Simulation Study of Hybrid ECAL for ILD

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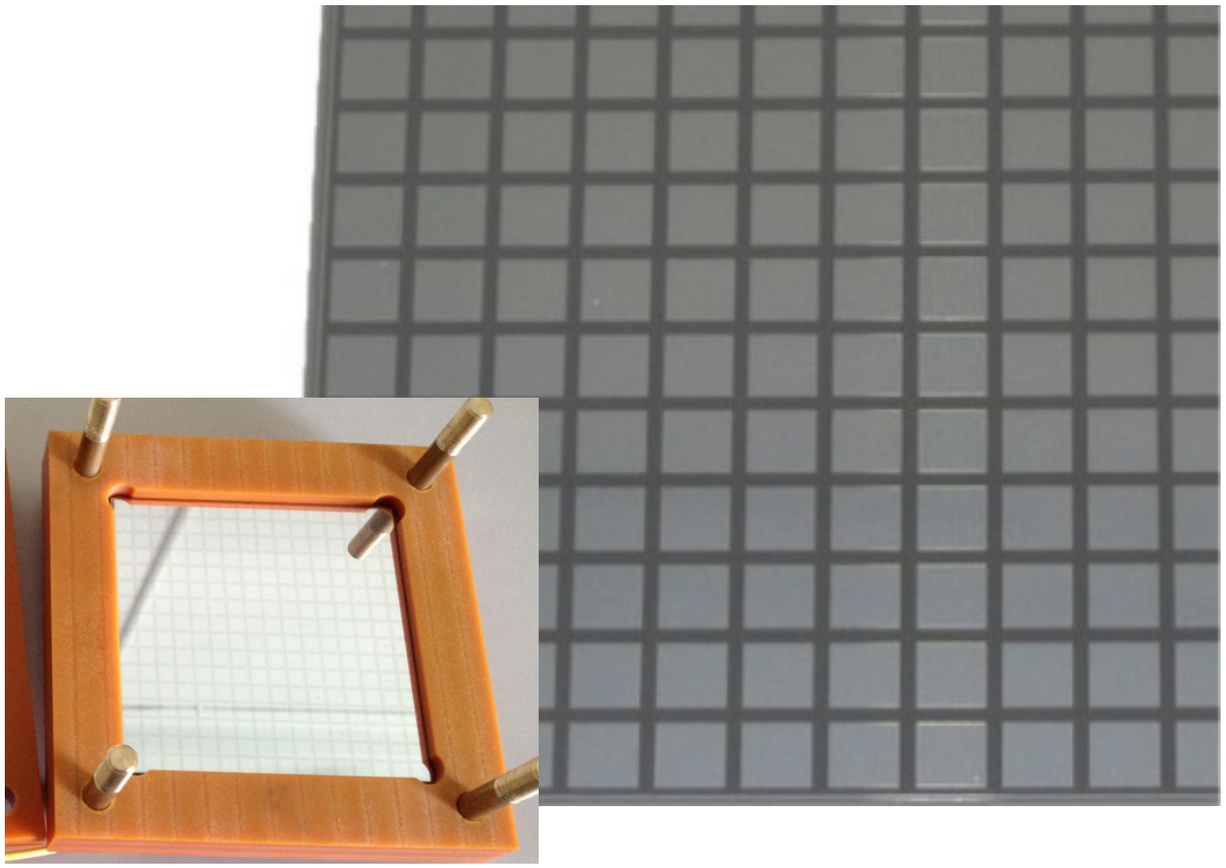
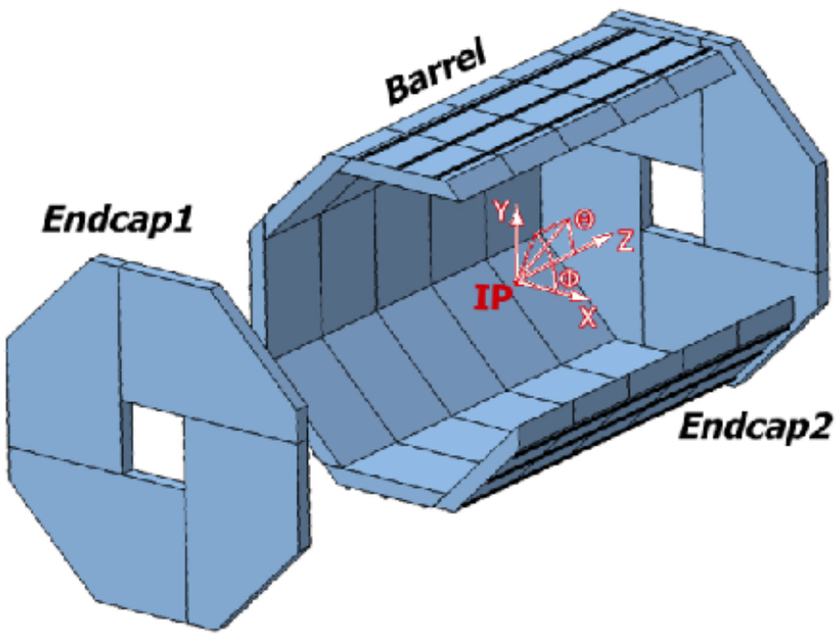
Motivation

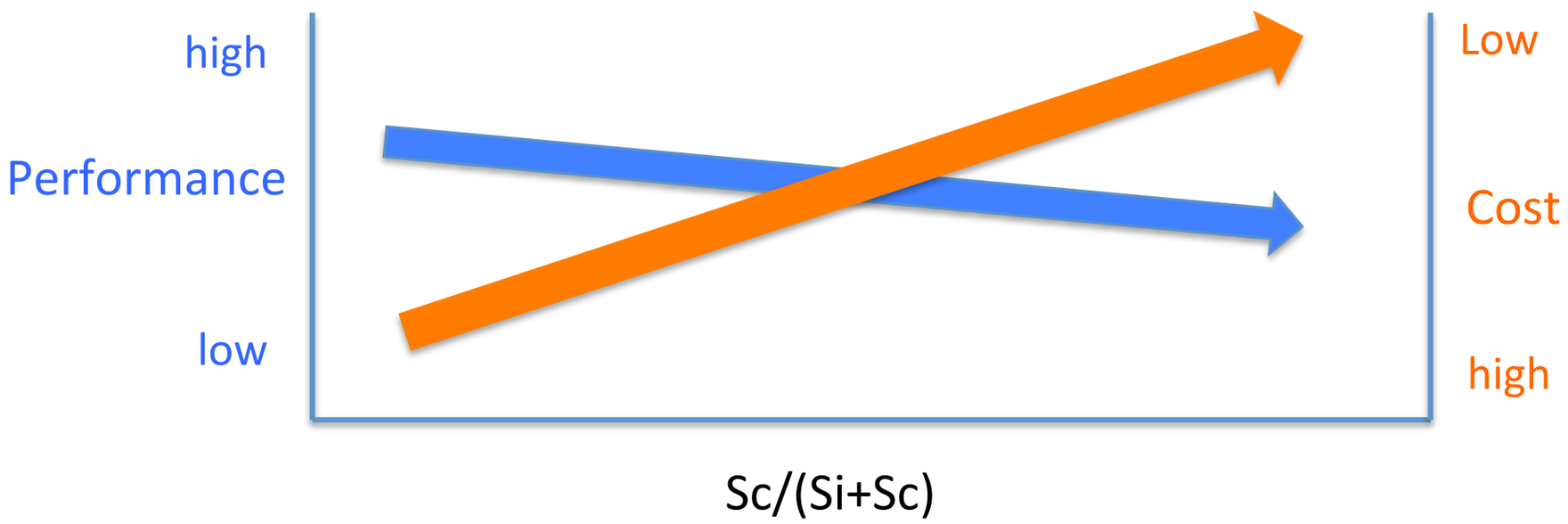
- An electromagnetic calorimeter (ECAL) with Si-pads as sensitive layers would show the best performance for the Particle Flow Algorithm in a linear collider detector.
- But the Si-pads are the dominant cost driver in the detector.





Motivation

- A solution to make the ECAL with a reasonable cost and keeping the performance as much as possible would be to replace some of the Si-pads layers by Scintillator-strip layers (Hybrid ECAL).
- We're therefore studying the performance of the Hybrid ECAL.



ECAL Simulation Setup

- We tested following ECAL setups.

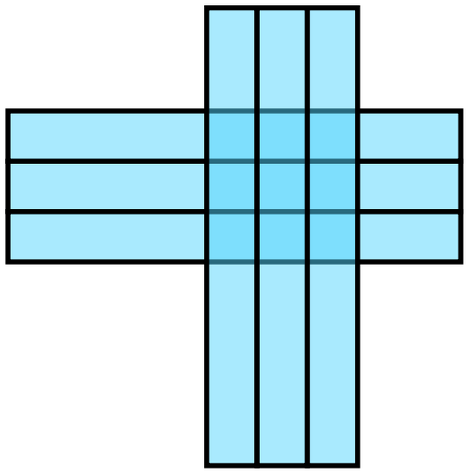
- We made both ScECAL and SiECAL the same configuration for comparing with Hybrid ECAL.

	Active Layer	Absorber Thickness	Total Number of Layers
HybridECAL	2.0mm (Scintillator) 0.5mm (Silicon)	2.1mm (inner 20 layer) 3.5mm (outer 7 layer)	27
ScECAL	2.0mm (Scintillator)		
SiECAL	0.5mm (Silicon)		

Hybrid ECAL Configuration

Sc layer

45mmx5mm strips

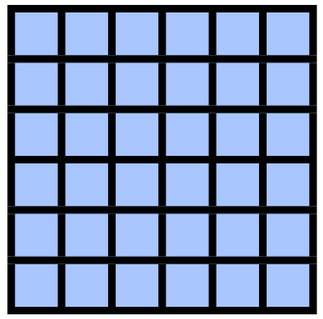


orthogonal

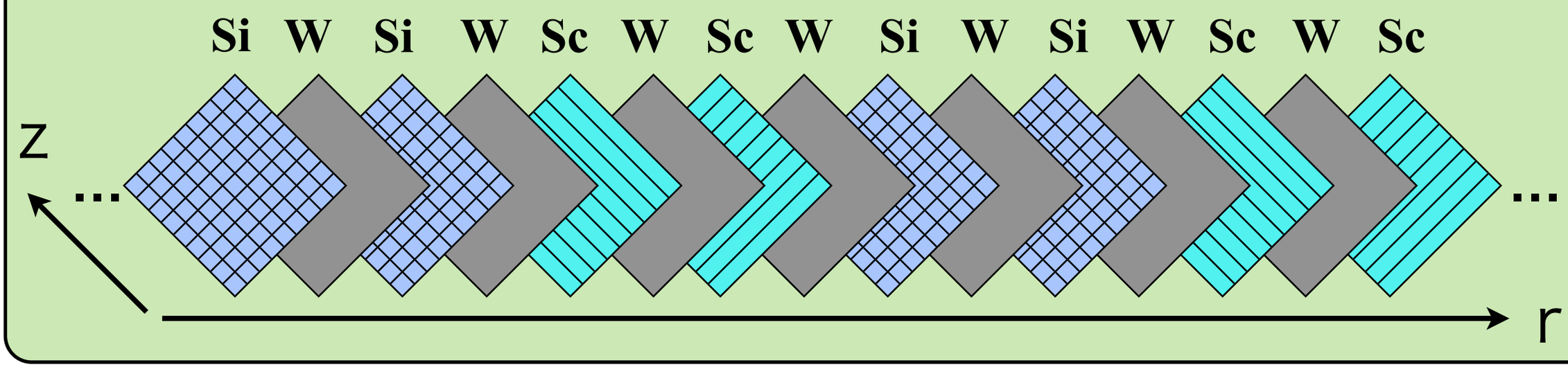
- 5mmx5mm spacial resolution
- possibility of ghost

Si layer

5mmx5mm cells



The configuration of Hybrid ECAL



Calibration Procedure

- As ILD ECAL and HCAL are sampling calorimeters, they measures only a part of deposit energy.
- We have to extract actual energy from the energy deposit in active layers. -> Calibration
  - ECAL : 10GeV photon
  - HCAL : 10GeV K_L
- Then we confirm those calibration by energy resolution and linearity of 1~50GeV photon for ECAL.
- At last, we adjust MIP response for noise reduction with 10GeV muon.

Hybrid ECAL Calibration

- Calibration constants should be determined for Scintillator layers and Silicon layers in Hybrid ECAL separately.
- We assumed the relation between them by taking their radiation length.

$$E_{true} = a \times E_{Sc}^{inner} + b \times E_{Si}^{inner} + c \times E_{Sc}^{outer} + d \times E_{Si}^{outer}$$

$$a : b = \frac{L_{Sc}}{X_0^{sc}} : \frac{L_{Si}}{X_0^{si}} = \frac{1}{21.2} : \frac{1}{18.73}$$

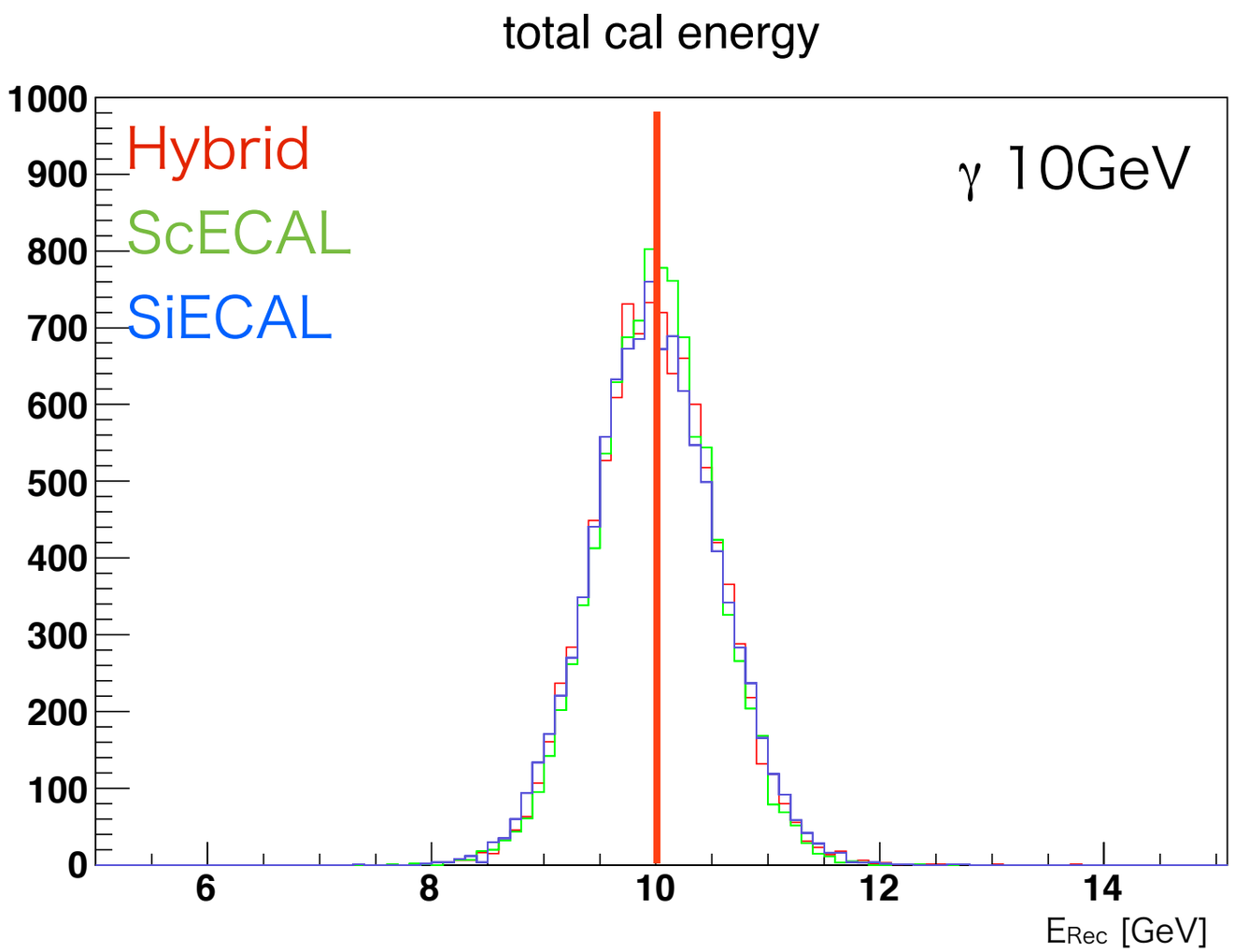
L:active layer thickness
X_0:radiation length

$$a : c = b : d = L_W^{inner} : L_W^{outer} = 2.1 : 3.5$$

$$\therefore \quad a : b : c : d = 1 : 1.13 : 1.67 : 1.89$$

Hybrid ECAL Calibration (cont'd)

- We determined the calibration constants so that the photon energy peak is at the right position.

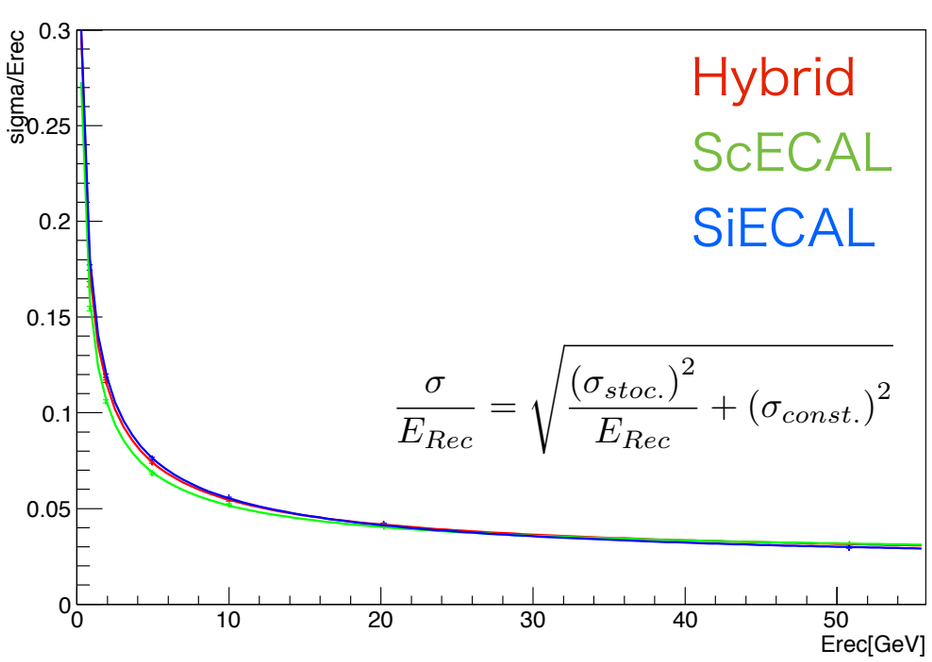


	inner layers	outer layers
ScECAL	27.4216	45.7028
SiECAL	31.0322	51.7024
Hybrid(Sc)	21.5164	35.8606
Hybrid(Si)	43.0116	71.6861

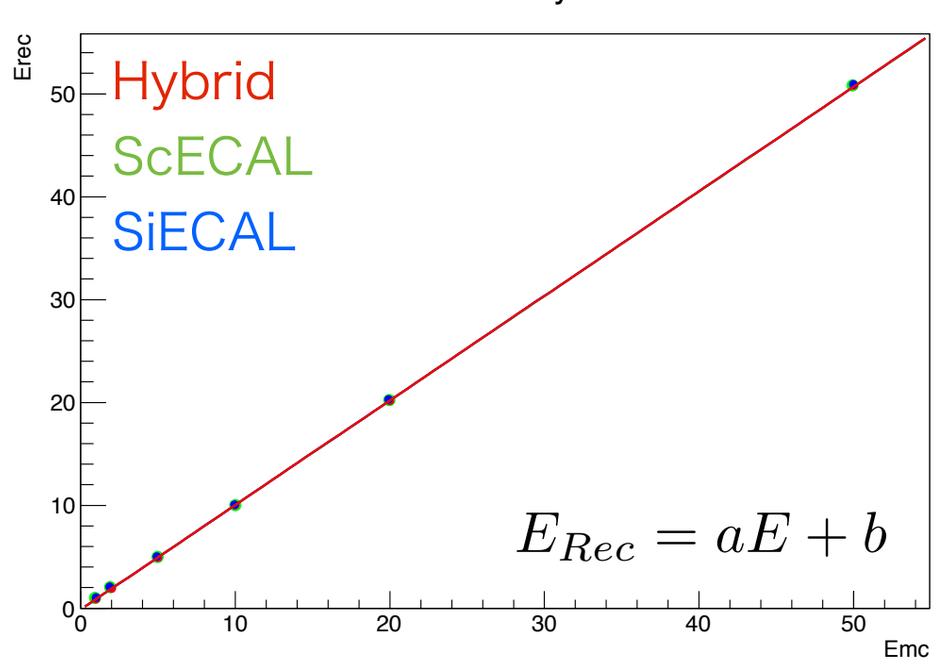
ECAL Performance

- We evaluate the performance of energy resolution and linearity using 1~50GeV single photon events to confirm whether our calibration is appropriate or not.

Resolution



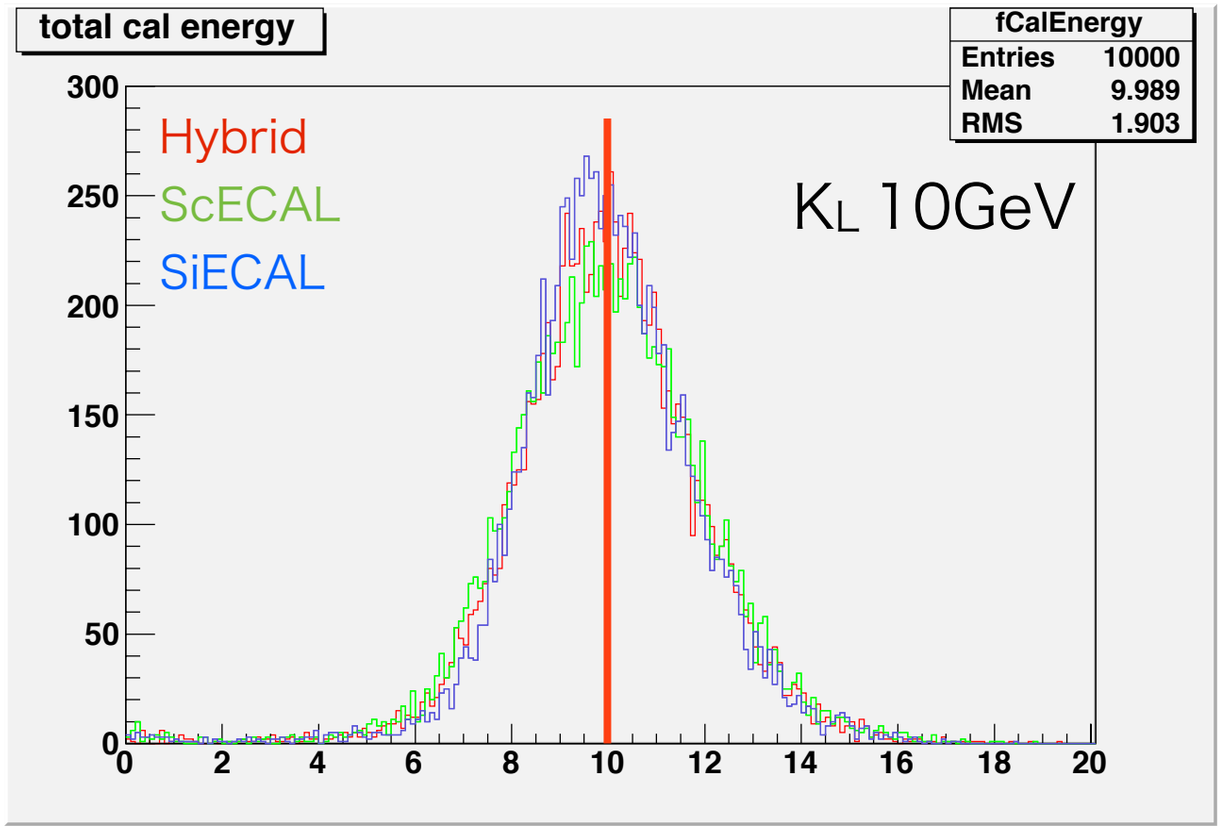
Linearity

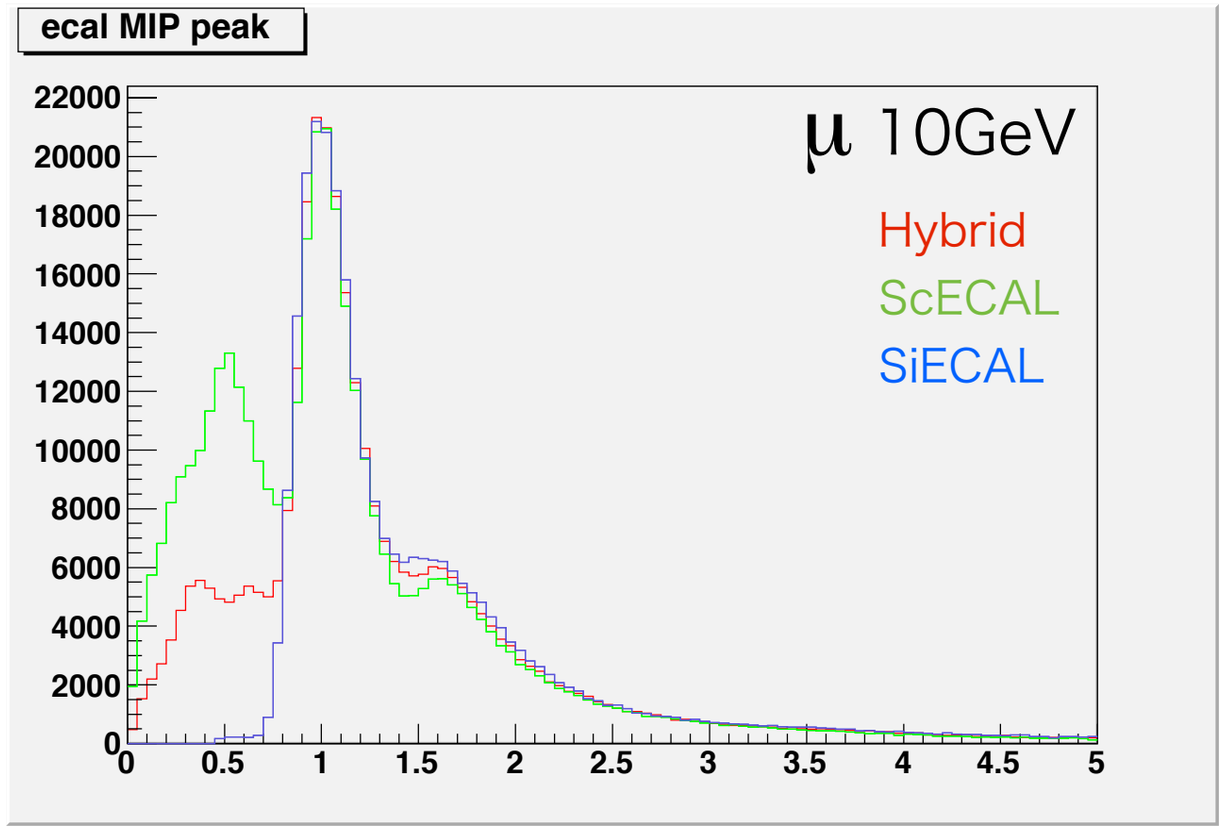


Reasonably Good!!

Other Calibrations

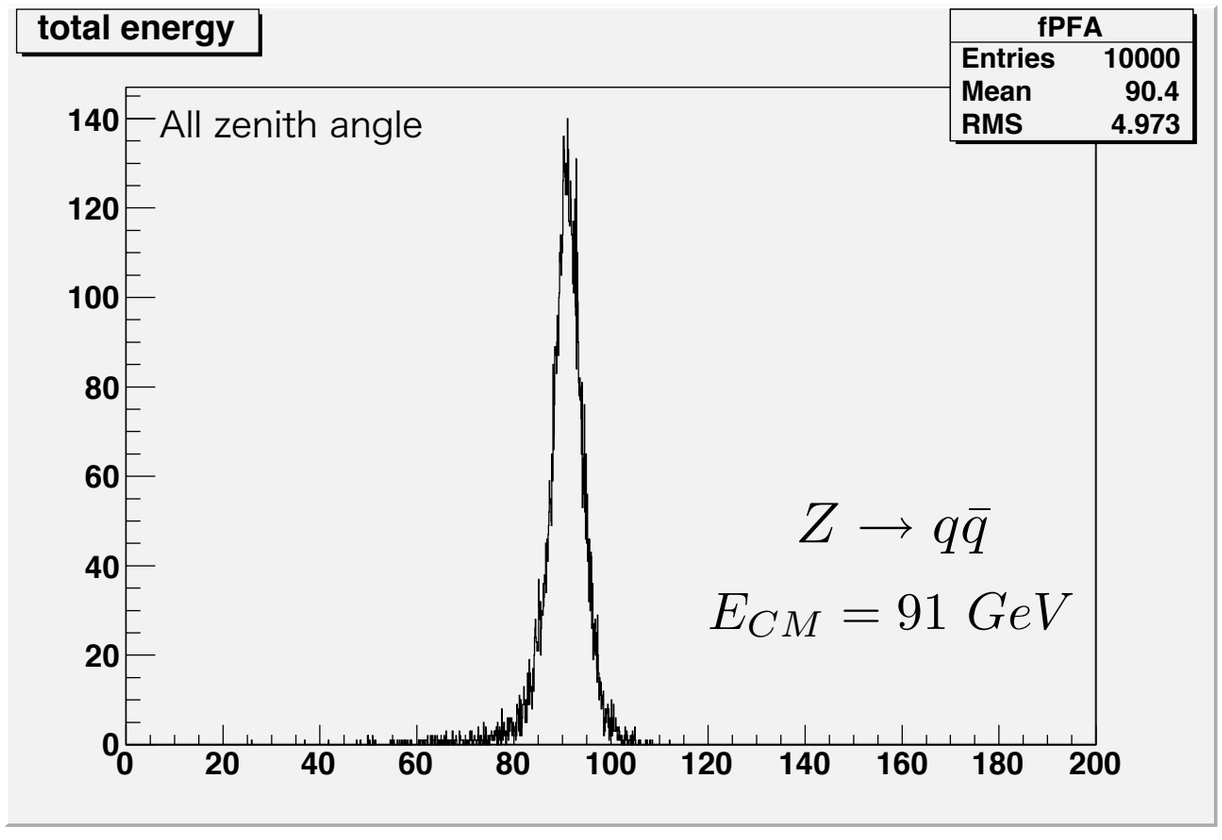
- We calibrate for HCAL as well as ECAL.
- At last, we calibrate MIP response for noise reduction.



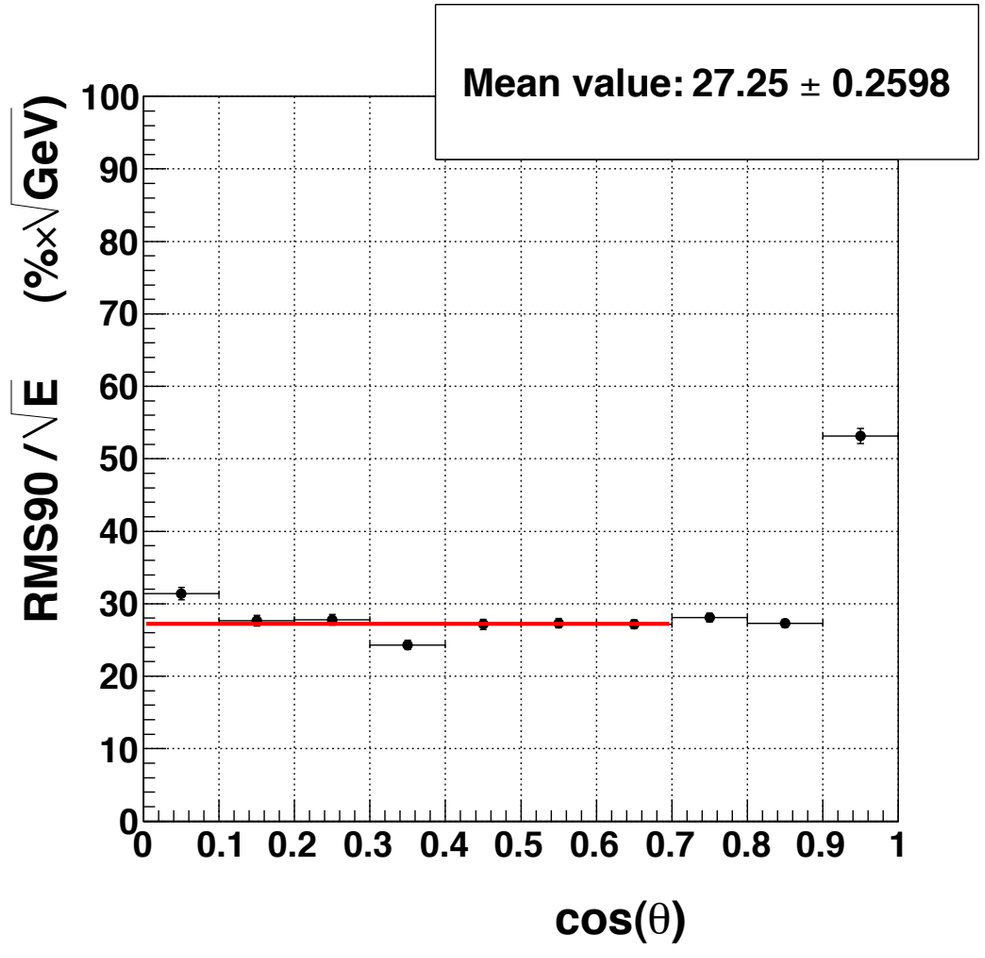


Jet Energy Resolution

- We started to evaluate Jet Energy Resolution of Hybrid ECAL.
- We use the data in the area within $\cos\theta$ <0.7.



Hybrid ECAL+Strip Splitting Algorithm(SSA)



Jet Energy Resolution

- These are the results.

$$\frac{\sigma}{\sqrt{E}} = \frac{RMS90}{\sqrt{E[GeV]}}[\%]$$

	JER (cos(thrust) <0.7)
ScECAL	27.64±0.26%
SiECAL	27.20±0.26%
HybridECAL	27.41±0.26%

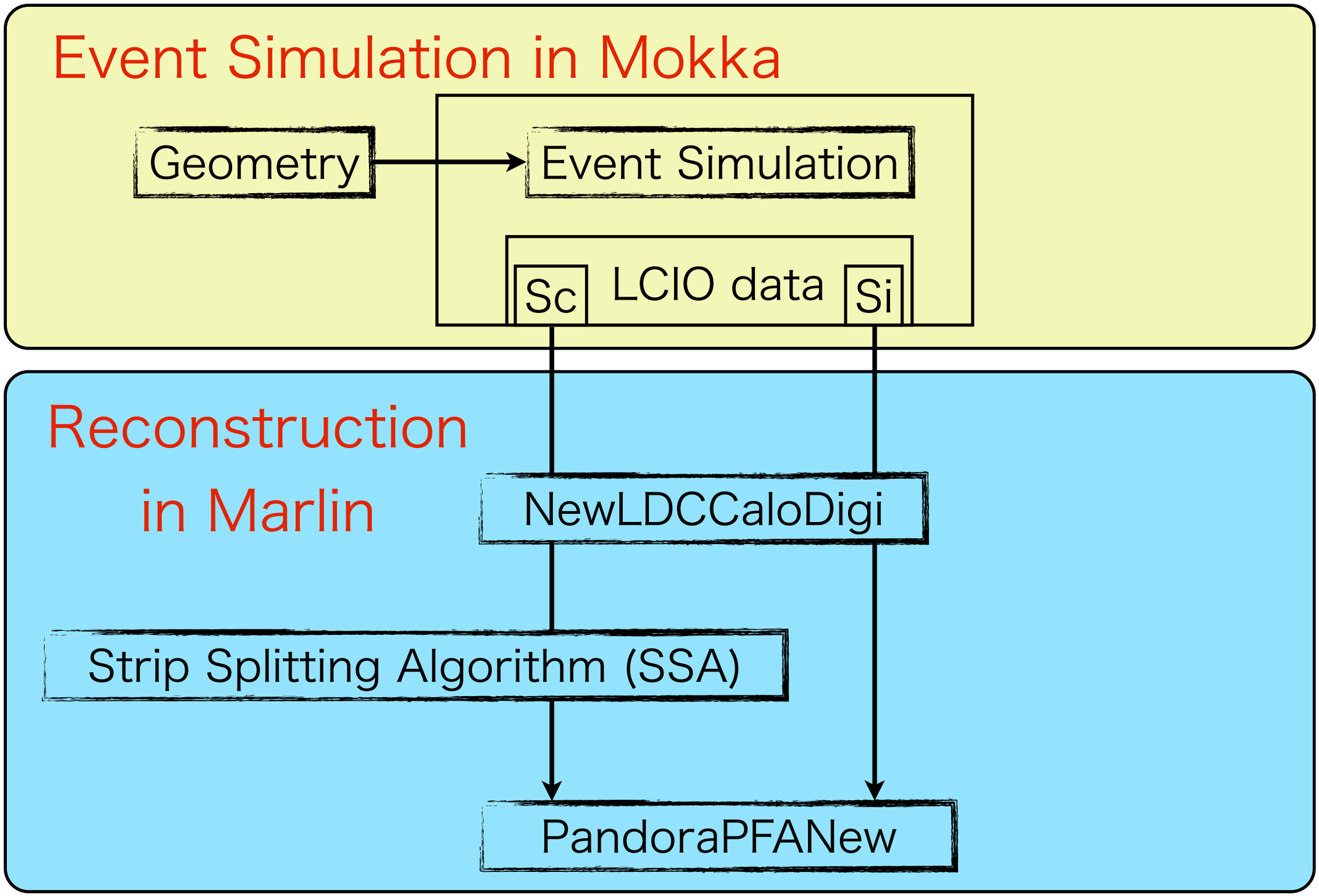
Summary

- established calibration method for Hybrid ECAL.
- evaluated the performances of jet energy resolution for each ECAL.

- After this,
  - evaluate JER with higher energy events.
  - repeat the procedure with various configuration.

Backup

Analysis Flow



ECAL Performance

Energy Resolution	$\sigma_{stoc.}$	$\sigma_{const.}$
Sc ECAL	0.1435±0.0007	0.0245±0.0003
Si ECAL	0.1644±0.0007	0.0190±0.0004
Hybrid ECAL	0.1574±0.0007	0.0223±0.0004

Linearity	a	b
Sc ECAL	1.016±0.0002	-0.126±0.001
Si ECAL	1.016±0.0002	-0.128±0.001
Hybrid ECAL	1.016±0.0002	-0.126±0.001

Calibration Results

		HybridECAL		ScECAL	SiECAL
		Sc layer	Si layer		
ECAL	inner	27.4216	31.0322	21.5164	43.0116
	outer	45.7028	51.7024	35.8606	71.6861
HCAL		31.4		30.7	35.2
MIP	ECAL	112.4	207.8	145.0	149.0
	HCAL	37.6		38.5	33.6

We evaluate jet energy resolution.

Software Version

- ilcsoft v01-09-02split
  - Mokka-07-05
  - Marlin v00-12
    - PandoraPFANew v00-01
    - MarlinPandora v00-02
    - MarlinReco v00-18-02