# Some progresses of SSA study

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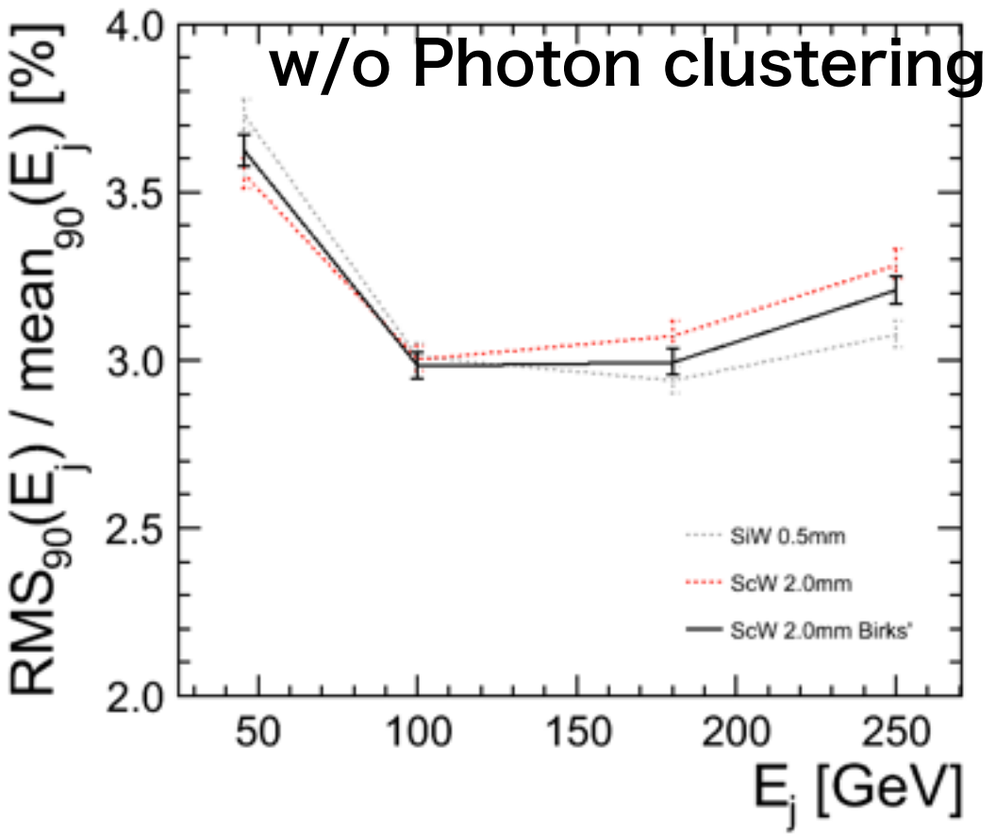
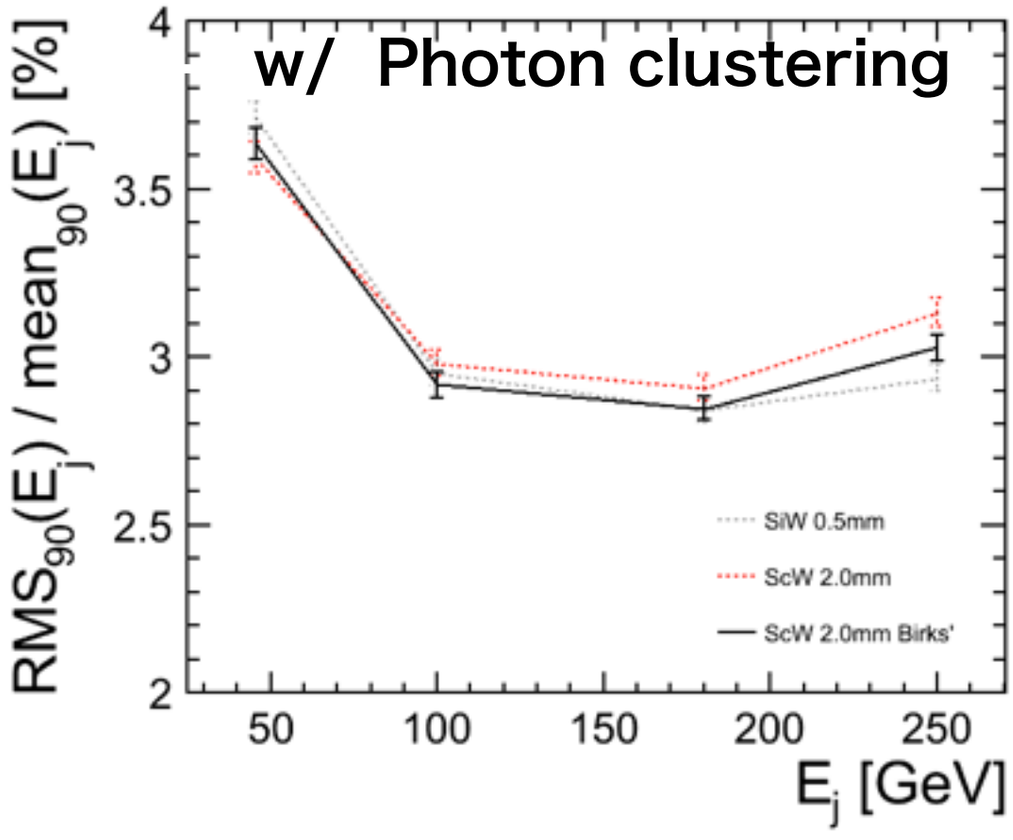
# Recent topics

John Marshall has optimized Sc-tile(5x5mm$^2$)-ECAL to make it have the comparable jet energy resolution with SiECAL.

His points:

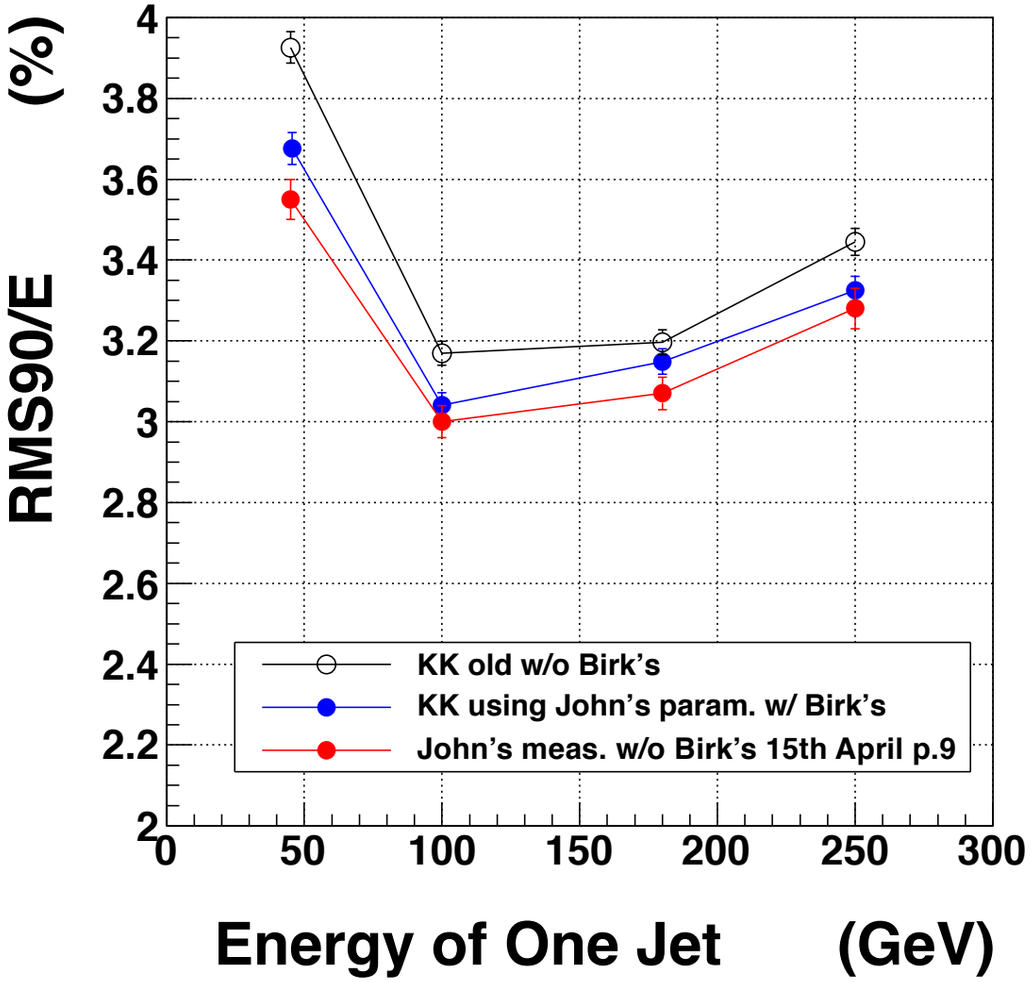
- EcalToHad factor (and CalbrECAL) should be tuned toward Jet energy resolution (after single particle tuning)
- Implement Birk's law (ilcsoft v01-16-02),SEcal05.cc,
- 20 ns timing window to reject late neutrons (v01-16-02)
- Initial photon clustering (req. training)



# uds jet energy: 5 x 5 x 2 mm³ Sc

## Resolution




Conditions

Marlin: ilcsoft v01-16-02

Mokka: ilcsoft v01-16-02 rev 441, SEcal05

CalibrEcal: tuned toward RMS90 mean of 10 GeV photons x 1.023

ECalScToHad: 1.378

ECalScToEM: 1.020

ECALTimeWindowMax: 20.0 ns

HCALTimeWindowMax:1000000 ns

- JER is improved than previous my result w/o Birk's law.
- Even with Birk's law, jet energy resolution by myself degrades than John's result w/o Birk's law

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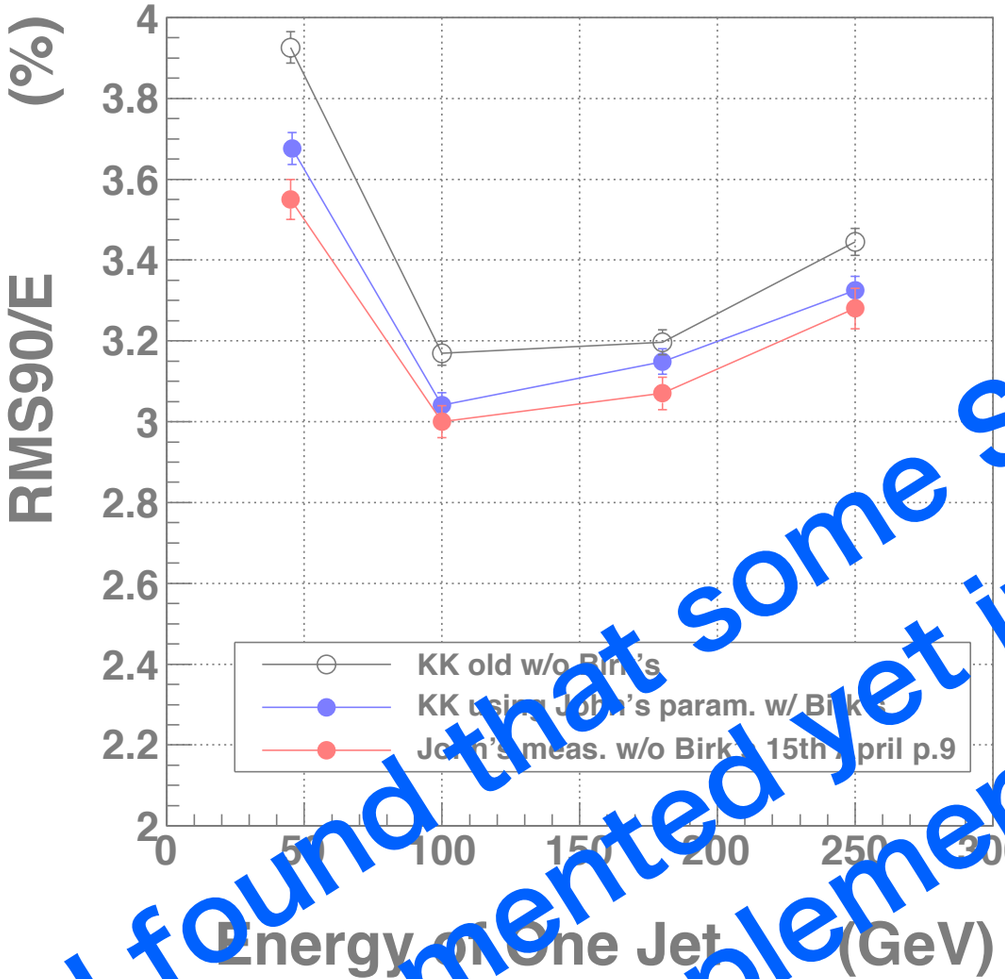


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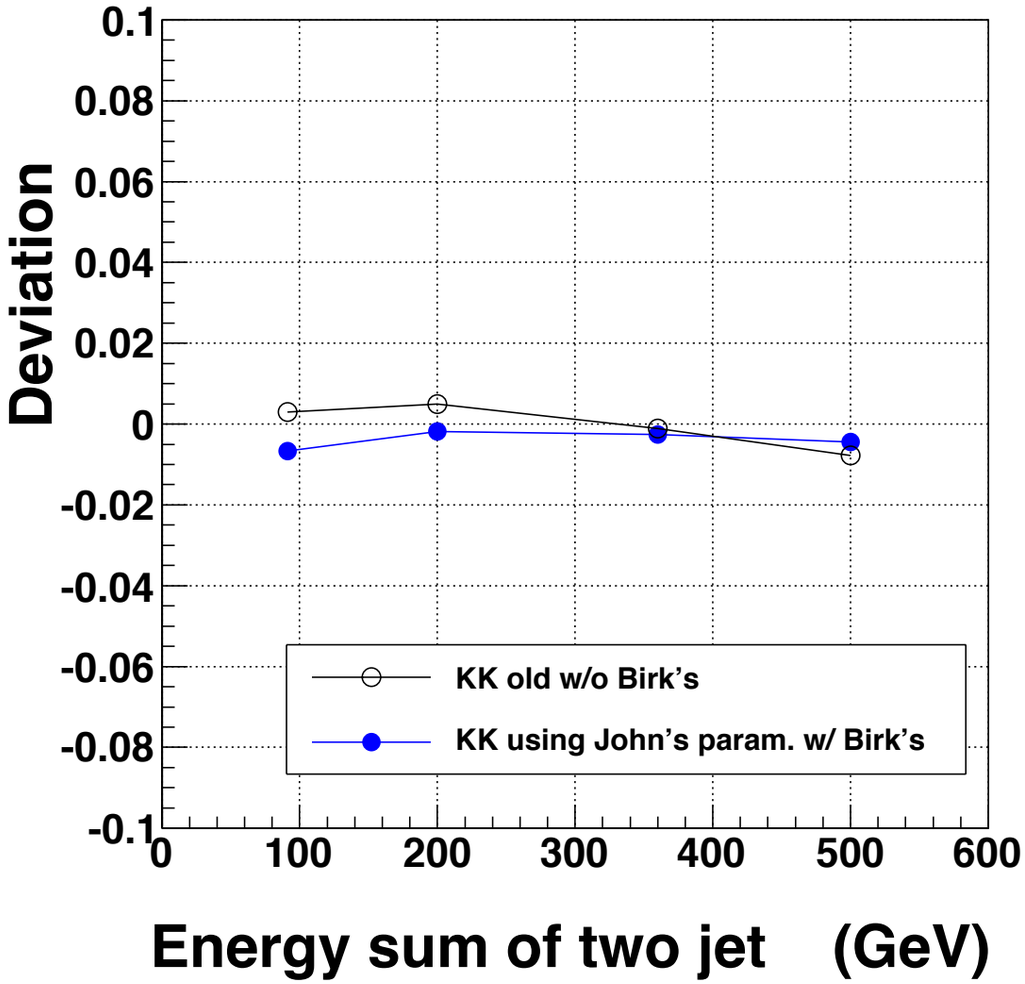
I found that some ScECAL issues were not implemented yet in v01-16-02 (maybe my misunderstanding) Now I implemented them and re-analyses are on going

- JER is improved than previous my result w/o Birk's law.
- Even with Birk's law, jet energy resolution by myself degrades than John's result w/o Birk's law

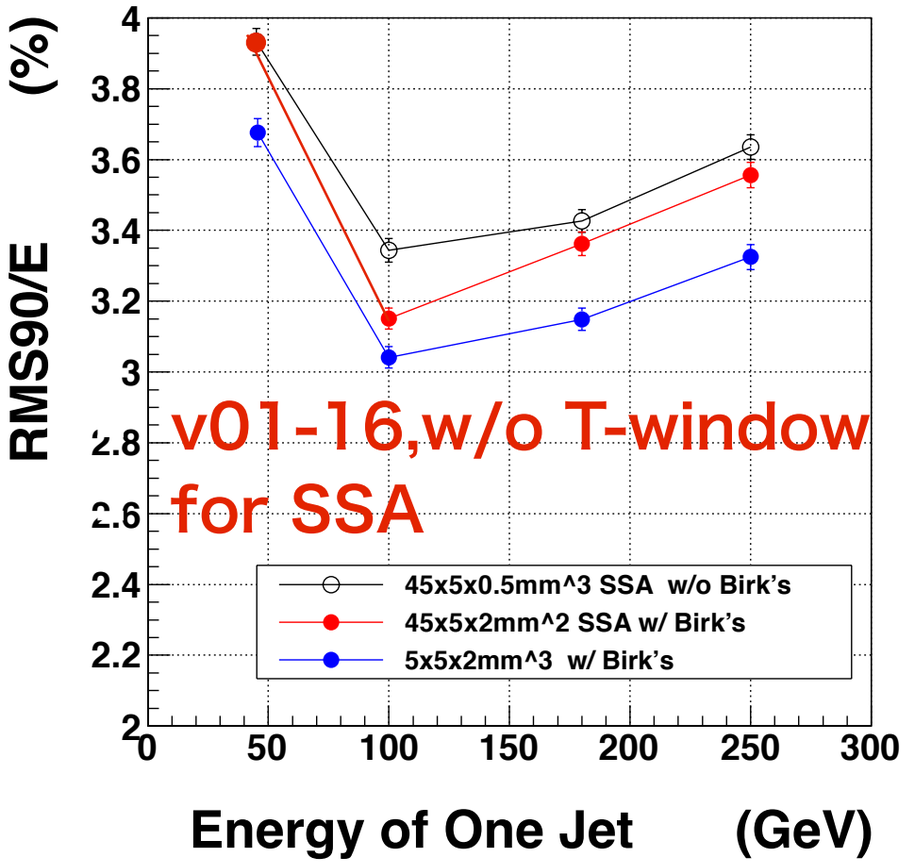
# uds jet energy: 5 x 5 x 2 mm³ Sc

## Linearity




- With Birk's law, linearity at high energy is improved.

# SSA with v01-16-02

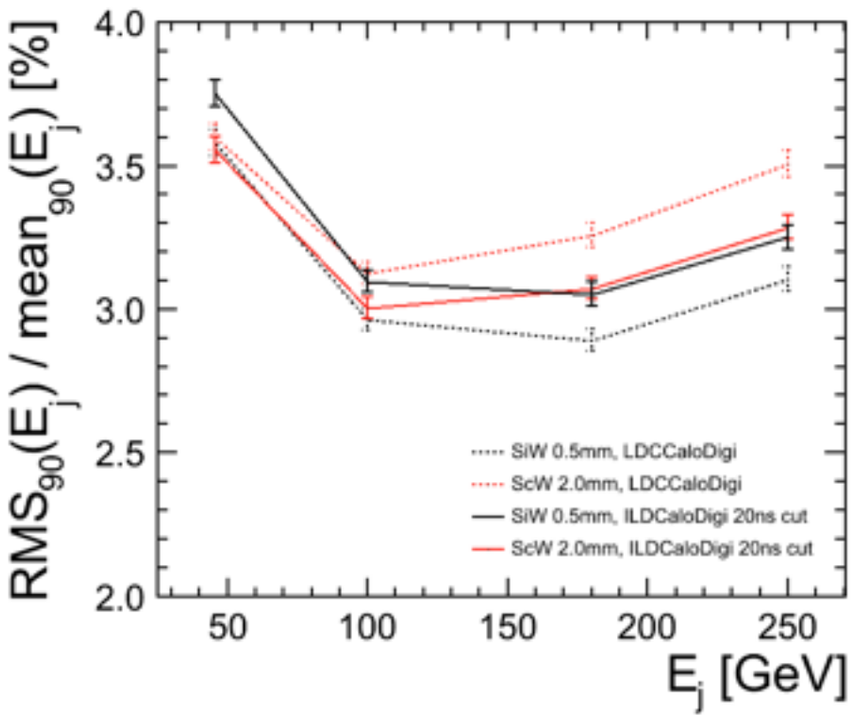



SSA does not work with MarlinPandora in ilcsoft v01-16-02.

I found the reason as mentioned in p.4

Before this, I tried analysis with v01-16 without T-window.

reanalysis with T-window in v01-16-02 is ongoing




time window significantly improve JER of ScECAL in John's case (5x5mm²)

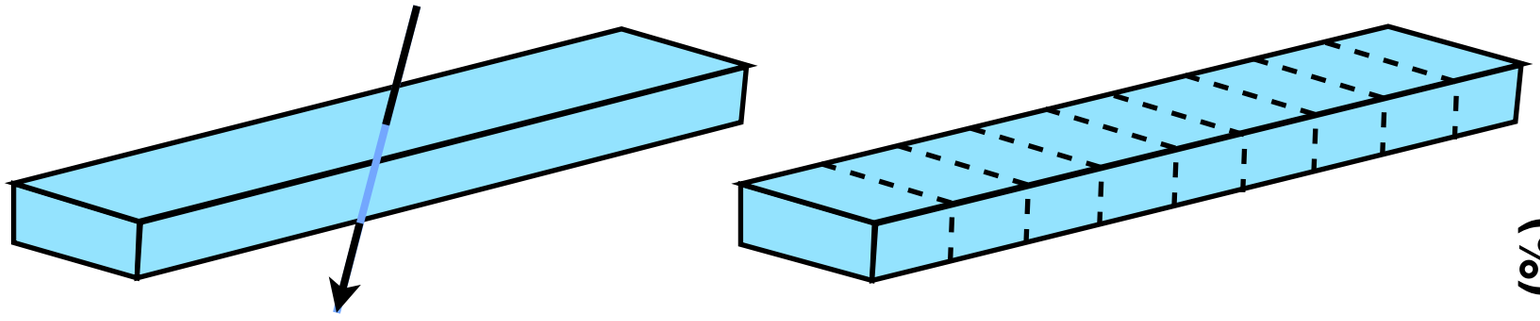
I will fix the problem of v01-16-02 MarlinPnadora for hybridSplitter.

# Threshold

Instead to tune threshold for scintillator output base, MIP threshold of virtual cells were optimized to let JER be better.

(Still without timing window for SSA)

Previously 0.0556 was used because:



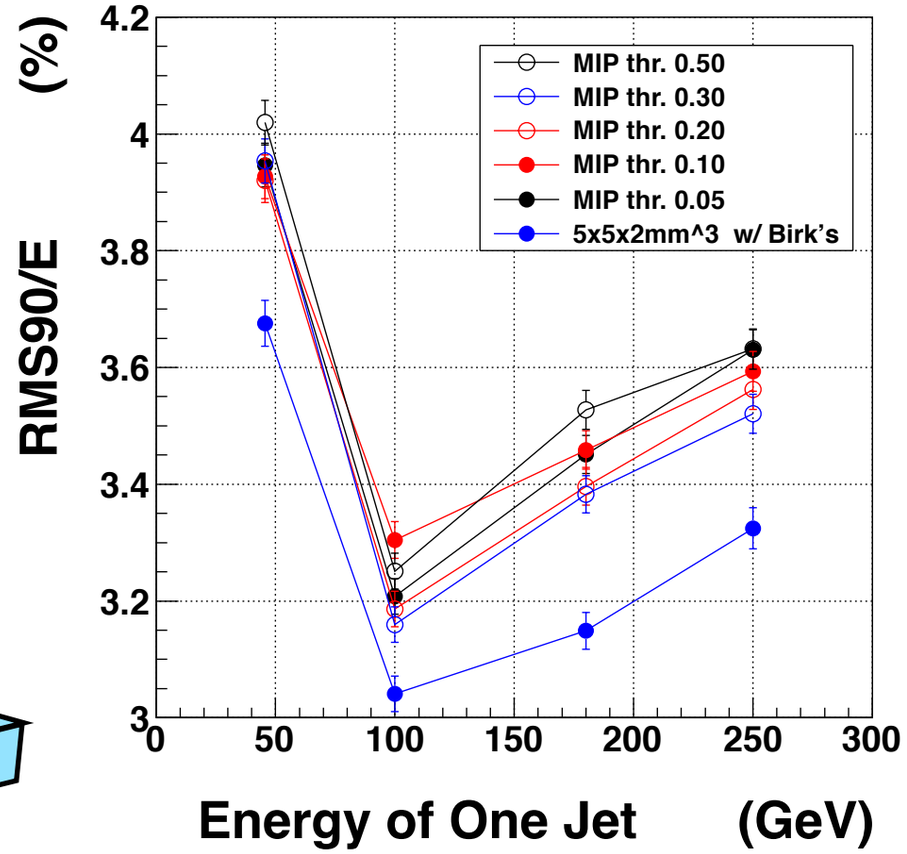
0.5 MIP threshold

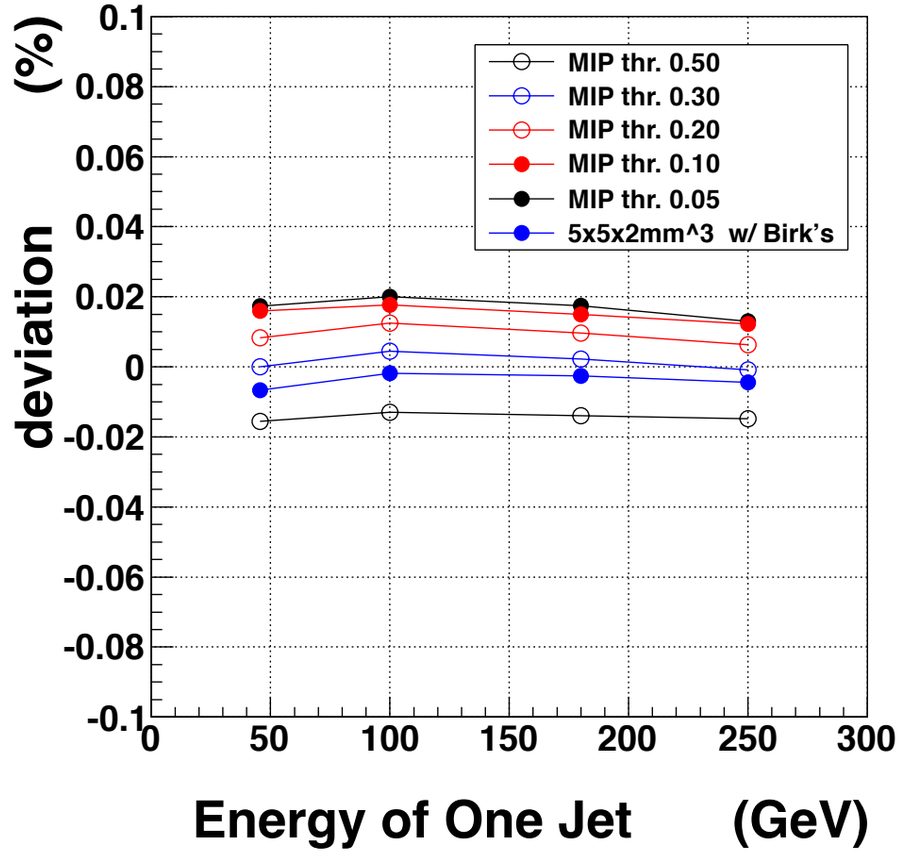
0.5/9 MIP threshold for each virtual cell?

But this maybe not true, because energy does not distributed in all virtual cells flatly...

So we need to optimize it.

Rather cause is that the best mean



# Summary on JER

- By following John Marshall, JER was significantly improved with implementation of the Birk's law, tuning "EcalToHCAL" toward having better JER, and 20 ns time window for ECAL

- 45x5 $mm^2$ ScECAL SSA has been also improved, but still there exists a room to improve by using 20 ns time window.

  ➡ next, fix the problem in v01-16-02.

- MIP threshold optimization gives impressive effect on the JER.

  ➡ We should set the threshold in the MarlinReco level and remove the threshold in PandoraPFA in near future.

# $\pi^0$ reconstruction ($\gamma$-$\gamma$ separation)

45 x 5 mm$^2$ x 1mm ScECAL is compared with 5 x 5 mm$^2$ x 1 mm ScECAL

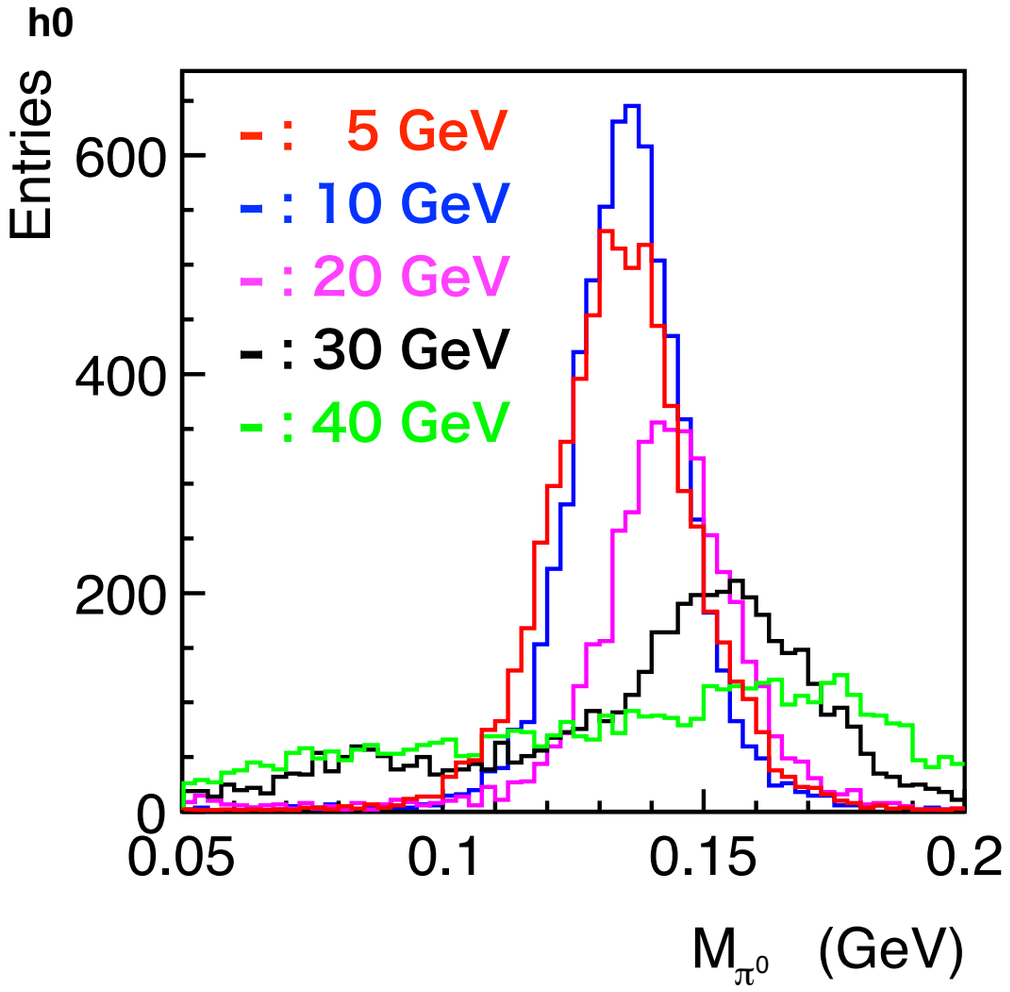
Only on Barrel near $\theta$ = 90°, but not exact the right angle to avoid TPC wall. $\phi$ = 0 - 360°,

$\pi$0 energies are 5, 10, 20, 30, 40 GeV

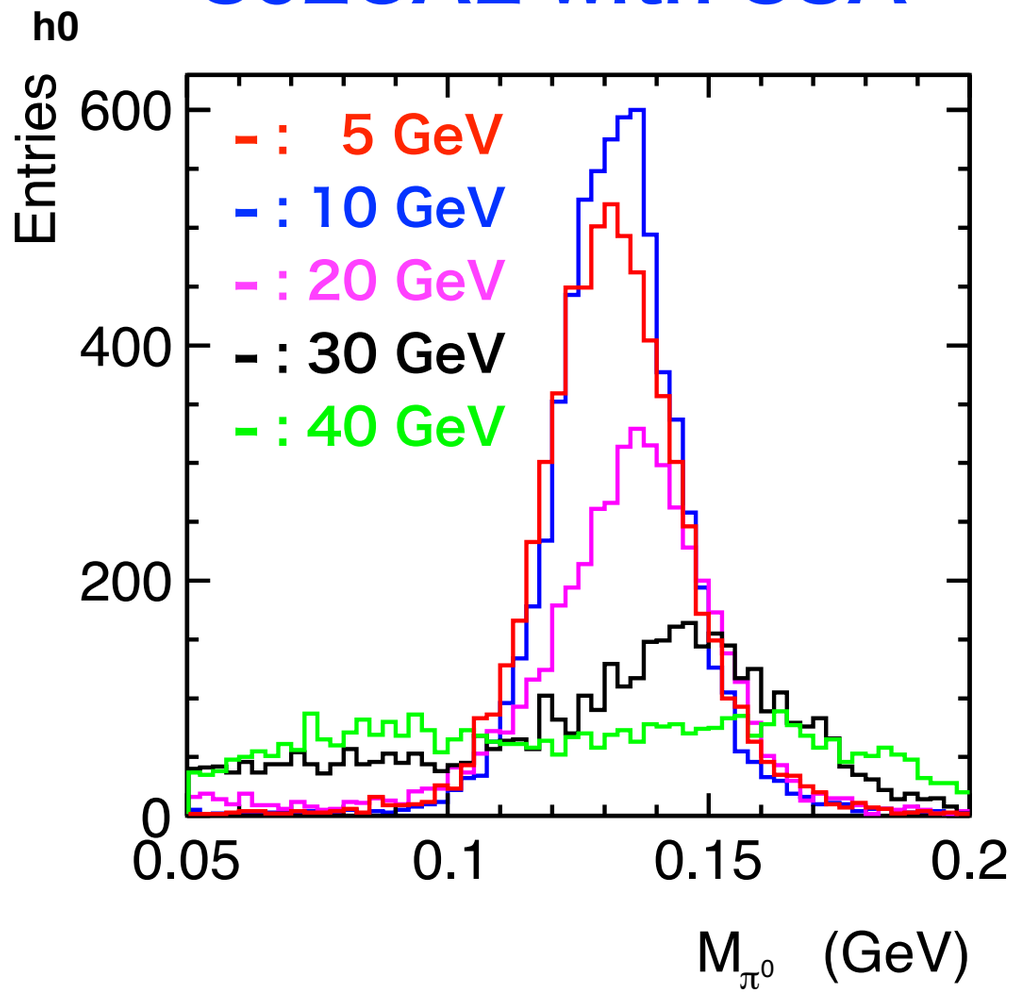
# $\pi^0$ mass

## $\pi^0$ energy: 5, 10, 20, 30, 40 GeV

### 5x5mm²x1mm ScECAL




### 45x5mm²x1mm ScECAL with SSA

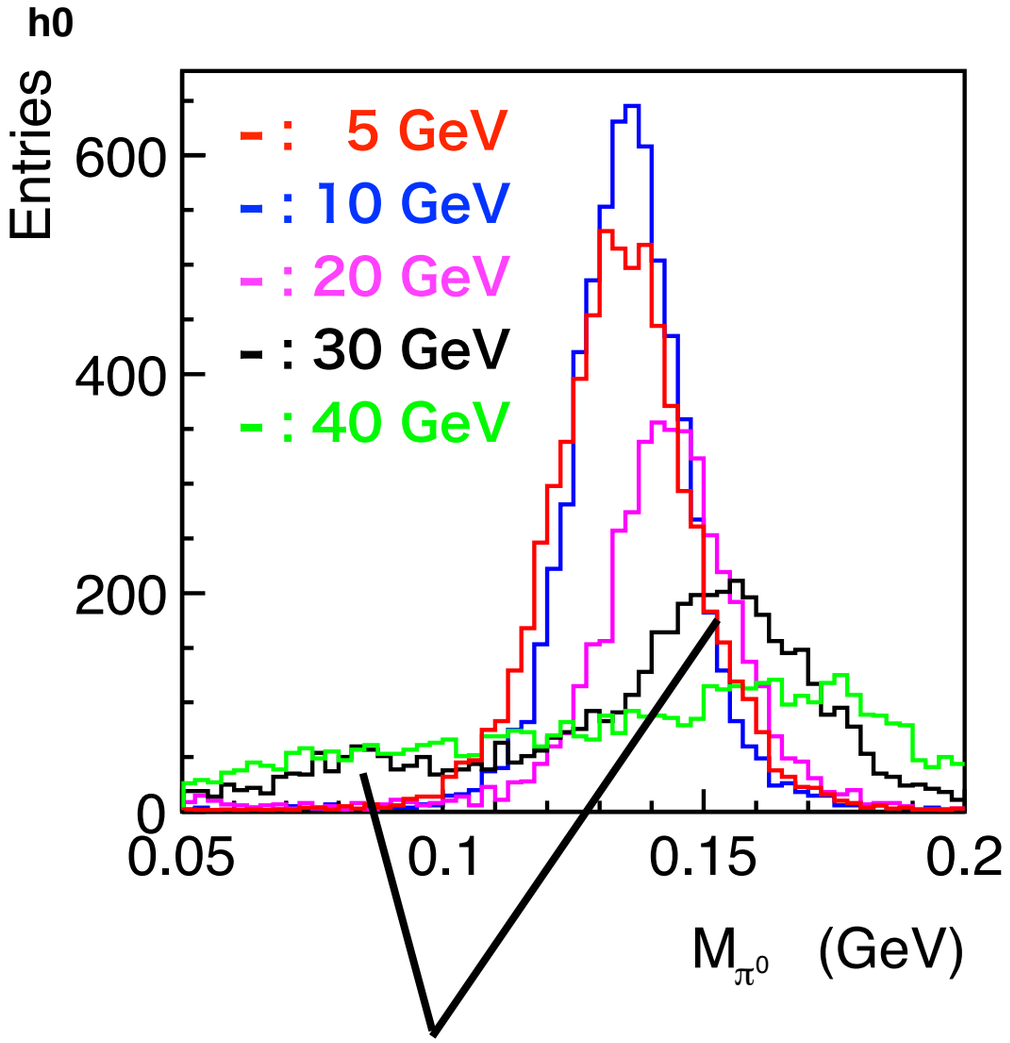



**There is not so large difference between 5x5mm² and 45x5mm² SSA.**

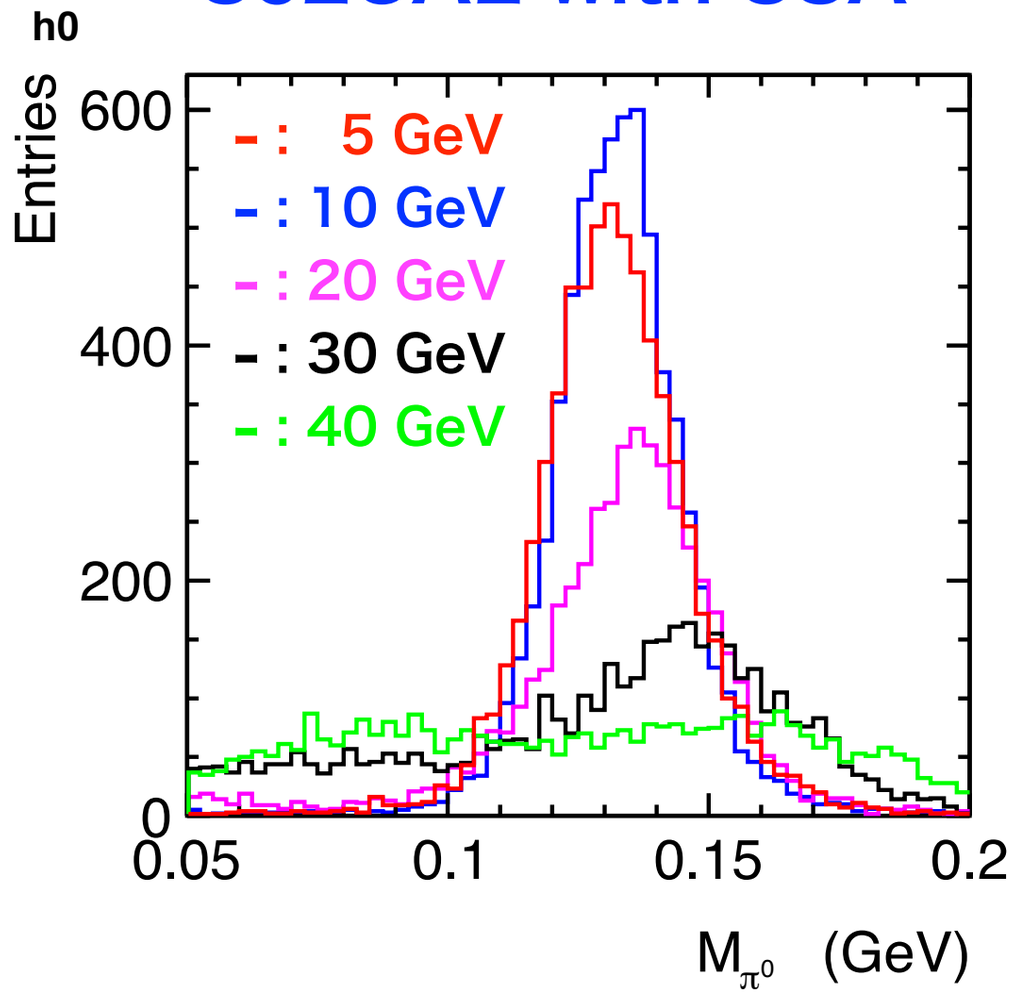
# $\pi^0$ mass

$\pi^0$ energy: 5, 10, 20, 30, 40 GeV

5x5mm²x1mm ScECAL




45x5mm²x1mm ScECAL with SSA




Energies of these peaks (30 GeV $\pi^0$) are similar to each others,.

The reconstructed mass depends on the opening angles.

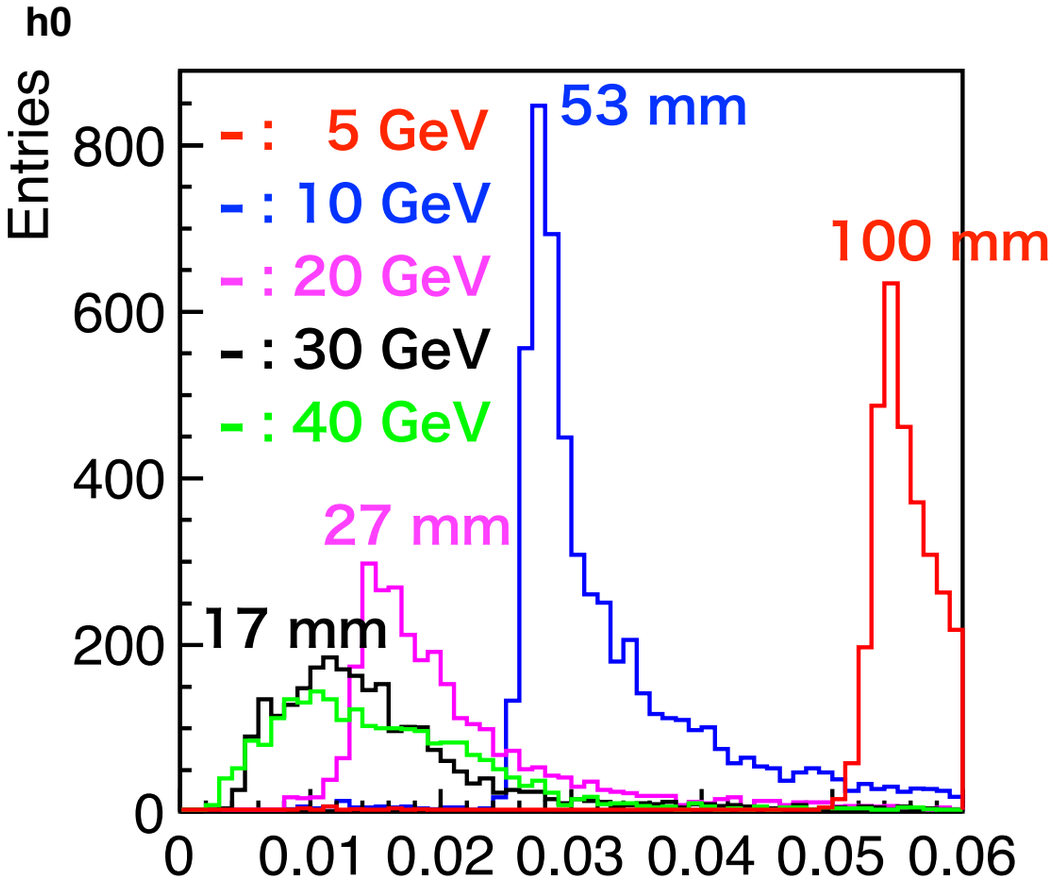
Corresponding Δopening angle of two gamma is ~5 mm on ECAL

# Opening angle of $\gamma$-$\gamma$

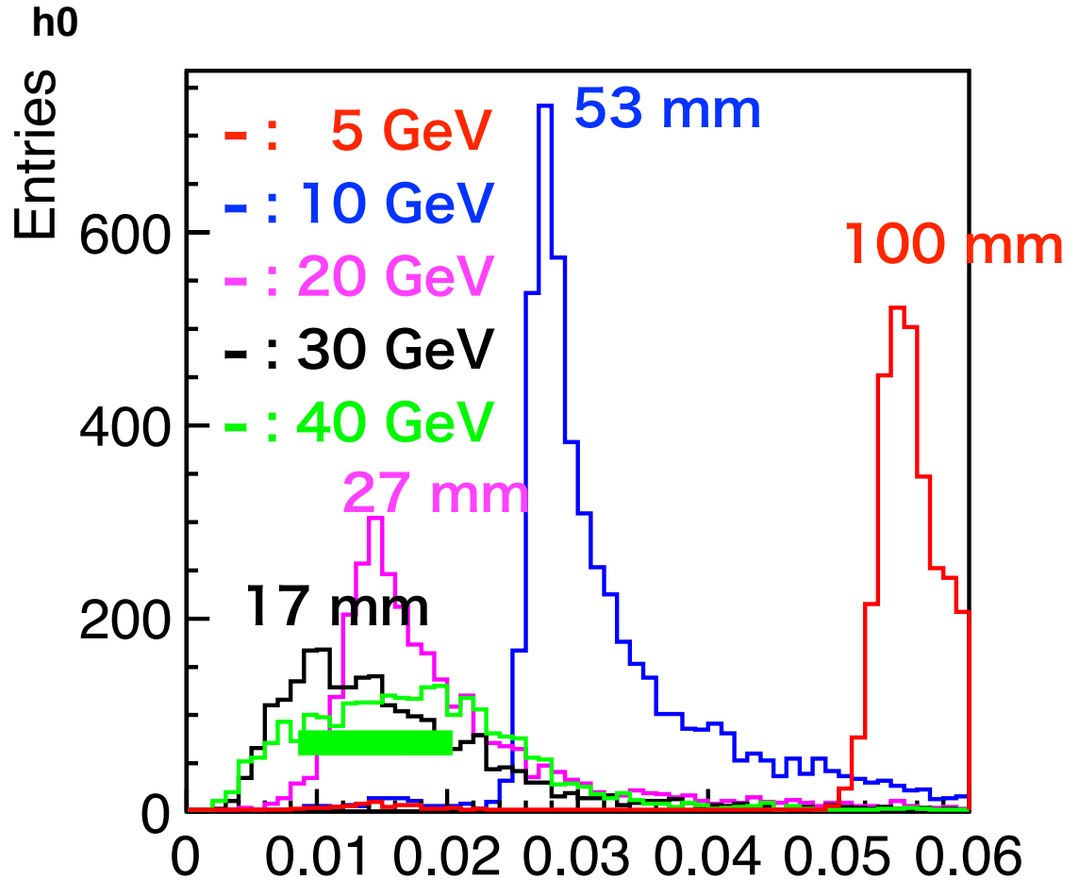
$\pi^0$ energy: 5, 10, 20, 30, 40 GeV

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

## 5x5mm²x1mm ScECAL



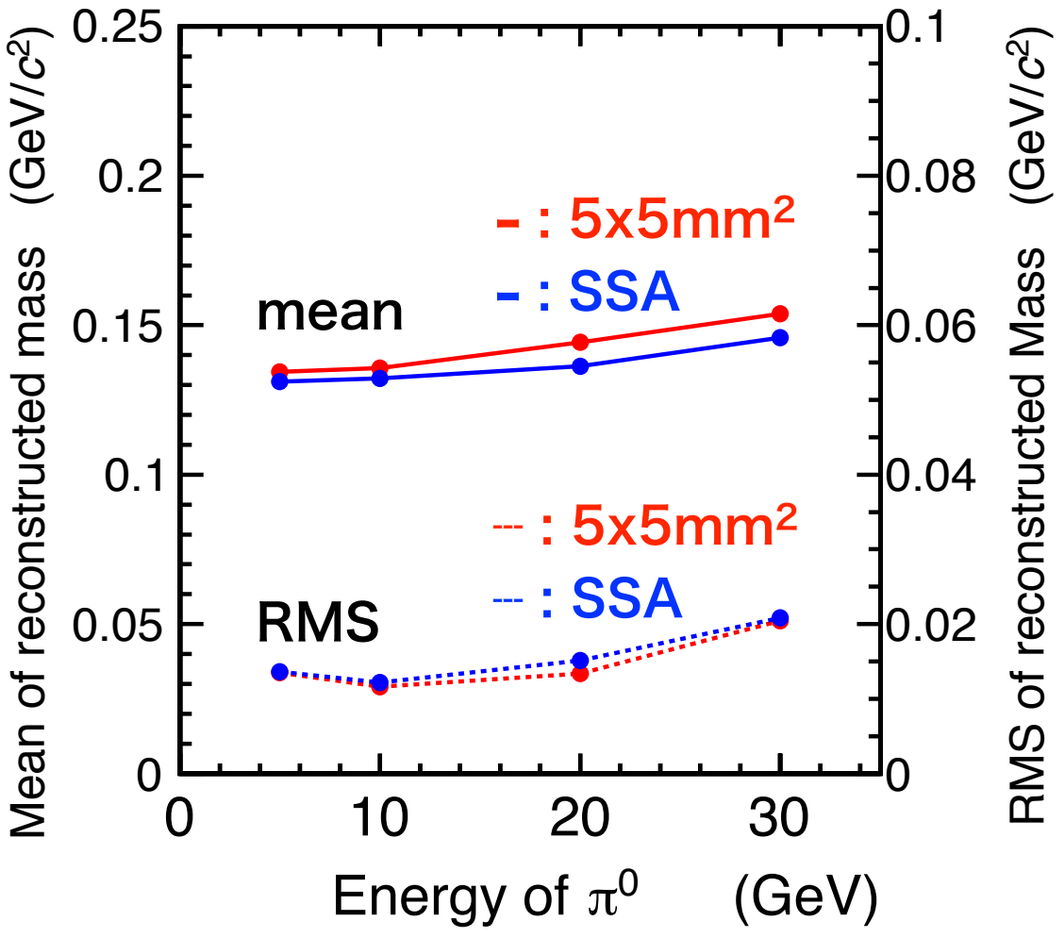

## 45x5mm²x1mm ScECAL with SSA



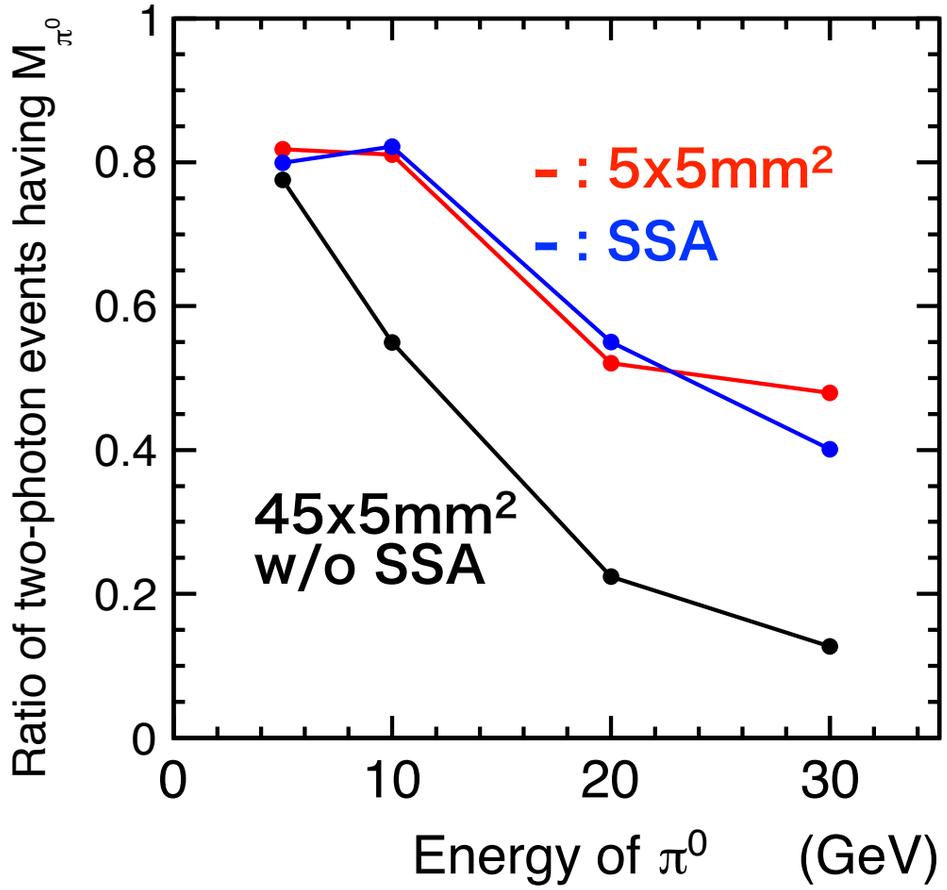

40 GeV $\pi^0$ by SSA is affected by ghost phenomenon?

# Numerical evaluations as a summary

## Mean and RMS



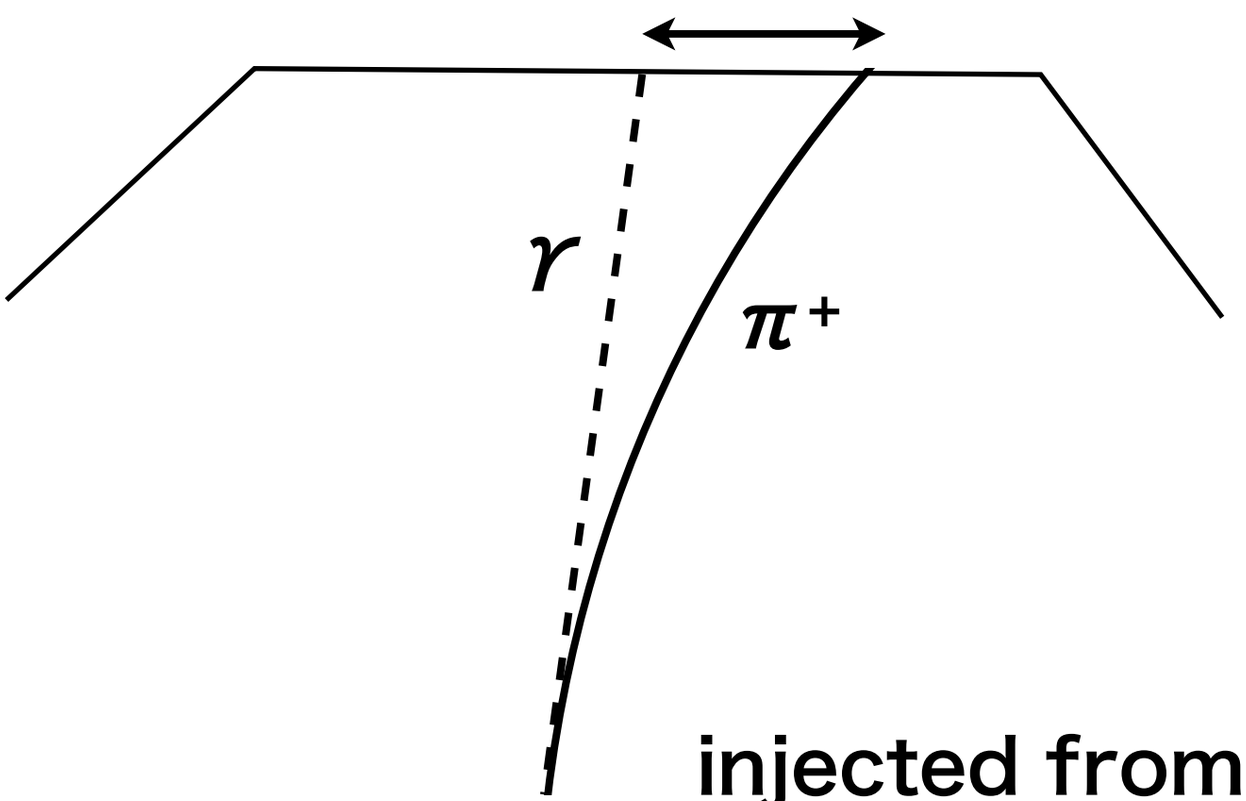

## Ratio two-photon events




- No significant difference between 5x5 mm² vs. 45x5mm²+SSA
- I will investigate distribution of $\pi^0$ in jets depending on $\pi^0$ energy ( if ~30 GeV is enough or not? ).

# $\pi^+$-$\gamma$ separation

distance at ECAL: 5,10,20,30,40 mm

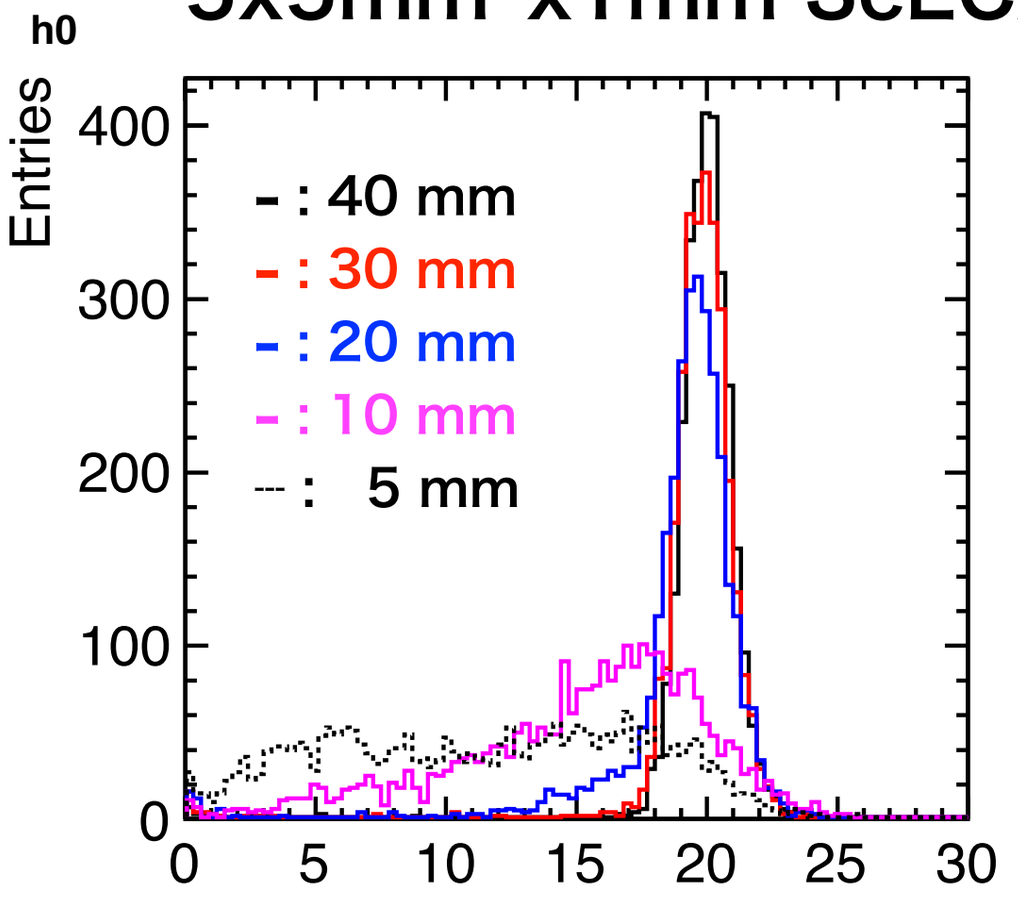



injected from IP,
Only on the barrel, $\theta$ ~ 90° , $\phi$ = 0.
10 GeV $\pi^+$ + 20 GeV photon → Today show
20 GeV $\pi^+$ + 20 GeV photon
30 GeV $\pi^+$ + 20 GeV photon

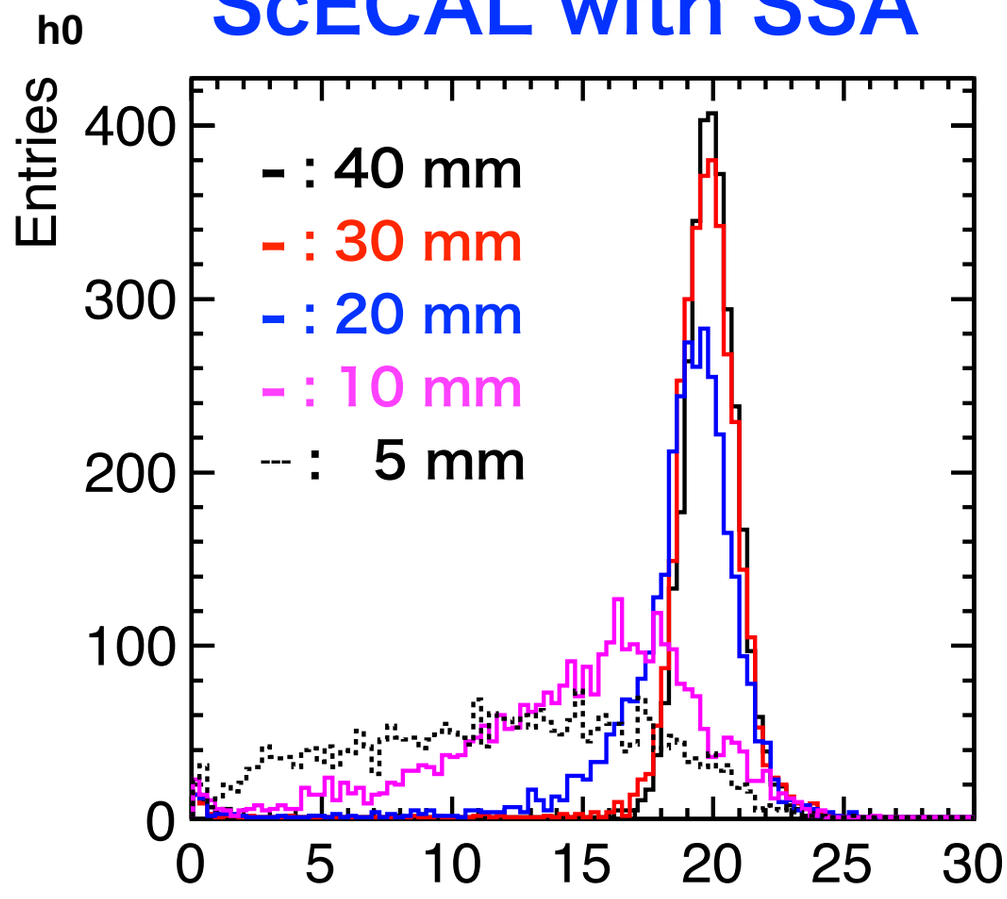
# $\pi^+$ 10GeV + photon 20 GeV

## photon energy of one-photon events

### 5x5mm²x1mm ScECAL




### 45x5mm²x1mm ScECAL with SSA

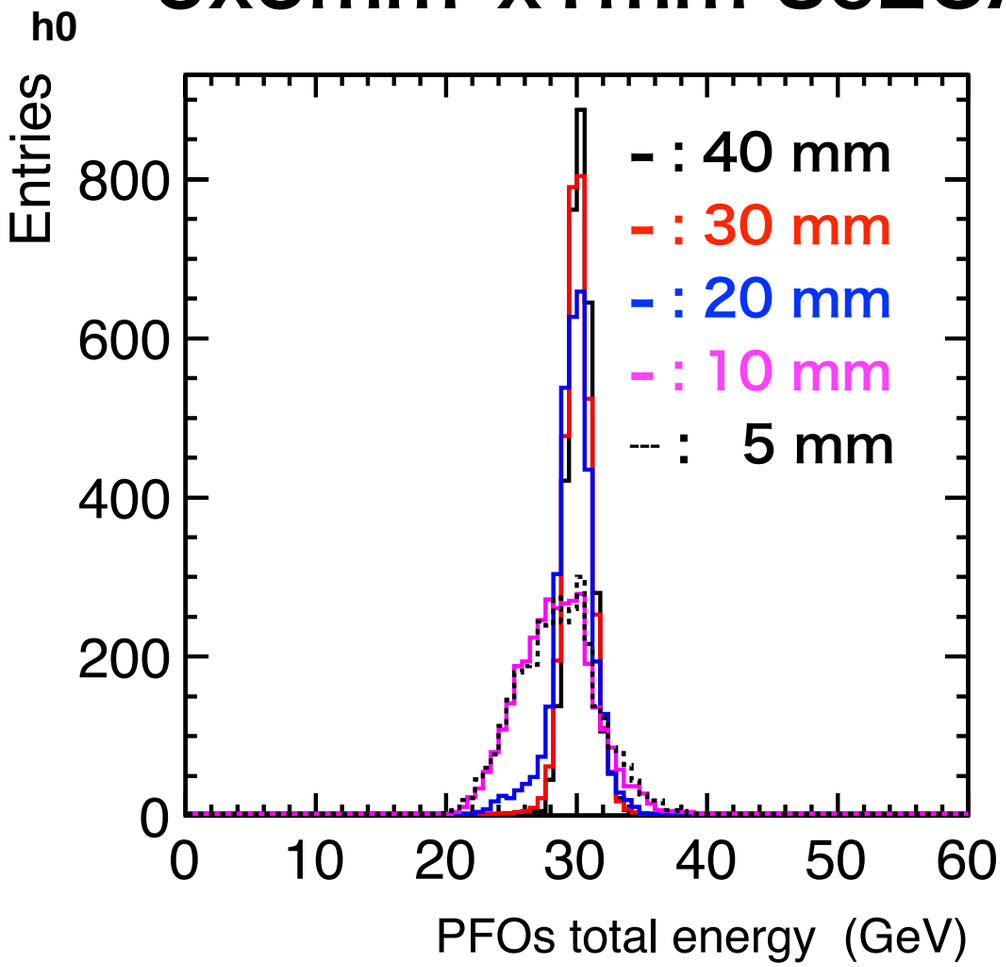



- at 20 mm distance, leading edge of strip SSA is larger than 5x5 mm²
- 10 mm, 5 mm, large degradation for both 5x5 mm² and strip+SSA.

# $\pi^+$ 10GeV + photon 20 GeV

## Total energy (all other particles than $\pi^+$ and photon)

### 5x5mm²x1mm ScECAL

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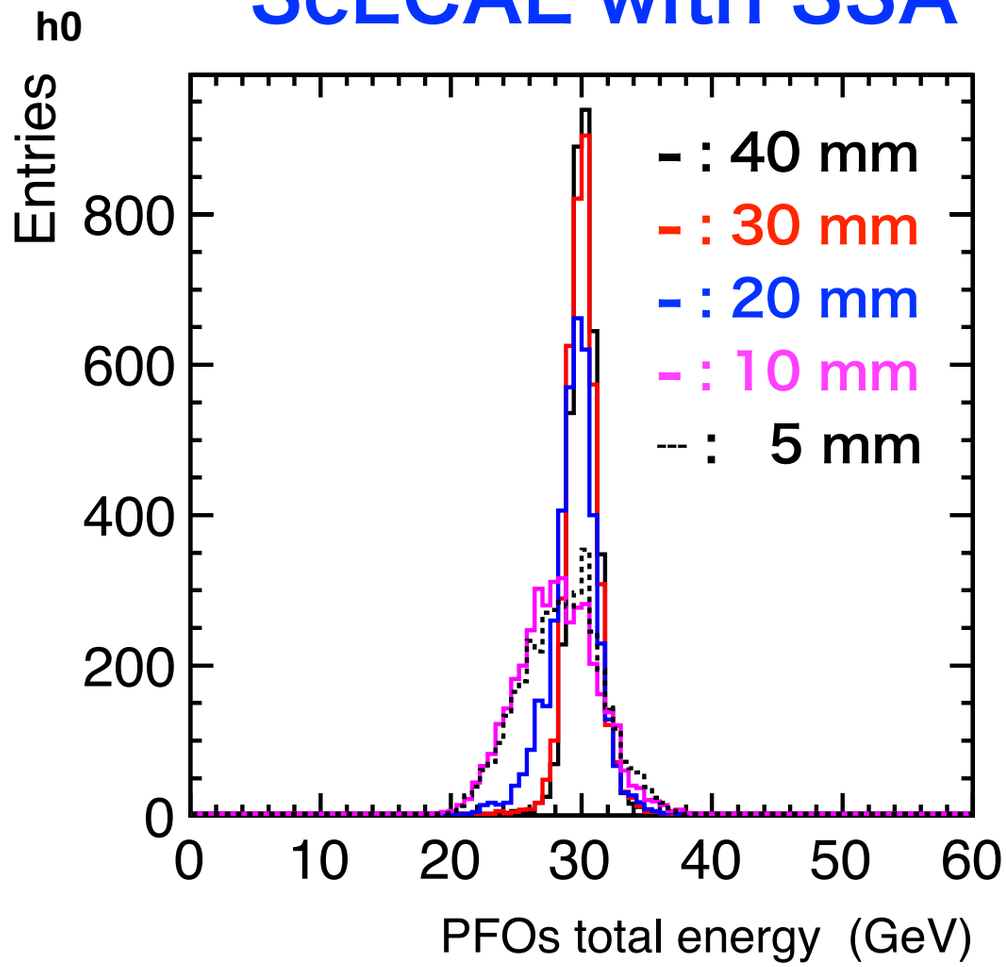
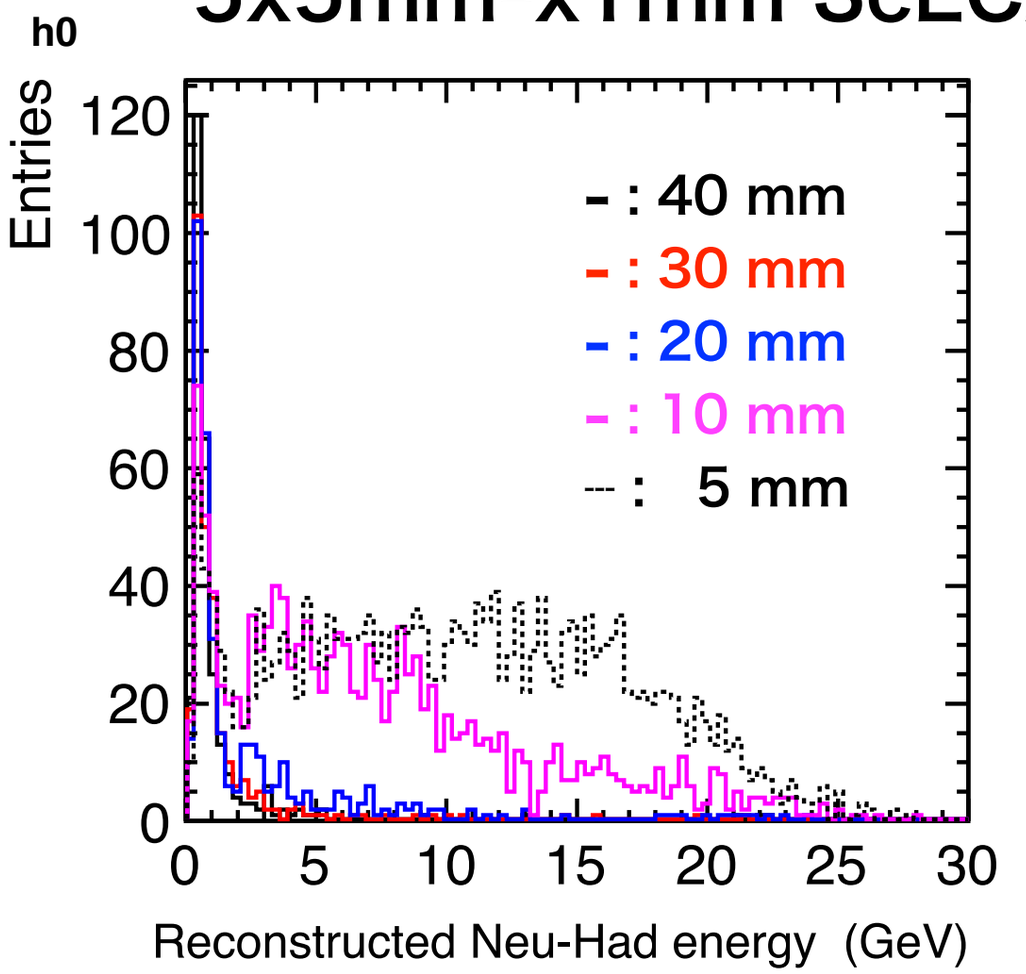
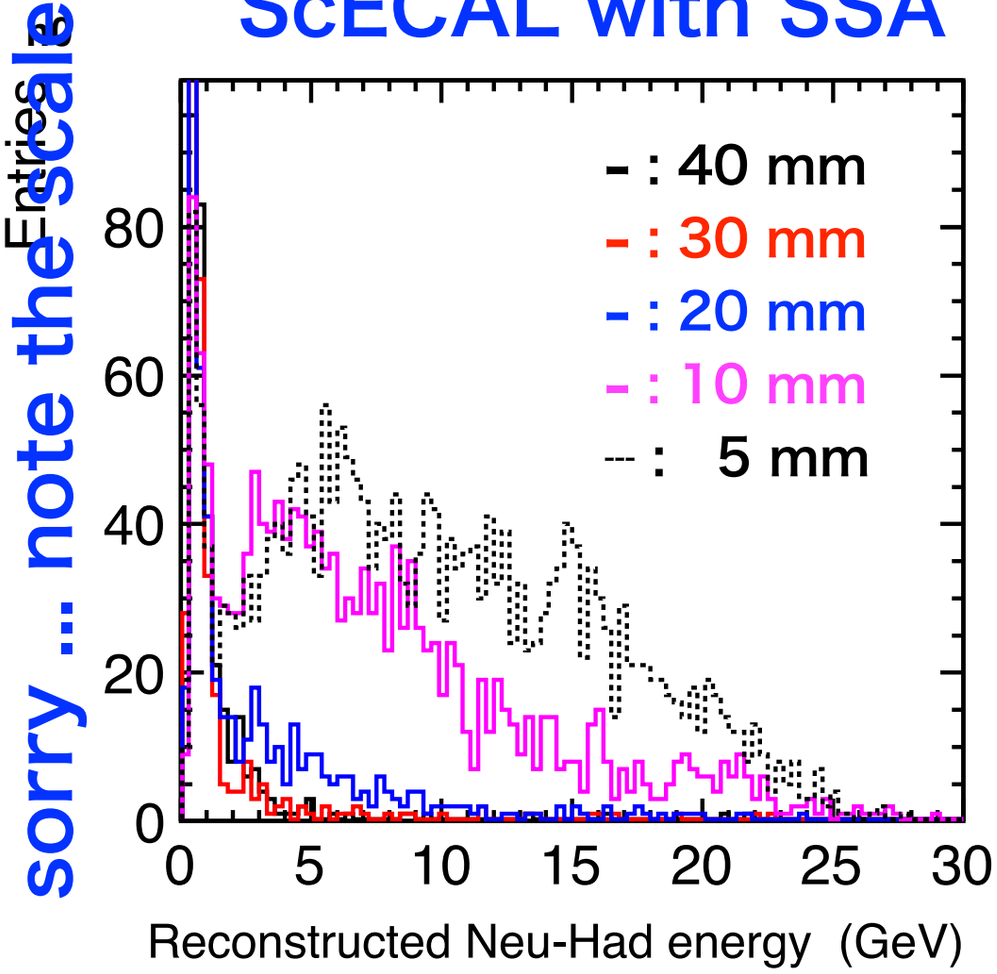



- Photon energy loss makes lower total energy.
- This phenomenon can degrade JER
- We need to investigate separation distance required from Physics.
- Where the energy has gone?

# $\pi^+$ 10GeV + photon 20 GeV

## neutral Hadron energy of one-photon events



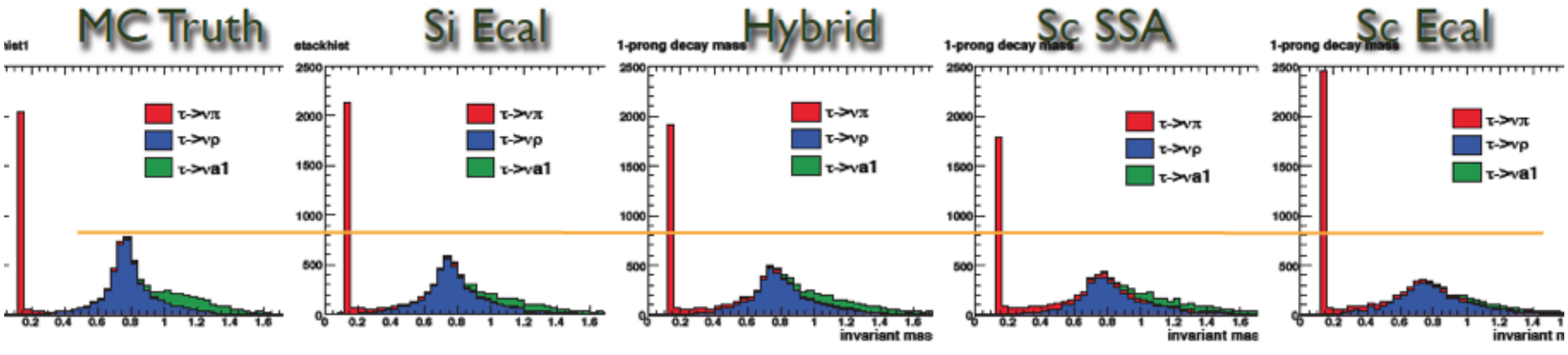

- Failed pattern recognition additionally makes neutral hadron to one photon and one $\pi^+$.

# Summary of $\pi^+$-$\gamma$ separation

- There is a bit difference between 5x5mm$^2$ tile ScECAL and 45x5mm$^2$ strip ScECAL with $\pi^+$-$\gamma$ distance 20 mm - 10 mm
- Investigate what happens between these distances.
- There is no difference of performance for the larger distance and smaller distance than 10 - 20 mm.
- Various cases of $\pi^+$ energy are the next.
- Quantitative evaluation is the next.

# Isolated $\pi^+$

Because Tomohisa has shown that photons in the $\tau$-$\pi^{\pm}$ decay can cause the degradation of reconstructed $\pi^{\pm}$ mass especially for the case of SSA




- Sc Ecal could not select a1.

  → γ separation is very bad.

- By strip splitting algorithm, γ separation performance of Sc ECal gets better, and also a1 mass is improved. π's peak reduced and π mass distribution spread out aside.

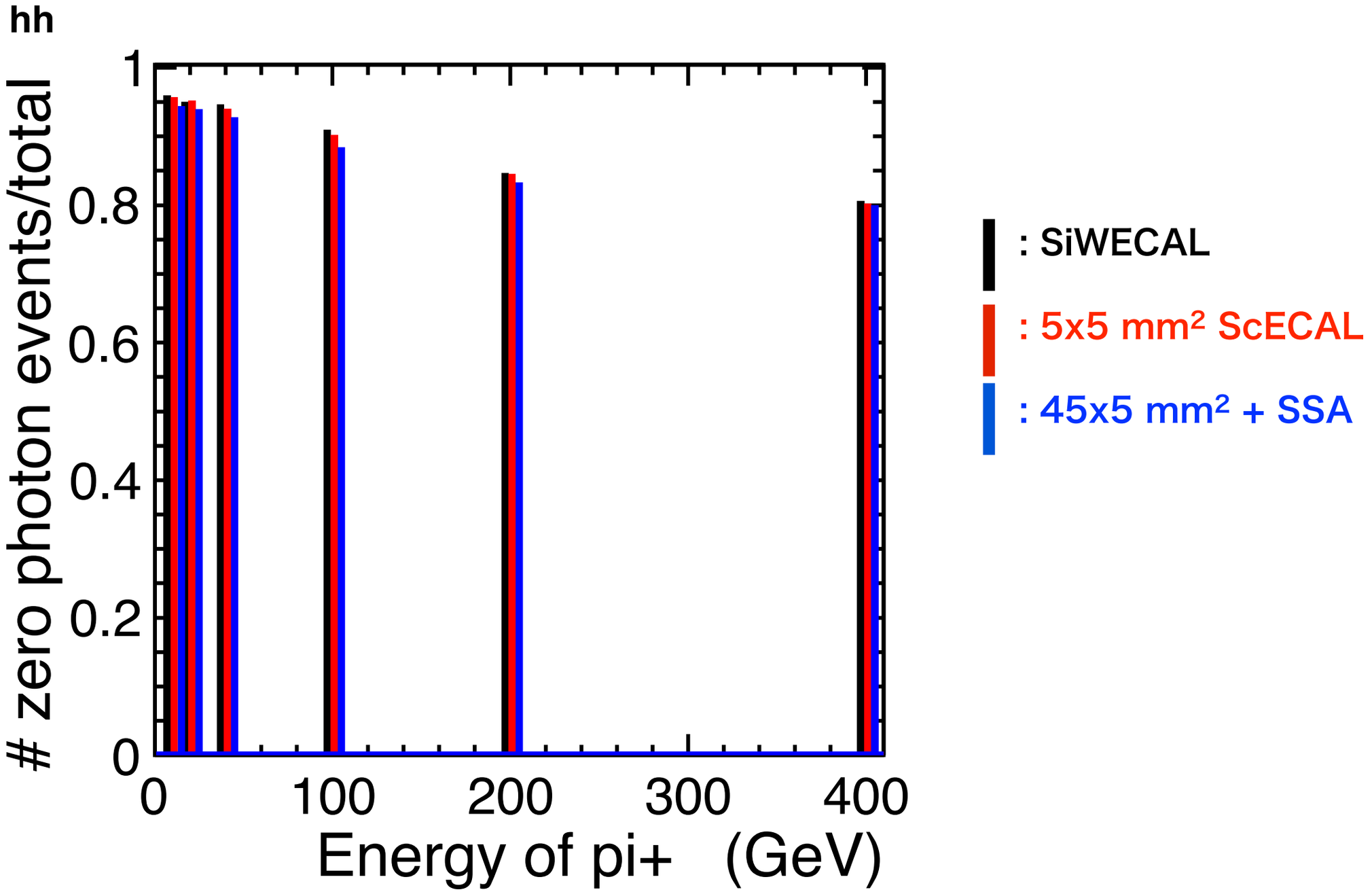
  → Probably, due to the τjet including many γ fragments generated by SSA ( mainly two hold ambiguity ).

  → By changing search angle(25degrees) more tight or improving PFA's cone-clustering, πmass with SSA is better or not.

- Even in case of alternative double layer Hybrid, two hold ambiguity occur probably.

  → alternative single layer Hybrid will have the same level of the performance as Si ECal have.

# Isolated $\pi^+$

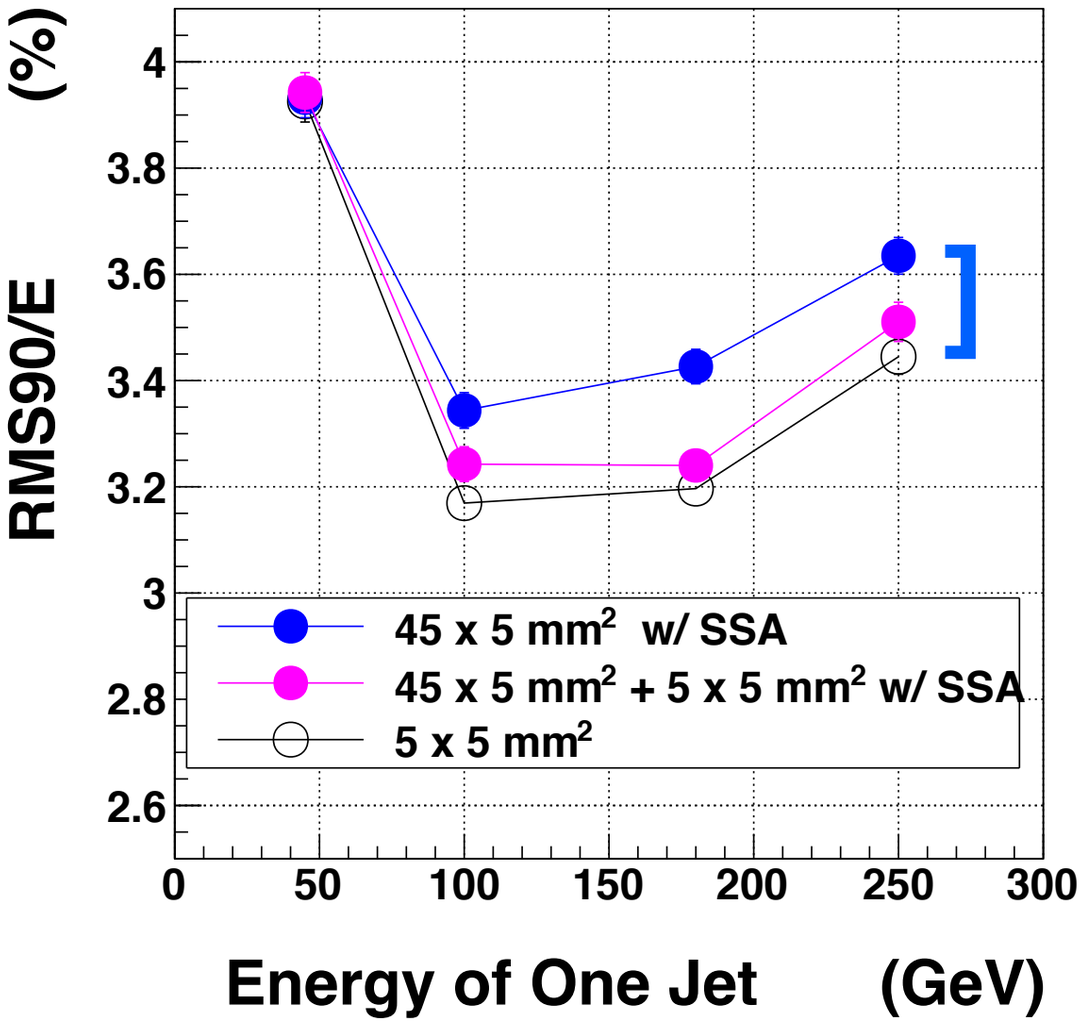



**There is no difference on the isolated $\pi$+ events among three types of ECAL.**

# Backup

# More improvement

## 45 x 5 mm² + 5 x 5 mm² alternate




Configuration of (45x5 + 5x5)mm²;
tile-stripX-tile-stripZ-...
all layers are scintillator sensors

- One of the reason of degrading JER with strip ECAL + SSA comes from the two fold ambiguity (ghost).
- Easiest way to avoid this phenomenon is to put 5 x 5 mm² segmentation layers in between strip layers.
- The 5 x 5 mm² layers between strip layers improve JER well.
- but 5 x 5 mm² is difficult:

➡ use Si-layers for 5 x 5 mm²

➡ use 10 x 10 or 15 x 15 mm² cells with a special algorithm.