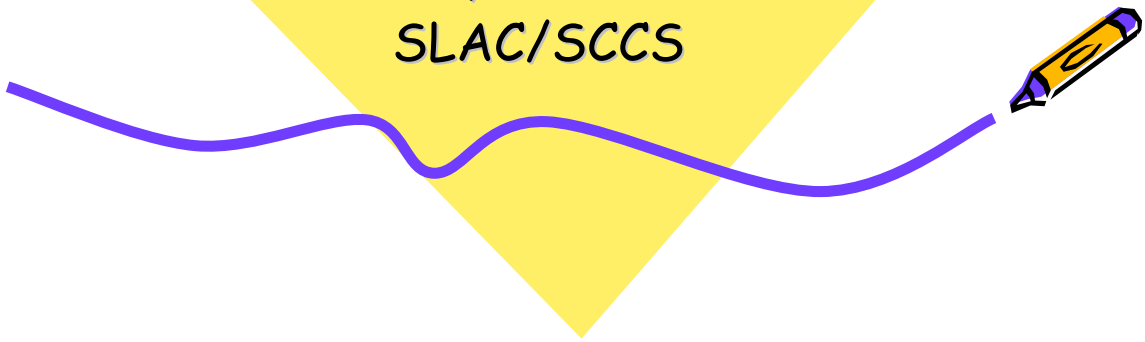




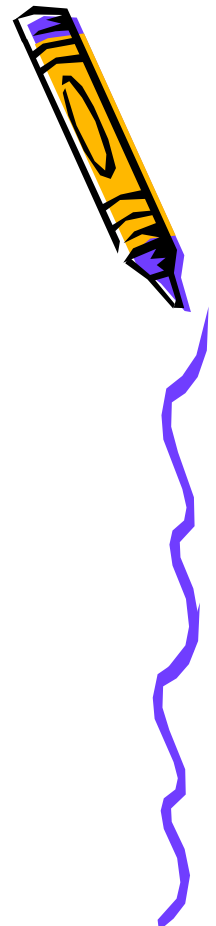
# Anomalous change of observed energies in Sandwich Calorimeter

Koi, Tatsumi  
SLAC/SCCS



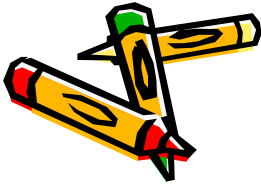
## Overview

- What is an anomalous change?
- Range Cut
- Step Limit
- Summary
- Appendix
  - EM Packages
  - Boundary Crossing
  - Nut-Husk
  - Configuration
  - Shower Shape

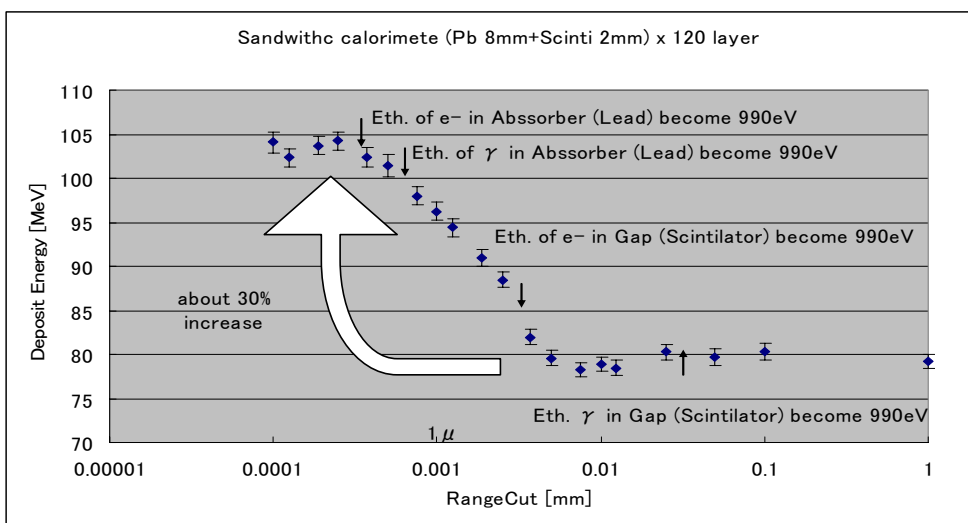


# What is a problem?

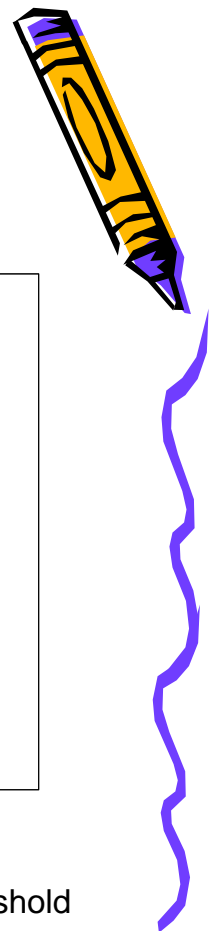
- Liner Collider Simulation and Reconstruction group at SALC reported anomalous change of observation energies in Sandwich Calorimeter according to the range cut values.
- Global Linear Collider group also aware this anomalous change independently.
- We SLAC Geant4 team considered this problem was quite important and started investigation with Geant4 EM developers.
- This report provides what we are observed and what efforts are carried out at SLAC, and Michel will report the current status of this problem from EM developers side.



## Energy Deposition vs Range Cut

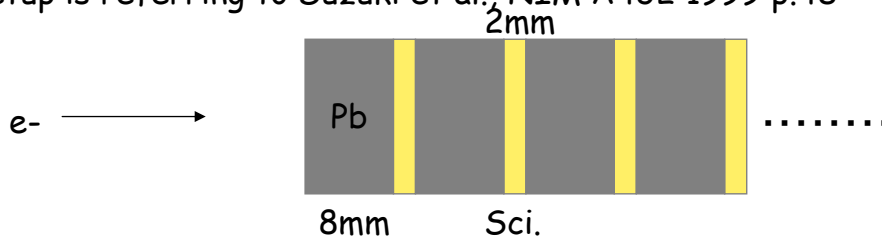


Energy Depositions increase until absorber's production threshold become minimum(990eV).

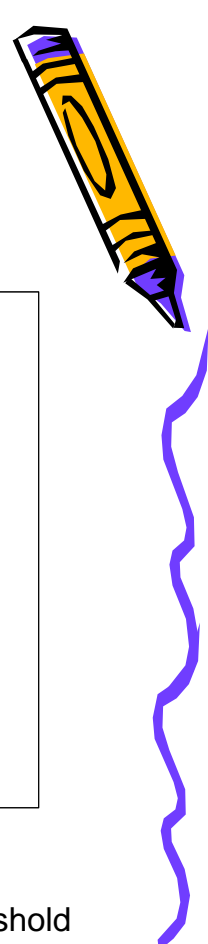
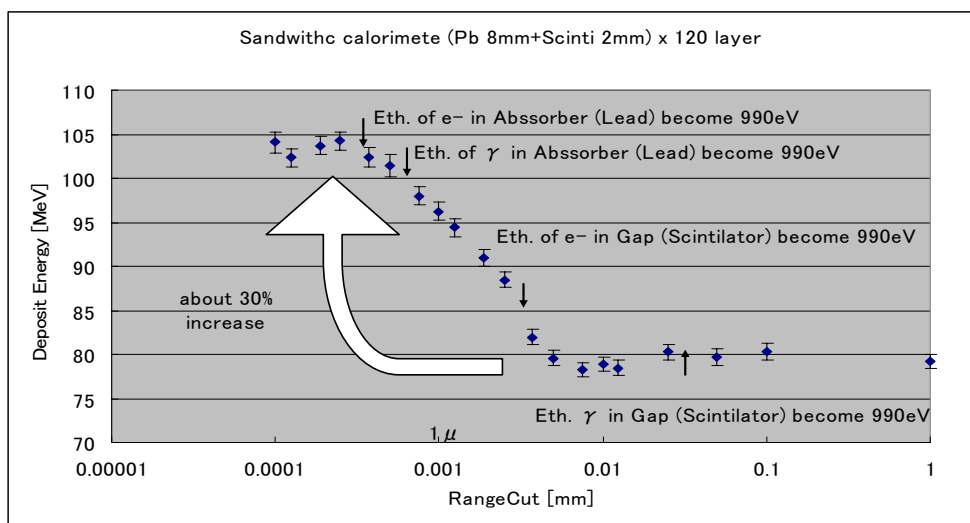


# Simulation overview

- Material
  - Pb (Lead)-Scintillator
- Thickness
  - Pb: 8.0 mm/layer, Sci: 2.0 mm/layer
- Layers
  - 120 layers
  - 1 m x 1 m – interaction surface
- Beam
  - Electron 4 GeV
- Range Cuts
  - 1 mm to 100nm (4 orders range)
- Geant4 v7.0.p01
- This setup is referring to Suzuki et al., NIM A432 1999 p.48

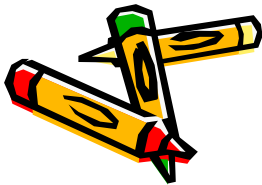
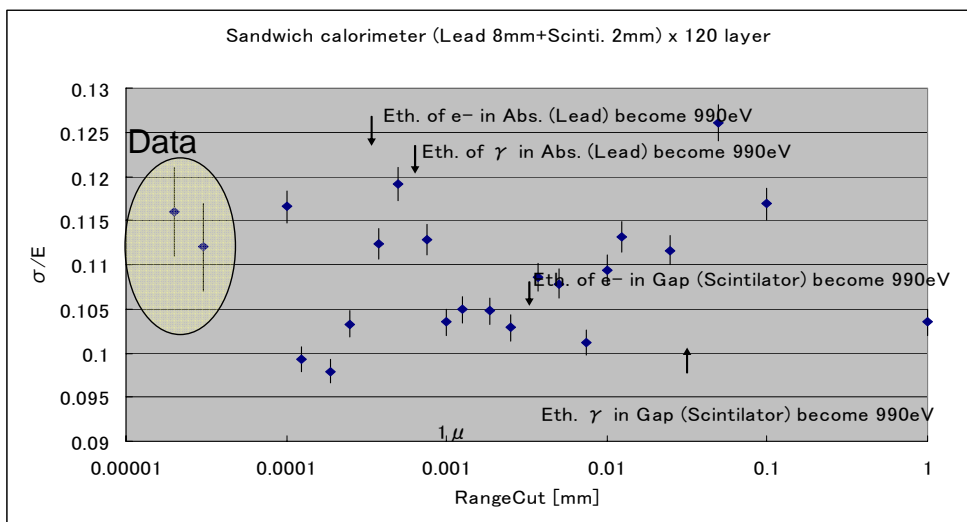


# Energy Deposition vs Range Cut



Energy Depositions increase until absorber's production threshold become minimum(990eV).

# Energy Resolution vs Range Cut

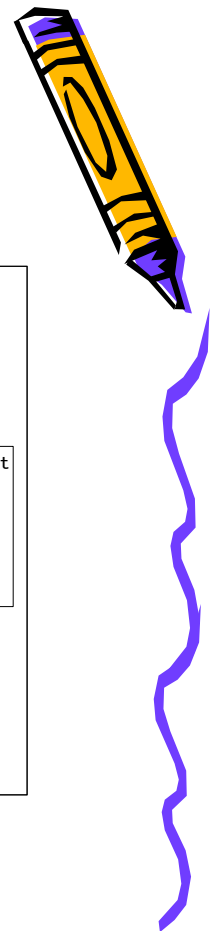
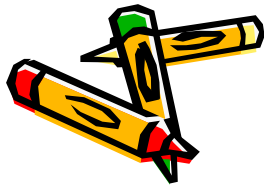
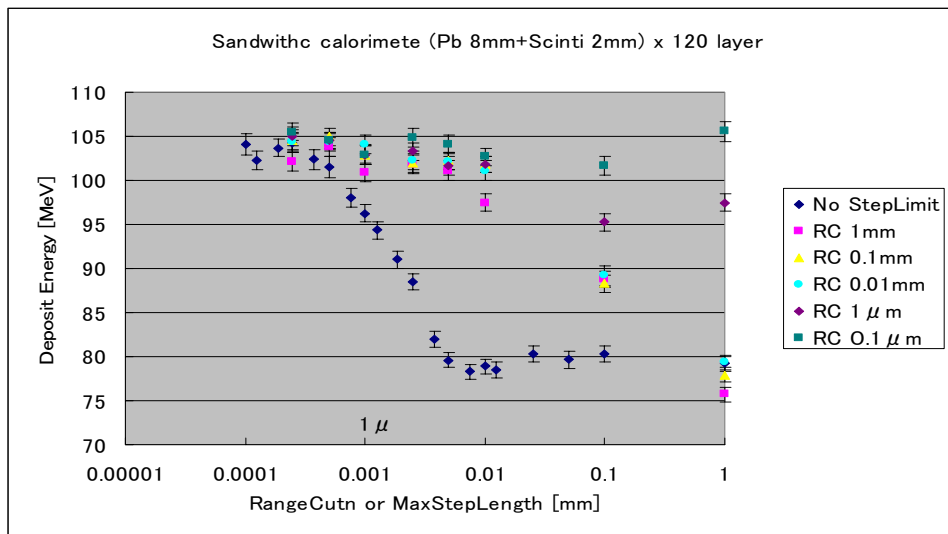


## First suggestion is using MaxStepLimit

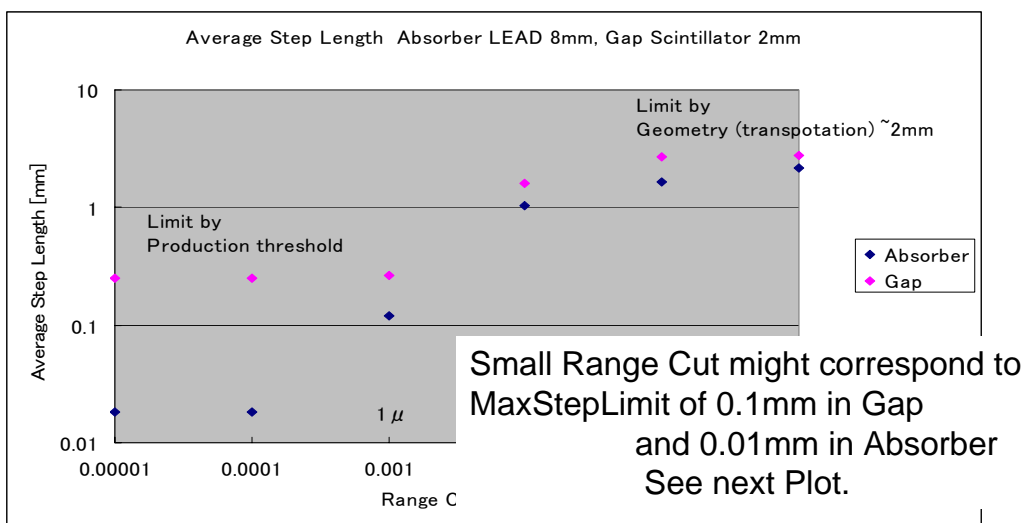
- Physics List
  - ExN03 + Step Limitter
- Step Limits do not apply for  $\gamma$
- Step Limits apply both Absorber and Gap



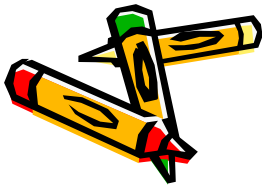
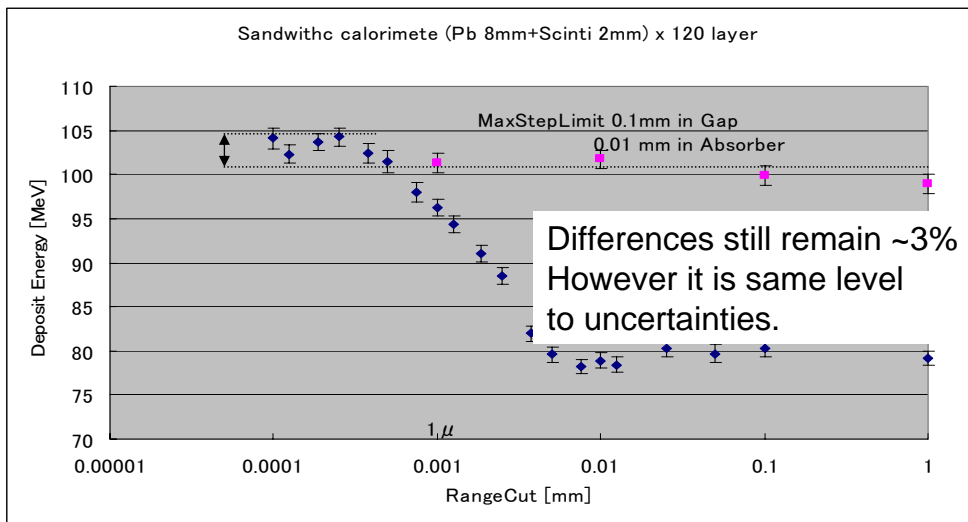
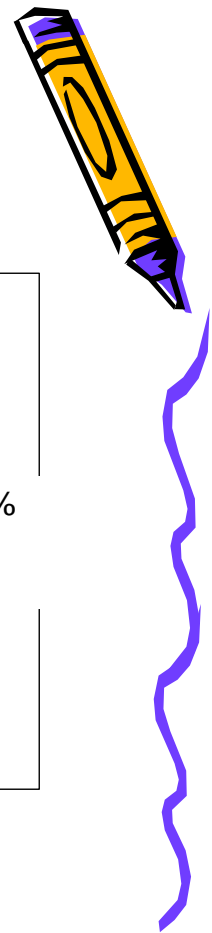
# Energy Deposition vs MaxStepLength



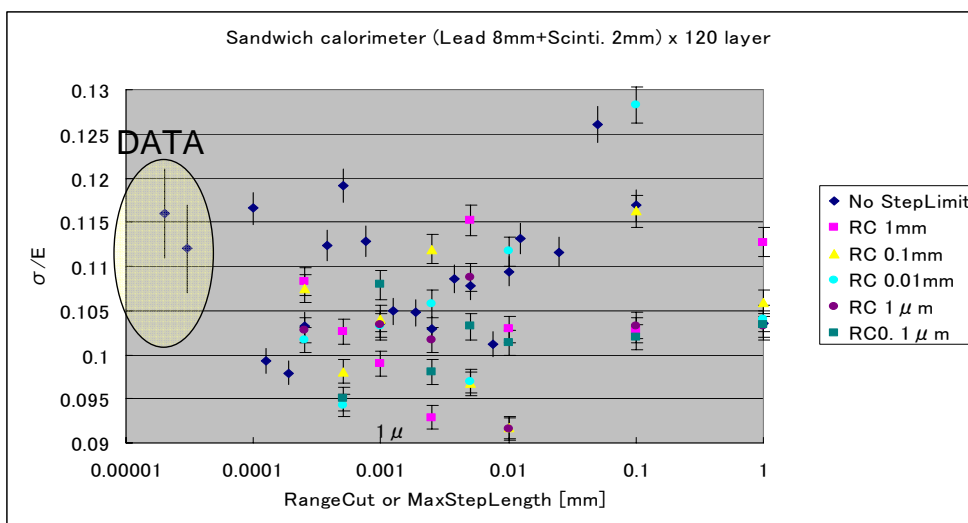
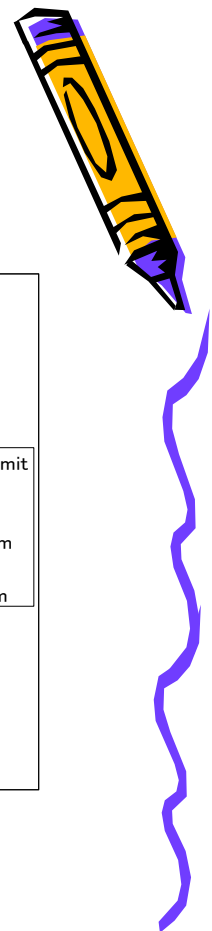
# Average Step length vs Range Cut



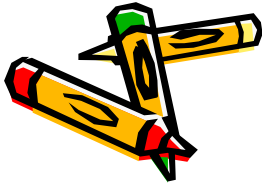
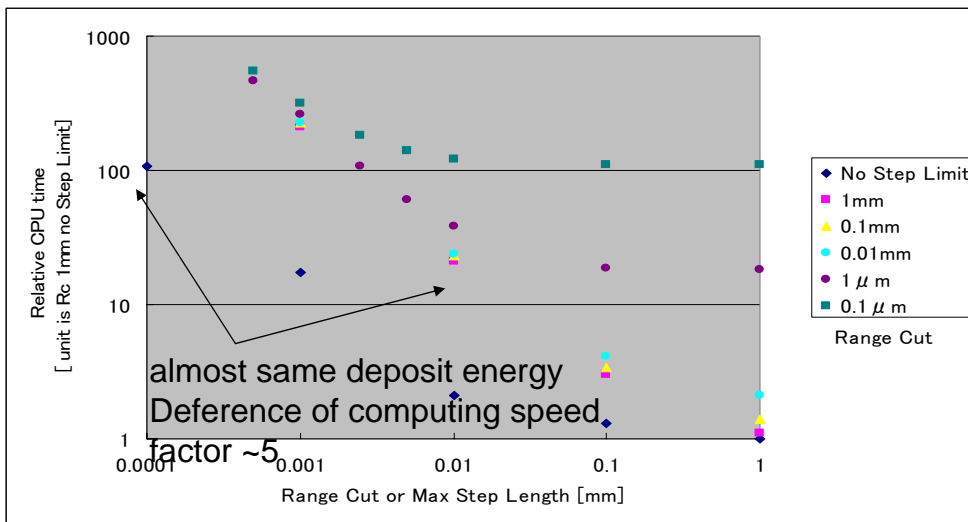
# Range cut and MaxStepLength



# Energy Resolution vs MaxStepLimit



# Computing Speed



Range cut 0.1 mm  
Max Step Limit 0.01mm  
is current recommendation values from Michel.

## Results Deposit energy

- Deposit energy increased about 30% by change of Range Cut from 1mm to 0.1  $\mu$  m.
- This increase stopped at where secondary production limit of absorber became minimum (990eV).
- Limitation of Max Step Limit also increase deposit energy.
- This increase terminated around limitation of 2.5  $\mu$  m without dependence of Range

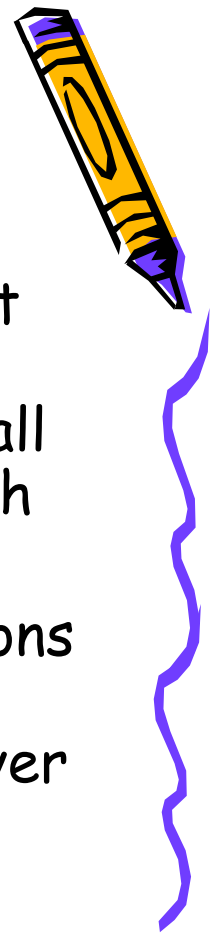


Both end points are same within uncertainties.

## Results Cont.

### Energy resolution ( $\sigma / E$ )

- Although average values of deposit energies are converged, energy resolutions are not converged at all and well scattered distributed with no significant trend.
- The agreement of energy resolutions to data (Suzuki et al.,) is not so bad(????) about  $2 \sim 3 \sigma$  level however it seems to incline toward the underestimate side.



## Results Cont.

- Small Range cut values corresponds to apply small Max Step Length.
- If we uses small Range cut value ( $< 0.01\text{mm}$ ) then we do not need to apply Step Limit to Gaps. This should effect computing speed. (Unfortunately, Absorbers mass is greater than Gaps, so the effect is limited.)
- Applying very small Max Step Length ( less than few  $\mu\text{m}$ ) is more CPU intense than the minimum range cut.



For average energy deposition, a result with Range Cut 0.01mm and MaxStepLenght 0.01mm gives almost same value as result with minimum range cut. Former is five time faster than later.



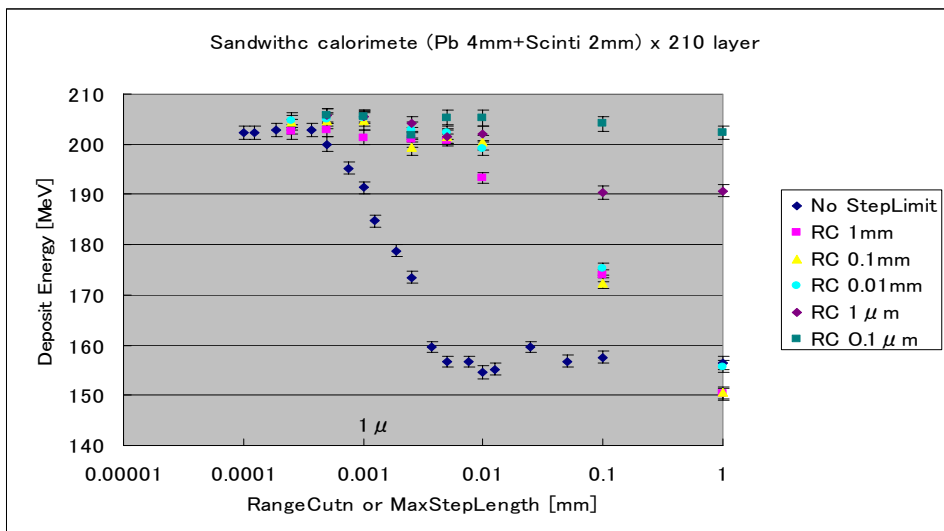


# Further investigation

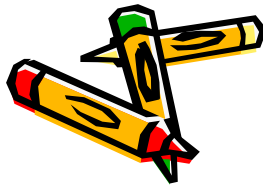
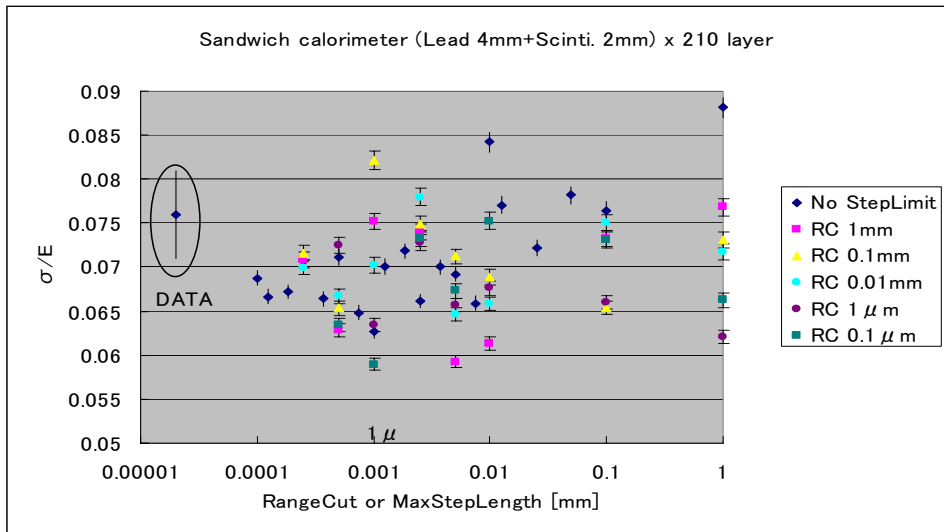
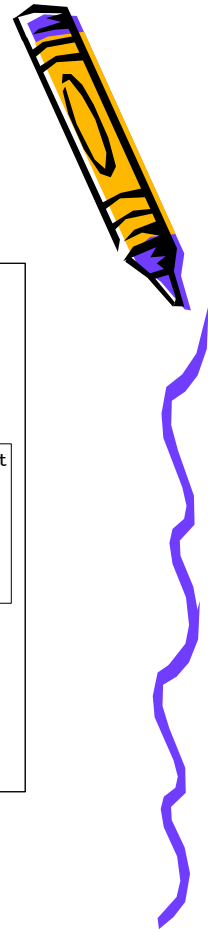
- I calculated several sandwich calorimeter, i.e., changing material (ex. W-Si) and ration between Absorber and Gap. Similar results are gotten.
- I calculated sandwich calorimeter which has same material for absorber and Gap. The feature we discussed here disappeared.

I also did simulation without Multiple Coulomb Scattering. The results shows very small or no increase on energy depositions.

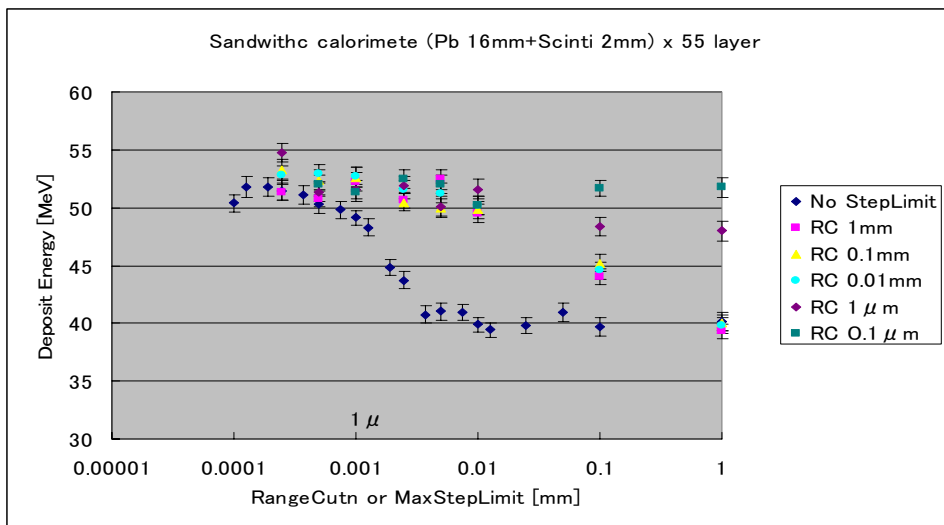
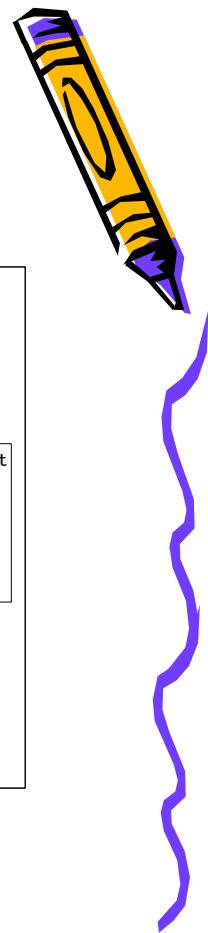
(Lead 4 mm + Scinti. 2mm) x  
210 layer



# (Lead 4 mm + Scinti. 2mm) x 210 layer

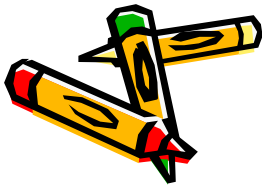
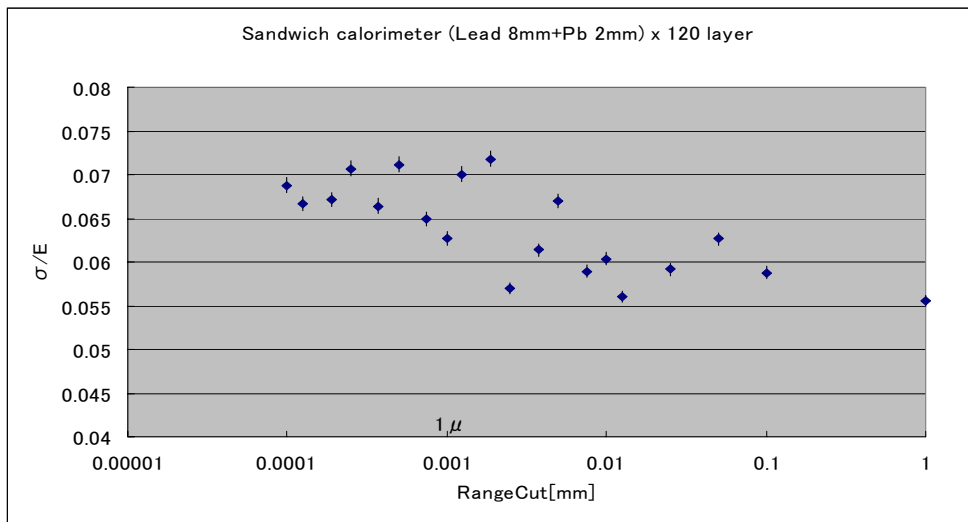
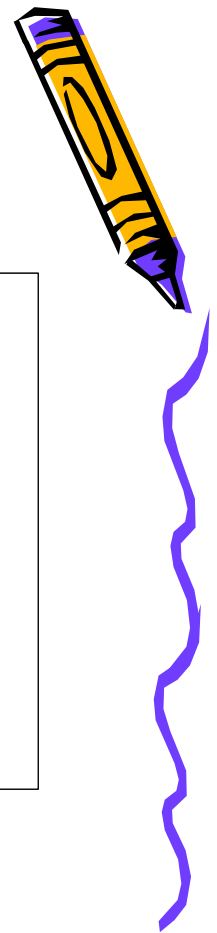


# (Lead 16 mm + Scinti. 2mm) x 55 layer

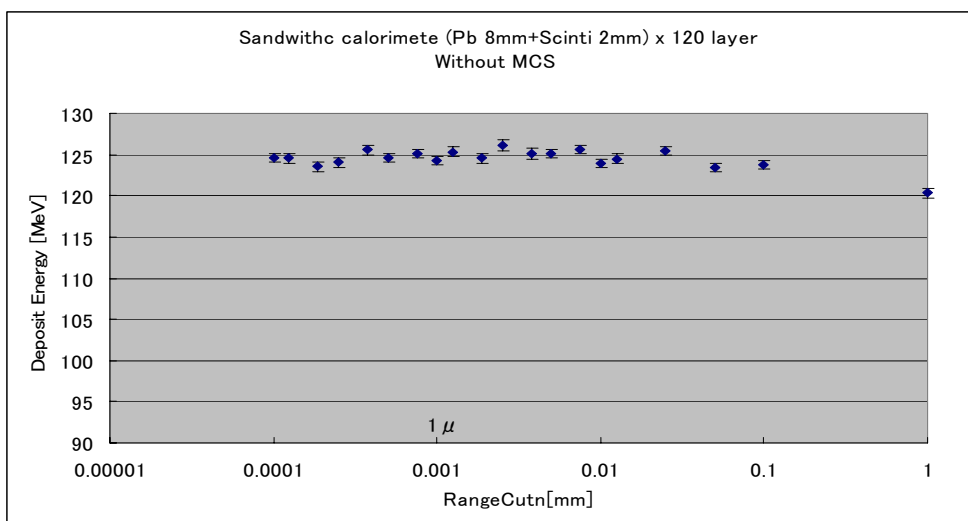
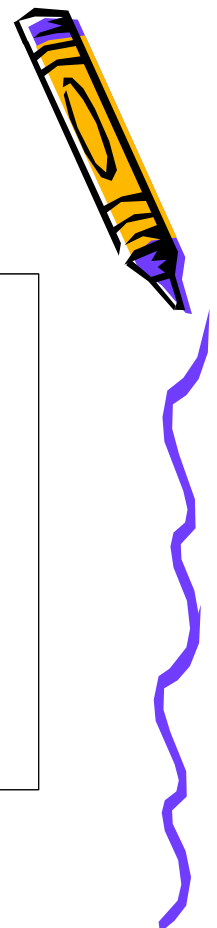




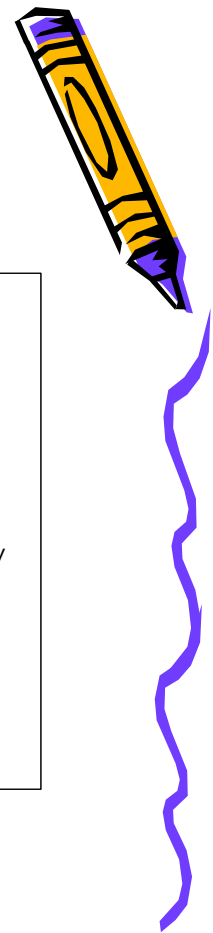
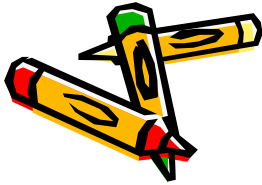
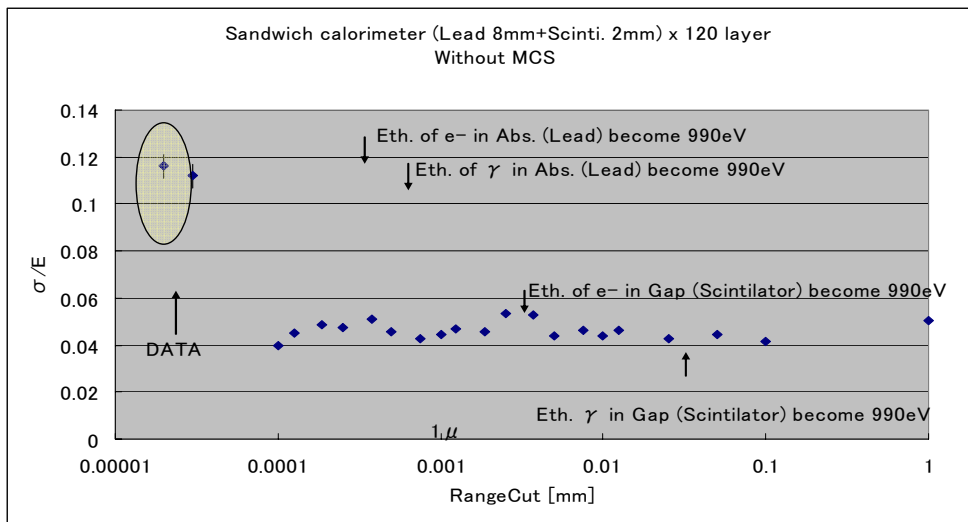
# Same material for Absorber and Gap.



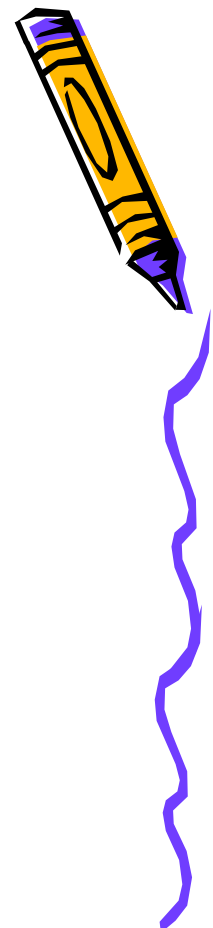
# Without Multiple Coulomb Scattering



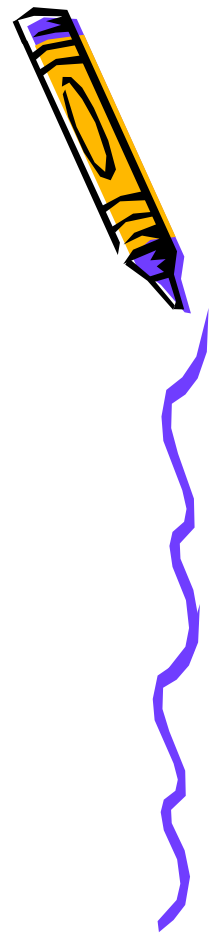
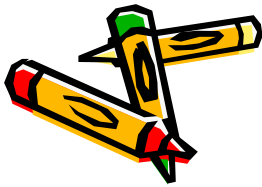
# Without Multiple Coulomb Scattering



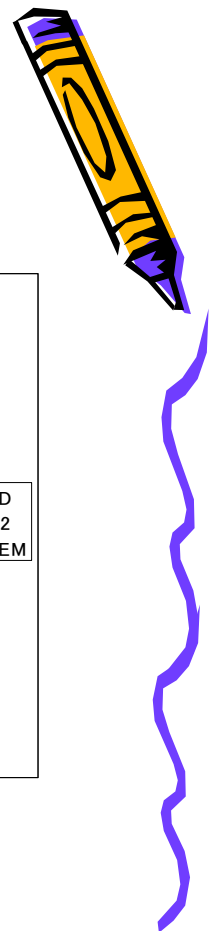
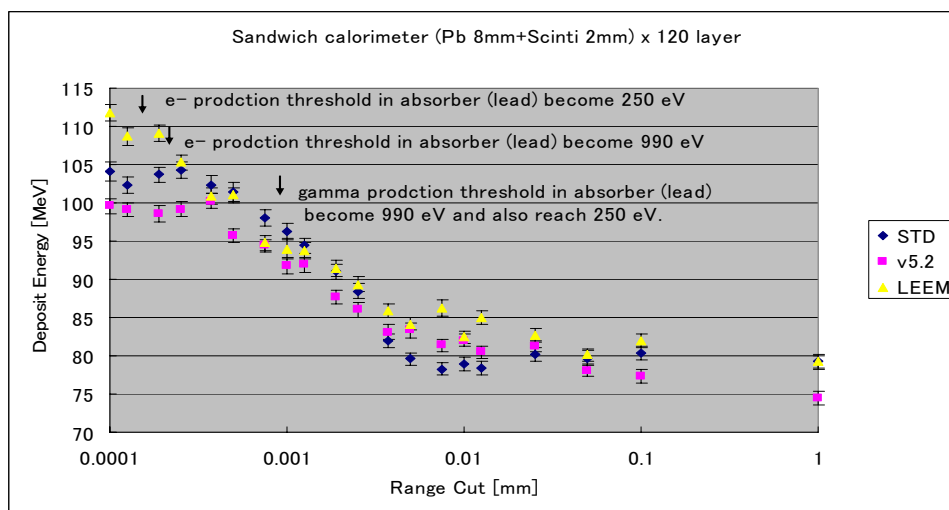
So that,  
Multiple Coulomb  
Scattering  
is most likely responsible to  
this problem.



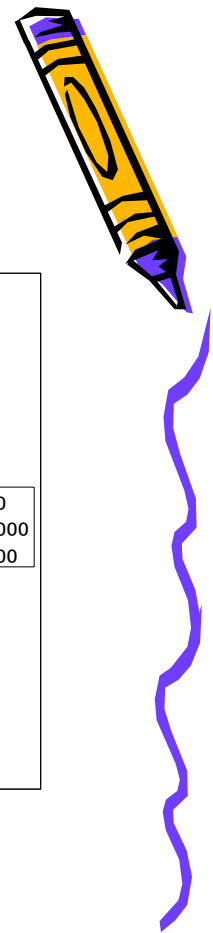
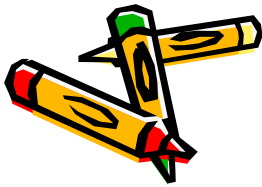
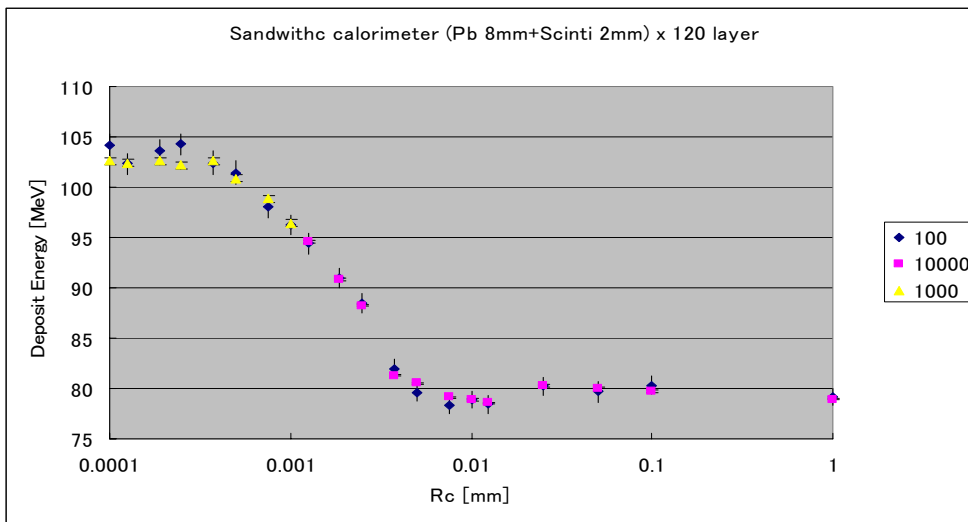
- Try for understood
  - EM package dependency
  - History ( especially for resolution)
  - Changing Configuration of a layer
- Try for Speed up
  - Boundary Crossing
  - Nut-Husk



## Comparison among EM packages

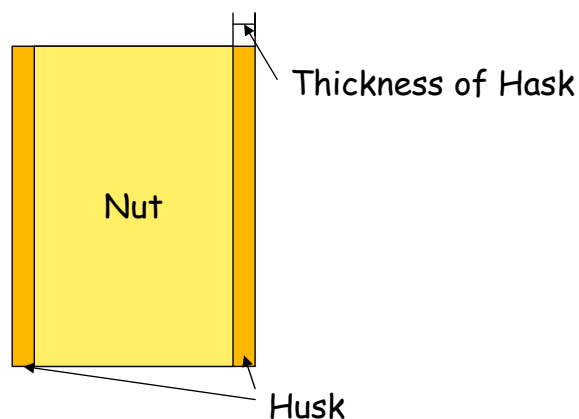


# Extend number of sample from 100 to 10000 (1000)

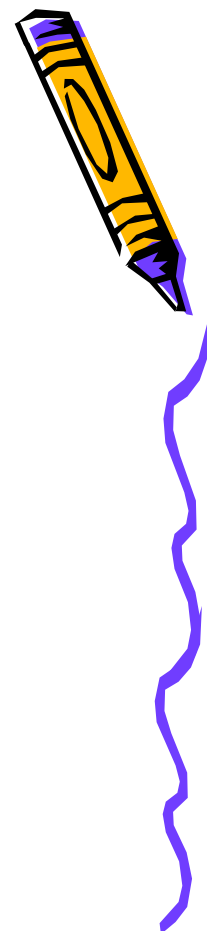
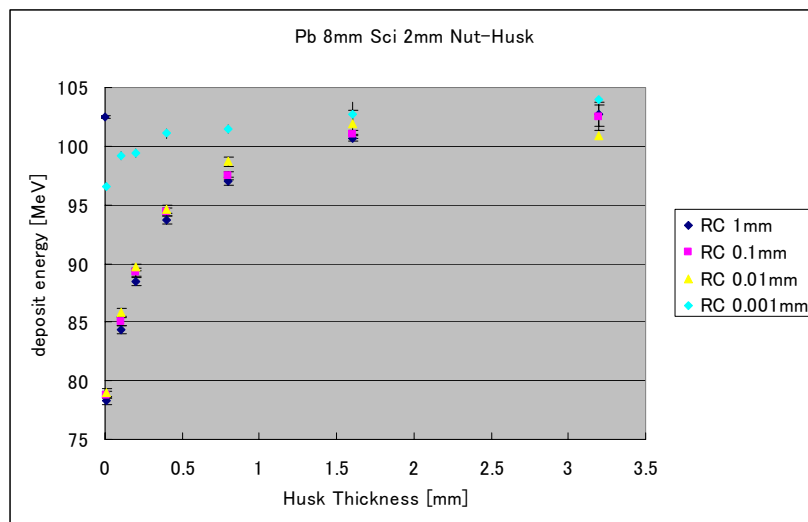


## Nut-Husk

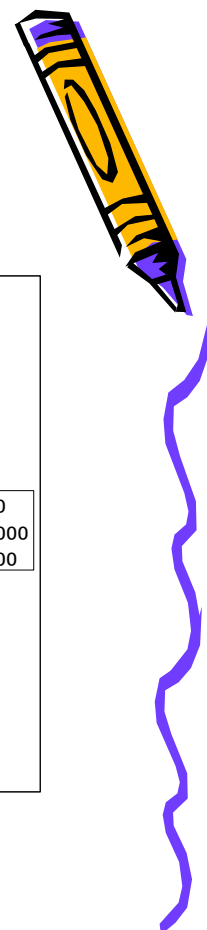
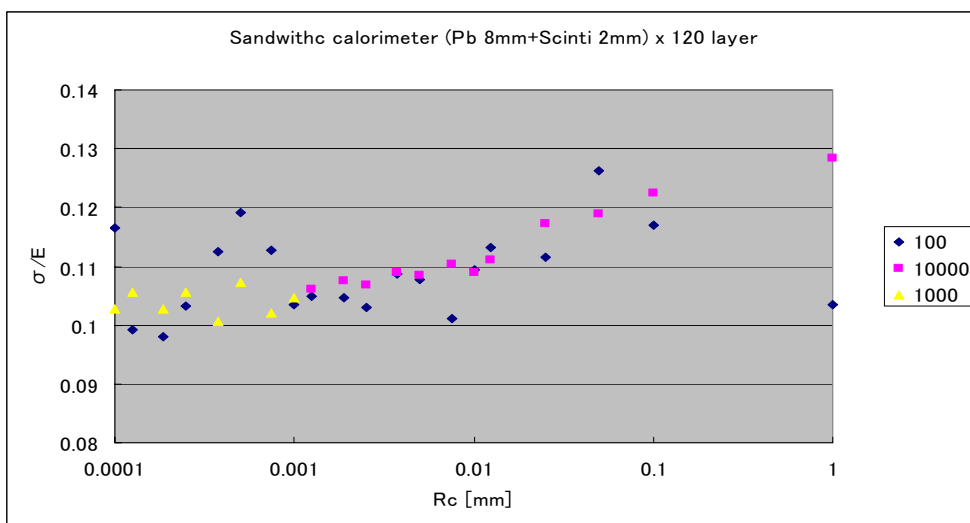
- Divide Absorber two parts as Nut and Husk.
- Apply different Range Cut values for Nut and Husk.



# Nut-Husk



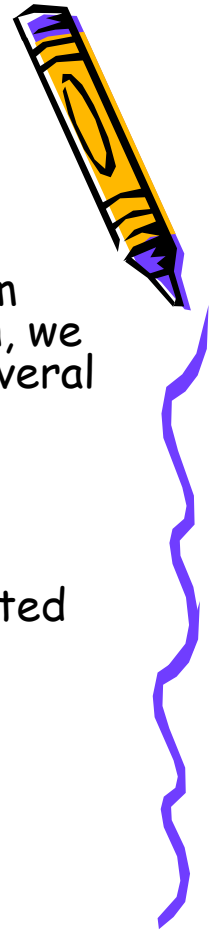
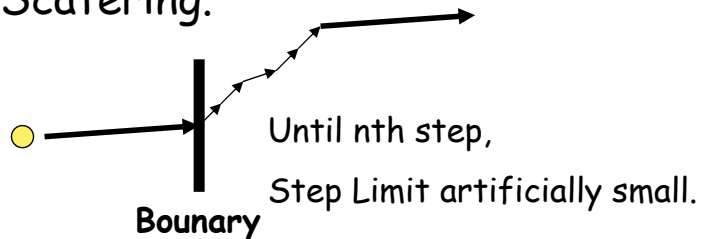
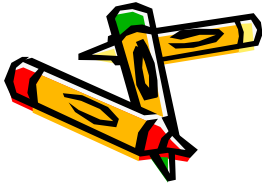
# Extend number of sample from 100 to 10000 (1000)



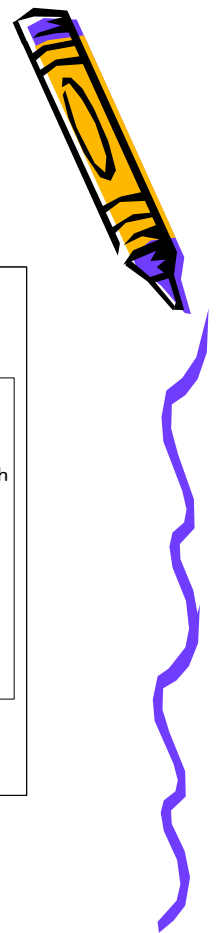
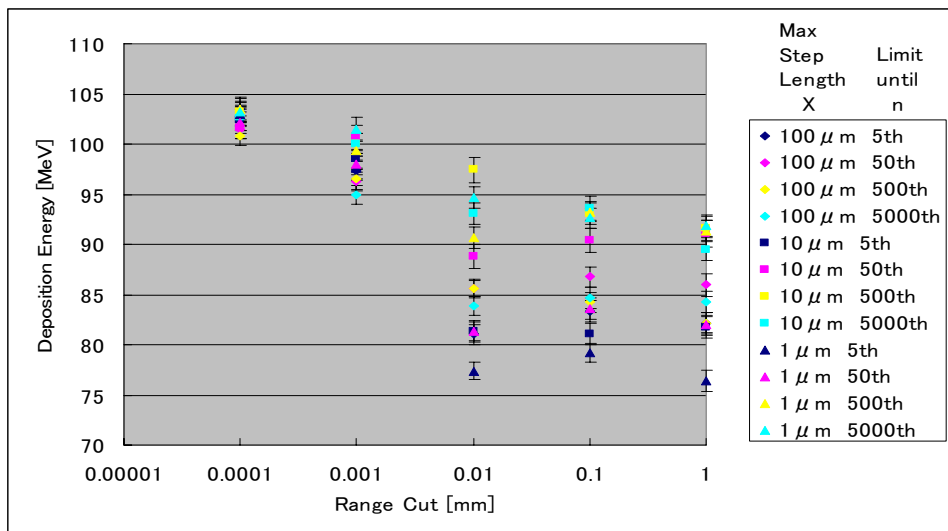


# Boundary Crossing limitation.

- If backward scattering of slow electrons from absorber makes increase of energy deposition, we may limit applying MaxStepLength only for several series of steps after crossing boundary.
- Check, is PreStepPoint limited by Geometrical Boundary.
- Then, n successive steps after crossing boundaries, MaxStepLength is artificially limited to x.
- The implementation is achieved in G4MultipleScattering.

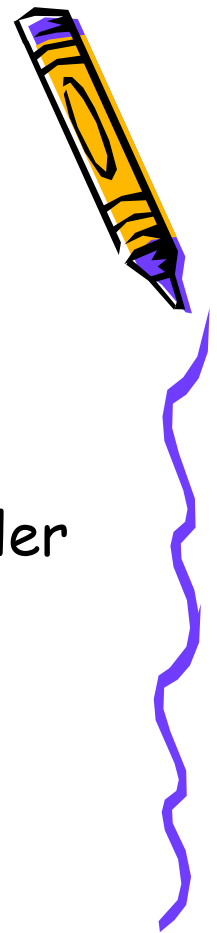
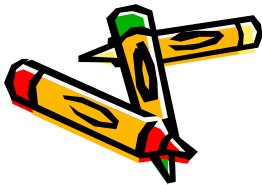


# Boundary Crossing Process



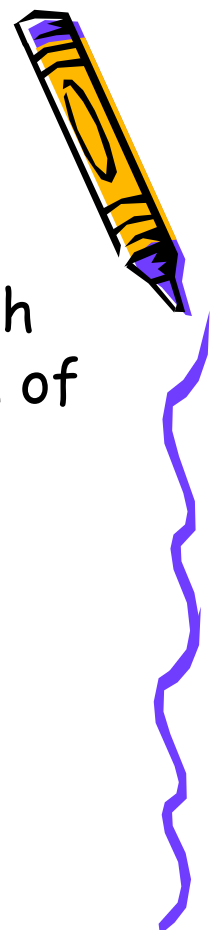
## Boundary Crossing Results

- I create Step Limits which only effect n steps after boundary crossing.
- However this limitation gives smaller energy deposition than usual MaxStepLength limitation.



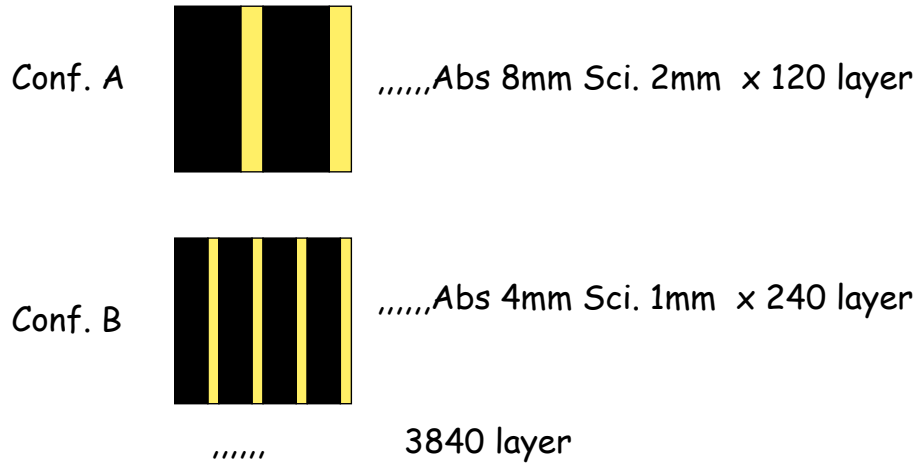
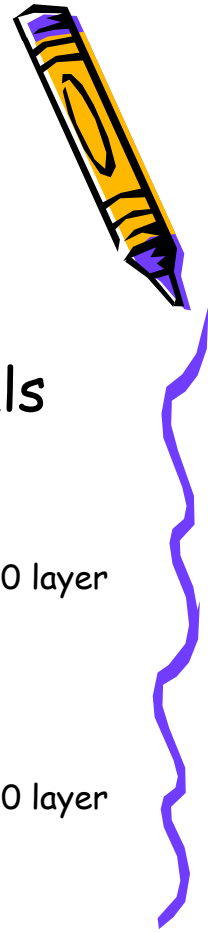
## Boundary Crossing Summary

- Both range cut and max step length effects average energy deposition of sandwich calorimeter.
- The amount of increases reaches about 30%.

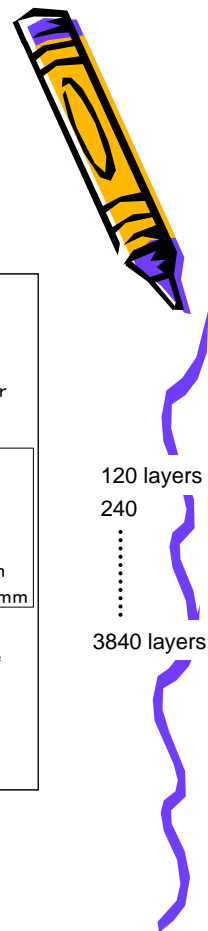
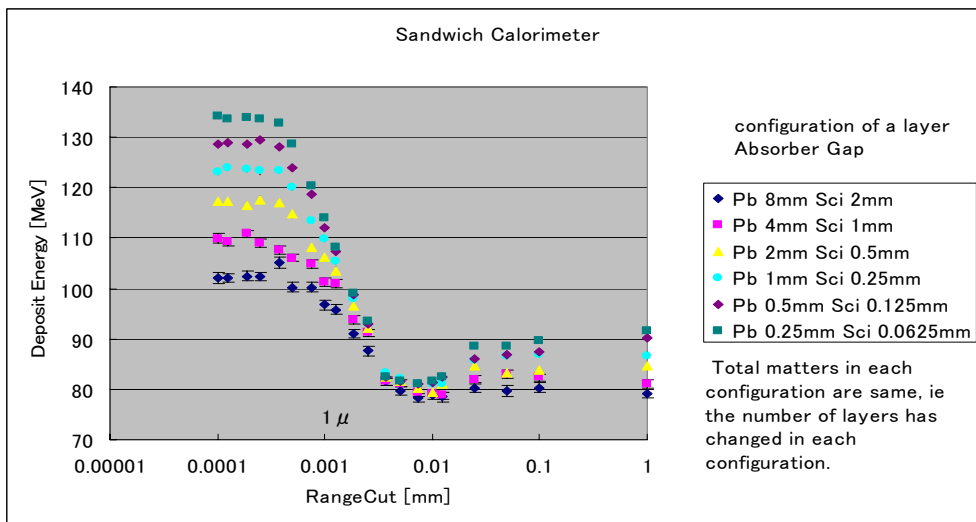


# Changing Configuration of a layer

- Keep ratio of material
- Keep total matter of each materials



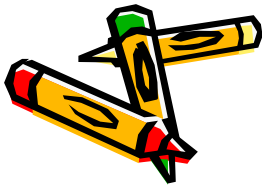
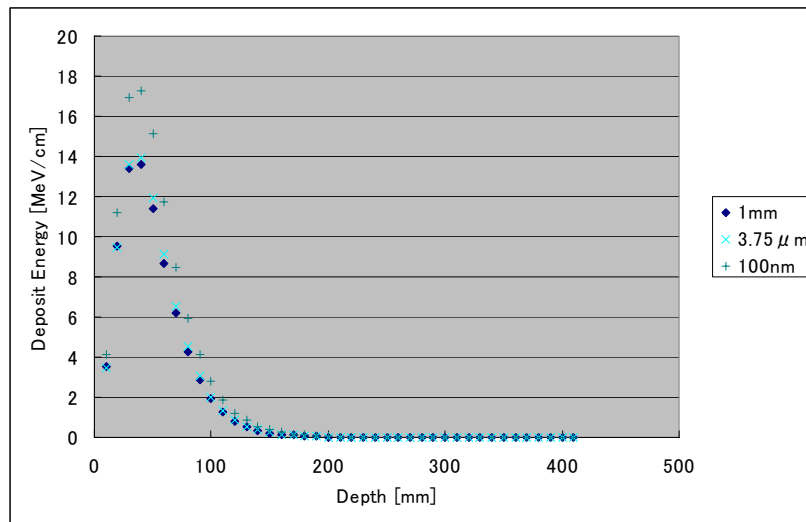
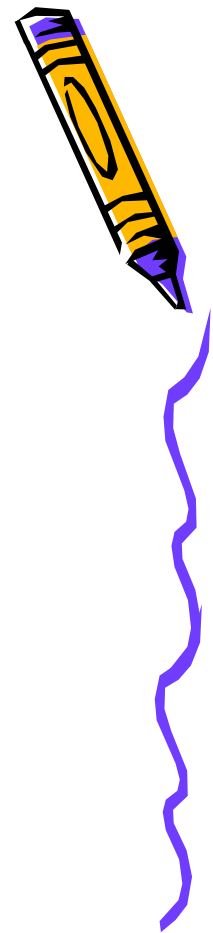
# Changing the Configuration of a Layer



120 layers  
240  
.....  
3840 layers

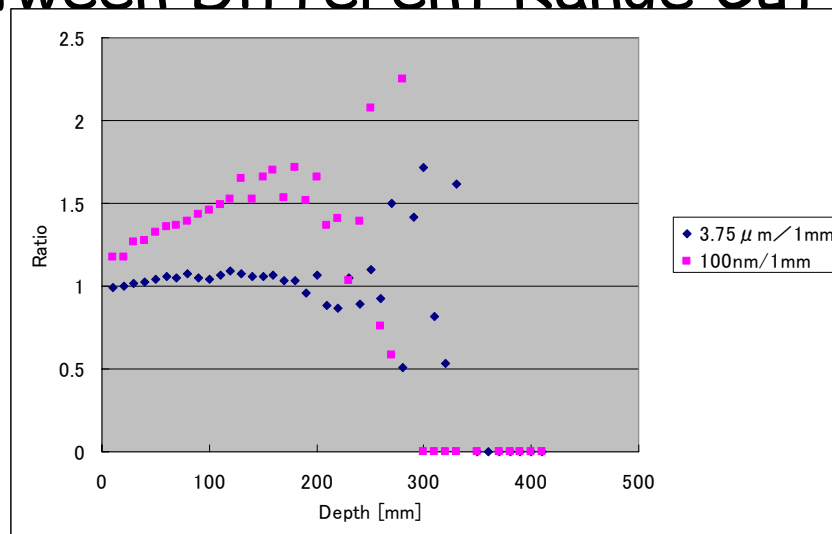
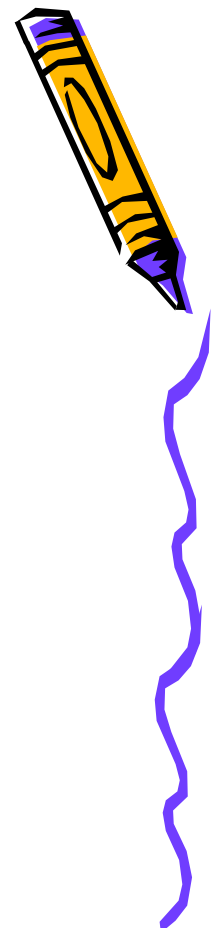


# Comparison of Shower Shape Between Different Range Cut



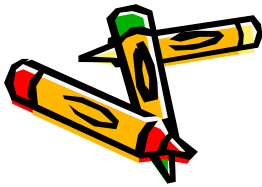
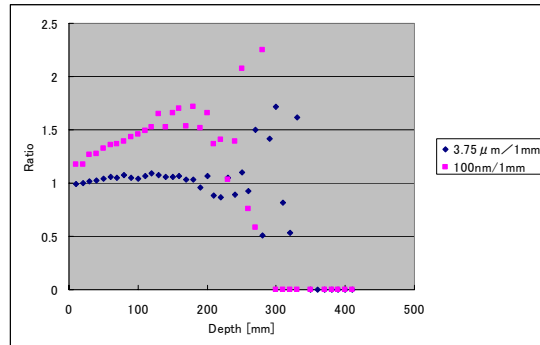
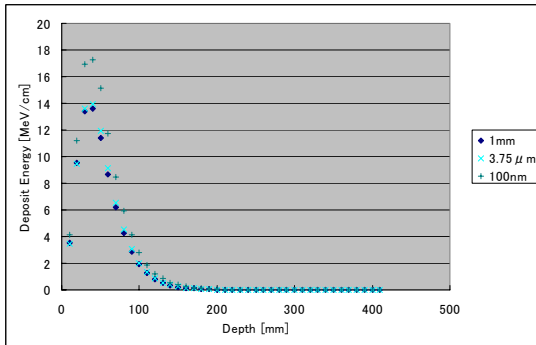
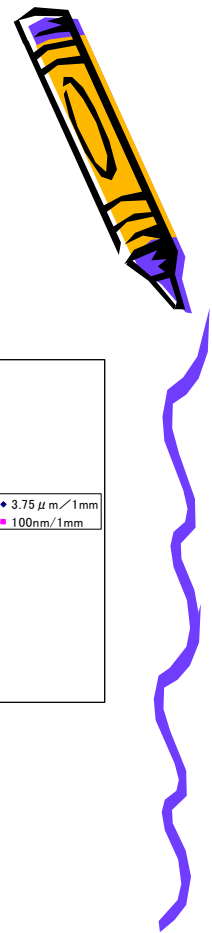
8mm Pb, 2mm Sci. x 120 layer

# Comparison of Shower Shape Between Different Range Cut



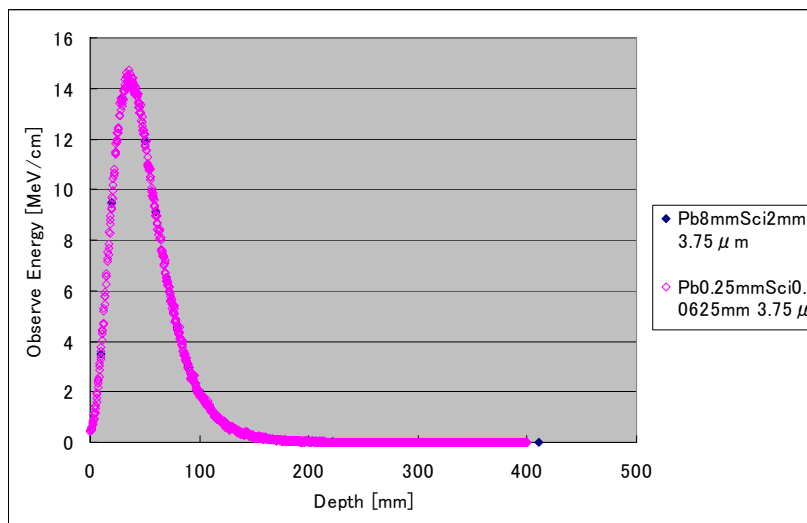
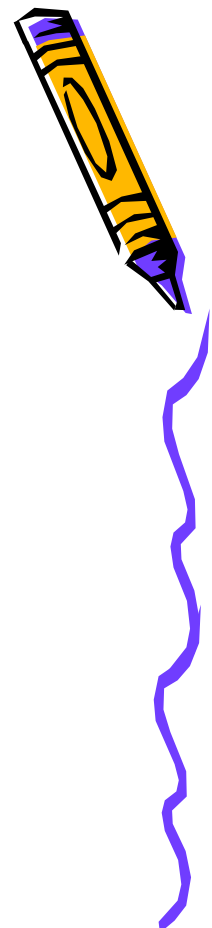
8mm Pb, 2mm Sci. x 120 layers

# Comparison of Shower Shape Between Different Range Cut



8mm Pb, 2mm Sci. x 120 layers

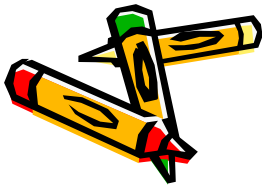
# Comparison of Shower Shape Between Different Configuration



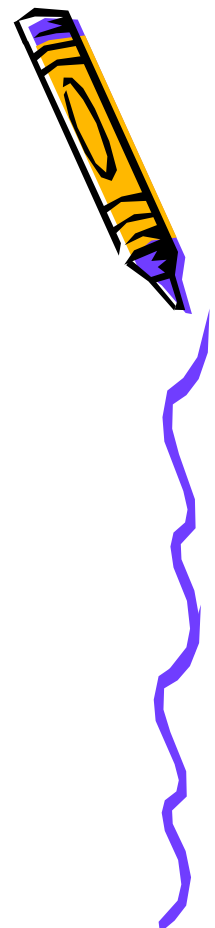
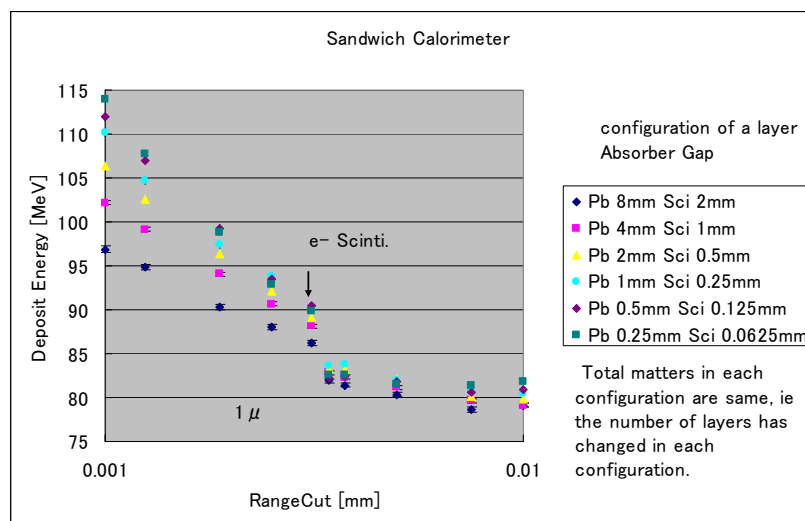
# Comment from Michel

In your exercises, of course the global ratio scintillator/lead is unchanged, but however the geometry is changed.

The results are not directly comparable. I switch off the msc. We know that in this case, the energy deposit is practically independent of cut or stepmax. But it not the same in the 6 cases you have shown : It ranges from 121 MeV (120 layers) to 137 MeV ( 3840 layers)



# Changing the Configuration of a Layer (Cont.)





Fin.

