Remarks on ECAL design and GEANT4 EM simulations

Slides from Cornell July 03 meeting

Comparison with Ray's EGS results using current GEANT4

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At SLAC, June 22nd, 2005.

ECAL Design Studies

- *Spring03* – had looked at conceptual design issues of sampling frequency, sampling thickness and compactness in the framework of estimates based on parametrisations available in the literature expected to be good to around 10%.
  - Eg. Eres = 2.7% $\sqrt{[t_{active}(mm)/f_{samp}]}$ (Wigmans p190) (labelled WPAR in some of following plots)
- Now using GEANT4 to repeat those studies and investigate actual hybrid geometries. GEANT4 results sensitive to range cut.
- Despite “EM showers are understood mantra”, is there really good data in the literature which can be used to test/benchmark GEANT4 sampling ECAL results ?

(Now OLD) New studies

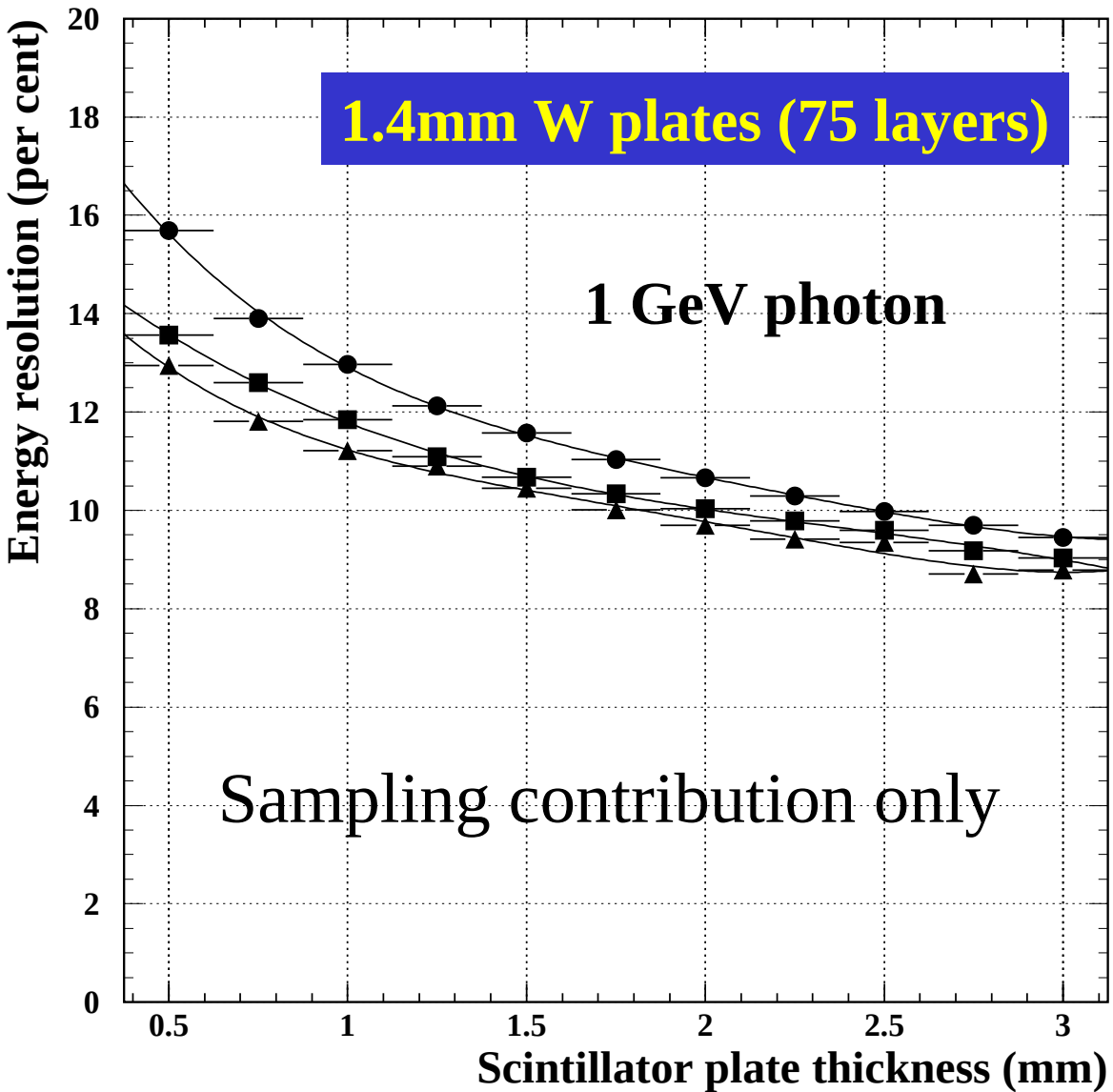
with Eric Benavidez (freshman)

- All calorimeter designs have 30 X_0 of W (105 mm) to ensure adequate longitudinal containment and a fair comparison.

- GEANT4 studies are done primarily with 1 GeV photons (which are definitely longitudinally contained)

- Used geant4.5.0.p01

Scintillator-Tungsten Calorimeter



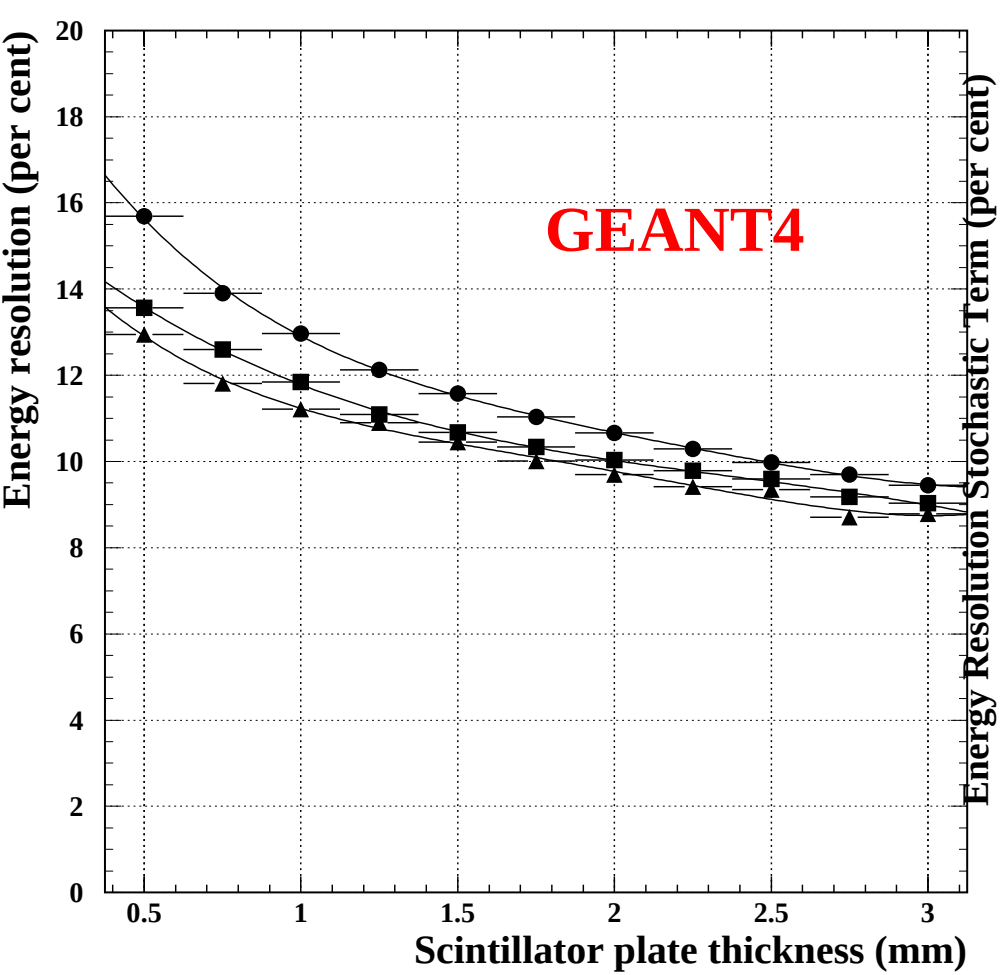
GEANT4 study based on TestEm3 example.

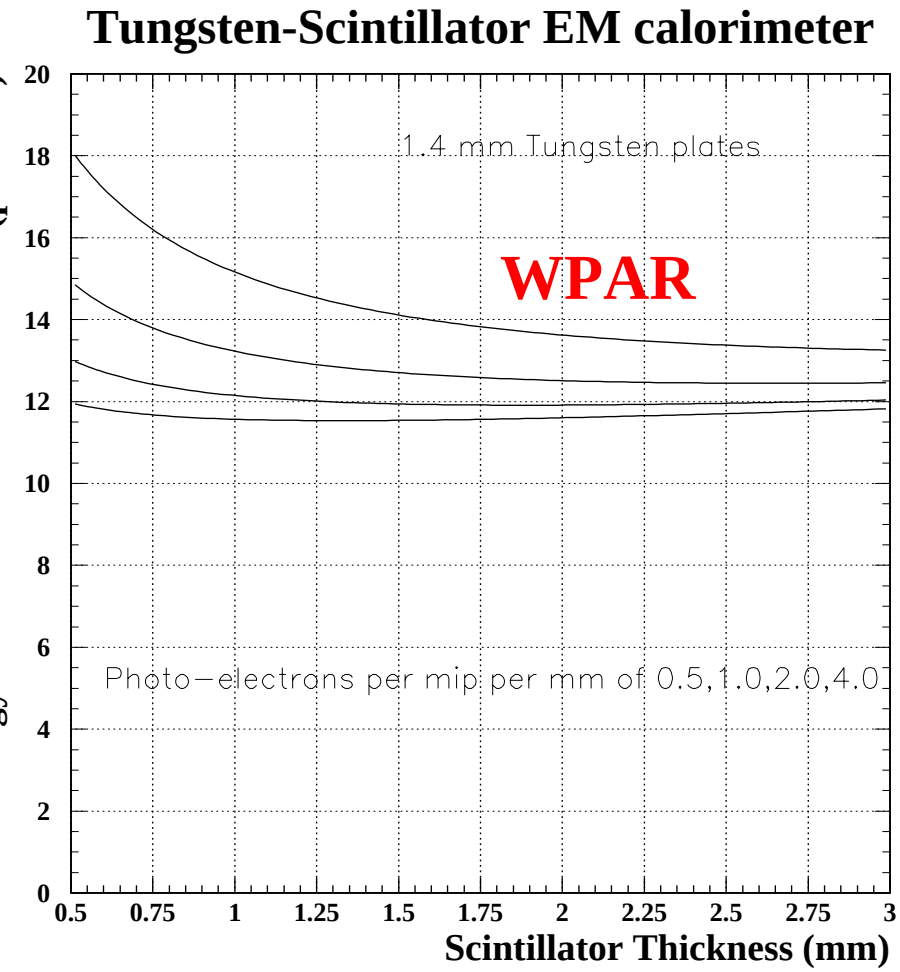
3 curves correspond to range cuts of 100, 10, 1 μm (from top to bottom)

NB differs substantially from WPAR estimate

Comparison (75 layers)

Focus just on the lowest line in both



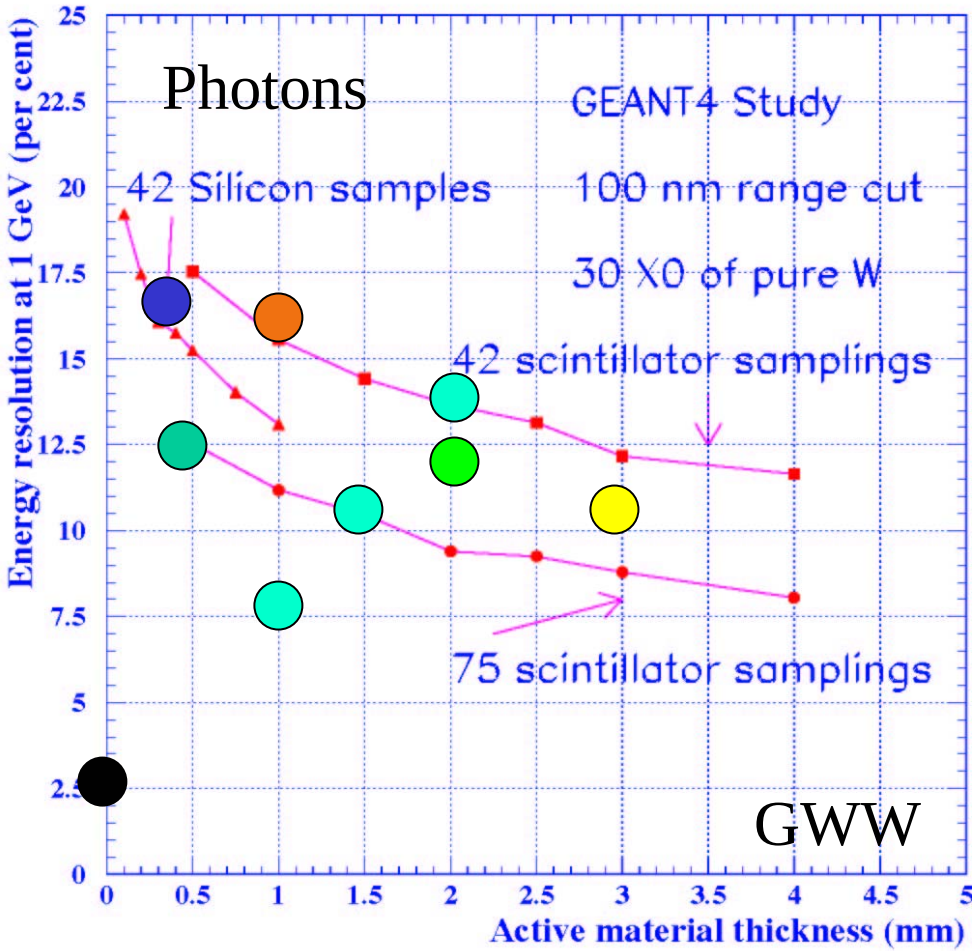


NB WPAR studies suggested E-res indep. of thickness. Not with G4.

Range cuts

- 1 μm range cut is sufficient to estimate resolution with 2-3% accuracy. This corresponds to cutoffs of 1.6 and 8.9 keV for γ and e in Tungsten
- However, the EM response still requires basically no cut (0.1 μm setting)
- (Sc/W 1.5mm/1.4mm), 1 GeV photon
- 100 μm: 47.8 MeV, 11.6%
- 10 μm: 50.5 MeV, 10.7%
- 1 μm: 55.7 MeV, 10.4%
- 0.1 μm: 63.5 MeV, 10.2%

Energy resolution for sampling W calorimeters



Also plotted, CALICE, Asian, LCCAL, $PbWO_4$

(geant4.5.0.p01)

42 layers = 2.5 mm W

56 layers = 1.75 mm W

75 layers = 1.4 mm W

135 layers = 0.78 mm W

Cost issues:

W cost ≈ independent of thickness if rolled ?

Si and scintillator scale as area, and can be more expensive if thinner.

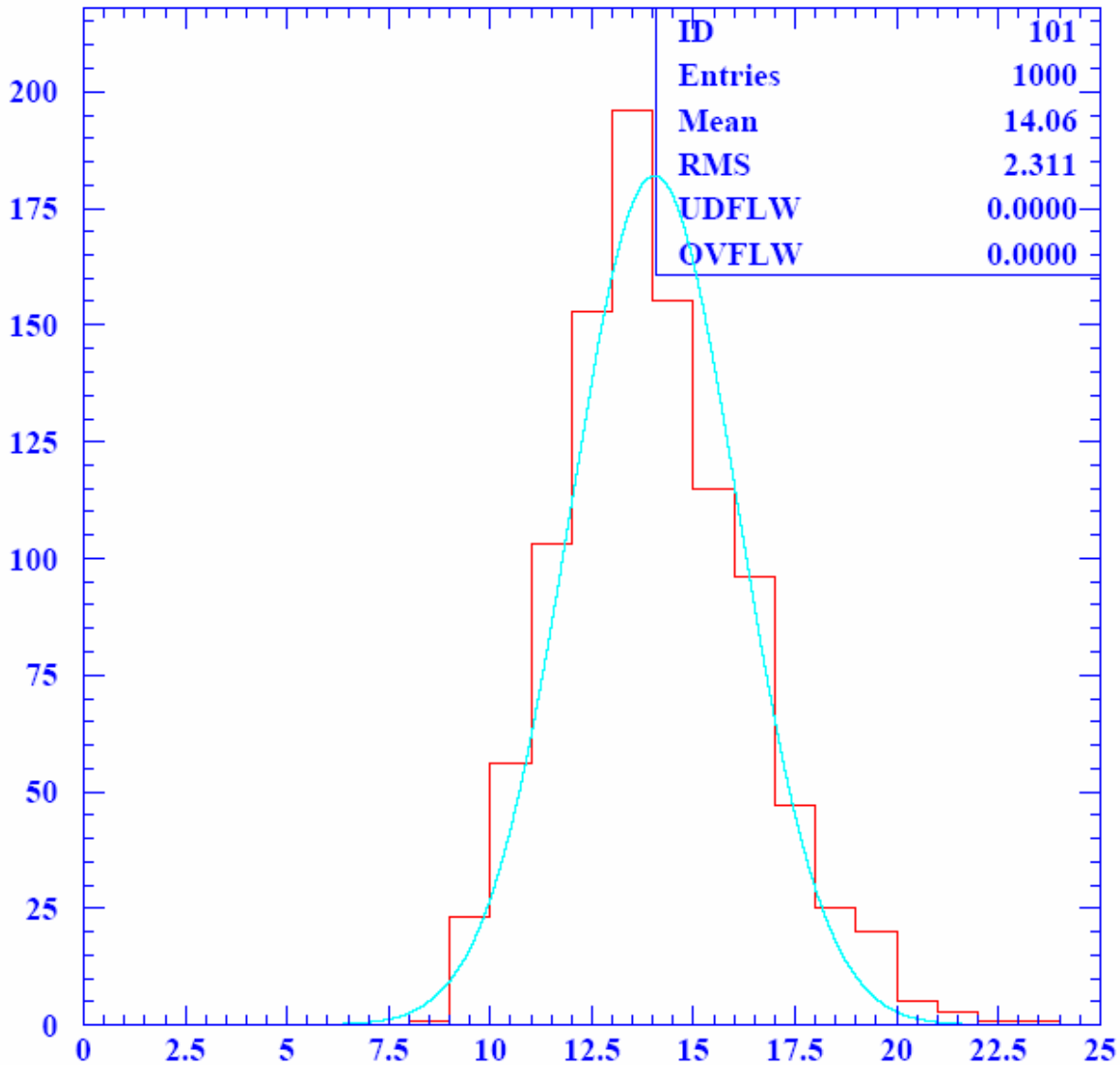
Recent GEANT4 studies using SLAC setup (geant4-07-00-ref02-patch00)

- sidmay05 (2.5mm W, 0.68 mm G10, 0.32mm Si, 0.25mm Air) × 30 layers
- 1 GeV photon, normal incidence, (“no skins”)
- Range cut dependence using TestEm3 example:
  - RANGE RESPONSE RESOLUTION
  - 100 μm: 12.36 ± 0.04 MeV 19.1 ± 0.2 %
  - 10 μm:
  - 1 μm: 14.05 ± 0.07 MeV 16.3 ± 0.4 %
  - 0.1 μm: 15.79 ± 0.08 MeV 16.4 ± 0.4 %

1 GeV photon

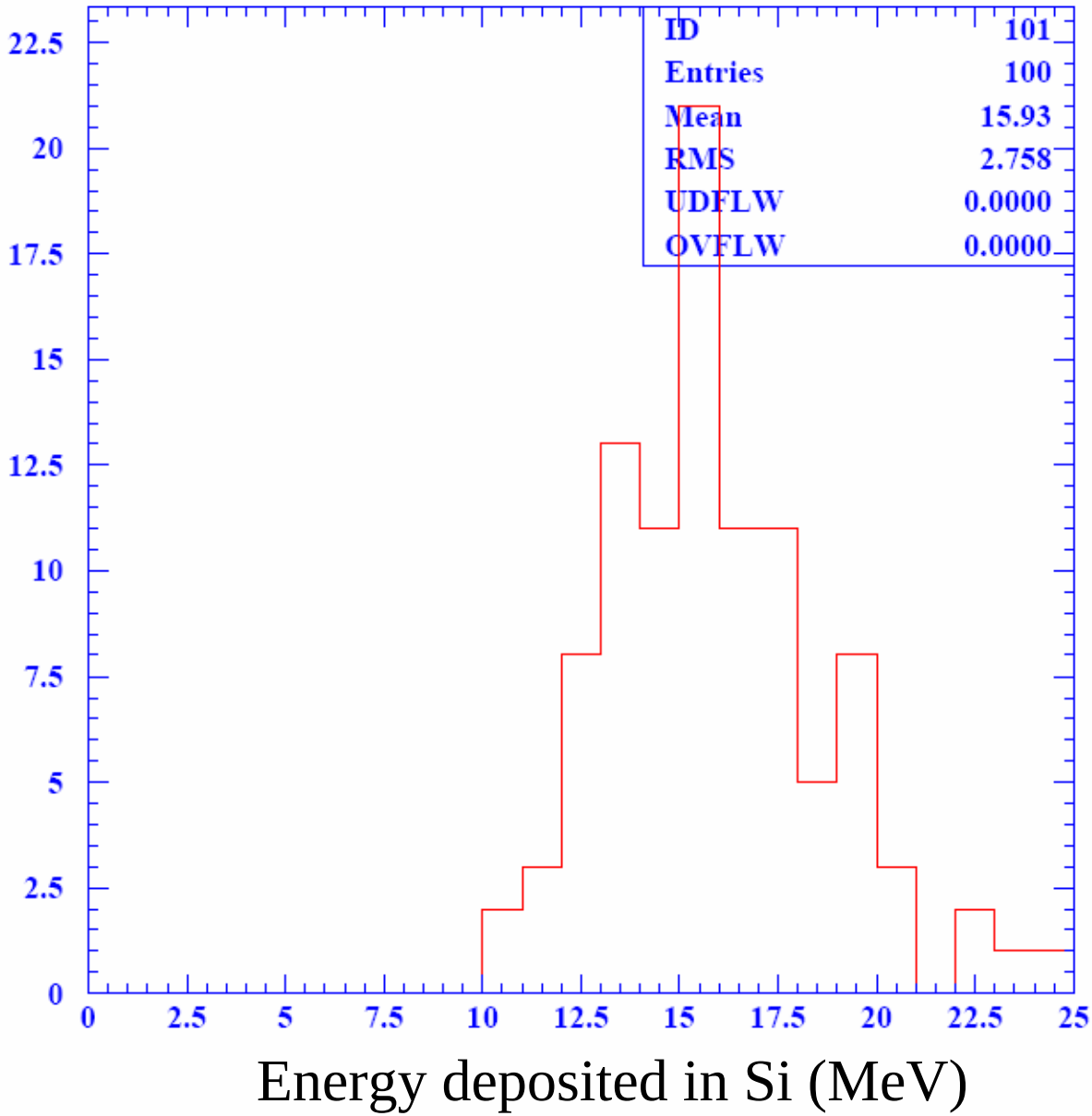
Range cut = 1 μm

Note, at 1 GeV the distribution is not gaussian.

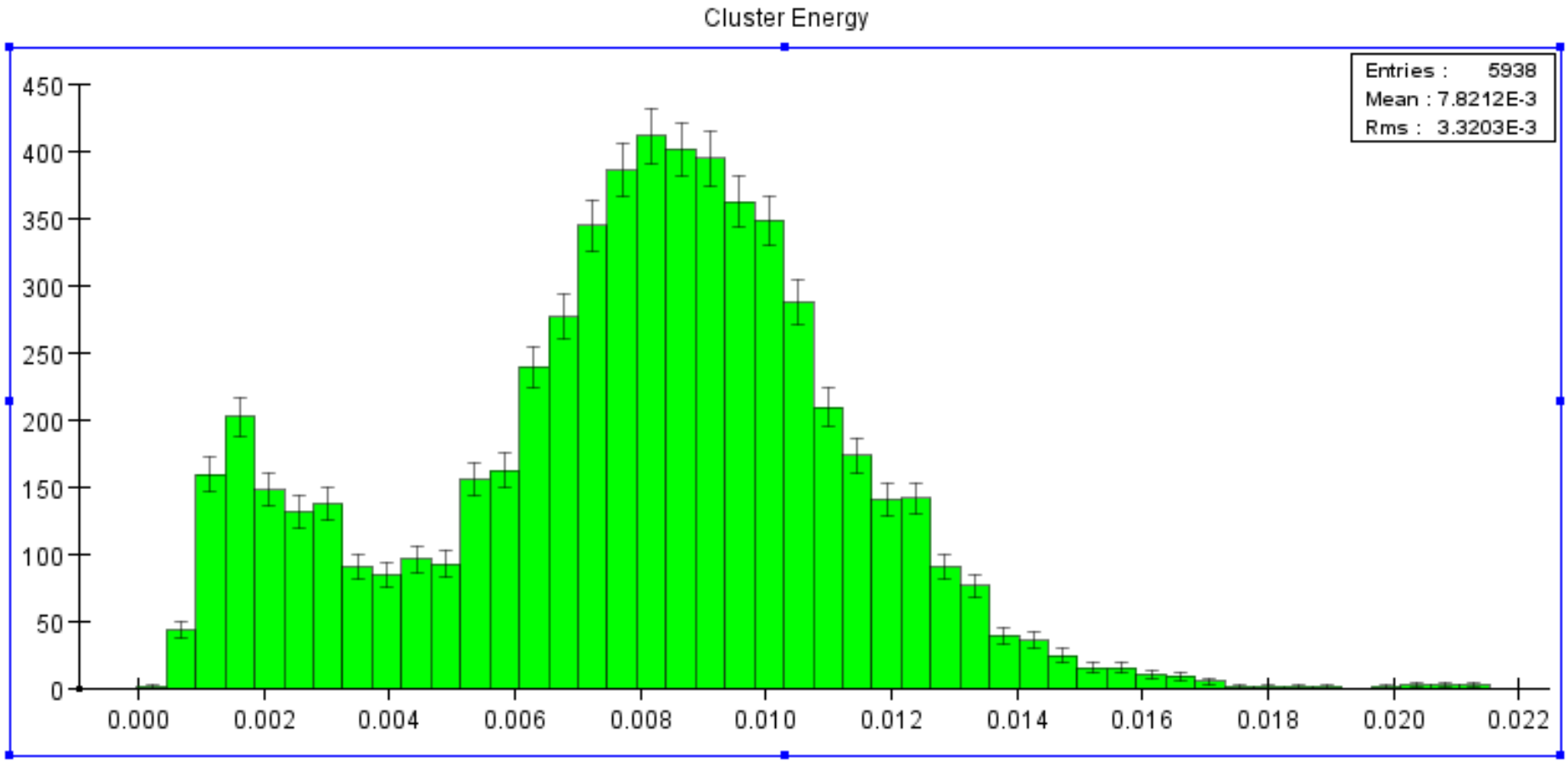


1 GeV photon

Range cut = 0.1 μm



sidmay05 1 GeV photon with SLIC and LCIO



Doesn’t look anything like 16%/√E

Conclusions

- GEANT4 EM simulation of response has been very sensitive to the range cut.
- Despite claims that this is fixed in recent versions, at least for the default sampling EM Calorimeter example, the current SLAC state-of-the-art installation shows the same issue.
  - Perhaps there is a more appropriate way of doing this.
- For fixed sampling frequency, the sampling fraction does intrinsically affect the energy resolution in the ECAL. HCAL the same ?
- G4 indicates 16%/√E for 1 GeV photons consistent with Ray's EGS studies.
- For the overall goal of Particle Flow, until we get it really established, it is probably wise to not give away intrinsic resolution to simulation approximations, and also to effects like longitudinal EM containment. (the things we believe we know how to do !)