PIBETA NOTE: **Photonuclear Interactions and Electron-Nucleus Scattering Reactions in GEANT Code**

By: E. Frlež

Date: 17 November 1995

Inclusion of Photonuclear and Electon-Nucleus Scattering Reactions in GEANT Code

The standard version 3.21 of the `GEANT` code does not take into account interactions of photons and electrons/positrons with nuclei.[1] Transport of photons generates the pair production, Compton and/or photoelectric effect, as well as photofission reactions on heavy nuclei (230≤A≤240). Electron/positron tracking routines incorporate multiple scattering, Bremsstrahlung, annihilation and Delta ray production.

We are in a process of including photonuclear reactions and electron/positron-nucleus elastic and inelastic scattering in the `GEANT`, for the energy range from threshold to 100 MeV. These additional reactions are been simulated in stand-alone routines called from the tracking subroutine `GUSTEP`.

The mean distance traveled by the particle of energy E without suffering an interaction is known as the mean free path λ:

$$\lambda = 1/N\sigma_t, \tag{1}$$

where N is the density of interaction centers and $\sigma_t(E)$ is the energy-dependent total interaction cross section. The probability of interaction P_{int} in step length x is calculated as[2]

$$P_{int} = 1 - \exp\left(-x/\lambda\right) = 1 - \exp\left(-6.022\rho\sigma_t x\right)/10^4 A, \tag{2}$$

where σ_t is expressed in mb, x in cm, ρ is density, and A is material atomic number.

Photonuclear Reactions

If the transported particle is photon, the photonuclear reaction was considered for the step length x with the probability (2), where the total photonuclear cross sections $\sigma_t^\gamma(E)$ are taken from the published experimental data.[3−8] We have simulated the photonuclear reactions following $\pi\beta$ decay in the PIBETA detector in Monte Carlo run with $3 \cdot 10^4$ $\pi\beta$ events.

Results can be summarized as follows: probability of photonuclear reactions for two photons following the π^0 decay in the stopping target, MWPCs material, plastic veto and air is $(0.066 \pm 0.011 \pm 0.022)\%$, where first uncertainty is statistical and second systematic. Probability of photonuclear reactions for two photons following π^0 decay in the CsI calorimeter is $(0.155 \pm 0.019 \pm 0.051)\%$.

Probability that any $\pi\beta$-event-generated final state photon undergoes photonuclear interactions outside the CsI calorimeter is $(0.360 \pm 0.007 \pm 0.120)\%$, and inside the calorimeter $(0.675 \pm 0.030 \pm 0.220)\%$.

We plan to model the details of photonuclear reactions and study how they affect the (tails of) energy spectra. Experimental data will be used to develop parameterizations for the multiplicity distributions and four-momenta of final state protons and neutrons, as is routinely done in Monte Carlo simulation packages.[9]

References

[1] GEANT—*Detector Description and Simulation Tool*, CERN Program Library Long Writeup W5013, Geneva (1994).

[2] W. R. Leo, *Techniques for Nuclear and Particle Physics Experiments*, 2nd Ed., Springer-Verlag, New York (1994).

[3] J. Ahrens et al., Nucl. Phys. **A251** (1975) 478.

[4] A. Lepretre et al., Nucl. Phys. **A367** (1981) 237.

[5] H. Hebach, A. Wortberg, and M. Gari, Nucl. Phys. **A267** (1076) 425.

[6] B. L. Berman et al., Phys. Rev. **177** (1969) 1745.

[7] R. L. Bramblett et al., Phys. Rev. **148** (1966) 1198.

[8] G. G. Jonsson and B. Forkman, Nucl. Phys. **A107** (1968) 52.

[9] H. Fesefeldt, *The Simulation of Hadronic Showers*, PITHA 85/02, RWTH Aachen (1985).

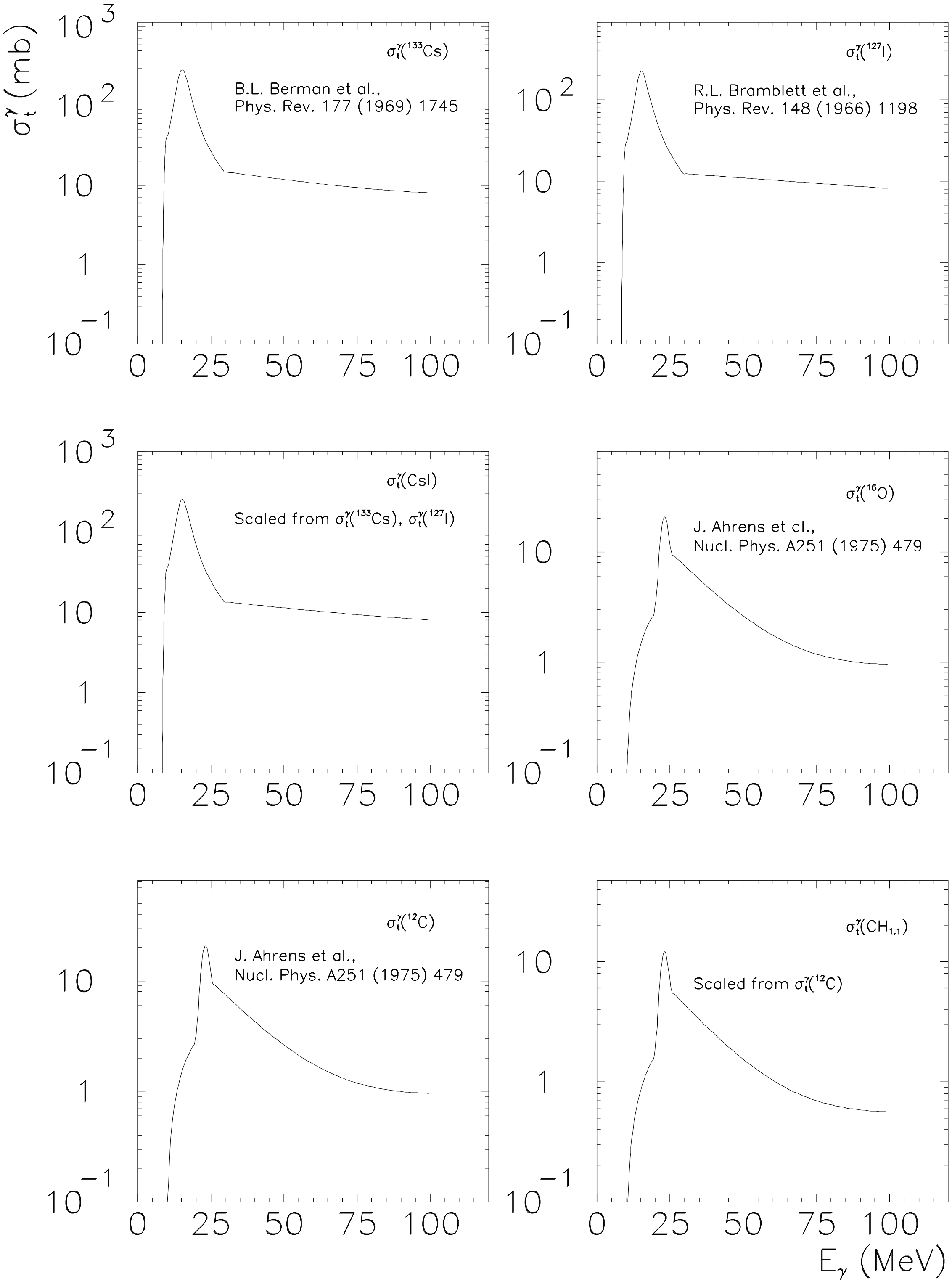

Fig. 1. The total photonuclear cross sections parameterizations as a function of the incident photon energy for ^{133}Cs, ^{127}I, CsI, ^{16}O, ^{12}C and $CH_{1.1}$.