Simulation Study of Hybrid ECAL for ILD

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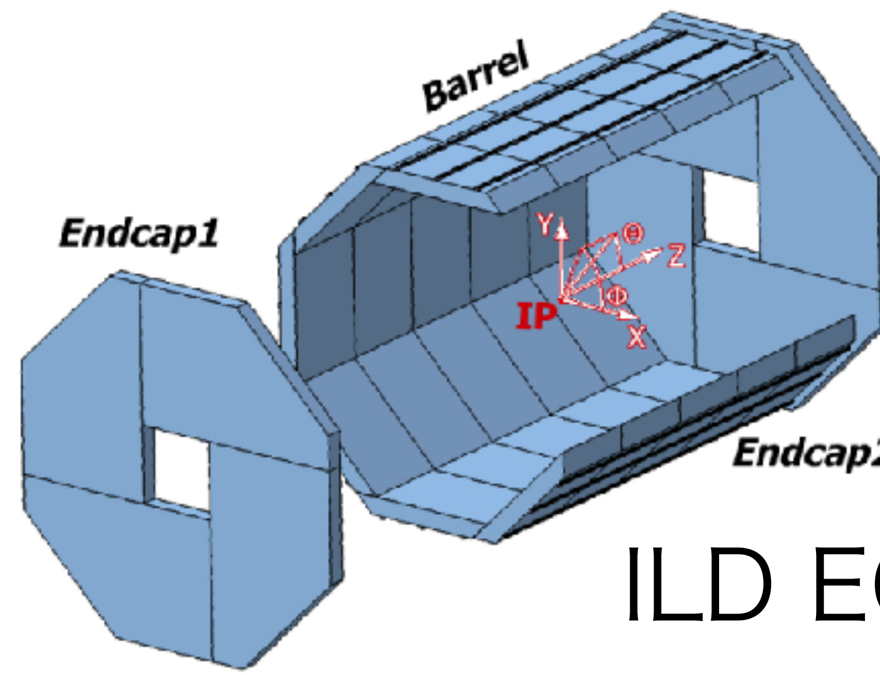
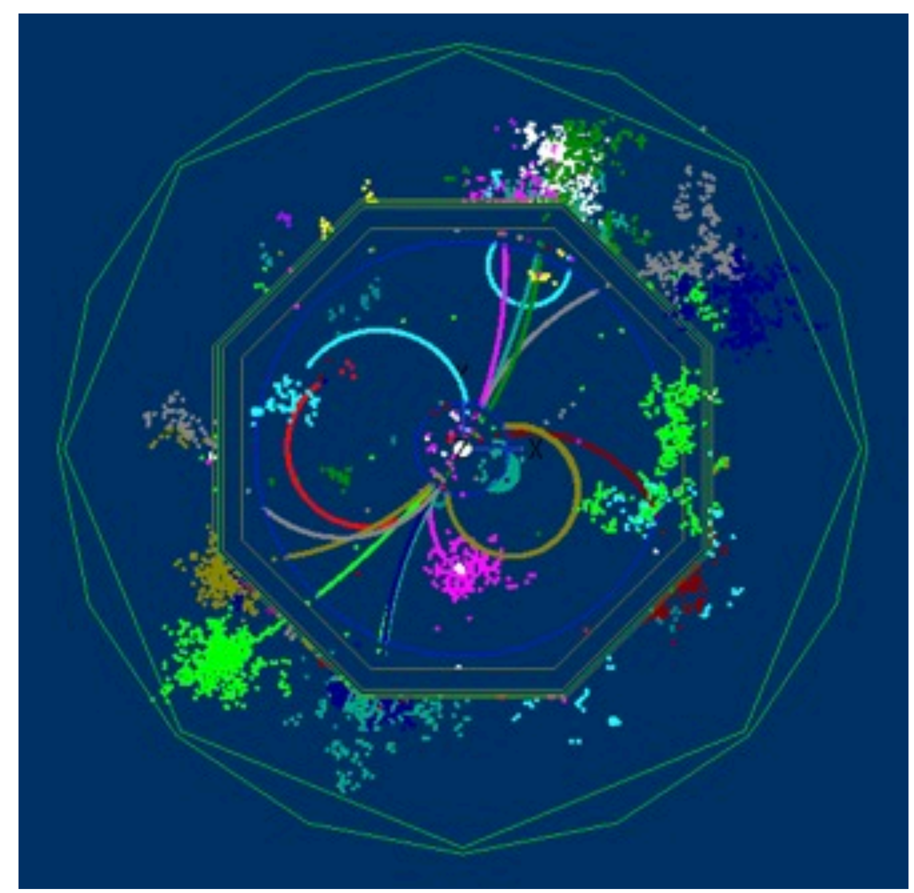
ILD & PFA

- ILD has been developed as the detector specific to Particle Flow Algorithm (PFA) for ILC.
- PFA is a method to identify neutral and charged particles in jets. For good PFA performance therefore fine-segmented calorimeter is required.
- There're two candidates for ILD ECAL solution.



ILD ECAL

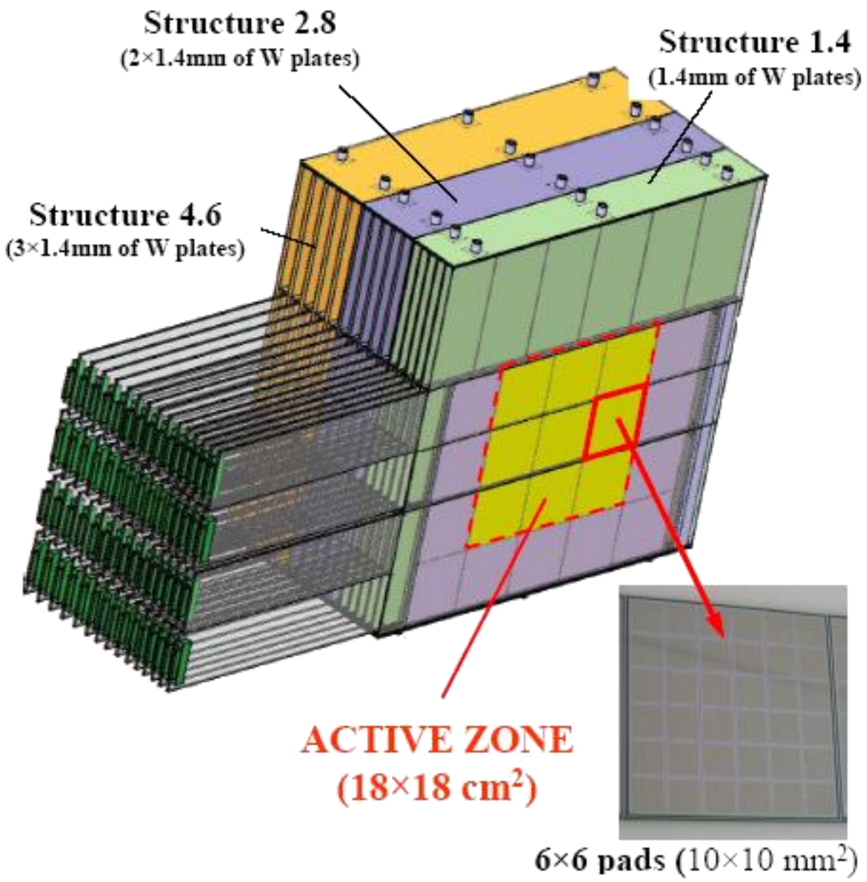


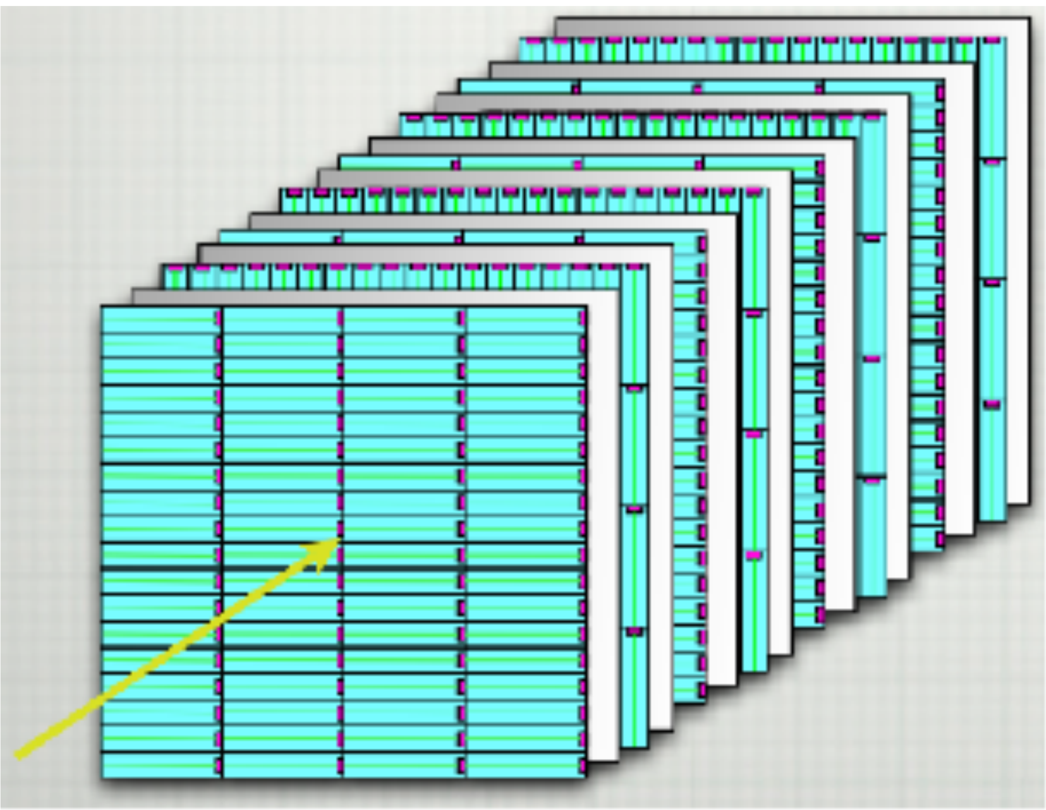
ECAL Candidates

- **Silicon-Tungsten ECAL**

  Good performance for PFA

  Dominant cost driver in the detector



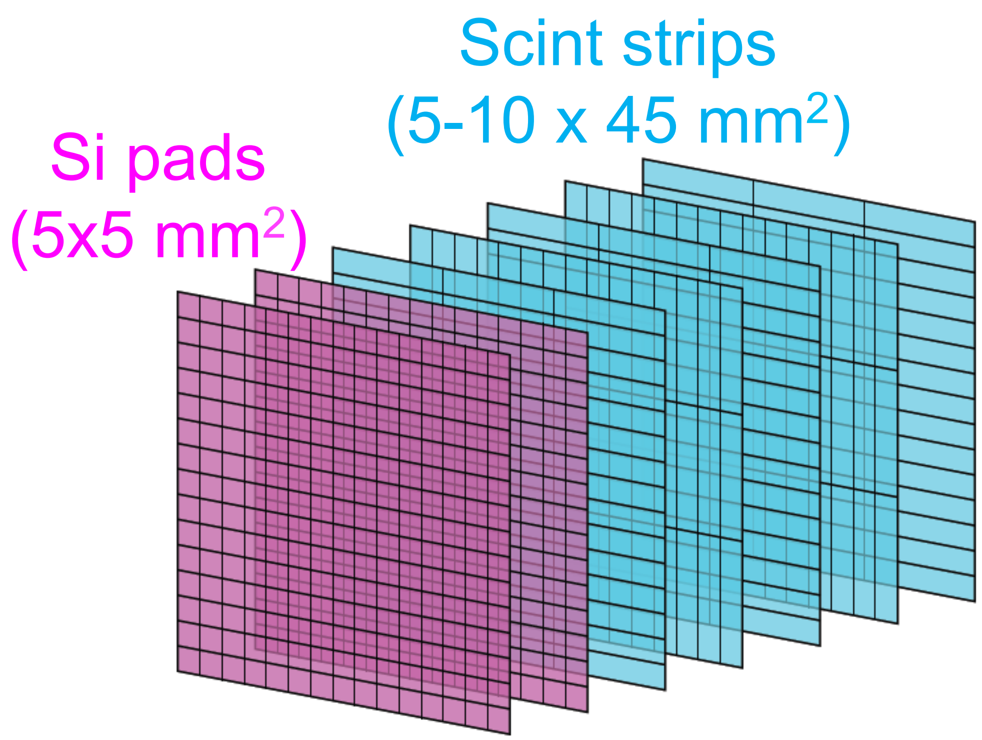


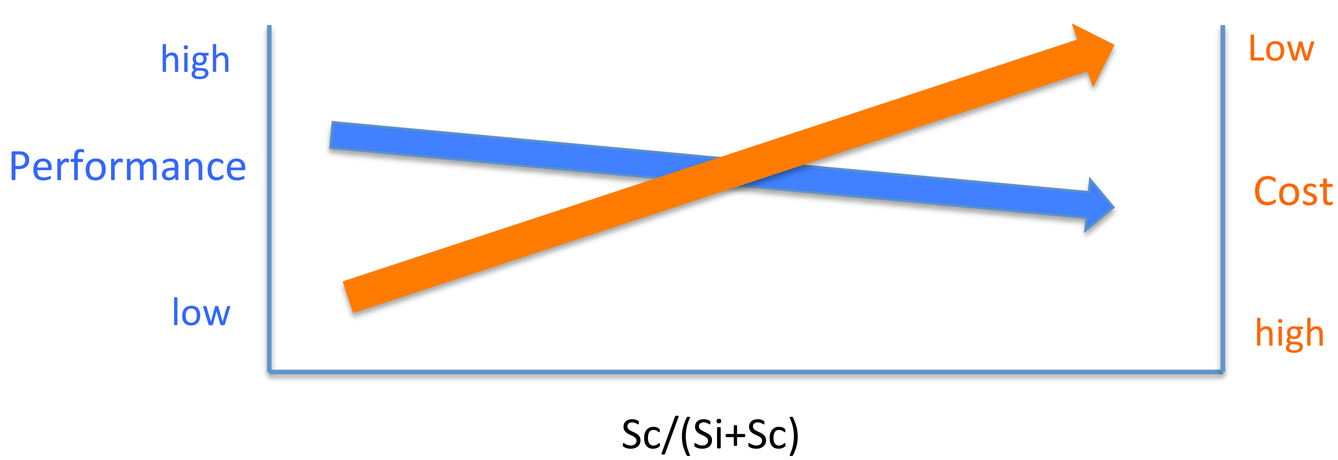
- **Scintillator-Tungsten ECAL**

  Good cost performance

  Due to its strip structure, more complicated software is needed for reconstruction

Hybrid ECAL

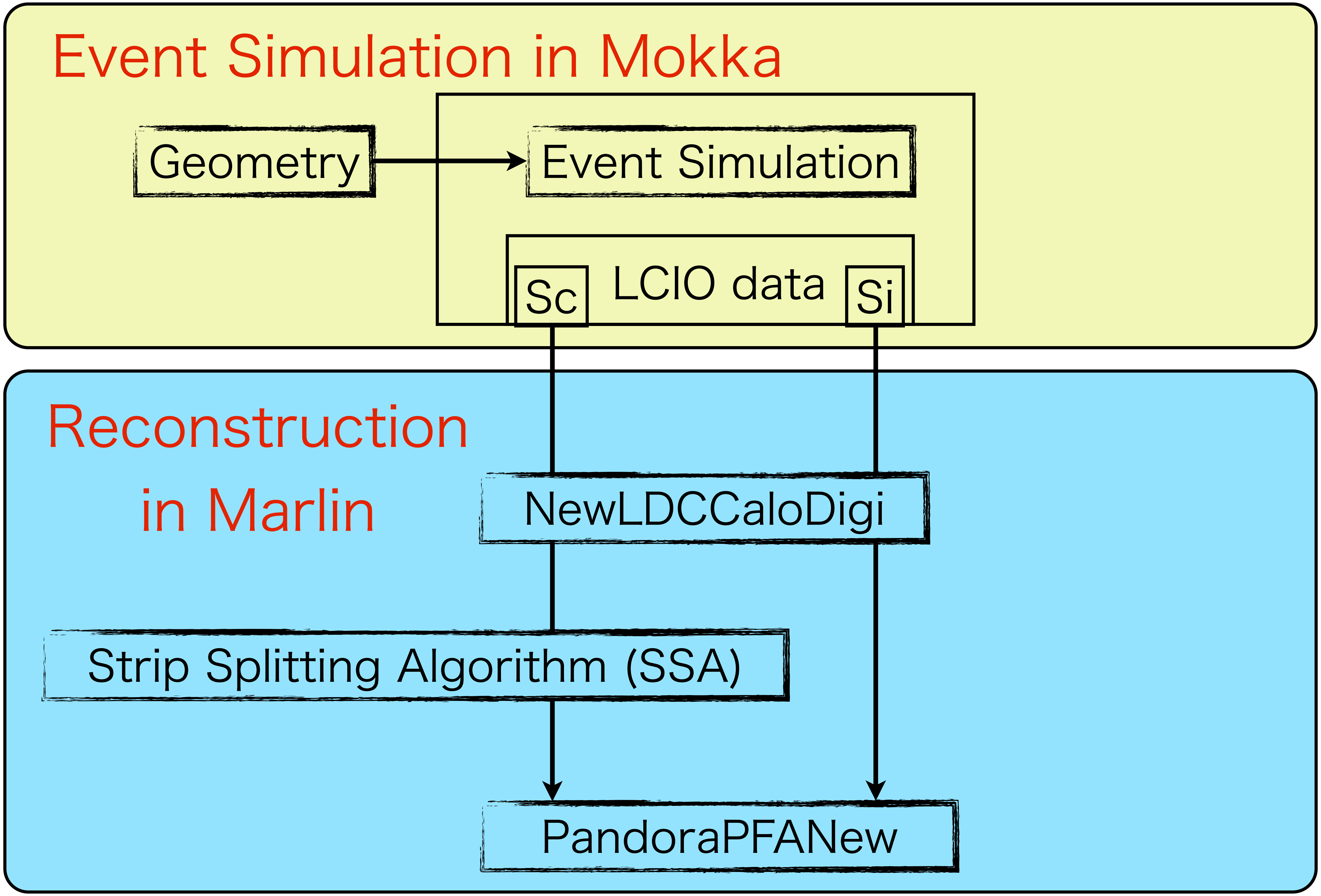




One of the solution is to use both of Silicon and Scintillator as active layer.

We've started simulation about Hybrid ECAL.

Analysis Flow



ECAL Simulation Setup

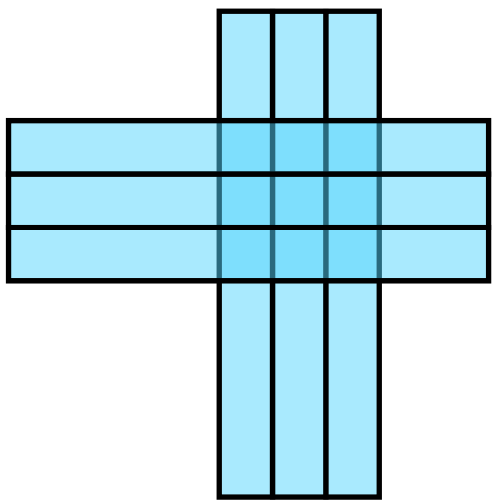
- We test following ECAL setups.

	Active layer thickness	the number of layers	Absorber(W) thickness
HybridECAL	2.0mm (Scintillator) 0.5mm (Silicon)	27	2.1mm (inner 20 layers) 3.5mm (outer 7 layers)
ScECAL	2.0mm (Scintillator)		
SiECAL	0.5mm (Silicon)		

Hybrid ECAL Configuration

Sc layer

45mmx5mm strips

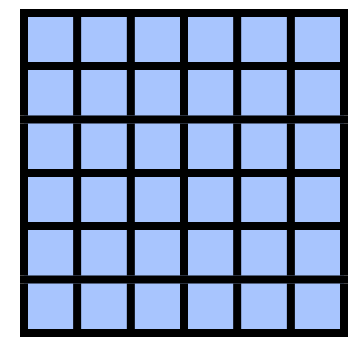


orthogonal

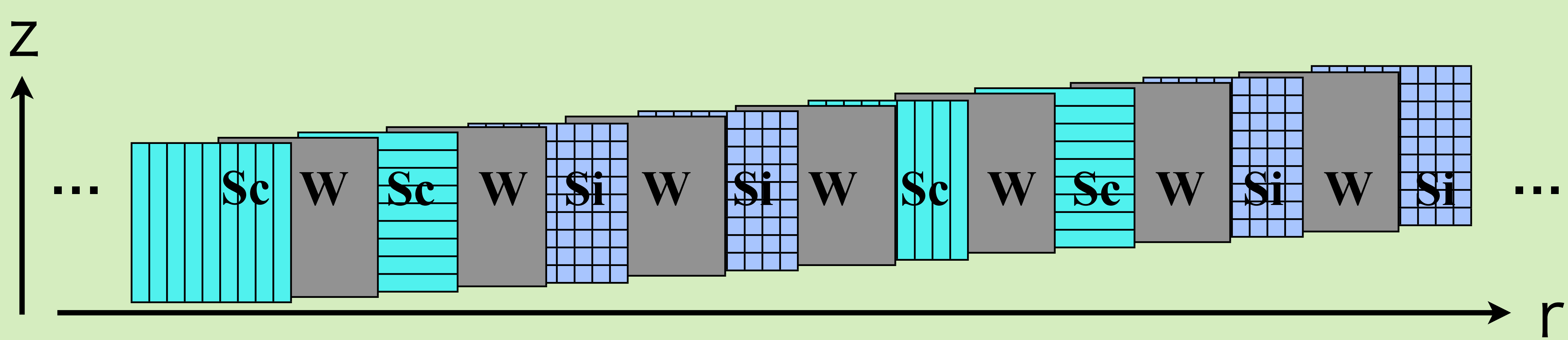
- 5mmx5mm spacial resolution
- possibility of ghost

Si layer

5mmx5mm cells



The configuration of Hybrid ECAL



Calibration Procedure

- As ILD ECAL is a sampling calorimeter, it 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
- 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.

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

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

L:thickness

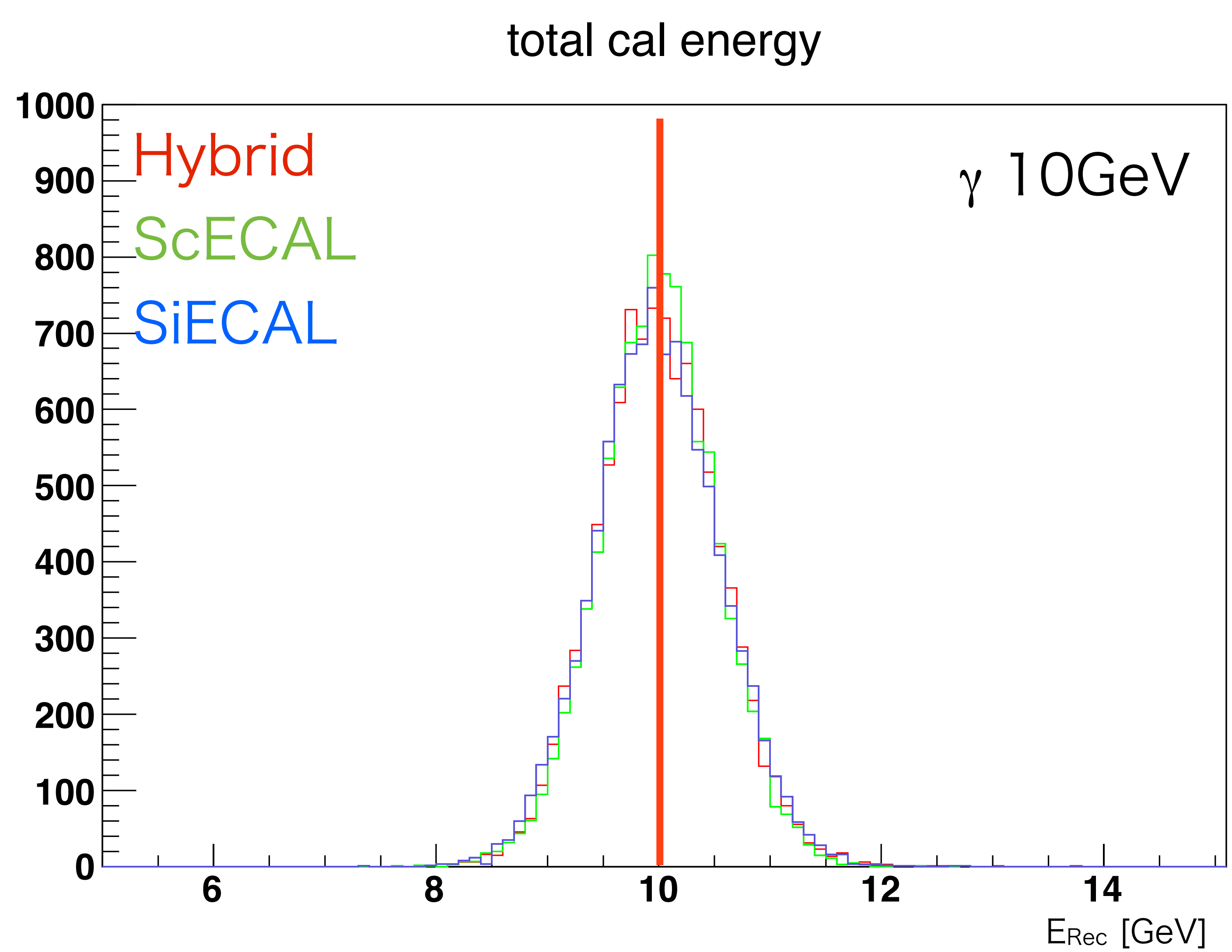
X_0:radiation length

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

$$\boxed{\therefore \quad a : b : c : d = 1 : 11.1317 : 1.67 : 1.8862}$$

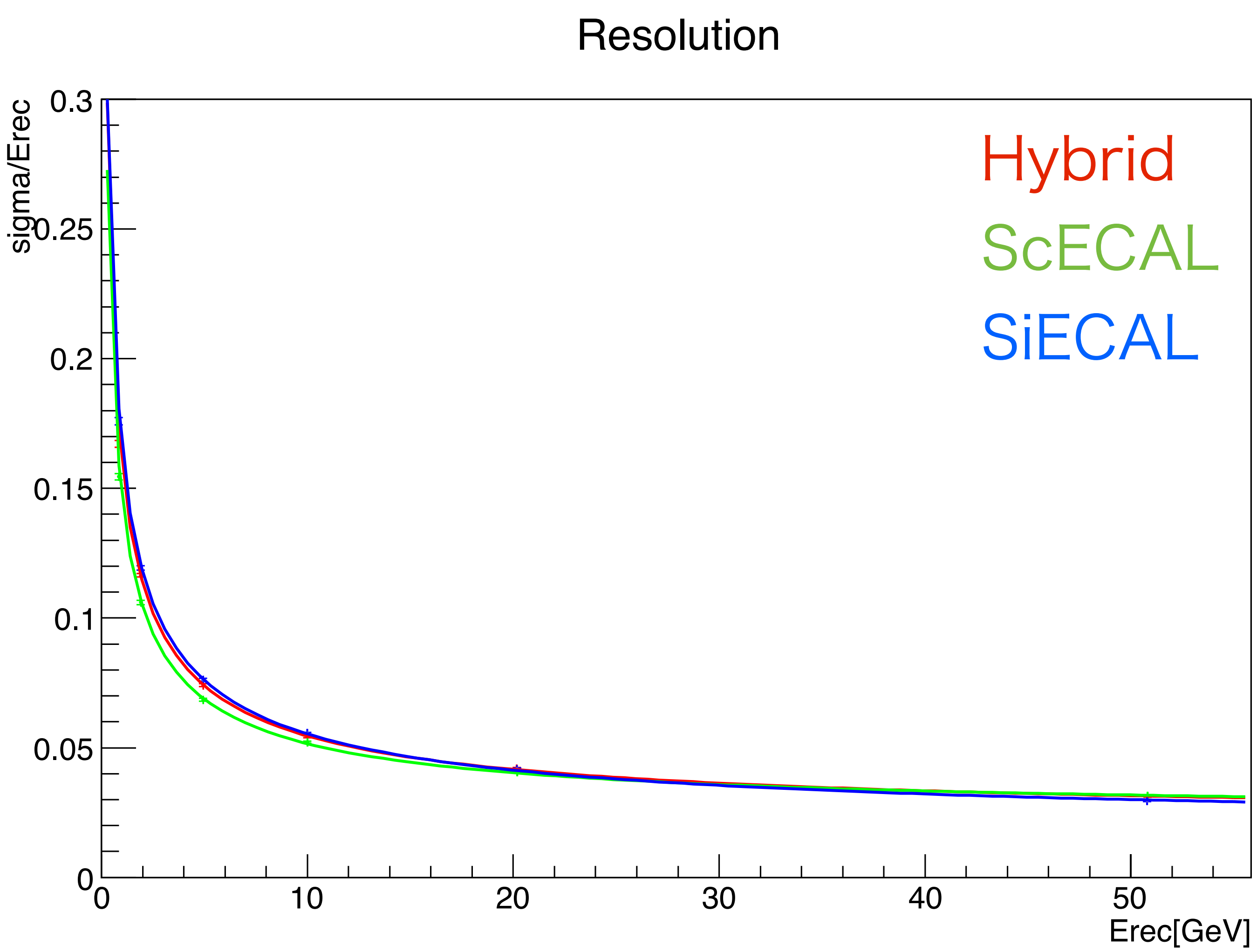
Hybrid ECAL Calibration (cont'd)

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



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.



$$\frac{\sigma}{E_{Rec}} = \sqrt{\frac{(\sigma_{stoc.})^2}{E_{Rec}} + (\sigma_{const.})^2}$$

ECAL Performance

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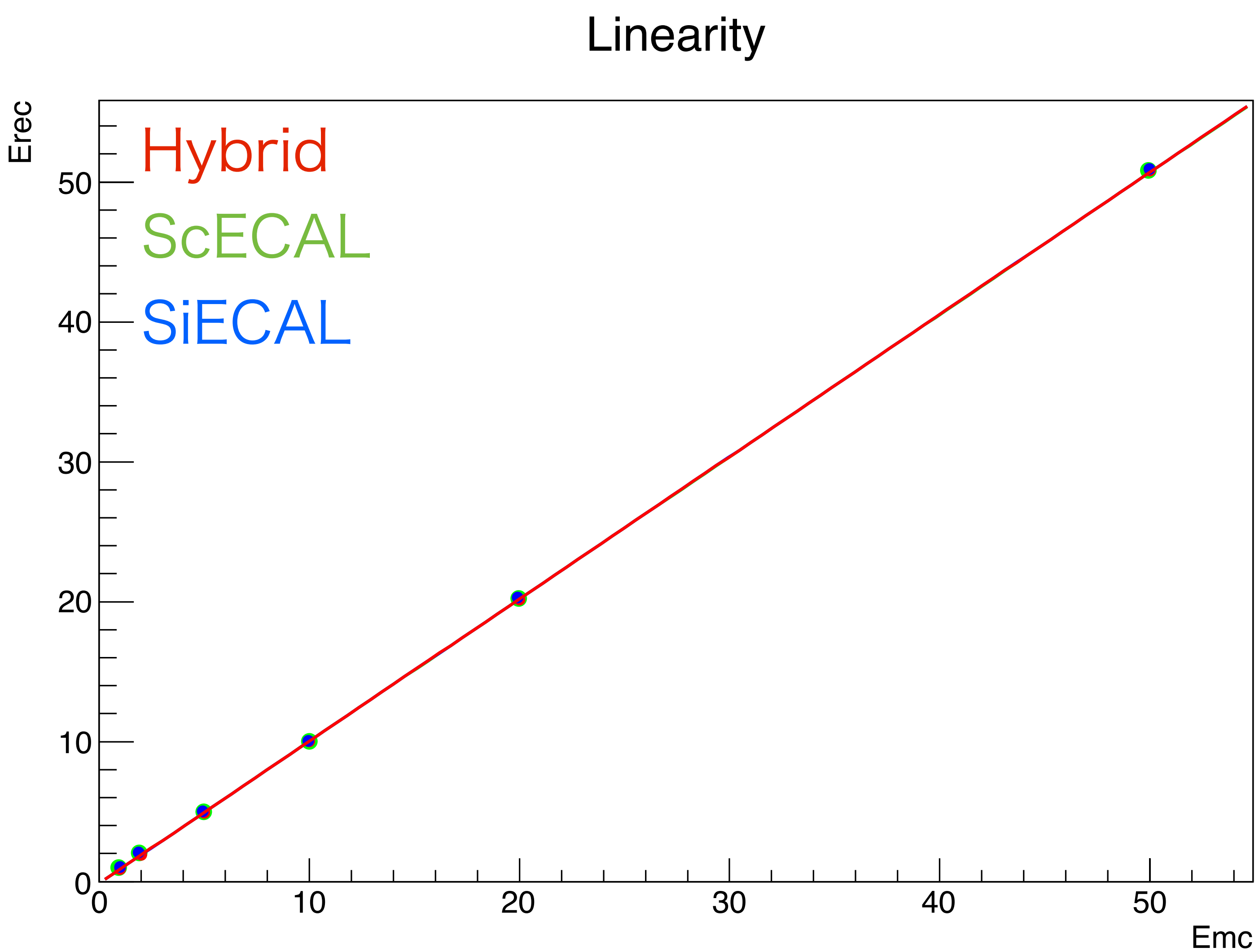
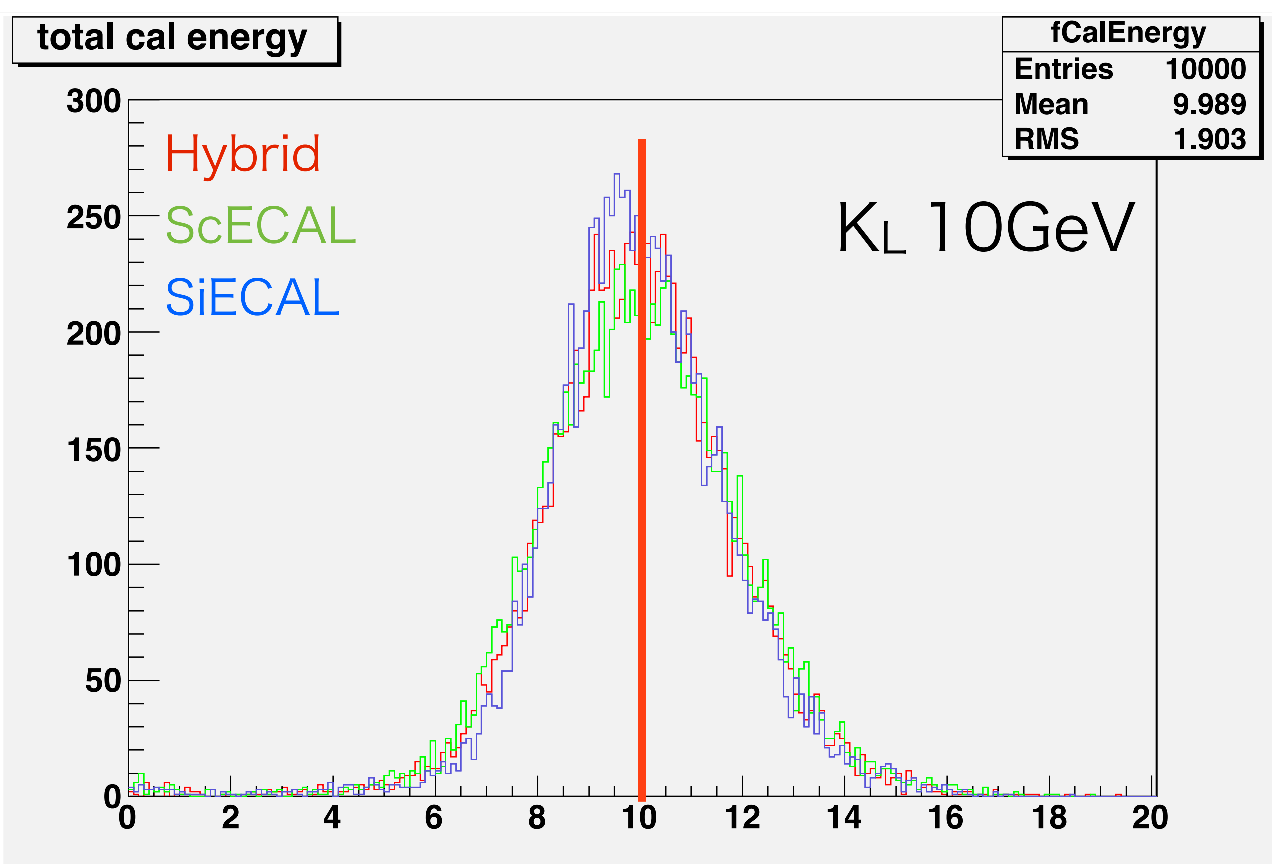


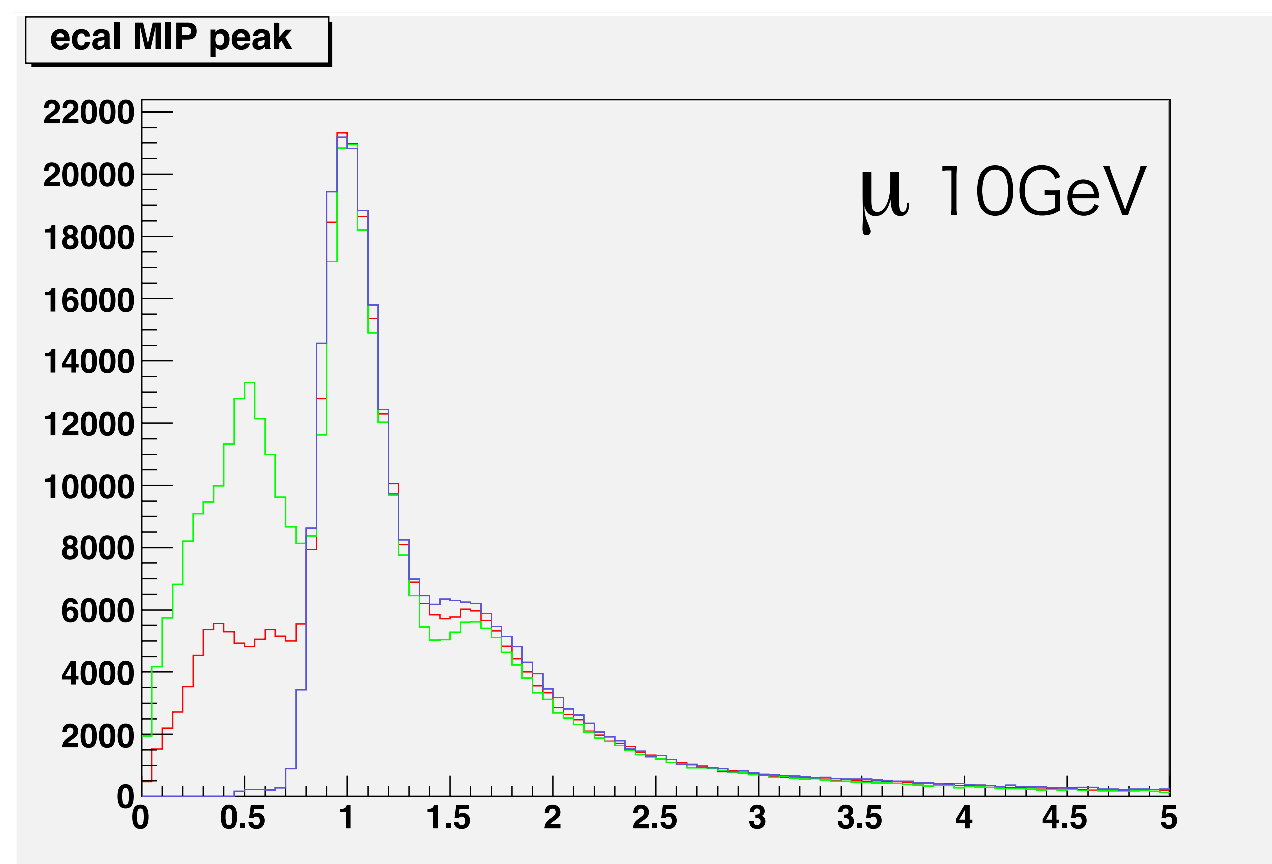
$$E_{Rec} = aE + b$$

Reasonably good

HCAL Calibration

- We calibrate for HCAL as well as ECAL.
- HCAL geometry doesn't change, therefore we confirmed its calibration constants.





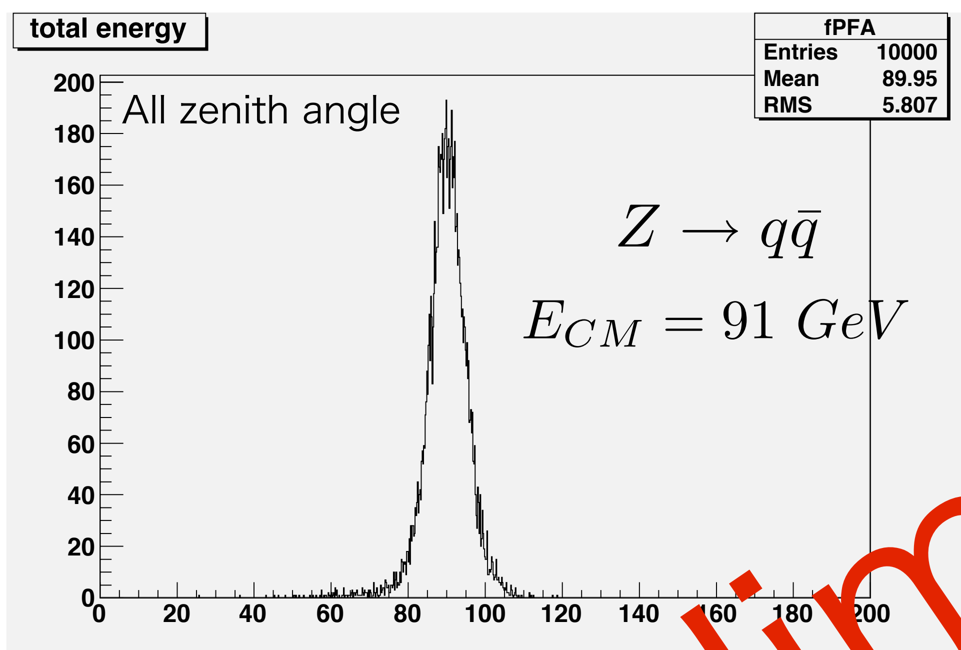
Calibration Results

		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

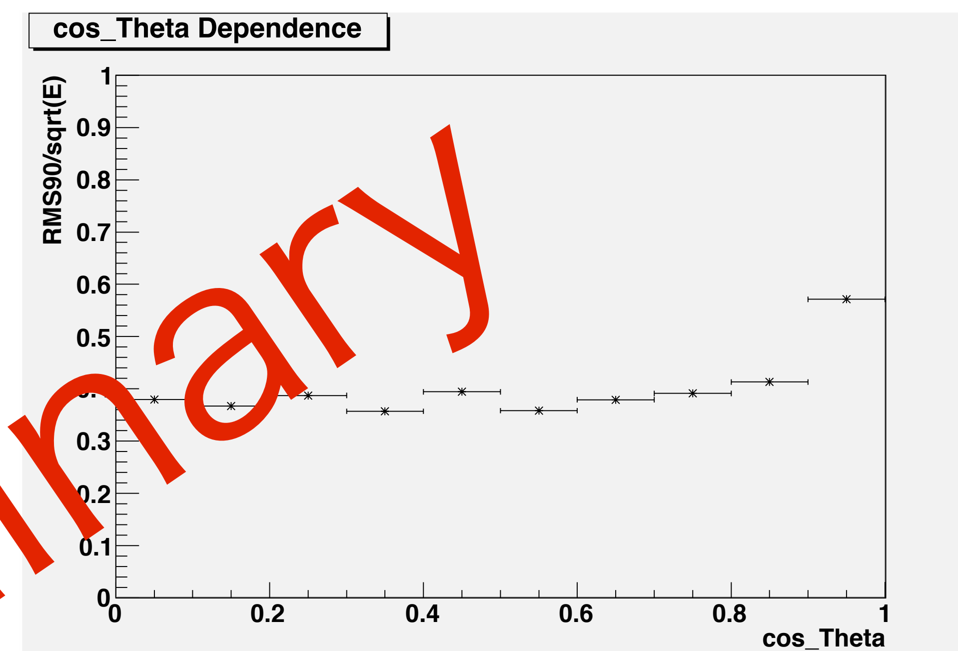
Then we evaluate jet energy resolution.

Jet Energy Resolution

- We've started to evaluate Jet Energy Resolution of Hybrid ECAL.



Hybrid ECAL+Strip Splitting Algorithm(SSA)



$RMS90_{mean} = 3.573(cos\theta \leq 0.7)$

$$\boxed{\sigma_E/E = 37.5\%/\sqrt{91GeV}}$$

preliminary

Further tuning is necessary.

Summary and Prospects

- We’ve established calibration method for Hybrid ECAL.
- We’ve just started to evaluate the performances of jet energy resolution for Hybrid ECAL.
- After improvements, this method is applied to various configurations for optimization.