Optimisation studies of the SiW-ECAL

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LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Calorimeter for ILC

Foreword

- Price vs Performances...
  - E_{CMS} (90, 250, 250, 500 GeV)
  - φ channels ⇒ jets, e, γ
- Price ƒ(Surface of Silicon, Number of chips/channels, Manufacturing (#of processes), ...)

$$\begin{aligned} S_{\text{Si}} &\propto \frac{\left[\pi(R_{\text{TPC}}+e)^2-\pi R_{\text{TPC}}^2\right]}{e_1}\times L_{\text{Barrel}}+\frac{\pi R_{\text{TPC}}^2\times e}{e_1} \\ &= \frac{2\pi R_{\text{TPC}}\times e+\pi e^2}{e_1}\times L_{\text{Barrel}}+\frac{\pi R_{\text{TPC}}^2\times e}{e_1} \end{aligned}$$

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

ECAL parameters

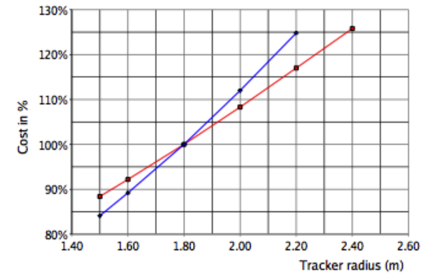


FIGURE 7.4-2. Dependence of the total cost with the size of the detector, in blue when the aspect ratio is kept, in red when the radius only changes.

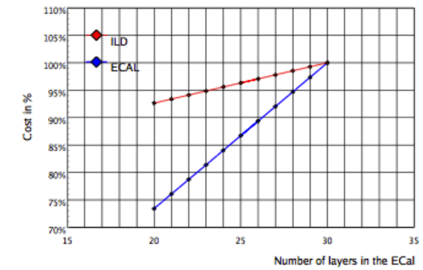


FIGURE 7.4-3. Dependence of the cost with the number of layers in the ECal.

LOI cost scaling laws

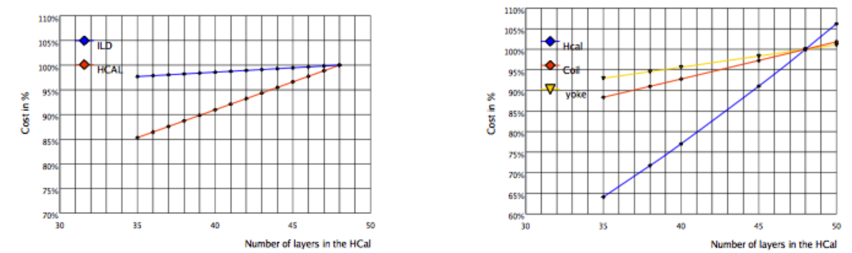
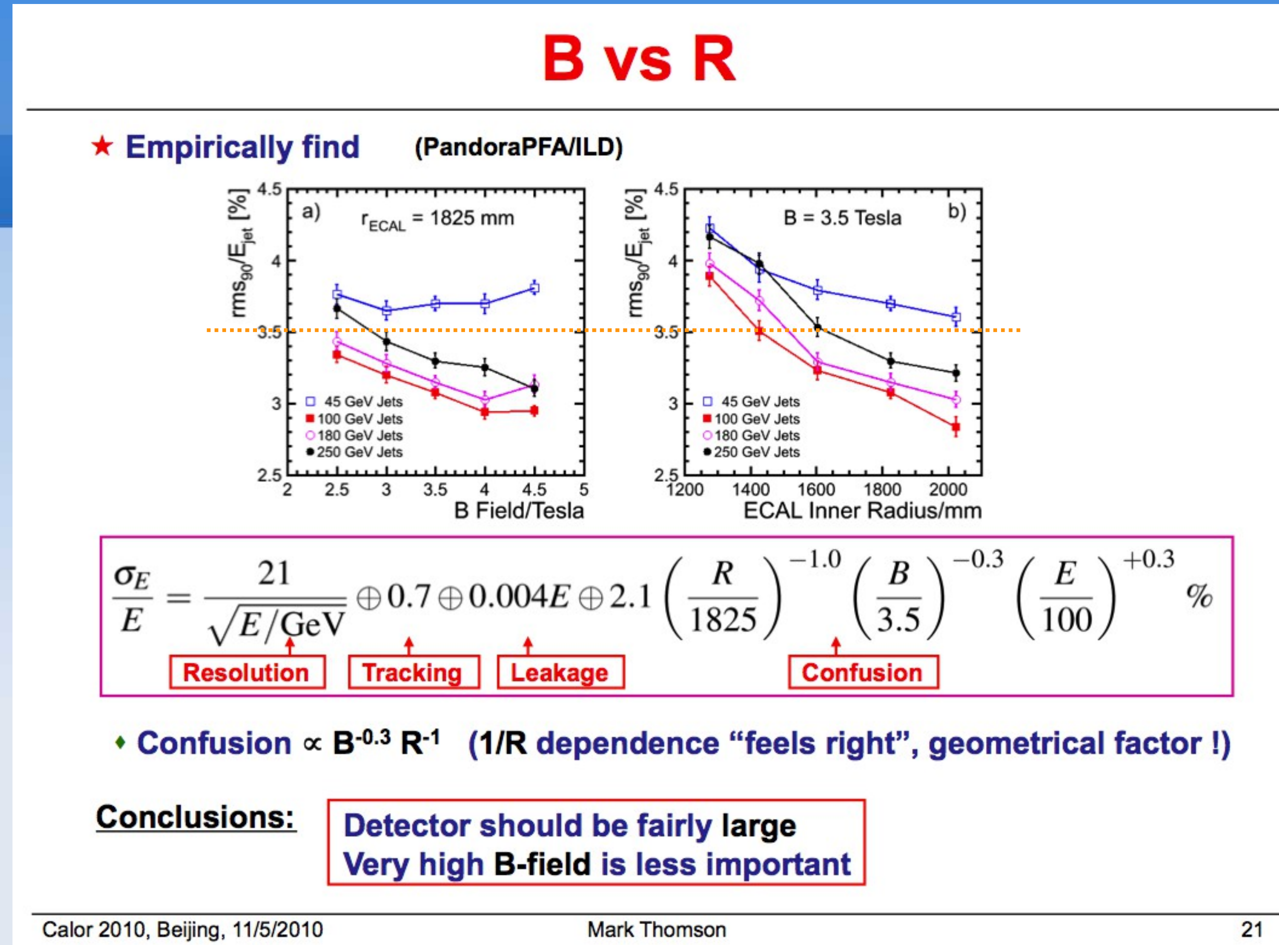


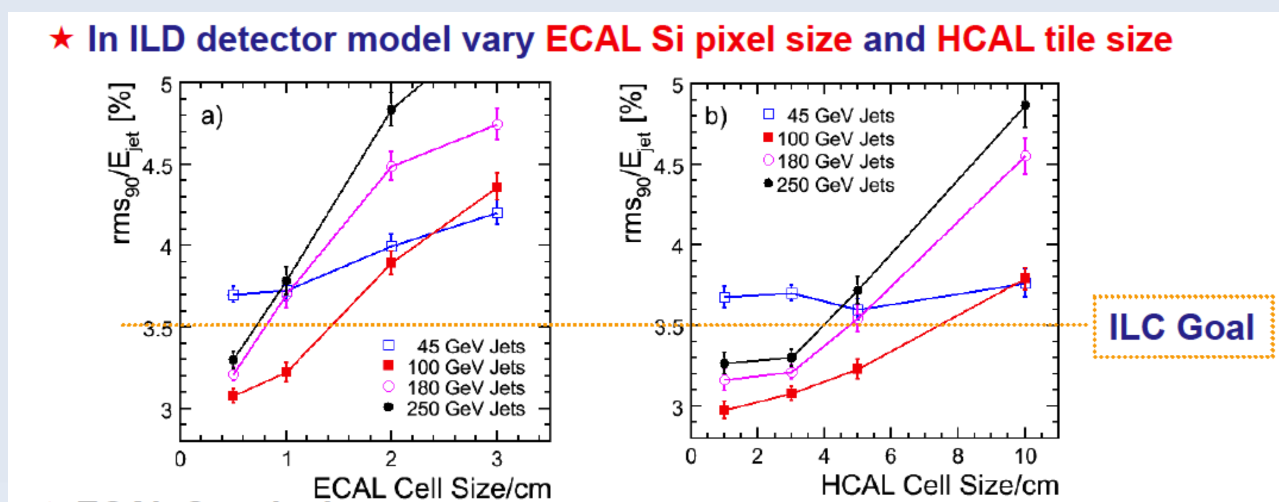
FIGURE 7.4-4. Dependence of the cost with the number of layers in the HCal, on the left if you keep the total number of interaction lengths, on the right if you keep the thickness of the layers.

- Global
  - Inner Radius of Barrel R → Cost ∝ R^2
  - length of TPC → tb checked.
- ECAL
  - Cell Size ℓ_c → Electronics channels ∝ ℓ_c^2
  - Number of layers N_L → Electronics channels, PCBs, manufacturing and Silicon surface ∝ N_L
  - Size of wafers ℓ_w → dead region ∝ $1/\ell_w^2$, cost lesser for small wafers
  - Wafer thickness d_w → Resolution ∝ $\sqrt{d_W}/f_{sample}$
  - Number of alveoli → Dead regions ∝ Number of alveoli (should be an odd number): 3 || 5

Studies for ILD LoI

- JER vs R
- jet Energy resolution vs Cell size.
  - PandoraPFA on uds jj events @ various energies
- Is R=1800mm optimal ?





Number of Layers

Trong Hieu Tran (LLR)

Simulated Models

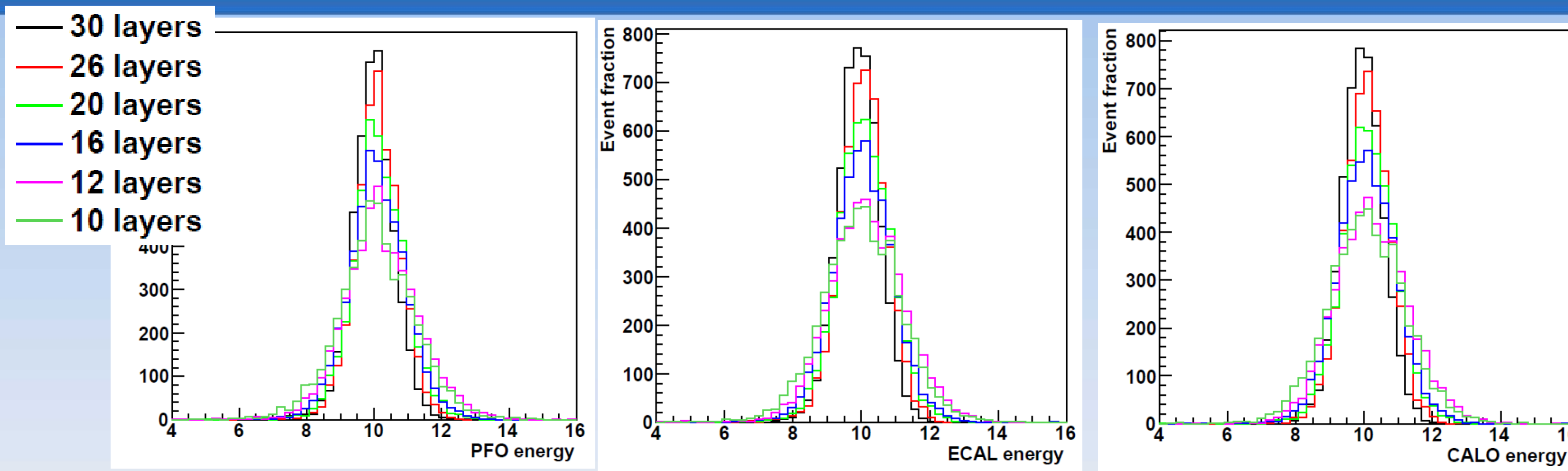
- 5 alternative SiW-ECAL models for baseline detector ILD_o1_v05
- Other configurations are the same for all models
  - total W thickness,
  - 2 stacks,
  - 1:2 ratio of W thickness,
  - cooling layers, carbon fibre, ...

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

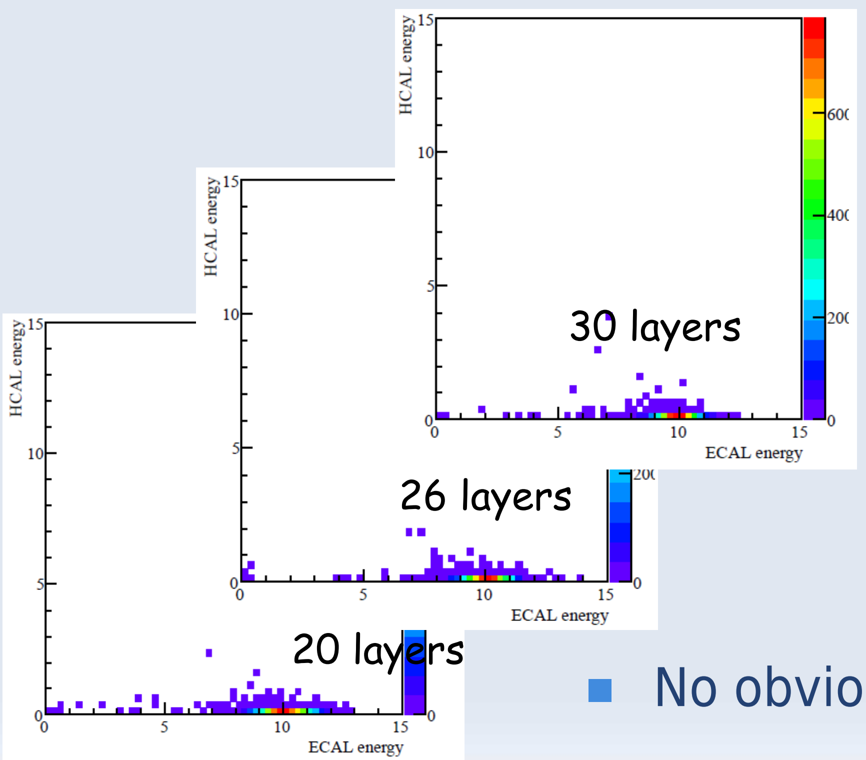
Simulations & softwares in use

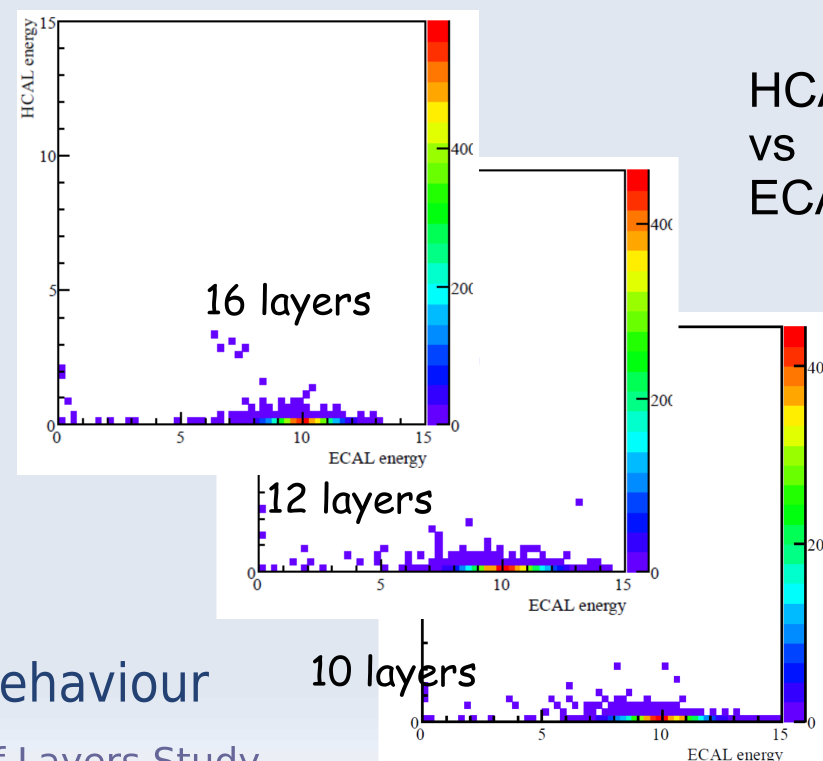
- Calibration are checked using
  - 5000 photons at 10 GeV
  - 5000 K_L's at 10 GeV
  - 5000 muons at 10 GeV
    - All events are with flat cos(θ) and flat φ,
    - a cut |cos(θ)|<0.7 is however applied to avoid barrel/endcap region
- Energy resolution is estimated for
  - Z → uds events at c.m. energies 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



PFO, ECAL, E+HCAL response



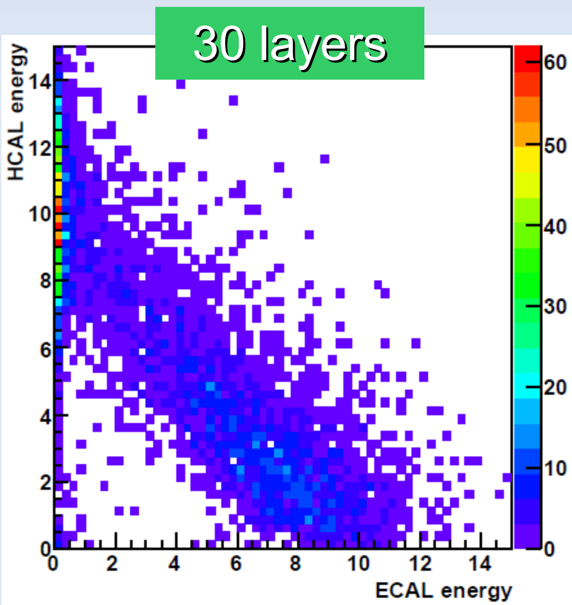


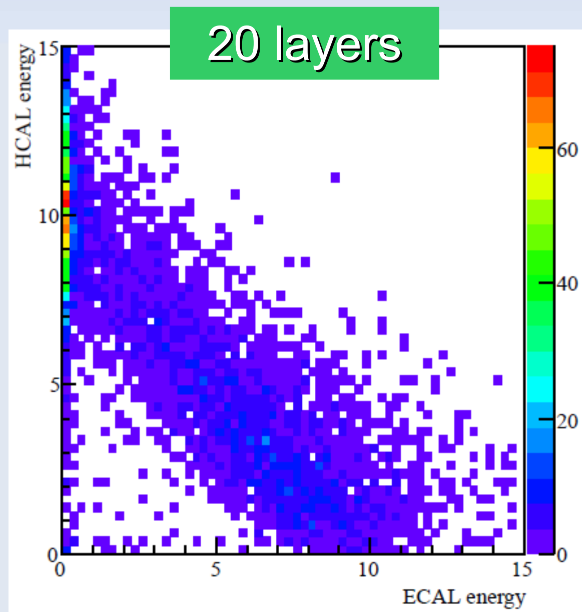
HCAL vs ECAL

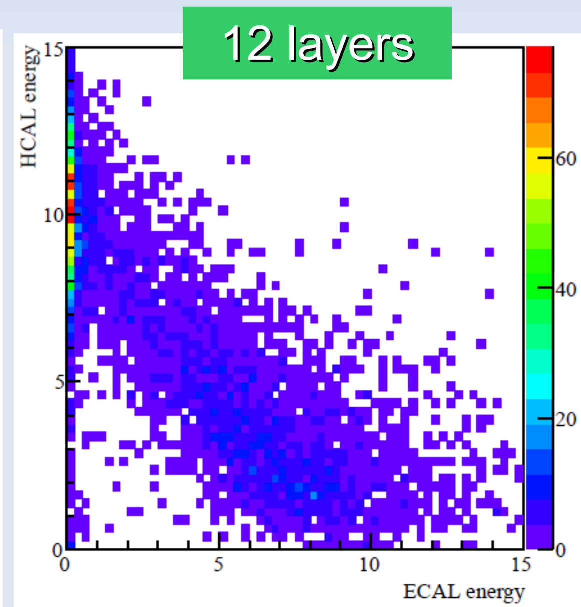
- No obvious mis-behaviour

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

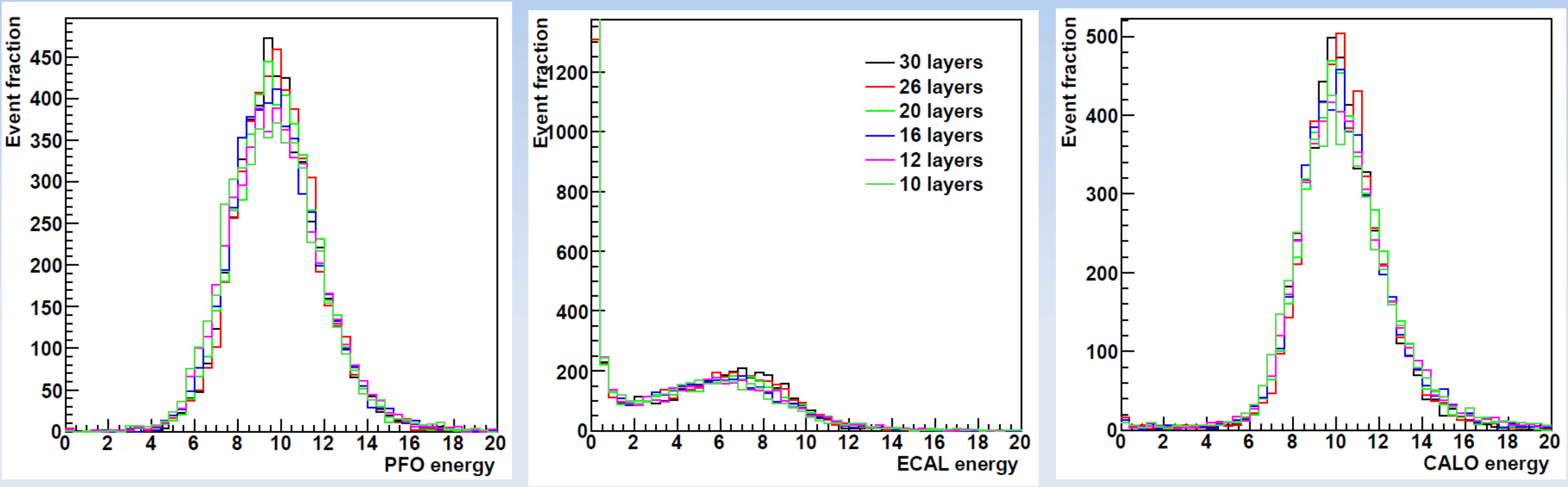






HCAL
vs
ECAL

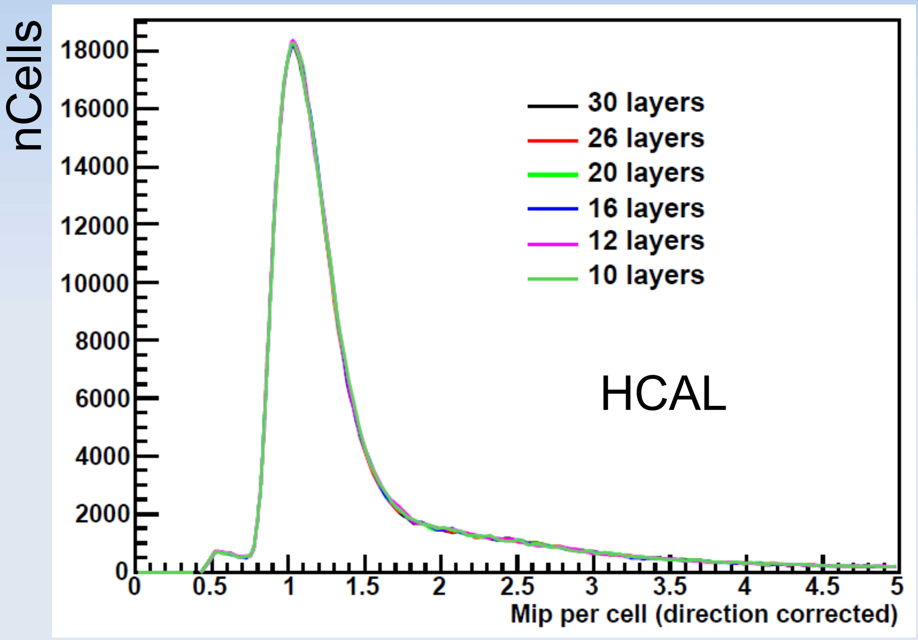
Check for HCAL calibration: K_L's at 10 GeV



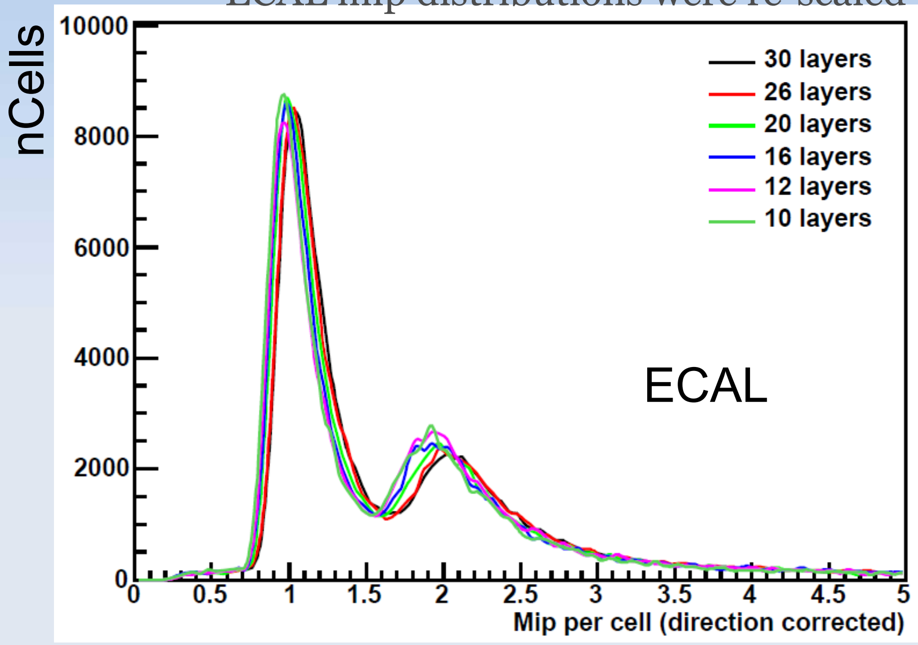
- Energy distributions of reconstructed K_L look reasonable
- Fraction of energy deposited in the ECAL is similar for all models (as expt'd: W thickness driven)

Check MIPS calibration: muon at 10 GeV

- MIP calibration looks reasonable.



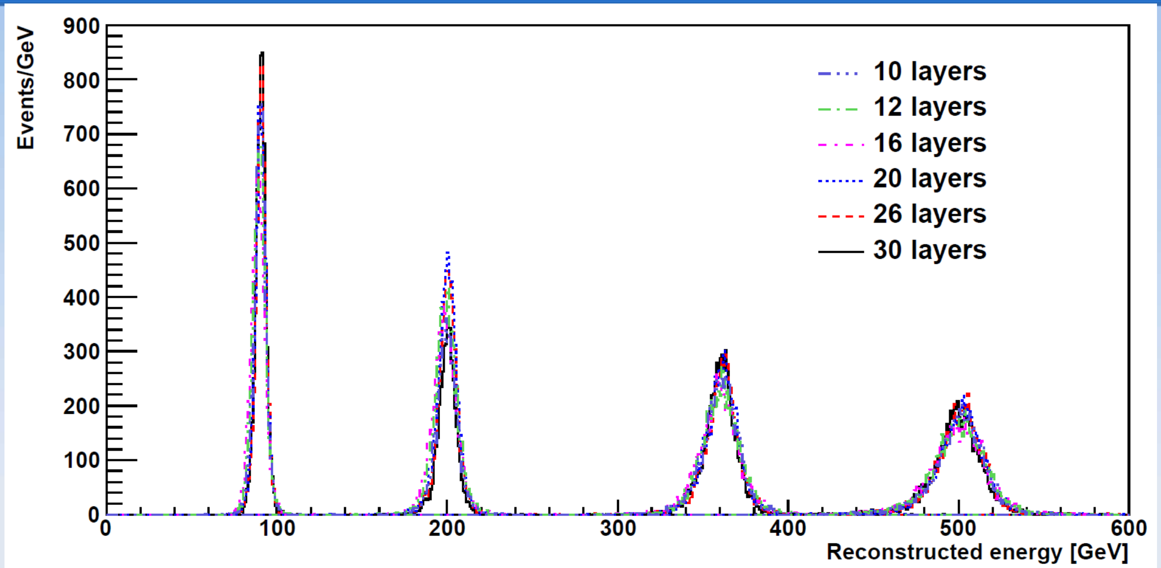
ECAL mip distributions were re-scaled



- 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 (sampling fraction)
- There are differences between models but the effect is very small

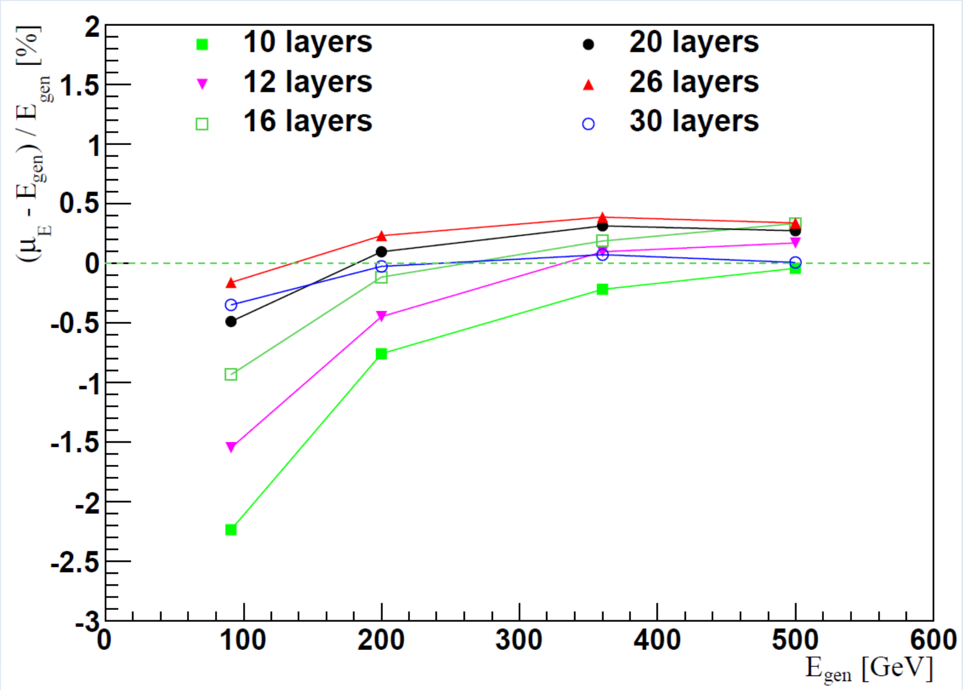
Jet & photon energy resolution study for ECAL performance

Z → uds events: linearity

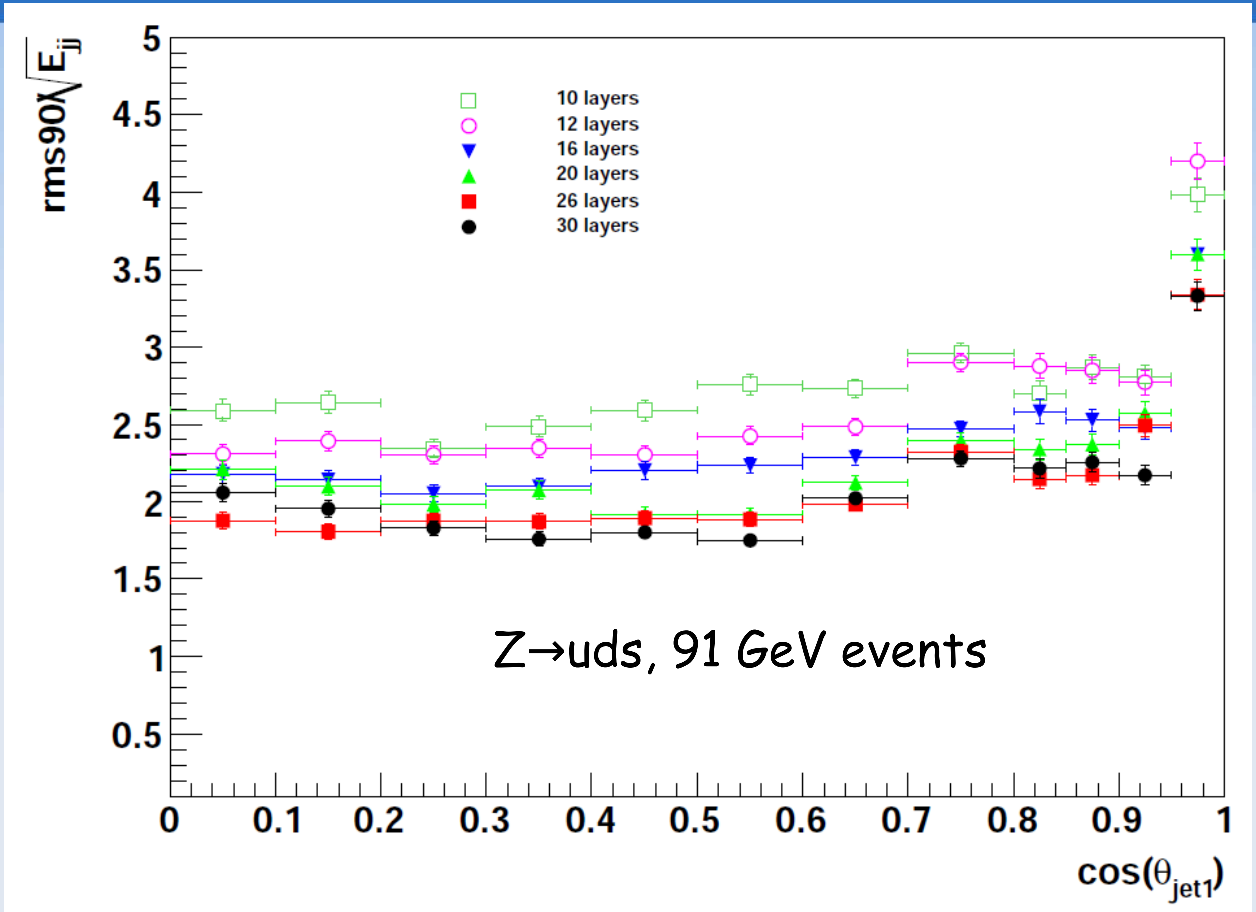


- Distributions of reconstructed total jet energy for all ECAL models and for events at c.m. energies 91, 200, 360, 500 GeV are shown.
- Reasonable mean values obtained.

- Residual value $(\mu_E\text{-}E_{gen})/E_{gen}$ shown in % as a function of E_{gen}
- where µE is the central value of the distribution and Egen the generated jet energy
- Linearity within 5 ‰ for 30-26-20 layers and significantly degraded for other ECAL models

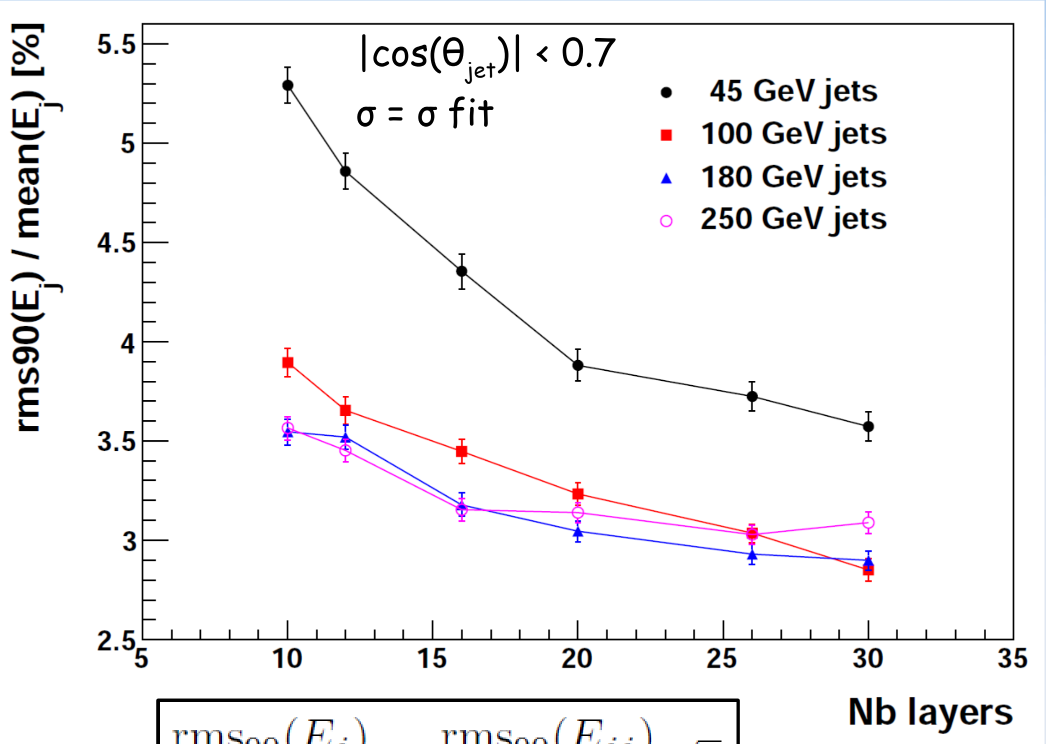


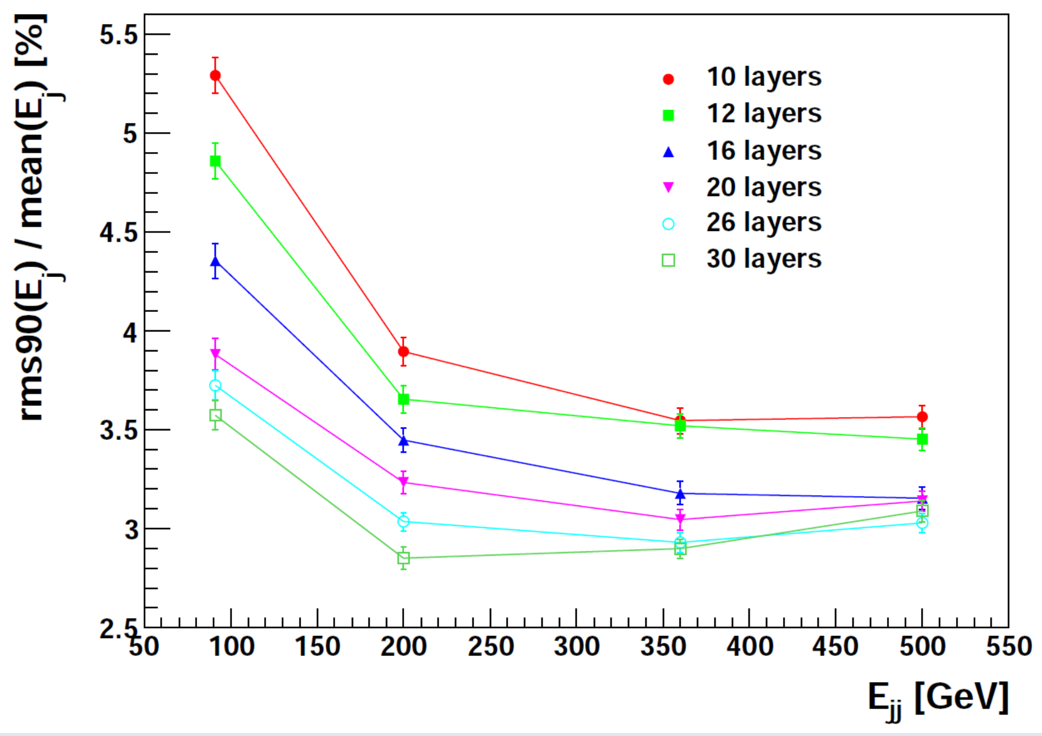
Jet energy resolution vs cos(θ_{jet})



- 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





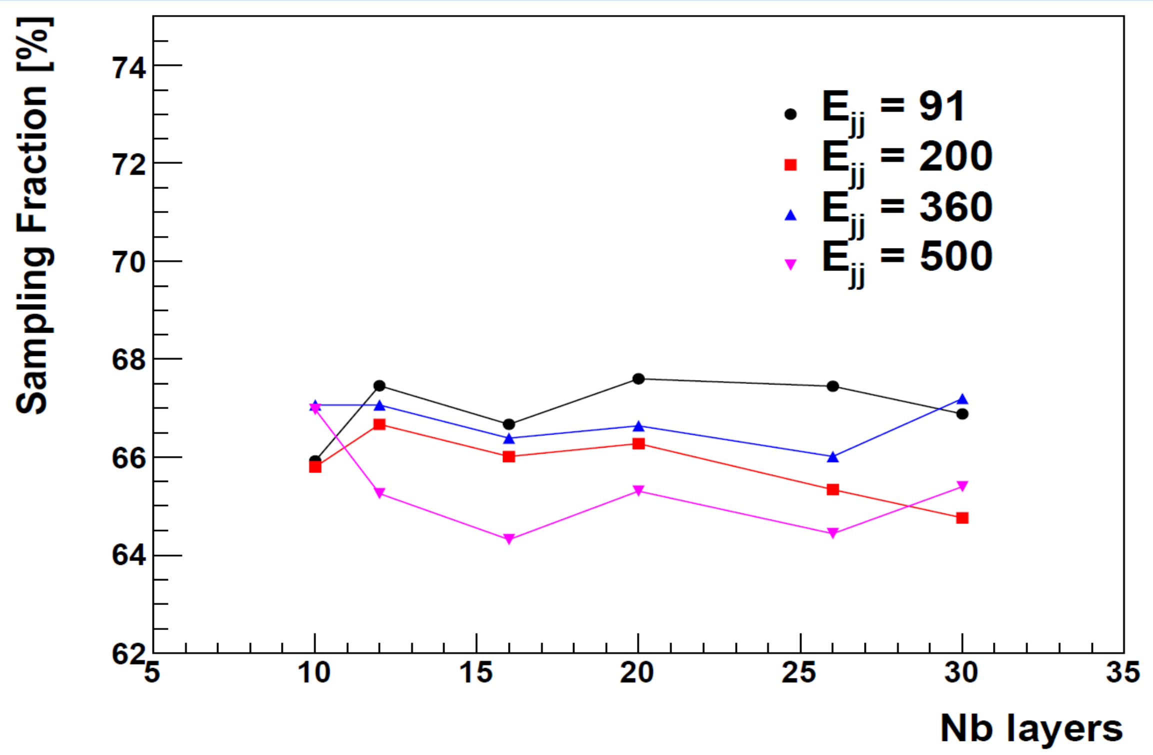
$$\frac{\mathrm{rms}_{90}(E_j)}{E_j} = \frac{\mathrm{rms}_{90}(E_{jj})}{E_{jj}}\sqrt{2}$$

- **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**

Purity of jet sample in ±1σ

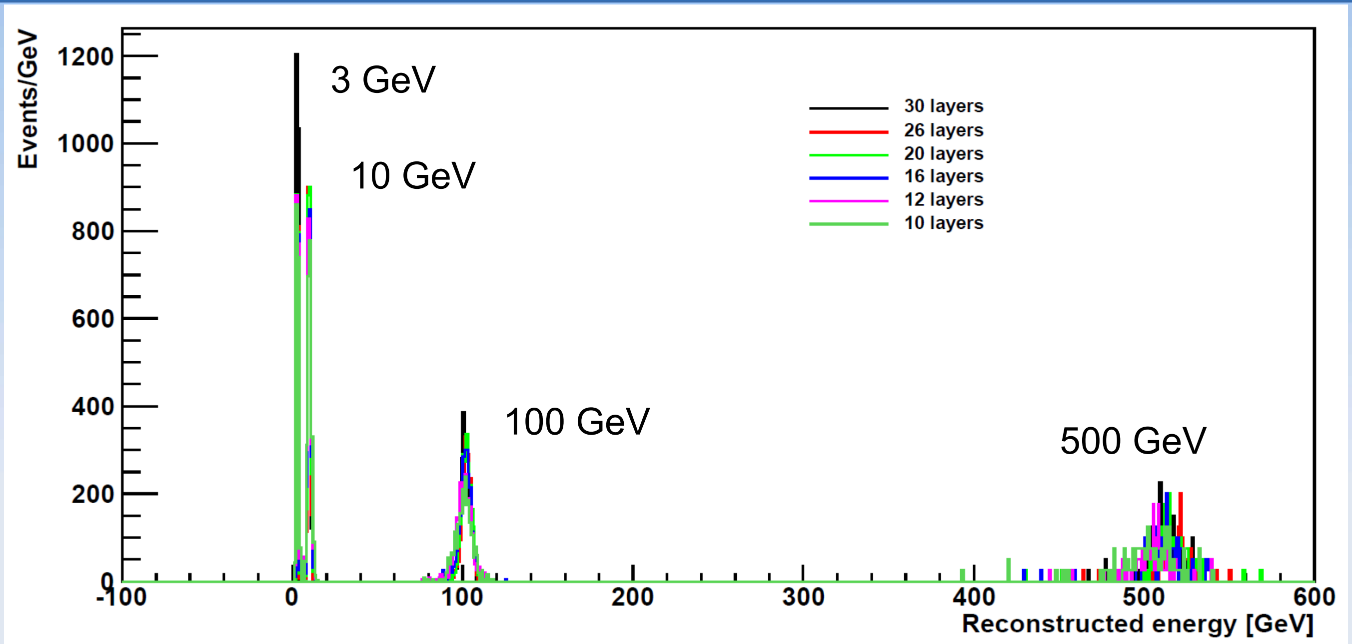
$$Sampling\ Fraction = \frac{n}{N}$$

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

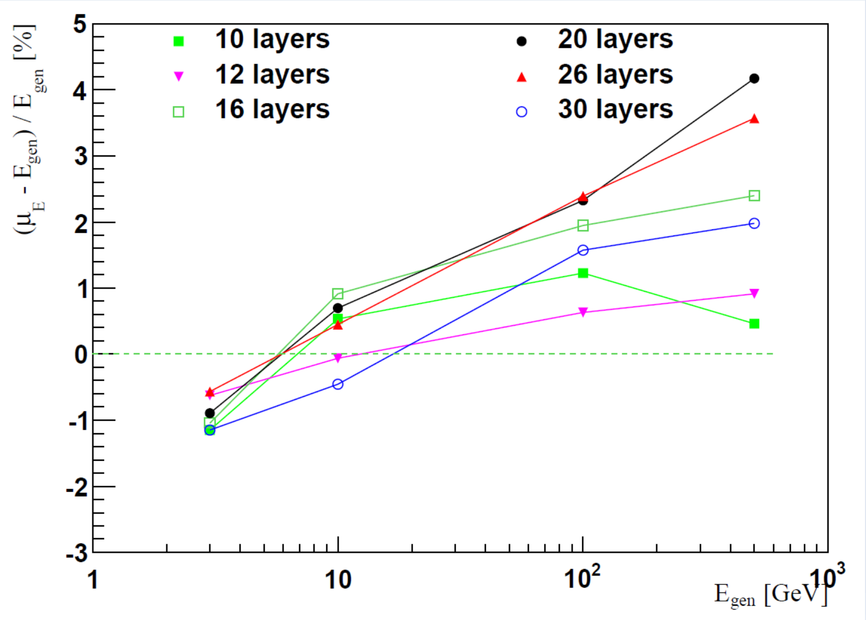


- Purity (or Sampling Fraction in the Bulk of the distribution) shown for different jet energy as a function of number of layers
- No dependance in N_{layers}

(PandoraPFA) Photon energy: linearity

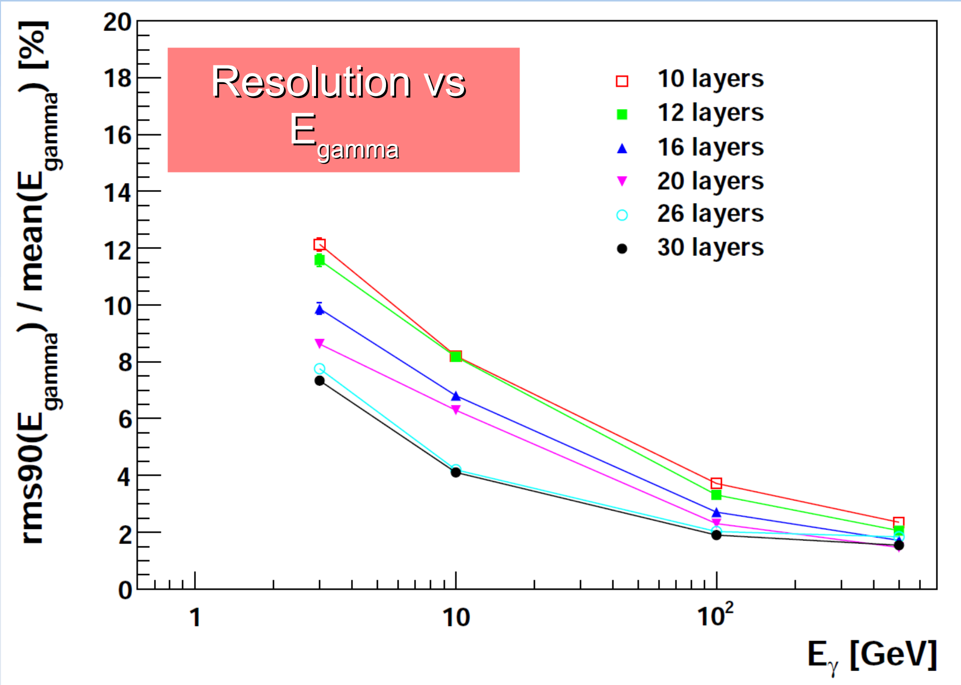


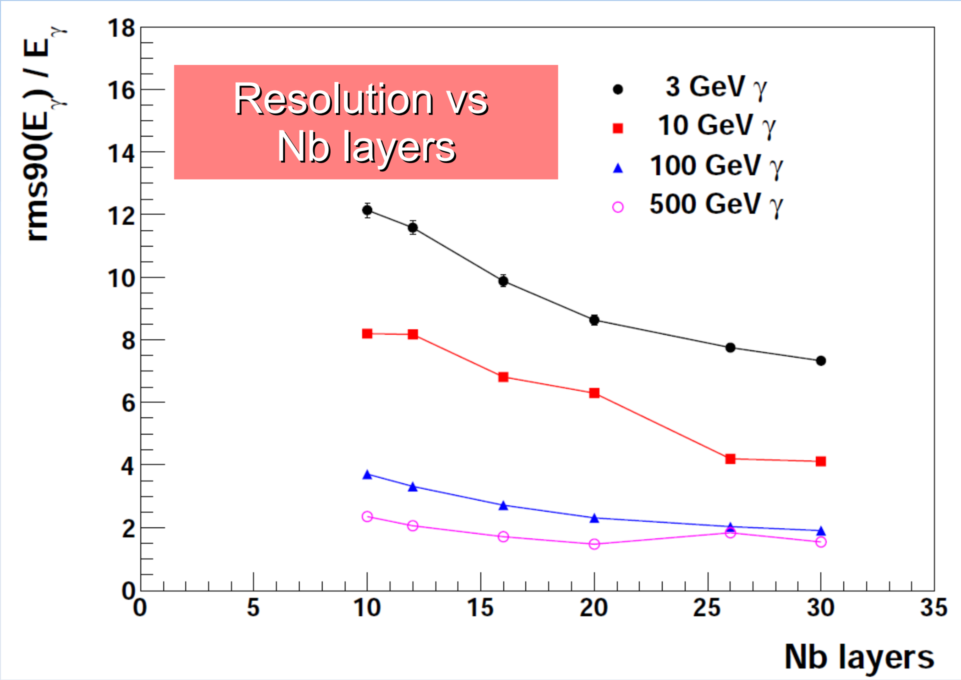
Distributions for photon at 3 GeV were normalised to a same number - just for plotting facilities.



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

Photon energy resolution





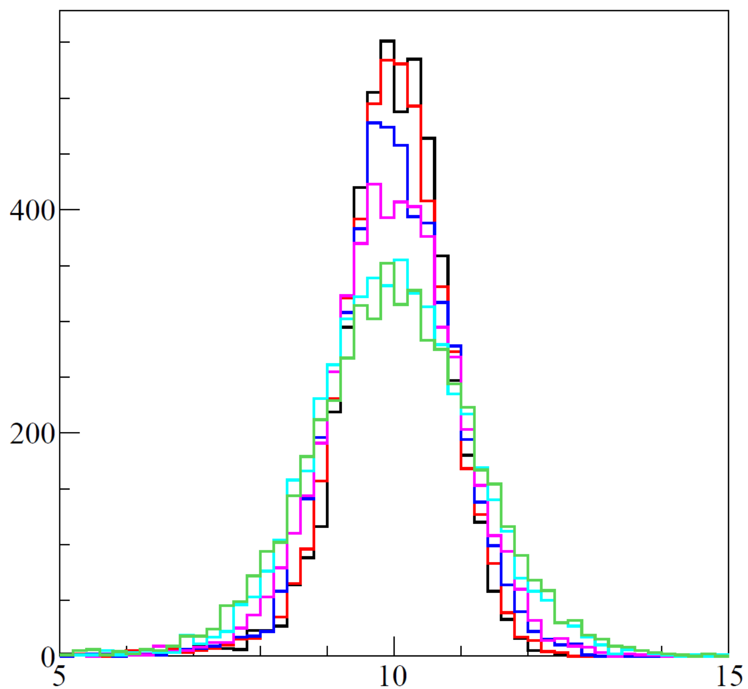
- Photon energy resolution shown in function of generated photon energy for different ECAL models (left) and in function of number of layers for different energy (right)
- Slight degradation observed going from 30 to 20 layers and quite significant with smaller number of layers (16 ↘ 10)

Ecal performance vs nb of layers using Garlic

Trong Hieu Tran (LLR)

(Preliminary results)

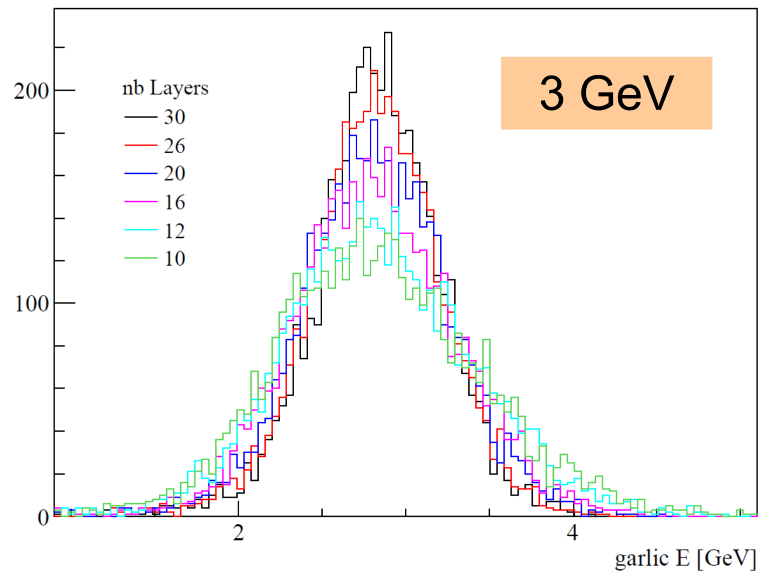
Garlic calibration

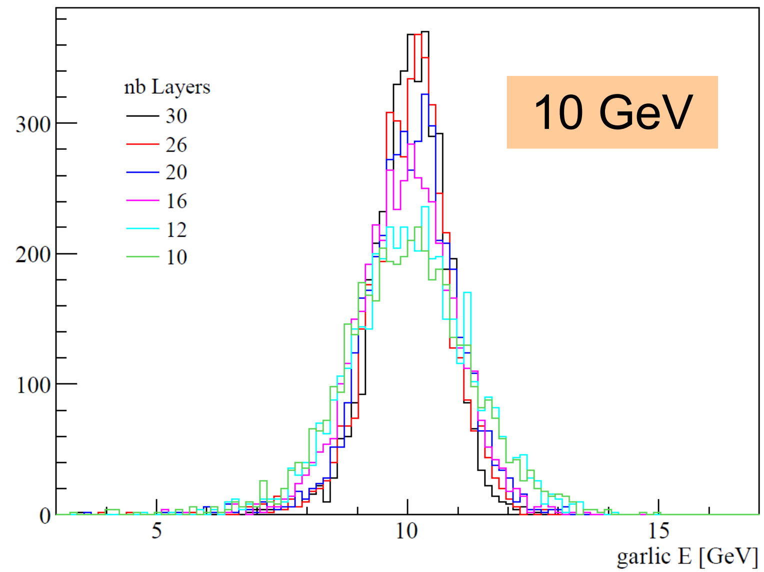


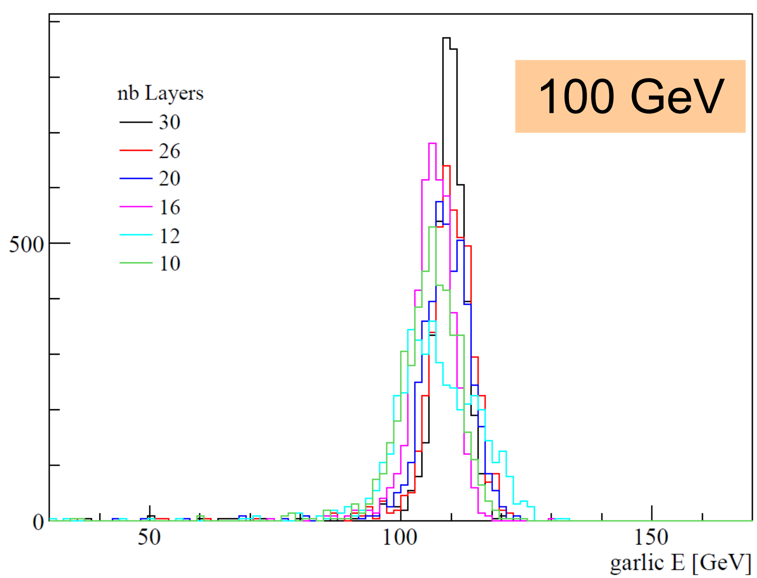
- Garlic: photon identification in ECAL
- Calibration using photon's at 10 GeV
- Constants are adjusted to give a total reconstructed energy by Garlic at 10 GeV

- Photon's are simulated with flat cos(θ)

Photon's at 3, 10, 100 GeV

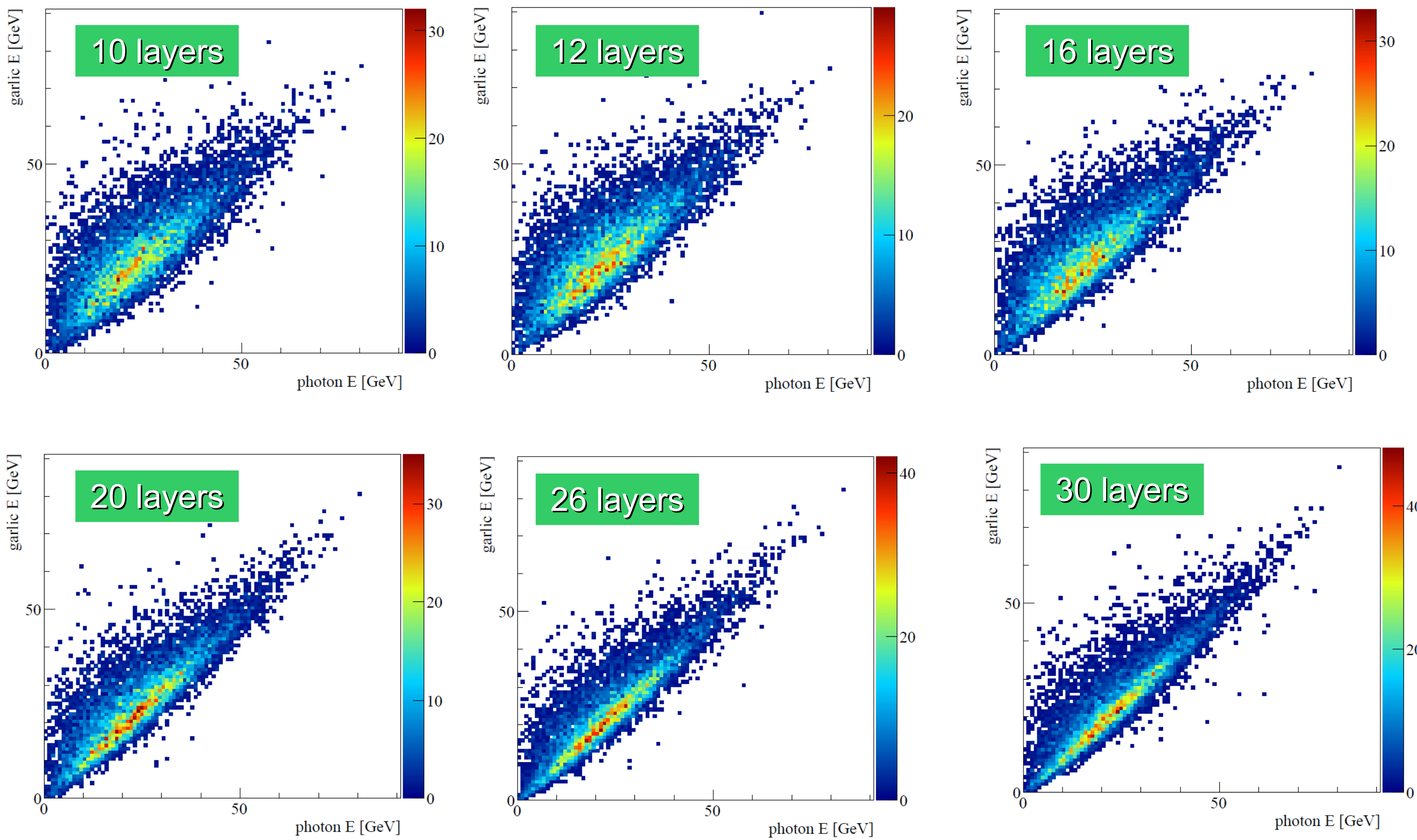






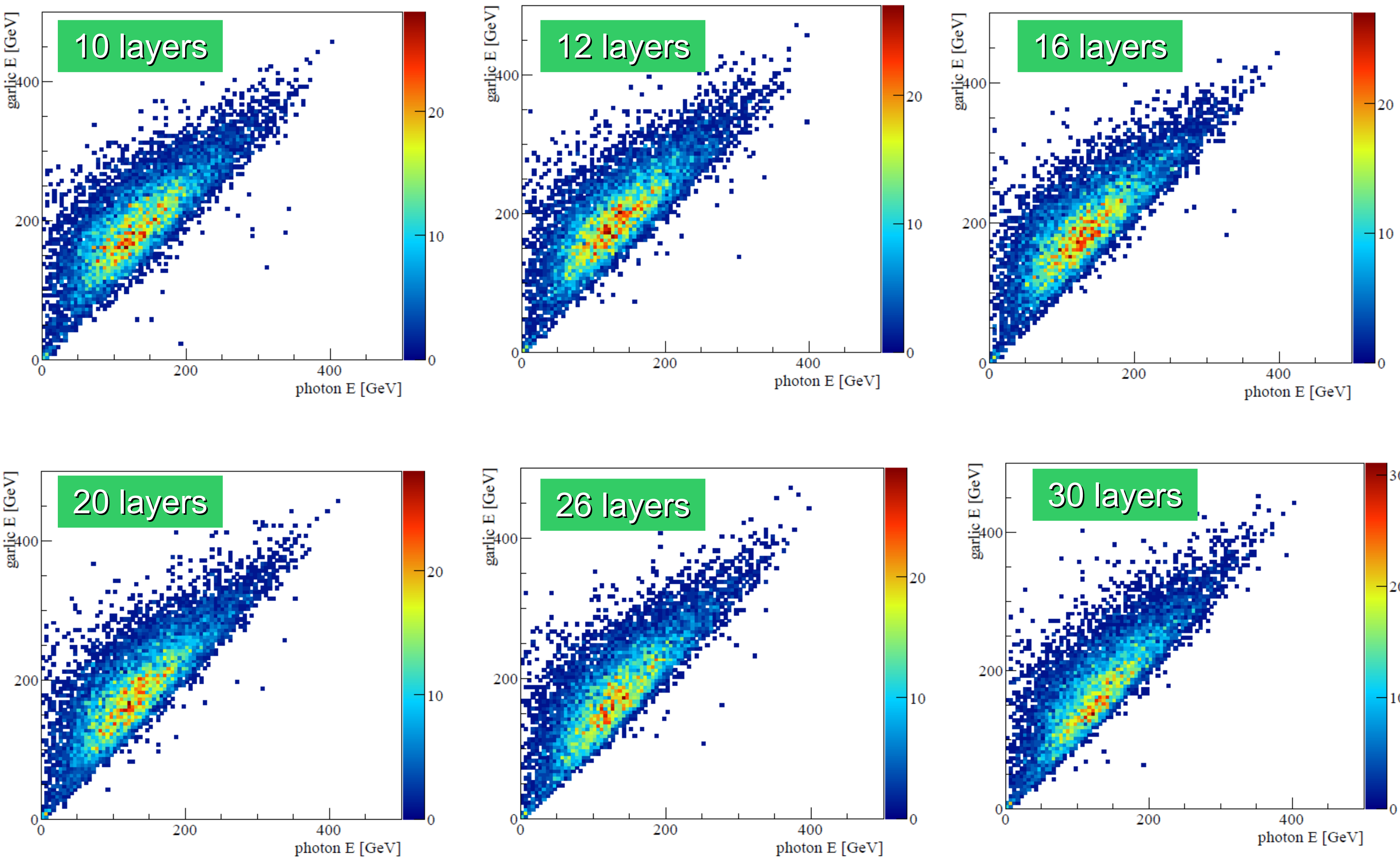
- Photon's are simulated with flat θ

Z → uds events @ √s = 91 GeV



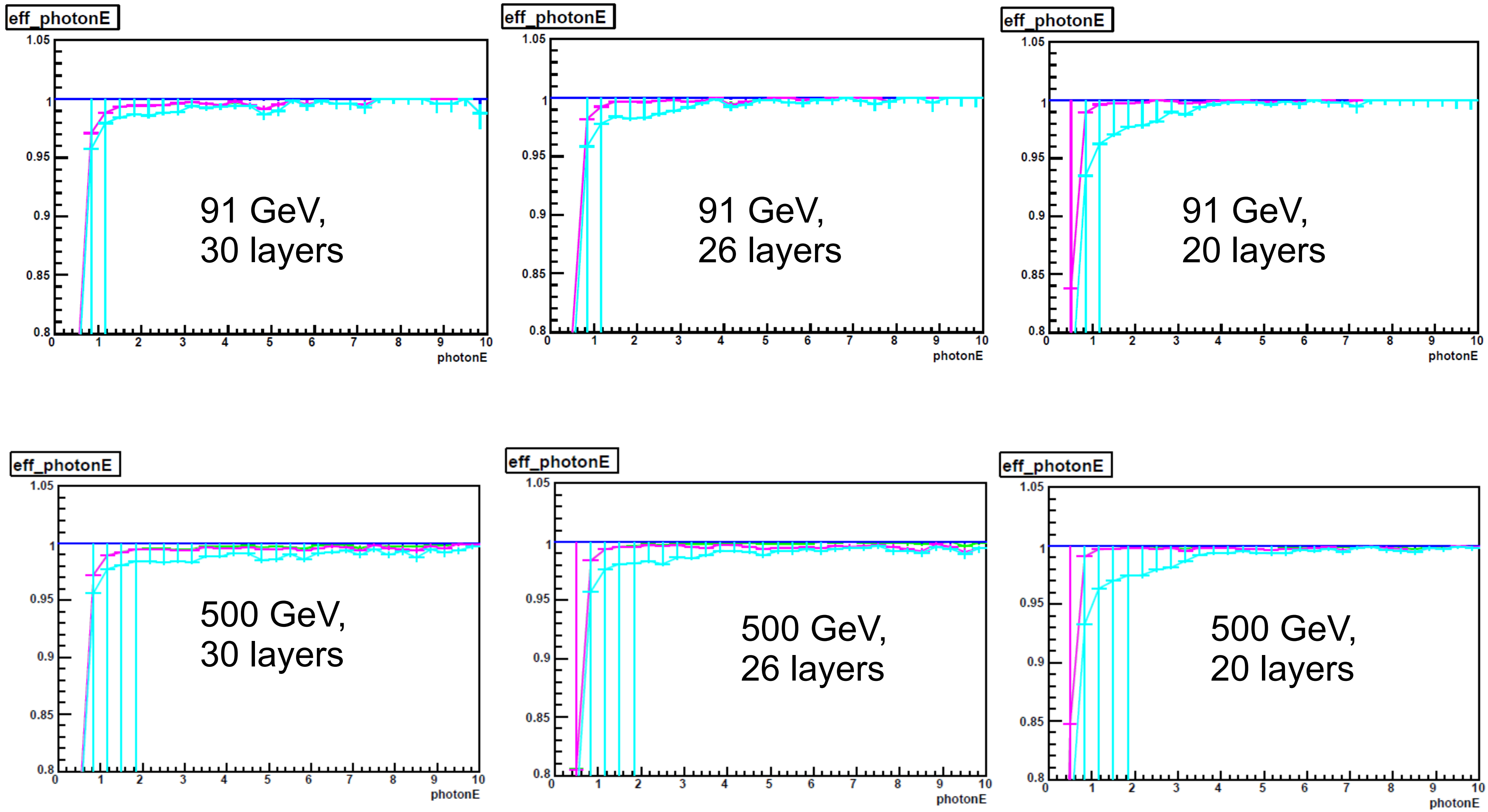
Sum of **reconstructed** photon energy VS sum of **generated** photon energy

$Z \rightarrow uds$ events @ $\sqrt{s} = 500$ GeV



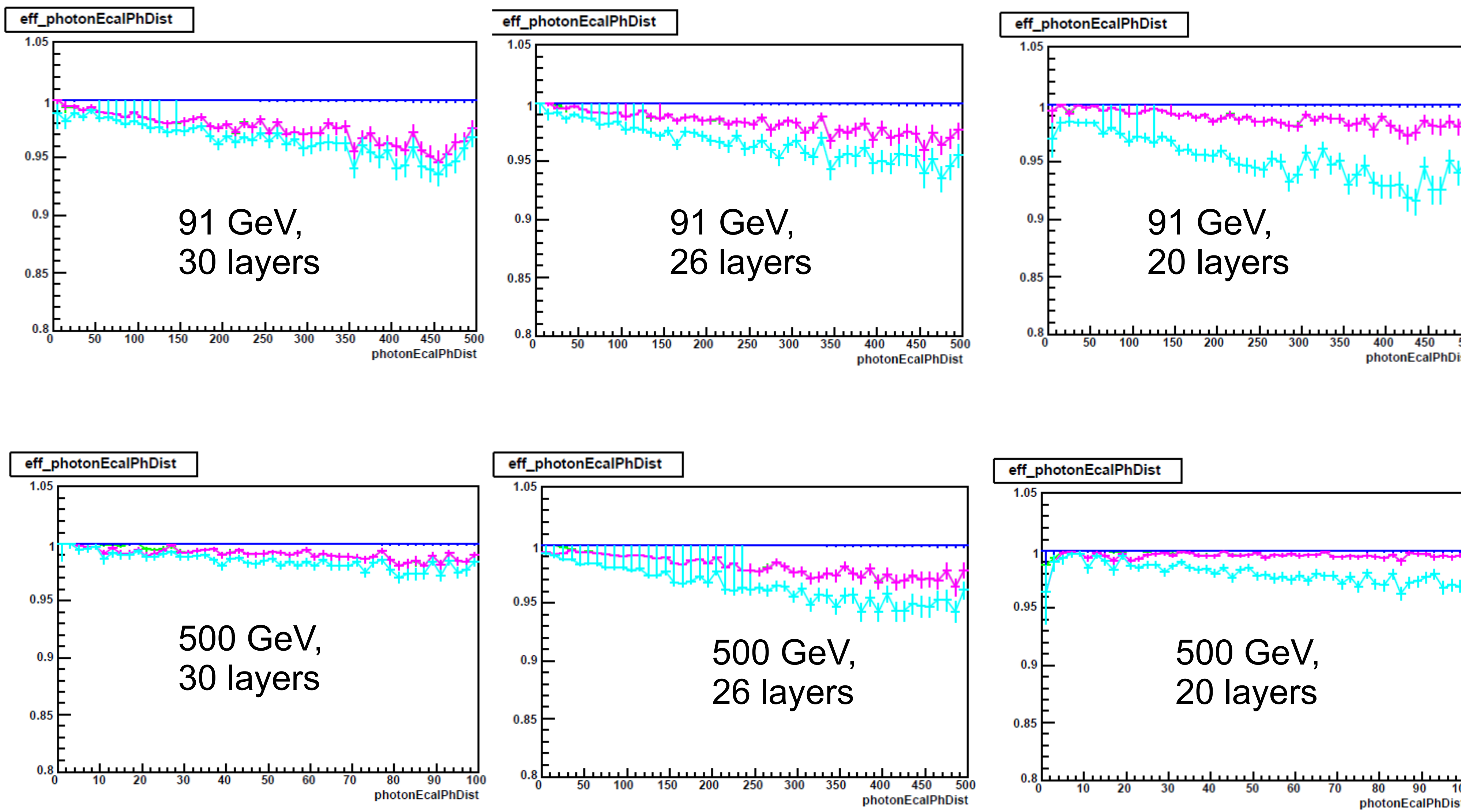
Sum of **reconstructed** photon energy VS sum of **generated** photon energy

Garlic efficiency vs generated photon energy

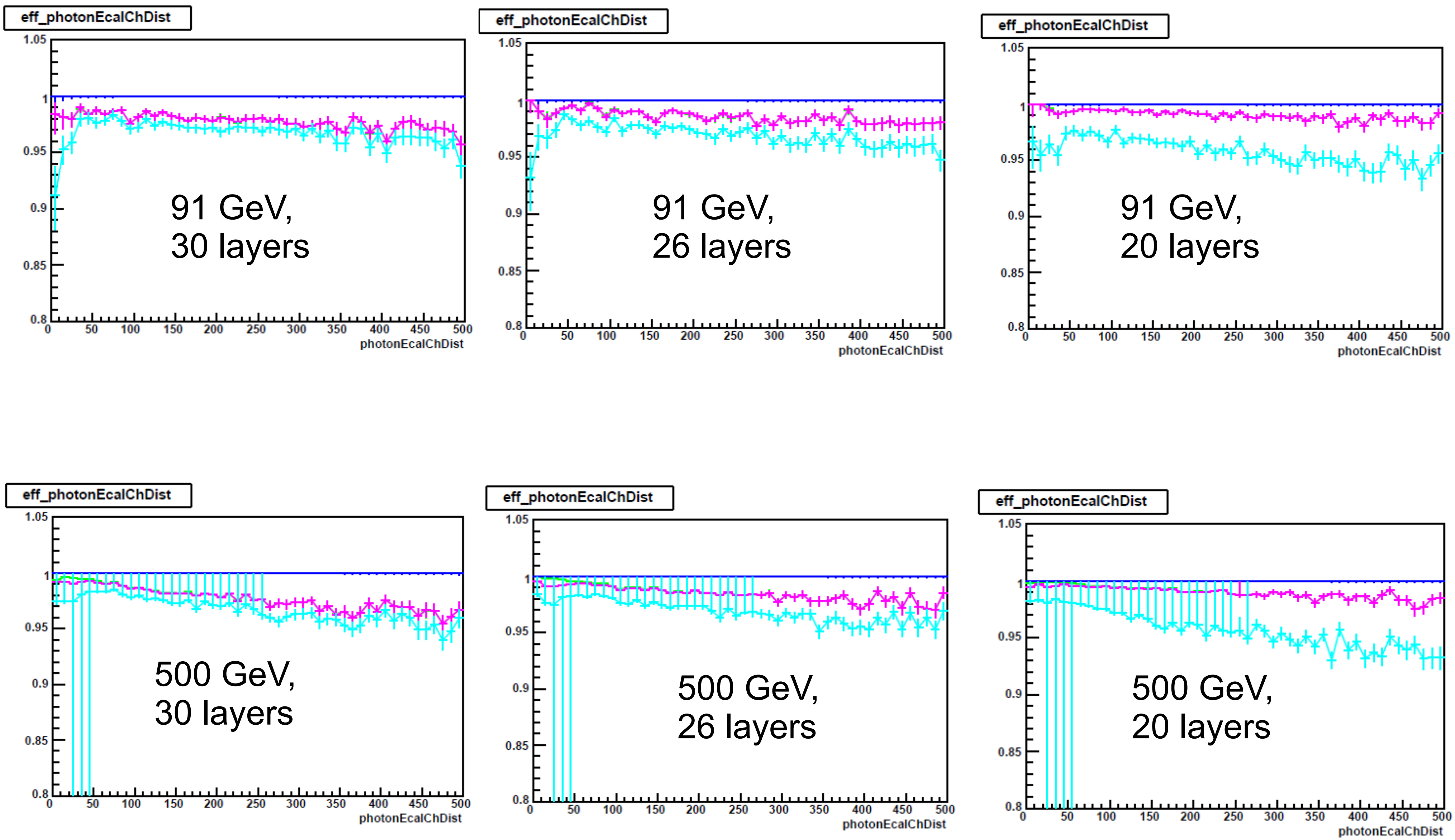


Efficiency of finding a cluster close to photon
Efficiency of finding good cluster close to photon

Efficiency vs distance to closest photon



Efficiency vs distance to closest charged particle



Summary on number of layers study

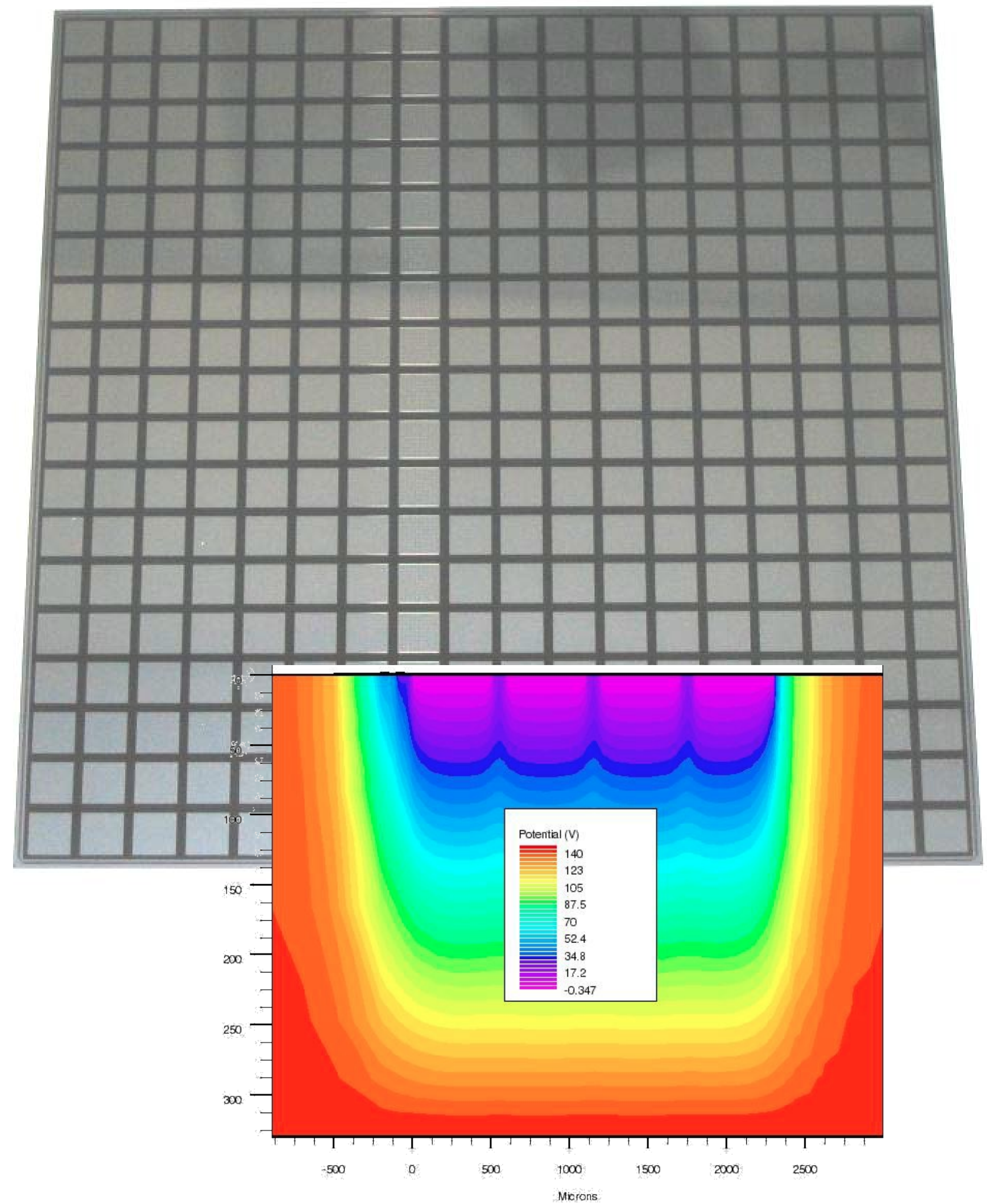
- Study was made with 10, 12, 16, 20, 26 and 30 layers
  - All other params constants (W thickness, ...)
- Degradation of ~9% in single JER observed for 45 GeV jets going from 30 to 20 layers
  - More significant degradation going to smaller number of layers
- Difference between ECAL models is less significant with jet at high c.m. energies (200 – 500 GeV)
- Study of photon energy resolution shows a similar behavior when reducing Si in ECAL
- Preliminary results using Garlic:
  - Some anomalies to be understood
  - To be done: same study for qqqq events

Guard ring studies for SiW Ecal of ILD

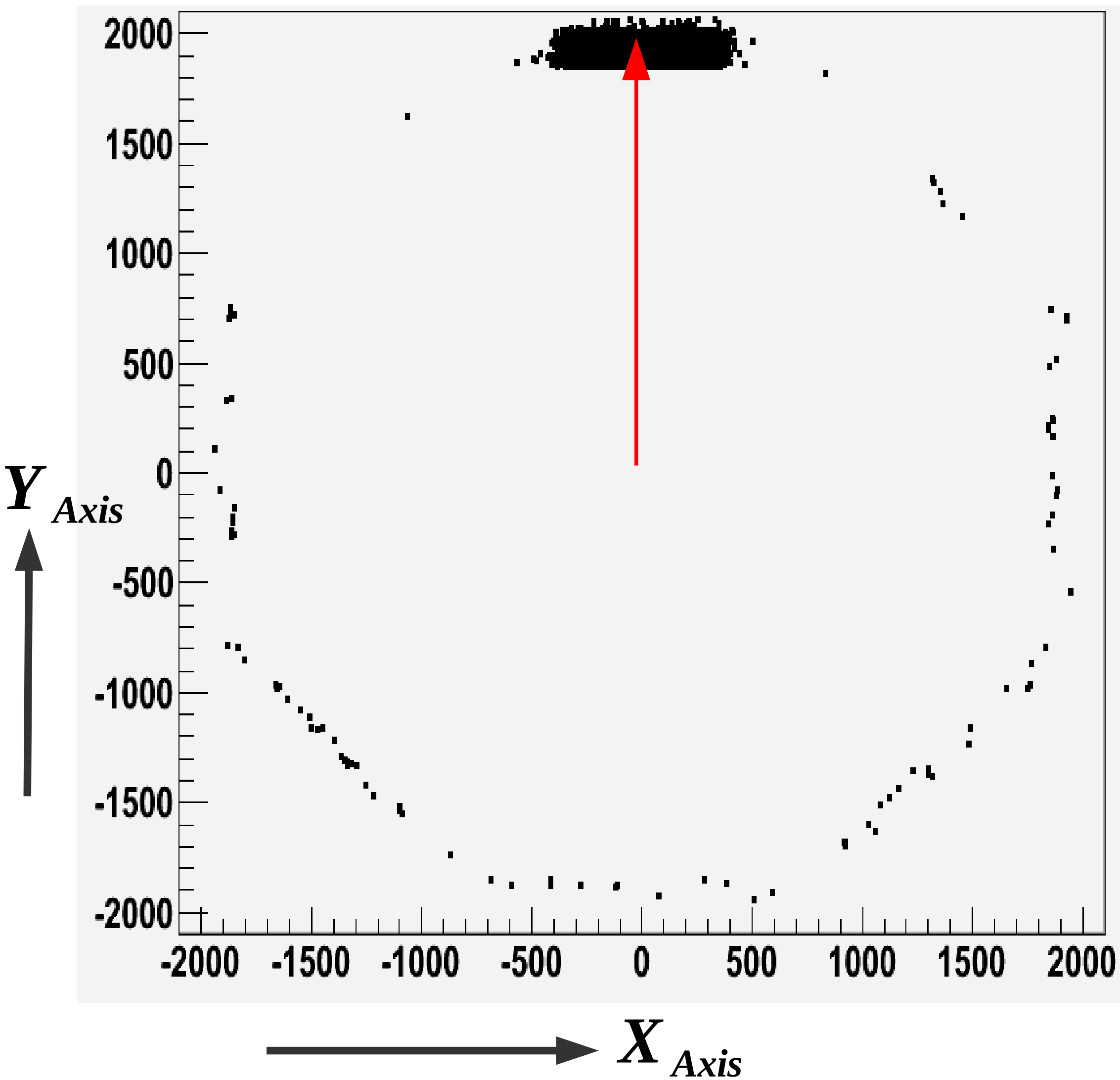
Amjad Suhail (LAL)

Some details on silicon wafers

- The wafer is surrounded by a guard ring to control the leakage currents.
- Studies conducted 18×18 Cells Wafer (Standard Mokka Implementation).
- Cell size 5×5 mm².
- The typical/**default** guard Ring size is **1 mm.**
  - (But no space between wafers)
- Purpose of the study is to optimize the guard ring size. (Important aspect of wafer design, see Remi's talk)

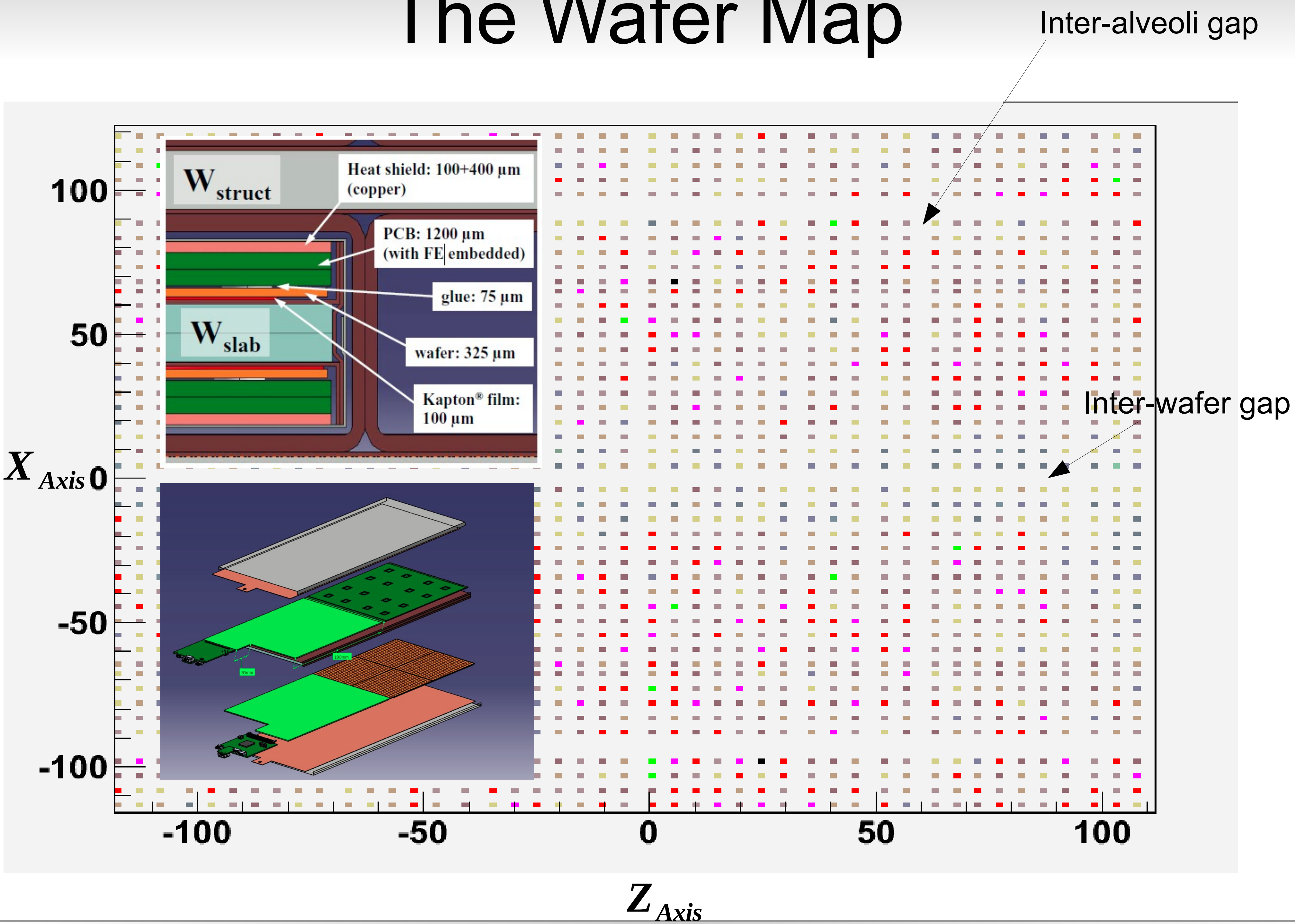


Systematic studies with photons

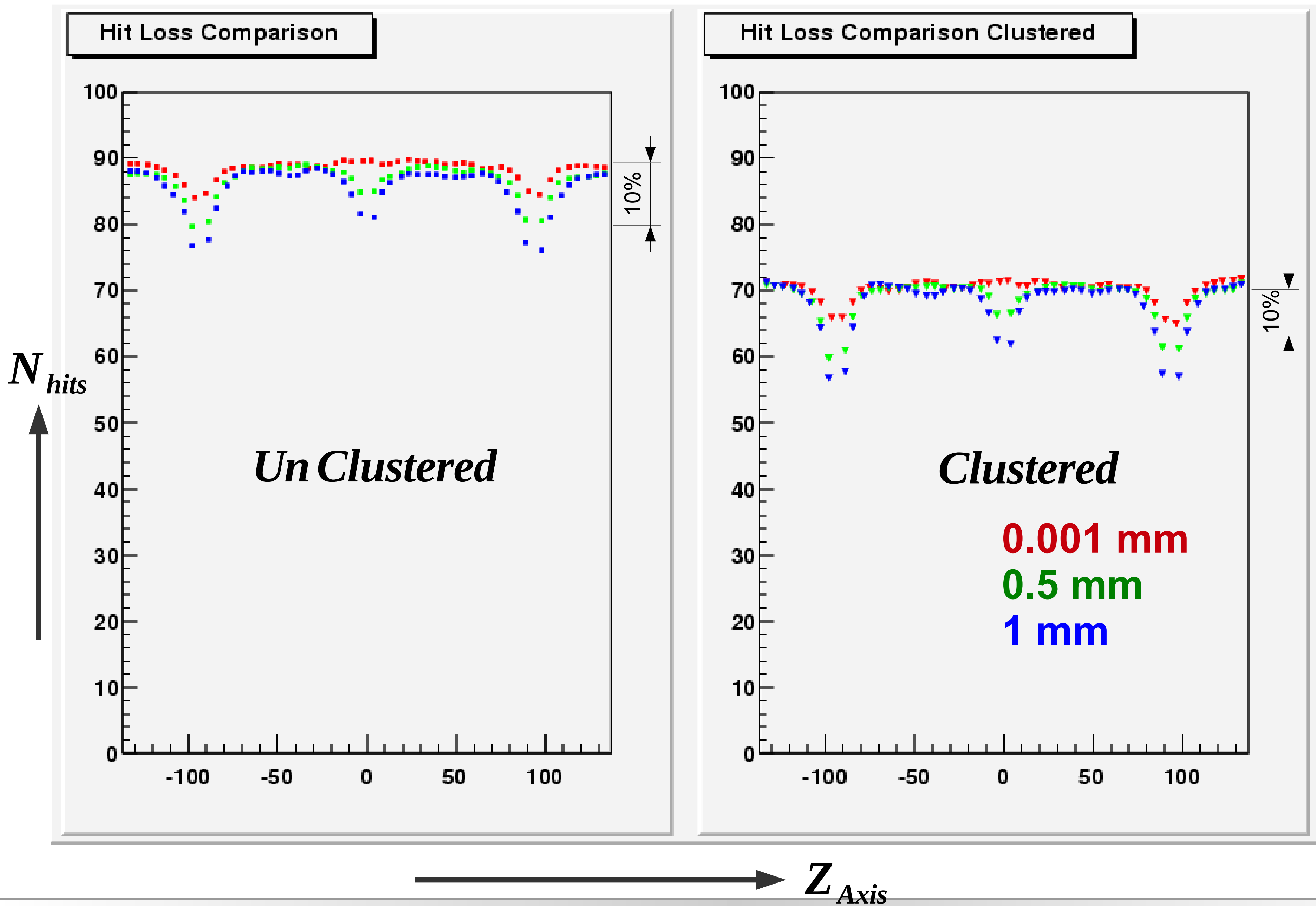


- Single Photons Events at 2 GeV .
- 3 different GR sizes
  0.001mm (~0), 0.5 mm and 1 mm.
- The study concentrates on the effects induced by varying the Guard Ring size.
- A Theta and Phi smearing of initially 10 Degree and later on of 4 Degree was applied to zoom into a particular region.

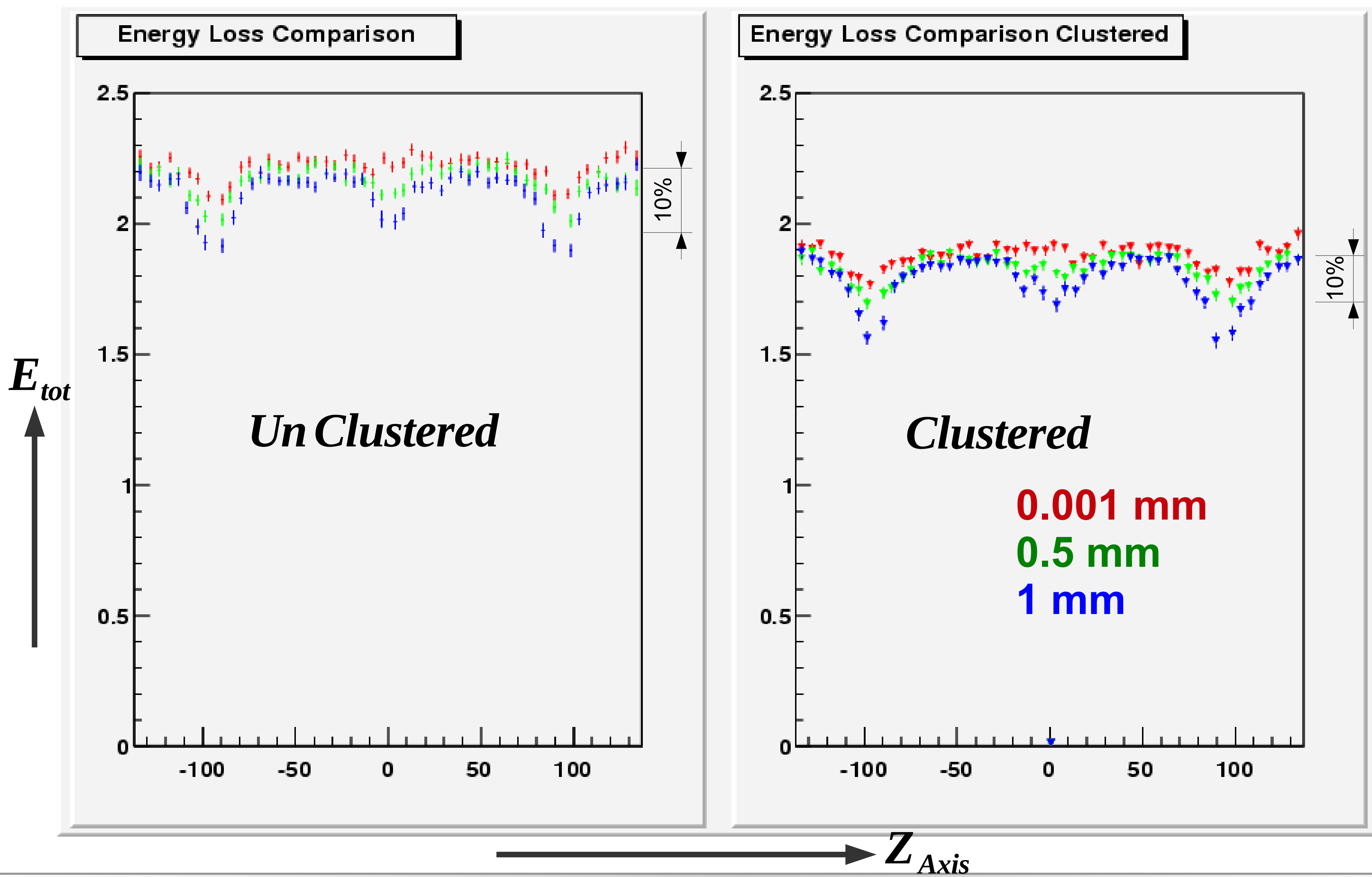
The Wafer Map



Hit Loss due to Guard Ring



Energy Loss due to Guard Ring



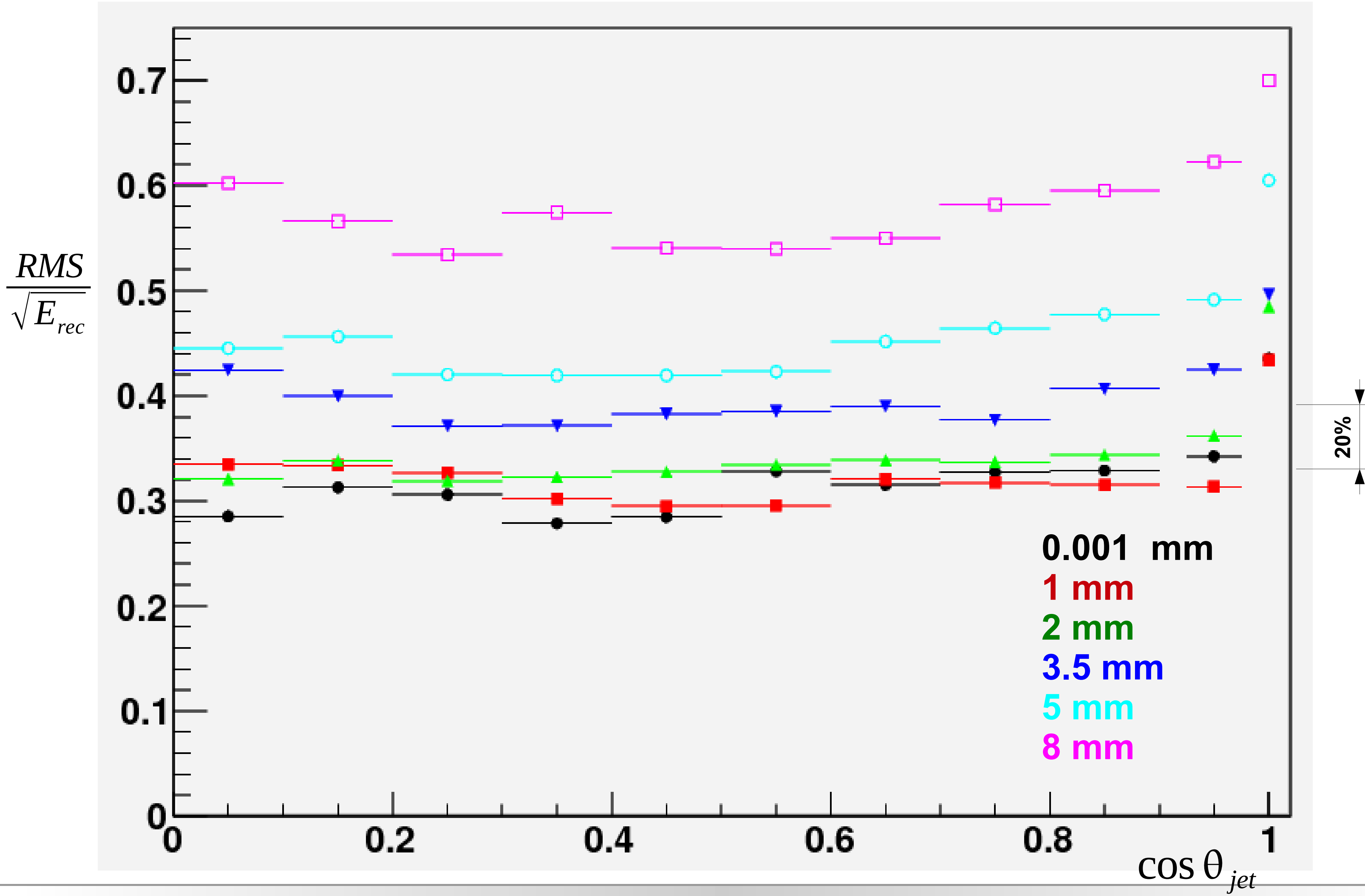
Physics Channels

- Two Important channels.
  - $Z \rightarrow j(uds)$ @ 91 GeV
  - $Z \rightarrow ee$ @ 91 GeV
- Six GR sizes in rang 0-8 mm.
- 1 mm standard, for redundancy.
- Mokka 06-07 and ILCSoft 01-10.
- Full detector simulation.

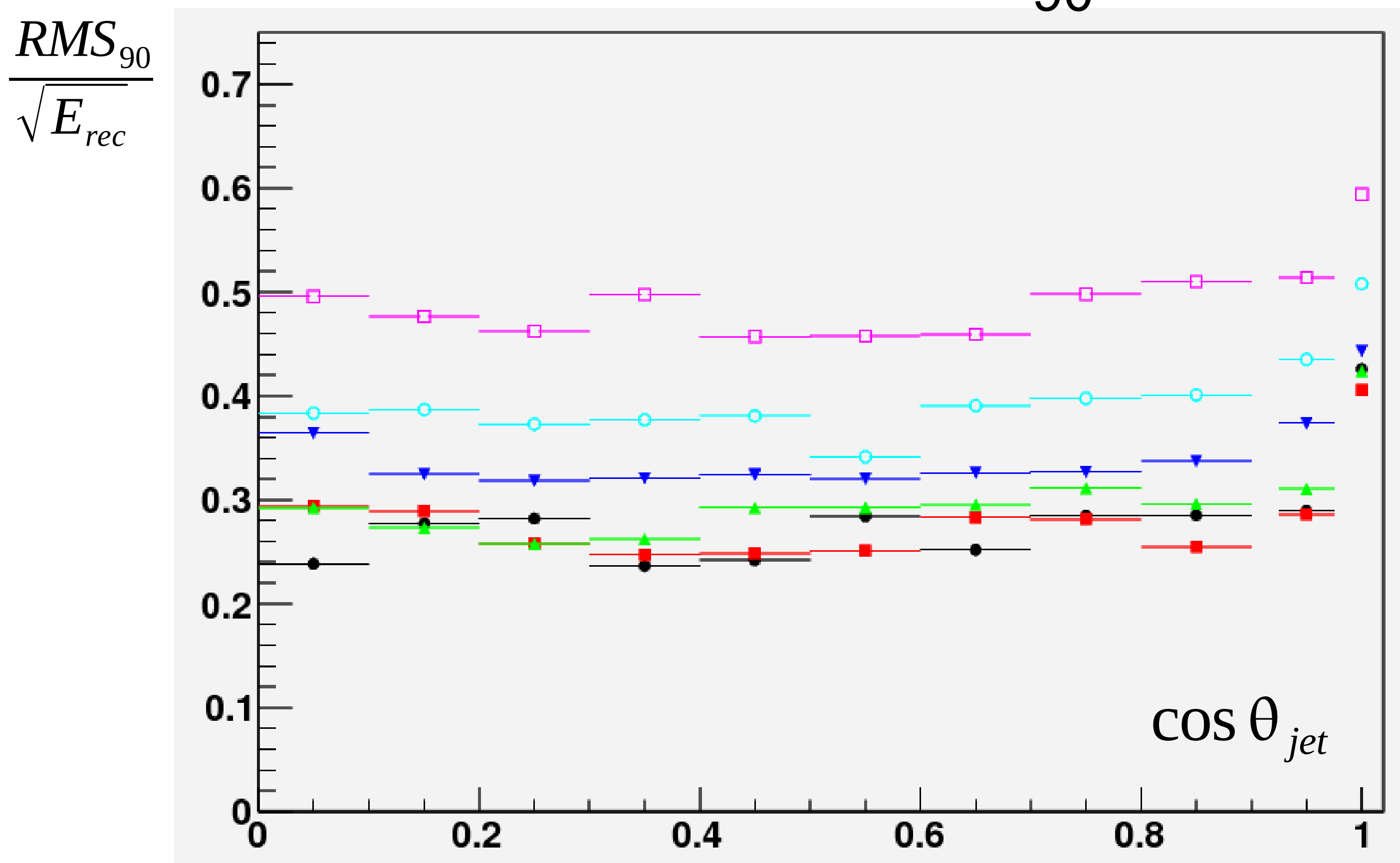
Z → uds jets (Hadronic Z decay at 91GeV)

- ILC will have multijet final states.
- Jets contain photons coming from π°.
- ~60% hadrons start showering in ECAL.
- ECAL resolution utmost important for precise reconstruction of Jets.

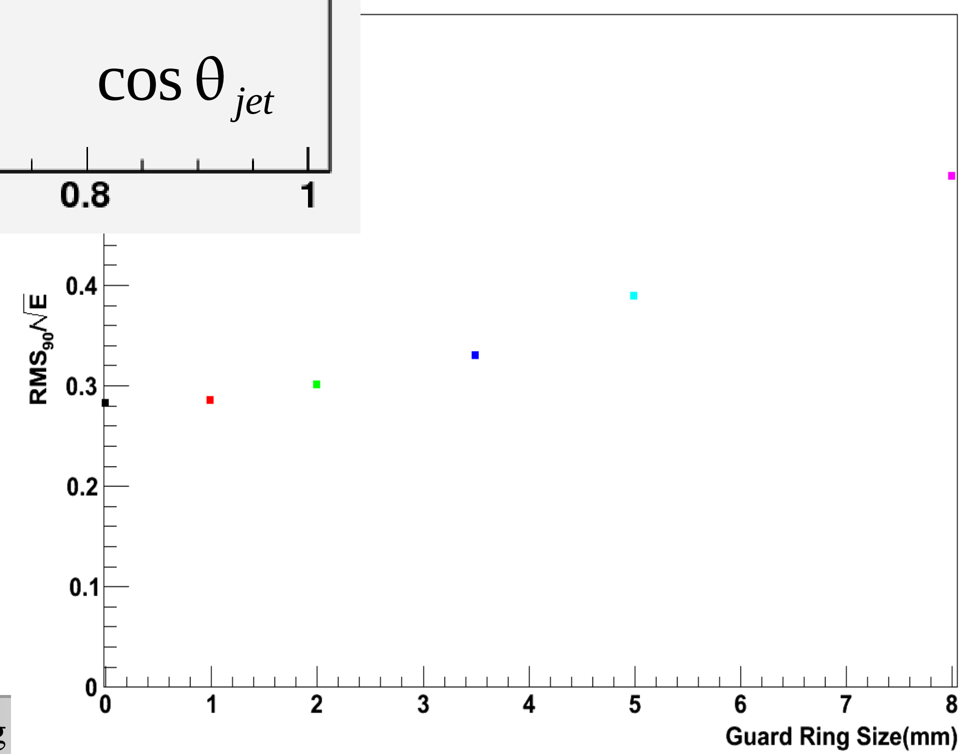
Comparison of RMS for different sizes



Comparison of RMS_{90} for different sizes



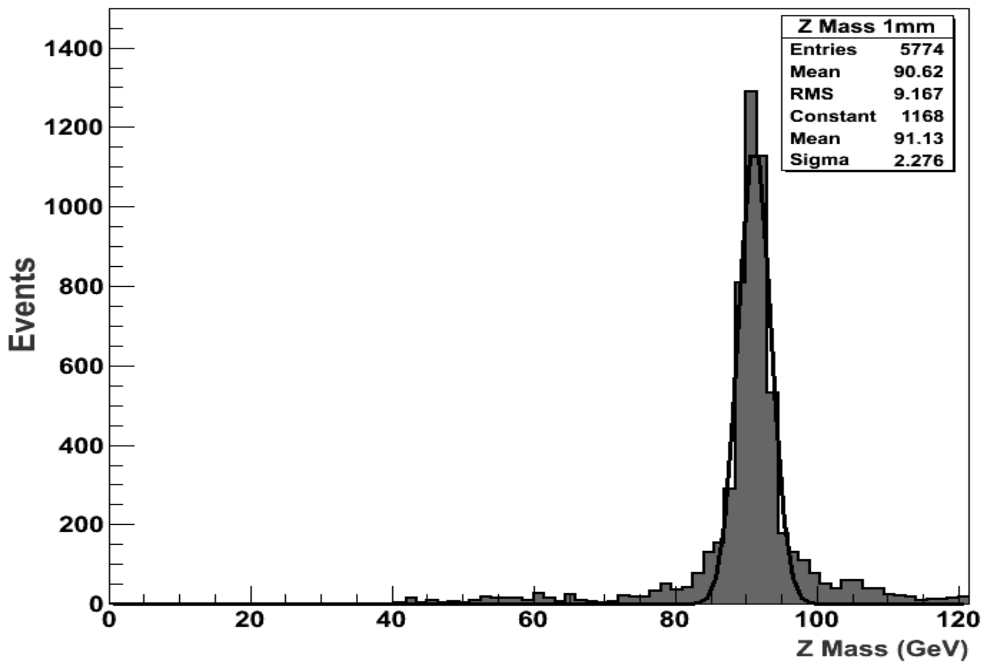
0.001 mm
1 mm
2 mm
3.5 mm
5 mm
8 mm

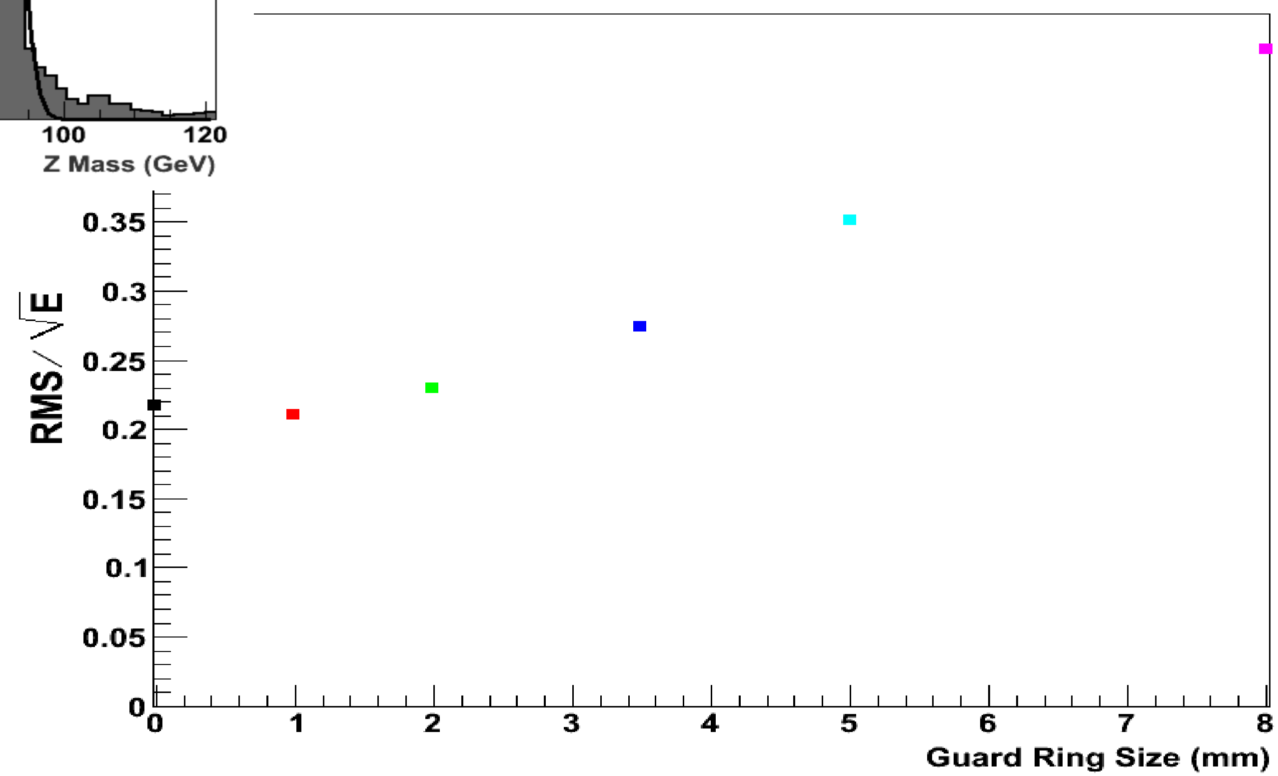


$Z \rightarrow ee$ Channel (Leptonic Z decay)

- Precisions on Z Mass.
- Calibration of detector.
- Leptons are reconstructed in ECAL.
- Bremsstrahlung photons recovery.
- Higgs via Z recoil Mass.

Z Mass reconstruction.



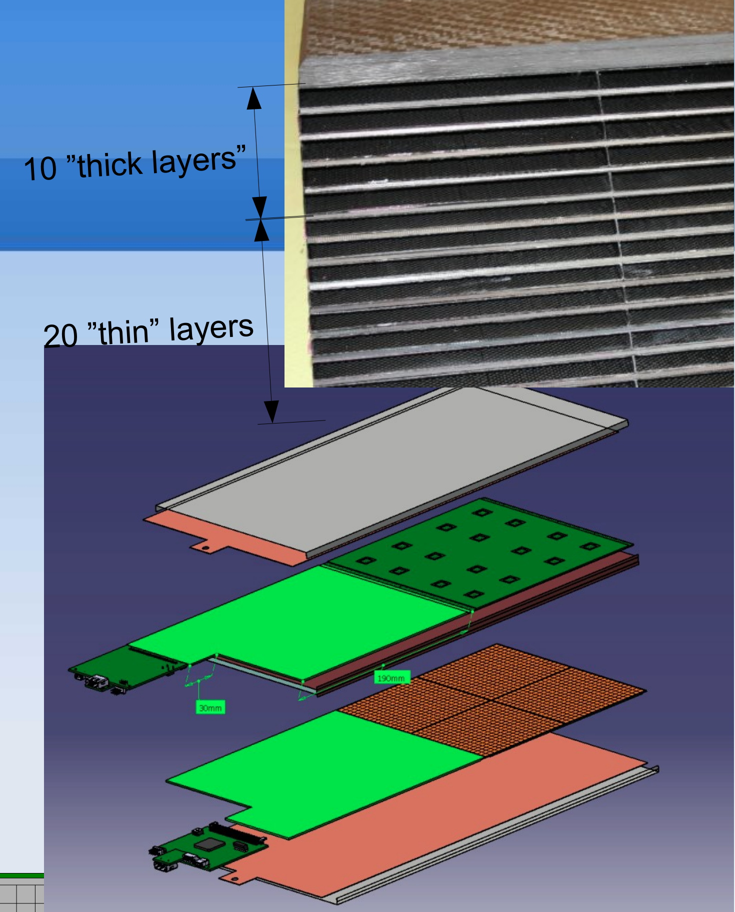


Conclusions

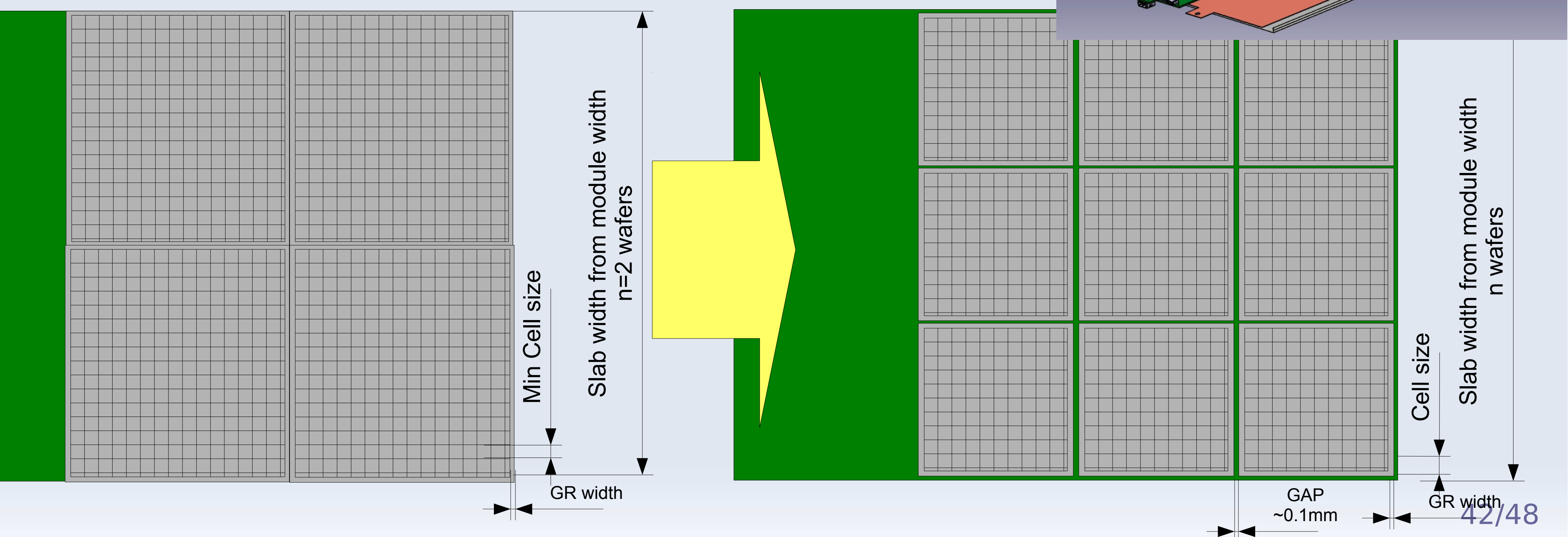
- Study on Guard ring sizes for single photon events and two standard physics channels at the ILC
- Using standard ILC reconstruction tools it looks as if guard rings of up to 2mm size does not affect the ECAL performance
  $\Rightarrow$ Flexibility of guard ring design
- The study has it's importance when defining the layout of the silicon wafers (e.g. when discussing with manufacturers)

Study on wafer size
(to be done)

Mokka adaptation



- Small wafers (4”) are cheaper than large ones (6”)
  - use smaller wafers in less critical regions (second half of ECAL)
- Adaptation of Mokka model on going
  - Add inter-wafer gap (as missing)
  - Add variable number of wafers per layer group
  - Training Work for Emilia Becheva (repl. Gabriel Musat)



Conclusion

- Fine studies have started... at last.
  - Educated guess always good
  - Intricated SW and HW issues
    - May lead to non trivial effects (e.g. GARLIC efficiencies correct ?)

- No strong breaking points
  - Full cost curves to be estimated (when ?) $\Rightarrow$ proper Perf/Cost ratio...

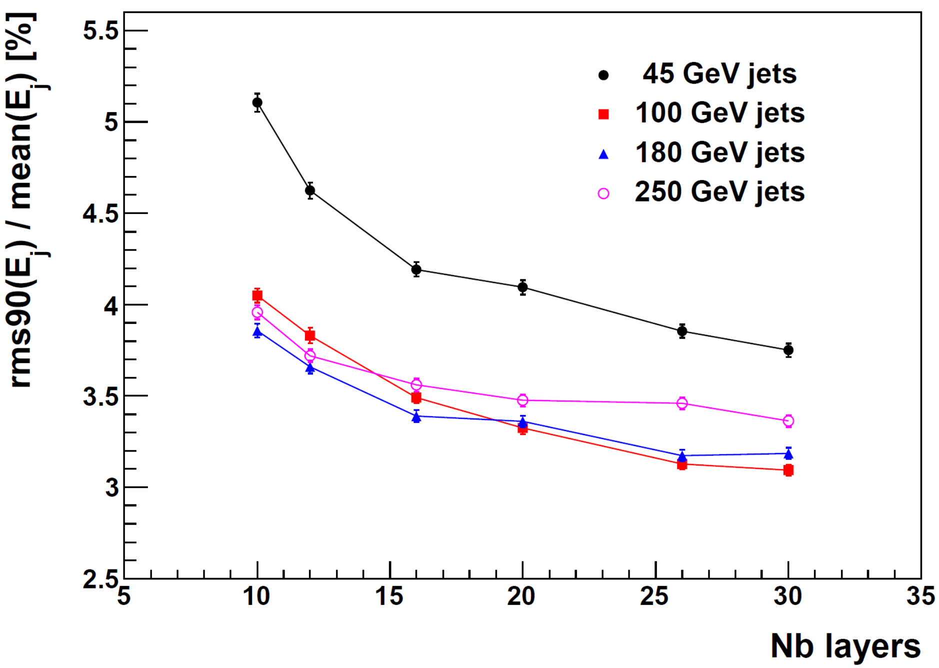
- First insights
  - 20 layers SiW ECAL seems to be almost as efficiencent as 30 layers
  - Gap (interwafer + GR) $\leq$2 mm seems OK.

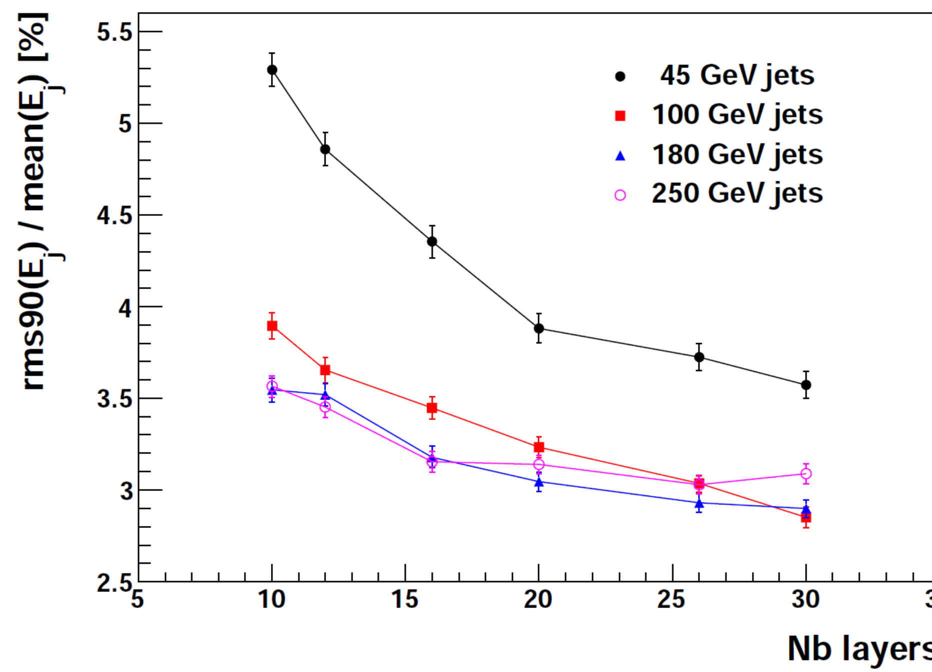
- To be consolidated...

Back up

Comparison

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



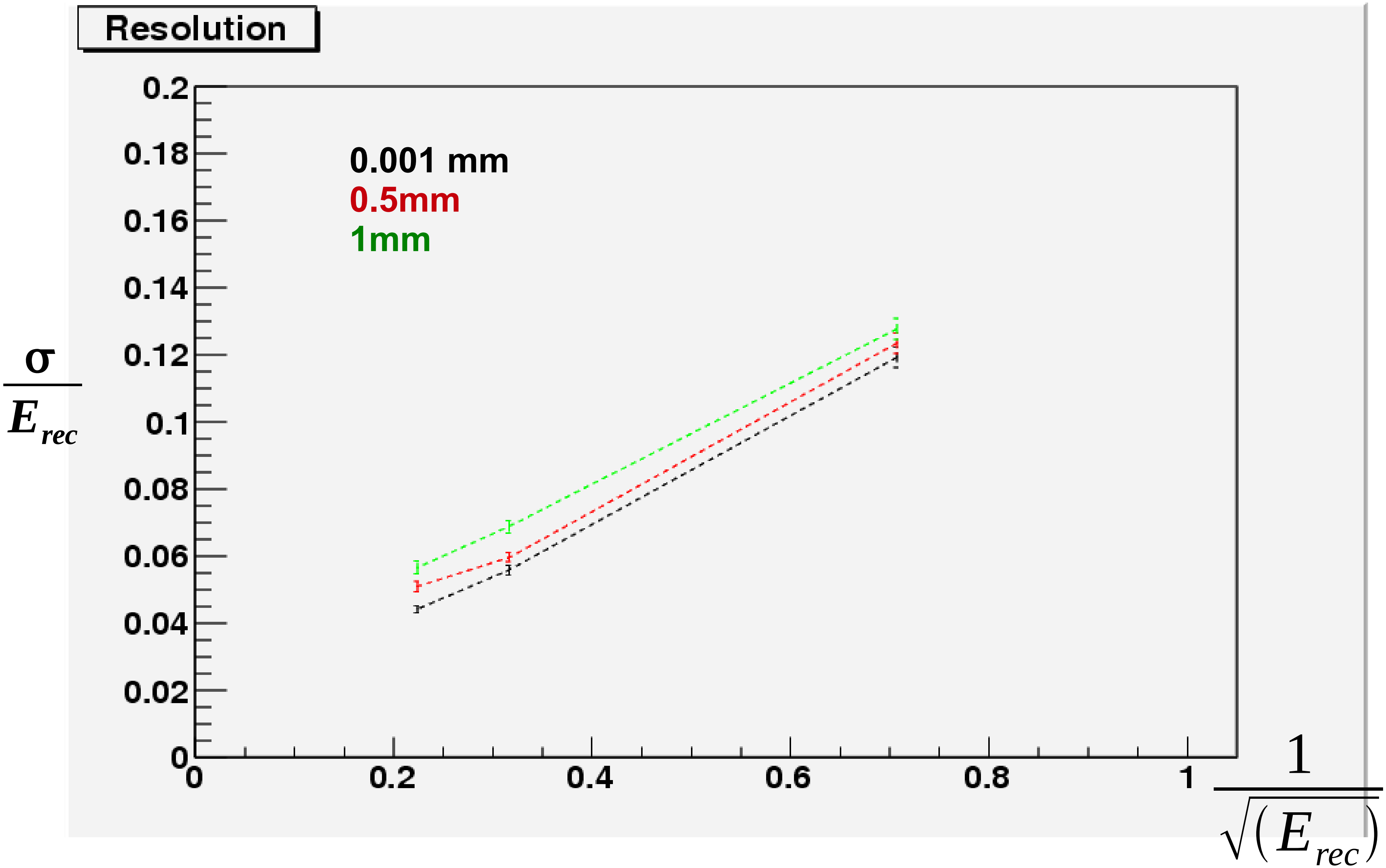


Presented at ILD analysis meeting 26 Sept 2012

Changes:

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

Effect on Resolution of ECAL



Z Mass reconstruction.