# Study of SiW-ECAL performance with reduced number of layers

Trong Hieu TRAN
Laboratoire Leprince-Ringuet, Ecole polytechnique, CNRS/IN2P3

LCWS12 International Workshop on Future Linear Colliders
University of Texas at Arlington, USA
22–26 October 2012

University of Texas @ Arlington, USA

# Outlook

- Motivation
- ECAL with different number of layers
- Performance for ECAL is studied by estimating energy resolution using PandoraPFANew
  - Check of calibration using photons, $K_L$'s , muons at 10 GeV
  - For Z → uds events at c.m. energies 91, 200, 360, 500 GeV
  - Single photon events at 1, 10, 100 and 500 GeV
- Software: ILCSOFT v01-16 (with latest tracking)
- Summary

# Motivations

- SiW-ECAL is one of the major cost drivers of ILD

$$S_{\mathrm{Si}} \propto \frac{[\pi(R_{\mathrm{TPC}}+e)^2-\pi R_{\mathrm{TPC}}^2]}{e_1}\times L_{\mathrm{Barrel}}+\frac{\pi R_{\mathrm{TPC}}^2\times e}{e_1}$$
$$= \frac{2\pi R_{\mathrm{TPC}}\times e+\pi e^2}{e_1}\times L_{\mathrm{Barrel}}+\frac{\pi R_{\mathrm{TPC}}^2\times e}{e_1}$$

$S_{si}$ : total Si surface
$R_{TPC}$: TPC radius
$e_1$: layer thickness
e : total thickness of all layers
$L_{barrel}$ : Barrel length

- For its cost-effectiveness, one may reduce
  - TPC radius (studied by M. Thomson @ LoI)
  - or the number of layers

- Five alternative SiW-ECAL models have been studied for baseline detector ILD_o1_v05
- Other configurations are the same for all models (total W thickness, 2 stacks, 1:2 ratio of W thickness, cooling layers, carbon fibre, ...)

| 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 |
| 12 layers | 7 | 5.32 |
| | 4 | 10.64 |
| 10 layers | 6 | 6.65 |
| | 3 | 13.30 |

# Simulations & softwares in use

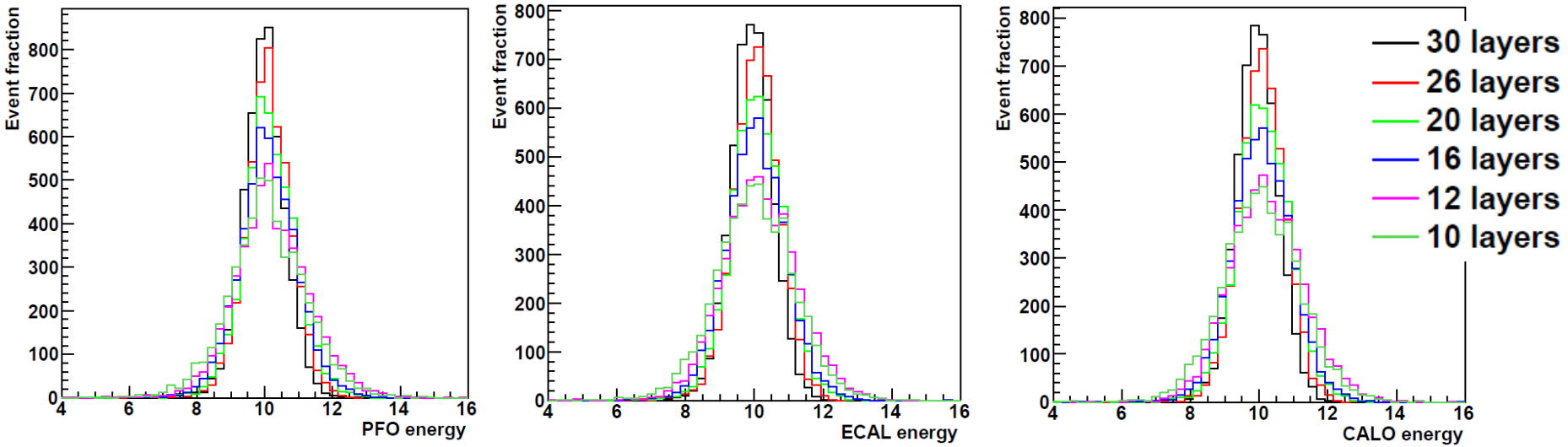
- Calibration are checked using
  - 5000 photons at 10 GeV
  - 5000 $K_L$'s at 10 GeV
  - 5000 muons at 10 GeV
  - **All events are with flat cos(θ) and flat φ,**
    a cut |cos(θ)|<0.7 is however applied to avoid barrel/endcap region

- Energy resolution is estimated for
  - Z → uds events at c.m. energies 91, 200, 360, 500 GeV
  - Photons at 3, 100, 200 and 500 GeV
  - 10k events for each energy

- The simulations are done for all ECAL models
- PandoraPFANew in ILCSOFT version: v01-16 with latest tracking.

# EM calibration: photons @ 10 GeV

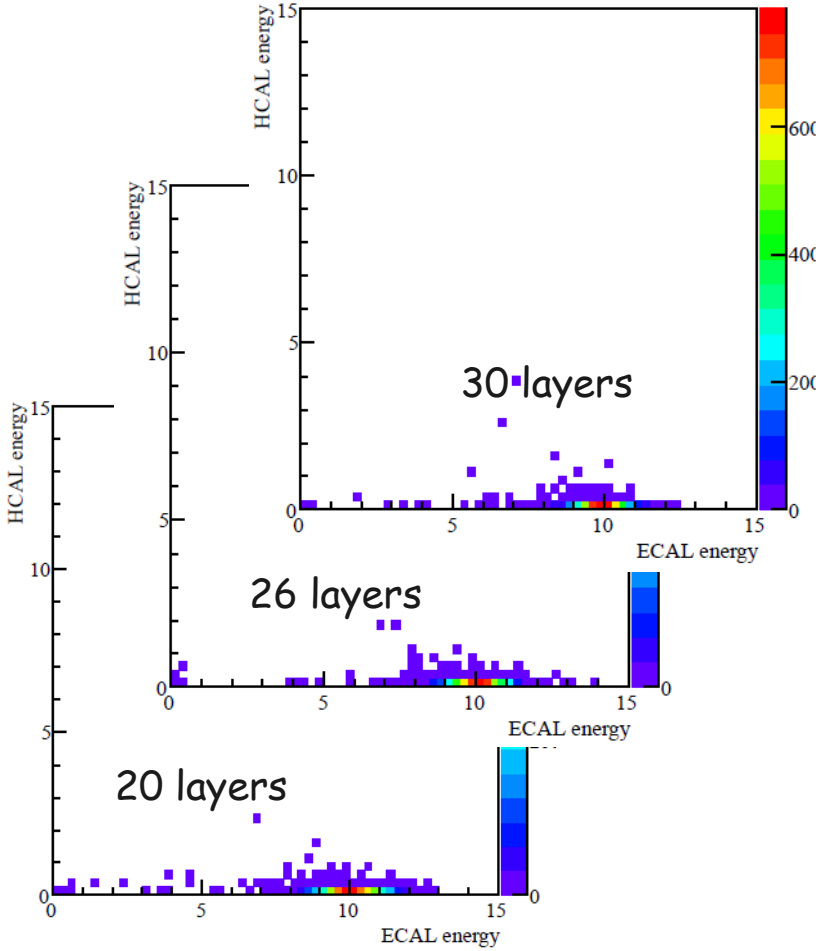
- The EM calibration was re-estimated for each ECAL model

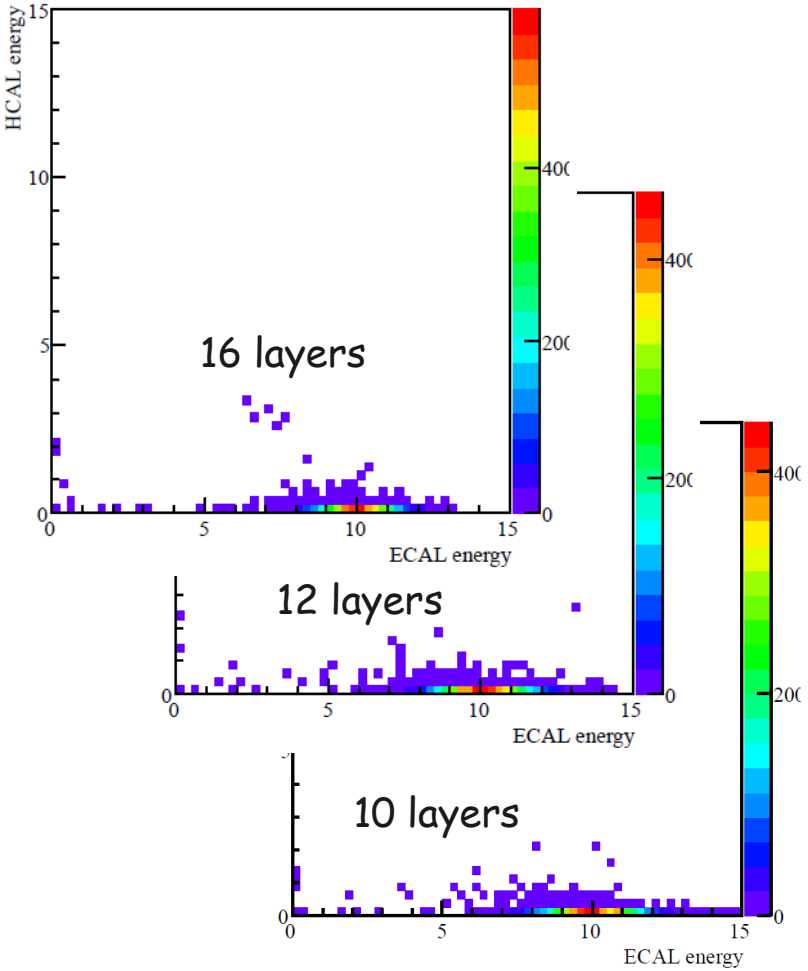



- Distribution of reconstructed energy, fraction of energy in ECAL and total calometer energy are shown
- Calibration looks good for all ECAL models

# EM calibration: photons @ 10 GeV

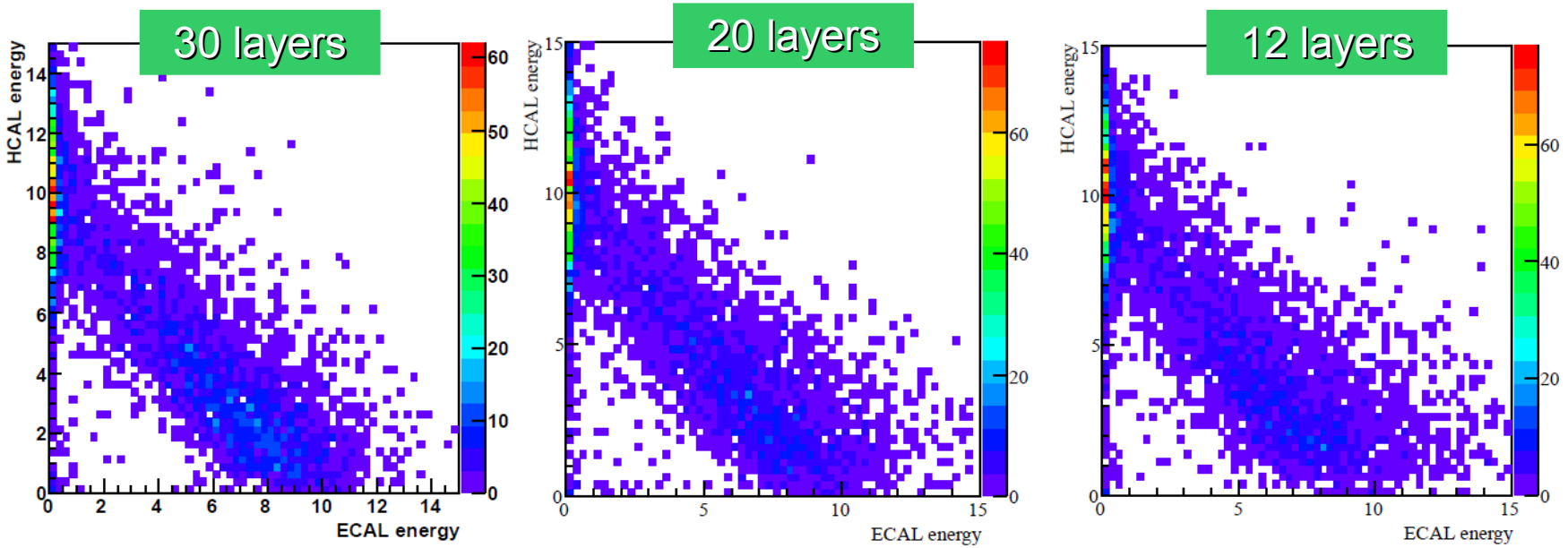
- Check of EM calibration by looking at HCAL energy vs ECAL energy
- Energy division between HCAL and ECAL looks reasonable for all models



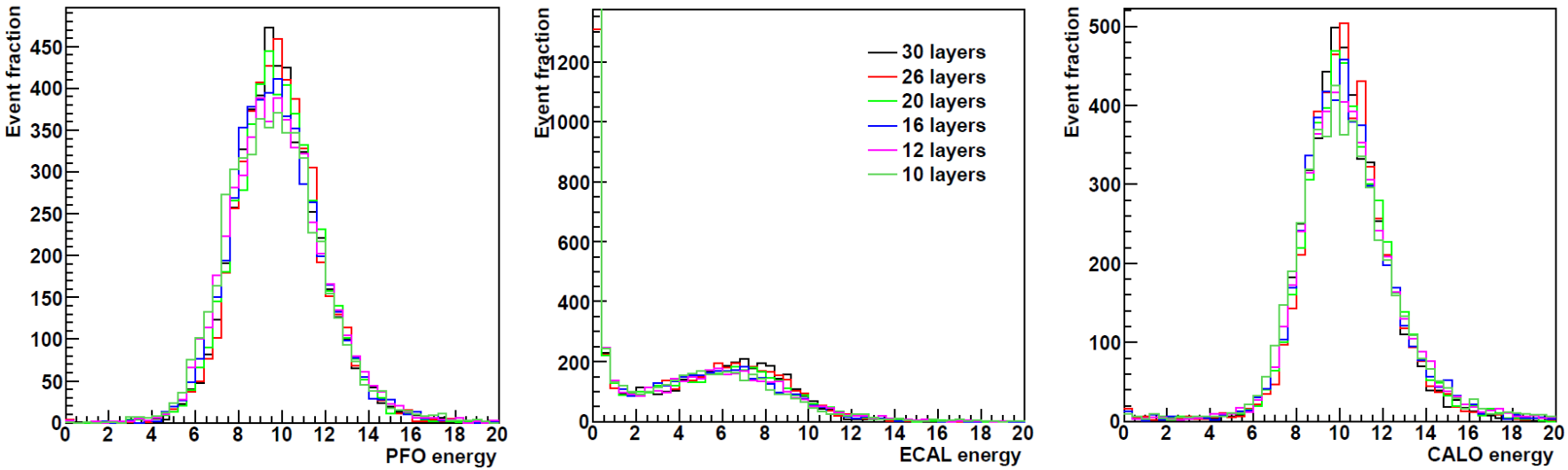
# Check for HCAL calibration: $K_L$'s at 10 GeV

- HCAL calibration is checked using $K_L$ events with energy 10 GeV with flat cos(theta) and phi
- Division between HCAL and ECAL energies needs to be taken in to account




- No large differences observed for different ECAL models

# Check for HCAL calibration: $K_L$ at 10 GeV

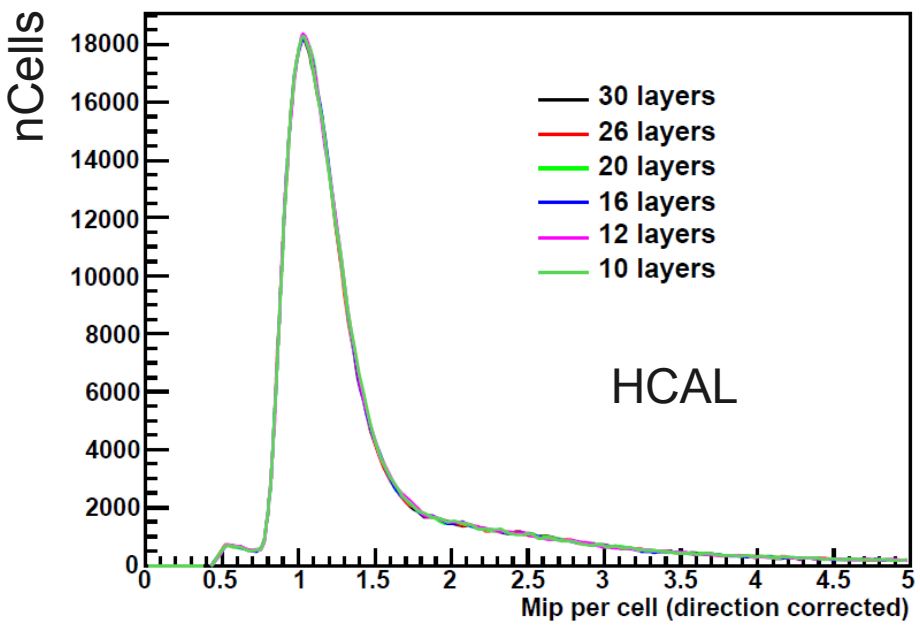


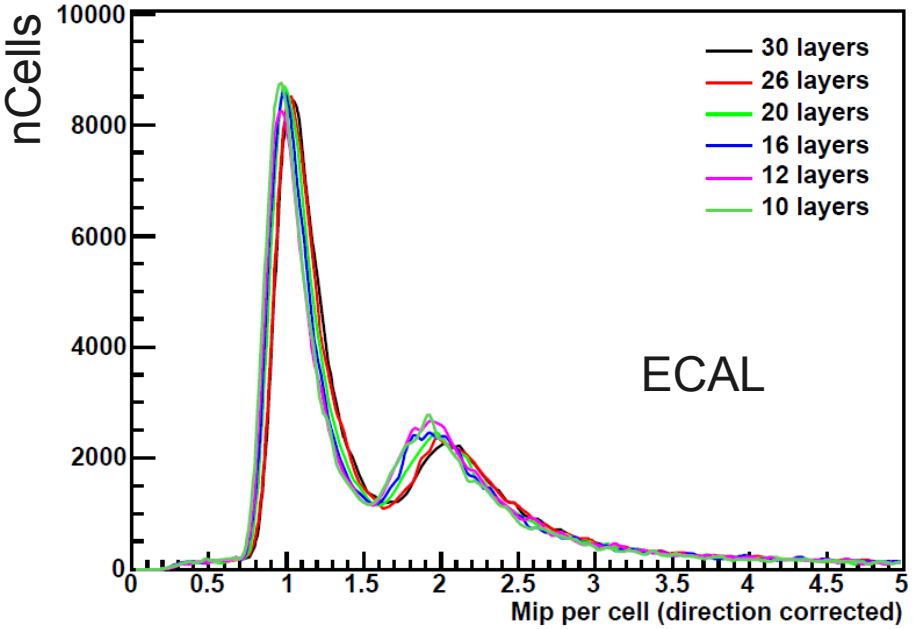

- Energy distributions of reconstructed $K_L$ look reasonable
- Fraction of energy deposited in the ECAL is similar for all models

# Check MIPS calibration: muon at 10 GeV

- MIP calibration looks reasonable.

ECAL mip distributions were re-normalised by number of entries

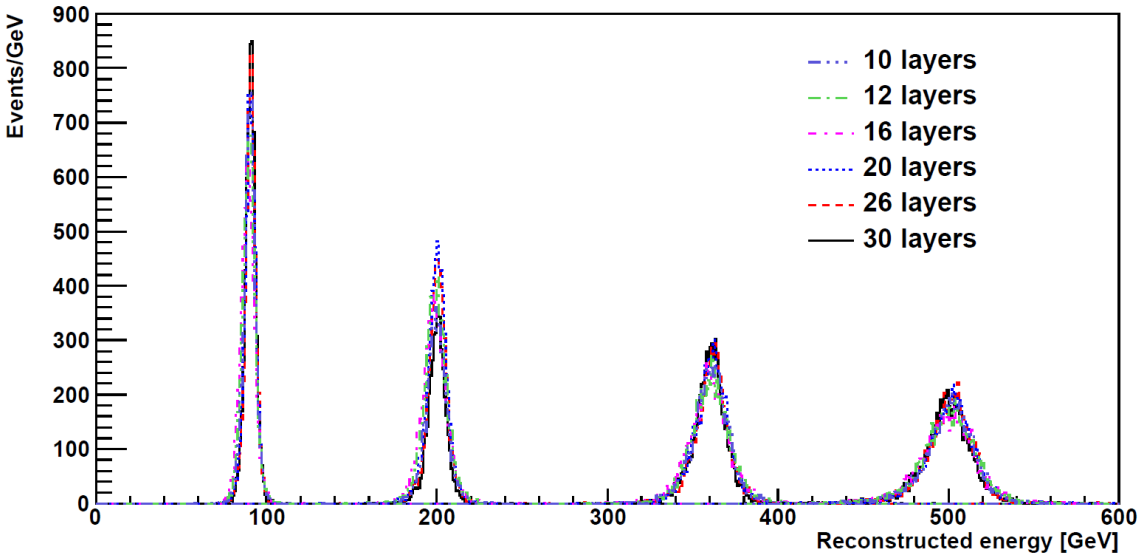



- The HCAL MIP calibration does not change between models
- However, the ECAL MIP calibration constants need to be retuned,
  - these constants were simply rescaled by W thickness
  - there are differences between models but the effect is very small

# Jet & photon energy resolution study for ECAL performance

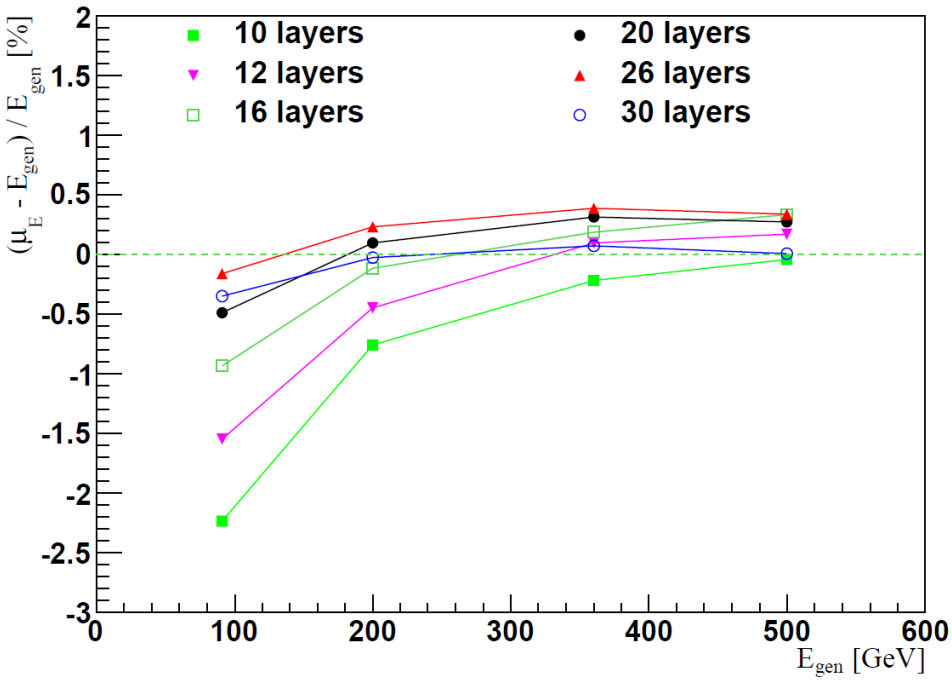
# Z → uds events: linearity



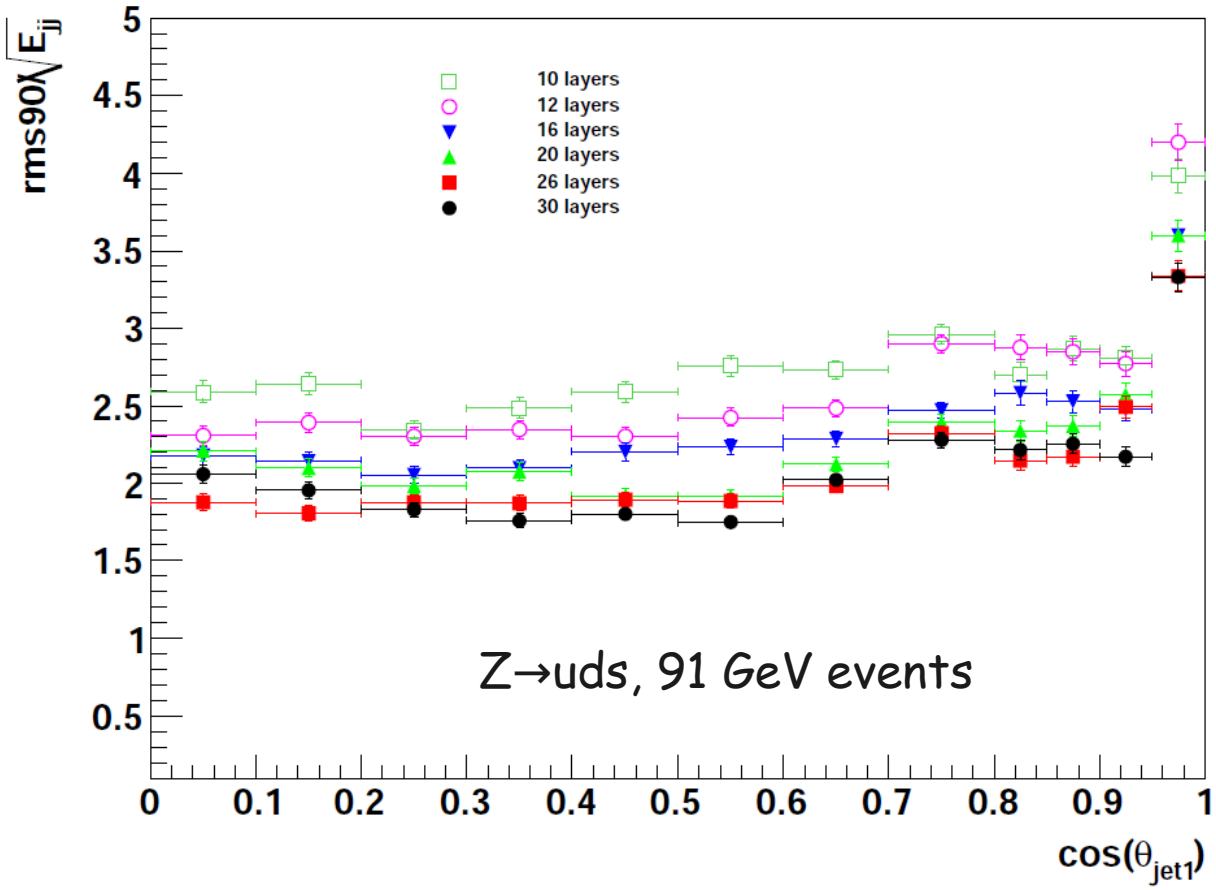

- Distributions of reconstructed total jet energy for all ECAL models and for events at c.m. energies 91, 200, 360, 500 GeV are shown.
- Reasonable mean values obtained.

- Residual value $(\mu_E - E_{gen})/E_{gen}$ shown in% as a function of $E_{gen}$

  where $\mu_E$ is the central value of the distribution and $E_{gen}$ the generated jet energy
- Linearity within 5 ‰ for 30-26-20 layers and significantly degraded for other ECAL models



# Jet energy resolution vs cos(θ_jet)



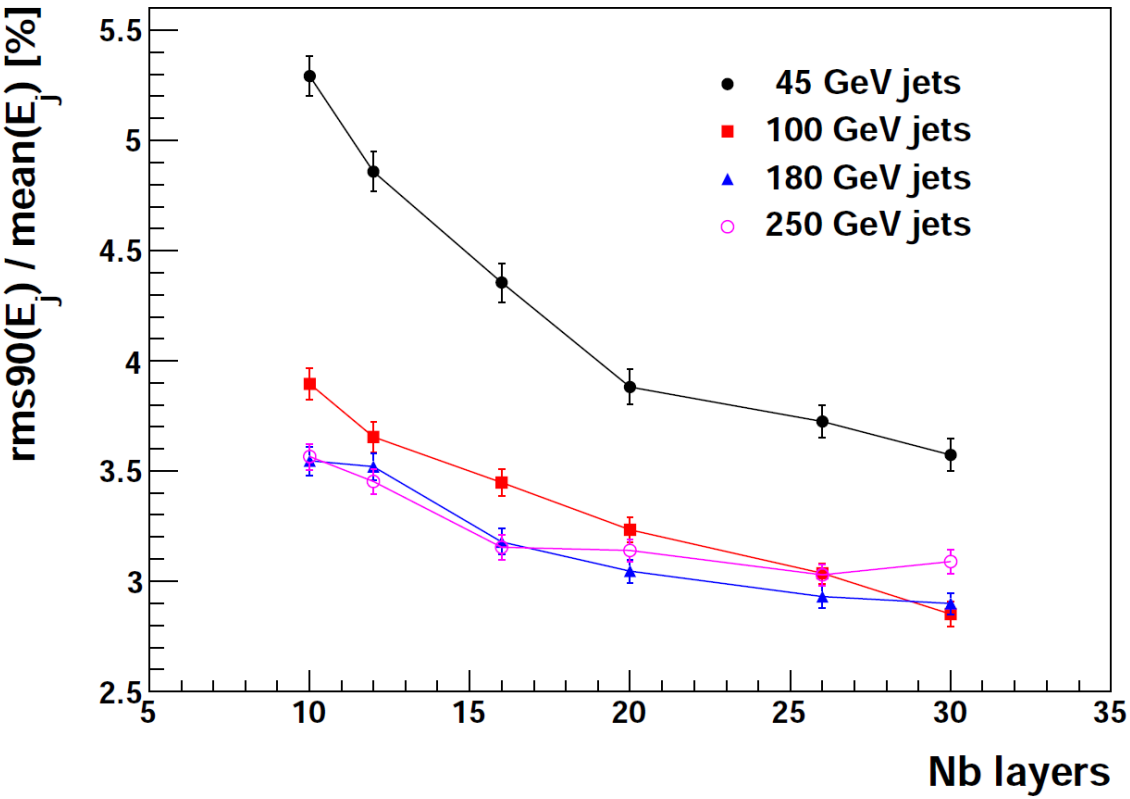

- Jet energy resolution presented in function of cos(θ) of first jet
- No significant problem found among full region of cos(θ)
- Example for Z→uds 91 GeV sample

# Jet energy resolution

- JER is transformed to single JER and plotted as a function of number of layers for 91, 200, 360, 500 GeV Z → u/d/s.

- 9% of degradation is observed going from 30 to 20 layers for 91 GeV sample and more significant to lower number of layers
- effect is less important for higher energies

Single JER presented in function of Nb of layers. A cut |cos(theta_jet)| < 0.7 is applied to avoid the Barrel/Endcap overlap area

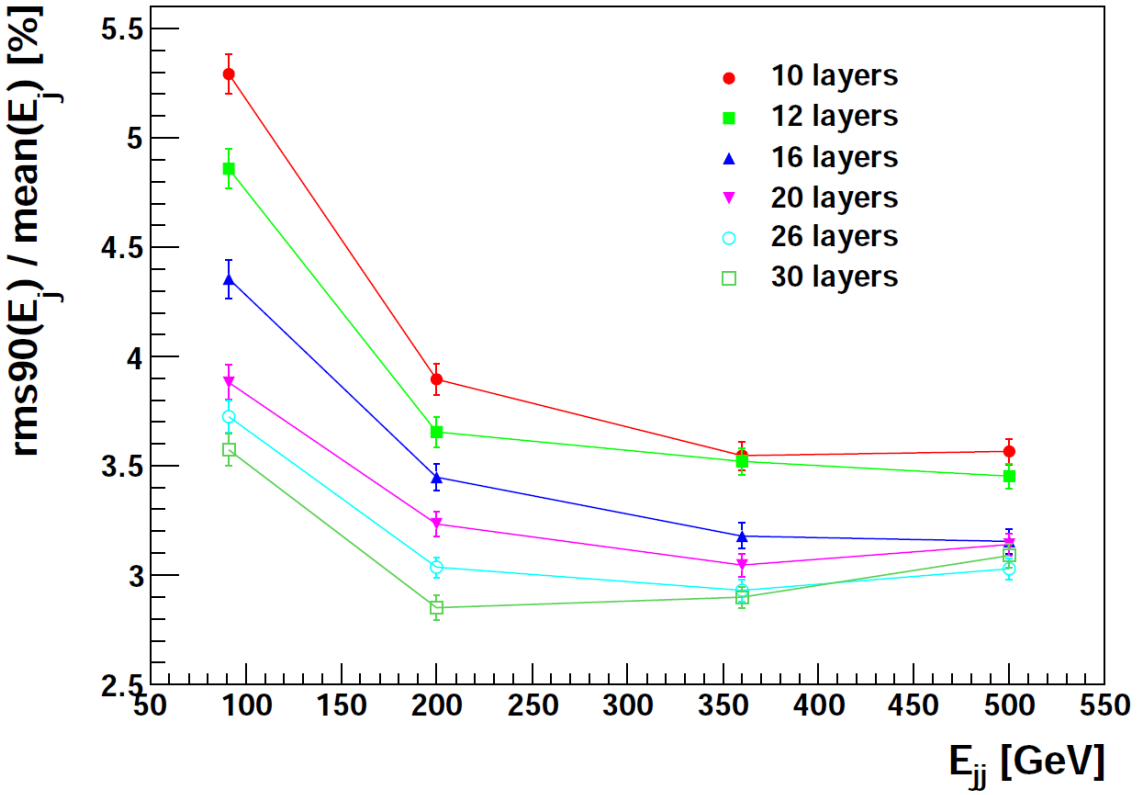



Single JER shown in function of number of layers. The error bars are taken from a fit.

$$\frac{\mathrm{rms}_{90}(E_j)}{E_j} = \frac{\mathrm{rms}_{90}(E_{jj})}{E_{jj}}\sqrt{2}$$

# Jet energy resolution vs Energy

- Same behavior for all models: JER rather flat for energies 200 – 500 GeV, increases towards low jet energy.
-

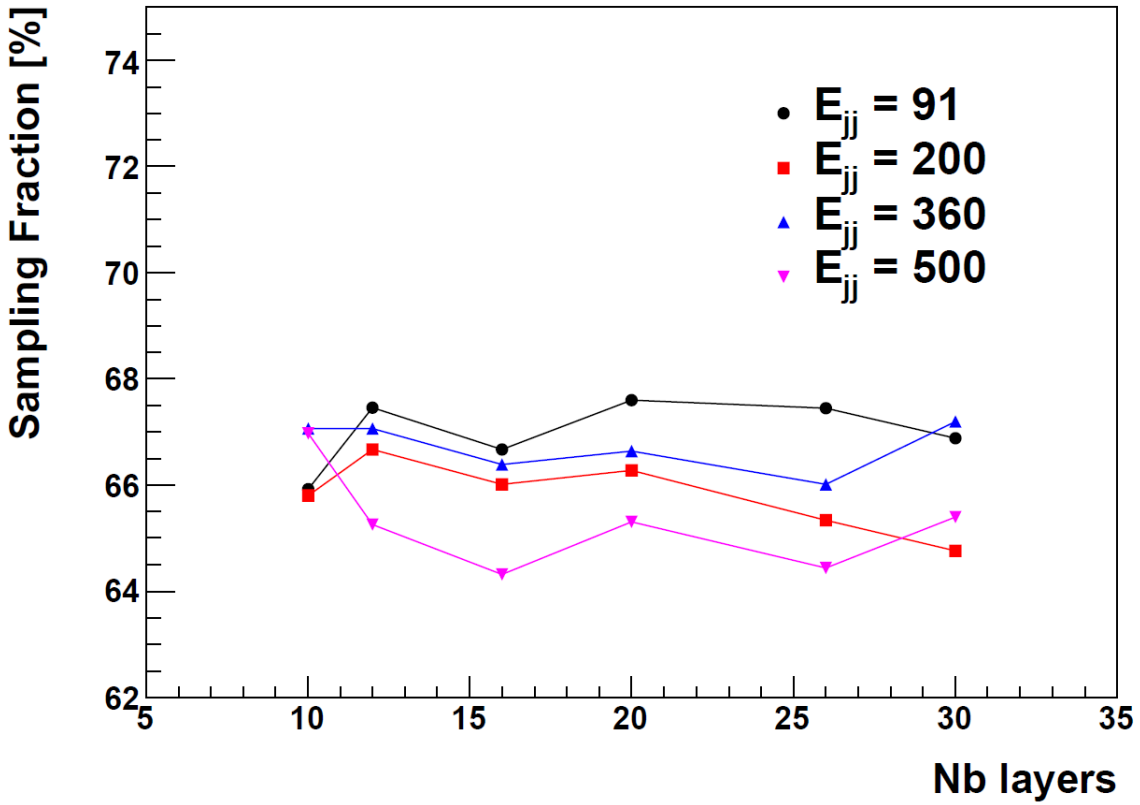



Single JER in function of C.M. energy for ECALs with different number of layers.

# Sampling fraction

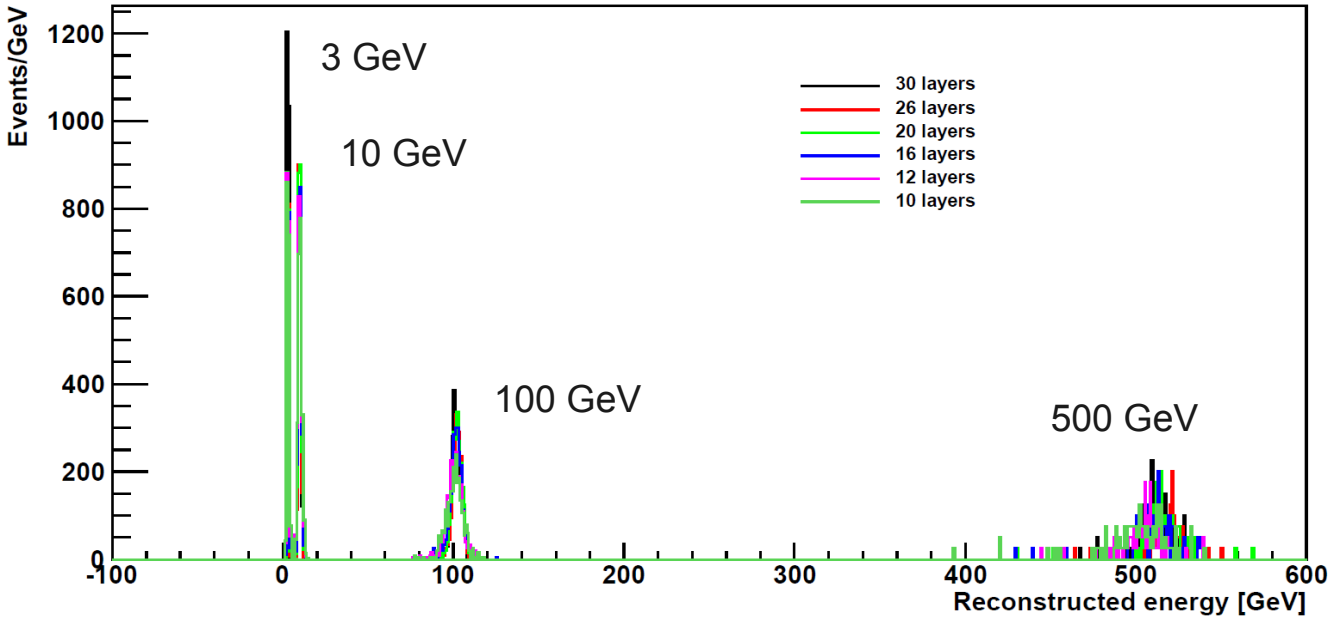
$$Sampling\ Fraction = \frac{n}{N}$$

N : population size (total number of events)
n : sample size – chosen to be within Mean ± σ



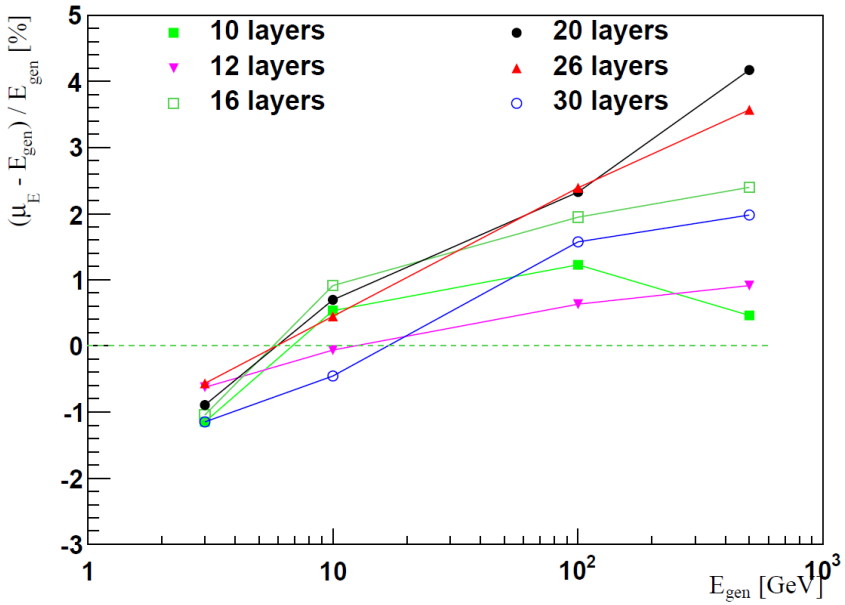

- Sampling fraction (SF) shown for different jet energy as a function of number of layers
- SF is comparable between ECAL models

# Photon energy: linearity

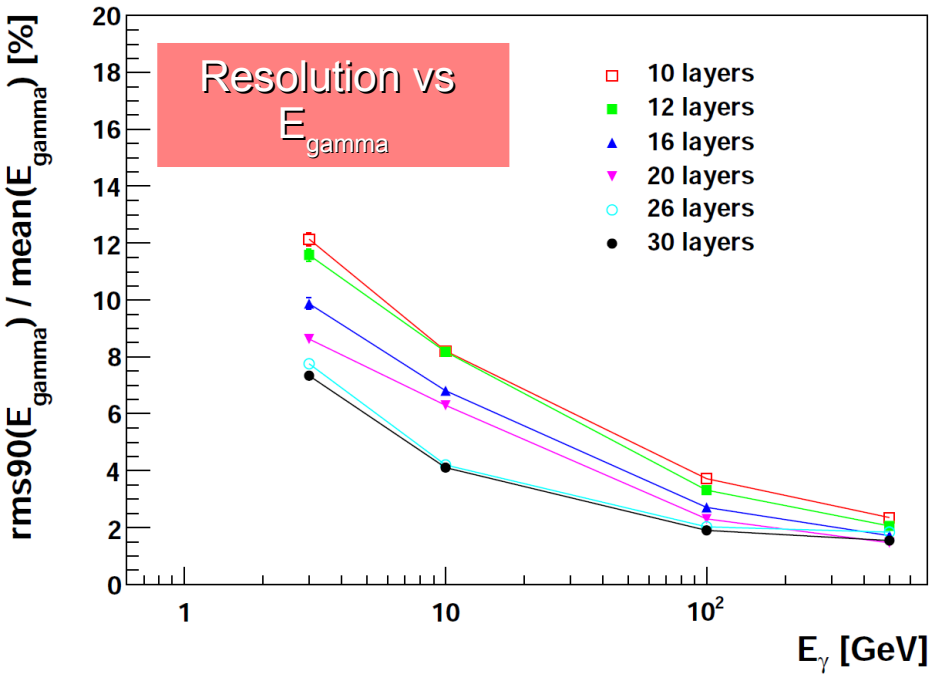


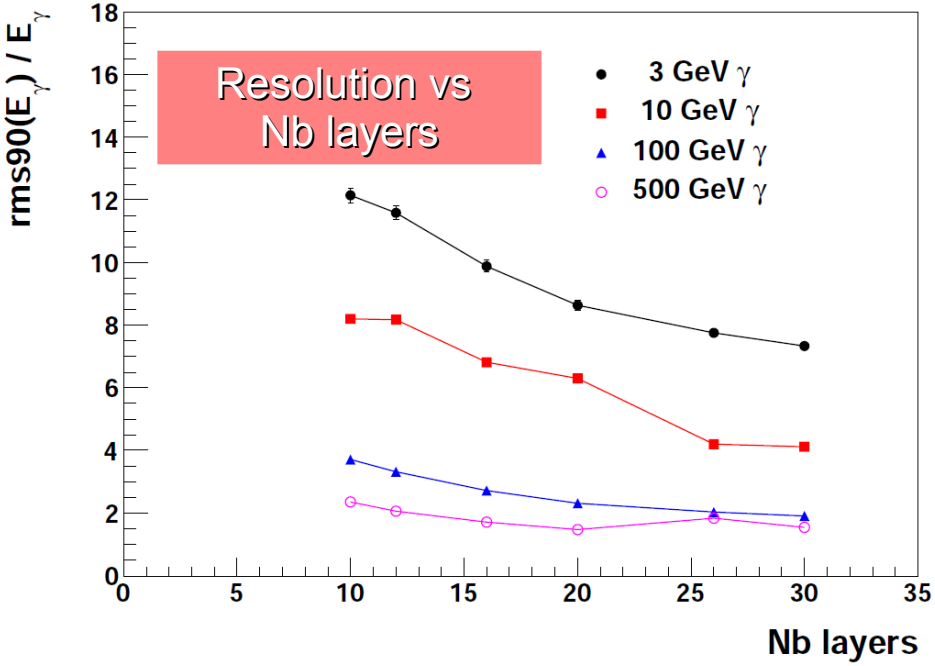

Distributions for photon at 3 GeV were normalised to a same number - just for plotting facilities.

- Reconstructed photon energy distributions for all ECAL models
- Mean values look reasonable



# Photon energy resolution




- Photon energy resolution shown in function of generated photon energy for different ECAL models (left) and in function of number of layers for different energy (right)
- Slight degradation observed going from 30 to 20 layers and quite significant with smaller number of layers (16 downto 10)

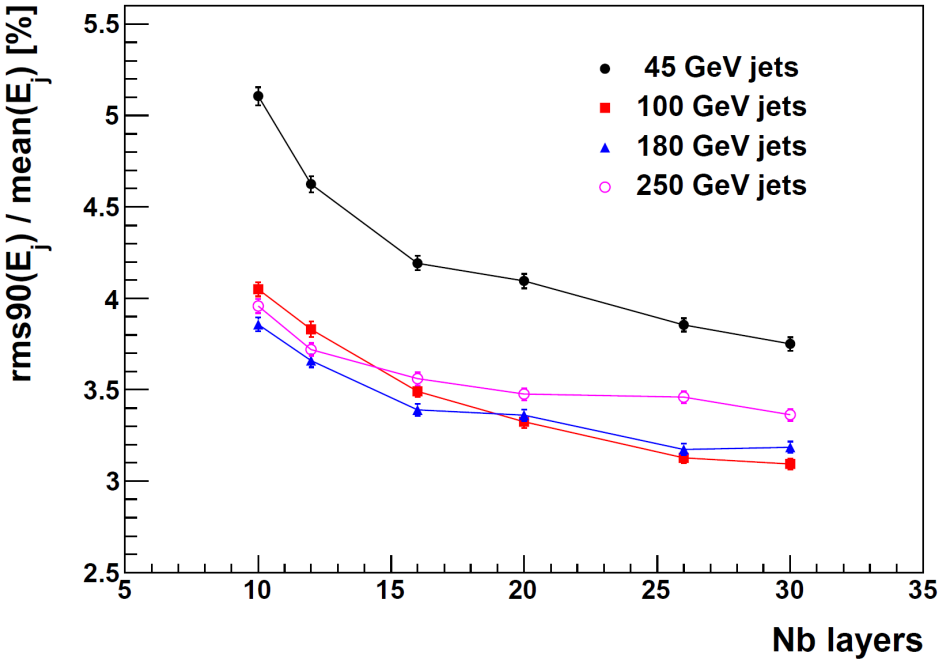
# Summary

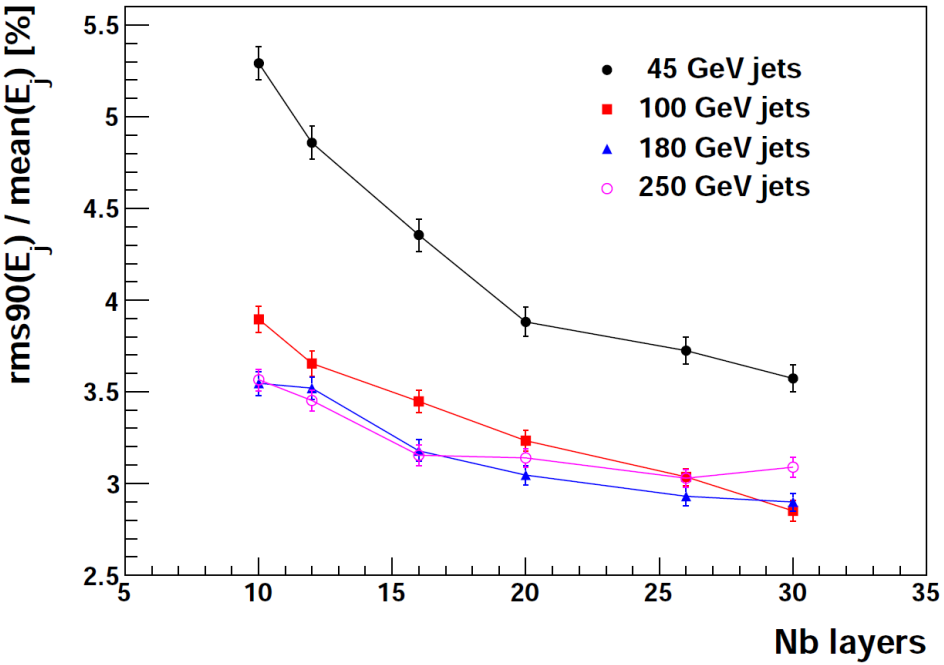
- Degradation of ~9% in single JER observed for 45 GeV jets going from 30 to 20 layers
- More significant degradation going to smaller number of layers
- Difference between ECAL models is less significant with jet at high c.m. energies (200 – 500 GeV)
- Study of photon energy resolution shows a similar behavior when reducing Si in ECAL

# Extra slides

# Comparison

results for ILD_00 with ILCSOFT v01-13-05
vs ILD_o1_v05 with ILCSOFT v01-16




Presented at ILD analysis meeting 26 Sept 2012

Changes:

- ILD_00 to ILD_o1_v05, new drivers for calorimeters
- New tracking
- PandoraPFA constants were optimised for Jet energy