Reconstruction method of Scintillator Strip ECAL

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4. ghost study with μ-μ events,
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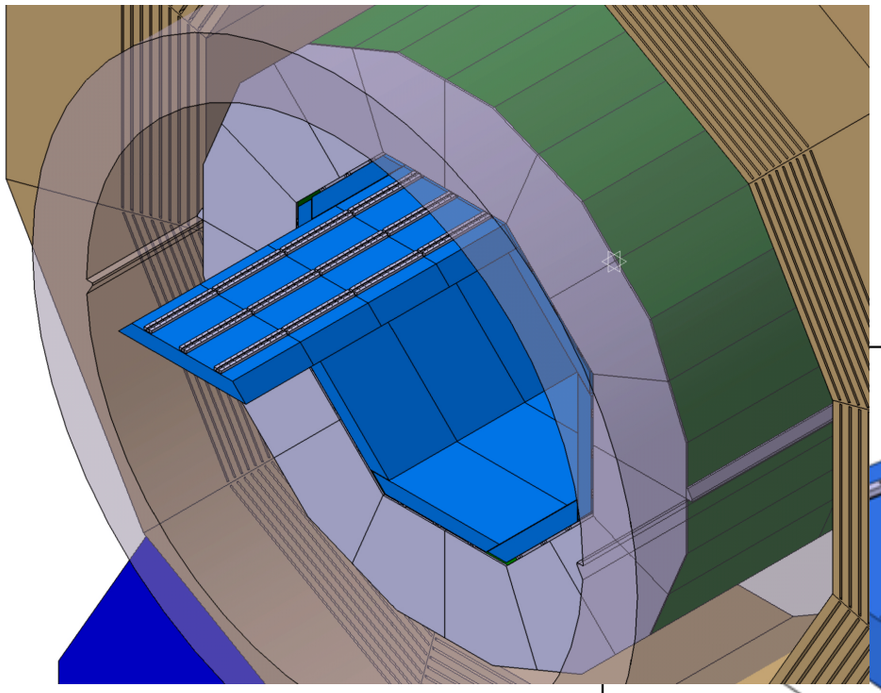
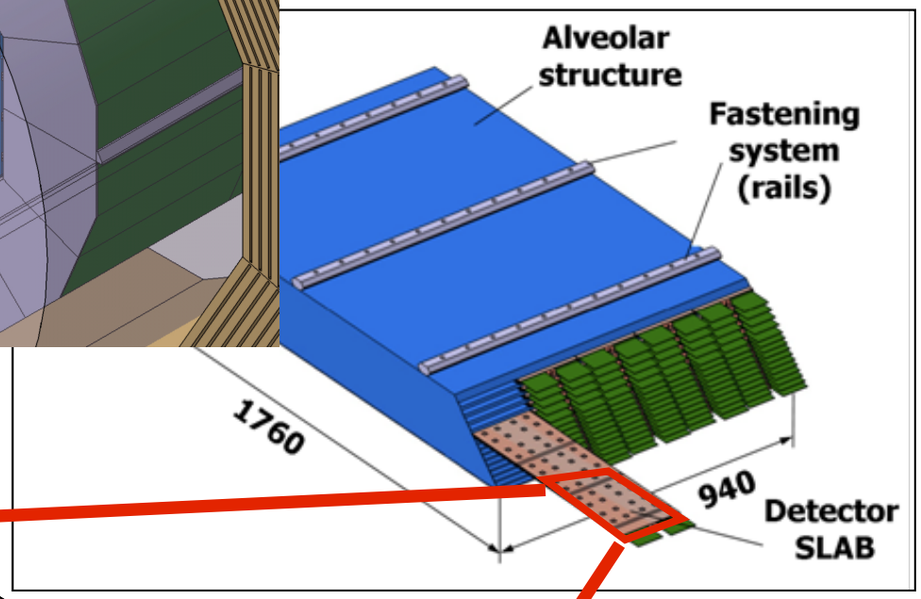
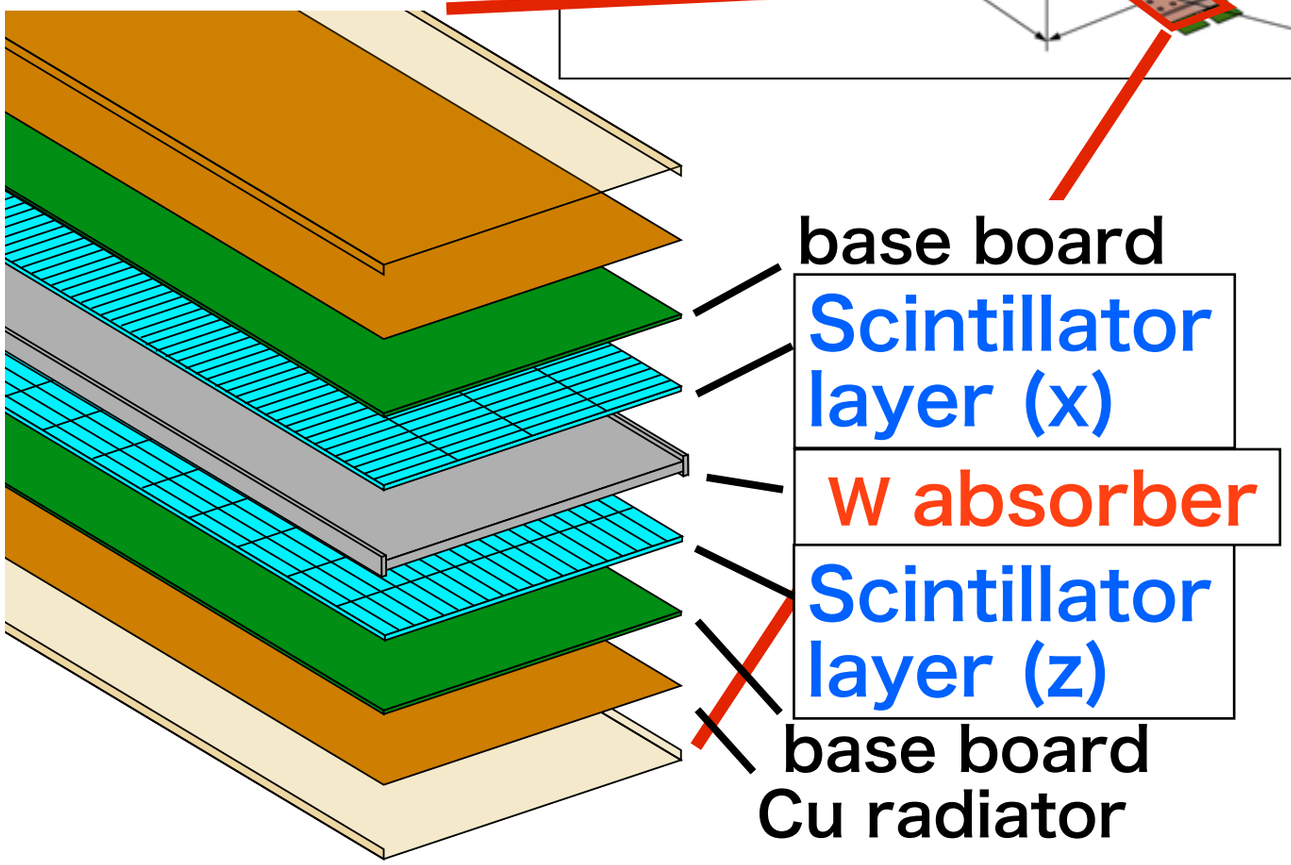
6. summary.

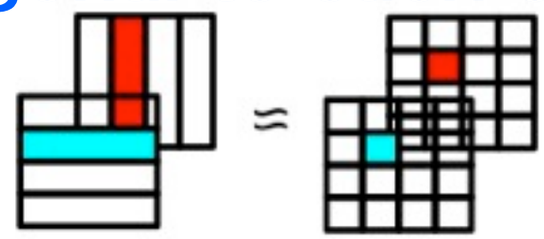
Strip ScECAL in ILD





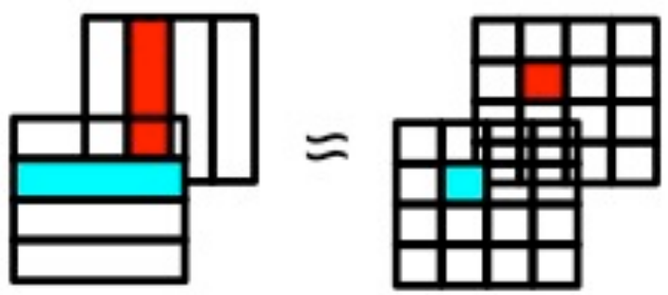


1. Mechanical design of the barrel and the endcaps: ILD_o3_V05
2. alveolar structure itself is made with W absorbers.
3. two scintillator layers in an alveolar make a sandwich structure with a tungsten absorber.
4. strip directions are orthogonal to each other.

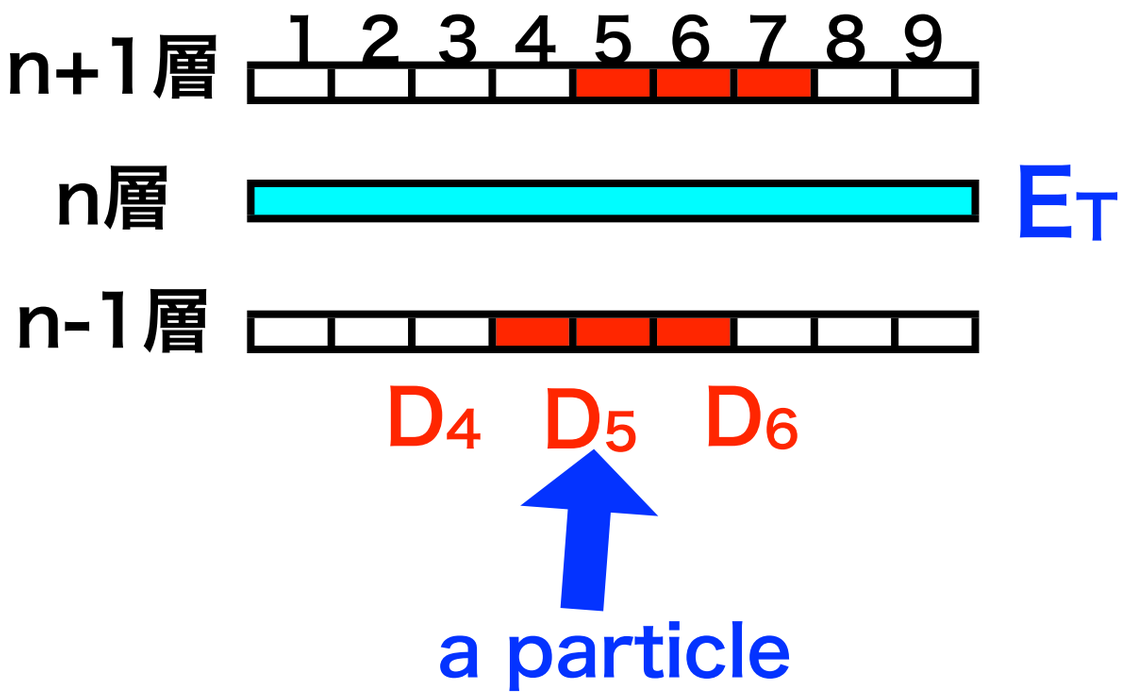


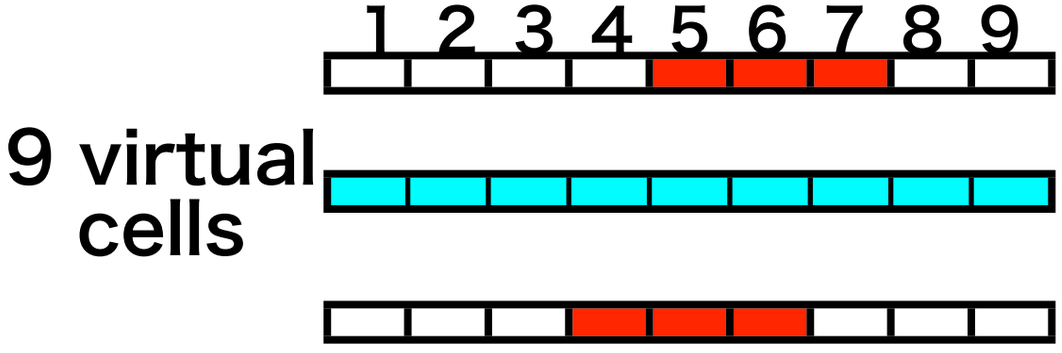
Strip Ecal reconstruction with the strip splitting algorithm

How to extract 5x5 mm² granularity from strip Scintillators



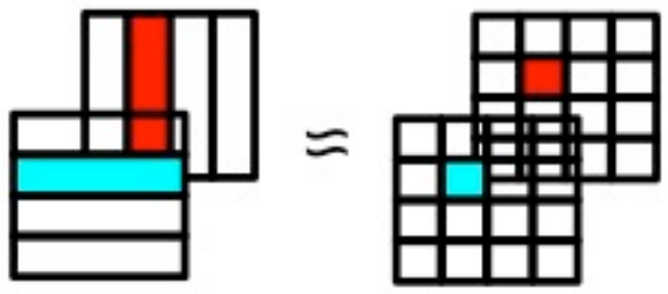
deposited energy on a strip
delivered into virtual square cells



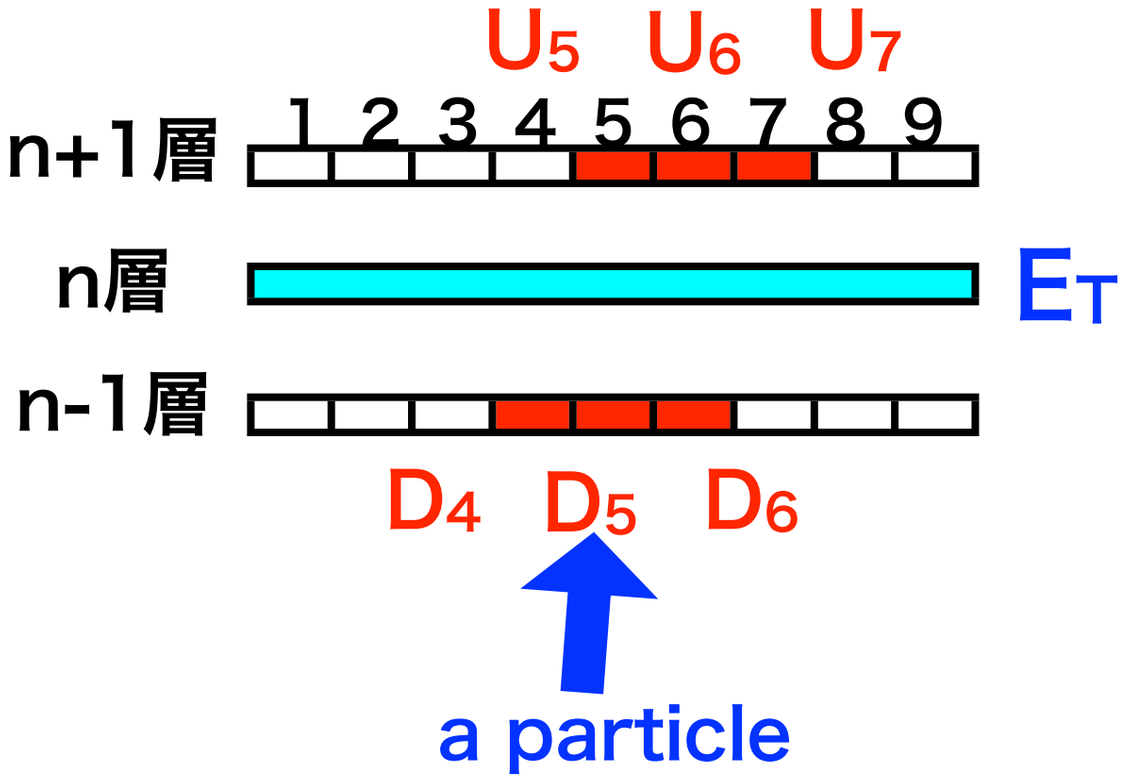


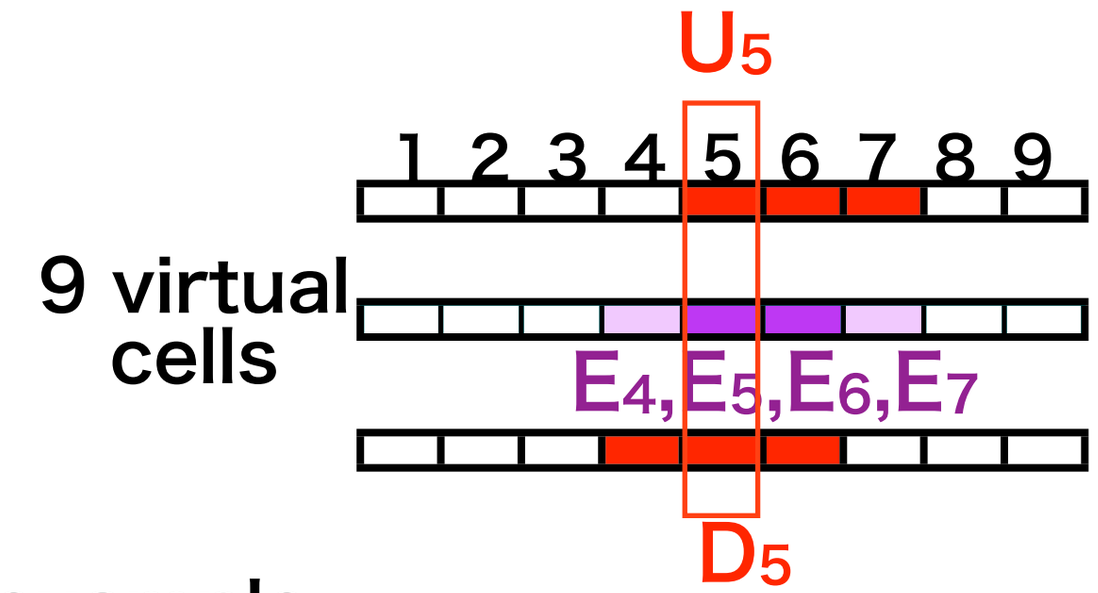
Strip Ecal reconstruction with the strip splitting algorithm

How to extract 5x5 mm² granularity from strip Scintillators



deposited energy on a strip
delivered into virtual square cells





example

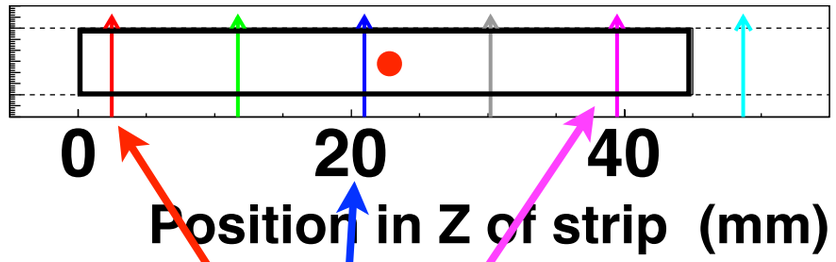
$$E_5 = E_T \times \frac{D_5 + U_5}{\sum_{9} D_j + \sum_{9} U_j}$$

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

Position reconstraction
Gravitational center of energy

10 GeV photons are injected on the ScECAL of ILD, changing injection position w.r.t. a scintillator of the first layer.

Side view of a scintillator of the first layer and injection point of photons



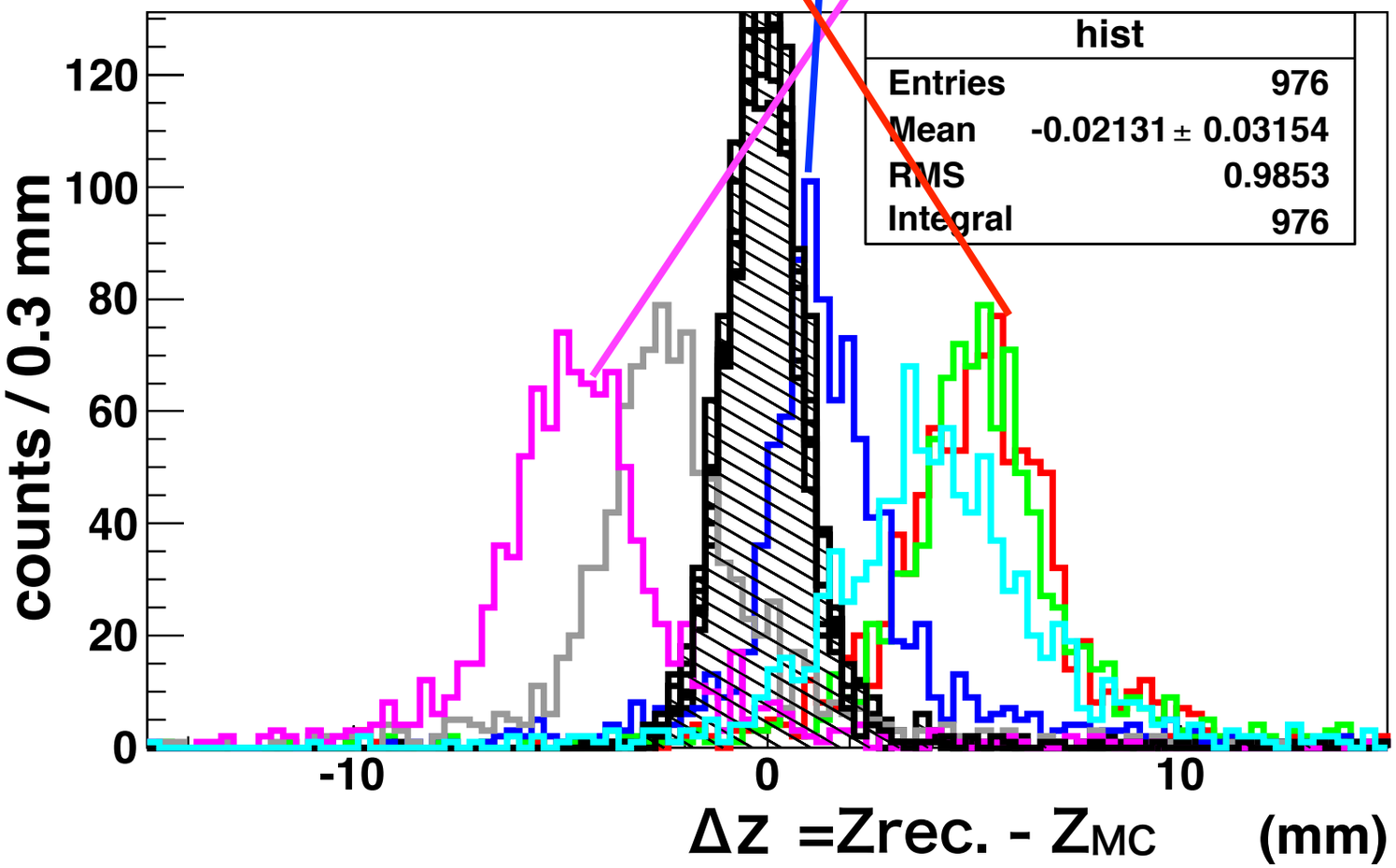
Colored open histogram: without SSA

Black hatched: reconstructed PF object with SSA, not depend on injection position.

Position resolution is ~1 mm

Systematic shift is removed by the SSA

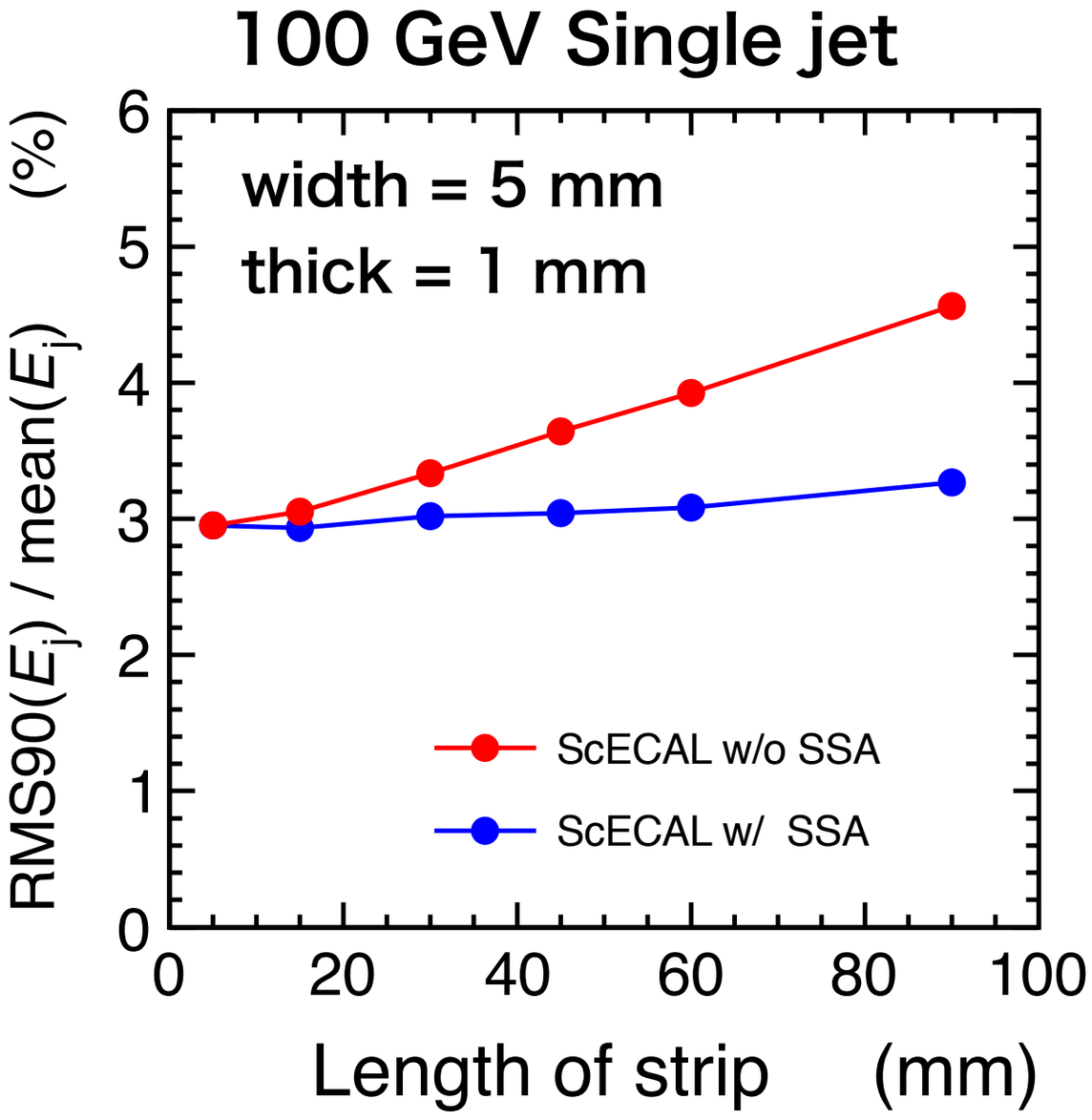
Distance btw. position of re-constructed PFO and MC true in z.



uds Jet Energy Resolution

depending on the strip length

$$e^+e^- \rightarrow q\bar{q} \quad q = u, d, s$$

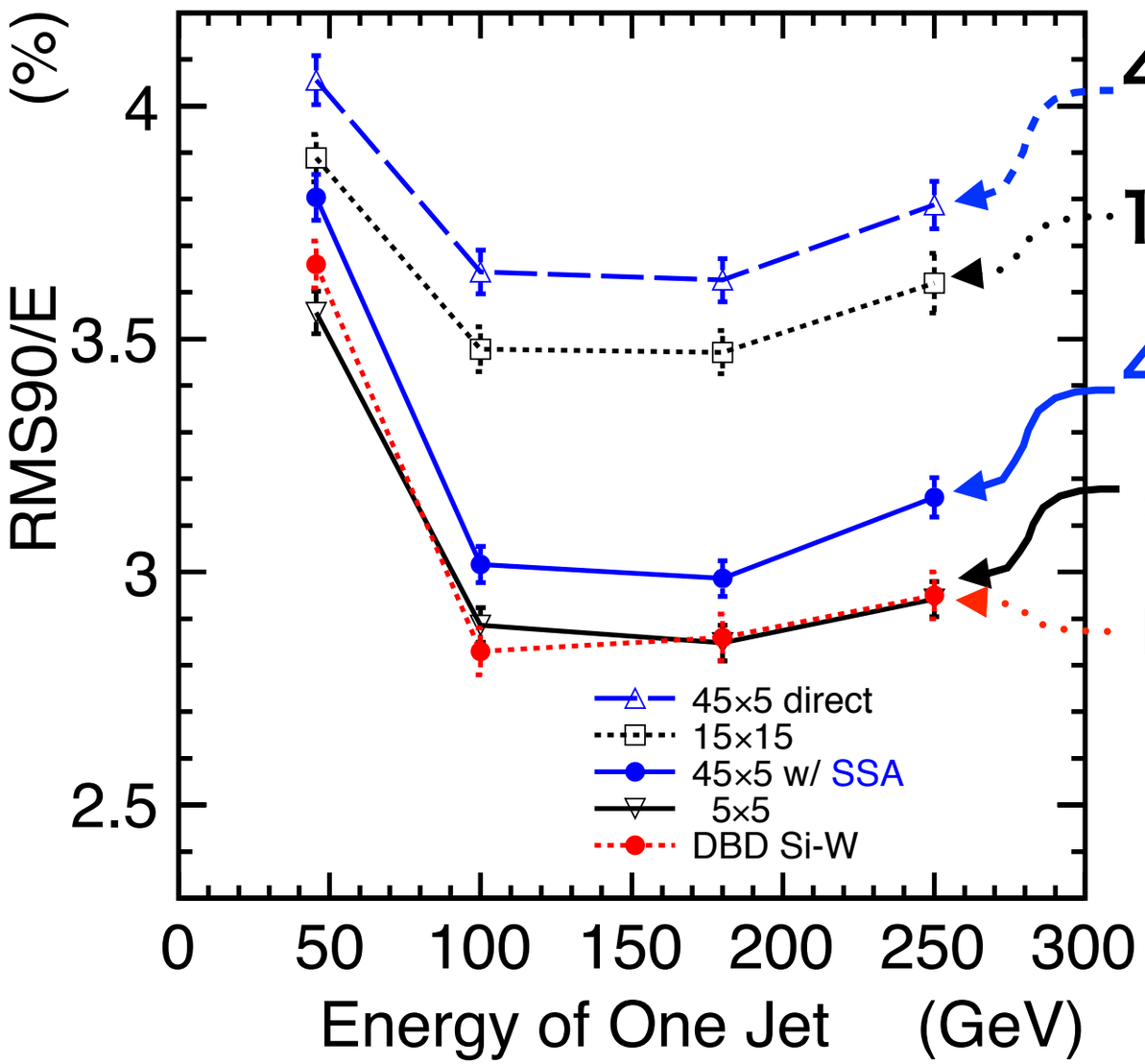


- No large deterioration with increasing the strip length up to 60 mm after applying SSA.
  ▶ we study on 45 mm strip as a standard length,

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

Jet energy resolution

$$e^+e^- \to q\bar{q} \quad q = u, d, s$$



45 x 5 mm² strip ScECAL w/o SSA

15 x 15 mm² tile ScECAL

45 x 5 mm² strip ScECAL w SSA

5 x 5 mm² tile ScECAL

DBD results (Si-W ECAL)

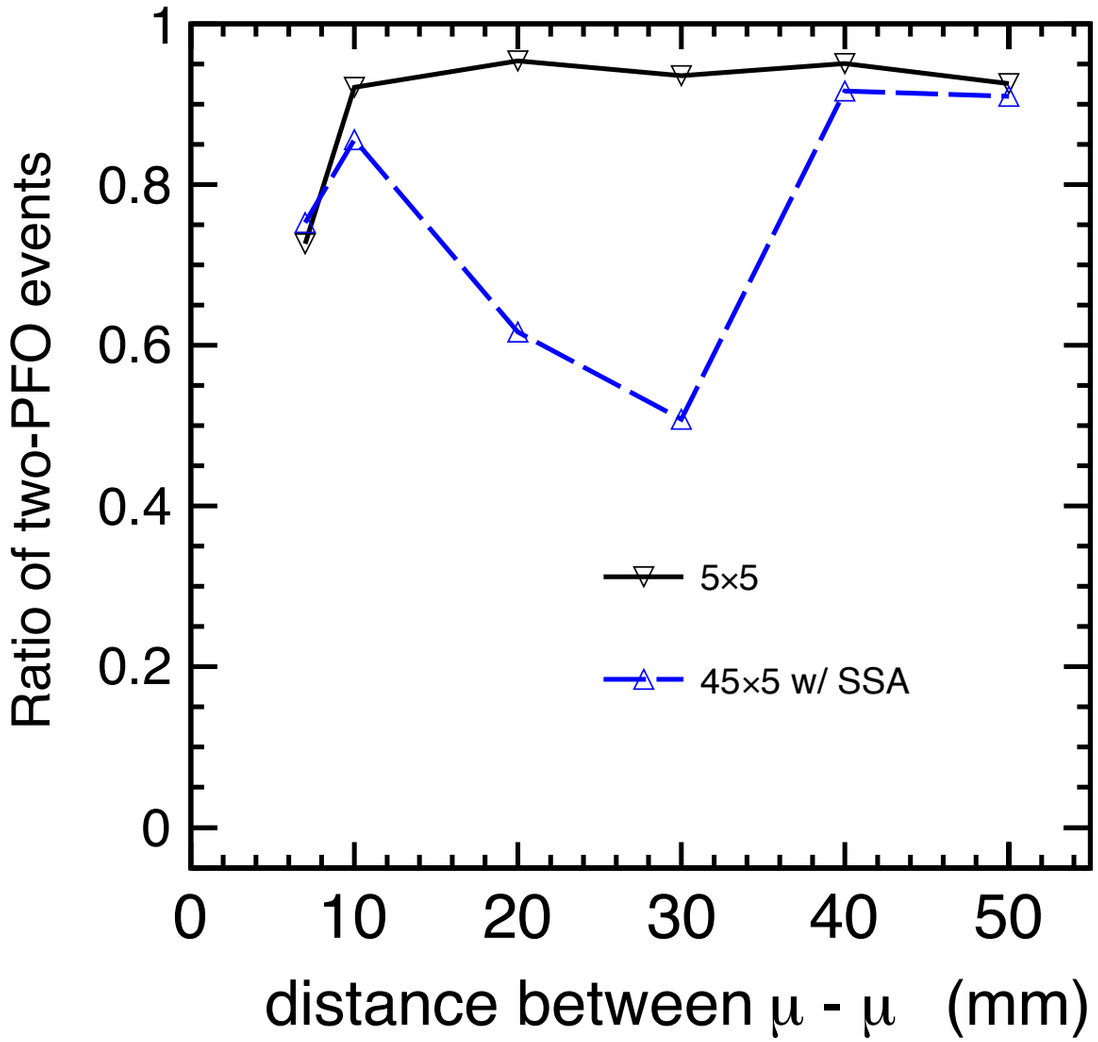
SSA works well,

leave ~0.2% difference from 5 x 5 mm² tile ScECAL and DBD results

Detail study with μ-μ events

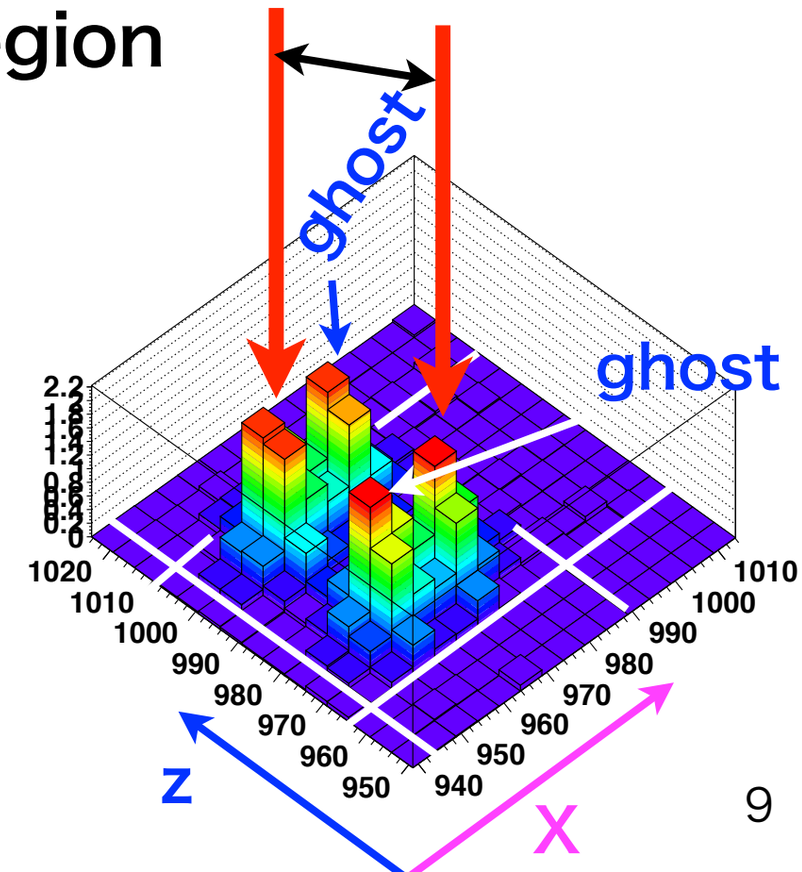
To reduce 0.2% difference of jet energy resolution between 45x5 mm² ECAL w/ SSA and 5 x 5 mm² ECAL,

Ratio of two Particle Flow Object (μ-μ) event

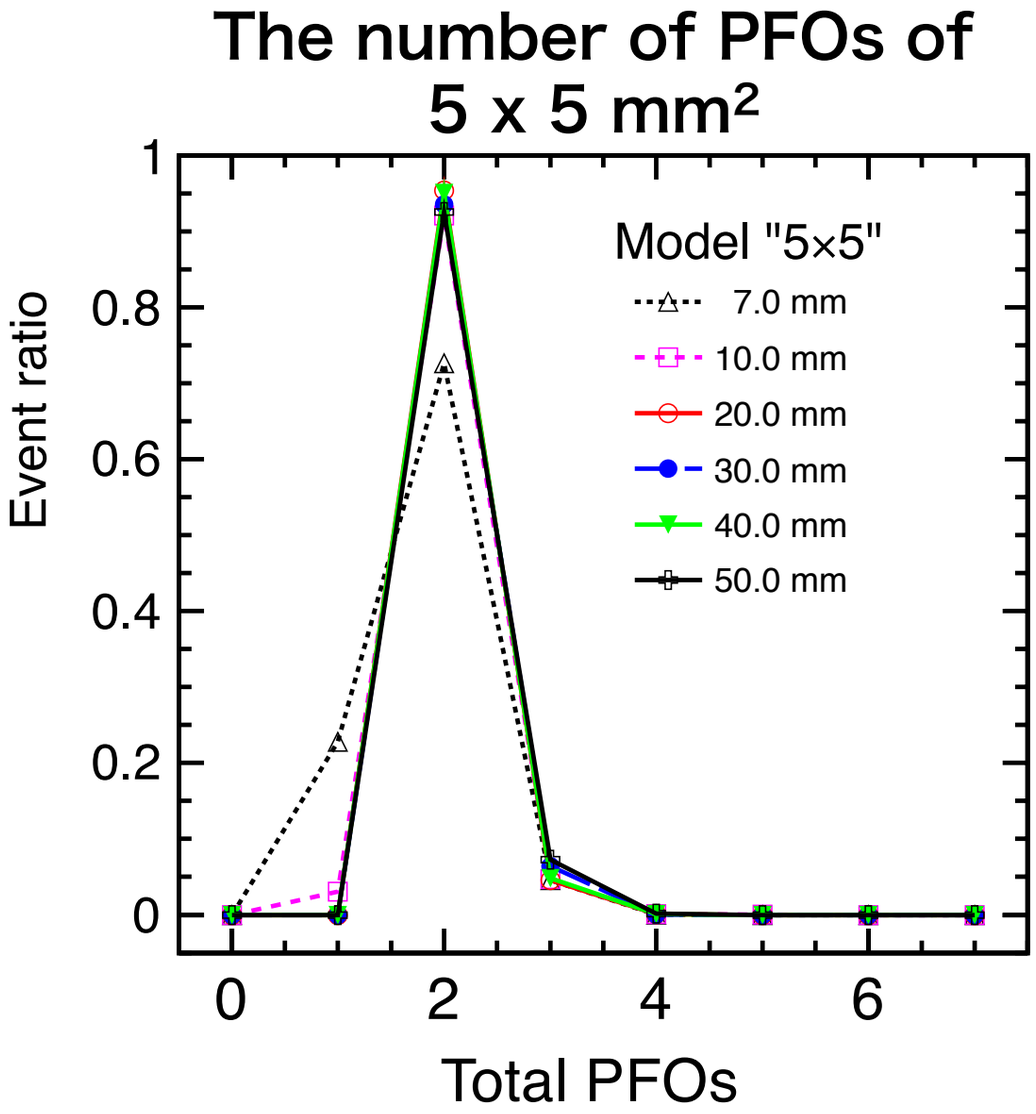


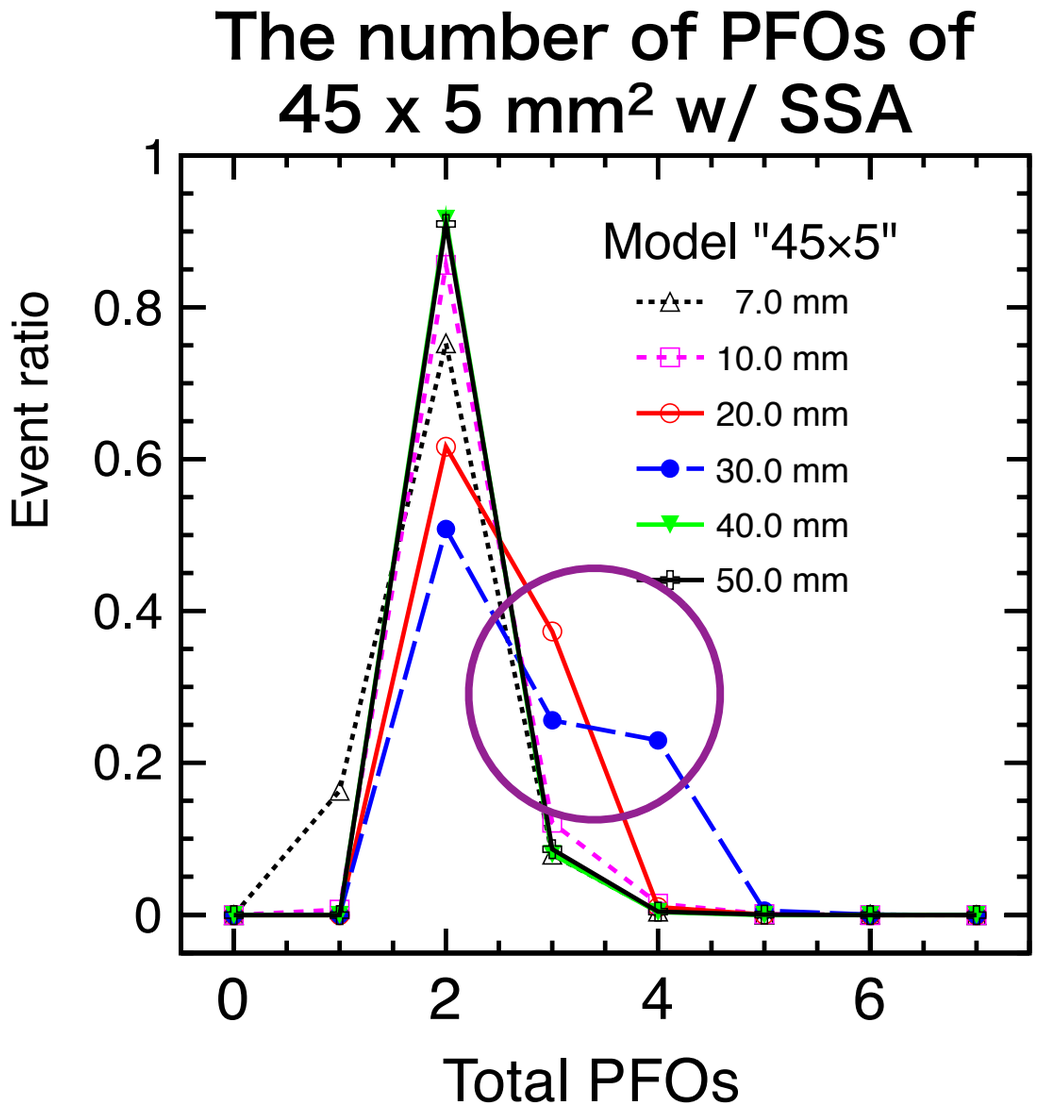
45x5 mm² ScECAL + SSA:
ratio of μ-μ events decrease at 20 - 30 mm μ-μ distance,

distance > 40 mm:
recover the ratio, since one μ reaches into the next 45x45 mm² region



What happens on 45 x 5 mm² + SSA



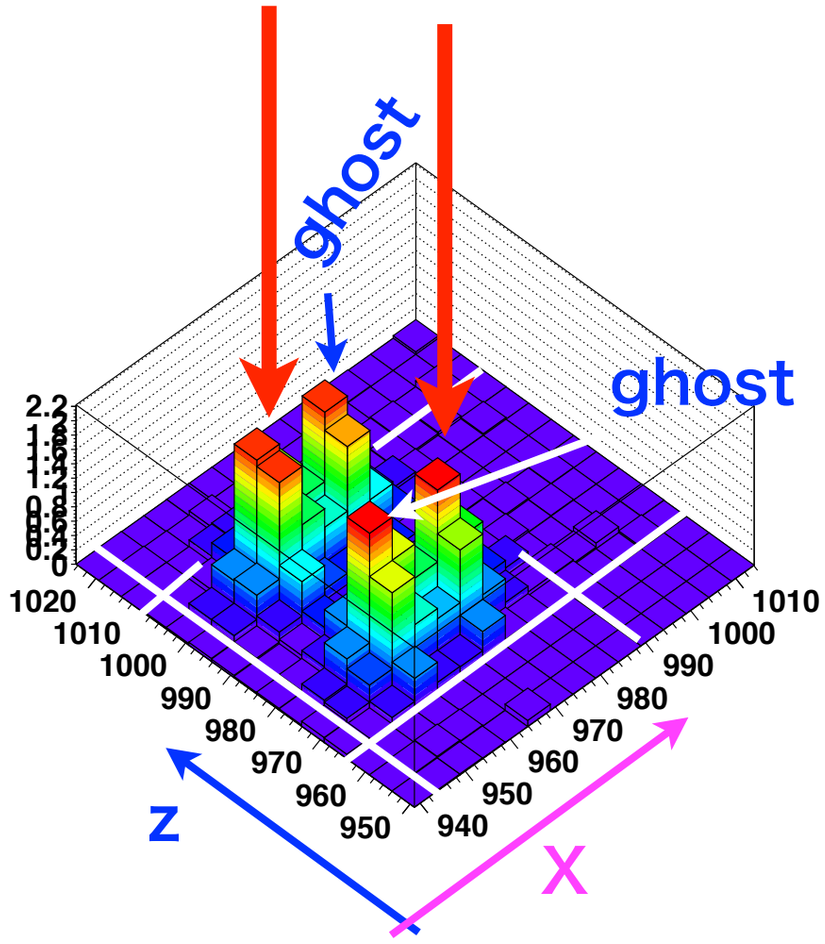


additional one PFOs or two PFOs to μ-μ events appear with 20 and 30 mm distance of μ-μ in the case of 45 x 5 mm² w/ SSA.

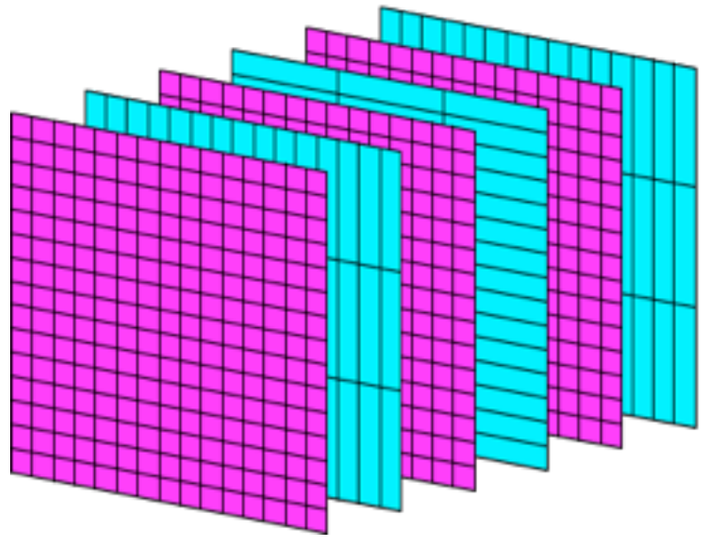
We confirmed

Excess PFOs are ghosts misidentified as almost photon or some neutral hadron.

How to remove ghosts



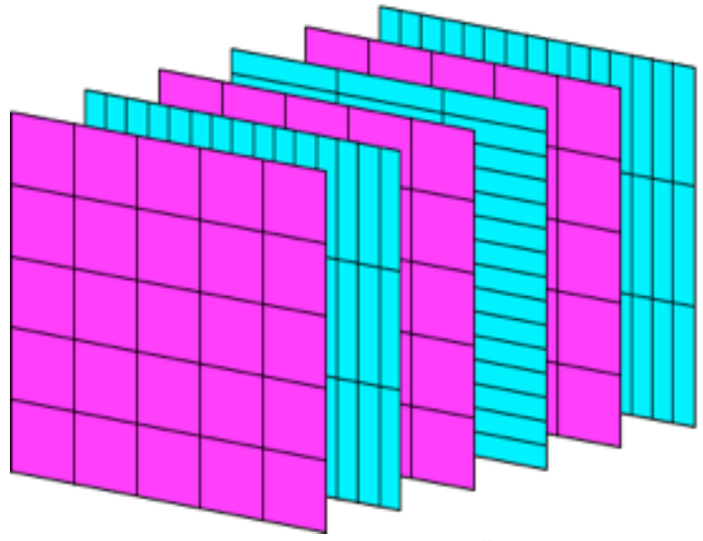
Alternately replace strip layers with 5x5mm² tile layers.



def: Alt5x5

▶ hybrid with Si-layers (next talk)

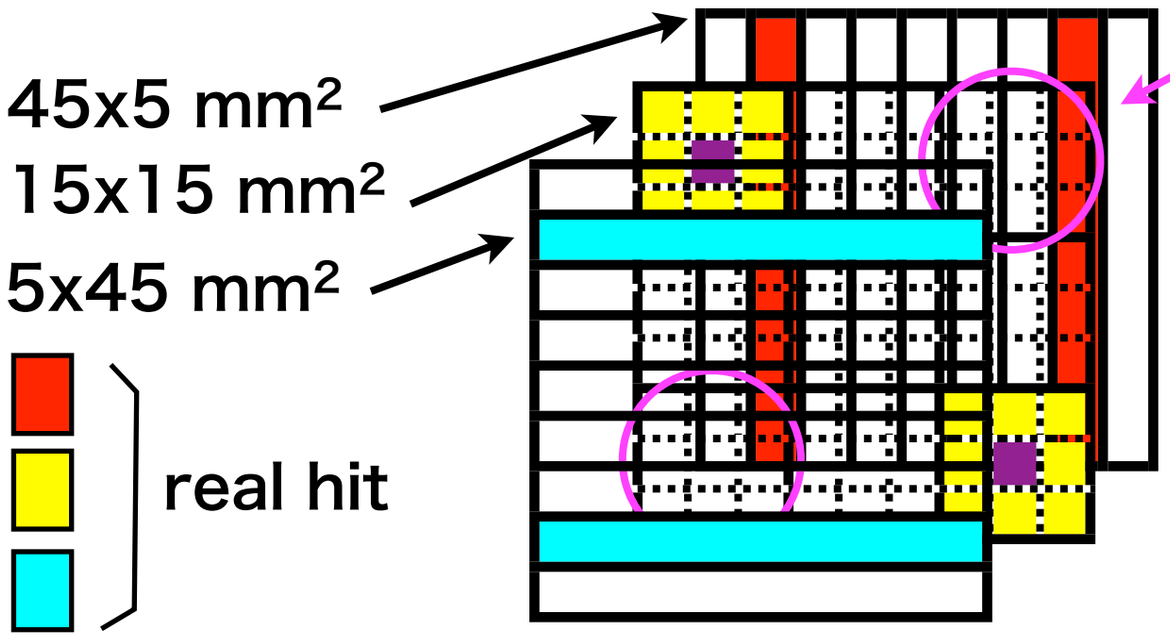
Alternately replace strip layers with large tile layers.



def: Alt10x10, Alt15x15

10x10 or 15x15mm² is easy to establish as pure scintillator layers

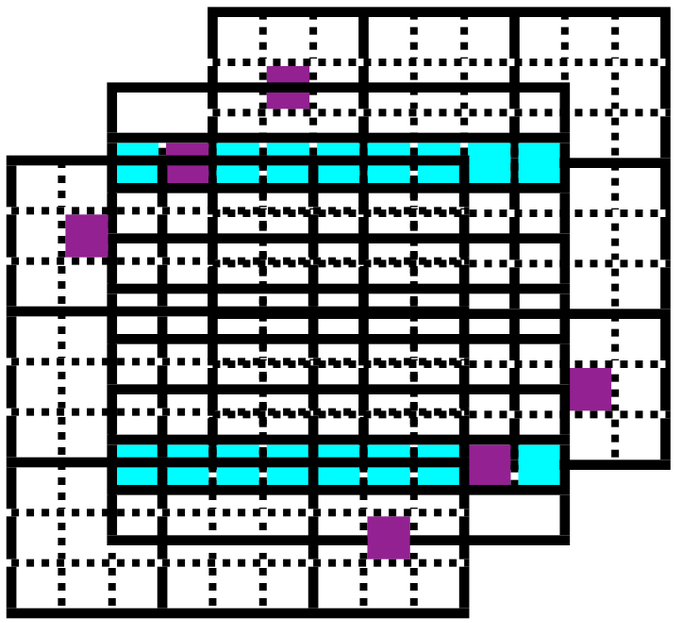
How to do SSA with large tiles



no ghost

1st Step

large tiles are sprit into virtual 5x5mm² cells using information from n±1 layer strip cells

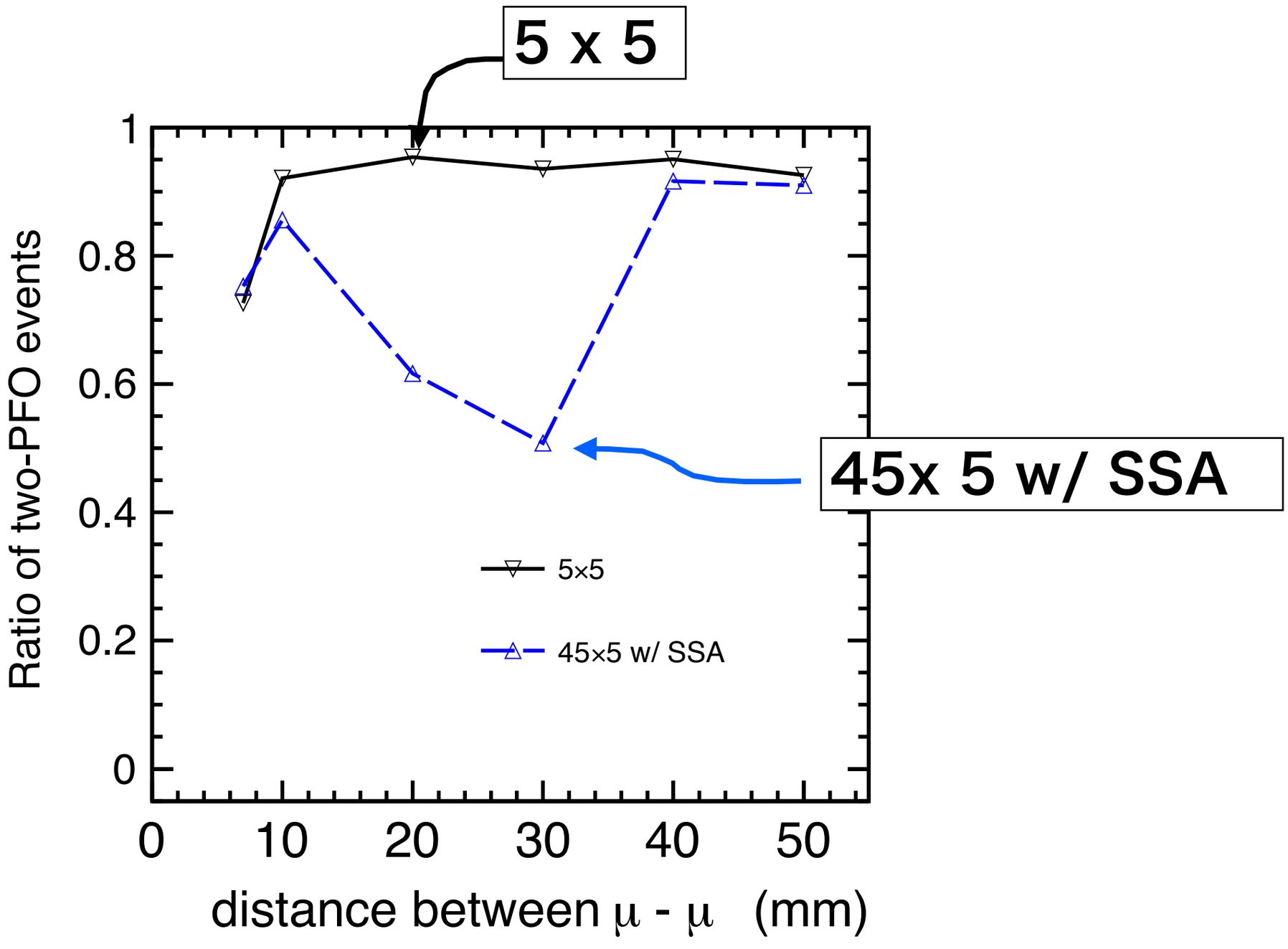


a layer is affected by the second nearest layers

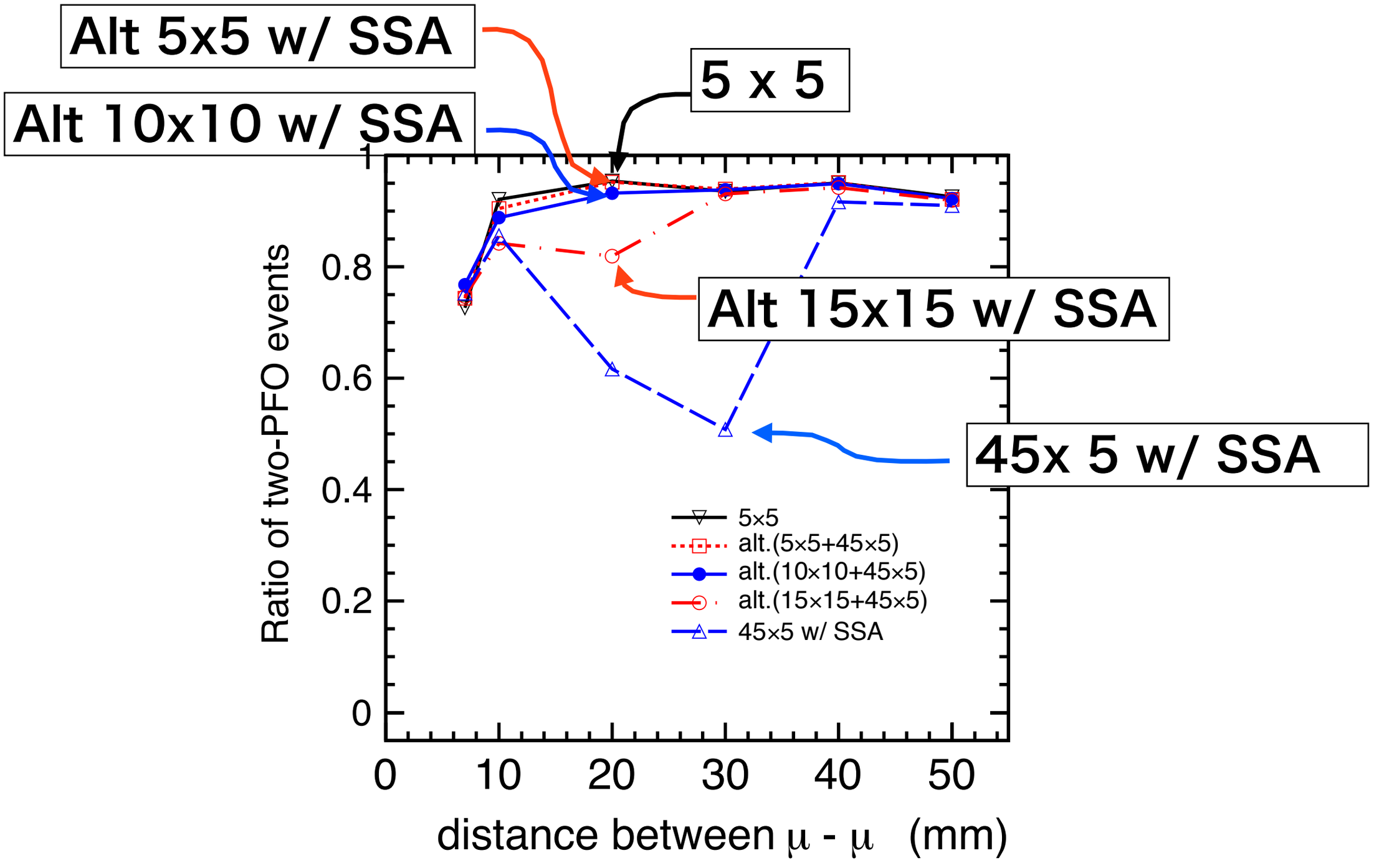
2st Step

strip cells are done SSA using virtual 5x5mm² cells created in the 1st step

Again ratio of exact μ-μ events



Again ratio of exact μ-μ events



Alt 5x5 and Alt 10x10 almost completely remove ghost.

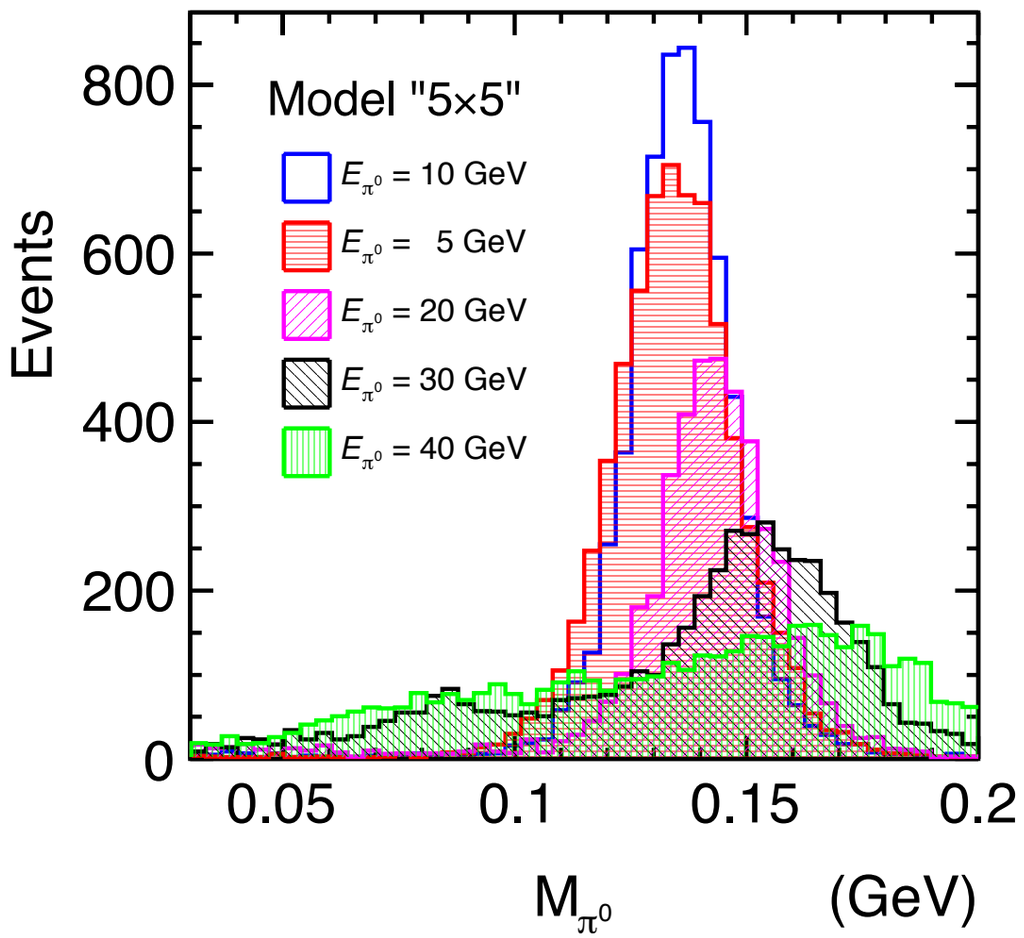
interleaving tile layers

π^0 reconstraction

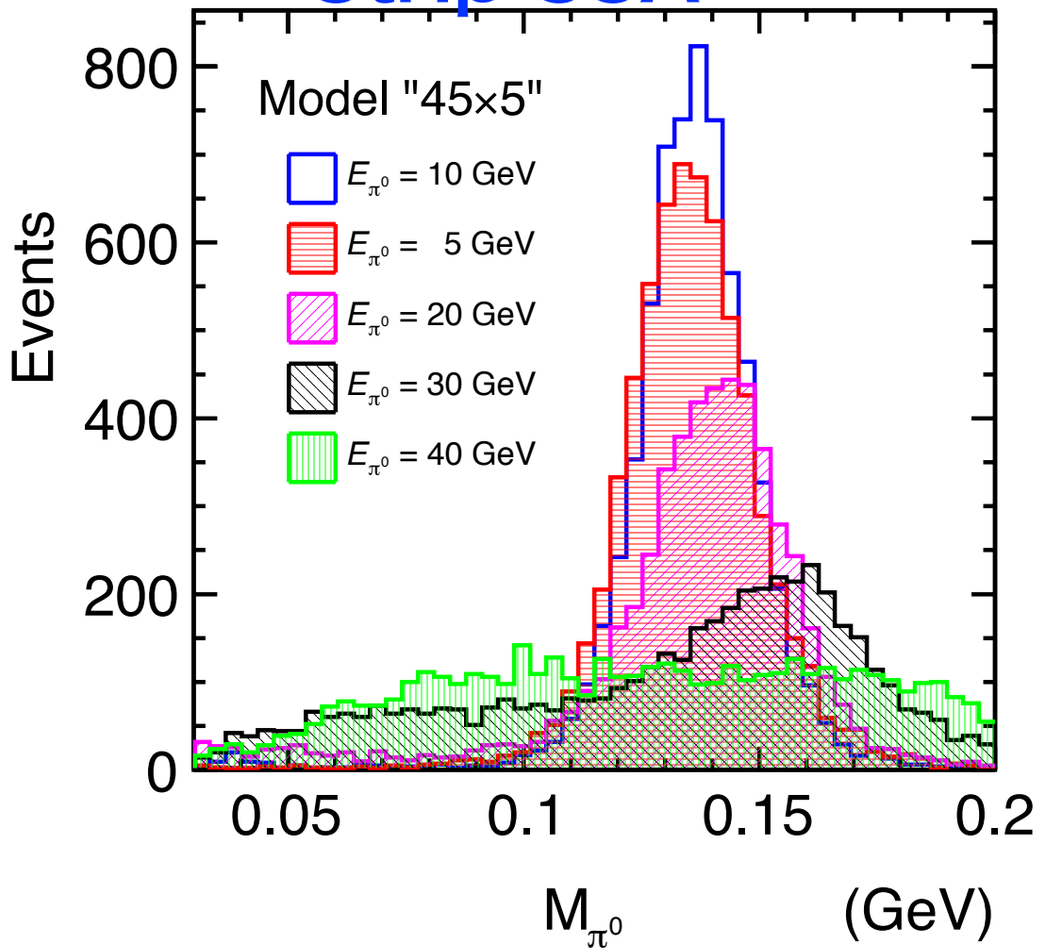
π^0 energy: 5, 10, 20, 30, 40 GeV

Select two photon events

5x5mm²x1mm Tile



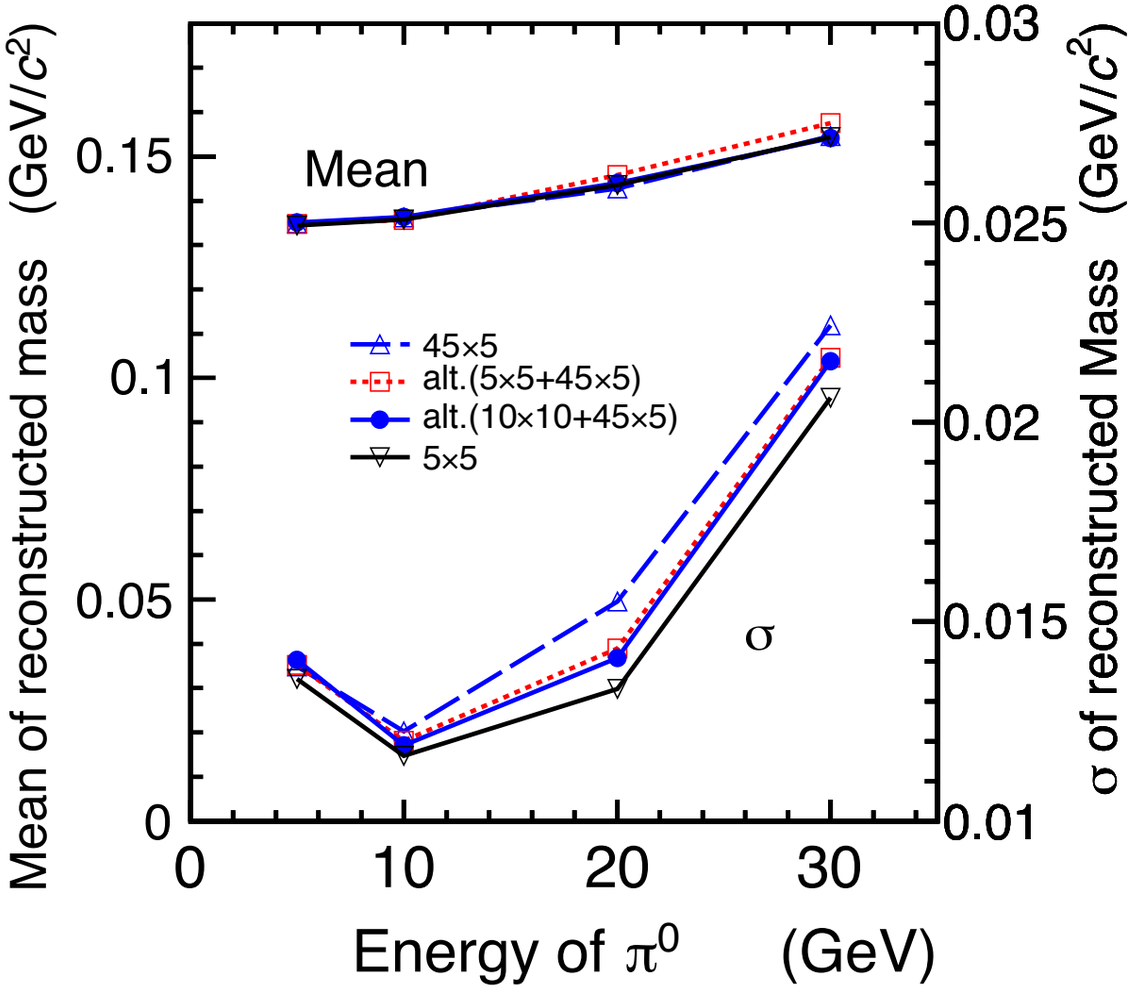
45x5mm²x1mm Strip SSA



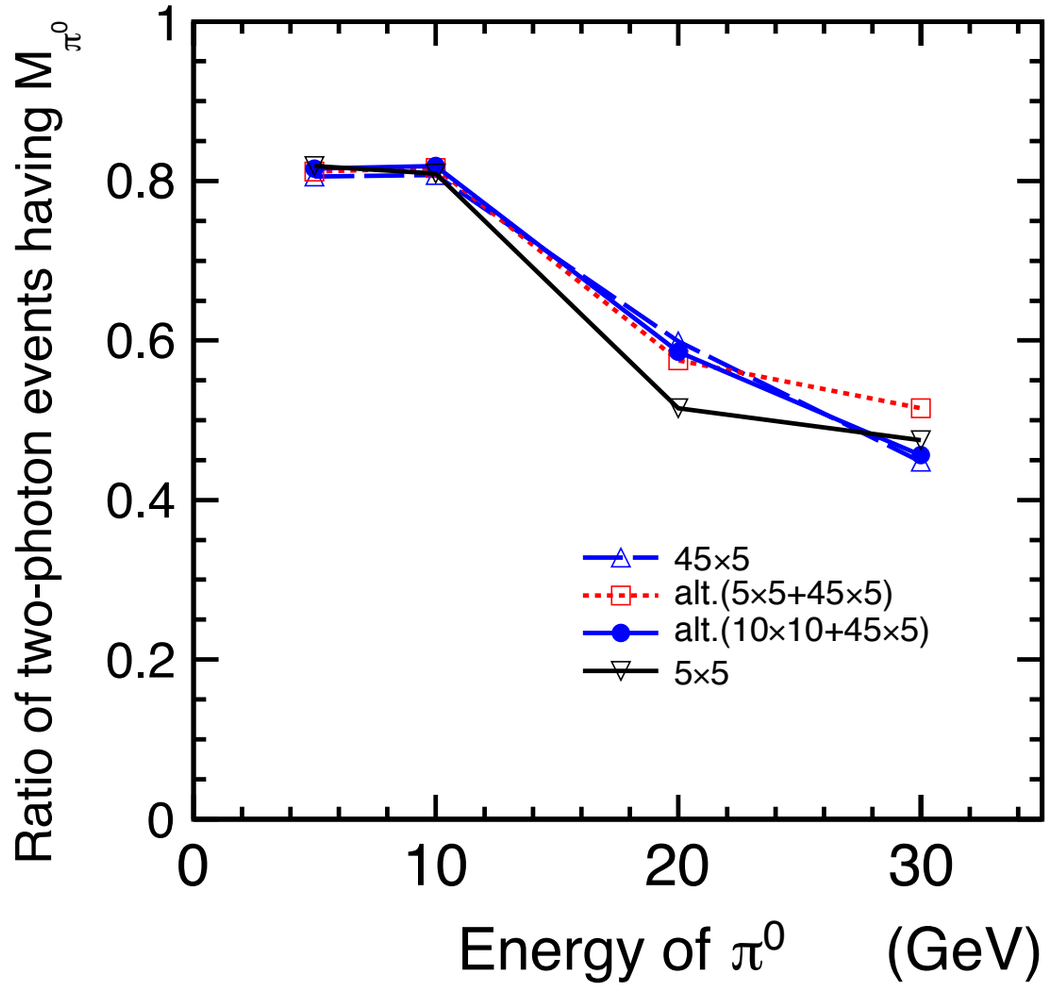
- There is no large difference in spectra of two detectors: E ≦ 10 GeV
- It is difficult for both detectors to reconstruct π^0 : E ≧ 40 GeV.
- Lets see more detail in quantitative analysis ▶

Quantitative evaluation

Mean and stDev. of Mπ^0



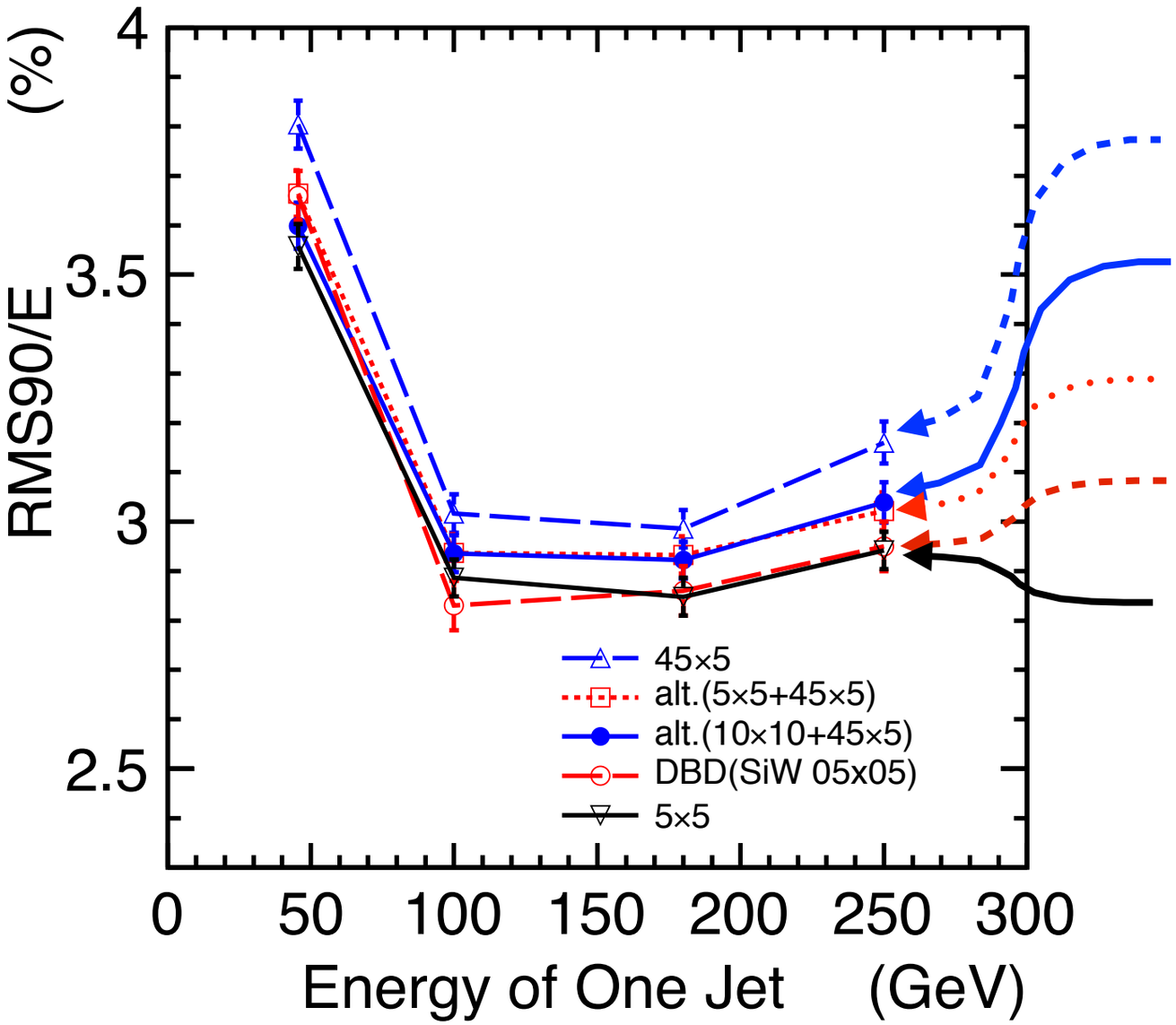
Ratio two-photon events



- A little bit degrading of standard deviation of Mπ^0 with strip SSA with Eπ^0 > 20 GeV.
- Note that those energy corresponding to 15 - 30 mm γ-γ distance ▶ consistent with μ-μ study.
- Alt.10x10 improves this situation.

Jet energy resolution of Alt.tile ScECAL with SSA

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



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

Effect on Alt.15x15 is small, then it was removed from this plot to clearly show Alt.10x10 result.

Summary

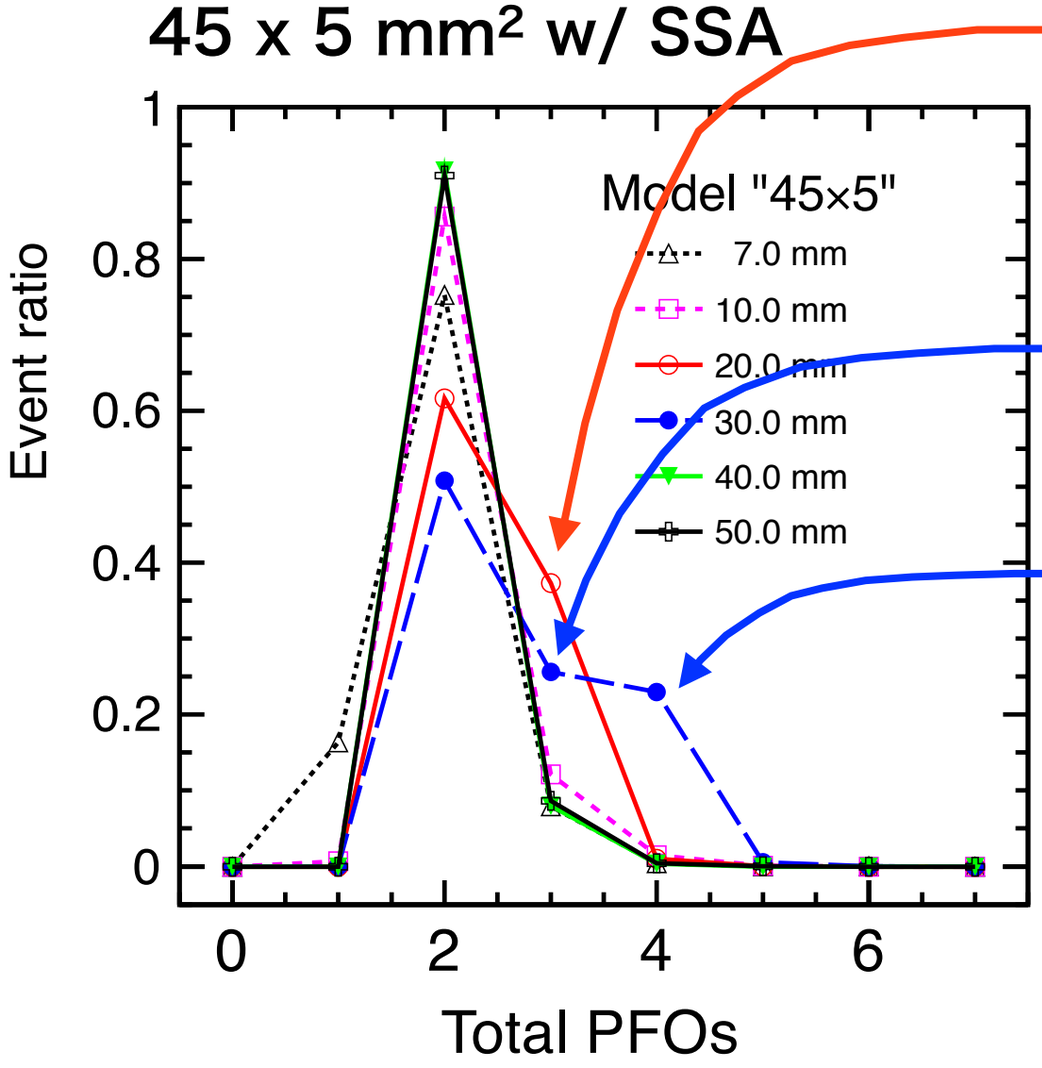
1. We are developing a scintillator strip ECAL for future linear colliders.
2. Reconstruction algorithm (SSA) to extract 5x5mm^2 granularity from strip cells is developed.
   - positions from strip cells are significantly corrected with SSA (position resolution ~ 1 mm).
   - Up to 60 - 90 mm strip length, jet energy resolution (JER) is kept by using SSA.
   - The jet energy resolution up to 250 GeV jet in 45x5 mm^2 strip ECAL with SSA is close to the case with 5x5 mm^2 tile ECAL (also DBD result), leaving 0.2% difference.
3. Ghost clusters are investigated.
   - 45x5 mm^2 strip ECAL with SSA makes large amount of photon ghost with 20-30 mm μ-μ distance.
4. ScECAL alternately replaced strip layers with large tile layers.
   - In Alt.10x10 ECAL the ghosts are almost removed.
   - π^0 reconstruction is also improves with Alt.10x10 ECAL.
   - Alt.10x10 ECAL has the same JER as 5x5mm^2 tile ECAL at $E_{jet} \leqq 100$ GeV, and 0.1% difference at high energy.
5. Started:“non-uniformity”, “saturation SiPM”, “Noise from SiPM”

Back up

Contents of additional PFOs

- excess PFOs are ghost misidentified as almost photon or some neutral hadrons

The number of PFOs of
45 x 5 mm² w/ SSA

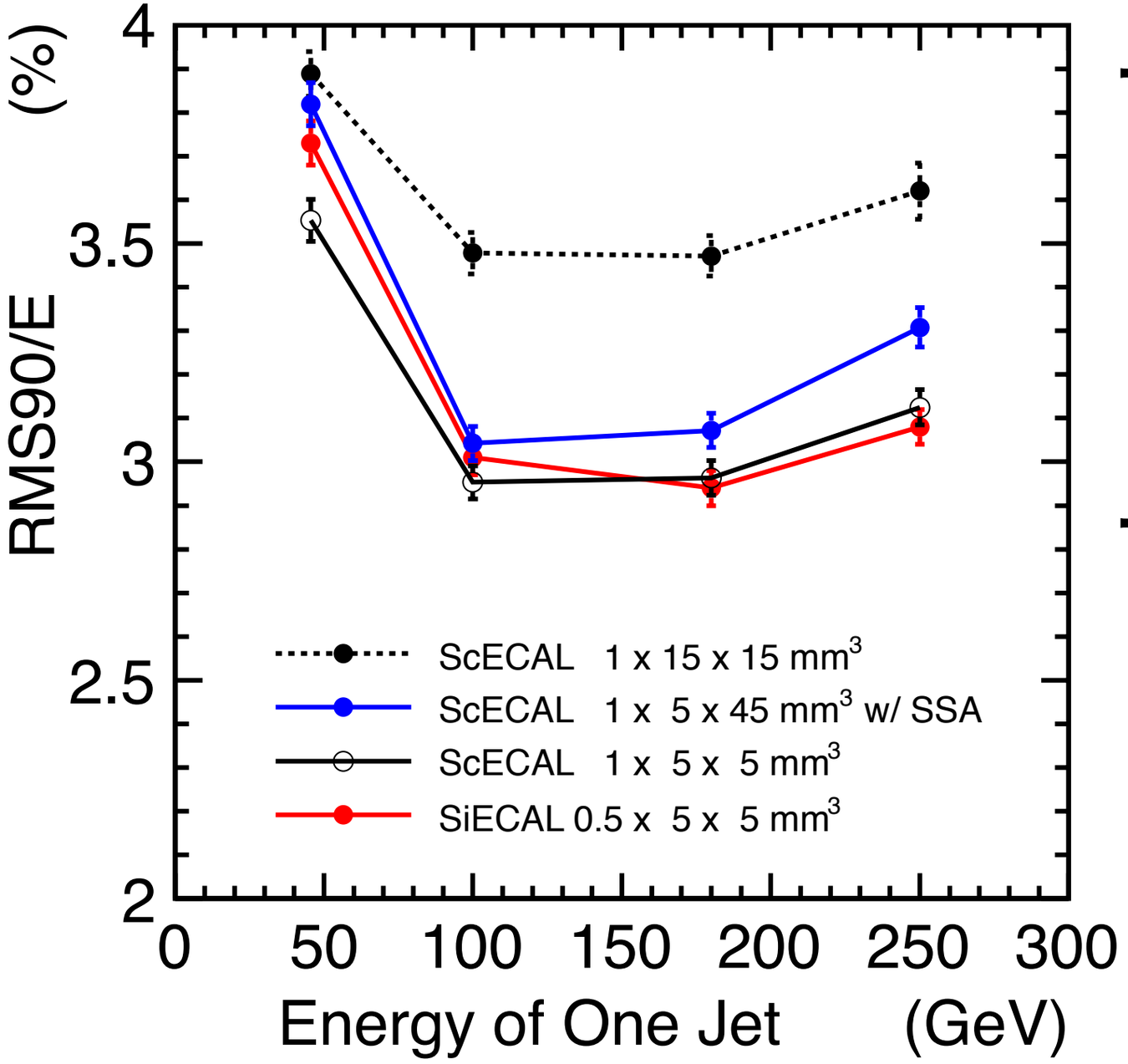


2 μ + (72% photon + 28% neutral Hadron)

2 μ + (48% photon + 52% neutral Hadron)

2 μ + { 98% 2- photon + 0.3% (photon, neutral Hadron) 2% two neutral Hadron }

a little more detail



- 5 x 5 mm² tile ScECAL and SiECAL are comparable with each other by John's study.

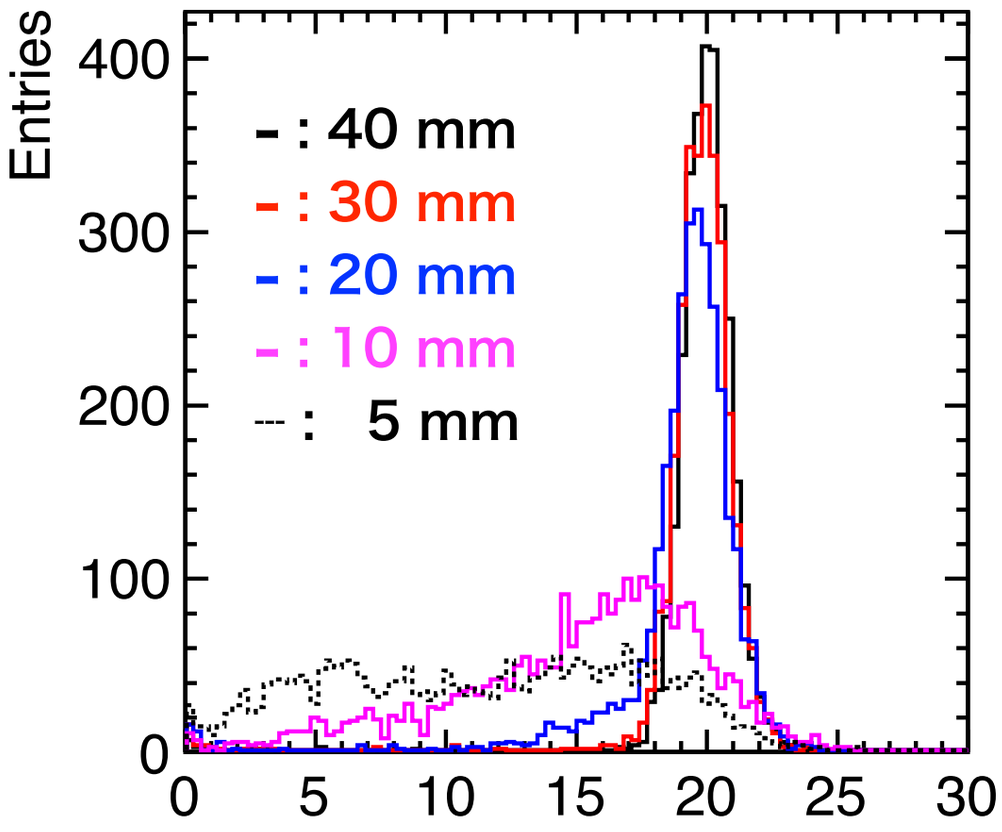
- difference between 5 x 5 mm² ScECAL and 45 x 5 mm² + SSA ScECAL are 0.3% maximum at 45 GeV jet and 0.1-0.2% up to 250 GeV jet.

What happens at 45 GeV and high energy jets?

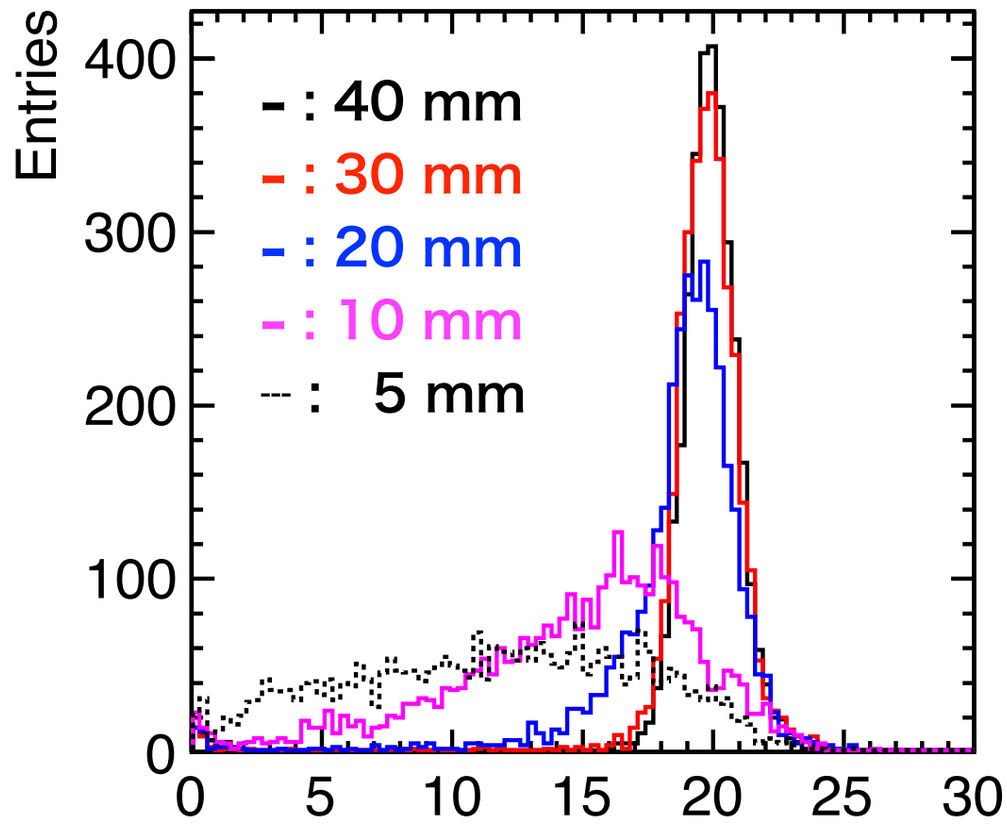
Measured photon energy (1 γ event)

π^+ 10GeV + photon 20 GeV

5x5mm²x1mm Tile



45x5mm²x1mm Strip SSA

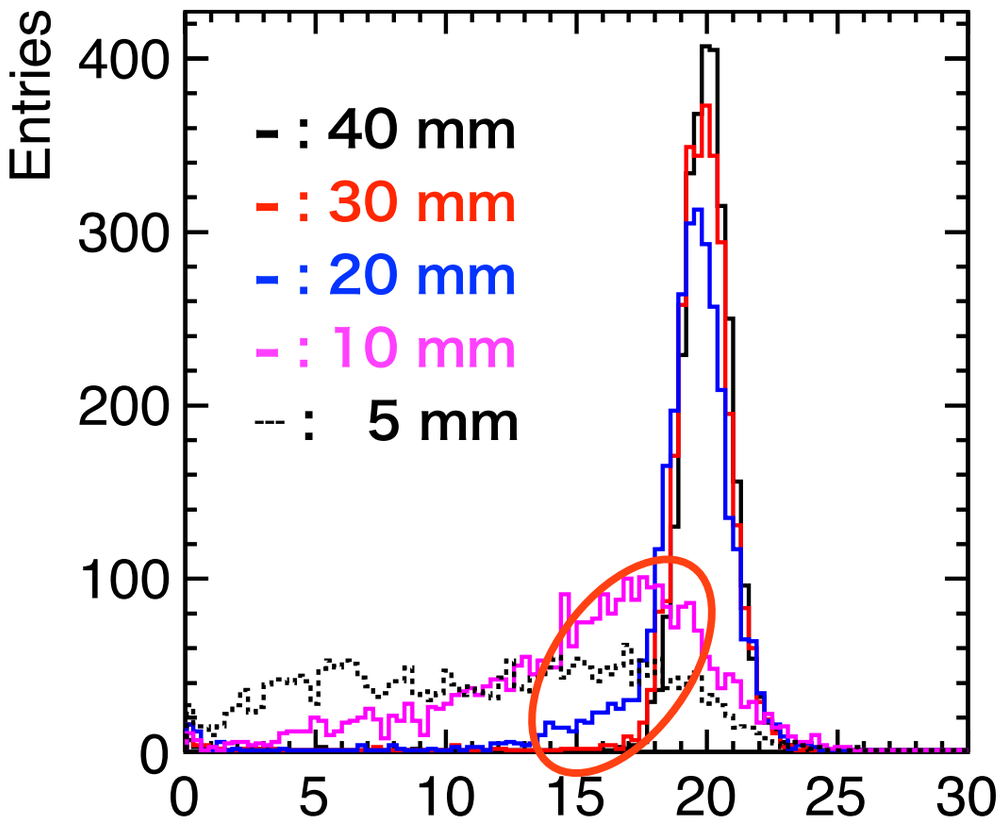


- distance > 30 mm ➡ Both types have good energy resolution.

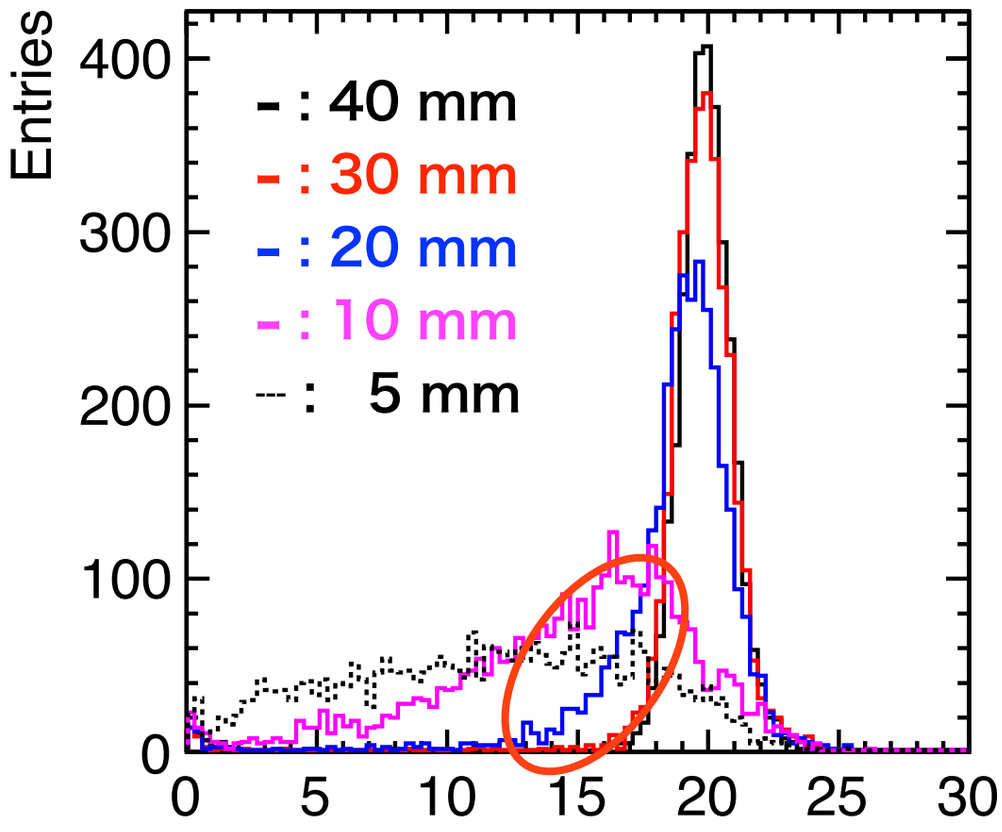
Measured photon energy (1 γ event)

π^+ 10GeV + photon 20 GeV

5x5mm²x1mm Tile



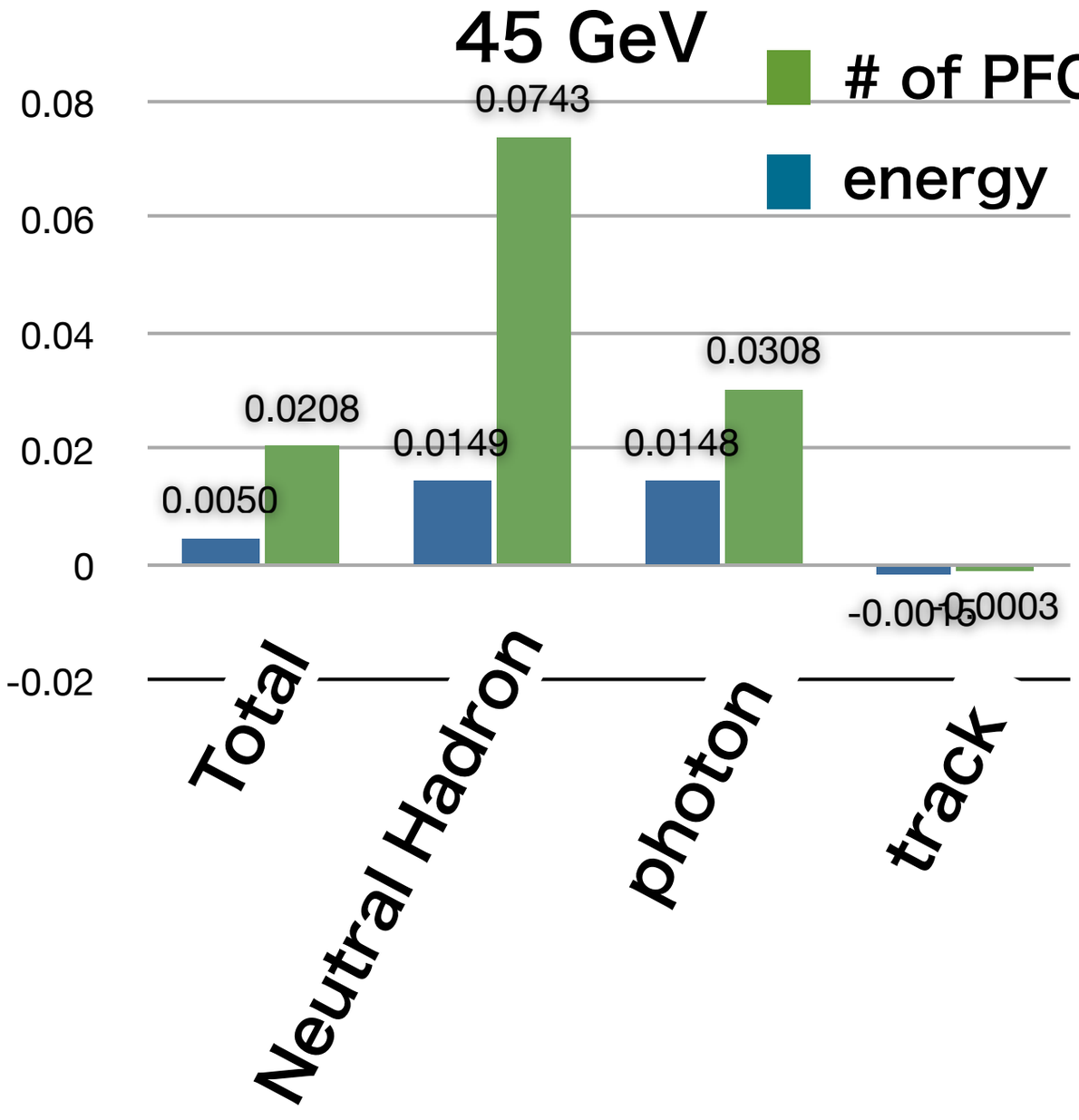
45x5mm²x1mm Strip SSA

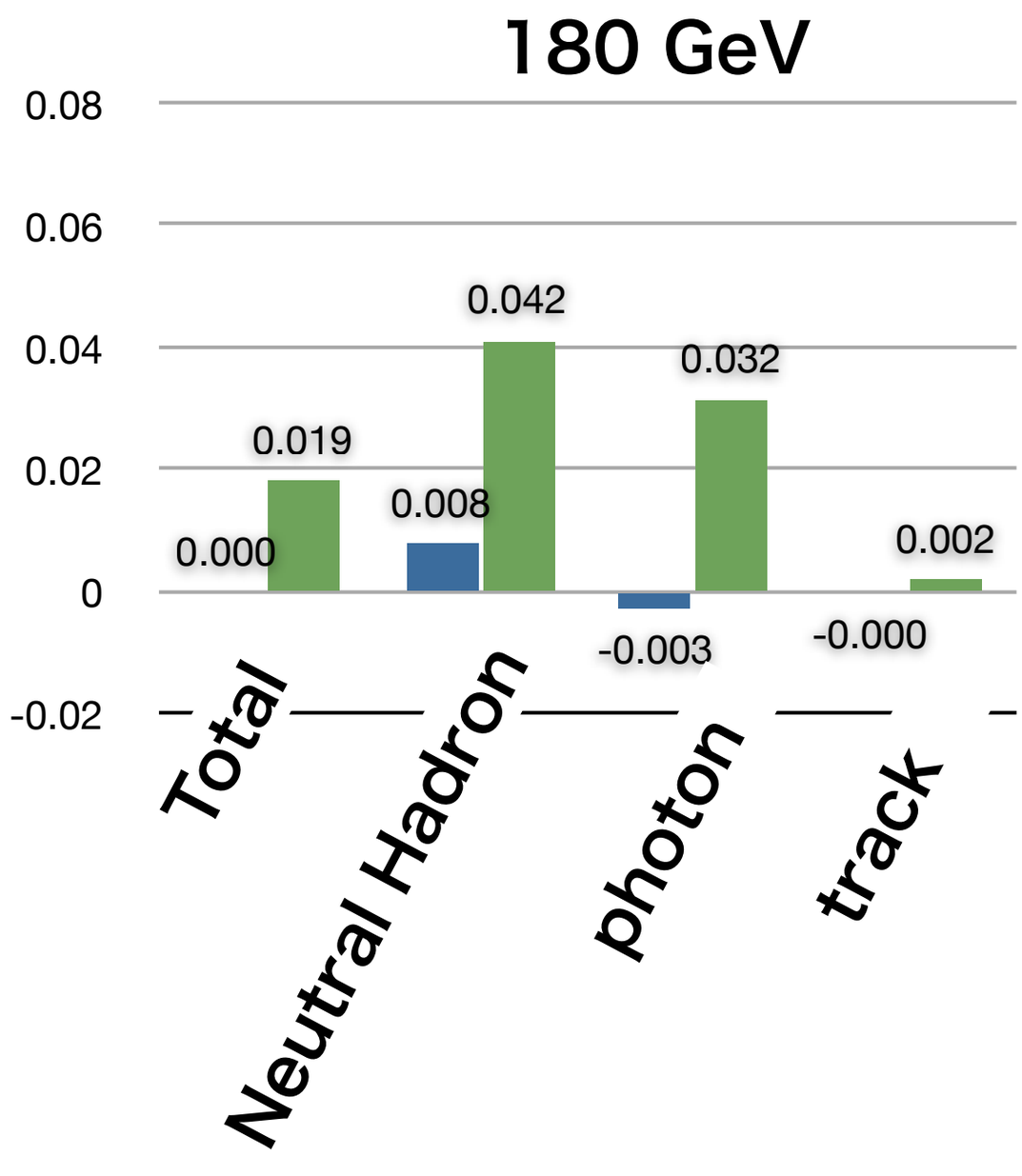


- distance > 30 mm ➡ Both types have good energy resolution.
- distance = 20 mm ➡ Strip SSA has a bit leading spread.
- distance <10 mm, 5 mm ➡ Both do not have good resolution.

of PFO and their energy

(45x5 strip SSA / 5x5 tile) - 1





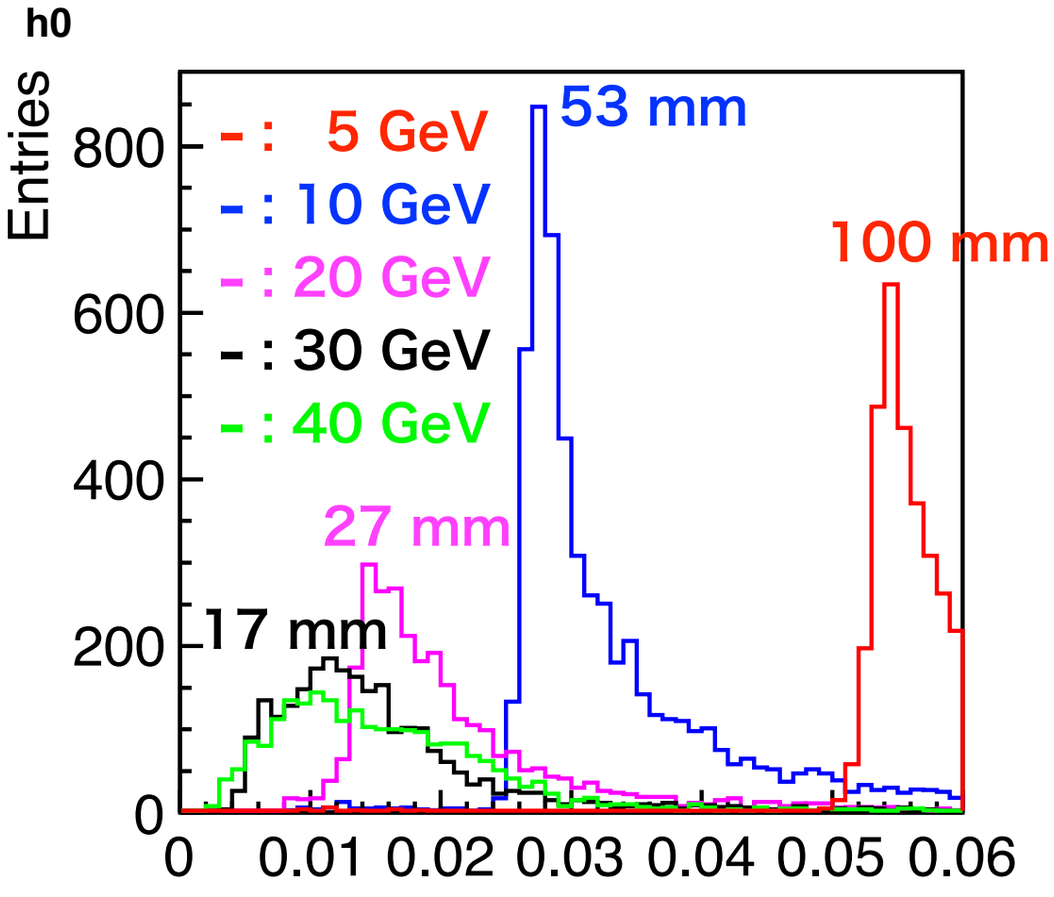
Excess of neutral Hadrons is larger in analysis of low energy (45 GeV) jet.

Opening angle of γ-γ

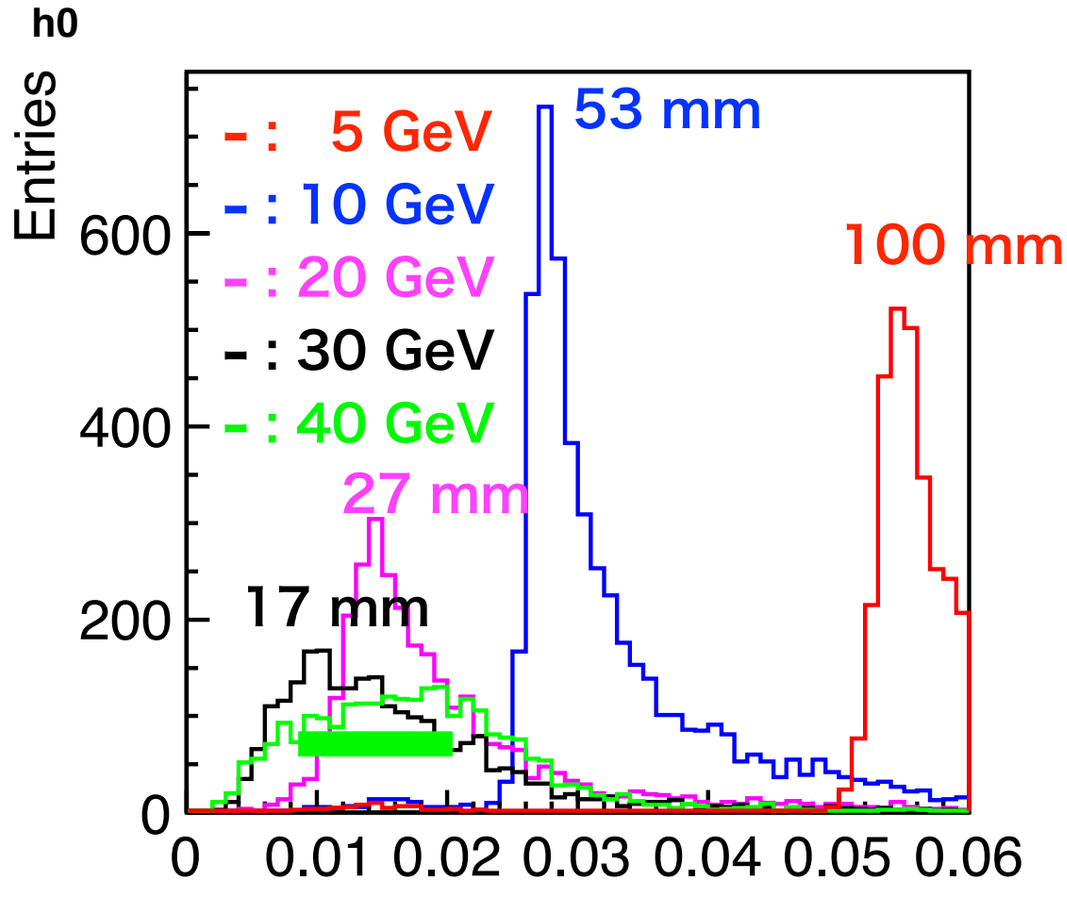
π^0 energy: 5, 10, 20, 30, 40 GeV

Numbers on the peak tops are distances between photons on ECAL.

5x5mm²x1mm ScECAL

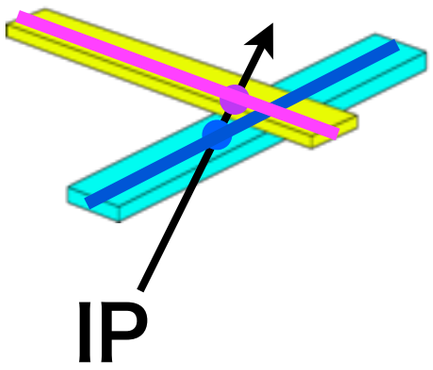


45x5mm²x1mm ScECAL with SSA



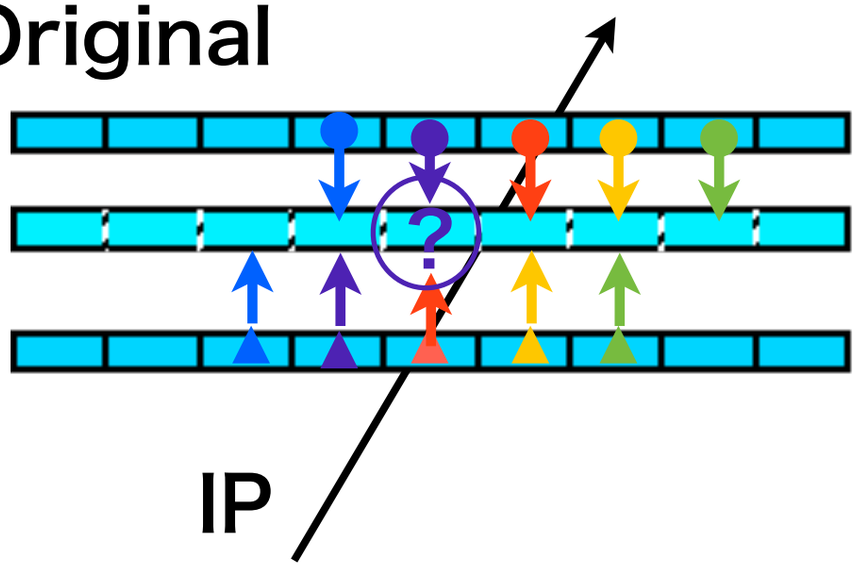
40 GeV π^0 by SSA is affected by ghost phenomenon?

Current version in MarlinReco takes more elegant way by Daniel Jeans

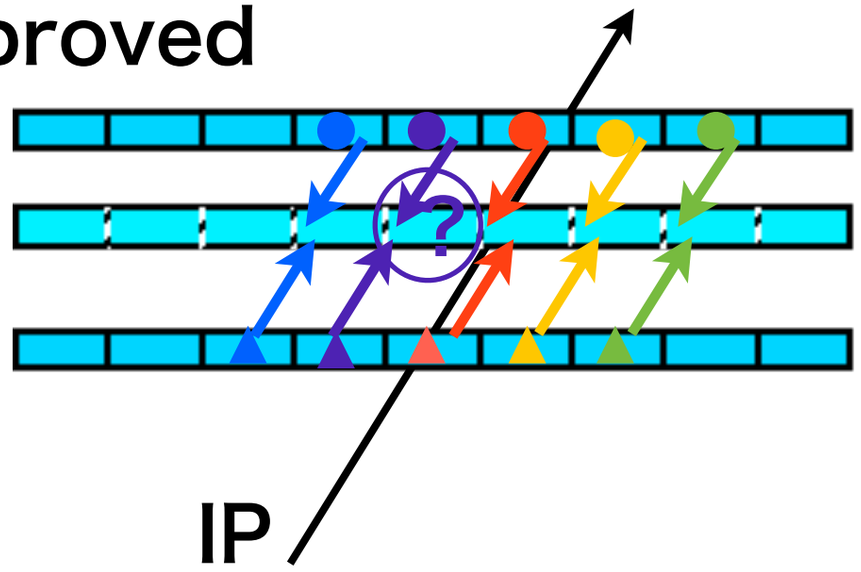


To refer the energy in the nearest neighbor layer, it scans intersection of center lines of respective scintillators toward the IP

Original



Improved



Energy in virtual cell (?) =
Energy on this strip ×
$$\frac{(\bullet+\blacktriangle)}{(\blacktriangle+\blacktriangle+\blacktriangle+\blacktriangle+\blacktriangle+\bullet+\bullet+\bullet+\bullet+\bullet)}$$

Energy on this strip ×
$$\frac{(\bullet+\blacktriangle)}{(\blacktriangle+\blacktriangle+\blacktriangle+\blacktriangle+\blacktriangle+\bullet+\bullet+\bullet+\bullet+\bullet)}$$