Simulation Study for the Hybrid ECAL for ILD

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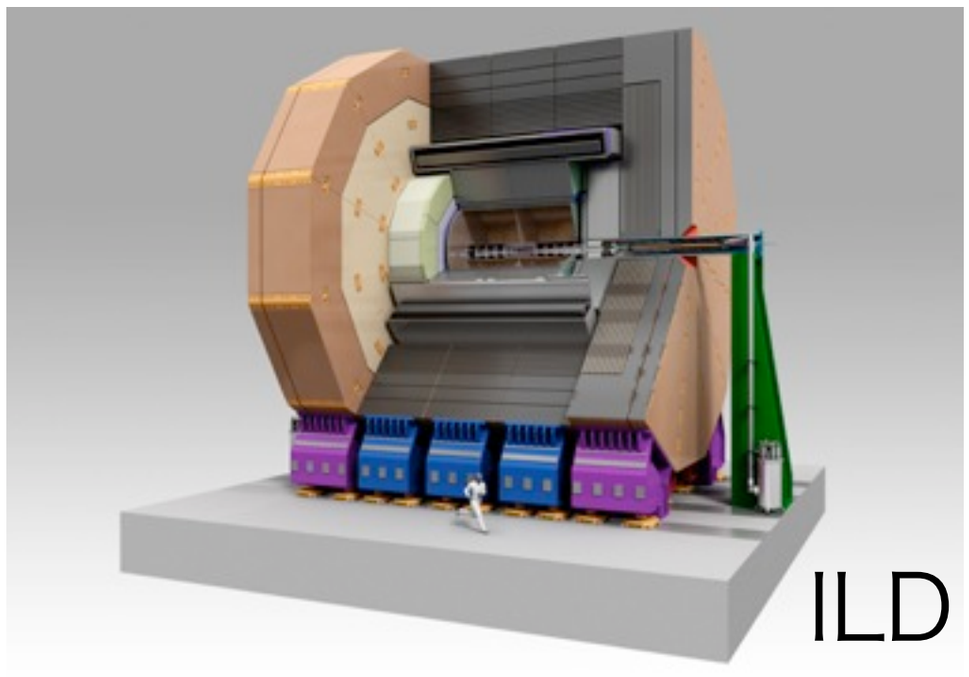
On behalf of ILD ECAL group

Contents

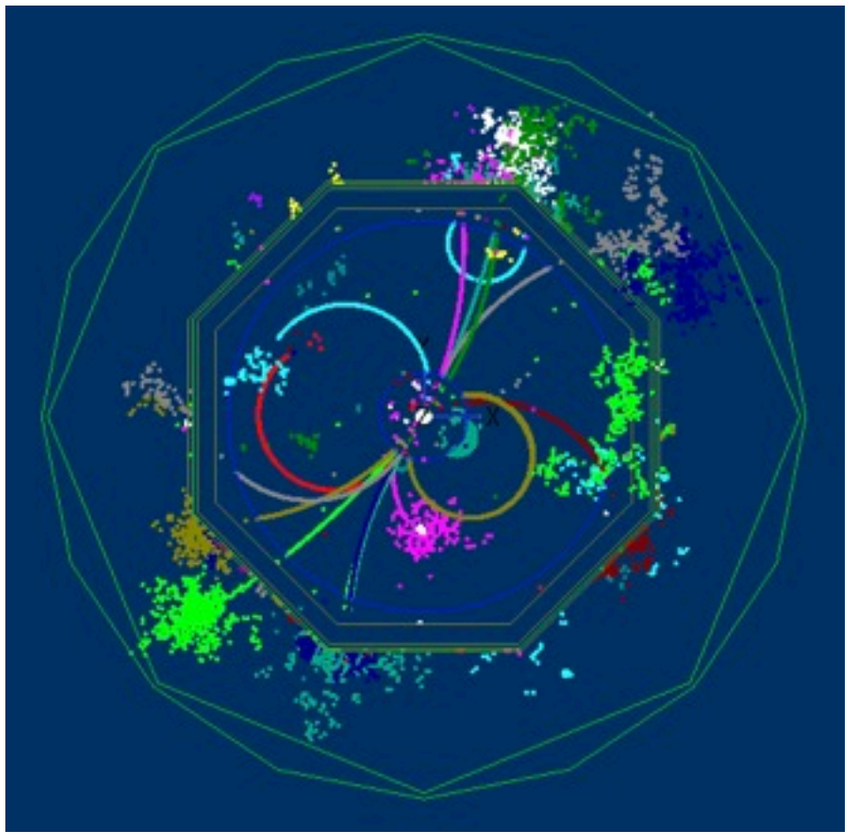
- Motivation for the Hybrid ECAL
- Calibration
- Jet Energy Resolution
  - same absorber thickness
  - same module thickness
  - alternating hybrid
- Summary

ILD ECAL & PFA

- A highly granular calorimeter is required for a future linear collider in order to optimally utilize Particle Flow Algorithm (PFA).
- ILD has developed as the detector optimizes for PFA.
- For ILD Electromagnetic Calorimeter(ECAL), there're two candidates for sensitive layers.

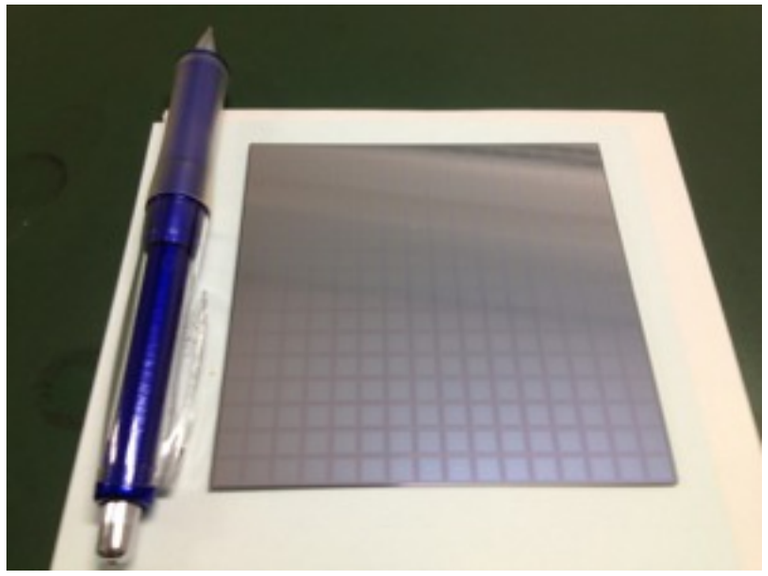


ILD



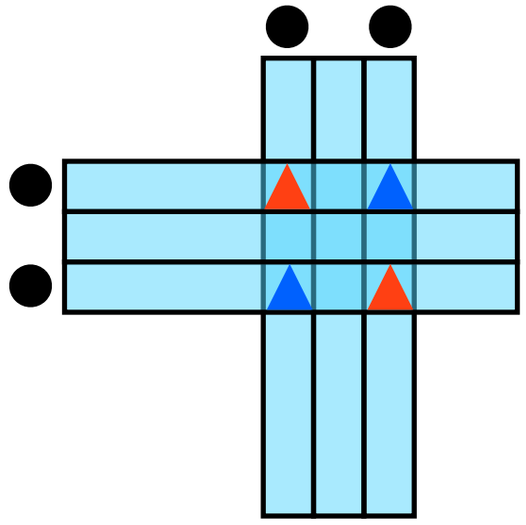
ECAL Candidates

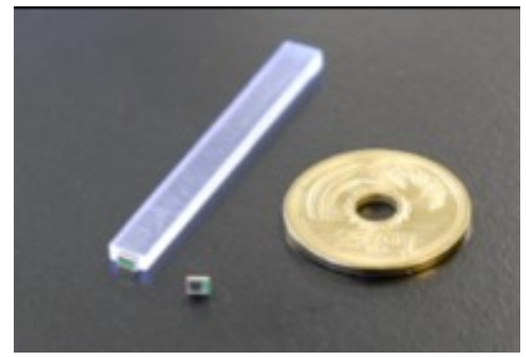
Silicon pads （Si ECAL）



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

Scintillator strips +MPPC （Sc ECAL）





- ✻ 45mm x 5mm orthogonal
  →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.

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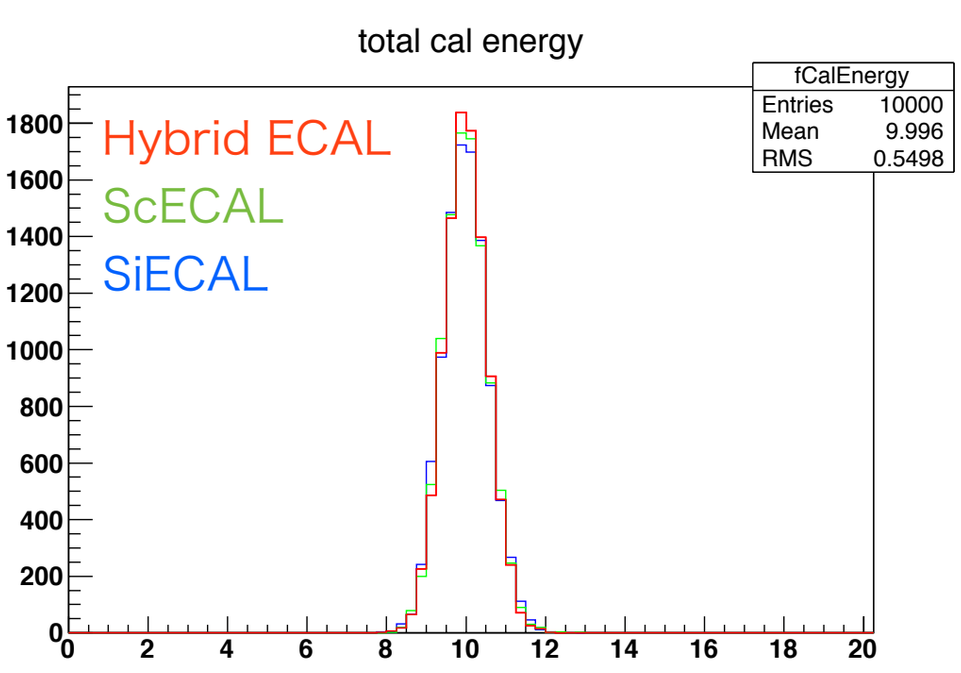
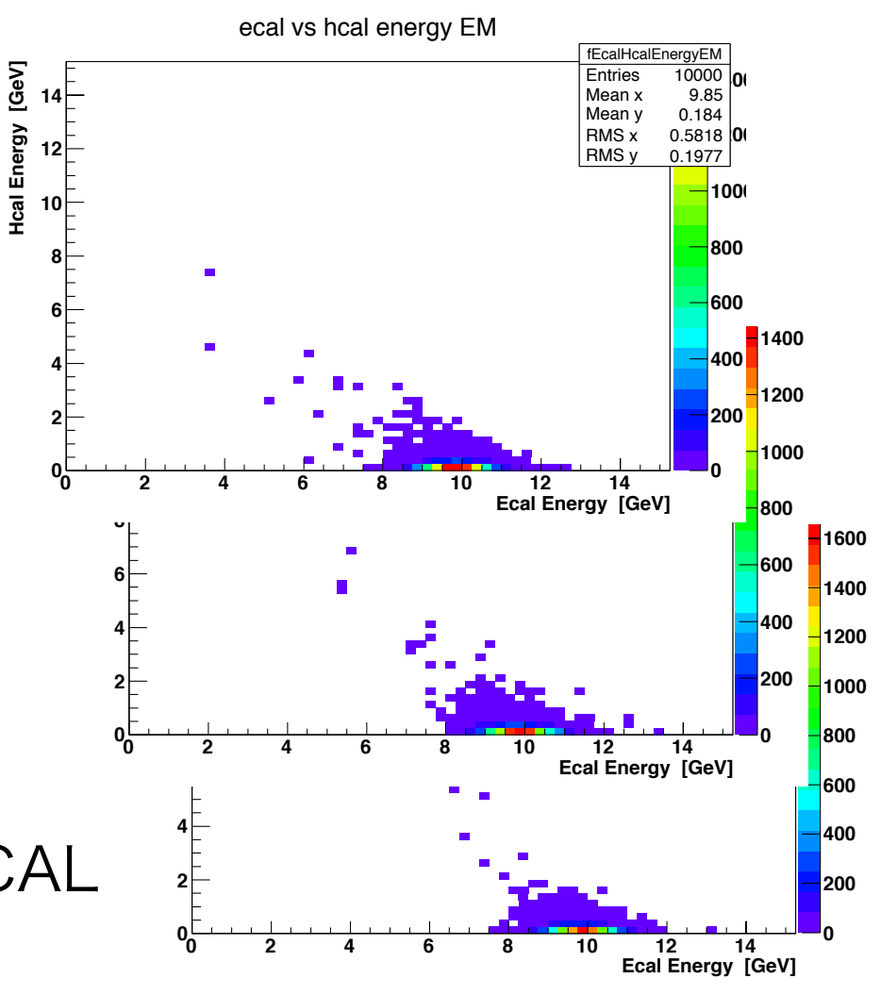
ECAL Calibration

- Calibration constants should be determined separately (Sc, Si)
  - determined using 10GeV photons

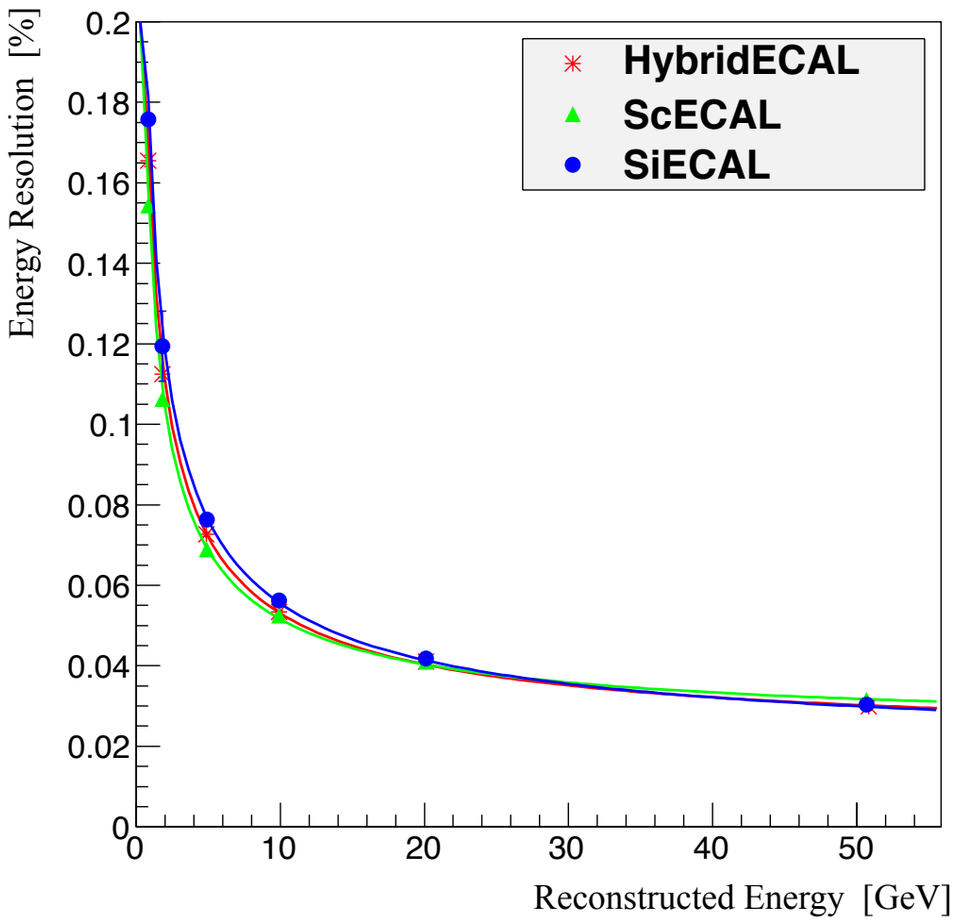




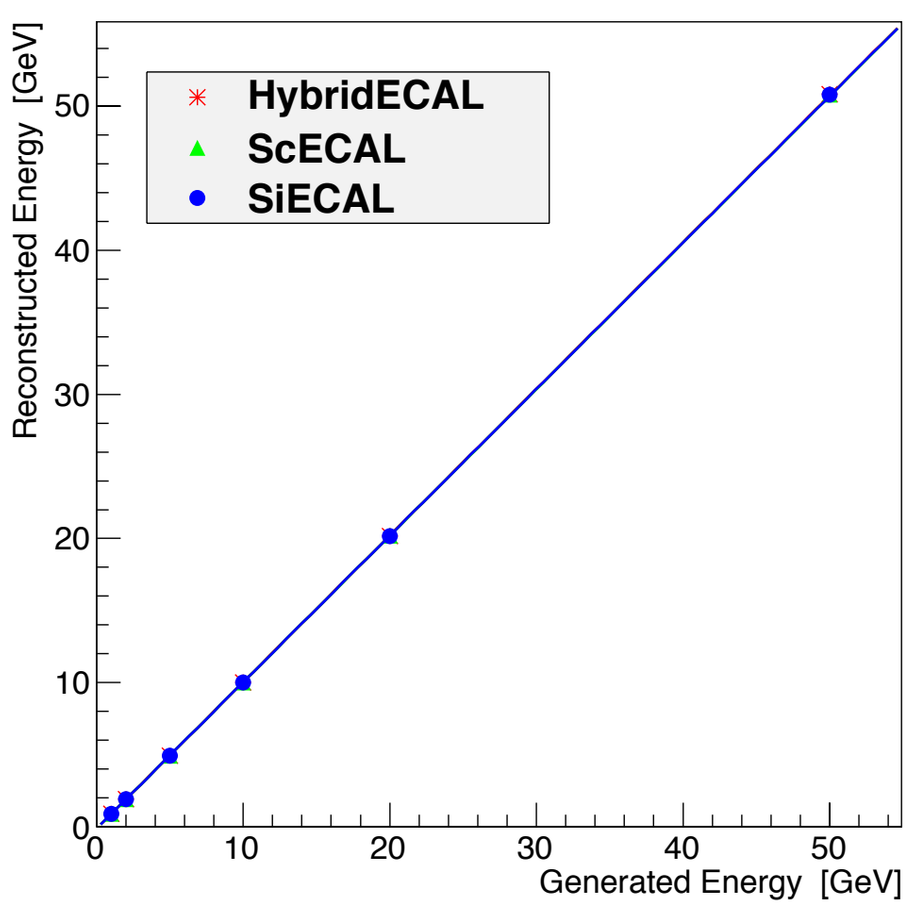
ECAL Performance

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

Photon Energy Resolution



Linearity



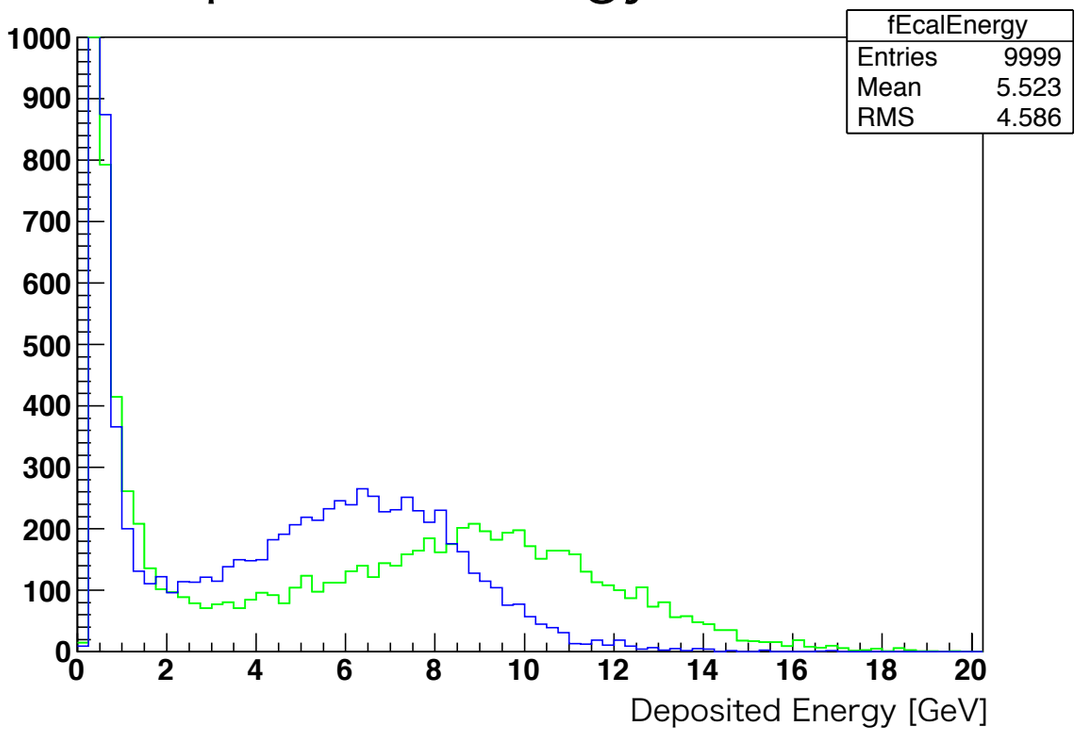
The calibration method works well.

ECAL Calibration

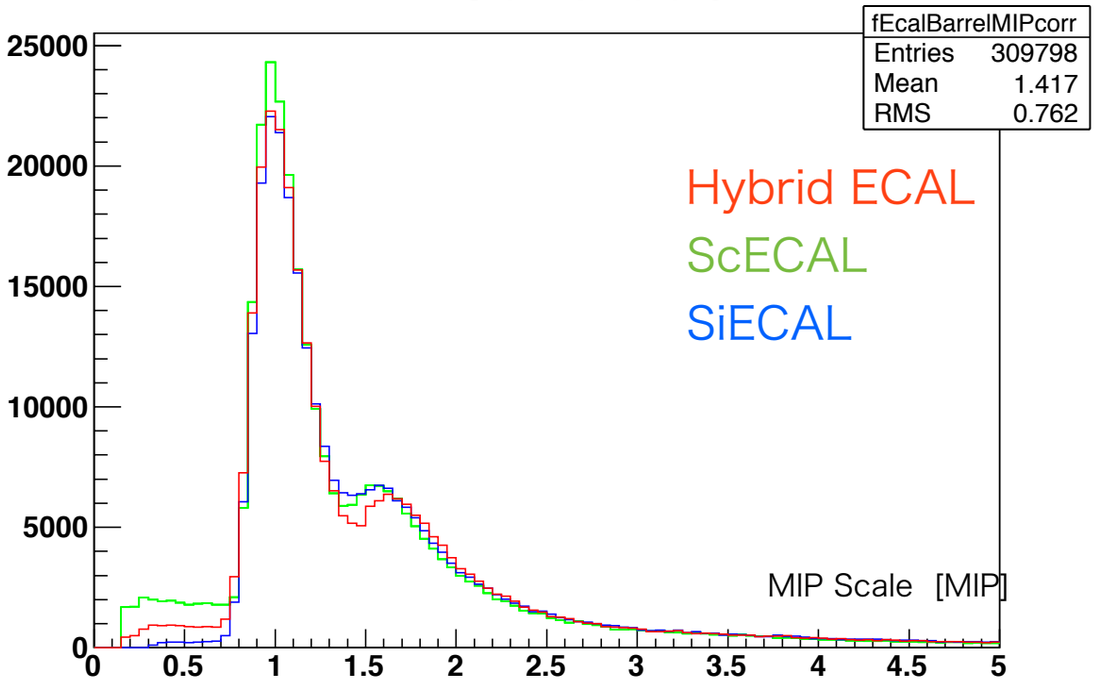
- Hadron Response : 10GeV π^+
- MIP calibration : 10GeV muons

e/h compensation

Deposited Energy in ECAL

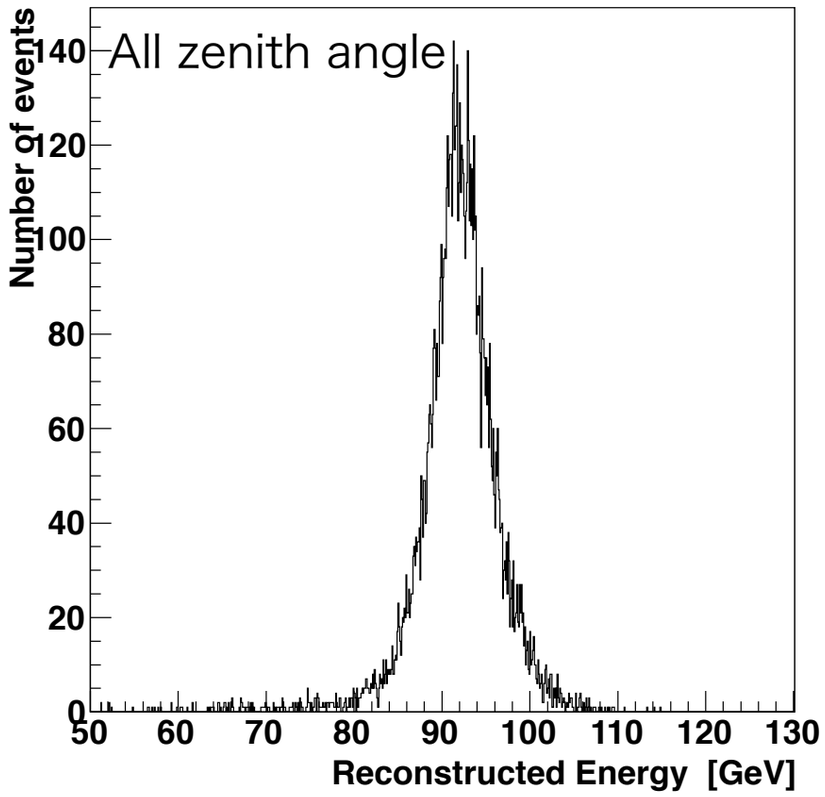


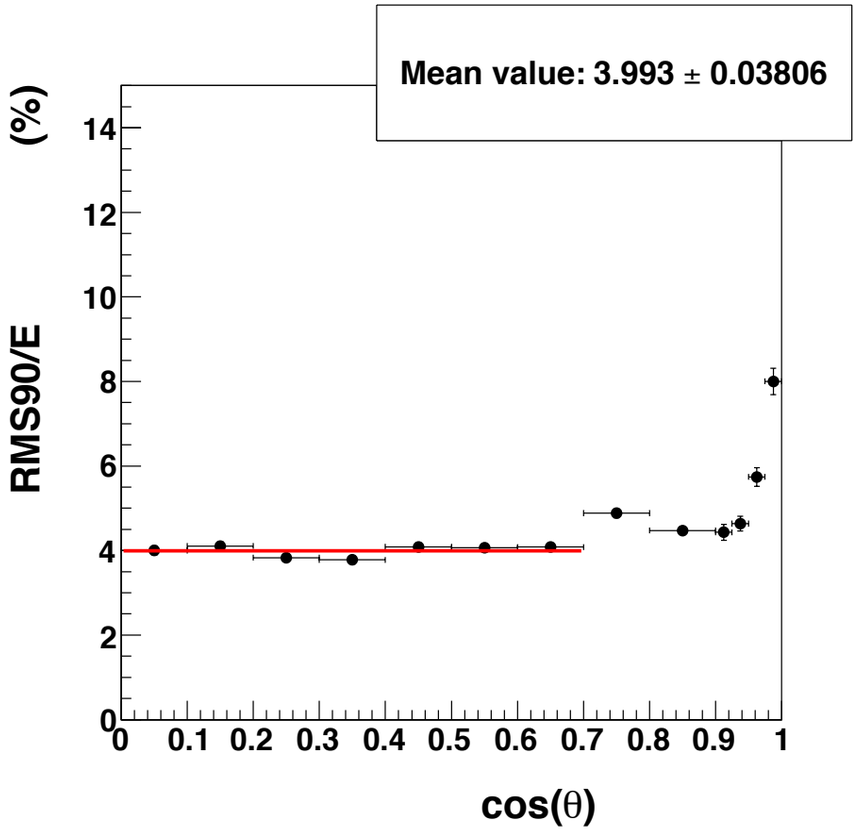
MIP Calibration



Hybrid ECAL Evaluation

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





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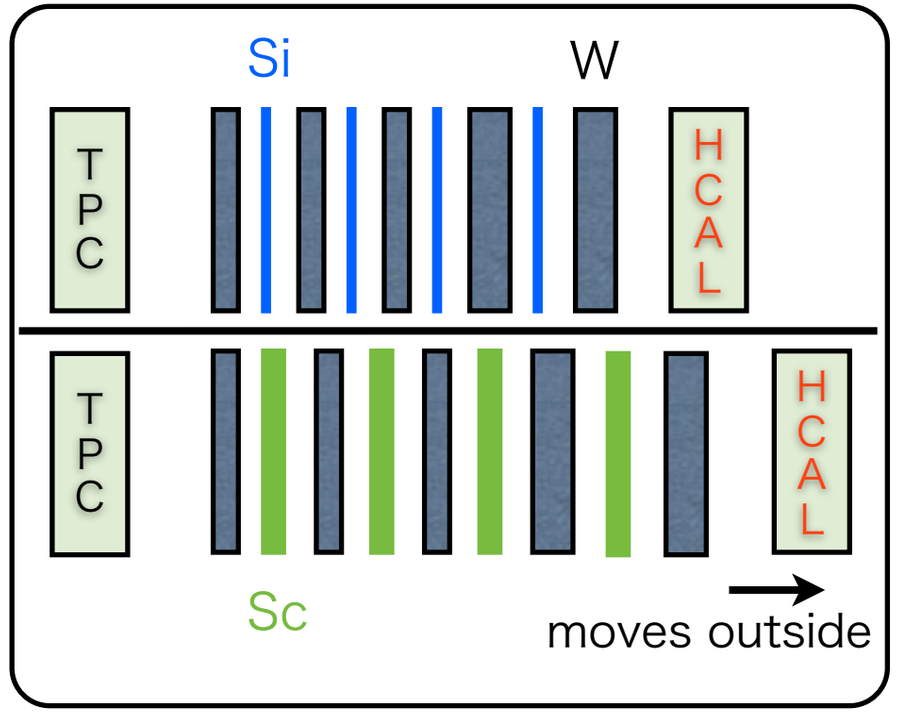
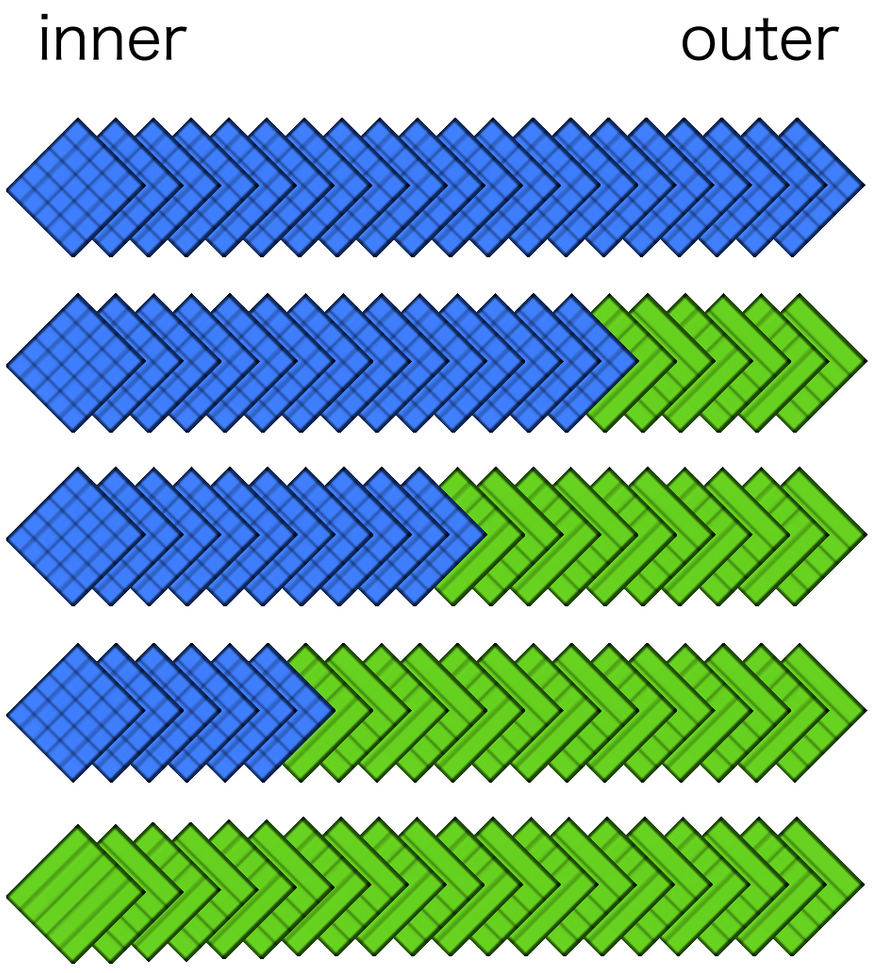
same absorber thickness

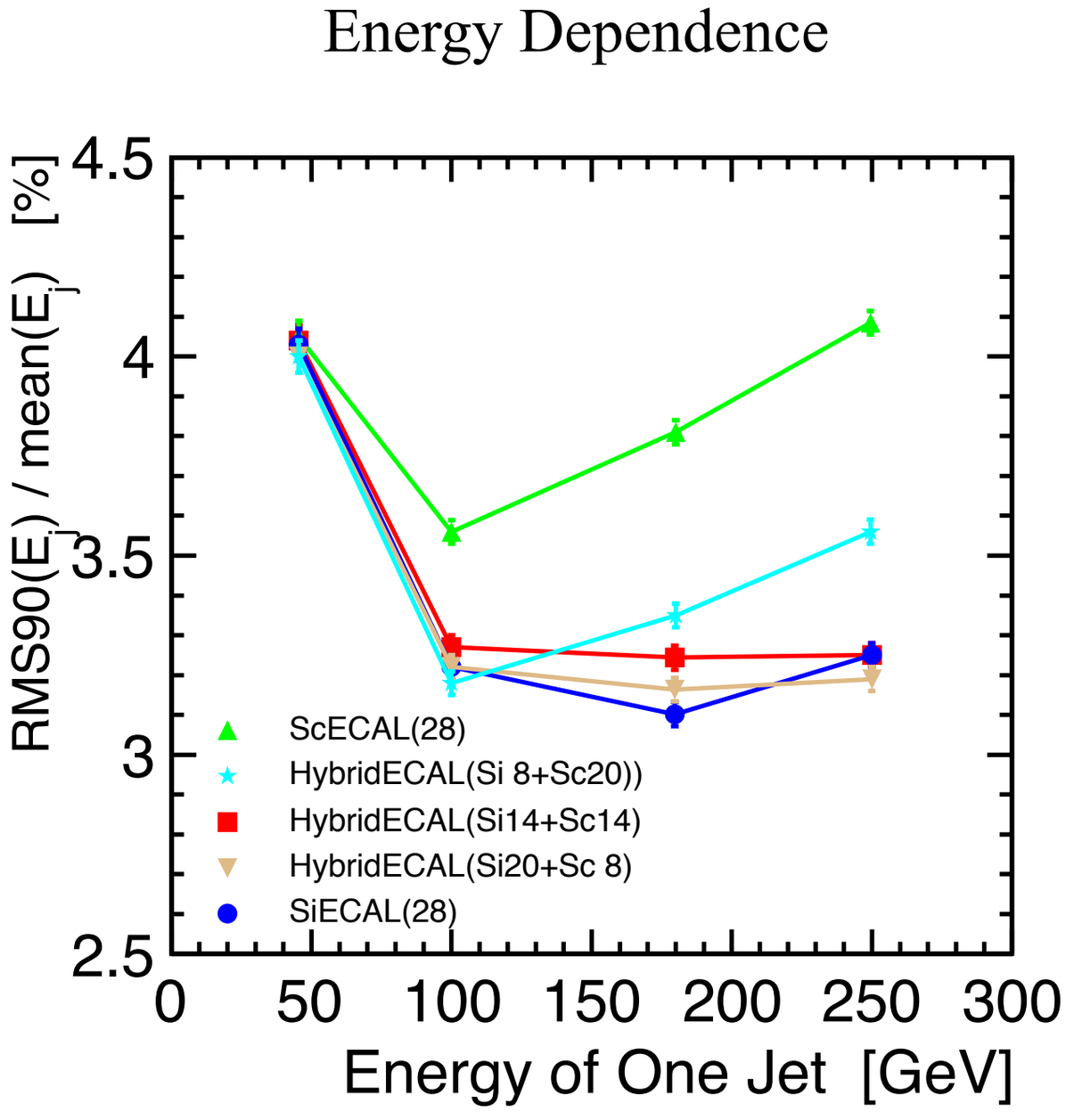
- performance difference between Si and Sc
- five configurations
- Scintillator thickness = 2.0mm
- different module thickness



	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



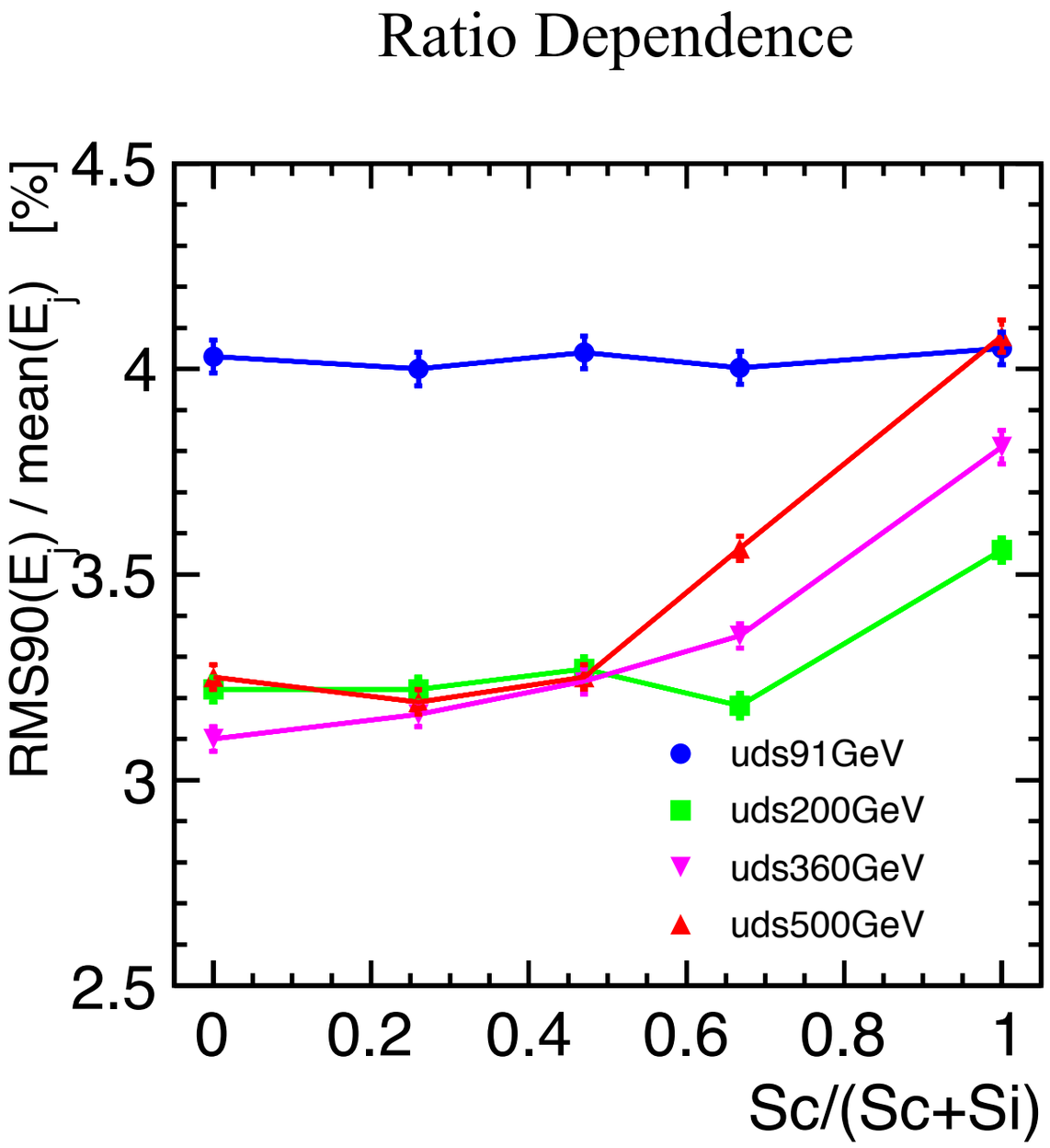
Jet Energy Resolution



- 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



- 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

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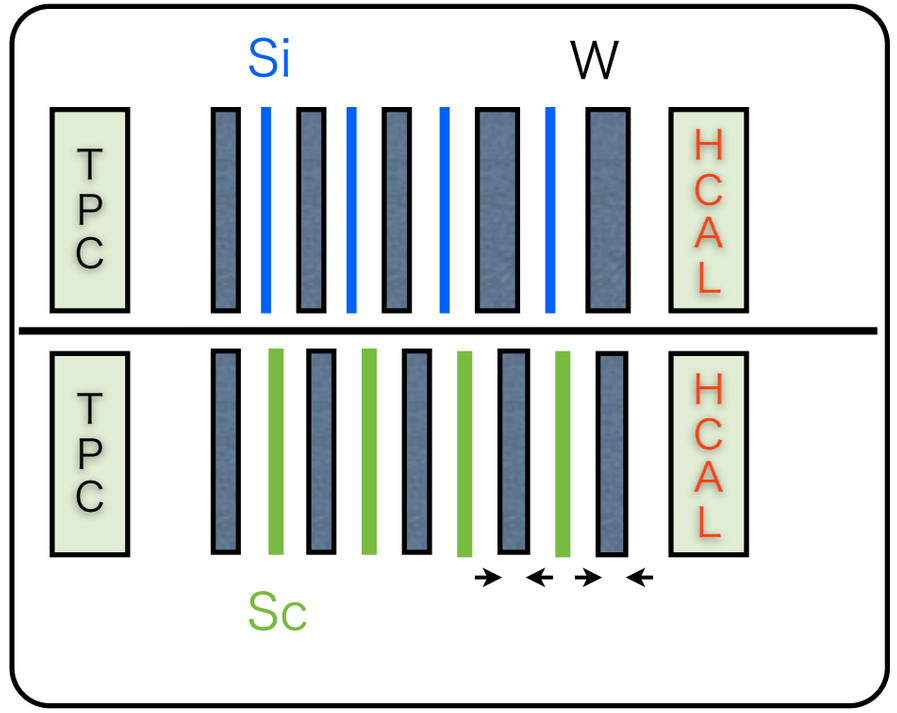
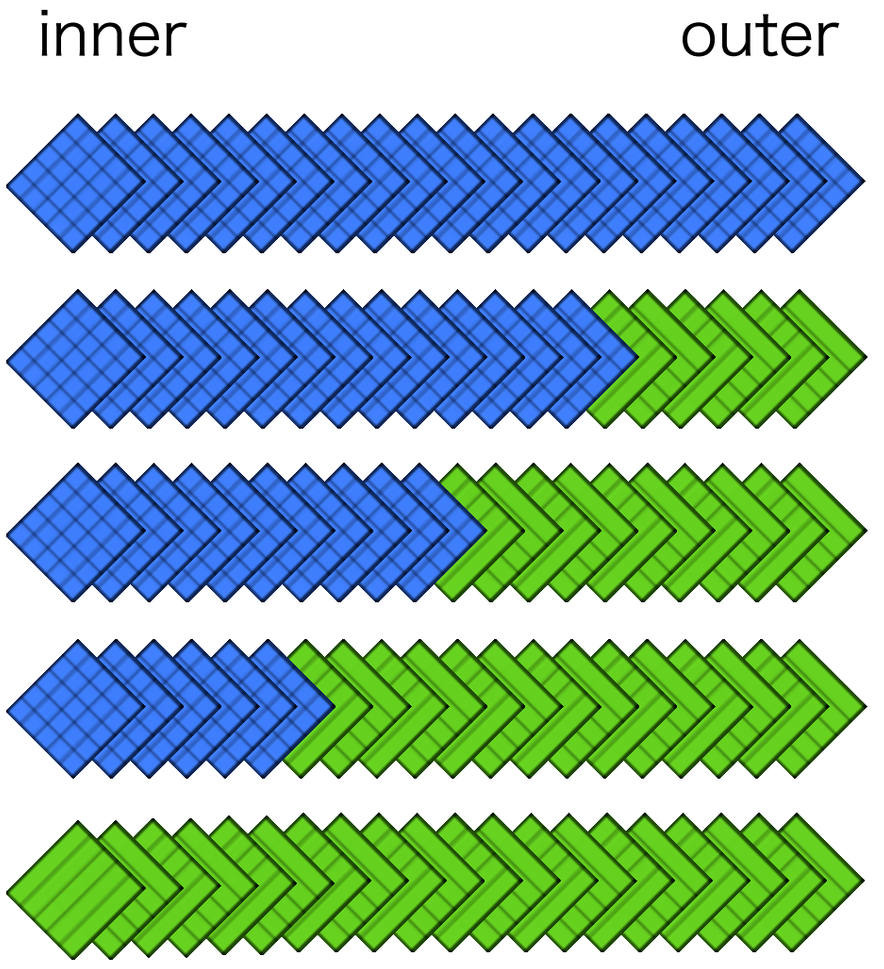
same module thickness

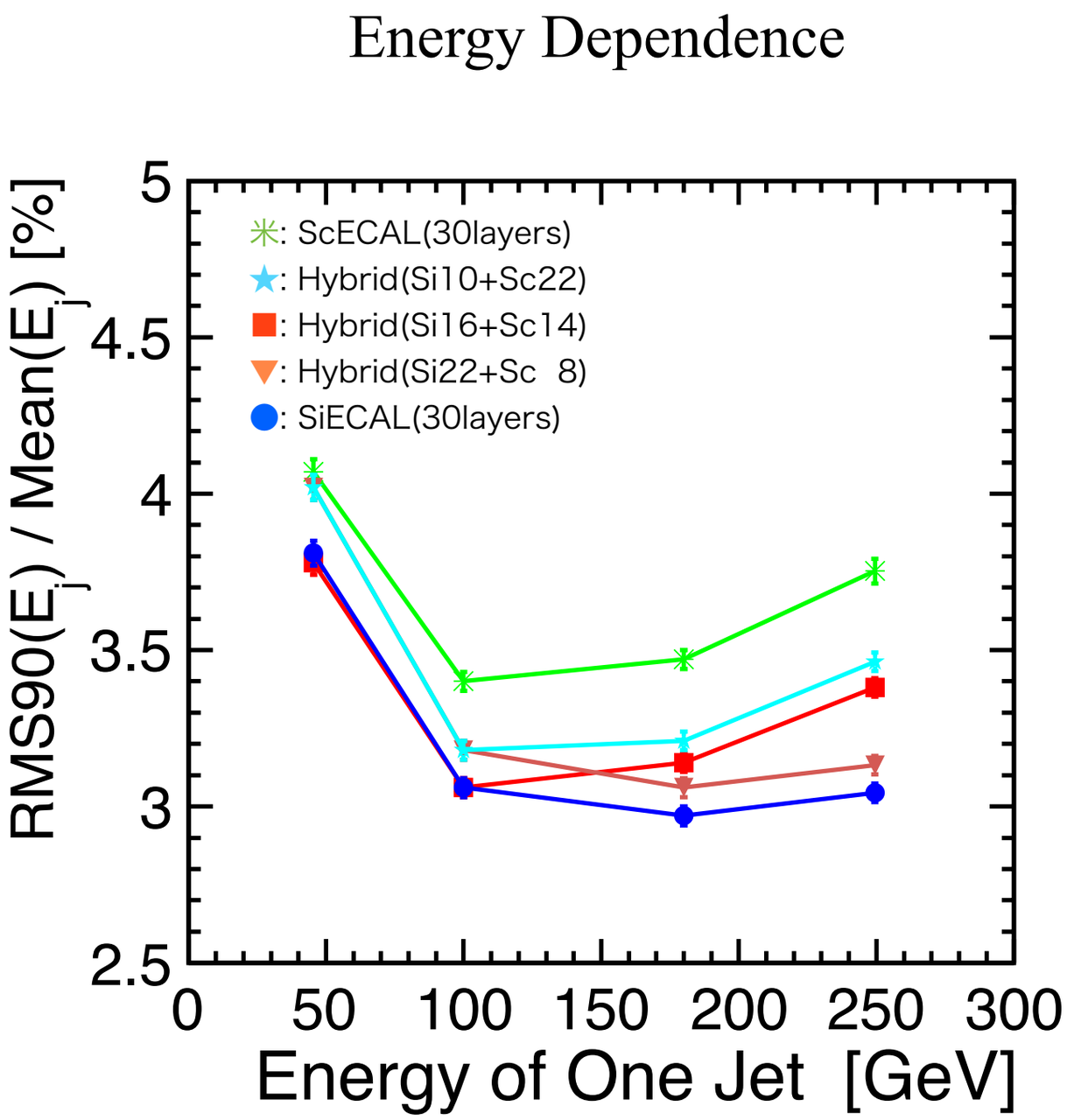
- to evaluate with official ECAL thickness
- five configurations
- scintillator thickness = 1.0mm
- change absorber thickness for outer layers



	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



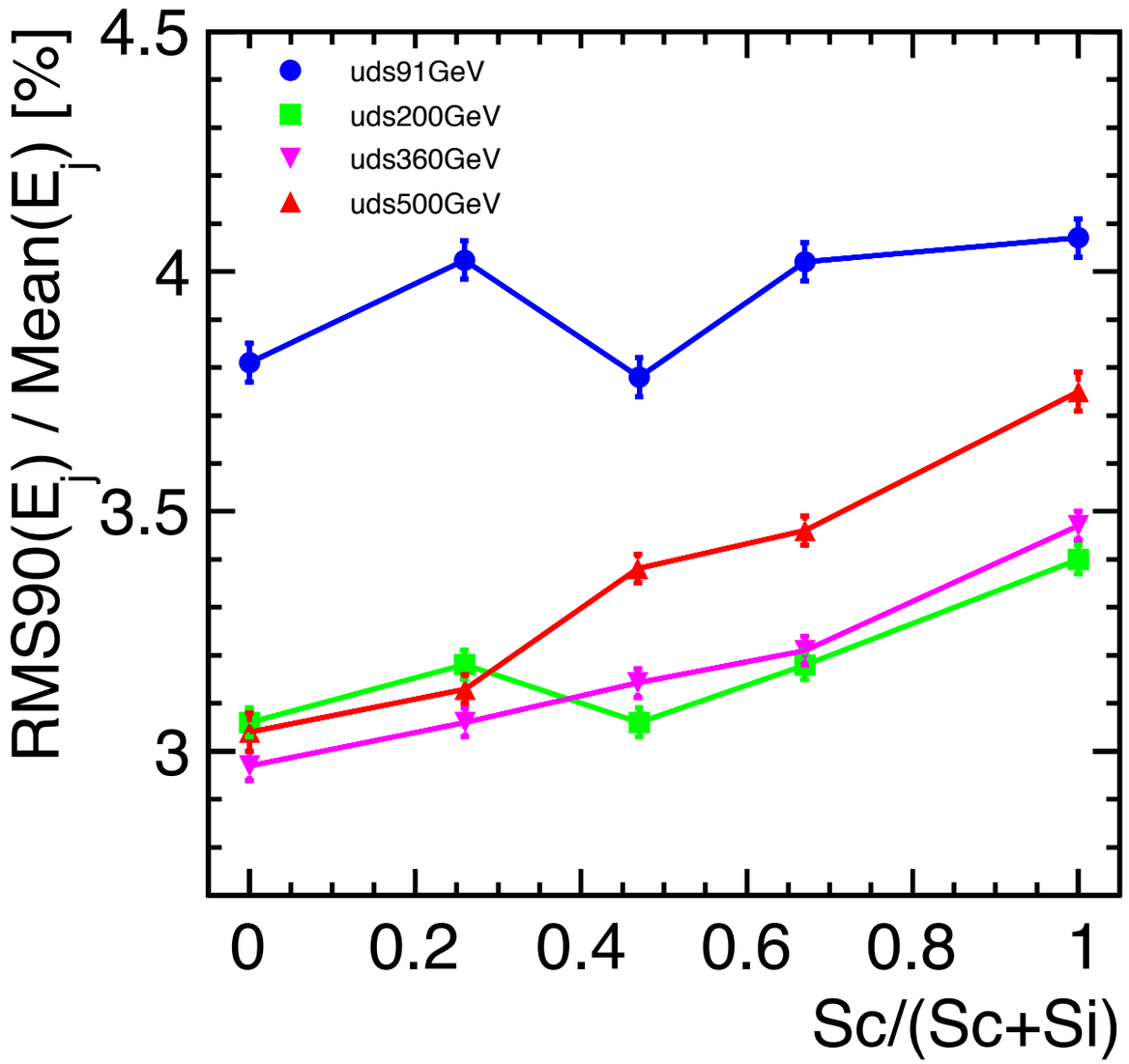
Jet Energy Resolution



- performance looks to depend on the number of silicon layers all over the energies
- Hybrid(Si14+Sc14) is about medium between SiECAL and ScEACL

Jet Energy Resolution

Ratio Dependence



- Performance becomes worse almost linearly as scintillator layers increase
- Hybrid(Si14+Sc14) is better than other Hybrids.
    - Strange behavior can be seen

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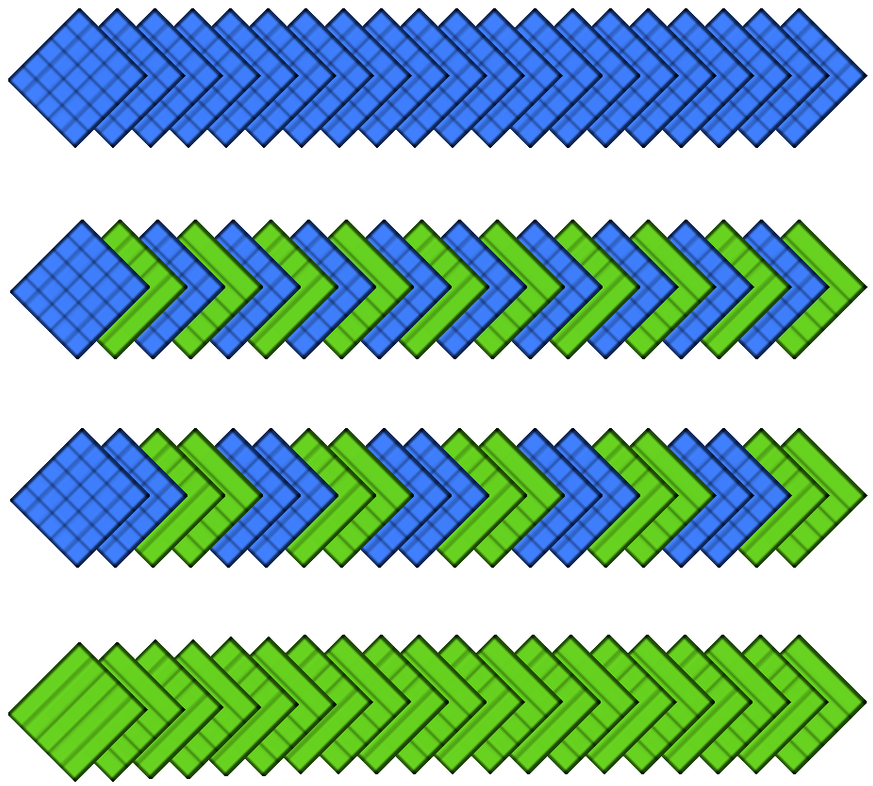
alternating hybrid

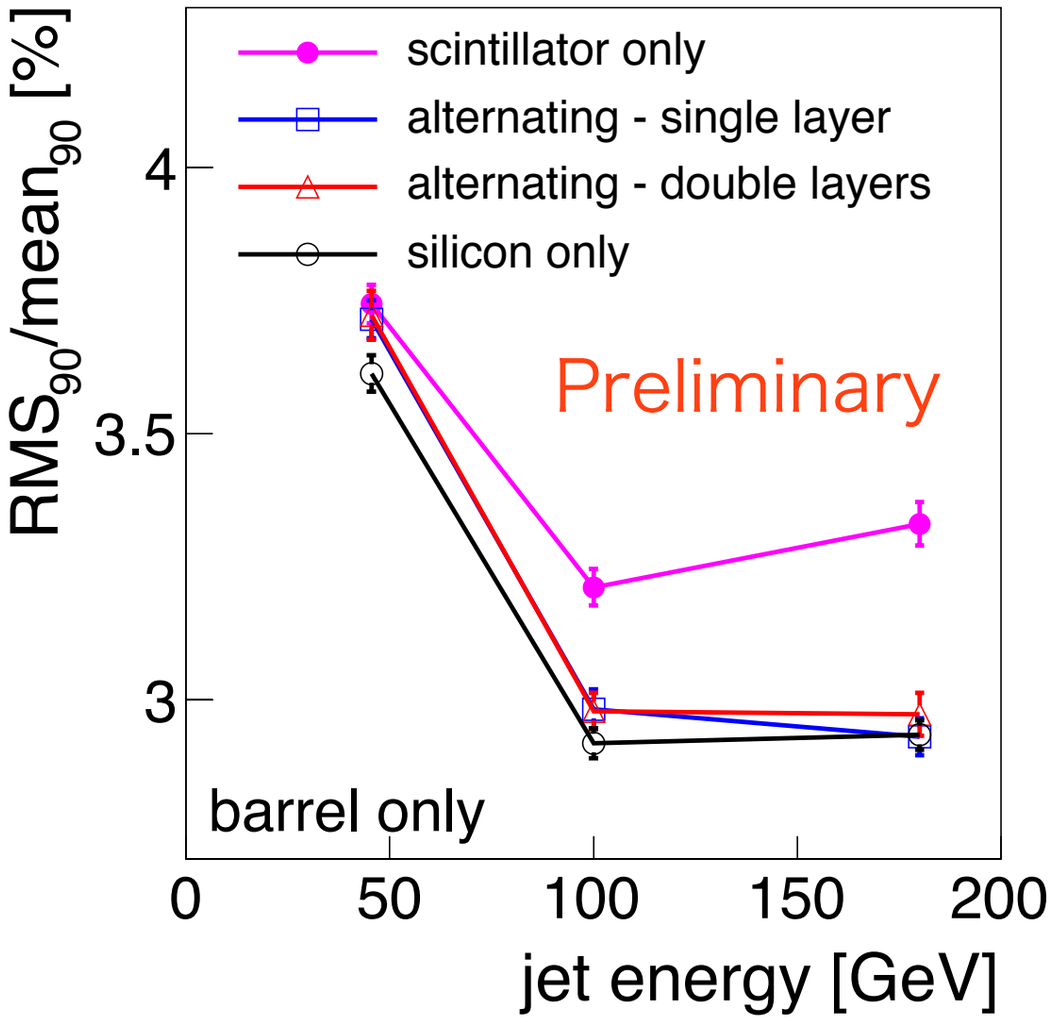
- to resolve ghost hits by putting on Si layers beside Sc layers
- Single layers, Double layers
- Scintillator thickness = 2.0mm
- same absorber thickness
- different module thickness

	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Single layer Alternate(Si15Sc15)	2.1/4.2	204.8
Double layers Alternate(Si16Sc14)	2.1/4.2	204.8
ScECAL(30)	2.1/4.2	227.4



alternating hybrids performance

Energy Dependence



by D.Jeans

- Both alternating hybrids are better than Sc-only and almost as good as Si-only.
- No big difference are seen between single layer and double layers alternating.
- looks very promising

Summary

- Hybrid ECAL is an option to make ILD ECAL with a lower cost while keeping performance as much as possible.

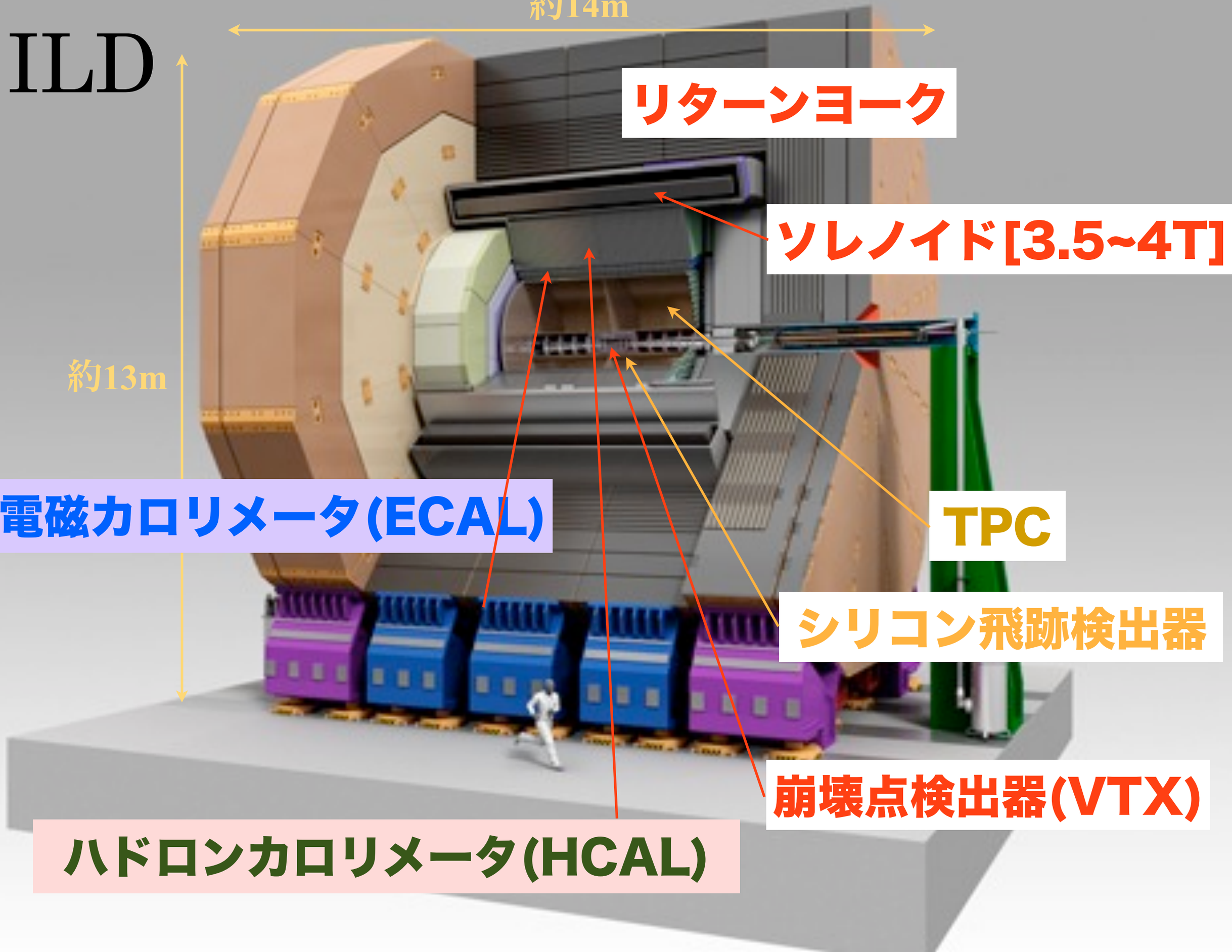
- We evaluated Jet Energy Resolution for 3 types of Hybrid ECALs.
  - same absorber thickness ... performance of Hybrid ECAL doesn’t degrade so much up to 50% of scintillator layers.
  - same module thickness ... performance becomes worse almost linearly as scintillator ratio increase.
  - alternating hybrid ... seems very promising.

Backup

ILD

約14m

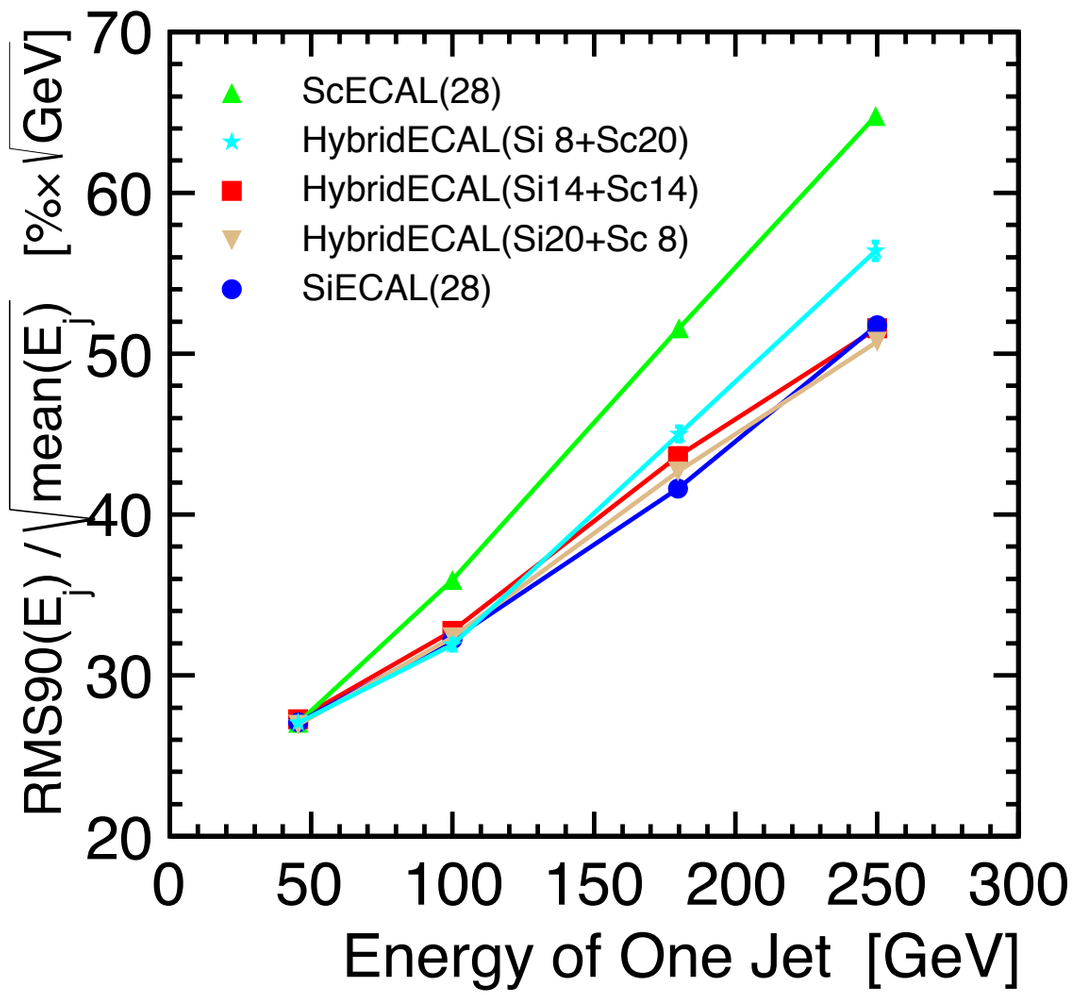
約13m



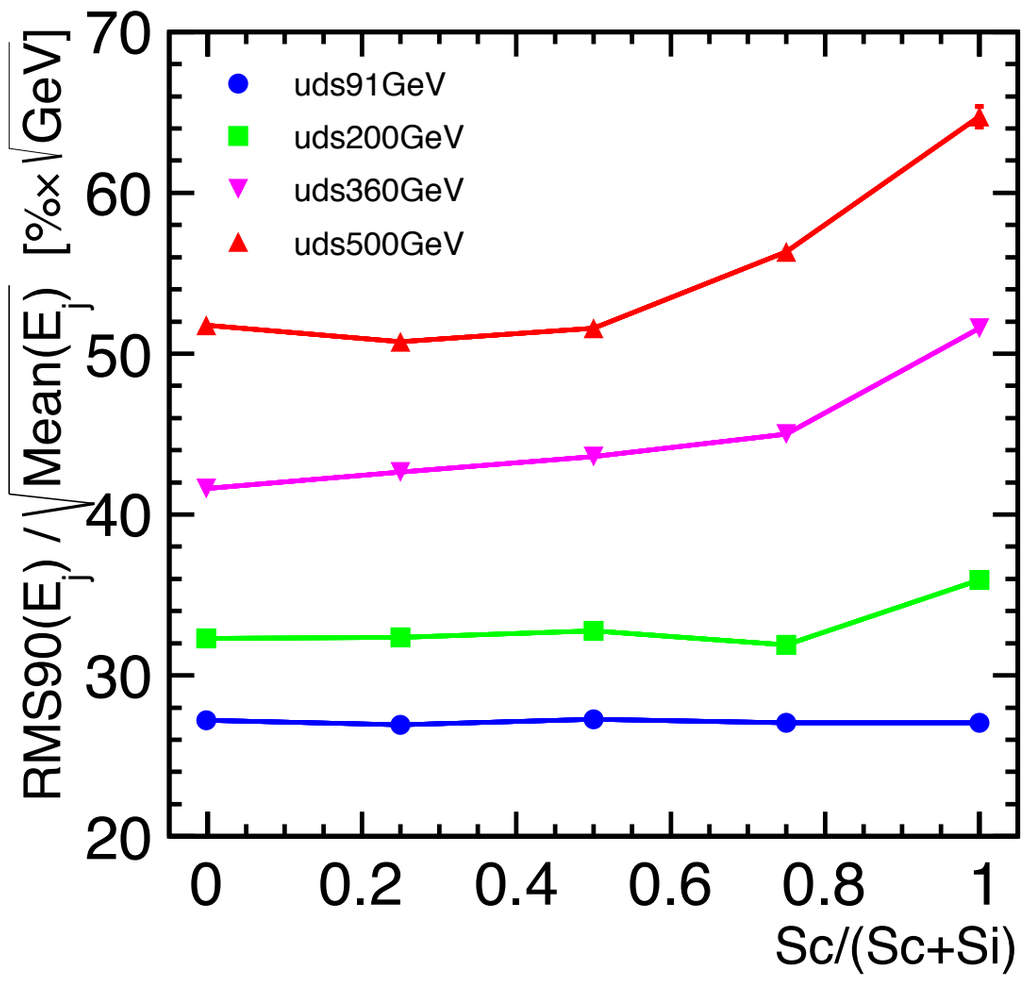
RMS90(E_j) / $\sqrt{\text{mean}(E_j)}$

same absorber thickness

Energy Dependence



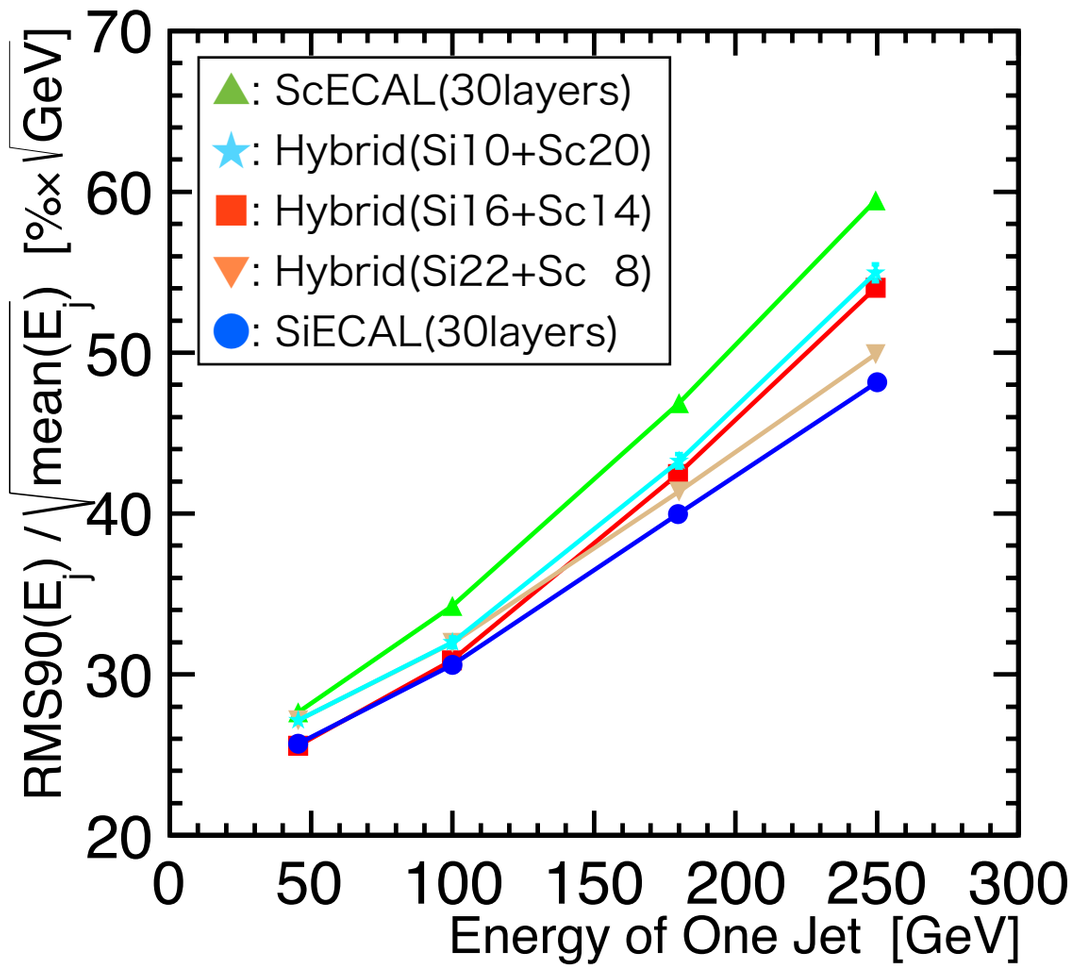
Ratio Dependence



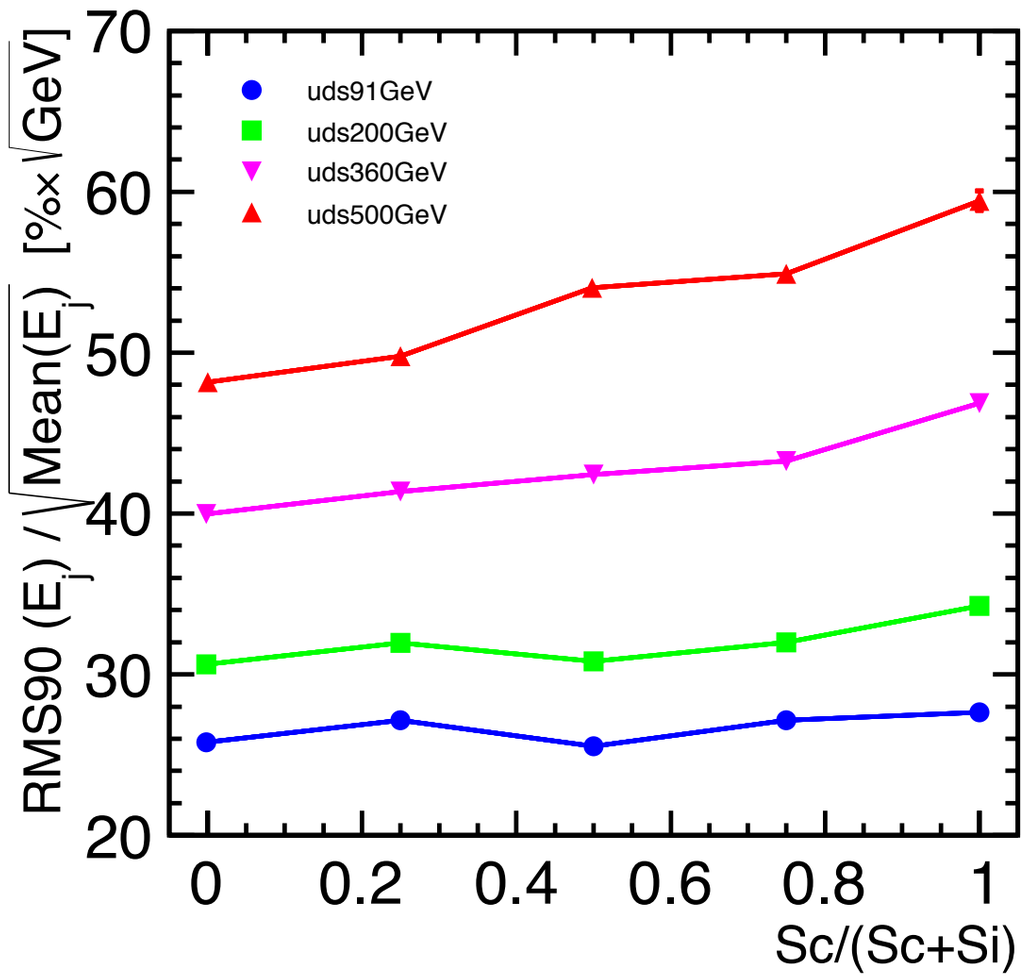
$RMS90(E_j) / \sqrt{mean(E_j)}$

same absorber thickness

Energy Dependence

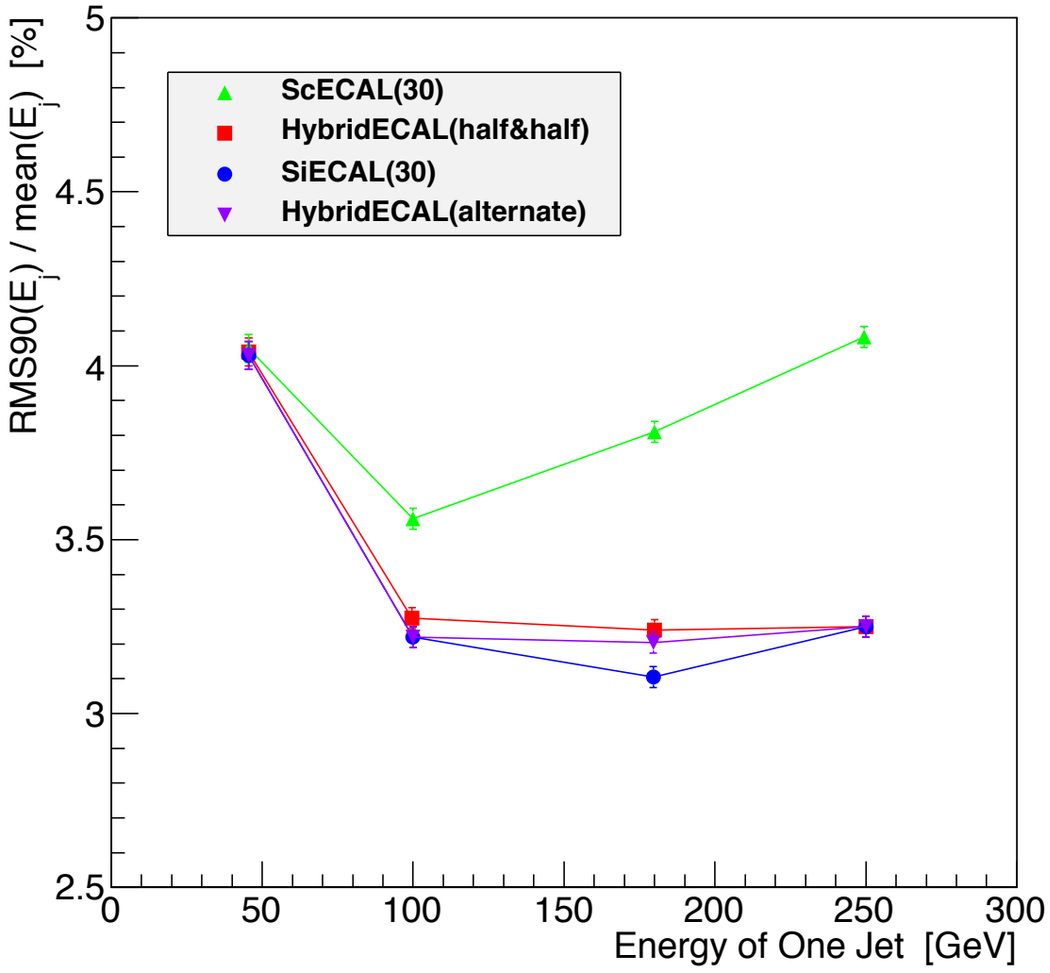


Ratio Dependence

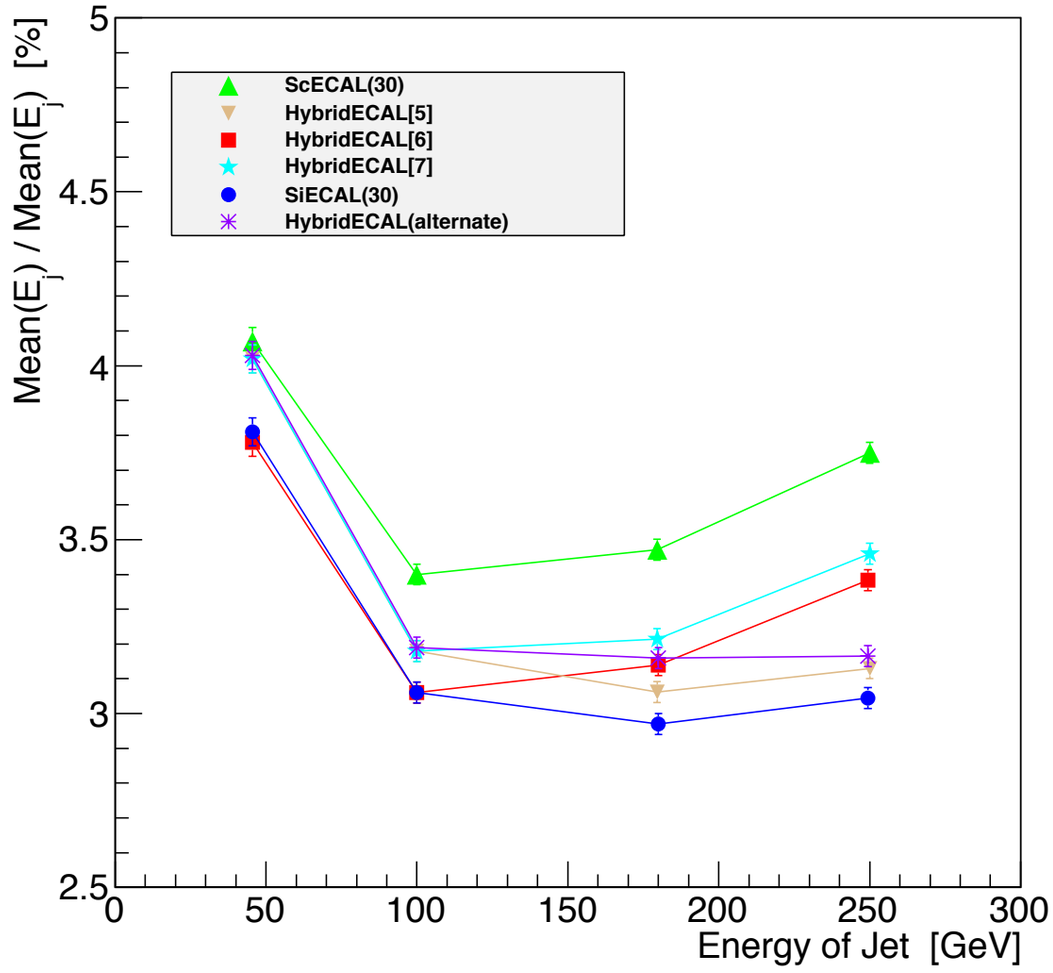


Alternating Hybrid

same absorber thickness

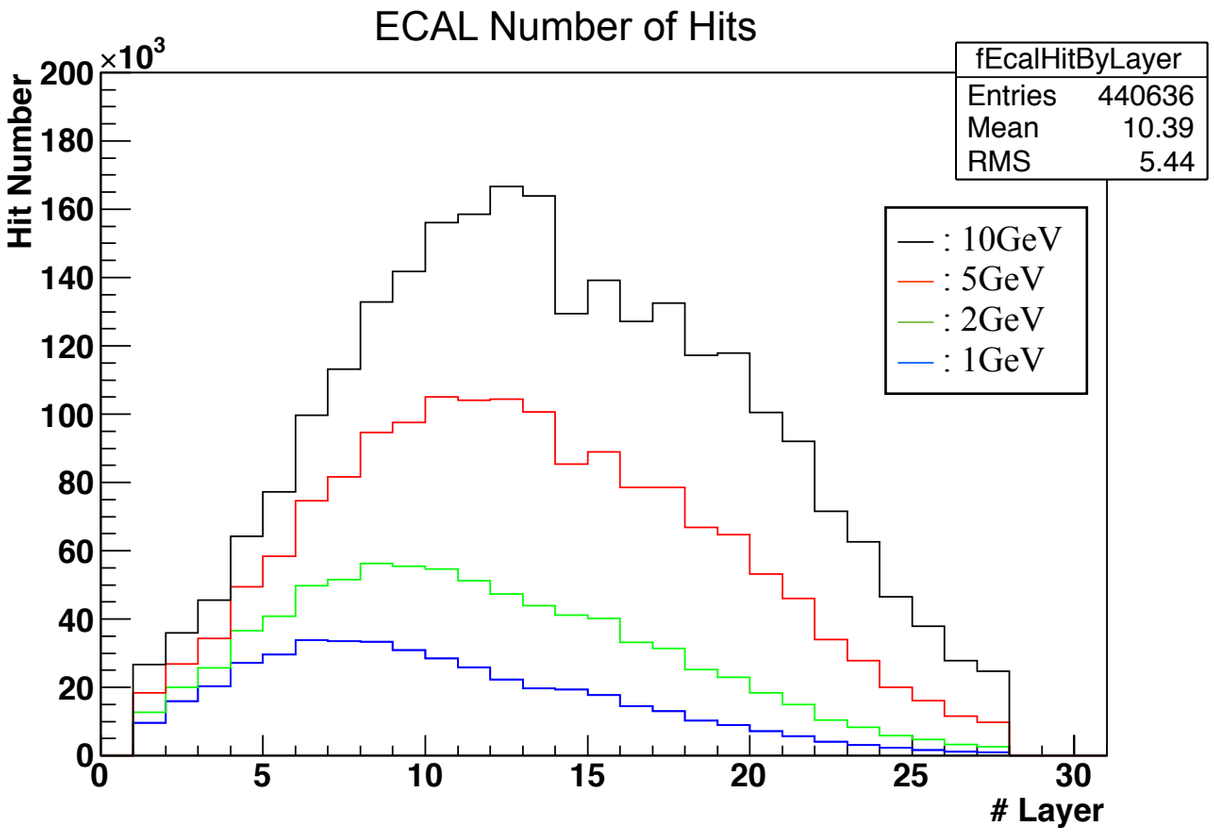


same module thickness

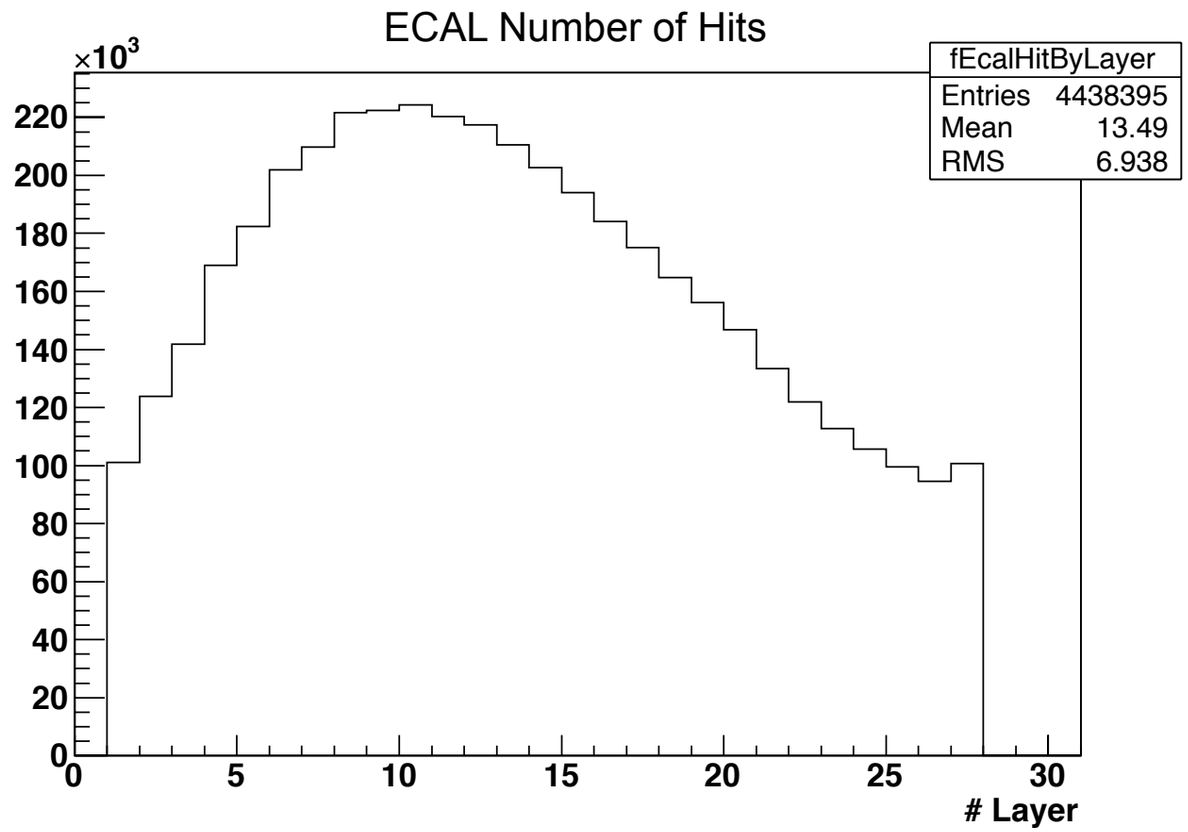


Number of Hits in ECAL

Number of Hits by Layer(photon 1~10GeV)

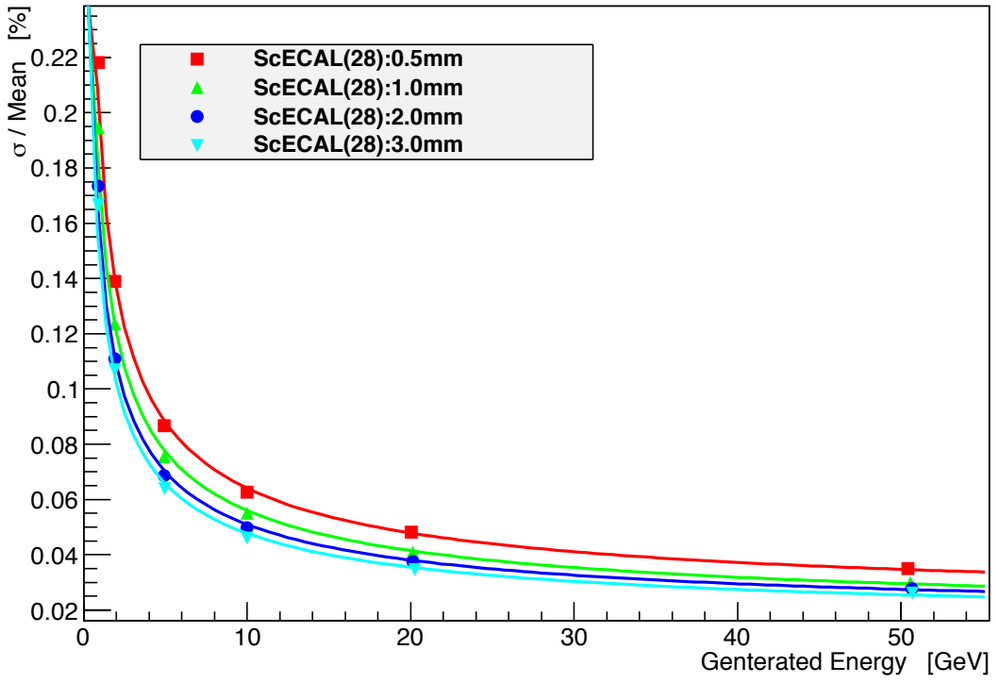


ECAL Hits by Layer(√s=500GeV)



Scintillator Thickness Difference

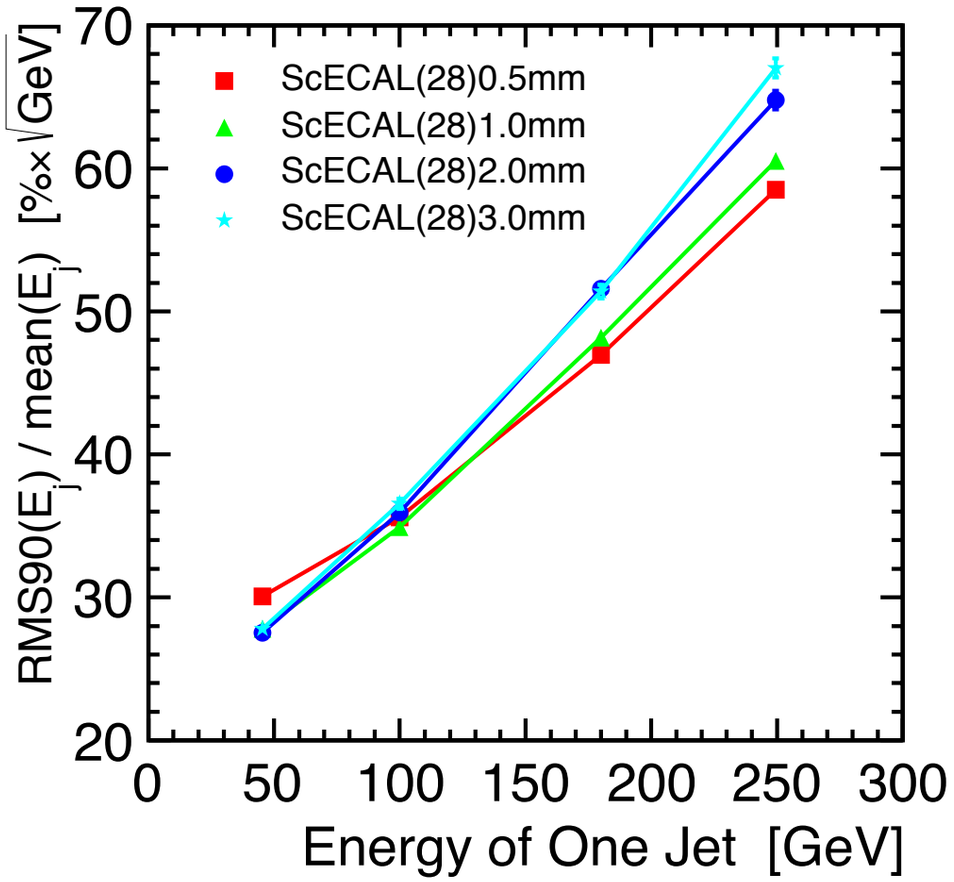
Photon Energy Resolution



ECAL Performance (photon 1~50GeV)

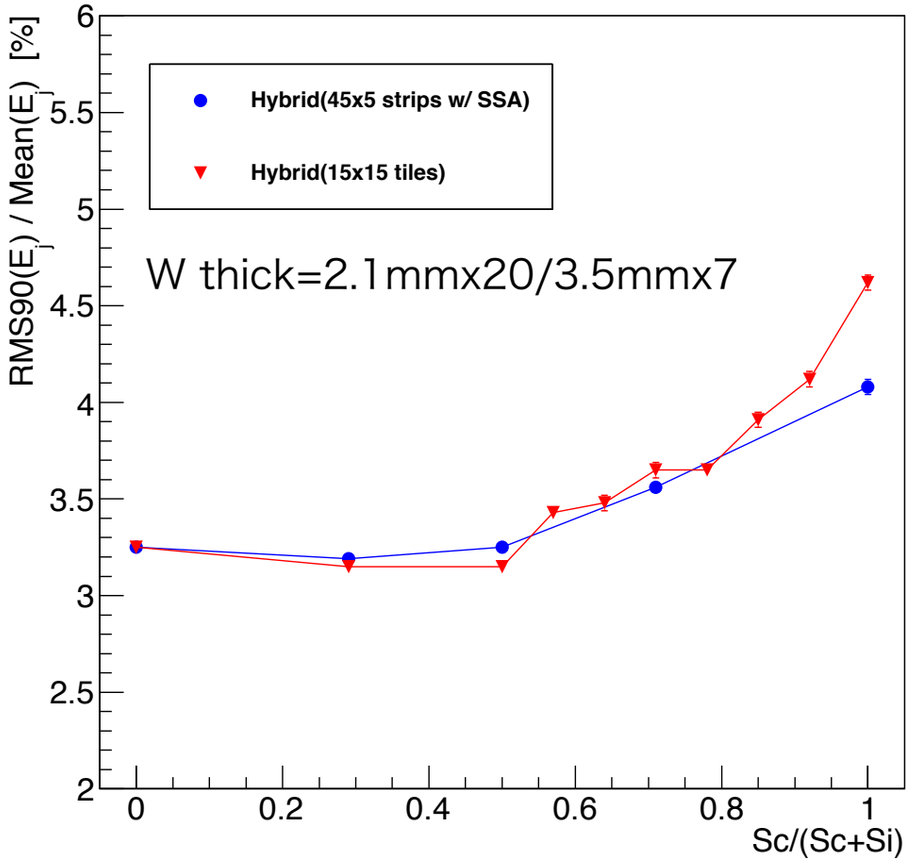
ScThick	σ stat	σ const
0.5mm	19.04%	2.19%
1.0mm	16.84%	1.71%
2.0mm	15.17%	1.72%
3.0mm	14.26%	1.56%

Jet Energy Resolution

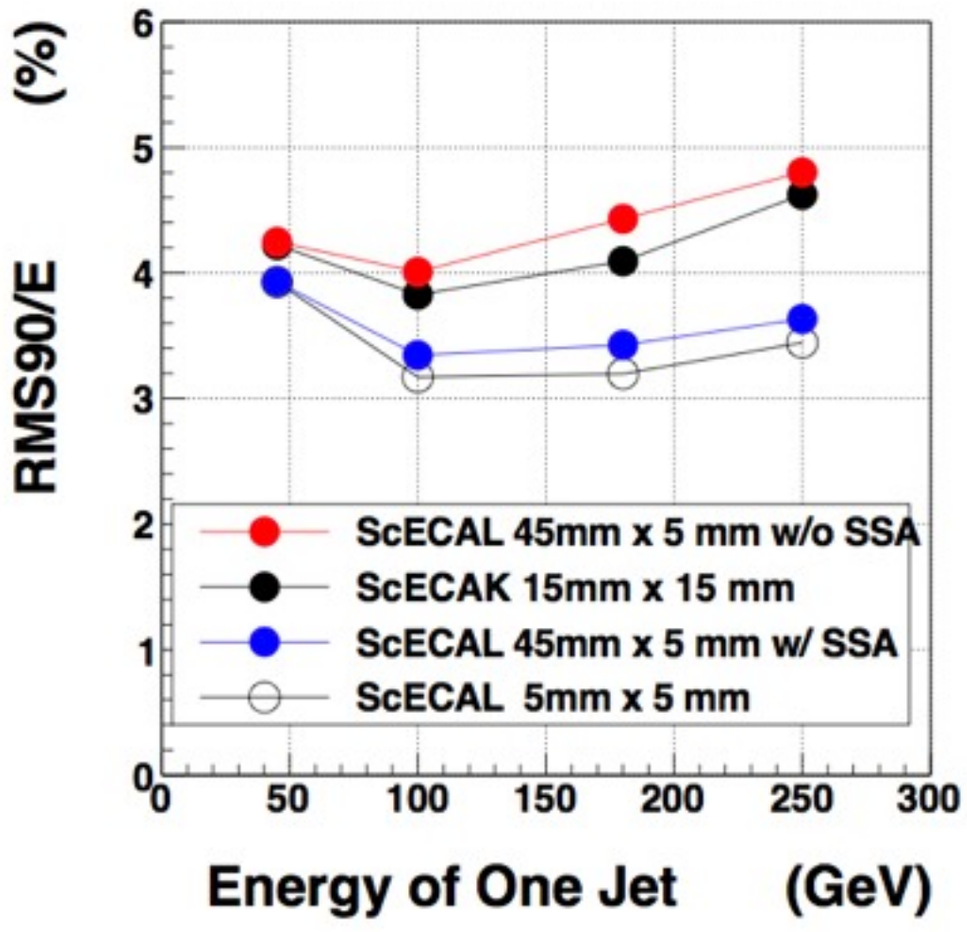


hybrid with Sc-tiles(15x15mm)

Hybrid with tiles

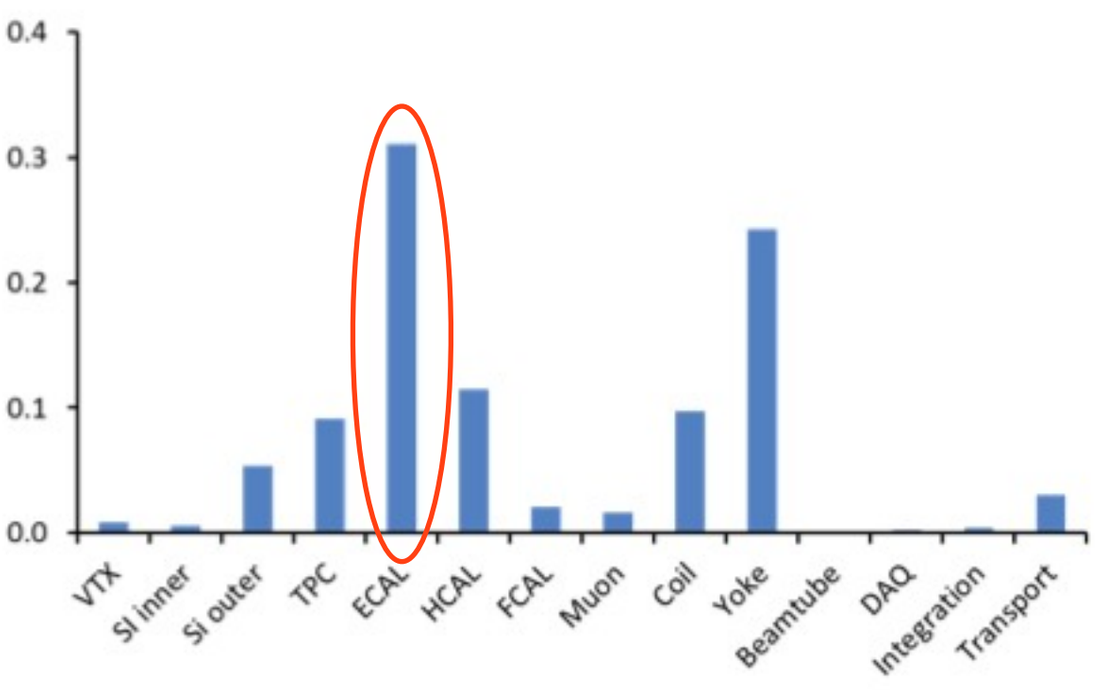


tile ScECAL



No big difference between Sc-strips and Sc-tiles up to 80% of Sc layers!!

Costing



System	Option	Cost [MILCU]	Mean Cost [MILCU]
Vertex			3.4
Silicon tracking	inner	2.3	2.3
Silicon tracking	outer	21.0	21.0
TPC		35.9	35.9
ECAL			116.9
	SiECAL	157.7	
	ScECAL	74.0	
HCAL			44.9
	AHCAL	44.9	
	SDHCAL	44.8	
FCAL		8.1	8.1
Muon		6.5	6.5
Coil, incl anciliaries		38.0	38.0
Yoke		95.0	95.0
Beamtube		0.5	0.5
Global DAQ		1.1	1.1
Integration		1.5	1.5
Global Transportation		12.0	12.0
Sum ILD			391.8