九州大学
KYUSHU UNIVERSITY

international linear collider

Progress Report of Optimization of Si and Hybrid ECAL

Hiroki Sumida
H.Ueno, Y.Sudo, T.Suehara, T.Yoshioka, K.Kawagoe,
T.Takeshita, K.Kotera, D.Jeans,
CALICE Asia group, ILD ECAL group
Kyushu Univ., Shinshu Univ., Univ. of Tokyo

CALICE Calorimeter for ILC

Kyushu University RCAPP

The Goal of My Study

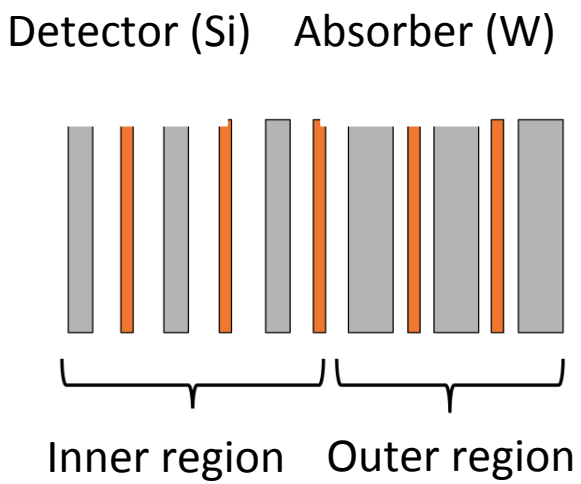
To optimize calorimeter *systematically*

I have to study effects
by changing some parameters independently

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

My Study

- This contents focus on **longitudinal structure**



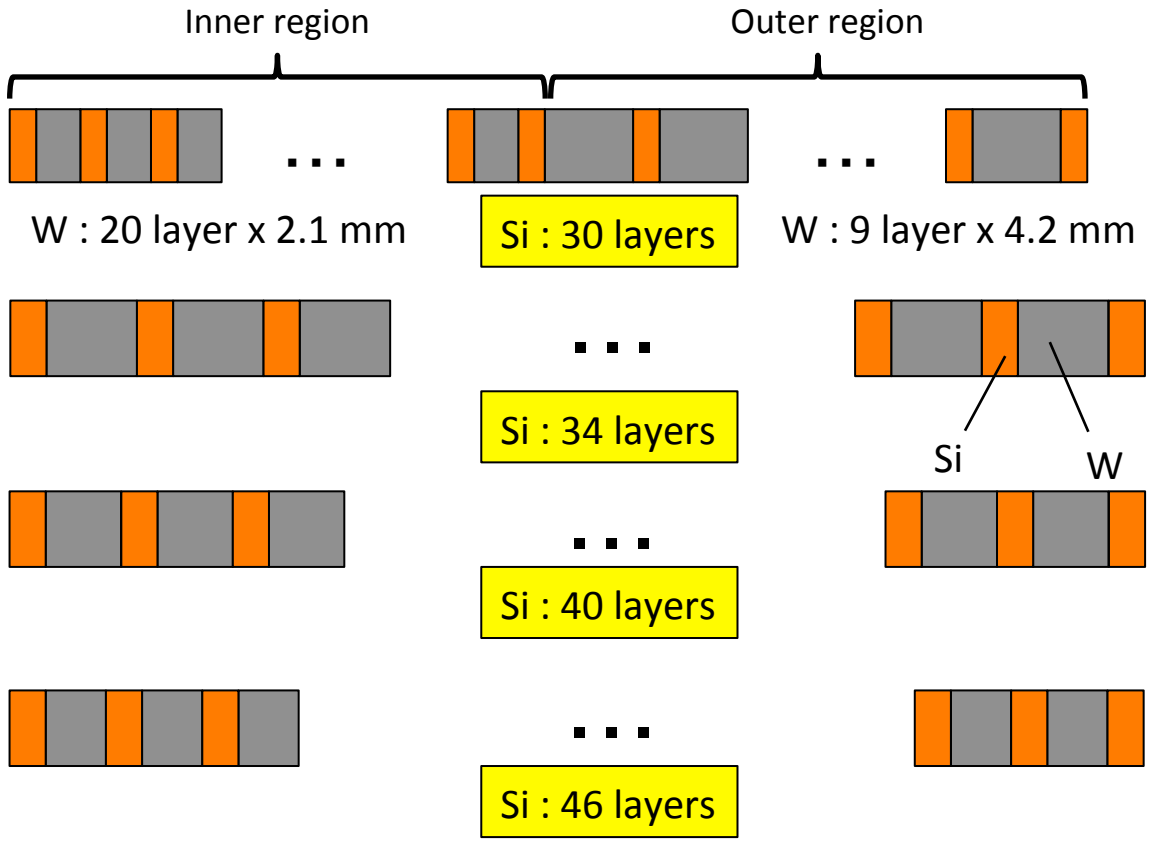
- The optimization
  1. All W thickness are the same
  2. The location of the boundary between inner and outer region is changed

- Whole thickness of ECAL is adjusted to be almost equal for each configuration
- Simulation
  - total : 10000 events
  - angle : > 75° (for photon and kaon), > 45° (for Jets)
  - Version : Detector model ILD-o1_v05 and PandoraPFANew v00-09

The Same Thickness

- Configuration

※ Si : 0.5mm



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

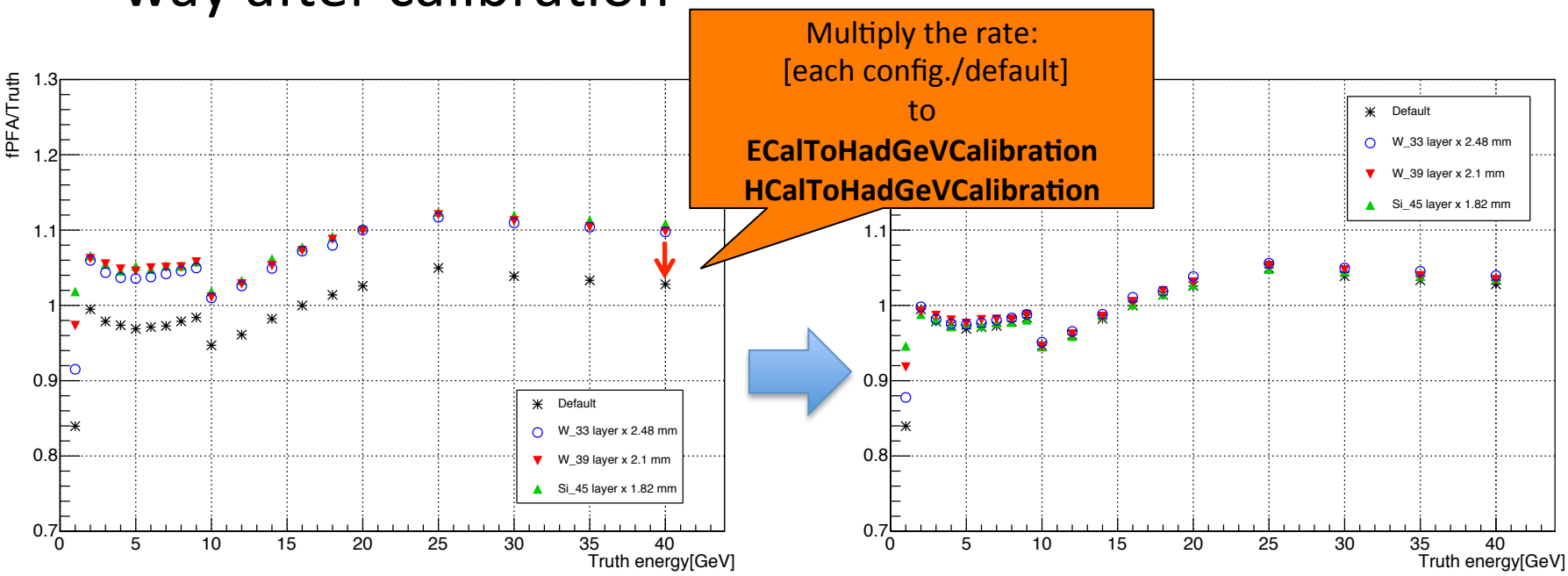
ECalToHadGeVCalibration

HCalToHadGeVCalibration

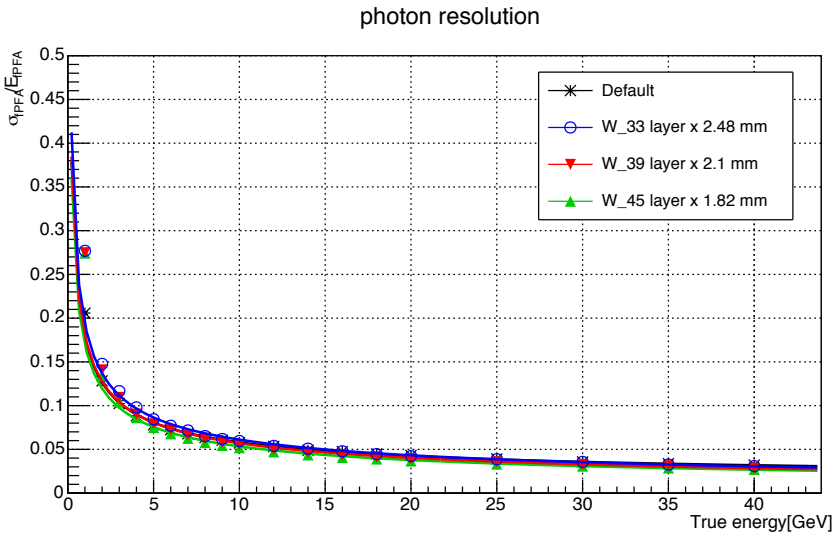
In PandoraPFA

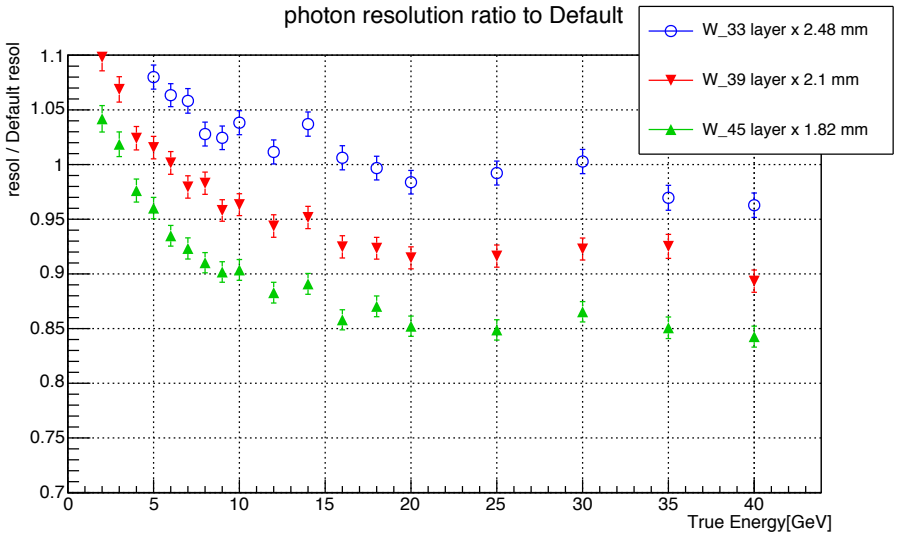
One Problem in Marlin

- 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



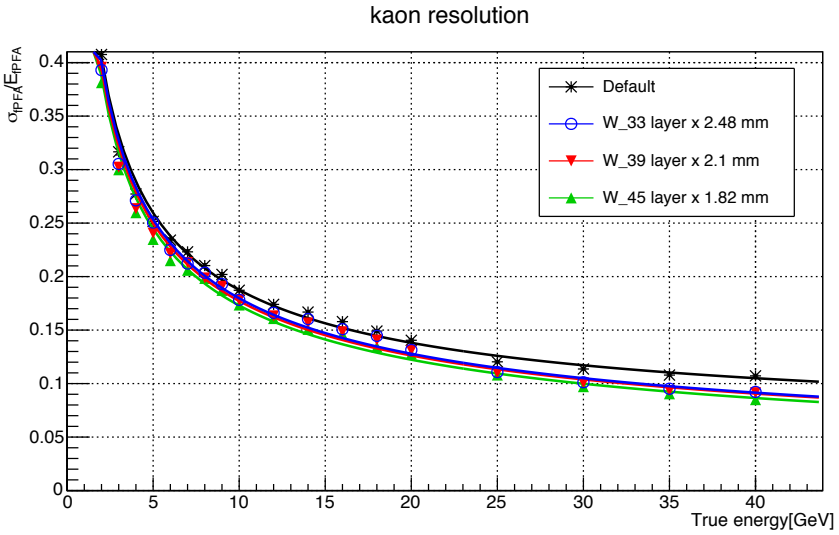


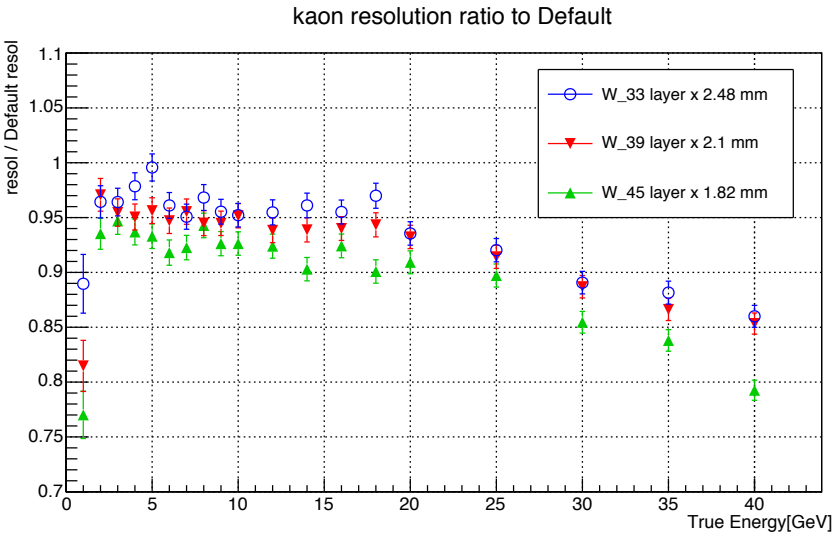
	stoch. [%]	const. [%]
Default	**17.16±0.06**	**1.82±0.04**
W_33 x 2.48	**18.83±0.07**	**0.77±0.10**
W_39 x 2.1	**17.56±0.06**	**0.67±0.10**
W_45 x 1.82	**16.58±0.06**	**0.31±0.19**

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



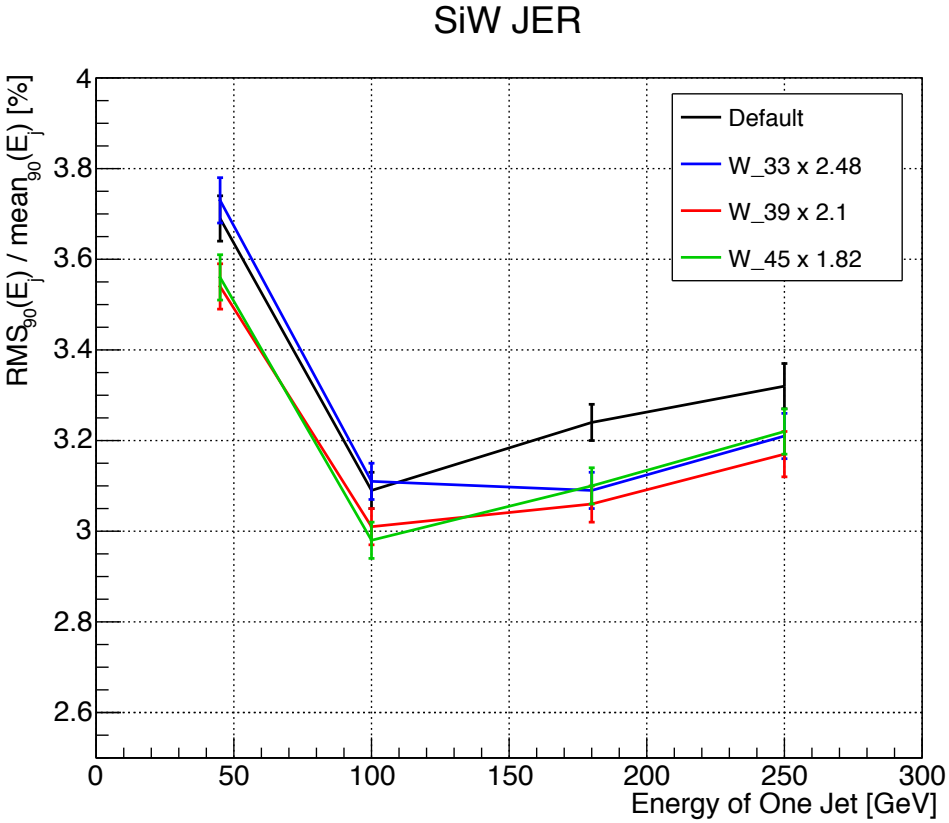


	stoch. [%]	const. [%]
Default	**55.24±0.24**	**6.18±0.14**
W_33 x 2.48	**55.07±0.22**	**3.73±0.19**
W_39 x 2.1	**54.12±0.21**	**3.79±0.18**
W_45 x 1.82	**53.03±0.21**	**3.32±0.19**

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 outer region of ECAL)
- There are no significant differences between each configuration

JER

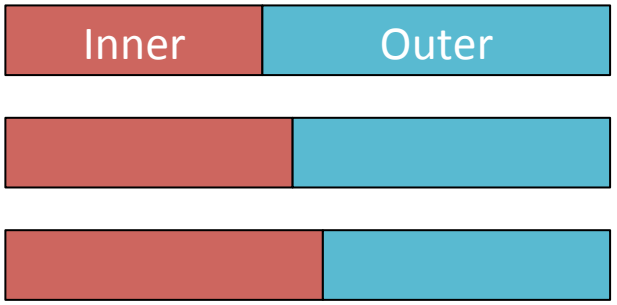


- JERs of W_39x2.1 and W_45x1.82 are better than that of other two configurations for all energies
- JER of W_33x2.48 is better at higher energy (more than 180GeV)

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**

Thickness of one layer

- The ratio of the thickness of one layer in outer region to that in inner region

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*
	Out / In	**4.31**	**3.49**	**2.83**
ii) In 20 + Out 9	real thick	*In 33.6 + Out 46.17*	*In 37.8 + Out 41.94*	*In 42 + Out 37.8*
	Out / In	**3.05**	**2.47**	**2.00**
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*
	Out / In	**2.26**	**1.81**	**1.47**
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*
	Out / In	**1.69**	**1.37**	**1.11**

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.	**18.32±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%**	**17.16±0.07%** *Default*
	const.	**2.35±0.04%**	**1.75±0.05%**	**1.82±0.04%**
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%**	**18.20±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%**

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±0.25%**	**55.49±0.24%**	**54.54±0.23%**
	const.	**7.11±0.13%**	**6.19±0.13%**	**6.09±0.13%**
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±0.23%**	**54.98±0.23%**	**55.24±0.24%**
	const.	**5.85±0.14%**	**5.58±0.14%**	**6.18±0.14%**
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±0.23%**	**55.67±0.22%**	**55.43±0.22%**
	const.	**5.68±0.14%**	**4.70±0.16%**	**4.51±0.16%**
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±0.22%**	**55.61±0.22%**	**55.76±0.22%**
	const.	**4.55±0.16%**	**4.26±0.17%**	**4.14±0.17%**

Default

There are also no any significant dependences

JER (only for 45GeV Jets)

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 left down region in this table look better than that of right up region

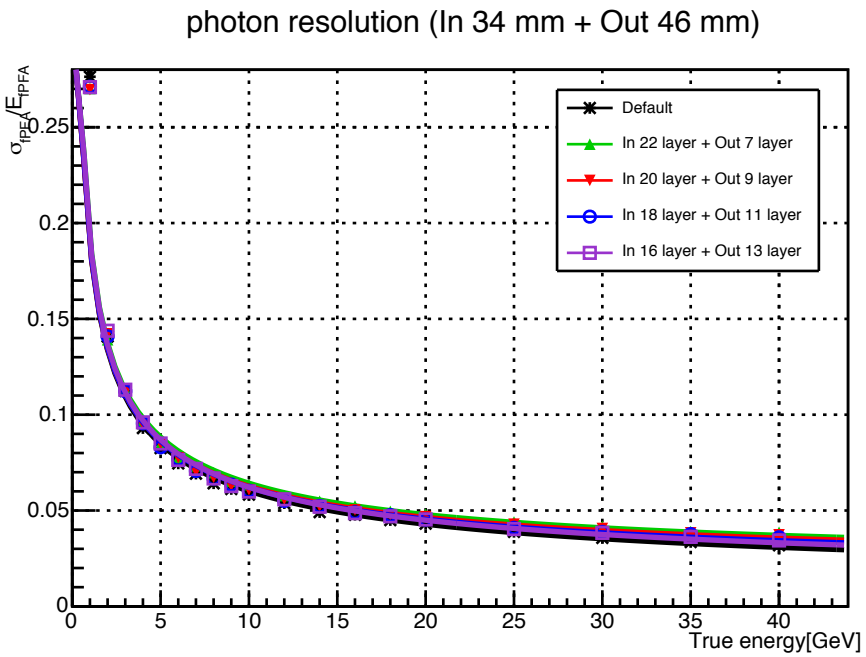
Outlook

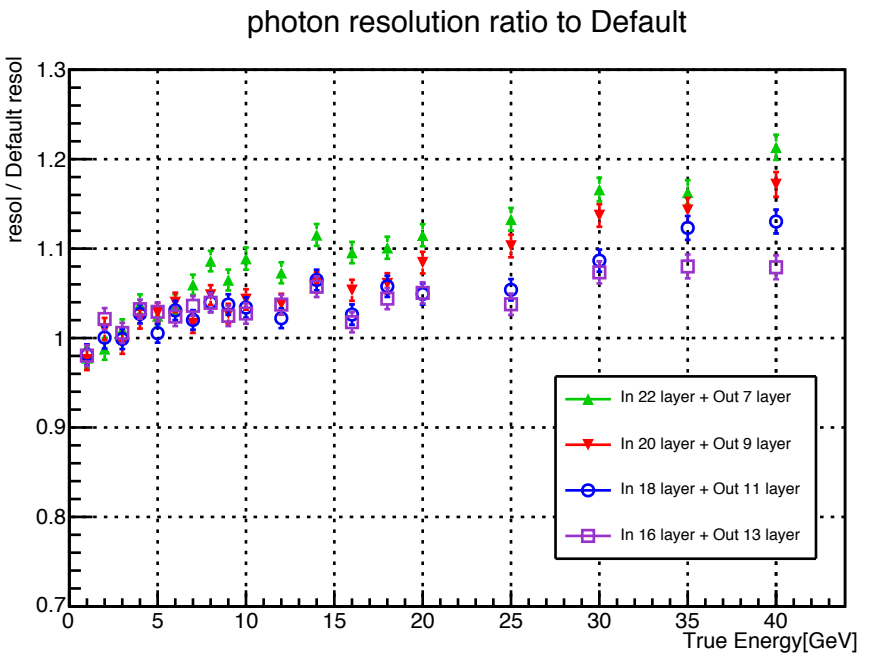
- I will study the longitudinal structure with
  - JER @ higher energy (>91GeV)
  - wider range of parameters
  - optimization by changing the number of layers
  - optimization by changing the pixel size of Si

Back up

Energy Resolution for Photon

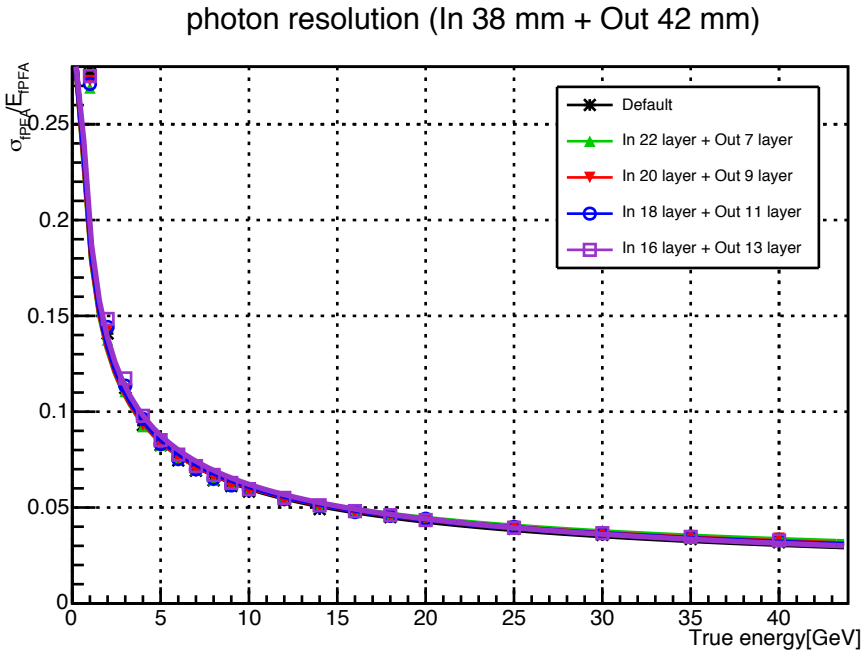
- Inner : Outer = 34 mm : 46 mm

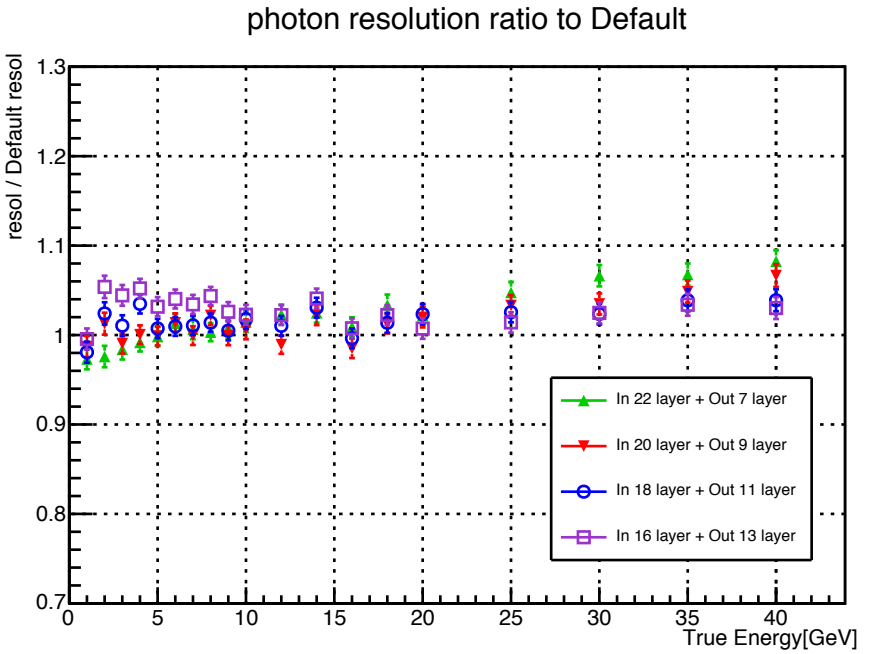




Energy Resolution for Photon

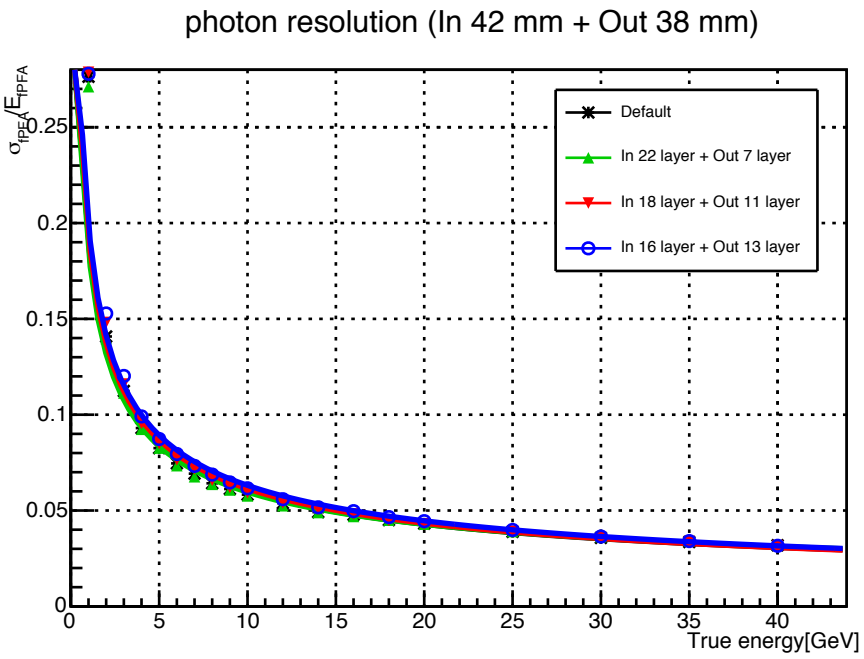
- Inner : Outer = 38 mm : 42 mm

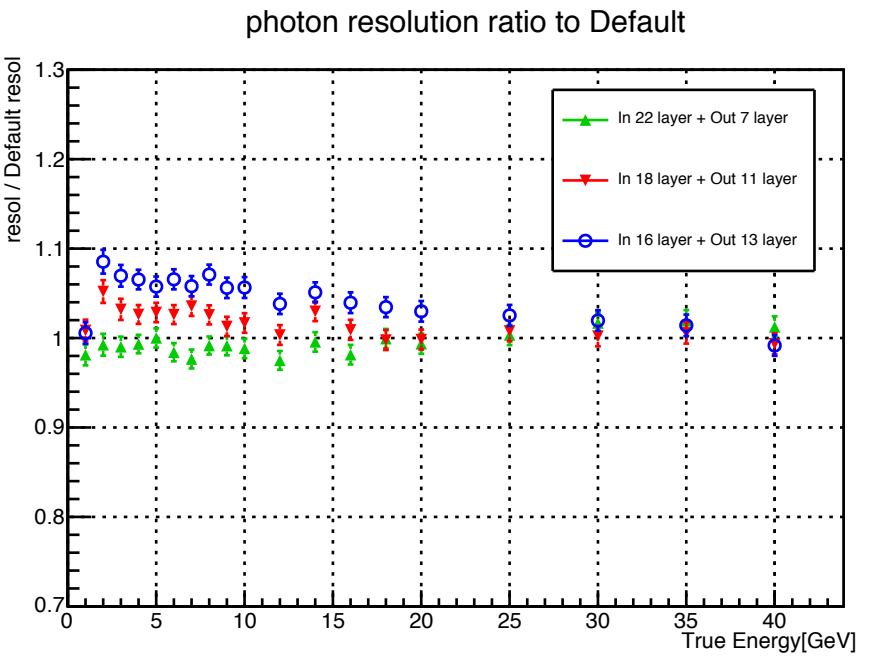




Energy Resolution for Photon

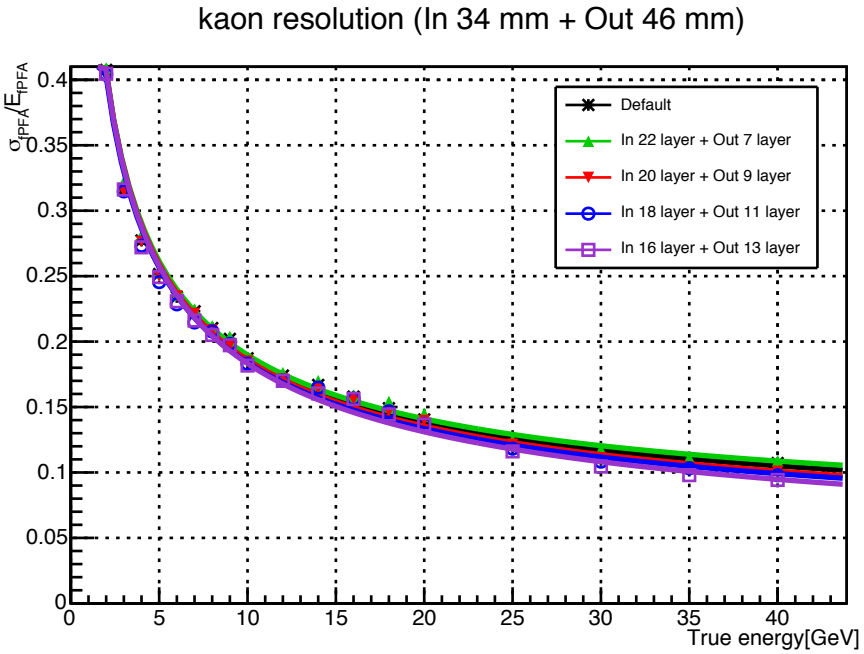
- Inner : Outer = 42 mm : 38 mm

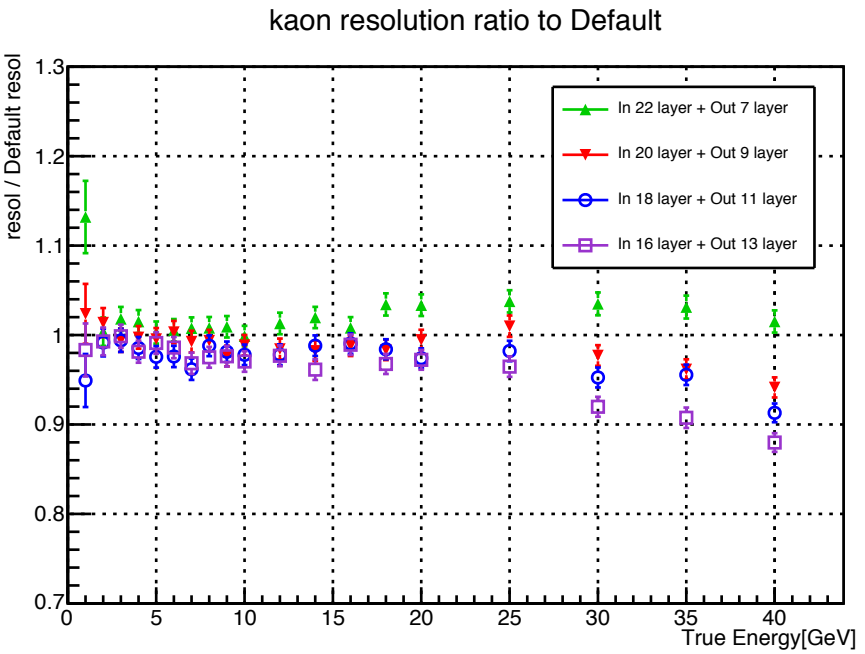




Energy Resolution for Kaon

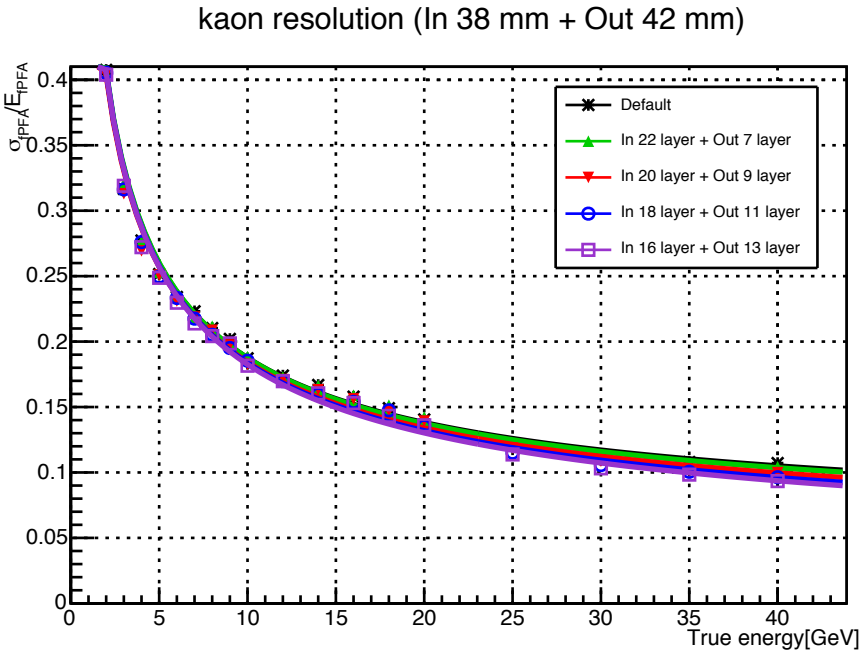
- Inner : Outer = 34 mm : 46 mm

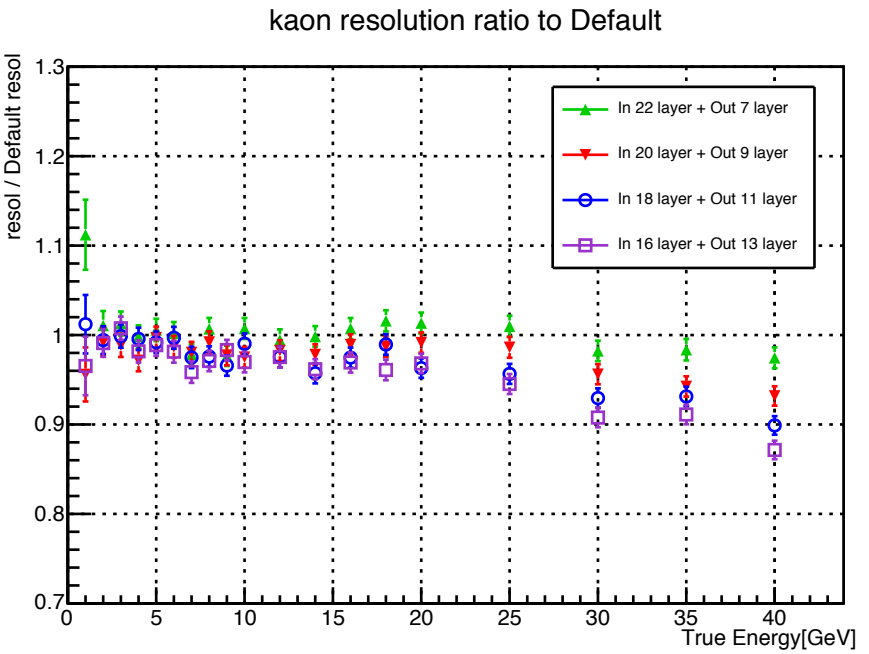




Energy Resolution for Kaon

- Inner : Outer = 38 mm : 42 mm





Energy Resolution for Kaon

- Inner : Outer = 42 mm : 38 mm