ITS: Integrated TIGER Series Monte Carlo Electron/Photon Transport

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ITS

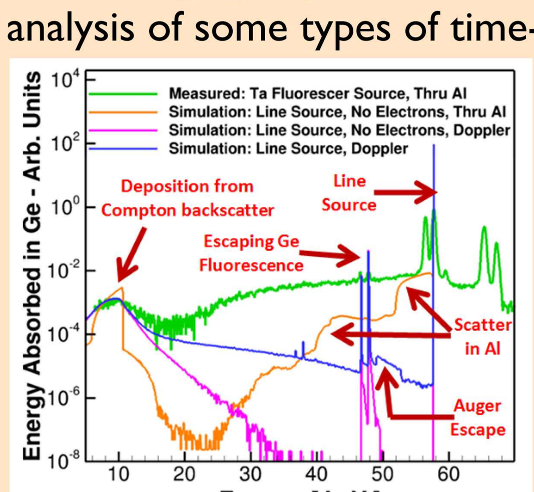
The Integrated TIGER Series (ITS) codes perform coupled electron-photon Monte Carlo radiation transport. They have a long pedigree ranging from the first release of EZTRAN in 1971 to release of ITS version 6.4 in 2008.

From the start, the primary goal has been to provide features that make it relatively easy for the user to analyze the problem they want to model and obtain useful results for gaining insight into the physics of the problem.

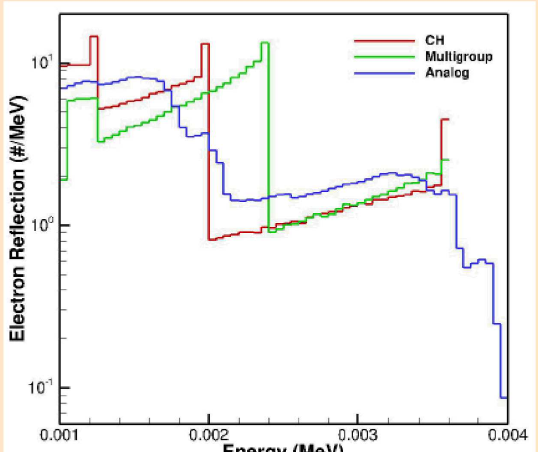
Here we give a brief overview of features of the code, with emphasis on recent developments.

Physics

ITS contains detailed physics for modeling electron and photon interactions from 1 GeV to 1 keV, with more detailed relaxation logic included in the PCODES physics. Recent development aims to extend the energy range below 1 keV based on the LLNL Evaluated Data Libraries (EDL) and provide analog transport. The EDL ionization and relaxation data provide even greater detail for examining fluorescence photons and Auger electrons at low energies and effects on electron energy loss. ITS now includes time-dependent sources, aging of particles, and time-binning of tallies, to permit analysis of some types of time-dependent problems.



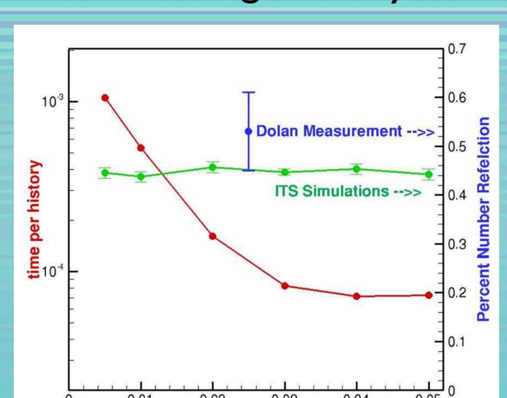
Results to the left show how physics controls can be used to study features of a pseudo-pulse-height distribution.



Results to the right show differences in low-energy photo-electron reflection, with more detail included in the analog relaxation model.

Biasing

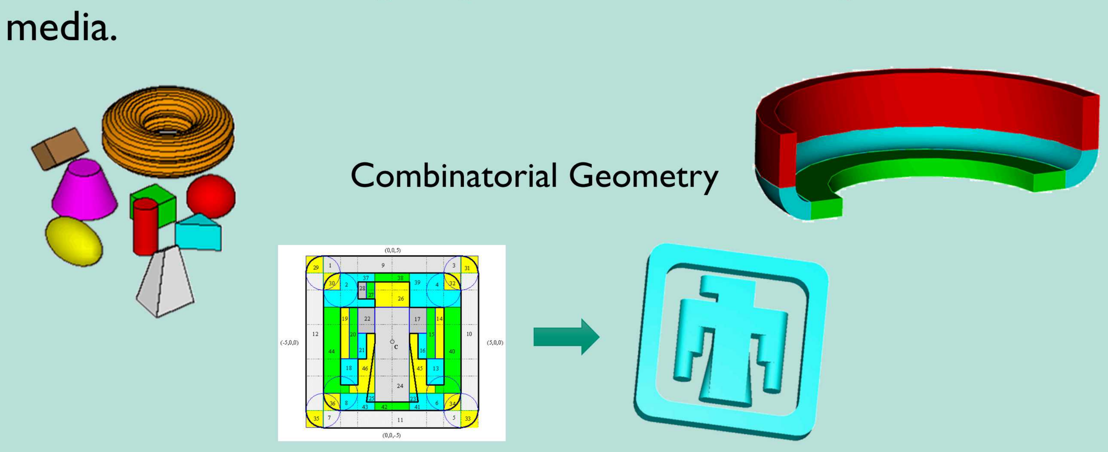
ITS includes a powerful biasing method for electron transport called "electron-trapping." This method applies a form of range rejection on local geometry. Below a user-specified energy, electrons that are "trapped" in the local geometry are terminated with local deposition, which can significantly reduce computation time. Results to the right show a dramatic effect on run time, with no statistically significant effect on the reflected photo-emission of electrons.



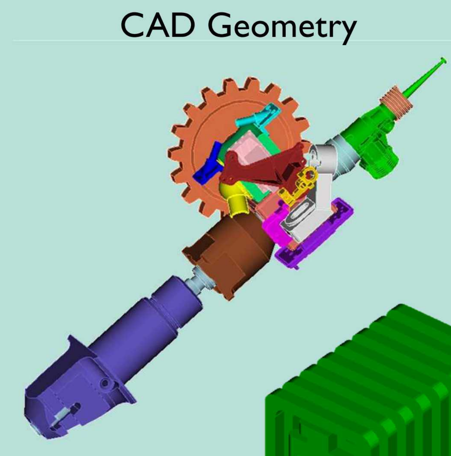
A variety of other biasing options are included, such as photon collision forcing, scaling of bremsstrahlung photon production, and weight windows, as the most recent addition.

Geometry

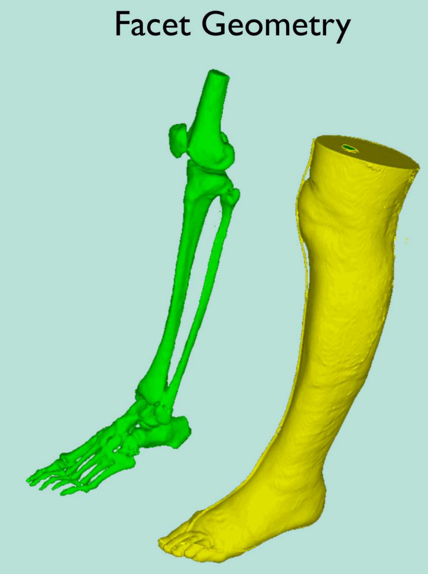
ITS includes 1D, 2D, and 3D geometry capabilities. The 2D code performs three-dimensional particle tracking but allows geometry to be constructed using a simplified interface to take advantage of cylindrical symmetry. The 3D geometry can be represented as combinatorial geometry, facetted geometry, CAD models (for users who have licensed the ACIS® CAD libraries), and hybrid models with any combination of these. We have been investigating methods of modeling stochastic media.



Combinatorial Geometry



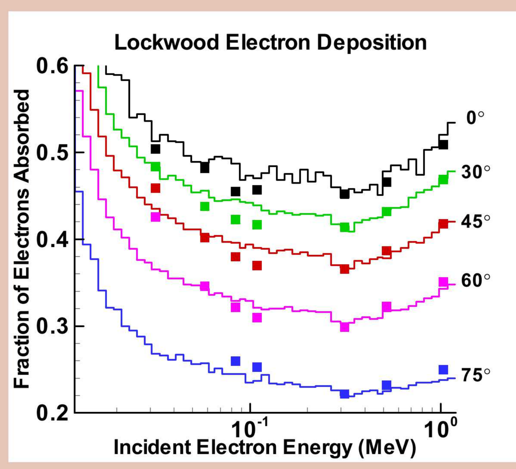
CAD Geometry

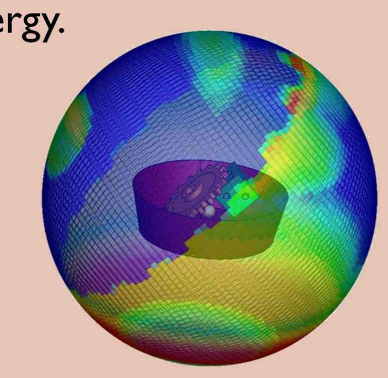


Facet Geometry

Adjoint

ITS enables adjoint simulations with a hybrid multigroup/continuous-energy method. This allows for evaluation of a dose, charge-deposition, or escape quantity for a variety of volumetric or surface sources as a function of space, angle, and energy.





Related to the adjoint capability, ITS also enables ray-tracing and mass-sectoring analyses to rapidly estimate dose contributions as a function of angle of exposure.

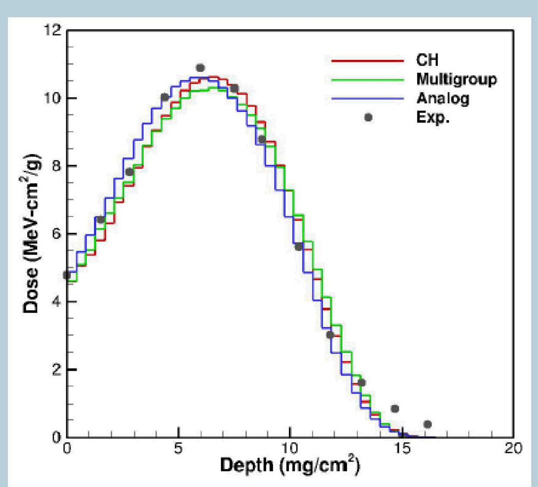
Parallel

MPI parallelism is batch-based with static and dynamic load-balancing options. The code uses domain replication, in which the entire problem is distributed to all processors. Some small messages coordinate work among the processors. Results are gathered at the end of batches, cycles, and the full calculation. This approach can achieve high parallel efficiency.

We are also investigating methods for next generation architectures, such as tally servers and event-based algorithms.

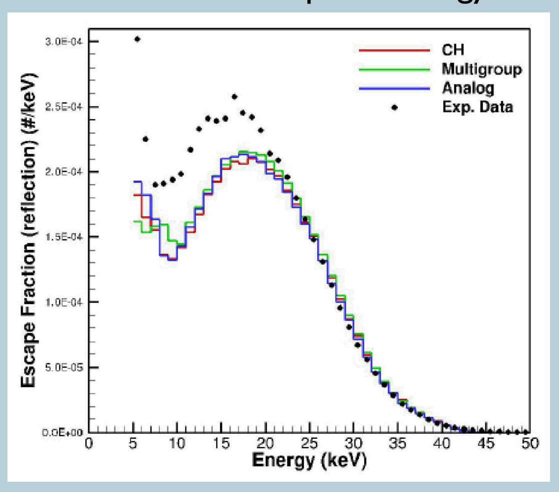
Output

Standard integral quantities are produced for every simulation, and a variety of distributional quantities can also be requested. These include energy and charge deposition, photon and electron escape and flux, and electron surface emission.

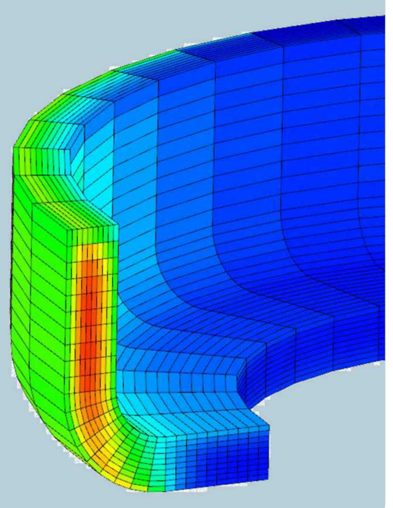


Validation comparison with McLaughlin dose in polystyrene from 100 keV electrons

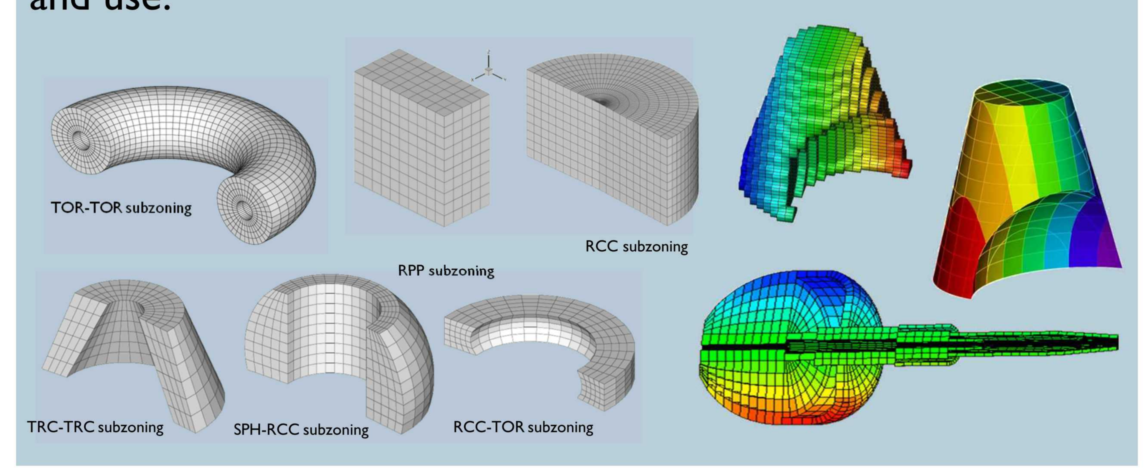
Validation comparison with Dolan electron photo-emission from a bremsstrahlung spectrum with 50 keV endpoint energy



The "subzoning" feature allows a user to apply a structured partition to the spatial tallies. These regular grids overlay the geometry on a zone-by-zone basis. Distributional variation can be resolved conformal to geometric boundaries for many CG models. For CAD or facet geometry (or CG), non-conformal subzoning can be applied. There are 15 different subzoning schemes. Energy and charge deposition in subzoning can be converted to a finite-element format for visualization and use.

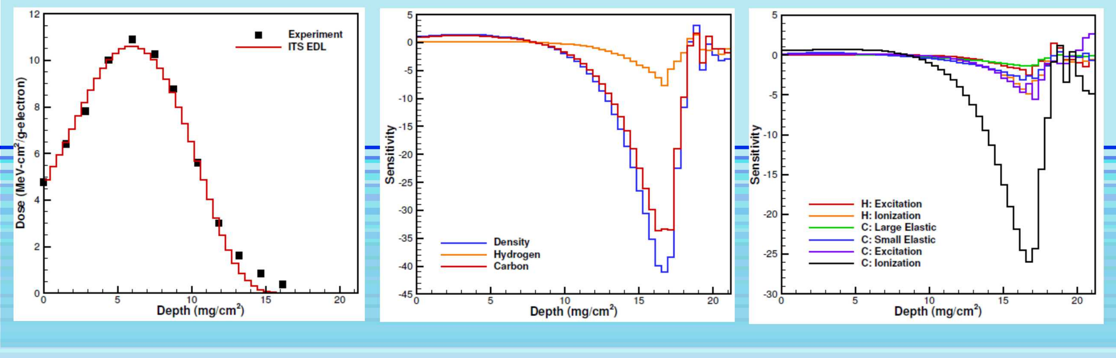


Energy deposition from 1 MeV electrons on cylindrical aluminum part



Sensitivities

Sensitivities for material density, elemental atomic density, and particle interaction cross sections are implemented with the LLNL-data using the differential operator technique.



Distribution

ITS 6.4 is released through the Radiation Safety Information Computational Center (RSICC) for U.S. Government Use. ITS 7.0 is planned for release in the near future.

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration

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LDRD Laboratory Directed Research & Development