Simulation Study of the Hybrid ECAL for ILD

Tokusui Annual Meeting @KEK

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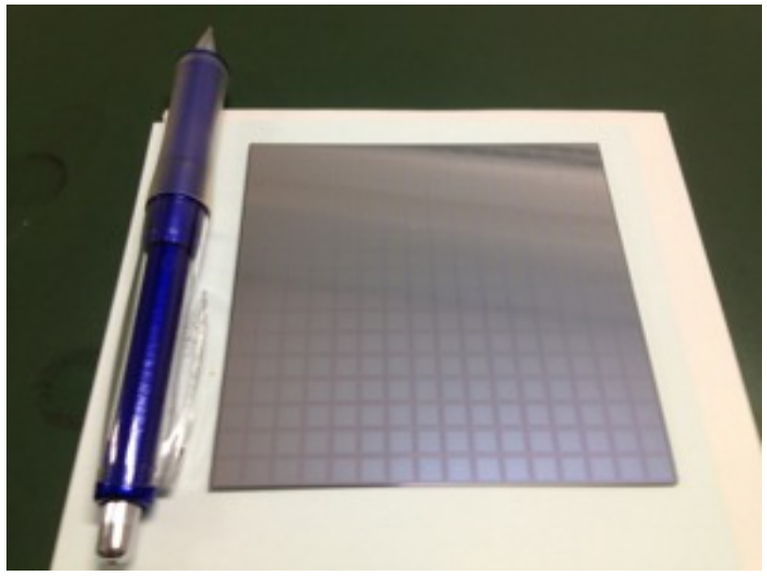
On behalf of ILD-ECAL group

Contents

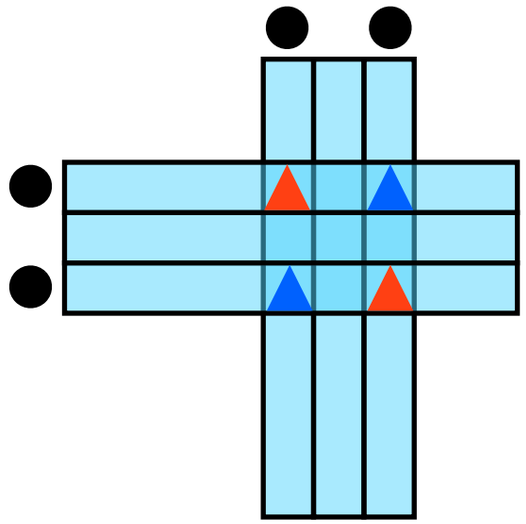
ILD ECAL Candidates

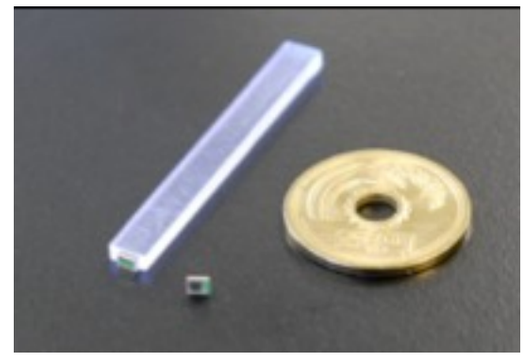
Silicon pads （Si ECAL）



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

Scintillator strips +MPPC （Sc ECAL）



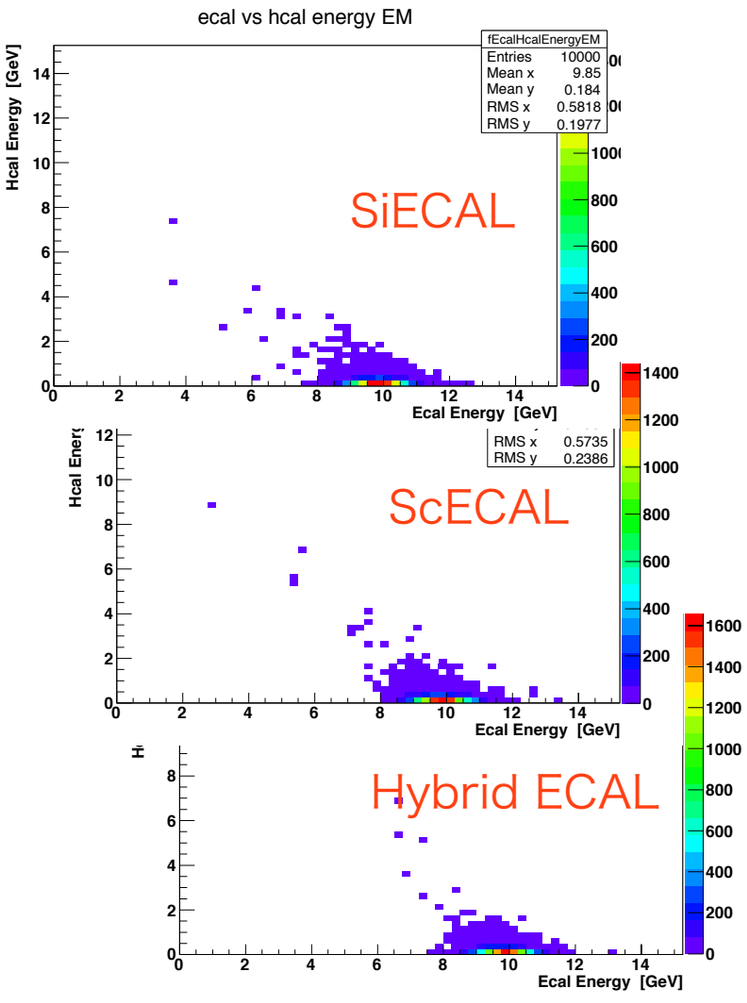


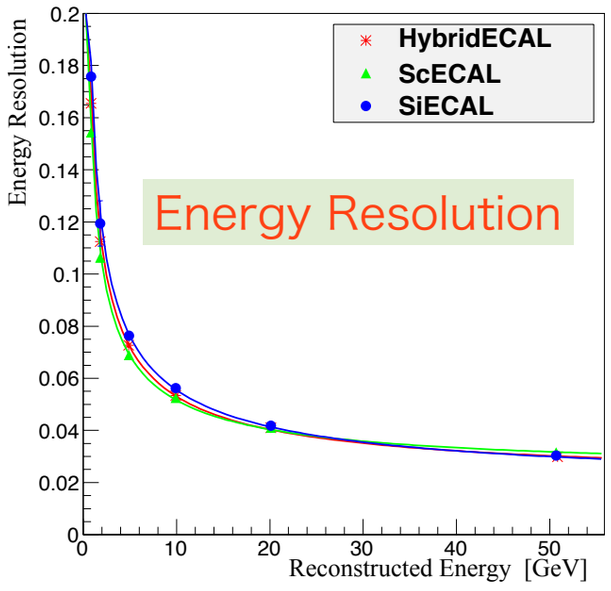
- 45mm x 5mm orthogonal & SSA
  --> 5mm x 5mm spatial resolution
- reasonable cost
- ghost hits

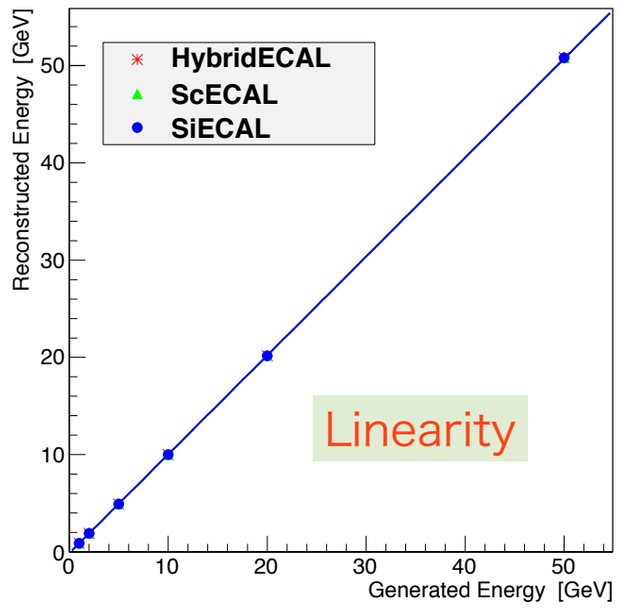
An option to make the ECAL at a lower cost while keeping performance as much as possible would be mixture of silicon and scintillator-strip layers.

ECAL Calibration

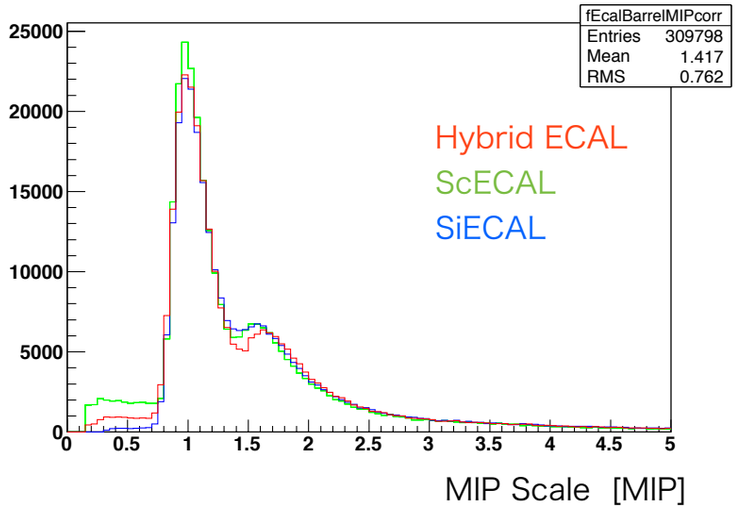
- Calibration constants should be determined for silicon layers and scintillator layers respectively.
  - calibrated using 10GeV photon.
- use 10GeV muon for MIP calibration.





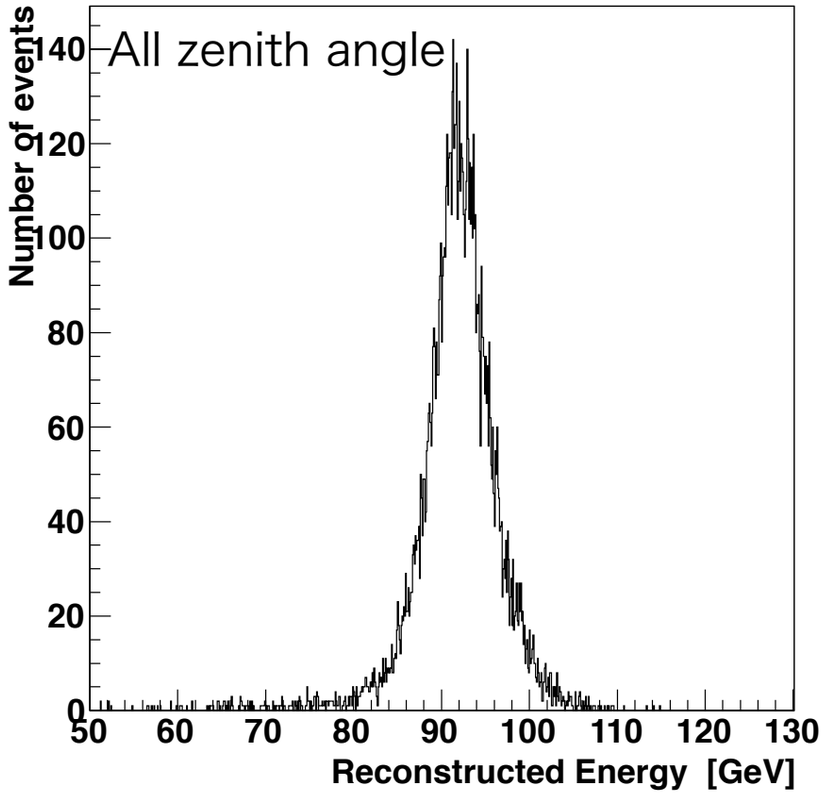


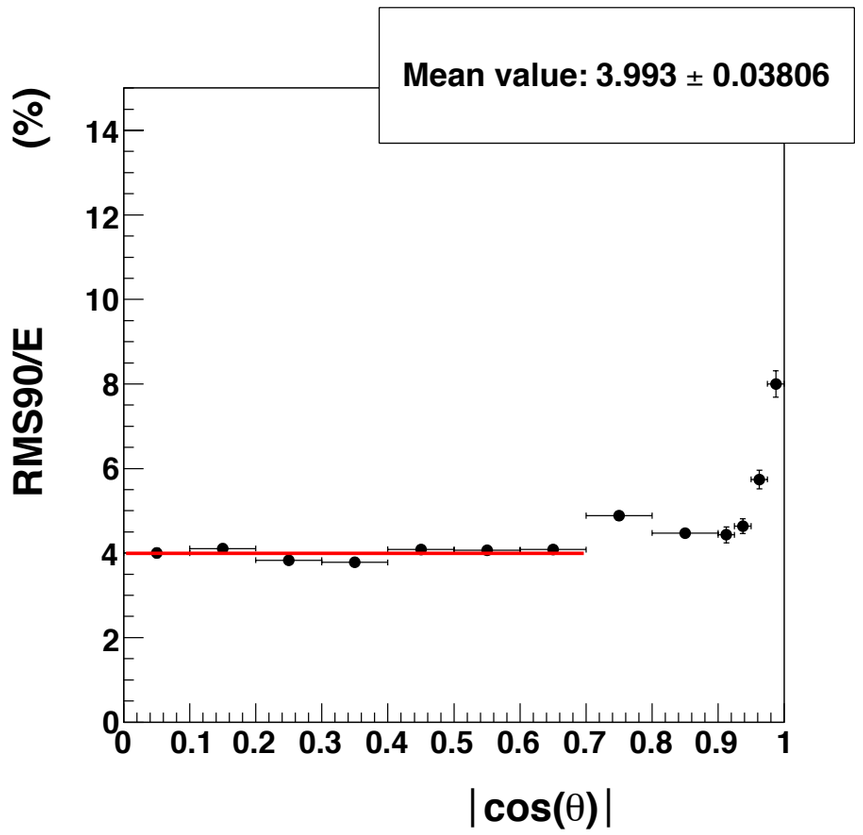
MIP Calibration



Hybrid ECAL Evaluation

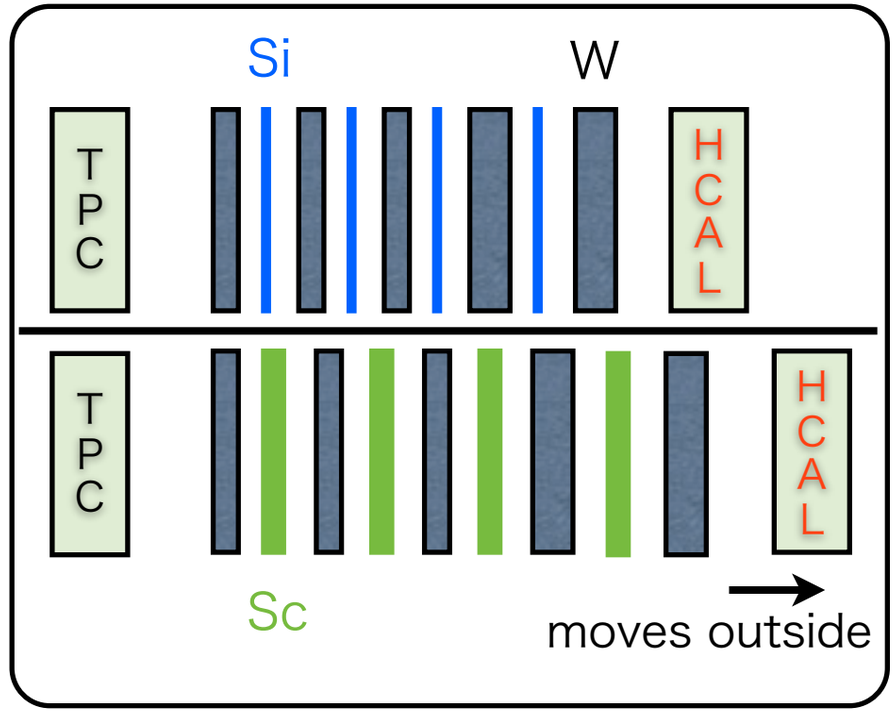
- We evaluated energy dependence and Sc:Si ratio dependence.
- software version : ilcsoft v01-16-02 with trunk version of some processors (Data were generated with ilcsoft v01-15)
- $e^+e^- \rightarrow q\bar{q}$ (q=u,d,s, √s=91, 200, 360, 500GeV)
- only barrel region |cos(thrust angle)<0.7| for evaluation.



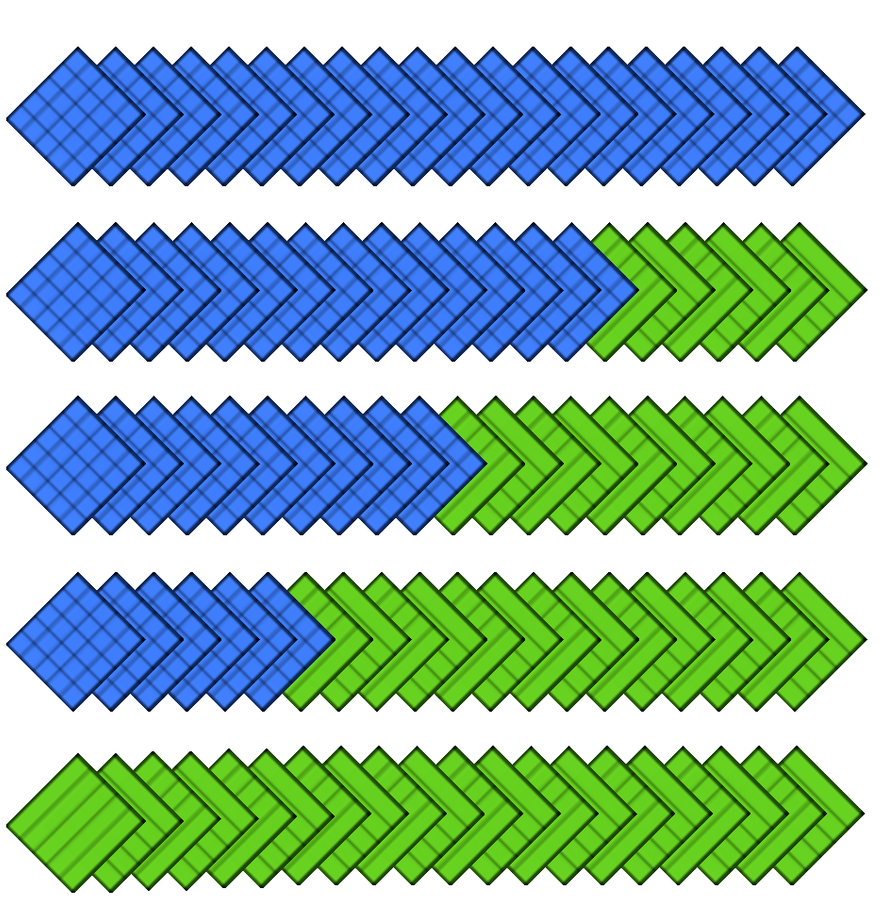


same absorber thickness

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

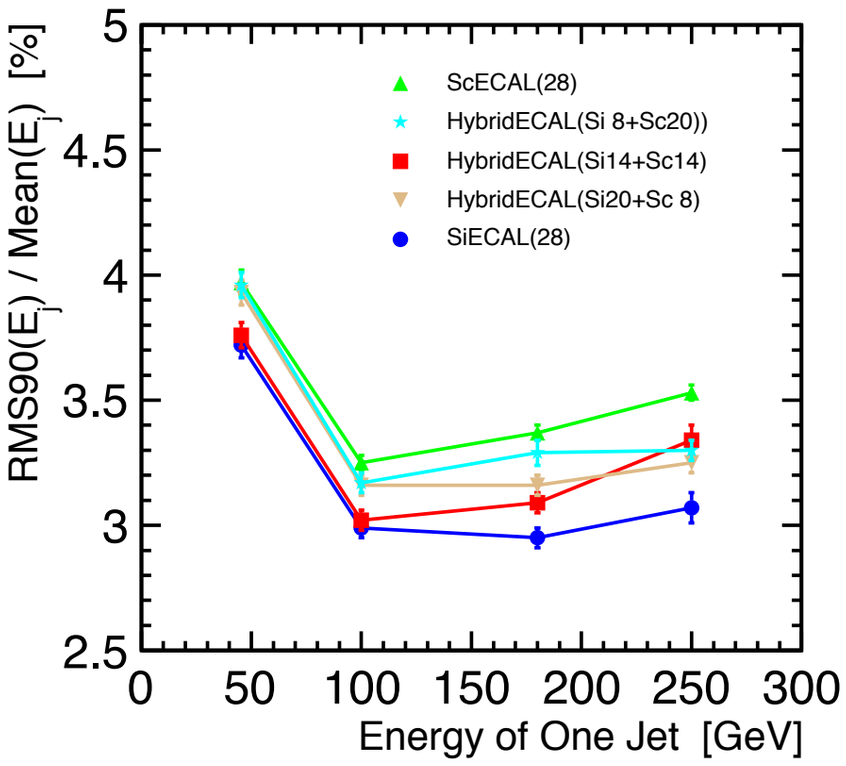


	W thickness (in20,out7)	Module thickness (mm)
SiECAL(28)	2.1/3.5	165.4
Hybrid(Si20Sc8)	2.1/3.5	176.7
Hybrid(Si14Sc14)	2.1/3.5	185.2
Hybrid(Si8Sc20)	2.1/3.5	193.7
ScECAL(28)	2.1/3.5	205.0



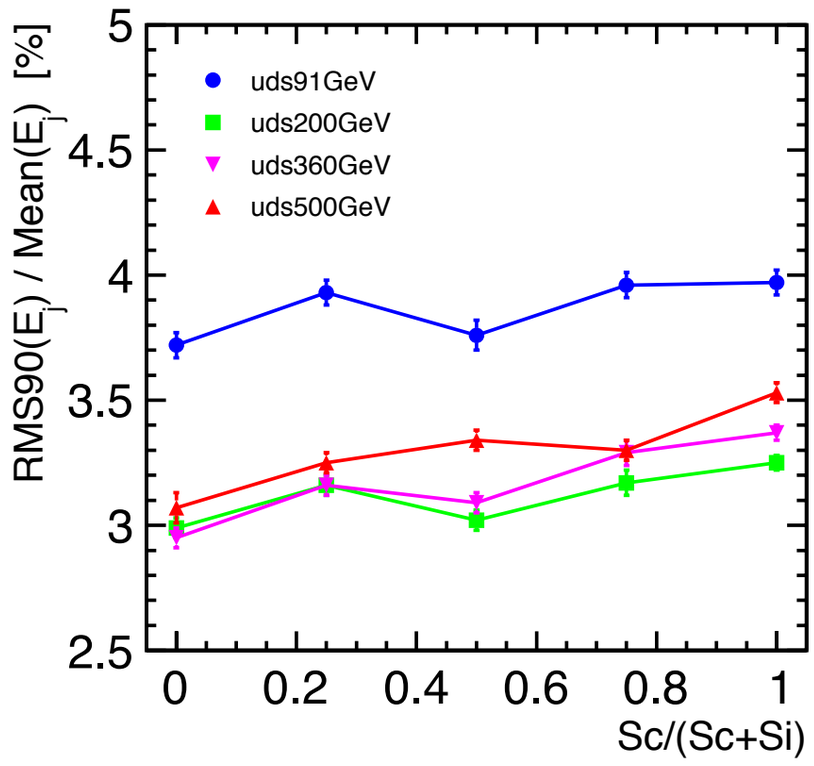
JER of same absorber thickness

Energy Dependence



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

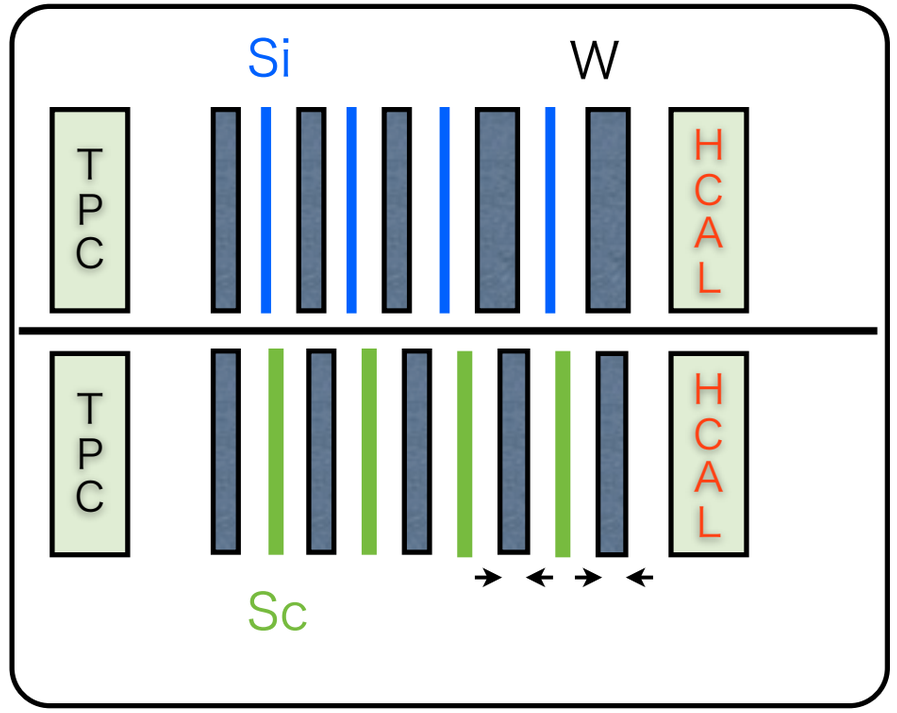
Ratio Dependence



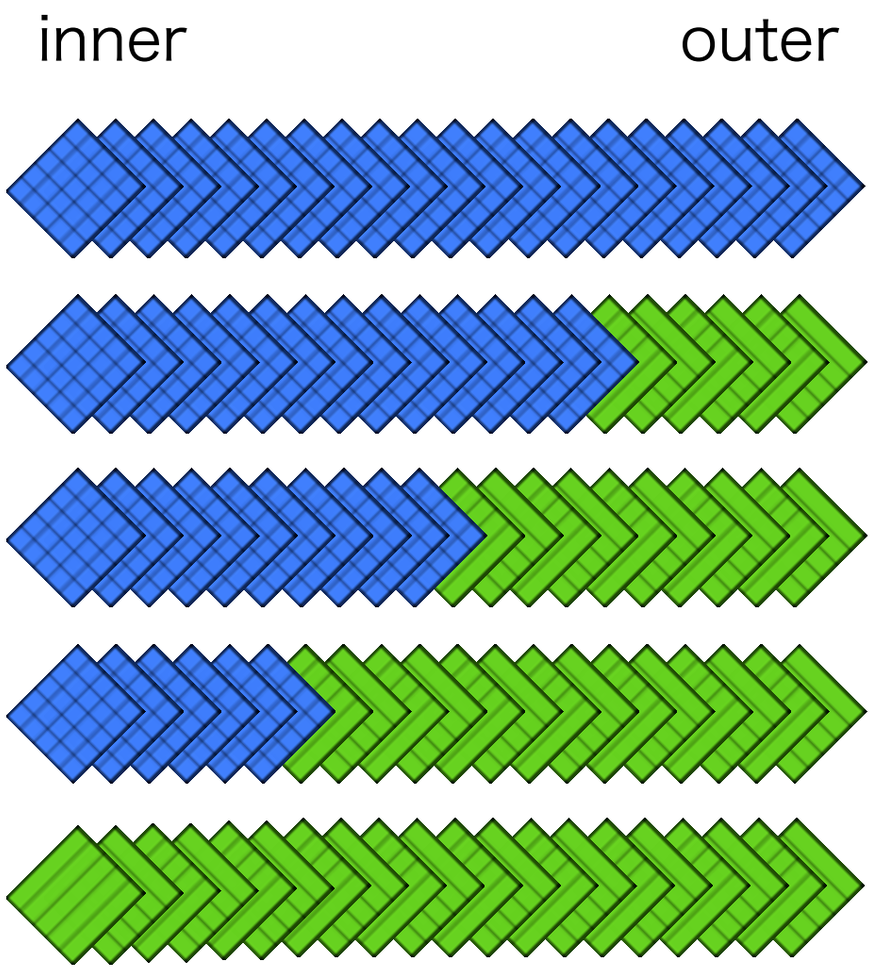
- Scintillator performance becomes much better than that with old version
- JER becomes worse gradually.

same module thickness

- to evaluate with keeping the ECAL thickness constant to be 185mm
- five configurations
- Sc thick = **1.0mm**, Si thick = **0.5mm**
- change absorber thickness for outer layers

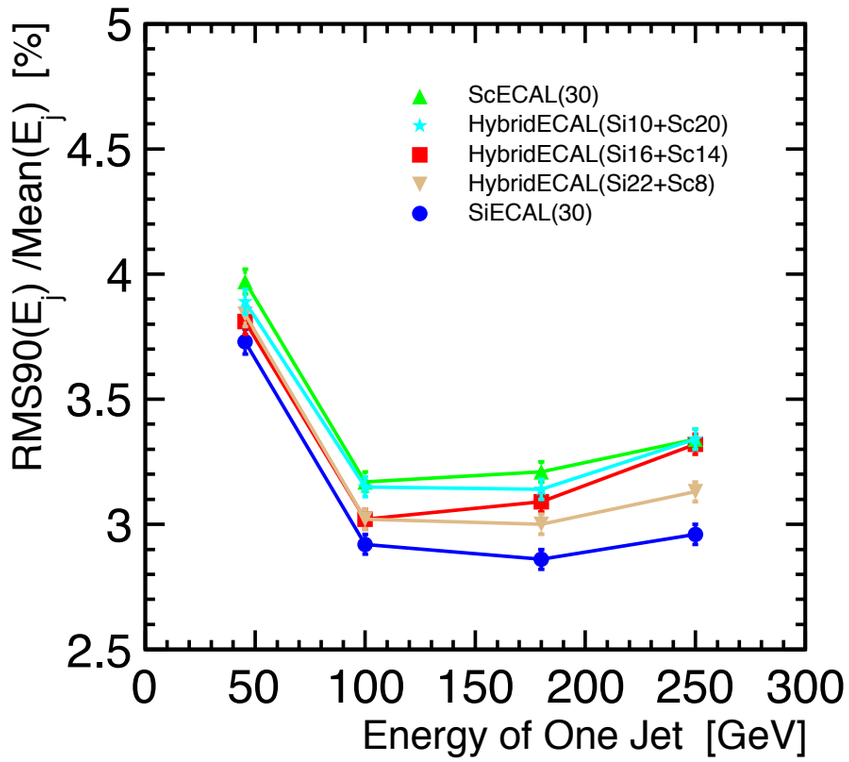


	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid(Si22Sc8)	2.1/3.9	185.6
Hybrid(Si16Sc14)	2.1/3.6	185.4
Hybrid(Si10Sc20)	2.1/3.3	185.2
ScECAL(30)	2.1/2.9	185.7



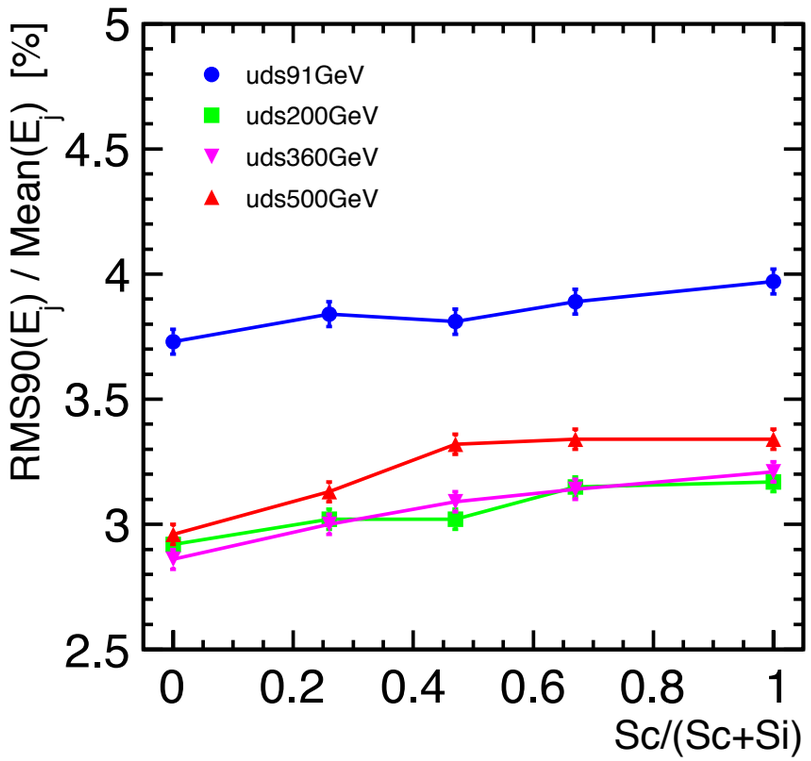
JER of same module thickness

Energy Dependence



- JER difference between SiECAL and ScECAL is ~0.4% 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

Ratio Dependence

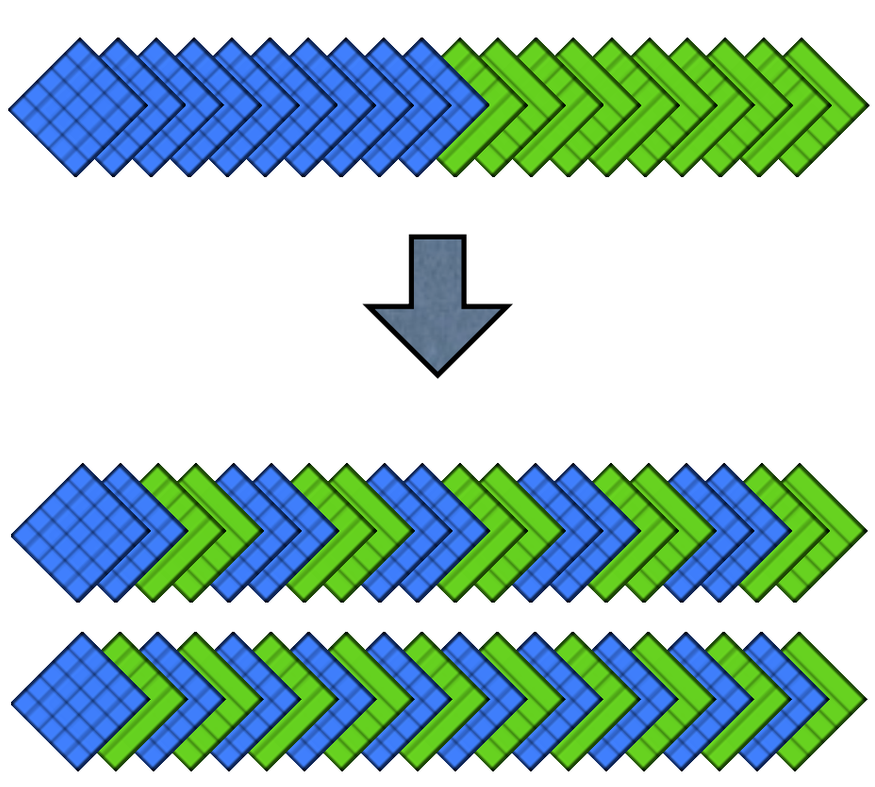


- JER degrades not so much up to 180GeV jet.
- For 250GeV, Hybrid(Si16+Sc14) is almost same performance as ScECAL.

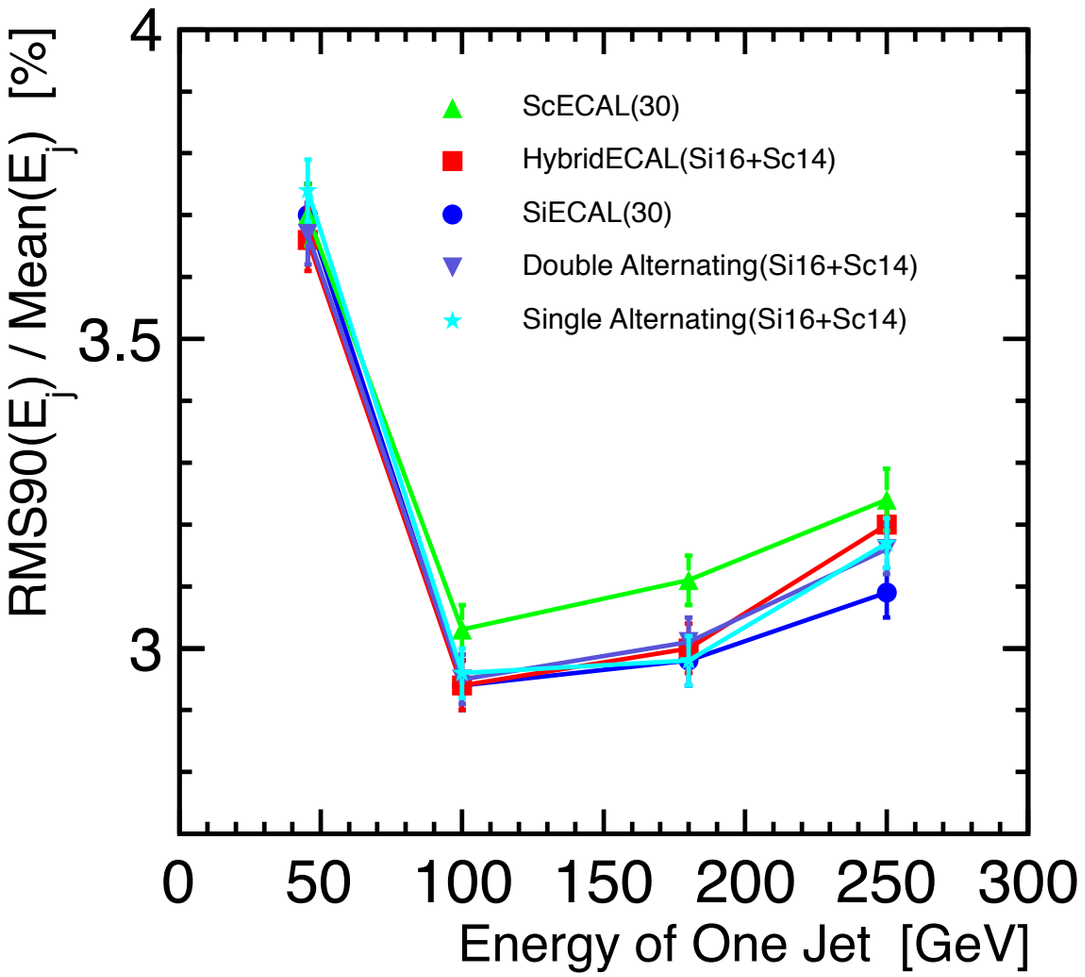
alternating hybrid

- to help SSA and resolve ghost hits
- double layers/single layer alternating
- Data were reproduced by newer version of Mokka
- Sc thick = **1.0mm**, Si thick = **0.5mm**

	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid(Si16Sc14) [not alternate]	2.1/4.2	190.8
Double layers Alternate(Si16Sc14)	2.1/4.2	190.8
Single layer Alternate(Si16Sc14)	2.1/4.2	190.8
ScECAL(30)	2.1/4.2	197.4



JER of alternating hybrid

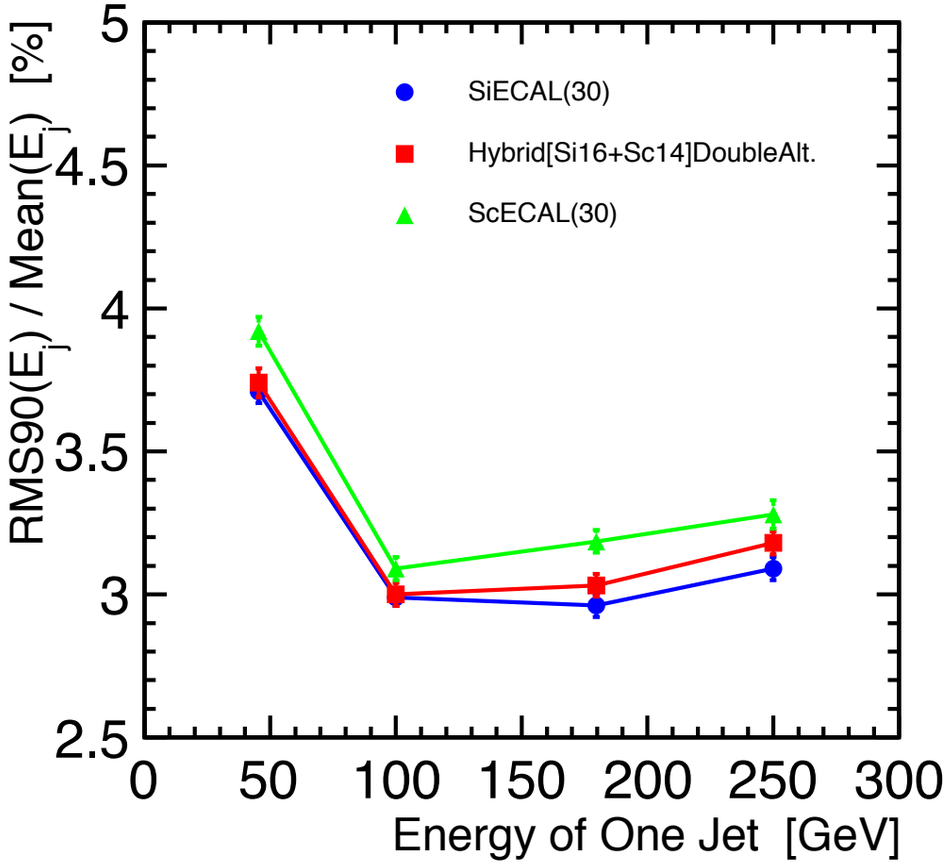


- Standard PandoraPFA reconstruction
- The difference between SiECAL and ScECAL is ~0.2% at 250GeV.
- Hybrid(Si16+Sc14), Hybrid(Double Alt.) and Hybrid(Single Alt.) are same performance as SiECAL up to 180GeV.
- Alternating configurations are slightly better than Hybrid(Si16+Sc14)
- Both alternating hybrids look promising for the best cost-performance.

Single alternating Hybrid will be used mainly for further study

Understanding JER

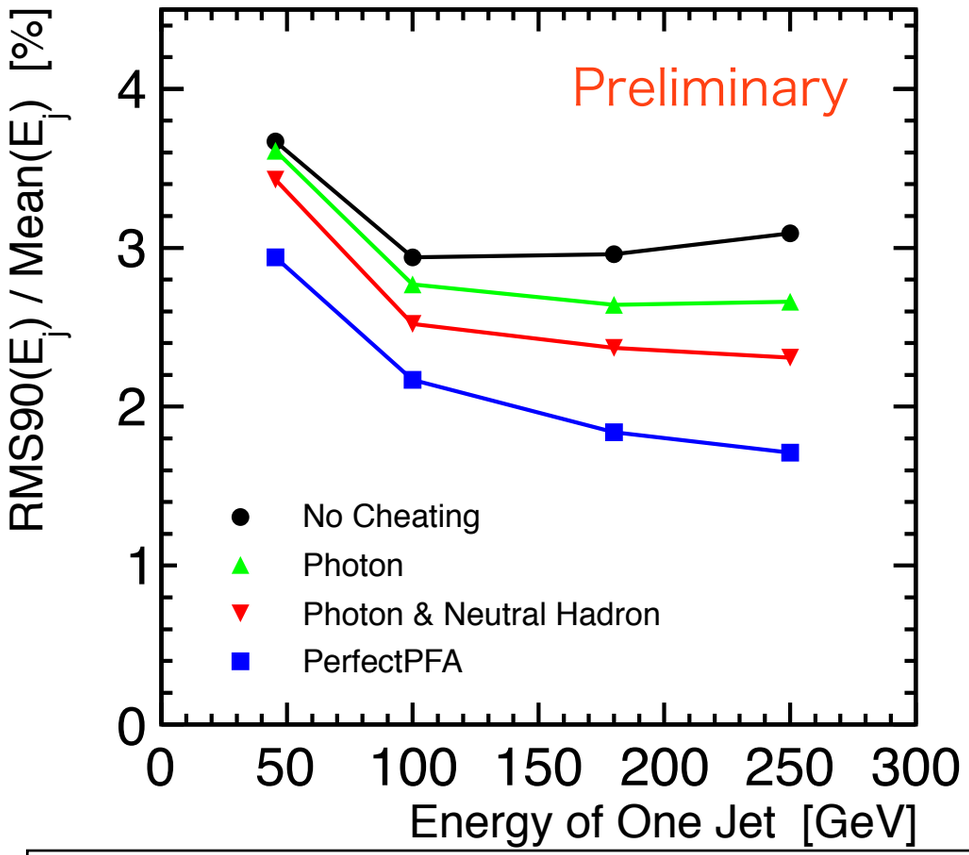
- We are trying to understand each JER by cheating MC information
- Data are generated with newer version of Mokka
- Cheating with SSA has a problem
    - use 5x5mm^2 scintillator for Hybrid[Si16+Sc14] and ScECAL



Sc = 1.0mm	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid[Si16+Sc14] (Sc5x5mm^2)	2.1/4.2	190.8
ScECAL(30) (Sc5x5mm^2)	2.1/4.2	197.4

SiECAL

- 30layers, W=2.1mmx20/4.2mmx9, w/o stand alone photon clustering

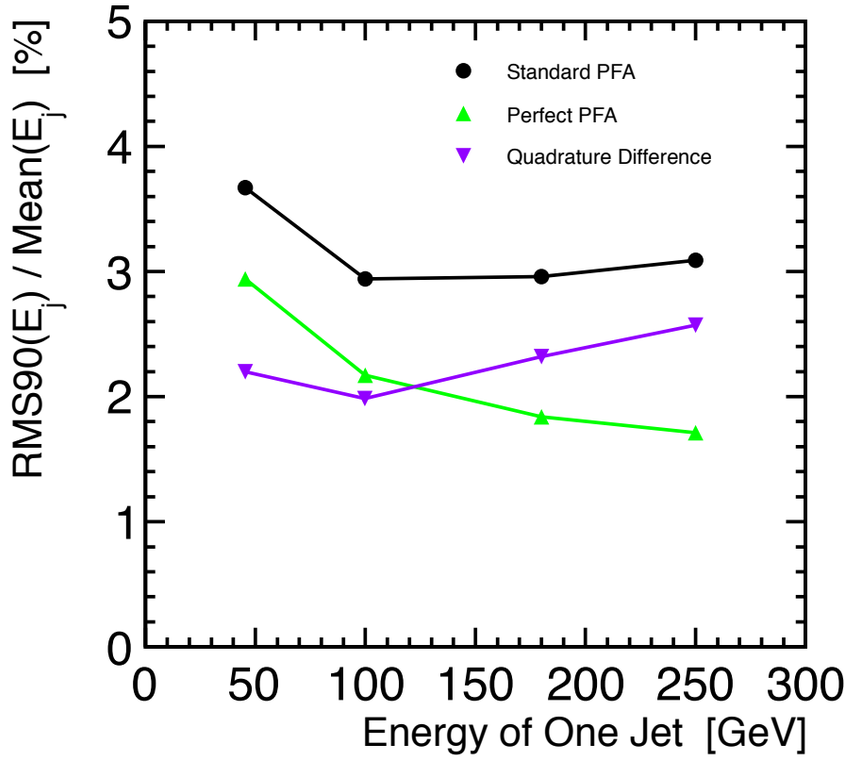


SiECAL : Standard PandoraPFA

SiECAL : photon

SiECAL : photon, n, K0L

SiECAL : Perfect Pattern Recognition



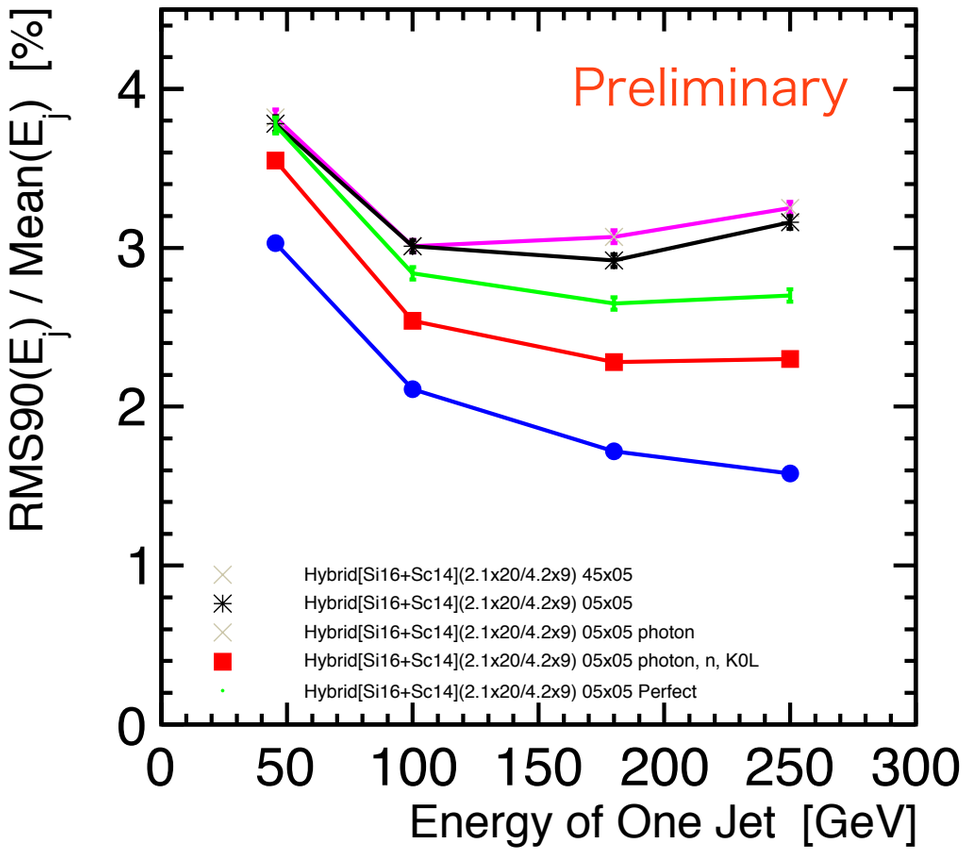
・Resolution (low energy jets)

・Confusion (high energy jets)

is main performance driver

Hybrid[Si16+Sc14] (5x5mm^2 cells)

- 30layers, W=2.1mmx20/4.2mmx9, w/o stand alone photon clustering



Hybrid with Sc-strip :Standard PandoraPFA

Hybrid with Sc-cell : Standard Pandora PFA

Sc-cell ECAL : photon

Sc-cell ECAL : photon, n, K0L

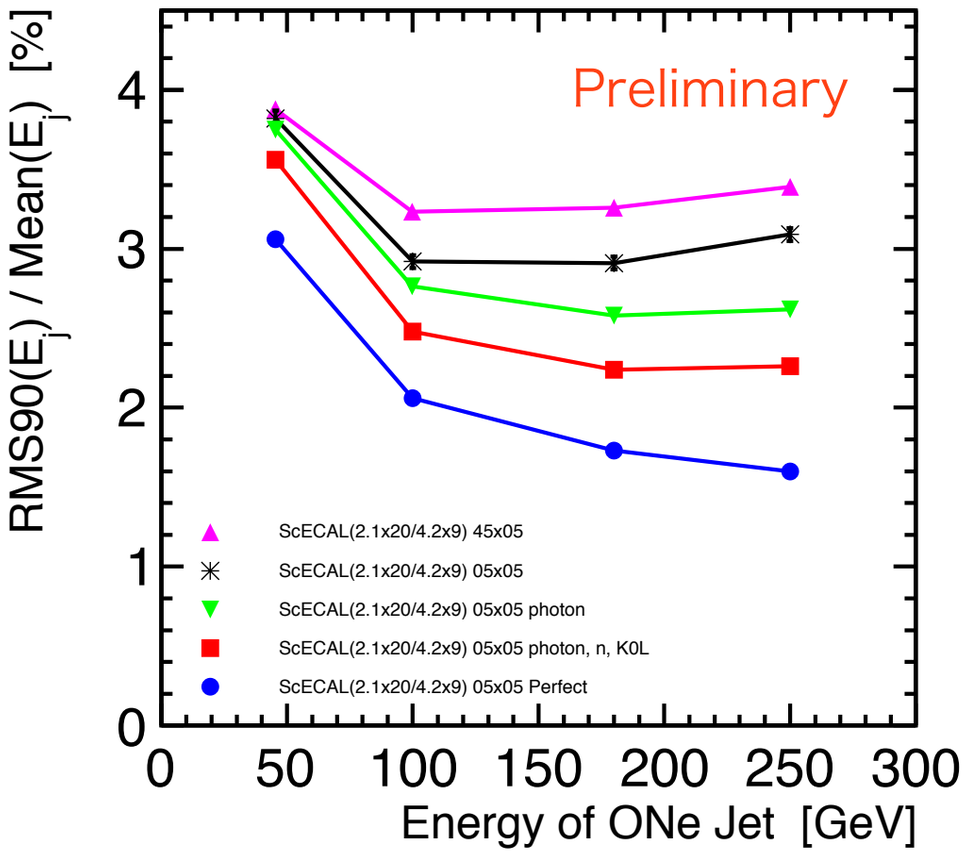
Sc-cell ECAL : Perfect Pattern Recognition

The difference between Sc-strip and Sc-cell is negligible at 45GeV and 100GeV jet.

The tendency is same as that of SiECAL.

ScECAL (5x5mm^2 cells)

- 30layers, W=2.1mmx20/4.2mmx9, w/o stand alone photon clustering



Sc-strip ECAL : Standard PandoraPFA

Sc-cell ECAL : Standard Pandora PFA

Sc-cell ECAL : photon

Sc-cell ECAL : photon, n, K0L

Sc-cell ECAL : Perfect Pattern Recognition

The difference between ▲ and ※ is caused by ghost and SSA uncertainty

All three ECALs are almost identical if pattern recognition is done perfectly.

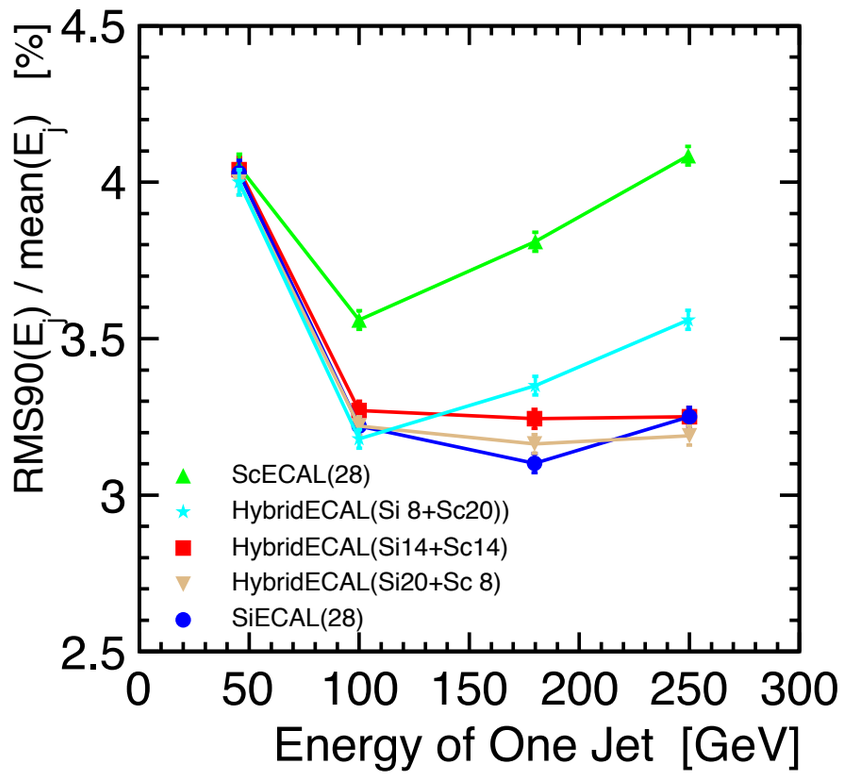
Summary

- 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 with newer version of ilcsoft
  - same absorber thickness ...degrades gradually
  - same module thickness ... 30% of Sc-layers is medium between SiECAL and ScECAL
  - alternating hybrid ... same performance as SiECAL up to 180GeV
  - They are being reevaluated with the data made with newer Mokka
- We are trying to understand the resolution,
  - will enable to cheat MC information using SSA
  - will investigate the cause of JER difference, and consider measures to improve

Backup

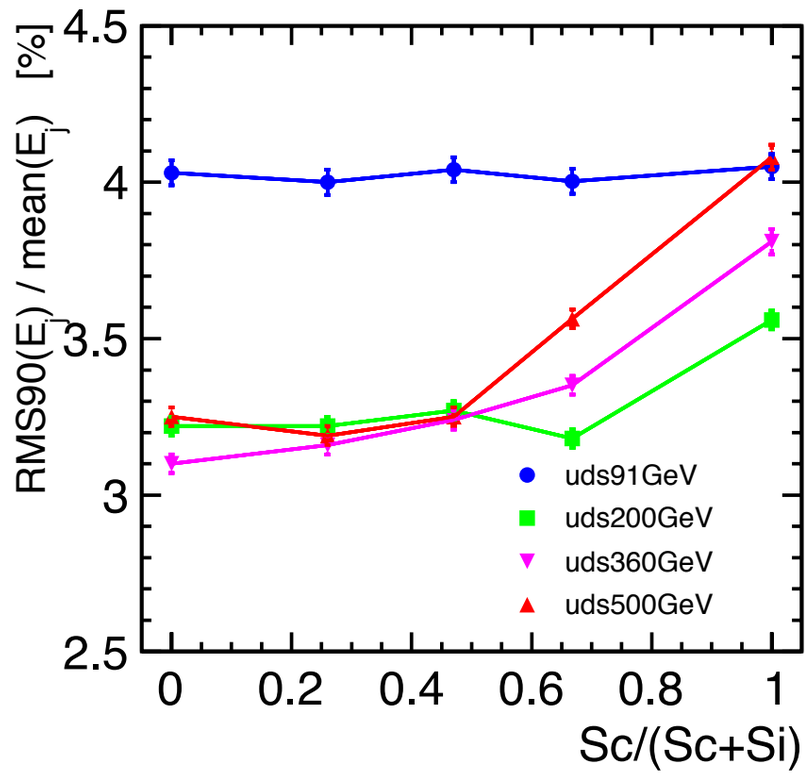
JER v01-15 (Same Absorber Thickness)

Energy Dependence



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

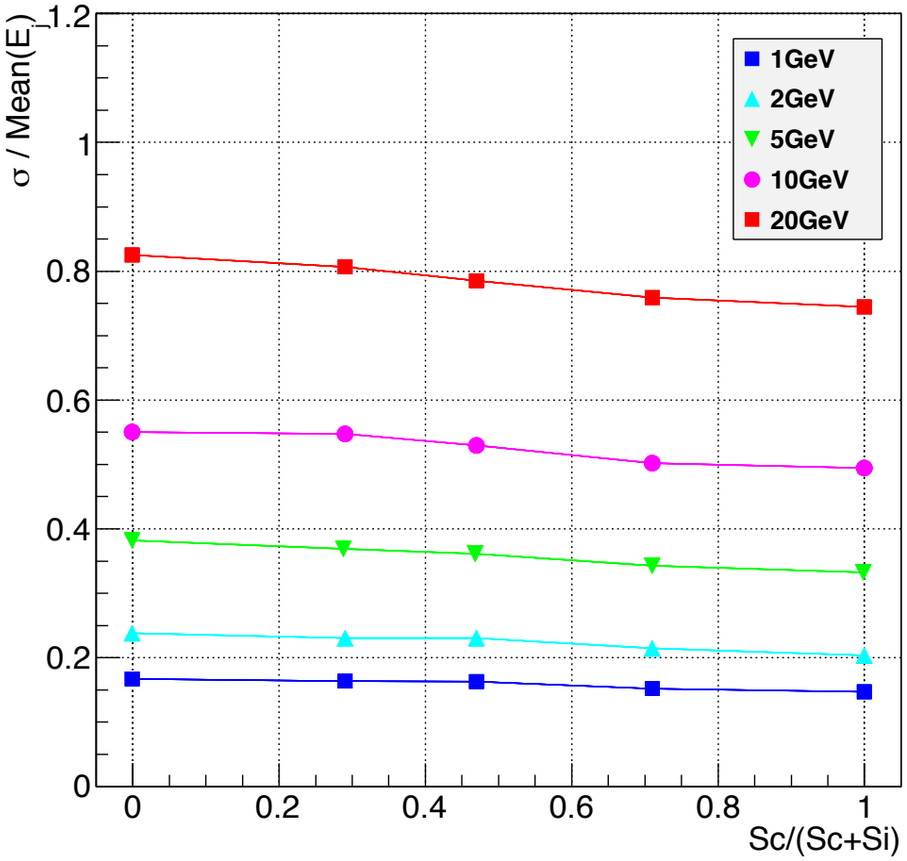
Ratio Dependence



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

Photon Energy Resolution

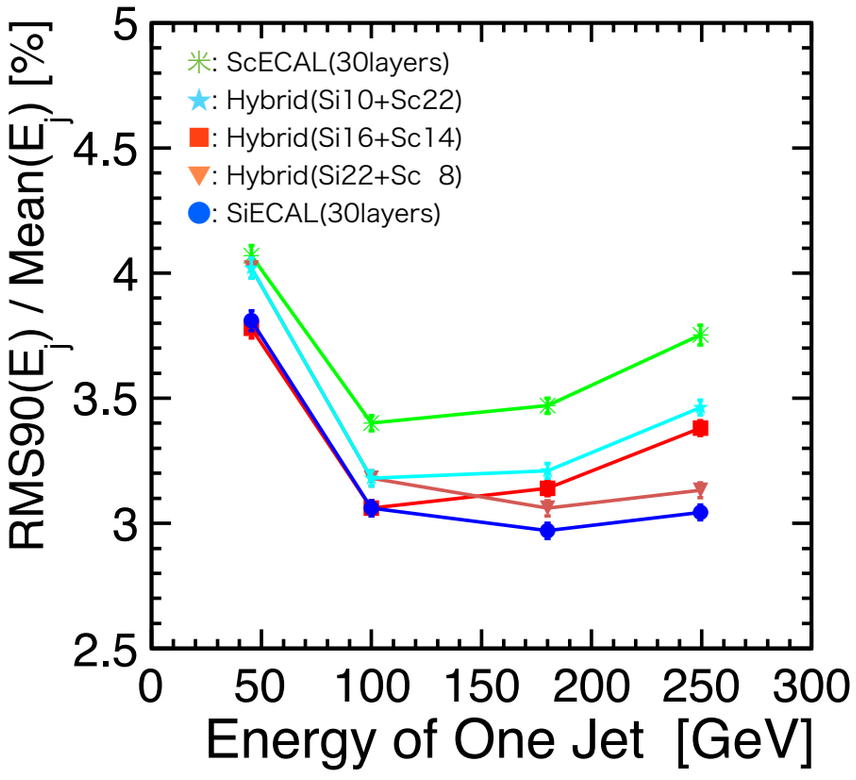
same absorber thickness



	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%

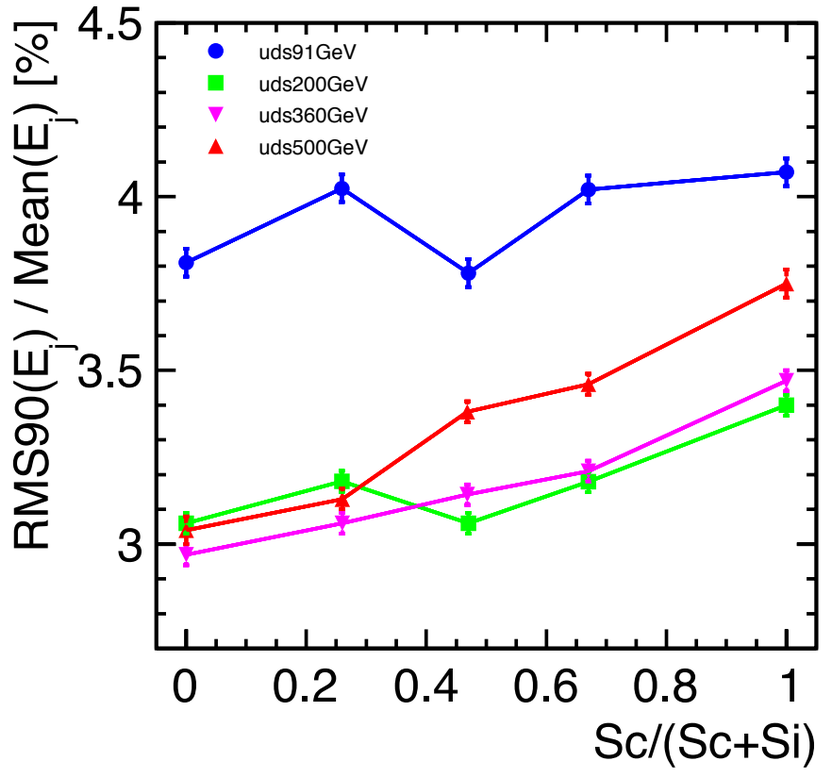
JER v01-15 (Same Module Thickness)

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.

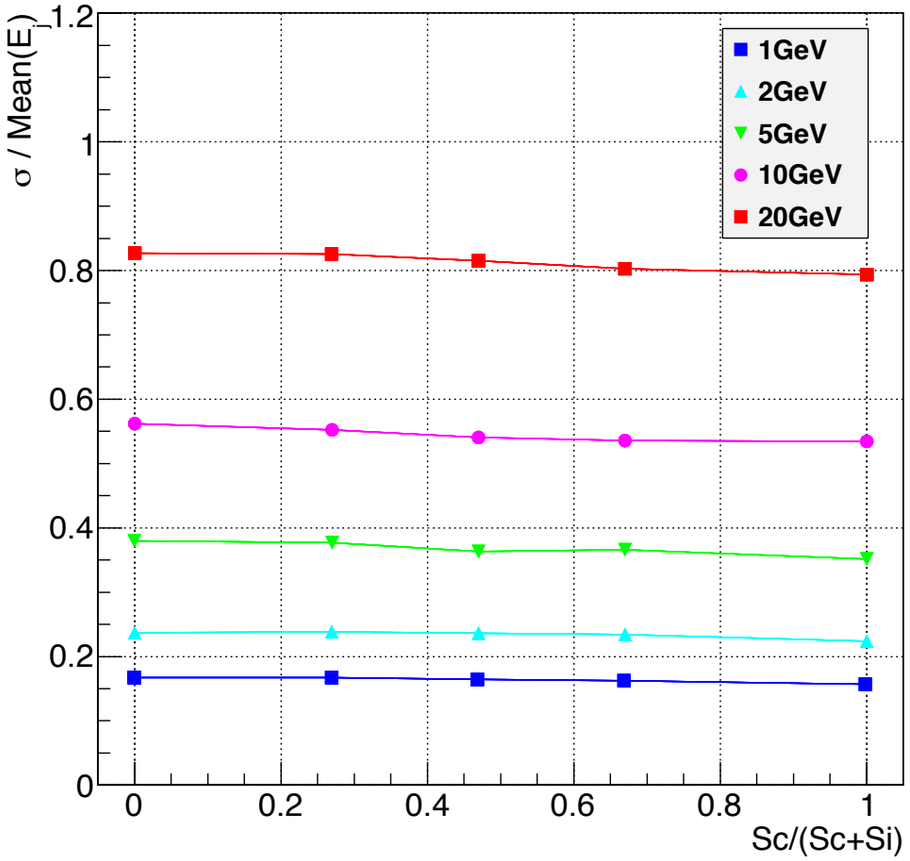
Ratio Dependence



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

Photon Energy Resolution

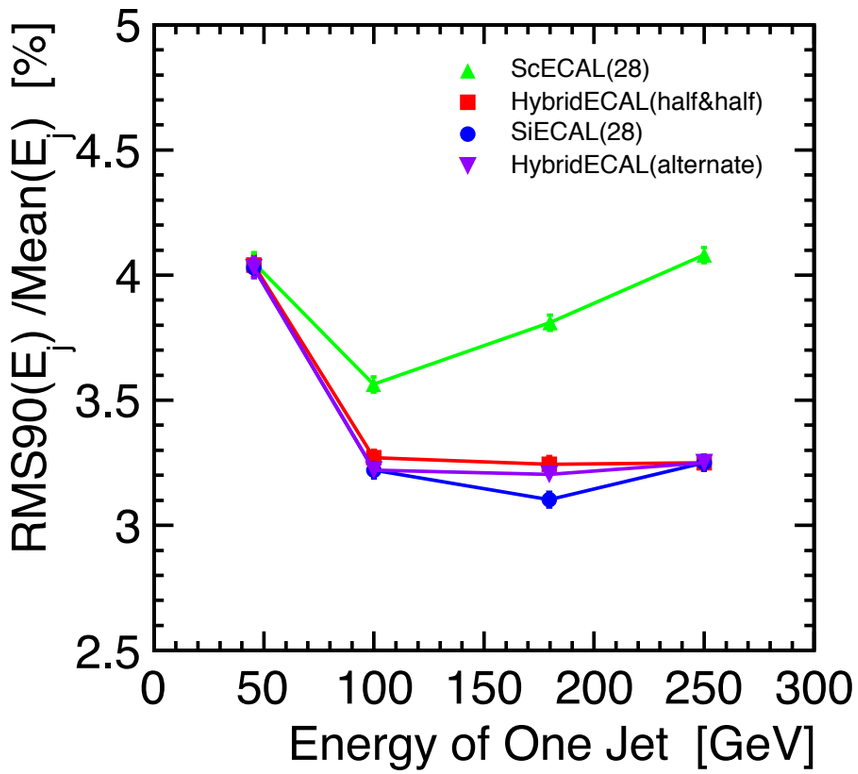
same module thickness



	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%

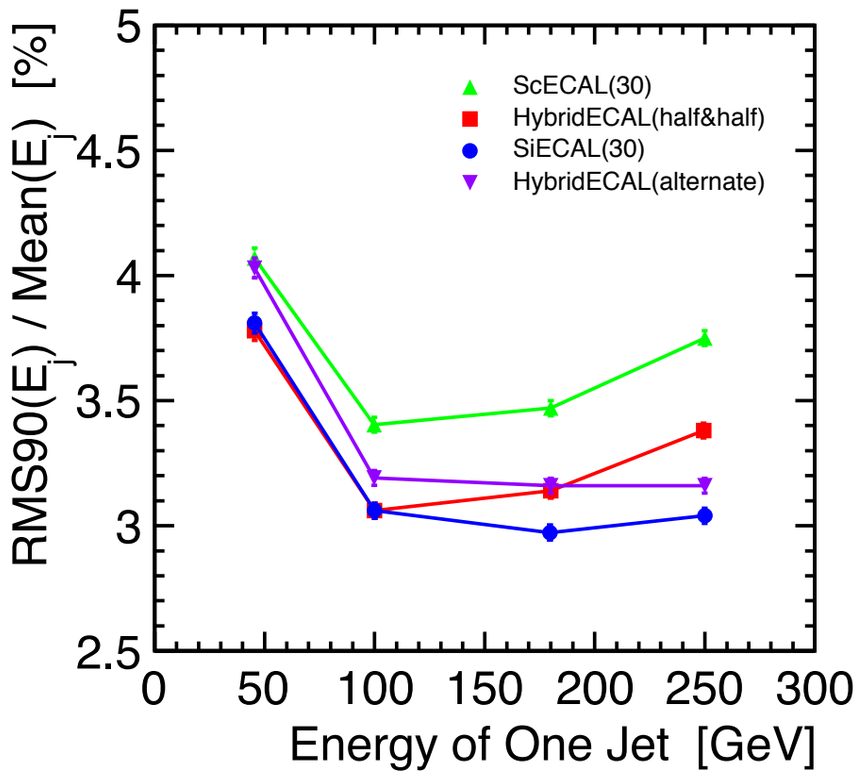
JER v01-15 (Alternating Hybrid)

same absorber thickness



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

same module thickness



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

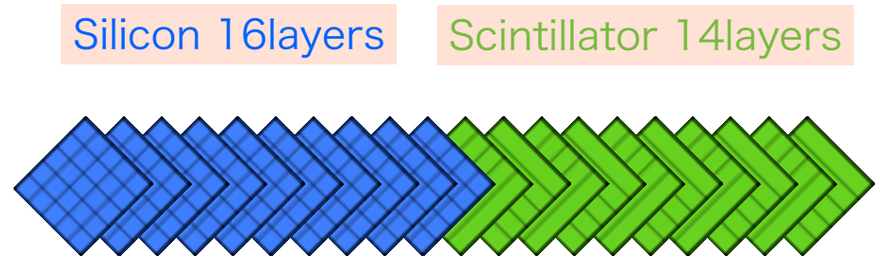
Single layer alternating will be evaluated

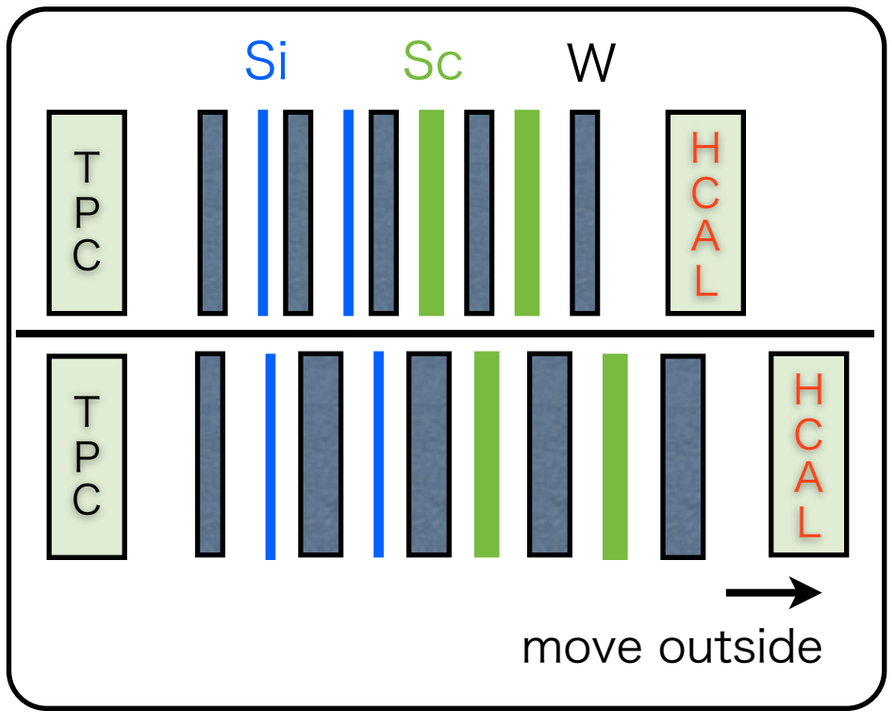
Absorber Thickness Dependence

- v01-15

Sc thickness = 1.0mm
Si thickness = 0.5mm

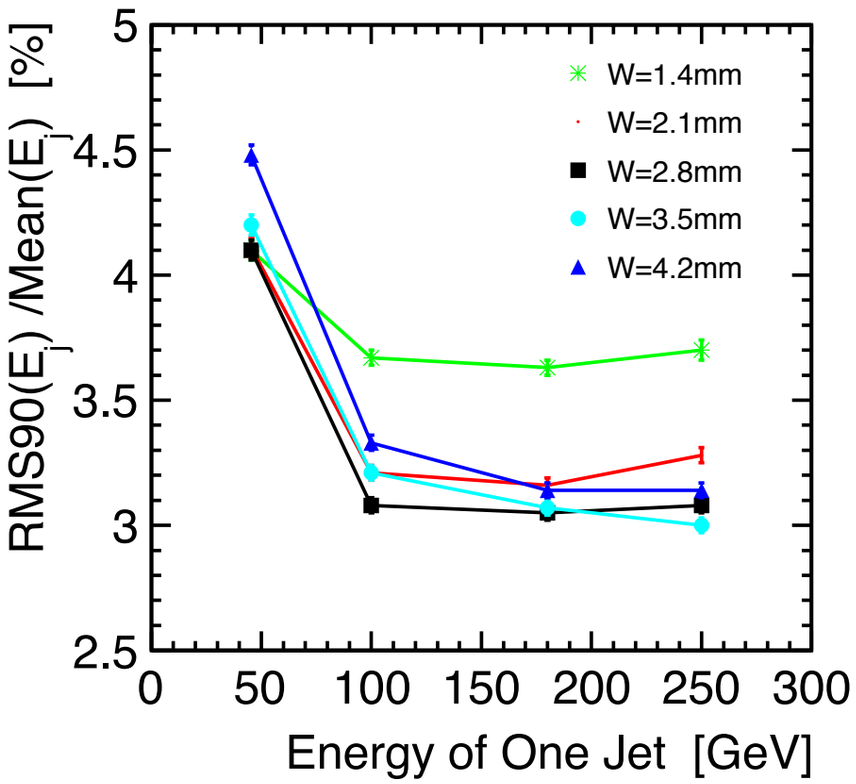
	W thickness (all 29 layers)	Total Radiation Length (X_0)
Hybrid(Si16Sc14)①	1.4	11.6
Hybrid(Si16Sc14)②	2.1	17.4
Hybrid(Si16Sc14)③	2.8	23.2
Hybrid(Si16Sc14)④	3.5	29.0
Hybrid(Si16Sc14)⑤	4.2	34.8





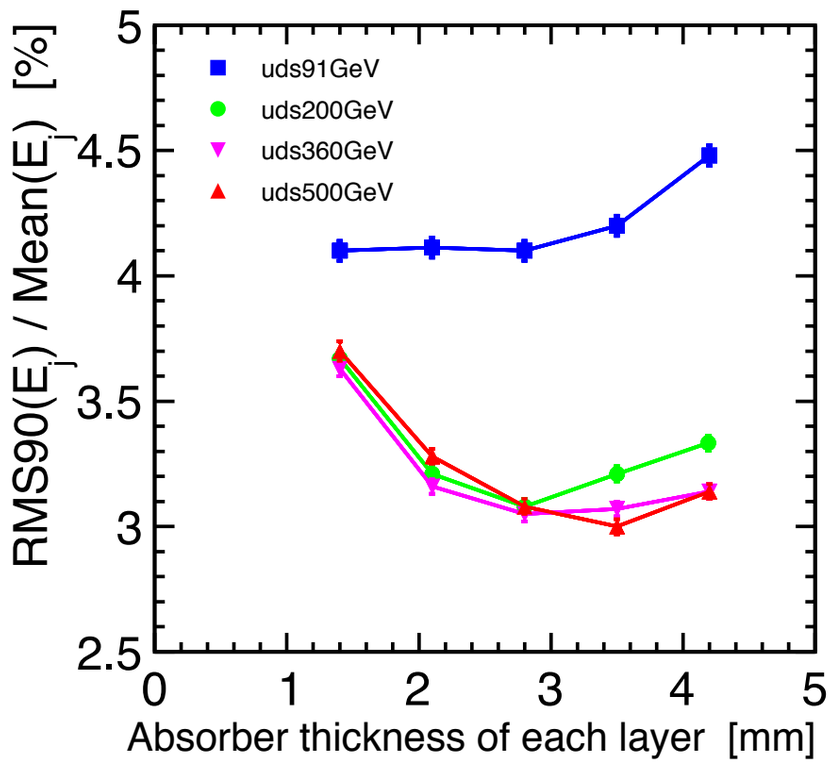
JER v01-15(Absorber thickness dependence)

Energy Dependence



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

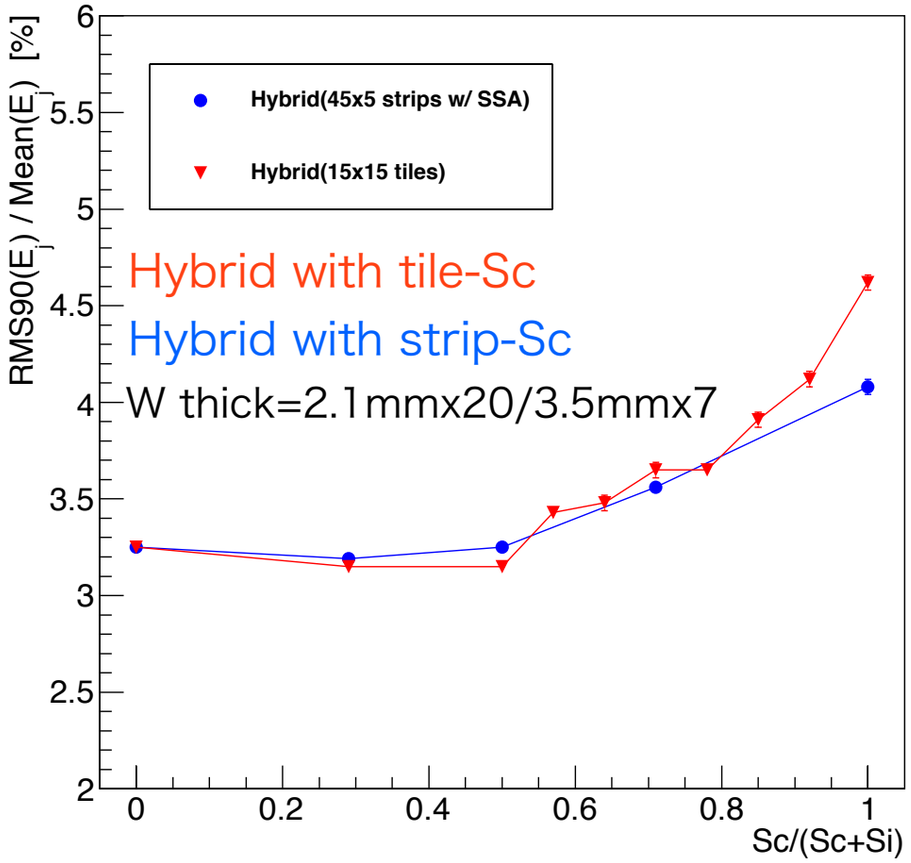
W thickness Dependence



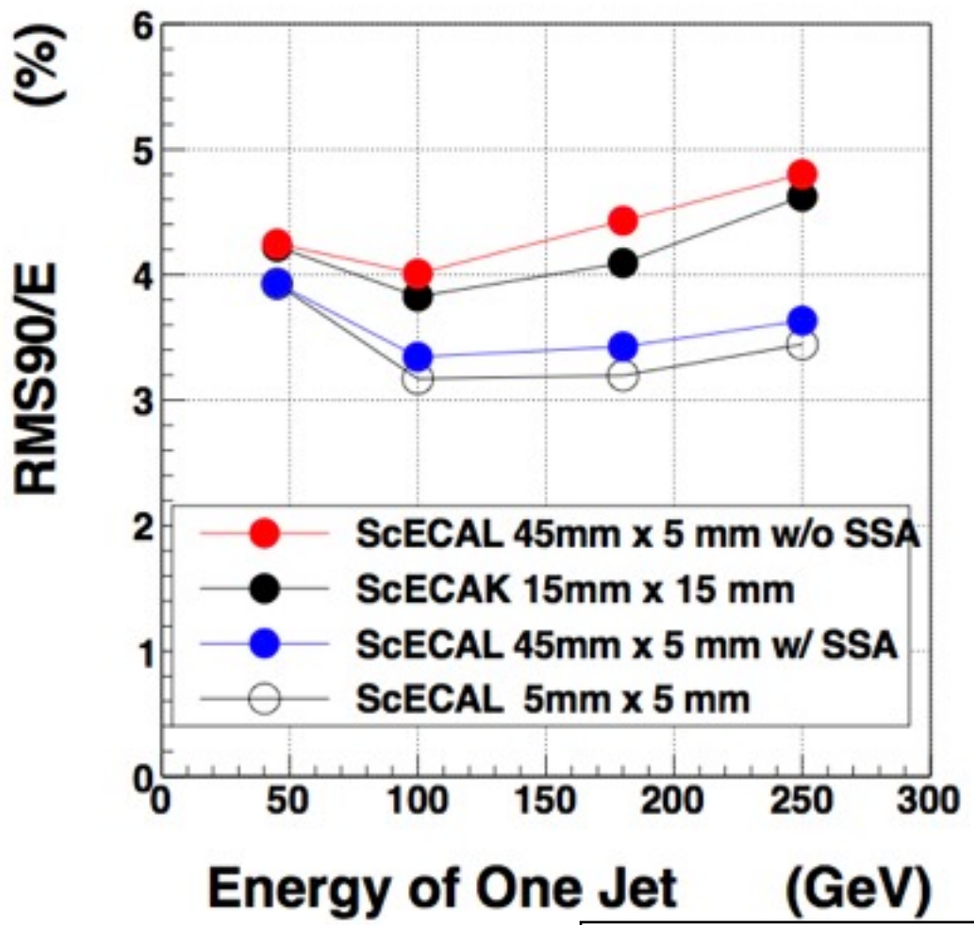
- performance becomes worse above 3.0mm at 45GeV
- ~2.8mm (~24X0) looks best for 100~250GeV jet

hybrid with Sc-tiles(15x15mm)

Hybrid with tile-Sc



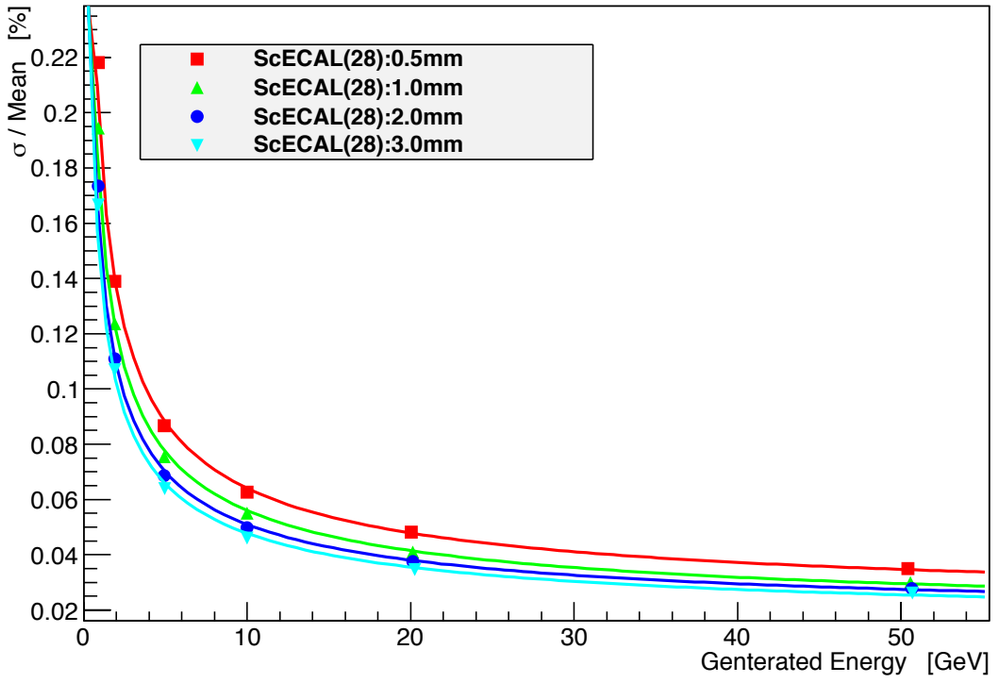
tile ScECAL



by K.Kotera

Scintillator Thickness Difference

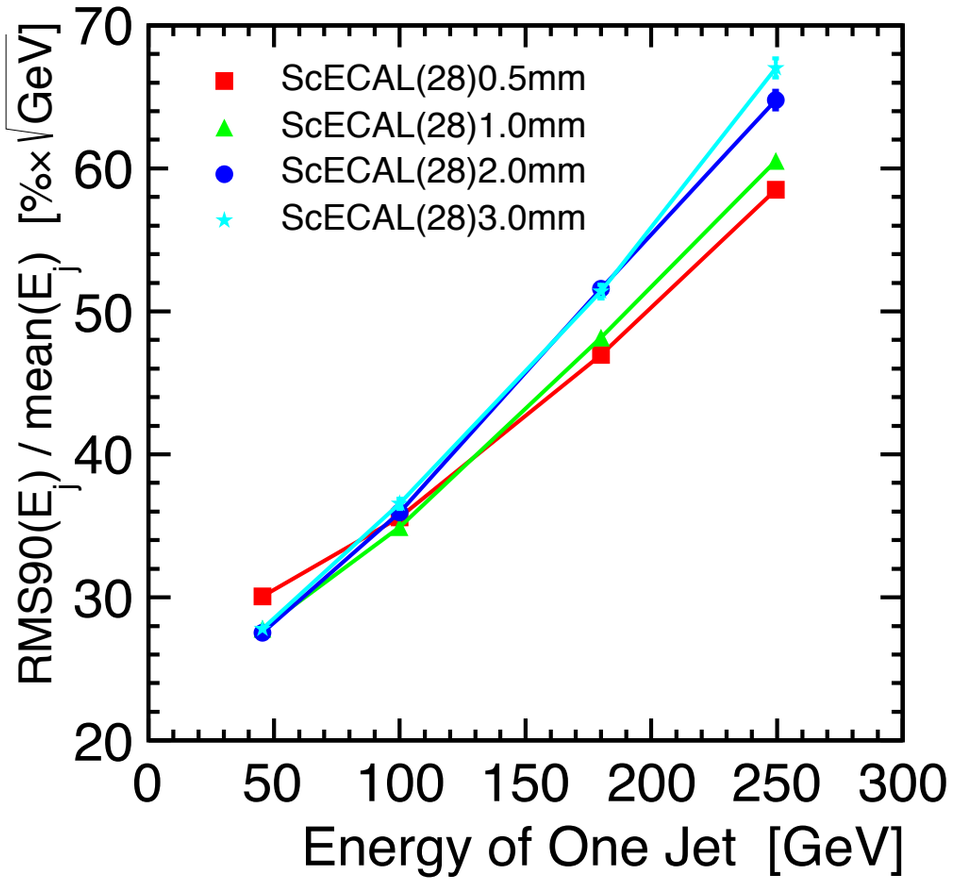
Photon Energy Resolution



ECAL Performance (photon 1~50GeV)

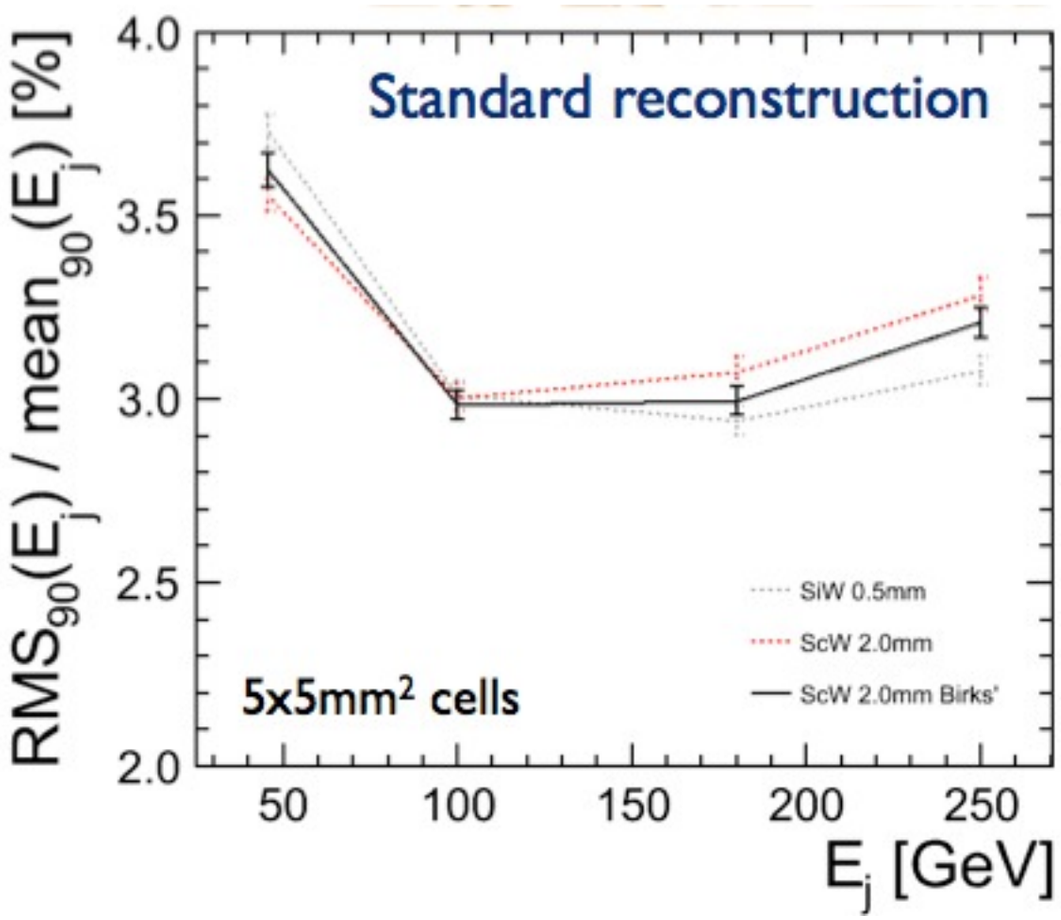
ScThick	σ stat	σ const
0.5mm	19.04%	2.19%
1.0mm	16.84%	1.71%
2.0mm	15.17%	1.72%
3.0mm	14.26%	1.56%

Jet Energy Resolution



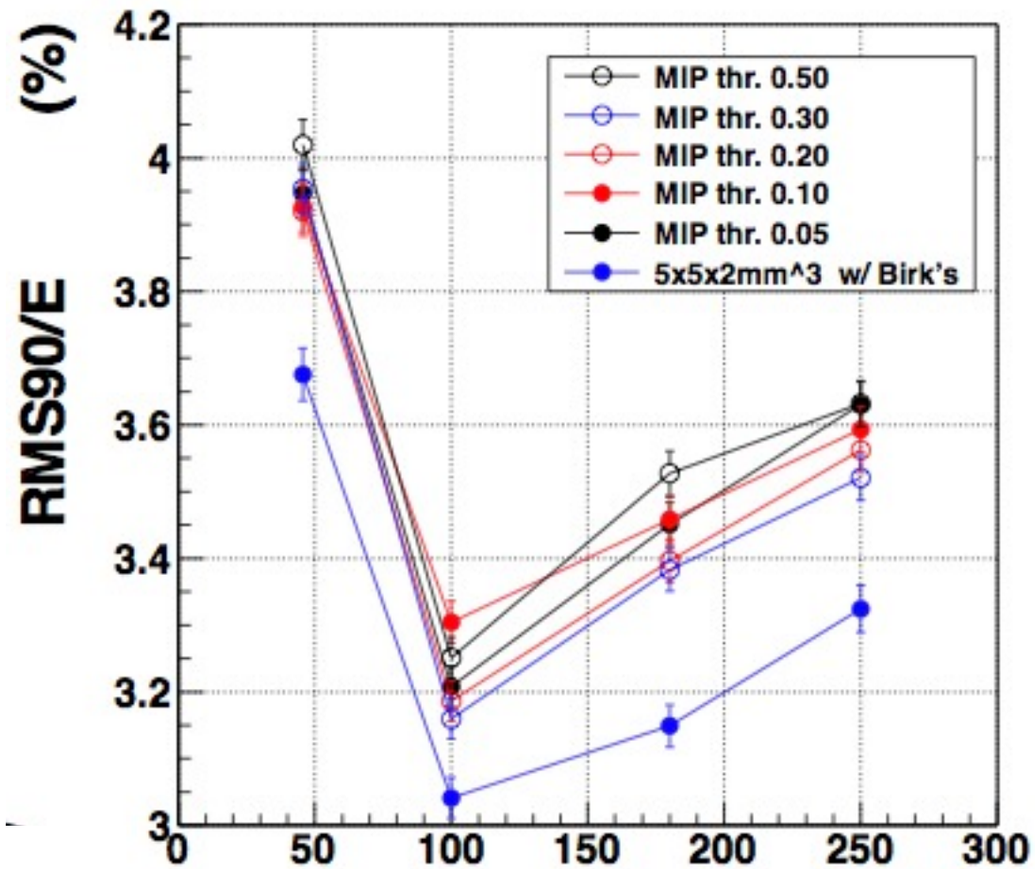
Improvements for ScECAL

Birk's Law



include Birk's Law

MIP threshold after SSA



MIP threshold : 0.5 → 0.3 / a virtual cell