Validation of EM Part of Geant4

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Purpose and Plan of this Talk

We have validated EM processes in Geant4 important for gamma-ray satellite GLAST. Energy range of GLAST is 20 MeV - 300 GeV. So we need to validate physics processed down to ~10 MeV and lower.

- Particle Ionization Energy Loss in Matters
  - Bethe-Bloch Formula (pp. 3-5)
  - Landau Distribution (pp. 3-5)
  - Range (p. 6)
- Processed related to electromagnetic shower
  - Pair creation (pp. 8-9)
  - Bremsstrahlung (p. 10)
  - Moller scattering/BhaBha scattering (pp. 11-12)
  - Comparison of shower profile with experimental data (pp. 13-14)
  - Comparison of shower profile with EGS4 (pp. 15-17)

- We use Geant4 2.0
Ionization Energy loss in matters

- Shoot proton/electron in Pb and Si.
- Cutoff Length:
  - 0.4mm (e-), 0.1mm (others)

For a thick absorber:
- Use the Bethe-Bloch formula.

For a thin absorber:
- Use the Landau distribution.

Check mean energy loss (thick absorber), shape and most probable energy loss (thin absorber).
Bethe-Bloch formula for protons

Geant4 well reproduces ionization energy loss in thick Si and Pb of proton down to 10 MeV.
Landau Distribution for protons and electrons

Fluctuation of energy loss and the most probable value in thin Si and Pb are appropriate.
Range of protons

Shoot protons of 200 MeV and 1 GeV in CsI, Pb and W.

Compare the results with NIST data: [http://physics.nist.gov/PhysRefData/Star/Text/contents.html](http://physics.nist.gov/PhysRefData/Star/Text/contents.html)

Show good agreement within 0.6%.
Processes related to EM shower

- Pair creation (pp. 8-9) (and Compton scattering and photo-electric effect)
- Bremsstrahlung (p. 10)
- Moller scattering (pp. 11-12)
- Bhabha scattering (pp. 11-12)

We need to validate these processes, especially in low-energy, since
- Pair creation and EM shower are key processes to determine gamma-ray energy and direction in the GLAST.
- Low energy electrons may suffer large-angle scattering and cause trigger in the GLAST.

Cutoff

- 0.04mm (e-)
- 0.01mm (others)

Tracker
(Si-Strip detectors)

Calorimeter
(Csl scintillator)
Pair creation – cross section

Compare the cross section in Pb calculated by Geant4 with that of a reference (http://physics.nist.gov/PhysRefData/Xcom/Text)

Geant4 correctly calculates cross section down to ~100 keV
Pair creation-angular distribution of emitted electrons

- Shoot 20 MeV gammas into Pb absorber (10% RL)
- Compare the angular distribution of generated e- with that of theoretical formula

- We found discrepancies for low energy electrons and fixed the code
Bremsstrahlung -- angular distribution of generated photons

- Shoot 20 MeV e- into Pb absorber (10% RL)
- Compare the angular distribution of generated photons with that of theoretical formula

Geant4 well reproduces the angular distribution of photons generated via bremsstrahlung down to ~1 MeV
Moller/Bhabha scattering (scattering with e-/e+)

- Shoot e- of 20 MeV and 100 MeV into Pb absorber (1% RL)
- Compare the angular distribution of scattered electrons with that of theoretical formula
Moller scattering (with e-) and Bhabha scattering (with e+)

G4 well reproduces the theoretical formula down to 20 MeV.
EM shower profile – Crannell experiment (1)

• Cranell experiments:

• Shoot 1GeV e- into water tank
  (10 rings and 11 layers)

• Compare the G4 results with that of experimental data and EGS4 (Professor Nelthon and Liu).
Shower profile of G4 is narrower than that of experiment and EGS4
To investigate the EM shower profile in the GLAST Tracker, we constructed 10 Pb layers (0.1RL each) with air (3cm). The radius is 0.2 Moliere radius (core of shower).
• Energy deposition is higher in Geant4 (low energy region)
• Geant4 shows narrower shower profile (and could not be solved by fixing the angular distribution of pair creation)
Effect of cutoff energy (length)

- The discrepancy cannot be attributed to cutoff length (energy)

0.4mm, 0.04mm (e-),
0.1mm, 0.01mm (others)

The reason of the narrower shower profile is unrevealed.
Summary

• We have validated EM part of Geant4 (2.0).
• Energy loss in matters is well simulated down to ~10 MeV.
• Angular distribution of pair-created e- was found to be inappropriate and fixed.
• Cross section of pair creation, angular distribution of bremsstrahlung/Moller scattering/Bhabha scattering were validated down to ~10 MeV.
• Shower profile of G4 is slightly narrower than that of experimental data and EGS4. The reason of this is unknown.