EGSnrc

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Web pages	http://www.irs.inms.nrc.ca/EGSnrc/EGSnrc.html (the main EGSnrc system) http://www.irs.inms.nrc.ca/BEAM/beamhome.html (the BEAMnrc home page)
Current versions	EGSnrc: V4, release 2.2.5 (Feb 2007) BEAMnrc: beam2007 (Feb 2007)
Particle types	electrons, positrons, photons
Energy range	1 keV $\cdots \sim$ 10 GeV
Materials	Elements from 1 to 100, arbitrary mixtures using the independent atom approximation
Operating systems	Linux, Unix, Windows NT/2000/XP, Mac OSX
Documentation	PIRS–701 is the main EGSnrc manual PIRS–877 describes the new multi-platform EGSnrc environment PIRS–702 is the manual for the NRC RZ user codes PIRS–703 describes an extensive set of benchmark calculations PIRS–801 is the RZ codes GUI manual PIRS–898 is the manual for the C++ class library and the C++ user codes PIRS–509 is the BEAMnrc user manual PIRS–794 is the DOSXYZnrc user manual all documentation is available at the above web addresses and also comes with the distribution
References	1. Iwan Kawrakow, *Accurate condensed history Monte Carlo simulation of electron transport. I. EGSnrc, the new EGS4 version*, Med. Phys. 27 (2000) 485 – 498. 2. I. Kawrakow and D. W. O. Rogers, *The EGSnrc Code System: Monte Carlo simulation of electron and photon transport*, NRC Report PIRS–701 (4th printing) (2003). If using BEAMnrc, DOSXYZnrc, or any of the user codes distributed with the system, please also cite the appropriate PIRS report, most noticeably 3. D. W. O. Rogers, B.R.B. Walters and I. Kawrakow, *BEAMnrc Users Manual*, NRC Report PIRS–509 (rev I) (2005) 4. B.R.B. Walters, I. Kawrakow and D. W. O. Rogers, *DOSXYZnrc Users Manual* NRC Report PIRS–794 (rev B) (2005)

1. General description The EGSnrc system was derived from EGS4 and therefore contains contributions from many people, most noticeably Ralph Nelson and Hideo Hirayama (together with Dave Rogers authors of EGS4), and Alex Bielajew, who maintained the Unix version of EGS4 for many years and made important contributions to its physics. Many people (too many to mention all) have also contributed to the development of BEAMnrc, which is an important part of the EGSnrc system. EGSnrc incorporates many improvements in the condensed history implementation of electron transport, better low energy photon physics, more efficient sampling algorithms and various bug fixes compared to EGS4. The first public release of EGSnrc was in 2000. EGSnrc V4 (a.k.a. EGSnrcMP) was released in December 2003 and represented a major re-work of the run-time environment with the goal to make it portable to all major operating systems. A C++ class library for EGSnrc (known as `egspp`) that contains a general purpose geometry package, several particles sources, and numerous utility classes was released in 2005. EGSnrc comes with a graphical installation wizard for Windows NT/2000/XP, Mac OSX and Linux systems. For all other Unix and Unix-like systems there is an interactive installation script provided. The system can be used with a command line interface in a DOS or Unix shell or with several GUI's. We distribute pre-compiled GUI binaries for Windows. Unix, Linux and Mac OSX users must compile the GUI's from source. This requires a C++ compiler and the Qt toolkit (see http://www.trolltech.com), which is available under the GPL for Unix/Linux and Mac OSX. The BEAMnrc/DOSXYZnrc GUI's require the Tcl/Tk toolkit, which is also available on all major operating systems.

The EGSnrc system is a set of subroutines that implement the modeling of the various interaction processes and the simulation of electron and photon transport. For a complete application the user must write an "user code". A typical user code consists of a main program, a scoring routine (called `ausgab`) and two subroutines that provide geometrical information to EGSnrc via a well defined interface. EGSnrc user codes have been traditionally written in Mortran, a Fortran-like language that is translated into Fortran by the Mortran pre-processor provided with the system. The advantage of using Mortran instead of plain Fortran is Mortran's powerful macro capability. Starting with EGSnrc V4, there is a C interface provided so that user codes can be written in C or C++. With the introduction of the `egspp` class library, it became much easier to write user codes in C++, and complex geometries can be defined in an input file using a well defined syntax. EGSnrc is distributed with a series of user codes for RZ and spherical geometries. The BEAMnrc package, distributed separately at http://www.irs.inms.nrc.ca/BEAM/beamhome.html, provides EGSnrc user codes for the simulation of the treatment head of medical linear accelerators or X-ray tubes and for dose calculations in rectilinear geometries. The power of the EGSnrc system is due to the fact that user codes can be tailor-made to calculate exactly what the user wants and needs, possibly implementing variance reduction techniques that speed up the simulation significantly. Although this approach may be intimidating for a novice user, it is very flexible and is perhaps one of the main reasons for the wide adoption of the EGS4 and EGSnrc packages for a variety of scientific applications.

2. Physics EGSnrc simulates all relevant processes in its range of applicability. The following table gives a brief summary of the modeling of the various interaction and transport processes.

Incoherent photon scattering

Theoretical total and differential cross sections. The user has the choice between using the free electron approximation (Klein-Nishina) or bound Compton scattering with Doppler broadening from the relativistic impulse approximation. Since 2006, radiative corrections can be taken into account by adding a set of macros distributed with the system (note: this is not yet documented in PIRS–701)

Coherent photon scattering

Total cross sections from a tabulation, differential cross sections use the form factors from Hubbell and Øverbø (this is the same as in EGS4). Independent atom approximation for compounds and mixtures.

Pair/triplet production

Total cross sections from a tabulation, differential cross sections are from the extreme relativistic first Born approximation (Coulomb corrected above 50 MeV). Since the 2007 release, one can use differential cross sections from a recent numerical evaluation (up to 85 MeV) of the screening-corrected exact partial wave analysis expressions due to Olsen, Mork and Øverbø, which takes into account the asymmetry in the distribution near the production threshold (note: this is not yet documented in PIRS–701). Triplet production is not explicitely modeled but taken into account by increasing the total pair cross section by the total triplet cross section. Note, however, that an implementation of the Votruba-Mork triplet cross section exists in our development version and will be made available with the next EGSnrc release. The angular distribution of e^+e^- pairs is sampled from the extreme relativistic first Born approximation or from its leading term.

Photo-absorption

Total cross sections from a tabulation. The direction of the photo-electron is sampled from the Sauter distribution. The absorbing shell is picked from the elemental cross sections (in case of mixtures) and from shell interaction probabilities.

Atomic relaxations

Relaxations of vacancies with binding energies above 1 keV are explicitely modeled. Such vacancies can be created in photo-absorption, bound Compton scattering, and electron impact ionization events. All radiative and non-radiative transitions from/to the K, LI, LII and LIII shells are taken into account. Transitions from/to M and N shells are taken into account using "average" M and N shell binding energies.

Electron/positron inelastic scattering

Inelastic collisions with atomic electrons that result in the creation of δ-particles with energies above user specified threshold are modeled using the Møller (e^-) or Bhabha (e^+) cross sections. Sub-threshold inelastic collisions are taken into account in the continuous slowing down approximation using restricted stopping powers from the Bethe-Bloch theory with density effect corrections recommended in ICRU Report 37. Electron impact ionization for K- and L-shells with binding energies above 1 keV can be taken into account (note: this is not yet documented in PIRS–701).

Bremsstrahlung

Choice between the extreme relativistic first Born approximation (Coulomb corrected above 50 MeV) and the NIST bremsstrahlung cross section data base, which is the basis for ICRU-37 radiative stopping powers. In the former choice an empirical correction is applied so that the ICRU-37 radiative stopping powers are reproduced. The angular distribution of bremsstrahlung photons can be sampled from Eq. 2BS of Koch and Motz or from its leading term. Explicit simulation of electron-electron bremsstrahlung is now under development and will be included in one of the next EGSnrc releases.

Elastic scattering

Choice between the screened Rutherford cross section with a screening angle from the theory of Moliere or from cross sections that take relativistic and spin effects into account. The latter is the product of screened Rutherford and the Mott correction factor. The screening angle in this case is selected such as to reproduce the first elastic scattering moment of partial wave analysis cross sections derived using the Riley code and electron densities from the Hartree-Fock program by Desclaux.

Multiple elastic scattering

Exact theory for all step-sizes based on the Legendre series expansion of the multiple scattering distribution and a transformation proposed by Kawrakow and Bielajew.

Electron-step algorithm

Choice between EGS4/PRESTA and the default EGSnrc algorithm. The default EGSnrc algorithm is the most accurate electron-step algorithm currently known. Together with the exact multiple scattering theory, the exact boundary crossing algorithm (see below) and a forth order technique for evaluating energy-dependent quantities, EGSnrc has been shown to produce artifact free and step-size independent results at the sub 0.1% level.

Boundary crossing algorithm

Choice between EGS4/PRESTA and exact boundary crossing in single scattering mode.

Note that the default total cross section tabulations for photo-absorption, pair/triplet and coherent scattering are from the somewhat outdated Storm & Israel compilation. However, since the 2007 release of EGSnrc, the user has the option of initializing photon cross sections on-the-fly also using the XCOM or EPDL tabulations (data files distributed with EGSnrc), or any other tabulation provided by the user in the appropriate format.