COLOR GRAPHICS DISPLAY OF LOW-HIGH ENERGY ELECTRON-PHOTON TRANSPORT USING EGS4†

R. J. Kloepping
San Jose State University, San Jose, CA 95192

C. J. Huntzinger
Varian Associates, Palo Alto, CA 94303

E. Benson and W. R. Nelson
Stanford Linear Accelerator Center, Stanford, CA 94305

INTRODUCTION

Visual presentations are widely accepted and are a dynamic tool in education. Aptly stated by the often quoted phrase, *one picture is worth ten-thousand words.* The technique of visual presentations of Monte Carlo simulated interaction and transport using the EGS4* Code System[1] via SLAC Unified Graphics[2], connected to an IBM-5080 High Resolution Color Monitor, has been previously demonstrated[3,4].

EGS was originally developed by the Stanford Linear Accelerator Center (SLAC) and the High Energy Physics Laboratory (HEPL) at Stanford University as an analytical tool for engineering and physics. The EGS4 version released in 1985 is capable of simulating radiation transport from several TeV down to 1 KeV (photons) and 10 KeV (electrons and positrons). EGS can not only transport monoenergetic particles, but also particles generated from an energy distribution (*e.g.*, a β-decay spectrum). Although the purpose of this paper is to demonstrate the graphics capability as a teaching tool, the EGS code has been thoroughly verified by comparison with experiment and theory. The reader is referred to SLAC-265 for these comparative studies[1].

THE EGS CODE AND UNIFIED GRAPHICS: GENERAL CONSIDERATIONS

The EGS4 code is a general purpose computer program for the coupled transport of electrons, positrons and photons. The code is composed of 13 subroutines, block data and user interface. Two subroutines of interest are `HATCH`, which brings in media data created beforehand by a preprocessor code called PEGS4, and `SHOWER`, which enters the initial particle data and starts the simulation. The EGS code itself is "driven" by a *user-defined* code written in the Mortran3 language[5]. This User Code defines a specific geometry by means of subroutine `HOWFAR`. Another *user-written* subroutine, `AUSGAB`, scores the results of interest, such as particle fluence, dE/dx, etc. Each particle being transported by EGS carries specific information about its current location, energy, direction, etc.—in other words, a *vector* is associated with each transport that takes place. An auxiliary subprogram package called SHOWGRAF has recently been created[6] in order to plot these vectors. The various subroutines of SHOWGRAF make multiple calls to the SLAC Unified Graphics package[2], which has been interfaced to an IBM-5080 High Resolution Color Monitor by means of an IBM-3033 mainframe computer.

SIMULATION OF THE β-DECAY SPECTRUM OF ^{32}P

For the example to be demonstrated, a three dimensional geometry of a finger was simulated by means of concentric cylinders of finite length (8 cm). The geometric parameters

* Electron-Gamma Shower (Version 4).

were based on measurements taken from a hand x-ray. The simulated bone diameter (1.0 cm) represents the average diameter of the middle, joint and proximid of the middle phalanges. The thickness of the dermis and epidermis was taken as 0.3 cm and 0.04 cm, respectively. The ^{32}P distributions considered were 1) a 4 cm isotropic line source positioned at the outer edge of the epidermis and 2) a 4 cm long isotropic volume source distributed uniformly throughout the bone. The bone was assumed to be of uniform composition and density (1.85 g/cm^3), as was the tissue (1.00 g/cm^3). All particles were followed down to 10 KeV.

The form used for the theoretical beta spectrum was that described by Konopiniski and Rose[7]. The probability density function (PDF) for ^{32}P was generated using the Fermi function tabulation of Fano[8] corrected for the screening effect. The spectrum was introduced into EGS in the form of a cumulative distribution function (CDF) look-up table.

To verify if the beta spectrum in EGS was correct, a comparison was made between the histogram obtained by sampling from the CDF and the theoretical distribution represented by the normalized PDF. As shown in Fig. 1, the histogram compares quite well with the ^{32}P spectrum.

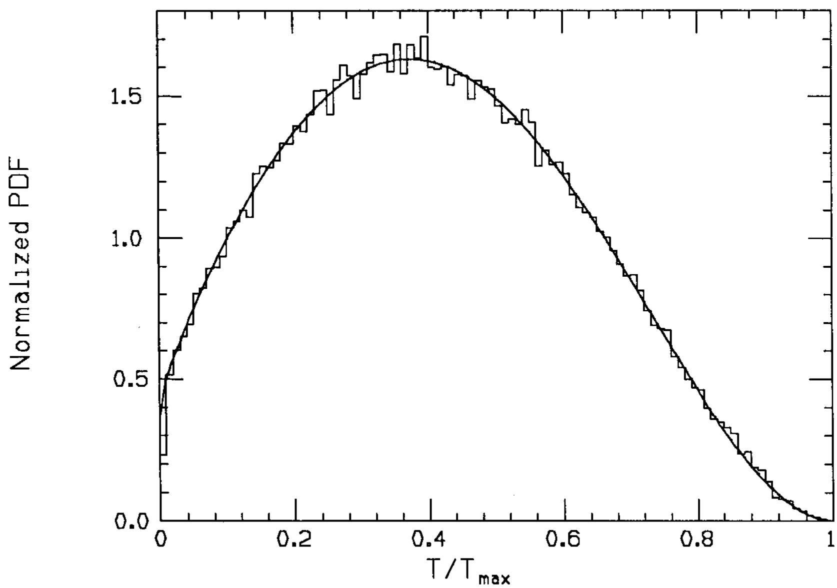

Figure 1. The β-decay spectrum of ^{32}P: sampled distribution (histogram), theoretical PDF (solid curve).

Figure 2 represents a view normal to the cylindrical axis of the simulated finger, where the ^{32}P line source is quite apparent at the top edge of the epidermis (*i.e.*, the outer cylinder). For purposes of clarity, all isotropically sampled betas emanating upwards were redirected 180° back into the finger. Some of the betas are observed to transport to the bone region (T_{max} ≈1.7 MeV corresponds to a CSDA range of 0.81 cm in water). A few bremsstrahlung photons are also shown (dotted lines). A slightly expanded end view of the same set of events is shown in Fig. 3. In all cases 200 events are shown.

The stochastic processes encountered in microdosimetry are nicely demonstrated in Fig. 4, where ^{32}P radioactivity is uniformly distributed within the bone. An expanded end view is show in Fig. 5.

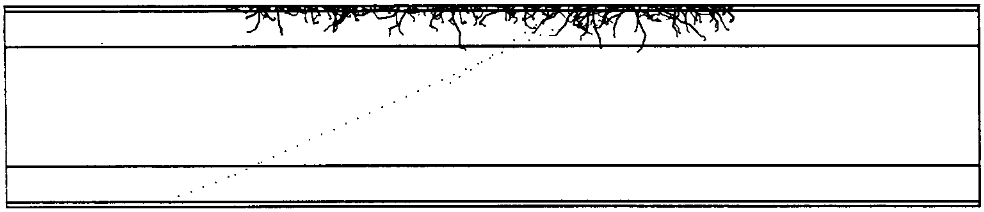

Figure 2. Side view of the finger with a ^{32}P line source positioned on the epidermis.

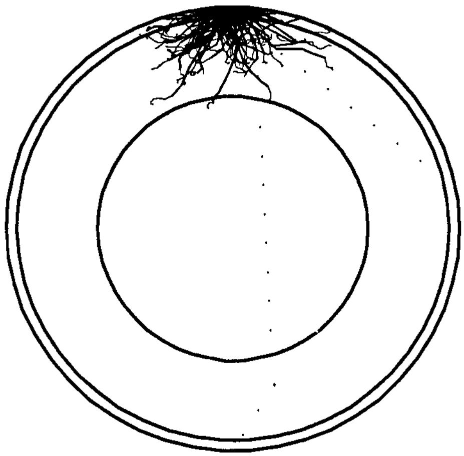

Figure 3. End view of the finger with a ^{32}P line source positioned on the epidermis.

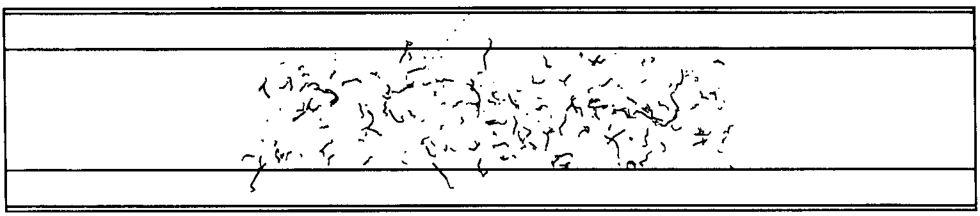

Figure 4. Side view of the finger with ^{32}P radioactivity uniformly distributed over a 4 cm length of the volume.

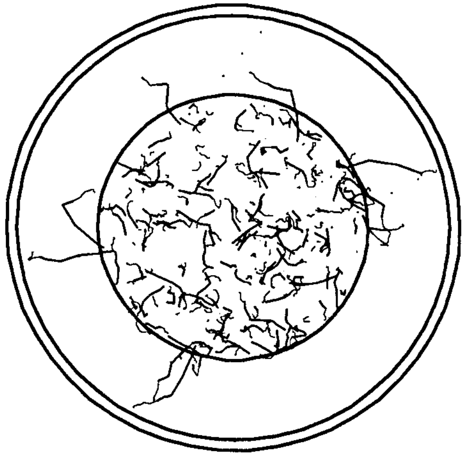

Figure 5. End view of the finger with ^{32}P radioactivity uniformly distributed over a 4 cm length of the volume.

DISCUSSION

The radiation transport and stochastic processes are clearly shown in the EGS4 generated 2-D black and white figures shown above. However, the full impact of the EGS4/Unified Graphics coupling can only begun to be appreciated as a dynamic teaching tool in the full 3-D color graphics that will be presented at the Poster Session of this meeting. In addition to the ^{32}P example above, additional examples will be presented at this session.

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