九州大学
KYUSHU UNIVERSITY

international linear collider

Progress Report of Optimization of Si and Hybrid ECAL

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CALICE Calorimeter for ILC

Kyushu University RCAPP

The Goal of My Study

To optimize calorimeter *systematically*

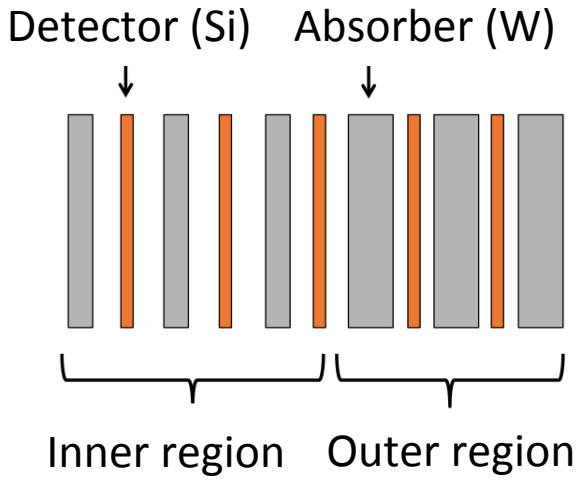
I have to study influences
by changing some parameters independently

- **Longitudinal structure** mainly influences single particle resolution
  - *thickness, the number of layers*
- **Transverse structure** mainly influences confusion
  - *pixel size, Si/Sc (or hybrid), overall size*
- **JER depends on both structures**

My Study

- This contents focus on **longitudinal structure**

- The optimization
  1. All W thickness is the same
  2. The location of the boundary between inner and outer region is changed

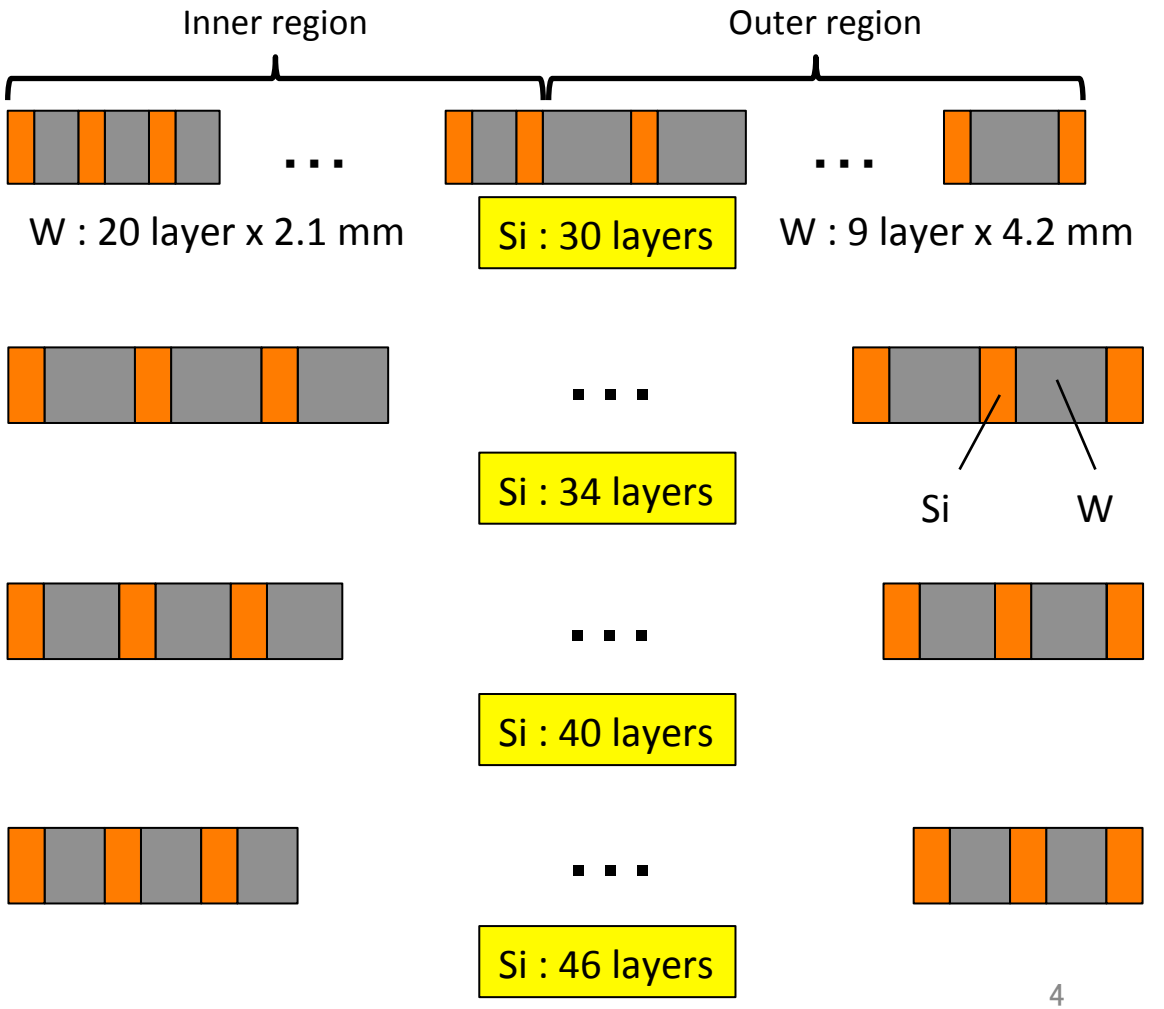


- Whole thickness of ECAL is adjusted to be almost equal for each configuration

The Same Thickness

- Configuration

※ Si : 0.5mm



Design value (Default)

Whole thickness : 22.8X_0

W_33 layer x 2.48 mm

Whole thickness : 23.38X_0

W_39 layer x 2.1 mm

Whole thickness : 23.4X_0

W_45 layer x 1.82 mm

Whole thickness : 23.4X_0

Calibration Method

In CaloDigi

EM calibration by using 10GeV photon hit energy @CAL

Changed parameters in xml file

CalibrECAL

In CaloDigi

MIP calibration by using 10GeV muon+ hit energy @CAL

ECalToMipCalibration

In CaloDigi

Neutral hadron calibration

Neutral hadron calibration by using 10GeV K_L^0 hit energy @CAL

CalibrHCAL

Neutral hadron calibration by using 10GeV K_L^0 PFO energy

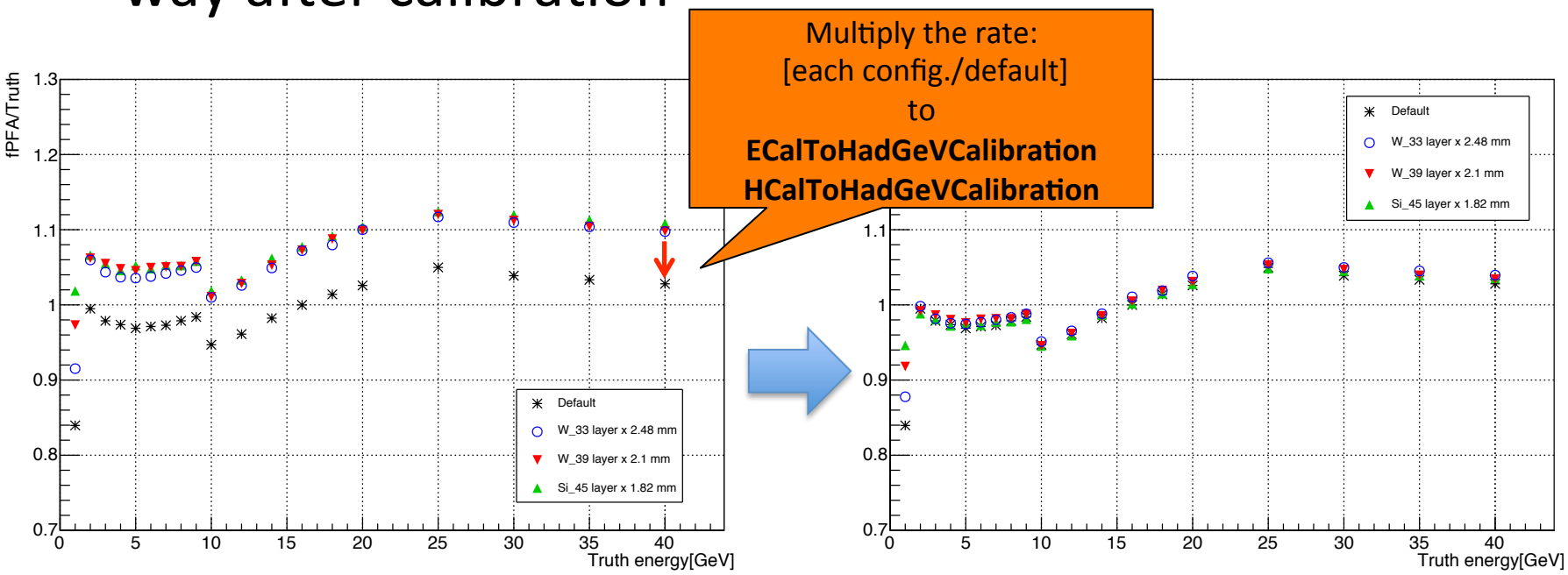
ECalToHadGeVCalibration

HCalToHadGeVCalibration

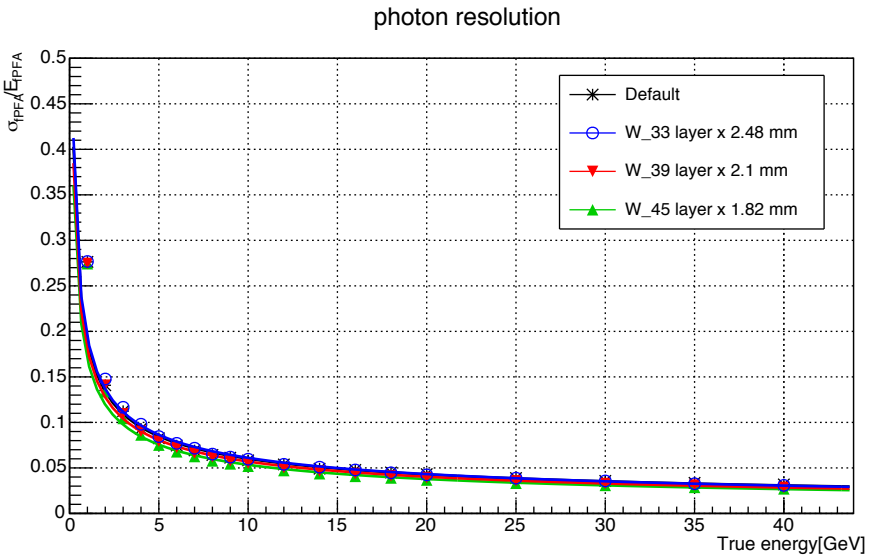
In PandoraPFA

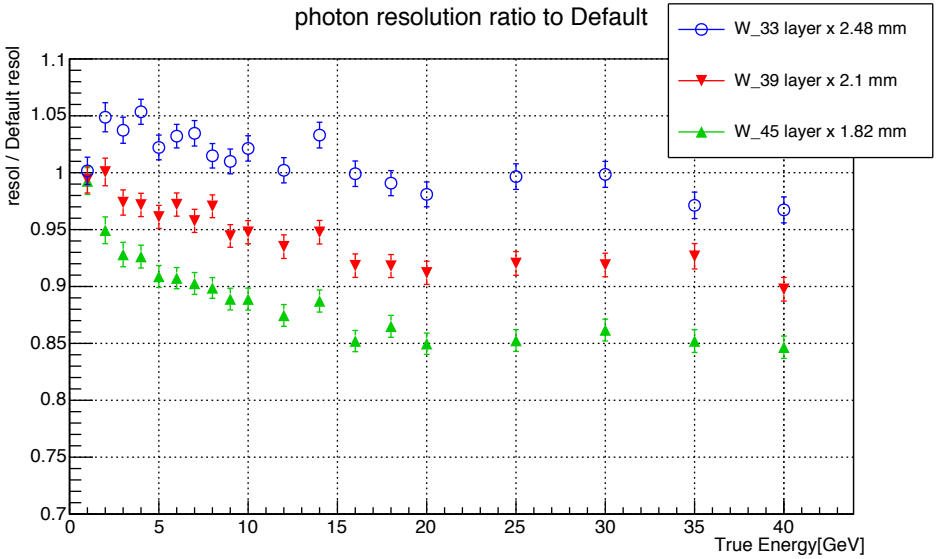
One Problem in Marlin

- The value of PFO data and that of Mokka data do not accord for neutral hadron (K_L^0) after calibration
- Now, I deal with this problem to use the following way after calibration



Energy Resolution for Photon



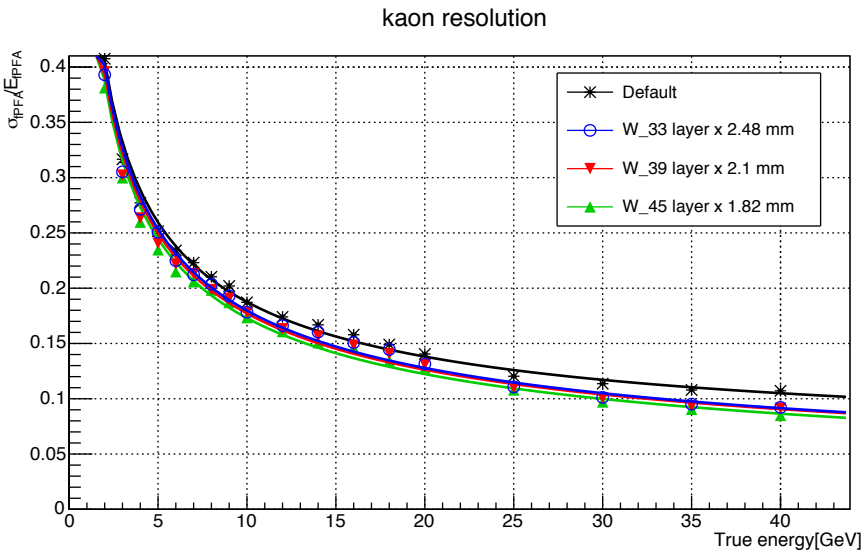


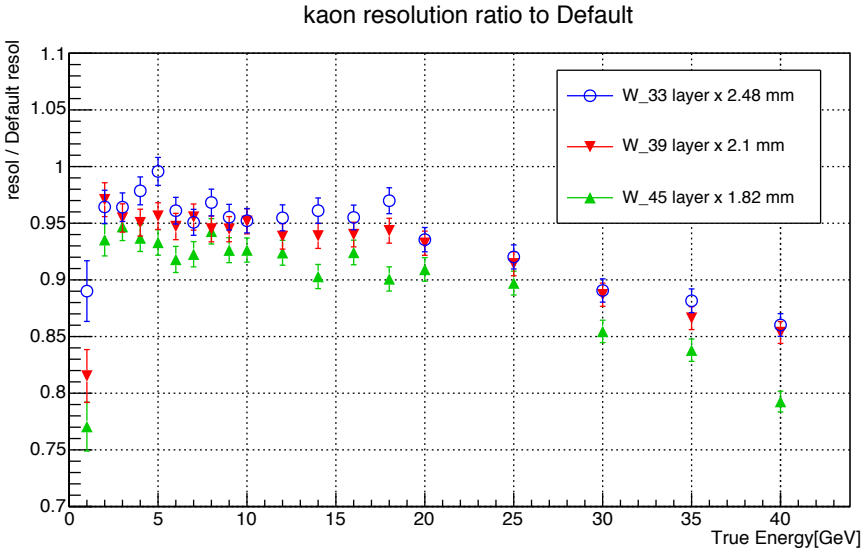
	stoch. [%]	const. [%]
Default	**18.05±0.07**	**1.42±0.06**
W_33 x 2.48	**18.83±0.07**	**0.77±0.10**
W_39 x 2.1	**17.56±0.06**	**0.67±0.10**
W_45 x 1.82	**16.58±0.05**	**0.31±0.19**

Fit function : $\frac{\sigma}{E} = \sqrt{\frac{(\text{stoch.})^2}{E} + (\text{const.})^2}$

- All configurations have good const. terms
- The resolutions @ >20GeV are better than that of default
- It can be caused by the number of Si layers in outer region of ECAL

Energy Resolution for kaon





	stoch. [%]	const. [%]
Default	**55.24±0.02**	**6.18±0.01**
W_33 x 2.48	**55.07±0.02**	**3.73±0.19**
W_39 x 2.1	**54.12±0.02**	**3.79±0.18**
W_45 x 1.82	**53.03±0.02**	**3.32±0.19**

Fit function : $\frac{\sigma}{E} = \sqrt{\frac{(\text{stoch.})^2}{E} + (\text{const.})^2}$

- const. term of default is worse than other configuration (caused by the number of Si layers in backward region of ECAL)
- There are no significant differences between each configuration

JER

91GeV	JER [%]
Default	3.69±0.05
W_33 x 2.48	3.73±0.05
W_39 x 2.1	3.55±0.05
W_45 x 1.82	3.56±0.05

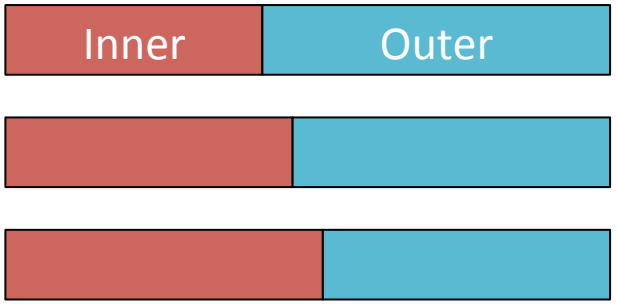
- There is no significant difference between W_39 x 2.1 and W_45 x 1.82

- It can be caused by the resolution of neutral hadron

The Thickness of Inner and Outer Region

- Configuration
  - The change of the boundary between inner and outer region

1. Inner : Outer = 34 mm : 46 mm
2. Inner : Outer = 38 mm : 42 mm
3. Inner : Outer = 42 mm : 38 mm



  - The number of W layers in inner and outer region are changed for upper configurations (Total 29 layers)
    i. Inner : Outer = 22 layer : 7 layer
    ii. Inner : Outer = 20 layer : 9 layer
    iii. Inner : Outer = 18 layer : 11 layer
    iv. Inner : Outer = 16 layer : 13 layer
  - **Si and W are alternated**

Energy resolution for photon

layer \ thickness		1) In 34 + Out 46	2) In 38 + Out 42	3) In 42 + Out 38
i) In 22 + Out 7	real thick	*In 33.66 + Out 46.2*	*In 37.84 + Out 42*	*In 42.02 + Out 37.8*
	stoch.	**18.31±0.08%**	**17.76±0.07%**	**17.72±0.07%**
	const.	**2.47±0.04%**	**1.97±0.04%**	**1.62±0.05%**
ii) In 20 + Out 9	real thick	*In 33.6 + Out 46.17*	*In 37.8 + Out 41.94*	*In 42 + Out 37.8*
	stoch.	**17.90±0.07%**	**17.89±0.07%**	**18.05±0.07%**
	const.	**2.35±0.04%**	**1.75±0.05%**	**1.42±0.06%**
iii) In 18 + Out 11	real thick	*In 33.48 + Out 46.2*	*In 37.8 + Out 41.91*	*In 41.94 + Out 37.73*
	stoch.	**18.08±0.07%**	**18.21±0.07%**	**18.61±0.07%**
	const.	**2.08±0.04%**	**1.59±0.05%**	**1.16±0.07%**
iV) In 16 + Out 13	real thick	*In 33.6 + Out 46.15*	*In 37.76 + Out 41.99*	*In 41.92 + Out 37.83*
	stoch.	**18.35±0.07%**	**18.80±0.07%**	**19.40±0.07%**
	const.	**1.84±0.05%**	**1.25±0.06%**	**0.90±0.09%**

Default

There are no any significant dependences

Energy resolution for kaon

layer \ thickness		1) In 34 + Out 46	2) In 38 + Out 42	3) In 42 + Out 38
i) In 22 + Out 7	real thick	*In 33.66 + Out 46.2*	*In 37.84 + Out 42*	*In 42.02 + Out 37.8*
	stoch.	**55.29±0.02%**	**55.49±0.02%**	**54.54±0.02%**
	const.	**7.11±0.01%**	**6.19±0.01%**	**6.09±0.01%**
ii) In 20 + Out 9	real thick	*In 33.6 + Out 46.17*	*In 37.8 + Out 41.94*	*In 42 + Out 37.8*
	stoch.	**55.28±0.02%**	**54.98±0.02%**	**55.24±0.02%**
	const.	**5.85±0.01%**	**5.58±0.01%**	**6.18±0.01%**
iii) In 18 + Out 11	real thick	*In 33.48 + Out 46.2*	*In 37.8 + Out 41.91*	*In 41.94 + Out 37.73*
	stoch.	**54.75±0.02%**	**55.67±0.02%**	**55.43±0.02%**
	const.	**5.68±0.01%**	**4.70±0.02%**	**4.51±0.02%**
iV) In 16 + Out 13	real thick	*In 33.6 + Out 46.15*	*In 37.76 + Out 41.99*	*In 41.92 + Out 37.83*
	stoch.	**55.61±0.02%**	**55.61±0.02%**	**55.76±0.02%**
	const.	**4.55±0.02%**	**4.26±0.02%**	**4.14±0.02%**

Default

There are also no any significant dependences

JER

layer \ thickness		1) In 34 + Out 46	2) In 38 + Out 42	3) In 42 + Out 38
i) In 22 + Out 7	real thick	*In 33.66 + Out 46.2*	*In 37.84 + Out 42*	*In 42.02 + Out 37.8*
	JER	**3.98±0.05%**	**3.84±0.05%**	**3.87±0.05%**
ii) In 20 + Out 9	real thick	*In 33.6 + Out 46.17*	*In 37.8 + Out 41.94*	*In 42 + Out 37.8* Default
	JER	**3.86±0.05%**	**3.71±0.05%**	**3.69±0.05%**
iii) In 18 + Out 11	real thick	*In 33.48 + Out 46.2*	*In 37.8 + Out 41.91*	*In 41.94 + Out 37.73*
	JER	**3.80±0.05%**	**3.82±0.05%**	**3.76±0.05%**
iV) In 16 + Out 13	real thick	*In 33.6 + Out 46.15*	*In 37.76 + Out 41.99*	*In 41.92 + Out 37.83*
	JER	**3.76±0.05%**	**3.81±0.05%**	**3.79±0.05%**

JER of default design is the best of all

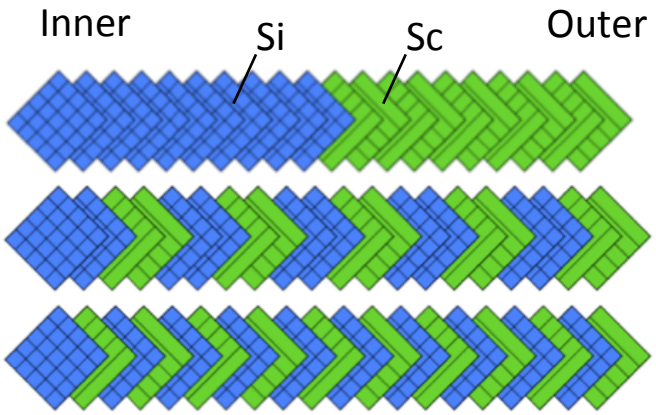
Outlook

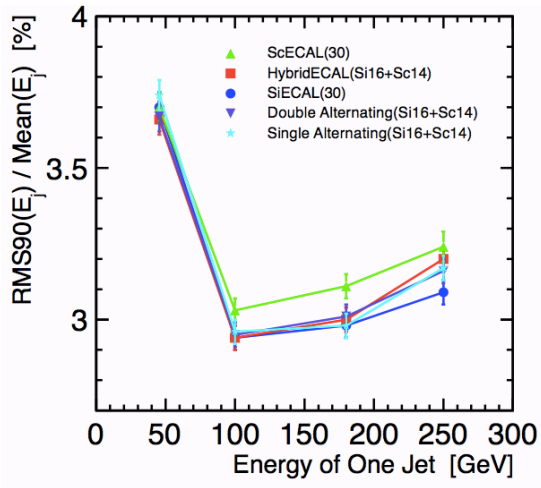
- I will study the longitudinal structure with
  - JER @ higher energy (>91GeV)
  - wider range of parameters
  - optimization by changing the number of layers

Previous Study of Transverse Structure by Hiraku

- Configuration of Si and Sc

Config. [Num of Si or Sc]	Si	Sc	W(inner/outer) [mm]	thickness of ECAL
SiECAL[Si30]	30	0	2.1x20/4.2x9	185.0mm
Hybrid[Si16+Sc14]	16	14	2.1x20/3.6x9	204.8mm
Double layers alternate[Si16+Sc14]	16	14	2.1x20/3.6x9	204.8mm
Single layer alternate[Si16+Sc14]	16	14	2.1x20/3.6x9	204.8mm
ScECAL[Sc30]	0	30	2.1x20/2.9x9	224.6mm

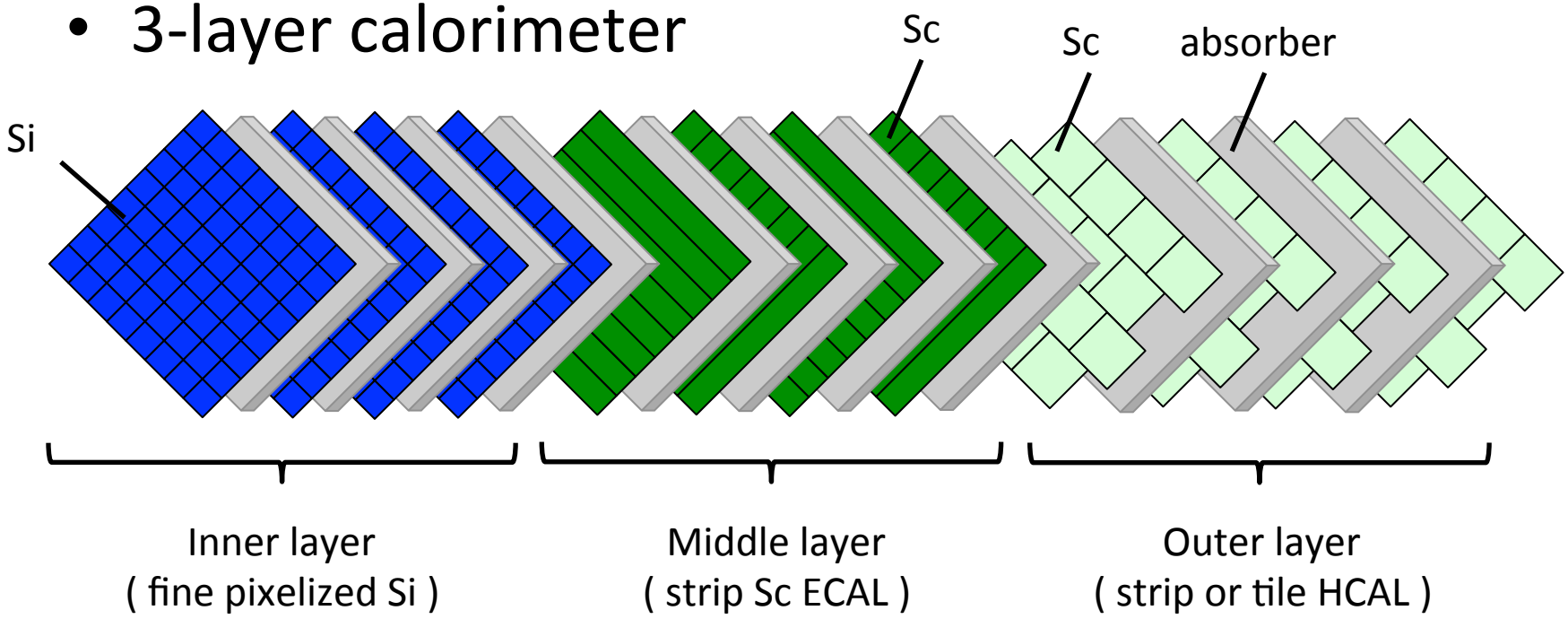




- There is no significant difference between hybrid and alternating hybrid
- In my study, the hybrid structures with no alternating can be used

Plan of New Structure

- 3-layer calorimeter

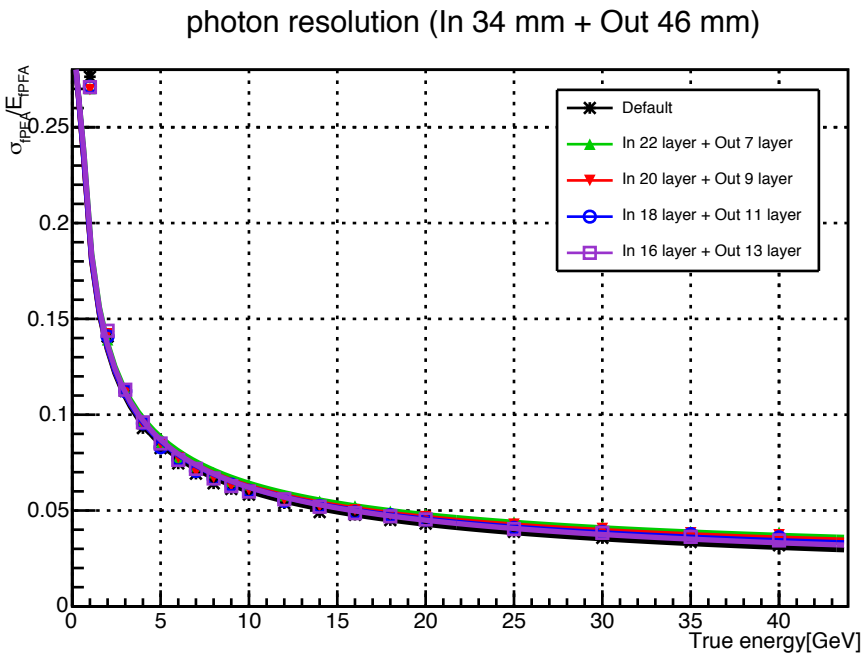


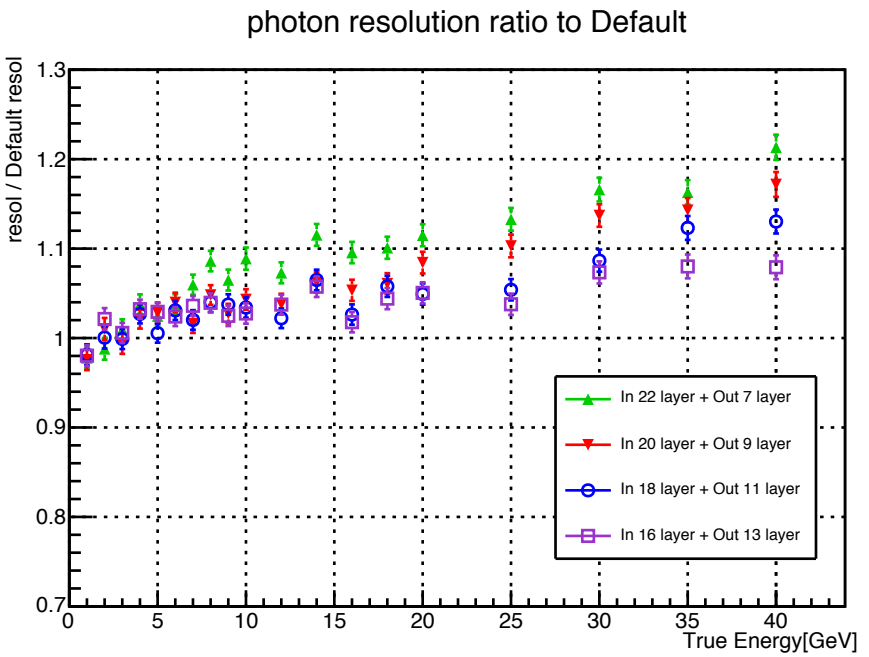
- I will also study this optimization by changing pixel size, radius of technology border and so on

Back up

Energy Resolution for Photon

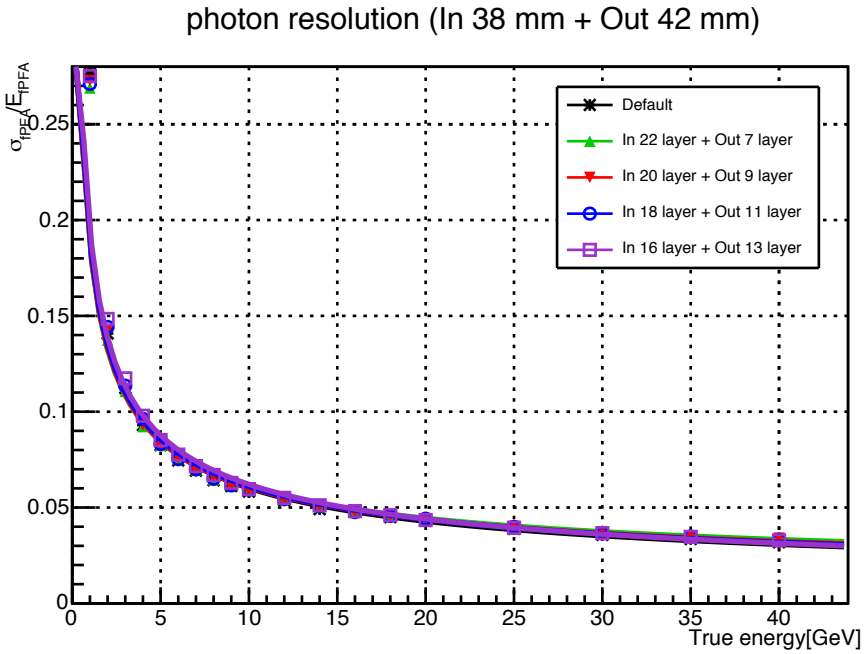
- Inner : Outer = 34 mm : 46 mm

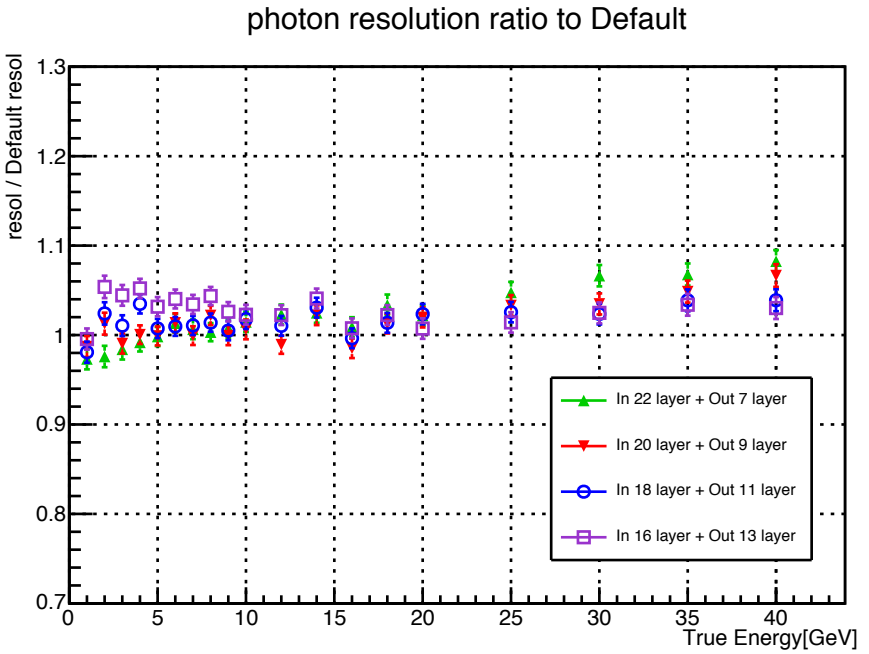




Energy Resolution for Photon

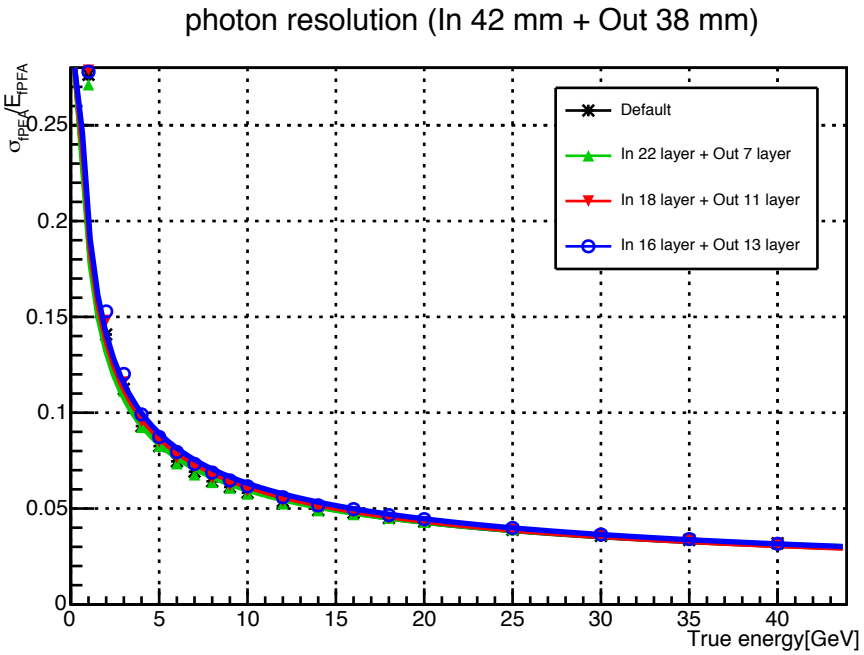
- Inner : Outer = 38 mm : 42 mm

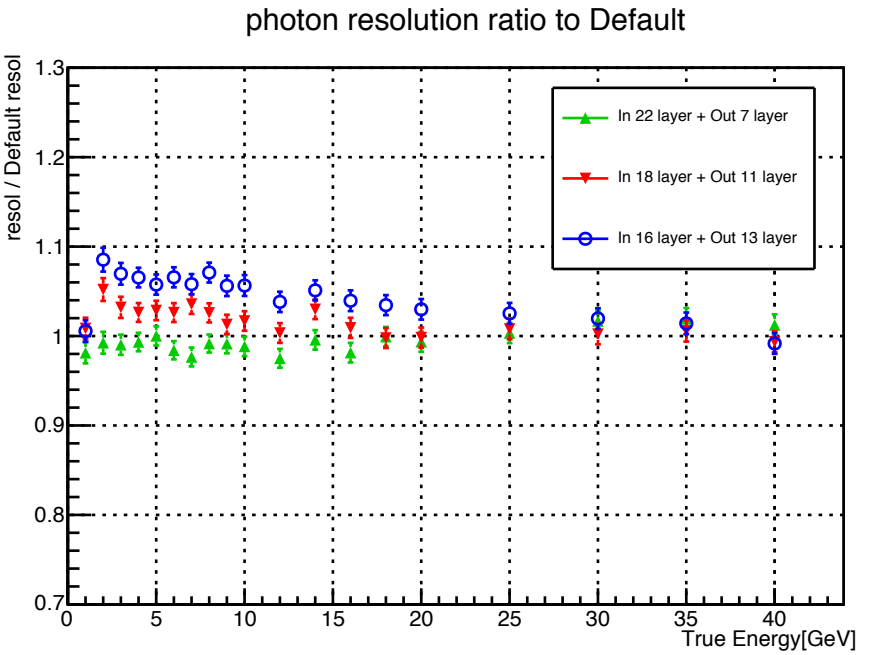




Energy Resolution for Photon

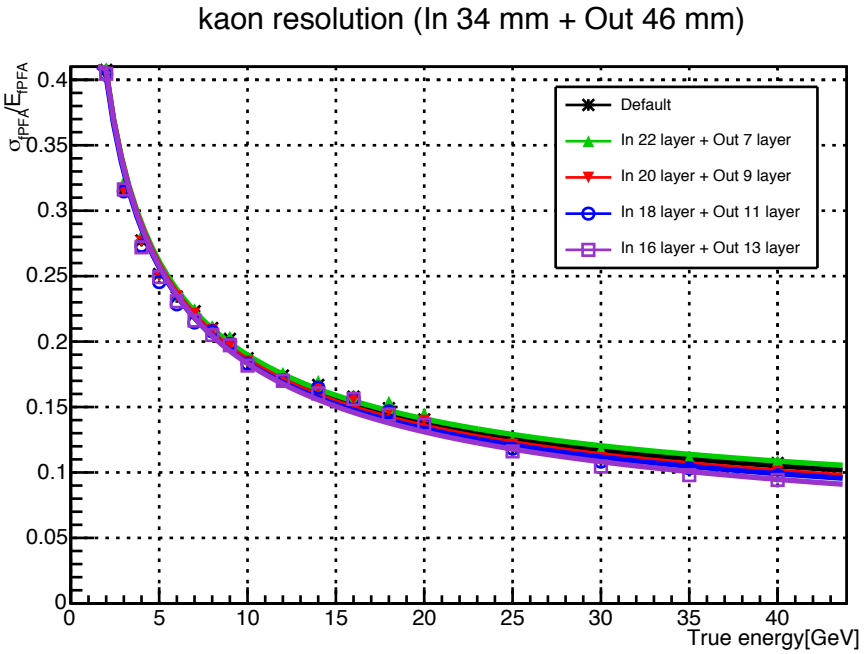
- Inner : Outer = 42 mm : 38 mm

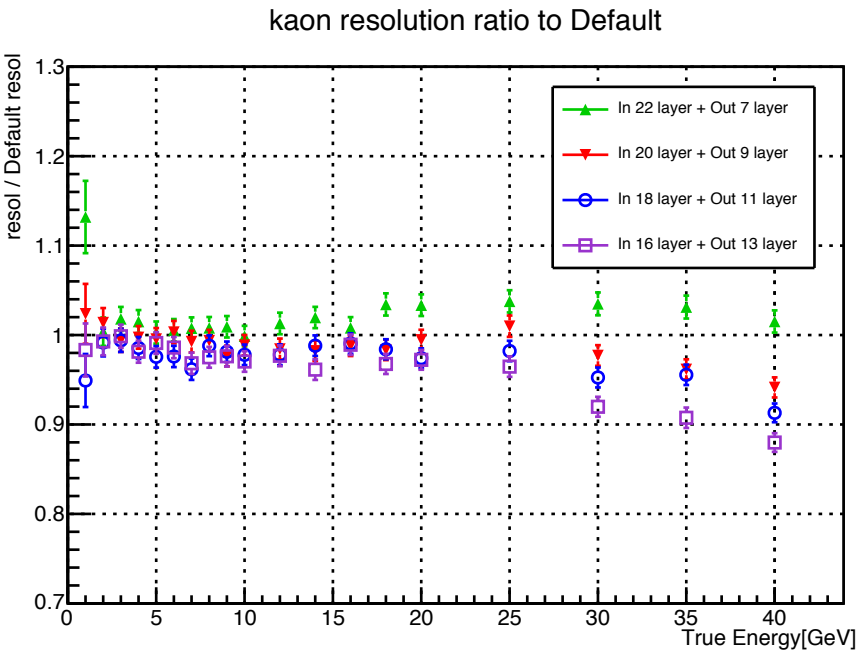




Energy Resolution for Kaon

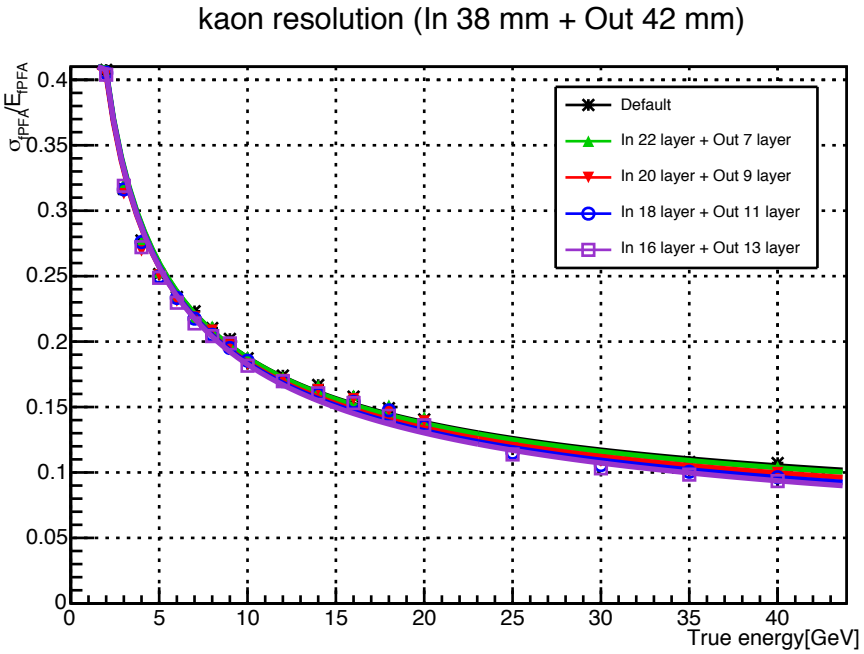
- Inner : Outer = 34 mm : 46 mm

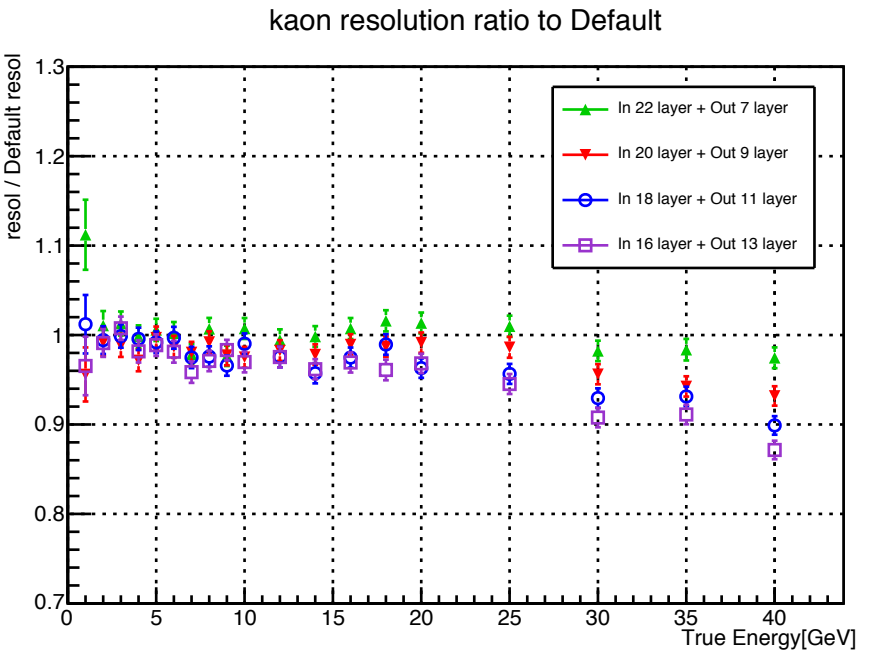




Energy Resolution for Kaon

- Inner : Outer = 38 mm : 42 mm





Energy Resolution for Kaon

- Inner : Outer = 42 mm : 38 mm