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Author(s): E. C. Selcow, G. W. McKinney, T. E. Booth
J. F. Briesmeister, L. J. Cox, R. A. Forster
J. S. Hendricks, R. D. Mosteller
R. E. Prael, A. Sood, S. W. White

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MCNP Capabilities at the Dawn of the 21st Century: Neutron-Gamma Applications

E.C. Selcow, G.W. McKinney,
T.E. Booth, J.F. Briesmeister, L.J. Cox, R.A. Forster,
J.S. Hendricks, R.D. Mosteller, R.E. Prael, A. Sood, S.W. White

Los Alamos National Laboratory, Diagnostic Applications Group, X-5,
P.O. Box 1663, MS F663, Los Alamos, NM 87545, USA

Abstract. The Los Alamos National Laboratory Monte Carlo N-Particle radiation transport code, MCNP, has become an international standard for a wide spectrum of neutron-gamma radiation transport applications. These include nuclear criticality safety, radiation shielding, nuclear safeguards, nuclear well-logging, fission and fusion reactor design, accelerator target design, detector design and analysis, health physics, medical radiation therapy and imaging, radiography, decontamination and decommissioning, and waste storage and disposal. The latest version of the code, MCNP4C[1], was released to the Radiation Safety Information Computational Center (RSICC) in February 2000. This paper described the new features and capabilities of the code, and discusses the specific applicability to neutron-gamma problems. We will also discuss the future directions for MCNP code development, including rewriting the code in Fortran 90.

1 Introduction

MCNP™ is a general purpose, three-dimensional, time-dependent, continuous-energy Monte carlo fully-coupled N-Particle transport code. Neutrons are modeled from 0-20 MeV, and photons and electrons are modeled from 1 keV to 100 GeV. The high fidelity simulation capability that MCNP[1] provides is widely used as a standard for the predicting the interaction of radiation with matter in complex systems. This invaluable simulation tool used for design, experimentation, and safety assessments often eliminates the need for expensive hardware manufacturating testing.

The overall development philisophy revolves around the edicts of quality, value, and features. MCNP4C contains ten new features[2,3] since version 4B, including macrobodies, unresolved resonances, superimposed weight windows, perturbation enhancements, electron physics enhancements, delayed neutrons, ENDF/B-VI upgrade, alpha eigenvalue, parallelization advances, and PC enhancements. Some of these new capabilities will be briefly discussed followed by the summary highlights of a recent MCNP timing study. The next section will describe some of the new developments for future versions of the code. The following section will present several neutron-gamma applications of MCNP.

2 New Capabilities in MCNP4C

2.1 Macrobodies

Macrobodies are new a new geometry feature for MCNP, which are similar to the combinatorial geometry modeling used in MORSE,KENO, and the Integrated Tiger Series. These new geometries supplement MCNP's fully three-dimensionsal surface-sense goemtry that is capable of modeling any space bounded by first and second degree surfaces (conic sections) and fourth degree elliptical tori.

2.2 Alpha Eigenvalues

MCNP4C now includes an alpha eigenvalue search in addition to the criticality eigenvalue source. The alpha eigenvalue is described by:

$$N=N_o e^{\alpha t}$$

where N is the neutron population at time t that evolves from the initial population. This has applications to describe a subcritical, critical, or supercritical system.

2.3 PC Enhancements

MCNP now is operational on personal computers using the Comaq Visual Fortran 90 compiler or the Lahey Fortran 95 compiler. There are two graphics options for each compiler: the QuickWin graphics and the X-Windows graphics options are available with Compaq Visual Fortran, and the Winteracter graphics and the X-windows graphics options are available with Lahey Fortran.

3 Results of Recent Timing Study

A timing study has recently been performed for MCNP4C[4] in which thirteen computer platforms were tested with MCNP4C using sequential processing. The results show that the fastest machine is the Compaq Alpha XP1000, with the 800 MHz PC showing comparable performance. The fastest machine in the last timing study for version 4B[5] was the DEC Alphastation 500, a predecessor to the XP1000. The timing performance between these two machines for MCP4C is within a factor of two. In the last timing study, which was performed in 1997, the tested PC was approximately a factor of four slower than the DEC Alphastation 500. The study also highlighted that the MCNP timing comparisons are test problem dependent. Overall, the timing study illustrated the fact that the developments in personal computers have made them an attractive option for the international MCNP user community.

4 Future Directions

The next version of MCNP will contain several new and enhanced features, including additional macrobodies, charged particle transport, and an interactive plotter[6] which significantly enhances the flexibility of geometry plotting with point-and-click features. We are also upgrading our Software Quality Assurance (SQA) practices by adopting the RAZOR software package for configuration management, regression testing, and bug tracking. We are further modernizing our code by converting the code from Fortran 77 to Fortran 90.

5 Neutron-Gamma Applications

In this section several neutron-gamma applications will be illustrated with selected specific examples.

5.1 Medical Applications: Radiation Therapy

Reactor neutron sources for Boron Neutron Capture Therapy (BNCT).

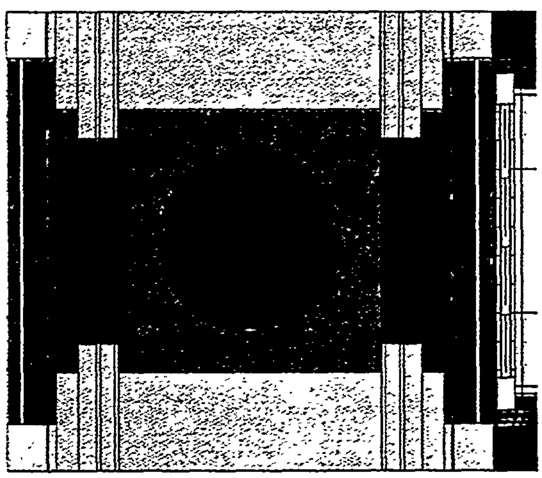

Fig. 1. Brookhaven Medical Research Reactor: BNCT Epithermal Neutron Irradiation Facility

Accelerator neutron sources for BNCT.

5.2 Medical Applications: Imaging

5.3 Critical Experiments

The user input is significantly shortened with the use of macrobodies.

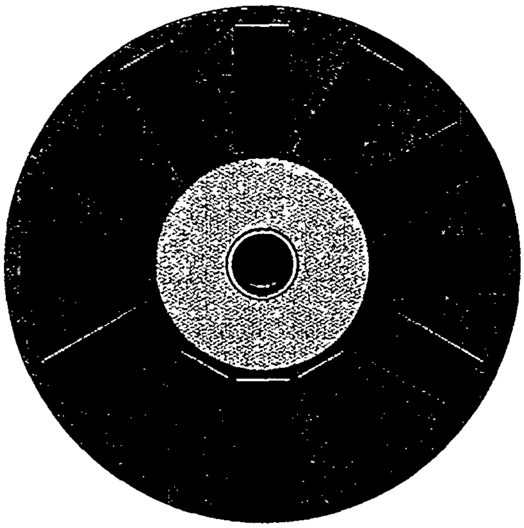

Fig. 2. Concept for BNCT using pulsed neutron generators for the neutron source

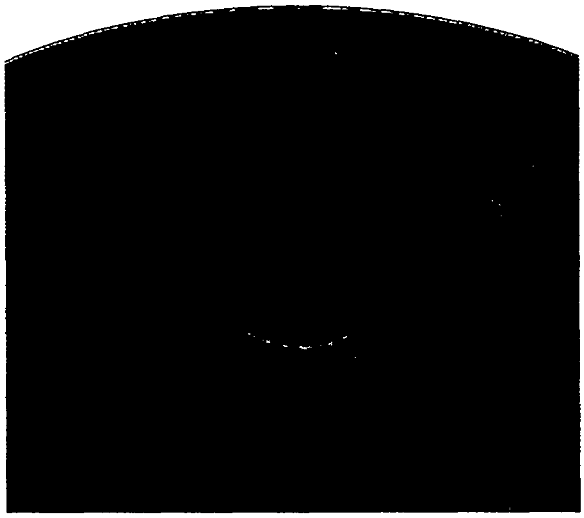

Fig. 3. Anthropomorphic model of a heart used in simulations of Single Photon Emission Computed Tomography

6 Summary

MCNP continues to provide an invaluable modeling and simulations tool for a wide spectrum of radiation transport applications. The code development efforts will focus on enhancing the physics features as well as upgrading the code to take advantage of the evolving capabilities in computer technologies. This

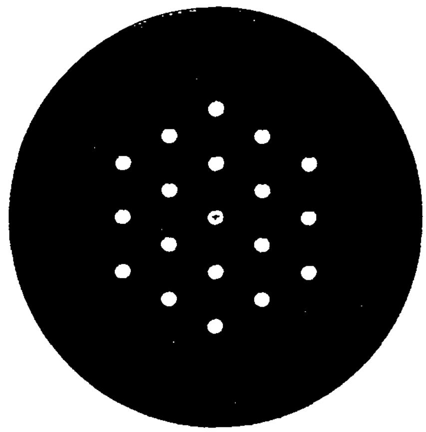

Fig. 4. Cross Sectional view of Nineteen Element Critical Experiment of Particle Bed Reactor Concept

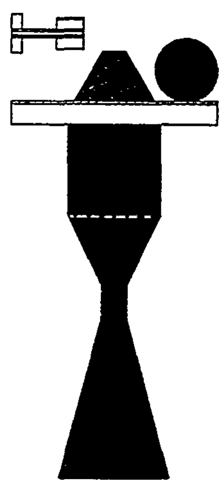

Fig. 5. Elevation view of a Rocket Ship Powered by a Particle Bed Reactor

will further enable users throughout the 21st century to simulate more complex problems, with greater fidelity, and in significantly faster time periods. These code developement efforts will be conducted in an environment that revolves around quality.

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