Simulation Study for the Hybrid ECAL

CALICE collaboration meeting @Argonne

19th-21st March, 2014

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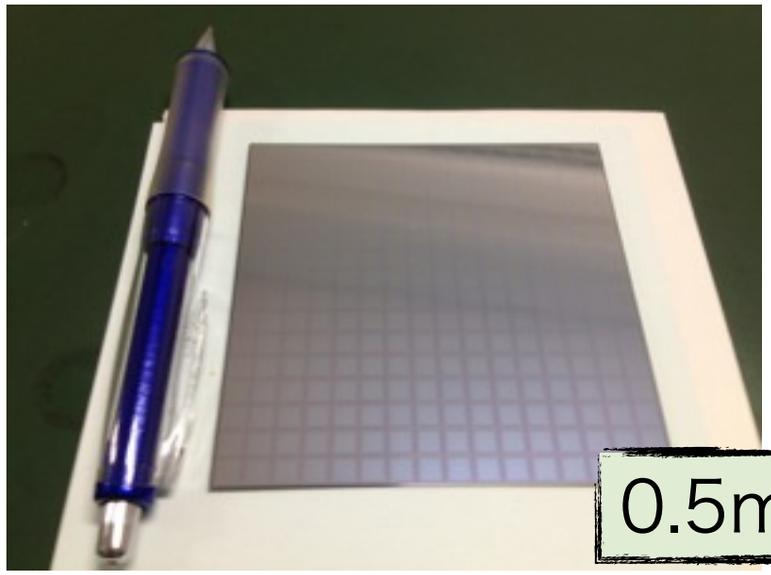
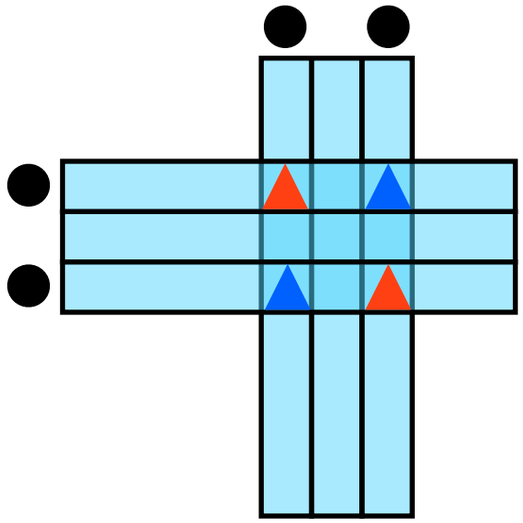
Motivation

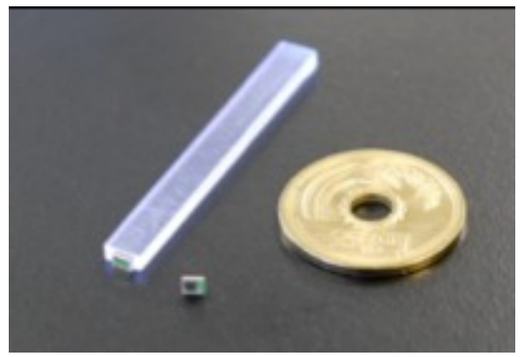
Silicon pads （Si ECAL）



- 5mm x 5mm cells
- good performance for PFA
- main driver of detector cost

Scintillator strips +MPPC （Sc ECAL）



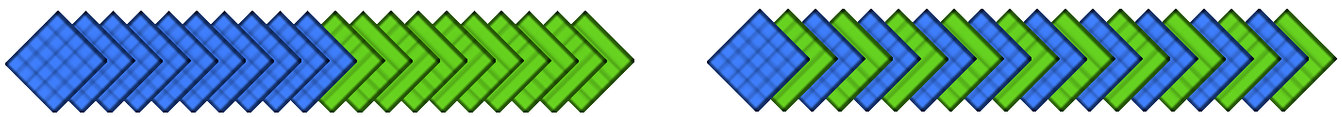


* 45mm x 5mm orthogonal & SSA
  --> 5mm x 5mm spatial resolution
* reasonable cost
* ghost hits

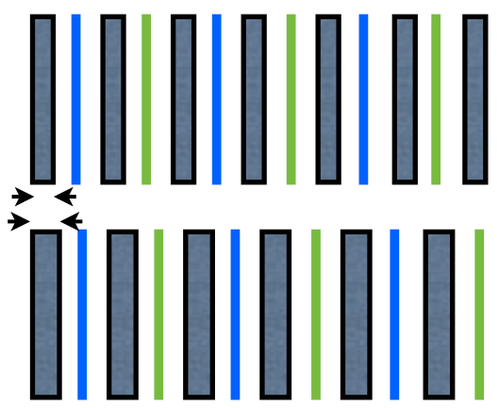
An option to make the ECAL at a lower cost while keeping performance as much as possible would be mixture of silicon and scintillator-strip layers.

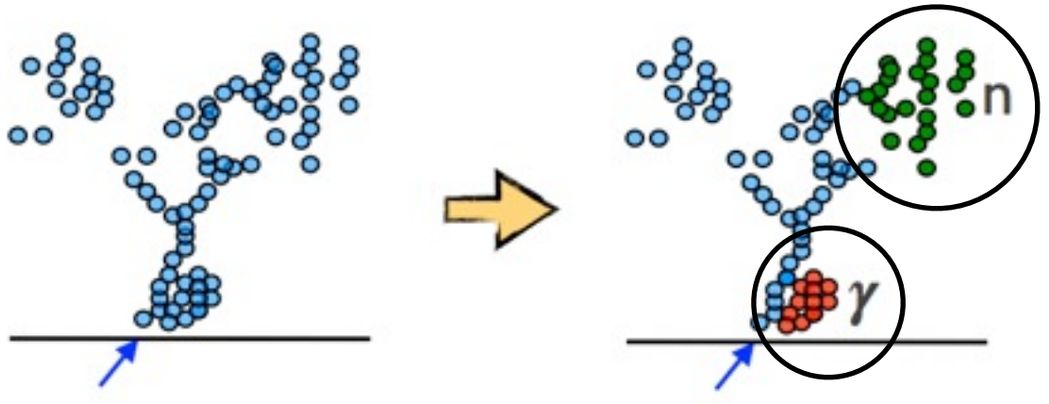
Topics for Hybrid ECAL Study

- **Active Layer**
  - ✓ **Si for inner layers**
  - ✓ **Alternating**
- **Absorber Layer**
  - ✓ **uniform**
  - ✓ **1:2 stacks**
- **Reduced Number of Layers**
- **Cheating PFA**
  - ✓ **with tile scintillator**
  - ✓ **with SSA**
- **Reduced Inner Radius**
- **More Realistic Simulation**
- **Cost Estimation**



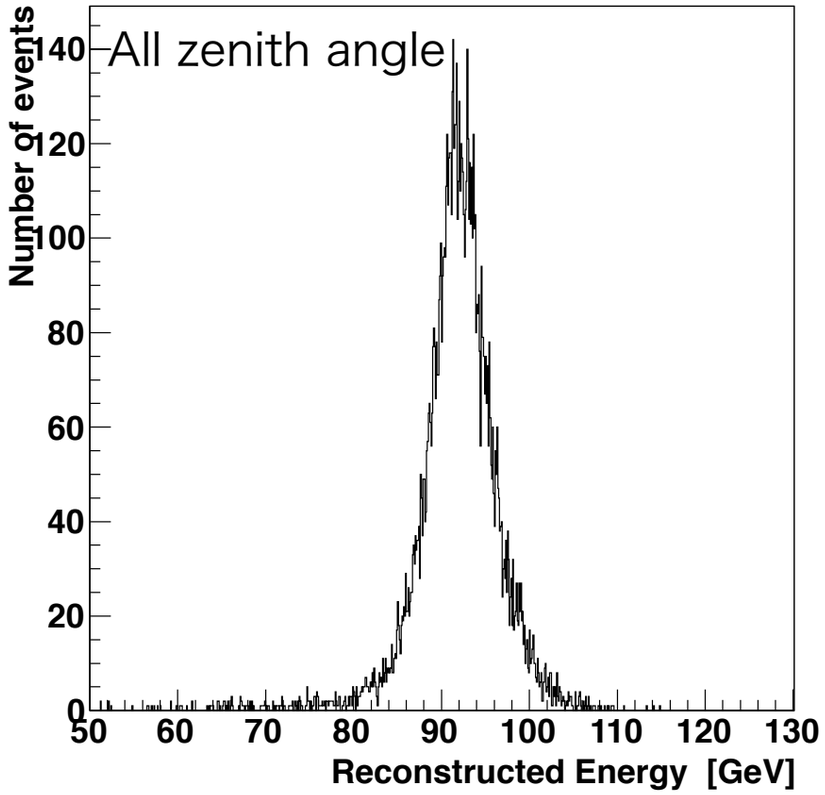
Reevaluated with ilcsoft v01-16-02

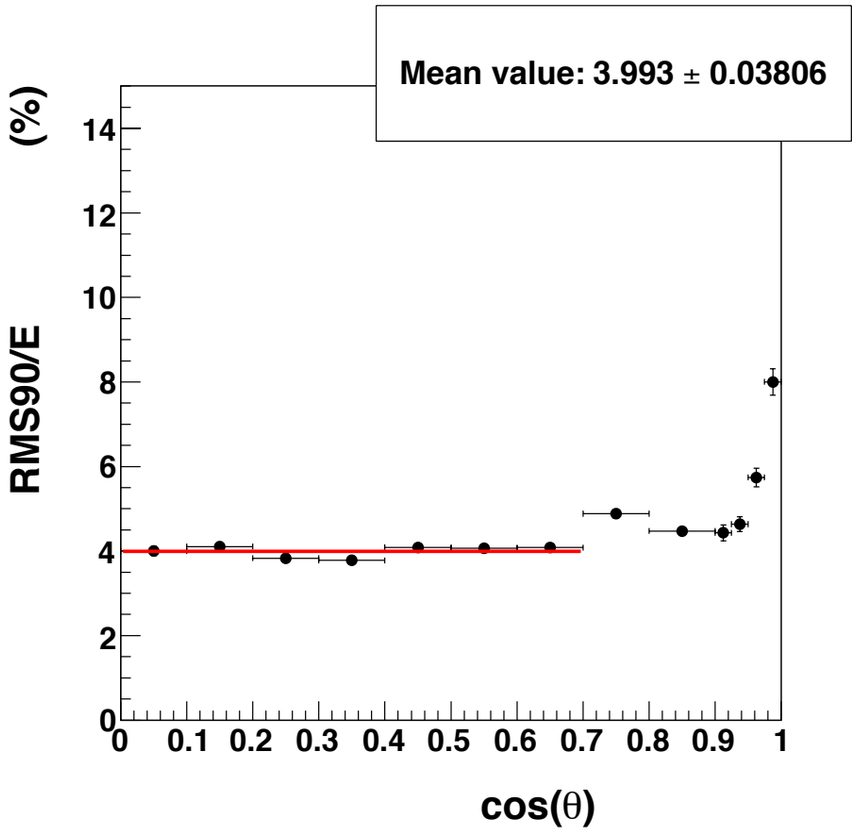




Hybrid ECAL Evaluation

- software version : ilcsoft v01-16-02
    - Pandora processors ... trunk version (in October 2013)
- $e^+e^- \rightarrow q\bar{q}$ (q=u,d,s, √s=91, 200, 360, 500GeV)
- only barrel region (cos(thrust angle)<0.7) for evaluation.





Topics for Hybrid ECAL Study

- **Active Layer**
  - ✓ **Si for inner layers**
  - ✓ **Alternating**
- **Absorber Layer**
  - ✓ **uniform**
  - ✓ **1:2 stacks**
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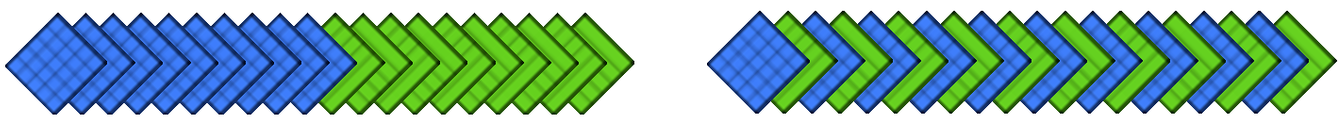

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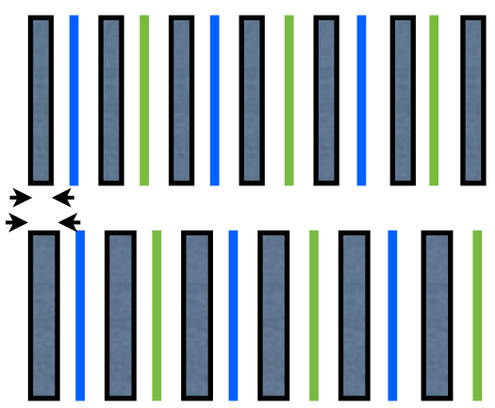
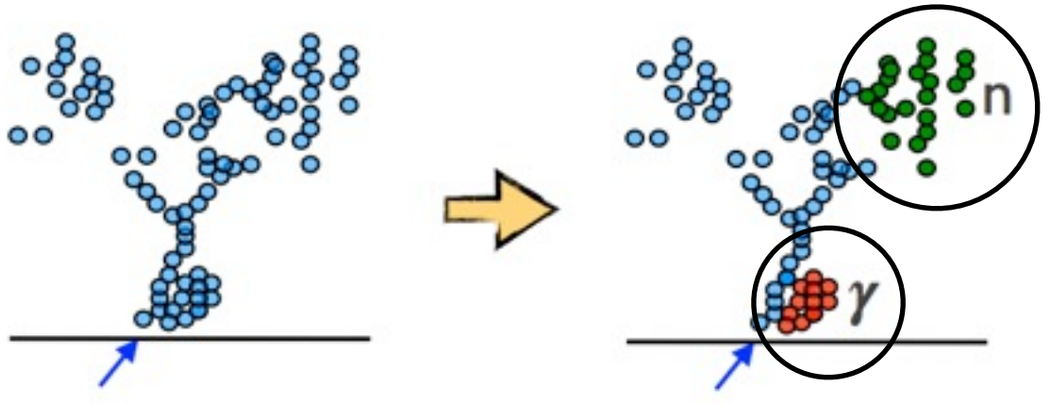
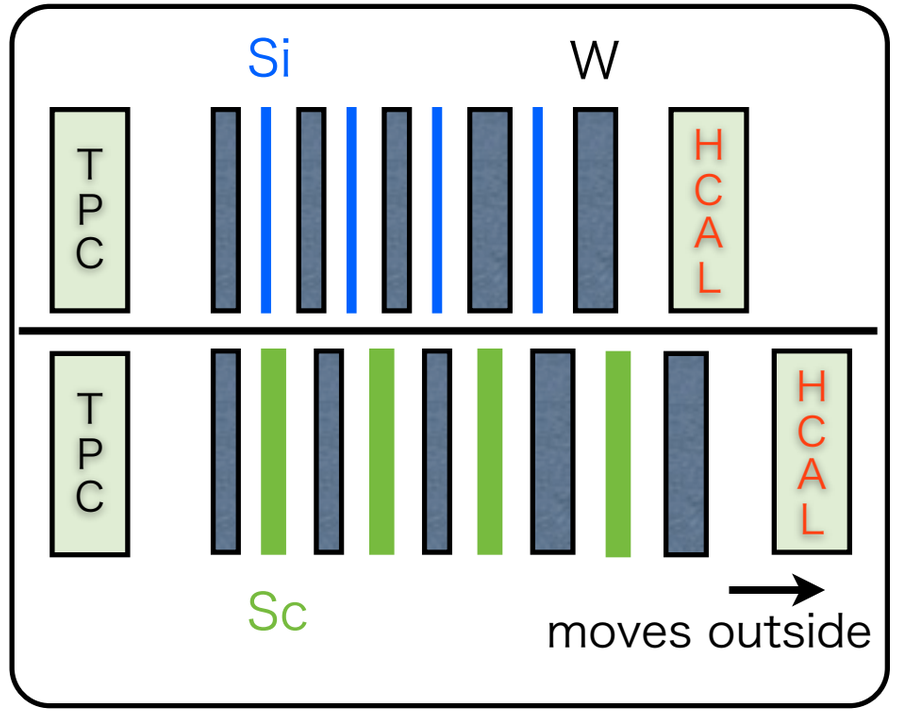


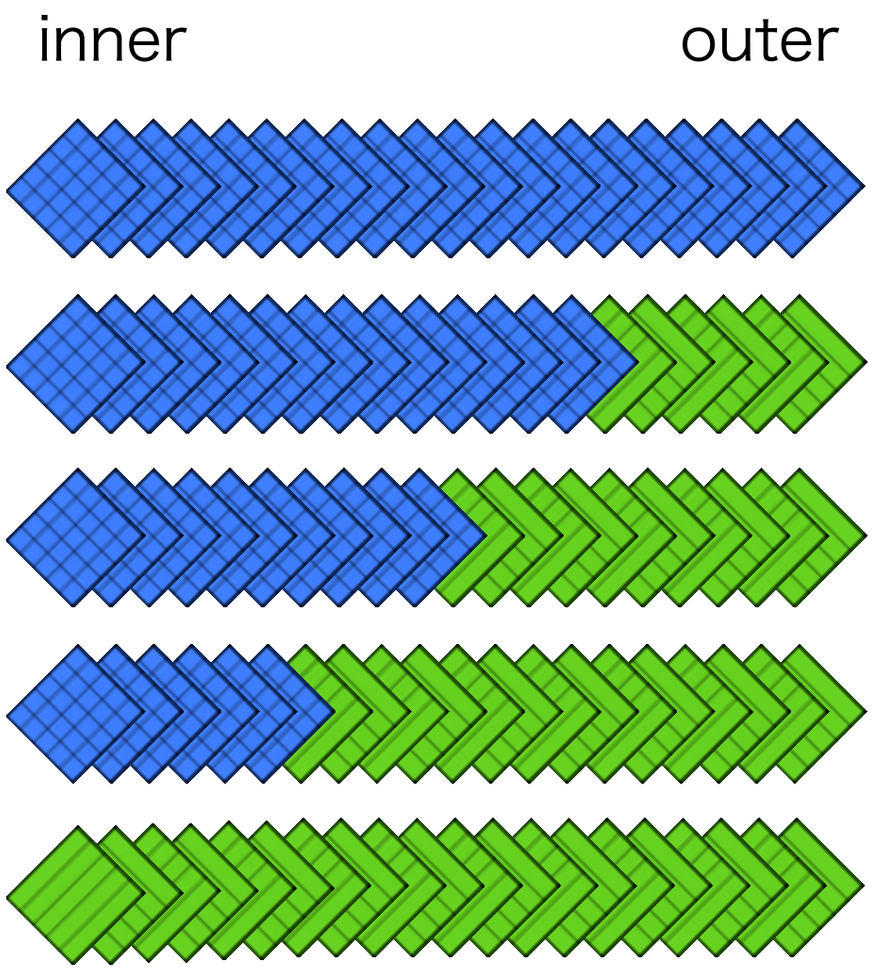


same absorber thickness

- same number of active layers and absorber configuration
- **Sc=1.0mm**, **Si=0.5mm**

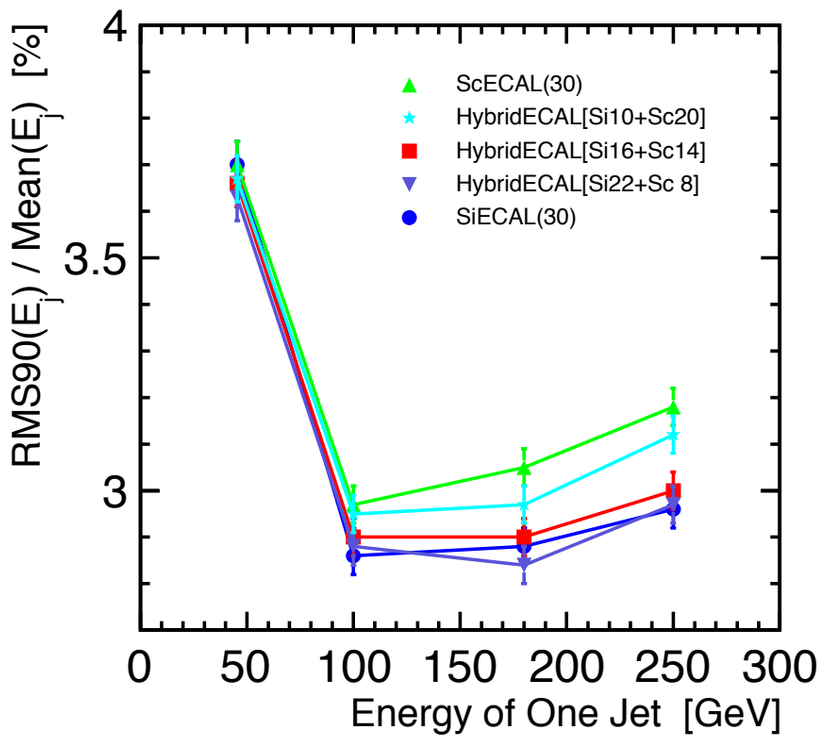


	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid(Si22Sc8)	2.1/4.2	188.3
Hybrid(Si16Sc14)	2.1/4.2	190.8
Hybrid(Si10Sc20)	2.1/4.2	194.9
ScECAL(30)	2.1/4.2	197.4



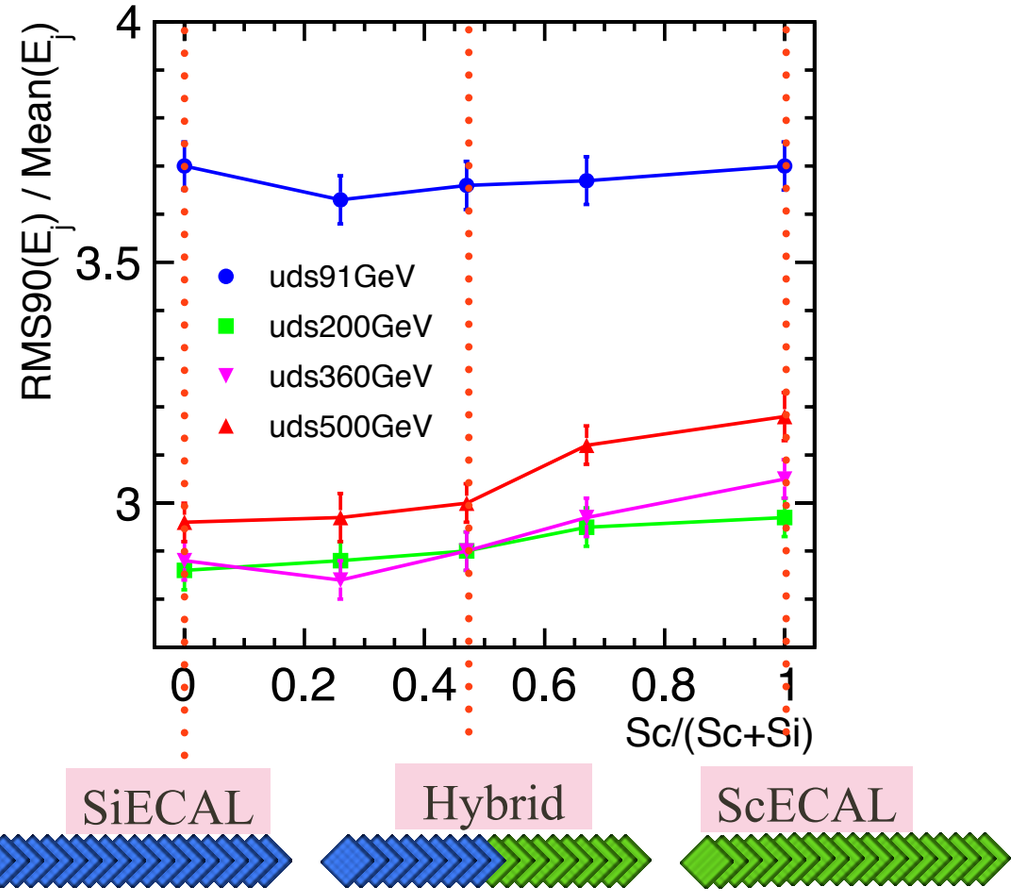
Jet Energy Resolution

Energy Dependence



- Jet Energy ↑
  - ScECAL > Hybrid[Si16+Sc14] ≒ SiECAL

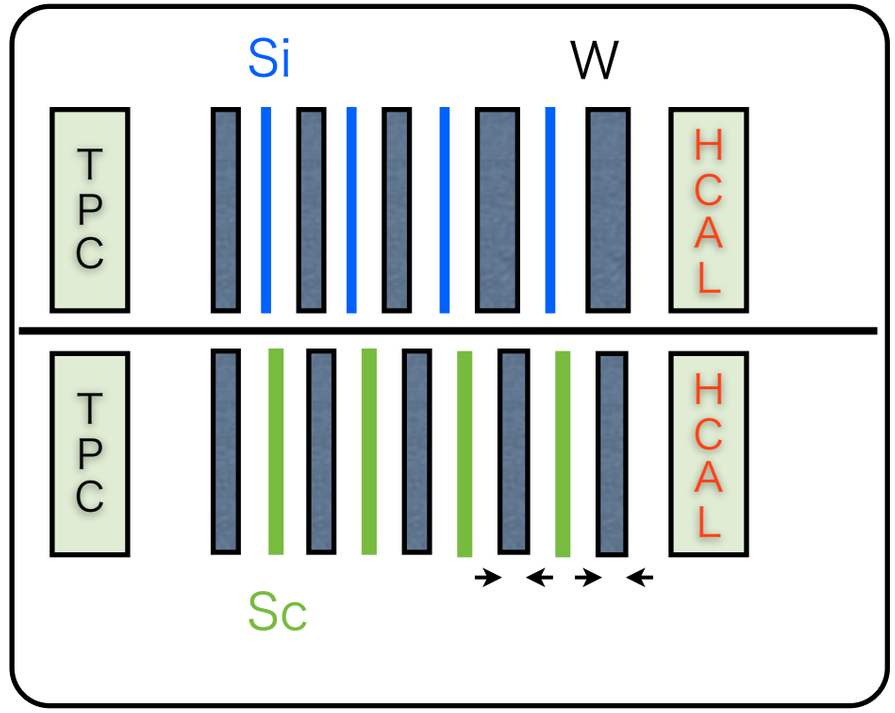
Ratio Dependence



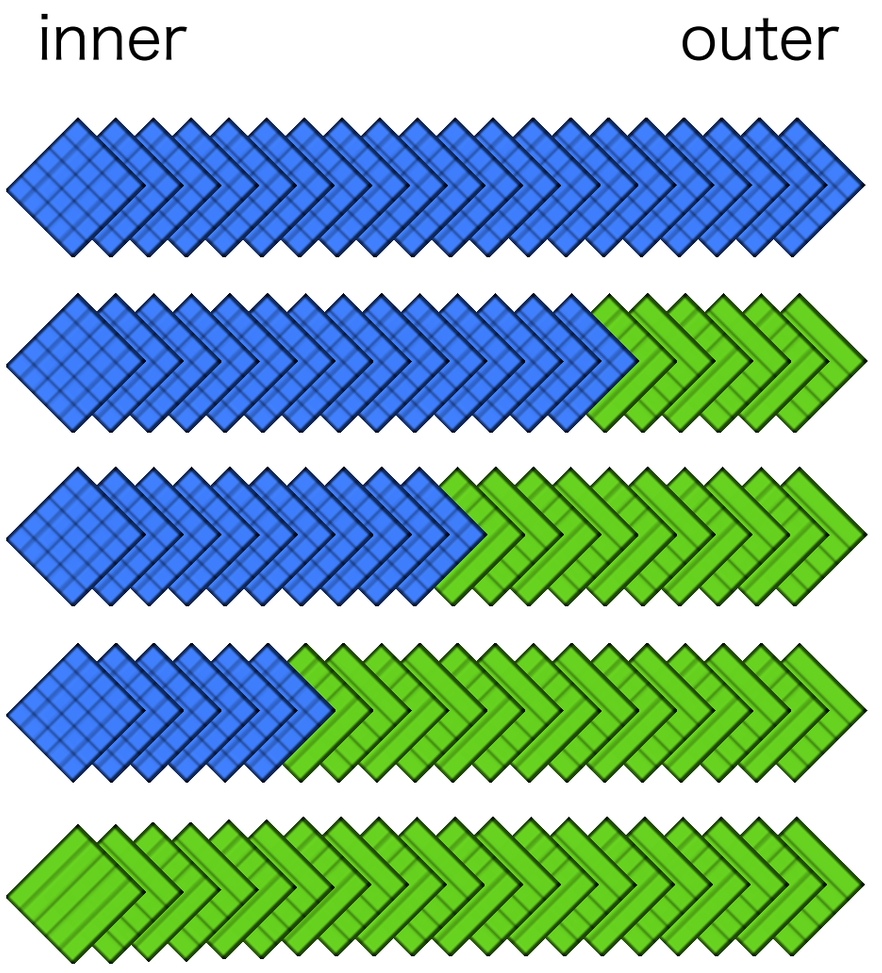
- Lower Energy
  - same JER
- Higher Energy
  - JER doesn't degrade up to 0.5

same module thickness

- keep whole ECAL thickness by reducing outer absorber thickness
- Sc = **1.0mm**, Si = **0.5mm**

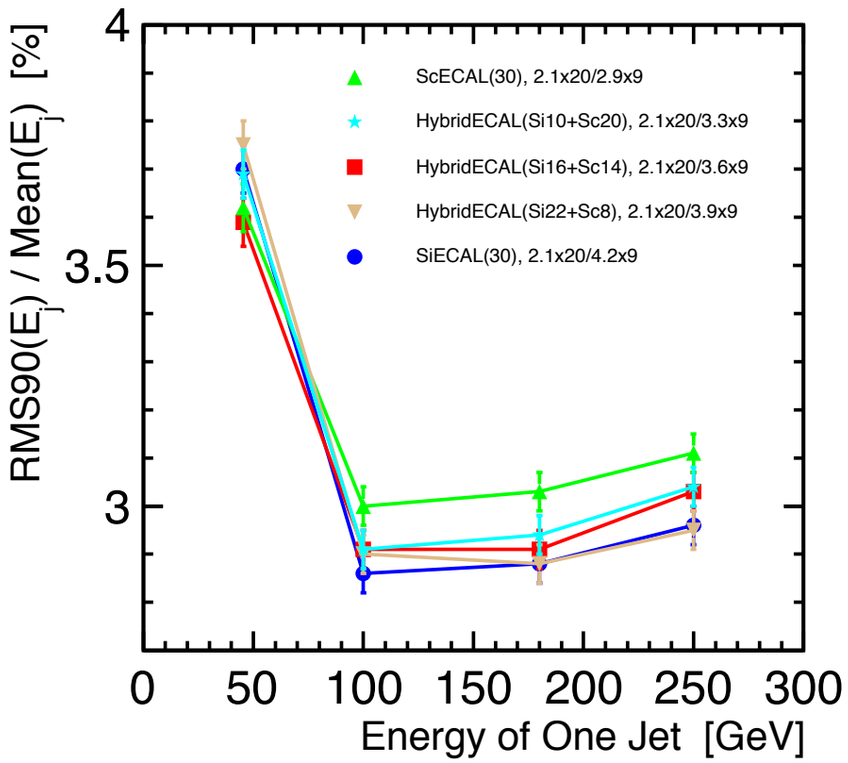


	W thickness (in20,out9)	Module thickness (mm)
SiECAL(30)	2.1/4.2	185.0
Hybrid(Si22Sc8)	2.1/3.9	185.6
Hybrid(Si16Sc14)	2.1/3.6	185.4
Hybrid(Si10Sc20)	2.1/3.3	185.2
ScECAL(30)	2.1/2.9	185.7



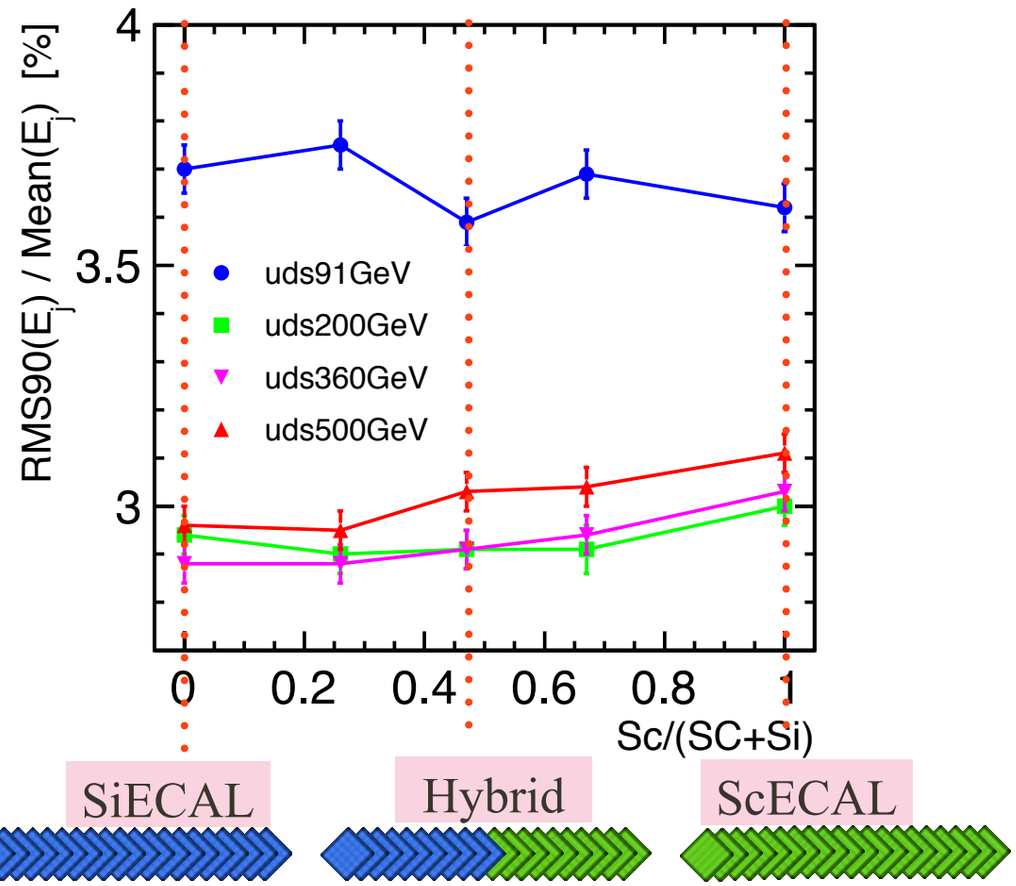
Jet Energy Resolution

Energy Dependence



- ScECAL > Hybrid[Si16+Sc14] > SiECAL

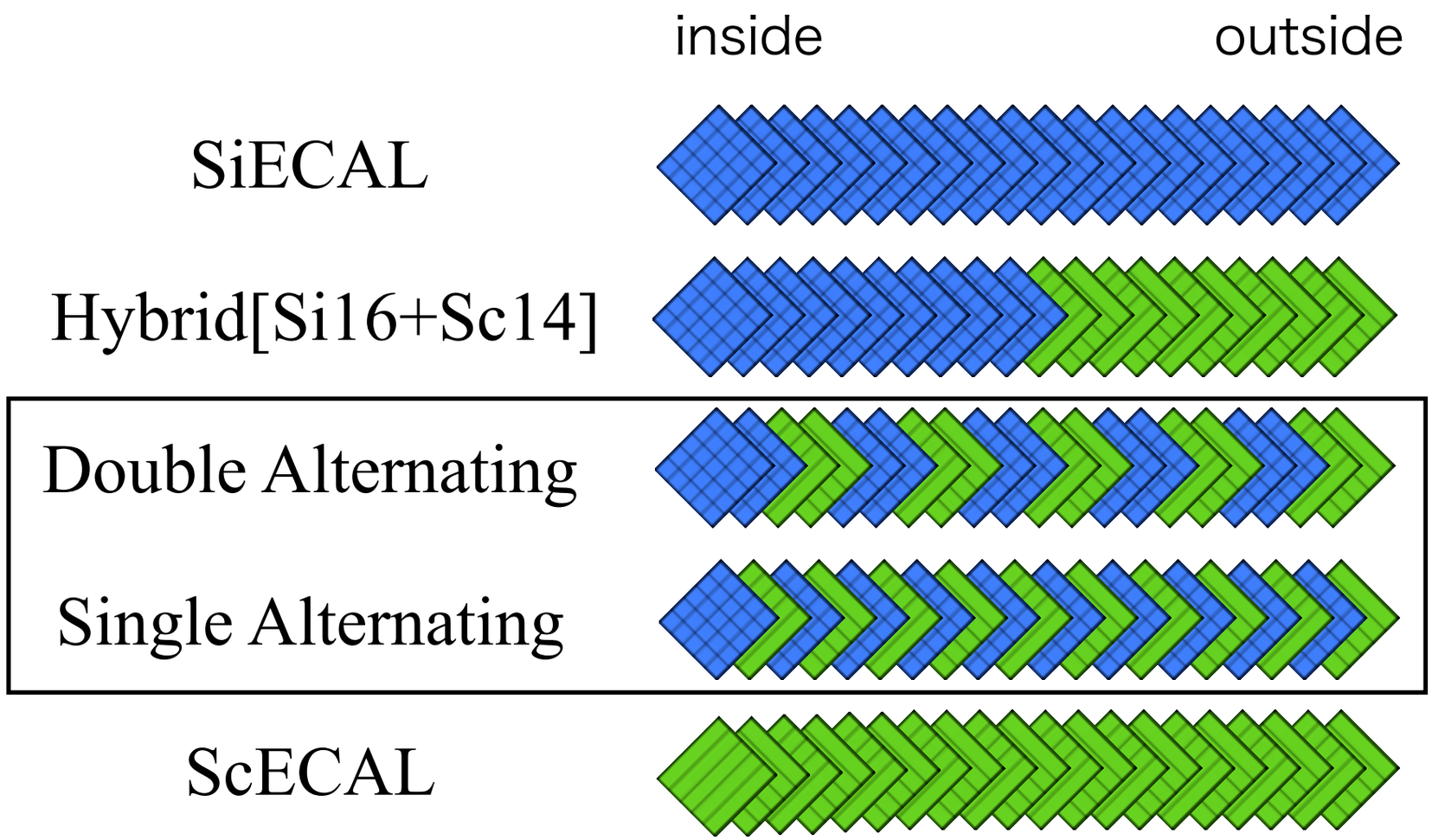
Ratio Dependence



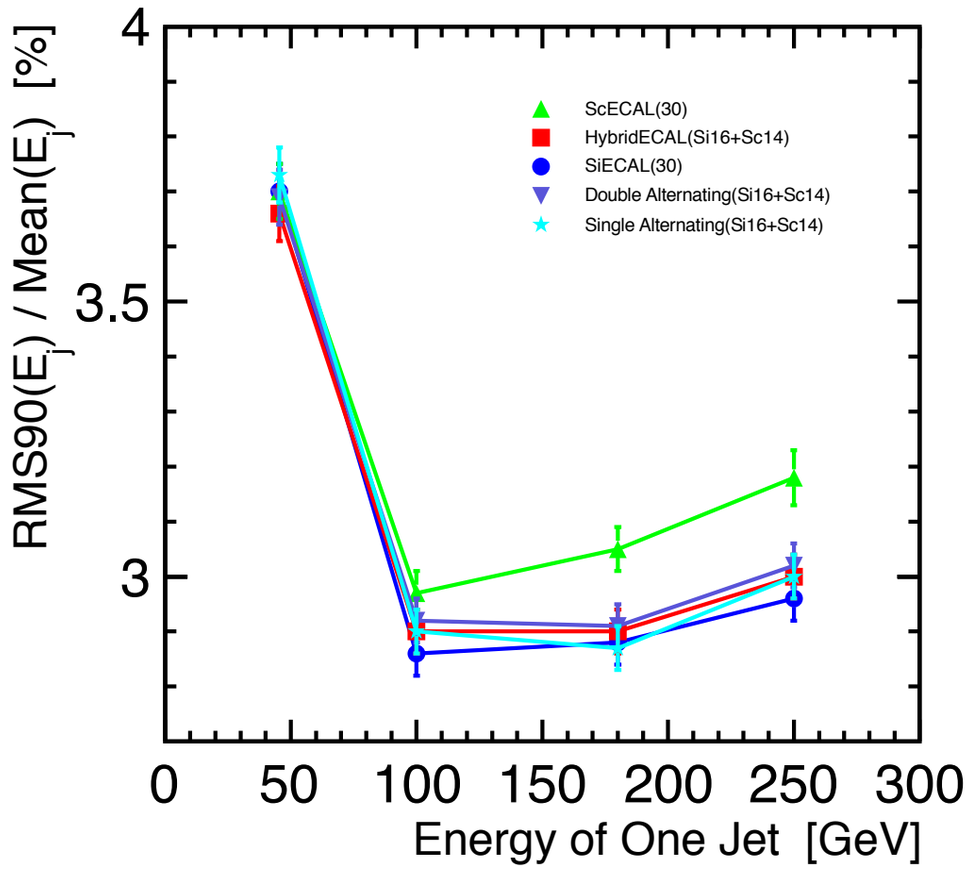
- Lower energy ... ScECAL looks slightly better
- Higher energy ... SiECAL is better
  - JER degrades almost linearly

alternating hybrid

- same number of active layers and absorber configuration
- **Sc=1.0mm**, **Si=0.5mm**
- absorber layers : 2.1mm x20/ 4.2mm x9



Jet Energy Resolution (alternating)



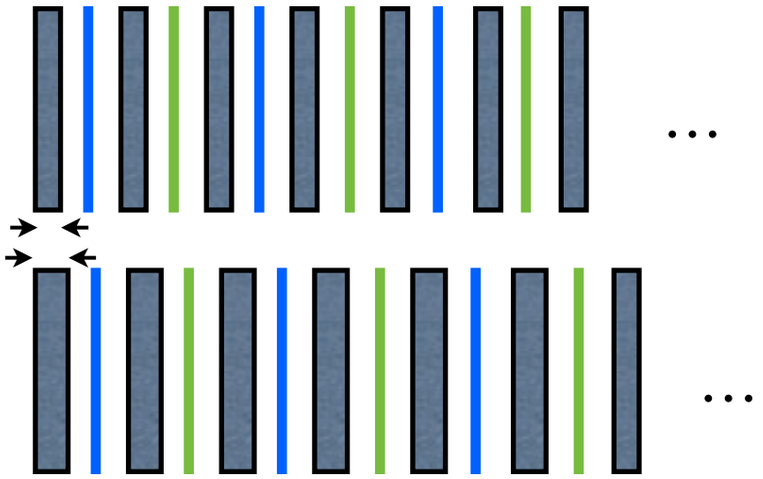
RMS90(E_j) / Mean(E_j) [%]

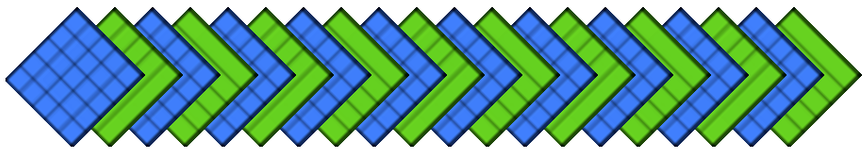
	45GeV	100GeV	180GeV	250GeV
SiECAL	3.70	2.86	2.88	2.96
Hybrid [Si16+Sc14]	**3.66**	**2.90**	**2.90**	**3.00**
Double	**3.69**	**2.92**	**2.91**	**3.02**
Single	**3.73**	**2.90**	**2.87**	**3.00**
ScECAL	3.70	2.97	3.05	3.18

Performances of the three hybrids are same

Absorber Thickness Study

- two cases
  - same thickness for all layers
  - 1:2 stacks
- Standard PFA (w/o stand alone photon clustering)
- Active Layer ... single alternating





uniform

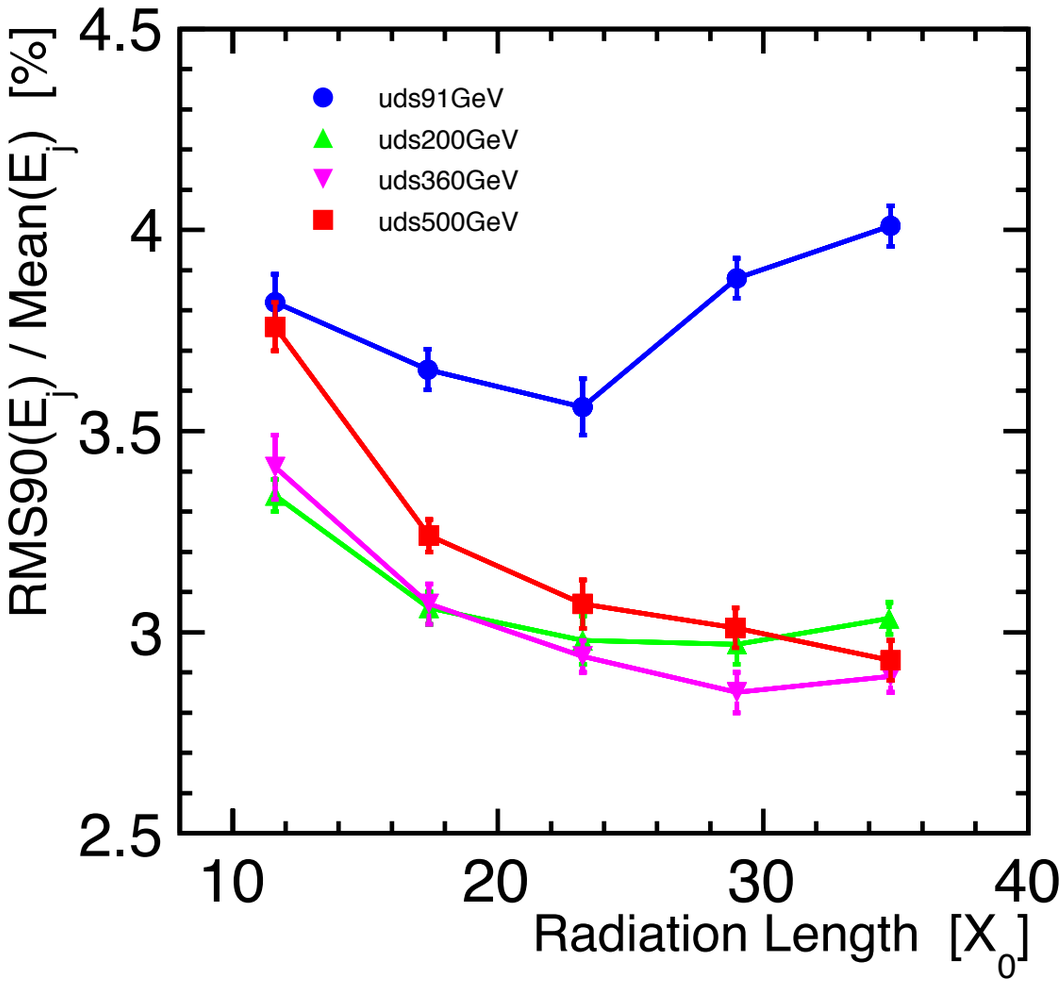
W thickness [mm]	Radiation Length(X_0)
1.4	11.6
2.1	17.4
2.8	23.2
3.5	29.0
4.2	34.8

1:2 stacks

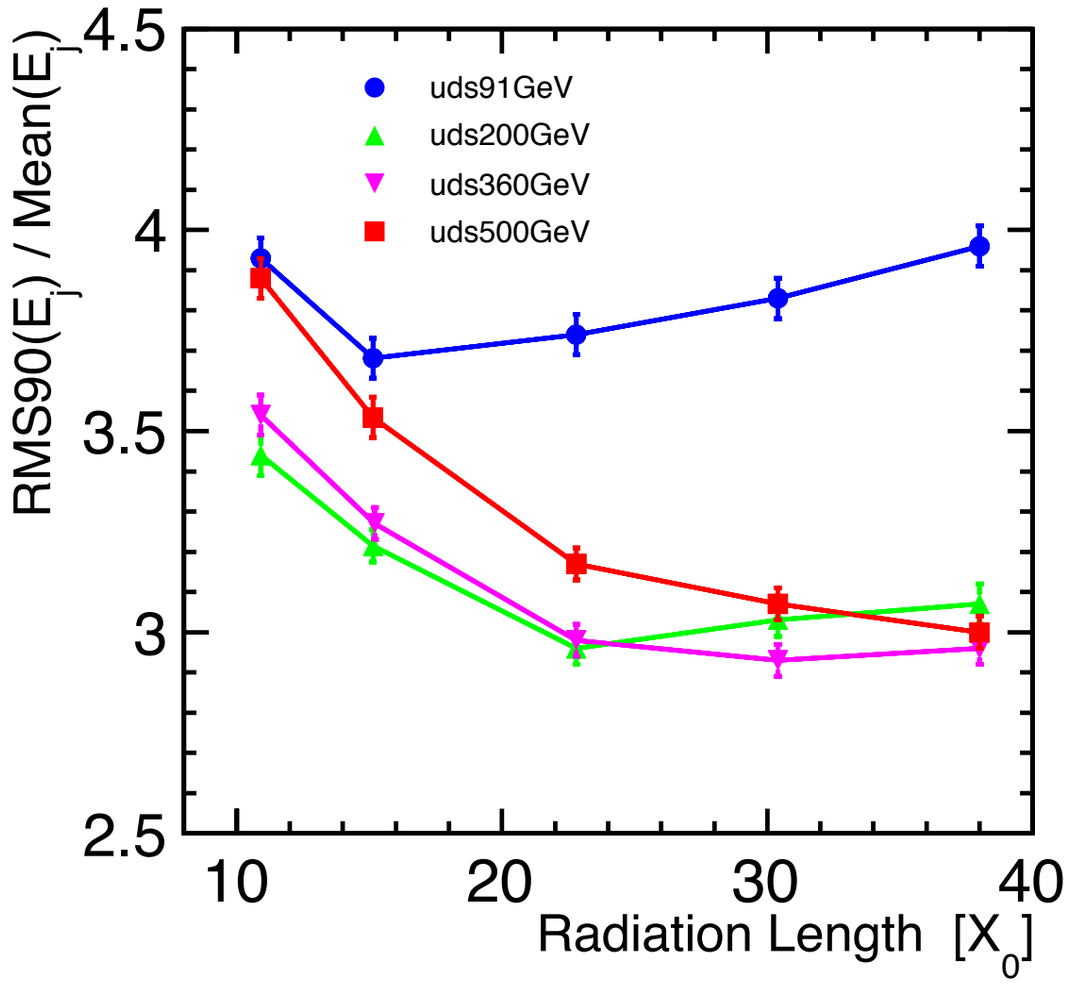
W thickness (in20, out9)[mm]	Radiation Length(X_0)
1.0/2.0	10.9
1.4/2.8	15.2
2.1/4.2	22.8
2.8/5.6	30.4
3.5/7.0	38.0

Jet Energy Resolution (absorber)

uniform

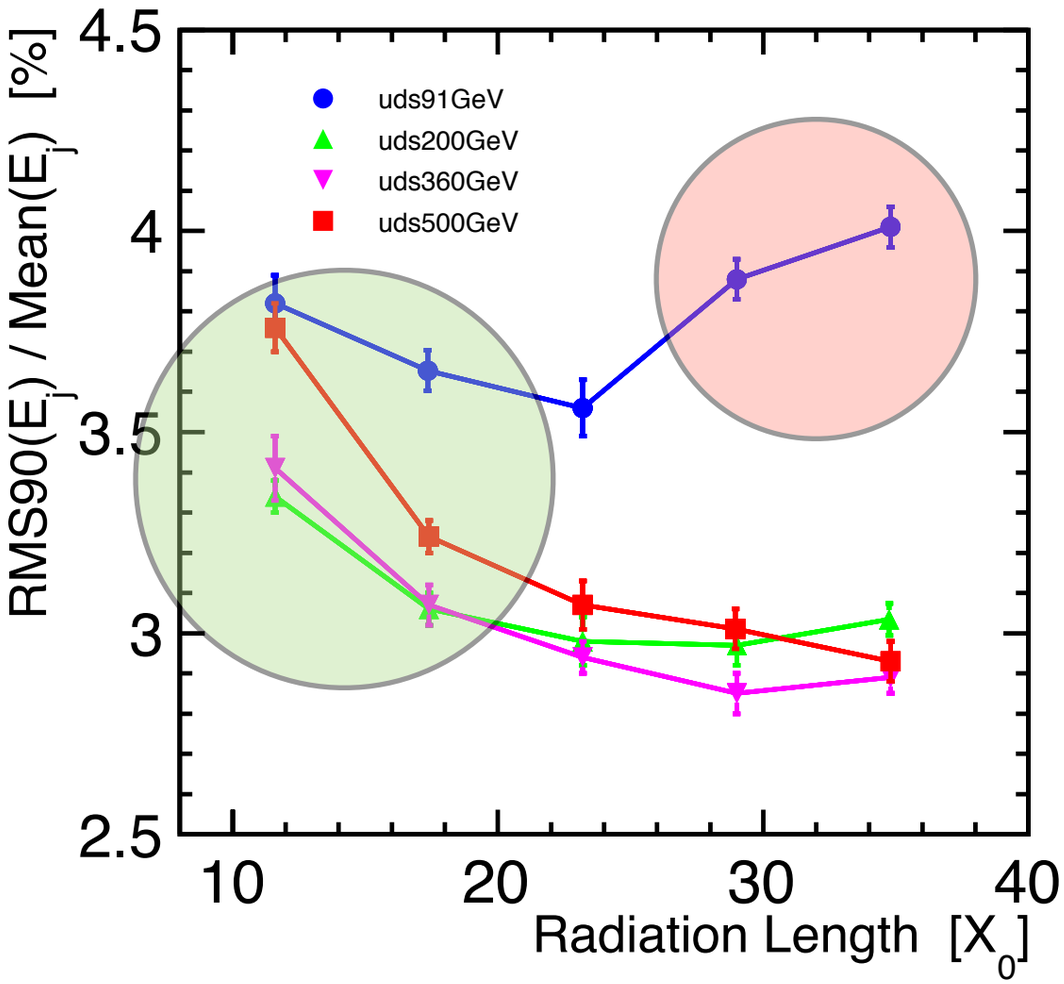


1:2 stacks

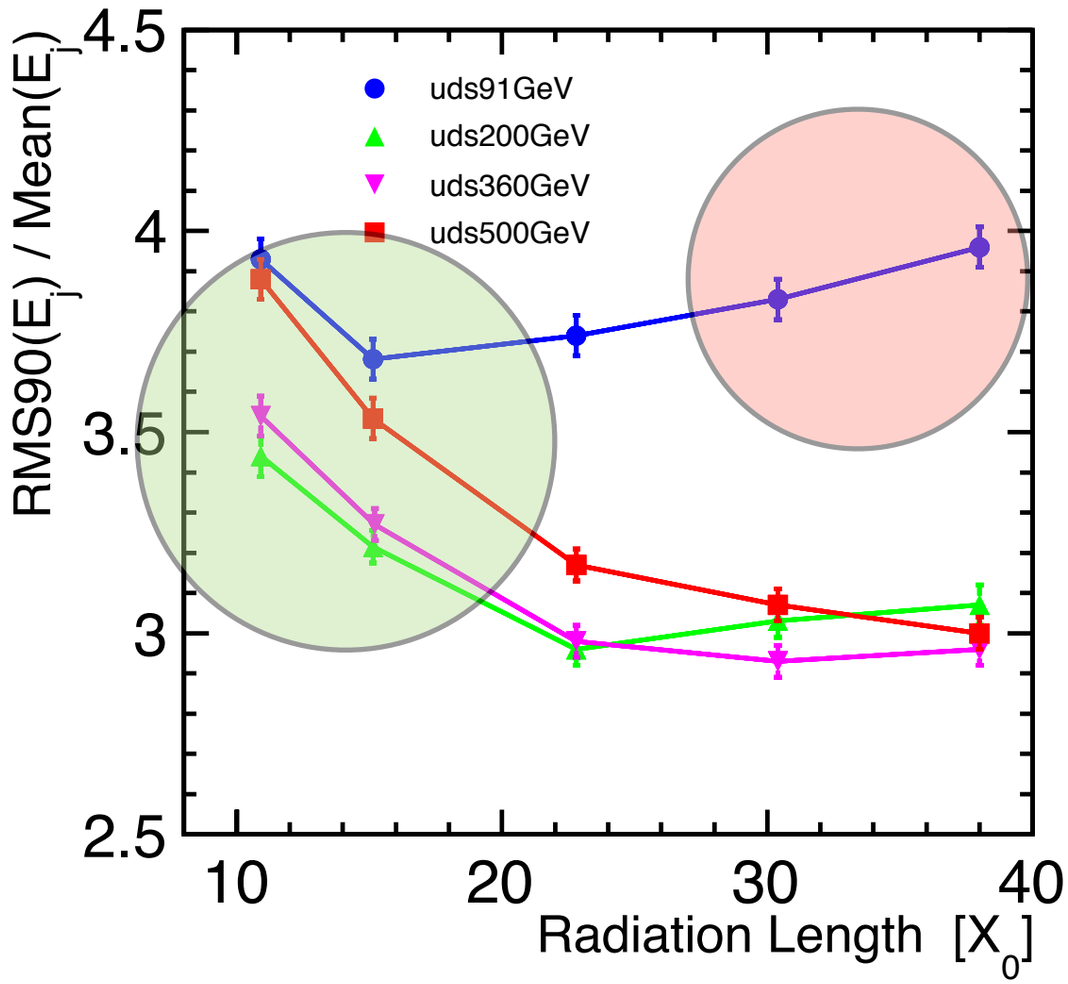


Jet Energy Resolution (absorber)

uniform



1:2 stacks

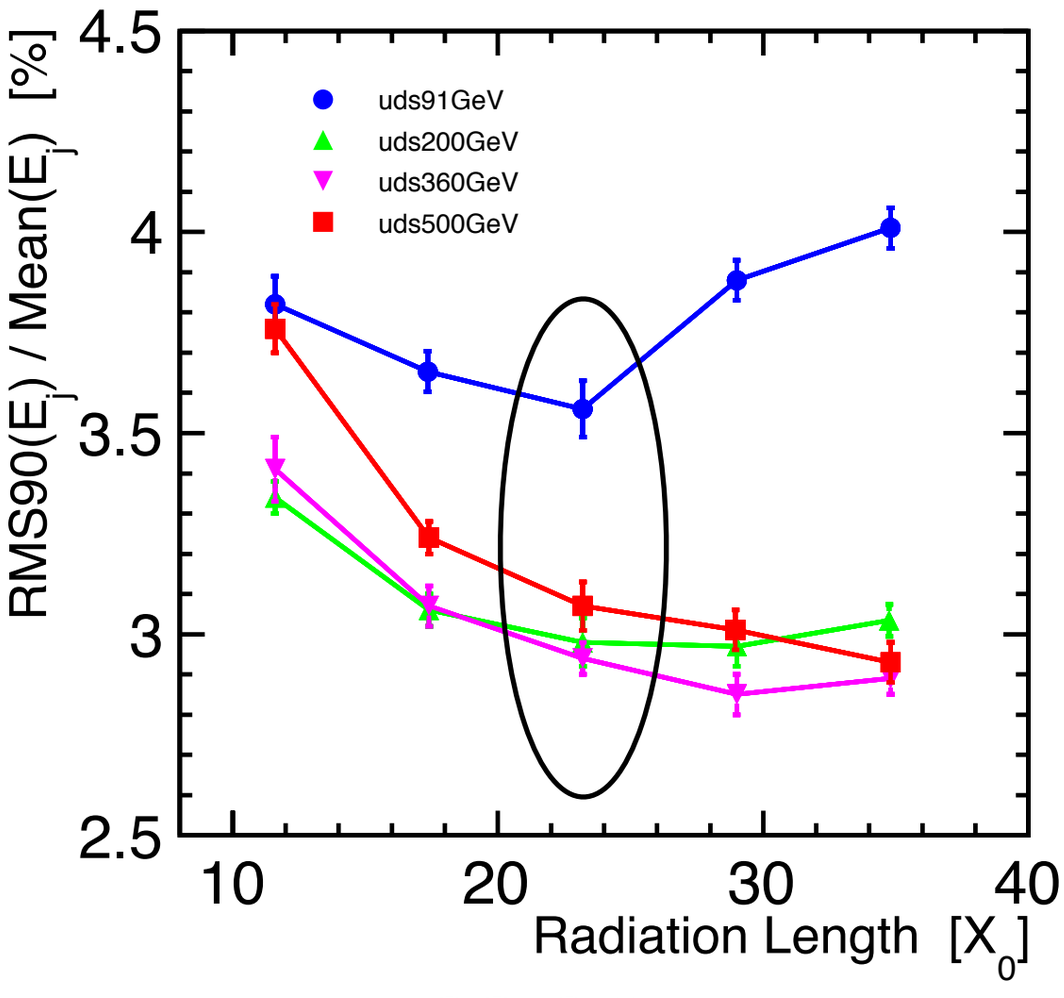


caused by smaller sampling ratio

caused by larger leakage into HCAL

Jet Energy Resolution (absorber)

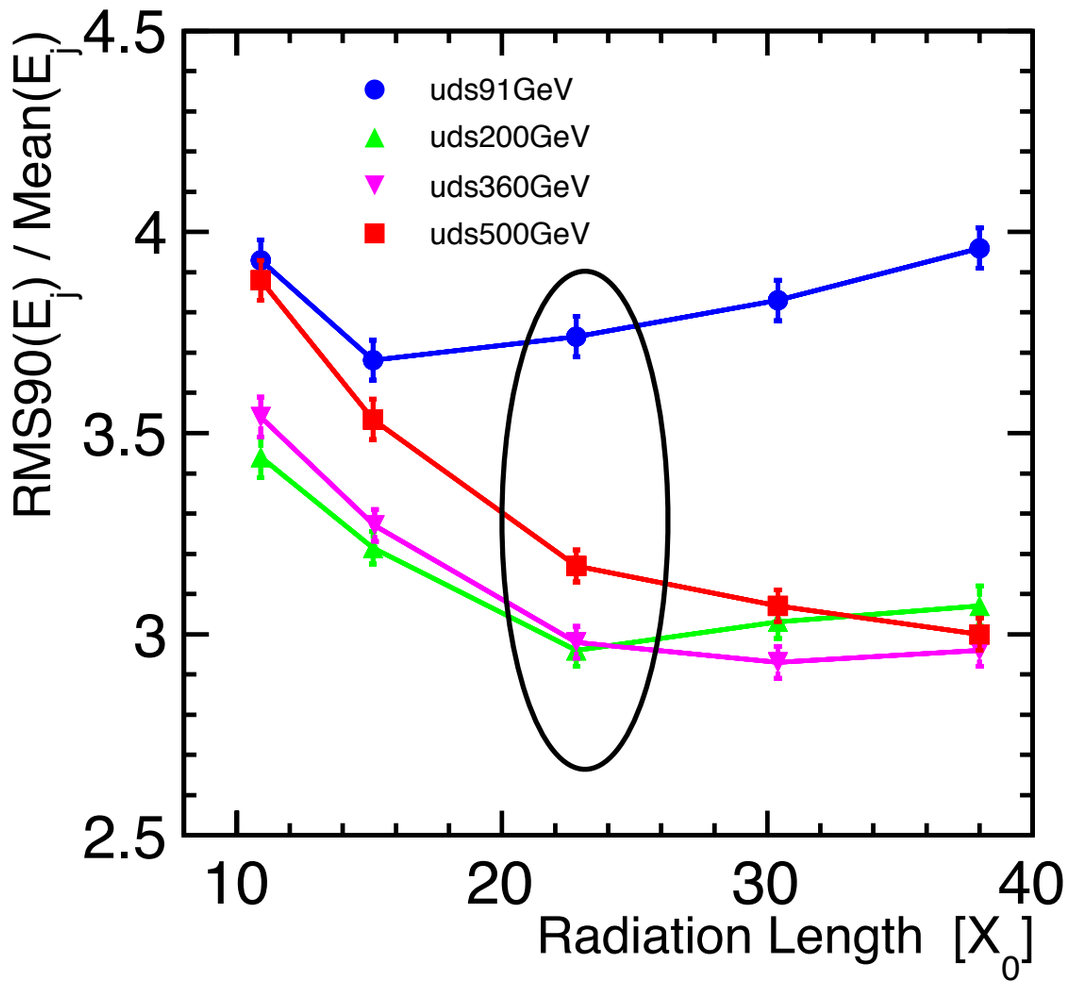
uniform



23.2X_0

(2.8mm x29)

1:2 stacks



22.8X_0

(2.1mm x20 / 4.2mm x9)

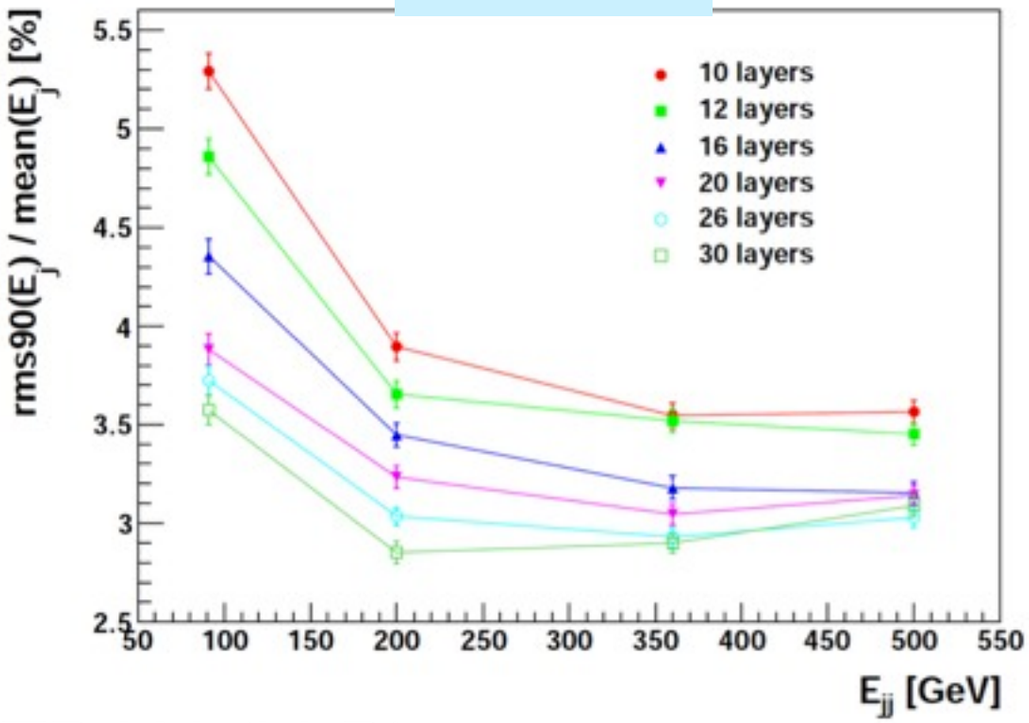
need to study around 23X_0

Reduced Number of Layers

- 5 configurations (10, 16, 20, 26, 30 layers)
- Hybrid[Si16Sc14], single alternating
- keep total absorber thickness

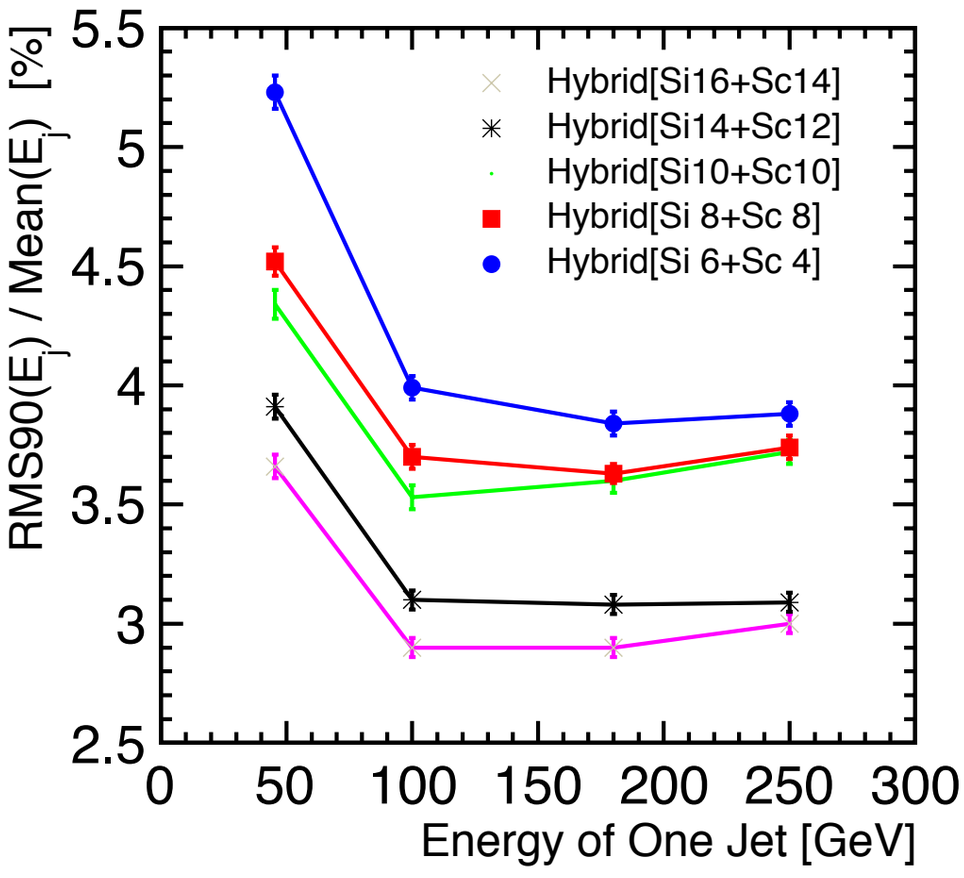
ECAL model	W layers	Layer thickness (mm)
30 layers	20	2.1
	9	4.2
26 layers	17	2.4
	8	4.8
20 layers	13	3.15
	6	6.3
16 layers	10	4.0
	5	8.0
10 layers	6	6.65
	3	13.30

SiECAL



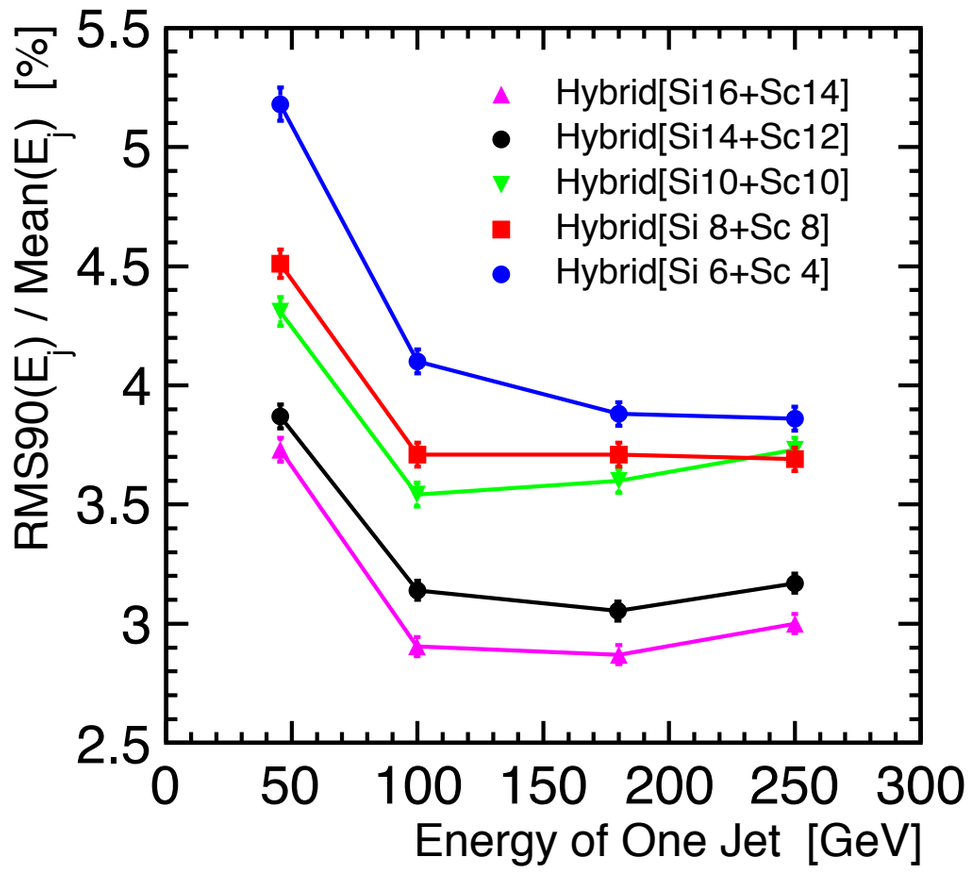
Reduced Number of Layers

Hybrid [Si16+Sc14]



10layers
16layers
20layers
26layers
30layers

Single Alternating



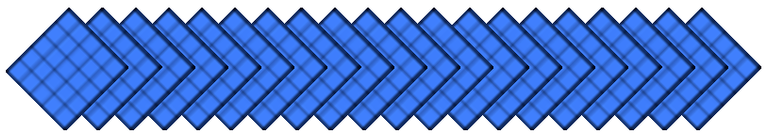
- large difference between 26 layers and 20 layers
- 10～20 layers → worse than SiECAL

- will study the case we keep 2.1mm for inner layers
- JERs are almost same between Hybrid[Si16+Sc14] and single alternating

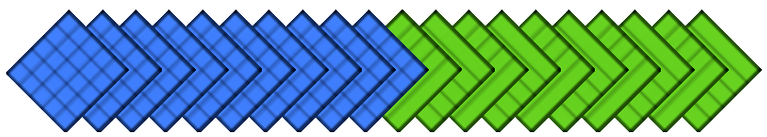
Cheating PFA

To compare the performance between configurations,

SiECAL(30)

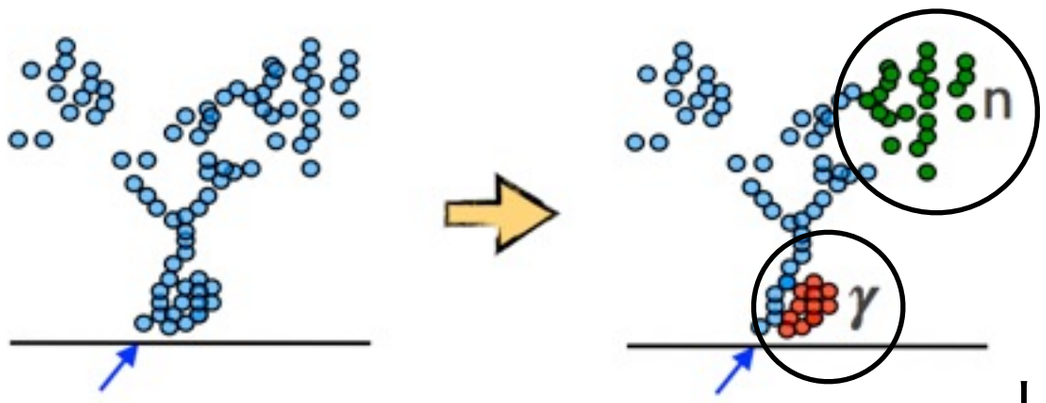


Hybrid[Si16Sc14]



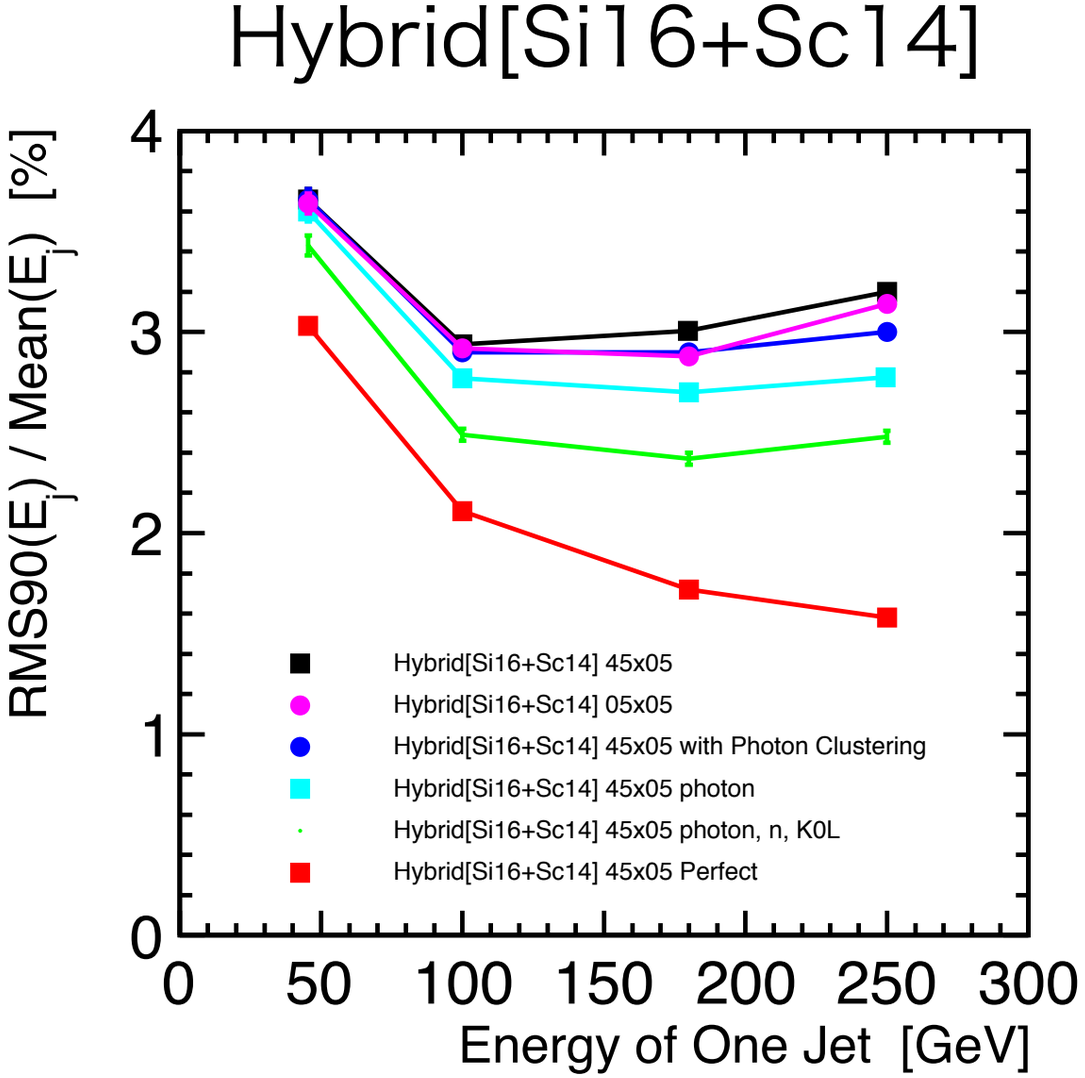
ScECAL(30)

Switch standard PFA
by clustering using MC information



J.S.Marshall

Cheating PFA



■ Standard PFA w/ strip-Sc(45x5)

● Standard PFA w/ tile-Sc(5x5)

● Standard PFA + photon clustering

■ Cheat photon clustering

▲ Cheat photon, n, K0L clustering

■ Perfect PFA

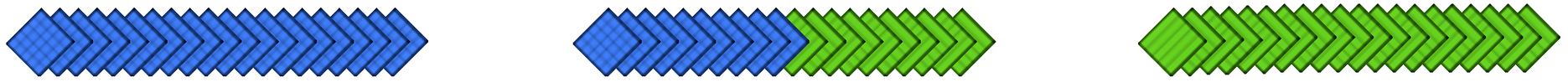
- strip ⇔ tile difference is small
- stand alone photon clustering improves JER especially in higher energy.

Cheating PFA

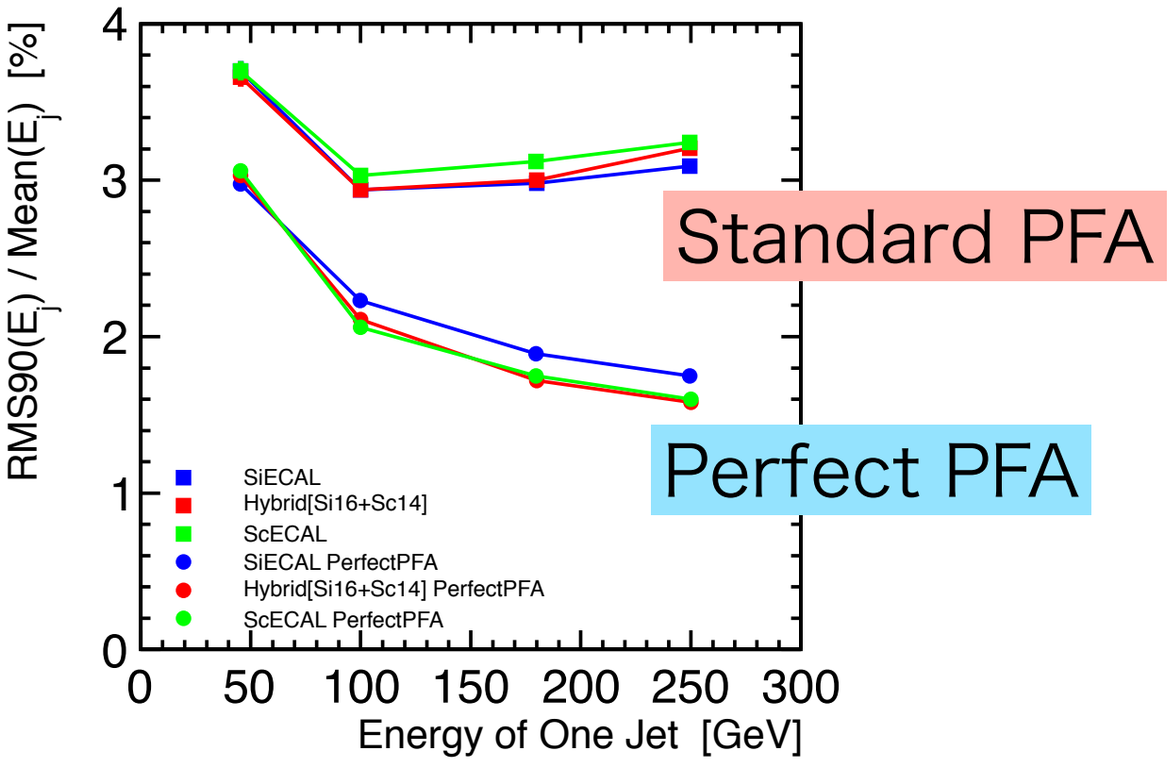
SiECAL(30)

Hybrid[Si16Sc14]

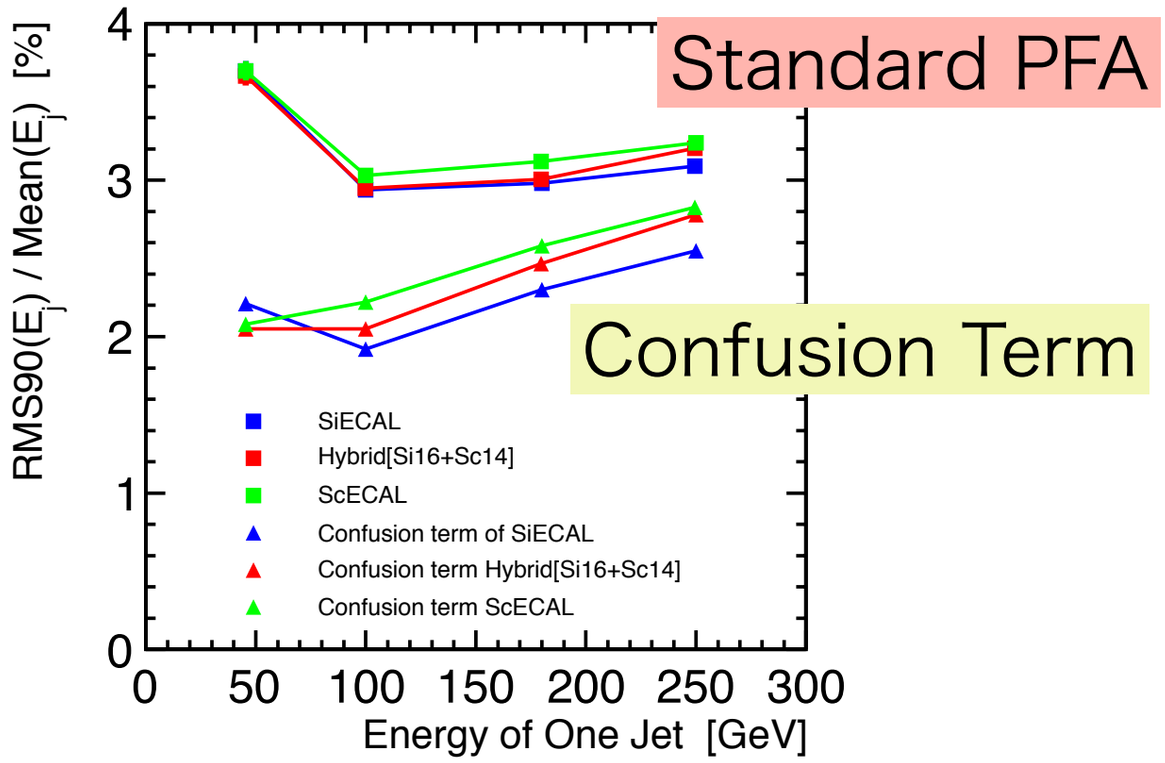
ScECAL(30)



PFA - PerfectPFA



PFA - Confusion



- perfect pattern recognition → same tendency as single photon
- difference → confusion term

Summary and Prospects

- Active layers
  - same absorber thickness ... not degrade up to 50% of Sc-layers
  - same module thickness ... degrade almost linearly
  - alternating structure ... same as Hybrid[Si16+Sc14]
- Absorber layers
  - around $23X_0$ seems good → will investigate more minutely
- Reduced number of layers
  - 26 layers seems good option
  - will investigate the case to keep 2.1mm for inner layers
- Cheating PFA
  - JER difference comes from performance of pattern recognition
- Reduced ECAL Inner Radius
- More Realistic Simulation
- Cost Estimation

Summary and Prospects

- **Active layers**
  - same absorber thickness ... not degrade up to 50% of Sc-layers
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- Chea
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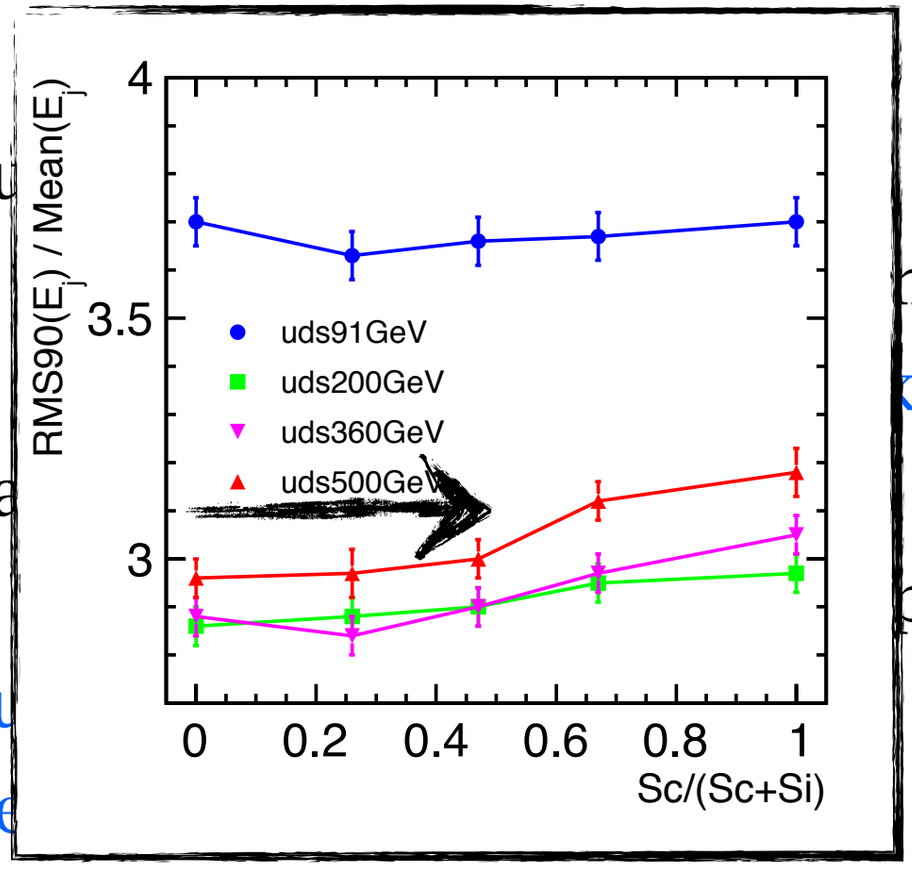

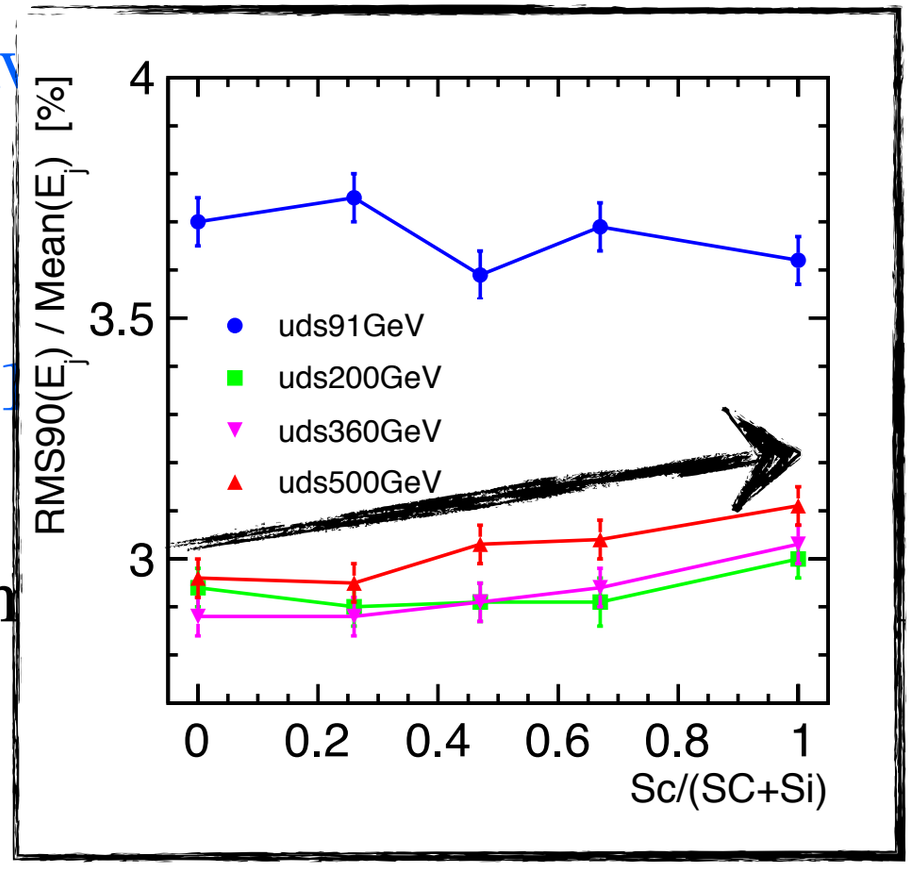

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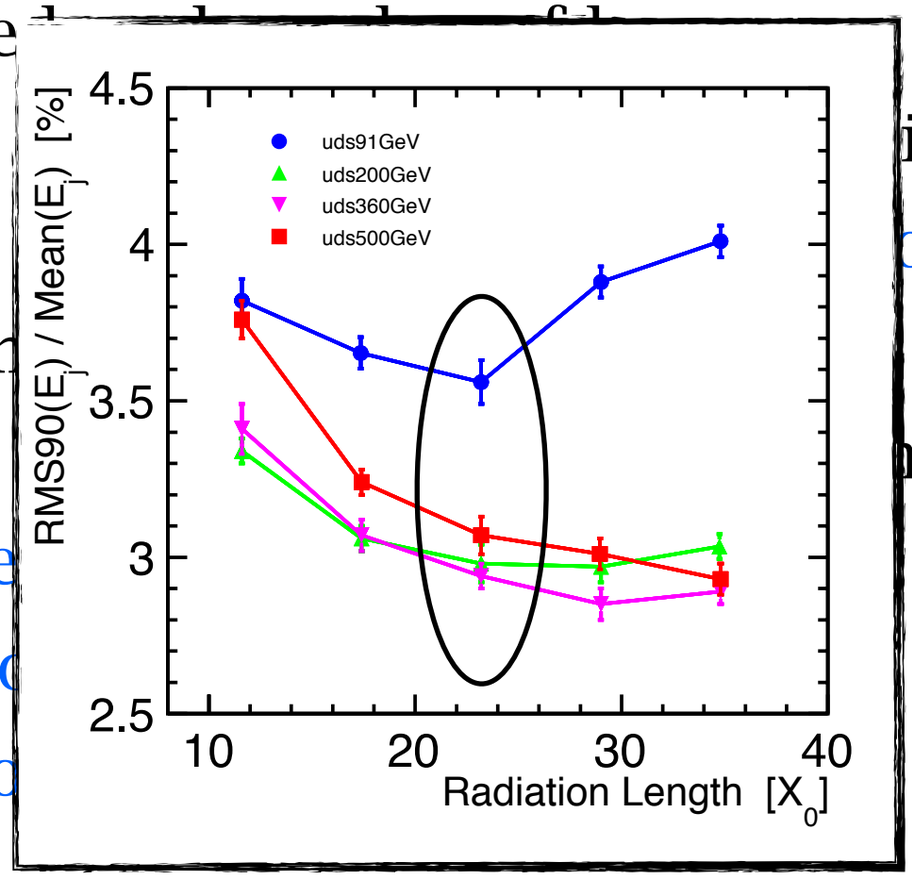
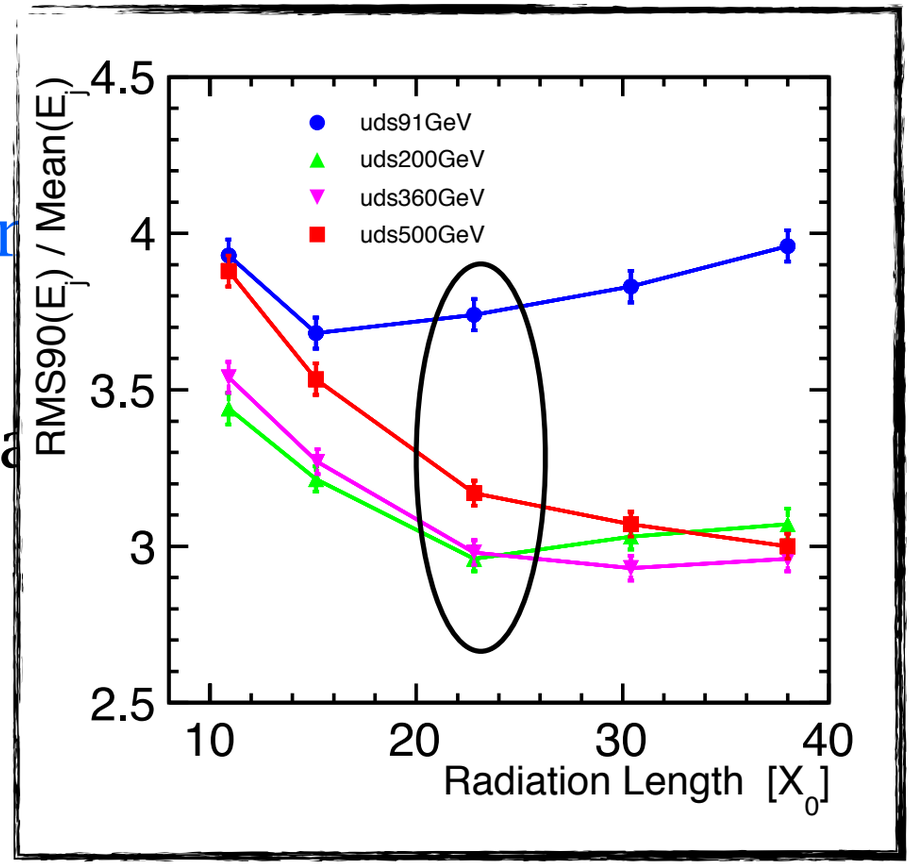
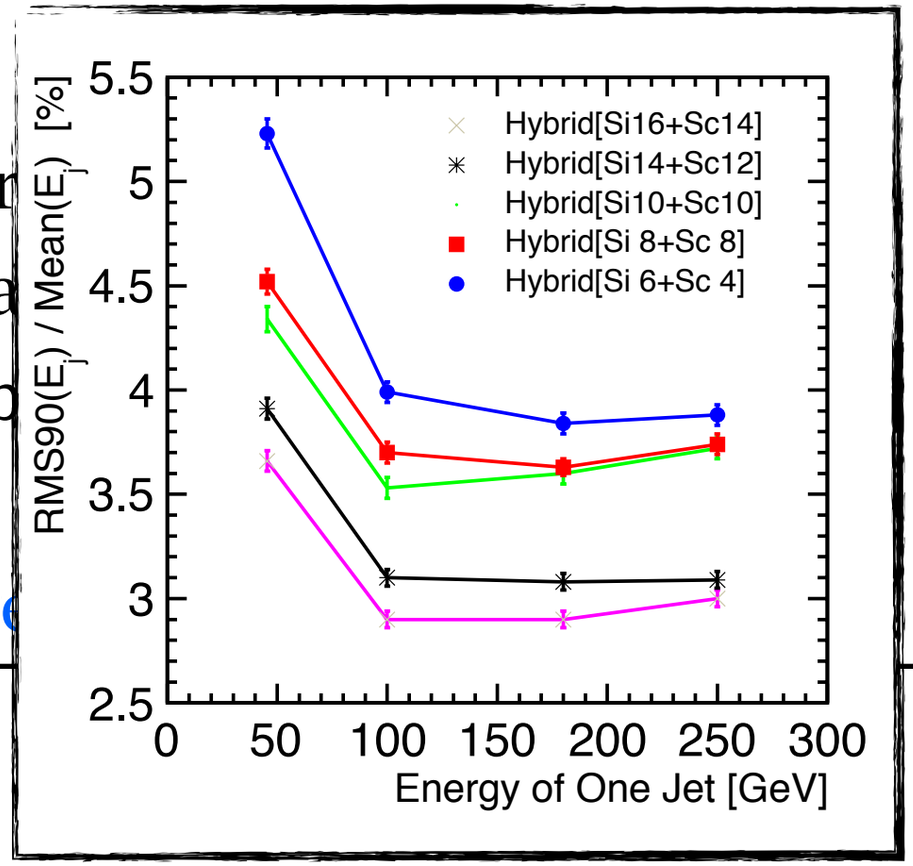




Summary and Prospects

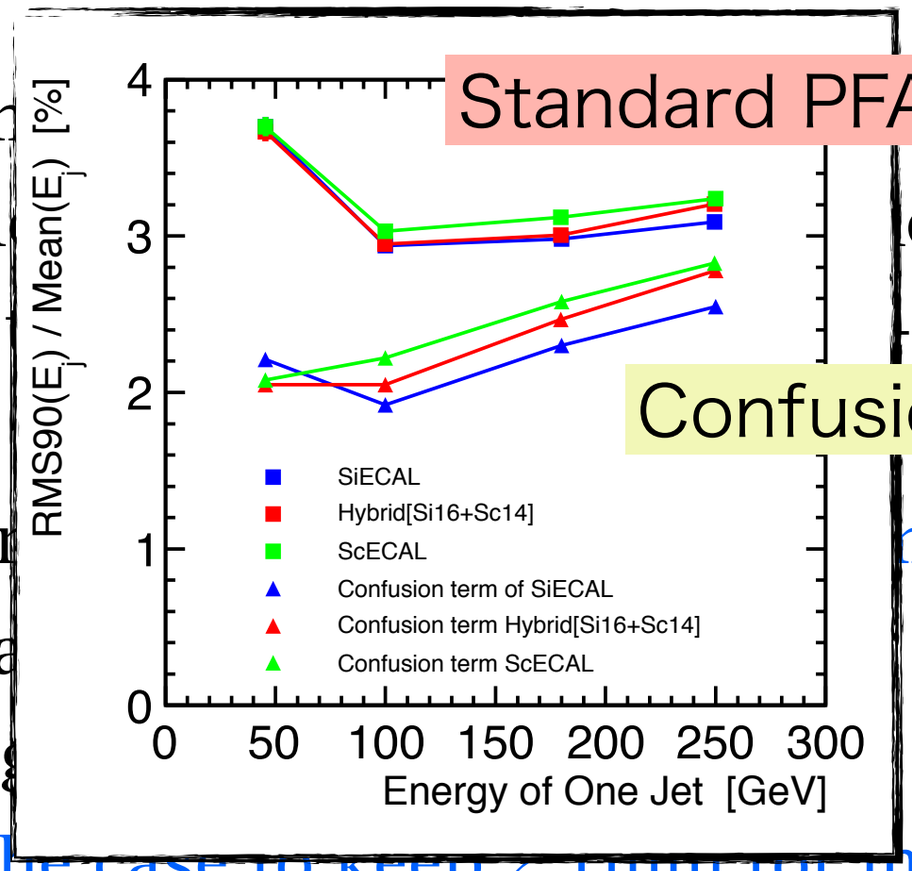
- Active layers
  - same absorber thickness ... not degr
  - same module thickness ... degrade a
  - alternating structure ... same as Hyb
- Absorber layers
  - around $23X_0$ seems good → will inve



- **Reduced number of layers**
  - 26 layers seems good option
  - will investigate the case to keep 2.1mm for inner layers
- Cheating PFA
  - JER difference comes from performance of pattern recognition
- Reduced ECAL Inner Radius
- More Realistic Simulation
- Cost Estimation

Summary and Prospects

- Active layers
  - same absorber th
  - same module thi
  - alternating struct
- Absorber layers
  - around $23X_0$ seer
- Reduced number of la
  - 26 layers seems g
  - will investigate the case to keep 2.1mm for inner layers



50% of Sc-layers

early

Sc14]

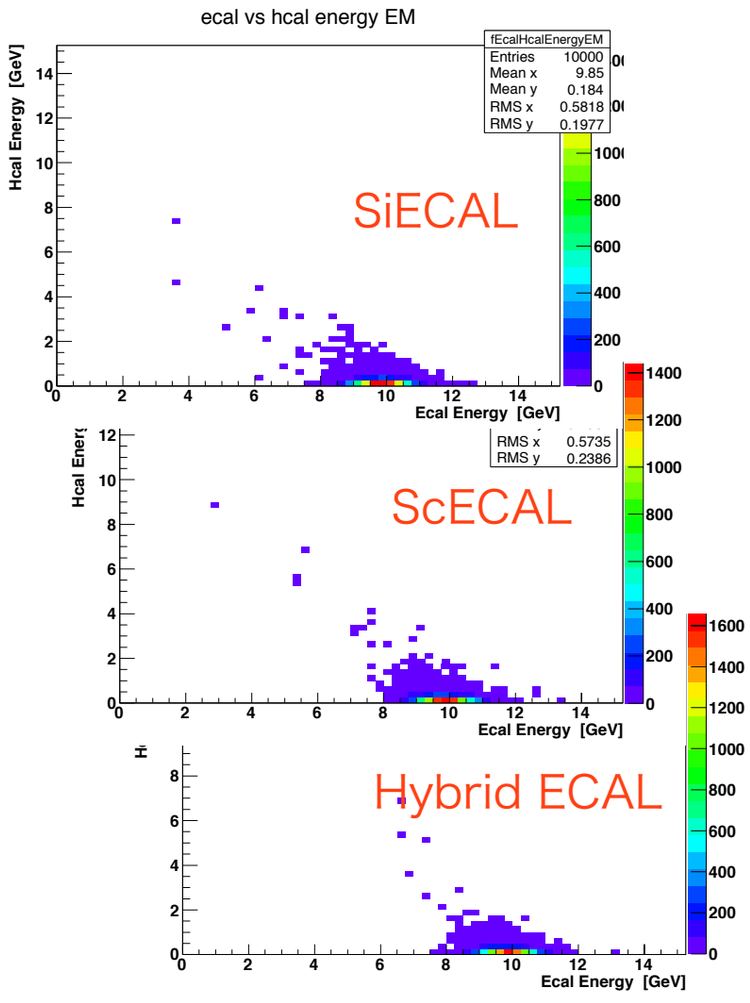
hore minutely

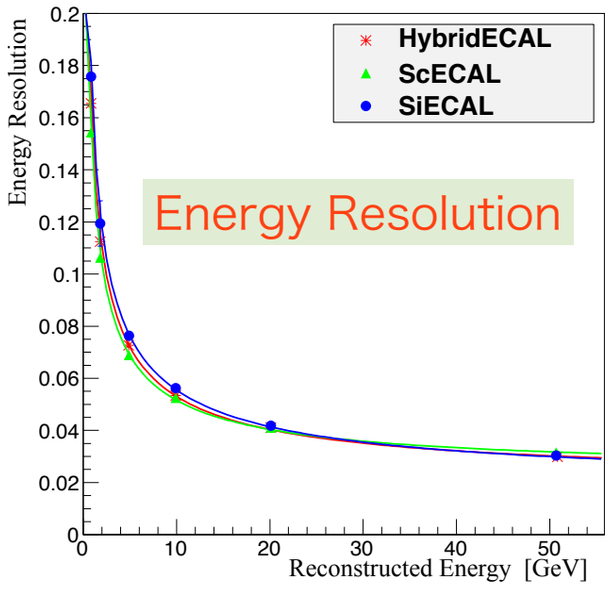
- **Cheating PFA**
  - JER difference comes from performance of pattern recognition
- Reduced ECAL Inner Radius
- More Realistic Simulation
- Cost Estimation

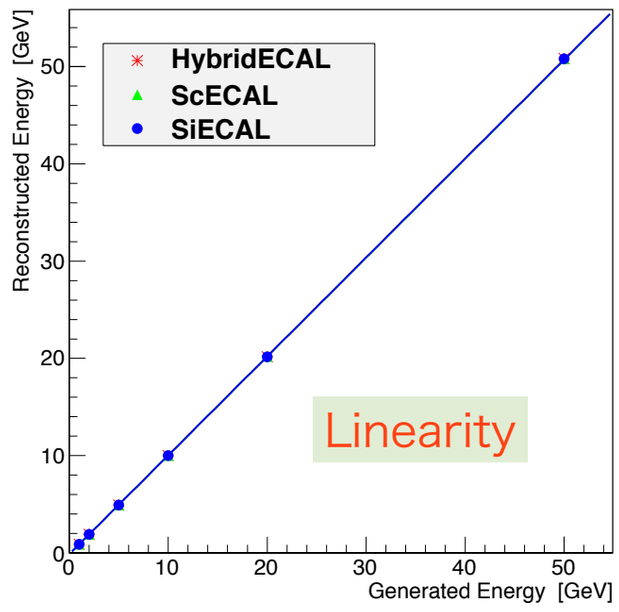
Backup

ECAL Calibration

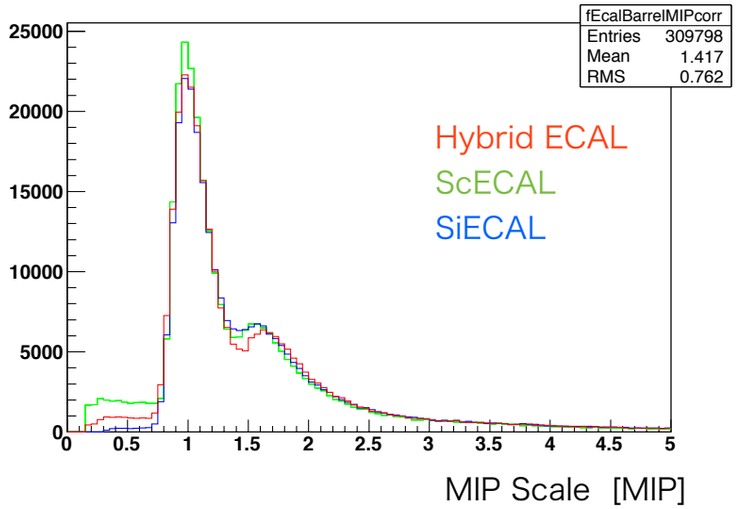
- Calibration constants should be determined for silicon layers and scintillator layers respectively.
  - calibrated using 10GeV photon.
- use 10GeV muon for MIP calibration.





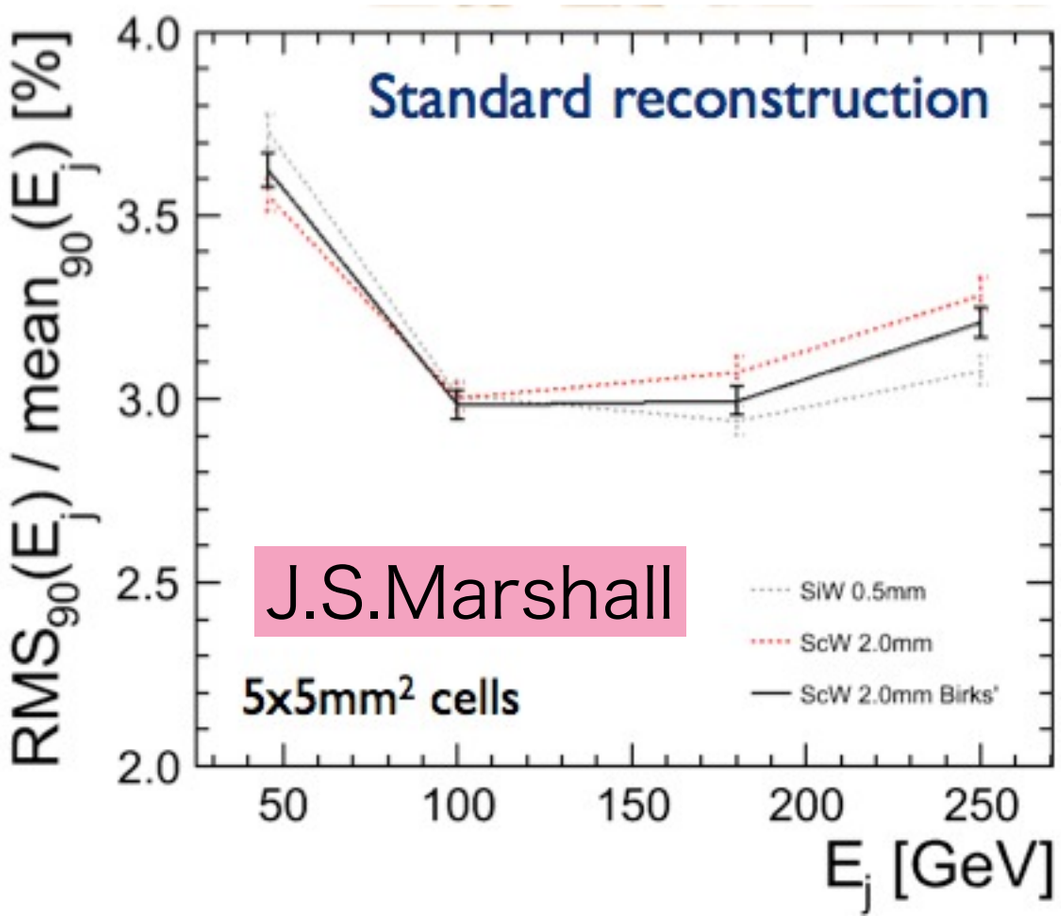


MIP Calibration



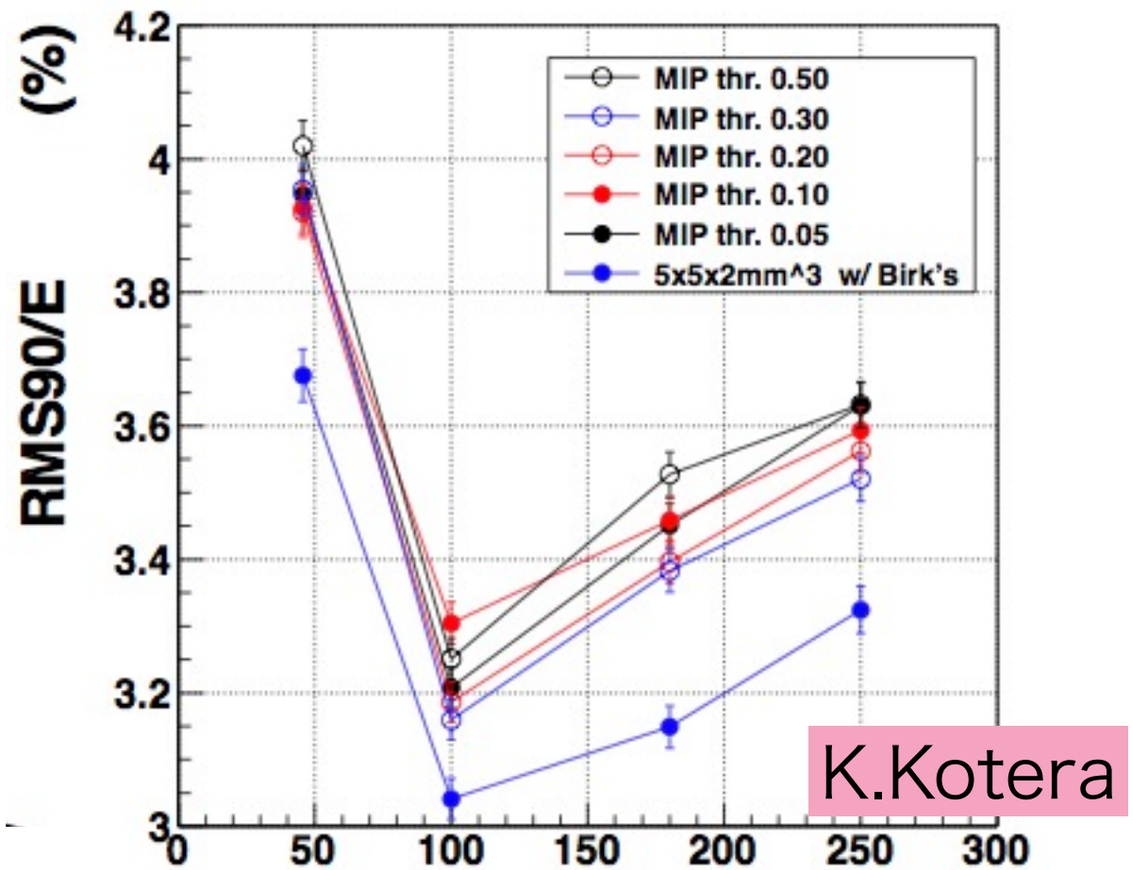
Improvements for ScECAL

Birk's Law



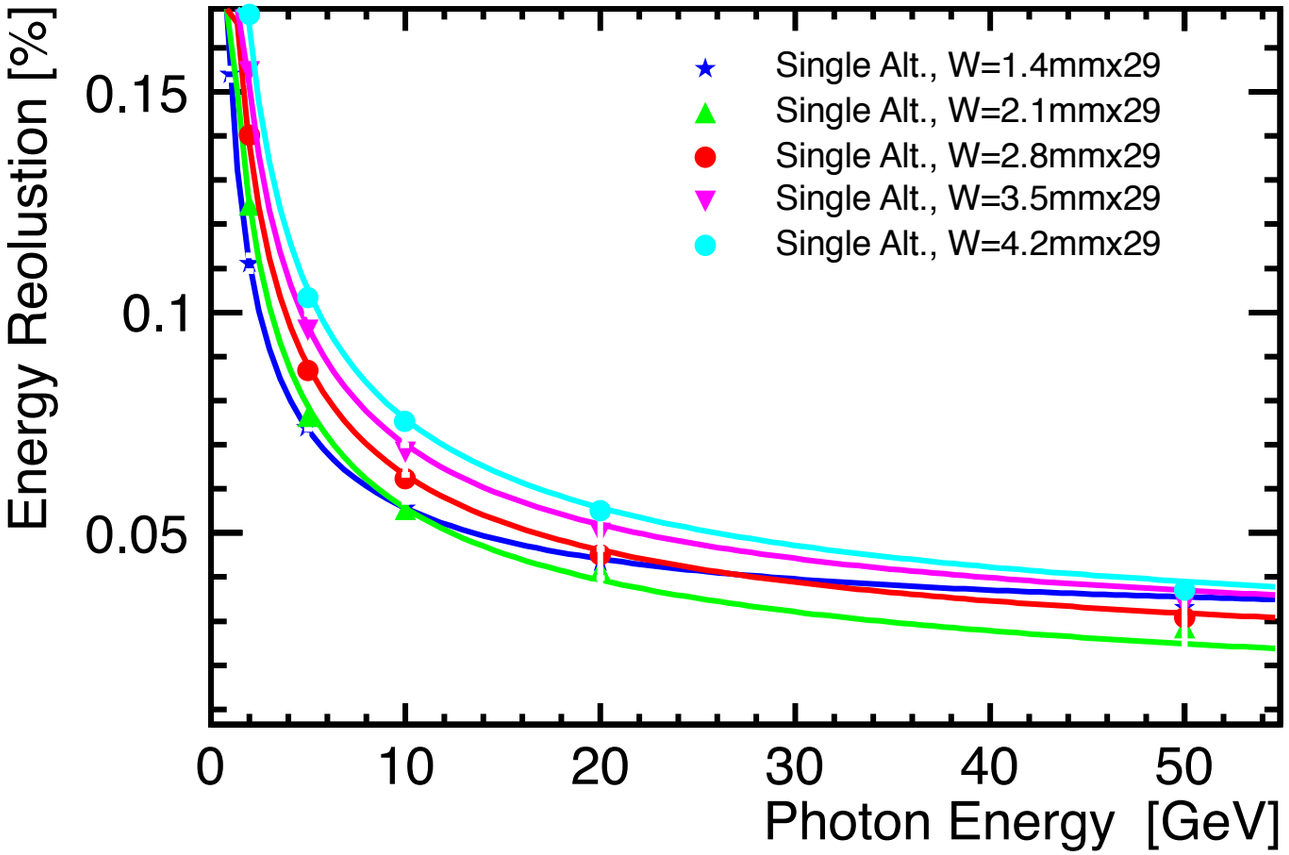
include Birk's Law

MIP threshold after SSA



MIP threshold : 0.5 → 0.3 / a virtual cell

Energy resolution to single photon

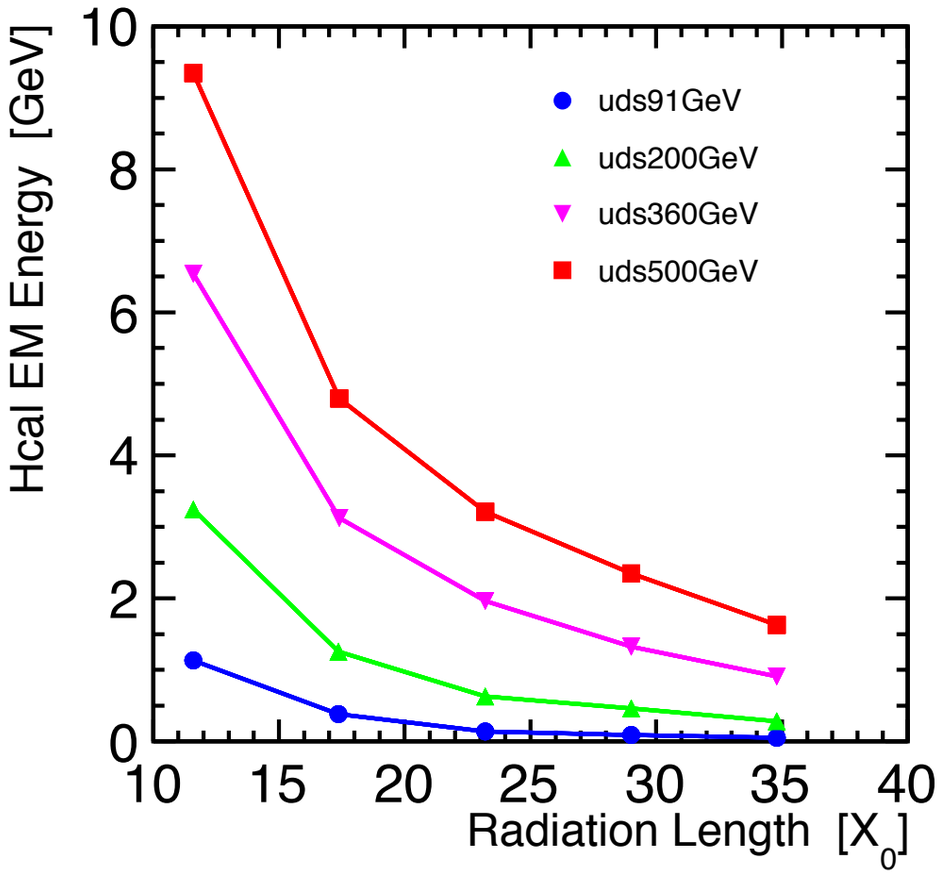


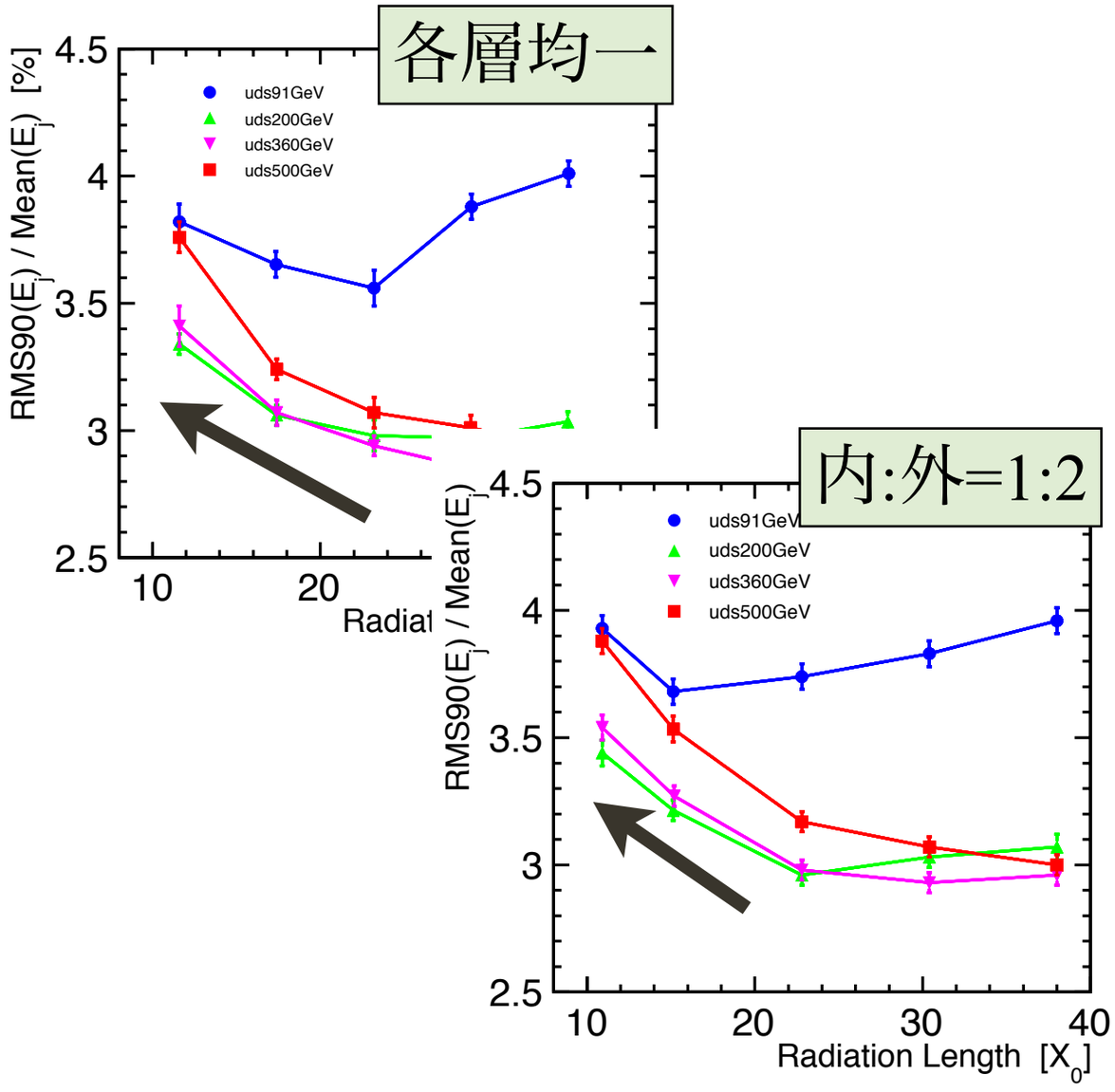
thickness	σ_{stoch}	σ_{const}
1.4mm	15.15%	2.83%
2.1mm	17.58%	0.00%
2.8mm	19.30%	1.63%
3.5mm	21.06%	2.19%
4.2mm	22.98%	2.16%

Thicker absorber layers makes single particle resolution worse.

EM Shower Leakage into HCAL

Average energy of EM shower in HCAL

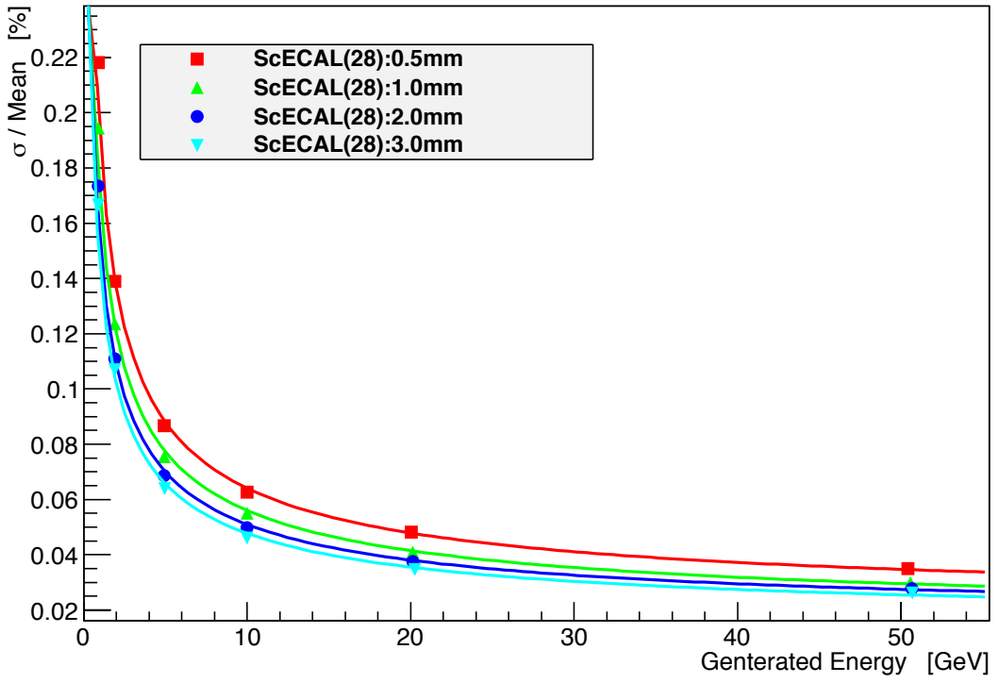




Deposited energy of EM shower in HCAL increases as absorber thickness decrease.

Scintillator Thickness Dependence

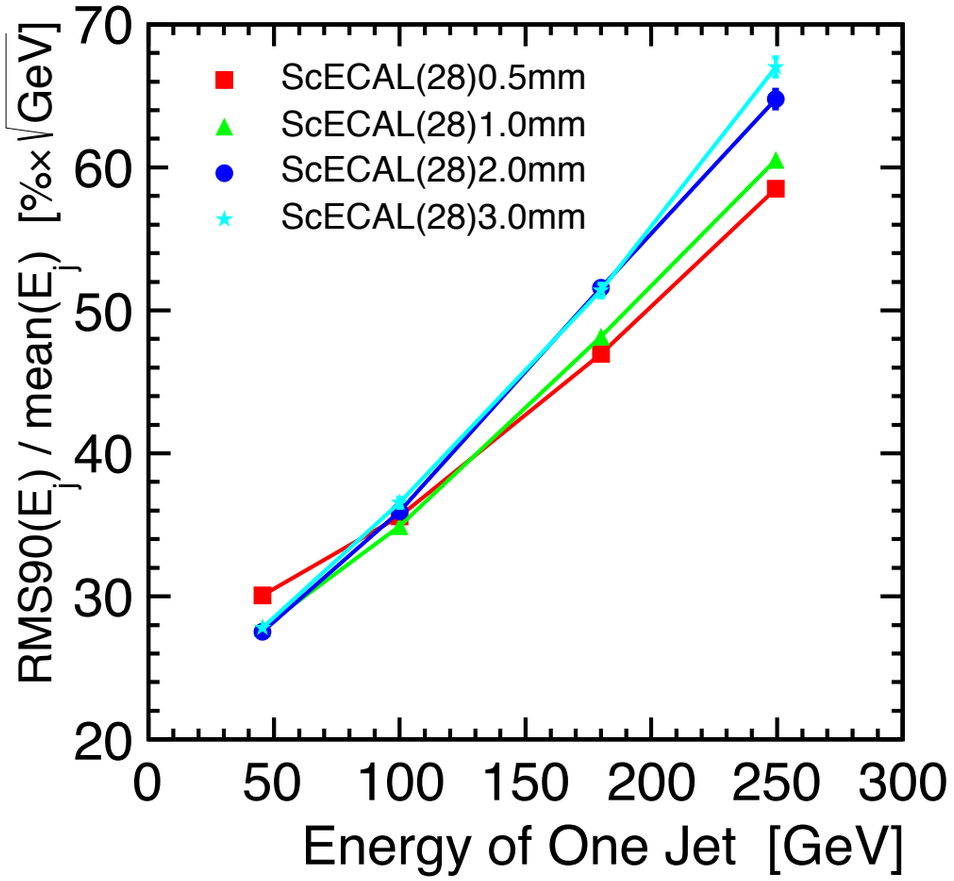
Photon Energy Resolution



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



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