LC cost-effective ECAL studies

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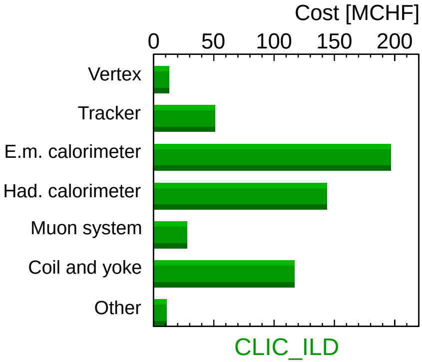
CLIC ECAL studies

ECAL in CLIC_ILD_CDR

- Sampling calorimeter: 30 (29?) layers of silicon-tungsten (23 X_0, 1 λ_I)
  - 30 tungsten absorber plates:
    2.1 mm $\times 20 \approx 0.6\ X_0$
    4.2 mm $\times 10 \approx 1.2\ X_0$
  - 0.5 mm thick silicon cells of 5.1×5.1 mm^2

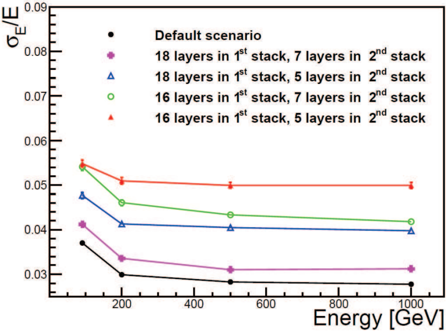
- CLIC_ILD_CDR: ECAL is the cost driver (35%), mostly due to the price of the Si wafers
- Would like to decrease the price without loosing performance
  $\Rightarrow$ optimisation studies



Previous studies: CLIC ECAL

- J. Nardulli, LCD-Open-2011-004, talk
- Idea: change number of layers and alter absorber thickness such that total absorber thickness (i.e. total X_0) remains constant
- Performance: **energy resolution** for single photons and $Z \to uds$ events
- Found that number of layers can be decreased (18 instead of 20 in first stack, 7 instead of 9 in second stack), with small degradation in performance $\Rightarrow$ ECAL cost decrease of 14%

- Example for $Z \to uds$ events:



Previous studies: ILD ECAL

- T. Yoshioka, H. Ueno, ▸ talk at CALICE meeting, Sept. 2012
- **Hybrid ECAL**: combination of silicon and scintillator planes
- Reconstruction : PandoraPFANew + Strip Splitting Algorithm (SSA) (see ▸ talk of T. Takeshita for an explanation of the algorithm)

- Calibration constants:
  - determined separately for Si-ECAL and Sc-ECAL
  - checked with 1–50 GeV photons (linearity, resolution)
- Performance: jet energy resolution

- 27 layers (not default)

	Thickness active	Thickness absorber
Hybrid ECAL	2.0 mm scintillator 0.5 mm silicon	2.1 mm for inner 20 layers
Sc-ECAL	2.0 mm scintillator	3.5 mm for outer 7 layers
Si-ECAL	0.5 mm silicon	

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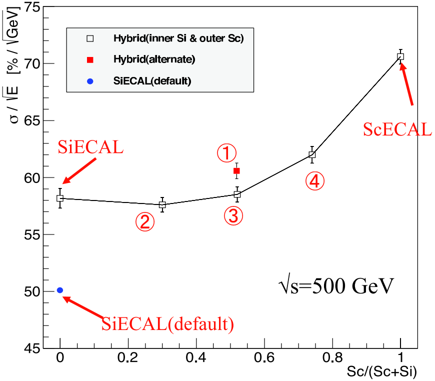
Jet energy resolution as a function of Sc/(Sc+Si) ratio (in number of layers)



①: alternate structure

②: 20 Si layers, 7 Sc layers

③: 13 Si layers, 14 Sc layers

④: 7 Si layers, 20 Sc layers

In these configurations, the performance does not degrade so much up to the layer ratio 50%.

- ⇒ Should not have more than half of the layers with scintillators

Previous studies: ILD ECAL

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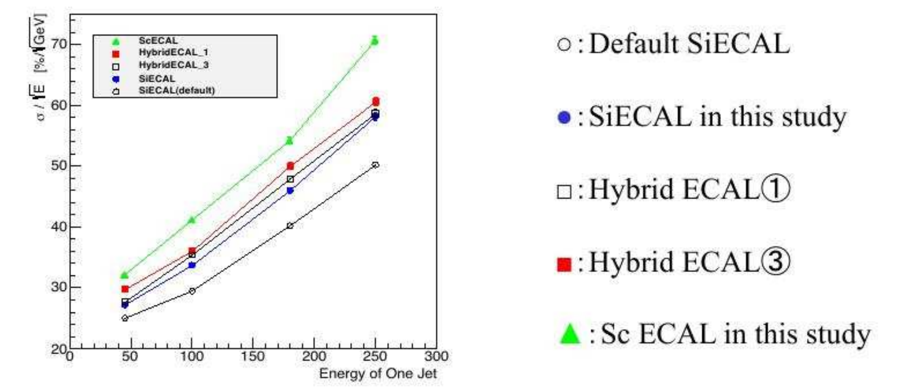
Energy dependence

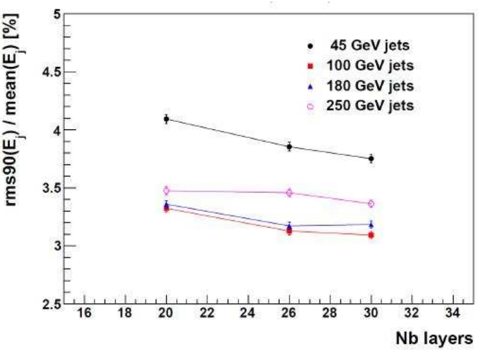


- Performance of default SiW-ECAL much better, probably due to different configuration
- Performance of alternate structure midway between SiW-ECAL and Sc-ECAL

Previous studies: ILD ECAL

- T. H. Tran, *SiW-ECAL with reduced number of layers,* ▸ talk at CALICE meeting, Sept. 2012, Cambridge

ECAL model	W layers	Layer thickness
30 layers	20 9	2.1 mm 4.2 mm
26 layers	17 8	2.4 mm 4.8 mm
20 layers	14 6	3.15 mm 6.3 mm

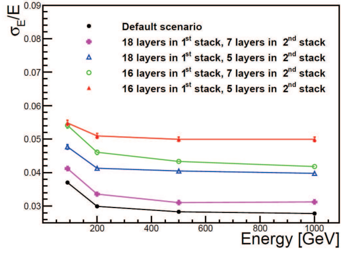


- 10% degradation is observed going from 30 to 20 layers for 91 GeV sample, 3–7% for other energies

Comparison of previous studies

J. Nardulli, CLIC ILD

ECAL model	W layers	Layer thickness
25 layers	18 7	2.333 mm 5.4 mm
23 layers	18 5	2.333 mm 7.56 mm
23 layers	16 7	2.625 mm 7.56 mm
21 layers	16 5	2.625 mm 7.56 mm



T. H. Tran, ILC ILD

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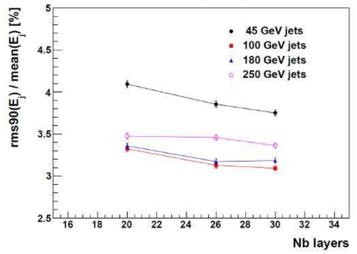

Sampling fraction and energy resolution

- Why 2 absorber thicknesses?
- Observation: H. Videau, *Detector design driven by simulations* , ▸ talk at ECFA workshop, Valencia 2006: for same total thickness, same number of X_0, resolution is systematically better with a finer sampling in front
- Explanation: significant fraction of electromagnetic energy comes from low energy photons ($E < 2$ GeV) $\Rightarrow$ using thinner sampling in the first part helps

Possible designs for a hybrid ECAL

Dimensions of scintillator tiles

- Talk by F. Sefkow, meeting on future ECAL technologies, CERN, July 2012
  $\Rightarrow$ 1 mm thick tiles seem possible
- Current developments: **2 mm thick tiles**
- What about tile size? 1×1 cm^2, 1.5×1.5 cm^2, 2×2 cm^2 ?

For the moment, assume total X_0 should be kept constant

Suggestions

1. Scintillator only, in default configuration:
   $20 \times 2.1 + 9 \times 4.2$ mm W $+ 29 \times 2$ mm scintillator
   - needed for determining calibration constants
   - and for comparison with Si-ECAL case

2. Half of the layers silicon, half of the layers scintillator:
   15×2.1 mm W$\times$0.5 mm Si $+14 \times 3.2$ mm W$\times$2 mm scintillator or
   15×2.5 mm W$\times$0.5 mm Si $+14 \times 3.0$ mm W$\times$2 mm scintillator
   - Not clear how important is the sampling in the beginning
     $\Rightarrow$ could look at photon energy in generated events

How to assess performance of a hybrid ECAL?

- Inspired from G. W. Wilson, *On evaluating the calorimetry performance of detector design concepts*, ▸ LCWS 2005
- **"Physics-based"**: optimize the detector using a specific benchmark process and looking at the final precision on physics quantities
  - Disadvantage: not a direct comparison of different detector designs, as sometimes not the same analysis methods can be applied
  - Examples:
    - τ-lepton production (tests separation of charged hardons from photons from π^0 decay),
    - slepton production (test lepton ID)
- **"Detector-based"**: evaluate detector performance using simple detector-level observables with full simulation
  - Preferred, offers direct comparison of different detector designs
  - Examples:
    - jet energy resolution
    - single particle response studies (γ, $e^{\pm}$, $\tau^{\pm}$)
    - two particles separation (e from γ, γ from charged/neutral hadron, etc. ...)
    - π^0 reconstruction?
    - photon angular resolution?

Available software tools

- CLIC ILD: driver SEcal04 (model ILD_00_EcalSc02)
  - Steering parameter *Ecal_Sc_Si_Mix*: a set of numbers (one for every two layers) to indicate the type of active material, and, in scintillator case, the orientation of the **strips**
- Maybe it can be used without many modifications for CLIC ILD

Some open questions

- Dimensions of scintillator tiles?
- Studies of X_0 or assume it constant?
- Is it important to keep 1:2 W ratio?
- PandoraPFA calibration with different samplings and active materials?
- Scintillator layers thicker than silicon layers $\Rightarrow$ impact of increased coil radius on total cost?

- Who are the people involved?
- What time scale?