Optimization of layer composition for ILD ECAL

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ilc
international linear collider

Kyushu University
RCAPP

CALICE

ILD ECAL

- Fine granular detector is necessary for PFA

- **Requirement : pixel size < 1cm²**

- ILD ECAL : **Sampling calorimeter**

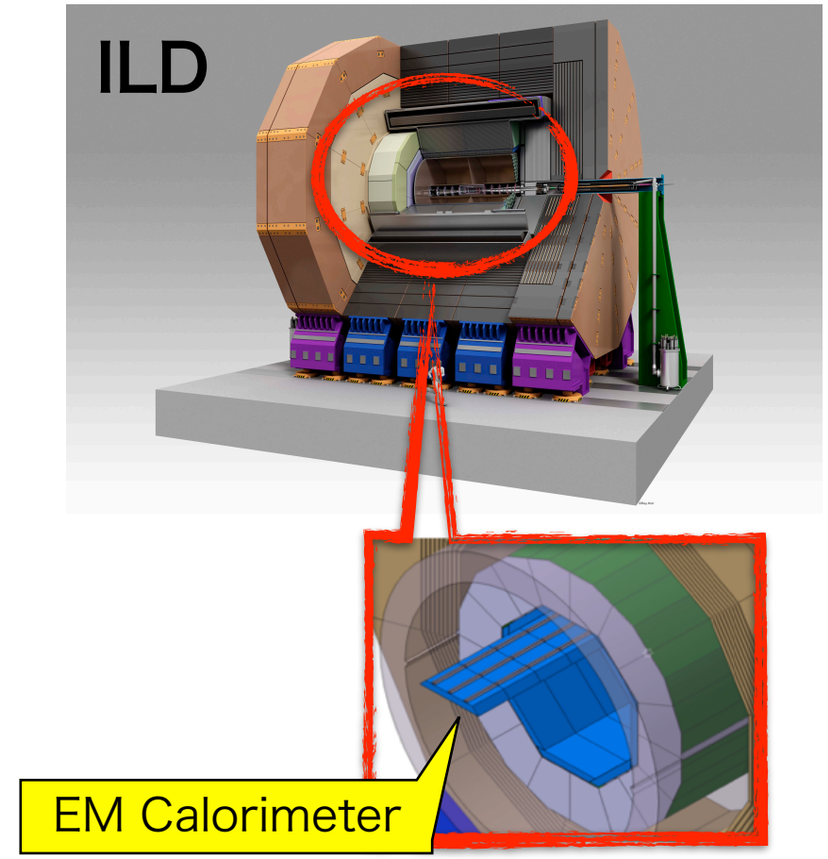
  ✓ Absorber : **Tungsten**

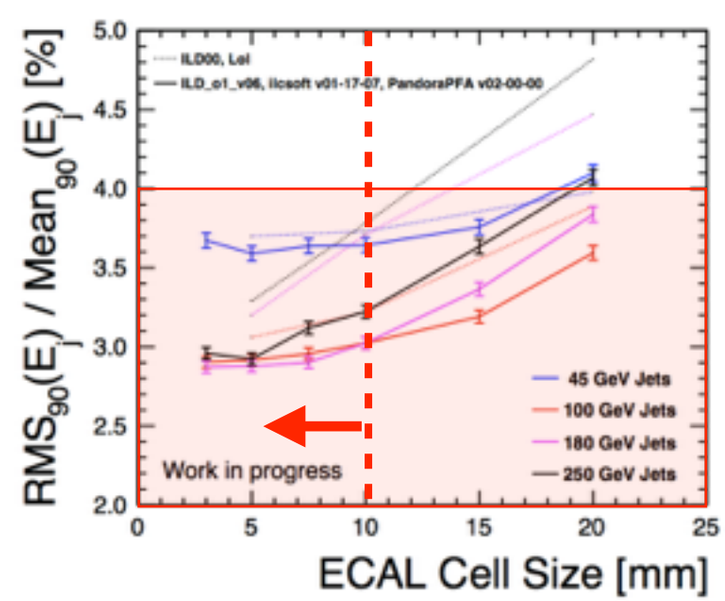
  - ρ_M : 9.3mm
  - X_0 : 3.5mm

  - DBD configuration
    Inner **2.1mm x 20 layers,** Outer **4.2mm x 9 layers**

  ✓ Candidates of sensitive detector

  - **Pixelized silicon**
  - **Scintillator-strip + MPPC**

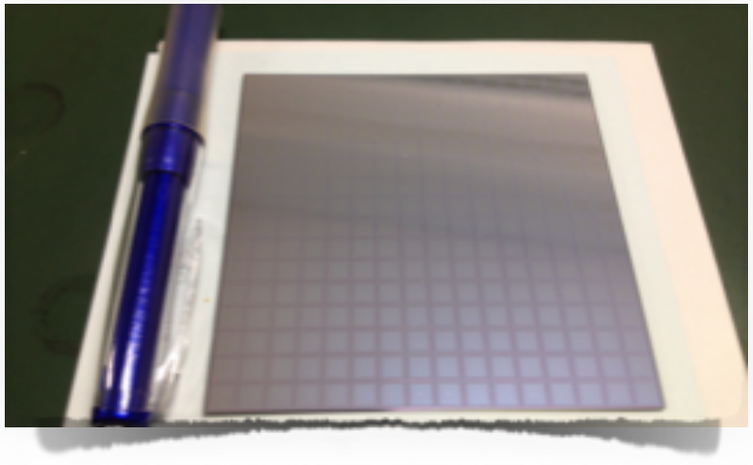




by J. S. Marshall

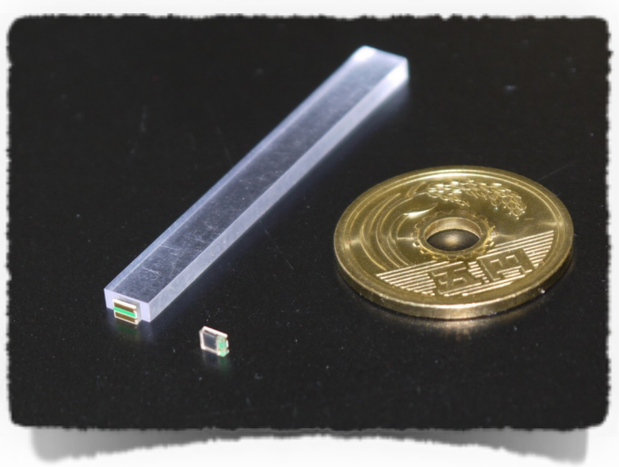
Candidates of sensitive detector

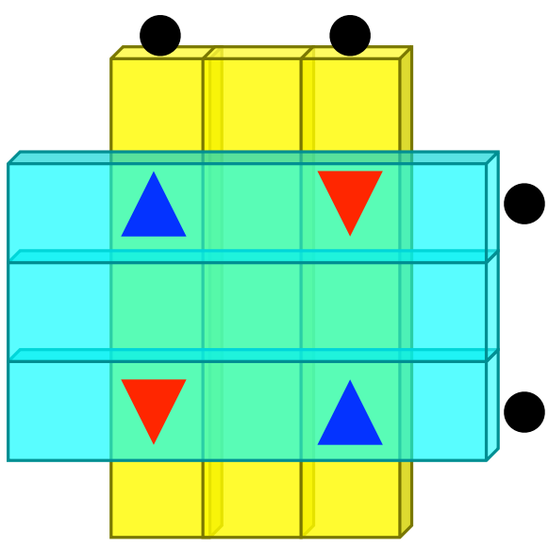
Pixelized silicon



- Pixel size : 5.5mm x 5.5mm
- Multi pixels are good advantage for PFA
- Need to reducing cost

Scintillator-strip + MPPC

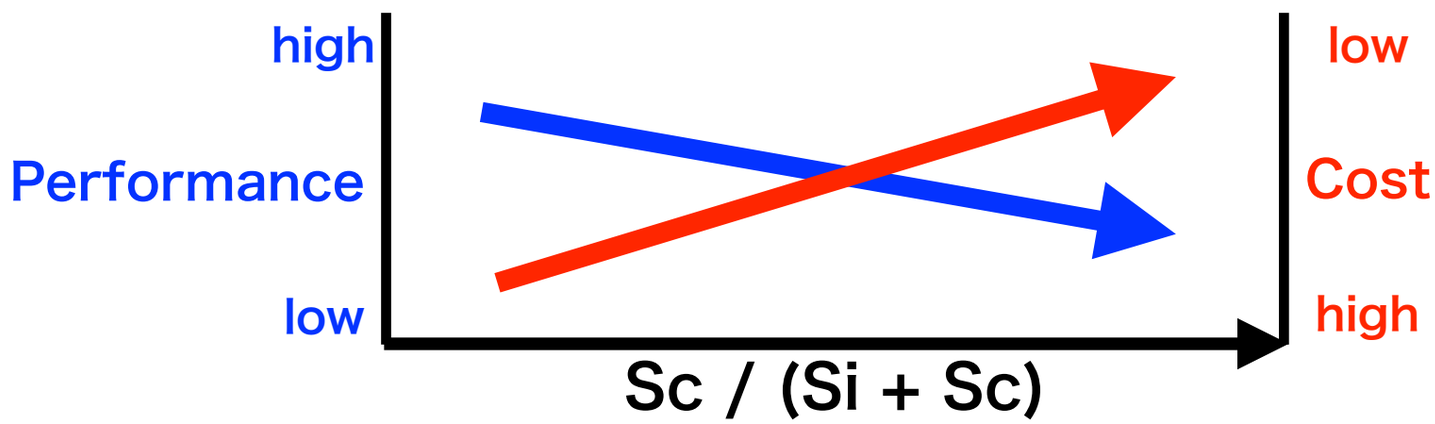


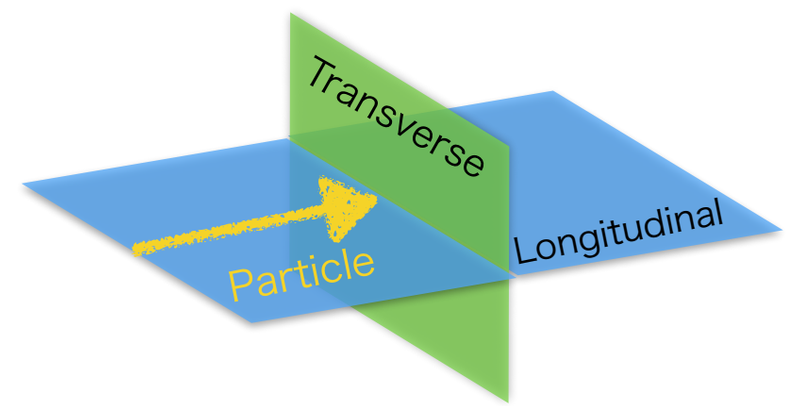


- Cross arrangement of 45mm x 5mm strip
- Relatively low cost
- Ghost hits make the precision worse

Motivation of optimization study

Find a cost-effective structure of ILD ECAL !!





Change some parameters in 2 structures independently

- ✓ **Longitudinal structure** mainly affects single particle resolution

  Thickness of absorber **Number of layers**

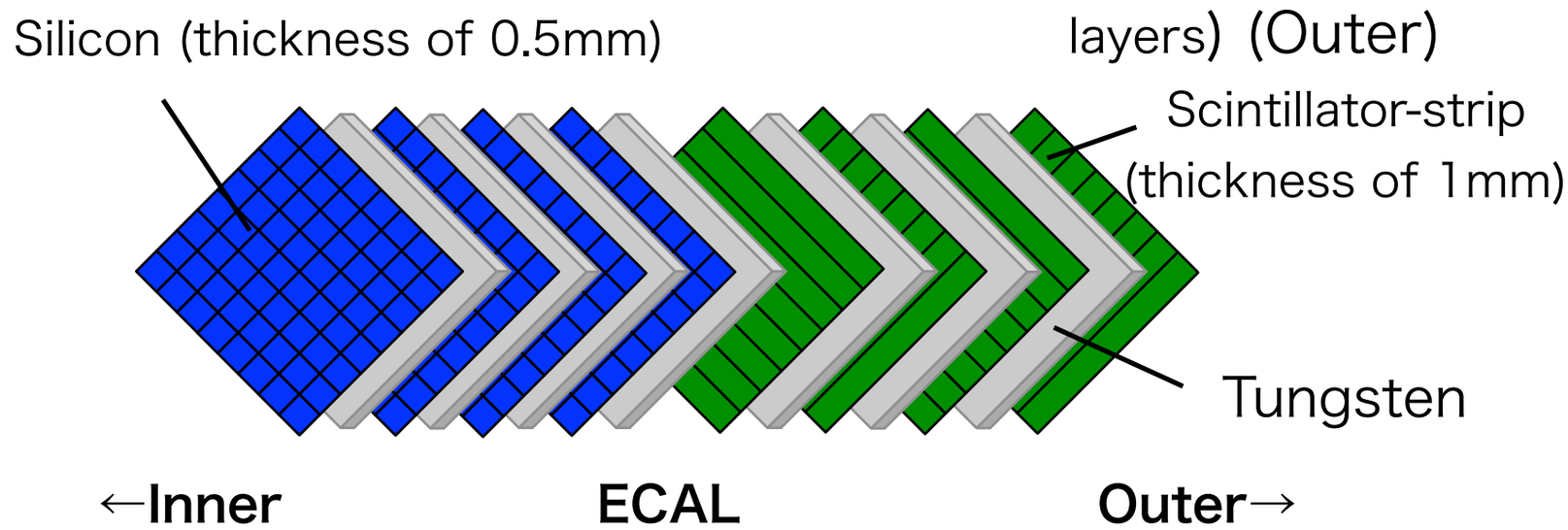
- ✓ **Transverse structure** mainly affects confusion

  Pixel size **Active material** **Overall size of ECAL**

Longitudinal study

- **Change number of Sc layers with hybrid ECAL**
- Sensitive detector : Si x 20 layers (Inner) (**fixed**)、Sc x (following number of layers) (Outer)

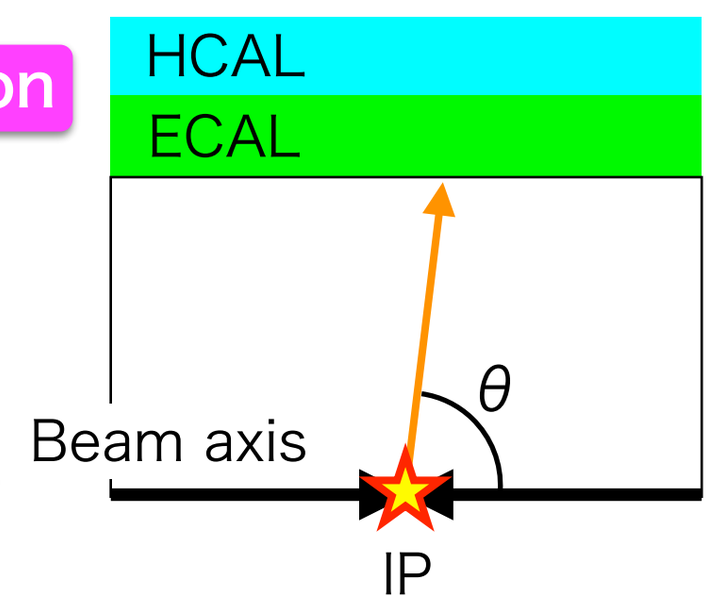
- **Sc x 6 layers**
- **Sc x 8 layers**
- **Sc x 10 layers**
- **Sc x 12 layers**
- **Sc x 14 layers**



- Total absorber (tungsten) thickness is 22.8X_0 (**fixed**)
  (Inner 12X_0 & Outer 10.8X_0)
- Simulation soft : ILCSoft (**v01-16-02**)

Old version

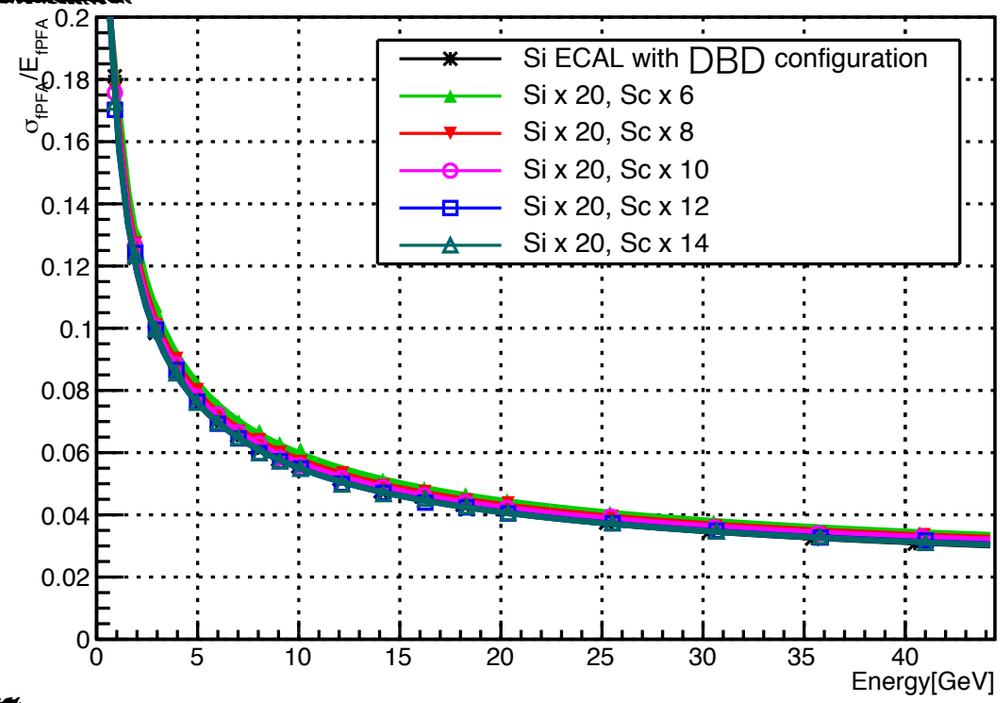
  - ✓ Number of events : 10,000 events from interaction point (IP)
  - ✓ Shot angle : $|\cos\theta| < 0.004$ (except $\theta=0$) for photon & kaon0L, All direction for jet



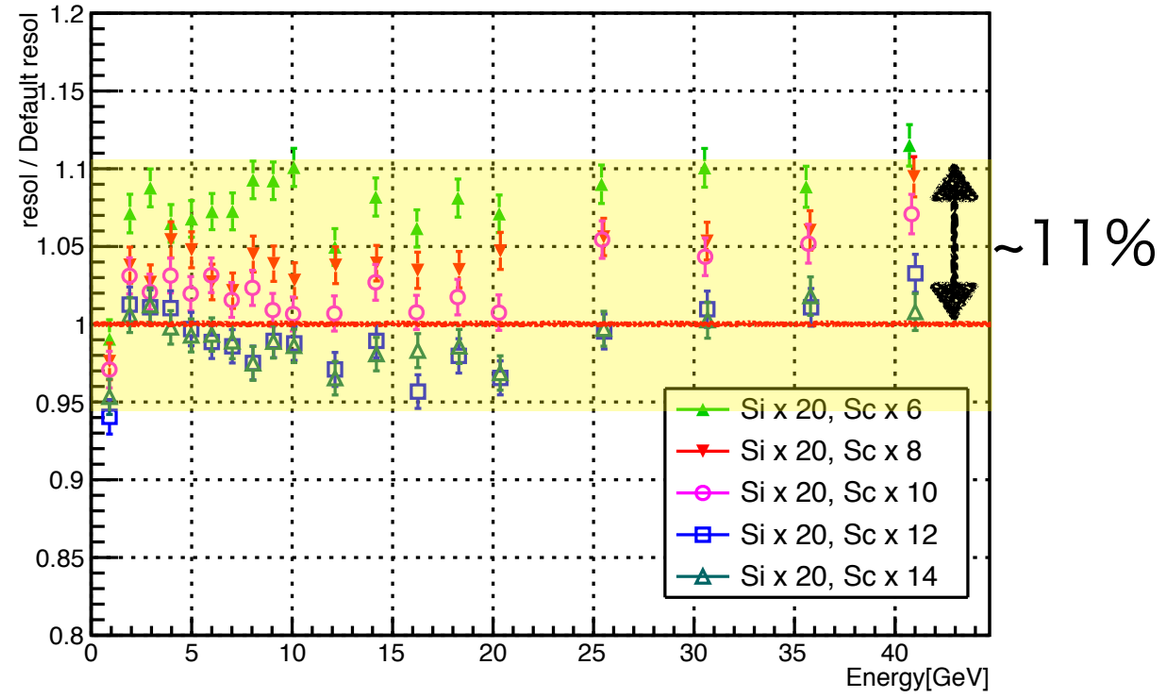
Energy resolution of single particle

Photon

PFO energy vs. resolution

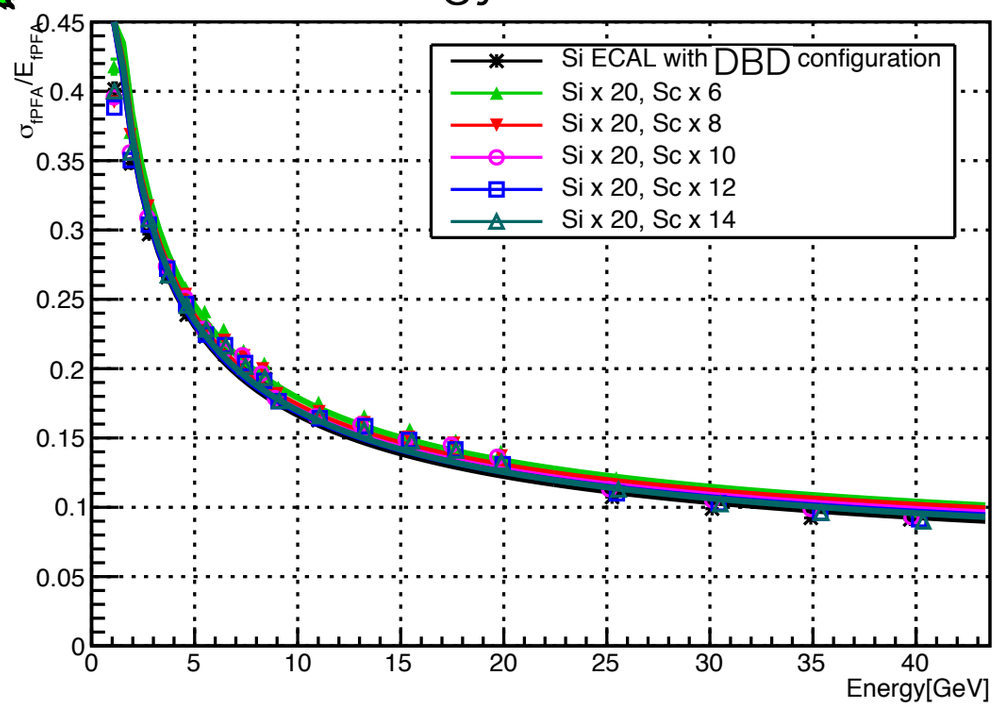


Comparison of resolution with Si ECAL



K^0_L

PFO energy vs. resolution



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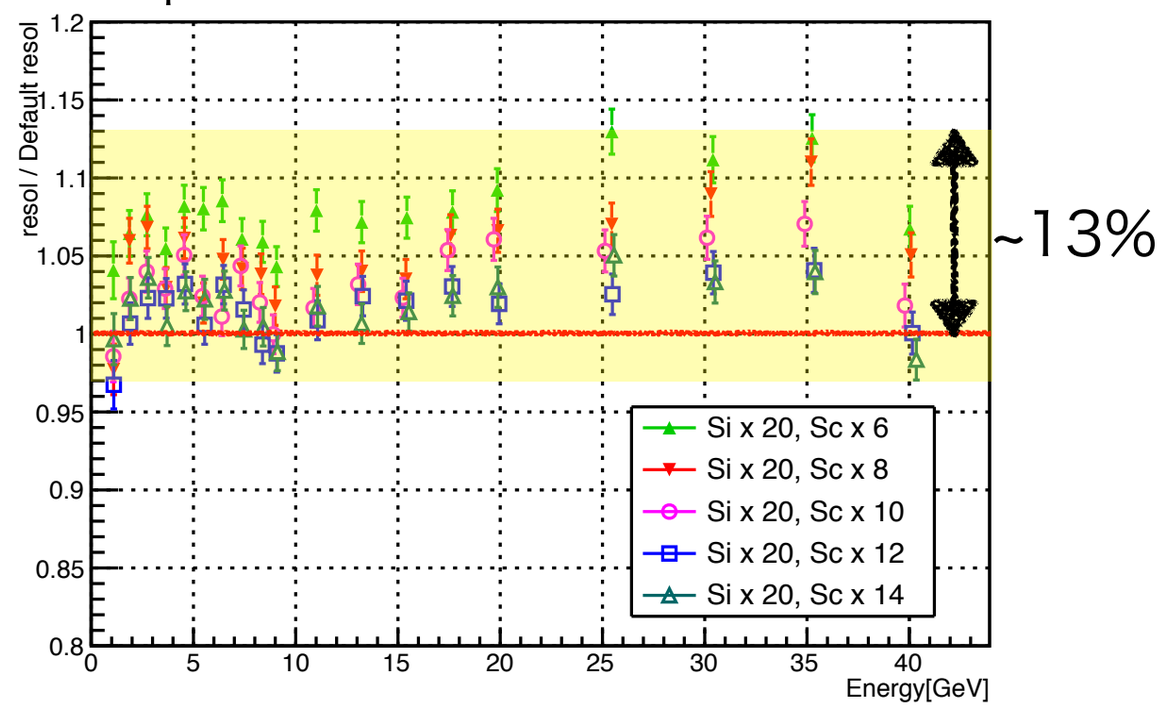
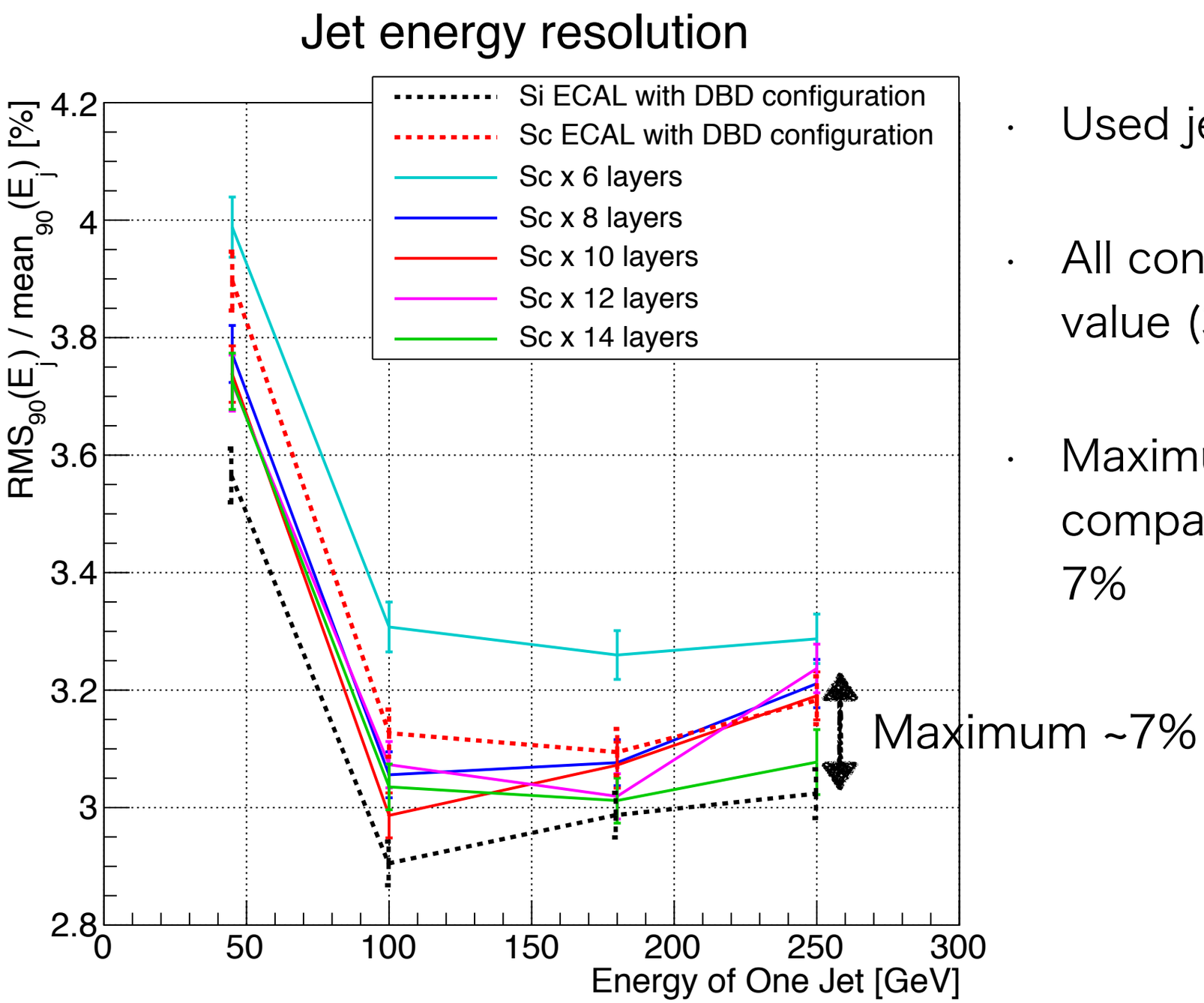
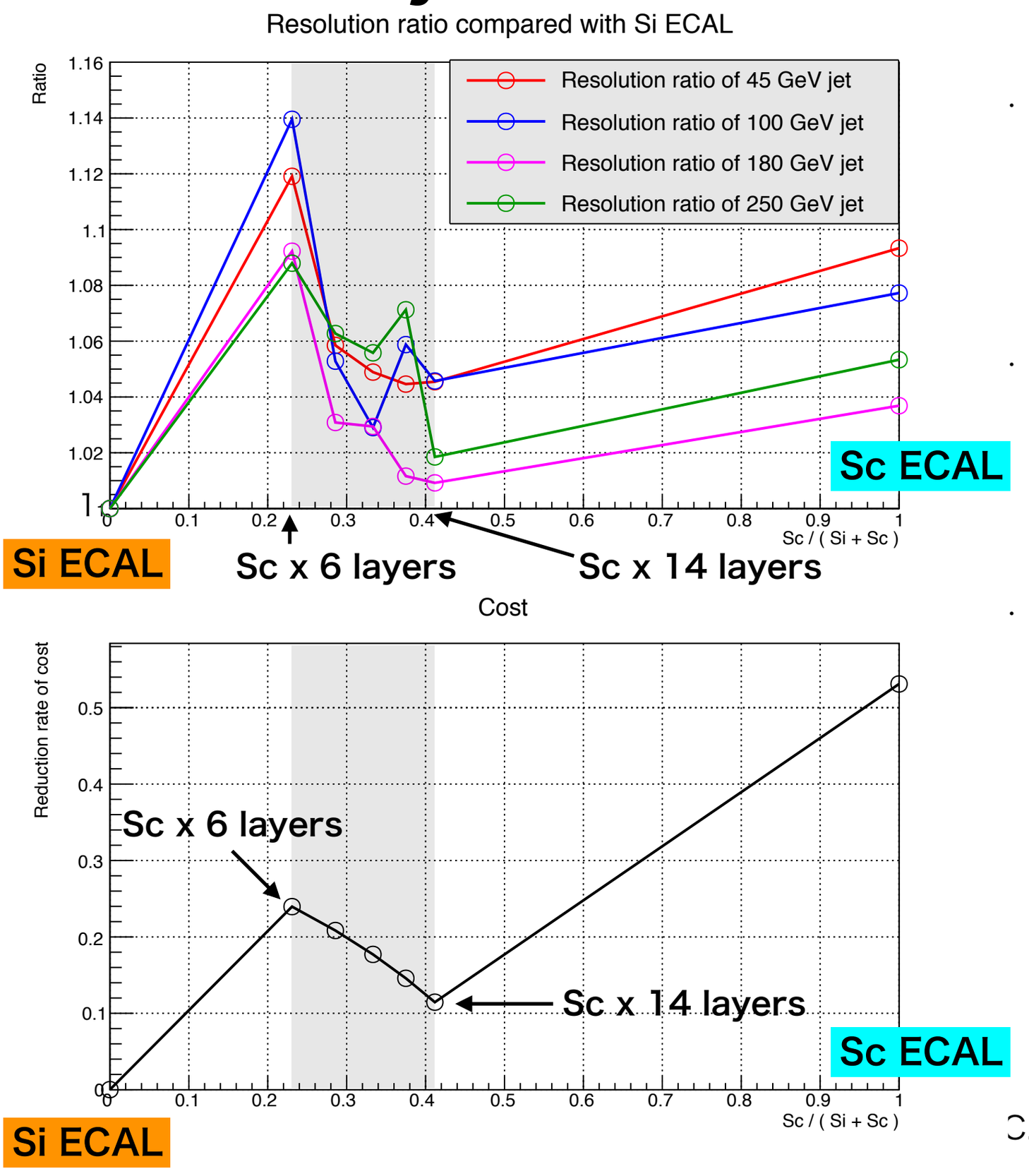


Jet energy resolution



- Used jet : di-jets (Z -> qqbar)
- All configurations satisfy required value (3~4%)
- Maximum gap of resolution compared with Si ECAL is about 7%

Hybrid structure vs. cost



- **Top graph** shows resolution ratio of each configuration defined as following equation

$$\mathrm{Ratio} = \frac{(\sigma/\mathrm{E})_{\mathrm{each\ configuration}}}{(\sigma/\mathrm{E})_{\mathrm{Si\ ECAL}}}$$

- **Down graph** shows reduction rate of cost for each configuration **compared with that of Si ECAL** (calibrated with total cost of Si ECAL and that of Sc ECAL by DBD)

- In this study (gray area),
  - **Resolution ratio**
    - Sc 6 layers have extremely bad result **at least 2.3%** compared with other hybrid configurations
    - Sc 8 layers and Sc 10 layers have almost same result
  - **Cost** increases by **~21%** as increasing **2** Sc layers in this hybrid configurations

Transverse study

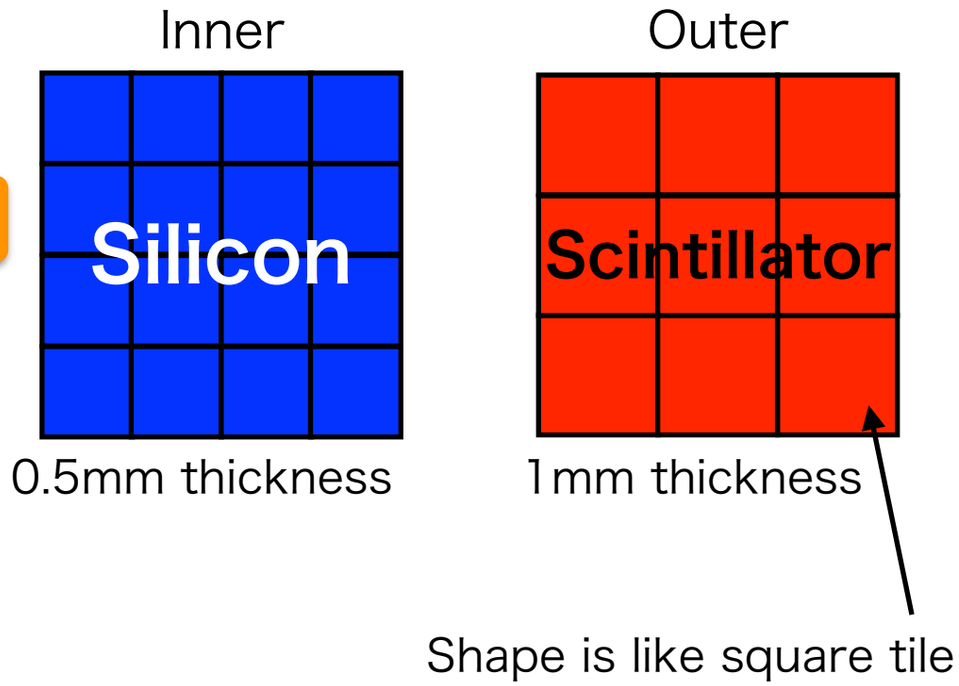
- **Change pixel size of detectors in inner and outer regions independently**

- Configuration is DBD configuration
  - ✓ Inner : **Si x 20 layers** and **tungsten (2.1mm) x 20 layers**
  - ✓ Outer : **Sc x 10 layers** and **tungsten (4.2mm) x 9 layers**

- Simulation soft : ILCSoft (**v01-17-08**)

The latest version

- Studied pixel sizes are
  - **Si 2mm x 2mm, Sc 5mm x 5mm**
  - **Si 3mm x 3mm, Sc 5mm x 5mm**
  - **Si 5mm x 5mm, Sc 5mm x 5mm**
  - **Si 5mm x 5mm, Sc 9mm x 9mm**
  - **Si 5mm x 5mm, Sc 12mm x 12mm**



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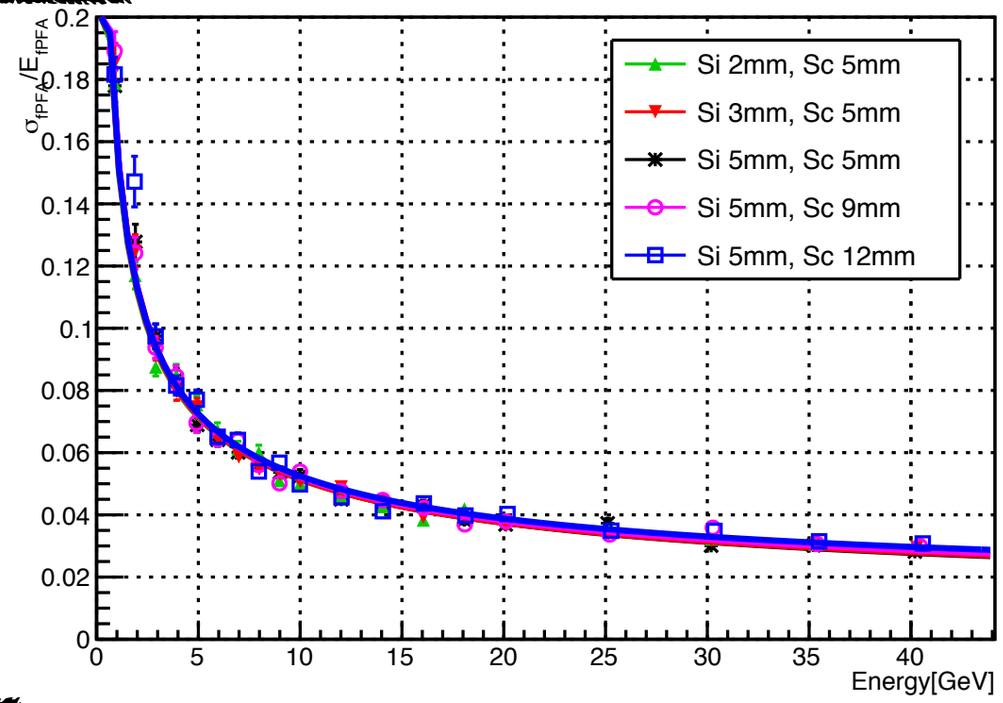
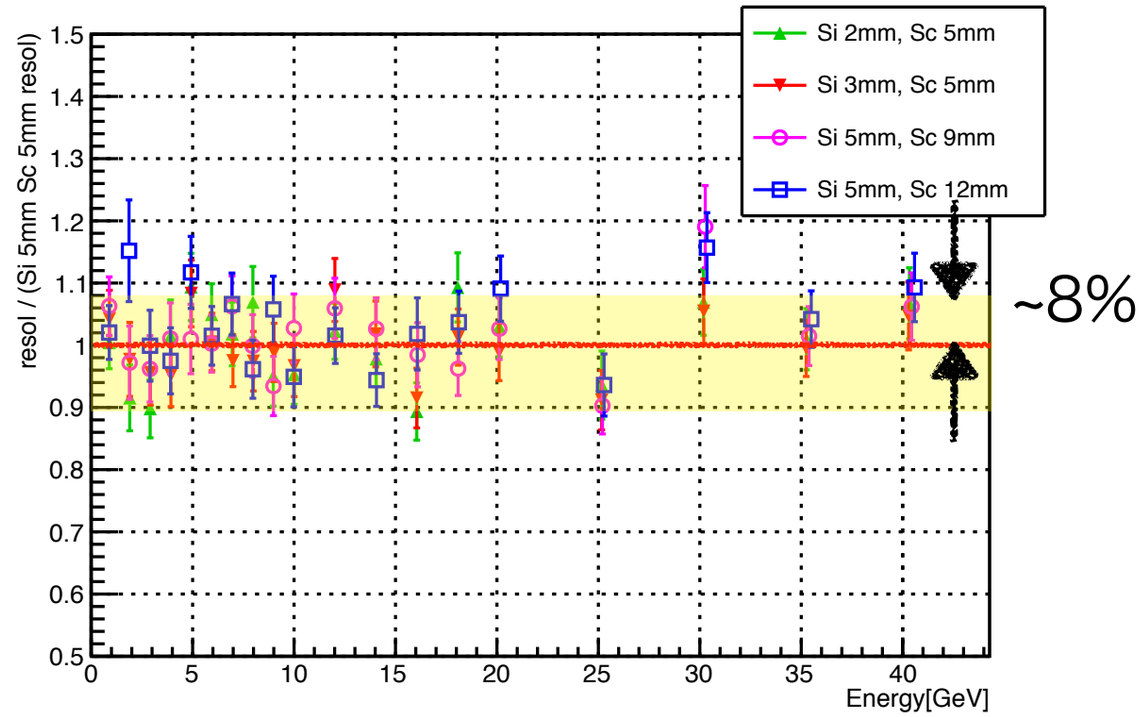
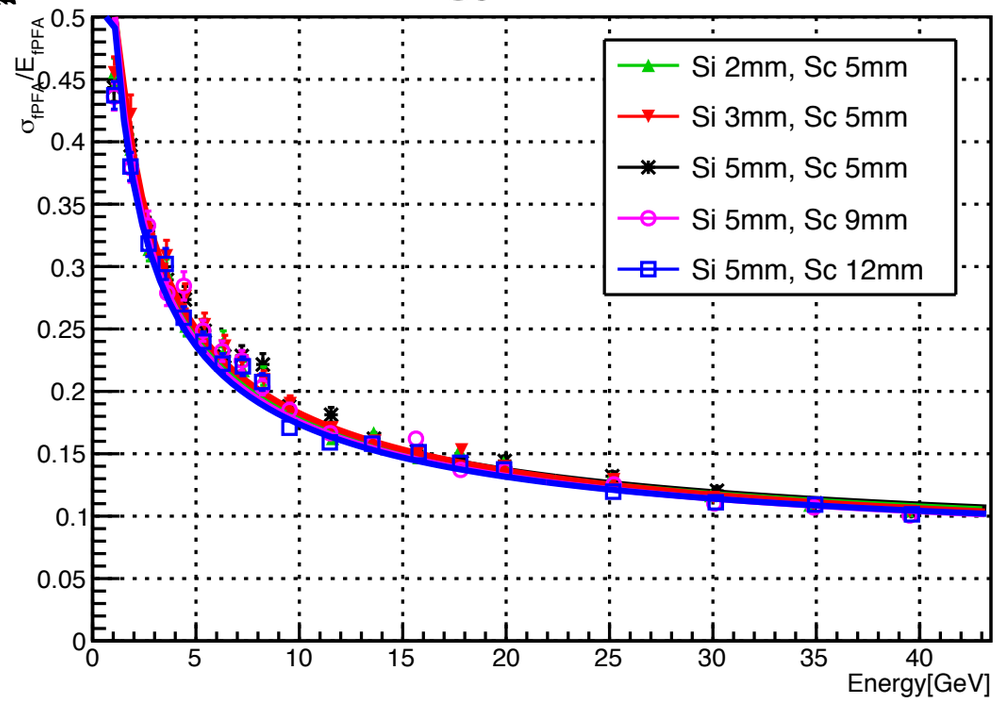


Comparison of resolution with Si 5mm, Sc5mm

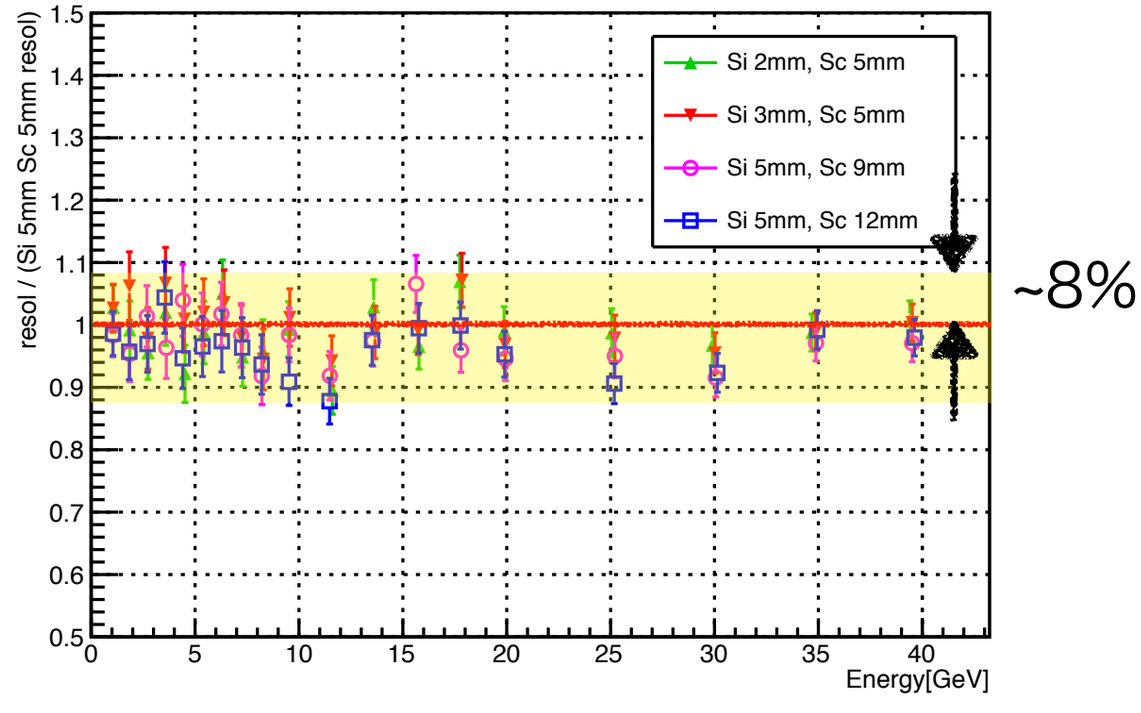


K^0_L

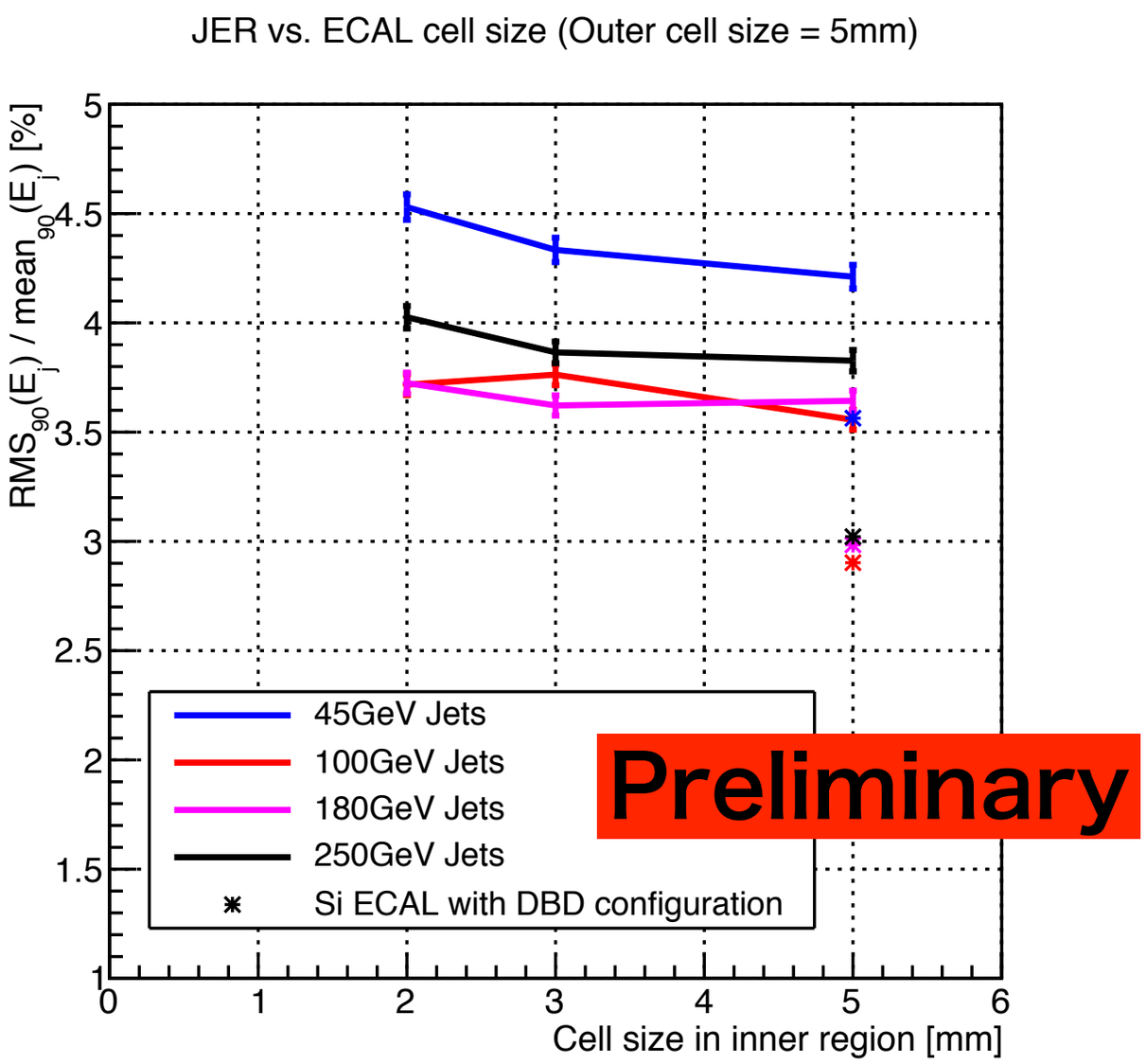
PFO energy vs. resolution

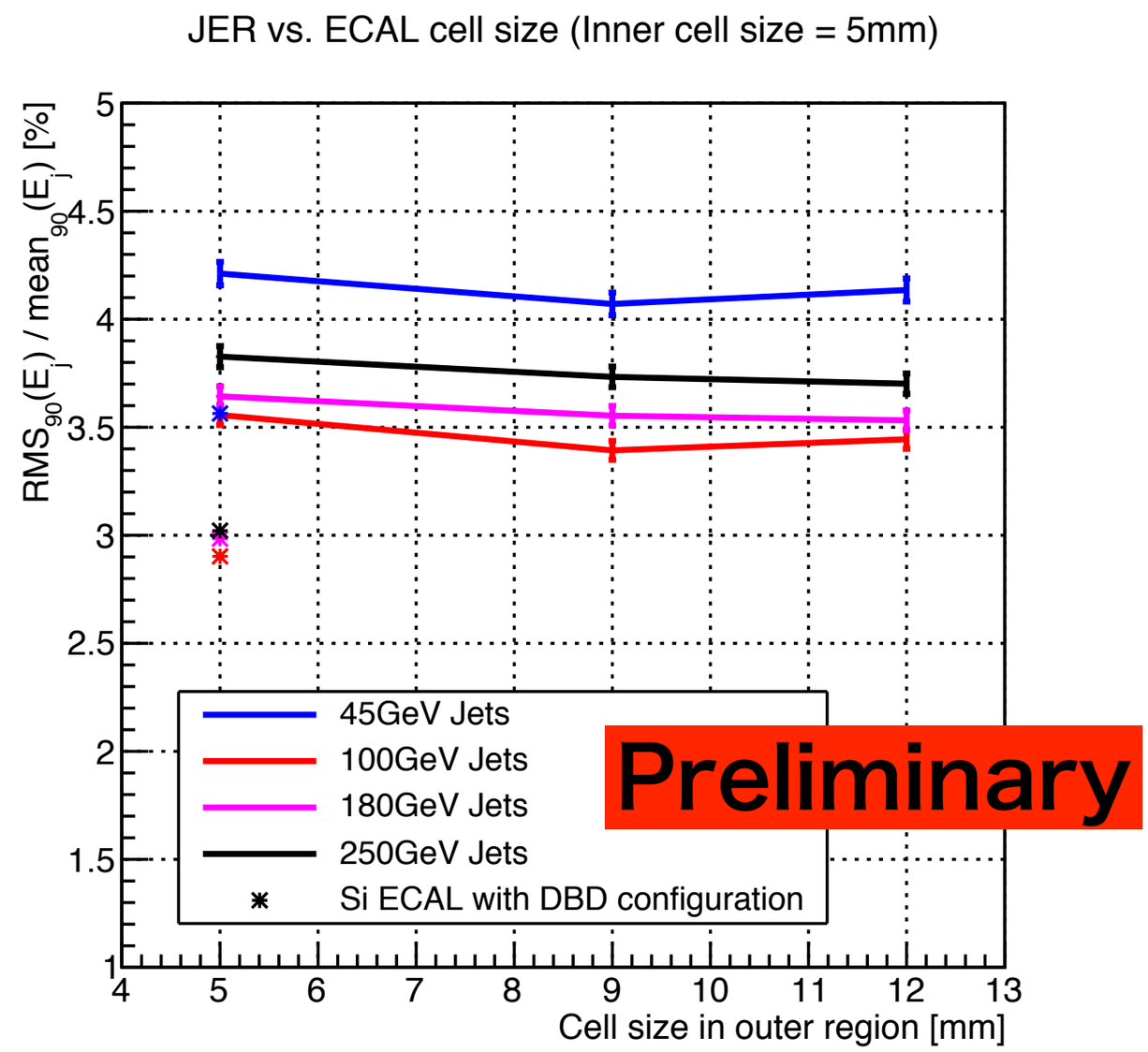


Comparison of resolution with Si 5mm, Sc5mm



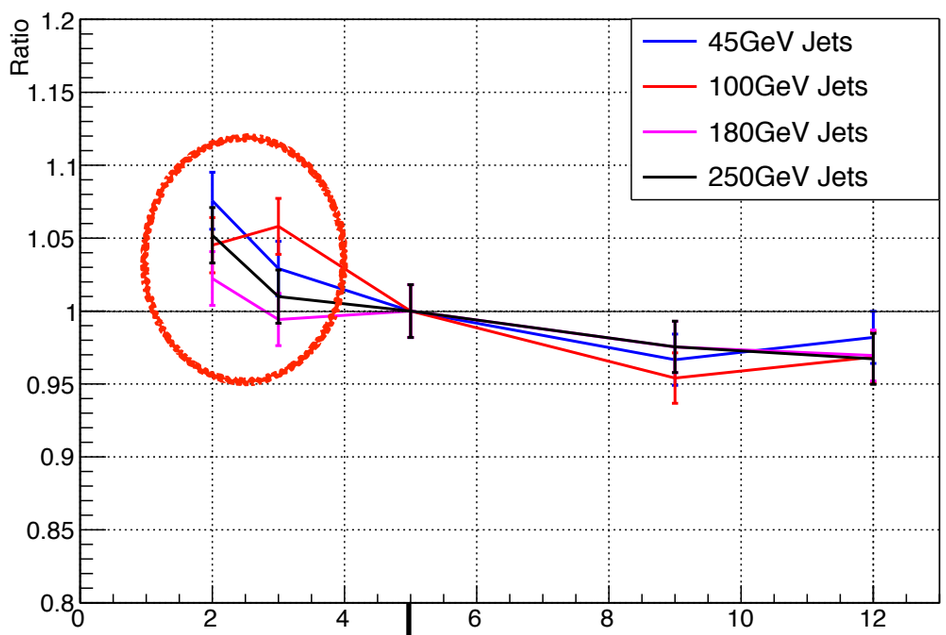
Jet energy resolution





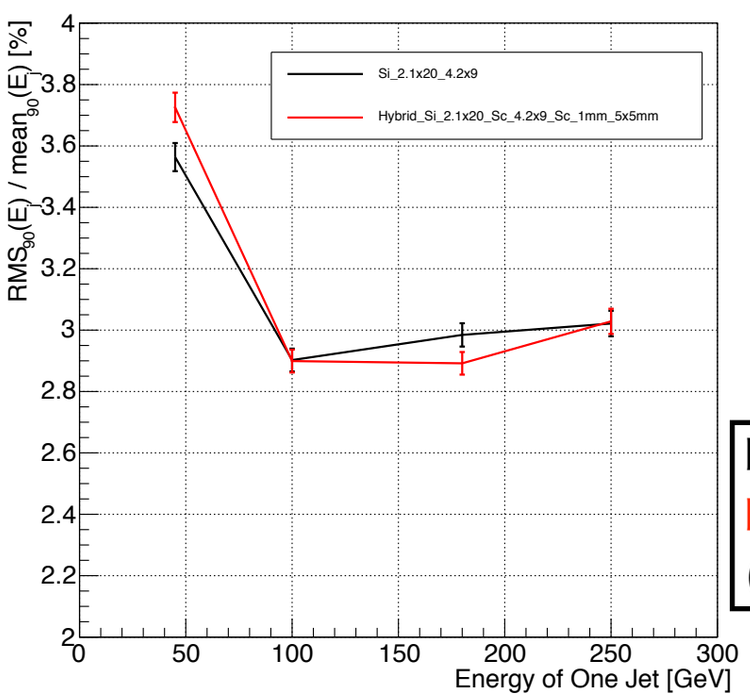
- Used jet : di-jets (Z -> qqbar)
- **It seems that there is offset by wrong simulation**

Discussion



Cell size in **inner** region [mm] ⟷ Cell size in **outer** region [mm]

(outer cell size = 5mm) (inner cell size = 5mm)



← cf. Comparison of Si 5mm & Sc 5mm with Si ECAL (DBD configuration) using ILCsoft v01-16-02

Black line : Si ECAL
Red line : Hybrid ECAL
(Si 5mm & Sc 5mm cells)

- Pandora parameter should be tuned to obtain better resolution for 2 and 3mm cell size in **red circle**
- No significant difference can be seen as change the pixel size in outer region
- A result using old version of ILCsoft shows that **there is no significant difference** during Si ECAL and Hybrid ECAL with the same situation of cell size of Si 5mm & Sc 5mm

➡ aim at least the same result of left graph using new version of ILCsoft (v-01-17-08)

Summary and Outlook

- **Optimization of longitudinal and transverse structure of ILD ECAL**
  - ✓ Longitudinal study with changing number of Sc layers of hybrid ECAL
    - Sc 8 layers (total number of layers = 28 layers) can have almost the same resolution of Sc 10 layers (DBD configuration)
      - ➡ Possibility of reducing number of detector layers
  - ✓ Transverse study with changing pixel size of sensitive detector in inner and outer region of ECAL
    - There are more simulation tunings to derive better resolution
- **Outlook**
  - Optimization of overall structure of calorimeter

BACKUP

Parameter tuning of cell size of 2.0mm