Past and Future of Monte Carlo in Medical Physics

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Oct 21,2009

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The beginnings: bombs

ENIAC computer completed in 1945
John von Neumann, Stan Ulam and Nicholas Metropolis all played a role.

They got Edward Teller on side for modelling the H-bomb.

The name "Monte Carlo" came from Stan Ulam's uncle who used to borrow money to go to Monte Carlo.

Enrico Fermi had independently developed the method in Rome 15 years earlier studying moderation of neutrons- but he didn't have a neat name for it.

ISI: First Monte Carlo publications

1949: Nicholas Metropolis and Stan Ulam,
The Monte Carlo Method

1950 : Robert R Wilson,
Monte Carlo calculations of showers in lead
(APS abstract, full paper 1952)

1950: Herman Kahn, Random Sampling (Monte Carlo)
techniques in neutron attenuation problems

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60-th anniversary (thanks Tommy Knoos)

JOURNAL OF THE AMERICAN STATISTICAL ASSOCIATION

Number 247 SEPTEMBER 1949 *Volume 44*

THE MONTE CARLO METHOD

NICHOLAS METROPOLIS AND S. ULAM
Los Alamos Laboratory

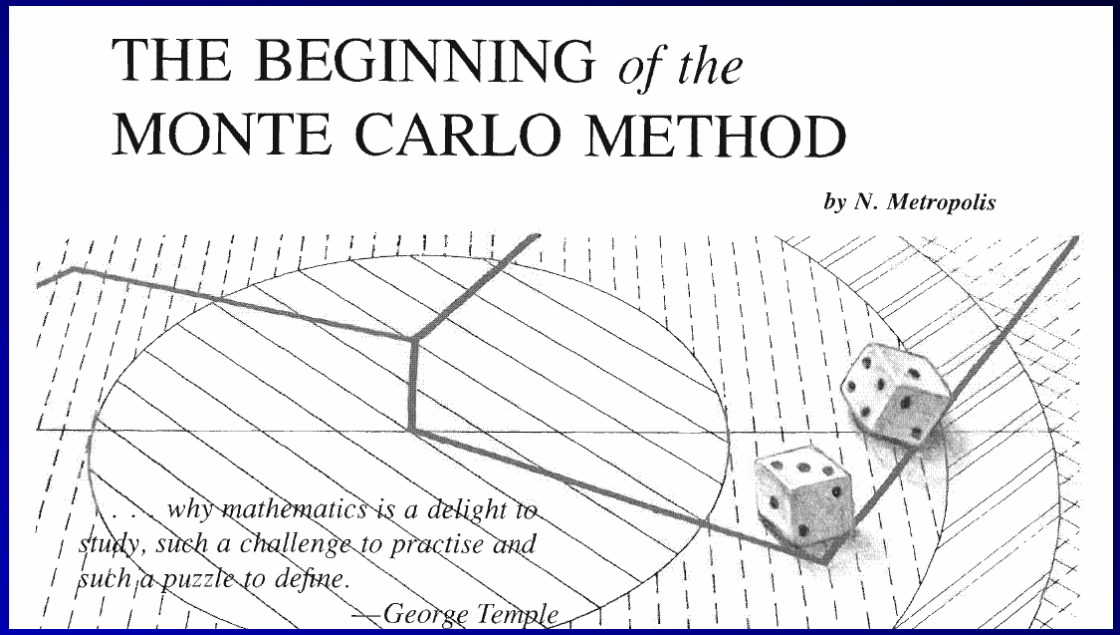
We shall present here the motivation and a general description of a method dealing with a class of problems in mathematical physics. The method is, essentially, a statistical approach to the study of differential equations, or more generally, of integro-differential equations that occur in various branches of the natural sciences.

cited 479 times

Los Alamos Science 1987 Special Issue

http://la-science.lanl.gov/lascience15.shtml

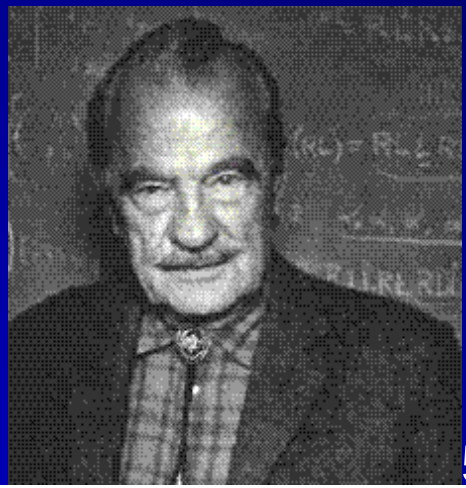
L to R
Stan Ulam
John von Neumann
Nicholas Metropolis



THE BEGINNING *of the*
MONTE CARLO METHOD

by N. Metropolis

. . . why mathematics is a delight to study, such a challenge to practise and such a puzzle to define.
—George Temple



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A major application

THE JOURNAL OF CHEMICAL PHYSICS VOLUME 21, NUMBER 6 JUNE, 1953

Equation of State Calculations by Fast Computing Machines

NICHOLAS METROPOLIS, ARIANNA W. ROSENBLUTH, MARSHALL N. ROSENBLUTH, AND AUGUSTA H. TELLER,
Los Alamos Scientific Laboratory, Los Alamos, New Mexico

AND

EDWARD TELLER,* *Department of Physics, University of Chicago, Chicago, Illinois*

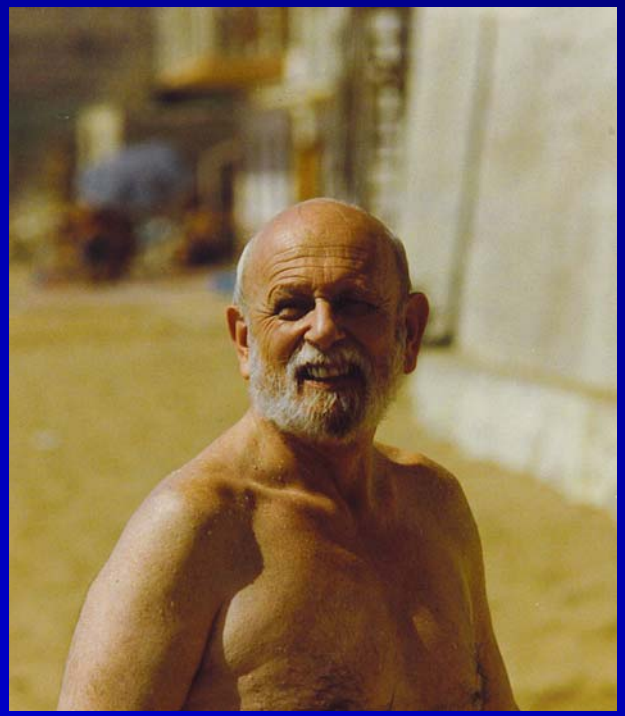
(Received March 6, 1953)

A general method, suitable for fast computing machines, for investigating such properties as equations of state for substances consisting of interacting individual molecules is described. The method consists of a modified Monte Carlo integration over configuration space. Results for the two-dimensional rigid-sphere system have been obtained on the Los Alamos MANIAC and are presented here. These results are compared to the free volume equation of state and to a four-term virial coefficient expansion.

cited > 11,700 times

Martin Berger

"Monte Carlo calculations of the penetration and diffusion of fast charged particles" in Methods in Computational Physics pp 135 - 215 (Academic Press, 1963)



1987 beach near Erice, Sicily

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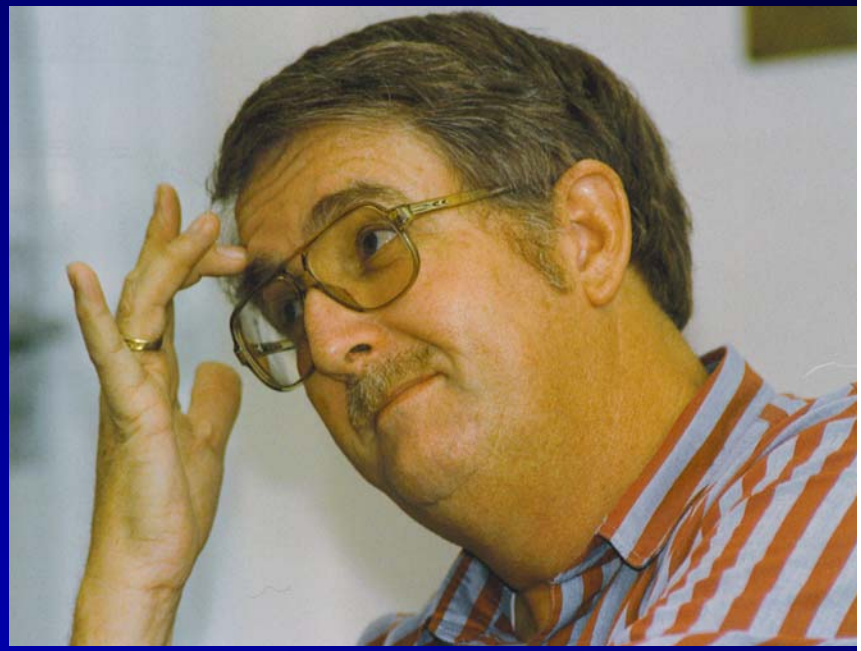
ETRAN and EGS

ETRAN: Steve Seltzer and Martin Berger



EGS: W Ralph Nelson

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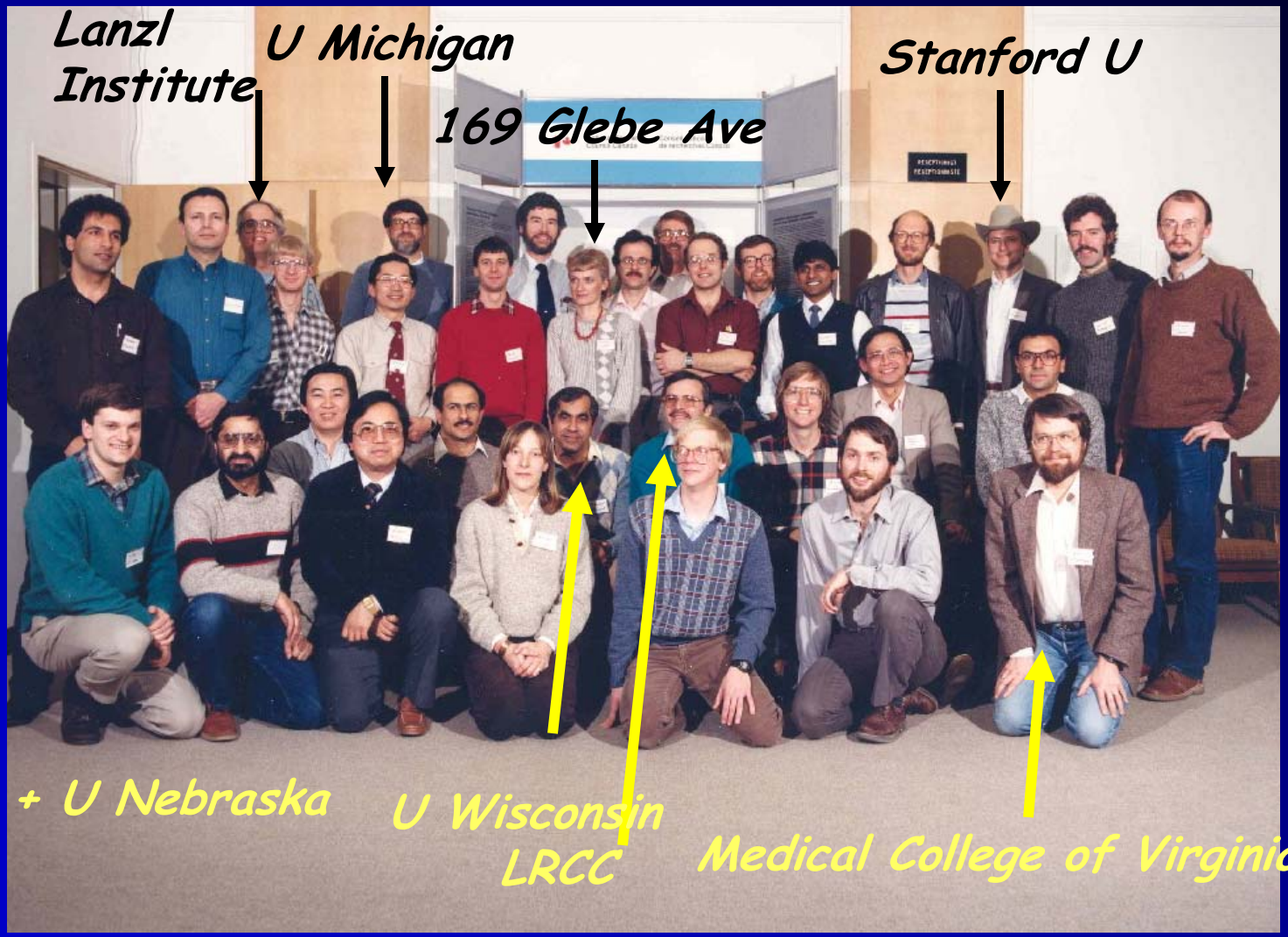
1986 EGS Course

EGS course attendees become department heads ☺



Slide accurate in 2002

Erice: The Monte Carlo Transport of Electrons and Photons Below 50 MeV

Ettore Majorana Centre for Scientific Culture, Erice Sicily Sept 24-Oct 3, 1987

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Erice: The Monte Carlo Transport of Electrons and Photons Below 50 MeV

Key to Participant Picture

Monte Carlo Transport of Electrons and
Photons below 50 MeV
Erice
September 24 - October 3, 1987

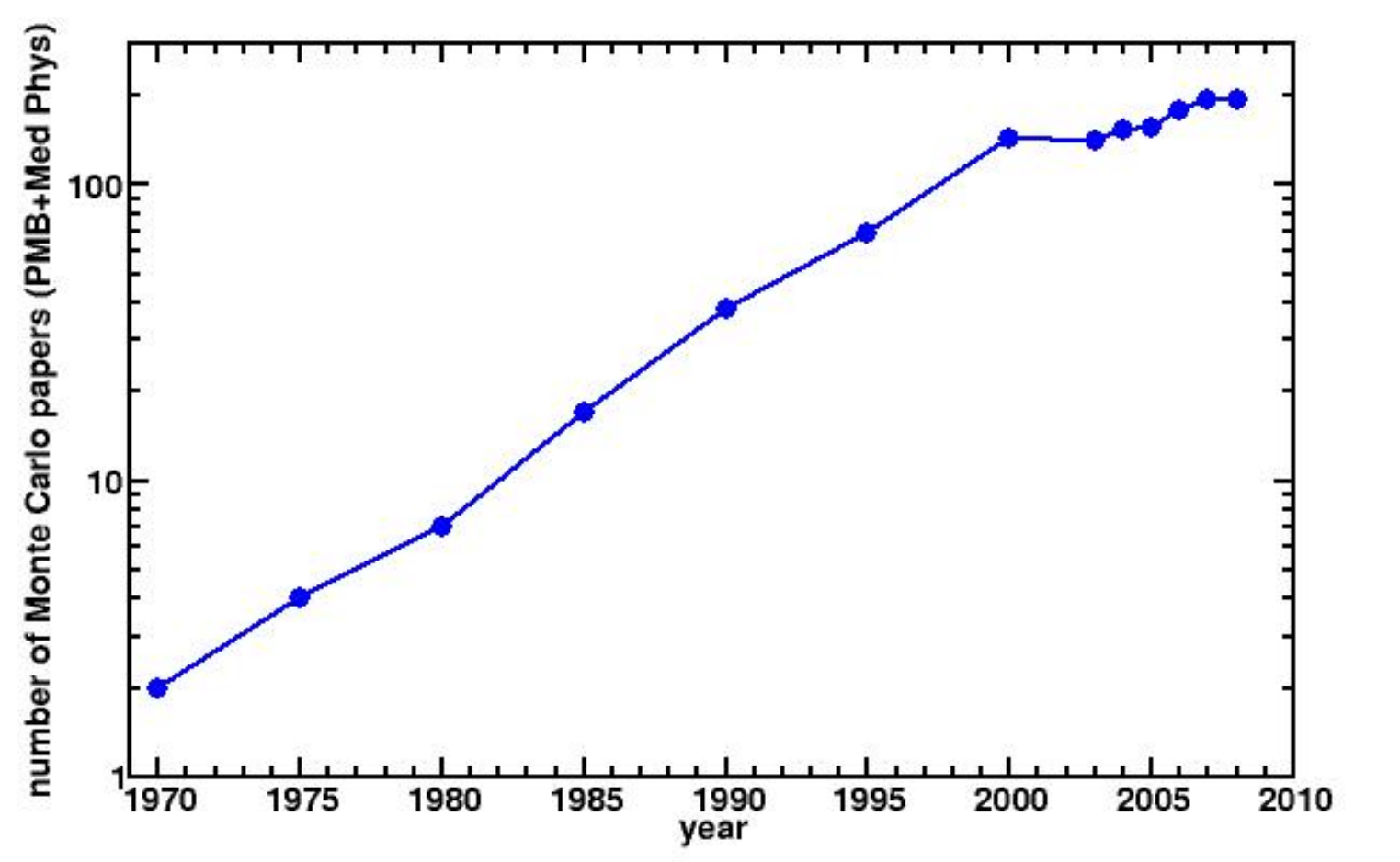
1. David E. Raeside
2. Sandro Rindi
3. Alan E. Nahum
4. John Halbleib
5. Alberto Del Guerra
6. Radhe Mohan
7. Martin J. Berger
8. Stephen M. Seltzer
9. Alex F. Bielajew
10. W. Ralph Nelson
11. Bernd Grosswendt
12. Pedro Andreo
13. Akira Ito
14. David W.O. Rogers
15. Flavia Groppi Garlandini
16. Hideo Hirayama
17. Claudio H. Sibata
18. Tony Aalbers
19. Peter Bloch
20. Gudrun Alm Carlsson
21. Daniel Mosse
22. Jatinder R. Palta
23. Chiri Yamaguchi
24. Keith A. Long
25. Simon Duane
26. H. Grady Hughes
27. Guiliene Tromba
28. Ugo Nastasi
29. Ted Jenkins
30. Mary Udale
31. Lorraine Love
32. W. George Pitchford
33. J. Gomes Da Silva
34. Franco Casali
35. Christian Michel
36. Ernst Bartels
37. Gabriele Sroka
38. Lennart Olofsson
39. Domenico Acchiappati
40. Hartwig Schaal
41. Hans Neuenschwander
42. John C. Garth
43. Olabode T. Ogunleye
44. Huu Phuoc Do
45. Bength K. Lind
46. Peter G. Christiansen
47. Jan Persliden
48. Richard Veit
49. Christoph Krass
50. Omer F. Goktepe
51. Julius J. Almasi
52. Michael Ljungberg
53. Carlos Malamut
54. Pietro Lauriola
55. Per Nilsson
56. Kenneth Adams
57. Shi-Ping Teng
58. Juhani E. Heinila
59. Fabrizio Cleri
60. Otto Sauer
61. David V. Webb
62. Jim Rathkopf
63. Pertti Aarnio
64. Annette Fransson
65. Vere G. Smyth

OMEGA Project: BEAM
Ottawa-Madison Electron Gamma Algorithm

- NIH funded - 1990-1996
- Rock Mackie & Paul Reckwerdt at U of Wisconsin, Madison
- my NRC group
  - George Ding. Jiansu Wei, Daryoush Sheikh-Bagheri
  - Blake Walters, Bruce Faddegon, Charlie Ma
  - more recently Iwan Kawrakow & Ernesto Mainegra-Hing

- PROBLEM: Rock and Paul invented Tomotherapy during the project!

Monte Carlo papers in Med Phys or PMB



"Monte Carlo" in title or abstract
updated from PMB **51** (2006) R287

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The future ?

- direct calculation of the response of ion chambers and other radiation detectors
  - both in reference conditions (open fields) and non-reference conditions (IMRT and small fields)
- do we need more accurate cross-section data?
- do we need experiments?

The future ?

- Monte Carlo treatment planning (of course)
  - will better dosimetry tighten up dose-response curves?
  - but possibly only as a research/verification tool
    - Attila/discrete ordinates?
    - is it really that fast?

Attila: do we need Monte Carlo?

FEASIBILITY OF A MULTIGROUP DETERMINISTIC SOLUTION METHOD FOR THREE-DIMENSIONAL RADIOTHERAPY DOSE CALCULATIONS

OLEG N. VASSILIEV, PH.D.,* TODD A. WAREING, PH.D.,† IAN M. DAVIS, M.S.,† JOHN MCGHEE, PH.D.,† DOUGLAS BARNETT, PH.D.,† JOHN L. HORTON, PH.D.,* KENT GIFFORD, PH.D.,* GREGORY FAILLA, M.S.,† UWE TITT, PH.D.,* AND FIRAS MOURTADA, PH.D.*

*Department of Radiation Physics, M. D. Anderson Cancer Center, Houston, TX; and †Transpire, Inc., Gig Harbor, WA

Purpose: To investigate the potential of a novel deterministic solver, Attila, for external photon beam radiotherapy dose calculations.

Methods and Materials: Two hypothetical cases for prostate and head-and-neck cancer photon beam treatment plans were calculated using Attila and EGSnrc Monte Carlo simulations. Open beams were modeled as isotropic photon point sources collimated to specified field sizes. The sources had a realistic energy spectrum calculated by Monte Carlo for a Varian Clinac 2100 operated in a 6-MV photon mode. The Attila computational grids consisted of 106,000 elements, or 424,000 spatial degrees of freedom, for the prostate case, and 123,000 tetrahedral elements, or 492,000 spatial degrees of freedom, for the head-and-neck cases.

Results: For both cases, results demonstrate excellent agreement between Attila and EGSnrc in all areas, including the build-up regions, near heterogeneities, and at the beam penumbra. Dose agreement for 99% of the voxels was within the 3% (relative point-wise difference) or 3-mm distance-to-agreement criterion. Localized differences between the Attila and EGSnrc results were observed at bone and soft-tissue interfaces and are attributable to the effect of voxel material homogenization in calculating dose-to-medium in EGSnrc. For both cases, Attila calculation times were <20 central processing unit minutes on a single 2.2-GHz AMD Opteron processor.

Conclusions: The methods in Attila have the potential to be the basis for an efficient dose engine for patient-specific treatment planning, providing accuracy similar to that obtained by Monte Carlo.

Int J Rad Oncol, Biol, Phys 72 (2008) 220-227

The future ?

- imaging (PET,CT)
  - more accurate scatter and other corrections
  - much may be possible with enough speed
  - use MC for design optimization
- more extensive use of electrons for radiotherapy
  - MERT, use of MLCs/FLEC
- micro-dosimetry related to use of nano-particles
- more and more detailed and efficient models to solve tough problems

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The future ?

- use Monte Carlo to link physical interactions with biological end effects
  - do we know enough?
    - how much is from direct radiation interactions at the molecular level (double strand breaks etc from modelling DNA details)
    - how much is from the chemical reactions induced – these might overwhelm the details of the physical interactions
  - do we have enough computing power
- use of radiobiological models with MC dose distributions to improve radiotherapy

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The future ?

- what will the role of GPUs be? Can we get the cheap speed ups for detailed Monte Carlo?

- is there a role for Monte Carlo methods other than in radiation transport?

Thanks to the organizers

- On behalf of all of us, I would like to thank
  - Emiliano Spezi as chair of the Organizing Committee
  - Nick Reynaert as chair of the scientific committee
  - the members of these two committees
    - Patrick Downes, Geraint Lewis, John Prichard
    - Sarah Townsend, Andrew Tyler, David Walker
    - Peter Wells, Michael Fix, Antonio Leal
    - Grisel Mora, Josep Sempau
    - Martin Soukup, Frank Verhaegen

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Acknowledgements

- Support from the Canada Research Chairs program and

Thanks for your attention

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