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HETC

A High Energy Transport Code

1. Name of Code: HETC[1]

2. Computers for Which Code Is Designed: IBM 360/75 and 360/91.

3. Nature of Physical Problem Solved: HETC is a Monte Carlo transport code for computing the properties of high-energy nucleon-meson cascades in matter. HETC is basically an extension of the code NMTC[2] (valid for energies $\lesssim$3 GeV) to allow particle transport up to several hundred GeV.

   The source-particle description is specified in a user-written subroutine and may be arbitrarily distributed in energy, direction, and space. Proton, neutron, π^+, π^-, μ^+, and μ^- sources are allowed.

   Although the maximum allowable source-particle energies are not well defined, HETC has been run successfully for energies up to 1 TeV. However, because of the lack of experimental data at very high energies, comparison of HETC results with experimental data have been made only for energies $\lesssim$ 30 GeV (e.g., Ref. 3).

   The code stores on magnetic tape a complete description of each "event" (nuclear interaction, geometry boundary crossing, pion decay, etc.) that occurs during the transport process. This information is then read and processed by user-written analysis programs to obtain results for a particular problem.

4. Method of Solution: HETC consists of two basic transport codes: HET and a modified version of 05R.[4] HET transports particles in the energy range from the source-particle energy down to a specified energy cutoff, which is commonly taken to be 15 MeV for protons and neutrons, 2 MeV for charged pions, and 0.2 MeV for muons. Neutrons produced in HET below the cutoff energy are transported via the 05R code.

   The description of nonelastic-collison products in HET is obtained using an intranuclear-cascade-extrapolation-evaporation model. At each nonelastic collision a calculation is performed using subprogram versions of Bertini and Guthrie's[5] latest intranuclear-cascade program and Guthrie's[6] evaporation program to determine the energy and direction of emitted cascade nucleons and pions and evaporated nucleons, deuterons, tritons, ^{3}He's, and alpha particles, and the mass, charge, and recoil energy of the residual nucleus. For nonelastic collisions $\lesssim$3 GeV, these intranuclear-cascade-evaporation results are used directly; for nonelastic collisions $\lesssim$3 GeV, the results from an intranuclear-cascade-evaporation calculation at ~3 GeV are scaled to the proper energy using the extrapolation method of Gabriel, Alsmiller, Jr., and Guthrie.[7] Nonelastic collisons with hydrogen nuclei are treated using experimental data and the calculational method of Gabriel, Santoro, and Barish.[8] Nonelastic collisions in 05R are treated using the evaporation model[4] in conjunction with experimental cross sections. Experimental data are used for elastic-collision cross sections.

   Charged-pion and muon decay in flight and at rest are taken into account using known lifetimes. Negative-pion capture at rest is treated via the intranuclear-cascade-evaporation model.[9]

   A detailed description of the methods used by HETC to treat various physical processes is given in Ref. 3.

5. Restrictions on the Complexity of the Problem: Present dimensions restrict the number of different media to 15 or less and the number of types of nuclei per medium to 11 or less. Virtually arbitrary geometries may be specified.

6. Typical Machine Time: Running time is extremely problem dependent. A sample problem included with the code documentation requires ~10 min on the IBM 360/91 and ~3 times longer on the IBM 360/75.

7. Unusual Features of the Code: Differential cross sections for nucleon-nucleus and pion-nucleus nonelastic collisions are not required as input since they are, in effect, computed in the course of the transport calculation using the intranuclear-cascade-extrapolation-evaporation model.

   Since HET provides a complete description of the low energy ($\lesssim$15 MeV) neutron production, HET may be readily coupled with codes other than 05R (e.g., ANISN,[10] DOT,[11] MORSE[12]) to obtain the low energy neutron transport.

8. Related and Auxiliary Programs: XSECT, an 05R cross-section preparation code, and user-written analysis programs.

9. Status: In use. Several comparisons (e.g., Refs. 3, 13, and 14) between results obtained using HETC and

experimental data have been made and, in general, good agreement has been obtained.

10. Machine Requirements: Approximately 1000K bytes of memory and 4 peripheral storage devices.

11. Operating System: IBM OS/360 with FORTRAN H compiler.

12. User Information: The code, documentation, and a sample problem can be obtained from the Radiation Shielding Information Center (RSIC) of the Oak Ridge National Laboratory. A specialized analysis program[15] for the transport data generated by HET is also available from RSIC:

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