# Simulation Study of the Hybrid ECAL for ILD

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On behalf of ILD ECAL Group

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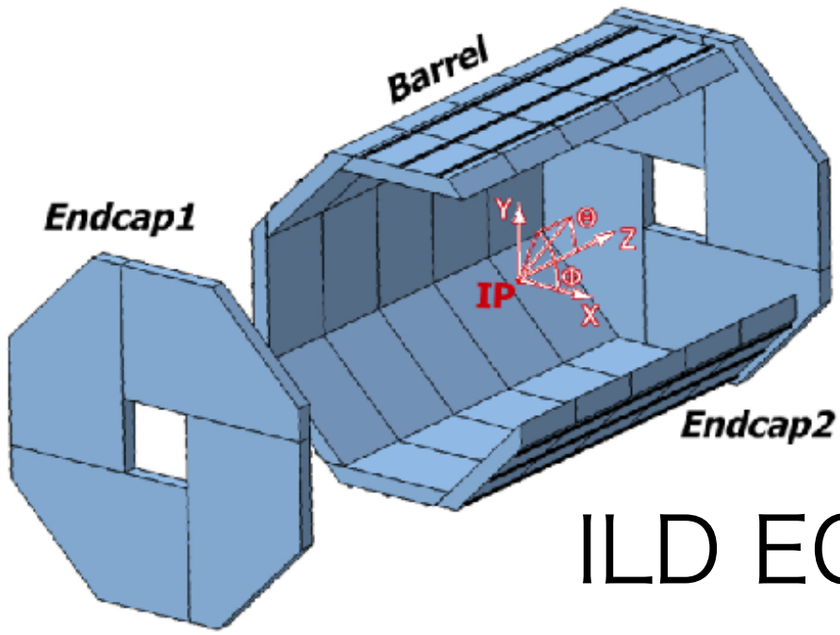
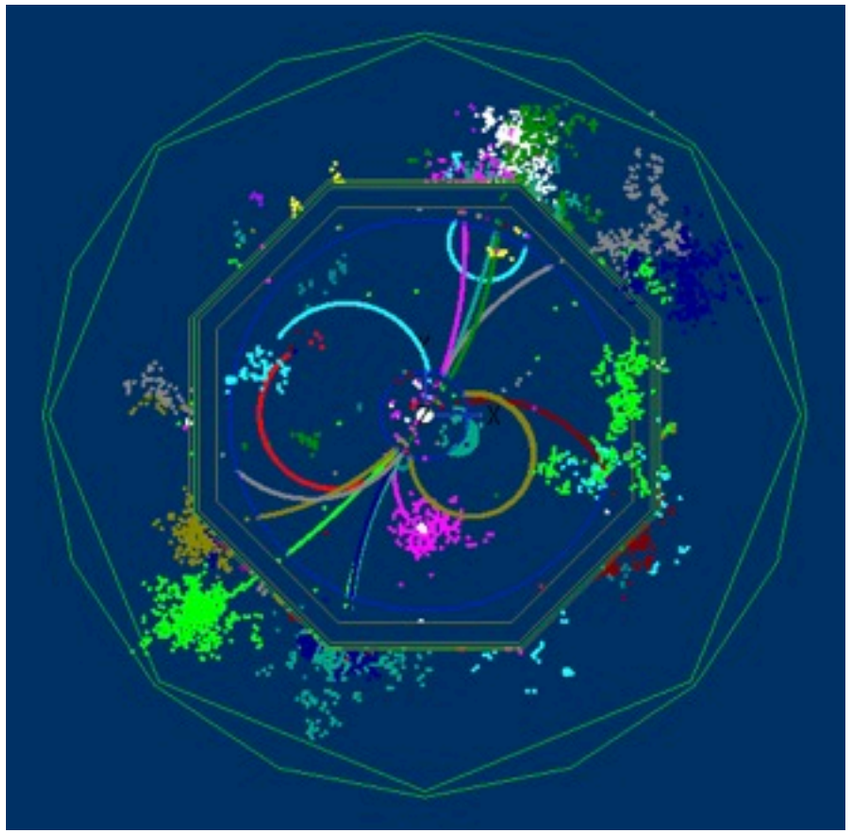
- Motivation for the Hybrid ECAL
- Calibration
- The Performances
  - same absorber thickness and number of layers
  - same module thickness
- Summary and Prospects

# ILD & PFA

- ILD has been developed as the detector optimizes for Particle Flow Algorithm (PFA).
- Fine granular calorimeter is required for good PFA performance.
- There’re two candidates for sensitive layers of ILD ECAL.

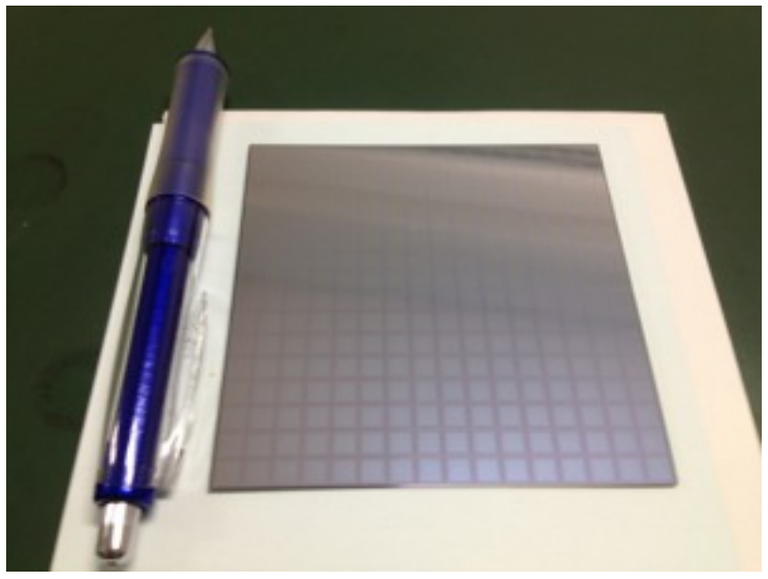



ILD ECAL



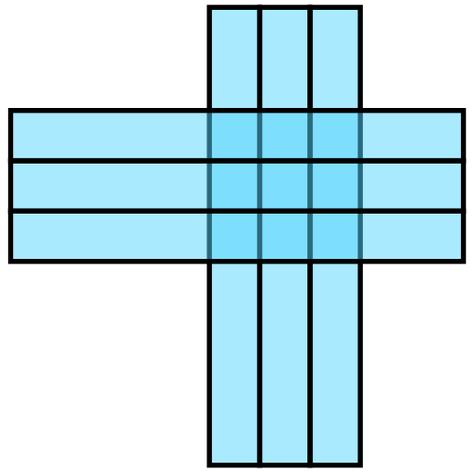
# ECAL Candidates

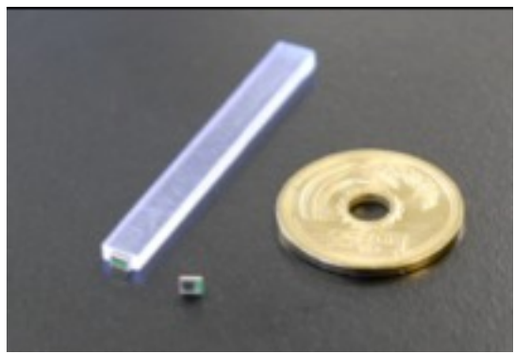
## Silicon （SiECAL）



- ❖ Si-pad : 5mm x 5mm cells
- ❖ Good performance for PFA
- ❖ Large fraction of detector cost

## Scintillator + MPPC （ScECAL）





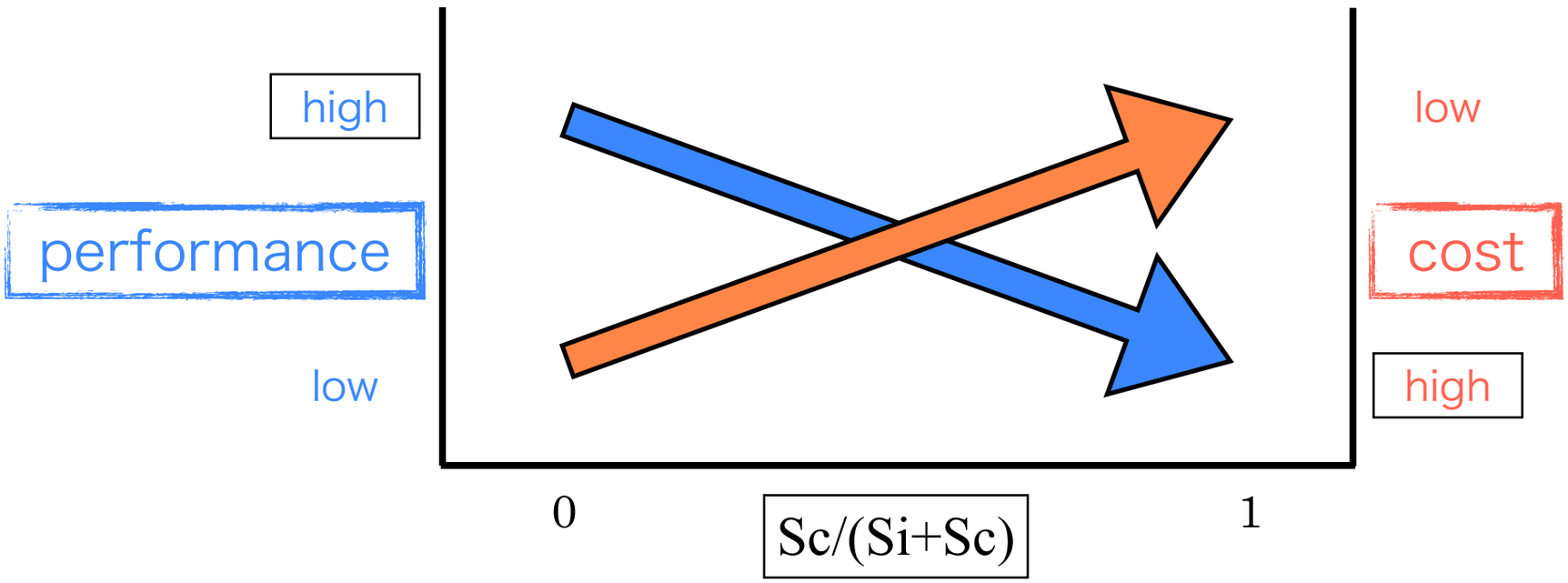
- ✻ 45mm x 5mm orthogonal
  → 5mm x 5mm spatial resolution
- ✻ Reasonable cost
- ✻ Possibility of ghost hits
- ✻ Need software
  (Strip Splitting Algorithm)

# Hybrid ECAL

- A solution to make the ECAL with a reasonable cost while keeping the performance as much as possible would be mixture of the Silicon layers and Scintillator-strip layers.

  → ***Hybrid ECAL***

- We're studying the performance of Hybrid ECAL.



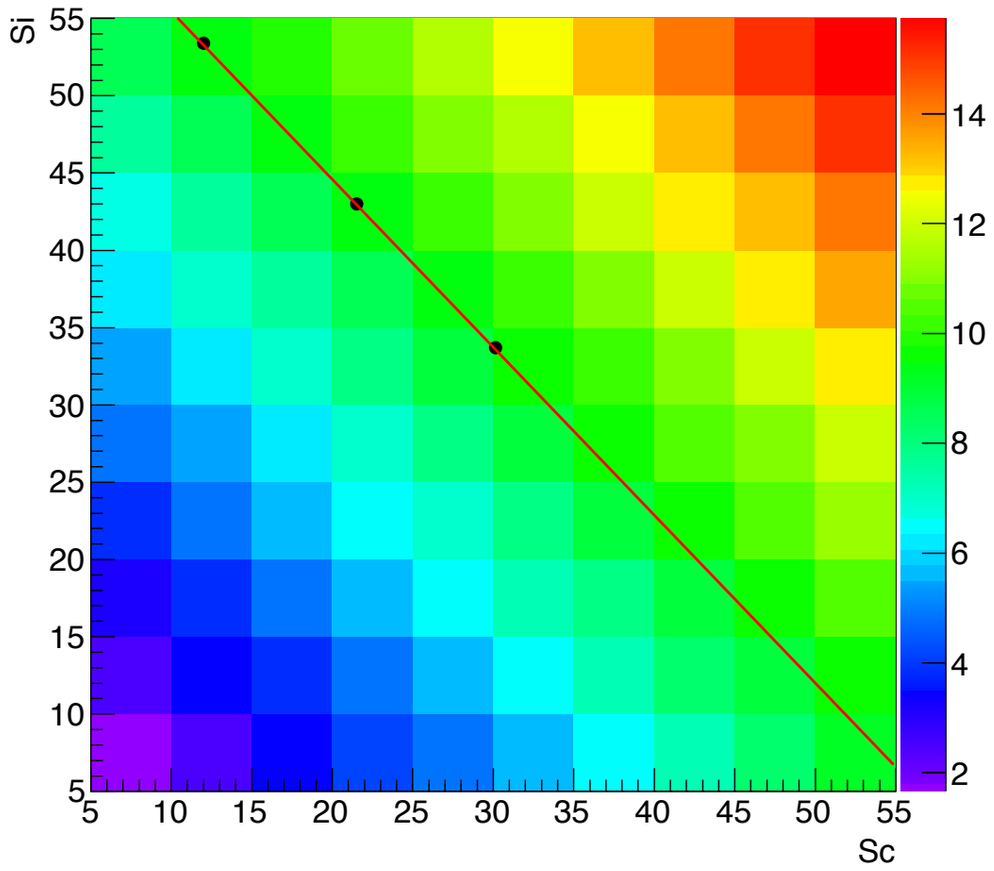
# Calibration

Calibration constants for Silicon layers and Scintillator layers should be determined separately.

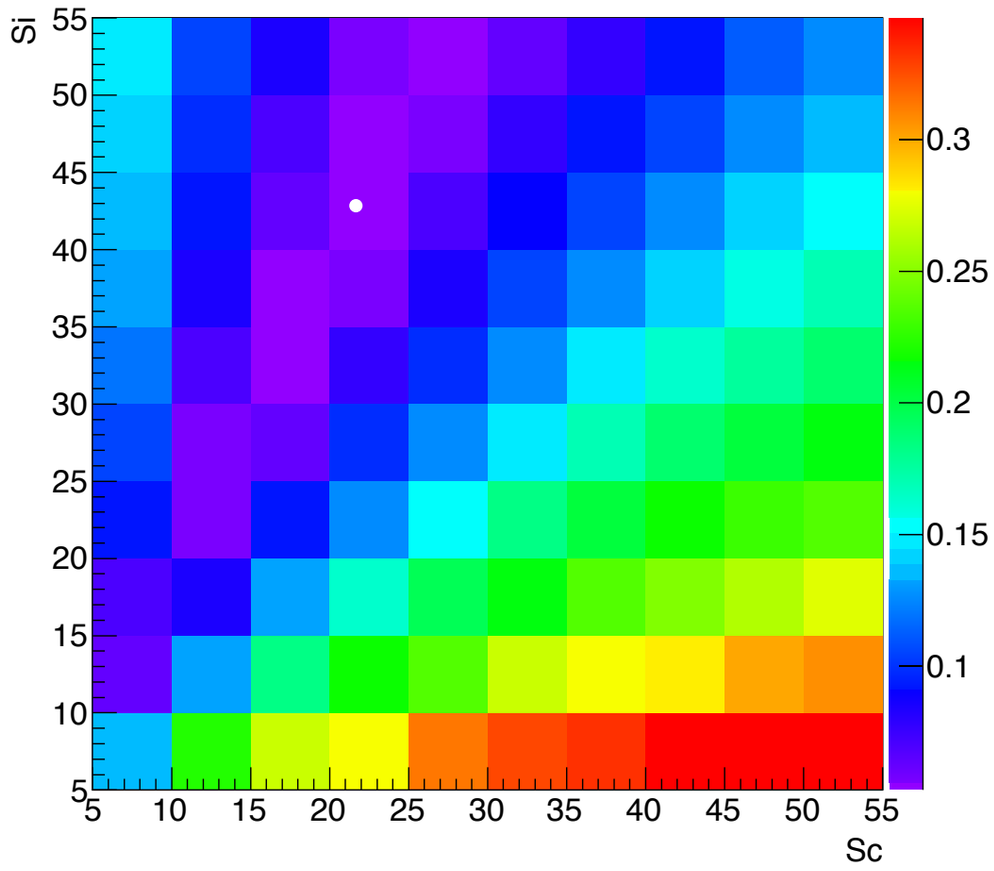
Calibration constants are determined by using 10GeV photon.

HybridECAL (Sc 2.0mm, Si 0.5mm)

mean




sigma/mean

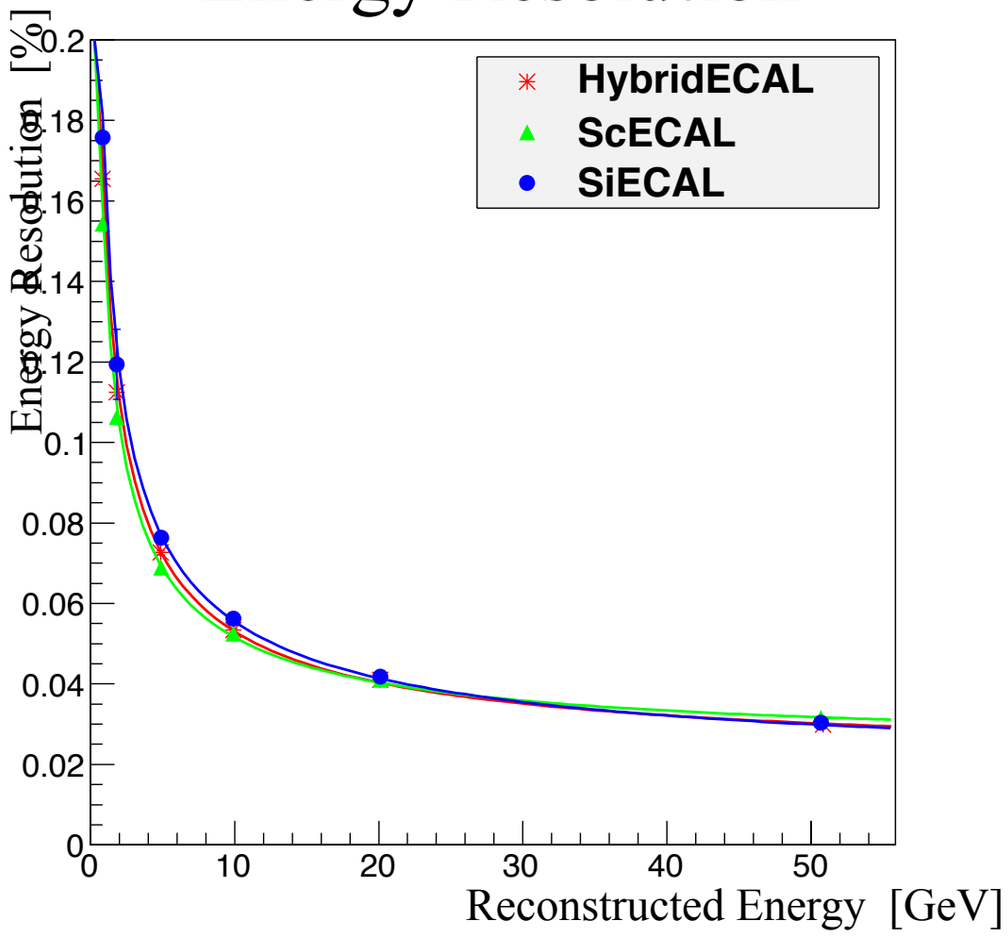


# ECAL Performance

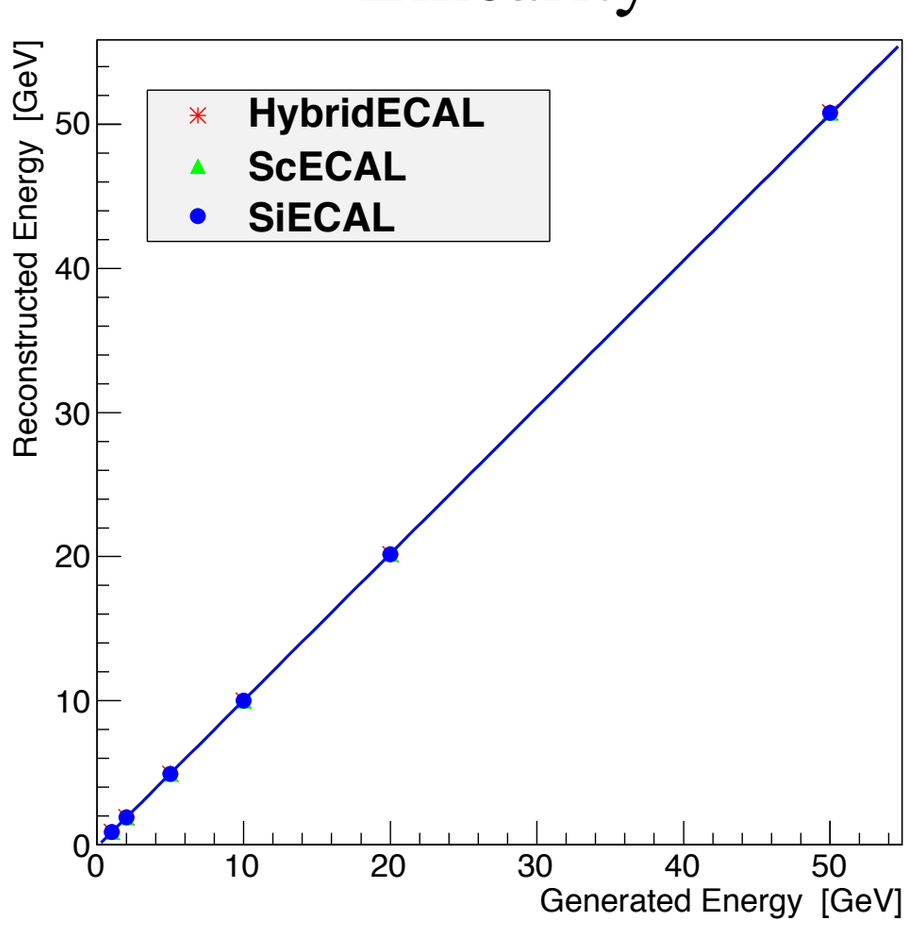
In order to check the calibration constants, we have evaluated the energy resolution and linearity of the ECALs by using 1~50GeV photons.

→The calibration method works well.

Energy Resolution

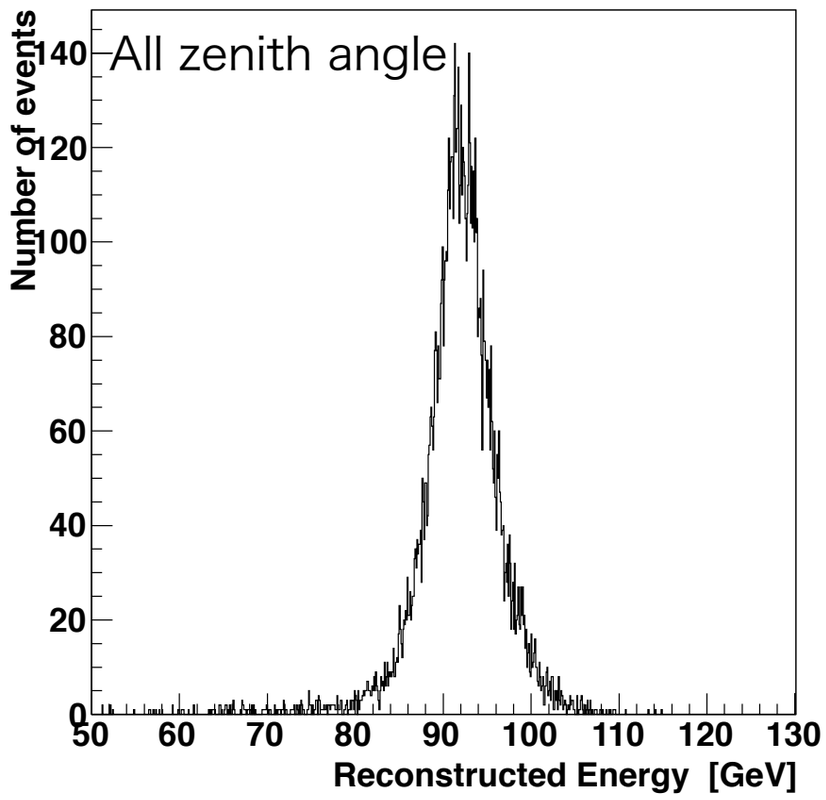


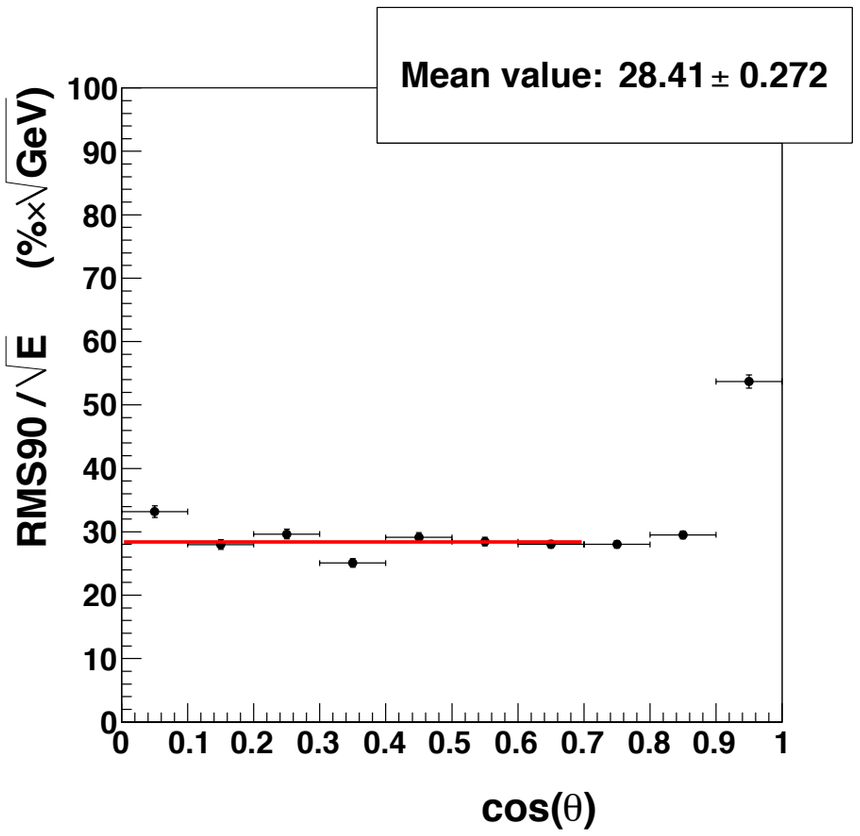

Linearity



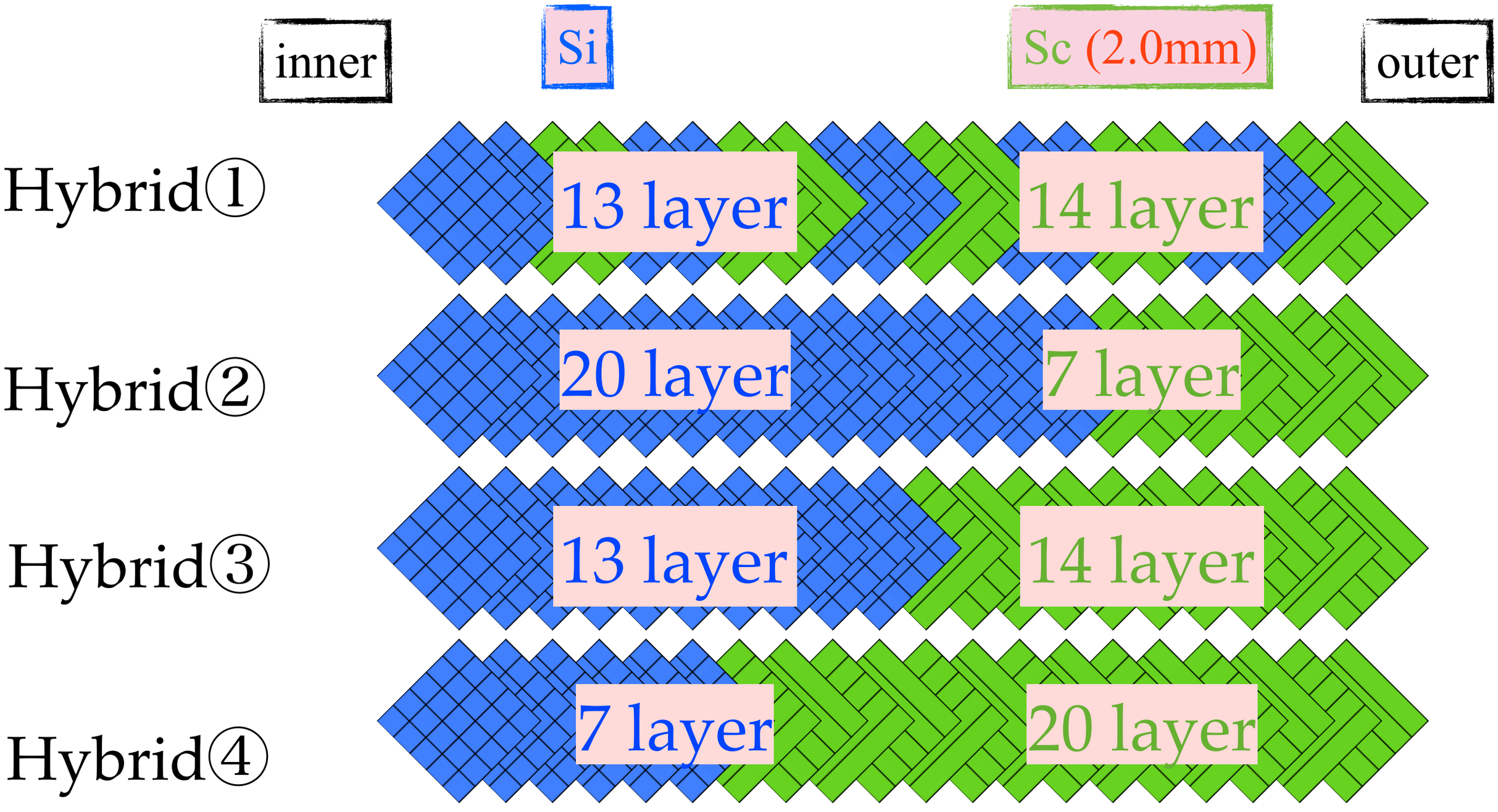
# Study of Hybrid ECAL

- We evaluated energy dependence and Sc:Si ratio dependence.
- Used events are $e^+e^- \rightarrow q\bar{q}$ ($\sqrt{s}$=91, 200, 360, 500GeV)
- Evaluated area is only barrel part (cos(thrust angle)<0.7) because energy resolution of endcap part is quite worse than barrel part.



# Hybrid Configurations① ~same absorber thickness~




pure ScECAL and pure SiECAL were also simulated for comparison.

# Hybrid Configurations①

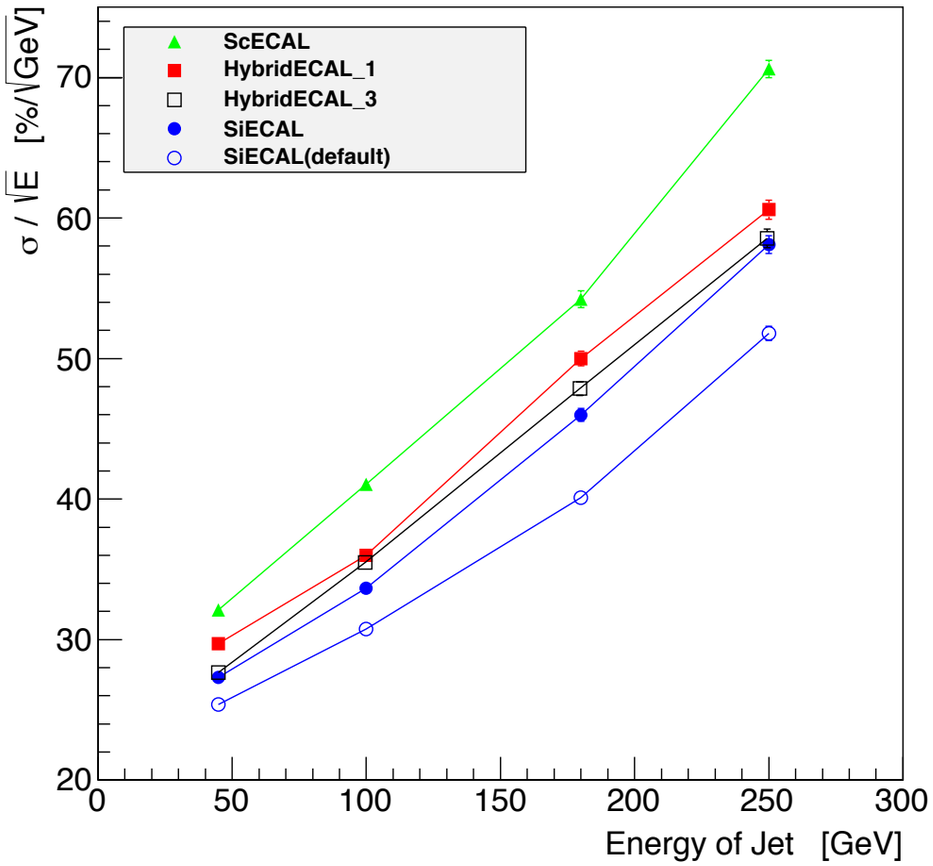
## ~same absorber thickness~

Sc thickness = 2.0mm
Si thickness = 0.5mm

| | number of Si layer(inner) | number of Sc layer(outer) | W thickness (in20,out7) | Module thickness | Radiation Length |
|---|---|---|---|---|---|
| SiECAL(27) | 27 | 0 | 2.1/3.5 | 165.400 | 19.144$X_0$ |
| Hybrid① | 13 | 14 | 2.1/3.5 | 185.196 | 19.136$X_0$ |
| Hybrid② | 19 | 8 | 2.1/3.5 | 176.712 | 19.729$X_0$ |
| Hybrid③ | 13 | 14 | 2.1/3.5 | 185.196 | 19.136$X_0$ |
| Hybrid④ | 7 | 20 | 2.1/3.5 | 193.680 | 19.981$X_0$ |
| ScECAL(27) | 0 | 27 | 2.1/3.5 | 204.992 | 20.274$X_0$ |

# Energy Dependence

## ~ same absorber thickness ~

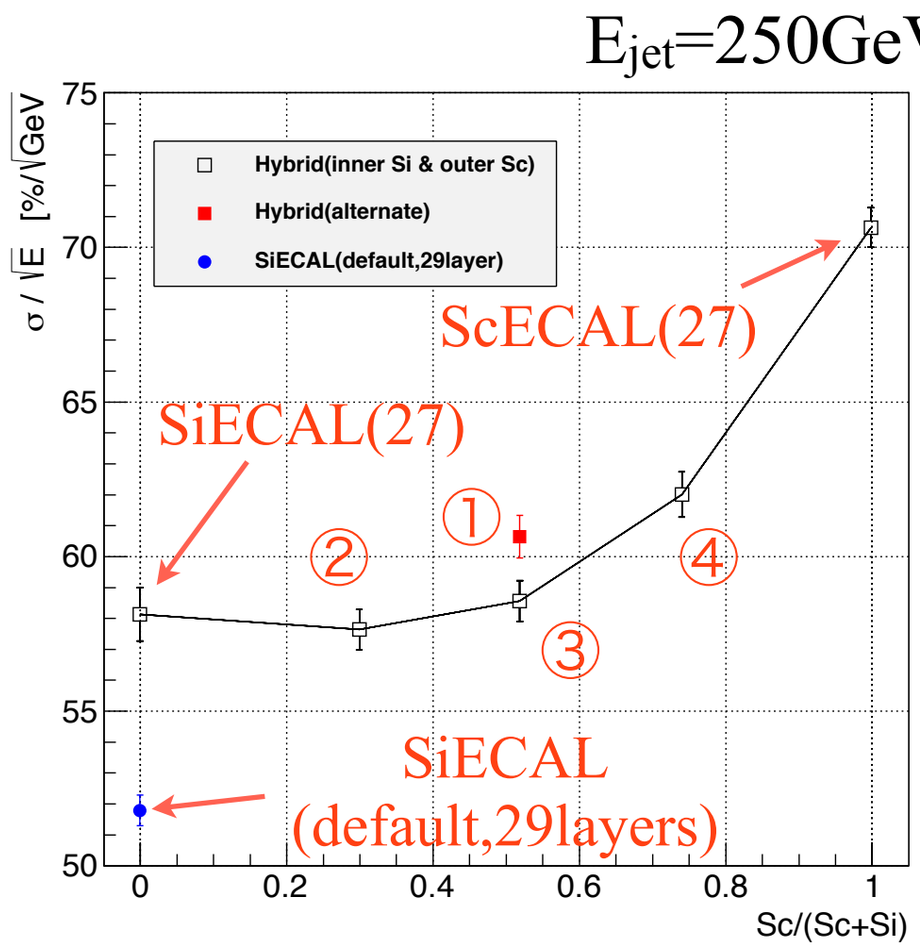



- ▲ : ScECAL (27 layers)
- ■ : alternate structure
- □ : 13 Si layers, 14 Sc layers
- ● :SiECAL (27layers)
- ○ : default SiW ECAL (29 layers)

- Default SiW ECAL is much better than SiW ECAL due to the difference of absorber thickness and number of layers.
- The performances of Hybrid① (alternate structure) are midway between SiECAL(27) and ScECAL(27).

# Sc:Si Ratio Dependence

## ~ same absorber thickness ~




- ① : alternate structure
- ② : 19 Si layers, 8 Sc layers
- ③ : 13 Si layers, 14 Sc layers
- ④ : 7 Si layers, 20 Sc layers

Energy Resolution doesn't degrade so much up to 50% of Scintillator layers.

# Hybrid Configurations②

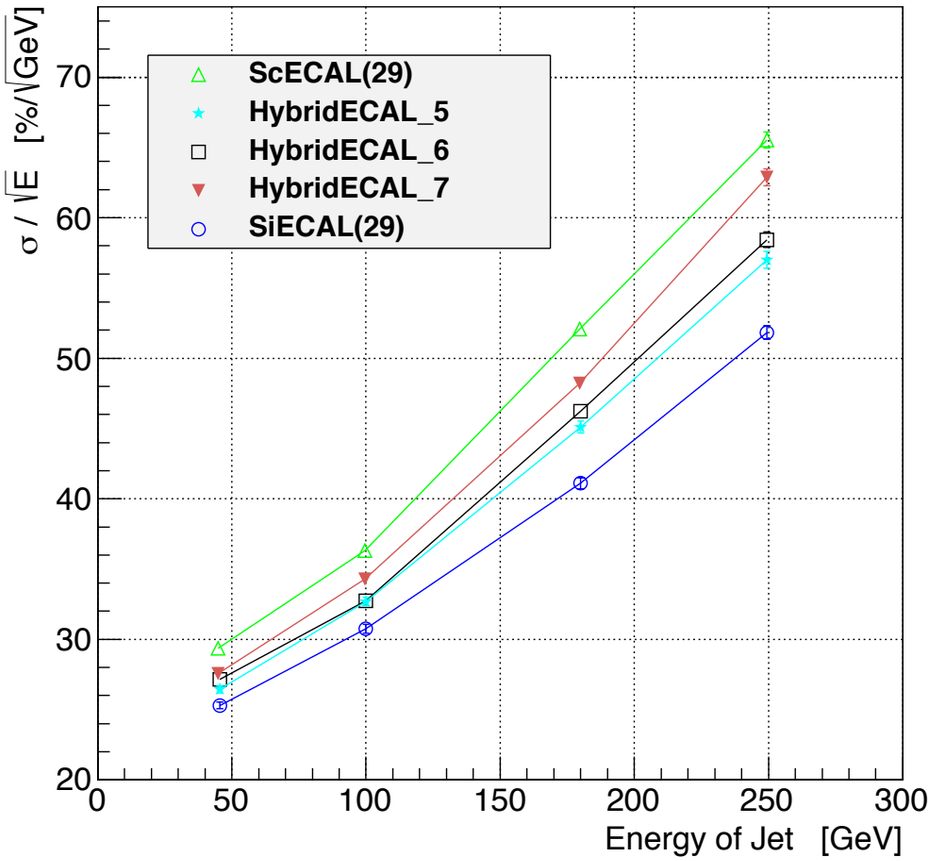
## ~same module thickness~

Sc thickness = 1.0mm
Si thickness = 0.5mm

| | number of Si layer(inner) | number of Sc layer(outer) | W thickness (in20,out9) | Module thickness | Radiation Length |
|---|---|---|---|---|---|
| SiECAL(29) | 29 | 0 | 2.1/4.2 | 185.000 | $22.96X_0$ |
| Hybrid⑤ | 21 | 8 | 2.1/3.9 | 185.612 | $22.33X_0$ |
| Hybrid⑥ | 15 | 14 | 2.1/3.6 | 185.396 | $21.67X_0$ |
| Hybrid⑦ | 9 | 20 | 2.1/3.3 | 185.180 | $21.00X_0$ |
| ScECAL(29) | 0 | 29 | 2.1/2.9 | 185.720 | $20.14X_0$ |

# Energy Dependence

## ~ same module thickness ~

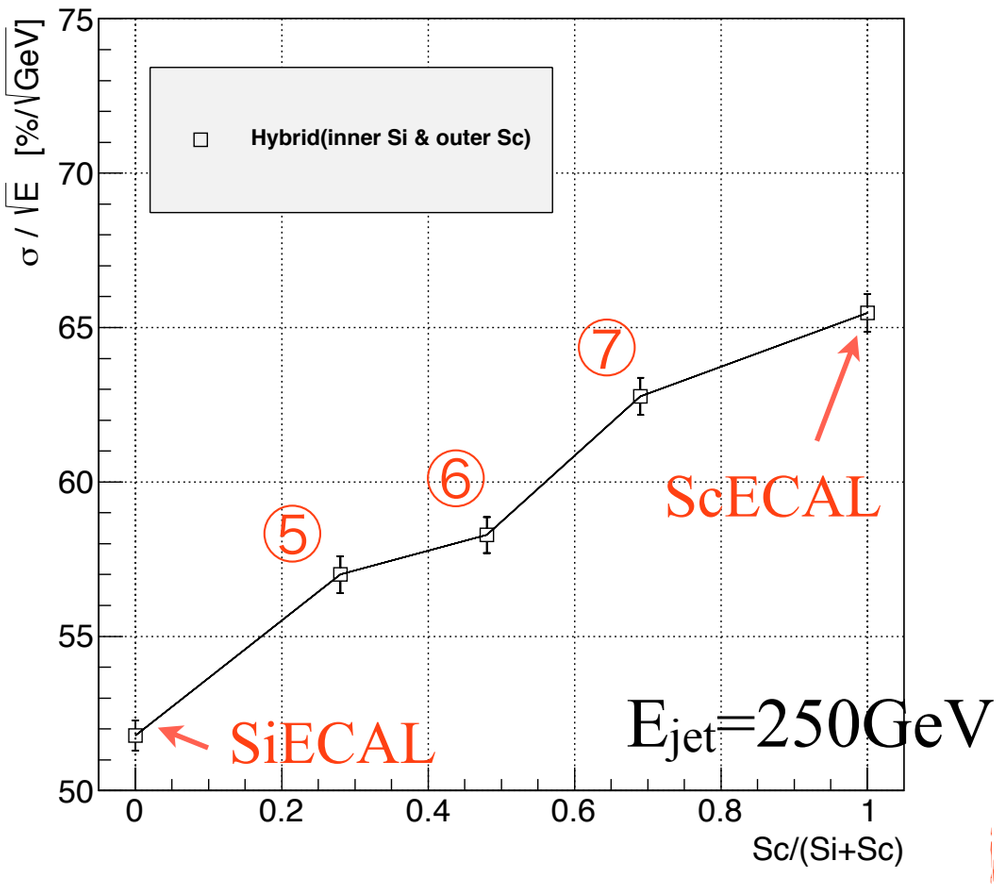



- △ : ScECAL (29layers)
- ▼ : 21 Si layers, 8 Sc layers
- □ : 15 Si layers, 14 Sc layers
- ★ : 9 Si layers, 20 Sc layers
- ○ : SiECAL (29 layers)

The performance of the Hybrid ECAL is reasonable compared with ScECAL and SiECAL.

# Sc:Si Ratio Dependence

~ same module thickness ~




- The performance is degraded as Sc ratio increases.
- Hybrid⑥ is nearly middle of ScECAL and SiECAL.

The performance of Hybrid ECAL become worse than SiECAL.

# Summary and Prospects

- We evaluated Sc:Si ratio dependence and energy resolution for 2 cases, same absorber thickness and keeping module thickness.
  - In same absorber thickness, the performance of the Hybrid ECAL is almost same as that of SiECAL.
  - In the case of keeping module thickness,  the performance of the Hybrid ECAL is about middle of that of SiECAL and ScECAL.

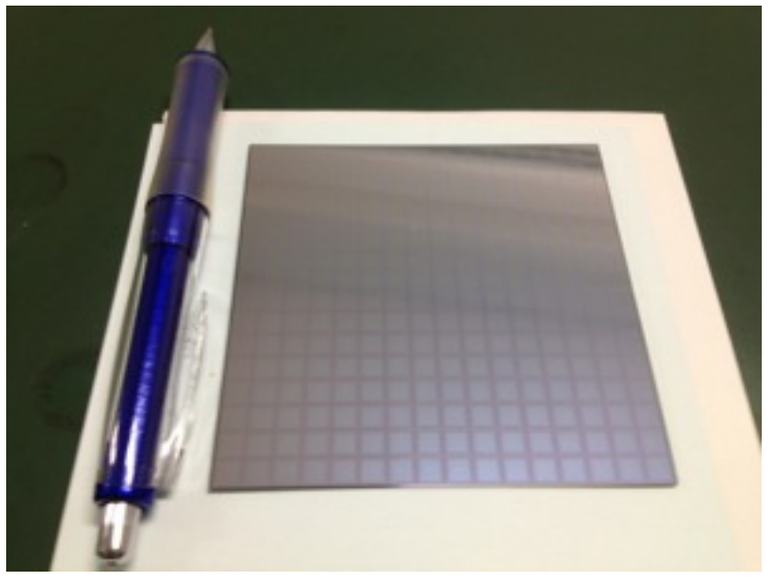
- We'll evaluate whether the performance degrades or not by replacing Silicon layers of Hybrid③ by Scintillator layers from inside.

Thank you!!

# Backup

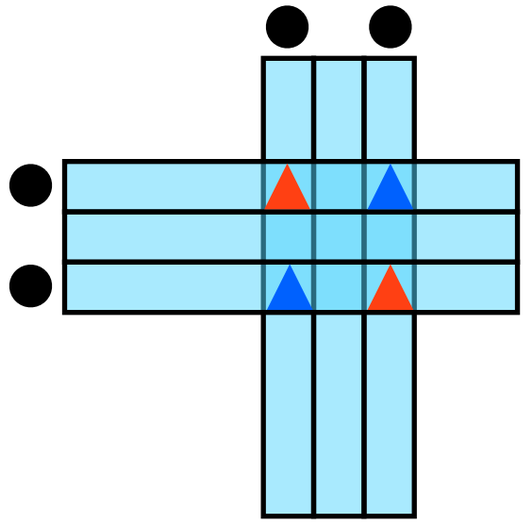
# ECAL Candidates

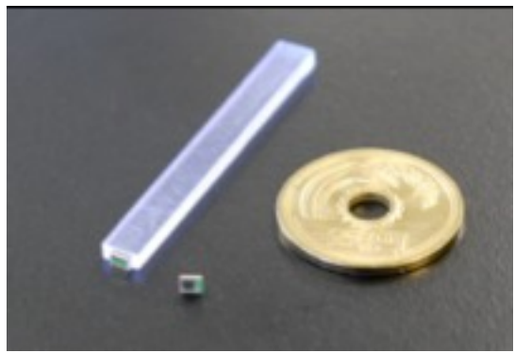
## Silicon （SiECAL）



- ❖ Si-pad : 5mm x 5mm cells
- ❖ Good performance for PFA
- ❖ Large fraction of detector cost

## Scintillator + MPPC （ScECAL）

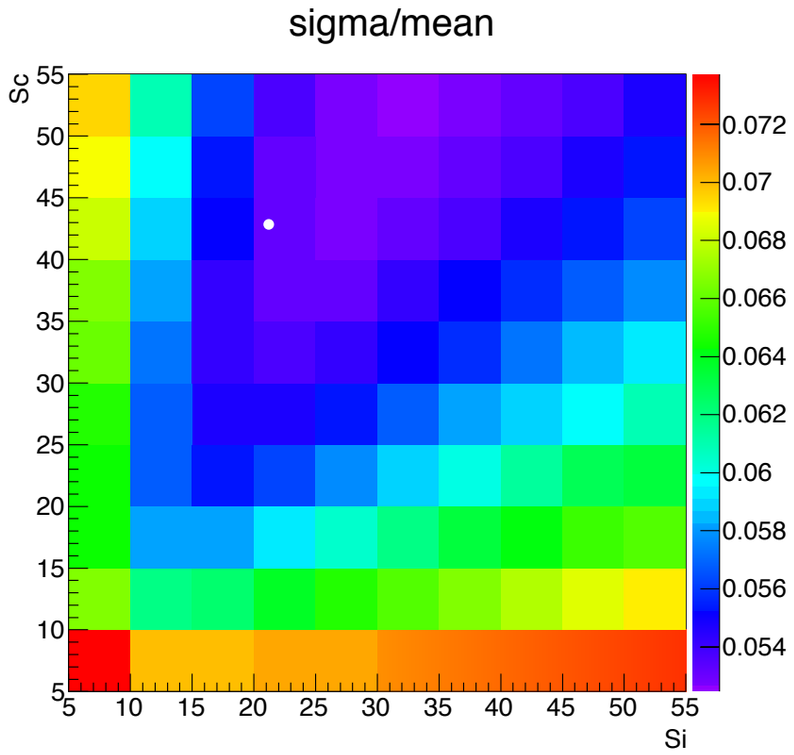




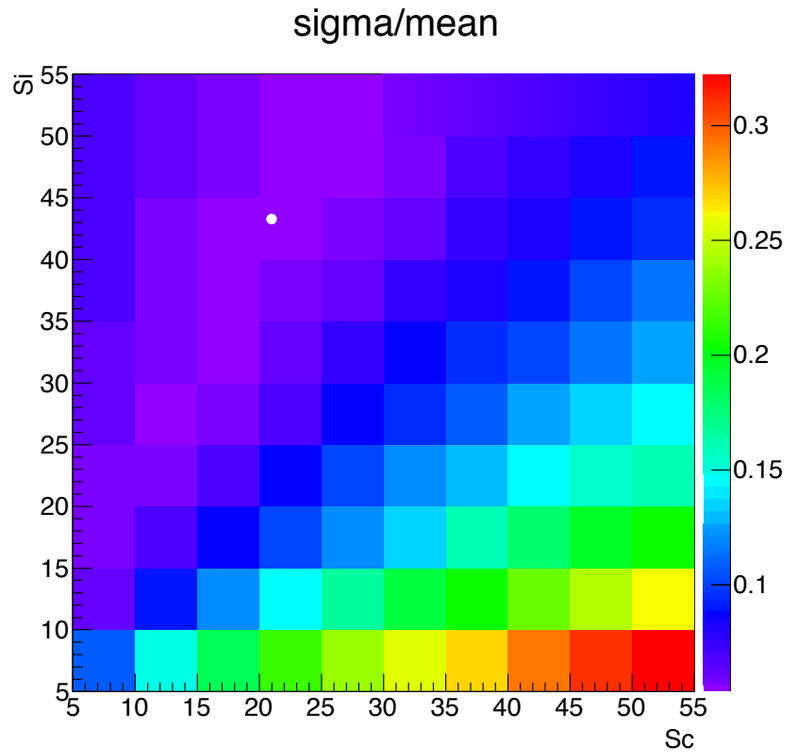
- ✻ 45mm x 5mm orthogonal
  → 5mm x 5mm spatial resolution
- ✻ Reasonable cost
- ✻ Possibility of ghost hits
- ✻ Need software (strip splitting algorithm)

# Energy Resolutions in each configurations

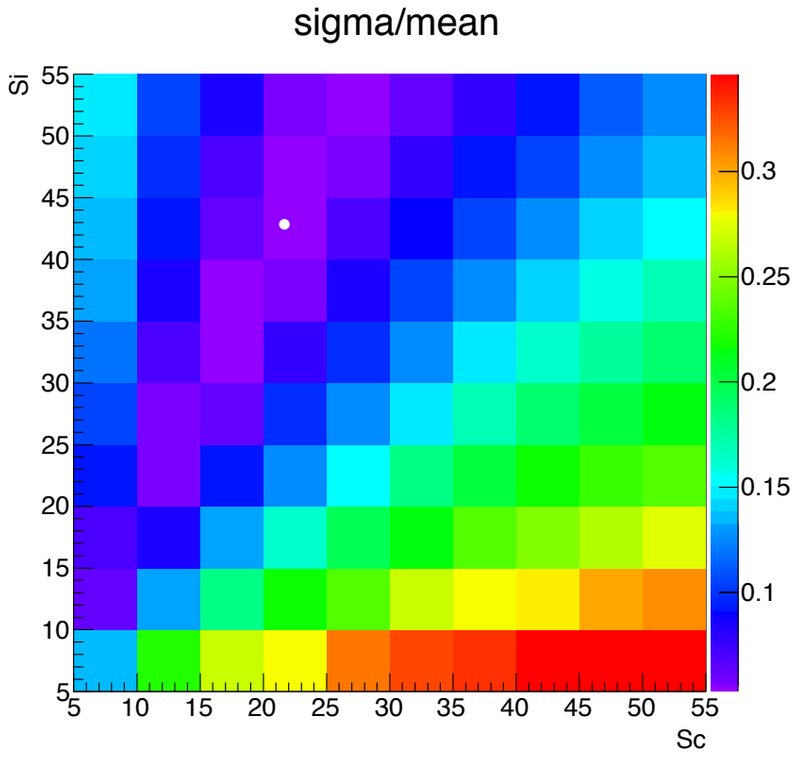
①



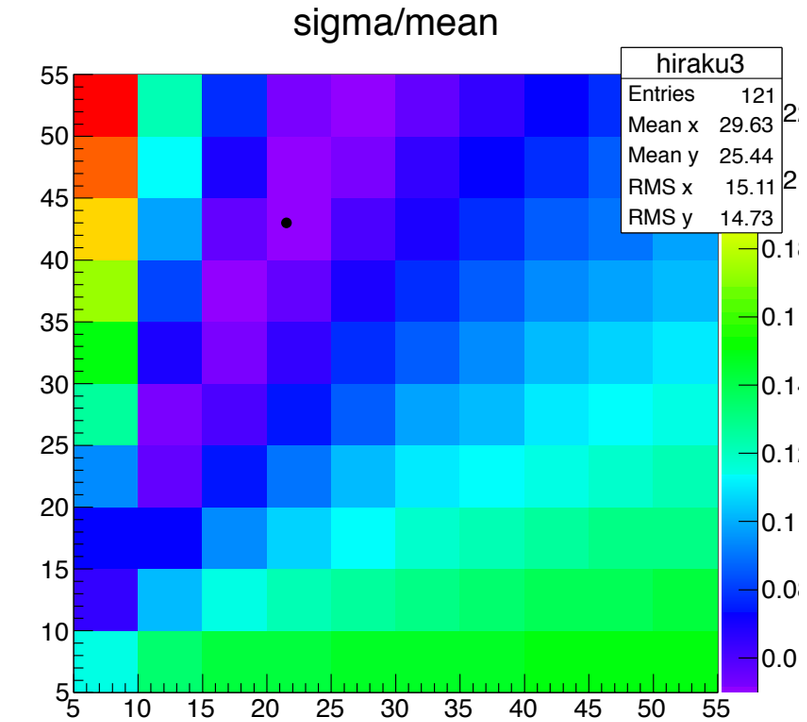

②




③




④



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- We evaluated energy dependence and Sc:Si ratio dependence.
- Used events are $e^+e^- \rightarrow q\bar{q}$ ($\sqrt{s}$=91, 200, 360, 500GeV)
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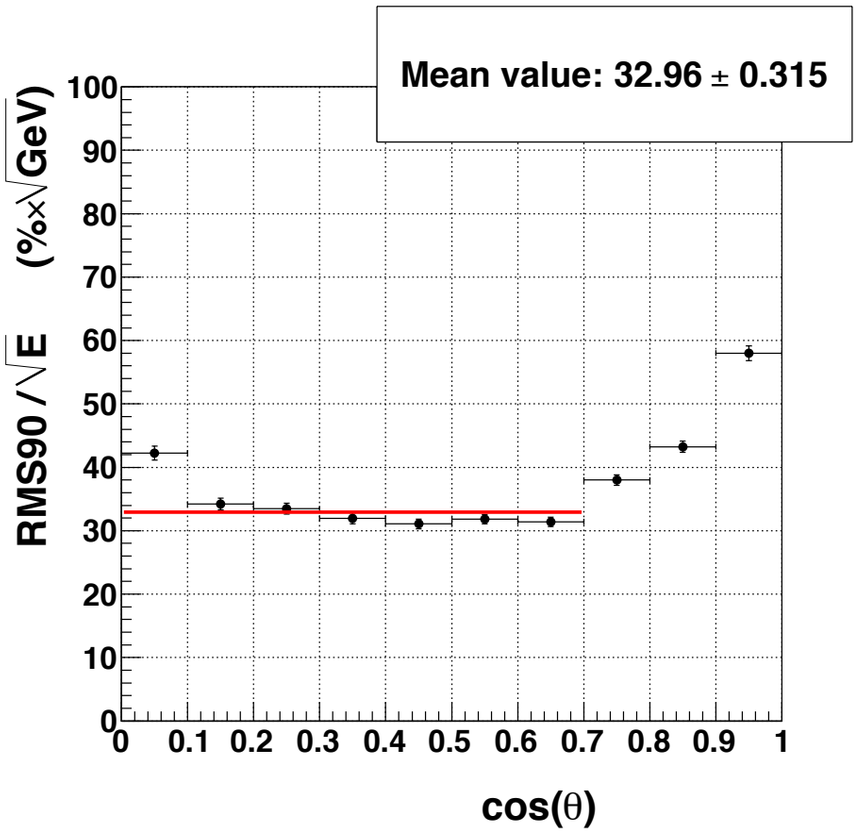
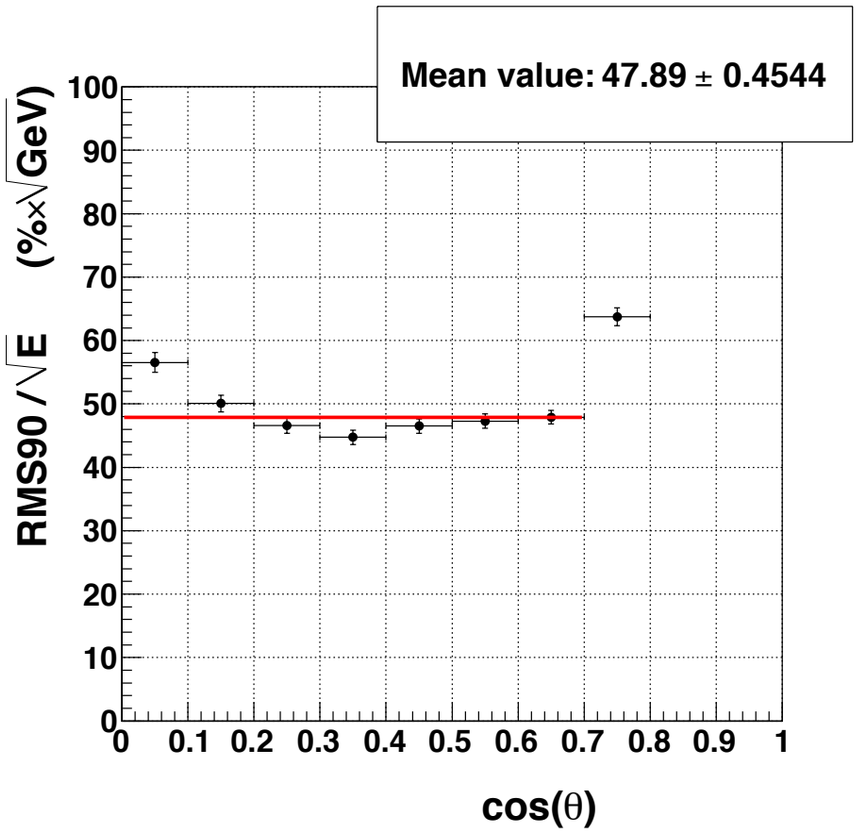



Hybrid⑥ 200GeV




Hybrid⑦ 360GeV