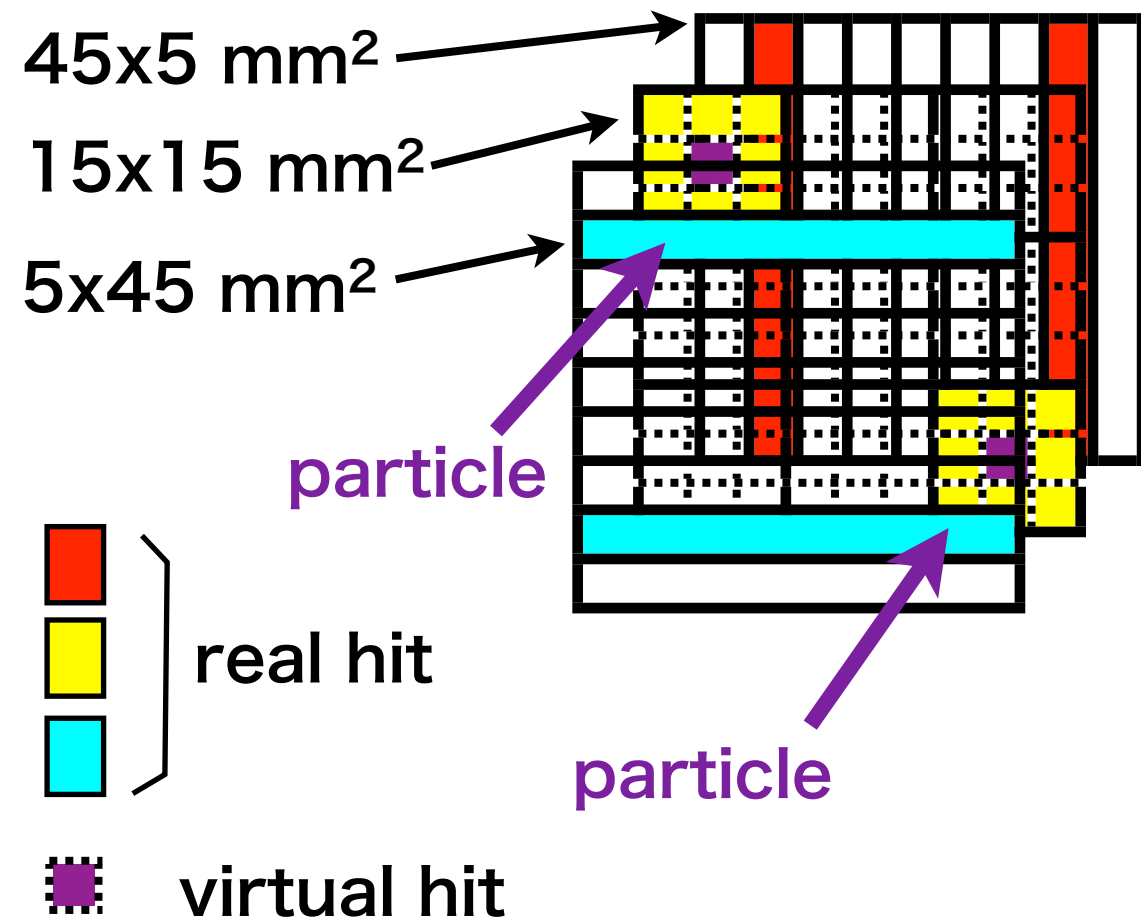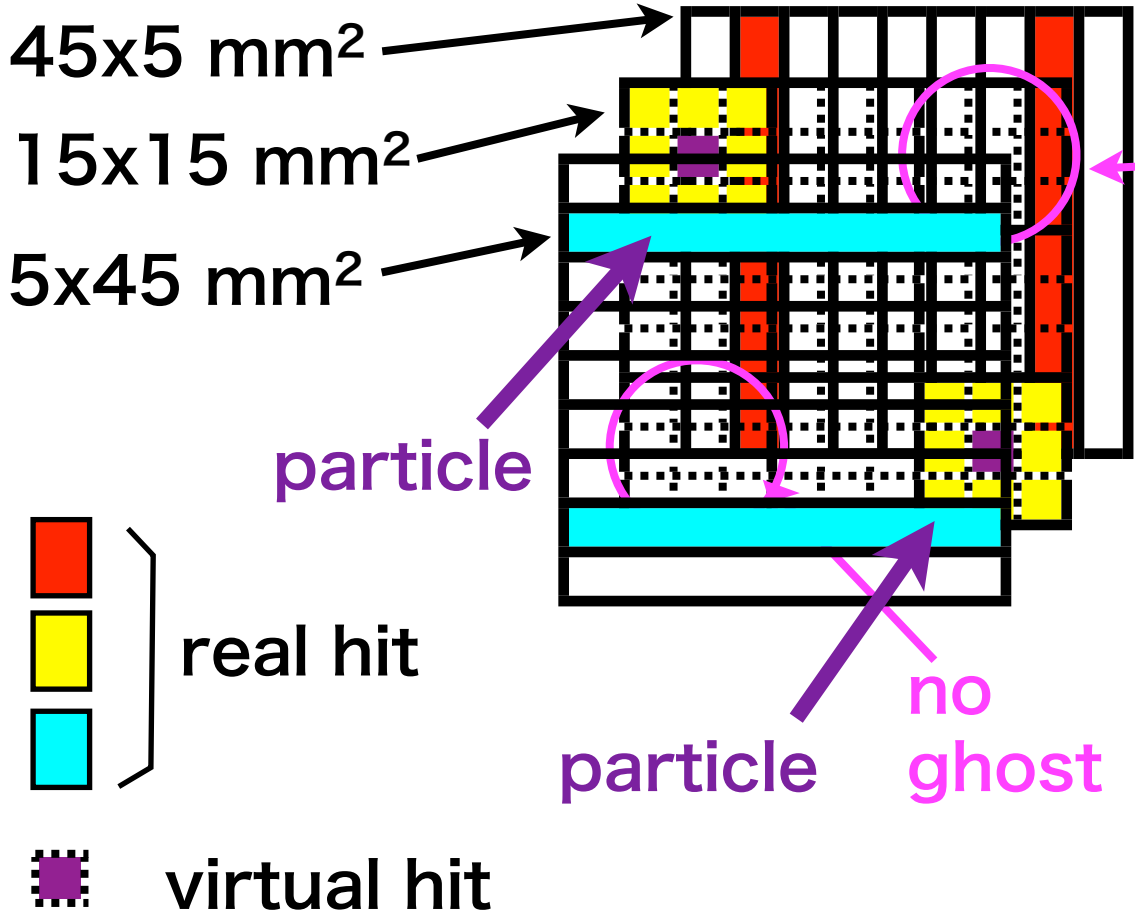**10x10 or 15x15 mm²**

4

How to reconstruct with large tile layers

45x5 mm²

15x15 mm²

5x45 mm²

particle

particle

real hit

How to reconstruct with large tile layers

45x5 mm²

15x15 mm²

5x45 mm²

particle

particle

real hit

virtual hit

1. SSA to 15x15mm² tile layers by using strip layers

How to reconstruct with large tile layers

45x5 mm²

15x15 mm²

5x45 mm²

no ghost

particle

no ghost

particle

real hit

virtual hit

1. SSA to 15x15mm² tile layers by using strip layers

How to reconstruct with large tile layers

45x5 mm²

15x15 mm²

5x45 mm²

no ghost

real hit

virtual hit
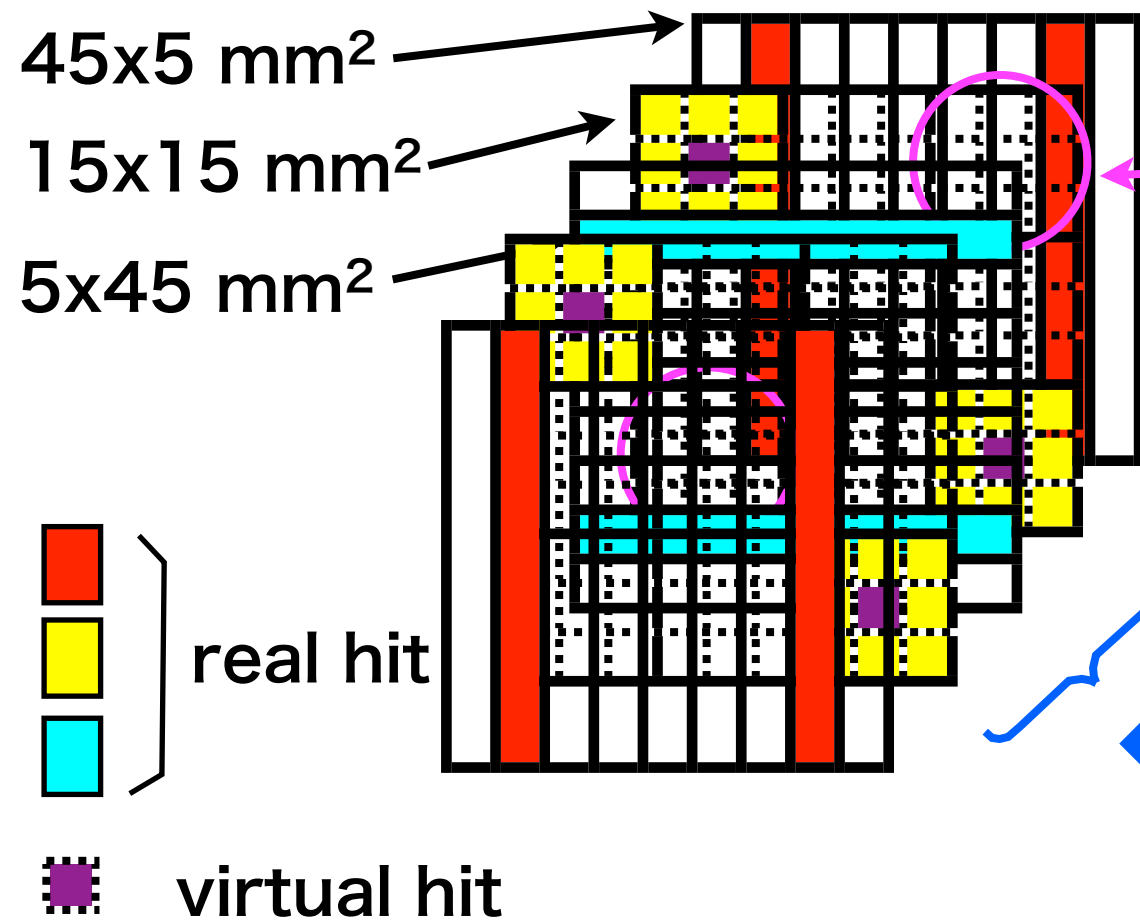
1. SSA to 15x15mm² tile layers by using strip layers

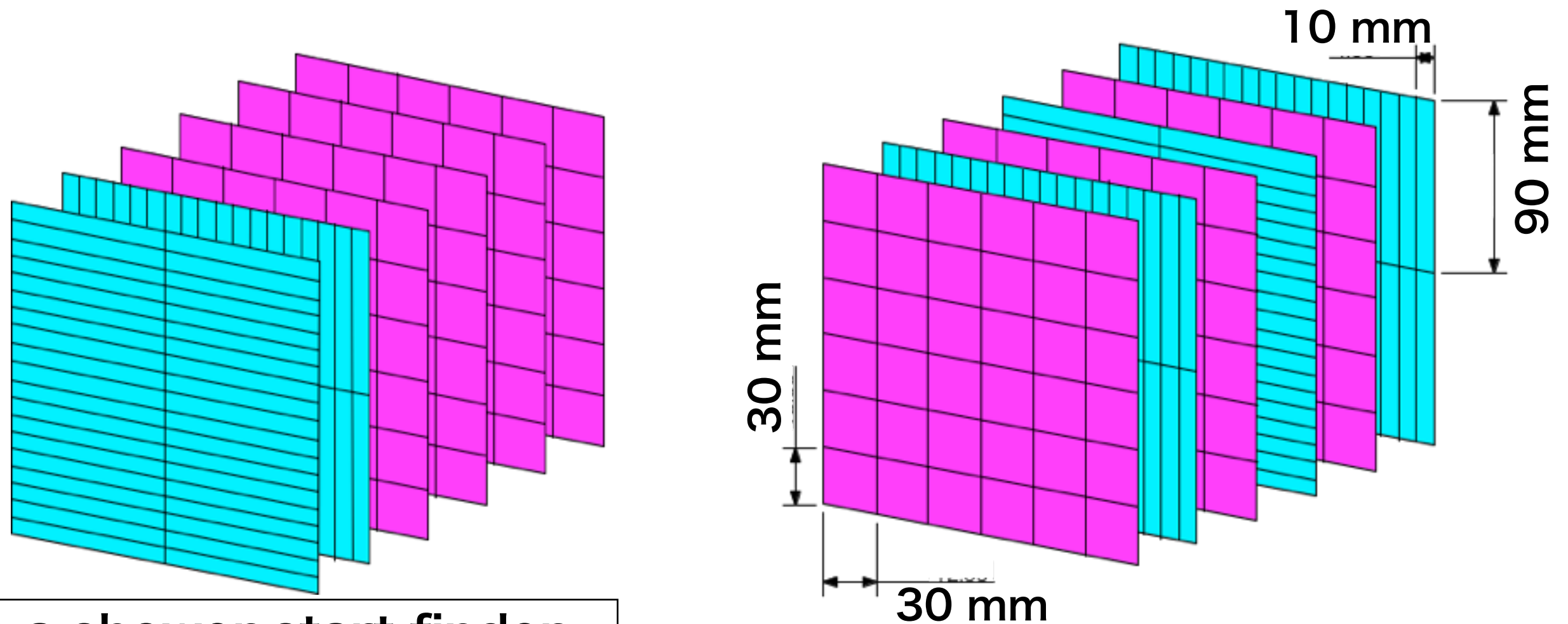2. SSA to strip layers by using virtual cells in tile layers

8
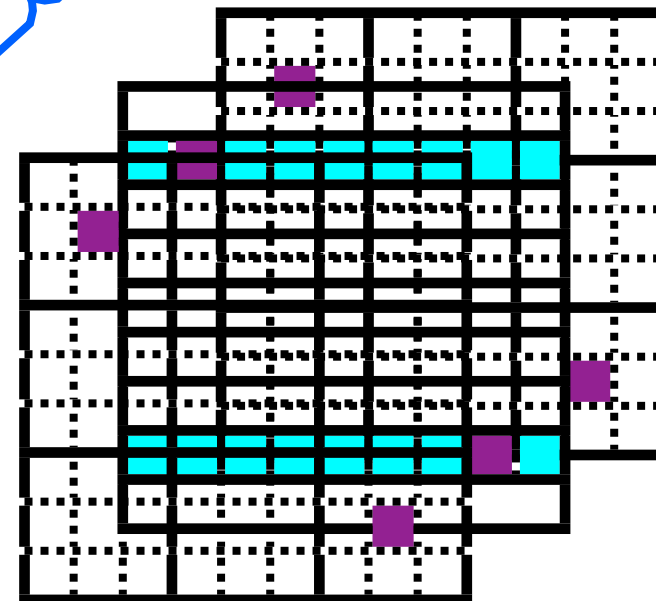
With Tile layers
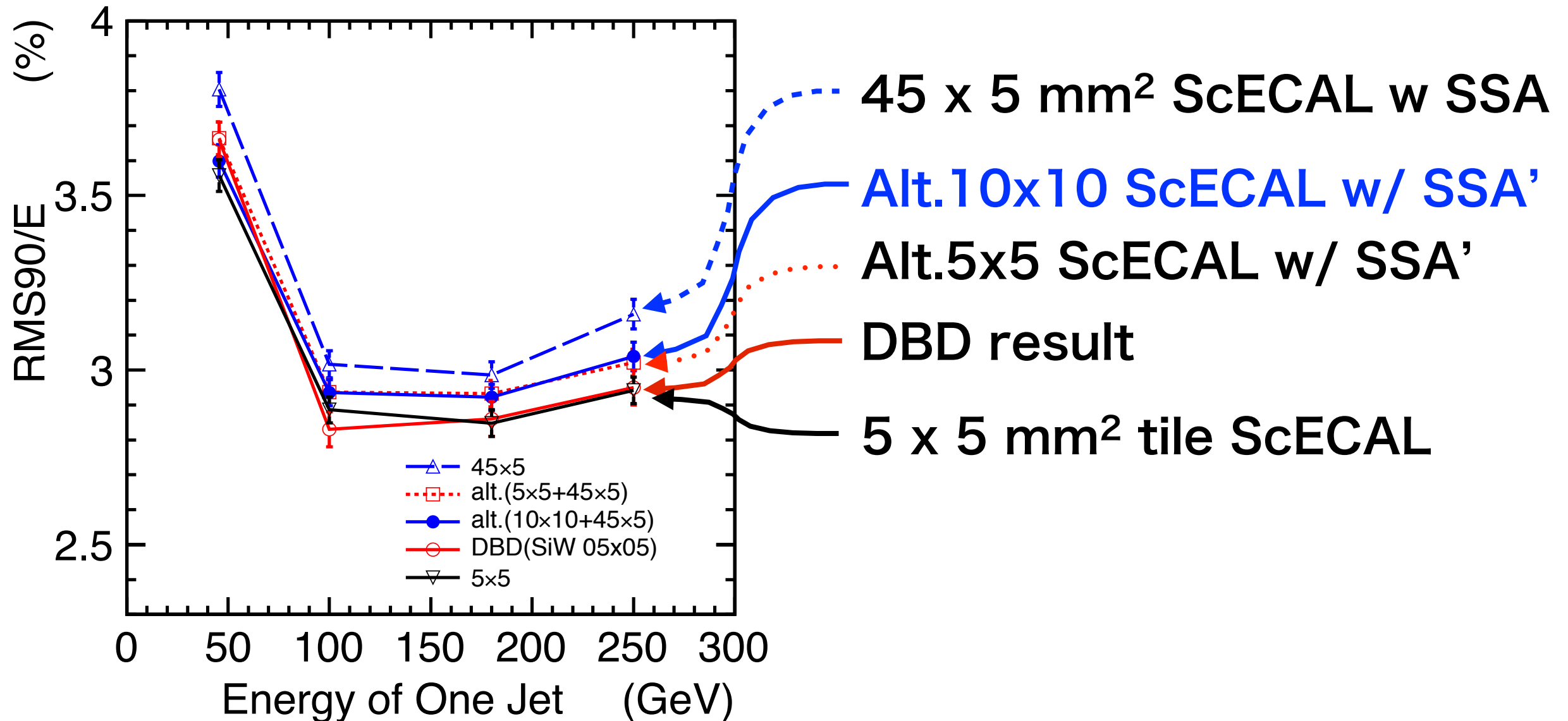
ScECAL **alternately** replaced strip layers with **10x10 mm^2** layers has similar energy resolution to 5x5 mm^2 tile **ScECAL** (also DBD result with SiW ECAL) at **$E_{jet} \leqq 100$ GeV,** only **0.1%** degrades at **high energy.**
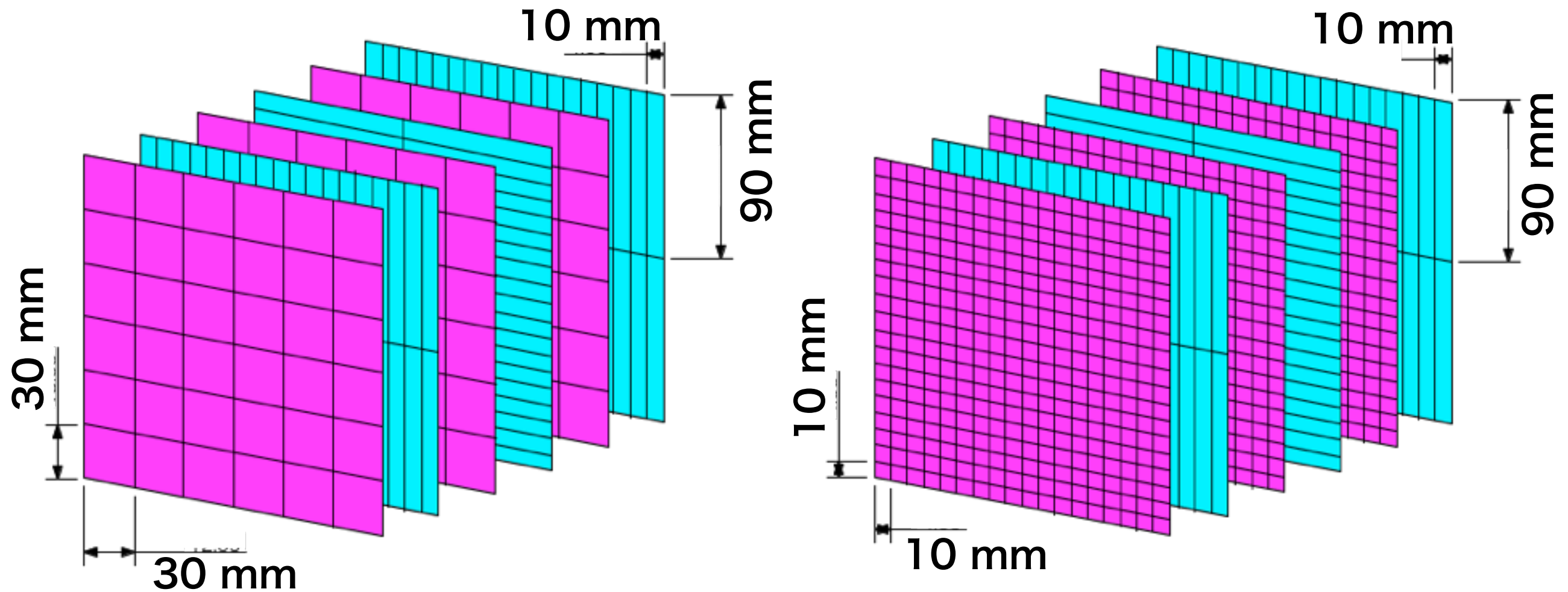
Alternate Strip-Tile HCAL

10 mm

90 mm

30 mm

30 mm

as a shower start finder

10 x 90 (or 180) mm² + 30 x 30 mm²

Same size of lateral area of cells as 30 x 30 mm² current AHCAL

Alternate Strip-Tile HCAL

In this talk we use only
10 x 90 mm² + 10 x 10 mm²

Di - K$_L$ separation (two 5 GeV K$_L$)

Fraction of events successfully reconstructed as two K$_L$ events
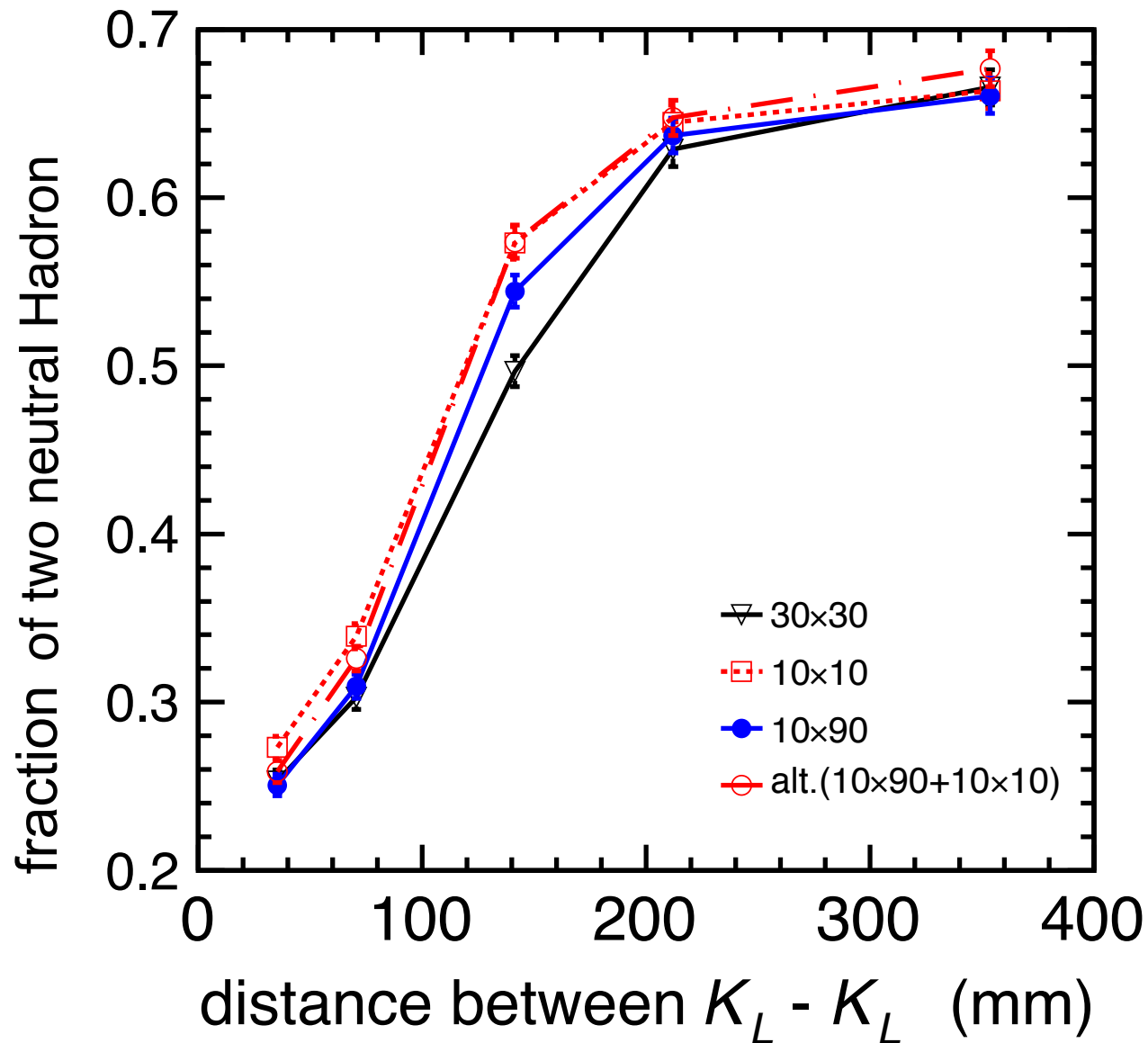
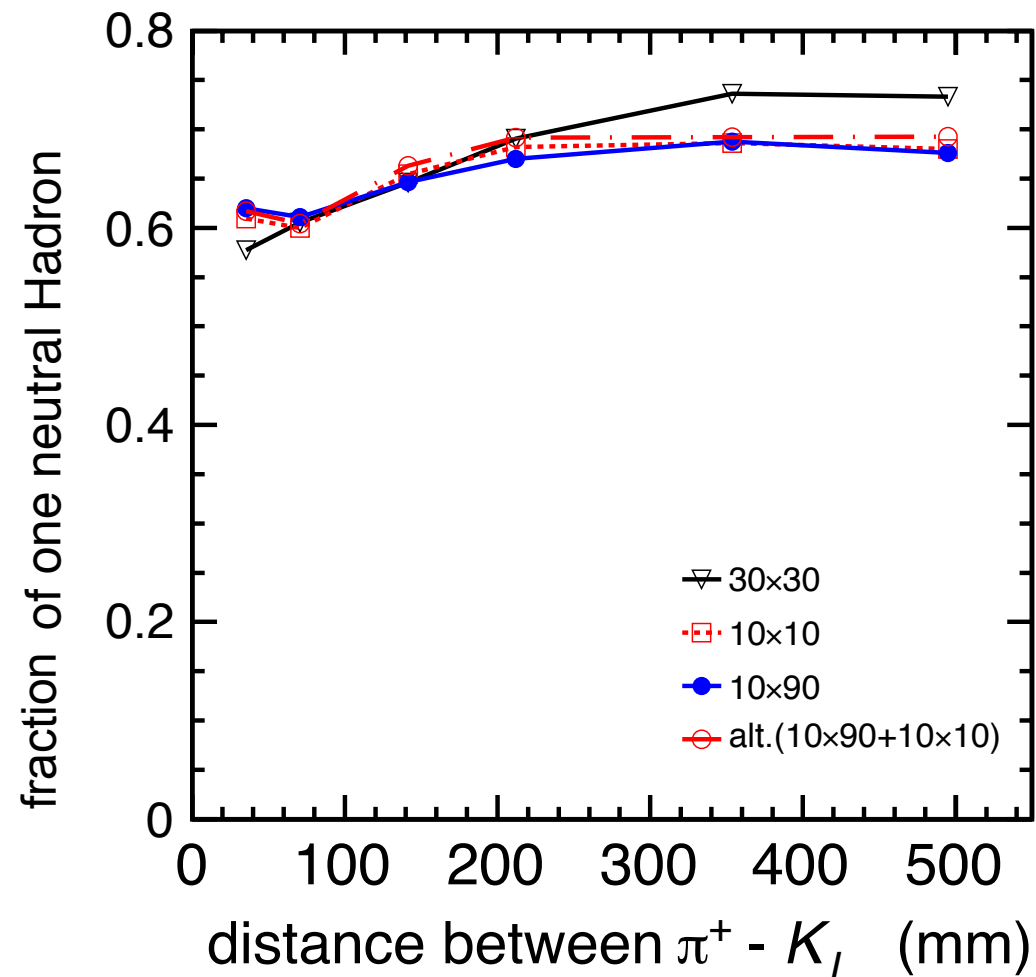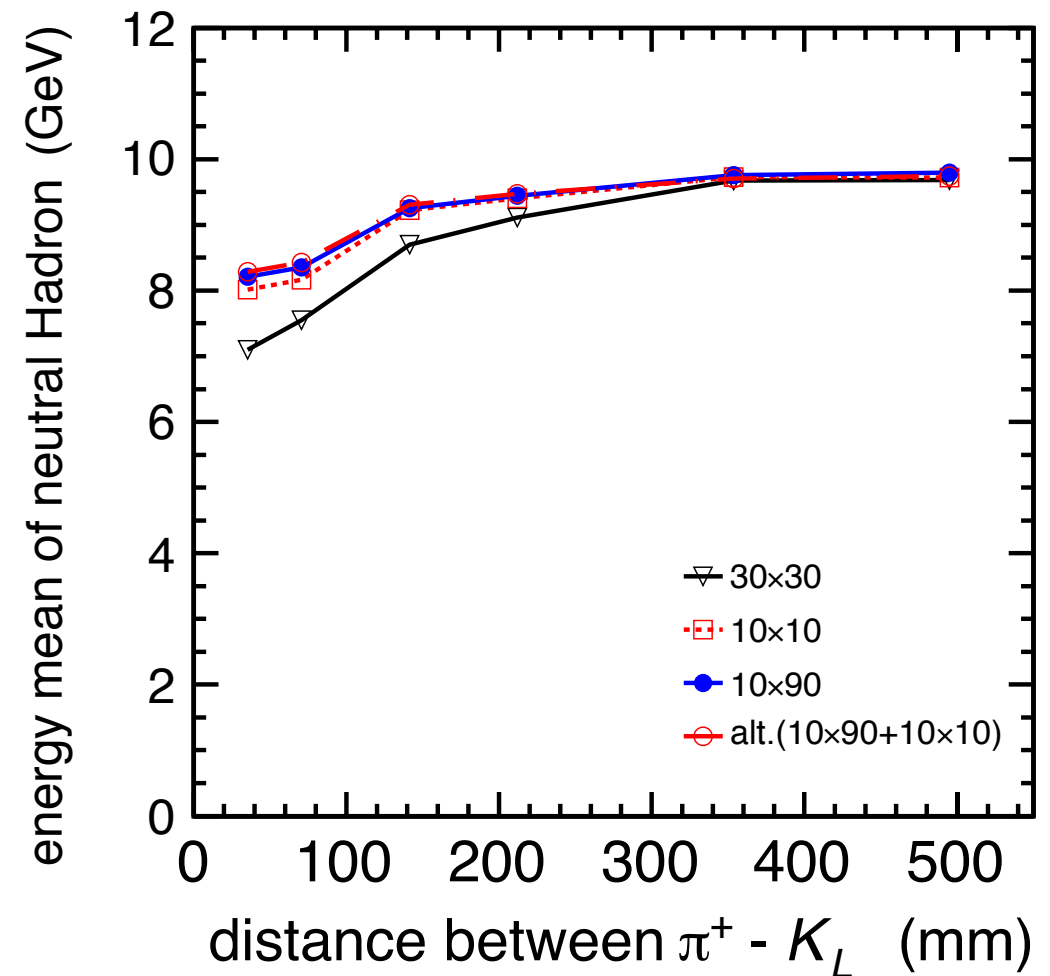With default PandoraPFA parameters.

Until distance of 200 mm,

10 × 10 and alt.(10×90 + 10×10) mm², have better performance than 30 × 30 mm², events

π^+ - K_L separation

30 GeV   10 GeV

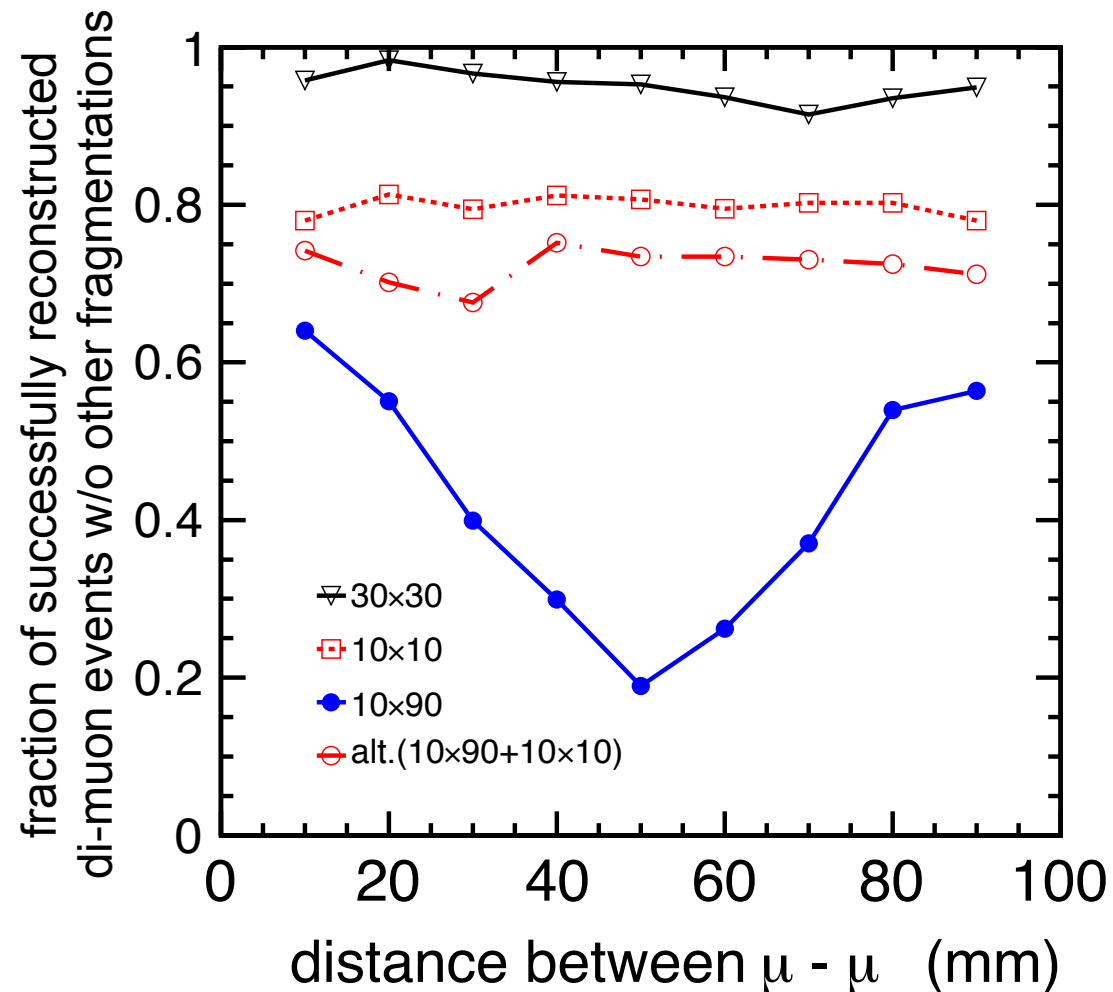**Energy mean of neutral hadron of one - neutral hadron events**

until 300 mm distance
10x10 mm² segmentation
has better energy

One faked neutral hadron
is created in 10x10 mm²
segmentation
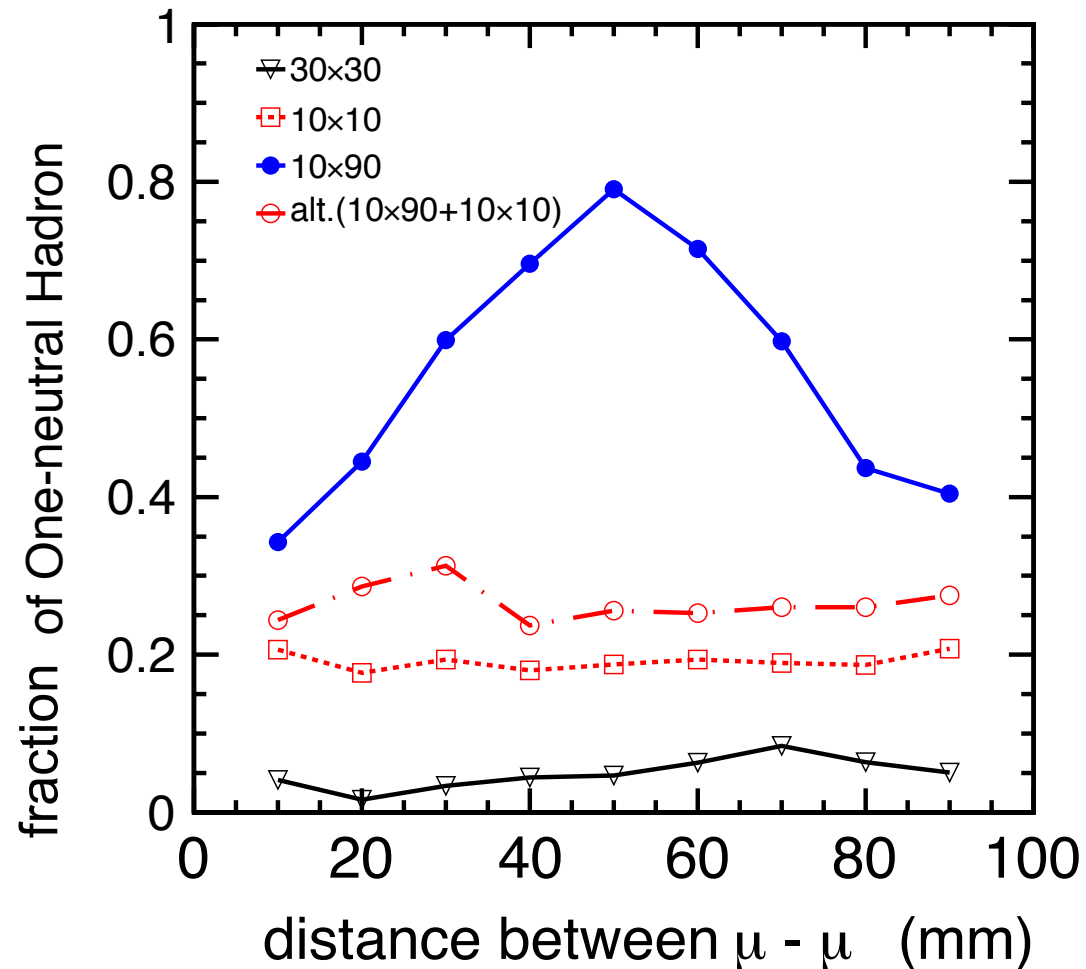
Di-muon separation

fraction of successfully reconstructed two muon events without any other fragmentation

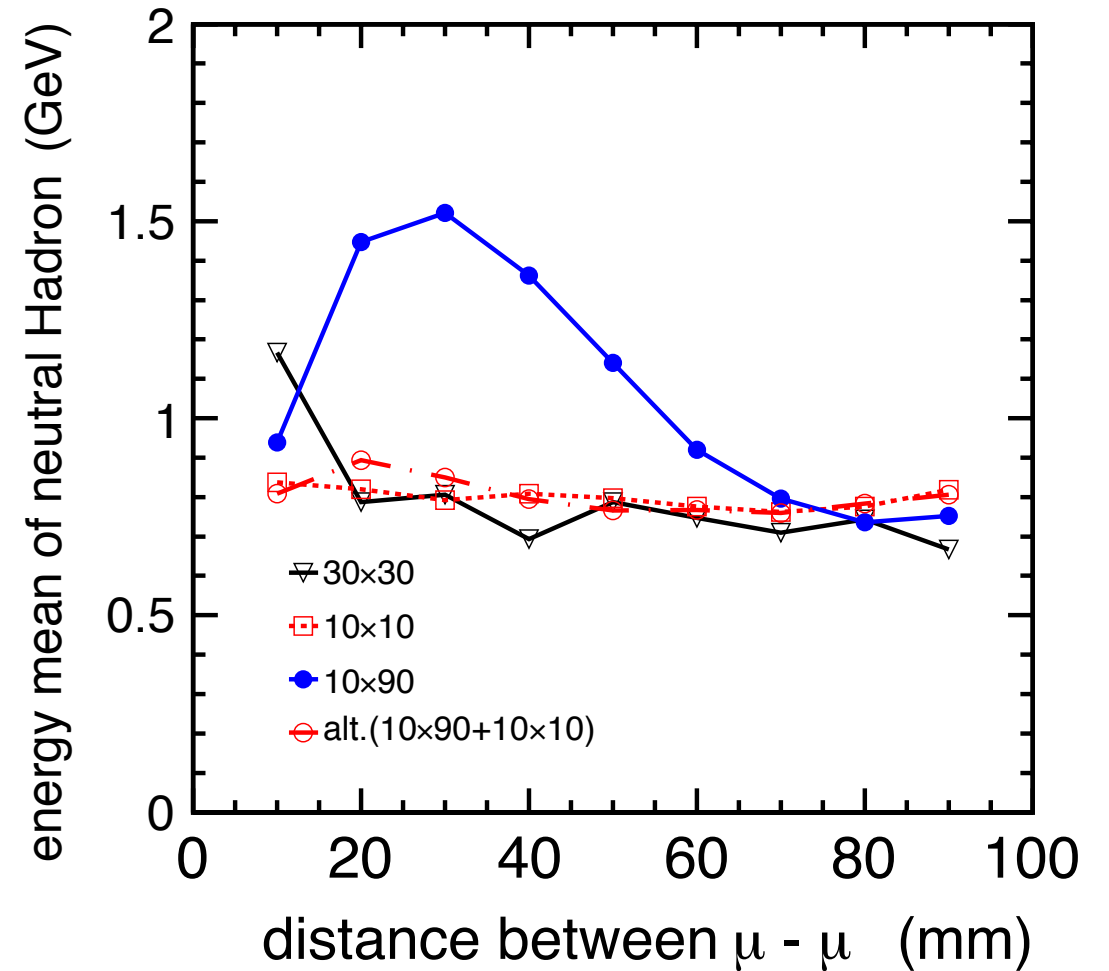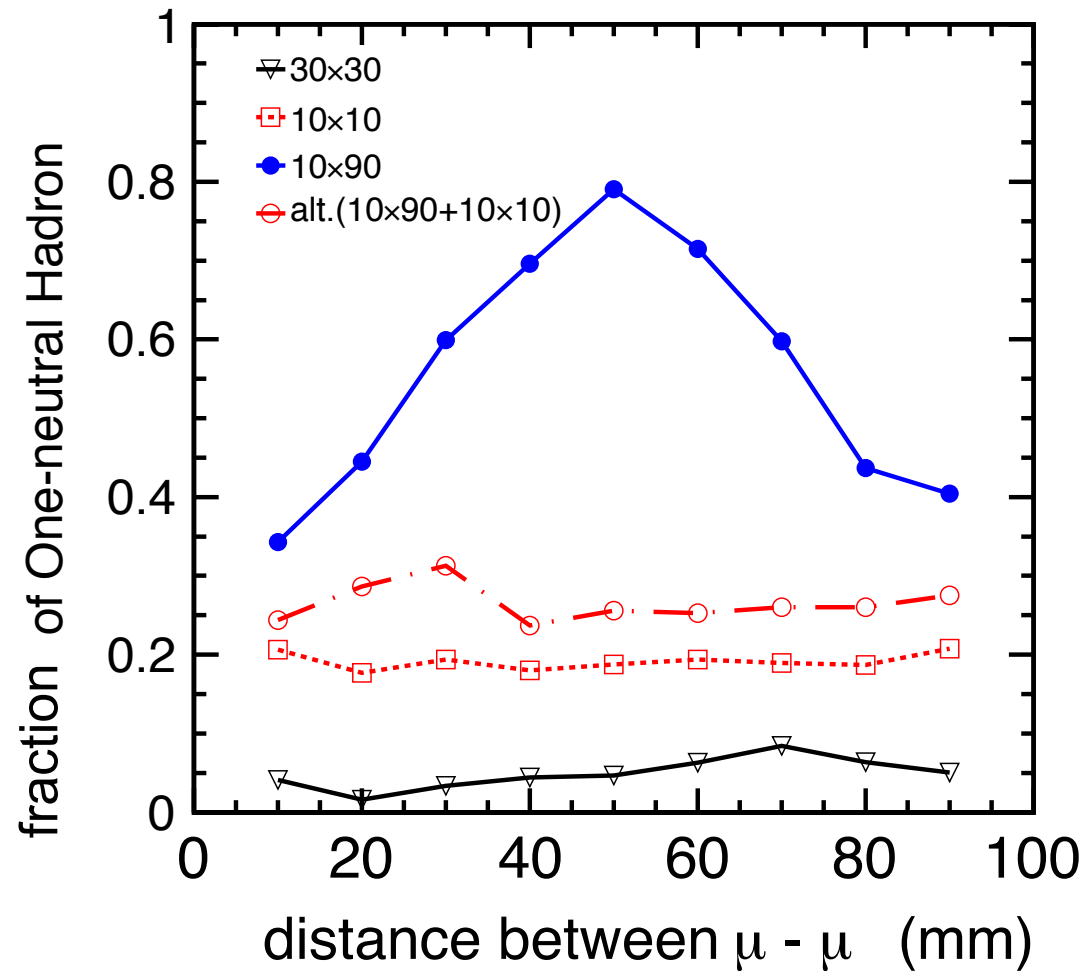complementary set of this is one additional neutral hadron events

14

Di-muon separation

fraction of events having one excess neutral hadron

10 x 90 strip HCAL with SSA makes a lot of faked neutral hadrons

15

Di-muon separation

energy of fake neutral
hadrons is ~ 0.8 GeV.

Summary of <u>particle separation</u>

1. HCAL of 10 x 10 mm^2 segmentation including strip HCAL with SSA has better ability of particle separation than 30 x 30 mm^2.

2. 10 x 10 has tendency to make fake neutral hadrons, especially strip segmentation even with SSA.

3. This phenomenon is moderated by tile layers interleaved into strip layers.

4. We will optimize PandoraPFA tuning for fine granular HCAL as a next step.

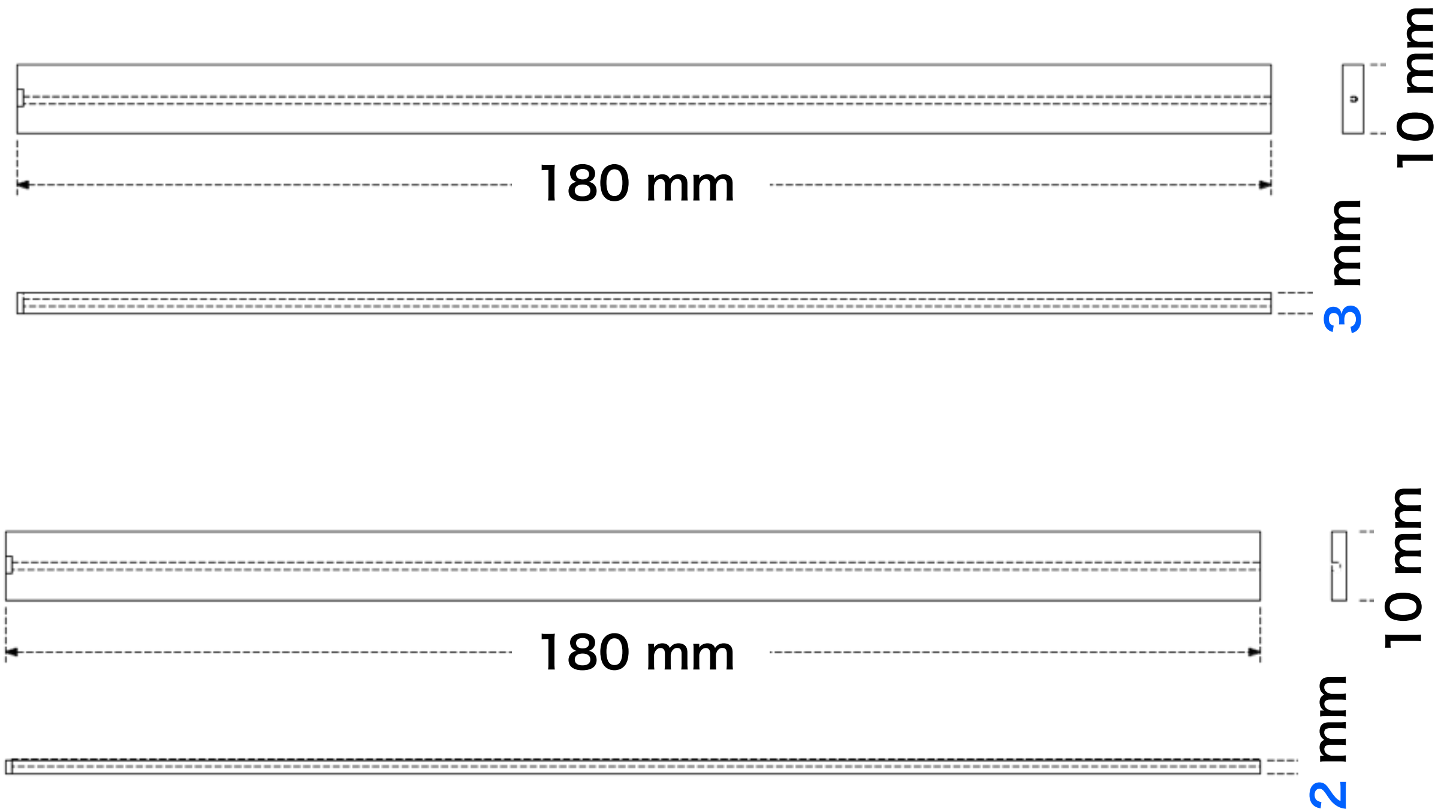# Jet energy resolution without new optimization
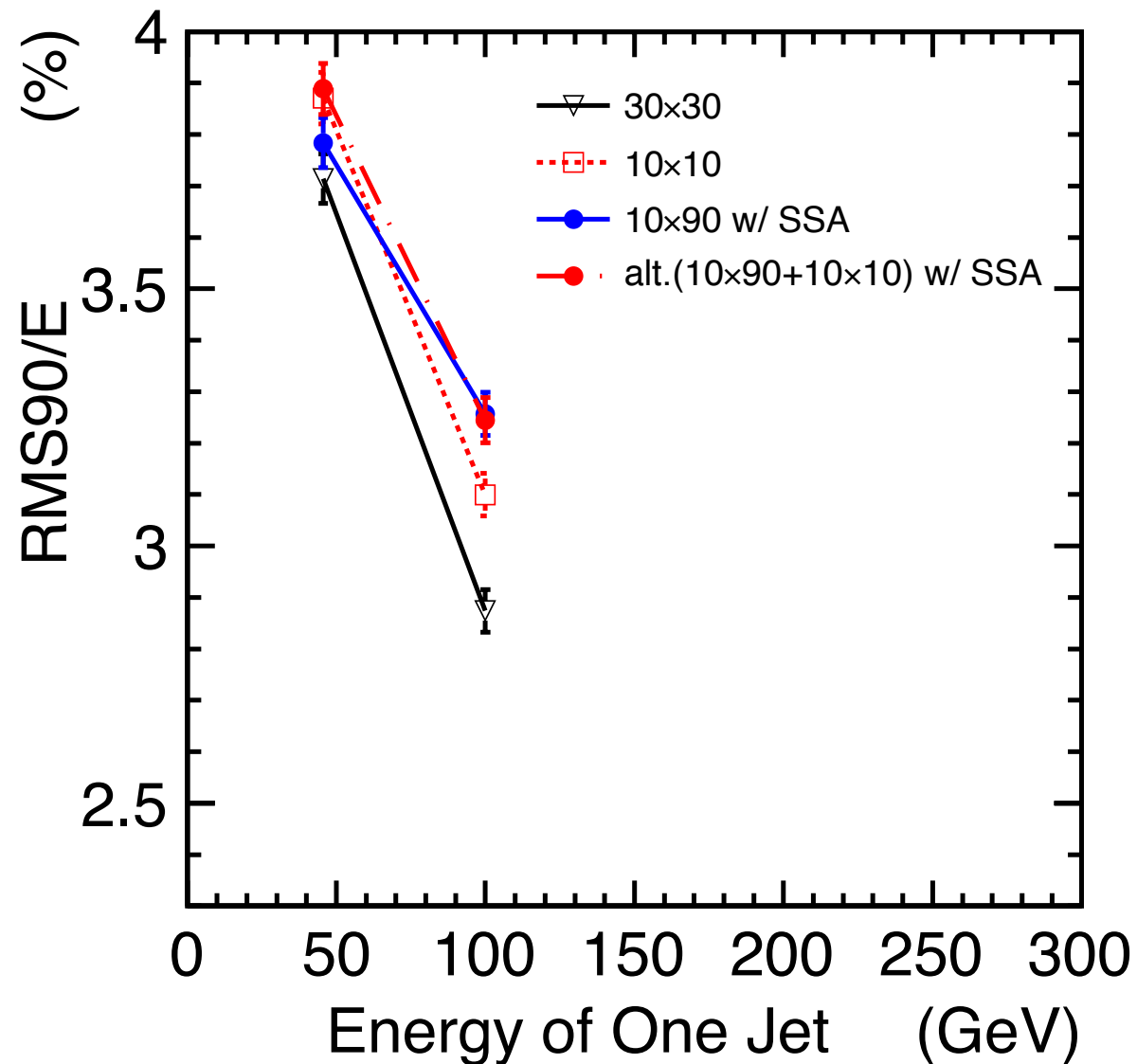
Without any new tuning, even 10 × 10 mm² tile AHCAL does not have better energy resolution than 30 × 30 mm² tile AHCAL has.

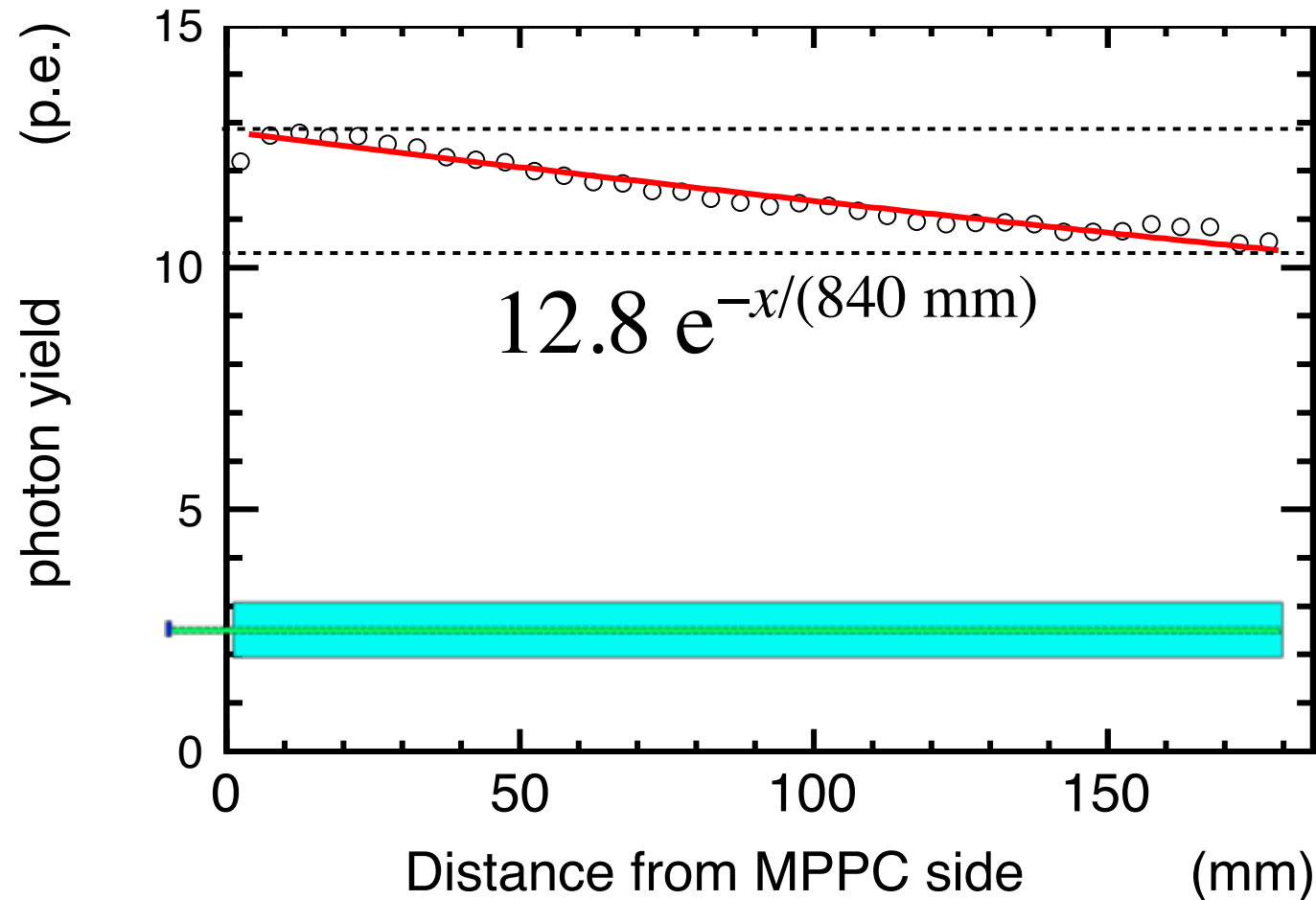So far, we've not yet succeeded to optimize it....
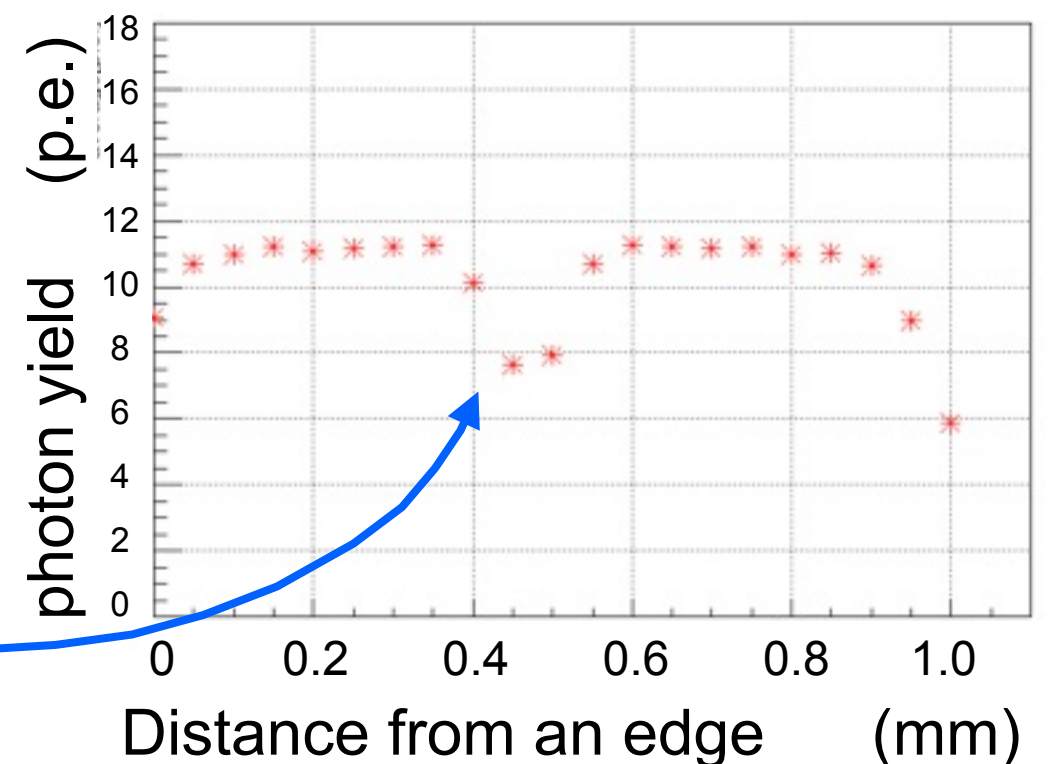
Hardware development

Scintillator strip

180 mm   10 mm   3 mm

180 mm   10 mm   2 mm

Uniformity of response

180×10 mm² × 2 mm thick scinti.

photon yield (p.e.)

$$12.8\ e^{-x/(840\ mm)}$$

20% loss

10% with 90 mm strip

Distance from MPPC side (mm)

Cross-section side at 100 mm far from MPPC side edge.

2 mm thick scintillator

photon yield (p.e.)

Distance from an edge (mm)

Effect of WLS fiber is pretty large for 2 mm thick scintillator

HBU for strip AHCAL

Only alignment will be changed from the tile 30×30 mm^2 HCAL

10×90 mm^2 × 144 channel

10×180 mm^2 × 72 channel
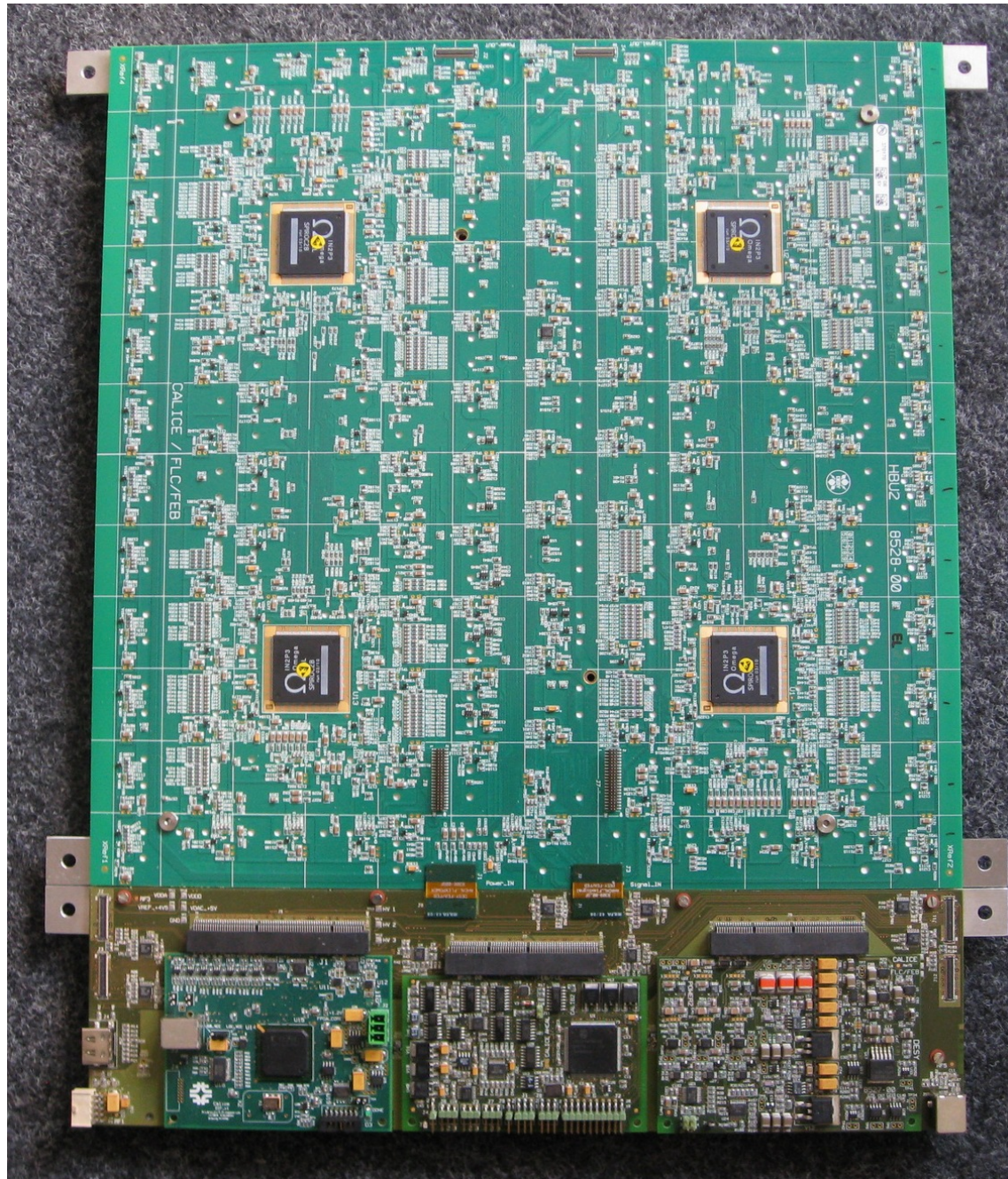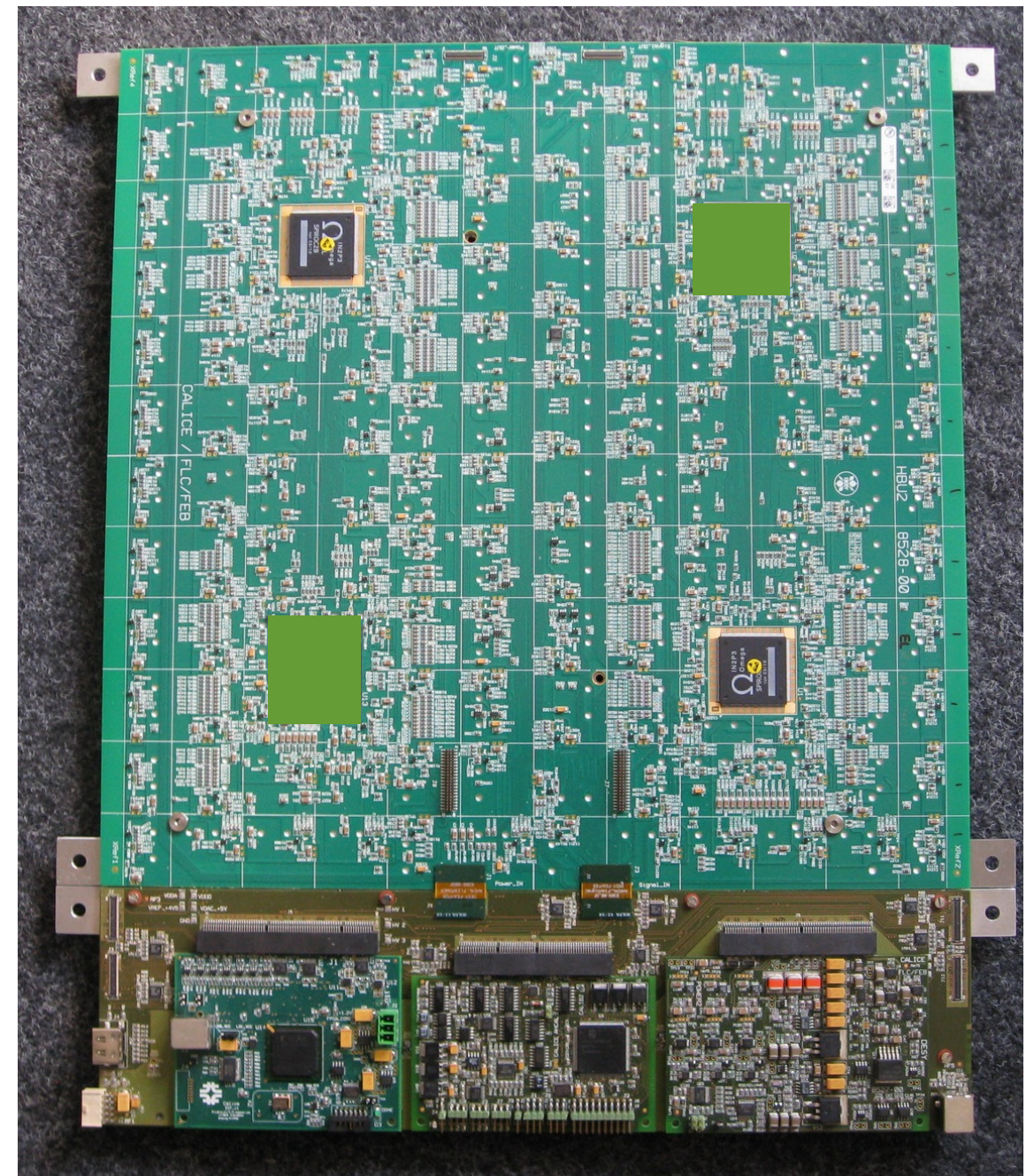
4 Chips / HBU

2 Chips / HBU

HBU

10×90 mm^2 × 144 channel
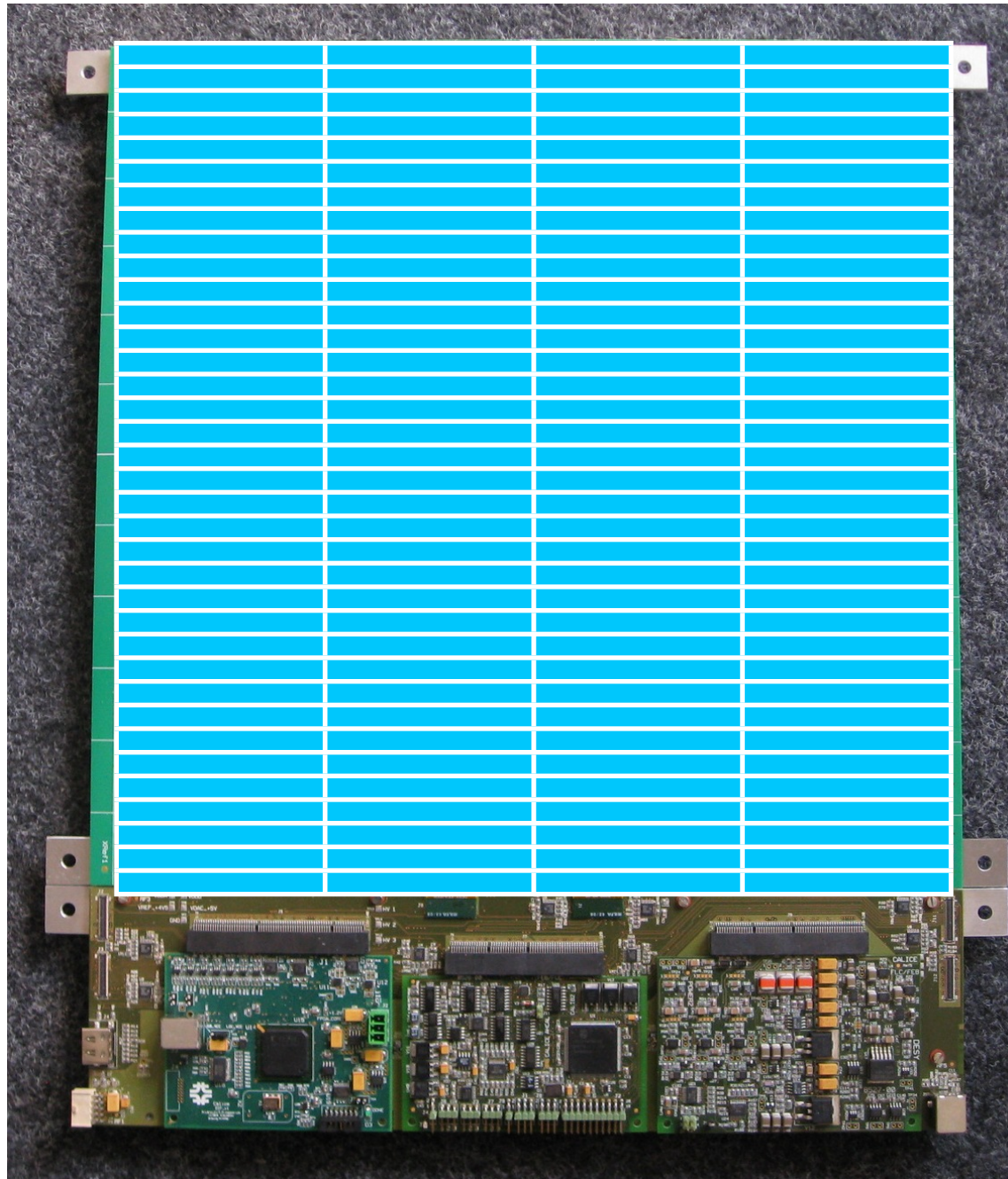
10×180 mm^2 × 72 channel
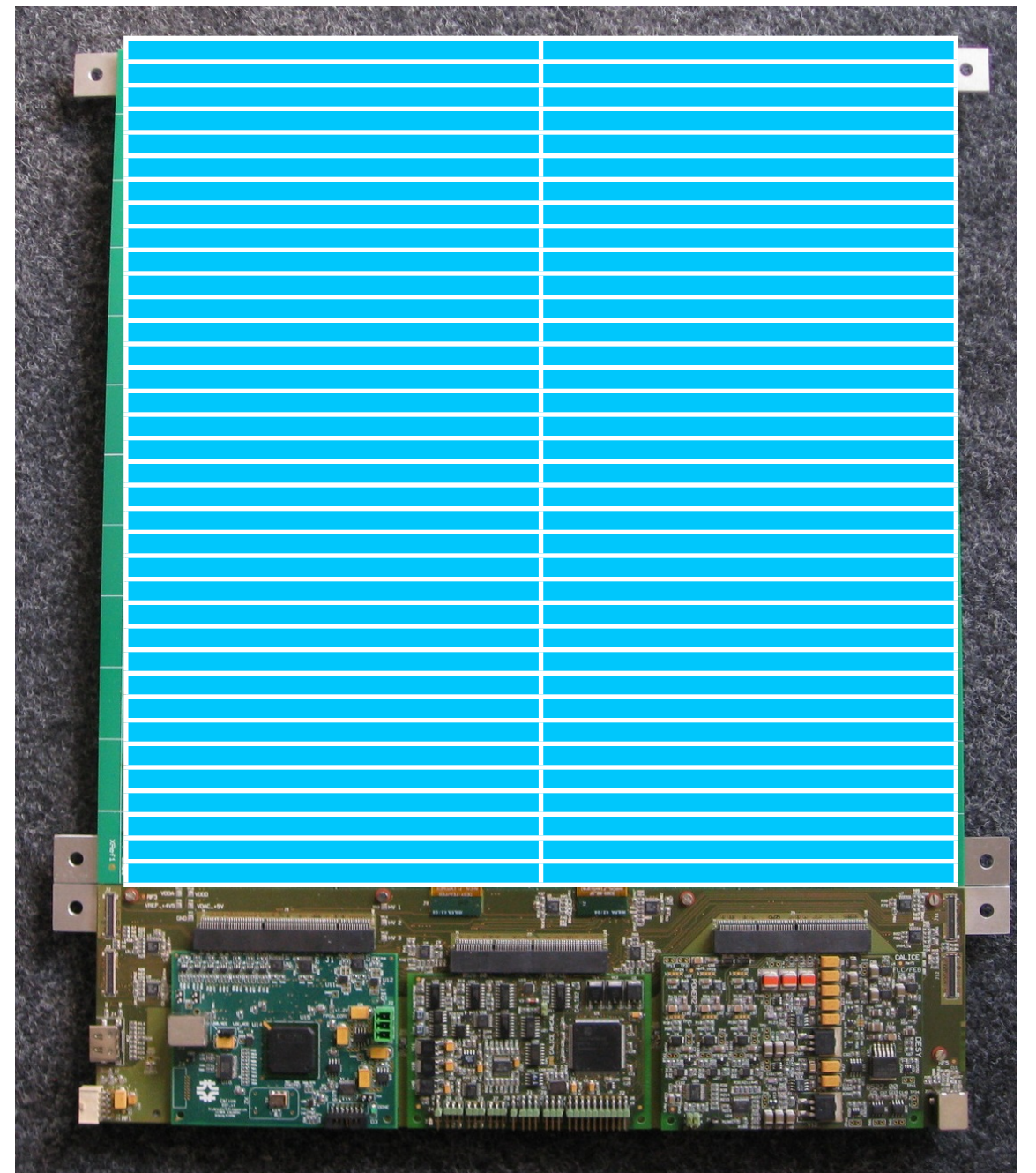
4 Chips / HBU

2 Chips / HBU

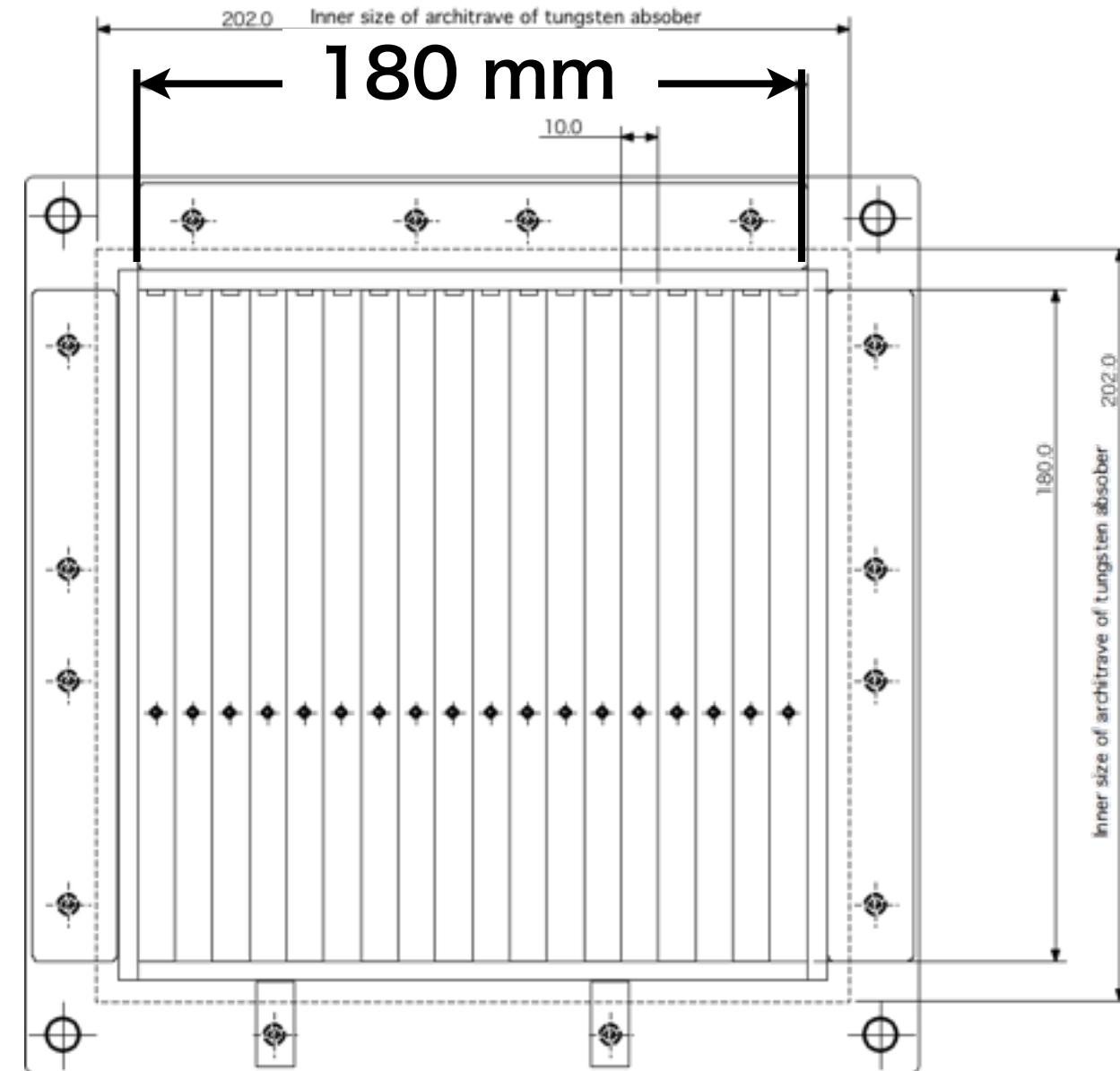# As first step TB before HBU
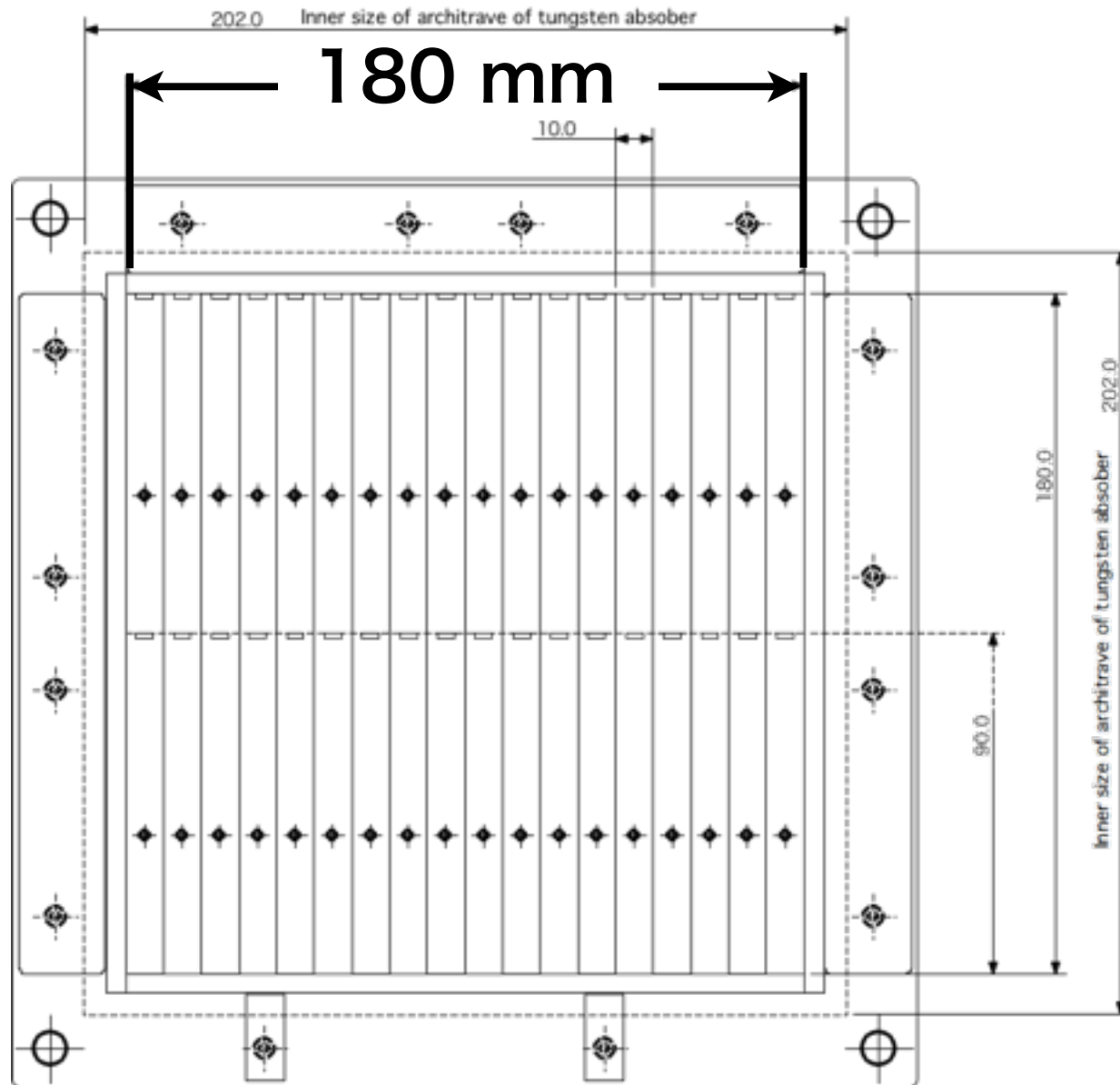
10×90 mm² × 36 channel   10×180 mm² × 18 channel

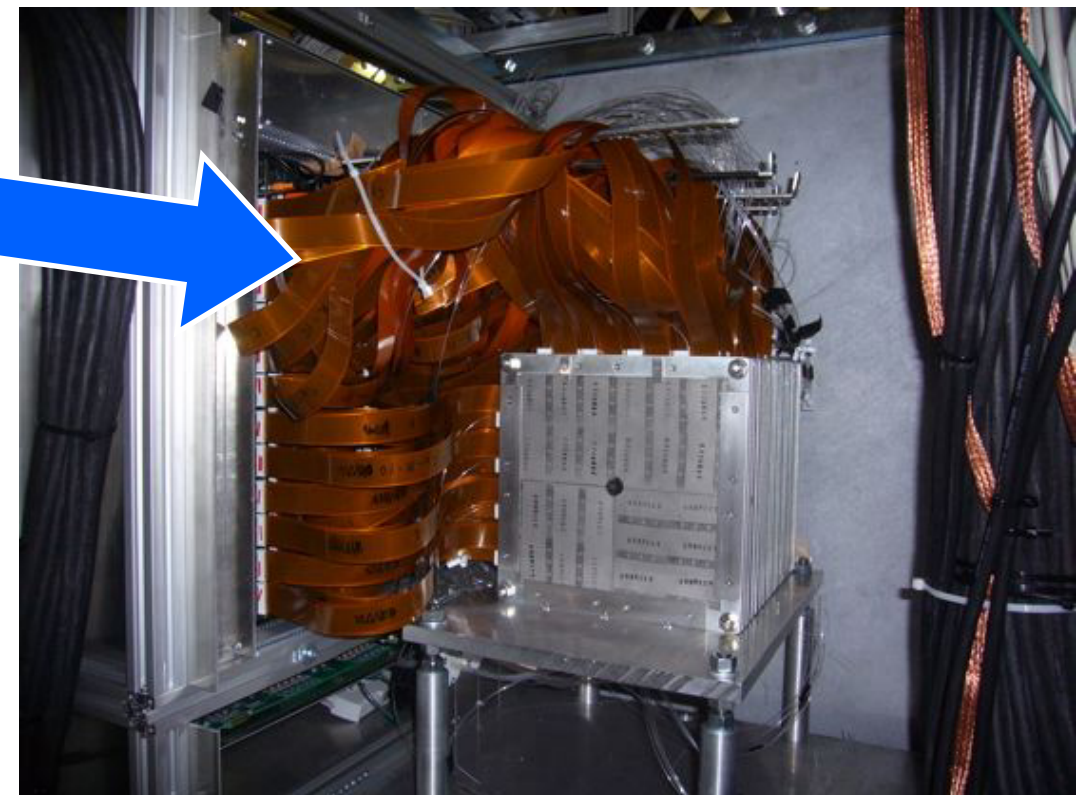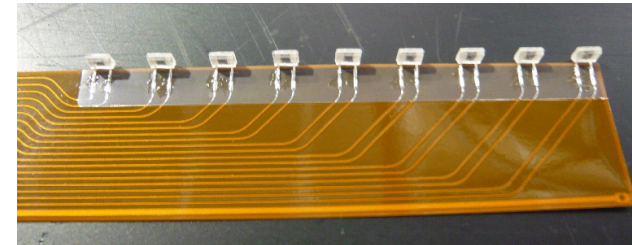× 2 layers(x and y)   +   × 2 layers(x and y)

MPPC cables

10×90 mm^2 × 36 channel
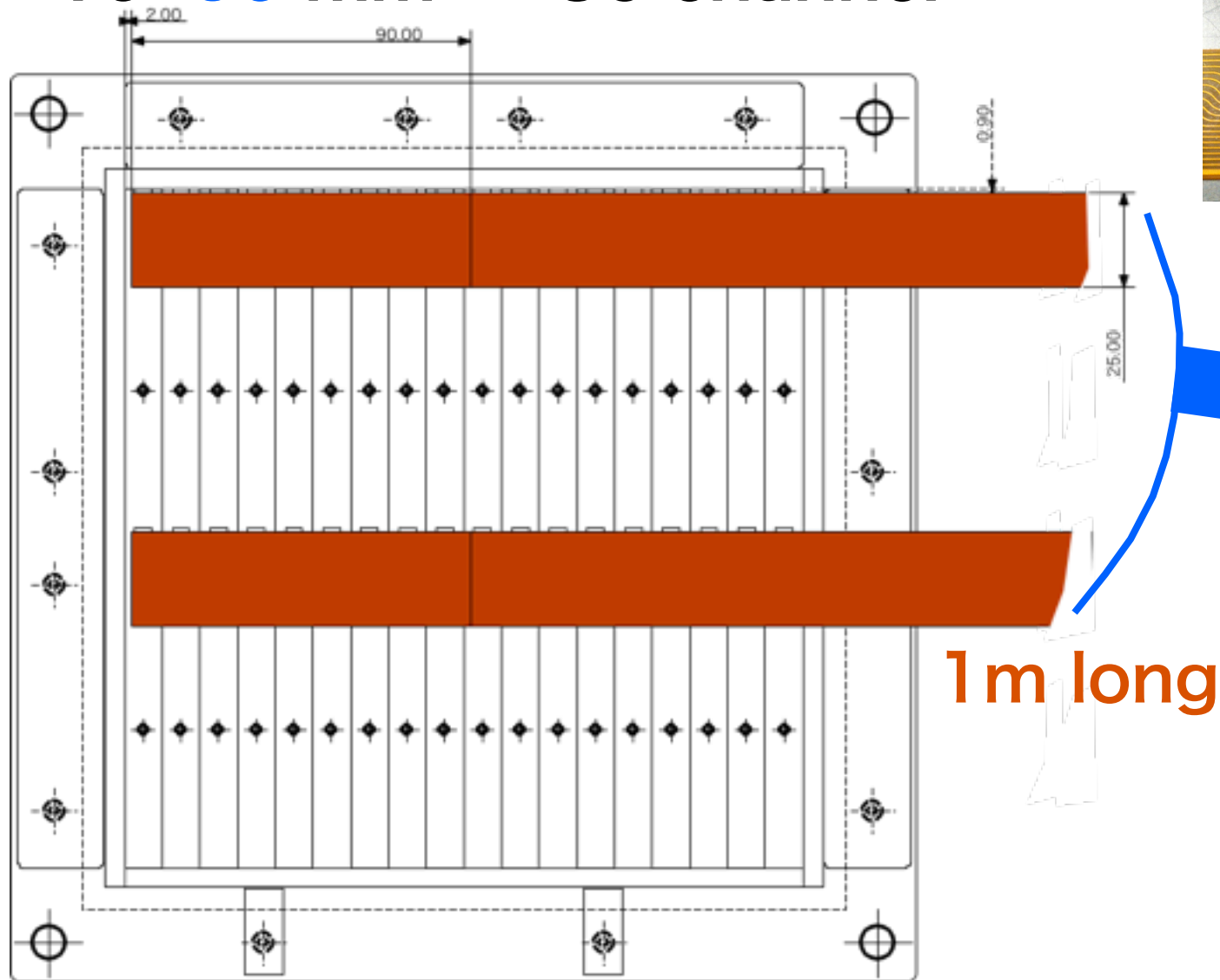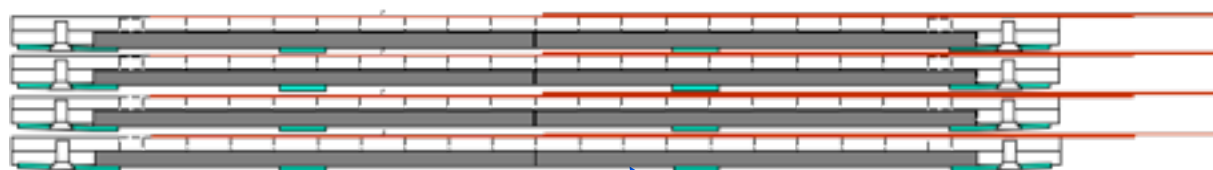
nine MPPC on a cable

1m long

ScECAL physics prototype

240 cables
but ~12 cables in this TB.

4-6 -layer stack

absorber is removable.

Setup and DAQ

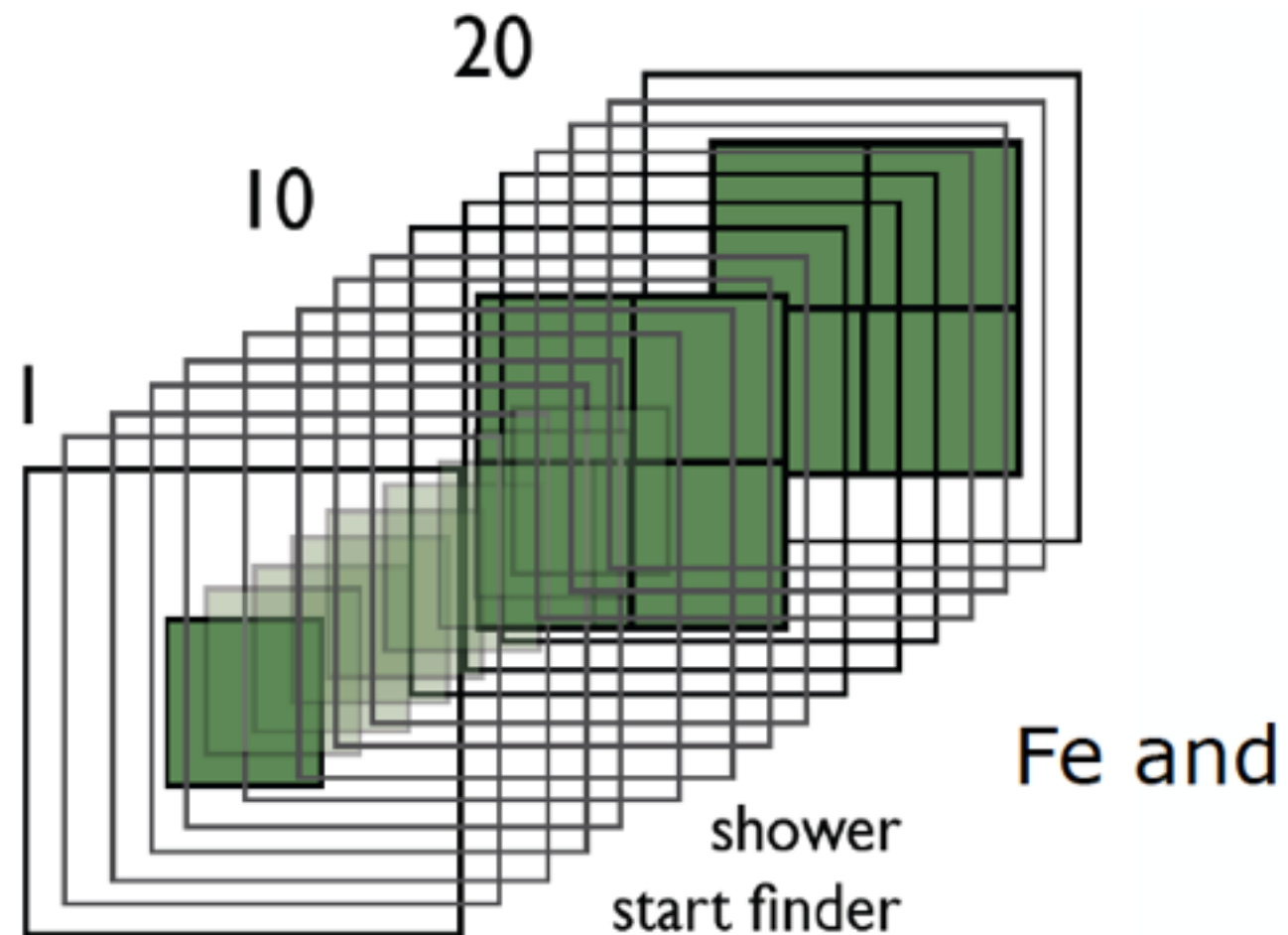~50 mm   240 mm

side view

back view

hight adjustable stand

1 m
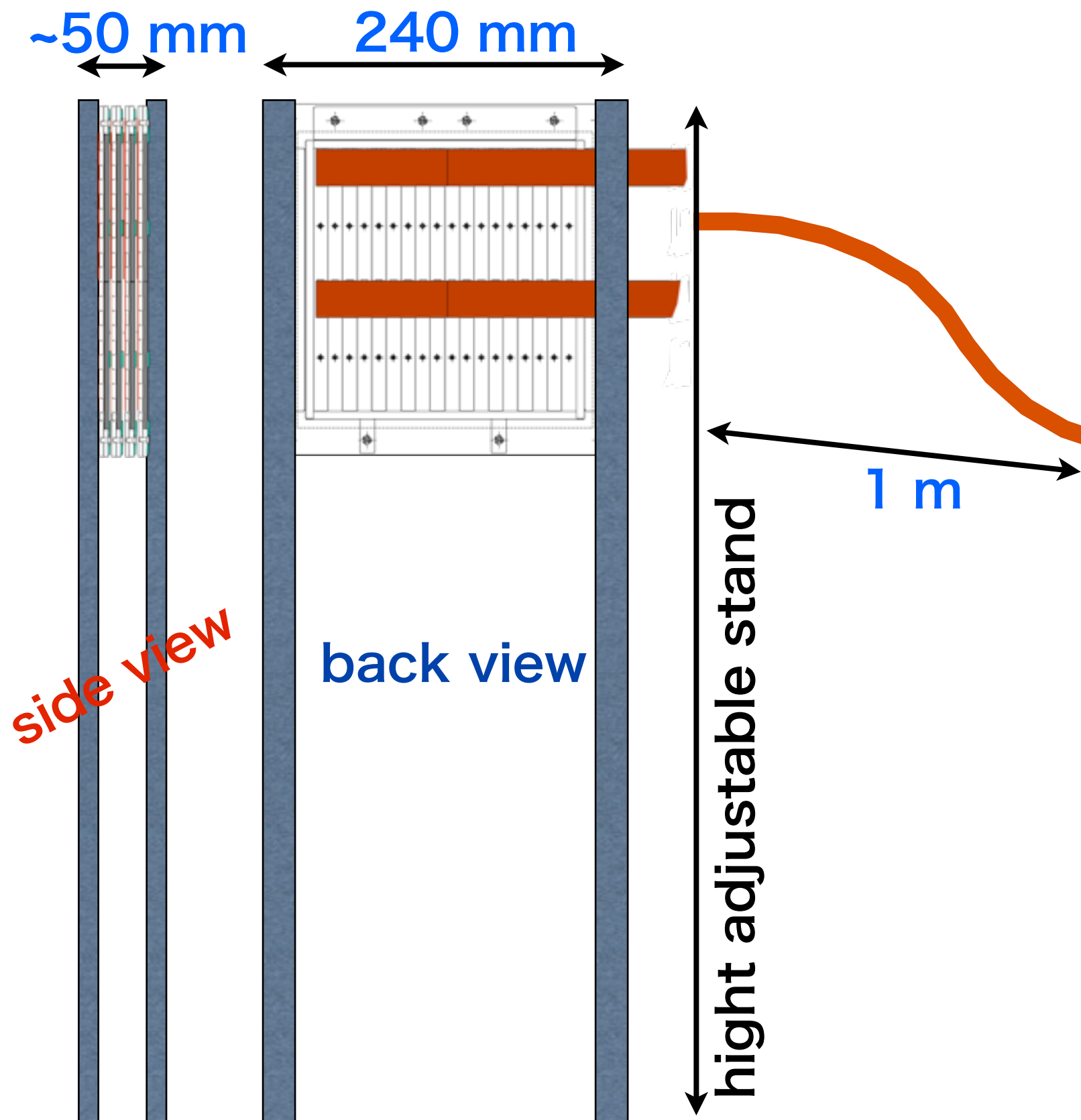
64 channels x
2 Easiroc

Temperature
compensation

Testbeam at CERN

From Felix's slides at CLICWS
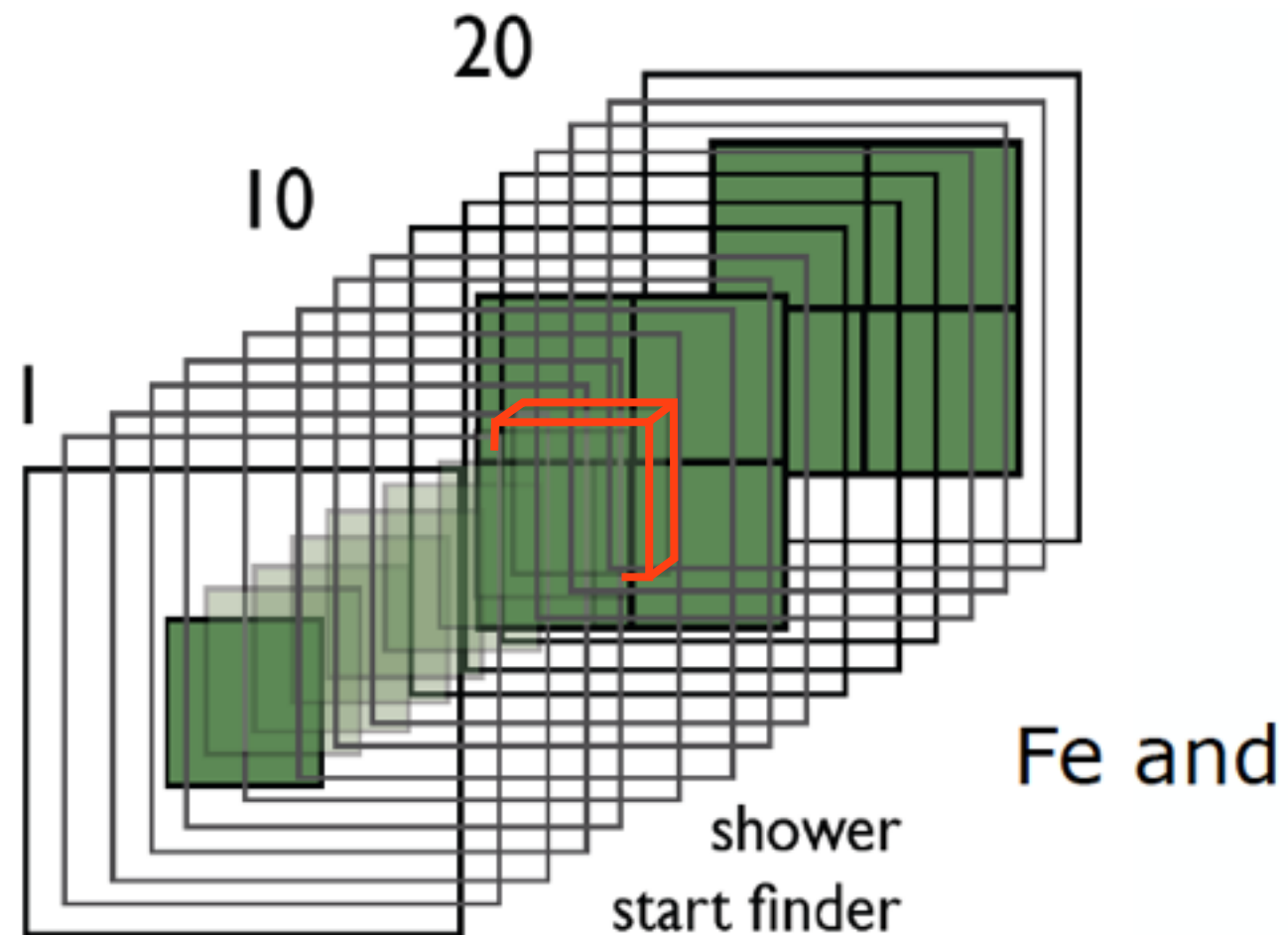
- applied for 2x 2weeks @ PS in fall 2014

shower start finder

Fe and

Testbeam at CERN

From Felix's slides at CLICWS

- applied for 2x 2weeks @ PS in fall 2014

   Between EBU (ScECAL) and AHCAL

   Lessen of ROC chips
   Muon calibration
   Response uniformity

   ....

Summary

1. We are developing strip AHCAL.

2. Strip AHCAL has potential to have good position resolution without degrading of the energy resolution of single cluster.

3. Strip splitting algorithm for the HCAL is implemented.

4. All 10 x 10 mm^2 segmentation including strip and alternate strip and tile have good separation ability.

5. All 10 x 10 mm^2 segmentation have tendency to make excess fragmentations.

6. need optimization of parameters in PFA.

7. We would like to have 180 × 180 mm^2 x 4-6 layers test beam at CERN Autumn 2014.

Back up

Two-layer trial

We've already constructed a two-layer prototype in the frame of ScECAL 2nd prototype with 10 mm x 180 mm strips.
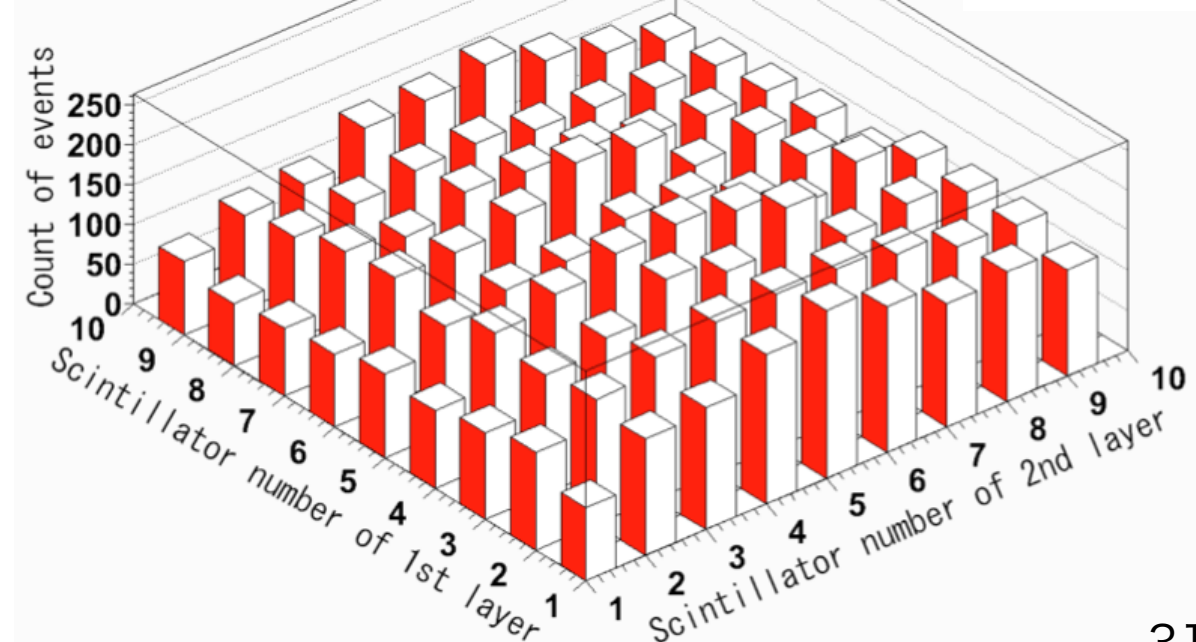
For the single muons, 10 mm x 10 mm granularity is not difficult with two layers.

Distribution of the zenith angle measured by this two-layer Strip - AHCAL prototype is consistent with MC result (by M. Harada 2011).
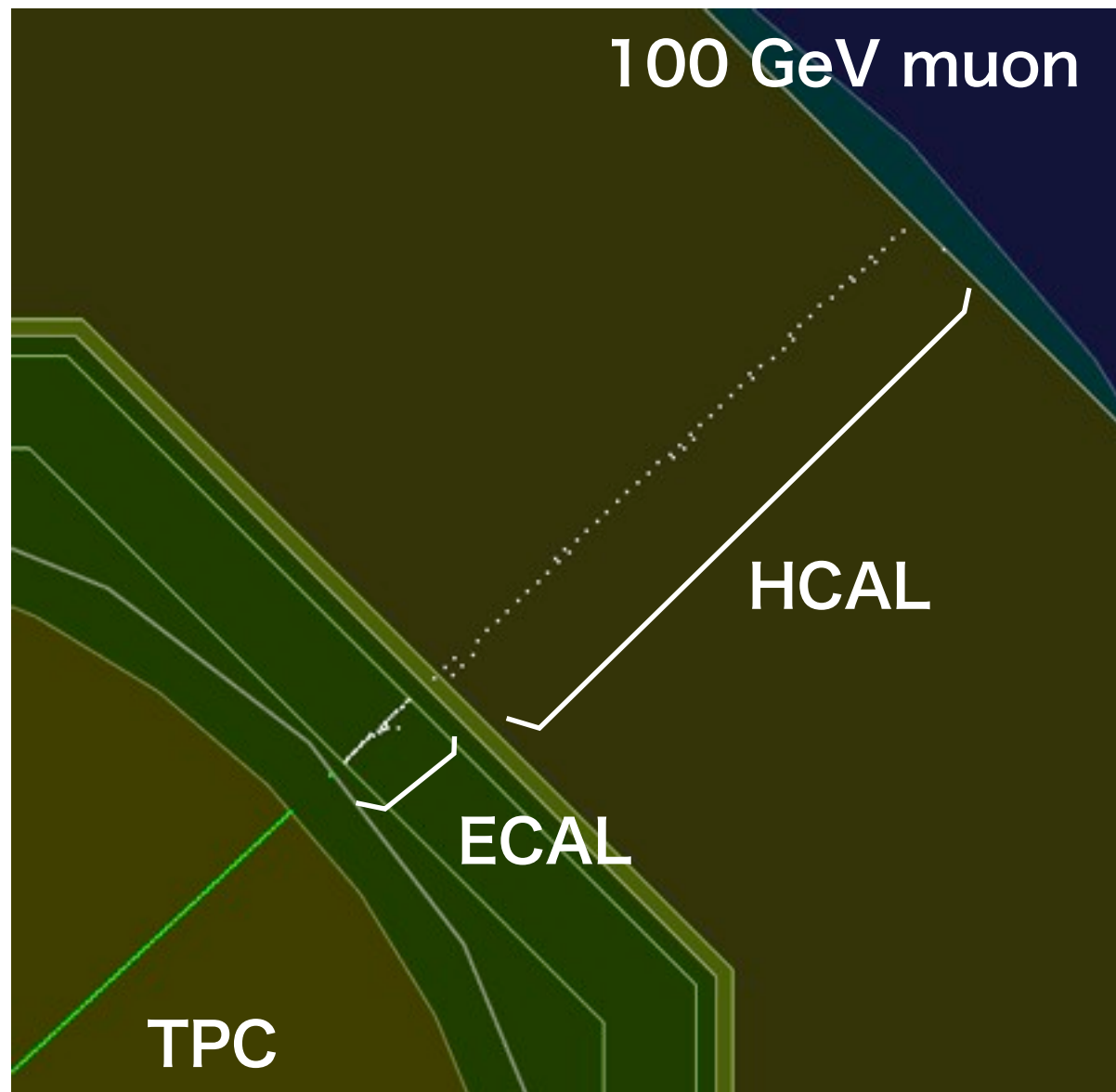

180 mm

18 channel/layer

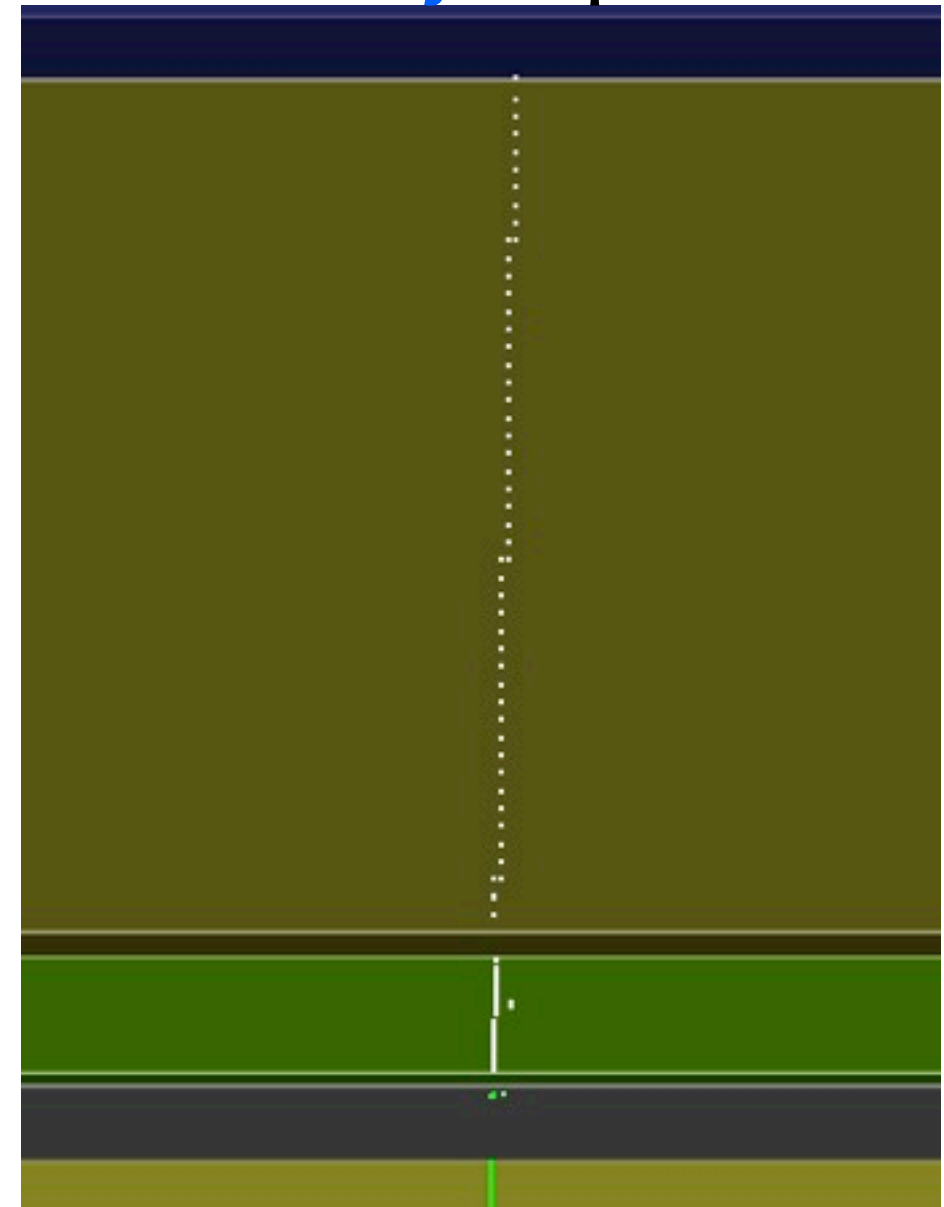180 mm
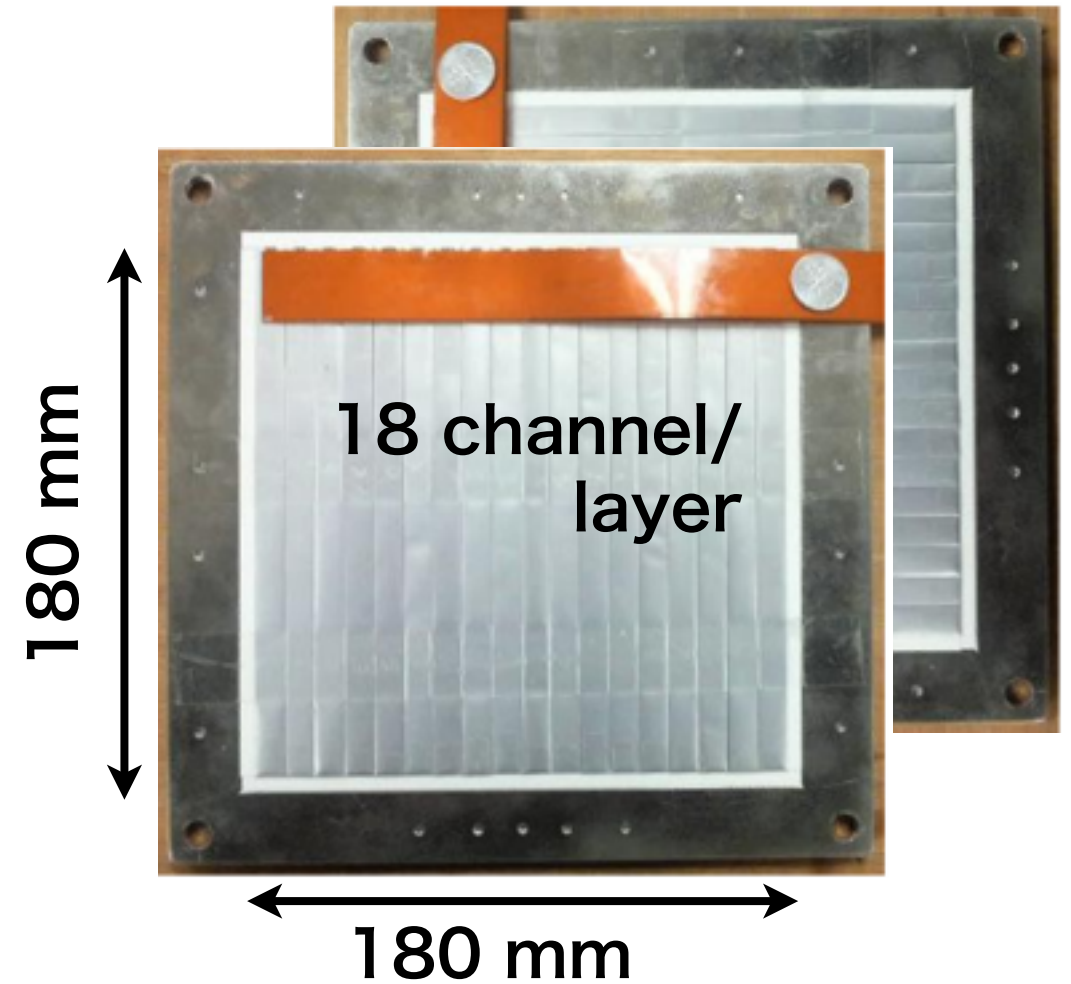
by M. Harada

Cosmic ray muons

Clear muon track appears with Strip Splitting Algorithm

after SSA : x - y plane

after SSA : y - z plane

100 GeV muon

HCAL

ECAL

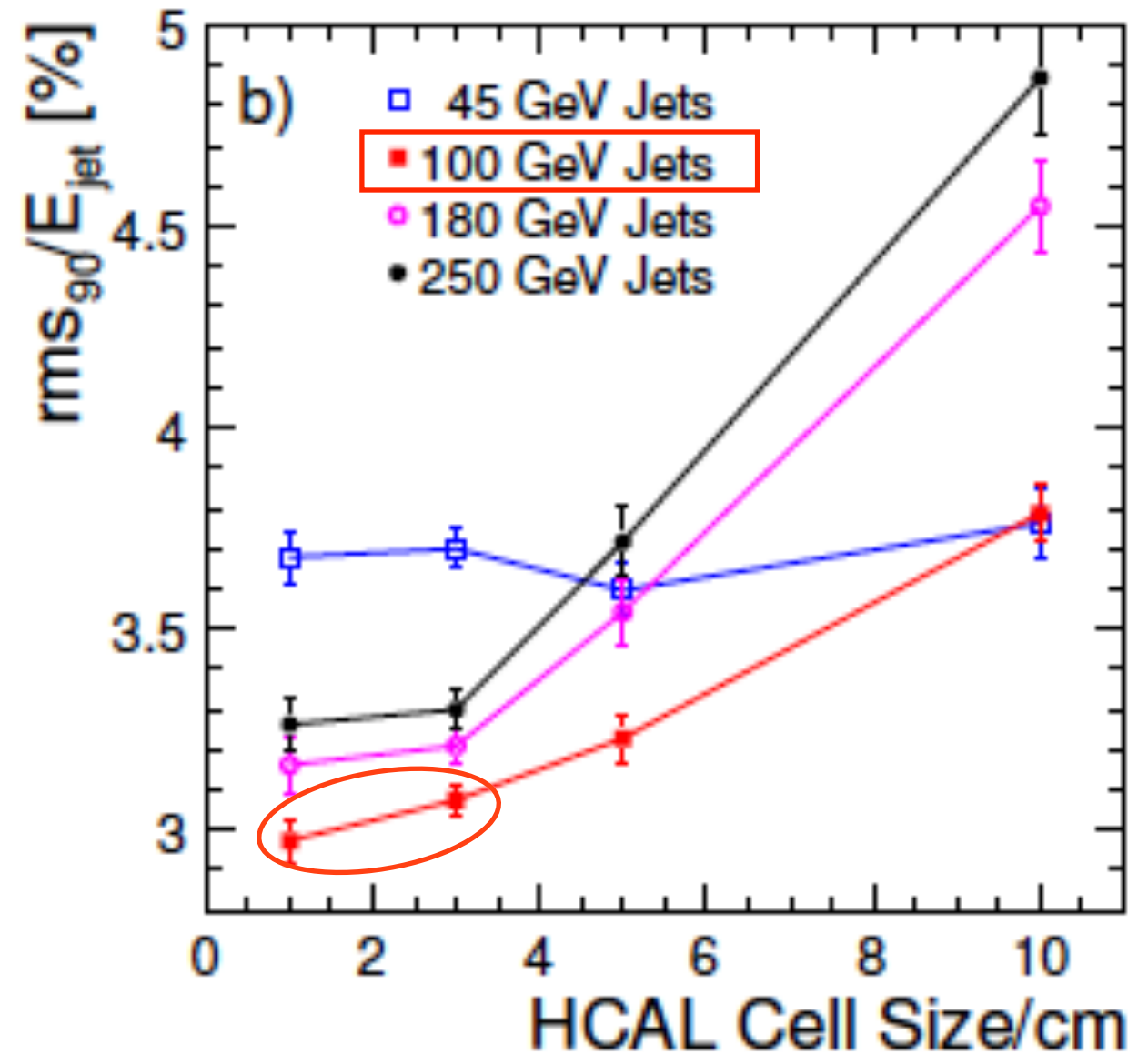TPC

10 mm x 90 mm strips in HCAL.

A famous plot in the LOI
(this is the reason why AHCAL tiles: 30 x 30 mm^2)

100 GeV Jets have a room to make evaluation to use 10 mm x 10 mm segmentation, so I will show the case we use 100 GeV uds jet events to evaluate the performance.

Plan

1. Tune of PFA to get better JER of 10x10mm^2 than 30x30mm^2,

2. comparison of the performance of 10 x 10 mm^2 and 30 x 30 mm^2 with severer conditions in order to show the effects of finer segmentation,

3. endcap issues.
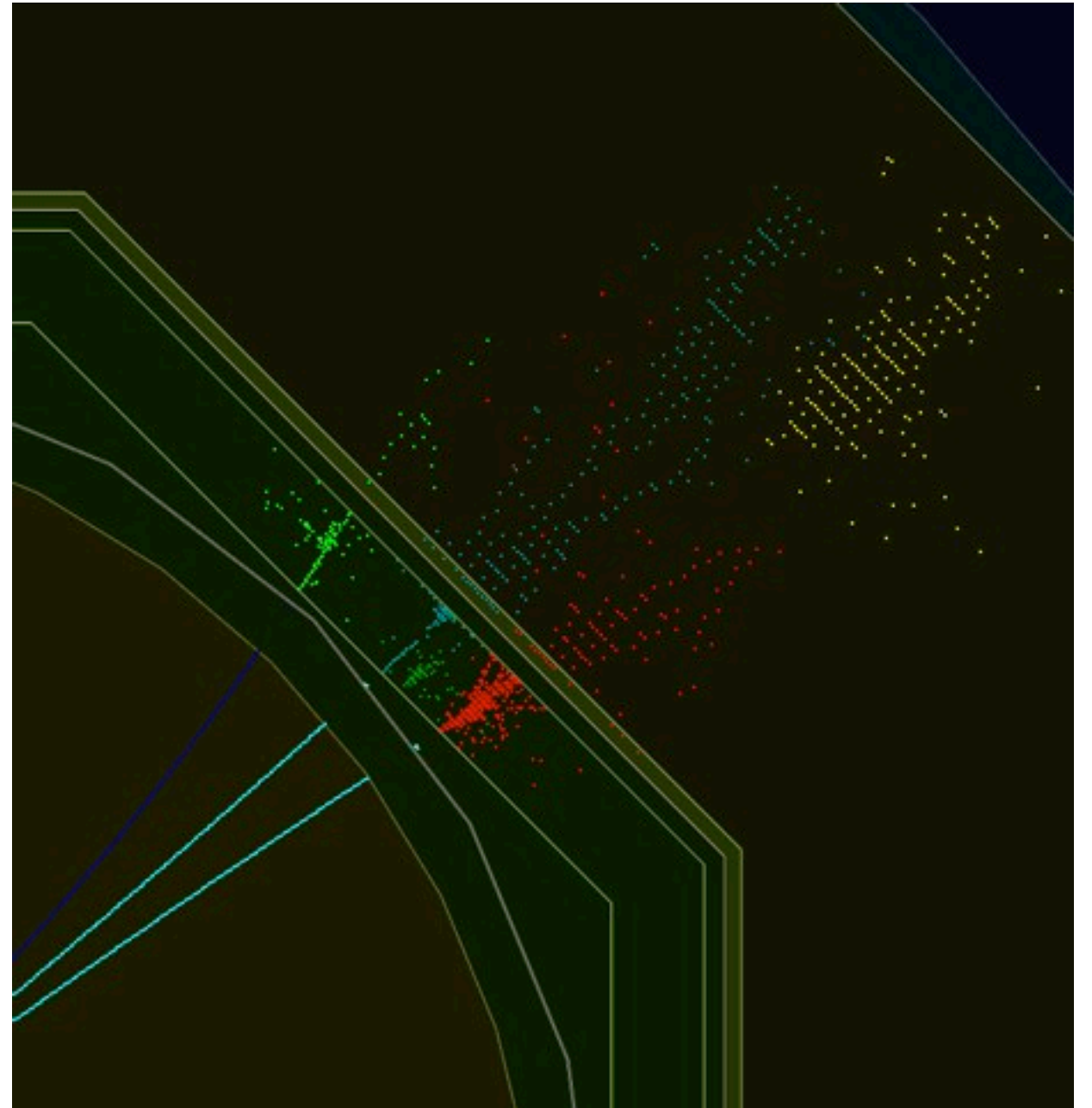
4. combinations of tile layers and strip layers,
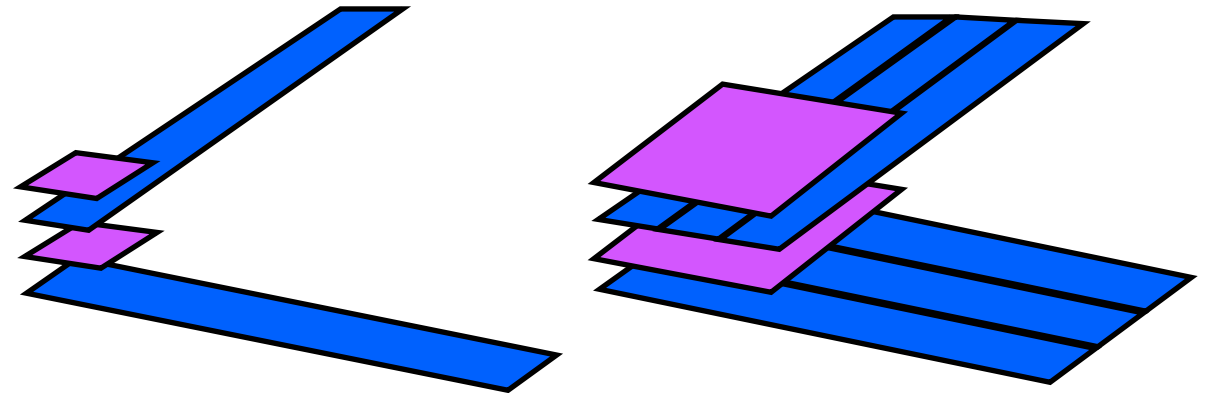
5. construction of a test beam module.

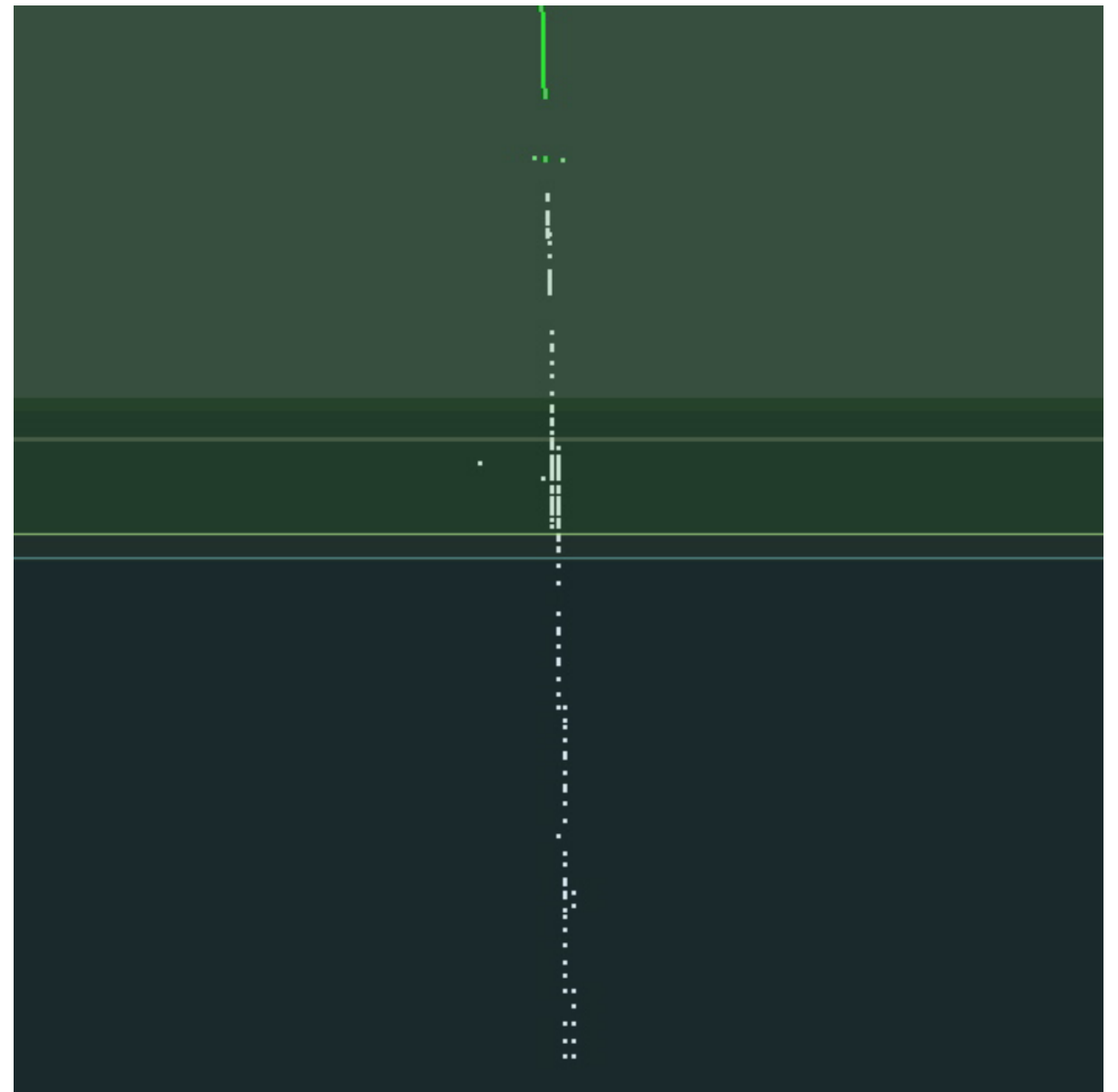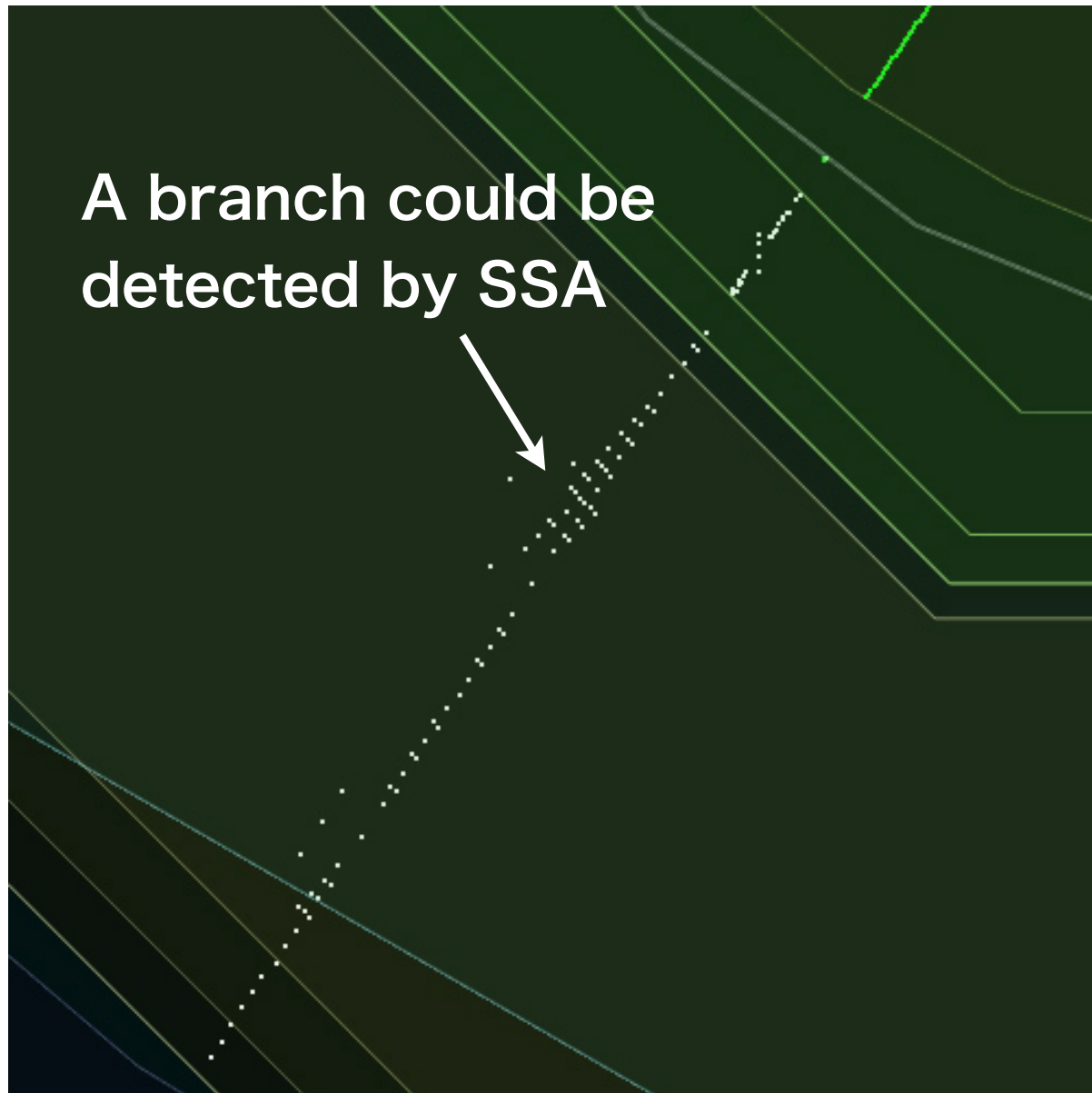   - strip size are decided according to the simulation results.

without the strip splitting.

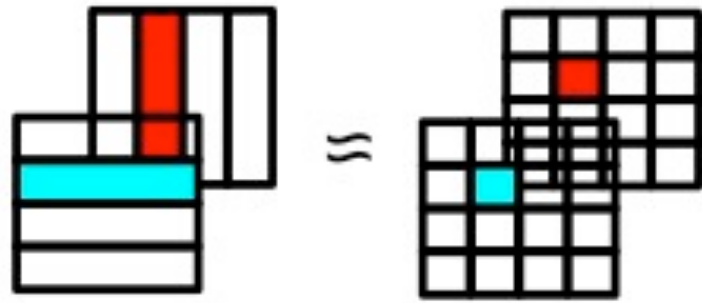White arrows show lacks of hit in the track and the circles show strange hits.

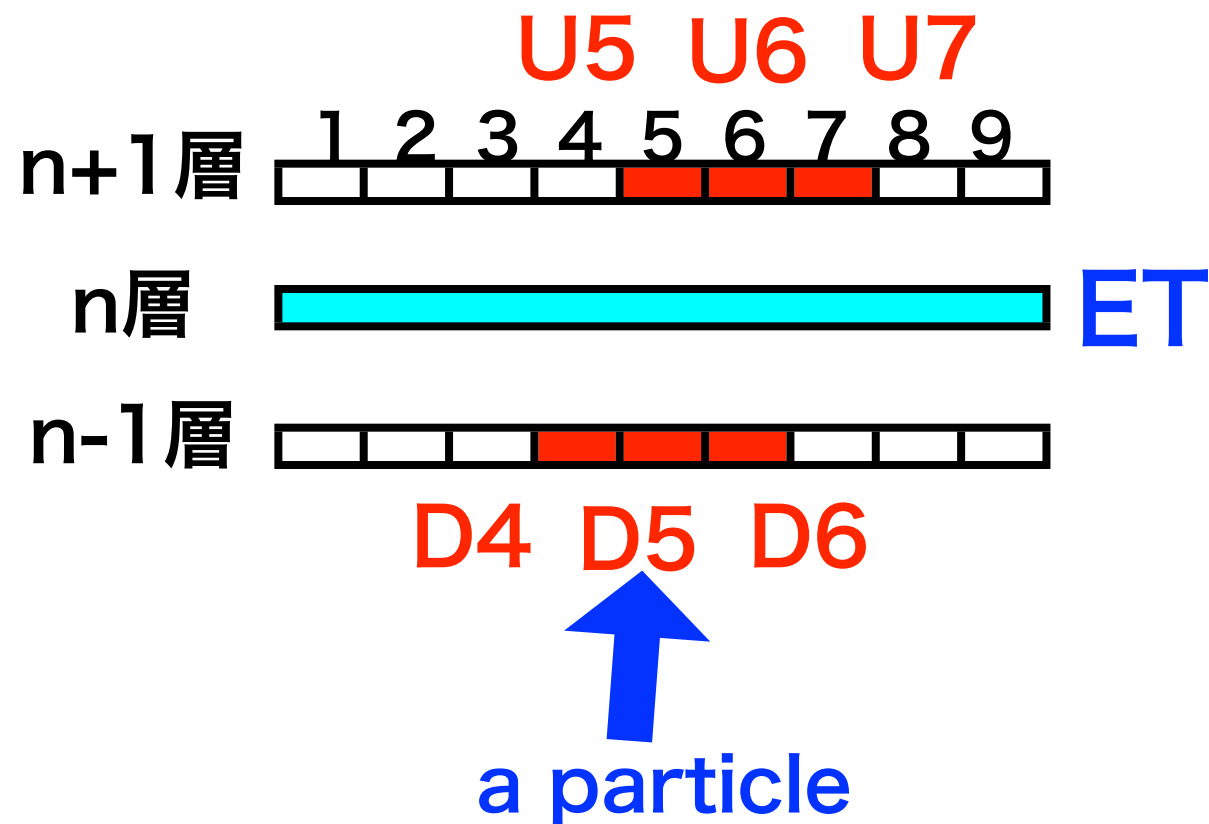I'm afraid bugs, but I've not yet found them.

A branch could be detected by SSA

Strip Ecal reconstruction with the strip splitting algorithm

deposited energy on a strip delivered into virtual square cells

U5 U6 U7

1 2 3 4 5 6 7 8 9

n+1層

n層   ET
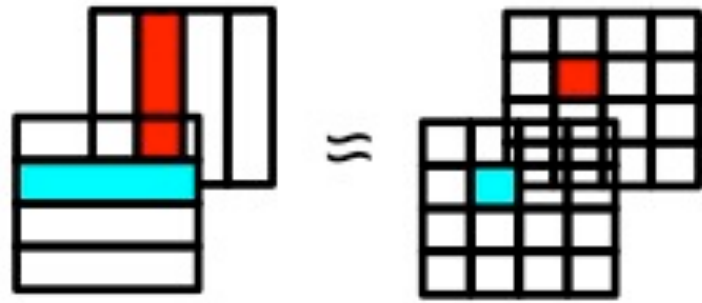
n-1層

D4 D5 D6

a particle

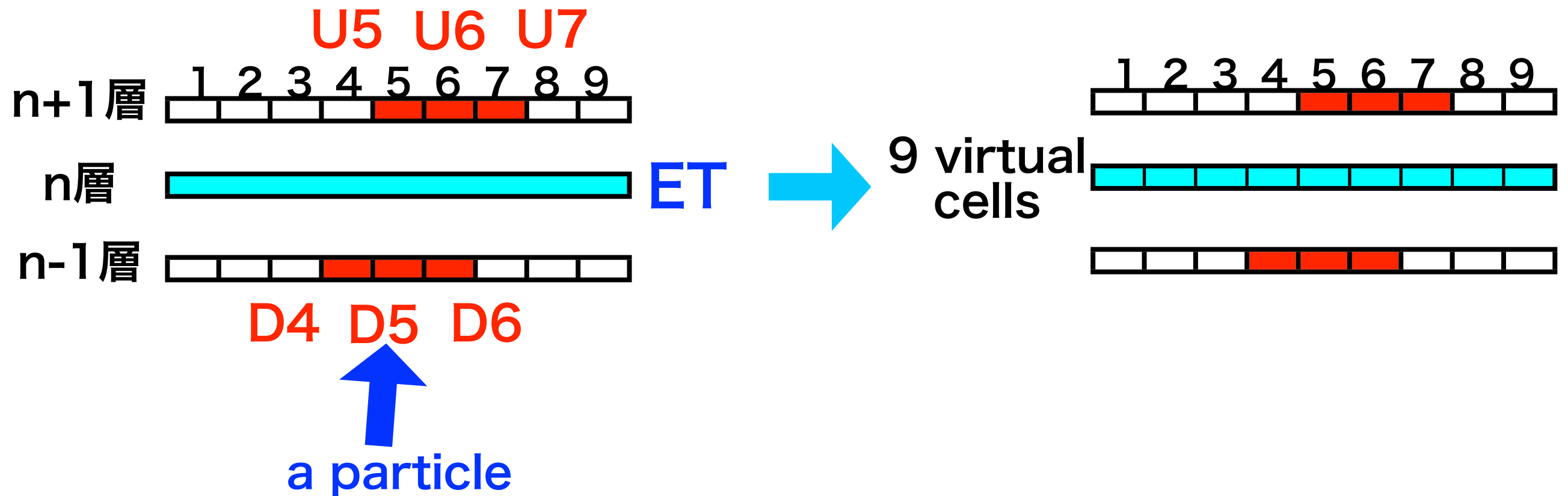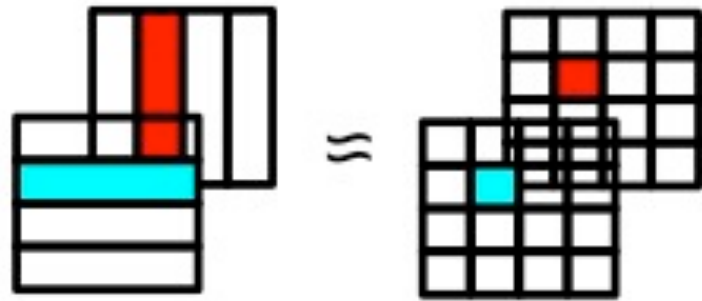# Strip Ecal reconstruction with the strip splitting algorithm
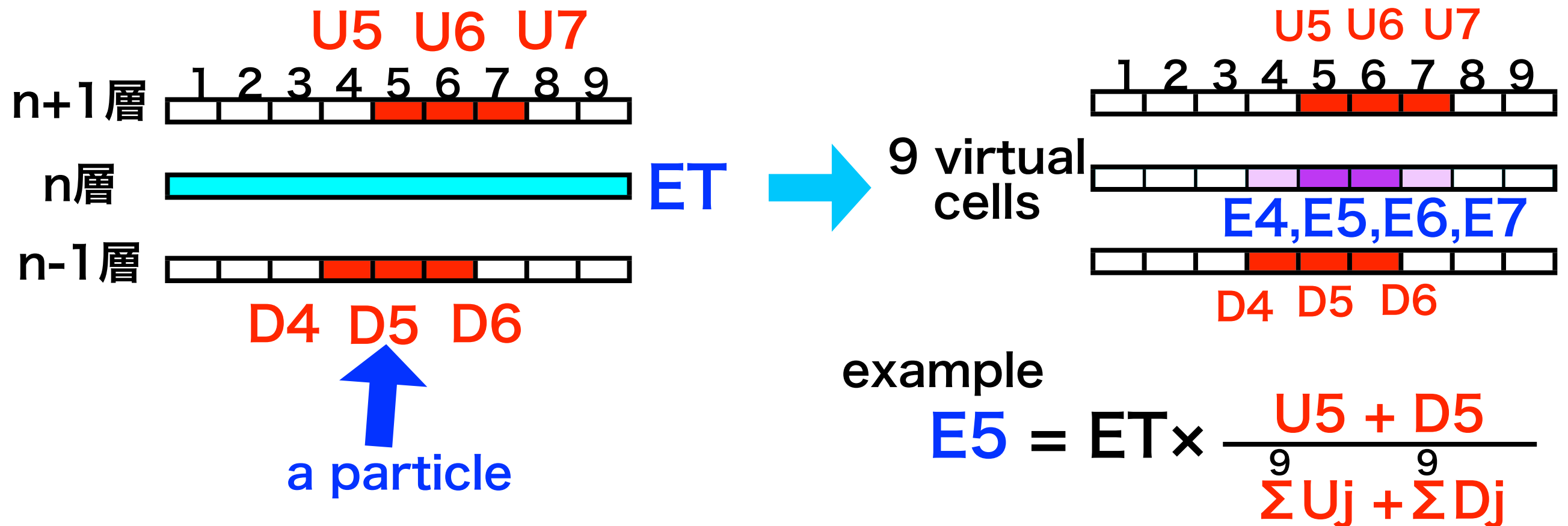

deposited energy on a strip delivered into virtual square cells

# Strip Ecal reconstruction with the strip splitting algorithm

deposited energy on a strip delivered into virtual square cells

U5 U6 U7

n+1層 1 2 3 4 5 6 7 8 9

n層 ET

n-1層

D4 D5 D6

↑

a particle

U5 U6 U7

1 2 3 4 5 6 7 8 9

9 virtual cells

E4,E5,E6,E7

D4 D5 D6

example

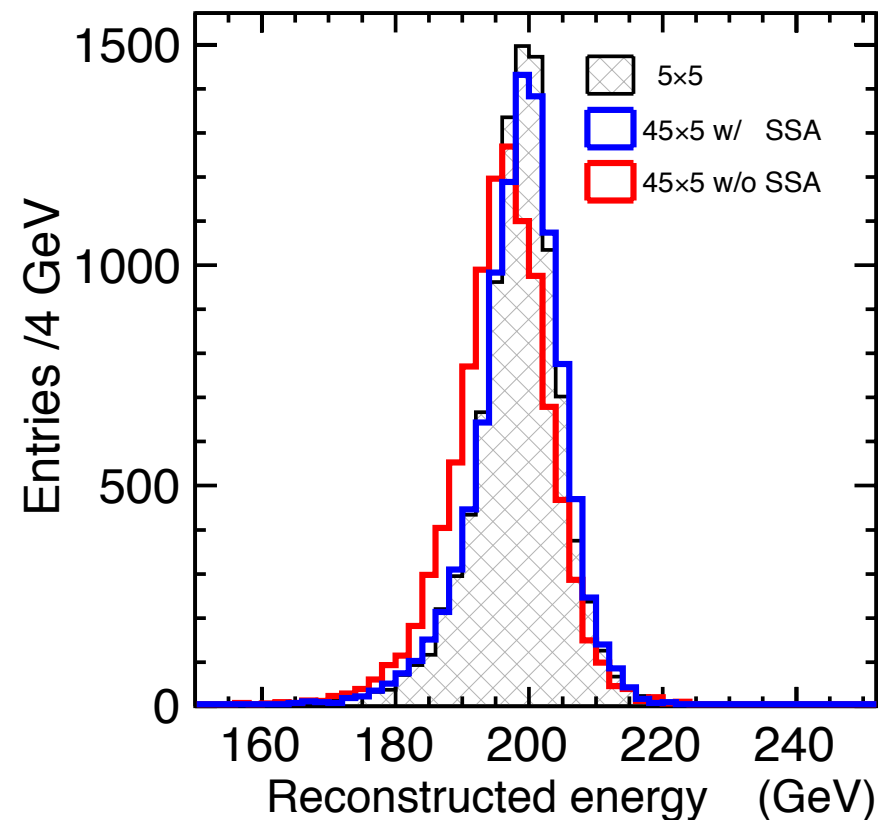$$E5 = ET \times \frac{U5 + D5}{\sum\limits_{9} Uj + \sum\limits_{9} Dj}$$

positions and energies of all virtual cells are fed into the PandoraPFA program

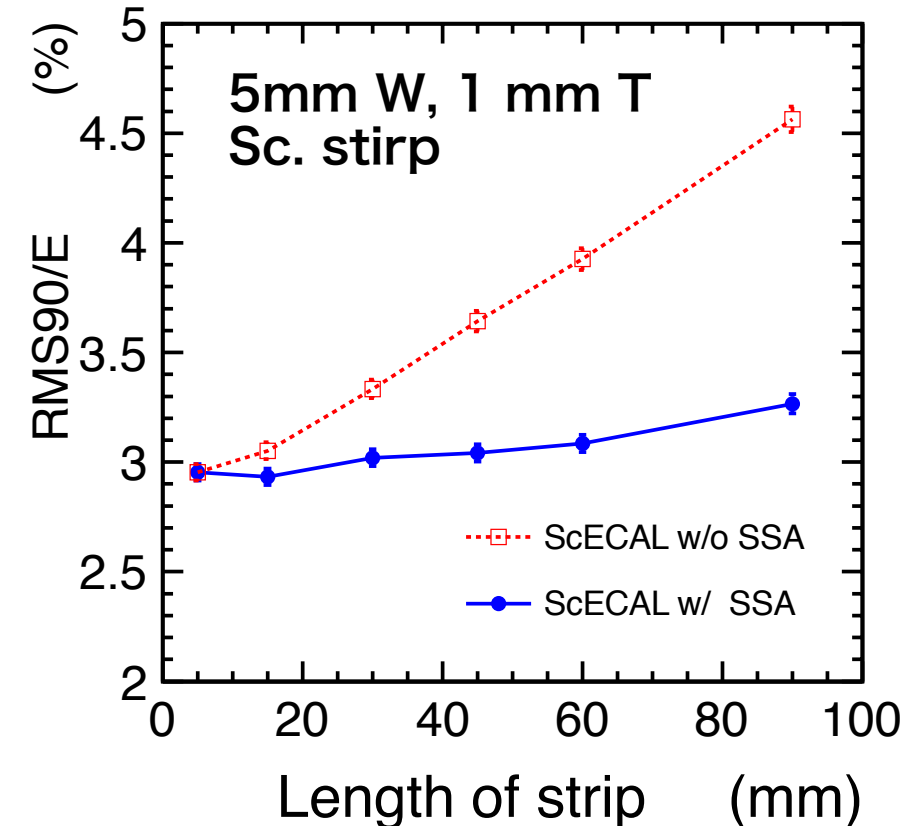# Comparisons of performance btwn. w/ SSA and w/o SSA

Position of 10 GeV photon
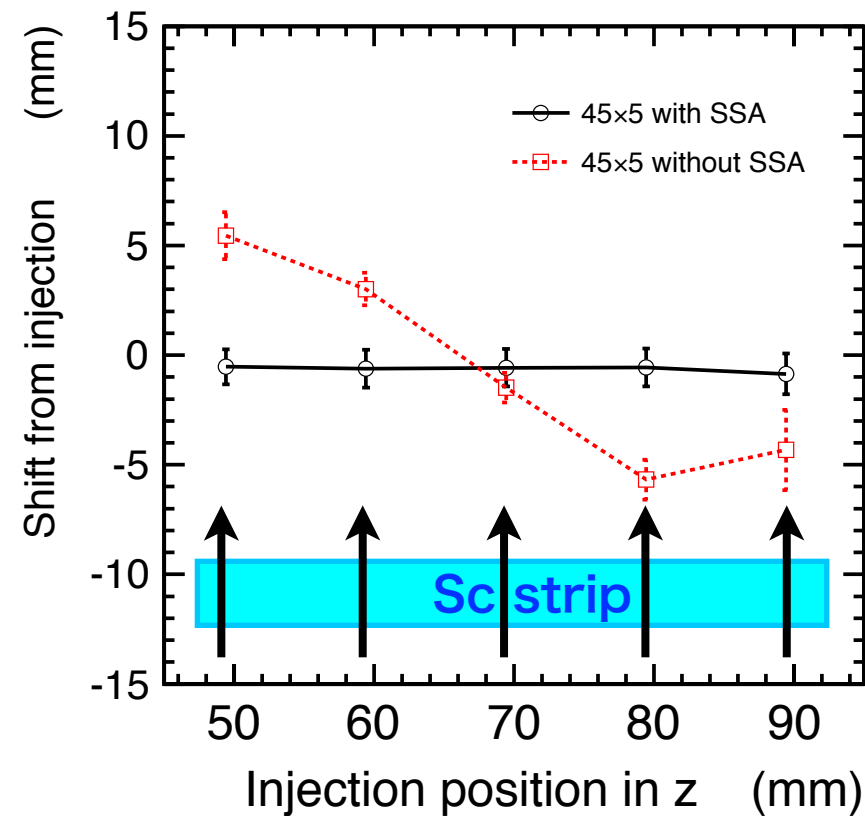
Energy sum of 2 x 100 GeV jet

Energy resln. 100 GeV Jet

Left: position accuracy and precision
    Error bar (RMS) < 1 mm w/ SSA.

Middle: Energy is recovered correctly w/ SSA.

Right: Jet energy resolution is kept w/ SSA.