Conf-940802--1

UCRL-JC-117419
PREPRINT

Photon and Electron Interaction Databases and Their Use in Medical Applications

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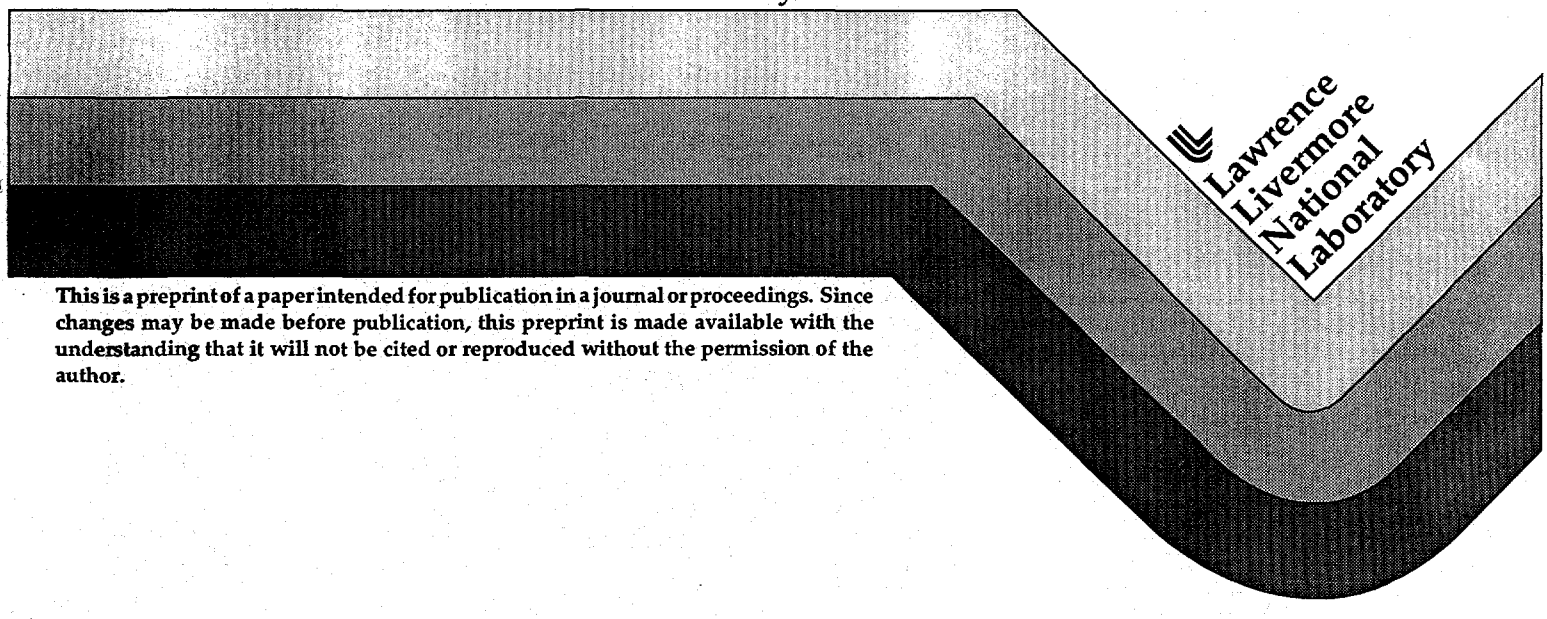
This paper was prepared for submittal to
1994 The World Congress on Medical Physics
and Biomedical Engineering
August 21–26 1994
Rio de Janeiro, Brazil

May 1994



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Photon and Electron Interaction Databases and Their Use in Medical Applications

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An invited paper to be presented at

The World Congress
on
Medical Physics
and
Biomedical Engineering

Rio de Janeiro, Brazil
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Abstract

PHOTON AND ELECTRON INTERACTION DATABASES AND THEIR USE IN MEDICAL APPLICATIONS

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INTRODUCTION: This paper discusses the All Particle Method photon and electron interaction, and atomic relaxation data bases, that were initially developed for use in medical applications. Currently these data bases are being used in both medical and industrial applications.
METHODS: The All Particle Method data bases are designed to allow modelling of individual collisions in as much detail as possible. Elastic scattering can be modelled as single, as opposed to multiple, scattering events. Ionization can be modelled at the atomic subshell level, to define which subshell was ionized, spectrum of the initially emitted electron, as well as the spectra of electron and photons emitted as the atom relaxes back to neutrality.
RESULTS: These data bases are currently being used in applications involving rather small spatial regions, where detailed calculations of individual events are required. While initially designed for use in medical applications, these data bases are now being used in a variety of industrial applications, e.g., transport in microelectronics.
CONCLUSIONS: We consider our current data bases to be merely a starting point toward developing standard data bases. Currently we are working with a number of individuals throughout the world to incorporate as much experience as possible into improving our data bases. If you are interested in helping in this effort please contact me.

Title: PHOTON AND ELECTRON INTERACTION DATABASES AND THEIR USE IN MEDICAL APPLICATIONS

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INTRODUCTION

The All Particle Method (1, 2) is being developed to allow transport of neutrons, photons, electrons, positrons and light charged particles all in the same system of Monte Carlo transport codes.

The project can be viewed as two parallel projects: 1) obviously we need to develop a Monte Carlo code, or system of linked codes, that can transport all of these types of projectiles, including coupling between all of the projectiles, e.g., photon induced electron emission, 2) develop a set of data bases to describe the interaction of each type of projectile and the coupling to all other types of projectiles.

An All Particle Method Monte Carlo transport code system is of interest only to those who actually use the system. However, the data bases are of general interest in the sense that potentially they can be used in any transport code. Therefore here I will only discuss the All Particle Method data bases, and in the limited time available, only the photon and electron data bases (3, 4).

PHOTON AND ELECTRON DATA BASES

As a starting point for discussions I will briefly describe the current contents of our photon and electron data bases. Both cover all elements from hydrogen (Z = 1) to fermium (Z = 100), over the energy range 10 eV to 100 GeV. Both are designed to model single events in as much detail as possible. Both include cross sections, to define the probability of each process occurring, energy and angular distributions, to define the result of any event, and expected energy changes, to allow either analogue or expectation Monte Carlo calculations to be performed. Energy and angular distributions, as well as expected energy changes are included for all "outgoing" particles for each process, e.g., for bremsstrahlung both the electron and photon are described.

The photon data base includes cross sections for photoelectric, coherent and incoherent scattering, pair and triplet production cross sections. Besides the total photoelectric cross sections, it also includes photoelectric subshell cross sections for each subshell. The angular distribution of incoherently scattered photons is described using scattering functions. The angular distribution of coherently scattered photons is described using form factors and anomalous scattering factors.

The electron data base includes cross sections for elastic (total and transport), ionization, excitation and bremsstrahlung. Besides the total ionization cross section, it also includes ionization cross sections for each subshell. The angular distribution of elastically scattered electrons is described in tabulator form, as are the spectra of electrons after an ionization event and the electrons and photons after a bremsstrahlung event.

In addition to these two data bases, a third data base, our evaluated atomic data library (6), is used to describe the relaxation of atoms back to neutrality following an ionizing event; the ionizing event can to photoelectric, electron ionization, internal conversion, etc. This library allows us to calculate the complete spectra of emitted photons (fluorescence) and electrons (Auger and Coster-Kronig) to return an atom to neutrality (7).

Used in combination these three data bases allow us to completely describe coupled photon-electron transport calculations.

APPLICATIONS

The data bases described above were initially designed to allow us to perform detailed transport calculations in medical applications. For example, the electron data base allows us model individual events in detail. We can perform single, as opposed to multiple, scattering calculations as appropriate to very small spatial regions. We can model ionization events at the subshell level, to define the spectrum of initially emitted electrons, as well as the spectra of electrons and photons emitted as the atom relaxes back to neutrality. However, these data bases are now also being used for a number of industrial applications which have similar needs to model individual events in very small spatial regions, e.g., transport in microelectronics.

A second use for these data bases is to establish benchmark results for comparison to the results obtained using simpler, faster models, that may be very appropriate for use in many applications. For example, we are now in a position to compare the results of single and multiple scattering calculations, in an attempt to define where each can be used to good advantage, thereby minimizing computer code running time while still maintaining accuracy.

WHERE DO WE GO FROM HERE?

We consider our current data bases to be merely a starting point. What we would like to do is work with as many interested people as possible to continue to improve these data bases and work toward establishing standards that we can all use. When calculational results are compared to experimental results and/or the results from other computer codes, without standards it is difficult, if not impossible, to determine the source of any differences that are found; which in turn makes it difficult to improve either the data bases or the computer codes.

I should make it clear that we by no means claim that our current photon and electron data bases are the only possible starting point from which we can begin to develop standards. Indeed there are other data bases which we consider to be equally good to use as a starting point. The important point to stress is that it is time to try and bring people together to start working toward a standard.

We have already established a number of working arrangements with people throughout the world, and these collaborative efforts are already paying off for everyone involved. If you are interested and feel that you can contribute something toward this effort please contact me; there is more than enough work to go around, and the more people involved the faster the work will be accomplished.

STANDARDS

In developing standards there are two important aspects to consider: 1) developing the actual numerical values to use, and 2) developing a standard format for exchange and use of the data. The first of these projects will generally only involve a limited number of data experts, whereas the second can involve anyone who will be using the data, e.g., once a standard format is established and documented anyone can write computer programs to use the data.

As far as standard formats, a review of the currently used photon and electron transport codes indicates that as yet there is little, if any standardization in this field. For example, as stated above there are currently a number of very good data bases available for photon and electron transport, but each has its own format. Even what should be the simple task of comparing these data bases is made difficult because there is no standard format. Trying to improve our data bases by using the best elements of all the existing data bases is made that much more difficult because of the lack of a standard format. A great deal of work still remains to be done in this area.

Hand in hand with establishing a standard format, is establishing a standard set of conventions for interpretation of the data in our data bases. The simplest possible example of conventions is how one should interpolate between tabulated values in a table to obtain accurate answers. For all of our tabulated data we provide not only the data itself, but also conventions as to how all users should interpolate the data. This may sound like trivia in the sense that it might seem that once we give someone a table of data they should be free to interpret it anyway that they feel like. Certainly everyone is indeed free to interpret data anyway they want, however they should NOT expect to obtain accurate results unless they interpret the data exactly as intended by the authors. As a concrete example, form factors used to describe coherent photon scattering can be very accurately described using log-log interpolation, and need not be tabulated at very many points to allow accurate results. Using linear interpolation in these tables can result in answers that are up to a factor of 10e+10 too large, while using spline fits can induce oscillations that also lead to inaccurate answers. The idea of establishing a common set of conventions to interpret data does not appear to be currently wide spread in electron-photon transport codes, which adds to the difficulty of comparing calculational results from various codes. Indeed from the conversations that I have had with numerous people, not too many people are as yet aware of the importance of a uniform interpretation of data, nor are they convinced that it is necessary. Believe me: it is.

Our experience in similar fields, particularly in developing standards for use in neutron and photon transport, indicates that this will not be either a simple, nor a rapidly convergent process. For example, in this field it is taken over 25 years to develop the current ENDF/B formats that is now used as an international standard (5). Standardizing these formats has been a slow, and sometimes painful, process, but it has now paid off in the sense that today there are millions of dollars worth of computer codes available, all of which use this common format. Today when new neutron data becomes available it is almost immediately put into this standard format, regardless of whether data is developed in Australia, China, Europe, Japan, Russia, U.S.A., or wherever. This makes it immediately available for comparison to existing data and for use in applications throughout the world. Hopefully in the not too distant future the same can be said for all of the data that we need for coupled electron-photon calculations.

CONCLUSIONS

Our current photon and electron interaction data bases used in combination with our atomic relaxation data bases are designed to allow complete electron-photon transport calculations. These data bases are currently available for general use; for a copy contact me.

Potentially more important than our current data base, is our effort to work with as many people as possible to develop standards, both in terms of numerical values, and a common format that can be used for the exchange of data. We invite all interested parties to become involved in this project.

ACKNOWLEDGEMENTS

This work was performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

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