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Title:

Using MCNP5 for Medical Physics Applications

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LA-UR-06-2347

Using MCNP5 for **Medical Physics Applications**

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ANS Computational Medical Physics Working Group
http://cmpwg.ans.org/

Schedule: 1 pm – 4 pm

1. Next Generation of Capabilities? TG – 10 min
2. Overview of new MCNP5 features TG – 30 min
3. Geometries and Modeling TG – 30 min
4. Misc (n scattering, VR, Benchmark) TG – 20 min
5. Break 15 min
6. gamma-ray radiation detection and simulation AS – 30 min
7. Comparisons with benchmark experiments for NaI and HPGe detectors. AS – 30 min
8. Additional References

Abstract

MCNP is a general-purpose Monte Carlo N-Particle code that can be used for neutron, photon, electron, or coupled neutron/photon/electron transport. MCNP5 has a wide range of abilities which make it useful for medical physics calculations. These abilities span its geometry representation, physics models, and source, tally and variance reduction capabilities. This workshop will demonstrate how MCNP5 can be used to calculate dose, simulate a radiograph, or even use CT data to create a voxel model of a human or phantom. A general review of MCNP5 source and tally capabilities, as well as new and future capabilities will also be included.

Next Generation of Capabilities?

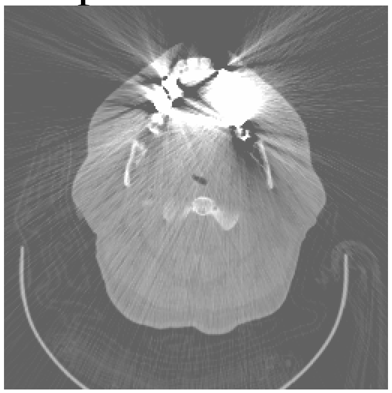
- In this conference:
  - Agreement of data and simulation < 3%.
  - Dose calculations ~ 2 mm tally grids or less
- This will drive a new evolution in the codes.
- New physics processes that cause dose "blurring" on these scales will need to be added to get more accurate simulations.

Medical Physics Brainstorming

- Add into codes:
  - Magnetic field (quadrapole) capabilities to model further upstream in beamline (bending magnets) to include slight beam spreading.
  - Better characteristic X-Ray production
  - Proton (& other heavy charged particles)
    - Proton recoil
    - Electron production from high energy protons as delta ray lengths exceed ~ few mm.
    - Inelastic collisions and subsequent gamma & conversion electrons
    - Very high fluxes: space charge effects

Medical Physics Brainstorming

- Add into codes / develop methodology:
  - Model CT scanner / MC simulation of CT images
    - Help create accurate geometric models when CT image is distorted.



    - Reconstruct Dose from CT imaging process:

J J DeMarco et al. “A Monte Carlo based method to estimate radiation dose from multidetector CT (MDCT): cylindrical and anthropomorphic phantoms. Phys. Med. Biol. 50 (2005) 3989–4004

  - Cross Section uncertainty / covariance
    - What is uncertainty in the dose due to uncertainty in the cross sections?

MCNP5 New Features for MP

• Mesh Tallies	1st Release	1.14
• Radiography Tallies	1st Release	1.14
• Photon Doppler Broadening	1st Release	1.14
• More Detectors & Tallies	2nd Release	1.20
• >2.1 Billion Histories & RAND #	3rd Release	1.30
• Lattice Tally Enhancements	3rd Release	1.30
• Mesh Tally Improvements	4th Release	1.40
• Electron Improvements	4th Release	1.40
• Stochastic Geometry	4th Release	1.40
• Large Lattice Improvements	5th Release	1.50
• FUTURE WORK for MCNP5 Teaser		

Mesh Tallies

- Original release in MCNP5_RSICC_1.14
- Geometry independent 3-D tally grid used to calculate volume averaged fluxes for each voxel in that grid.
- Cylindrical or rectangular mesh.
- Can be used with DE DF and FM cards to calculate volume averaged doses and reaction rates.
- Can be used with TR cards (transformation).
- Particles must track through mesh to tally.

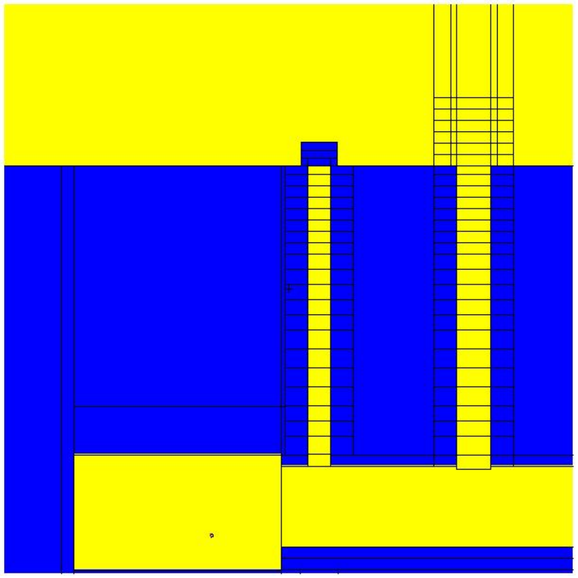
Mesh Tallies

- **Built-in MCNP5 plotter now plots mesh tally grid superimposed over geometry**

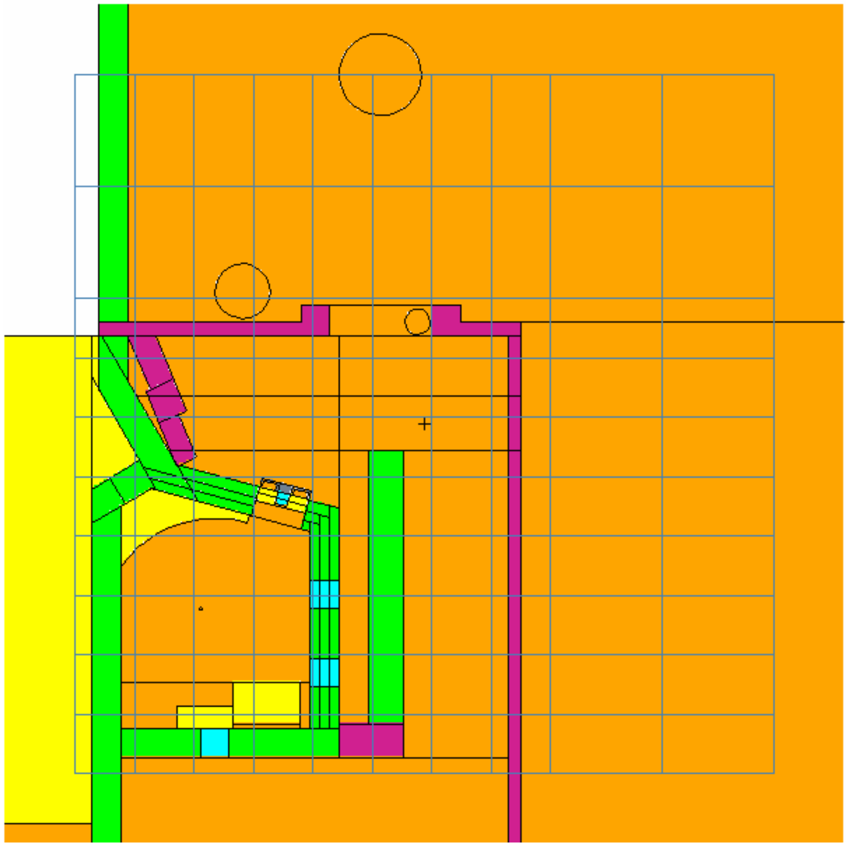
Geometry

Blue = concrete

Yellow = air



Images from mcnp5 plotter



Mesh Tally – Card Format

FMESHn:p create a mesh track-length tally where n is the tally number. Can be used with DEn, DFn, and FMn cards.

Caution: It is easy to create huge mesh tallies that can overflow computer memory.

Keywords GEOM{xyz} ORIGIN{0,0,0} AXS{0,0,1} VEC{1,0,0} IMESH IINTS{1} JMESH JINTS{1} KMESH KINTS{1} EMESH EINTS{1} FACTOR{1.} OUT(col} TR

GEOM = mesh geometry: Cartesian ("xyz" or "rec") or cylindrical ("rzt" or "cyl")
ORIGIN = x,y,z coordinates in MCNP cell geometry superimposed mesh origin
AXS = direction vector of the cylindrical mesh axis
VEC = direction vector, along with AXS that defines the plane for angle theta=0
IMESH = coarse mesh locations in x (rectangular) or r (cylindrical) direction
IINTS = number of fine meshes within corresponding coarse meshes
JMESH = coarse mesh locations in y (rectangular) or z (cylindrical) direction
JINTS = number of fine meshes within corresponding coarse meshes
KMESH = coarse mesh locations in z (rectangular) or theta (cylindrical) direction
KINTS = number of fine meshes within corresponding coarse meshes
EMESH = values of coarse meshes in energy
EINTS = number of fine meshes within corresponding coarse energy meshes
FACTOR = multiplicative factor for each mesh
TR = transformation number to be applied to the tally mesh

HINT: MCNP5 Manual Index – FMESH Card, Mesh Tally,

WARNING: MESH refers to weight windows mesh, used for variance reduction, not tally mesh.

Radiography Tallies

- Introduced in MCNP5_RSICC_1.14. Allows the user to generate images from neutral particles as one would expect from an x-ray or pinhole projections.

- FIR – Flux image radiograph
- FIP – Flux image pinhole
- FIC – Flux image cylinder
- Distinguish between scattered and unscattered flux
- Uses point detector methods.

Radiography Tallies

Radiograph of Anthropomorphic MCAT phantom

Picture from Sabrina

Picture generated with results from MCNP calculation.

Simulated Radiograph

1 M pixels

Lambeth, Melissa. “Development of a computerized anthropomorphic phantom for determination of organ dose from diagnostic radiology.” Thesis, B.S., Massachusetts Institute of Technology, Dept. of Nuclear Engineering, 1997.

Radiography Tally – Card Format

- General card format for FIR tally:
  - FIRn:p X1 Y1 Z1 R0 X2 Y2 Z2 F1 F2 F3
- NOTRN: Run only direct contribution to all point detector tallies
- TALNP: Eliminate tally prints with many bins from OUTP file
- NPS: 2nd entry controls the direct contribution for FIR tallies
- FSn and Cn cards control number of pixels in image plane
- Example for simulation of medical radiograph:

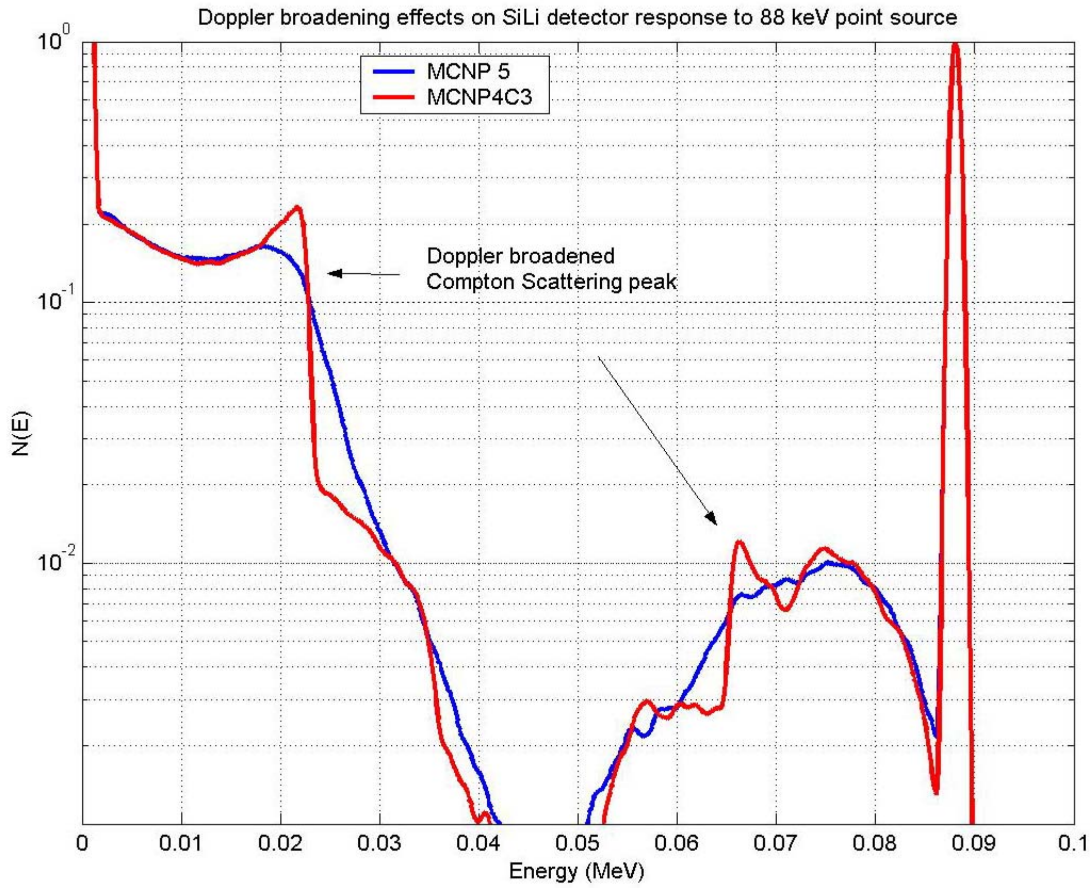
```
fir5:p 0 0 15. 0 0 0 -1000. 0 1e20 0
fs5 -55.0 999i 50.0
c5 -30.0 999i 30.0
notrn
talnp
```

HINT: MCNP5 Manual Index – Radiography Tallies, Pinhole, Flux Image Radiographs

HINT: Use with NOTRN card for faster calculations if scattered contributions are not needed.

Photon Doppler Broadening

- Released in MCNP5_RSICC_1.14
- Incoherent Compton event, includes electron binding energy.
- Causes reduction of the photon's total scattering xs in the foreward direction.
- Causes broadening of photons energy spectrum.
- Important $E_p < 1$ MeV.
- Bug fix in MCNP5_RSICC_1.40 release



Doppler - Card Format

- By default, this option is on.
- Photon Doppler broadening will be used if appropriate data (xs library - #000.04p) is available. If xs library not available, comment is issued: "#000.0#p lacks Compton profile data for photon energy broadening"
- To turn off, set 4th entry of phys:p to 1.

HINT: MCNP5 Manual Index – Doppler Broadening, PHYS card

More Detectors & Tallies

- With release of MCNP5_RSICC_1.20
- Maximum # of detectors increased from 20 to 100.
- Maximum # of tallies increased from 100 to 1000.
- Limit for a specific tally type still 100

>2.1 Billion Histories

- With MCNP5_RSICC_1.30, more than 2.1 billion histories can be run (<1E20)
- Done by explicitly declaring ~30 variables as 8 byte integers.
- Supported Cards: NPS, PRDMP, RAND, PTRAC, MPLOT
- Large PTRAC files also supported (250+ Gigabytes)
- Larger random # stride (not default): RAND card
  - Prevent re-use of random numbers
  - Old Period : $\sim 10^{14}$ New Period: $\sim 10^{19}$

HINT: MCNP5 Manual Index - NPS card, other card entries.

WARNING: # of histories does not correlate to simulated source strength!

Lattice Tally Speed Enhancement

- With release of MCNP5_RSICC_1.30, if certain conditions are meet, then runtimes can be significantly reduced (5-500 times shorter, depending on problem).
- Stringent Conditions: F4, DE DF, 1st level lattice.
- MCNP will attempt to determine if these conditions have been meet or not, and will attempt to use the enhancement if appropriate. Messages either way. Fast and slow runs will track.
- Card: SPDTL

SPDTL – Card Format

- In data card section: spdtl <force or off>
- "spdtl force" will cause the lattice tally enhancements to be used if at all appropriate.
- "spdtl off" will enforce the older (slower) tally routines.
- MCNP5 will automatically check for nearly all conflicts and respond.
- Documentation – LA-UR-04-3400 provided with MCNP5 distribution

HINT: MCNP5 Manual Index – SPDTL card

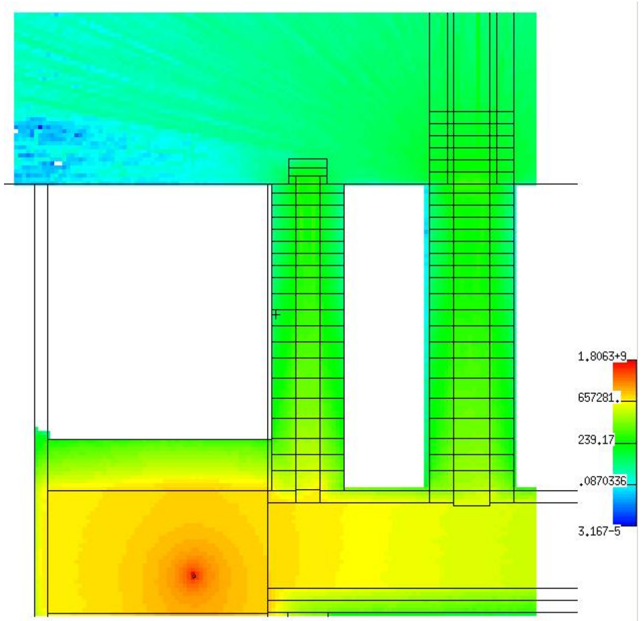
MCNP5 Mesh Tally Plotting

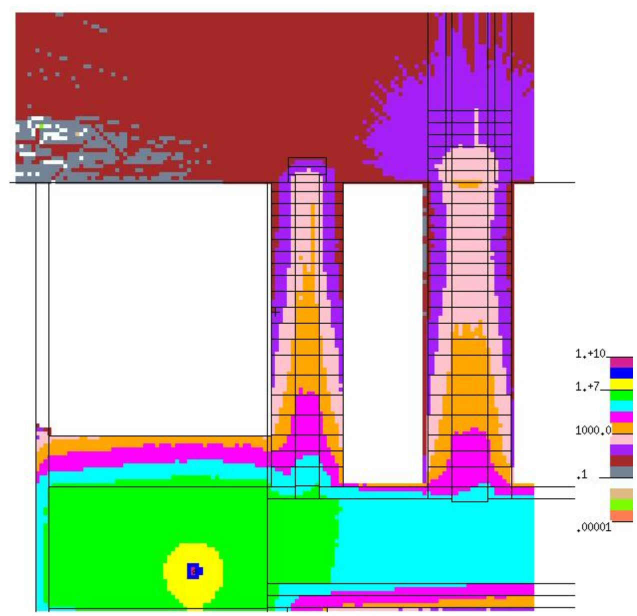
- Released in MCNP5_RSICC_1.40
- Built-in plotter now plots mesh tally results on top of geometry outline

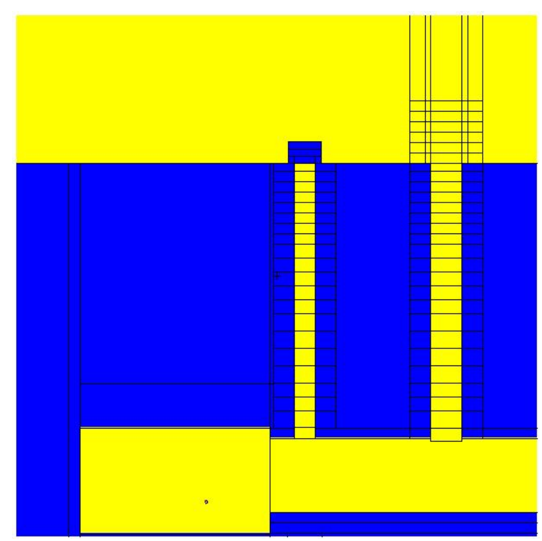
Proton Storage Ring at LANSCE accelerator

Images from MCNP5 plotter

Dose rate calculation for cable penetrations





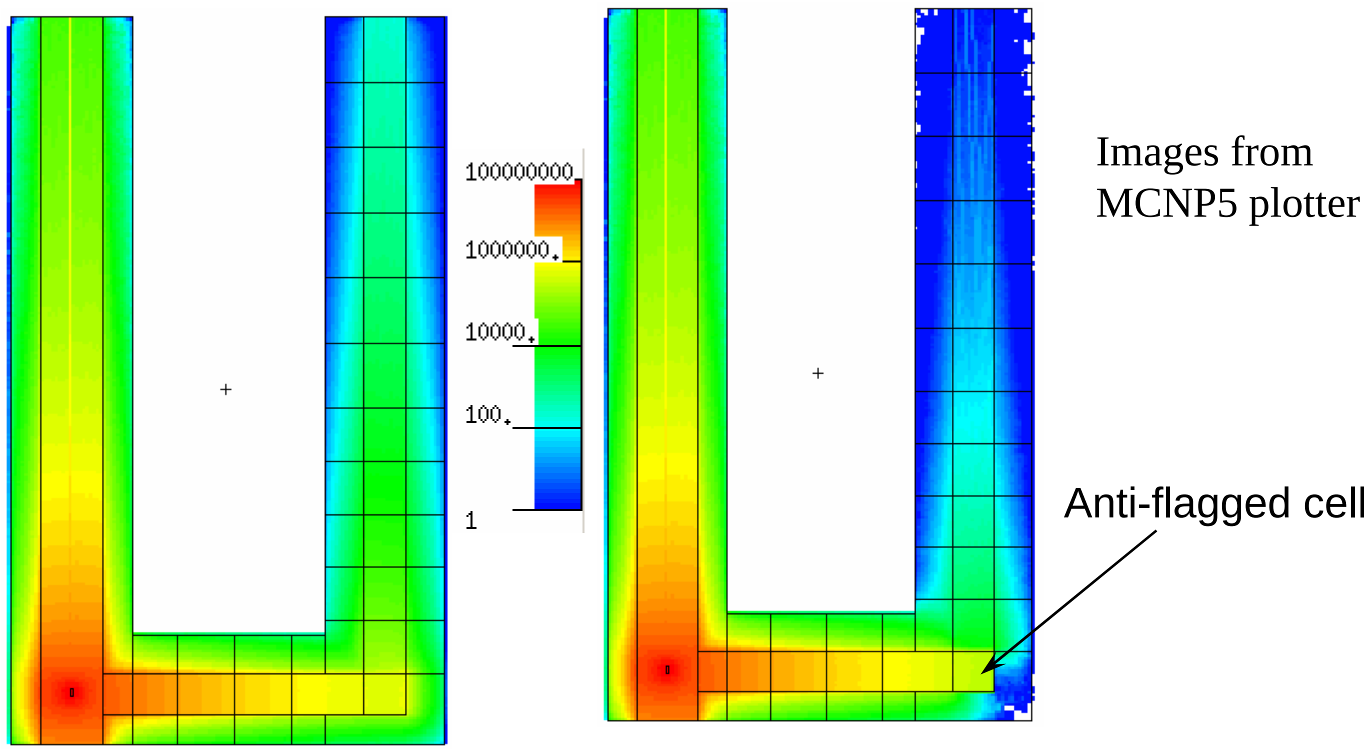


MCNP5 Mesh Tally Plotting

Use SF (Surface Flag) and CF (Cell Flag) cards as for a regular tally, except:

- **Only one tally (the flagged tally) is produced**
- **Negative cell or surface values interpreted as "anti-flag". Scores only those particles that do not cross the surface or leave the cell**

Released in MCNP 5.1.40

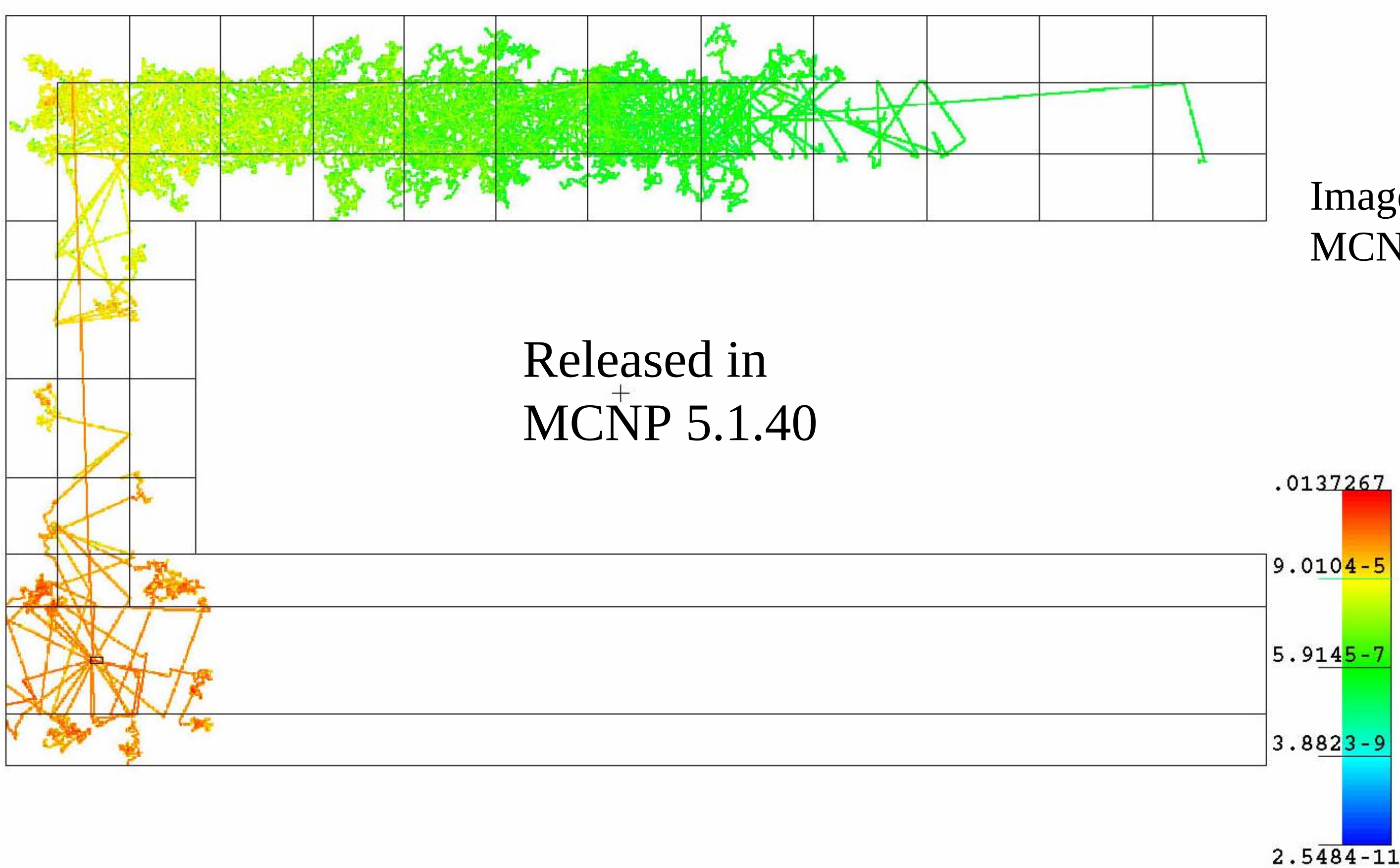


Images from MCNP5 plotter

MCNP5 Mesh Tally Plotting

By using a very fine mesh, particle tracks from individual histories can be plotted.

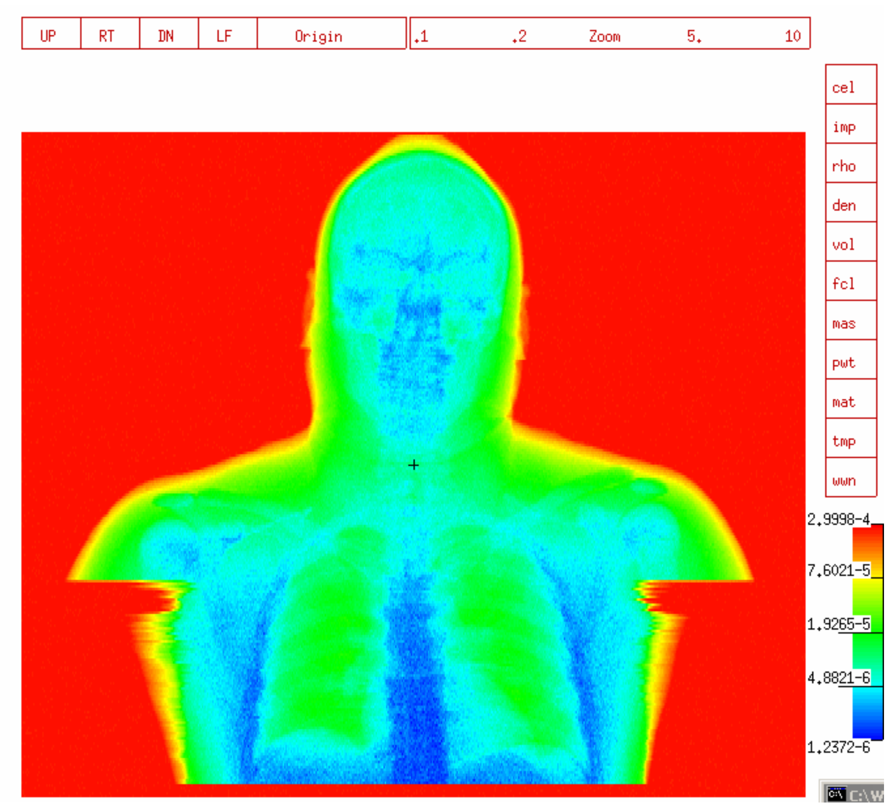
2000 x 1100 x 1 mesh

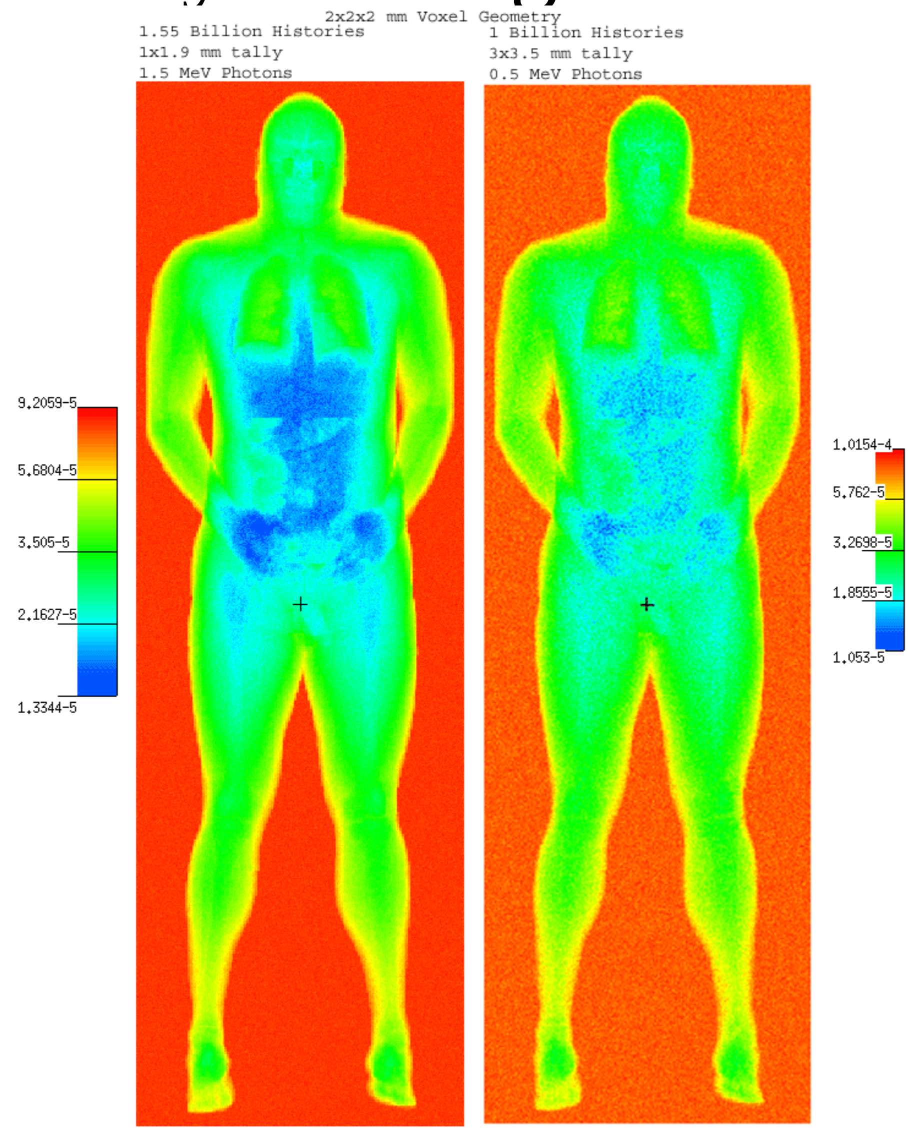


Released in
MCNP 5.1.40

Image from
MCNP5 plotter

MCNP5 Mesh Tally Plotting





Radiographs (Mesh Tally) of VIPMan model,

1x1x1 mm voxels (above),

2x2x2 mm voxels (right)

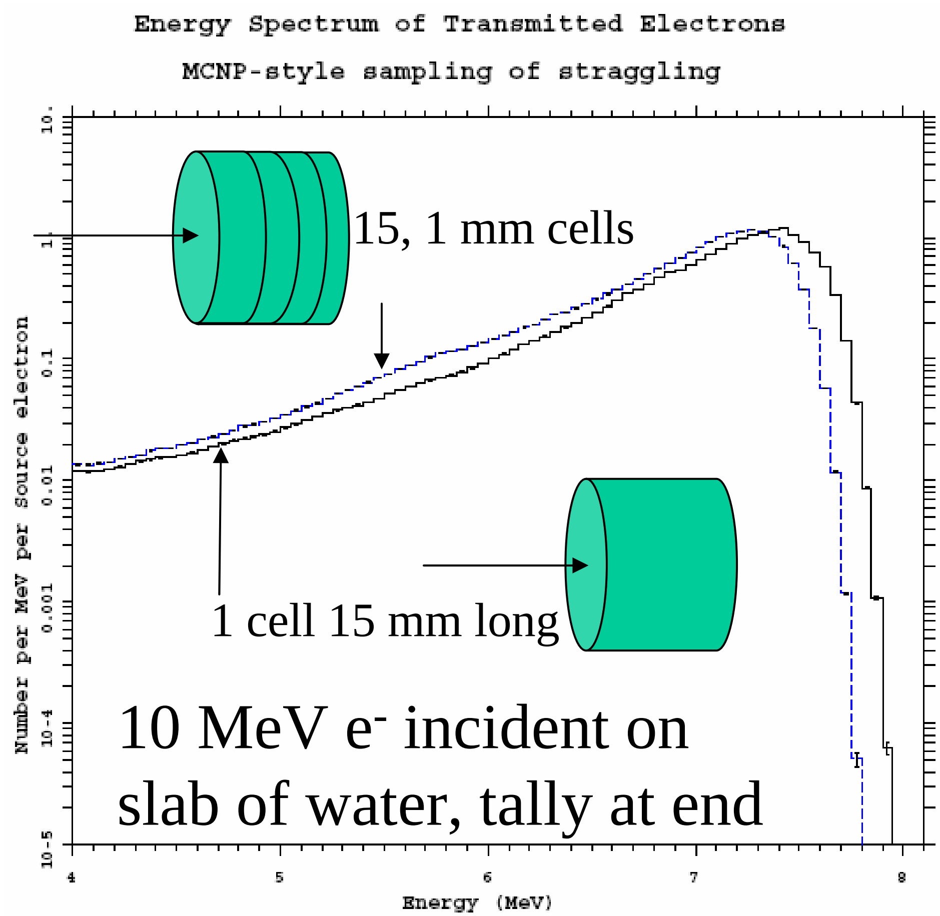
Images from MCNP5 plotter

http://www.rpi.edu/dept/radsafe/public_html/home.htm

Electron Improvements

- Released in MCNP 5.1.40
- Positron Source (SDEF par=4)

- For condensed-history electron transport, tables of Landau parameters were precomputed for a fixed step-size
- This could introduce errors for geometry with spacings less than the assumed Landau step-size
- Computing the Landau parameters on-the-fly for the current step-size & geometric distance eliminates these problems
- 18th entry on DBCN card to 2
- DBCN 17j 2



Hughes M&C 2005 Conference Paper

Stochastic Geometry

- Released in MCNP 5.1.40
- On-the-fly random translations of embedded universes in lattice
- Developed for pebble bed reactors.
- Potential for medical physics applications?
  - Alveoli
  - Sinuses
  - Bone marrow
- Use URAN card
  - See MCNP5 Manual

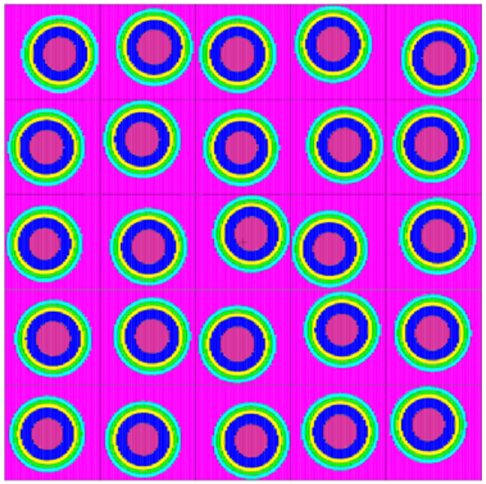


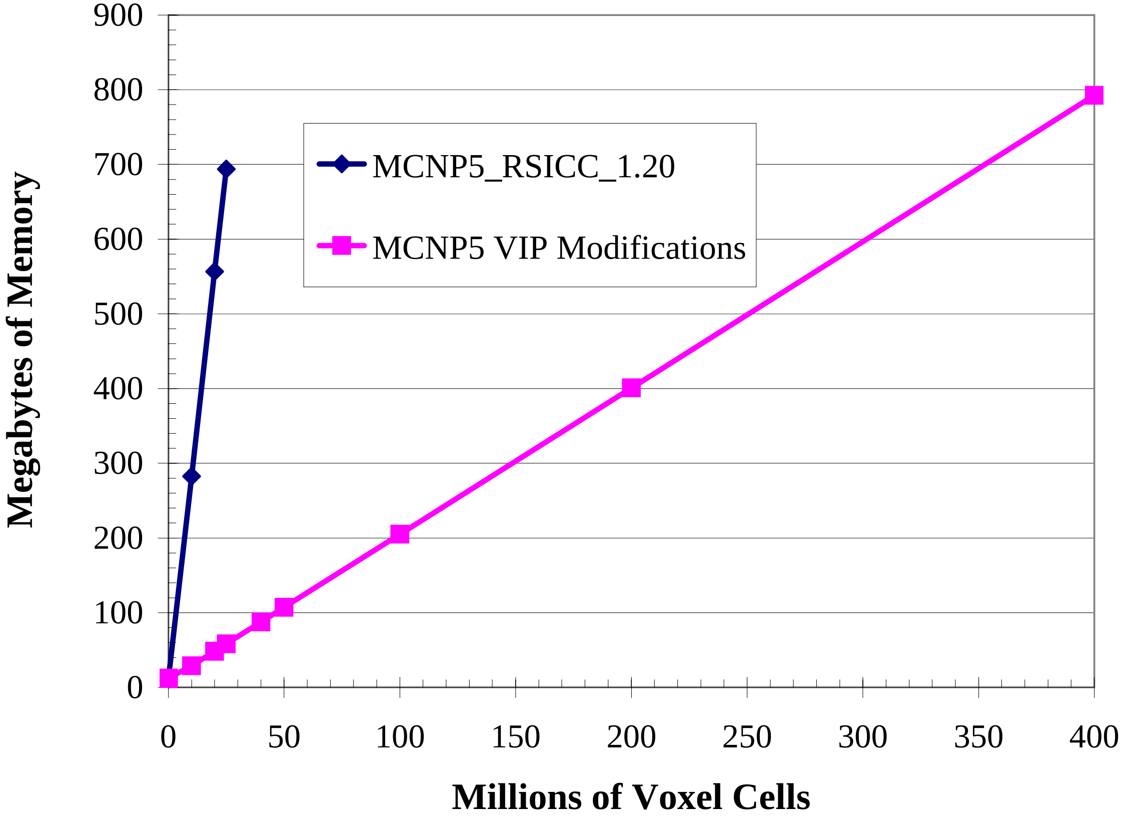
Image of the stochastic geometry of fuel kernels from MCNP5 plotter

Fuel kernel displaced randomly within lattice element each time that particle enters

Large Lattice Improvements

- Increase limit on number of voxels from ~20 Million to ~200+ Million.
- Reduce startup times from hours or days to a few hours.
- Windows OS limit of 2 Gigabytes of Memory per program. (Use 64 bit chip & OS)

MCNP5 1.50



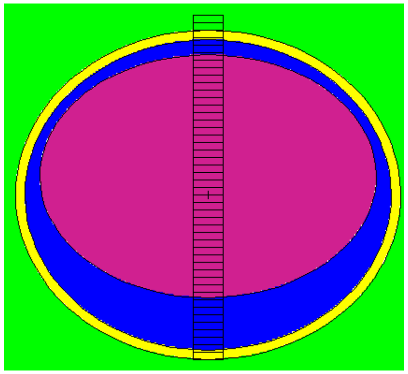
Goorley, "Issues Related to the use of MCNP code for an Extremely Large Voxel Model VIP-MAN" Monte Carlo 2005.

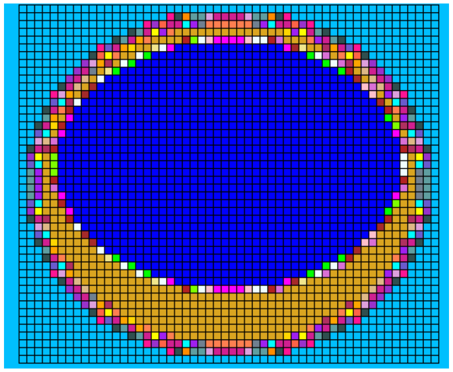
Anticipated next release – Summer 2006

- Pulse Height Tally Variance Reduction
- Improved S(α,β) thermal neutron treatment
- Large Lattice Memory Improvements
- Long Path and File names
- Ignore tabs reading input deck
- Temperature adjusted neutron xs
- MCNP Medical Physics Primer
  - Lazarine, Goorley, ANS Winter Meeting, Washington DC, Nov 2005.

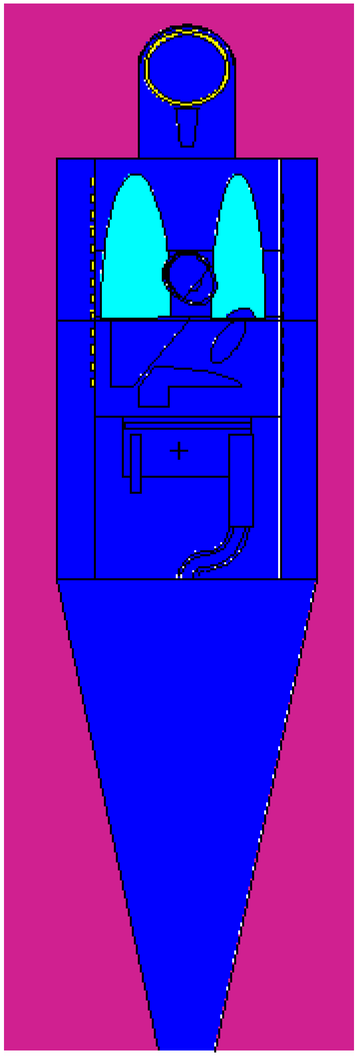
FUTURE WORK for MCNP5/6 Teaser

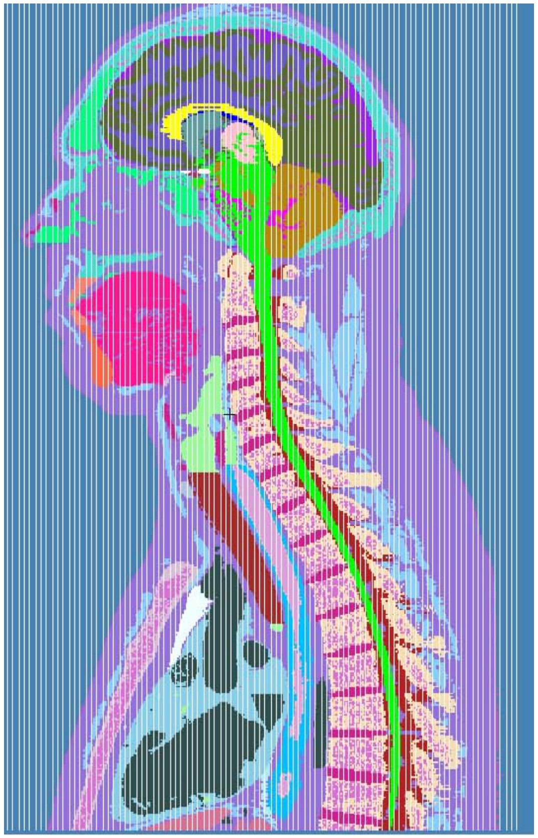
- Proton transport
  - Continuous-energy physics up to 50 GeV
  - Direct tracking through magnetic fields
  - COSY-map tracking through magnetic fields
- Many additional particle types
- ENDF/B-VII (Data Team)
- Improved electron transport
- Automated variance reduction, using deterministic adjoint
- Continuously varying tallies

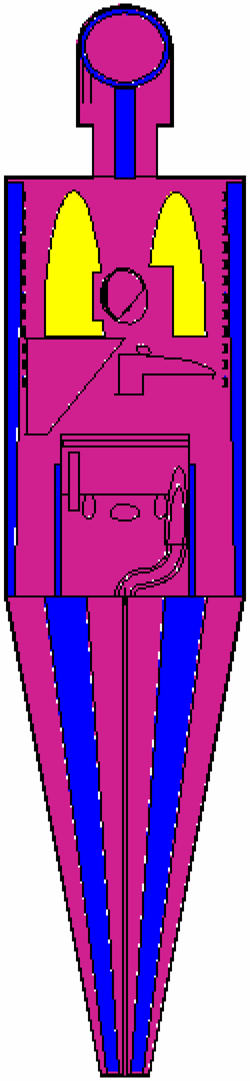




Geometries & Modeling

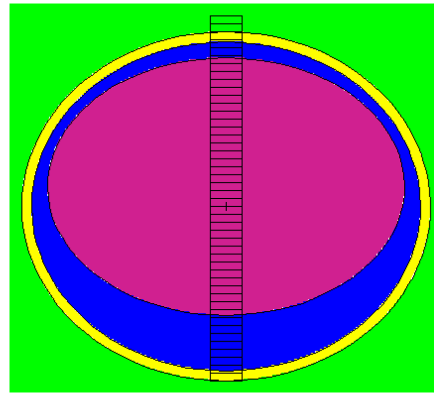






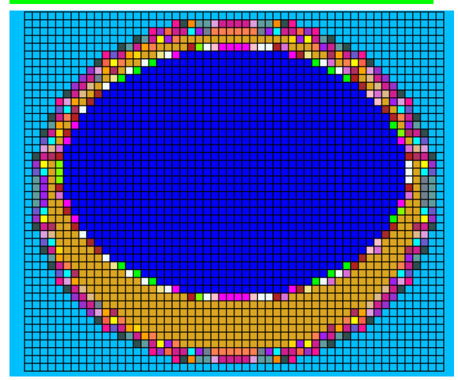
Geometries and Modeling

- Analytical Phantoms
  - MIRD Phantoms



Images of Snyder Head Phantom from MCNP5 plotter.

- Voxel Phantoms
  - CT based Geometries



Input decks in MCNP5_1.40

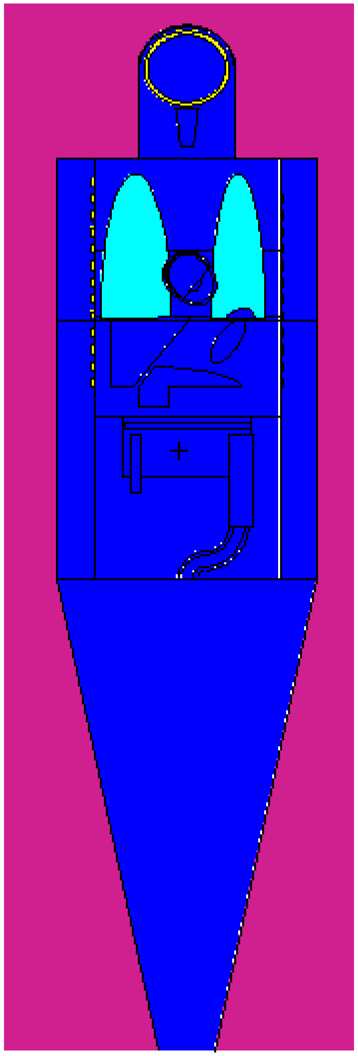
Sample_Problems / Medical_Physics

- Phantom Database
  - Set of MIRD and CT based Phantoms Distributed with MCNP5_RSICC_1.40

Analytical Models

- Conversion of equations into input deck, usually by hand. (sometimes tedious)
- MCNP Cells correspond to specific organs
  - Easy to tally organ average
  - Easy to define materials (ICRU 46 for bio mats)
- Calculate (flux/dose/reaction rate) distribution within organ with mesh tally or other user-defined surfaces
- Usually requires little memory

Analytical Models

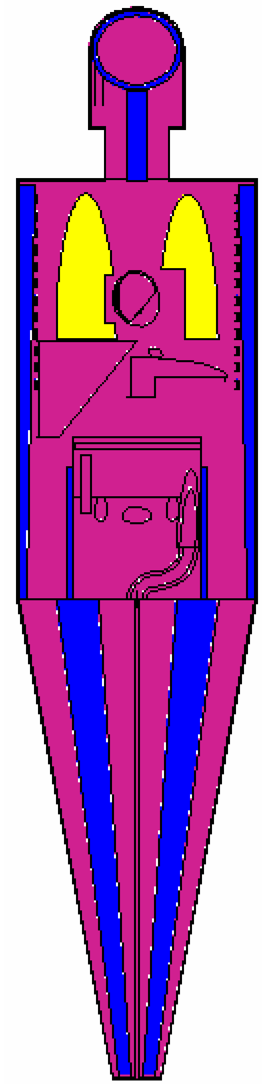


Yanch - MIT

Geometry plots from MCNP5 plotter

Observe differences in organs and materials.

Input decks in MCNP5_1.40 Sample_Problems/ Medical_Physics

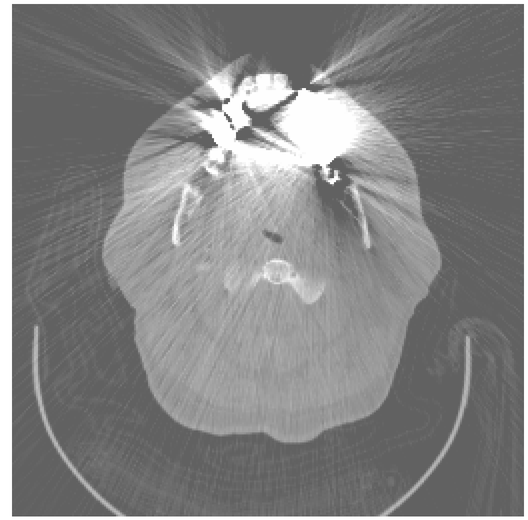


ORNL

Voxel Models

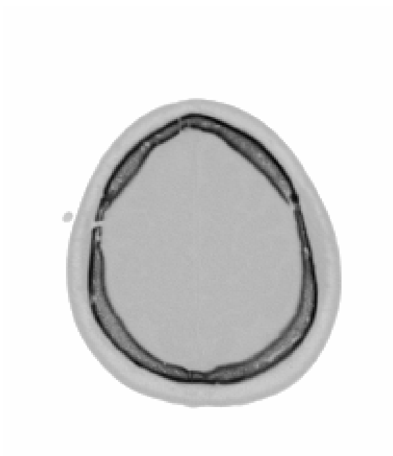
- Obtain CT image data
  - Can be patient specific
  - CTs preserve distances and volumes (better than MRI)
  - Can take CT of experimental phantom to compare calculations to experiments
    - (Reverse is possible - see talk by George Xu, where he starts with CT image and then build 3D phantom)
  - Possible use of CT contrast agent

Voxel Models



- Image manipulation
  - Remove artifacts from CT (dental fillings, for example)
  - Align multiple data set with fiducial markers

Images from NIH Image, Data from Beth Israel Deaconess Medical Center



Voxel Models

- Image conversion from DICOM or other medical format into MCNP input.
  - Reduction in # of voxels and increase voxel size.
  - Homogenization of small voxels into large voxels.
  - Threshold Hounsfield # (12 bit) to correspond to materials (air, tissue, bone – or more complex)
  - Manually define certain regions (outline tumor and fill it with different material, for example).
- Uses the MCNP lattice feature
  - Each different material corresponds to different filling universes and at a lower level, different cells. If possible, different organs have different materials.
  - Example on following page.

```
Memory Test of large lattices in MCNP5.   1K * 1K * 20 = 20,000,000 = 20M voxels.
 1000    0   -11 10   -21 20   -31 30                   $ Lattice Cell, bounding planes for single voxel
         lat=1 fill=    0: 999    0: 999    0: 19           $   fill=i1:i2 j1:j2 k1:k2, change k1,k2
         56  50 19999998r                                   $   56 Xr, change X equal to (# voxels - 1)
         u=100                                              $   lattice cell is universe 100
    56     156  -1.29300E-03     -70  u=   56           $ Cell which fills each lattice voxel
    50     150  -1.29300E-03     -70  u=   50           $ Cell which fills each lattice voxel
 1001  0     10  -12  20 -22  30 -32        fill=100   $ "Window" Cell, looking into lattice
 1002  0  ( -10:  12:-20: 22:-30: 32) -1000           $ Outside window cell, inside bounding sphere
 1003  0                             1000                  $ Exterior of problem, particles die here
c     BLANK LINE

   10  px    -10.500000
   11  px    -10.479000      $  size to generate 1,000 lattice locations across x dimension
   12  px     10.500000
   20  py    -10.500000
   21  py    -10.479000      $  size to generate 1,000 lattice locations across y dimension
   22  py     10.500000
   30  pz    -12.500000
   31  pz    -11.250000      $ size to generate 20 lattice locations across z dimension
   32  pz     12.500000
c    Lattice entries = 1K * 1K * 20 = 20,000,000 = 20M voxels.
 1000   so  10.0E+01
   70   so  5.0E+01
c     BLANK LINE

mode    n p
imp:n     1     3r  0
imp:p     1     3r  0
m156    7014 -0.77780  8016 -0.22220        $ Air
m150    1001 2  8016 1         $ Water
```

Voxel Models

- Tally in regions of interest
  - Tally over entire lattice (use of lattice speed tally capability possible)
  - Tally over cells (i.e. organs) of interest.
  - Use Mesh Tally to overlay geometry.
- Possibly use post-processor to visualize isodose contours.

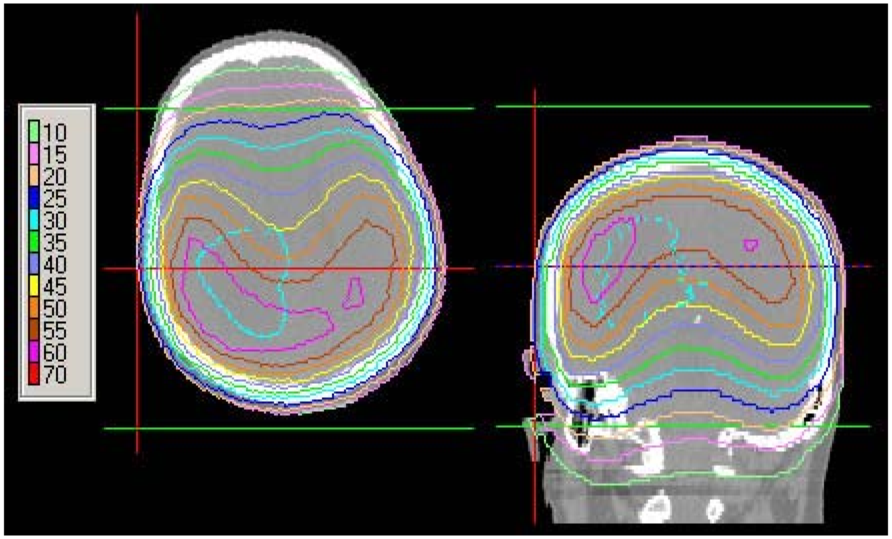


Image from clinical trials using NCTPlan (Harvard-MIT & CNEA)

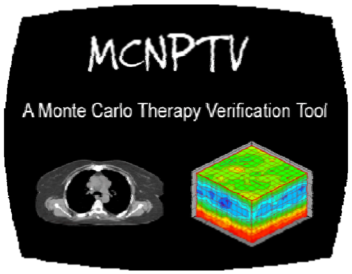
Voxel Models

- Can easily consume Gigabytes of memory
- Large input decks 100s of MBytes, difficult to modify
- Limit in MCNP v 5.1.40 to ~20 million voxels (lattice locations) [Fixed in MCNP v 5.1.50]
- Many users have created their own patches to speed up large voxel model calculations. (ORANGE, Speed Tally Patch)
  - Monte Carlo 2005 Talk – Tues 4:45 Fast Monte Carlo Dose Calculations For All Particles: ORANGE By Steven Van Der Marck
- Users are welcome to submit their patches for review and potential inclusion into MCNP.

Conversion Programs

- Currently available to the public:
  - NCTPlan: Neutron Capture Therapy Plan. By Harvard-MIT & CNEA, Argentina (free – wskiger@mit.edu)*
  - Scan2MCNP: by White Rock Science (commercial - website)

- Not ready for public release (but soon)
  - MiMMC: MultiModal Monte Carlo Treatment Planning System. By Harvard/Beth Israel Deaconess Medical Center.
  - MCNPTV: MCNP Therapy Verification. By Mark Wyatt (University of TN)
  - JCDS: JAERI Computational Dosimetry System.*
  - ImageJ & OEDIPE, by IRNS, France (irns.org)



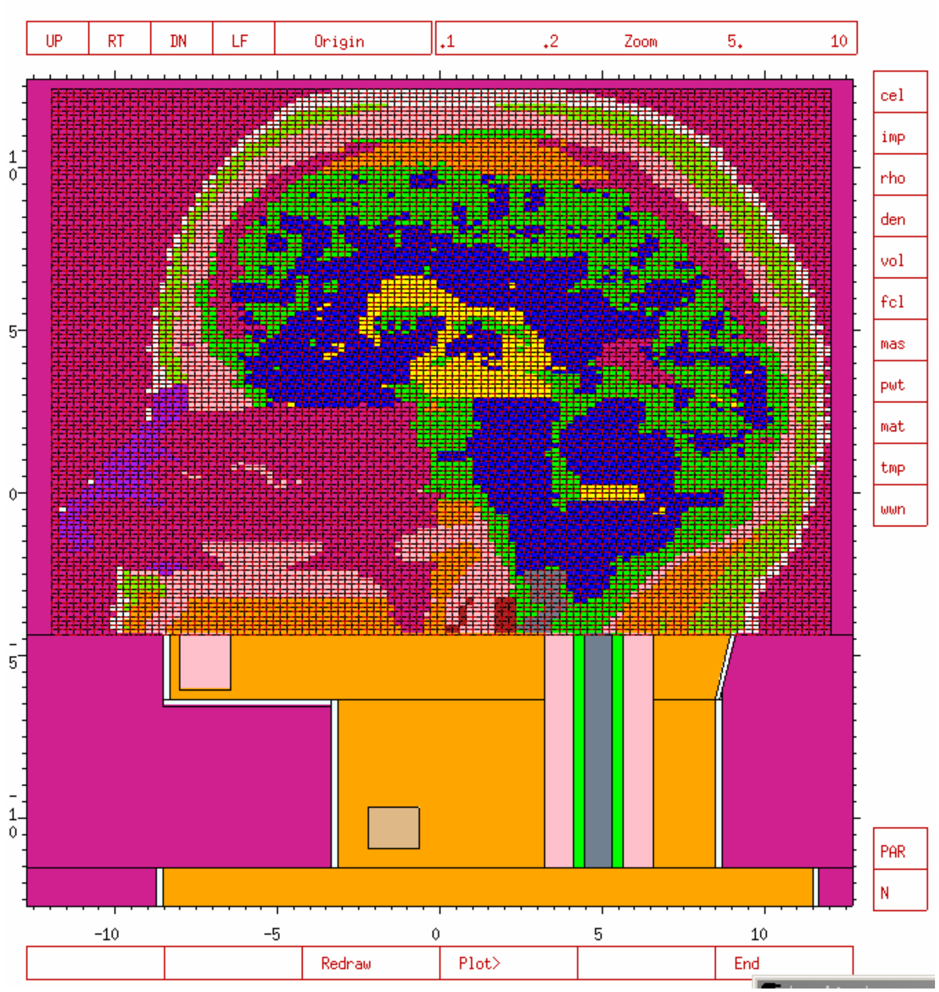
- Not for public release?
  - In-house versions at Ohio State, RPI.
  - THORPlan: By TsingHua University in Taiwan.

* Indicates use in human clinical trial irradiations.

Zubal Phantom

Image from
MCNP5 plotter

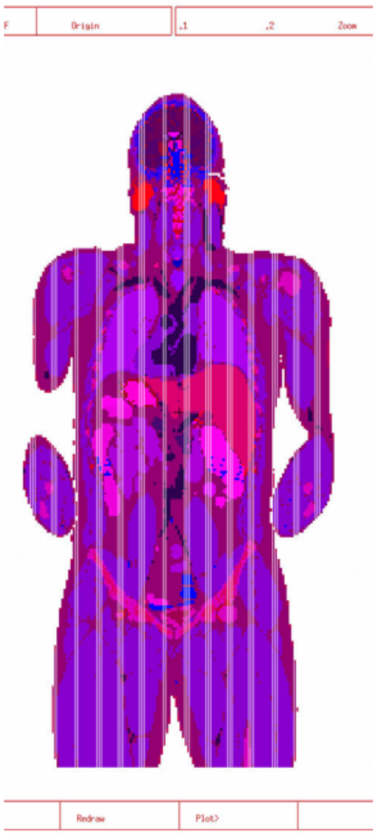
- Voxel Phantom of Head
- 85 x 109 x 120 voxels
- 2.2 x 2.2 x 1.4 mm^3
- 25 Brain structure tallies
- 15 materials
- Jeff Evans, Ohio State

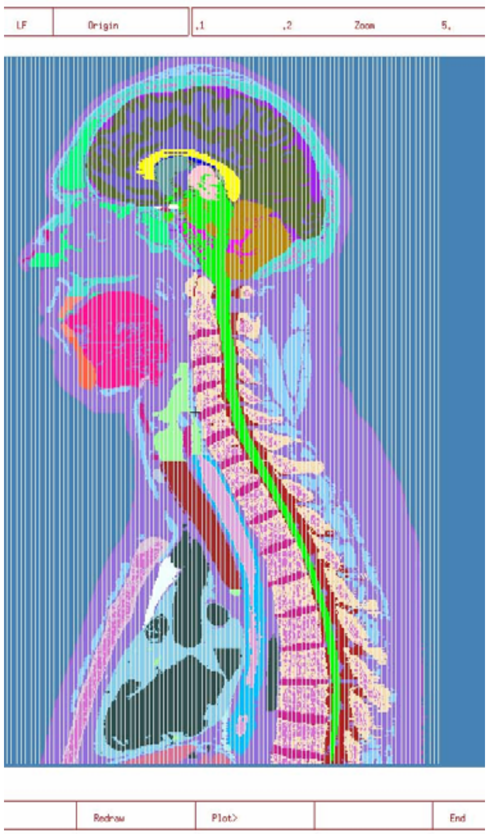


Input deck in MCNP5_1.40
Sample_Problems/ Medical_Physics

VIP Man

- Whole Body Phantom
- Based on NIH VIP-Man Project
- 6, 100, 300 Million Voxel Models
- 1 or 4 mm^3
- Available from Prof. Xu of RPI – not in MP database





http://www.rpi.edu/dept/radsafe/public_html/home.htm

Image from MCNP5 plotter

MP Geometry Database

- A database of Medical Physics phantom input decks distributed with MCNP5 or on MCNP website
- Analytical
  - Snyder Head, ORNL MIRD, MIT MIRD
- Voxel
  - Snyder Head, Water Cubes, Zubal Head, Male Pelvis
- Contributions Welcome!

Misc MP Issues

- S(α,β) neutron scattering treatment
- Benchmarking Studies
  - Computing Radiation Dosimetry – CRD 2002, Sacavem, Portugal June 22-23 2002 (published by OECD)
  - QUADOS (EU intercomparison) Bologna, Italy July 14-16 2003 http://www.nea.fr/download/quados/quados.html
  - EURADOS & CONRAD (EU intercomparison) Deadline: Sept 2006 http://www.eurados.org/
  - ANS: Computational Medical Physics Working Group http://cmpwg.ans.org/
- What MCNP5 cannot do
  - High-Energy Particles (muons, pions, etc..)
  - Heavy Charged Particle Transport (protons, alphas, etc.)
  - Coincident Counting (lacks code and data)
  - Photon Polarization
- MCNP Help & Obtaining MCNP

Neutron Scattering Treatment

- Accounts for molecular effects on target nucleus velocity for low energy (few eV) n scattering.
- Usually low Z, varies with molecule

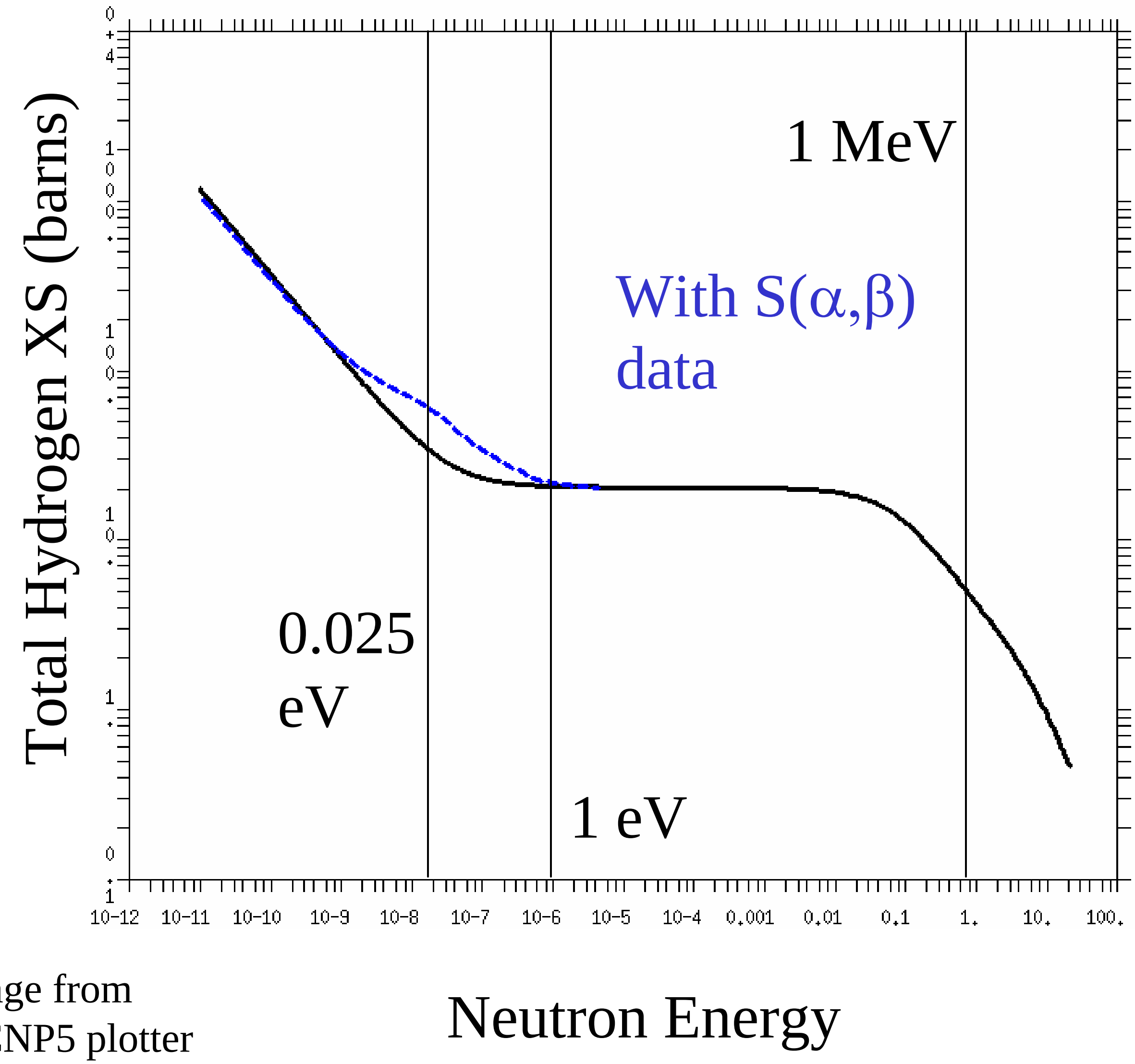
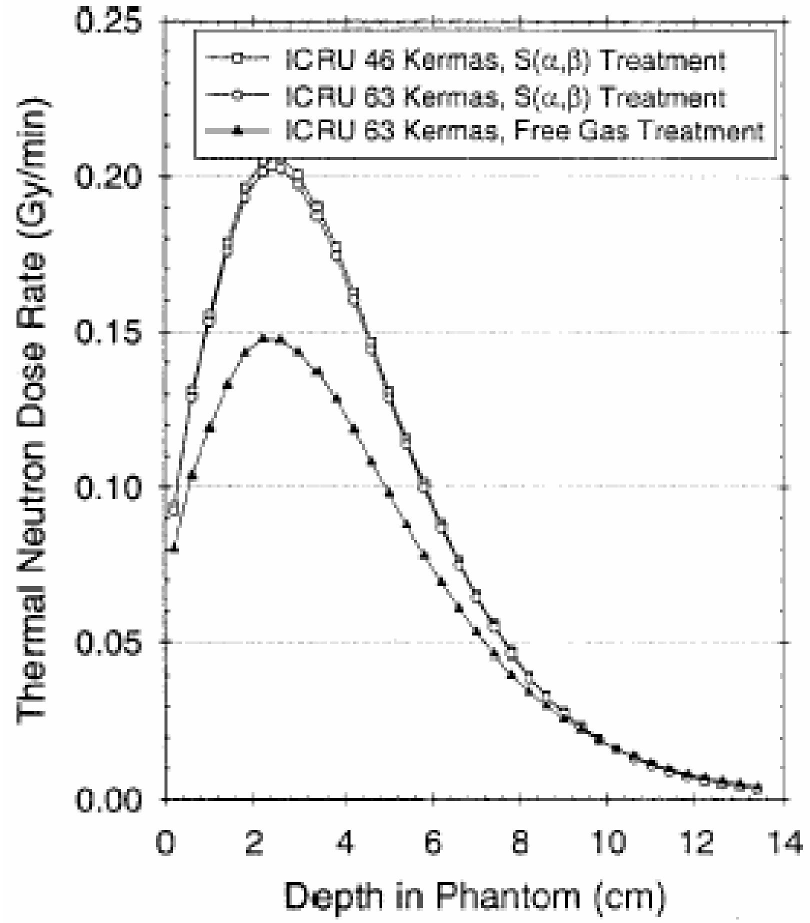


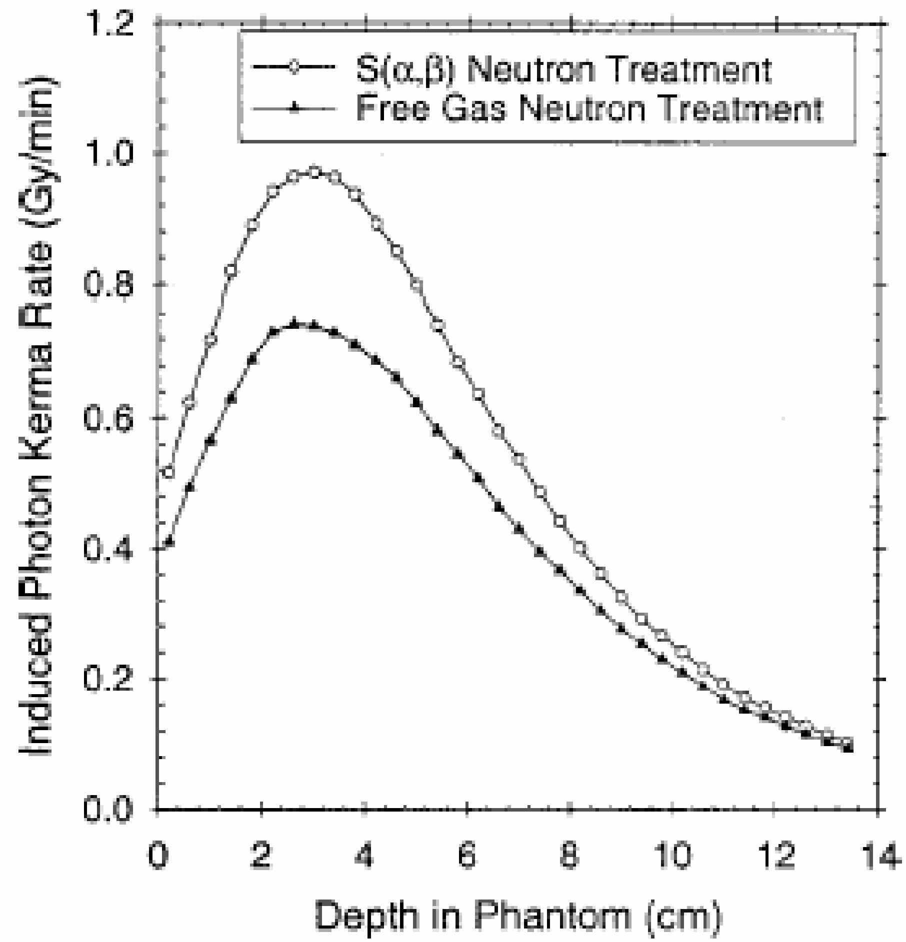
Image from MCNP5 plotter

Neutron Scattering Treatment

- Use can cause significant differences.

Goorley T, et. al. Med. Phys. 29 (2) 2002. pp. 145-156.





Verification & Validation

- Electron Benchmarks - in resource section
- Computing Radiation Dosimetry - CRD
- QUADOS Code Comparison
- EURADOS - CONRAD Code Comparison
- ANS: Computational Medical Physics Working Group
  - http://cmpwg.ans.org/
  - Additional Presentations
  - Code comparison effort

QUADOS

- Quality Assurance of Computational Tools for Dosimetry
- Results presented June 14-16, 2004 Italy
- http://www.nea.fr/download/**quados/quados**.html
- 8 Case Studies, some had 10+ participants
- Used MCNP5 for 6 cases, most good agreement

- Book of proceedings FREE! Irp@bologna.enea.it

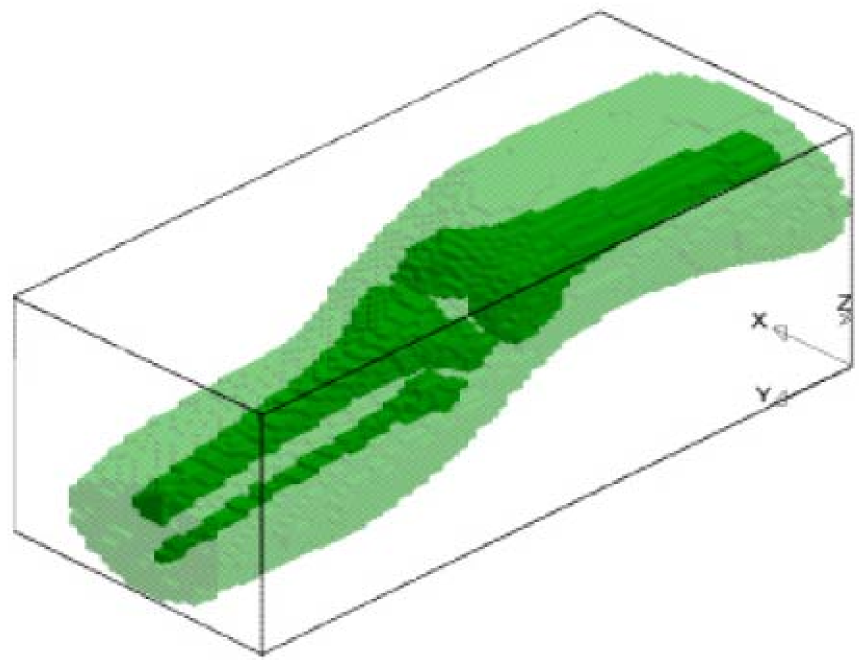
QUADOS

- Brachytherapy – ^{192}Ir γ, dose distribution in H2O
- Endovascular – ^{32}P β-, dose in vessel wall
- Proton Therapy of Eye – 50 MeV p, depth dose
- TLD-Albedo Response – n + γ, 4 element TLD
- Phantom Backscatter – X ray ISO beams, slab
- Environmental Scatter – ^{252}Cf n, concrete room
- HPGe Detector – 15 keV – 1 MeV γ, pulse height
- Consistency check device – ^{241}Am-Be, ^{3}He detector

- Input decks available w/ MCNP5 1.40 Distribution

EURADOS

- European Radiation Dosimetry Group
- http://www.eurados.org/
- Active Code Comparison
  - Monte Carlo modeling for in-vivo measurements of Americium in knee phantom
  - Deadline: November 2006
  - CONRAD - 4 Problems
  - Internal Dosimetry
  - Compex Rad Fields,
  - Medical Staff Dose
  - Computation Dosimetry
  - Results & uncertainties
  - Deadline: September 2006



What MCNP5 Can’t Do

- High-Energy Particles (muons, pions, etc.)
  - Will be available with MCNP6
- Heavy Charged Particle Electron Production
- Proton Generation and Transport
  - Can calculate number of (n,p) reactions
  - Will be available with MCNP6
- Magnetic Field Tracking
  - Will be available with MCNP6
- Coincident Counting
  - lacks code and data
  - Monte Carlo 2005 Talk - An Upgraded Multidetector Pulse Height Tally For MCNP By Andriy Berlizov
- Photon Polarization

Obtaining MCNP

- Can be obtained from RSICC (even if outside US)
  - http://www-rsicc.ornl.gov/
  - 2 DVD versions
    - Executables, Source and Full Manual – limited release
    - Executables, no source, and Vol I & II of Manual – broader release
- Free for limited time
- All DVDs Contain
  - MCNP5, MCNPX, and MCNP Data
  - MCNP5 executables for Linux, Mac, Windows
  - the latest data (pre ENDF/B-VII)
  - MCNPVisual Editor
  - Test Suite to ensure proper installation and compatibility
  - MCNP5 Manual and other documentation
  - Medical Physics Sample Problems

Help with MCNP

- Read the manual
- User forum: **mcnp-forum@lanl.gov**
- X-3 (limited): **mcnp@lanl.gov**
- MCNP home page:
  - **http://www-xdiv.lanl.gov/x5/MCNP/index.html**
- RSICC e-notebook:
  - **http://www-rsicc.ornl.gov/**
  - Go to eNotebooks tab

2006 MCNP Classes

- X-3:
- April 17-21 Advanced MCNP - LANL
- June 12-16: Introduction to MCNP - LANL
- July 10-14: Introduction to MCNP - Tokyo
- Aug : Advanced Variance Reduction – LANL
- Aug : Advanced Criticality - LANL

- HSR-4:
- July 17-21: Practical MCNP for the Health Physicist, Medical Physicist, and Radiological Engineer - LANL

2006 MCNPX Classes

- June 12-16: Introduction - Santa Fe, NM
- July 17-21: Intermediate - Bologna, Italy
- July 31-Aug 4: Intermediate – West Point, NY
- Sept 18-22: Intermed/Advanced - Santa Fe, NM
- Oct 30 - Nov 3: Intermediate - Tokyo, Japan

Additional References

- Variance Reduction overview
- Electron Transport V&V papers
- Monte Carlo 2005 - Chattanooga
- MCNP V&V papers

STOP - Break

Radiation Detection Simulation with MCNP

a. Review the basic physics involved with gamma-ray radiation detection and discuss the limits of the simulation physics.

b. Review MCNP features useful in comparing typical calculations (eg. efficiency, spectroscopy) with experimental measurements for both active and passive gamma-rays.

c. Discuss comparisons with MCNP calculations and benchmark experiments for NaI and HPGe detectors.

Variance Reduction

- Exchange user time for computational time
- Few hours of user time often reduces computational time by 10-1000
- Truncation methods – truncates parts of phase space that do not contribute significantly
- Population control – use particle splitting and Russian roulette to control # samples in phase sp
- Modified sampling – alters statistical sampling of problem to increase # of tally contributions
- Partially deterministic methods – circumvent part of the random walk process by using know expected values.

Simple Variance Reduction

- Implicit Capture
  - Reduces weight of particle by probability of capture
  - Automatically on
  - WC1 parameter on PHYS card
  - Population control technique
- Geometry Splitting
  - Cause splitting or Russian Roulette when changing to cell of different importance
  - Change with the IMP card
  - Population control technique.

Simple Variance Reduction

- Point Detectors
  - Covered in Tally section of this workshop
  - F5 tally type
- Source Biasing
  - Sample from a fictitious density function instead of the true density function. This distortion must be corrected for by altering the particle's weight.
  - SB card w/ SI SP cards
- Weight Cutoff
  - Kills particles whose weight falls below a certain limit
  - Automatically on
  - WC1 and WC2 parameters on CUT card

Electron Transport

- Gierga, DP, Adams KJ, Ballinger CT, Electron Transport using the macro Monte Carlo method for Medical Physics Applications, ANS Transactions 1997, vol 77, p. 356-7
- Gierga, DP, Adams KJ, Electron/Photon Verification Calculations Using MCNP4B. Los Alamos National Laboratory, LA-13440, 1999. 89 pages.
- Schaart, DR, Jansen JTM, Zoetelief J, de Leege, PFA, A Comparison of MCNP4C electron transport with ITS 3.0 and experiment at incident energies between 100 keV and 20 MeV: Influence of voxel size, substeps and energy indexing algorithm. Phys Med Biol, May 2002, vol 47 (9) p. 1459-84
- Chibani, O, Li, XA, Monte Carlo calculations in homogeneous media and at interfaces: A comparison between GEPTS, EGSnrc, MCNP and measurements. Medical Phys, May 2002, vol 29 (5), p. 835-47.

Monte Carlo 2005 MCNP Talks

- Mon 10:50 am Ballroom E - MCNP5 For Proton Radiography, H. Grady Hughes
- Tues 10:50 am Meeting Room 5 - Issues Related To The Use Of MCNP Code For An Extremely Large Voxel Model VIP-MAN, Tim Goorley
- Tues 3:30 Meeting Room 4 - Stochastic Geometry & HTGR Modeling with MCNP5, Forrest Brown, WR Martin, W Ji, J Conlin, JC Lee
- Wed 9:00 am Ballroom E - Monte Carlo Methods & MCNP5 Code Development, Forrest Brown
- Wed 9:25 am Meeting Room 6 - Analysis Of The Fourth Zeus Critical Experiment With MCNP5, Russell Mosteller
- Wed 10:50 am Meeting Room 5 - Comparison Of Phantom Models For External Dosimetry Computations, Richard Olsher

Voxel Model Talks at Monte Carlo 2005

papers available on conference CDROM

- Mon, 1:15 GSF Male And Female Adult Voxel Models Representing ICRP Reference Man By Keith Eckerman
- Mon, 1:45 Effective Dose Ratios For The Tomographic Max And Fax Phantoms By Richard Kramer
- Mon, 2:05 Reference Korean Human Models: Past, Present and Future By Choonsik Lee
- Mon, 2:25 The UF Family of Pediatric Tomographic Models By Wesley Bolch and Choonik Lee
- Mon, 2:45 Development And Anatomical Details Of Japanese Adult Male/ Female Voxel Models By Tomoaki Nagaoka
- Mon 3:25 Dose Calculation Using Japanese Voxel Phantoms For Diverse Exposures By Kimiaki Saito
- Mon 3:45 Stylized Versus Tomographic Models: An Experience On Anatomical Modeling At RPI By X. George Xu
- Mon 4:05 Use Of MCNP With Voxel-Based Image Data For Internal Dosimetry Applications By Michael Stabin
- Mon 4:45 Application Of Voxel Phantoms For Internal Dosimetry At IRSN Using A Dedicated Computational Tool By Isabelle Aubineay-Laniece
- Tues 10:45 Issues Related To The Use Of MCNP Code For An Extremely Large Voxel Model VIP-MAN By Tim Goorley
- Tue 2:40 Conversion Of Combinatorial Geometry To Voxel Based Geometry In Moritz By Kenneth Van Riper

Additional References

- Goorley T, Kiger WS III, Zamenhof RG. Reference Dosimetry Calculations for Neutron Capture Therapy with Comparison of Analytical and Voxel Models. Med. Phys. 29 (2) 2002. pp. 145-156.
- Goorley, T. "MCNP5 Tally Enhancements for Lattices (aka Lattice Speed Tally Patch)," Los Alamos National Laboratory report LA-UR-04-3400 (June 2004).
- J. H. Hubbell and S. M. Seltzer, ''Tables of x-ray mass attenuation coefficients and mass energy–absorption coefficients,'' http:/physics.nist.gov/ xaamdi, National Institute of Standards and Technology, Gaithersburg, MD, 1997.
- Hughes, H. Grady , "Improved Logic for Sampling Landau Straggling in MCNP5", Submitted to M&C 2005, ANS Mathematics and Computation Topical Meeting, Avignon, France, Sept 12-15, 2005.
- ICRU 46, ''Photon, electron, proton, and neutron interaction data for body tissues,'' International Commission on Radiation Units and Measurements, Bethesda, MD, 1992.
- Kiger WSIII, Hochberg HK, Albritton JR, Goorley T, "Performance Enhancements of MCNP4B, MCNP5 and MCNPX for Monte Carlo Radiotherapy Planning Calculations in Lattice Geometries", 11th International Symposia on Neutron Capture Therapy. Boston, USA, Oct 11-15, 2004.

Additional References

- Borisov, N; Franck, D; de Carlan, L; Laval, L. A new graphical user interface for fast construction of computation phantoms and MCNP calculations: Application to calibration of in vivo measurement systems. Health Physics; Aug. 2002; 83(2) p.272-9
- Franck, D; Borissov, N; de Carlan, L; Pierrat, N; Genicot, JL; Etherington, G. Application of Monte Carlo calculations to calibration of anthropomorphic phantoms used for activity assessment of actinides in lungs. Radiation Protection Dosimetry; 2003; vol.105, no.1-4, p.403-8 Conference: Internal Dosimetry of Radionuclides. Occupational, Public and Medical Exposure, 9-12 Sept. 2002, Oxford, UK
- Wyatt, MS, Miller, LF, Implementation of a Methodology for Converting CT Images to MCNP Input. 2004 ANS Winter Meeting,November 14 – 18, 2004, Washington, DC.