Simulation Study for the Hybrid ECAL

ILD ECAL Meeting @Paris

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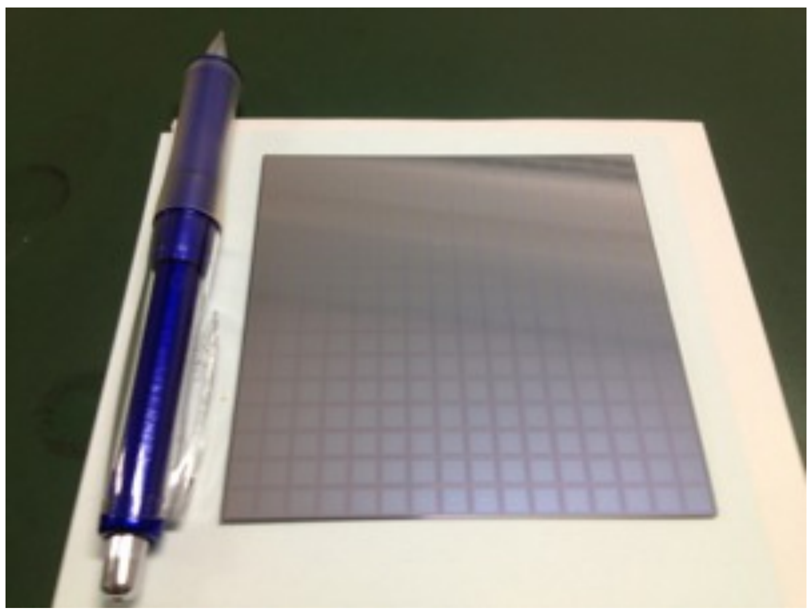
Contents

- Motivation for the Hybrid ECAL
- Calibration
- Jet Energy Resolution
    - same absorber thickness
    - same module thickness
    - alternating hybrid
- Summary

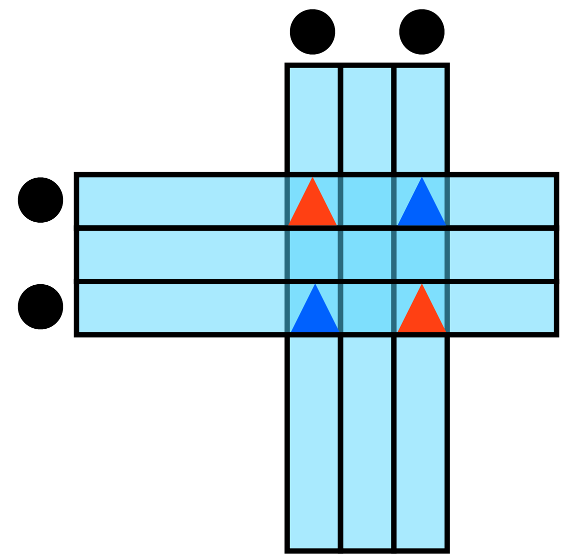
ILD ECAL Candidates

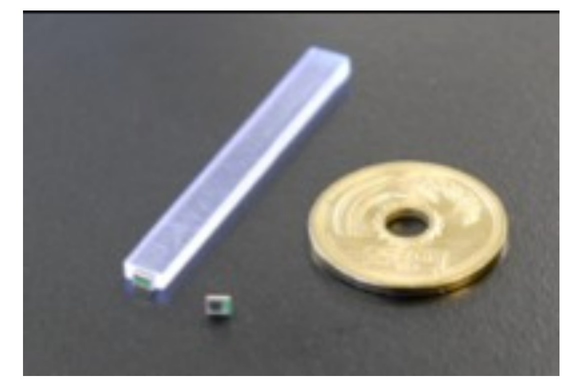
Silicon pads（Si ECAL）



❖ 5mm x 5mm cells
❖ good performance for PFA
❖ large fraction of detector cost

Scintillator strips +MPPC（Sc ECAL）



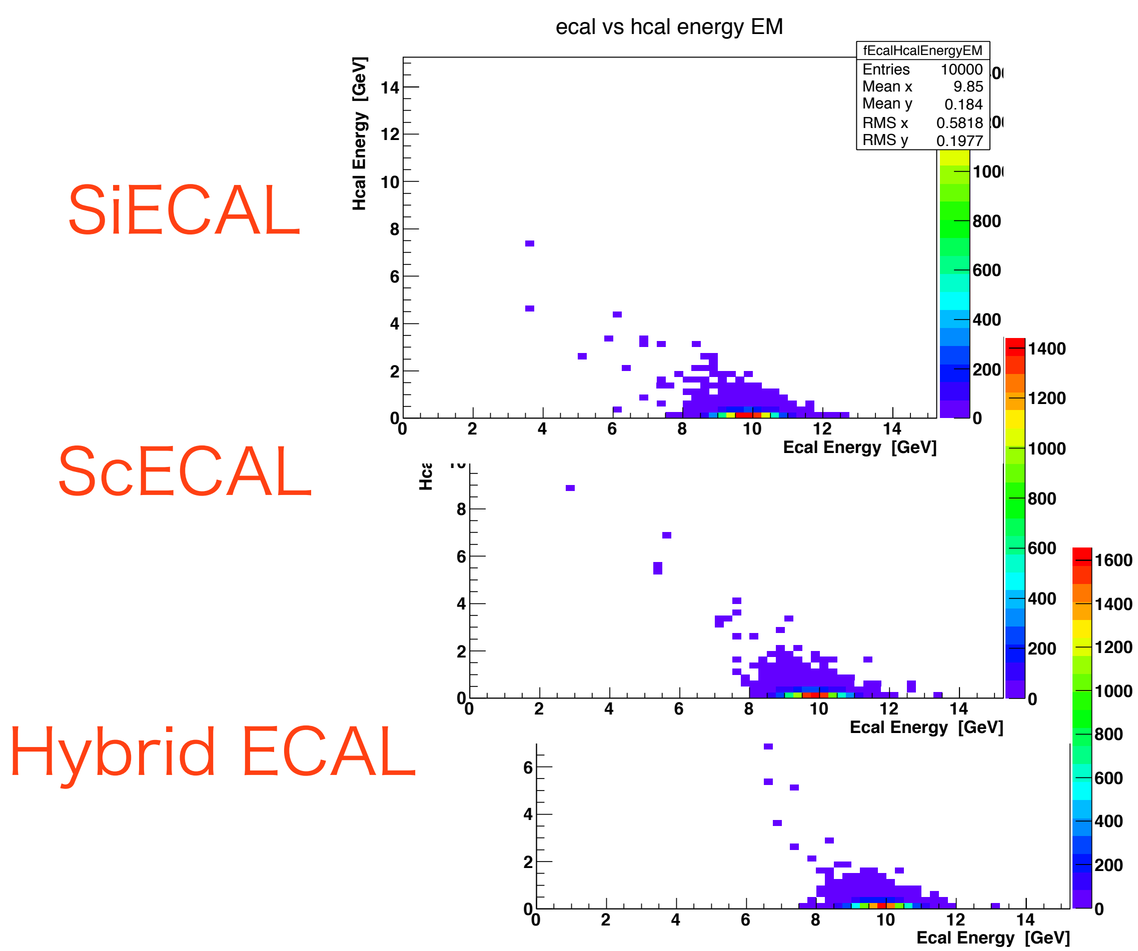


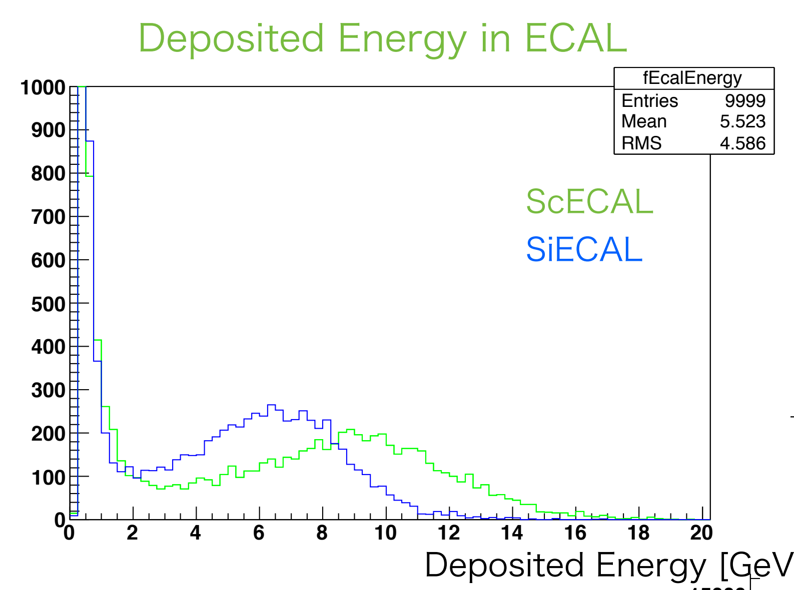
✻ 45mm x 5mm orthogonal & SSA
--> 5mm x 5mm spatial resolution
✻ reasonable cost
✻ ghost hits
✻ thicker than silicon

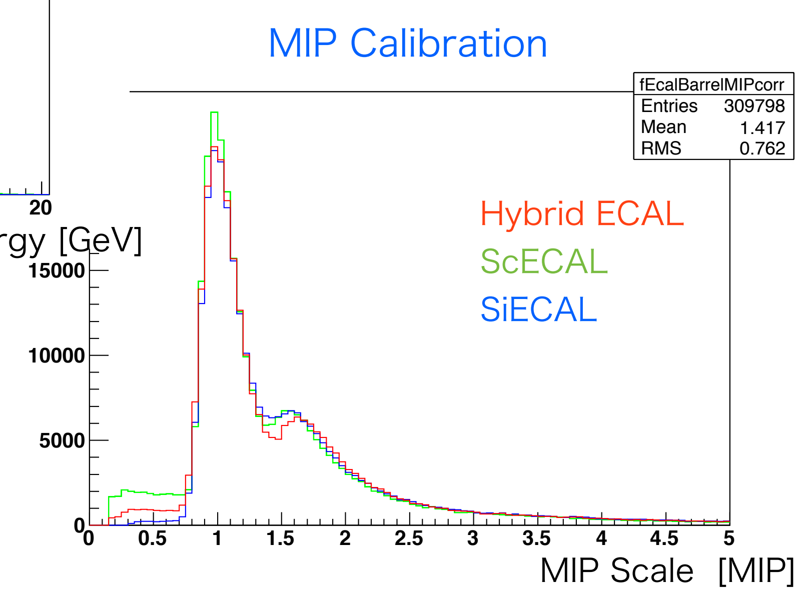
An option to make the ECAL at a lower cost while keeping performance as much as possible would be mixture of silicon and scintillator-strip layers.

Calibration

- ECAL Calibration : 10GeV photon
- HCAL Calibration : maintain default value
- e/h compensation in ECAL : 10GeV π^+
- MIP calibration : 10GeV muon



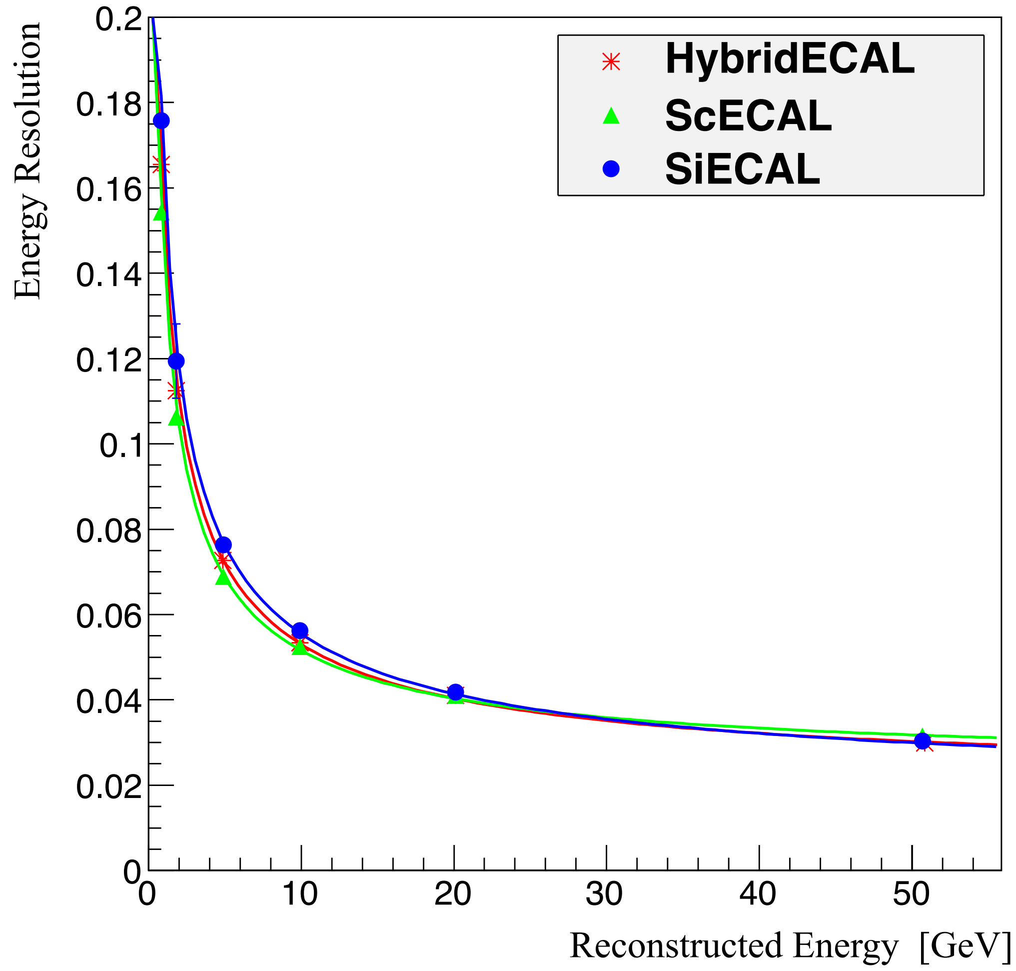




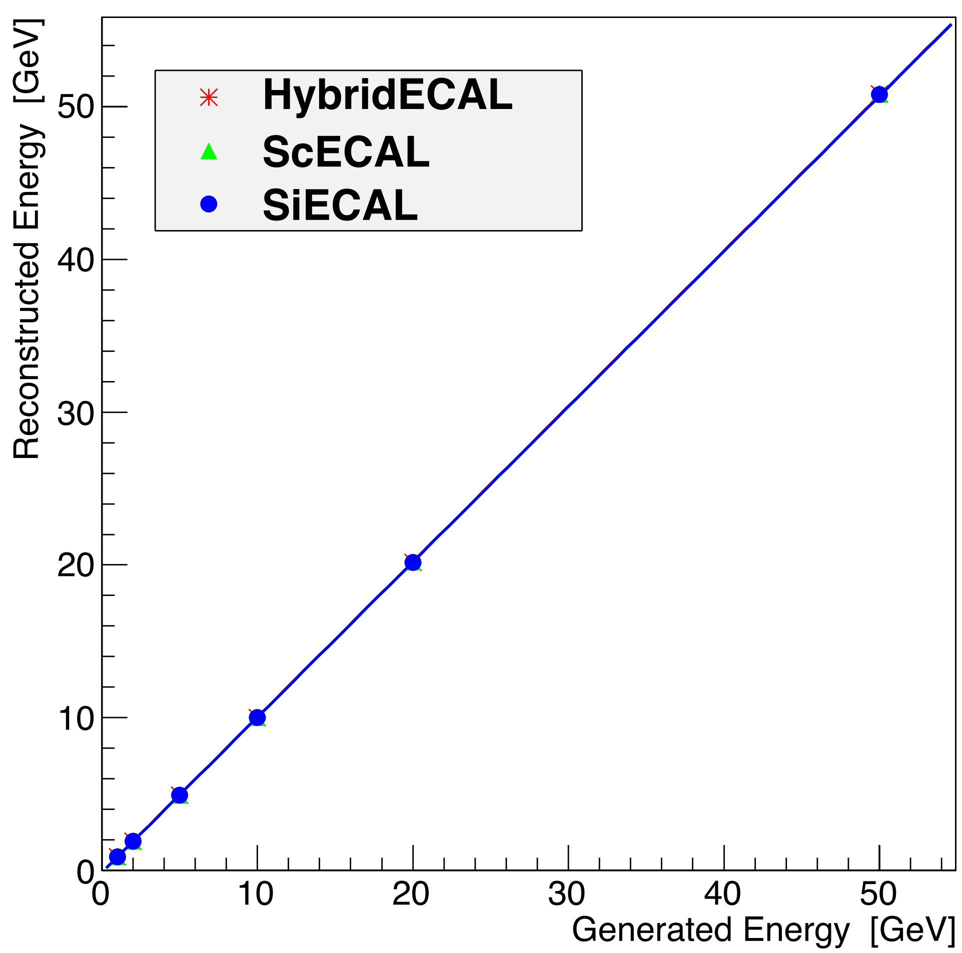
ECAL Performance

- photon energy resolution and linearity using 1~50GeV photons.

Photon Energy Resolution



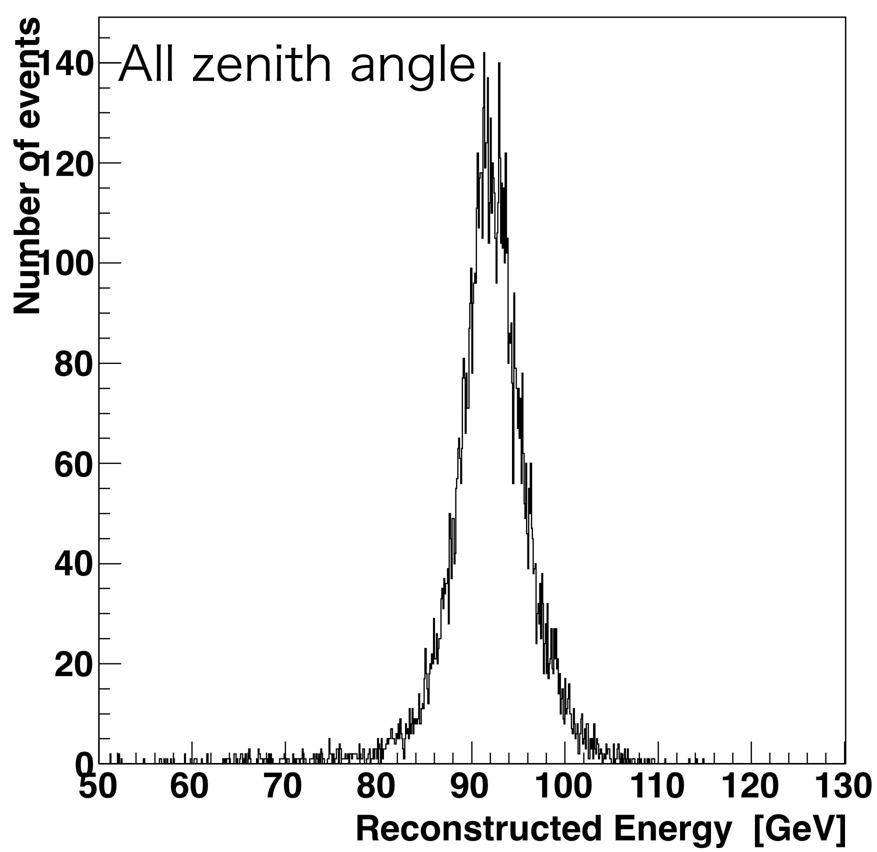
Linearity

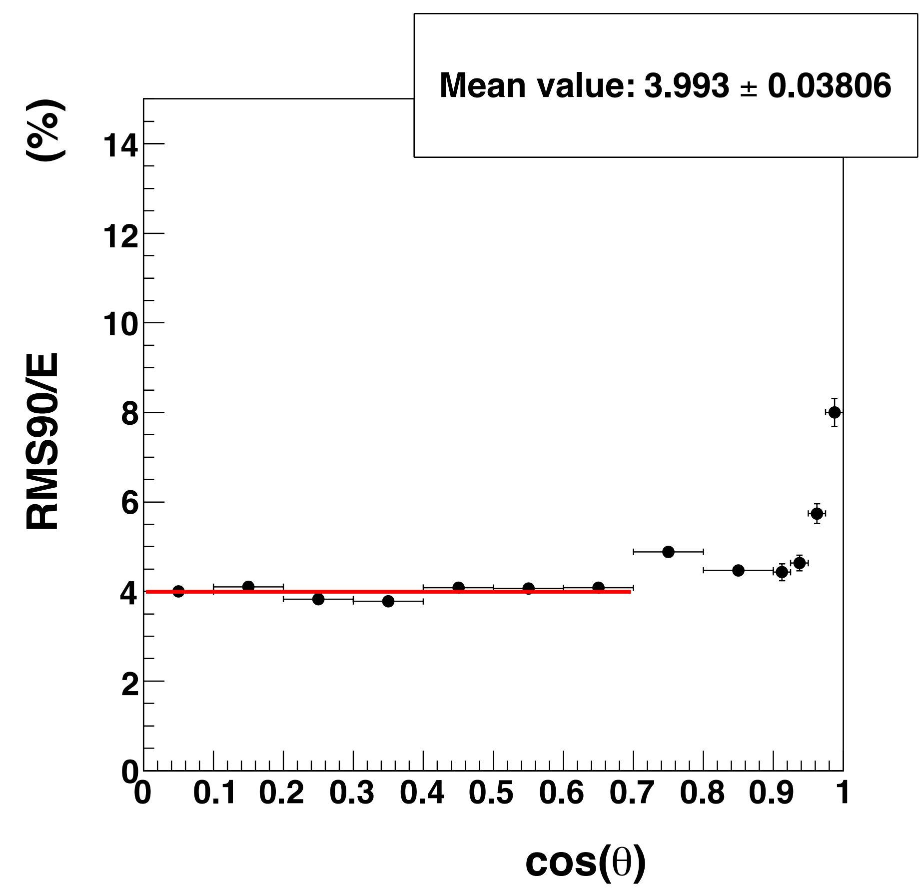


The calibration method works well.

Hybrid ECAL Evaluation

- We evaluated energy dependence and Sc:Si ratio dependence.
- software version : ilcsoft v01-15
- Used events are $e^+e^- \to q\bar{q}$ (q=u,d,s, √s=91, 200, 360, 500GeV)
- We use only barrel region (cos(thrust angle)<0.7) for evaluation.

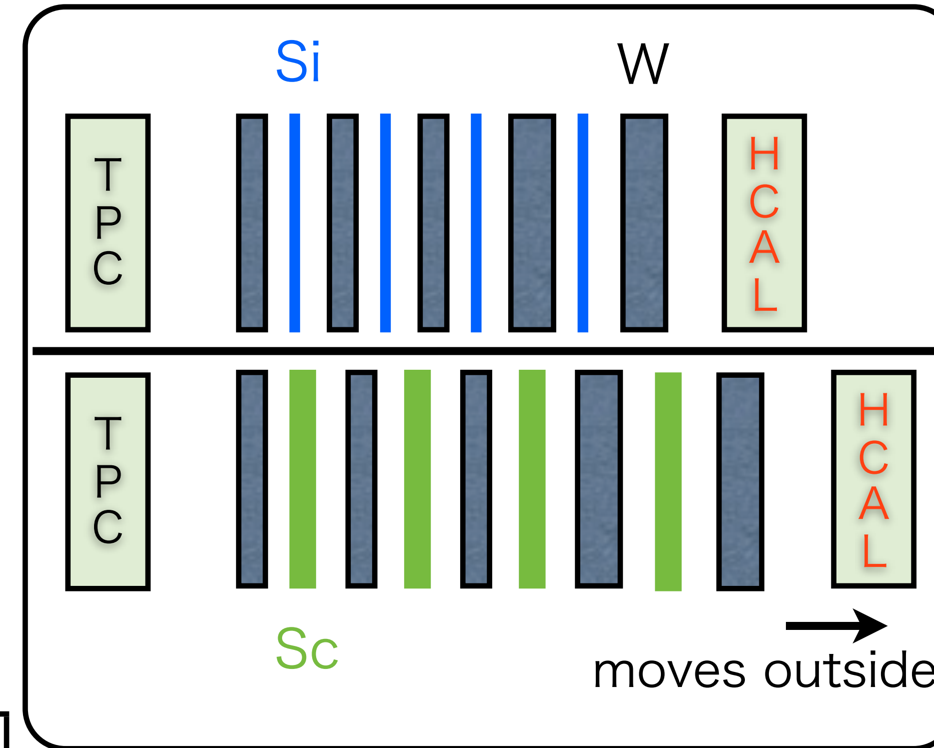




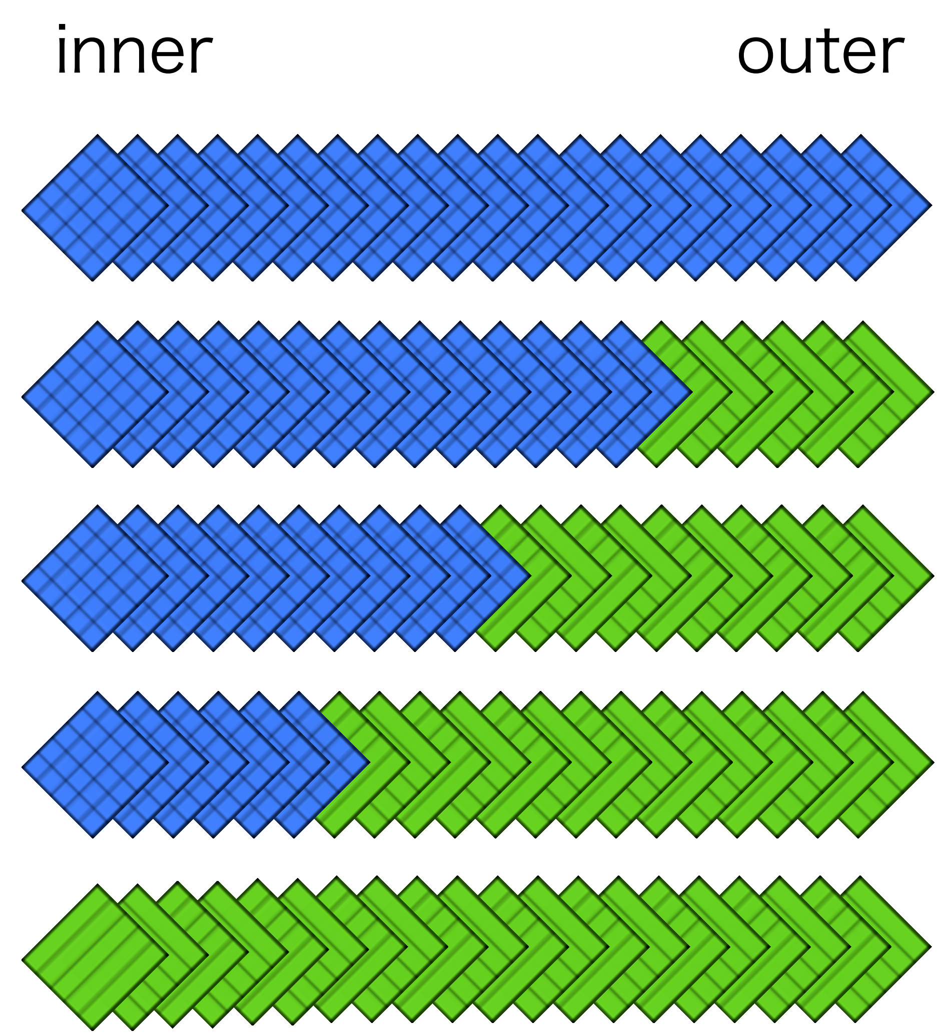
Contents

same absorber thickness

- performance difference between Si and Sc
- five configurations
- Sc thick = **2.0mm**, Si thick = **0.5mm**
- different module thickness

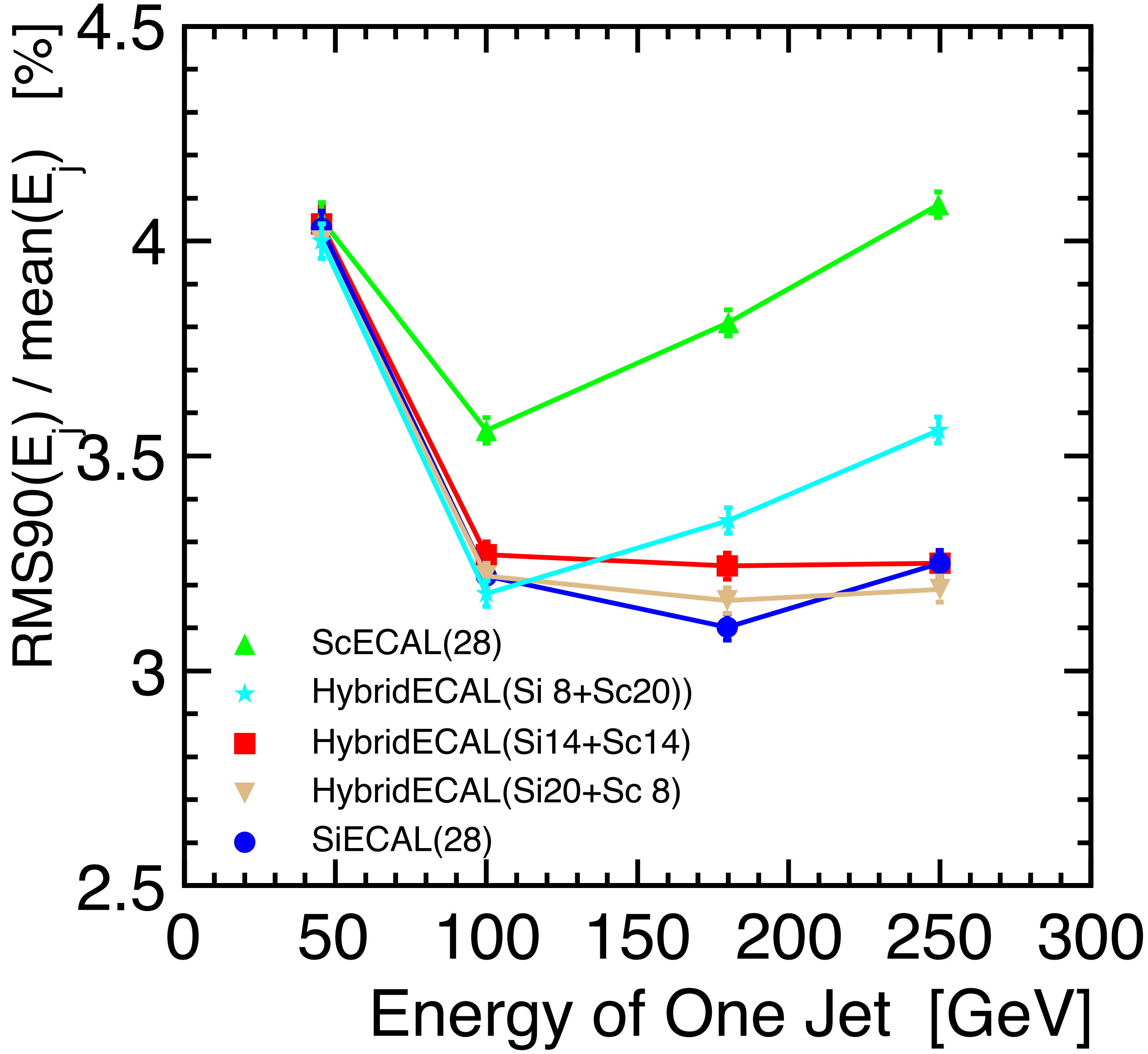


	W thickness (in20,out7)	Module thickness (mm)
SiECAL(28)	2.1/3.5	165.4
Hybrid(Si20Sc8)	2.1/3.5	176.7
Hybrid(Si14Sc14)	2.1/3.5	185.2
Hybrid(Si8Sc20)	2.1/3.5	193.7
ScECAL(28)	2.1/3.5	205.0



Jet Energy Resolution

Energy Dependence

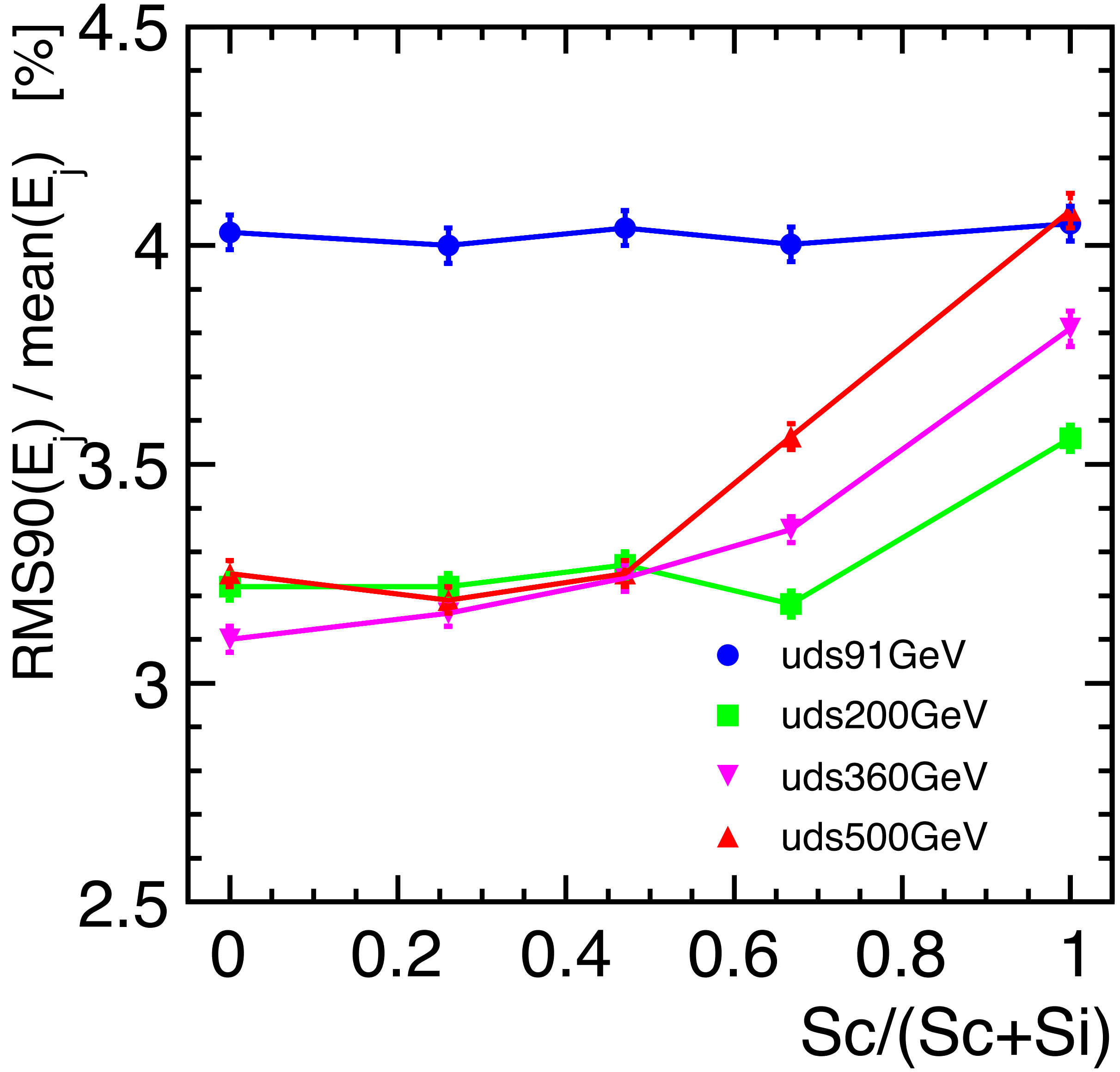


- no big difference between SiECAL, Hybrid(Si14+Sc14), Hybrid(Si20+Sc8)

- We can keep performance with less silicon layers at low energies.

Jet Energy Resolution

Ratio Dependence



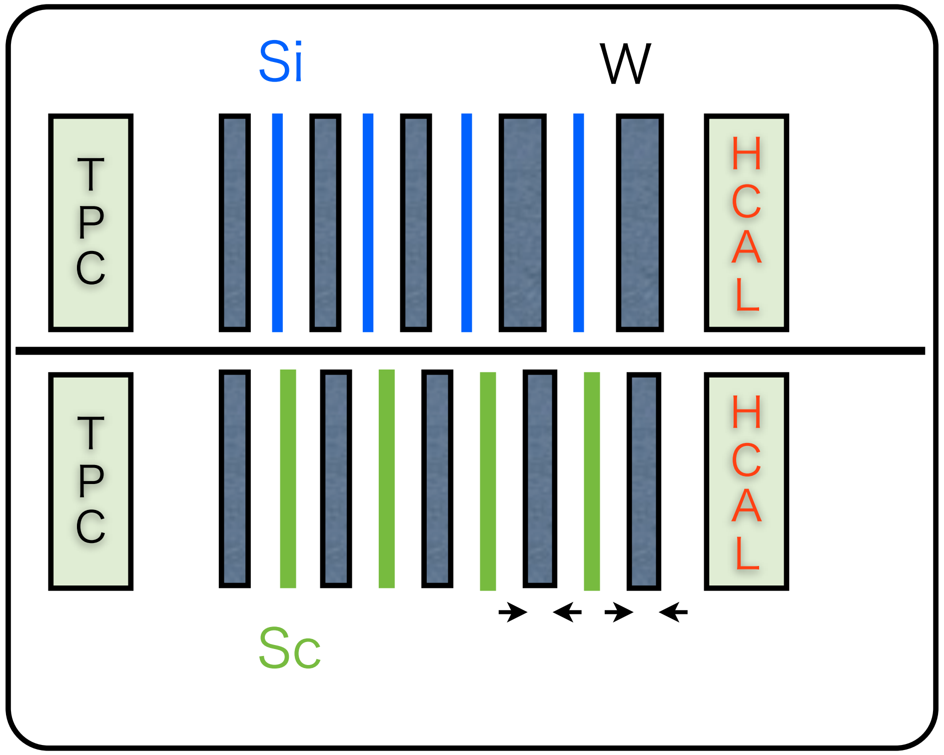
- almost same performance at low energies
- the more scintillator, the worse performance at high energies
- not degrade so much up to 50% of scintillator layers

Contents

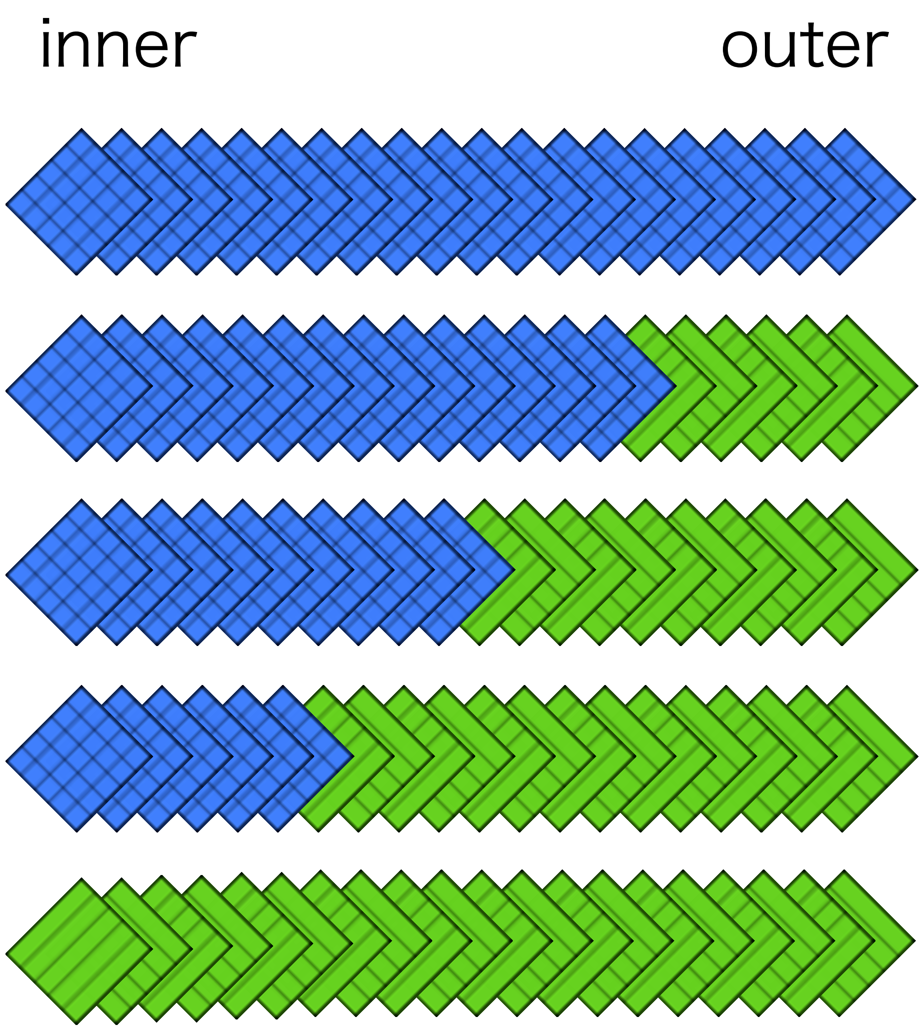
- Motivation for the Hybrid ECAL
- Calibration
- Jet Energy Resolution
  - same absorber thickness
  - same module thickness
  - alternating hybrid
- Summary

same module thickness

- to evaluate with official ECAL thickness
- five configurations
- Sc thick = 1.0mm, Si thick = 0.5mm
- change absorber thickness for outer layers

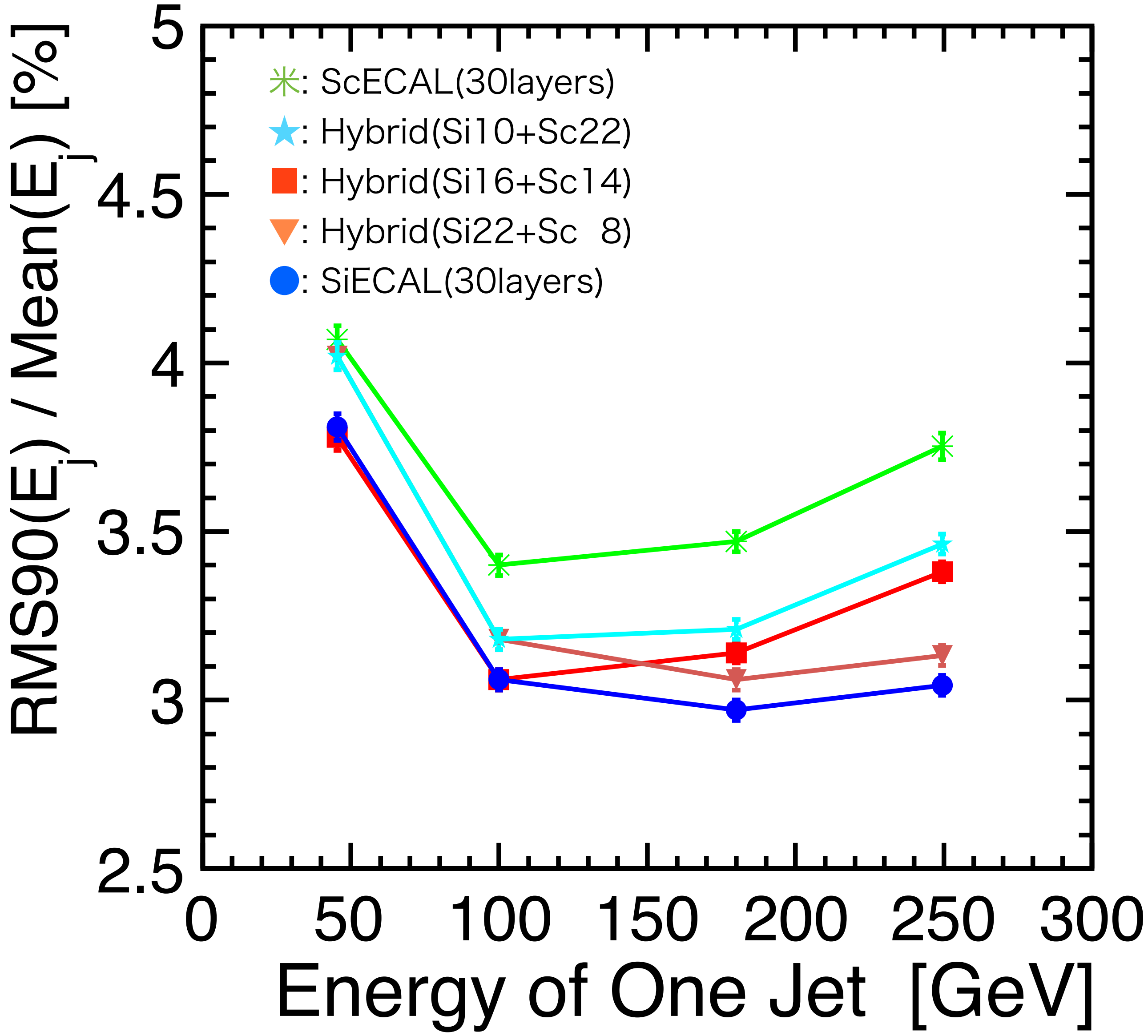


	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid(Si22Sc8)	2.1/3.9	185.6
Hybrid(Si16Sc14)	2.1/3.6	185.4
Hybrid(Si10Sc20)	2.1/3.3	185.2
ScECAL(30)	2.1/2.9	185.7



Jet Energy Resolution

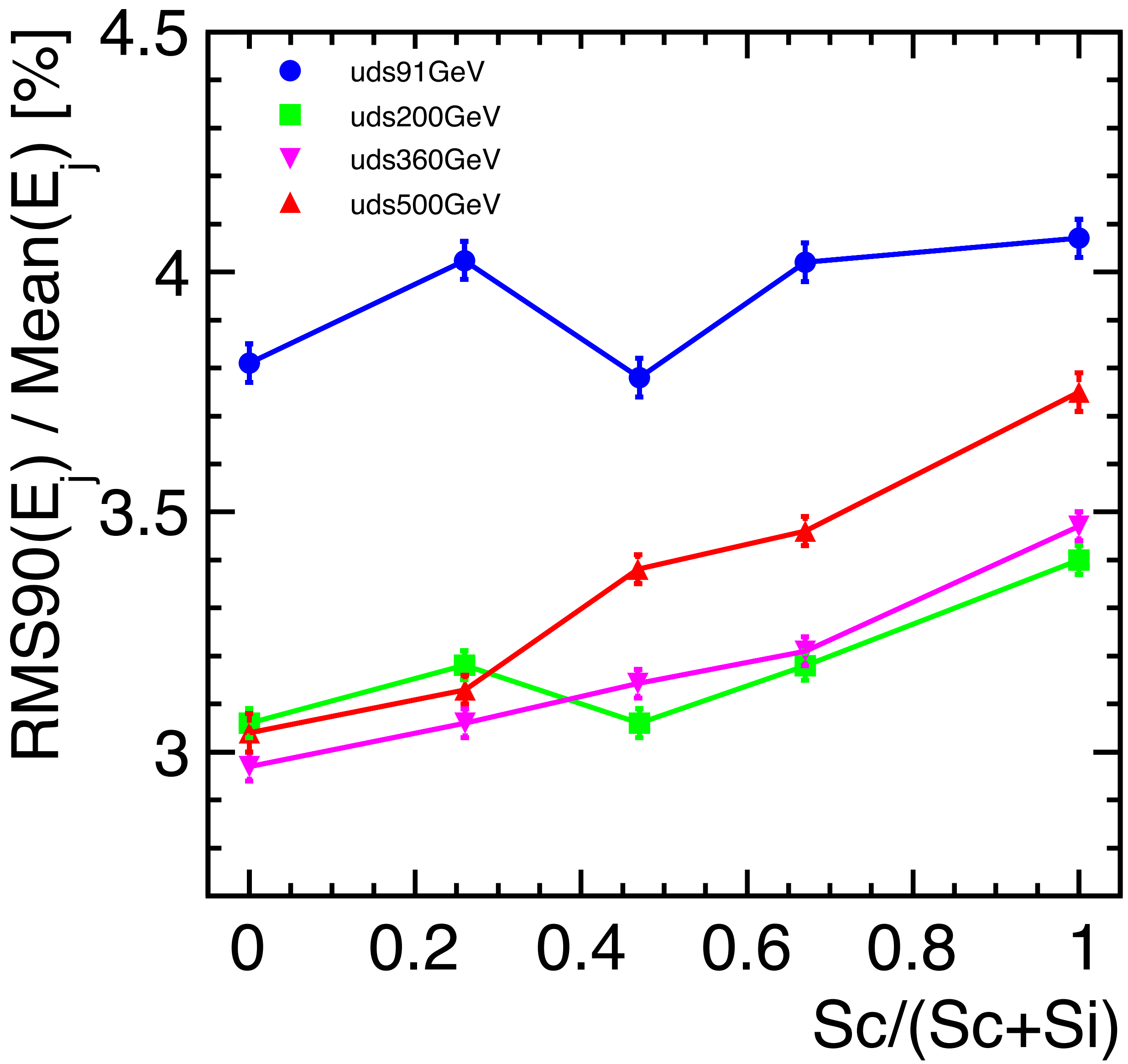
Energy Dependence



- performance looks to depend on the number of silicon layers all over the energies
- Hybrid(Si16+Sc14) is about medium between SiECAL and ScECAL at high energies.

Jet Energy Resolution

Ratio Dependence



- Performance becomes worse almost linearly as scintillator layers increase

- Hybrid(Si16+Si14) is better than other hybrid at low energies.

Contents

- Motivation for the Hybrid ECAL
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    - same absorber thickness
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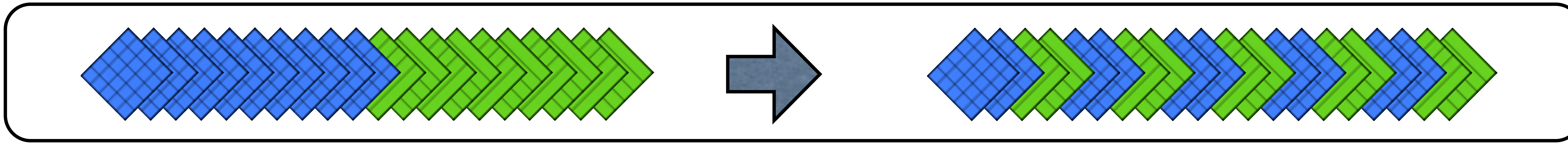
alternating hybrid

- to help SSA and resolve ghost hits
- double layers alternate



same absorber thickness

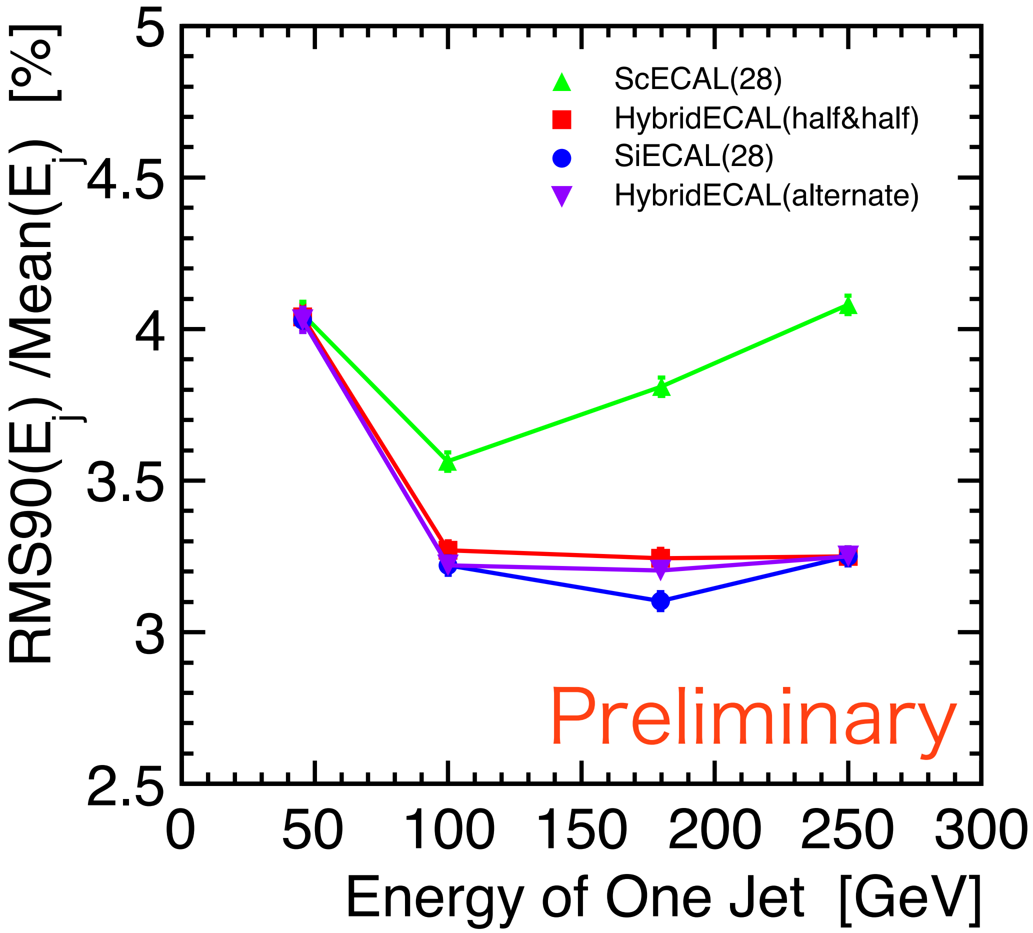
	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/3.5	165.4
Hybrid(Si16Sc14) [not alternate]	2.1/3.5	185.2
Double layers Alternate(Si16Sc14)	2.1/3.5	185.2
ScECAL(30)	2.1/3.5	205.0

same module thickness

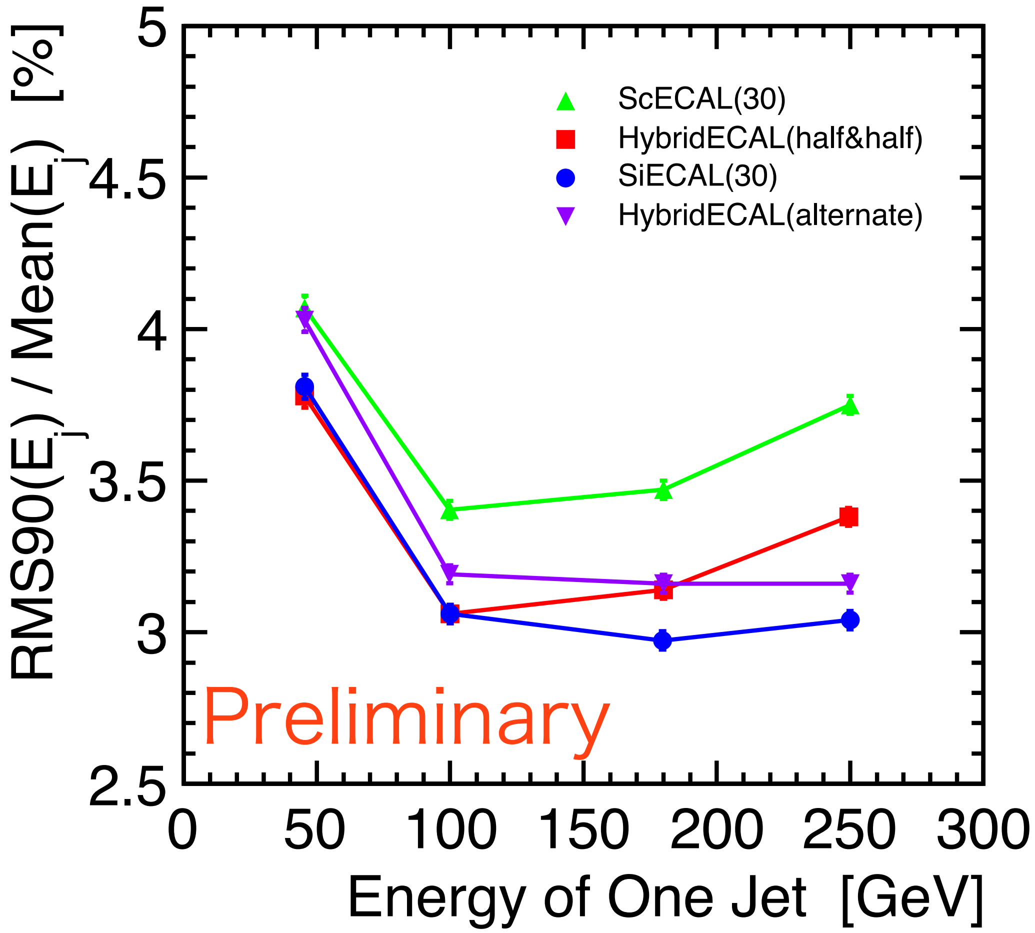
	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid(Si16Sc14) [not alternate]	2.1/3.6	185.4
Double layers Alternate(Si16Sc14)	2.1/3.6	185.4
ScECAL(30)	2.1/2.9	185.7

Performance of alternating hybrid

same absorber thickness



same module thickness



Summary

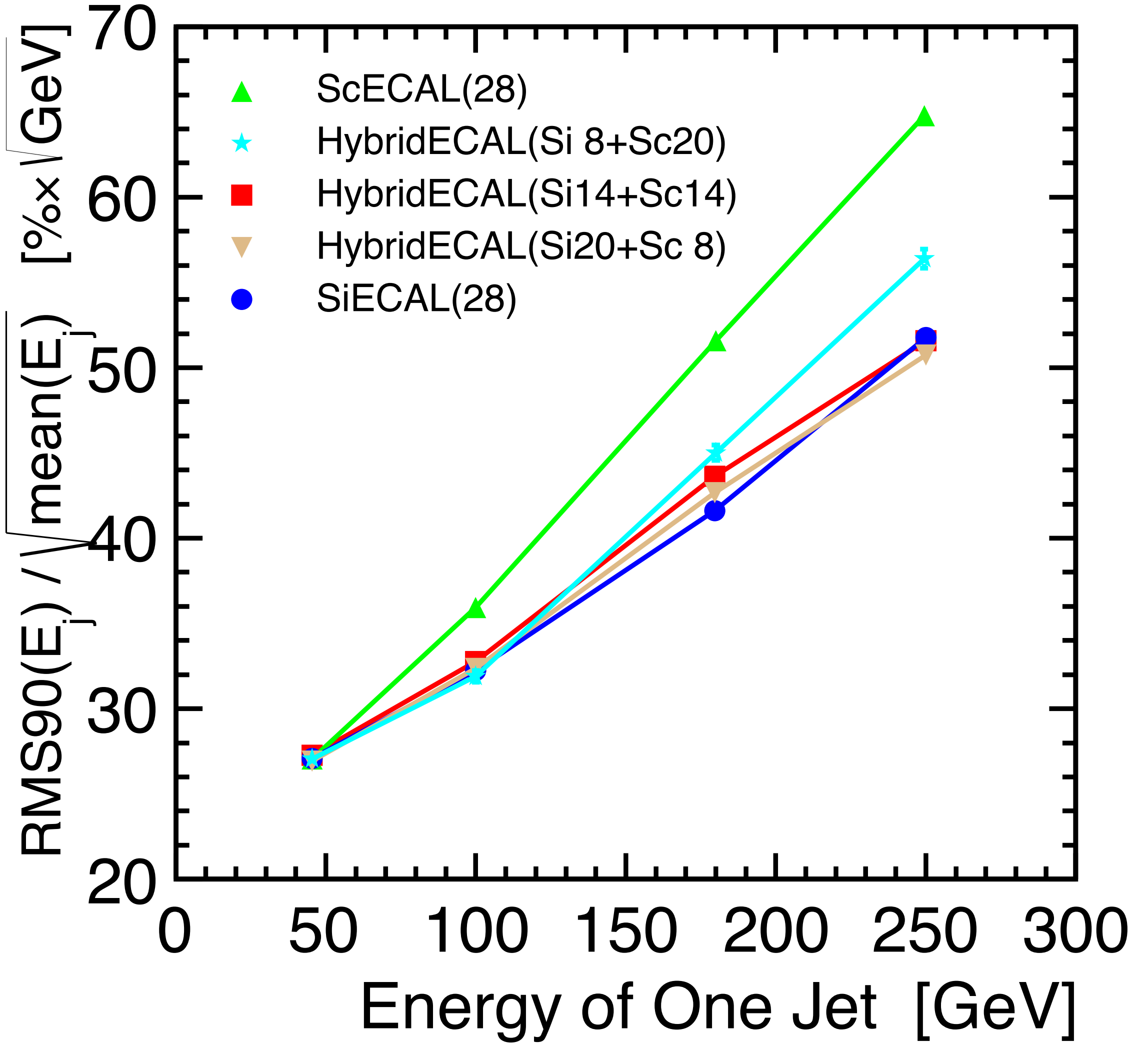
- Hybrid ECAL is an option to make ILD ECAL with a lower cost while keeping performance as much as possible.
- We evaluated Jet Energy Resolution for 3 types of Hybrid ECALs.
  - same absorber thickness ... performance of Hybrid ECAL doesn't degrade so much up to 50% of scintillator layers.
  - same module thickness ... performance becomes worse almost linearly as scintillator ratio increase.
  - alternating hybrid ... looks good for the case of same absorber thickness, and at high energy in the case of same module thickness.

Backup

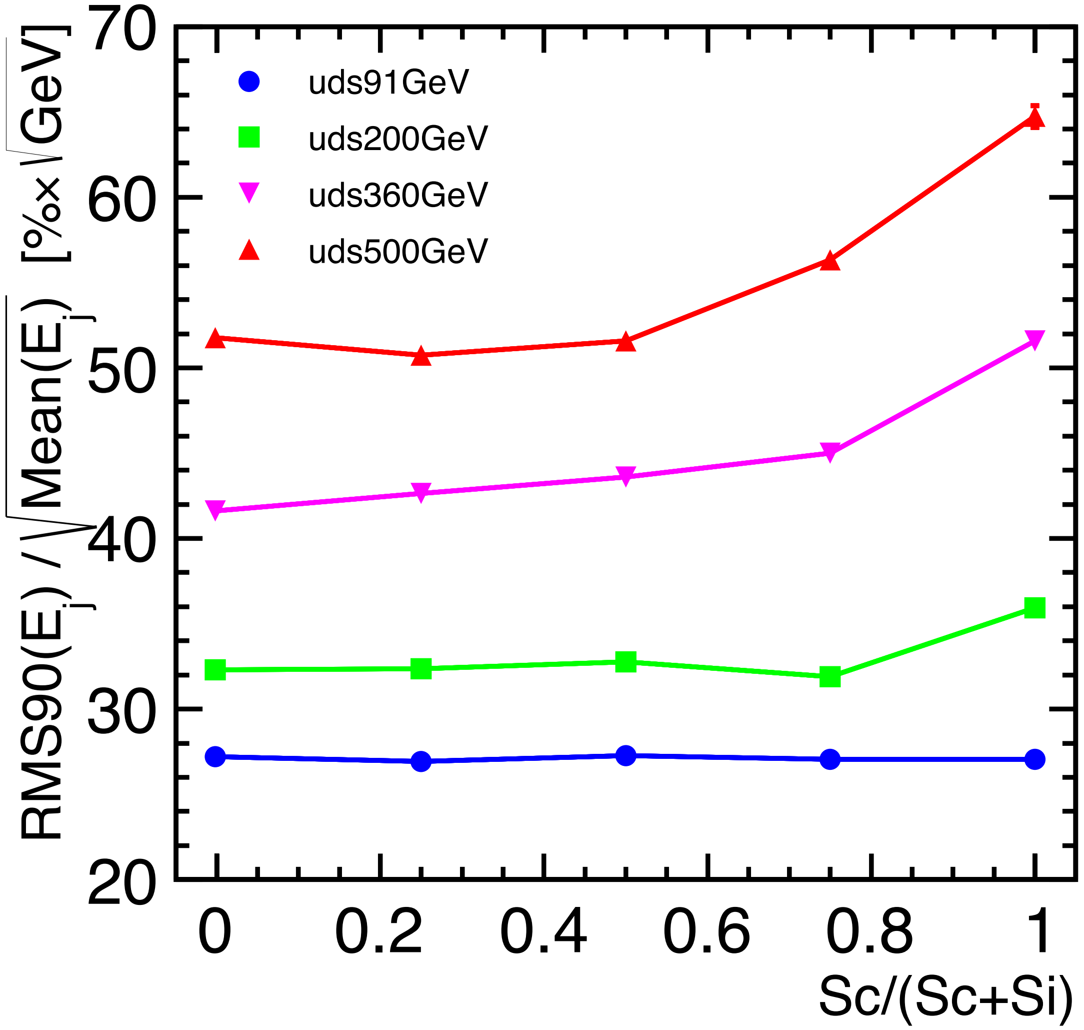
RMS90(E_j) / √mean(E_j)

same absorber thickness

Energy Dependence



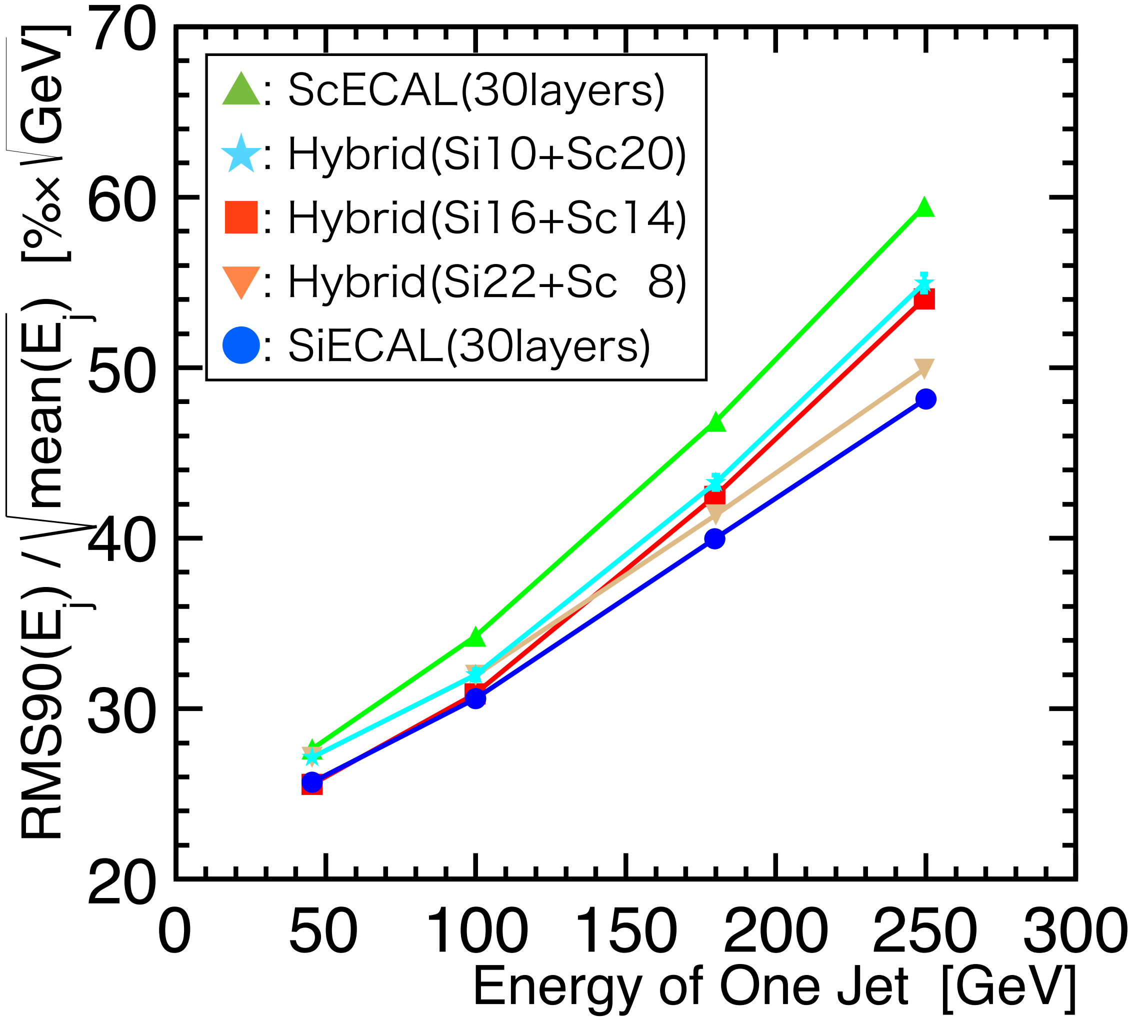
Ratio Dependence



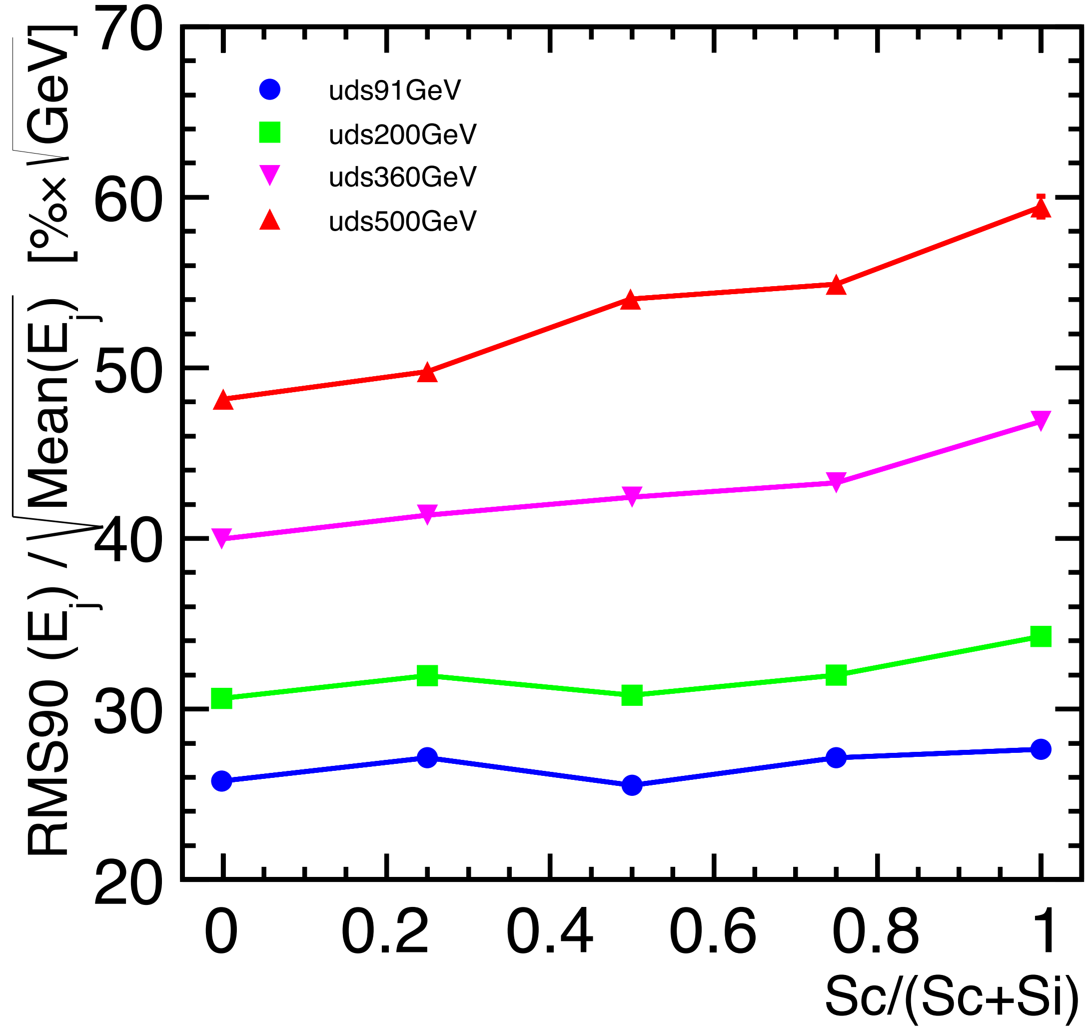
RMS90(E_j) / $\sqrt{\text{mean}(E_j)}$

same absorber thickness

Energy Dependence

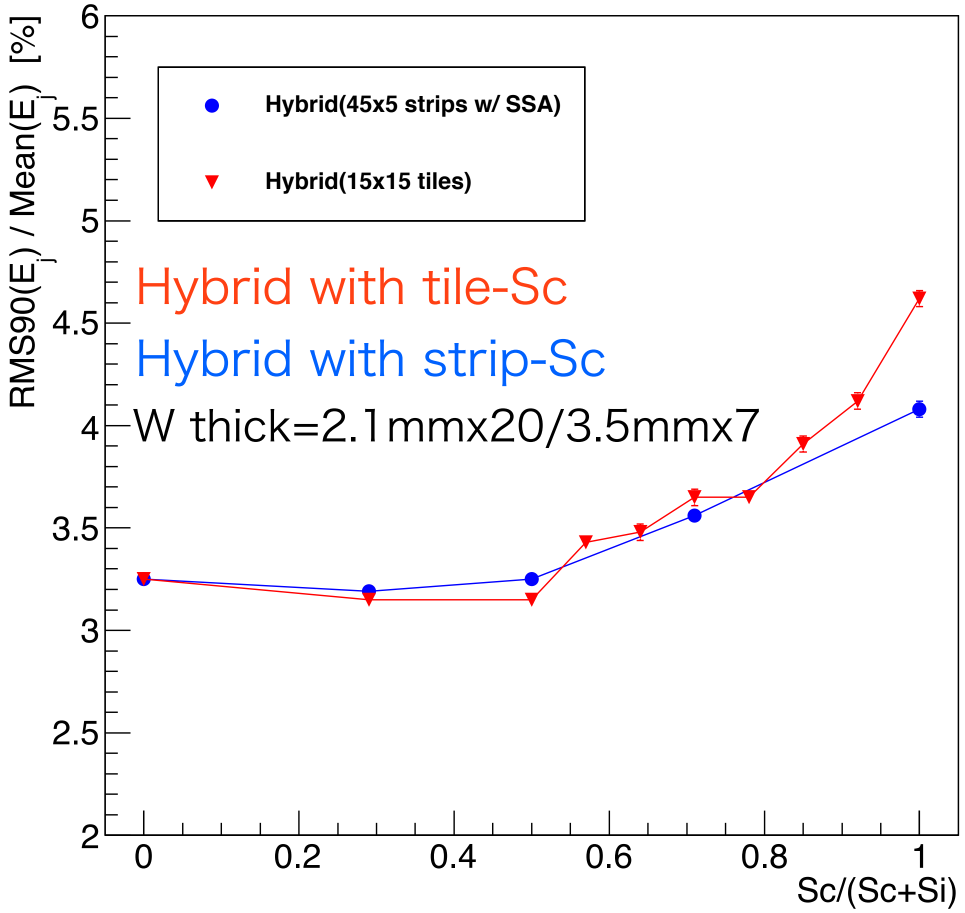


Ratio Dependence

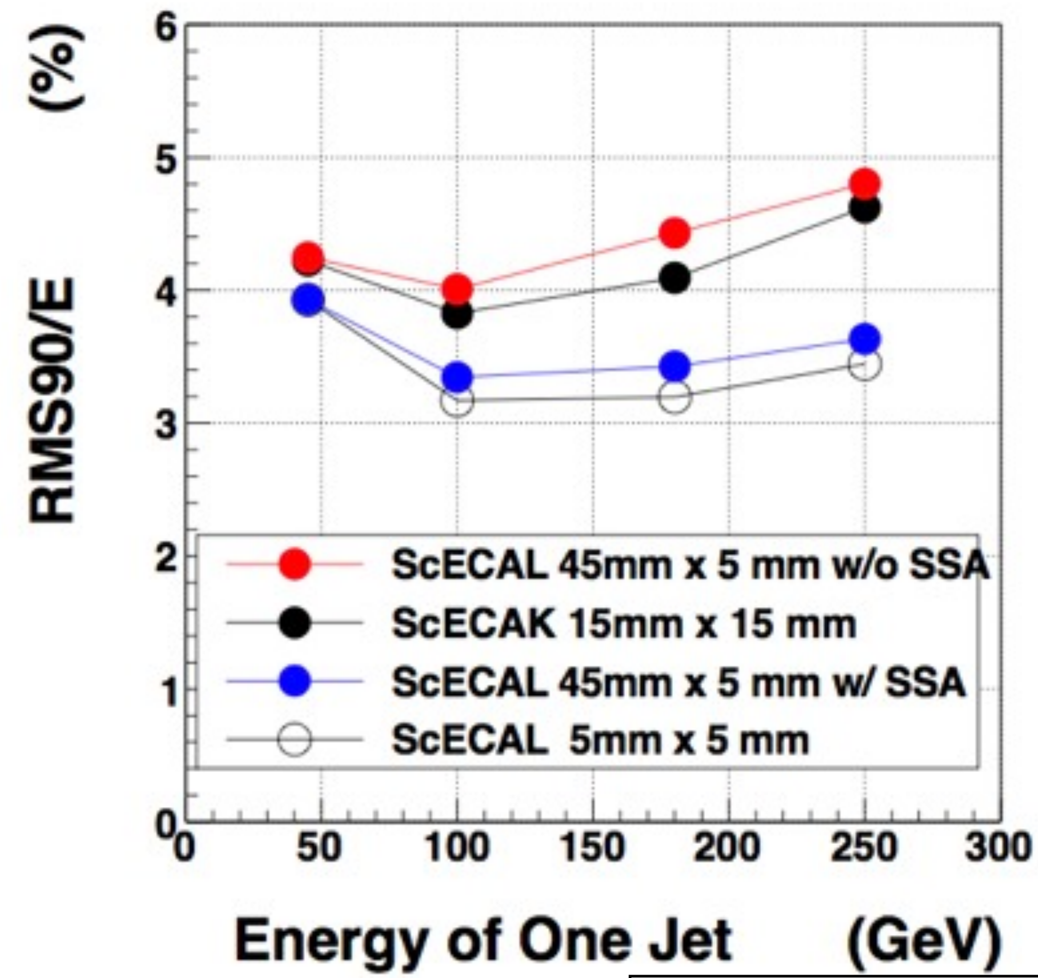


hybrid with Sc-tiles(15x15mm)

Hybrid with tile-Sc



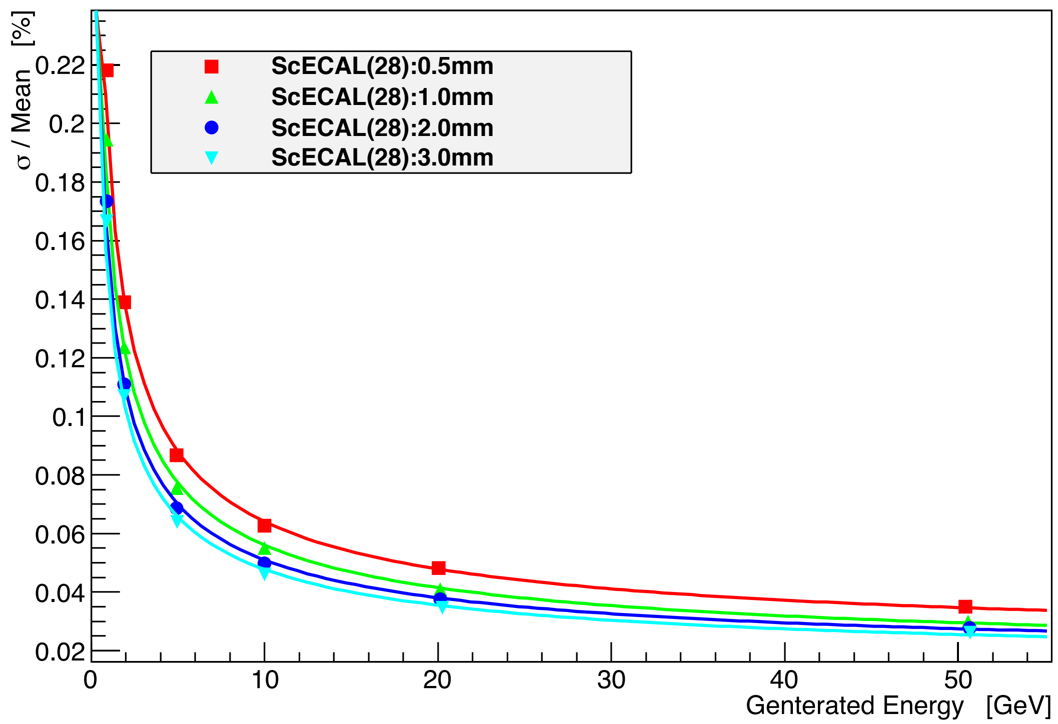
tile ScECAL



by K.Kotera

Scintillator Thickness Difference

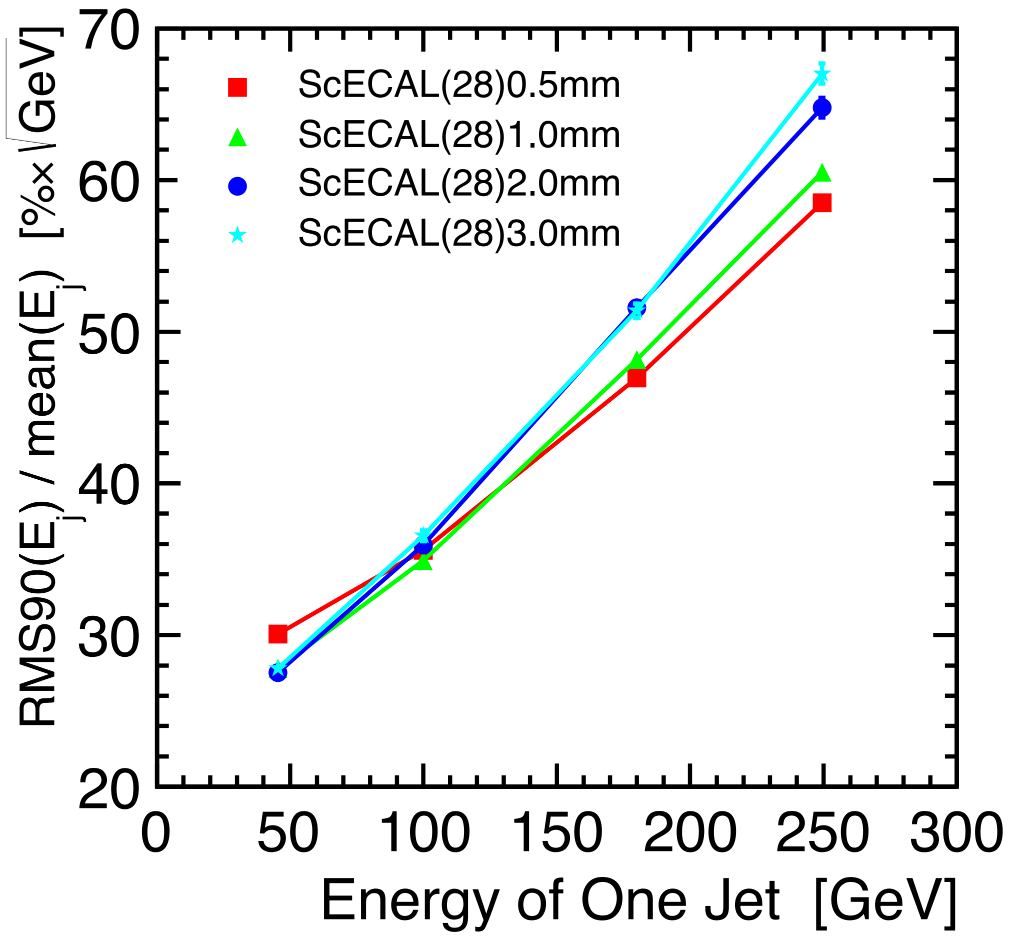
Photon Energy Resolution



ECAL Performance (photon 1~50GeV)

ScThick	σ stat	σ const
0.5mm	19.04%	2.19%
1.0mm	16.84%	1.71%
2.0mm	15.17%	1.72%
3.0mm	14.26%	1.56%

Jet Energy Resolution

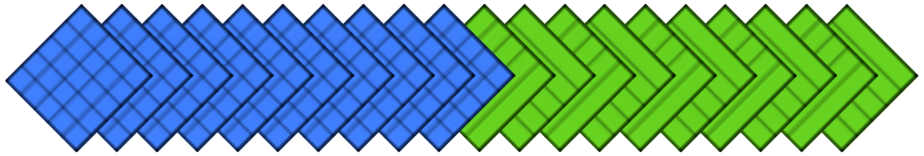


W thickness dependence

~same module thickness~

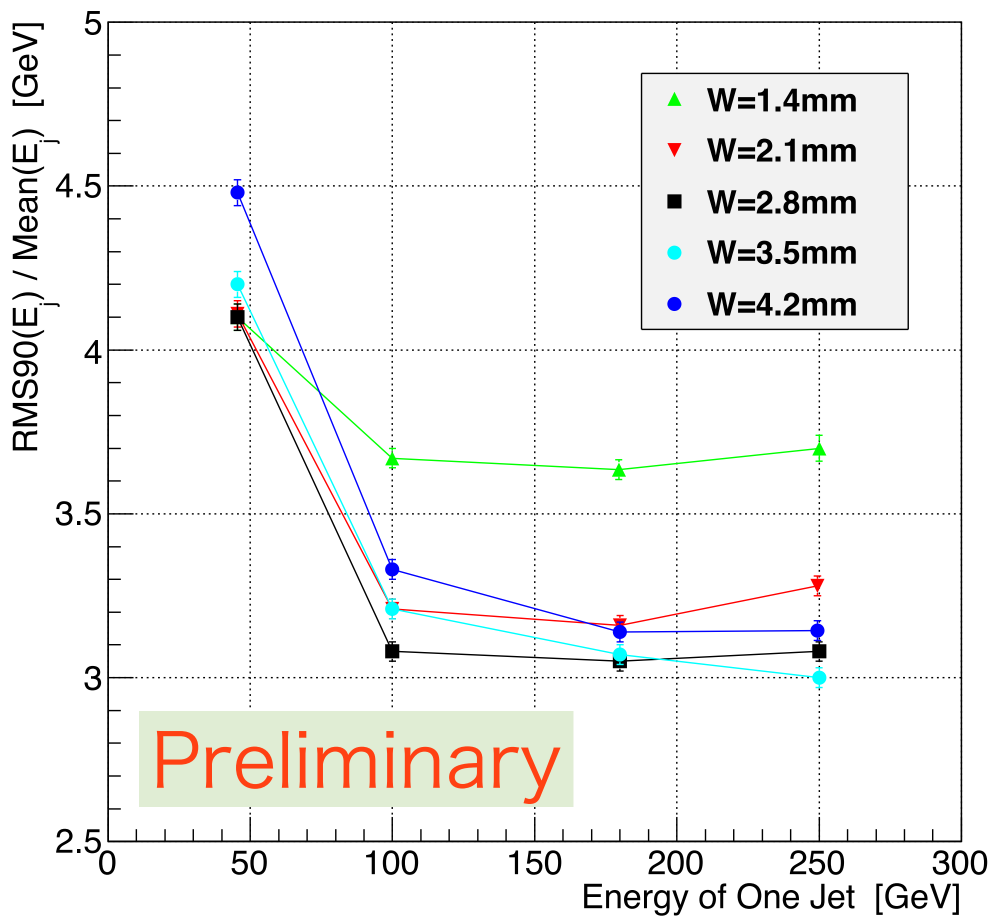
Sc thickness = 1.0mm
Si thickness = 0.5mm

	W thickness (all 29 layers)	Total Radiation Length (X0)
Hybrid(Si16Sc14)①	1.4	11.6
Hybrid(Si16Sc14)②	2.1	17.4
Hybrid(Si16Sc14)③	2.8	23.2
Hybrid(Si16Sc14)④	3.5	29.0
Hybrid(Si16Sc14)⑤	4.2	34.8

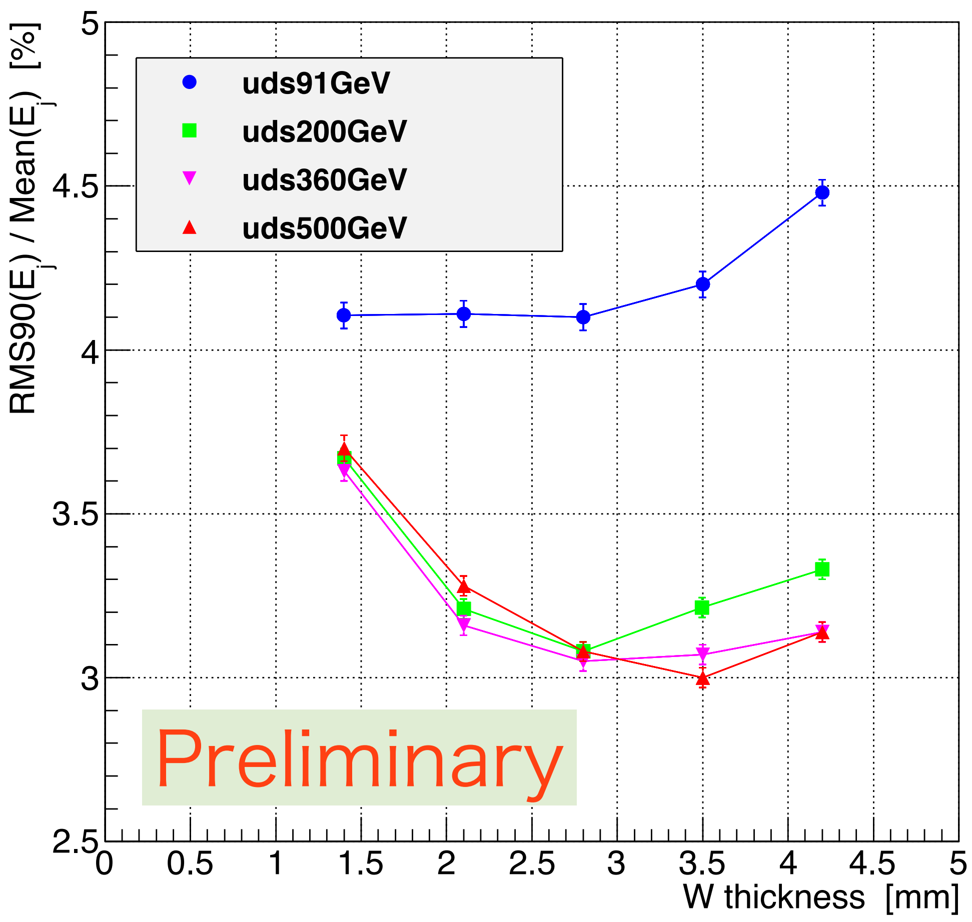


Thickness Dependence

Energy Dependence



Thickness Dependence



For Total thickness, ×29

Hybrid Configurations

~same module thickness~

Sc thickness = 1.0mm
Si thickness = 0.5mm

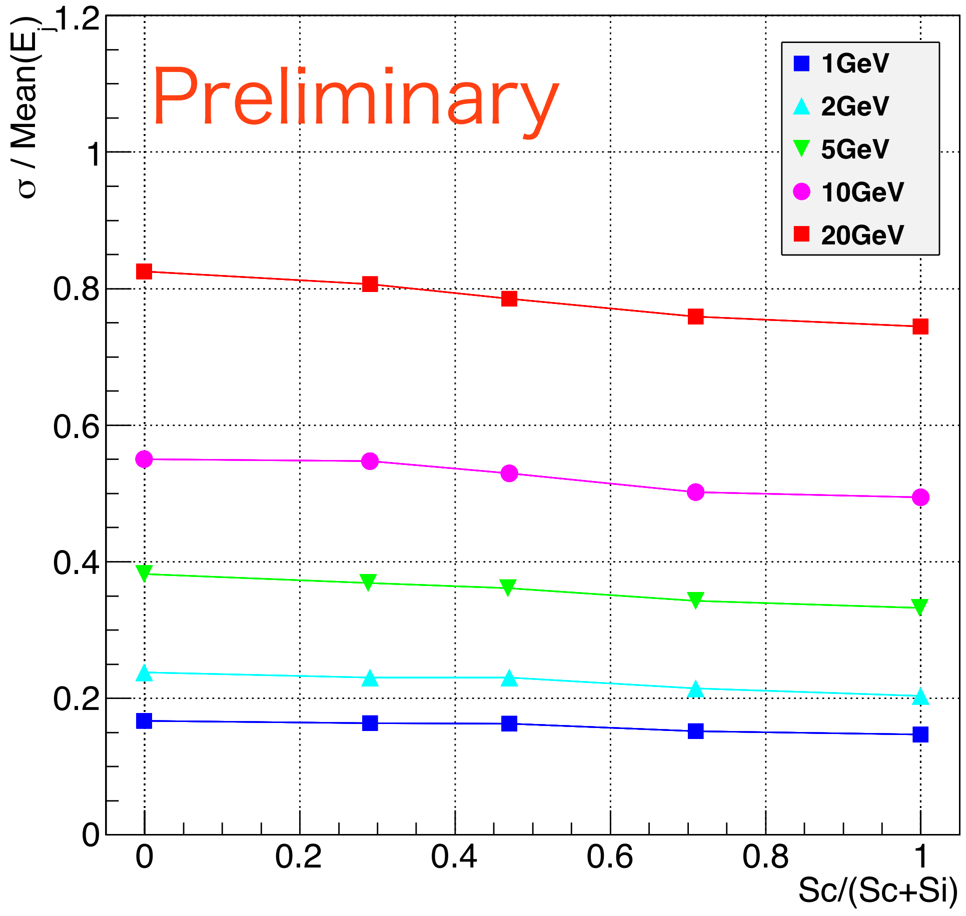
	W thickness (mm)	Total Radiation Length (X0)	Module Thickness (mm)
SiECAL(30)	2.1x20/4.2x9	22.8	185.000
Hybrid(Si22Sc8)②	2.45x20/4.9x7	23.8	185.512
Hybrid(Si16Sc14)③	2.35x20/4.7x7	22.8	184.596
Hybrid(Si10Sc20)④	2.65x18/5.3x7	24.2	184.852
ScECAL(26)	2.5x18/5.0x7	22.9	183.364

Performance of Hybrid ECAL

- Jet Energy Resolution
  - same absorber thickness
  - same module thickness
  - alternating hybrid
- Photon Energy Resolution
  - same absorber thickness
  - same module thickness

Photon Energy Resolution

same absorber thickness



	σ stoc.	σ const.
SiECAL(30)	16.9±0.08%	1.70±0.05%
Hybrid(Si22+Sc8)	16.6±0.08%	1.52±0.05%
Hybrid(Si16+Sc14)	16.4±0.04%	1.36±0.05%
Hybrid(Si10+Sc20)	15.4±0.07%	1.65±0.05%
ScECAL(30)	14.7±0.07%	1.83±0.03%

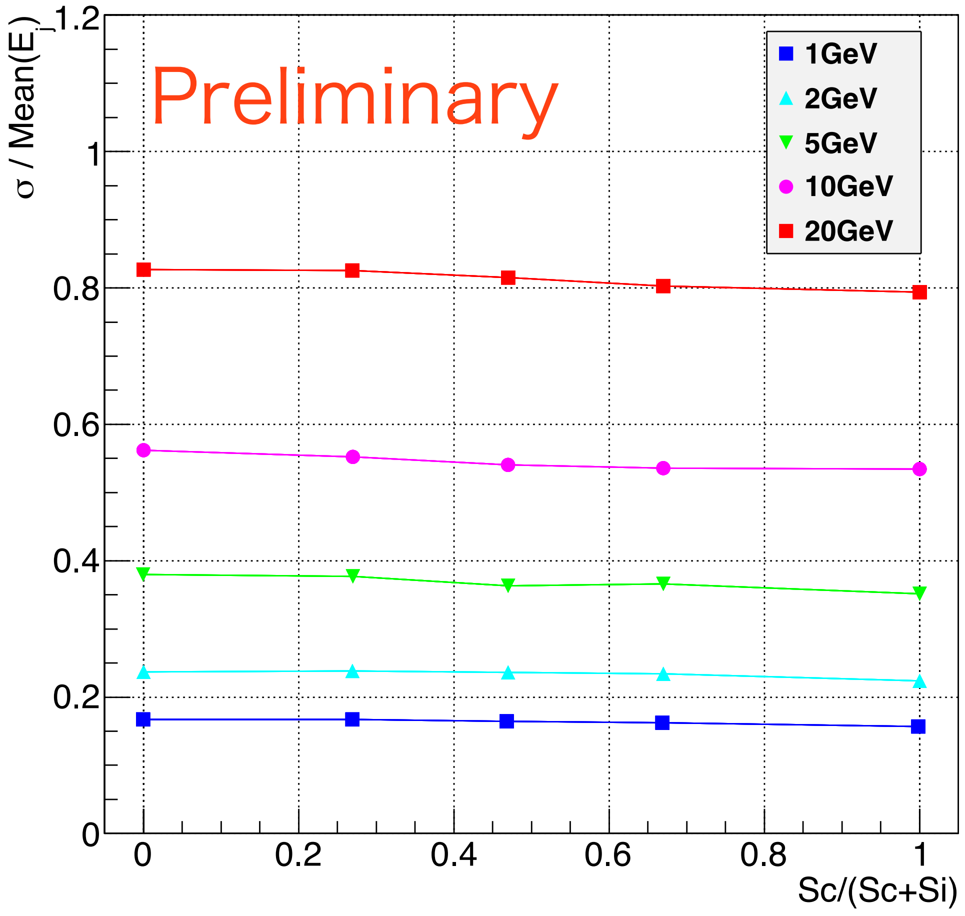
- Photon Energy Resolution becomes better as Sc ratio increases.
- ScECAL is better than SiECAL about 2%.

Performance of Hybrid ECAL

- Jet Energy Resolution
  - same absorber thickness
  - same module thickness
  - alternating hybrid
- Photon Energy Resolution
  - same absorber thickness
  - same module thickness

Photon Energy Resolution

same module thickness



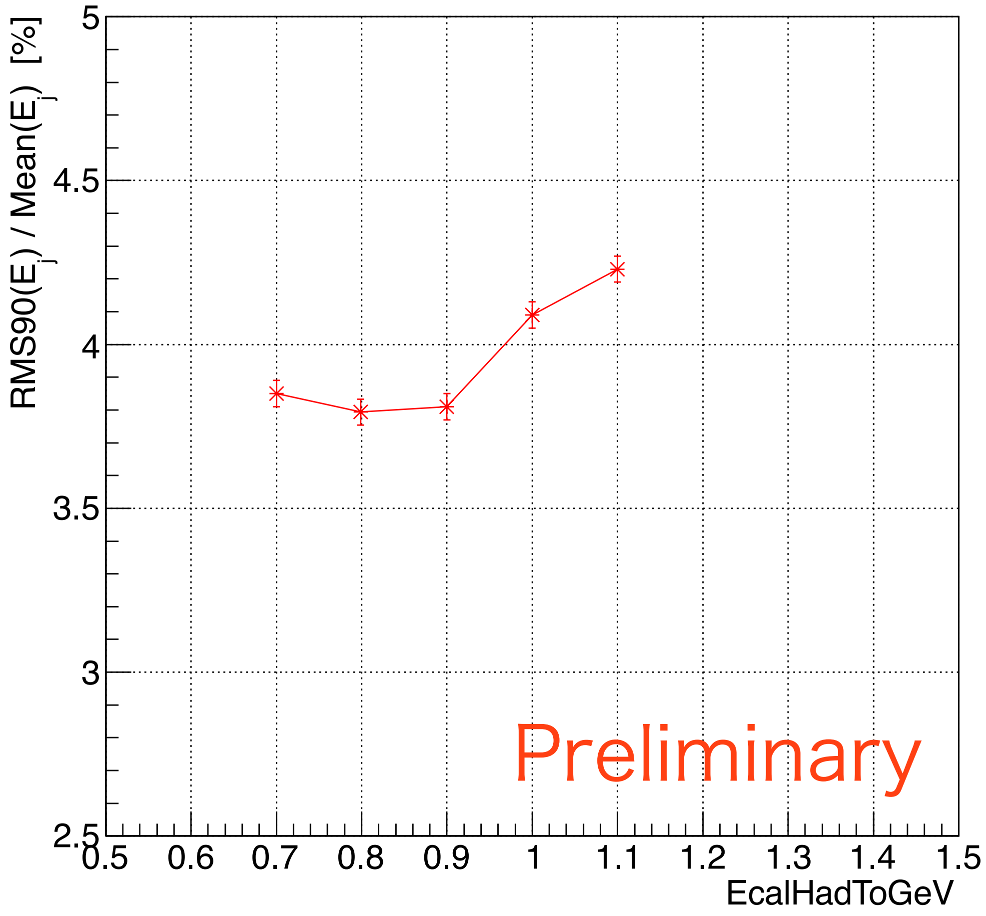
	σ stoc.	σ const.
SiECAL(30)	17.0±0.08%	1.65±0.05%
Hybrid(Si22+Sc8)	17.0±0.08%	1.50±0.05%
Hybrid(Si16+Sc14)	16.7±0.08%	1.55±0.05%
Hybrid(Si10+Sc20)	16.6±0.08%	1.56±0.05%
ScECAL(30)	16.0±0.07%	1.77±0.04%

- Photon Energy Resolution becomes a little better as Sc ratio increases.
- Any Hybrids aren't better than SiECAL.

Hadronic Response in ECAL

For Sc-layers in Hybrid(Si16+Sc14, 2.1/3.6)

Jet Energy Resolution



Mean Energy