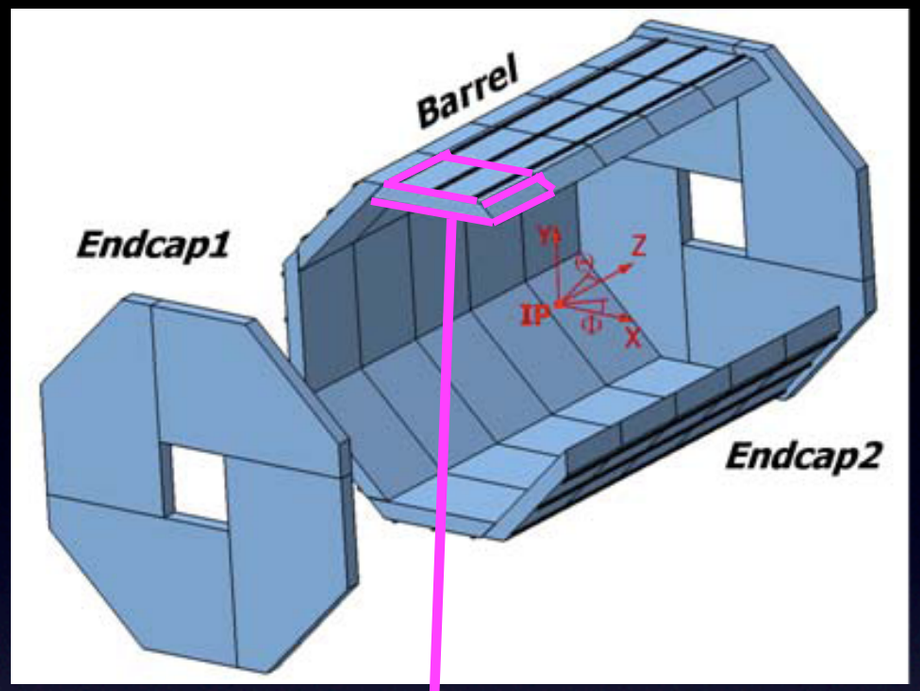
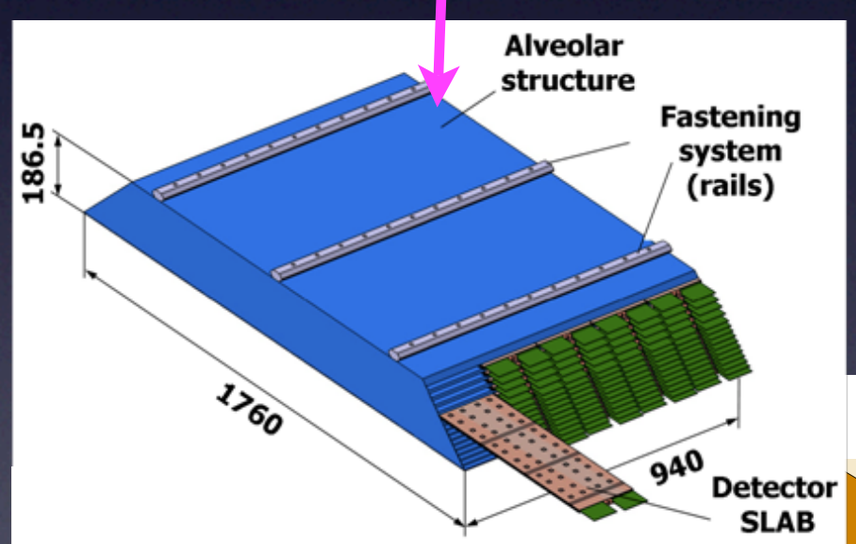
Scintillator ECAL Reconstraction

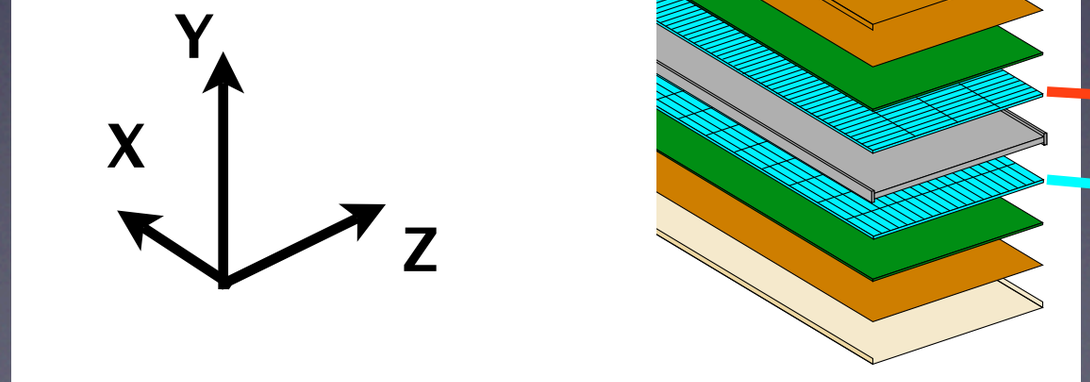
24th April 2012 @ KILC12 Daegu Korea

Katsushige KOTERA
Shinshu University

Scintillator strip ECAL for ILD

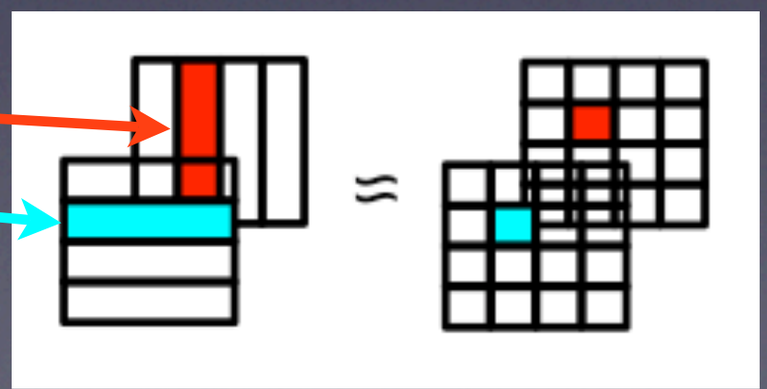


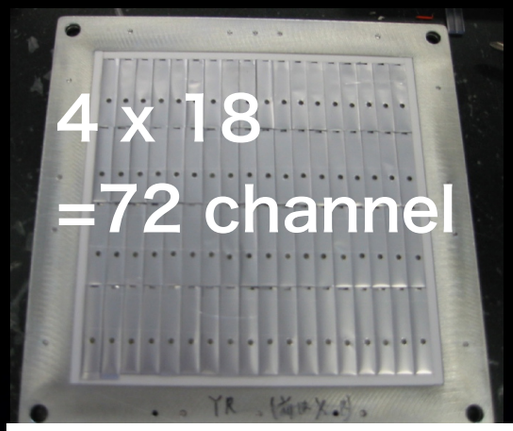




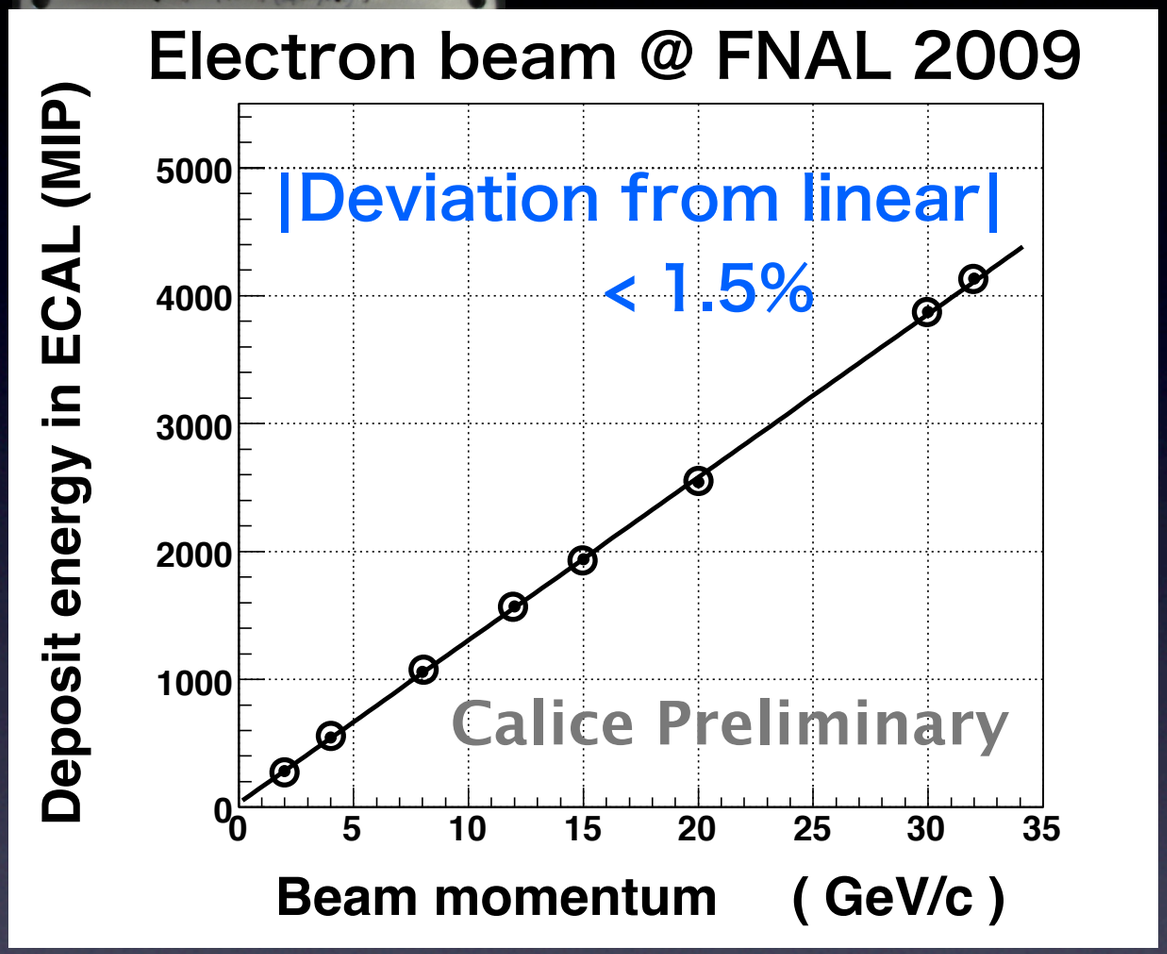
- In an example of Model
  - 25 absorber layers
    - 3 mm thick W ➡ 21.5X_0
  - plastic scintillator
    - 5 mm wide
    - 45 mm length
    - 2 mm thick
- JER/√E < 30% @ √s =91 GeV necessary.

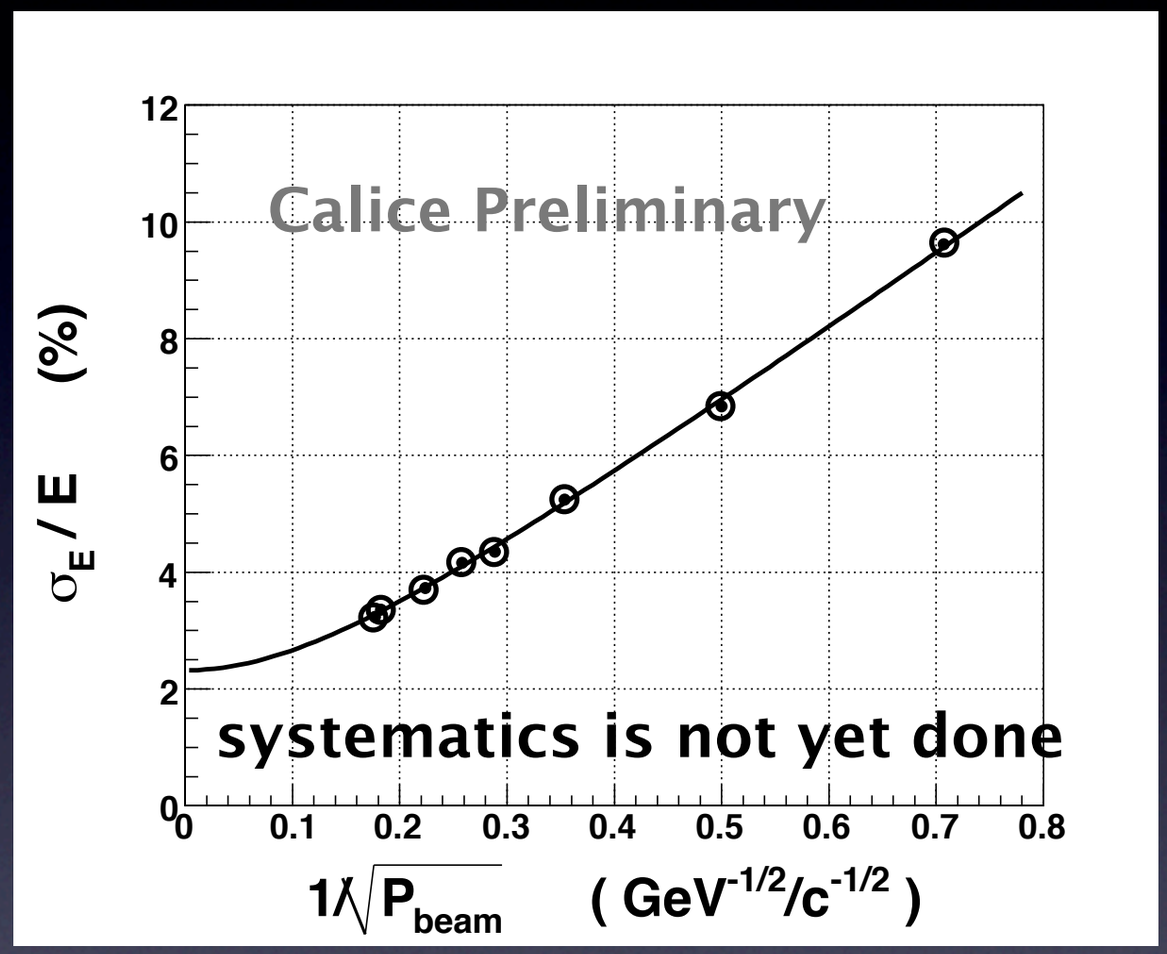
strips in odd layers are orthogonal with respect to those in even layers.





Basic performance





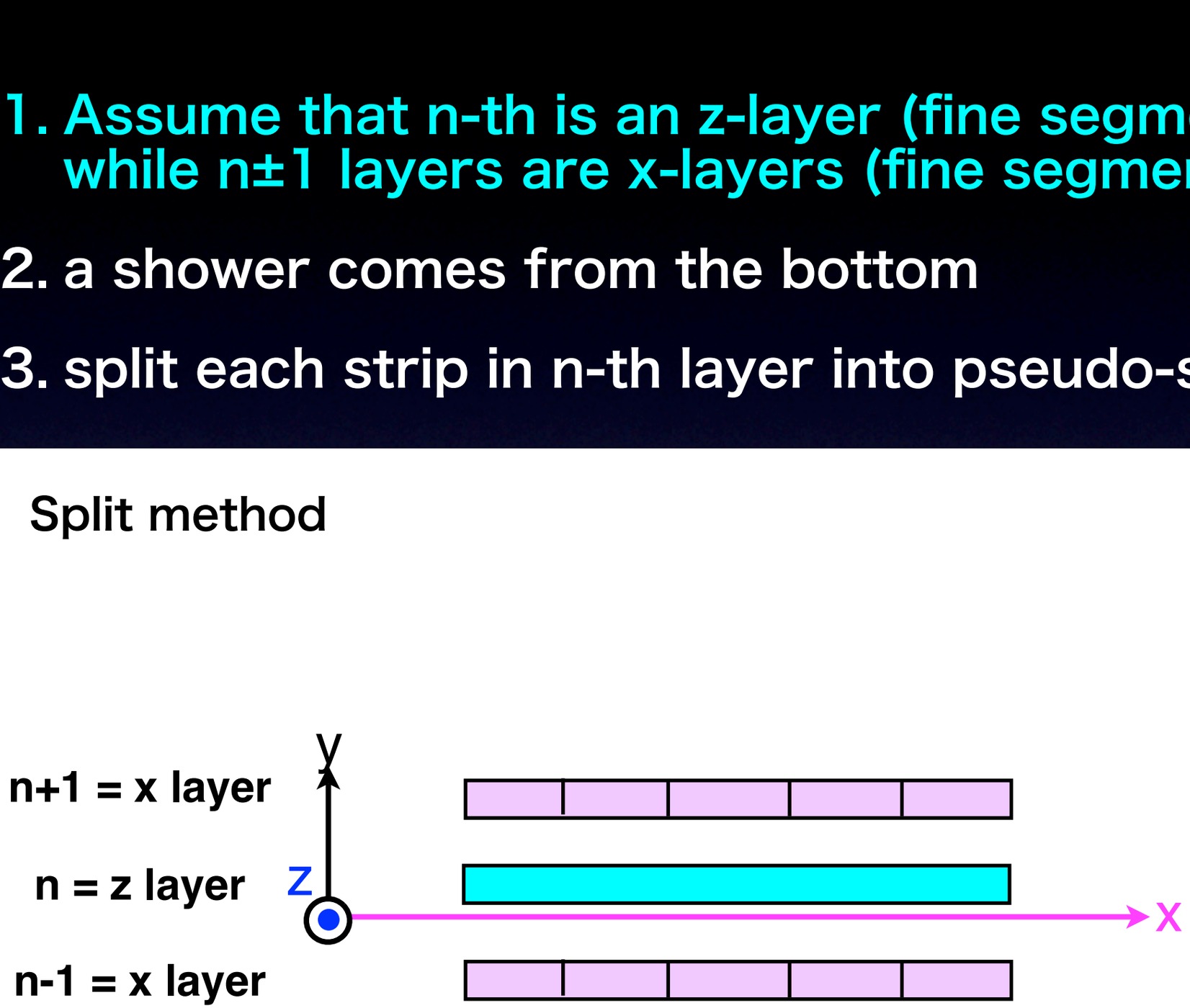
- 2160 channel prototype (10 x 45 x 3 mm²) 2009 at FNAL,
- deviation from linear fit : < 1.5%,
- Energy resolution for electron (2-32 GeV) :
  $\delta_E = (13.16\pm0.05)\%/\sqrt{E} + (2.32\pm0.02)\%$ ← intrinsic beam spread

good basic performance

granularity is more important!
for PFA

1. Assume that n-th is an z-layer (fine segmented in z direction), while n±1 layers are x-layers (fine segmented in x direction).
2. a shower comes from the bottom
3. split each strip in n-th layer into pseudo-square cells

Split method



4. energy deposit in n-th layer is distributed in pseudo cells referring adjacent n±1th layers.
5. The position and energy of pseudo square cells are fed into PandoraPFA.

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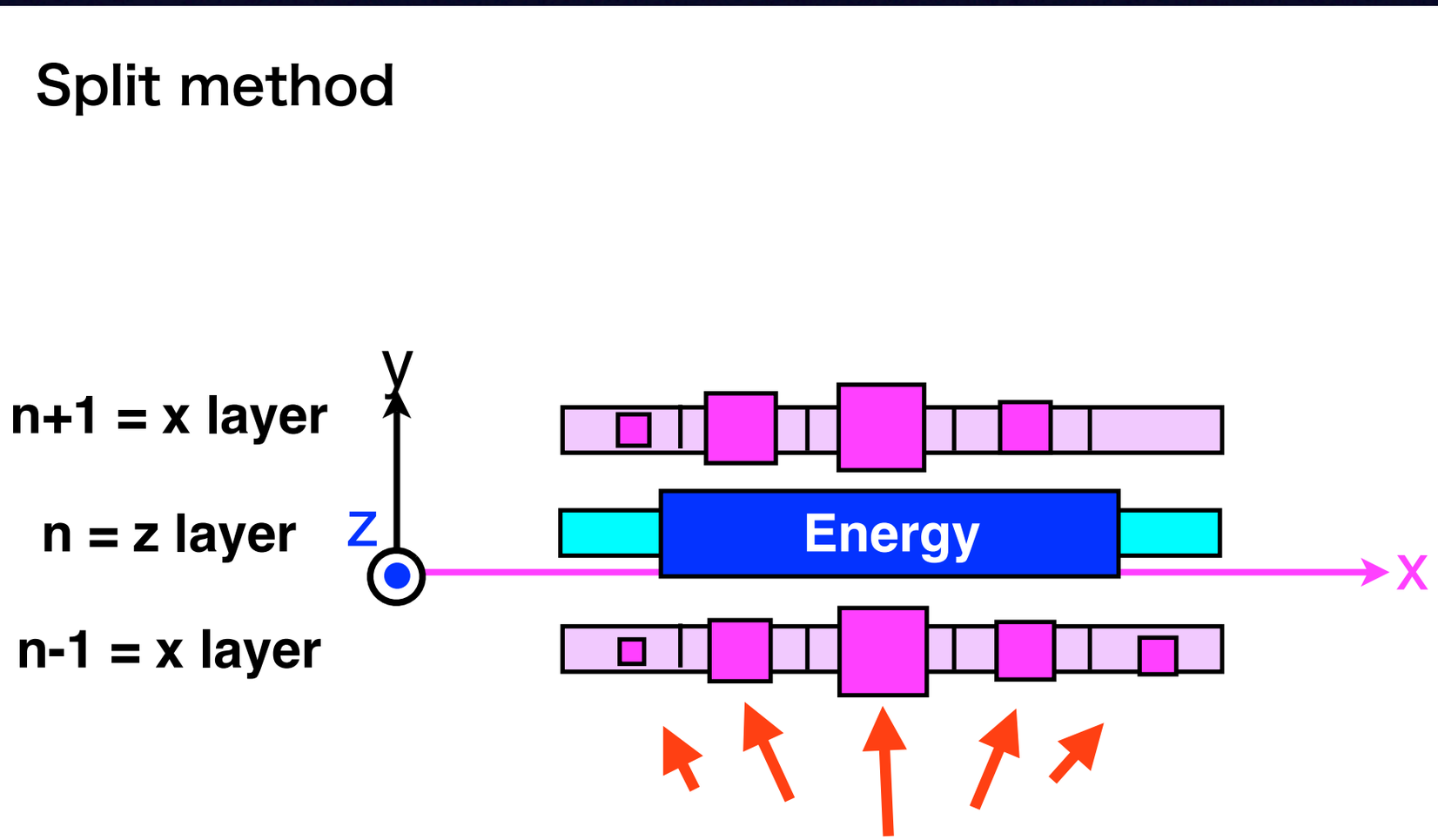

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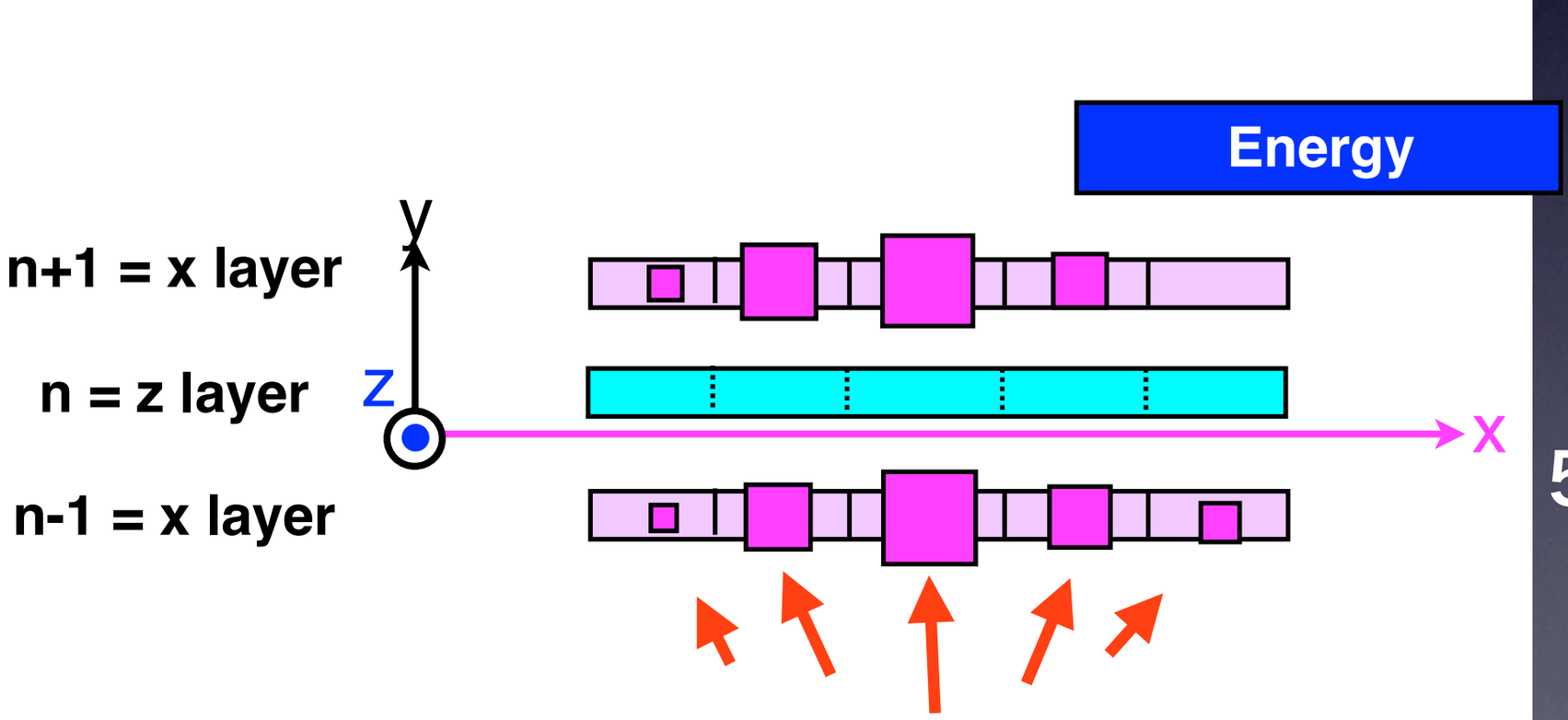

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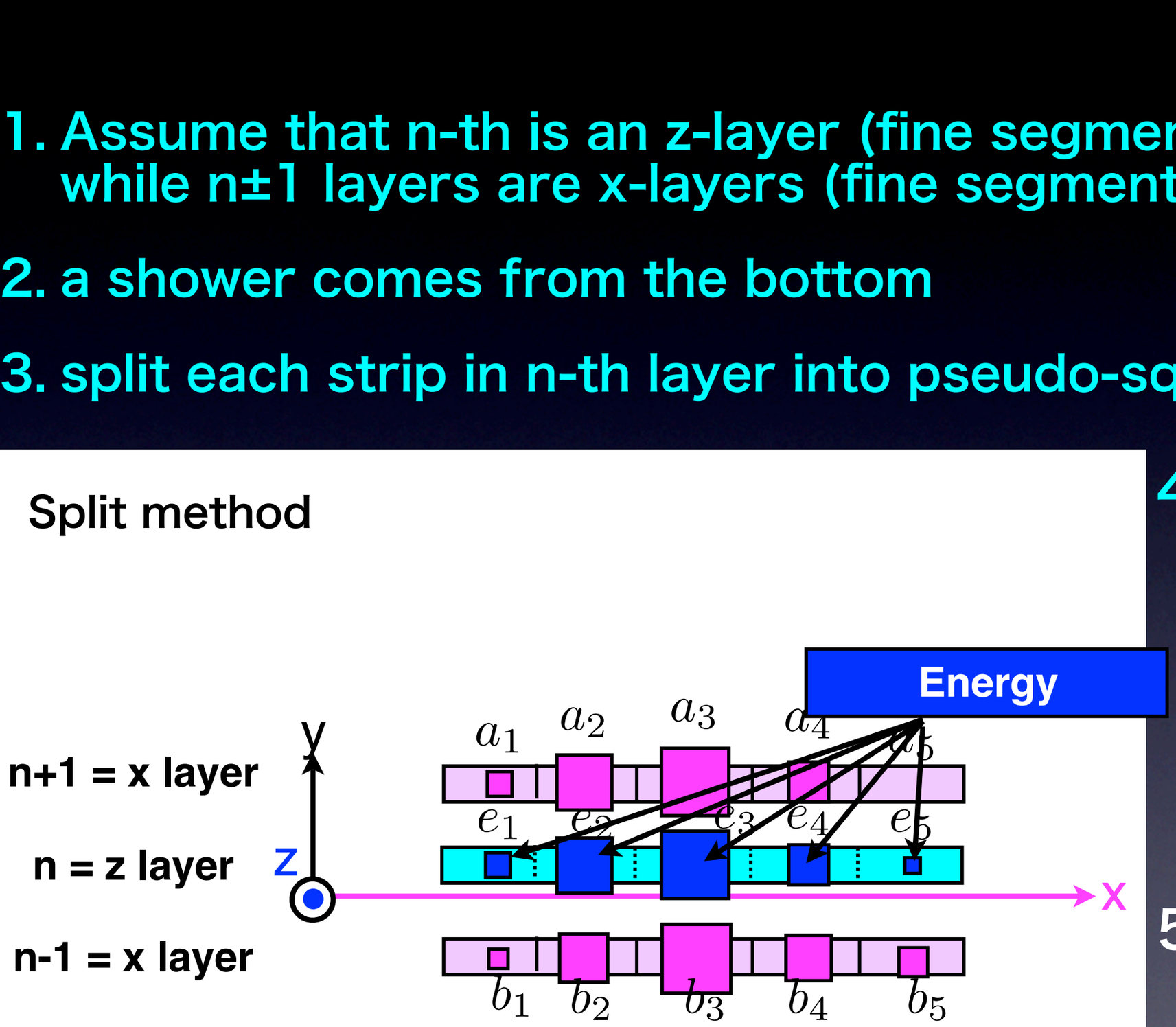

$$e_i = E_{\mathrm{n}} \cdot \frac{a_i + b_i}{\sum a_i + \sum b_i}$$

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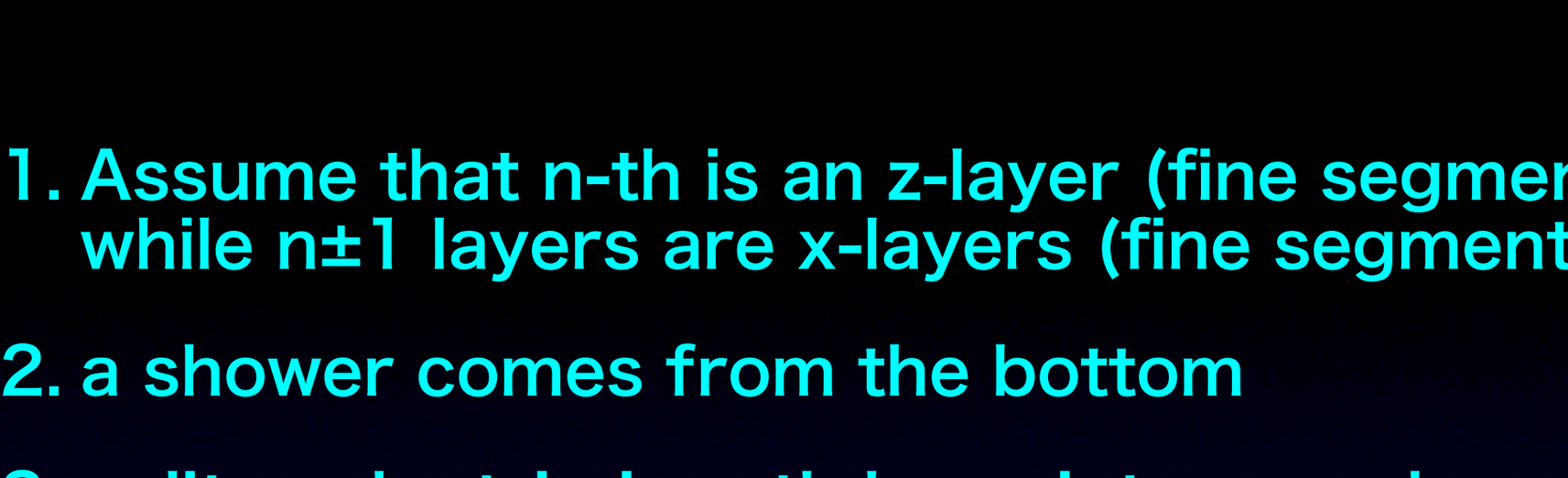


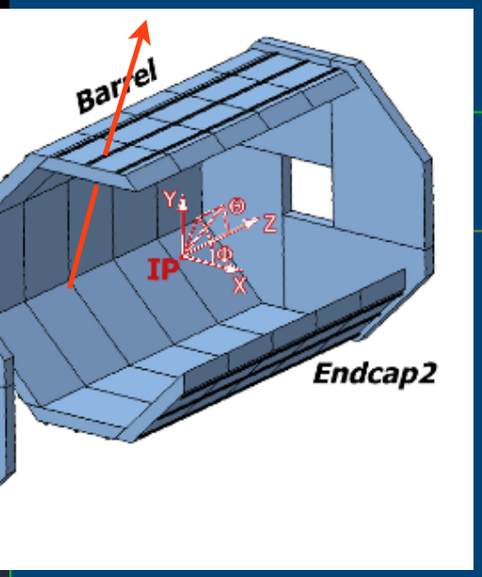
Strip Splitting Algorithm

4. energy deposit in n-th layer is distributed in pseudo cells referring adjacent n±1th layers.
5. position and energy of pseudo square cells are fed into PandoraPFA.

A track like cluster

500 GeV muon+ going through top stave of ScECAL barrel

Before SSA

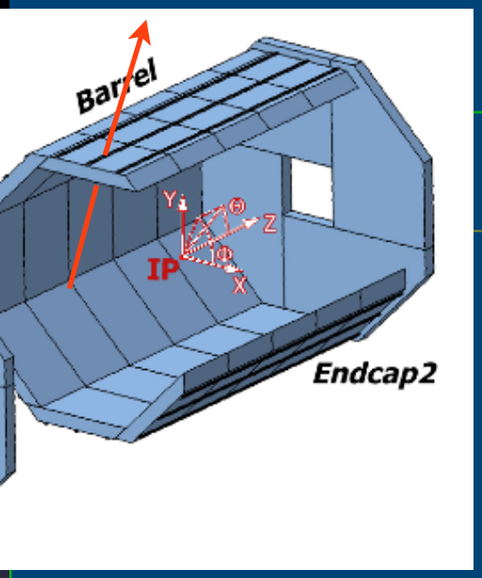


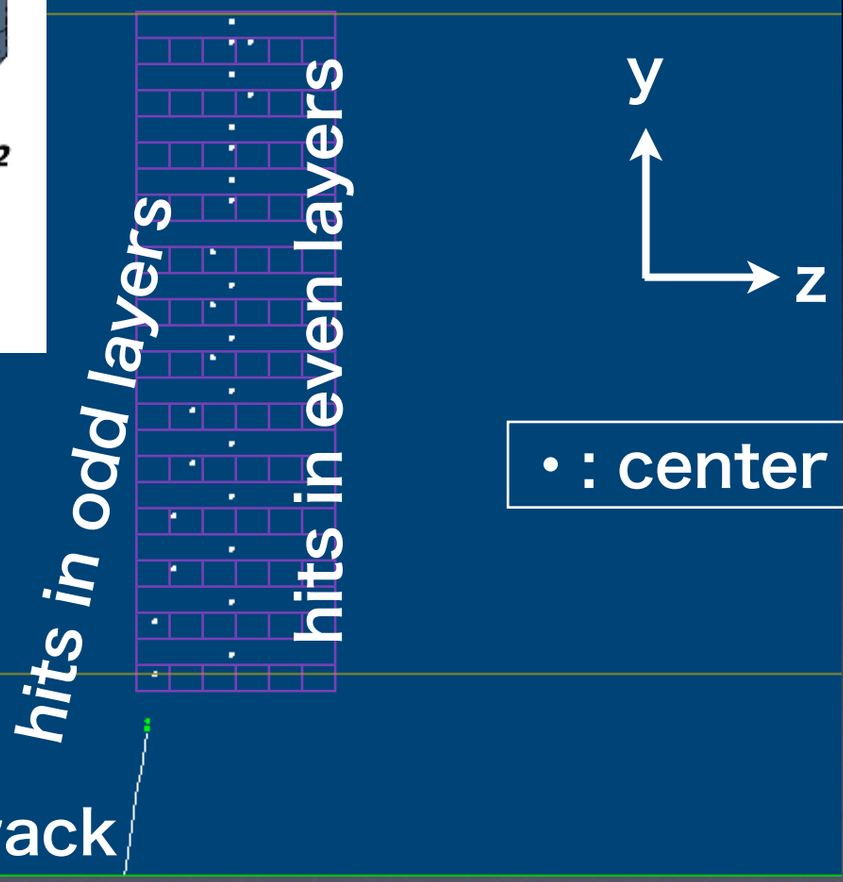
odd layers have fine segmentation from this view, so we can see the oblique incidence. But even layers do not know that.

A track like cluster with SSA

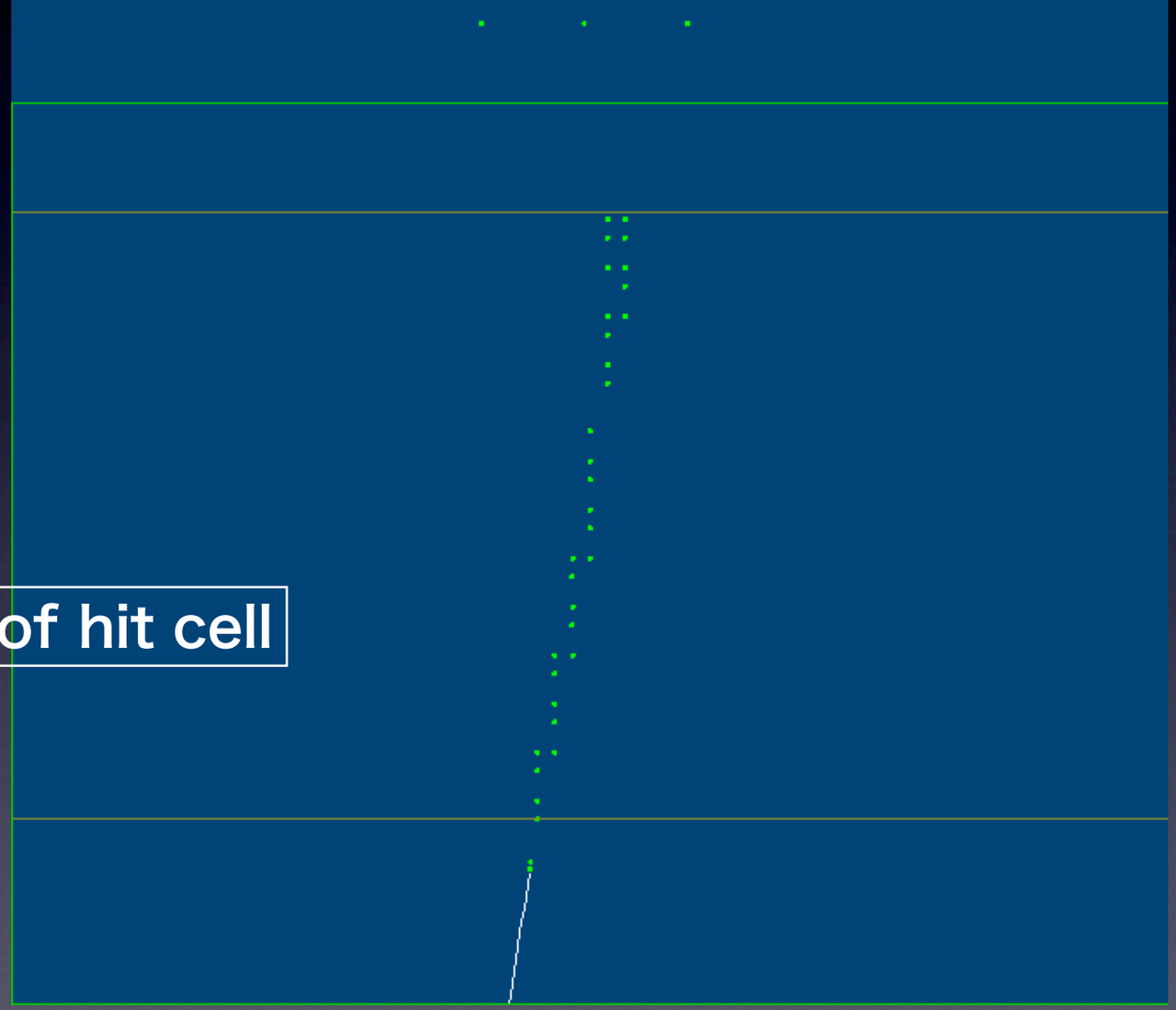
500 GeV muon+ going through top stave of ScECAL barrel

Before SSA





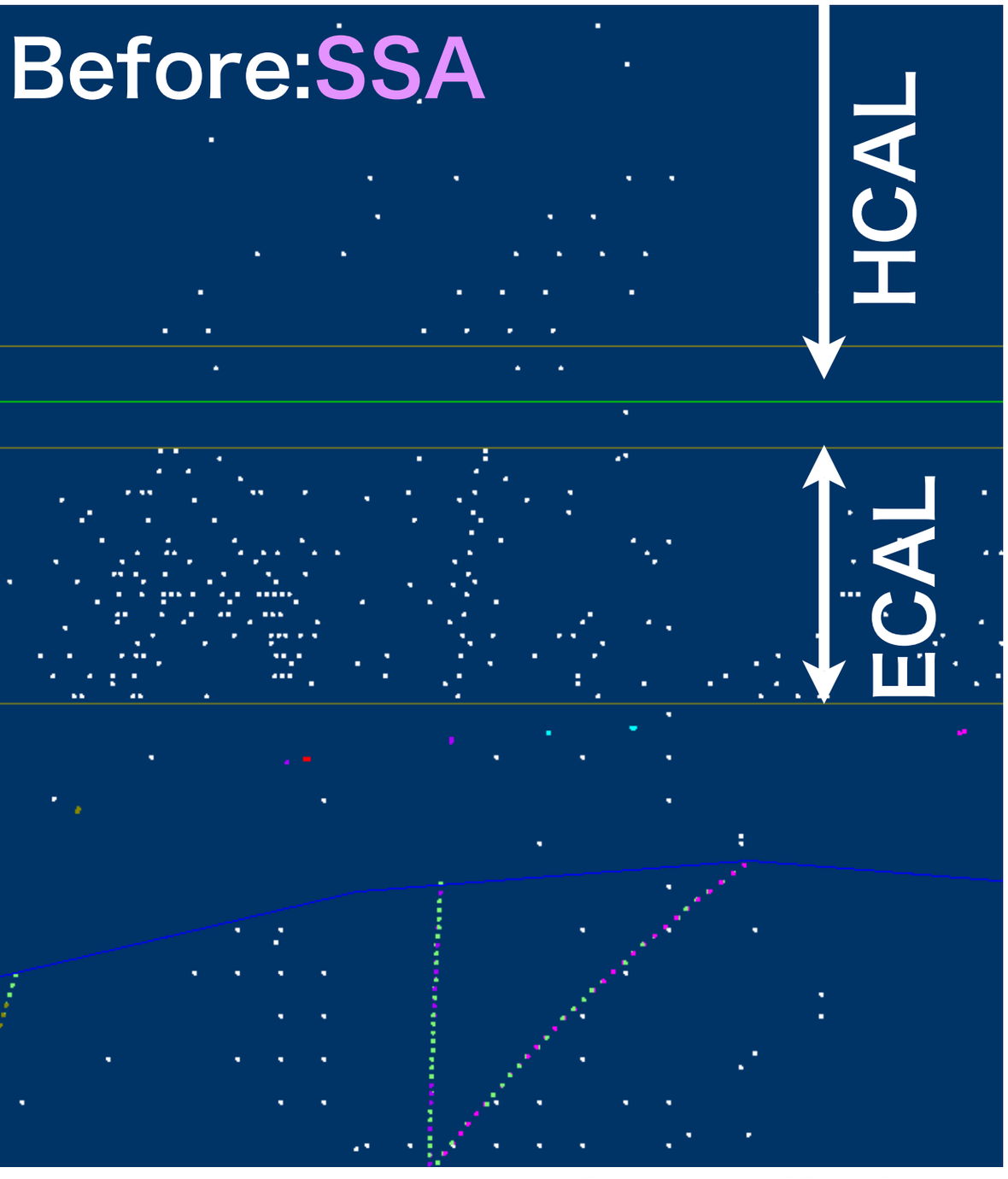
After SSA

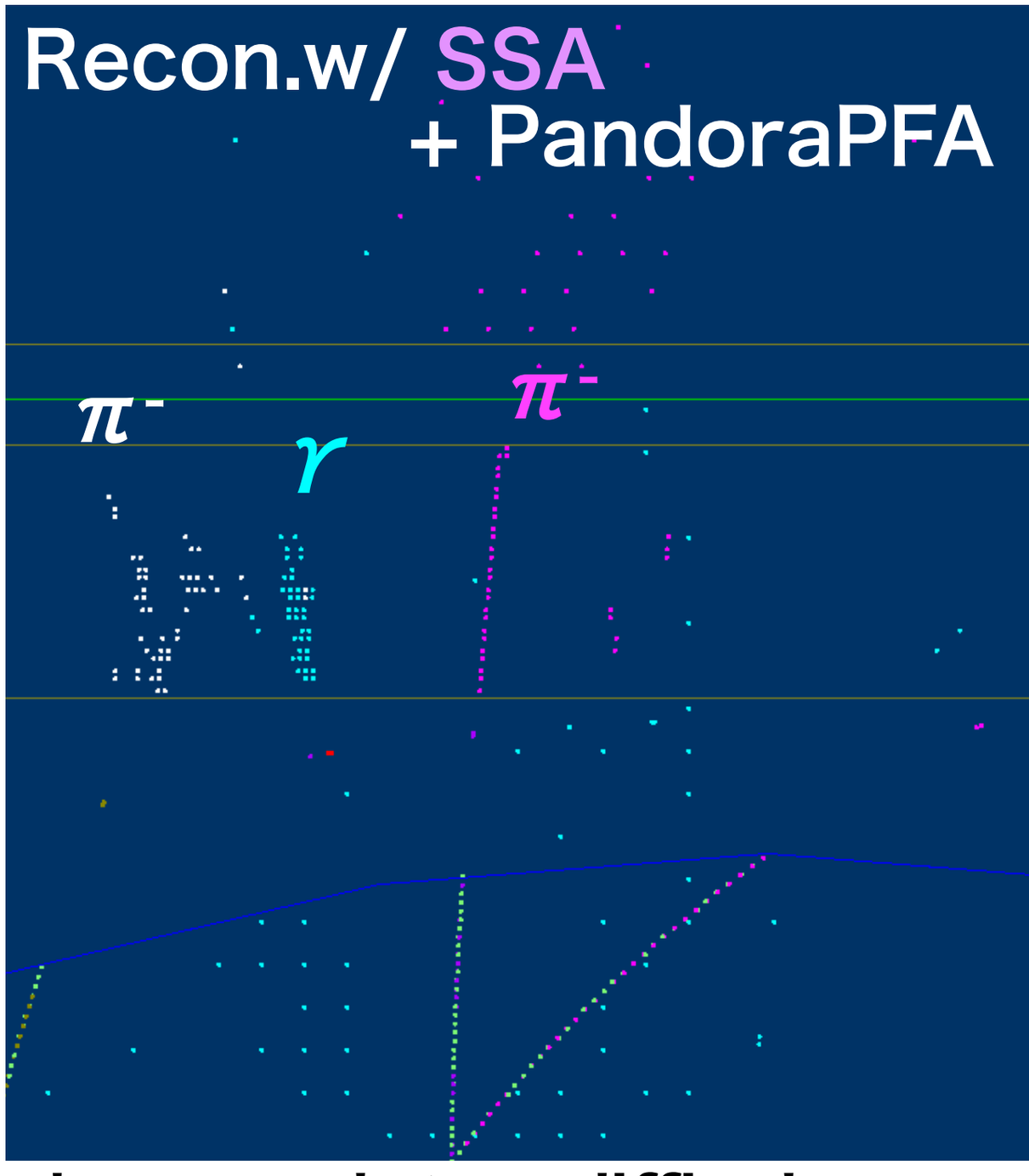


- With SSA, a track appears

Strip Splitting Algorithm

100 GeV Jet x 2: easy case

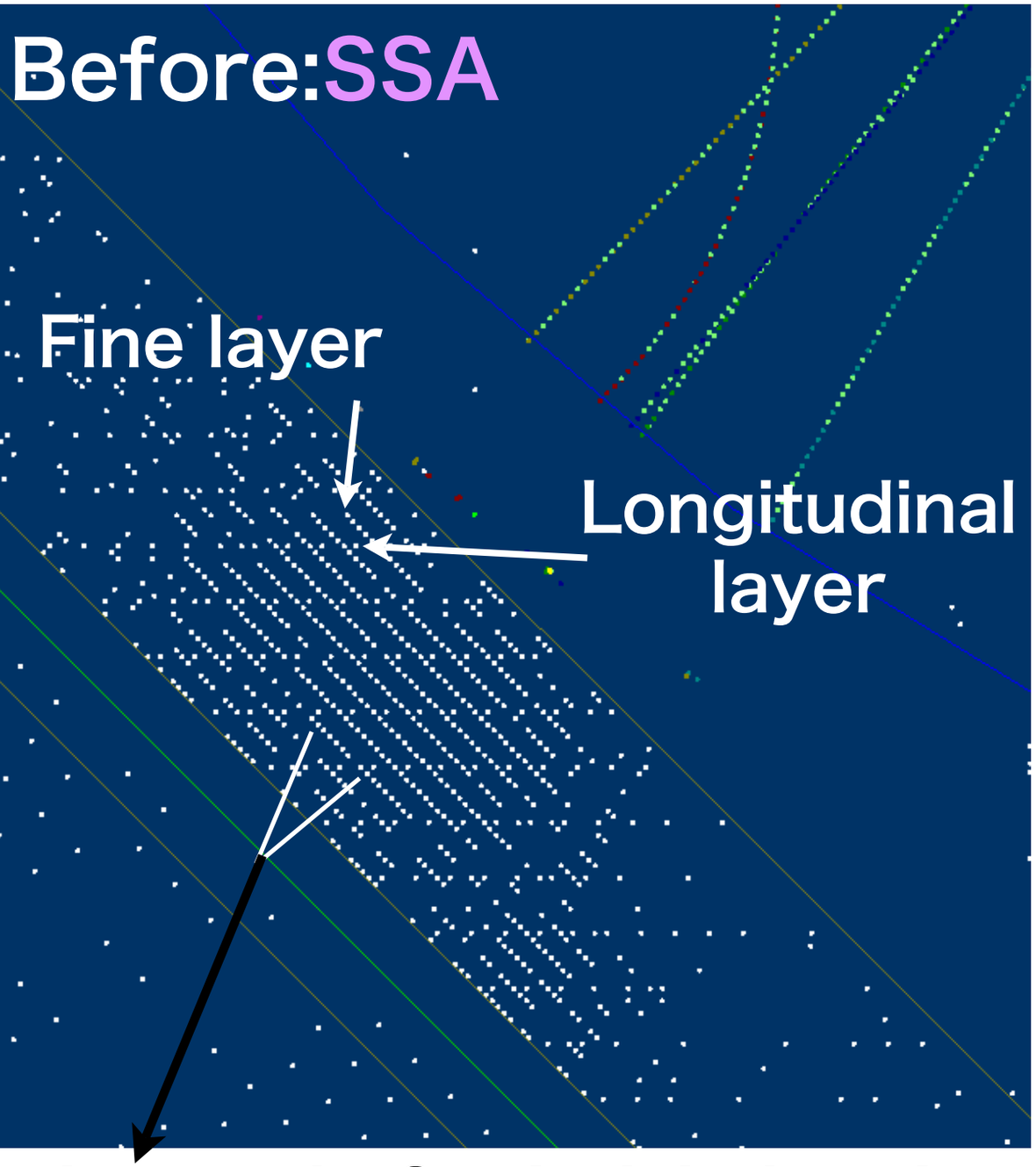


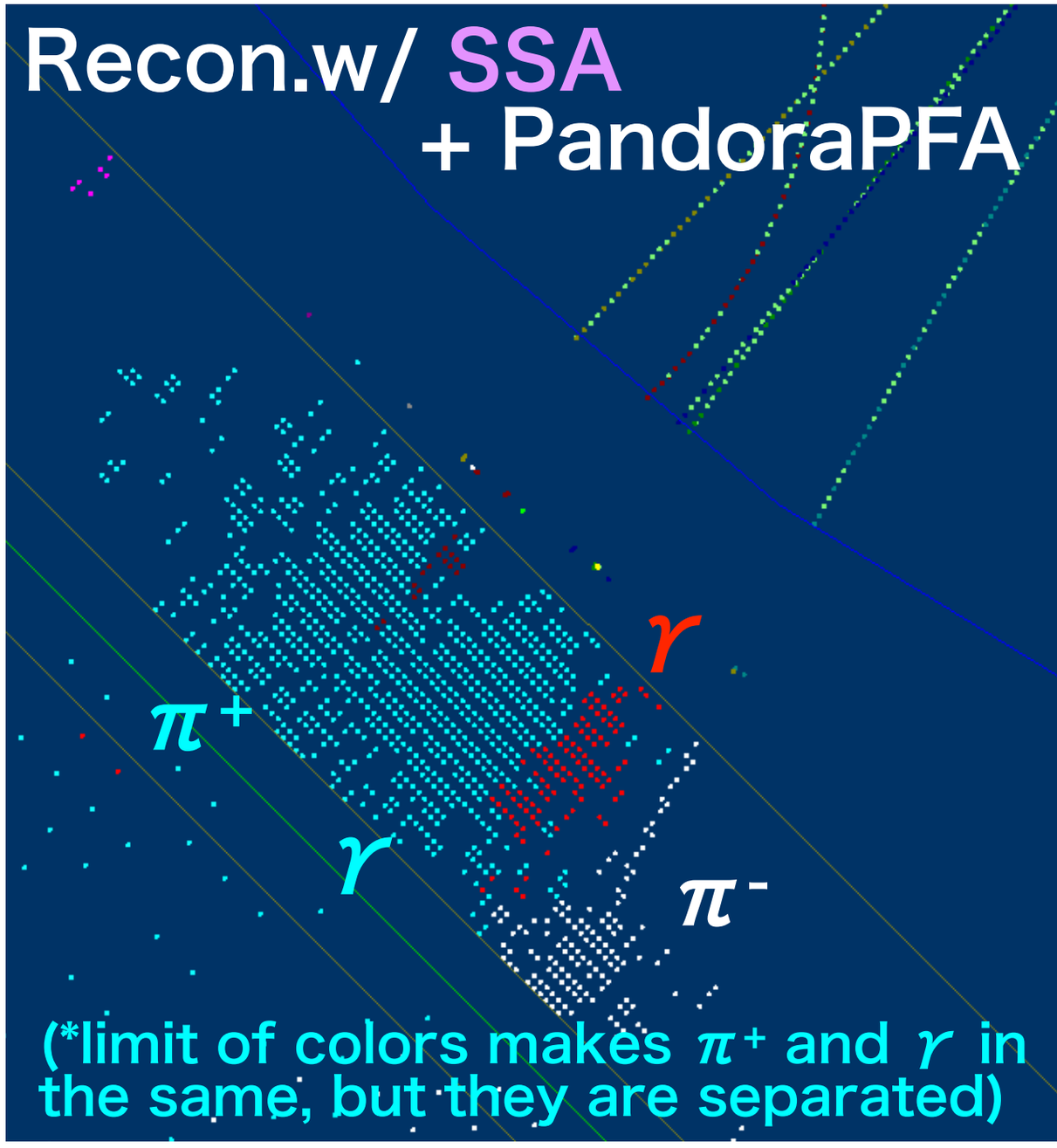


A small shower looks a track➡no difficulty

Strip Splitting Algorithm

100 GeV Jet x 2: more difficult case

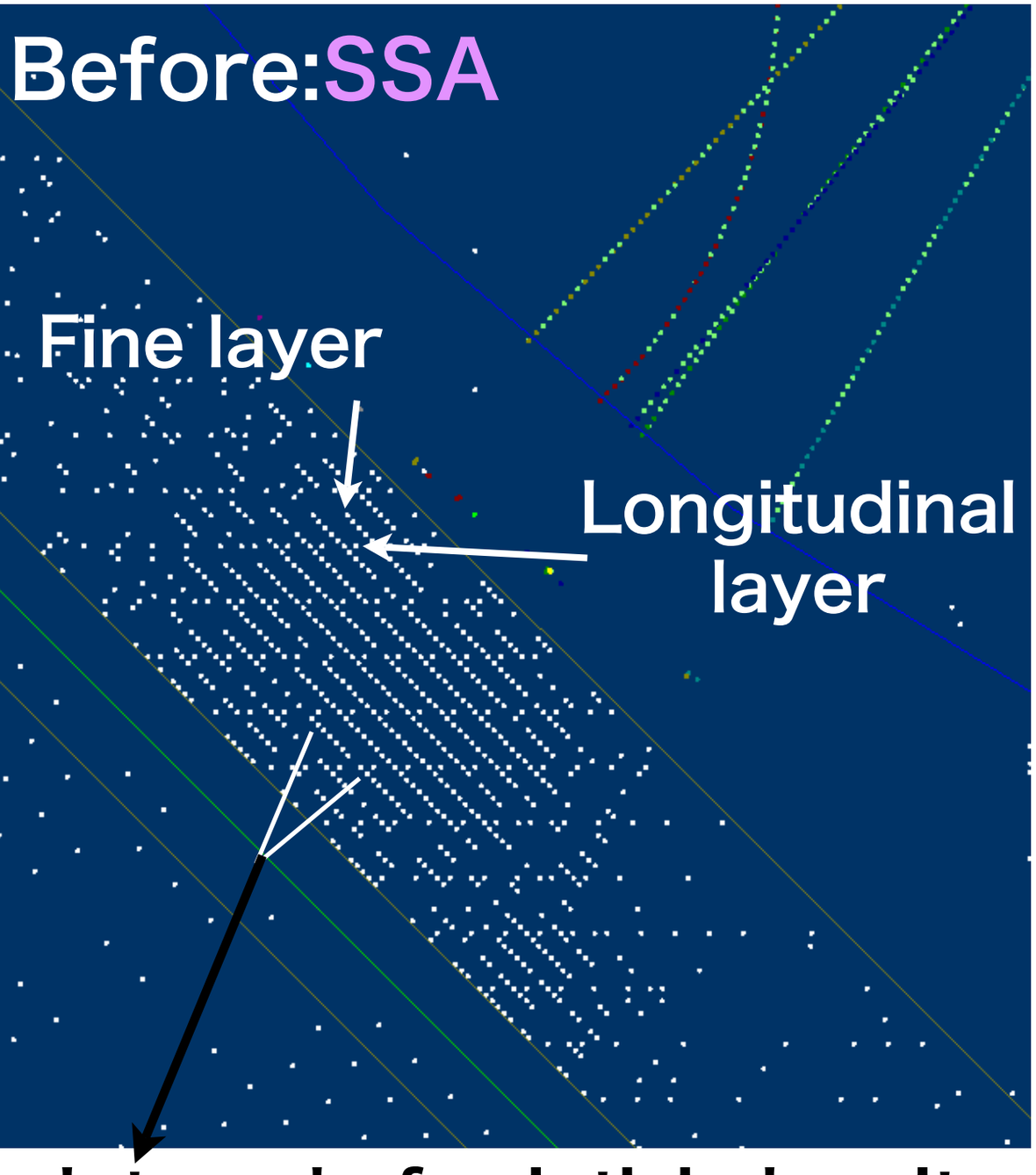


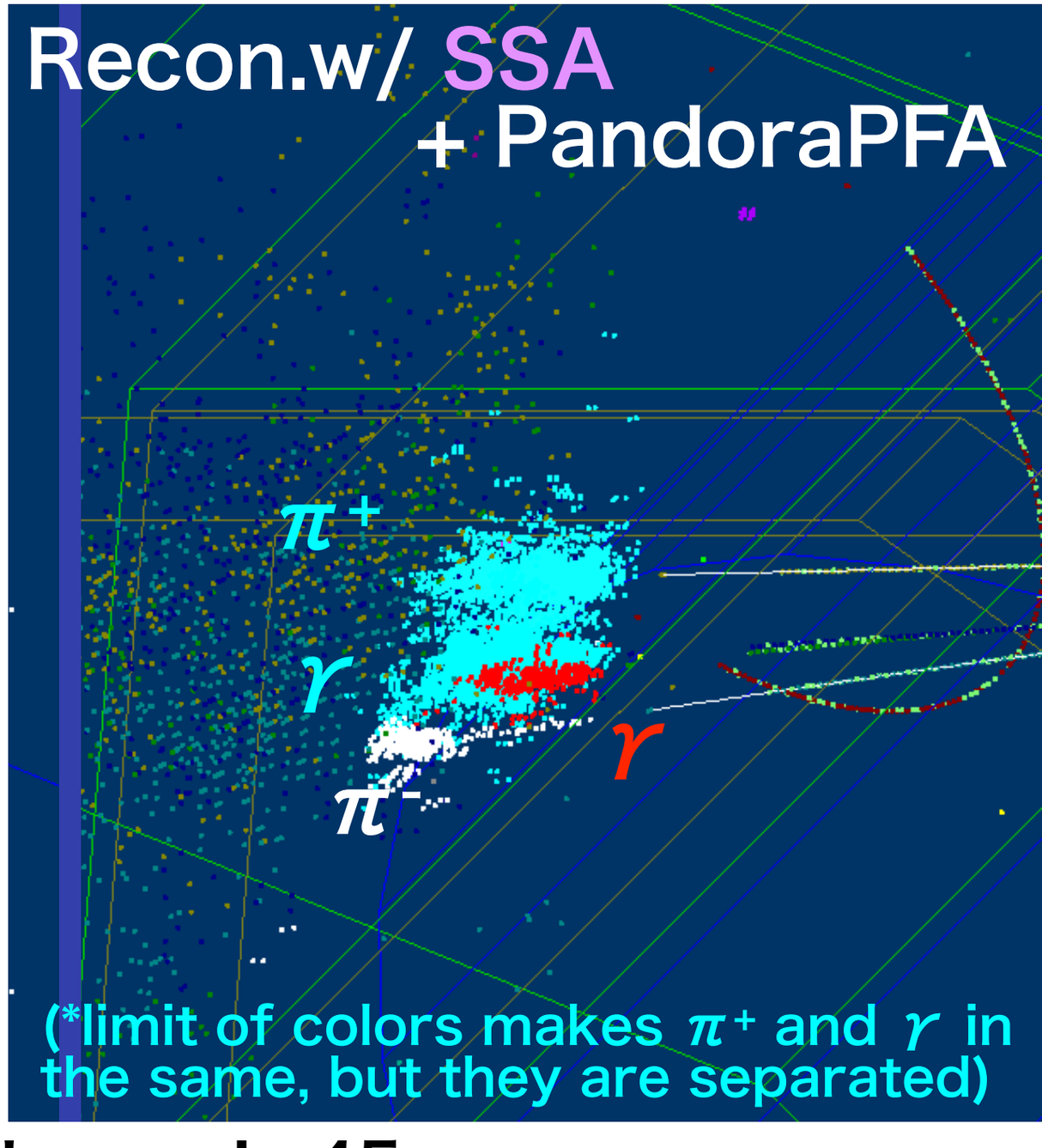


Interval of scinti. in longitudinal layers is 45 mm,
while fine segmented layers: 5 mm (width of scinti.)

Strip Splitting Algorithm

100 GeV Jet x 2: more difficult case





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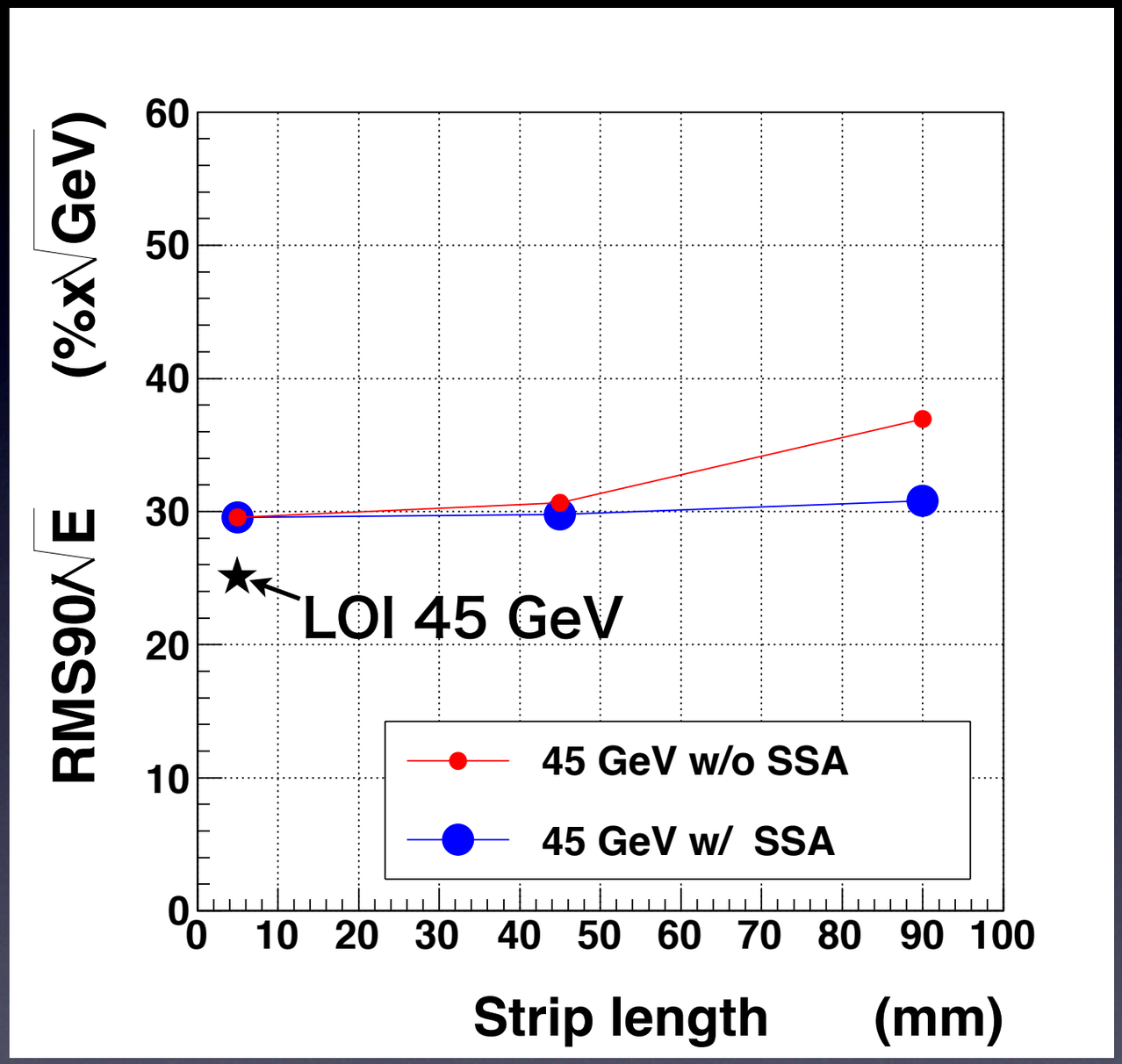
JER of 25-layer ScECAL in ILD



- uds two-jet events

- cos(thrust) < 0.7

SSA works well, but for 45 GeV jet, 45 mm strip ScECAL w/o SSA does not have so much degraded energy resolution.
We need more sever case.

➡ higher energy,

➡ more jets in an events,

➡ More severe tune for ScECAL so that ScECAL also has energy resolution near LOI level.

➡ instead of those ....

How does Strip Si-ECAL work?

Because of difference of sensor thickness between Si: 0.5 mm and Sc: 2.0 mm, layer structure of ScECAL is different from Si-ECAL. This may leads different JER between ScECAL and Si-ECAL.

Once postpone to tune ScECAL layer structure and PFA tuning to have the best performance.

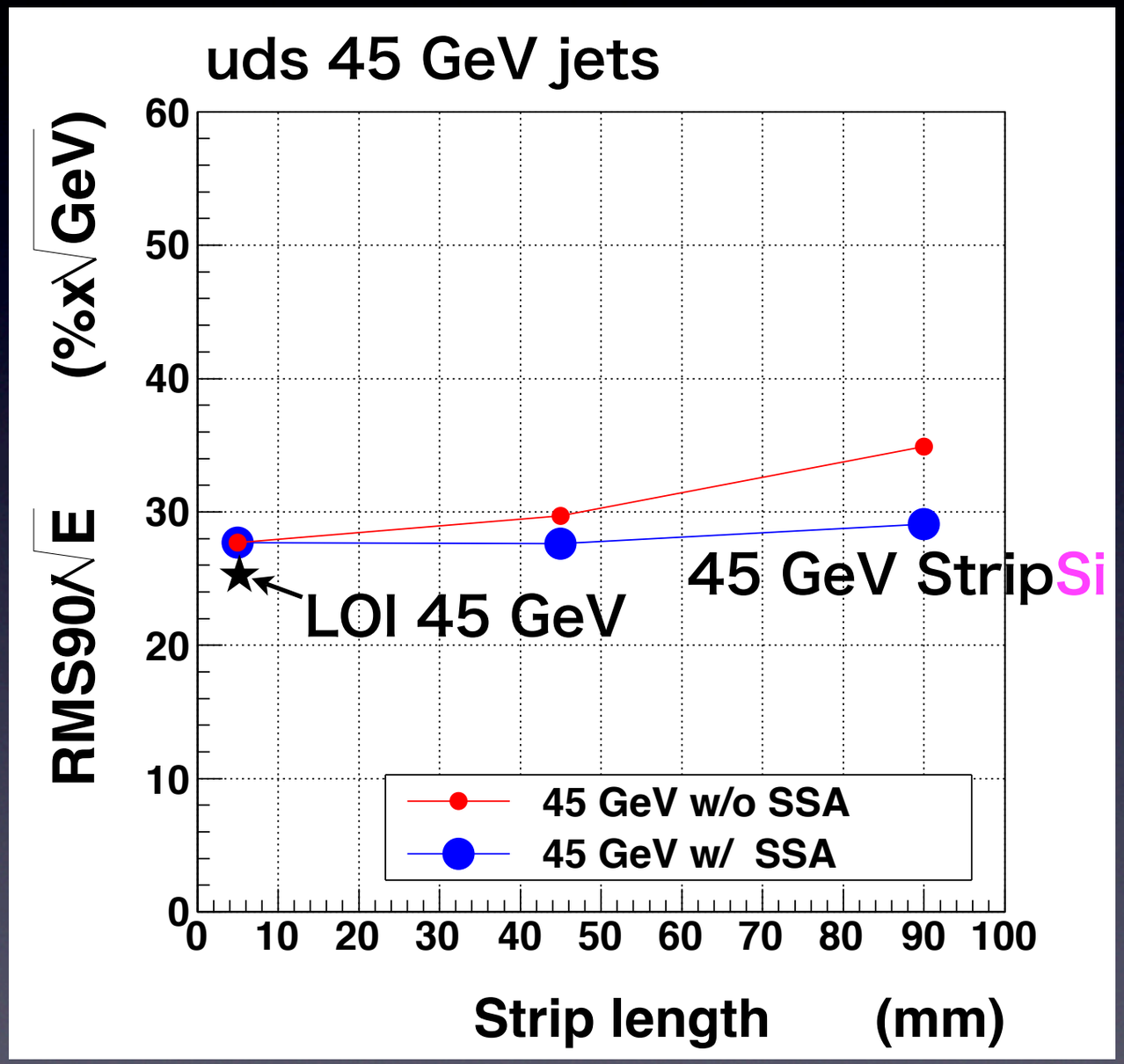
To see the performance of SSA itself and to extract any problems of SSA without being confused by PandoraPFA tune, Strip Si-ECAL cases are studied.

for this purpose:

In Mokka sensitive material of ScECAL is replaced with silicone 2.33g/cm^3,

Similar layer structure to Si-ECAL default;
0.5 mm thick sensor,
20 x 2.1 mm thick W absorbers,
9 x 4.2 mm thick W absorbers.

Jet energy resolution of Strip Si- ECAL depending on strip length



- SSA works well for 45 mm strip Si-ECAL
- with 90 mm Strip Si-Ecal, still JER < 30%
- LOI result is a little bit better than my job.
  - difference of Geant4 physics Model?
  - we need to investigate the reason.

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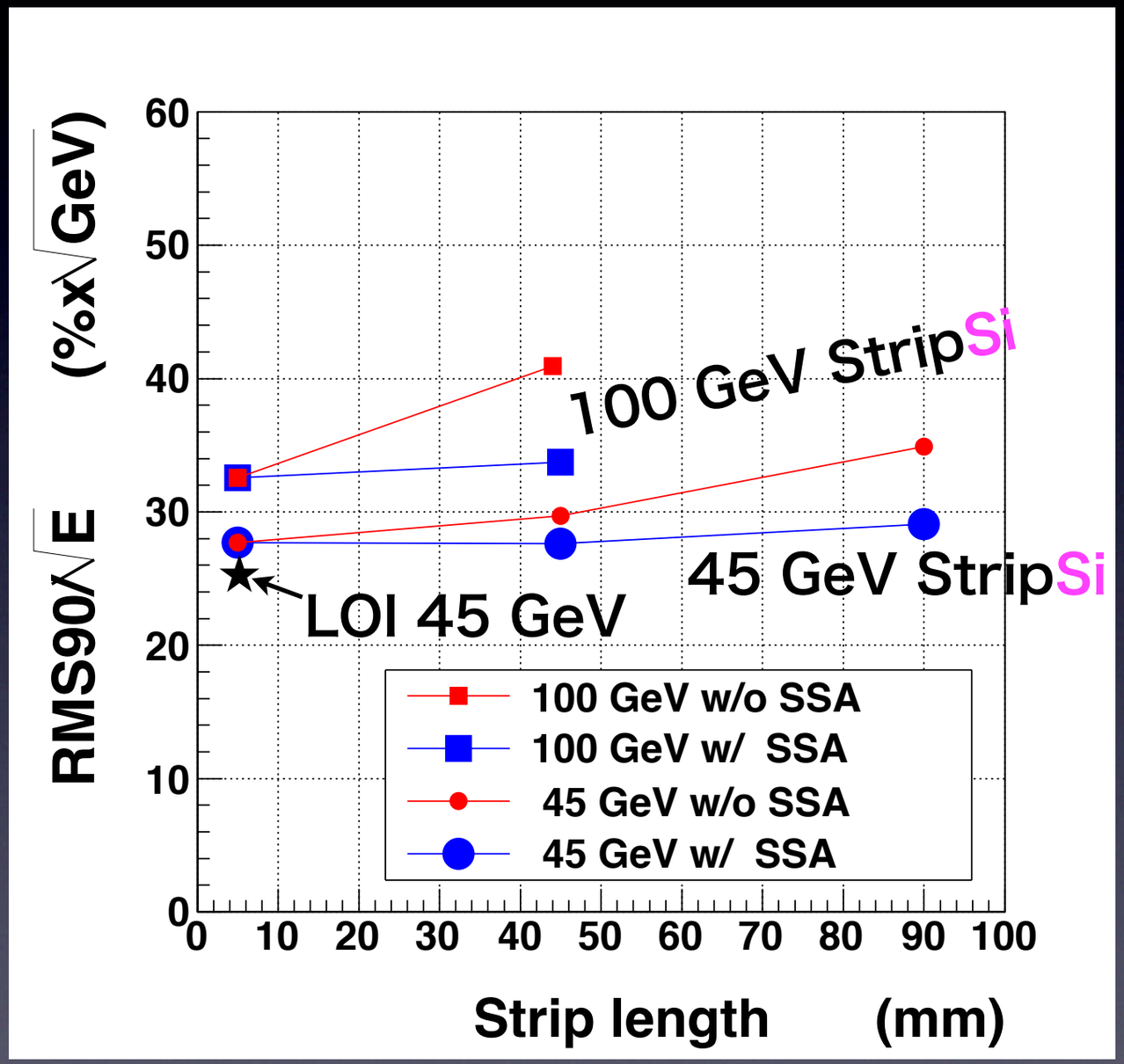

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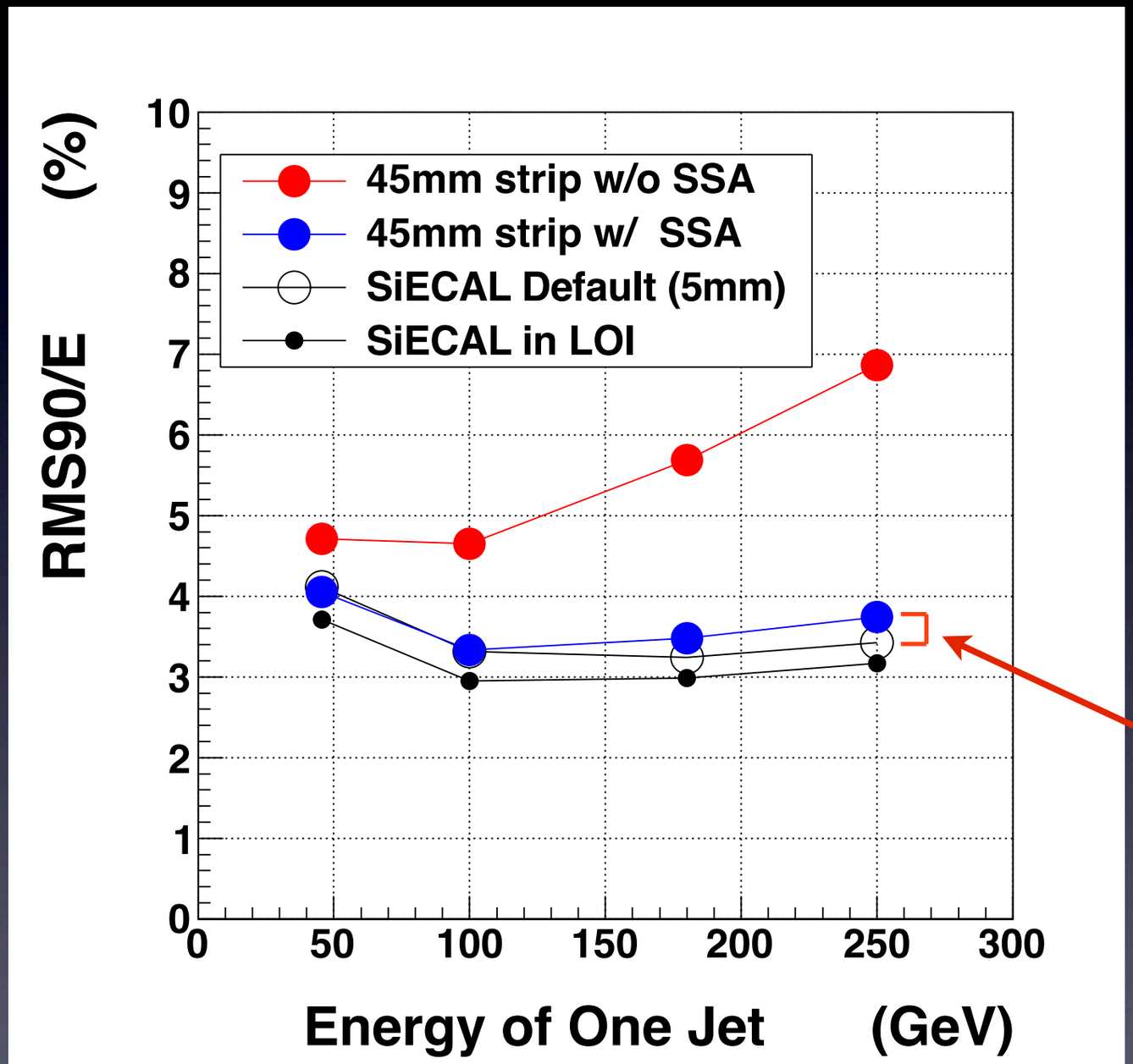
  - difference of Geant4 physics Model?
  - we need to investigate the reason.
- For 100 GeV jets, SSA works well

Jet energy resolution of Strip Si- ECAL depending on the jet energy



- SSA works well even with JER near LOI level.
- With good layer geometry and best tune of PFA, ScECAL can have comparable performance with SiECAL
- a little degradation appears as jet energy increases greater than 180 GeV.

Summary

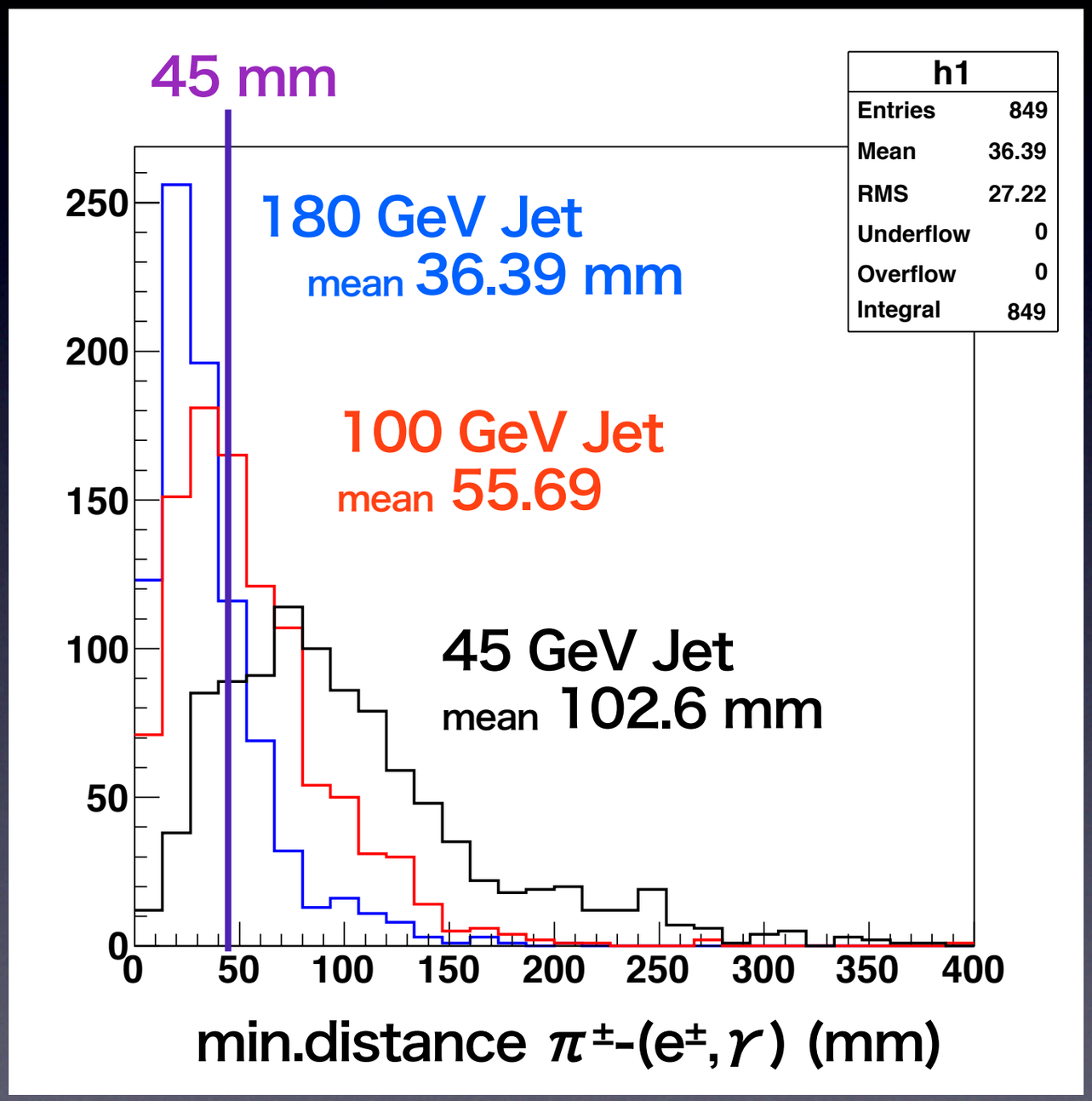
- Scintillator strip ECAL has good basic energy resolution.
- Granularity is more important for Particle flow algorithm.
- Strip Splitting Algorithm is developing.
- To dedicate to see the performance of SSA, Strip Silicon W ECAL has been studied.
- JER of 45 mm Strip Silcon ECAL has almost similar JER to the 5 x 5 mm^2 Si W ECAL.
- Developing the best layer structure and PFA tune have potential to make better JER for ScECAL also.
- Need to study about a little bit degrading with higher energy.

hybridEcalSplitter

- hybridEcalSplitter written by Daneil Jeans can be used to achieve SSA.
- it already exists in MarlinReco/trunk/Clustering/hybridEcalSplitter/
- You can try to use it, but not yet released
- Because a modification of CaloHitCreator in MarlinPandora is needed to make correct SSA.
- I've already contact with John Marshall and we will implement it near future in the public.

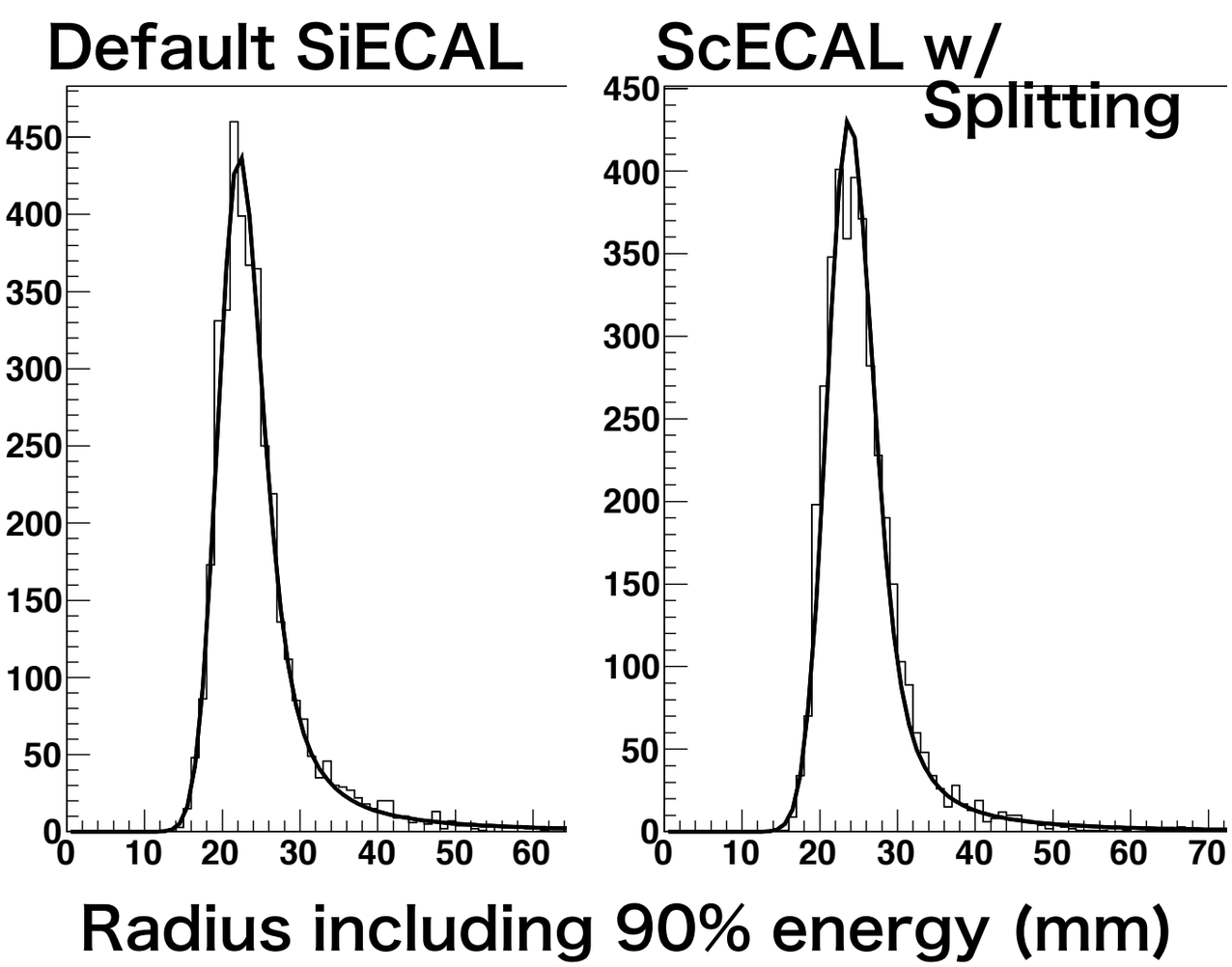
backup

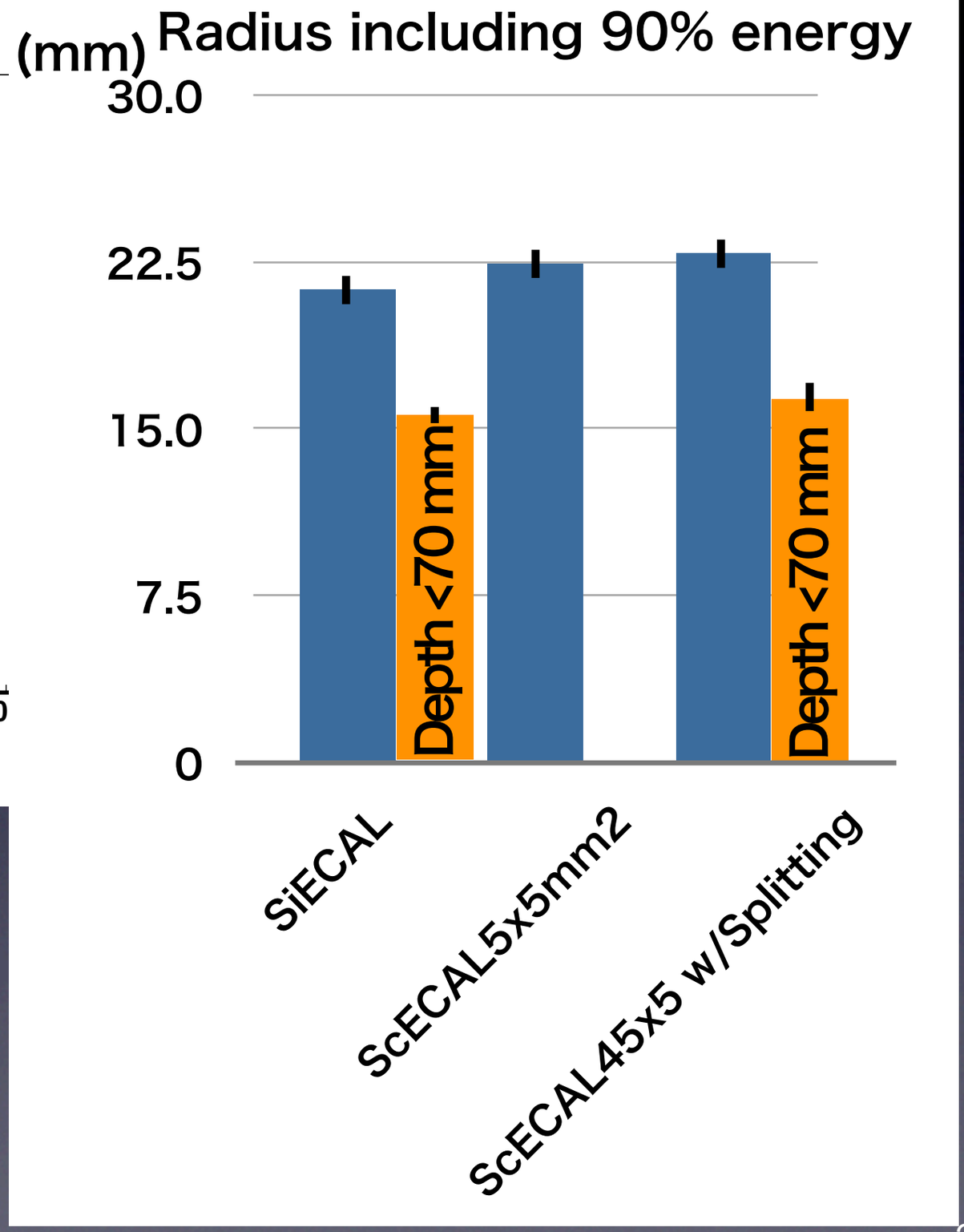
Minimum distance between $\pi^{\pm}$ and photon (+ $e^{\pm}$) depending on jet energy



- In 45 GeV jet, most of minimum distances of clusters are greater than 45 mm. This leads that the JER w/o SSA does not degrade so much.
- In greater than 100 GeV jet, cluster distances become closer in 45 mm. still good energy resolution with SSA.
- Cause of a little discrepancy between 5x5 mm^2 SiECAL and 45x5 mm^2 SiECAL w/ SSA for larger energy jet than 180 GeV will be investigated.

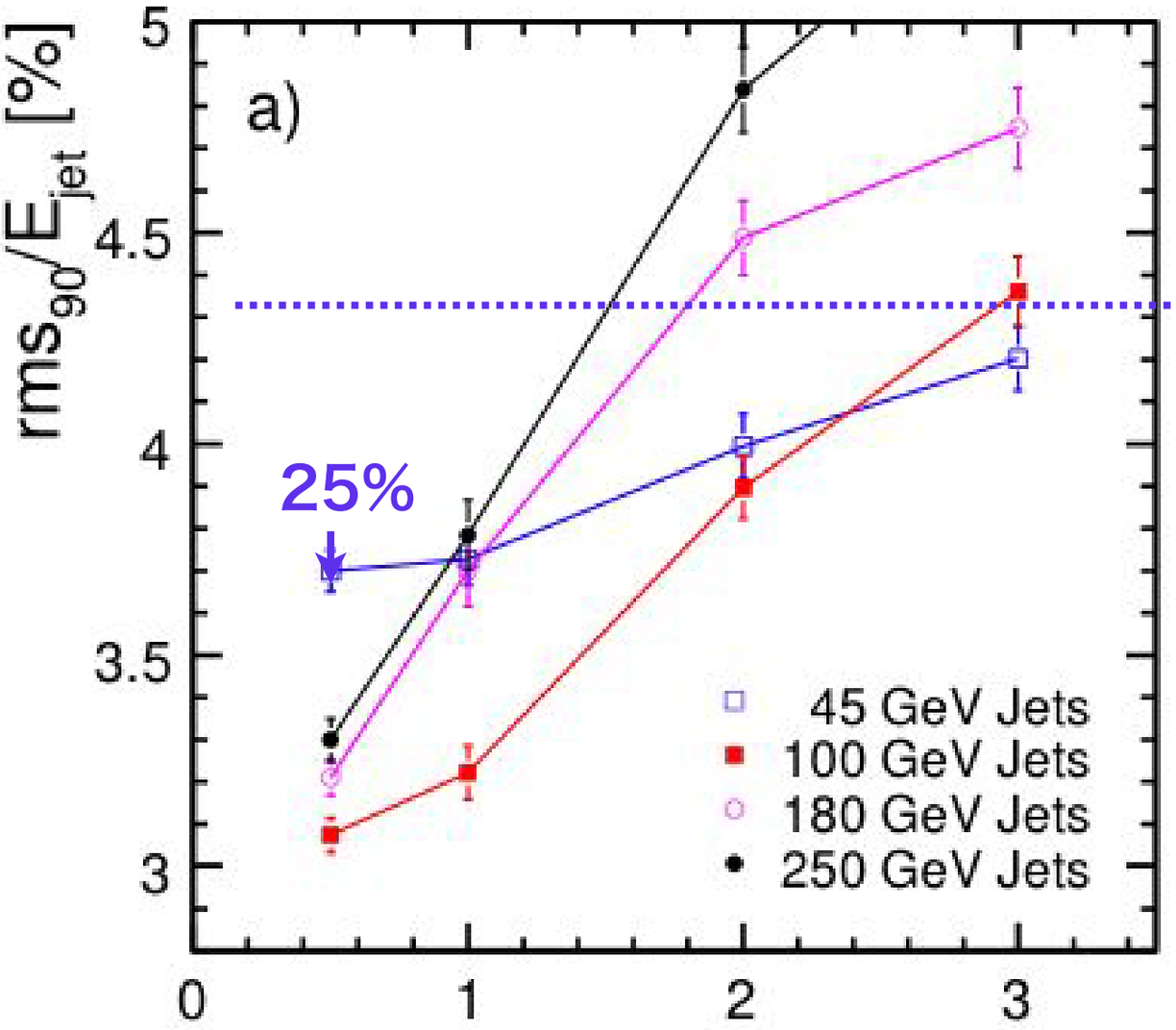
Radius of 10 GeV photon in ECAL





-MPV of Landau-gaussian fit to cluster radius including 90% energy is not so different between SiECAL and ScECAL

この方法 (PFA) で要求される横方向の分割度



$\sigma_E/\sqrt{E}$(GeV) = 30%
for 45 GeV Jet

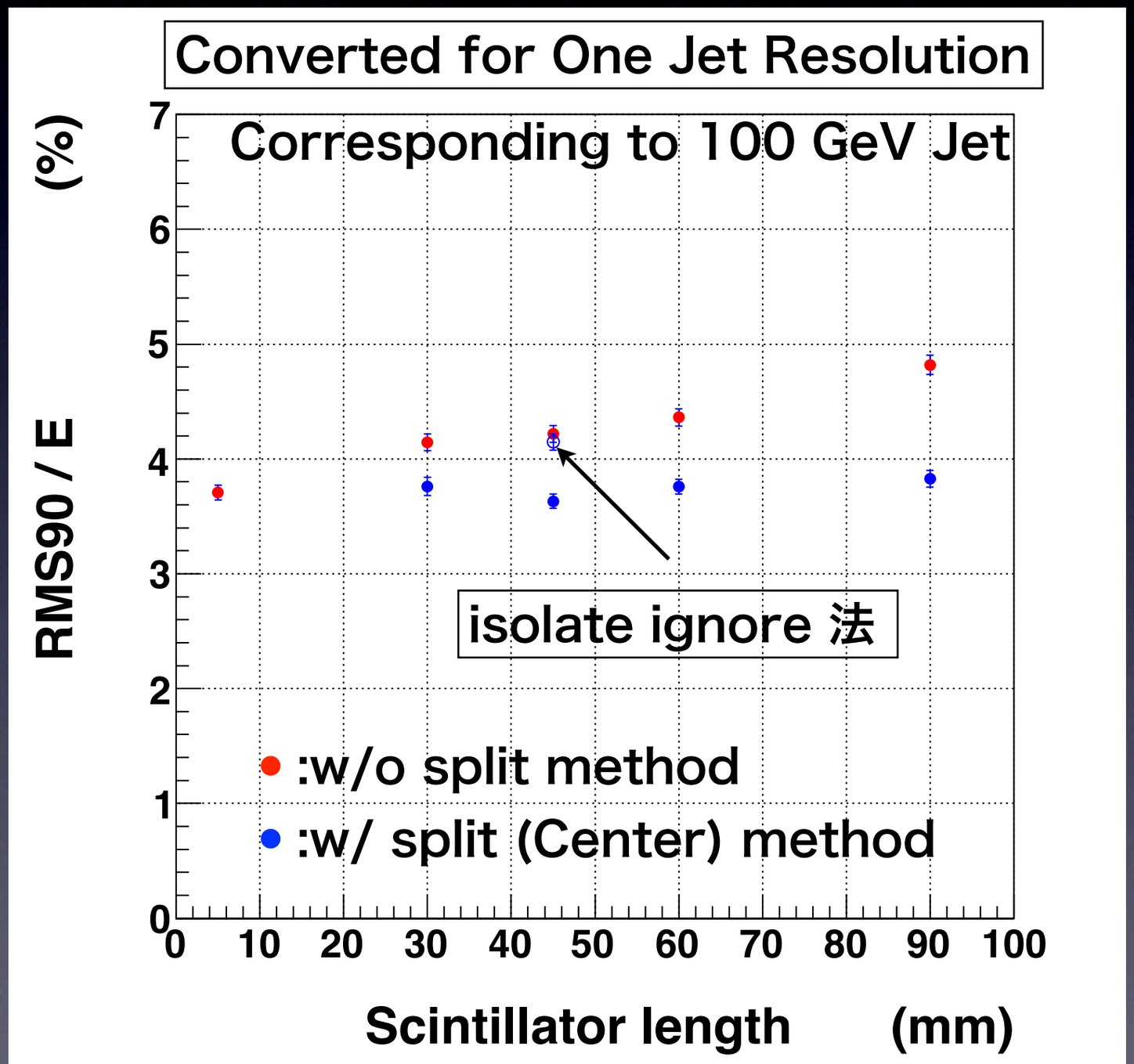
PandoraPFA からの要求
横方向分割 < 5x5 mm^2

ECAL Cell Size/cm : HCAL セル 3 cm x 3 cm 固定

Geant4 base の simulation by M.Thomson

Jet energy resolution depending on Scinti. length

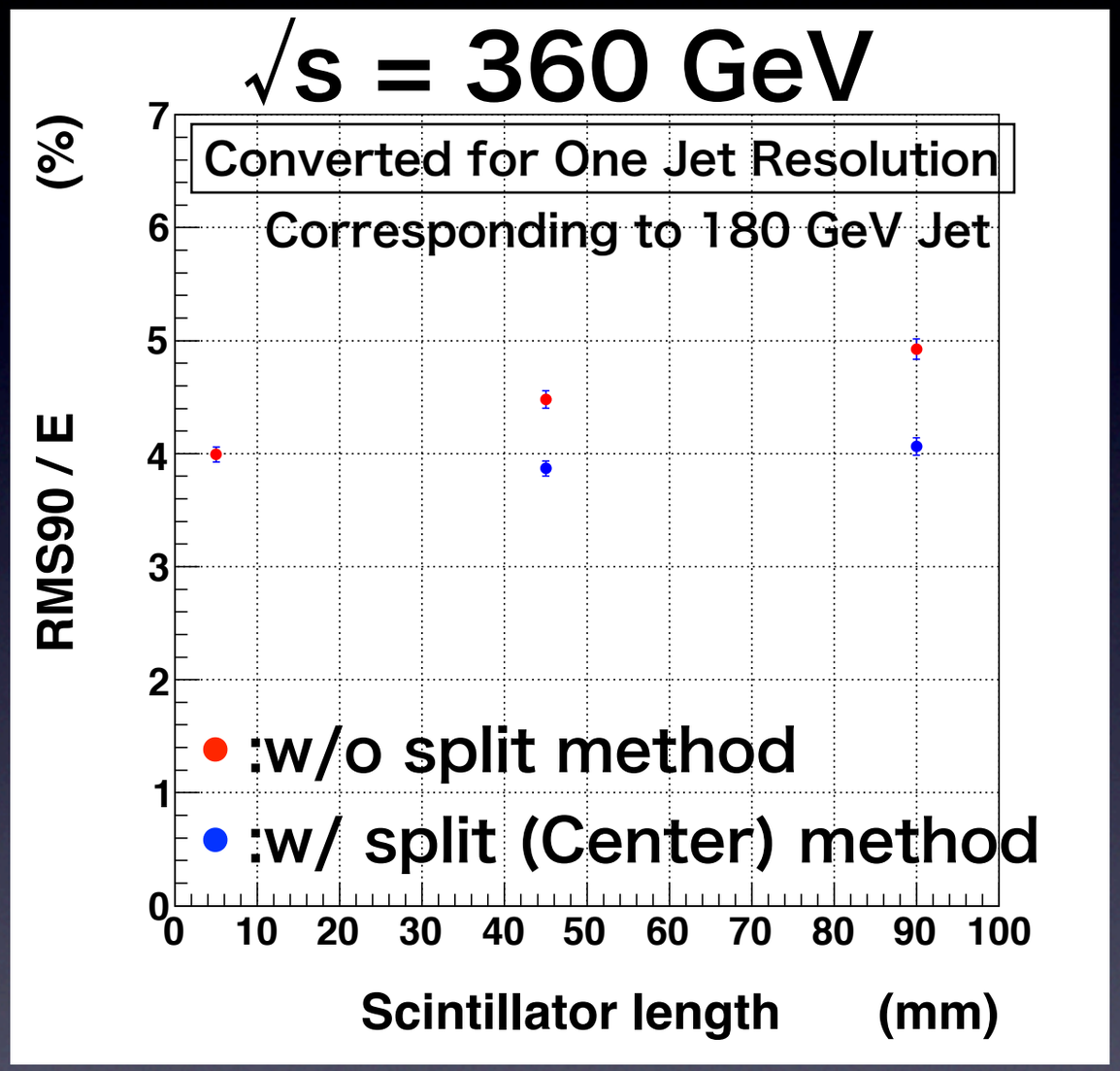
√s = 200 GeV 2 jet events

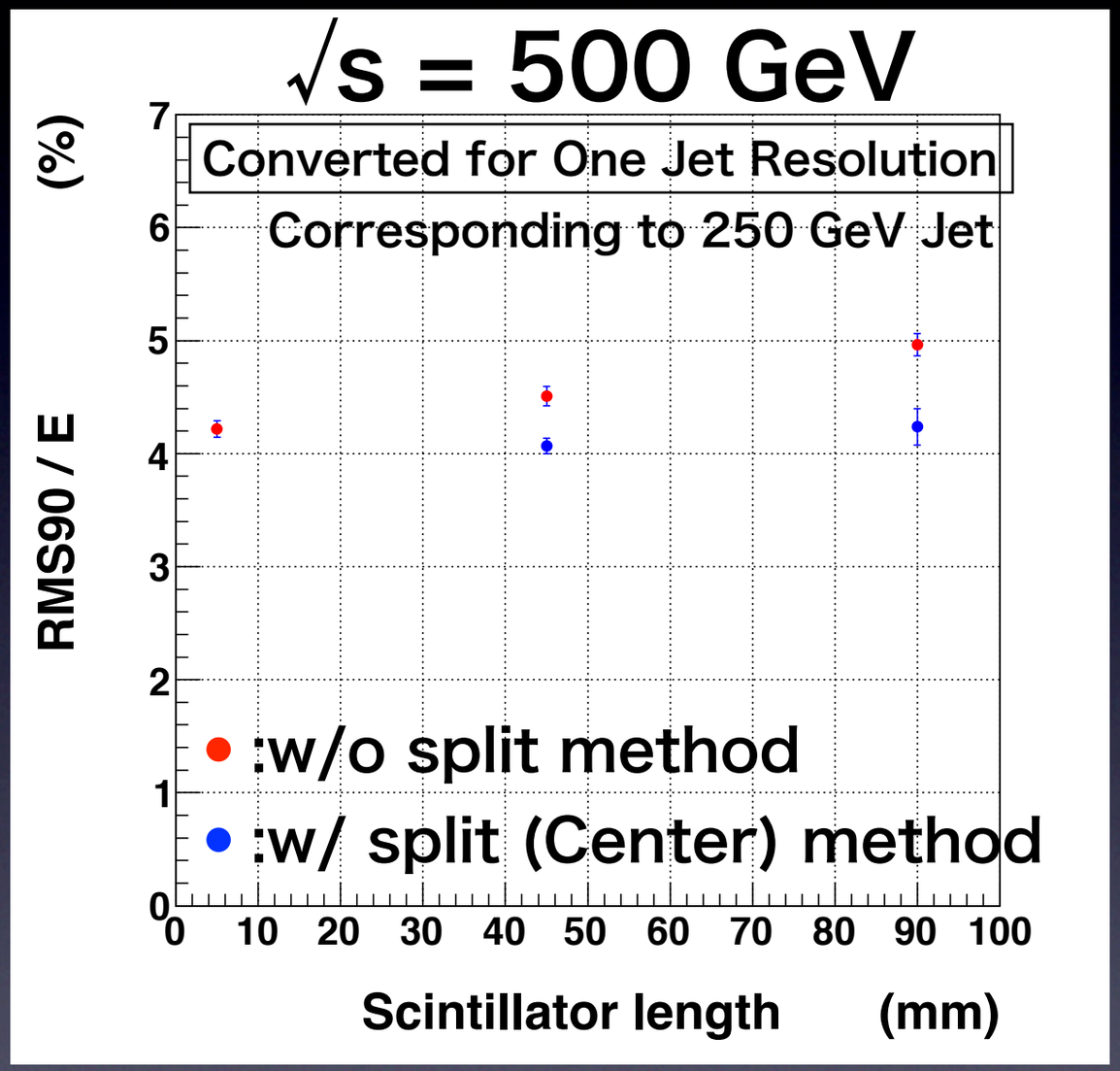


Split 法は √s = 200 GeV でもなお有効

isolate ignore 法では Energy resolution が center 法におとる

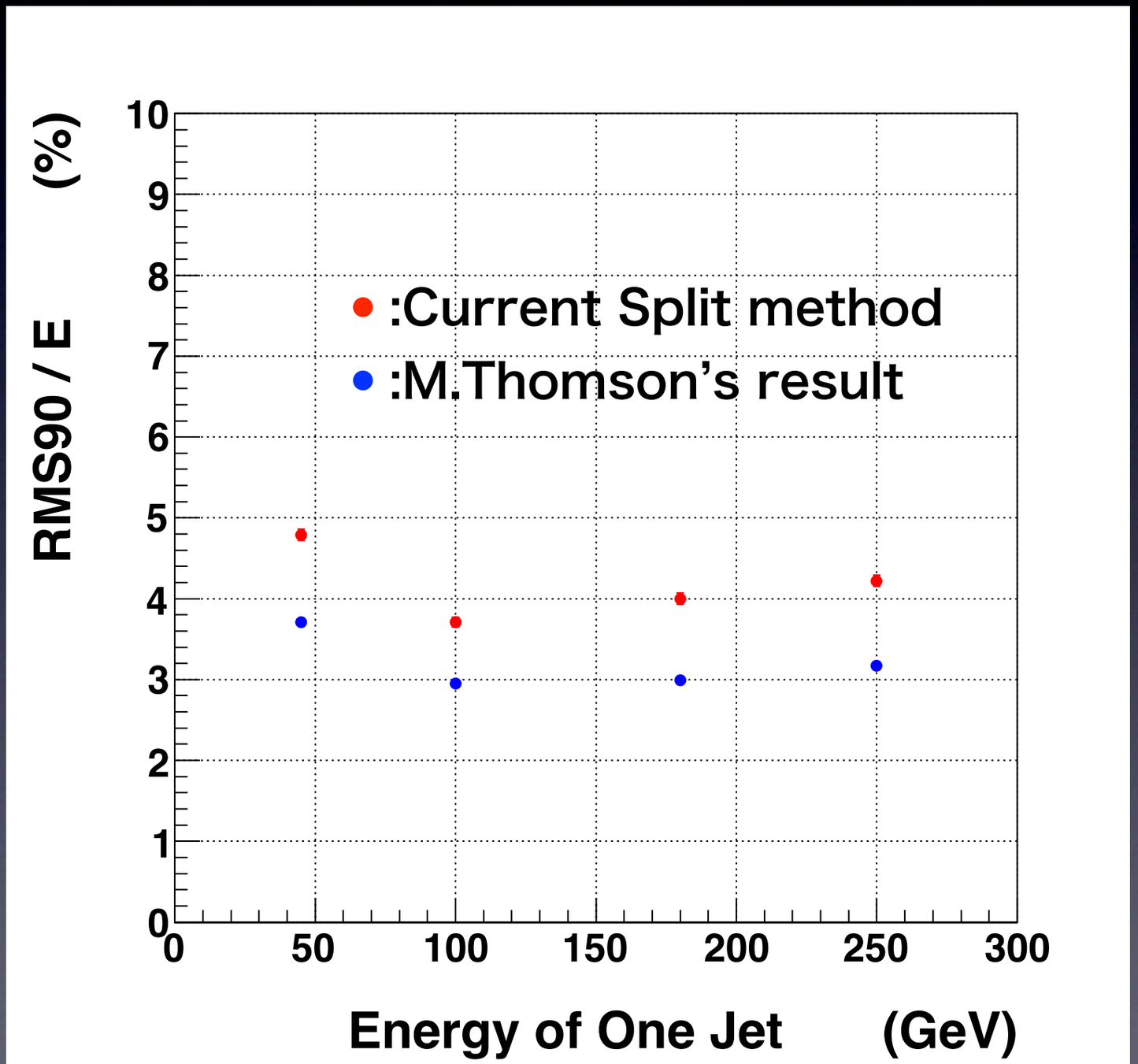
Jet energy resolution depending on Scinti. length





√s = 500 GeV まで Split 法が有効である事を確認

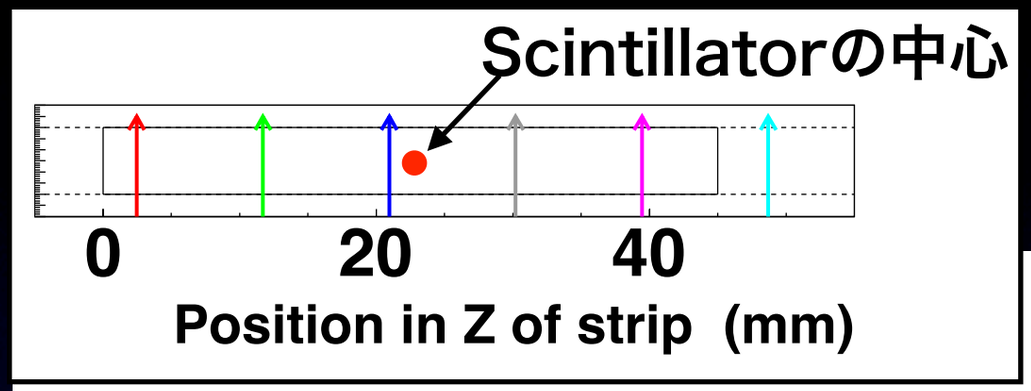
Energy dependence of the Jet energy resolution



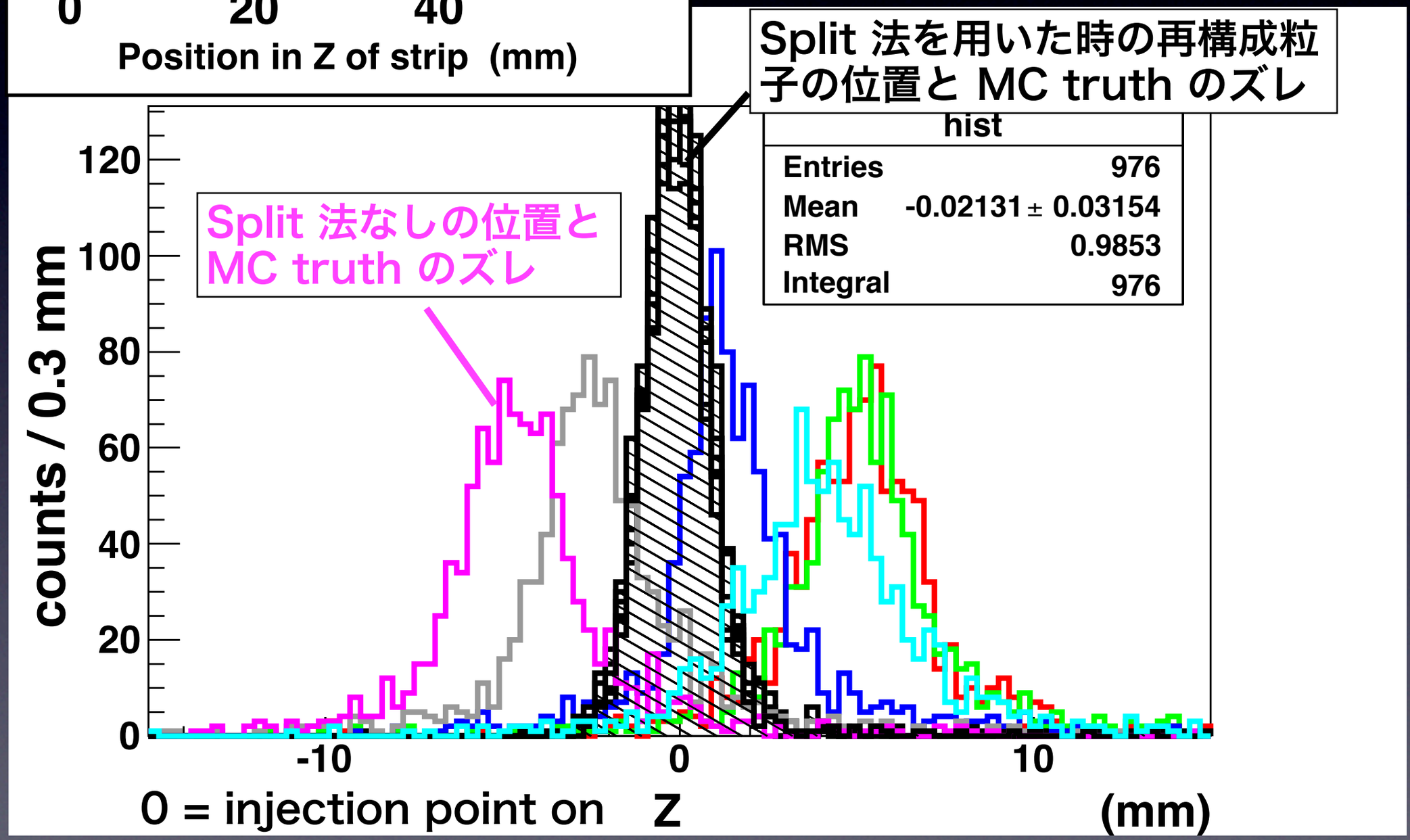
Jet Energy resolution の Jet energy に対する依存性は PandoraPFA の開発者の結果とあっており，PandoraPFA の設定パラメータの調節などで，本研究の結果を改善できる可能性を示唆

Scintillator に対して色々な位置に光子を入射した時の位置結果と MC truth からのズレ

10 GeV 1000 photons



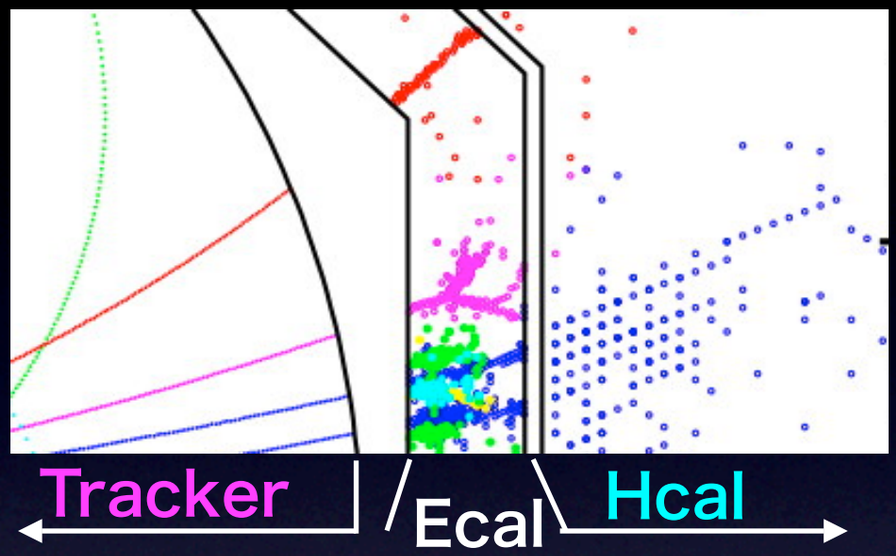
histogram の色は入射位置を示す矢印の色に対応



- Split 法により，正しい位置が求められている

細分化カロリメータの効能

- 別名 “イメージングカロリメータ”
- 細分化 ➡ クラスターを粒子毎に識別
  ➡ トラック/クラスタ対応をとれる



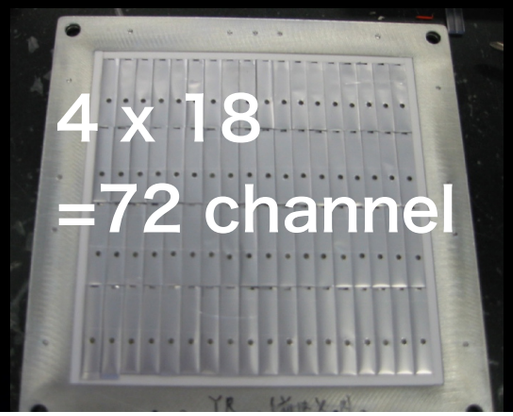
従来の細分化されていないCAL

Calori-meter	fraction	σ/E x √E(GeV)
HCAL	72%	55%
ECAL	28%	15%

Calori-meter	fraction	σ/E x √E(GeV)
HCAL	10%	55%
ECAL	30%	15%
Track	60%	(σ/E x E^2(GeV^2) 3.6×10^{-5}

LEP best σ/E ~ 65%/√E(GeV) ➡ ILC 物理の要求 30%/√E(GeV)

Particle Flow Algorithm と呼ばれれる.



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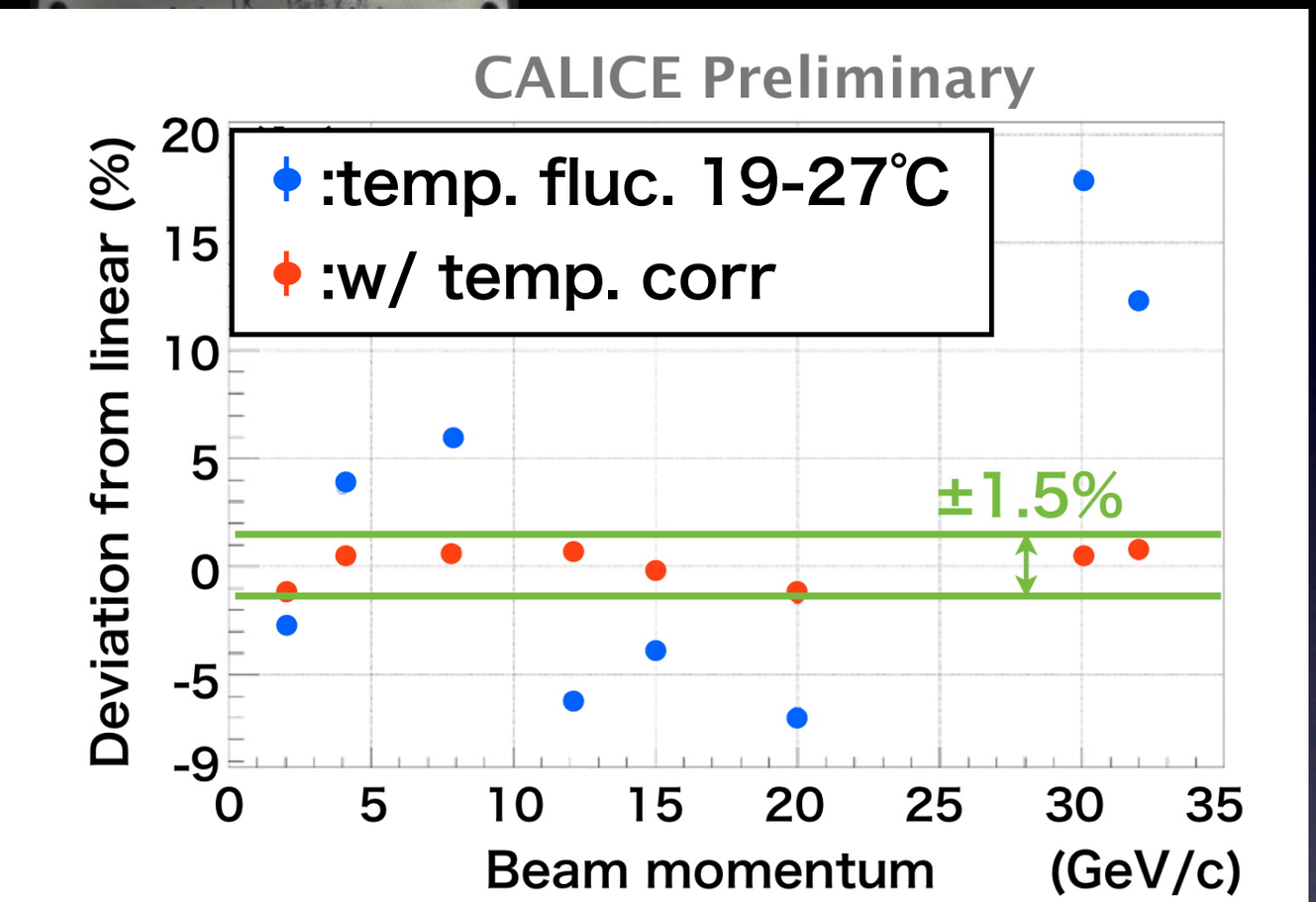

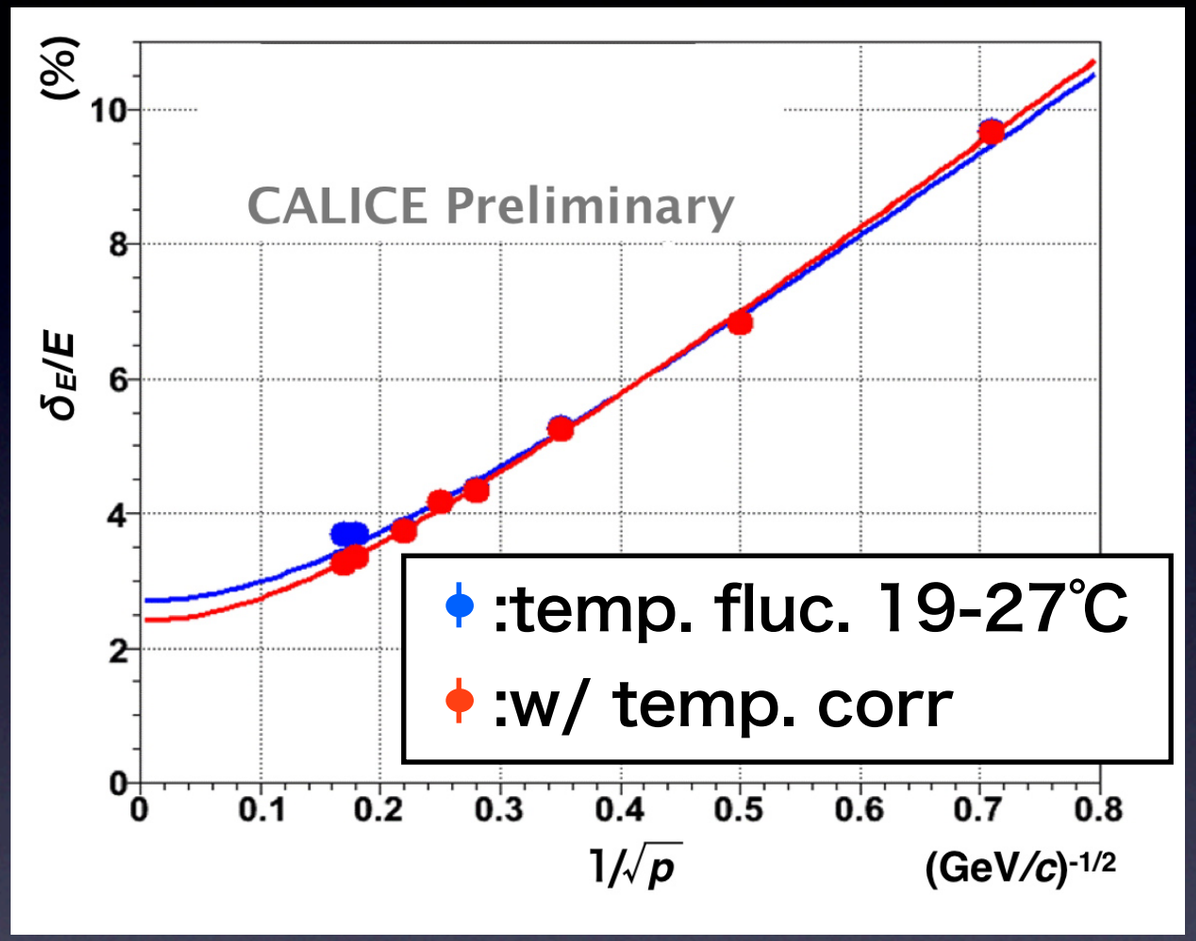

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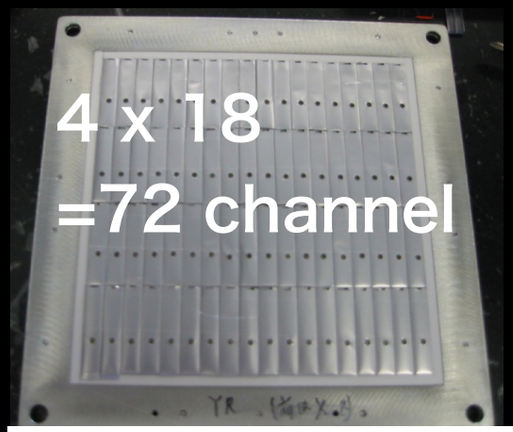
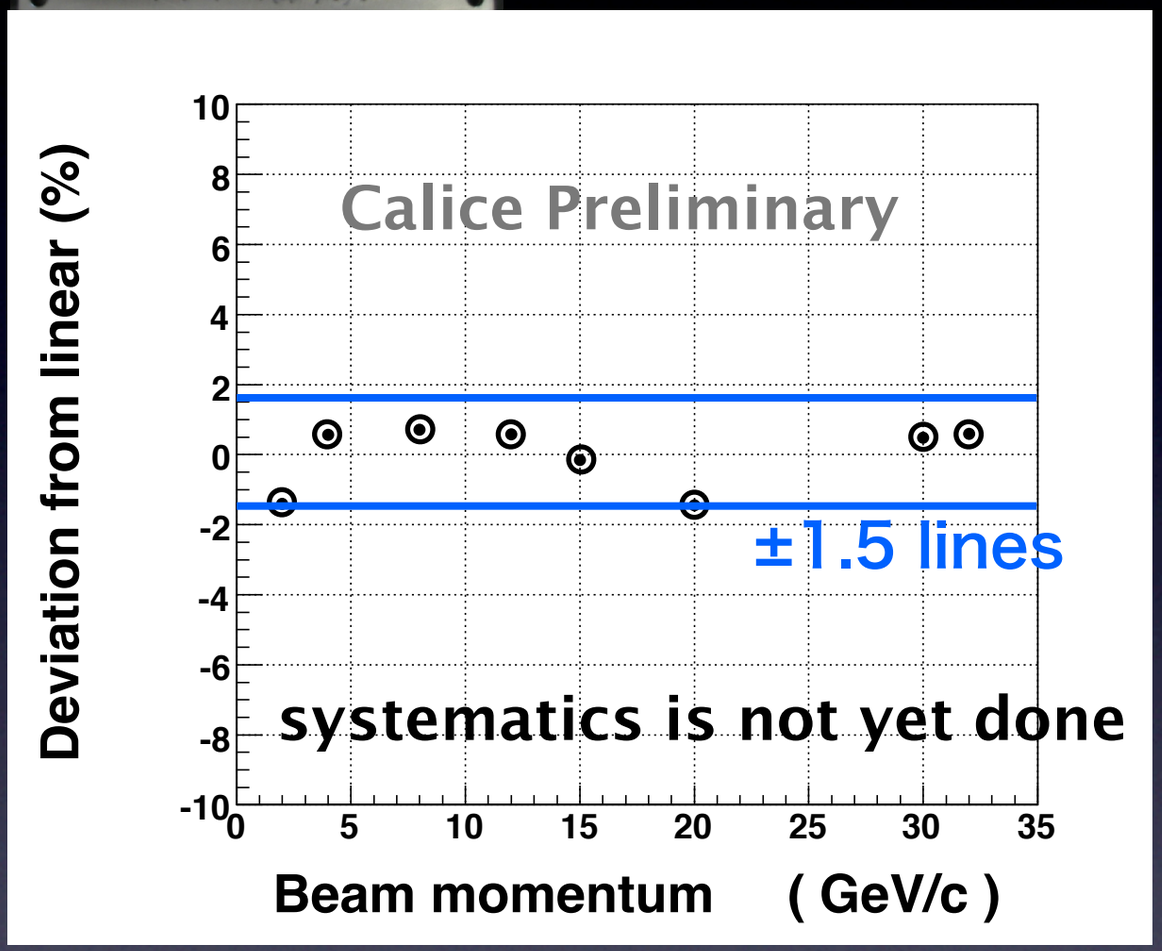
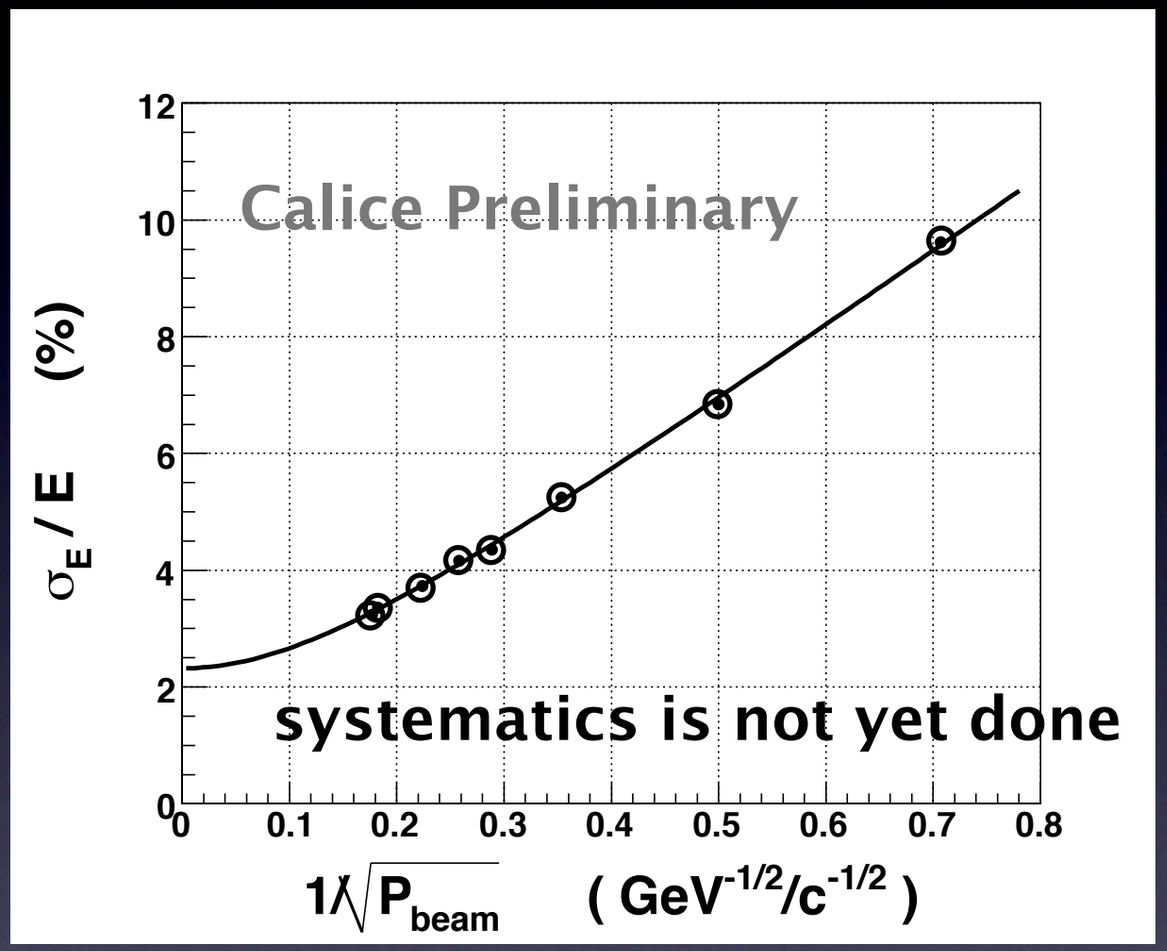
  $\delta_E = (13.16\pm0.05)\%/\sqrt{E} + (2.32\pm0.02)\%$ ← intrinsic beam spread

good performance



Basic performance





- 2160 channel prototype (10 x 45 x 3 mm²) 2009 at FNAL,
- deviation from linear fit : < 1.5%,
- Energy resolution for electron (2-32 GeV) :
  $\delta_E = (13.16\pm0.05)\%/\sqrt{E} + (2.32\pm0.02)\%$ ← intrinsic beam spread

good basic performance