Simulation Study of the Hybrid ECAL for ILD

LCWS13 @Tokyo

11th-15th November, 2013

Hiraku Ueno (Kyushu University)

John Marshall (University of Cambridge)

Kiyotomo Kawagoe, Tamaki Yoshioka, Taikan Suehara, Yuji Sudo,
Yohei Miyazaki, Tatsuhiko Tomita (Kyushu University)

Tohru Takeshita, Katsushige Kotera, Tomohisa Ogawa (Shinshu University)

Daniel Jeans, Shion Chen, Chihiro Kozakai (The University of Tokyo)

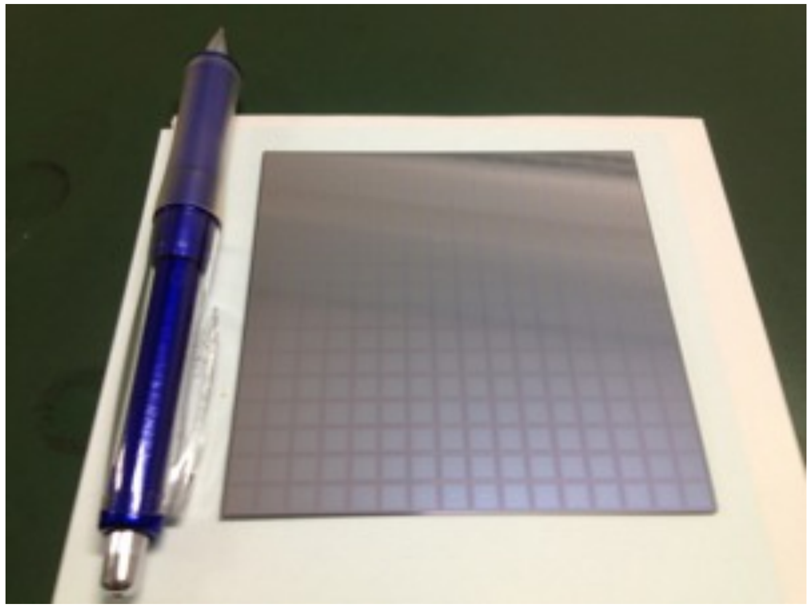
On behalf of ILD-ECAL group

Contents

- Motivation for the Hybrid ECAL
- Calibration, Evaluation
- Jet Energy Resolution
  - Same Absorber Thickness
  - Same Module Thickness
  - Alternating Hybrid
- Understanding Jet Energy Resolution
- Summary

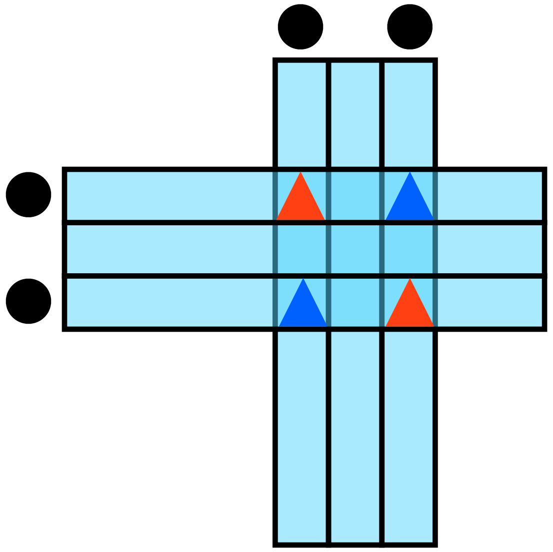
ILD ECAL Candidates

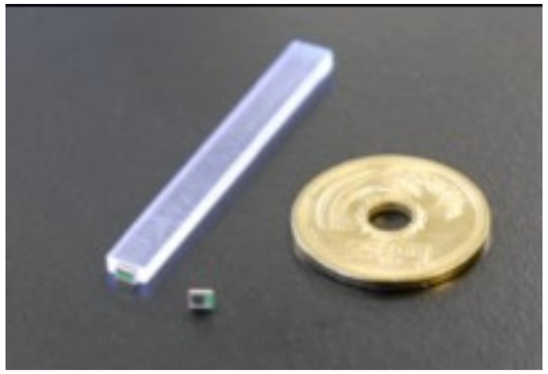
Silicon pads（Si ECAL）



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

Scintillator strips +MPPC（Sc ECAL）



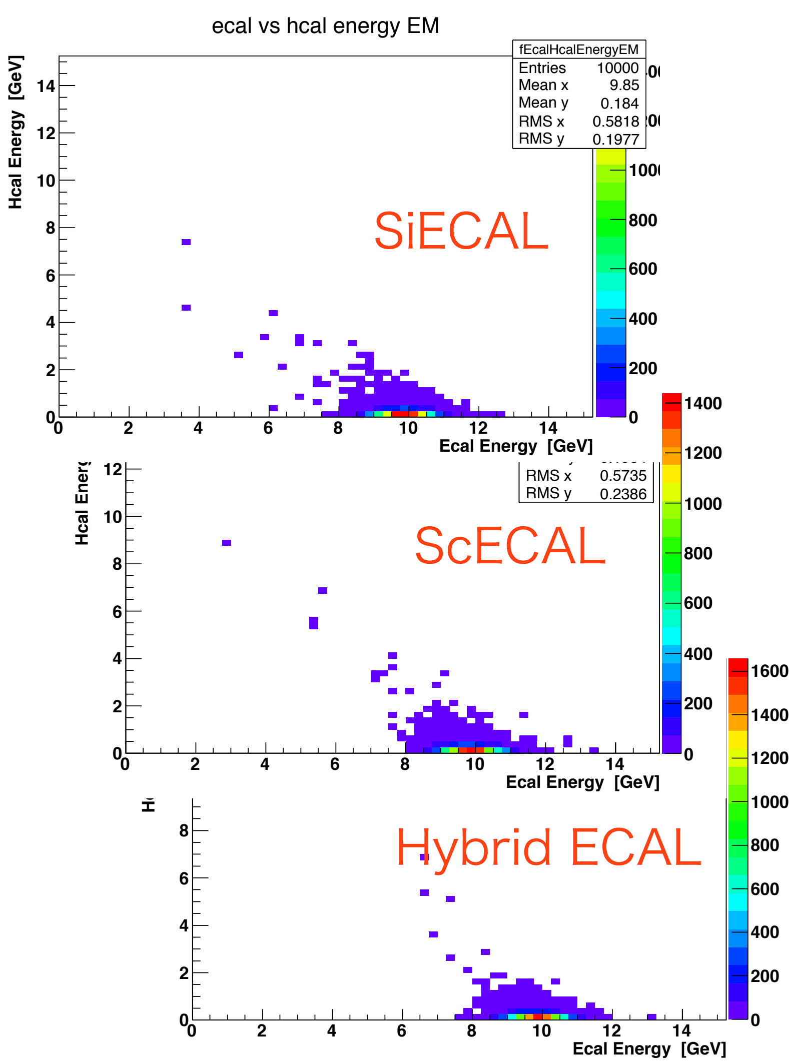


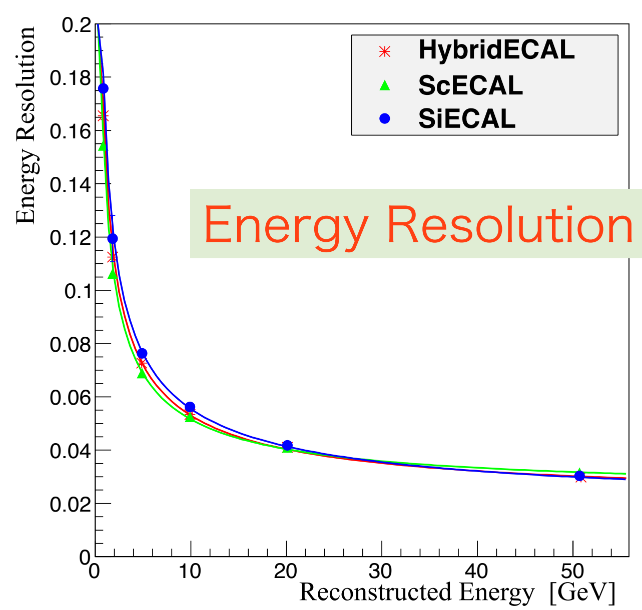
* 45mm x 5mm orthogonal & SSA
  --> 5mm x 5mm spatial resolution
* reasonable cost
* ghost hits

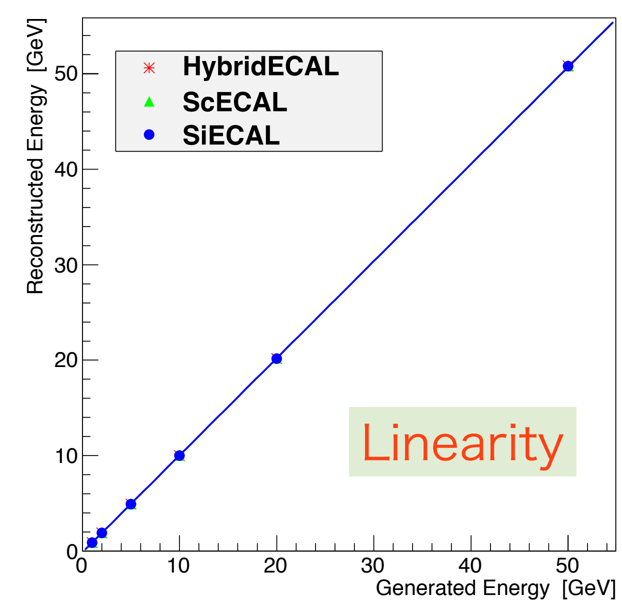
An option to make the ECAL at a lower cost while keeping performance as much as possible would be mixture of silicon and scintillator-strip layers.

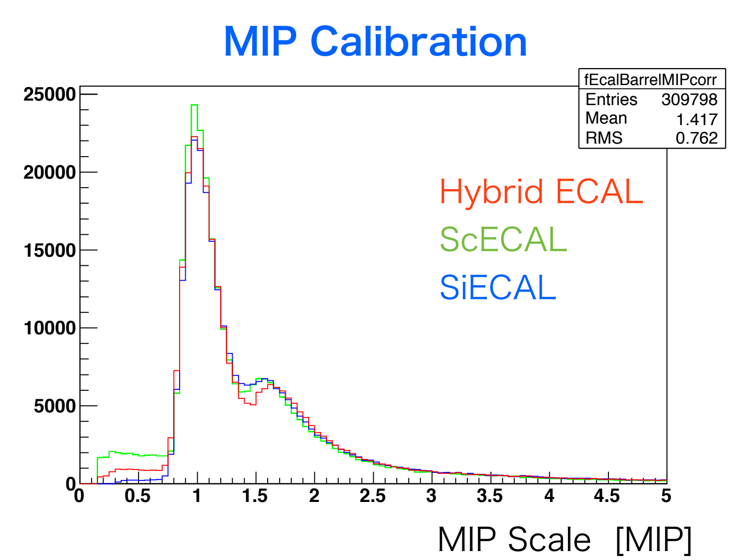
ECAL Calibration

- Calibration constants should be determined for silicon layers and scintillator layers respectively.
- calibrated using 10GeV photon, and confirmed our method.
- use 10GeV muon for MIP calibration.



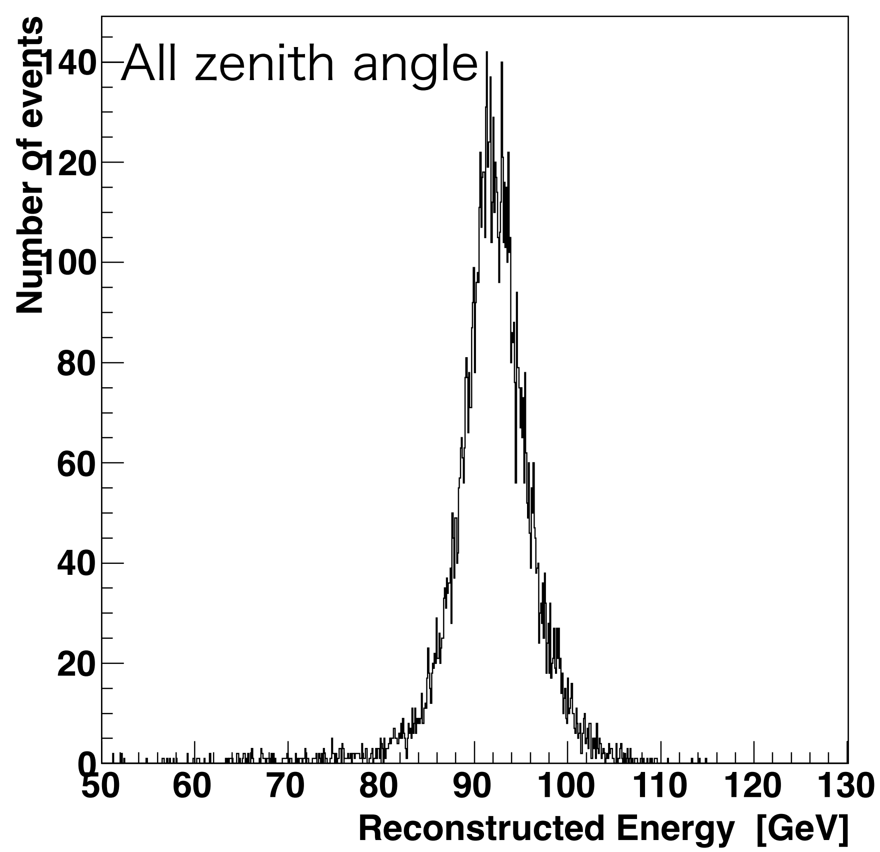


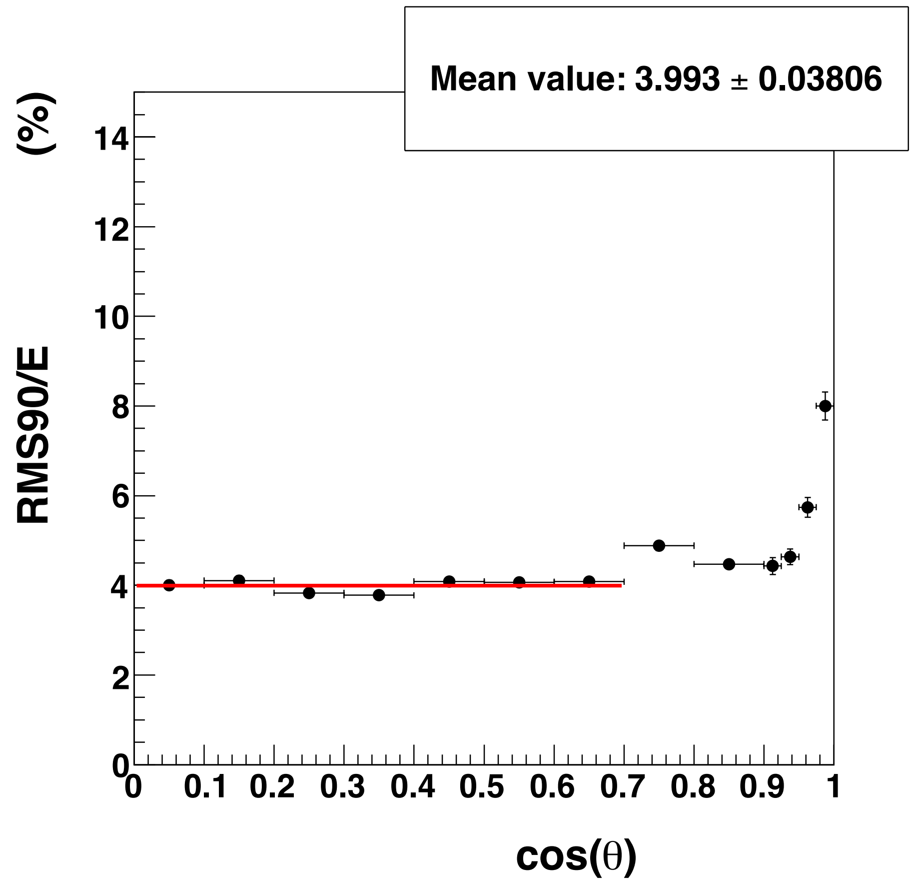




Hybrid ECAL Evaluation

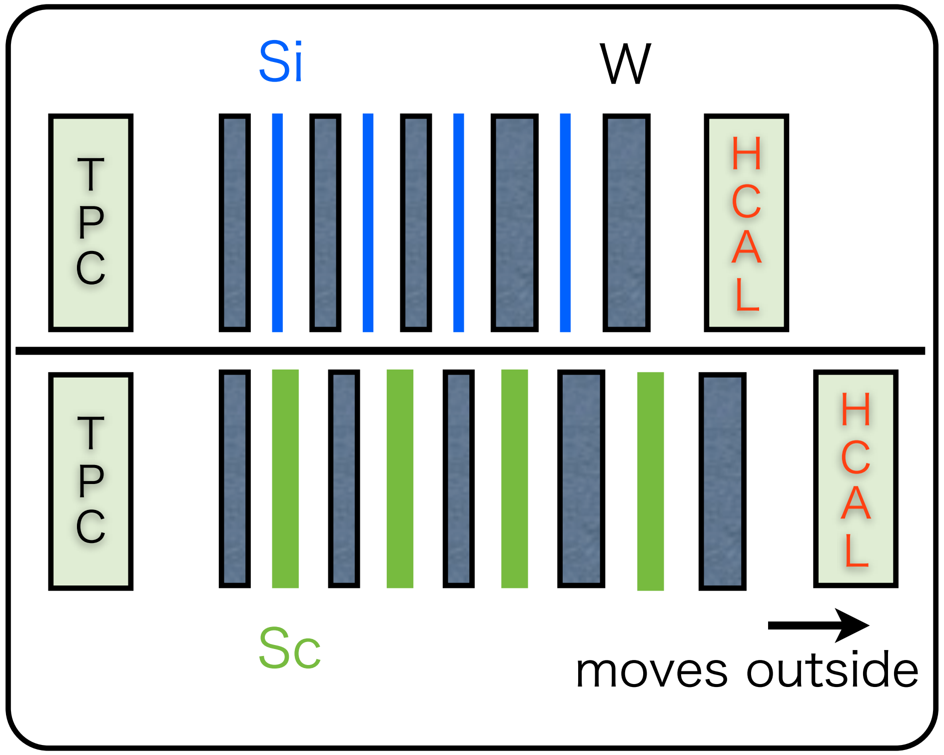
- We evaluated energy dependence and Sc:Si ratio dependence.
- software version : ilcsoft v01-16-02 with trunk version of some processors (Data were generated with old version of Mokka)
- $e^+e^- \rightarrow q\bar{q}$ (q=u,d,s, √s=91, 200, 360, 500GeV)
- only barrel region (cos(thrust angle)<0.7) for evaluation.



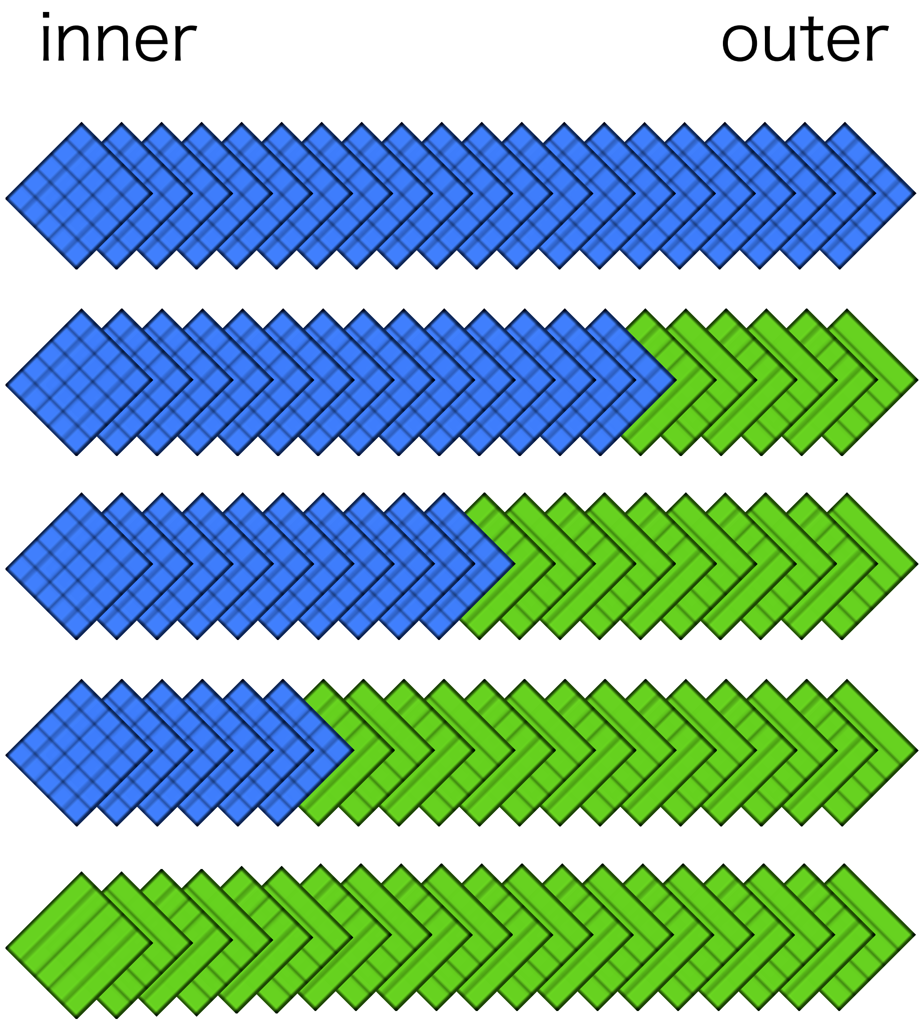


same absorber thickness

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

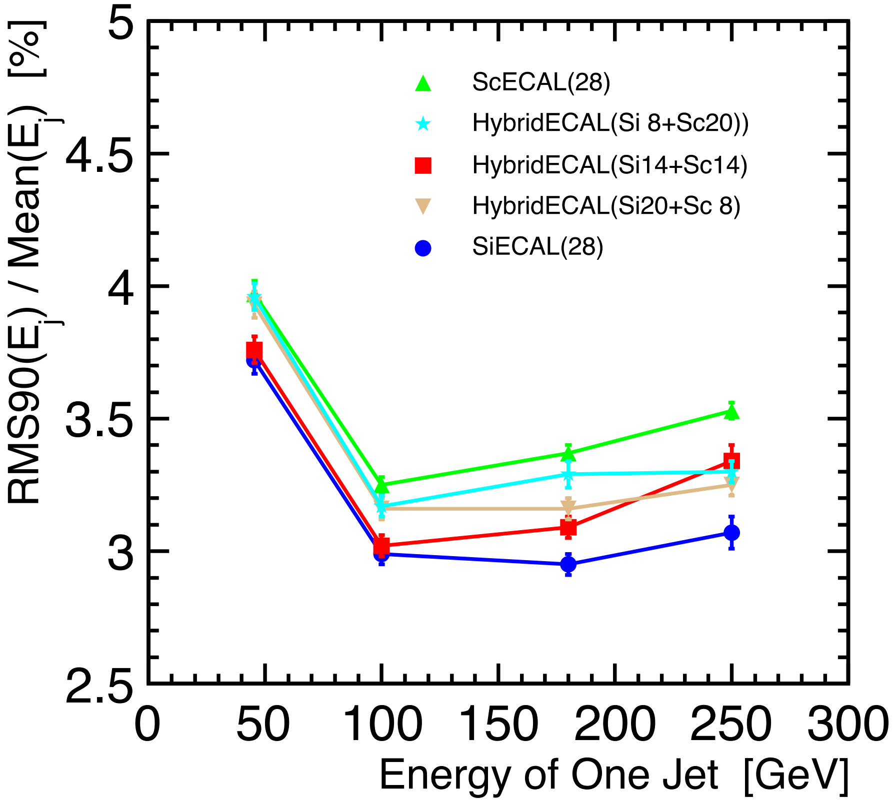


	W thickness (in20,out7)	Module thickness (mm)
SiECAL(28)	2.1/3.5	165.4
Hybrid(Si20Sc8)	2.1/3.5	176.7
Hybrid(Si14Sc14)	2.1/3.5	185.2
Hybrid(Si8Sc20)	2.1/3.5	193.7
ScECAL(28)	2.1/3.5	205.0



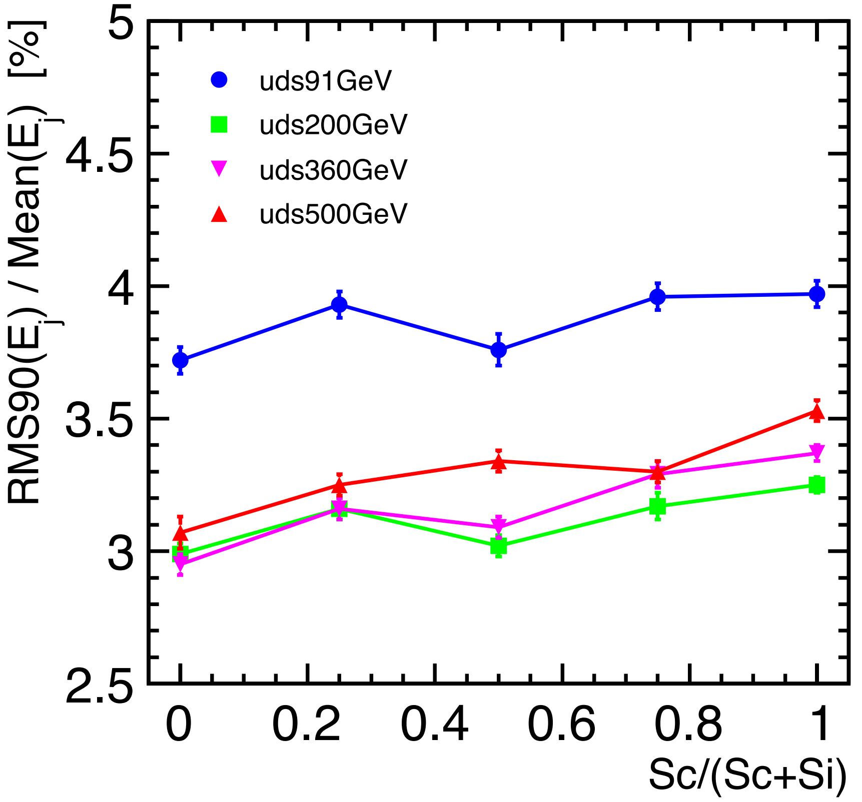
Jet Energy Resolution

Energy Dependence



- JER difference between SiECAL and ScECAL is ~0.5% at 180, 250GeV.
- Hybrid(Si20+Sc8) is about medium between SiECAL and ScECAL.

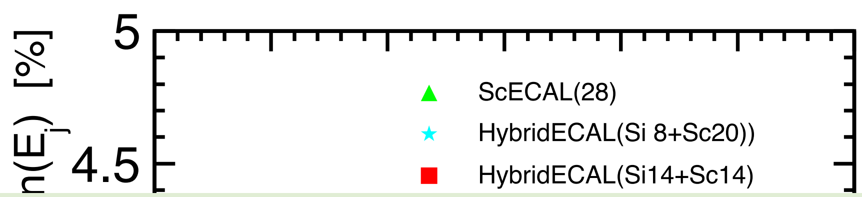
Ratio Dependence



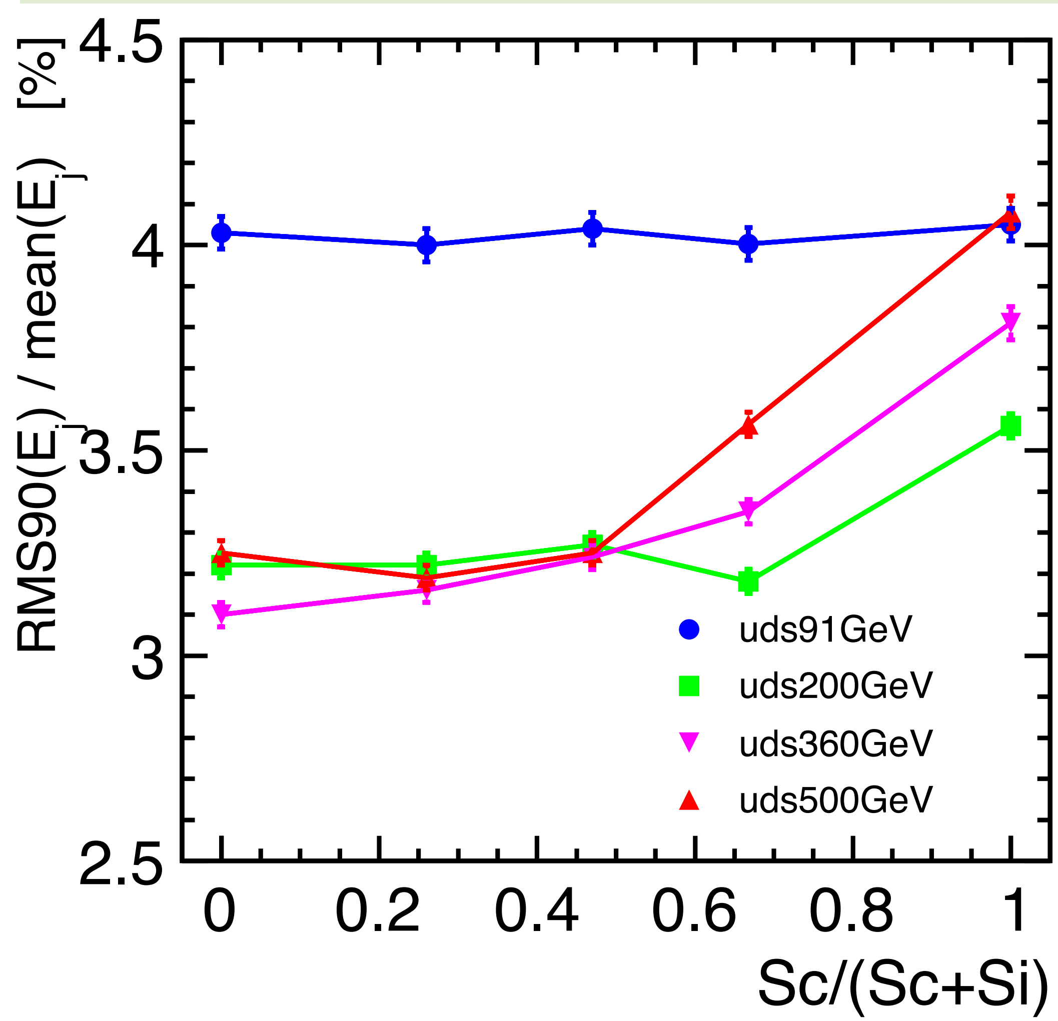
- Scintillator performance becomes much better than that with old version
- JER becomes worse gradually.
- The performance doesn't degrade up to 50% of Scintillator layers up to 100GeV jet.

Jet Energy Resolution

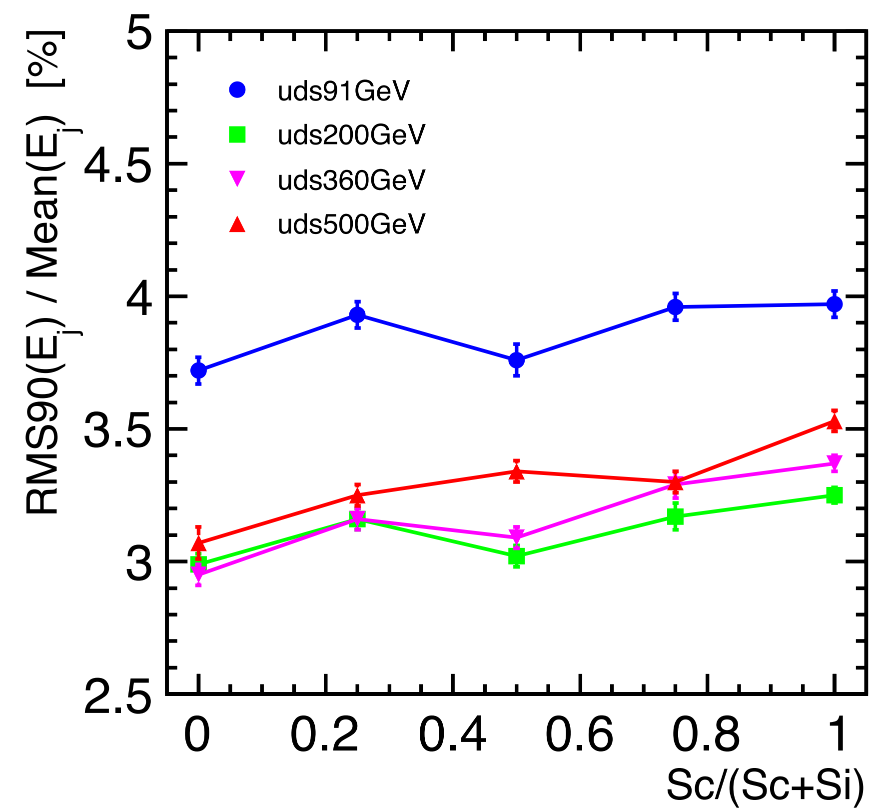
Energy Dependence



Ratio Dependence (v01-15)



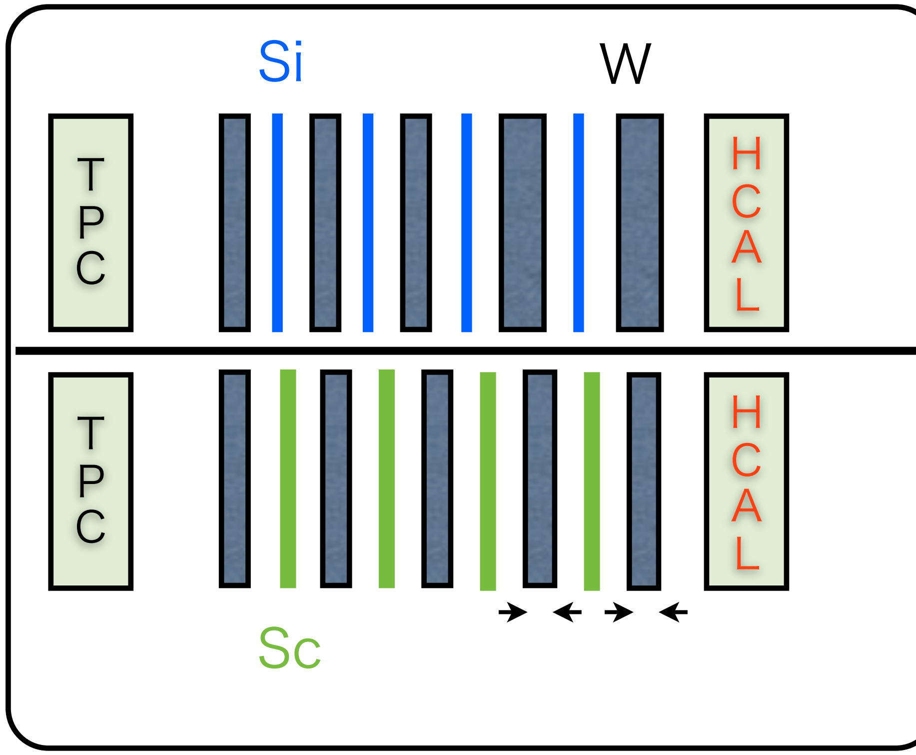
Ratio Dependence



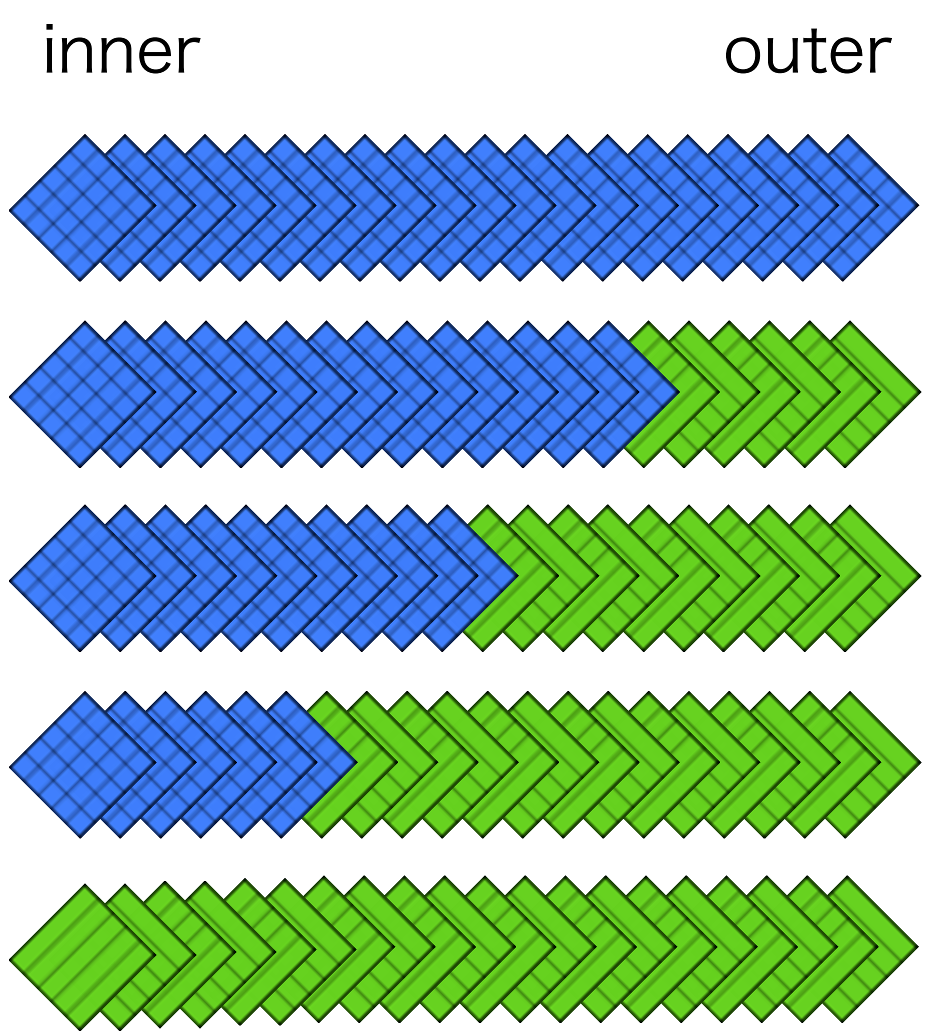
- Scintillator performance becomes much better than that with old version
- JER becomes worse gradually.
- The performance doesn't degrade up to 50% of Scintillator layers up to 100GeV jet.

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

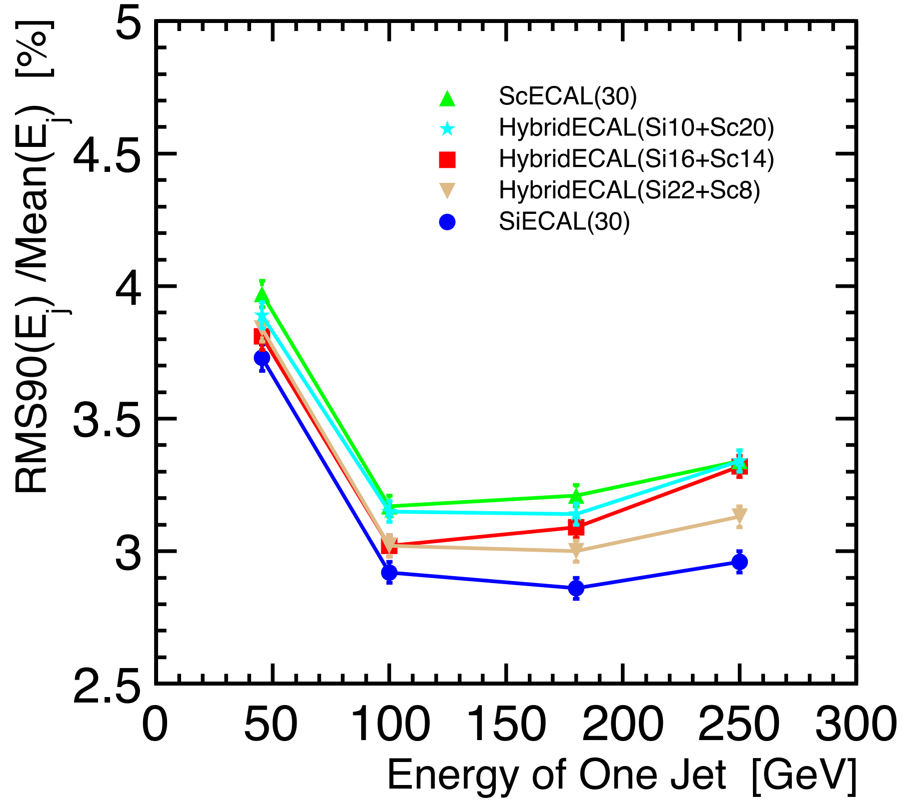


	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid(Si22Sc8)	2.1/3.9	185.6
Hybrid(Si16Sc14)	2.1/3.6	185.4
Hybrid(Si10Sc20)	2.1/3.3	185.2
ScECAL(30)	2.1/2.9	185.7

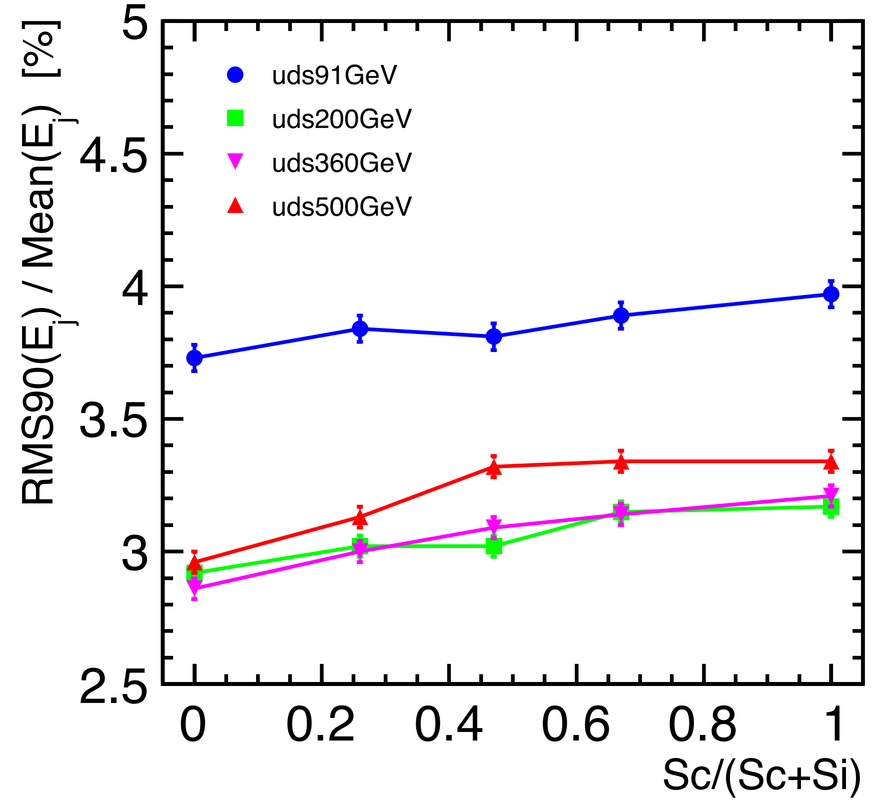


Jet Energy Resolution

Energy Dependence



Ratio Dependence

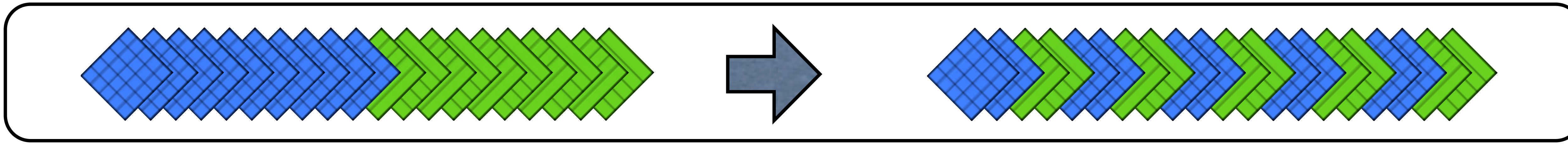


- JER difference between SiECAL and ScECAL is ~0.3% at 180, 250GeV
- The performances of ECALs contains Sc-layers more than half are same at 250GeV.
- Hybrid(Si22+Sc8) is about medium between SiECAL and ScECAL

- JER degrades not so much up to 180GeV jet.
- The difference between SiECAL and ScECAL or Hybrid(Si16+Sc14) is ~0.3% at 250GeV

alternating hybrid

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



same absorber thickness

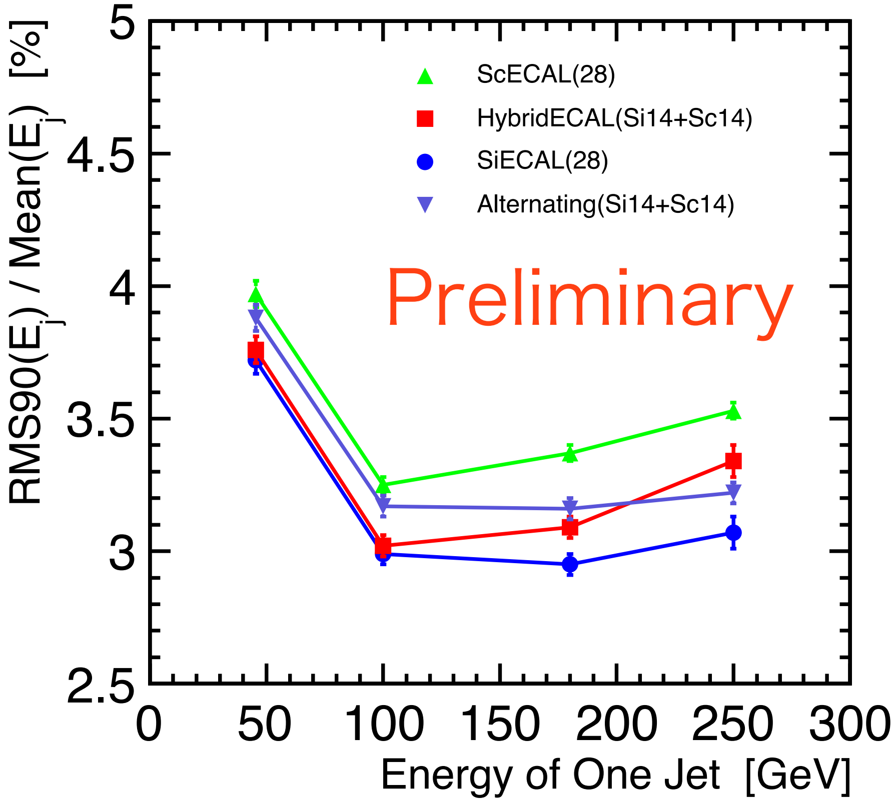
	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/3.5	165.4
Hybrid(Si16Sc14) [not alternate]	2.1/3.5	185.2
Double layers Alternate(Si16Sc14)	2.1/3.5	185.2
ScECAL(30)	2.1/3.5	205.0

same module thickness

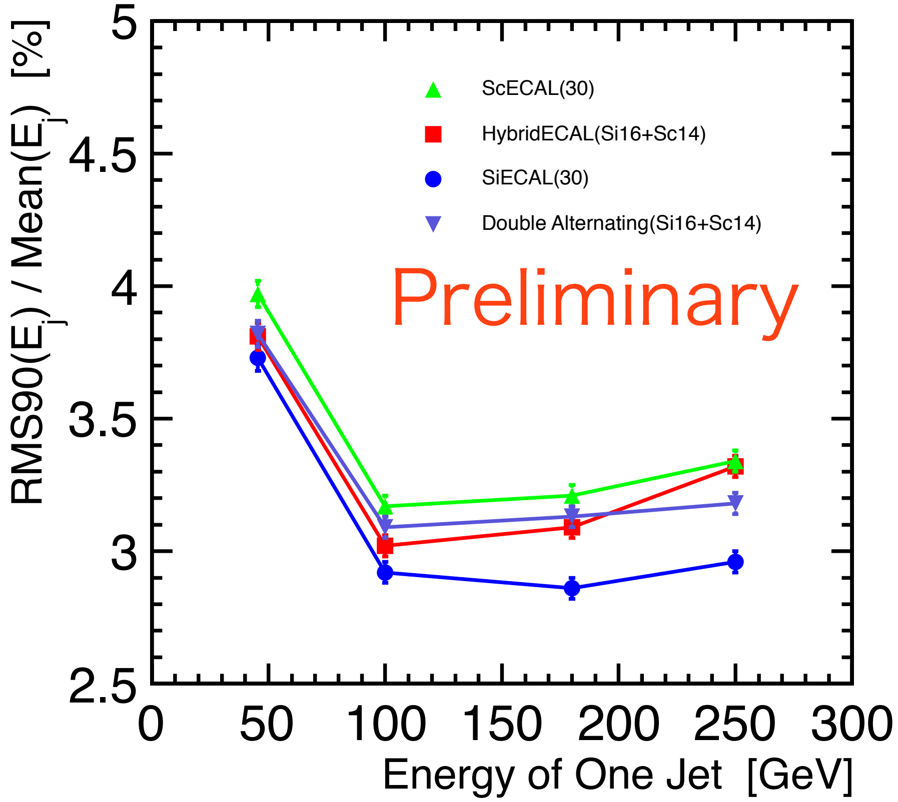
	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid(Si16Sc14) [not alternate]	2.1/3.6	185.4
Double layers Alternate(Si16Sc14)	2.1/3.6	185.4
ScECAL(30)	2.1/2.9	185.7

Performance of alternating hybrid

same absorber thickness



same module thickness

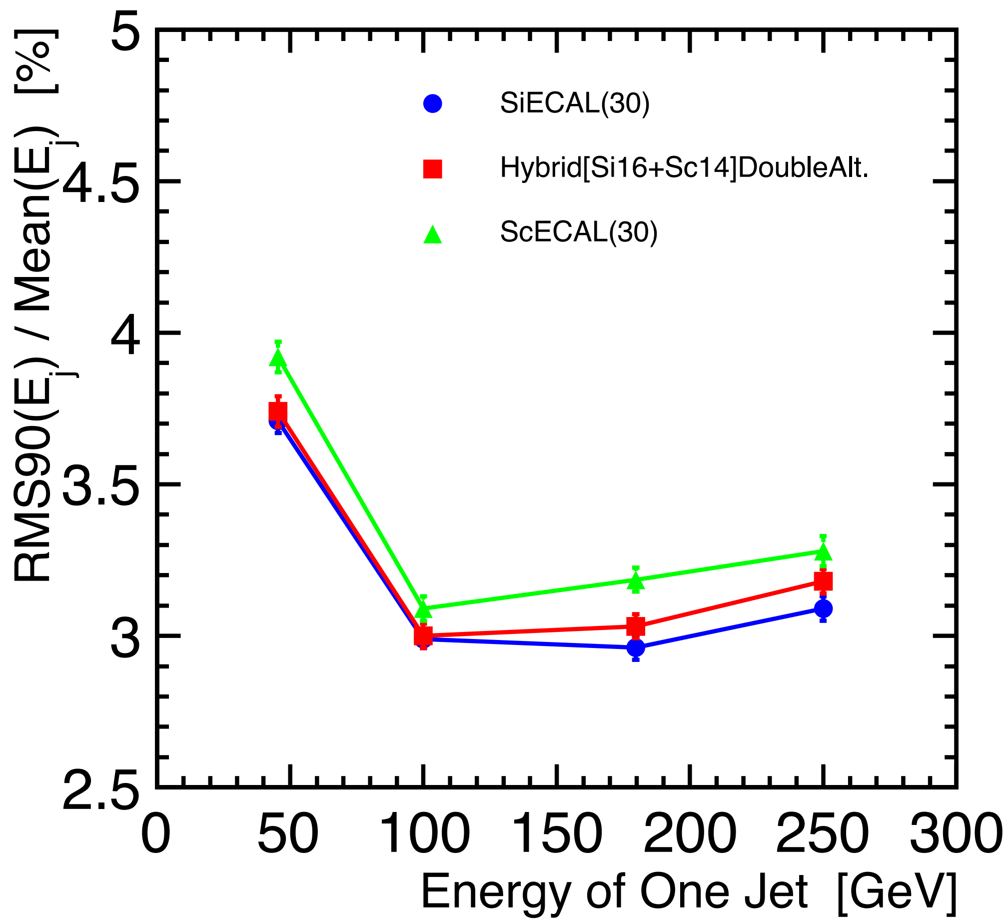


- For both case,
  - worse than half and half at low energies
  - a little bit better at high energies

Single layer alternating will be evaluated

Understanding ECAL Performance

- the contributions to JER by cheating MC information
- Data are generated with trunk version of Mokka

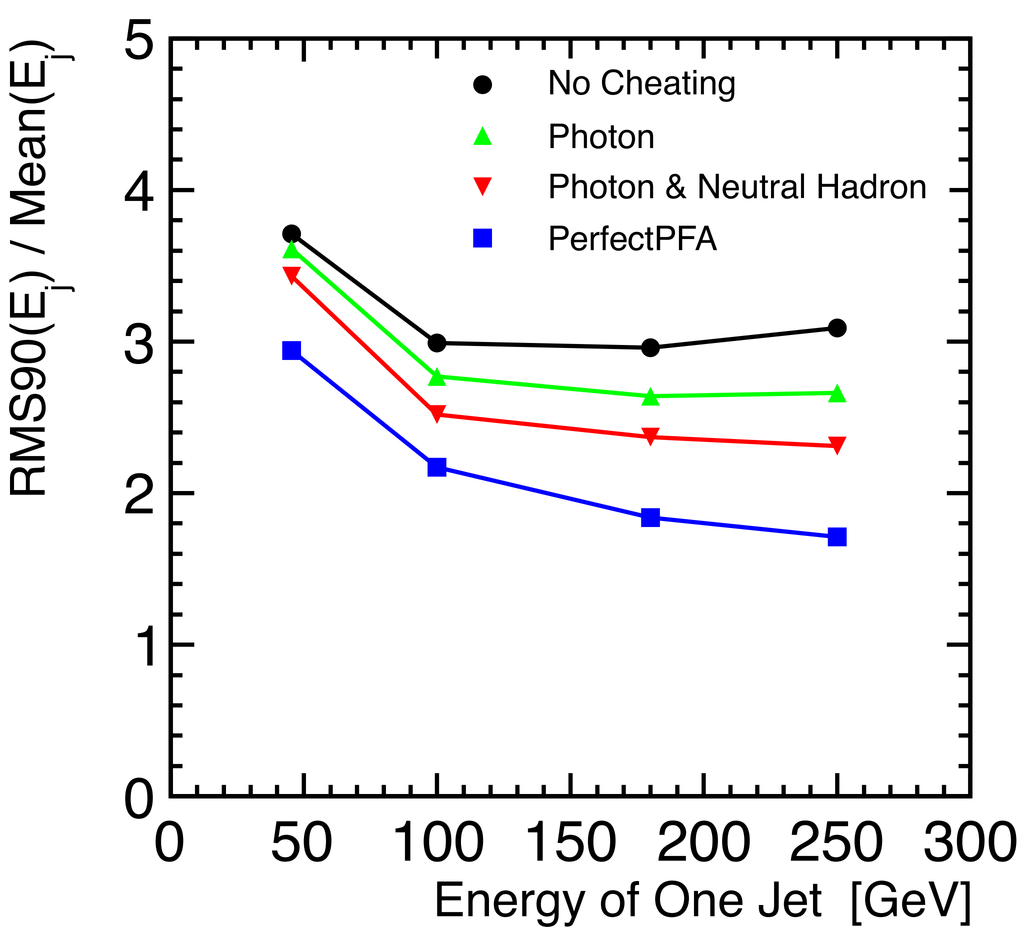


Sc = 1.0mm	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid[Si16+Sc14] Double Alternating	2.1/4.2	190.8
ScECAL(30)	2.1/4.2	197.4

Understanding ECAL Performance

- switched standard PFA algorithm to MC cheating version
- We are evaluating three cases,
  - cheat photon
  - cheat photon & Neutral Hadron (neutron, K_L)
  - Perfect Pattern Recognition

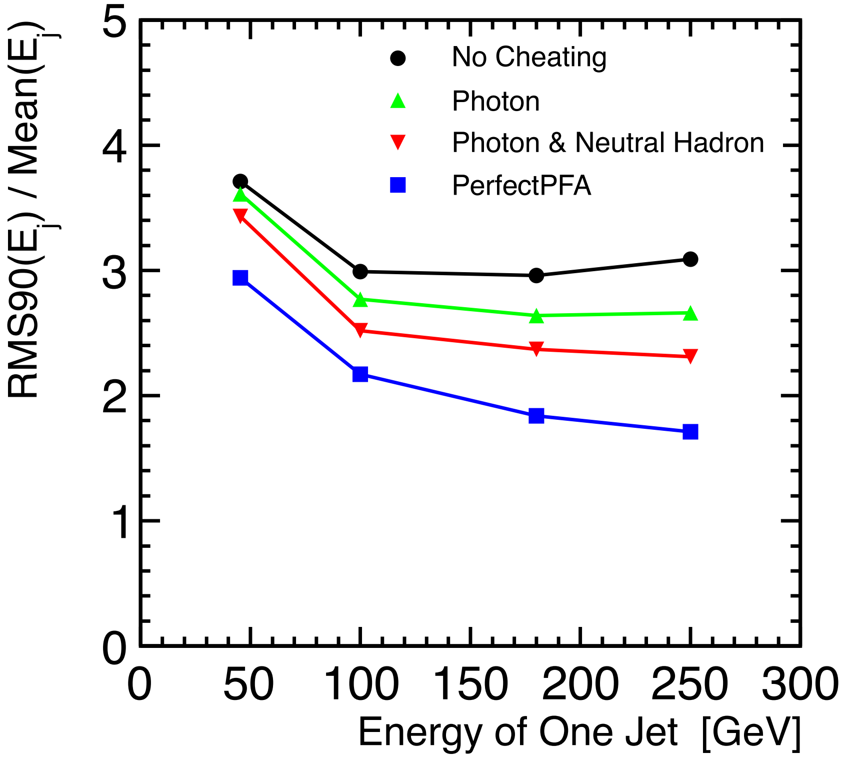
SiECAL(30)



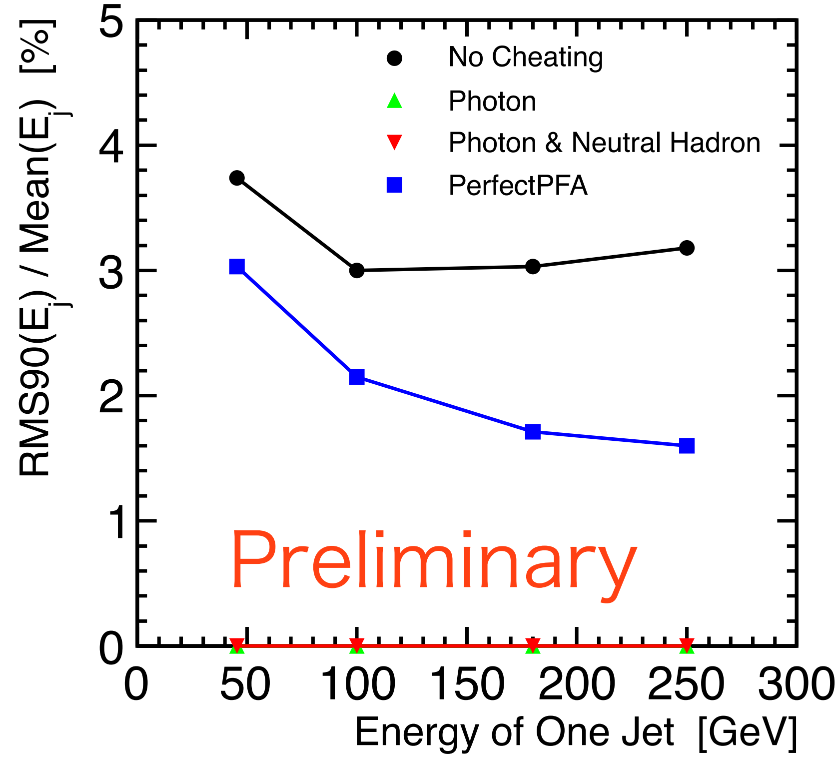
	45GeV	100GeV	180GeV	250GeV
Photon	0.10%	0.22%	0.32%	0.43%
Neutral Hadron	0.22%	0.25%	0.27%	0.35%
Others	0.49%	0.35%	0.53%	0.60%
Total Confusion	0.77%	0.82%	1.12%	1.68%

Understanding ECAL Performance

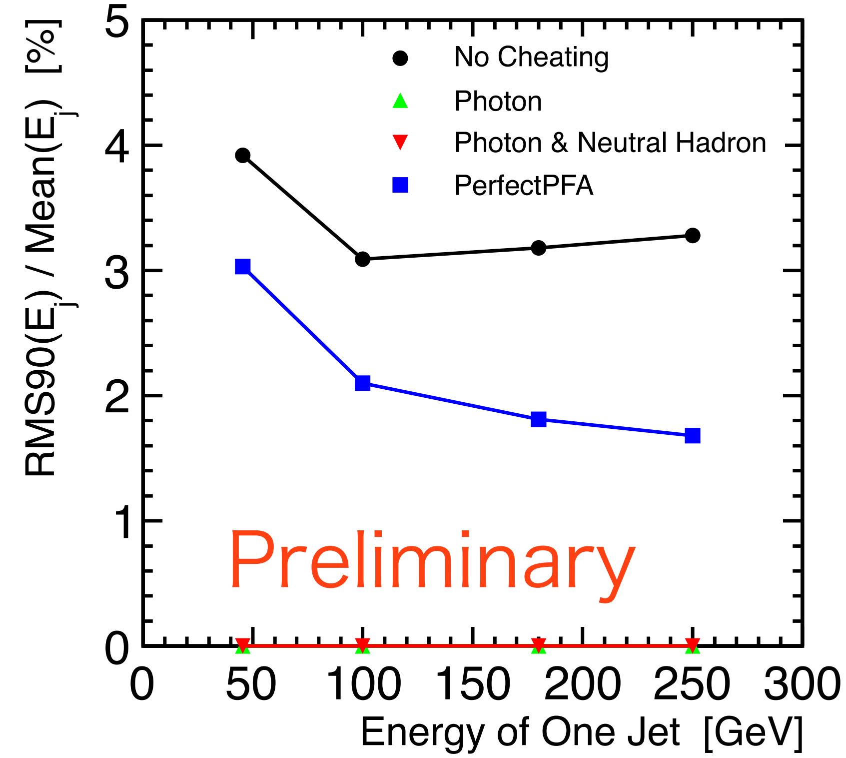
SiECAL



Hybrid[Double Alt.]



ScECAL



- Cheating with SSA has problem.
  - only PerfectPFA for Hybrid and ScECAL
- If pattern recognition is done completely, JERs are almost same.
- Each contribution to JER of Hybrid and ScECAL will be investigated.

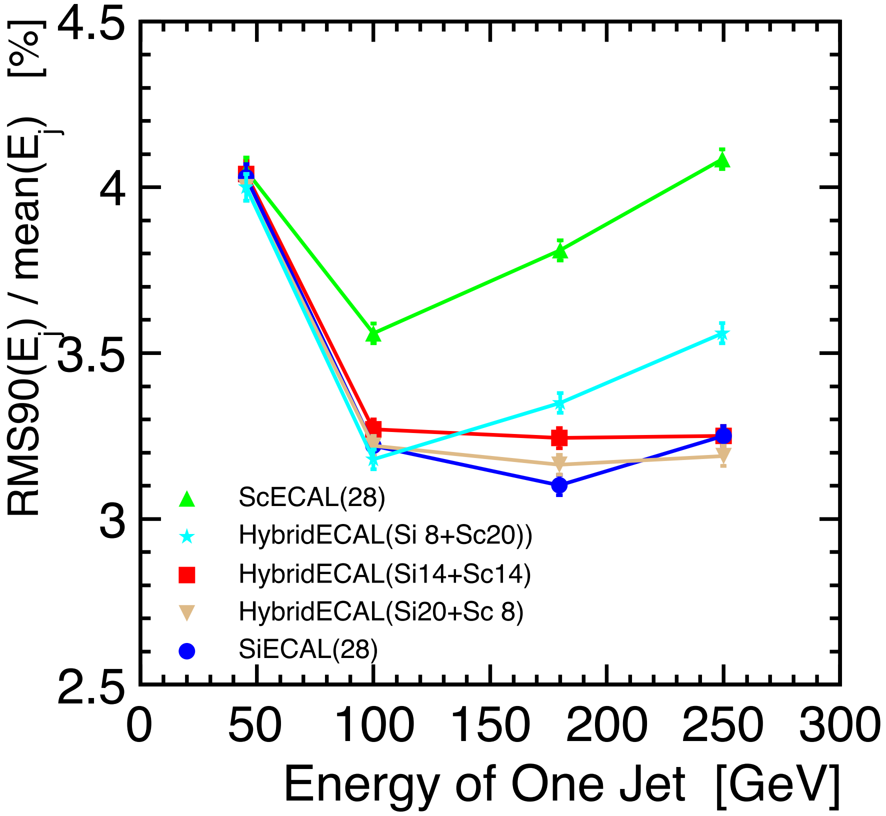
Summary

- We are studying the hybrid option to make ILD ECAL with a lower cost while keeping performance as much as possible.
- evaluated various hybrid configurations
  - same absorber thickness ... 50% of Sc-layers is same as SiECAL up to 100GeV jet
  - same module thickness ... 30% of Sc-layers is medium between SiECAL and ScECAL
  - alternating hybrid ... better at 250GeV than half and half, worse at lower energies
    - single layer alternating will be also evaluated
- We are trying to understand the resolution,
  - will improve to cheat MC information using SSA
  - will investigate the cause of JER difference, and consider measures to improve

Backup

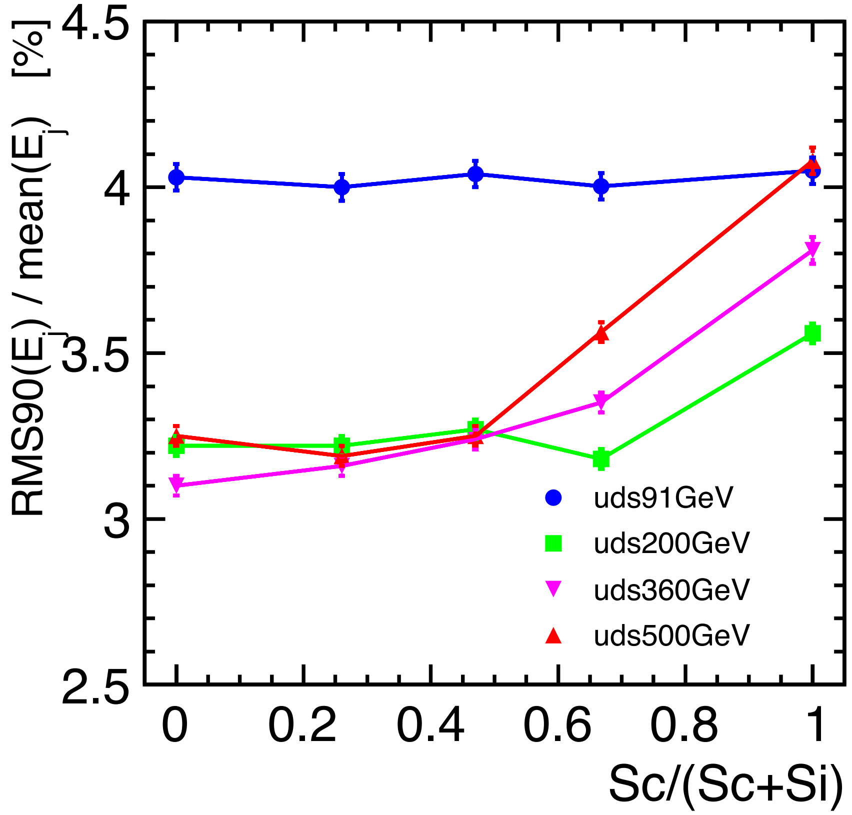
JER v01-15 (Same Absorber Thickness)

Energy Dependence



- can keep performance with less silicon layers at low energies.
- no big difference among SiECAL, Hybrid(Si14+Sc14), Hybrid(Si20+Sc8)

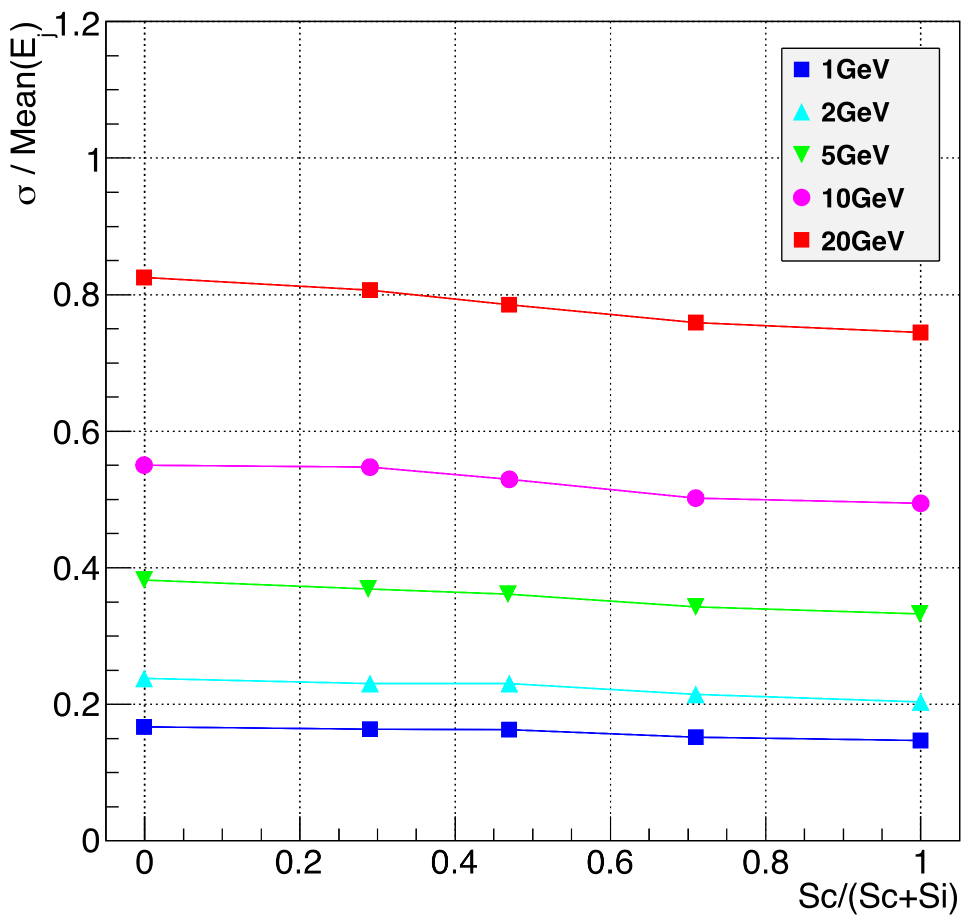
Ratio Dependence



- same performance at 45GeV jet
- becomes worse above 50%
- not degrade up to 50% of scintillator layers

Photon Energy Resolution

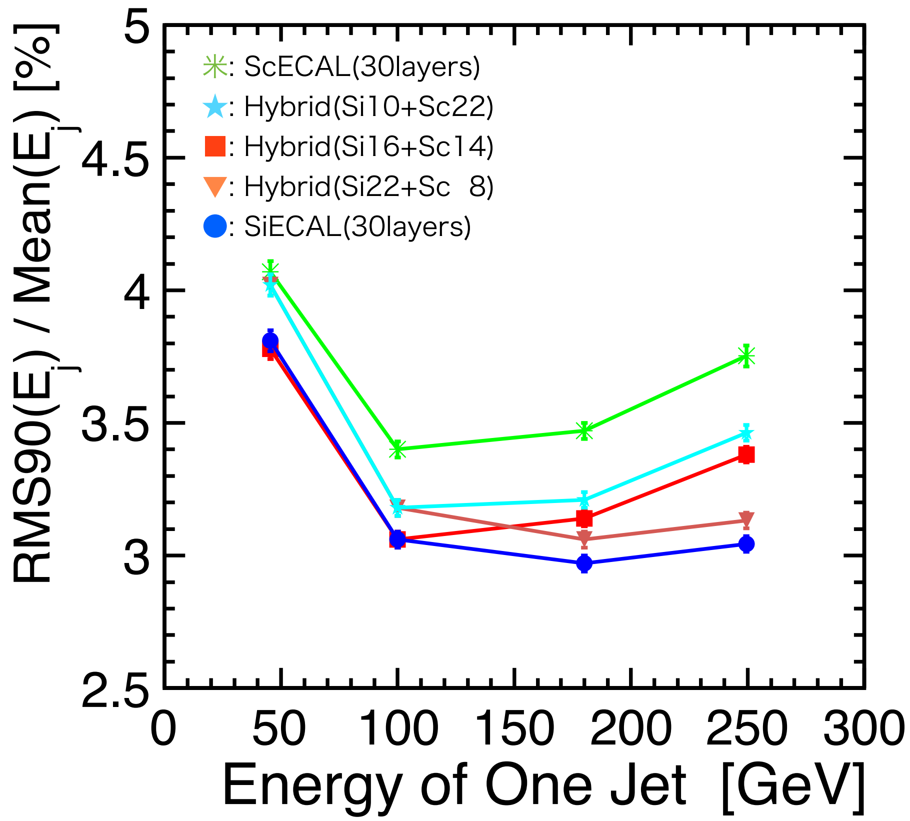
same absorber thickness



	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%

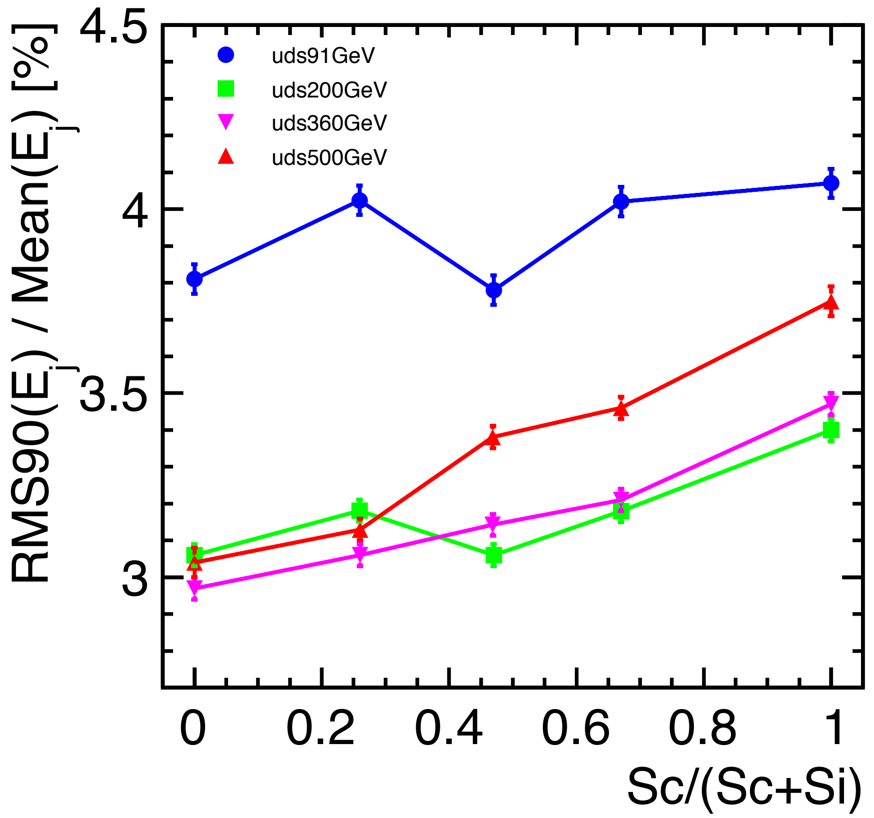
JER v01-15 (Same Module Thickness)

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.

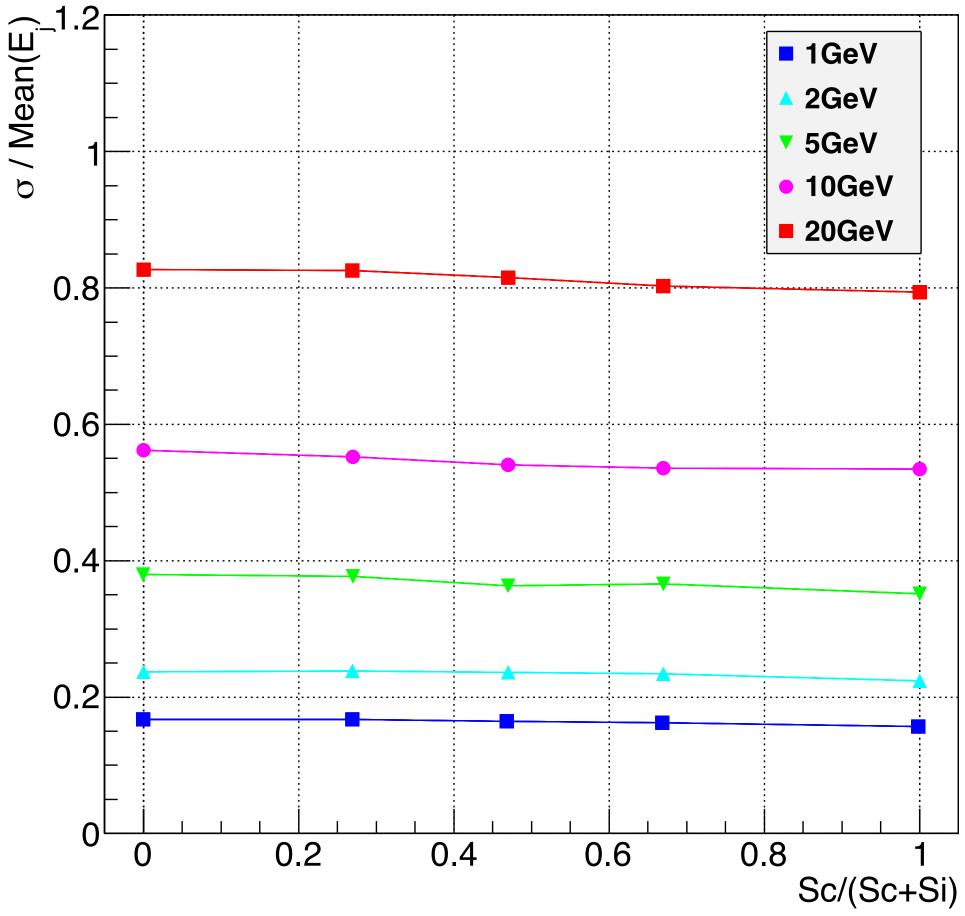
Ratio Dependence



- Performance becomes worse almost linearly as scintillator layers increase
- not so degrade up to ~30%

Photon Energy Resolution

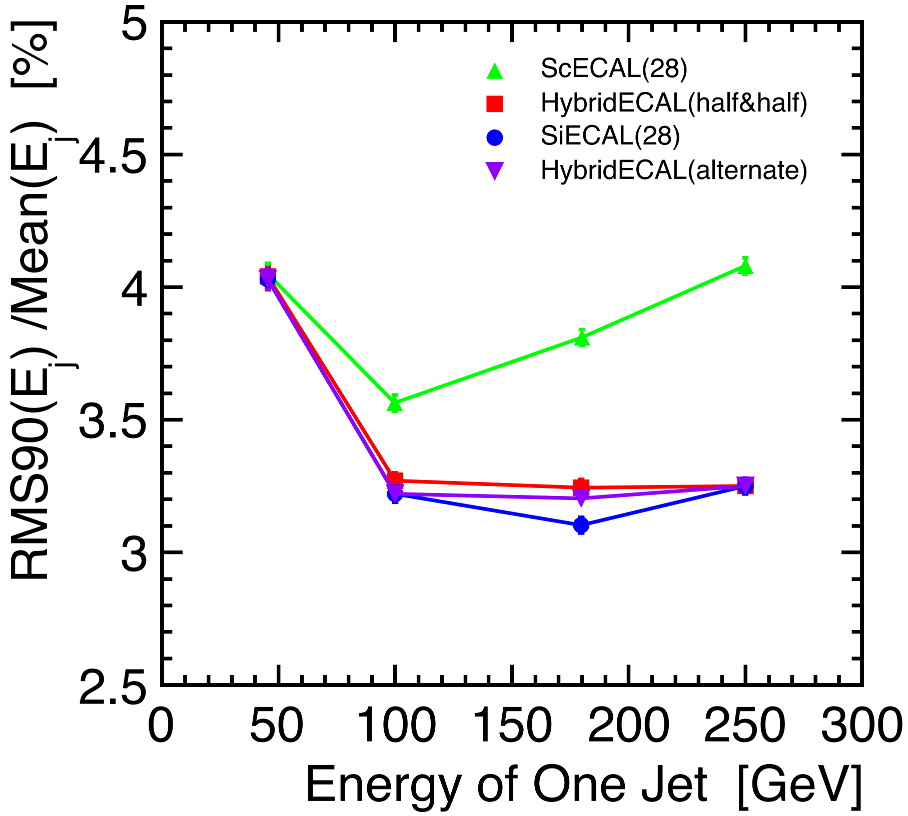
same module thickness



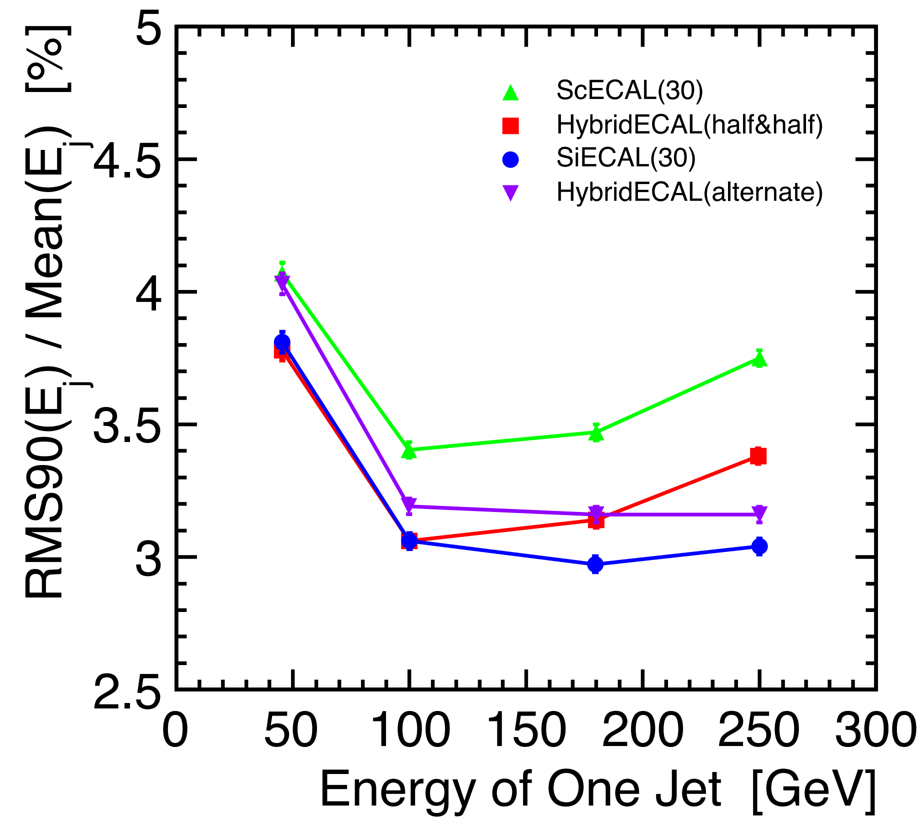
	σ stoc.	σ const.
SiECAL(30)	17.0±0.08%	1.65±0.05%
Hybrid(Si22+Sc8)	17.0±0.08%	1.50±0.05%
Hybrid(Si16+Sc14)	16.7±0.08%	1.55±0.05%
Hybrid(Si10+Sc20)	16.6±0.08%	1.56±0.05%
ScECAL(30)	16.0±0.07%	1.77±0.04%

JER v01-15 (Alternating Hybrid)

same absorber thickness



same module thickness



- alternating is much better than ScECAL
- almost same as SiECAL and Hybrid[Si14+Sc14]

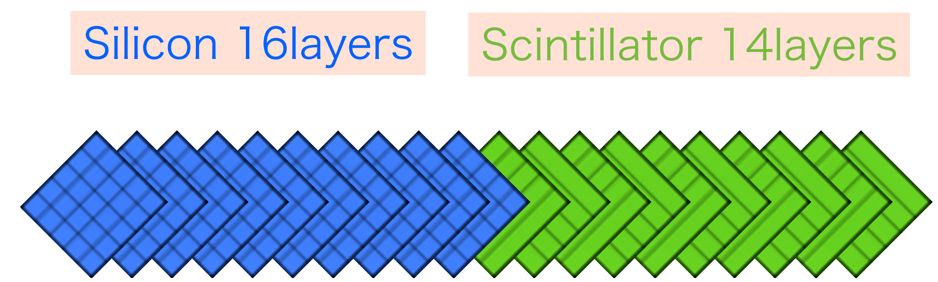
- alternating is much better than ScECAL
  - medium between SiECAL and ScECAL
  - better than Hybrid[Si16+Sc14] at 250GeV

Single layer alternating will be evaluated

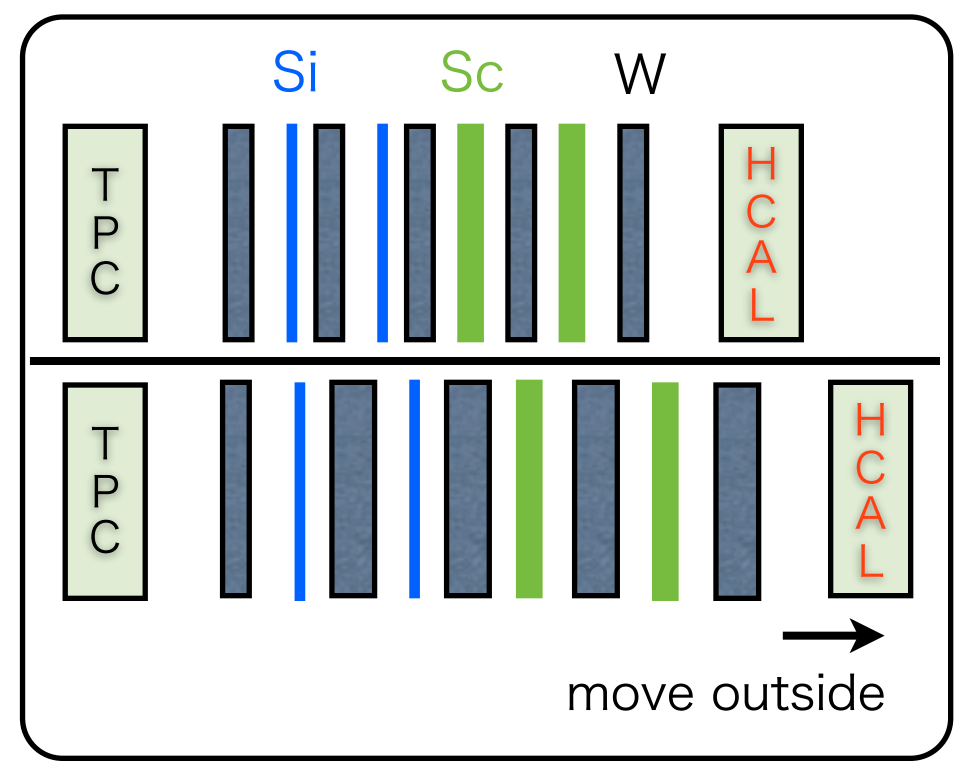
Absorber Thickness Dependence

- v01-15

Sc thickness = 1.0mm
Si thickness = 0.5mm

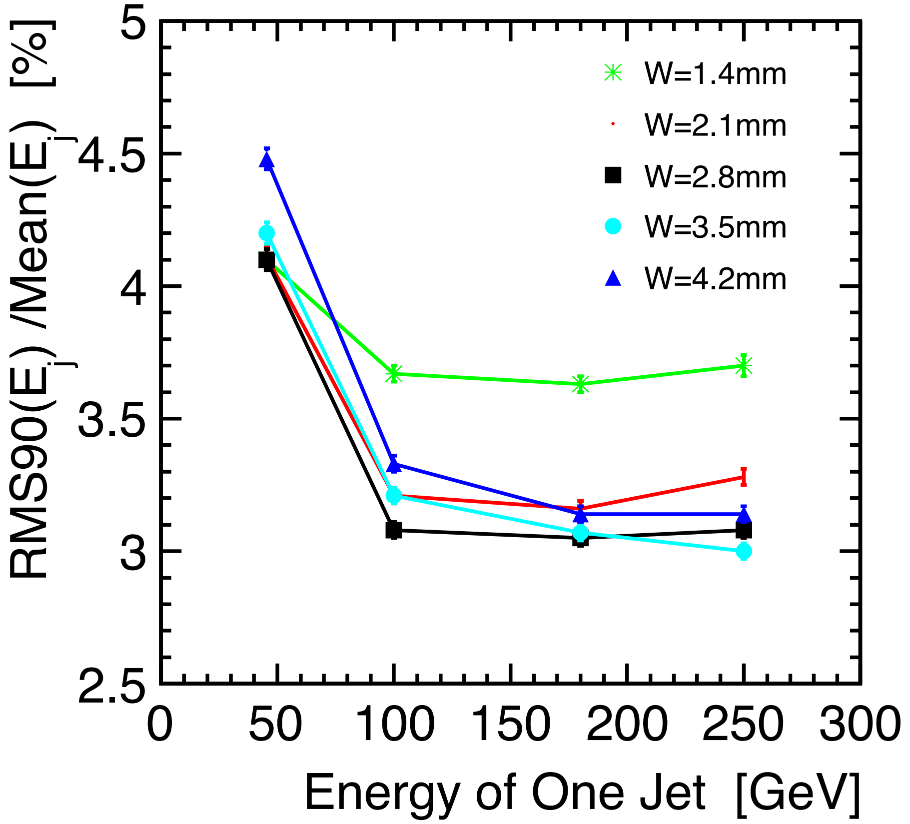


	W thickness (all 29 layers)	Total Radiation Length (X_0)
Hybrid(Si16Sc14)①	1.4	11.6
Hybrid(Si16Sc14)②	2.1	17.4
Hybrid(Si16Sc14)③	2.8	23.2
Hybrid(Si16Sc14)④	3.5	29.0
Hybrid(Si16Sc14)⑤	4.2	34.8

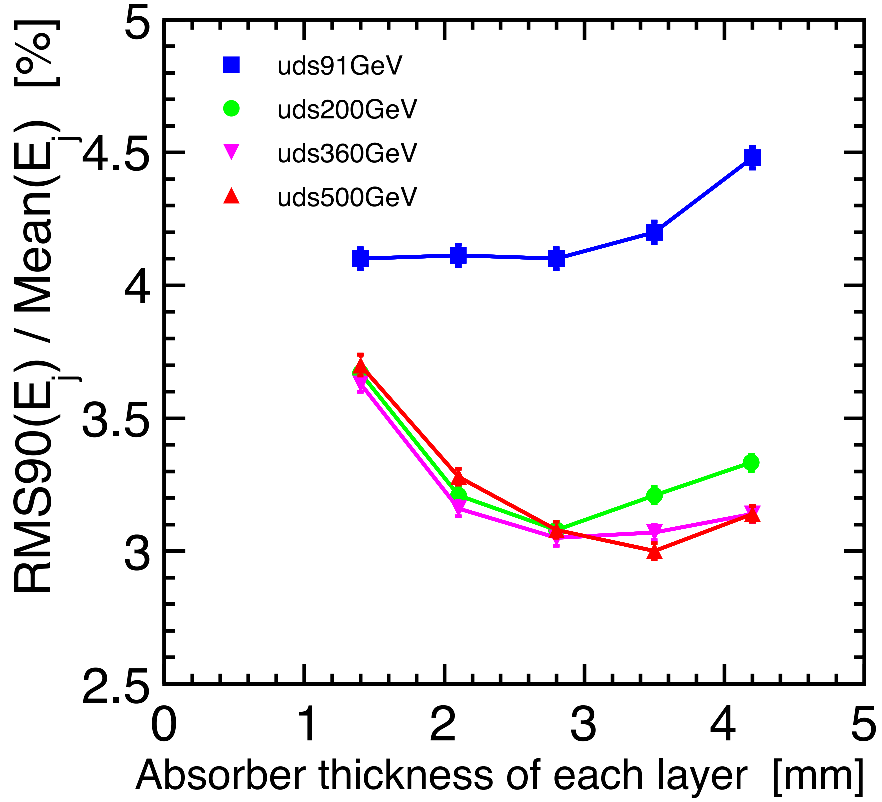


JER v01-15(Absorber thickness dependence)

Energy Dependence



W thickness Dependence

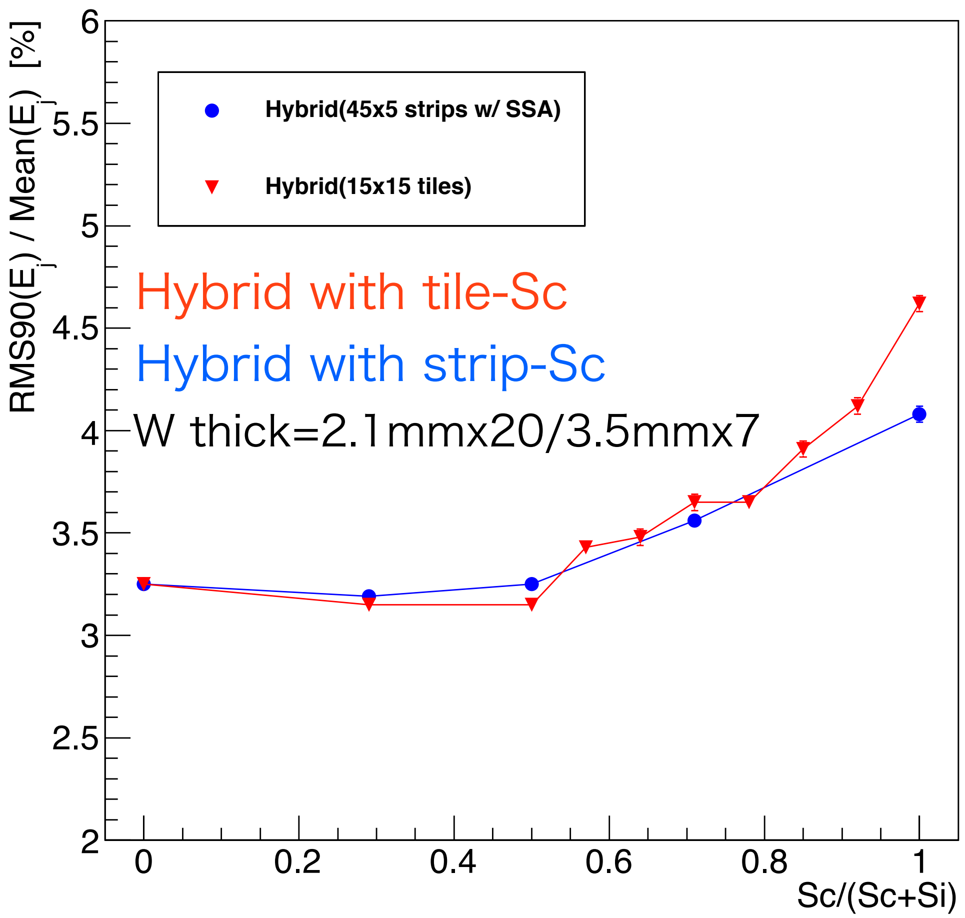


- 1.4mm is worse all over the energy
  - seems to be shower leakage
- 3.5mm seems enough to absorb EM showers

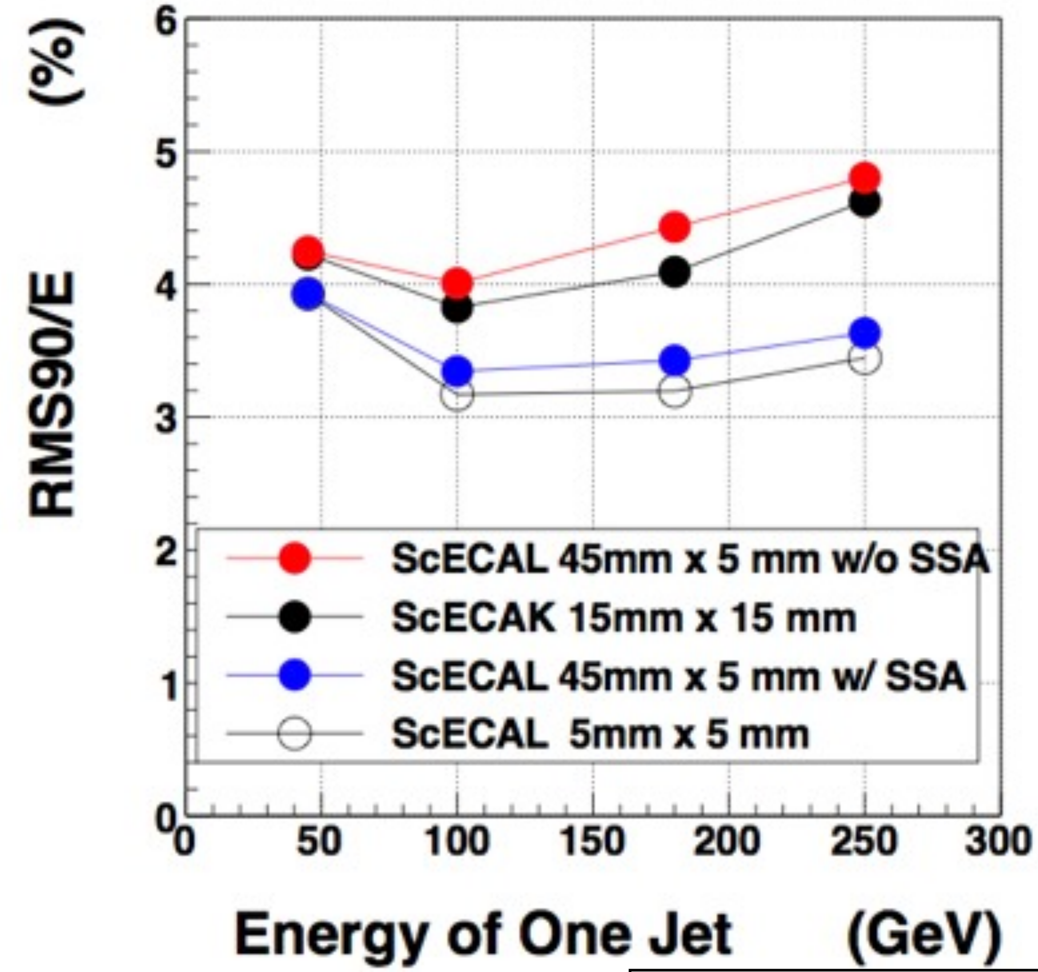
- performance becomes worse above 3.0mm at 45GeV
- ~2.8mm (~24X0) looks best for 100~250GeV jet

hybrid with Sc-tiles(15x15mm)

Hybrid with tile-Sc



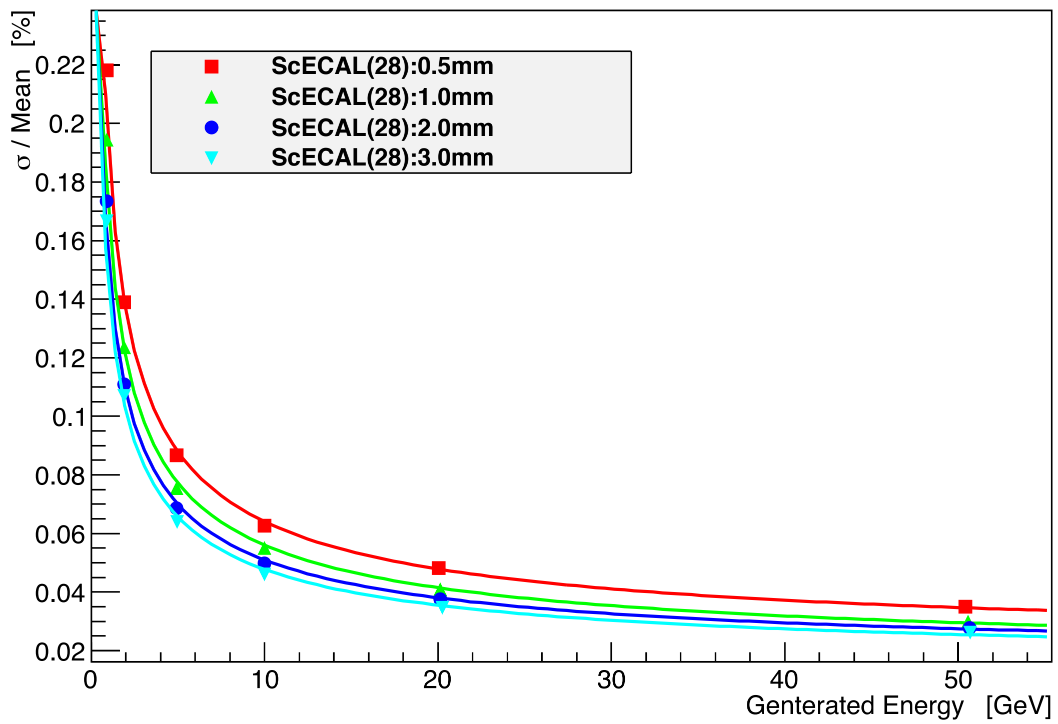
tile ScECAL



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